ROOT Lecture 6

Functions and Fitting

It still runs ROOT!!

Lecture 5

Ntuples and Trees

Exercise 1)

Download the root-file on the website:
http://kvir03.kvi.nl/rootcourse/.

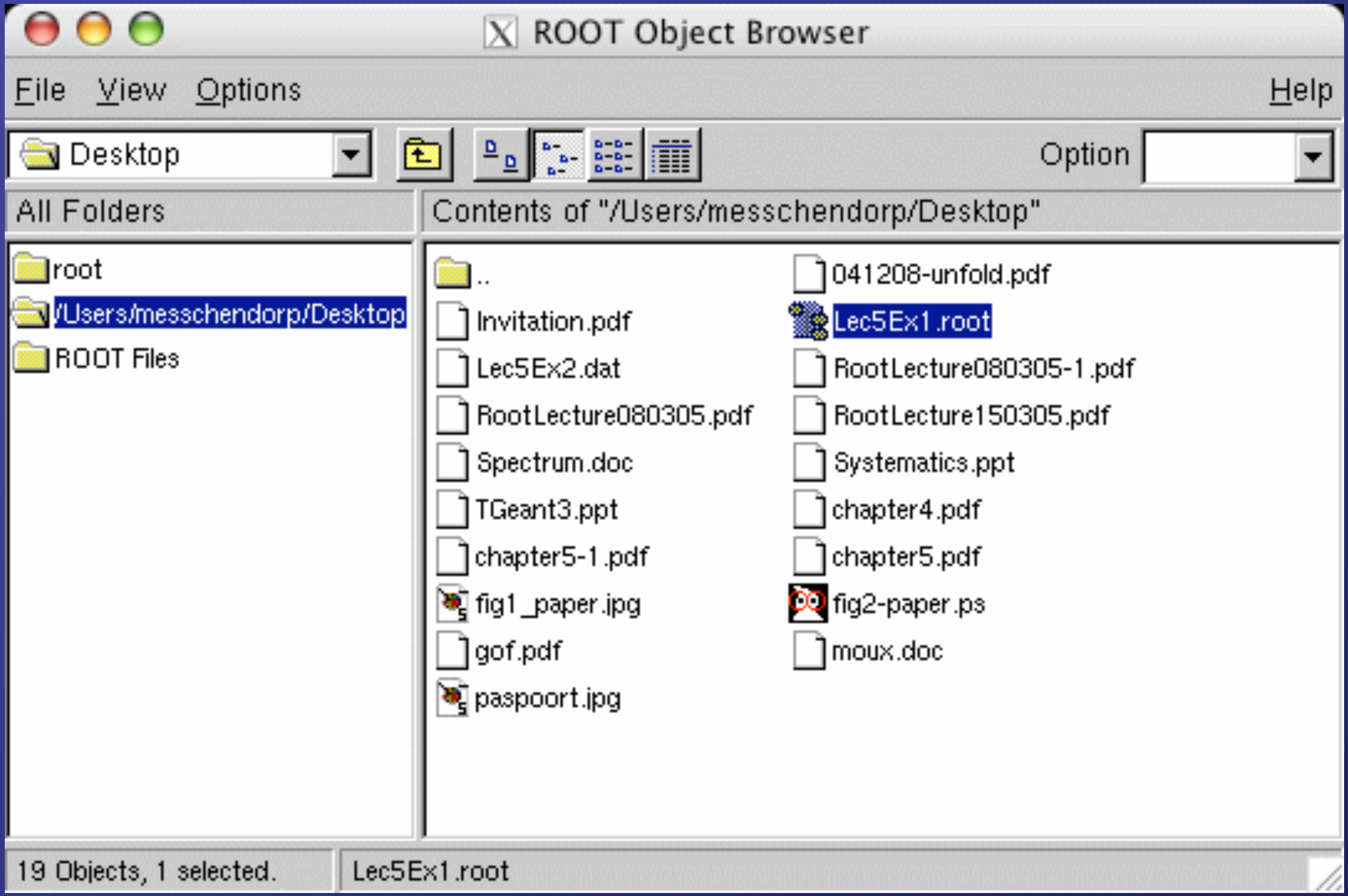
Inside you'll find a tree containing histograms and an array of Double_t's. Write a macro that draws the histogram of the third entry and prints the values of the array.

WARNING

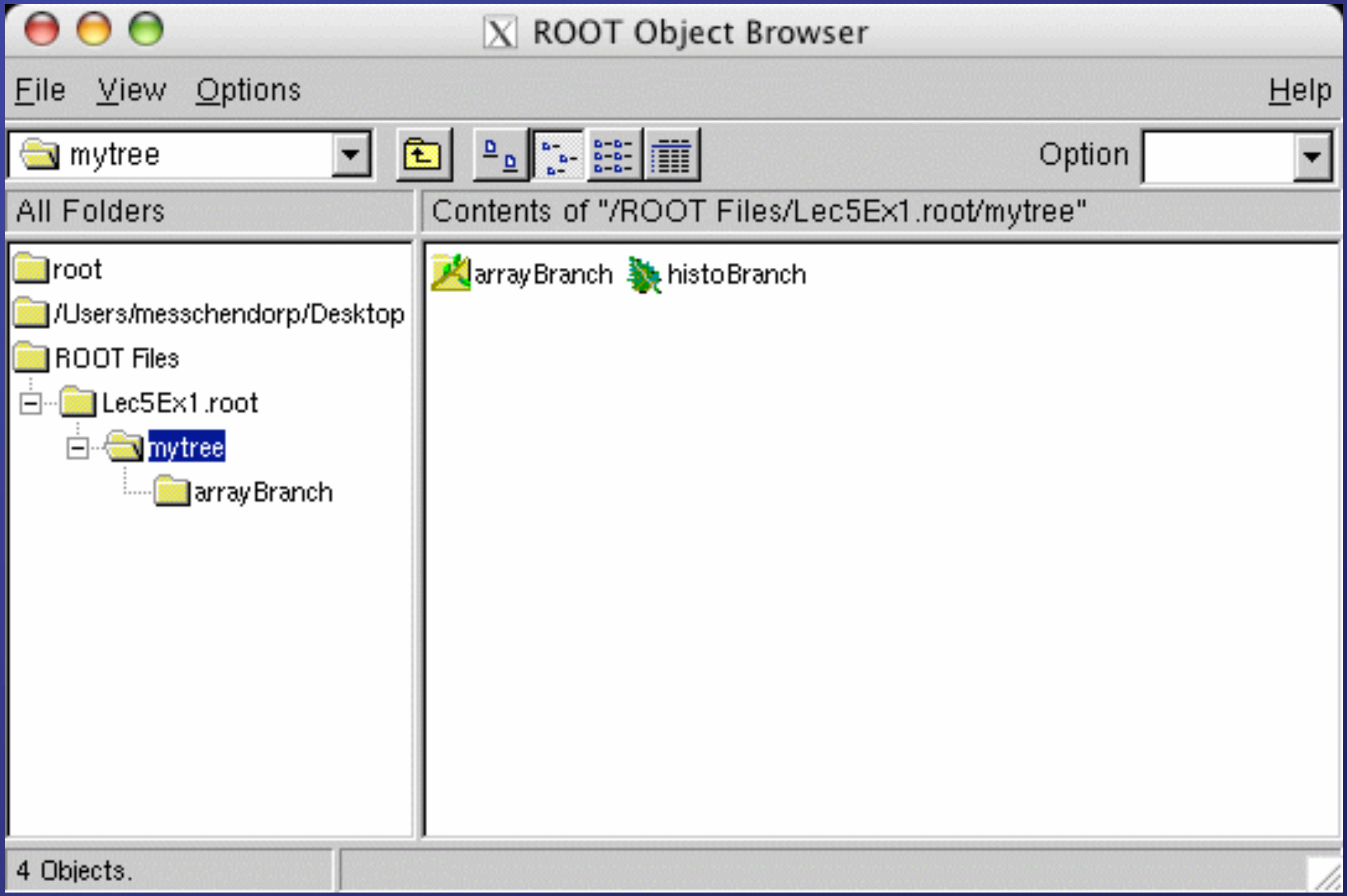
The root-file is made with ROOT version 4.03. Those who are trying to open this file using an older version of ROOT will likely encounter problems.

ROOT is - in general - NOT downwards compatible!

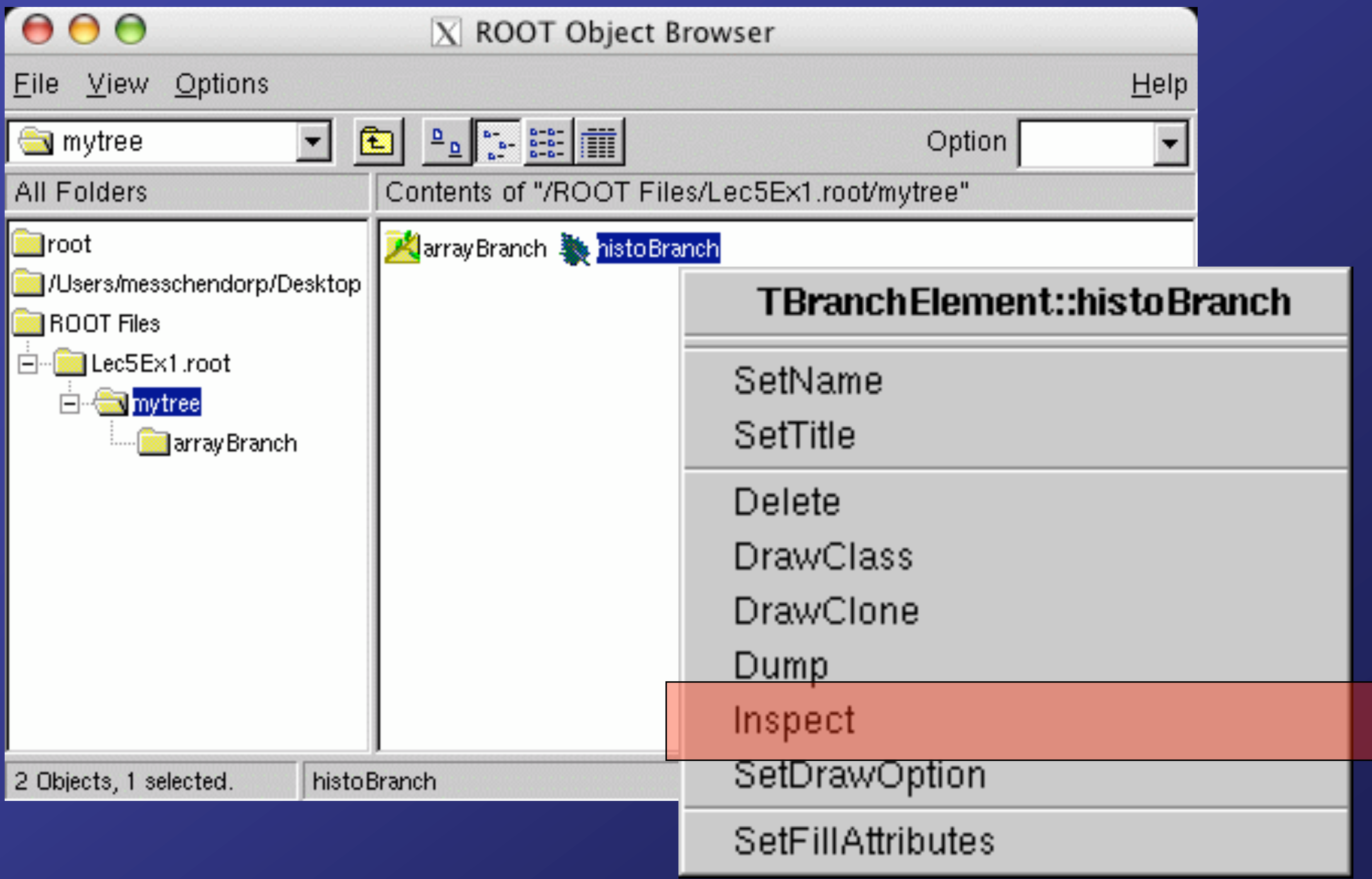
new TBrowser



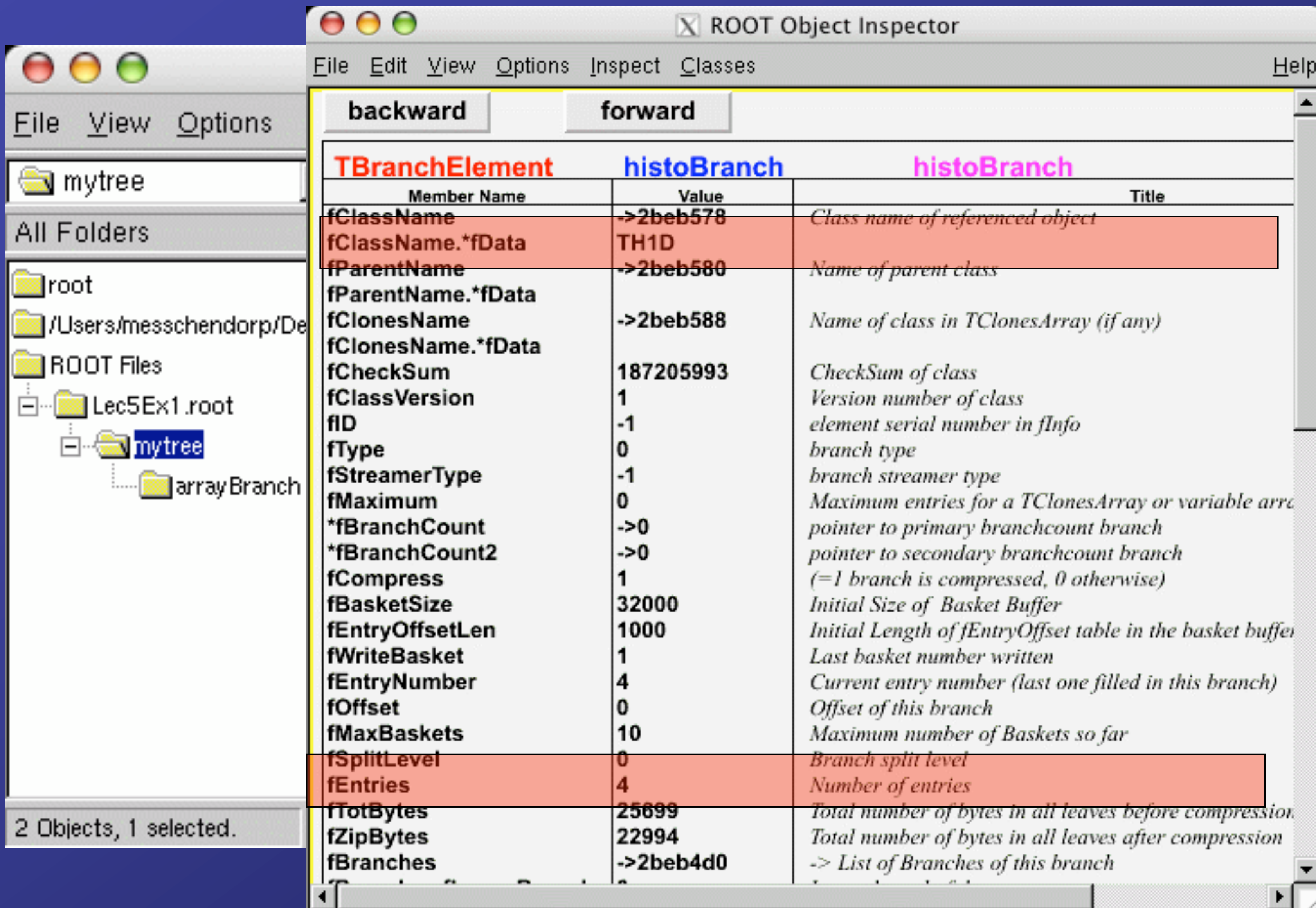
new TBrowser



new TBrowser

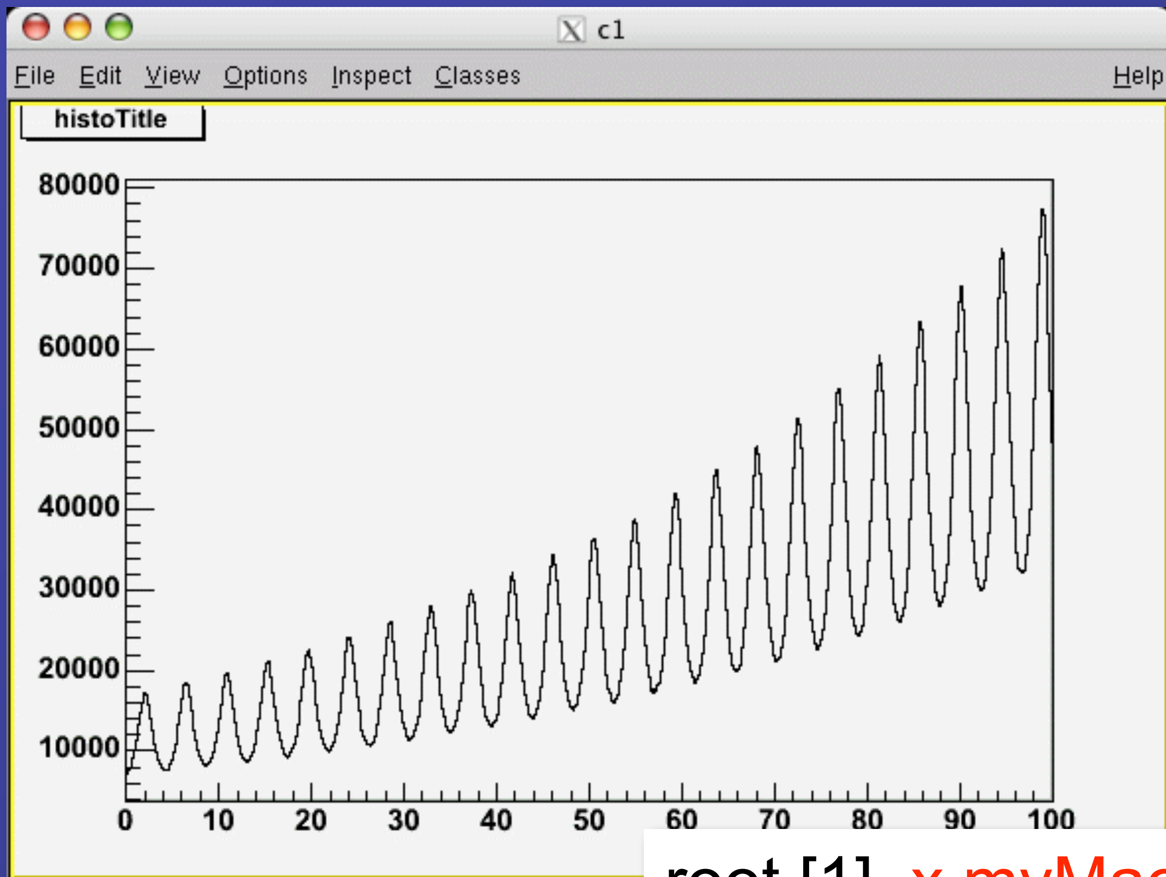


new TBrowser



myMacro.C

```
{
  gROOT->Reset();
  TFile *f = new TFile("Lec5Ex1.root");
  TTree *mytree = f->Get("mytree");

  // Declaration of leaves types
  TH1D*          histo = NULL;
  Double_t       array[5];

  // Set branch addresses.
  mytree->SetBranchAddress("histoBranch",&histo);
  mytree->SetBranchAddress("arrayBranch",&array);

  Int_t nentries = mytree->GetEntries();

  // Loop over all entries
  for (Int_t i=0; i<nentries;i++)
  {
   mytree->GetEntry(i);
   cout << i << " " << array[0] << "/" << array[1] << "/"
        << array[2] << "/" << array[3] << "/" << array[4]
        << endl;
   if (i==2) histo->Draw();
  }
}
```




```
root [1] .x myMacro.C
0 1/50/20/0/0
1 1/-0.0045516/0/0/0
2 1/64.4/0.4/4.4/0.22
3 1/0.015528/2.5/0.227273/4.54545
root [4]
```

Lecture 5

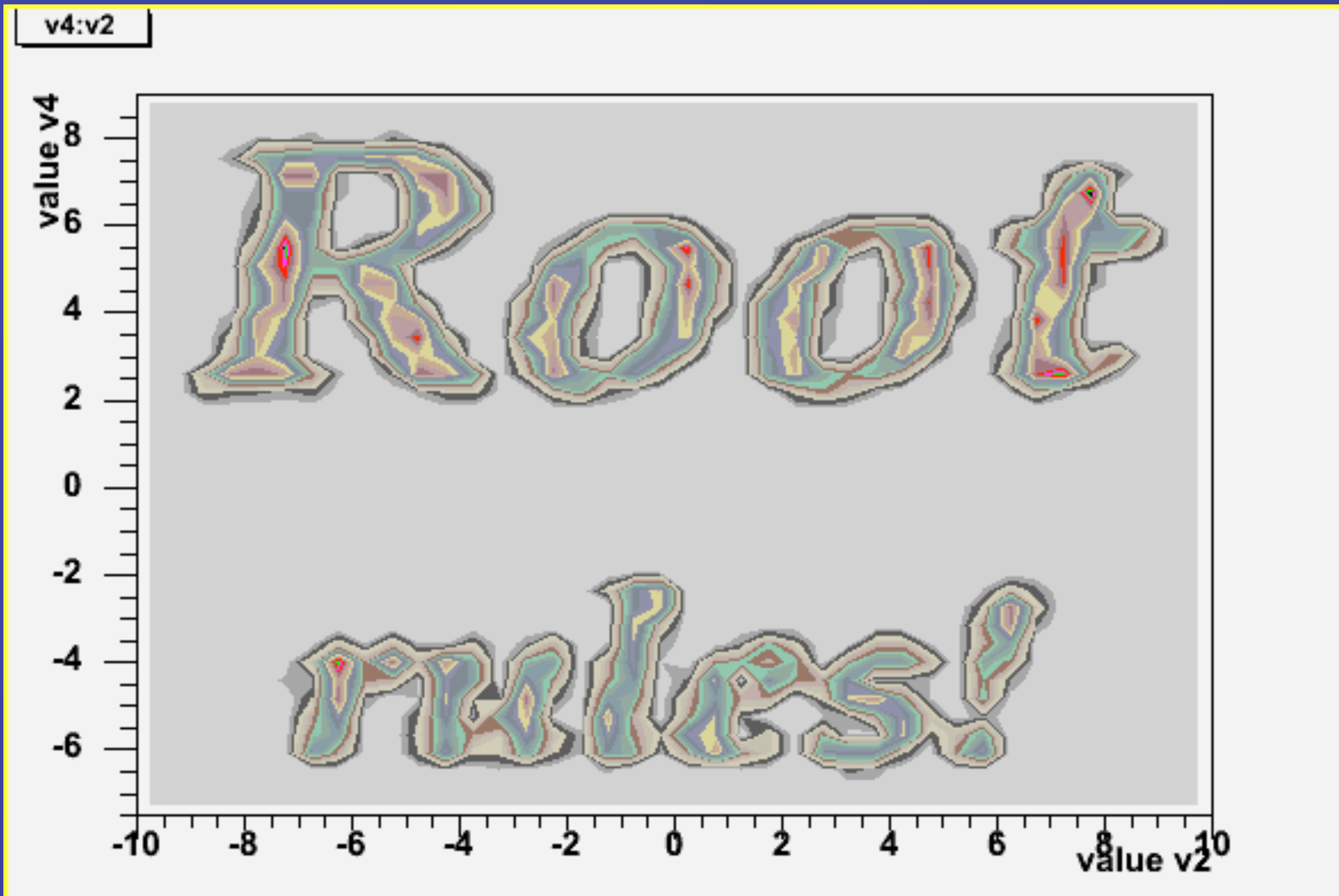
Ntuples and Trees

Exercise 2)

Download the ascii file from the root-course website and convert it into an Ntuple. Make a 2D histogram with the second value on the x-axis and the fourth on the y-axis. Plot it with a smooth surface and label the axes. Send me the postscript file of this plot….

Macro “basic.C” : derived from tutorials of ROOT

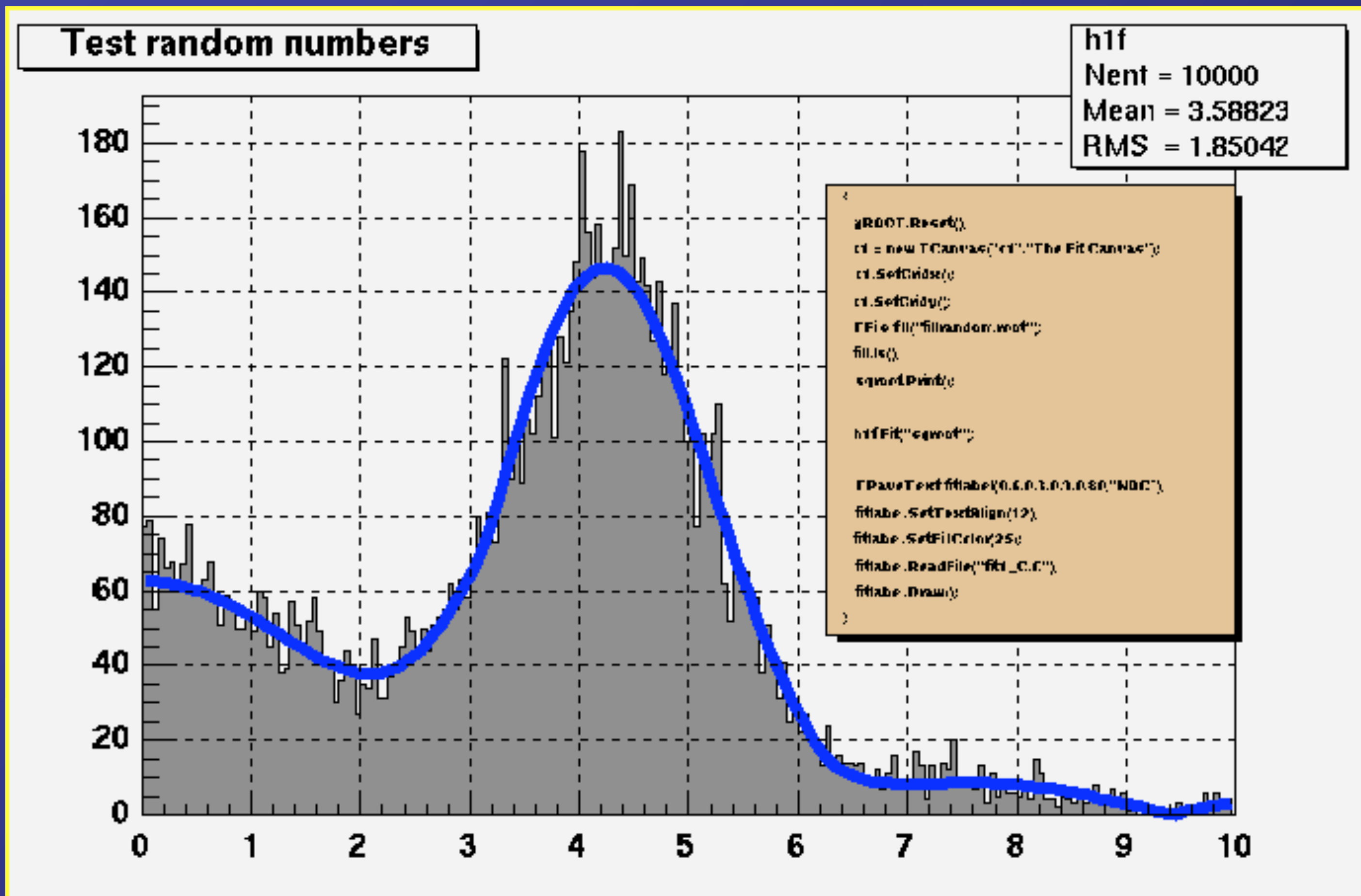
```
{
   gROOT->Reset();
#include "Riostream.h"

   ifstream in;
   in.open("/Users/messchendorp/Desktop/Lec5Ex2.dat");

   Float_t v1,v2,v3,v4,v5;
   Int_t nlines = 0;
   TNtuple *ntuple = new TNtuple("ntuple","Ntuple example","v1:v2:v3:v4:v5");

   while (1) {
     in >> v1 >> v2 >> v3 >> v4 >> v5;
      if (!in.good()) break;
      ntuple->Fill(v1,v2,v3,v4,v5);
      nlines++;
   }
   printf(" found %d points\n",nlines);

   in.close();
}
```



root [1] .x basic.C
  found 10000 points
root [2] ntuple->Draw(“v4:v2>histo”,””,”cont4”)
root [3] histo->GetXaxis()->SetTitle(”value v2")
root [4] histo->GetYaxis()->SetTitle(”value v4")
root [5] c1->Update()

Lecture 6

Functions and Fitting



1-Dim Function Class TF1

class TF1 : **public** TFormula, **public** TAttLine, **public** TAttFill, **public** TAttMarker

Class Description

A TF1 object is a 1-Dim function defined between a lower and upper limit.
The function may be a simple function or a precompiled user function.
The function may have associated parameters.

The following types of functions can be created:

A- Expression using variable x and no parameters

B- Expression using variable x with parameters

C- A general C function with parameters

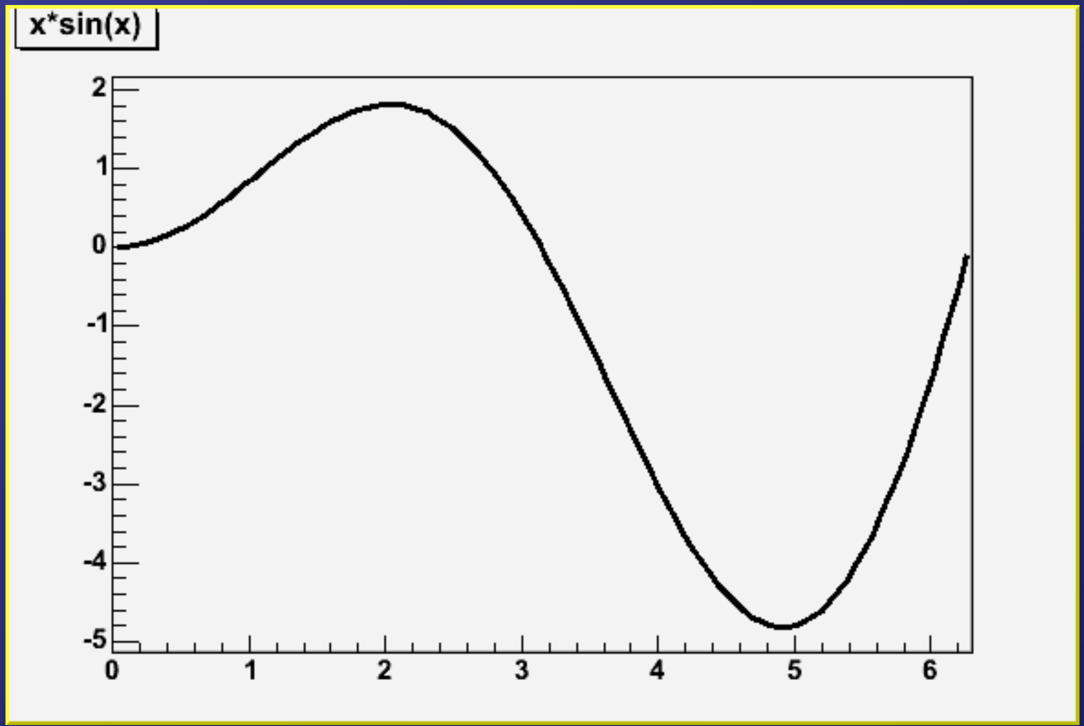
TF1 with “simple” expressions

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

Examples :

root [1] TF1 *f = **new** TF1(“myfunc”, ”x*sin(x)”, 0., 6.3)

root [2] f->**Draw**()



TF1 with "simple" expressions

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

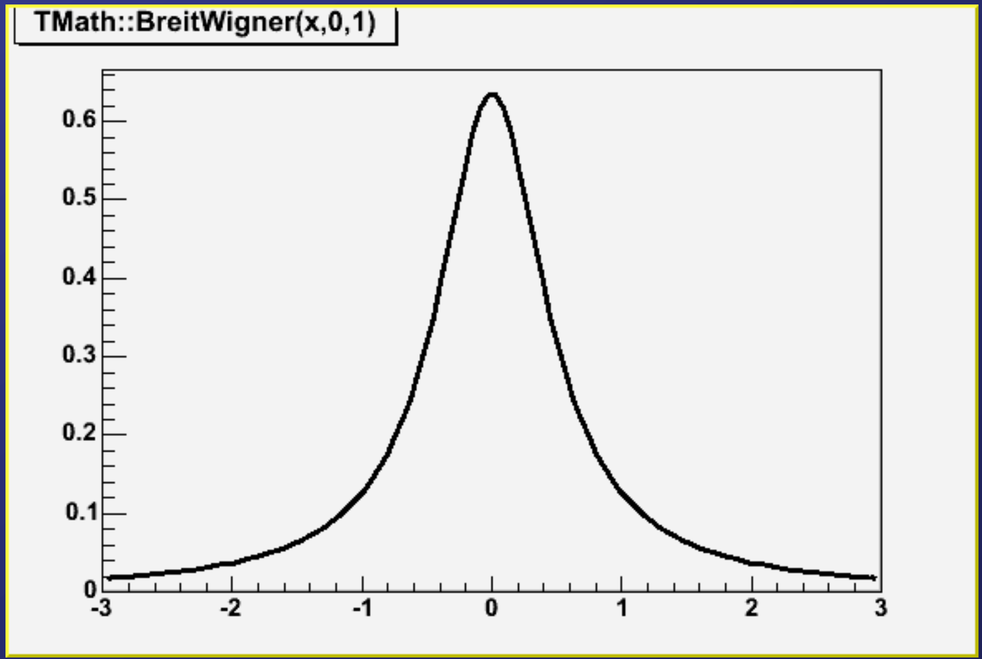
Examples :

root [1] TF1 *f = **new** TF1("myfunc", "TMath::BreitWigner(x,0,1)", -3, 3)

root [2] f->**Draw**()

TMath Class contains a variety of encapsulated mathematical functions and constants, accessible via

TMath::*Function(...)*

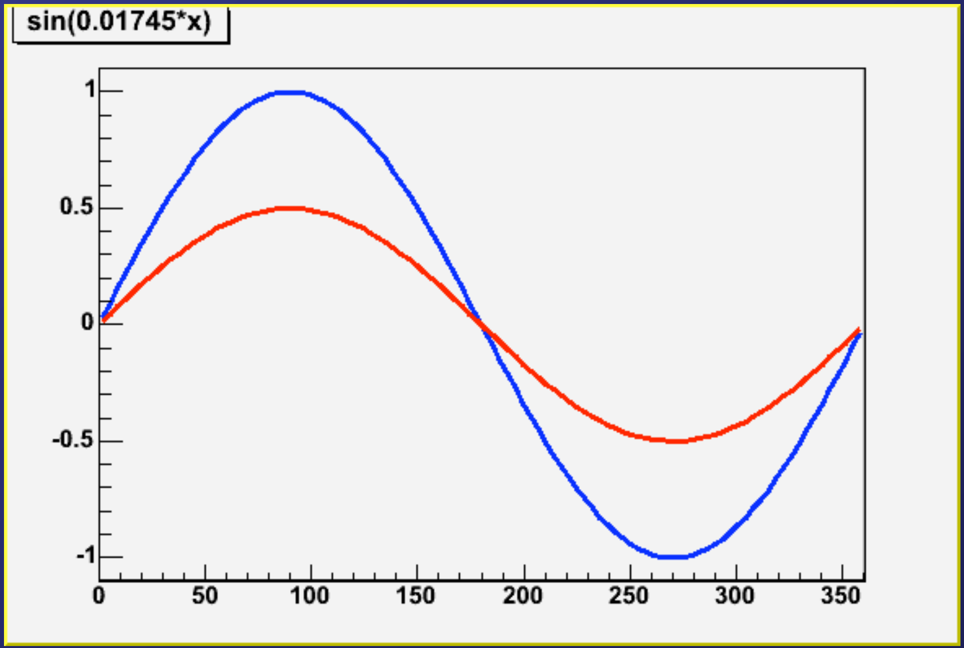


TF1 with "simple" expressions

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

Examples :

```
root [1] TF1 *f1 = new TF1("myf1","sin(0.01745*x)", 0, 360)
root [2] TF1 *f2 = new TF1("myf2","0.5*myf1", 0, 360)
root [3] f1->SetLineColor(kBlue)
root [4] f2->SetLineColor(kRed)
root [5] f1->Draw()
root [6] f2->Draw("SAME")
```



TF1 with parameters

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

Examples :

root [1] TF1 *f = **new** TF1(“myfunc”,”[0]*sin([1]*x)”, 0, 6.3)

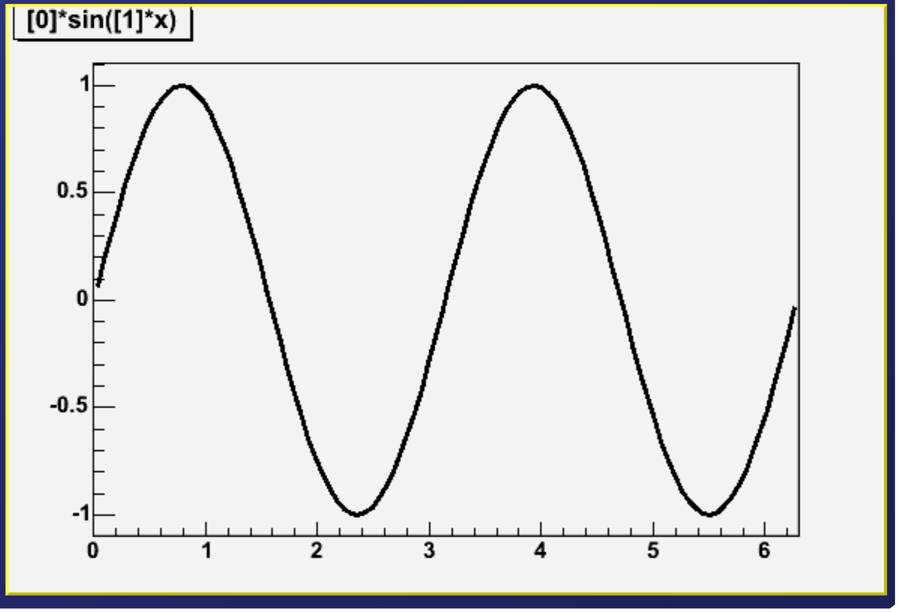
root [2] f->**SetParameter**(0, 1.0)

root [3] f->**SetParameter**(1, 2.0)

root [4] f->**SetParName**(0, “Amplitude”)

root [5] f->**SetParName**(1, “Frequency”)

root [6] f->**Draw**()



TF1 with user-defined function

TF1(***const char**** name, ***void**** fcn, ***Double_t*** xmin, ***Double_t*** xmax, ***Int_t*** npar)

Double_t **fcn**(***Double_t*** *x, ***Double_t*** *param)

Example :

```
Double_t myFunction(Double_t *x, Double_t *par)
{
    return (par[0]*sin(par[1]*x[0]);
}
```

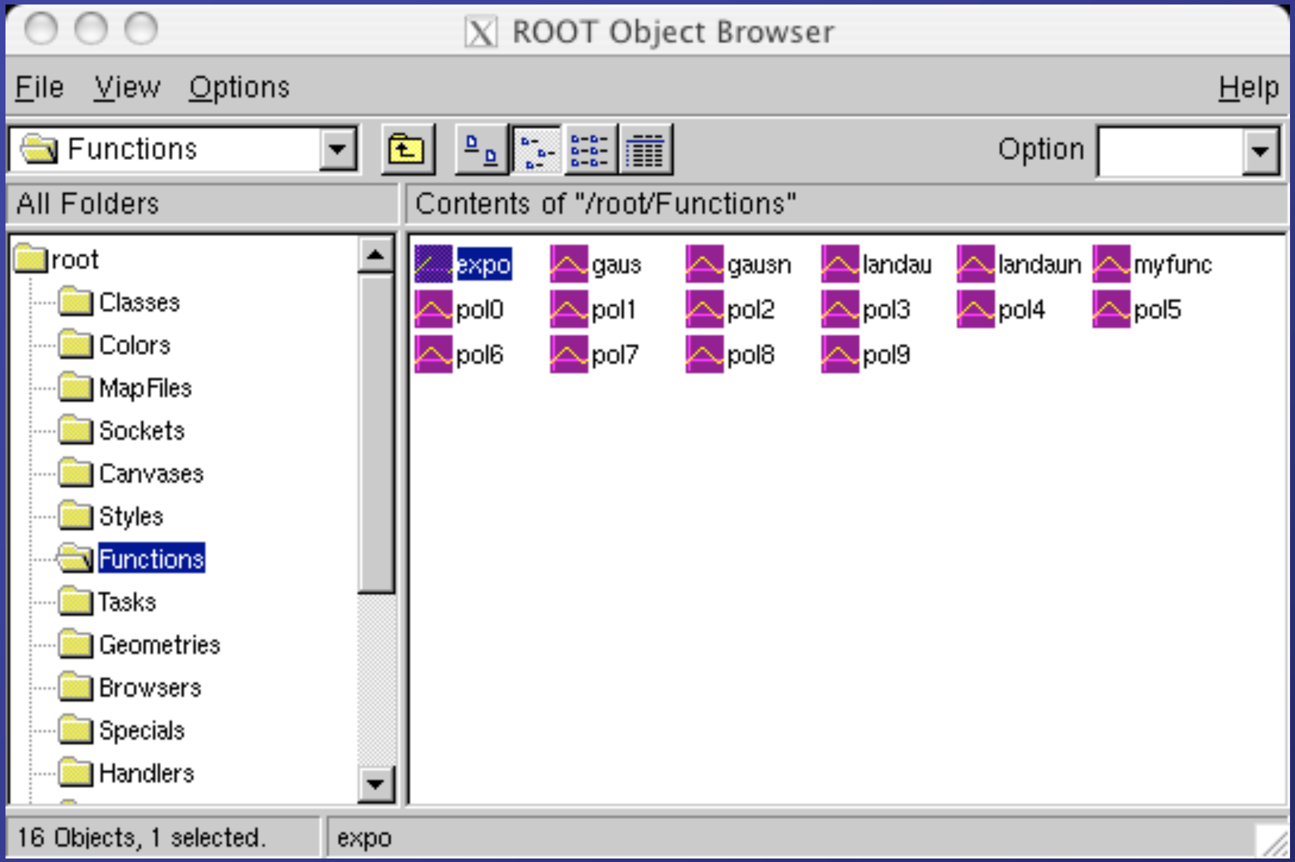
testFunction.c

root [1] .L testFunction.c

root [2] TF1 *f = **new** TF1("myfunc", myFunction, 0, 6.3, 2)

root [3] f->**SetParameter**(0, 1.0); f->**SetParameter**(1, 2.0)

Pre-defined 1-Dim functions



expo - exp([0]+[1]*x)
gaus - [0]*exp(-0.5*((x-[1])/[2])**2)
gausn- [0]*exp(-0.5*((x-[1])/[2])**2)/(sqrt(2*pi)*[2]))
polN - [0]+[1]*x+[2]*x**2+…+[N]*x**N

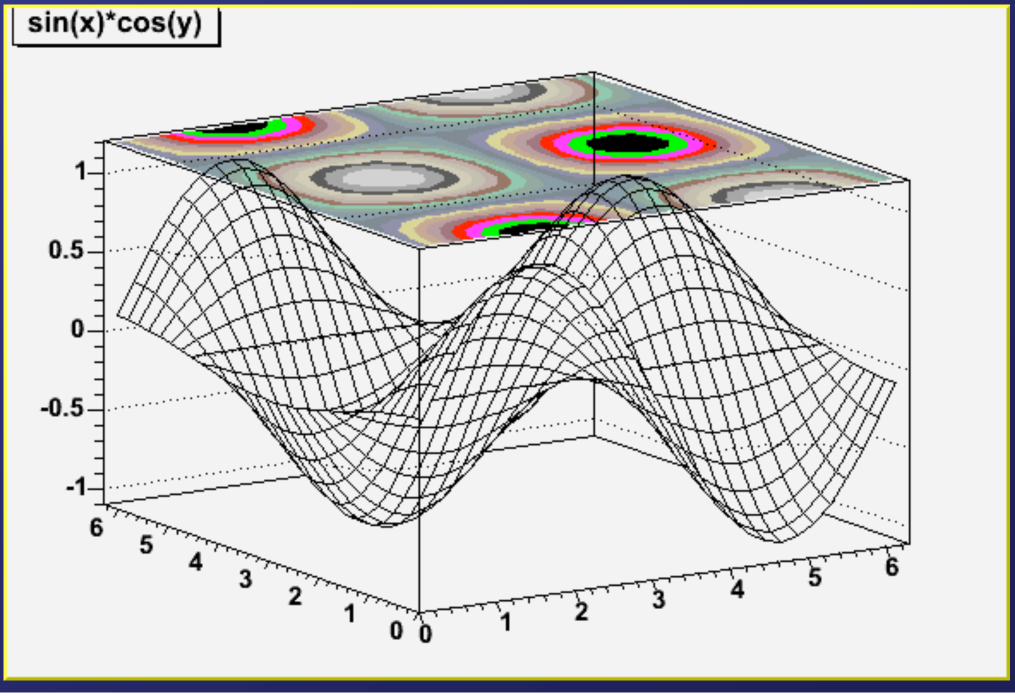
Beyond 1-Dim functions

class TF2 : **public** TF1	2-Dim functions
class TF3 : **public** TF2	3-Dim functions

Example :

root [1] TF2 *f = **new** TF2("myfunc","sin(x)*cos(y)", 0, 6.3, 0, 6.3)

root [2] f->**Draw**("surf3")



Things you can do with TFn objects

What?	How?
Draw	f->Draw()
Print	f->Print()
Evaluate values	f->Eval(1.4)
Integrate	f->Integral(0.2,1.7)
Differentiate	f->Derivative(0.4)
Change line attributes	f->SetLineColor(kRed)
	f->SetLineStyle(2)
	f->SetLineWidth(1)
Set titles and axis	f->SetTitle("My Function")
	f->GetXaxis()->SetTitle("x-axis")
	f->GetYaxis()->SetTitle("y-axis")
Set parameters and names	f->SetParameters(1,4)
	f->SetParNames("par1","par2")
Set ranges	f->SetRange(0,10)

……… (many more)

Things you can do with TFn objects

….. and use for Fitting!!

A couple of words about Fitting

Fitting in a nut-shell:

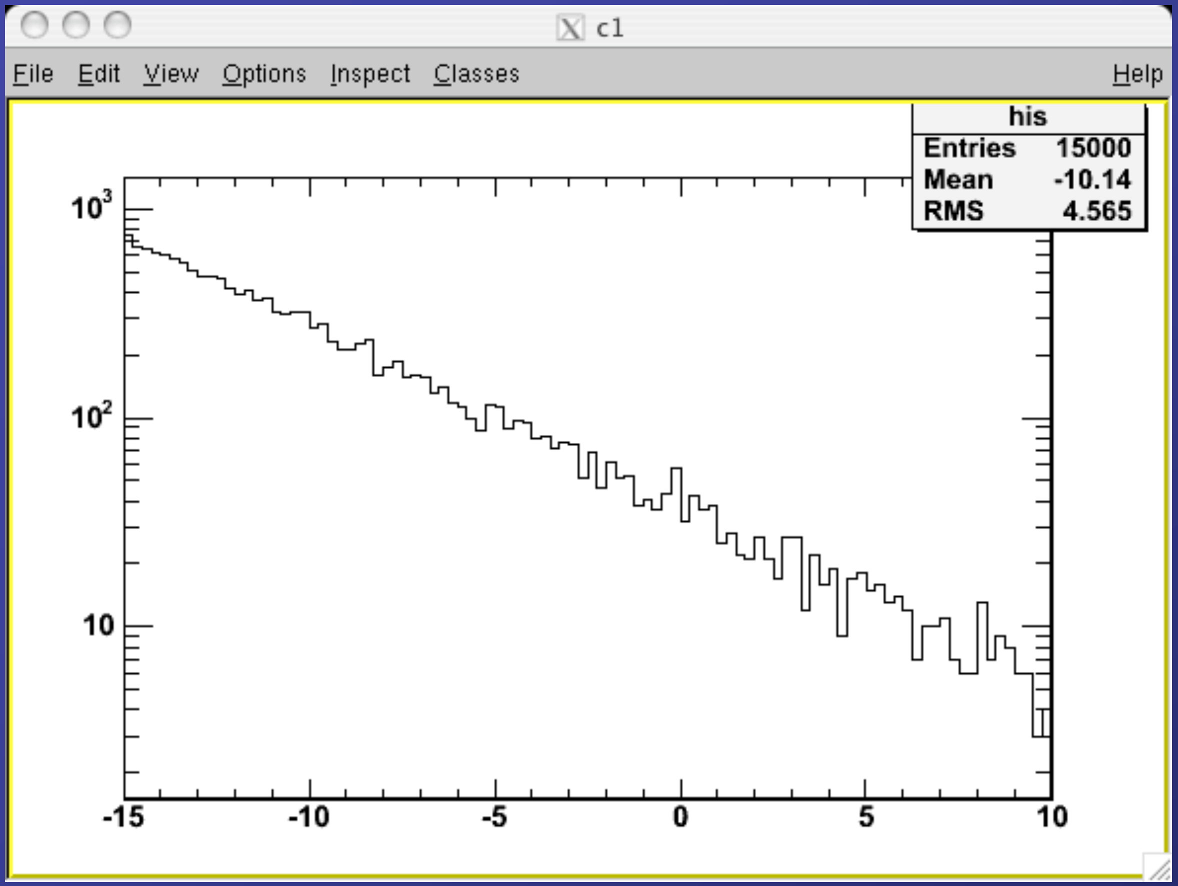
A mathematical procedure to find parameter values of a TFn function, ***f***, describing *the best* your histogram or graph ***(x,y)***. The most commonly used criteria for an optimum fit is to *minimize* the χ^2-function:

$$\chi^2 = \sum \left(\frac{y_i - f(x_i)}{\sigma_i} \right)^2$$

Thumb rule for *Goodness of Fit*: **χ^2/NDF ~ 1**

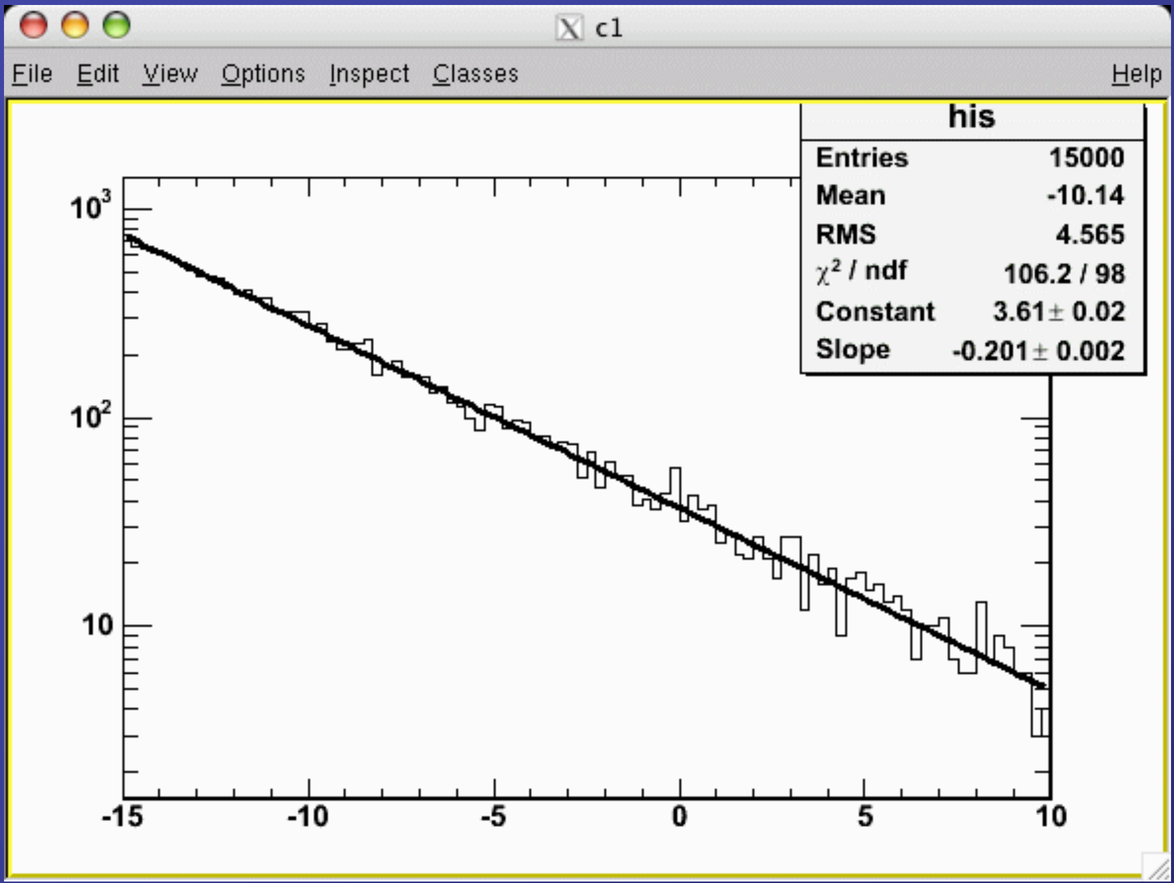
…but there is *much much more* to fitting and statistical data analysis, which fills a course by itself…

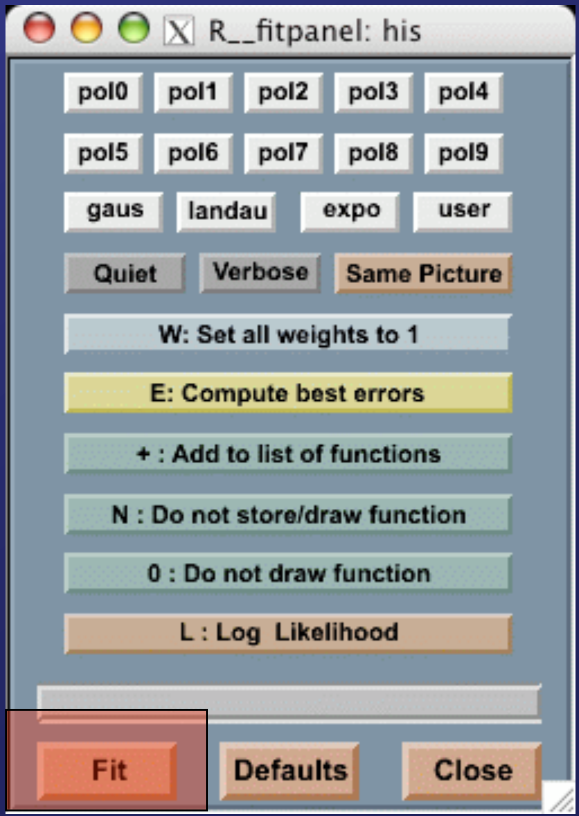
Fitting a histogram (professor style)



Minimum χ^2-fit with pre-defined TF1 function ***expo*** (2 parameters)

Fitting a histogram (professor style)





Minimum χ^2-fit with pre-defined TF1 function ***expo*** (2 parameters)

Fitting a histogram

TH1::Fit(*const char fname, ***Option_t**** option,
Option_t* goption, ***Axis_t*** xmin, ***Axis_t*** xmax)

fname - function name

option - Fitting options:

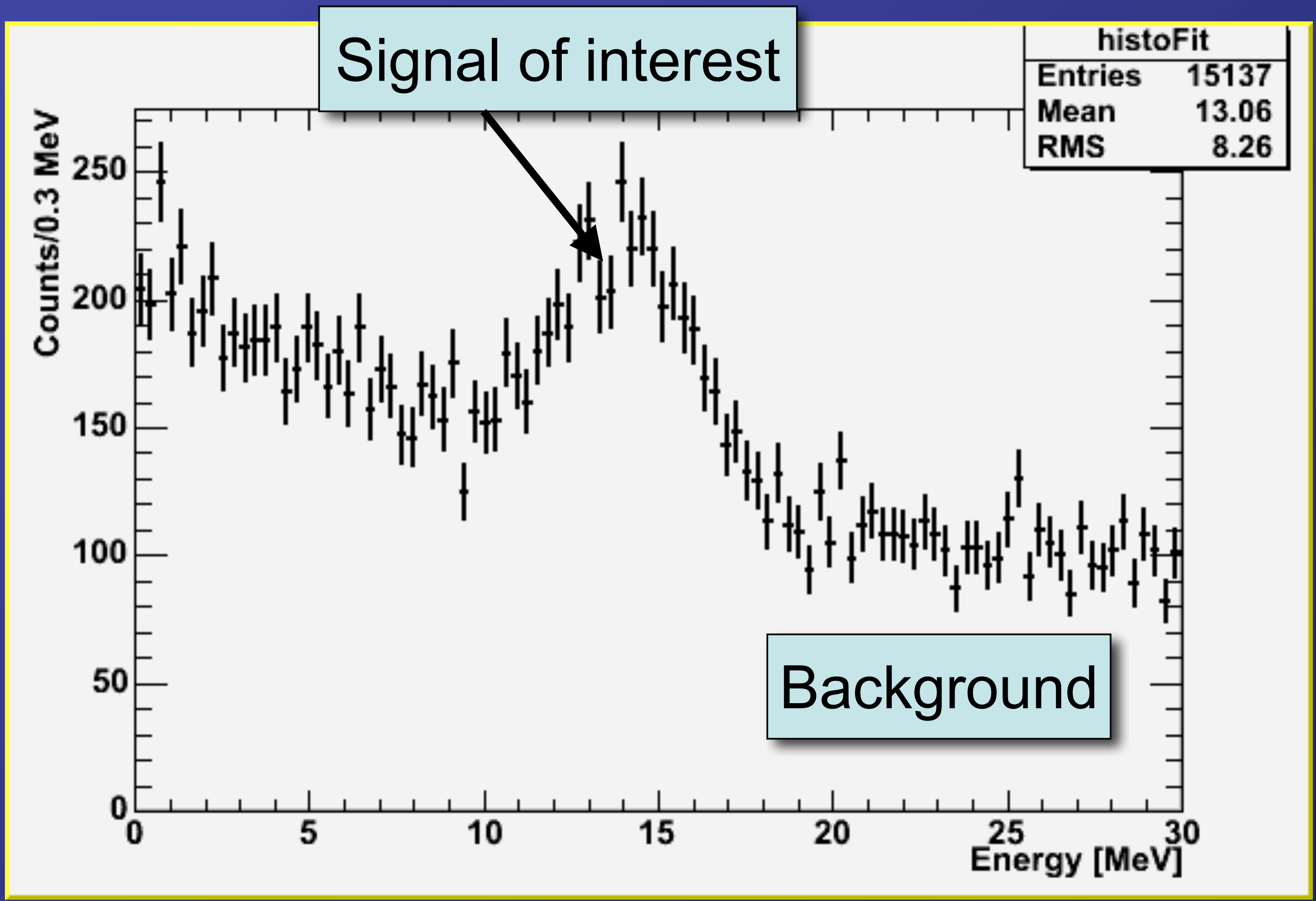
"W" Set all errors to 1
"I" Use integral of function in bin instead of value at bin center
"L" Use Loglikelihood method (default is chisquare method)
"LL" Use Loglikelihood method and bin contents are not integers)
"U" Use a User specified fitting algorithm (via SetFCN)
"Q" Quiet mode (minimum printing)
"V" Verbose mode (default is between Q and V)
"E" Perform better Errors estimation using Minos technique
"B" Use this option when you want to fix one or more parameters and the fitting function is like "gaus","expo","poln","landau".
“M" More. Improve fit results
"R" Use the Range specified in the function range
"N" Do not store the graphics function, do not draw
"0" Do not plot the result of the fit.
"+" Add this new fitted function to the list of fitted functions.

goption - Graphical options

xmin-xmax - Fitting range

Fitting a histogram

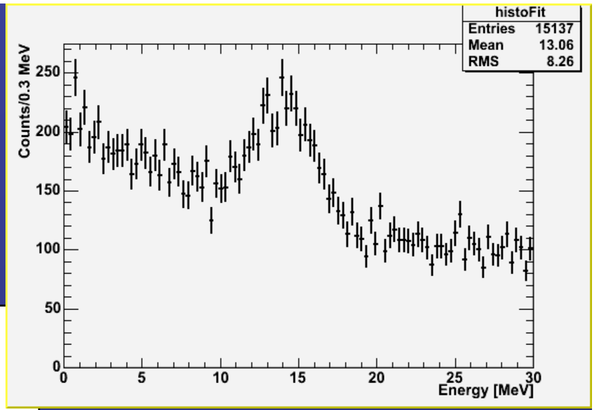
An example



Q: Find the position, width, and strength of the signal !

Fitting a histogram

An example



Signal of interest

$$[0] \cdot e^{-\frac{1}{2}\left(\frac{x-[1]}{[2]}\right)^2}$$

Gaussian with 3 parameters:

gaus

Background

$$[0] + e^{([1]+[2]\cdot x)}$$

0-order polyn.+exp., 3 parameters:

pol0 + expo(1)

Signal + Background

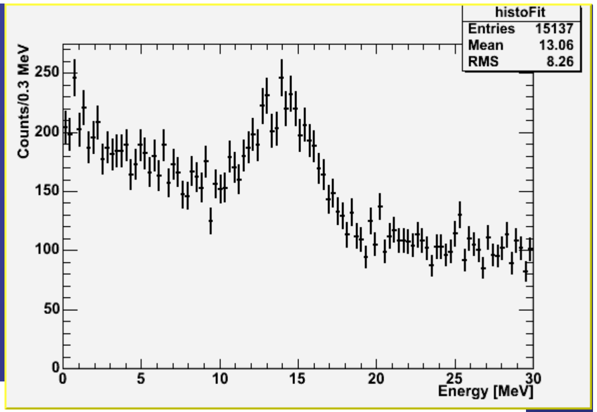
6 parameters:

gaus + pol0(3) + expo(4)

Fitting a histogram

An example

(A part of the macro)




```
{
```

Retrieve histogram

```
TFile  *file  = new TFile("/Users/messchendorp/rootCourse/fitExample.root");
TH1D *his  = file->Get("histoFit");
```

Setup TF1 functions

```
TF1 *fSignal         = new TF1("fSignal","gaus",0.,30.);
TF1 *fBackground = new TF1("fBackground","pol0+expo(1)",0.,30.);
TF1 *fSpectrum     = new TF1("fSpectrum","gaus+pol0(3)+expo(4)",0.,30.);
```

Initialize parameters

```
fSpectrum->SetParNames("Strength","Mean","Sigma","Back1","Back2","Back3");
fSpectrum->SetParameters(100, 15, 2, 50, 0, 0);
```

FIT the spectrum

```
his->Fit("fSpectrum", "", "", 0., 30.);

Double_t param[6];
```

Set all TF1 functions to fitted parameters

```
fSpectrum->GetParameters(param);
fSignal->SetParameters(&param[0]);
fBackground->SetParameters(&param[3]);
```

Subtract background

```
TH1D *hisSignal = new TH1D(*his);
hisSignal->Sumw2();
hisSignal->Add(fBackground, -1);
```

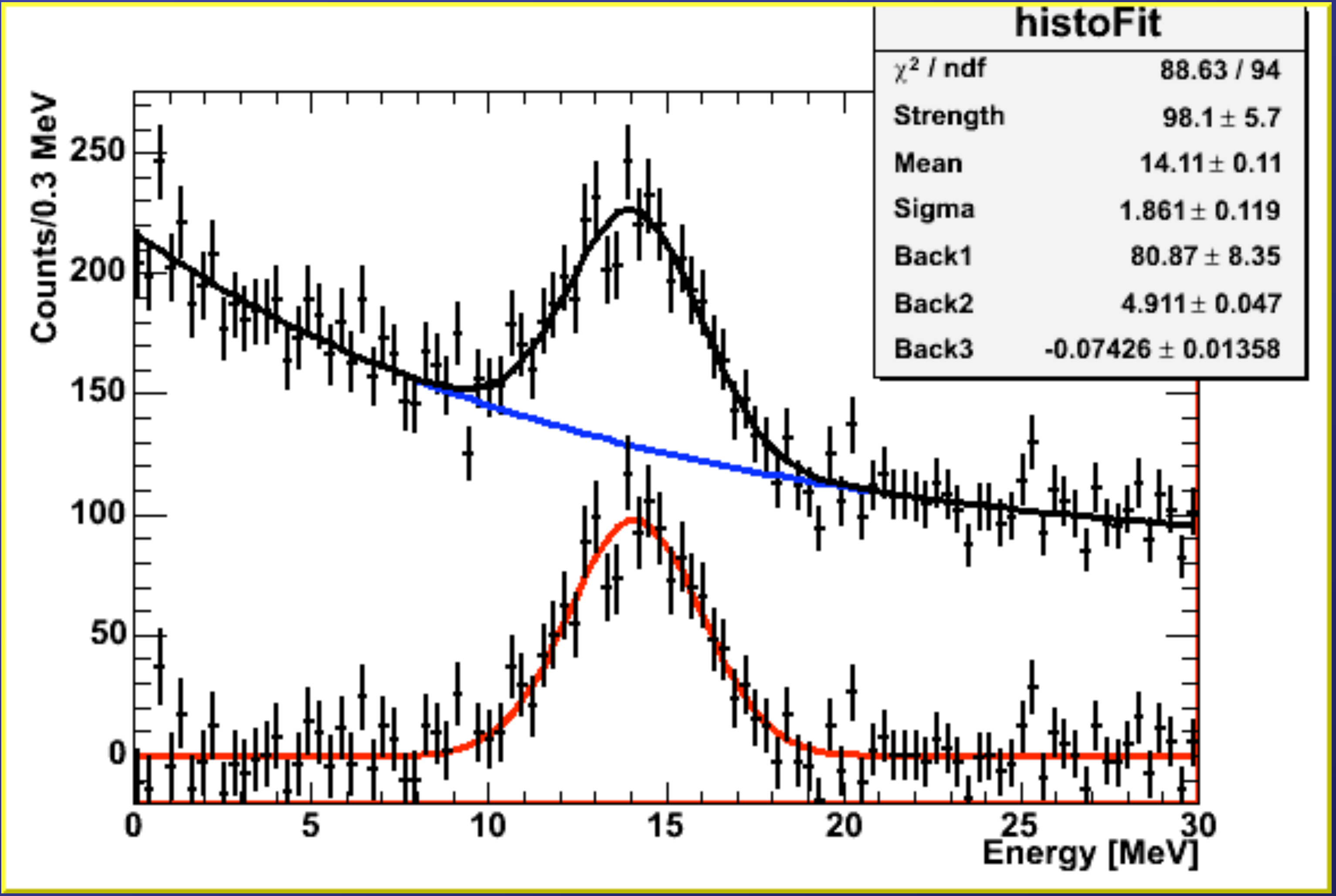
Plot spectra and functions

```
his->Draw("e"); hisSignal->Draw("SAME");
fSignal->Draw("SAME"); fBackground->Draw("SAME");
}
```

Fitting a histogram

An example

The result…



Access to Fit Parameters and Results

By default: Fitting a histogram makes the associated fit function a part of the histogram object. The function and therefore the results of the fit can be accessed via TH1::GetFunction() method.

Example:

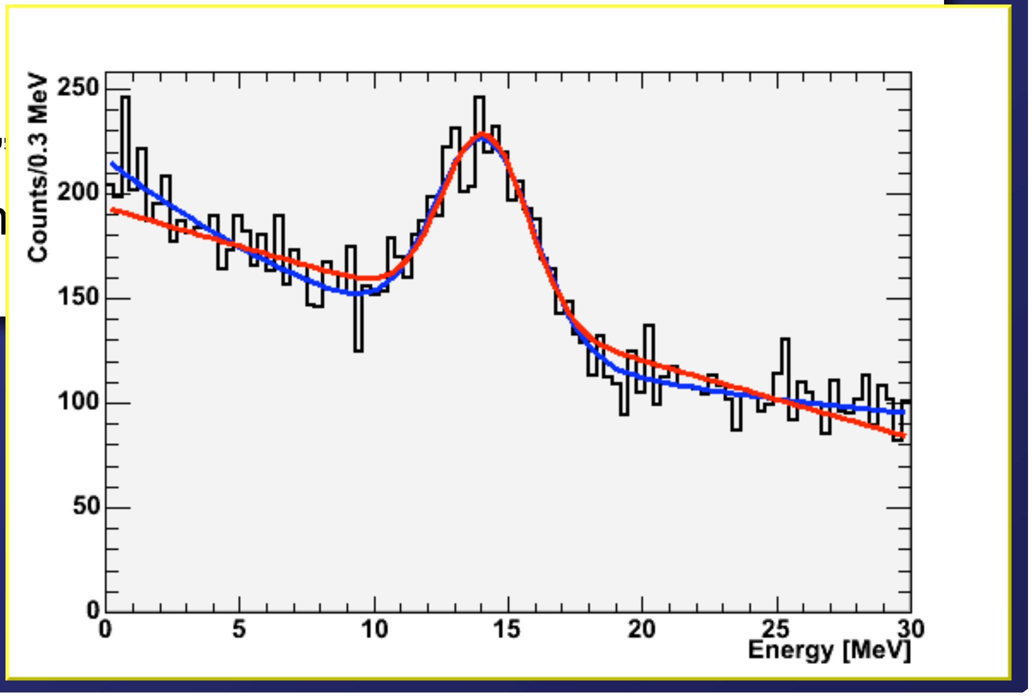
```
root [1] his->Fit("fSpectrum");
root [2] TF1 *fitResult = his->GetFunction("fSpectrum");
root [3] fitResult->GetParameter(1);
(const Double_t)1.41112959451275266e+01
root [4] fitResult->GetParError(1);
(const Double_t)1.11549835948657111e-01
root [5] fitResult->GetChisquare();
(const Double_t)8.86253580822090470e+01
root [6] fitResult->GetNDF();
(const Int_t) 94
```

Fitting more than 1 function

More than one TFn fit-function can be stored in your histogram using option: TH1::Fit(fitFunc,”+”,…).

<u>Example:</u>

```
root [1] TF1 *fSpectrum=new TF1("fSpectrum","gaus+pol0(3)+expo(4)",0.,30.);
root [2] TF1 *fSpectrum2=new TF1("fSpectrum2","gaus+pol1(3)",0.,30.);
root [3] …
root [7] his->Fit(“fSpectrum”);
root [8] his->Fit(“fSpectrum2”,”+”);
root [9] his->GetFunction(“fSpectrum”
root [10] his->GetFunction(“fSpectrun
root [11] his->Draw();
```



Useful fitting-related methods

What?	How?
Perform a fit	TH1::Fit(“fitFunction”,..)
Obtain the fitted TF1 function	TH1::GetFunction(“fitFunction”)
Get Nr of parameters	TF1::GetNpar()
Set fit parameters	TF1::SetParameter(parNo,value)
	TF1::SetParameters(val1,val2,…)
Get fit parameters	TF1::GetParameter(parNo)
	TF1::GetParameters(parArray)
Set parameter errors	TF1::SetParError(parNo,value)
	TF1::SetParErrors(val1,val2,…)
Get parameter errors	TF1::GetParError(parNo)
	TF1::GetParErrors(eParArray)
Get χ^2 of fit	TF1::GetChisquare()
Get Nr of Degrees of Freedom	TF1::GetNDF()
Fix a parameter	TF1::FixParameter(parNo)
Limit parameter range	TF1::SetParLimits(parNo,min,max)

……… (many more)

Beyond fitting histograms…

Graphs:	**TGraph**::**Fit**(…) identical to **TH1**::**Fit**(…)
Ntuples/Trees:	**TTree**::**Fit**(…) **TTree**::**UnbinnedFit**(…)
Most general minimalization package:	**TMinuit/TFitter** (derived from PACKLIB)
Neural Networks:	**TMultiLayerPerceptron**

Exercises for Lecture 6

Exercise 1)

Download the root-file on the website: http://kvir03.kvi.nl/rootcourse/.
Inside you'll find a 1-Dim histogram showing a Gaussian distributed signal on top of a - to-be determined - background signal. Write a macro that fits this spectrum using a user-defined function.

Exercise 2)

Figure out how to obtain the error matrix (i.e. the co-variance matrix) of the fit performed in Exercise 1. *Hint:* Explore the global **gMinuit** instance after fitting.

Send your results to messchendorp@kvi.nl