

CERN Program Library Long Writeup Q121

PAW

Physics Analysis Workstation

The Complete Reference

Version 1.14 (July 1992)

Application Software Group

Computing and Networks Division

CERN Geneva, Switzerland

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PAW – Physics Analysis Workstation

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Second edition - July 1992

About this guide

Preliminary remarks

This **Complete Reference** of PAW (for **Physics Analysis Workstation**), consists of three parts:

- 1 A **step by step** tutorial introduction to the system.
- 2 A **functional description** of the components.
- 3 A **reference guide**, describing each command in detail.

The PAW system is implemented on various mainframes and personal workstations. In particular versions exist for IBM VM/CMS and MVS/TSO, VAX/VMS and various Unix-like platforms, such as APOLLO, DEC Station 3100, Silicon Graphics and SUN.

In this manual examples are in monotype face and strings to be input by the user are underlined. In the index the page where a command is defined is in **bold**, page numbers where a routine is referenced are in normal type.

In the description of the commands parameters between square brackets [. . .] are optional.

Acknowledgements

The authors of PAW would like to thank all their colleagues who, by their continuous interest and encouragement, have given them the necessary input to provide a modern and easy to use data analysis and presentation system.

They are particularly grateful to Michel Goossens as main author of part one and as technical editor of the present document and to Michael Metcalf for his work on improving the index.

Vladimir Berezhnoi (IHEP, Serpukhov, USSR), the main author of the Fortran interpreter COMIS, provided one of the essential components of our system. Nicole Cremel has collaborated to the first versions of H PLOT. The PAW/HBOOK to MINUIT interface has been implemented in collaboration with Eliane Lessner (FNAL, USA) and Fred James. Jim Loken (Oxford, UK) has been our expert on VAX global sections. David Foster, Frederic Hemmer, Catherine Magnin and Ben Segal have contributed to the development of the PAW TCP/IP interface. Ben has also largely contributed to the TELNETG and 3270G systems. Per Scharff-Hansen and Johannes Raab from the OPAL collaboration have made possible the interface with the OS9 system. Harald Johnstad (FNAL, now SSC, USA) and Lee Roberts (FNAL, USA) have contributed to the debugging phases of PAW in the DI3000 and DECGKS environments. Initial implementations of PAW on MVS/TSO, the Sun and the DEC Station 3100 were made by Alain Michalon (Strasbourg, France), François Marabelle (Saclay, France) and Walter Bruckner (Heidelberg, FRG), respectively. Lionel Cons (now at ENSIMAG, Grenoble) has contributed to the implementation of the selection mechanisms for Ntuples. Isabelle Moulinier (Paris) has been working, as a summer student, on various improvements in the HIGZ/H PLOT packages. Federico Carminati, the main distributor of the CERN program library had to suffer from the many imperfections of our first releases. His collaboration for PAW consultancy is appreciated. Gudrun Benassi has always kindly organized the distribution of the various PAW manuals.

Related Manuals

This document can be complemented by the following manuals:

- COMIS, Compilation and Interpretation System [1]
- HBOOK User Guide — Version 4 [2]
- HIGZ — High level Interface to Graphics and ZEBRA [3]
- HPLOT User Guide — Version 5 [4]
- KUIP — Kit for a User Interface Package [5]
- MINUIT — Function Minimization and Error Analysis [6]
- ZEBRA — Data Structure Management System [7]

This document has been produced using L^AT_EX [8] with the `cernman` style option, developed at CERN. All pictures shown are produced with PAW and are included in PostScript [9] format in the manual.

A PostScript file `pawman.ps`, containing a complete printable version of this manual, can be obtained by anonymous ftp as follows (commands to be typed by the user are underlined):

```
ftp asis01.cern.ch
Trying 128.141.201.136...
Connected to asis01.cern.ch.
220 asis01 FTP server (Version 6.10 Mon Apr 13 15:59:17 MET DST 1992) ready.
Name (asis01:username): anonymous
331 Guest login ok, send e-mail address as password.
Password: your_mailaddress
ftp> cd doc/cernlib
ftp> get pawman.ps
ftp> quit
```

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Part I

PAW – Step by step

Chapter 1: A few words on PAW

1.1 A short history

Personal workstations equipped with a 1 Mbit bitmap display, a speed of several tens of MIPS, with at least 20-30 Mbytes of main memory and 1 Gbyte of local disk space (e.g. DEC, HP-700, IBM RS6000, Sun Sparc and Silicon Graphics workstations) are now widely available at an affordable price for individual users. In order to exploit the full functionality of these workstations, at the beginning of 1986 the **Physics Analysis Workstation project PAW** was launched at CERN. The first public release of the system was made at the beginning of 1988. At present the system runs on most of the computer systems used in the High Energy Physics (HEP) community but its full functionality is best exploited on personal workstations. In addition to its powerful data analysis, particular emphasis has been put on the quality of the user interface and of the graphical presentation.

1.2 What is PAW?

PAW is an interactive utility for visualizing experimental data on a computer graphics display. It may be run in batch mode if desired for very large data analyses; typically, however, the user will decide on an analysis procedure interactively before running a batch job.

PAW combines a handful of CERN High Energy Physics Library systems that may also be used individually in software that processes and displays data. The purpose of PAW is to provide many common analysis and display procedures that would be duplicated needlessly by individual programmers, to supply a flexible way to invoke these common procedures, and yet also to allow user customization where necessary.

Thus, PAW's strong point is that it provides quick access to many facilities in the CERN library. One of its limitations is that these libraries were not designed from scratch to work together, so that a PAW user must eventually become somewhat familiar with many dissimilar subsystems in order to make effective use of PAW's more complex capabilities. As PAW evolves in the direction of more sophisticated interactive graphics interfaces and object-oriented interaction styles, the hope is that such limitations will gradually become less visible to the user.

PAW is most effective when it is run on a powerful computer workstation with substantial memory, rapid access to a large amount of disk storage, and graphics support such as a large color screen and a three-button mouse. If the network traffic can be tolerated, PAW can be run remotely over the network from a large, multiuser client machine to more economical servers such as an X-terminal. In case such facilities are unavailable, substantial effort has been made to ensure that PAW can be used also in noninteractive or batch mode from mainframes or minicomputers using text terminals.

1.3 What Can You Do with PAW?

PAW can do a wide variety of tasks relevant to analyzing and understanding physical data, which are typically statistical distributions of measured events. Below we list what are probably the most frequent and best-adapted applications of PAW; the list is not intended to be exhaustive, for it is obviously possible to use PAW's flexibility to do a huge number of things, some more difficult to achieve than others within the given structure.

Typical PAW Applications:

- **Plot a Vector of Data Fields for a List of Events.** A set of raw data is typically processed by the user's own software to give a set of physical quantities, such as momenta, energies, particle identities, and so on, for each event. When this digested data is saved on a file as an Ntuple, it may be read and manipulated directly from PAW. Options for plotting Ntuples include the following:
 - *One Variable.* If a plot of a one variable from the data set is requested, a histogram showing the statistical distribution of the values from all the events is automatically created. Individual events are not plotted, but appear only as a contribution to the corresponding histogram bin.
 - *Two or Three Variables.* If a plot of two or three variables from the data set is requested, no histogram is created, but a 2D or 3D scatter plot showing a point or marker for each distinct event is produced.
 - *Four Variables.* If a plot of four variables is requested, a 3D scatter plot of the first three variables is produced, and a color map is assigned to the fourth variable; the displayed color of the individual data points in the 3D scatter plot indicates the approximate value of the fourth variable.
 - *Vector Functions of Variables.* PAW allows the user to define arbitrary vector functions of the original variables in an Ntuple, and to plot those instead of the bare variables. Thus one can easily plot something like $\sqrt{(P_x^2 + P_y^2)}$ if P_x and P_y are original variables in the data without having to add a new data field to the Ntuple at the time of its creation.
 - *Selection Functions (Cuts).* PAW does not require you to use every event in your data set. Several methods are provided to define Boolean functions of the variables themselves that pick out subsets of the events to be included in a plot.
 - *Plot presentation options.* The PAW user can set a variety of options to customize the format and appearance of the plots.

- **Histogram of a Vector of Variables for a List of Events.** Often one is more interested in the statistical distribution of a vector of variables (or vector functions of the variables) than in the variables themselves. PAW provides utilities for defining the desired limits and bin characteristics of a histogram and accumulating the bin counts by scanning through a list of events. The following are some of the features available for the creation of histograms:
 - *One Dimensional Histograms.* Any single variable can be analyzed using a one-dimensional histogram that shows how many events lie in each bin. This is basically equivalent to the single-variable data plotting application except that it is easier to specify personalized features of the display format. A variety of features allow the user to slice and project a 2D scatter plot and make a 1D histogram from the resulting projection.
 - *Two-Dimensional Histograms.* The distribution of any pair of variables for a set of events can be accumulated into a 2D histogram and plotted in a various of ways to show the resulting surface.
 - *Three-Dimensional Histograms.* Will be supported soon.
 - *Vector Functions of Variables.* User-defined functions of variables in each event can be used to define the histogram, just as for an Ntuple plot.

- *Selection Functions (Cuts)*. Events may also be included or excluded by invoking Boolean selection functions that are arbitrary functions of the variables of a given event.
 - *Event Weights*. PAW allows the user to include a multiplicative statistical bias for each event which is a scalar function of the available variables. This permits the user to correct for known statistical biases in the data when making histograms of event distributions.
 - *Histogram Presentation Options*. Virtually every aspect of the appearance of a histogram can be controlled by the user. Axis labels, tick marks, titles, colors, fonts, and so on, are specified by a large family of options. A particular set of options may be thought of as a “style” for presenting the data in a histogram; “styles” are in the process of becoming a formal part of PAW to aid the user in making graphics that have a standard pleasing appearance.
- **Fit a Function to a Histogram.** Once a histogram is defined, the user may fit the resulting shape with one of a family of standard functions, or with a custom-designed function. The parameters of the fit are returned in user-accessible form. Fitted functions of one variable may be attached to a 1D histogram and plotted with it. The capability of associating fits to higher dimensional histograms and overlaying their representations on the histogram is in the process of being added to PAW.

The fitting process in PAW is normally carried out by the MINUIT library. To use this package effectively, users must typically supply data with reasonable numerical ranges and give reasonable initial conditions for the fit before passing the task to the automated procedure.

- **Annotate and Print Graphics.** A typical objective of a PAW user is to examine, manipulate, and display the properties of a body of experimental data, and then to prepare a graph of the results for use in a report, presentation, or publication. PAW includes for convenience a family of graphics primitives and procedures that may be used to annotate and customize graphics for such purposes. In addition, any graphics display presented on the screen can be converted to a PostScript file for black-and-white or color printing, or for direct inclusion in a manuscript.

1.4 A User's View of PAW

In order to take advantage of PAW, the user must first have an understanding of its basic structure. Below we explain the fundamental ways in which PAW and the user interact.

Intialization. PAW may be invoked in a variety of ways, depending on the user's specific computer system; these are described in the following chapter. As PAW starts, it prompts the user to select an interaction mode (or non-interactive mode) and window size and type (if interactive). The available window sizes and positions are specified in the user file "higz_windows.dat". User-specific intializations are specified in the file "pawlogon.kumac".

Text Interface. The most basic interface is the **KUIP text interface**. KUIP provides a basic syntax for commands that are parsed and passed on to the PAW application routines to perform specific tasks. Among the basic features of KUIP with which the user interacts are the following:

- *Command Entry.* Any unique partially entered command is interpreted as a fully entered command. KUIP responds to an ambiguous command by listing the possible alternatives. On Unix systems, individual command lines can be edited in place using individual control keystrokes similar to those of the emacs editor, or the bash or tcsh Unix command shells. On other systems, a command line that is in error can only be revised after it is entered, using an “ed” style text line editing language.

- *Parameters.* Parameters are entered after the basic command on the same line and are separated by spaces, so algebraic expressions may not have embedded blanks. An exclamation point (!) can be used to keep the default parameters in a sequence when only a later parameter is being changed. If an underscore (_) is the last character on a line, the command may be continued on the next line; no spaces are allowed in the middle of continued parameter fields.
- *Command History.* A command history is kept both in memory for interactive inspection and on a disk file. The command history file can be recovered and used to reconstruct a set of actions carried out interactively.
- *On-Line Assistance.* The "usage" and "help" commands can be used to get a short or verbose description of parameters and features of any command.
- *Aliases.* Allow the abbreviation of partial or complete command sequences.
- *Macros.* A text file containing PAW commands and flow control statements.

KUIP/MOTIF Interface. If the user's workstation supports the X-window MOTIF graphics management system, PAW can be started in the KUIP/MOTIF mode. A small text panel and a command history panel keep track of individual actions and permit entry and recall of typed commands similar to the Text Interface mode. Other basic features of this interface include the following:

- *Pull-Down Menu Commands.* Each PAW command that can be typed as a text command has a corresponding item in a hierarchy of pull-down menus at the top of the MOTIF panel. Commands that require arguments cause a parameter-entry dialog box to appear; when the arguments are entered, the command is executed as though typed from the text interface.
- *Action Panel.* A user may have a family of frequently executed macros or commands assigned to specific buttons on the action panel.

Graphics Output Window. The graphics image produced by PAW commands, regardless of the command interface, appears on a separate graphics output window. The actual size and position of this window on the screen is controlled by a list of numbers of the form `x-upper-left y-upper-left x-width y-height` in the user file `higz_windows.dat`. The width and height of the drawing area within this window are subject to additional user control, and the user can specify "zones," which are essentially ways of dividing the window into panes to allow simultaneous display of more than one plot. Some facilities are available in the current version of PAW to use the mouse to retrieve data such as the height of a histogram bin. Applications currently under development will extend this style of interaction.

1.5 Fundamental Objects of PAW

PAW is implicitly based on a family of fundamental objects. Each PAW command performs an action that either produces another object or produces a "side-effect" such as a printed message or graphics display that is not saved anywhere as a data structure. Some commands do both, and some may or may not produce a PAW data structure depending on the settings of global PAW parameters. In this section, we describe the basic objects that the user needs to keep in mind when dealing with PAW. The reader should perhaps note that the PAW text commands themselves do not necessarily reflect the nature of PAW objects as clearly as they might, while the MOTIF interactive graphics interface currently in development in fact displays distinct icons for most of the object types listed below.

Objects:

- **Ntuples.** An Ntuple is the basic type of data used in PAW. It consists of a list of identical data structures, one for each event. Typically, an Ntuple is made available to PAW by opening a ZEBRA file; this file, as created by HBOOK, contains one or more Ntuples and possibly also ZEBRA logical directories, which may store a hierarchy of Ntuples. A storage area for an Ntuple may be created directly using `ntuple/create`; data may then be stored in the allocated space using the `ntuple/loop` or `ntuple/read` commands. Other commands merge Ntuples into larger Ntuples, project vector functions of the Ntuple variables into histograms, and plot selected subsets of events.
- **Cuts.** A cut is a Boolean function of Ntuple variables. Cuts are used to select subsets of events in an Ntuple when creating histograms and plotting variables.
- **Masks.** Masks are separate files that are logically identical to a set of boolean variables added on the end of an Ntuple's data structure. A mask is constructed using the Boolean result of applying a cut to an event set. A mask is useful only for efficiency; the effect of a mask is identical to that of the cut that produced it.
- **1D Histograms.** A histogram is the basic statistical analysis tool of PAW. Histograms are created ("booked") by choosing the basic characteristics of their bins, variables, and perhaps customized display parameters; numbers are entered into the histogram bins from an Ntuple (the histogram is "filled") by selecting the desired events, weights, and variable transformations to be used while counts are accumulated in the bins. Functional forms are frequently fit to the resulting histograms and stored with them. Thus a fit as an object is normally associated directly with a histogram, although it may be considered separately.
- **2D Histograms.** 2D (and higher-dimensional) histograms are logical generalizations of 1D histograms. 2D histograms, for example, are viewable as the result of counting the points in a the sections of a rectangular grid overlaid on a scatter plot of two variables. Higher-dimensional histograms can also be fitted, and support for associating the results of a fit to a higher-dimensional histogram is currently being incorporated in PAW.
- **Styles.** A "style" is a set of variables that control the appearance of PAW plots. Commands of the form `igset parameter value` determine fundamental characteristics of lines, axis format, text, and so on. Commands of the form `option attribute` choose particular plotting options such as logarithmic/linear, bar-chart/scatter-plot, and statistics display. Commands of the form `set parameter value` control a vast set of numerical format parameters used to control plotting. While the "style" object will eventually become a formal part of PAW, a "style" can be constructed by the user in the form of a macro file that resets all parameters back to their defaults and then sets the desired customizations.
- **Metafile.** In normal interactive usage, images created on the screen correspond to no persistent data structure. If one wishes to create a savable graphics object, the user establishes a *metafile*; as a graphics image is being drawn, each command is then saved in a text file in coded form that allows the image to be duplicated by other systems. PostScript format metafiles are especially useful because they can be directly printed on most printers; furthermore, the printed quality of graphics objects such as fonts can be of much higher quality than the original screen image.

- **Pictures.** Metafiles describing very complex graphics objects can be extremely lengthy, and therefore inefficient in terms of storage and the time needed to redraw the image. A *picture* is an exact copy of the screen image, and so its storage and redisplay time are independent of complexity. On the other hand, a printed picture object will never be of higher quality than the original screen image.
- **ZEBRA(RZ) Logical Directories.** In a single PAW session, the user may work simultaneously with many Ntuples, histograms, and hierarchies of Ntuple and histograms. However, this is not accomplished using the native operating system's file handler. Instead, the user works with a set of objects that are *similar* to a file system, but are instead managed by the ZEBRA RZ package. This can be somewhat confusing because a single operating system file created by RZ can contain an entire hierarchy of ZEBRA logical directories; furthermore, sections of internal memory can also be organized as ZEBRA logical directories to receive newly-created PAW objects that are not written to files. A set of commands CDIR, LDIR, and MDIR are the basic utilities for walking through a set of ZEBRA logical directories of PAW objects; Each set of directories contained in an actual file corresponds to a logical unit number, and the root of the tree is usually of the form //LUNx; the PAW objects and logical directories stored in internal memory have the root //PAWC.
- **Operating System File Directories.** Many different ZEBRA files, some with logically equivalent Ntuples and histograms, can be arranged in the user's operating system file directories. Thus one must also keep clearly in mind the operating system file directories and their correspondence to the ZEBRA logical directories containing data that one wishes to work with. In many ways, the operating system file system is also a type of "object" that forms an essential part of the user's mental picture of the system.

1.6 The Component Subsystems of PAW

The PAW system combines different tools and packages, which can also be used independently and some of which have already a long history behind them (e.g. HBOOK and HPLOT, SIGMA, Minuit). Figure 1.1 shows the various components of PAW.

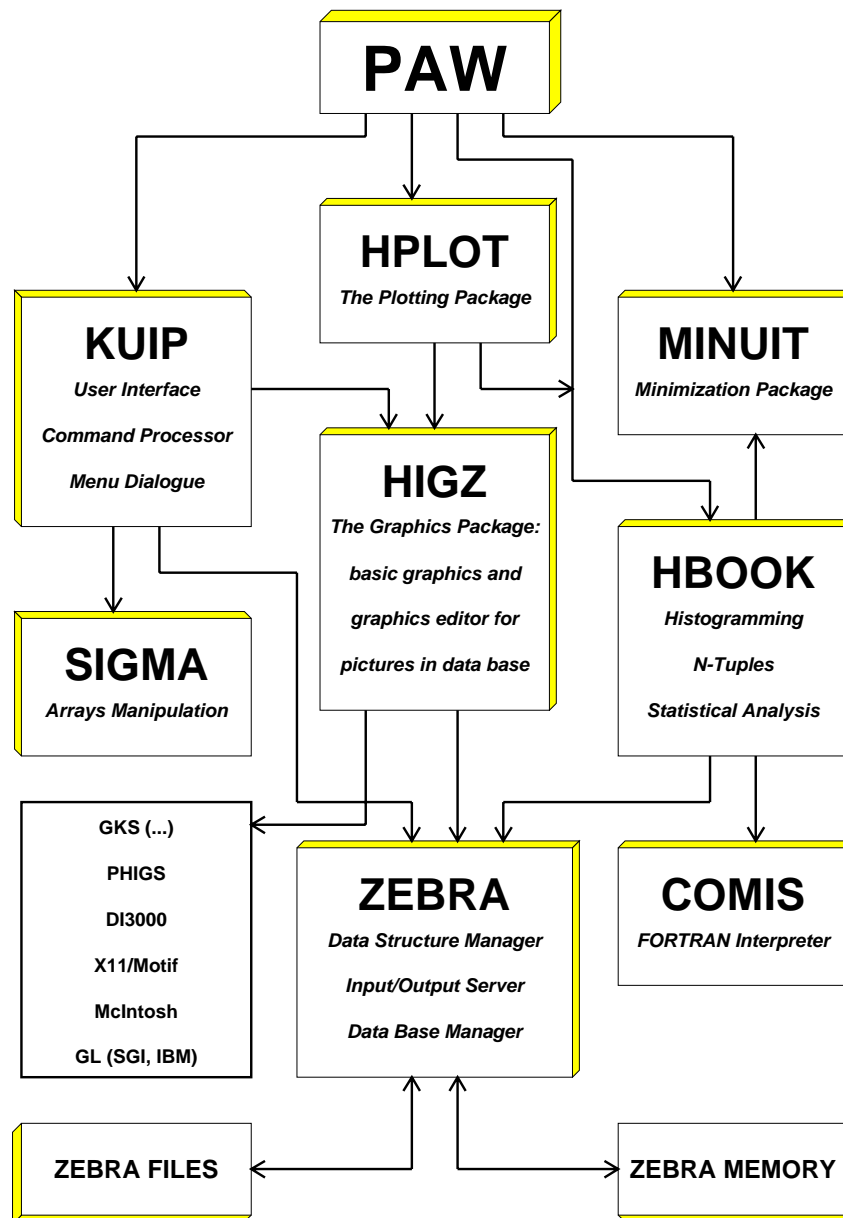


Figure 1.1: PAW and its components

1.6.1 KUIP - The user interface package

The purpose of KUIP (**K**it for a **U**ser **I**nterface **P**ackage) is to handle the dialogue between the user and the application program (PAW in our case). It parses the commands input into the system, verifies them for correctness and then hands over control to the relevant action routines.

The syntax for the commands accepted by KUIP is specified using a **Command Definition File** (CDF) and the information provided is stored in a ZEBRA data structure, which is accessed not only during the parsing stage of the command but also when the user invokes the **online help** command. Commands are grouped in a tree structure and they can be **abbreviated** to their shortest unambiguous form. If an ambiguous command is typed, then KUIP responds by showing all the possibilities. **Aliases** allow the user to abbreviate part or the whole of commonly used command and parameters. A sequence of PAW commands can be stored in a text file and, combined with flow control statements, form a powerful **macro** facility. With the help of **parameters**, whose values can be passed to the macros, general and adaptable task solving procedures can be developed.

Different **styles of dialogue** (command and various menu modes) are available and the user can switch between them at any time. In order to save typing, **default values**, providing reasonable settings, can be used for most parameters of a command. A **history file**, containing the n most recently entered commands, is automatically kept by KUIP and can be inspected, copied or re-entered at any time. The history file of the last PAW session is also kept on disk.

1.6.2 HBOOK and HPLOT - The histogramming and plotting packages

HBOOK and its graphics interface HPLOT are libraries of FORTRAN callable subroutines which have been in use for many years. They provide the following functionality:

- One- and two-dimensional histograms and Ntuples
- Projections and slices of two-dimensional histograms and Ntuples
- Complete control (input and output) of the histogram contents
- Operations and comparison of histograms
- Minimization and parameterization tools
- Random number generation
- Histograms and Ntuples structured in memory (directories)
- Histograms and Ntuples saved onto direct access ZEBRA files
- Wide range of graphics options:
 - Normal contour histograms, bar chart, shaded histograms, error bars, colour
 - Smoothed curves and surfaces
 - Scatter, lego, contour and surface plots
 - Automatic windowing
 - Graphics input

1.6.3 HIGZ - The graphics interface package

A **H**igh level **I**nterface to **G**raphics and **Z**EBRA (HIGZ) has been developed within the PAW project. This package is a layer between the application program (e.g. PAW) and the basic graphics package (e.g. GKS) on a given system. Its basic aims are:

- Full transportability of the picture data base.
- Easy manipulation of the picture elements.
- Compactness of the data to be transported and accessibility of the pictures in direct access mode.
- Independence of the underlying basic graphics package. Presently HIGZ is interfaced with several GKS packages, X windows, GL (Silicon Graphics), GDDM (IBM), GPR and GMR3D (Apollo) as well as with the DI3000 system.

These requirements have been incorporated into HIGZ by exploiting the data management system ZEBRA.

The implementation of HIGZ was deliberately chosen to be close to GKS. HIGZ does not introduce new basic graphics features, but introduces some macroprimitives for frequently used functions (e.g. arcs, axes, boxes, pie-charts, tables). The system provides the following features:

- Basic graphics functions, interfaced to the local graphics package, but with calling sequences nearly identical to those of GKS.
- Higher-level macroprimitives.
- Data structure management using an interface to the ZEBRA system.
- Interactive picture editing.

These features, which are available simultaneously, are particularly useful during an interactive session, as the user is able to “replay” and edit previously created pictures, without the need to re-run the application program. A direct interface to PostScript is also available.

1.6.4 ZEBRA - The data structure management system

The data structure management package ZEBRA was developed at CERN in order to overcome the lack of dynamic data structure facilities in FORTRAN, the favourite computer language in high energy physics. It implements the **dynamic creation and modification** of data structures at execution time and their transport to and from external media on the same or different computers, memory to memory, to disk or over the network, at an **insignificant cost** in terms of execution-time overheads.

ZEBRA manages any type of structure, but specifically supports linear structures (lists) and trees. ZEBRA input/output is either of a sequential or direct access type. Two data representations, **native** (no data conversion when transferred to/from the external medium) and **exchange** (a conversion to an interchange format is made), allow data to be transported between computers of the same and of different architectures. The direct access package **RZ** can be used to manage hierarchical data bases. In PAW this facility is exploited to store histograms and pictures in a hierarchical direct access directory structure.

1.6.5 MINUIT - Function minimization and error analysis

MINUIT is a tool to find the **minima of a multi-parameter function** and analyse the **shape around the minimum**. It can be used for **statistical analysis** of curve fitting, working on a χ^2 or log-likelihood function, to compute the **best fit** parameter values, their uncertainties and correlations. **Guidance** can be provided in order to find the correct solution, parameters can be kept fixed and data points can be easily added or removed from the fit.

1.6.6 COMIS - The FORTRAN interpreter

The COMIS interpreter allows the user to execute interactively a set of FORTRAN routines in interpretive mode. The interpreter implements a large subset of the complete FORTRAN language. It is an extremely important tool because it allows the user to specify his own complex data analysis procedures, for example selection criteria or a minimisation function.

1.6.7 SIGMA - The array manipulation language

A scientific computing programming language SIGMA (System for Interactive Graphical Mathematical Applications), which was designed essentially for mathematicians and theoretical physicists and has been in use at CERN for over 10 years, has been integrated into PAW. Its main characteristics are:

- The basic data units are scalars and one or more dimensional rectangular arrays, which are automatically handled.
- The computational operators resemble those of FORTRAN.

1.7 A PAW Glossary

Data Analysis Terminology

DST	A “Data Summary Tape” is one basic form of output from a typical physics experiment. A DST is generally not used directly by PAW, but is analyzed by customized user programs to produce Ntuple files, which PAW can read directly.
Ntuple	A list of identical data structures, each typically corresponding to a single experimental event. The data structures themselves frequently consist of a row of numbers, so that many Ntuples may be viewed as two-dimensional arrays of data variables, with one index of the array describing the position of the data structure in the list (i.e., the row or event number), and the other index referring to the position of the data variable in the row (i.e., the column or variable number). A meaningful name is customarily assigned to each column that describes the variable contained in that column for each event. However, the underlying utilities dealing with Ntuples are currently being generalized to allow the name of an element of the data structure to refer not only to a single number, but also to more general data types such as arrays, strings, and so on. Thus it is more general to view an Ntuple as a sequence of tree-structured data, with names assigned to the top-level roots of the tree for each event.
Event	A single instance of a set of data or experimental measurements, usually consisting of a sequence of variables or structures of variables resulting from a partial analysis of the raw data. In PAW applications, one typically examines the statistical characteristics of large sequences of similar events.
Variable	One of a user-defined set of named values associated with a single event in an Ntuple. For example, the (x, y, z) values of a momentum vector could each be variables for a given event. Variables are typically useful experimental quantities that are stored in an Ntuple; they are used in algebraic formulas to define boolean cut criteria or other dependent variables that are relevant to the analysis.
Cut	A boolean-valued function of the variables of a given event. Such functions allow the user to specify that only events meeting certain criteria are to be included in a given distribution.

Mask	A set of columns of zeros and ones that is identical in form to a new set of Ntuple variables. A mask is typically used to save the results of applying a set of cuts to a large set of events so that time-consuming selection computations are not repeated needlessly.
Function	Sequence of one or more statements with a FORTRAN-like syntax entered on the command line or via an external file.

Statistical Analysis Terminology

Histogram	A one- or two-dimensional array of data, generated by HBOOK in batch or in a PAW session. Histograms are (implicitly or explicitly) declared (booked); they can be filled by explicit entry of data or can be derived from other histograms. The information stored with a histogram includes a title, binning and packing definitions, bin contents and errors, statistic values, possibly an associated function vector, and output attributes. Some of these items are optional. The ensemble of this information constitutes an histogram .
Booking	The operation of declaring (creating) an histogram.
Filling	The operation of entering data values into a given histogram.
Fitting	Least squares and maximum likelihood fits of parametric functions to histograms and vectors.
Projection	The operation of projecting two-dimensional distributions onto either or both axes.
Band	A band is a projection onto the X (or Y) axis restricted to an interval along the other Y (or X) axis.
Slice	A slice is a projection onto the X (or Y) axis restricted to one bin along the other Y (or X) axis. Hence a slice is a special case of a band, with the interval limited to one bin.
Weight	PAW allows the user to include a multiplicative statistical bias for each event which is a scalar function of the available variables. This permits the user to correct for known statistical biases in the data when making histograms of event distributions.

KUIP/ZEBRA User Environment Terminology

Macro	A text file containing PAW commands and logical constructs to control the flow of execution. Parameters can be supplied when calling a macro.
Vector	The equivalent of a FORTRAN array supporting up to three dimensions. The elements of a vector can be stored using a real or an integer representation; they can be entered interactively on a terminal or read from an external file.
Logical Directory	The ZEBRA data storage system resembles a file system organized as logical directories. PAW maintains a global variable corresponding to the “current directory” where PAW applications will look for PAW objects such as histograms. The ZEBRA directory structure is a tree, and user functions permit the “current directory” to be set anywhere in the current tree, as well as creating new “directories” where the results of PAW actions can be stored. A special directory called //PAWC corresponds to a memory-resident branch of this virtual file system. ZEBRA files may be written to the operating system file system, but entire hierarchies of ZEBRA directories typically are contained in a single binary operating system file.

Graphics Production Terminology

- GKS** The Graphical **K**ernel **S**ystem is ISO standard document ISO 8805. It defines a common interface to interactive computer graphics for application programs.
- Metafile** A file containing graphical information stored in a device independent format, which can be replayed on various types of output devices. (e.g. the GKS Appendix E metafile and PostScript, both used at CERN).
- Picture** A graphics object composed of graphics primitives and attributes. Pictures are generated by the HIGZ graphics interface and they can be stored in a picture direct-access database, built with the RZ-package of the data structure manager ZEBRA.
- PostScript** A high level page description language permitting the description of complex text and graphics using only text commands. Using PostScript representations of graphics makes it possible to create graphics files that can be exchanged with other users and printed on a wide variety of printers without regard to the computer system upon which the graphics were produced. Any graphics display produced by PAW can be expressed in terms of PostScript, written to a file, and printed.

Chapter 2: General principles

2.1 Access to PAW

At CERN the PAW program is interfaced on all systems via a command procedure which gives access to the three release levels of the CERN Program Library (PR0duction, 0LD and the NEW areas) and sets the proper environment if necessary. Users who are not at CERN or who are using non-central computer systems should contact their system administrator for help on PAW.

2.1.1 IBM/VM-CMS

There are three versions available:

- GKS** For any ASCII graphic terminal capable of emulating Tektronix or PG.
- GDDM** For IBM 3192G graphic terminals or its emulators (e.g. tn3270 on a Mac-II)
- X11** For any X-window display connected to VM

You need a machine size of at least 7 Mb, that may be defined either temporarily for the current session (command `DEFINE STORAGE 7M` followed by an `IPL CMS`) or permanently for all subsequent sessions (command `DIRM STOR 7M`; you need to logoff once to make the definition effective).

An interface Rexx exec file `PAW EXEC` is located on the Q-disk and has the following interface:

```
PAW ( ver driver
```

The first parameter `ver` can have the values `PRO`, `NEW` and `OLD` and the second parameter `driver` the values `GKS`, `GDDM` or `X11`. The defaults are: `PRO GKS`. Help is available via `FIND CMS PAW`.

2.1.2 VAX/VMS

There are two versions available on VXCERN: `GKS` and `X11`. A command file `CERN_ROOT:[EXE]PAW.COM` is defined system-wide via the logical symbol `PAW`; its interface is:

```
PAW/ver/driver
```

(default is `PRO GKS`). You may set the initialization of `PAW` either as a `PAWLOGON.KUMAC` located in your home directory, or through the logical symbol `DEFINE PAW$LOGON disk:[user.subdir]file.kumac` to be defined usually in your `LOGIN.COM`. Help is available via `HELP @CERNLIB PAW`.

2.1.3 Unix systems

There are three versions available: `GKS`, `GPR` and `X11`. The driver shell script is located in the file `/cern/pro/bin/paw`. In order to access it automatically you could add the directory `/cern/pro/bin` to your command search path. The command syntax is:

```
paw -v ver -d driver
```

(default is `-v PRO -d GKS`). In the `GKS` case this shell script sets the proper `GKS` environment.

2.1.4 Note on the X11 version

The X11 version needs to know the X-host where graphics must be displayed; this can be specified on each system on the command line:

```
VM/CMS:   PAW ( X11 HOST yourhost
Vax/VMS:  PAW/X11/host=yourhost
Unix:     paw -d X11 -h yourhost
```

or at the “Workstation” prompt in PAW: Workstation type (?=HELP) [CR]=1 : 1.yourhost

On Vax/VMS the default X-window protocol is TCP/IP. If you want DECNET (e.g. when running from a Vaxstation) add the DECNET option to the command as follows:

```
PAW/X11/DECNET/host=yourhost
```

2.1.5 Important modes to run PAW

- A **batch** version of PAW is available (note that batch implies workstation type 0):

```
On Unix   do: PAW -b macroname
On VMS    do: PAW/BATCH=macroname
On VM     do: PAW (BATCH=macroname
```

- One can **disable** the automatic execution of the PAWLOGON macro:

```
On Apollo do: PAW -n
On VMS    do: PAW/NOLOG
On VM     do: PAW (NOLOG
```

2.2 Initialising PAW

When PAW is started, a **system** startup procedure is initiated, which indicates the current version of PAW and requests the **workstation type** of the terminal or workstation which you are using.

```
$ PAW
*****
*
*           W E L C O M E   to   P A W           *
*
*           Version 1.13/00  9 March 1992       *
*
*****
Workstation type (?=HELP) <CR>=10 : ?
```

List of valid workstation types:

```
0: Alphanumeric terminal
101: Tektronix 4010, 4014
102: Tektronix 4012
103: Tektronix 4014 with enhanced graphics option
121: Tektronix 4107, 4207, Pericom MX2000
122: Tektronix 4109
123: Tektronix 4111
125: Tektronix 4113
127: Tektronix 4115, Pericom MX8000
7800: MG600, MG200
```

```

7878: Falco, Pericom Graph Pac (old Pericom)
1020: VT240
1030: VT340
8601-6: Vaxstation GPX
10002: Apollo DNXXXX monochrome (GPR)
10003-4: Apollo DNXXXX colour (GPR)
9701-8: Apollo DNXXXX (GSR)
32120-9: X-Window

```

```

Metafile workstation types:
-111: HIGZ/PostScript (Portrait)
-112: HIGZ/PostScript (Landscape)
-113: HIGZ/Encapsulated PostScript
-777/8: HIGZ/LaTeX

```

Note that if you specify Q, PAW will not open a graphics workstation. This may be appropriate if one wants to use PAW on an alphanumeric terminal.

Before passing control to the user, the system looks for a user-supplied file `pawlogon.kumac` or `PAWLOGON KUMAC (VM/CMS)`. The latter can contain commands which the user wants to be executed at PAW startup, e.g. declaration of files, creation of aliases, definition of HPLLOT parameters. A simple version of this PAW initialisation file, displaying date and time, can be:

```

mess '*****'
mess '* *'
mess '* Starting PAW session on '//$date//' at '//$time//' *'
mess '* *'
mess '*****'

```

In order to only have one version of this file on VAX/VMS the user should define a **logical name** `PAW$LOGON` in his `LOGIN.COM`, as explained on the previous page. On a Unix workstation the file `pawlogon.kumac`, should be put into the directory. On IBM/VM-CMS the minidisk file search rule takes care of finding the file.

2.3 Command structure

PAW is based on the KUIP[5] User Interface package, which can provide different types of dialogue styles:

- Command mode, where the user enters a command line via the terminal keyboard.
- Alphanumeric menu mode, where the command is selected from a list.
- Graphics menu modes:
 - Pull-down menus, fixed layout reflecting the command structure;
 - Panels of function keys, interactive user definable multiple layouts.

It is possible to change interactively from one style to another.

The general format of a PAW command line is:

command parameters

The first part of the **command** has the format:

object/verb

where the **object** is the item on which the action is performed (e.g. HISTOGRAM, VECTOR, NTUPLE) and the **verb** is the action to be performed (e.g. CREATE, DELETE, PLOT). In some cases the object needs to be specified further (e.g. GRAPHICS/PRIMITIVE), while in other cases the verb's action needs to be clarified further (e.g. CREATE/1D). All components can be **abbreviated** to their shortest unambiguous form. For example the two following lines will have the same effect of creating a vector A with nine components:

```
VECTOR/CREATE A(9)
or
VE/CR A(9)
```

In the case that the form is ambiguous all possible interpretations for the given abbreviation are displayed. The second part of a command are its **parameters** and their meaning is determined by their **position**. Some of these can be **mandatory** with the remaining ones **optional**. If all mandatory parameters are not provided on the command line, PAW will prompt the user to specify them, indicating the default values if defined. If the user wants to assign the default value to a parameter from the command line he can use the **place-holder** character **exclamation mark (!)** to signify this to PAW. In the case of optional parameters, the user **must** provide them in the correct sequence if he wants to **change** their values, otherwise the corresponding defaults are taken. Parameters containing blanks must be enclosed within single quotes.

In the example below we create a one-dimensional histogram, providing the parameters one by one answering the PAW query:

```
PAW > histogram/create/1dhisto
Histogram Identifier (<CR>= ): 10
Histogram title (<CR>= ): title1
Number of channels (<CR>=100): <CR>
Low edge (<CR>=0): 10.
Upper edge (<CR>=100): 20.
```

On the command below we provide all parameters on the command line, including an optional one (1000.), which by default has the value 0. Note that this parameter **must** be specified explicitly, since PAW **does not** prompt for it, as seen in the previous example. Note also the use of the exclamation mark to take the default for the number of channels (100).

```
PAW > hi/cr/1d 20 title2 ! 10. 20. 1000.
```

2.4 Getting help

Once inside PAW, one can start entering commands. An interesting first try would be the HELP command, which displays a list of items, preceded by a number and followed by one line of explanation. In the next example we search for a command to create a one-dimensional histogram.

```
PAW > help
From /...
1:  KUIP           Command Processor commands.
2:  MACRO          Macro Processor commands.
3:  VECTOR         Vector Processor commands.
4:  HISTOGRAM      Manipulation of histograms, Ntuples.
```

```

5:  FUNCTION      Operations with Functions. Creation and plotting.
6:  NTUPLE       Ntuple creation and related operations.
7:  GRAPHICS     Interface to the graphics packages HPLOT and HIGZ.
8:  PICTURE      Creation and manipulation of HIGZ pictures.
9:  ZEBRA        Interfaces to the ZEBRA RZ, FZ and DZ packages.
10: FORTRAN      Interface to the COMIS FORTRAN interpreter.
11: NETWORK      To access files on remote computers.

```

Enter a number ('\'=one level back, 'Q'=command mode): 4

/HISTOGRAM

Manipulation of histograms, Ntuples.
Interface to the HBOOK package.

From /HISTOGRAM/...

```

1: * FILE        Open an HBOOK direct access file.
2: * LIST        List histograms and Ntuples in the current directory.
3: * DELETE      Delete histogram/Ntuple ID in Current Directory (memory).
4: * PLOT        Plot a single histogram or a 2-Dim projection.
5: * ZOOM        Plot a single histogram between channels ICMIN and ICMAX.
6: * MANY_PLOTS  Plot one or several histograms into the same plot.
7: * PROJECT     Fill all booked projections of a 2-Dim histogram.
8: * COPY        Copy a histogram (not Ntuple) onto another one.
9: * FIT         Fit a user defined (and parameter dependent) function
10: 2D_PLOT      Plotting of 2-Dim histograms in various formats.
11: CREATE       Creation ("booking") of HBOOK objects in memory.
12: HIO          Input/Output operations of histograms.
13: OPERATIONS  Histogram operations and comparisons.
14: GET_VECT     Fill a vector from values stored in HBOOK objects.
15: PUT_VECT     Replace histogram contents with values in a vector.
16: SET         Set histogram attributes.

```

Enter a number ('\'=one level back, 'Q'=command mode): 11

/HISTOGRAM/CREATE

Creation ("booking") of new HBOOK objects.

From /HISTOGRAM/CREATE/...

```

1: * 1DHISTO     Create a one dimensional histogram.
2: * PROFILE     Create a profile histogram.
3: * BINS        Create a histogram with variable size bins.
4: * 2DHISTO     Create a two dimensional histogram.
5: * PROX        Create the projection onto the x axis.
6: * PROY        Create the projection onto the y axis.
7: * SLIX        Create projections onto the x axis, in y-slices.
8: * SLIY        Create projections onto the y axis, in x-slices.
9: * BANX        Create a projection onto the x axis, in a band of y.
10: * BANY       Create a projection onto the y axis, in a band of x.
11: * TITLE_GLOBAL Set the global title.

```

Enter a number ('\'=one level back, 'Q'=command mode): 1

* /HISTOGRAM/CREATE/1DHISTO ID TITLE NCX XMIN XMAX [VALMAX]

```

ID          C 'Histogram Identifier'
TITLE       C 'Histogram title' D=' '
NCX         I 'Number of channels' D=100
XMIN        R 'Low edge' D=0
XMAX        R 'Upper edge' D=100
VALMAX      R 'Valmax' D=0

```

Creates a one dimensional histogram. The contents are set to zero.

If VALMAX=0, a full word is allocated per channel, else VALMAX is used as the maximum bin content allowing several channels to be stored into the same machine word.

The meaning of the notation used in the text displayed by the HELP command is explained on page III. Moreover an item preceded by a **star** indicates a **terminal leaf** in the command tree, i.e. an **executable** command (see on Page 91 for more details).

One can also inquire about **creating a one-dimensional histogram** by typing simply:

```

HELP histogram/create/1dhisto
or
HELP his/cre/1d
or even
HELP 1

```

The system will then display the following information:

```

* /HISTOGRAM/CREATE/1DHISTO  ID TITLE NCX XMIN XMAX [ VALMAX ]

ID          C 'Histogram Identifier'
TITLE       C 'Histogram title' D=' '
NCX         I 'Number of channels' D=100
XMIN        R 'Low edge' D=0
XMAX        R 'Upper edge' D=100
VALMAX      R 'Valmax' D=0

```

Creates a one dimensional histogram. The contents are set to zero.
 If VALMAX=0, a full word is allocated per channel, else VALMAX is used as the maximum bin content allowing several channels to be stored into the same machine word.

2.4.1 Usage

Very often a single line description of the usage of a command is sufficient as a reminder. This can be obtained by the USAGE command, e.g.:

```

PAW > USAGE 1d

* /HISTOGRAM/CREATE/1DHISTO  ID TITLE NCX XMIN XMAX [ VALMAX ]

```

2.5 Special symbols for PAW

One should pay attention to the fact that, in addition to their common arithmetic meaning, the symbols in table 2.1 have a special connotation when working with PAW .

2.6 PAW entities and their related commands

Relations which exist between various PAW entities as described in section 1.6 on page 9 and the operations which can be performed upon them have been schematically represented in figure 2.1. All commands shown in the picture next to the lines connecting the objects have been abbreviated in a way that they are unambiguous and can be typed to PAW, which will then detail the various parameters to be supplied.

There are three main input/output formats, namely a simple text file (e.g. with data points or commands), a direct access ZEBRA RZ file (used by HBOOK and HIGZ for storing histograms and pictures on a

Symbol	Meaning
blank	Separator between command and parameter and between different parameters
/	Separator between command elements
#	Comment line (if first character of the command line)
|	Inline comments
'	String delimiter
-	Line continuation in KUIP commands
@	Escape character to be put in front of | and ' to interpret them as literal
!	Place-holder for command parameter (i.e. default value is taken)
	At beginning of command line: Unix C shell-like history (e.g. !!, !number, !-number, !string)
[]	Macro argument delimiters
#	Separator between macro file and macro member
()	Vector subscript delimiters
:	Vector subscript range
,	Multi-dimensional vector subscript dimensions delimiter
Note: These special characters lose their effect when imbedded in single quotes.	

Table 2.1: Special symbols

given machine) and a ZEBRA FZ sequential file, which can be used to transfer structured ZEBRA data between various computers. The RZ and FZ representations can be transformed into each other using the TOALFA and FRALFA commands.

The three main PAW objects, Ntuples, histograms and vectors, can be **printed** on an alphanumeric screen (PRINT commands) or they can be plotted on a graphics screen (PLOT commands). The picture can be transformed into a ZEBRA data structure and stored in a HIGZ database for later reference (e.g. editing by the HIGZ editor), or an external presentation can be obtained via the creation of a **metafile**. This “metafile” can for instance consist of GKS or PostScript commands, which can then be interpreted by the relative drivers and printed on an output device, if so desired.

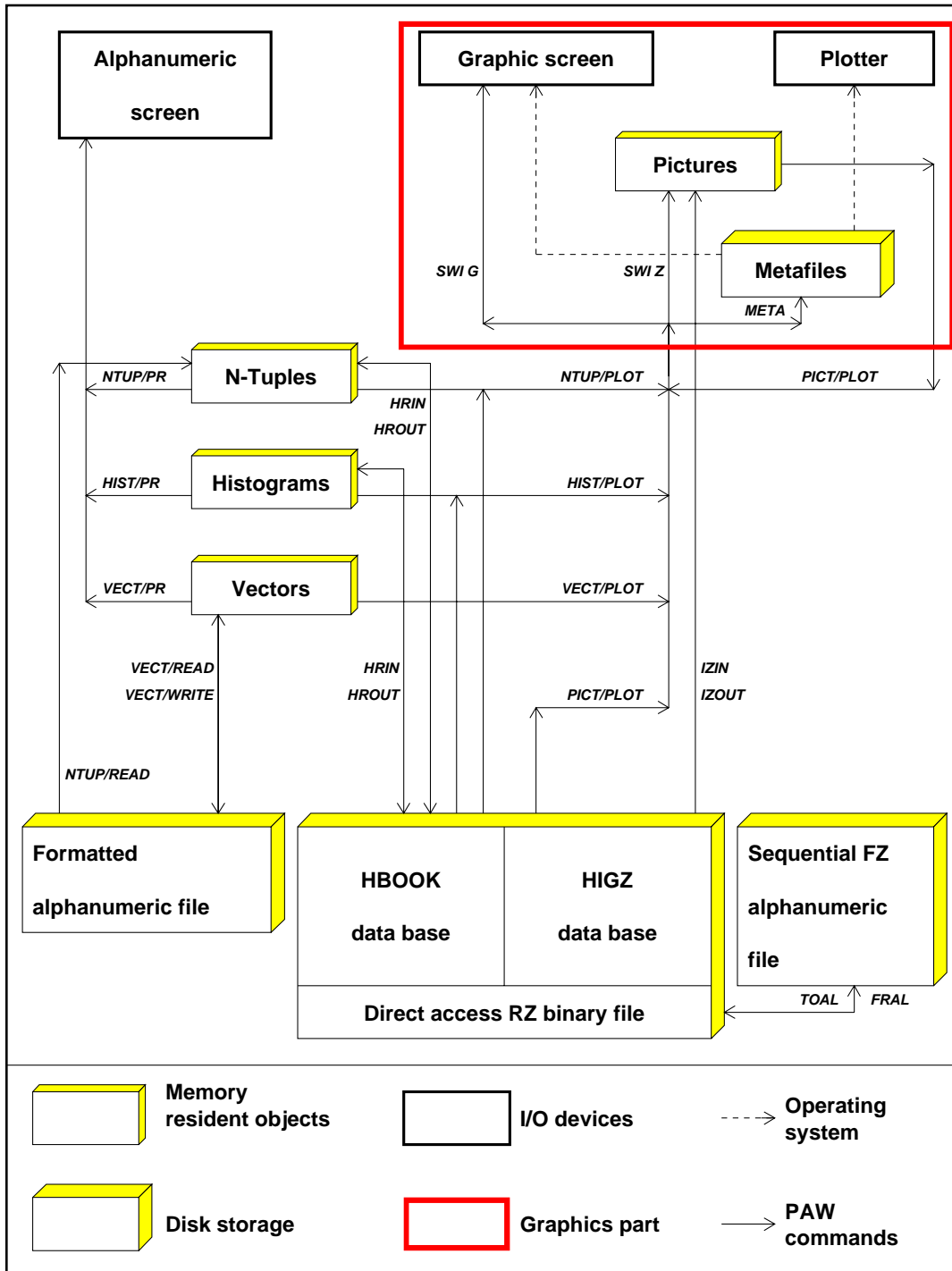


Figure 2.1: PAW entities and their related commands

Chapter 3: PAW by examples

This chapter shows how to use the basic functionality of the PAW system with the help of a series of simple examples. It is advisable to step through the complete series since most entries use information from examples upstream.

The so called **command mode**, available on all systems, is used throughout this chapter. For more details on other possible dialog modes, see Part 2.

List of examples in this chapter

- 1 Simple vector commands
- 2 Further vector commands and writing vectors to disk
- 3 Various data representations
- 4 Difference between VECTOR/DRAW and VECTOR/PLOT
- 5 Vector operations
- 6 Simple macro with loop and vector fit
- 7 Plotting one-dimensional functions
- 8 One-dimensional functions and loops
- 9 Plotting two-dimensional functions
- 10 Plotting a two-dimensional function specified in an external file
- 11 Creation of one- and two-dimensional histograms
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- 13 One-dimensional plotting and histogram operations
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- 15 The use of sub-ranges in histogram specifiers
- 16 Ntuples - Creation and output to a file
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- 18 Ntuples - A first look at selection criteria
- 19 Ntuples - Masks and loop
- 20 Ntuples - Using cuts
- 21 Ntuples - Two dimensional data representation
- 22 Using the SIGMA processor - Trigonometric functions
- 23 Using the SIGMA processor - More complex examples
- 24 Histogram operations (Keep and Update)
- 25 Merging several pictures into one plot
- 26 Pie charts with hatch styles and PostScript colour simulation
- 27 A complex graph with PAW
- 28 Making slides with PAW using PostScript

Notes

1. The files needed for these examples are available in the PAW account on the various machines (see also section 2.1).

```
VM/CMS    PAWEX* KUMAC on the PAW 201 minidisk.  
           All text files must be created with RECFM=F, LRECL=80.  
VAX/VMS   DISK$DL: [PAW.PAWMANUAL]PAWEX*.KUMAC  
Apollo    /user/paw/pawmanual/pawex*.kumac
```

2. The pictures shown in the present chapter have been produced using the HIGZ/PostScript metafile -113. What is actually displayed on the screen when running a given example, might be slightly different, depending on the workstation type specified at PAW initialisation. For example the fill area style index -3 is frequently used (SET HTYP -3). It displays a grey shadowing on the pictures, but will look different on the screen. The same remark applies to line-widths and -styles.

3.1 Vectors and elementary operations

The aim of the present section is to introduce the basic syntax of PAW. It assumes that the user has already succeeded to login to the PAW system and that PAW is waiting for input.

Simple vector commands

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX1                *
PAW > * Some simple vector commands                            *
PAW > * Lines starting with a * are comments and are ignored by PAW *
PAW > *****
PAW > *
PAW > | similarly everything following a VERTICAL BAR is ignored
PAW > | so this character can be used to provide INLINE COMMENTS
PAW > *
PAW > vector/create VECT1(10) | Create vector VECT1 with 10 elements
PAW > vector/input VECT1 10 8 6 4 2 3 5 7 9 11 | Input values of the 10 elements
PAW > | **** PAW commands are NOT CASE SENSITIVE
PAW > * The underscore _ is the continuation character
PAW > VECTOR/CREATE VX(20) R 1. 2. 3. 4. 5. 6. _
PAW > 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20.
PAW > VECTOR/create VY(20) R 1.1 3.2 5.3 7.4 7.5 _
PAW > 6.6 4.3 2.1 6.6 11.1 16.2 18.3 19.0 17.8 16.0 12.1 9.1 6.1 3.1 6.6
PAW > zone 1 2 | 2 pictures on the same page
PAW > set HTYP -3 | set hatch style for histogram
PAW > vector/draw VECT1 | Draw contents of vector VECT1
PAW > GRAPH 20 VX VY | Graph VX and VY (defaults)
PAW > igset mtyp 21 | Set HIGZ polymarker
PAW > GRAPH 20 VX VY P | Graph VX and VY with polymarker
PAW > set DMOD 2 | Change line style
PAW > GRAPH 20 VX VY C | Graph VX and VY (using splines)
PAW > set DMOD 0 | Reset line style
PAW > vector/delete * | Delete vectors
PAW > zone | Reset picture layout

```

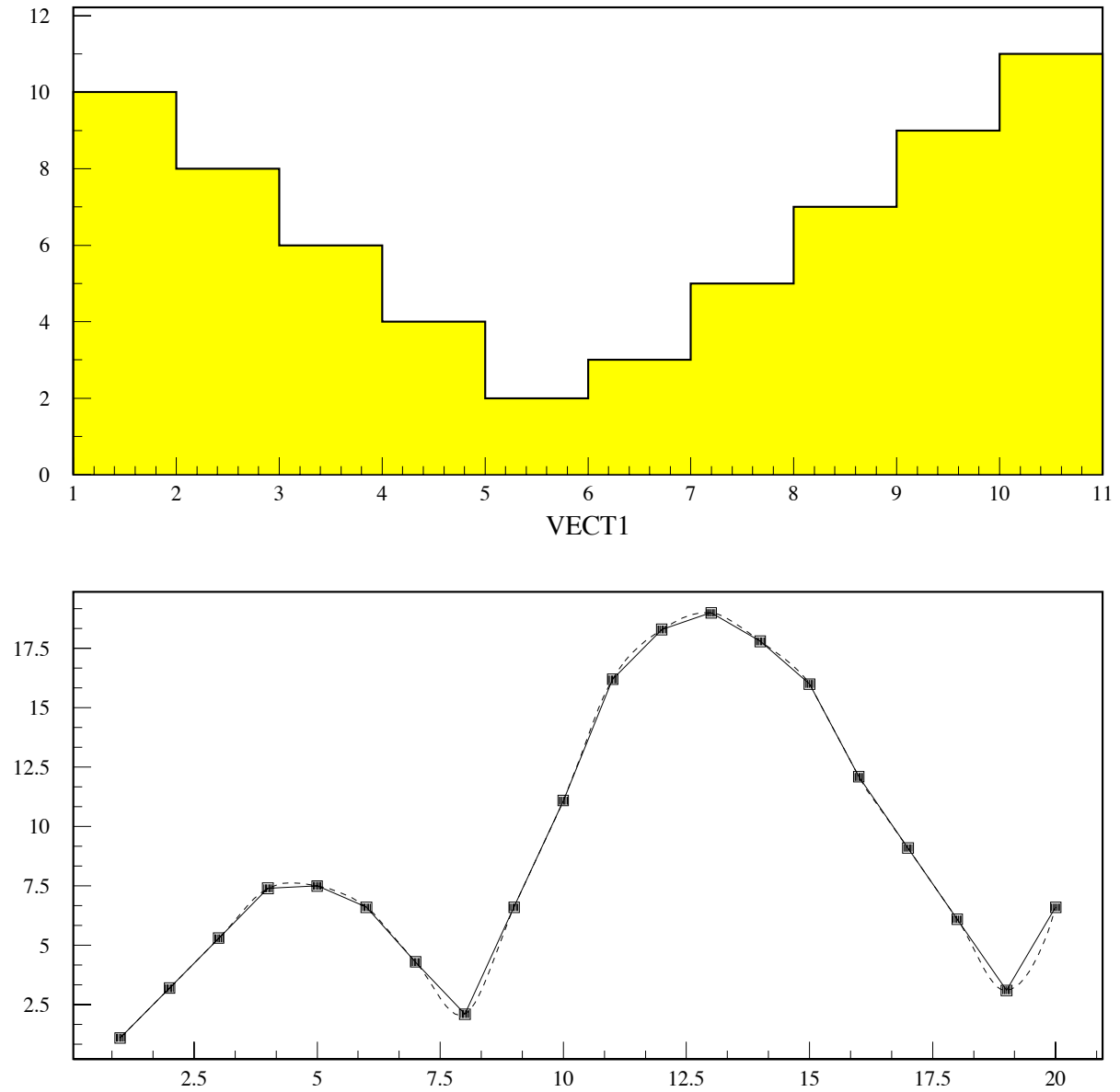


Figure 3.1: Simple vector commands

Further vector commands

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX2                *
PAW > * Example showing further vector commands                *
PAW > *****
PAW > size 20 18 _ | Set picture size
PAW > vector/create VECT(10,3) R _ | Create a 2 dimensional vector VECT
PAW > 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. _
PAW > 9.1 8.1 7.1 6.1 5.1 4.1 3.1 2.1 1.1 0.1 _
PAW > 6.2 4.2 3.2 2.2 1.2 1.2 2.2 3.2 4.2 5.2
PAW > VECTOR/CREATE VECT1(10) R _ | Create a one-dimensional vector VECT1
PAW > 1.1 2.2 3.3 4.4 5.5 6.6 5.5 4.4 3.3 2.2 | Input the values of the 10 elements
PAW > *
PAW > * PAW commands can be ABBREVIATED to their shortest non-ambiguous form
PAW > *
PAW > set htyp -3 | Define hatch style
PAW > ve/dr VECT(1:10,3) | Draw contents of third row on VECT
PAW > set htyp 0 | Reset hatch style
PAW > set hwid 12 | Define histogram line width
PAW > *
PAW > * Draw third row of VECT once more, now as a continuous curve
PAW > *
PAW > ve/dr VECT(1:10,3) ! SC
PAW > set dmod 13 | Set line style
PAW > igset MTYP 29 | Define marker type
PAW > igset MSCF 3. | Marker scale factor
PAW > set HWID 6 | Redefine histogram line width
PAW > *
PAW > * Draw contents of VECT1 as line with marker
PAW > *
PAW > vector/draw VECT1 ! LPS
PAW > *
PAW > * Notice the use of the EXCLAMATION MARK ! as a placeholder.
PAW > * It indicates that the default should be taken for the omitted parameter.
PAW > *
PAW > ve/list | List vectors in order of creation

```

Vector Name	Type	Length	Dim-1	Dim-2	Dim-3
VECT	R	30	10	3	
VECT1	R	10	10		

Total of 2 Vector(s)

```

PAW > ve/write VECT 'vector.data' '(3(10f5.0,/))' | Write VECT to text output file
PAW > ve/delete * | Delete all vectors in memory

```

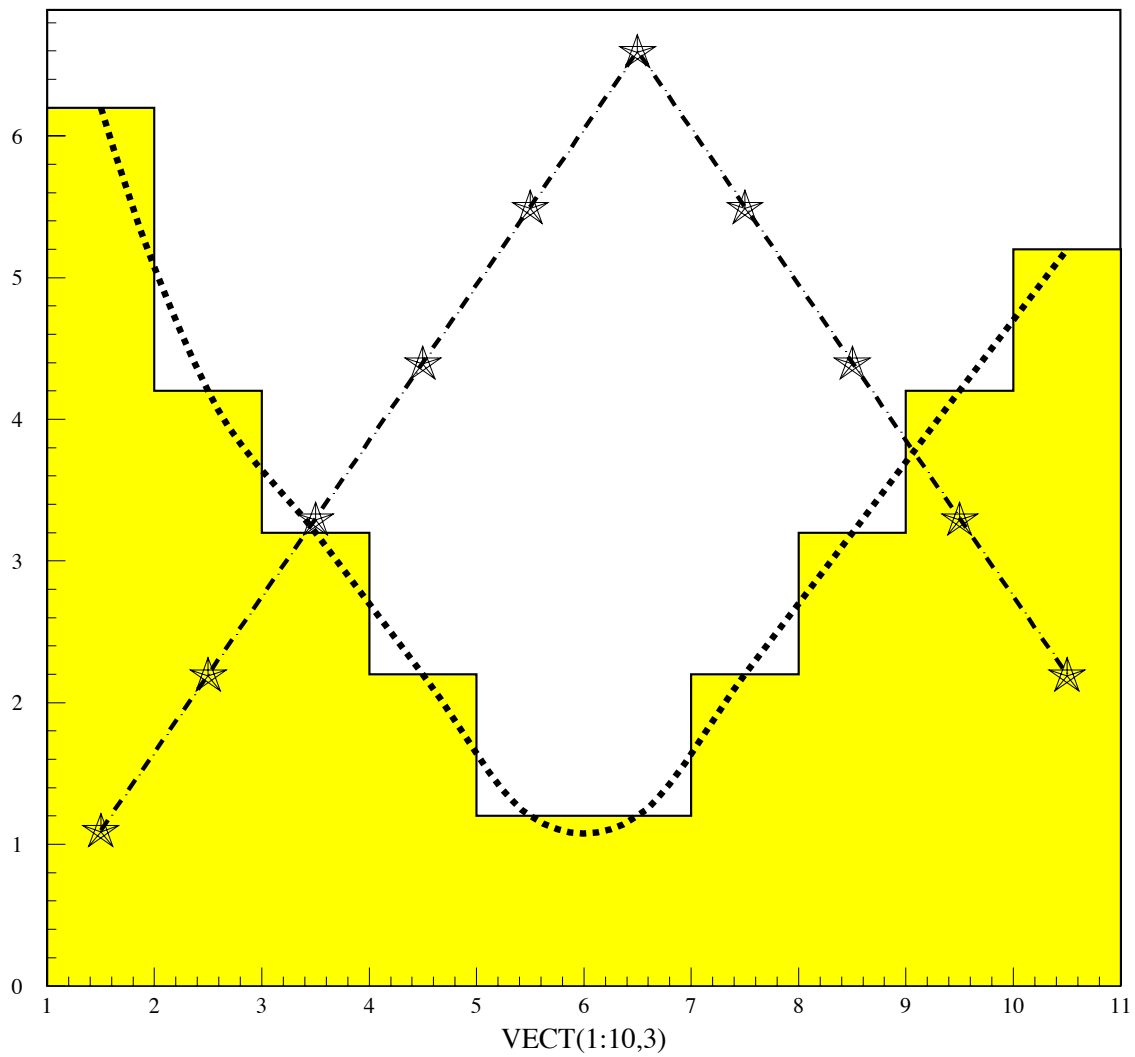


Figure 3.2: Further vector commands and writing vectors to disk

Vector draw data presentations

PAW > *****	
PAW > *	TUTORIAL EXAMPLE PAWEX3
PAW > * Example showing various possible data representation with VECTOR/DRAW *	
PAW > *****	
PAW > *	
PAW > * Divide picture page in 2 by 3 images	
PAW > *	
PAW > <u>zone 2 3</u>	
PAW > <u>ve/create v(10) R 5 1 3 2 4 1 3 1 8 6</u>	| Create vector V
PAW > <u>set htyp -3</u>	| Define hatch style
PAW > <u>ve/draw v</u>	| Default plot
PAW > <u>ve/draw v ! b</u>	| Plot as bar chart
PAW > <u>ve/draw v ! l</u>	| Plot as lines
PAW > <u>ve/draw v ! l*</u>	| Lines and a star
PAW > <u>ve/draw v ! bl*</u>	| and bar option
PAW > <u>igset mtyp 21</u>	| Choose HIGZ marker
PAW > <u>ve/draw v ! e</u>	| Plot error bars
PAW > <u>ve/de V</u>	| Delete vector V
PAW > <u>zone</u>	| Reset zone to default

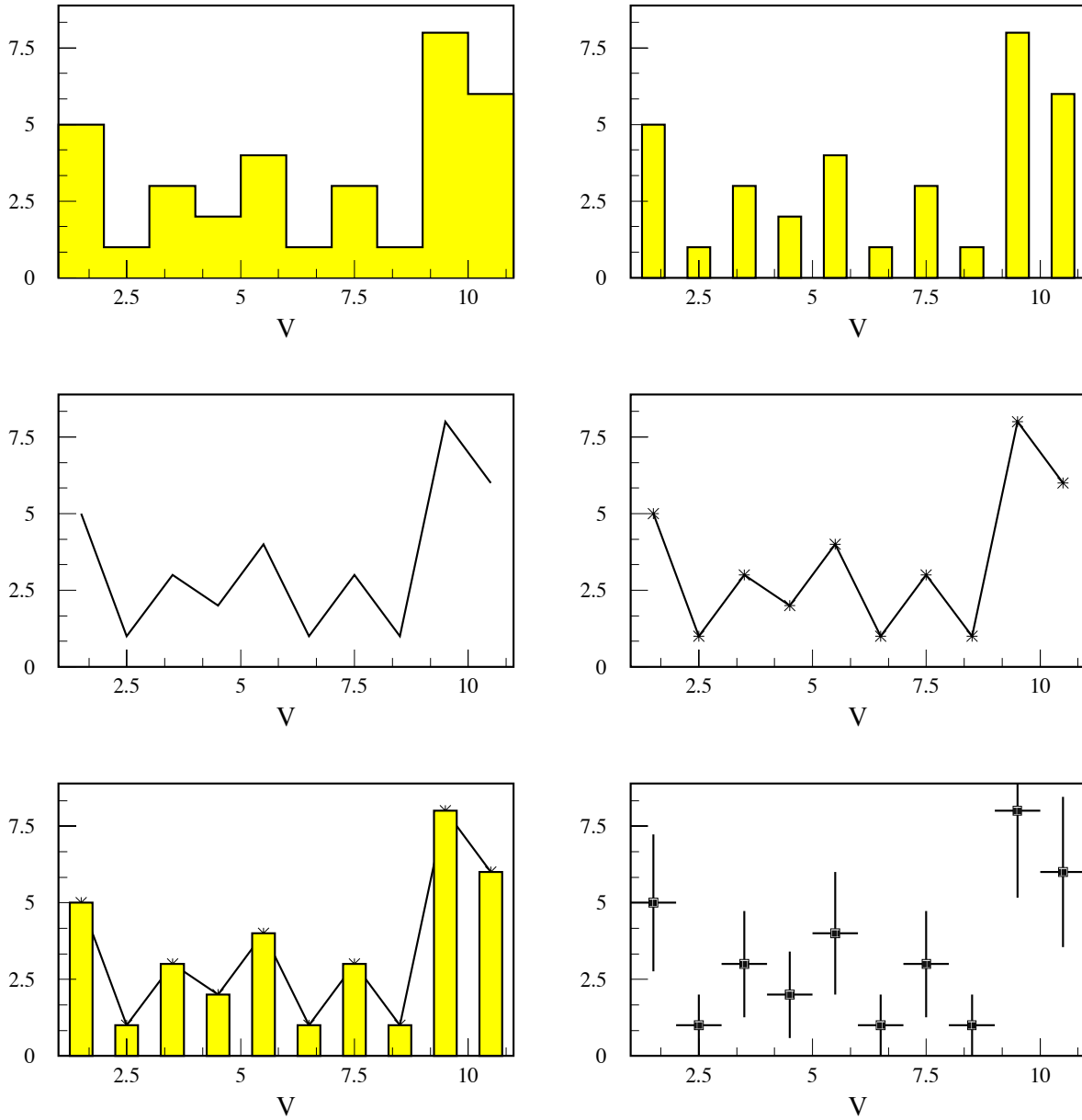
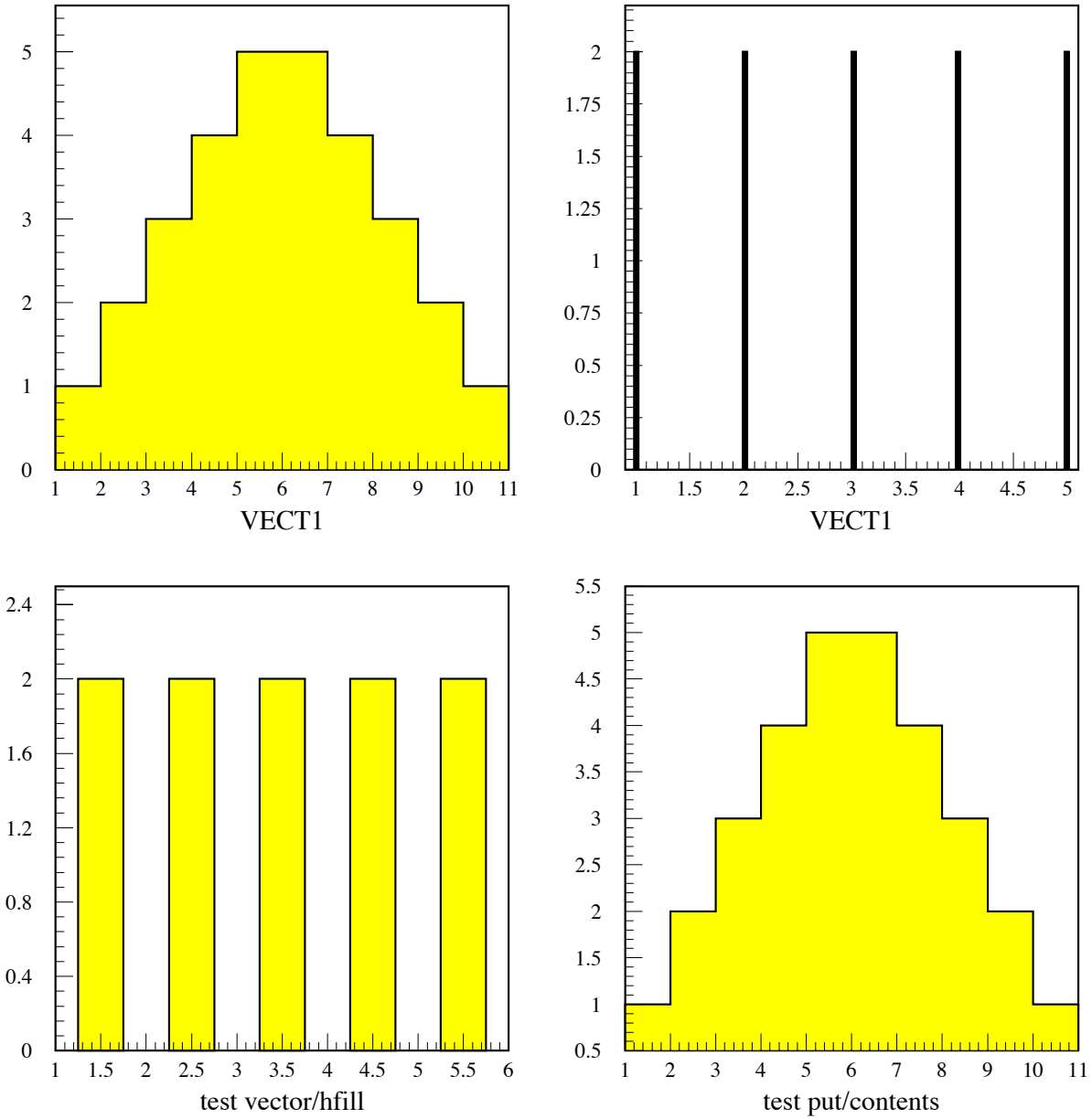


Figure 3.3: Various data representations

Figure 3.4: Difference between `VECTOR/DRAW` and `VECTOR/PLOT`

Operations on vectors

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX5                *
PAW > * Example showing vector operations. The resulting vectors are created *
PAW > * automatically.                                          *
PAW > *****
PAW > zone 1 2
PAW > ve/create V1(10) R 1 2 3 4 5 5 4 3 2 1 | Define vector V1 of 10 elements
PAW > vector/operations/vscale V1 0.5 V12 | Divide V1 by 2 into V12
PAW > ve/op/vscale V1 0.25 V14 | Divide V1 by 4 into V14
PAW > set htyp 0 | No hatch
PAW > *
PAW > * Differences between various plots are shown using different line styles
PAW > *
PAW > ve/dr V1 | Draw V1
PAW > ve/dr V12 ! S | Draw V12 onto same graph
PAW > ve/dr V14 ! S | ditto for V14
PAW > vsub V1 V14 V14M | Subtract V14 from V1 into V14M
PAW > *
PAW > * Differences between various plots are shown using different hatch styles
PAW > *
PAW > ve/dr V1 | Draw V1
PAW > set htyp 344 | Change hatch style
PAW > ve/dr V14M ! S | Draw V14M on same graph
PAW > set htyp 144 | Change hatch style once more
PAW > ve/dr V12 ! S | Draw V12 on same graph
PAW > ve/de * | Delete all vectors in memory
PAW > zone | Reset zone

```

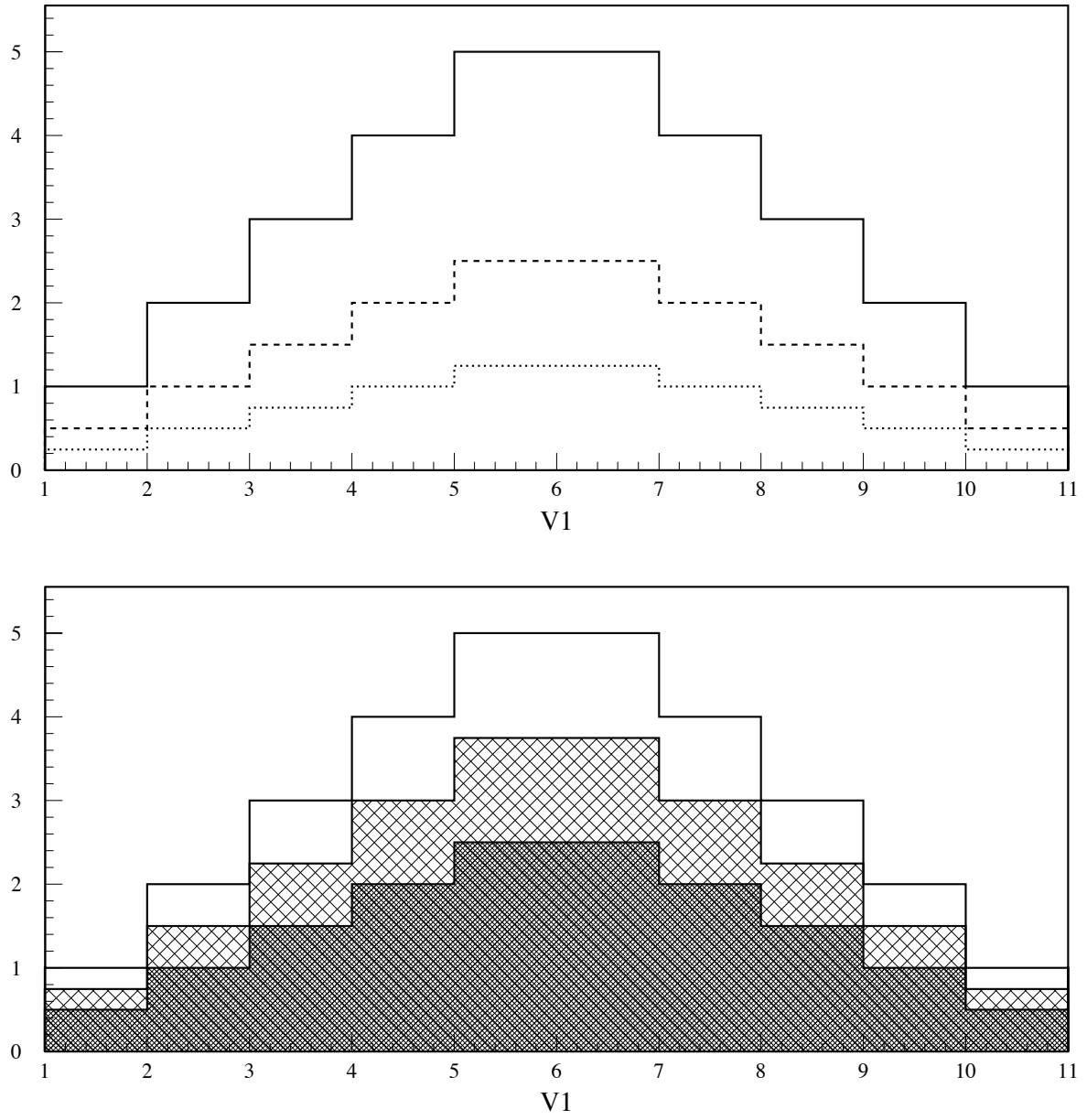


Figure 3.5: Vector operations

Using loops and fitting

```

PAW > EDIT PAWEX6          | Edit MACRO PAWEX6.KUMAC
MACRO PAWEX6
*****
*              TUTORIAL EXAMPLE PAWEX6              *
* Example showing a simple macro, with a loop and a VECTOR fit.          *
*****
ve/create VECT(10,3)       | Create a 2 dimensional vector
ve/read VECT 'vector.data' | Read vector values from external file
                           | created in example PAWEX2
ve/print VECT(1:10,3)     | Print last row of VECT (see Example 2)
vbias vect(1:10,1) 0.5 vect(1:10,1)
zone 1 2
ip = 2                    | Loop counter
set htyp -3
* Start of a loop over the three rows of vector VECT
LOOP:                    | <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<
  ve/draw VECT(1:10,[ip]) | draw next row |
  order = ip - 1         | Define order for fit |
  ve/fit VECT(1:10,1) VECT(1:10,[IP]) ! P[order] WS | Fit polynomial to given row |
  ip = ip + 1           | Increment counter |
  if ip < 4             | loop test >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
    GOTO LOOP
ve/delete VECT           | Delete VECT
RETURN

```

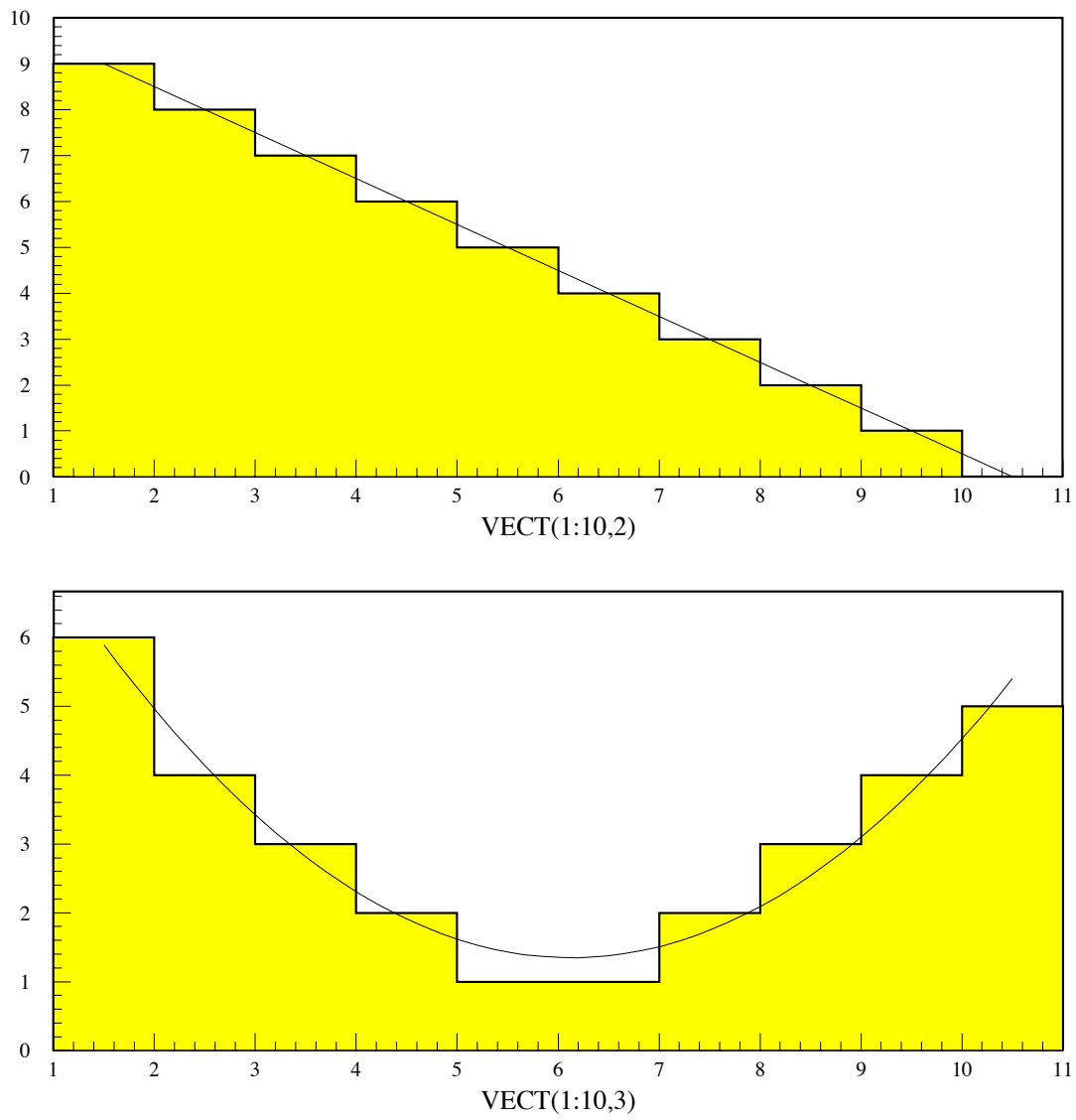


Figure 3.6: Simple macro with loop and vector fit

 Output generated by previous macro

```

PAW > TRACE | Trace the macro execution
PAW > EXEC PAWEX6 | Execute Macro PAWEX6.KUMAC
>>>> ve/create VECT(10,3)
>>>> ve/read VECT 'vector.data'
>>>> ve/print VECT(1:10,3)
VECT ( 1 ) = 6.000000
VECT ( 2 ) = 4.000000
VECT ( 3 ) = 3.000000
VECT ( 4 ) = 2.000000
VECT ( 5 ) = 1.000000
VECT ( 6 ) = 1.000000
VECT ( 7 ) = 2.000000
VECT ( 8 ) = 3.000000
VECT ( 9 ) = 4.000000
VECT ( 10 ) = 5.000000
>>>> vbias vect(1:10,1) 0.5 vect(1:10,1)
>>>> zone 1 2
>>>> IP=2
>>>> set htyp -3
>>>> ve/draw VECT(1:10,2)
>>>> ORDER=1
>>>> ve/fit VECT(1:10,1) VECT(1:10,2) ! P1 WS
MINUIT RELEASE 89.05b INITIALIZED. DIMENSIONS 100/ 35 EPSMAC= 0.11E-18
*****
*** 1 ***SET EPS 0.10000E-05
*****
FLOATING-POINT NUMBERS ASSUMED ACCURATE TO 0.100E-05
*****
* *
* Function minimization by SUBROUTINE HFITV *
* Variable-metric method *
* ID = 0 CHOPT = WWS *
* *
*****
Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

FCN= 0.0000000 FROM MIGRAD STATUS=CONVERGED CALLS= 18 EDM= 0.88E-11
STRATEGY= 1 ERROR DEF= 1.0000

INT EXT PARAMETER STEP FIRST
NO. NO. NAME VALUE ERROR SIZE DERIVATIVE
1 1 P1 10.500 0.73236 0.10000 0.00000
2 2 P2 -1.0000 0.11010 0.15033E-01 -0.38147E-04

CHISQUARE = 0.0000E+00 NPFIT = 10

>>>> IP=3
>>>> ve/draw VECT(1:10,3)
>>>> ORDER=2
>>>> ve/fit VECT(1:10,1) VECT(1:10,3) ! P2 WS
*****
* *
* Function minimization by SUBROUTINE HFITV *
* Variable-metric method *
* ID = 0 CHOPT = WWS *
* *

```

```
*****
Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

FCN= 0.8969682    FROM MIGRAD    STATUS=CONVERGED  CALLS= 47 EDM= 0.36E-09
                STRATEGY= 1    ERROR DEF= 1.0000

INT EXT PARAMETER
NO. NO.  NAME      VALUE      ERROR      STEP      FIRST
                DERIVATIVE
  1  1  P1         9.3136     1.4106     0.10000    0.95368E-05
  2  2  P2        -2.6000     0.53292    0.15033E-01 0.19392E-03
  3  3  P3         0.21212    0.43457E-01 0.17681E-02 0.15594E-02

CHISQUARE = 0.1281E+00  NPFIT = 10

>>>> IP=4
>>>> ve/delete VECT
```

3.2 One and two-dimensional functions

PAW allows the plotting of **functions**. A function can be specified on the command line, or in an external file, which is read by the FORTRAN interpreter **COMIS**.

One-dimensional trigonometric function	
PAW > *****	
PAW > *	TUTORIAL EXAMPLE PAWEX7
PAW > *	*
PAW > * Plot a few one-dimensional trigonometric functions	*
PAW > *****	
PAW > <u>opt utit</u>	| No title on histogram
PAW > <u>opt grid</u>	| Put a grid on the plot
PAW > <u>func/plot</u> x*sin(x)*exp(-0.1*x) -10. 10.	| Plot first function
PAW > <u>set dmod 2</u>	| Set new line style
PAW > <u>func/plot</u> (sin(x)+cos(x))**5 -10. 10. s	| Plot second function on same plot
PAW > <u>set dmod 3</u>	| Set new line style
PAW > <u>func/plot</u> (sin(x)/(x)-x*cos(x)) -10. 10. s	| Plot third function on same plot
PAW > <u>set dmod 1</u>	| Reset line style
PAW > <u>opt htit</u>	| Reset to histogram title
PAW > <u>opt ngri</u>	| No grid

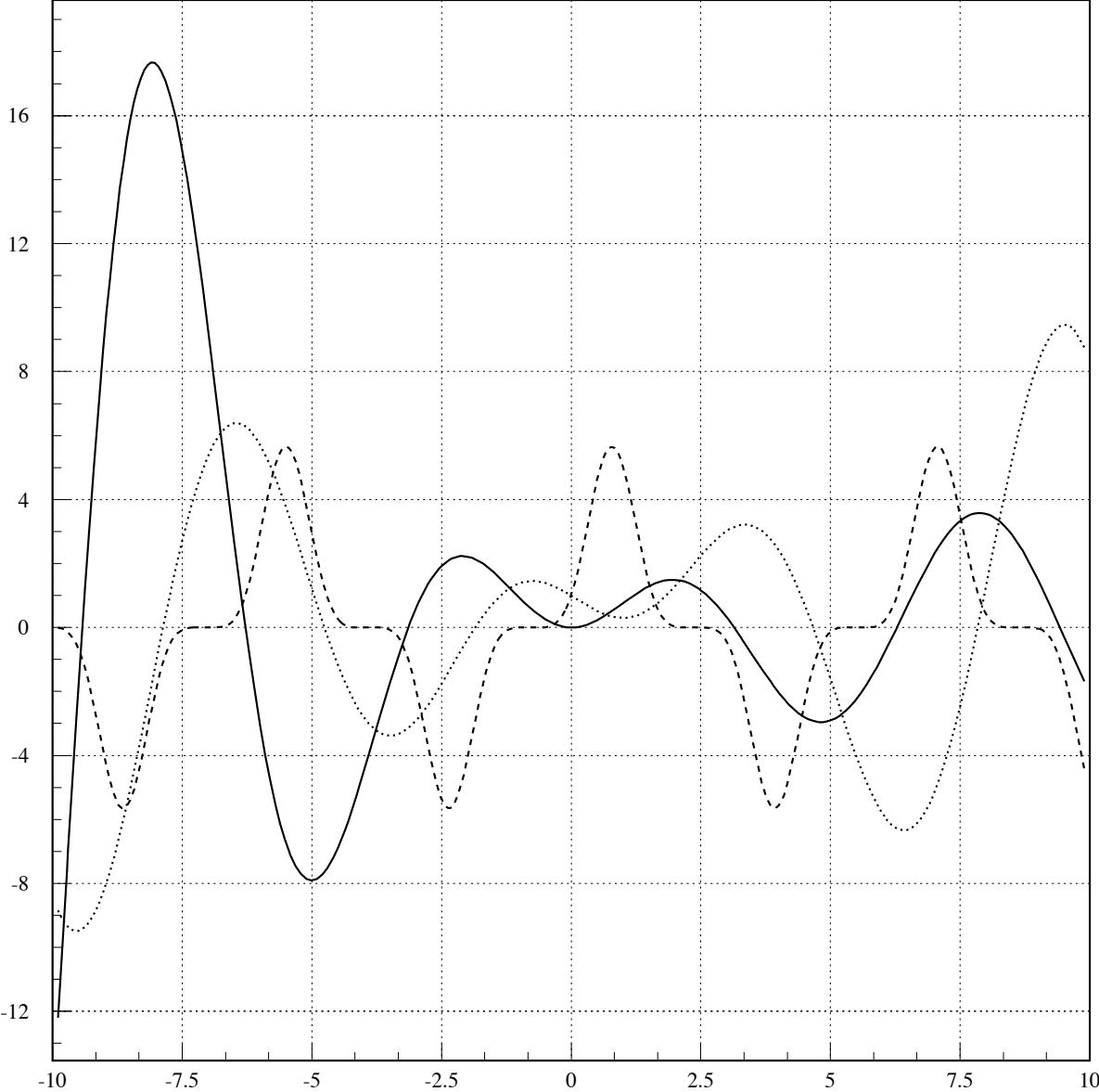


Figure 3.7: Plotting one-dimensional functions

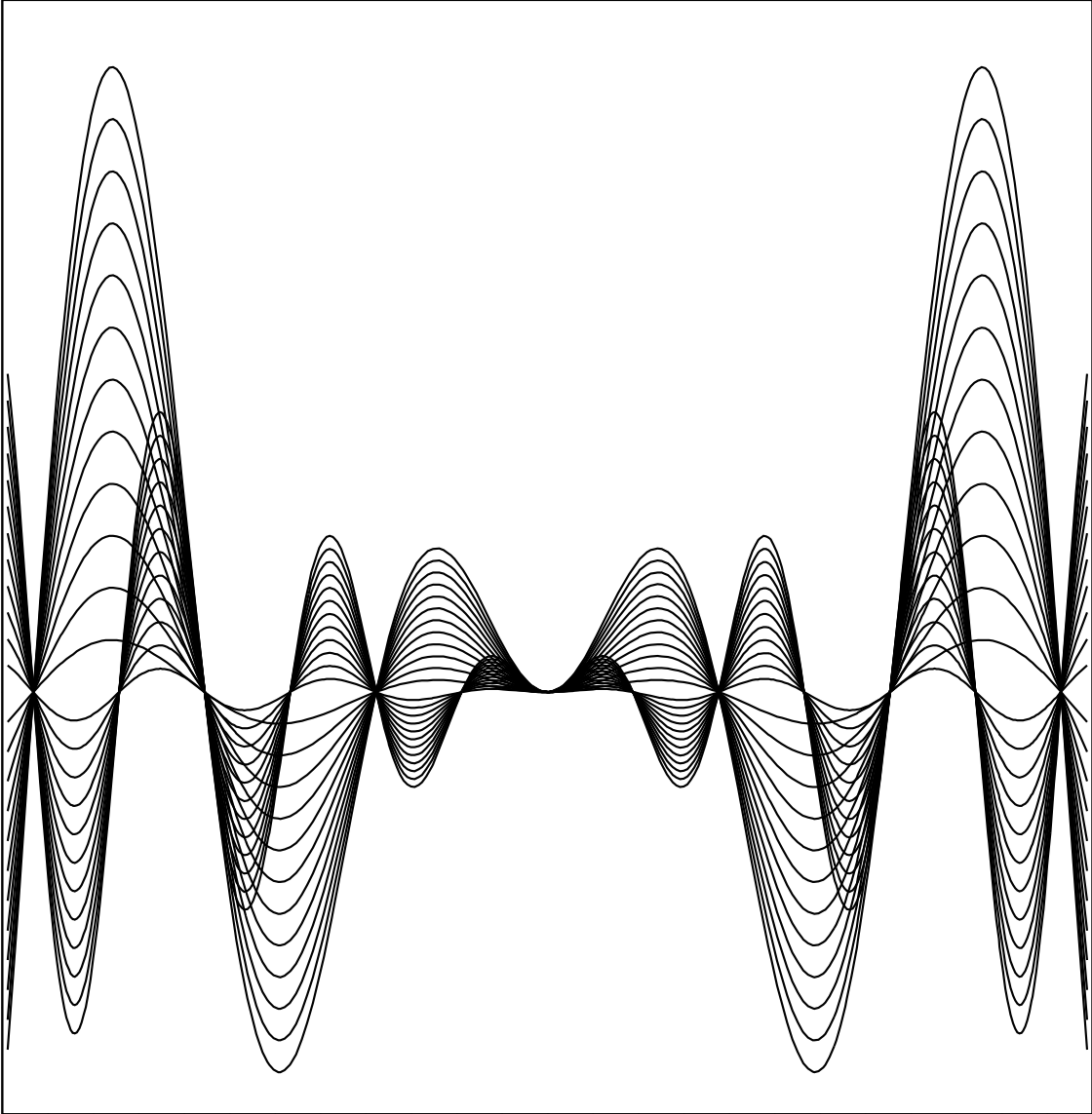


Figure 3.8: One-dimensional functions and loops

Two-dimensional representations

```
PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX9                *
PAW > * Plot two-dimensional functions                          *
PAW > *****
PAW > zone 2 2 | Divide picture in two by two
PAW > FUN2 10 abs(sin(x)/x)*(cos(y)*y) _ | First 2-dim function using
PAW > 40 -6.0 6.0 40 -6.0 6.0 |
PAW > contour 10 40 0 | Contour plot representation
PAW > hi/de 10 | Delete histogram 10
PAW > FUN2 10 x*sin(x)*y*sin(y) 40 -10. 10. 40 -10. 10. C | Second 2-dim function
PAW > surf 10 | Surface plot representation
PAW > hi/de 10 | Delete histogram 10
```

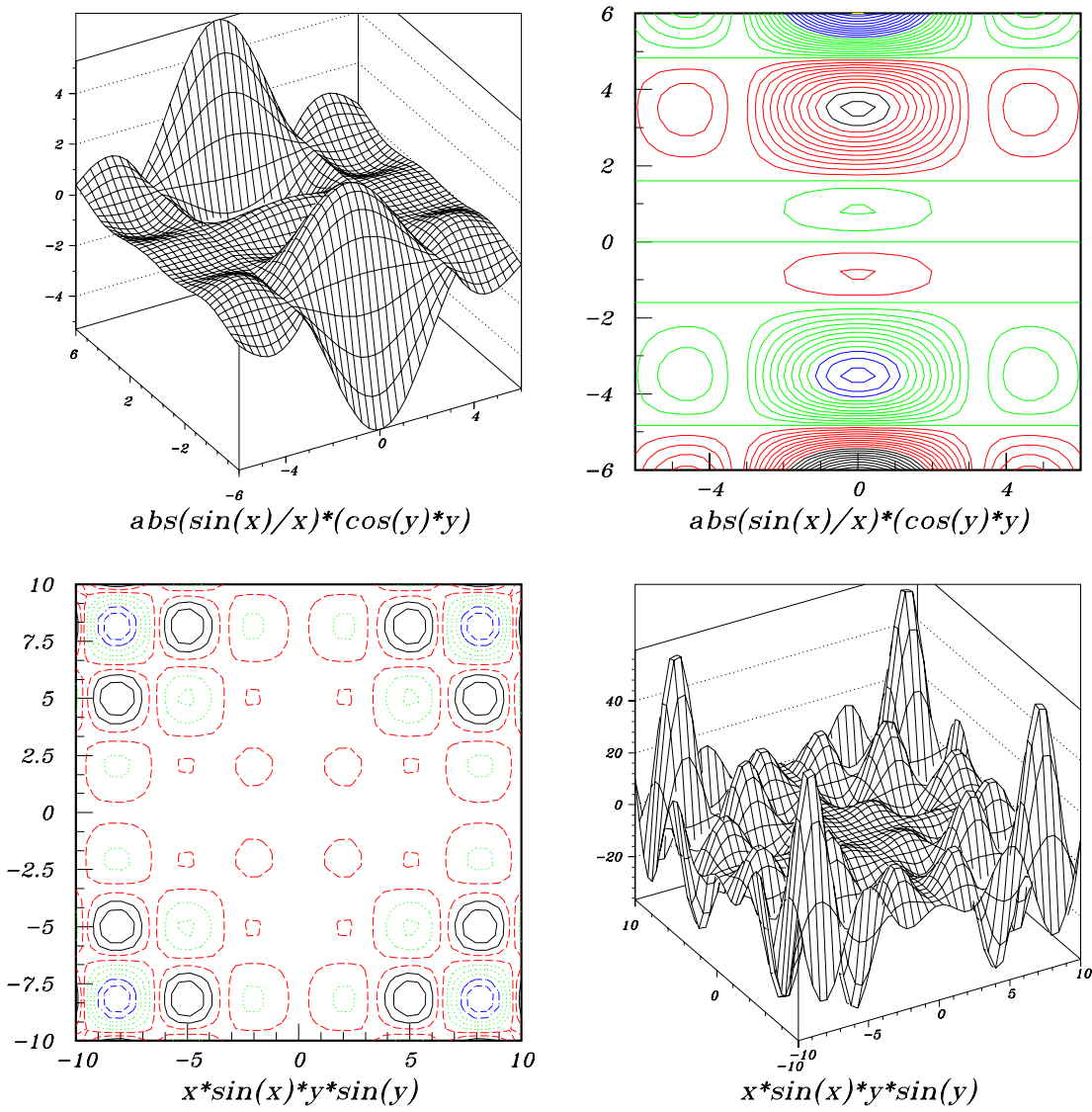


Figure 3.9: Plotting two-dimensional functions

Plotting a file from an external file

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX10                *
PAW > * Calculate and plot (BOX option) Mandelbrot distribution *
PAW > *****
PAW > edit mandel.ftn | Look at FORTRAN function
      REAL FUNCTION MANDEL(XP)
      DIMENSION XP(2)
      DATA NMAX/30/
      X=XP(1)
      Y=XP(2)
      XX=0.
      YY=0.
      DO 30 N=1,NMAX
        TT=XX*XX-YY*YY+X
        YY=2.*XX*YY+Y
        XX=TT
        IF (4..LT.XX*XX+YY*YY) GO TO 1
30     CONTINUE
1     MANDEL=FLOAT(N)/FLOAT(NMAX)
      END
PAW > *
PAW > * Calculate the mandel function defining the limits of the plot
PAW > *
PAW > fun2 10 mandel.ftn 100 -2.4 .8 100 -1.2 1.2 ' '
PAW > *
PAW > * Open "metafile" for PostScript image
PAW > *
PAW > fortran/file 66 mandel.ps
PAW > metafile 66 -113 | HIGZ/PostScript portrait mode
PAW > hi/pl 10 BOX | Plot histogram with BOX option
PAW > close 66 | Close metafile

```

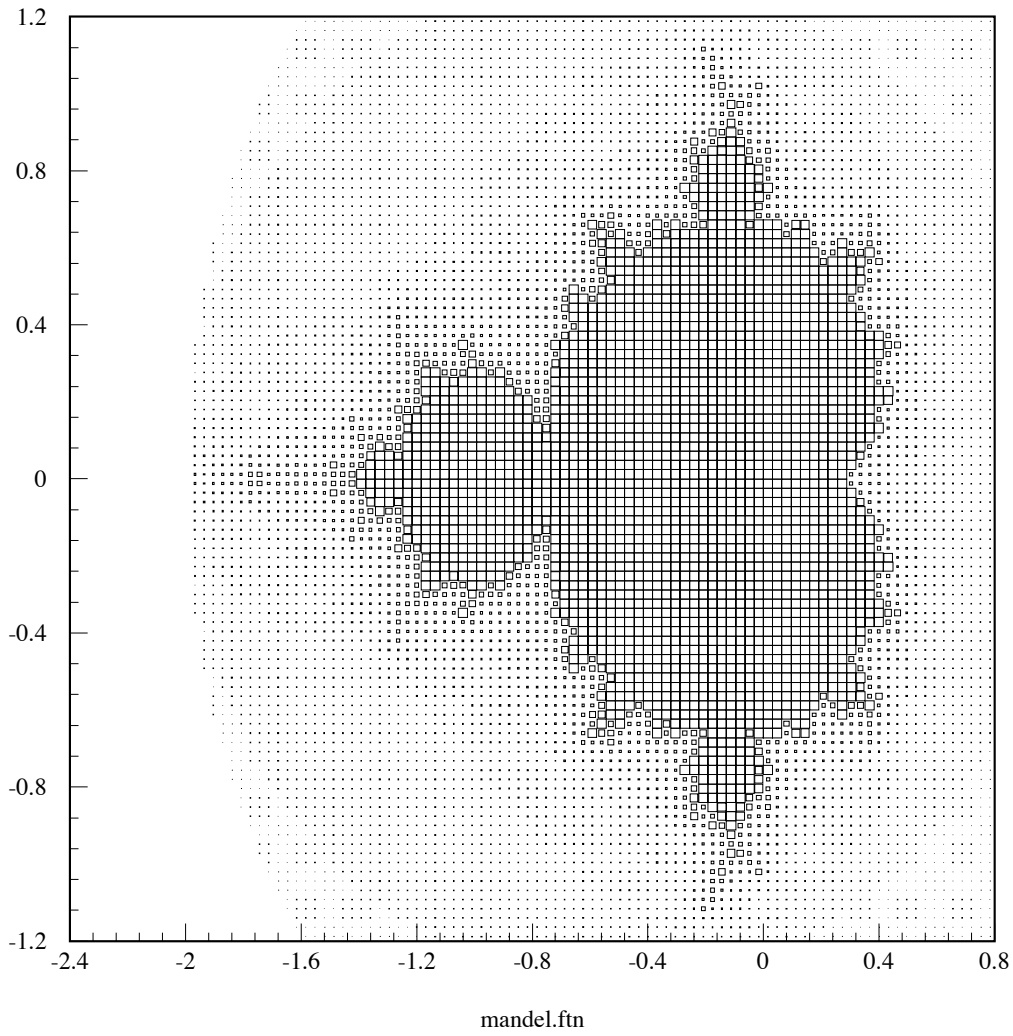


Figure 3.10: Plotting a two-dimensional function specified in a external file

3.3 Using histograms

Creating histograms

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX11                *
PAW > * Creation of one and two-dimensional histograms          *
PAW > *****
PAW > edit htfun1.ftn | Look at FORTRAN function
      FUNCTION HTFUN1(X)
      DATA C1,C2, XM1, XM2, XS1, XS2/1.,0.5,0.3,0.7,0.07,0.12/
      A1=-0.5*((X-XM1)/XS1)**2
      A2=-0.5*((X-XM2)/XS2)**2
      X1=C1
      X2=C2
      IF(ABS(A1).GT.1.E-4)X1=C1*EXP(A1)
      IF(ABS(A2).GT.1.E-4)X2=C2*EXP(A2)
      HTFUN1=X1+X2
      END
      FUNCTION HTFUN2(X,Y)
      HTFUN2=HTFUN1(X)*HTFUN1(Y)
      END
PAW > edit urout.ftn | Edit COMIS Fortran routine
      SUBROUTINE UROUT(NEV)
      DO 10 I=1,NEV
      X=HRNDM1(100)
      CALL HFILL(110,X,0.,1.)
10 CONTINUE
      END
PAW > opt GRID | Add grid to plot
PAW > zone 1 2 | Divide plot in two
PAW > * -- Read functions from file htfun1.ftn into memory
PAW > * -- Fill 1-dimensional histogram 100 according to 1-dim function htfun1 and plot
PAW > fun1 100 htfun1.ftn 100. 0. 1.
PAW > 1dhisto 110 'Test 1-dim Histo' 100 0. 1. 1000. | Create a 1-dimensional histogram
PAW > * -- Fill histogram 110 according to function 100 (5000 events)
PAW > call urout.ftn(5000)
PAW > * -- Fill and plot as a contour 2-dimensional histogram 200 according to the
PAW > * -- 2-dim function htfun2 in memory
PAW > fun2 200 htfun2 25. 0. 1. 25. 0. 1. C
PAW > hi/li | List known histograms
      ==> Directory : //PAWC
           100 (1)  htfun1.ftn
           110 (1)  Test 1-dim Histo
           200 (2)  htfun2
PAW > histogram/file 1 pawhists.rzdat ! N | Define output unit 1
PAW > hrout 0 | Write all histograms
PAW > close 1 | Close the output unit
PAW > hi/de 0 | Delete all histograms in memory

```

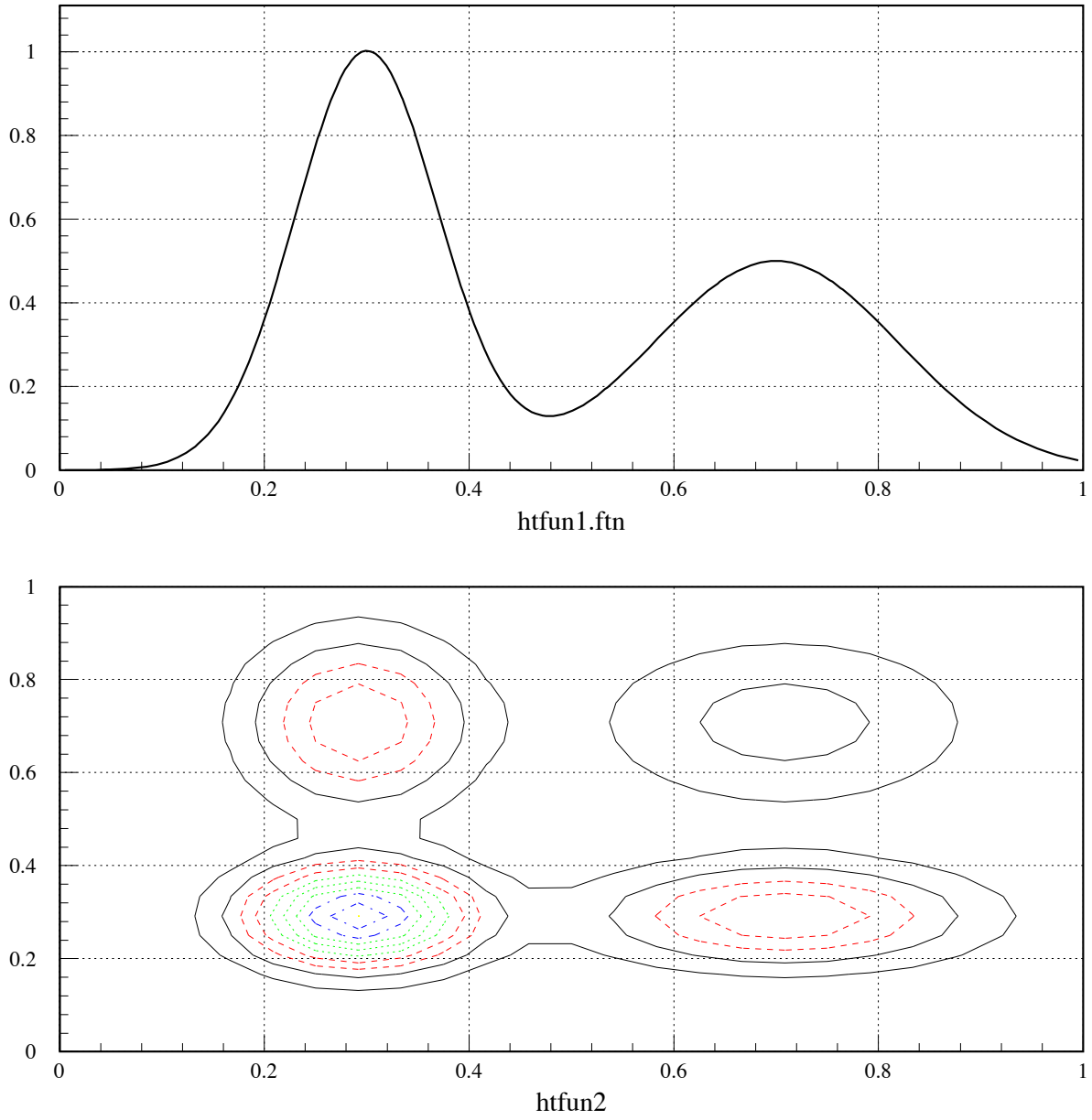


Figure 3.11: Creation of one- and two-dimensional histograms

Inputting histograms from an external file

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX12                *
PAW > * Read histograms from file and plot                        *
PAW > *****
PAW > histogram/file 1 pawhists.rzdat | Open histogram file created in PAWEX11
PAW > hrin * | Read all histograms from file
PAW > ldir | List current directory
      ***** Directory ===> //LUN1 <===
                Created 890915/1653 Modified 890917/1116

      ===> List of objects
                HBOOK-ID  CYCLE  DATE/TIME  NDATA  OFFSET  REC1  REC2
                100      1    890915/1653   152    1       3
                110      1    890915/1653    85   153     3
                200      1    890915/1653   779   238     3

      NUMBER OF RECORDS = 3 NUMBER OF MEGAWORDS = 0 + 3056 WORDS
      PER CENT OF DIRECTORY QUOTA USED = 0.075
      PER CENT OF FILE USED = 0.075
      BLOCKING FACTOR = 66.146
PAW > hi/list | List histograms on file
      ===> Directory : //LUN1
                100 (1)  htfun1.ftn
                110 (1)  Test 1-dim Histo
                200 (2)  htfun2.ftn

PAW > opt GRID | Put a grid on the picture
PAW > zone 2 2 | Divide picture in two by two parts
PAW > hi/pl 100 | Plot histogram 100
PAW > set htyp -3 | Choose hatch style
PAW > hi/pl 110 | Plot histogram 110 with option E
PAW > zone 1 2 2 'S' | Redefine zone
PAW > hi/plot 200 | Plot 2-dim histogram 2 (Box option)
PAW > h/del 0 | Delete histograms from memory
PAW > close 1 | Close input unit
PAW > zone | Reset zone

```

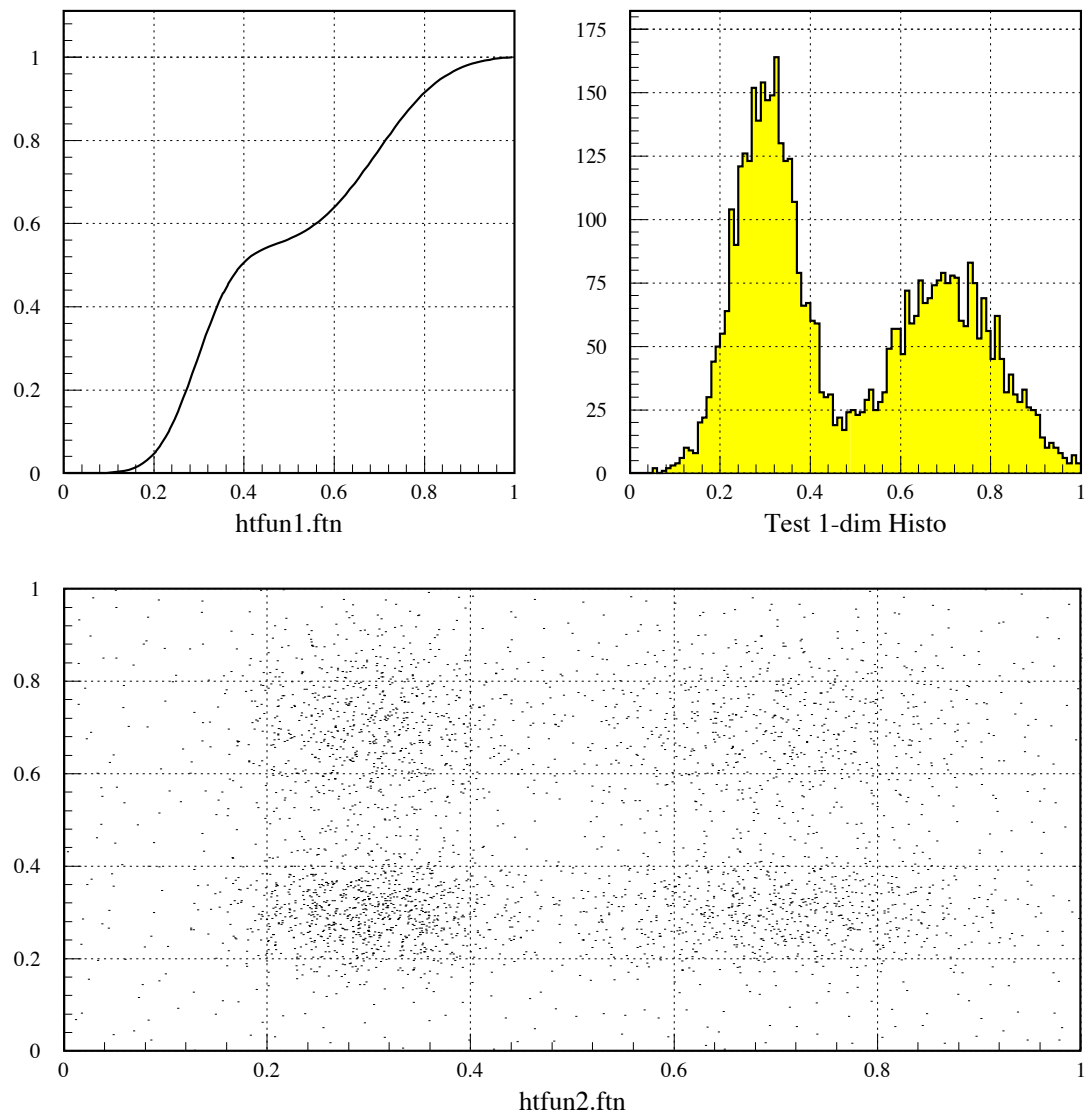


Figure 3.12: Reading histograms on an external file

Histogram operations

PAW > *****	
PAW > *	TUTORIAL EXAMPLE PAWEX13
PAW > * Perform operations on histograms read from file and save result *	
PAW > *****	
PAW > <u>histogram/file 1 pawhists.rzdat ! U</u>	| Open histogram file
PAW > <u>hrin 0</u>	| Read all histograms on file
PAW > <u>zon 2 2</u>	| Divide picture in two by two parts
PAW > <u>opt grid</u>	| Put a grid on the picture
PAW > <u>igset mtyp 26</u>	| Polymarker
PAW > <u>set KSIZ 0.2</u>	| Set size of polymarker (in cm)
PAW > <u>hi/pl 110 e</u>	| Plot histo 110 with E option
PAW > <u>hi/pl 110 pl</u>	| Plot histo 110 with polymarker
PAW > <u>set CFON 2</u>	| Set font for comments
PAW > <u>set CSIZ 0.4</u>	| Set size for comments (in cm)
PAW > <u>key 0.5 130 26 '[p^+!,p^-!,m^+!,m^-']</u>	| Example of HIGZ software fonts
PAW > <u>zon 1 2 2 s</u>	| Redefine picture layout
PAW > <u>hi/op/add 110 110 120 0.5 0.</u>	| Histogram 120 is half of 110
PAW > <u>hi/op/add 110 110 130 0.25 0.</u>	| Histogram 130 is quarter of 110
PAW > <u>set htyp -3</u>	| Hatch style for histogram
PAW > <u>hi/pl 110</u>	| Plot histogram 110
PAW > <u>set htyp 444</u>	| Set hatch styles for histogram 120
PAW > <u>hi/pl 120 s</u>	| Plot histogram 120 on same plot
PAW > <u>set htyp 244</u>	| Set hatch styles for histogram 130
PAW > <u>hi/pl 130 s</u>	| Plot histogram 120 on same plot
PAW > <u>text 0.55 95. 'LEP Very Preliminary' 0.35 25.</u>	| Add text to plot
PAW > <u>hrout 0</u>	| Write histograms to file
PAW > <u>close 1</u>	| Close input/output unit

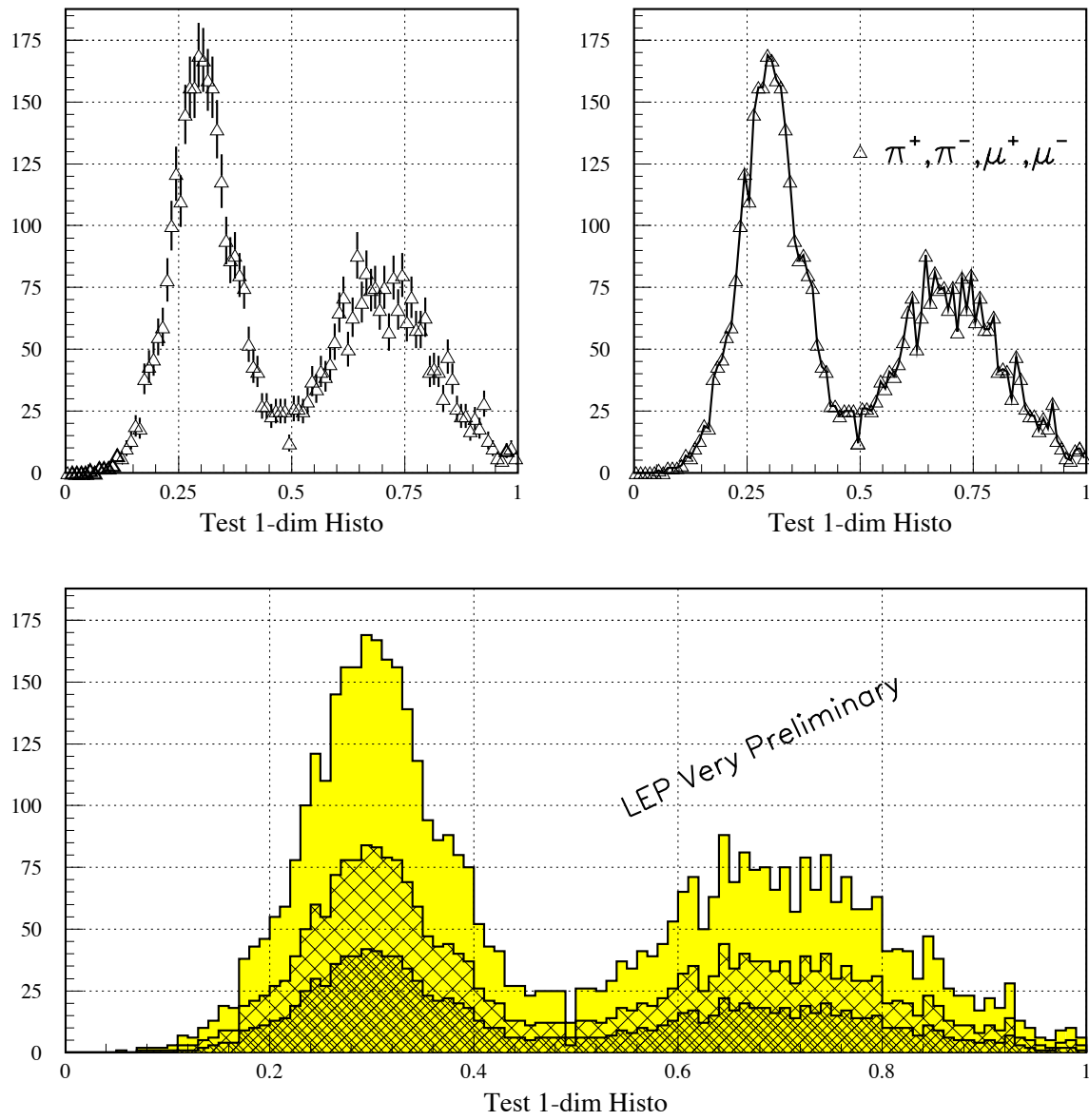


Figure 3.13: One-dimensional plotting and histogram operations

Two-dimensional data presentations

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX14                *
PAW > * Different representations of 2-dim histograms            *
PAW > *****
PAW > *
PAW > * Open histogram file created in PAWEX11, modified in PAWEX13
PAW > *
PAW > histogram/file 1 pawhists.rzdat
PAW > hrin 0                | Read all histograms on file
PAW > hi/li                 | List histograms on file
    ==> Directory : //LUN1
           100 (1)  htfun1.ftn
           110 (1)  Test 1-dim Histo
           200 (2)  htfun2
           120 (1)  Test 1-dim Histo
           130 (1)  Test 1-dim Histo

PAW > close 1                | Close input unit
PAW > opt UTIT                | Turn off HBOOK titles
PAW > zone 2 2                | Divide picture in two by two parts
PAW > hi/plot 200 BOX        | Plot histogram 200 with BOX option
PAW > contour 200 20 0       | Plot histogram 200 as contour plot
PAW > lego 200                | Plot histogram 200 as lego plot
PAW > surf 200                | Plot histogram 200 as surface plot
PAW > hi/del 0                | Delete histograms in memory
PAW > zone                    | Reset zone

```

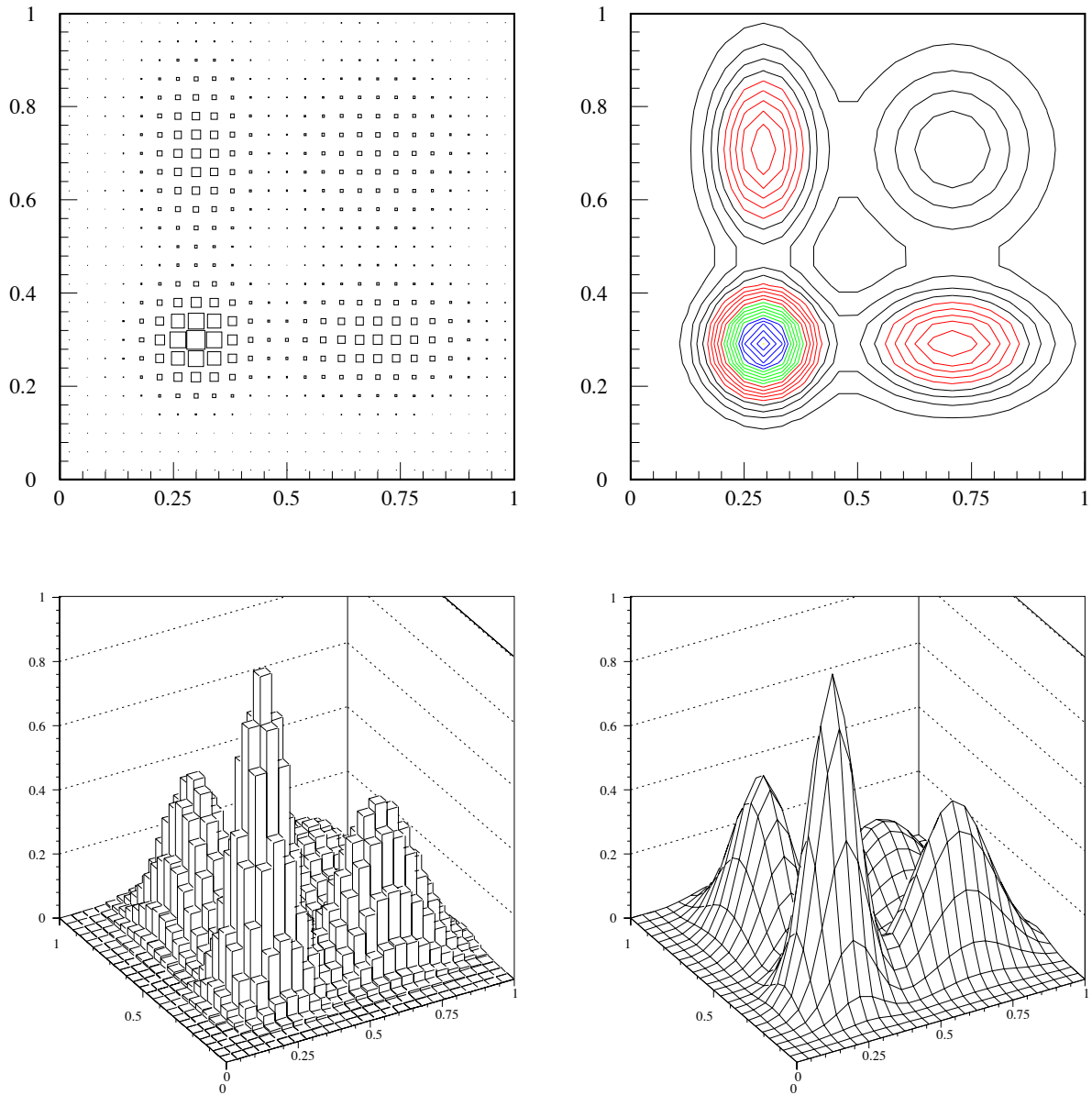


Figure 3.14: Two-dimensional data representations

Sub-ranges in histogram identifiers
--

PAW > *****	
PAW > *	*
TUTORIAL EXAMPLE PAWEX15	
PAW > * Use of subranges in histogram specifiers *	
PAW > *****	
PAW > <u>histogram/file 1 pawhists.rzdat</u>	| Open histogram file created in PAWEX11
PAW > <u>hrin 0</u>	| Read all histograms from file
PAW > <u>close 1</u>	| Close input unit
PAW > <u>opt GRID</u>	| Draw grid on picture
PAW > <u>opt UTIT</u>	| Turn off HBOOK titles
PAW > <u>zone 2 2</u>	| Divide picture in two by two parts
PAW > <u>hi/pl 110(56:95) e</u>	| Plot subrange of histogram 110
PAW > <u>opt NGRI</u>	| No grid on picture
PAW > <u>set htyp -3</u>	| Set hatch styles for histogram
PAW > <u>hi/pl 200(8:8,) BOX</u>	| Plot subrange of 200 with BOX option
PAW > <u>hi/pl 200(3:15,3:15) CONT</u>	| Plot subrange of 200 as a CONTOUR plot
PAW > <u>hi/pl 200(4:12,4:12) LEGO</u>	| Plot subrange of 200 as a LEGO plot
PAW > <u>hi/del 0</u>	| Delete histograms in memory
PAW > <u>zone</u>	| Reset zone

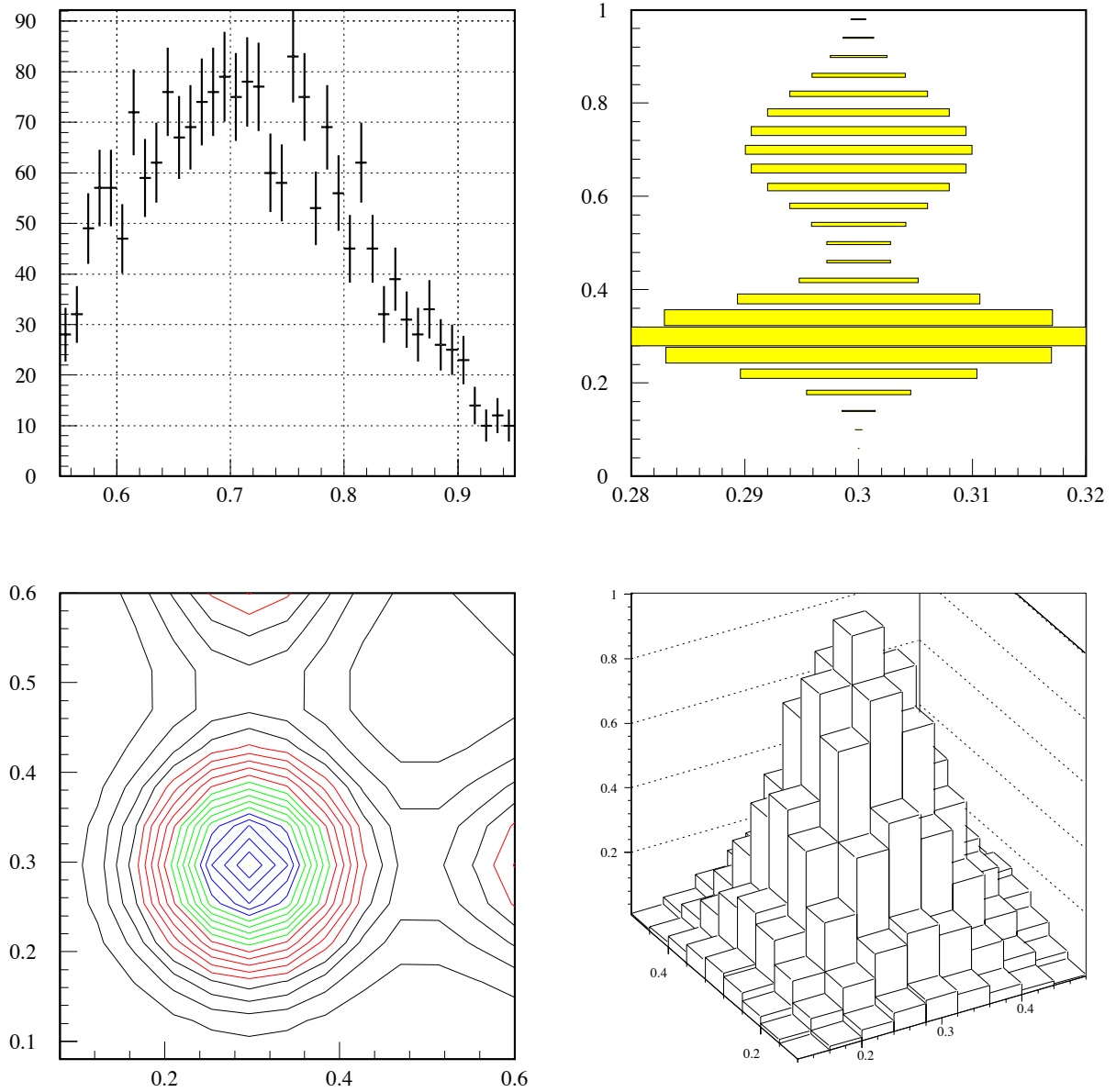


Figure 3.15: The use of sub-ranges in histogram specifiers

3.4 Examples with Ntuples

Ntuples are large named two-dimensional arrays. From the physicist's point of view they can be considered as **event** files. Ntuples can be accessed as a whole or single columns, or even single components. **Columns** can be identified by a name or by an index. A rather complete set of **operators** is available to deal with Ntuples - these include capabilities to apply **cuts** or **selection criteria** to the Ntuple data, using a notation where arithmetic and boolean operators and mathematical functions can be freely used. A powerful **mask** facility exists to enable the user to select a Ntuple subset which has particular characteristics, allowing in this way very fast access to a data subset (see section 7.5 on page 131).

3.4.1 A first example - CERN personnel statistics

In order to introduce and explain the main functionalities of the Ntuples, a simple data sample containing some characteristics of the CERN staff, will be used. For each member of the staff there exists one entry in the file. Each entry consists of 11 values, described in table 3.1.

Variable Name	Description and possible values
CATEGORY:	Professional category (integer between 100 and 600) 100-199: Scientific staff 200-299: Engineering staff 300-399: Technical support staff 400-499: Crafts and trade support staff 500-529: Supervisory administrative staff 530-559: Intermediate level administrative staff 560-599: Lower level administrative staff
DIVISION:	Code for each division (integer between 1 and 13) 1=AG 2=DD 3=DG 4=EF 5=EP 6=FI 7=LEP 8=PE 9=PS 10=SPS 11=ST 12=TH 13=TIS
FLAG:	A flag where the first four bits have the following significance Bit 1 = 0 means female otherwise male Bit 2 = 0 means resident otherwise non-resident Bit 3 = 0 means single otherwise head of family Bit 4 = 0 means fixed term contract otherwise indefinite duration contract
AGE:	Age (in years) of staff member
SERVICE:	Number of years of service that the staff member has at CERN
CHILDREN:	Number of dependent children
GRADE:	Staff member 's position in Grade scale (integer between 3 and 14)
STEP:	Staff member 's position (step) inside given grade (integer between 0 and 15)
NATION:	Code for staff member's nationality (integer between 1 and 15) 1=AT 2=BE 3=CH 4=DE 5=DK 6=ES 7=FR 8=GB 9=GR 10=IT 11=NL 12=NO 13=PT 14=SE 15=ZZ (non-member states)
HRWEEK:	Number of contractual hours worked per week (between 20 and 44)
COST:	Cost of the staff member to CERN (in CHF)

Table 3.1: Definition of the variables of the CERN staff Ntuple

3.4.2 Creating Ntuples

Ntuples can be created interactively, using PAW (see figure 3.16) or in an independent batch job, using HBOOK, using the following calling sequence [2]

```
CALL HBOOKN(IDN,TITLE,NCOLUM,CHRZPA,NPRIME,CHTAGS)
```

Two kinds of Ntuples are supported: **memory-resident** Ntuples for small data samples, which can be completely contained in memory, or **disk-resident** Ntuples for large data samples which need the use of an extended store. For example the FORTRAN program equivalent to the code for the creation of the memory-resident Ntuple in figure 3.16 is as follows:

Creating a memory-resident Ntuple	
PROGRAM APTUPLE PARAMETER (NCOLUM=11) CHARACTER*8 CHTAGS(NCOLUM) COMMON/PAWC/H(70000) REAL XTUPLE(NCOLUM) DATA NPRIME/1000/ * DATA CHTAGS/'category','division','flag','age','service', + 'children','grade','step','nation','hrweek','cost'/ * CALL HLIMIT(70000) OPEN(UNIT=1,FILE='APTUPLE.DAT',STATUS='OLD') CALL HBOOKN(10,'CERN Population',NCOLUM,' ',NPRIME,CHTAGS) DO 100 I=1,10000 READ(1,'(10F4.0,F7.0)',END=1000) XTUPLE CALL HFN(10,XTUPLE) 100 CONTINUE * 1000 CALL HRPOT(0,'aptuple.rzdat','N') END	

Memory-resident Ntuple: CHRZPA=' '

The storage required for a memory-resident Ntuple is approximately the product of the number of columns NCOLUM multiplied by the number of events. With a call to HBOOKN an initial bank of size NPRIME words is created in memory. When the bank is full, a new bank with the same size is created and is linked to the previous bank, and so on up to the maximum memory allocation declared by the call to HLIMIT. A memory-resident Ntuple can be saved on a HBOOK file with a call to HROUT or HRPOT.

Disk-resident Ntuple: CHRZPA='RZ directory name to store Ntuple'

In this case a bank with a size of NPRIME words is also created in memory. However, when the bank is full, its contents is written to disk into the directory CHRZPA, and the **same** bank is used to store the data for the next events, thus overwriting the initial contents. As for a memory-resident Ntuple, a header is kept in memory. It contains among other things the number of events already treated as well as the number and the address of the disk extensions. This header **must** be saved (after filling the Ntuple) on the disk file after having set the current directory to CHRZPA. The number of extensions on disk can be interactively displayed using the command:

```
PAW > LDIR ' ' A
```

The example above could be modified in the following way to create a disk-resident Ntuple:

Creating a disk-resident Ntuple

```

      . . . . .
OPEN(UNIT=1,FILE='aptuple.dat',STATUS='OLD')
LRECL=1024
CALL HROPEN(2,'APTUPLE','aptuple.rzdat','N',LRECL,ISTAT)
CALL HBOOKN(10,'CERN Population',NCOLUM,'APTUPLE',NPRIME,CHTAGS)
      . . . . .
1000 CALL HROUT(0,ICYCLE,' ')
      CALL HREND('APTUPLE')
      END

```

When dealing with very large Ntuples, it is recommended to open the HBOOK file with a large block size (e.g. LRECL=8192 words and a large primary allocation (e.g. NPRIME=60000)). Routine HROPEN allocates a maximum of 8000 records each LRECL words long. If more is required, put CHOPT='NQ' and IQUEST(10)=Number of records, where the vector IQUEST is defined in the ZEBRA common COMMON/QUEST/IQUEST(100).

Listing the directory of the memory-resident Ntuple

```

PAW > LDIR
SIGMA
***** Directory ==> //aptuple <===

          Created 890627/1620  Modified 890627/1621

==> List of objects
   HBOOK-ID  CYCLE  DATE/TIME  NDATA  OFFSET  REC1  REC2
          10     1  890627/1621  38107     1     3     4 ==> 40

NUMBER OF RECORDS = 39  NUMBER OF MEGAWORDS = 0 + 39131 WORDS
PER CENT OF DIRECTORY QUOTA USED = 0.975
PER CENT OF FILE USED = 0.975
BLOCKING FACTOR = 95.420

```

It is seen that 38107 words were needed to store all the data associated to the Ntuple. The file aptuple.rzdat created in batch by the program or the one created interactively in figure 3.16 are completely interchangeable. Generally speaking, a Ntuple (or any HBOOK histogram RZ file) can be created in batch on a mainframe and then transferred to a machine running PAW. See chapter 9 on page 187 for more details.

In the listing below extensions are identified by 10000*Extension_Number+Ntuple_ID.

Listing the directory of the disk-resident Ntuple

```

PAW > LDIR ' ' A

***** Directory ==> //LUN2 <===

          Created 891010/1038  Modified 891010/1038

==> List of objects
   HBOOK-ID  CYCLE  DATE/TIME  NDATA  OFFSET  REC1  REC2

```

10010	1	891010/1038	1005	1	3	
20010	1	891010/1038	1005	1006	3	4
30010	1	891010/1038	1005	987	4	5
40010	1	891010/1038	1005	968	5	6
50010	1	891010/1038	1005	949	6	7
60010	1	891010/1038	1005	930	7	8
70010	1	891010/1038	1005	911	8	9
80010	1	891010/1038	1005	892	9	10
90010	1	891010/1038	1005	873	10	11
100010	1	891010/1038	1005	854	11	12
110010	1	891010/1038	1005	835	12	13
120010	1	891010/1038	1005	816	13	14
130010	1	891010/1038	1005	797	14	15
140010	1	891010/1038	1005	778	15	16
150010	1	891010/1038	1005	759	16	17
160010	1	891010/1038	1005	740	17	18
170010	1	891010/1038	1005	721	18	19
180010	1	891010/1038	1005	702	19	20
190010	1	891010/1038	1005	683	20	21
200010	1	891010/1038	1005	664	21	22
210010	1	891010/1038	1005	645	22	23
220010	1	891010/1038	1005	626	23	24
230010	1	891010/1038	1005	607	24	25
240010	1	891010/1038	1005	588	25	26
250010	1	891010/1038	1005	569	26	27
260010	1	891010/1038	1005	550	27	28
270010	1	891010/1038	1005	531	28	29
280010	1	891010/1038	1005	512	29	30
290010	1	891010/1038	1005	493	30	31
300010	1	891010/1038	1005	474	31	32
310010	1	891010/1038	1005	455	32	33
320010	1	891010/1038	1005	436	33	34
330010	1	891010/1038	1005	417	34	35
340010	1	891010/1038	1005	398	35	36
350010	1	891010/1038	1005	379	36	37
360010	1	891010/1038	1005	360	37	38
370010	1	891010/1038	1005	341	38	39
10	1	891010/1038	1107	322	39	40

NUMBER OF RECORDS = 39 NUMBER OF MEGAWORDS = 0 + 39316 WORDS
 PER CENT OF DIRECTORY QUOTA USED = 0.975
 PER CENT OF FILE USED = 0.975
 BLOCKING FACTOR = 95.883

Creating Ntuples

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX16                *
PAW > * Creation of a Ntuple and first look at its contents      *
PAW > *****
PAW > *
PAW > * Create Ntuple 10 with 11 variables
PAW > *
PAW > Ntuple/create 10 'CERN Population' 11 ' ' 3500 _
PAW > Category Division Flag Age Service Children Grade Step Nation Hrweek Cost
PAW > Ntuple/read 10 aptuple.dat | Read the elements of the ntuple
PAW > Histo/file 1 aptuple.rzdat 1024 N | Open Histogram file on unit 1
PAW > hrout 10 | Write the ntuple to the file
PAW > ntuple/print 10 | Look what Ntuple 10 contains
*****
* NTUPLE ID= 10 ENTRIES= 3354 CERN Population *
*****
* Var numb * Name * Lower * Upper *
*****
* 1 * CATEGORY * 0.102000E+03 * 0.567000E+03 *
* 2 * DIVISION * 0.100000E+01 * 0.130000E+02 *
* 3 * FLAG * 0.000000E+00 * 0.310000E+02 *
* 4 * AGE * 0.210000E+02 * 0.640000E+02 *
* 5 * SERVICE * 0.000000E+00 * 0.350000E+02 *
* 6 * CHILDREN * 0.000000E+00 * 0.600000E+01 *
* 7 * GRADE * 0.300000E+01 * 0.140000E+02 *
* 8 * STEP * 0.000000E+00 * 0.150000E+02 *
* 9 * NATION * 0.100000E+01 * 0.150000E+02 *
* 10 * HRWEEK * 0.200000E+01 * 0.440000E+02 *
* 11 * COST * 0.391000E+03 * 0.188530E+05 *
*****
PAW > zone 1 2 | Divide the plot into two
PAW > opt stat | Print statistics on plot
PAW > set stat 110 | Number entries and average
PAW > opt grid | Add grid to pictures
PAW > set htyp -3 | Define hatch style for histograms
PAW > Ntuple/plot 10.Age | Plot Age distribution
PAW > Ntuple/plot 10.Cost | Cost distribution
PAW > Close 1 | Close file 1
PAW > hi/delete 10 | Delete Ntuple 10 from memory
PAW > zone | Reset zone

```

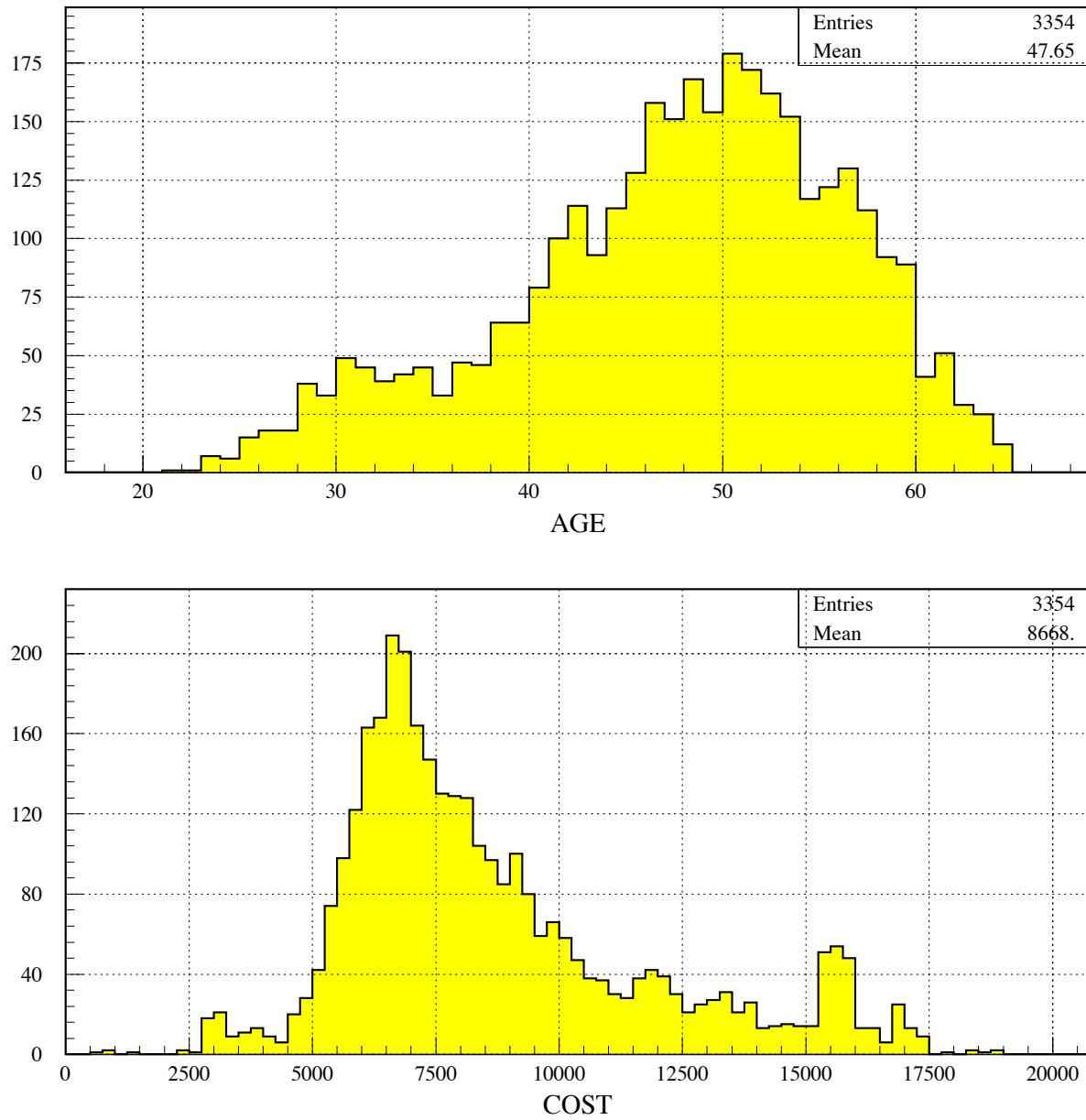


Figure 3.16: Ntuples - Creation and output to a file

Ntuples - automatic and user binning

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX17                *
PAW > * Read a Ntuple from a histogram file                      *
PAW > * Difference between automatic and user binning          *
PAW > *****
PAW > hi/file 2 'aptuple.rzdat' | Open histogram file
PAW > * -- Divide plot into two by two squares
PAW > zone 2 2
PAW > opt nsta | No statistics on plot
PAW > opt grid | Add grid to pictures
PAW > set XTIC 0.15 | X-axis tick mark length (in cm)
PAW > set YTIC 0.15 | Y-axis tick mark length (in cm)
PAW > set HTYP -3 | Define hatch style for histograms
PAW > * -- Age distribution with automatic binning
PAW > Ntuple/pl 10.age
PAW > hi/create/1dhisto 11 'Age - User binning' 45 20. 65. | Book histogram 11
PAW > * -- Exactly 5 secondary and 9 primary divisions
PAW > set ndvx -509
PAW > * -- Age distribution with user binning
PAW > Ntuple/project 11 10.Age
PAW > hi/plot 11 | Plot histogram 11
PAW > hi/create/1dhisto 12 'Cost - User binning' 50 0. 20000. | Book histogram 12
PAW > set ndvx | Default divisions
PAW > * -- Cost distribution with automatic binning
PAW > Ntuple/plot 10.cost
PAW > * -- Exactly 5 secondary and 4 primary divisions
PAW > set ndvx -504
PAW > * -- Cost distribution with user binning
PAW > Ntuple/pl 10.Cost ! -12
PAW > close 2 | Close histogram file
PAW > zone | Reset zone
PAW > hi/de 0 | Delete histograms from memory

```

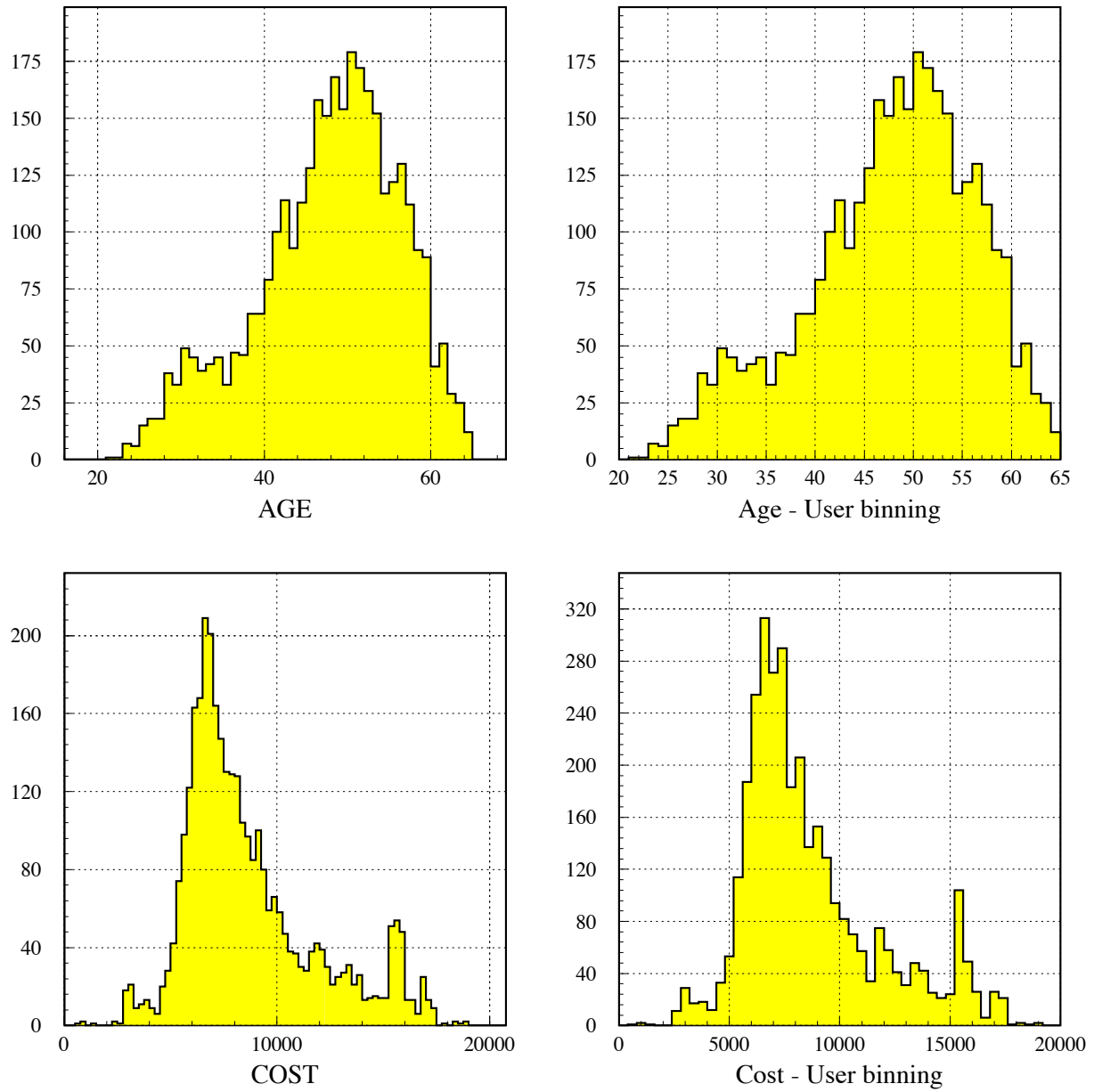


Figure 3.17: Ntuples - Automatic and user binning

```

Ntuples – selection criteria

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX18                *
PAW > * Ntuple SCAN and the use of simple selection criteria      *
PAW > *****
PAW > hi/file 2 'aptuple.rzdat' | Open histogram file
PAW > opt grid | Add grid to pictures
PAW > opt stat | Print statistics on plot
PAW > set stat 110 | Indicate number of entries and average
PAW > ALIAS/CREATE DIVEP 5 | Create alias for EP Division
PAW > ALIAS/CREATE NATFR 7 | Create alias for French nationality
PAW > * -- Scan and look for French CERN staff in EP division printing the variables indicated
PAW > NT/SCAN 10 nation=NATFR.and.division=DIVEP !! 5 age service children grade step
*****
* ENTRY *   AGE      * SERVICE * CHILDREN * GRADE   * STEP    *
*****
!  48 !   56.000   !  34.000  ! 0.00000  !  7.0000  !  8.0000  !
! 194 !   62.000   !  27.000  ! 0.00000  !  7.0000  ! 13.0000  !
! 213 !   56.000   !  26.000  ! 0.00000  !  6.0000  ! 13.0000  !
! 214 !   45.000   !  26.000  ! 0.00000  !  6.0000  ! 12.0000  !
! 216 !   56.000   !  19.000  ! 0.00000  !  5.0000  ! 13.0000  !
! 266 !   63.000   !  26.000  ! 0.00000  ! 13.0000  ! 10.0000  !
! 267 !   59.000   !  32.000  ! 0.00000  ! 13.0000  ! 10.0000  !
! 273 !   55.000   !  26.000  !  1.0000  ! 12.0000  ! 13.0000  !
! 275 !   53.000   !  26.000  !  1.0000  ! 11.0000  ! 13.0000  !
! 279 !   51.000   !  30.000  ! 0.00000  !  6.0000  ! 13.0000  !
! 315 !   56.000   !  25.000  ! 0.00000  !  8.0000  !  6.0000  !
! 318 !   64.000   !  26.000  ! 0.00000  !  6.0000  ! 13.0000  !
! 320 !   49.000   !  26.000  ! 0.00000  !  6.0000  ! 13.0000  !
! 327 !   59.000   !  19.000  ! 0.00000  !  5.0000  ! 13.0000  !
! 328 !   51.000   !  25.000  ! 0.00000  !  5.0000  ! 13.0000  !

More...? ( <CR>/N ): n
==>      15 events have been scanned

PAW > hi/create/1d 200 'Number of years at CERN' 35 0. 35. | Create histogram 200
PAW > max 200 250 | Maximum for histogram 200
PAW > * -- Maximum 5 secondary and 7 primary divisions
PAW > set ndvx 507
PAW > set htyp -3 | Define hatch style
PAW > Nt/pl 10.Service ! -200 | Plot years of service
PAW > ATITLE 'Years at CERN' 'Number of staff' | Define axis titles
PAW > set htyp 344 | Change hatch style
PAW > * -- Number of years at CERN for French staff members
PAW > Nt/pl 10.Service nation=NATFR -200 !! S
PAW > set htyp 144 | Change hatch style
PAW > * -- Number of years at CERN for French Staff in EP
PAW > Nt/pl 10.Service division=DIVEP.and.nation=NATFR -200 !! S
PAW > close 2 | Close histogram file
PAW > set htyp 0 | Reset hatch style
PAW > hi/de 0 | Delete histograms from memory
PAW > zone | Reset zone

```

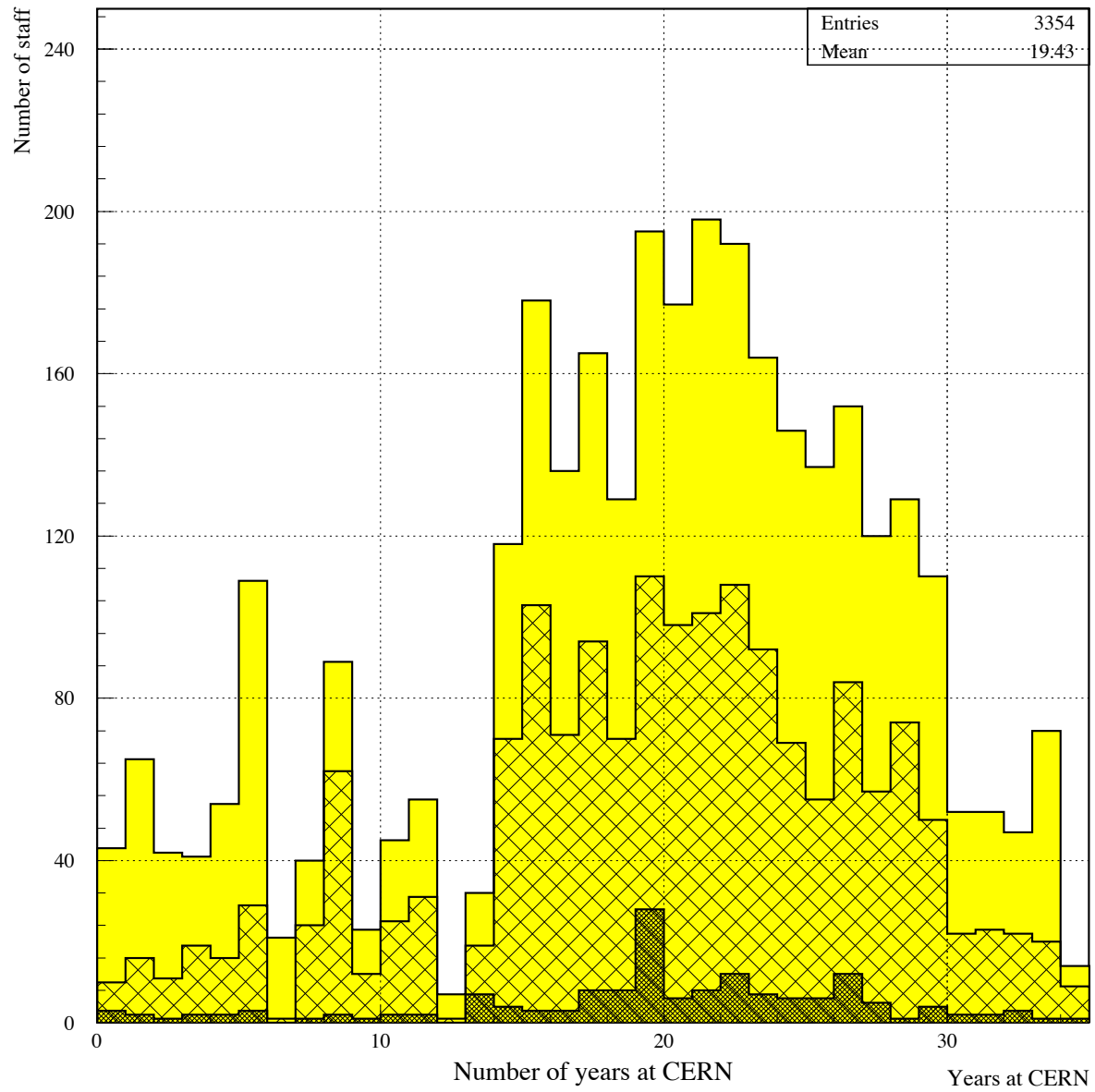


Figure 3.18: Ntuples - A first look at selection criteria

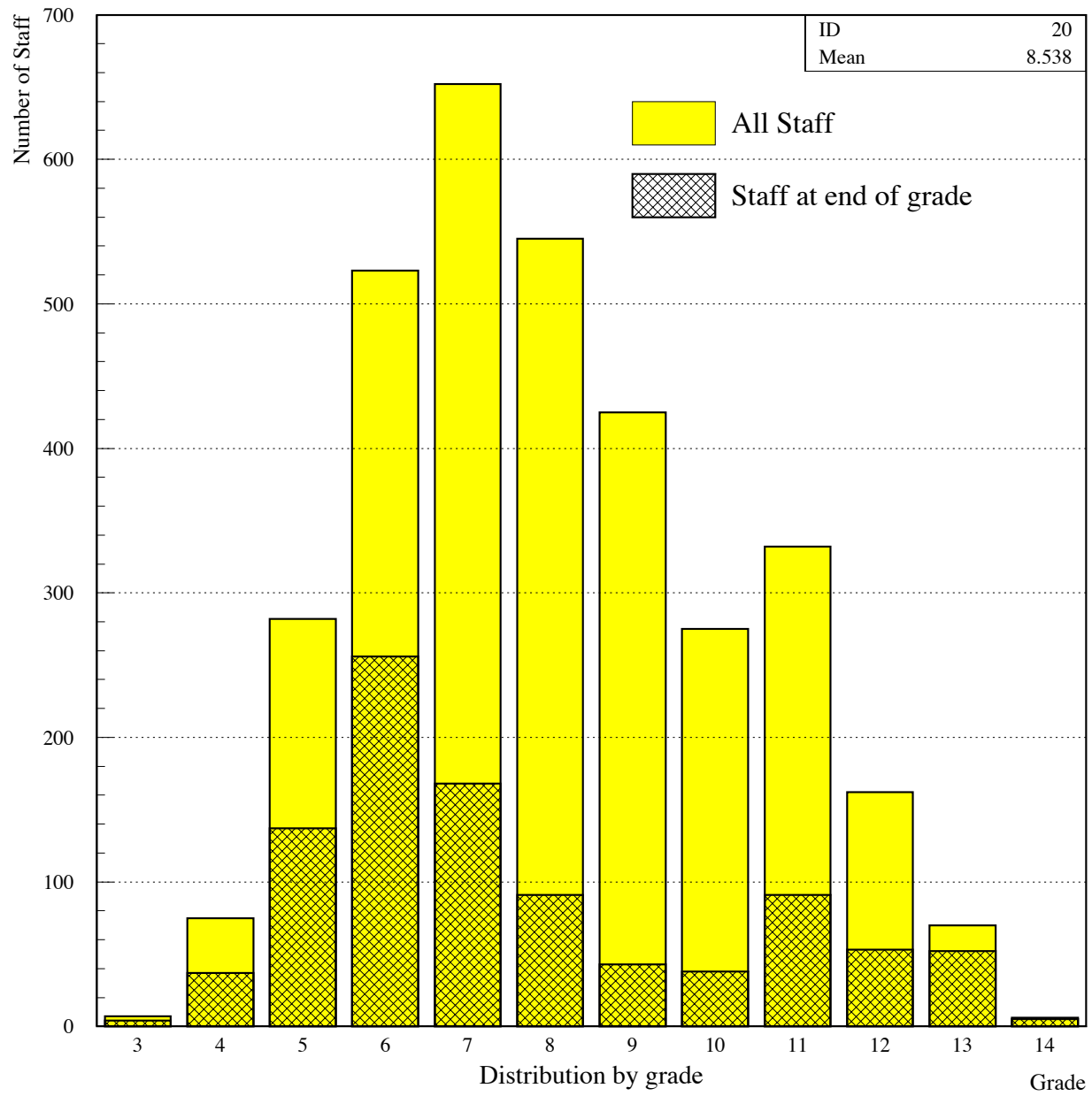


Figure 3.19: Ntuples - Masks and loop

Ntuple cuts	
PAW > *****	
PAW > *	*
PAW > * The use of Ntuple Cuts	*
PAW > *****	
PAW > <u>hi/file 2 'aptuple.rzdat'</u>	| Open histogram file
PAW > <u>Ntuple/cut 1 MOD(FLAG,2).EQ.0</u>	| CUT 1 : Female staff
PAW > <u>Ntuple/cut 2 MOD(FLAG,4)>1</u>	| CUT 2 : Non-resident staff
PAW > <u>1d 20 'Male/female and resident/non-resident Staff' 13 1 14</u>	
PAW > <u>opt grid</u>	| Draw grid on picture
PAW > * -- Only horizontal grid lines with line type 3	
PAW > <u>set grid 1003</u>	
PAW > <u>opt bar</u>	| Activate the bar chart option
PAW > <u>opt stat</u>	| Print statistics on plot
PAW > <u>set stat 10</u>	| Only number of entries on plot
PAW > <u>set xtic 0.0001</u>	| Eliminate tick marks
PAW > <u>igset barw 0.4</u>	| Set bar origin
PAW > <u>igset baro 0.1</u>	| Set bar width
PAW > <u>max 20 600</u>	| Maximum for histogram 20
PAW > <u>labels 1 13 AG DD DG EF EP FI LEP PE PS SPS ST TH TIS</u>	| Define labels for X axis
PAW > <u>set NDVX 13.15</u>	| X axis should centre the labels
PAW > * -- Plot all staff per division into histogram 20	
PAW > <u>Ntuple/plot 10.division ! -20</u>	
PAW > <u>set htyp -3</u>	| Choose hatch style
PAW > * -- Plot staff per division (satisfying cut 2)	
PAW > <u>Ntuple/plot 10.division 2 -20 !! s</u>	
PAW > <u>igset baro 0.5</u>	| Reset bar origin
PAW > <u>set htyp 145</u>	| Change hatch style
PAW > * -- Plot staff per division (satisfying cut 1)	
PAW > <u>Ntuple/plot 10.division 1 -20 !! s</u>	
PAW > <u>set htyp 154</u>	| Change hatch style
PAW > * -- Plot staff per division (satisfying cuts 1 and 2)	
PAW > <u>Ntuple/plot 10.division 1.and.2 -20 !! s</u>	
PAW > <u>atitle ' ' 'Number of staff'</u>	| Axis title
PAW > <u>close 2</u>	| Close histogram file
PAW > <u>set htyp 0</u>	| Reset hatch style
PAW > <u>hi/de 0</u>	| Delete histograms from memory

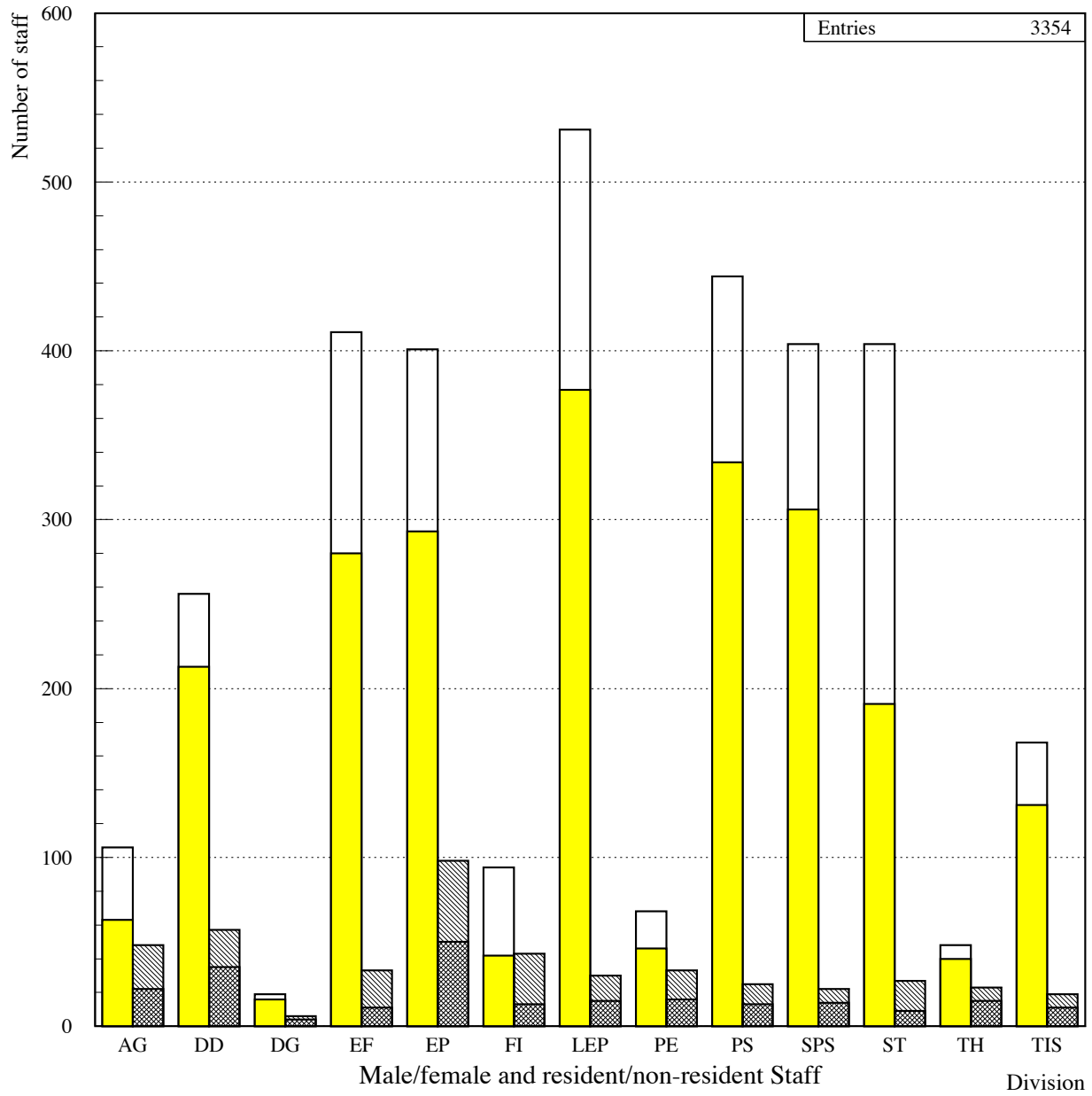


Figure 3.20: Ntuples - Using cuts

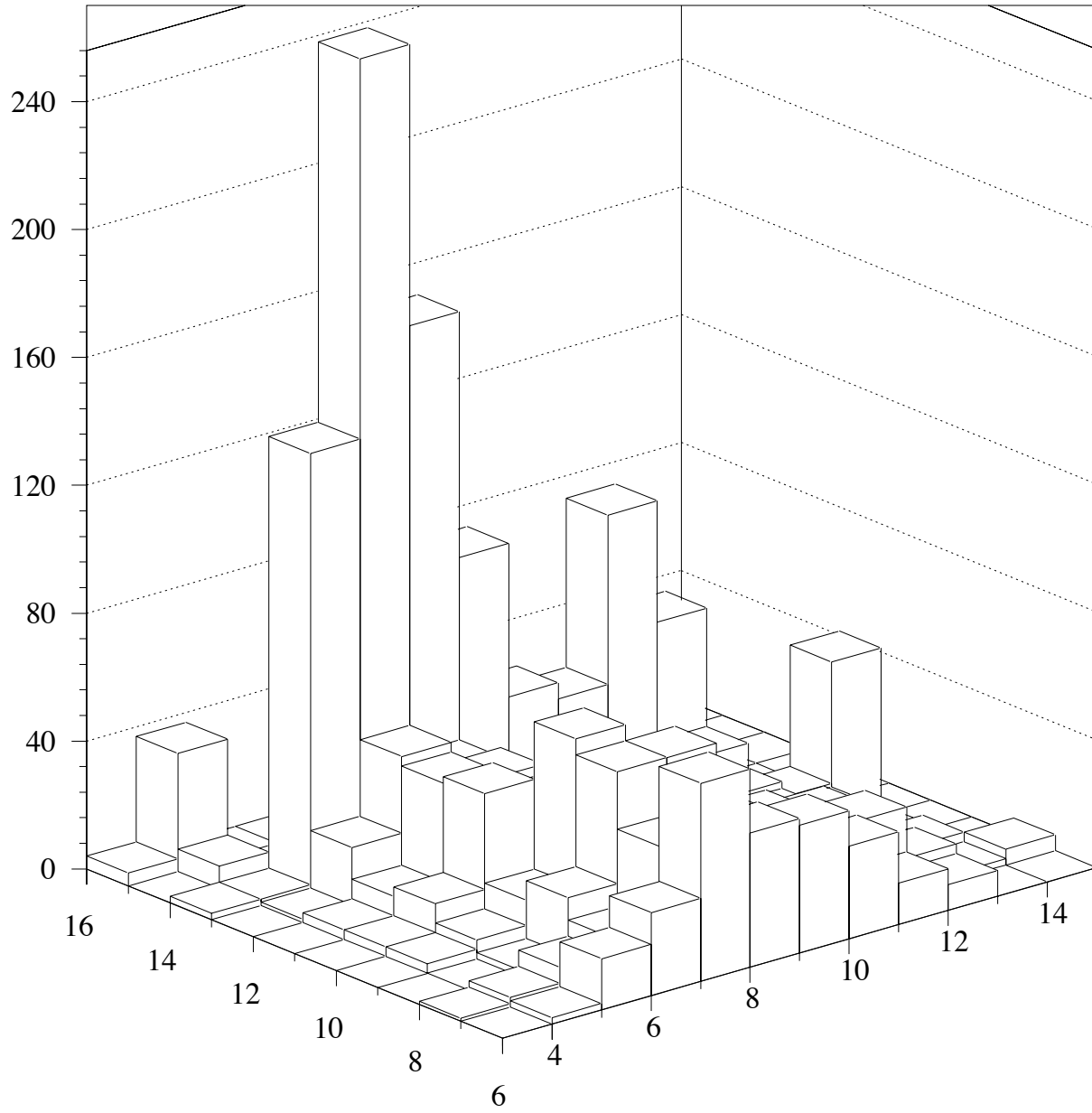


Figure 3.21: Ntuples - Two dimensional data representation

3.5 The SIGMA application and more complex examples

Using the SIGMA processor

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX22                *
PAW > * Examples of the SIGMA processor - 1                      *
PAW > *****
PAW > zone 2 2 | Divide picture two by two
PAW > opt GRID | Draw grid on picture
PAW > SET NDVX 520 | Ask for 20 primary divisions
PAW > * -- Define array x with 200 elements values between 0 and 2 pi
PAW > sigma x=array(200,0#2*PI)
PAW > sigma sinus=sin(x) | sinus is array defined implicitly
PAW > sigma sinx=sin(x)/x | sinx ditto
PAW > gra 200 x sinus | Make graph of array sinus
PAW > set dmod 2 | New line style
PAW > gra 200 x sinx 1 | Make graph of array sinx
PAW > set dmod 0 | Default line style
PAW > * -- Define array x with 300 elements filled with values between 0 to 8
PAW > SIGMA x=array(300,0#8)
PAW > * -- Hyperbolic cosine oscillations are invisible
PAW > SIGMA g=cosh(x)+sin(1/(.1+X*X))
PAW > gra 300 X G | Plot the vectors x and g
PAW > * -- Define array x with 300 elements filled with values between 0 to 3
PAW > SIGMA x=array(300,0#3)
PAW > SIGMA g=cosh(x)+sin(1/(.1+X*X)) | Calculate the ordinate
PAW > gra 300 X G | Plot the vectors x and g
PAW > * -- Define array x with 300 elements filled with values between 0 to 1
PAW > SIGMA x=array(300,0#1)
PAW > SIGMA g=cosh(x)+sin(1/(.1+X*X)) | Calculate the ordinate
PAW > gra 300 X G | Plot vectors x against g

```

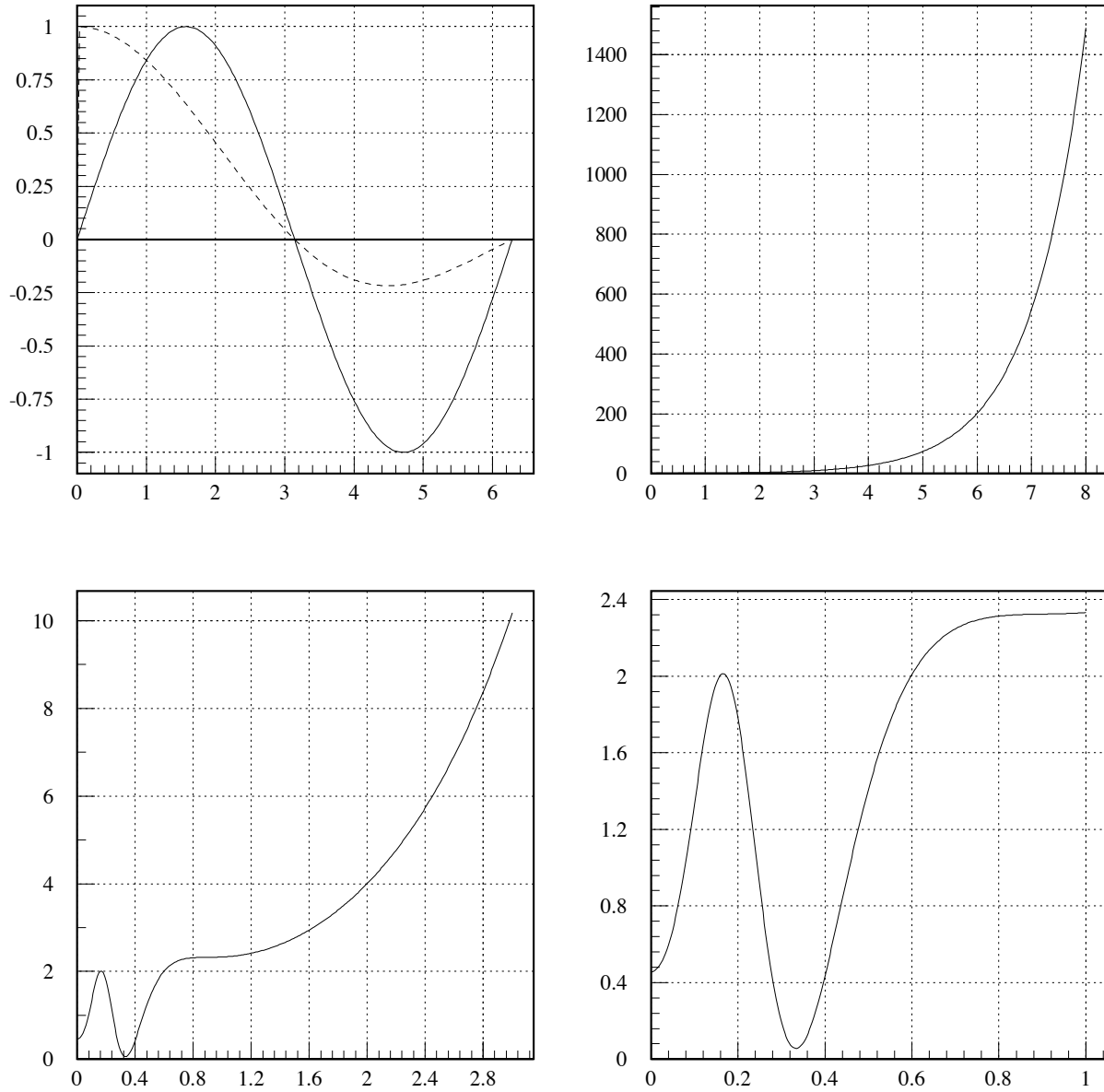


Figure 3.22: Using the SIGMA processor - Trigonometric functions

More examples of using the SIGMA processor

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX23                *
PAW > * Examples of the SIGMA processor - 2                      *
PAW > *****
PAW > zone 2 2 | Divide picture two by two
PAW > * -- Define array x with 200 elements filled with values between 0 to 5
PAW > sigma x=array(200,0#5)
PAW > sigma A=8 | Assign scalar A
PAW > sigma B=.01 | Assign scalar B
PAW > sigma Y=EXP(-X)*SIN(A*X)+B*X*X | Y is an array function of A and B
PAW > opt GRID | Draw grid on picture
PAW > SET NDVX 520 | Ask for 20 primary divisions
PAW > gra 200 x y | 2-dim representation y versus x
PAW > opt NGRI | No grid on picture
PAW > SIGMA x=array(200,0#2*pi) | Array between 0 and 2 pi
PAW > *
PAW > * -- Define some more arrays
PAW > *
PAW > SIGMA s=sin(x) | (automatic creation of array s)
PAW > SIGMA S2=S/2 | ditto s2
PAW > SIGMA c=cos(x) | ditto c
PAW > SIGMA c2=c/2 | ditto c2
PAW > SIGMA s4=s/4 | ditto s4
PAW > SIGMA c4=c/4 | ditto c4
PAW > *
PAW > * -- Plot all arrays on same plot
PAW > *
PAW > gra 200 s c
PAW > gra 200 s2 c 1
PAW > gra 200 s4 c 1
PAW > gra 200 s c2 1
PAW > gra 200 s2 c2 1
PAW > gra 200 s4 c2 1
PAW > gra 200 s c4 1
PAW > gra 200 s2 c4 1
PAW > gra 200 s4 c4 1
PAW > *
PAW > * -- An array of 100 elements with values between 0 and 59.77 (19*pi)
PAW > *
PAW > sigma a=array(100,0#59.77)
PAW > SIGMA NC=NCO(A) | interrogate SIGMA to know array length
PAW > SIGMA y=cos(a)*a | y becomes an array of length 100
PAW > SIGMA x=sin(a)*a | x becomes an array of length 100
PAW > GRA NC X Y | Plot x versus y
PAW > SIGMA a=a*2.55555 | Increase the amplitude
PAW > SIGMA y=cos(a)*a | y becomes an array of length 100
PAW > SIGMA x=sin(a)*a | x becomes an array of length 100
PAW > GRA NC X Y | Plot x versus y

```

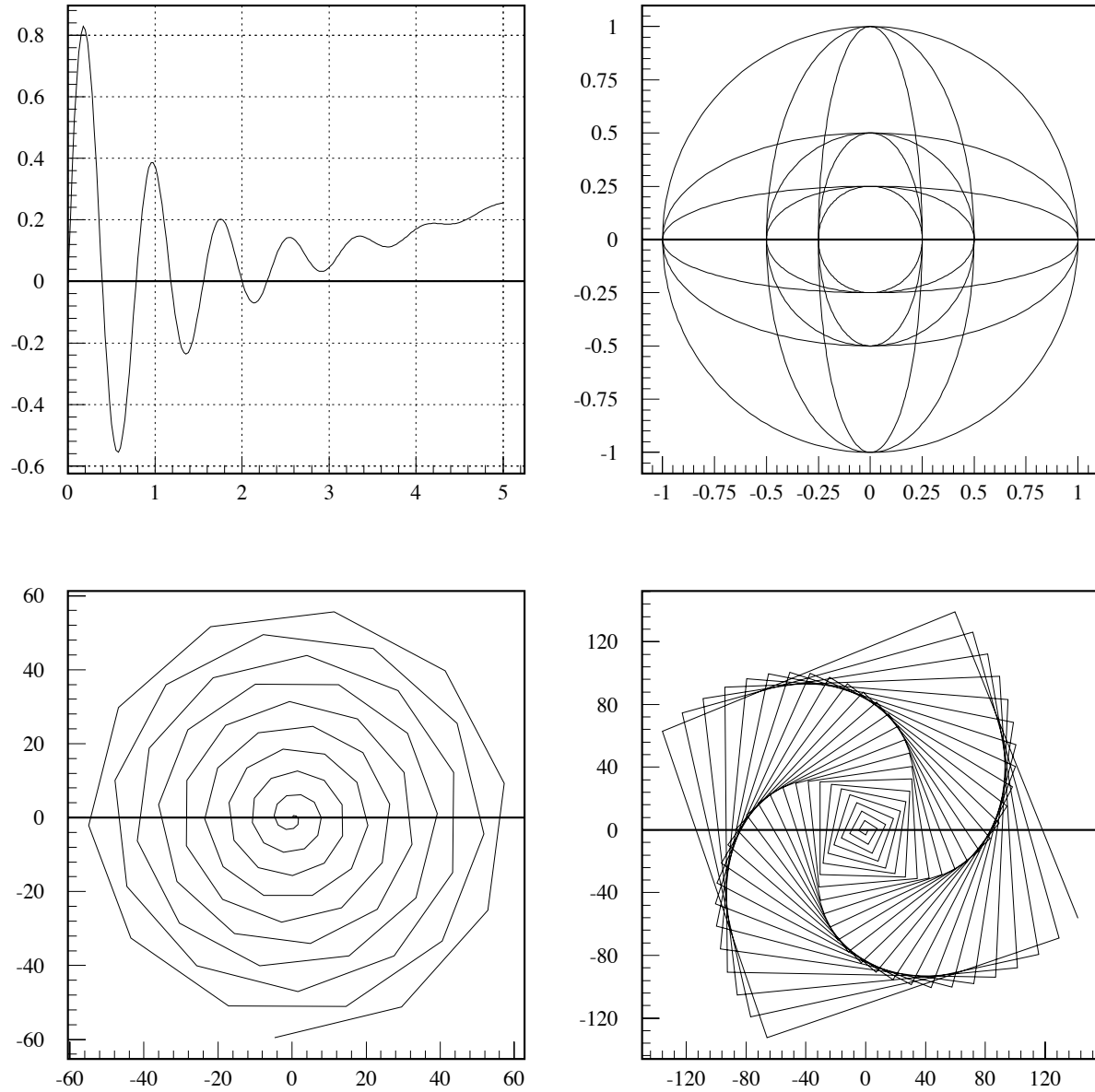


Figure 3.23: Using the SIGMA processor - More complex examples

Updating histogram contents

PAW > *****	
PAW > *	TUTORIAL EXAMPLE PAWEX24
PAW > *	*
PAW > * Operations on histograms (Keep and Update)	*
PAW > *****	
PAW > <u>histogram/file 1 pawhists.rzdat</u>	| Open histogram file
PAW > <u>Zone 1 2</u>	| Divide plot in 2 vertically
PAW > <u>opt grid</u>	| Draw grid on picture
PAW > <u>set grid 1003</u>	| Horizontal grid only with line type 3
PAW > <u>set hcol 1005</u>	| Histogram colour
PAW > <u>h/pl 120 k</u>	| Plot hist 120 and keep in memory
PAW > <u>set grid</u>	| Default grid (horizontal + vertical)
PAW > <u>set htyp -3</u>	| Hatch style histogram colour
PAW > <u>h/pl 110</u>	| Plot histogram 120
PAW > <u>set hcol 1002</u>	| Histogram colour
PAW > <u>h/pl 110 +</u>	| Add 110 on the last kept Histogram
PAW > <u>set htyp 144</u>	| Histogram hatch style
PAW > <u>h/pl 130 +</u>	| Add 130 on the last kept Histogram
PAW > <u>zone</u>	| Reset zone
PAW > <u>close 1</u>	| Close input unit

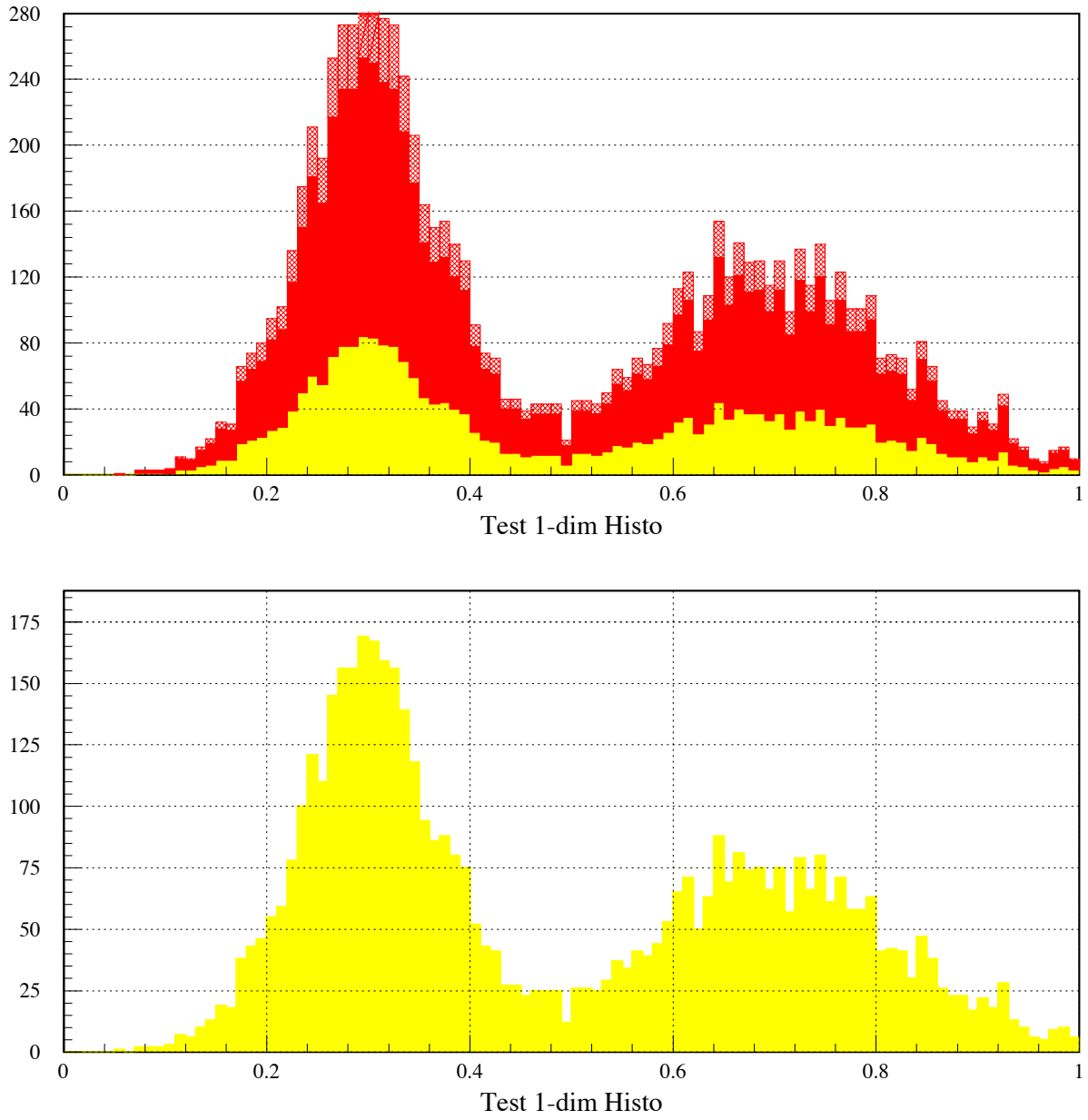


Figure 3.24: Histogram operations (Keep and Update)

Merging pictures

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX25                *
PAW > * Merge pictures onto one plot                            *
PAW > *****
PAW > edit PICTMERGE | Look at the macro for merging plots
Macro PICTMERGE HID=0 S1=1 S2=100
*****
* Macro Merge : Companion macro to PAW TUTORIAL EXAMPLE PAWEX25 *
*****
next | Initialise next picture
set * | Reset Graphics settings
opt * | Reset options
opt NBOX | No box around picture
set hwid 4 | Width of histogram lines
set bwid 4 | Width of box lines
set pwid 4 | Width of picture lines
igset lwid 4 | Width of lines
set vfon -1042 | Axes font (GKSGRAL font -104, precision 2)
set lfon -1042 | Axis labels font
swi Z | Z mode only
pic/cr MERGE2 | Create a picture with name MERGE2
set HTYP -3 | Set hatch type -3
hi/pl [hid] | Plot histo HISTID into picture MERGE2
set htyp 244 | Set histo hatch style
hi/pl [hid]([s1]:[s2]) s | Hatch sub-range of histo HISTID
pic/cr MERGE1 | Create next picture
set HTYP -3 | Reset hatch style
opt utit | No histogram title
opt grid | Draw grid on inset
hi/pl [hid]([s1]:[s2]) | Plot the subrange into picture MERGE1
opt ngri | Eliminate option grid
izpict MERGE2 c | Make MERGE2 current picture
pi/merge MERGE1 .45 .45 .47 D | Merge picture MERGE1 with current picture
swi G | G mode only
return
PAW > histogram/file 1 pawhists.rzdat | Open histogram file
PAW > EXEC PICTMERGE hid=110 s1=31 s2=40 | Plot histo 110 with subrange as inset
PAW > close 1 | Close input unit

```

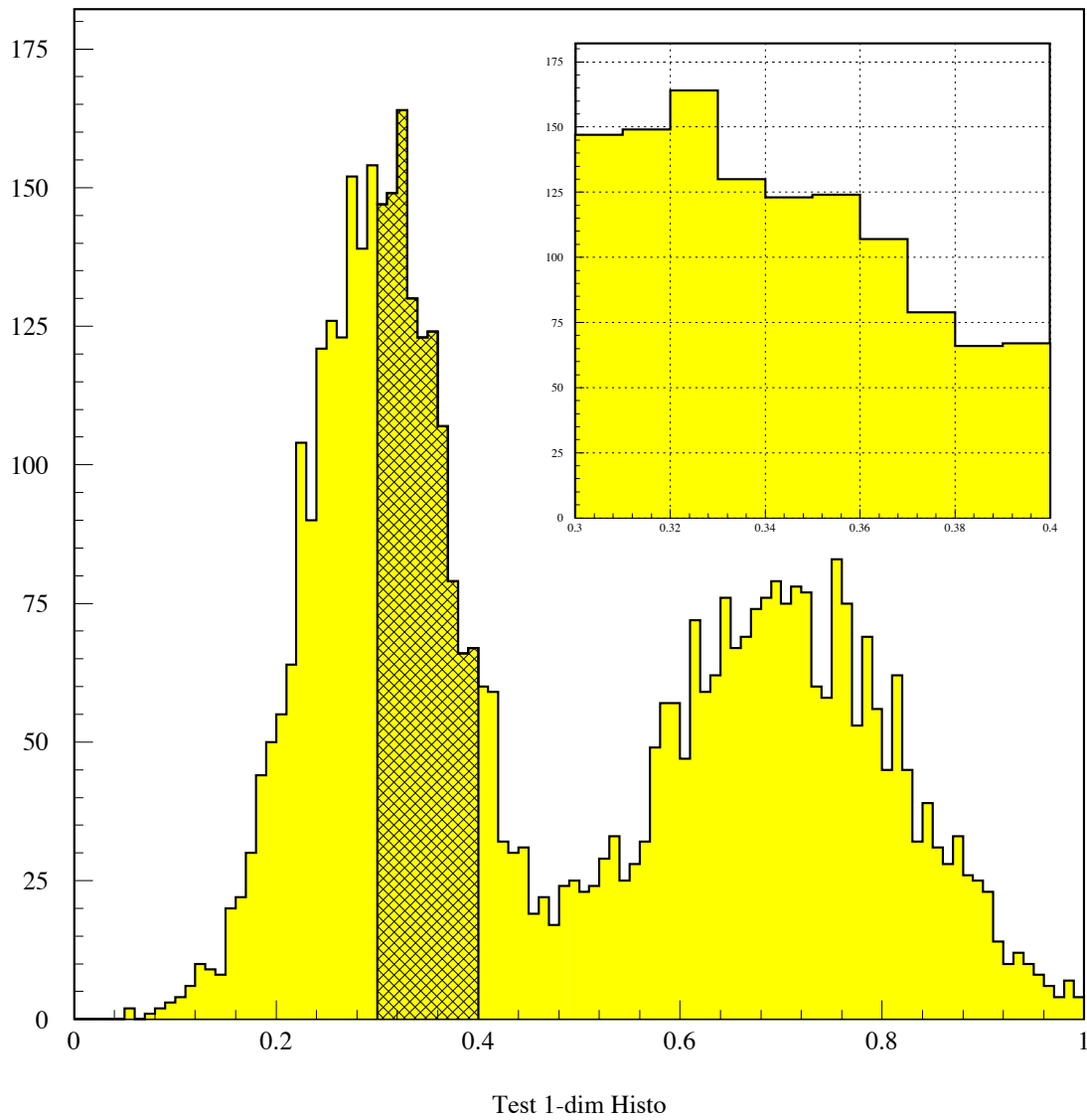


Figure 3.25: Merging several pictures into one plot

Pie chart and PostScript simulation
--

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX26                *
PAW > * Various forms of a PIE chart                            *
PAW > *****
PAW > edit PIE                                | Look at the macro for pie chart
MACRO PIE
*****
*      Macro PIE : Companion macro to PAW TUTORIAL EXAMPLE PAWEX26      *
*****
alias/cre colbackg 0                | background colour
alias/cre colcompl 1                | complement of background
alias/cre colred   2                | red
alias/cre colgreen 3                | green
alias/cre colblue  4                | blue
alias/cre colyellow 5              | yellow
alias/cre colpurple 6              | purple
alias/cre colcyan  7                | cyan

v/cre values(5) R 28.3 18.6 16.9 13.5 22.7                | create vector with values
v/cre offset(5) R 2*0. 2*20. 0.                | C
v/cre colour(5) R colred colgreen colblue colyellow colpurple
v/cre style(5) R 111 222 333 444 265
label 1 5 'Sun' 'DEC' 'HP' 'Apollo' 'Other'

igset bord 1                | Draw border on pie chart
zone 2 2                    | Divide picture in 2 by 2
null 0 20 0 20 A            | Initialize first picture part
igset fais 1
pie 10. 10. 7. 5 vws p offset ! colour
null 0 20 0 20 A
igset fais 1
pie 10. 10. 7. 5 vws l offset ! colour
null 0 20 0 20 A
pie 10. 10. 7. 5 vws n offset style
null 0 20 0 20 A
pie 10. 10. 7. 5 vws l offset style
al/de *
RETURN
PAW > EXEC PIE                                | Execute macro for pie and bar chart

```

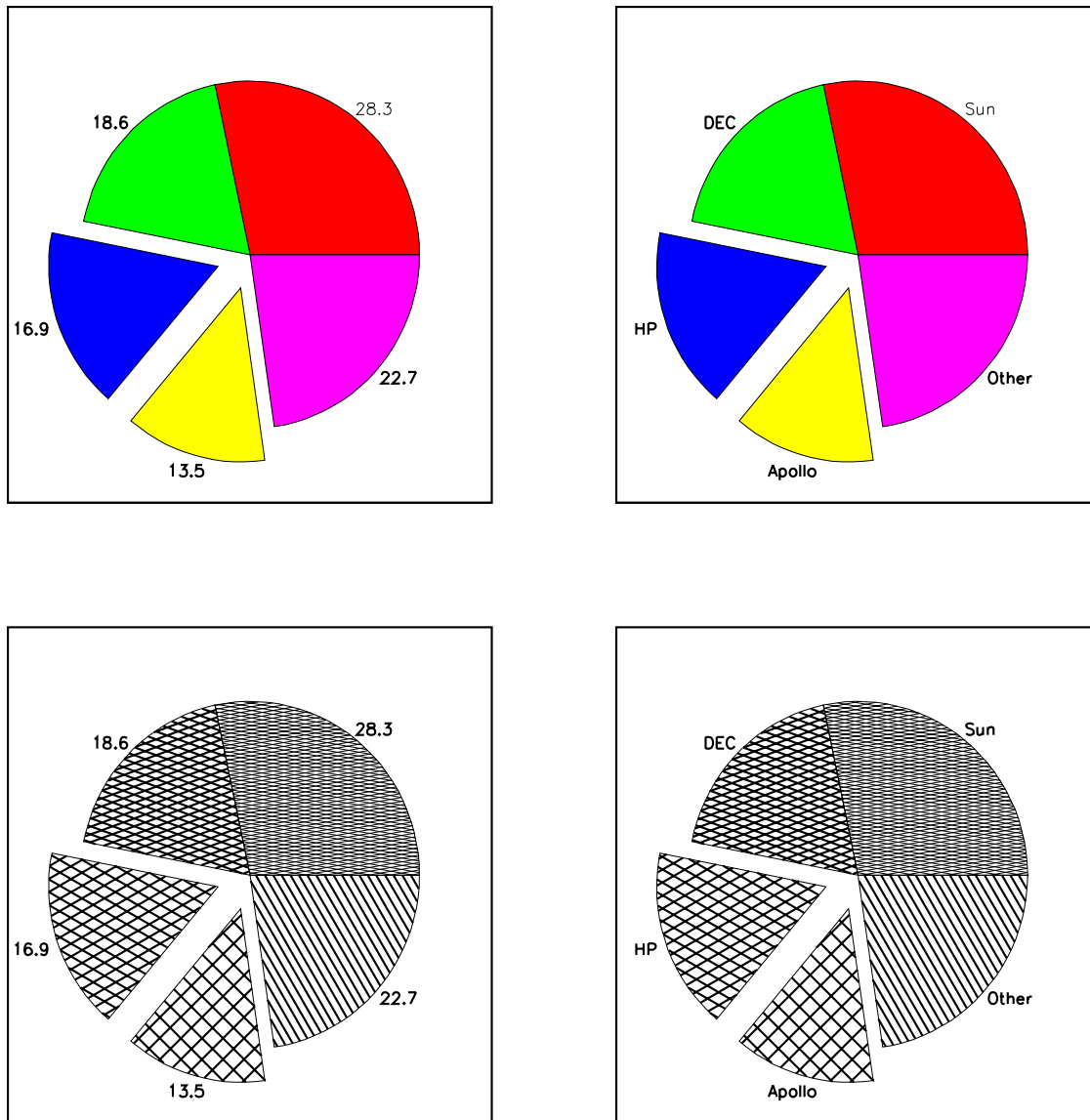


Figure 3.26: Pie charts with hatch styles and PostScript colour simulation

Making a complex graph with PAW

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX27                *
PAW > * Make a complex graph with PAW using PostScript fonts    *
PAW > *****
PAW > edit COMPTIME | Look at the macro for computer time
MACRO COMPTIME
*****
*                Companion macro to PAW TUTORIAL EXAMPLE 27        *
*****
OPT * | Reset options
SET * | Reset HPLOT settings
igset * | Reset HIGZ settings
ve/de * | Delete all vectors
OPT NBOX | No box on plot
OPT LOGY | Logarithmic plot in y
OPT TIC | Tic marks
OPT UTIT | User title
opt ZFL1 | Keep picture in memory
size 16 20 | Size of picture
set hwid 4 | Width of histogram lines
set fwid 4 | Width of fit lines
set bwid 4 | Width of box lines
set pwid 4 | Width of picture lines
igset lwid 4 | Width of lines
set VSIZ 0.20 | Size of axis values smaller
set YGTI 1.2 | Y position of global title
set XVAL 0.4 | Distance y axis to axis values
set YVAL 0.2 | Distance x axis to axis values
set XLAB 1.0 | Distance y axis to label
set YLAB 0.8 | Distance x axis to label
set XTIC 0.15 | Length x axis tick marks
set YTIC 0.15 | Length y axis tick marks
set ASIZ 0.26 | Size of axis text
set GSIZ 0.35 | Global title size
set gfon -60 | Global title font
set vfon -60 | Font of axis values
set lfon -10 | Font of axis labels
igset lwid 4 | Quadruple line width
title_gl 'CERN Central Computer Usage' | Global title of picture
* -- IBM168 equivalent hours used for each year since 1960
vector/create vy(30) R 9.2 11.8 34.9 60.7 87.1 217.8 360 1250 2500 4006 _
  4478 5590 5910 6246 10879 12849 18429 19481 21171 25005 _
  31219 33928 37057 45520 57000 75957 98806 118993 131800 151138
sigma vx=array(30,60#89) | Define vector of x values 60 to 89
ve/cre f1(2) r 2*0.0 | Create vector V1 for fit 1 result
ve/cre f2(2) r 2*0.0 | Create vector v2 for fit 2 result
* -- Exactly 30 divisions in X with labels centered on divisions
SET NDVX -30.05
NULL 60 90 5 250000 | Draw empty plot with given limits
igset MSCF 0.75 | Specify marker scale factor
igset mtyp 21 | Data points with polymarker
graph 30 vx vy p | Plot data points
ve/fi vx(:10) vy(:10) ! e ws ! f1 | Fit first part of data points
ve/fi vx(10:) vy(10:) ! e ws ! f2 | Fit second part of data points
arrow 64. 62. 10. 10. 0.15 | Draw arrow
igset txal 20 | Center text horizontally
igset chhe 0.18 | Character height
itx 63. 12. 'IBM 709' | Write text
arrow 65. 63. 35. 35. -0.11 | Draw arrow
itx 64. 40 'IBM 7090' | Write text
arrow 75. 65. 150. 150. -0.11 | Draw arrow
itx 70. 200. 'CDC 6600' | Write text
arrow 85. 72. 4000. 4000. -0.11 | Draw arrow
itx 78.5 4500. 'CDC 7600' | Write text
arrow 82. 78. 6500. 6500. -0.11 | Draw arrow

```

```

itx 80. 7500. 'IBM 168 ' | Write text
arrow 81. 79. 10000. 10000. -0.11 | Draw arrow
itx 80. 12000. 'IBM 3032' | Write text
arrow 85. 81. 18000. 18000. -0.11 | Draw arrow
itx 83. 20000. 'IBM 3081' | Write text
igset txal 10 | Left align text
arrow 84. 82. 27000. 27000. -0.11 | Draw arrow
itx 82. 30000. 'SIEMENS 7880' | Write text
igset txal 20 | Center text horizontally
arrow 90. 84. 42000. 42000. 0.11 | Draw arrow
itx 87. 50000. 'SIEMENS 7890' | Write text
arrow 90. 85. 68000. 68000. 0.11 | Draw arrow
itx 87.5 72000. 'IBM 3090' | Write text
arrow 90. 88. 100000. 100000. 0.11 | Draw arrow
itx 89. 110000. 'CRAY' | Write text

arise=$sigma(int((exp(f1(2))-1)*100+0.5))//'% per Annum rise' | Get slope of annual increase from fit 1
xhand=68. | X coordinate for hand and text
yhand=$sigma(exp(f1(1)+f1(2)*[xhand])) | Calcualte y coordinate from fit 1
EXEC DRAW X=[xhand] Y=[yhand] TEXT=[arise] | Draw the hand and text
arise=$sigma(int((exp(f2(2))-1)*100+0.5))//'% per Annum rise' | Get slope of annual increase from fit 2
xhand=84. | X coordinate for hand and text
yhand=$sigma(exp(f2(1)+f2(2)*[xhand])) | Calcualte y coordinate from fit 2
EXEC DRAW X=[xhand] Y=[yhand] TEXT=[arise] | Draw the hand and text
atitle 'Year ' 'IBM 168 Units used ' | Add axis title to picture
RETURN

MACRO DRAW
igset TXAL 30 | Right align
igset TANG -35. | Text angle
igset TXFP -140 | Zapfdinbats font
igset CHHE 0.50 | Character height
itx $SIGMA([X]-0.9) [Y] + | A hand in the font ZapfDingbats
igset TXAL 30 | right align text
igset TANG 0. | Text angle
igset TXFP -30 | Font for accompanying text
igset CHHE 0.22 | Character height
y = y * 1.70 | Start text somewhat above hand
itx [X] [Y] [TEXT] | The text to be written
RETURN

PAW > EXEC COMPTIME | Execute macro for computer time

```

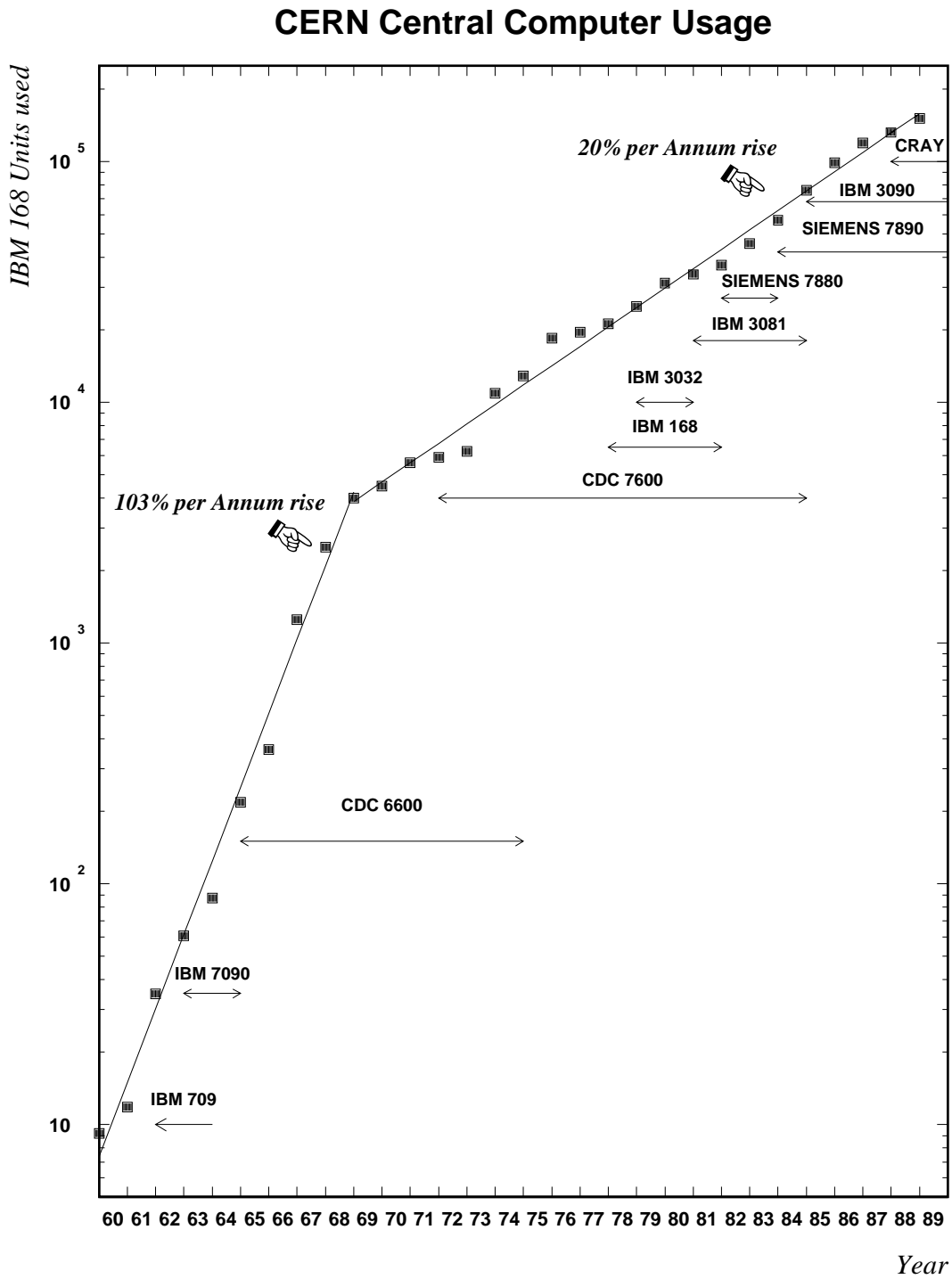



Figure 3.27: A complex graph with PAW

PAW, PostScript and making slides

```

PAW > *****
PAW > *                TUTORIAL EXAMPLE PAWEX30                *
PAW > * Making slides with PAW and PostScript                *
PAW > *****
PAW > edit slide                | Look at master macro to produce slide
macro SLIDE xsize=18 ysize=22 width=0.4 name='Author/CERN CONF99' sn=' ' title=' '
*****
*                PAW TUTORIAL EXAMPLE 30 - SLIDE                *
* General macro to draw contours of SLIDE                *
*****
xmax = [xsize]-[width]                | X range for slide
ymax = [ysize]-[width]                | Y range for slide
size [xsize] [ysize]                | Total size for slide
next                | Initialize next frame
igset lwid 2                | Double line width
pave 0 [xmax] 0 [ymax] [width] 0 1005 tr                | Draw a shaded box around the picture
igset lwid 1                | Single line width
xtitle = $sigma(([xsize]-0.2)/2.)                | X coordinate for title
ytitle = [ysize]-1.5                | Y coordinate for title
igset txfp -70                | Defined new font (Helvetica-Bold-Oblique)
igset txal 20                | Text alignment Hor-Centered / Vert-Base
igset chhe 0.6                | Set character height
itx [xtitle] [ytitle] [title]                | Write text (title)
igset chhe 0.3                | Set character height
igset txal 10                | Text alignment Hor-Left / Vert-Base
xtext = [xmax]-0.2                | X coordinate for name
ytext = 0.1                | Y coordinate for name
igset txfp -1042                | Defined new font (Helvetica-Bold-Oblique)
igset chhe 0.2                | Set character height
igset txal 30                | Text alignment Hor-Right / Vert-Base
itx [xtext] [ytext] [name]                | Write text (name)
igset txal 10                | Text alignment Hor-Left / Vert-Base
itx 0.1 0.1 [sn]                | Write text (slide name)
igset chhe 0.3                | Set character height
igset lwid 2                | Double line width
return
PAW > edit discomp                | Look at example macro showing use of slide
MACRO DISCOMP
*****
*                PAW TUTORIAL EXAMPLE 30 - DISCOMP                *
* Text for slide example DISCOMP                *
*****
exec slide sn='DisComp' title='Distributed Computing'                | Define the outline of the slide
igset txfp mainfont                | Defined font via alias
igset chhe 0.5                | set character height
itx 2 17 'With a distributed operating system (not yet !)'                | Write text
itx 2 15 'With tools on top (RPCs, NCS,.. ?)'                | Write text
igset chhe 0.4                | Set character height
itx 3 14 Tmess                | Write text
itx 3 13 Tfork                | Write text
itx 3 12 Tdata                | Write text
itx 3 11 Tcomp                | Write text
* -- Defined new font (Helvetica-Bold-Oblique)
igset txfp -70
itx 5 14 'Time to send message to remote process'                | Write text
itx 5 13 'Time to fork a process'                | Write text

```


Distributed Computing

☆ **With a distributed operating system (not yet !)**

☆ **With tools on top (RPCs, NCS,.. ?)**

Tmess *Time to send message to remote process*

Tfork *Time to fork a process*

Tdata *Time to pass data (in and out)*

Tcomp *Time used for computation on remote process*

$$\text{Efficiency} = \frac{T_{\text{comp}}}{T_{\text{comp}} + T_{\text{mess}} + T_{\text{fork}} + T_{\text{data}}}$$

Many time consuming applications today have:

Efficiency > 0.9

Figure 3.28: Making slides with PAW using PostScript

Part II

PAW - Commands and Concepts

Chapter 4: User interface - KUIP

4.1 The PAW command structure

All PAW commands may be seen as a path along the PAW tree structure:

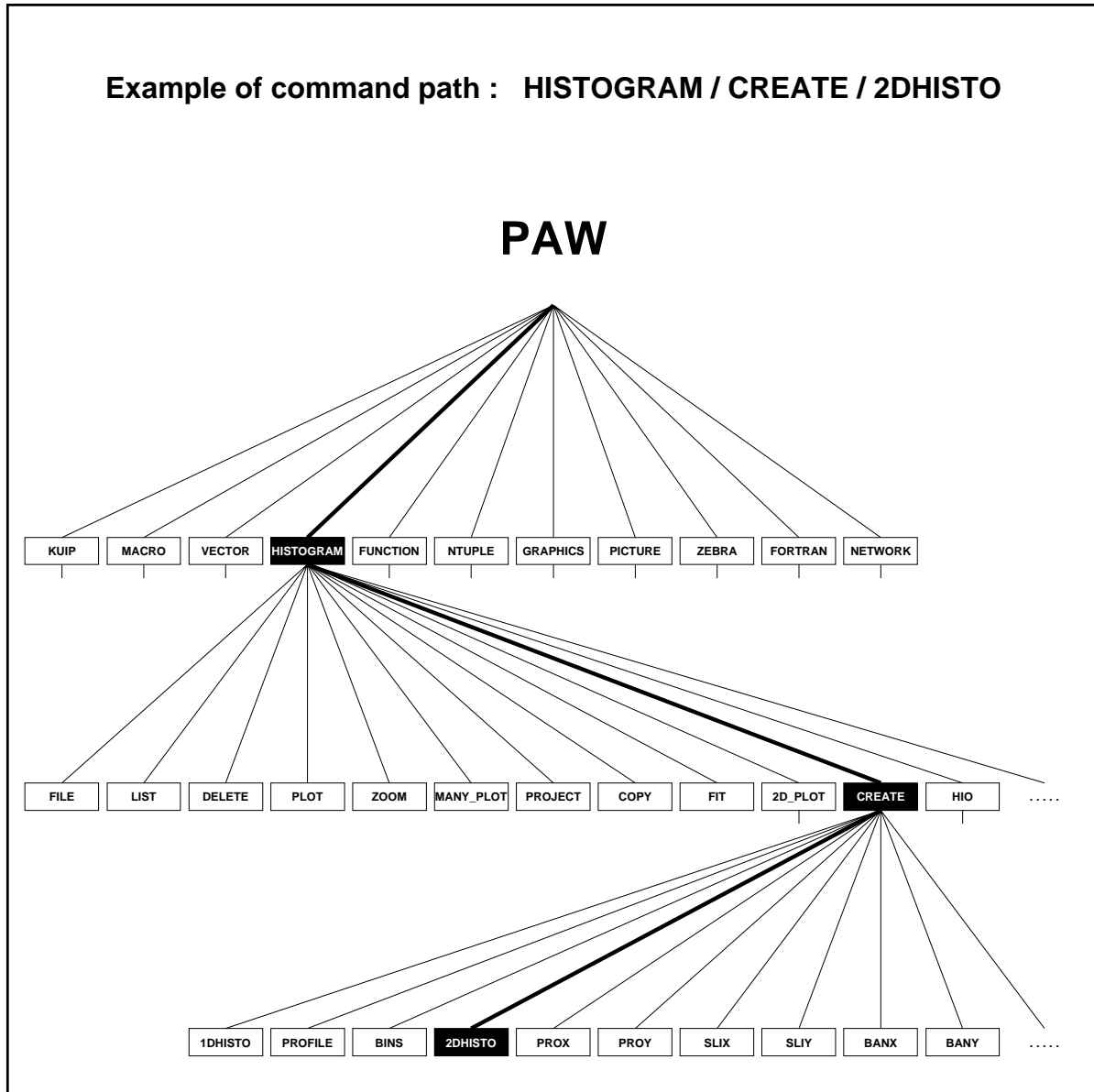


Figure 4.1: Example of the PAW command tree structure

4.2 Multiple dialogue styles

PAW is based on the KUIP [5] User Interface package, which can provide different types of dialogue styles. It is possible to change interactively from one style to another using the command `STYLE`.

4.2.1 Command line mode

In command mode the user enters a command line via the terminal keyboard.

The general syntax of a `command_line` is a `command_name` optionally followed by a `parameter_list`. The `command_name` and `parameter_list` are separated by one or more blanks (therefore, no blanks should appear within the `command_name`). Using regular expressions notation one can write:

```
command_line ::= command_name ( blank+ parameter_list )?
```

where the postfix unary operator `'+'` means “one or more instances of the postfixed item” and `'?'` means “zero or one instances of the postfixed item”. The parameters in the `parameter_list` are again separated by one or more blanks:

```
parameter_list ::= parameter ( blank+ parameter )*
```

where `'*'` means “zero or more instances of the postfixed item”. No blanks should then appear within a parameter, unless the whole parameter is enclosed in single quotes, like for example “This parameter has blanks” or the blank filled parameter `' '`.

The command name is a structured name representing the path along the inverted tree structure handled by KUIP. Each element of the path, called `command_element`, is separated from the others by one slash:

```
command_name ::= command_element ( / command_element )*
```

The rightmost `command_element` of a `command_name` must be a leaf of the tree, i.e. a terminal `command_element`, while the others are considered menus. The `command_name` can have up to 10 levels of command elements (i.e. 9 levels of menus).

Command abbreviations

A command can always be abbreviated, as long as it does not become ambiguous with other commands, by omitting:

- the leftmost command elements
- the rightmost characters of a command element

The shortest unambiguous abbreviation for any command is not fixed, but depends on the whole command tree structure: KUIP takes care to list all possible ambiguities should the user enter an ambiguous command.

The list of all executable commands can be obtained just by typing one slash. This is a command line having a null command element both to the left and to the right of the separator slash; by definition a null command element is ambiguous with every non-null command element, therefore all the available commands will be listed as possible ambiguities.

Examples of ambiguous commands

```
PAW > CONT
*** Ambiguous command. Possible commands are :
/HISTOGRAM/2D_PLOT/CONTOUR
/HISTOGRAM/GET_VECT/CONTENTS
/HISTOGRAM/PUT_VECT/CONTENTS
PAW > PUT_VECT/CONTENTS
Histogram Identifier (<CR>=110): 100
Vector name (<CR>=XYZ): VEC
```

```
PAW > P/C
*** Ambiguous command. Possible commands are :
/HISTOGRAM/PUT_VECT/CONTENTS
/PICTURE/CREATE
/PICTURE/COPY
```

```
PAW > P/CO
*** Ambiguous command. Possible commands are :
/HISTOGRAM/PUT_VECT/CONTENTS
/PICTURE/COPY
PAW > PU/C
Histogram Identifier (<CR>=100): 110
Vector name (<CR>=VEC): VV
```

The shortest unambiguous abbreviation for any command is not fixed, but depending on the whole command tree structure: KUIP takes care to list all possible ambiguities should the user have entered an ambiguous command.

The list of all executable commands can be obtained just by typing one slash. This is a command line having a null command element both to the left and to the right of the separator slash; by definition a null command element is ambiguous with every non-null command element, therefore all the available commands will be listed as possible ambiguities.

Parameters

As explained above, a command line consists of a **command** part optionally followed by a **parameter** part. For example, the PAW command NTUPLE/LIST has no parameters, while NTUPLE/PRINT has one parameter, i.e. the Ntuple identifier.

Using the USAGE command

```
PAW > USAGE NTUPLE/LIST

* NTUPLE/LIST

PAW > USAGE NTUPLE/PRINT

* NTUPLE/PRINT IDN
```

Parameters can be **mandatory** or **optional**. For example the command ZEBRA/DZ/STORE has one optional parameter, i.e. the “ZEBRA store number”. An optional parameter always has a **default value**, which is used when the user does not specify the parameter. In the example above the default value is 0, therefore entering just STORE is equivalent to STORE 0.

On the other hand the command ZEBRA/FZ/TOALPHA has one mandatory parameter, i.e. the name of a FZ text file. If the user enters just TOALPHA, he will be prompted also for the file name:

```
PAW > TOALPHA
Name of the FZ text file (<CR>=FF.DAT): GG.DAT
```

The **order** of parameters in the command line is important and must match the semantic definition of the command. Mandatory parameters are always specified before any optional parameters.

An **exclamation mark** may be used as default value filler character. As an example consider the following PAW command:

```
PAW > USAGE NTUPLE/PLOT
* NTUPLE/PLOT IDN [ UWFUNC NEVENT IFIRST NUPD CHOPT ]
```

which has one mandatory and five optional parameters. If only the fourth parameter, IFIRST, needs to be specified (hence taking the default values for all other optional parameters), then one may enter:

```
PAW > NTUPLE/PLOT 30 ! ! 1000
```

Parameters can be entered in command lines also by their name, i.e. independently from their position. This is particularly useful when an optional parameter has to be specified for a command with several optional parameters. Values are assigned to parameters by indicating the name of the parameter, followed by an equal sign, followed by the value, with no blanks in between (see first line of the example below). When the parameter's name is CHOPT a shortcut is possible: a minus sign preceding a (non-numerical) value means 'CHOPT=' (see third and fourth line of the example below). If a parameter (with no NAME=) is specified after a named parameter, it will refer to the parameter following the named one (see second line of the example below).

For example, consider the following command:

```
NTUPLE/PLOT IDN [ UWFUNC NEVENT IFIRST NUPD CHOPT ]
```

One could then enter:

```
N/PL 123.x NUPD=100      instead of N/PL 123.x ! ! ! 100
N/PL NEVENT=1000 500   instead of N/PL idn ! 1000 500 (idn must be given interactively)
N/PL 123.x CHOPT=B     instead of N/PL 123.x ! ! ! ! B
N/PL 123.x -B          same as above
```

Note that, unlike command elements, parameter names cannot be abbreviated.

4.2.2 An overview of KUIP menu modes

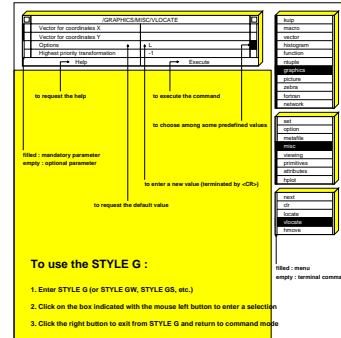
Only a short overview is given here. See the KUIP manual for more details.

Alphanumeric, entered by STYLE AN or STYLE AL.

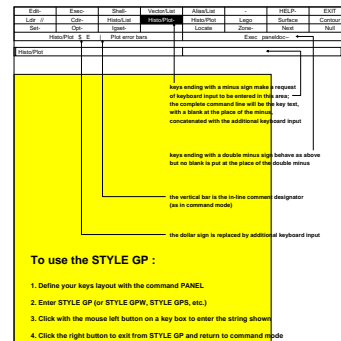
The desired command is selected from a list by number or by letter.

Graphics, entered by STYLE G or STYLE GP. This mode is particularly interesting for workstations. It should not be used with simple terminals.

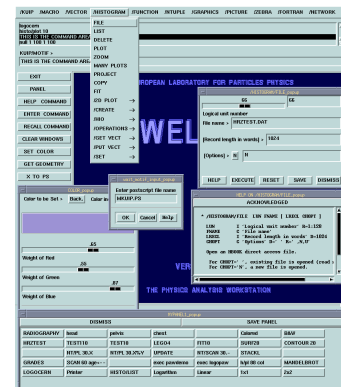
- **STYLE G**: Pull-down menus, fixed layout, reflecting the command structure;



- **STYLE GP**: Panels of function keys, allowing interactive user definable multiple layouts.



Motif This mode, to be released soon, is suited for X11 based WorkStations or X-terminals.



User:

This mode must be used in conjunction with routine KUSER (see KUIP manual).

4.3 Macros

A macro is a set of command lines stored in a file, which can be created/edited with a local editor and executed with the command EXEC. For example the command

```
PAW > EXEC MNAME
```

executes the command lines contained in the macro file MNAME. As a macro file can contain several macros, a dash sign (#) is used to select a particular macro inside a file:

- If MNAME does not contain the character '#', the file MNAME.KUMAC is searched and the first macro is executed (it may be an unnamed macro if a MACRO statement is not found as first command line in the file)
- If MNAME is of the form FILE#MACRO, the file named FILE.KUMAC is searched and the macro named MACRO is executed

Example of macro calls

```
PAW > EXEC ABC | Execute first (or unnamed) macro of file ABC.KUMAC
PAW > EXEC ABC#M | Execute macro M of file ABC.KUMAC
```

In addition to all available KUIP commands the special “macro statements” in table 4.1 are valid only inside macros (except for EXEC, which is valid both inside and outside) In the last line of the table par stands for either an argument passed with the command EXEC (in the command mode or from another macro) or a local variable of the macro.

arithmetic_expression and logical_expression are expressions with only two terms, which are defined as follows (“|” stands for “or” and juxtaposition stands for “and”):

```
operand          = par | constant
arithmetic_expression = operand arithmetic_operator operand
arithmetic_operator = + | - | * | /
logical_expression  = operand logical_operator operand
logical_operator    = = | < | <= | > | >= | <>
```

A label is any string in a line that is terminated by a colon (therefore labels must stand alone on a line). A label definition is local to a macro, so that the same label can be re-used in different macros.

The ON ERROR GOTO statement is activated by error conditions of the system and by the application program¹. In executing a macro, the latest ON ERROR GOTO executed is the active one (i.e. the previous one is superseded).

¹More precisely, after execution of a line inside a macro, the variable IQUEST(1) (in COMMON/QUEST/IQUEST(100)) is checked. If it is different from 0, then the ON ERROR GOTO logic is triggered.

Macro Statements	
STATEMENT	DESCRIPTION
MACRO mname par1=val1 ...	begin macro mname
EXEC mname par1 par2=val2 ...	execute macro mname
RETURN	end of a macro
READ par	read macro parameter par from keyboard
SHIFT	control parameters list
label:	label (must terminate with a colon)
GOTO label	jump to label
ON ERROR GOTO label	resume at label on error condition
OF ERROR	temporarily deactivate the ON ERROR GOTO handling
ON ERROR	reactivate the latest ON ERROR GOTO handling
IF logical_expression GOTO label	conditional statement
IF-THEN, ELSEIF, ELSE, ENDIF	Macro flow control
CASE, ENDCASE	Macro flow control
WHILE-DO, ENDWHILE	Macro flow control
REPEAT, UNTIL	Macro flow control
DO, ENDDO	Macro flow control
FOR, ENDFOR	Macro flow control
BREAKL	Macro flow control
EXITM	Macro termination
par = arithmetic_expression	assignment statement

Table 4.1: List of statements possible inside KUIP macros

Positional parameters can be passed to a macro, separated by blanks. Inside a macro, positional parameters can be retrieved by including in brackets the number representing their order in the list.

Example of macro file	Example of macro execution
<pre>MACRO ABC MESSAGE [1] [3] [2] RETURN</pre>	<pre>PAW > EXEC ABC P1 123 'This is P3'</pre> <pre>P1 This is P3 123</pre>

Note that normal variables are not translated if they have not been assigned a value, whereas unassigned positional parameters are **always** replaced by the blank character ' '. Macro parameters can be concatenated to anything in the command line; whenever a parameter number (or name - see below), enclosed in brackets, is encountered in the command line, it will be substituted by its value before execution of the command line.

Example of macro file	Example of parameter substitution
<pre>MACRO OPEN HISTO/FILE 20 DST[1].DAT RETURN</pre>	<pre>PAW > EXEC OPEN 123TEST will execute the command: HISTO/FILE 20 DST123TEST.DAT</pre>

Non-positional (i.e. named) parameters can also be passed. This is useful when several parameters are associated to a macro. Initial values of parameters should be specified in the MACRO statement. For example, changing the macro OPEN above to:

Example of macro with lot of parameters
<pre>MACRO OPEN LUN=20 NAME=JUNK EXT=DAT LRECL=1024 CHOPT=' ' HISTO/FILE [LUN] [NAME].[EXT] [LRECL] [CHOPT] RETURN</pre>

Example of macro call	Output generated by macro call
<pre>PAW > EXEC OPEN EXT=TEMP LUN=10</pre>	<pre>HISTO/FILE 10 JUNK.TEMP 1024</pre>

Parameters can also be read in at macro run time. When a READ statement is executed the user will be asked to provide values for the given parameters. If just <CR> is entered, the values remain unchanged.

Example of macro reading parameters at run time
<pre>MACRO INP READ PPP READ 1 MESSAGE 'The value of the parameter PPP is ... ' [PPP] MESSAGE 'The value of the parameter 1 is ' [1] RETURN</pre>

The order of priority for macro parameters is such that the values given in the EXEC statement supersede those given in the MACRO statement.

4.3.1 Special Parameters

The following Three special parameters are always defined inside any macro:

- [#] number of arguments given to the macro in the EXEC command which called it.
- [*] String containing the arguments given to the macro in the EXEC command, separated by spaces.
- [@] Return code (see the description of EXITM) of the last macro called by the current one (0 if no macro has been called).

In addition, it is possible to use **indexed positional parameters** of the form:

- [%var] var is a variable with an integer value. This accesses the positional parameter corresponding to the value of var. If var does not have an integer value then parameters of this form will not be replaced by a value. This can be used in conjunction with the parameter [#] to loop through all of the parameters given to a macro.

Note that positional parameters may not be assigned values using this form.

4.3.2 Macro Flow Control

There are several constructs available for controlling the flow of macro execution, which include conditional statement blocks, several looping constructs and variable assignments.

Assignments

Assignments to a variable simply take the form

```
variable = expression
```

where `variable` is the name of the variable to be assigned, and `expression` is the expression which is evaluated to obtain the new value of `variable`.

Inside a macro, values may be assigned to variables without distinction of their type: an automatic mechanism is used to distinguish between integer, real or character type variables.

Example of macro	Output when executing
<pre>MACRO DOC1 A = 10 NN = 1.5 TOT = [A]+[NN] IF [TOT] > 11 THEN MESSAGE Sum of [A] and [NN] is [TOT] AOK = correct ELSE AOK = wrong ENDIF MESSAGE KUIP arithmetic is [AOK]. RETURN</pre>	<pre>PAW > EXEC DOC1 Sum of 10 and 1.5 is 11.5 KUIP arithmetic is correct.</pre>

Unassigned variables cannot be substituted by their values.

Example of macro	Output when executing
<pre>MACRO DOC2 A = 10 NN = 1.5 TOT = [A]+[XX] MESSAGE Result of sum is [TOT] RETURN</pre>	<pre>PAW > EXEC DOC2 Result of sum is 10+[XX] XX is unassigned, hence no value is substituted.</pre>

The right hand side of an assignment command may be a vector name with an optional subscript, as in the following.

Example of a macros containing subscripted vector

```
MACRO DOC3
  A=10
  IF $VEXIST(VV)>0 THEN
    VEC/DEL VV
  ENDIF
  VEC/CRE VV(5)
  VEC/INP VV 10 20 30 2*0
  VECVAR=VV
  MESSAGE First component of vector VV is [VECVAR]
  VECVAR=VV(2)
  MESSAGE Second component of vector VV is [VECVAR]
  VECVAR=VV($VLEN(VV,1))
  MESSAGE Last non-zero component of vector VV is [VECVAR]
  VECVAR=VV($VDIM(VV,1))
  MESSAGE Last component of vector VV is [VECVAR]
RETURN
```

Output generated when running DOC3

```
PAW > EXEC DOC3
First component of vector VV is 10
Second component of vector VV is 20
Last non-zero component of vector VV is 30
Last component of vector VV is 0
```

Note that if no subscript is given, the first component of the vector is used.

4.4 Aliases

Aliases are defined to provide shortcut abbreviations for the input line (either in the command elements or in the parameter list) or for some part of it. An alias name can be any string of characters (except the single quote and the blank) and whenever encountered in an input line it will be replaced literally by its value (another string of characters). Alias substitution does not apply in quoted strings. Aliases are defined by using the command `ALIAS/CREATE`.

Example of a KUIP session
PAW > <u>ALIAS/CREATE M7 'EXEC MACRO7'</u>
PAW > <u>ALIAS/CREATE PP '10 20 30'</u>
PAW > <u>ALIAS/LIST</u>
M7 => EXEC MACRO7
PP => 10 20 30
PAW > <u>M7PP</u>
*** Unknown command
PAW > <u>M7 PP</u>
... Executing: MACRO7 10 20 30
PAW > <u>MESSAGE M7</u>
EXEC MACRO7
PAW > <u>MESSAGE 'M7'</u>
M7

Note that if `CHOPT='C'` then the alias is a command alias, i.e. an alias that will only be translated when it is the first token on a command line, e.g.

PAW > Alias/Create LS DIR C is equivalent to: PAW > DIR

Only when LS is the first token on a command line, i.e. in the case below LS will not be translated:

PAW > SHELL LS

Aliases need separators to be recognized in the input line, as evident from the `M7PP` line in the example above. Possible separators are blank / , = : . % ' ().

A double slash `//` can be used to concatenate aliases without any separator (i.e. to juxtapose them):

```
PAW > Alias/Create DIR disk$dl:[paw]
PAW > Alias/Create FIL mydatafile
PAW > HISTO/FILE 3 DIR//FIL
... Executing: HISTO/FILE 3 disk$dl:[paw]mydatafile
```

Note that aliases are **recursive**. Example:

```
PAW > a/cr aa bb
PAW > a/cr bb cc
PAW > mess aa
cc
PAW > a/cr doc3 'exec doc3'
PAW > doc3
*** Line is too long after alias expansion
```

Another way of legally omitting `EXEC` before the name of a macro, is using the command `DEFAULTS -AUTO`. After having typed this command, a macro is searched whenever a command is not found: when `CMD` fails, `EXEC CMD` is issued automatically. But this is valid only in command mode: this logic is not active within macros, for security and portability reasons.

A more complex example of the use of aliases

Consider the use of ALIAS on a macro file DOC9 (containing three macros):

Example of input macro	Output when executing
<pre>macro doc9 message '... Executing: DOC9' return macro m1 message '... Executing: DOC9#M1' exec m2 return macro m2 message '... Executing: DOC9#M2' return</pre>	<pre>PAW > <u>a/cre m1 'exec doc9#m1'</u> PAW > <u>m1</u> ... Executing: DOC9#M1 ... Executing: DOC9#M2 PAW > <u>a/cre m2 'exec doc9#m2'</u> PAW > <u>m2</u> *** Unknown file EXEC.kumac</pre>

This happens because when the string m2 is substituted by its alias value `exec doc9#m2`, the macro m1 becomes:

```
macro m1
  message '... Executing: MACRO DOC9#M1'
  exec exec doc9#m2
return
```

To avoid this, one could simply add a character (for example an underscore) before the macro names, as:

Example of input macro	Output when executing
<pre>macro _doc9 message '... Executing: _DOC9' return macro _m1 message '... Executing: _DOC9#_M1' exec _m2 return macro _m2 message '... Executing: _DOC9#_M2' return</pre>	<pre>PAW > <u>a/cr m1 'exec doc9new#_m1'</u> PAW > <u>m1</u> ... Executing: _DOC9#_M1 ... Executing: _DOC9#_M2 PAW > <u>a/cr m2 'exec doc9new#_m2'</u> PAW > <u>m2</u> ... Executing: _DOC9#_M2</pre>

4.5 System functions

While aliases have a fixed value, system functions can be seen as aliases whose value is variable and dependent on the function name and its arguments (if any). Therefore, also system functions are literally replaced by their current value whenever encountered in a KUIP command line. System functions, unlike aliases, do not need separators because they are predefined and known by KUIP. Their names always start with a dollar sign, and some of them have a parameter list, enclosed in parentheses. System functions are mainly used inside macros.

Table 4.2: KUIP system functions

System Functions	
Function (arguments)	Returned value
\$STYLE	Current style as defined by command SET/STYLE
\$ANUM	Number of aliases
\$ANAM(I)	Name of I-th alias
\$AVAL(I)	Value of I-th alias
\$LAST	Latest command line executed
\$KEYNUM	Address of latest clicked key in STYLE GP
\$KEYVAL	Value of latest clicked key in STYLE GP
\$ARGS	Command line at program invocation
\$DATE	Current date in format DD/MM/YY
\$TIME	Current time in format HH.MM.SS
\$CPTIME	CP time elapsed since last call (sec)
\$RTIME	Real time elapsed since last call (sec)
\$VDIM(VNAME, IDIM)	Physical length of vector VNAME on dimension IDIM(1..3)
\$VLEN(VNAME, IDIM)	Logical length (stripping trailing '0') of vector VNAME
\$NUMVEC	Current number of vectors
\$VEXIST(VNAME)	Index of vector VNAME (1..\$NUMVEC (0 if inexistent))
\$SUBSTRING(String, IX, NCH)	STRING(IX:IX+NCH-1)
\$UPPER(String)	STRING changed to upper case
\$LOWER(String)	STRING changed to lower case
\$LEN(String)	STRING length, stripping quotes and leading/trailing blanks
\$SIGMA(SIGMA_Expression)	Result of SIGMA_Expression, as computed by SIGMA
\$OS	Returns Operating System in capital letters (UNIX, VM, etc.)
\$MACHINE	Returns machine type in capital letters (HP/UX, VAX, etc.)
\$PID	Returns UNIX process PID id (1 for non-UNIX systems)

4.5.1 The \$SIGMA system function in more detail

A SIGMA expression can involve scalar or vector types of operands, and, according to the type of the result, the string \$SIGMA(Sigma_expression) will be substituted by either the numerical value of Sigma_expression, if the result is a scalar, or the name of a temporary vector (generated by SIGMA) containing the result of the evaluation of the Sigma_expression.

Example of the use of a SIGMA function

```
PAW > MESSAGE $SIGMA(SQRT(100)*PI)
31.41593

PAW > VEC/CR WWW R 10          | Create vector WWW
PAW > VEC/CR SSS R 10 20 30 40 50 | Create vector SSS
```

SIGMA uses temporary vectors (?SIGMA1, ?SIGMA2,...). They are deleted automatically after the execution of the command.

Example showing how SIGMA uses a temporary vector

```
PAW > VEC/PRINT WWW
WWW ( 1 ) = 10.00000
PAW > VEC/PRINT SSS
SSS ( 1 ) = 10.00000
SSS ( 2 ) = 20.00000
SSS ( 3 ) = 30.00000
SSS ( 4 ) = 40.00000
SSS ( 5 ) = 50.00000
PAW > VEC/PRINT $SIGMA(WWW*10+PI)
?SIGMA1 ( 1 ) = 103.1416
PAW > VEC/PRINT $SIGMA(SSS*10+PI)
?SIGMA1 ( 1 ) = 103.1416
?SIGMA1 ( 2 ) = 203.1416
?SIGMA1 ( 3 ) = 303.1416
?SIGMA1 ( 4 ) = 403.1416
?SIGMA1 ( 5 ) = 503.1416
```

Multiple vector references are possible in the same command line.

Example of the use of multiple vector references

```
PAW > GRAPH 100 $SIGMA(SIN(XVEC)) $SIGMA(COS(XVEC))
```

4.6 More on aliases, system functions and macro variables

Substitutions for aliases and system functions are performed “literally”, i.e. “as a character string” and regardless of the type of parameter. For example, a system function resulting in a Character string value can be inserted in place of a numeric type parameter (Integer or Real). KUIP will complain when executing that line only if the string cannot be interpreted as a numeric parameter.

As an example consider the PAW command /GRAPHICS/PRIMITIVES/ITX X Y TEXT which has the first two parameters of type Real and the third one of type Character:

```
PAW > ITX $SUBSTRING(ABC100,4,2) 15 'Test of ITX'
PAW > ITX $SUBSTRING(ABC100,1,2) 15 'Test of ITX'
*** Error in decoding 'real' parameter: AB
*** Default is taken
*** Default is not defined, unpredictable returned value !
```

the first call to ITX draws the text string Test of ITX at coordinates (10,15); the second call ends up with an error.

Macro variables, aliases and system functions resolution

The general rules governing the resolution of macro variables, aliases and system functions are:

- Any string within brackets, like [variable], is replaced **everywhere** in a macro by its “literal” value. It is left unchanged only when:
 - it is within a quoted string
 - the variable is undefined, i.e. neither variable=value was executed within the macro nor the calling sequence was of the type EXEC MACRO variable=value.
- At the left hand side of an assignment statement a variable appears always **without** square brackets, while at the right hand side of an assignment statement a variable appears always **between** square brackets.

```
ABC=15
E=[ABC]+10      | E is set to 25
```

- Variables and aliases are resolved **before** system functions, e.g.

```
ABC=15
D=$SUBSTRING([ABC],2,1) | D is set to 5
```

- System functions cannot be nested, e.g. D=\$LEN(\$SUBSTRING([ABC],2,1)) is invalid.
- Macro control statements cannot be aliased, e.g. the following code will produce an error:

```
ALIAS/CREATE JUMP GOTO
IF 1=1 JUMP 10
10:
```

- Arguments of EXEC and GOTO may be aliases or macro variables, e.g.

```
MACRO JUNK
  EXEC [1]
RETURN
```

where entering EXEC JUNK M1 is equivalent to enter EXEC M1.

4.7 Recalling previous commands

In addition to the host machine local facilities in recalling previous commands, KUIP allows the user to:

- Enter the command `LAST` which writes all (or some) commands typed in the session to a disk file (by default `LAST.KUMAC`) and invokes the local editor on the same file.

The history file is updated automatically every 25 commands (but the rate can be changed with the command `RECORDING`) and at the end of a session. At the beginning of another session the old history file `LAST.KUMAC` is renamed into `LAST.KUMACOLD` and a new `LAST.KUMAC` is opened. In this way the user always keeps track of all the commands entered in the previous and in the current sessions. The history files contain also heading and trailing comment lines, showing the date and time at which the sessions were started and stopped.

The command `LAST 0 MYFILE` may be put in the user's `LOGON.KUMAC` to define the name of the history files as `MYFILE.KUMAC` and `MYFILE.KUMACOLD`. This is useful to avoid sharing the same `LAST.KUMAC` file by several KUIP-based applications running on the same disk directory (e.g. PAW, GEANT [11], CMZ [12], etc.)

- Use a UNIX C-shell-like history mechanism, starting a command with an exclamation mark followed by:
 - An absolute number `n`, to re-execute the `n`-th command entered since the beginning of the session (e.g. `!3`)
 - A minus sign and a relative number, to re-execute the command identified by the current command number minus `n` (e.g. `!-2`)
 - Another exclamation mark, to re-execute the last command entered (i.e. `!!`)
 - Anything else (i.e. a non-numeric string), to re-execute the latest command entered which starts with the specified string (e.g. `!EXE`)
 - Nothing else, to show the list of recallable commands (i.e. `just !`)

To obtain the numbering of the command lines the prompt string must be defined as containing an open and closed brackets (e.g. by the command `SET/PROMPT 'MYPROG []'`), inside which KUIP will put the command line number.

4.8 Exception condition handling

User breaks (e.g. `CTRL/C`) are handled within PAW: when a break is issued the execution of the current command is aborted and PAW is waiting again for the next command.

This feature is not available in the IBM version.

Program exception conditions (for example, floating-point overflow, negative square root, etc.) are handled separately (also on IBM): when such an exception occurs, a warning message is issued and the program goes into a state waiting for the next command, as for user breaks.

Chapter 5: Vectors

Vectors are named arrays of numerical data, memory resident, which can be created during a session, loaded from HBOOK objects, typed in by hand, read from disk files, operated upon using the full functionality of SIGMA or COMIS. Vectors can be used to produce graphics output, and, if necessary, stored away on disk files for further usage. Vectors provide a very convenient mechanism to transport numerical information between different PAW objects, and to manipulate mathematically their content. At the end of an interactive session, they are lost, unless previously saved onto disk files.

Vectors can have up to 3 dimensions (in fact they are “arrays”, called “vectors” for historical reasons). They can be handled in PAW either interactively, by using VECTOR/. . . commands, or by means of KUIP routines which return the addresses of a given vector.

Simple arithmetic operations can be applied to vectors. In addition, as SIGMA is part of PAW, powerful array manipulation operations are available, through the SIGMA, \$SIGMA and APPLICATION SIGMA commands (see section 6.1 on page 110).

An “invisible” vector named `?`, mono-dimensional and of length 100, is always present. It is used for communication between arrays in the user code (for instance in a COMIS[1] routine) and KUIP vectors, being equivalenced with the real array VECTOR(100) in the labelled common block /KCWORK/.

5.1 Vector creation and filling

A vector is **created** either by the **PAW command** VECTOR/CREATE, by the **SIGMA function** ARRAY, or by the **COMIS statement** VECTOR.

Example of vector creation

<u>VECTOR/CREATE X(100)</u>	will create a 100-components vector, values = 0.
<u>SIGMA X=ARRAY(100,1#100)</u>	will create a 100-components vector and assign to each element the values 1,2,...100
<u>VECTOR X(100)</u>	in a COMIS routine creates a 100-components vector and initialises each element to zero

Once the vector is created, it can be manipulated using the following PAW commands:

VECTOR/INPUT vlist	Input from the terminal values into the vector elements specified by the list vlist.
VECTOR/READ vlist	Values can be read in from a file into the vector elements specified by the list vlist.
VECTOR/COPY v1 v2	Values in v1 are copied into v2.
VECTOR/WRITE vlist	Values in the vector elements specified by the list vlist can be saved on a file.
VECTOR/PRINT vlist	Values of the vector elements specified in vlist will be printed on the terminal.
VECTOR/LIST	A list of existing vectors and their characteristics is printed on the terminal.
VECTOR/DELETE	Allows global or selective deletion of vectors.

5.2 Vector addressing

Indexing of vectors is possible¹.

Example of vector indices

<code>Vec</code>	for all elements
<code>Vec(13)</code>	for element 13
<code>Vec(12:)</code>	for elements 12 up to the last
<code>Vec(:10)</code>	for elements 1 to 10
<code>Vec(5:8)</code>	for elements 5 to 8

Sub-elements of the two-dimensional vector `Vec(3,100)` (3 columns by 100 rows) may be addressed by:

Using two-dimensional vectors

<code>Vec(2,5:8)</code>	for elements 5 to 8 in column 2
<code>Vec(2:3,5:8)</code>	for elements 5 to 8 columns 2 to 3
<code>Vec(2,5)</code>	for element 5 in column 2
<code>Vec(:,3)</code>	for all elements in row 3
<code>Vec(2)</code>	for all elements in the 2-nd column (SPECIAL CASE)

5.3 Vector arithmetic operations

A number of basic vector arithmetic operations is available:

<code>VBIAS v1 bias v2</code>	$v2(I) = bias + v1(I)$
<code>VSCALE v1 scale v2</code>	$v2(I) = scale * v1(I)$
<code>VADD v1 v2 v3</code>	$v3(I) = v1(I) + v2(I)$
<code>VMULTIPLY v1 v2 v3</code>	$v3(I) = v1(I) * v2(I)$
<code>VSUBTRACT v1 v2 v3</code>	$v3(I) = v1(I) - v2(I)$
<code>VDIVIDE v1 v2 v3</code>	$v3(I) = v1(I) / v2(I)$, if $v2(I) \neq 0$

In all operations only the minimum vector length is considered, i.e. an operation between a vector A of dimension 10 and a vector B of dimension 5 will involve the first 5 elements for both vectors. If the destination vector does not exist, it is created with the same length as specified in the source vector.

5.4 Vector arithmetic operations using SIGMA

A more complete and convenient mechanism for the mathematical manipulation of entire vectors is provided by SIGMA. SIGMA-generated arrays are stored as PAW vectors and therefore are accessible to PAW commands, and PAW vectors are accessible to SIGMA. The facilities available via SIGMA are described in the next chapter.

¹Note that the indexing permitted in PAW can be considered as a superset of that permitted by FORTRAN. This feature cannot be used from within SIGMA.

5.5 Using KUIP vectors in a COMIS routine

The declaration `VECTOR vector_name` may be used inside a COMIS routine to address a KUIP vector. If the vector does not exist, it is created with the specifications provided by the declared dimension.

5.6 Usage of vectors with other PAW objects

Vectors can be used to transport numerical information between different PAW objects, and to manipulate mathematically their content.

<code>VECTOR/HFILL VNAME ID</code>	Each vector element of VNAME is used to fill the existing histogram ID.
<code>HISTOGRAM/GET_VECTOR/CONTENTS</code>	Provides an interface between vectors and histograms.
<code>HISTOGRAM/PUT_VECTOR/CONTENTS</code>	Provides an interface between histograms and vectors.

5.7 Graphical output of vectors

<code>VECTOR/DRAW VNAME</code>	Interprets the content of the vector VNAME as a histogram contents and draw a graph .
<code>VECTOR/PLOT VNAME</code>	Vector elements are considered as individual values to be entered into a histogram and a graph is produced. If VNAME is the name of a vector, then each vector element of VNAME is used to fill a histogram which is automatically booked with 100 channels and plotted. If VNAME has the form <code>VNAME1%VNAME2</code> then a scatter-plot of vector VNAME1 versus VNAME2 is plotted.

See figure 3.4 in the tutorial section for an explanation of the difference between `VECTOR/DRAW` and `VECTOR/PLOT`.

A number of HIGZ [3] macro-primitives are available in PAW. Those directly related to the graphical output of vectors are:

<code>GRAPH N X Y</code>	Draw a curve through a set of points defined by arrays X and Y.
<code>HIST N X Y</code>	Draw an histogram defined by arrays X and Y.
<code>PIE XO YO RAD N VAL</code>	Draw a pie chart, of N slices, with size of slices given in VAL, of a radius RAD, centered at XO, YO.

5.8 Fitting the contents of a vector

A user defined (and parameter dependent) function can be fitted to the points defined by the two vectors X and Y and the vector of associated errors EY. The general syntax of the command to fit vectors is:

```
VECTOR/FIT x y ey func [ chopt np par step pmin pmax errpar ]
```

For more information the reader is referred to the reference part of the present manual.

Chapter 6: SIGMA

6.1 Access to SIGMA

The SIGMA array manipulation package can be accessed in three different ways in PAW:

Precede the statement by the prefix SIGMA

Example
PAW > <u>SIGMA xvec=array(100,-pi#pi*2)</u>
PAW > <u>SIGMA y=sin(xvec)*xvec</u>

Note the use of the predefined constant PI in SIGMA with the obvious value.

The PAW command: APPLication SIGMA

All commands typed in after this command will be directly processed by SIGMA. The command EXIT will return control to PAW, e.g.

```
PAW > APPLication SIGMA
SIGMA > xvec=array(100,-pi#pi*2)
SIGMA > sinus=sin(xvec)*xvec
SIGMA > cosinus=cos(xvec)*xvec
SIGMA > exit
PAW > vector/list
Vector Name           Type      Length   Dim-1   Dim-2   Dim-3
-----
XVEC                  R         100      100
SINUS                 R         100      100
COSINUS               R         100      100

Total of 3 Vector(s)
```

The PAW system function \$SIGMA

The expression to be evaluated must be enclosed in parentheses. The function will return the numerical value of the expression (if the result is a scalar) or the name of a temporary vector (if the result is a vector).

Assuming that the computation of the function $\sin(x)*x$ in the above example would be only for the purpose of producing a graph, (i.e. the result is not needed for further calculations), then one could just have typed the following commands:

```
PAW > SIGMA xvec=array(100,-pi#pi*2)
PAW > GRaph 100 xvec $SIGMA(SIN(XVEC)*XVEC)
```

6.2 Vector arithmetic operations using SIGMA

A complete and convenient mechanism for the mathematical manipulation of vectors is provided by SIGMA. In the following, we use the words “array” and “vector” as synonyms. In both cases, we refer to PAW vectors, in the sense that SIGMA offers an alternative way to generate and to manipulate PAW vectors (see section 5 on page 107). The notation of SIGMA is similar to that of FORTRAN, in the sense that is based upon formulae and assignment statements.

The special operator ARRAY is used to generate vectors:

```
vname = ARRAY (arg1, arg2)
```

vname Name of the vector (array) being created.

arg1 Defines the array **structure**, i.e. the Number of COmponents (NCO) of the array.

arg2 Provides the **numerical values** filling the array row-wise.
If arg2 is absent (or does not provide enough values) the array is filled with 1.

6.2.1 Basic operators

+ Add
- Subtract
* Multiply
/ Divide
** Exponentiation
& Concatenation

Note that ill defined operations will give 0. as result. For instance: a division by zero gives zero as result.

6.2.2 Logical operators

Logical operators act on entities that have **Boolean** values 1 (true) or 0 (false). The result is Boolean.

AND Logical operation AND
NOT Logical operation NOT
OR Logical operation OR
EQ Equal to
GE Greater or Equal to
GT Greater Than
LE Less or Equal to
LT Less Than
NE Not Equal

6.2.3 Control operators

!PRINT Provides the automatic printing of every newly created array or scalar.
!NOPRINT Suppresses the automatic printing of every newly created array or scalar.

Examples

<u>A=ARRAY (6,1#6)</u>	1 2 3 4 5 6
<u>A=ARRAY (4)</u>	1 1 1 1
<u>A=ARRAY (5,2&3&-1&2&1.2)</u>	2 3 -1 2 1.2
<u>A=ARRAY (3)*PI</u>	3.1415927 3.1415927 3.1415927
<u>A=ARRAY (1,123E4)</u>	1230000.0

6.3 SIGMA functions

SIGMA provides some functions which perform a task on a whole array. These functions have no analogues in FORTRAN because all FORTRAN functions operate on one or more single numbers. Presently available SIGMA functions are listed in table 6.1 below.

Name	Result	Explanation
ANY	Scalar	The result is a Boolean scalar of value 1 (true) if at least one component of the argument is true and 0 (false) otherwise.
DEL	Vector	Analog to the Dirac-DELta Function . $V1=DEL(V)$ sets each element of V1 to 0.0 (if corresponding element in V is non-zero) or to 1.0 (if corresponding element is zero).
DIFF	Vector	$V2=DIFF(V)$ forward difference of V. The rightmost value in V1 is obtained by quadratic extrapolation over the last three elements of V.
LS	Vector	$V1=LS(V, N)$ shifts index of V to the left by N steps (cyclic).
LVMAX	Scalar	$S1=LVMAX(V1)$ sets S1 equal to the index (location) of the maximum value in vector V1.
LVMIM	Scalar	$S1=LVMIN(V1)$ sets S1 equal to the index (location) of the minimum value in vector V1.
MAX	Vector	$V3=MAX(V1, V2)$ sets each element of V3 equal to the maximum of the corresponding elements in V1 and V2.
MAXV	Vector	$V1=MAXV(V)$ sets each element of V1 equal to the maximum value in V.
MIN	Vector	$V3=MIN(V1, V2)$ sets each element of V3 equal to the minumum of the corresponding elements in V1 and V2.
MINV	Vector	$V1=MINV(V)$ sets each element of V1 equal to the minimum value in V.
NCO	Scalar	$V1=NCO(V)$ Number of COmponents of vector of V.
ORDER	Vector	$V1=ORDER(V, V2)$ finds a permutation that brings V2 in a non-descending order and applies it to V to generate V1.
PROD	Vector	$V1=PROD(V)$ V1 is the running product of V.
QUAD	Vector	$V2=QUAD(V1, H)$ The quadrature function QUAD numerically integrates each row of V1 with respect to the scalar step size H.
SUMV	Vector	$V2=SUMV(V1)$ running sum of V.
VMAX	Scalar	$S1=VMAX(V1)$ sets S1 equal to the maximum value in vector V1.
VMIN	Scalar	$S1=VMIN(V1)$ sets S1 equal to the minimum value in vector V1.
VSUM	Scalar	$S1=VSUM(V)$ sum of all components of V.

Table 6.1: SIGMA functions

6.3.1 SIGMA functions - A detailed description.

In the following description of the SIGMA functions, the letter R always denotes the **result** and arg denotes one or more **arguments**. Any argument may itself be an expression. In that case arg means the result of this expression. Let OP denote any of the above array functions, then the statement:

```
R = OP (arg1, arg2, ...)
```

produces R without doing anything to the contents stored under the names appearing in arg1, arg2, ... Thus, although in the description we may say "...OP does such and such to arg ...", in reality it leaves arg intact and works on the argument to produce R.

```
R = ANY (arg)
```

The function ANY considers the result of the argument expression as a Boolean array. SIGMA represents "true" by 1 and "false" by 0. Thus the components of arg must be either 0 or 1, otherwise an error is generated.

If at least one component of the result of the argument expression is 1, then ANY returns the scalar 1. If all components of the result of the argument expression are 0 then ANY returns the scalar 0. If arg is a Boolean scalar, $R = \text{arg}$.

Example of the ANY command

```
PAW > APPL SIGMA
SIGMA > !PRINT | Print newly created vectors and scalars
SIGMA > W=(-2)**ARRAY(10,1#10)
NCO(W) = 10
W
=
-2.000    4.000    -8.000    16.00    -32.00    64.00
-128.0    256.0    -512.0    1024.
SIGMA > X=W GT 0
NCO(X) = 10
X
=
0.0000    1.000    0.0000    1.000    0.0000    1.000
0.0000    1.000    0.0000    1.000
SIGMA > R=ANY(X)
NCO(R) = 1
R
1.000
```

```
R = DEL (arg)
```

DEL is a discrete analogue of a **Dirac delta function**. DEL works independently on each row of the argument array. If the elements of any row of the argument are denoted by $X_1, X_2, \dots, X_i, \dots, X_n$ then the corresponding row of the result of the delta function operation will be $Z_1, Z_2, \dots, Z_i, \dots, Z_n$ where all $Z_i = 0$ except in three cases, in which $Z_i = 1$, namely:

- 1 When the component X_i is itself zero.
- 2 When X_{i-1}, X_i are of opposite sign and $|X_i| < |X_{i-1}|$ If $i = 1$ then linear extrapolation to the left is used.
- 3 When X_i, X_{i+1} are of opposite sign and $|X_i| \leq |X_{i+1}|$ If $i = 1$ then linear extrapolation to the right is used.

If arg is a scalar, the value of DEL(arg) will be 1 if arg is zero, and 0 otherwise.

Example of the del command

```

SIGMA > W=array(11,-1#1)
NCO(W) = 11
W =
-1.0000  -0.8000  -0.6000  -0.4000  -0.2000  -0.2980E-07
 0.2000   0.4000   0.6000   0.8000   1.0000

SIGMA > X= (W+1.01)*W*(W-.35)*(W-.42)
NCO(X) = 11
X =
-0.1917E-01 -0.2357  -0.2384  -0.1501  -0.5524E-01-0.4425E-08
 0.7986E-02 -0.5640E-03 0.4347E-01 0.2476  0.7578

SIGMA > R=del(x)
NCO(R) = 11
R =
 1.0000  0.0000  0.0000  0.0000  0.0000  1.0000
 0.0000  1.0000  0.0000  0.0000  0.0000

```

R = DIFF (arg)

The DIFF function generates the **forward difference** of each row of the argument array, say $X_1, X_2, \dots, X_i, \dots, X_n$ and creates an array with components equal to the forward difference of X : $X_2 - X_1, X_3 - X_2, \dots, X_n - X_{n-1}, X_0$ where the rightmost value X_0 is obtained by quadratic extrapolation over the last three elements of the result of arg. Applied to a scalar DIFF gives a zero result.

Example of the DIFF command

```

SIGMA > x=array(6,5#0)
NCO(X) = 6
X =
 5.0000  4.0000  3.0000  2.0000  1.0000  0.0000
SIGMA > Y=x*x
NCO(Y) = 6
Y =
 25.00  16.00  9.000  4.000  1.000  0.0000
SIGMA > Z=Diff(Y)
NCO(Z) = 6
Z =
-9.000  -7.000  -5.000  -3.000  -1.000  1.000

```

R = LS (arg1, arg2)

The LS rearrangement function performs a **left shift**. arg1 is the array to be shifted; arg2 must be a scalar value (rounded if necessary by the system), interpreted as the number of places the array has to be shifted to the left. The scalar arg2 can be negative, in which case LS shifts to the right a number of places equal to the absolute value of arg2.

It should be noted the the shift is performed circularly modulo N , where N is the number of components in the rows of the array to be shifted. Hence, $LS(X, N+1)$ shifts the N component rows of X by 1 to the left, and $LS(X, -1)$ shifts the rows by $N-1$ to the left (or by 1 to the right). If arg1 is a scalar, $R = arg1$.

Example of the left shift command
--

```

SIGMA > X=array(4&5,array(20,1#20))
NCO(X      )= 4 5
X
=
 1.000    2.000    3.000    4.000
 5.000    6.000    7.000    8.000
 9.000   10.00   11.00   12.00
13.00   14.00   15.00   16.00
17.00   18.00   19.00   20.00

SIGMA > y=ls(x,1)
NCO(Y      )= 4 5
Y
=
 2.000    3.000    4.000    1.000
 6.000    7.000    8.000    5.000
10.00   11.00   12.00    9.000
14.00   15.00   16.00   13.00
18.00   19.00   20.00   17.00

SIGMA > y=ls(x,-3)
NCO(Y      )= 4 5
Y
=
 2.000    3.000    4.000    1.000
 6.000    7.000    8.000    5.000
10.00   11.00   12.00    9.000
14.00   15.00   16.00   13.00
18.00   19.00   20.00   17.00

SIGMA > X=array(5,1#5)
NCO(X      )= 5
X
 1.000    2.000    3.000    4.000    5.000
SIGMA > z=ls(x,3)
NCO(Z      )= 5
Z
 4.000    5.000    1.000    2.000    3.000
SIGMA > z1=ls(x,-4)
NCO(Z1     )= 5
Z1
 2.000    3.000    4.000    5.000    1.000

```

R = LVMAX(arg1) and R = LVMIN(arg1)

The functions LVMAX and LVMIN returns as a scalar result the index (position) of the largest or smallest element, respectively, in the argument array.

Example of using the LVMAX and LVMIN commands
--

```

SIGMA > x=sin(array(10,1#10))
NCO(X      )= 10
X
=
 0.841    0.909    0.141   -0.757   -0.959   -0.279    0.657
 0.989    0.412   -0.544
SIGMA > r=lvmax(x)
NCO(R      )= 1
R
 8.00

```

$R = \text{MAX}(\text{arg1}, \text{arg2})$ and $R = \text{MIN}(\text{arg1}, \text{arg2})$

The functions MAX and MIN work independently on each element of their arguments. arg2 can be a scalar. The result has the same dimension as the argument array arg1 and each element of the result is set equal to the largest or smallest element, respectively, of the corresponding element of the argument arrays.

Example of using the MAX and MIN commands

```
SIGMA > x=sin(array(10,1#10))
NCO(X      )= 10
X      =
0.841   0.909   0.141  -0.757  -0.959  -0.279   0.657
0.989   0.412  -0.544

SIGMA > y=cos(array(10,1#10))
NCO(Y      )= 10
Y      =
0.540  -0.416  -0.990  -0.654   0.284   0.960   0.754
-0.146  -0.911  -0.839

SIGMA > z=min(x,y)
NCO(Z      )= 10
Z      =
0.540  -0.416  -0.990  -0.757  -0.959  -0.279   0.657
-0.146  -0.911  -0.839
```

$R = \text{MAXV}(\text{arg})$ and $R = \text{MINV}(\text{arg})$

The extrema functions MAXV and MINV work on each element of their argument and the result has the same dimension as the argument array arg1. Each element of the result is set equal to the largest or smallest element, respectively, of the corresponding row of the argument array.

All these functions, if applied to a scalar argument, yield $R=\text{arg}$.

Example of using the MAX and MIN commands

```
SIGMA > x=array(10,0#10)
NCO(X      )= 10
X      =
0.0000   1.111   2.222   3.333   4.444   5.556
6.667   7.778   8.889   10.00

SIGMA > s=sin(x)*x
NCO(S      )= 10
S      =
0.0000   0.9958   1.767  -0.6352  -4.286  -3.695
2.494   7.755   4.539  -5.440

SIGMA > x=minv(s)
NCO(X      )= 10
X      =
-5.440  -5.440  -5.440  -5.440  -5.440  -5.440
-5.440  -5.440  -5.440  -5.440
```


R = NCO (arg)

The “Number of COmponents” (NCO) control function obtains the NCO vector of the arg. The NCO vector of a scalar is the scalar 1. For any argument the NCO (NCO (arg)) gives the number of dimensions of the arg.

Using the NCO command	
SIGMA >	<u>x=array(4&3&2,array(24,2#48))</u>
NCO(X)	)= 4 3 2
X	=
	2.000 4.000 6.000 8.000
	10.00 12.00 14.00 16.00
	18.00 20.00 22.00 24.00
	26.00 28.00 30.00 32.00
	34.00 36.00 38.00 40.00
	42.00 44.00 46.00 48.00
SIGMA >	<u>r=nco(x)</u>
NCO(R)	)= 3
R	4.000 3.000 2.000
SIGMA >	<u>ndim=nco(nco(x))</u>
NCO(NDIM)	)= 1
NDIM	3.000

R = ORDER (arg1,arg2)

The ordering function ORDER acts independently on each row of arg1. arg2 must have the same row length as arg1.

ORDER finds the permutation that brings arg2 into a non-descending sequence (row-wise) and constructs the result by applying this permutation to arg1. It may in some cases be expanded to that structure by using the techniques of the topological arithmetic. This is particularly useful if arg2 is a single vector with the length of the rows of arg1.

Using the ORDER command	
SIGMA >	<u>X = 1&1&2&4&-3&1&3</u>
NCO(X)	)= 7
X	=
	1.00 1.00 2.00 4.00 -3.00 1.00 3.00
SIGMA >	<u>P = ORDER(X,X)</u>
NCO(P)	)= 7
P	=
	-3.00 1.00 1.00 1.00 2.00 3.00 4.00
SIGMA >	<u>P = ORDER(X,-X)</u>
NCO(P)	)= 7
P	=
	4.00 3.00 2.00 1.00 1.00 1.00 -3.00
SIGMA >	<u>Y = ARRAY(7,1# 7)</u>
NCO(Y)	)= 7
Y	=
	1.00 2.00 3.00 4.00 5.00 6.00 7.00
SIGMA >	<u>P = ORDER(Y,X)</u>
NCO(P)	)= 7
P	=
	5.00 1.00 2.00 6.00 3.00 7.00 4.00

R = PROD (arg)

The PROD function generates the **running product** of each row of the argument array, say X_1, X_2, \dots, X_n and creates an array with components equal to the running product of the component of the argument: $X_1, X_2, \dots, X_n, X_1, X_1 \times X_2, \dots, X_1 \times X_2 \times \dots \times X_n$

Using the TIMES command

```
SIGMA > x=array(6&4,array(24,1#24))
NCO(X) = 6 4
X =
1.000 2.000 3.000 4.000 5.000 6.000
7.000 8.000 9.000 10.00 11.00 12.00
13.00 14.00 15.00 16.00 17.00 18.00
19.00 20.00 21.00 22.00 23.00 24.00

SIGMA > y=prod(x)
NCO(Y) = 6 4
Y =
1.000 2.000 6.000 24.00 120.0 720.0
7.000 56.00 504.0 5040. 0.5544E+05 0.6653E+06
13.00 182.0 2730. 0.4368E+05 0.7426E+06 0.1337E+08
19.00 380.0 7980. 0.1756E+06 0.4038E+07 0.9691E+08
```

R = QUAD (arg1, arg2)

The **quadrature function** QUAD numerically integrates each row of arg1 with respect to the scalar step size h defined by arg2.

The result R has the same dimension as arg1 and the integration constant is fixed by choosing the first point of the result to be zero.

The method uses a four-point forward and backward one-strip-formula based on Lagrange interpolation. We have for the first point of the result:

$$R_1 = \int_{x_1}^{x_1} (arg1) dx = 0$$

for the second and third points

$$R_{i+1} = R_i + \frac{h}{24}(9f_i + 19f_{i+1} - 5f_{i+2} + f_{i+3})$$

and for all subsequent points

$$R_i = R_{i-1} + \frac{h}{24}(f_{i-3} - 5f_{i-2} + 19f_{i-1} + 9f_i)$$

where the f_i are elements of arg1 and are assumed to be values of some functions evaluated at equidistant intervals with interval width equal to h (h being equal to the value of arg2).

```

SIGMA > *****
SIGMA > * SIGMA application *
SIGMA > * showing use of *
SIGMA > * QUAD numeric *
SIGMA > * integration *
SIGMA > *****
SIGMA > x=array(101,0#2*pi)
SIGMA > * Function value array
SIGMA > y=sin(x)
SIGMA > * Step size
SIGMA > dx=0.6283186E-01
SIGMA > print dx
NCO(DX)= 1
DX 0.6283186E-01
SIGMA > * Integration of SIN(X)
SIGMA > * in interval 0<=X<+2*PI
SIGMA > f=quad(y,dx)
SIGMA > * Analytical result
SIGMA > * is 1-COS(X)
SIGMA > g=1-cos(x)
SIGMA > * Compute the difference
SIGMA > erro=(g-f)*10**6
SIGMA > * Plot the difference
SIGMA > * in units of 10-6
SIGMA > exit
PAW > opt GRID
PAW > gra 101 x erro

```

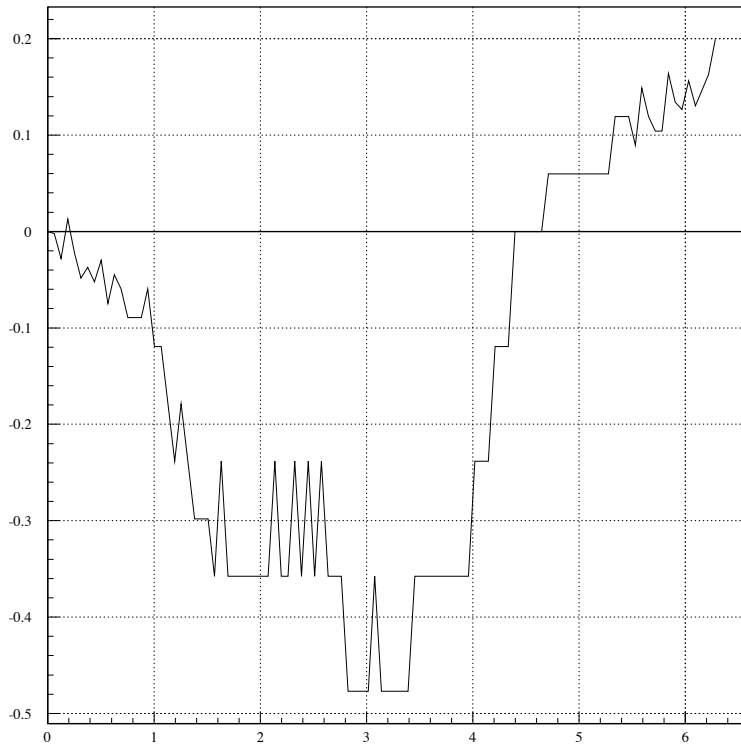


Figure 6.1: Using numerical integration with SIGMA

```
R = SUMV (arg)
```

The SUMV function generates the **running summation** of each row of the argument array, say $X_1, X_2, \dots, X_i, \dots, X_n$ and creates an array with components equal to the running sum of the X_i namely: $X_1, X_1 + X_2, \dots, X_1 + X_2 + \dots + X_i, \dots, X_1 + X_2 + \dots + X_n$.

Using the SUM function

```

SIGMA > x=array(6&4,array(24,1#24))
NCO(X)= 6 4
X =
  1.000    2.000    3.000    4.000    5.000    6.000
  7.000    8.000    9.000   10.00   11.00   12.00
 13.00   14.00   15.00   16.00   17.00   18.00
 19.00   20.00   21.00   22.00   23.00   24.00

SIGMA > y=sumv(x)
NCO(Y)= 6 4
Y =
  1.000    3.000    6.000   10.00   15.00   21.00
  7.000   15.00   24.00   34.00   45.00   57.00
 13.00   27.00   42.00   58.00   75.00   93.00
 19.00   39.00   60.00   82.00  105.00  129.00

```

$R = \mathbf{VMAX}(\text{arg})$ and $R = \mathbf{VMIN}(\text{arg})$

The functions VMAX and VMIN return a scalar equal to the largest or smallest element of the array arg.

$R = \mathbf{VSUM}(\text{arg1})$

The VSUM function generates the **sum** of each element of the argument array, say $X_1, X_2, \dots, X_i, \dots, X_n$ and creates a scalar whose value is equal to the sum of all the components of X namely: $X_1 + X_2 + X_3, \dots, X_n$

Using the VSUM function

```
SIGMA > x=array(10)
NCO(X) = 10
X
=
  1.00    1.00    1.00    1.00    1.00    1.00    1.00
  1.00    1.00    1.00

SIGMA > r=vsun(x)
NCO(R) = 1
R      10.0
```

6.4 Available library functions

The library functions available under SIGMA are listed below. All these functions have a single argument, unless otherwise indicated. The number indicated between parentheses corresponds to the number of the same function in the CERN program library.

ABS	ABSolute value
ACOS	ArCOSine
ALOGAM	LOGarithm of the GAMma Function (C341)
ASIN	ArcSINe
ATAN	ArcTANgent
ATAN2	ArcTANgent2 (2 arguments)
BESIO	Mod. Bessel Function I0 (C313)
BESI1	Mod. Bessel Function I1 (C313)
BESJ0	Bessel Function J0 (C312)
BESJ1	Bessel Function J1 (C312)
BESK0	Mod. Bessel Function K0 (C313)
BESK1	Mod. Bessel Function K1 (C313)
BESY0	Bessel Function Y0 (C312)
BESY1	Bessel Function Y1 (C312)
COS	COSine
COSH	Hyperbolic COSine
COSINT	COSine INTegral (C336)
DILOG	DILOGarithm Function (C304)
EBESIO	$\exp(-|x|)I_0(x)$ (C313)
EBESI1	$\exp(-|x|)I_1(x)$ (C313)

EBESKO	$\exp(x)K_0(x)$ (C313)
EBESK1	$\exp(x)K_1(x)$ (C313)
ELICK	Complete Elliptic Integral K (C308)
ELLICE	Complete Elliptic Integral E (C308)
ERF	Error Function ERF (C300)
ERFC	Error Function ERFC (C300)
EXP	EXponential
EXPINT	EXponential INTegral (C337)
FREQ	Normal Frequency Function FREQ (C300)
GAMMA	GAMMA Function (C305)
INT	Takes INTegral part of decimal number
LOG	Natural LOGarithm
LOG10	Common LOGarithm
MOD	Remaindering
RNDM	Random Number Generator: $V1=RNDM(V)$, with $NC0(V1)=NC0(V)$ generates random numbers between 0 and 1.
SIGN	Transfer of SIGN: $V2=SIGN(V, V1)$, $V2=|V|*V1/|V1|$
SIN	SINe Function
SINH	Hyperbolic SINe
SININT	SINe INTegral (C336)
SQRT	SQuare RooT
TAN	TANgent
TANH	Hyperbolic Tangent

Ill defined functions will return 0 . as result. (e.g. SQRT of a negative number is taken as 0).
--

Chapter 7: HBOOK

7.1 Introduction

Many of the ideas and functionality in the area of data presentation, manipulation and management in PAW find their origin in the HBOOK subroutine package [2], which handles statistical distributions (histograms and Ntuples). HBOOK is normally run in a batch environment, and it produces generally graphics output on the line printer or, optionally, via the H PLOT [4] package on a high resolution graphic output device.

The HBOOK system consists of a few hundred FORTRAN subroutines which enable the user to symbolically define, fill and output one- and two-dimensional density estimators, under the form of **histograms**, **scatter-plots** and **tables**.

Furthermore the analysis of large data samples is eased by the use of **Ntuples**, which are two-dimensional arrays, characterised by a **fixed** number N , specifying the number of entries per element, and by a **length**, giving the total number of elements. An element of a Ntuple can be thought of as a physics “event” on e.g. a Data Summary Tape (micro-DST). **Selection criteria** can be applied to each “event” or element and a complete Ntuple can be statistically analysed in a fast, efficient and interactive way.

7.1.1 The functionality of HBOOK

The various user routines of HBOOK can be subdivided by functionality as follows:

Booking	Declare a one- or two-dimensional histogram or a Ntuple
Projections	Project two-dimensional distributions onto both axes
Ntuples	Way of writing micro data-summary-files for further processing. This allows to make later projections of individual variables or correlation plots. Selection mechanisms may be defined
Function representation	Associates a real function of 1 or 2 variables to a histogram
Filling	Enter a data value into a given histogram, table or Ntuple
Access to information	Transfer of numerical values from HBOOK-managed memory to Fortran variables and back
Arithmetic operations	On histograms and Ntuples
Fitting	Least squares and maximum likelihood fits of parametric functions to histogrammed data
Smoothing	Splines or other algorithms
Random number generation	Based on experimental distributions
Archiving	Information is stored on mass storage for further reference in subsequent programs
Editing	Choice of the form of presentation of the histogrammed data

7.2 Basic ideas

The basic data elements of HBOOK are the **histogram** (one- and two-dimensional) and the **Ntuple**. The user identifies his data elements using a **single integer**. Each of the elements has a number of **attributes** associated with it.

The HBOOK system uses the ZEBRA [7] data manager to store its data elements in a COMMON block /PAWC/, shared with the KUIP [5] and HIGZ [3] packages, when the latter are also used (as is the case in PAW). In fact the first task of a HBOOK user is to declare the length of this common to ZEBRA by a call to HLIMIT, as is seen in figures 7.3 and 7.5¹.

In the /PAWC/ data store, the HBOOK, HIGZ and KUIP packages have all their own **division** (see [7] for more details on the notion of divisions) as follows (figure 7.1):

LINKS Some locations at the beginning of /PAWC/ for ZEBRA pointers.
 WORKS Working space (or division 1) used by the various packages storing information in /PAWC/
 HBOOK Division 2 of the store. Reserved to HBOOK
 HIGZ A division reserved for the HIGZ graphics package.
 KUIP A division reserved for the KUIP user interface package.
 SYSTEM The ZEBRA system division. It contains some tables, as well as the Input/Output buffers for HRIN and HROUT.

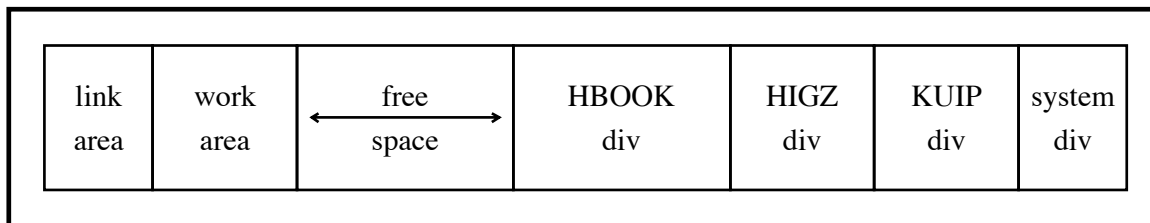


Figure 7.1: The layout of the /PAWC/ dynamic store

7.2.1 RZ directories and HBOOK files

An advantage of using ZEBRA in HBOOK is that ZEBRA's direct access **RZ package** is available. The latter allows data structures to be uniquely addressed via **pathnames**, carrying a mnemonic meaning and showing the relations between data structures. Related data structures are addressed from a **directory**. Each time a RZ file is opened via a call to HRFILE a supplementary top directory is created with a name specified in the calling sequence. This means that the user can more easily keep track of his data and also the **same** histogram identifiers can be used in various files, what makes life easier if one wants to study various data samples with the same program, since they can be addressed by changing to the relevant file by a call to HCDIR first.

¹This is of course not necessary in PAW, which is already precompiled when it is run. However when treating very large data samples or in other special applications, it might be necessary to specify a different value for the length of the dynamic store, which is defined by a call to PAWINT from the main initialisation routine PAMAIN. The "default" value for the length of /PAWC/ is 500000 (Apollo), 200000 (IBM) or 300000 (other systems), with respectively 10000 and 68000 words initially reserved for HIGZ and KUIP.

Example of using directories	
CALL HRFILE(1,'HISTO1',' ')	! Open first HBOOK RZ file (read only)
CALL HRFILE(2,'HISTO2','U')	! Open second HBOOK RZ file (update)
CALL HCDIR('//HISTO1',' ')	! Make HISTO1 current directory
CALL HRIN(20,9999,0)	! Read ID 20 on file 1
....	
CALL HCDIR('//HISTO2',' ')	! Make HISTO2 current directory
CALL HRIN(10,9999,0)	! Read ID 10 on file 2
....	
CALL HROUT(20,ICYCLE,' ')	! Write ID 20 to file 2
CALL HREND('HISTO1')	! Close file 1
CALL HREND('HISTO2')	! Close file 2

In the previous example (and also in figures 7.3 and 7.5) it is shown how an external file is available via a directory name inside HBOOK (and PAW), and that one can change from one to the other file by merely **changing directory**, via the PAW command CDIR, which calls the HBOOK routine HCDIR.

7.2.2 Changing directories

One must pay attention to the fact that **newly** created histograms go to **memory** in the //PAWC directory (i.e. the /PAWC/ common). As an example suppose that the current directory is //LUN1, and an operation is performed on two histograms. These histograms are first copied to memory //PAWC, the operation is performed and the result is **only** available in //PAWC,

```
PAW > CDIR //LUN1           | Set current directory to //LUN1
PAW > ADD 10 20 30          | Add histograms 10 and 20 into 30
                               | Histogram 30 is created in //PAWC
PAW > Histo/Plot //PAWC/30 | Show the result of the sum
PAW > CD //PAWC           | Set the current directory to memory
PAW > Histo/plot 30        | Show the result once more
```

Similarly when histograms or Ntuples are plotted (e.g. by the HISTO/PLOT command), they are copied to memory possibly replacing an old copy of the same ID. As long as the copy in memory is not changed, each time the ID is read from the **external** file. This is because in a **real time** environment, e.g. using **global sections** on VMS or **modules** with OS9, the data base on the external medium can be changed by concurrent processes. However if the HBOOK data structure, associated with the histogram or Ntuple in memory is **altered** (e.g. by a MAX, IDOPT, FIT command), then it becomes the **default** for subsequent operations. If one wants the **original copy** one first must delete the copy from memory or **explicitly** use the pathname for the external file.

```
PAW > Histo/file 1 his.dat | The file contains ID=10
PAW > Histo/Plot 10       | ID=10 read from file and plotted
PAW > H/plot 10          | ID=10 read again from file and plotted
PAW > H/fit 10 ! G       | Read from file, make a Gaussian fit on //PAWC/10
PAW > H/plot 10          | ID=10 read from memory since it changed
PAW > H/del 10           | Delete histogram 10 from memory
PAW > H/plot 10          | ID=10 read again from file and plotted
```


7.3 HBOOK batch as the first step of the analysis

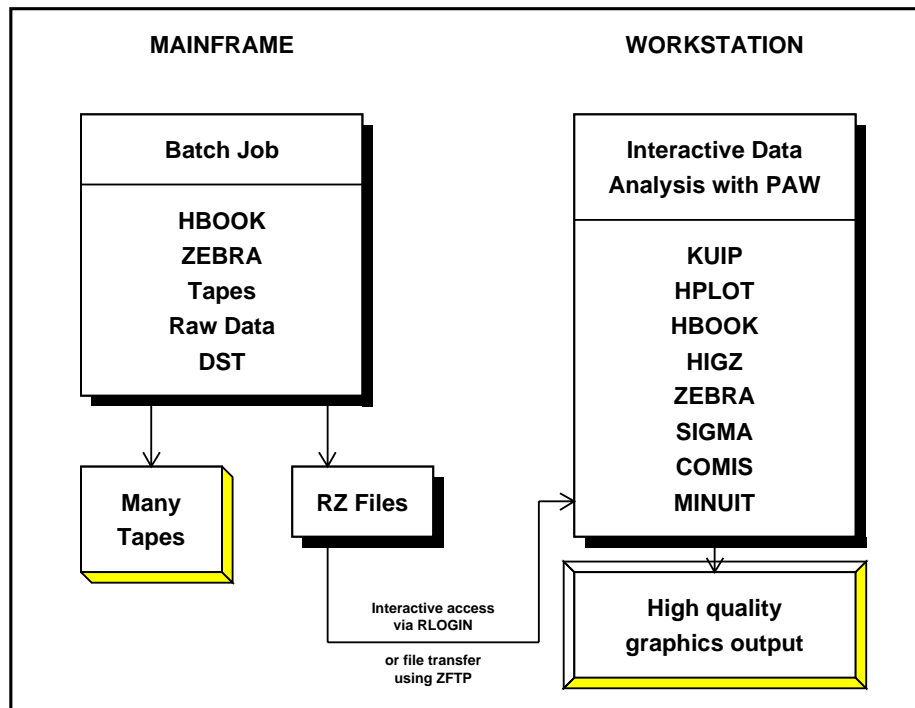


Figure 7.2: Schematic presentation of the various steps in the data analysis chain

Although it is possible to define histograms interactively in a PAW session, and then read the (many thousands of) events, in general for large data samples the relevant variables are extracted from the **Data Summary Files** or **DSTs** and stored in **histograms** or an **Ntuple**. The histogram needs already that a certain choice has to be made as to the range of values for the plotted parameter, because the **binning**, or the coarseness, of the distribution has to be specified when the histogram is defined (**booked**). Also only one- and two-dimensional histograms are possible, hence the correlations between various parameters can be difficult to study. Hence it seems in many cases more appropriate to store the value of the important parameters for each event in an **Ntuple**. This approach preserves the correlation between the parameters and allows selection criteria to be applied on the (reduced) data sample at a later stage.

In general, the time consuming job of analysing all events available on tape is run on a mainframe or CPU server, and the important event parameters are stored in a Ntuple to allow further detailed study. For convenience the Ntuple can be output to disk for each run, and then at a later stage the Ntuples can be **merged** in order to allow a global interactive analysis of the complete data sample.

A typical batch job in which data are analysed offline and some characteristics are stored in HBOOK is given in 7.3. After opening the RZ HBOOK file, HBOOK is initialised by a call to HLIMIT, which declares a length of 20000 words for the length of the /PAWC/ dynamic store. Then the one- and two- dimensional histograms 110 and 210 are filled respectively according to the functions HTFUN1 and HTFUN2. The output generated by the program is shown in Figure 7.4.

7.3.1 Adding some data to the RZ file

The second run using program HTEST1 shows how to add some data to the HBOOK RZ file created in the job HTEST. After opening the file in question in update mode ('U' option) with the name EXAM2, a new directory NTUPLE is created, known as //EXAM2/NTUPLE as seen in the output of HLDIR command at the end of the output. A one- and a two-dimensional histogram and a Ntuple with identifiers of respectively 10, 20 and 30 are booked. Each Ntuple element or "event" is characterised by three **variables** (labelled 'X', 'Y' and 'Z'). The Ntuple data, when the initial size of 1000 words is exhausted, will be written to the directory specified in the call to HBOOKN, i.e. //EXAM2/NTUPLE, and the data in memory are replaced with those newly read. A one- and a two-dimensional projection of X and X Y are then made onto histograms 10 and 20 respectively, before they are printed and written on the HBOOK RZ file. At the end the **current** and **parent** directories are listed. The contents of the latter shows that the data written in the first job (HTEST) are indeed still present in the file under the top directory //EXAM2. The call to RZSTAT shows usage statistics about the RZ file.

Example of adding data to a HBOOK RZ file

```

PROGRAM HTEST1
PARAMETER (NWPWC=20000)
COMMON/PAWC/H(NWPWC)
DIMENSION X(3)
CHARACTER*8 CHTAGS(3)
DATA CHTAGS/' X ',' Y ',' Z '/
* -----
CALL HLIMIT(NWPWC)
*
  Reopen data base
CALL HROPEN(1,'EXAM2','HTEST.DAT',0,'U')
CALL HMDIR('NTUPLE','S')
CALL HBOOK1(10,'TEST1',100,-3.,3.,0.)
CALL HBOOK2(20,'TEST2',30,-3.,3.,30,-3.,3.,250.)
CALL HBOOKN(30,'N-TUPLE',3,'//EXAM2/NTUPLE',
+           1000,CHTAGS)
*
DO 10 I=1,10000
  CALL RANNOR(A,B)
  X(1)=A
  X(2)=B
  X(3)=A*A+B*B
  CALL HFN(30,X)
10 CONTINUE
*
CALL HPROJ1(10,30,0,0,1,999999,1)
CALL HPROJ2(20,30,0,0,1,999999,1,2)
CALL HPRINT(0)
CALL HROUT(0,ICYCLE,' ')
CALL HLDIR(' ',' ')
CALL HCDIR(';',' ')
CALL HLDIR(' ',' ')
CALL RZSTAT(' ',999,' ')
CALL HREND('EXAM2')
END

```


7.4 Using PAW to analyse data

After transferring the HBOOK RZ file, which was created in the batch job as explained in the previous section, we start a PAW session to analyse the data which were generated². The PAW session below shows that the file HTEST.DAT is first opened via a call to HISTO/FILE. The data on the file are now accessible as the top directory //LUN1. When listing with the LDIR command the contents of the top directory //LUN1 and its NTUPLE subdirectory, the same information (histograms and Ntuples) is found as in the batch job (figure 7.5)

```

Reading a HBOOK direct access file
PAW > histo/file 1 htest.dat | open the HBOOK RZ file
PAW > ldir | list current directory

***** Directory ==> //LUN1 <===

                Created 890902/1958 Modified 890902/1958

==> List of subdirectories
NTUPLE          Created 890902/1958 at record      9

==> List of objects
   HBOOK-ID  CYCLE  DATE/TIME  NDATA  OFFSET  REC1  REC2
         100     1   890902/1955   153     1     3
         110     1   890902/1955    88    154     3
         200     1   890902/1955  4335    242     3     4 ==> 7
         210     1   890902/1955   767    481     7     8

NUMBER OF RECORDS = 7 NUMBER OF MEGAWORDS = 0 + 6367 WORDS
PER CENT OF DIRECTORY QUOTA USED = 0.175
PER CENT OF FILE USED = 0.175
BLOCKING FACTOR = 74.540
PAW > ldir ntuple | list directory in NTUPLE

***** Directory ==> //LUN1/NTUPLE <===

                Created 890902/1958 Modified 890902/1958

==> List of objects
   HBOOK-ID  CYCLE  DATE/TIME  NDATA  OFFSET  REC1  REC2
         30     2   890902/1958  1082    215    41    42
             1   890902/1958  1082    725    39    40
         10     1   890902/1958   151    783    40
         20     1   890902/1958   305    934    40    41

NUMBER OF RECORDS = 34 NUMBER OF MEGAWORDS = 0 + 34064 WORDS
PER CENT OF DIRECTORY QUOTA USED = 0.851
PER CENT OF FILE USED = 0.850
BLOCKING FACTOR = 94.899

```

Figure 7.6: Reading a HBOOK direct access file

²In fact it is possible to leave the data on the disk of the machine where they were written in the batch job, and connect with NETWORK/RLOGIN host to the machine in question, getting access to the file via TCP/IP. See page 187 for more details.

7.4.1 Plot histogram data

The analysis of the data can now start and we begin by looking at the histograms in the top directory. Figure 7.7 shows the commands entered and the corresponding output plot. They should be compared with the lineprinter output in figure 7.4.

Plotting histogram data	
PAW > <u>zon 1 2</u>	| Divide picture into 2 vertically
PAW > <u>set htyp -3</u>	| Set hatch style for histogram
PAW > <u>hi/pl 110</u>	| Plot 1-dimensional histogram 110
PAW > <u>hi/pl 210</u>	| Plot 2-dimensional histogram 210

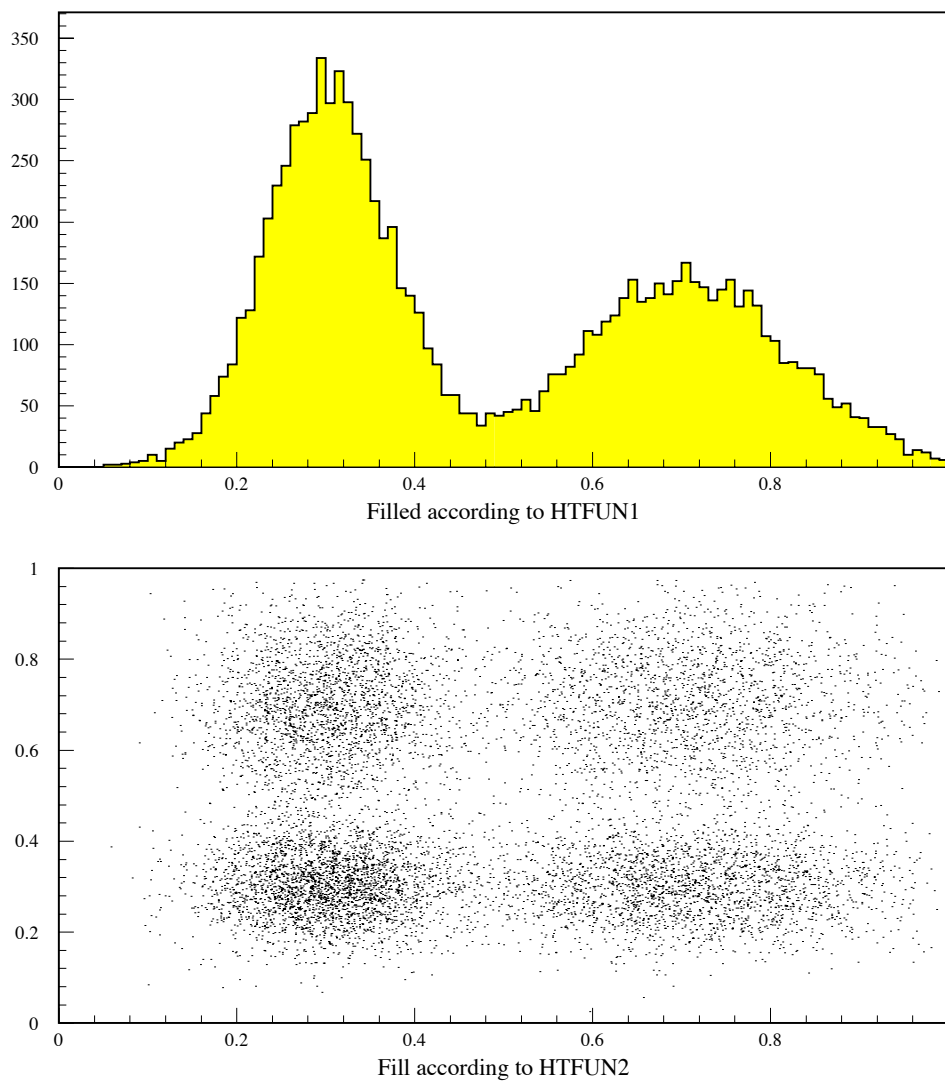


Figure 7.7: Plot of one- and two-dimensional histograms

7.5 Ntuples: A closer look

We now turn our attention to the NTUPLE directory to show the functionality and use of Ntuples. After making NTUPLE the **current** directory the available HBOOK objects are listed. The structure of the Ntuple with identifier 30 is PRINTed. The contents of the various Ntuple elements (“events”) can be viewed by the NTUPLE/SCAN command. As with most Ntuple commands a **selection criterion** can be given to treat only given “selected” subsamples of the Ntuple (two examples are seen with the further NTUPLE/SCAN commands (see figure 7.8).

```

Looking at Ntuple elements

PAW > cd ntuple | move to NTUPLE directory
PAW > hi/li | list HBOOK objects

==> Directory : //LUN1/NTUPLE
      30 (N)  N-TUPLE
      10 (1)  TEST1
      20 (2)  TEST2

PAW > nt/print 30 | print summary for Ntuple 30

*****
* NTUPLE ID= 30 ENTRIES= 10000 N-TUPLE *
*****
* Var numb * Name * Lower * Upper *
*****
* 1 * X * -.422027E+01 * 0.386411E+01 *
* 2 * Y * -.411077E+01 * 0.378365E+01 *
* 3 * Z * 0.485188E-04 * 0.179518E+02 *
*****

PAW > nt/scan 30 | scan the first elements
*****
* ENTRY * X * Y * Z *
*****
! 1 ! -1.0765 ! 1.4405 ! 3.2337 !
! 2 ! -1.2429 ! -1.6043 ! 4.1185 !
! 3 ! 0.54489 ! 1.7043 ! 3.2017 !
! 4 ! -0.81803 ! 0.66588 ! 1.1126 !
! 5 ! -1.8752 ! 0.38176 ! 3.6621 !
! 6 ! 0.37968 ! -1.0601 ! 1.2680 !
! 7 ! -0.52406 ! -0.68243E-01! 0.27930 !
! 8 ! 1.2175 ! 0.91701 ! 2.3231 !
! 9 ! -0.21487 ! -0.26670 ! 0.11730 !
! 10 ! 0.70368 ! 0.82514 ! 1.1760 !
! 11 ! 0.93648E-01! -2.0311 ! 4.1343 !
! 12 ! -0.48216 ! -2.5980 ! 6.9820 !
! 13 ! -0.45801 ! 0.71523 ! 0.72132 !
! 14 ! -0.60272 ! 0.98909E-01! 0.37306 !
! 15 ! 0.70454 ! -0.25562 ! 0.56172 !
More...? ( <CR>/N ): N
==> 15 events have been scanned

```

```

PAW > nt/sc 30 z>16 | example of a condition on the Z variable
*****
* ENTRY *      X      *      Y      *      Z      *
*****
!   43 !   3.8641   ! -1.5822   !   17.435   !
!  1964 !  -4.2203   ! -0.37562  !   17.952   !
!  7480 !   0.94503   ! -4.1108   !   17.791   !
!  9213 !   0.71434   ! -4.0068   !   16.565   !
==>      4 events have been scanned

PAW > nt/sc 30 abs(x)>4.or.abs(y)>4 | example of a more complex selection criterium
*****
* ENTRY *      X      *      Y      *      Z      *
*****
!  1964 !  -4.2203   ! -0.37562  !   17.952   !
!  7480 !   0.94503   ! -4.1108   !   17.791   !
!  9213 !   0.71434   ! -4.0068   !   16.565   !
==>      3 events have been scanned

```

Figure 7.8: Print and scan Ntuple elements

7.5.1 Ntuple plotting

The general format of the command NTUPLE/PLOT to project and plot a Ntuple as a (1-Dim or 2-Dim) histogram with automatic binning, possibly using a selection algorithm is:

```
NTUPLE/PLOT idn [ uwfunc nevent ifirst nupd chopt]
```

IDN Ntuple Identifier and variable(s) (see table 7.1)
UWFUNC Selection function (see table 7.2) - Default no function
NEVENT Number of events to be processed (default is 999999)
IFIRST First event to be processed (default is 1)
NUPD Frequency with which to update histogram (default is 1000000)
CHOPT HPLOT options (C,S,+,B,L,P,*,U,E,A)

7.5.2 Ntuple variable and selection function specification

Format	Explanation	Example
IDN.CHNAME	The variable named "CHNAME"	30.x variable x
IDN.n	The Ntuple variable at position n	30.3 variable 3
IDN.expression	Expression is any numerical expression of Ntuple variables. It may include a call to a COMIS function.	30.X**2+Y**2 30.X*COMIS.FOR
IDN.B%A	Scatter-plot of variable B versus A for each event	30.Y%X Y versus X
IDN.2%1	Scatter-plot of variable nb. 2 versus variable nb. 1	30.1%3 1 versus 3
IDN.expr1%expr2	expr1 and expr2 can be any numerical expression of the Ntuple variables. They can be COMIS functions.	30.SQRT(X**2+Y**2)%SIN(Z) 30.COMIS1.FTN%COS(Z)
	Any combination of the above	30.3%COMIS2.FTN*SIN(X)

Table 7.1: Syntax for specifying Ntuple variables

Format	Explanation	Example
0 or missing	No selection is applied (weight is 1).	<u>NT/PLOT 30.X</u>
Combination of cuts	A CUT or combination of CUTs, each created by the command NTUPLE/CUTS	<u>NT/PLOT 30.X 1</u> (use cut 1) <u>NT/PLOT 30.X 1.AND.2</u> <u>NT/PLOT 30.X .NOT.(1.AND.3).OR.2</u>
Combination of masks	A MASK or combination of MASKs, each created by the command NTUPLE/MASK	Assuming there exists a mask vector MSK: <u>NT/PLOT 30.X MSK(4)</u> (bit 4) <u>NT/PLOT 30.X MSK(1).OR.MSK(6)</u>
Logical expression	Any logical combination of conditions between Ntuple variables, cuts and masks.	<u>NT/PLOT 30.X X>3.14.AND.(Y<Z+5.)</u> <u>NT/PLOT 30.X 1.AND.MASK(3).OR.Z<10</u>
Numerical expression	Any numerical combination of constants and Ntuple variables. In this case the value of the expression will be applied as a weight to the element being plotted.	<u>NT/PLOT 30.X Y</u> weight X by Y <u>NT/PLOT 30.X X**2+Y**2</u> weight X by X^2+Y^2
Selection function	Name of a selection function in a text file of the form fun.ftn (Unix), FUN FORTRAN (IBM) and FUN.FOR (VAX). The function value is applied as a weight	<u>NTUPLE/PLOT 30.X SELECT.FOR</u> For each event the plotted value of X will be multiplied by the value of the selection function SELECT calculated for that event.
	Any combination of the above	<u>NT/PL 30.3%F1.FTN*SIN(X) 1.OR.F2.FTN</u>

Table 7.2: Syntax of a selection function used with a Ntuple

7.5.3 Ntuple selection mechanisms

With most Ntuple operations a selection “function” UWFUNC of a form described in table 7.2 can be used, i.e. it can take the form of a simple or composed **expression** or an **external FORTRAN function**, executed by COMIS [1], a **cut** or a **mask**. When used together with the NTUPLE/PLOT command the selection function also acts as a **weighting** factor.

7.5.4 Masks

The mask facility allows the user to specify up to **32** selection criteria associated with a Ntuple. These criteria are defined like cuts, but their value for each event are written to an external direct access file, from which the information can be readily retrieved at a later stage, without recalculating the condition value in question. In the example session below first a **new** mask file MNAME.MASK is defined, which can contain information for up to 10000 Ntuple elements. Next we define event election criteria and store their result at various bit positions in the mask vector MNAME.

```

Defining cuts and masks

PAW > NT/CUT 4 Z>X**2 | Define cut 4
PAW > NT/MASK MNAME N 10000
PAW > NT/PLOT 30.X X**2+Y**2>2>>MNAME(1)
PAW > NT/PLOT 30.X 4.AND.Y>1>>MNAME(2)
PAW > NT/PLOT 30.Y SIN(Z).GT.SIN(Y)>>MNAME(3)
PAW > NT/MASK MNAME P | Print mask definitions

=====> Current active selections in mask MNAME

Bit  Nevents  Selection
  1    3723   X**2+Y**2>2
  2    1558   4.AND.Y>1
  3    7051   SIN(Z)>SIN(Y)
PAW > NT/MASK MNAME C | close MNAME.MASK file

```

Of course doing this kind of gymnastics makes sense only if a **time consuming** selection mechanism is used and only a few events are selected. In a subsequent run the mask file can then be read to display the information much more quickly.

```

Using a mask file of a previous run

PAW > NT/MASK MNAME | open the mask file for read
PAW > NT/PLOT 30.X MNAME(1) | plot using bit 1
PAW > NT/PLOT 30.X MNAME(2) | plot using bit 2
PAW > NT/PLOT 30.Y MNAME(3) | plot using bit 3
PAW > NT/MASK MNAME C | close MNAME.MASK file

```

Cuts

A **cut** is identified by an integer (between 0 and 100) and is a **logical** expression of Ntuple elements, other cuts, masks or functions.

Example of cuts

```
PAW > NT/CUT 1 4<X | variable
PAW > NT/CUT 2 0.4<X<0.8.AND.Y<SQRT(Z) | ditto
PAW > NT/CUT 3 FUN.FOR | external function
PAW > NT/CUT 4 FUN.FOR.AND.Z>X**2 | ditto plus variable
PAW > NT/CUT 5 (1.AND.2).OR.4 | combination of cuts
PAW > NT/CUT 6 1.AND.Z<0 | cut and variable
PAW > NT/CUT 7 X | event weight
PAW > NT/CUT 8 SQRT(Y) | ditto
PAW > NT/CUT 9 MASK(23).AND.8 | mask and cut
```

Cut definitions can be written to a file and later re-read.

```
PAW > NT/CUT 0 W cuts.dat | write all cuts to file
PAW > NT/CUT 4 R cuts.dat | read cut 4 from file
PAW > NT/CUT 4 P | print cut 4
```

```
CUT number= 4 Points= 1 Variable= 1
FUN.FOR.AND.Z>X**2
```

Graphical cut

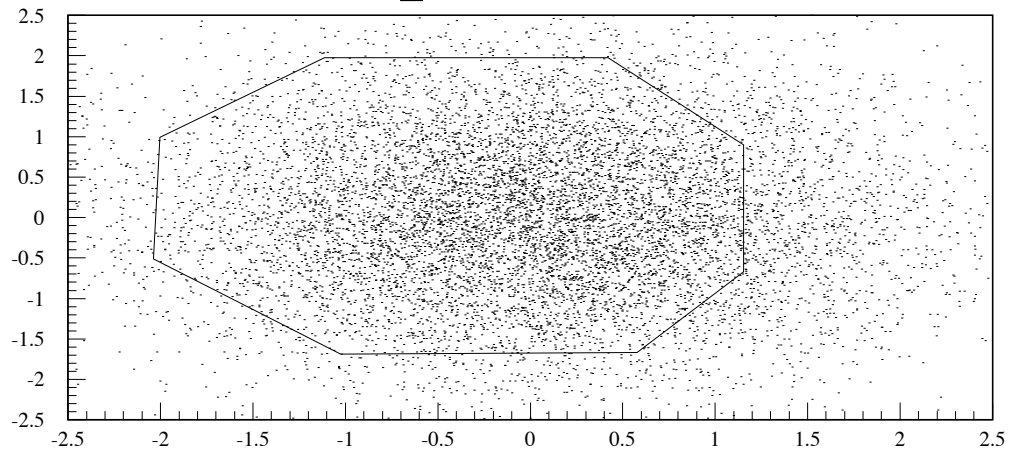
One can also define a cut on the screen in a **graphical** way, by pointing out the upper and lower limits (1-dimensional case) or an area defined by up to 20 points (2-dimensional case) by using the mouse or arrow keys (see figure 7.9).

Note that graphical cuts are only valid for the **original** Ntuple variables and not for combinations of the latter.

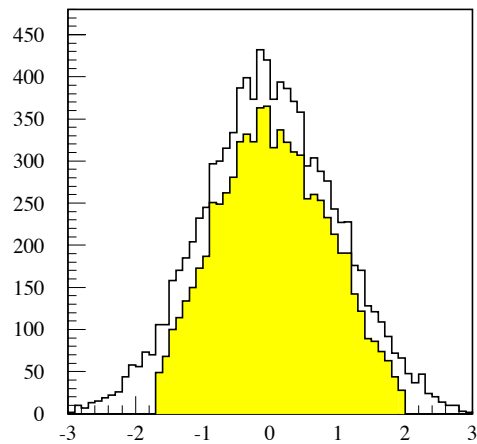
Using graphical cuts

```
PAW > nt/pl 30.x%y | plot y versus x
PAW > CUT 1 G | graphical cut 1 for current plot
PAW > zon 1 2 | define picture layout
PAW > title 'Graphical cuts' | title for picture
PAW > 2d 211 'X versus Y' 50 -2.5 2.5 50 -2.5 2.5 0. | user binning
PAW > 1d 212 'X - Before and after cut' 60 -3. 3. 0. | ditto
PAW > 1d 213 'Y - Before and after cut' 60 -3. 3. 0. | ditto
PAW > nt/pl 30.x%y ! -211 | plot y versus x in histogram 211
PAW > cut 1 d | draw graphical cut 1
PAW > zon 2 2 3 s | redefine the picture layout
PAW > nt/pl 30.x ! -212 | plot x BEFORE cut in histogram 212
PAW > set htyp -3 | use hatch for plot after cut
PAW > nt/pl 30.x 1 -212 ! ! S | plot x AFTER cut on same plot
PAW > set htyp 0 | no hatch for plot without cut
PAW > nt/pl 30.y ! -213 | plot y BEFORE cut in histogram 213
PAW > set htyp -3 | use hatch for plot after cut
PAW > nt/pl 30.y 1 -213 ! ! S | plot y AFTER cut on same plot
```

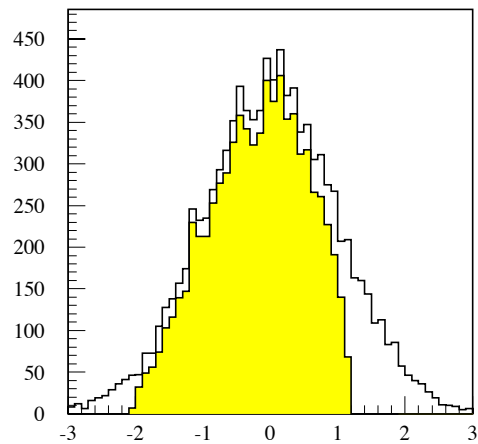
Graphical cuts



X versus Y



X - Before and after cut



Y - Before and after cut

Figure 7.9: Graphical definition of cuts

COMIS selection function

In the definition of a selection criterion an external function (in the sense that it has not been compiled and linked together with PAW) can be used. This function is interpreted by the COMIS [1] package. The functions which are callable from within such a function are given below.

Type of function	List of callable routines
FORTRAN library	SQRT LOG LOG10 EXP SIN COS TAN ASIN ACOS ATAN2 ABS MOD MIN MAX INT REAL DBLE LEN INDEX
HBOOK package	HBOOK1 HBOOK2 HBOOKN HFILL HF1 HPRINT HDELET HRESET HFITGA HFITPO HFITEX HPROJ1 HPROJ2 HFN HGMPAR HROPEN PAOPEN PACLOS PAREAD PAWRIT HPAK HPAKE HUNPAK HGIVE HGN HGNF HF2 HFF1 HFF2 HBFUN1 HBFUN2 HRIN HROUT HI HIE HIX HIJ HIDALL HNOENT HX HXY HCOPY HSTATI HBPROF HOPERA HIDOPT HDERIV HRNDM1 HRNDM2 HBARX HBARY
ZEBRA package	FZIN FZOUT FZENDI FZENDO FZFILE RZCDIR RZLDIR RZFILE RZEND RZIN RZOUT RZVIN RZVOUT
HLOT package	HLOT HPLSYM HPLERR HPLEGO HPLNT HPLSUR HPLSOF HPLSET HPLGIV HPLC HPLSET HPLGIV HPLC
KUIP package	KUGETV KUDPAR KUVECT KILEXP KUTIME KUEXEL
HIGZ package	IPL IPM IFA IGTEXT IGBOX IGAXIS IGPIE IGRAPH IGHIST IGARC IGLBL IGRNG IGMETA IGSA IGSET IRQLC IRQST ISELNT ISFAIS ISFASI ISLN ISMK ISVP ISWN ITX ICLRWK ISCR
KERNLIB library	JBIT JBYT LENNOC RANNOR RNDM SBITO SBIT1 SBYT UCOPY UCTOH UHTOC VZERO
COMMON blocks	/PAWC/, /QUEST/, /KCWORK/, /PAWPAR/, /PAWIDN/

Table 7.3: Function callable and common blocks which can be referenced from an external function with PAW.

The command NTUPLE/UWFUNC allows a selection function for a Ntuple to be prepared more easily. It generates a function with a name specified by the user and with code making available the variables corresponding to the given Ntuple identifier via a COMMON block. As an example consider the Ntuple number 30 used previously.

Specifying a user selection function

```
PAW > NTUPLE/UWFUNC 30 SELECT.FOR PT | Generate SELECT.FOR
PAW > EDIT SELECT.FOR | Look at file SELECT.FOR
REAL FUNCTION SELECT(XDUMMY)
REAL X , Y , Z
COMMON/PAWIDN/IDNEVT,VIDN1,VIDN2,VIDN3,
+ X , Y , Z
DIMENSION XDUMMY( 3)
CHARACTER*8 CHTAGS( 3)
DATA CHTAGS/' X ',' Y ',' Z '/
*
SELECT=1.
PRINT 1000, IDNEVT
DO 10 I=1, 3
PRINT 2000, I, CHTAGS(I), XDUMMY(I)
10 CONTINUE
*
1000 FORMAT(8H IDNEVT=, I5)
2000 FORMAT(5X, I3, 5X, A, 1H=, G14.7)
END
```

The user can add further FORTRAN code with the command EDIT. Remember that the value of the function can be used for weighting each event.

7.5.5 Examples

To put into practice the syntax explained above let us consider figure 7.10. We first plot variable Z with the binning automatically calculated by HBOOK. Then we define a histogram with identifier 300 into which we want HBOOK to plot the squared sums of the elements X and Y. This corresponds to the definition of the Z variable as can be seen in the FORTRAN listing in figure 7.5. As the MEAN and RMS are only calculated on the events within the histogram boundaries, they differ slightly between the top and bottom plot in figure 7.10.

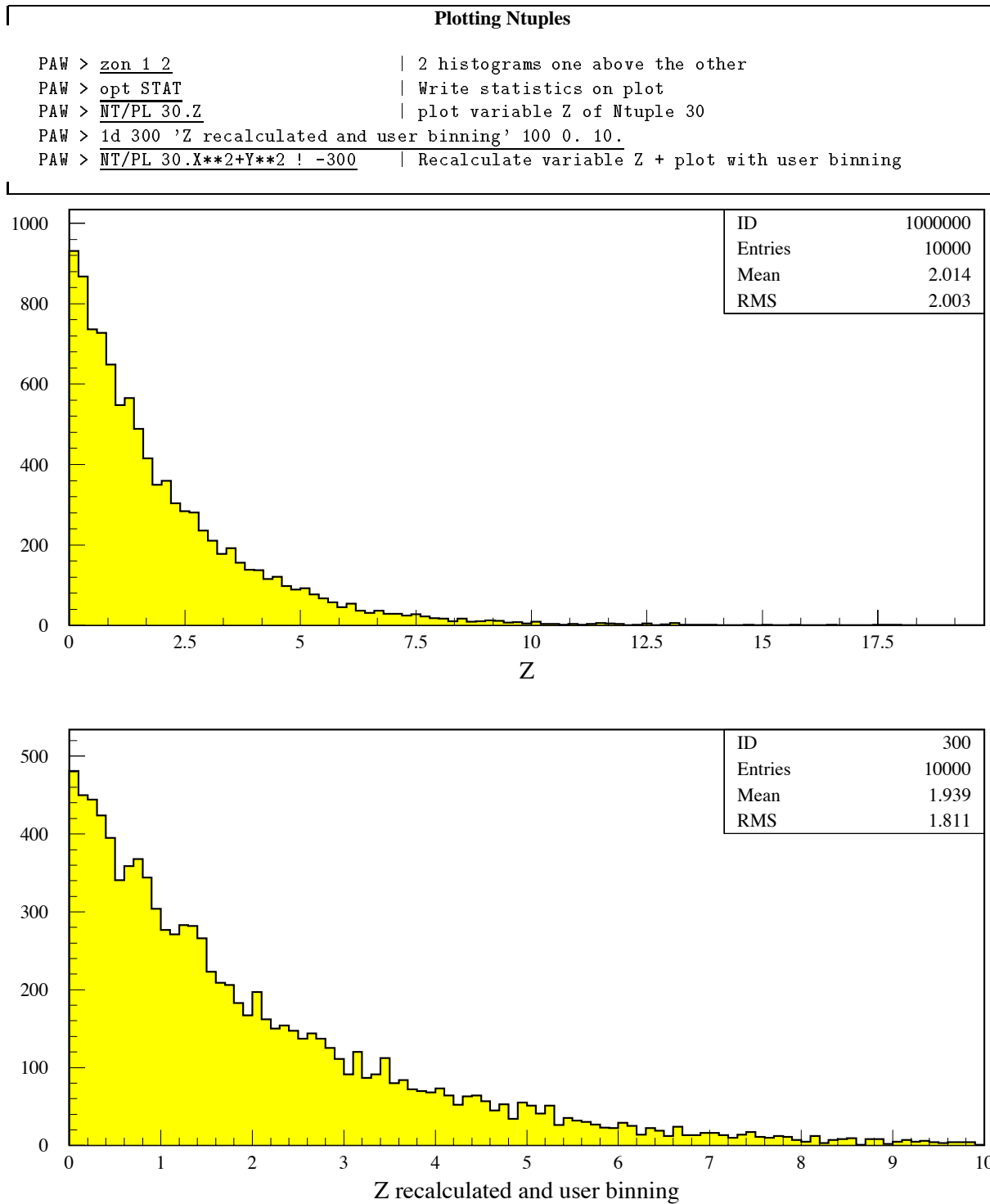


Figure 7.10: Read and plot Ntuple elements

More complex Ntuple presentations

```

PAW > zon 2 2 | Divide plot in 4 zones
PAW > opt STAT | Select option to write statistics on plot
PAW > set HTYP -3 | Define histogram hatch type
PAW > 1d 401 'NT/PL - X' 100. -2.5 2.5 | Book 1 dim histogram
PAW > nt/pl 30.1 ! -401 | Plot variable 1 (x) using histogram 401
PAW > 1d 402 'NT/PL E option - Y' 100. -2.5 2.5 | 1 dim histogram (different title)
PAW > igset mtyp 21 | Select market type for points on plot
PAW > nt/pl 30.y ! -402 ! ! E | Plot y variable with Error bar option
PAW > 1d 403 'NT/PL B option - X' 40. -2.5 2.5 | 1 dim histogram (different title + binning)
PAW > set barw 0.4 | Define bar width for bar chart
PAW > set baro 0.3 | Define bar origin for bar chart
PAW > csel NB 0.33 | Print selection criterion on plot
PAW > set hcol 1001 | Histogram colour black
PAW > nt/pl 30.x y>0 -403 ! ! b | Plot x variable as bar chart
PAW > 1d 404 'NT/PL PL option - Y' 100. -2.5 2.5 | 1 dim histogram (different title)
PAW > max 404 160 | Fix maximum for plotting hist 404
PAW > nt/pl 30.y sqrt(z)>1 -404 ! ! pl | Plot y variable with PL option

```

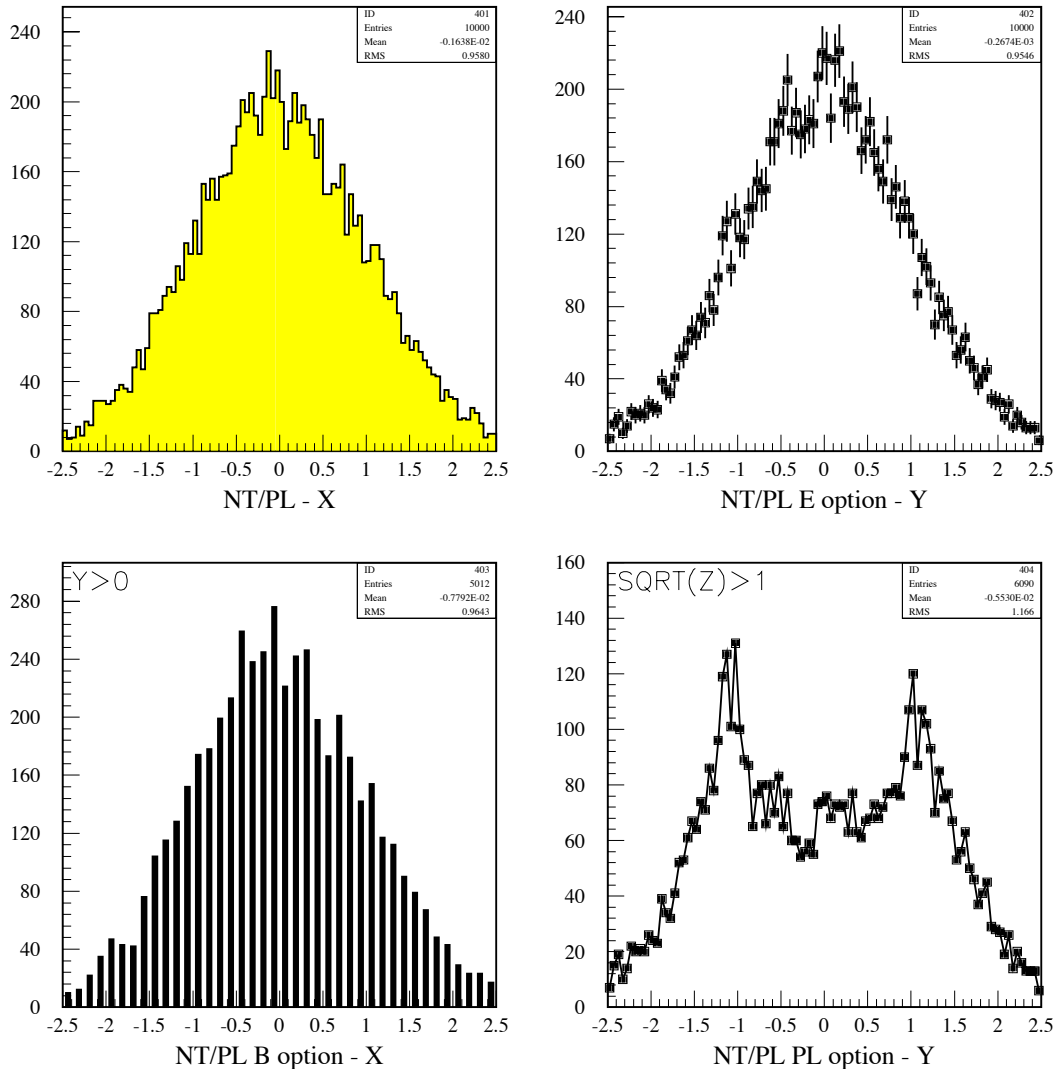


Figure 7.11: Selection functions and different data presentations

7.6 Fitting with PAW/HBOOK/MINUIT

Minuit[6]³ is conceived as a tool to find the minimum value of a multi-parameter function and analyze the shape of the function around the minimum. The principal application is foreseen for statistical analysis, working on chisquare or log-likelihood functions, to compute the best-fit parameter values and uncertainties, including correlations between the parameters. It is especially suited to handle difficult problems, including those which may require guidance in order to find the correct solution.

7.6.1 Basic concepts of MINUIT.

The MINUIT package acts on a multiparameter FORTRAN function to which one must give the generic name FCN. In the PAW/HBOOK implementation, the function FCN is called HFCNH when the command Histo/Fit (PAW) or the routine HFITH are invoked. It is called HFCNV when the command Vector/Fit or the routine HFITV are invoked. The value of FCN will in general depend on one or more variable parameters.

To take a simple example, suppose the problem is to fit a polynomial through a set of data points with the command Vector/Fit. Routine HFCNV called by HFITV calculates the chisquare between a polynomial and the data; the variable parameters of HFCNV would be the coefficients of the polynomials. Routine HFITV will request MINUIT to minimize HFCNV with respect to the parameters, that is, find those values of the coefficients which give the lowest value of chisquare.

7.6.2 Basic concepts - The transformation for parameters with limits.

For variable parameters with limits, MINUIT uses the following transformation:

$$P_{\text{int}} = \arcsin \left(2 \frac{P_{\text{ext}} - a}{b - a} - 1 \right) \qquad P_{\text{ext}} = a + \frac{b - a}{2} (\sin P_{\text{int}} + 1)$$

so that the internal value P_{int} can take on any value, while the external value P_{ext} can take on values only between the lower limit a and the upper limit b . Since the transformation is necessarily non-linear, it would transform a nice linear problem into a nasty non-linear one, which is the reason why limits should be avoided if not necessary. In addition, the transformation does require some computer time, so it slows down the computation a little bit, and more importantly, it introduces additional numerical inaccuracy into the problem in addition to what is introduced in the numerical calculation of the FCN value. The effects of non-linearity and numerical roundoff both become more important as the external value gets closer to one of the limits (expressed as the distance to nearest limit divided by distance between limits). The user must therefore be aware of the fact that, for example, if he puts limits of $(0, 10^{10})$ on a parameter, then the values 0.0 and 1.0 will be indistinguishable to the accuracy of most machines.

The transformation also affects the parameter error matrix, of course, so MINUIT does a transformation of the error matrix (and the “parabolic” parameter errors) when there are parameter limits. Users should however realize that the transformation is only a linear approximation, and that it cannot give a meaningful result if one or more parameters is very close to a limit, where $\partial P_{\text{ext}} / \partial P_{\text{int}} \approx 0$. Therefore, it is recommended that:

- Limits on variable parameters should be used only when needed in order to prevent the parameter from taking on unphysical values.

³The following information about Minuit has been extracted from the Minuit documentation.

- When a satisfactory minimum has been found using limits, the limits should then be removed if possible, in order to perform or re-perform the error analysis without limits.

7.6.3 How to get the right answer from MINUIT.

MINUIT offers the user a choice of several minimization algorithms. The MIGRAD (Other algorithms are available with Interactive MINUIT, as described on Page 151) algorithm is in general the best minimizer for nearly all functions. It is a variable-metric method with inexact line search, a stable metric updating scheme, and checks for positive-definiteness. Its main weakness is that it depends heavily on knowledge of the first derivatives, and fails miserably if they are very inaccurate. If first derivatives are a problem, they can be calculated analytically inside the user function and communicated to PAW via the routine HDERIV.

If parameter limits are needed, in spite of the side effects, then the user should be aware of the following techniques to alleviate problems caused by limits:

Getting the right minimum with limits.

If MIGRAD converges normally to a point where no parameter is near one of its limits, then the existence of limits has probably not prevented MINUIT from finding the right minimum. On the other hand, if one or more parameters is near its limit at the minimum, this may be because the true minimum is indeed at a limit, or it may be because the minimizer has become “blocked” at a limit. This may normally happen only if the parameter is so close to a limit (internal value at an odd multiple of $\pm \frac{\pi}{2}$ that MINUIT prints a warning to this effect when it prints the parameter values.

The minimizer can become blocked at a limit, because at a limit the derivative seen by the minimizer $\partial F / \partial P_{\text{int}}$ is zero no matter what the real derivative $\partial F / \partial P_{\text{ext}}$ is.

$$\frac{\partial F}{\partial P_{\text{int}}} = \frac{\partial F}{\partial P_{\text{ext}}} \frac{\partial P_{\text{ext}}}{\partial P_{\text{int}}} = \frac{\partial F}{\partial P_{\text{ext}}} = 0$$

Getting the right parameter errors with limits.

In the best case, where the minimum is far from any limits, MINUIT will correctly transform the error matrix, and the parameter errors it reports should be accurate and very close to those you would have got without limits. In other cases (which should be more common, since otherwise you wouldn’t need limits), the very meaning of parameter errors becomes problematic. Mathematically, since the limit is an absolute constraint on the parameter, a parameter at its limit has no error, at least in one direction. The error matrix, which can assign only symmetric errors, then becomes essentially meaningless.

7.6.4 Interpretation of Parameter Errors:

There are two kinds of problems that can arise: the **reliability** of MINUIT’s error estimates, and their **statistical interpretation**, assuming they are accurate.

Statistical interpretation:

For discussion of basic concepts, such as the meaning of the elements of the error matrix, or setting of exact confidence levels, see [13, 14, 15].

Reliability of MINUIT error estimates.

MINUIT always carries around its own current estimates of the parameter errors, which it will print out on request, no matter how accurate they are at any given point in the execution. For example, at initialization, these estimates are just the starting step sizes as specified by the user. After a MIGRAD or HESSE step, the errors are usually quite accurate, unless there has been a problem. MINUIT, when it prints out error values, also gives some indication of how reliable it thinks they are. For example, those marked `CURRENT GUESS ERROR` are only working values not to be believed, and `APPROXIMATE ERROR` means that they have been calculated but there is reason to believe that they may not be accurate.

If no mitigating adjective is given, then at least MINUIT believes the errors are accurate, although there is always a small chance that MINUIT has been fooled. Some visible signs that MINUIT may have been fooled are:

- Warning messages produced during the minimization or error analysis.
- Failure to find new minimum.
- Value of EDM too big (estimated Distance to Minimum).
- Correlation coefficients exactly equal to zero, unless some parameters are known to be uncorrelated with the others.
- Correlation coefficients very close to one (greater than 0.99). This indicates both an exceptionally difficult problem, and one which has been badly parameterized so that individual errors are not very meaningful because they are so highly correlated.
- Parameter at limit. This condition, signalled by a MINUIT warning message, may make both the function minimum and parameter errors unreliable. See the discussion above “*Getting the right parameter errors with limits*”.

The best way to be absolutely sure of the errors, is to use “independent” calculations and compare them, or compare the calculated errors with a picture of the function. Theoretically, the covariance matrix for a “physical” function must be positive-definite at the minimum, although it may not be so for all points far away from the minimum, even for a well-determined physical problem. Therefore, if MIGRAD reports that it has found a non-positive-definite covariance matrix, this may be a sign of one or more of the following:

A non-physical region: On its way to the minimum, MIGRAD may have traversed a region which has unphysical behaviour, which is of course not a serious problem as long as it recovers and leaves such a region.

An underdetermined problem: If the matrix is not positive-definite even at the minimum, this may mean that the solution is not well-defined, for example that there are more unknowns than there are data points, or that the parameterization of the fit contains a linear dependence. If this is the case, then MINUIT (or any other program) cannot solve your problem uniquely, and the error matrix will necessarily be largely meaningless, so the user must remove the underdeterminedness by reformulating the parameterization. MINUIT cannot do this itself.

Numerical inaccuracies: It is possible that the apparent lack of positive-definiteness is in fact only due to excessive roundoff errors in numerical calculations in the user function or not enough precision. This is unlikely in general, but becomes more likely if the number of free parameters is very large, or if

the parameters are badly scaled (not all of the same order of magnitude), and correlations are also large. In any case, whether the non-positive-definiteness is real or only numerical is largely irrelevant, since in both cases the error matrix will be unreliable and the minimum suspicious.

An ill-posed problem: For questions of parameter dependence, see the discussion above on positive-definiteness.

Possible other mathematical problems are the following:

Excessive numerical roundoff: Be especially careful of exponential and factorial functions which get big very quickly and lose accuracy.

Starting too far from the solution: The function may have unphysical local minima, especially at infinity in some variables.

7.6.5 Fitting histograms

The general syntax of the command to fit histograms is:

```
HISTOGRAM id func [ chopt np par step pmin pmax errpar ]
```

Only the parameters, which are of more general use, are described in detail. The full description can be found in part 3 of this manual.

ID A histogram identifier (1-dim or 2-dim)

A bin range may be specified, e.g. Histo/Fit 10(25:56) ...

FUNC Name of a function to be fitted to the histogram.

This function can be of various forms:

- 1 The name of a file which contains the user defined function to be minimized. Function name and file name must be the same. For example file FUNC.FOR is:

```
FUNCTION FUNC(X) or FUNC(X,Y) for a 2-Dim histogram
COMMON/PAWPAR/PAR(2)
FUNC=PAR(1)*X +PAR(2)*EXP(-X)
END
```

- 2 One of the keywords below (**1-dim histograms only**), which will use the parameterization described at the right for the fit.

G Func=par(1)*exp(-0.5*((x-par(2))/par(3))**2)

E Func=exp(par(1)+par(2)*x)

Pn Func=par(1)+par(2)*x+par(3)*x**2...+par(n+1)*x**n, 0<n<20

- 3 A combination of the keywords above with the 2 operators + or *.

Note that in this case, the order of parameters in PAR must correspond to the order of the basic functions. Blanks are not allowed in the expression.

CHOPT All options of the HISTO/PLOT command plus the following additional ones:

0 Do not plot the result of the fit. By default the fitted function is drawn unless the option "N" below is specified.

B Some or all parameters are bounded. In this case vectors STEP, PMIN, PMAX must be specified. Default is: All parameters vary freely.

- D The user is assumed to compute derivatives analytically using routine HDERIV. By default, derivatives are computed numerically.
- L Use Log Likelihood method. Default is χ^2 method.
- M Invokes interactive Minuit (See on Page 151)
- N Do not store the result of the fit bin by bin with the histogram. By default the function is calculated at the centre of each bin and the fit results stored with the histogram data structure.
- Q Quiet mode. No output printed about the fit.
- V Verbose mode. Results are printed after each iteration. By default only final results are printed.
- W Sets weights equal to 1.
- NP Number of parameters in fit ($0 \leq NP \leq 34$)
- PAR Vector containing the fit parameters.
Before the fit: Vector containing the initial values
After the fit: Vector containing the fitted values.
- STEP Vector with step size for fit parameters
- PMIN Vector with lower bounds for fit parameters
- PMAX Vector with upper bounds for fit parameters
- ERRPAR Vector with errors on the fitted parameters

When using predefined functions (case 2 for the FUNC parameter) initial values need not be specified when NP=0. In this case the parameter vector PAR, if specified, is only filled with the fitted parameters on **output**.

7.6.6 A simple fit with a gaussian

Example of simple fit with gaussian in PAW

```
PAW > opt stat | Select option to show histogram statistics on plot
PAW > opt fit | Select option to show fitted parameters on plot
PAW > hi/fit 10 G | Fit histogram 10 with a single gaussian
*****
*                               *
* Function minimization by SUBROUTINE HFITGA *
* Variable-metric method *
* ID =          10  CHOPT = T *
*                               *
*****
Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

FCN=  96.97320      FROM MIGRAD      STATUS=CONVERGED  CALLS=  549 EDM=  0.26E-03
          STRATEGY= 1      ERROR DEF=  1.0000

INT EXT PARAMETER
NO. NO.  NAME      VALUE      ERROR      STEP      FIRST
      NAME      VALUE      ERROR      SIZE      DERIVATIVE
  1  1  Constant    239.83     2.8178     0.00000    0.57627E-02
  2  2  Mean      -0.53038E-02  0.77729E-04  0.00000    22.025
  3  3  Sigma      0.98766     0.70224E-02  0.00000   -0.88534

CHISQUARE = 0.1021E+01  NPFIT =  98
```

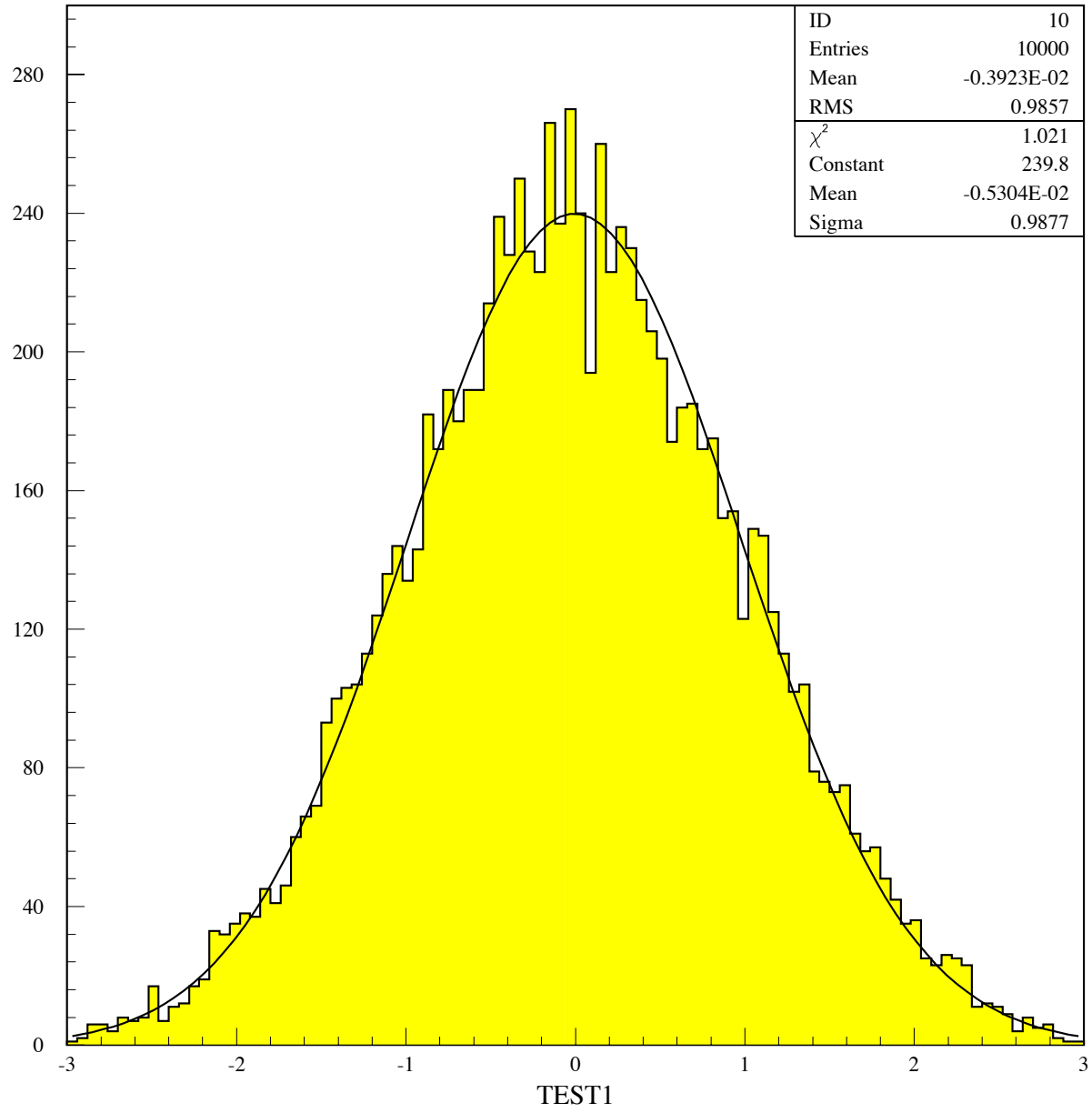


Figure 7.12: Example of a simple fit of a one-dimensional distribution

```

Fit parts of histogram separately
PAW > opt NSTA | Turn off option showing statistics on plot
PAW > ve/cr par(6) | Create a vector with 6 elements
PAW > set fit 111 | Show fitted parameters + errors on plot
PAW > hi/fit 110(1:50) G ! 0 par | Fit first half with a gaussian and plot

*****
*                               *
* Function minimization by SUBROUTINE HFITGA *
* Variable-metric method          *
* ID =          110  CHOPT = TR    *
*                               *
*****
Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

FCN=   90.66560      FROM MIGRAD      STATUS=CONVERGED  CALLS=  152 EDM=  0.68E-05
                STRATEGY= 1      ERROR DEF=      1.0000

INT EXT PARAMETER
NO. NO.  NAME      VALUE      ERROR      STEP      FIRST
                SIZE      DERIVATIVE
  1  1  Constant    300.28      5.0681      0.13342    0.97075E-04
  2  2  Mean        0.30698     0.10511E-02 -0.13885E-04 -0.57797
  3  3  Sigma        0.73832E-01 0.67896E-03 -0.57602E-04 -4.6407

CHISQUARE = 0.2159E+01  NPFIT = 45

PAW > hi/fit 110(50:99) G 0 0 par(4) | Fit second half with gaussian, do not plot

*****
*                               *
* Function minimization by SUBROUTINE HFITGA *
* Variable-metric method          *
* ID =          110  CHOPT = TR    *
*                               *
*****
Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

FCN=   30.16534      FROM MIGRAD      STATUS=CONVERGED  CALLS=  221 EDM=  0.87E-04
                STRATEGY= 1      ERROR DEF=      1.0000

INT EXT PARAMETER
NO. NO.  NAME      VALUE      ERROR      STEP      FIRST
                SIZE      DERIVATIVE
  1  1  Constant    153.27      3.0227      0.65005E-01 0.36877E-02
  2  2  Mean        0.70186     0.19599E-02 0.40388E-03 4.8103
  3  3  Sigma        0.11965     0.18242E-02 -0.25292E-03 6.9011

CHISQUARE = 0.6418E+00  NPFIT = 50

PAW > hi/plot 110 SFUNC | Plot result of fit on Same plot
PAW > ve/pr par(1:6) | Print the fitted parameters in PAR
PAR ( 1 ) = 300.2846
PAR ( 2 ) = 0.3069752
PAR ( 3 ) = 0.7383241E-01
PAR ( 4 ) = 153.2716
PAR ( 5 ) = 0.7018576
PAR ( 6 ) = 0.1196475

```

Parameter	Input value	Result of Figure 7.13	Result of Figure 7.14
First Gaussian:			
Height	1. (normalised)	300. \pm 5.	308. \pm 5.
Mean value	0.3	0.307 \pm 0.001	0.303 \pm 0.001
Width (sigma)	0.07	0.074 \pm 0.001	0.070 \pm 0.001
Second Gaussian:			
Height	0.5 (normalised)	153. \pm 3.	154. \pm 4.
Mean value	0.7	0.702 \pm 0.002	0.703 \pm 0.002
Width (sigma)	0.12	0.120 \pm 0.002	0.119 \pm 0.002

Table 7.4: Results for the fitted parameters of the gaussian distributions as compared to the initial values which the gaussian distributions were generated in the “batch” job in figure 7.3. The table also includes the result of the double gaussian fit in section 7.14

Example of a more complex fit

```
PAW > * Create vector of 6 elements and give initial values for combined fit of two gaussians
PAW > ve/cr par2(6) r 200 0.3 0.1 100 0.7 0.1 | initial values for the 6 fit parameters
PAW > set fit 111 | display fitted parameters plus errors
PAW > hi/fit 110(2:99) G+G ! 6 par2 | perform the fit (sum of 2 gaussians)
```

```
*****
*
* Function minimization by SUBROUTINE HFITH *
* Variable-metric method *
* ID = 110 CHOPT = R *
*
*****
```

Convergence when estimated distance to minimum (EDM) .LT. 0.10E-03

```
FCN= 57.41251 FROM MIGRAD STATUS=CONVERGED CALLS= 597 EDM= 0.10E-03
STRATEGY= 1 ERROR DEF= 1.0000
```

INT NO.	EXT NO.	PARAMETER NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	1	P1	307.86	5.3896	1.3393	-0.51814E-03
2	2	P2	0.30265	0.10750E-02	0.18577E-03	3.5622
3	3	P3	0.70029E-01	0.86285E-03	0.19967E-03	11.689
4	4	P4	153.62	3.0170	0.73111	0.30406E-02
5	5	P5	0.70303	0.20652E-02	0.43051E-03	-1.2694
6	6	P6	0.11865	0.18645E-02	0.39360E-03	3.2237

CHISQUARE = 0.6524E+00 NPFIT = 94

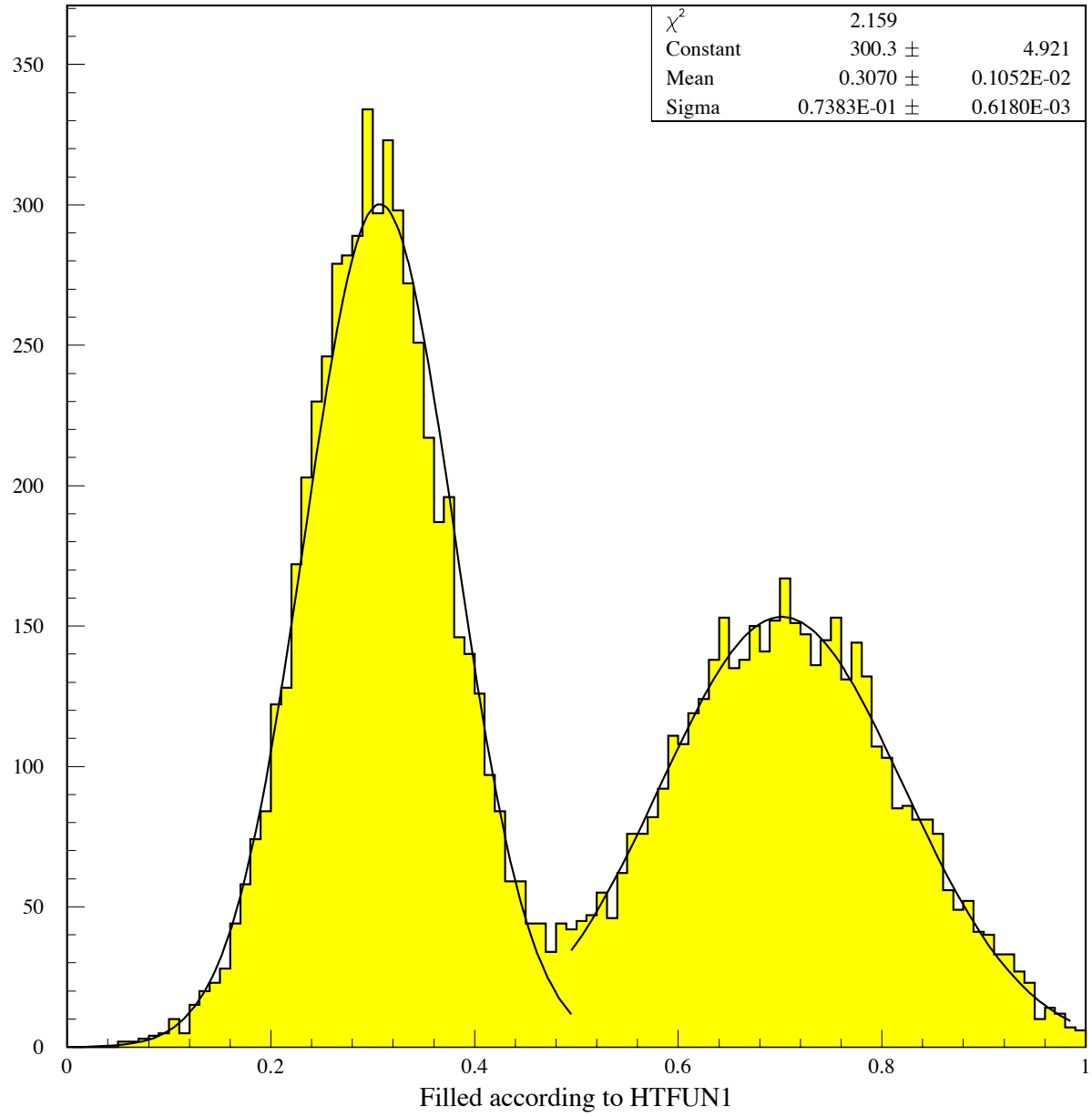


Figure 7.13: Example of a fit using sub-ranges bins

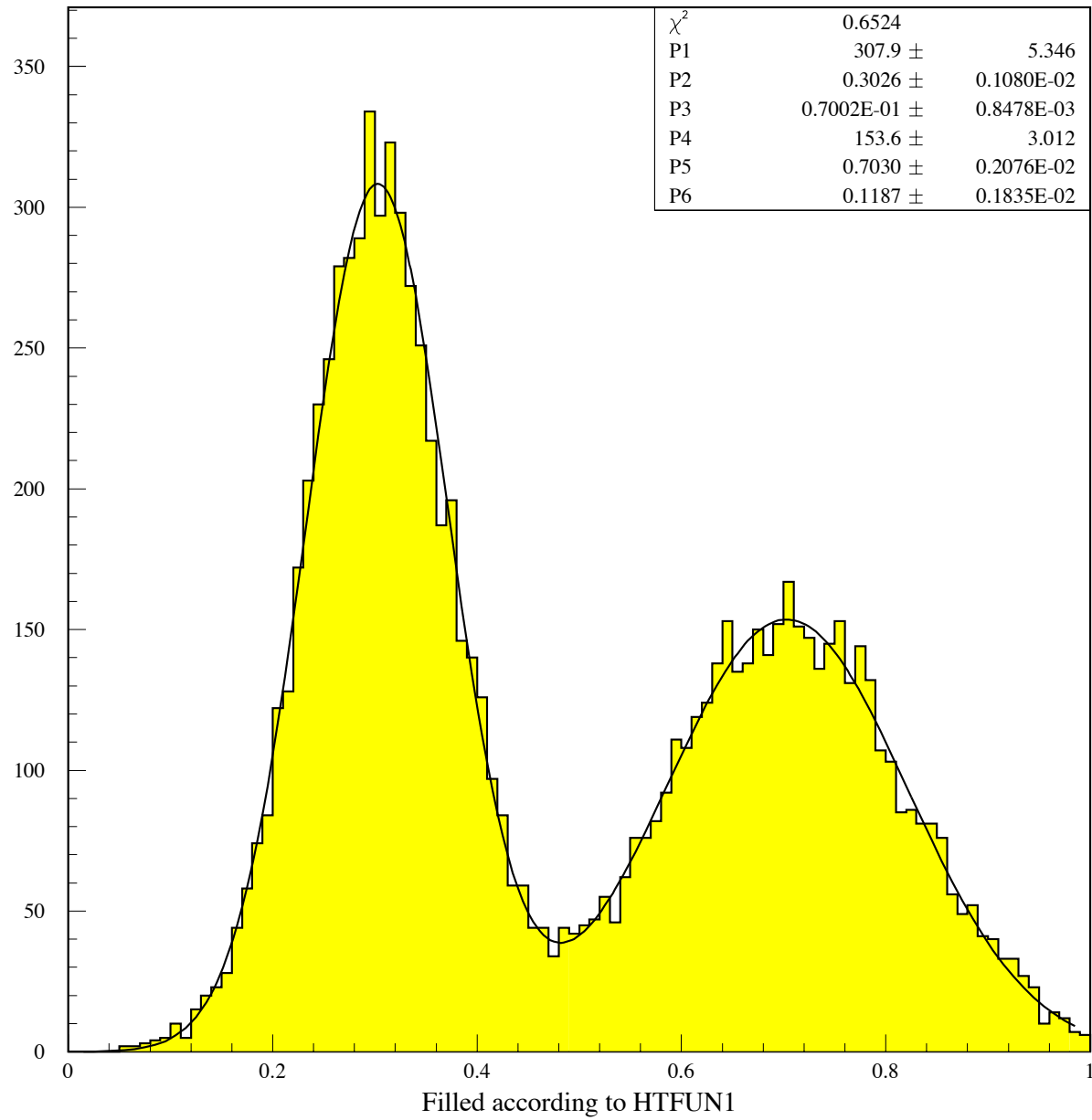


Figure 7.14: Example of a fit using a global double gaussian fit

7.7 Doing more with Minuit

When the HISTO/FIT or VECTOR/FIT command is invoked, PAW/HBOOK will set a default environment for Minuit. Control may be given to Minuit if the option “M” is specified in the command. In this case, the user may enter Minuit control statements.

Overview of available MINUIT commands

CLEAr

Resets all parameter names and values to undefined. Must normally be followed by a PARAMETER command or equivalent, in order to define parameter values.

CONtour par1 par2 [devs] [ngrid]

Instructs MINUIT to trace contour lines of the user function with respect to the two parameters whose external numbers are **par1** and **par2**. Other variable parameters of the function, if any, will have their values fixed at the current values during the contour tracing. The optional parameter **[devs]** (default value 2.) gives the number of standard deviations in each parameter which should lie entirely within the plotting area. Optional parameter **[ngrid]** (default value 25 unless page size is too small) determines the resolution of the plot, i.e. the number of rows and columns of the grid at which the function will be evaluated.

EXIT

End of Interactive MINUIT. Control is returned to PAW.

FIX parno

Causes parameter **parno** to be removed from the list of variable parameters, and its value will remain constant (at the current value) during subsequent minimizations, etc., until another command changes its value or its status.

HELP [SET] [SHOw]

Causes MINUIT to list the available commands. The list of SET and SHOw commands must be requested separately.

HESse [maxcalls]

Instructs MINUIT to calculate, by finite differences, the Hessian or error matrix. That is, it calculates the full matrix of second derivatives of the function with respect to the currently variable parameters, and inverts it, printing out the resulting error matrix. The optional argument **[maxcalls]** specifies the (approximate) maximum number of function calls after which the calculation will be stopped.

IMProve [maxcalls]

If a previous minimization has converged, and the current values of the parameters therefore correspond to a local minimum of the function, this command requests a search for additional distinct local minima. The optional argument **[maxcalls]** specifies the (approximate) maximum number of function calls after which the calculation will be stopped.

MIGrad [**maxcalls**] [**tolerance**]

Causes minimization of the function by the method of Migrad, the most efficient and complete single method, recommended for general functions (see also MINImize). The minimization produces as a by-product the error matrix of the parameters, which is usually reliable unless warning messages are produced. The optional argument [**maxcalls**] specifies the (approximate) maximum number of function calls after which the calculation will be stopped even if it has not yet converged. The optional argument [**tolerance**] specifies required tolerance on the function value at the minimum. The default tolerance is 0.1. Minimization will stop when the estimated vertical distance to the minimum (EDM) is less than $0.001 * [\text{tolerance}] * \text{UP}$ (see SET ERR).

MINImize [**maxcalls**] [**tolerance**]

Causes minimization of the function by the method of Migrad, as does the MIGrad command, but switches to the SIMplex method if Migrad fails to converge. Arguments are as for MIGrad.

MINOs [**maxcalls**] [**parno**] [**parno**] ...

Causes a Minos error analysis to be performed on the parameters whose numbers [**parno**] are specified. If none are specified, Minos errors are calculated for all variable parameters. Minos errors may be expensive to calculate, but are very reliable since they take account of non-linearities in the problem as well as parameter correlations, and are in general asymmetric. The optional argument [**maxcalls**] specifies the (approximate) maximum number of function calls *per parameter requested*, after which the calculation will be stopped for that parameter.

RELease parno

If **parno** is the number of a previously variable parameter which has been fixed by a command: **FIX parno**, then that parameter will return to variable status. Otherwise a warning message is printed and the command is ignored. Note that this command operates only on parameters which were at one time variable and have been **FIXed**. It cannot make constant parameters variable; that must be done by redefining the parameter with a **PARAMETER** command.

REStore [**code**]

If no [**code**] is specified, this command restores all previously **FIXed** parameters to variable status. If [**code**]=1, then only the last parameter **FIXed** is restored to variable status.

SCAN [**parno**] [**numpts**] [**from**] [**to**]

Scans the value of the user function by varying parameter number [**parno**], leaving all other parameters fixed at the current value. If [**parno**] is not specified, all variable parameters are scanned in sequence. The number of points [**numpts**] in the scan is 40 by default, and cannot exceed 100. The range of the scan is by default 2 standard deviations on each side of the current best value, but can be specified as from [**from**] to [**to**]. After each scan, if a new minimum is found, the best parameter values are retained as start values for future scans or minimizations. The curve resulting from each scan is plotted on the output unit in order to show the approximate behaviour of the function. This command is not intended for minimization, but is sometimes useful for debugging the user function or finding a reasonable starting point.

SEEk [maxcalls] [devs]

Causes a Monte Carlo minimization of the function, by choosing random values of the variable parameters, chosen uniformly over a hypercube centered at the current best value. The region size is by default 3 standard deviations on each side, but can be changed by specifying the value of [devs].

SET ERROrdef up

Sets the value of **up** (default value= 1.), defining parameter errors. MINUIT defines parameter errors as the change in parameter value required to change the function value by **up**. Normally, for chisquared fits **up=1**, and for negative log likelihood, **up=0.5**.

SET LIMits [parno] [lolim] [uplim]

Allows the user to change the limits on one or all parameters. If no arguments are specified, all limits are removed from all parameters. If [parno] alone is specified, limits are removed from parameter [parno]. If all arguments are specified, then parameter [parno] will be bounded between [lolim] and [uplim]. Limits can be specified in either order, MINUIT will take the smaller as [lolim] and the larger as [uplim]. However, if [lolim] is equal to [uplim], an error condition results.

SET PARAmeter parno value

Sets the value of parameter **parno** to **value**. The parameter in question may be variable, fixed, or constant, but must be defined.

SET PRIntout level

Sets the print level, determining how much output MINUIT will produce. The allowed values and their meanings are displayed after a **SHOw PRInt** command. Possible values for **level** are:

- 1 No output except from SHOW commands
- 0 Minimum output (no starting values or intermediate results)
- 1 Default value, normal output
- 2 Additional output giving intermediate results.
- 3 Maximum output, showing progress of minimizations.

SET STRategy level

Sets the strategy to be used in calculating first and second derivatives and in certain minimization methods. In general, low values of **level** mean fewer function calls and high values mean more reliable minimization. Currently allowed values are 0, 1 (default), and 2.

SHOw XXXX

All **SET XXXX** commands have a corresponding **SHOw XXXX** command. In addition, the **SHOw** commands listed starting here have no corresponding **SET** command for obvious reasons. The full list of **SHOw** commands is printed in response to the command **HELP SHOw**.

SHOw CORrelations

Calculates and prints the parameter correlations from the error matrix.

SHOw COVariance

Prints the (external) covariance (error) matrix.

SIMplex [maxcalls] [tolerance]

Performs a function minimization using the simplex method of Nelder and Mead. Minimization terminates either when the function has been called (approximately) [maxcalls] times, or when the estimated vertical distance to minimum (EDM) is less than [tolerance]. The default value of [tolerance] is $0.1 * UP$ (see SET ERR).

Chapter 8: Graphics (HIGZ and HPLOT)

8.1 HPLOT, HIGZ and local graphics package

Graphics input/output in PAW is handled by the two packages HPLOT (Histograms PLOTting) and HIGZ (High level Interface to Graphics and Zebra). HIGZ is the basic graphics system of PAW interfacing the local graphics package while HPLOT, sitting on top of HIGZ, is used for plotting HBOOK objects (Histograms, Ntuples, etc.). The figure below shows the hierarchy between HPLOT, HIGZ and the local basic graphics package (GKS, DI3000, X Windows, etc.).

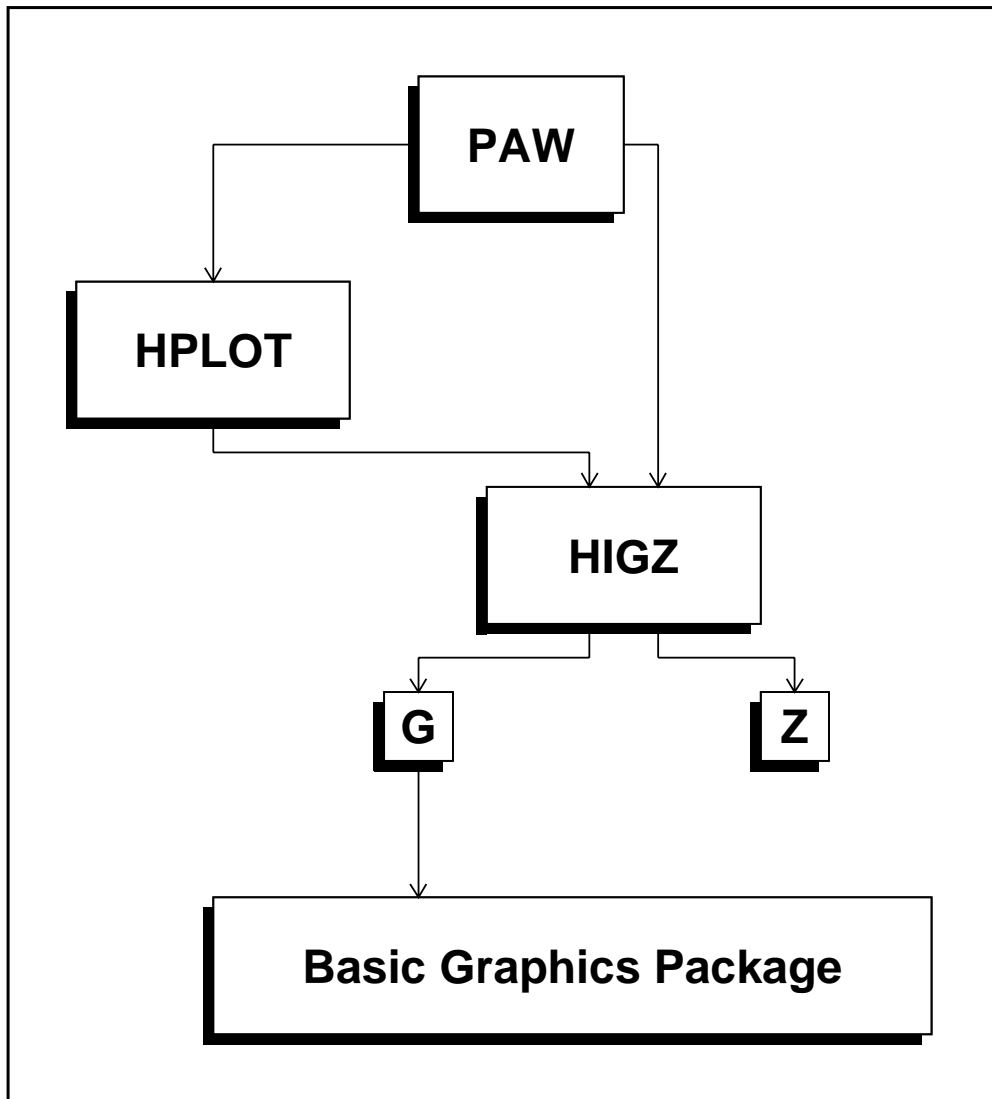


Figure 8.1: HPLOT and HIGZ in PAW

Graphics could be produced in PAW either directly by HIGZ commands or by HPLOT commands. In both cases, all the graphics is under the control of HIGZ. Two distinct modes are available in HIGZ: one is purely graphics (the G mode) interfacing the local graphics package, and the second (the Z mode) allows the management of the HIGZ structures (pictures). As an example, the simple PAW command HISTOGRAM/PLOT is handled at the different levels as follows:

PAW Level	HISTOGRAM/PLOT ID
HPLOT Level	Takes care of ZONE, SET, OPTION, etc.
HIGZ Level	Windows and Viewport, Axis, Boxes, Histogram, Text and Attributes
Basic graphics	Line, Text, Attributes, etc.

8.2 The metafiles

Metafiles are text files used as device independent sources of graphics output for printers of different type. PAW is able to produce two types of metafiles.

The first one is the local graphics package metafile (for example a GKS metafile). This file is produced by the local graphics package and it usually needs a special interpreter to be sent to the printers. For example, at CERN, the GKS metafile (workstation type 4) must be printed with GRPLOT

The second type of metafile is directly produced by HIGZ and is independent from the basic graphics package used. This type of metafile is a PostScript metafile (workstation type -111: portrait; -112: landscape) and could be sent directly to a PostScript printer (at CERN GKS metafiles type 12201 and 12202 could be also used to produce PostScript metafiles).

The command GRAPHICS/METAFILE LUN METAFL is designed to produce metafiles. LUN is the logical unit number of an open FORTRAN file and METAFL the metafile type. For example, the following four commands will produce a HIGZ/PostScript metafile with the name "PAW.PS" containing the graphics representation of histogram number 10:

```
PAW > FORTRAN/FILE 66 PAW.PS
PAW > GRAPHICS/META 66 -111
PAW > HISTO/PLOT 10
PAW > FORTRAN/CLOSE 66
```

8.3 The HIGZ pictures

The HIGZ pictures have three main goals:

- HIGZ graphics primitives and attributes can be stored in a ZEBRA structure in memory in order to display them later.
- They can be stored on direct access files (in a very compact way), in order to build a picture data base.
- They can be modified with the graphics editor.

8.3.1 Pictures in memory

The general command to manage pictures in memory is: PICTURE/IZPICT. This command has two parameters:

PNAME Picture name:

- CH Character string specifying picture name (must begin with a letter)
- N Picture number as displayed by PICT/LIST.
- * All pictures in memory.
- ' ' A blank indicates the current picture.

CHOPT Option value:

- AL Give a full listing of the pictures in memory.
- C Picture PNAME becomes the current picture.
- D Display the picture PNAME.
- F First picture in memory becomes the current picture.
- L List pictures in memory.
- M Make a new picture in memory with the name PNAME.
- N Next picture in memory becomes the current picture.
- P Print the contents of the picture PNAME.
- S Scratch picture PNAME from memory.

In addition, simpler and more mnemonic commands are available:

```
PAW > PICT/CREATE PNAME          | Create a picture in memory
PAW > PICT/LIST                    | List pictures in memory
1: PNAME <-- Current Picture
```

The last created picture in memory is called the **current** picture. All graphics primitives (line, text, histogram, etc.) produced by PAW commands will be stored in this picture if it is **active**, i.e. if mode Z is on.

```
PAW > SWITCH Z                      | Switch Z mode on
PAW > PICT/LIST
1: PNAME <-- Current Picture (Active)
```

Note that the command PICTURE/CREATE will switch automatically Z mode on.

```
PAW > PICT/PLOT PNAME
```

will display picture PNAME. If picture PNAME is not in memory and if the current working directory (as given by CDIR) is a picture file, PAW will try to take this picture from the file before displaying it.

HIGZ pictures can be created automatically by HPLOT via the command:

```
PAW > OPTION ZFL
```

If this command has been typed, each new plot produced by HPLOT will result in a HIGZ picture created in memory. The following example shows how for each HIST/PLOT ID command a new HIGZ picture is created with an automatic naming:

```
PAW > HIST/PLOT 10
PAW > HIST/PLOT 110
PAW > HIST/PLOT 20
PAW > PICT/LIST
  1: PICT1
  2: PICT2
  3: PICT3 <-- Current Picture (Active)
```

A similar command is given by:

```
PAW > OPTION ZFL1
```

which works exactly like OPTION ZFL except that only the last created picture is kept in memory. For example, if we had typed OPTION ZFL1 instead of OPTION ZFL in the example above, the result would be:

```
PAW > PICT/LIST
  1: PICT3 <-- Current Picture (Active)
```

The following example is a useful macro showing how to use the HIGZ pictures (via OPTION ZFL1) and the metafiles in order to produce a hard copy of the graphics screen:

Macro showing how to print current picture in PostScript
<pre>MACRO POST FORTRAN/FILE 66 PAW.PS META -66 -111 PICT/PLOT ' ' CLOSE 66 SHELL PRINT PAW.PS RETURN</pre>

Typing EXEC POST, the current HPLOT picture on the screen will be sent to the printer using the SHELL command which issues a system-dependent “pr int” command to the local operating system (e.g. lp or lpr on Unix).

Other available commands working on pictures in memory are:

```
PAW > PICT/RENAME PNAME PNAME2
PAW > PICT/COPY PNAME PNAME2
PAW > PICT/DELETE PNAME
```

- PNAME can be the complete name, the picture number in memory or ' '.
- PNAME2 is the complete picture name.

8.3.2 Pictures on direct access files

HIGZ pictures are stored on direct-access files and hence access times to pictures are fast. Moreover, due to the fact that HIGZ uses high level primitives to describe the picture’s structural tree, a storage compaction factor as compared to the equivalent GKS metafiles of between 10 and 100 is routinely obtained.

As HIGZ is interfaced to various basic graphics packages, a picture file can be created on one system (e.g. DECGKS) and transported to another machine to be interpreted with a different graphics package (e.g. GKSGRAL or DI3000).

8.4 HIGZ pictures generated in a HPLLOT program

HIGZ pictures can be generated in a batch HPLLOT program and later visualized in an interactive session with PAW. The HIGZ picture file, like any HBOOK file, can be exchanged between computers using the ZFTP facility, as described in on page 190. As the size of the picture data base (see page 156), and hence the associated disk storage requirements, is much smaller than the size of the metafile generated by the underlying graphics package, transfer times are drastically reduced. The example below show how to interactively visualize (with PAW) HIGZ pictures produced by HPLLOT. In the same way we can visualize and edit pictures generated by any HIGZ based application (GEANT, event scanning programs, etc.)

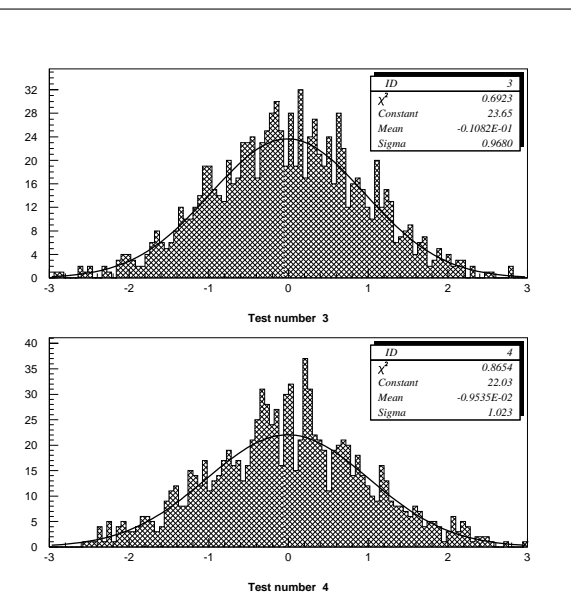
Store HPLLOT pictures with HIGZ	Using the picture in Paw																				
<pre> PROGRAM HPICT *===== * HPLLOT Program to demonstrate how to store HPLLOT * pictures onto direct access HIGZ picture file *===== CORROH/PAWC/H(20000) DIMENSION SIG(2) CHARACTER*20 TITLE *----- * CALL HLIBIT(20000) * -- Create histograms DO 10 ID=1,10 WRITE(TITLE,1000)ID 1000 FORMAT('Test number',I3) CALL HBOOK1(ID,TITLE,100,-3.,3.,0.) 10 CONTINUE * -- Fill histograms DO 30 ID=1,10 DO 20 I=1,1000 CALL RANROR(A,B) CALL HFILL(ID,A,0.,1.) 20 CONTINUE CALL HFITGA(ID,COEFF,AV,SIG,CHI2,2,SIG) 30 CONTINUE * -- Initialize HPLLOT. Set various graphics options. CALL HPLINT(0) CALL HPLZOH(1,2,1,' ') CALL HPLOPT('ZFL',1) CALL HPLOPT('FIT',1) CALL HPLOPT('STAT',1) CALL HPLSET('STAT',1.) CALL HPLSET('HTYP',244.) CALL HPLSET('FWID',5.) CALL HPLSET('VFOV',-40.) CALL HPLSET('VFOV',-60.) CALL HPLSET('PWID',4.) CALL HPLSET('BCOL',1.01) CALL HPLSET('CSIZ',0.25) CALL HPLSET('CFON',-10.) * * Open a picture file called "hpict.dat". * Option 'A' means "Automatic saving of pictures" * Option 'N' means "New file" * (option 'U' instead of 'N' updates an existing file) * CALL IZOPEN(1,'Pictures','hpict.dat','AN',1024,ISTAT) * * Select HIGZ option to store graphics in ZEBRA memory only * No calls to the local graphics package. * CALL IGZSET('Z') * -- Plot all histograms CALL HPLLOT(0,' ',' ',0) CALL HPLEND * END </pre>	<pre> % PAW > PICT/FILE 20 HPICT.DAT PAW > <u>LDIR</u> Directory ==> //LUN20 <== Created 891006/1026 Modified 891006/1026 ==> List of objects PICTURE NAME CYCLE PICT1 1 PICT2 1 PICT3 1 PICT4 1 PICT5 1 PAW > <u>META 10 -111</u> PAW > <u>PICT/PLOT PICT2</u> PAW > <u>CLOSE 10</u> PAW > * Print metafile PAW > * (see pages 156 and following) PAW > <u>SHELL print PAW.METAFILE</u> PAW > <u>EXIT</u> </pre>																				
	 <p>The figure displays two histograms. The top histogram, labeled 'Test number 3', shows a distribution of data points with a fitted curve. The statistics box for this histogram is as follows:</p> <table border="1"> <tr><td>ID</td><td>3</td></tr> <tr><td>χ^2</td><td>0.6923</td></tr> <tr><td>Constant</td><td>23.65</td></tr> <tr><td>Mean</td><td>-0.1082E-01</td></tr> <tr><td>Sigma</td><td>0.9680</td></tr> </table> <p>The bottom histogram, labeled 'Test number 4', shows a similar distribution. Its statistics box is:</p> <table border="1"> <tr><td>ID</td><td>4</td></tr> <tr><td>χ^2</td><td>0.8654</td></tr> <tr><td>Constant</td><td>22.03</td></tr> <tr><td>Mean</td><td>-0.9535E-02</td></tr> <tr><td>Sigma</td><td>1.023</td></tr> </table>	ID	3	χ^2	0.6923	Constant	23.65	Mean	-0.1082E-01	Sigma	0.9680	ID	4	χ^2	0.8654	Constant	22.03	Mean	-0.9535E-02	Sigma	1.023
ID	3																				
χ^2	0.6923																				
Constant	23.65																				
Mean	-0.1082E-01																				
Sigma	0.9680																				
ID	4																				
χ^2	0.8654																				
Constant	22.03																				
Mean	-0.9535E-02																				
Sigma	1.023																				

Figure 8.2: Visualising a HIGZ picture produced in a batch HPLLOT program

8.5 Setting attributes

Attributes are parameters like: colour, character font, etc. which could be changed interactively in PAW via the commands `PICTURE/IGSET`, `GRAPHICS/SET` and `GRAPHICS/OPTION`. Each attribute is linked to one or more objects (lines, histogram, etc.). The aim of this section is to give a complete description of the attributes available in PAW and to clarify the differences between `IGSET`, which changes attributes at the `HIGZ` level, and `SET` and `OPTION`, which act at the `HPLLOT` level.

IGSET (CHOPT, VAL)

Routine used to set the value of attributes related to primitives and/or macropimitives. The first parameter is the mnemonic name of the parameter, the second is the value to be assigned. Note that all the basic primitives attributes can also be set with this routine.

CHOPT Character variable specifying the name of the parameter to be set (type `CHARACTER*4`). This is an **UPPERCASE** character string.

VAL **Floating point** value of the parameter (must be specified as a **REAL** number).
A value of `0.0` indicates that the parameter value must be reset to its default value.

Examples of IGSET commands

```
PAW > IGSET MTPY 20      | Change marker type to 20.
                          | This new marker is used by all subsequent
                          | commands using the current marker type.

PAW > IGSET LWID        | Set the line width to its default value.

PAW > IGSET              | Display actual and default values of all HIGZ attributes
PAW > IGSET *           | Set ALL HIGZ attributes to their default values
```

OPTION (CHOPT)

The `OPTION` command has one optional parameter:

CHOPT Option name (four characters). Special values are:
 ' * ' Set all `HPLLOT` options to their default values
 ' ' Display actual and default values of all `HPLLOT` options

SET (CHOPT, VAL)

Sets an `HPLLOT` parameter; see table 8.3 for details.

CHOPT Character variable of length 4 identifying the parameter to be redefined (must be given in uppercase). Special values are:

' * ' All parameters are set to their default values.
 ' SHOW ' A list of all parameters and their values is printed.

VAR New value for the parameter specified. Special values are:
 0. The corresponding parameters is set to its default value.

NAME	default	Explanation
'AURZ'	0.	If 1. the last current picture is automatically saved on disk when a new picture is created.
'AWLN'	0.0	Axis wire length. Default is length=0 (no grid)
'BARO'	0.25	Offset of the left edge of the bar with respect to the left margin of the bin for a bar chart (expressed as a fraction of the bin width).
'BARW'	0.50	Width of the bar in a bar chart (expressed as a fraction of the bin width).
'BASL'	0.01	Basic segment length in NDC space (0-1) by (0-1) for dashed lines
'BORD'	0.	Border flag. If = 1., a border is drawn in boxes, pie charts, . . .
'CHHE'	0.01	CHAracter HEight.
'CSHI'	0.02	Distance between each shifted drawing of a character (in percentage of character height) for characters drawn by TEXT
'FACI'	1.	Fill Area Colour Index.
'FAIS'	0.	Fill Area Interior Style (0.,1.,2.,3.).
'FASI'	1.	Fill Area Style Index.
'LAOF'	0.013	LAbels OFFset.
'LASI'	0.018	LAbels SIze (in World coordinates).
'LTYP'	1.	Line TYPe.
'LWID'	1.00	Line WIDth.
'MSCF'	1.00	Marker SCAle Factor.
'MTYP'	1.	Marker TYPe.
'PASS'	1.	Text width (given by number of PASSes) of characters drawn by TEXT. The width is simulated by shifting the "pen" slightly at each pass.
'PICT'	1.	Starting number for automatic pictures naming.
'PLCI'	1.	PolyLine Colour Index.
'PMCI'	1.	PolyMarker Colour Index.
'TANG'	0.00	Text ANGLE (for calculating Character up vector).
'TMSI'	0.019	Tick Marks SIze (in world coordinates)
'TXAL'	0.	10*(horizontal alignment)+(vertical alignment).
'TXCI'	1.	TeXt Colour Index.
'TXFP'	10.	10*(TeXt Font) + (TeXt Precision). (0: hard, 1: string, 2: soft)
'*'		All attributes are set to their default values.
'SHOW'		The current and default values of the parameters controlled by IGSET are displayed.

Table 8.1: Parameters and default values for IGSET

CHOPT	alternative	Explanation
A4	A0/6	Page format for the plotter (A0,A1,A2,A3,A4,A5,A6)
BOX	NBOX	A box is (BOX) or is not (NBOX) drawn around picture
DVXR	DVXI	Integer (DVXI) or Real (DVXR) divisions for X axis
DVYR	DVYI	Integer (DVYI) or Real (DVYR) divisions for Y axis
HTIT	UTIT	HBOOK TITLE (HTIT) or User TITLE (UTIT) is printed
LINX	LOGX	LINear or LOGarithmic scale in X
LINY	LOGY	LINear or LOGarithmic scale in Y
LINZ	LOGZ	LINear or LOGarithmic scale in Z
NAST	AST	Functions are drawn with (AST) or without (NAST) asterisks
NBAR	BAR	BAR charts for histogram
NCHA	CHA	Scatter plots are drawn with dots (NCHA) or one char/bin (CHA)
NDAT	DATE	DATE is printed (DATE) or not (NDAT) on each plot
NEAH	EAH	Error bars And Histogram are plotted (if both are present)
NFIL	FILE	FILE name is printed (FILE) or not (NFIL) on each plot
NFIT	NFIT	FIT parameters are printed (FIT) or not (NFIT) on each plot
NGRI	GRID	GRID or not grid (NGRI) on X and Y axis
NOPG	P	Page number is (P) or is not (NOPG) printed
NPTO	PTO	PTO (Please Turn Over)
NSQR	SQR	Size is set to the largest square (SQR)
NSTA	STA	STATistics are printed (STA) or not (NSTA) on each plot
NTIC	TIC	Cross-wires are drawn (TIC) or not (NTIC) on each plot
NZFL	ZFL	Picture is (ZFL) or is not (NZFL) put in Z data base
SOFT	HARD	SOFTware or HARDware characters are used
TAB	NTAB	Table printed as TABles (TAB) or scatter plots (NTAB)
VERT	HORI	VERTical or HORIZontal orientation of paper

Table 8.2: Parameters and default values for OPTION

CHOPT	Default	Explanation (units are cm unless otherwise specified)
ASIZ	0.28	axis label size
BARO	0.25	bar offset for "bar charts"
BARW	0.5	bar width for "bar charts"
BCOL	1	zone fill area colour index
BTYP	0	zone fill area style index
BWID	1.	line width of the histogram rounding box
CSHI	0.03	character shift between two passes
CSIZ	0.28	comment size
DASH	0.15	length of basic dashed segment for dashed lines
DMOD	1	line style for histogram contour (see HPLOT)
GFON	2	global title font (10*font+precision)
GSIZ	0.28	global title size
HCOL	1	histogram fill area colour index (10*font+precision)
HMAX	0.90	histogram maximum for scale
HTYP	0	histogram fill area style index
KSIZ	0.28	Hershey character size
LFON	2	axis labels font (10*font+precision)
NDVX	510	number of divisions for X axis
NDVY	510	number of divisions for Y axis
PASS	1.	number of passes for software characters
PCOL	1	picture fill area colour index
PSIZ	0.28	page number size
PTYP	0	picture fill area style index
SSIZ	0.28	asterisk size (for functions)
TFON	2	general text (comments) font (10*font+precision)
TSIZ	0.00	histogram title size
VFON	2	axis values font (10*font+precision)
VSIZ	0.28	axis values size
XLAB	1.40	distance Y axis to labels
XMGL	2.00	X margin left
XMGR	2.00	X margin right
XSIZ	20.00	length of picture along X
XTIC	0.30	X axis tick mark length
XVAL	0.40	distance Y axis to axis values
XWIN	2.00	X space between zones
YGTI	1.50	Y position of global title
YHTI	1.20	Y position of histogram title
YLAB	0.80	distance X axis to labels
YMGL	2.00	Y margin low
YMGU	2.00	Y margin up
YNPG	0.60	Y position for number of page
YSIZ	20.00	length of picture along Y
YTIC	0.30	Y axis tick mark length
YVAL	0.20	distance X axis to axis values
YWIN	2.00	Y space between zones
ZSIZ	0.28	scatter plot and table character. size

Table 8.3: Parameters and default values in SET

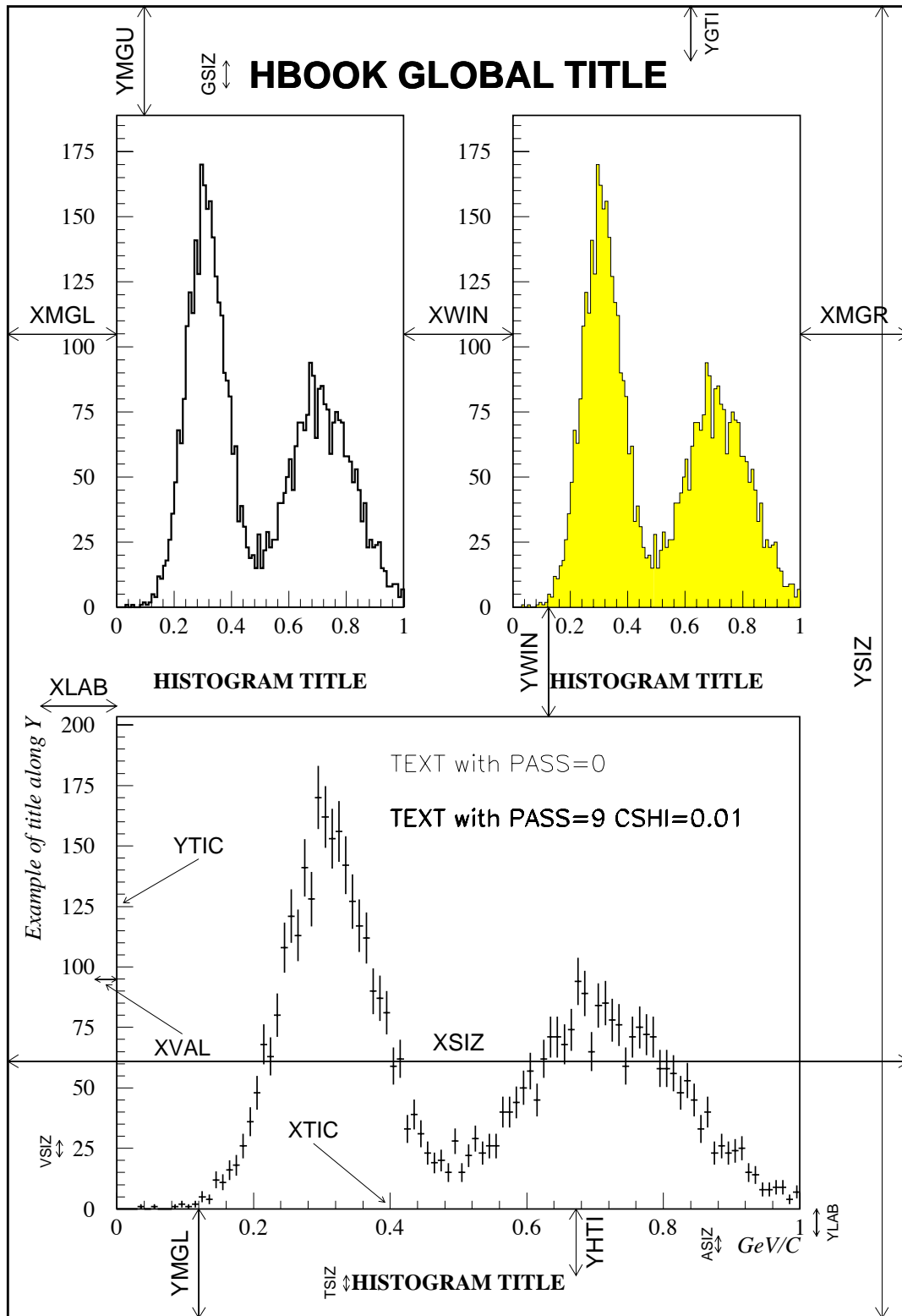


Figure 8.3: A graphical view of the SET parameters

8.6 More on labels

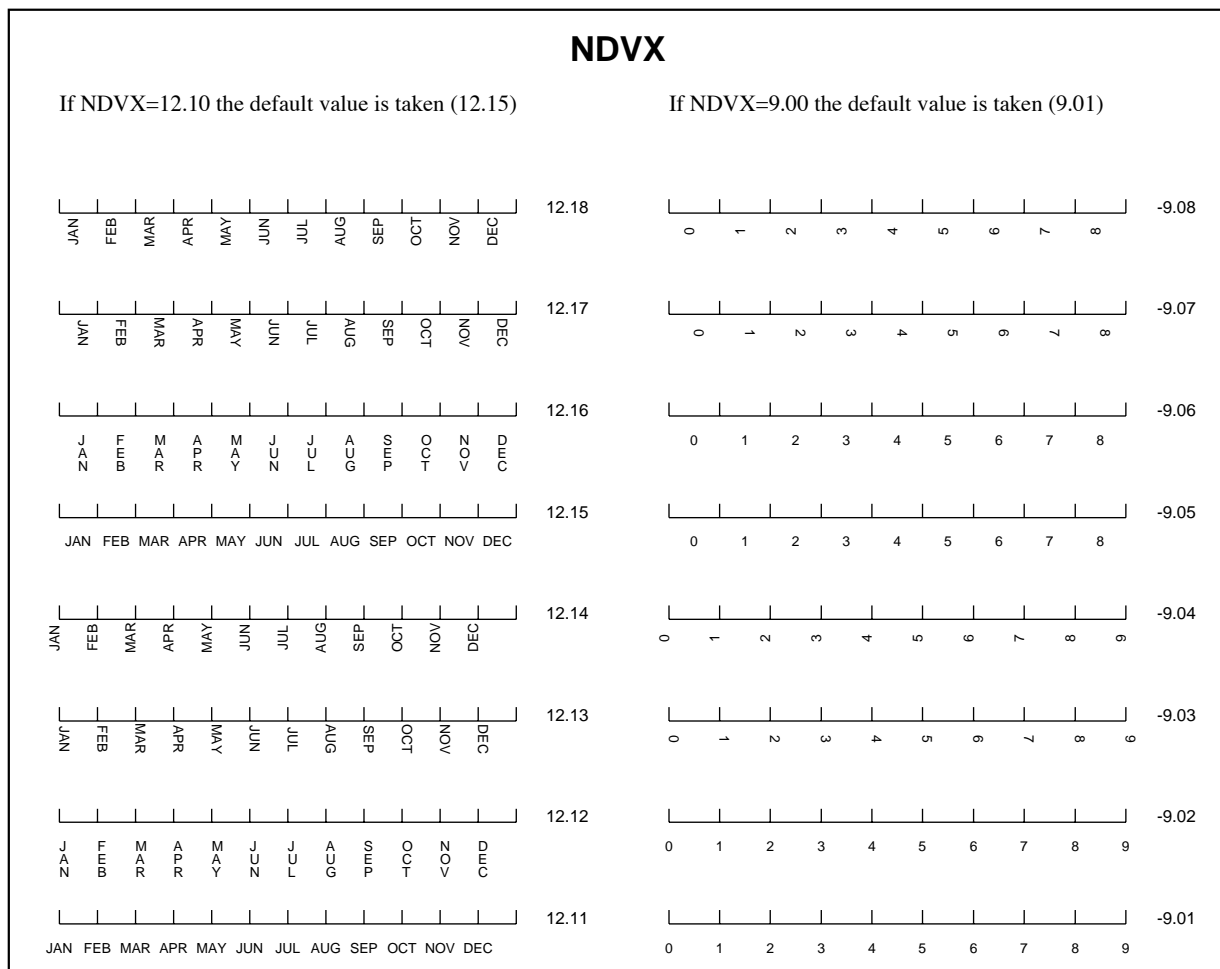


Figure 8.4: Example of labelling for horizontal axes

By default, labels used by `AXIS` and `PIE` are numeric labels. The command `GRAPHICS/PRIMITIVES/LABELS` (or `LABELS` for short), allows the user to define up to nine alphanumeric set of labels (numbered from 1 to 9). These labels can then be used in subsequent commands using `PIE` or `AXIS` primitives of `HIGZ`.

The `LABELS` command has three parameters:

- `LABNUM` An integer between 1 and 9. It identifies the labels set.
- `NLABS` The number of items to be placed on the labels (up to 50).
- `CHLABS` `NLABS` character strings specifying the label items.

The label sets thus defined can be used for axes on all plots produced by PAW (HPLOT histograms, graphs, vectors drawing, etc.) via the SET NDVX (NDVY) command. These commands have the following structure:

Example of NXDV specification	
SET NDVX i	e.g. SET NDVX 512
or	
SET NDVX i.jk	e.g. SET NDVX 10.25

In the first case the number *i* contains 100 times the number of secondary divisions plus the number of primary divisions. (e.g. 512 means 12 primary and 5 secondary division. By adding 10000 times N3 to *i* a third level of divisions is available.

In the second case the number in front of the dot (*i*) indicates the total number of divisions, the first digit following the dot (*j*) the label identifier (LABNUM) (if this number is equal to 0 numeric labels are drawn). The second digit after the (*k*) dot indicates the position where the labels have to be drawn (i.e. the **text justification** parameter, in this case 5, indicating horizontally written text centered on the interval). Study figures 8.4 and 8.5 for details. These two figures show that the labels can be centered on the tick marks (1 to 4) or on the divisions (5 to 8). If the labels are centered on the tick marks, note that the number of items in the command LABELS must be equal to the number of tick marks (which is equal to the number of divisions **plus one**), otherwise the last alphanumeric label on the axis will be undefined.

By default, the number of primary divisions given by SET NDVX *n* or SET NDVY *n* is optimized to have a reasonable labelling. If the number of divisions has to be exactly equal to the number given by SET NDVX *n* or SET NDVY *n*, a negative value must be used i.e.:

Forcing an exact number of divisions	
SET NDVX -i	e.g. SET NDVX -512
or	
SET NDVX -i.jk	e.g. SET NDVX -10.25

For example to label each subsequent X-axis with the names of the months of the year centered in the middle of each bin one can use:

Example of alphanumeric label on an axis	
PAW > LABEL 1 12 JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC	
PAW > SET NDVX -12.15	

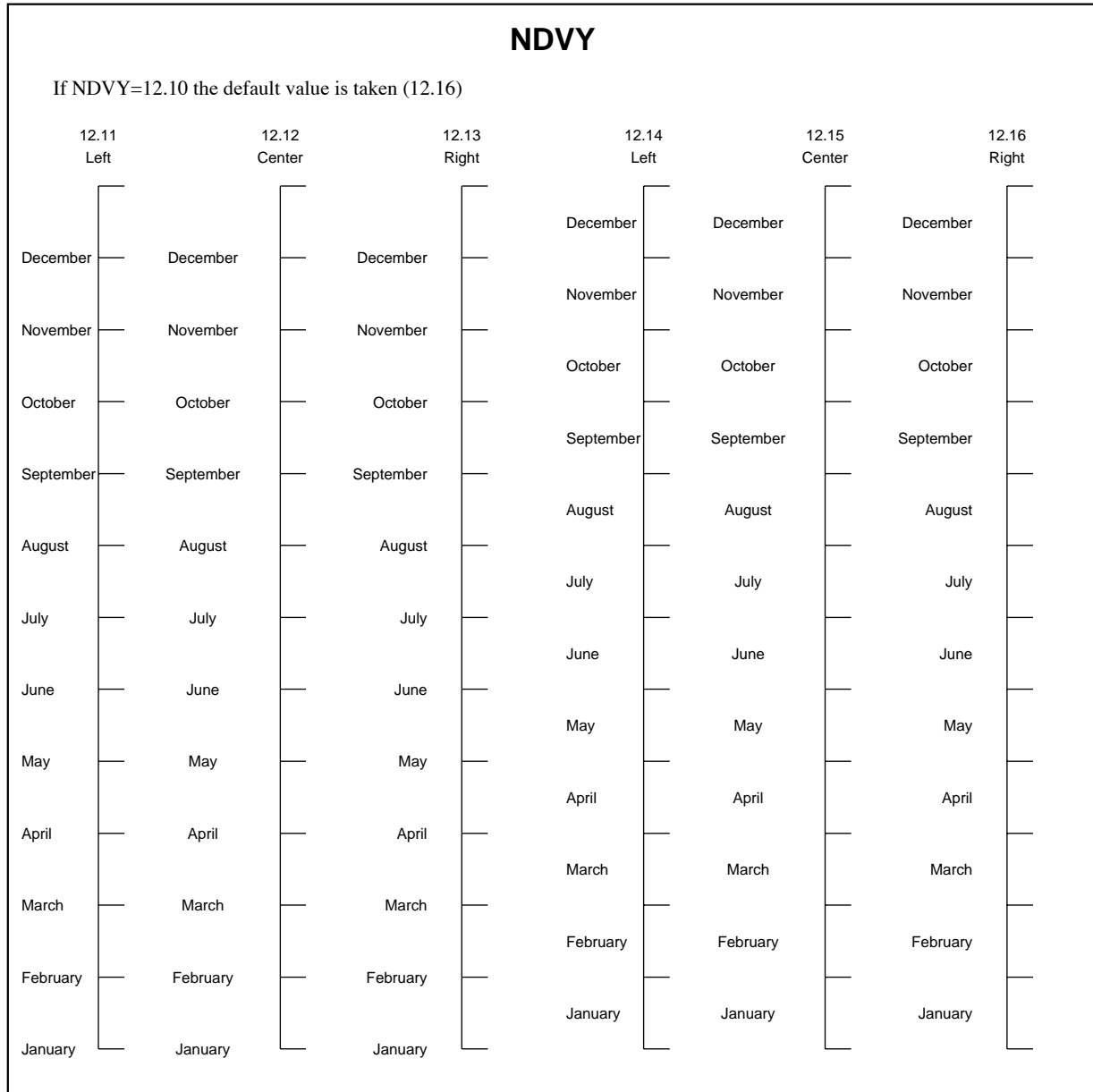


Figure 8.5: Example of labelling for vertical axes

8.7 Colour, line width, and fill area in HPLOT

The aspect of HPLOT pictures can be modified via the `xWID`, `xTYP` and `xCOL` attributes, where `x` can be H, B, P, or F, defined as follows:

B zone Box
F Function
H Histogram
P Page

The values given to the parameters `PTYP`, `BTYP`, `HTYP`, and `FTYP` are the HIGZ/GKS fill area interior styles. GKS styles are installation-dependent and even device-dependent. If the same result is desired on all devices, numbers greater than 100 (HIGZ styles: 8.7) should be used. Figure 8.6 shows how to use the `xTYP` parameter.

The parameters `PCOL`, `BCOL`, `HCOL` and `FCOL` are equivalent to `PTYP`, `BTYP`, `HTYP`, and `FTYP` respectively, but instead of changing the hatch style, they change the colour of the same areas.

If `PCOL`, `BCOL`, `HCOL` or `FCOL` are between 1 and 999, then only the contour of the corresponding area is changed. If they are between 1001 and 1999, then the surface is filled with the colour determined by the corresponding fill area colour index. and the corresponding value of the Fill Area Interior Style (for `HTYP`, `BTYP`, `PTYP` or `FTYP`) is automatically set to 1 (solid).

In addition, `BCOL` has two digits after the dot. The first one specifies the colour of the zone box shadowing and the second the colour of the statistic box shadowing.

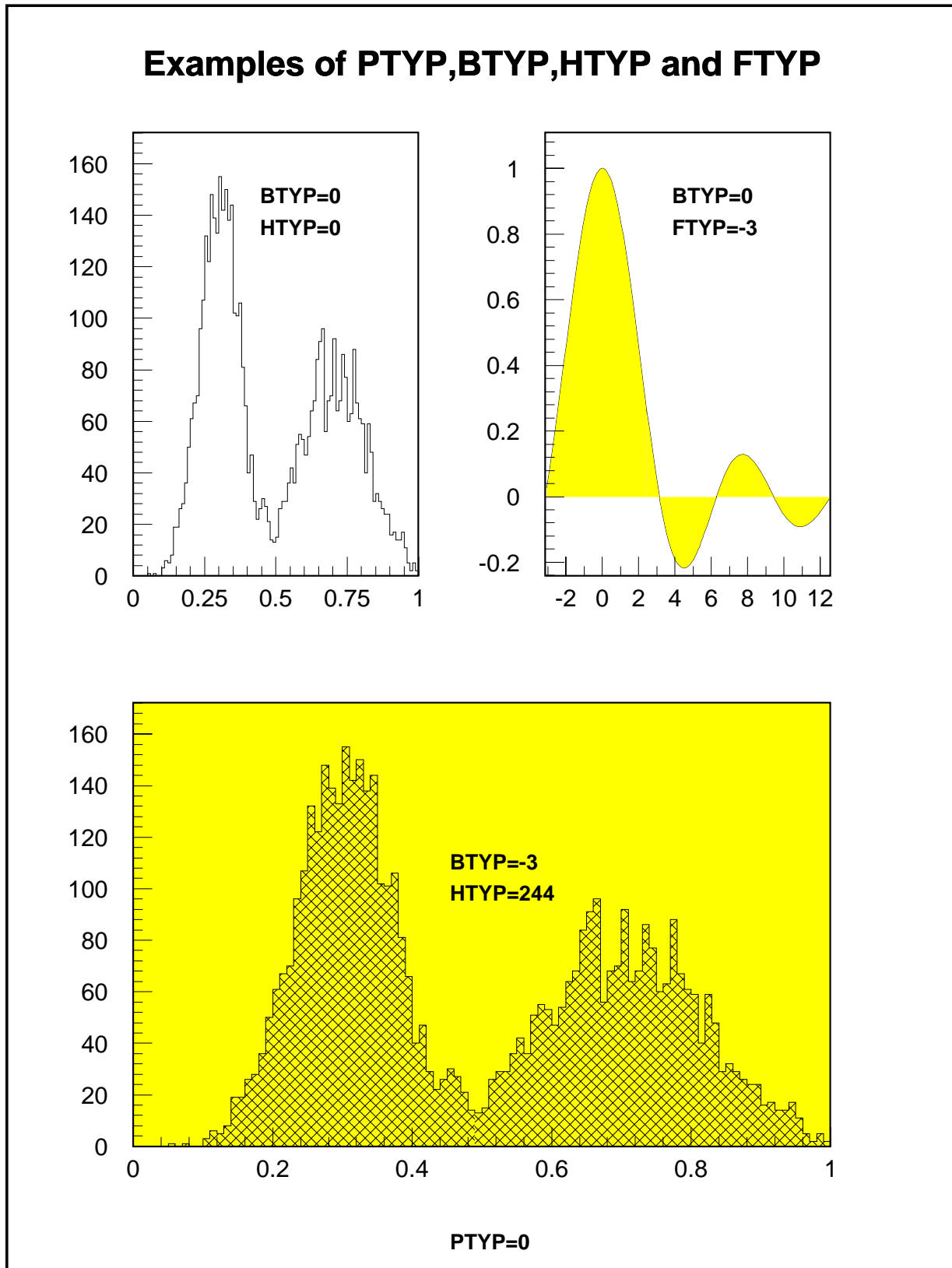


Figure 8.6: Example of fill area types in HPLOT

8.8 Information about histograms

Four options are available to plot additional informations on H PLOT pictures: DATE, FILE, STAT and FIT.

```
PAW > OPTION DATE           | Plot date and hour on current H PLOT picture
PAW > OPTION FILE          | Plot file name of current histogram
PAW > OPTION STAT         | Plot statistics of current histogram
PAW > OPTION FIT          | Plot Fit parameters of current histogram
```

For each of these OPTION commands a corresponding SET parameter is available:

```
PAW > SET DATE i           | Default is 2
PAW > SET FILE i          | Default is 1
```

where *i* defines the position of the date or file name:

```
i = 1 :   Top left corner of page/current histogram.
i = 2 :   Top right corner
i = 3 :   Bottom left corner
i = 4 :   Bottom right corner
```

For example the command:

```
PAW > SET DATE 3
```

sets the position of the date to the bottom left corner of the H PLOT pictures.

```
PAW > SET STAT i           | Default is 1111
```

where *i* corresponds to binary status bits OURMEIA as follows:

```
O=1   Draw number of overflows
U=1   Draw number of underflows
R=1   Draw R.M.S.
M=1   Draw mean value
E=1   Draw number of entries
I=1   Draw histogram identifier
A=1   Draw the contents of all channels
```

For example the command:

```
PAW > SET STAT 10
```

sets the statistics informations to be only the number of entries.

```
PAW > SET FIT i           | Default is 101
```

where *i* corresponds to binary status bits CEP as follows:

```
C=1   Draw  $\chi^2$ 
E=1   Draw errors
P=1   Draw fit parameters
```

For example to draw only the result of the χ^2 fit one would use:

```
PAW > SET FIT 100
```

For all these OPTIONs, the **character size** is specified with the command SET CSIZ and the character font used with SET CFON.

8.9 Additional details on some IGSET commands

Store pictures in memory

If the AURZ mode is on, after typing the command:

```
PAW > IGSET AURZ 1
```

all subsequent created pictures are stored automatically in the last picture file opened via the command PICTURE/FILE.

Example of the use of pictures in memory	
PAW > <u>PICT/FILE 4 PICT.DAT ! N</u>	| Open a new picture file PICT.DAT
PAW > <u>HIST/FILE 3 HEXAM.DAT</u>	| Open an existing histogram RZ file
PAW > <u>LDIR</u>	| List the contain of HEXAM.DAT

```

***** Directory ==> //LUN3 <===

                Created 880104/1414  Modified 880104/1414

==> List of objects
      HBOOK-ID  CYCLE   DATE/TIME   NDATA   OFFSET   REC1   REC2
            10      1   880104/1414     75     725     32
            20      1   880104/1414    1815     800     32     33
            30      1   880104/1414    1066     567     34     35

PAW > OPT ZFL           | Each new plot will result in a HIGZ picture
PAW > IGSET AURZ 1       | Each new HIGZ picture is stored in PICT.DAT
PAW > HIST/PLOT 0        | All histograms in HEXAM.DAT are plotted
PAW > CDIR //LUN4       | Set the current working directory on PICT.DAT
PAW > LDIR              | List the content of PICT.DAT

***** Directory ==> //LUN4 <===

                Created 890928/1024  Modified 890928/1024

==> List of objects
      PICTURE   NAME                               CYCLE
      PICT1                                1
      PICT2                                1
      PICT3                                1

```

Text font and precision

Text font and precision attributes for use by later invocations of ITX are set with TXFP as follows:

```
PAW > IGSET TXFP (10*(Text font) + (text precision))
```

The same syntax is used in all xFON option of the HPLOT command SET. Text font selects the desired character font e.g. a roman font, a sans-serif font, etc. Text precision specifies how closely the graphics package implementation must follow the current size and orientation attributes. String (0) precision is most liberal (hardware), stroke (2) precision is most strict. Character precision is in the middle (1). The value of text font is dependent upon the basic graphics package used. However, font number 0, with precision 2 is always available, independently from the basic graphics package used (see figure 8.12). Hardware characters are available by specifying

PAW > IGSET TXFP 10 | Choose hardware characters, i.e. font 1, precision 0

Text alignment

The text alignment attributes for use by future invocations of ITX are set using the TXAL parameter as follows:

PAW > IGSET TXAL (10*(horizontal alignment) + (vertical alignment))

Text alignment controls the placement of the character string with respect to the specified position in the call to ITX. The horizontal alignment parameter ITXALH must be in the range 0-3 while the vertical alignment parameter ITXALV must be in the range 0-5. The following parameter definitions are standardized by the graphics package for text alignment: the horizontal alignment specifies which end of the string (or its geometric center) is aligned with the specified point in ITX. For a given horizontal alignment, the vertical alignment controls whether the top of tall characters (or the bottom of capital letters) line up with the specified point (see table 8.4).

Alignment parameter	Description
ITXALH=0	normal (usually same as 1)
ITXALH=1	left end of string at specified point
ITXALH=2	center of string at specified point
ITXALH=3	right end of string at specified point
ITXALV=0	normal
ITXALV=1	top of tallest chars plus any built in spacing
ITXALV=2	top of tallest chars
ITXALV=3	halfway between 2 and 4
ITXALV=4	bottoms of capital letters and most other chars
ITXALV=5	bottoms of descenders (e.g. “g”, “y”) plus any built in spacing.

Table 8.4: Text alignment parameters

Fill area style, marker and line type

The Fill Area Interior Style, The Fill Area Style Index, the Marker TYPE and the Line TYPE are set respectively using the IGSET parameters FAIS, FASI, MTYP and LTYPE.

Example	
PAW > <u>IGSET FAIS 3</u>	| Fill area are hatched
PAW > <u>IGSET FASI -101</u>	| with the GKSGRAL style index -101
PAW > <u>IGSET MTYP 25</u>	| Marker type is an empty square
PAW > <u>IGSET LTYPE 15</u>	| Line type is dotted

Figure 8.8 shows the available GKSGRAL fill area styles indexes.

In addition, HIGZ provides some portable fill area styles index coded using three digits *ijk* as follows:

- i*: Distance between each hatch in mm
- j*: Angle between 90 and 180 degrees
- k*: Angle between 0 and 90 degrees

These numbers are coded according to table 8.5 and examples are shown in figure 8.7.

i	Distance	j	Angle	k	Angle
		0	180°	0	0°
1	0.75mm	1	170°	1	10°
2	1.50mm	2	160°	2	20°
3	2.25mm	3	150°	3	30°
4	3.00mm	4	135°	4	45°
5	3.75mm	5	not drawn	5	not drawn
6	4.50mm	6	120°	6	60°
7	5.25mm	7	110°	7	70°
8	6.00mm	8	100°	8	80°
9	6.75mm	9	90°	9	90°

Table 8.5: Codification for the HIGZ portable fill area interior styles

Example	
PAW > <u>IGSET FAIS 3</u>	| Fill area interior style is hatched
PAW > <u>IGSET FASI 190</u>	| Hatch type is 190

These commands will yield hatching with two sets of lines at 90° and 0° spaced 1 mm apart.

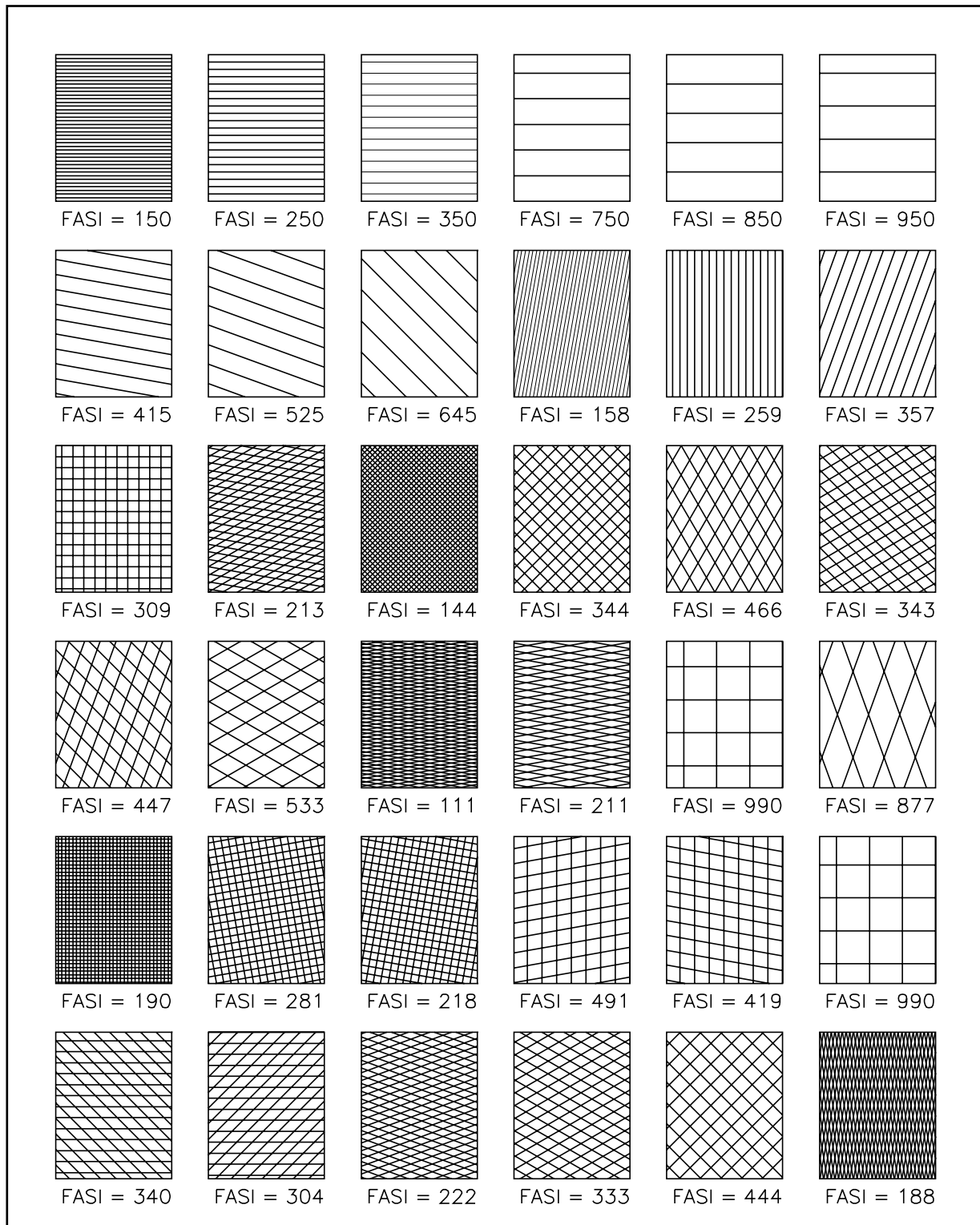


Figure 8.7: Examples of HIGZ portable hatch styles

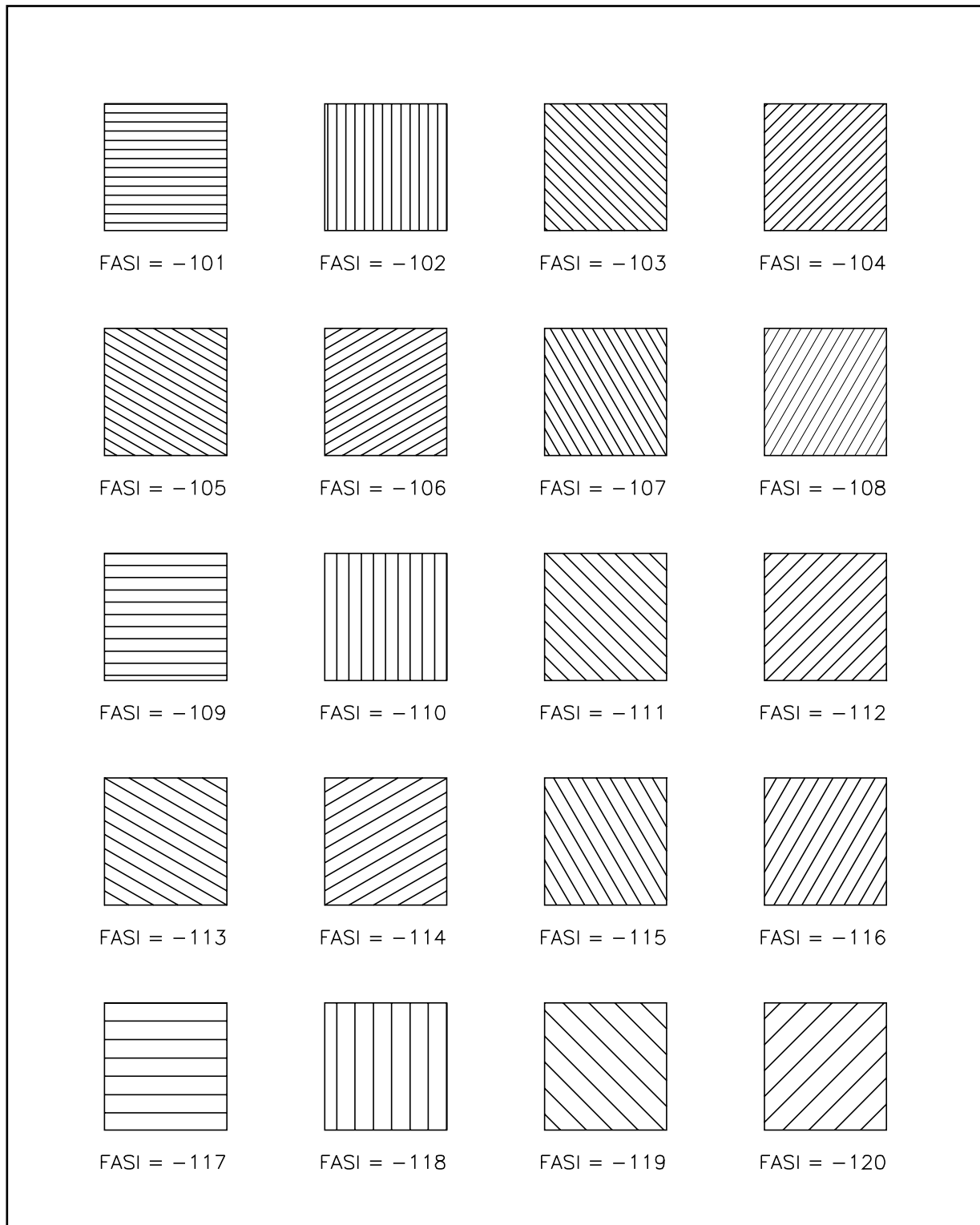


Figure 8.8: GKSGRAL Device independent hatch styles

Marker Index	Marker Type
31	✱
30	☆
29	★
28	+
27	◇
26	△
25	□
24	○
23	▽
22	▲
21	▣
20	⊝

Figure 8.9: HIGZ portable marker types

Line Index	Line Type
15
14
13	-----
12	-----

Figure 8.10: HIGZ portable line types

8.10 Text fonts

Text in PAW can be produced by two commands:

```
PAW > TEXT 10. 10. 'This is a text' 0.3
PAW > ITX 10. 10. 'This is a text'
```

The command TEXT draws software characters text, independently of the basic graphics package used by HIGZ. TEXT can produce over 200 different graphics signs, allowing to mix different types of characters (roman, greek, special, upper- and lowercase, sub- and superscript). The text to be printed is defined using a string of characters, separated by “escape” characters, which are defined in table 8.6. The repertoire of possible symbols is shown in figure 8.12.

<	go to lower case ¹	>	go to upper case (default)
[	go to greek (roman = default)	]	end of greek
"	go to special symbols	#	end of special symbols
^	go to superscript	?	go to subscript
!	go to normal level of script	&	backspace one character

Table 8.6: List of HPLOT escape sequences and their meaning

Boldface characters may be simulated by using the attributes PASS and CSHI. The meaning of these attributes is the following: every stroke used to display the character is repeated PASS times, at a separation CSHI*CHHE, where CHHE is the character height.

Software fonts are available using the TXFP attribute of the IGSETcommand as follows:

```
PAW > IGSET TXFP fffp
```

where fff is the **font identifier** as defined in the figures on the following pages and p is the **software precision** parameter (i.e. 0 for hardware precision and 2 for software precision).

The command ITX draws a character string with the font given by IGSET TXFP. Via the ITX command the PostScript fonts described in Figures 8.13 and 8.14 using metafile types -111 and -112 are available. Figures 8.15, 8.16 and 8.17 display lists of PostScript characters accessible via an octal code preceded by a backslash, e.g. to print a “copyright” character © use:

Example on how to get special symbols with PostScript

```
PAW > IGSET TXFP -120 | Choose Symbol font
PAW > ITX 10. 10. '\323' | Copyright sign at position (10,10)
```

¹Characters can also be entered directly in lower case.

Important Note

The characters '(', ')', ' ' and '\ ' are control characters for PostScript. To produce these characters in a PostScript metafile (-111 or -112) they must be escaped by a backslash.

Printing special PostScript characters

```
PAW > IGSET TXFP -20 | Choose font Times-Bold
PAW > ITX 10. 10. '\(' | Open parenthesis at position (10,10)
```

French accented, German umlauted or other special **national characters** in any of the PostScript fonts are available by using their octal code as found in figure 8.15, e.g.:

Example of using national PostScript characters

```
PAW > IGSET TXFP -130 | Choose PostScript font Times-Roman
PAW > ITX 1. 4. 'K\355nstler in den gr\345\373ten St\311dten.'
PAW > ITX 1. 3. '\253\265 l@\372uvre on conna\333t l@\372artisan\273'
PAW > ITX 1. 2. '\(proverbe fran\321ais\).' | quote escaped by @ character
PAW > ITX 1. 1. '\252\241Ma\337ana!\272, dit l@\323l\325ve.'
```

The output would be:

Künstler in den größten Städten.
 «À l'œuvre on connaît l'artisan»
 (proverbe français).
 “¡Mañana!”, dit l'élève.

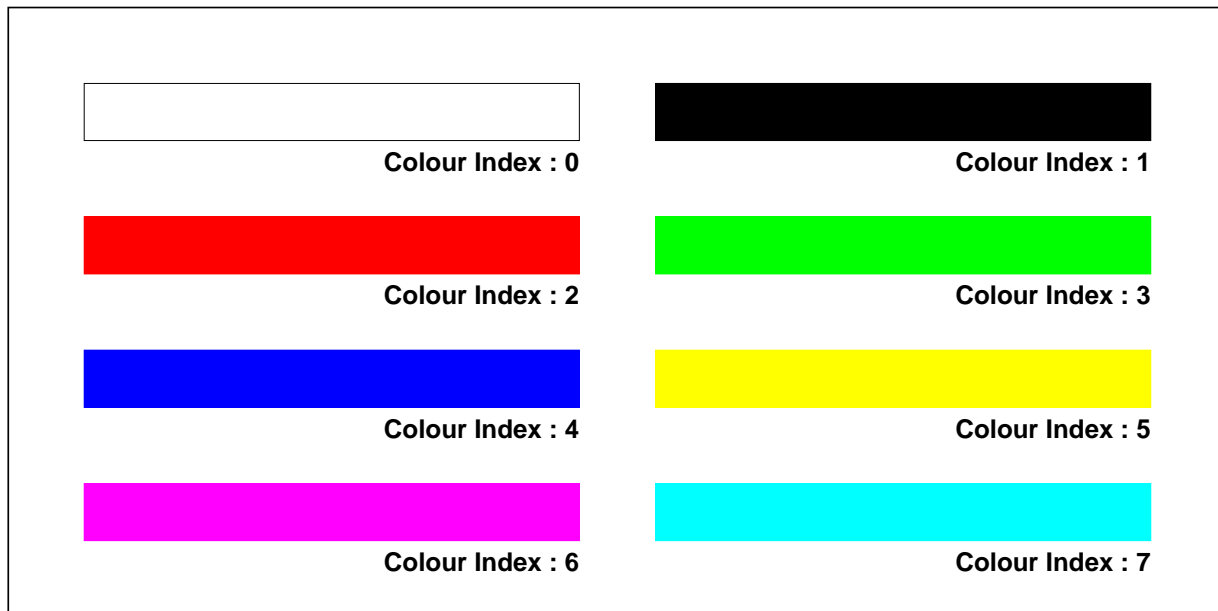


Figure 8.11: PostScript grey level simulation of the basic colours

Upper Roman	Lower Roman	Upper Greek	Lower Greek	Upper Special	Lower Special
A B C D E F G H I J K L M N O P Q R R S T U V W X Y Z 0 1 2 3 4 5 6 7 8 9 . , + - * / = ()	a b c d e f g h i j k l m n o p q r s t u v w x y z o 1 2 3 4 5 6 7 8 9 . , + - * / = ()	A B H Δ E Φ Γ X I K Λ M N O Π Θ P Σ Τ Υ X Ω Ψ Z 0 1 2 3 4 5 6 7 8 9 . , + - * / = ()	α β η δ ε φ γ χ ι κ λ μ ν ο π ρ σ τ υ χ ω ψ z 0 1 2 3 4 5 6 7 8 9 . , + - * / = ()	† — ‡ \$ # · ! @ ~ ^ & * % X N O ∞ ∅ ■ ▲ ▼ ★ ↓ ↑ ← ↘ ◇ ◊ + - * / =	† — ‡ \$ # · ! @ ~ ^ & * % X N O ∞ ∅ □ △ ◇ ☆ ↓ ↑ ← ↘ □ ◊ + - * / =

Figure 8.12: HIGZ portable software characters (Font 0, Precision 2)

Font/Prec	Font Style (HIGZ/PostScript Interface)	
-1/0	<i>ABCDEFGHabcdef</i>	<i>Times-Italic</i>
-2/0	ABCDEFGHabcdef	<i>Times-Bold</i>
-3/0	<i>ABCDEFGHabcdef</i>	<i>Times-BoldItalic</i>
-4/0	ABCDEFGHabcdef	<i>Helvetica</i>
-5/0	<i>ABCDEFGHabcdef</i>	<i>Helvetica-Oblique</i>
-6/0	ABCDEFGHabcdef	<i>Helvetica-Bold</i>
-7/0	<i>ABCDEFGHabcdef</i>	<i>Helvetica-BoldOblique</i>
-8/0	ABCDEFGHabcdef	<i>Courier</i>
-9/0	<i>ABCDEFGHabcdef</i>	<i>Courier-Oblique</i>
-10/0	ABCDEFGHabcdef	<i>Courier-Bold</i>
-11/0	<i>ABCDEFGHabcdef</i>	<i>Courier-BoldOblique</i>
-12/0	ABXΔEΦΓαβχδεφ	<i>Symbol</i>
-13/0	ABCDEFGHabcdef	<i>Times-Roman</i>
-14/0	☆+·✦✧◆◇✧⊗*✧*✧*	<i>ZapfDingbats</i>
-15/0	<i>ABCDEFGHabcdef</i>	<i>Times-Italic</i>
-16/0	ABCDEFGHabcdef	<i>Times-Bold</i>
-17/0	<i>ABCDEFGHabcdef</i>	<i>Times-BoldItalic</i>
-18/0	ABCDEFGHabcdef	<i>Helvetica</i>
-19/0	<i>ABCDEFGHabcdef</i>	<i>Helvetica-Oblique</i>
-20/0	ABCDEFGHabcdef	<i>Helvetica-Bold</i>
-21/0	<i>ABCDEFGHabcdef</i>	<i>Helvetica-BoldOblique</i>
-22/0	ABXΔEΦΓαβχδεφ	<i>Symbol</i>
-23/0	ABCDEFGHabcdef	<i>Times-Roman</i>
-24/0	☆+·✦✧◆◇✧⊗*✧*✧*	<i>ZapfDingbats</i>
0/2	ABCDEFGHabcdef	<i>HIGZ-Software</i>

Figure 8.13: PostScript fonts

A	✧	a	✿	0	✎	[*
B	✦	b	⊗	1	✎]	*
C	✦	c	✿	2	✎	;	+
D	✦	d	❄	3	✓	.	✎
E	✦	e	❄	4	✓	/	✎
F	◆	f	❄	5	✕	\	*
G	◇	g	✿	6	✕	}	‘
H	★	h	✿	7	✕	}	”
I	☆	i	✿	8	✕	:	+
J	⊗	j	✿	9	+	"	✂
K	☆	k	✿	-	✎	<	+
L	☆	l	●	=	+	>	†
M	☆	m	○	‘	✿	|	’
N	☆	n	■	!	✂		
O	☆	o	□	@	✕		
P	☆	p	□	#	✂		
Q	✿	q	□	\$	✂		
R	✿	r	□	%	✎		
S	✿	s	▲	^	✿		
T	✿	t	▼	&	✎		
U	✿	u	◆	*	✎		
V	★	v	✦	(✎		
W	★	w	◐)	✎		
X	★	x	|	_	✿		
Y	✨	y	┆	+	✎		
Z	✨	z	┆	~	”		

Figure 8.14: Correspondence between ASCII and ZapfDingbats font (-14)

173	{	270	,	323	é	356	Û
174	|	271	„	324	É	357	å
175	}	272	”	325	è	361	æ
176	~	273	»	326	È	362	Å
241	ı	274	...	327	ê	363	ÿ
242	ç	275	%	330	Ê	364	ÿ
243	£	276	â	331	ë	365	ı
244	/	277	ı	332	Ë	366	á
245	¥	300	À	333	î	367	Á
246	f	301	`	334	Î	370	ł
247	§	302	´	335	ï	371	ø
250	α	303	^	336	İ	372	œ
251	ı	304	~	337	ñ	373	ß
252	“	305	-	340	Ñ	374	ù
253	«	306	˘	341	Æ	375	Ù
254	<	307	·	342	ô	376	□
255	>	310	¨	343	a		
256	fi	311	ä	344	Ô		
257	fl	312	°	345	ö		
260	à	313		346	Ö		
261	—	314	À	347	û		
262	†	315	”	350	Ł		
263	‡	316	˘	351	Ø		
264	·	317	˘	352	Œ		
265	À	320	—	353	◦		
266	Œ	321	ç	354	Û		
267	•	322	Ç	355	ü		

Font/Prec -13/0

Figure 8.15: Octal codes for PostScript characters in Times font

173	‘	270	③	323	⑩	356	↩
174	’	271	④	324	➔	357	↪
175	“	272	⑤	325	→	361	↪
176	”	273	⑥	326	↔	362	↪
241	♯	274	⑦	327	↕	363	↪
242	•	275	⑧	330	↘	364	↪
243	•	276	⑨	331	➔	365	↪
244	♥	277	⑩	332	↗	366	↪
245	♣	300	①	333	➔	367	↪
246	♠	301	②	334	➔	370	↪
247	♠	302	③	335	→	371	↪
250	♣	303	④	336	➔	372	↪
251	♦	304	⑤	337	➔	373	↪
252	♥	305	⑥	340	➔	374	↪
253	♠	306	⑦	341	➔	375	↪
254	①	307	⑧	342	➔	376	➔
255	②	310	⑨	343	➔		
256	③	311	⑩	344	➔		
257	④	312	①	345	➔		
260	⑤	313	②	346	➔		
261	⑥	314	③	347	➔		
262	⑦	315	④	350	➔		
263	⑧	316	⑤	351	➔		
264	⑨	317	⑥	352	➔		
265	⑩	320	⑦	353	➔		
266	①	321	⑧	354	➔		
267	②	322	⑨	355	➔		

Font/Prec -14/0

Figure 8.16: Octal codes for PostScript characters in ZapfDingbats font (-14)

173	}	270	÷	323	©	356	}
174	}	271	⌘	324	™	357	
175	}	272	≡	325	⇕	361	
176	~	273	≈	326	√	362	
241	Y	274	∴	327	•	363	
242	'	275	—	330	└	364	
243	≡	276	—	331	^	365	
244	/	277	↖	332	∇	366	
245	∞	300	⌘	333	↔	367	
246	f	301	⌘	334	↔	370	
247	♣	302	⌘	335	↕	371	
250	♦	303	⌘	336	↕	372	
251	♥	304	⊗	337	↕	373	
252	♠	305	⊕	340	◇	374	
253	↕	306	⊖	341	∞	375	
254	↕	307	⊘	342	®	376	
255	↕	310	⊙	343	©		
256	↕	311	⊚	344	™		
257	↕	312	⊛	345	Σ		
260	⊙	313	⊜	346	}		
261	⊙	314	⊝	347	}		
262	⊙	315	⊞	350	}		
263	⊙	316	⊟	351	}		
264	⊙	317	⊠	352	}		
265	⊙	320	⊡	353	}		
266	⊙	321	⊢	354	}		
267	•	322	®	355	}		

Font/Prec -12/0

Figure 8.17: Octal codes for PostScript characters in Symbol font

8.11 The HIGZ graphics editor

The HIGZ pictures in memory can be modified interactively with the HIGZ graphics editor. The command PICT/MODIFY invokes the HIGZ editor (see figure 8.18 for more details):

PAW > PICT/MODIFY PNAME

PNAME can be the complete name, the picture number in memory or ' '.

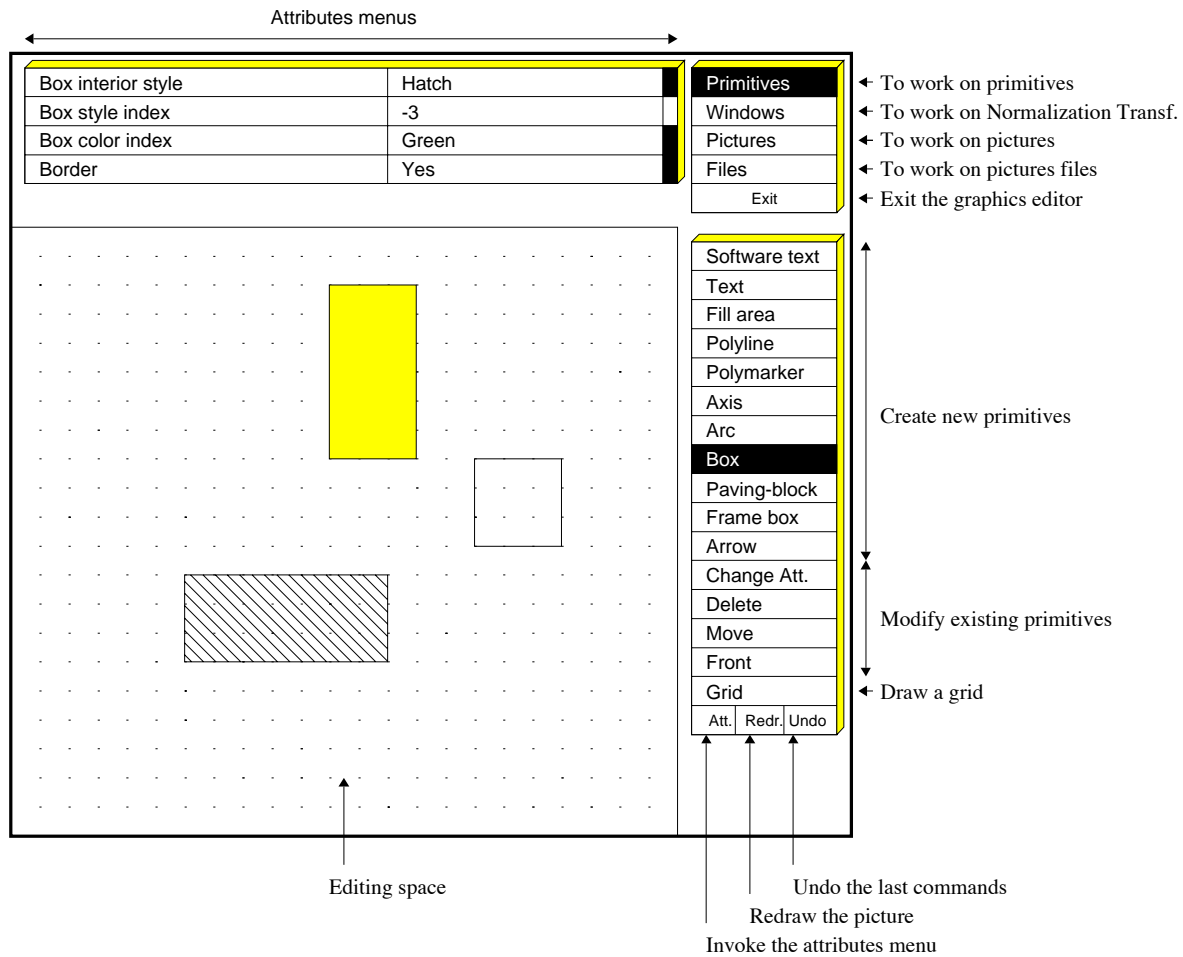


Figure 8.18: The HIGZ graphics editor

Chapter 9: Distributed PAW

With the increasing number of workstations, it happens more and more frequently that a user wants to run PAW on a mainframe or on a workstation. Several tools described in this chapter have been developed in order to use in the most convenient way all the resources available in an heterogeneous environment of workstations, superminis, data acquisition systems and mainframes.

TELNETG: A powerful terminal emulator. An alphanumeric window (line mode) is created on the local workstation (e.g. Apollo) to create a session (like with TELNET) on a remote computer (e.g. VAX). On the remote computer, a graphics program is run and a window is automatically created on the local workstation to receive the graphics output.

3270G Same as the TELNETG emulator for the case of a connection with an IBM machine in full screen mode under VM/CMS.

ZFTP The ZEBRA file transfer program optimized to transport ZEBRA RZ or FZ files between machines with different data representations.

There exists also the possibility to access files on a **remote computer** from a PAW session on a workstation. PAW can be used in a **real time** environment. Access to HBOOK histograms being filled by a different process on the same machine (Global sections on VAX) or a computer on the network (e.g. OS9 modules). Both ZFTP and real time access to histograms on a remote computer require the implementation of a **PAW server** on this computer. The PAW server is automatically started from a PAW session, if PAW has been implemented with the relevant options (PATCHY [16] flag CZ). PAW and the PAW server must be linked with two special modules called **CZ** and **TCPAW** [17, 18].

CZ is a small FORTRAN package (about 300 lines). It provides an interface between the ZEBRA Input/Output routines and the high level transport routines of the TCPAW package.

TCPAW[17] is a networking package, written in C by Ben Segal (about 1500 lines). It provides a very simple FORTRAN-callable interface to TCP/IP services. It supports client and server modules running on UNIX, Apollo, VMS, VM/CMS and OS9 environments. Small parts of TCPAW are CERN specific but it would be perfectly possible to transport it elsewhere with minor modifications. The package currently requires the Wollongong (TWG) TCP/IP software to be present on VMS connected systems, the IBM FAL 1.2 Product on VM/CMS, and Microware TCP/IP on OS9. The UNIX systems Ultrix, CRAY Unicos, SUN OS, IBM AIX, Apollo/Aegis, Apple A/UX and HP-UX are supported as delivered.

9.1 TELNETG and 3270G

Figure 9.1 describes the functionality of these two programs. They allow to run a graphics application based on HIGZ (e.g. PAW, GEANT, etc.) on a host machine and to receive the graphics output on the local machine. TELNETG is designed to work with operating systems supporting a command line interface and 3270G for a full screen interface.

TELNETG and 3270G supports both graphics Input and Output. The graphics locator (commands LOCATE, VLOCATE, etc.) as well as the various KUIP graphics menu styles (G and GP) may be used.

Both programs exploit the fact that the HIGZ macro primitives are very compact, therefore reducing the amount of information to be sent through the network. Compared to more conventional emulators (4014, 4207, etc.) gains in speed are typically a factor of 10 when drawing one-dimensional histograms and may reach a factor 100 for two-dimensional plots (lego, surface, scatterplot).

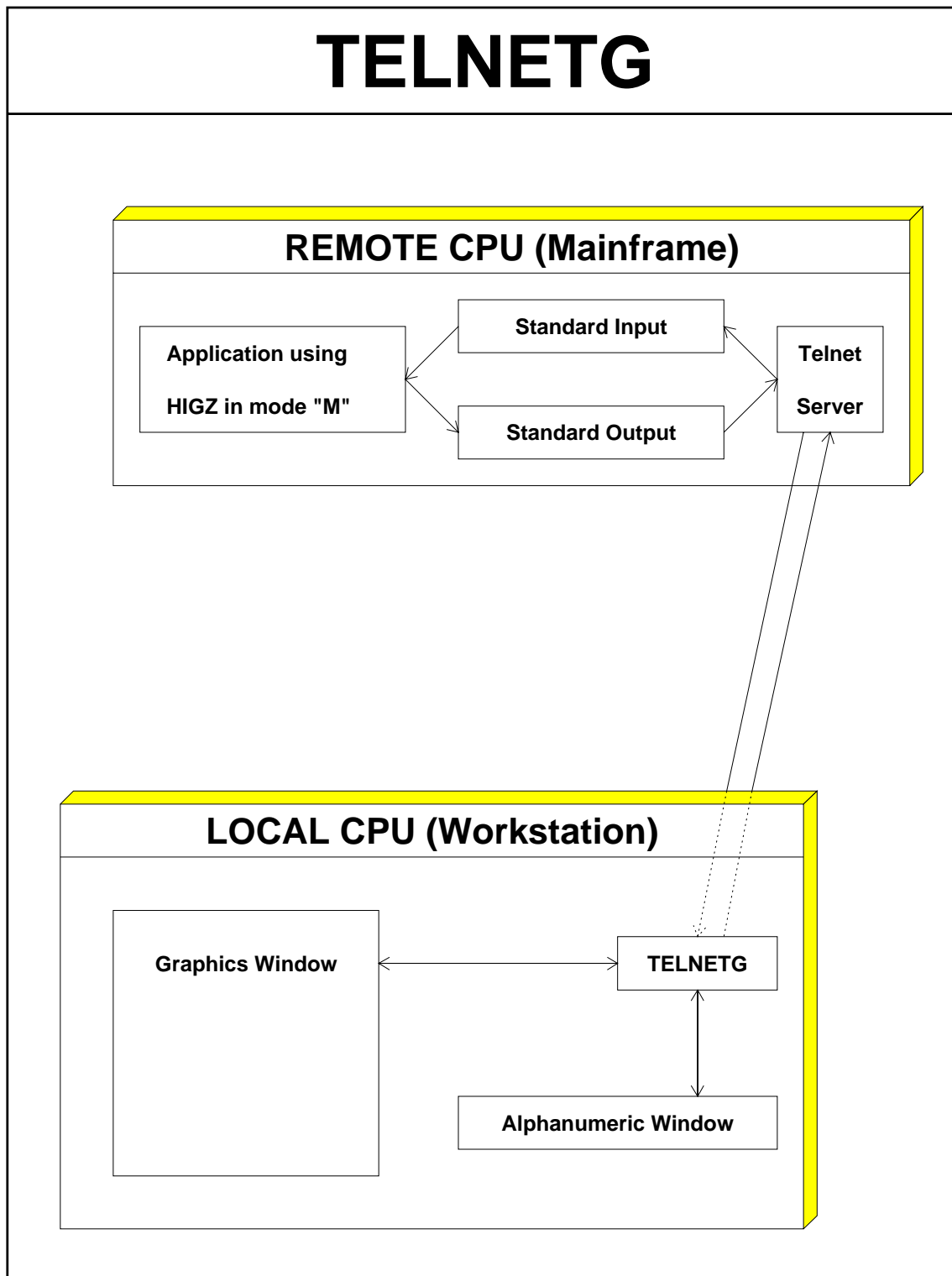


Figure 9.1: The TELNETG program

TELNETG combines a slightly modified version of the standard TELNET program written in the C language and an interface to the HIGZ system written in FORTRAN.

The following example shows how to use TELNETG from an Apollo to a VAX. The integer identifier of the workstation type must be preceded by a **minus sign** (e.g. for an Apollo DN3000):

Example of a TELNETG session

```

$ TELNETG vxcrna
Trying...
Open
    This is the CERN Central VAXcluster running VMS V5.1

Username: USERNAME
Password: PASSWORD(not echoed)
    Welcome to VAX/VMS version V5.1 on node VXCRNA
    TERMINAL TYPE <? for HELP; No default>:D1
VxCrnA$ PAW
*****
*                                     *
*           W E L C O M E   to   P A W           *
*                                     *
*           Version 1.11/02  29 March 1991           *
*                                     *
*****
Workstation type (?=HELP) <CR>=7878 : -10002
VERSION 7.4/2.6 OF GKSGRAL STARTED
PAW > hi/plot 10           | The graphics is sent to the Apollo
PAW > locate              | Graphics input using the Apollo mouse

```

9.2 ZFTP

The ZFTP program (ZEBRA File Transfer Program) provides the same functionality as the FTP program which is available like TELNET on all workstations and mainframes supporting TCP/IP. In addition ZFTP has been optimized to allow the transfer of ZEBRA binary files both sequential and direct access.

The direct access ZEBRA/RZ files (used for HBOOK histograms and HIGZ pictures) contain data in the local data representation. Because ZEBRA is an object oriented language supporting machine independent Input/Output, ZFTP is able to translate in flight all the ZEBRA data structures in a transparent way in the network buffers. ZFTP copies the RZ files on the local machine with the same parameters (RECL, quota, etc.) than on the remote machine. The original date and time of the objects is also preserved.

In addition to binary file transfer, ZFTP can also transfer alphanumeric text files (up to 80 characters/line). On IBM/VM-CMS, these files must be of type RECFM=F, LRECL=80.

The ZFTP user interface is based on KUIP and is the same on all systems. If several files have to be transferred (maybe on a regular basis), KUIP macros may be used. The following commands are available:

OPEN	To start a communication with a remote machine.
CLOSE	Close the current communication.
GETA	Transfer an Alphanumeric text file from the remote machine.
PUTA	Transfer an Alphanumeric text file to a remote machine.
GETRZ	Transfer a RZ file from a remote machine.
PUTRZ	Transfer a RZ file to a remote machine.
GETFZ	Transfer a FZ file from a remote machine.
PUTFZ	Transfer a FZ file to a remote machine.
RSHELL	Send a command to a remote machine.

Example of a ZFTP session

```
# Start execution of the program from inside the PAW directory
$ ZFTP
ZFTP > open CERNVM                |Starts communication with CERNVM
                                     | (prompt for username/password)
ZFTP > getrz RZFILE.DAT.D local.dat | Transfer IBM file "RZFILE.DAT"
                                     | to local file "local.dat"
ZFTP > puta local.car              | Transfer local alphanumeric file
                                     | "local.car" to IBM
                                     | IBM file name will be "LOCAL CAR A"
ZFTP > quit
```


9.4 Using PAW as a presenter on VMS systems (global section)

```

PROGRAM PRODUCE
PARAMETER MAXPAGES=100
COMMON/PAWC/IPAWC(128*MAXPAGES)
CHARACTER*8 GNAME
INTEGER*4 HCREATEG
*
GNAME='GTEST'
WAIT_TIME=1.
NUMEVT=1000
*.....          Create Global section
NPAGES=HCREATEG(GNAME,IPAWC,128*MAXPAGES)
IF(NPAGES.GT.0) THEN
  PRINT 1000,GNAME
1000  FORMAT(' Global Section: ',A,' created')
ELSE
  IERROR=-NPAGES
  PRINT 2000,IERROR
2000  FORMAT(' Global Section Error', I6)
  GO TO 99
ENDIF
CALL HLIMIT(128*NPAGES)
*.....          Book histos.
CALL HBOOK1(10,'Test1$',50,-4.,4.,0.)
CALL HBOOK1(20,'Test2$',50,-4.,4.,0.)
*.....          Fill histos.
DO 20 I=1,NUMEVT
  DO 10 J=1,100
    CALL RANNOR(A,B)
    CALL HFILL(10,A,0.,1.)
    CALL HFILL(20,B,0.,1.)
  10  CONTINUE
  CALL LIB$WAIT(WAIT_TIME)
  20  CONTINUE
*
99  STOP
END

$ fort produce
$ link produce,SYS$INPUT/OPTIONS,-
cern$library:packlib/lib,kernlib/lib
PSECT=PAWC,PAGE

```

```

PAW > edit produce
macro produce ntimes=100
  nt=[ntimes]
  zone 1 2
  histo/plot 10 K
  histo/plot 20 K
loop:
  histo/plot 10 U
  histo/plot 20 U
  wait ' ' 1
  nt=[nt] -1
  if nt>0 goto loop
return
PAW > global GTEST
PAW > exec produce ntimes=20

```

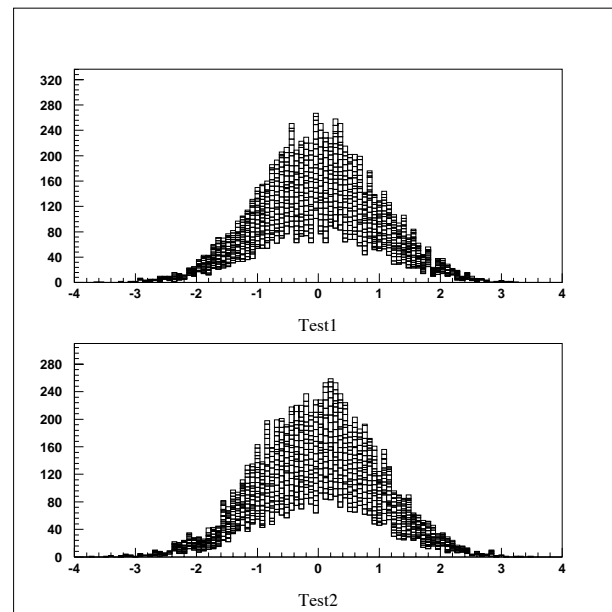


Figure 9.2: Visualise histograms in global section

In addition to the facilities described in the previous section, the standard version of PAW may be used as an online presenter on VMS systems using the mechanism of global sections. It is possible for two processes to reference the same histograms using **global sections**. For example, the first process may be a **histogram producer** (e.g. a monitoring task) and the second process **PAW**. As the histograms are being gradually filled by the first task, PAW can view them, and even reset them. To use the global sections, it is also necessary to "page align" the common which is in the global section. This is achieved in the "link step" when making the process (see example). The relevant statements are `SYS$INPUT/OPTIONS` to tell the linker that some options follow the link statement, and `PSECT=PAWC,PAGE` which is the option to page align the `/PAWC/` common.

Part III

PAW - Reference section

Notation used in the reference section

Optional parameters are enclosed in square brackets, e.g. [optpar]

The **type** of a parameter is indicated following its name as follows:

- C Character data
- I Integer data
- R Real (floating point) data

Supplementary information is given at the end of the line describing the parameter:

- D= Default value
e.g. D='S' for Character data or D=40 for Integer data
- R= Range of possible values
e.g. R=0 : 1 means that the variable's value lies between 0 and 1.
R=' ,L,P,* ,+' enumerates the possible values for the given Character variable.

Chapter 10: KUIP

Command Processor commands.

HELP [item]

ITEM Command name C D=' '

Give the help of a command. If a command is supplied as parameter ITEM, its full explanation is given: syntax (as given by the command USAGE), explanation of the functionality, list of parameters with their attributes (prompt, type, default, range, etc.). 'HELP /' gives the help for all commands.

If HELP is entered without parameters, the dialogue style is switched to 'AN', guiding the user in traversing the tree command structure.

'HELP -EDIT' (or just 'HELP -E') switch the help in the edit mode. This mode is currently implemented on IBM/VM-CMS and Apollo: instead of writing the help text on the terminal output, it is written into a temporary file and the editor is invoked, XEDIT on IBM/VM-CMS or a new pad window on the Apollo (see also command SET_SHOW/HOST_EDITOR). 'HELP -NOEDIT' (or just 'HELP -N' or 'HELP -') switch the help in the standard mode.

USAGE [cmdnd]

CMND Command name C D=' '

Give the syntax of a command. If CMND='/' the syntax of all commands is given.

MANUAL [item outfil docsys]

ITEM Command name or help (key)word C D=' '

OUTFIL Output file name C D=' '

DOCSYS Text formatting system C D=' ' R=' ,SGML,TEX,LATEX'

Write on a file the text formatted help of a command. If OUTFIL=' ' the text is written to the terminal. It works like the command HELP ITEM, plus a text formatting option: if DOCSYS is not a blank the output is formatted according to the selected documentation and text formatting system (ex. SGML, TEX, LATEX, etc.). Example:

```
MANUAL / FILE.DOC SGML
```

will produce a file named FILE.DOC containing the SGML input to be processed by SGML in order to have the documentation of all the available commands.

LISTHELP [lstnam]

LSTNAM List name C D=' '

Help for lists. If a list is specified, display its attributes (D='dynamic', S='static', T='temporary', P='permanent') and a description of the list and its use. Otherwise display the names of all of the known lists. 'LISTHELP /' gives help for all lists.

EDIT [fname]

FNAME File name *C*

Invoke the default host editor. The file FNAME.KUMAC (the extension KUMAC is taken automatically unless FNAME contains already a dot) is given to the editor and, if it does not exist, a new file is created with this name. Use the command SET_SHOW/HOST_EDITOR to change the default editor.

LAST [n fname]

N N last commands to be saved *I* *D*=-1

FNAME File name *C* *D*=' '

Perform various operations with the history file.

If FNAME is not specified, the current history file is assumed by default (the startup history file name is LAST.KUMAC). To change the history file the command LAST 0 NEWFNAME must be entered.

If N=-1 (default case) the default host editor is called to edit the current history file, containing all the commands of the session.

If N=0 the history file FNAME is rewound and set as the current one (the command LAST 0 FNAME itself is not recorded).

If N>0 the last N commands of the session are saved in the current history file.

See also the command SET_SHOW/RECORDING.

MESSAGE [string]

STRING Message string *C* *D*=' '

Write a message string on the terminal. A useful command inside a macro. Several message strings can be given in the same command line, each of them separated by one or more spaces (the usual parameter separator); therefore multiple blanks will be dropped and only one will be kept. If multiple blanks have not to be dropped, the string must be surrounded by single quotes.

SHELL [cmd]

CMD Shell command *C* *D*=' '

Execute a command of the host operating system. To execute just one command enter SHELL COMMAND; otherwise enter just SHELL and wait for the system prompt. After the last command enter RETURN (the full word, not just <CR>) to go back to the application.

WAIT [string sec]

STRING Message string *C* *D*=' '

SEC Number of seconds *R* *D*=0

Make a pause (e.g. inside a macro). Wait a given number of seconds (if SEC.GT.0) or just until <CR> is entered (if SEC.LE.0). A message string is also written on the terminal before waiting.

UNITS

List all Input/Output logical units currently open. The files attached to them are also shown.

EXIT

End of the interactive session.

QUIT

End of the interactive session.

FUNCTIONS

KUIP System Functions. The function name (and arguments) is literally replaced, at run-time, by its current value. At present, the following functions are available:

\$DATE	.....	Current date in format DD/MM/YY
\$TIME	.....	Current time in format HH.MM.SS
\$CPTIME	.....	CP time elapsed since last call (in sec)
\$RTIME	.....	Real time elapsed since last call (in sec)
\$VDIM(VNAME, IDIM)	.....	Physical length of vector VNAME on dimension IDIM (1..3)
\$VLEN(VNAME, IDIM)	.....	As above, but for the logical length (i.e. stripping trailing zeroes)
\$NUMVEC	.....	Current number of vectors
\$VEXIST(VNAME)	.....	Index of vector VNAME (1..\$NUMVEC or 0 if VNAME does not exist)
\$SUBSTRING (STRING, IX, NCH)	...	STRING(IX:IX+NCH-1)
\$UPPER (STRING)	.....	STRING changed to upper case
\$LOWER (STRING)	.....	STRING changed to lower case
\$LEN (STRING)	.....	Length of STRING, stripping leading/trailing blanks and single quotes
\$SIGMA (SIGMA_Expression)	...	Result of SIGMA_Expression, computed by SIGMA
\$ARGS	.....	Command line at program invocation
\$KEYNUM	.....	Address of latest clicked key in style GP
\$KEYVAL	.....	Value of latest clicked key in style GP
\$LAST	.....	Latest command line executed
\$ANUM	.....	Number of aliases
\$ANAM(I)	.....	Name of I-th alias
\$AVAL(I)	.....	Value of I-th alias
\$STYLE	.....	Current style as defined by SET/STYLE

10.1 ALIAS

Operations with aliases. Aliases are defined to provide shortcut abbreviations for the input line or some part of it. An alias name can be any string of characters (excepted the single quote and the blank) and whenever encountered in an input line it will be literally replaced by its value (another string of characters). Alias substitution does not apply in quoted strings. Aliases need separators to be recognized in the input line, namely:

blank / , = : . % ' ()

To juxtaposition aliases, a double slash can be used as concatenation sign. Be careful not defining aliases recursively.

```
CREATE  aname string [ chopt ]
```

```
ANAME   Alias name      C
STRING  Equivalent string C
CHOPT   Option          C  D=' ' R=' ,C'
```

Create an alias named ANAME corresponding to STRING. Also switch ON the alias translation, i.e. ALIAS/TRANSLATION ON. If CHOPT='C' then the alias is a command alias, i.e. an alias that will only be translated when it is the first token on a command line. Example:

```
Alias/Create GG Graph/Struct/Scratch
Alias/Create FF File1/Name1/Name2
GG FF/ID
```

is equivalent to

```
Graph/Struct/Scratch File1/Name1/Name2/ID

Alias/Create LS DIR C
```

is equivalent to

```
DIR
```

only when LS is the first token on a command line. In the following case LS will not be translated

```
SHELL LS
```

LIST

List all aliases (name, equivalent string).

```
DELETE  alist
```

```
ALIST   Alias list  C
```

Delete the definition of aliases in the list ALIST. The aliases are separated in the list by a comma and imbedded blanks are not allowed. If ALIST='*' then delete all aliases and the alias translation is switched OFF (i.e.: ALIAS/TRANSLATION OFF is executed).

```
TRANSLATION [ option ]
```

```
OPTION  Option  C  D='ON' R='ON,OFF,?'
```

Switch ON/OFF the alias translation. If OFF, alias definitions are not used in parsing the command lines. It is automatically switched ON when an alias is created. If OPTION='?' the current value is shown. The startup value is OFF.

10.2 SET_SHOW

Set or show various KUIP parameters and options.

```
STYLE [ option sgylen sgsize sgyspa sgbord wktype ]
```

```
OPTION  Option                               C  D='?'  R='?,C,AN,AL,G,GW,GS,GP'
SGYLEN  max Y LENgth of each menu item box  R  D=0.025 R=0.005:0.25
SGSIZE  space available for the application  R  D=0.8 R=0:0.9
SGYSPA  max Y length of space between menus R  D=0.02 R=-0.5:0.5
SGBORD  X or Y border for menus             R  D=0.015 R=0:0.25
WKTYPE  Graphics workstation type           I  D=0
```

Set the user dialogue style (or working mode). If OPTION='?' the current style is shown. The startup value is C (command mode). Currently available options are:

```
C    for Command
AN   for general Alpha menu (with Numbers)
AL   for general Alpha menu (with Letters)
G    for Graphics menu (with hardware character fonts)
GW   for Graphics menu (with shadowed Width effect)
GS   for Graphics menu (with Software character fonts)
GP   for Graphics menu (with Panel keys only, i.e. no command tree menu)'
```

When using OPTION='G' (or 'GW', 'GS', 'GP') the 4 parameters following the style can be defined to control the geometrical layout of the menus on the screen, and the the fifth one to set the graphics workstation type (without being prompted afterwards, if case of HIGZ was not initialized).

```
PANEL line [ gkey ]
```

```
LINE  Line number          R  D=0
GKEY  Graphics key value(s) C  D=' '
```

Set up the panel of graphics keys (used by STYLE GP).

Examples:

```
PANEL  0                | reset the panel
PANEL  2 A/L QUIT V/L   | initialize line 2 with 3 graphics keys,
                        | respectively A/L, QUIT, V/L
PANEL  2 A/L ' ' V/L ' ' ' ' | initialize line 2 with 5 graphics keys,
                        | and fill 1st and 3rd keys
PANEL  2.04 MESSAGE    | initialize 4th key of 2nd line to MESSAGE
PANEL  2.04            | clear 4th key of 2nd line
PANEL  -2.08           | initialize line 2 with 8 graphics keys
PANEL  -6.16          | initialize line 6 with 16 graphics keys
```

Note that the key number on the right of the decimal point must always be defined with two digits.

Keys ending with a minus sign make an additional request of keyboard input; the complete command line will be the key text, with a blank at the place of the minus, concatenated with the additional keyboard input. Example:

```
PANEL  1.03 'VEC/PRI-' | entering VAB will execute VEC/PRI VAB.
```

Keys ending with a double minus sign behave as above but no blank is put at the place of the double minus. Example:

```
PANEL 1.03 'VEC/PRI V--' | entering AB will execute VEC/PRI VAB
```

The dollar sign inside a key is replaced by additional keyboard input. Example:

```
PANEL 1.03 'VEC/PRI V($)' | entering 11:20 will execute VEC/PRI V(11:20)
```

Maximum values for the key layout are: 1 panel, 10 lines/panel, 30 keys/line, 32 characters/key

COMMAND [chpath]

CHPATH Path name for command line C D=' '

Set a filter for the parsing of command lines. If it has been called, it means that whenever a command line is entered, if and only if it is not an existing command (not just ambiguous), it is inserted into the CHPATH string, with \$n (n=1..9) being replaced by the n-th token of the command (tokens are separated by spaces), or \$* being replaced by the whole command line. Examples:

```
COMMAND 'V/CR $*(10)'
```

```
AA => V/CR AA(10)
BB => V/CR BB(10)
V/LIST => V/LIST
```

```
COMMAND 'VECTOR/PLOT $1 555 $2'
```

```
AA E => VECTOR/PLOT AA 555 E
BB => VECTOR/PLOT BB 555
```

```
COMMAND => shows its current value
```

```
COMMAND * => reset (equivalent to COMMAND $*)
```

Note that COMMAND and subsequent command lines can be used inside macros, excepted when producing macro statements (like EXEC, IF, GOTO, etc.). For example, the above examples would work also inside macros, while COMMAND 'EXEC \$*' or COMMAND 'GOTO \$1' will not.

The same remark applies also to the command DEFAULT -Auto, which is in fact equivalent to COMMAND 'EXEC \$*'

The COMMAND logic is superseded by the DEFAULT -A (or -AR) logic.

APPLICATION [path cmdex]

PATH Application name C D=' '

CMDEX Exit command C D='EXIT'

Set the application name. This means that all input lines will be concatenated to the string PATH (until the command specified by the parameter CMDEX is executed, which resets the application to the null string). The value of CMDEX may be specified if the default value EXIT has to be changed (i.e. because already used by the application). APPLICATION can also be inserted in a macro: in this case at least 4 characters must be specified (i.e. APPL).

ROOT [path]

PATH Root directory C D='/'

Set the root for searching commands. If PATH='?' the current root is shown. This allows to access commands regardless of possible ambiguities with different menus. Commands are first searched starting from the current root: if a command is found it is executed. Only if a command is not found a second pass of search is done, starting now from the top root of the command tree (i.e. '/').

TIMING [option]

OPTION Option C D='ON' R='ON,OFF,ALL'

Set ON/OFF/ALL the timing of commands. If ON, the real time and the CPU time for the latest executed command (or macro) are presented. If ALL, the time is shown for each command being executed within a macro. The startup value is OFF.

PROMPT [option]

OPTION Prompt string C D=' '

Set the prompt string for the command mode dialogue. If OPTION is blank the current prompt is left unchanged.

BREAK [option]

OPTION Option C D='ON' R='ON,OFF,TB,?'

Set ON/OFF the break handling. If OPTION='?' the current value is shown. The startup value is ON.

Hitting the keyboard interrupt (CTRL/C on VAX or CTRL/Q on the Apollo) under break ON condition, the current command or macro execution will be interrupted and the user will get again the application prompt.

BREAK TB switch ON the traceback of the routines called, with their line numbers, when an error occurs. This allows the detection of the routines which provoked the error.

COLUMNS [ncol]

NCOL Number of columns for terminal output I D=80 R=0:132

Set the maximum number of columns for terminal output. If NCOL=0 the current number of columns is shown. The startup value is 80.

RECORDING [nrec]

NREC Rate for recording on history file I D=25 R=0:25

Set the recording rate for the history file. Every NREC commands of the session the current history file is updated. If NREC=0 the history is not kept at all (i.e. the file is not written). See also the command LAST.

HOST_EDITOR [option top left width height dxpad dypad npads]

OPTION	Name of default host editor	C	D='?'	R='?,EDT,TPU,DM,VI,WINDOW,PAD'
TOP	Top position of the edit window	I	D=20	
LEFT	Left position of the edit window	I	D=20	
WIDTH	Width of the edit window	I	D=0	
HEIGHT	Height of the edit window	I	D=0	
DXPAD	X offset for help PAD windows	I	D=30	R=0:
DYPAD	Y offset for help PAD windows	I	D=20	R=0:
NPADS	Maximum number of shifted pads	I	D=4	R=1:

Set the default host editor (only for VAX/VMS, Apollo and Unix). If OPTION='?' the current host editor is shown. The EDIT command will invoke this editor. The startup value is EDIT/EDT (VAX/VMS), dm (Apollo) or the value assigned to the EDITOR environment variable (Unix).

On the Apollo, if OPTION='WINDOW' or 'PAD' and some parameters are following, they will be used as edit window positions (in pixel units). If no parameters are following (i.e. typing just HOST WINDOW or HOST PAD) they will be asked graphically on a dummy window. OPTION='WINDOW' is used to specify window pad parameters used by commands like EDIT, LAST, etc., while OPTION='PAD' is used to specify help pad parameters used by the command HELP in EDIT mode.

This command is not meaningful on IBM/VM-CMS where it is always XEDIT.

HOST_SHELL [option]

OPTION	Name of default host shell	C	D='?'	R='sh,csh,ksh,/com/sh'
--------	----------------------------	---	-------	------------------------

Set the default host shell (only for Apollo and Unix machines). If OPTION='?' the current host shell is shown. The SHELL command will invoke this shell. The startup value is the value assigned to the SHELL environment variable.

VISIBILITY cmd [chopt1 chopt2]

CMD	Command name	C	D=' '	
CHOPT1	?, OFF, ON	C	D='?'	R='?,OFF,ON'
CHOPT2	?, CLEAR, KEEP	C	D='?'	R='?,CLEAR,KEEP'

Set or show the visibility attributes of a command.

If CHOPT1='OFF':

- the command it is not executable anymore
- STYLE G draws a shadowed box on the command
- HELP may be still requested on the command

The startup value is ON.

CHOPT2 allows the user to customize the 'Style Motif':

- if CHOPT2='KEEP' the parameters window is not cleared upon execution

The startup value is CLEAR.

MODE mode

MODE KUIP Mode C D='M' R='M,A'
Set or Show KUIP mode for Command Area.

Chapter 11: MACRO

Macro Processor commands.

EXEC `mname`

MNAME Macro name *C*

Execute the command lines contained in the macro **MNAME**. As a file can contain several macros, the character '#' is used to select a particular macro inside a file as explained below.

If **MNAME** does not contain the character '#', the file **MNAME.KUMAC** is searched and the first macro is executed (it may be an unnamed macro if a **MACRO** statement is not found as first command line in the file).

If **MNAME** is of the form **FILE#MACRO**, the file named **FILE.KUMAC** is searched and the macro named **MACRO** is executed.

Examples:

```
EXEC ABC    to exec first (or unnamed) macro of file ABC.KUMAC
EXEC ABC#M  to exec macro M of file ABC.KUMAC
```

LIST [`mname`]

MNAME Macro name restrictions *C* *D=' '*

List all macros on disk. Macros are files with the extension **KUMAC**. **MNAME** may be specified to restrict the list to the macros containing such a string in the first part of their name, for example **MACRO/LIST ABC** will list all macros starting with **ABC**.

TRACE [`option level prompt`]

OPTION Option *C* *D='ON' R='ON,OFF'*

LEVEL Level *C* *D=' ' R=',TEST,WAIT,FULL'*

PROMPT Prompt string *C* *D=' '*

Set ON/OFF the trace of commands during macro execution. If **TRACE='ON'** the command being executed is written on the terminal, after the prompt defined in the parameter **PROMPT**. If **LEVEL='TEST'** the command is only echoed but not executed. If **LEVEL='WAIT'** the command **WAIT** is automatically inserted after the execution of each command. If **LEVEL='FULL'** all the names of macros and labels are printed at the end of macro interpretation. If **PROMPT=' '** (default) the prompt written is replaced by a number of '>' equal to the current prompt length. At the end of the macro execution the prompt is switched back to the original one. The startup values are **OPTION='OFF'** and **LEVEL=' '**.

DEFAULTS [`chpath`]

CHPATH Path name for macro files *C* *D=' '*

Set or show various **MACRO** attributes.

Entered without parameters, it show the current "extra path" to the 'default working directory', as well as all macro parameters (name, default value) relative to the latest **EXEC** command entered.

If **CHPATH** is supplied, set its value representing the "extra path". The "extra path" is a string (e.g. the name of a disk directory) which is added in front of the macro file names, whenever they are used in the commands **EDIT**, **EXEC** and **MACRO/LIST**. The extra path is ignored if a dash sign '-' is put in front of the file name. If **CHPATH='*'**, the extra path is reset and the host computer's current working directory is used. Example:

```

DEFAULT 'DISK$DL:[PAW]'
MACRO/LIST          | list macros in DISK$DL:[PAW]
EXEC FUNCTION      | executes DISK$DL:[PAW]FUNCTION.KUMAC
EXEC -MYMACRO      | executes MYMACRO.KUMAC
EXEC PALETTE       | executes DISK$DL:[PAW]PALETTE.KUMAC
DEFAULT *
EXEC PALETTE       | executes PALETTE.KUMAC

```

In addition to what described above, the command DEFAULTS may be used to control whether commands and/or macros are searched (and in which order):

```

DEFAULT -Command
CMD          | CMD is executed (error if not found)
DEFAULT -Auto
CMD          | try CMD first; if not found, try EXEC CMD
DEFAULT -AutoReverse
CMD          | try EXEC CMD first; if not found, try CMD

```

The lower case letters following the minus sign are optional. The startup value (also re-set by DEFAULT *) is DEFAULT -C

The DEFAULT -A (or -AR) logic supersedes the COMMAND logic.

Important note:

Inside macros the DEFAULT -A (or -AR) logic is not active: DEFAULT -C is always assumed.

RECURSION [option]

```
OPTION Option C D='ON' R='ON,OFF'
```

Set ON/OFF the option to execute macros recursively. The startup value is OFF.

Chapter 12: VECTOR

Vector Processor commands. Vectors are equivalent to FORTRAN 77 arrays and they use the same notation except when omitting indexes (see last line below). Up to 3 dimensions are supported. Examples:

```
Vec(20) (mono-dimensional with 20 elements)
```

may be addressed by:

```
Vec          for all elements
Vec(13)      for element 13-th
Vec(12:)     for elements 12-th to last
Vec(:10)     for elements first to 10-th
Vec(5:8)     for elements 5-th to 8-th
```

```
Vec(3,100) (bi-dimensional with 3 columns by 100 rows):
```

may be addressed by:

```
Vec(2,5:8)   for elements 5-th to 8-th in 2-nd column
Vec(2:3,5:8) for elements 5-th to 8-th in 2-nd to 3-rd columns
Vec(2,5)     for element 5-th in 2-nd column
Vec(:,3)     for all elements in 3-rd row
Vec(2)       for all elements in 2-nd column (SPECIAL CASE)
```

The latest line shows the special (and non-standard with FORTRAN 77) notation such that missing indexes are substituted to the right.

An 'invisible' vector called '?', mono-dimensional and of length 100, is always present. It is used for communicating between user arrays and KUIP vectors, being equivalenced with the real array VECTOR(100) in the labelled common block /KCWORK/.

```
CREATE vname [ type ]
```

```
VNAME Vector name(length) C
```

```
TYPE Vector type C D='R' R='R,I'
```

Create a vector named VNAME (elements are set to zero). The dimensions are taken from the name, for example VEC(20), VEC(3,100), VEC(2,2,10). Up to 3 dimensions are supported. Dimensions which are not specified are taken to 1, for example VEC(10) → VEC(10,1,1) and VEC → VEC(1,1,1). The vector may be of type Real or Integer. A vector is filled at the same time if parameters are given after the TYPE:

```
VEC/CREATE V(10) R 1 2 3 4 5 66 77 88 99 111
VEC/CREATE W(20) R 1 2 3
```

In the last example only the first three elements are filled. Vector elements may be changed later with the command VECTOR/INPUT.

If many equal values have to be entered consecutively, one can specify just one value and precede it by a repetition factor and an asterisk. Example:

```
VEC/CREATE Z(20) R 5*1 2 4*3 ---> VEC/CREATE Z(20) R 1 1 1 1 1 2 3 3 3 3
```

Enter HELP VECTOR for more information on vector addressing.

LIST

List all vectors (name, dimensions, type).

DELETE vlist

VLIST Vector list C D= ' '

Delete from memory all vectors in the list VLIST. The vectors are separated in the list by a comma and imbedded blanks are not allowed. An asterisk at the end of VLIST acts as string placeholder:

```
VEC/DEL AB*      ---> deletes all vectors starting by AB
VEC/DEL *        ---> deletes all vectors
```

COPY vnam1 vnam2

VNAM1 Source vector name C

VNAM2 Destination vector name C

Copy a vector into another one. Mixed vector type copy is supported (e.g. Integer → Real and viceversa). If VNAM2 does not exist it is created with the required dimensions, not necessarily the same as the source vector if a sub-range was specified. For example, if A is a 3 x 100 vector and B does not exist, COPY A(2,11:60) B will create B as a 50 elements mono-dimensional vector; a special (and non-standard with FORTRAN 77) notation is used such that, still using the above vectors, COPY A(2,1:100) B and COPY A(2) B have the same effect.

Note that VECTOR/COPY does not allow a range for the destination vector not specifying consecutive elements (i.e. along the first dimension):

```
VEC/COPY V(5)      W(3,4)      | O.K.
VEC/COPY V1(2:3,5) V2(4:5,9)  | O.K.
VEC/COPY V1(5,2:3) V2(4:5,9)  | O.K.
VEC/COPY V1(3,3:4) V2(4,4:5)  | NOT allowed
VEC/COPY V1(2:3,5) V2(2,4:5)  | NOT allowed
```

Enter HELP VECTOR for more information on vector addressing.

INPUT vname

VNAME Vector name C

Enter values into a vector from the terminal. Example:

```
VEC/INPUT V(6:10) 1.1 2.22 3.333 4.4444 5.55555
```

If many equal values have to be entered consecutively, one can specify just one value and precede it by a repetition factor and an asterisk. Example:

```
VEC/INPUT V 5*1 2 4*3 ---> VEC/INPUT V 1 1 1 1 1 2 3 3 3 3
```

Enter HELP VECTOR for more information on vector addressing.

PRINT vname

VNAME Vector name C

Write to the terminal the content of a vector. Enter HELP VECTOR for more information on vector addressing.

READ vlist fname [format opt match]

VLIST Vector list C
 FNAME File name C D=' '
 FORMAT Format C D=' '
 OPT Options C D='0C' R='0C,0, ,C'
 MATCH Matching pattern C D=' '

Enter values into vector(s) from a file. A format can be specified, e.g. FORMAT='F10.5,2X,F10.5', or the free format is used if FORMAT is not supplied.

If vector(s) are not existing they will be created of the size as read from the file.

Vectors in the list VLIST are separated by a comma and imbedded blanks are not allowed. If subscripts are present in vector names, the smallest one is taken.

OPT is used to select between the following options:

'0C' file is Opened, read and then Closed (default case)
 '0' file is Opened and then read (left open for further reading)
 ' ' file is read (already open, left so for further reading)
 'C' file is read and then Closed (already open)

If the character 'Z' is present in OPT, the vector elements equal to zero after reading are set to the latest non-zero element value (for example reading 1 2 3 0 0 4 0 5 will give 1 2 3 3 3 4 4 5).

MATCH is used to specify a pattern string, restricting the vector filling only to the records in the file which verify the pattern. Example of patterns:

/string/ match a string (starting in column 1)
 -/string/ do not match a string (starting in column 1)
 /string/(n) match a string, starting in column n
 /string/(*) match a string, starting at any column

Enter HELP VECTOR for more information on vector addressing.

WRITE vlist [fname format chopt]

VLIST Vector list C
 FNAME File name C D=' '
 FORMAT Format C D='5(1X,G13.7)'
 CHOPT Options C D='0C' R='0C,0, ,C'

Write to a file the content of vector(s). If FNAME=' ' the content is written to the terminal. A format can be specified, e.g. FORMAT='F10.5,2X,F10.5', or the default one is used if FORMAT is not supplied.

Vectors in the list VLIST are separated by a comma and imbedded blanks are not allowed. If subscripts are present in vector names, the smallest one is taken.

CHOPT is used to select between the following options:

```
'OC' file is Opened, written and then Closed (default case)
'O'  file is Opened and then written (left open for further writing)
' '  file is written (already open, left so for further writing)
'C'  file is written and then Closed (already open)
```

Enter HELP VECTOR for more information on vector addressing.

DRAW vname [id chopt]

```
VNAME Vector name      C
ID     Histogram Identifier C D='12345'
CHOPT  Options          C D=' ' R=' ,C,S,+,B,L,P,*'
```

Draw vector VNAME interpreting it as a histogram. Optionally save the contents in histogram ID. CHOPT may be a combination of the following characters:

```
'C' Draw a smooth curve.
'S' Superimpose plot on top of existing picture.
+' Add contents of ID to last plotted histogram.
'B' Select Bar chart format.
'L' Connect channels contents by a line.
'P' Draw the current polymarker at each channel.
'*' Draw a * at each channel.
```

HFILL vname id

```
VNAME Vector name      C
ID     Histogram Identifier C
```

Fill the existing histogram ID with vector VNAME. Note that the command VECTOR/PLOT can automatically book, fill and plot the contents of a vector.

PLOT vname [id chopt]

```
VNAME Vector name      C
ID     Histogram Identifier C D='12345'
CHOPT  Options          C D=' ' R=' ,C,S,+,B,L,P,*'
```

Each element of VNAME is used to fill an histogram which is automatically booked with 100 channels and then plotted. If VNAME has the form VNAME1%VNAME2 then a scatter-plot of vector VNAME1 versus VNAME2 is plotted. If ID is given different of 12345, then a 2-Dim histogram is created with 40 bins by 40 bins and filled. One can use the command VECTOR/HFILL to fill an already existing histogram. CHOPT may be a combination of the following characters:

```
'C' Draw a smooth curve.
'S' Superimpose plot on top of existing picture.
+' Add contents of ID to last plotted histogram.
'B' Select Bar chart format.
'L' Connect channels contents by a line.
'P' Draw the current polymarker at each channel.
'*' Draw a * at each channel.
```

FIT x y ey func [chopt np par step pmin pmax errpar]

X	Vector of X coordinates	C	
Y	Vector of Y coordinates	C	
EY	Vector of errors on Y	C	D='?'
FUNC	Function name	C	
CHOPT	Character options	C	D=' ' R=' ,O,N,Q,V,B,D,W,M'
NP	Number of parameters	I	D=0 R=0:20
PAR	Vector of parameters	C	
STEP	Vector of steps size	C	
PMIN	Vector of lower bounds	C	
PMAX	Vector of upper bounds	C	
ERRPAR	Vector of errors on parameters	C	

Fit a user defined function to the points defined by the two vectors X and Y and the vector of associated errors EY. See command Histo/Fit for explanation of parameters. Note that if option 'W' is specified or EY='?' (default), the array EY is ignored. Option 'L' is not available.

12.1 OPERATIONS

Simple arithmetic operations between vectors. In all the operations only the minimum vector length is considered, i.e. an operation between a vector A of dimension 10 and a vector B of dimension 5 will involve the first 5 elements in both vectors. If the destination vector does not exist, it is created with the same length as the source vector.

VBIAS vnam1 bias vnam2

VNAM1	Source vector name	C
BIAS	Bias value	R
VNAM2	Destination vector name	C
VNAM2(I) = BIAS + VNAM1(I)		

VSCALE vnam1 scale vnam2

VNAM1	Source vector name	C
SCALE	Scale factor	R
VNAM2	Destination vector name	C
VNAM2(I) = SCALE * VNAM1(I)		

VADD vnam1 vnam2 vnam3

VNAM1	First source vector name	C
VNAM2	Second source vector name	C
VNAM3	Destination vector name	C
VNAM3(I) = VNAM1(I) + VNAM2(I)		

VMULTIPLY vnam1 vnam2 vnam3

VNAM1 First source vector name C

VNAM2 Second source vector name C

VNAM3 Destination vector name C

VNAM3(I) = VNAM1(I) * VNAM2(I)

VSUBTRACT vnam1 vnam2 vnam3

VNAM1 First source vector name C

VNAM2 Second source vector name C

VNAM3 Destination vector name C

VNAM3(I) = VNAM1(I) - VNAM2(I)

VDIVIDE vnam1 vnam2 vnam3

VNAM1 First source vector name C

VNAM2 Second source vector name C

VNAM3 Destination vector name C

VNAM3(I) = VNAM1(I) / VNAM2(I) (or 0 if VNAM2(I)=0)

Chapter 13: HISTOGRAM

Manipulation of histograms, Ntuples. Interface to the HBOOK package.

```
FILE lun fname [ lrecl chopt ]
```

LUN Logical unit number *I* R=1:128
FNAME File name *C*
LRECL Record length in words *I* D=1024
CHOPT Options *C* D=' ' R=' ,N,U'

Open an HBOOK direct access file.

For CHOPT=' ', existing file is opened (read mode only).

For CHOPT='N', a new file is opened.

For CHOPT='U', existing file is opened to be modified.

```
LIST [ chopt ]
```

CHOPT Options *C* D=' ' R=' ,I'

List histograms and Ntuples in the current directory. If CHOPT='I' a verbose format is used (HINDEX).

```
DELETE id
```

ID Histogram Identifier *C*

Delete histogram/Ntuple ID in Current Directory (memory). If ID=0 delete all histograms and Ntuples. To delete histograms in disk files use command HIO/HSCRATCH.

```
PLOT [ id chopt ]
```

ID Histogram Identifier *C*

CHOPT Options *C* D=' ' R=' ,C,S,+,-,B,L,P,*,K,U,E,A'

Plot a single histogram or a 2-Dim projection. Each plotted histogram will start either a new picture or a new zone in the current picture. A channel range may be specified for 1-Dim and 2-Dim histograms. Ex: Histo/plot 10(25:64) or Histo/plot 20(4:18,5:10). CHOPT may be a combination of the following characters:

'C' Draw a smooth curve.
'S' Superimpose plot on top of existing picture.
'+' Add contents of ID to last plotted histogram.
'-' Subtract contents of ID to last plotted histogram.
'+-' Draw the delta with the last plotted histogram.
'B' Select Bar chart format.
'L' Connect channels contents by a line.
'P' Draw the current polymarker at each channel or cell.
'*' Draw a * at each channel.
'K' Must be given if option 'U' is given later.
'U' Update channels modified since last call.
'E' Draw error bars and current marker.

'A' Axis labels and tick marks are not drawn.
 'BOX' Draw 2-Dim with proportional boxes.
 'COL' Draw 2-Dim with a color table.
 'Z' Used with COL or SURF, it draws the color map.
 'SURF' Draw as a surface plot (angles are set via the command angle).
 'SURF1' Draw as a surface with color levels
 'SURF2' Same as SURF1 but without cell lines.
 'SURF3' Same as SURF but with the contour plot (in color) on top.
 'SURF4' Draw as a surface with Gouraud shading.
 'LEGO' Draw as a lego plot (angles are set via the command angle).
 'LEGO1' Draw lego plot with light simulation.
 'LEGO2' Draw lego plot with color levels.
 'CONT' Draw 2-Dim as a contour plot (15 levels).
 'TEXT' Draw 2-Dim as a table.
 'CHAR' Draw 2-Dim with characters (a la HBOOK).
 'HIST' Draw only histogram (no errors or associated function).
 'FUNC' Draw only the associated function (not the histogram).

1 Dim histograms could be plotted with option LEGO or SURF. In this case the angles are THETA=1 and PHI=-1. When option 'E' is used, the marker type can be changed with SMK, the marker size with SET KSIZ, the marker color with SPMCI. To plot projection X of ID type

```
HI/PLOT ID.PROX
```

To plot band 1 in Y of ID type

```
HI/PLOT ID.BANY.1
```

To plot slice 3 in Y of ID type

```
HI/PLOT ID.SLIY.3
```

```
ZOOM [ id chopt icmin icmax ]
```

ID	Histogram Identifier	C	
CHOPT	Options	C	D=' ' R=' ,C,S,+,B,L,P,*'
ICMIN	First channel	I	D=1
ICMAX	Last channel	I	D=9999

Plot a single histogram between channels ICMIN and ICMAX. Each plotted histogram will start either a new picture or a new zone in the current picture. If no parameters are given to the command, then the system waits for two points using the graphics cursor. To quit ZOOM, click the right button of the mouse or CTRL/E. CHOPT may be a combination of the following characters:

'C' Draw a smooth curve.
 'S' Superimpose plot on top of existing picture.
 '+' Add contents of ID to last plotted histogram.
 'B' Select Bar chart format.
 'L' Connect channels contents by a line.
 'P' Draw the current polymarker at each channel.
 '*' Draw a * at each channel.

MANY_PLOTS idlist

IDLIST List of histogram Identifiers *C*

Plot one or several histograms into the same plot. Plotted histograms are superimposed on the same zone of the picture.

PROJECT id

ID Histogram Identifier *C*

Fill all booked projections of a 2-Dim histogram. Filling is done using the 2-D contents of ID.

COPY id1 id2 [title]

ID1 First histogram Identifier *C*

ID2 Second histogram Identifier *C*

TITLE New title *C* D=' '

Copy a histogram (not Ntuple) onto another one. Bin definition, contents, errors, etc. are preserved. If TITLE is not given, ID2 has the same title as ID1.

FIT id func [chopt np par step pmin pmax errpar]

ID Histogram Identifier *C*

FUNC Function name *C* D=' '

CHOPT Options *C* D=' ' R=' ,O,N,Q,V,B,L,D,W,M,E'

NP Number of parameters *I* D=0 R=0:34

PAR Vector of parameters *C*

STEP Vector of steps size *C*

PMIN Vector of lower bounds *C*

PMAX Vector of upper bounds *C*

ERRPAR Vector of errors on parameters *C*

Fit a user defined (and parameter dependent) function to a histogram ID (1-Dim or 2-Dim) in the specified range. FUNC may be:

A- The name of a file which contains the user defined function to be minimized. Function name and file name must be the same. For example file FUNC.FOR is:

```

FUNCTION FUNC(X) or FUNC(X,Y) for a 2-Dim histogram
COMMON/PAWPAR/PAR(2)
FUNC=PAR(1)*X +PAR(2)*EXP(-X)
END
Ex: His/fit 10 func.for ! 5 par
```

B- One of the following keywords (1-Dim only):

G : to fit $\text{Func}=\text{par}(1)*\exp(-0.5*((x-\text{par}(2))/\text{par}(3))**2)$

E : to fit $\text{Func}=\exp(\text{par}(1)+\text{par}(2)*x)$

Pn: to fit $\text{Func}=\text{par}(1)+\text{par}(2)*x+\text{par}(3)*x**2+\dots+\text{par}(n+1)*x**n$

Ex: His/fit 10 g

C- A combination of the keywords in B with the 2 operators + or *.

Ex: His/Fit 10 p4+g ! 8 par

His/Fit 10 p2*g+g ! 9 par

Note that in this case, the order of parameters in PAR must correspond to the order of the basic functions.

For example, in the first case above, par(1:5) apply to the polynomial of degree 4 and par(6:8) to the gaussian while in the second case par(1:3) apply to the polynomial of degree 2, par(4:6) to the first gaussian and par(7:9) to the second gaussian.. Blanks are not allowed in the expression.

For cases A and C, before the execution of this command, the vector PAR must be filled (via Vector/Input) with the initial values. For case B, if NP is set to 0, then the initial values of PAR will be calculated automatically. After the fit, the vector PAR contains the new values of parameters. If the vector ERRPAR is given, it will contain the errors on the fitted parameters. A bin range may be specified with ID.

Ex. Histo/Fit 10(25:56).

CHOPT : Possible options '0NQVBLDWM' + HPLOT options

- '0' Do not plot the result of the fit. By default the fitted function is drawn unless the option 'N' below is specified.
- 'N' Do not store the result of the fit bin by bin with the histogram. By default the function is calculated at the middle of each bin and the fit results stored with the histogram data structure.
- 'Q' Quiet mode. No print
- 'V' Verbose mode. Results after each iteration are printed
By default only final results are printed.
- 'B' Some or all parameters are bounded. The vectors STEP,PMIN,PMAX must be specified.
Default is: All parameters vary freely.
- 'L' Use Log Likelihood.
Default is chisquare method.
- 'D' The user is assumed to compute derivatives analytically using the routine HDERIV.
By default, derivatives are computed numerically.
- 'W' Sets weights equal to 1. Default weights taken from the square root of the contents or from HPAKE/HBARX (PUT/ERRORS).
- 'M' The interactive Minuit is invoked.
- 'E' Performs a better Error evaluation (MIGRAD + HESSE + MINOS).

13.1 2D_PLOT

Plotting of 2-Dim histograms in various formats.

LEGO [id theta phi chopt]

ID Histogram Identifier C
 THETA Angle THETA in degrees R D=30.
 PHI Angle PHI in degrees R D=30.
 CHOPT Options C D=' ' R=' ,1,2'

Draw a lego plot from 2-Dim or 1-Dim histograms. By default (CHOPT=' ') a hidden line algorithm is used. CHOPT='1' A hidden surface algorithm is used. The colour of the lego

is given by SET HCOL CI where CI is a colour index. For the top and the sides of the lego the same hue is used but with a different light.

CHOPT='2' A hidden surface algorithm is used. The colour of each bar

changes according to the value of Z. It is possible to change the set of colours used with SET HCOL c.L where L define a palette of colours given by the command ATT/PALETTE.

It is also possible to produce stacked lego plots. A stacked lego plot consists of a superimposition of several histograms, whose identifiers are given in the command LEGO separated by the character "+".

PAW > LEGO ID1+ID2+ID3 | Maximum number of ID's is 10. The colours of each IDn is given by the command ATT/PALETTE

Examples:

PAW > SET HCOL 2 | The colour the histogram is 2 (red)
 PAW > LEGO 20 | Display a lego with lines
 PAW > LEGO 20 ! ! 1 | Display a lego with different lights
 PAW > LEGO 20 ! ! 2 | Display a lego with colours

 PAW > PALETTE 1 3 2 3 4 | Create the palette number 1 with 3 elements: 2,3
 PAW > SET HCOL 0.1 | The subsequent stack lego plots will use list 1
 PAW > LEGO 10+20+30 | Plot a stack of lego plots with lines
 PAW > LEGO 10+20+30 ! ! 1 | Plot a stack of lego plots with light

Notes: - The commands OPTION BAR, SET BARW and SET BARO act on lego plots

- The options 1 and 2 must be used only on selective erase devices.

SURFACE [id theta phi chopt]

ID Histogram Identifier C
 THETA Angle THETA in degrees R D=30.
 PHI Angle PHI in degrees R D=30.
 CHOPT Options C D=' ' R=' ,1,2,3,4'

Draw a surface plot from 2-Dim or 1-Dim histograms. By default (CHOPT=' ') a hidden line algorithm is used. CHOPT='1' A hidden surface algorithm is used and each cell is filled

with a colour corresponding to the Z value (or grey scale with PostScript). It is possible to change the set of colours used with SET HCOL ic.L where L define a palette of colours given by the command ATT/PALETTE.

CHOPT='2' Is similar to option '1' except that the cell lines

are not drawn. This is very useful to draw contour plots with colours if THETA=90 and PHI=0.

CHOPT='3' A surface is drawn with a contour plot in color on top. The

contour plot is drawn with the colors defined with the command PALETTE.

CHOPT='4' A surface is drawn with Gouraud shading. With this command it is possible to draw color contour plots:

```
PAW > ATT/PAL 1 3 2 3 4 | Define the palette 1 with 3 elements
PAW > SET HCOL 0.1      | Set the list 1 as colours for histograms
PAW > SET NDVZ 4        | Set the number of Z divisions to 4
PAW > SURF id 90 0 2    | Draw the contour
```

Note: - The options 1 to 4 must be used only on selective erase devices.

CONTOUR [id nlevel chopt param]

ID	Histogram Identifier	C	
NLEVEL	Number of contour lines	I	D=10
CHOPT	Options	C	D=' ' R=' ,0,1,2,S'
PARAM	Vector of contour levels	C	

Draw a contour plot from a 2-Dim histogram. CHOPT may be a combination of the following characters:

- '0' use colour to distinguish contours.
- '1' use line style to distinguish contours.
- '2' line style and colour are the same for all contours.
- '3' The contour is drawn with filled colour levels. The levels are equidistant. The color indices are taken in the current palette (defined with the command PALETTE). If the number of levels (NLEVEL) is greater than the number of entries in the current palette, the palette is explore again from the beginning in order to reach NLEVEL.
- 'S' Superimpose plot on top of existing picture.

If PARAM is not given, contour levels are equidistant. If given, the vector PARAM may contain up to 50 values.

13.2 CREATE

Creation ("booking") of HBOOK objects in memory.

IDHISTO id title ncx xmin xmax [valmax]

ID	Histogram Identifier	C	
TITLE	Histogram title	C	D=' '
NCX	Number of channels	I	D=100
XMIN	Low edge	R	D=0.
XMAX	Upper edge	R	D=100.
VALMAX	Maximum bin content	R	D=0.

Create a one dimensional histogram. The contents are set to zero. If VALMAX=0, then a full word is allocated per channel, else VALMAX is used as the maximum bin content allowing several channels to be stored into the same machine word.

PROFILE id title ncx xmin xmax ymin ymax [chopt]

ID	Histogram Identifier	C	
TITLE	Histogram title	C	D=' '
NCX	Number of channels	I	D=100
XMIN	Low edge in X	R	D=0.
XMAX	Upper edge in X	R	D=100.
YMIN	Low edge in Y	R	D=-1.E30
YMAX	Upper edge in Y	R	D=1.E30
CHOPT	Options	C	D=' ' R=',S'

Create a profile histogram. Profile histograms accumulate statistical quantities of a variable y in bins of a variable x. The contents are set to zero.

BINS id title ncx xbins [valmax]

ID	Histogram Identifier	C	
TITLE	Histogram title	C	D=' '
NCX	Number of channels	I	D=100
XBINS	Vector of NCX+1 low-edges	C	
VALMAX	Maximum bin content	R	D=0.

Create a histogram with variable size bins. The low-edge of each bin is given in vector XBINS (NCX+1) values. The contents are set to zero. See IDHISTO for VALMAX.

2DHISTO id title ncx xmin xmax ncy ymin ymax [valmax]

ID	Histogram Identifier	C	
TITLE	Histogram title	C	D=' '
NCX	Number of channels in X	I	D=40
XMIN	Low edge in X	R	D=0.
XMAX	Upper edge in X	R	D=40.
NCY	Number of channels in Y	I	D=40
YMIN	Low edge in Y	R	D=0.
YMAX	Upper edge in Y	R	D=40.
VALMAX	Maximum bin content	R	D=0.

Create a two dimensional histogram. The contents are set to zero. See 1DHISTO for VALMAX.

PROX id

ID Histogram (2-Dim) Identifier *C*

Create the projection onto the x axis. The projection is not filled until the Histo/Project command is executed.

PROY id

ID Histogram (2-Dim) Identifier *C*

Create the projection onto the y axis. The projection may be filled with Histo/Project.

SLIX id nslices

ID Histogram (2-Dim) Identifier *C*

NSLICES Number of slices *I*

Create projections onto the x axis, in y-slices. The projection may be filled with Histo/Project.

SLIY id nslices

ID Histogram (2-Dim) Identifier *C*

NSLICES Number of slices *I*

Create projections onto the y axis, in x-slices. The projection may be filled with Histo/Project.

BANX id ymin ymax

ID Histogram (2-Dim) Identifier *C*

YMIN Low edge in Y *R*

YMAX Upper edge in Y *R*

Create a projection onto the x axis, in a band of y. The projection may be filled with Histo/Project.

BANY id xmin xmax

ID Histogram (2-Dim) Identifier *C*

XMIN Low edge in X *R*

XMAX Upper edge in X *R*

Create a projection onto the y axis, in a band of x. The projection may be filled with Histo/Project.

TITLE_GLOBAL [chtitl chopt]

CHTITL Global title *C* D=' '

CHOPT Options *C* D=' ' R=' ,U'

Set the global title. The global title is plotted at the top of each picture if the CHOPT=' '. If CHOPT='U' and if the option 'UTIT' is on, a user title is plotted at the bottom of each histogram. The size and the Y position of the global title may be changed by the commands SET GSIZ and SET YGTI respectively. The size and the Y position of the user title may be changed by the commands SET TSIZ and SET YHTI respectively.

13.3 HIO

Input/Output operations of histograms.

HRIN id [icycle iofset]

ID Histogram Identifier C
 ICYCLE Cycle number I D=999
 IOFSET Offset I D=0

Read histogram/Ntuple ID from the current directory on direct access file to memory. An identical histogram is created but with an ID equal to that of the original histogram plus the offset IOFSET. Identifier may be '0' or '*' (for all histograms). If ICYCLE > 1000 and ID=0 read all histograms in all subdirectories as well. If IOFSET = 99999 then the contents of histogram ID on the disk file are added to the current histogram in memory if it exists. For example to add all histograms from FILE1 and FILE2 in memory, the sequence of commands can be:

```
PAW > Histo/File 1 FILE1
PAW > Hrin 0
PAW > Histo/File 2 FILE2
PAW > Hrin 0 ! 99999
```

HROUT id [chopt]

ID Histogram Identifier C
 CHOPT Options C D=' ' R=' ,T'

Write histo/Ntuple ID from memory to current directory. Identifier may be '0' or '*' (for all histograms). If CHOPT='T' writes all histograms in subdirectories as well.

HSCRATCH id

ID Histogram Identifier C

Delete histogram ID in Current Directory on disk. If ID='0' or '*' delete all histograms. To delete histograms in memory use command HISTO/DELETE.

HFETCH id fname

ID Histogram Identifier C
 FNAME File name C

Fetch histogram ID from file FNAME. FNAME has been created by the old version of HBOOK3 (Unformatted).

HREAD id fname

ID Histogram Identifier C
 FNAME File name C

Read histogram ID from file FNAME. FNAME has been created by the old version of HBOOK3 (Formatted).

PRINT id [chopt]

ID Histogram Identifier C

CHOPT Options C D=' ' R=' ,S'

Print histograms (line-printer format) on screen. The command OUTPUT_LP may be used to change the output file. If CHOPT='S', then only statistics (Number of entries, mean, RMS, underflow, overflow) are printed.

DUMP id

ID Histogram Identifier C

Dump the histogram ZEBRA data structure on the terminal.

OUTPUT_LP [lun fname]

LUN Logical unit number I D=6

FNAME File name C D=' '

Change the HBOOK "line printer" file name. If FNAME=' ' then OUTPUT is appended to an already opened file on unit LUN. If LUN is negative, the file is closed and subsequent output is directed to unit 6.

GLOBAL_SECT gname

GNAME Global section name C D=' '

Map the global section GNAME (VAX only). The current directory is changed to //GNAME.

GRESET id

ID Histogram Identifier C

Reset histogram ID in the global section.

13.4 OPERATIONS

Histogram operations and comparisons.

ADD id1 id2 id3 [c1 c2]

ID1 First histogram Identifier C

ID2 Second histogram Identifier C

ID3 Result histogram Identifier C

C1 Scale factor for ID1 R D=1.

C2 Scale factor for ID2 R D=1.

Add histograms: $ID3 = C1 * ID1 + C2 * ID2$. Applicable to 1-Dim and 2-Dim histograms. See command HRIN to add histograms with same IDS from different files.

SUBTRACT id1 id2 id3 [c1 c2]

ID1 First histogram Identifier C

ID2 Second histogram Identifier C

ID3 Result histogram Identifier C

C1 Scale factor for ID1 R D=1.

C2 Scale factor for ID2 R D=1.

Subtract histograms: $ID3 = C1*ID1 - C2*ID2$. Applicable to 1-Dim and 2-Dim histograms.

MULTIPLY id1 id2 id3 [c1 c2]

ID1 First histogram Identifier C
 ID2 Second histogram Identifier C
 ID3 Result histogram Identifier C
 C1 Scale factor for ID1 R D=1.
 C2 Scale factor for ID2 R D=1.

Multiply histogram contents: $ID3 = C1*ID1 * C2*ID2$. Applicable to 1-Dim and 2-Dim histograms.

DIVIDE id1 id2 id3 [c1 c2]

ID1 First histogram Identifier C
 ID2 Second histogram Identifier C
 ID3 Result histogram Identifier C
 C1 Scale factor for ID1 R D=1.
 C2 Scale factor for ID2 R D=1.

Divide histograms: $ID3 = C1*ID1 / C2*ID2$. Applicable to 1-Dim and 2-Dim histograms.

RESET id [title]

ID Histogram Identifier C
 TITLE New title C D=' '

Reset contents and errors of an histogram. Bin definition is not modified.

DIFF id1 id2 [chopt]

ID1 First Histogram Identifier C
 ID2 Second Histogram Identifier C
 CHOPT Options C D='D' R='D,N, ,0,U,L,R,B,T'

Test of compatibility for two 1-Dim histograms ID1 and ID2. A probability PROB is calculated as a number between zero and one, where PROB near one indicates very similar histograms, and PROB near zero means that it is very unlikely that the two arose from the same parent distribution. For two histograms sampled randomly from the same distribution, PROB will be (approximately) uniformly distributed between 0 and 1. See discussion in HBOOK manual under "HDIFF- Statistical Considerations". By default (if no options are selected with CHOPT) the comparison is done only on the shape of the two histograms, without consideration of the difference in numbers of events, and ignoring all underflow and overflow bins. The string CHOPT allows specification of the following options:

- N Include also comparison of the relative normalization of the two histograms, in addition to comparing the shapes. PROB is then a combined confidence level taking account of absolute contents.
- D Debug printout, produces a blank line and two lines of information at each call, including the ID numbers, the number of events in each histogram, the PROB value, and the maximum Kolmogorov distance between the two histograms. For 2-Dim histograms, there are two Kolmogorov distances

(see below). If 'N' is specified, there is a third line of output giving the PROB for shape alone, and for normalization.
 O Overflow, requests that overflow bins be taken into account.
 U Underflow, requests that underflow bins be taken into account.

SMOOTH id [isel]

ID Histogram Identifier C

ISEL Option flag I D=2

Smooth histogram ID using the 353QH algorithm.

ISEL = 0,1 replace original histogram by smoothed.
 = 2 superimpose result of smoothing as a function when editing.

SPLINE id [isel knotx kx]

ID Histogram Identifier C

ISEL Option flag I D=2

KNOTX Number of knots I D=10

KX Degree of the spline I D=3

Smooth 1-Dim or 2-Dim histogram ID using B-splines. If ID is a 1-Dim histogram then:

ISEL = 0,1 replace original histogram by smoothed.
 = 2 superimpose as a function when editing.

If ID is a 2-Dim histogram then original contents are replaced.

PARAM id [isel r2min maxpow]

ID Histogram Identifier C

ISEL Control word I D=11

R2MIN Min correlation coefficient R D=1.

MAXPOW Max degree of polynomials I D=5 R=1:20

Perform a regression on contents of the 1-Dim histogram ID. Find the best parameterization in terms of elementary functions (regressors). See HBOOK guide HPARAM. Control word ISEL=1000*T+100*W+10*S+P

S = 1 resulting parametric fit superimposed on histogram
 0 no superposition

P = 0 minimal output: the residual sum of squares is printed
 1 normal output: in addition, the problem characteristics and options are printed; also the standard deviations and confidence intervals of the coefficients.
 2 extensive output: the results of each iteration are printed with the normal output.

W = 0 weights on histogram contents are already defined via HBARX or HPAKE. If not they are taken to be equal to the

square-root of the contents.
 1 weights are equal to 1.
 T = 0 monomials will be selected as the elementary functions
 1 Chebyshev polynomials with a definition region: [-1,1]
 2 Legendre polynomials with a definition region: [-1,1]
 3 shifted Chebyshev polynomials with a definition region: [0,1]
 4 Laguerre polynomials with a definition region: [0,+infinite]
 5 Hermite polynomials with a definition region: [-inf,+inf]

The FORTRAN code of the parameterization is written onto the file FPARAM.DAT.

HSETPR param value

PARAM Parameter name C D='FEPS'

VALUE Parameter value R D=0.001

Set various parameters for command PARAM.

13.5 GET_VECT

Fill a vector from values stored in HBOOK objects.

CONTENTS id vname

ID Histogram Identifier C

VNAME Vector name C

Get contents of histogram ID into vector VNAME.

ERRORS id vname

ID Histogram Identifier C

VNAME Vector name C

Get errors of histogram ID into vector VNAME.

FUNCTION id vname

ID Histogram Identifier C

VNAME Vector name C

Get function associated to histogram ID into vector VNAME.

ABSCISSA id vname

ID Histogram Identifier C

VNAME Vector name C

Get values of center of bins abscissa into vector VNAME.

```
REBIN id x y ex ey [ n ifirst ilast ]
```

ID	Histogram Identifier	<i>C</i>
X	Name of vector X	<i>C</i>
Y	Name of vector Y	<i>C</i>
EX	Name of vector EX	<i>C</i>
EY	Name of vector EY	<i>C</i>
N	Number of elements to fill	<i>I</i> D=100
IFIRST	First bin	<i>I</i> D=1
ILAST	Last bin	<i>I</i> D=100

Get contents and errors into vectors, grouping bins. Bin width and centers are also extracted. Allow to combine 2, 3 or more bins into one.

E.g.: REBIN 110 X Y EX EY 25 11 85
 will group by 3 channels 11 to 85 and return
 new abscissa, contents and errors.
 Errors in X are equal to 1.5*BINWIDTH.

N.B.:
 REBIN ID X Y EX EY is a convenient way to return in
 one call abscissa, contents and errors for 1-Dim histogram.
 In this case the errors in X are equal to 0.5*BINWIDTH.

13.6 PUT_VECT

Replace histogram contents with values in a vector.

```
CONTENTS id vname
```

ID	Histogram Identifier	<i>C</i>
VNAME	Vector name	<i>C</i>

Replace contents of histogram with values of vector VNAME.

```
ERRORS id vname
```

ID	Histogram Identifier	<i>C</i>
VNAME	Vector name	<i>C</i>

Replace errors of histogram with values of vector VNAME.

13.7 SET

Set histogram attributes.

```
MAXIMUM id vmax
```

ID	Histogram Identifier	<i>C</i>
VMAX	Maximum value	<i>R</i>

Set the maximum value on the Y axis. To select again an automatic scale, just set VMAX less than the minimum.

MINIMUM id vmin

ID Histogram Identifier C

VMIN Minimum value R

Set the minimum value on the Y axis. To select again an automatic scale, just set VMIN greater then the maximum.

NORMALIZE_FACTOR id [xnorm]

ID Histogram Identifier C

XNORM Normalization factor R D=1

Set the contents/errors normalization factor. Only valid for histograms (1-Dim). (does not change contents, only presentation).

SCALE_FACTOR_2D id [xscale]

ID Histogram Identifier C

XSCALE Scale factor R D=0

Set the scale factor for histograms (2-Dim).

IDOPT id option

ID Histogram Identifier C

OPTION Options C

Set options for histogram ID. (* means default).

```

SETD* Set all options to the default values
SHOW Print all the options currently set
BLAC 1 Dim histogram printed with X characters
CONT* 1 Dim histogram is printed with the contour option
STAR 1 Dim histogram is printed with a * at the Y value
SCAT* Print a 2 Dim histogram as a scatter-plot
TABL Print a 2 Dim histogram as a table
PROS* Plot errors as the Spread of each bin in Y for
      profile histograms
PROE Plot errors as the mean of each bin in Y for
      profile histograms
STAT Mean value and RMS computed at filling time
NSTA* Mean value and RMS computed from bin contents only
ERRO Errors bars printed as SQRT(contents)
NERR* Do not print print error bars
INTE Print the values of integrated contents bin by bin
NINT* Do not print integrated contents
LOGY 1 Dim histogram is printed in Log scale in Y
LINY* 1 Dim histogram is printed in linear scale in Y
PCHA* Print channel numbers
NPCH Do not print channel numbers
PCON* Print bin contents

```

NPCO Do not print bin contents
PLOW* Print values of low edge of the bins
NPLO Do not print the low edge
PERR Print the values of the errors for each bin
NPER* Do not print the values of the errors
PFUN Print the values of the associated function bin by bin
NPFU* Do not print the values of the associated function
PHIS* Print the histogram profile
NPHI Do not print the histogram profile
PSTA* Print the values of statistics (entries,mean,RMS,etc.)
NPST Do not print values of statistics
ROTA Print histogram rotated by 90 degrees
NROT* Print histogram vertically
1EVL Force an integer value for the steps in the Y axis
AEVL* Steps for the Y axis are automatically computed
2PAG Histogram is printed over two pages
1PAG* Histogram is printed in one single page
AUTO* Automatic scaling

Chapter 14: FUNCTION

Operations with Functions. Creation and plotting.

```
FUN1 id ufunc ncx xmin xmax [ chopt ]
```

ID	Histogram Identifier	C	
UFUNC	Name of the function	C	
NCX	Number of channels	I	D=100 R=1:
XMIN	Low edge	R	D=0.
XMAX	Upper edge	R	D=100.
CHOPT	Options	C	D='P'

Create a one dimensional histogram and fill the bins with the values of a (single-valued) function. The function UFUNC may be given in two ways:

-An expression of the variable x in case of a simple function.

```
Ex: FUN1 10 sin(x)/x 100 0 10
```

-UFUNC is the name of a COMIS function in a text file with the name UFUNC.FTN or UFUNC.FOR or UFUNC FORTRAN (Apollo, VAX, IBM).

If CHOPT='P' the function is drawn.

```
FUN2 id ufunc ncx xmin xmax ncy ymin ymax [ chopt ]
```

ID	Histogram (2-Dim) Identifier	C	
UFUNC	Name of the function	C	
NCX	Number of channels in X	I	D=40 R=1:
XMIN	Low edge in X	R	D=0.
XMAX	Upper edge in X	R	D=40.
NCY	Number of channels in Y	I	D=40 R=1:
YMIN	Low edge in Y	R	D=0.
YMAX	Upper edge in Y	R	D=40.
CHOPT	Options	C	D='S' R='S, ,L,C'

Create a two dimensional histogram and fill the bins with the values of a (two-valued) function. The function UFUNC may be given in two ways:

-An expression of the variables x and y in case of a simple function.

```
Ex: FUN2 10 abs(sin(x**2+y**2)) 40 -2 2 40 -2 2 C
```

-UFUNC is the name of a COMIS function in a text file with the name UFUNC.FTN or UFUNC.FOR or UFUNC FORTRAN (Apollo, VAX, IBM).

If CHOPT='S' the function is drawn as a surface. If CHOPT='L' the function is drawn as a lego plot. If CHOPT='C' the function is drawn as a contour plot.

DRAW ufunc [chopt]

UFUNC Name of function C

CHOPT Options C D=' ' R=' '

Draw the function UFUNC in the current ranges specified by the command: RANGE XLOW XUP YLOW YUP ZLOW ZUP and with THETHA and PHI angles specified by the command ANGLE THETA PHI. The number of points to evaluate the function between XLOW, XUP YLOW, YUP, and ZLOW, ZUP can be changed by the command POINTS NPX NPY NPZ.

The function UFUNC may be given in two ways: - As an expression of the variables X, Y, Z in the case of a simple function.

Ex:

```
PAW > FUN/DRAW X*Y*Z          | equivalent to :
PAW > FUN/DRAW X*Y*Z=0
PAW > FUN/DRAW X**2+Y**2+Z**2=1
PAW > FUN/DRAW X**2+Y**2=1-Z**2
```

- As a COMIS function in a text file with the name UFUNC.FTN or UFUNC.FOR or UFUNC FORTRAN (Apollo, VAX, IBM).

Ex:

The file FTEST.FOR contains:

```
FUNCTION FTEST(X,Y,Z)
IF(X.LE.0..AND.Y.LE.0.)THEN
  FTEST=(X+0.5)**2+(Y+0.5)**2+(Z+0.5)**2-0.2
ELSE
  FTEST=(X-0.5)**2+(Y-0.5)**2+(Z-0.5)**2-0.1
ENDIF
END
```

```
PAW > RANGE -1 1 -1 1 -1 1 | Define the range as a cube between -1 1 in the 3
                             | directions
PAW > POINTS 20 20 20      | FUN/DRAW will use 20 points in the 3 directions
PAW > FUN/DRAW FTEST.FOR   | Draw 2 spheres centered on (-0.5,-0.5,-0.5)
                             | and (0.5,0.5,0.5) with the radius SQRT(0.2)
                             | and SQRT(0.1)
```

PLOT ufunc xlow xup [chopt]

UFUNC Name of function C

XLOW Lower limit R

XUP Upper limit R

CHOPT Options C D=' ' R=' ',C,S,+,L,P,*'

Plot single-valued function UFUNC between XLOW and XUP. The function UFUNC may be given in two ways:

-An expression of the variable x in case of a simple function.

Ex: FUN/PLOT $\sin(x)/x$ 0 10

-UFUNC is the name of a COMIS function in a text file with the name UFUNC.FTN or UFUNC.FOR or UFUNC FORTRAN (Apollo, VAX, IBM). For example, if the file FTEST.FOR contains:

```
FUNCTION FTEST(X)
  FTEST=SIN(X)*EXP(-0.1*X)
END
```

Then, FUN/PLOT FTEST.FOR 0 10, will interpret the Fortran code in the file FTEST.FOR and draw the function for x between 0 and 10.

The number of points to evaluate the function between XLOW and XUP can be changed by the command /FUN/POINTS. Only 1-Dim functions are supported. For 2-Dim use FUN2. CHOPT may be a combination of the following characters:

- 'C' Draw a smooth curve (default if CHOPT not specified)
- 'S' Superimpose plot on top of existing picture.
- '+' Add contents of ID to last plotted histogram.
- 'L' Connect channel contents by a line.
- 'P' Draw the current polymarker at each channel.
- '*' Draw a * at each channel.

POINTS [npx npy npz]

NPX Number of points on X axis *I* D=20 R=2:1000

NPY Number of points on Y axis *I* D=20 R=2:1000

NPZ Number of points on Z axis *I* D=20 R=2:1000

Change the number of points to be used by FUN/DRAW and FUN/PLOT. Note that the default for NPX is 20 for 3-Dim plots (FUN/DRAW) but it is 100 for 1-Dim plots (FUN/PLOT).

RANGE [xlow xup ylow yup zlow zup]

XLOW X Lower limit *R* D=-1.

XUP X Upper limit *R* D=1.

YLOW Y Lower limit *R* D=-1.

YUP Y Upper limit *R* D=1.

ZLOW Z Lower limit *R* D=-1.

ZUP Z Upper limit *R* D=1.

Change the range used by FUN/DRAW.

ANGLE [theta phi]

THETA Angle THETA in degrees *R* D=30.

PHI Angle PHI in degrees *R* D=30.

Change the angle used by FUN/DRAW and HISTO/PLOT.

Chapter 15: NTUPLE

Ntuple creation and related operations.

```
CREATE idn title nvar chrzpa nprime varlist
```

IDN	Ntuple Identifier	C
TITLE	Ntuple title	C D=' '
NVAR	Number of variables	I D=1 R=1:512
CHRZPA	RZ path	C D=' '
NPRIME	Primary allocation	I D=1000
VARLIST	Names of the NVAR variables	C

Create an Ntuple. The Ntuple may be created either purely in memory or possibly using an automatic overflow to an RZ file. Memory allocation works in the following way. If CHRZPA = ' ', then a bank of NPRIME words is created. When the space in this bank is exhausted at filling time, a new linear structure of length NPRIME is created and this process will be repeated should the structure become exhausted. If CHRZPA contains the top directory name of an already existing RZ file (as declared with HISTO/FILE), then a bank of length NPRIME is also created, but at filling time, this bank is moved to the RZ file when full, and then it is overwritten by any new entries. The Ntuple can be filled by calling HFN from an interactively defined subroutine called by the command NTUPLE/LOOP or by NTUPLE/READ. The number of variables per data point is given in the parameter NVAR.

LIST

List all Ntuples in the Current Directory. Note that the command HISTO/LIST lists all histograms and Ntuples in the Current Directory.

```
PRINT idn
```

IDN	Ntuple Identifier	C
-----	-------------------	---

Print a summary about Ntuple IDN. Number of entries, variables names and limits are listed.

```
SCAN idn [ chfunc nevent ifirst nvars varlis ]
```

IDN	Ntuple Identifier	C
CHFUNC	User cut function	C D='0'
NEVENT	Number of events	I D=999999
IFIRST	First event	I D=1
NVARS	Number of variables to scan	I D=8 R=0:8
VARLIS	Names of the NVARS variables to scan	C

Scan the entries of an Ntuple subject to user cuts. Scan the variables for NEVENT events starting at IFIRST, requiring that the events satisfy cut CHFUNC. Up to 8 variables may be scanned, the default is to scan the first 8 variables. VARLIS may contain a list of the original variables or/and expressions of the original variables. For example, if IDN=30 has the 3 variables X,Y,Z, one can do:

```
PAW > scan 30
PAW > scan 30 z>10
PAW > scan 30 z>10 ! ! 5 z abs(x) y+z x func.for
```

where `func.for` is a COMIS function returning an expression of the original variables. This function `func.for` may be generated automatically by the PAW command:

```
PAW > uwfunc 30 func.for
```

LOOP `idn uwfunc [nevent ifirst]`

IDN	Identifier of Ntuple	C	
UWFUNC	Selection function or cut number	C	D=' '
NEVENT	Number of events	I	D=999999
IFIRST	First event	I	D=1

Invoke the selection function UWFUNC for each event starting at event IFIRST. In UWFUNC, the user can fill one or several histograms previously booked. The loop will be terminated if UWFUNC returns a negative value. For more information about UWFUNC, see command NTUPLE/PLOT.

MERGE `idn1 idn2 [uwfunc nevent ifirst]`

IDN1	Identifier of first Ntuple	C	
IDN2	Identifier of second Ntuple	C	
UWFUNC	Selection function or cut number	C	D=' '
NEVENT	Number of events	I	D=999999
IFIRST	First event	I	D=1

Merge two Ntuples. Invoke the selection function UWFUNC for each of the NEVENT events starting at event IFIRST of Ntuple IDN1. Suppose you have 4 files containing Ntuple ID=10 and you want to merge the 4 files into the file 4, the sequence is:

```
PAW >Histo/file 1 file1
PAW >Histo/file 2 file2
PAW >Histo/file 3 file3
PAW >Histo/file 4 file4 1024 U
PAW >Ntuple/Merge //lun1/10 //lun4/10
PAW >Ntuple/Merge //lun2/10 //lun4/10
PAW >Ntuple/Merge //lun3/10 //lun4/10
PAW >Ntuple/plot 10.x .....
```

Only the events with `UWFUNC>0` are appended to IDN2. IDN2 may be empty. Note that the Ntuple variables may be redefined inside UWFUNC. For more information about UWFUNC, see command NTUPLE/PLOT.

PROJECT `idh idn [uwfunc nevent ifirst]`

IDH	Identifier of histogram to fill	C	
IDN	Identifier of Ntuple	C	
UWFUNC	Selection function or cut number	C	D=' '
NEVENT	Number of events	I	D=999999
IFIRST	First event	I	D=1

Project an Ntuple onto a 1-Dim or 2-Dim histogram, possibly using a selection function or predefined cuts. IDN may be given as IDN or IDN.X , IDN.Y%X , IDN.1, IDN.2%1. Y%X means variable Y of Ntuple IDN versus variable X. For more information about UWFUNC, see command NTUPLE/PLOT. The histogram IDH is not reset before filling. This allows several PROJECTs from different Ntuples.

```
READ idn fname [ format chopt nevent ]
```

IDN	Ntuple Identifier	C	
FNAME	File name	C	
FORMAT	Format	C	D='*'
CHOPT	Options	C	D=' '
NEVENT	Number of events	I	D=1000000

Read Ntuple values from the alphanumeric file FNAME with the format specifications in FORMAT. Before executing this command, the Ntuple IDN must have been created with the command Ntuple/Create.

```
PLOT idn [ ufunc nevent ifirst nupd option ]
```

IDN	Ntuple Identifier	C	
UWFUNC	Selection function	C	D='0'
NEVENT	Number of events	I	D=999999
IFIRST	First event	I	D=1
NUPD	Frequency to update histogram	I	D=1000000
OPTION	Options	C	D=' ' R=',C,S,+,B,L,P,*,U,E,A'

Project and plot an Ntuple as a (1-Dim or 2-Dim) histogram with automatic binning (ID=1000000), possibly using a selection algorithm. See parameter CHOPT in command HISTO/PLOT for explanation of OPTION.

IDN may be given as

```
IDN
IDN.X
IDN.Y%X
IDN.1
IDN.2%1
IDN.expression1
IDN.expression1%expression2
```

Y%X means a scatter-plot Y(I) versus X(I) where I is the event number. 2%1 means a scatter-plot variable 2 versus variable 1. In this example, X and Y are the names of the variables 1 and 2 respectively. Expression 1 is any numerical expression of the Ntuple variables. It may include a call to a COMIS function.

UWFUNC may have the following forms:

- 1- UWFUNC='0' or missing (only IDN given). No selection is applied.
- 2- UWFUNC is a CUT or combination of valid CUTS created by the command NTUPLE/CUTS. Ex:

```
UWFUNC=1           means use cut number 1
UWFUNC=1.AND.2
UWFUNC=.NOT.(1.AND.2)
```


- UWFUNC=(1.OR.2).AND.3
- 3- UWFUNC is a FORTRAN expression
 Ex: X>3.14.AND.(Y<Z+3.15)
- 4- UWFUNC is a variable name or an arithmetic expression
 Ex: NT/PLOT 30.X Y weight of each event is variable Y
 NT/PLOT 30.X X**2+Y**2
- 5- UWFUNC is the name of a selection function in a text file with the name UWFUNC.FTN, UWFUNC.FOR, UWFUNC FORTRAN (Apollo, VAX, IBM).

The command UWFUNC may be used to generate automatically this function. For example if IDN=30 is an Ntuple with 3 variables per event and 10000 events, then

```
NTUPLE/PLOT 30.X SELECT.FOR
```

will process the 10000 events of the Ntuple IDN=30. For each event, the function SELECT is called. It returns the weight of the event. Example:

```
FUNCTION SELECT(X)
DIMENSION X(3)
IF(X(1)**1+X(2)**2.LT.1.5)THEN
  SELECT=0.
ELSE
  SELECT=1.
ENDIF
END
```

The file SELECT.FOR (VAX), SELECT.FTN (Apollo) or SELECT FORTRAN (IBM) can be edited from PAW using the command EDIT. Note that if the suffix (.FTN, .FORTRAN or .FOR) is omitted, then COMIS will start from the precompiled version in memory and not from the file. Results of a selection can be saved in a MASK (See NTUPLE/MASK).

Ex: NT/PLOT 30.X Z<0.4>>MNAME(4)
 means mark bit 4 in mask MNAME for all events satisfying the condition Z<0.4

A MASK may also be given as input to a selection expression.

Ex: NT/PLOT 30.X MNAME(4).and.Z<0.4
 means all events satisfying bit 4 of MNAME AND Z<0.4

It is possible to plot expressions of the original variables.

Ex 1: NT/PLOT 30.SIN(X)%SQRT(Y**2+Z**2) Z<0.4
 plots a scatter-plot of variable U versus V for all events satisfying the condition Z<0.4. U and V are defined as being U=SIN(X) and V=SQRT(X**2+Y**2)

Ex 2: NT/PLOT 30.FUNC.FTN(X)%(SIN(Y)+3.) Z<0.2.and.TEST.FTN>6
 plots a scatter-plot of variable U versus V for all events satisfying the condition (Z<0.2 and the result of the COMIS function TEST.FTN >6). U and V are defined as being U=Result of the COMIS function FUNC.FTN, V=SIN(Y)+3.

The default identifier of the histogram being filled is `IDF=1000000`. At the next invocation of this command, it will be overwritten. If either `NEVENT` or `IFIRST` or `NUPD` are negative, then the identifier of the histogram being filled will be taken as `IDF=-NEVENT` or `IDF=-IFIRST` or `IDF=-NUPD`. `IDF` may have been created with `H/CREATE`. Before filling `IDF`, the contents of `IDF` are reset if `IDF` already exists. Use `NTUPLE/PROJECT` to cumulate several passes into `IDF`. Note that `IDF` not equal to `1000000` is a convenient way to force user binning. This option must be used when options `'+'`, `'U'`, `'S'` are specified in `OPTION`. Every `NUPD` events, the current status of the histogram is displayed.

```
CUTS  icut [ option fname ]
```

```
ICUT    Cut number  I   R=0:100
OPTION  Options     C   D='P' R='P,G, ,S,-,R,W,D'
FNAME   File name   C   D='  '
```

Define cut number `ICUT` for an Ntuple. This cut can then be used in subsequent commands `NTUPLE/PLOT`, `PROJECT`.

```
OPTION='G' define a new cut ICUT using graphics input on the latest
           1-Dim or 2-Dim projection of the Ntuple.
           For a 1-Dim projection, give 2 points cutmin,cutmax.
           For a 2-Dim projection, give up to 20 points to delimit
           the selected area. The polygon will automatically
           be closed by PAW.
```

```
OPTION='P' Print definition of cut number ICUT.
           'S' same as P
           '-' Reset cut ICUT
           'R' read definition of cut ICUT from file FNAME.
           'W' write definition of cut ICUT on file FNAME (text file).
           'D' Draw cut contour.
```

```
OPTION='expression' Ex: 0.4<X<0.8.and.Y<SQRT(X)
```

Note that `ICUT=0` means all cuts except for `'G'` option. When option `G` is selected, graphical cuts are only operational for plots of the original Ntuple variables, not for expressions of these variables.

```
CSELECT [ chopt csize ]
```

```
CHOPT  Options      C   D='N' R='N, ,R,B,C'
CSIZE  Comment size R   D=0.28
```

To write selection mechanism as a comment on the picture. If option `N` is given, then all subsequent `NTUPLE/PLOT` commands will print the selection mechanism with the options specified in `CHOPT`. By default, the comment is drawn left justified above the top zone line. The options are :

```
'R' comment is right adjusted to the current zone
'C' comment is centered to the current zone
'B' comment is drawn below the top zone line
```

Example:

```
CSEL           All coming NT/PLOT commands will draw a comment
```

of size CSIZE=0.28cm Left justified.
 CSEL NRB 0.4 All coming NT/PLOT commands will draw a comment
 of size 0.4 cm Right justified Below the top line.
 CSEL CB Draw previous selection mechanism Centered Below
 the top zone line.

MASK mname [chopt number]

MNAME Mask name C
 CHOPT Options C D=' ' R=' ,U,N,P,C,R'
 NUMBER Bit number I D=0

Perform Operations with masks. A mask is a direct-access file with the name MNAME.MASK. It must contain as many 32 bit words as there are events in the associated Ntuple. Masks are interesting when only a few events of a Ntuple are selected with a time consuming selection algorithm. For example if the command:

```
NT/PLOT 30.X Z<0.4.AND.SELECT.FTN>>MNAME(6)
```

then for all events in Ntuple 30 satisfying the condition above, the bit 6 in the corresponding mask words will be set. One can then use the mask as selection mechanism. Example:

```
NT/PLOT 30.X MNAME(6)
```

will produce the same results than the NT/PLOT command above, but will be much faster if only a small fraction of all the events is selected. MASKS are automatically saved across PAW sessions on files.

CHOPT=' ' Existing mask on file MNAME.MASK is attached for READ only.
 CHOPT='U' Existing mask on file MNAME.MASK is attached for UPDATE.
 CHOPT='N' A new mask on file MNAME.MASK is created for NUMBER events.
 CHOPT='P' The comments for all active bits is printed.
 CHOPT='C' Mask is closed.
 CHOPT='R' Reset bit number NUMBER.If NUMBER=99, resets all bits.

Example:

```
MASK TEST N 10000
  creates a new mask on file TEST.MASK with enough words to
  process a Ntuple with 10000 events
MASK TEST UP
  opens an existing mask for update and
  prints the active selection bits with explanation
```

UWFUNC idn fname [chopt]

IDN Ntuple Identifier C
 FNAME File name C
 CHOPT Options C D=' ' R=' ,E,P,T'

To generate the FORTRAN skeleton of a selection function. Example: If Ntuple ID=30 has variable names [X,Y,Z,ETOT,EMISS,etc] then:

NTUPLE/UWFUNC 30 SELECT.FOR will generate the file SELECT.FOR with:

```

FUNCTION SELECT(XDUMMY)
COMMON/PAWIDN/IDNEVT,VIDN1,VIDN2,VIDN3,X,Y,Z,ETOT,EMISS,etc
SELECT=1.
END

```

Then using the command EDIT one can modify this file which could then look something like (IDNEVT is the event number):

```

FUNCTION SELECT(XDUMMY)
COMMON/PAWIDN/IDNEVT,VIDN1,VIDN2,VIDN3,X,Y,Z,ETOT,EMISS,etc
IF(X**2+Y**2.GT.Z**2.OR.ETOT.GT.20.)THEN
  SELECT=1.
ELSE
  SELECT=0.
ENDIF
END

```

If in a subsequent command NTUPLE/PLOT, the selection function SELECT is used, then:

```

If NTUPLE/PLOT 30.ETOT SELECT.FOR
  VIDN1=ETOT
If NTUPLE/PLOT 30.SQRT(X**2+Y**2)%(ETOT-EMISS)
  VIDN1=ETOT-EMISS
  VIDN2=SQRT(X**2+Y**2)

```

If CHOPT='E' then the local editor is invoked on FNAME.

= 'P' code to print events is generated.

= 'T' Names of the Ntuple variables are generated in DATA.

```
LINTRA idn [ chopt nevent ifirst nvars varlis ]
```

IDN	Ntuple Identifier	C
CHOPT	Options	C D=' ' R=' ,N,P'
NEVENT	Number of events	I D=999999
IFIRST	First event	I D=1
NVARS	Number of the most significant variables	I D=20 R=0:20
VARLIS	Names of the NVARS most significant variables	C

Data reduction on Ntuple. The method used is the PRINCIPAL COMPONENTS ANALYSIS. The Principal Components Analysis method consists in applying a linear transformation to the original variables of a ntuple. This transformation is described by an orthogonal matrix and is equivalent to a rotation of the original space to a new set of coordinates vectors, which hopefully provide easier identification and dimensionality reduction. This matrix is real positive definite and symmetric and has all its eigenvalues greater than zero. Among the family of all complete orthonormal bases, the basis formed by the eigenvectors of the covariance matrix and belonging to the largest eigenvalues corresponds to the most significant features for the description of the original ntuple. Reduction of the variables for NEVENT events starting at IFIRST The default is to take all the 20 first variables. CHOPT : Possible options 'NP'

- 'N' The variables are normalized
This option is useful in the case the ranges of variables
are very different
- 'P' Print more results about the analysis

This command creates a file : -> XTOXSI.FORTRAN or xtoxsi.for, xtoxsi.ftn. This file contains a Fortran function which computes the new variables. These new variables can be visualized in PAW with for example:

```
PAW > Ntuple/plot id.xtoxsi.ftn(1)
PAW > Ntuple/plot id.xtoxsi.ftn(1)%xtoxsi.ftn(3)
```

Chapter 16: GRAPHICS

Interface to the graphics packages HPLOT and HIGZ.

SET [chatt value]

CHATT Attribute name C D='SHOW'

VALUE Attribute value R D=0

Set a specific HPLOT attribute. If CHATT='SHOW', print defaults and current values for all attributes. If CHATT='*', restore default values for all attributes. If VALUE=0, the attribute is set to its default value.

OPTION [choptn]

CHOPTN Option name C D='SHOW'

Set general plotting options for HPLOT. If CHOPTN='SHOW' print all current and default options. If CHOPTN='*', restore all default options.

METAFILE [lun metafl chmeta]

LUN Logical unit number I D=0

METAFL Metafile ID I D=0

CHMETA Metafile name C D=' '

Set the metafile logical unit and metafile type. This command controls the destination of the subsequent graphics output. Example:

```
LUN =-10 output only on metafile opened on unit 10;
LUN = 0 output only on screen;
LUN = 10 output on both screen and metafile opened on unit 10;
```

Use the command FORTRAN/FILE to open a new file, FORTRAN/CLOSE to close it. Note that PAW opens the file PAW.METAFILE on the unit 10 at initialization time.

```
METAFL= 4 Appendix E GKS.
METAFL=-111 HIGZ/PostScript (Portrait).
METAFL=-112 HIGZ/PostScript (Landscape).
METAFL=-113 HIGZ/Encapsulated PostScript.
METAFL=-114 HIGZ/PostScript Color (Portrait).
METAFL=-115 HIGZ/PostScript Color (Landscape).
METAFL=-777 HIGZ/LaTex Encapsulated.
METAFL=-778 HIGZ/LaTex.
```

WORKSTATION iwkid [chopt iwtyp]

IWKID Workstation ID I D=1

CHOPT Options C D='0A'

IWTYP Workstation type I D=1

To create/delete workstations or change status.

```

CHOPT='O'  Open a new workstation
CHOPT='C'  Close a workstation
CHOPT='A'  Activate a workstation
CHOPT='D'  Deactivate a workstation
CHOPT='L'  Give the list of open workstations
IWKID > 0  Do the action specified by CHOPT on the
           workstation identified by IWKID.
IWKID=0    Do the action specified by CHOPT on all
           workstations.
IWKID < 0  Do the action specified by CHOPT on the
           workstation identified by -IWKID and the
           complementary action on all the others.

```

SLIDE

Invoke the SLIDE package.

16.1 MISC

Miscellaneous HPLOT functions.

NEXT

Clear the screen. Initialize a new HIGZ picture if option ZFL or ZFL1 has been selected. Select the Normalization Transformation number 1 (cm).

CLR

Clear the screen.

LOCATE [ntpri chopt]

```

NTPRI  Transformation with highest priority  I  D=-1
CHOPT  Options                               C  D='R' R='R,S,+

```

Locate points on the screen using the graphics cursor and output coordinates on terminal. Control is returned when the BREAK (right) mouse button is clicked (or CRTL/E) or when 20 points are located. The optional parameter NTPRI may be specified to locate a point in the specific transformation number NTPRI. NTPRI=-1 (default) means that all the histogram transformation numbers (10, 20, etc.) have priority on transformation number 1.

```

CHOPT='R' Request mode is used to locate the points (default)
      'S' Sample mode is used to locate the points
      'I' Integrate an histogram between 2 bins
      '+' use the tracking cross (default is cross-hair)

```

VLOCATE *vecx vecy [chopt ntpri]*

VECX Vector for coordinates X *C*
VECY Vector for coordinates Y *C*
CHOPT Options *C* D=' ' R=' ,L,P,*,+,-,S'
NTPRI Transformation with highest priority *I* D=-1

Locate a set of points using the graphics cursor. Return corresponding coordinates in vectors X and Y. If vectors X or Y do not exist, they are automatically created. Control is returned when the point is outside picture limits or when the BREAK (right) mouse button is clicked (or CRTL/E).

```

CHOPT=' ' use the cross-hair
      '+' use the tracking cross
      '-' use the rubber line
      'L' connect points by a polyline
      'P' draw the current polymarker at each point
      '*' draw a * at each point
      'S' sample mode is used. Allows to see the coordinates of
          point before clicking
  
```

The optional parameter NTPRI may be specified to locate a point in the specific transformation number NTPRI (see LOCATE).

HMOVE

Change the contents of a histogram channel using the cursor. Position the cursor to the channel to be changed, trigger graphics input, position the cursor to the new channel value (a rubber band box is used to visualize the change), trigger graphics input to fix the new value.

16.2 VIEWING

To define Normalization transformations. Either automatically (ZONE and SIZE) or 'by hand' (SVP, SWN and SELNT).

ZONE [*nx ny ifirst chopt*]

NX Number of divisions along X *I* D=1
NY Number of divisions along Y *I* D=1
IFIRST First division number *I* D=1
CHOPT Option *C* D=' ' R=' ,S'

Subdivide the picture into NX by NY zones, starting at zone IFIRST (count along X first). If CHOPT='S', redefine zones on current picture.

SIZE [*xsize ysize*]

XSIZE Size along X *R* D=20.
YSIZE Size along Y *R* D=20.

Set the size of the picture. On the terminal, the pictures will have the ratio YSIZE/XSIZE, and, if a metafile is produced, pictures will be YSIZE by XSIZE cm. This command sets the parameters for the normalisation transformation number 1 to [0-XSIZE], [0-YSIZE].

SVP nt x1 x2 y1 y2

- NT Normalization transformation number *I*
- X1 Low X of viewport in NDC *R* D=0 R=0:1
- X2 High X of viewport in NDC *R* D=1 R=0:1
- Y1 Low Y of viewport in NDC *R* D=0 R=0:1
- Y2 High Y of viewport in NDC *R* D=1 R=0:1

Set the viewport of the normalization transformation NT in the Normalized Device Coordinates (NDC).

SWN nt x1 x2 y1 y2

- NT Normalize transformation number *I*
- X1 Low X of window in WC *R* D=0
- X2 High X of window in WC *R* D=20
- Y1 Low Y of window in WC *R* D=0
- Y2 High Y of window in WC *R* D=20

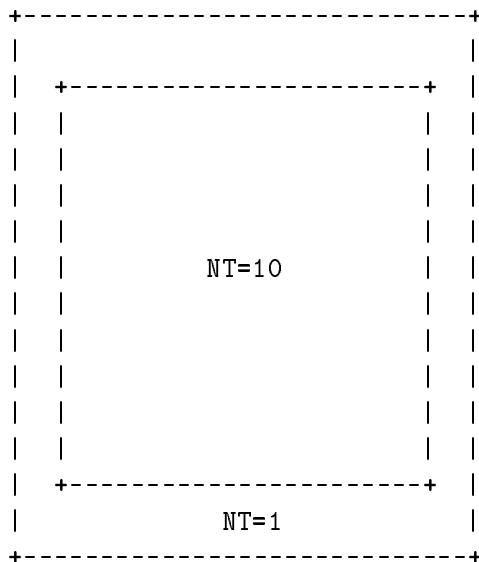
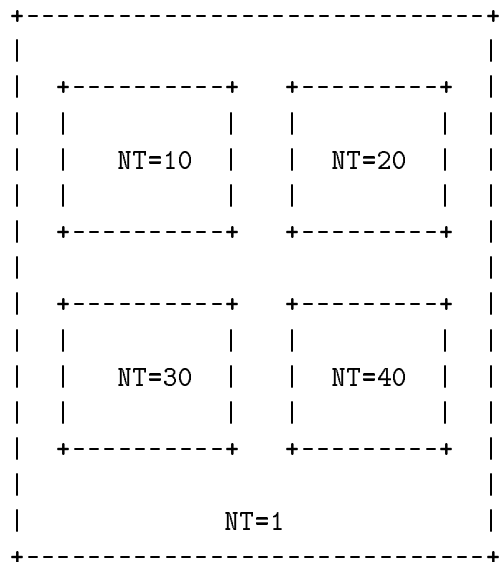
Set the window of the normalization transformation NT in World Coordinates (WC).

SELNT nt

- NT Normalization transformation number *I*
- Select a normalization transformation number.

If ZONE 2 2 is active , then:

If ZONE 1 1 is active, then:



16.3 PRIMITIVES

Call HIGZ drawing primitives

PLINE *n x y*

N Number of points *I*
X Vector name for X coordinates *C*
Y Vector name for Y coordinates *C*

Draw a polyline of *N* points *X,Y* in the current Normalization transformation. Use commands *SLN*, *SLWSC* and *SPLCI* (or *IGSET*) to change line attributes.

LINE *x1 y1 x2 y2*

X1 X first coordinate *R*
Y1 Y first coordinate *R*
X2 X second coordinate *R*
Y2 Y second coordinate *R*

Draw a line connecting points (*X1,Y1*) and (*X2,Y2*) in the current Normalization transformation. Use commands *SLN*, *SLWSC* and *SPLCI* (or *IGSET*) to change line attributes.

FAREA *n x y*

N Number of points *I*
X Vector name for X coordinates *C*
Y Vector name for Y coordinates *C*

Fill the area defined by the *N* points *X,Y* in the current Normalization transformation. Use commands *SFASI*, *SFAIS* and *SFACI* (or *IGSET*) to change fill area attributes.

PMARKER *n x y*

N Number of points *I*
X Vector name for X coordinates *C*
Y Vector name for Y coordinates *C*

Draw polymarkers at the *N* points *X,Y* in the current Normalization transformation. Use commands *SMK* and *SPMCI* (or *IGSET*) to change polymarker attributes.

BOX *x1 x2 y1 y2*

X1 X coordinate of first corner *R*
X2 X coordinate of second corner *R*
Y1 Y coordinate of first corner *R*
Y2 Y coordinate of second corner *R*

Draw and fill a box with the current fill area attributes. Use the current Normalization transformation.

FBOX *x1 x2 y1 y2 x3 x4 y3 y4*

X1 X coord of 1st corner of ext box R
 X2 X coord of 2nd corner of ext box R
 Y1 Y coord of 1st corner of ext box R
 Y2 Y coord of 2nd corner of ext box R
 X3 X coord of 1st corner of int box R
 X4 X coord of 2nd corner of int box R
 Y3 Y coord of 1st corner of int box R
 Y4 Y coord of 2nd corner of int box R

Draw and fill a frame (2 nested boxes) with the current fill area attributes. Use the current Normalization transformation.

ARROW x1 x2 y1 y2 [size]

X1 X coordinate of start point R
 X2 X coordinate of end point R
 Y1 Y coordinate of start point R
 Y2 Y coordinate of end point R
 SIZE Arrow size R D=0.4

Draw an arrow (X1,Y1) --> (X2,Y2) if SIZE>0. Draw an arrow (X1,Y1) <--> (X2,Y2) if SIZE<0. Use the current Normalization transformation.

AXIS x0 x1 y0 y1 wmin wmax ndiv [chopt]

X0 X axis origin in WC R
 X1 X end axis in WC R
 Y0 Y axis origin in WC R
 Y1 Y end axis in WC R
 WMIN Lowest value for labels R
 WMAX Highest value for labels R
 NDIV Number of divisions I D=510
 CHOPT Options C D=' '

Draw an axis in the current Normalization transformation.

NDIV=N1 + 100*N2 + 10000*N3

N1, N2, N3 = Number of 1st, 2nd, 3rd divisions respectively, eg:.

NDIV=0 --> no tick marks.

NDIV=2 --> 2 divisions, one tick mark in the middle
 of the axis.

CHOPT='G' : loGarithmetic scale, default is linear.

CHOPT='B' : Blank axis. Useful to superpose axis.

Orientation of tick marks on axis: Tick marks are normally drawn on the positive side of the axis. However, if X0=X1, then Negative .

CHOPT='+' : tick marks are drawn on Positive side. (default)

CHOPT='-': tick marks are drawn on the negative side.

i.e: '+-' --> tick marks are drawn on both sides of the axis.

CHOPT='U' : Unlabeled axis, default is labeled.

Position of labels on axis. Labels are normally drawn on side opposite to tick marks. However:

CHOPT='=' on Equal side

Orientation of labels on axis. Labels are normally drawn parallel to the axis. However if X0=X1, then Orthogonal
if Y0=Y1, then Parallel

CHOPT='P' : Parallel to the axis

CHOPT='O' : Orthogonal to the axis (Top to Down).

CHOPT='O' : Orthogonal to the axis (Down to Top).

Position of labels on tick marks. Labels are centered on tick marks. However , if X0=X1, then they are right adjusted.

CHOPT='R': labels are Right adjusted on tick mark.
(default is centered)

CHOPT='L': labels are Left adjusted on tick mark.

CHOPT='C': labels are Centered on tick mark.

CHOPT='M': In the Middle of the divisions.

Direction of labels. Default is RIGHT

CHOPT='Y': Down

Format of labels. Blank characters are stripped, and then the label is correctly aligned. The dot, if last character of the string, is also stripped, unless

CHOPT='.' Dot obligatory

In the following, we have some parameters, like tick marks length and characters height (in percentage of the length of the axis). The default values are as follows:

Primary tick marks: 3.0 %

Secondary tick marks: 1.5 %

Third order tick marks: .75 %

Characters height for labels: 2%

Characters spacing (related to height): 40%

Labels offset: 4.0 %

Type of labels. Labels are normally numeric . However, alphanumeric labels can be drawn (see command LABEL).

CHOPT='T': Alphanumeric labels .

Intrinsic parameters.

CHOPT='S': Tick marks Size

CHOPT='H': Labels Height

CHOPT='D': Distance labels-axis

Axis binning optimization. By default the axis binning is optimized .

CHOPT='N': No binning optimization

CHOPT='I': Integer labeling

ARC x1 y1 r1 [r2 phimin phimax]

X1 X coordinate of centre R
 Y1 Y coordinate of centre R
 R1 Inner radius R
 R2 Outer radius R D=-1.
 PHIMIN Minimum angle R D=0.
 PHIMAX Maximum angle R D=360.

Draw an arc of circle in the current Normalization transformation. If R1 is not equal to R2 the area between the two arcs of radius R1 and R2 is filled according to the current fill area attributes. The border is never drawn unless the interior style is hollow or the command IGSET BORD 1 has been called. If R1 is equal to R2 a polyline is drawn.

PIE x0 y0 radius n values [chopt iao ias iac]

X0 X coordinate of centre of the pie R
 Y0 Y coordinate of centre of the pie R
 RADIUS Radius of the pie chart R
 N Number of values I
 VALUES Vector name for N values C
 CHOPT Options C D=' ' R=' ,P,N,L'
 IAO Name of vector with offsets C D=' '
 IAS Name of vector with styles C D=' '
 IAC Name of vector with colors C D=' '

Draw a pie chart in the current Normalization transformation.

CHOPT Character variable specifying the option:

'P' Labels of each slice will be in percentage.

'N' Labels of each slice will be the numeric value in VALUES.

'L' Labels of each slice will be the text given in command LABEL.

TEXT x y text size [angle chopt]

X X coordinate R
 Y Y coordinate R
 TEXT Text to be drawn C
 SIZE Text size R D=0.3
 ANGLE Comment angle R D=0
 CHOPT Justification option C D='L' R='L, ,C,R'

Draw text at position X,Y in the current normalization transformation using the software font IGTEXT. SIZE is always given in centimeters (as defined by the command SIZE). Boldface effects can be obtained using the parameters PASS and CSHI of the command SET.

CHOPT='L' Text is Left justified.

CHOPT='C' Text is Centered.

CHOPT='R' Text is Right justified.

The text color can be changed by IGSET TXCI.

ITX x y text

X X coordinate R
 Y Y coordinate R
 TEXT Text to be drawn C

Draw text at position X,Y in the current Normalization transformation, using the current font parameters. The font and the precision can be changed by IGSET TXFP. The character size can be changed by IGSET CHHE. The text color can be changed by IGSET TXCI. The text orientation can be changed with IGSET TXAL. The text angle can be changed by IGSET TANG.

LABELS labnum nlabs chlabs

LABNUM Label identifier I D=1 R=1:9
 NLABS Number of labels I D=0 R=0:50
 CHLABS List of labels C D=' '

Define a list of labels to be used by subsequent commands such as PIE and AXIS. The position of the labels on the axis may be changed with SET NDVX (NDVY).

PAVE x1 x2 y1 y2 [dz isbox isfram chopt]

X1 X bottom left corner of box R
 X2 X top right corner of box R
 Y1 Y bottom left corner of box R
 Y2 Y top right corner of box R
 DZ Box width R D=0.4
 ISBOX Box style I D=0
 ISFRAM Frame style I D=5
 CHOPT Option C D='TR'

Draw a paving-block (box with 3D effect). ISBOX (ISFRAM) may be 1000+ICOLOR where ICOLOR is the color index of the box (frame), otherwise the style index. If ISBOX (ISFRAM) =0, only the box contour is drawn with the current polyline attributes.

CHOPT='TR' (or just 'T') Top and Right frame are drawn (default)
 CHOPT='TL' Top and Left frame
 CHOPT='BR' (or just 'B') Bottom and Right frame
 CHOPT='BL' Bottom and Left frame
 CHOPT='L' Left frame only
 CHOPT='R' Right frame only
 CHOPT='T-' Top frame only pointing left
 CHOPT='B-' Bottom frame only pointing left
 CHOPT='S' Shadow mode
 CHOPT='K' Key mode

HIST *n x y [chopt]*

N Number of values *I*
X Vector name for X coordinates *C*
Y Vector name for Y coordinates *C*
CHOPT Options *C* *D='AHW' R='AHW,A,W,R,N,H,F,C,L,*,P,B, '*

Draw an histogram defined by arrays X and Y. The number of components needed in vectors X and/or in Y may be dependent upon the value of CHOPT (see options 'R' and 'N').

CHOPT:

'A' X and Y axes are drawn (default).
'H' An histogram is drawn as a contour (default).
'W' The Window/Viewport parameters are automatically computed from the X and Y values (default).
'R' The histogram is Rotated, i.e. the values in X are used for the ordinate and the values in Y for the abscissa (default is the contrary).
If option R is selected (and option 'N' is not selected), the user must give:
 2 values for Y (Y(1)=YMIN and Y(2)=YMAX)
 N values for X, one for each bin.
Otherwise the user must give:
 N values for Y, one for each bin.
 2 values for X (X(1)=XMIN and X(2)=XMAX)
If option 'N' is selected see below.
'N' Non equidistant bins (default is equidistant).
The arrays X and Y must be dimensioned as follows:
If option R is not selected (default) then give:
 (N+1) values for X (limits of bins).
 N values for Y, one for each bin.
Otherwise give:
 (N+1) values for Y (limits of bins).
 N values for X, one for each bin.
'F' The area delimited by the histogram is filled according to the fill area interior style and the fill area style index or colour index.
Contour is not drawn unless CHOPT='H' is also selected.
'C' A Smooth curve is drawn across points at the centre of each bin of the histogram.
'L' A straight Line is drawn across points at the centre of each bin of the histogram.
'*' A star is plotted at the center of each bin of the histogram.
'P' Idem as '*' but with the current marker.
'B' A Bar chart with equidistant bins is drawn as fill areas. (Contours are drawn). The bar origin and the bar

width can be controlled by the routine IGSET using the options BAR0 and BARW respectively.

To set Log scales in X and/or Y, use OPT LOGX/LOGY. Note that when an option is specified, it is also necessary to specify the options 'AW' or 'AHW' in order to start a new zone or/and draw the axes.

GRAPH n x y [chopt]

N	Number of values	I
X	Vector name for X coordinates	C
Y	Vector name for Y coordinates	C
CHOPT	Options	C D='ALW' R='ALW,W,L,C,F, ,*,P,R,B'

Draw a curve through a set of points.

- 'A' X and Y axes are drawn (default).
- 'L' Every point is connected with a straight line. (default)
- 'W' The Window/Viewport parameters are automatically computed from the X and Y values (default).
- 'C' The values in Y are plotted in the form of a smooth curve. A Spline approximation algorithm is used.
- 'F' A fill area is drawn. If the option 'CF' is used the contour of the fill area is smooth. The border of the fill area is drawn if the command IGSET BORD 1 has been typed. The fill area type may be changed via the IGSET parameters FASI and FASI
- 'R' The graph is Rotated, i.e. the values in X are used for the ordinate and the values in Y for the abscissa (default is the contrary).
- 'B' A Bar chart with equidistant bins is drawn as fill areas. (Contours are drawn). The bar origin and the bar width can be controlled by the routine IGSET using the options BAR0 and BARW respectively.
- '*' A star is plotted at every point.
- 'P' A marker is plotted at every point, according to current marker type and polymarker colour index.

To set Log scales in X and/or Y, use OPT LOGX/LOGY. Note that when an option is specified, it is also necessary to specify the options 'AW' or 'ALW' in order to start a new zone or/and draw the axes.

16.4 ATTRIBUTES

Change HIGZ/GKS attributes.

SLN [iln]

ILN	Line style	I	D=1	R=1:
-----	------------	---	-----	------

Set the line style.

SFAIS [ints]

INTS Fill area interior style *I* D=0 R=0:3

Set the fill area interior style :

Hollow=0, Solid=1, Pattern=2, Hatch=3

SFASI [styli]

STYLI Fill area style index *I* D=1

Set the fill area style index.

SFACI [ifaci]

IFACI Fill area color index *I* D=1

Set the fill area color index.

SPLCI [iplci]

IPLCI Polyline color index *I* D=1

Set the polyline color index.

SPMCI [ipmci]

IPMCI Polymarker color index *I* D=1

Set the polymarker color index.

STXCI [itxci]

ITXCI Text color index *I* D=1

Set the text color index.

STXFP [ifont iprec]

IFONT Font number *I* D=0

IPREC Font precision *I* D=2

Set text font and precision.

SCHH [chh]

CHH Character height *R* D=0.28

Set the character height.

SLWSC [lw]

LW Line width *I* D=1 R=1:

Set the line width.

SMK [mkt]

MKT Marker type *I* D=1

Set the marker type.

COLOR_TABLE icol [red green blue]

ICOL Color Index *I* D=1

RED Weight of red *R* D=0. R=0.:1.

GREEN Weight of green *R* D=0. R=0.:1.

BLUE Weight of blue *R* D=0. R=0.:1.

Define the color ICOL.

PALETTE palnb [nel list]

PALNB Palette number *I* D=0 R=0:9

NEL Number of elements in the palette *I* D=0 R=0:50

LIST List of the palette elements *I* D=0

Define a palette of attributes. The palette number is used in the command SET. The command SET HCOL 0.1 defines the palette number 1 as colour indices used by the command LEGO in case of stacked lego plots and plotting of SURFACE with options 1 or 2, LEGO with option 2 and CONTOUR with option 3.

By default the palettes are initialized with 6 elements: 2,3,4,5,6,7.

If the number of elements (NEL) is equal to 0 (default), the palette is filled automatically according to the number of colours defined with the command IGSET NCOL. If NCOL is smaller than 8, the palette is filled with a subset of the 8 basic colours. If NCOL is greater than 8, the palette is filled with colours varying continuously for blue to red. This is called a "geographical" palette. Note that the command IGSET NCOL reset the colours 8 to NCOL with gray levels.

Examples:

```
PAW > IGSET NCOL 8      | Define the number of colours
PAW > PALETTE 1        | The palette 1 is filled with
                        | 8 elements: 0,5,7,3,6,2,4,1
PAW > IGSET NCOL 4      | Define the number of colours
PAW > PALETTE 1        | The palette 1 is filled with
                        | 4 elements: 0,5,7,3
PAW > IGSET NCOL 16     | Define the number of colours
PAW > PALETTE 1        | Fill palette 1 with 8 elements
                        | (8,9,10,11,12,13,14,15) varying
                        | continuously from blue to red
```

16.5 HPLOT

Draw various HPLOT objects (symbols, errors, key, etc.).

SYMBOLS *x y n [isymb ssize]*

X	Vector of X coordinates	C	
Y	Vector of Y coordinates	C	
N	Number of points	I	D=1
ISYMB	Symbol number	I	D=24
SSIZE	Symbol size	R	D=0.28

Draw the same symbol at several points *x,y* in the current normalization transformation.

ERRORS *x y ex ey n [isymb ssize]*

X	Vector of X coordinates	C	
Y	Vector of Y coordinates	C	
EX	Vector of X error bars	C	
EY	Vector of Y error bars	C	
N	Number of points	I	D=1
ISYMB	Symbol number	I	D=24
SSIZE	Symbol size	R	D=0.28

Draw a series of points using a symbol and error bars in horizontal and vertical direction in the current normalization transformation.

KEY *x y [isymb text]*

X	X coordinate of comment	R	
Y	Y coordinate of comment	R	
ISYMB	Symbol number	I	D=24
TEXT	Legend	C	D=' '

Draw one symbol and its explanation (legend) at a point *x,y* in the current normalization transformation.

TICKS *[chopt xval yval]*

CHOPT	Options	C	D=' '
XVAL	X position	R	D=1.E30
YVAL	Y position	R	D=1.E30

Draw 'cross-wires' on a picture, optionally with tick marks and values. Cross-wires are lines perpendicular to the X and/or Y axis.

CHOPT is a string to denote which cross-wires to draw, and where to draw the values:

- ' ' tick marks are drawn on the edges of the picture
- 'X' cross-wire drawn perpendicular to the X-axis
- 'Y' cross-wire drawn perpendicular to the Y-axis
- 'A' value drawn Above cross-wire
- 'B' value drawn Below cross-wire
- 'L' value drawn Left of cross-wire
- 'R' value drawn Right of cross-wire

XVAL intersection on the X-axis
 YVAL intersection on the Y-axis

The values of XVAL are always histogram coordinates. The tick marks will be drawn on both side of the cross wire, unless the cross-wires are requested on the boundary of the box surrounding the histogram (i.e. at the extreme limits of the drawn histogram). In this case tick marks will only be drawn inside the box. The options 'A' and 'B' (for Above and Below) refer only to the cross-wire perpendicular to the Y axis. In each case only one cross-wire will be drawn. Similarly 'L' and 'R' (Left and Right) refer only to the cross-wires perpendicular to the X-axis. It is possible to redefine the length of tick marks on the X or Y axis with SET XTIC or SET YTIC. The position of the axis values may be changed with SET XVAL or SET YVAL.

ATITLE [xtit ytit]

XTIT X Axis title C D=' '
 YTIT Y Axis title C D=' '

Draw axis titles on the axes of the present plot zone.

GRID

Draw a grid in cm.

NULL [xmin xmax ymin ymax chopt]

XMIN Low range in X R D=0.
 XMAX High range in X R D=1.
 YMIN Low range in Y R D=0.
 YMAX High range in Y R D=1.
 CHOPT Options C D=' ' R=' ,S,A,B'

Draw a frame box only. If XMIN, XMAX, etc. are given, draw a frame box with the window coordinates set to XMIN, XMAX, YMIN, YMAX. Axis labels and tick marks are drawn by default. If option 'S' is also specified, this command is a convenient way to redefine the scale for the current zone. If the option 'A' is given then axis labels and tick marks are not drawn. The box is not drawn if the option 'B' is given.

Chapter 17: PICTURE

Creation and manipulation of HIGZ pictures.

```
FILE lun fname [ lrecl chopt ]
```

LUN Logical unit number *I* R=1:128
FNAME File name *C*
LRECL Record length in words *I* D=1024
CHOPT Options *C* D=' ' R=' ,A,N,U,AN,AU'

Open a HIGZ direct access picture file.

For CHOPT=' ', existing file is opened.
For CHOPT='N', a new file is opened.
For CHOPT='U', existing file is modified.

If CHOPT='AU' or 'AN', pictures will be automatically saved on the direct access file. This automatic saving facility can be switched off using IGSET AURZ 0.

```
LIST
```

List all the HIGZ pictures currently stored in memory.

```
CREATE pname
```

PNAME Picture name *C*

Create a new picture, named PNAME, in memory. Note that all commands which start a new picture (clear workstation) automatically create pictures named PICT1, PICT2, etc. if the command OPTION ZFL or OPTION ZFL1 has been executed.

```
DELETE pname
```

PNAME Picture name *C* D=' '

Delete the picture PNAME from memory. PNAME='*' means all pictures.

```
SCRATCH pname [ icycle ]
```

PNAME Picture name *C* D=' '

ICYCLE Cycle number *I* D=9999

Delete the picture PNAME from current directory on disk.

```
PLOT [ pname ]
```

PNAME Picture name *C* D=' '

Plot the picture PNAME. PNAME=' ' means the current picture. PNAME='*' means all pictures.

```
MODIFY [ pname chopt ]
```

PNAME Picture name *C* D=' '

CHOPT Options *C* D=' ' R=' ,S,A'

Edit the picture PNAME. PNAME=' ' means the current picture. Various options can be selected with the graphics menu. This command is only available on workstations.

CHOPT='S' Software characters are used for the text in menus.
CHOPT='A' the option shAdow is used.

MERGE pname [x y scale chopt]

PNAME Picture name C
 X X coord(NDC) where to draw PNAME R D=0
 Y Y coord(NDC) where to draw PNAME R D=0
 SCALE Scale factor R D=1.
 CHOPT Options C D=' ' R=' ,D'

Add the picture PNAME to the current picture.

CHOPT='D' Picture PNAME is displayed during merging.

COPY pname1 pname2

PNAME1 Picture name C
 PNAME2 New picture name C

Copy a picture.

RENAME pname1 pname2

PNAME1 Old picture name C
 PNAME2 New picture name C

Rename a picture.

IZOUT [pname]

PNAME Picture name C D=' '

Write the picture PNAME to a direct access picture file (see command PICTURE/FILE). PNAME=' ' means the current picture. PNAME='*' means all pictures.

IZIN pname [icycle]

PNAME Picture name C
 ICYCLE Cycle number I D=9999

Read picture into memory from a direct access picture file. (see command PICTURE/FILE). PNAME='*' means all pictures.

IZPICT pname [chopt]

PNAME Picture name C
 CHOPT Options C D='M' R='M, ,D,S,N,L,F,P,C'

Perform various operations on a picture.

CHOPT:

'M' Make a new picture in memory with name PNAME.

An empty structure is created in memory and becomes the current picture. If PNAME = ' ', the picture is automatically named as PICTnnn, where the starting value of nnn is either 0 (default), or the value assigned by

IGSET to the parameter PICT.

- 'D' Display the picture PNAME in memory.
- 'S' Scratch the picture PNAME from memory. If PNAME = ' ' the current picture is scratched.
- 'N' The picture following the current picture in memory becomes the current picture. If the current picture is the last one in memory, the first picture in memory becomes the current picture.
- 'L' Give the list of the pictures in memory, following the sequence of their storage in memory.
- 'F' The First picture in memory becomes the current picture.
- 'P' Print the picture data structure. Useful to debug programs.
- 'C' Set Current picture. All calls to HIGZ graphic functions are stored in the current structure according to the option selected by IGZSET.

PNAME=' ' means the current picture. PNAME='*' means all pictures.

SWITCH [chopt]

CHOPT Options C D='G' R='G,Z,GZ'

Set the graphics switch to control plotting output to terminal (G) and/or picture in memory (Z).

If CHOPT='G' Graphics output only.

If CHOPT='Z' graphics primitives stored in ZEBRA memory only.

If CHOPT='GZ' both.

IGSET [chatt value]

CHATT Attribute name C D='SHOW'

VALUE Attribute value R D=0.

Set a HIGZ attribute. If CHATT='SHOW' print default and current values for all attributes. If CHATT='*' restore default values for all attributes. If VALUE=0, the attribute is set to its default value.

Chapter 18: ZEBRA

Interfaces to the ZEBRA RZ, FZ and DZ packages.

18.1 RZ

ZEBRA/RZ package: direct access Input/Output.

```
FILE lun fname [ lrecl chopt ]
```

LUN	Logical unit number	<i>I</i>	R=1:128
FNAME	File name	<i>C</i>	
LRECL	Record length in WORDS	<i>I</i>	D=1024
CHOPT	Options	<i>C</i>	D=' ' R=' ,U'

Open an existing direct access file.

```
CHOPT=' ' read only mode  
CHOPT='U' update mode
```

```
MAKE lun fname [ lrecl nrec nwkey chform chtags ]
```

LUN	Logical unit number	<i>I</i>	R=1:128
FNAME	File name	<i>C</i>	
LRECL	Record length in WORDS	<i>I</i>	D=1024
NREC	Number of records	<i>I</i>	D=1000
NWKEY	Number of words per Key	<i>I</i>	D=1
CHFORM	Key format	<i>C</i>	D=' I' R=' I,B,A,H'
CHTAGS	List of Tags	<i>C</i>	D=' HBOOK-ID'

Open a new direct access file.

```
MDIR chdir [ nwkey chform chtags ]
```

CHDIR	Directory name	<i>C</i>	
NWKEY	Number of words per Key	<i>I</i>	D=1
CHFORM	CHFORM	<i>C</i>	D=' I'
CHTAGS	List of Tags	<i>C</i>	D=' HBOOK-ID'

Create a new RZ directory below the current directory.

```
DDIR chdir
```

CHDIR	Directory name	<i>C</i>	
-------	----------------	----------	--

Delete the directory CHDIR from the current directory.

LDIR [chpath chopt]

CHPATH Path name C D=' '

CHOPT Options C D=' ' R=',A,T'

List contents of a directory (memory or disk). To list all RZ files currently opened, type 'LD //'. Note that if the Current Directory is //PAWC, this command uses the same format as HISTO/LIST.

CHOPT='A' to list all the Ntuple extensions.

CHOPT='T' to list a directory Tree.

CDIR [chpath chopt]

CHPATH Path name C D=' '

CHOPT Options C D=' '

Change the current working directory (CWD). IF CHPATH is given make it the new CWD. Otherwise, print the pathname of the CWD.

```
Ex.  CD dir1           ; make DIR1 the new CWD
      CD //file1/dir2 ; make //FILE1/DIR2 the new CWD
      CD              ; print the name of the CWD
```

PURGE [keep]

KEEP Number of cycles to be kept I D=1

Purge an RZ directory.

LOCK [chlock]

CHLOCK Lock identifier C D='RZFILE'

Lock an RZ directory.

FREE [chlock]

CHLOCK Lock identifier C D='RZFILE'

Free an RZ directory.

STAT chpath

CHPATH Name of top directory C

Print space statistics for an RZ file.

18.2 FZ

ZEBRA/FZ package: sequential access Input/Output.

FILE lun fname [lrecl chopt]

LUN Logical unit number *I* R=1:128
 FNAME File name *C*
 LRECL Record length in words *I* D=900
 CHOPT Options *C* D='IX' R='IX,0,X,A,I,OX,IA,OA'

Open an FZ sequential formatted or unformatted file.

CHOPT = 'I' Input file.
 CHOPT = 'O' Output file
 CHOPT = 'X' binary eXchange mode.
 CHOPT = 'A' Alphanumeric exchange mode.

TOFZ lun [chopt]

LUN Logical unit number of FZ file *I* R=1:128
 CHOPT Options *C* D=' '

Copy the current directory tree onto an FZ file.

FRFZ lun [chopt]

LUN Logical unit number of FZ file *I* R=1:128
 CHOPT Options *C* D=' '

Copy the FZ file into the current directory tree.

TOALPHA fname

FNAME Name of the FZ text file *C*

Copy the current directory tree onto a FZ file. An alphanumeric format is used. The file FNAME can be exchanged between different machines.

FRALPHA fname

FNAME Name of the FZ text file *C*

Copy the FZ alphanumeric file into the current directory.

18.3 DZ

ZEBRA/DZ package: debugging.

SHOW name [number chopt]

NAME Bank name *C*
 NUMBER Bank number *I* D=1
 CHOPT Options *C* D='BSV'

Display the contents of a bank or a data structure identified by its NAME and NUMBER. The output format of the data part is controlled by the internal or external I/O characteristic.

CHOPT='B' Print the bank.
 CHOPT='S' Print the bank contents from left to right Sideways
 with up to ten elements per line.
 CHOPT='V' Print the vertical (down) structure.
 CHOPT='D' Print the bank contents from top to bottom Downwards
 with five elements per line.
 CHOPT='L' Print the linear structure.
 CHOPT='Z' Print the data part of each bank in hexadecimal format

SURV name [number]

NAME Bank name C
 NUMBER Bank number I D=1

Print a survey of the structure identified by NAME, NUMBER.

SNAP [idiv chopt]

IDIV Division number I D=2 R=0:24
 CHOPT Options C D='M'

Snapshot of one or more divisions. Provides a snapshot of one or more divisions in a ZEBRA store. The kind of information provided is controlled by CHOPT.

CHOPT='M' Print Map entry for each bank
 CHOPT='E' Extend map entry to dump all links of each bank
 (otherwise only as many links as will fit on a line)
 CHOPT='F' Full. Dump all active banks, links and data
 CHOPT='K' Kill. Dropped banks to be treated as active
 (dropped banks are not normally dumped under D or F option)
 CHOPT='L' Dump all Link areas associated with the store
 CHOPT='W' Dump the Working space, links and data
 CHOPT='Z' Dump the information in hexadecimal.

VERIFY [idiv chopt]

IDIV Division number I D=0 R=0:24
 CHOPT Options C D='CLSU'

Check the structure of one or more ZEBRA divisions. The verification detail depends on the settings in CHOPT.

CHOPT='C' Check chaining of banks only
 CHOPT='L' Check validity of the structural links (implies 'C')
 CHOPT='S' Check the store parameters
 CHOPT='U' Check the validity of the up and origin (implies 'C')
 CHOPT='F' Errors are considered fatal and generate a call to ZFATAL

STORE [ixstor]

IXSTOR Store number *I* D=0 R=0:24

Display the structure of the ZEBRA store IXSTOR. Output the parameters characterizing the store, followed by a list of all divisions and all link areas associated with the store in question.

Chapter 19: FORTRAN

Interface to COMIS, SIGMA and FORTRAN Input/Output.

COMIS

Invoke the COMIS FORTRAN interpreter. COMIS allows to execute FORTRAN routines without recompiling and relinking. It communicates with PAW commands through vectors and functions. COMIS has its PAW-independent command structure. Example in command mode:

```
PAW > Comis
CS >   do 10 i=1,10
MND>   x=sqrt(i)*10.
MND>   print *,i,x
MND> 10 continue
MND>   END
CS > quit
PAW >
```

COMIS code may be inserted into a macro. Example:

```
Vector/Create Y(10) r 1 2 3 4 5 6 7 8 9 10
*
* In the following COMIS code, the statement "Vector Y" declares
* to COMIS an existing KUIP vector. KUIP dimension is assumed.
* The statement "Vector X(10)" creates a new KUIP vector.
* (Note that SUBROUTINES must be declared before the MAIN program)
* (KUIP vectors cannot be created into the MAIN program)
*
APPLIcation COMIS QUIT
  SUBROUTINE DEMO
    Vector Y
    Vector X(10)
    do 10 i=1,10
      XX=i
      X(i)=Y(i)*sqrt(XX)*10.
10 CONTINUE
  END
  CALL DEMO
  END
QUIT
Vector/print X      | Print KUIP vector created by COMIS
```

CALL urout

UROUT User routine C

Execute the routine UROUT. UROUT may be a routine compiled and linked with PAW. For example : CALL HPRINT(10). UROUT may also be the name of a file which can be edited interactively with the command EDIT. For example if file UROUT.FOR contains:

```

SUBROUTINE UROUT(N)
SUM=0.
DO 10 I=1,N
    SUM=SUM+I
10 CONTINUE
PRINT *,SUM
END

```

Then one can type `CALL UROUT.FOR(10)`. The routine `UROUT` may also contains references to the library routines mentioned below. The following routines from the CERN Program Library can be called:

LOOP `ntimes urout`

`NTIMES` Number of calls *I* `D=1`
`UROUT` User routine *C*

The routine `UROUT` is called `NTIMES` times. See command `CALL` for explanation of `UROUT`.

FILE `lun fname`

`LUN` Logical unit number *I* `R=1:128`
`FNAME` File name *C*

Open a FORTRAN formatted text file.

CLOSE `lun`

`LUN` Logical unit number *I* `R=1:128`

Close the file on unit `LUN`. If the file has been opened with `HISTO/FILE`, `PICTURE/FILE`, etc, then before closing the unit, `PAW` will close correctly the file with `CALL HREND` or `FZENDI(O)`, `ICLWK`, etc.

REWIND `lun`

`LUN` Logical unit number *I* `R=1:128`

Rewind the file on unit `LUN`.

SIGMA

Invoke the `SIGMA` package. `SIGMA` is an array manipulation package using its own vector-oriented language, outside the `PAW` command conventions. `SIGMA` may be invoked in one of the three following ways:

- 1- Using the `KUIP $SIGMA` function. Example:
`PAW > Vector/Create x(10) r 1 2 3 4 5 6 7 8 9 10`
`PAW > Graph 10 x $sigma(sqrt(x))`
- 2- Using the `SIGMA` command. Example:
`PAW > sigma x=array(10,1#10)`
`PAW > sigma y=sqrt(x)`
`PAW > Graph 10 x y`

3- Using the APPLication command. Example:

```
PAW > APPLication SIGMA
SIGMA > x=array(10,1#10)
SIGMA > y=sqrt(x)
SIGMA > exit
PAW > Graph 10 x y
```


Chapter 20: OBSOLETE

Obsolete commands.

20.1 HISTOGRAM

20.1.1 FIT

Fitting and smoothing (1-Dim or 2-Dim) histograms. Results are given as histogram-associated functions, and fit parameters printed on screen.

```
EXPONENTIAL id [ isel iftlow iftup ]
```

ID	histogram Identifier	C	
ISEL	option flag	I	D=12
IFTLOW	First channel	I	D=1
IFTUP	Last channel	I	D=99999

Fit histogram ID with an exponential function between channels IFTLOW and IFTUP. Obsolete command. Use Command Hist/Fit instead. Control word ISEL = 100*W+10*P+S.

```
S=2 superimposes function to histogram
  1 no superimposing
P=1 output from final iteration
  >1 output at iterations from 0 to (P-1), N=0,1,2,..
  0 no output
W=1 sets weights equal to 1
  0 calculates statistical errors as
    E=SQRT(CONTENTS) unless the 1-Dim histogram
    ID is weighted with HBARX or HPAKE
```

```
GAUSS id [ isel iftlow iftup ]
```

ID	histogram Identifier	C	
ISEL	option flag	I	D=12
IFTLOW	First channel	I	D=1
IFTUP	Last channel	I	D=99999

Fit histogram ID with a Gaussian between channels IFTLOW and IFTUP. Obsolete command. Use Command Hist/Fit instead. Control word ISEL = 100*W+10*P+S.

```
S=2 superimposes function to histogram
  1 no superimposing
P=1 output from final iteration
  >1 output at iterations from 0 to (P-1), N=0,1,2,..
  0 no output
W=1 sets weights equal to 1
  0 calculates statistical errors as
    E=SQRT(CONTENTS) unless the 1-Dim histogram
    ID is weighted with HBARX or HPAKE
```

POLYNOMIAL id ncoeff [isel iftlow iftup]

ID	histogram Identifier	C	
NCOEFF	Number of coefficients	I	D=3
ISEL	option flag	I	D=12
IFTLOW	First channel	I	D=1
IFTUP	Last channel	I	D=99999

Fit histogram ID with a polynomial between channels IFTLOW and IFTUP. NCOEFF is the degree of the polynomial plus one. Obsolete command. Use Command Hist/Fit instead. Control word ISEL = 100*W+10*P+S.

S=2 superimposes function to histogram
 1 no superimposing
 P=1 output from final iteration
 >1 output at iterations from 0 to (P-1), N=0,1,2,..
 0 no output
 W=1 sets weights equal to 1
 0 calculates statistical errors as
 E=SQRT(CONTENTS) unless the 1-Dim histogram
 ID is weighted with HBARX or HPAKE

FUNCTION id func np dpar [isel iftlow iftup step pmin pmax]

ID	Histogram Identifier	C	
FUNC	Function name	C	
NP	Number of parameters	I	
DPAR	Vector of parameters	C	
ISEL	option flag	I	D=12
IFTLOW	First channel	I	D=1
IFTUP	Last channel	I	D=99999
STEP	Vector of steps size	C	
PMIN	Vector of lower bounds	C	
PMAX	Vector of upper bounds	C	

Obsolete command. Use Command Hist/Fit instead. Fit a user defined (and parameter dependent) function to a histogram ID between channels IFTLOW and IFTUP. FUNC is the name of a file which contains the user defined function to be minimized. For example file FUNC.FOR is:

```
DOUBLE PRECISION FUNCTION FUNC(X)
DOUBLE PRECISION X,DPAR
COMMON/PAWPAR/DPAR(100)
FUNC=DPAR(1)*X +DPAR(2)*EXP(-X)
END
```

After the fit, the vector DPAR contains the new values of parameters. Control word ISEL = 10000*B+100*W+10*P+S.

S=2 superimposes function to histogram
1 no superimposing
P=1 output from final iteration
>1 output at iterations from 0 to (P-1), N=0,1,2,..
0 no output
W=1 sets weights equal to 1
0 calculates statistical errors as
E=SQRT(CONTENTS) unless the 1-Dim histogram
ID is weighted with HBARX or HPAKE
B=0 All parameters vary freely (vectors STEP,PMIN,PMAX not required)
1 Some or all parameters are bounded
STEP(I)=0 means parameter I is fixed to its initial value

Chapter 21: NETWORK

To access files on remote computers. To send messages to a remote process (ZEBRA server)

RLOGIN host

HOST Host name C D=' '

Start a communication with a remote machine HOST. Current Directory will be changed to //HOST.

RSHELL message

MESSAGE Message to remote host C D=' '

Send MESSAGE to current remote host. Note that the Current Directory must be //HOST (see RLOGIN). Some PAW commands (Histo/Plot, Histo/List) can communicate directly with HOST.

Appendix A: PAW tabular overview

Table A.1: Alphabetical list of PAW commands

Calling sequence	Page
1DHISTO (/HISTOGRAM/CREATE) id title ncx xmin xmax [valmax]	219
2DHISTO (/HISTOGRAM/CREATE) id title ncx xmin xmax ncy ymin ymax [valmax]	220
ABSCISSA (/HISTOGRAM/GET_VECT) id vname	227
ADD (/HISTOGRAM/OPERATIONS) id1 id2 id3 [c1 c2]	223
ANGLE (/FUNCTION) [theta phi]	233
APPLICATION (/KUIP/SET_SHOW) [path cmdex]	202
ARC (/GRAPHICS/PRIMITIVES) x1 y1 r1 [r2 phimin phimax]	248
ARROW (/GRAPHICS/PRIMITIVES) x1 x2 y1 y2 [size]	247
ATITLE (/GRAPHICS/HPLOT) [xtit ytit]	257
AXIS (/GRAPHICS/PRIMITIVES) x0 x1 y0 y1 wmin wmax ndiv [chopt]	247
BANX (/HISTOGRAM/CREATE) id ymin ymax	221
BANY (/HISTOGRAM/CREATE) id xmin xmax	221
BINS (/HISTOGRAM/CREATE) id title ncx xbins [valmax]	220
BOX (/GRAPHICS/PRIMITIVES) x1 x2 y1 y2	246
BREAK (/KUIP/SET_SHOW) [option]	203
CALL (/FORTRAN) urout	266
CDIR (/ZEBRA/RZ) [chpath chopt]	262
CLOSE (/FORTRAN) lun	267
CLR (/GRAPHICS/MISC)	243
COLOR_TABLE (/GRAPHICS/ATTRIBUTES) icol [red green blue]	255
COLUMNS (/KUIP/SET_SHOW) [ncol]	203
COMIS (/FORTRAN)	266
COMMAND (/KUIP/SET_SHOW) [chpath]	202
CONTENTS (/HISTOGRAM/GET_VECT) id vname	227
CONTENTS (/HISTOGRAM/PUT_VECT) id vname	228
CONTOUR (/HISTOGRAM/2D_PLOT) [id nlevel chopt param]	219
COPY (/HISTOGRAM) id1 id2 [title]	216
COPY (/PICTURE) pname1 pname2	259
COPY (/VECTOR) vnam1 vnam2	209
CREATE (/KUIP/ALIAS) aname string [chopt]	199
CREATE (/NTUPLE) idn title nvar chrzpa nprime varlist	234
CREATE (/PICTURE) pname	258
CREATE (/VECTOR) vname [type]	208
CSELECT (/NTUPLE) [chopt csize]	238
CUTS (/NTUPLE) icut [option fname]	238
DDIR (/ZEBRA/RZ) chdir	261
DEFAULTS (/MACRO) [chpath]	206
DELETE (/HISTOGRAM) id	214
DELETE (/KUIP/ALIAS) alist	200
DELETE (/PICTURE) pname	258
DELETE (/VECTOR) vlist	209
DIFF (/HISTOGRAM/OPERATIONS) id1 id2 [chopt]	225
DIVIDE (/HISTOGRAM/OPERATIONS) id1 id2 id3 [c1 c2]	225
DRAW (/FUNCTION) ufunc [chopt]	231
DRAW (/VECTOR) vname [id chopt]	211
DUMP (/HISTOGRAM/HIO) id	223
EDIT (/KUIP) fname	197
ERRORS (/GRAPHICS/HPLOT) x y ex ey n [isymb ssize]	256
ERRORS (/HISTOGRAM/GET_VECT) id vname	227
ERRORS (/HISTOGRAM/PUT_VECT) id vname	228

Table A.1: Overview of PAW command sequences (continued)

Calling sequence	Page
EXEC (/MACRO) mname	206
EXIT (/KUIP)	198
EXPONENTIAL (/OBSOLETE/HISTOGRAM/FIT) id [isel iftlow iftup]	269
FAREA (/GRAPHICS/PRIMITIVES) n x y	246
FBOX (/GRAPHICS/PRIMITIVES) x1 x2 y1 y2 x3 x4 y3 y4	246
FILE (/FORTRAN) lun fname	267
FILE (/HISTOGRAM) lun fname [lrecl chopt]	214
FILE (/PICTURE) lun fname [lrecl chopt]	258
FILE (/ZEBRA/FZ) lun fname [lrecl chopt]	262
FILE (/ZEBRA/RZ) lun fname [lrecl chopt]	261
FIT (/HISTOGRAM) id func [chopt np par step pmin pmax errpar]	216
FIT (/VECTOR) x y ey func [chopt np par step pmin pmax errpar]	211
FRALPHA (/ZEBRA/FZ) fname	263
FREE (/ZEBRA/RZ) [chlock]	262
FRFZ (/ZEBRA/FZ) lun [chopt]	263
FUN1 (/FUNCTION) id ufunc ncx xmin xmax [chopt]	231
FUN2 (/FUNCTION) id ufunc ncx xmin xmax ncy ymin ymax [chopt]	231
FUNCTION (/HISTOGRAM/GET_VECT) id vname	227
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