ROOT Tutorial

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ROOT

- What is ROOT ?
  - ROOT is an object-oriented C++ analysis package
  - User-compiled code can be called to produce 1-d, 2-d, and 3-d graphics and histograms…
- ROOT uses a language called CINT (C/C++ Interpreter) which contains several extensions to C++
  - CINT allows the use of a dot "." while an arrow "->" is used in C++
  - CINT commands always start with "."

Useful Links

ROOT web-page: http://root.cern.ch/

ROOT can be downloaded from
http://root.cern.ch/twiki/bin/view/ROOT/Download

ROOT Tutorials:

- http://root.cern.ch/root/Tutorials.html
- Babar ROOT Tutorial I
- Babar ROOT Tutorial II
- Nevis tutorial:
  http://www.nevis.columbia.edu/~seligman/root-class/

All files used in this tutorial can be found at
http://home.fnal.gov/~tulika/NEPPSR/

ROOT Basics

Start ROOT:

- type “root”
- (to skip the introductory welcome type “root -l”)

```
[tulika@cmslpc04 ~]$ root
  *******************************************
  *                                         *
  *        W E L C O M E  to  R O O T       *
  *                                         *
  *   Version   5.14/00f       29 May 2007  *
  *                                         *
  *  You are welcome to visit our Web site  *
  *          http://root.cern.ch            *
  *                                         *
  *******************************************

FreeType Engine v2.1.9 used to render TrueType fonts.
Compiled on 29 June 2007 for linux with thread support.

CINT/ROOT C/C++ Interpreter version 5.16.16, November 24, 2006
Type ? for help. Commands must be C++ statements.
Enclose multiple statements between { }.
root [0]
```

For help: type “.?”, “.h”

Quit ROOT: type “.q”

ROOT analysis

A typical ROOT analysis could be:

- Take variables in an n-tuple, make histograms, calculate quantities, and perform fits…
  - How does one make a histogram ?
  - What is an n-tuple ?
  - How are calculations done ?
  - How does one fit ?

Histograms

Making your first histogram:

- Histograms can be 1-d, 2-d and 3-d
- Declare a histogram to be filled with floating point numbers:

TH1F *histName = new TH1F("histName", "histTitle", num_bins,x_low,x_high)

```
TH1F *my_hist = new TH1F("my_hist", "My First Histogram", 100, 2, 200)
```

Note: Bin 0 → underflow (i.e. entries < x_low)

Bin (num_bins+1) → overflow (i.e. entries > x_high)

2-d and 3-d histograms can be booked similarly…

```
TH2F *myhist = new TH2F("myhist", "My Hist", 100, 2, 200, 200, 0,500)
```

Drawing Histograms

- To draw:
  - my_hist->Draw();
- To fill a histogram:
  - my_hist->Fill(50);
  - my_hist->Fill(100, 3); // the number 100 has weight=3
- Update the histogram:
  - my_hist->Draw();

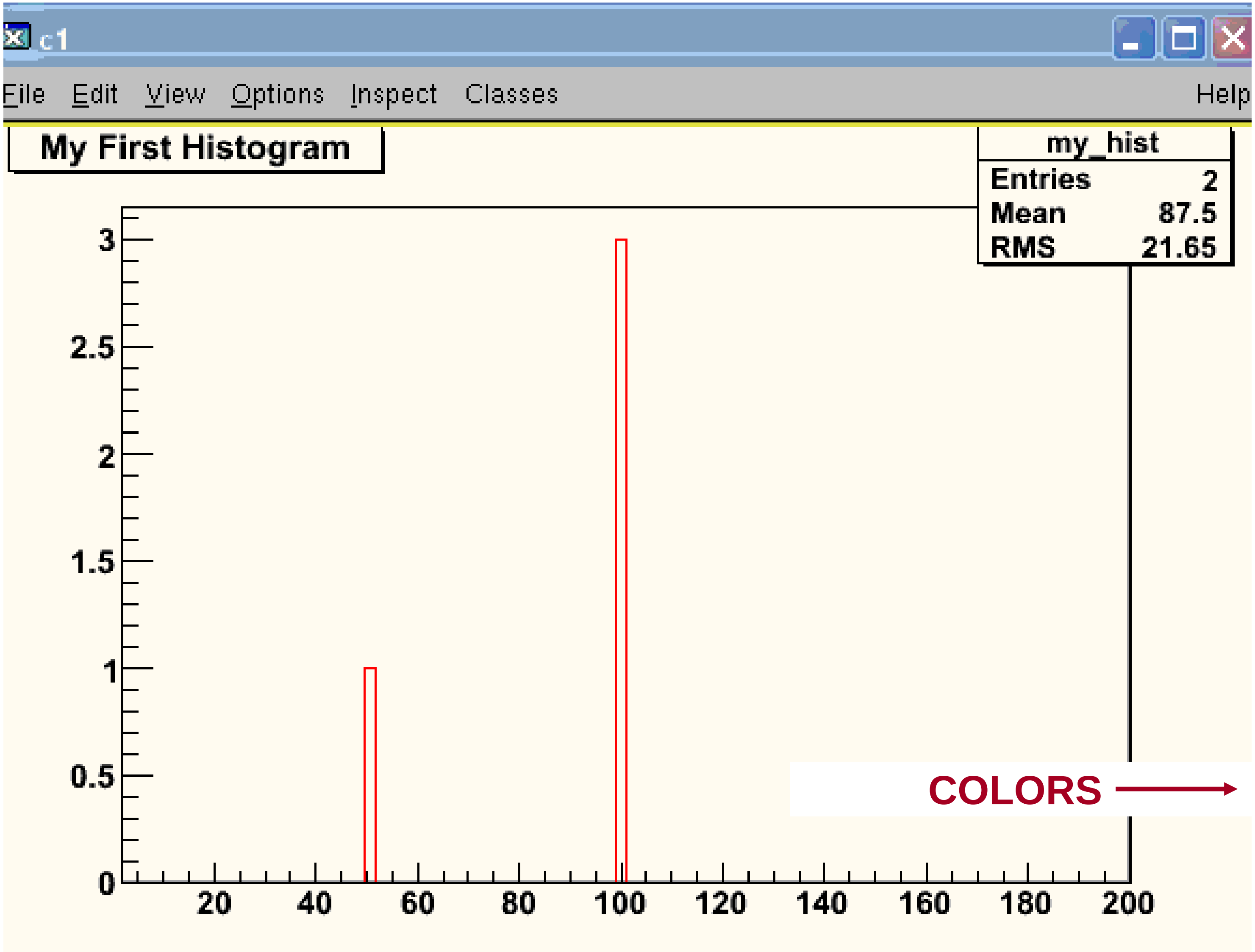
Histogram attributes:

- Change line color:
  - my_hist->SetLineColor(2); //red
  - or my_hist->SetLineColor(kRed);
  - my_hist->Draw();

Look at the official documentation for the different drawing options

```
[tulika@cmslpc04 ~]$ root -l
root [0]
root [0] TH1F *my_hist = new TH1F("my_hist", "My First Histogram", 100, 2, 200);
root [1] my_hist->Draw()
<TCanvas::MakeDefCanvas>: created default TCanvas with name c1
root [2] my_hist->Fill(50);
root [3] my_hist->Fill(100,3);
root [4] my_hist->Draw();
root [5] my_hist->SetLineColor(2);
root [6] my_hist->Draw();
root [7]
```

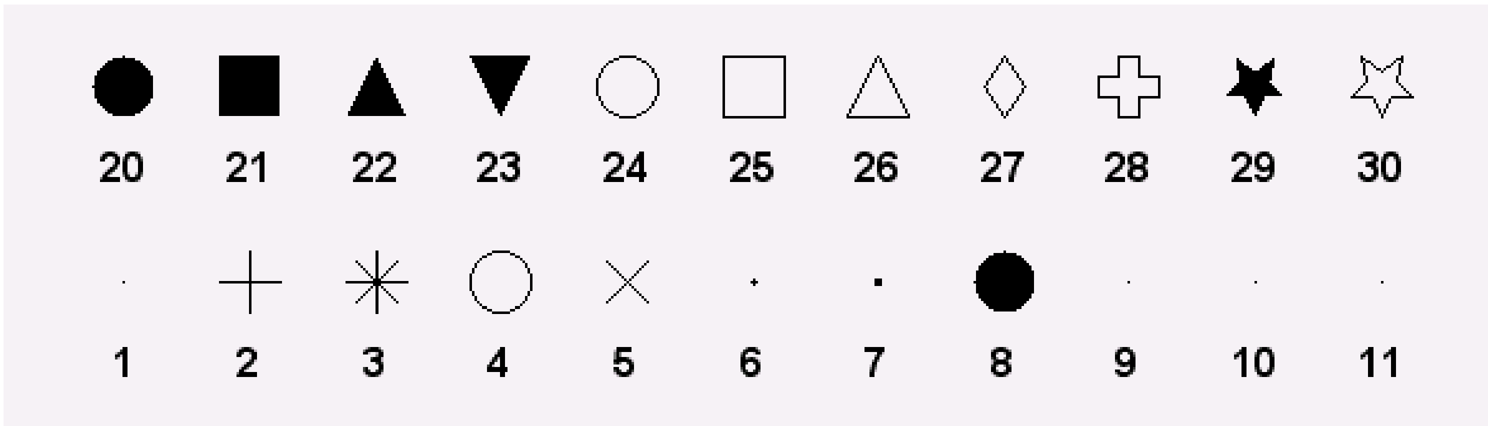
ROOT Session



1	Black
2	Red
3	Light green
4	Blue
5	Yellow
6	Magenta
7	Cyan
8	Green

Drawing Options

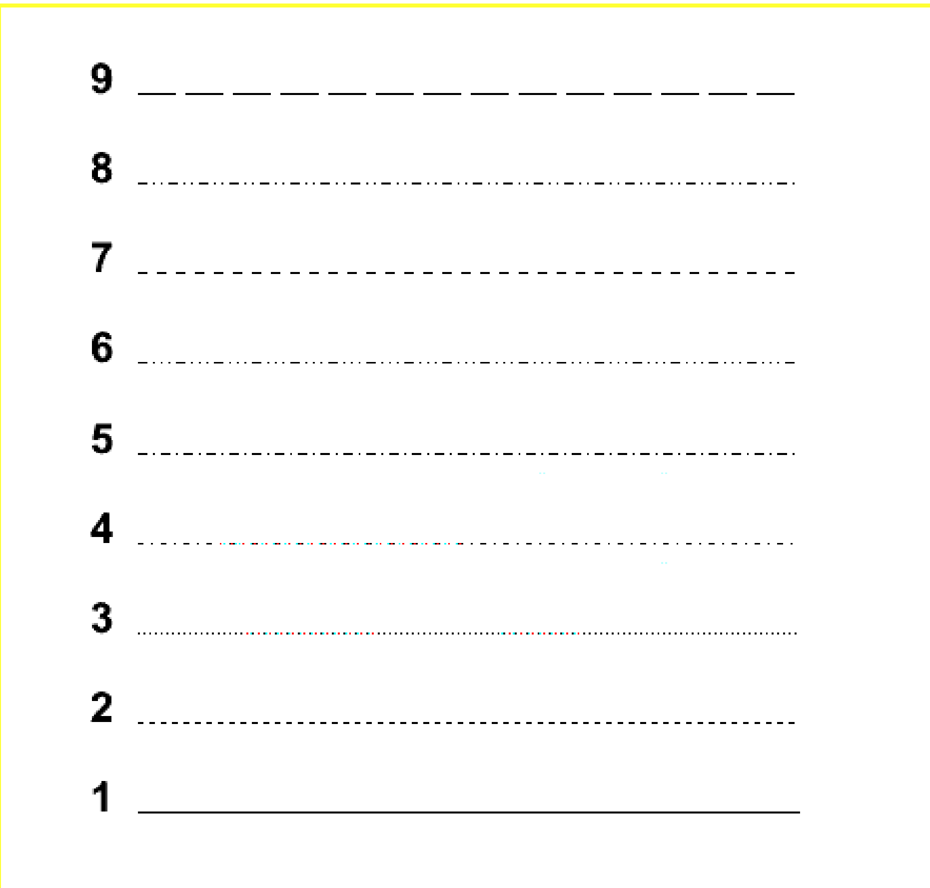
Marker Styles



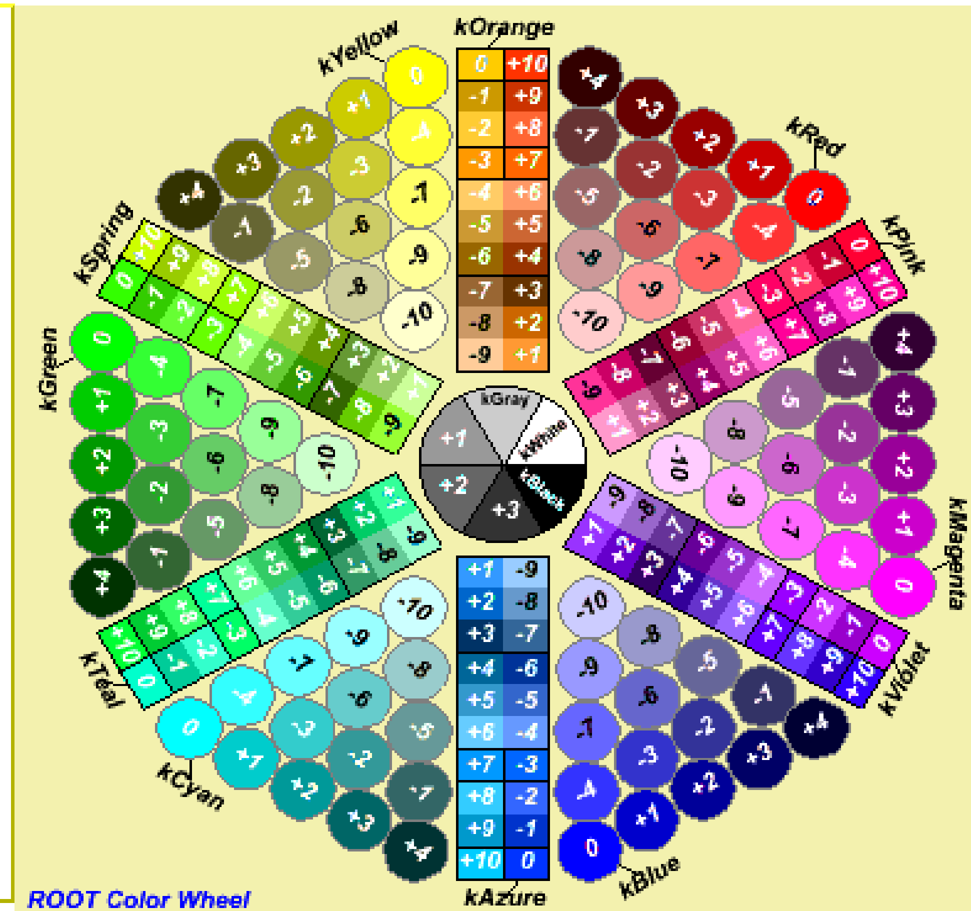
Colors

Drawing Options

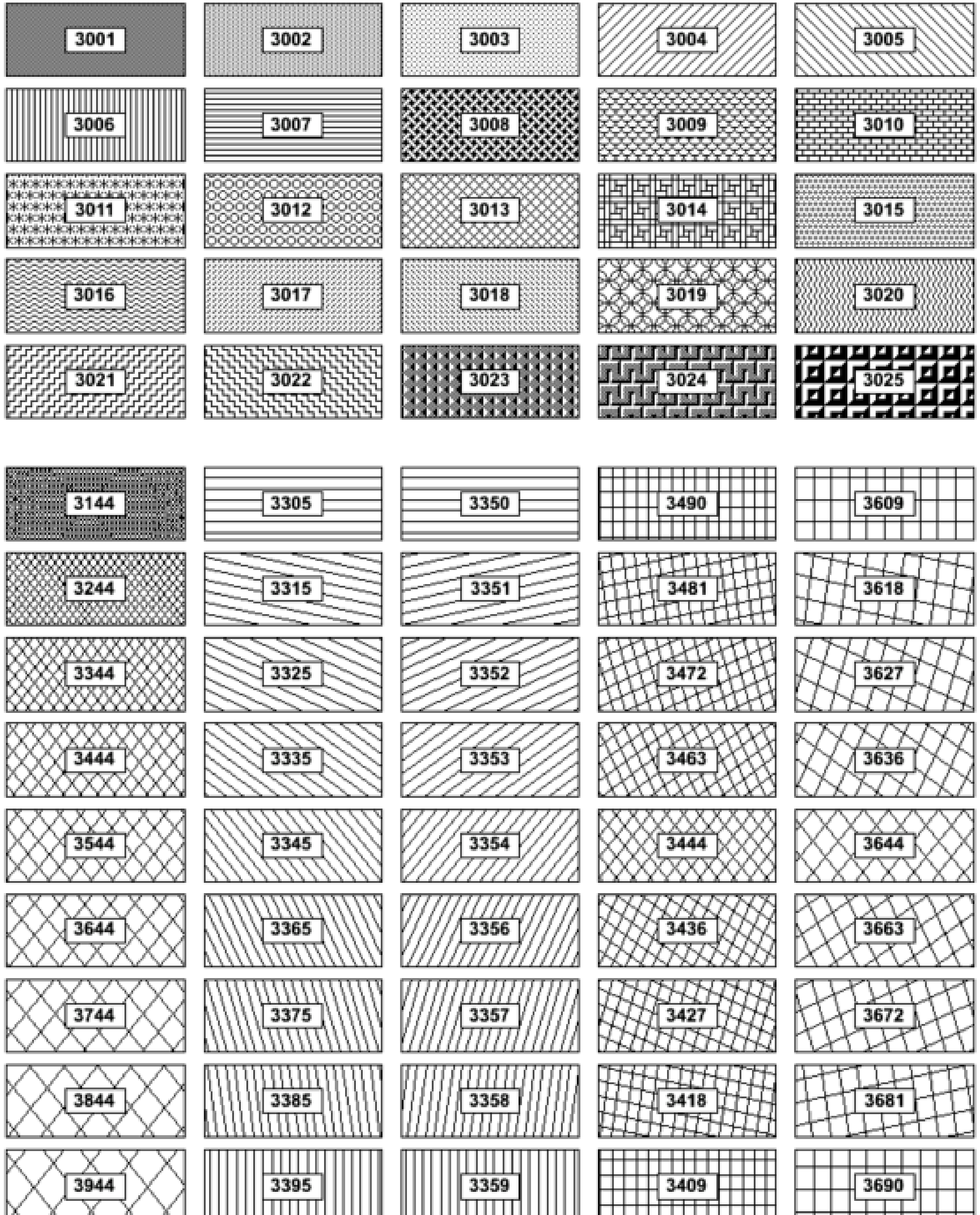
LINE STYLES



COLOR WHEEL



FILL STYLES


3001
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3409
3690

LaTeX in ROOT

≤	#leq	/	#/	∞	#infty	ƒ	#voidb
♣	#club	♦	#diamond	♥	#heart	♠	#spade
↔	#leftrightarrow	←	#leftarrow	↑	#uparrow	→	#rightarrow
↓	#downarrow	°	#circ	±	#pm	″	#doublequote
≥	#geq	×	#times	∝	#propto	∂	#partial
•	#bullet	÷	#divide	≠	#neq	≡	#equiv
≈	#approx	…	#3dots	∣	#cbar	—	#topbar
↵	#downleftarrow	ℵ	#aleph	ℑ	#Jgothic	ℜ	#Rgothic
℘	#voidn	⊗	#otimes	⊕	#oplus	∅	#oslash
∩	#cap	∪	#cup	⊃	#supset	⊇	#supseteq
⊄	#notsubset	⊂	#subset	⊆	#subseteq	∈	#in
∉	#notin	∠	#angle	∇	#nabla	®	#oright
©	#ocopyright	™	#trademark	∏	#prod	√	#surd
·	#upoint	¬	#corner	∧	#wedge	∨	#vee
⇔	#Leftrightarrow	⇐	#Leftarrow	⇑	#Uparrow	⇒	#Rightarrow
⇓	#Downarrow	♦	#diamond	〈	#LT	®	#void1
©	#copyright	™	#void3	∑	#sum	⎛	#arctop
∣	#lbar	⎝	#arcbottom	—	#topbar	∣	#void8
⌊	#bottombar	⎜	#arcbar	⎨	#ltbar	Å	#AA
å	#aa		#void06	〉	#GT	∫	#int

The "Stats Box"

The Statistics Box :

- Setup with:
  - gStyle->SetOptStat(mode)
  - (ksiourmen)

- Default is (000001111):

- To show overflows and underflows:
  - gStyle->SetOptStat(111111);

- To remove entirely:
  - gStyle->SetOptStat(0);

k=1	kurtosis
K=2	Kurtosis+error
s=1	Skewness
S=2	Skewness+error
i=1	Integral
o=1	Overflow
u=1	Underflow
r=1	RMS
R=2	RMS+error
m=1	Mean
M=2	Mean+error
e=1	Entries
n=1	Name

More on histograms

- Draw a second histogram on top of the first:
  - First book the histogram
  - Use another color to differentiate
  - Fill the histogram
  - Draw the histogram
  - my_hist_2->Draw("same")

- Errors:
  - my_hist_2->Draw("esame")
- Default : errors = sqrt(entries)
- To get error as sqrt(sum of weights), enter
  - my_hist_2->Sumw2() before filling the histogram

Exercises

Exercises:

- Add axis labels
- Add a legend
- Add a text box

Save Histograms:

```
c1->SaveAs("myhisto.eps");
c1->SaveAs("myhisto.ps");
c1->SaveAs("myhisto.gif");
```

Also can save source code for histogram:

```
c1->SaveAs("myhisto.C");
```

Recreate histogram in a brand new ROOT session:

```
.x myhisto.C
```

Functions and Histograms

- Define a function:

```
TF1 *myfunc = new TF1("myfunc", "gaus", 0, 3);
myfunc->SetParameters(10.,1.5,0.5);
myfunc->Draw();
```

- Generate histograms from functions:

```
(myfunc->GetHistogram())->Draw();
```

- Generate histograms with random numbers from a function:

```
TH1F *myhist = new TH1F("myhist", "Histo from gaus", 50, 0, 3);
myhist->FillRandom("myfunc", 10000);
myhist->Draw();
```

- Write histogram to a root file:

```
TFile *myfile = new TFile("fillrandom.root", "RECREATE");
myhist->Write();
myfile->Close();
```

Fitting Histograms

Let us try to fit the histogram created by the previous step:

Interactively:

- Open root file containing histogram:

  root -l fillrandom.root
- Draw histogram:

  myhist->Draw()
- Right click on the histogram and select "Fit Panel"
- Check to ensure:
- "gaus" is selected in the Function->Predefined pop-up menu
- "Chi-square" is selected in the Fit Settings->Method menu
- Click on "Fit" at the bottom

[Display fit parameters: Select Options-> Fit Parameters]

Fitting contd:

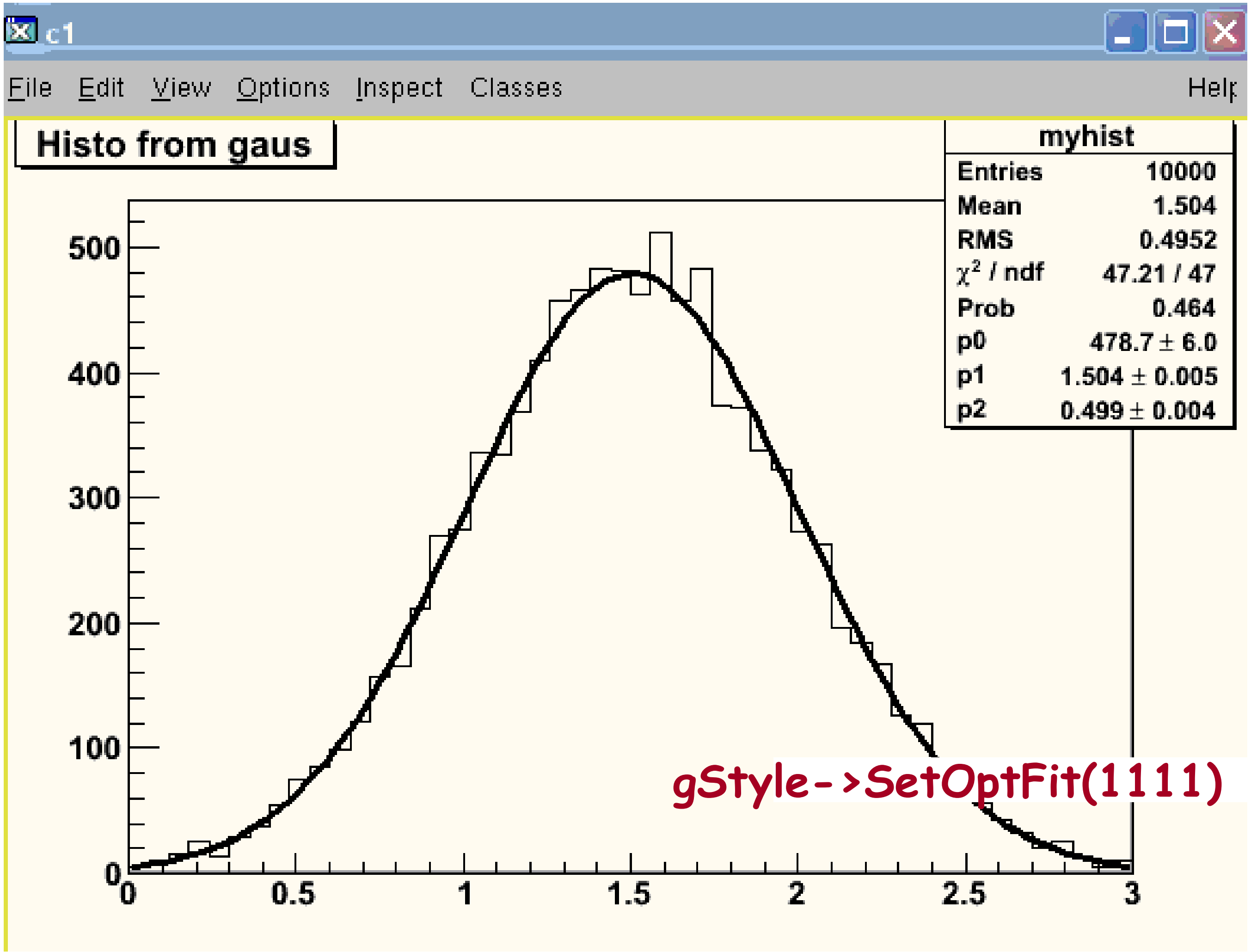
Using user defined functions:

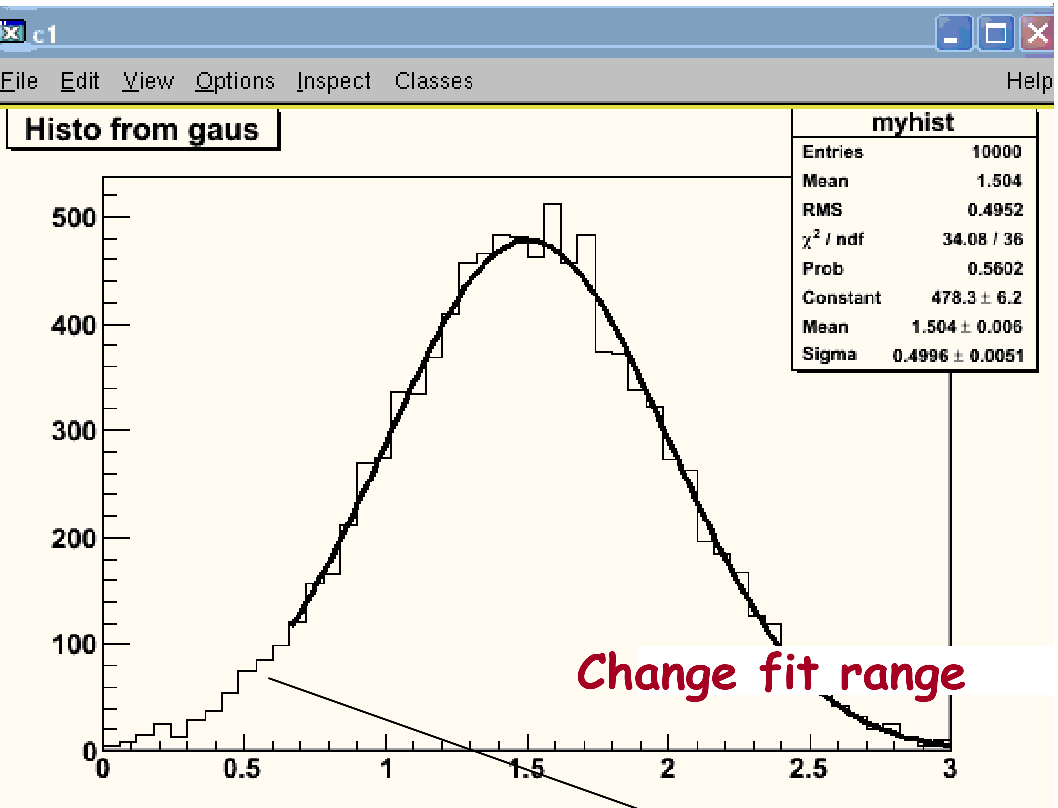
- Create a file called user_func.C with the following contents:

```
double user_func(double *x, double *par) {
double arg = 0;
if (par[2]) arg = (x[0] - par[1])/par[2];
return par[0]*TMath::Exp(-0.5*arg*arg);
}
```

```
[tulika@cmslpc04 NEPPSR]$ root -l fillrandom.root
root [0]
Attaching file fillrandom.root as _file0...
root [1] .L user_func.C
root [2] TF1 *f1 =  new TF1("f1", user_func, 0, 3, 3);
root [3] myhist->Draw()
<TCanvas::MakeDefCanvas>: created default TCanvas with name c1
root [4] f1->SetParameters(10,myhist->GetMean(), myhist->GetRMS());
root [5] myhist->Fit("f1");
```

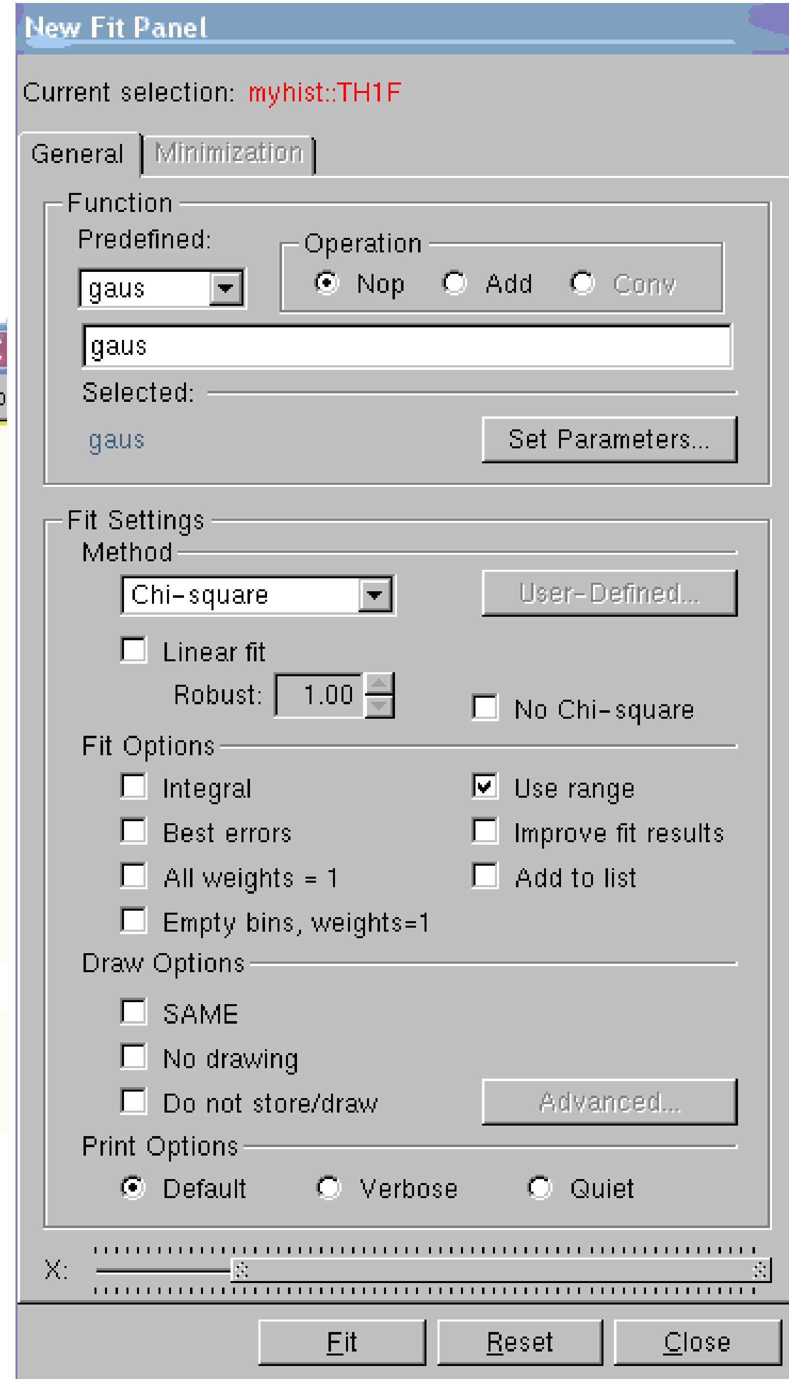
Fitting contd:





Change fit range

Move the slider



N-tuples and trees

- An n-tuple is an ordered list of numbers

Row	event	ebeam	px	py	pz	zv	chi2
0	0	150.14	14.33	-4.02	143.54	22.26	0.94
1	1	149.79	0.05	-1.37	148.60	0.61	1.02
2	2	150.16	4.01	3.89	145.69	16.57	0.89
3	3	150.14	1.46	4.66	146.71	11.47	1.02
4	4	149.94	-10.34	11.07	148.33	0.37	0.85
5	5	150.18	17.08	-12.14	143.10	22.09	0.90
6	6	150.02	5.19	7.79	148.59	2.28	1.06
7	7	150.05	7.55	-7.43	144.45	21.40	0.97
8	8	150.07	0.23	-0.02	147.78	6.96	0.93
9	9	149.96	1.21	7.27	146.99	7.17	1.02
10	10	149.92	5.35	3.98	140.70	38.81	1.08
11	11	149.88	-4.63	-0.08	147.91	4.01	0.86
12	12	150.11	-1.96	11.46	147.41	6.76	1.08
13	13	150.02	-4.97	4.29	145.06	17.79	0.92
14	14	149.86	0.26	0.10	144.69	22.26	0.93

- A ROOT Tree can be an ordered list of any collections of C++ objects
  - It has branches which can hold many other objects, for eg. vectors
- An n-tuple in ROOT is just a simple Tree, where each branch contains floating point data

Getting started with trees

Download the file at
http://home.fnal.gov/~tulika/NEPPSR/histo-174.root

Use the following commands to open the file and list contents
The root-file consists of a tree called "ttbar".

To display the names of the variables stored in the tree
use the "Print()" command

```
[tulika@cmslpc04 NEPPSR]$ root -l histo-174.root
root [0]
Attaching file histo-174.root as _file0...
root [1] .ls
TFile**         histo-174.root
 TFile*         histo-174.root
  KEY: TTree    ttbar;1
root [2] ttbar->Print();
```

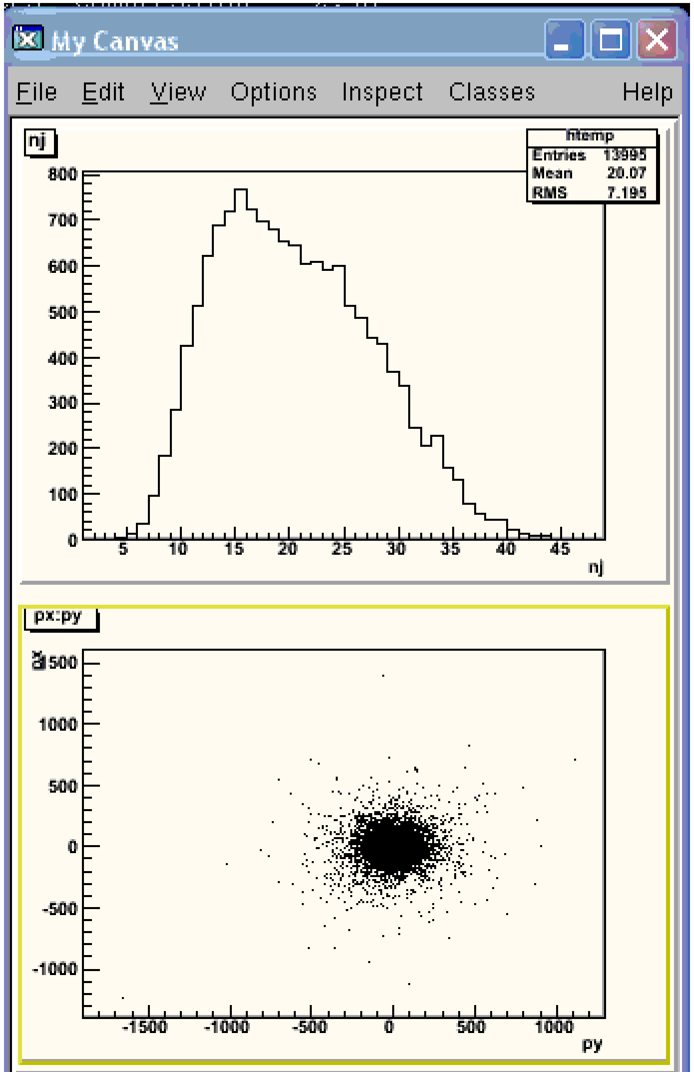
Plotting tree variables

```
root [3] TCanvas *c2= new TCanvas ("c2", "My Canvas",400, 600)
```

```
root [4] c2->Divide(1,2);
root [5] c2->cd(1);
root [6] ttbar->Draw("nj")
root [7] c2->cd(2);
root [8] ttbar->Draw("px:py")
```

To apply cuts:

```
root[9] TCanvas c3;
root [10] ttbar->Draw("nj", "nj>15");
```



Analyzing trees

```
[tulika@cmslpc04 NEPPSR]$ root -l histo-174.root
root [0]
Attaching file histo-174.root as _file0...
root [1] .ls
TFile**         histo-174.root
 TFile*         histo-174.root
  KEY: TTree    ttbar;1
root [2] ttbar->MakeClass("Analyze")
Info in <TTreePlayer::MakeClass>: Files: Analyze.h and Analyze.C
generated from TTree: ttbar
(Int_t)0
```

Add your analysis code to Analyze.C and then execute in ROOT:

`root [0] .L Analyze.C`	"L"oad the file
`root [1] Analyze t`	Create an object of type t
`root [2] t.Loop()`	Execute Loop command of object t

“Analyze” trees

```
#define Analyze_cxx
#include "Analyze.h"
#include <TH2.h>
#include <TStyle.h>
#include <TCanvas.h>

void Analyze::Loop()
{
//   In a Root session, you can do:
//      Root > .L Analyze.C
//      Root > Analyze t
//      Root > t.GetEntry(12); // Fill t data members with entry number 12
//      Root > t.Show();       // Show values of entry 12
//      Root > t.Show(16);     // Read and show values of entry 16
//      Root > t.Loop();       // Loop on all entries
//

//     This is the loop skeleton
//       To read only selected branches, Insert statements like:
// METHOD1:
//    fChain->SetBranchStatus("*",0);  // disable all branches
//    fChain->SetBranchStatus("branchname",1);  // activate branchname
// METHOD2: replace line
//    fChain->GetEntry(i);  // read all branches
//by  b_branchname->GetEntry(i); //read only this branch
   if (fChain == 0) return;

   Long64_t nentries = fChain->GetEntries();

   Long64_t nbytes = 0, nb = 0;
   for (Long64_t jentry=0; jentry<nentries;jentry++) {
      Long64_t ientry = LoadTree(jentry);
      nb = fChain->GetEntry(jentry);   nbytes += nb;
      // if (Cut(ientry) < 0) continue;
   }
}
```

Setup code goes here

Loop code goes here

Exercises

Look at the example code in
http://home.fnal.gov/~tulika/NEPPSR/AnalyzeExample.C

1. Modify it to plot "px", "py", and "pz" for all jets in the event

2. Calculate η of the jets

3. Calculate the invariant mass of all possible di-jet and three-jet combinations

4. Require pt > 20 GeV and abs(η) < 3.0 and repeat Step 3.

Search for new particles while learning ROOT :
http://www-clued0.fnal.gov/~tulika/brown/root-proj.htm