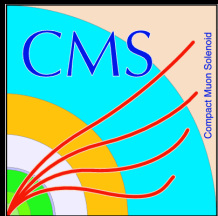


Alternative HEP software approaches at an undergraduate institution

Matt Bellis, *Siena College/Cornell University*
CMS Software R&D Upgrade meeting
6/8/2015



What do we do at Siena?

Undergraduate-only

Joined CMS in 2013 through

Cornell (~3 hour drive)

NSF funded

Previously **BaBar**, Jefferson Lab

Other current projects: *CoGeNT (dark matter detection),
Cosmological calculations with GPUs*



What do we do at Siena?

My students after graduation:

Grad school

- Medical physics (3)
- Engineering
- Business/sports analytics
- Environmental
- *Neutrino physics*
- *LHCb*

Jobs

- Electronics lab tech

Current research students: (2 CS, 3 engineering-focus)



Computing languages

Students learn

- Python
- MATLAB
- *Maybe R, Java*
- ***No C/C++!***

No ROOT

- Little post-Siena use
- No time (even for PyROOT)
- ***Personal choice to commit to alternatives***

My work on CMS

Physics analysis

- Contribute to boosted top $d\sigma/dp_T$ analysis
- Baryon-number violating top decays

Data preservation

- Learning tools for <http://opendata.cern.ch/>
- New outreach tools

Tools for undergraduates, high-
school students, and citizen
scientists

CMS Made Simple

Tool for undergrads and outreach efforts

- Data is simplified text (zipped) files
 - 4-vecs + (b-tag, charge, etc)
- Python accessors
 - Maintain Python-esque syntax
 - 4-vector viewers
 - *Sacrifice speed for readability*

<https://github.com/mattbellis/CMS-Made-Simple>

CMS Made Simple

```
import cms_made_simple as cms

filename = 'mc_ttbar.zip'

collisions = cms.get_collisions(filename)

for collision in collisions:

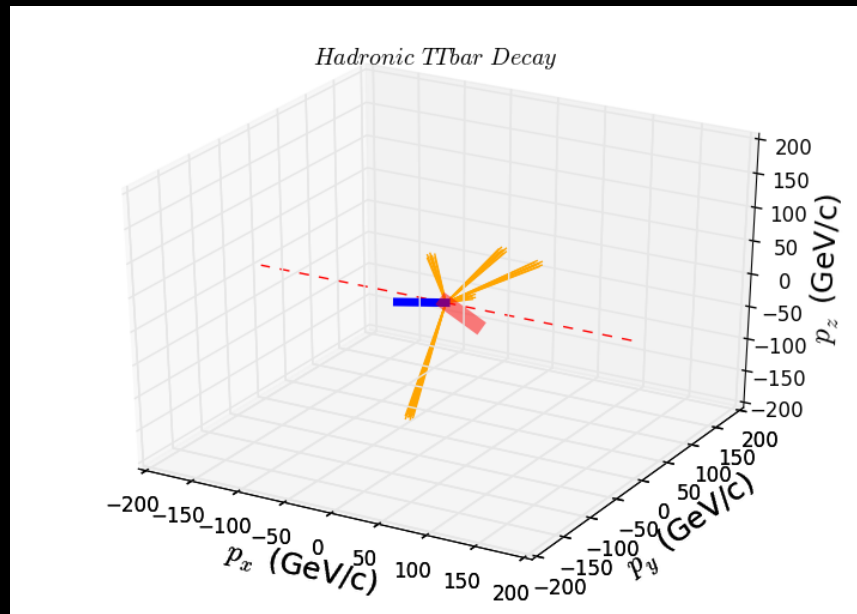
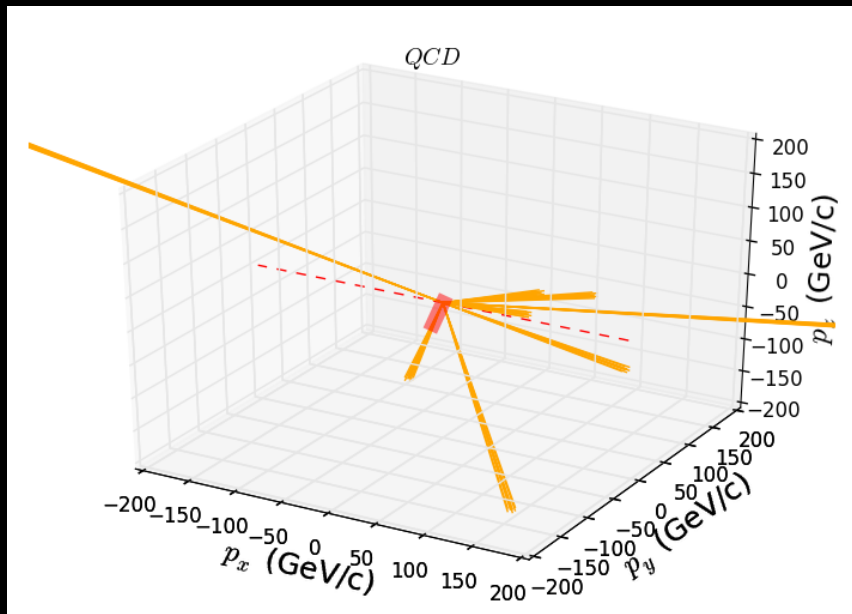
    jets,muons,electrons,photons,met = collision

    for jet in jets:
        energy,px,py,pz,btag = jet

    for muon in muons:
        energy,px,py,pz,charge = muon

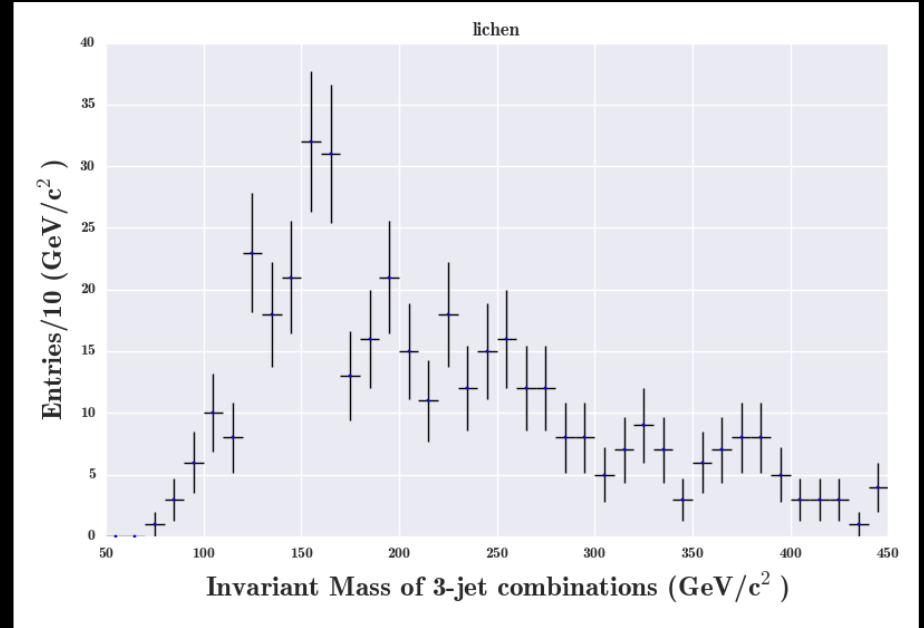
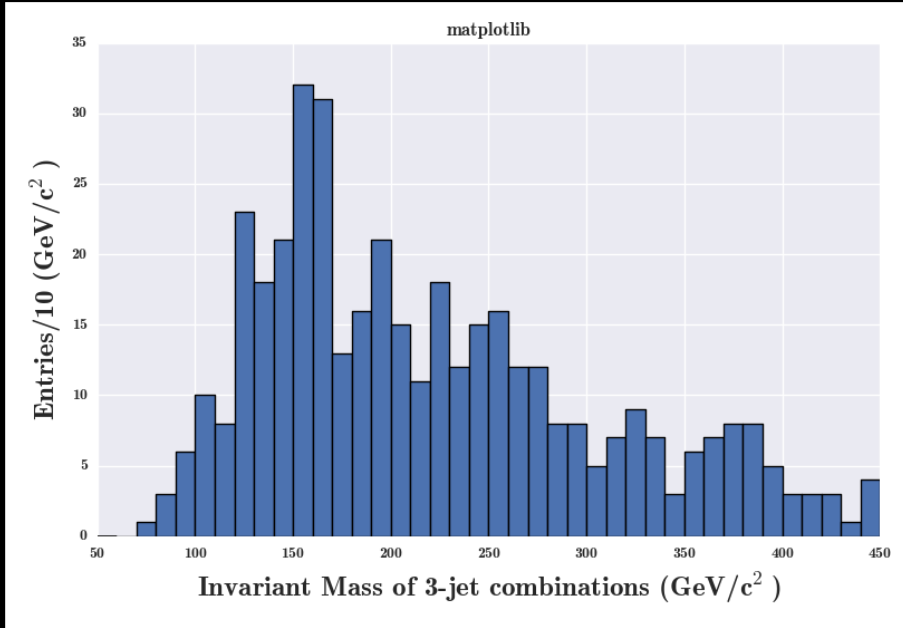
....
```


CMS Made Simple



4-vector viewer

lichen



Wrapper to matplotlib.

<https://github.com/mattbellis/lichen>

iminuit

Python wrapper to Minuit

Written by *Piti Ongmongkolkul*

- Caltech grad student, BaBar

Most all of Minuit's functionality

Allows me to teach what is going on under the hood

<https://github.com/iminuit/iminuit>

CERN Open Data Portal

The screenshot shows the homepage of the CERN Open Data Portal. The browser address bar displays "opendata.cern.ch". The page features a navigation menu with "ABOUT", "SEARCH", "EDUCATION", and "RESEARCH". A central graphic consists of a network of orange lines radiating from a central point, with various physics symbols (muon, photon, tau, electron, quark) placed at the ends of the lines. To the left, the "Education" section is titled "Visualise events, check reconstructed data, run tools or build your own!" and includes a "Start learning" button. To the right, the "Research" section is titled "Get the genuine working environments, virtual machines and datasets to start your research" and includes a "Start analysing" button.

The screenshot shows the "CMS Primary Datasets" page on the CERN Open Data Portal. The browser address bar displays "opendata.cern.ch/collection/CMS-Primary-Datasets". The page title is "CMS Primary Datasets". The main text explains that CMS primary datasets are AOD (Analysis Object Data) files, which contain the information needed for analysis: (1) all the high-level physics objects (such as muons, electrons, etc.) (2) tracks with associated hits, calorimetric clusters with associated hits, vertices and (3) information about event selection (triggers), data needed for further selection and identification criteria for the physics objects.

The page lists three datasets:

- /Mu/Run2010B-Apr21ReReco-v1/AOD**
Mu primary dataset in AOD format from RunB of 2010
Collection: CMS-Primary-Datasets
DOI: 10.7483/OPENDATA.CMS.B8MR.C4A2
- /ZeroBias/Run2010B-Apr21ReReco-v1/AOD**
ZeroBias primary dataset in AOD format from RunB of 2010
Collection: CMS-Primary-Datasets DOI: 10.7483/OPENDATA.CMS.ACV6.SYP3
- /Photon/Run2010B-Apr21ReReco-v1/AOD**
Photon primary dataset in AOD format from RunB of 2010
Collection: CMS-Primary-Datasets
DOI: 10.7483/OPENDATA.CMS.QKAX.PSW6

Particle Physics Playground

Particle-Physics-Playg x Matthew

particle-physics-playground.github.io/#sec2

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p³ ABOUT ACTIVITIES PHILOSOPHY CONTRIBUTORS

p³ Particle Physics Playground

Repo of particle physics data from CMS and other experiments with code and tutorials on how to interact with these data.

VIEW ON GITHUB

DOWNLOAD ZIP TAR

IPython Dashboard IPy spectrogram

127.0.0.1:8888/a5222740-848b-4ac1-b212-d732c9f8f78b

IP[y]: Notebook spectrogram Last saved: Mar 07 11:14 PM

File Edit View Insert Cell Kernel Help

Simple spectral analysis

An illustration of the [Discrete Fourier Transform](#)

$$\tilde{X}_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} kn} \quad k = 0, \dots, N-1$$

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 spectrogram routine:

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

Raw audio signal

Spectrogram

Particle Physics Playground

nbviewer.ipython.org/g x

Particle-Physics-Playground/blob/gh-pages/discovering_particles_1.ipynb » | ≡

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Challenge!

Copy this sample code and use it to calculate the mass of the muons. Make a histogram of this quantity.

Hint!

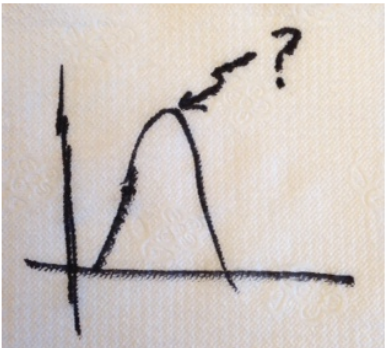
Make sure you do this for all the muons! Each collision can produce differing numbers of muons, so take care when you code this up.

Your histogram should look something like the following sketch. The value of the peak, should be the mass of the muon. [Check your answer!](#)

In [4]:

```
from IPython.display import Image
Image(filename='muons_sketch.jpeg')
```

Out[4]:



nbviewer.ipython.org/g x https://raw.githubusercontent.com x nbviewer.ipython.org/g x

nbviewer.ipython.org/github/mattbellis/Siena_College_Amanda_Depoia » | ≡

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```
# To find the mass of a muon

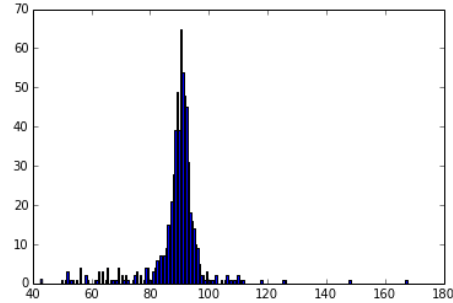
if len(muons) == 2:
    energy0,px0,py0,pz0,charge0 = muons[0]
    energy1,px1,py1,pz1,charge1 = muons[1]
    masssq = (energy0+energy1)**2 - ((px0+px1)**2 + (py0+py1)**2 +
    (pz0+pz1)**2)
    if masssq > 0.0:
        mass.append(np.sqrt(masssq))

fig = plt.figure()
plt.hist(mass,bins=200)

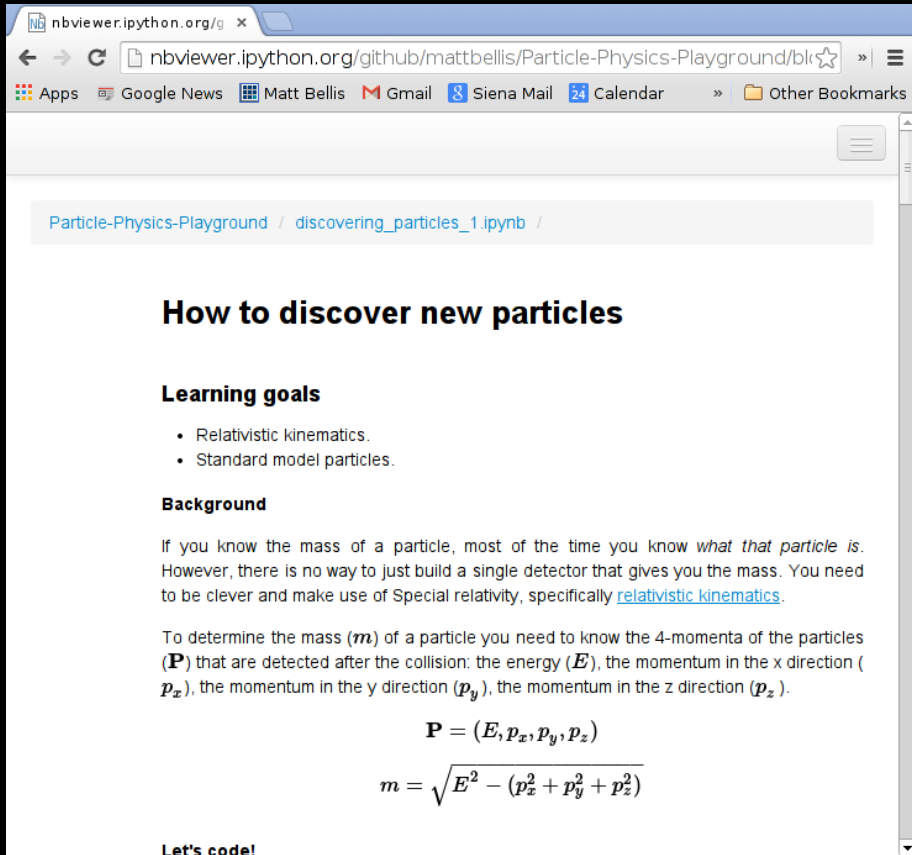
plt.show()
```

Reading in the data...

1000



Particle Physics Playground



The screenshot shows a web browser window with the URL `nbviewer.ipython.org/g`. The page title is "Particle-Physics-Playground / discovering_particles_1.ipynb". The main content is a notebook titled "How to discover new particles".

How to discover new particles

Learning goals

- Relativistic kinematics.
- Standard model particles.

Background

If you know the mass of a particle, most of the time you know *what that particle is*. However, there is no way to just build a single detector that gives you the mass. You need to be clever and make use of Special relativity, specifically [relativistic kinematics](#).

To determine the mass (m) of a particle you need to know the 4-momenta of the particles (\mathbf{P}) that are detected after the collision: the energy (E), the momentum in the x direction (p_x), the momentum in the y direction (p_y), the momentum in the z direction (p_z).

$$\mathbf{P} = (E, p_x, p_y, p_z)$$
$$m = \sqrt{E^2 - (p_x^2 + p_y^2 + p_z^2)}$$

Let's code!

Will soon be adding
CLEO data, as well as
more CMS data.

Have spoken with ATLAS
about contributing

Will reach out to BaBar
and LHCb

Python and GPUs

Continuum Analytics

- Anaconda distribution

`numba.cuda`

Wrapper to CUDA libraries

Slower than compiled C/CUDA, but....

Can engage my students with Python

Exploring nearest-neighbor density with multidimensional fits



Comments and inquiries are
welcome!

Student poster at GPU Tech Conference 2015

“Undergraduate GPU-enabled Research Through Python”

[http://on-demand.gputechconf.](http://on-demand.gputechconf.com/gtc/2015/posters/GTC_2015_Education_Training_01_P5236_WEB.pdf)

[com/gtc/2015/posters/GTC_2015_Education_Training_01_P5236_WEB.pdf](http://on-demand.gputechconf.com/gtc/2015/posters/GTC_2015_Education_Training_01_P5236_WEB.pdf)

Student poster at April APS meeting

“CMS Made Simple: A ROOT-less Workflow for Educating Undergraduates about CMS Analysis”

[https://cms-mgt-conferences.web.cern.ch/cms-mgt-](https://cms-mgt-conferences.web.cern.ch/cms-mgt-conferences/conferences/pres_display.aspx?cid=1550&pid=10635)

[conferences/conferences/pres_display.aspx?cid=1550&pid=10635](https://cms-mgt-conferences.web.cern.ch/cms-mgt-conferences/conferences/pres_display.aspx?cid=1550&pid=10635)

<http://particle-physics-playground.github.io/>

<https://github.com/mattbellis/SCMS-Made-Simple>

<https://github.com/mattbellis/lichen>

<https://github.com/iminuit/iminuit>

<http://ipython.org/notebook.html>

<http://docs.continuum.io/numbapro/CUDAjit.html>

<https://github.com/mattbellis/GTC15-Python-and-CUDA>