ROOT user experience

ROOT Users Workshop

Ruggero Turra

Università degli Studi di Milano & INFN

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Introduction

My background

- I work in the ATLAS collaboration since 2010
- I am involved in data analysis ($H \to \gamma\gamma$) and in performance (energy calibration)
- I started to use ROOT in the first year of university, during the "Physics laboratory 1.0.1"
- I work 80% in python using various libraries: ROOT, numpy/scipy, matplotlib, . . . , Proof, TMVA, RooFit, RooStats

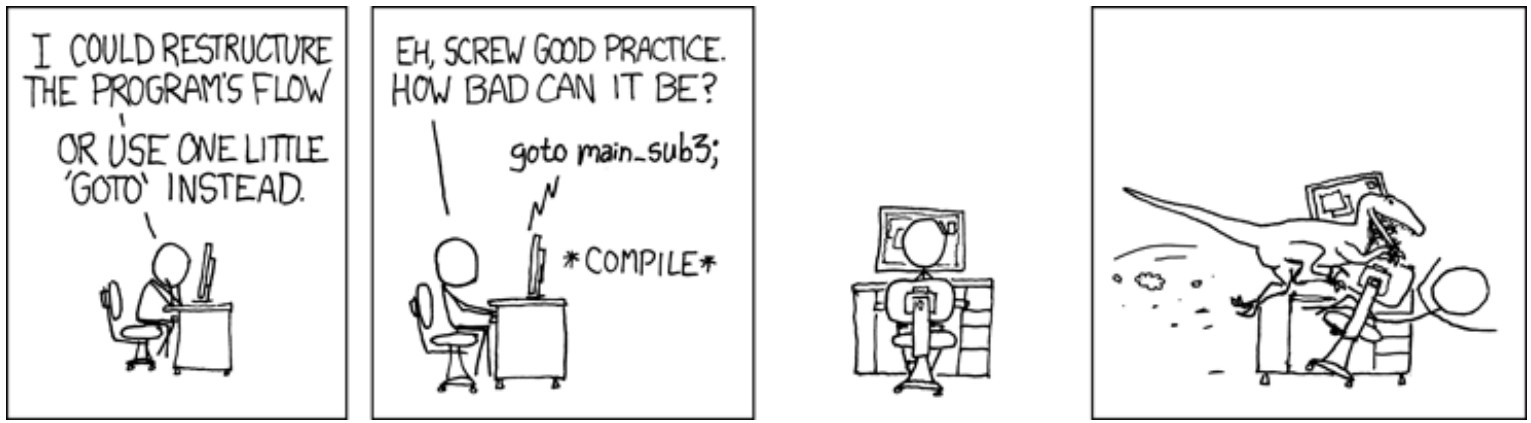
- ROOT is widely used and supported
- it provides you many useful tools (TString, TPRegexp, . . .), no need to include other libraries, very easy to share code
- very fast
- flexible I/O
- nice integration with python

```
1  import ROOT
2  ROOT.gROOT.ProcessLine(".x \$ROOTCOREDIR/scripts/load_packages.C+");
3  ROOT.my_cpp_function()
```

Some considerations about ROOT users

A lot of users...

- prefer a quick and dirty approach



- don't compile code
- have only a basic C++ knowledge
- don't know any alternative package for data analysis (PAW)
- don't know about ownership in ROOT (white canvases, double delete)
- have troubles with pointers (memory leaks)
- very small feedback, they prefer workarounds

Some considerations about ROOT users/2

Personal utilities

- some of them have their own `MyRootUtils`, very simple tasks (convert histograms to graphs, . . .)

```
from PyH4l import ROOTDefs, PyH4lTools

fPowHeg = ROOT.TFile("Hgg_mc10b_VBFH120_PowHeg.root")
fHerwig = ROOT.TFile("Hgg_mc10b_VBFH120_Herwig.root")

tPowHeg = fPowHeg.tree
tHerwig = fHerwig.tree

x = ROOTDefs.Draw([tPowHeg, tHerwig],
      "pT", "20./(20 + 10*(pT > 200) + 30*(pT > 300) + 50*(pT>400))",
      binning=range(0,200,10) + range(200, 300, 20) + [300, 350, 400, 500], ↩
           norm=1,
      legend_labels=["PowHeg", "Herwig"], logy=1, min=1e-5, max=0.2, ↩
           markersize=0.8,
      legend_options="PL", ytitle = "dN/dP_{T} / 10 GeV", xtitle="P_{T}^{#↩
           gamma#gamma} [GeV]")

hDiv = ROOTDefs.H1Divide(x.plots[0], x.plots[1], xtitle="P_{T}^{#gamma#gamma} [↩
     GeV]", ytitle="PowHeg / Herwig")
hDiv.Draw()
```

Some consideration about ROOT and C++

ROOT and C++ don't help them very much:

- C++ is extremely difficult
- C++ is not quick, but it can be very dirty
- ROOT is not forcing the user to write safe code (avoiding pointers for example)
- some internal ROOT mechanisms are too implicit and magic[1]

[1] from Wikipedia: "magic is an informal term for abstraction - it is used to describe code that handles complex tasks while hiding that complexity to present a simple interface. The term is somewhat tongue-in-cheek and carries bad connotations, implying that the true behavior of the code is not immediately apparent"

ROOT Object Ownership

average user

```
1  void f(TCanvas *canvas)
2  {
3      canvas->cd();
4      TH1F* h = new TH1F("h", "h", 10, 0, 10);
5      h->Fill(2);
6      h->Fill(3);
7      h->Draw();
8  }
9
10 int main()
11 {
12     TCanvas* canvas = new TCanvas();
13     f(canvas);
14 }
```

ROOT Object Ownership

try to avoid memory leak is (blank canvas)

```
1  void f(TCanvas *canvas)
2  {
3      canvas->cd();
4      TH1F* h = new TH1F("h", "h", 10, 0, 10);
5      h->Fill(2);
6      h->Fill(3);
7      h->Draw();
8      delete h;
9  }
10
11 int main()
12 {
13     TCanvas* canvas = new TCanvas();
14     f(canvas);
15     // wait here
16     delete canvas;
17 }
```

ROOT Object Ownership

try to avoid pointers

```
1  void f(TCanvas & canvas)
2  {
3      canvas->cd();
4      TH1F h("h", "h", 10, 0, 10);
5      h.Fill(2);
6      h.Fill(3);
7      h.Draw();
8  }
9
10 void a()
11 {
12     TCanvas* canvas = new TCanvas();
13     f(*canvas);
14 }
```

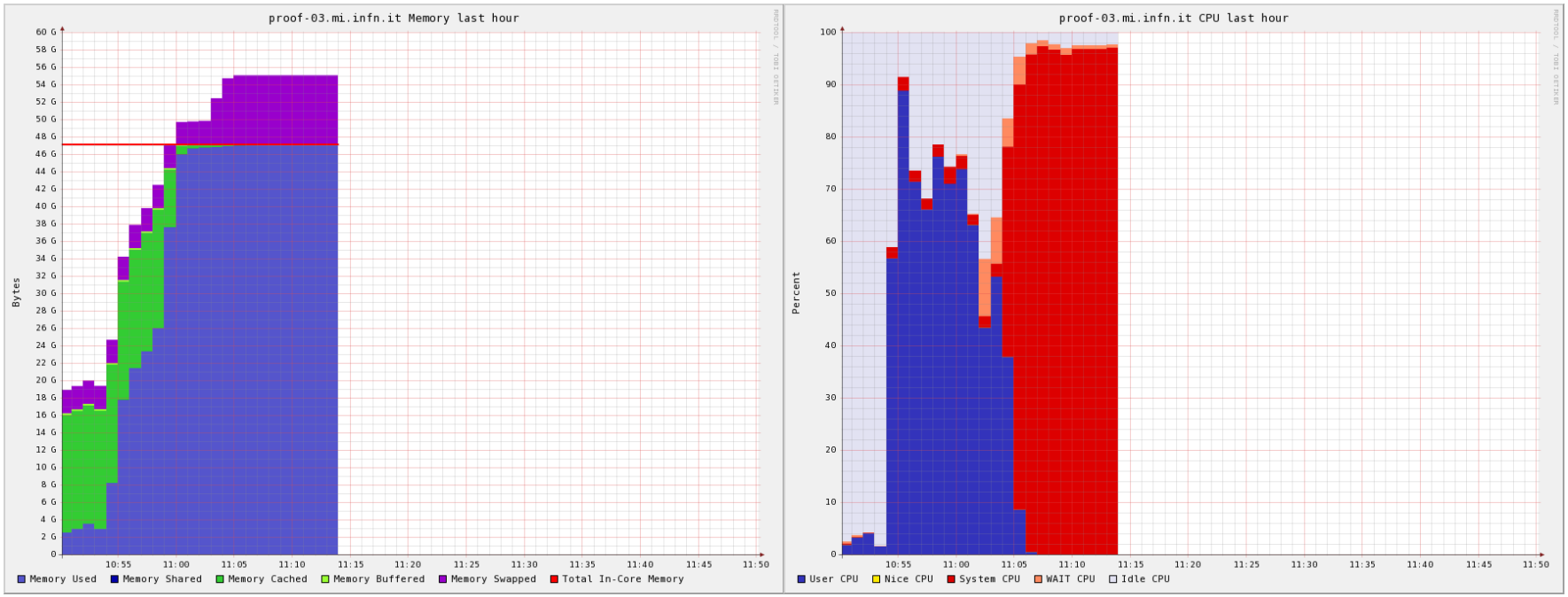
ROOT Object Ownership

try to use python

```
1  import ROOT
2
3  def f(canvas):
4      canvas.cd()
5      h = ROOT.TH1F("h", "h", 10, 0, 10)
6      h.Fill(2)
7      h.Fill(3)
8      h.Draw()
9
10 if __name__ == "__main__":
11     canvas = ROOT.TCanvas()
12     f(canvas)
13     raw_input()
```

Consequences

Very frequent: this morning!



- in addition al lot of ROOT method return pointer: it not always clear who has the responsibility for the memory (`TProfile* TH2::ProfileX`)

Other memory model: matplotlib example

matplotlib example

```
1  import matplotlib.pyplot as plt
2
3  def f(pad):
4      n, bins, patches = pad.hist([2,3], bins=10, range=(0,10))     (1)
5
6  if __name__ == "__main__":
7      fig = plt.figure()
8      ax = fig.add_subplot(111)     (2)
9      f(ax)
10     plt.show()     (3)
```

- explict ownership: (2) `fig` owns `ax`, (1) `ax(pad)` owns the histogram
- (3) explict show

Other memory model: gtk+

gtk+ example

```
1  void f(GtkWidget* window) {
2      GtkWidget *button = gtk_button_new_with_label ("Hello World");
3      gtk_container_add(GTK_CONTAINER (window), button);     (1)
4      gtk_widget_show(button);     (2)
5  }
6
7  int main() {
8      GtkWidget *window = gtk_window_new(GTK_WINDOW_TOPLEVEL);     (3)
9      f(window);
10     gtk_widget_show(window);     (4)
11     gtk_main();
12 }
```

- (1) explict ownership
- (2) (4) explict show
- (3) reference counter

Other memory model: gtkmm

gtkmm example

```
1  struct HelloWorldWindow : public Gtk::Window
2  {
3    HelloWorldWindow() : m_button("Hello World") {
4      add(m_button);      (1)
5      m_button.show();    (2)
6    }
7    Gtk::Button m_button;   (3)
8  };
9
10 int main(int argc, char** argv) {
11   Glib::RefPtr<Gtk::Application> app = Gtk::Application::create(argc, argv);   (4)
12   HelloWorldWindow helloworld;   (5)
13   return app->run(helloworld);
14 }
```

- (1) explict ownership
- (2) explict show
- (3) (5) no pointers at all
- (4) reference-counting smartpointer

Another common mistake

gtkmm example

```
1  std::vector<TObject*> get_histograms(std::string filename) {
2     std::vector<TObject*> result;
3     TFile f(filename.c_str());
4     result.append(f.Get("histo1"));
5     result.append(f.Get("histo2"));
6     return result;
7  };
8
9  int main() {
10    std::vector<TObject*> histograms = get_histograms("my_file.root");
11    draw_with_mystyle(histograms);
12 }
```

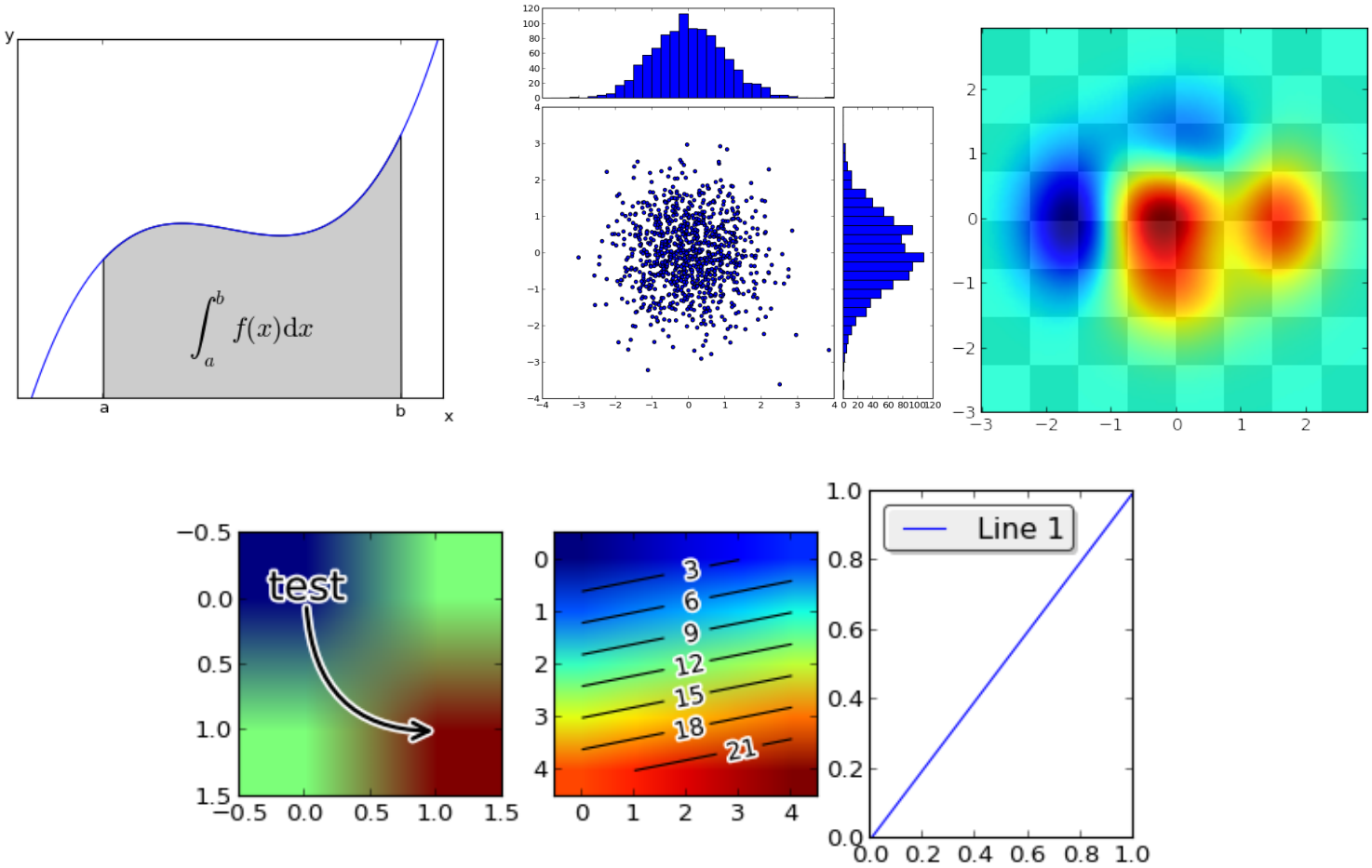
Why I am using python

- productivity
- C++ doesn't have a large std library (as java)
- because I can do:

```
1 "histo_" + str(10)
2 logging.error("file not found")
3 os.listdir(".")
4 files = glob("data8TeV*_p1234")
5 re.match(r"(?P<first_name>\w+) (?P<last_name>\w+)", "Ruggero Turra")
6 p = multiprocessing.Pool(5); p.map(f, data)
```

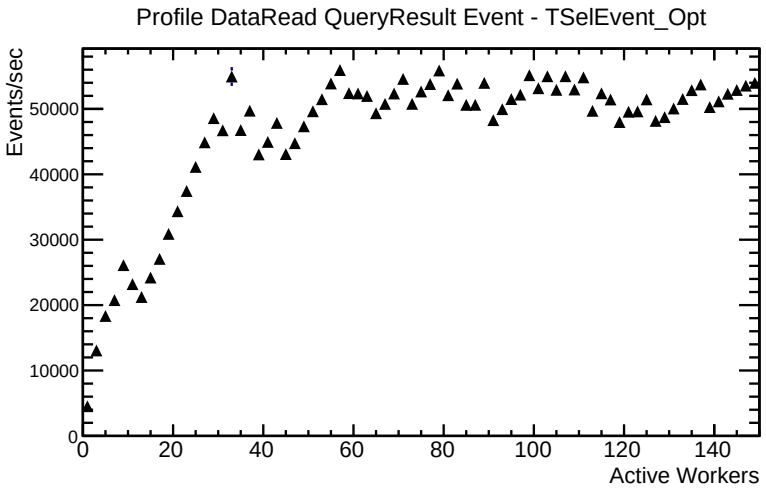
- no pointers
- no compilation, try and fix approach
- everybody can learn python in one week
- of course you can't do everything in python (e.g. cutflow, skimming, ...)
- time = time to develop + time to run

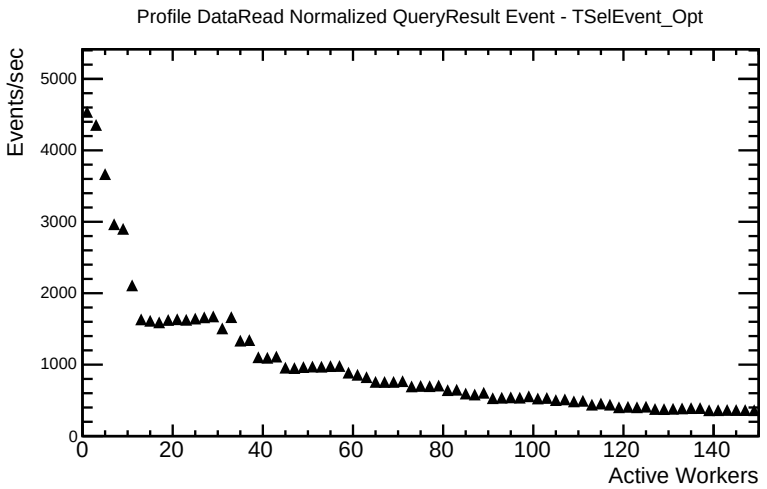
Why I am using matplotlib

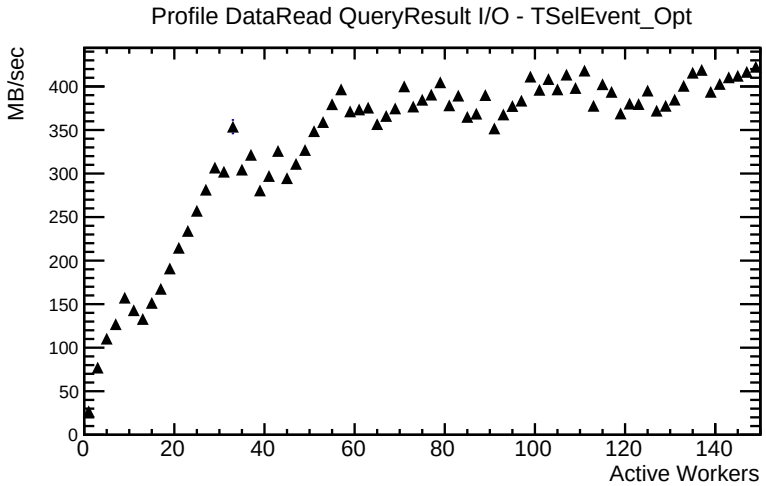


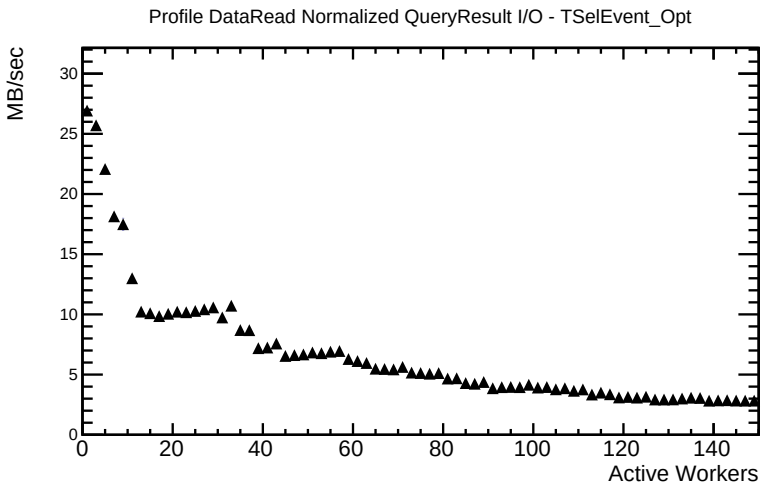
- it is a bit slow
- very high customizability

Why I am using proof









My workflow

First dump the data: branch → memory (array)

dump data (simplified)

```
1  import ROOT
2  import numpy as np
3
4  def GetValuesFromTreeWithProof(tree, variable, cut = ""):
5    variable = "Entry\$:" + variable    (1)
6    if not hasattr(ROOT, "gProof"):
7      ROOT.TProof.Open("")
8    if not isinstance(tree, ROOT.TChain):    (2)
9      chain = ROOT.TChain(tree.GetName())
10     chain.Add(tree.GetDirectory().GetName())
11     tree = chain
12   tree.SetProof(True)
13
14   N = tree.Draw(variable, cut)    (3)
15
16   output = ROOT.gProof.GetOutputList()[2]
17   i, y = output.GetX(), output.GetY()
18   i.SetSize(N)
19   y.SetSize(N)
20
21   i = np.array(i, dtype=int)
22   y = np.array(y)
23
24   sorting_index = np.argsort(i)    (4)
25   y = y[sorting_index]
26
27   return y
```

- (1) (4) sort the output with entry number
- (2) why `TTree` doesn't have `SetProof`?
- (3) use `Draw` method to dump the values

My workflow

select categorize compute and draw

```
1   selection = "el_is_tight"
2   el_EoverEtrue = GetValuesFromTreeWithProof(mychain, "el_E/el_truth_E",
3                                              selection)    (1)
4   el_eta = GetValuesFromTreeWithProof(mychain, "el_eta", selection)
5
6   is_barrel = np.abs(el_eta) < 1.425
7   is_endcap = np.abs(el_eta) > 1.55
8   el_EoverEtrue_barrel = el_EoverEtrue[is_barrel]
9   el_EoverEtrue_endcap = el_EoverEtrue[is_endcap]
10
11  resolution_barrel = np.std(el_EoverEtrue_barrel)    (2)
12  resolution_endcap = np.std(el_EoverEtrue_endcap)
13
14  # produce histograms, correlations, ...
```

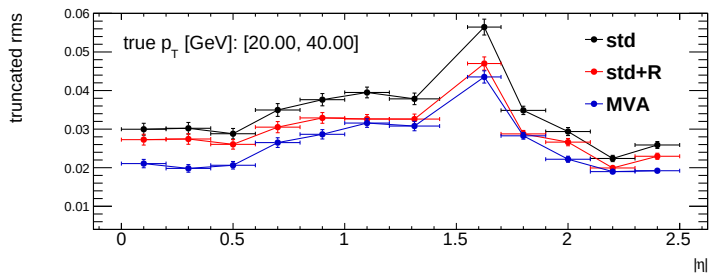
- (1) dump values in memory (can be problematic with large datasets)
- (2) easy to parallelize

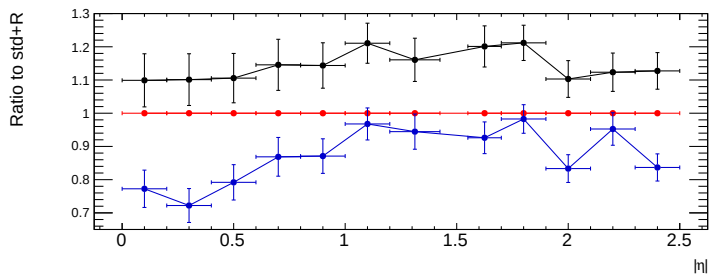
What I am actually doing

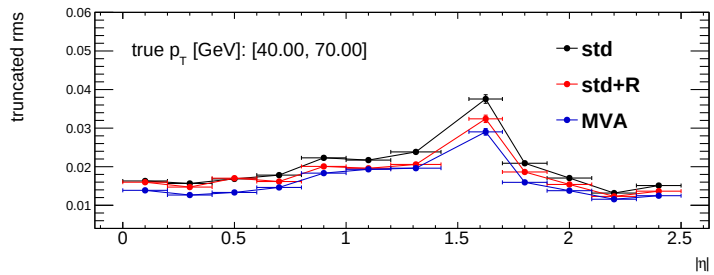
some point in common with WebOOT by Peter

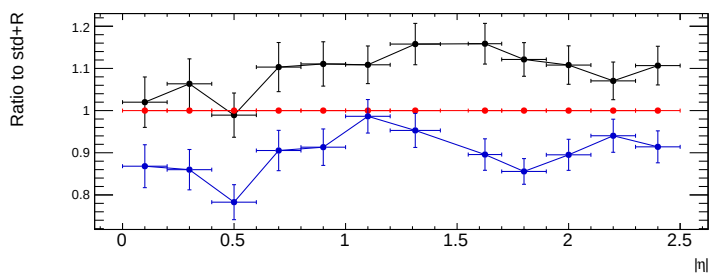
```
1  import BinAndDraw as bad
2
3  quantities = ("ph_E/ph_truth_E",)
4  estimators = bad.estimators(bad.truncated_rms(outliers=0.95), bad.↩
       gaussian_width(), bad.FWHM())), display_as=bad.CANVAS)
5
6  dataset_std = bad.dataset_from_glob("std_calibration/*.root", label="std")
7  dataset_stdR = bad.dataset_from_glob("stdR_calibration/*.root", label="std+R")
8  dataset_MVA = bad.dataset_from_glob("MVA_calibration/*.root", label="MVA")
9  datasets = (dataset_std, dataset_stdR, dataset_MVA)
10
11 var_dataset = bad.vartype.different_dataset(datasets, display_as=bad.COLOR)
12 var_eta = bad.vartype.branch("abs(ph_eta)", bins=np.linspace(0,2.5,10), ↩
       display_as=bad.XAXIS, label="|#eta|")
13 var_pt = bad.vartype.branch("ph_truth_pt/1E3", bins=(20,40,70,100,500), ↩
       display_as=bad.CANVAS, label="true p_{T} [GeV]")
14
15 loops = bad.loop(var_dataset * var_eta * var_pt, var_dataset * var_pt) * bad.↩
       loop(estimators)
16
17 bad.run(quantities, loops,
18         global_selection="ph_is_tight", output_dir = "output",
19         plot_ratio = ("x/y", dataset_stdR),
20         use_proof=True, workers=4)
```

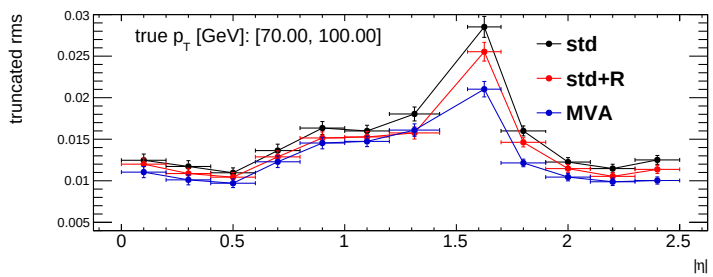
result of `(var_dataset * var_eta * var_pt) * truncated_rms`

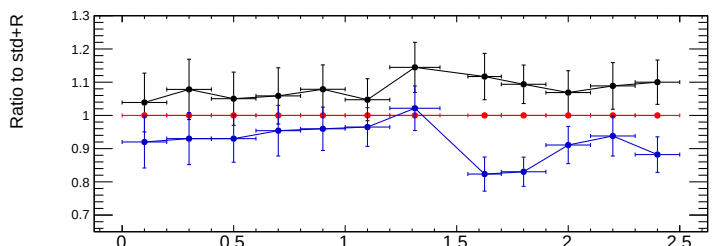


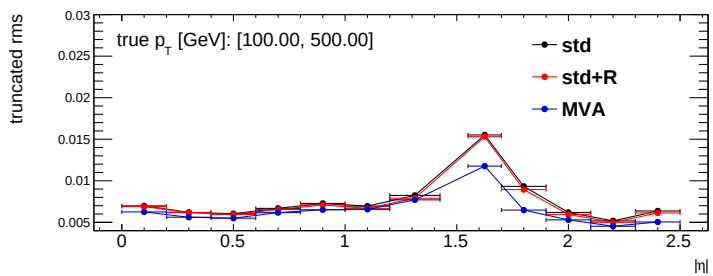


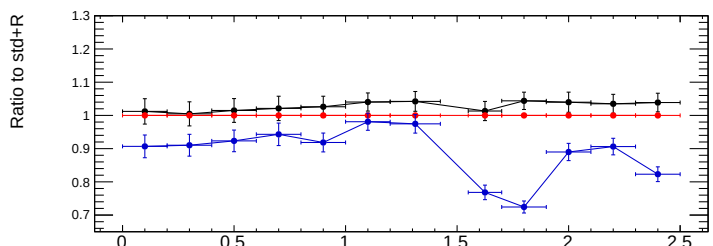












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10. python as interactive session? notebook as Mathematica/Maple/. . . (ipython notebook?)

IPy IPython Dashboard | IPy spectrogram

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Markdown

Simple spectral analysis

An illustration of the Discrete Fourier Transform

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} kn} \qquad k = 0, \ldots, N-1$$

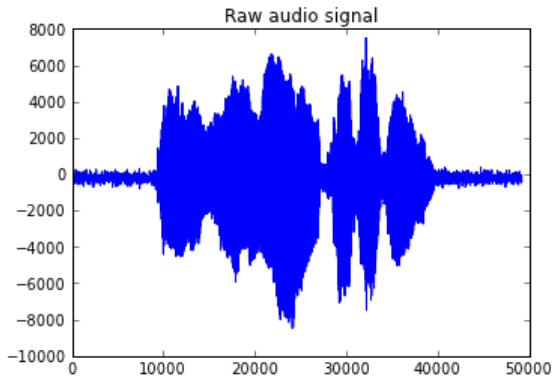
using windowing, to reveal the frequency content of a sound signal.

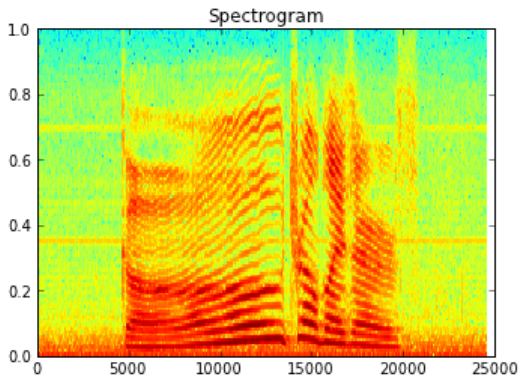
We begin by loading a datafile using SciPy's audio file support:

In [1]:
```
from scipy.io import wavfile
rate, x = wavfile.read('test_mono.wav')
```

And we can easily view its spectral structure using matplotlib's builtin `specgram` routine:

In [2]:
```
fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(12, 4))
ax1.plot(x); ax1.set_title('Raw audio signal')
ax2.specgram(x); ax2.set_title('Spectrogram');
```





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4. improve the visual result (e.g. support alpha channel, automatic legend placement)
5. better class hierarchy (e.g. why `TGraph` inherits from `TAttLine`? why `TH1::GetZaxis()`?)
6. proof: support sharing of resources: why declare one histogram for every workers instead of sharing it?

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11. better communication of new features (e.g. `TEfficiency`): blog, ..., release note is not enough

ATLAS data model

- RAW data $\rightarrow$ ESD / AOD $\rightarrow$ ROOT ntuple (D3PD)
- data object model inside ESD/AOD (particles are objects: electron.pt, electron.energy, electron.track, ...)
- D3PD is a TTree of (vector of) floats, no object model (el_pt, el_E, el_track_index, track_pt, ...)
- when dumping information from AOD to D3PD some new quantities are computed
- many D3PD flavours, now we are trying to merge someones

(actual) ATLAS analysis model

- very few analyses are made from AODs inside the core software (Athena), most of them uses D3PDs (ntuples) with plain ROOT
- most users uses MakeClass
- someone uses Proof (MakeSelector)
- few people use D3PDReader (from Physics Analysis Tools)
- D3PDReader restores the object model from D3PD (el_pt, el_E, el_track_index, track_pt, ... $\rightarrow$ el.pt, el.E, el.track, ...)
- with D3PDReader many feautures are provided:
  - every variables is a template proxy: it is readed only when it is needed (very efficient), no need of TTree.SetBranchStatus
  - EventLoop interfacing with proof, grid, batch queues, ...

See Attila presentation