More data analysis tools

I. PAW macros

- the PAWN macros

II. n-tuples

- in FORTRAN
- in PAW

III. Using CERN library routines

- numerical methods, random numbers, etc.
- CERNLIB with C++

The PAWN macros

- Many operations in PAW can be painfully tedious

  → PAWN macros by Gerry Lynch (LBL), see course web site

- Need to download **pawn.f, pawn.kumac, pawn_alias.kumac**, and do **exec pawn_alias** in e.g. **.pawlogon.kumac**

- Based on macros that call HBOOK subroutines

- The basic commands on e.g. histogram 17 (type **pawn** to see all):

pdef 17	show booking info about histogram 17
chbn 17 4	reduce number of bins by a factor (e.g. by 4); new id chosen and histogram created automatically
chti 17	prompts for new title for histogram 17
mami 17 0 100	sets min/max of vertical axis (e.g. to 0, 100)
som 17	integrates histogram
blow 17 x1 x2	blows up histogram to be between **x1** and **x2**
scal 17 s	scale histogram by factor **s**

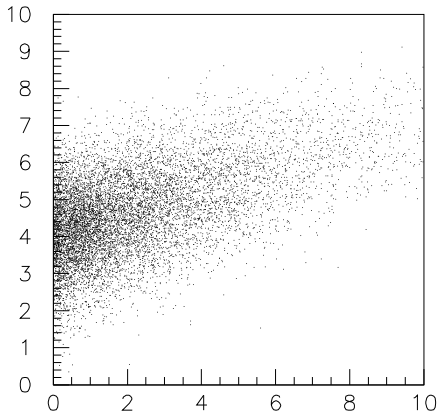
- More commands for operations on scatter plots:

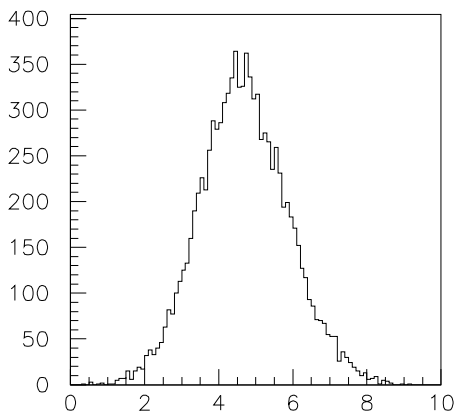
  chbn2, blo2, prox, proy, regx, regy, avx, avy

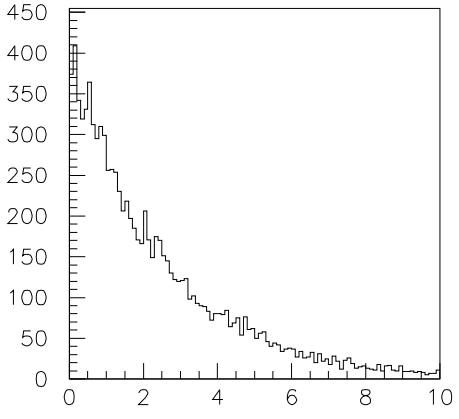
  N.B. these work on 2-d histograms created with HBOOK2, not on scatter plots displayed with e.g. **nt/pl y%x**

Projections from scatter plots with PAWN macros

```
zone 2 2                    ← makes 2 × 2 windows
h/pl 1                      ← show the scatter plot, id=1
proy 1                      ← make projection onto y axis
NEW HISTOGRAM ID 10001      ← appears on screen
h/pl 10001                  ← plot histogram as usual
prox 1                      ← make projection onto x axis
NEW HISTOGRAM ID 10002      ← appears on screen
h/pl 10002
```







n-tuples

- An n-tuple is a matrix of numbers, e.g. m instances of an n-dimensional vector:

$$\left.\begin{array}{l} (x_1, x_2, \quad \ldots \quad , x_n)_1 \\ (x_1, x_2, \quad \ldots \quad , x_n)_2 \\ (x_1, x_2, \quad \ldots \quad , x_n)_3 \\ \\ \qquad\qquad \vdots \\ \\ (x_1, x_2, \quad \ldots \quad , x_n)_m \end{array}\right\} m \text{ 'events' (rows)}$$

$\underbrace{\qquad\qquad\qquad\qquad\qquad\qquad}$

n columns, i.e. n variables for each event

- Example: for 3-body decays of a certain type of particle, record:

$$p_{x_1}, p_{y_1}, p_{z_1}, p_{x_2}, p_{y_2}, p_{z_2}, p_{x_3}, p_{y_3}, p_{z_3}$$

- Data volume = number of events $\times$ number of columns

- Compare to histogram with n dimensions: data volume $= N_{\text{bins}}^n$

  $\Rightarrow$ for large enough n (usually 2 or more), n-tuple wins

- Use n-tuple to store event properties for use in further analysis, e.g. to make histogram of invariant mass of two of the particles

$$m_{12} = \left[(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2\right]^{1/2}$$

  after making a cut on m_{23} .

n-tuples with HBOOK

- HBOOK provides two types of n-tuples:

  (1) Row wise:

  each event (row) stored sequentially;

  events have fixed length;

  only real (floating point) variables allowed;

  to book: `HBOOKN`

  to fill: `HFN`

  to read: `HGN, HGNPAR, HGNF` (or use PAW)

  (2) Column wise:

  columns stored sequentially

  → faster access if only a few columns out of many needed

  events can contain mixed variable types;

  events can contain data structures of variable length;

  to book: `HBNT, HBNAME`

  to fill: `HFNT, HFNTB`

  to read: `HGNT, HGNTB, HGNTV, HGNTF` (or use PAW)

- See examples on course web site, PAW/HBOOK documentation.

n-tuples with PAW

- The usual procedure:

  create n-tuple in analysis program, then analyze it with PAW

- Suppose we've created an n-tuple with 3 columns: x, y, z.
  Read in with `h/file` as before; suppose n-tuple id is 17.
  The basic commands:

```
ntuple/plot 17.x          ← plot histogram of x
nt/pl 17.y%x              ← make scatter plot of y vs. x
nt/print 17               ← show variable names, min/max values
nt/scan 17                ← show entire contents of n-tuple
nt/pl 17.x 2*y-z<1.5      ← histogram x after cut on y, z
nt/cut $1 2*y-z<1.5       ← define cut number 1
nt/pl 1.x $1              ← histogram of x after cut 1
```

- To set histogram properties (e.g. id=20, 100 bins from 0 to 50):

```
1dhisto 20 'histo of x' 100 0.  50.
nt/proj 20 17.x   ← project contents into histogram
h/pl 20           ← display histogram as usual
```

- More advanced features possible (loops, masks, ...) but at some point it's better to use a high level program (FORTRAN, C++).

The CERN program library (CERNLIB)

- Web site: `http://wwwinfo.cern.ch/asd/index.html`

- CERNLIB contains FORTRAN subprograms for:

  numerical analysis

  Monte Carlo

  data handling (histograms, search, sort, . . .)

  event generators, detector simulation, particle kinematics, . . .

- LHC++ project: replace CERNLIB with OO (e.g. C++) libraries

  only partially complete, rapid state of flux

- Provisional solution for C++:

  call CERNLIB routines from C++ using `cfortran.h`, see

  `http://wwwinfo.cern.ch/asdcgi/listpawfaqs.pl/21`

- To use, include at end of link command:

  `` `cernlib` `` or if more libraries needed, try e.g.

  `` `cernlib graflib mathlib kernlib packlib` ``

- Some other libraries (see links on course web site):

  Statlib (Carnegie Mellon)

  Netlib (University of Tennessee)

  Numerical Algorithms Group (NAG)

  Numerical Recipes (Press et al.)

  Datenanalyse (Brandt)

Calling CERNLIB routines from C++ programs

- For details see

  http://wwwinfo.cern.ch/asdcgi/listcernlibfaqs.pl/10

  and example `test_radom.cc` on SDA web site.

- Need C++ header files in `/cern/pro/include/cfortran`

- To call a FORTRAN CERNLIB routine from C++,

  (1) Include the necessary header files:

```
#include "cfortran/cfortran.h"
#include "cfortran/hbook.h"
```

  (2) Call routine (name in capitals) with same parameters:

```
main(){
                    ⋮
   HBOOK (1, "test histogram", 100, 0., 1., 0.);
   for (int i = 1; i<1000; i++){
      float x = random(seed);
      HF1 (1, x, 1.);
   }
                    ⋮
}
```

- Special flags needed to compile/link (see documentation on web)