

Based on a tutorial given  
with Yvonne Ng

# ROOT Tutorial

— How to draw in High Energy Physics

Tadej Novak

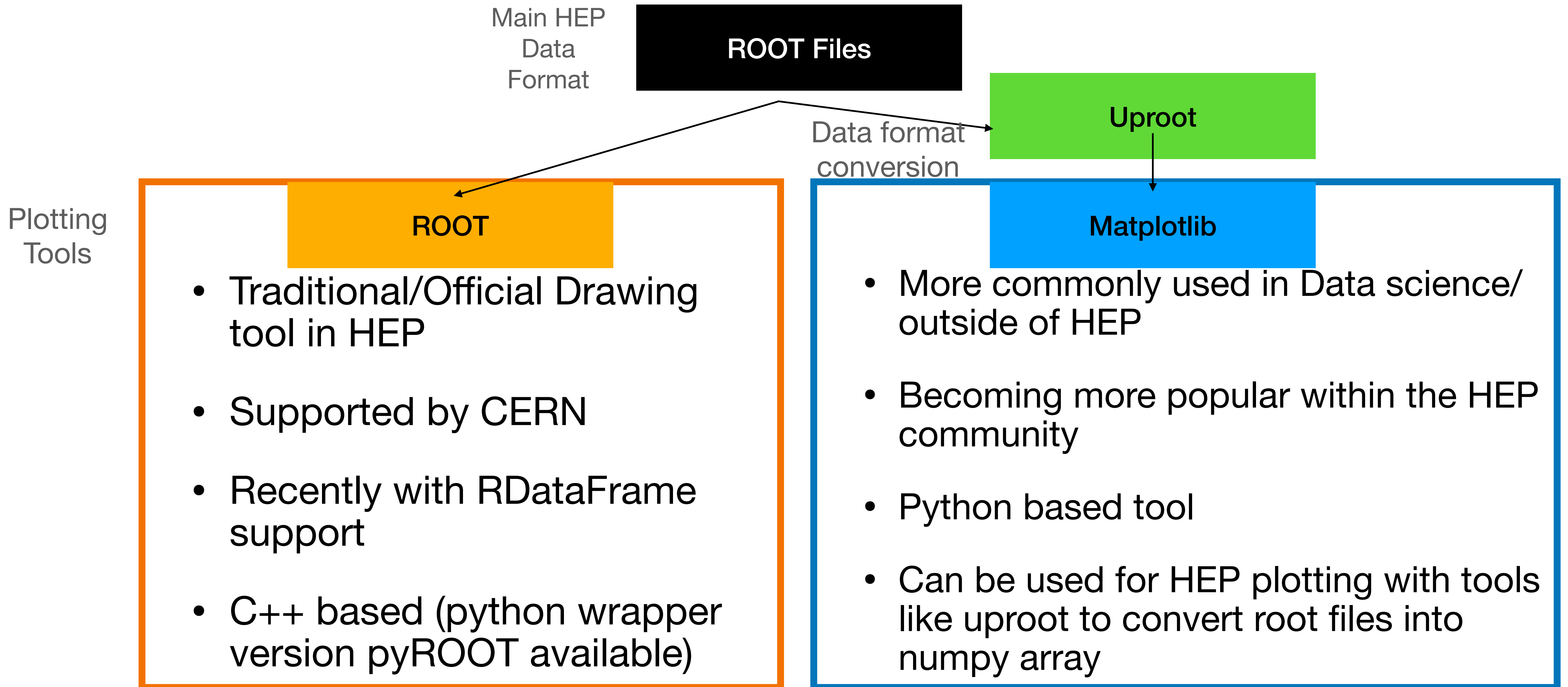
DESY Summer Students 2023

26th July 2023



# How do I draw in HEP?

– The two main players:



# Interactive tutorial

- Also available at <https://www.desy.de/~tadej/tutorial/>
  - File that we will use: <https://www.desy.de/~tadej/tutorial/Zmumu.root>
  - `$ wget https://www.desy.de/~tadej/tutorial/Zmumu.root`
- Simple steps to get the code running:
  - `$ ssh -Y school01@naf-school01.desy.de`
  - make the python file e.g. `ExerciseHist.py`, later you execute with `python3 ExerciseHist.py`
  - to copy files: `$ scp school01@naf-school01.desy.de:/path/to/file /local/path/to/file`

# What is ROOT?

- ROOT is a powerful tool in HEP analysis. Three main functions:

1. Data storage structure/format:  
Tree-Branch base data structure for event based format common in HEP

2. Analysis

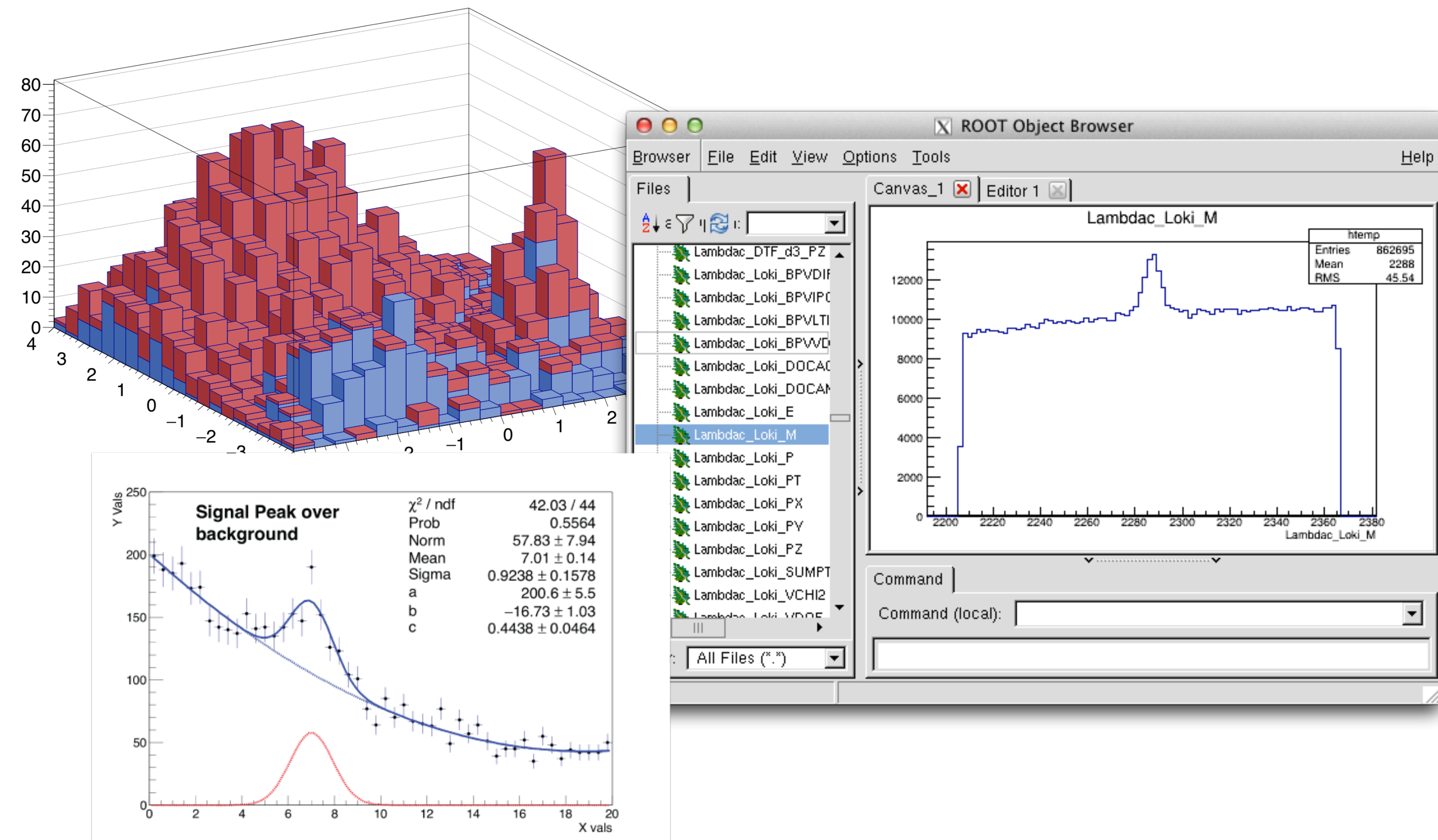
- Math libraries
- stats library (e.g. RooFit/RooStats)
- machine learning libraries (e.g. TMVA)

3. Plotting (Drawing)



# ROOT

Data Analysis Framework



# ROOT and Plotting

- ROOT is a powerful tool in HEP analysis. Three main functions:

1. **Data storage structure/format:**  
Tree-Branch base data structure for event based format common in HEP

2. Analysis

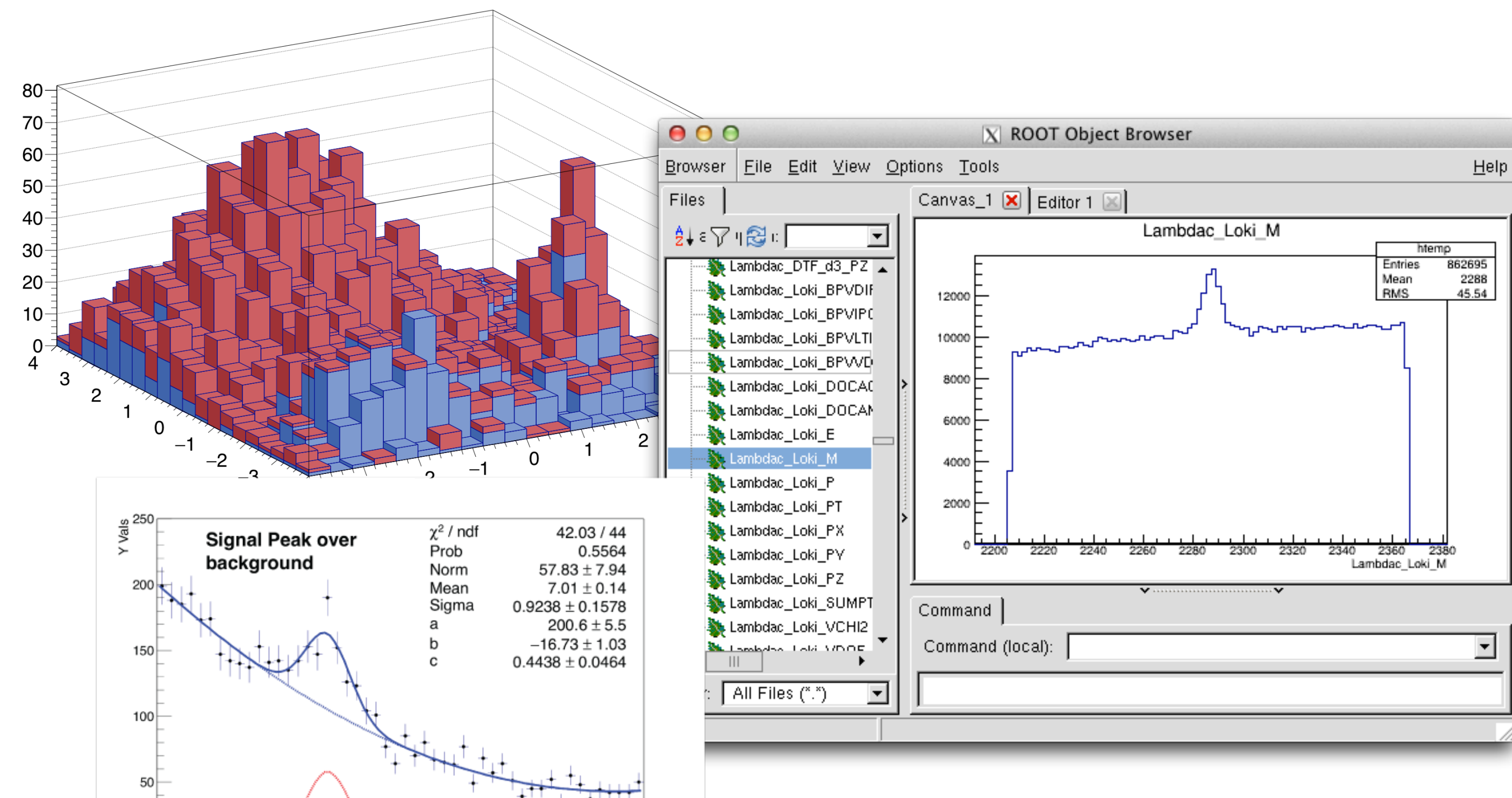
- Math libraries
- stats library (e.g. RooFit/RooStats)
- machine learning libraries (e.g. TMVA)

3. **Plotting (Drawing)**



# ROOT

Data Analysis Framework



ROOT is a [c++ based tool](#), this tutorial will focus on the python wrapper (PyROOT)

# ROOT as a object based tool

- **TObject**: base class for all ROOT objects
- **TFile**: class for reading/writing root files
- **TTree**: basic storage format in ROOT
- **TH1**: base class for 1-, 2-, 3-D Histograms
- **TCanvas**: class for graphical display
- **TStyle**: class for style of histograms, axis, title, markers, etc...
- **TGraph**: class of graphic object based on x and y-arrays
- **TF1**: base class for functions

```
import ROOT as r
```

```
Welcome to JupyROOT 6.26/06
```

```
#TFile: Opening input TFile  
input_file = r.TFile.Open("Zprime_dimuon_signal_sample.root")
```

```
#TTree: Getting tree from the root file and storing it in a TTree object  
input_tree = input_file.Get("myTree")
```

```
#TH1: Initializing a histogram object  
my_histogram = r.TH1D("myHistogram", "This is my histogram", 100, 0, 100)
```

```
#TTree & TH1: Filling the histogram from existing tree branch directly  
input_tree.Draw("truth_mu_pt>>myHistogram")
```

```
#TCanvas: creating a canvas for drawing  
my_canvas = r.TCanvas()
```

```
#TH1: Make histogram look nice  
my_histogram.SetLineColor(r.kRed)
```

```
#TH1: drawing the histogram to the canvas  
my_histogram.Draw("E")
```

```
#TCanvas: saving the canvas as a pdf  
my_canvas.SaveAs("histogram.pdf")
```

```
Info in <TCanvas::Print>: pdf file histogram.pdf has been created
```

Complete list: <https://root.cern/doc/master/classes.html>

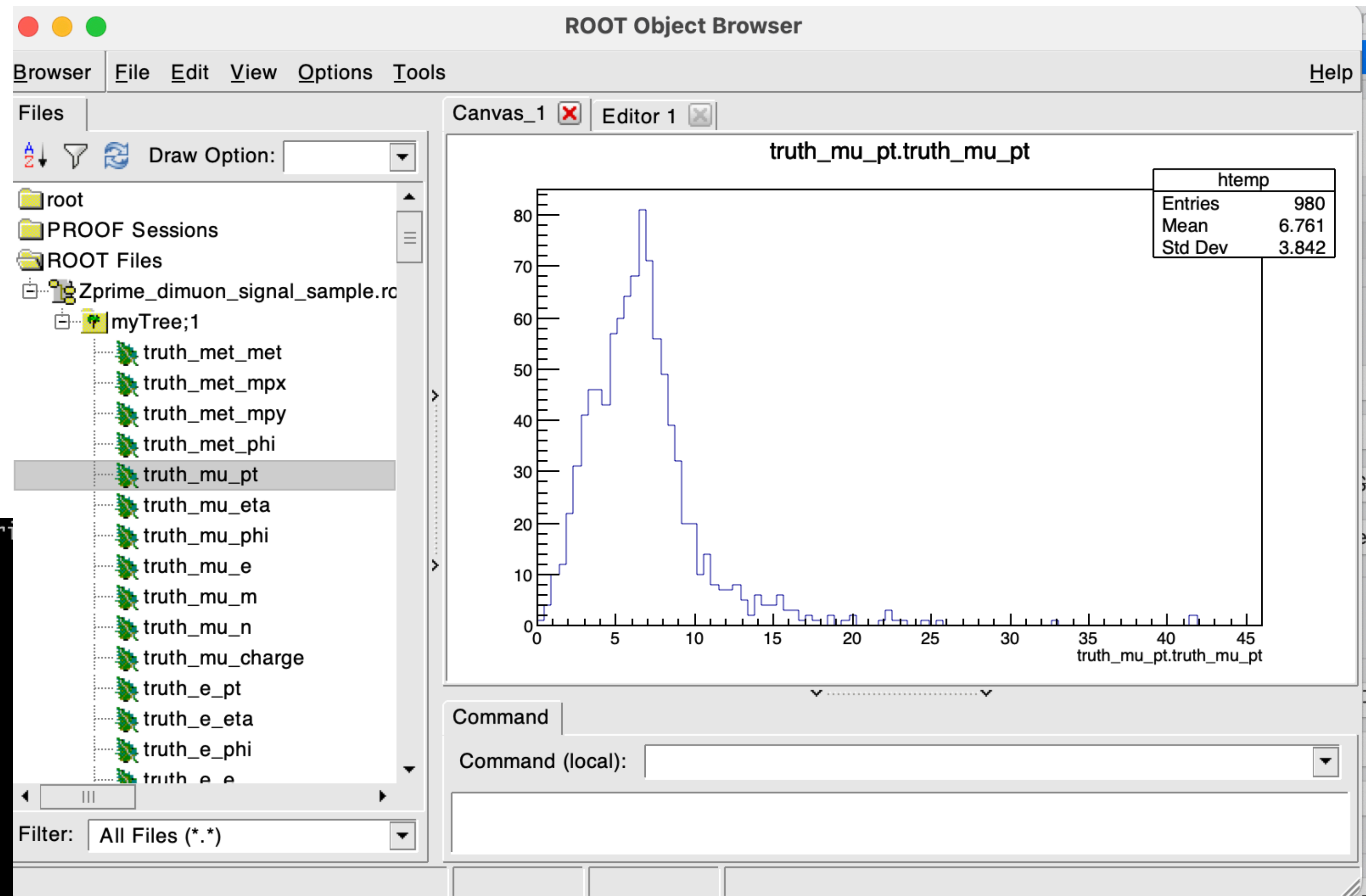
# TBrowser

## –Drawing option manipulation with GUI/command line

- TBrowser can be used for ROOT file inspection. Run:
  - `$ root Zmumu.root`  
(use “root –web=off” for later versions)
  - `$ TBrowser newBrowser`

```
(base) yvonne@yvonne-MacBook-Pro TerascaleRootTutorial_2023 % root Zprime_dimuon_signal_sample.root
-----
| Welcome to ROOT 6.26/06                               https://root.cern |
| (c) 1995-2021, The ROOT Team; conception: R. Brun, F. Rademakers |
| Built for macosxarm64 on Jul 28 2022, 18:08:51 |
| From tags/v6-26-06@v6-26-06 |
| With Apple clang version 14.0.0 (clang-1400.0.29.202) |
| Try '.help', '.demo', '.license', '.credits', '.quit'/.q' |
-----

root [0]
Attaching file Zprime_dimuon_signal_sample.root as _file0...
(TFile *) 0x13ec5d180
root [1] TBrowser k
(TBrowser &) Name: Browser Title: ROOT Object Browser
```





# TBrowser Drawing Manipulation

## – Example: Changing histogram outlook

- **GUI:**

Right click on the

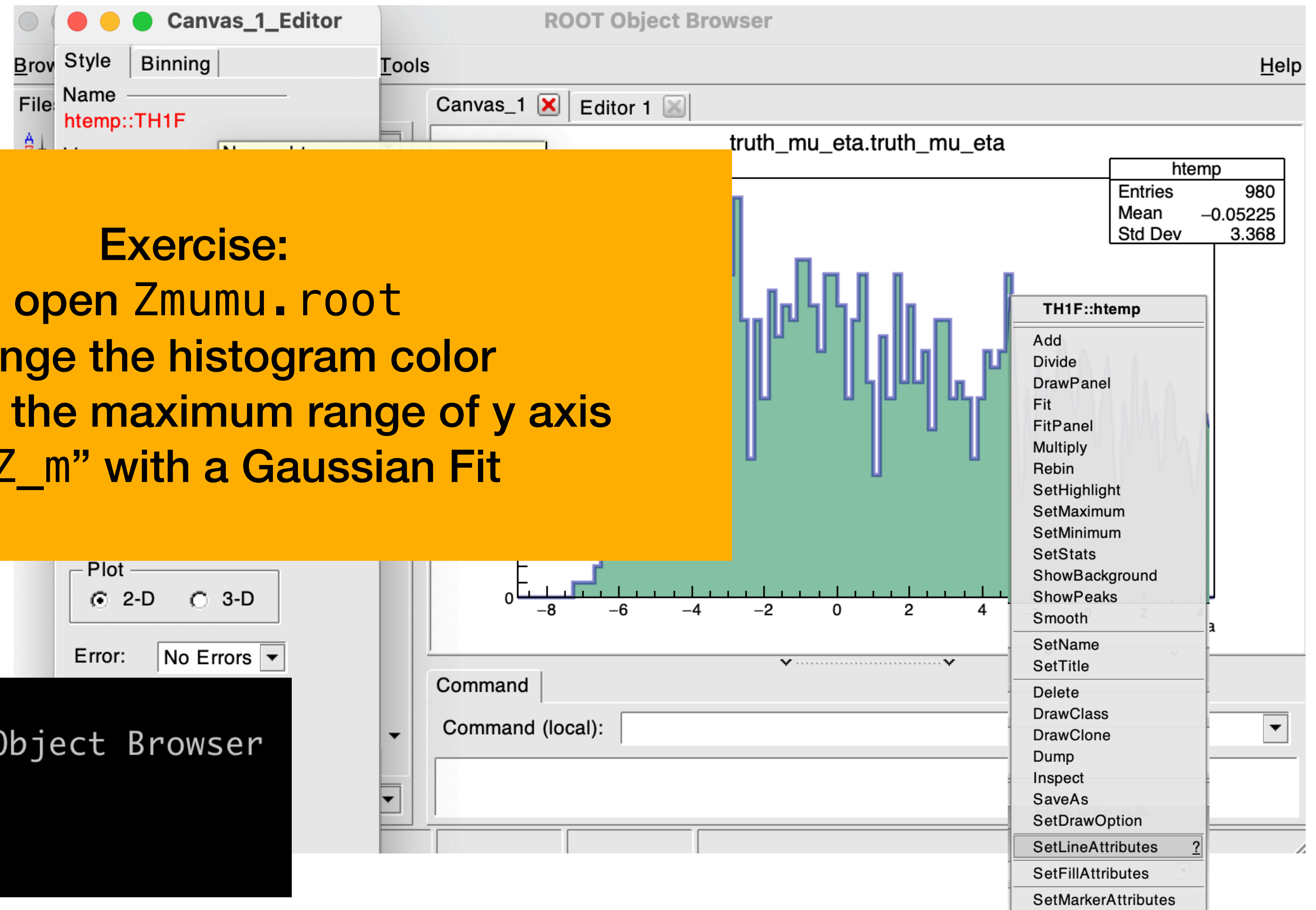
- Choose **SetLineAttributes**

- Change line color, line width, set Fill color

- **C**root [1] TBrowser k  
(TBrowser &) Name: Browser Title: ROOT Object Browser  
root [2] htemp->SetLineColor(kRed)  
root [3] htemp->SetLineWidth(5)  
root [4] htemp->SetFillColor(kBlue)

**Exercise:**

- open Zmumu.root
- change the histogram color
- changing the maximum range of y axis
- fit "Z\_m" with a Gaussian Fit



Same effect! TBrowser GUI is a good choice for quick plot making.

# Classes: TFile and TTree

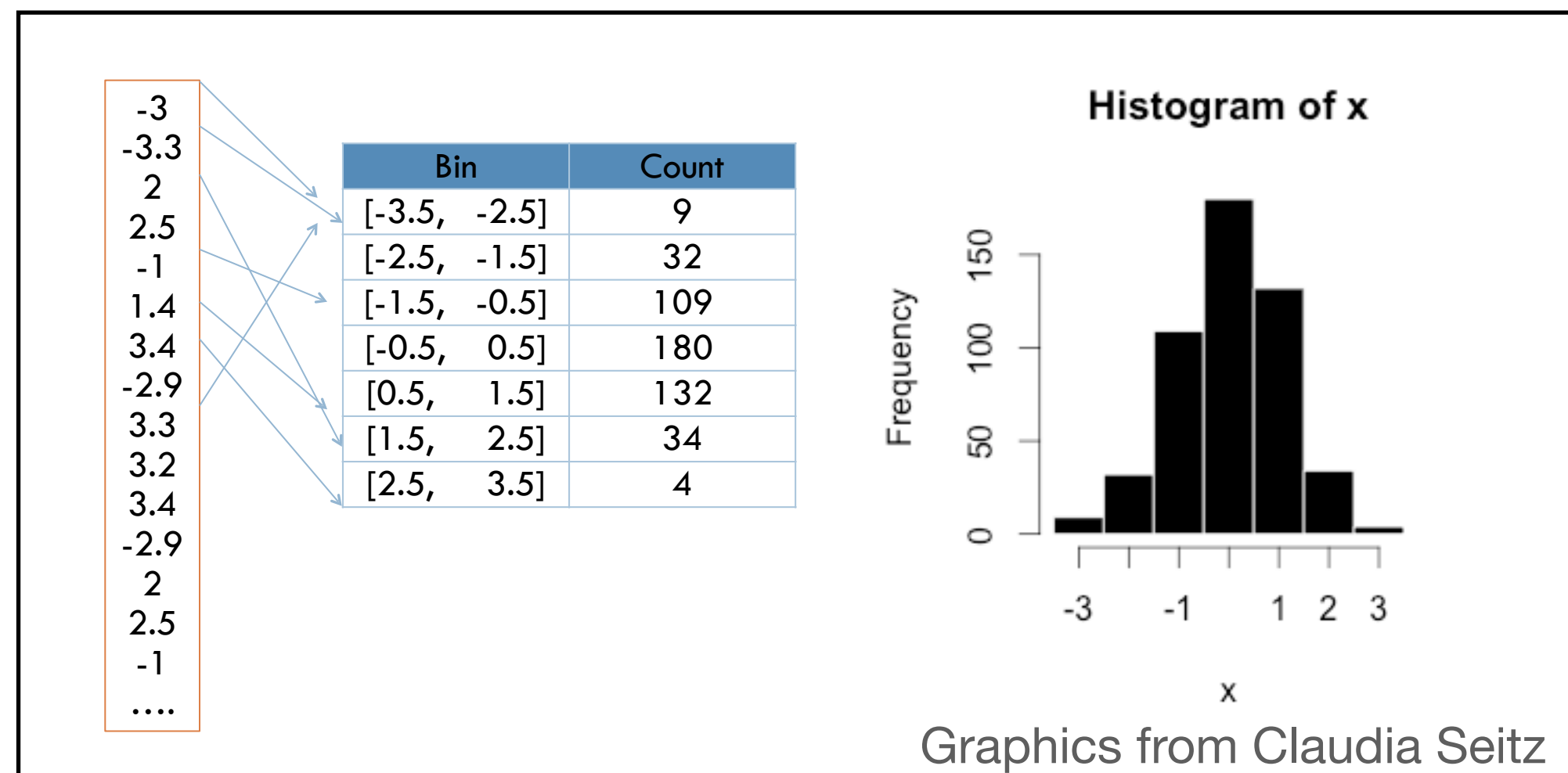
- TFile is basic I/O format in ROOT.
- Open an existing file (read only):
  - `file = TFile.Open("Zmumu.root")` (or `TFile::Open("Zmumu.root")` in C++)
- Make a new file:
  - `file = TFile("Zmumu.root", "OPTION")`
  - OPTION = "RECREATE" (replace file), "UPDATE" (append to file)
- Files can contain directories, histograms and trees (ntuples) etc. → for analysis data we usually use TTree.
- Tree has "entries" (e.g. collision events), each with identical data structure.
- Can contain floats, integers, or more complex objects (whole classes, vectors, etc...).

# Classes: Histograms

## – Plotting with ROOT

- When you are interested in the distribution/frequency of the data
- ROOT Classes : TH1 (1D histogram), TH2 (2D histogram), TH3 (3D histogram)
  - Child classes: TH1F (1D single-precision floating-point histogram), TH1D (1D double-precision), TH2I (1D integer histogram)

(some) histogram drawing options:



Option	Explanation
"E"	Draw error bars.
"HIST"	When an histogram has errors it is visualized by default with error bars. To visualize it without errors use the option "HIST".
"SAME"	Superimpose on previous picture in the same pad.
"TEXT"	Draw bin contents as text.
<b>Options just for TH1</b>	
"C"	Draw a smooth Curve through the histogram bins.
"E0"	Draw error bars. Markers are drawn for bins with 0 contents.
"E1"	Draw error bars with perpendicular lines at the edges.
"E2"	Draw error bars with rectangles.
"E3"	Draw a fill area through the end points of the vertical error bars.
"E4"	Draw a smoothed filled area through the end points of the error bars.

Histogram: Sorting information into bins

Creating information about the frequency/distribution of the data

Correlation information between different variables in 2D or higher dimensions

# Interactive tutorial

- Will present the next part interactively
- Also available at <https://www.desy.de/~tadej/tutorial/>
  - File that we will use: <https://www.desy.de/~tadej/tutorial/Zmumu.root>
  - `$ wget https://www.desy.de/~tadej/tutorial/Zmumu.root`
- Simple steps to get the code running:
  - make the python file e.g. `ExerciseHist.py`, later you execute with `python3 ExerciseHist.py`
  - All ROOT macros should start with  
`import ROOT`  
`ROOT.gROOT.SetBatch(True)`