QUARKS TO COSMOS

Chronis Dimitrios
Florou Konstantina
Papacharalampous Ioanna
Schinas Christos

Project goals

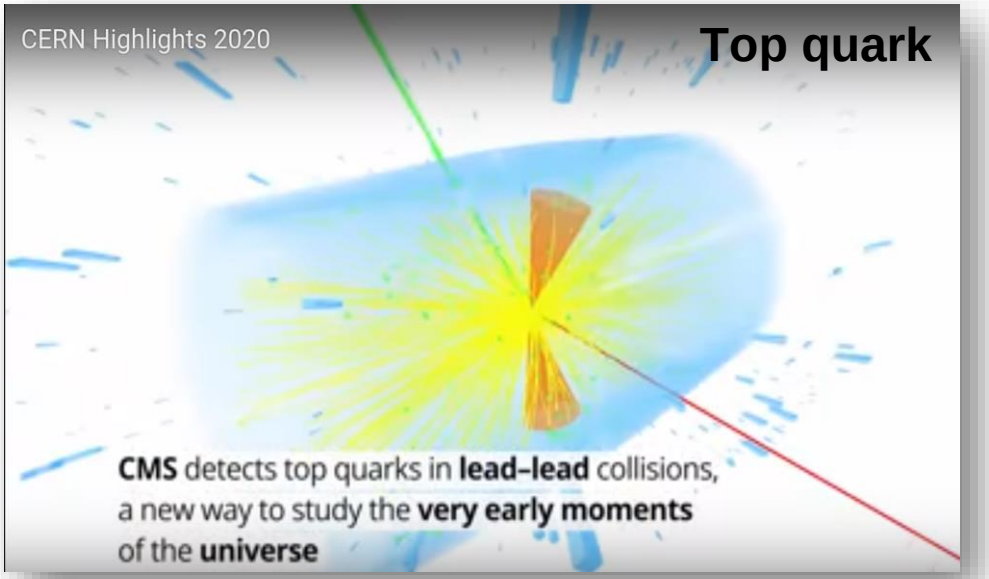
The basics of physics analyses at the Compact Muon Solenoid (CMS) experiment:

Analyzing **heavy ion collisions** recorded by CMS

Search for heavy elementary particles (Z bosons and top quarks)

Use of the software available for basic-level usage of **open data**

Visualizing the CMS data



Project Roadmap

Introduction to **particle** and **nuclear physics**

Getting to know **VirtualBox, C++ and ROOT**

Basics of **CMS offline software**

Final Code

Analyzing the results

Introduction to particle and nuclear physics

What are we made of?

- **Elementary particles** and **elementary forces**

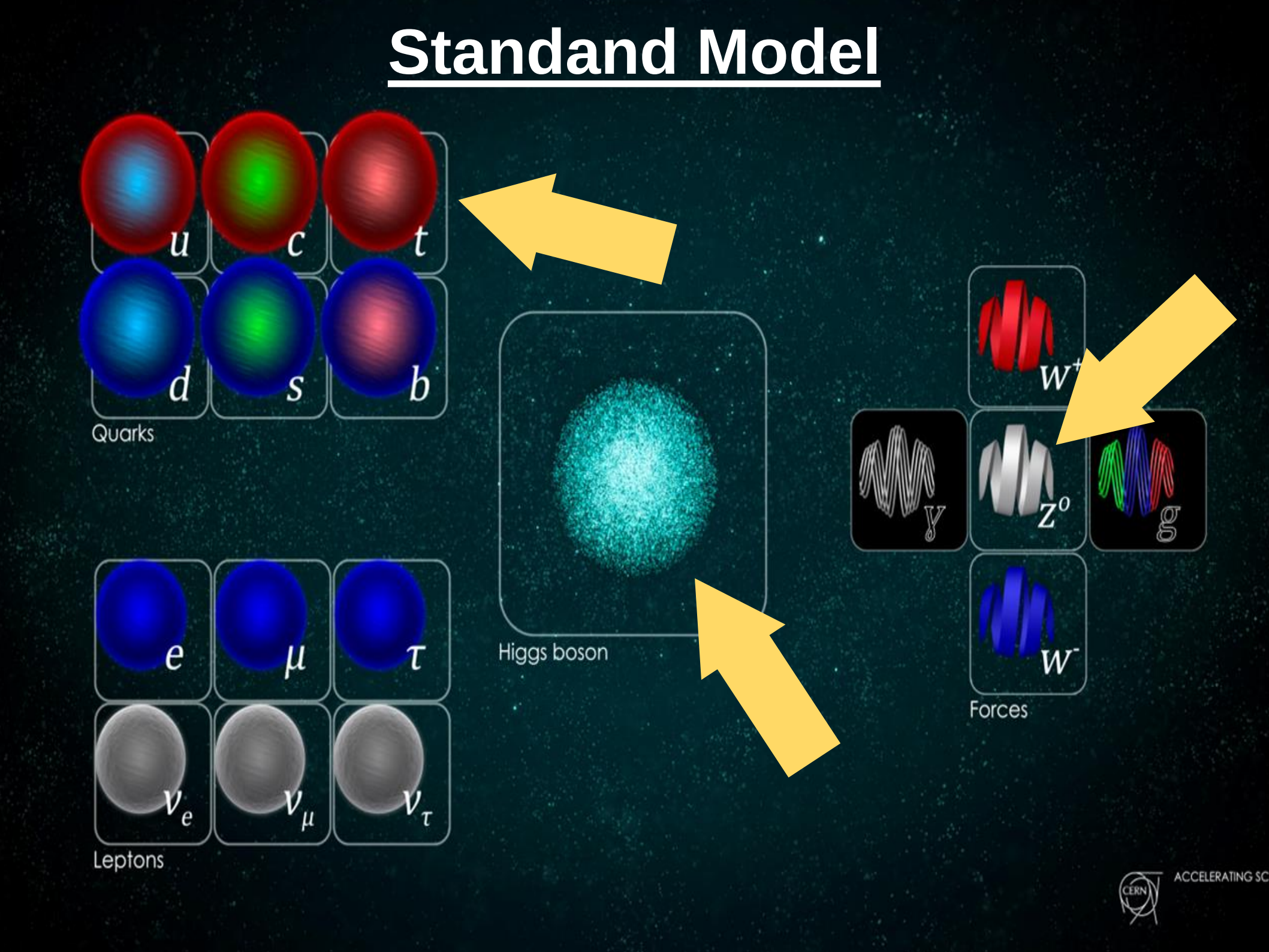
QGP: the hottest state of matter

- studying it with Z boson and top quarks

A glimpse to **heavy ion physics**

- a case to understand **asymptotic freedom**

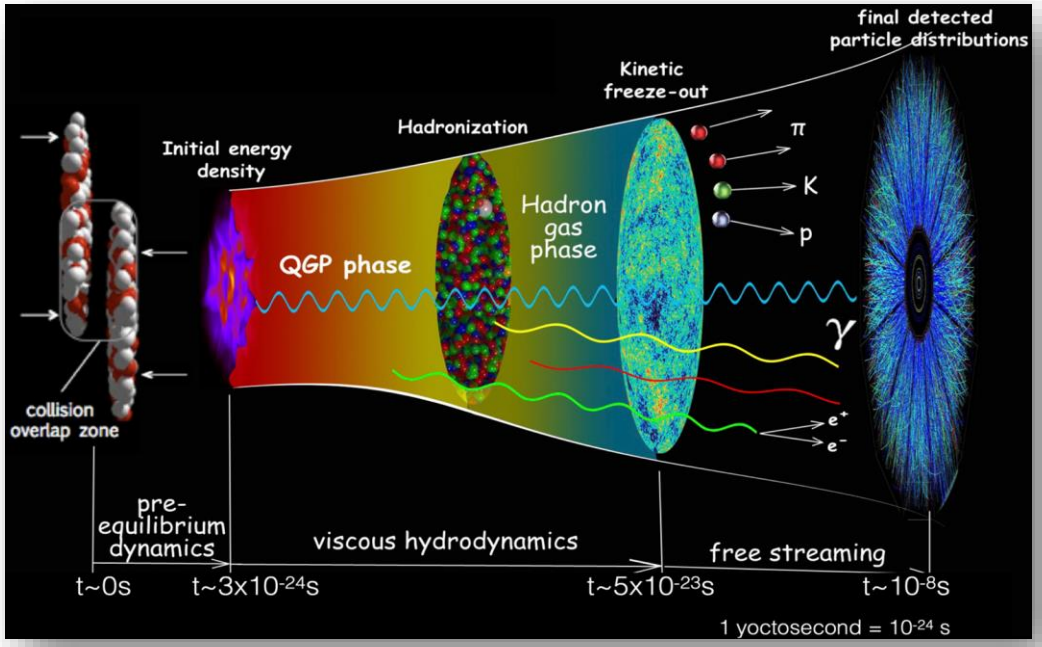
Standand Model



A Glimpse to Heavy Ion Physics

As the two heavy ions collide and then move apart:

- A plasma, called **quark gluon plasma**, is continually produced
- Each drop of QGP evolves in time and disintegrates quickly
- Hadrons are finally created and detected by experiments



From quarks to cosmos

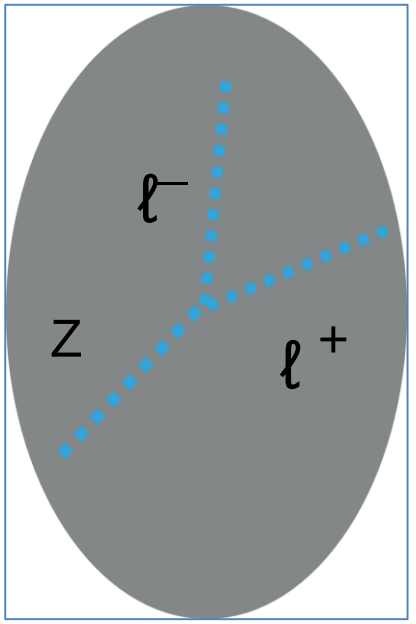
Heavy Ion Collision Event: Thousands of particles!

Z boson and top quark in heavy ion collisions

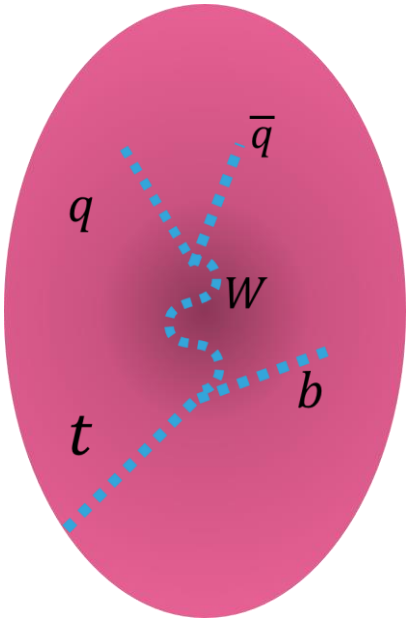
Z bosons and **leptons** are colorless

They **don't interact** with **Quark–gluon plasma**

In contrast to **top quarks**



No energy loss due to QGP interaction



Energy loss due to QGP interaction

Final Code

- Use of **CMSSW EDAnalyzers**

software to acquire, produce, process, analyze CMS data

  - Extract **trigger and lepton** information
  - Produce **ROOT files** from **CMS public heavy-ion data**

cms-sw/**cmssw**

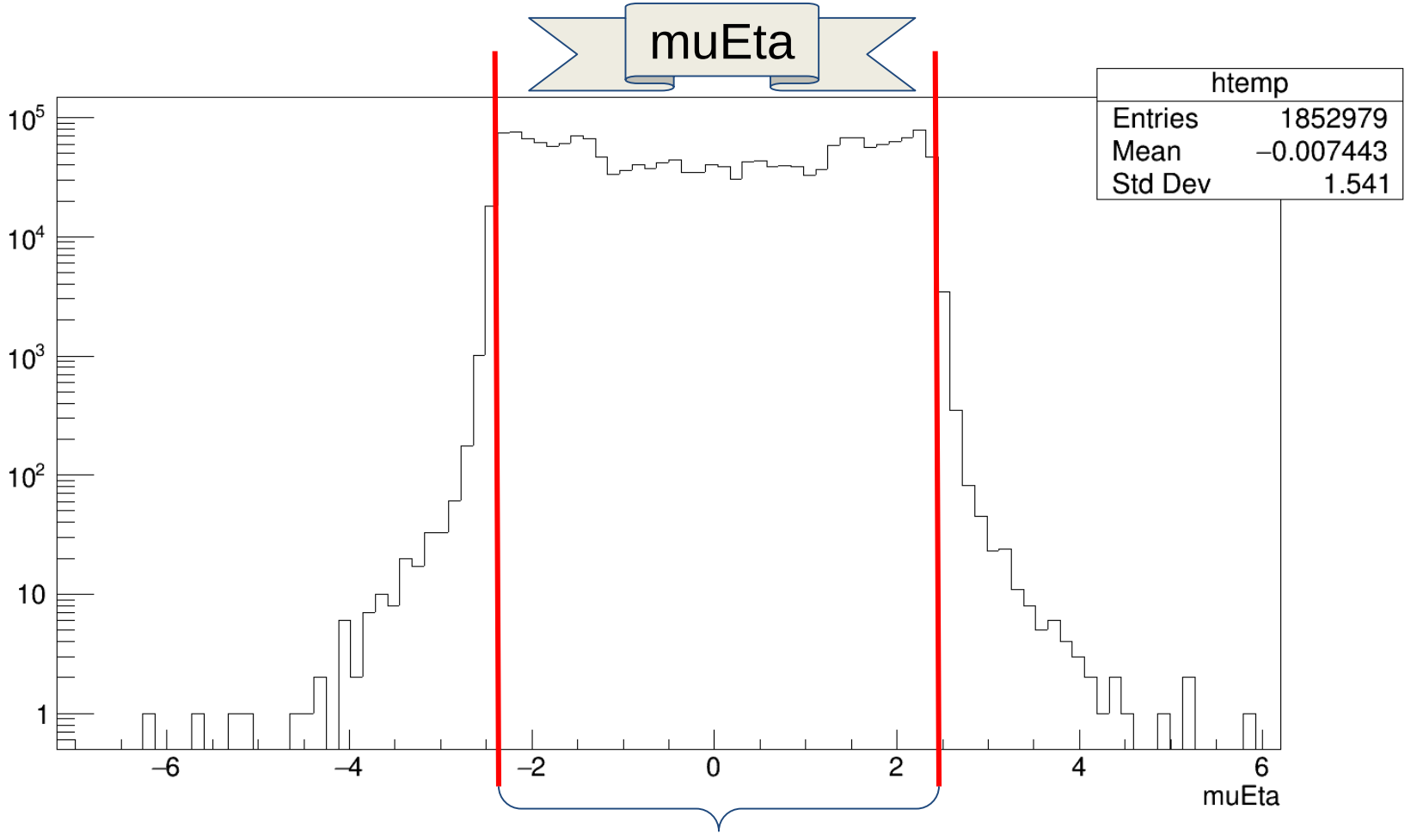
CMS Offline Software

Final Code

Triggers + Muon Selection

filtering the data

```
if (TMath::Abs(MuEta[j])>2.4) continue; //
```

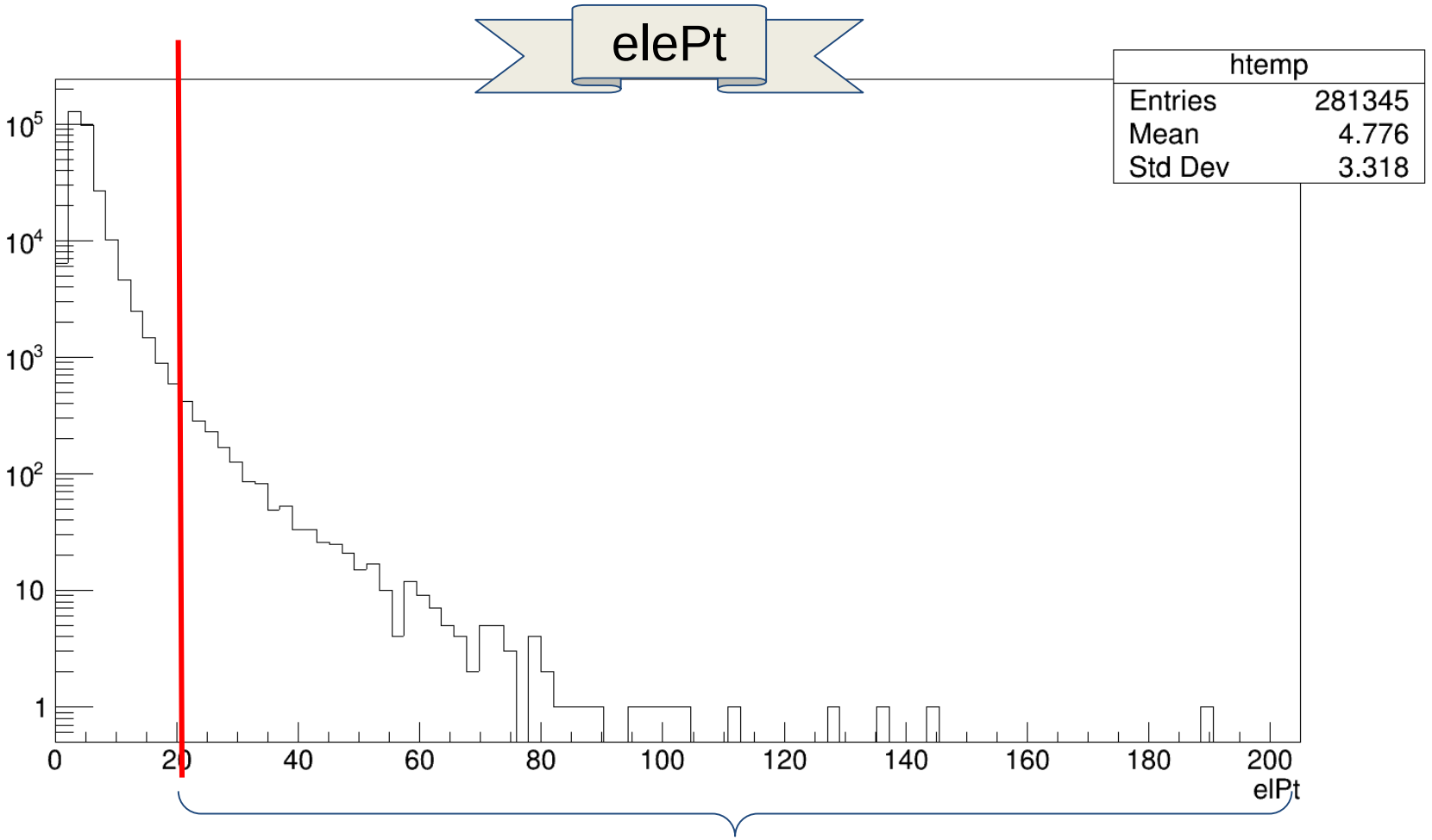


Accepted values

Final Code

Triggers + Electron Selection

```
if (ElePt[i]< 20) continue;
```

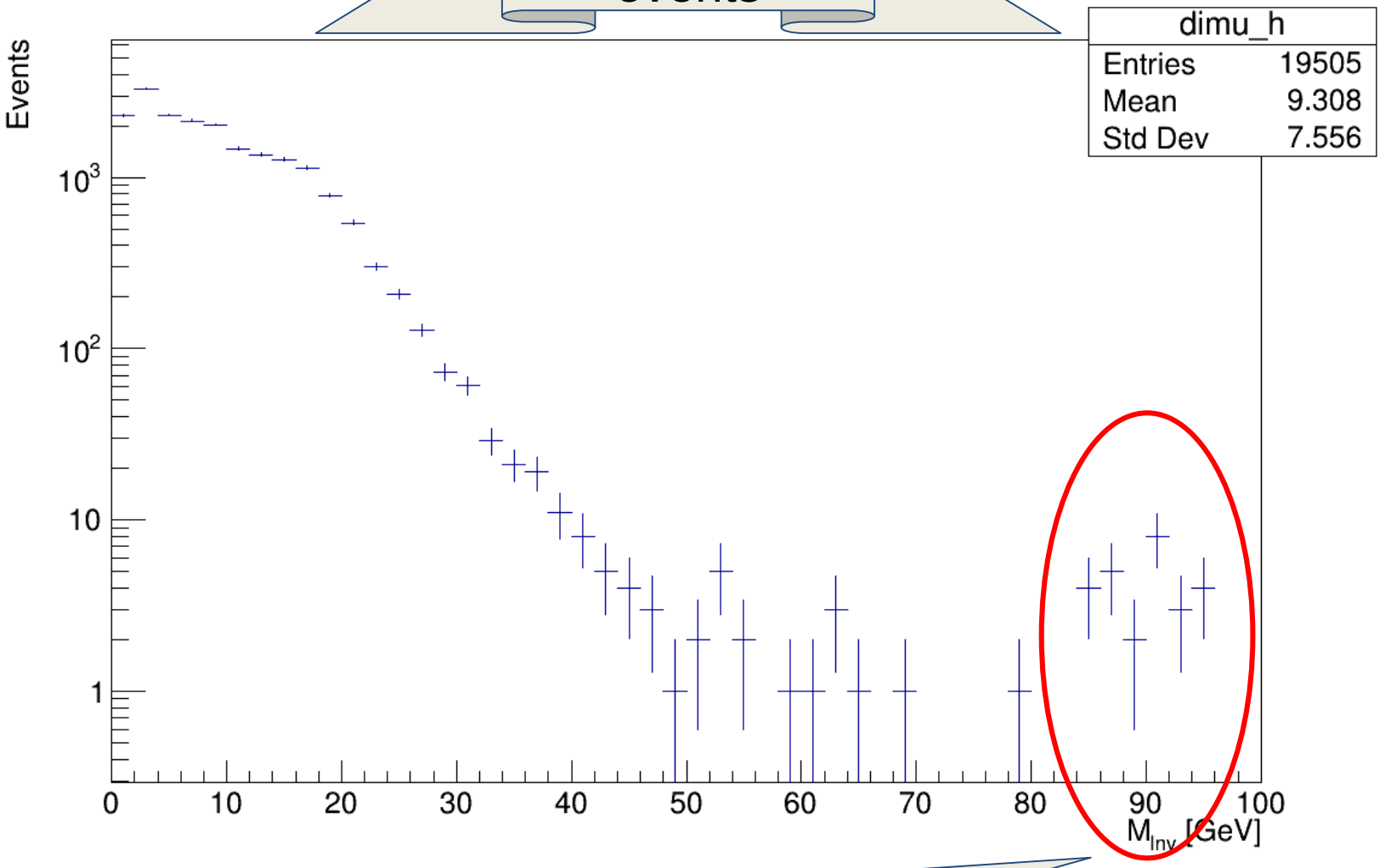


Accepted values

Analyzing Results

searching for Z bosons

double **muon** events

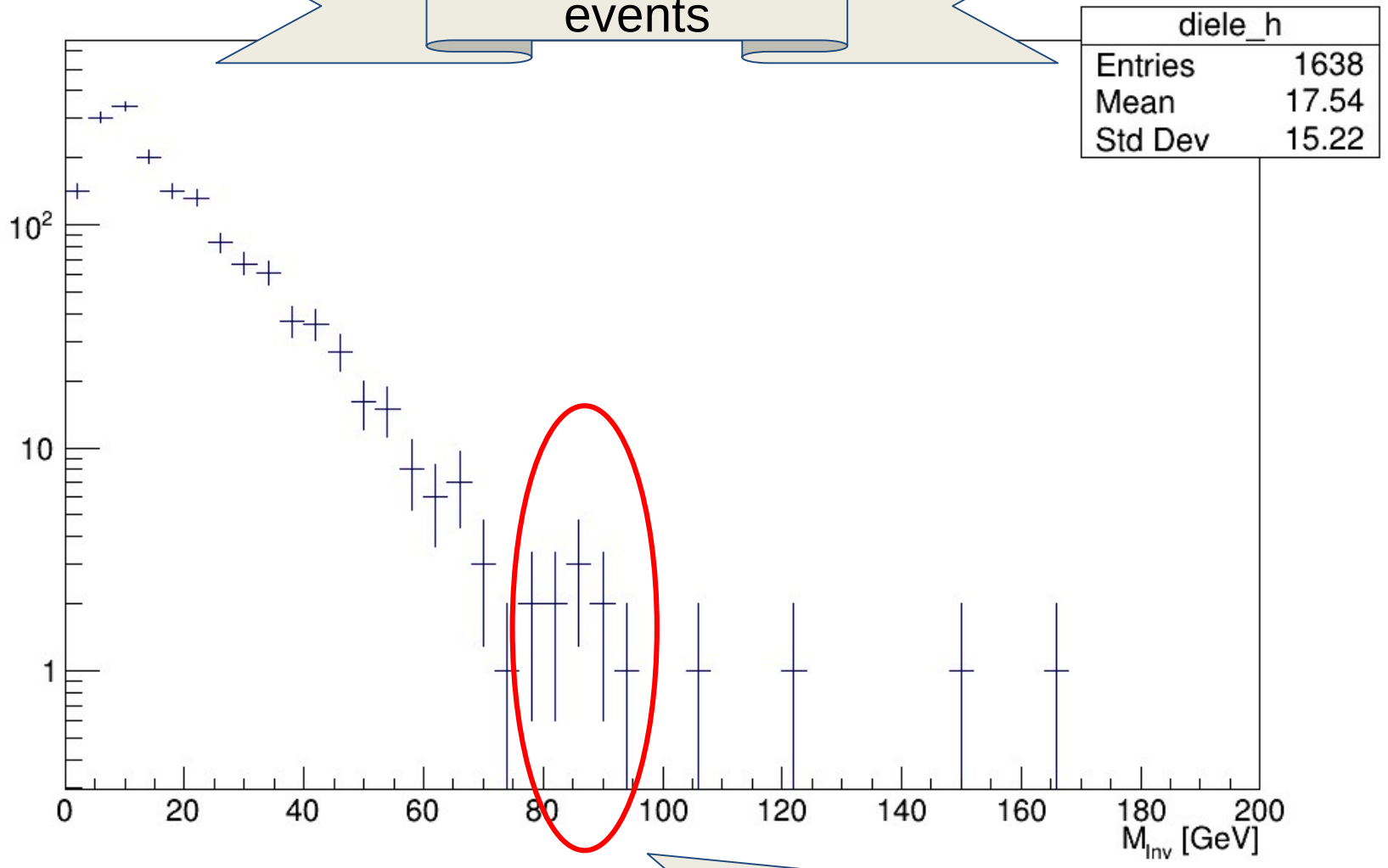


We found Z bosons with events around 90GeV!

Analyzing Results

searching for Z bosons

double **electron** events

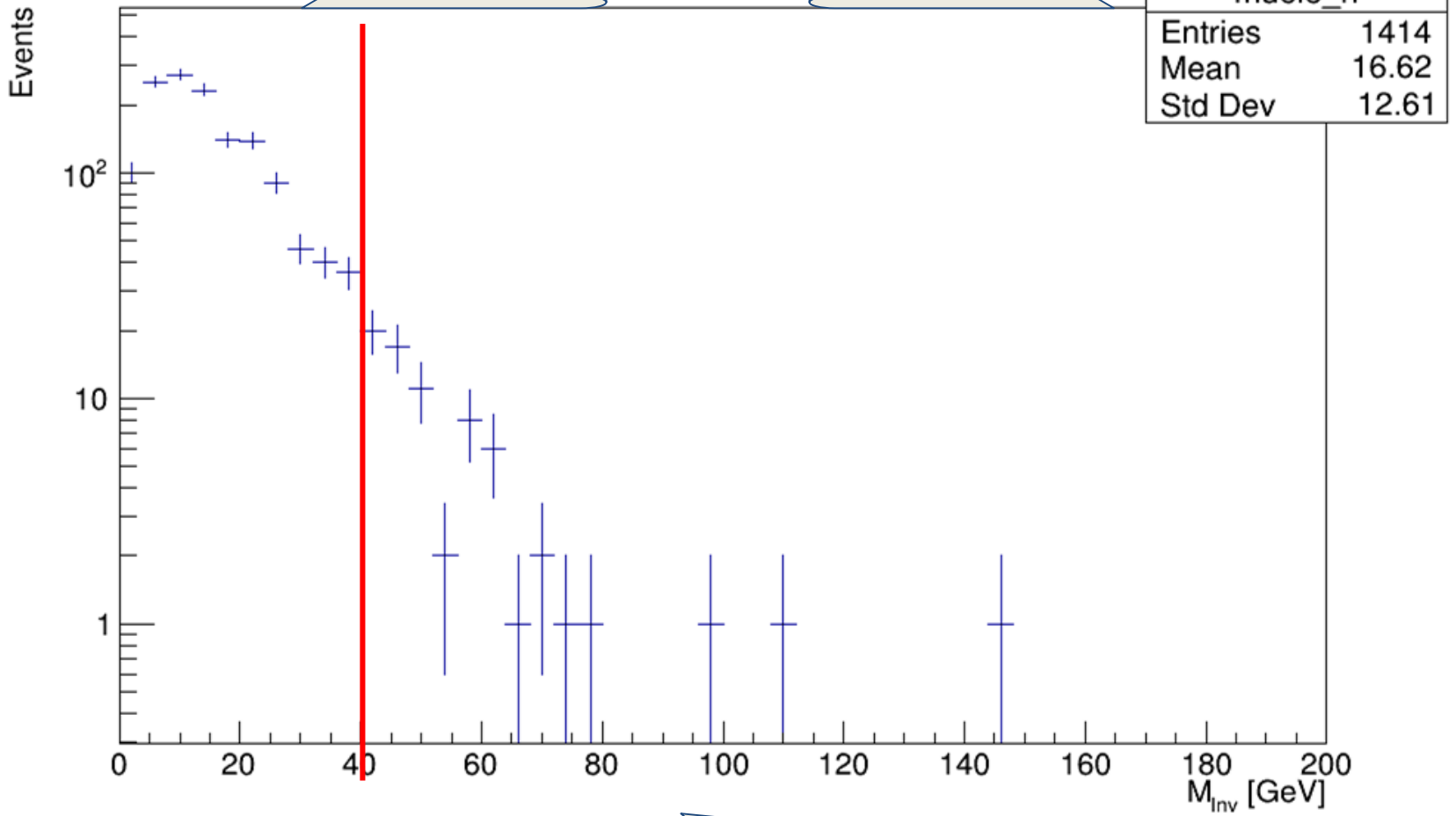


We also found Z bosons with events around 90GeV!

Analyzing Results

searching for top quarks

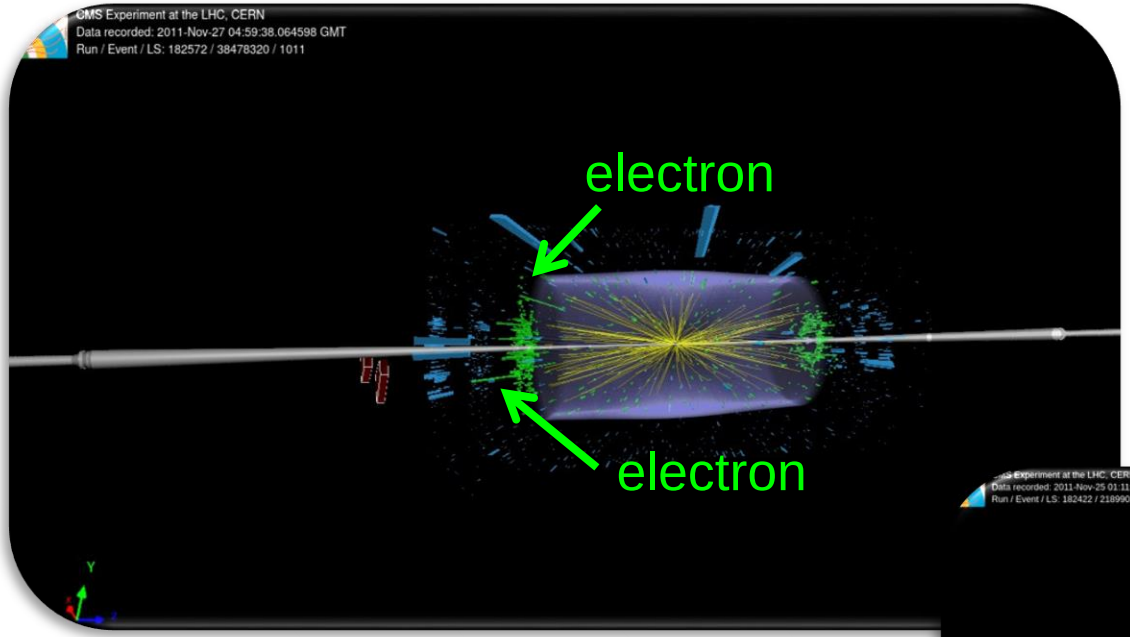
muon-electron events



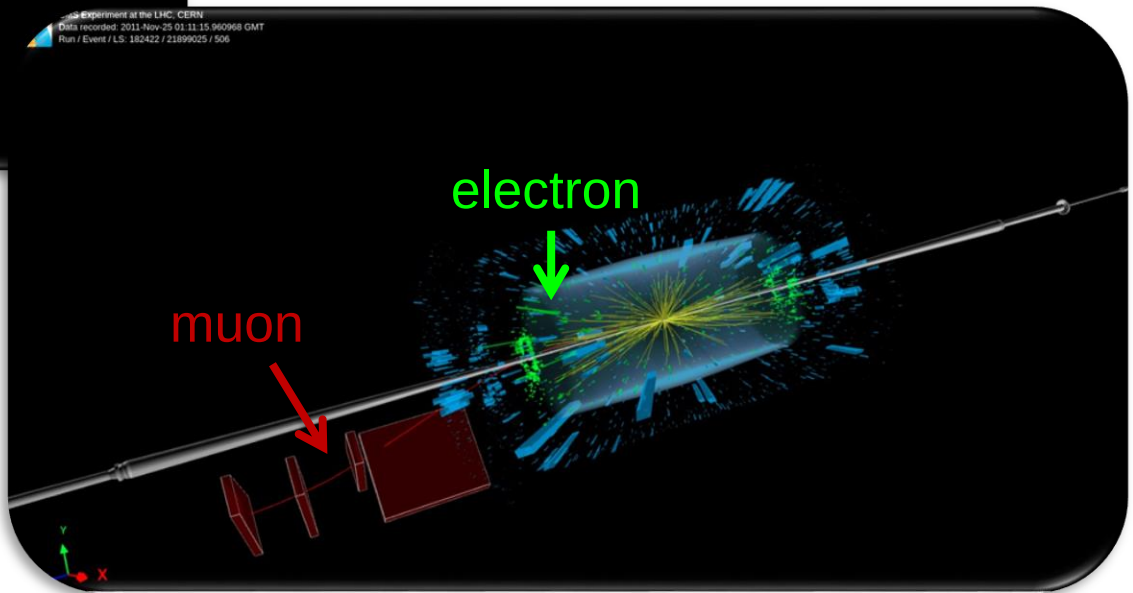
We can find top quarks with events above 40GeV

Visualizing the Data

- Use of ISpy Analyzers for 2011 Heavy Ion data
- Production of event display files

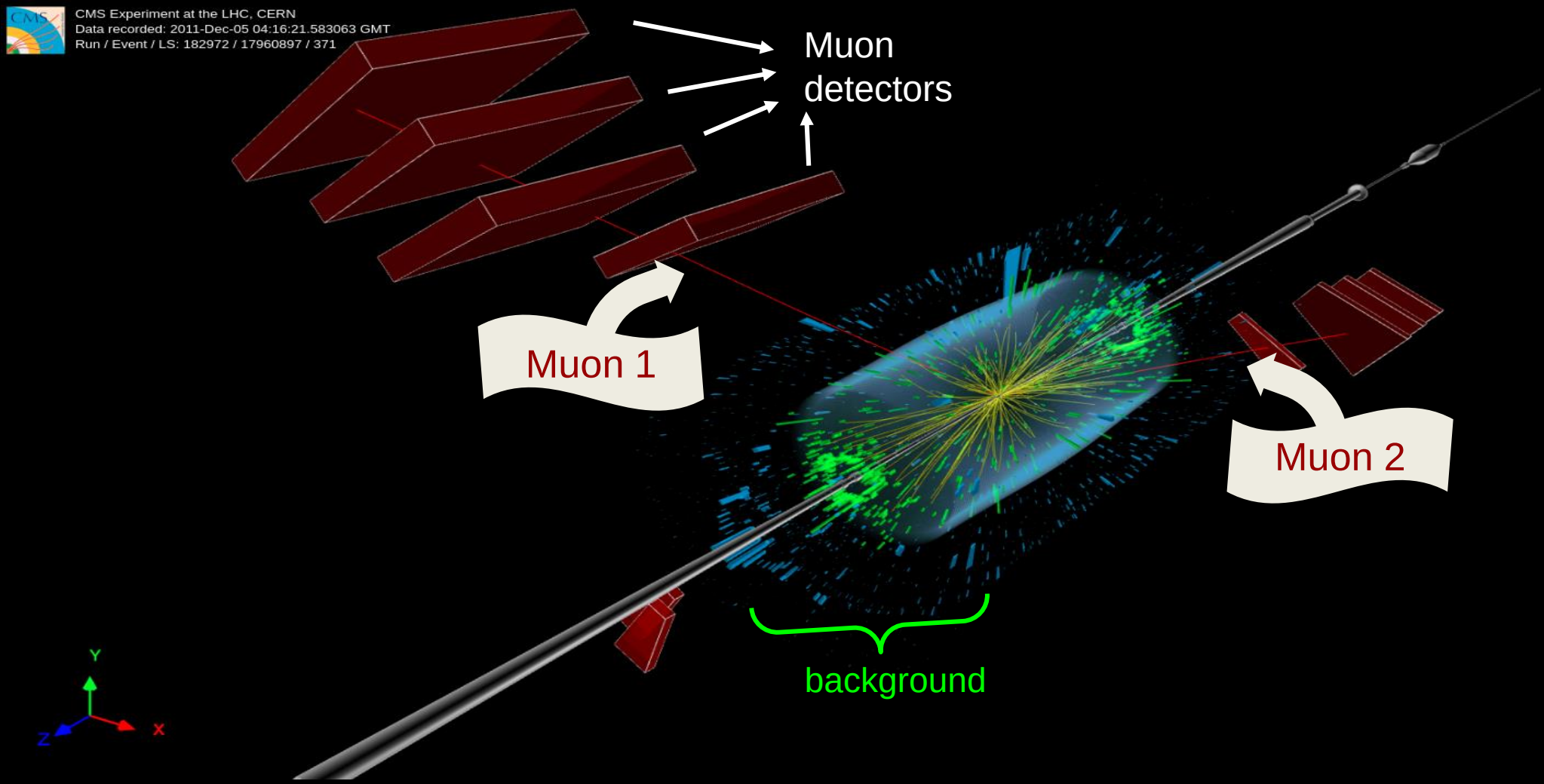


Double Electron Event



Muon-Electron Event

Double Muon Event



THANK YOU FOR YOUR ATTENTION!

EXTRA SLIDES

Virtual Box and C++

- CMS-specific CernVM image
- Learning the basics of bash and CMS offline software
- A simple demo for testing and validating
- Processed the first event records (!)
- How do we write and execute C++ code
- How do we use ROOT (with C++)

C++ and ROOT

Write and execute C++ code

- “include”, “main”, and “make”

use ROOT (with C++)

- Int_t, Float_t, TFile, TTree, TBranch

Write a .root file

- filling a histogram with a “for” loop

Browse and read a .root file

- TBrowser X and GetEntry()

Basics of CMS offline software

Compile and execute CMSSW

- **“cmsrel”, “cmsenv”, “scram b”, “csmRun”**

EDAnalyzer and what does it contain

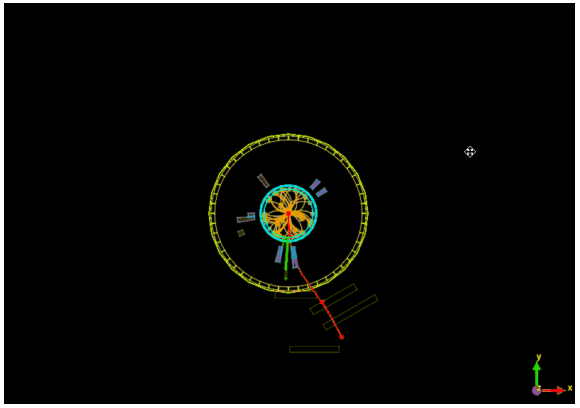
- **.xml, src/X.cc, and X_cfg.py**

Modify the src/X.cc

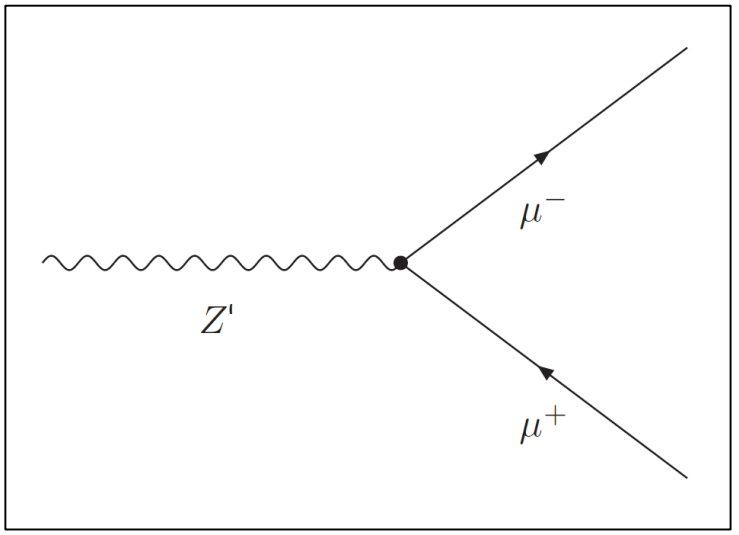
- **storing lepton info in the output .root file**

What the interesting events are

- **triggering at > 20 GeV**



Z boson in heavy ion collisions

Z boson: is one of the weak force "messengers".

We cannot "see" it directly: we now it's there for its decay products.