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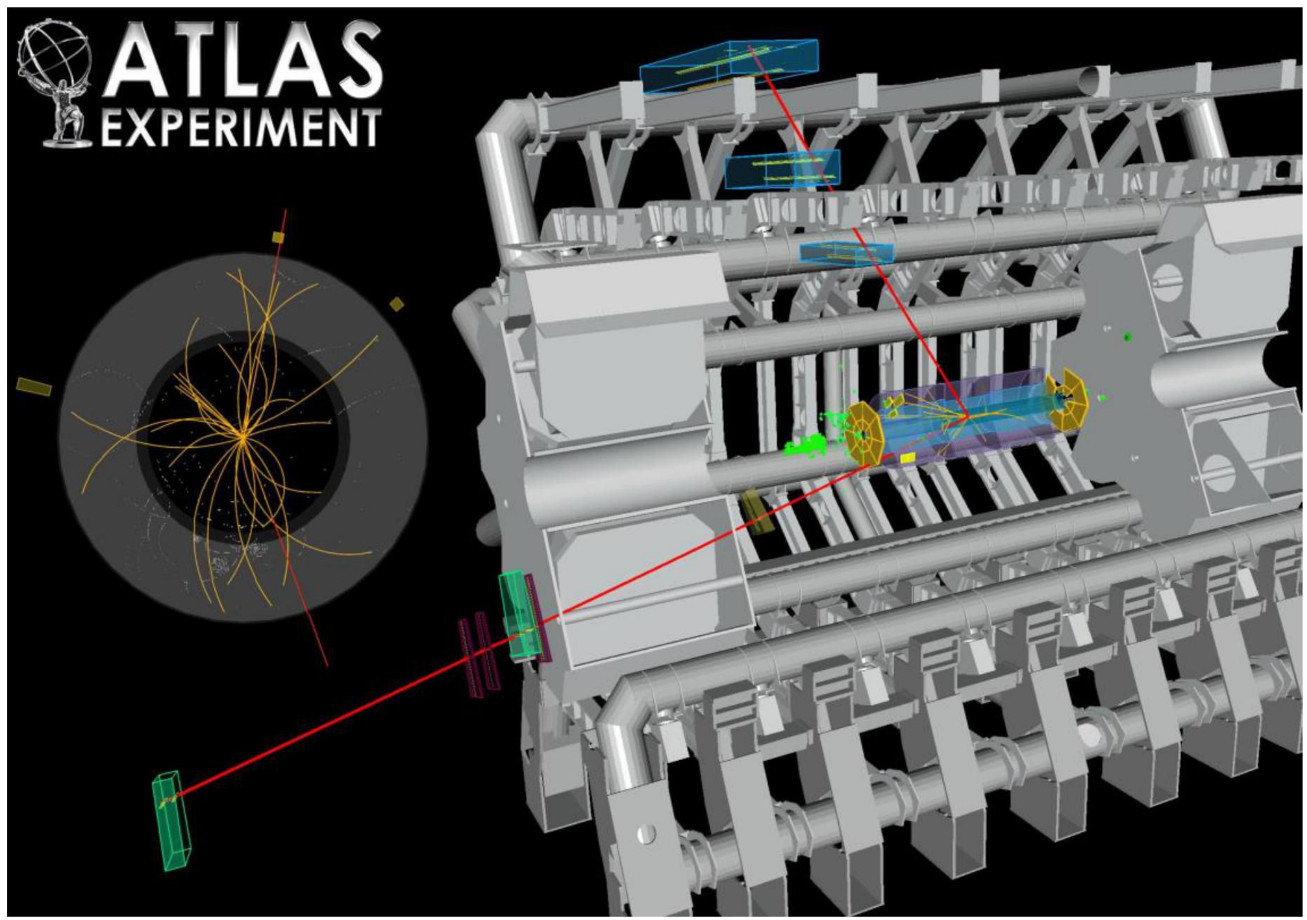
INTERNATIONAL MASTERCLASSES
hands on particle physics

# Big Analysis of Muons in ATLAS (BAMA)

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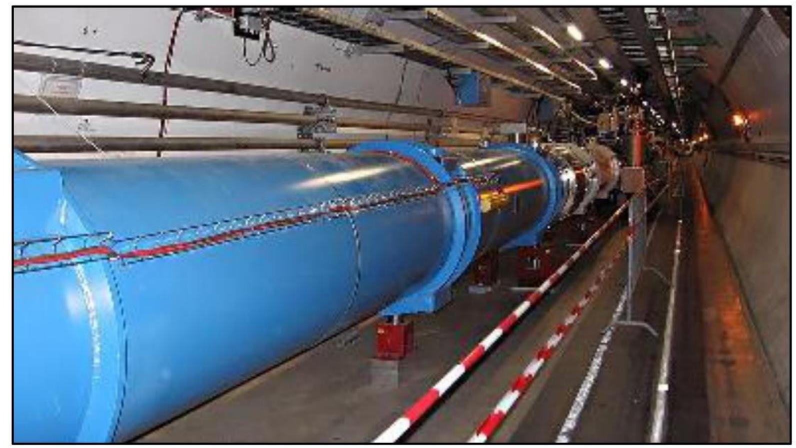
# The LHC and New Physics

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



*At CERN, the LHC's Run I, at 8 TeV of collision energy, ran from 2009 to 2013, confirming Standard Model predictions and finding the Higgs Boson. Run II operated at a much greater energy of 13 TeV from 2015 to 2018.*

*Run III is just now starting at 13.6 TeV, hoping to continue the collection of data at this high energy.*

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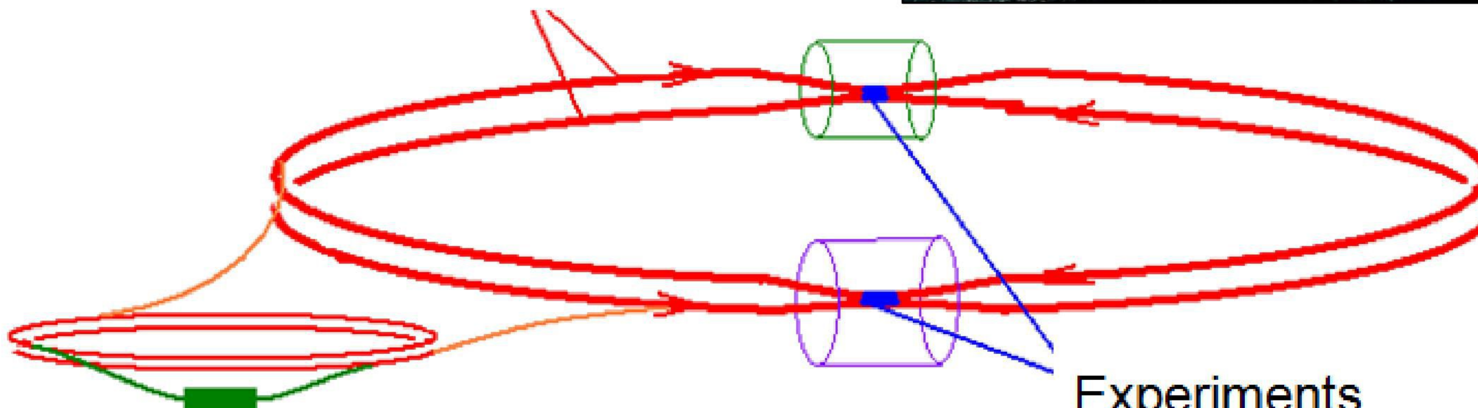
# The LHC and New Physics

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



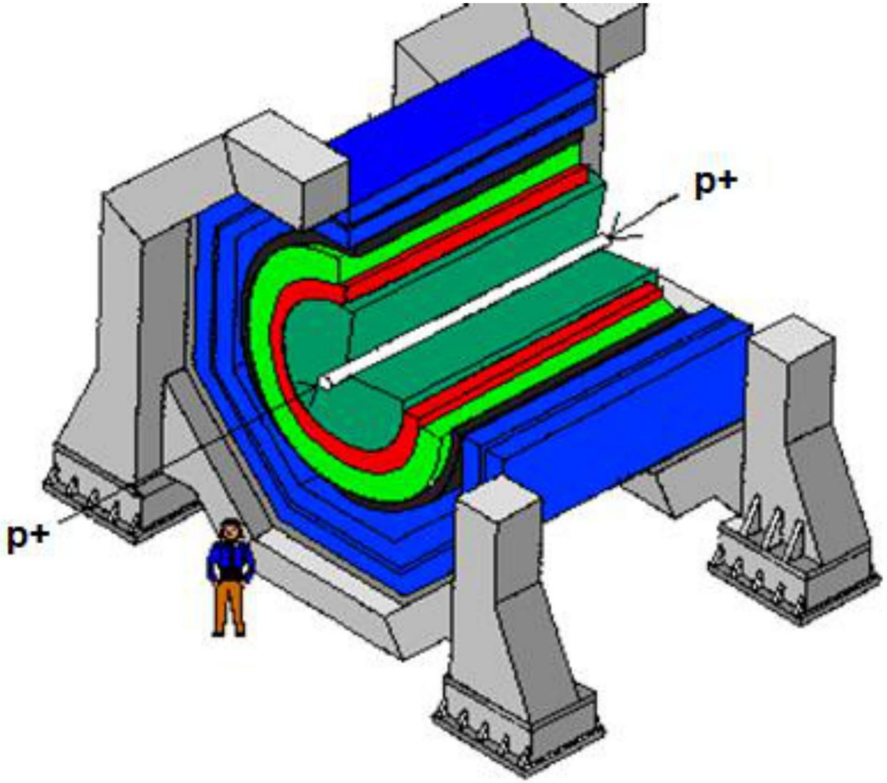
# Detectors

## Generic Design

Cylinders wrapped around the beam pipe

From inner to outer . . .

- Tracking
- Electromagnetic calorimeter
- Hadronic calorimeter
- Magnet*
- Muon chamber

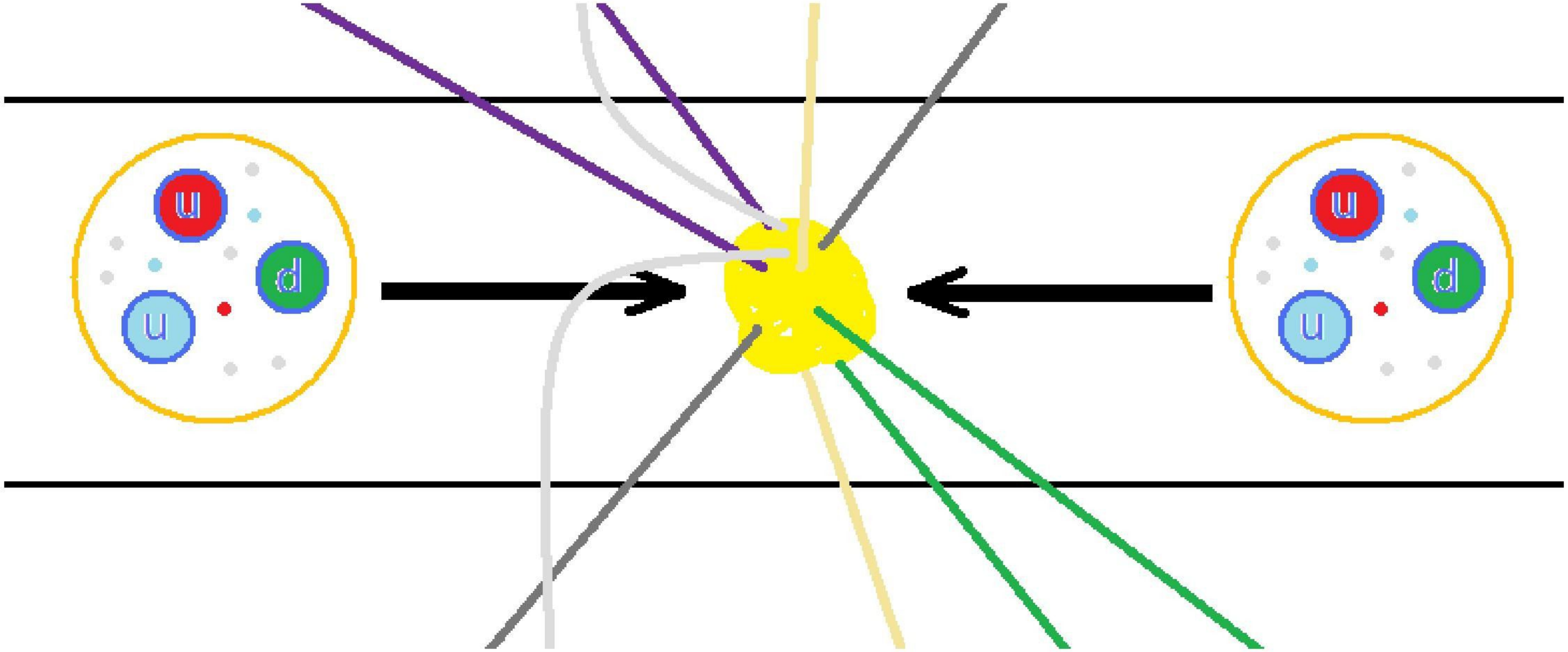



*Location of magnet depends on specific detector design.*

# Proton Interactions

If each beam proton has energy 6.8 TeV...

- The total collision energy is 2 x 6.8 TeV = 13.6 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.

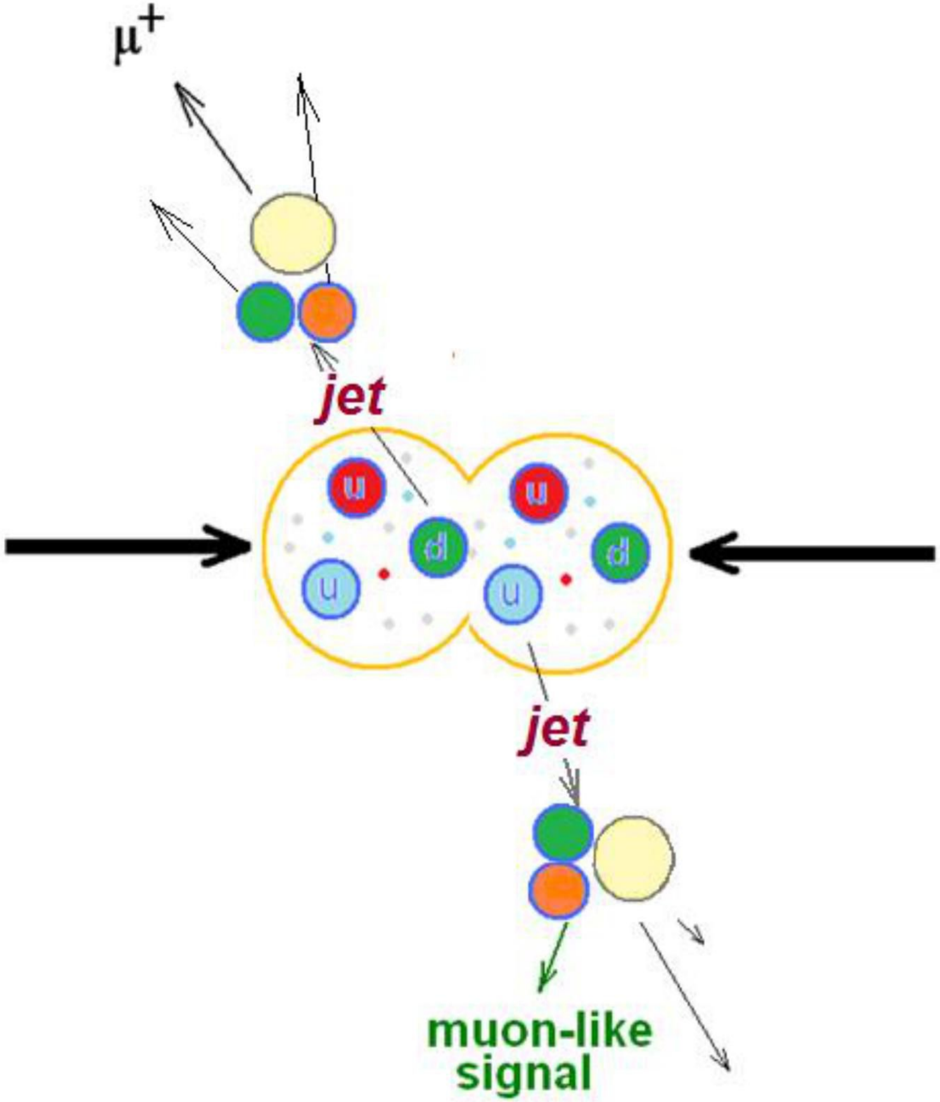


# Particle Decays

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.

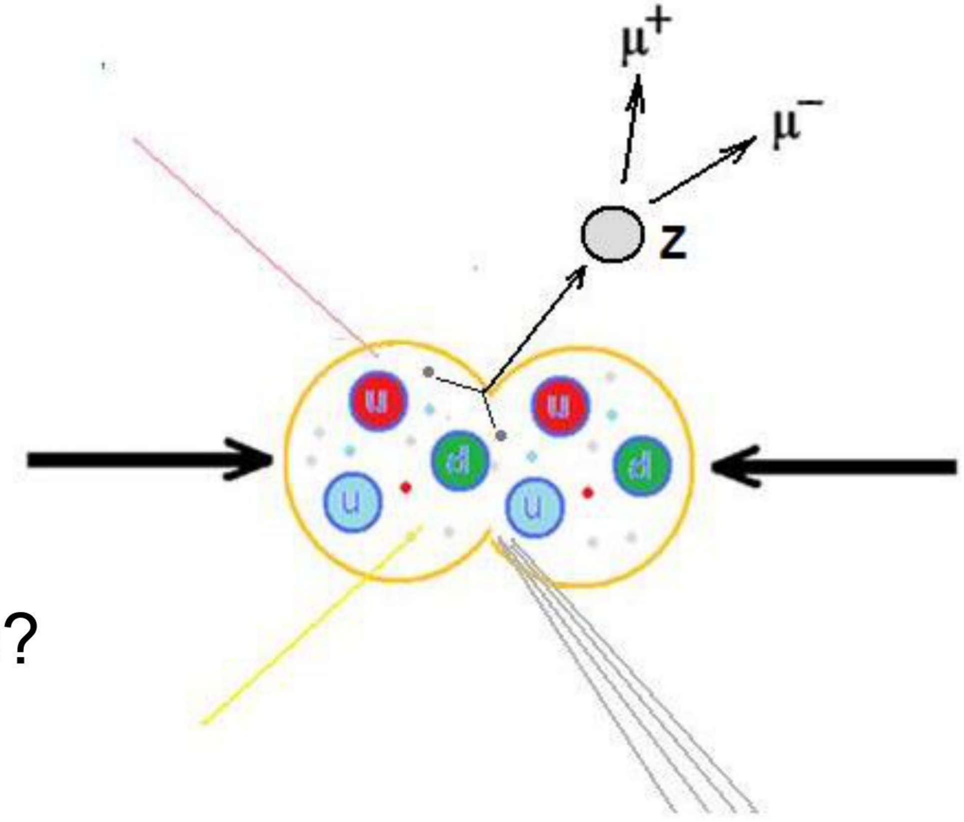
They are not what we are looking for.



# Particle Decays

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

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

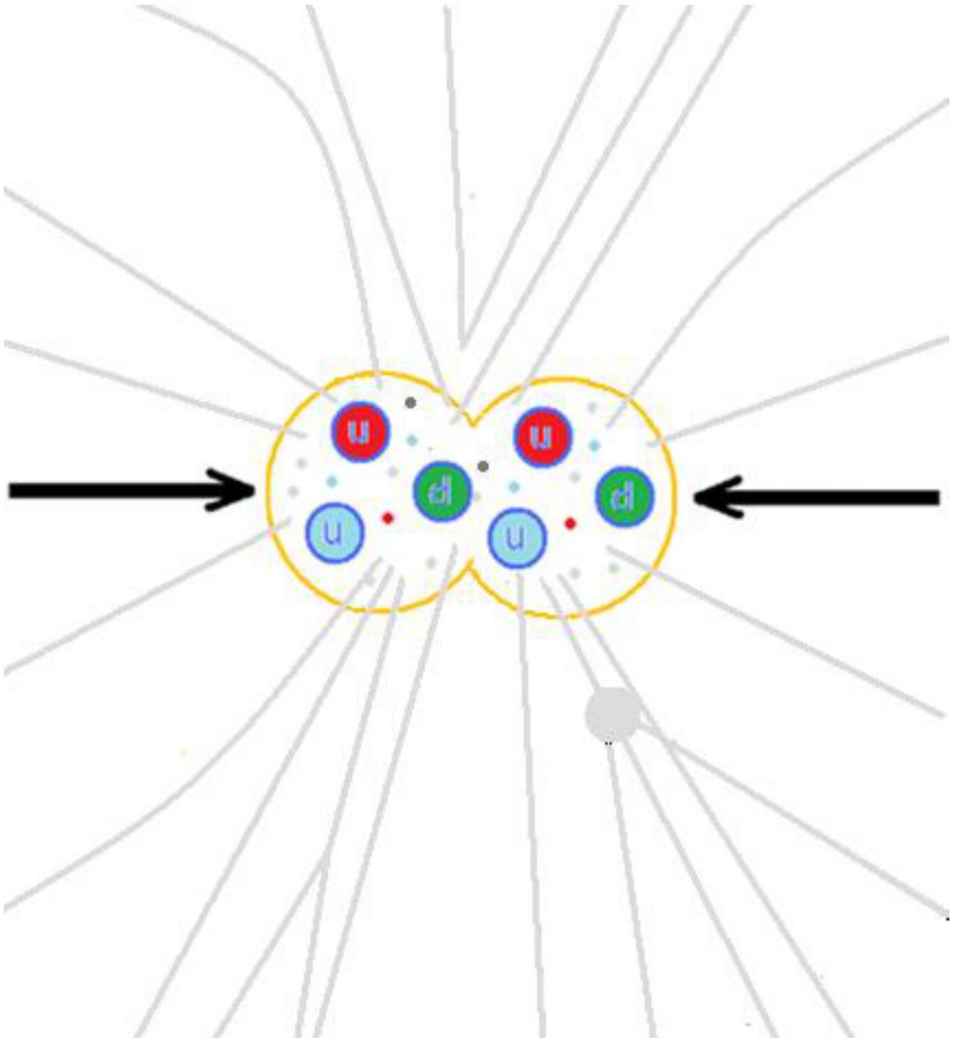



**The Z has other decays . . . but these are not what we are looking for.*

# Particle Decays

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

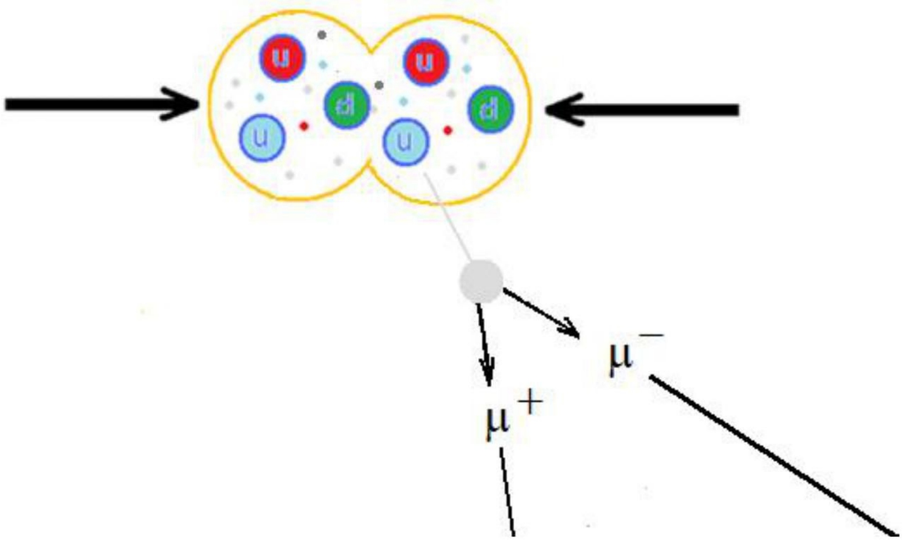
It may be hard to find the tracks we want unless we make a “cut” on low- energy tracks.



# Particle Decays

If we cut out all tracks below, say, 10 GeV momentum, the picture is clearer.

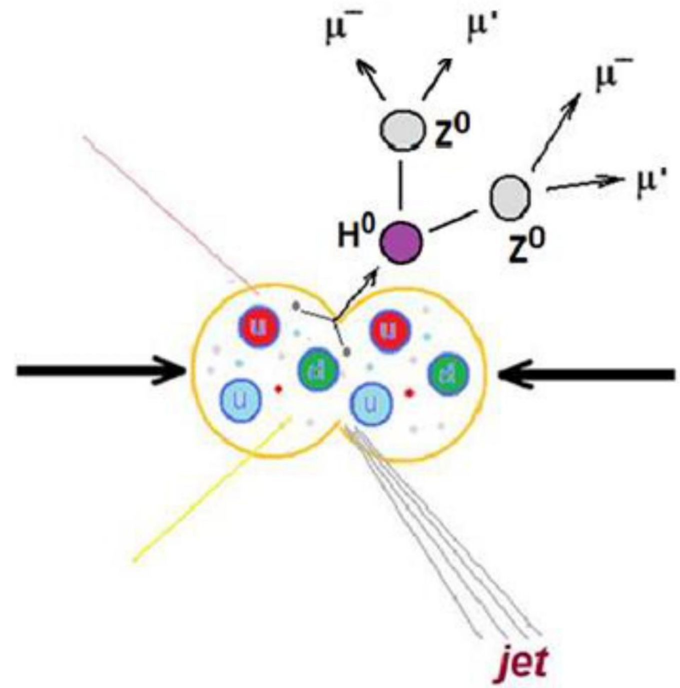
Today, we will filter many events to find Z→μ μ signals and use momentum information from these to find the mass of the Z boson.



# 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.



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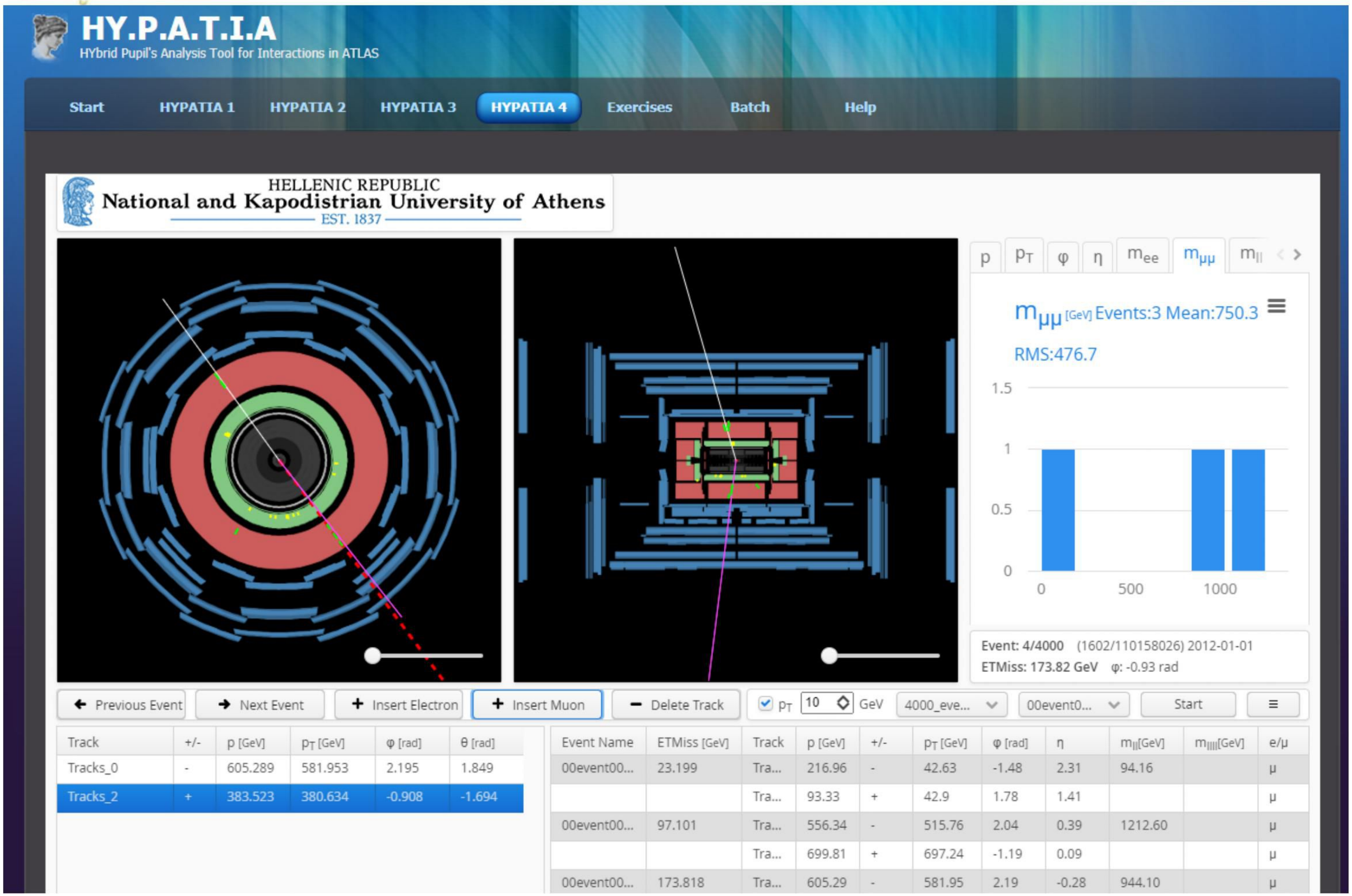
# HYPATIA 4 Event Display



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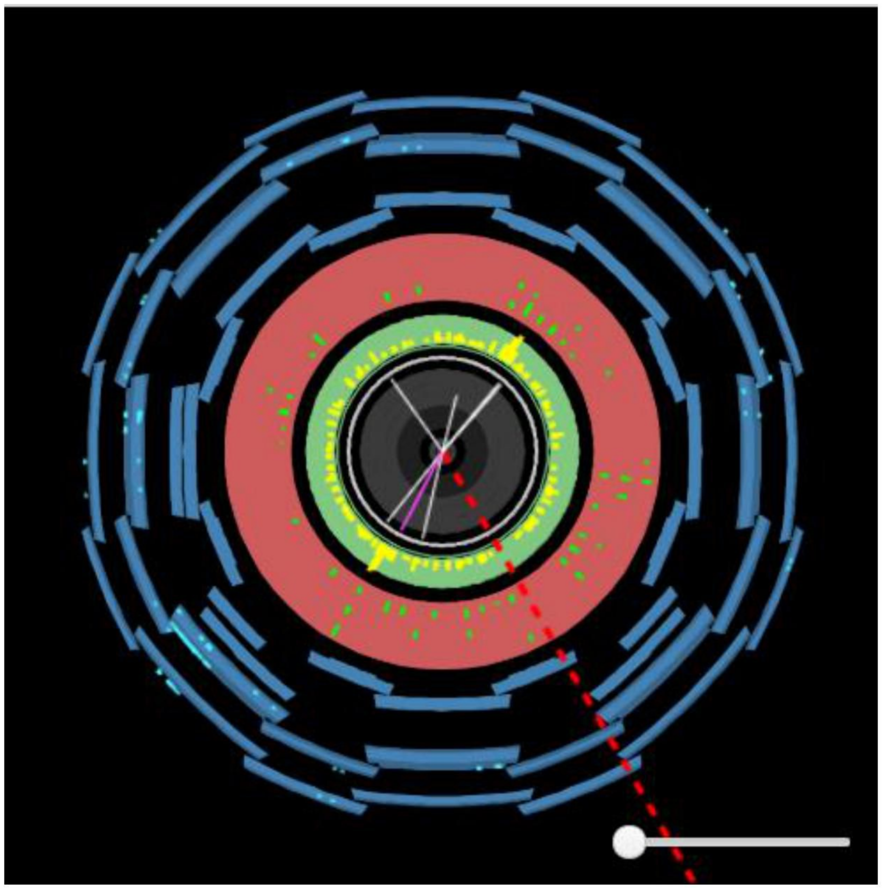
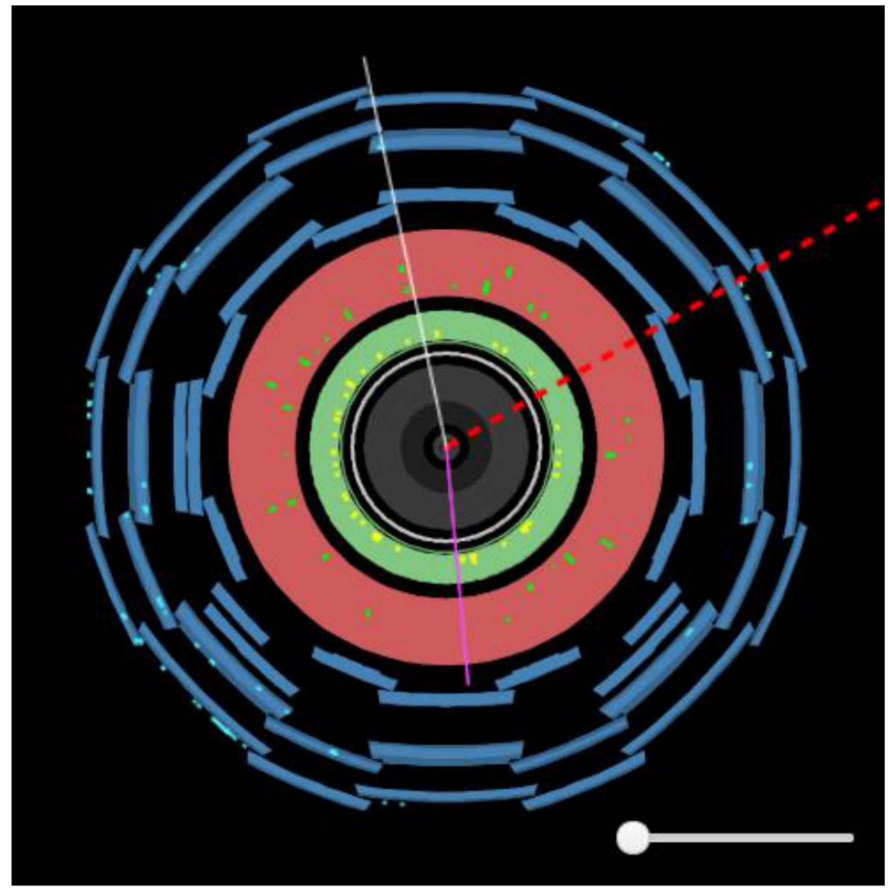
# HYPATIA Event Display





Which of these events has 2 muons? 4 muons?

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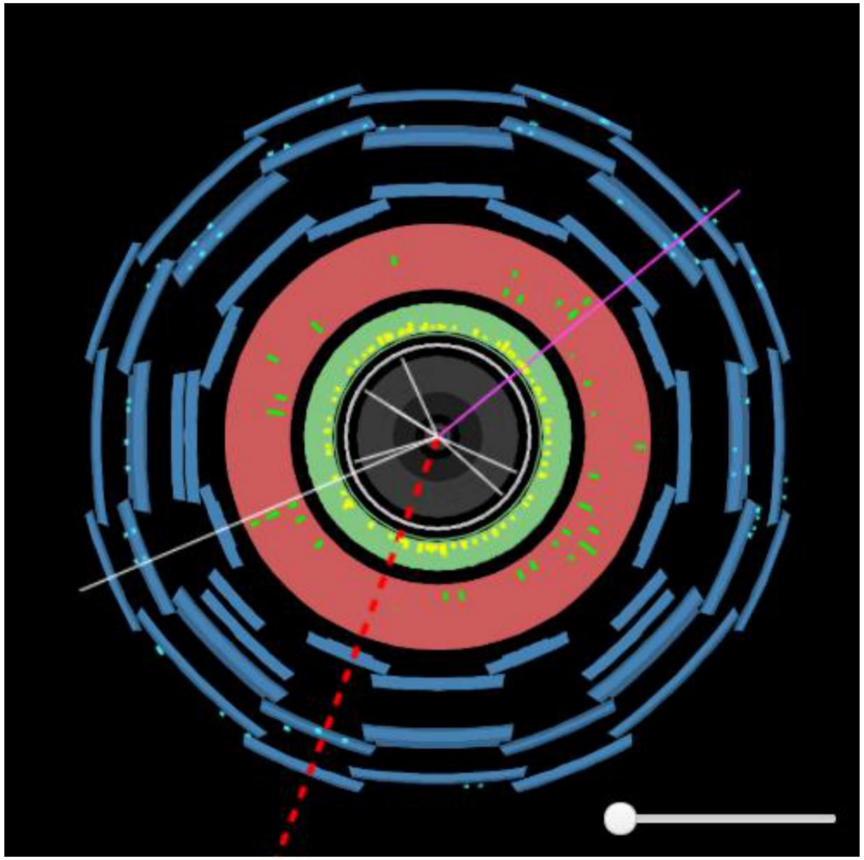
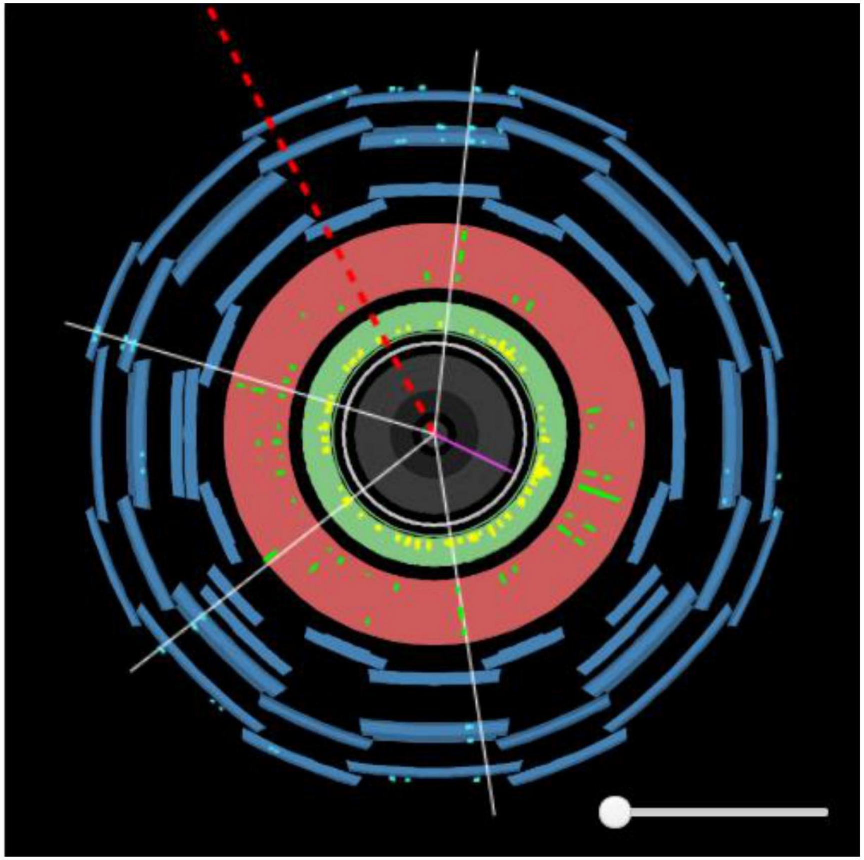
# HYPATIA Event Display





Which of these events has 2 muons? 4 muons?

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# Guidelines for BAMA Analysis

1. Pick out the long (muon) tracks that go beyond the electromagnetic calorimeter, which is green in HYPATIA.
2. Look for events with 2 or 4 muons.
3. The net charge of the muons must be zero, so a pair would be a $\mu^+$ and a $\mu^-$.
4. If an event does not have 2 or 4 muons, skip it.
5. Don't get hung up on any one event.
6. Don't worry if you do not get all 50 events.