
# Introduction to ROOT
# Practical Part

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# Content

- Practical introduction to the ROOT framework
  - Starting ROOT
  - Macros
  - Histograms
  - Trees
  - Creating ROOT classes
  - Basics of debugging
  - ROOT prompt
  - Functions
  - Files
  - TBrowser
- Nomenclature
  - **Blue: you type it**
  - **Red: you get it**

**Example macros and histograms are in http://www.cern.ch/jgrosseo/permanent/summerschool2010.tgz**


# ROOT Prompt

- Starting ROOT

  **$ root** **$ root -l** (without splash screen)

- The ROOT prompt

  **root [ ] 2+3** **root [ ] int i = 42**

  **root [ ] log(5)** **root [ ] printf("%d\n", i)**

- Command history
  - Scan through with **arrow keys** ↑↓
  - Search with **CTRL-R** (like in bash)
- Online help

  **root [ ] new TF1(<TAB>**

  **TF1 TF1()**

  **TF1 TF1(const char* name, const char* formula, Double_t xmin = 0, Double_t xmax = 1)**

  …


# ROOT Prompt (2)

- Typing multi-line commands

```
root [ ] for (i=0; i<3; i++)
   printf("%d\n", i)
```

or

```
root [ ] for (i=0; i<3; i++) {
end with '}', '@':abort >
   printf("%d\n", i);
end with '}', '@':abort > }
```

- Aborting wrong input

```
root [ ] printf("%d\n, i)
end with ';', '@':abort > @
```

**Don't panic!**

**Don't press CTRL-C!**

**Just type @**


# Macros

- Combine lines of codes in macros
- Unnamed macro
  - No parameters
  - For example: macro1.C

```
{
   for (Int_t i=0; i<3; i++)
     printf("%d\n", i);
}
```

**Data types in ROOT**
**Int_t (4 Bytes)**
**Long64_t (8 Bytes)**
**…**
**to achieve platform-independency**

- Executing macros

**root [ ] .x macro1.C**
**$ root –l macro1.C**
**$ root –l –b macro1.C** (batch mode → no graphics)
**$ root –l –q macro1.C** (quit after execution)

# Macros (2)

- Named macro
  - May have parameters
  - For example macro2.C:

```
void macro2(Int_t max = 10)
{
    for (Int_t i=0; i<max; i++)
      printf("%d\n", i);
}
```

- Running named macro

```
root [ ] .x macro2.C(12)
```

- Loading macros

```
root [ ] .L macro2.C
root [ ] macro2(12)
```

- Prompt vs. Macros
  - Use the prompt to test single lines while developing your code
  - Put code that is to be reused in macros

**Don't forget to change the function name after renaming a macro**

**Plots for Papers**

**It is very useful to have all the code that creates a plot in one macro. Do not create "final" plots using the prompt or the mouse (you'll be doing it again and again).**

# Functions

- The class TF1 allows to draw functions

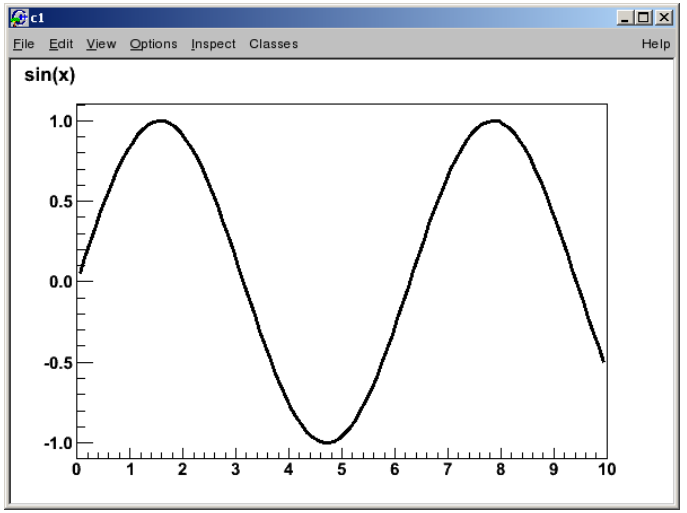
  **root [ ] f = new TF1("func", "sin(x)", 0, 10)**

  – **"func"** is a (unique) name

  – **"sin(x)"** is the formula

  – **0, 10** is the x-range for the function

  **root [ ] f->Draw()**




- The style of the function can be changed on the command line or with the context menu (→ right click)

  **root [ ] f->SetLineColor(kRed)**

- The class TF2(3) is for 2(3)-dimensional functions

**Canvas**


# Pointers vs. Value Types

- A value type contains an instance of an object
- A pointer *points* to the instance of an object
- Create a pointer

```
root [ ] TF1* f1 = new TF1("func", "sin(x)", 0, 10)
```

- Create a value type

```
root [ ] TF1 f2("func", "cos(x)", 0, 10)
```

- One can point to the other

```
TF1 f1b(*f1)          // dereference and create a copy
TF1* f2b = &f2        // point to the same object
```

# Histograms

- Contain binned data – probably the most important class in ROOT for the physicist
- Create a TH1F (= one dimensional, float precision)

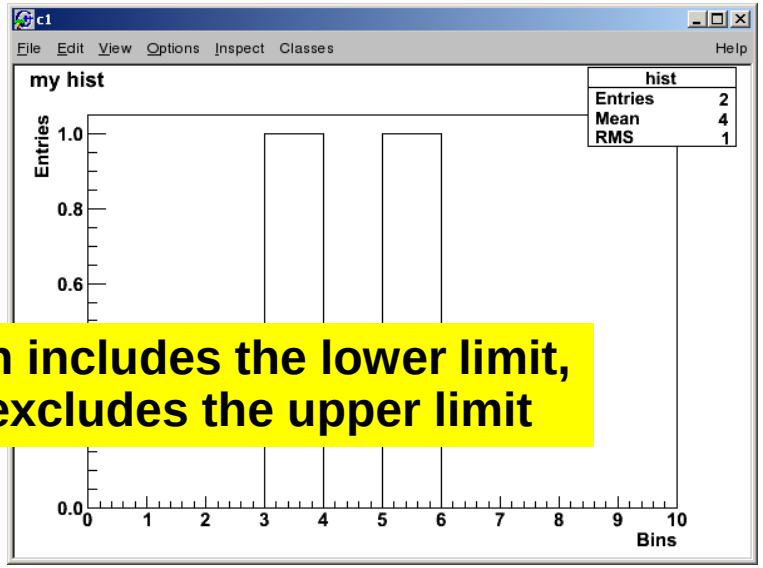
```
root [ ] h = new TH1F("hist", "my hist;Bins;Entries", 10, 0, 10)
```

  - **"hist"** is a (unique) name
  - **"my hist;Bins;Entries"** are the title and the x and y labels
  - **10** is the number of bins
  - **0, 10** are the limits on the x axis. Thus the first bin is from 0 to 1, the second from 1 to 2, etc.
- **Fill the histogram**

```
root [ ] h->Fill(3.5)
root [ ] h->Fill(5.5)
```

- **Draw the histogram**

```
root [ ] h->Draw()
```




**A bin includes the lower limit, but excludes the upper limit**

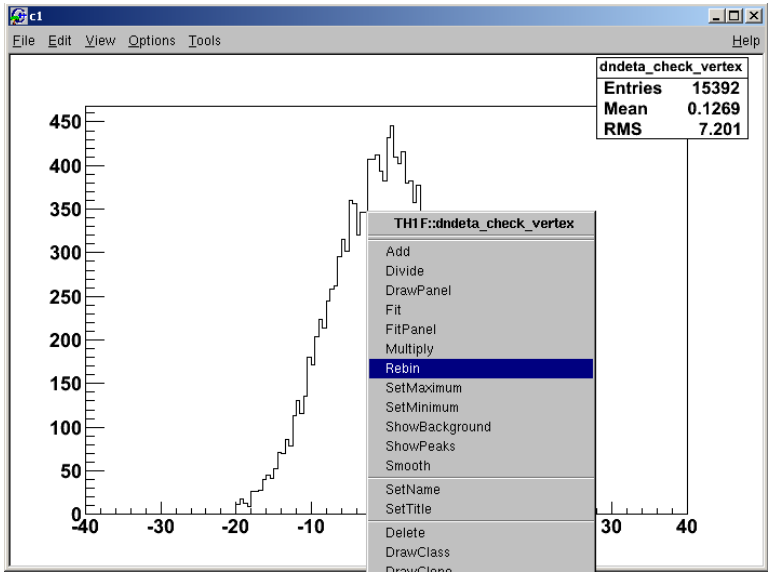
# Histograms (2)

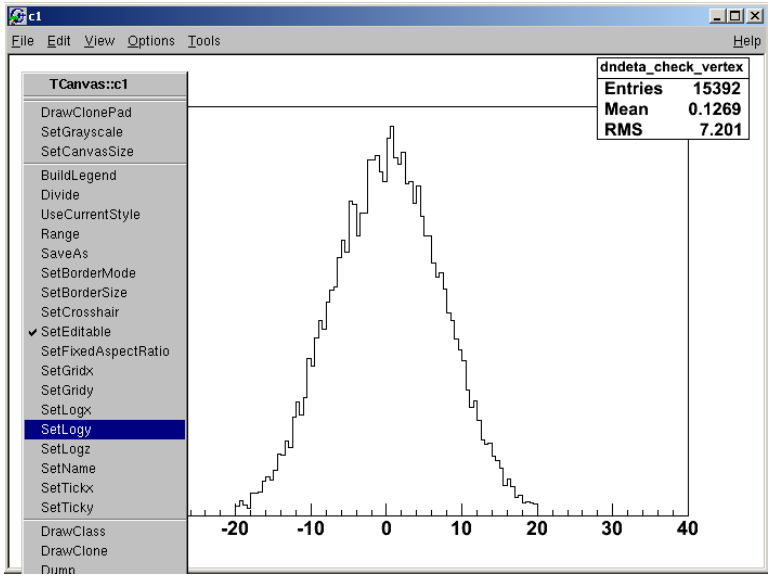
- Rebinning
  **root [ ] h->Rebin(2)**
- Change ranges
  - with the mouse
  - with the context menu
  - command line

  **root [ ] h->GetXaxis()->**
  **SetRangeUser(2, 5)**
- Log-view
  - right-click in the white area at the side of the canvas and select SetLogx (SetLogy)
  - command line

  **root [ ] gPad->SetLogy()**

NB: example histogram in file hist.root

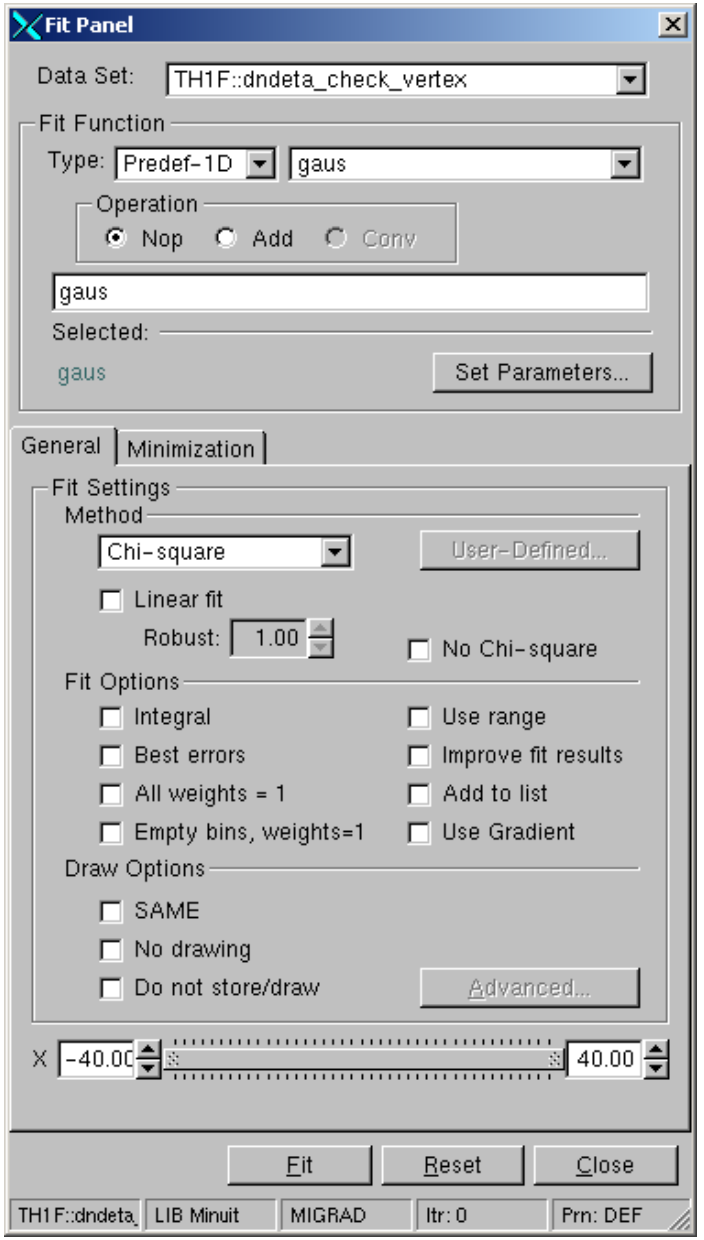


# Fitting Histograms

- Interactive
  - Right click on the histogram and choose "fit panel"
  - Select function and click fit
  - Fit parameters
    - are printed in command line
    - in the canvas: options - fit parameters
- Command line

  **root [ ] h->Fit("gaus")**
  - Other predefined functions polN (N = 0..9), expo, landau

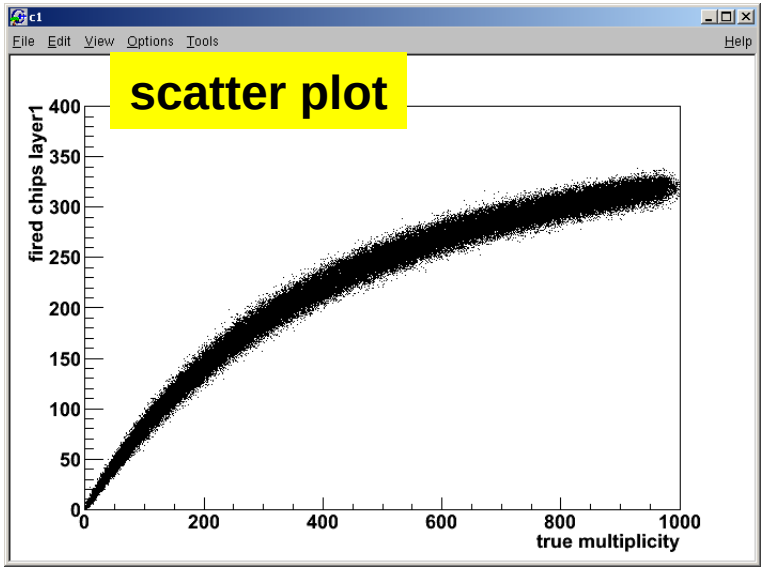


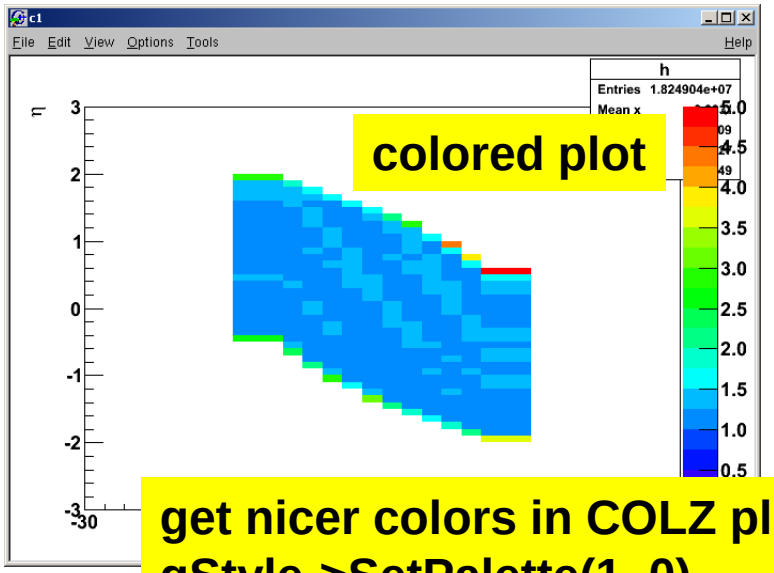
# 2D Histograms

**root [ ] h->Draw()**

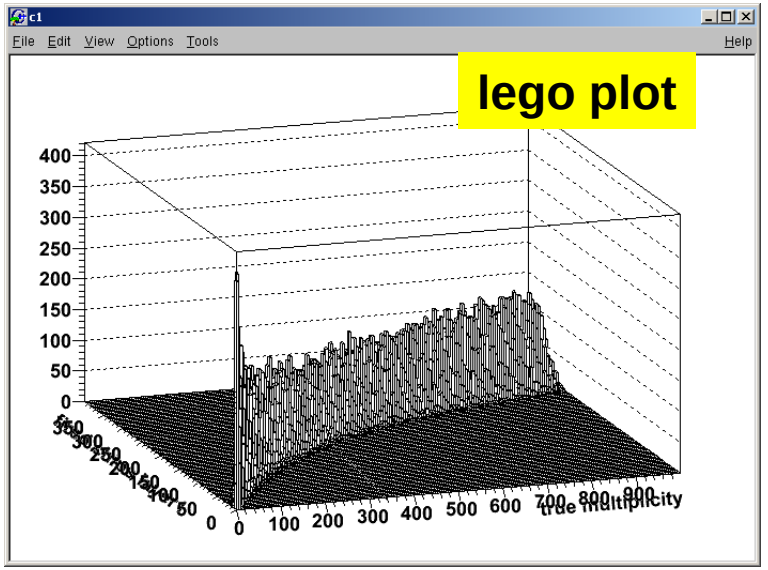
**root [ ] h->Draw("LEGO")**

**root [ ] h2->Draw("COLZ")**




**get nicer colors in COLZ plots by gStyle->SetPalette(1, 0)**




NB: h and h2 are in file hist2.root


# Files

- The class TFile allows to store any ROOT object on the disk
- Create a histogram like before with
  **h = new TH1F("hist", "my hist;…", 10, 0, 10)**
  etc.

**"hist" will be the name in the file**

- Open a file for writing

  **root [ ] file = TFile::Open("file.root", "RECREATE")**
- Write an object into the file

  **root [ ] h->Write()**
- Close the file

  **root [ ] file->Close()**

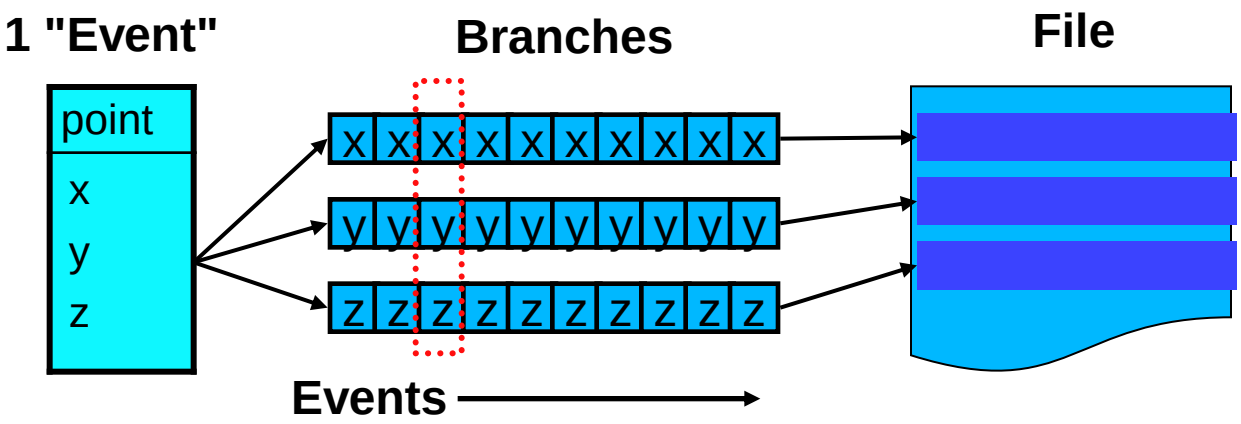

# Files (2)

- Open the file for reading
  **root [ ] file = TFile::Open("file.root")**
- Read the object from the file
  **root [ ] hist->Draw()**
  (only works on the command line!)
- In a macro read the object with
  **TH1F* h = 0;**
  **file->GetObject("hist", h);**
- What else is in the file?
  **root [ ] .ls**
- Open a file when starting root
  **$ root file.root**
  – Access it with the **_file0** or **gFile** pointer

**Object ownership**
**After reading an object from a file don't close it! Otherwise your object is not in memory anymore**

# Trees

- The class TTree is the main container for data storage
  - It can store any class and basic types (e.g. Float_t)
  - When reading a tree, certain branches can be switched off
    → speed up of analysis when not all data is needed
- First example: the class TNtuple which is derived from TTree and contains only Float_t




# TNtuple

- Create a TNtuple

  **root [ ] ntuple = new TNtuple("ntuple", "title", "x:y:z")**

  – **"ntuple"** and **"title"** are the name and the title of the object

  – **"x:y:z"** reserves three variables named x, y, and z
- Fill it

  **root [ ] ntuple->Fill(1, 1, 1)**
- Get the contents

  **root [ ] ntuple->GetEntries()** number of entries

  **root [ ] ntuple->GetEntry(0)** for the first entry

  **root [ ] ntuple->GetArgs()[1]** for y (0 for x, and 2 for z)

  – These could be used in a loop to process all entries
- List the content

  **root [ ] ntuple->Scan()**

NB: The file ntuple.C produces this TNtuple with some random entries

# TNtuple (2)

- Draw a histogram of the content
  - to draw only x

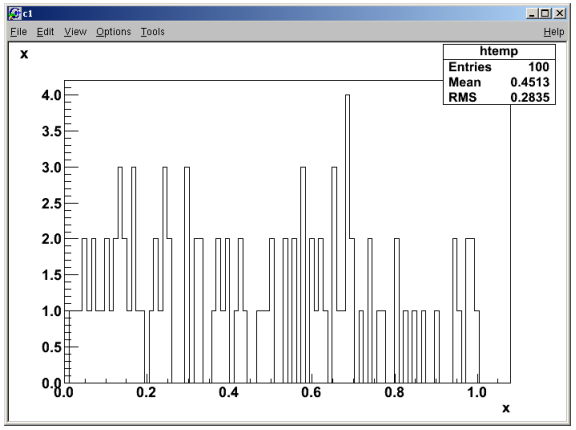
**root [ ] ntuple->Draw("x")**

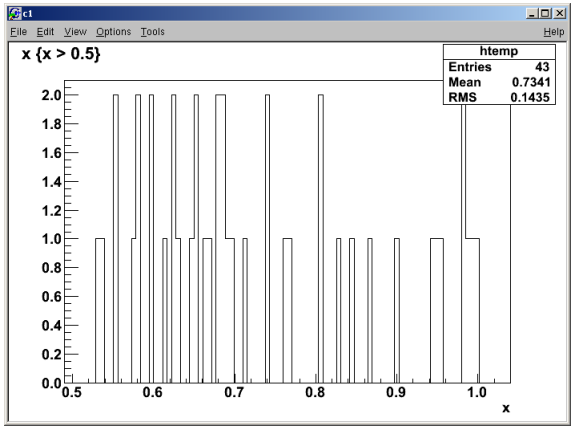
  - draw all x that fulfill x > 0.5

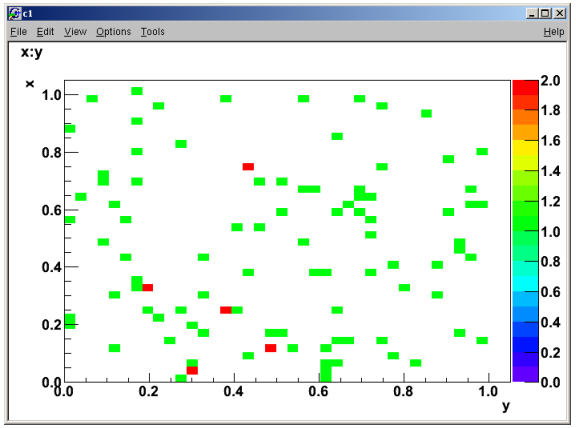
**root [ ] ntuple->Draw("x", "x > 0.5")**

  - to draw x vs. y in a 2d histogram

**root [ ] ntuple->Draw("x:y", "", "COLZ")**



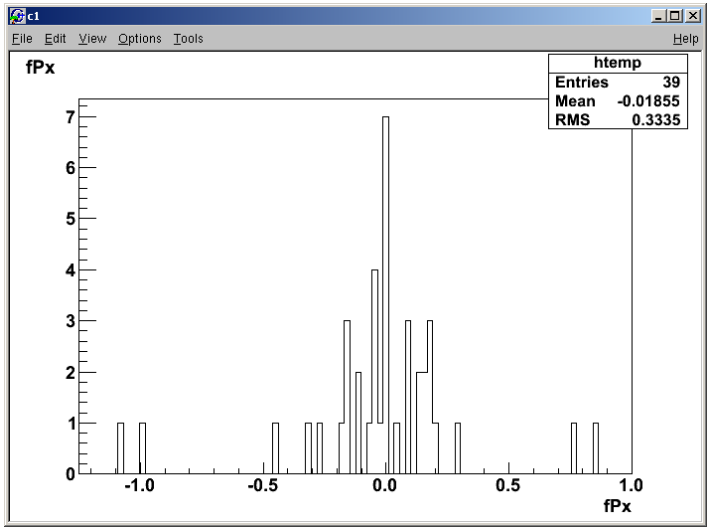

**TNtuple (or TTree) with many entries may not fit in memory**
**→ open a file before creating it**

# Trees (2)

- Accessing a more complex tree that contains classes
  - Members are accessible even without the proper class library
  - Might not work in all LHC experiments' frameworks
- Example: tree.root (containing kinematics from ALICE)

```
$ root tree.root
root [ ] tree->Draw("fPx")
root [ ] tree->Draw("fPx", "fPx < 0")
root [ ] tree->Draw("fPx",
    "abs(fPdgCode) == 211")
```

**PDG code of pions**




- From where do you know fPx, fPdgCode?
  - The tree contains TParticles
  - Check ROOT documentation: http://root.cern.ch/root/html/TParticle


# Trees (3)

- Connecting a class with the tree

  **root [ ] TParticle* particle = 0**

  **root [ ] tree->SetBranchAddress("Particles", &particle)**

- Read an entry

  **root [ ] tree->GetEntry(0)**

  **root [ ] particle->Print()**

  **root [ ] tree->GetEntry(1)**

  **root [ ] particle->Print()**

  – These commands could be used in a loop to process all particles

**The content of the TParticle instance is replaced with the current entry of the tree**

```
root [5] particle->Print()
TParticle: pi0                  p: -0.036864 -0.0
```

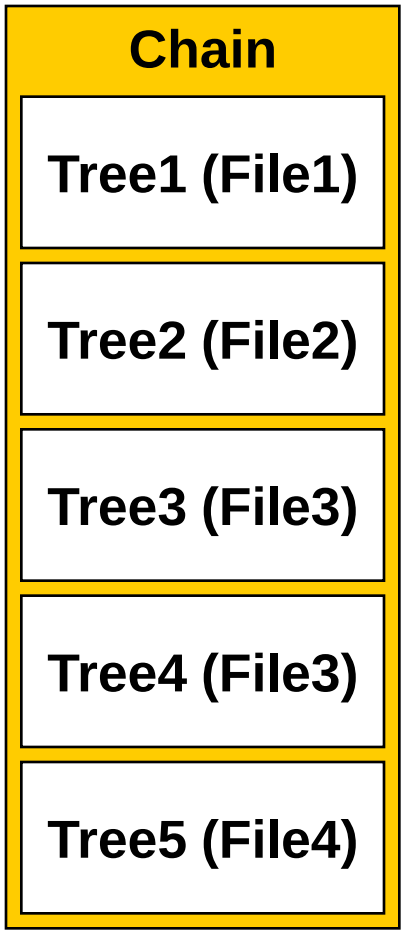
# TChain

- A chain is a list of trees (in several files)
- Normal TTree functions can be used

```
root [ ] chain = new TChain("tree")
root [ ] chain->Add("tree.root")
root [ ] chain->Add("tree2.root")
root [ ] chain->Draw("fPx")
```

  - The Draw function iterates over both trees

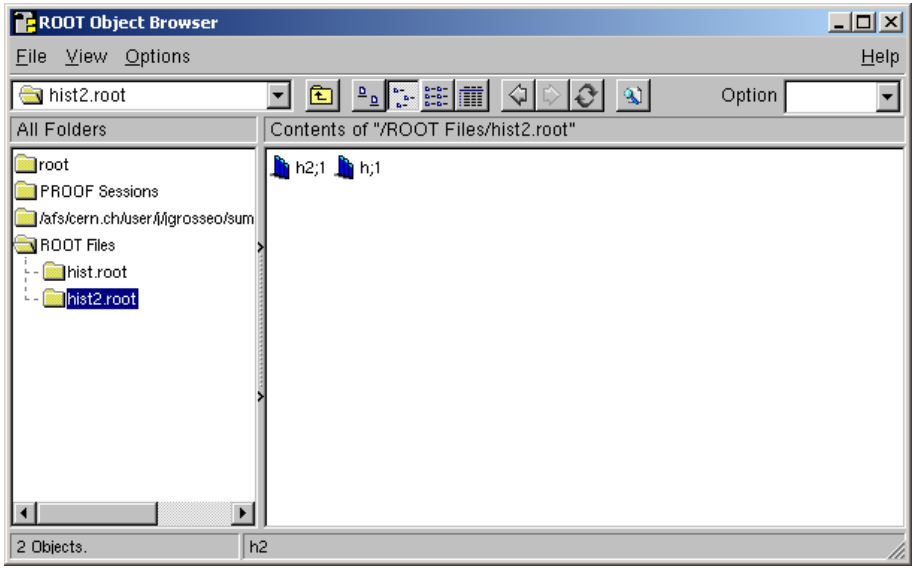
**Name of the tree in the files tree.root and tree2.root**

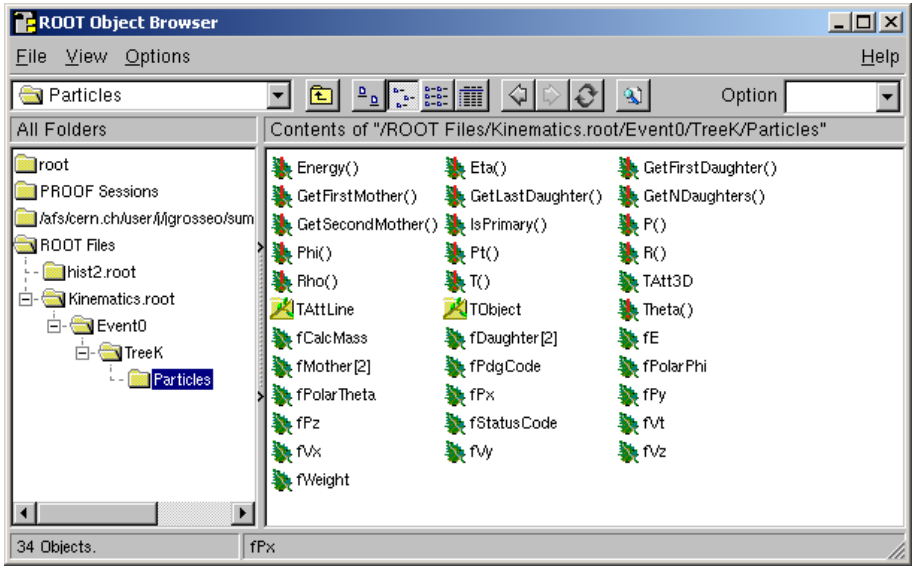


# TBrowser

- The TBrowser can be used
  - to open files
  - navigate in them
  - to look at TTrees
- Starting a TBrowser

  **root [ ] new TBrowser**
- Open a file
- Navigate through the file
- Draw a histogram
- Change the standard style
  - Drop down menu in the top right corner
- Access a tree
- Plot a member



# Creating Classes

NB: This code is in TSummerStudent.C

- Any C++ class can be used with ROOT
- Classes derived from TObject can be used directly with many other ROOT classes (e.g. TList, TObjArray)

```
#include <TObject.h>
#include <TString.h>
class TSummerStudent : public TObject {
  private:
    TString fFirstName;
    Int_t fAge;
  public:
    const char* GetFirstName() const { return fFirstName; }
    Int_t GetAge() const { return fAge; }
    TSummerStudent(const char* firstname, Int_t age)
              : fFirstName(firstname), fAge (age) { }
    virtual ~TSummerStudent () {}
    ClassDef(TSummerStudent, 1)
};
```

**TString to store strings**

**version number of class layout**

**when you add or change a member, increase the version number!**

**0 = not streamable**

**This macro adds some ROOT magic by including a dictionary created by CINT**


# Creating Classes (2)

- Include the class in ROOT

  **root [ ] .L TSummerStudent.C+g**

  **"g" adds debug symbols**

- Use it

  **root [ ] s = new TSummerStudent(“Lena", 22)**

  **root [ ] s->GetFirstName()**

- The object can be written in a file, send over the network etc.
- You can show the content of any ROOT class

  **root [ ] s->Dump()**


# Understanding Errors

Distinguish

- Compiling error
  - Syntax errors
  - Missing declarations

→ **TSummerStudent_error1.C**

- Error while loading the library "dlopen error"
  - Missing implementation of a declared function (much more subtle)
  - Might even be in parent class

→ **TSummerStudent_error2.C**

- Read error messages from top. Many other (weird) messages follow. Examples:
  - missing }
  - Missing include file
- Problems with macros? → Compile them to find errors

  **root [ ] .L macro2.C+**


# Basics of Debugging

- When there is a segmentation violation, you get the stack trace
  - It tells you where the crash happens
  - Find the relevant piece in the stack trace
    - Start from top
    - Few lines after "signal handler called"
    - Most of the times it makes only sense to look at lines that reference to your own code
  - Compile with debug ("g") to see line numbers


# Stack Trace

```
 *** Break *** segmentation violation
Using host libthread_db library "/lib/tls/libthread_db.so.1".
Attaching to program: /proc/23893/exe, process 23893
[Thread debugging using libthread_db enabled]
[New Thread -1208858944 (LWP 23893)]
0x0077c7a2 in _dl_sysinfo_int80 () from /lib/ld-linux.so.2
#1  0x002b34b3 in __waitpid_nocancel () from /lib/tls/libc.so.6
#2  0x0025c779 in do_system () from /lib/tls/libc.so.6
#3  0x0022198d in system () from /lib/tls/libpthread.so.0
#5  0x009db83e in TUnixSystem::StackTrace (this=0x9daa440) at core/unix/src/TUnixSystem.cxx:2132
#6  0x009d962d in TUnixSystem::DispatchSignals (this=0x9daa440, sig=kSigSegmentationViolation) at core/unix/src/TUnixSys
#7  0x009d745d in SigHandler (sig=kSigSegmentationViolation) at core/unix/src/TUnixSystem.cxx:350
#8  0x009de7aa in sighandler (sig=11) at core/unix/src/TUnixSystem.cxx:3368
#9  <signal handler called>
#10 0x003effd8 in TSummerStudent::SomeFunction (this=0xa0154b0) at /home/shuttle/Fiete/./TSummerStudent_debug.C:14
#11 0x003ee355 in G__TSummerStudent_debug_C_ACLiC_dict_2564_0_3 (result7=0xbffe0420, funcname=0xa0153f8 "\001", libp=0xb
    at /home/shuttle/Fiete/./TSummerStudent_debug_C_ACLiC_dict.cxx:186
#12 0x00ed8dbf in Cint::G__ExceptionWrapper (funcp=0x3ee32e <G__TSummerStudent_debug_C_ACLiC_dict_2564_0_3>, result7=0xb
    hash=0) at cint/cint/src/Api.cxx:384
#13 0x00f81786 in G__execute_call (result7=0xbffe0420, libp=0xbffda5a0, ifunc=0xa0153f8, ifn=0) at cint/cint/src/newlink
#14 0x00f81ea6 in G__call_cppfunc (result7=0xbffe0420, libp=0xbffda5a0, ifunc=0xa0153f8, ifn=0) at cint/cint/src/newlink
#15 0x00f6295a in G__interpret_func (result7=0xbffe0420, funcname=0xbffe0020 "SomeFunction", libp=0xbffda5a0, hash=1242,
    at cint/cint/src/ifunc.cxx:5277
#16 0x00f4907c in G__getfunction (item=0xbffe3263 "SomeFunction()", known3=0xbffe267c, memfunc_flag=1) at cint/cint/src/
#17 0x0103b145 in G__getstructmem (store_var_type=112, varname=0xbffe0670 "@/5", membername=0xbffe3263 "SomeFunction()",
    varglobal=0x10d9ea0, objptr=2) at cint/cint/src/var.cxx:6691
#18 0x0102f234 in G__getvariable (item=0xbffe3260 "s->SomeFunction()", known=0xbffe267c, varglobal=0x10d9ea0, varlocal=0
#19 0x00f3ccc9 in G__getitem (item=0xbffe3260 "s->SomeFunction()") at cint/cint/src/expr.cxx:1884
#20 0x00f3b338 in G__getexpr (expression=0xbffe4b50 "s->SomeFunction()") at cint/cint/src/expr.cxx:1470
```


# Basics of Debugging (2)

- Reproduce the problem in the debugger
- Most linux systems include gdb (GNU debugger)
- **$ gdb root.exe** (gdb root does not work)
  - Parameter to root have to be passed with
    **$ gdb --args root.exe macro.C**
  - On the gdb prompt, start the program: **(gdb) run**
- You will see the line where the crash happened
- Basic commands
  - **bt** = backtrace, gives the stack
  - **up**, **down** to navigate in the stack → go to the first frame with your code
  - **p <var>** → prints the variable <var> (of your code, e.g. particle)
  - **quit** to exit

**→ TSummerStudent_debug.C**


# Resources

- Main ROOT page
  - http://root.cern.ch
- Class Reference Guide
  - http://root.cern.ch/root/html
- C++ tutorial
  - http://www.cplusplus.com/doc/tutorial/
  - http://www-root.fnal.gov/root/CPlusPlus/index.html
- Hands-on tutorials (especially the last one)
  - http://root.cern.ch/drupal/content/tutorials-and-courses