# MINERVA

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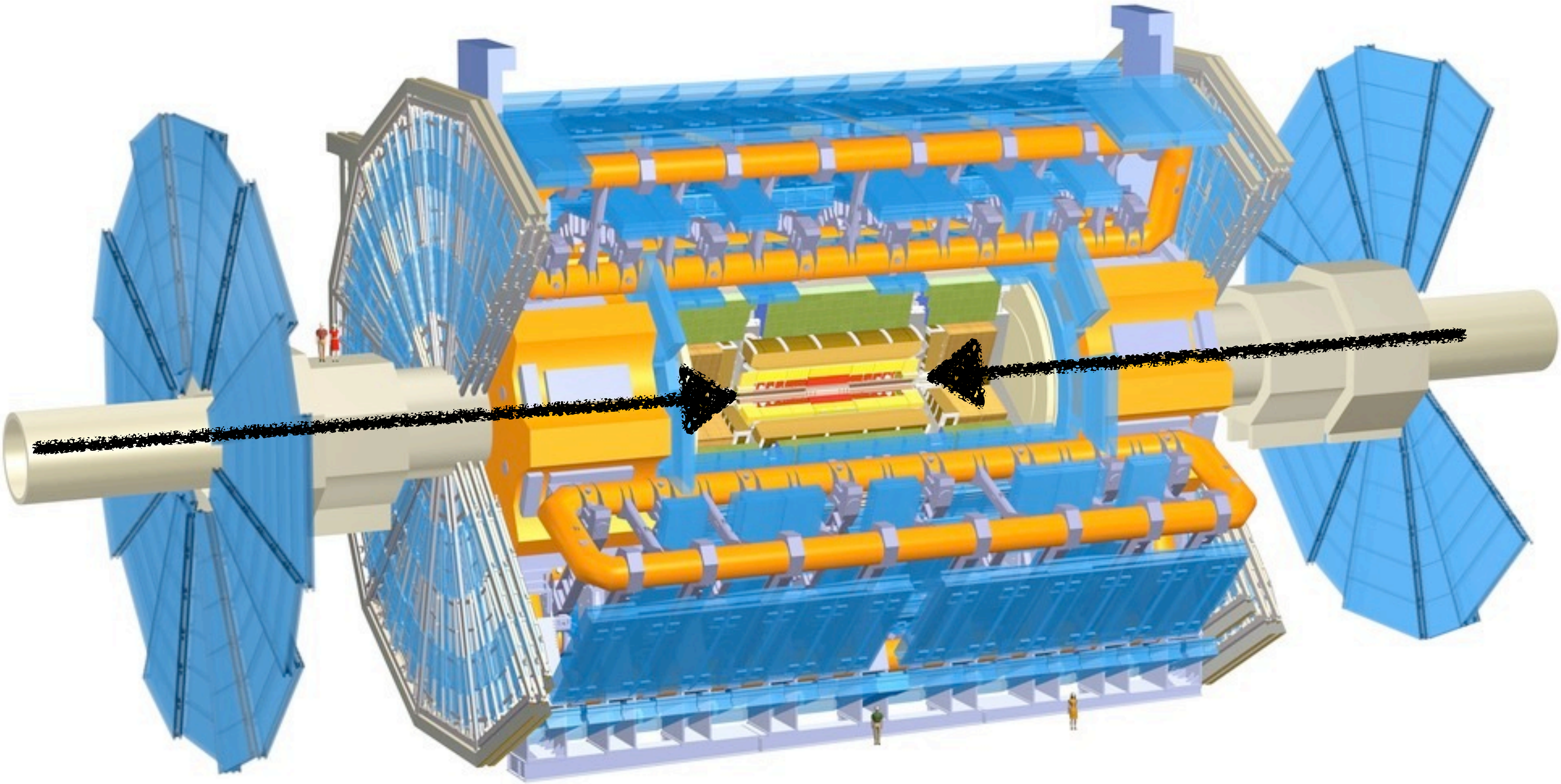
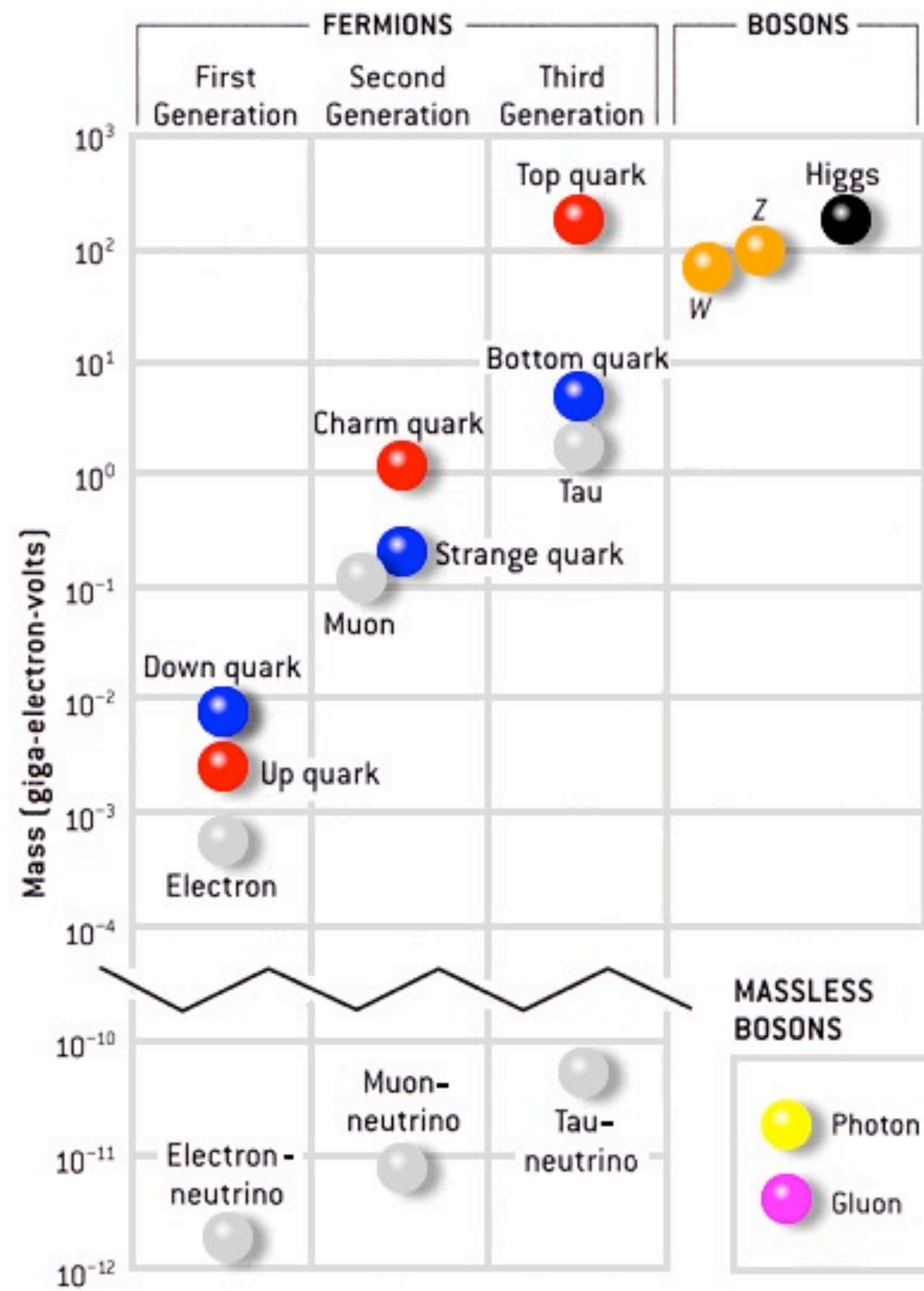
# ATLAS - A Toroidal LHC ApparatuS



# The Standard Model

- The W and Z bosons are some of the most massive particles we know of
- From $E=mc^2$, we know that the energy stored in a W is enough to create pairs of lighter particles

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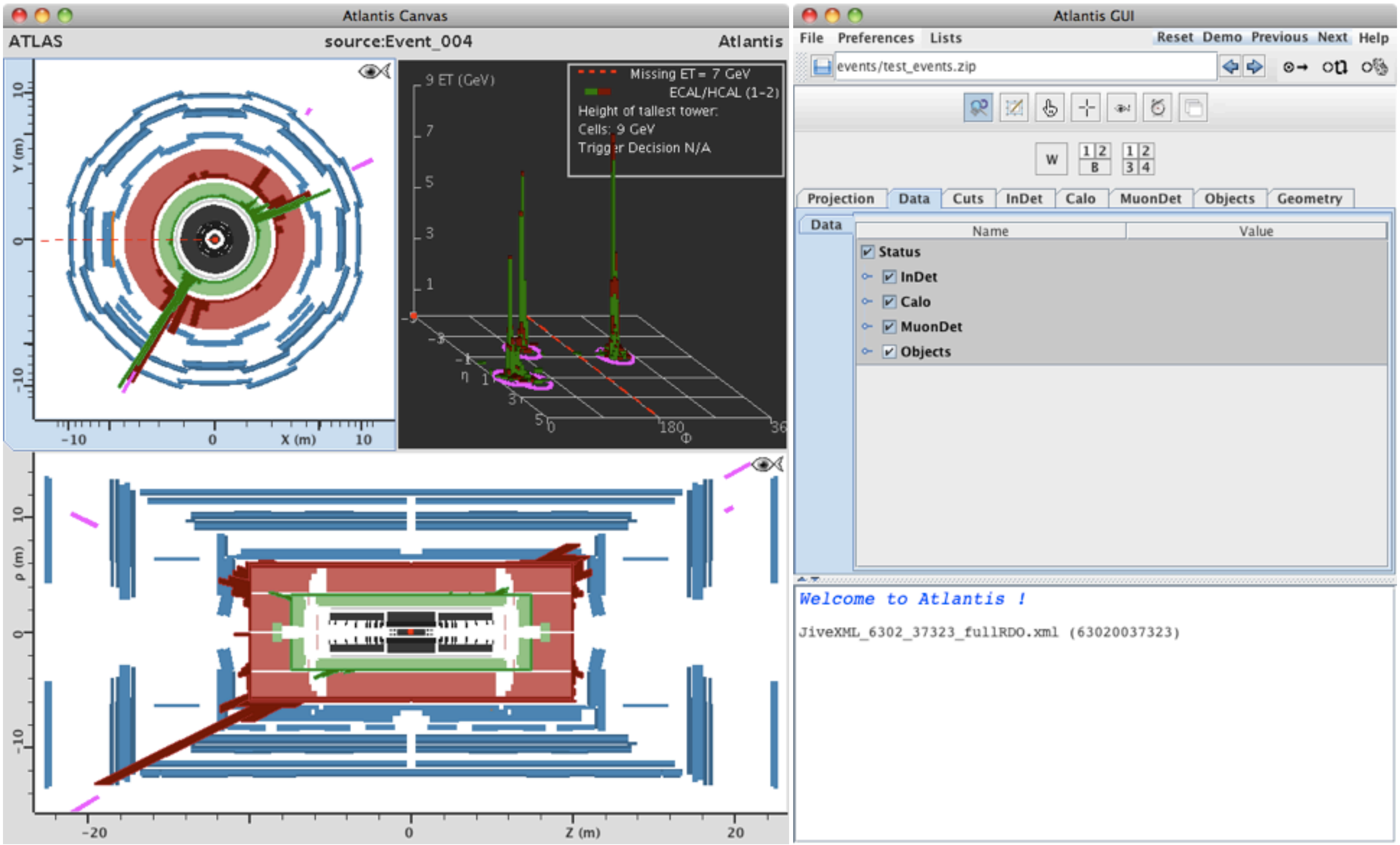
# Why do we care?

- We have studied the W and Z in much depth at previous experiments
- They are still very important in understanding new physics, however
- For example, the Higgs Boson may be massive enough to create a pair of Z bosons

# Aims of the Exercise

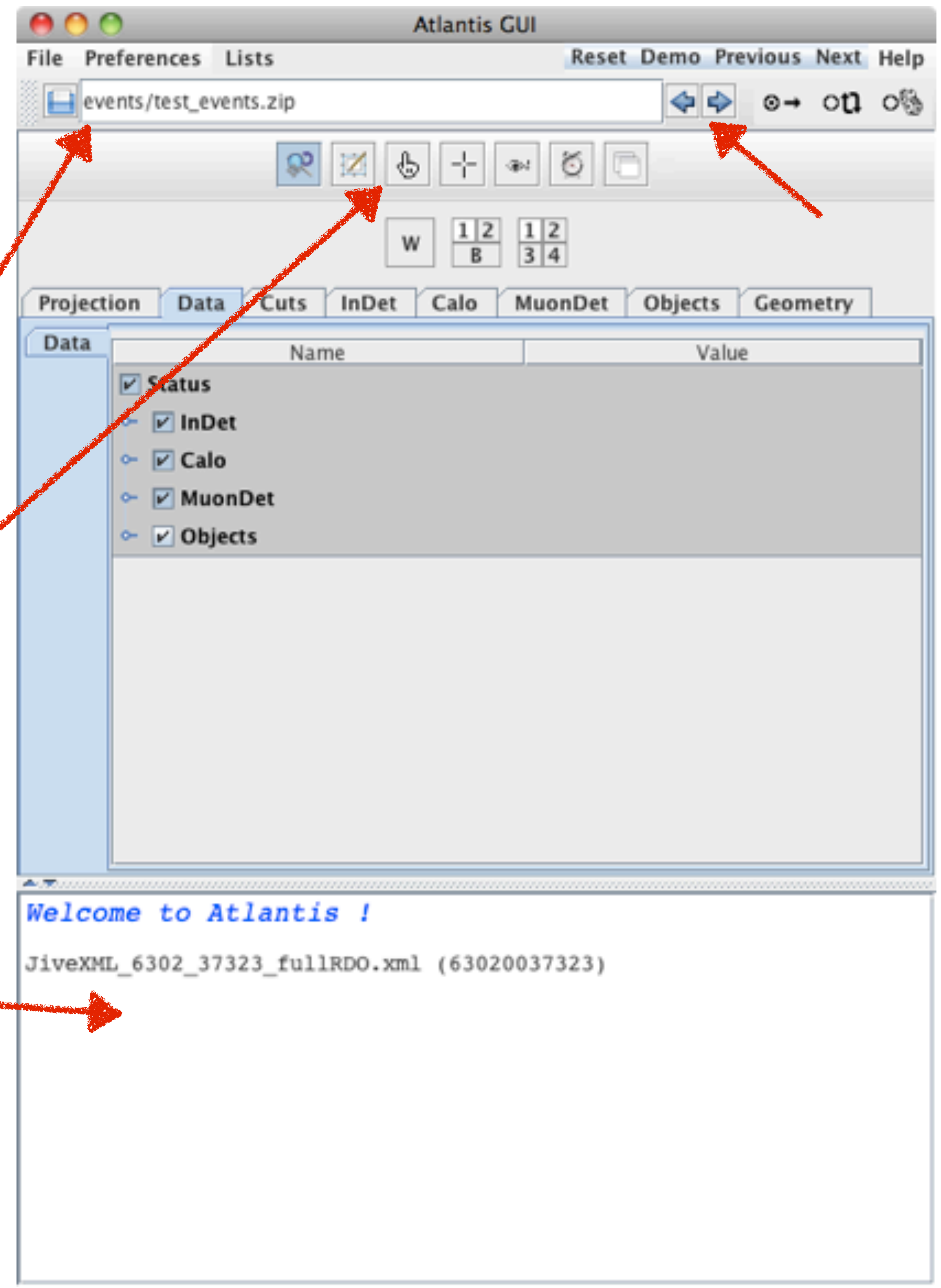
- Identify the particles detected by ATLAS with the Atlantis Event Display
- Determine the types of events you are looking at:
  - W → electron + neutrino
  - W → muon + neutrino
  - Z → electron + positron
  - Z → muon + anti-muon
  - Background from jet production

# Atlantis

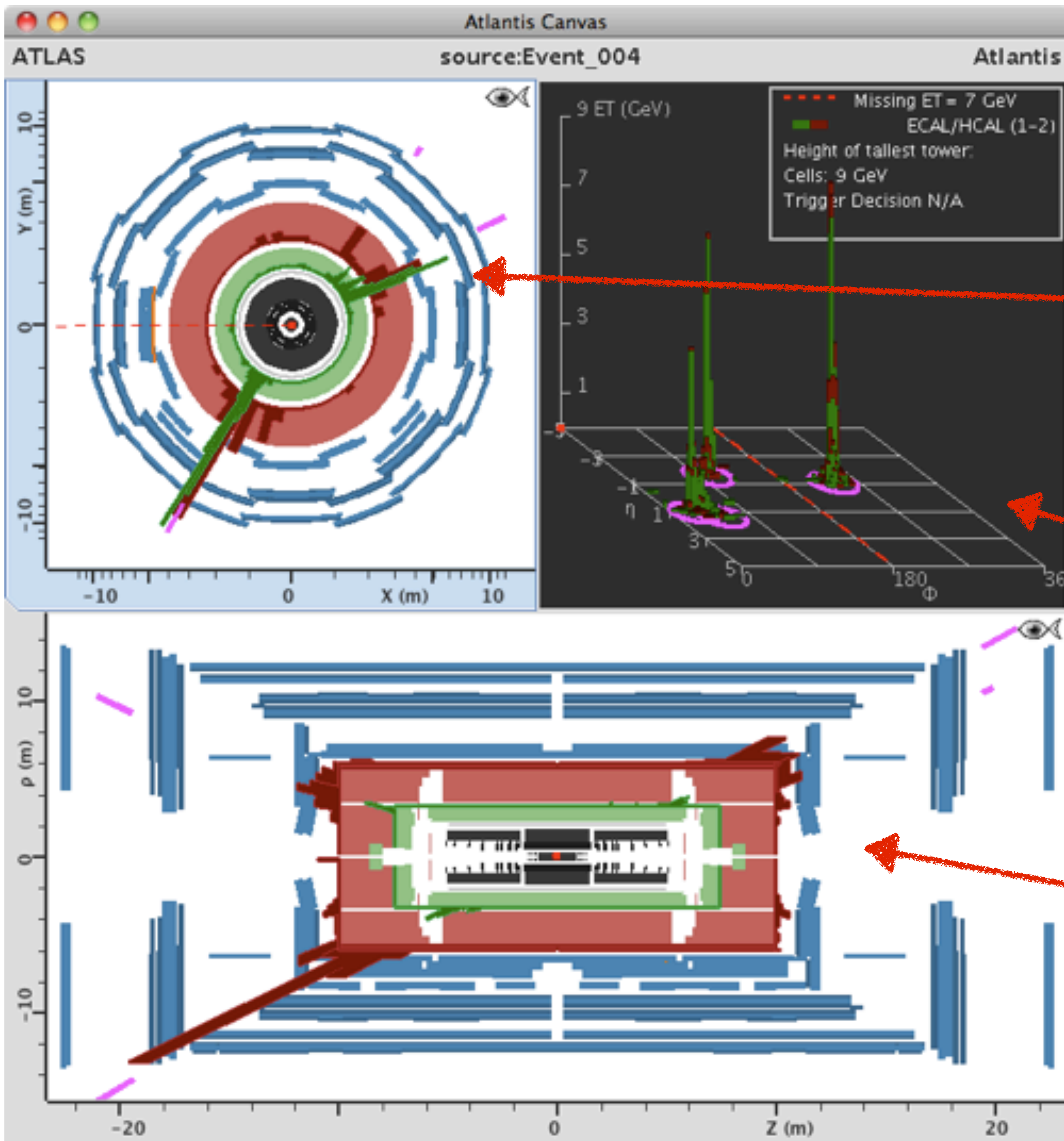

Atlantis Canvas
ATLAS
source:Event_004
Atlantis
Missing ET = 7 GeV
ECAL/HCAL (1-2)
Height of tallest tower:
Cells: 9 GeV
Trigger Decision N/A
ET (GeV)
X (m)
Y (m)
ρ (m)
Z (m)
Atlantis GUI
File Preferences Lists
Reset Demo Previous Next Help
events/test_events.zip
Projection Data Cuts InDet Calo MuonDet Objects Geometry
Data
Name
Value
Status
InDet
Calo
MuonDet
Objects
Welcome to Atlantis !
JiveXML_6302_37323_fullRDO.xml (63020037323)

# The Graphical User Interface (GUI)

- From the GUI you can:
- Load and navigate through a collection of events
- Interact with the event picture
- View output data from the event



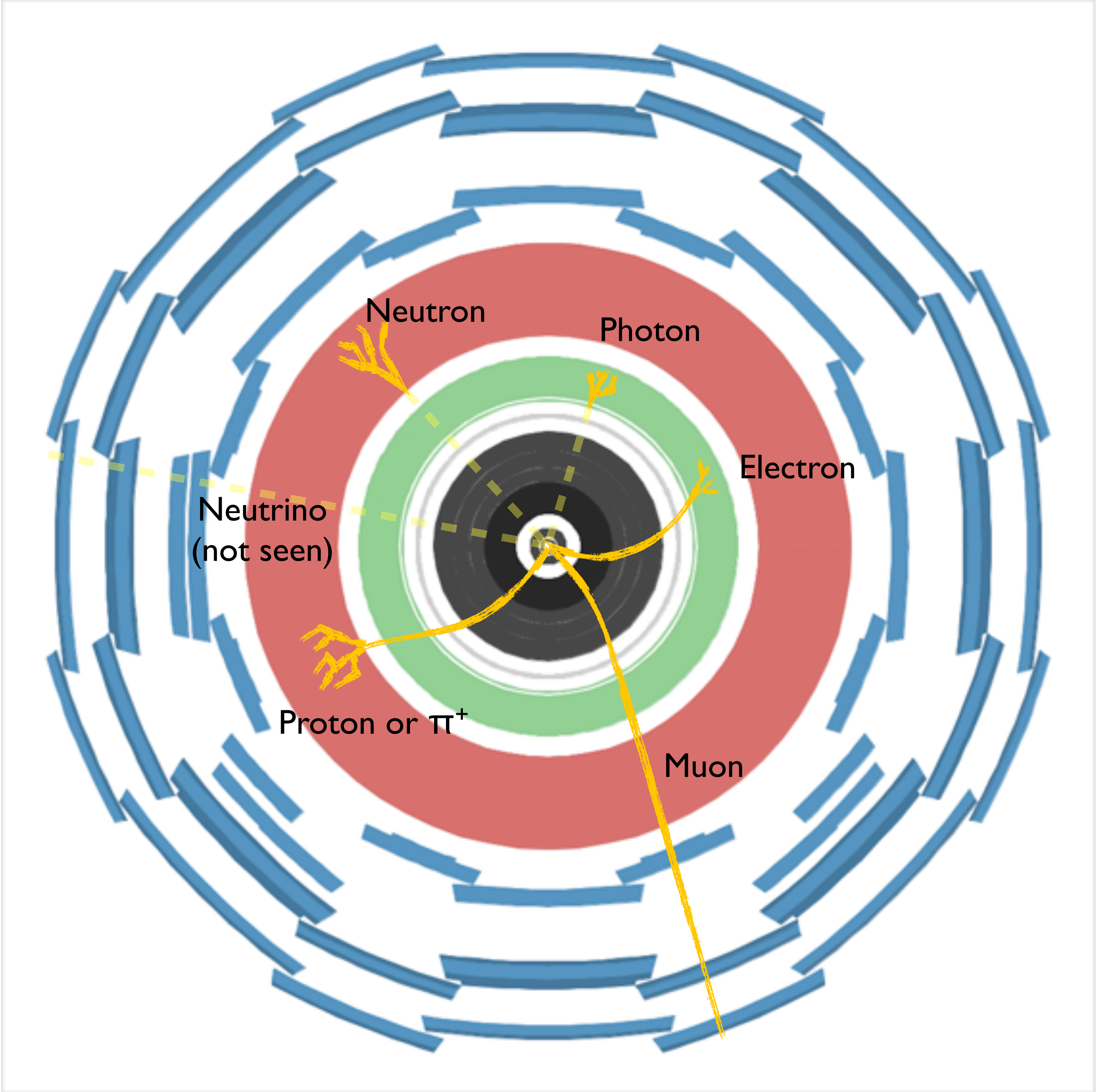
# The Canvas




- The Canvas shows:
- The end-on view of the detector
- Energy shown in 'rolled out' calorimeters
- The side view of the detector

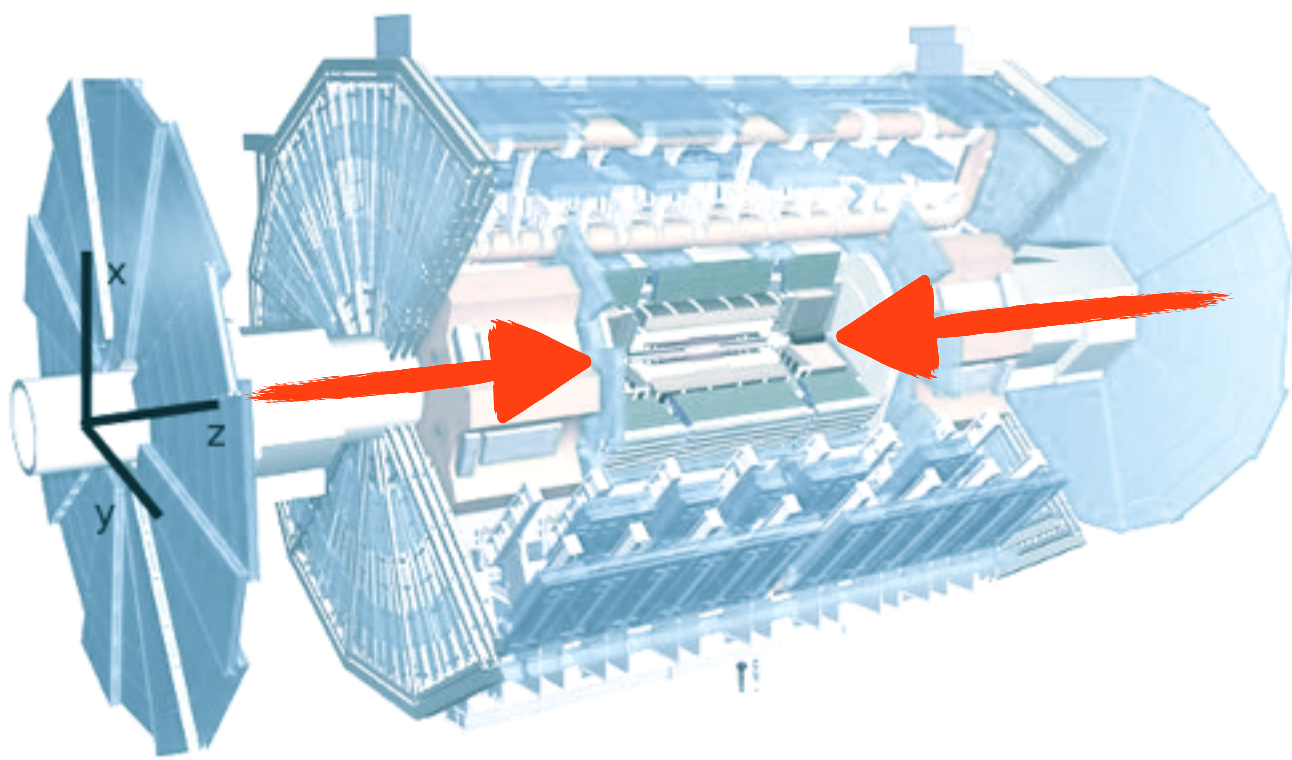
# Identifying Particles

- The Inner Detector measures the charge and momentum of charged particles, neutral particles don't leave tracks
- The Electromagnetic Calorimeter measures the energy of electrons, positrons and photons
- The Hadronic Calorimeter measures the energy of particles containing quarks, such as protons, pions and neutrons
- The Muon Spectrometer measures the charge and momentum of muons



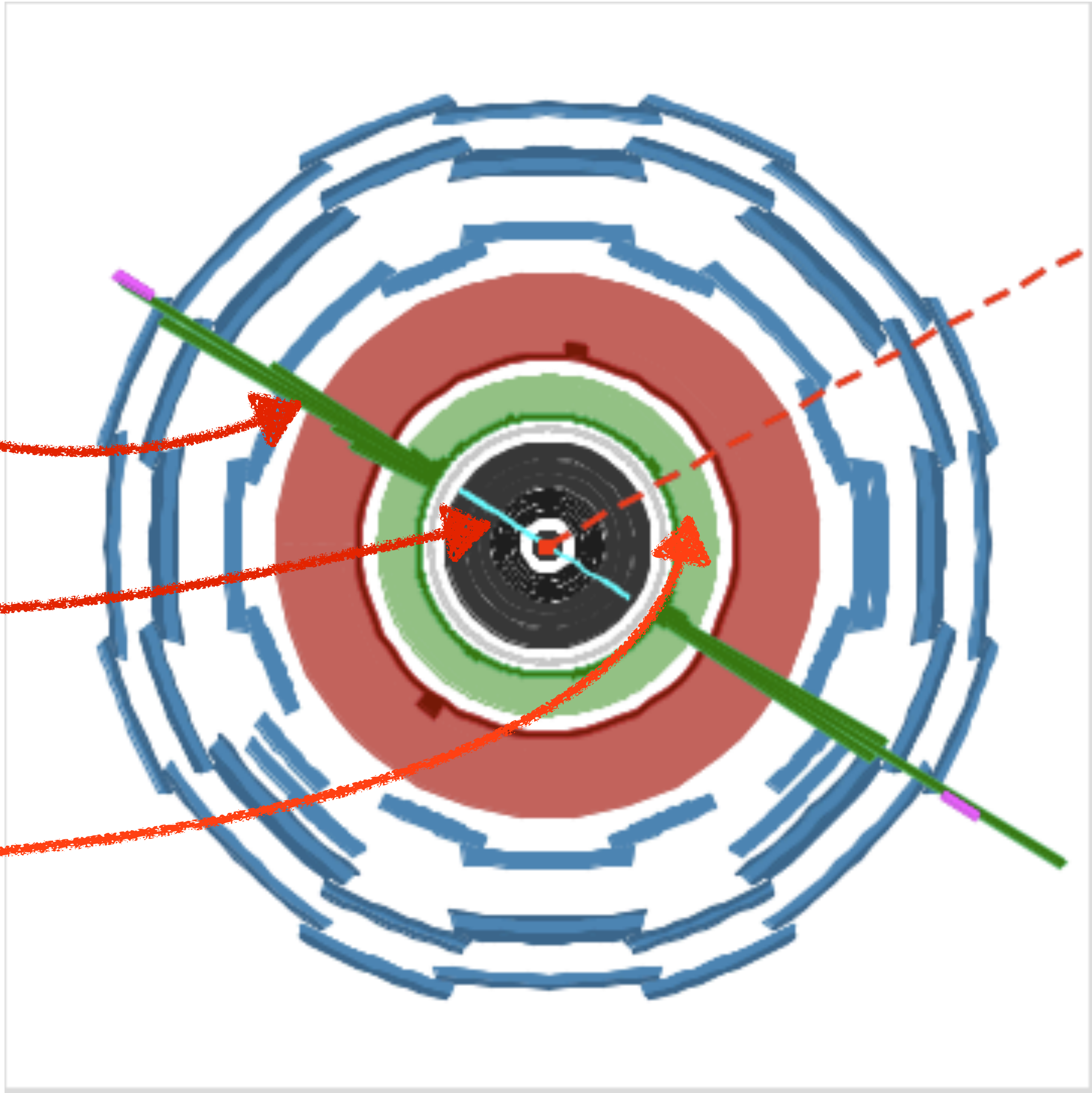
# Explanation: Missing Energy

- Before colliding, the protons in ATLAS move only in the z-direction
- Therefore, we know that in x and y, the momentum is zero and this must be conserved after the collision
- If a neutrino is created, the detector doesn't see it, so when we add up the momenta of all the particles we see, there is a deficit - this is Missing Energy



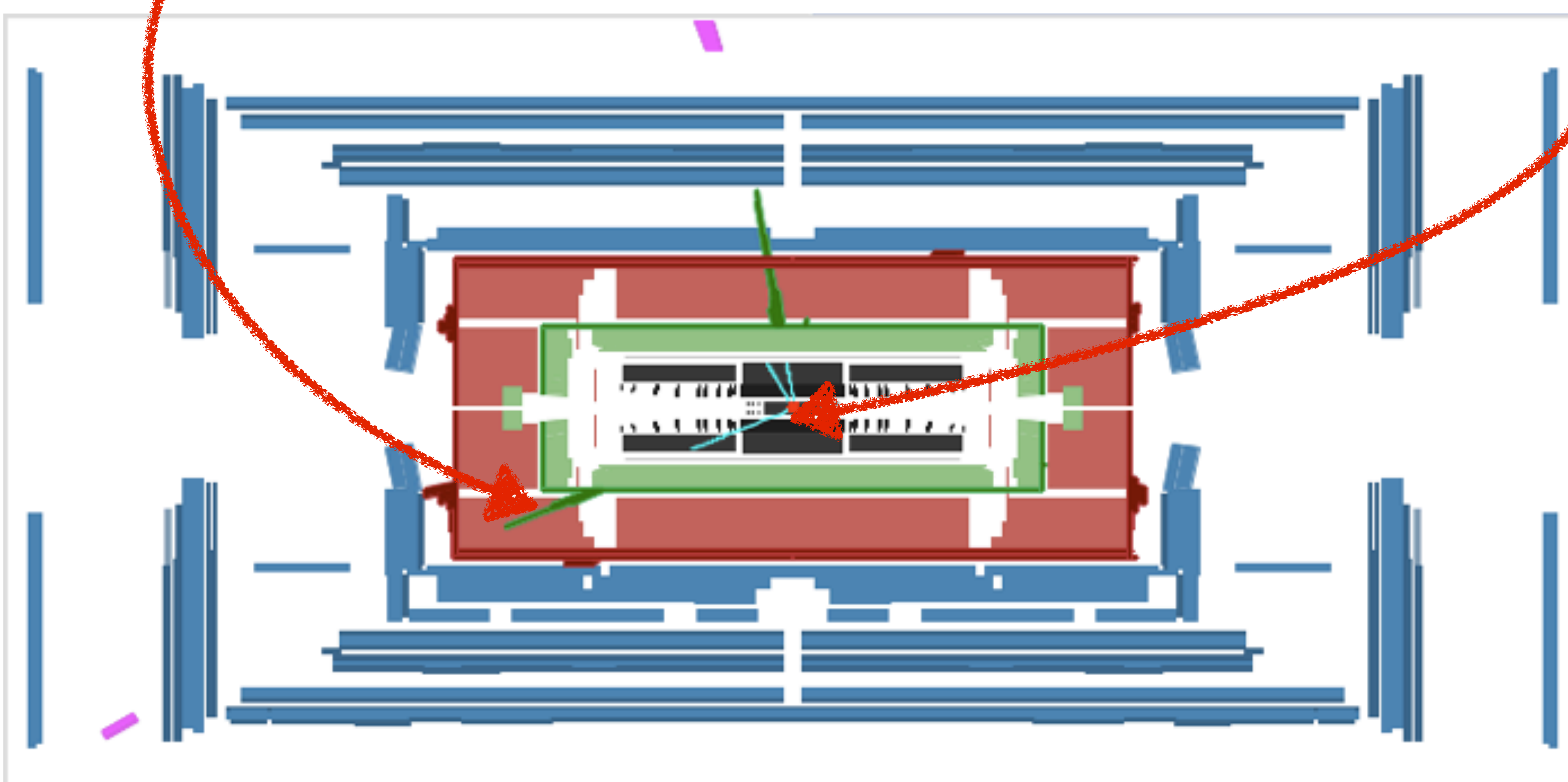
# Example: Finding Electrons

- First look at end-on view:
- Energy deposit in EM calorimeter
- Track in Inner Detector
- 'Missing Energy' represented by dashed line



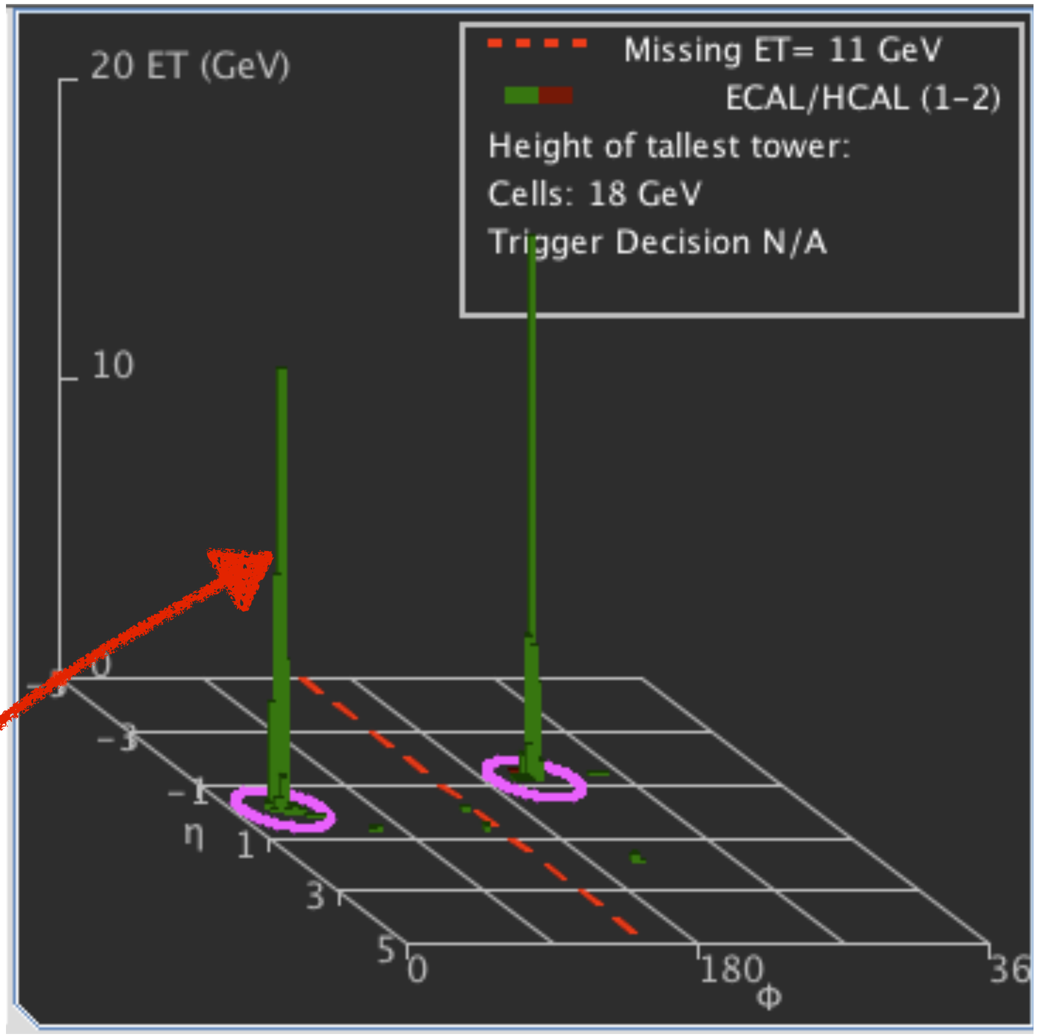
# Example: Finding Electrons

- In the side view:
- Track in Inner Detector
- Energy deposit in EM calorimeter



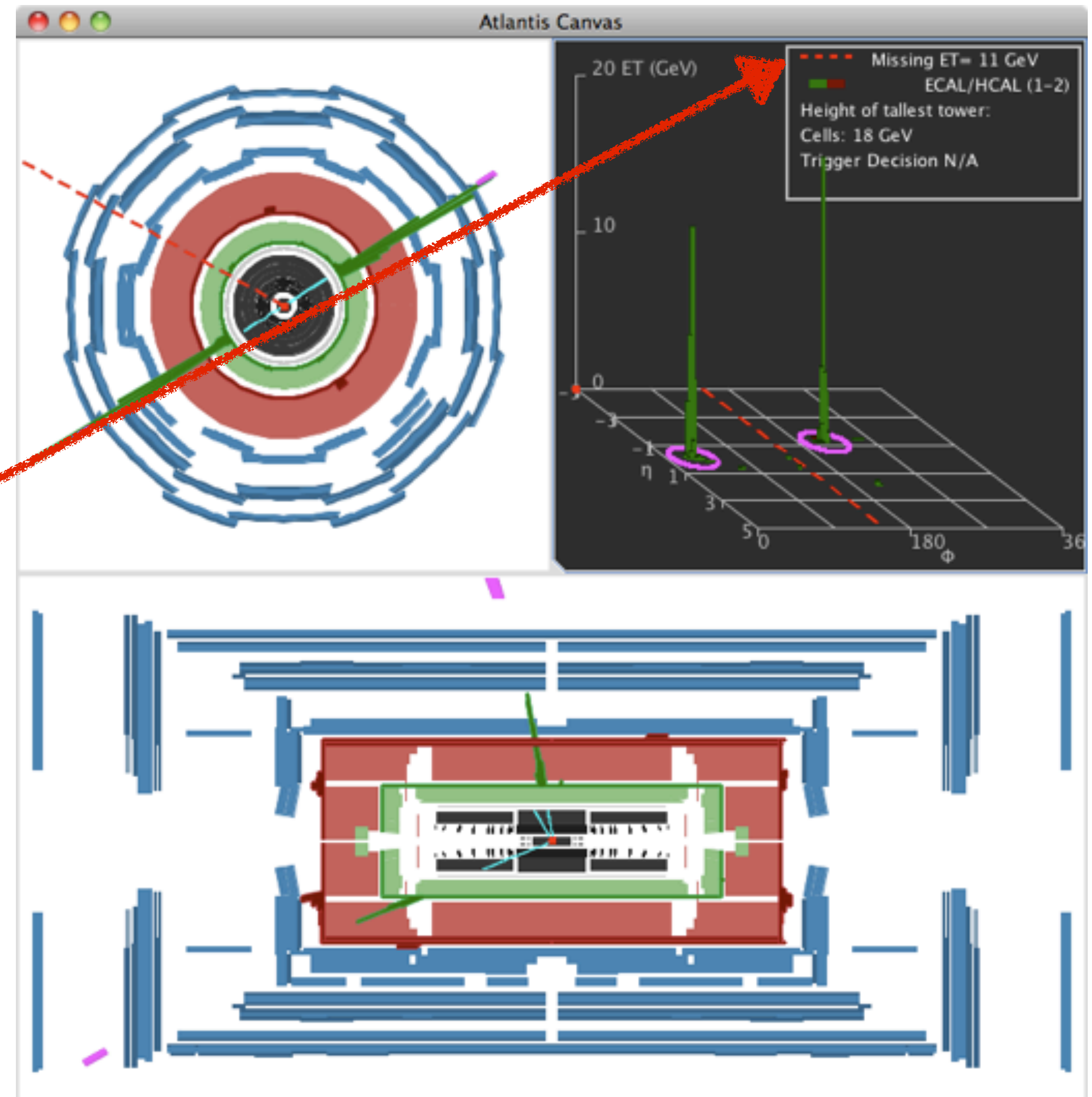
# Example: Finding Electrons

- This plot is known as the 'Lego Plot'
- Think of it as showing the calorimeters rolled out flat
- In the Lego Plot:
- Energy deposited in the EM calorimeter (green)



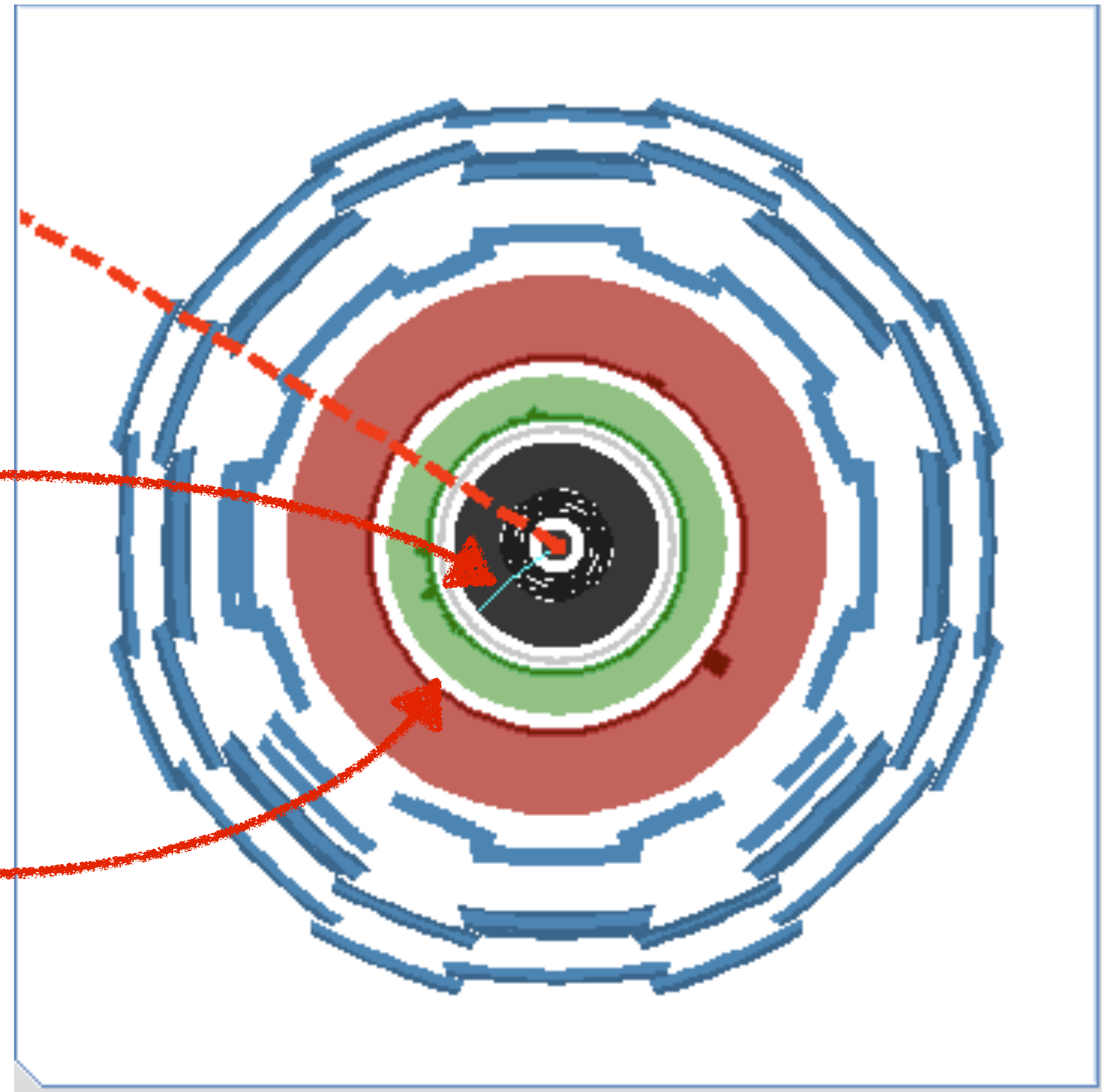
# Example: Classifying an Event

- This event actually contains 2 electrons
- With very little missing energy
- Therefore this event must be a $Z \rightarrow ee$



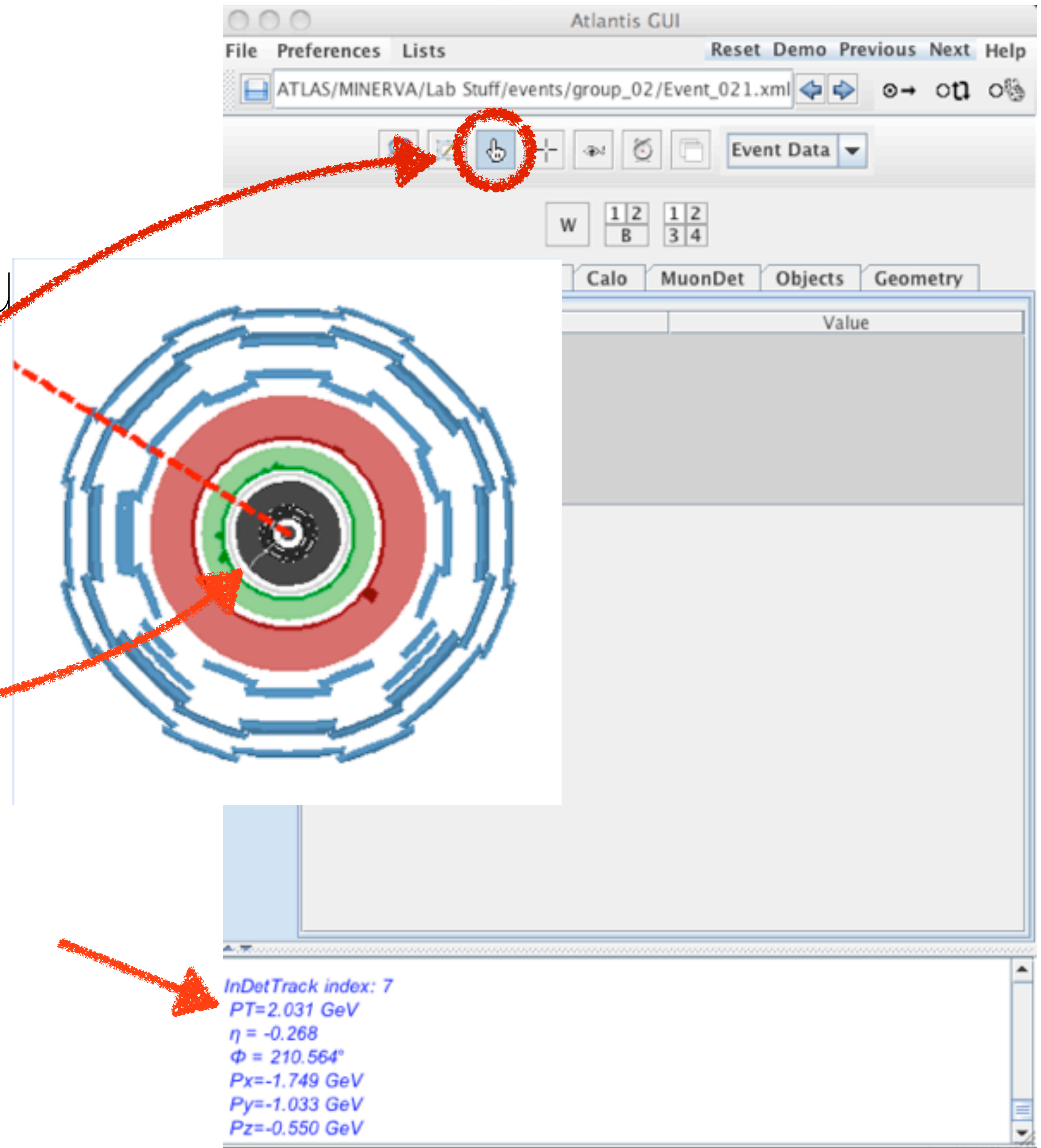
# Example: Another Electron?

- Is this another electron?
- Track in Inner Detector
- But not much calorimeter activity



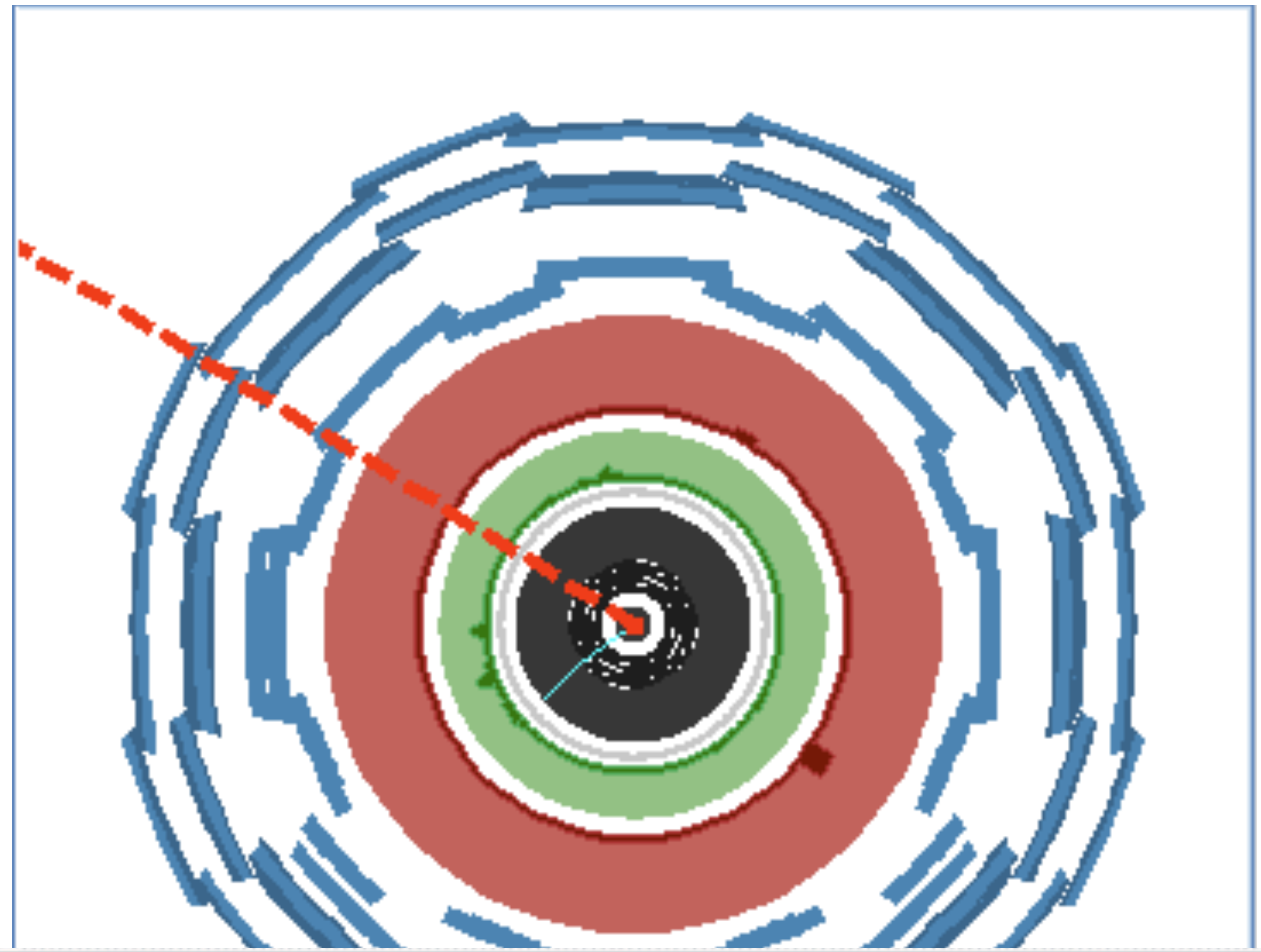
# Check the Output

- Use the 'Pick' tool to measure the momentum of the particle
- Click 'Pick'
- Click on the track
- The track will turn grey and data will appear in the output box



# Check the Output

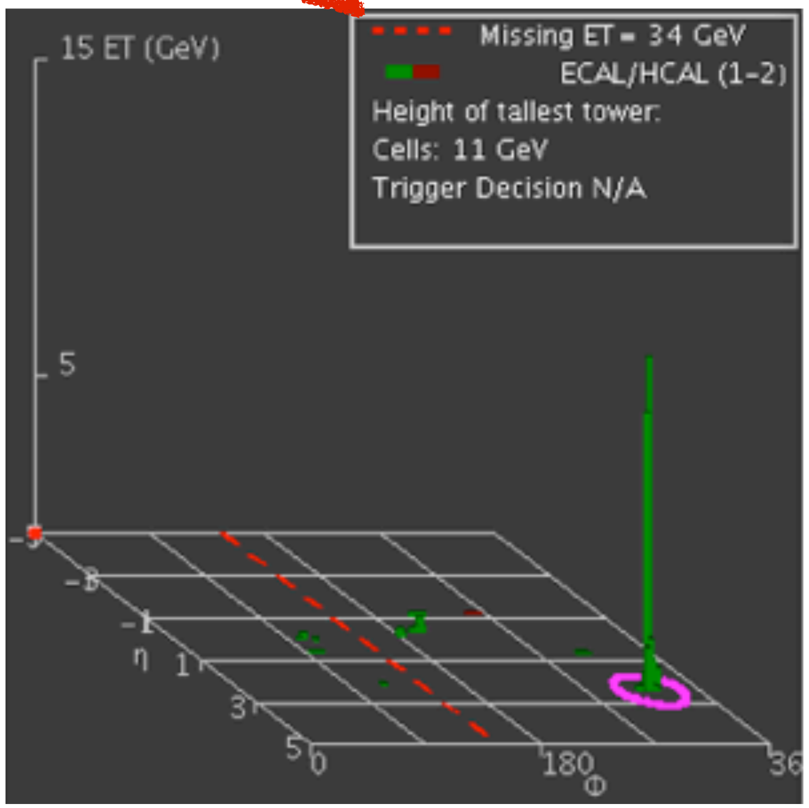
- This track has too low momentum (*P*) to be of interest
- The lack of calorimeter activity also suggests that this is an uninteresting track
- This means nothing happened in the barrel region...

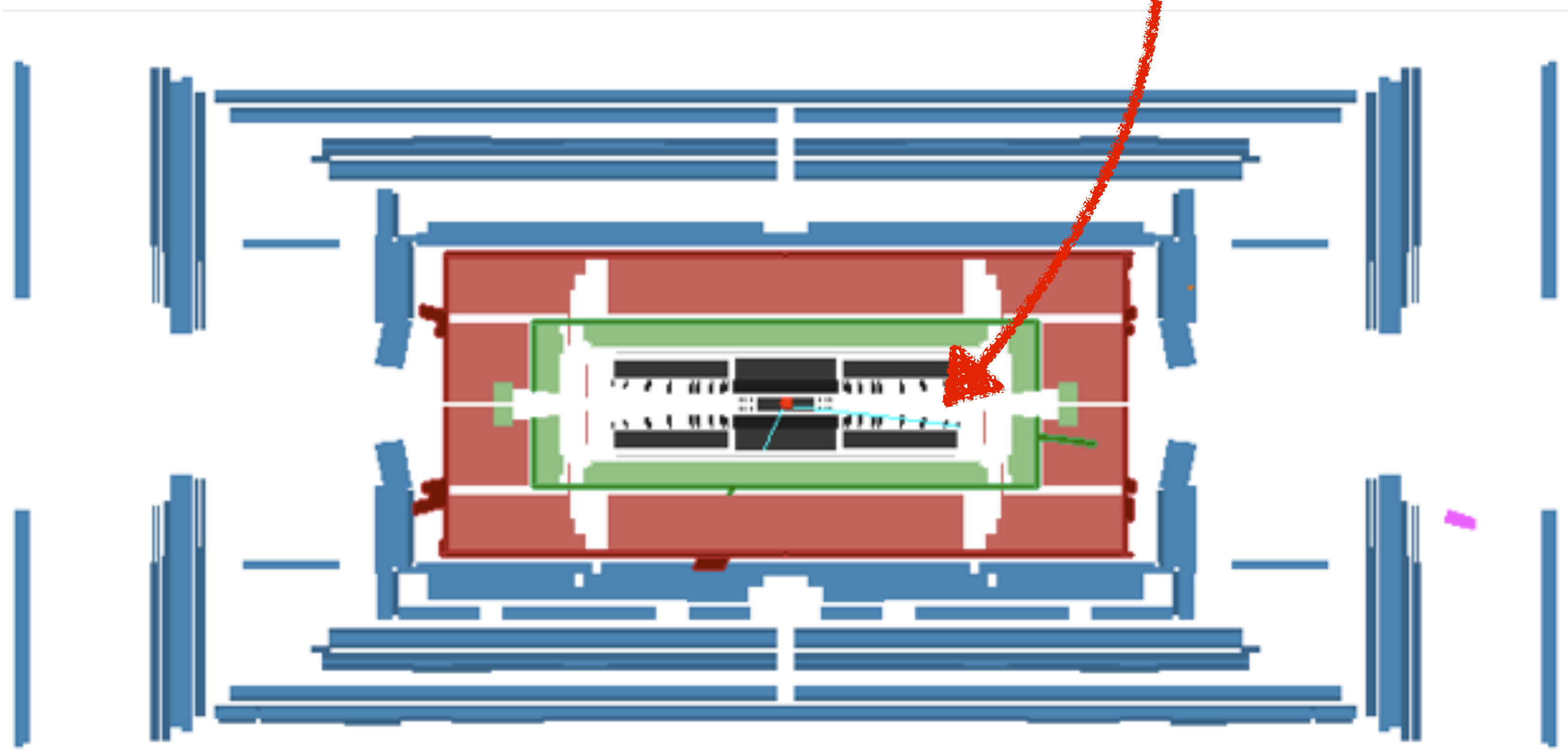


InDetTrack index: 7
PT=2.031 GeV
$\eta$ = -0.268
$\Phi$ = 210.564°
Px=-1.749 GeV
Py=-1.033 GeV
Pz=-0.550 GeV

# Checking the Endcaps

- This could still be an interesting event, however
- Check in the other views
- Here is a track with an energy deposit in the EM calorimeter endcap
- Also a large amount of Missing Energy
- This event is a $W \rightarrow e\nu$

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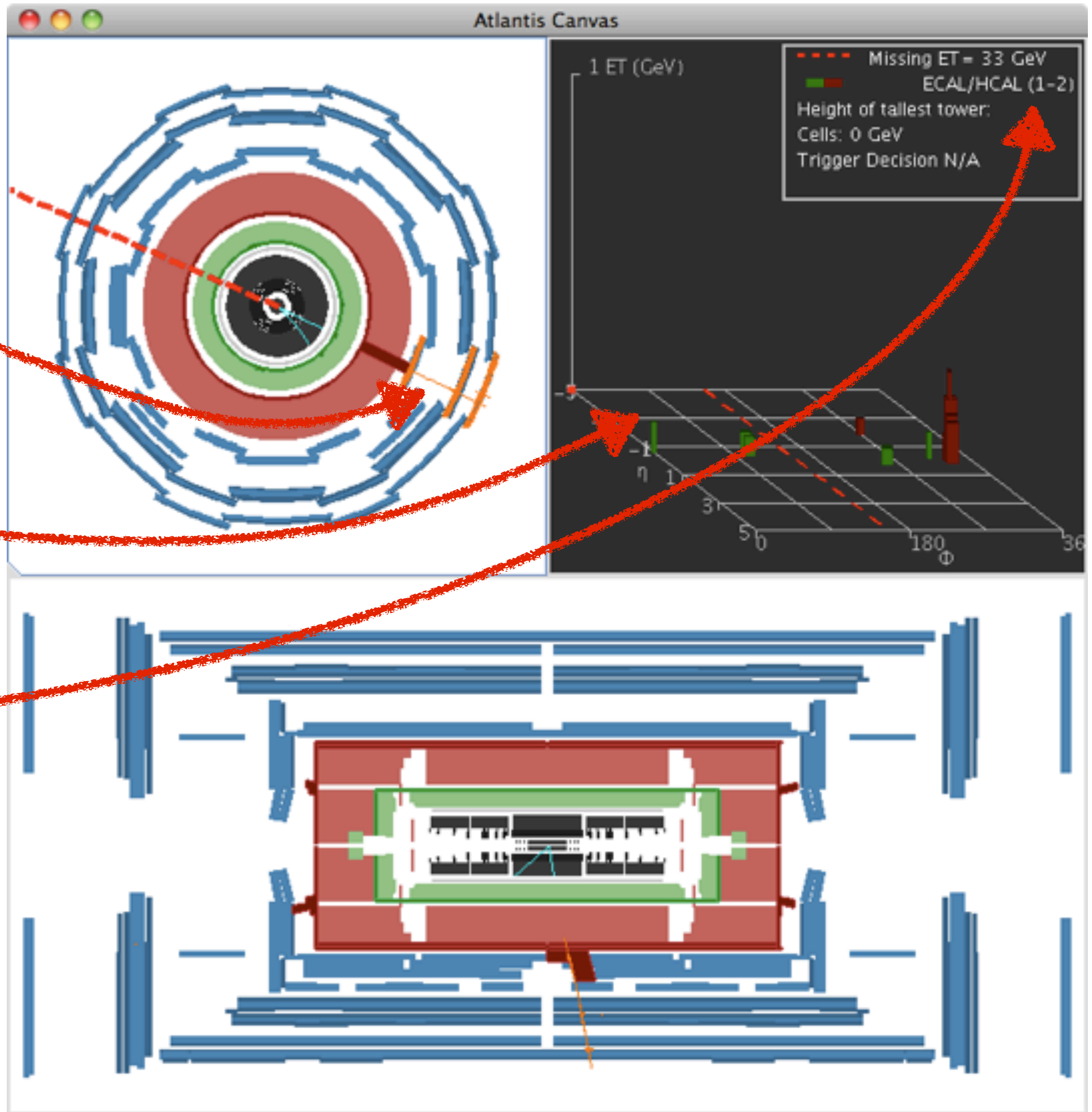
# Identifying Electrons

- Now we know how to classify events containing electrons
- Make sure you make note of which events you have seen as you go along
- We are not only looking at electrons, however...

# Example: Finding Muons

- Track in Inner Detector and Muon Spectrometer
- Not much calorimeter activity
- Lots of missing energy
- This event is a $W \rightarrow \mu\nu$

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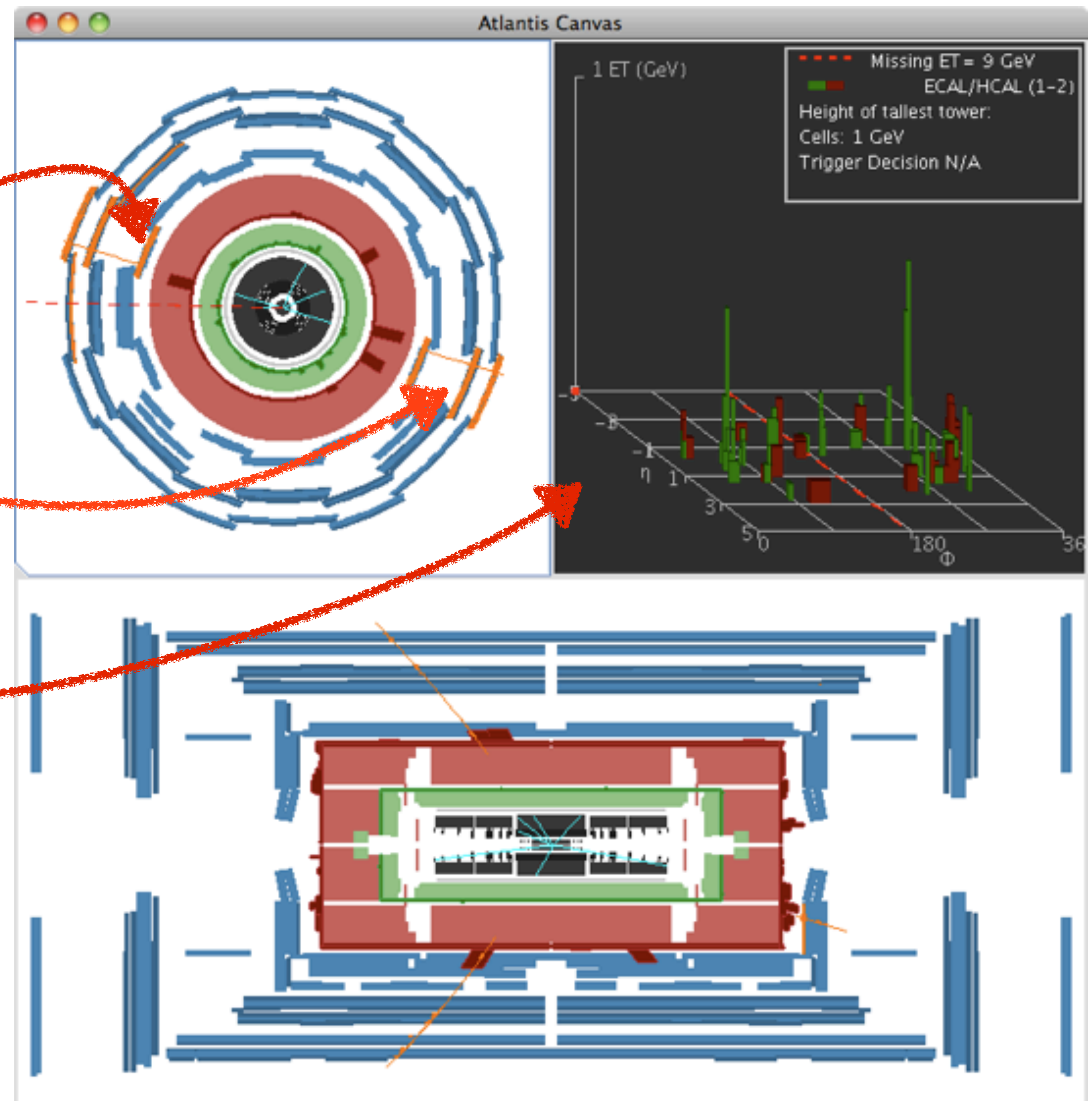
# Example: More Muons

- Two inner detector tracks extending into the Muon Spectrometer
- Not much calorimeter activity
- This event is a Z→μμ

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# Identifying Muons

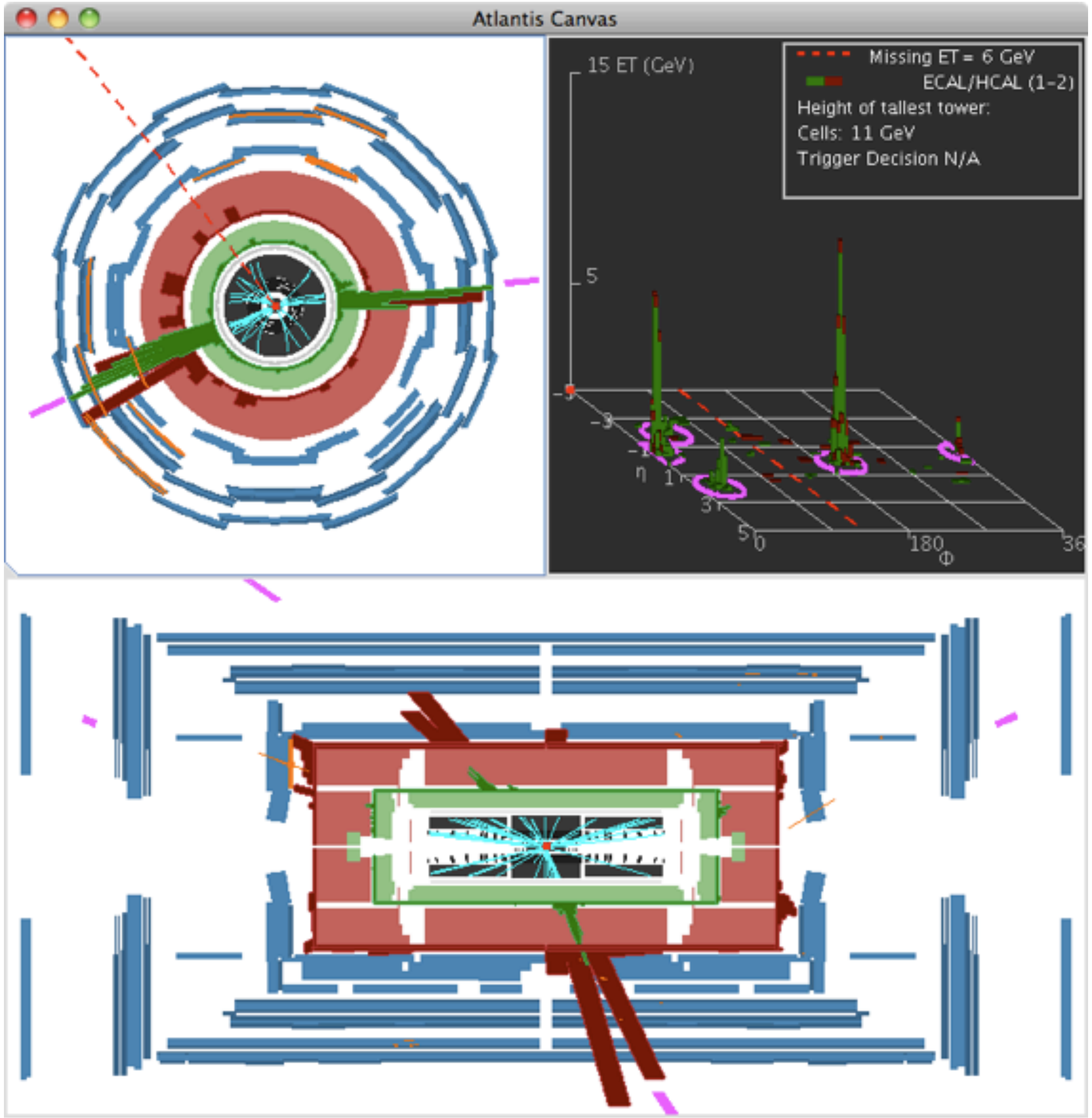
- Now we know how to identify muons
- You now have everything you need to identify the interesting events, but be careful…

# Background

- Some events may look interesting, but are just background events
- This may be due to the production of streams of hadrons (known as jets), for example
- So, we also need to know how to identify the background events…

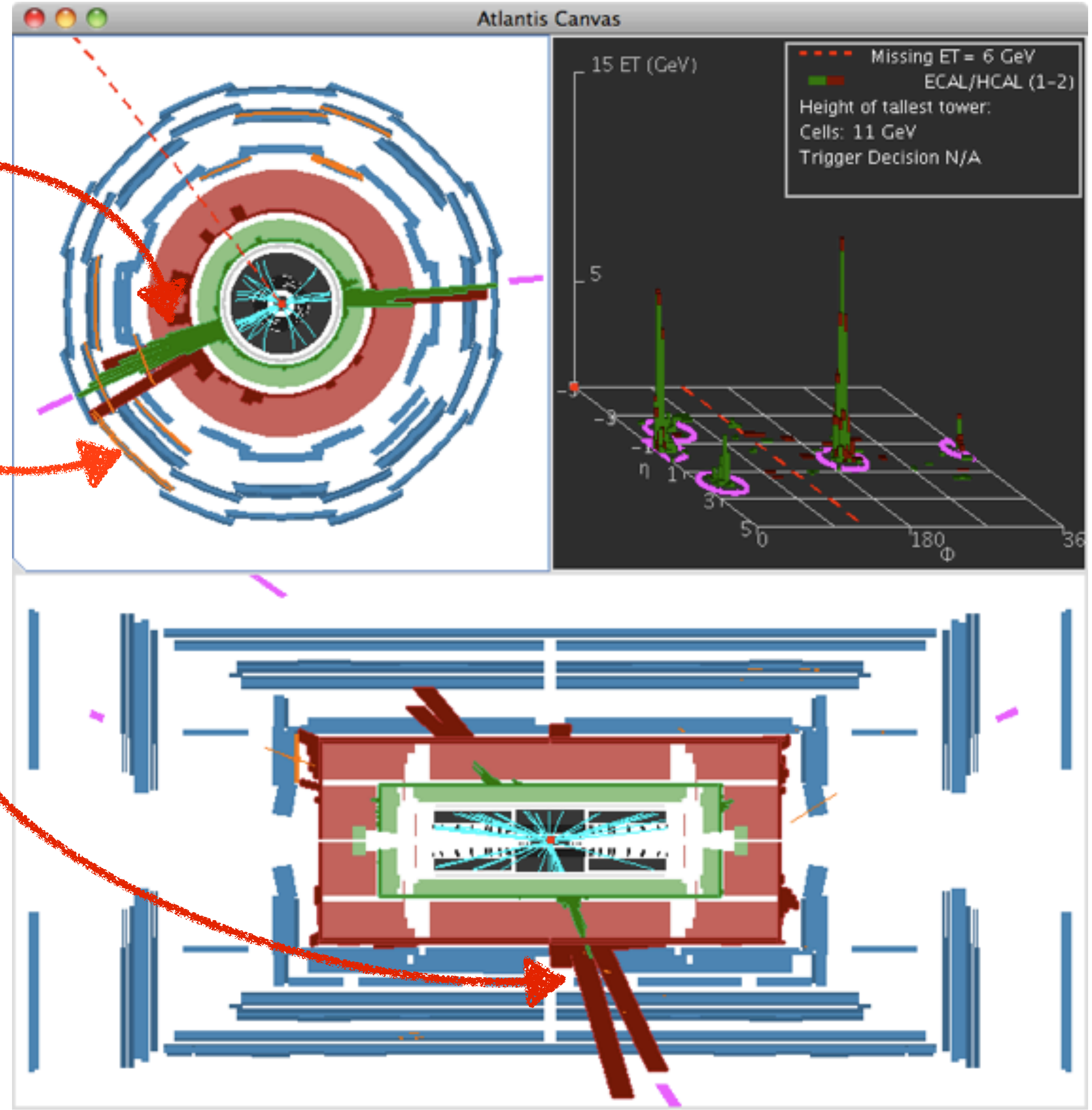
# Identifying Background

- Could this event contain an interesting electron or muon?



# Identifying Background

- Lots of EM calorimeter activity and some Muon hits
- But also a lot of Hadronic calorimeter activity
- This event is a background event

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# Summary

- Look through your group of events and classify each event into one of the five categories:
  - $Z \rightarrow ee$
  - $W \rightarrow e\nu$
  - $W \rightarrow \mu\nu$
  - $Z \rightarrow \mu\mu$
  - Background

# Summary

- Once you have identified all of your events and written down your results, open up the Higgs boson event group
- One of the events in this group is a Higgs boson, which can decay in one of these ways:
  - $H \rightarrow ZZ \rightarrow \mu\mu\mu\mu$, $H \rightarrow ZZ \rightarrow eeee$, or $H \rightarrow ZZ \rightarrow ee\mu\mu$

# Summary

- We will now move over to the computer rooms
- You will get a set of instructions which tell you how to get started with MINERVA
- Have fun!

# Credits

- MINERVA is developed by staff and students at RAL and the University of Birmingham
- Atlantis is developed by staff and students at Birmingham, UCL and Nijmegen