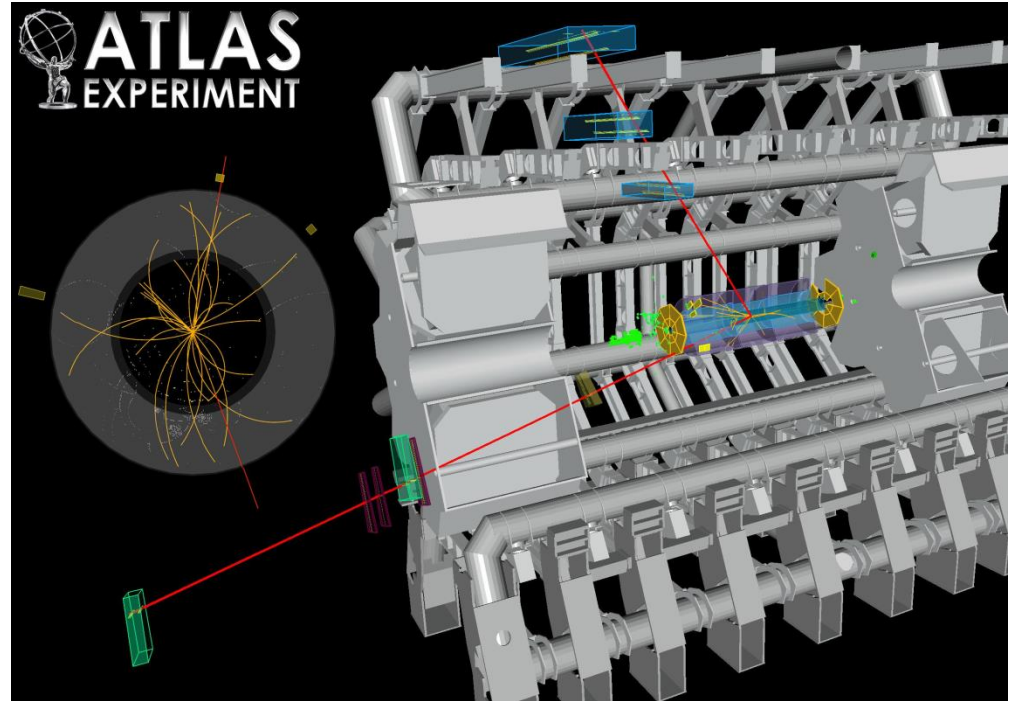
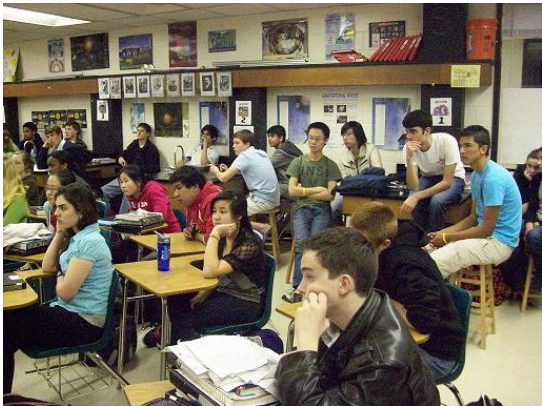
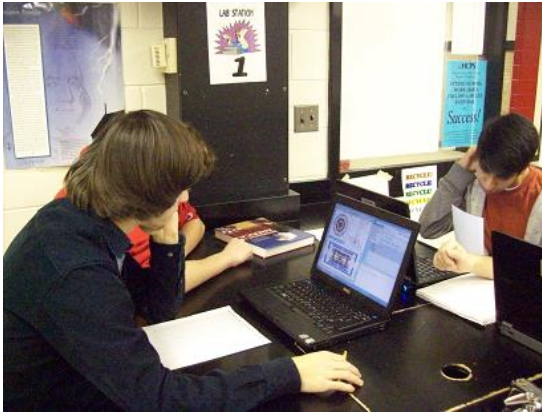


ATLAS Z-Path Masterclass



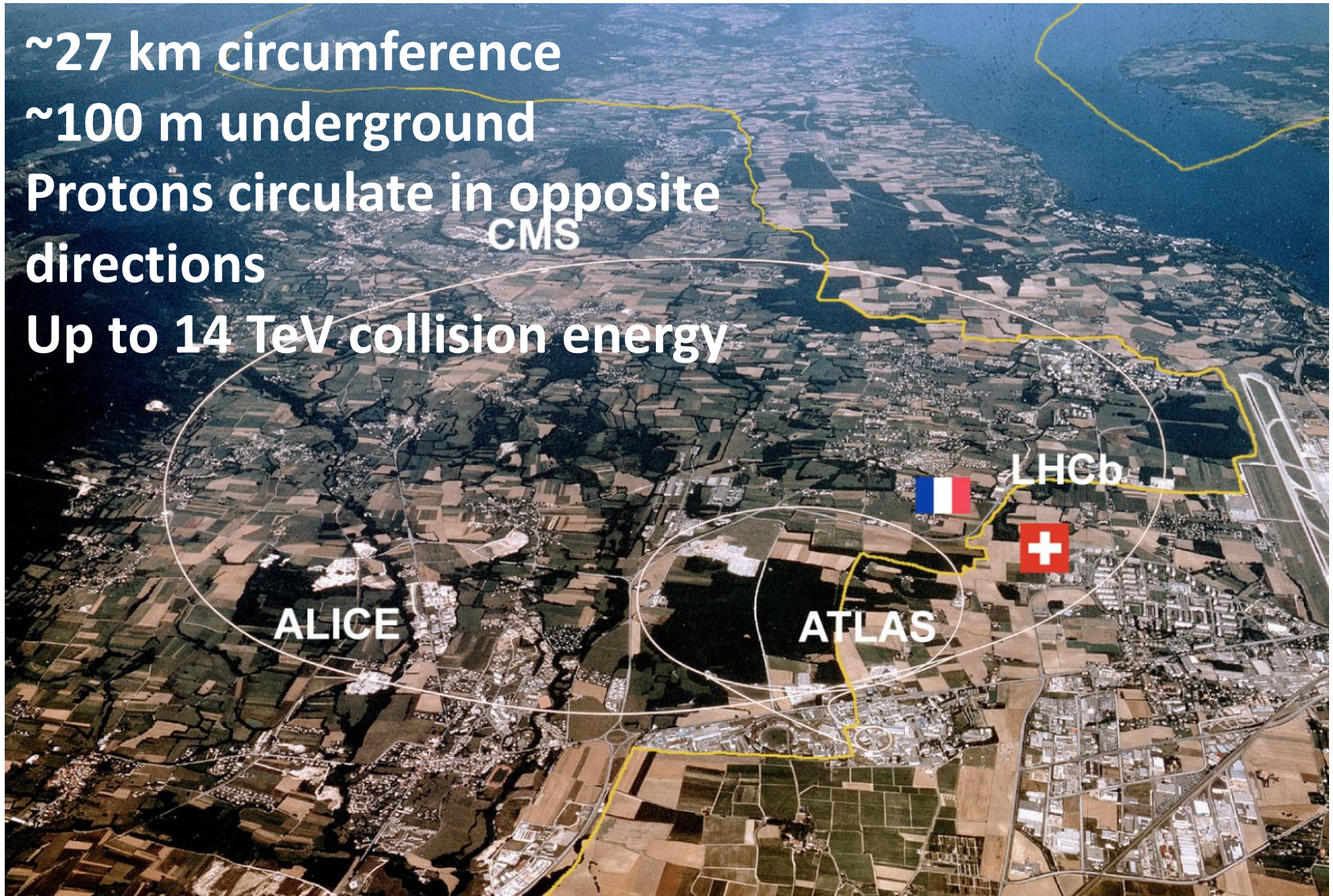
It's a time of exciting new discoveries in particle physics!

At CERN, the LHC is now in Run 3, with its highest collision rates and energies yet. At the same time, there are new questions as the few experimental results vary from the highly reliable Standard Model.

The LHC and CMS are where we need to be to explore these new mysteries.



~27 km circumference
~100 m underground
Protons circulate in opposite
directions
Up to 14 TeV collision energy



Generic Design

Cylinders wrapped around the beam pipe

From inner to outer . . .

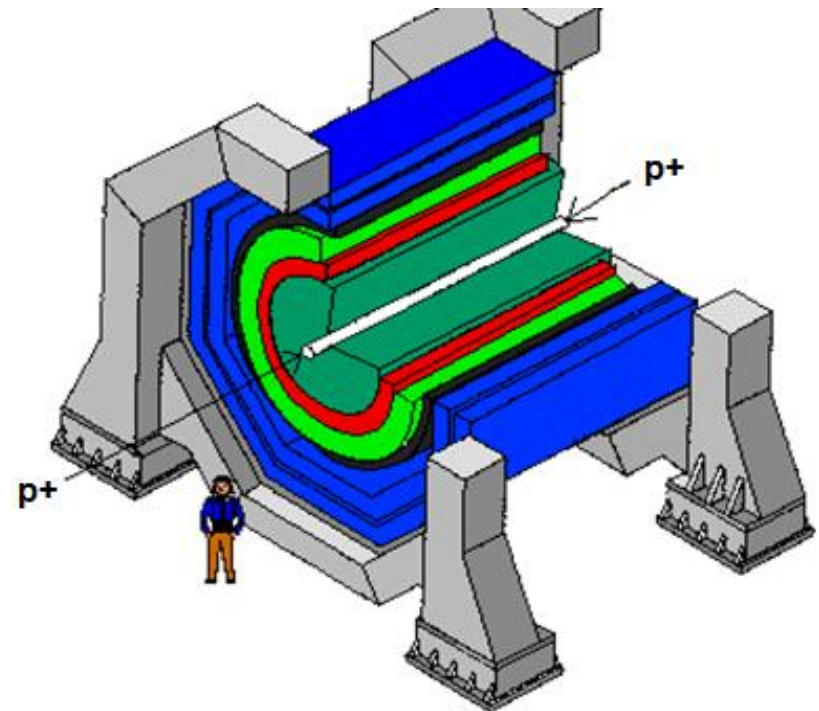
Tracking

Electromagnetic calorimeter

Hadronic calorimeter

Magnet*

Muon chamber

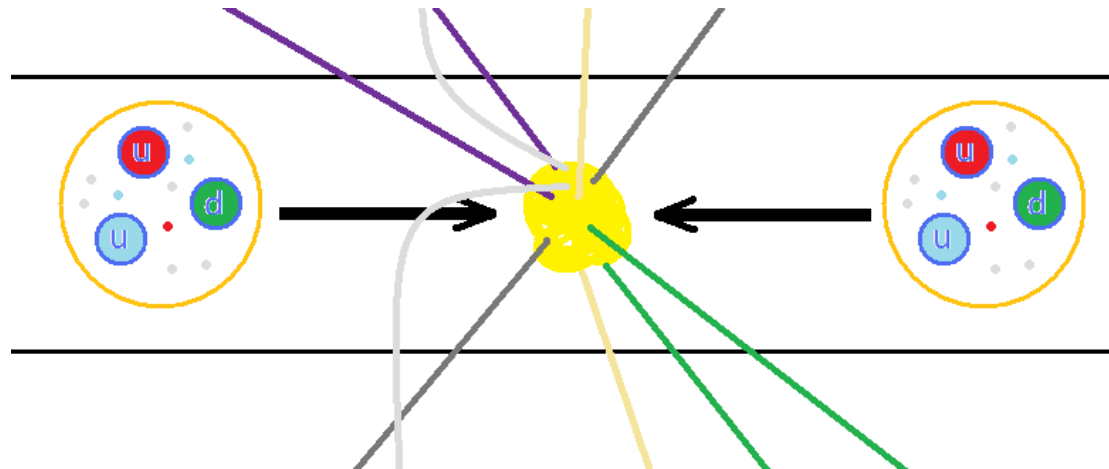


* *Location of magnet depends on specific detector design.*

Protons collide inside ATLAS

The LHC accelerates protons to almost 7500 times the energy equivalent of their mass. The protons circulate in opposite directions and collide in the center of ATLAS.

But protons are not just particles: they are more like bags of quarks and gluons. When protons collide, all sorts of very short-lived particles can be made from all that energy.

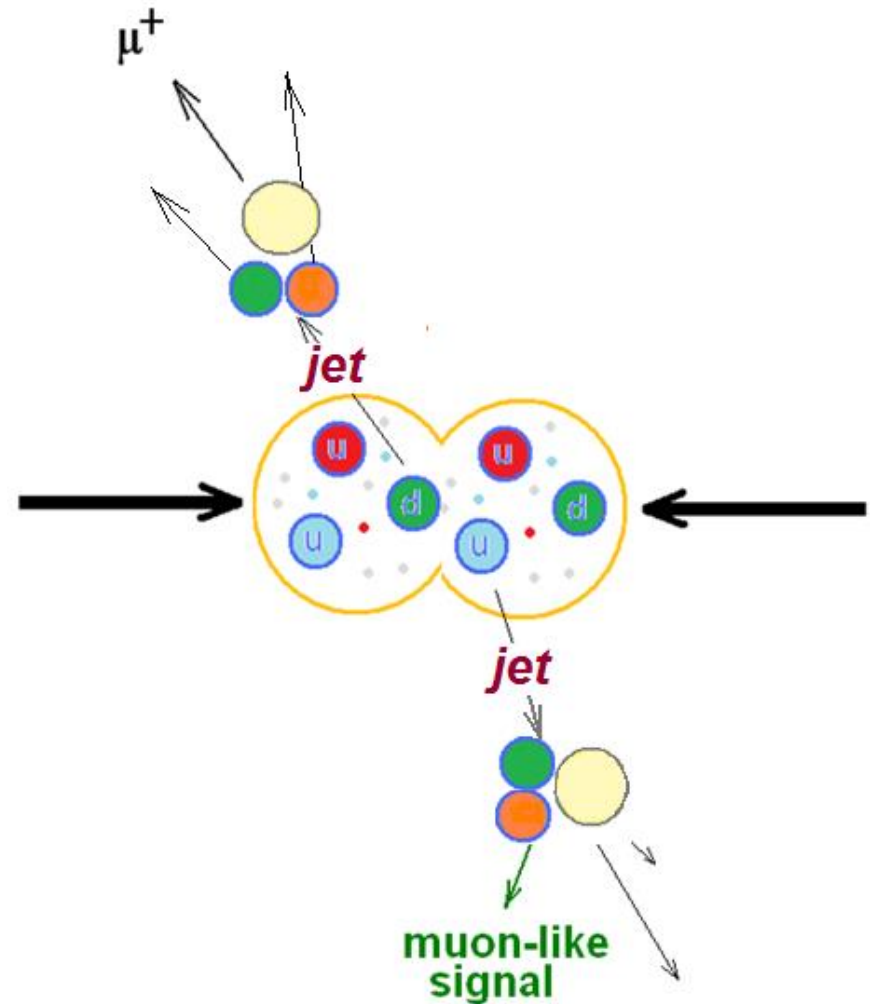


Particle Decays

Often, quarks are scattered in collisions.

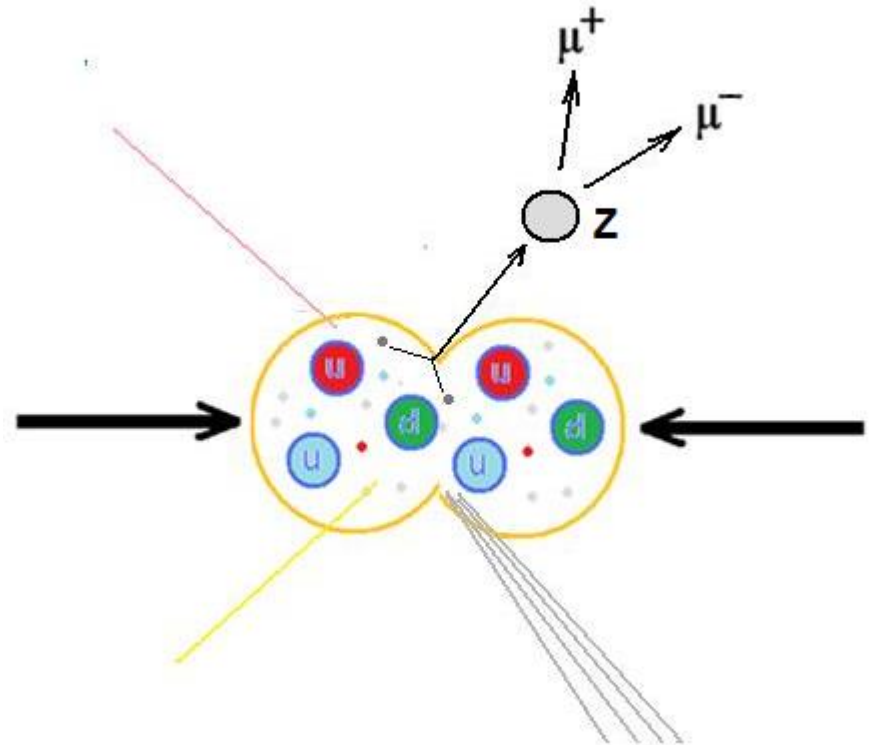
As they separate, the binding energy between them converts to sprays of new particles called jets. Also, lower energy electrons and muons can emerge.

They are not what we are looking for.



We are looking for the Z boson, a particle with no charge that decays into two muons or two electrons.*

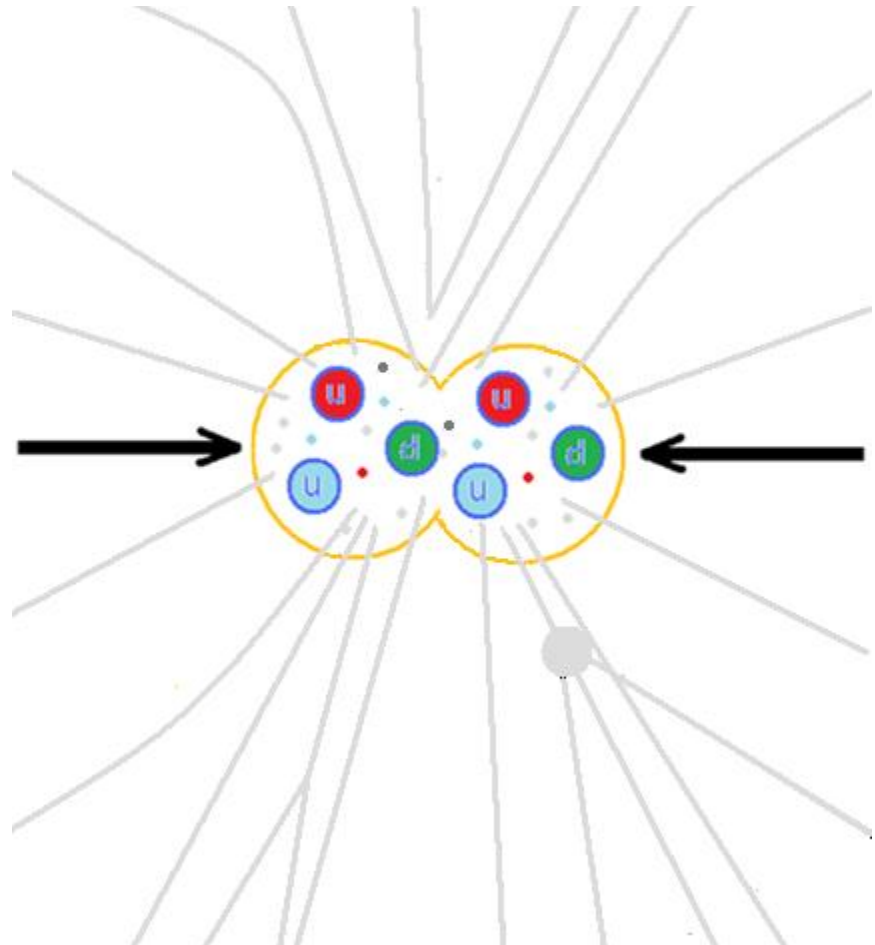
What do we know about the charges of the muons or electrons? What is the charge of the Z?



**The Z has other decays . . . but these are not what we are looking for.*

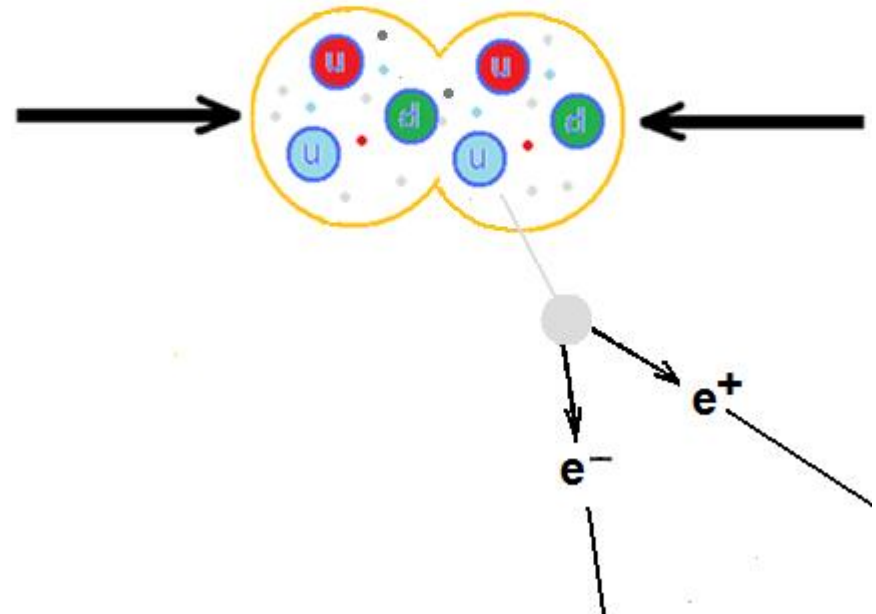
A “dimuon” or “dielectron” event *might* be a decay of the particle that we are interested in.

It may be hard to find the tracks we want unless we make a “cut” on low- energy tracks.



If we cut out all tracks below, say, 5 GeV momentum, the picture is clearer.

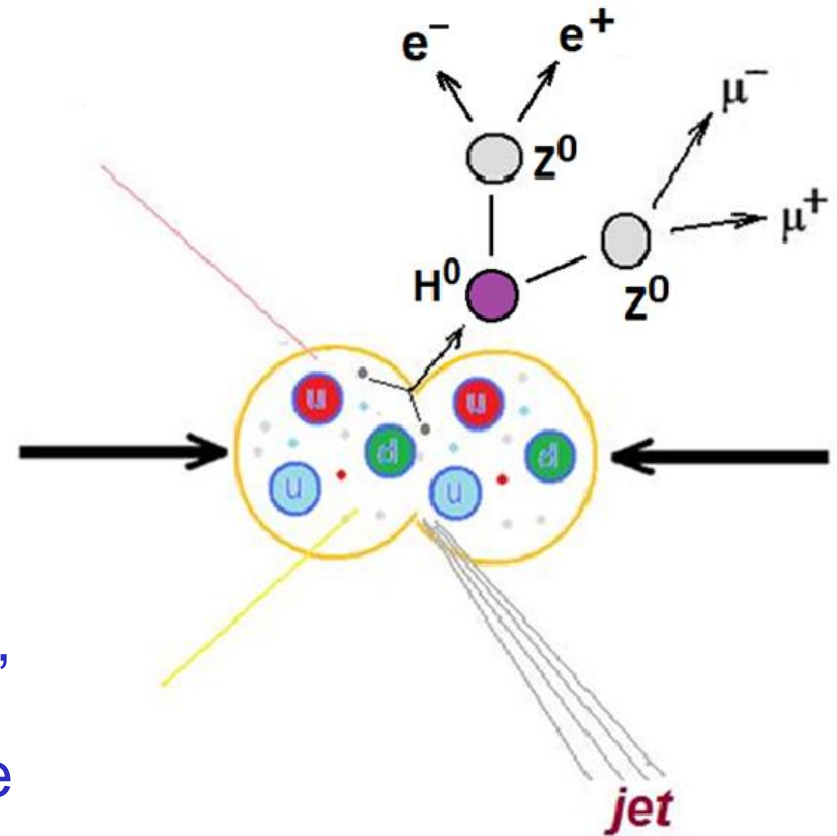
Today, we will filter many events to find $Z \rightarrow e^- e^+$ and $Z \rightarrow \mu^- \mu^+$ signals and use momentum information from these to find the mass of the Z boson.



Particle Decays

The Higgs boson was discovered by CMS and ATLAS and announced on July 4, 2012.

This long-sought particle is part of the “Higgs mechanism” that accounts for other particle having mass.



HYPATIA Event Display

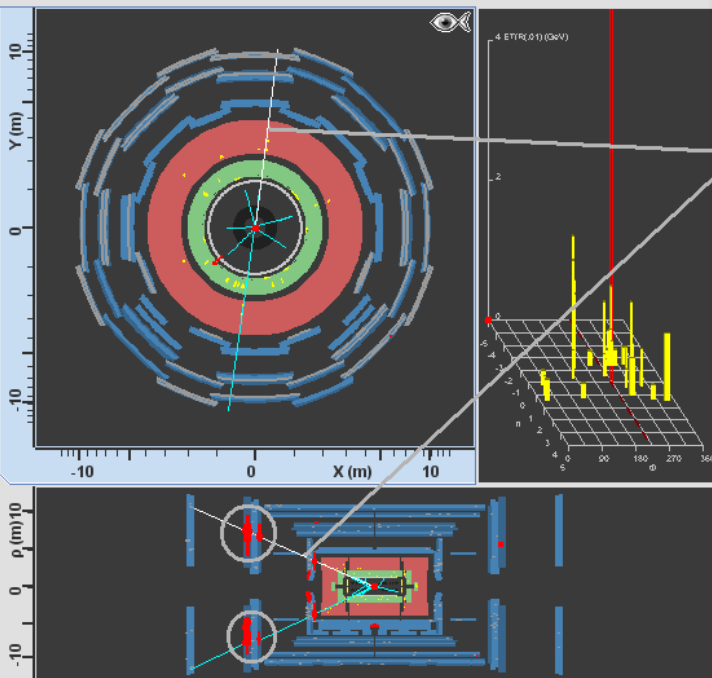
Hybrid pupils' analysis tool for interactions in ATLAS - version 6.0 - Invariant Mass Window

File View Histograms Preferences Help

| File Name | ETMis [GeV] | Track | P [GeV] | +/- | Pt [GeV] | ϕ | η | M(2 γ) [GeV] | M(4l) [GeV] | e/ μ |
|---------------------------------|-------------|-----------|---------|-----|----------|--------|--------|----------------------|-------------|----------|
| 00036_JiveXML_166964_987982.xml | 19.626 | Tracks 3 | 112.6 | + | 49.4 | 1.441 | -1.464 | 95.325 | | μ |
| | | Tracks 69 | 96.8 | - | 45.9 | -1.720 | -1.378 | | | μ |

Canvas Window - File: 00036_JiveXML_166964_987982.xml Run: 166964 Event: ...

ATLAS 2010-10-18 04:39:34 CEST run:166964 ev:987982 HYPATIA



HYPATIA - Track Momenta Window

File Previous Event Next Event Insert Electron Insert Muon Delete Track Reset Canvas

ETMis: 20.808 GeV ϕ : -2.415 rad Collection: MET RefFinal

C:\installers\HYPATIA\groupA\00036_JiveXML_166964_987982.xml

Reconstructed Tracks

| Track | +/- | P [GeV] | Pt [GeV] | ϕ | θ |
|------------|-----|---------|----------|--------|----------|
| Tracks 3 | + | 112.57 | 49.42 | 1.441 | 2.687 |
| Tracks 69 | - | 96.83 | 45.88 | -1.720 | 2.648 |
| Tracks 127 | - | 37.93 | 30.81 | 1.803 | 0.948 |
| Tracks 128 | + | 25.73 | 12.70 | 0.303 | 2.625 |
| Tracks 134 | + | 121.30 | 89.22 | -0.597 | 2.315 |
| Tracks 136 | - | 34.18 | 8.63 | -3.123 | 0.255 |
| Tracks 154 | + | 14.19 | 8.35 | -2.346 | 2.513 |
| Tracks 176 | - | 13.53 | 12.74 | 0.259 | 1.915 |

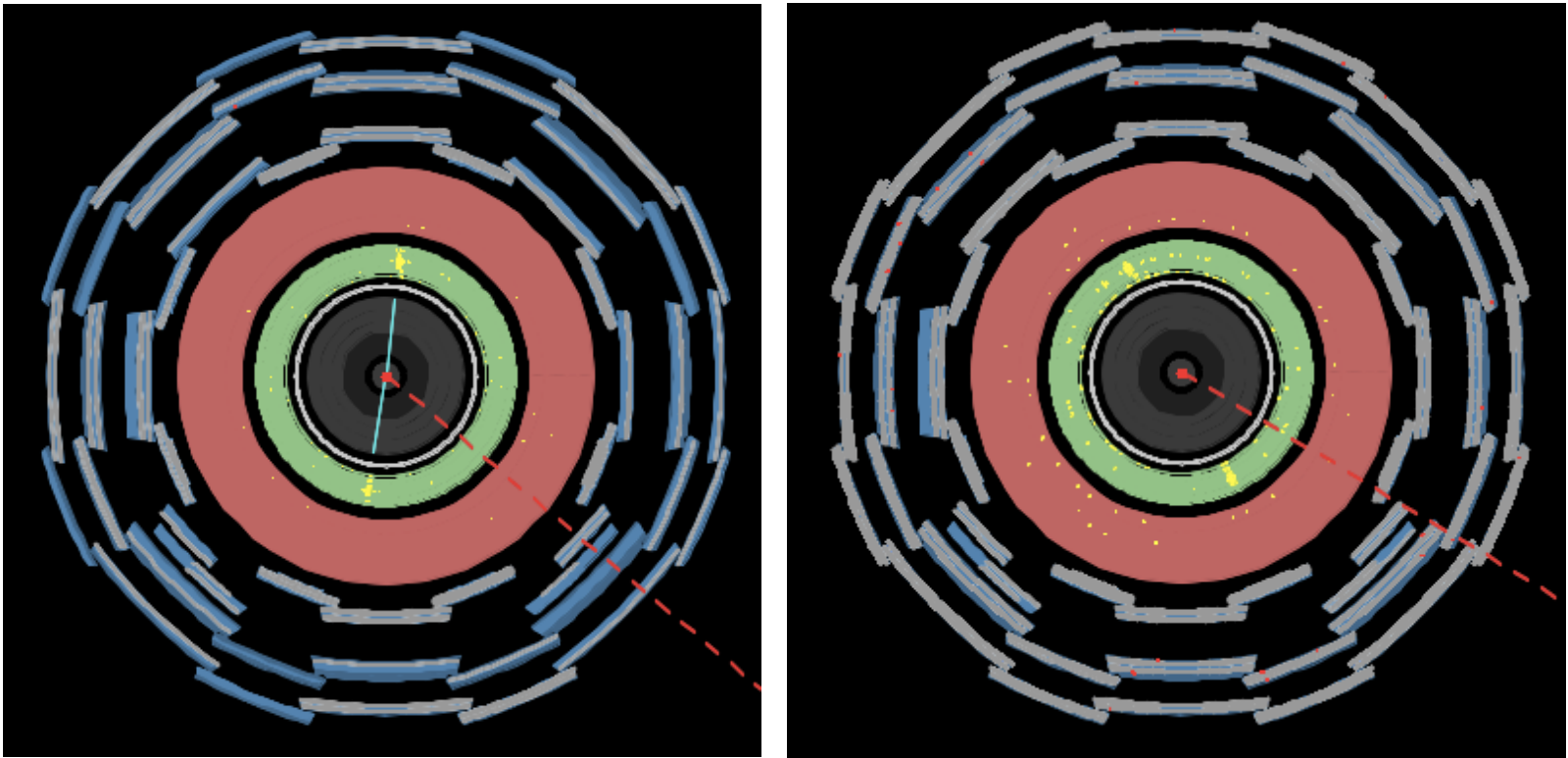
HYPATIA - Control Window

Parameter Control Interaction and Window Control Output Display

Projection Data Cuts InDet Calo MuonDet Objects Geometry

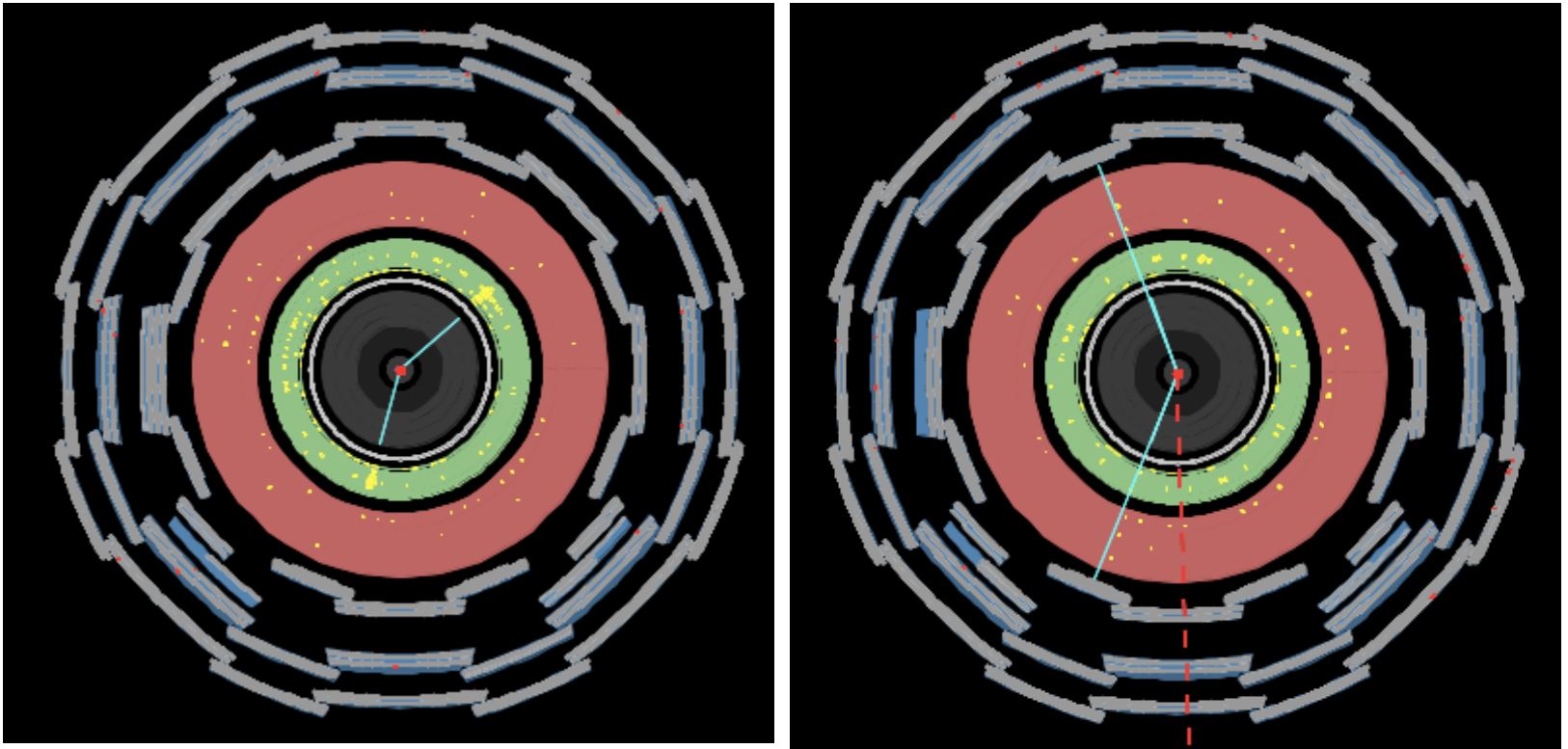
| InDet | Name | Value |
|---------|---|-----------|
| Calo | <input checked="" type="checkbox"/> Pt | > 5.0 GeV |
| MuonDet | <input type="checkbox"/> d0 | < 2.5 mm |
| Objects | <input type="checkbox"/> z0 | < 20.0 cm |
| ATLAS | <input type="checkbox"/> d0 Loose | < 2.0 cm |
| | <input type="checkbox"/> z0-zvtx | < 2.5 mm |

HYPATIA Event Display



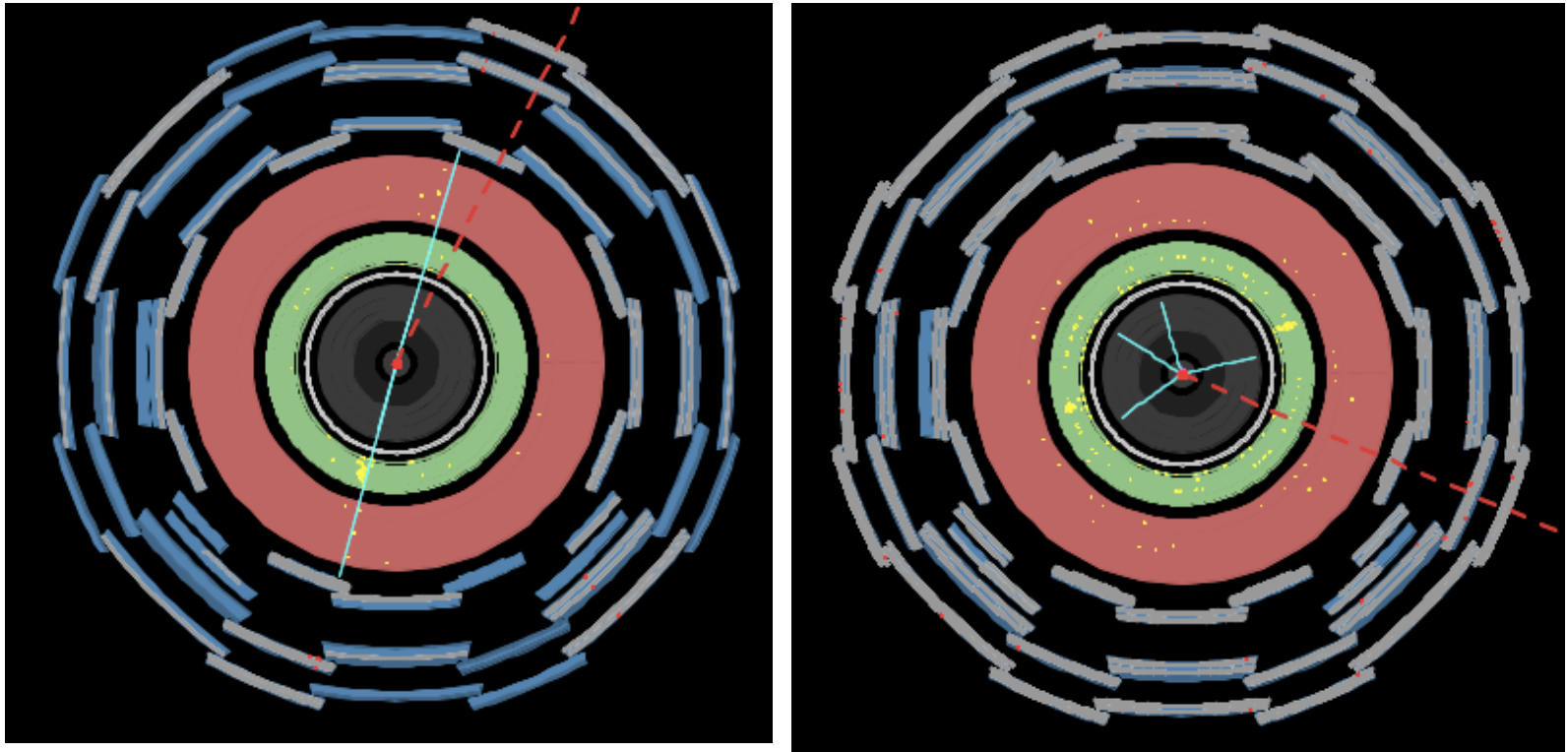
How are these events similar? Different? Why?

HYPATIA Event Display



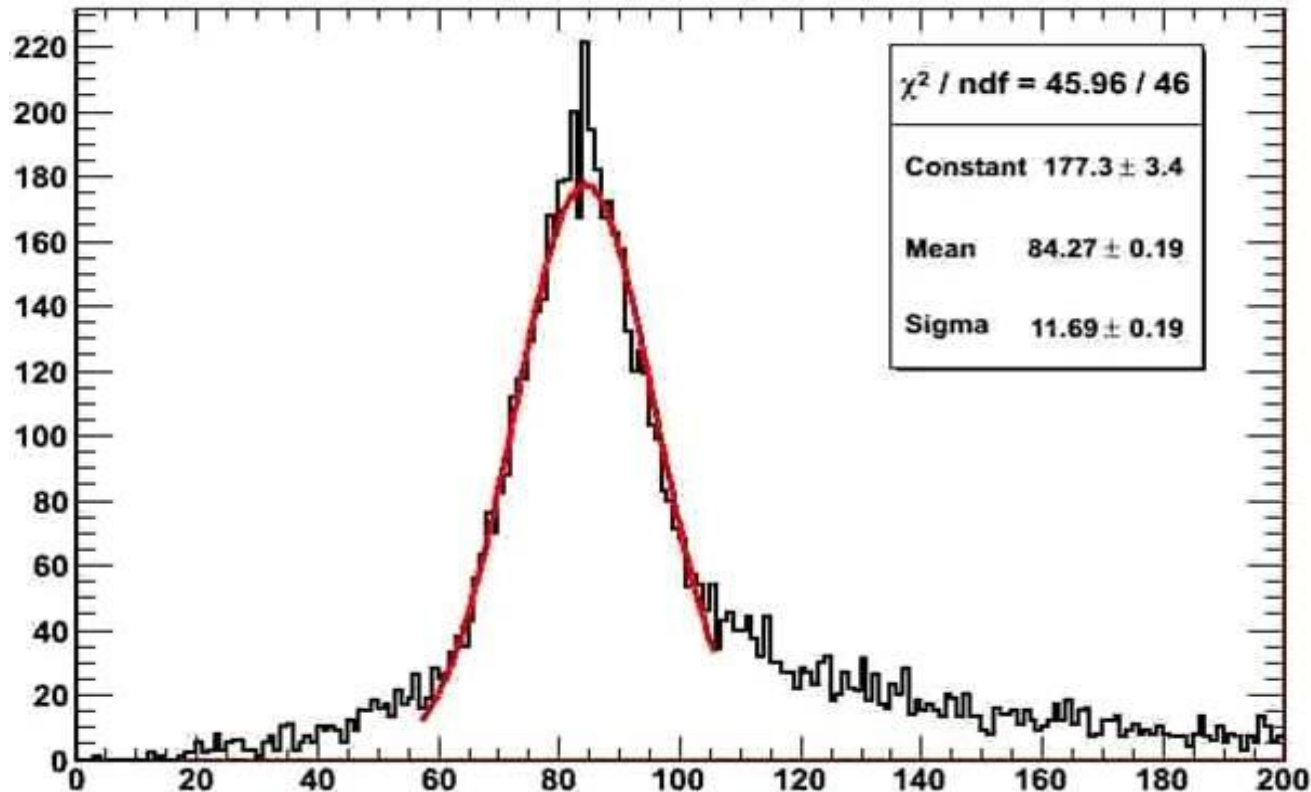
How are these events similar? Different? Why?

HYPATIA Event Display



How are these events similar? Different? Why?

ATLAS Mass Plot



From: *W Mass as a Calibration of the Jet Energy Scale in ATLAS* (poster, 2008)
 Daniel Goldin, Southern Methodist University, for the ATLAS
 Collaboration <http://cdsweb.cern.ch/record/1132028/files/ATL-SLIDE-2008-100.ppt>

“Science is nothing but developed perception, interpreted intent, common sense rounded out and minutely articulated.” *George Santayana*

- Indirect observations and imaginative, critical, logical thinking can lead to reliable and valid inferences.
- Therefore: work together, think (sometimes outside the box), and be critical of each other's results to figure out what is happening.

Make teams of two.

Practice.

Talk with physicists.

Find good Z and H candidates...and more.

Which events will be included in the mass plot?

AND plot the mass!

Report! Rapport! Rejoice! Relax!