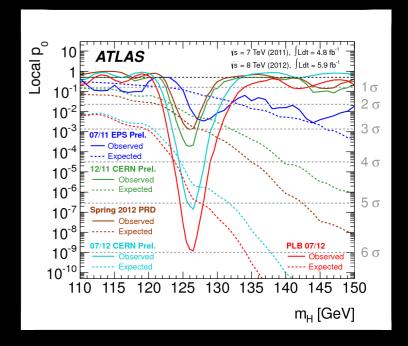
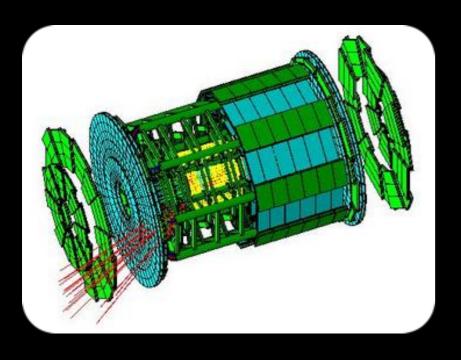
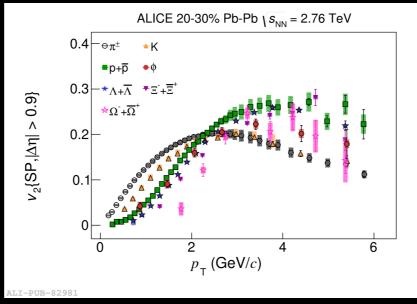
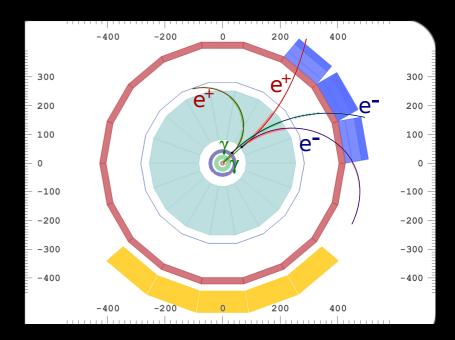


Introduction to ROOT













- ROOT homepage
 - https://root.cern.ch/
- Installing ROOT howto
 - https://root.cern.ch/downloading-root
- User's guide
 - <u>https://root.cern.ch/guides/users-guide</u>
- Basic tutorials
 - https://root.cern.ch/root/html/tutorials/
- Howto
 - https://root.cern.ch/howtos
- Courses
 - <u>https://root.cern.ch/courses</u>



Connecting to your machine



- When you are at Nikhef: use your login name and password to connect to your machine
 - bash is the default shell requested for you
 - For more info about shells and how to use them check <u>here</u>
- When you are outside the Nikhef domain: first connect to the login server

```
test — ssh panosch@login.nikhef.nl — 91×47

[[AliPhysics/latest] ~ $> ssh panosch@login.nikhef.nl

[panosch@login.nikhef.nl's password:

Last login: Wed Sep 13 14:34:27 2017 from 145.136.144.30

-bash-4.1$
```

- Then connect to whichever machine of the group using ssh
 - The following hostnames belong to the group: mole, hamme, blavet, inn, jaba, todd, nass
- Alternatively you can connect to one of the interactive nodes of stoomboot: stbc-i1, stbc-i2, stbc-i4
- Never use the login server to run jobs!!!

Connecting to your machine (cont.)

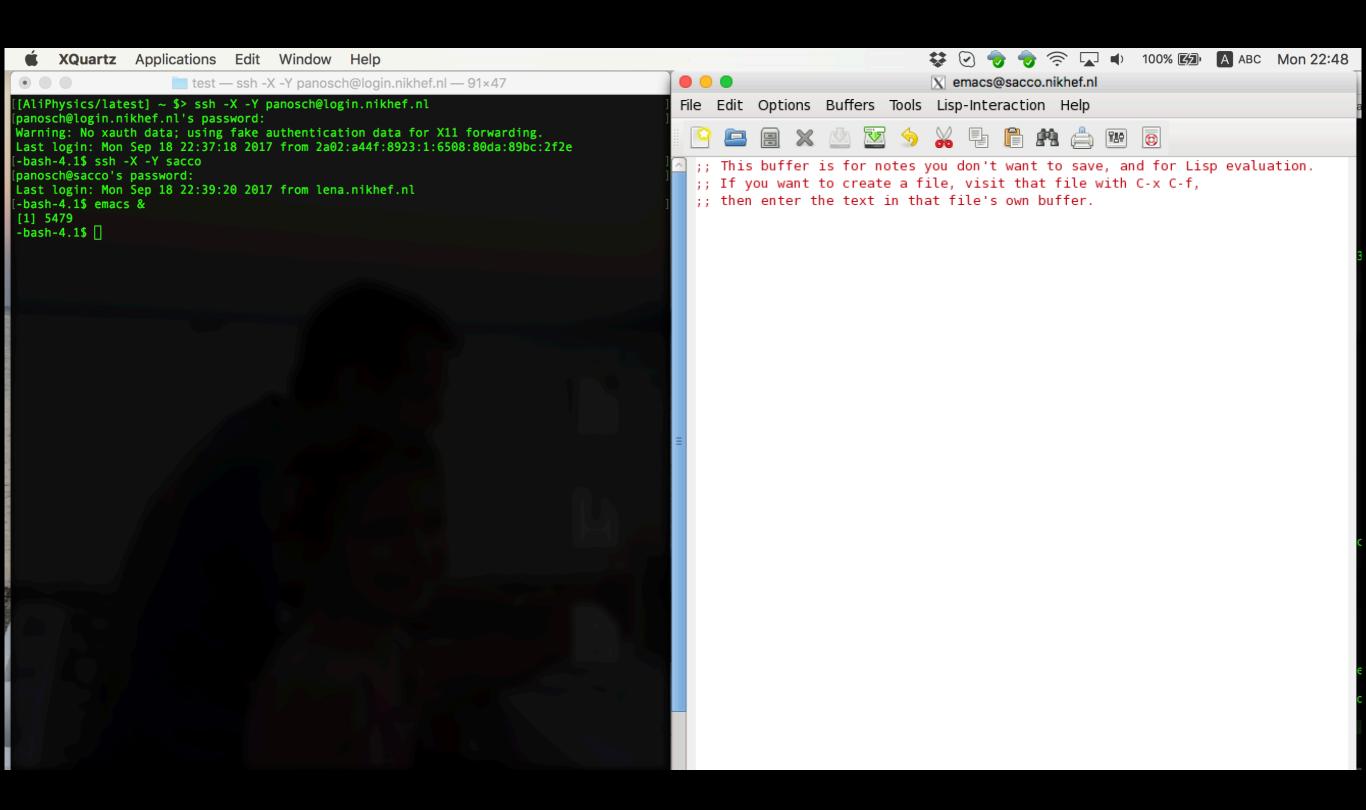


- When you connect to another machine and you want to be able to use the X-server (e.g. open a window) then connect with the "-X -Y" option
 - -X: enables X11 forwarding
 - Y: enables trusted X11 forwarding
 - X-server is the program that handles the connection to all graphic cards of a system
- ✓ All these are part of the way you access and control the operating system
 - A helpful Linux primer can be found <u>here</u>



Connecting to your machine (cont.)







Setting up the environment (cont.)



- To be able to setup your environment add the following in your .bashrc
 - source /cvmfs/alice.cern.ch/ etc/login.sh
 - This will allow you to access the "CERN virtual machine file system" or cvmfs
 - Low maintenance software distribution service
 - Provides link to preinstalled packages
- To query which ROOT (or AliRoot or AliPhysics → see later) versions are available do

```
Terminal
                Shell
                              View
                                      Window
                        Edit
                                                Help
                         test — ssh -X -Y panosch@login.nikhef.nl — 91×47
[bash|sacco.nikhef.nl> alienv q | grep ROOT
VO ALICE@ROOT::v5-30-02
VO_ALICE@ROOT::v5-30-06-1
VO ALICE@ROOT::v5-33-02b-1
VO ALICE@ROOT::v5-34-01-1
VO ALICE@ROOT::v5-34-02-1
VO ALICE@ROOT::v5-34-04
VO_ALICE@ROOT::v5-34-05
VO_ALICE@ROOT::v5-34-05-1
VO_ALICE@ROOT::v5-34-07
VO ALICE@ROOT::v5-34-08
VO ALICE@ROOT::v5-34-08-3
VO ALICE@ROOT::v5-34-08-4
VO ALICE@ROOT::v5-34-08-5
VO ALICE@ROOT::v5-34-08-6
VO ALICE@ROOT::v5-34-08-7
VO_ALICE@ROOT::v5-34-08-alice8-1
VO_ALICE@ROOT::v5-34-09
VO_ALICE@ROOT:: v5-34-10
VO ALICE@ROOT::v5-34-11
VO_ALICE@ROOT::v5-34-11-1
VO ALICE@ROOT::v5-34-11-2
VO ALICE@ROOT::v5-34-13
VO ALICE@ROOT::v5-34-18
VO_ALICE@ROOT::v5-34-26
VO_ALICE@ROOT::v5-34-26-gcc4-8-4
VO_ALICE@ROOT::v5-34-30
VO ALICE@ROOT::v5-34-30-1
VO ALICE@ROOT::v5-34-30-alice-1
VO ALICE@ROOT::v5-34-30-alice-10
VO ALICE@ROOT::v5-34-30-alice-11
VO ALICE@ROOT::v5-34-30-alice-12
VO ALICE@ROOT::v5-34-30-alice-15
VO_ALICE@ROOT::v5-34-30-alice-18
VO ALICE@ROOT::v5-34-30-alice-19
VO ALICE@ROOT::v5-34-30-alice-2
VO ALICE@ROOT::v5-34-30-alice-21
VO_ALICE@ROOT::v5-34-30-alice-22
VO ALICE@ROOT::v5-34-30-alice-24
VO ALICE@ROOT::v5-34-30-alice-26
VO ALICE@ROOT::v5-34-30-alice-27
VO ALICE@ROOT::v5-34-30-alice-3
VO_ALICE@ROOT::v5-34-30-alice3-3
VO_ALICE@ROOT::v5-34-30-alice3-4
VO ALICE@ROOT::v5-34-30-alice3-5
VO ALICE@ROOT::v5-34-30-alice3-xrd-1
VO_ALICE@ROOT::v5-34-30-alice5-1
```



Setting up the environment



```
Terminal Shell Edit View Window Help

test — ssh -X -Y panosch@login.nikhef.nl — 91×47

[bash|sacco.nikhef.nl> alienv enter VO_ALICE@ROOT::v5-34-30-alice-1

[ROOT/v5-34-30-alice-1] ~ >
```

✓ To select a given version of ROOT (or AliRoot or AliPhysics → see later) do







```
E-TTree::SetBranchStatus: unknown branch -> fNTPCClust
ROOT/v5-34-30-alice-1] ~ >
                                                                                              I-AliAnalysisManager::GetRunFromAlienPath: Run 244340
ROOT/v5-34-30-alice-1] ~ >
                                                                                              I-AliESDInputHandler::Notify: Directory change /dcache
ROOT/v5-34-30-alice-11 ~ >
                                                                                              .root
R00T/v5-34-30-alice-11 ~ >
ROOT/v5-34-30-alice-1] ~ >
                                                                                              I-AliMCEventHandler::Notify: Path: -/dcache/alice/pand
R00T/v5-34-30-alice-1] ~ >
ROOT/v5-34-30-alice-11 ~ >
                                                                                              I-AliMCEventHandler::Init: Number of events in this d
ROOT/v5-34-30-alice-11 ~ >
ROOT/v5-34-30-alice-1] ~ >
R00T/v5-34-30-alice-1] ~ >
                                                                                                                                           AnalysisRe
ROOT/v5-34-30-alice-1] ~ >
ROOT/v5-34-30-alice-11 ~ >
                                                                    ROOT
ROOT/v5-34-30-alice-11 ~ >
R00T/v5-34-30-alice-1] ~ >
ROOT/v5-34-30-alice-1] ~ >
ROOT/v5-34-30-alice-1] ~ >
ROOT/v5-34-30-alice-1] ~ >
                                                                                      Version
ROOT/v5-34-30-alice-1] ~
ROOT/v5-34-30-alice-1]
ROOT/v5-34-30-alice-1]
                                                                    Conception: Rene Brun, Fons Rademakers
                                                                                                                                           8-57-gec27
          WELCOME to ROOT
                                                                    Lead Developers: Rene Brun, Philippe Canal,
                                                                     Fons Rademakers
                                                                                                                                             July 2, 1
              5.34/30
                           23 April 2015
     Version
                                                                                                                                            ents.
                                                                    Core Engineering: Bertrand Bellenot, Olivier Couet,
                                                                     Gerardo Ganis, Andrei Gheata, Lorenzo Moneta,
    You are welcome to visit our Web site
                                                                     Axel Naumann, Paul Russo, Matevz Tadel
            http://root.cern.ch
                                                                    CINT C/C++ Intepreter: Masaharu Goto
                                                                                                                                            iTHnT<TAri
 ****************
                                                                    Version 5.34/30.
                                                                                                                                            rary.vecto
00T 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 20
lgcc)
                                                                                              [AliPhysics/vAN-20170813-1] Local > packet write wait
                                                                                              [ROOT/latest] ~/UU/Courses/QCD/Lectures/master $> cp
CINT/ROOT C/C++ Interpreter version 5.18.00, July 2, 2010
ype ? for help. Commands must be C++ statements.
                                                                                              Last login: Fri Sep 8 20:33:09 on ttys000
inclose multiple statements between { }.
                                                                                              Panoss-MacBook-Pro:AliPhysics pchrist$ ☐
oot [0]
```





```
Window Help
     Terminal Shell
                      Edit View
                      test — ssh -X -Y panosch@login.nikhef.nl — 91×47
bash|sacco.nikhef.nl> alie v enter VO ALICE@ROOT::v5-34-30-alice-1
[ROOT/v5-34-30-alice-1] ~
                          root.exe
                         ******
          WELCOME to ROOT
     Version 5.34/30
                          23 April 2015
    You are welcome to visit our Web site
            http://root.cern.ch
  ***********
ROOT 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 2015, 09:24:39 on linuxx866
4gcc)
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]
```

Same as before but faster and w/o the fancy splash screen

CINT: C Interpreter of ROOT



- ✓ CINT is a C++ interpreter
 - It is not a compiler!!!
- ✓ Allows to write simple piece of code
 - Good for fast checks of few lines of code
 - Or as a calculator

```
[root [0] Int_t i = 9;
[root [1] Int_t j = 10;
[root [2] i*j
  (Int_t)90
  root [3]
```

```
[root [3] for(Int_t i = 0; i < 10; i++) {
[end with '}', '@':abort > cout<<"The value of i is: "<<i<endl;
[end with '}', '@':abort > }
The value of i is: 0
The value of i is: 1
The value of i is: 2
The value of i is: 3
The value of i is: 4
The value of i is: 5
The value of i is: 6
The value of i is: 7
The value of i is: 8
The value of i is: 9
root [4] ■
```





Quit ROOT

```
[root [4]
[root [4] .q
[ROOT/v5-34-30-alice-1] ~ >
```

Load an existing macro

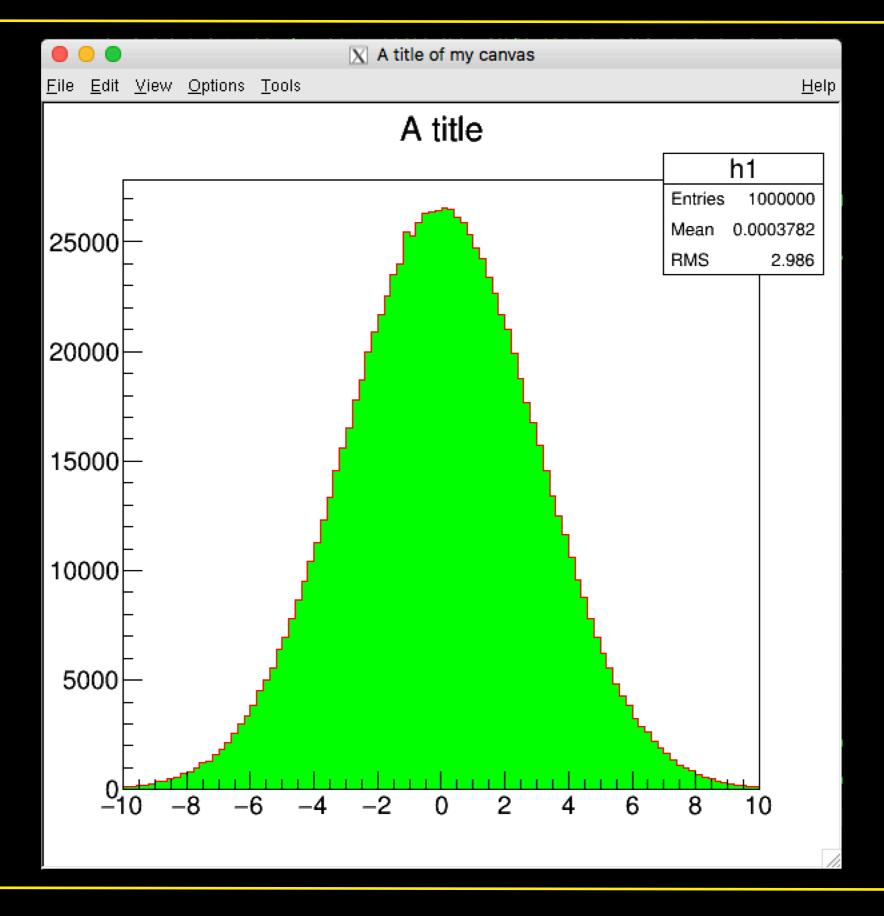
```
[root [1]
[root [1] .L testRandom.C
root [2]
```

Run an existing macro

```
[root [2]
[root [2] .x testRandom.C
```

CINT commands (cont.)









Lists the entries of the working (ROOT) directory

Lists the entries of the working (filesystem) directory





This is a rather bad example of writing a piece of code (more on that later)!!!

```
AliPhysics — ssh panosch@login.nikhef.nl — 110×45

~/Alice/alice-sw/ali-master/AliPhysics — -bash ... ...alice-sw/ali-master/AliPhysics — ssh panosch@login.nikhef.nl +

File Edit Options Buffers Tools C++ Help
void testMacro() {
    //This is our first macro
    cout<<"Welcome to the tutorial"<<endl;
    cout<<"This is the first encounter with functions..."<<endl;

Int_t var1 = 0;
    var1 = multiplication(3,5);
    cout<<"The outcome of the multiplication is: "<<var1<<endl;
}

Int_t multiplication(Int_t i1, Int_t i2) {
    cout<<"Multiplying "<<i1<<" by "<<i2<<endl;
    return i1*i2;
}
```





```
[[KOO1/YJ-J4-J0-alice-1] lutorial /
[[ROOT/v5-34-30-alice-1] Tutorial > root.exe testMacro.C
          WELCOME to ROOT
     Version 5.34/30
                          23 April 2015
     You are welcome to visit our Web site
            http://root.cern.ch
  ************
ROOT 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 2015, 09:24:39 on linuxx866
4gcc)
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]
Processing testMacro.C...
Welcome to the tutorial
This is the first encounter with functions...
Multiplying 3 by 5
The outcome of the multiplication is: 15
root [1]
```

Running a macro (not directly)



```
[ROOT/v5-34-30-alice-1] Tutorial > root.exe
          WELCOME to ROOT
     Version 5.34/30
                          23 April 2015
    You are welcome to visit our Web site
            http://root.cern.ch
  ************
ROOT 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 2015, 09:24:39 on linuxx866
4gcc)
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] .L testMacro.C
[root [1] multiplication(5,5)
Multiplying 5 by 5
(Int_t)25
root [2]
```





- ROOT provides aliases for the standard datatypes for better cross-platform compatibility
 - \odot E.g. int \rightarrow Int_t, float \rightarrow Float_t, etc.
 - Their use is not necessary, but recommended, especially for larger projects
 - In addition there are ROOT specific types, like
 - O Double32_t (8 bytes in memory, written as 4 bytes float)
 - For a list of all types visit <u>here</u>



Histograms



The TH1 histogram class.

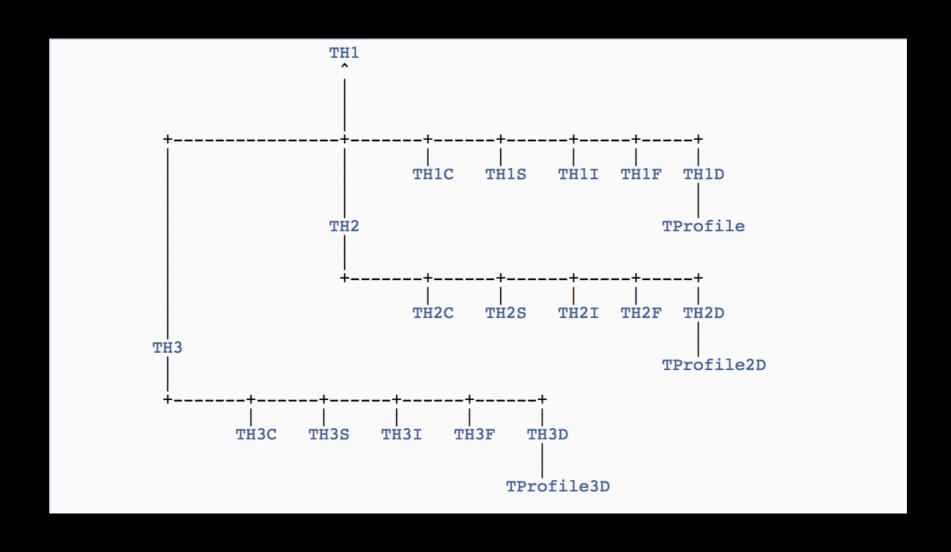
The Histogram classes

ROOT supports the following histogram types:

- 1-D histograms:
 - TH1C: histograms with one byte per channel. Maximum bin content = 127
 - TH1S: histograms with one short per channel. Maximum bin content = 32767
 - TH1I: histograms with one int per channel. Maximum bin content = 2147483647
 - TH1F: histograms with one float per channel. Maximum precision 7 digits
 - TH1D: histograms with one double per channel. Maximum precision 14 digits
- 2-D histograms:
 - TH2C: histograms with one byte per channel. Maximum bin content = 127
 - TH2S: histograms with one short per channel. Maximum bin content = 32767
 - TH2I: histograms with one int per channel. Maximum bin content = 2147483647
 - TH2F: histograms with one float per channel. Maximum precision 7 digits
 - TH2D: histograms with one double per channel. Maximum precision 14 digits
- 3-D histograms:
 - TH3C: histograms with one byte per channel. Maximum bin content = 127
 - TH3S: histograms with one short per channel. Maximum bin content = 32767
 - TH3I: histograms with one int per channel. Maximum bin content = 2147483647
 - TH3F: histograms with one float per channel. Maximum precision 7 digits
 - TH3D: histograms with one double per channel. Maximum precision 14 digits
- Profile histograms: See classes **TProfile**, **TProfile2D** and **TProfile3D**. Profile histograms are used to display the mean value of Y and its standard deviation for each bin in X. Profile histograms are in many cases an elegant replacement of two-dimensional histograms: the inter-relation of two measured quantities X and Y can always be visualized by a two-dimensional histogram or scatter-plot; If Y is an unknown (but single-valued) approximate function of X, this function is displayed by a profile histogram with much better precision than by a scatter-plot.







Histograms (cont.)

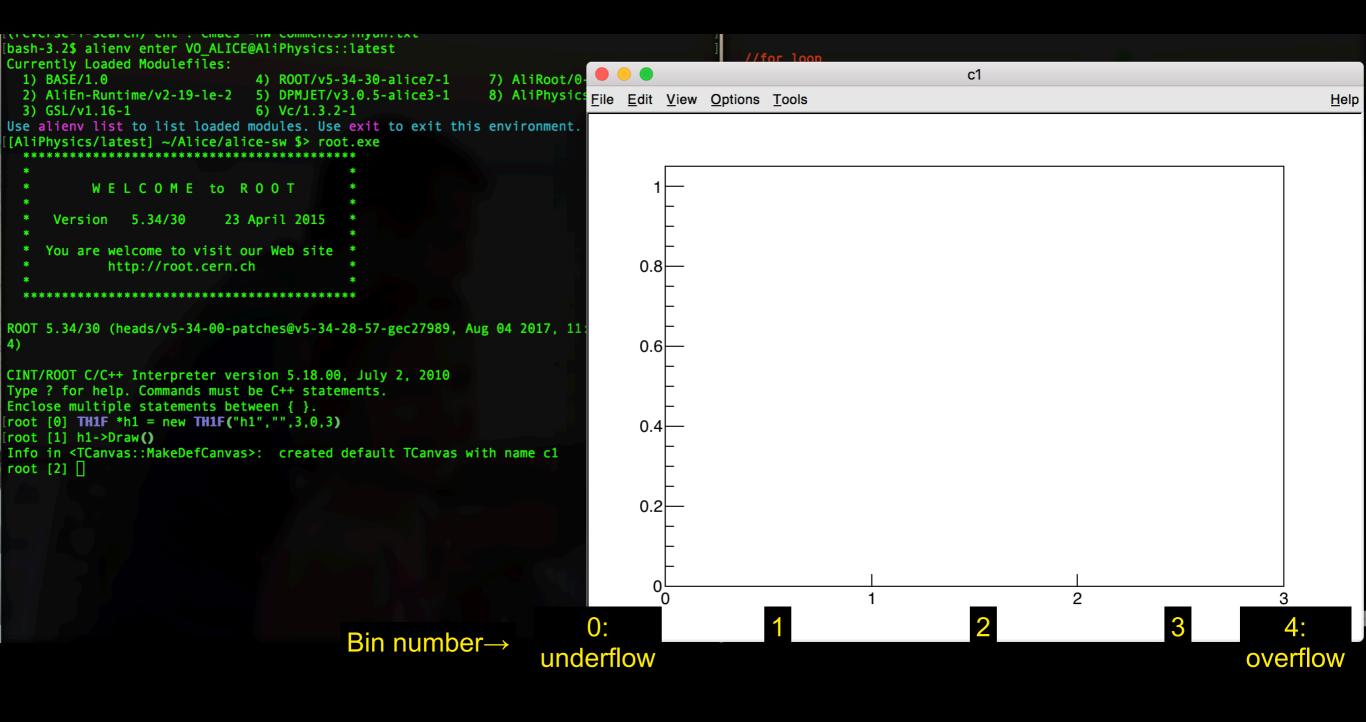


- Constructor
 - TH1<T>(const char* name, const char* title, Int_t nbinsx, Double_t xlow, Double_t xup)
 - TH1<T>(const char* name, const char* title, Int_t nbinsx, const Float_t* xbins)
 - <T>: data type filled in the hist: C,D,F,I,S (char,double,float,int,short)
- ✓ Histograms have 2 more bins than then ones defined during their creation.
 - Overflows: contain all entries outside i.e. beyond the max range
 - Bin number 0
 - Underflows: contain all entries outside i.e. below the min range
 - ☐ Bin number nbinsx+1



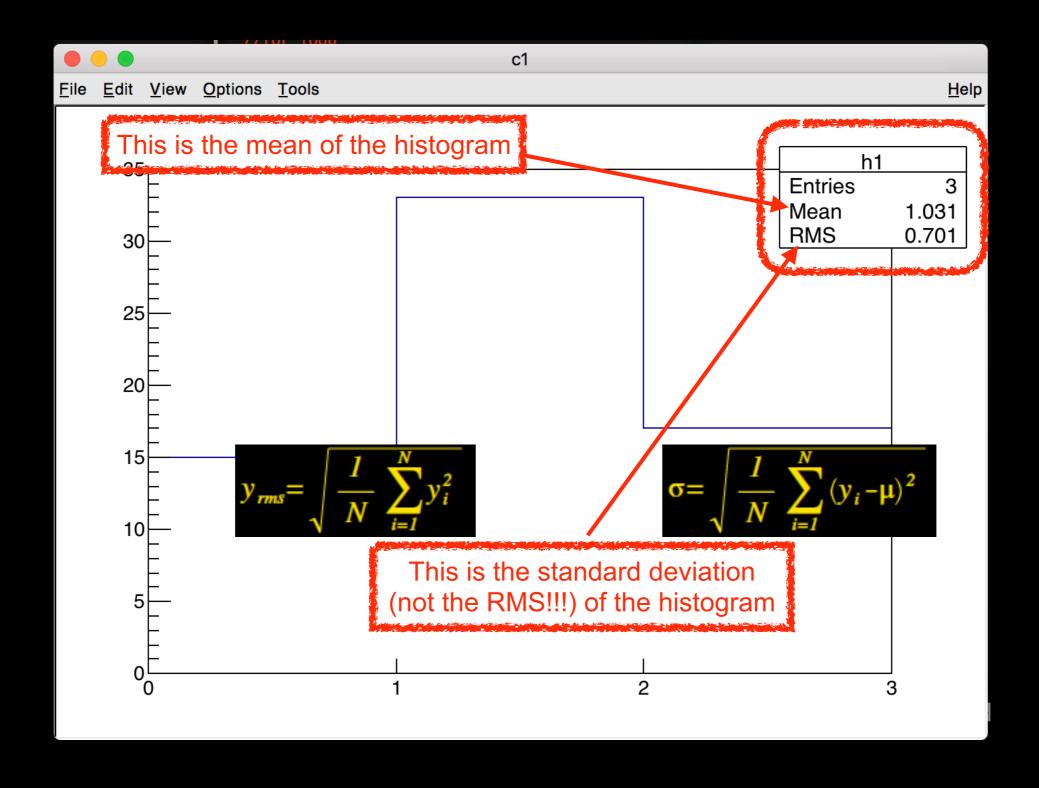






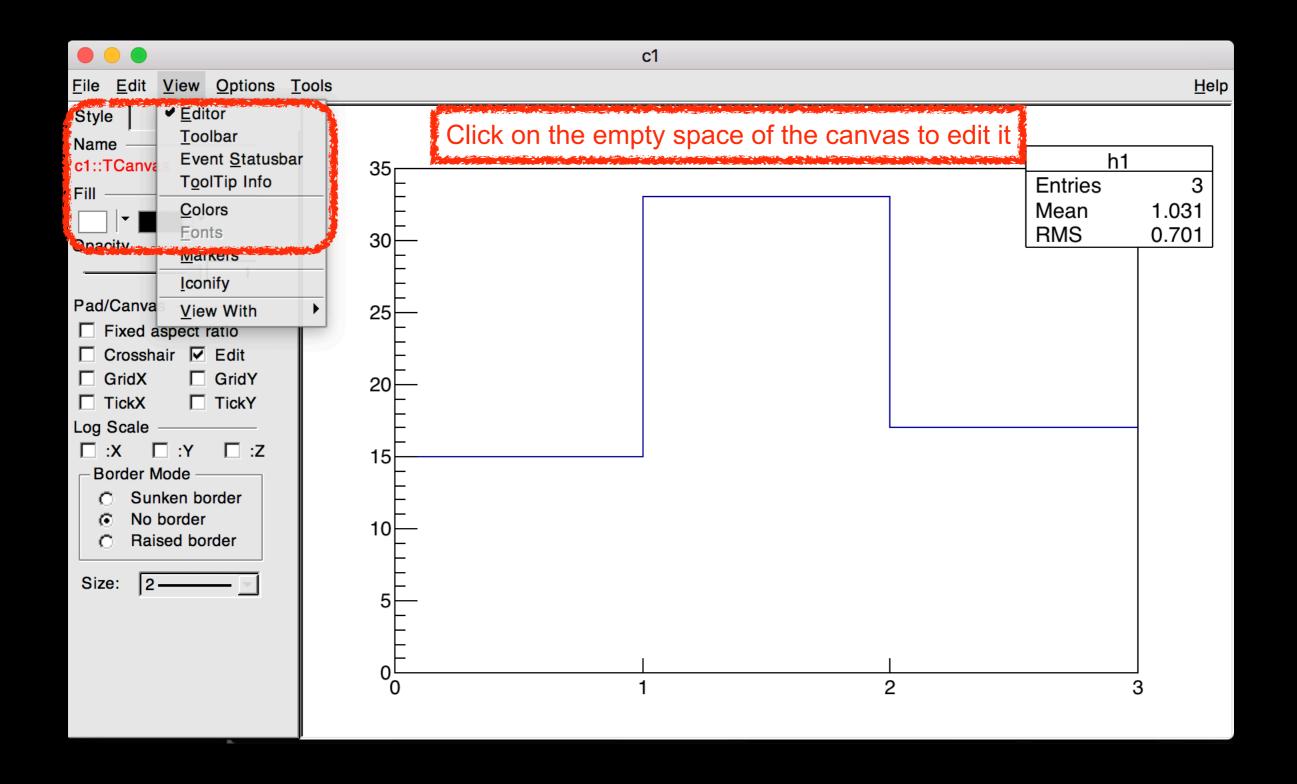






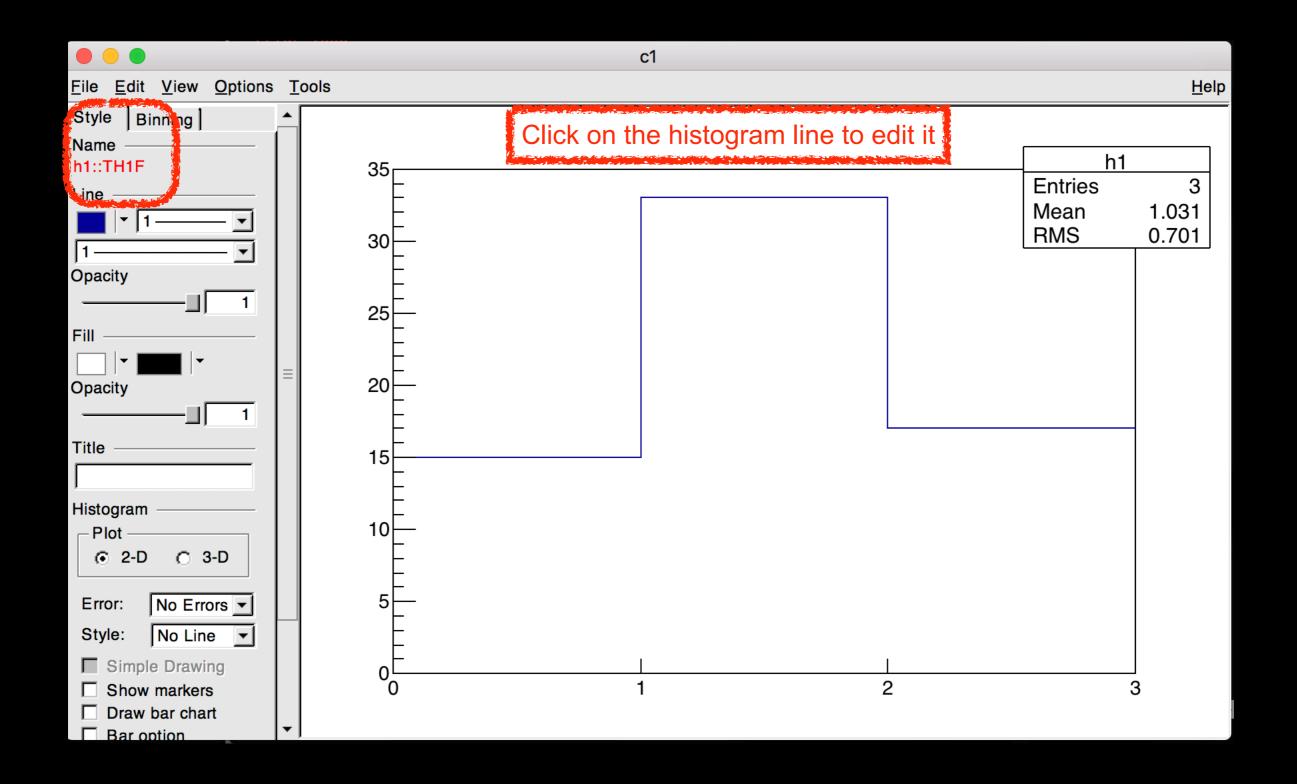
Style of a histogram





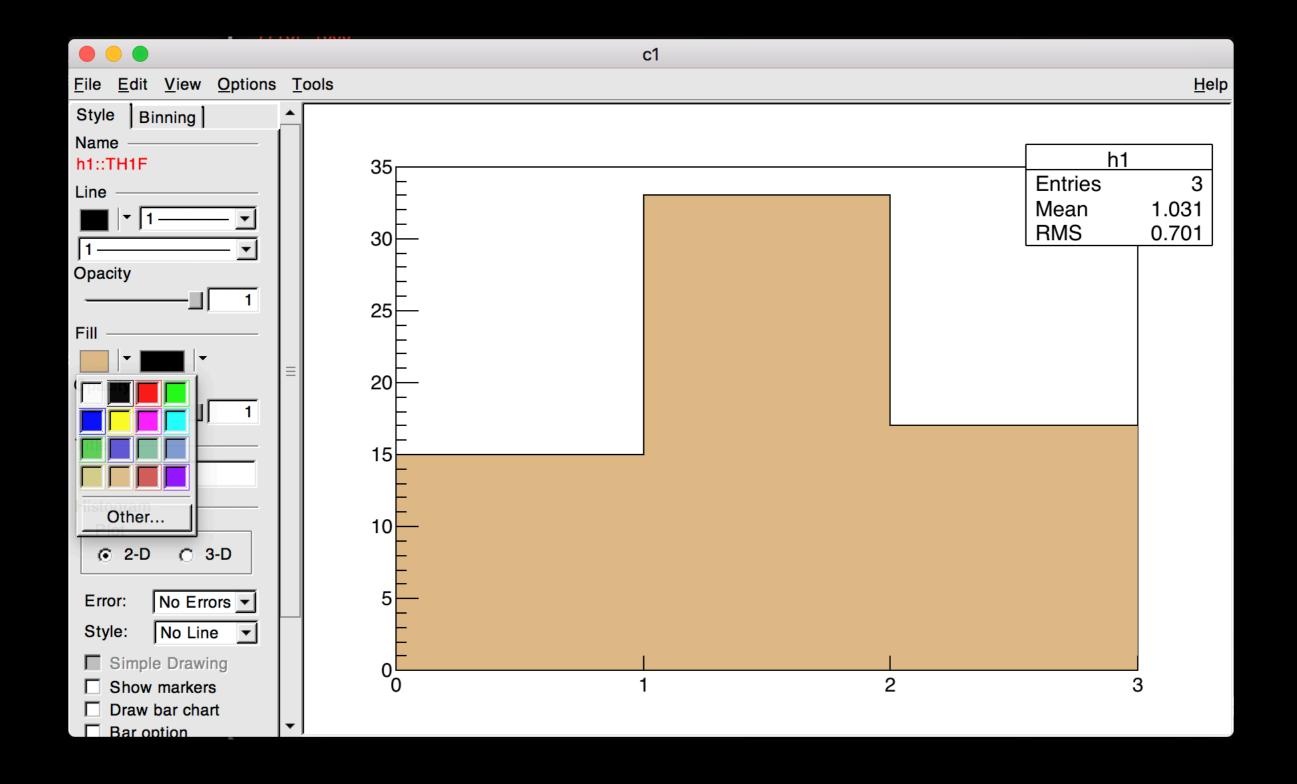
Style of a histogram (cont.)





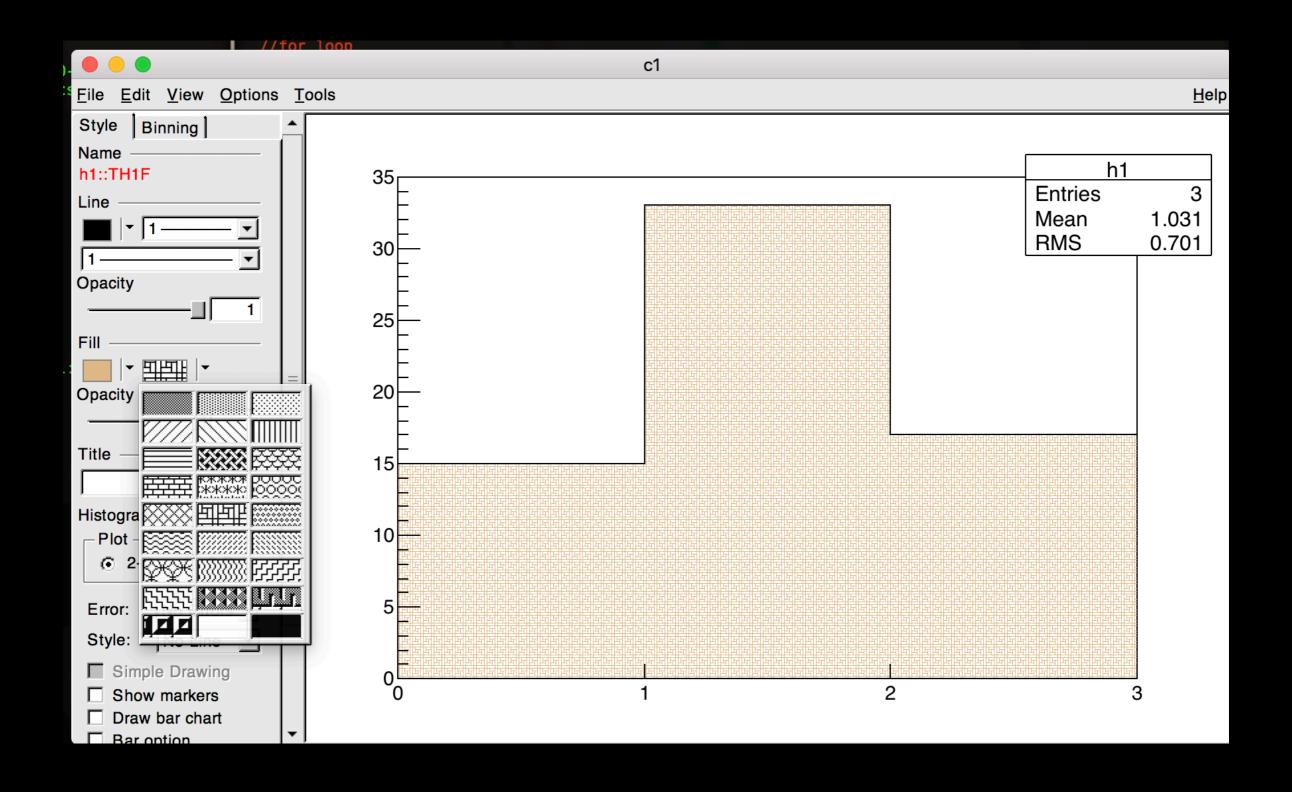














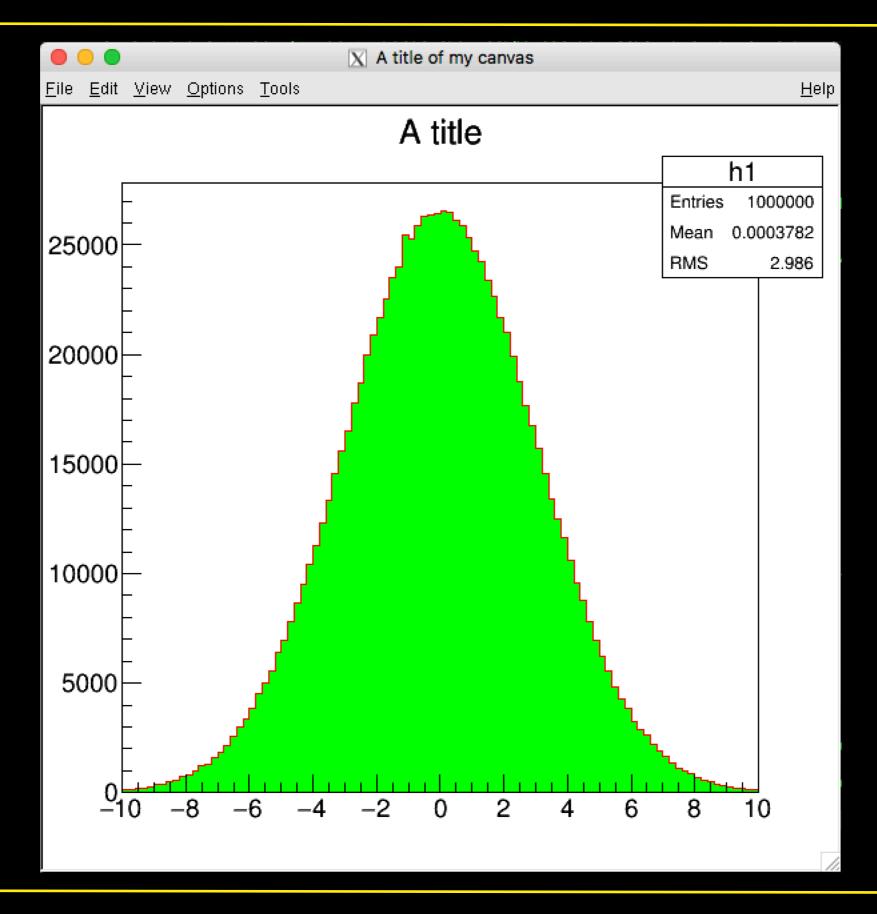


```
• •
                                   AliPhysics — ssh panosch@login.nikhef.nl — 110×45
         ~/Alice/alice-sw/ali-master/AliPhysics — -bash
                                                            ...alice-sw/ali-master/AliPhysics — ssh panosch@login.nikhef.nl
File Edit Options Buffers Tools C++ Help
void testRandom() {
  //Creting histogram
  TH1F *h1 = new TH1F("h1", "A title", 100, -10., 10);
 h1->SetLineColor(2);
 h1->SetFillColor(3);
  //for loop
  for(Int_t i = 0; i < 1000000; i++) {
    Double_t gValue = gRandom->Gaus(0.,3.);
    //cout<<"Entry: "<<i<<"\t Value: "<<gValue<<endl;</pre>
    //filling histogram
    h1->Fill(gValue);
  }//end of for loop
  //Draw the result
  TCanvas *c1 = new TCanvas("c1", "A title of my canvas", 0, 0, 600, 600);
 h1->Draw();
  TFile *gFile = new TFile("output.root", "recreate");
 h1->Write();
  gFile->Close();
```



Macro with a histogram: output





Opening the output with a browser

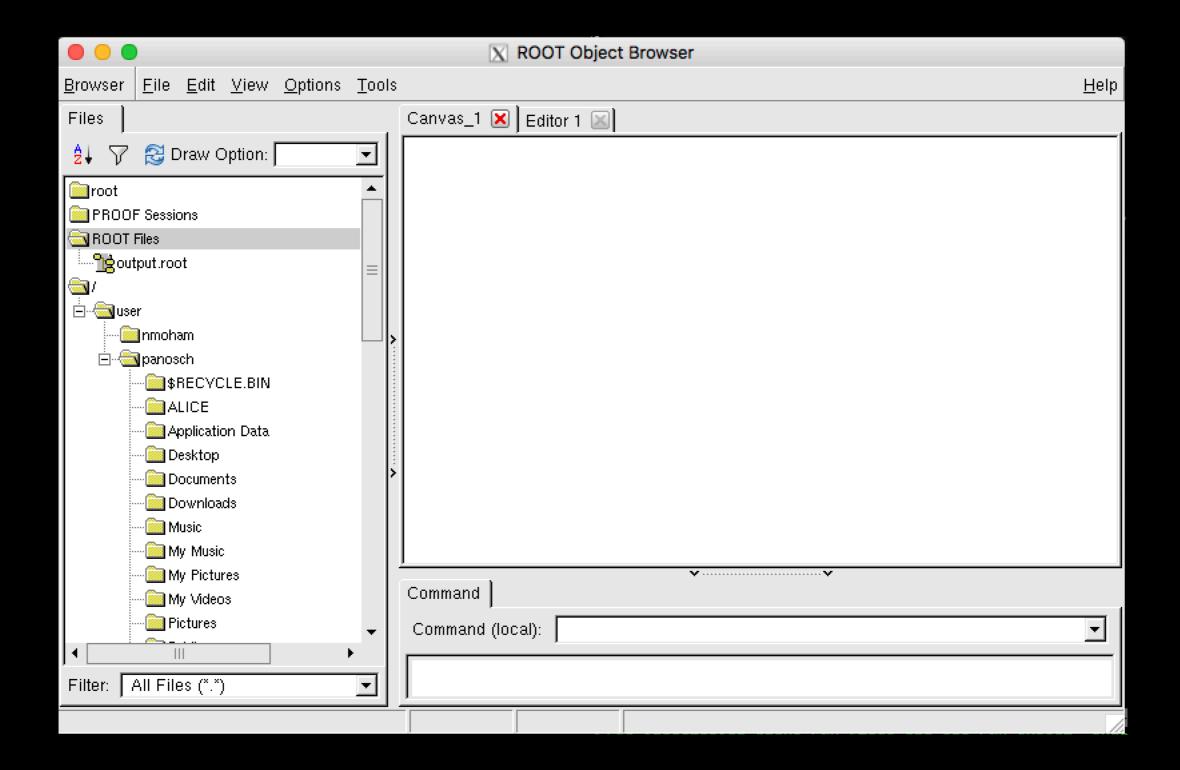


```
[[ROOT/v5-34-30-alice-1] Tutorial > ls
output.root testMacro.C testRandom.C
[ROOT/v5-34-30-alice-1] Tutorial > root.exe output.root
          WELCOME to ROOT
     Version 5.34/30
                          23 April 2015
     You are welcome to visit our Web site
            http://root.cern.ch
  *************
ROOT 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 2015, 09:24:39 on linuxx866
4gcc)
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]
Attaching file output.root as _file0...
[root [1] TBrowser b;
root [2]
```



Opening the output with a browser (cont.)

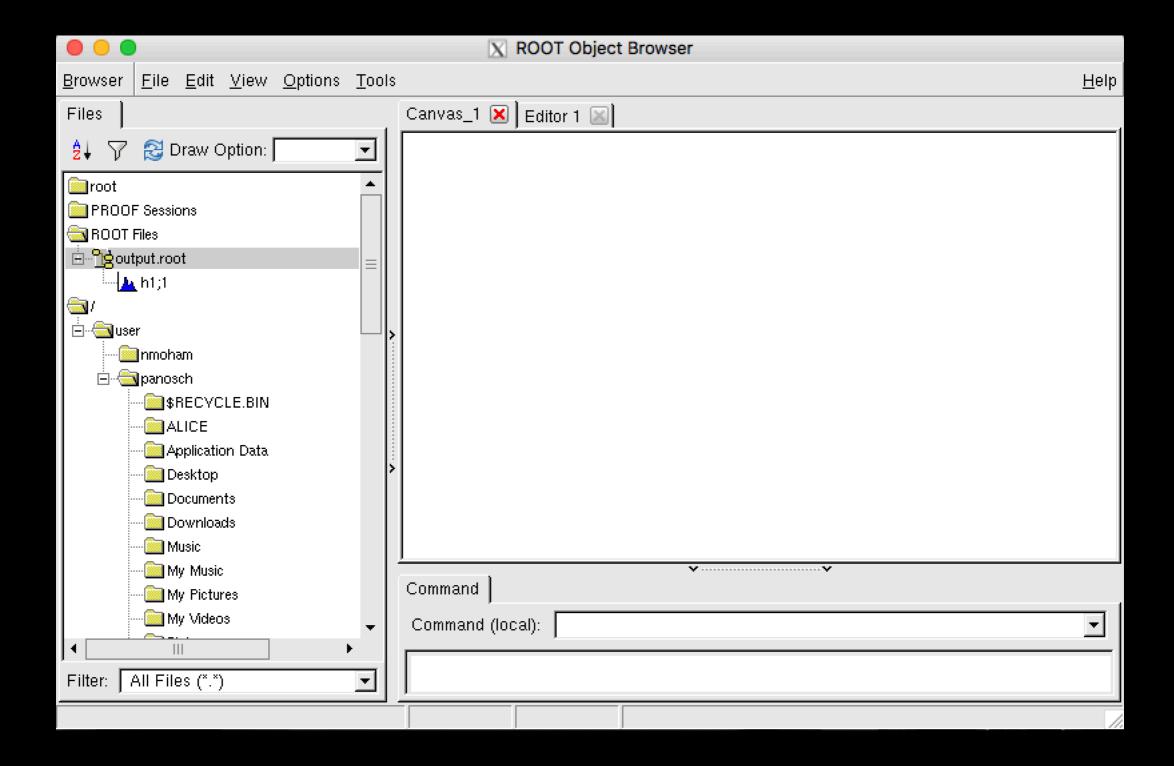






Opening the output with a browser (cont.)

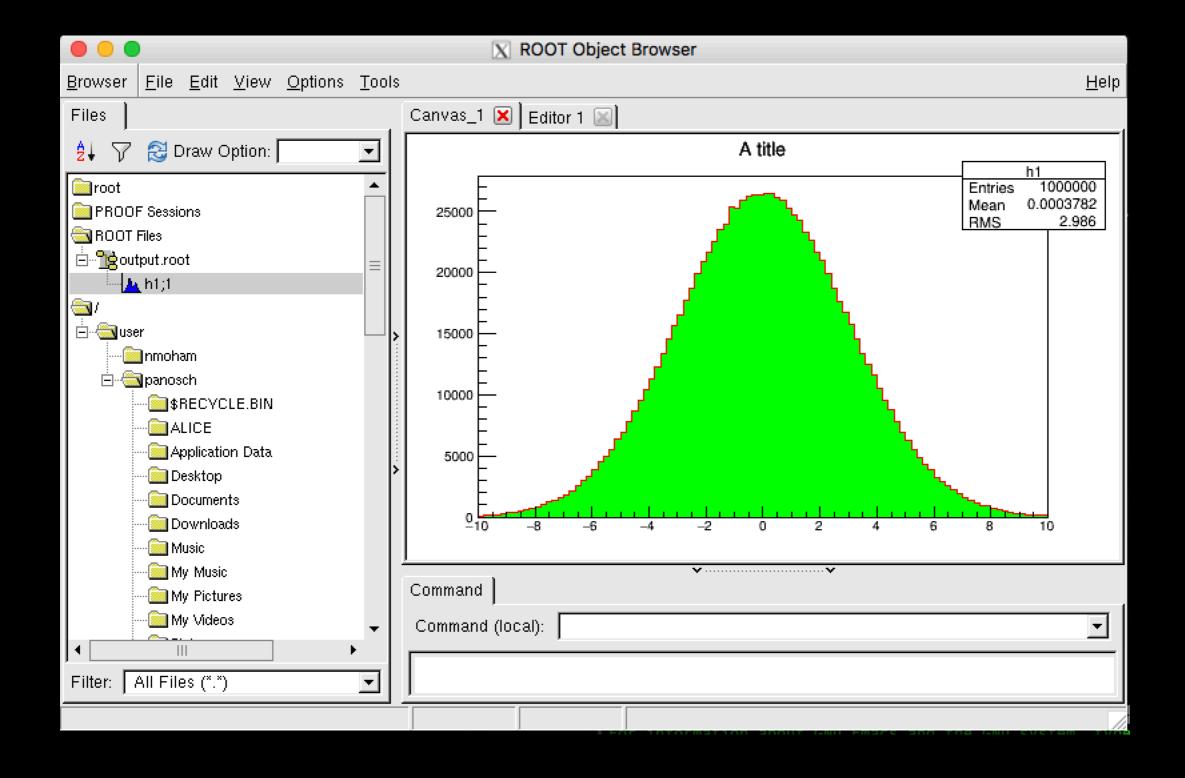






Opening the output with a browser (cont.)







Opening a file with a macro

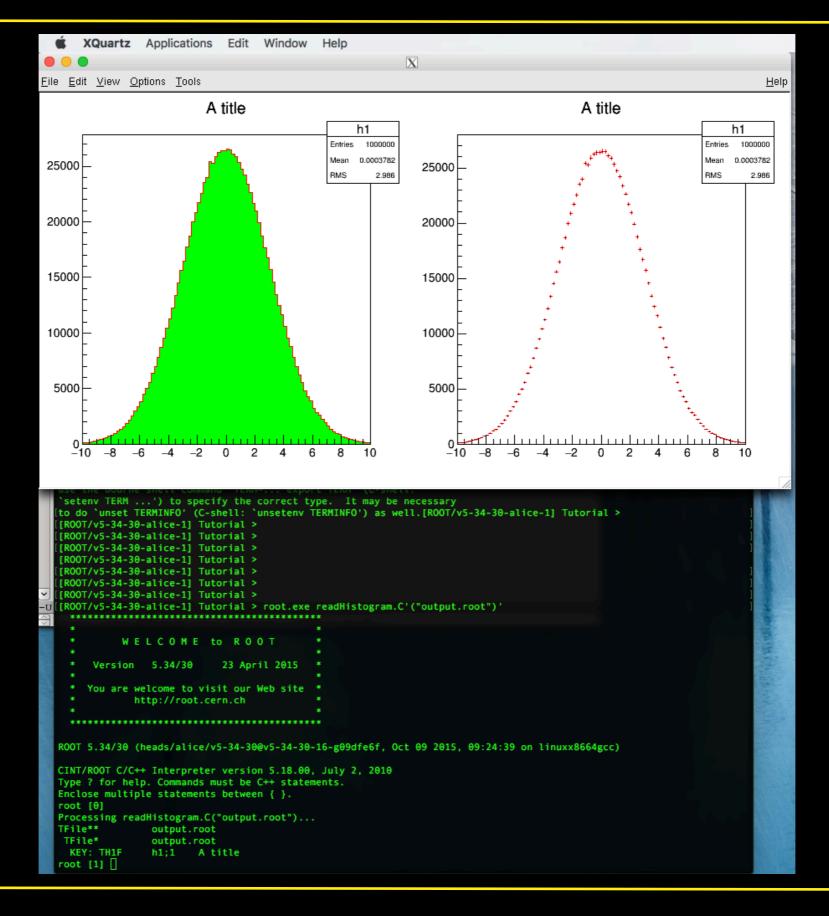


```
XQuartz Applications Edit Window Help
                              X emacs@stbc-i1.nikhef.nl
        Options Buffers Tools C++ Help
 void readHistogram(const char* filename) {
   //Macro that extracts a histogram from an existing file
   //and draws it on a canvas
   //Open the file
   TFile *fInput = TFile::Open(filename);
   if((!fInput)||(!fInput->IsOpen())) {
     cout<<"The file you provided with the name "<<filename<<" does not exist! Wh₽
¶at the hell is wrong with you??? No coffee yet???"<<endl;</p>
     return;
   fInput->1s();
   //Get the histogram from the file
   TH1F *h = dynamic_cast<TH1F *>(fInput->Get("h1"));
   if(!h) {
     cout<<"The histogram object is not found! I give up with you..."<<endl;</pre>
     return;
   //Draw the histogram on a canvas
   TCanvas *c1 = new TCanvas("c1", "", 0, 0, 900, 500);
   c1->Divide(2,1);
   c1->cd(1);
   h->DrawCopy();
   c1->cd(2);
   h->DrawCopy("E");
```



Opening a file with a macro (cont.)





Programming tips (not an exhaustive list)



- Add (meaningful) comments to your code
 - You have no idea how useful you will find them e.g. on Mondays after a hangover
 - Respect your colleagues that might also have a look at your code
- ✓ Use meaningful names to your variables
 - Int_t var1 → ok so this is the first variable but what is it for???
 - Int_t gNumberOfAcceptedTracks → even I can understand what is it for
- When you open/create an object you have to close/destroy it when you are done working with it
 - Release memory





```
//Get the histogram from the file
TH1F *h = dynamic_cast<TH1F *>(fInput->Get("h1"));
if(!h) {
  cout<<"The histogram object is not found! I give up with you..."<<endl;
  return;
}</pre>
```

```
Processing readHistogram.C("output1.root")...
Error in <TFile::TFile>: file output1.root does not exist
The file you provided with the name output1.root does not exist! What the hell is wrong with you??? No coffee yet???
[root [1] .q
[[ROOT/v5-34-30-alice-1] Tutorial > root.exe readHistogram.C'("output1.root")'
           WELCOME to ROOT
      Version 5.34/30
                            23 April 2015
     You are welcome to visit our Web site
             http://root.cern.ch
ROOT 5.34/30 (heads/alice/v5-34-30@v5-34-30-16-g09dfe6f, Oct 09 2015, 09:24:39 on linuxx8664gcc)
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 [θ]
Processing readHistogram.C("output1.root")...
Error in <TFile::TFile>: file output1.root does not exist
The file you provided with the name output1.root does not exist! What the hell is wrong with you??? No coffee yet???
root [1]
```





