Lecture1

July 21, 2016

1 ROOT basics: Important objects

1.1 Objectives:

- What are random numbers and how random are they?
- How to create a one-dimensional histogram?
- How to create a two-dimensional histogram?
- How to create a TProfile?
- How to create a TGraph?
- How to perform a simple fit?
- How to save to a ROOT file?
- How to access a TTree?
- How to draw stacked histograms?

1.2 One-dimensional histogram

Create a 1D histogram:

```
In [1]: TH1F hpx("hpx","random gaussian",30,-3,3);
```

Create a new canvas:

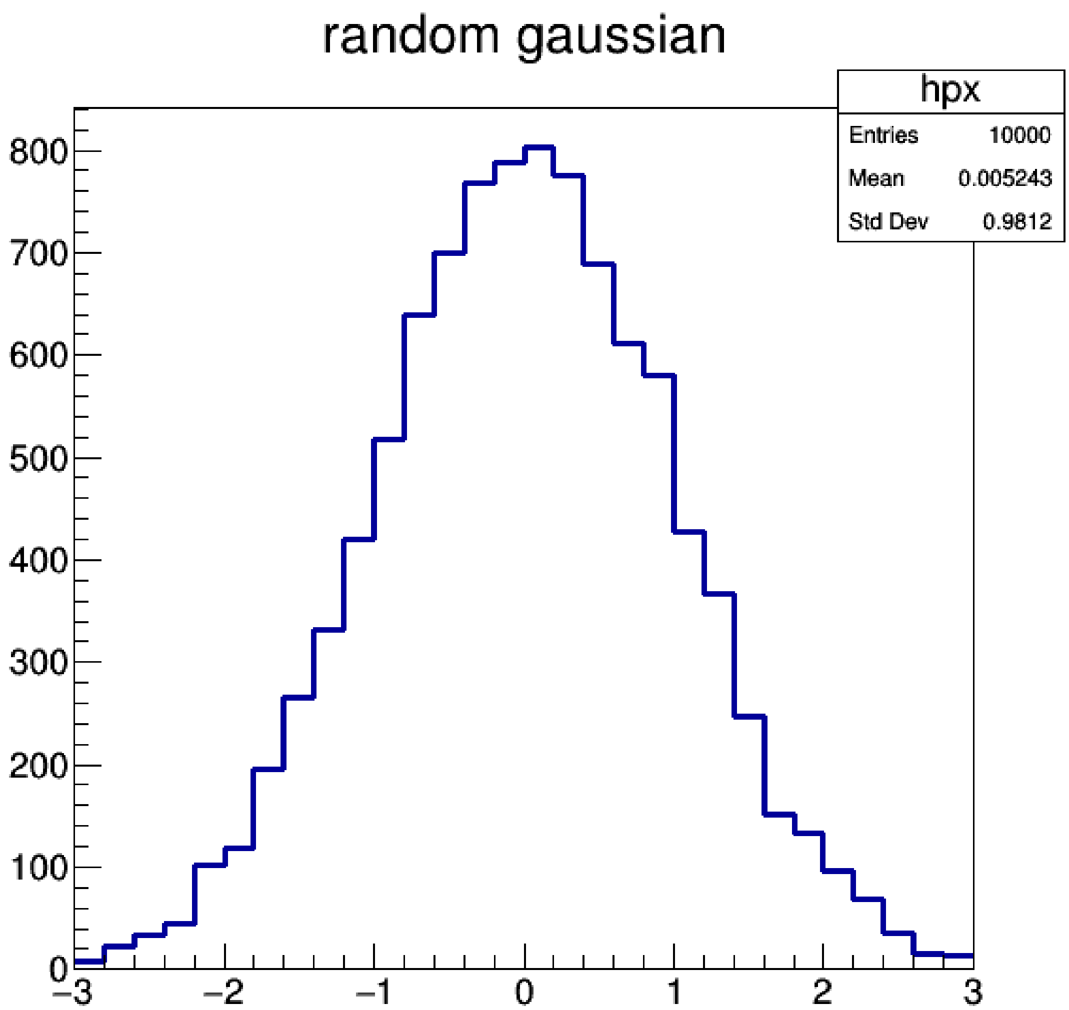
```
In [2]: TCanvas c1("c1","Filling Example",600,600);
```

Fill histograms with random numbers following a Gaussian shape with mean 0 and width 1:

```
In [3]: TRandom3 r;
        int stats = 10000;
        Float_t px;
        for (Int_t i = 0; i < stats; i++) {
            double value = r.Gaus(0.0,1.0);
            hpx.Fill(value);
        }
```

Always use TRandom3, which has the highest periodicity and is fast!
Draw histogram and canvas:

```
In [4]: hpx.Draw();
        c1.Draw();
```



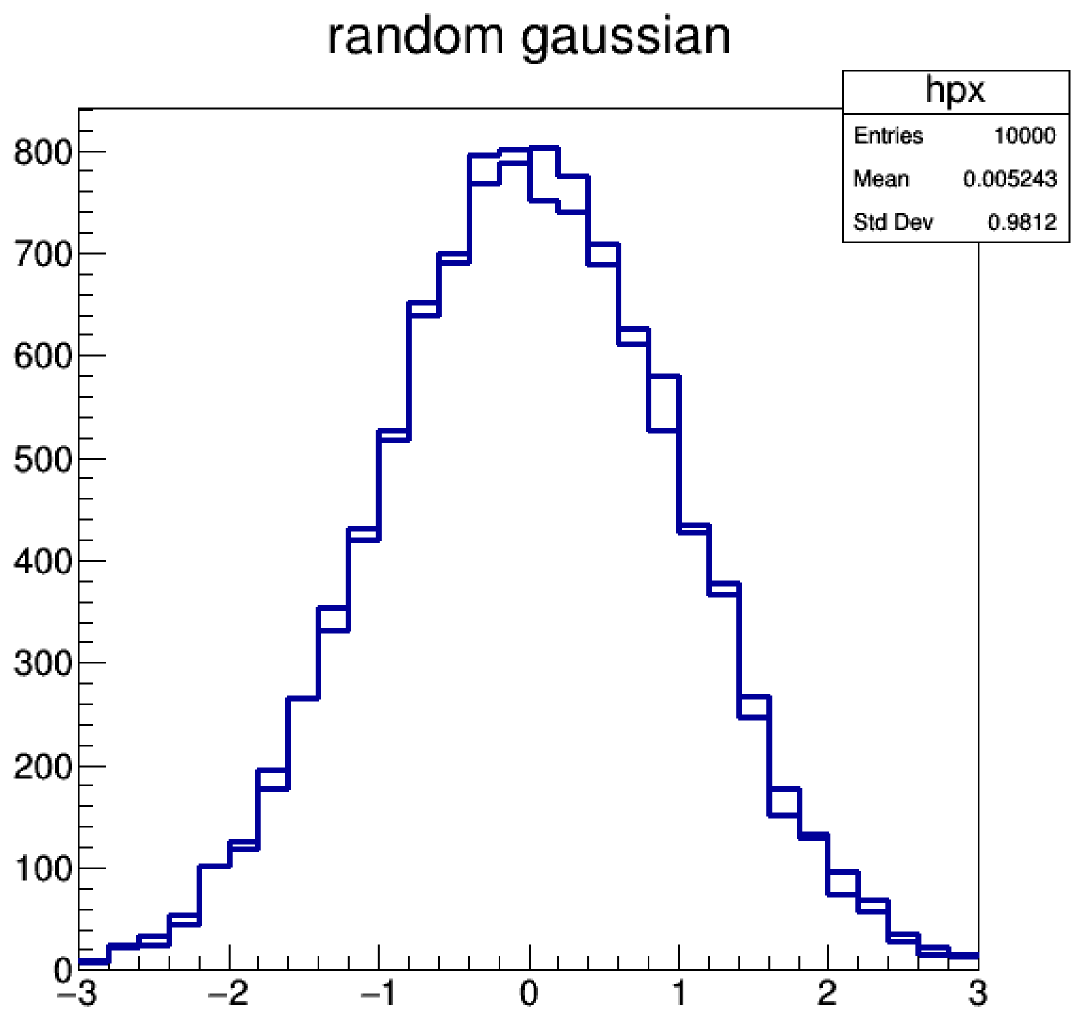
How random is this? Do we get the same distribution if we run again?

```
In [5]: TH1F hpx2("hpx2","random gaussian",30,-3,3);
        for (Int_t i = 0; i < stats; i++) {
            double value = r.Gaus(0.0,1.0);
            hpx2.Fill(value);
        }
```

And now draw again. . .

Note that you need to use the `SAME` option in order to have it in the same canvas.

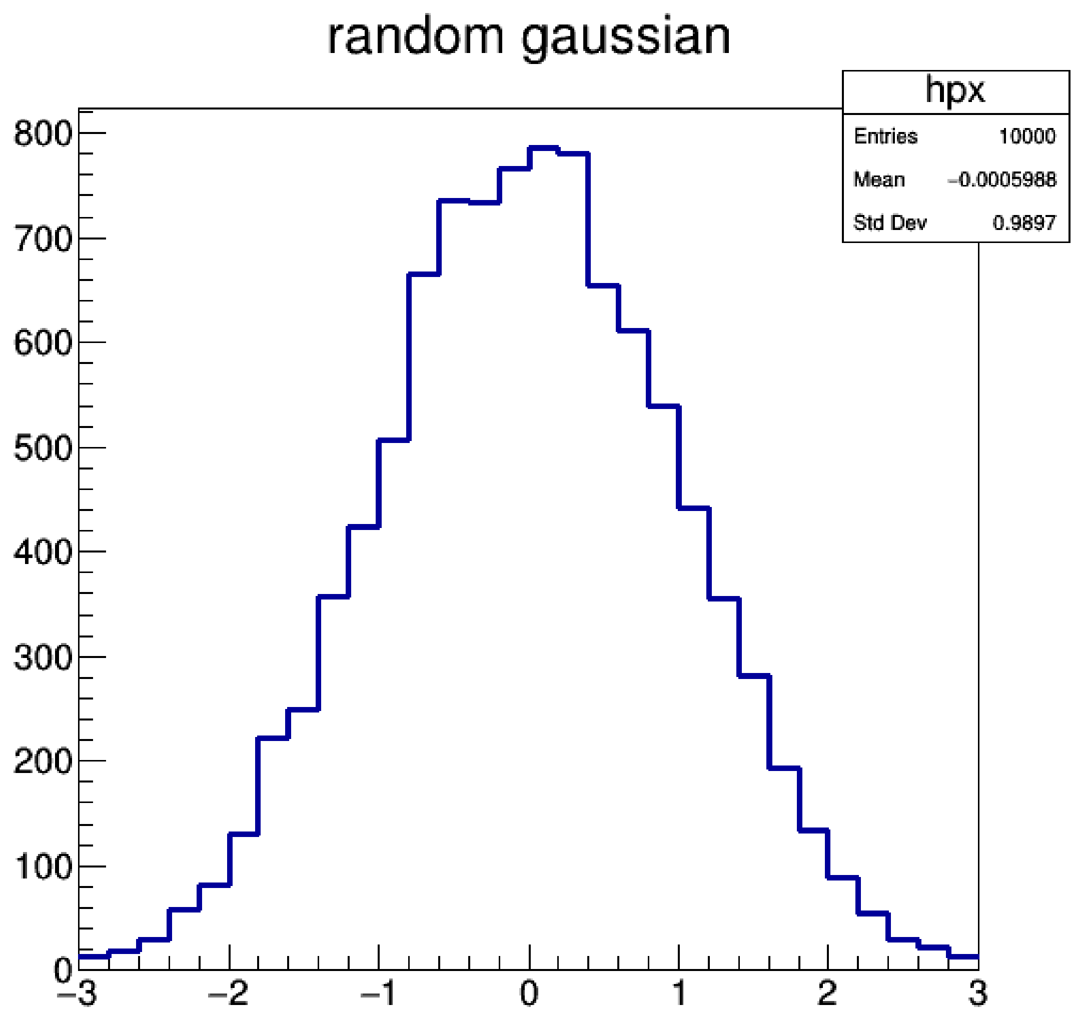
```
In [6]: hpx2.Draw("SAME");
        c1.Draw();
```



Apparently, it is random and the distributions look different, why is that?
Any random number generator needs a seed, by default
`r.SetSeed(0);`
is used which means, the **system time of the computer** is used.
If you want to get the exact same random distributions you need to set the same seed for both generations:

In [7]:
```
//Reset histograms
hpx.Reset();
hpx2.Reset();

//Set a seed=1234
r.SetSeed(1234);

//Loop
```

```
for (Int_t i = 0; i < stats; i++) {
    double value = r.Gaus(0.0,1.0);
    hpx.Fill(value);
}

//Set a seed=1234
r.SetSeed(1234);

//Loop
for (Int_t i = 0; i < stats; i++) {
    double value = r.Gaus(0.0,1.0);
    hpx2.Fill(value);
}

//Draw histogram
hpx.Draw("SAME");
hpx2.Draw("SAME");
c1.Draw();
```



Ok, now we don't see any difference in the distributions. It is often very useful to reproduce results!

1.3 Two-dimensional histogram

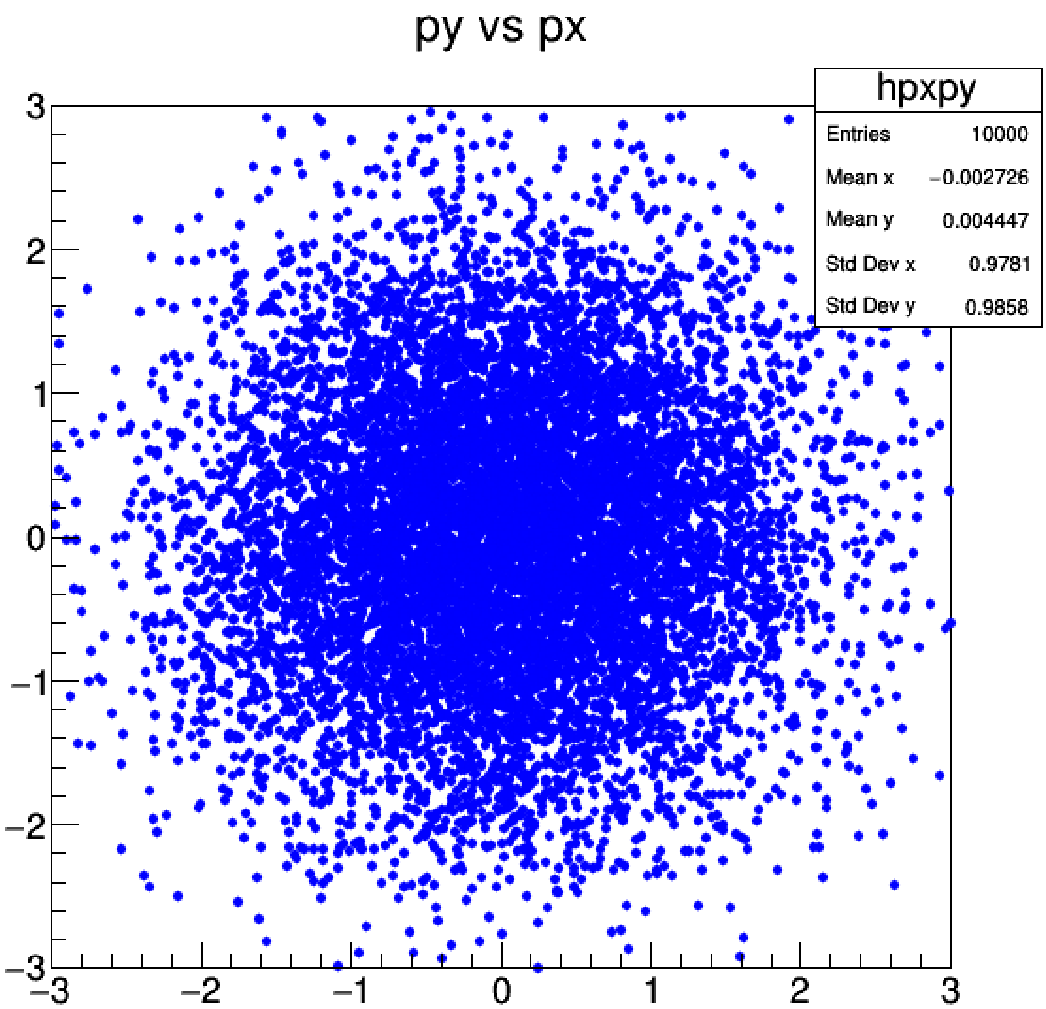
Create a 2D histogram:

```
In [8]: TH2F hpxpy("hpxpy","py vs px",30,-3,3,30,-3,3);
```

Use a 2-dimensional Gaussian with mean 0, width 1 (Rannor), fill the 2D histogram and draw:

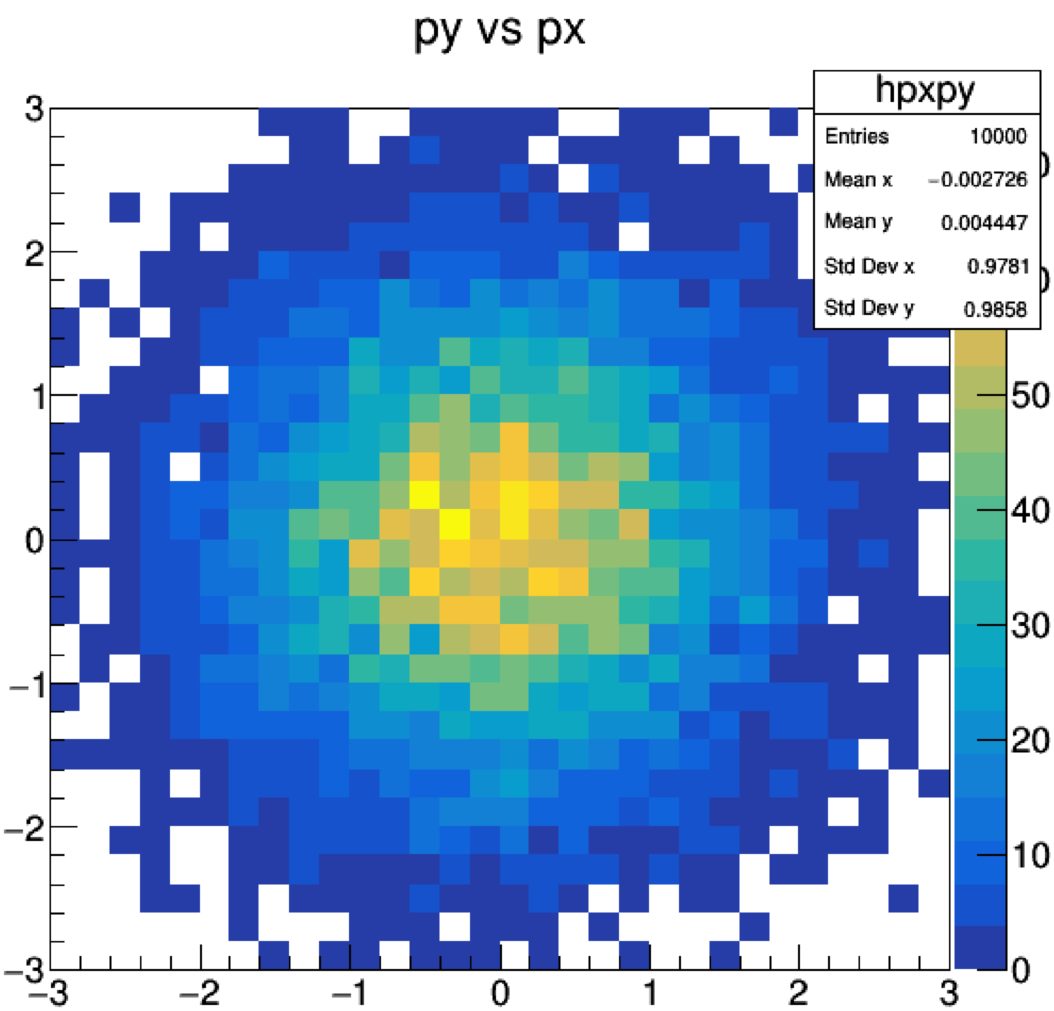
```
In [9]: Float_t py;
        for (Int_t i = 0; i < stats; i++) {
            r.Rannor(px,py);
            hpxpy.Fill(px,py);
        }
```

```
hpxpy.Draw();
c1.Draw();
```



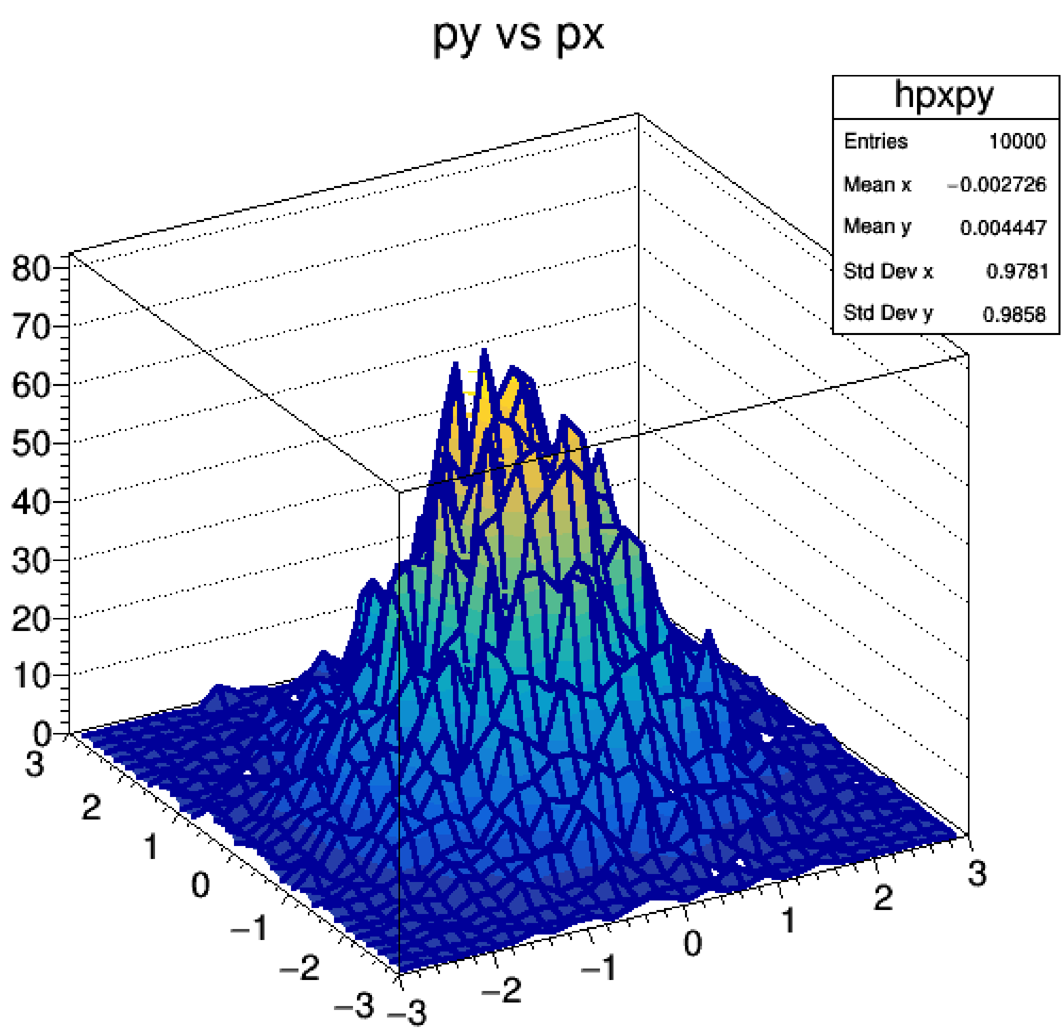
Now we just see the *hit* distribution but it is hard to tell how many events are in each bin. We can use the `COLZ` draw option instead:

```
In [10]: hpxpy.Draw("COLZ");
         c1.Draw();
```



Now we can see from the colour code the number of entries.
Or we can even draw it in a 3D-style:

```
In [11]: hpxpy.Draw("SURF1");
         c1.Draw();
```



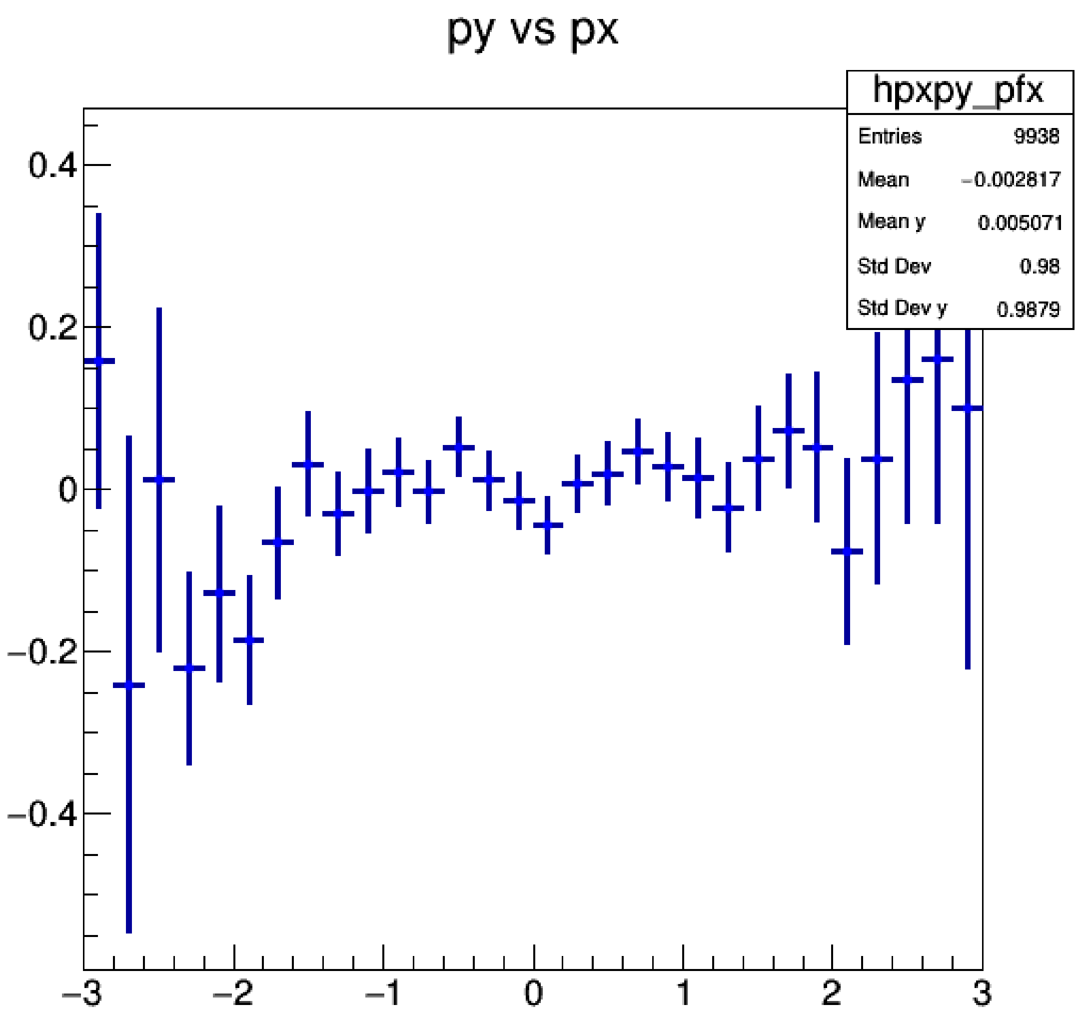
1.4 Profiling a histogram

Two-dimensional histograms are sometimes difficult to read, so it often makes sense to look at the one-dimensional profile.

```
In [12]: TProfile *hprof = new TProfile("hprof","Profile along px",30,-3,3,0,20);
         hprof = hpxpy.ProfileX();
```

This is now a pointer to an object! We need to use -> instead of .

```
In [13]: hprof->Draw();
         c1.Draw();
```



Well, that makes sense, the mean should be zero!

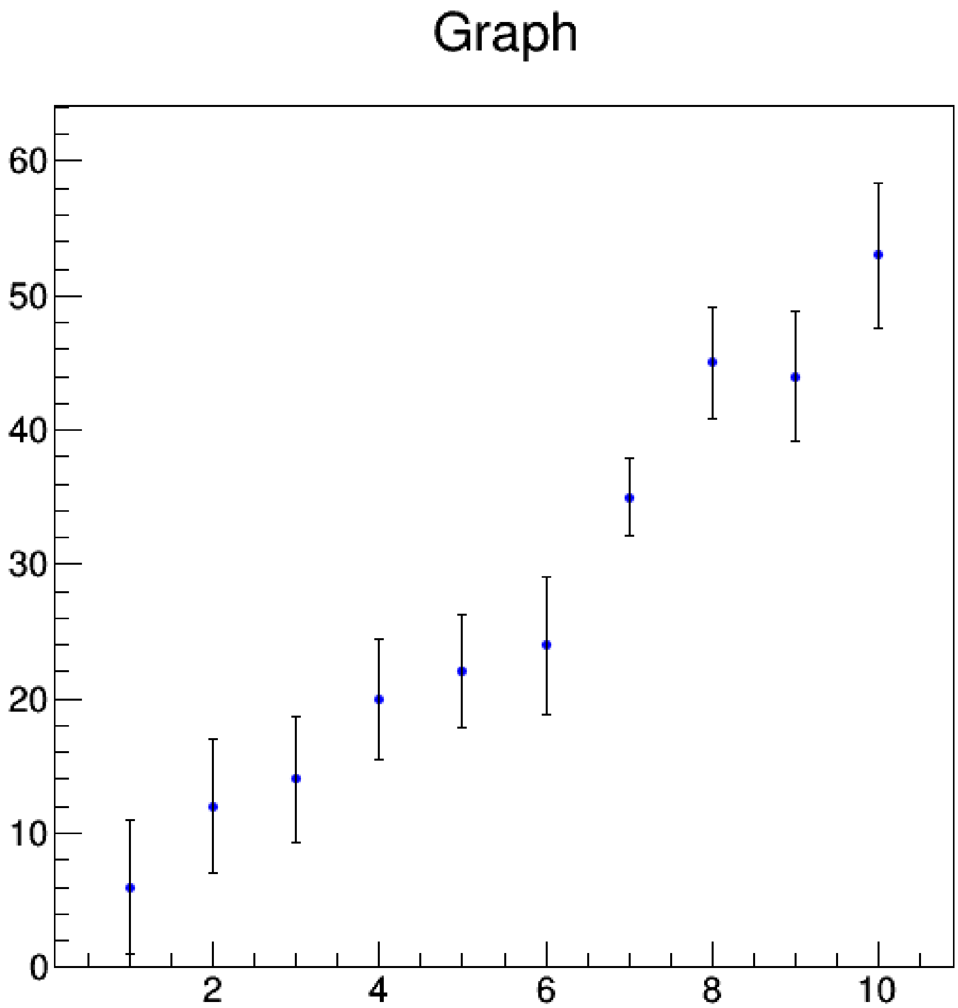
1.5 Graph with Errors

Assume that we measure a variable y vs x for a certain number of points n and we have an uncertainty on the measurement of y:

```
In [14]: const int n=10;
         double x[n]     = {1,2,3,4,5,6,7,8,9,10};
         double y[n]     = {6,12,14,20,22,24,35,45,44,53};
         double y_err[n]= {5,5,4.7,4.5,4.2,5.1,2.9,4.1,4.8,5.43};
```

We can then display our measurement using TGraphErrors, which allows for symmetric uncerstainties.
By using the `APE` draw option the graph is shown with a new axis (A) markers (P) and errors (E).

```
In [15]: TGraphErrors graph(n, x, y, nullptr, y_err);
         graph.Draw("APE");
         c1.Draw();
```



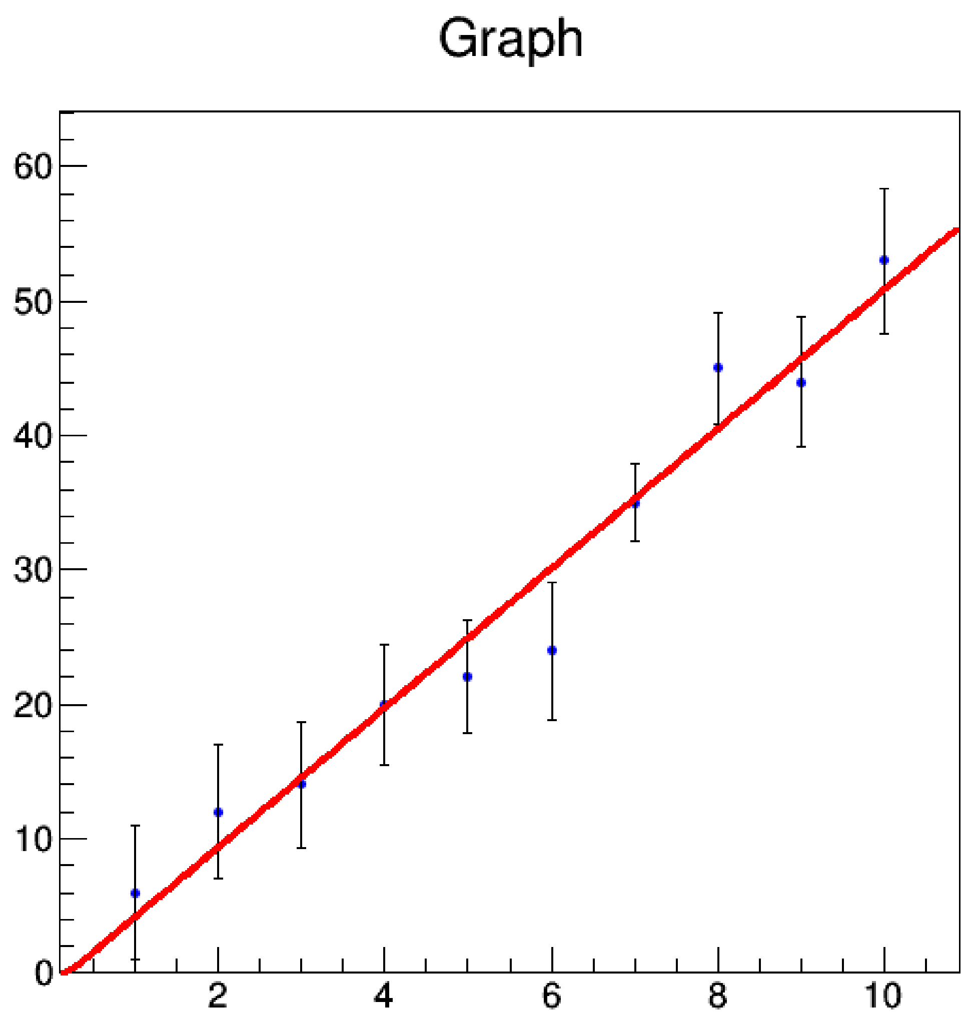
1.6 Fit with a one-dimensional function

Define a linear function using TF1 and fit the Graph

```
In [16]: TF1 *f = new TF1("linear","[0]+x*[1]",.5,10.5);
         graph.Fit(f);
         f->Draw("SAME");
         c1.Draw();
```

```
 FCN=3.84883 FROM MIGRAD    STATUS=CONVERGED      31 CALLS          32 TOTAL
                     EDM=5.96982e-22    STRATEGY= 1      ERROR MATRIX ACCURATE
```

```
EXT PARAMETER                                    STEP         FIRST
NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
 1  p0         -1.01604e+00   3.33409e+00   1.48321e-03  -8.98235e-12
 2  p1          5.18756e+00   5.30717e-01   2.36095e-04   9.40487e-12
```



1.7 Write a ROOT file

Open ROOT file with option `RECREATE`, save all objects we have created in it and close it:

```
In [17]: TFile hfile("test.root","RECREATE","Test ROOT file");
         hpx.Write();
         hpx2.Write();
         hpxpy.Write();
         hprof->Write();
```

```
graph.Write();
hfile.Write();
hfile.Close();
```

Now we can have a look at the content:

```
In [18]: .! rootls -l test.root
```

```
TGraphErrors  Jul 21 14:42  Graph       "Graph"
TH1F          Jul 21 14:42  hpx         "random gaussian"
TH1F          Jul 21 14:42  hpx2        "random gaussian"
TH2F          Jul 21 14:42  hpxpy       "py vs px"
TProfile      Jul 21 14:42  hpxpy_pfx   "py vs px"
```

1.8 Open a root file and read in variables from a tree

Similarly, we can open an exisiting root file with option `READ`:

```
In [19]: TFile *fSig = new TFile("Signal_1fb.root", "READ");
```

Information is often stored in so called `Trees` which can contain `Branches` and `Leaves` representing the content.
We can retrieve a tree using its name "tree":

```
In [20]: TTree *tSig = (TTree*)fSig->Get("tree");
```

To get the content of the tree we need to link a branch variable `invariantMass` to a local variable `mass`:

```
In [21]: double mass;
         tSig->SetBranchAddress("invariantMass", &mass);
```

We now create a new histogram in order to plot the content and get the number of entries of the tree.

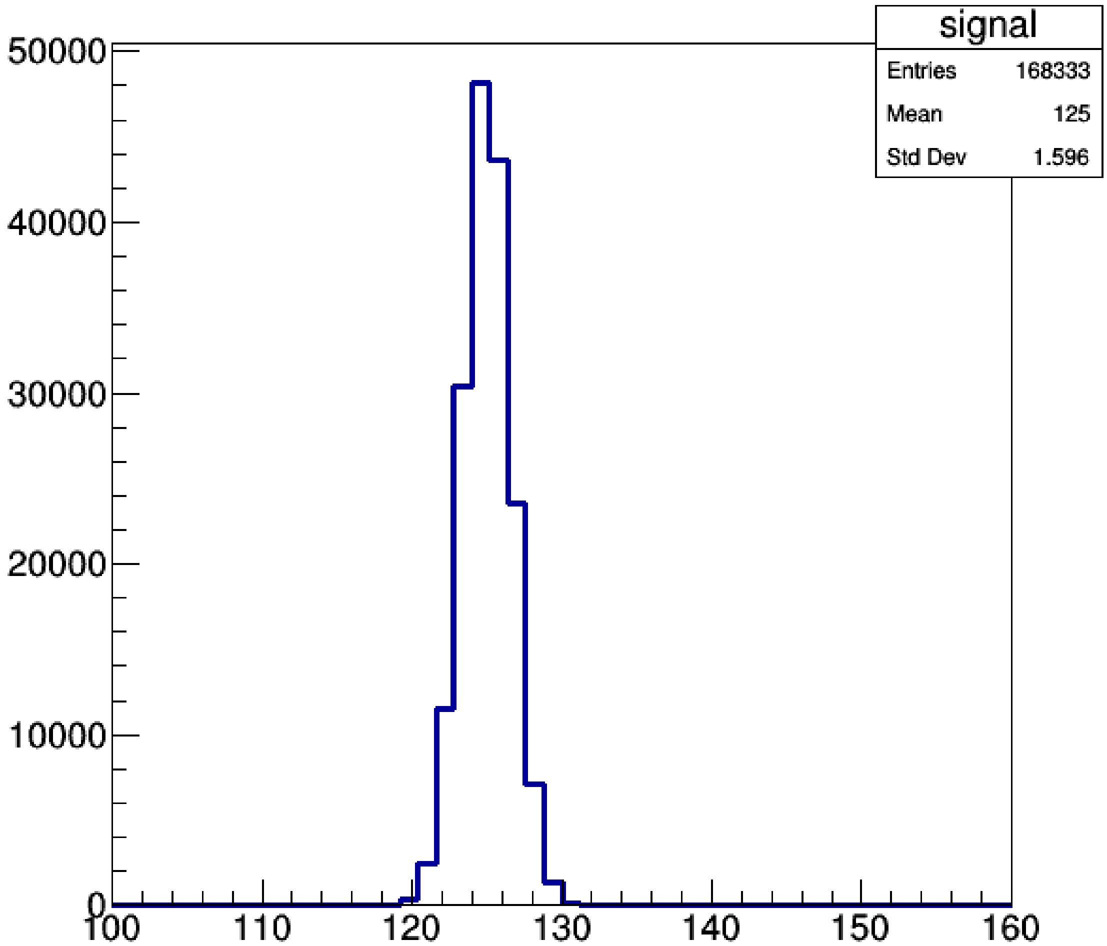
```
In [22]: TH1F *hSig = new TH1F("signal", "", 50, 100, 160);
         int nEntries_Sig = tSig -> GetEntries();
```

One entry of a tree can often be understood as one event with many different properties stored in the branches. To fill the histogram with all events, we need to loop over the tree:

```
In [23]: for(int i = 0; i < nEntries_Sig; ++i){
             tSig->GetEntry(i);
             hSig->Fill(mass);
         }
```

Finally, we can draw the histogram on the canvas:

```
In [24]: hSig->Draw();
         c1.Draw();
```



1.9 Stacked histograms

Last, but not least we want to create a stacked histgram, which are often used to show the different process contributions in simulations.

```
In [25]: THStack hstack("stack","Stacked histograms");
```

We can now simply add the created signal histogram to the `THStack` object:

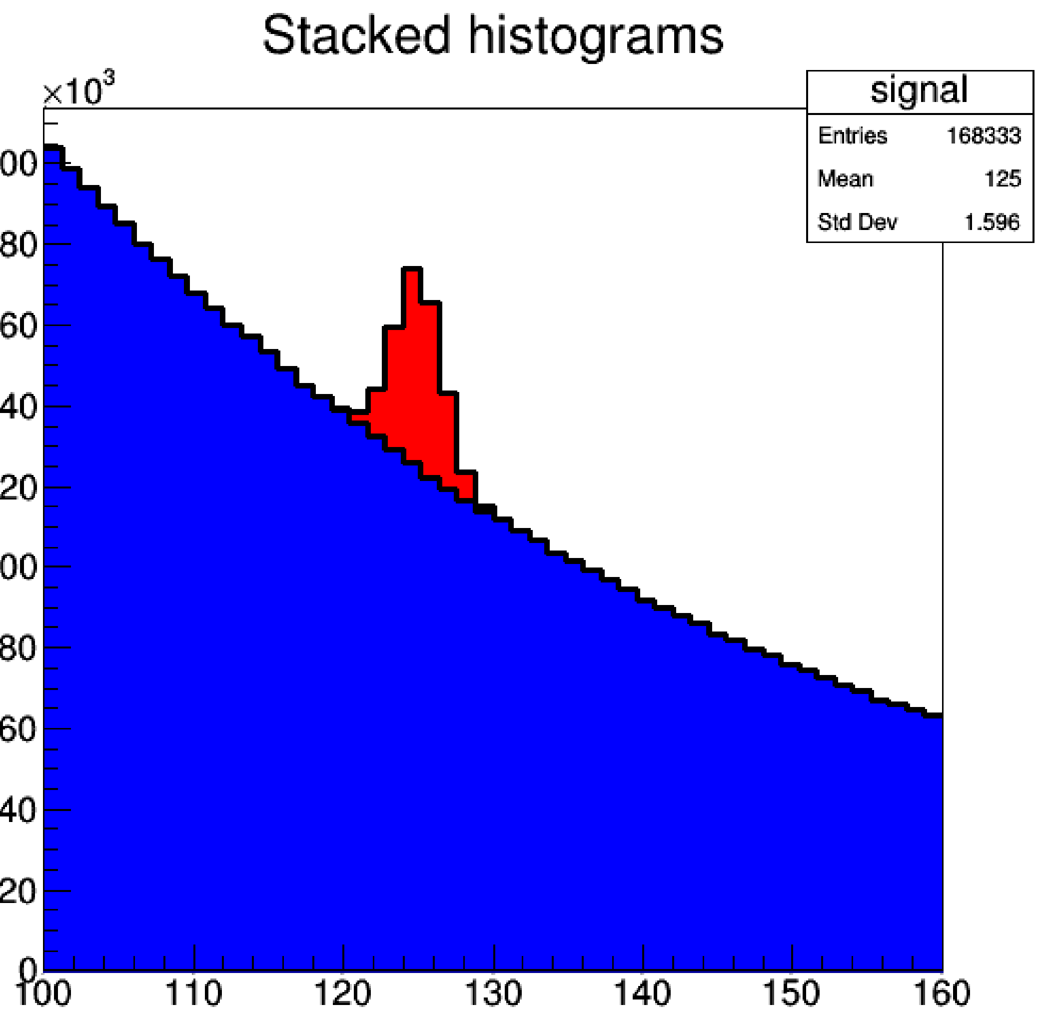
```
In [26]: hstack.Add(hSig);
```

Ok, nice but to have a stacked histogram we need another histogram, let's read in the background and fill a histogram:

```
In [27]: TFile *fBkg = new TFile("Background_1fb.root", "READ");
         TTree *tBkg = (TTree*) fBkg -> Get("tree");
         TH1F *hBkg = new TH1F("bkg","", 50, 100, 160);

         double mass_bkg;
         tBkg->SetBranchAddress("invariantMass", &mass_bkg);

         int nEntries_Bkg = tBkg -> GetEntries();
         for(int i = 0; i < nEntries_Bkg; ++i){
             tBkg->GetEntry(i);
             hBkg->Fill(mass_bkg);
         }
```

Now we can also add it to the stack, fill the histograms with color and draw it:

```
In [28]: hstack.RecursiveRemove(hSig);
         hstack.Add(hBkg);
         hstack.Add(hSig);
         hBkg->SetFillColor(kBlue);
         hBkg->SetLineColor(kBlack);
         hSig->SetFillColor(kRed);
         hSig->SetLineColor(kBlack);
         hstack.Draw();
         c1.Draw();
```



1.9.1 Disclaimer: This is of course not a complete list of important objects, but knowing all these will give you a good basis!