ROOT

Documentation about ROOT

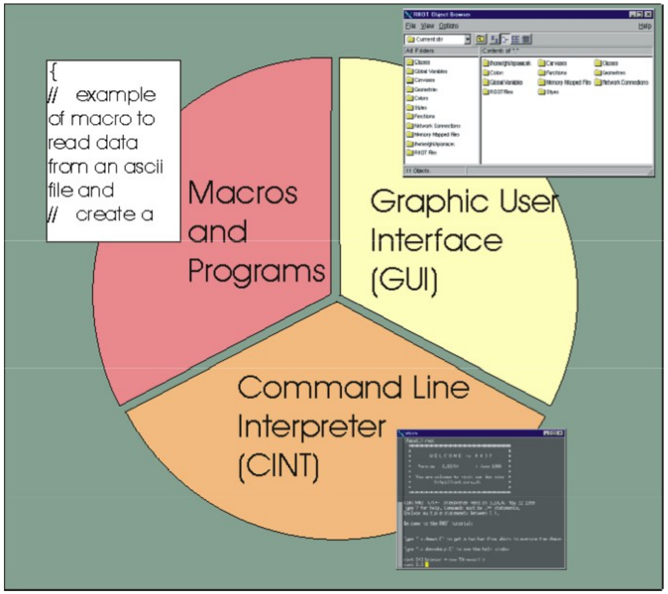
- www.root.cern.ch
  - Tutorials, user's guide, class reference guide, FAQs, how to's, ...

Contents

- Root basics
- Opening/closing files
  - Persistency in ROOT
- Histograms
- Storing data
- Library of classes and tools for data analysis and processing
- Exercises

What is ROOT?

- Framework for data analysis based on C++ (Object Oriented)
  - Store/read data
  - Process data
  - Analyse the data (histograming, statistical treatment, …)
- Developed and supported by the High Energy Physics community
  - www.root.cern.ch
- Widely used
- Tree possible ways to use it
  - Graphical User Interface
  - CINT: C++ interpreter
  - Macros, programs, libraries
- Can be used as a collection of libraries



The CINT interpreter

- The most basic way to use ROOT
  - Can execute instruction by instruction
  - Can be used interactively

```
pconde — root.exe — 80×24
[Amelias-MacBook-Air]: ~ > root
  *******************************************
  *                                         *
  *        W E L C O M E  to  R O O T       *
  *                                         *
  *   Version   5.34/01      13 July 2012   *
  *                                         *
  *  You are welcome to visit our Web site  *
  *          http://root.cern.ch            *
  *                                         *
  *******************************************

ROOT 5.34/01 (tags/v5-34-01@45048, Jul 13 2012, 15:31:31 on macosx64)

CINT/ROOT C/C++ Interpreter version 5.18.00, July 2, 2010
Type ? for help. Commands must be C++ statements.
Enclose multiple statements between { }.
root [0] int test = 6
root [1] test
(int)6
root [2] cout << "test = " << test
test = 6(class ostream)140735252709232
root [3] cout << "test = " << test;
test = 6root [4]
```

Many, many, many different objects

- TH1, TH1F, TH2, TH2F, … : histograms
- TFiles: object to handle input/output files
- TCanvas: object to handle screens to plot histograms or other graphical objects
- Ttrees, Tntuples: objects to structure data
- TGraph: object to store sets of measurement points
- TVector,TMatrix, TRotation, …
- TFormula: object to create your own mathematical functions
- TFit: object to do fits
- …
- No need to know all of them: will use these objects as a library that provides functionality for our simulations

✯ Example

Function Members (Methods)

public:

	TFile ()
	TFile (const char* fname, Option_t* option = "", const char* ftitle = "", Int_t compress = 1)
virtual	**~TFile** ()
void	TObject::**AbstractMethod** (const char* method) const
virtual void	TDirectoryFile::**Add** (TObject* obj, Bool_t replace = kFALSE)
static void	TDirectory::**AddDirectory** (Bool_t add = kTRUE)
static Bool_t	TDirectory::**AddDirectoryStatus** ()
virtual void	TDirectoryFile::**Append** (TObject* obj, Bool_t replace = kFALSE)
virtual Int_t	TDirectoryFile::**AppendKey** (TKey* key)
virtual void	TObject::**AppendPad** (Option_t* option = "")
static TFileOpenHandle*	**AsyncOpen** (const char* name, Option_t* option = "", const char* ftitle = "", Int_t compress = netopt = 0)
virtual void	TDirectoryFile::**Browse** (TBrowser* b)
virtual void	TDirectoryFile::**Build** (TFile* motherFile = 0, TDirectory* motherDir = 0)
virtual Bool_t	TDirectoryFile::**cd** (const char* path = 0)
static Bool_t	TDirectory::**Cd** (const char* path)

class TFile -

library: libRIO
#include "TFile.h"

Display options:
☑ Show inherited
☑ Show non-public

[↑ Top] | [? Help]

ROOT Memory management

- ROOT objects (Histograms, Canvas, etc) are managed in memory (and disk) by root using "names"
- In the same directory you cannot have two object with the same name (ROOT will complain about memory leaks)
  - ROOT does not like the following

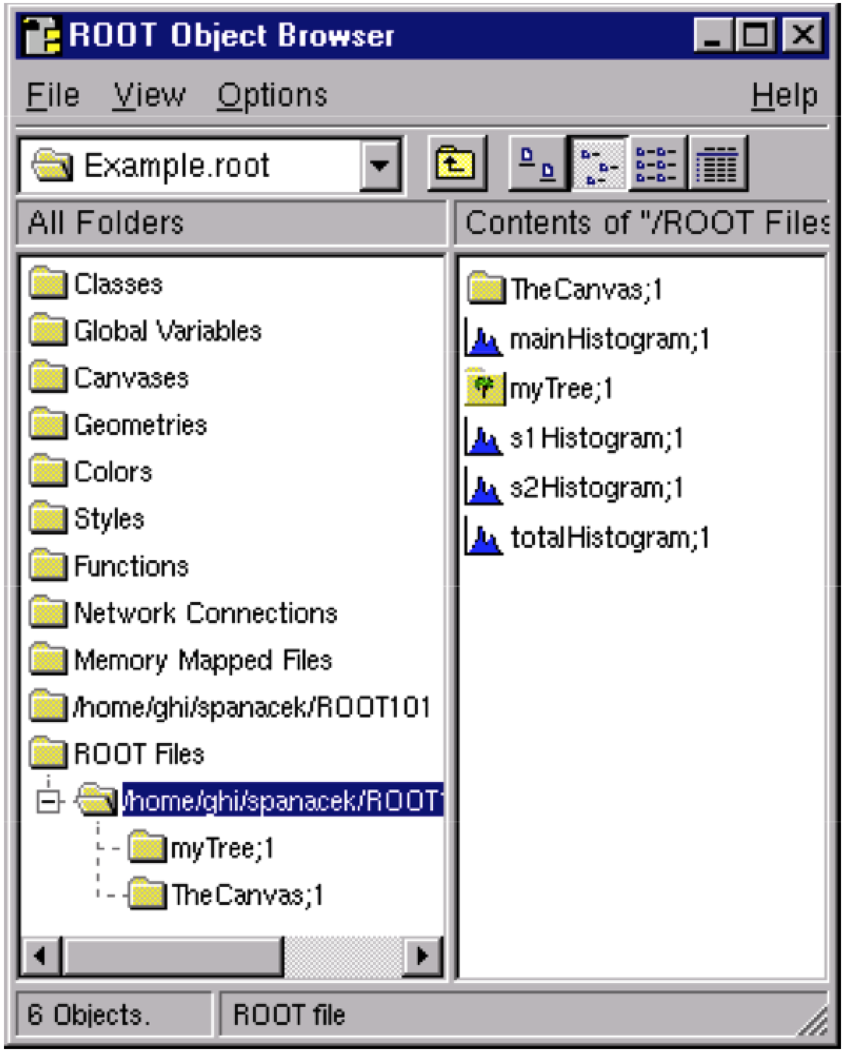
Same name!

```
TH1F * histos[10];
for(int i = 0; i < 10 ; i++) histos[i]= new TH1F("hist","hist",1,2,3);
```

- Objects member functions can be accessed with "." (for instance and reference) or "->" (for pointers) root ""understand" both
  - Interactive ROOT fixes for you wrong usage of pointer vs reference, but when you compile you MUST use the correct syntax.

File structure

- A directory structure like UNIX
- Items in a directory can be:
  - Subdirectory
  - Objects (canvas, histograms, etc.)



Opening/closing files

- Opening files using the command line (CINT interpreter)

```
  *******************************************

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 Type ? for help. Commands must be C++ statements.
 Enclose multiple statements between { }.
 root [0] TFile myFile("TestFile.root","READ")
 root [1] myFile.ls()
 TFile**         TestFile.root
  TFile*         TestFile.root
   KEY: TH1F     hGaus;1
 root [2]
```

- Accessing the histogram stored on the file:

```
root [2] TH1F *h1 = (TH1F *) myFile.Get("hGaus")
root [3] h1->Draw()
Info in <TCanvas::MakeDefCanvas>:  created default TCanvas with name c1
root [4]
```

Opening/closing files

- Opening files using the command line (CINT interpreter)

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root [2] TH1F *h1 = (TH1F *) myFile.Get("hGaus")
root [3] h1->Draw()
Info in <TCanvas::MakeDefCanvas>:  created default
root [4]
```

- Create a pointer of type TH1F (histogram 1D, float)
- Retrieve the object "hGaus" from the file
- Dynamic cast the output to a TH1F (it is a generic type TObject)
- Initialize pointer to the retrieved object

Opening/closing files

- Opening files using the command line (CINT interpreter)

```
  ********************************************

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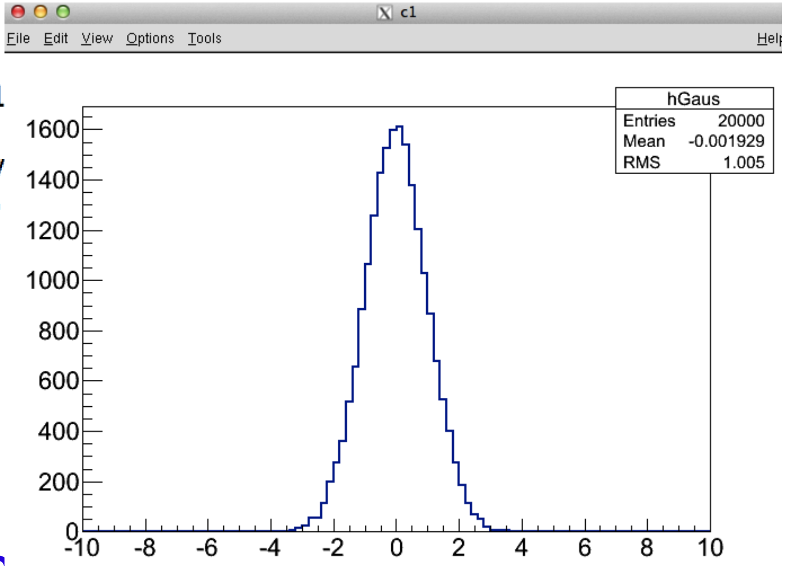


- Accessing the histogram stored o

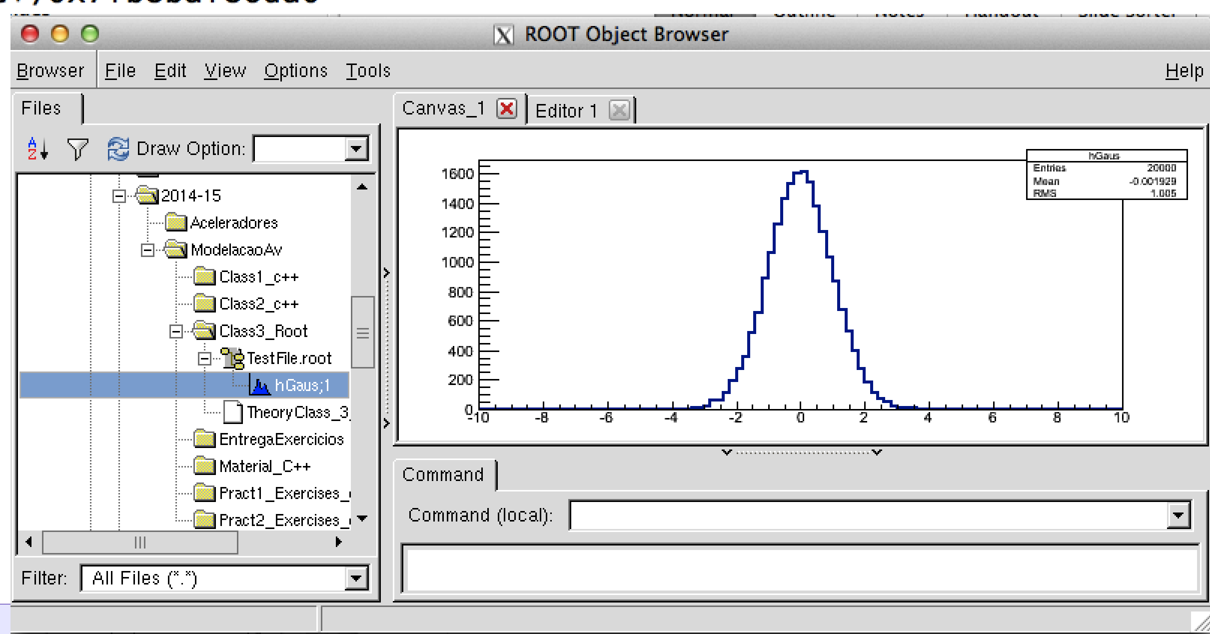
```
root [2] TH1F *h1 = (TH1F *) myFile.Get("hGaus")
root [3] h1->Draw()
Info in <TCanvas::MakeDefCanvas>:  created default
root [4]
```

- Draw the histogram.
- It creates a TCanvas for visualization

Using the GUI

- Create a Tbrowser object
- Navigate to the file, double click to open it, double click to draw the histogram

```
CINT/ROOT C/C++ Interpreter version 5.18.00, July 2, 2010
Type ? for help. Commands must be C++ statements.
Enclose multiple statements between { }.
root [0] TBrowser tb
root [1] (class TFile*)0x7fb8baf86da0
```



Useful member functions for files

- Options to open the file:

```
If option = NEW or CREATE   create a new file and open it for writing,
                            if the file already exists the file is
                            not opened.
          = RECREATE        create a new file, if the file already
                            exists it will be overwritten.
          = UPDATE          open an existing file for writing.
                            if no file exists, it is created.
          = READ            open an existing file for reading (default).
          = NET             used by derived remote file access
                            classes, not a user callable option
          = WEB             used by derived remote http access
                            class, not a user callable option
If option = "" (default), READ is assumed.
```

Useful member functions for files

- Enter the file:
  - File.cd()
- List the contents:
  - File.ls()
- Close:
  - File.Close()
- Get:
  - File.Get("name_of_object")
  - Returns a pointer of type TObject
  - Can be casted to the right type for further manipulation

- ROOT's own convention
  - Member functions start with capital letters
- cd, ls: copied from linux, use lower case letters

Using ROOT from a macro

```
void OpenFileExample(){


   std::cout << "ROOT program starting " << std::endl;


   // Opening the file
  TFile myFile("TestFile.root");

  //Retrieving the histogram:
  TH1F *h1 = (TH1F*) myFile->Get("hGaus");

  // Create a canvas to draw the histogram:
  TCanvas *myCanvas = TCanvas::MakeDefCanvas();

   // Drawing the histogram:
   h1->Draw();

  // Save canvas as a picture:
  myCanvas->SaveAs("outputHistogram.png");

 // Close file:
  myFile->Close();


  std::cout << "ROOT program finishing. Returning success " << std::endl;
}
```

Using ROOT from a macro

- Executing the macro from the CINT command line:

```
  *********************************************

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Type ? for help. Commands must be C++ statements.
Enclose multiple statements between { }.
root [0] .L example1.cxx+
root [1] OpenFileExample()
ROOT program starting
Info in <TCanvas::Print>: png file outputHistogram.png has been created
ROOT program finishing. Returning success
root [2]
```

- Load and compile the macro
  - Can be loaded without compilation
    - .L example1.cxx
  - Compilation helps resolving problems that might end in malfunctioning

Using ROOT from a macro

- Executing the macro from the CINT command line:

```
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root [0] .L example1.cxx+
root [1] OpenFileExample()
ROOT program starting
Info in <TCanvas::Print>: png file outputHistogram.png has been created
ROOT program finishing. Returning success
root [2]
```

- Execute the macro
  - Produced some printouts
  - Draws the histogram and saves the canvas in a png file
  - When closing the file, the histogram is removed from the canvas!

Using ROOT from a program

```
int main(){

   std::cout << "ROOT program starting " << std::endl;

   // Opening the file
  TFile myFile("TestFile.root");

  //Retrieving the histogram:
  TH1F *h1 = (TH1F*) myFile.Get("hGaus");

  // Create a canvas to draw the histogram:
  TCanvas myCanvas(true);

   // Drawing the histogram:
   h1->Draw();

  // Save canvas as a picture:
  myCanvas.SaveAs("outputHistogram.png");

 // Close file:
  myFile.Close();


  std::cout << "ROOT program finishing. Returning success " << std::endl;
}
```

Using ROOT from a program

- The makefile has to link with the ROOT libraries:
    - In this example linking with all possible root libraries
        - Less efficient but same makefile can be used for all possible programs

Examples — vim — 108×33

```
CC = g++
CFLAGS  = -W -Wall -fPIC
# Flags: -fPIC used to create a library that might be later on included in another library
#        -Wall: enables compiler's warning messages.
#
RCFLAGS = $(shell root-config --cflags)
RGLIBS  = $(shell root-config --glibs)

example : example.o
	$(CC) -o example $(CFLAGS) $(RCFLAGS) example.o $(RGLIBS)
example.o : example.cxx
	$(CC) $(CFLAGS) $(RCFLAGS) -c example.cxx

# make clean
clean :
	rm -rf example *.o *.d *.so
```

Notice

- When using the root interpreter or non-compiled macros:
  - No need to use includes
  - In many cases wrong syntax doesn't produce errors
    - may be interpreted correctly or not!
- When using compiled macros or programs
  - Need to use include files
  - Syntax errors during compilation
    - Safer! Reduce malfunctioning due to syntax errors
  - Faster execution
    - Important for long programs or running over long input data files

Notice

- When using the root interpreter or non-compiled macros:
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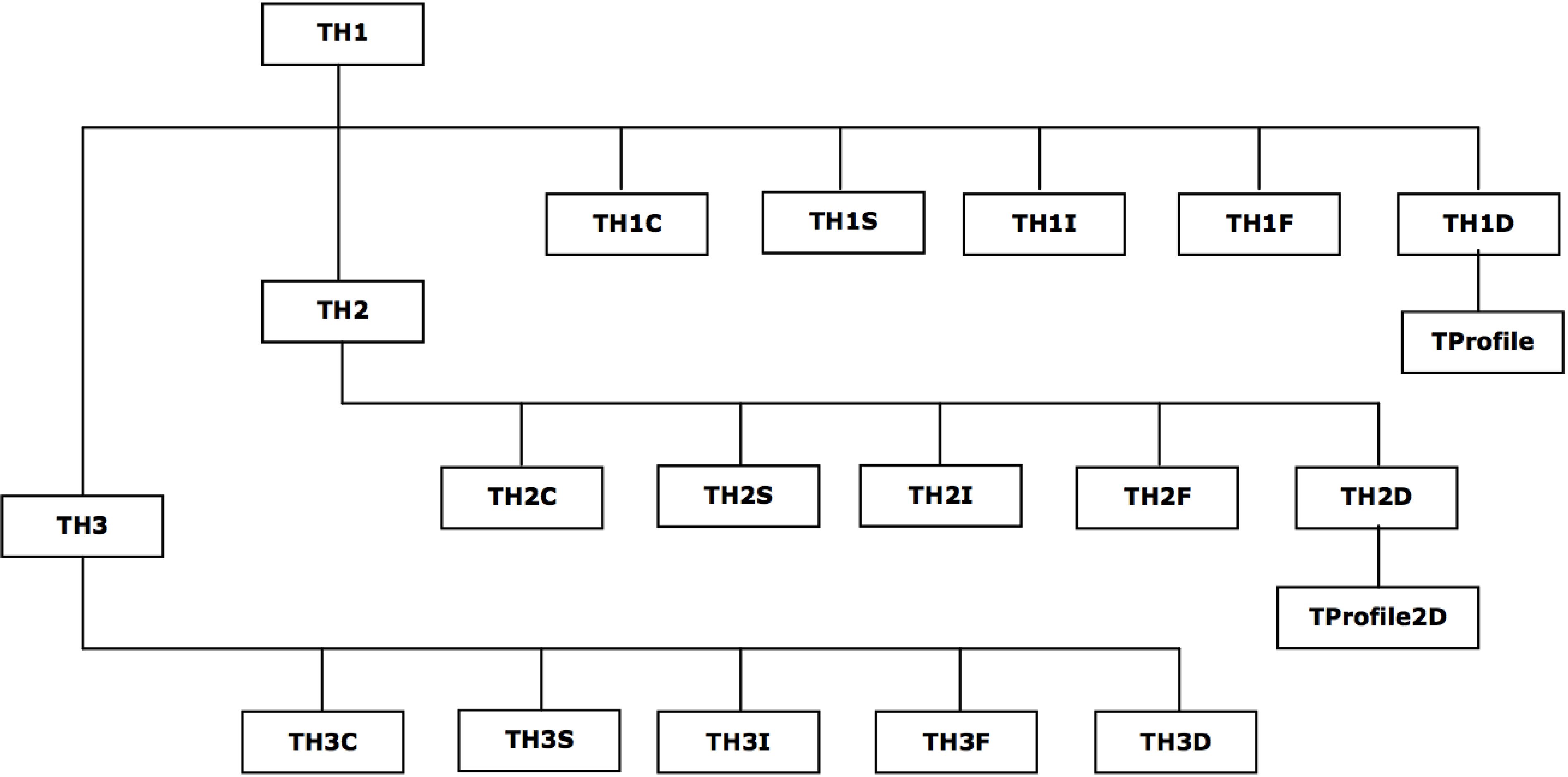
Histograms


TH1
TH1C
TH1S
TH1I
TH1F
TH1D
TProfile
TH2
TH2C
TH2S
TH2I
TH2F
TH2D
TProfile2D
TH3
TH3C
TH3S
TH3I
TH3F
TH3D

Histograms

Dimensions

- Histogram objects are called TH1F,TH1D, TH2F,TH3D

Float, Double

- To create a new histograms with 20 bins, in range [0,400] you have to do:

```
root[2] TH1F hist("hist","hist",20,0,400);
root[3] calls->Draw("time>>hist")
```

- Now we can do a lot of things on the histograms
  - Changing the properties, fitting, asking integrals, value of bins, overflow, uderflow, scaling, drawing normalized, etc…

Histograms

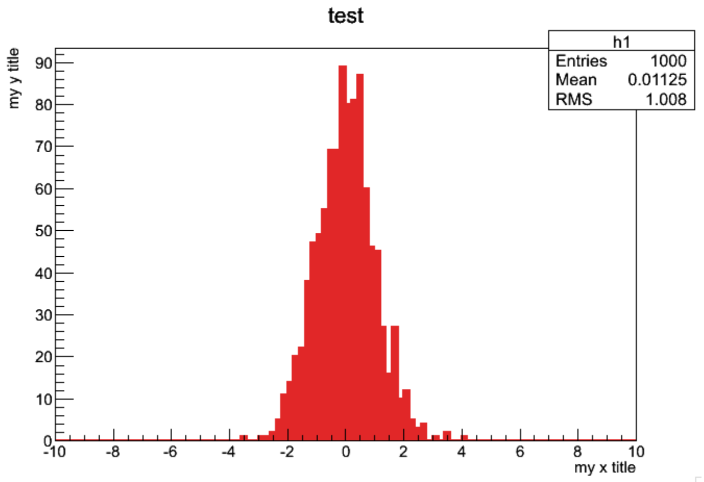
- Drawing:

  h->Draw("E");

- Many possible options (see manual):

"AXIS"	Draw only axis
"AH"	Draw histogram, but not the axis labels and tick marks
"]["	When this option is selected the first and last vertical lines of the histogram are not drawn.
"B"	Bar chart option
"C"	Draw a smooth Curve throught the histogram bins
"E"	Draw error bars
"E0"	Draw error bars including bins with o contents
"E1"	Draw error bars with perpendicular lines at the edges
"E2"	Draw error bars with rectangles
"E3"	Draw a fill area throught the end points of the vertical error bars
"E4"	Draw a smoothed filled area through the end points of the error bars
"L"	Draw a line throught the bin contents
"P"	Draw current marker at each bin except empty bins
"P0"	Draw current marker at each bin including empty bins

Useful histograms operations



- histogram->SetXTitle(“my x title”);
- histogram->SetYTitle(“my y title”);
- histogram->SetLineColor(kRed);
- histogram->SetLineWidth(2);
- histogram->SetFillColor(2);
- histogram->Fill(x): adds an entry on the bin corresponding to the value of x
- histo->Write(): stores the histogram in the current open file
- histo->GetEntries(): returns the number of entries
- histo->Fit(“gaus”): fits the histogram with a gaussian
- ...

Filling histograms

- A histogram can be also filled by calling `TH1F::Fill`

```
root [0] TH1F::Fill(

Int_t Fill(Double_t x)
Int_t Fill(Double_t x, Double_t w)
Int_t Fill(const char* name, Double_t w)
```

```
// Create a histogram:

TH1F *h1 = new TH1F("h1","",100,0.,10.);
h1->SetXTitle("x title");
h1->SetYTitle("Number of entries");
h1->SetLineColor(kBlue);

// Fill the histogram with integers
for (int i=0; i<10.; i++)
   h1->Fill(i);
```

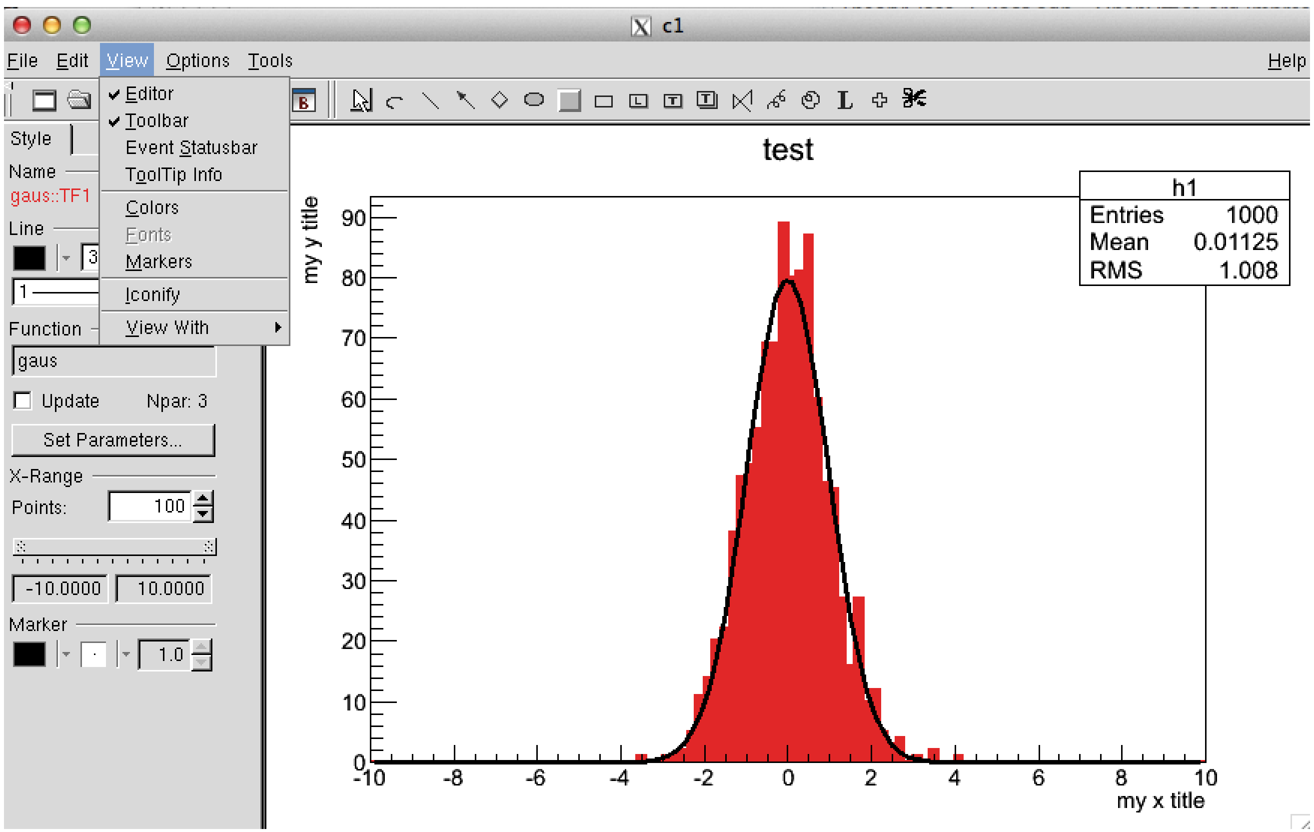
Print or save plots in different formats

void **SaveAs** (const char* filename = "", Option_t* option = "") const

```
Save Pad contents in a file in one of various formats.

  if filename is "", the file produced is padname.ps
  if filename starts with a dot, the padname is added in front
  if filename contains .eps, an Encapsulated Postscript file is produced
  if filename contains .pdf, a PDF file is produced
  if filename contains .svg, a SVG file is produced
  if filename contains .tex, a TeX file is produced
  if filename contains .gif, a GIF file is produced
  if filename contains .gif+NN, an  animated GIF file is produced
  if filename contains .xpm, a XPM file is produced
  if filename contains .png, a PNG file is produced
  if filename contains .jpg, a JPEG file is produced
```

Using the graphical editor



- Very easy to change the style
- Can be used to store a macro for later reference

  Fast to learn how to use different styles!

TTrees

- Class designed to store large quantities of same class objects
    - Optimized to reduce disk space
    - Enhanced access speed

  See example BasicTree