Helping Develop America's Technological Workforce

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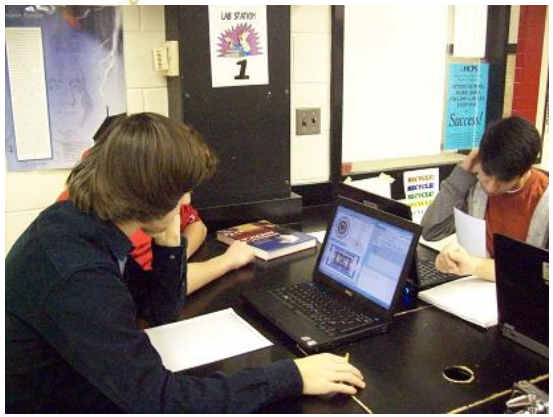
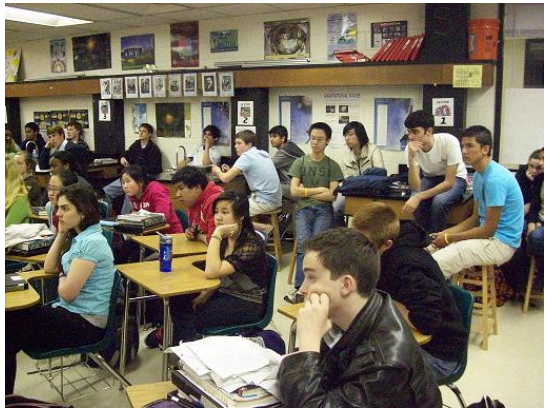
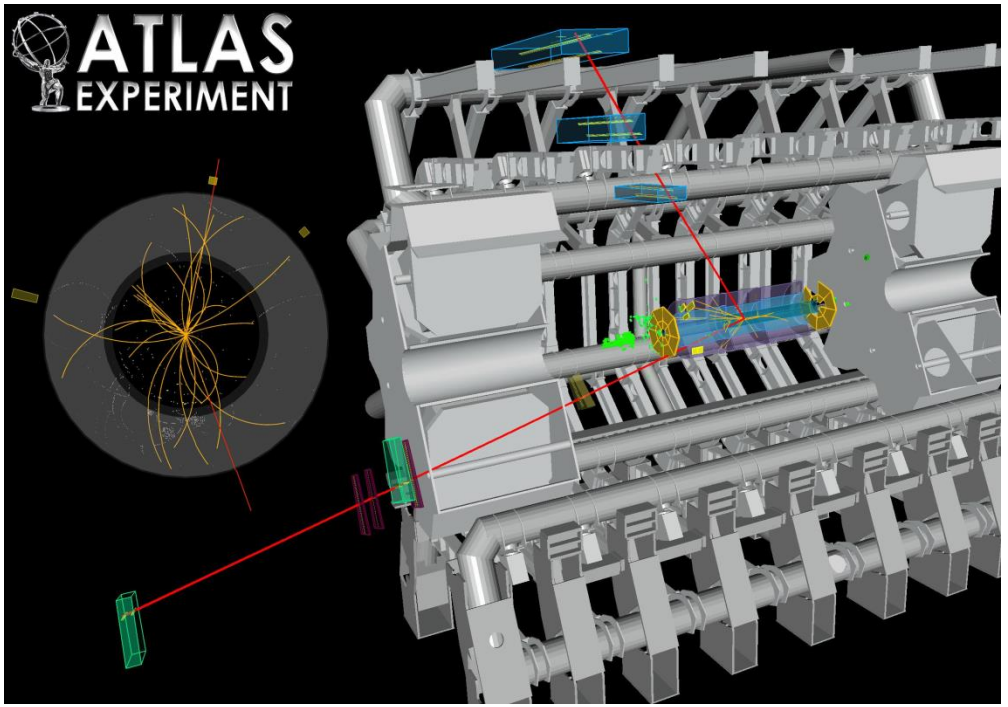


ATLAS Z-Path Masterclass Start-up

INTERNATIONAL MASTERCLASSES
hands on particle physics





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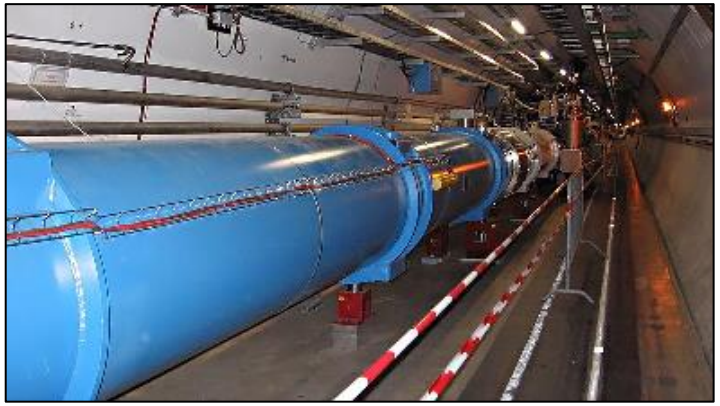
The LHC and New Physics



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

At CERN, the LHC successfully completed Run 1 at 8 TeV of collision energy, confirming that the measurements correspond well to the ***Standard Model*** *and then finding the Higgs boson. The LHC has completed Run 2 at 13 TeV, and is now shut down in order to make upgrades for Run 3 which is scheduled to begin in 2022.*

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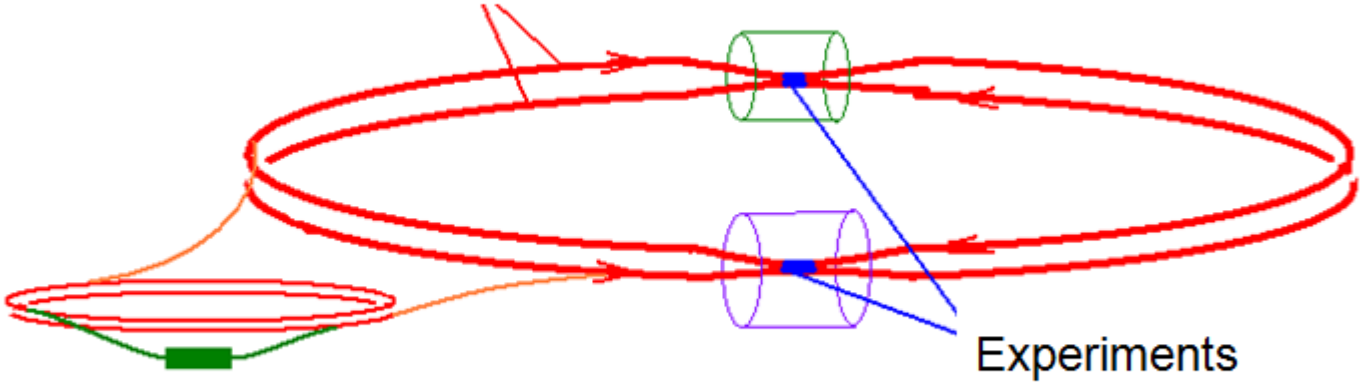
The LHC and New Physics

The LHC is buried ~100 m below the surface near the Swiss-French border.

beams accelerated in large rings
(27 km circumference at CERN)



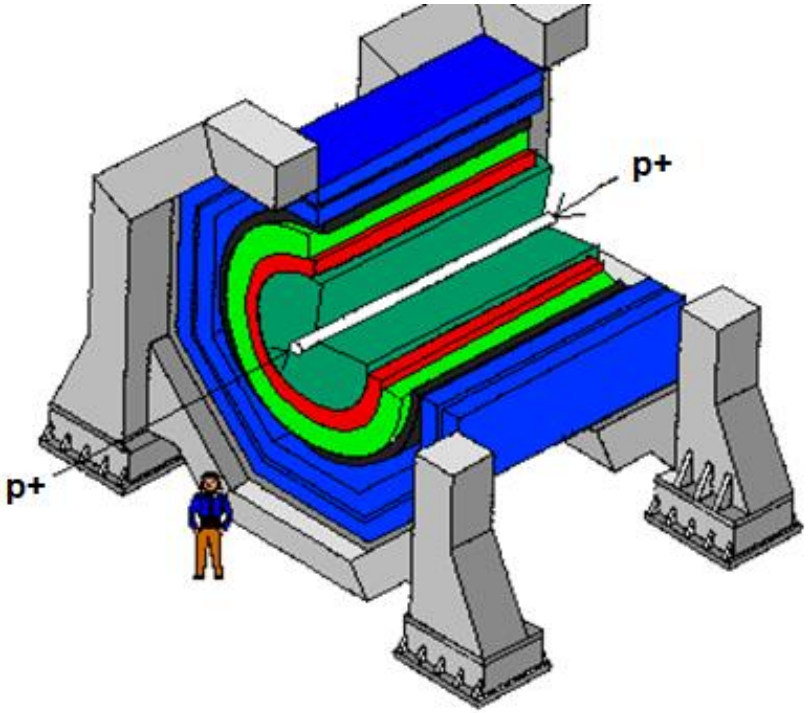
Detectors

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.*

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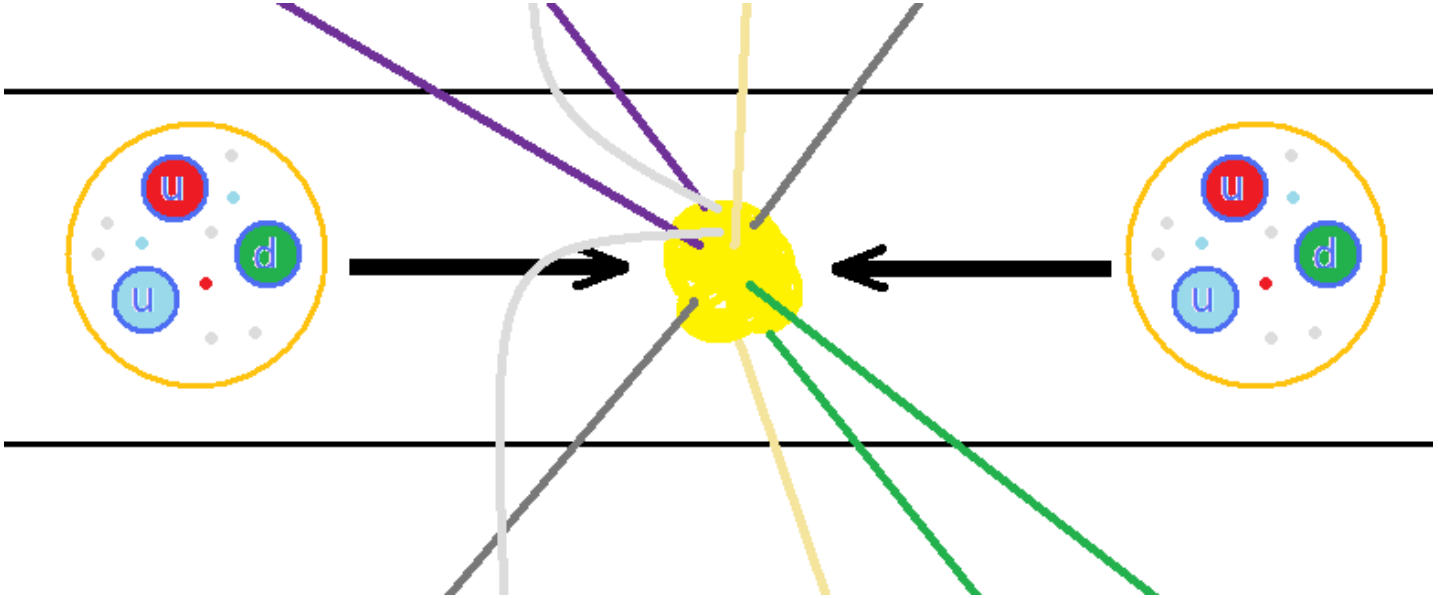
Proton Interactions

If each beam proton has energy 4 TeV....

- The total collision energy is 2 x 4 TeV = 8 TeV.
- But each particle inside a proton shares only a portion.
- So a newly created particle's mass ***must be*** smaller than the total energy.



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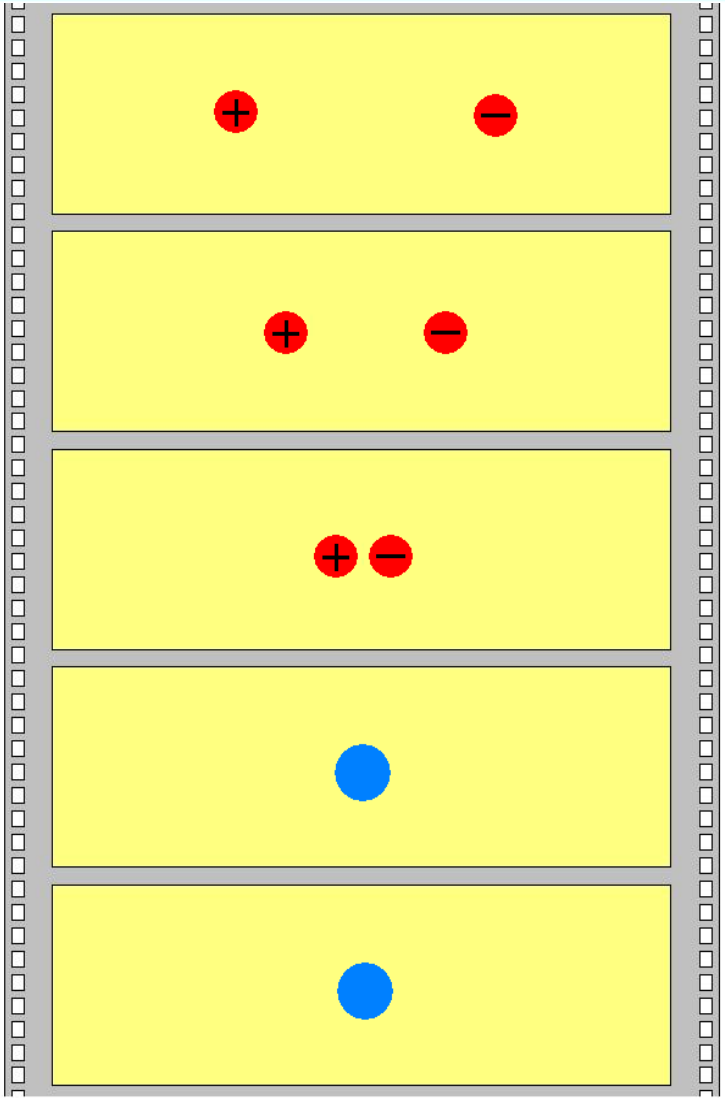
Particle Decays

The collisions create new particles that promptly decay. Decaying particles *always* produce lighter particles.

Conservation laws allow us to see patterns in the decays.

Can you name some of these conservation laws?

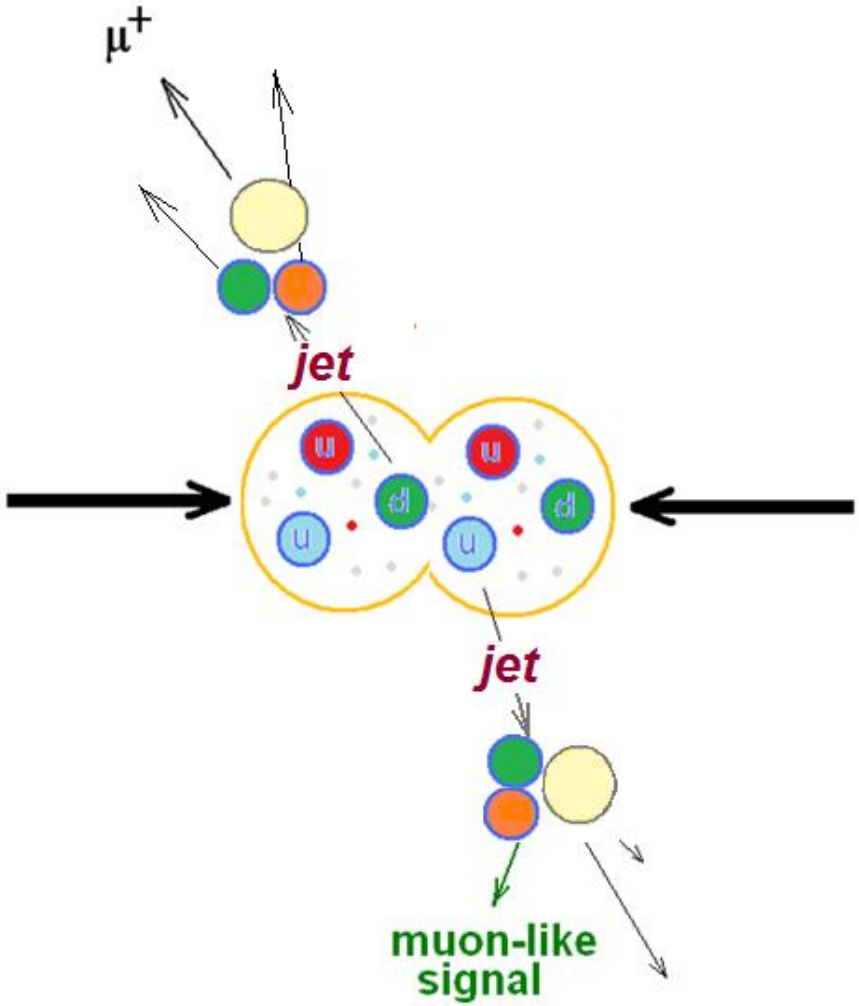


Particle Decays

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.

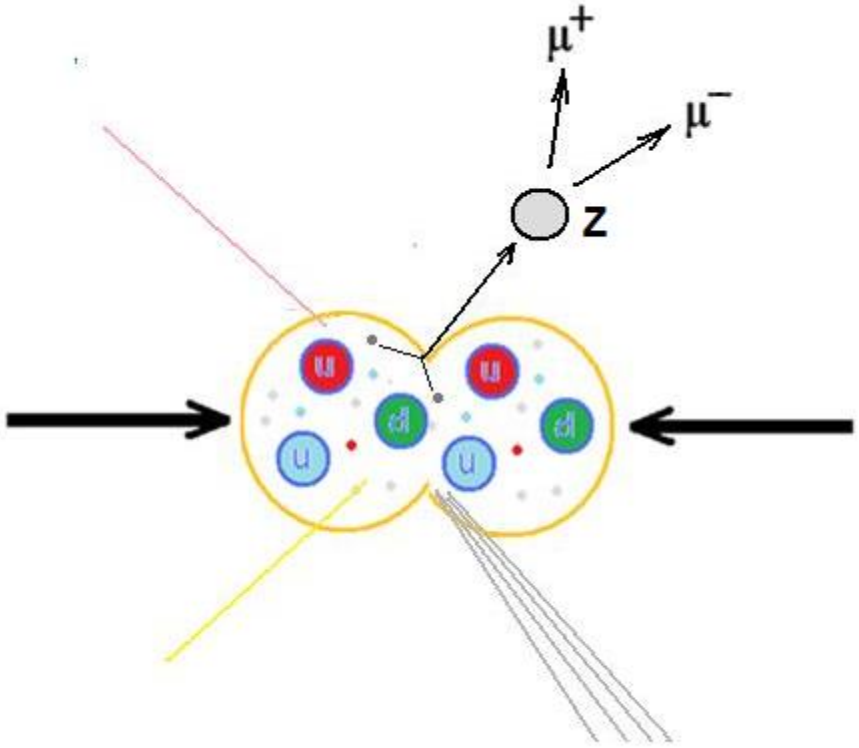
They are not what we are looking for.



Particle Decays

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.*

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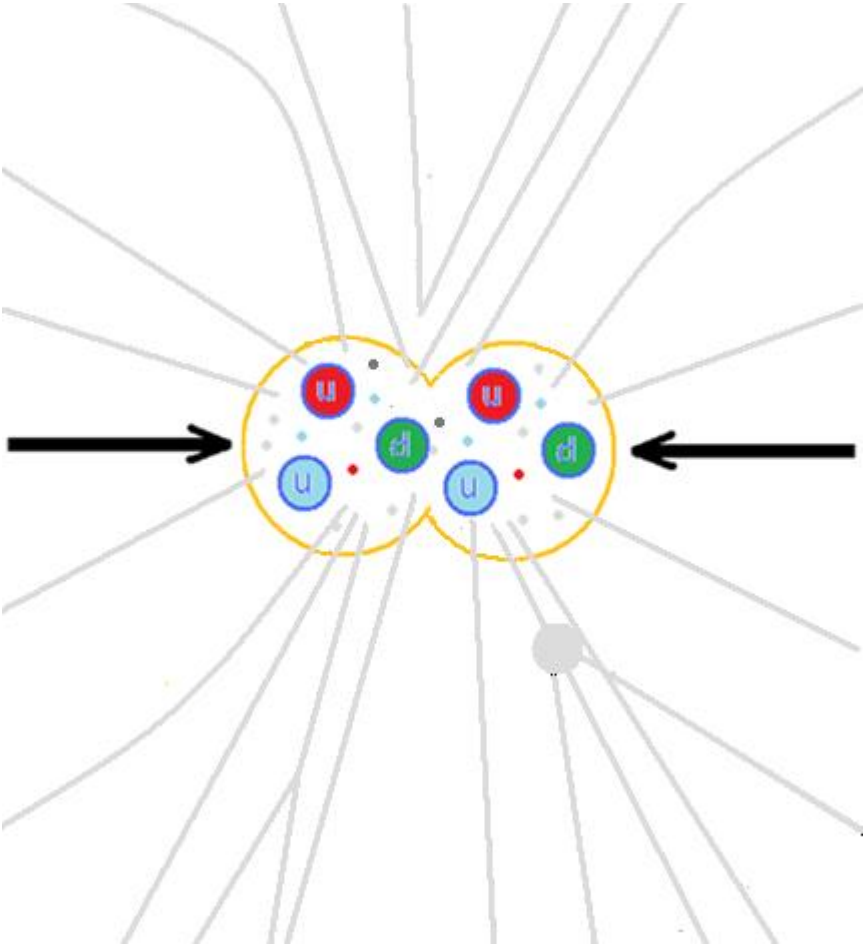
Particle Decays

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

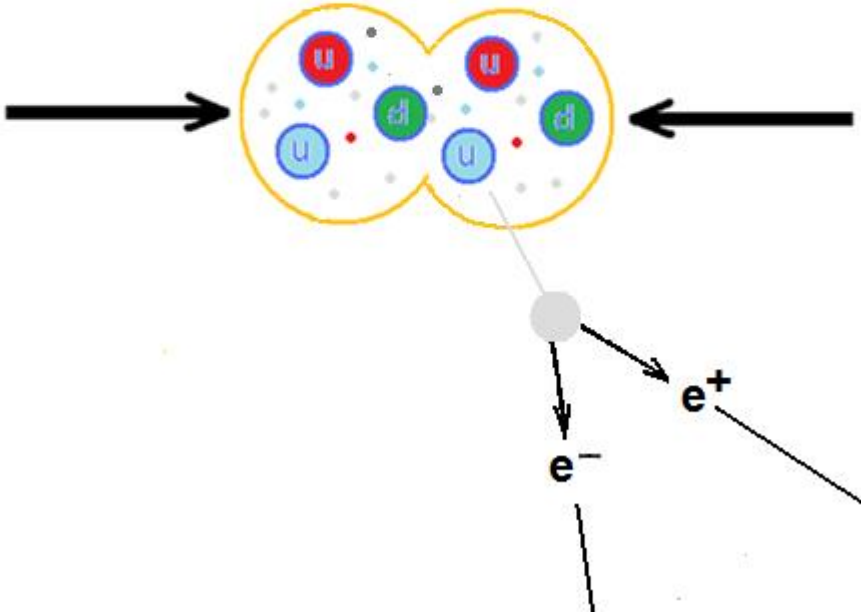
It may be hard to find the tracks we want unless we make a "cut" on low- energy tracks.



Particle Decays

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

Today, we will filter many events to find Z→e e and Z→μ μ signals and use momentum information from these to find the mass of the Z boson.



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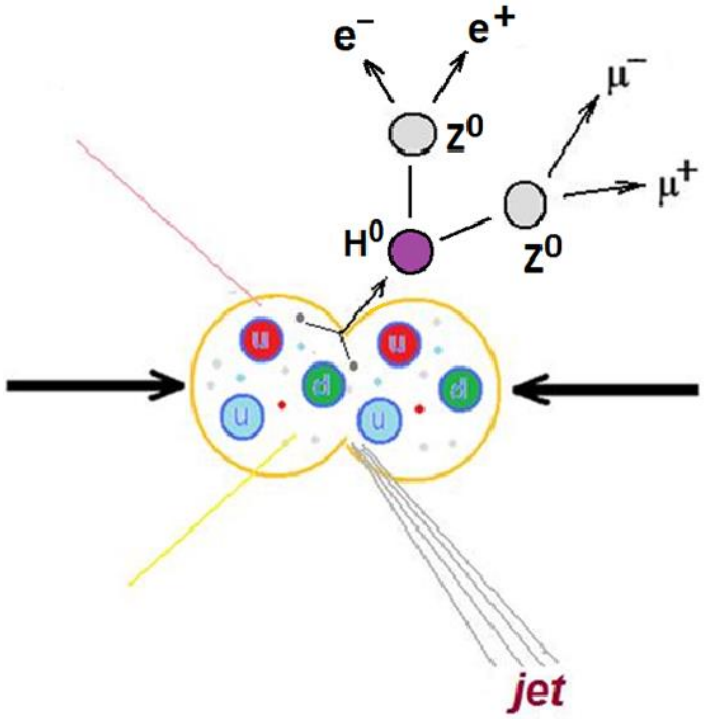
Particle Decays

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.

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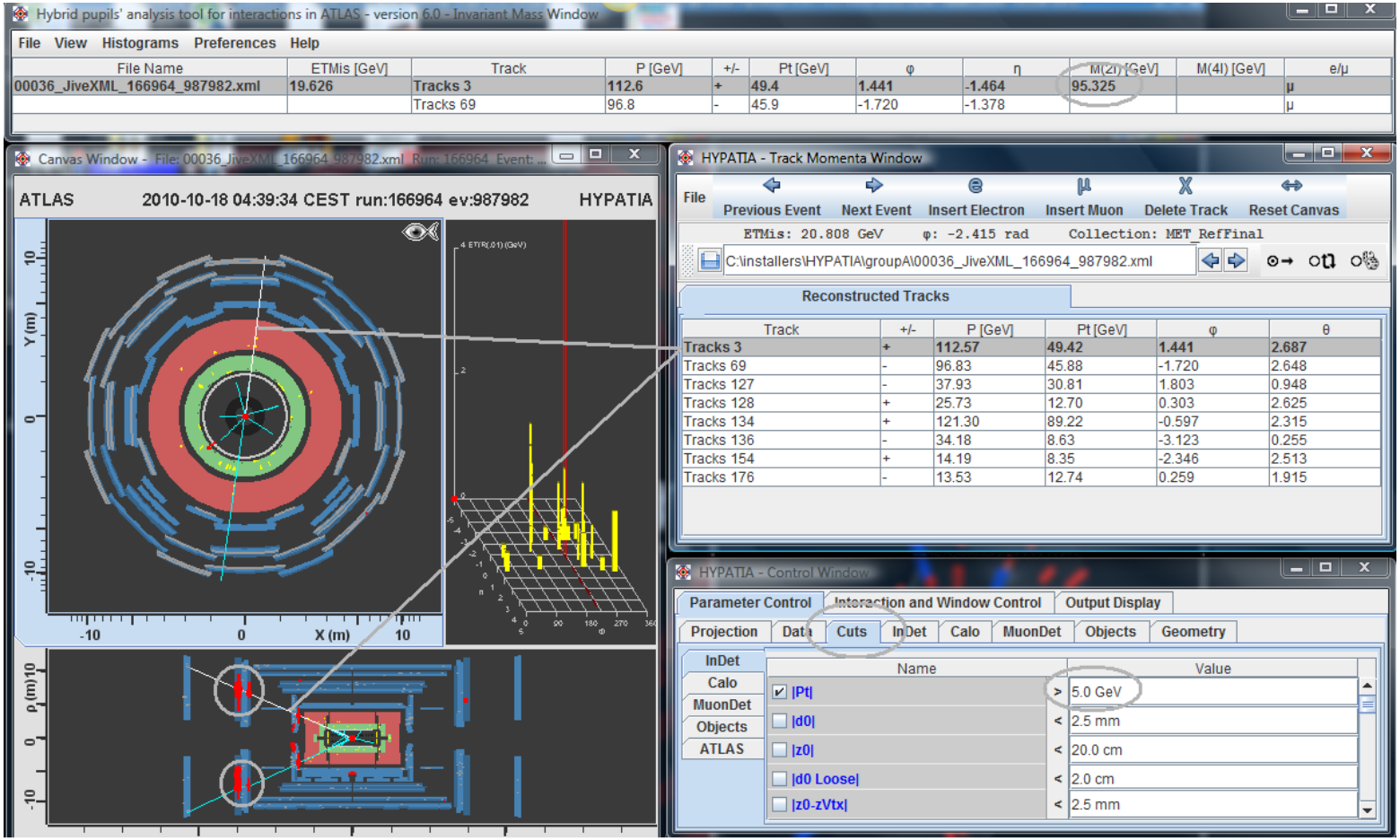
HYPATIA Event Display



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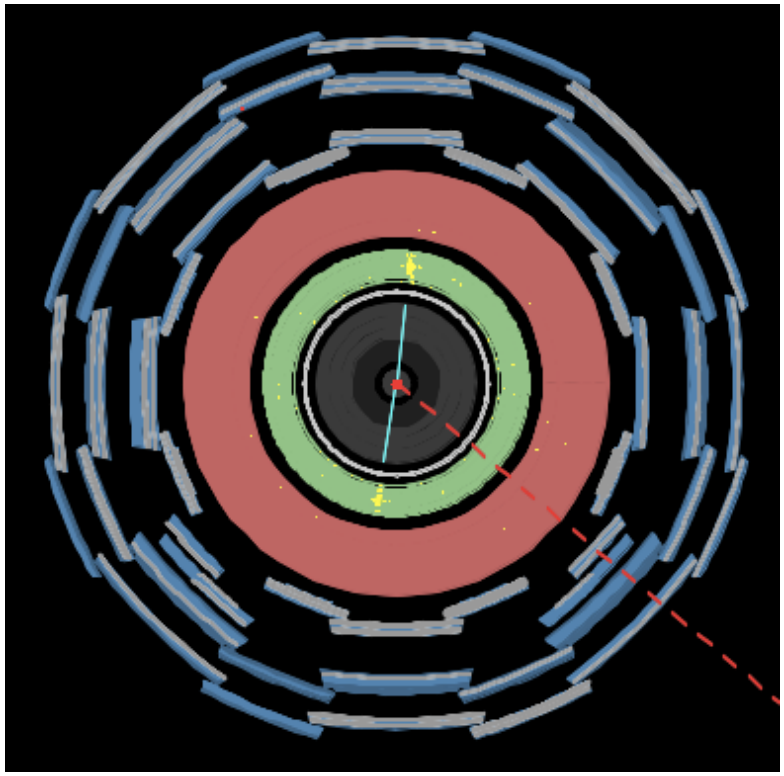
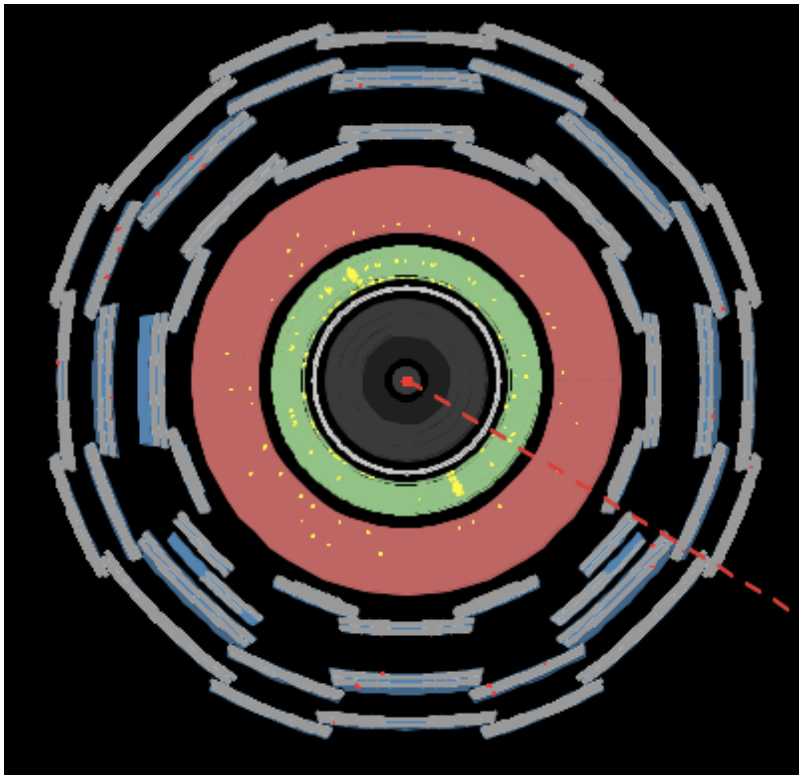
HYPATIA Event Display





How are these events similar? Different? Why?

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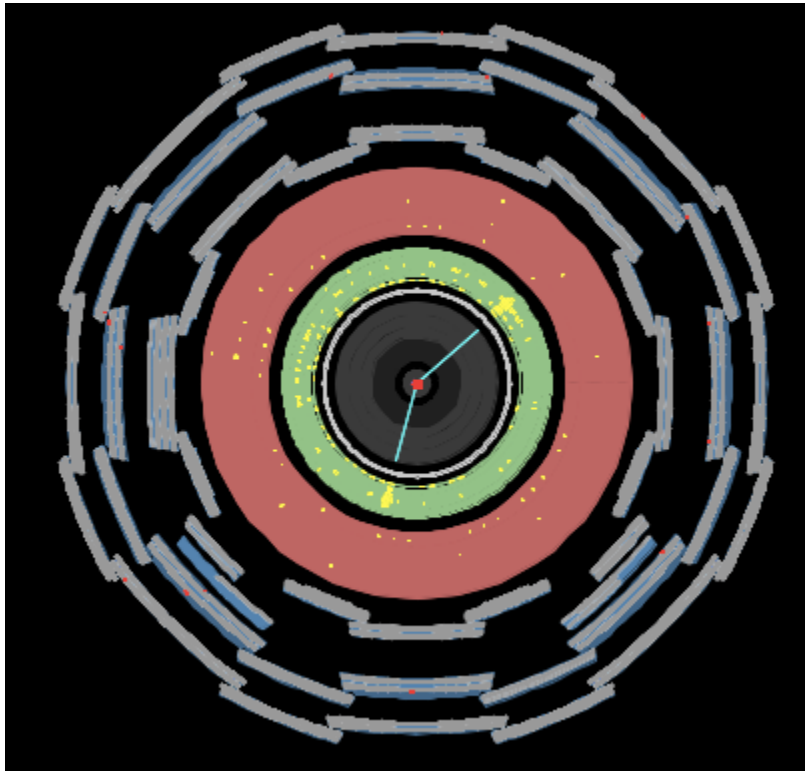
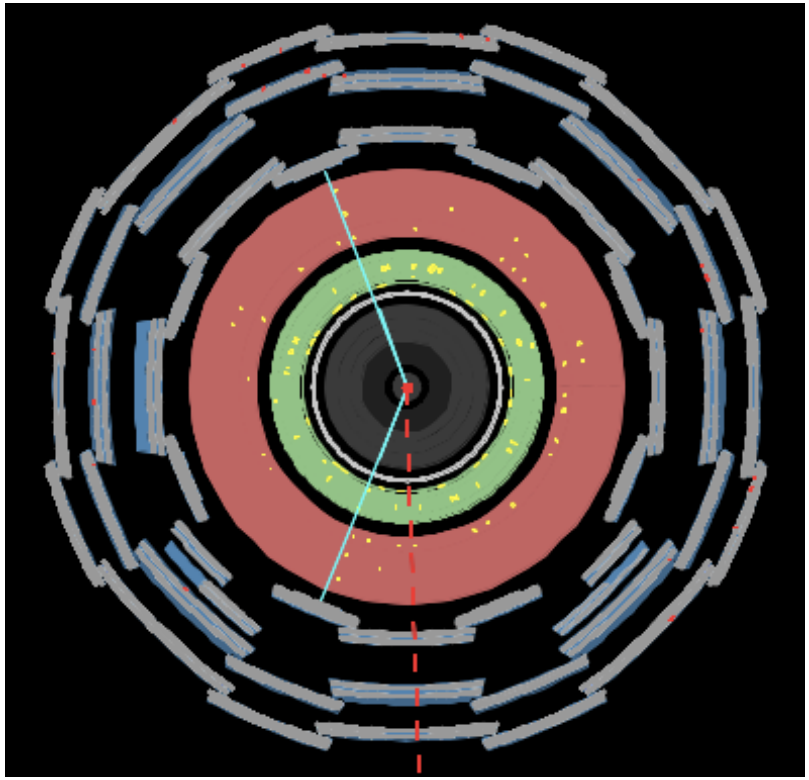
HYPATIA Event Display





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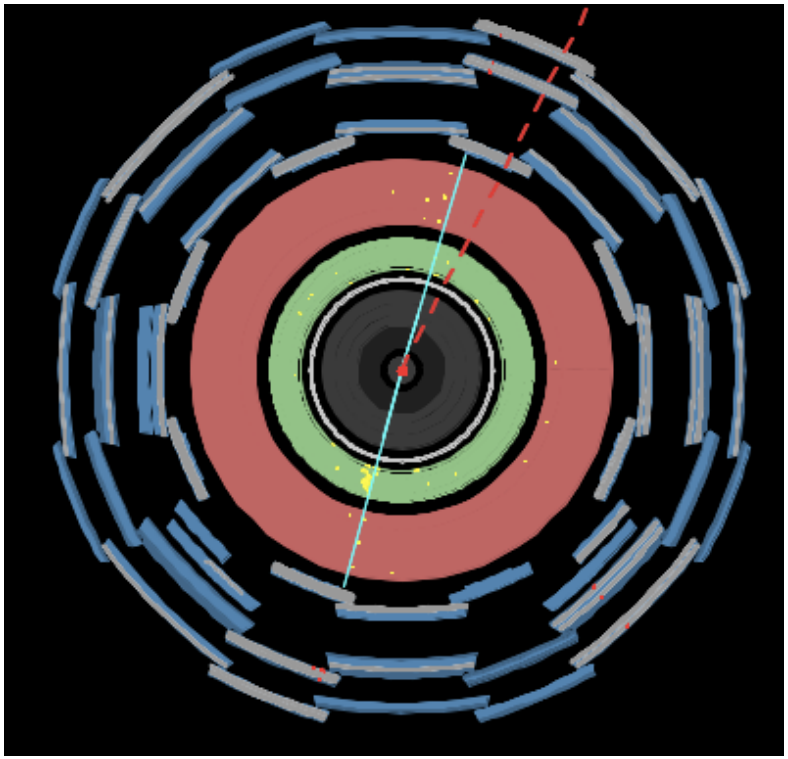
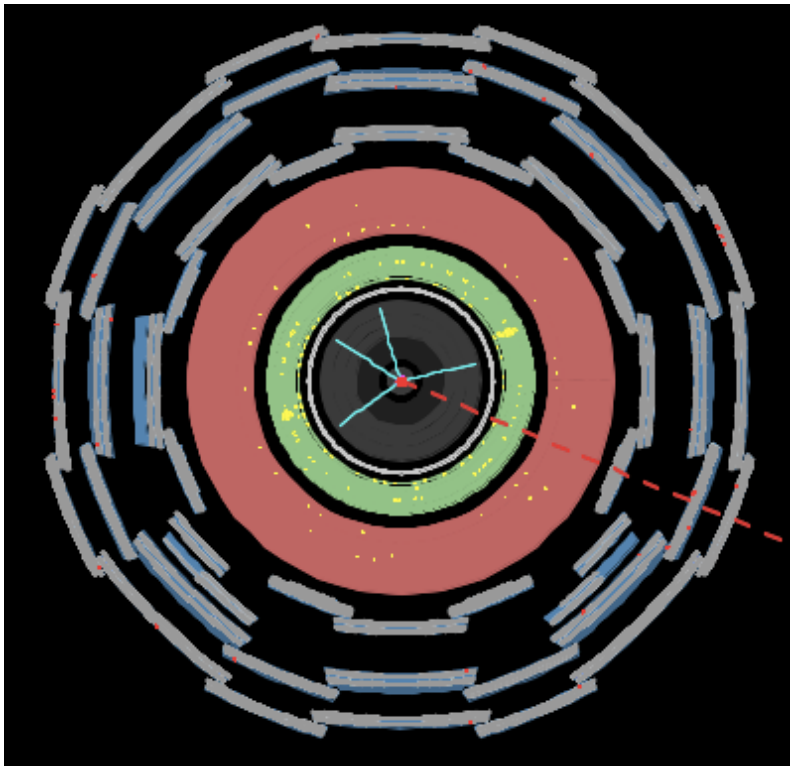
HYPATIA Event Display





How are these events similar? Different? Why?

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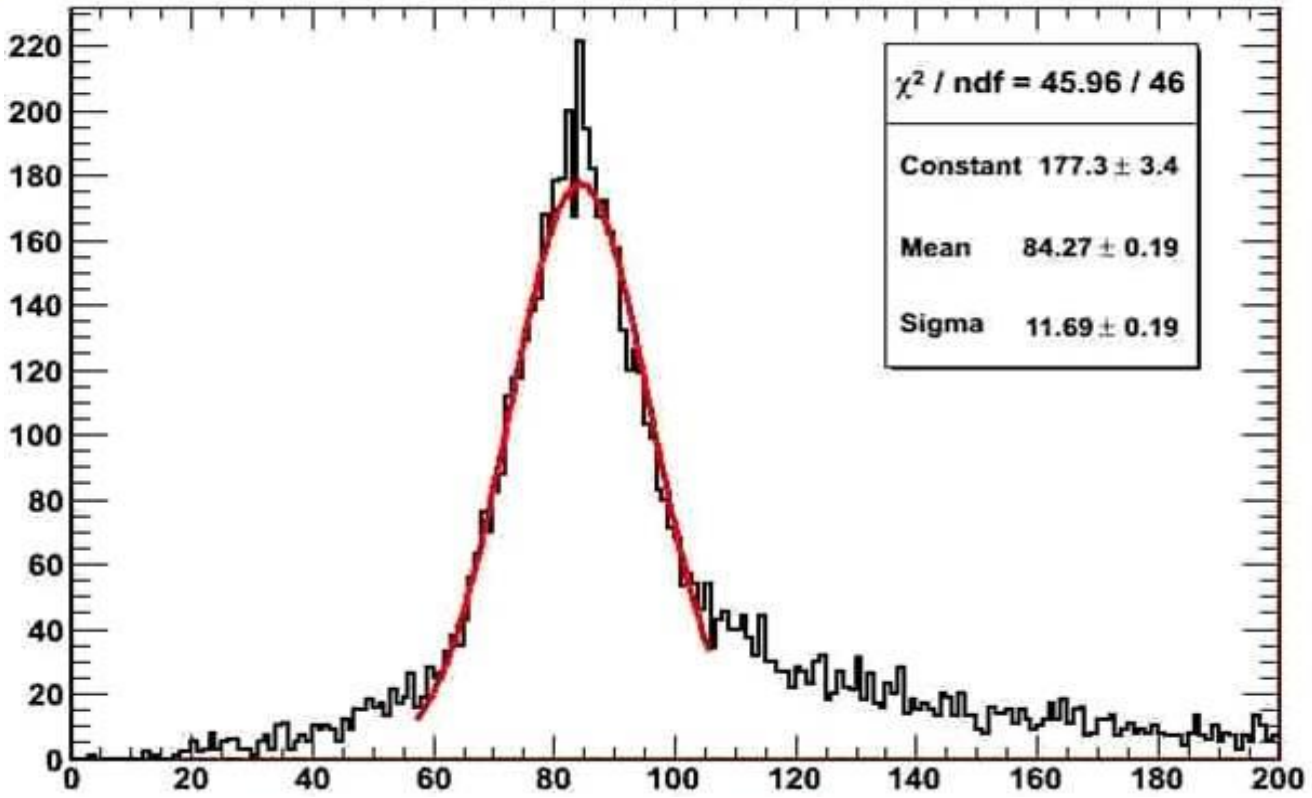
ATLAS Mass Plot



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

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Keep in Mind . . .

"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.

Let's Analyze Events!

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!