

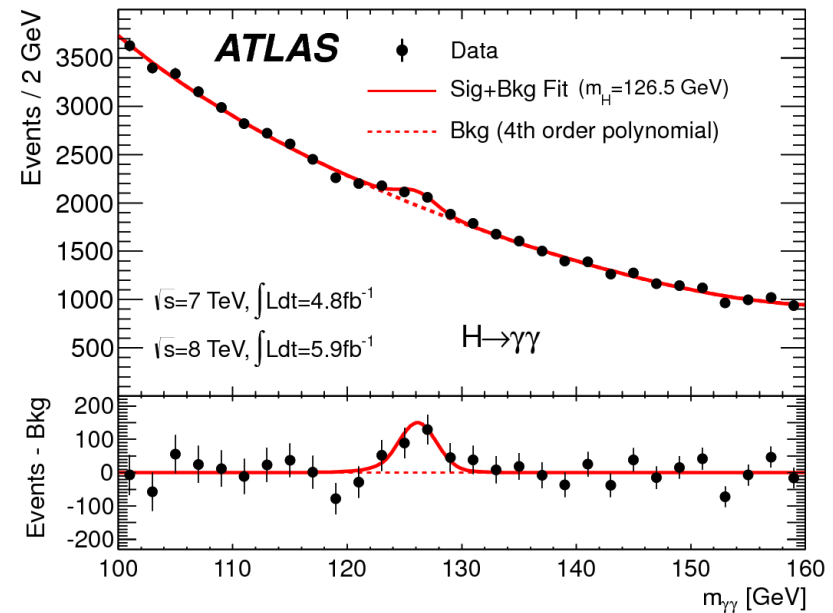


# Introduction to ROOT

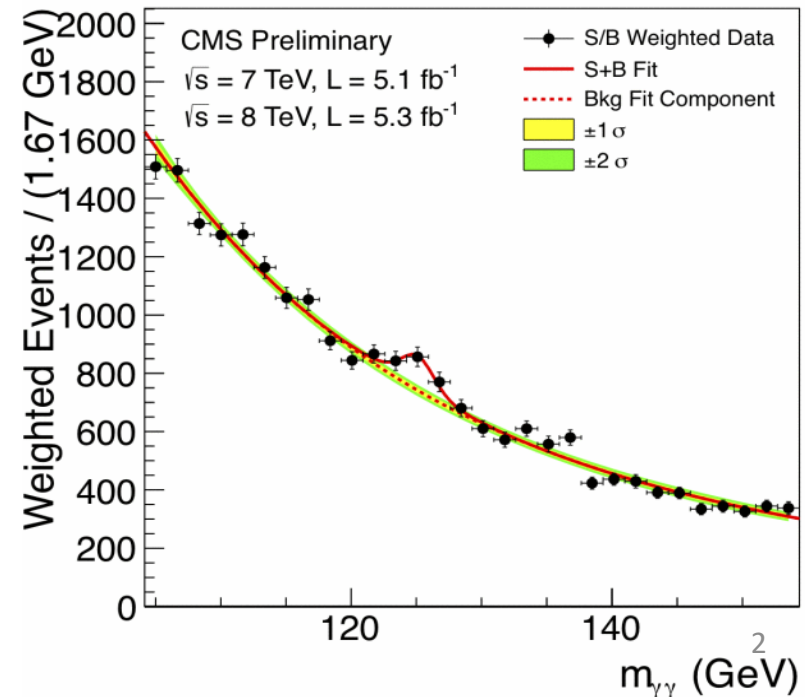
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# What is ROOT?

- **ROOT** is an object-oriented framework for large-scale data handling & analysis.
- It is originally developed for high energy physics experiments (still used by *most* particle physics experiments), but now also finds application in astronomy, data mining, etc.
- For example, the analysis and plots of recent Higgs Boson discovery are mostly done using ROOT.



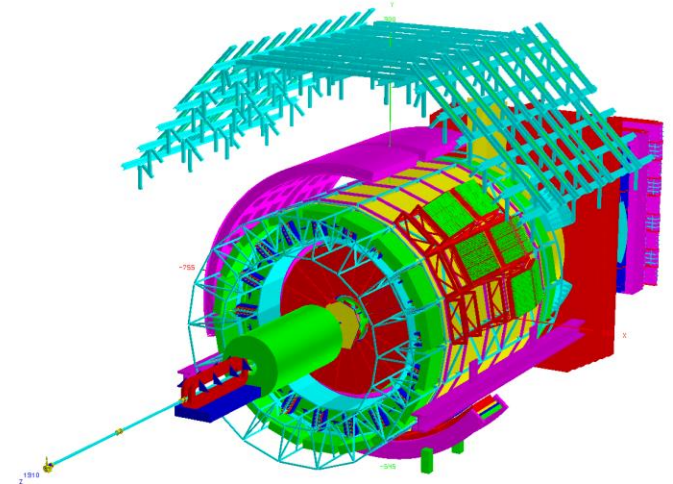
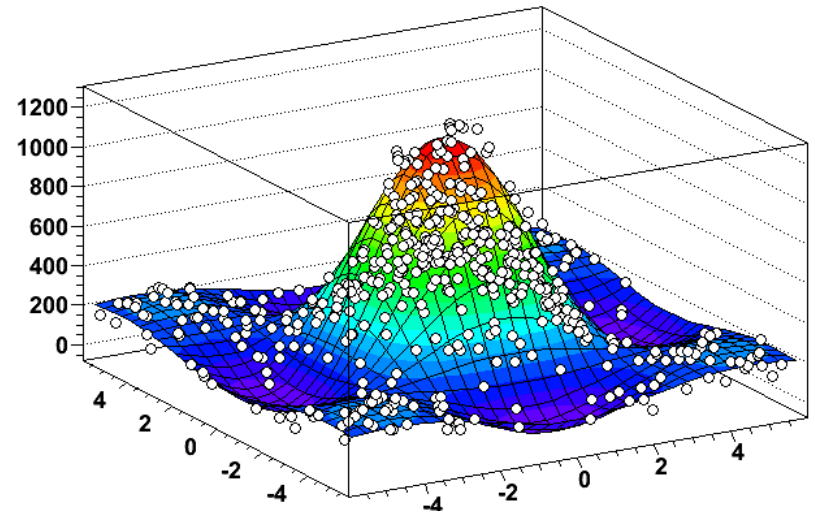
## Higgs Boson Discovery



# Why use ROOT?

- ROOT can efficiently handle structured **large data sets** (PetaBytes  $\triangle!$ ).
- ROOT has **advanced statistical analysis algorithms** (multi-dimensional fitting, neural network, etc).
- ROOT has scientific **visualization tools** with 2D and 3D graphics; not as ‘pretty’ as e.g. Origin, but functional.
- ROOT is an **open-source** project. It is free, and available for **Windows, Mac, and Linux** machines.

Minuit fit result on the Graph2DErrors points



ALICE Detector

# Using ROOT

Three user interfaces:

- Graphic User Interface
- Command line
- Macros and scripts

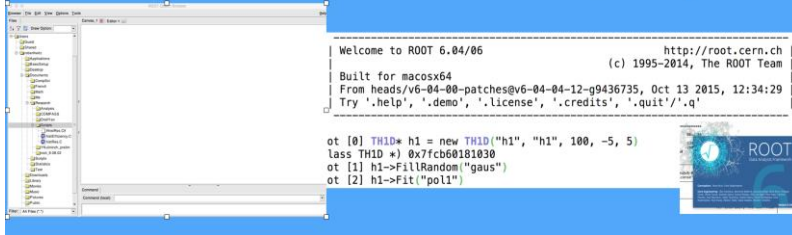
We will use all of them to help us with the analysis, you will write your own (or modify existing) analysis scripts.

```
void histEfficiency() {
  const Int_t nPer = 5;
  Double_t U2efficiency[nPer] = {92.8, 39.72, 40.61, 40.77, 36.35};
  Double_t U1efficiency[nPer] = {93.79, 39.72, 40.61, 40.77, 36.35};

  Double_t V2efficiency[nPer] = {, 39.72, 40.61, 40.77, 36.35};
  Double_t V2efficiency[nPer] = {93.79, 39.72, 40.61, 40.77, 36.35};

  Double_t X1efficiency[nPer] = {93.79, 39.72, 40.61, 40.77, 36.35};
  Double_t X2efficiency[nPer] = {93.79, 39.72, 40.61, 40.77, 36.35};

  Double_t Y2efficiency[nPer] = {46.50, 39.72, 40.61, 40.77, 36.35};
  Double_t Y1efficiency[nPer] = {46.50, 39.72, 40.61, 40.77, 36.35};
}
```



The screenshot shows the ROOT software interface. At the top, there is a C++ code editor with a function named `histEfficiency()` that defines several arrays of efficiency values. Below the code editor, there is a terminal window displaying the ROOT welcome message, including the version (6.04/06), the website (http://root.cern.ch), and the build information. The terminal also shows the execution of a macro `h1` which creates a `TH1D` object, fills it with random Gaussian data, and fits it with a polynomial. To the right of the terminal, there is a small window showing a ROOT logo and a plot.

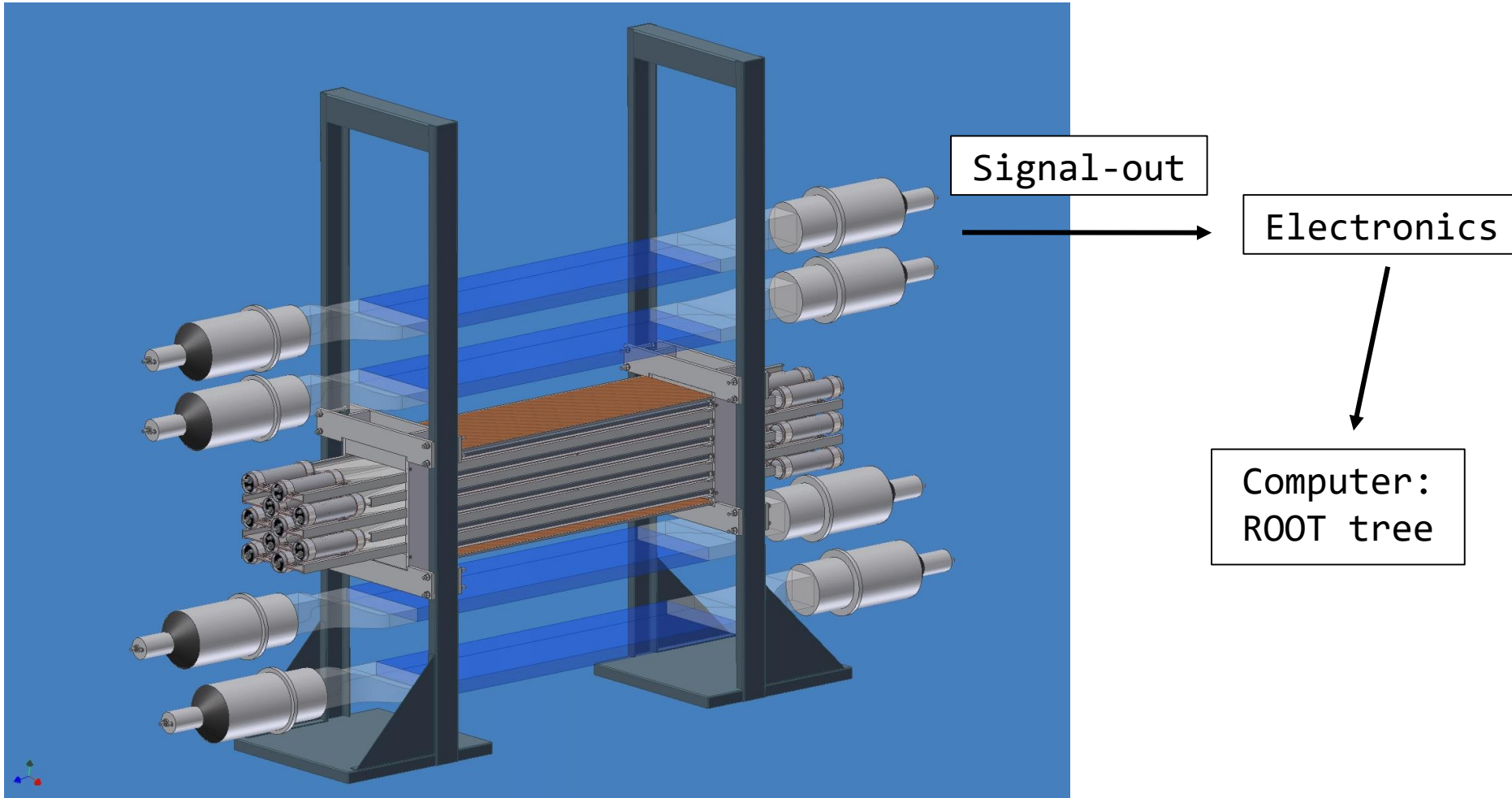
→ ROOT is installed on the LINUX machine in 5103.

→ You can also do your work by remotely logging into the machine (ask Daniel).

→ Finally, you can install it on your own computer... There is an extremely useful blog post by a physicist on medium.com that will take you through each step:

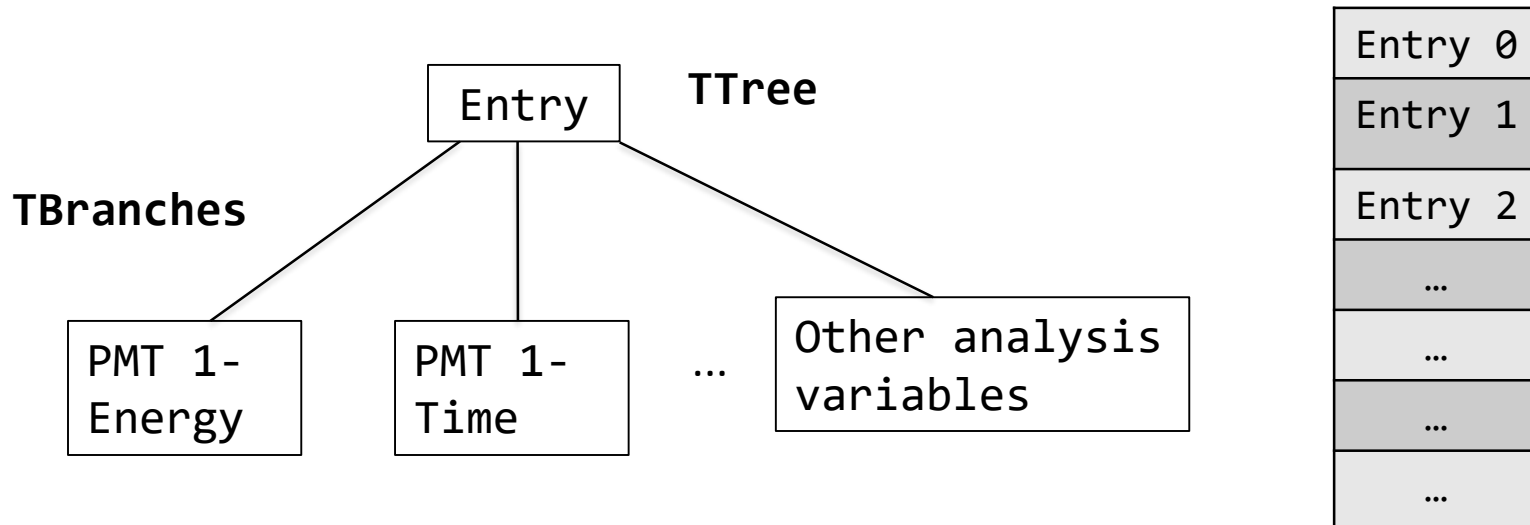
<https://medium.com/@blake.leverington/installing-cern-root-under-windows-10-with-subsystem-for-linux-beta-75295defc6d4>

# Muon Experiment



→ 16 PMT signals, w/both **energy** and **timing** information, are recorded by the data acquisition system (DAQ). An analyzer program converts the binary data into a ROOT tree.

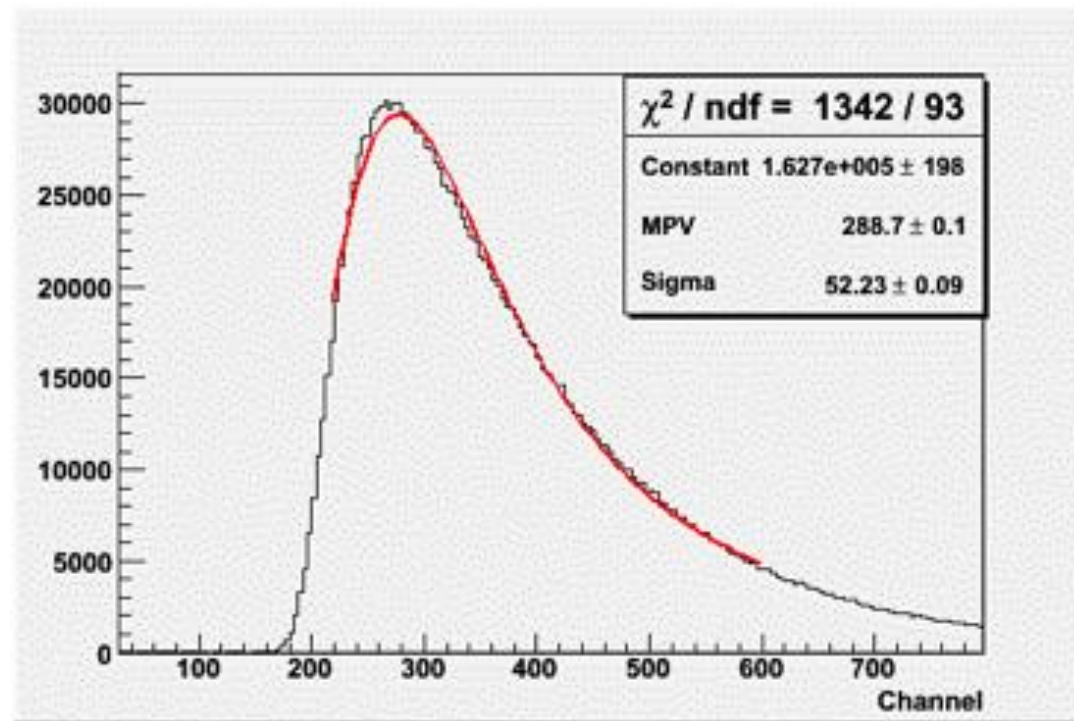
# Data Structure (TTree)



- TTree is one of the most commonly used structures in ROOT.
- One can store variables, arrays and any other C++ datatype in the tree 'branches'
- If we store only floating number variables in the branches, this tree structure is also called a Ttuple
- Usually we "loop" over a TTree to obtain relevant information from each entry and make **plots**



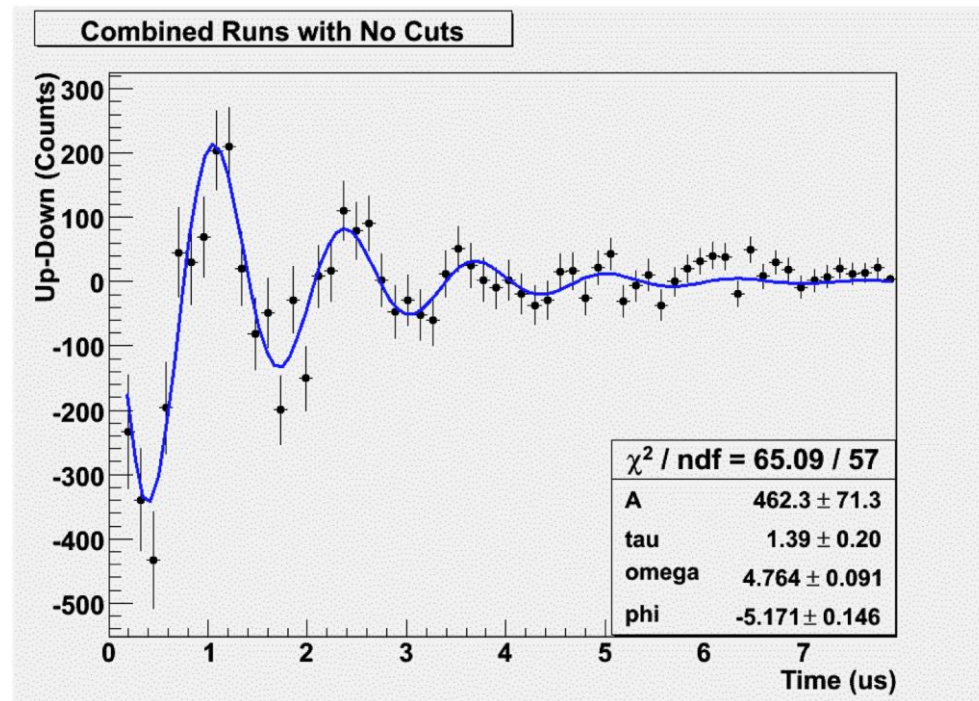
# Histogram and Fitting



Histogram of a PMT energy signal

- From the ROOT tree, one can extract information recorded by each PMT & make histograms.
- You can then fit them with appropriate functions.

# Data Cuts and Analysis



Muon g-factor measurement

- Data analysis involves the selection of interesting events, called data cuts.
- You will also perform fitting and other analysis work to perform calibrations & extract important physics quantities.



# Where to find more information?

- Users Guide and Reference Manuals are available at: <http://root.cern.ch>
- Online tutorials are very useful:  
<http://root.cern.ch/root/html/tutorials/>
- Sample scripts can also be found in MyRoot on the course portal (for plotting MCA spectrum,  $\gamma$ - $\gamma$  coincidence experiments, etc)
- Online forums, such as roottalk:  
<http://root.cern.ch/phpBB3/>, where you can ask help from the user community.