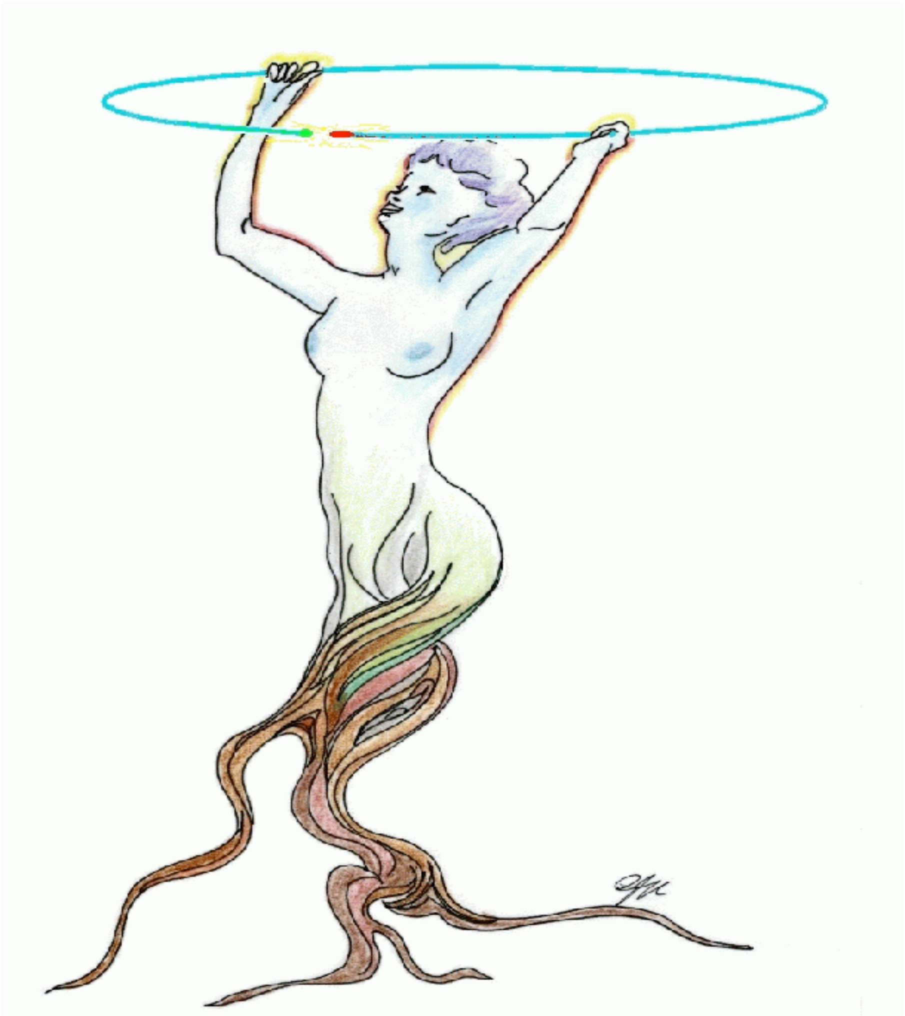
ROOT for beginners

First Day

Discovering the
graphical environment



Welcome to ROOT !

Today's menu:

Handling ROOT files
Plotting 1-D spectra
Handling canvases
Decorating a figure
Fitting a 1-D spectrum
Operations on 2-D spectra
Saving figures

We present a guided tour of basic use of ROOT in order to plot spectra and make pretty pictures !

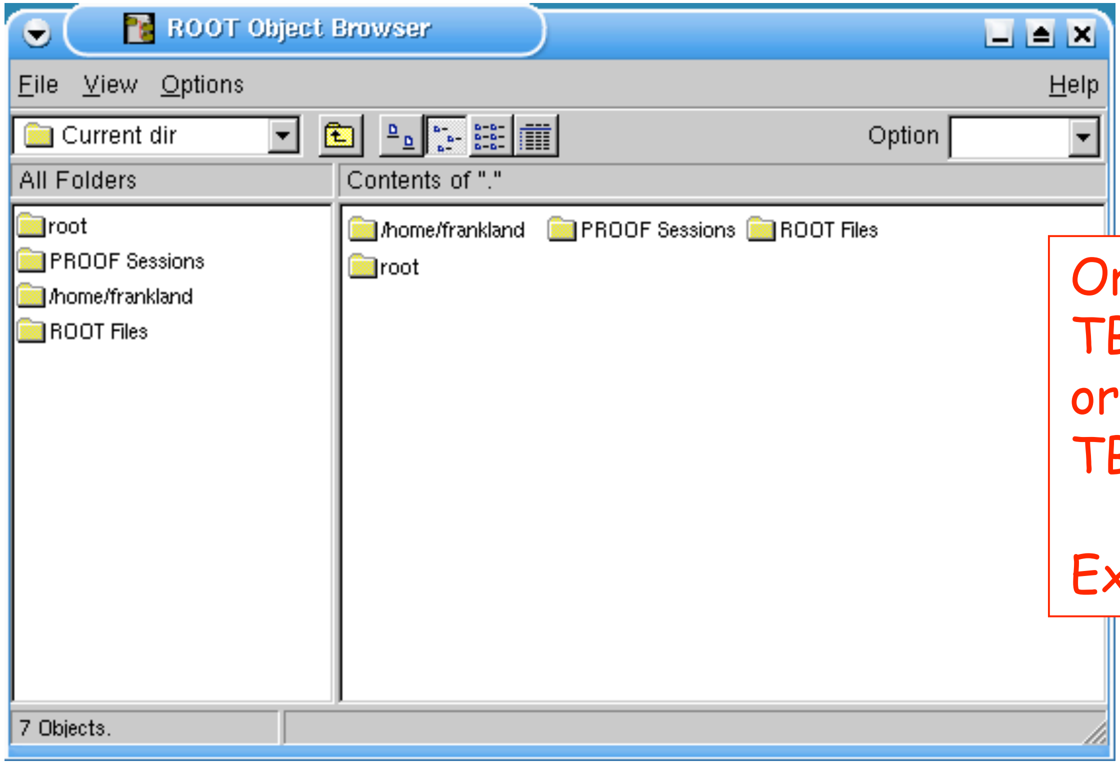
For further information, you should consult the "User's Guide" at http://root.cern.ch

Handling ROOT files

TBrowser - the ROOT navigator

- You just need to know one command in order to start the ROOT file/spectra browser :

```
root [0] new TBrowser
```



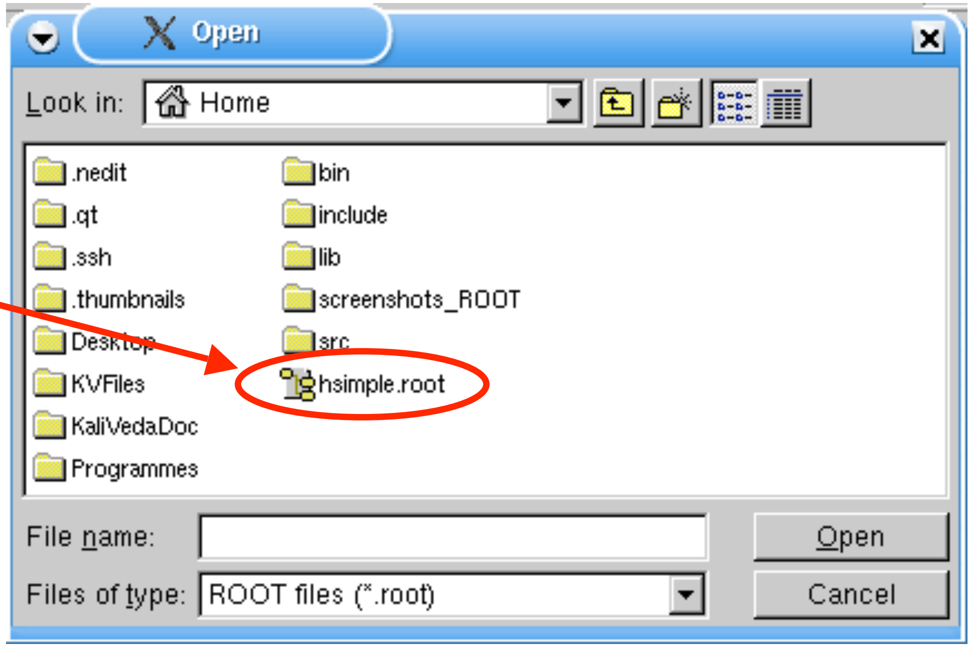
Or you could do:
TBrowser toto
or
TBrowser *tata = new TBrowser

Explanations tomorrow (Day 2)!

http://caeinfo.in2p3.fr/root/Formation/en/Day1/hsimple.root

Open a ROOT file with TBrowser

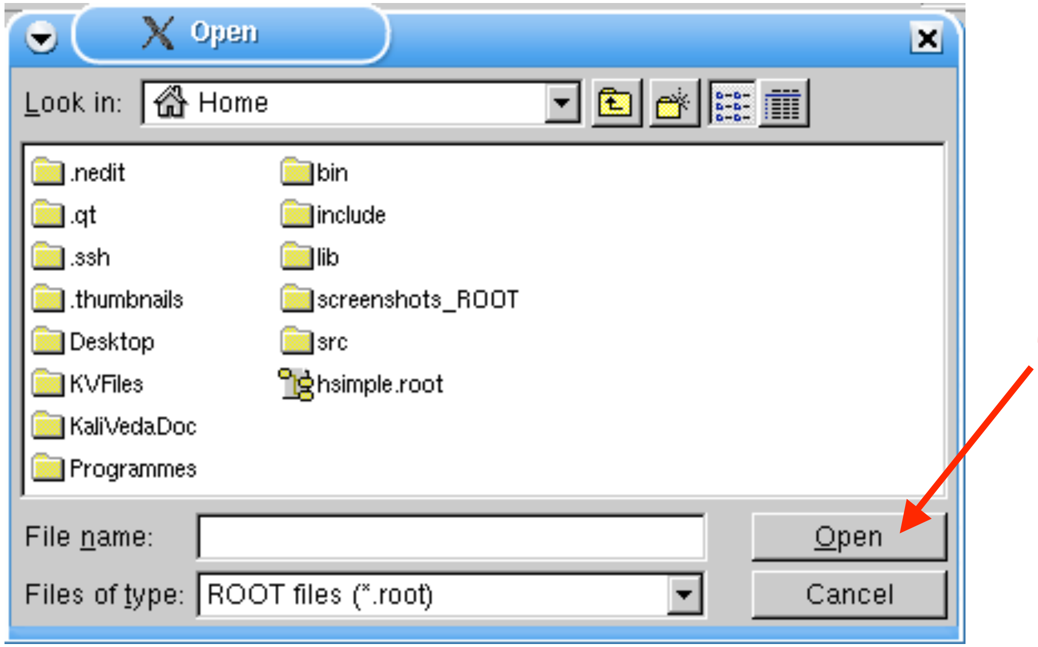
- In the **File** menu of TBrowser, select **"Open…"**
- Select a file in the dialogue box which appears:



1. Select the file

Open a ROOT file with TBrowser

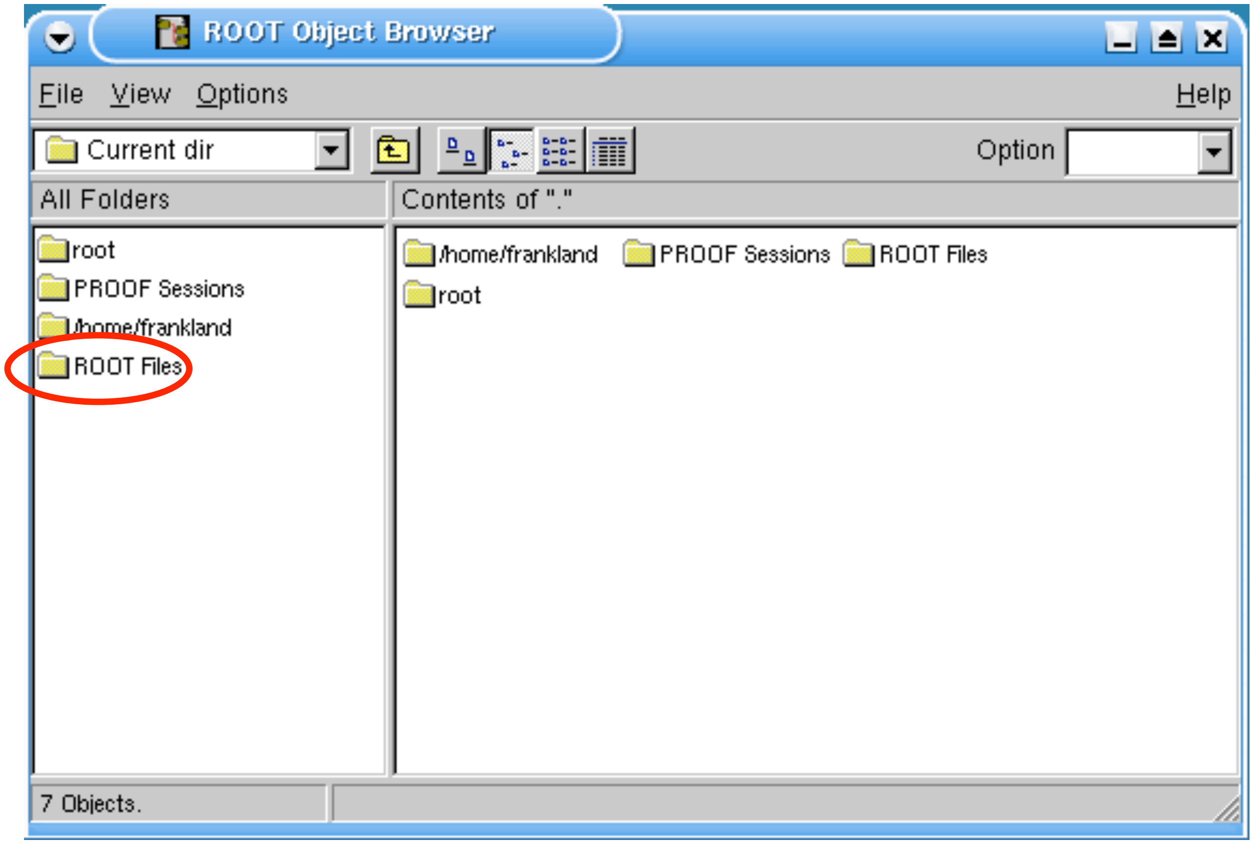
- In the **File** menu of TBrowser, select **"Open…"**
- Select a file in the dialogue box which appears:



2. Click "Open"

Looking at ROOT file contents

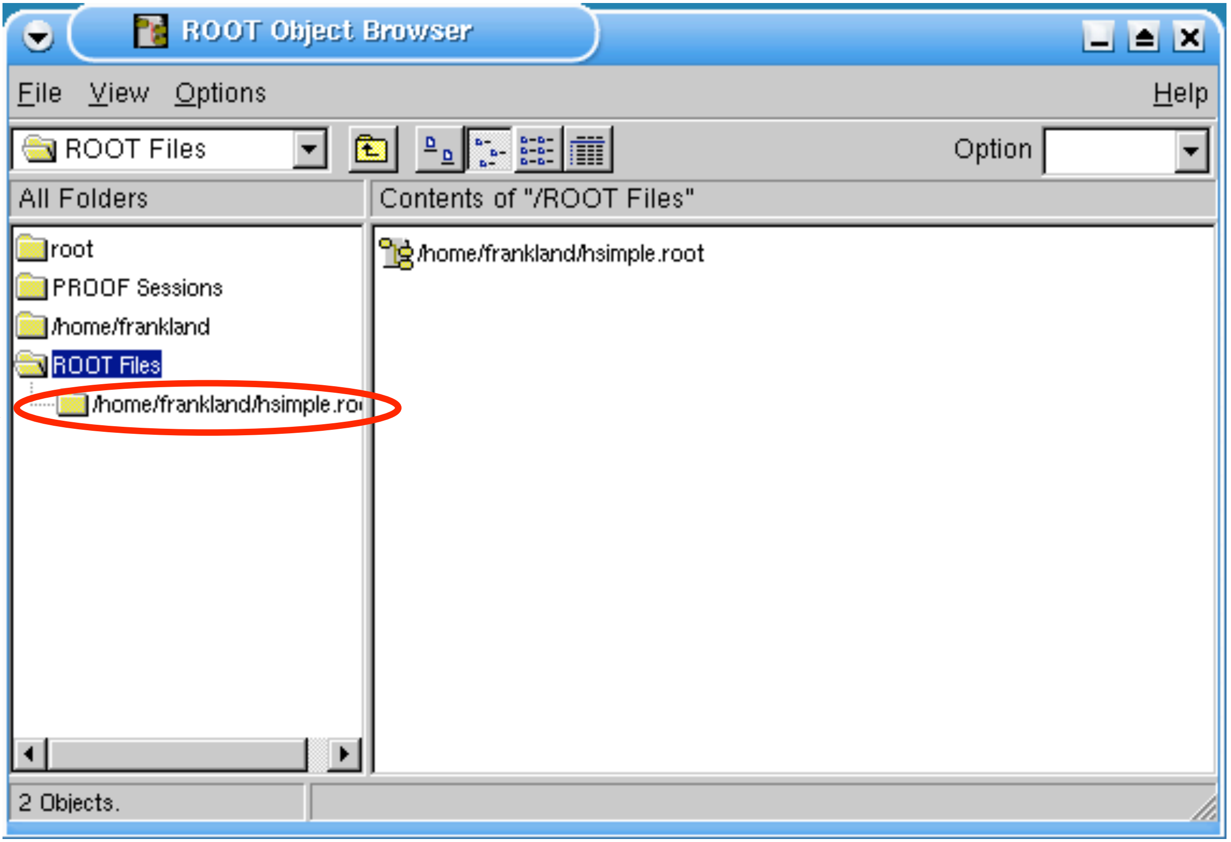
- The file has been added to the list of open ROOT files - to see it, you have to display the list



1. Double click on ROOT Files

Looking at ROOT file contents

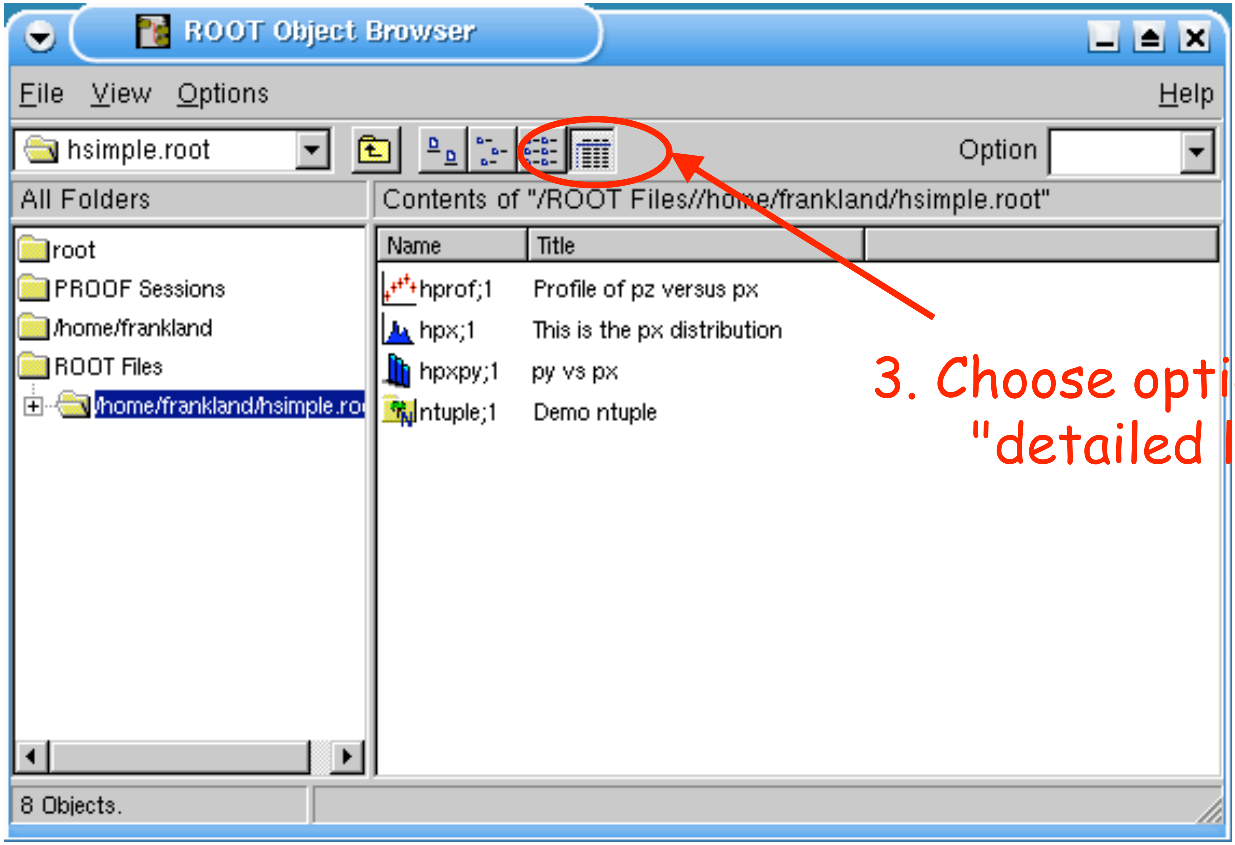
- Next click on the file to see its contents:



2. Click the file

Looking at ROOT file contents

- You see (if you choose the right options) a list of spectra with their titles



Contents of "/ROOT Files//home/frankland/hsimple.root"

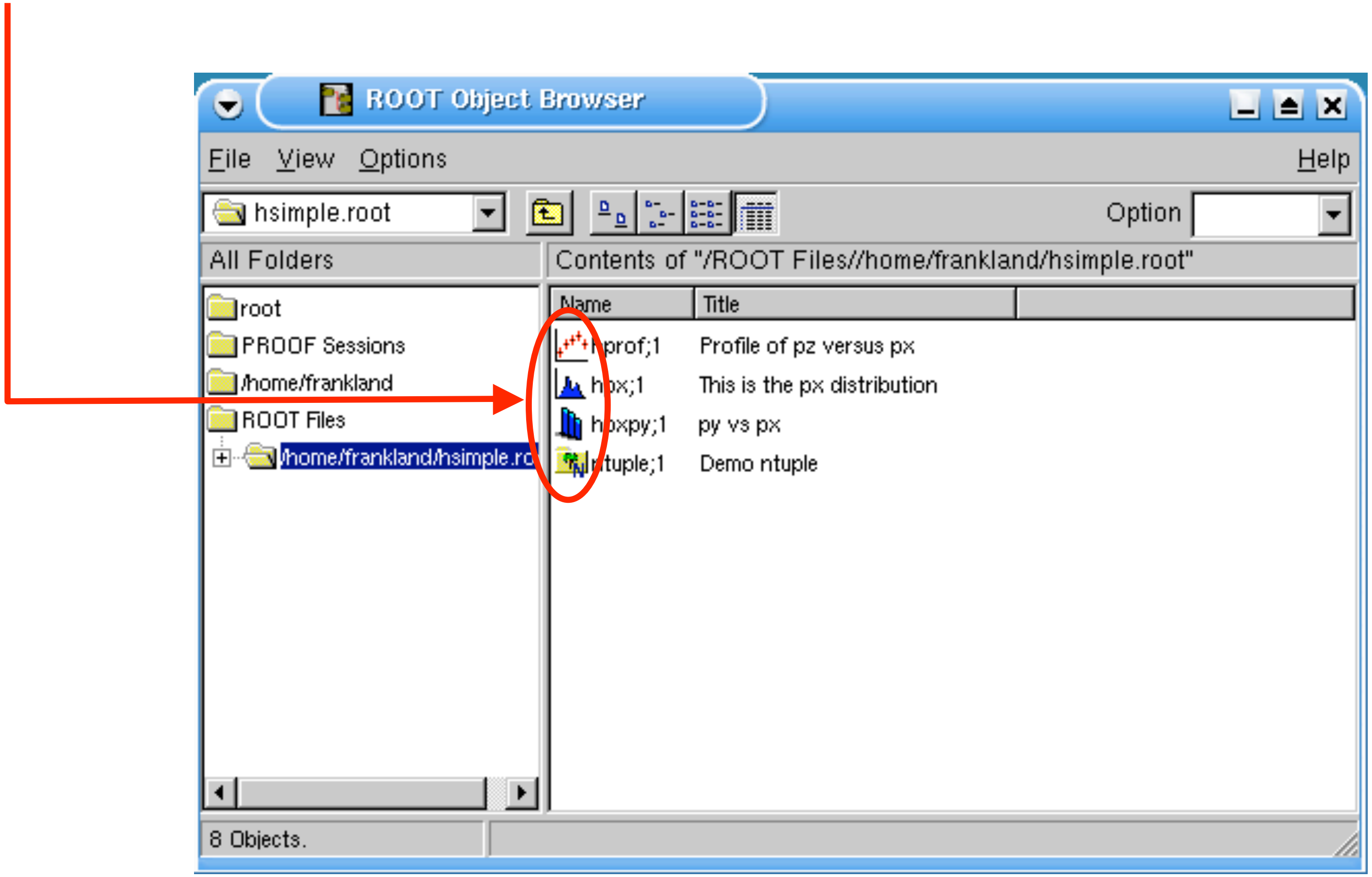
Name	Title
hprof;1	Profile of pz versus px
hpx;1	This is the px distribution
hpxpy;1	py vs px
ntuple;1	Demo ntuple

8 Objects.

3. Choose option "detailed list"

Looking at ROOT file contents

- Icons represent the different types of spectra:
  - profile, 1-D histogram, 2-D histogram, N-tuple…



Contents of "/ROOT Files//home/frankland/hsimple.root"

Name	Title
hprof;1	Profile of pz versus px
hpx;1	This is the px distribution
hpxpy;1	py vs px
ntuple;1	Demo ntuple

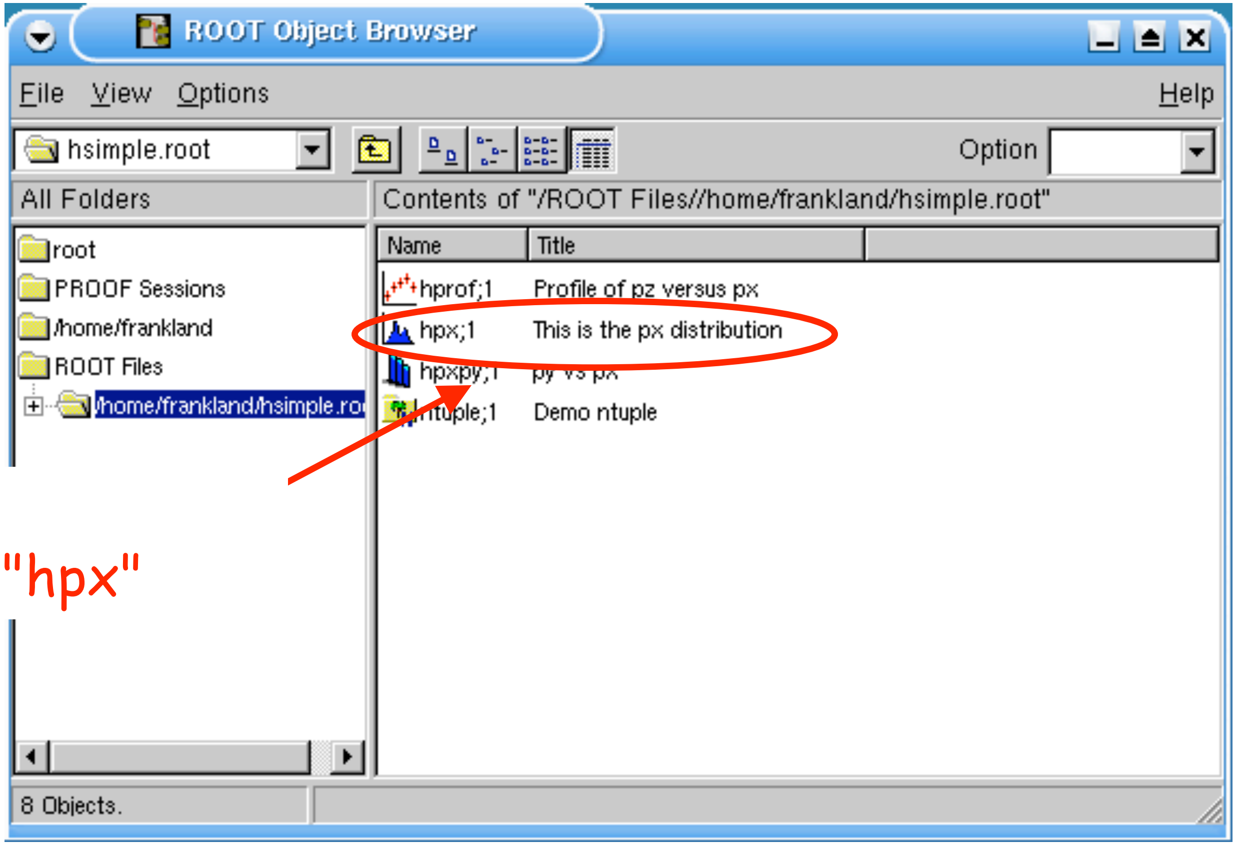
8 Objects.

Plotting spectra

First of all, 1-D spectra

Plotting a spectrum

- To plot a 1-D histogram, nothing could be simpler: double-click it!

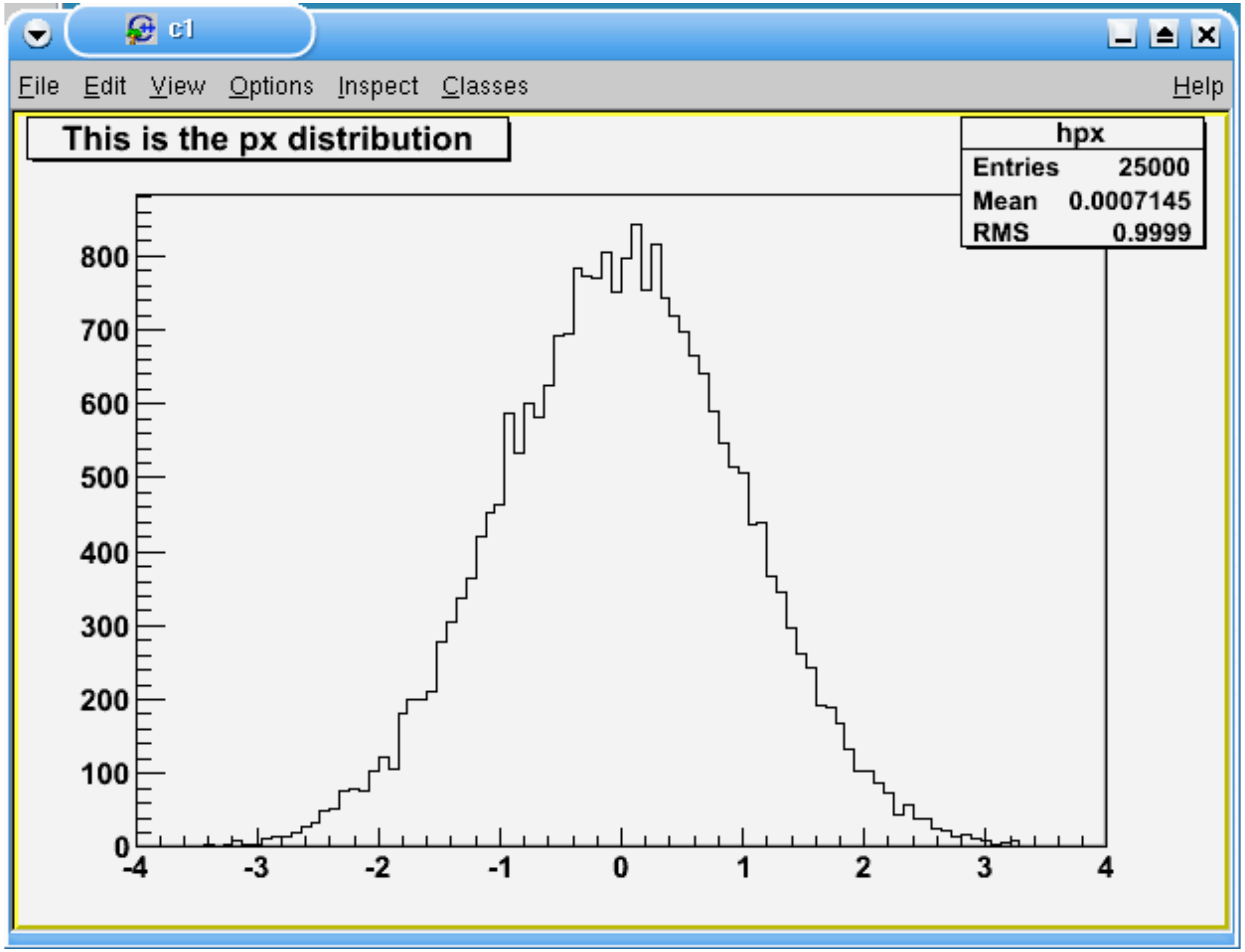


Name	Title
hprof;1	Profile of pz versus px
hpx;1	This is the px distribution
hpxpy;1	py vs px
ntuple;1	Demo ntuple

1. Double-click histogram "hpx"

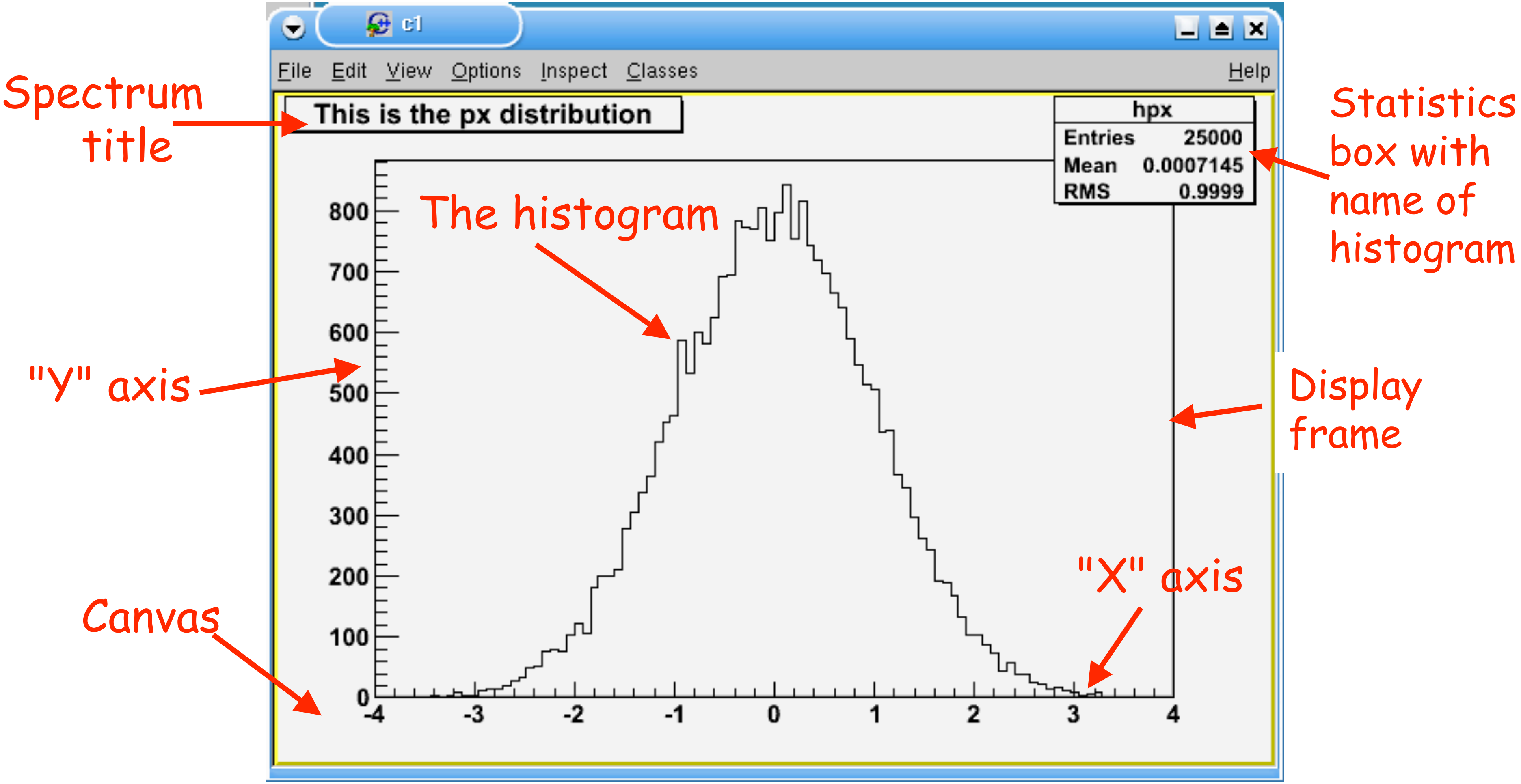
Discovering the canvas (TCanvas)

- A new window appears - the *canvas*



The canvas objects

- This canvas contains many objects which we can manipulate:



Spectrum title

The histogram

Statistics box with name of histogram

"Y" axis

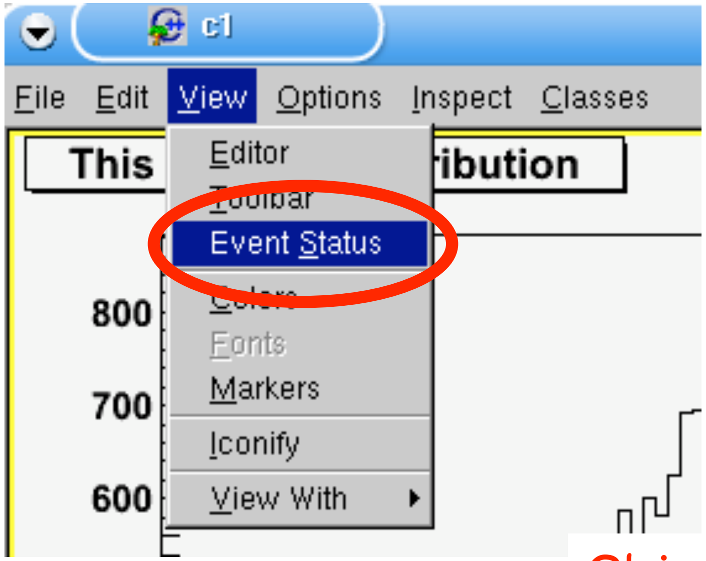
Display frame

"X" axis

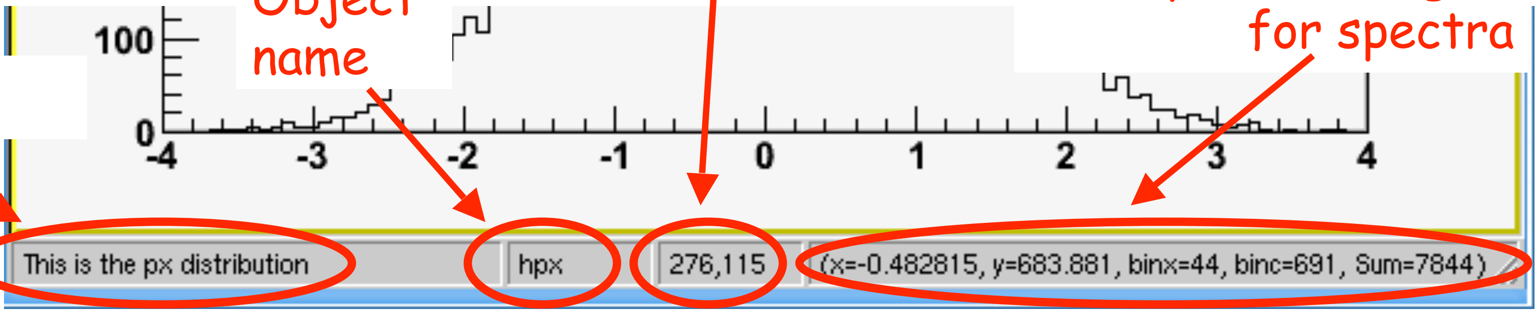
Canvas

What is this object ?

- To see the identity of every object the mouse passes over, activate the "Event Status" bar in the "View" menu :



The bar appears below the canvas:



```
This is the px distribution | hpx | 276,115 | (x=-0.482815, y=683.881, binx=44, binc=691, Sum=7844)
```

Object title

Object name

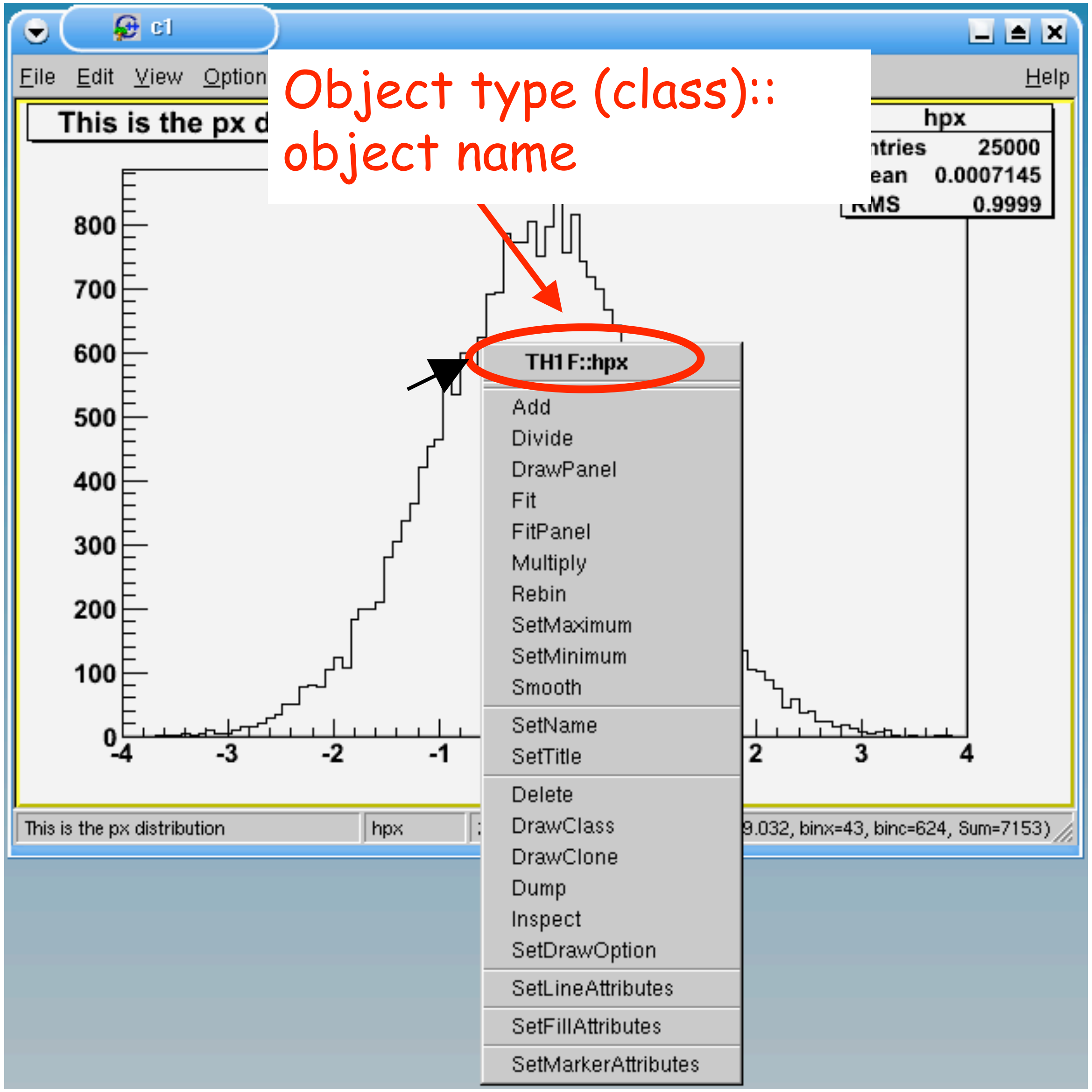
Mouse position in pixel units (0,0)=top left corner

Position in "spectrum" units + bin contents & partial integral for spectra

What is this object ?

- Or, you can "right-click" on an object and access its context menu:

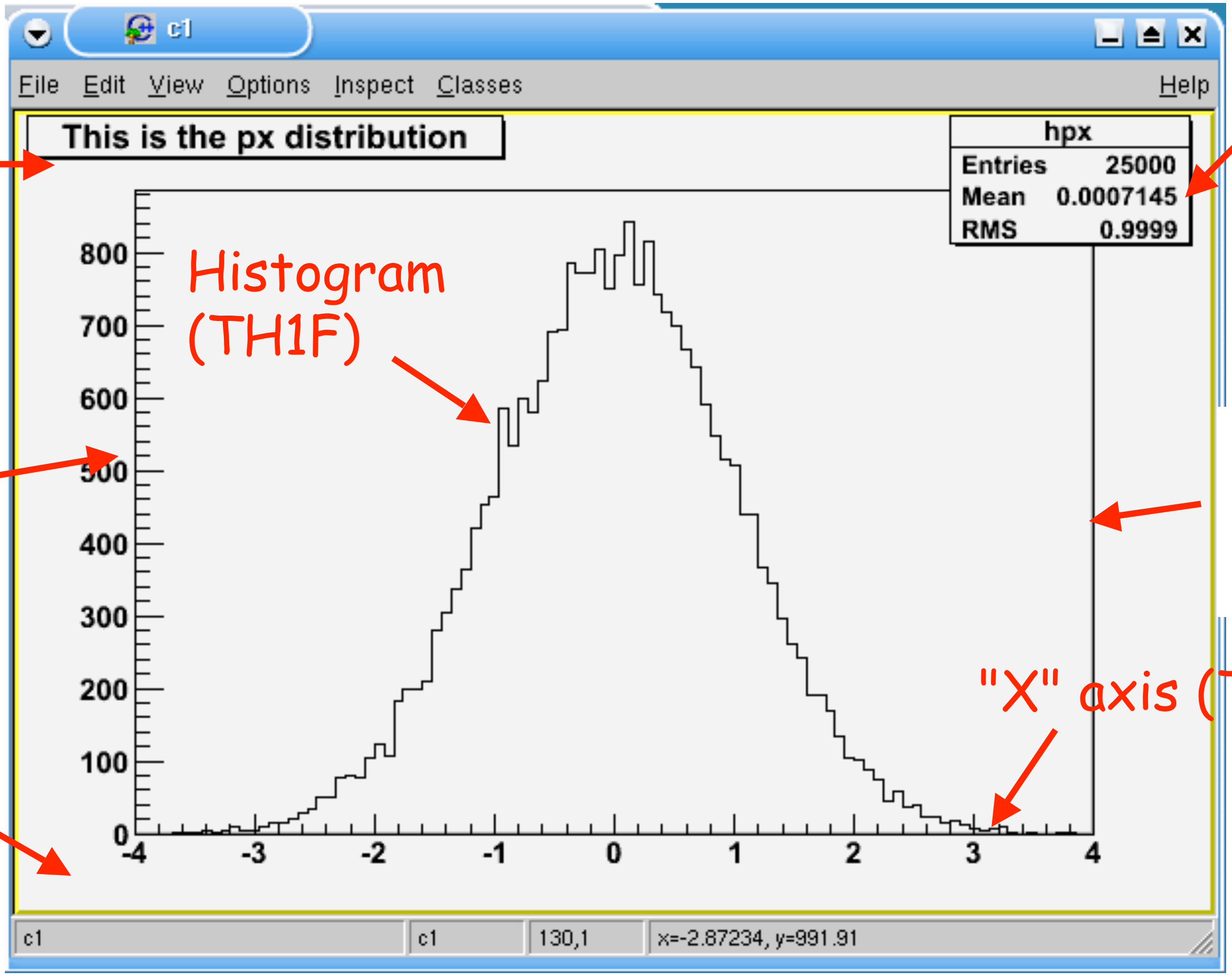
Right-click on histogram "hpx":



Object type (class):: object name

The canvas objects (again)

- So we can identify the type (*class*) of every object used in the canvas:



Spectrum title (TPaveText)

Statistics box with name of histogram (TPaveStats)

Histogram (TH1F)

"Y" axis (TAxis)

Display frame (TFrame)

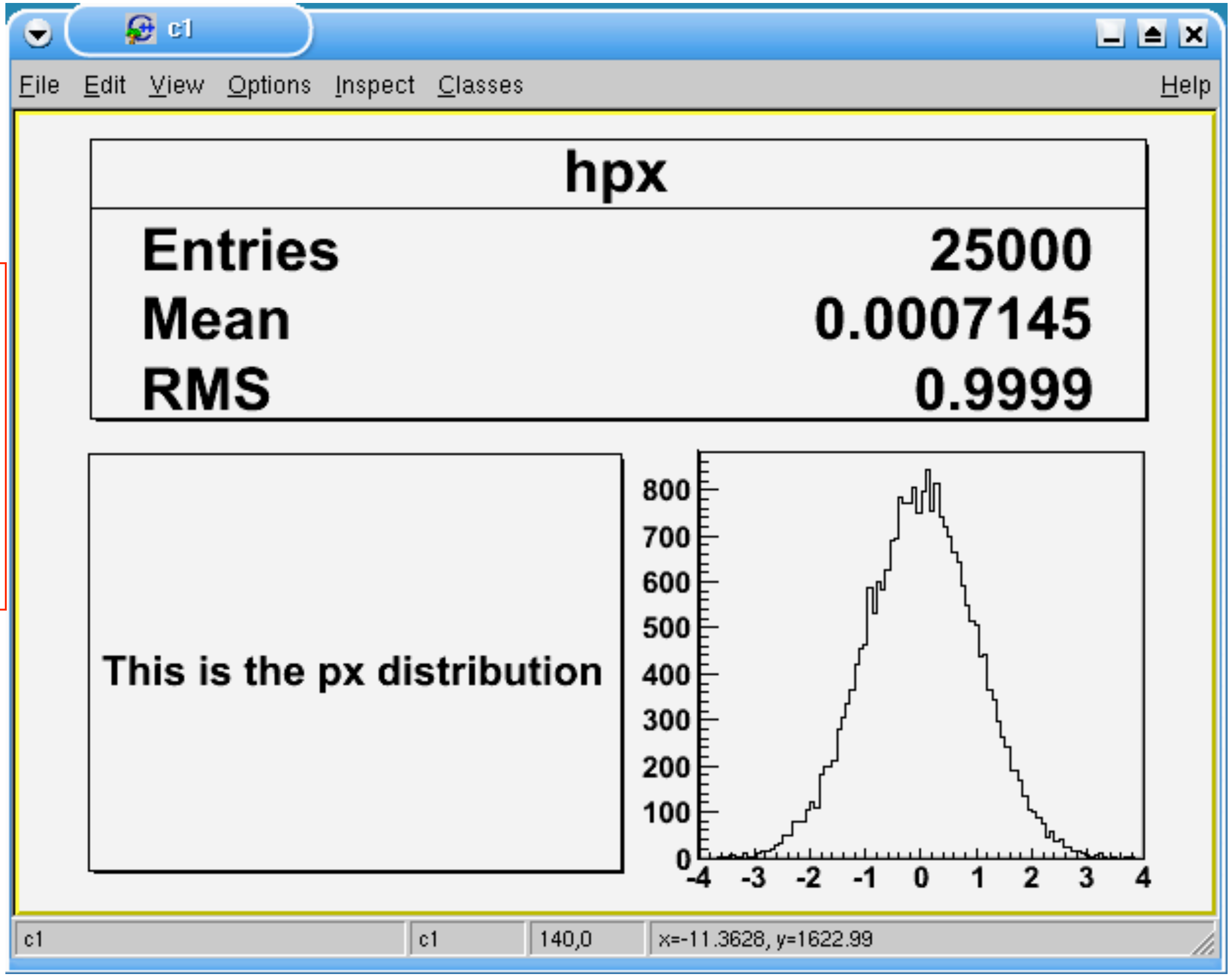
"X" axis (TAxis)

The canvas (TCanvas)

Manipulating objects

- Use the mouse to move and resize objects…

With the left button of the mouse you can reposition and redimension all objects in the canvas



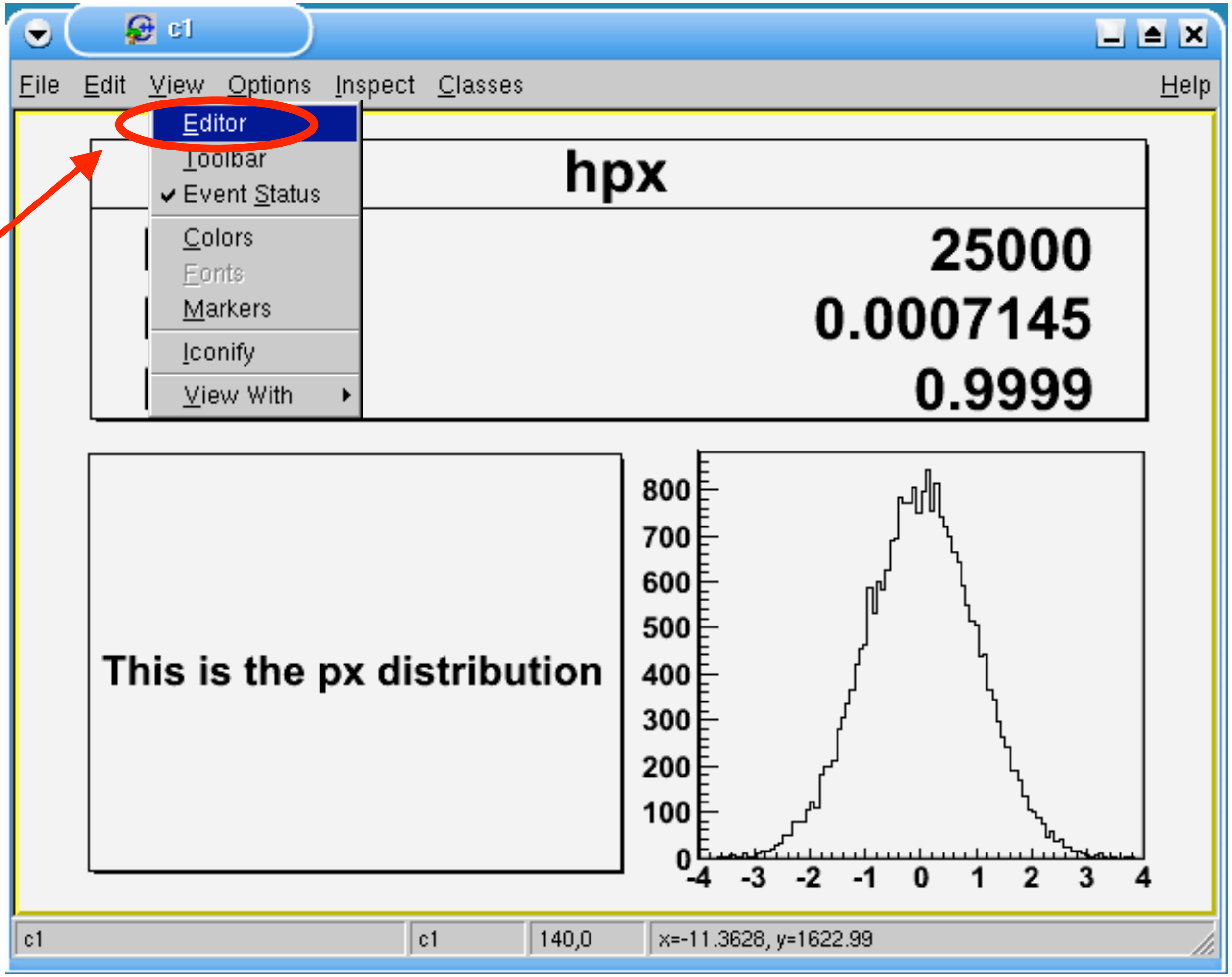
hpx	
Entries	25000
Mean	0.0007145
RMS	0.9999

This is the px distribution

c1 | c1 | 140,0 | x=-11.3628, y=1622.99

Activate the canvas editor

- To change colours, line widths, etc. we use the **canvas editor**

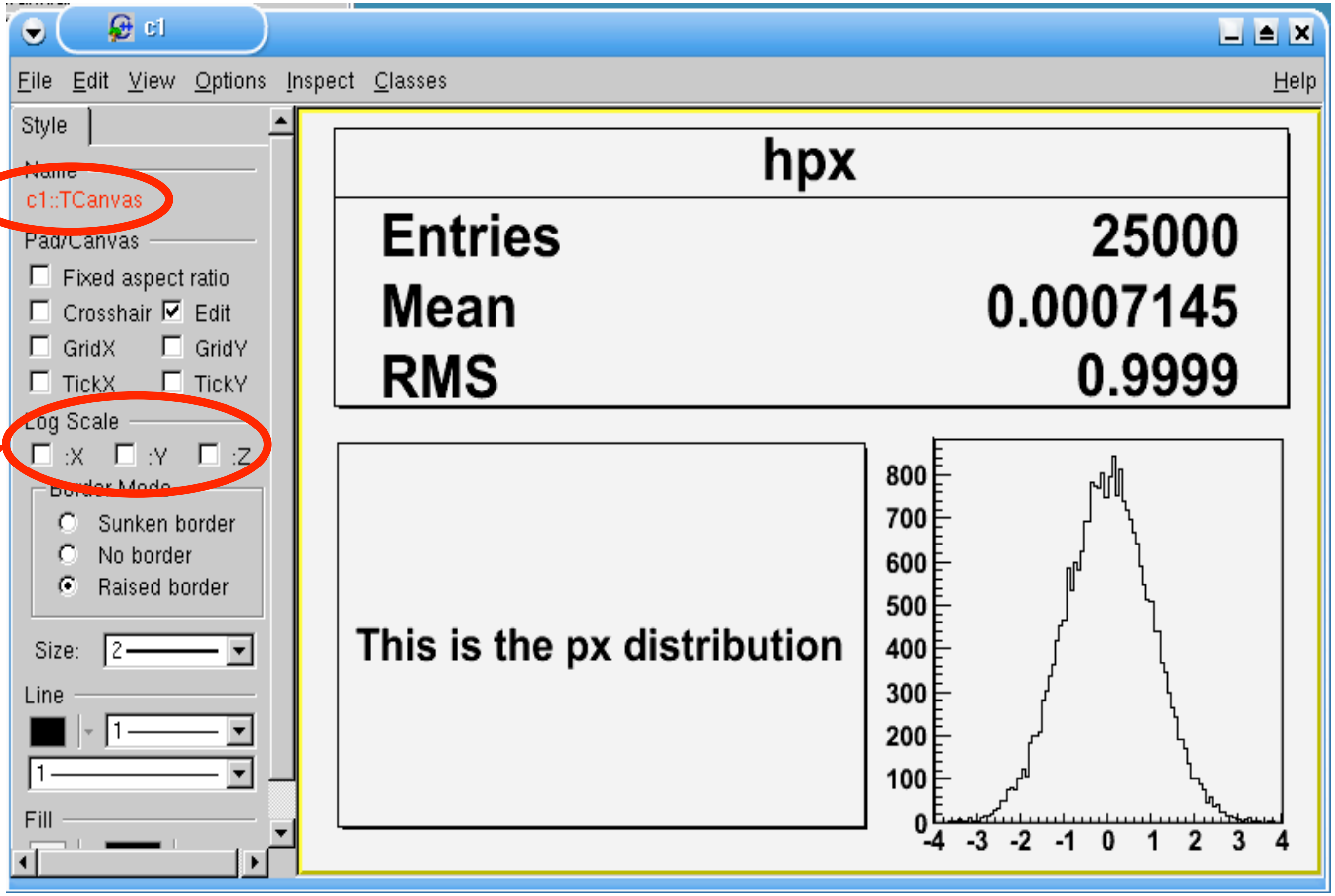


Activate the editor by selecting "Editor" in the "View" menu

Canvas editor

- The editor appears to the left of the canvas
- It displays/modifies the characteristics of the last object selected with the mouse (careful!)

Name & type (class) of last-clicked object



Name

c1::TCanvas

Pad/Canvas

□ Fixed aspect ratio

□ Crosshair ☑ Edit

□ GridX □ GridY

□ TickX □ TickY

Log Scale

□ :X □ :Y □ :Z

Border Mode

○ Sunken border

○ No border

● Raised border

Size: 2

Line

1

1

Fill

hpx

Entries 25000

Mean 0.0007145

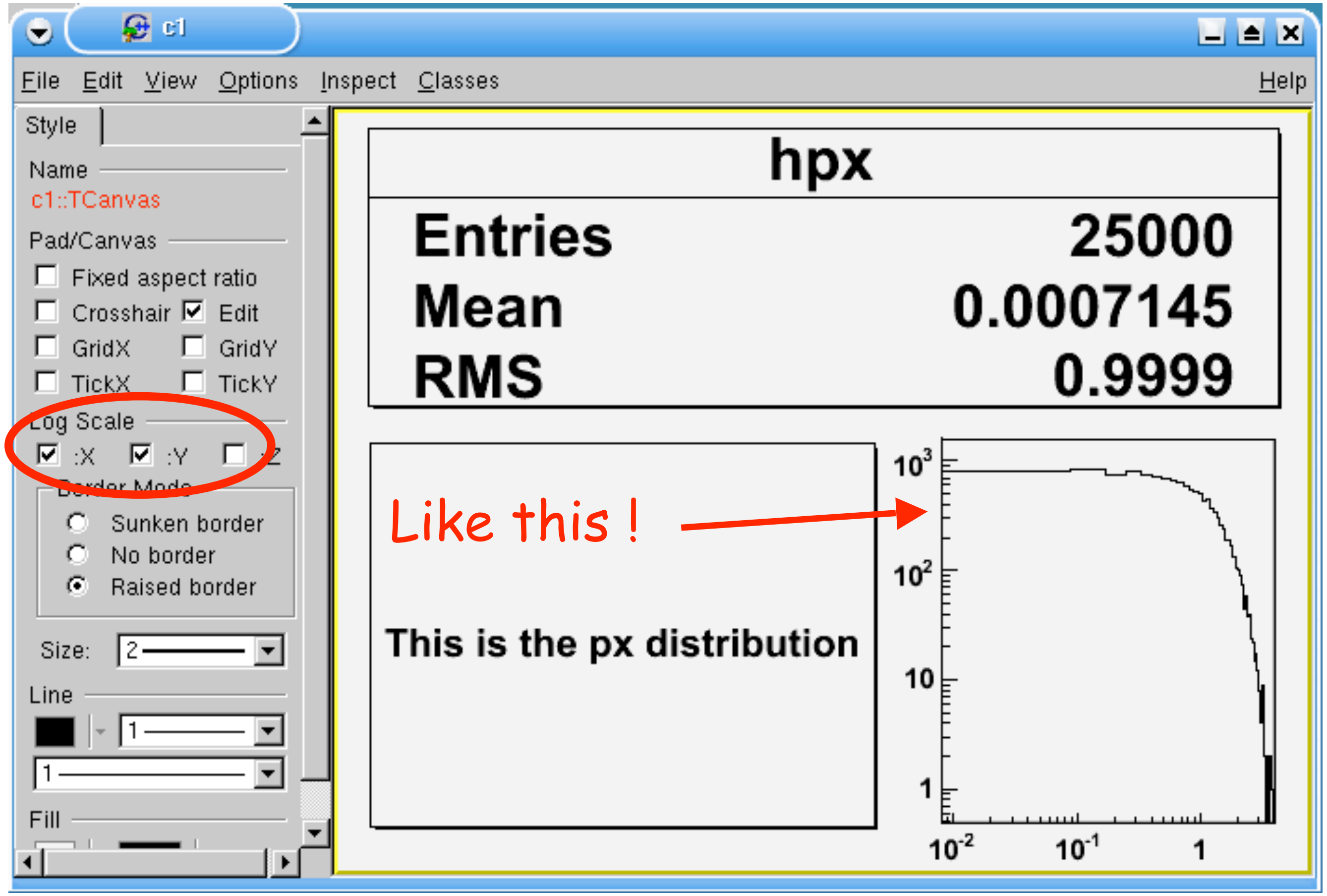
RMS 0.9999

This is the px distribution

E.g. Tick here to make all spectra scales on this canvas logarithmic

Canvas editor

- The editor appears to the left of the canvas
- It displays/modifies the characteristics of the last object selected with the mouse (careful!)



Name
c1::TCanvas

Pad/Canvas
□ Fixed aspect ratio
□ Crosshair ☑ Edit
□ GridX □ GridY
□ TickX □ TickY

Log Scale
☑ :X ☑ :Y □ :Z

Border Mode
○ Sunken border
○ No border
● Raised border

Size: 2

Line
1
1

Fill

hpx

Entries	25000
Mean	0.0007145
RMS	0.9999

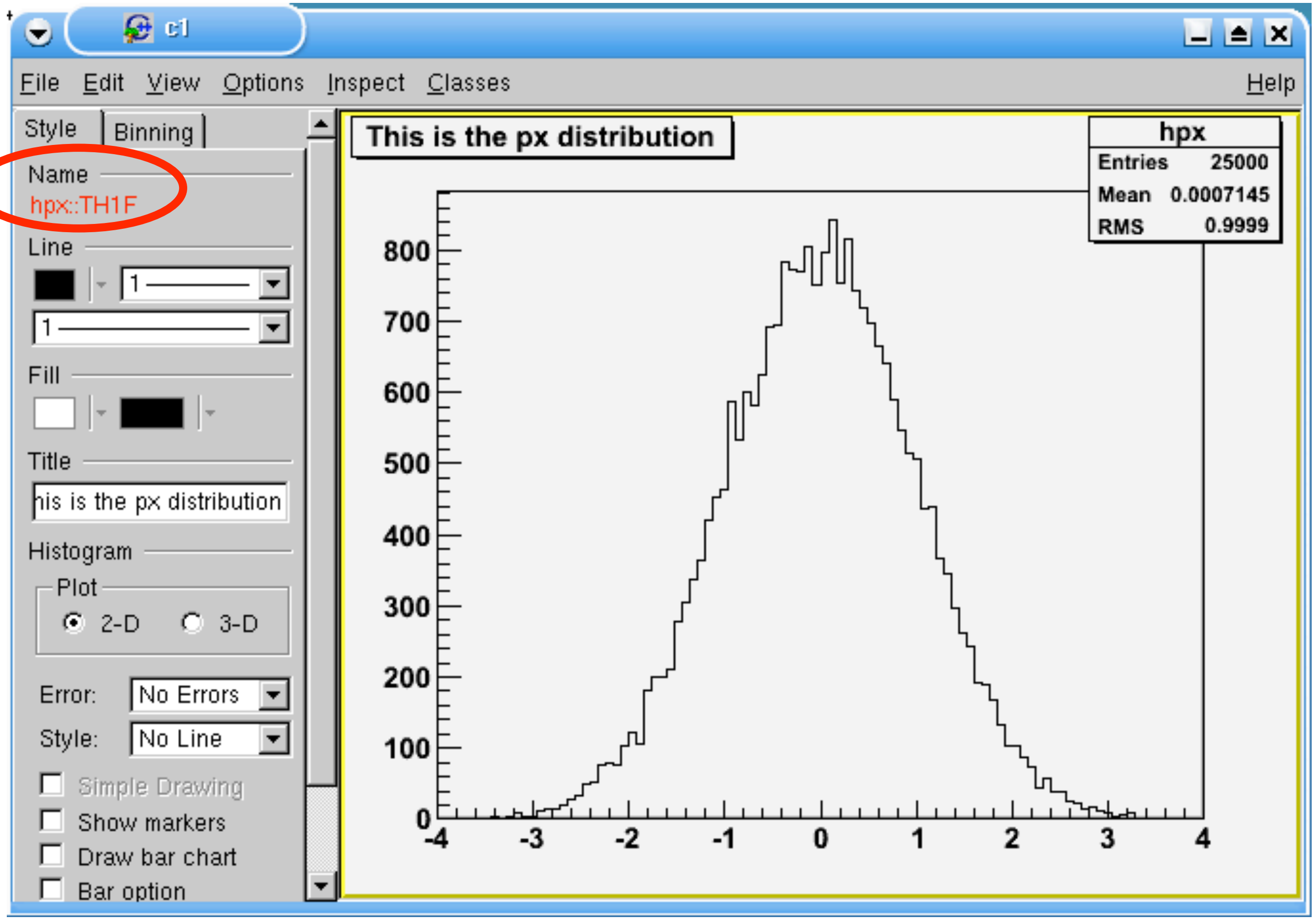
Like this !

This is the px distribution

Changing the look of a spectrum

- or "the art of clicking in the right place at the right time"…

1. Check you have selected the right object


c1
File Edit View Options Inspect Classes Help
Style Binning
This is the px distribution
hpx
800
700
600
500
400
300
200
100
0
-4
-3
-2
-1
0
1
2
3
4

Name
hpx::TH1F

Line
1
1

Fill

Title
his is the px distribution

Histogram
Plot
● 2-D ○ 3-D

Error: No Errors
Style: No Line

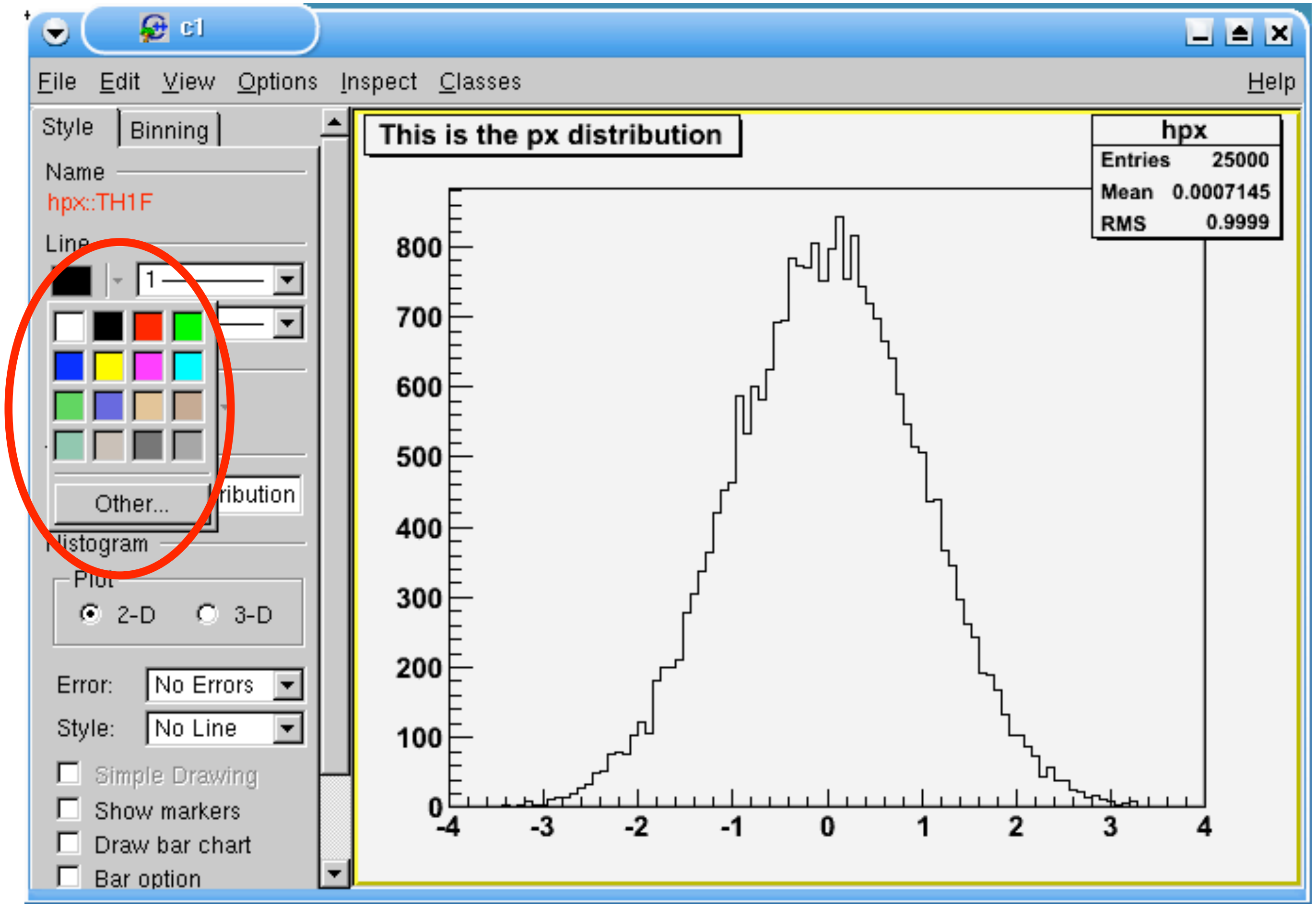
□ Simple Drawing
□ Show markers
□ Draw bar chart
□ Bar option

hpx	
Entries	25000
Mean	0.0007145
RMS	0.9999

Changing the look of a spectrum

- or "the art of clicking in the right place at the right time"…

2. Click the line-colour box to the palette



Name
hpx::TH1F

1

ribution

● 2-D ○ 3-D

Error: No Errors

Style: No Line

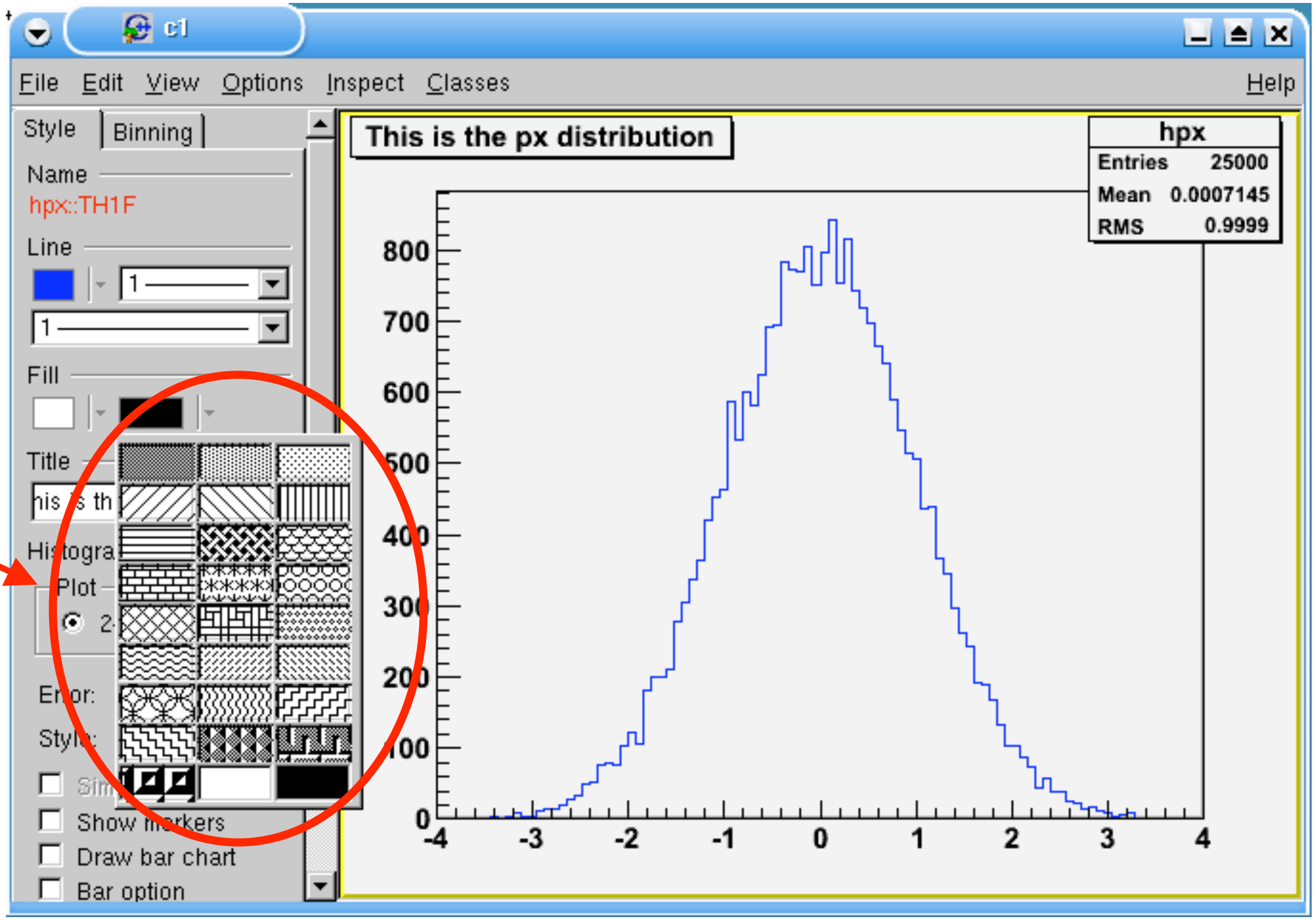
□ Show markers
□ Draw bar chart
□ Bar option

hpx	
Entries	25000
Mean	0.0007145
RMS	0.9999

Changing the look of a spectrum

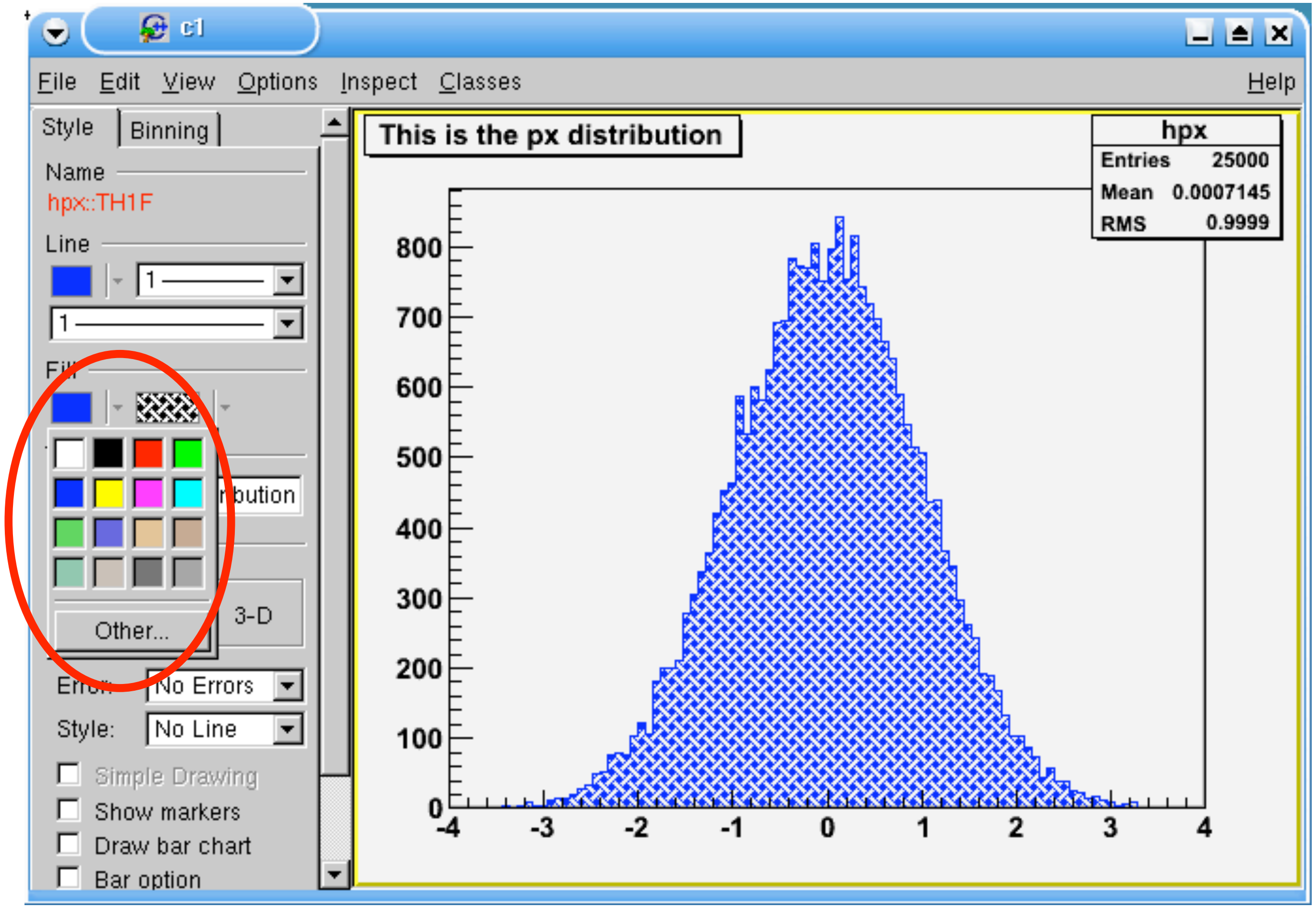
- or "the art of clicking in the right place at the right time"…

3. Choose a fill style…



Changing the look of a spectrum

- or "the art of clicking in the right place at the right time"…



Name
hpx::TH1F

Error: No Errors

Style: No Line

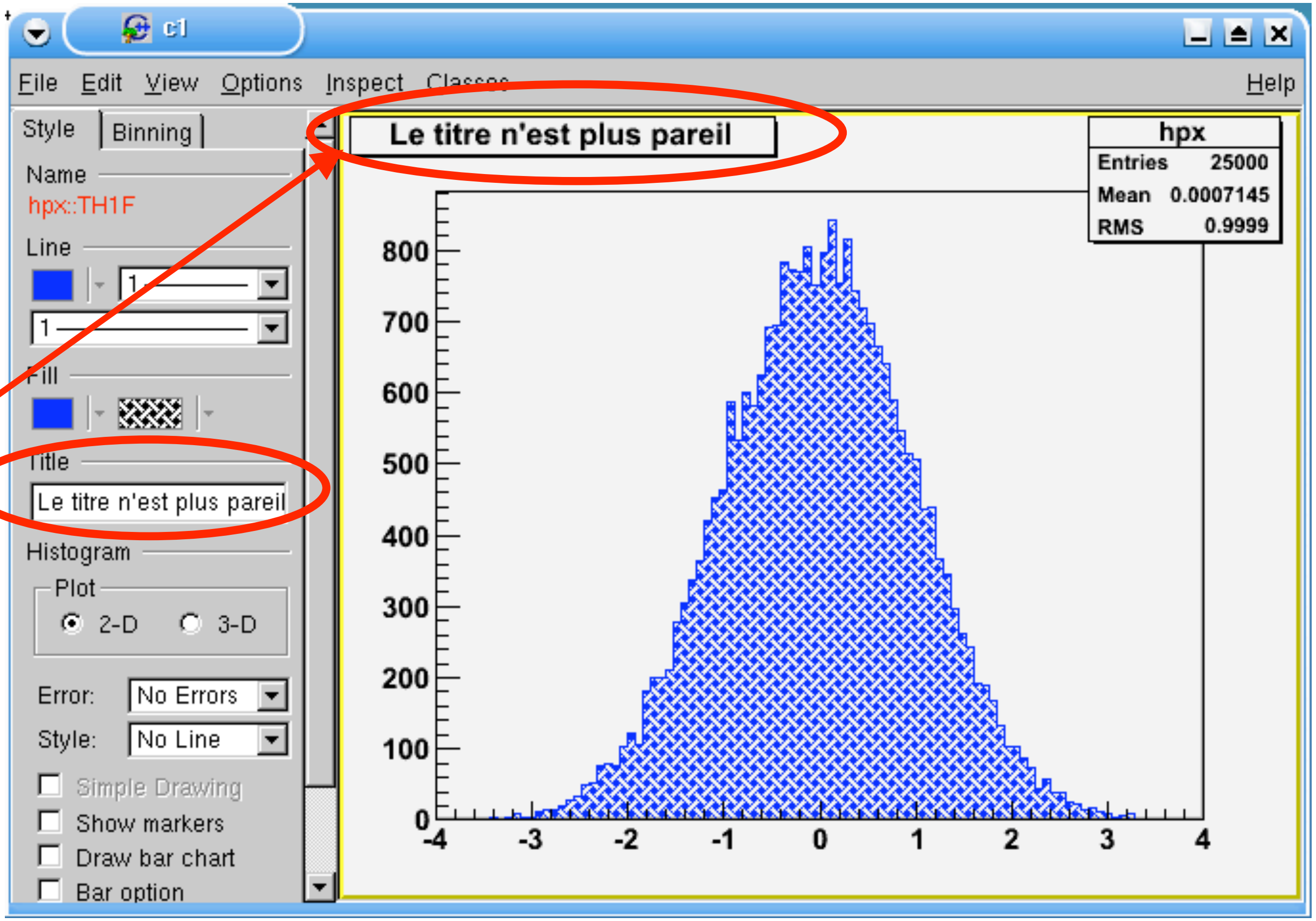
hpx

Entries	25000
Mean	0.0007145
RMS	0.9999

4. …and a colour in order to activate it

Changing the look of a spectrum

- or "the art of clicking in the right place at the right time"…



Name
hpx::TH1F

Line
1
1

Fill

Title
Le titre n'est plus pareil

Histogram

Plot
● 2-D ○ 3-D

Error: No Errors

Style: No Line

□ Simple Drawing
□ Show markers
□ Draw bar chart
□ Bar option

Le titre n'est plus pareil

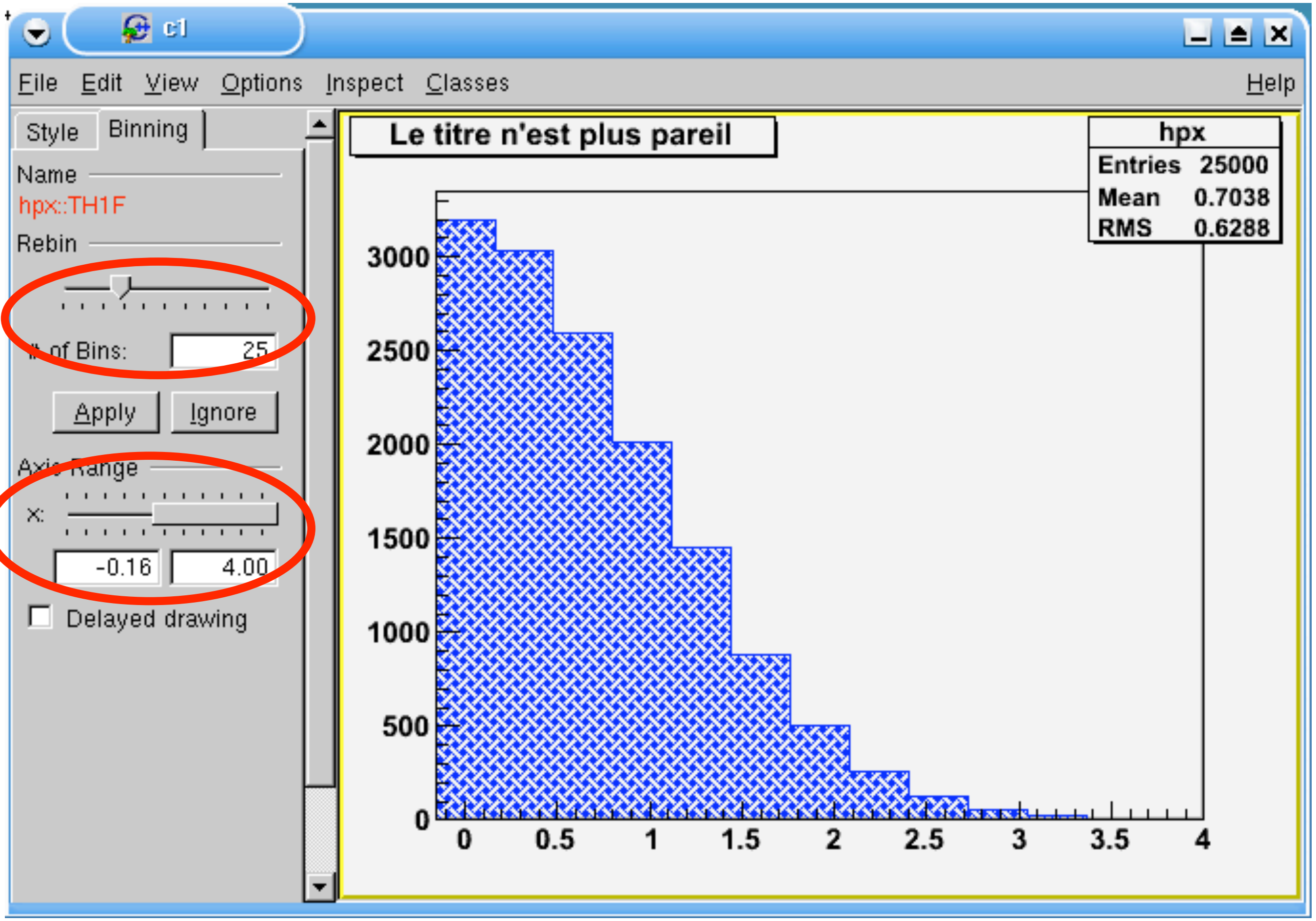
hpx	
Entries	25000
Mean	0.0007145
RMS	0.9999

5. And why not change the title while we're at it ?

Changing the look of a spectrum

- or "the art of clicking in the right place at the right time"…

On the second tab you can change the binning…



…as well as the range of displayed axis values

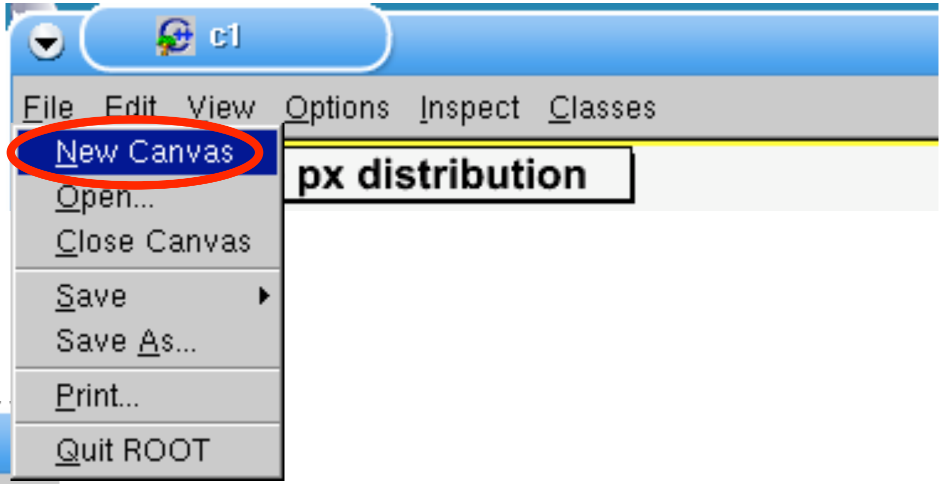
*Handling the canvas**

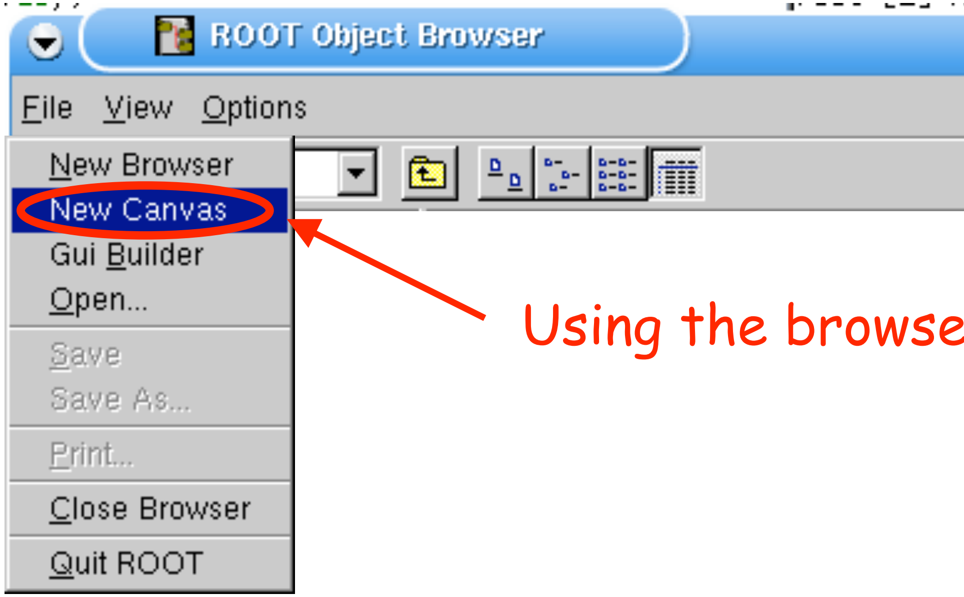
*without smudging the artwork

Canvas manipulation

- If you want a new canvas:

Using an existing one…



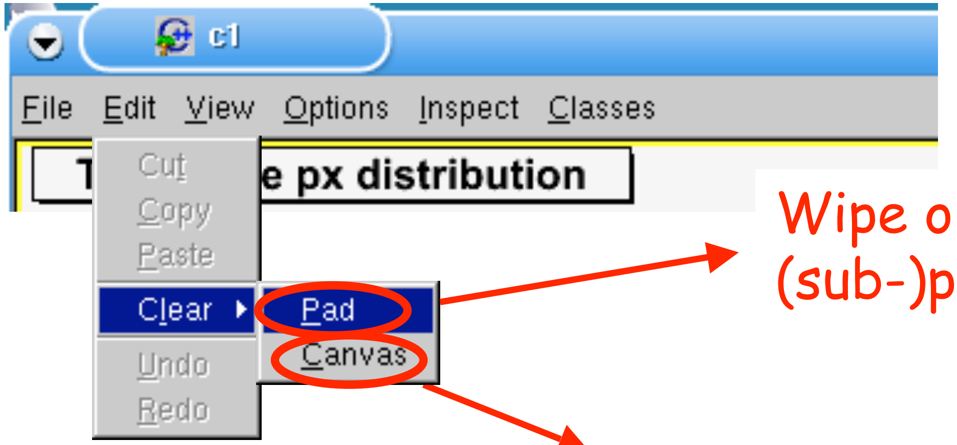


Using the browser…

WARNING !
Double-click on a spectrum and it will be drawn on the active canvas, replacing any previous content

Canvas manipulation

- To wipe the canvas clean:



Wipe only the active (sub-)pad…

Wipe the WHOLE canvas (careful!)

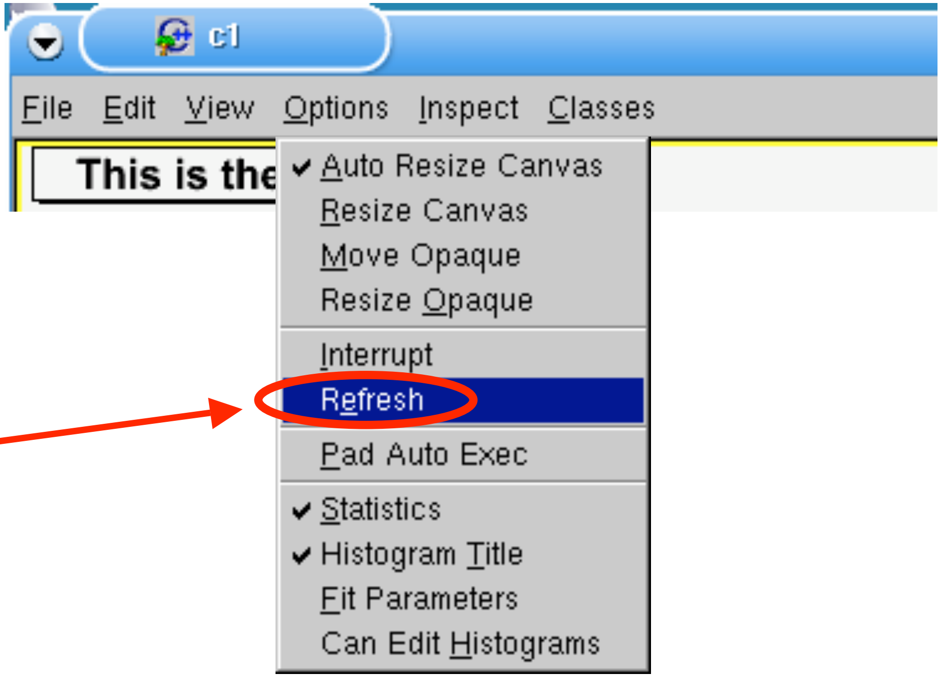
Manipulating the canvas

- To refresh the canvas display:

Sometimes, the result of a modification is not visible straight away.

To force an update of all the objects on the canvas, option "Refresh" can help*

*(and reduce stress levels and anxiety…)



Manipulating the canvas

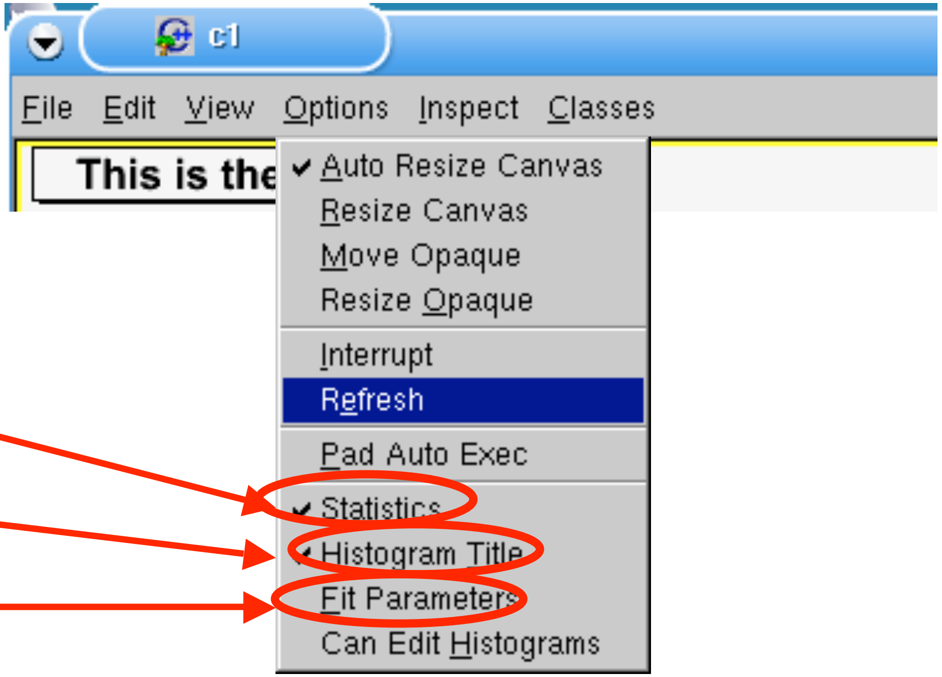
- Some useful options:

In the "Options" menu of the canvas we also control whether or not to show :

statistics boxes

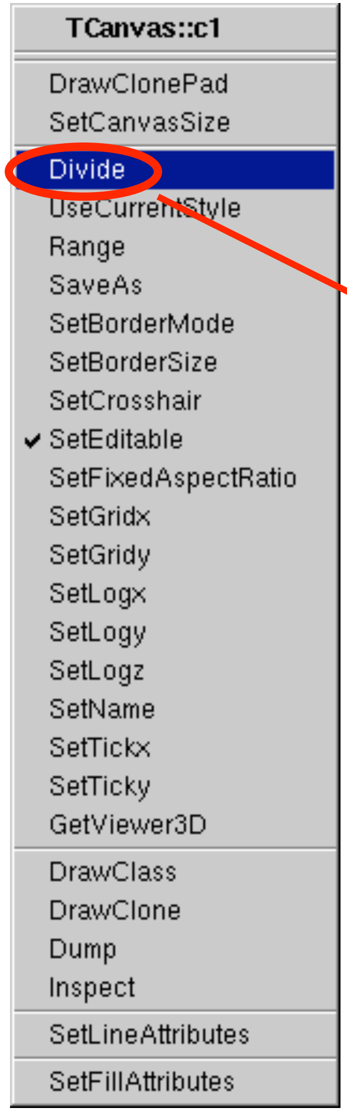
histogram title

fit parameters



Manipulating the canvas

- Dividing the canvas to display several spectra at once:



Open the context menu of the canvas (right-click on the canvas)

Select "Divide"

Manipulating the canvas

- Dividing the canvas to display several spectra at once:

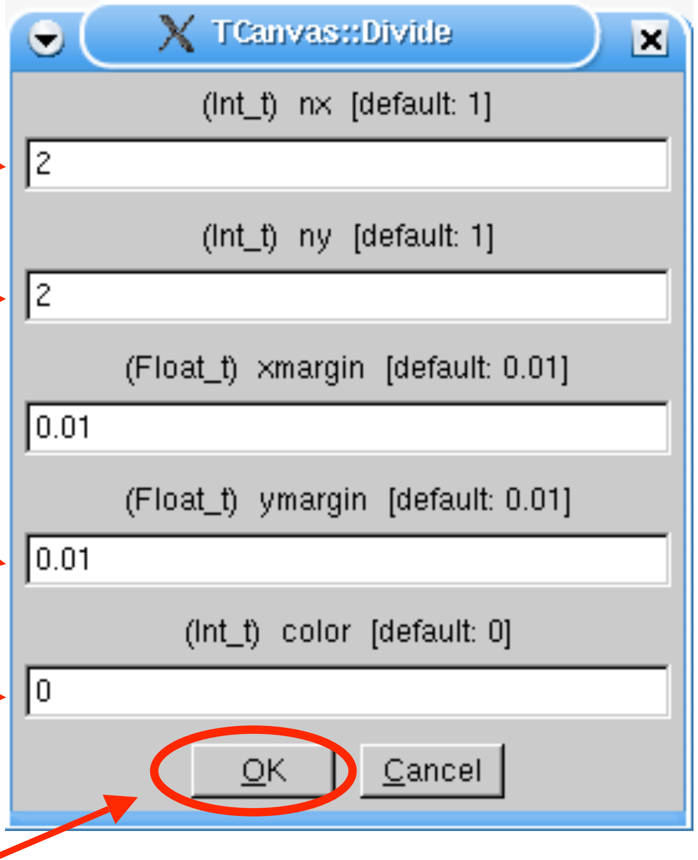
Fill in the form,
e.g. to have 2x2 pads:

Number of columns

Number of rows

Margins between pads

Pad colour



TCanvas::Divide

(Int_t) nx [default: 1]

2

(Int_t) ny [default: 1]

2

(Float_t) xmargin [default: 0.01]

0.01

(Float_t) ymargin [default: 0.01]

0.01

(Int_t) color [default: 0]

0

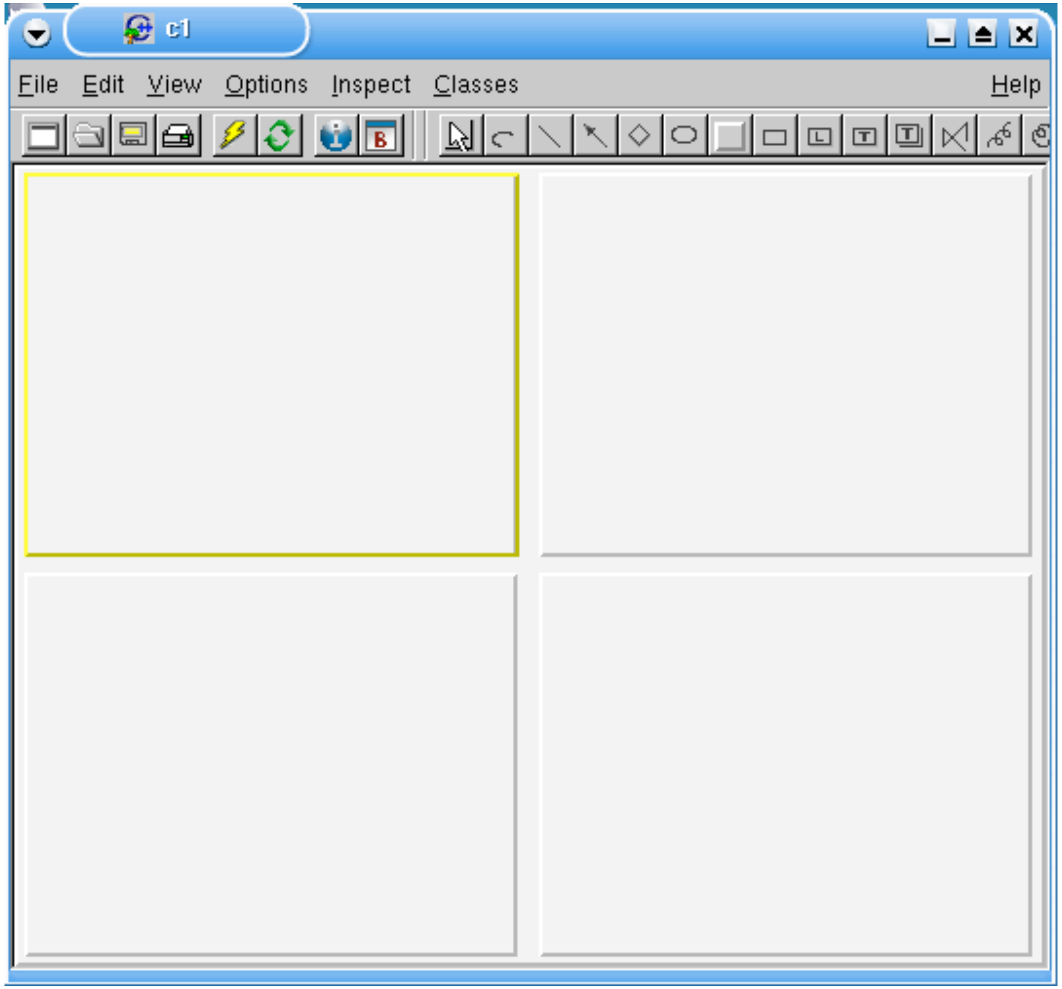
And click "OK"

Manipulating the canvas

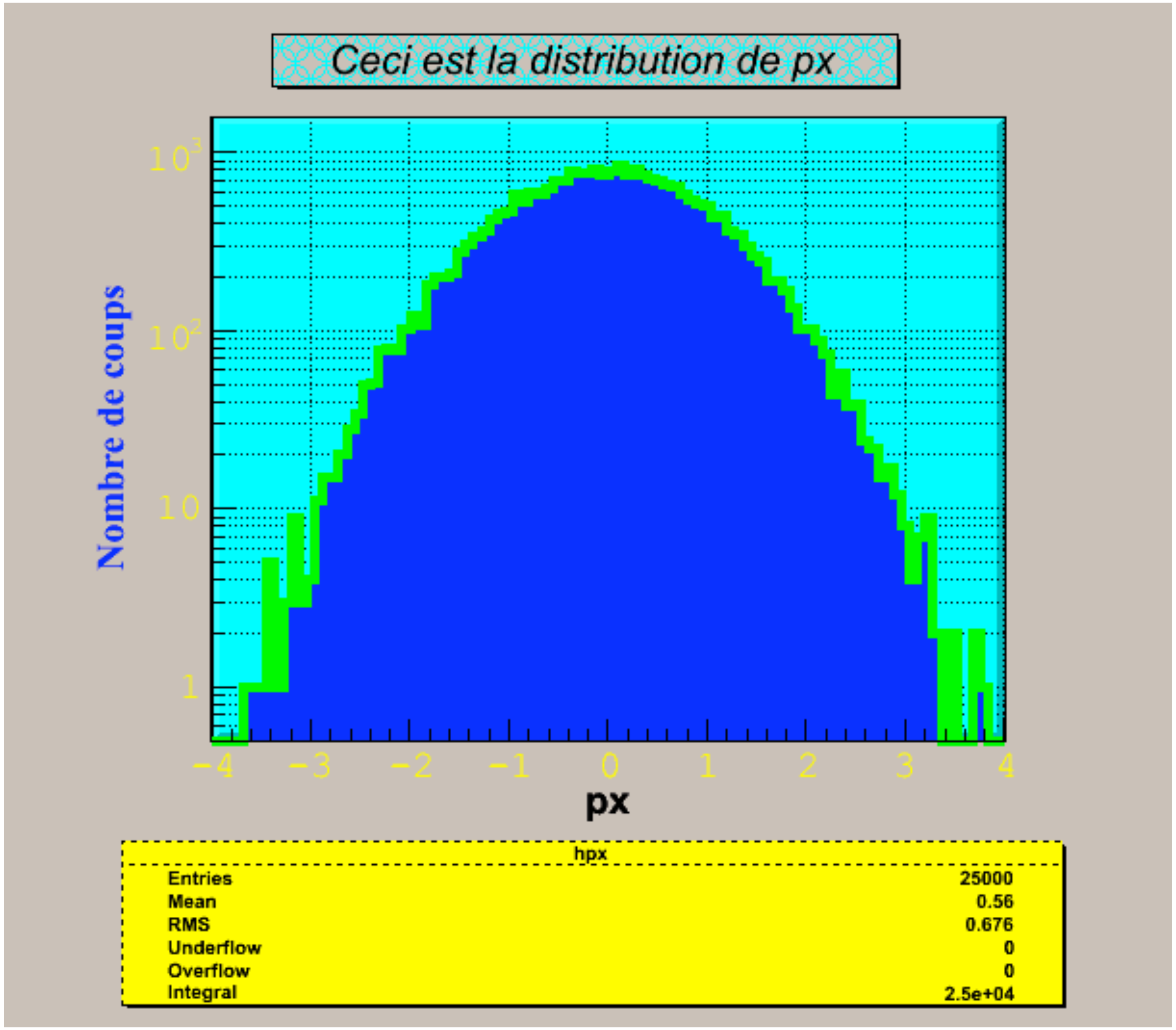
- Dividing the canvas to display several spectra at once:

Next, choose the pad where you want to display your spectrum
(click with middle button)

WARNING!
The first sub-pad is not automatically selected



Exercise



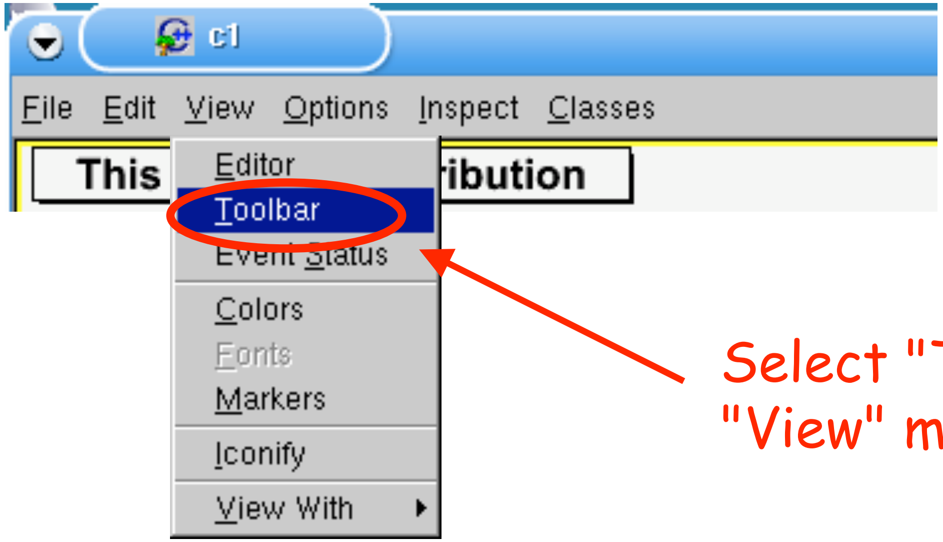
```
                         hpx
Entries                                   25000
Mean                                       0.56
RMS                                       0.676
Underflow                                     0
Overflow                                      0
Integral                                2.5e+04
```

Decorating a figure

Making pretty pictures

Adding objects to the canvas

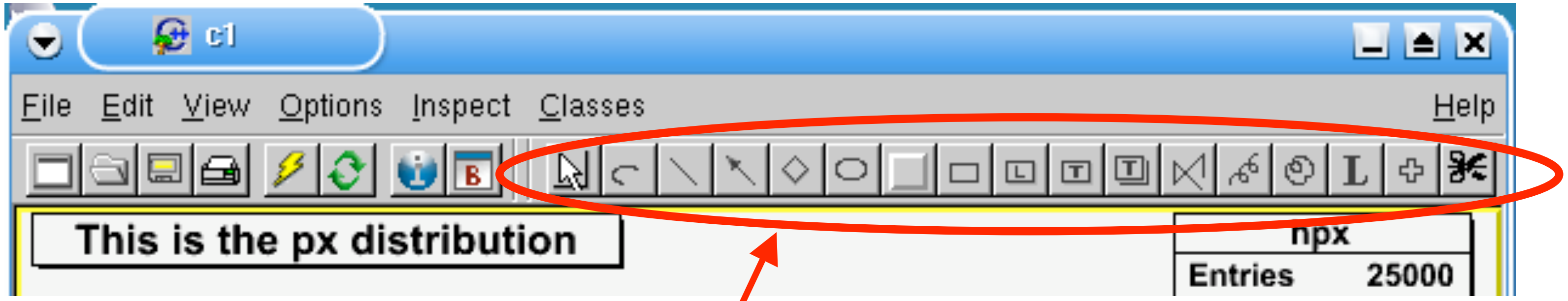
- Open the **toolbar**



Select "Toolbar" in the "View" menu

Adding objects to the canvas

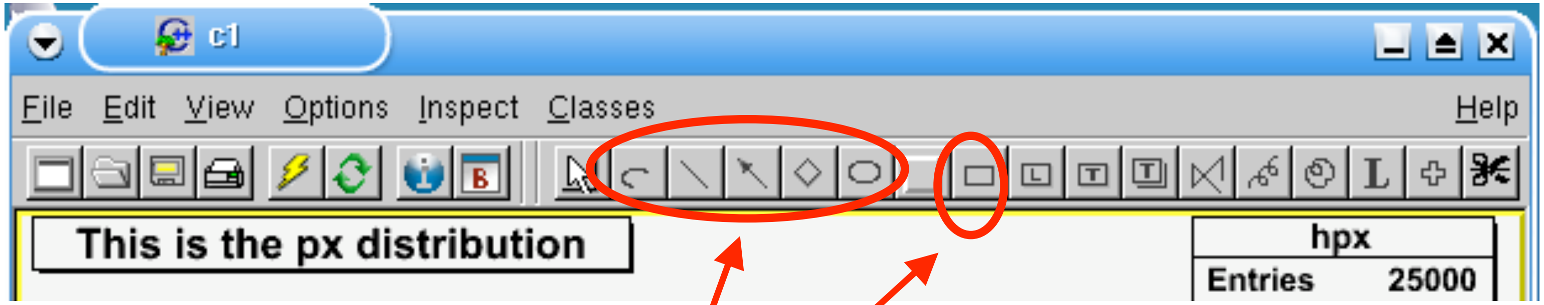
- Open the **toolbar**


c1
File Edit View Options Inspect Classes Help
This is the px distribution
npx
Entries 25000

With the buttons we can draw all sorts of graphical objects on the canvas…

Adding objects to the canvas

- Open the **toolbar**

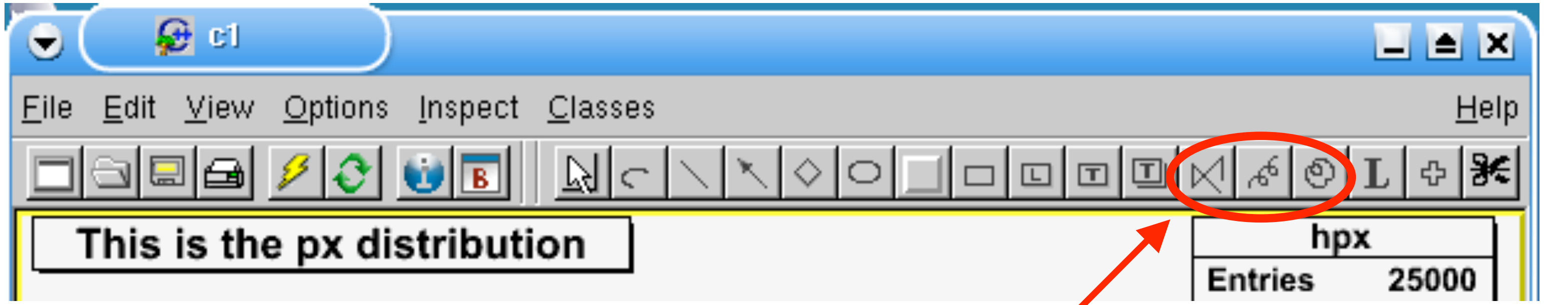


This is the px distribution

…arc/circle, line,
arrow, diamond, ellipse,
rectangle, …

Adding object to the canvas

- Open the **toolbar**



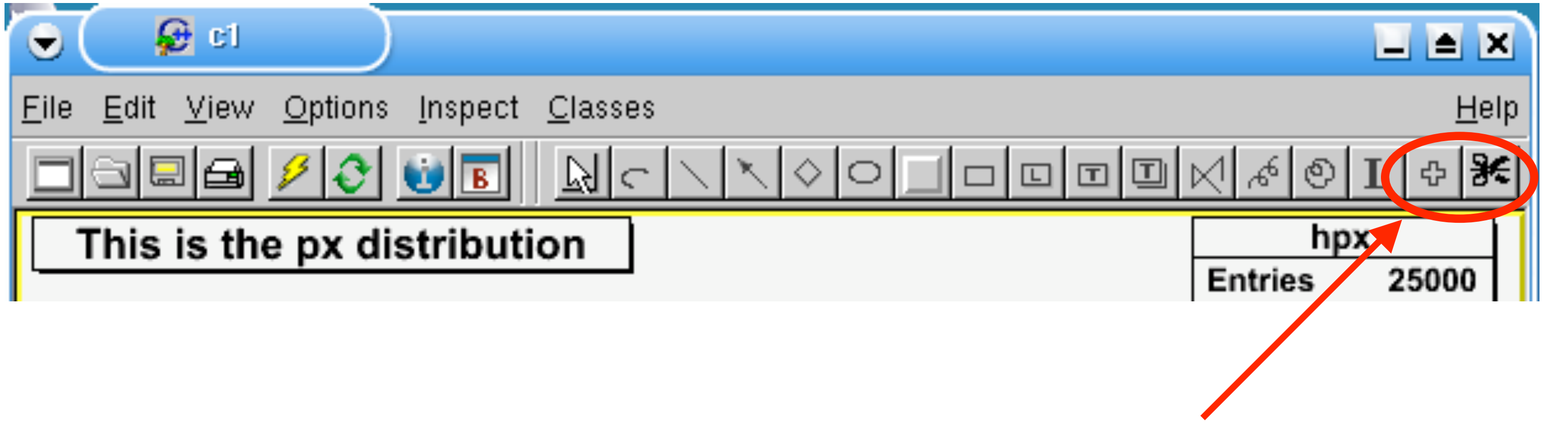
This is the px distribution

hpx	
Entries	25000

…polyline, "curly line",
"curly arc", …

Adding objects to the canvas

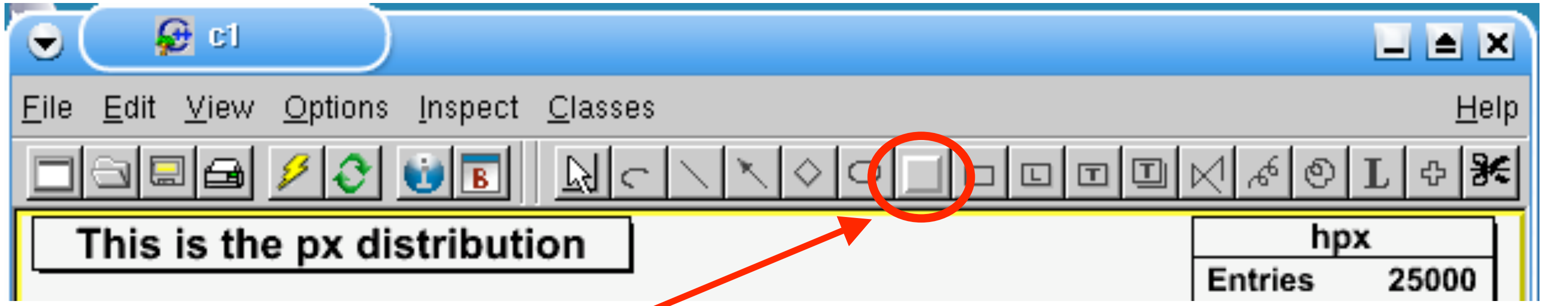
- Open the **toolbar**



...marker, closed contour (graphical cut selection - Day 4!)

Add a pad to the canvas

- Spectra within spectra within…



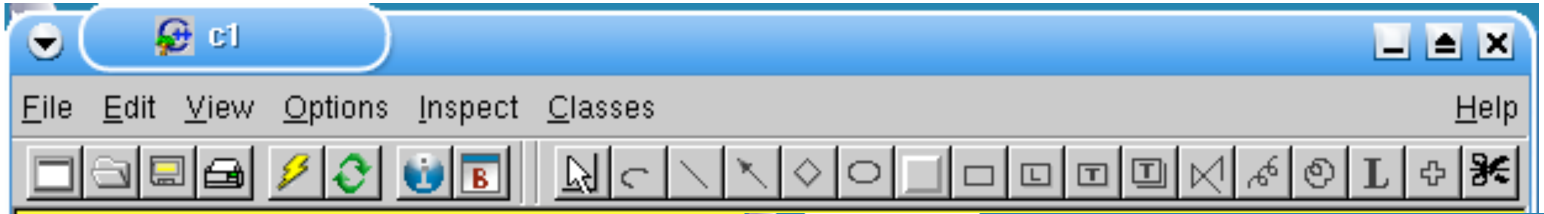
Why add a pad ?

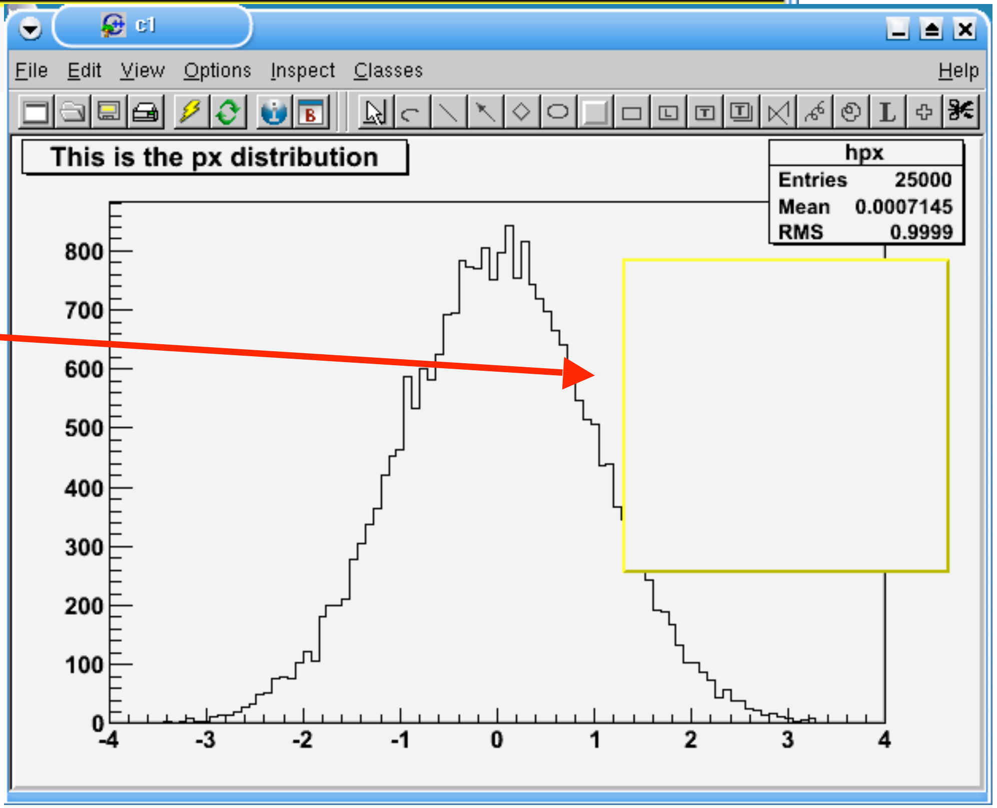
=> Easy way to have an 'insert' showing e.g. a zoom

Pad = mini-canvas inside a canvas (or a pad… etc. etc.)

Adding a pad

- Spectra within spectra within…



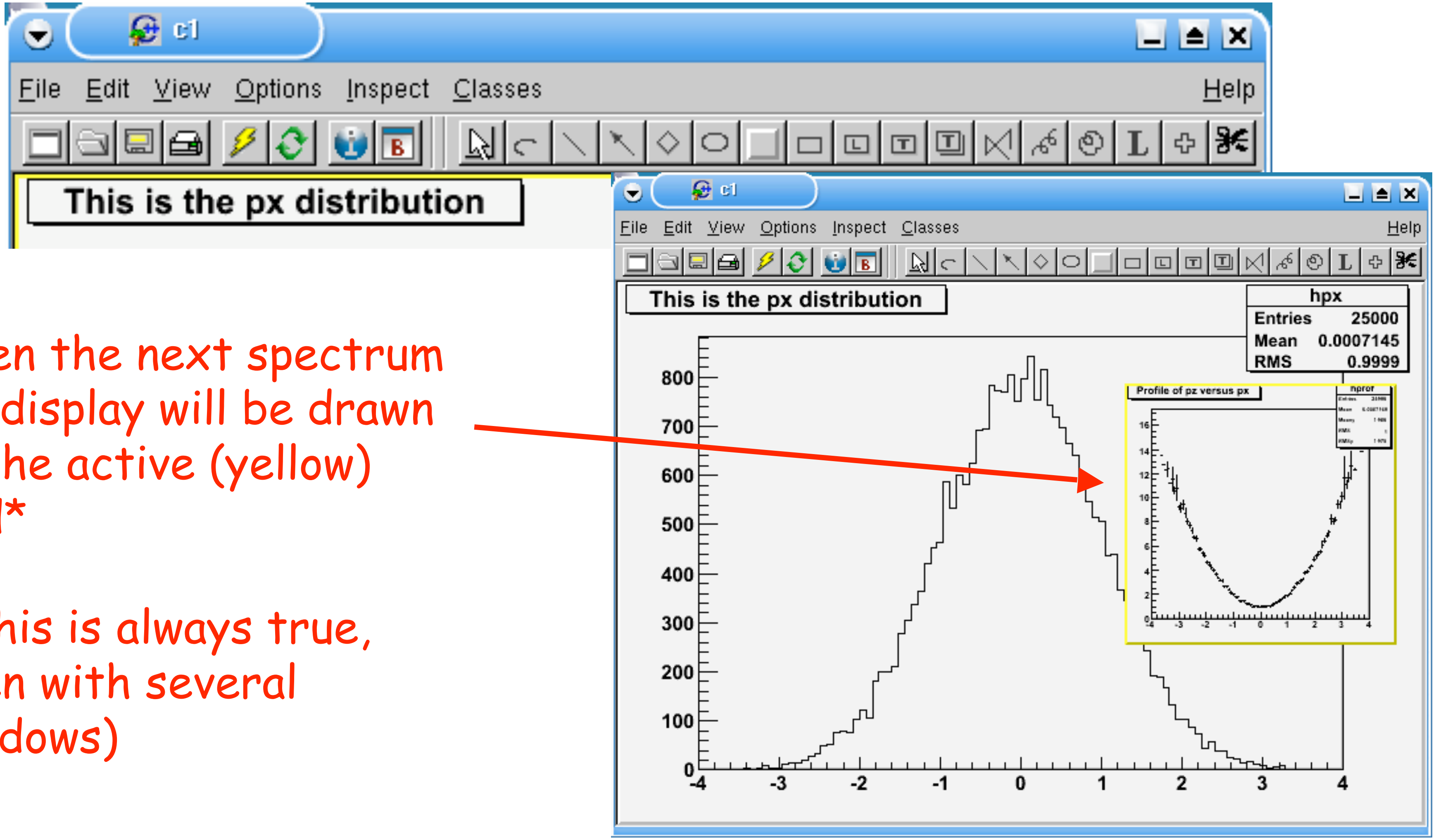


Draw the pad, then click on it with the middle button to make it active (yellow border)*

*(true for all pads/ canvases)

Adding a pad

- Spectra within spectra within…



This is the px distribution

This is the px distribution

hpx	
Entries	25000
Mean	0.0007145
RMS	0.9999

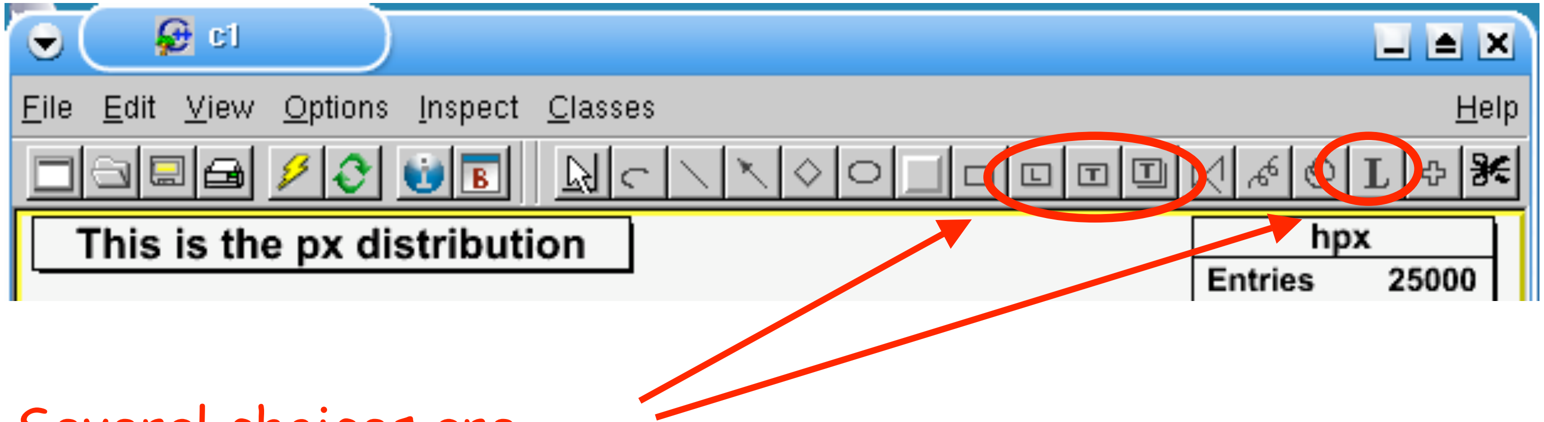
Profile of pz versus px

Then the next spectrum we display will be drawn in the active (yellow) pad*

*(this is always true, even with several windows)

Adding text

- To make the figure self-explanatory, add a legend…

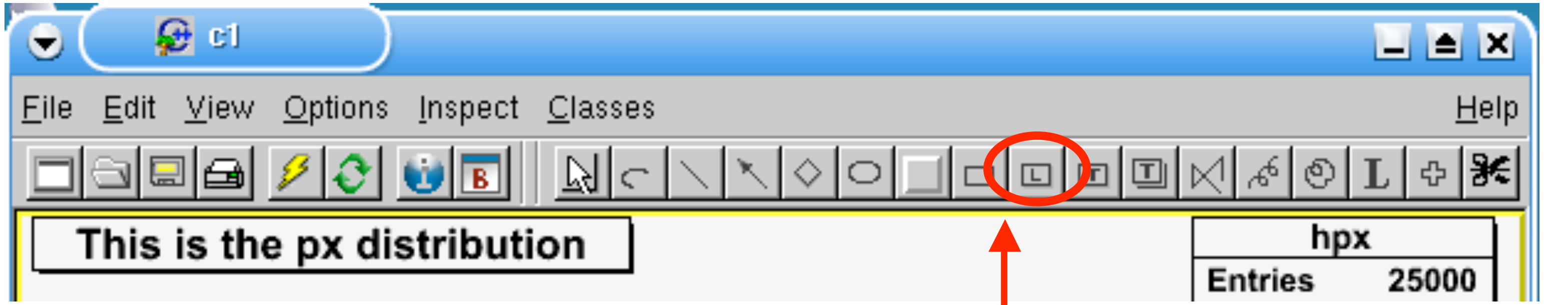


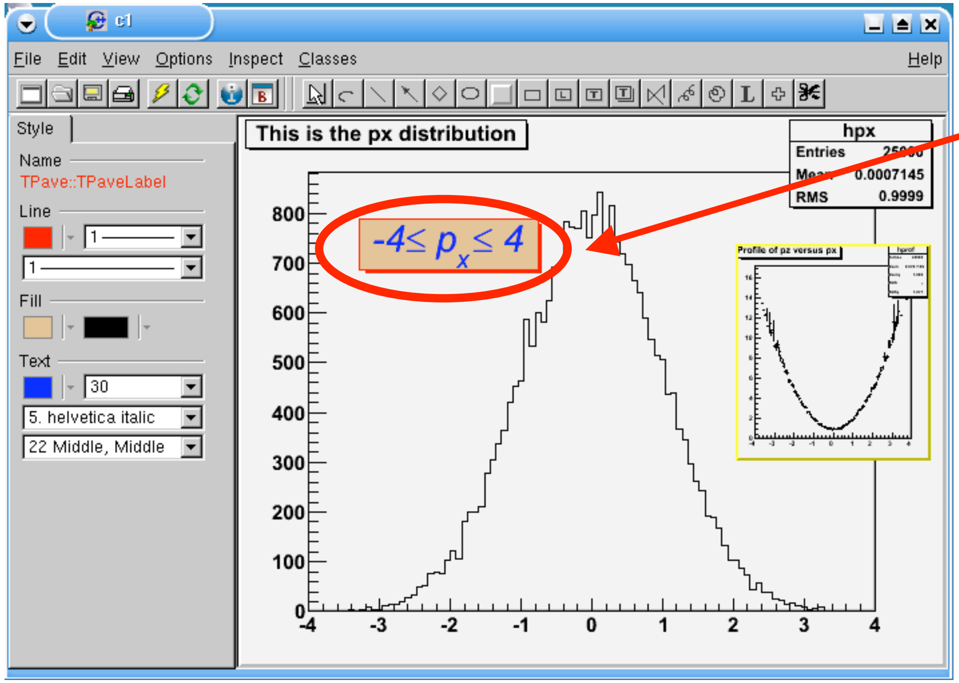
Several choices are available for adding text, do you want just text ('L' button)* or text in a box ?

*(it's 'L' for 'LaTeX')

Adding text

- …using LaTeX (well, almost)





Name
TPave::TPaveLabel

Line
1
1

Fill

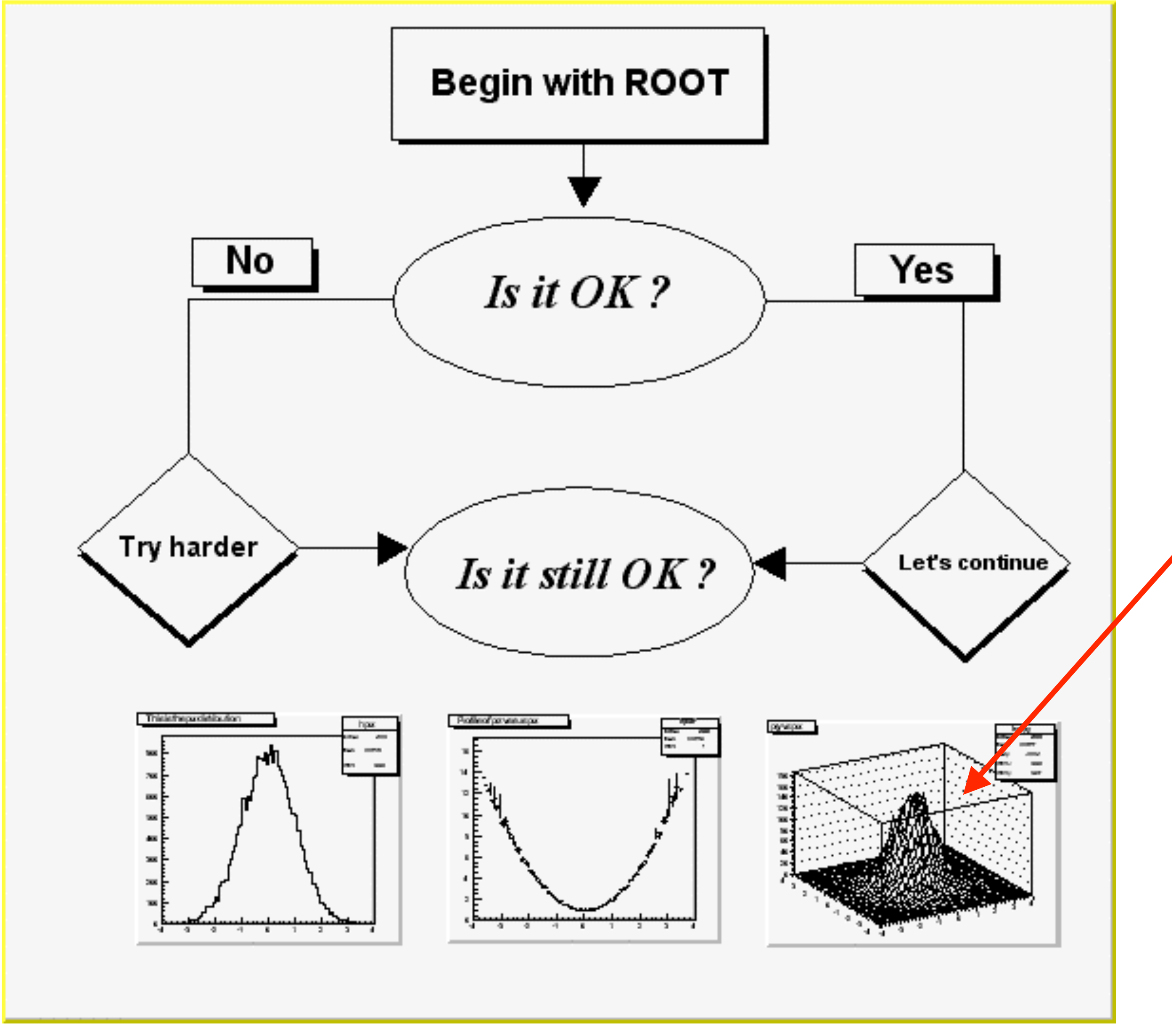
Text
30
5. helvetica italic
22 Middle, Middle

Example of a 'TPaveLabel'

Raw text entered:
-4#leq p_{x}#leq 4

To change font, size, colour of text, use the canvas editor

Exercise



Begin with ROOT

Is it OK ?

No

Yes

Try harder

Let's continue

Is it still OK ?

Tip:
it's the 2-D spectrum 'hpxpy' drawn with option "lego" (use the 'Options' drop-down menu in the browser)

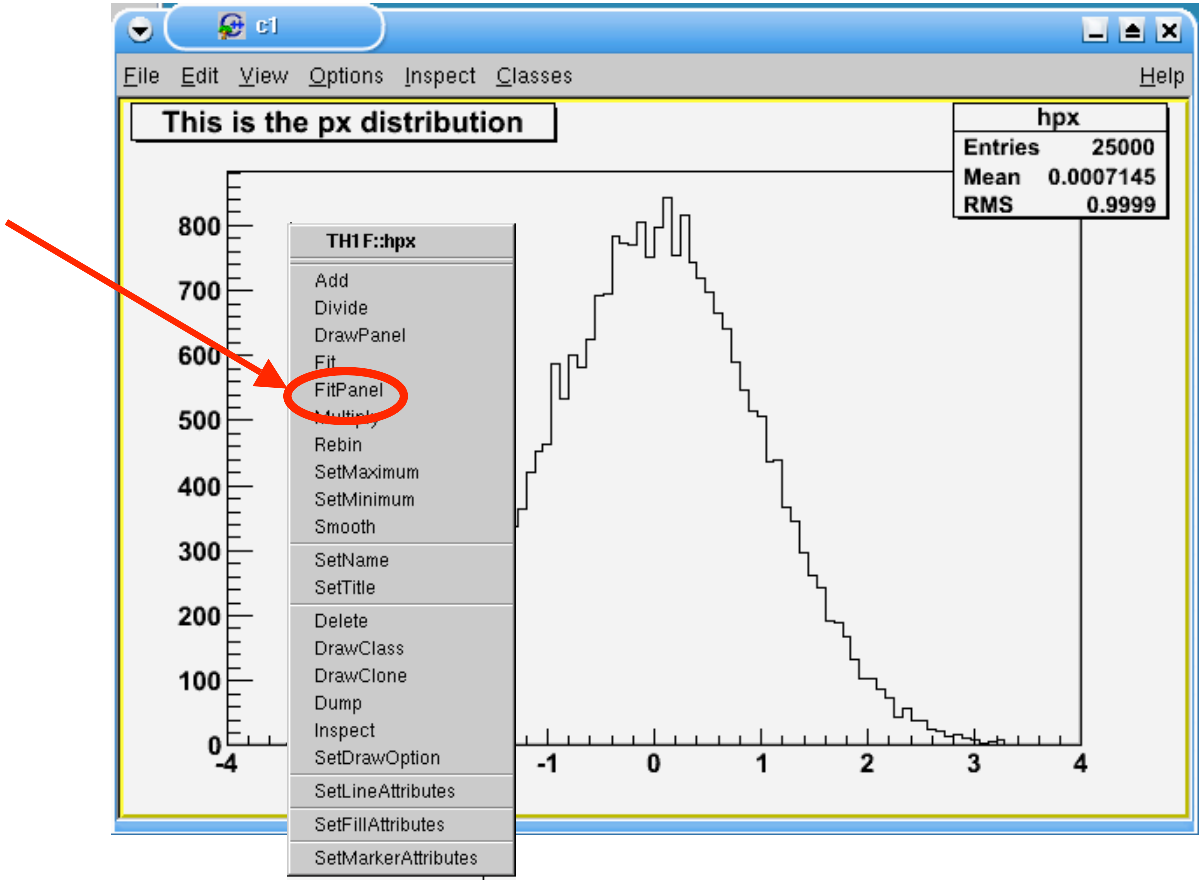
Fitting a 1-D spectrum

Fits

- Simple fitting can easily be done using the graphical interface

Draw spectrum 'hpx' and open its context menu

Select "FitPanel"



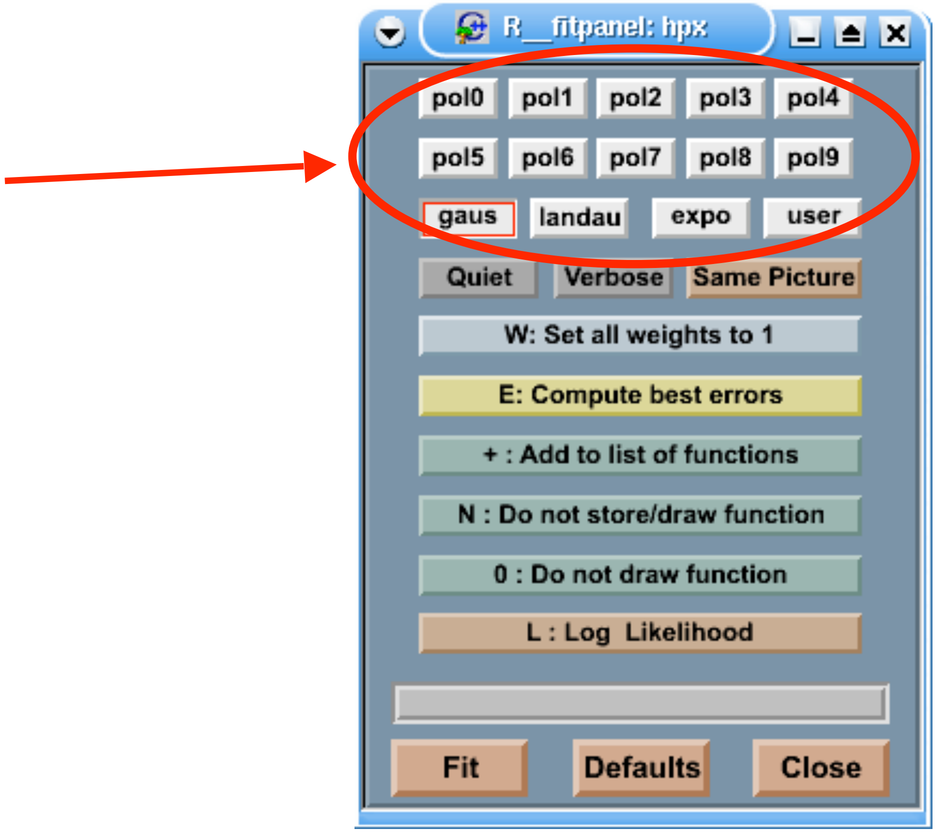
Fits

- Simple fitting can easily be done using the graphical interface

Choose a function:

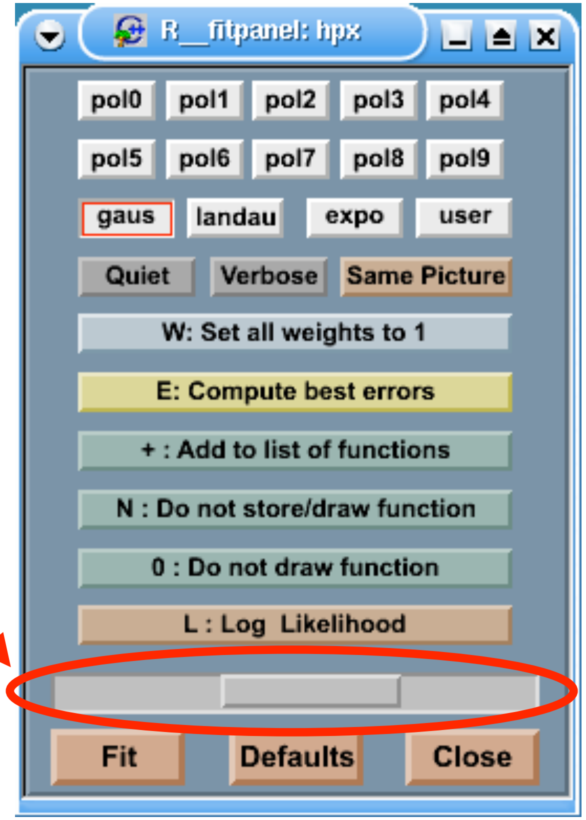
polN = Nth order polynomial

user = user-defined function (Day 3)



Fits

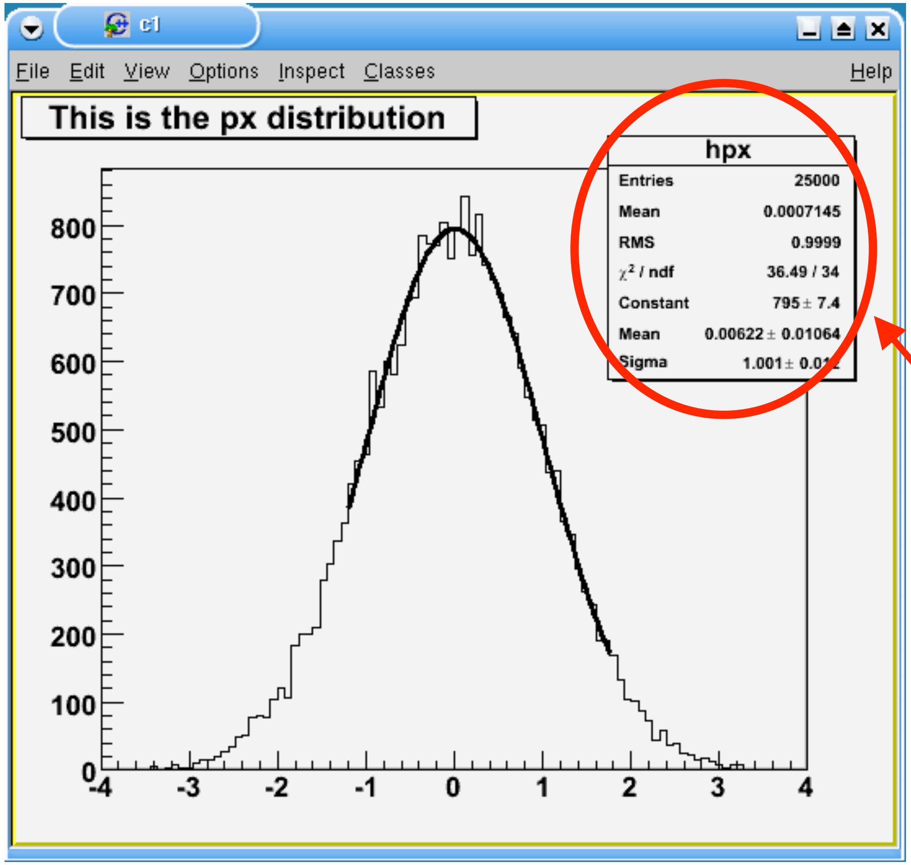
- Simple fitting can easily be done using the graphical interface



Change the range of the fit

Fits

- Simple fitting can easily be done using the graphical interface

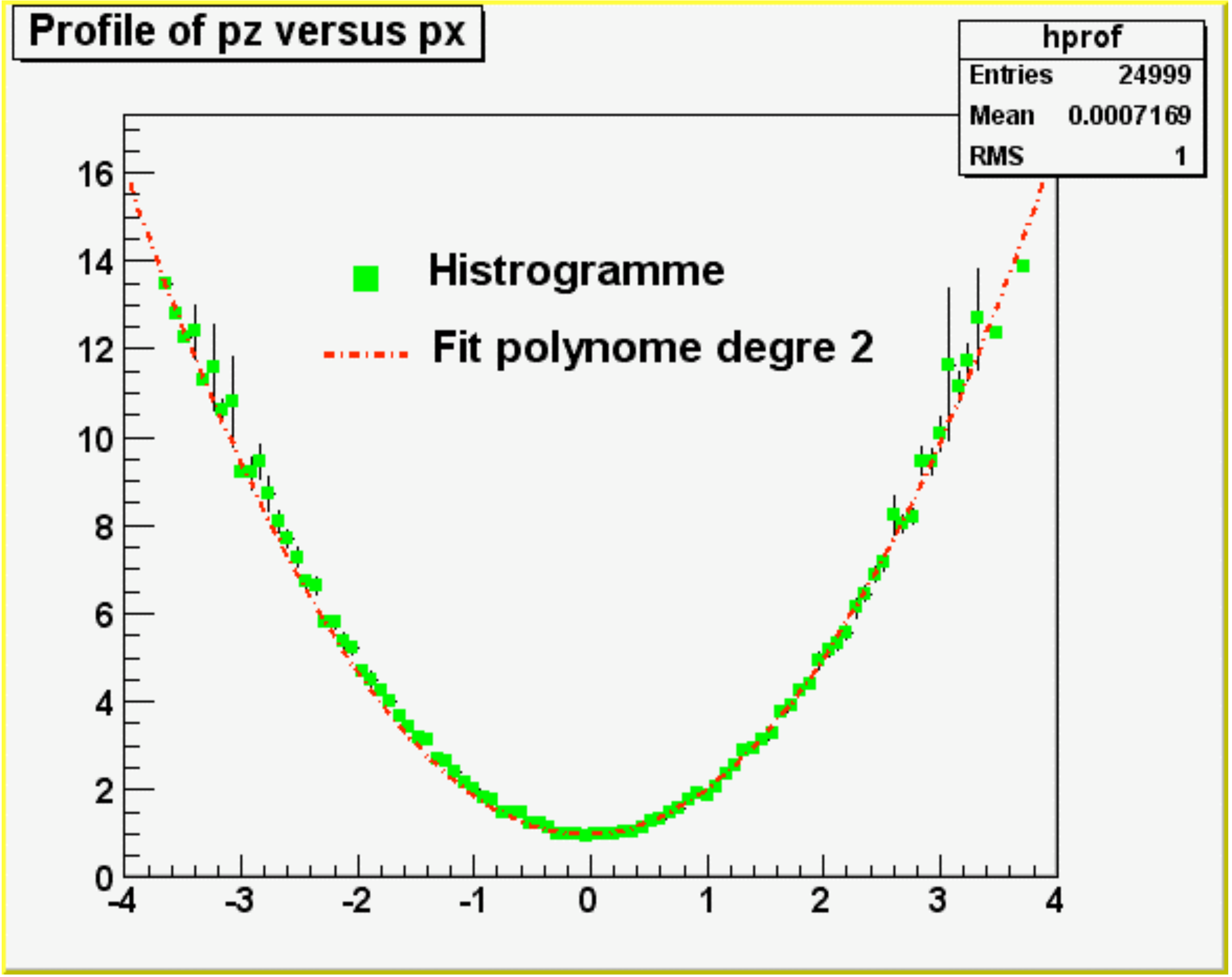


```
hpx
Entries        25000
Mean           0.0007145
RMS            0.9999
χ² / ndf       36.49 / 34
Constant       795 ± 7.4
Mean           0.00622 ± 0.01064
Sigma          1.001 ± 0.01
```

Click 'Fit' and the fit will be performed, the result appears in the active pad/canvas (unless you choose option "N")

To see the fit parameters : menu "Options", "Fit Parameters"

Exercise


Profile of pz versus px
hprof
Entries 24999
Mean 0.0007169
RMS 1
Histrogramme
Fit polynome degre 2
16
14
12
10
8
6
4
2
0
-4
-3
-2
-1
0
1
2
3
4

Working with 2-D spectra

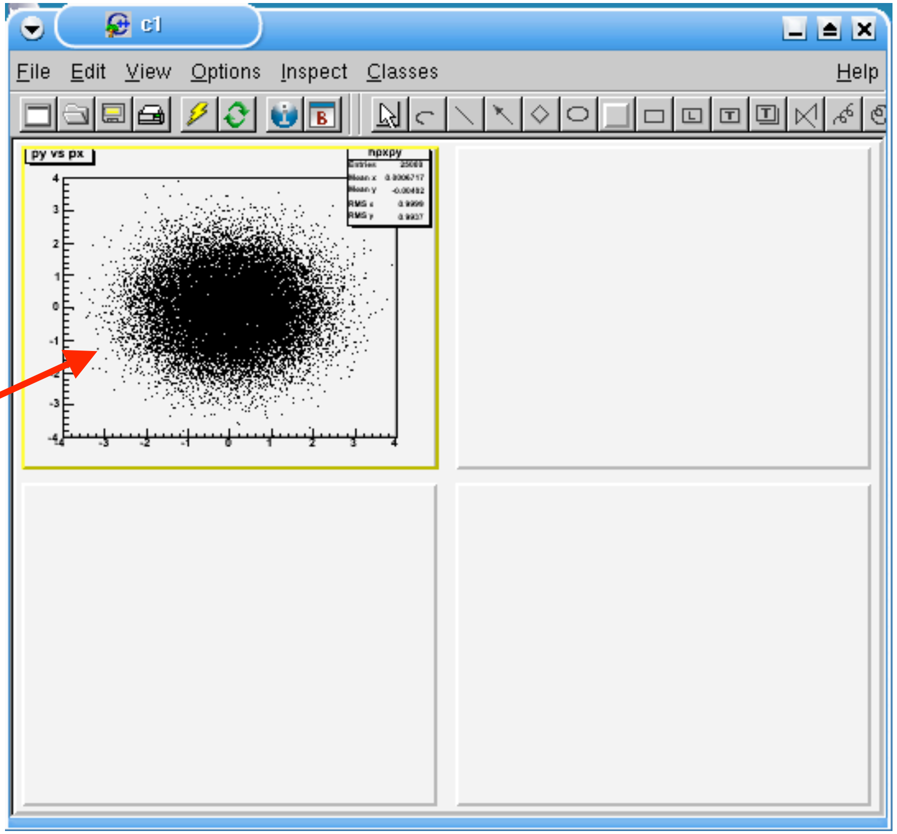
Displaying 2-D spectra

- Several options are available for displaying 2-D histograms:

Divide a new canvas in 4.
In the browser,
double-click the spectrum
"hpxpy" of file
"hsimple.root"

By default, a "scatter-plot" is drawn

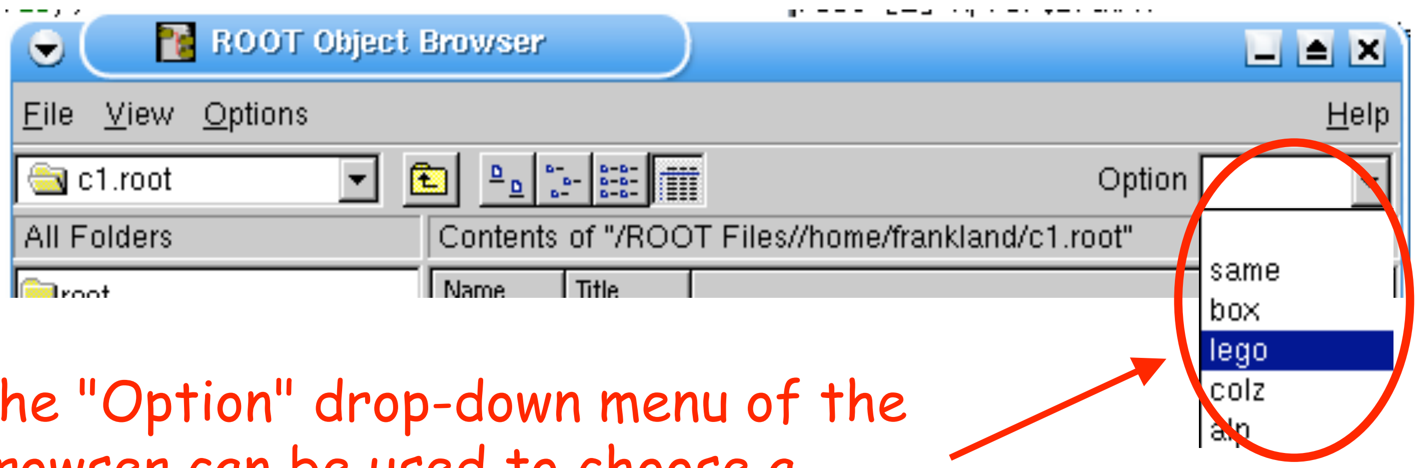
Not very nice (but sometimes useful)...



Entries 25000
Mean x 0.0006717
Mean y -0.00482
RMS x 0.9999
RMS y 0.9937

Displaying 2-D spectra

- Several options are available for displaying 2-D histograms:

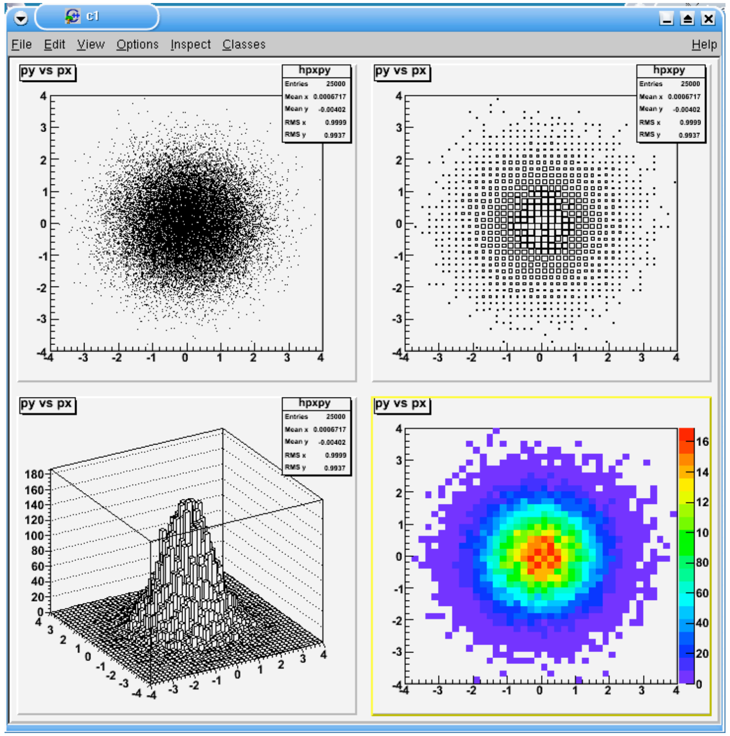


The "Option" drop-down menu of the browser can be used to choose a display option: "box", "lego", "colz" *

*Actually, there are more of them - "surf", "lego2", "arrow"…

An instructive little worked example

- Let's use our 2x2 canvas & the browser to display the 2-D histo "hpxpy" with 4 different plotting options:



hpxpy	
Entries	25000
Mean x	0.0006717
Mean y	-0.00402
RMS x	0.9999
RMS y	0.9937

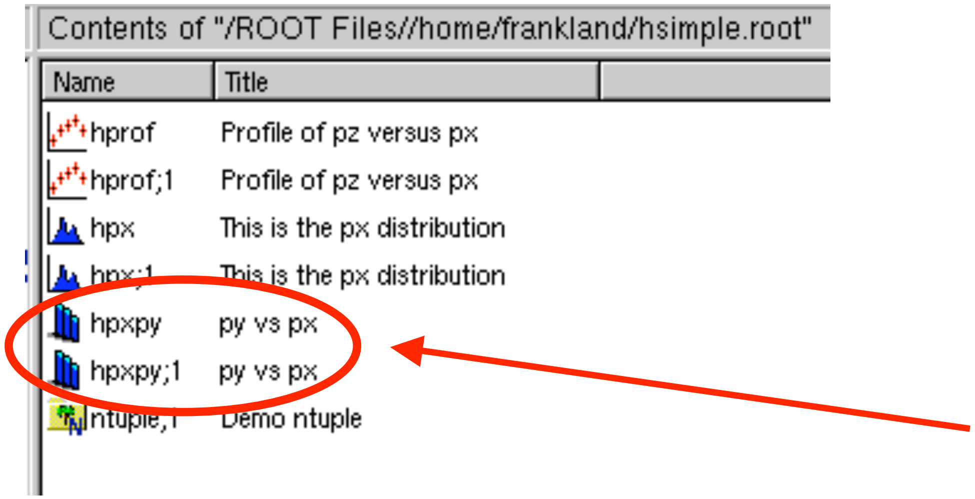
hpxpy	
Entries	25000
Mean x	0.0006717
Mean y	-0.00402
RMS x	0.9999
RMS y	0.9937

hpxpy	
Entries	25000
Mean x	0.0006717
Mean y	-0.00402
RMS x	0.9999
RMS y	0.9937

Can you do it using what you have learned so far ?

An instructive little worked example

- Can't get the same spectrum to appear in 2 pads at the same time ?



Contents of "/ROOT Files//home/frankland/hsimple.root"

Name	Title
hprof	Profile of pz versus px
hprof;1	Profile of pz versus px
hpx	This is the px distribution
hpx;1	This is the px distribution
hpxpy	py vs px
hpxpy;1	py vs px
ntuple;1	Demo ntuple

Look at the spectrum list in the browser.

Does something seem a little strange ?

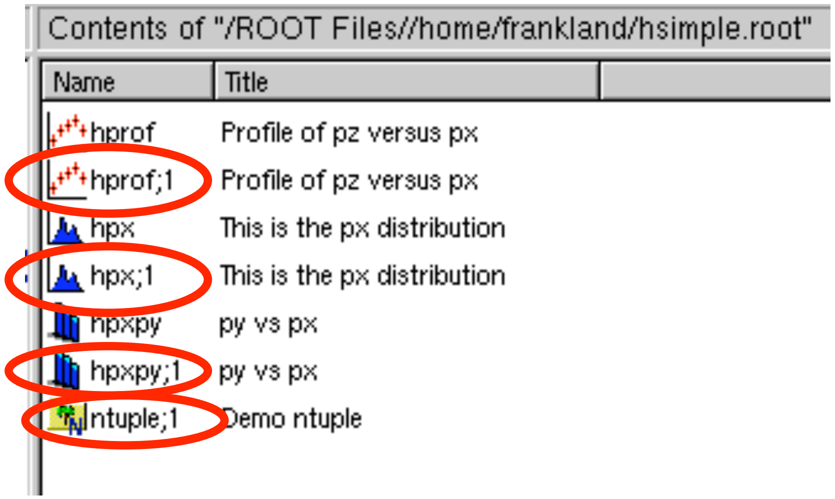
Why does 'hpxpy' appear twice in the list ? *

(Maybe it's not the only one)

*You might need to update the browser: "View"->"Refresh"

An instructive little worked example

- Can't get the same spectrum to appear in 2 pads at the same time ?



Contents of "/ROOT Files//home/frankland/hsimple.root"

Name	Title
hprof	Profile of pz versus px
hprof;1	Profile of pz versus px
hpx	This is the px distribution
hpx;1	This is the px distribution
hpxpy	py vs px
hpxpy;1	py vs px
ntuple;1	Demo ntuple

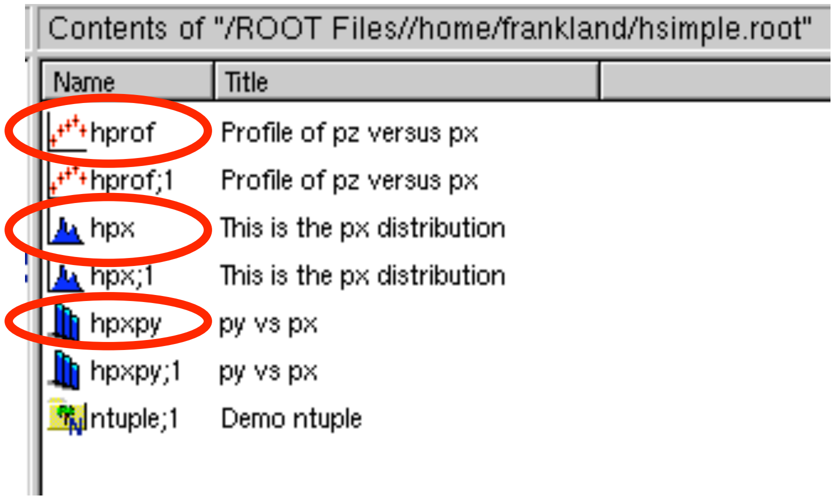
Names ending in ";1" or ";N" (N>=1) * are the objects in the file (on disk)

They cannot be modified (we opened the file in "Read Only" mode).

*the 'N' is a version or 'cycle' number

An instructive little worked example

- Can't get the same spectrum to appear in 2 pads at the same time ?



Contents of "/ROOT Files//home/frankland/hsimple.root"

Name	Title
hprof	Profile of pz versus px
hprof;1	Profile of pz versus px
hpx	This is the px distribution
hpx;1	This is the px distribution
hpxpy	py vs px
hpxpy;1	py vs px
ntuple;1	Demo ntuple

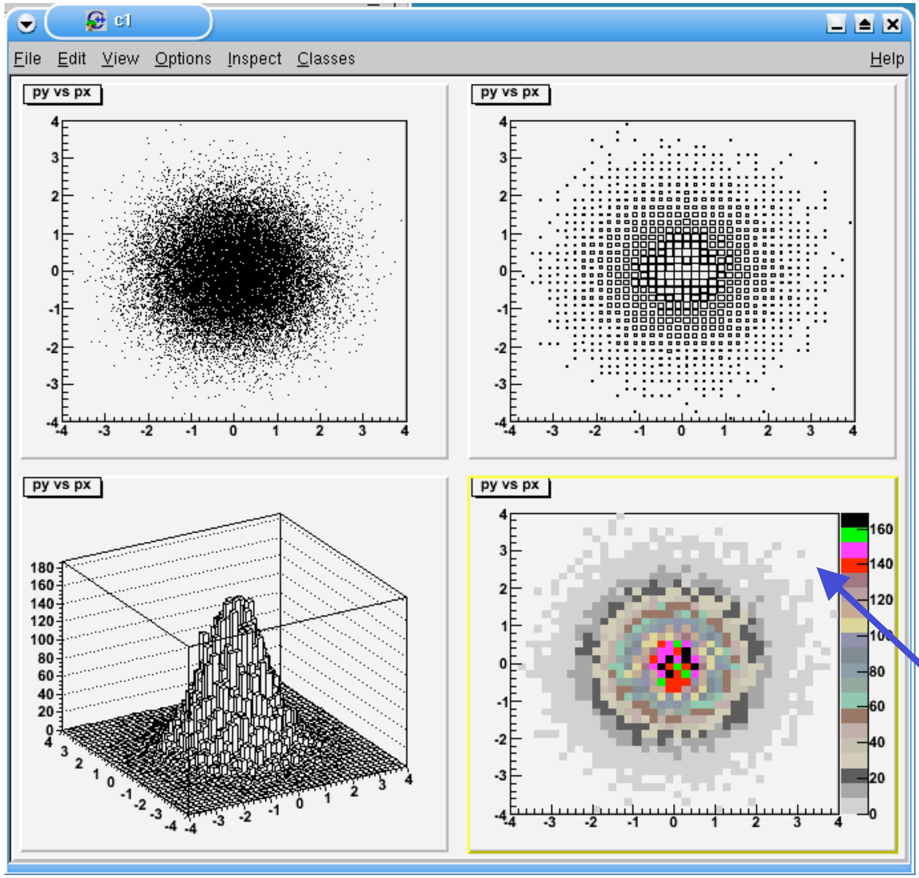
Names without ";" are memory-resident copies of the spectra: these we can modify.

A new copy is made every time you double-click a disk-resident object.

The previous copy is destroyed !

An instructive little worked example

- Disk-resident vs. memory-resident objects

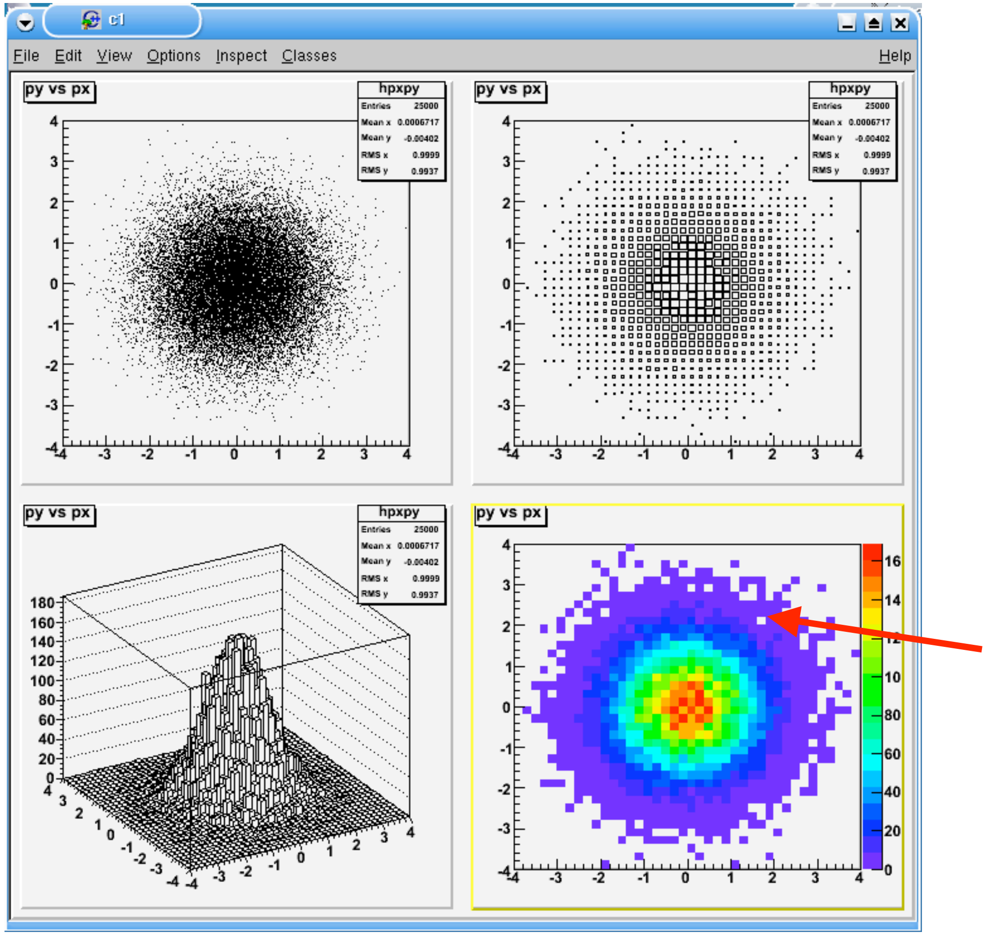


So to get the right result, you have to make sure to always click on 'hpxpy' (copy in memory) and not 'hpxpy;1' (disk-resident).

To remove the statistics box, use the 'Options' menu

An instructive little worked example

- Tip: nice colours if you can get them…



```
hpxpy
Entries      25000
Mean x   0.0006717
Mean y    -0.00402
RMS x       0.9999
RMS y       0.9937
```

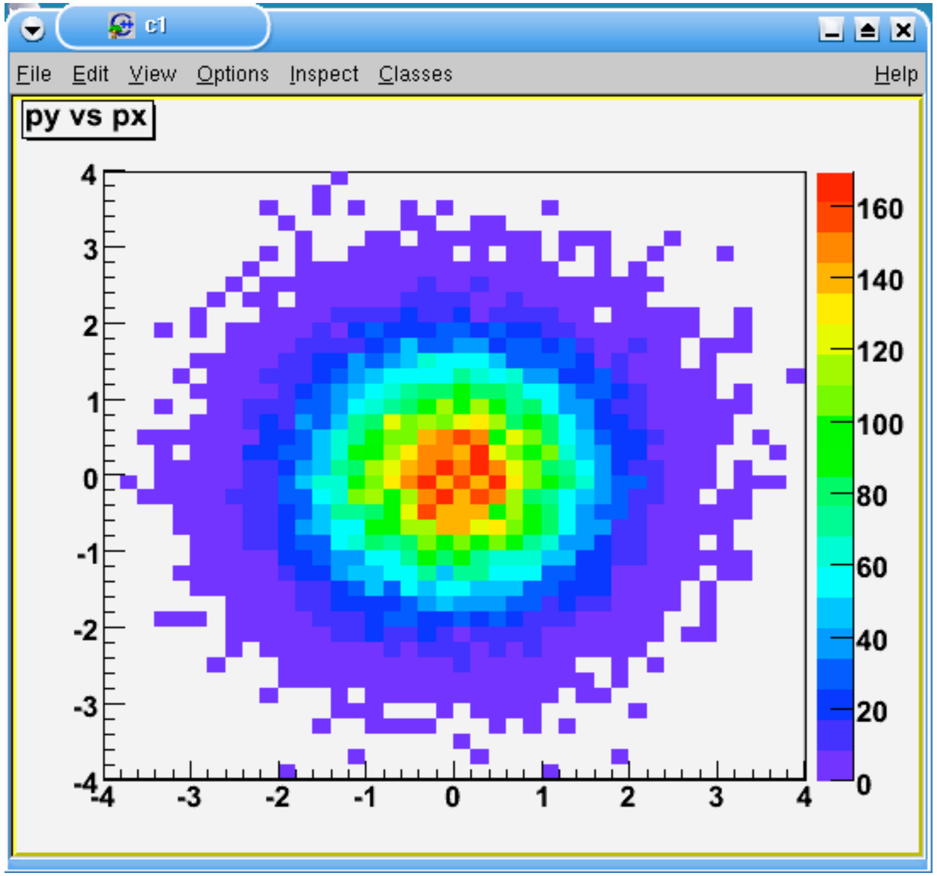
With option 'col'/'colz', the default colours are not very attractive.

This will make a great improvement:
root [0] gStyle->SetPalette(1)

Then update the canvas (menu "Options"->"Refresh") or click on the histogram.

Operations on 2-D spectra

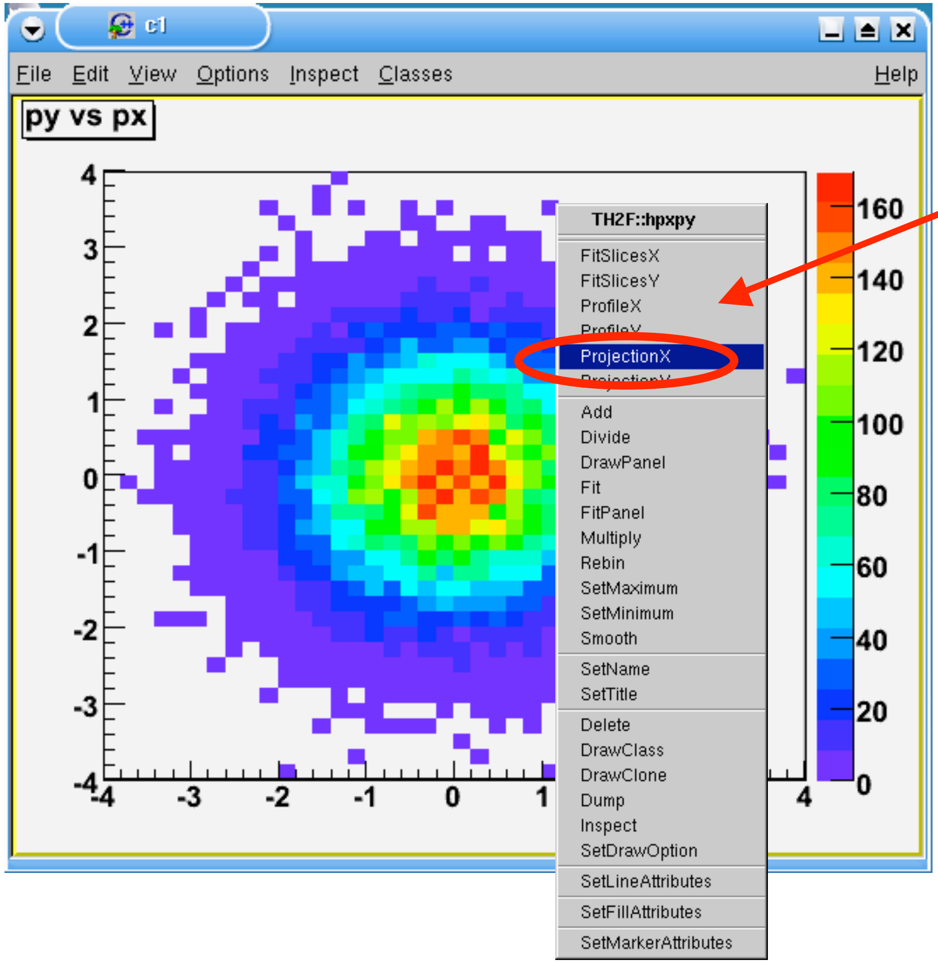
- It's easy to generate projections or profile histograms* from 2-D spectra



*i.e. plot the mean and s.d. of one of the two variables versus the other

Operations on 2-D spectra

- It's easy to generate projections or profile histograms from 2-D spectra

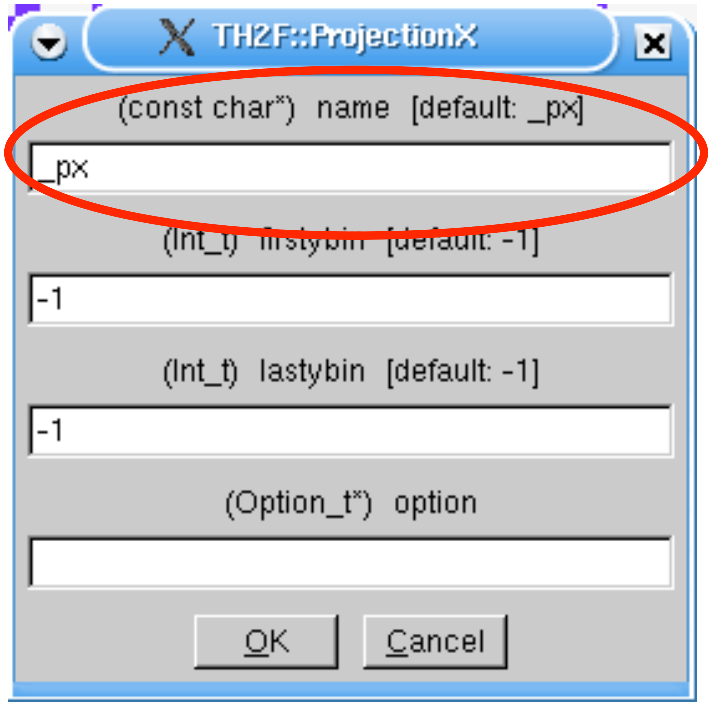


Right-click to open the context menu

Then select e.g. ProjectionX

Operations on 2-D spectra

- It's easy to generate projections or profile histograms from 2-D spectra



TH2F::ProjectionX

(const char*) name [default: _px]

_px

(Int_t) firstybin [default: -1]

-1

(Int_t) lastybin [default: -1]

-1

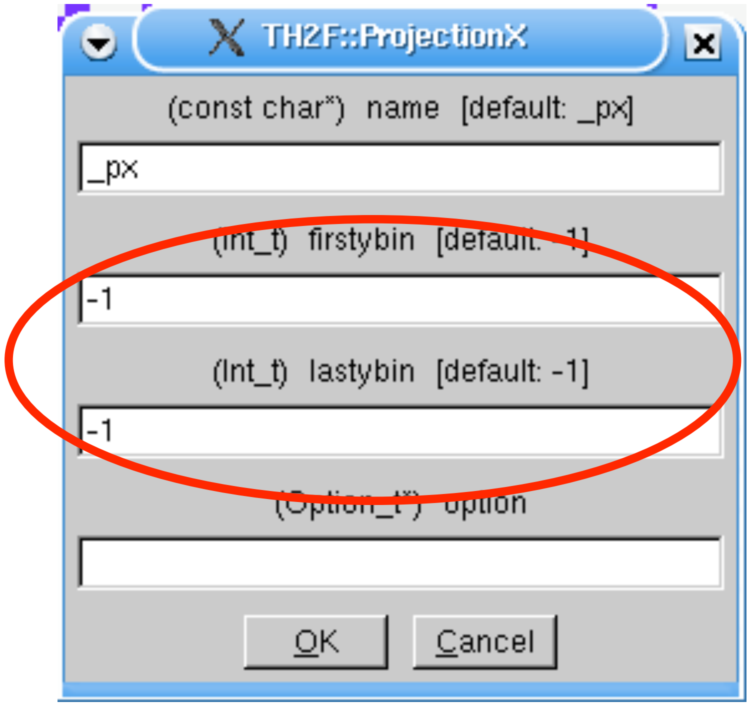
(Option_t*) option

You can give a name for the new projection.

By default (if you leave "_px") the name will be "hpxpy_px".

Operations on 2-D spectra

- It's easy to generate projections or profile histograms from 2-D spectra



TH2F::ProjectionX

(const char*) name [default: _px]

_px

(Int_t) firstybin [default: -1]

-1

(Int_t) lastybin [default: -1]

-1

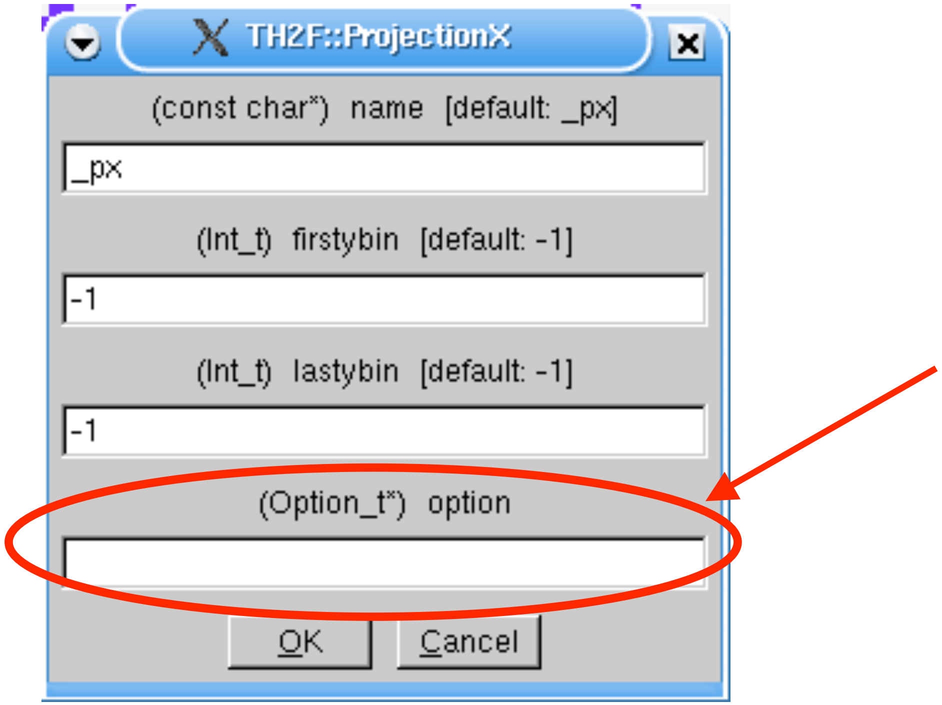
(Option_t*) option

You can limit the range of bins included in the projection.

By default, as here, all bins are included.

Operations on 2-D spectra

- It's easy to generate projections or profile histograms from 2-D spectra



TH2F::ProjectionX

(const char*) name [default: _px]

_px

(Int_t) firstybin [default: -1]

-1

(Int_t) lastybin [default: -1]

-1

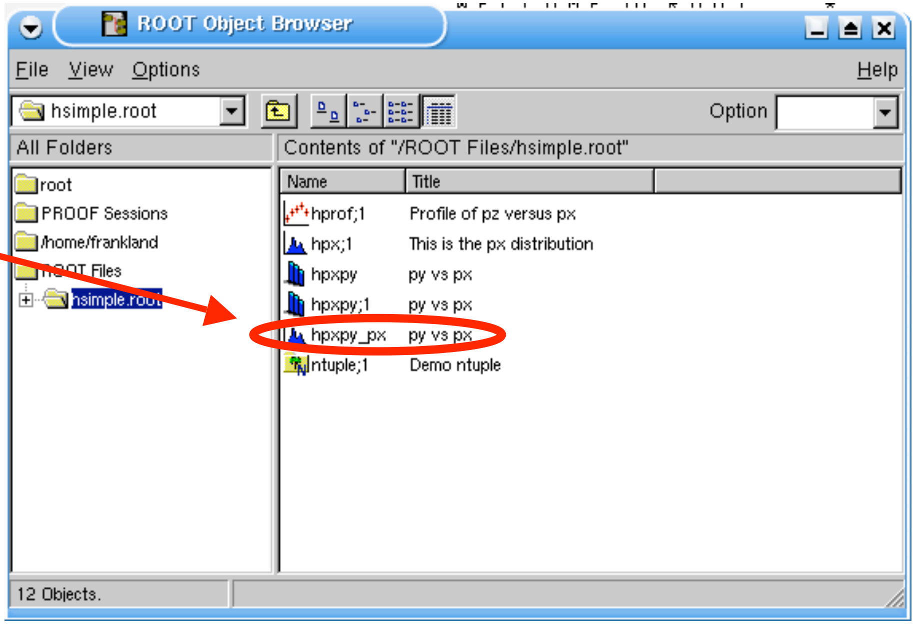
(Option_t*) option

Options:
"d" - plot in active canvas/pad
"e" - calculate errors
"[cut]" - use named graphical cut to select bins (Day 4!)

Operations on 2-D spectra

- It's easy to generate projections or profile histograms from 2-D spectra

By default, the projection is not displayed, but should be present in the browser (after a "Refresh")

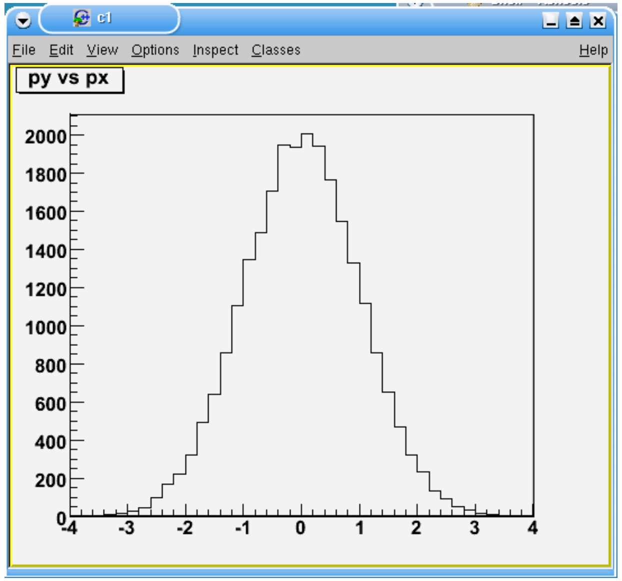


Contents of "/ROOT Files/hsimple.root"

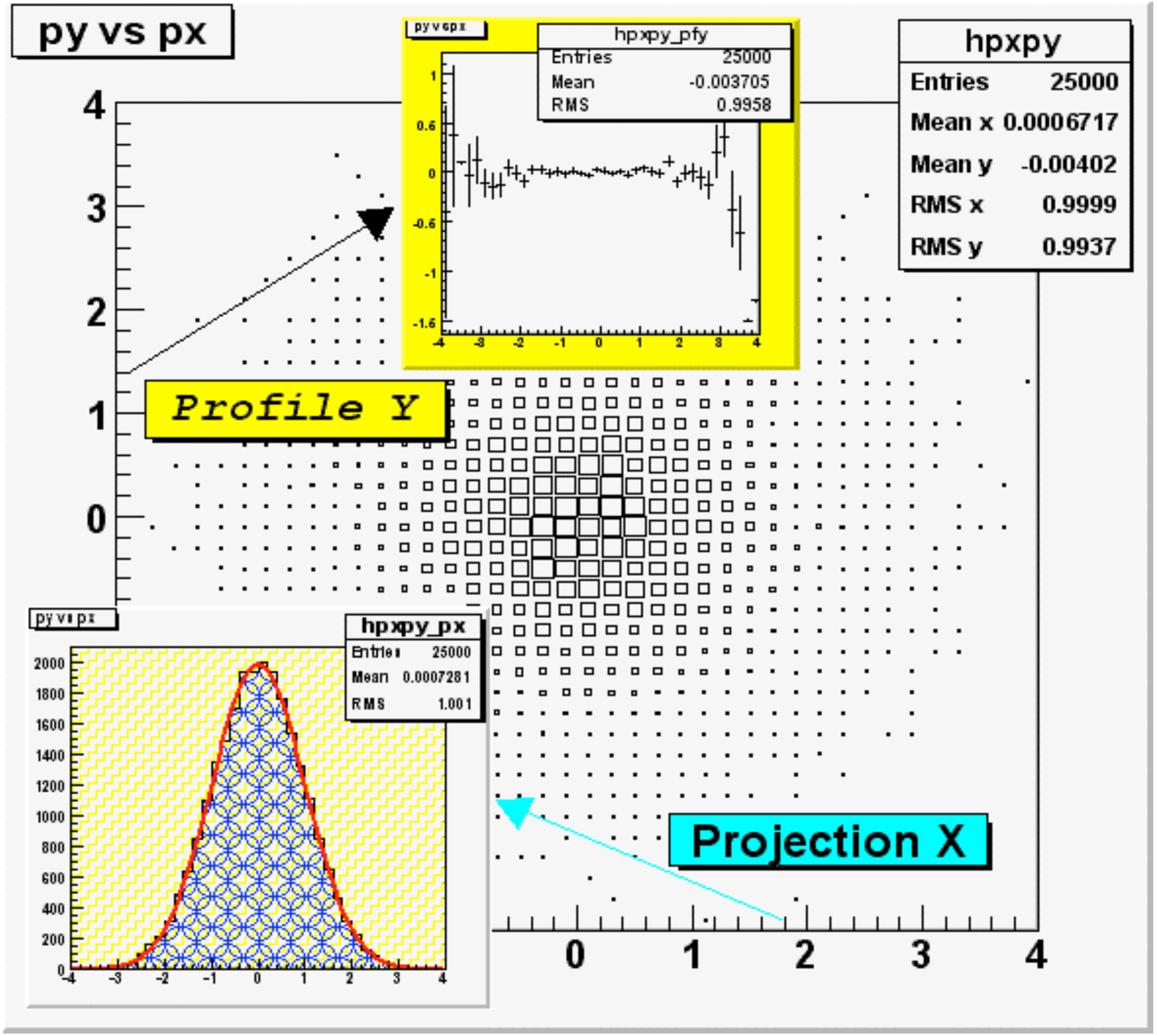
- root
- PROOF Sessions
- /home/frankland
- ROOT Files
- hsimple.root

Name	Title
hprof;1	Profile of pz versus px
hpx;1	This is the px distribution
hpxpy	py vs px
hpxpy;1	py vs px
hpxpy_px	py vs px
ntuple;1	Demo ntuple

12 Objects.



Exercise



hpxpy_pfy

Entries	25000
Mean	-0.003705
RMS	0.9958

hpxpy

Entries	25000
Mean x	0.0006717
Mean y	-0.00402
RMS x	0.9999
RMS y	0.9937

hpxpy_px

Entries	25000
Mean	0.0007281
RMS	1.001

Profile Y

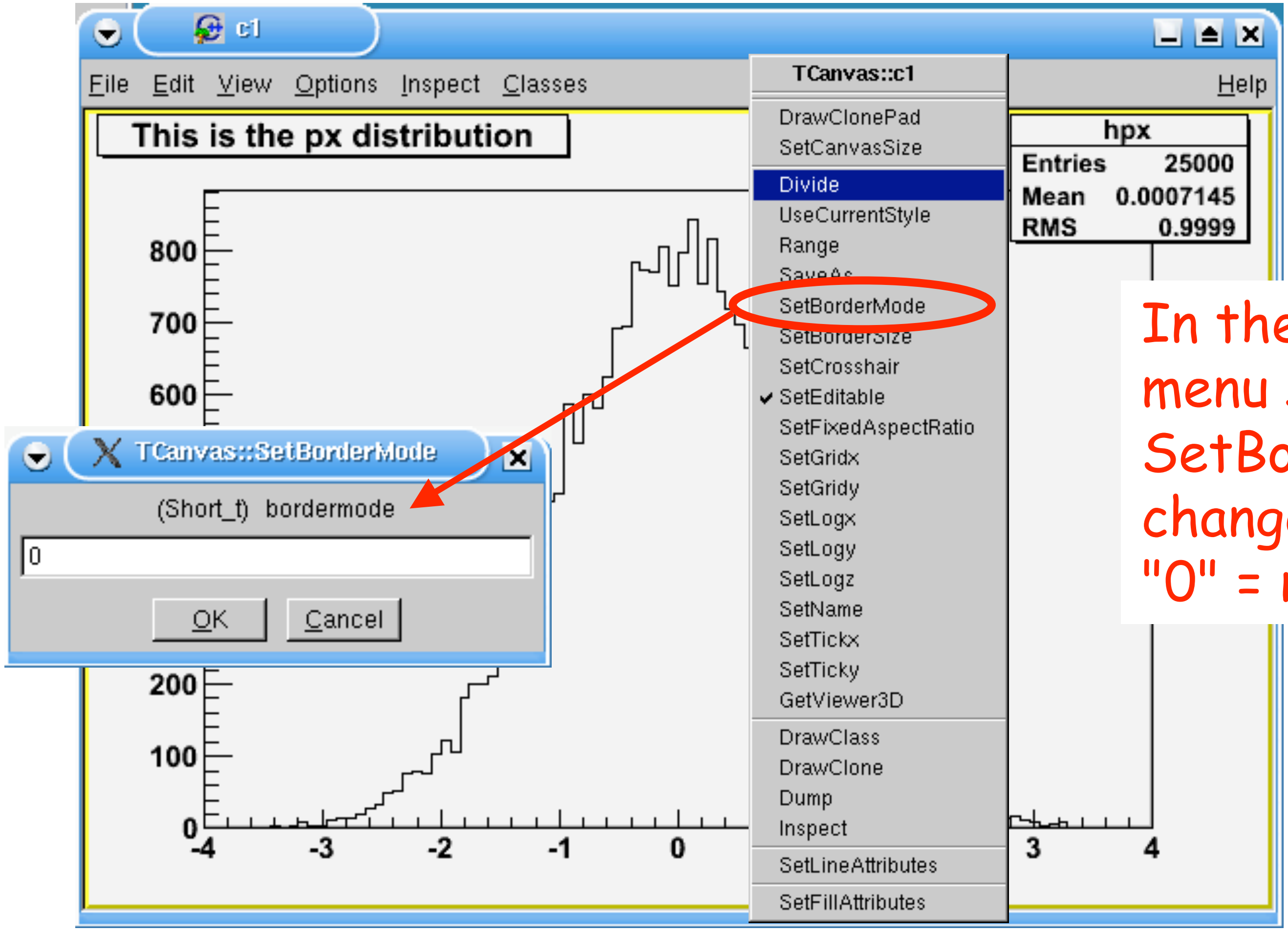
Projection X

Saving your figures

It'd be a pity to lose everything…

Saving a masterpiece

- Before saving, we'll remove the yellow border of the active canvas - otherwise it'll be in the figure



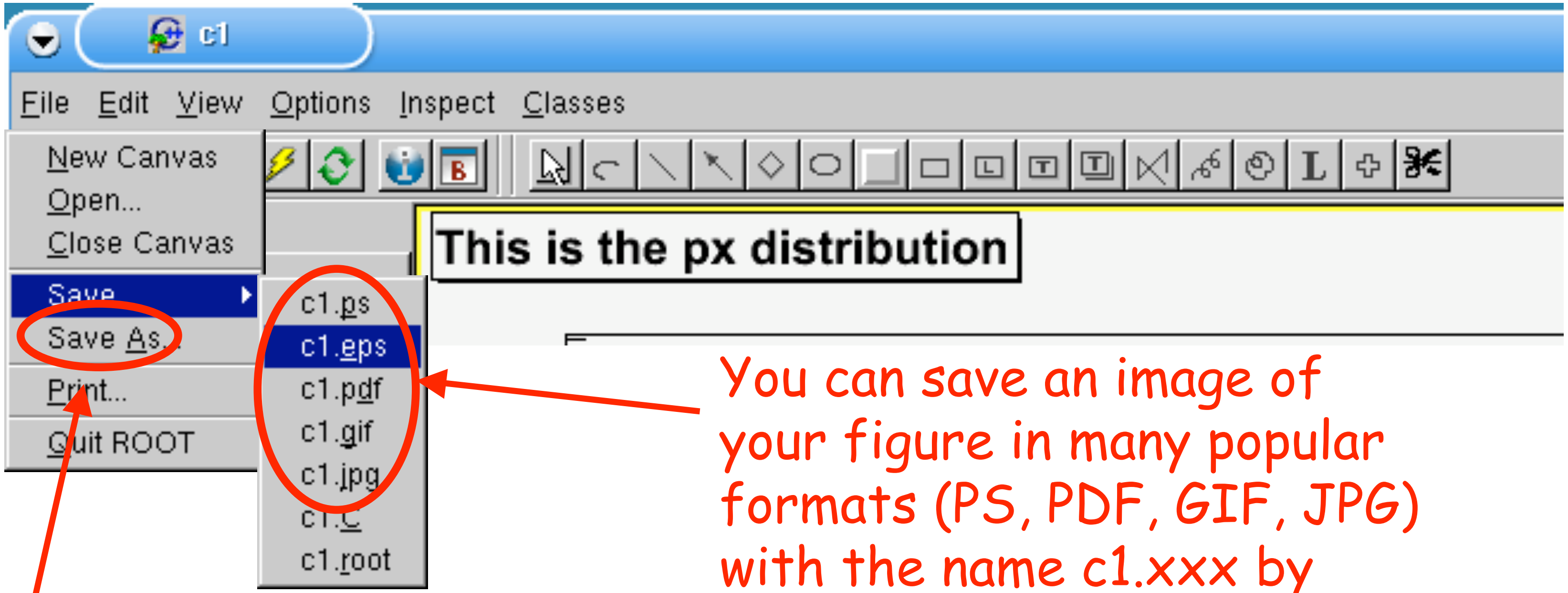
(Short_t) bordermode

0

In the canvas' context menu select SetBorderMode change the value: "0" = no border

Saving a masterpiece

- Open the menu "File", sub-menu "Save"

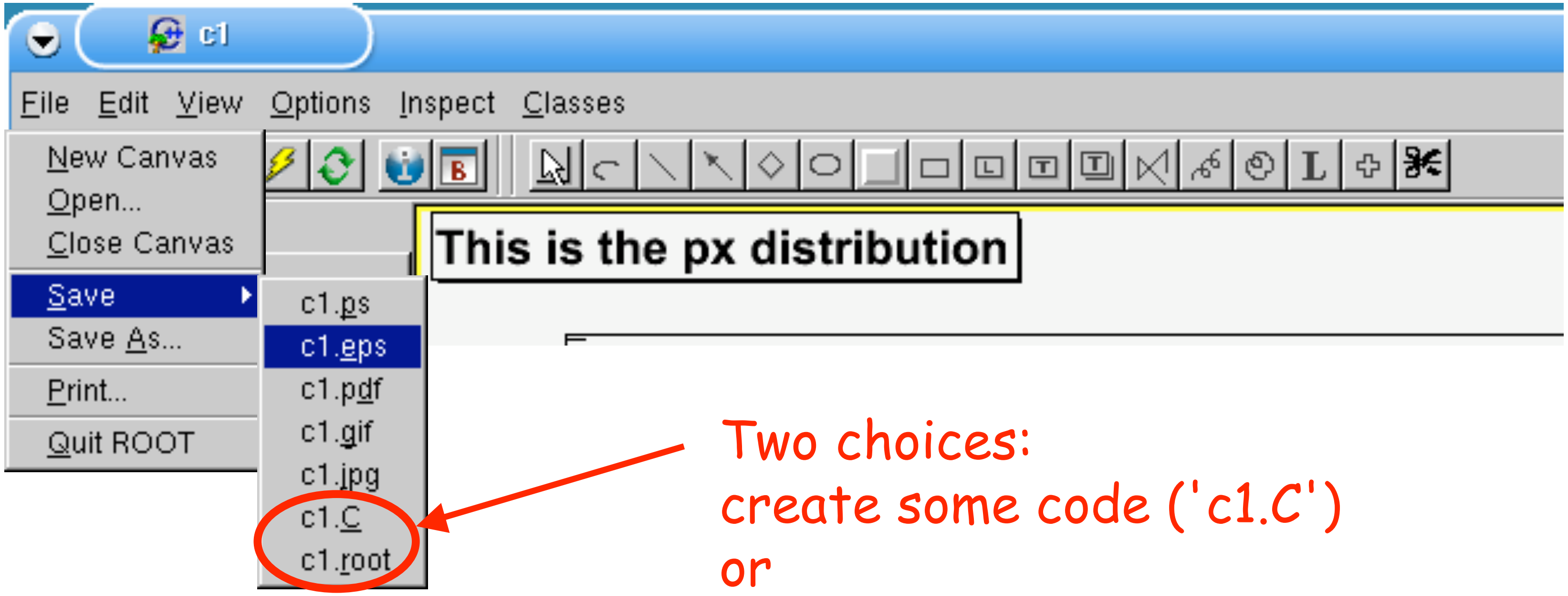


You can save an image of your figure in many popular formats (PS, PDF, GIF, JPG) with the name c1.xxx by default*

*With "Save As..." you can even choose the name you want

Saving a masterpiece

- What if I want to change the figure later ?

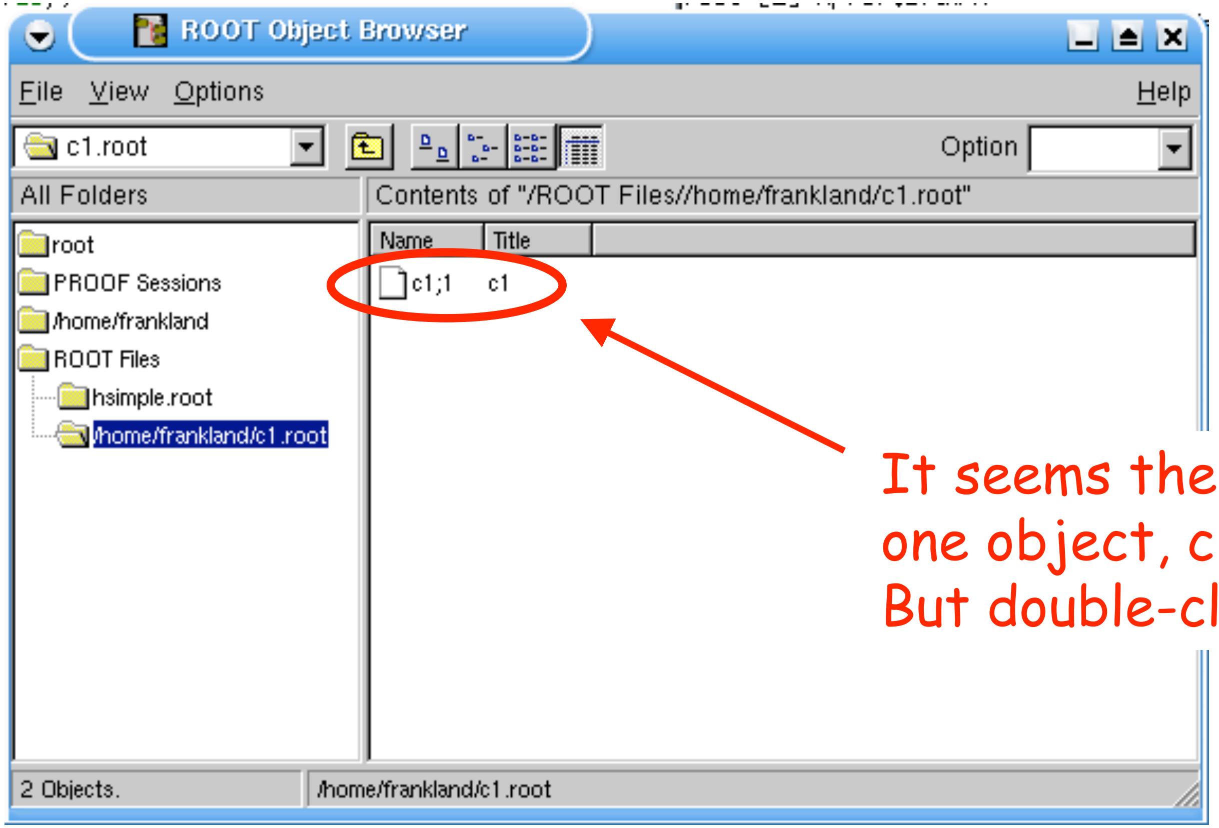


This is the px distribution

Two choices:
create some code ('c1.C')
or
save the objects ('c1.root')

Save the objects ???

- By choosing ".root" in menu "Save", a file 'c1.root' is created.
- In order to display the image later, you need to open this file, e.g. with the browser:



Contents of "/ROOT Files//home/frankland/c1.root"

Name	Title
c1;1	c1

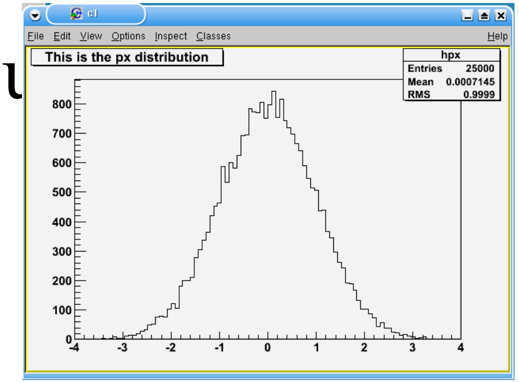
2 Objects.

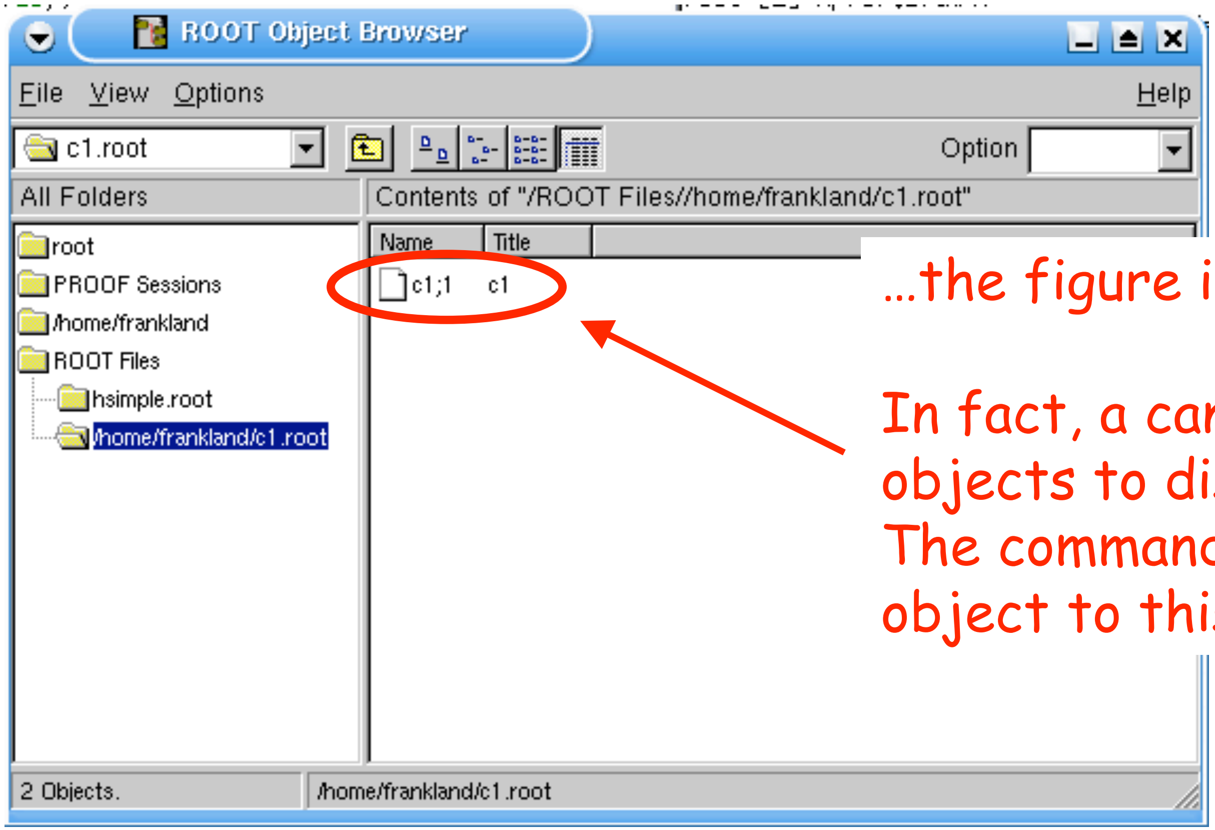
/home/frankland/c1.root

It seems the file only contains one object, c1.
But double-click it and…

Save the objects ???

- By choosing ".root" in menu "Save", a file 'c1.root' is created.
- In order to display the image later, you open this file, e.g. with the browser:





Contents of "/ROOT Files//home/frankland/c1.root"

c1;1 c1

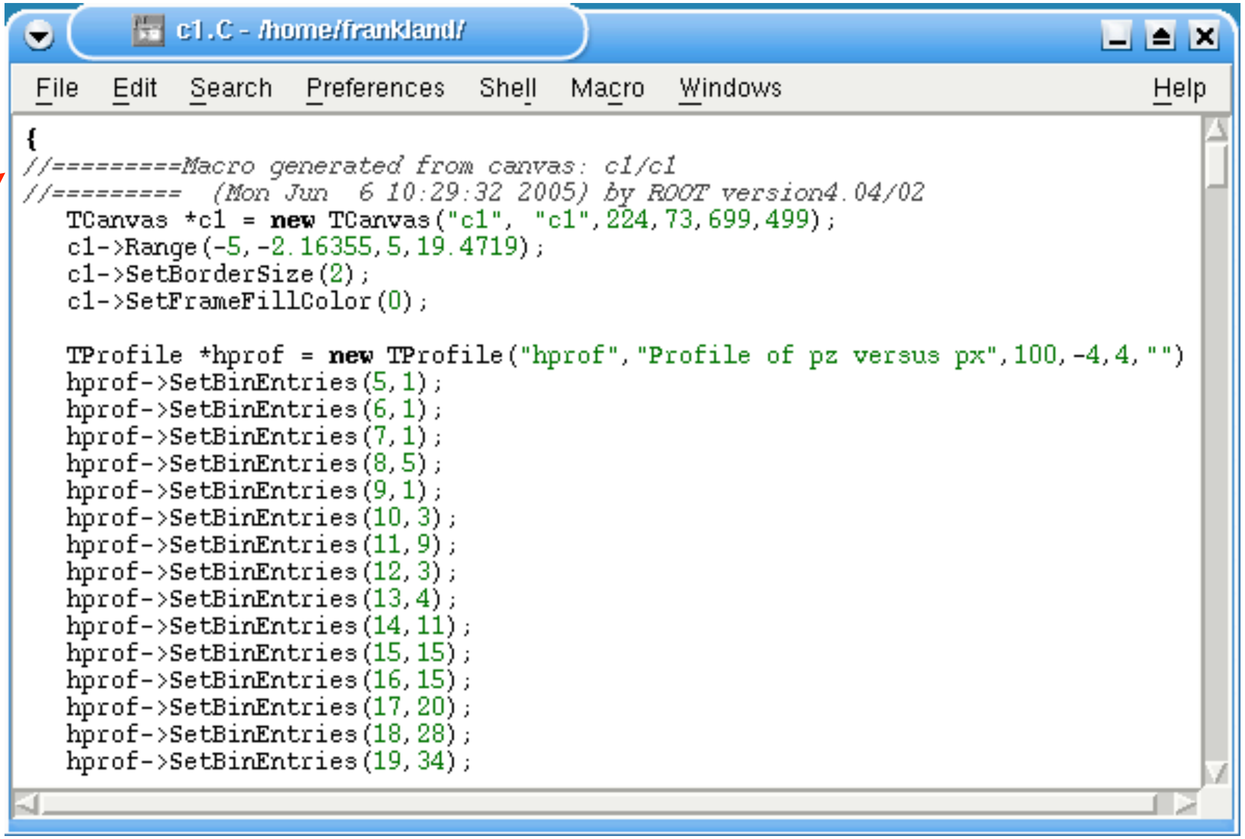
2 Objects. /home/frankland/c1.root

…the figure is displayed.

In fact, a canvas is a sort of list of objects to display on the screen. The command "Draw" just adds an object to this list…

Create some code ?

- By choosing "c1.C" in the menu, a file is created which contains all the (C++) instructions necessary to recreate our figure



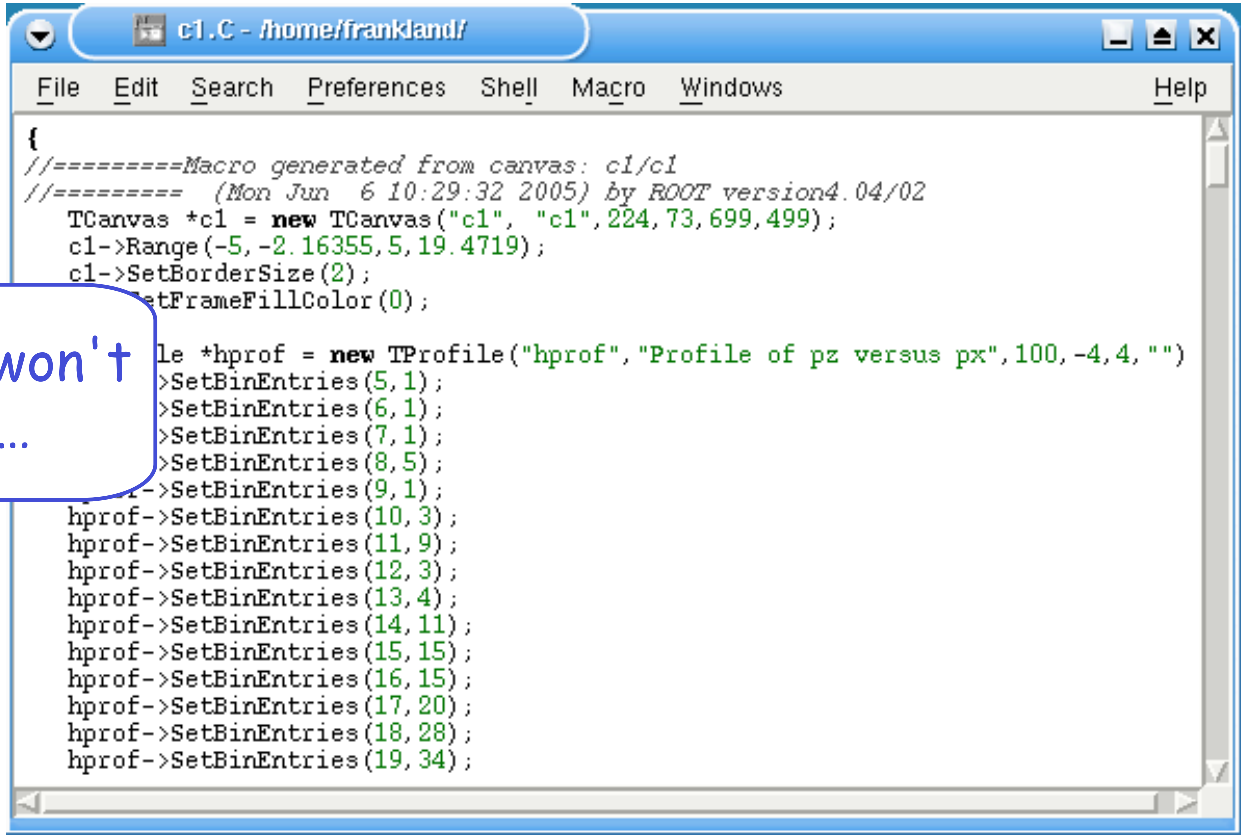
```
{
//=========Macro generated from canvas: c1/c1
//=========  (Mon Jun  6 10:29:32 2005) by ROOT version4.04/02
   TCanvas *c1 = new TCanvas("c1", "c1",224,73,699,499);
   c1->Range(-5,-2.16355,5,19.4719);
   c1->SetBorderSize(2);
   c1->SetFrameFillColor(0);

   TProfile *hprof = new TProfile("hprof","Profile of pz versus px",100,-4,4,"")
   hprof->SetBinEntries(5,1);
   hprof->SetBinEntries(6,1);
   hprof->SetBinEntries(7,1);
   hprof->SetBinEntries(8,5);
   hprof->SetBinEntries(9,1);
   hprof->SetBinEntries(10,3);
   hprof->SetBinEntries(11,9);
   hprof->SetBinEntries(12,3);
   hprof->SetBinEntries(13,4);
   hprof->SetBinEntries(14,11);
   hprof->SetBinEntries(15,15);
   hprof->SetBinEntries(16,15);
   hprof->SetBinEntries(17,20);
   hprof->SetBinEntries(18,28);
   hprof->SetBinEntries(19,34);
```

You can look at the result in any text editor…

Create some code ?

- Tomorrow we will see how to use this kind of code to create analysis scripts, etc.



```
{
//=========Macro generated from canvas: c1/c1
//=========  (Mon Jun  6 10:29:32 2005) by ROOT version4.04/02
   TCanvas *c1 = new TCanvas("c1", "c1",224,73,699,499);
   c1->Range(-5,-2.16355,5,19.4719);
   c1->SetBorderSize(2);
        etFrameFillColor(0);

         le *hprof = new TProfile("hprof","Profile of pz versus px",100,-4,4,"")
          >SetBinEntries(5,1);
          >SetBinEntries(6,1);
          >SetBinEntries(7,1);
          >SetBinEntries(8,5);
          >SetBinEntries(9,1);
   hprof->SetBinEntries(10,3);
   hprof->SetBinEntries(11,9);
   hprof->SetBinEntries(12,3);
   hprof->SetBinEntries(13,4);
   hprof->SetBinEntries(14,11);
   hprof->SetBinEntries(15,15);
   hprof->SetBinEntries(16,15);
   hprof->SetBinEntries(17,20);
   hprof->SetBinEntries(18,28);
   hprof->SetBinEntries(19,34);
```