

What is ROOT?
Why do we use it?

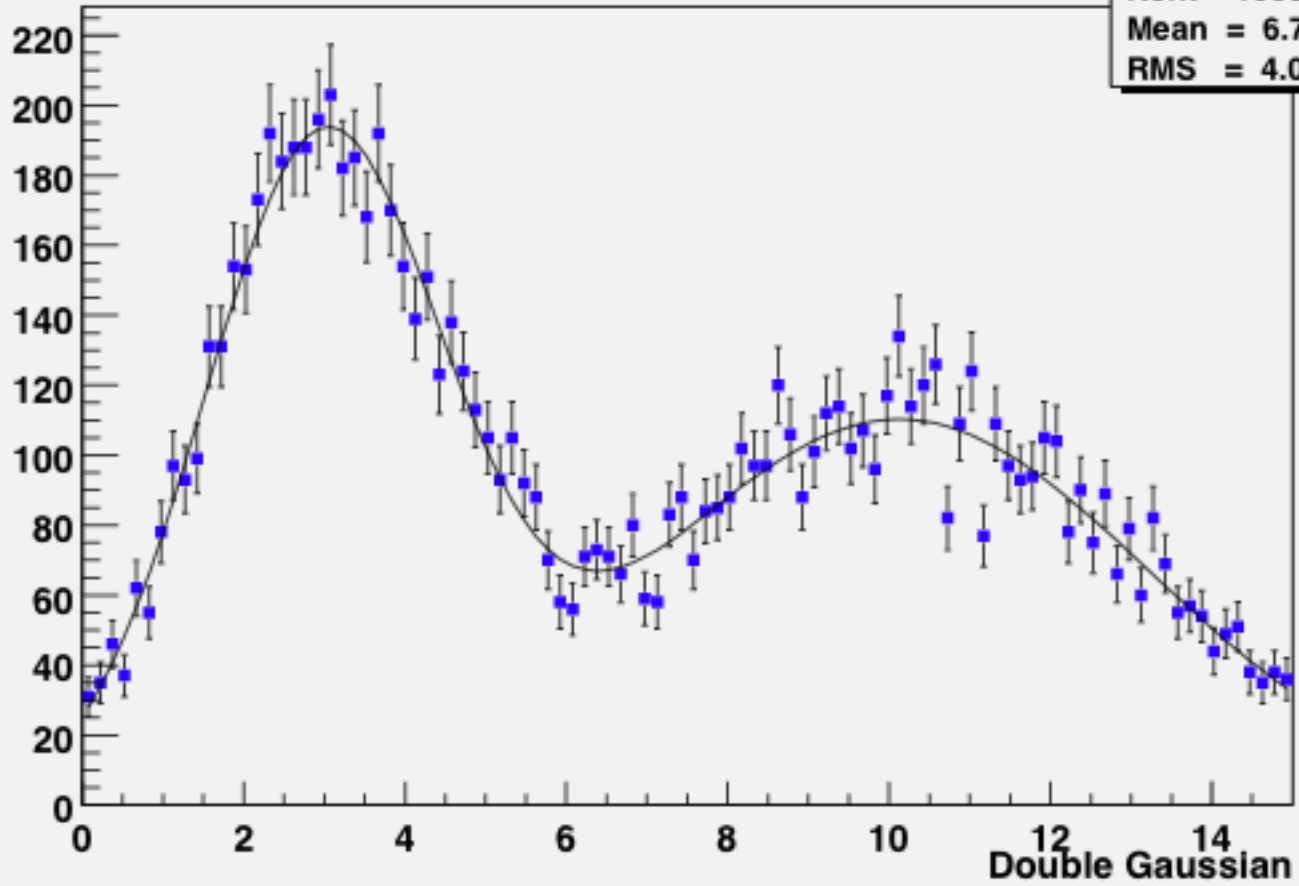
Answer:

ROOT does what physicists do:

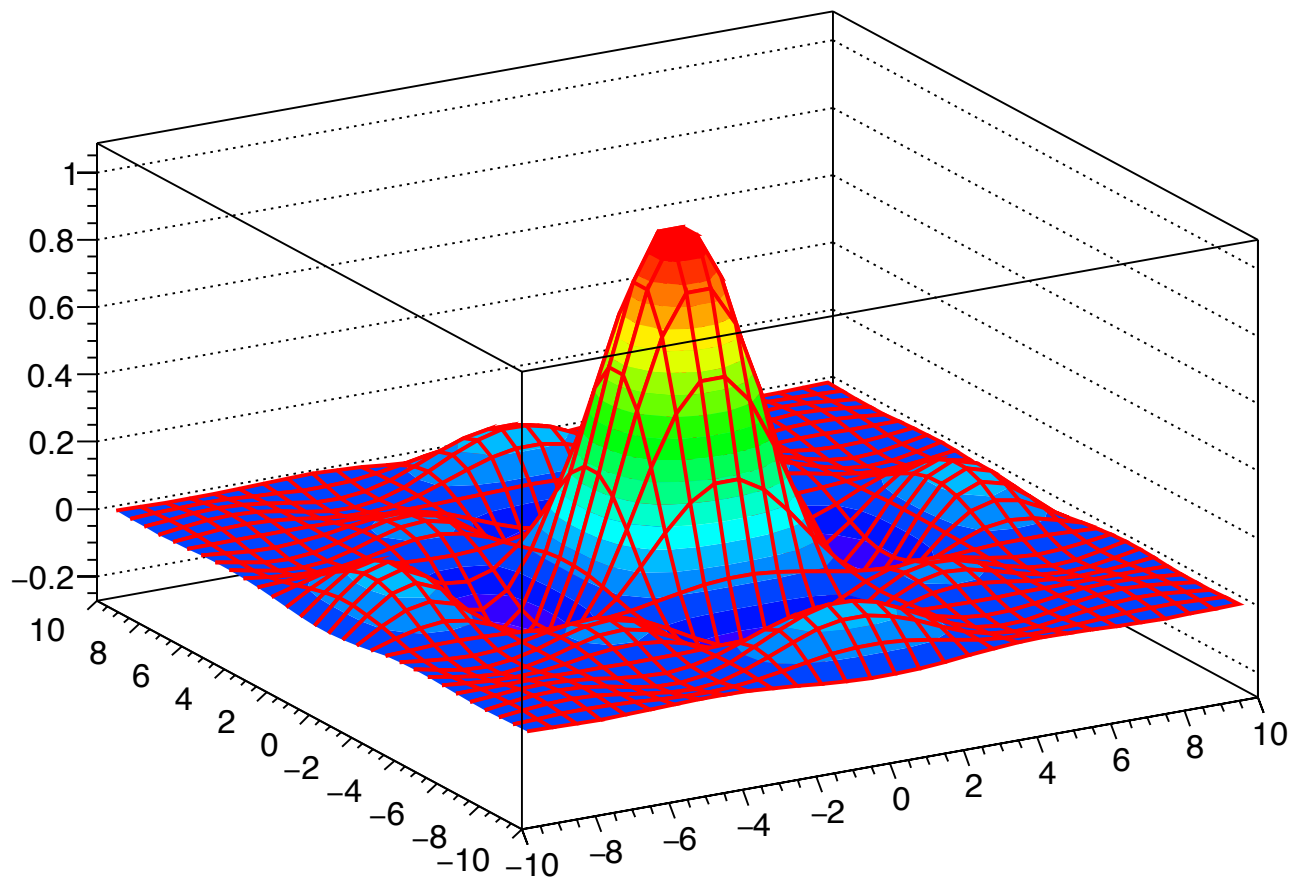
It makes plots.

Another function to be fit

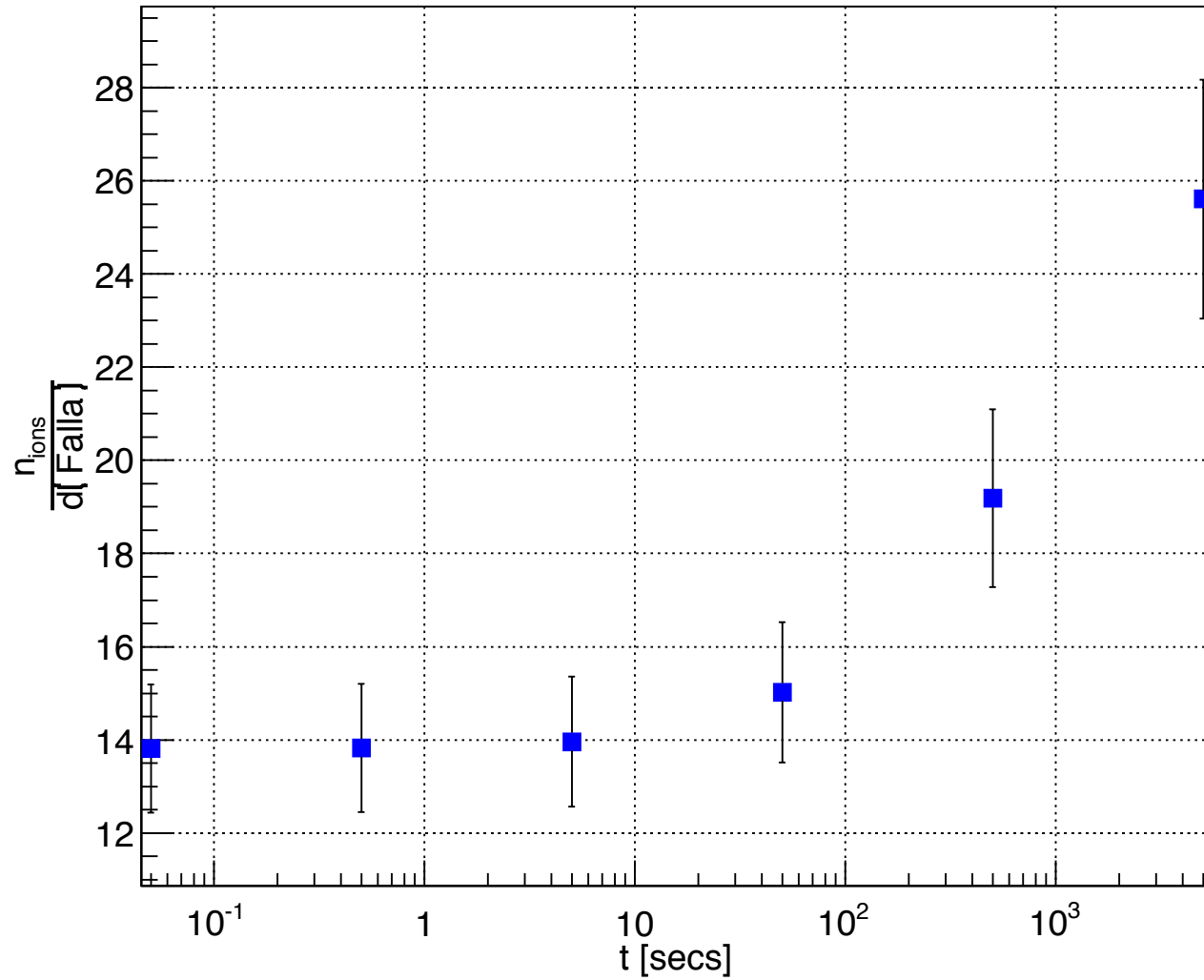
h1st2
Nent = 10000
Mean = 6.714
RMS = 4.012



$$\sin(x)\sin(y)/(x*y)$$



Number of charged atoms in 'Nights in the Gardens of Spain'



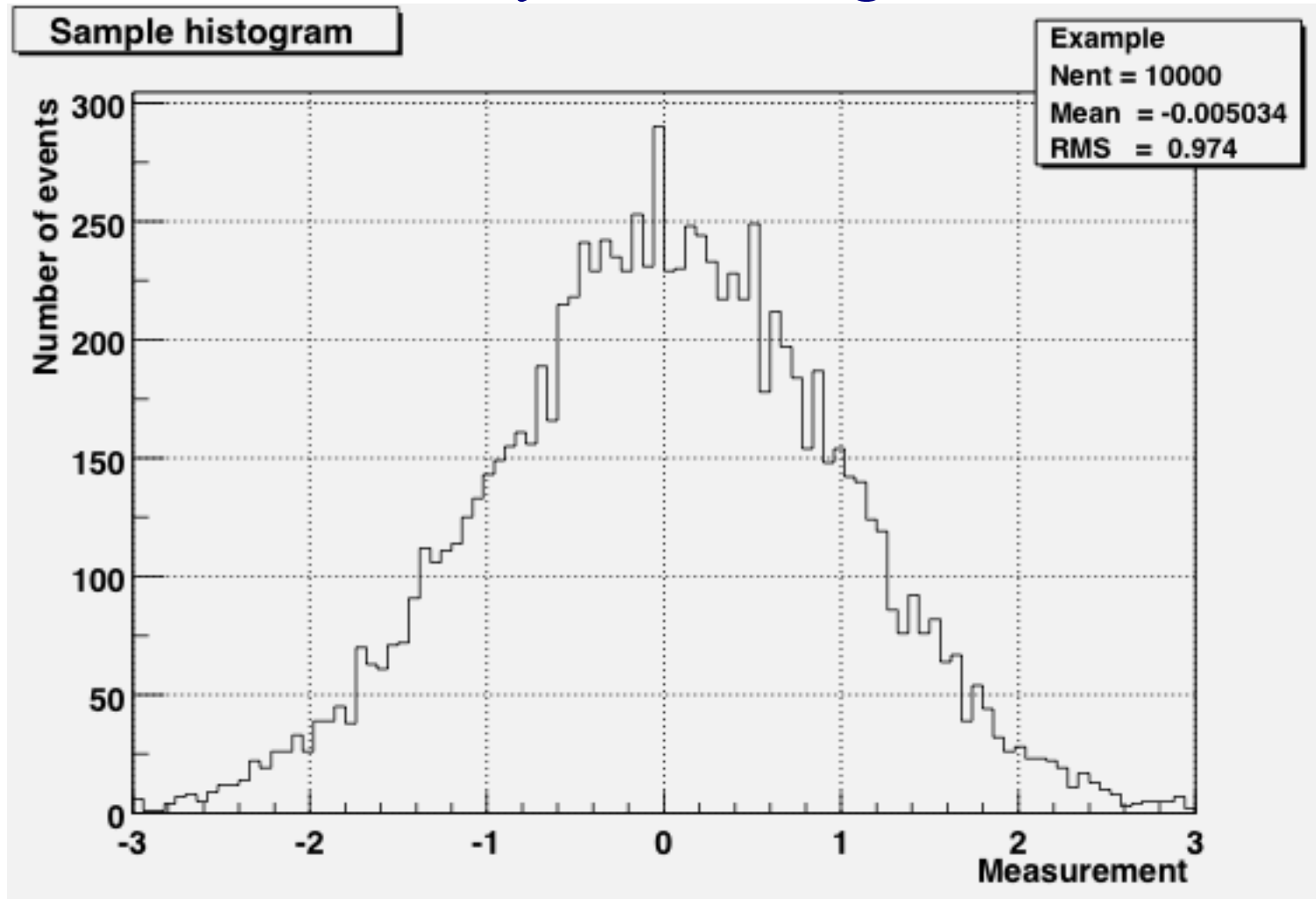
Can you spot the pun in this plot?

The typical analysis task that you will be asked to do:

Take variables in an **n-tuple**, perform some computations, and make **histograms**.

So what is a **histogram**, what is an **n-tuple**, and how do we perform the computations?

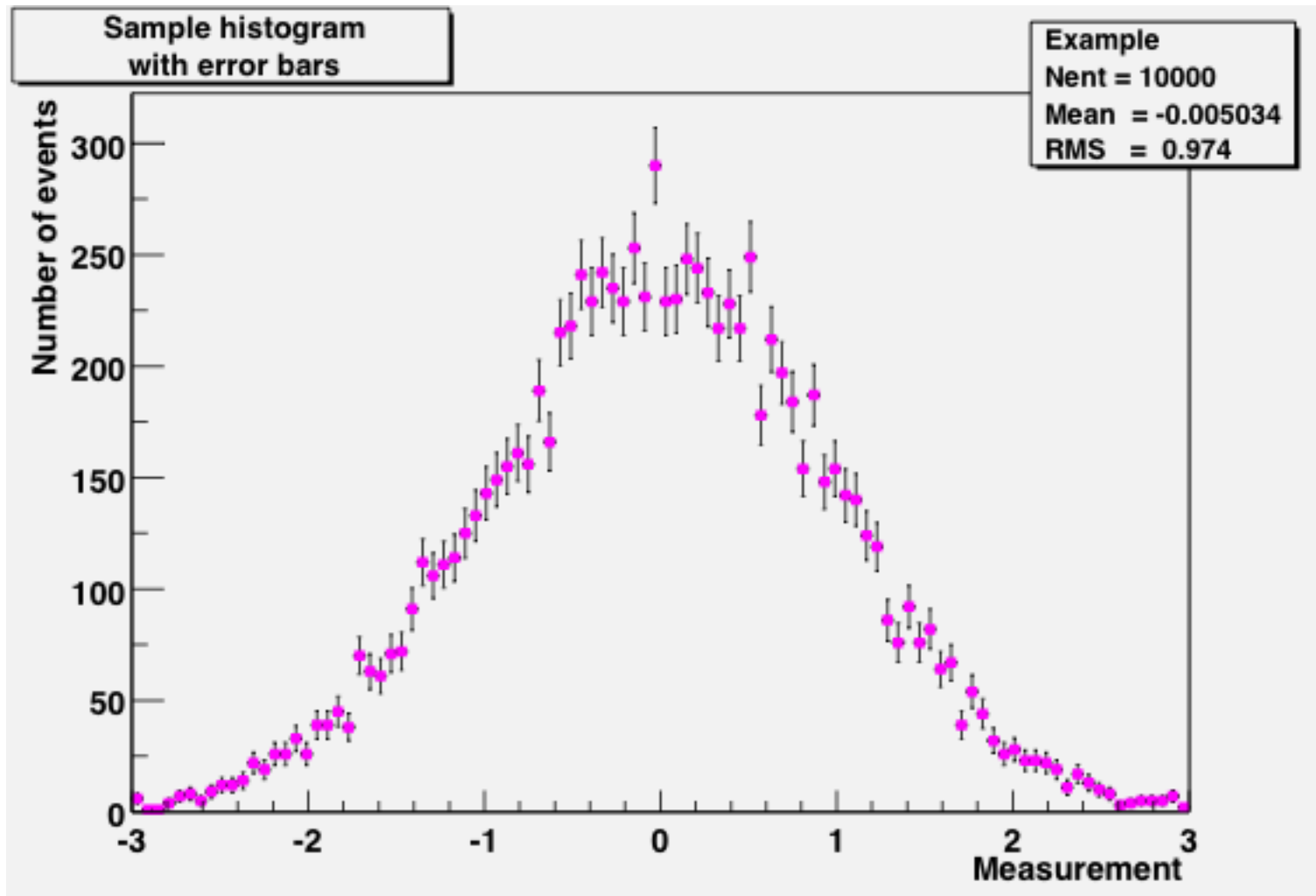
Anatomy of a histogram



Properties of a histogram

A ROOT command that might be used to define this histogram:

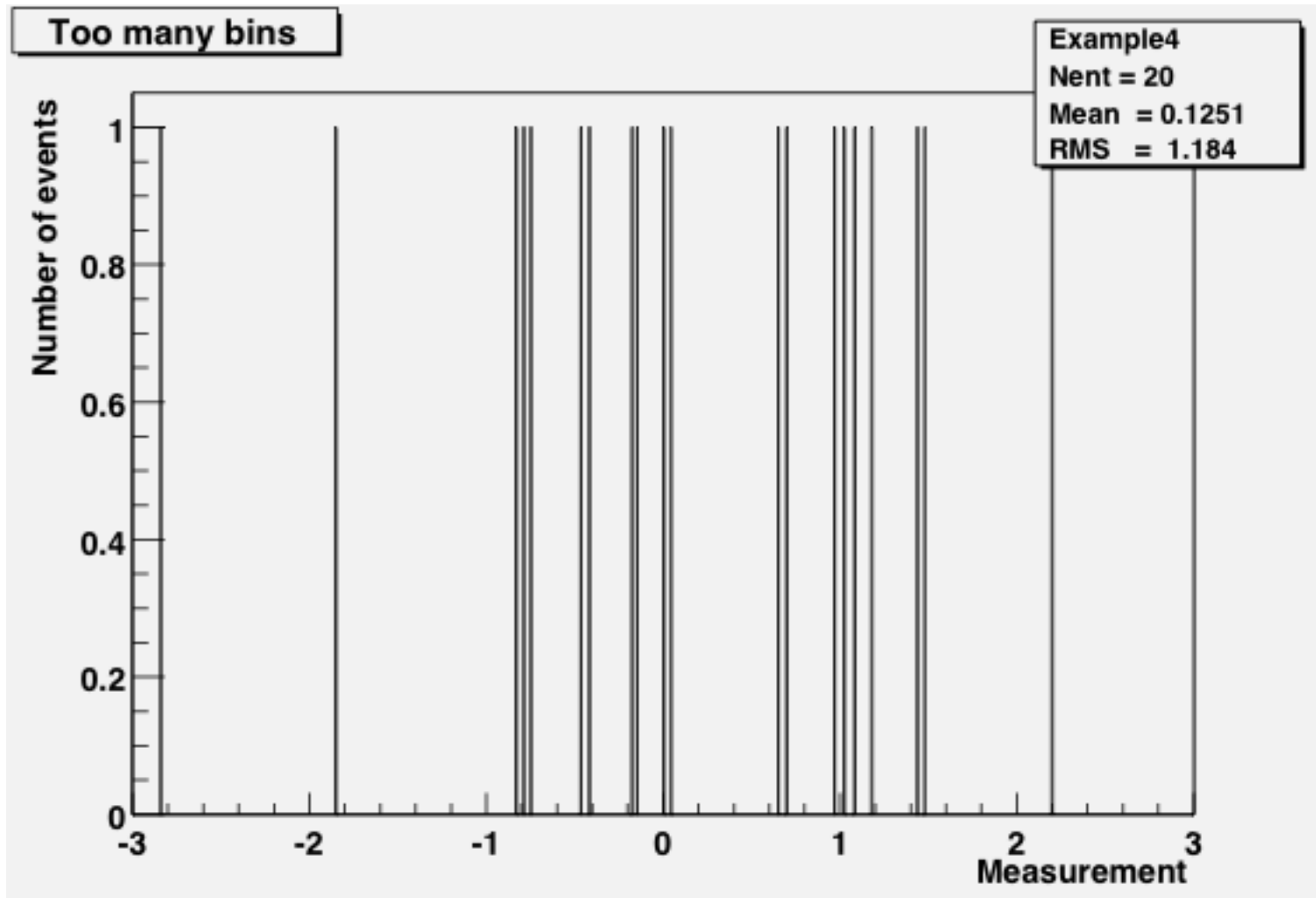
- Name or Identifier
 - Title (to be displayed on plot)
 - Number of bins
 - Lower bin limit
 - Upper bin limit
- ```
TH1F myPlot("Example","Sample histogram",100,-3,3)
```



Don't forget the errors!

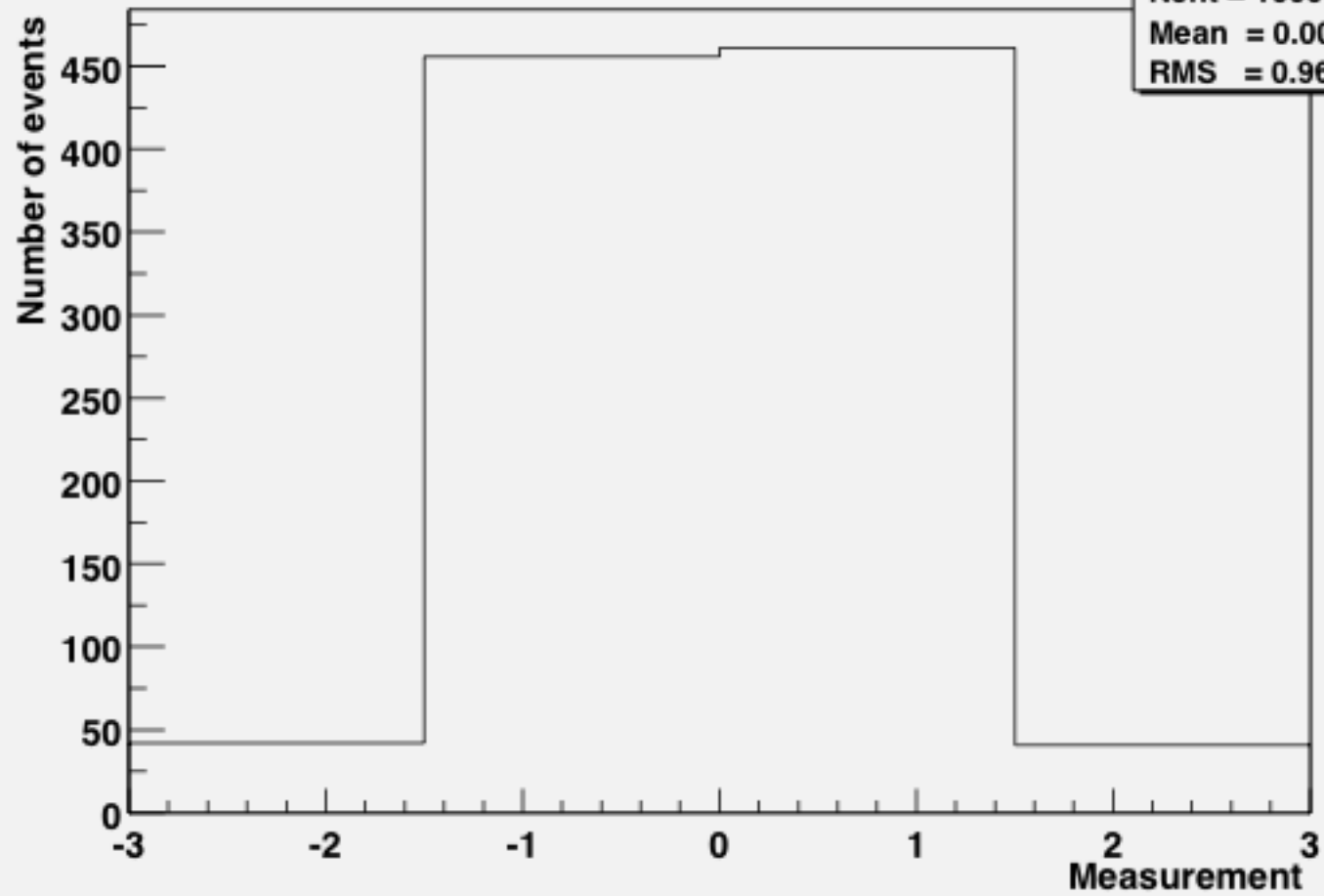
For simple histograms, the error in one bin is the square root of the number of events in that bin.

There's an art to histogram design...





**Too few bins**



# Anatomy of an n-tuple (a simple form of a ROOT Tree)

Branches -->

<-- Entries

| Row | event | ebeam  | px     | py     | pz     |
|-----|-------|--------|--------|--------|--------|
| 0   | 0     | 150.14 | 14.33  | -4.02  | 143.54 |
| 1   | 1     | 149.79 | 0.05   | -1.37  | 148.60 |
| 2   | 2     | 150.16 | 4.01   | 3.89   | 145.69 |
| 3   | 3     | 150.14 | 1.46   | 4.66   | 146.71 |
| 4   | 4     | 149.94 | -10.34 | 11.07  | 148.33 |
| 5   | 5     | 150.18 | 17.08  | -12.14 | 143.10 |
| 6   | 6     | 150.02 | 5.19   | 7.79   | 148.59 |
| 7   | 7     | 150.05 | 7.55   | -7.43  | 144.45 |
| 8   | 8     | 150.07 | 0.23   | -0.02  | 147.78 |
| 9   | 9     | 149.96 | 1.21   | 7.27   | 146.99 |
| 10  | 10    | 149.92 | 5.35   | 3.98   | 140.70 |
| 11  | 11    | 149.88 | -4.63  | -0.08  | 147.91 |

An n-tuple is an ordered list of numbers.

A ROOT Tree can be an ordered list of any collections of C++ objects.

Probably you'll only be asked to work with n-tuples this summer, but in Part Six of the tutorial you can see what it's like to work with a ROOT Tree.

# Why ROOT?

- It knows about **n-tuples** and **histograms**  
and 4-vectors and object persistency and schema evolution  
and detector geometry and Feynmann diagrams  
and linear algebra and function-fitting and multi-variable analysis and...
- It can handle large volumes of data  
millions of physics events; files of gigabytes->terabytes in size; multi-threaded and batch processing
- Multi-platform (Windows, Mac, many UNIX flavors)
- It's free.

## But...

- It's open-source, with a complicated design history.
- User-interface issues and documentation are often neglected.
- It's not a pre-packaged “app.” ROOT is not easy to install.
- ROOT is pretty much only used in high-energy physics.
- You have to know some C++ in order to use ROOT effectively, in order to perform computations.
- What does C++ look like? Well...

```

#define AnalyzeHistogram_cxx

#include "AnalyzeHistogram.h"
#include <TH2.h>
#include <TStyle.h>

//***** Definition section *****/
TH1* chi2Hist = 0;

void AnalyzeHistogram::Begin(TTree * /*tree*/)
{
 TString option = GetOption();

 //***** Initialization section *****/
 chi2Hist = new TH1F("chi2", "Histogram of Chi2", 100, 0, 20);
 chi2Hist->GetXaxis()->SetTitle("chi2");
 chi2Hist->GetYaxis()->SetTitle("number of events");
}

void AnalyzeHistogram::SlaveBegin(TTree * /*tree*/)
{
 TString option = GetOption();
}

Bool_t AnalyzeHistogram::Process(Long64_t entry)
{
 //***** Loop section *****/
 treel->GetEntry(entry);
 chi2Hist->Fill(chi2);

 return kTRUE;
}

void AnalyzeHistogram::SlaveTerminate()
{}

void AnalyzeHistogram::Terminate()
{
 //***** Wrap-up section *****/
 chi2Hist->Draw();
}

```

# If you prefer Python, there's pyroot

```
import ROOT

Open the file.
myfile = ROOT.TFile('experiment.root')

Retrieve the n-tuple of interest.
mychain = ROOT.gDirectory.Get('tree1')
entries = mychain.GetEntriesFast()

Create a 2D histogram
myHist = ROOT.TH2D("hist2D", "chi2 vs ebeam", 100, 0, 20, 100, 149, 151)
myHist.GetXaxis().SetTitle("chi2")
myHist.GetYaxis().SetTitle("ebeam [GeV]")

for jentry in xrange(entries):

 # Copy next entry into memory and verify.
 nb = mychain.GetEntry(jentry)
 if nb <= 0:
 continue

 # Fetch the variables from the entry and fill the histogram.
 chi2 = mychain.chi2
 ebeam = mychain.ebeam
 myHist.Fill(chi2, ebeam)

Display the scatterplot.
myHist.Draw()
```

# Web Links

(the only part you should bother to write down)

All the documents you've seen (and will see) during the class today and tomorrow can be found at:

<http://www.nevis.columbia.edu/~seligman/root-class/>

ROOT and C++ links, including links to reference books on C++ and statistics, can be found at:

<http://www.nevis.columbia.edu/~seligman/root-class/links.html>

# The Hands-on Course:

## Basic Data Analysis using ROOT

### ROOT basics

Over the next two days, you will learn how to:

- look up ROOT command references
  - plot a function
  - histogram a variable
  - fit a histogram
  - get a variable from an n-tuple
  - apply cuts
  - do a quick study using TreeViewer (optional)
  - create C++ or python code for an n-tuple
  - use the Jupyter notebook server for quick coding
- but not necessarily in this order!

The advanced tutorial (which you may not get to) includes sets of additional exercises to help turn you into a ROOT expert:

- Creating an x-y plot
- Working with large numbers of histograms
- Extracting your own n-tuples



# A Brief ROOT Demonstration

- Using the command line
- Using the notebook server