INTRODUCTION TO THE MEASUREMENT

MAIN CHARACTERS OF OUR MEASUREMENT

The **W boson**

The **Higgs boson**

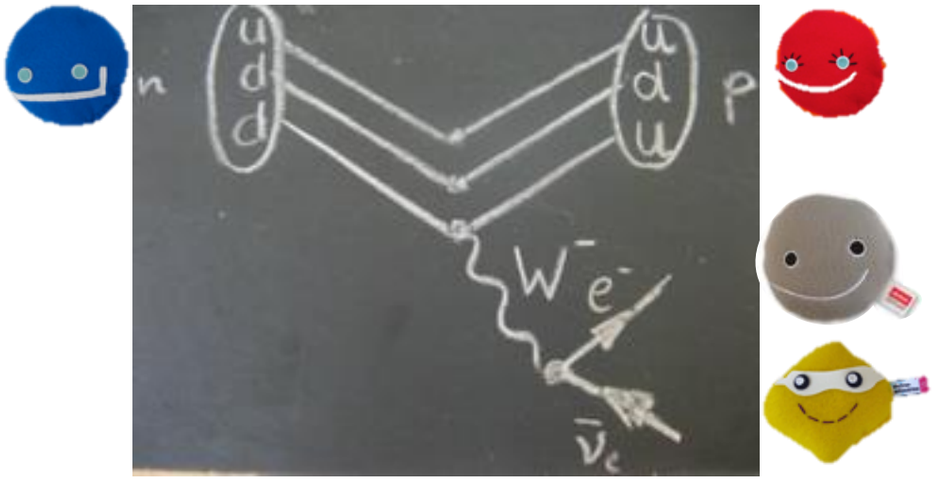
THE W-BOSON

The **W boson**

The **Higgs boson**

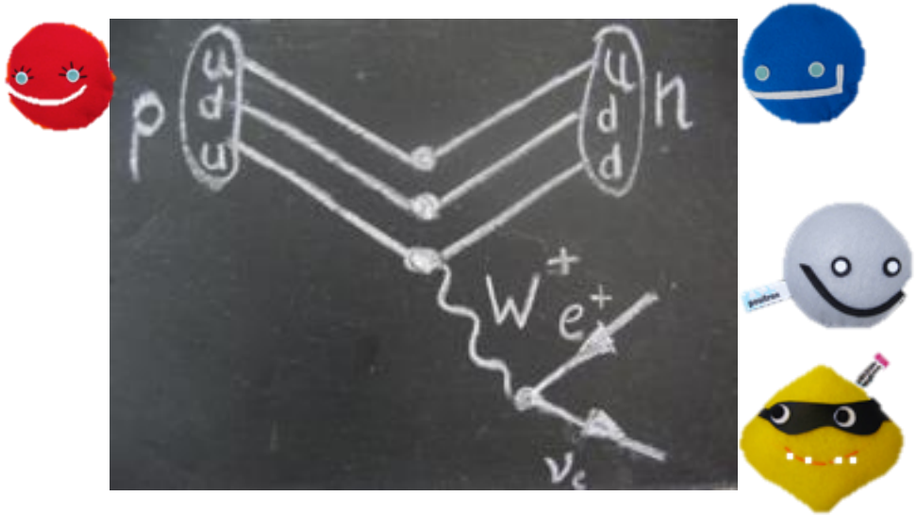
W BOSON DECAY

Betaminus decay (W^-)



$$n \rightarrow pe^-\bar{\nu}$$

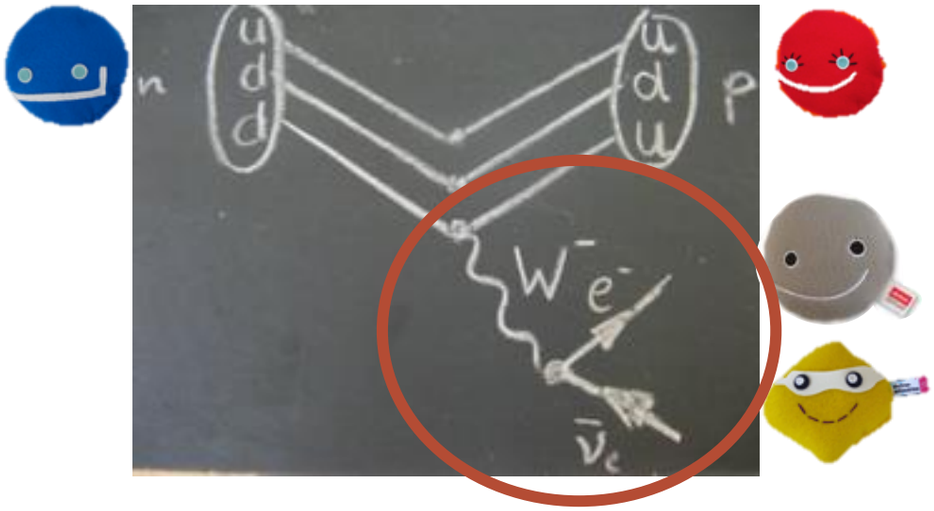
Betaplus decay (W^+)



$$p \rightarrow ne^+\nu$$

W BOSON DECAY

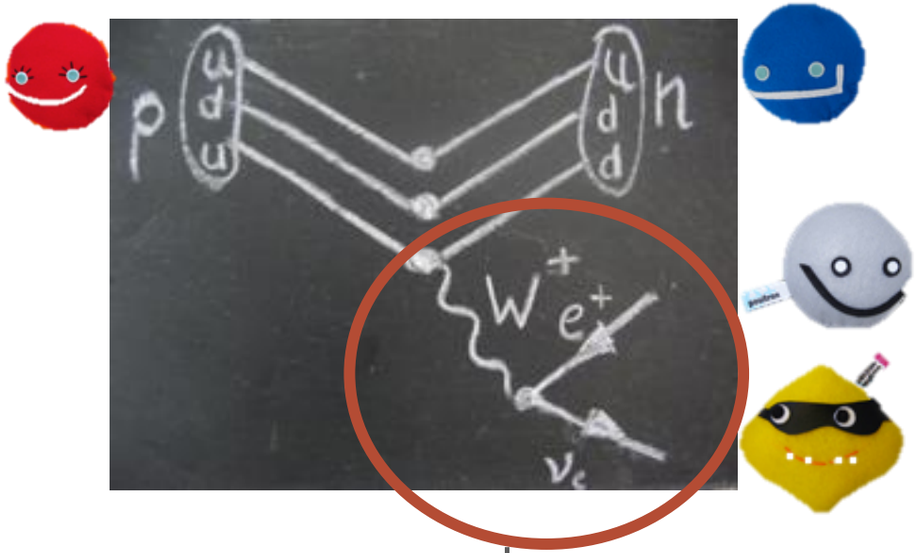
Betaminus decay (W^-)



$$n \rightarrow pe^-\overline{\nu}$$

$$W^- \rightarrow e^-\overline{\nu}$$

Betaplus decay (W^+)

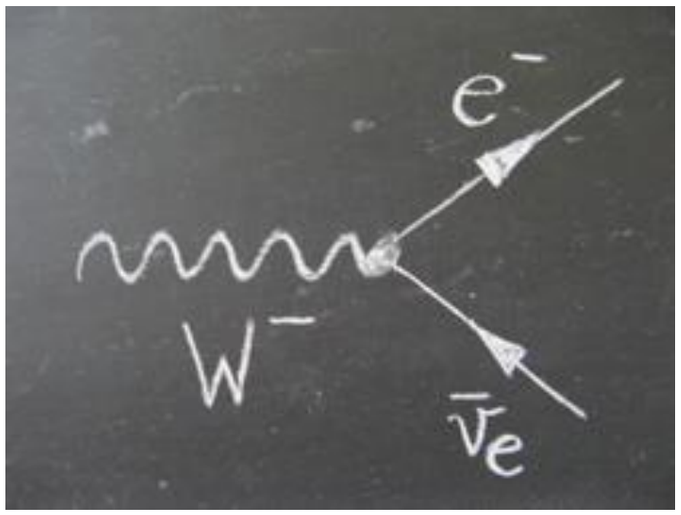


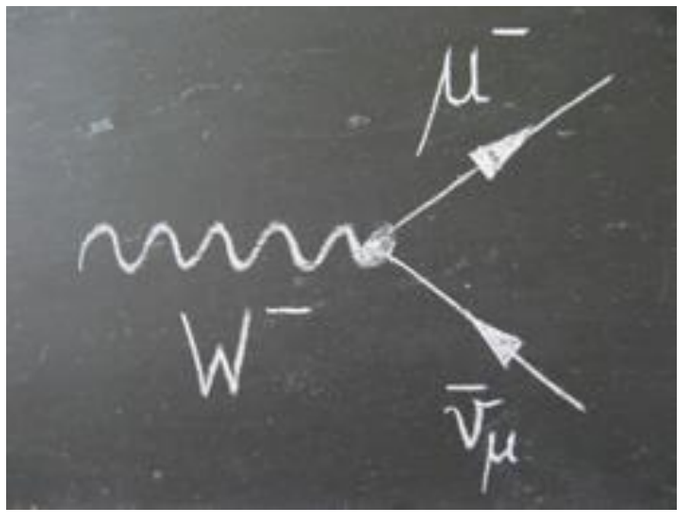
$$p \rightarrow ne^+\nu$$

$$W^+ \rightarrow e^+\nu$$

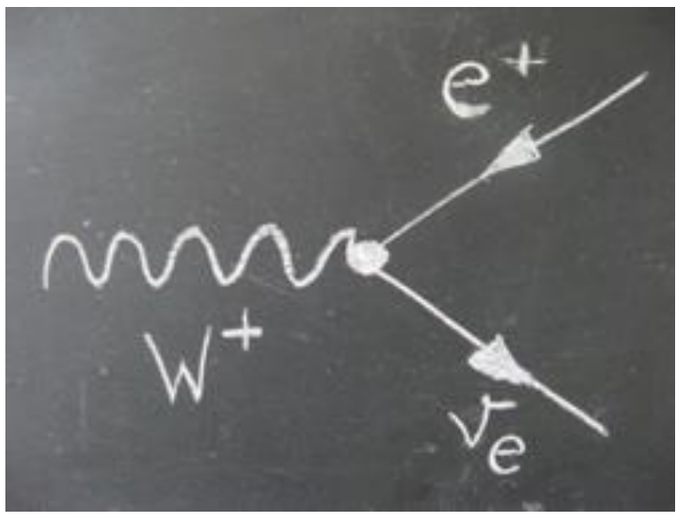
1. CATEGORY: $W^{+/-} \rightarrow e^{+/-}/\mu^{+/-} + \boldsymbol{NEUTRINO}$

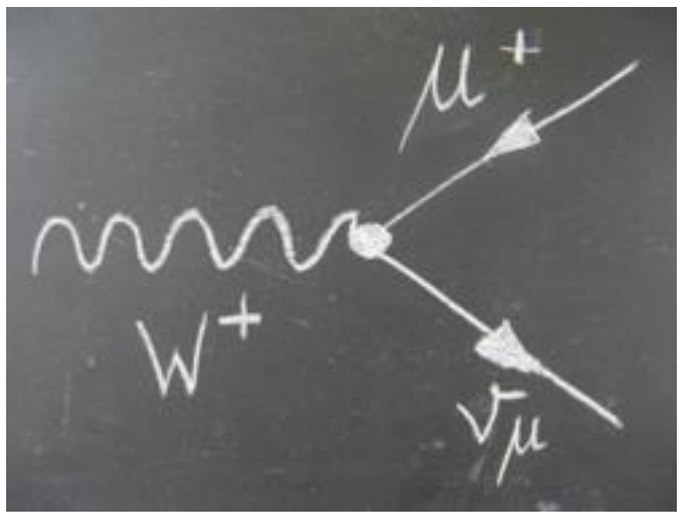
W^-





W^+





Mark in the table which of the 4 cases applies:

- $W^+ \rightarrow e^+$
- $W^- \rightarrow e^-$
- $W^+ \rightarrow \mu^+$
- $W^- \rightarrow \mu^-$

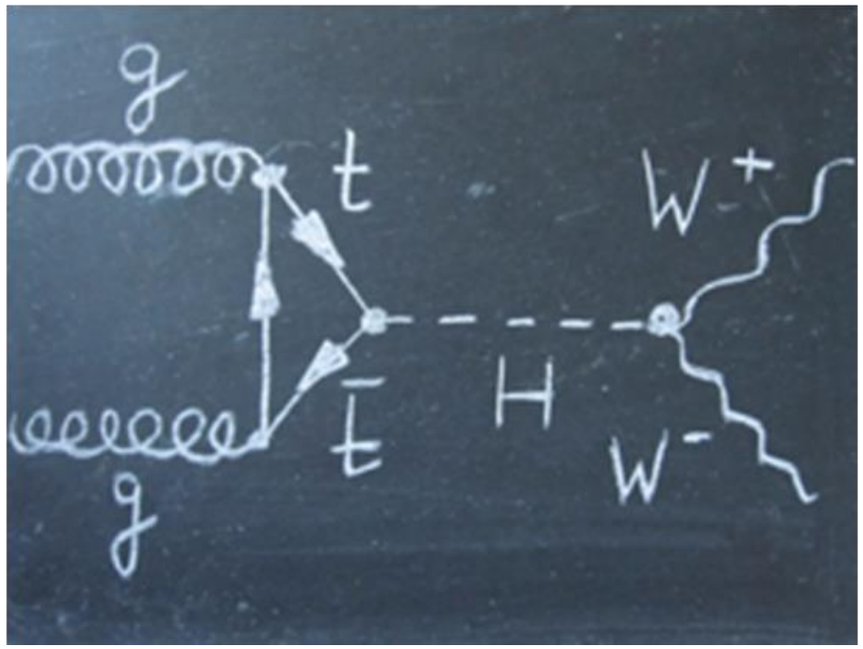
THE HIGGS BOSON

The **W boson**

The **Higgs boson**

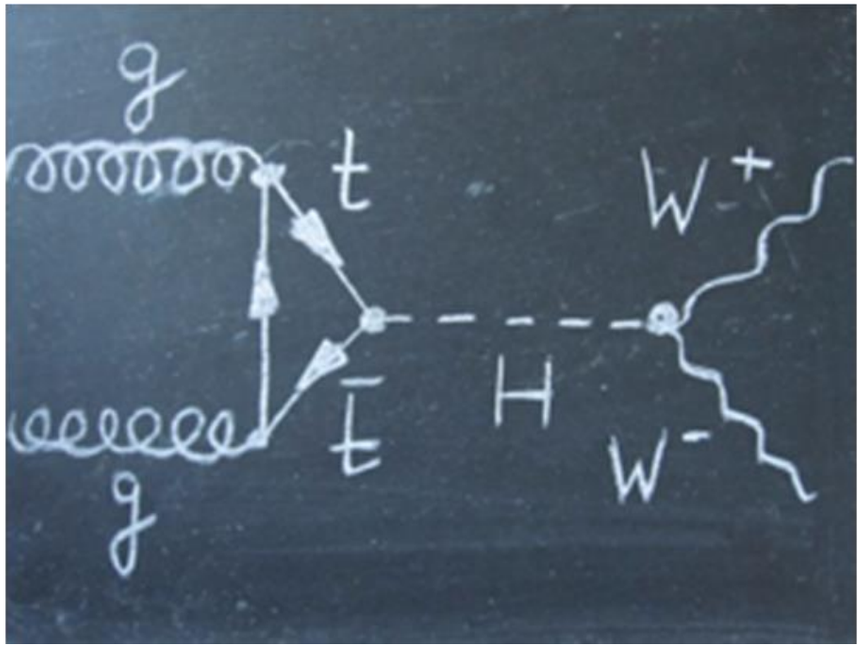
DECAY OF HIGGS BOSONS AT THE LHC

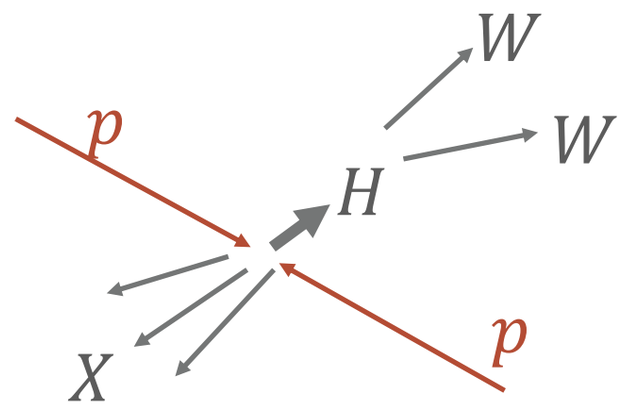
- We measure the decay into 2 W bosons

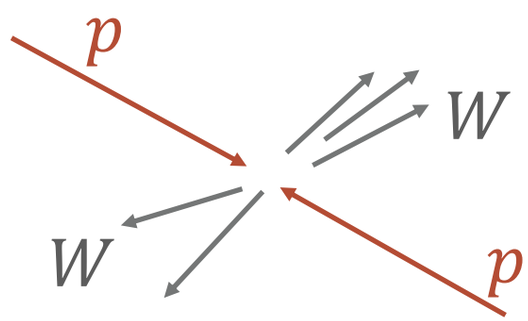


DECAY OF HIGGS BOSONS AT THE LHC

- We measure the decay into 2 W bosons



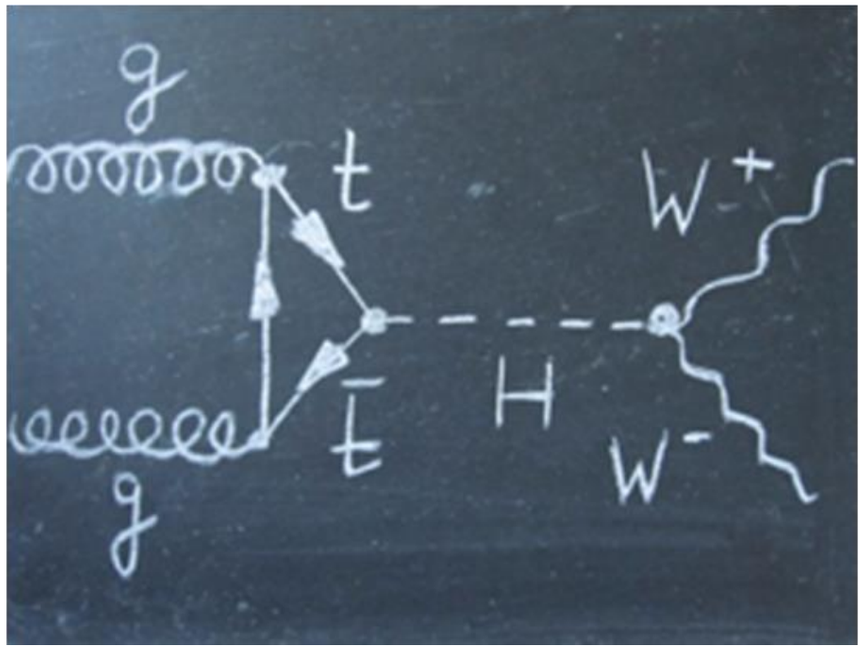


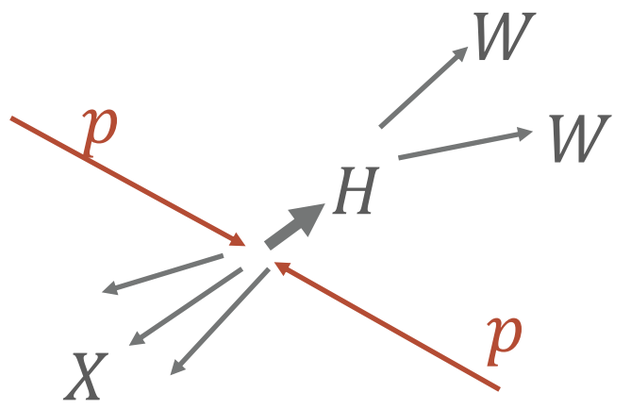


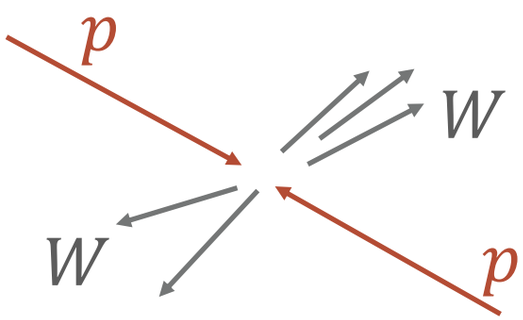
DECAY OF HIGGS BOSONS AT THE LHC

- We measure the decay into 2 W bosons

1. For all WW events, measure the angular distance $\Delta\phi$ between the two charged leptons!
2. At the end all $\Delta\phi$ of the WW events are compared
3. Theory says: We expect
   Higgs events rather in $0^\circ < \Delta\phi < 90^\circ$
   WW events everywhere in $0^\circ < \Delta\phi < 180^\circ$

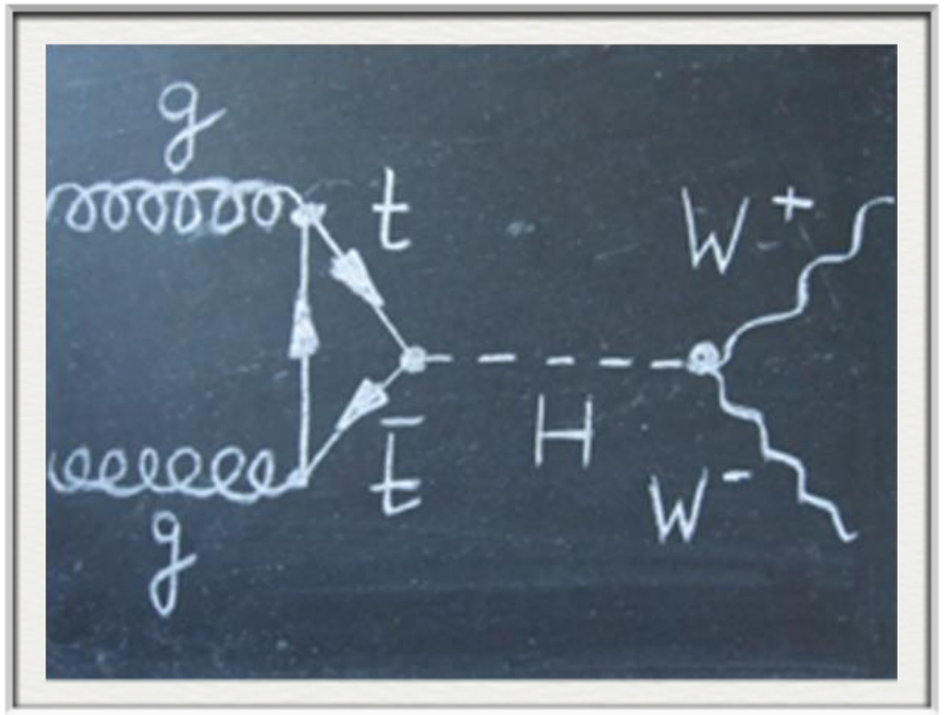






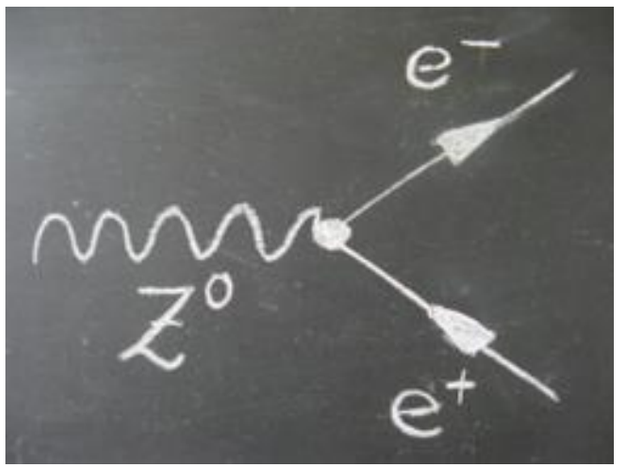
2. CATEGORY: $W^- + W^+ \rightarrow e^-/\mu^- + e^+/\mu^+ +$ ***2 NEUTRINOS***

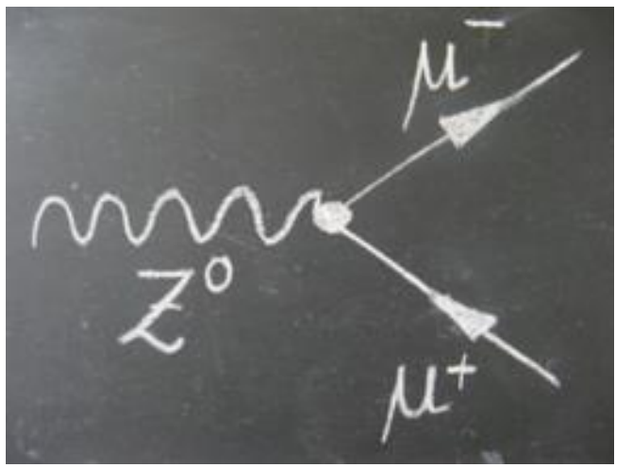
- Either Higgs→ WW event
  or WW event without Higgs
- Measure the angle between the charged decay products of the W bosons



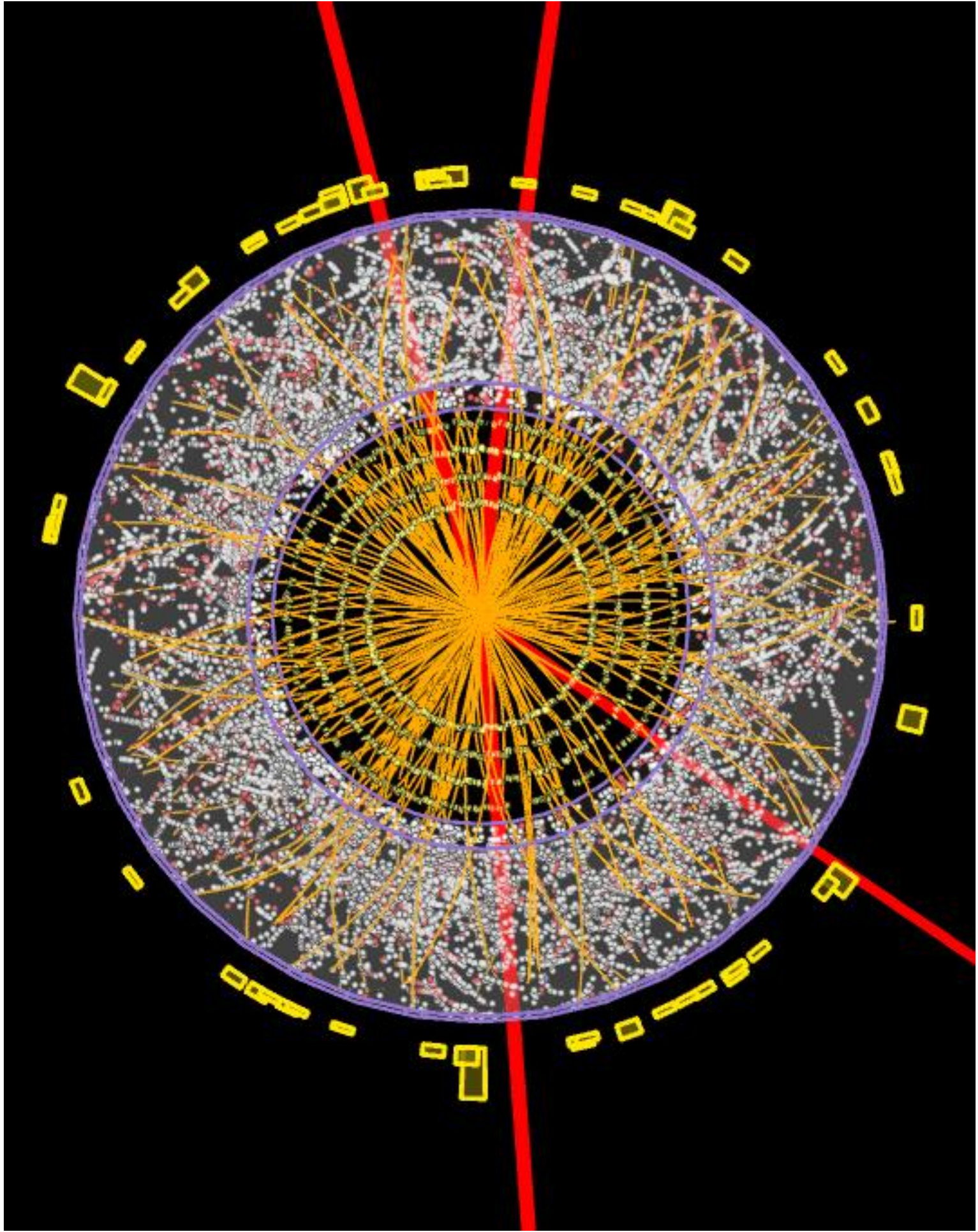
3. CATEGORY: BACKGROUND

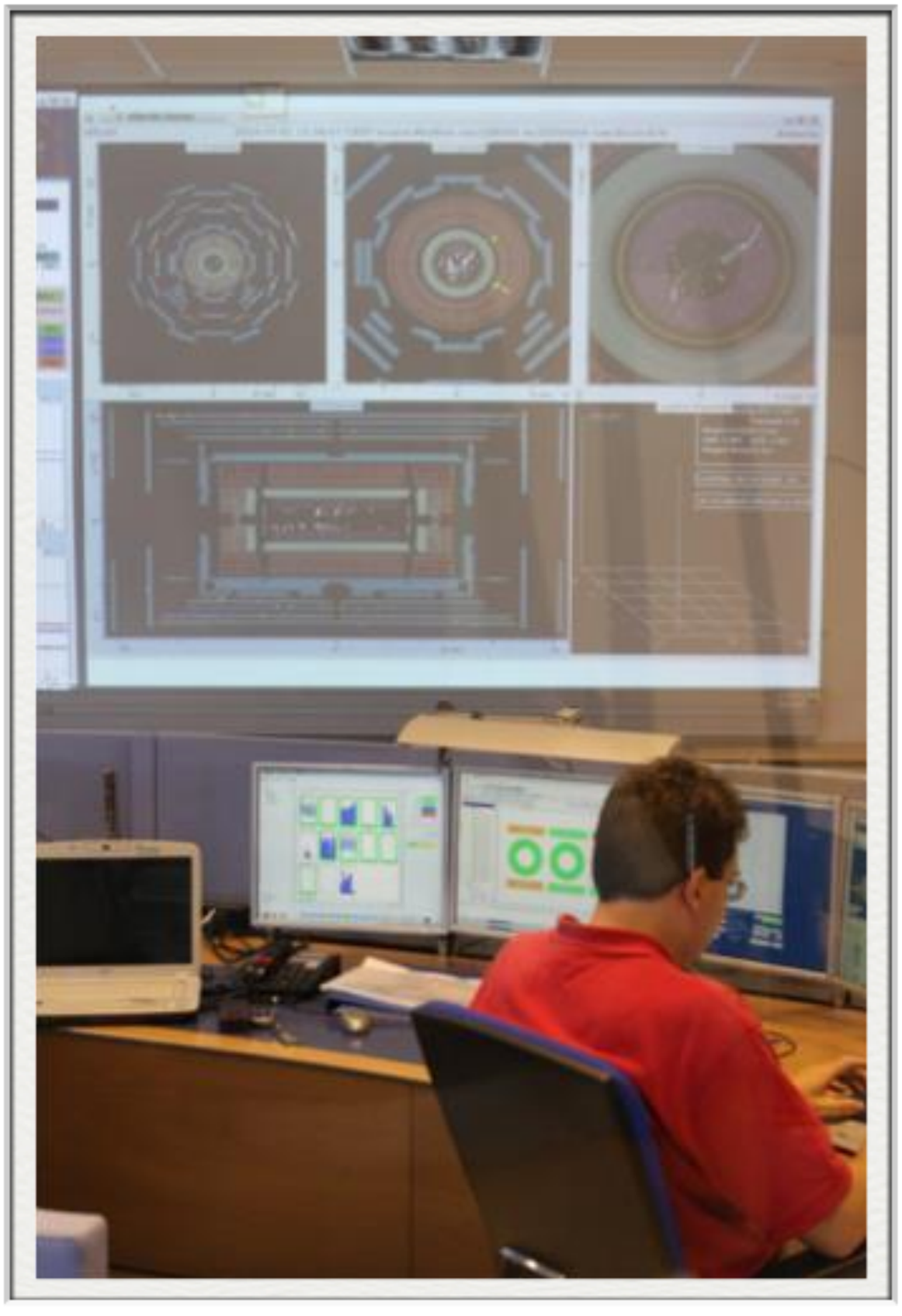
- Everything else – for example:
  - i) Events with **Jets**: One gluon or quark is ejected from the proton
  - ii) Z^0 particle decays into 2 leptons





EVENT IDENTIFICATION





MINERVA

Masterclass **IN**volving **E**vent
Recognition **V**isualised with **A**tlantis

Based on official ATLAS event display (ATLANTIS)

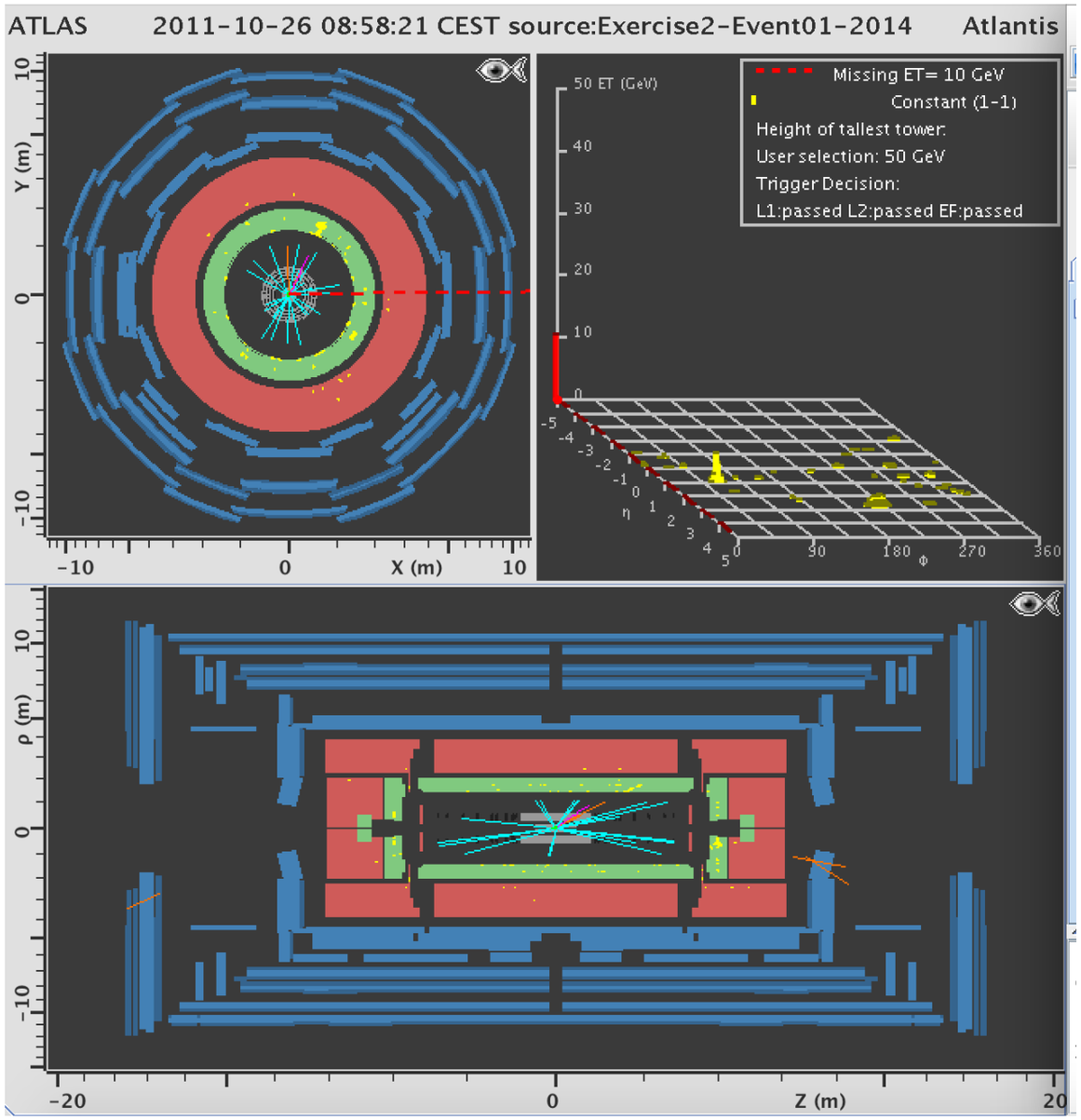
HOW WILL THE MEASUREMENT WORK?

- Each group gets events.
- You will use Minerva to find out what happened in each event.
- At the end we count up the events of all groups and see what we have found out together.

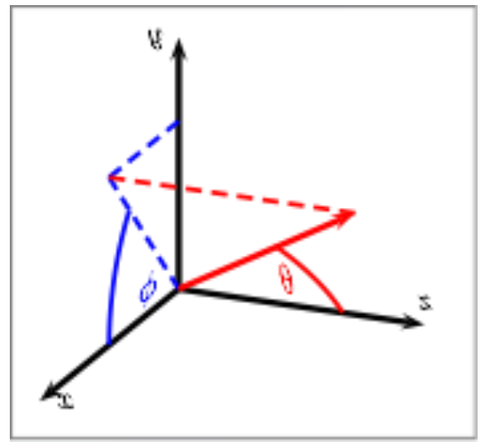
EVENT DISPLAYS WITH MINERVA

FRONT VIEW

SIDE VIEW

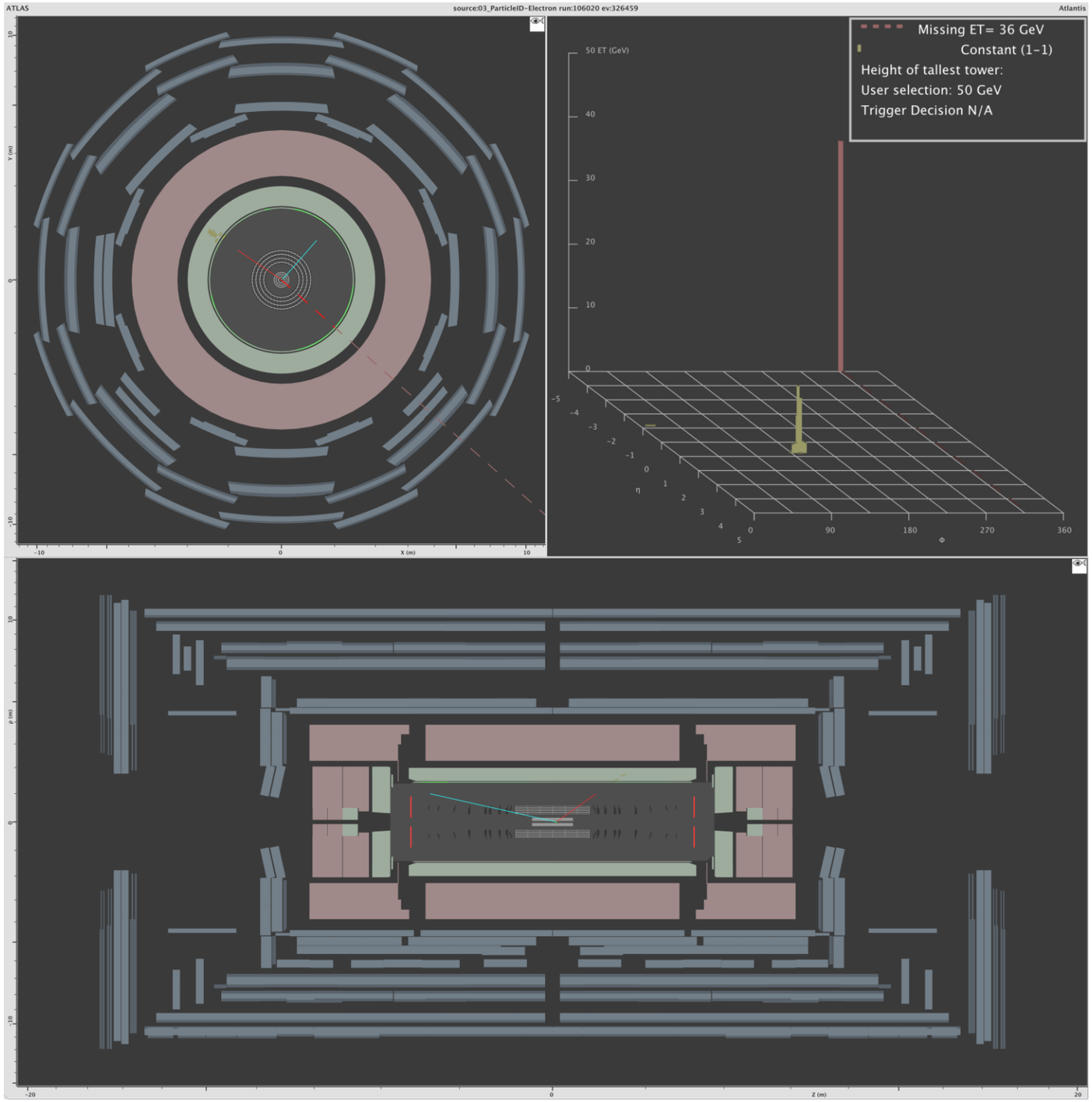


ENERGY HISTOGRAM



ATLAS DETECTOR SETUP

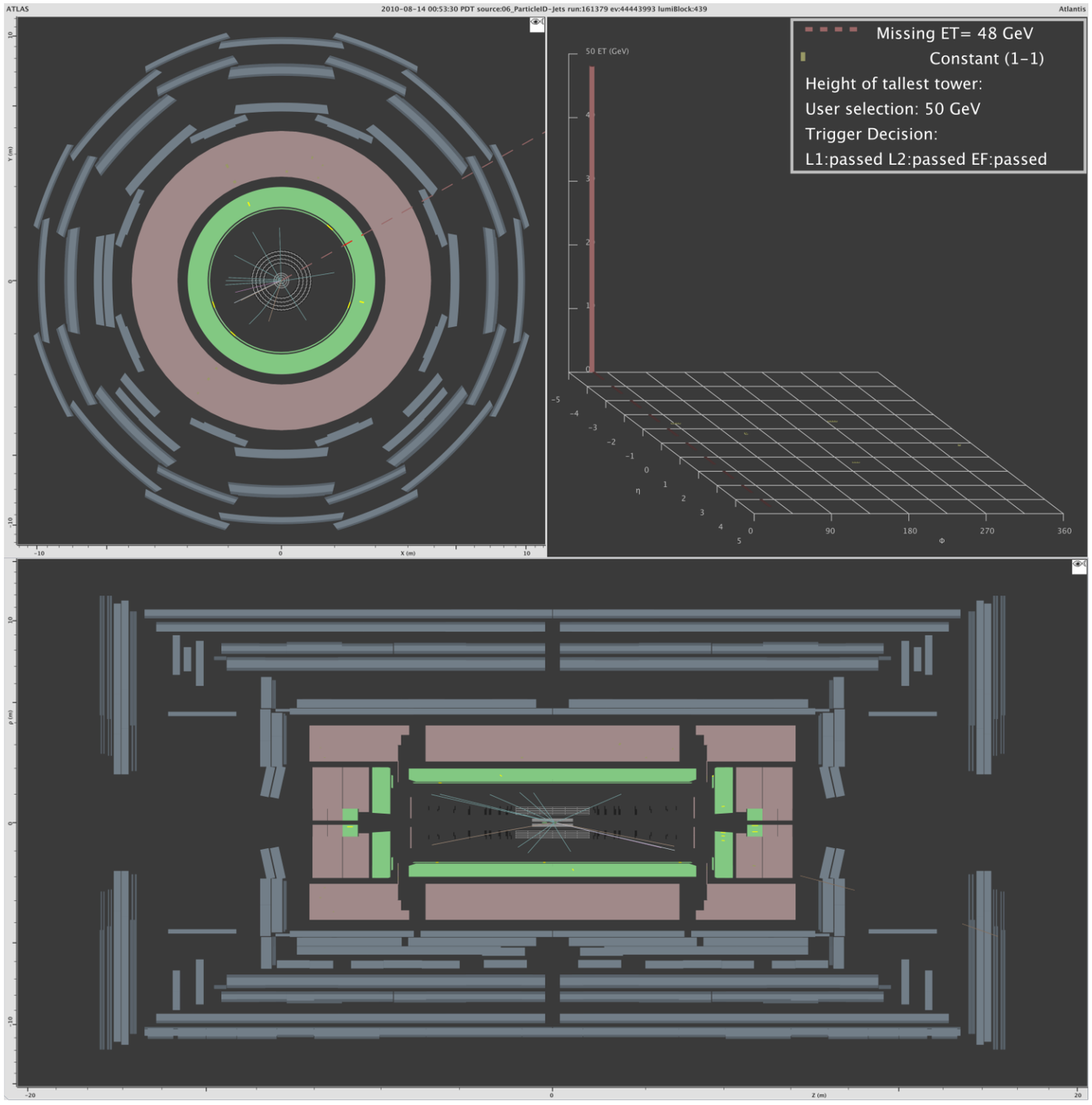
TRACKING DETECTOR



ATLAS DETECTOR SETUP

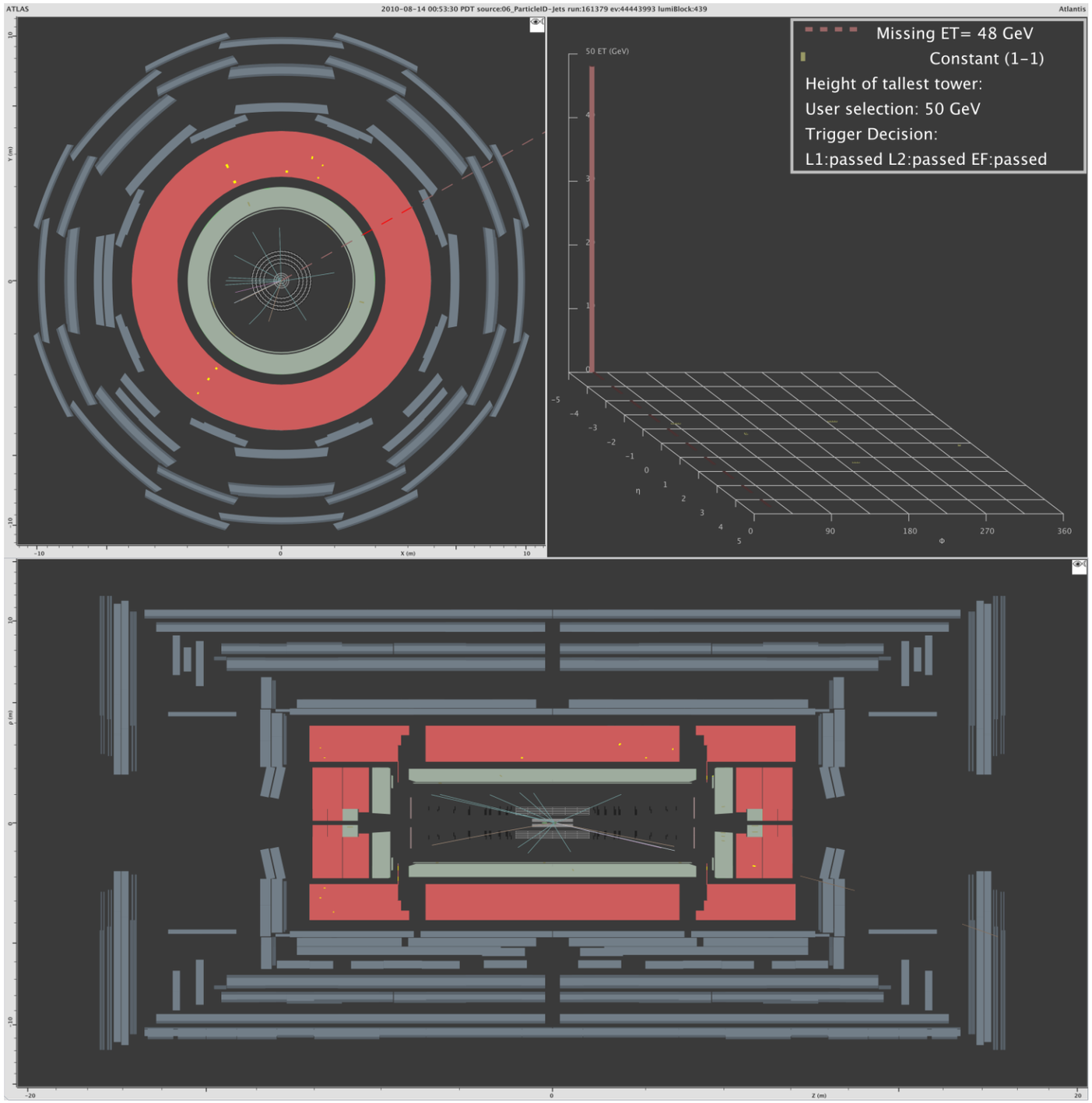
ELECTROMAGNETIC CALORIMETER

(E-CAL)



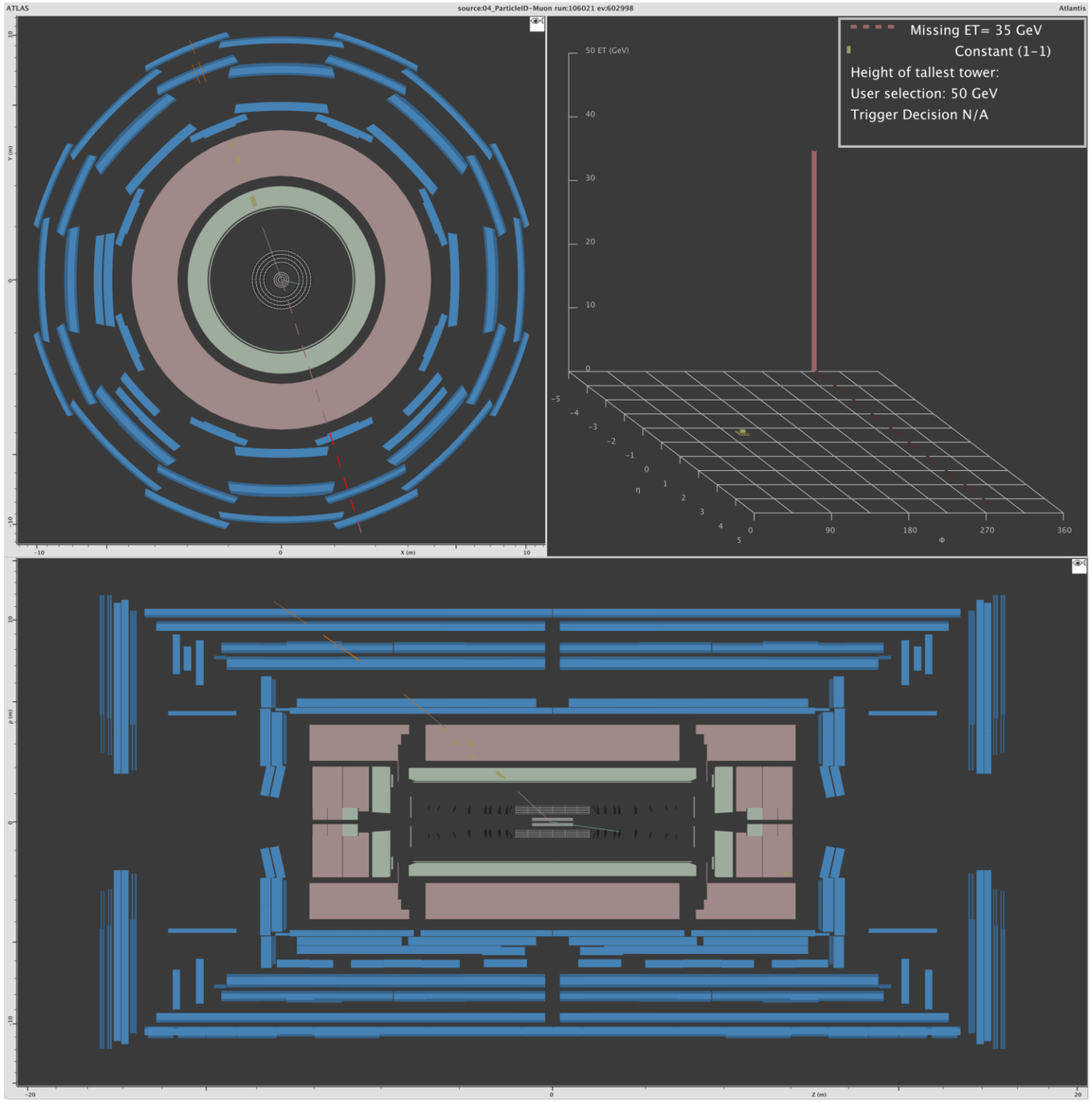
ATLAS DETECTOR SETUP

HADRONIC CALORIMETER (H-CAL)



ATLAS DETECTOR SETUP

MUON DETECTOR



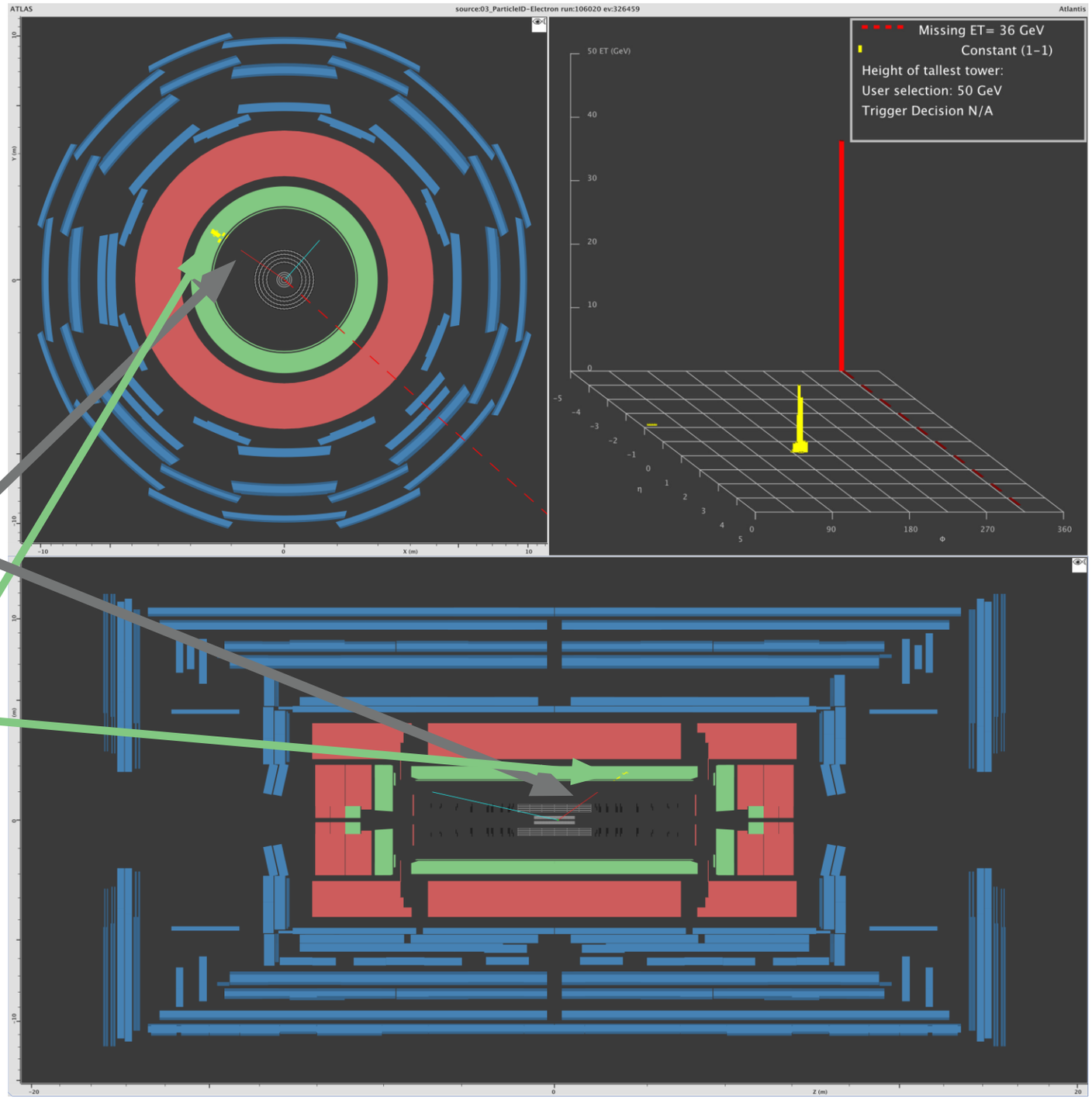
PARTICLE IDENTIFICATION

?

track in tracking detector

+

energy in E-CAL



PARTICLE IDENTIFICATION

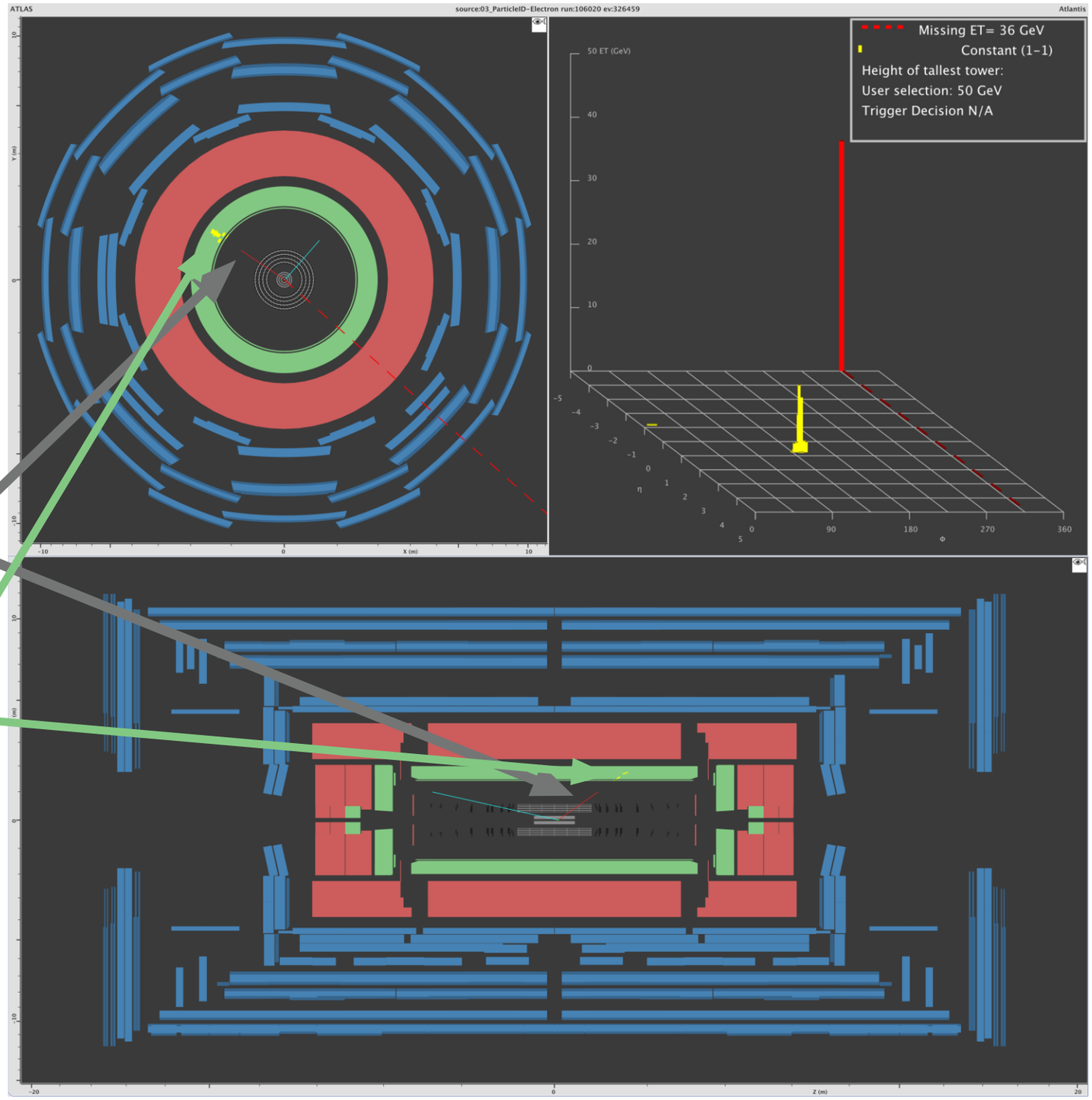
electron/

positron

track in tracking detector

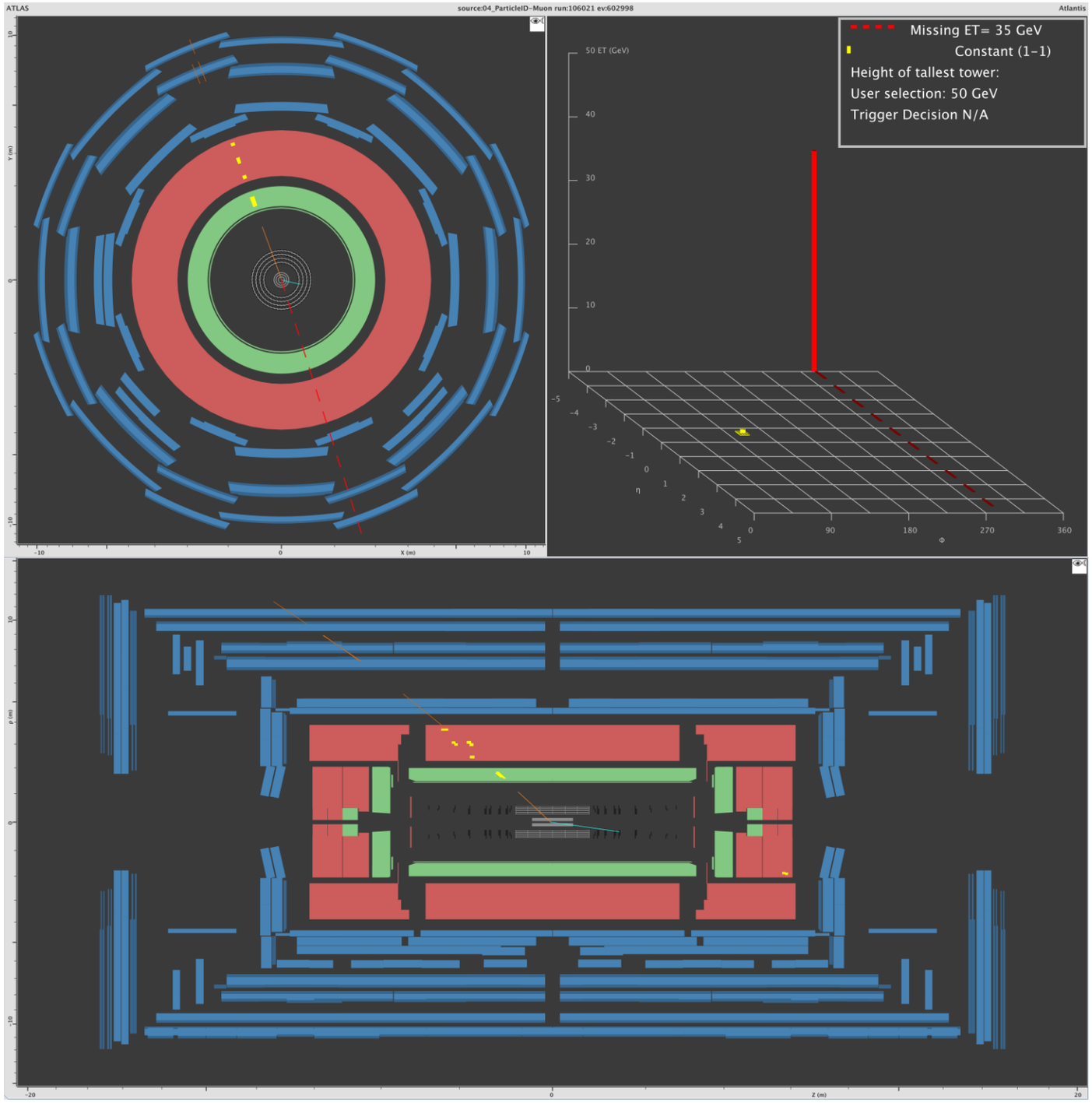
+

energy in E-CAL



PARTICLE IDENTIFICATION

?



PARTICLE IDENTIFICATION

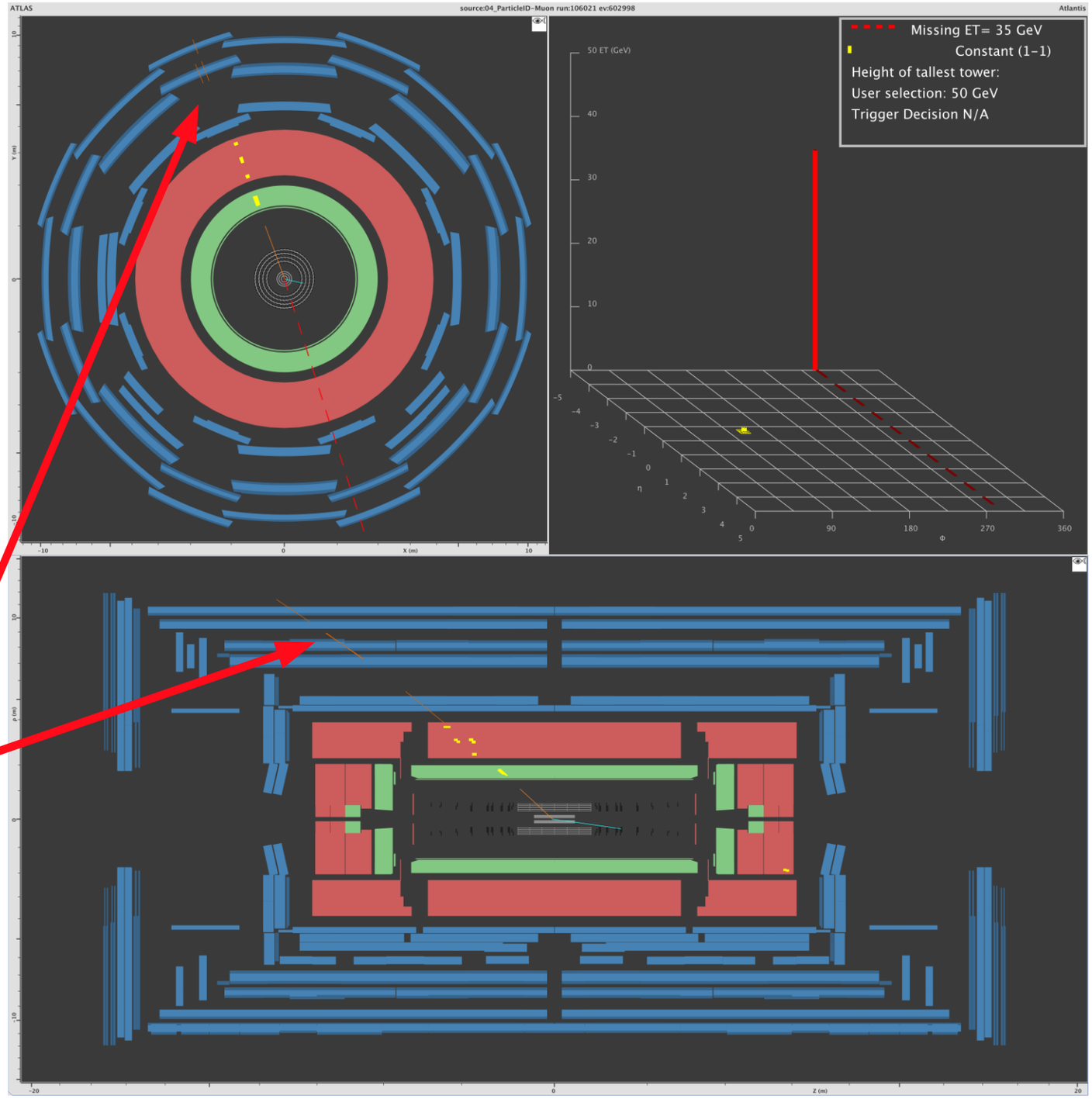
muon/

antimuon

weak signal everywhere

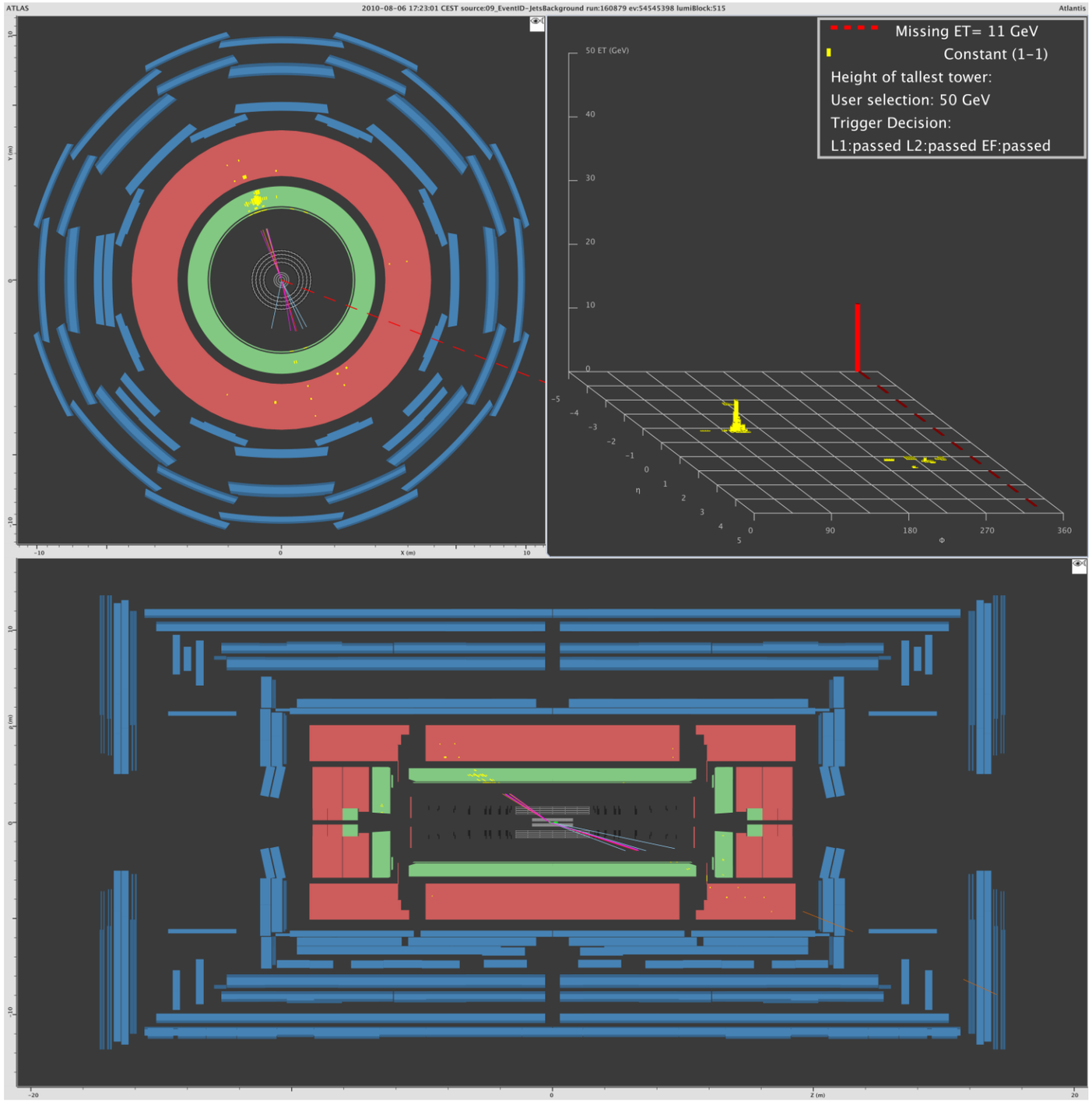
+

muon detector



PARTICLE IDENTIFICATION

?



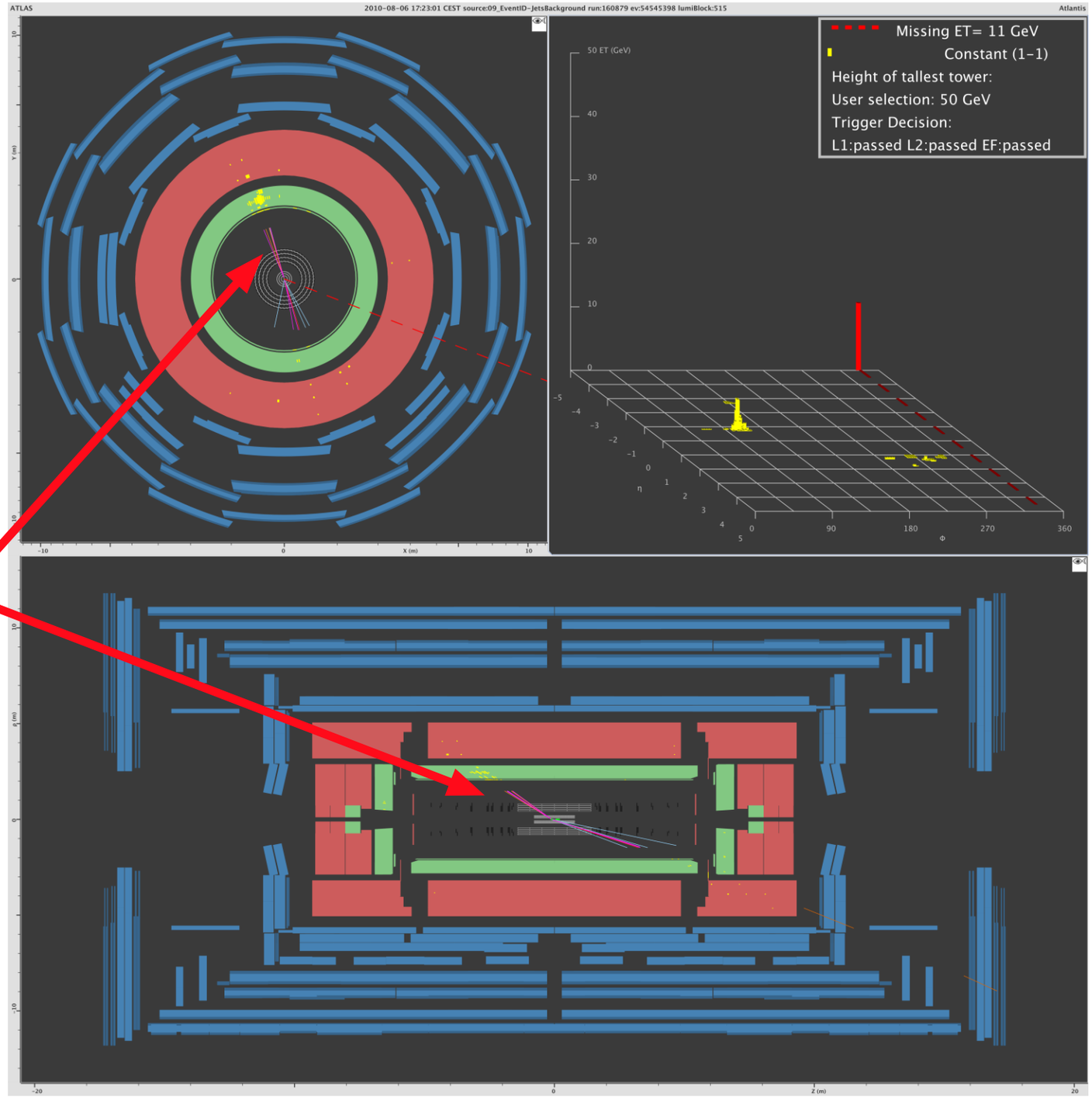
PARTICLE IDENTIFICATION

jets

particle bundle

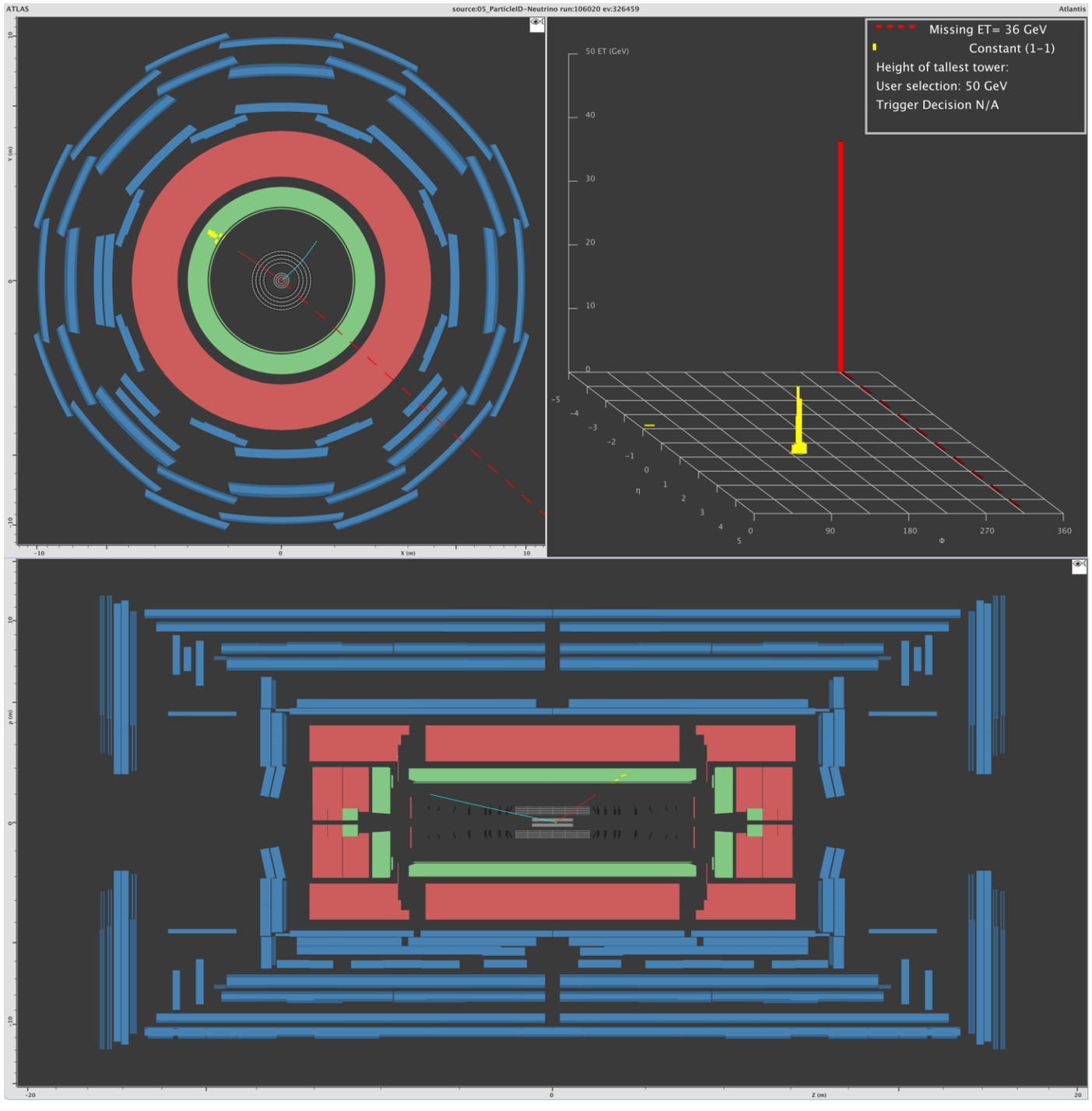
+

high isolation



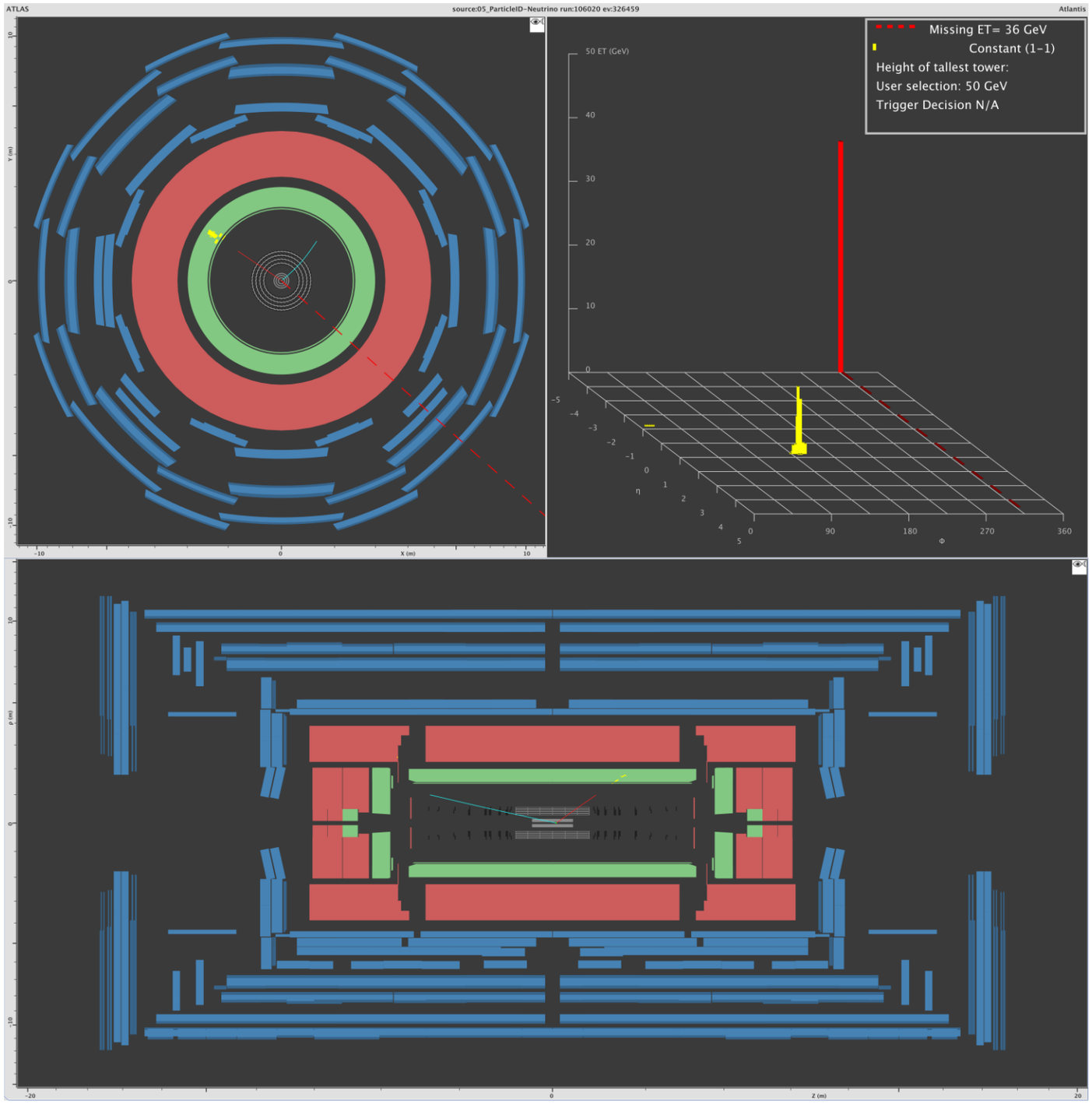
PARTICLE IDENTIFICATION

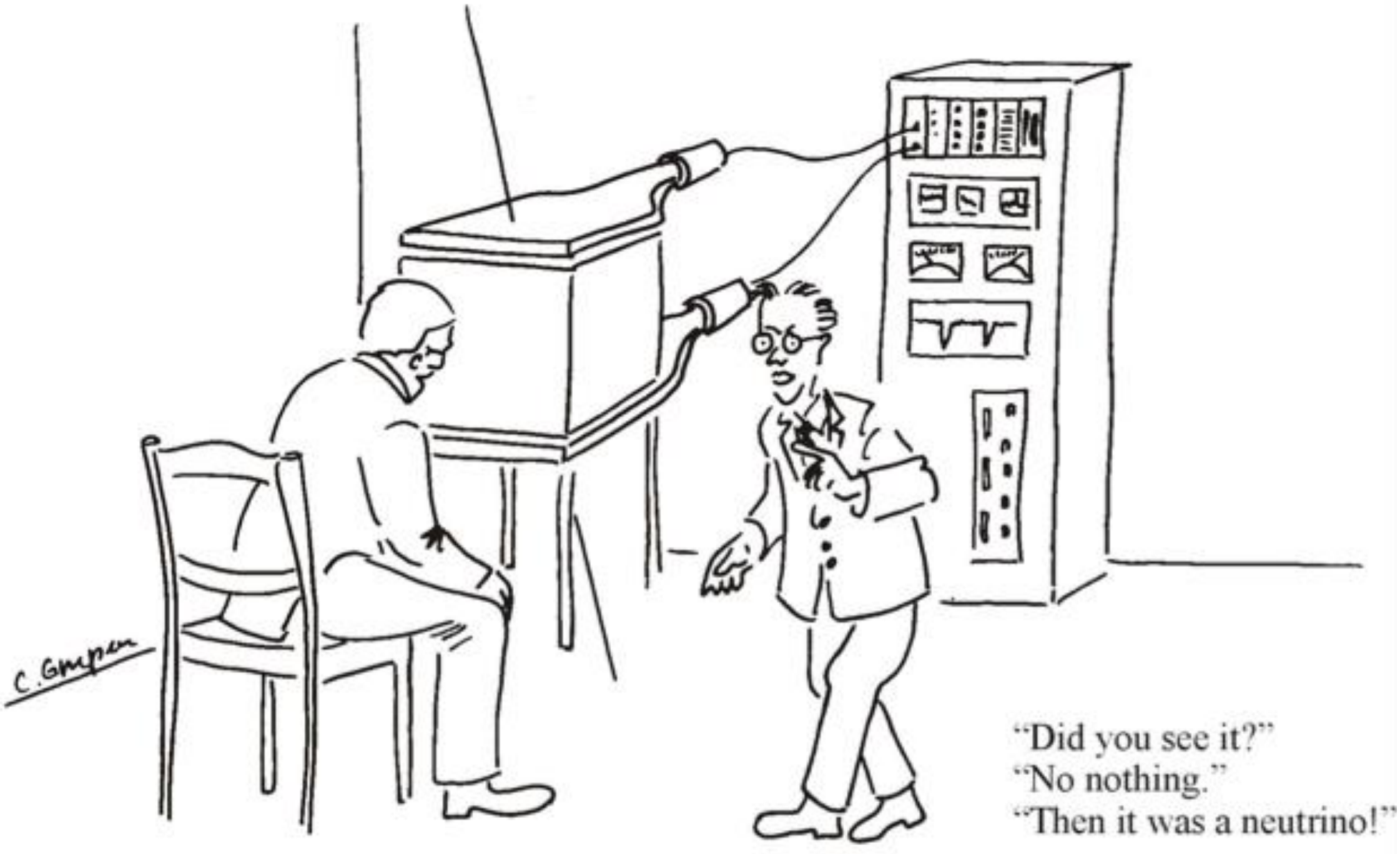
What is missing?



PARTICLE IDENTIFICATION

neutrino





"Did you see it?"
"No nothing."
"Then it was a neutrino!"

PARTICLE IDENTIFICATION

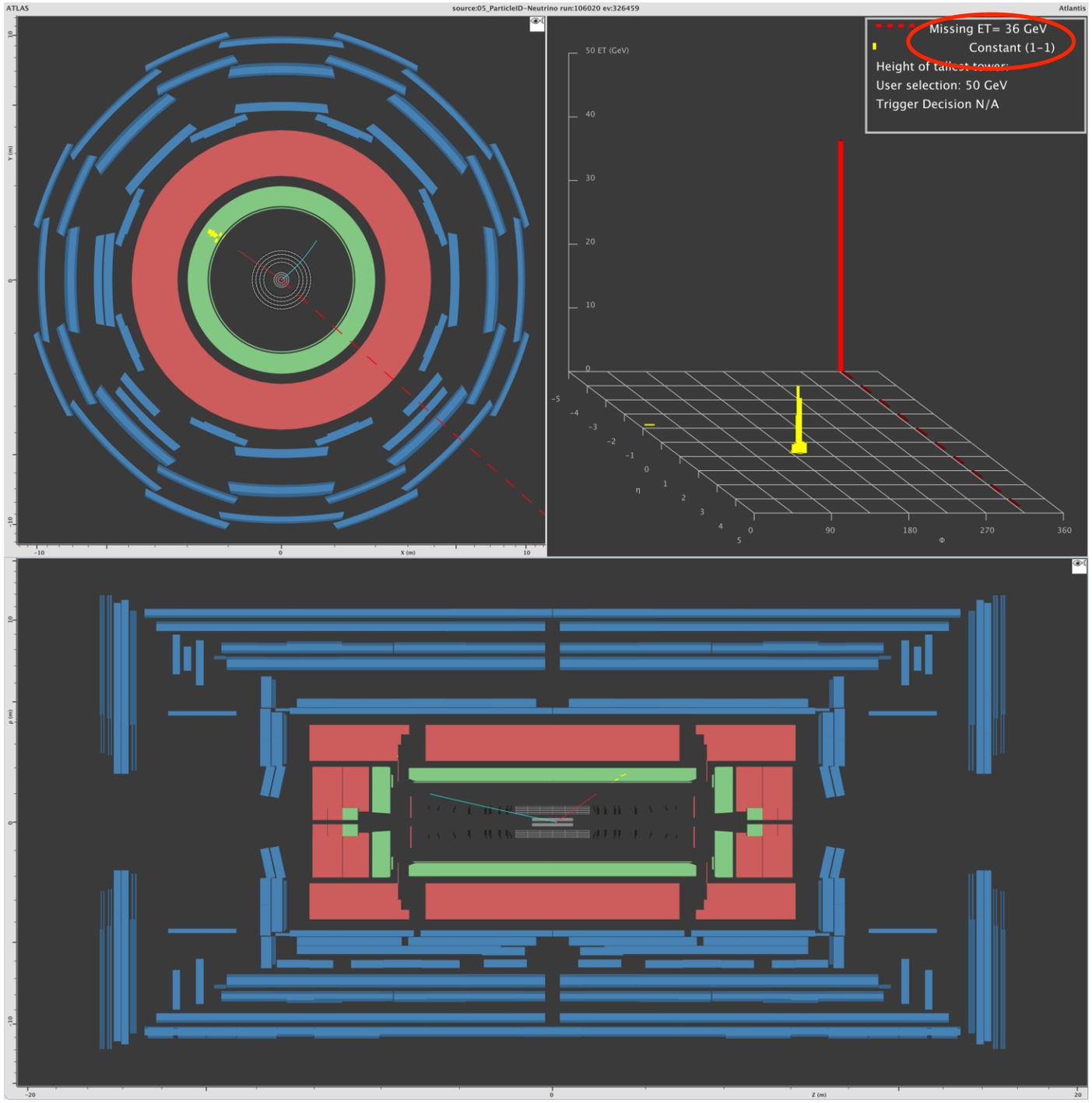
neutrino

Momentum conservation reveals that it was there!

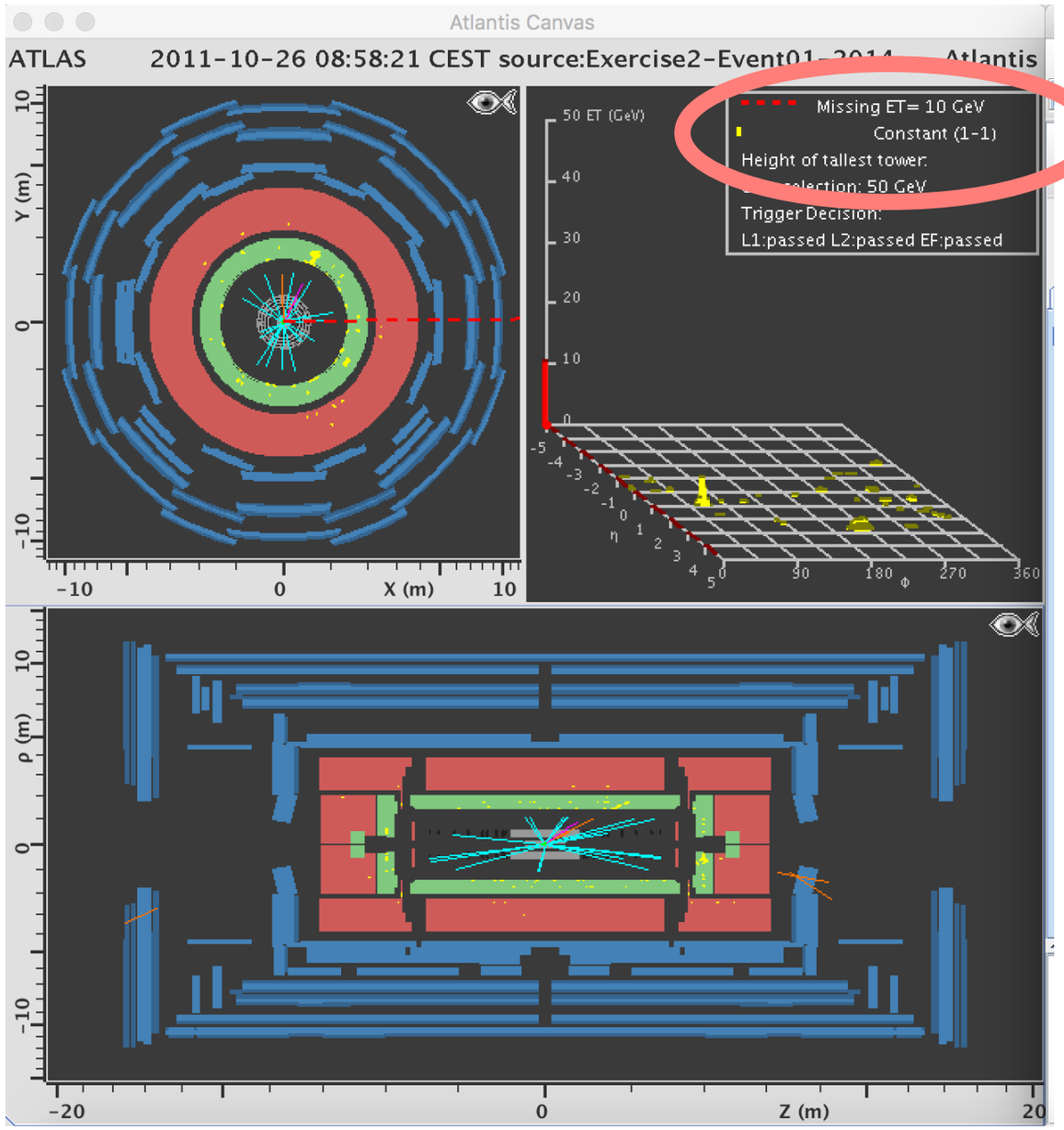
momentum of neutrino

=

momentum which is missing afterwards!



MINERVA: MISSING TRANSVERSE ENERGY (MET)

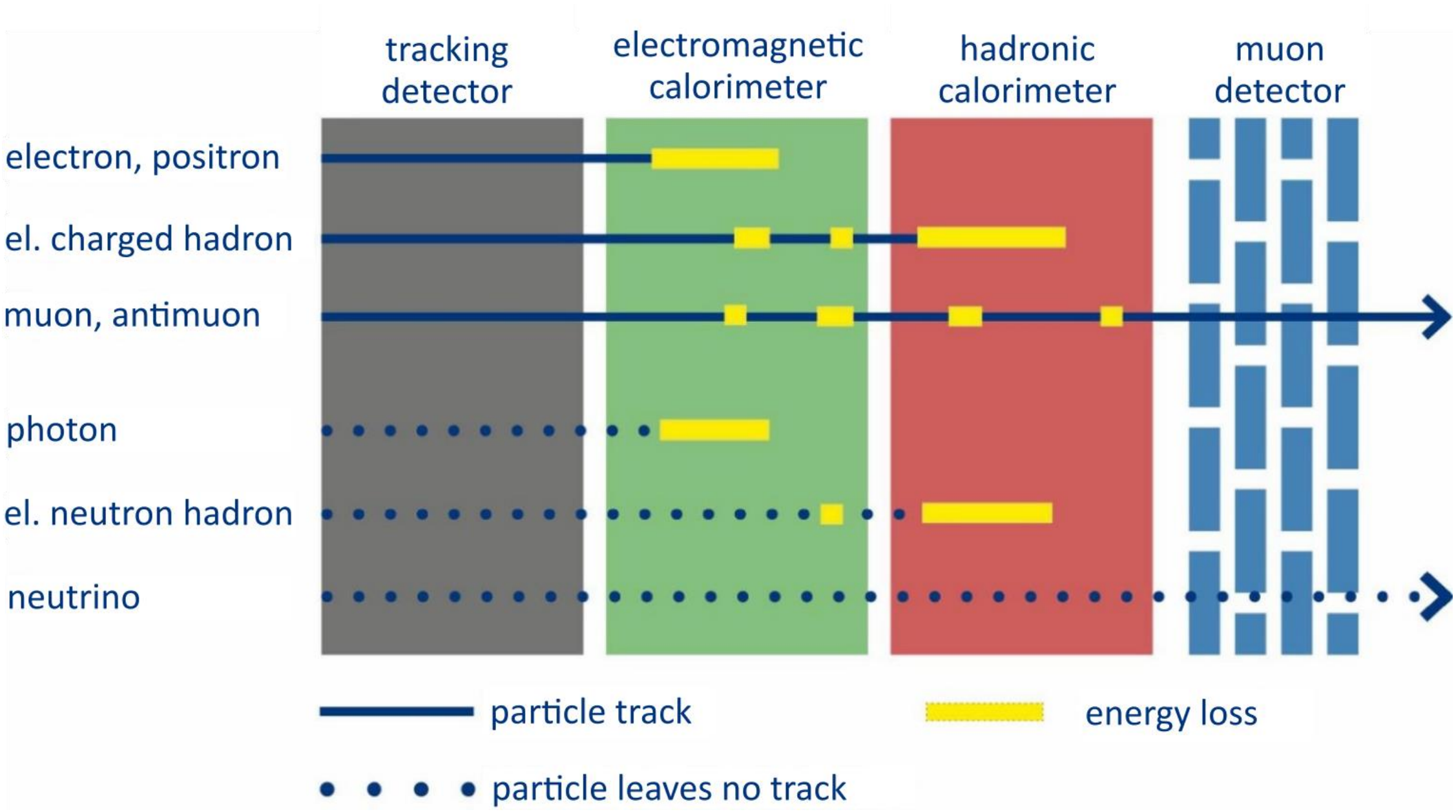


Missing energy (MET) is indicated by the red dashed line.

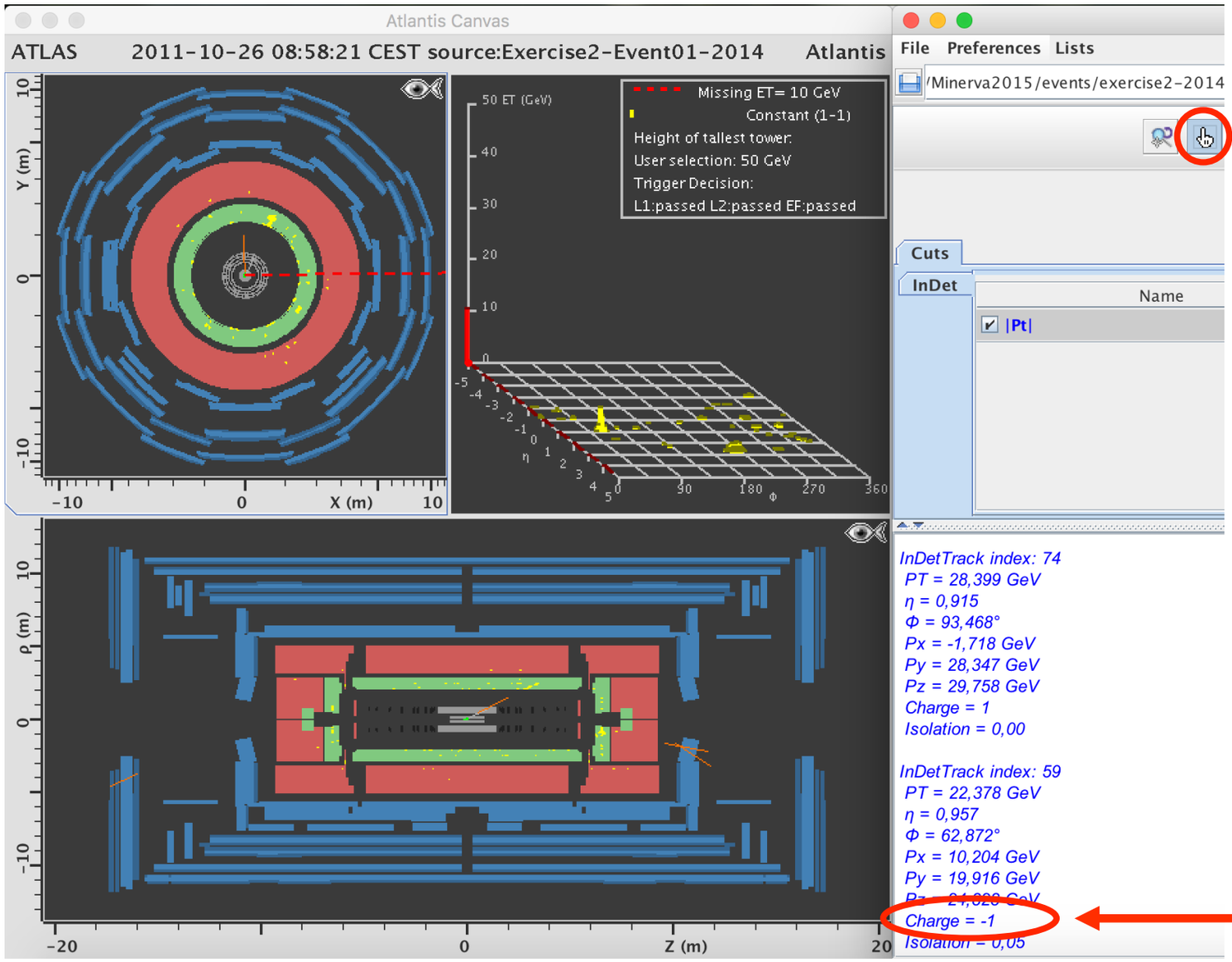
Here 10 GeV are missing.

For an event not to be background, we require MET > 20 GeV.

GAME RULES


tracking detector
electromagnetic calorimeter
hadronic calorimeter
muon detector
electron, positron
el. charged hadron
muon, antimuon
photon
el. neutron hadron
neutrino
particle track
energy loss
particle leaves no track

ELECTRON OR POSITRON?



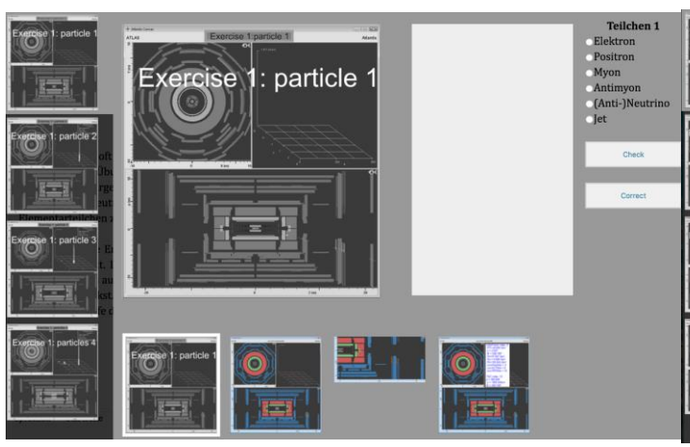
1. Select hand
2. Click on track
3. Information is displayed at the bottom right.

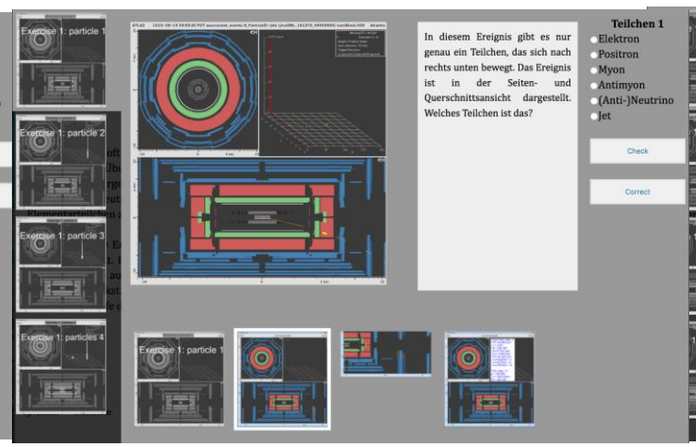
+1 positron

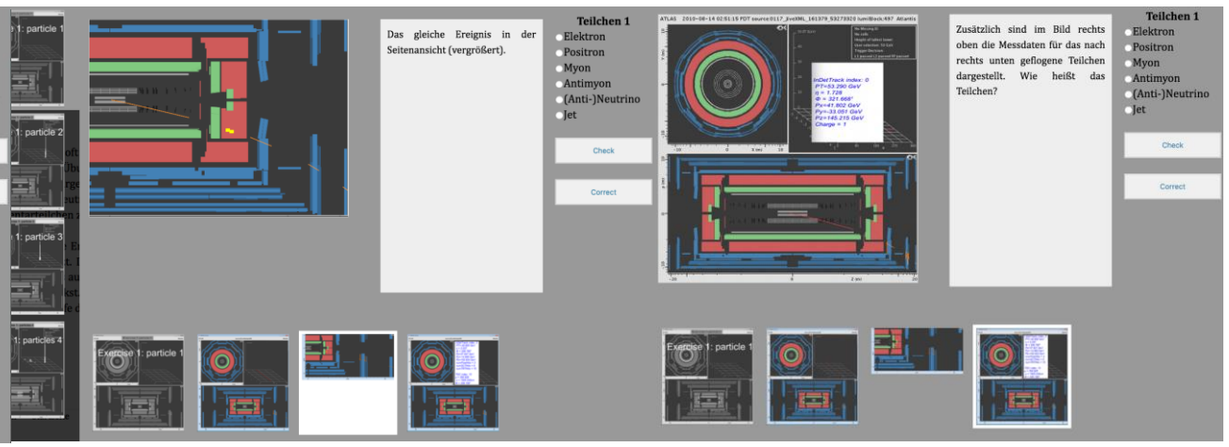
-1 electron

IT‘S YOUR TURN!

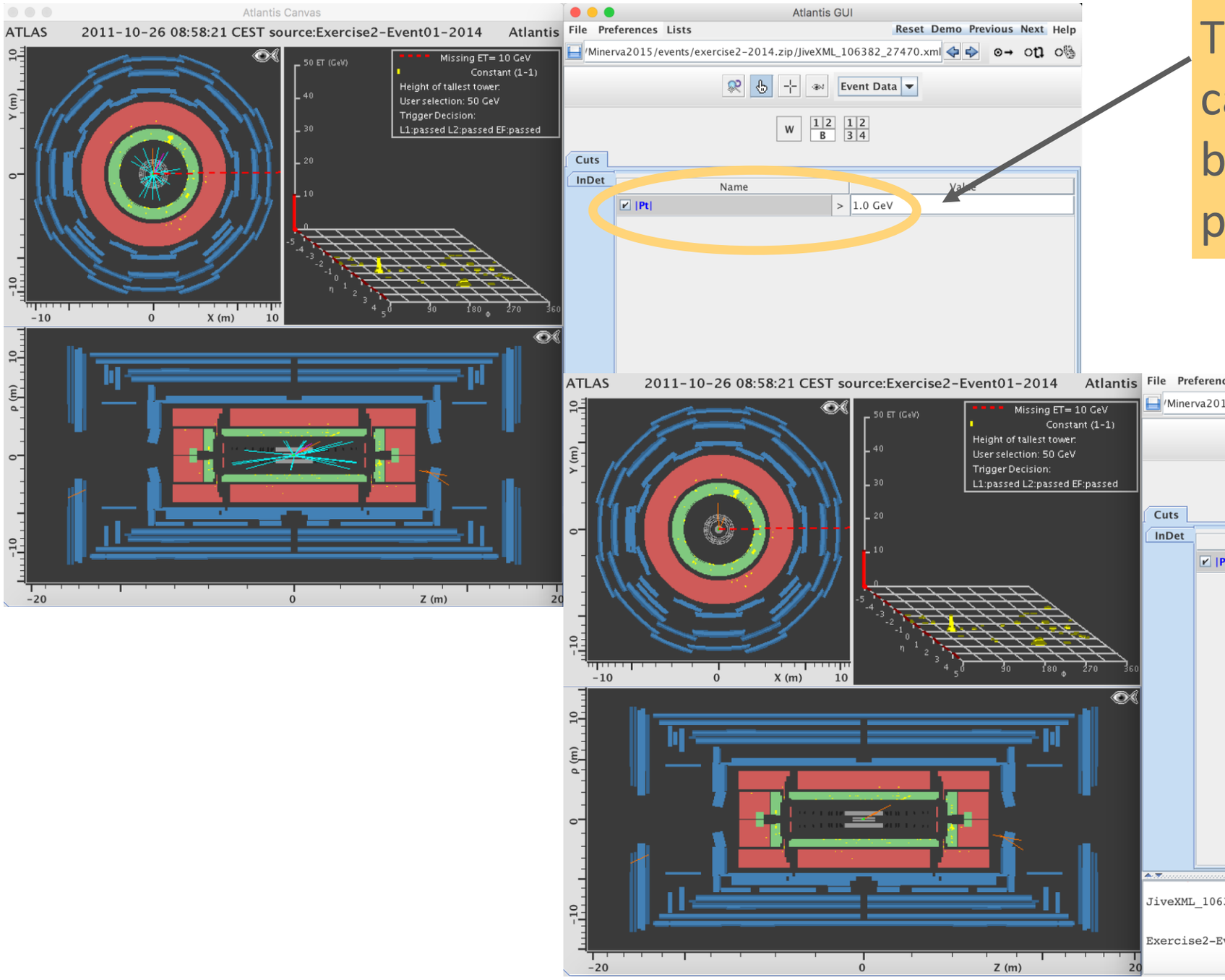
- http://atlas.physicsmasterclasses.org/en/wpath.htm
- Click on identifying particles and perform exercise 1
  - Look at particles in all views and identify them





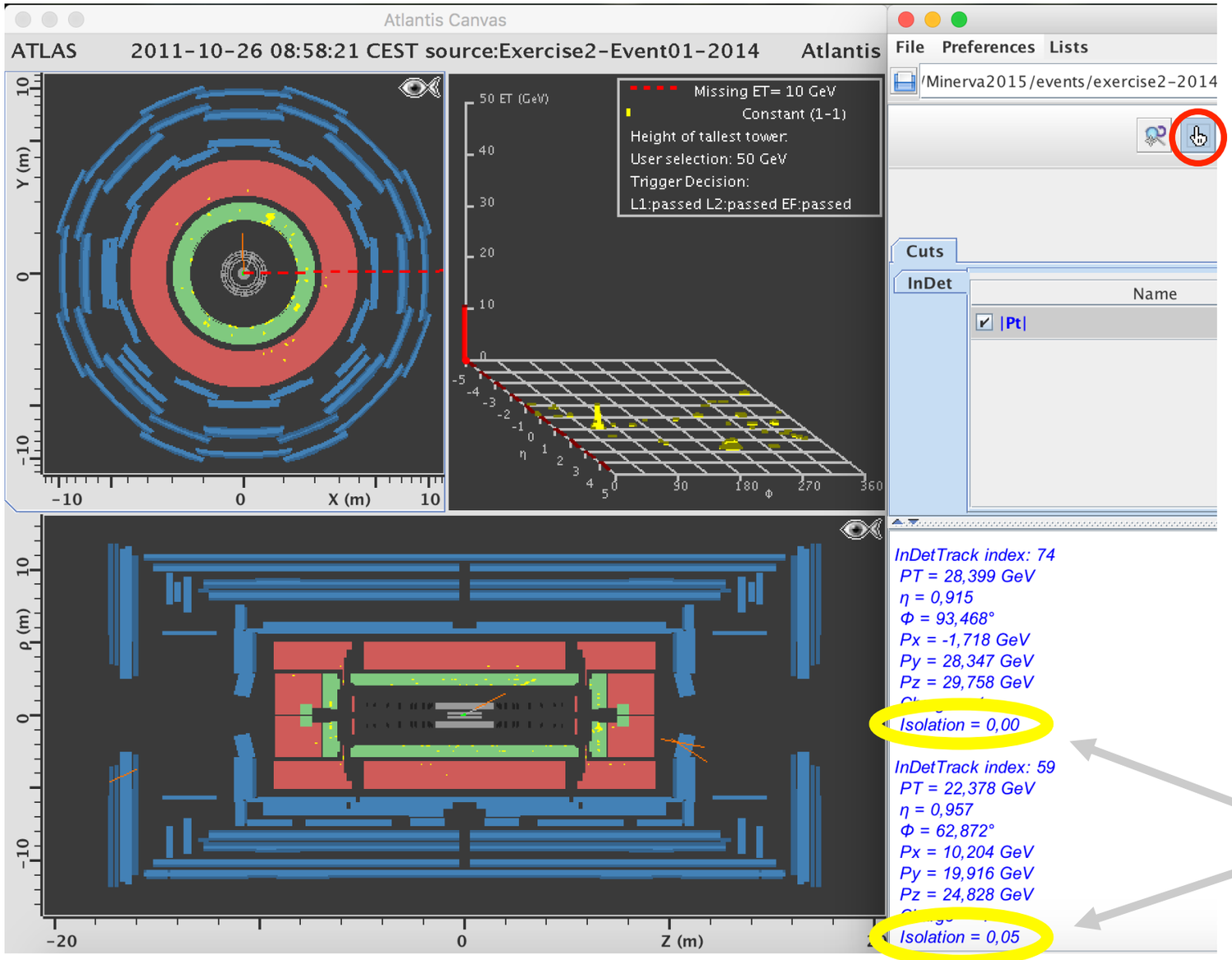


TOOLS: PT CUTS



The tracks with low pT can be filtered out by cutting to pT > 1/10/20 GeV.

TOOLS: ISOLATION



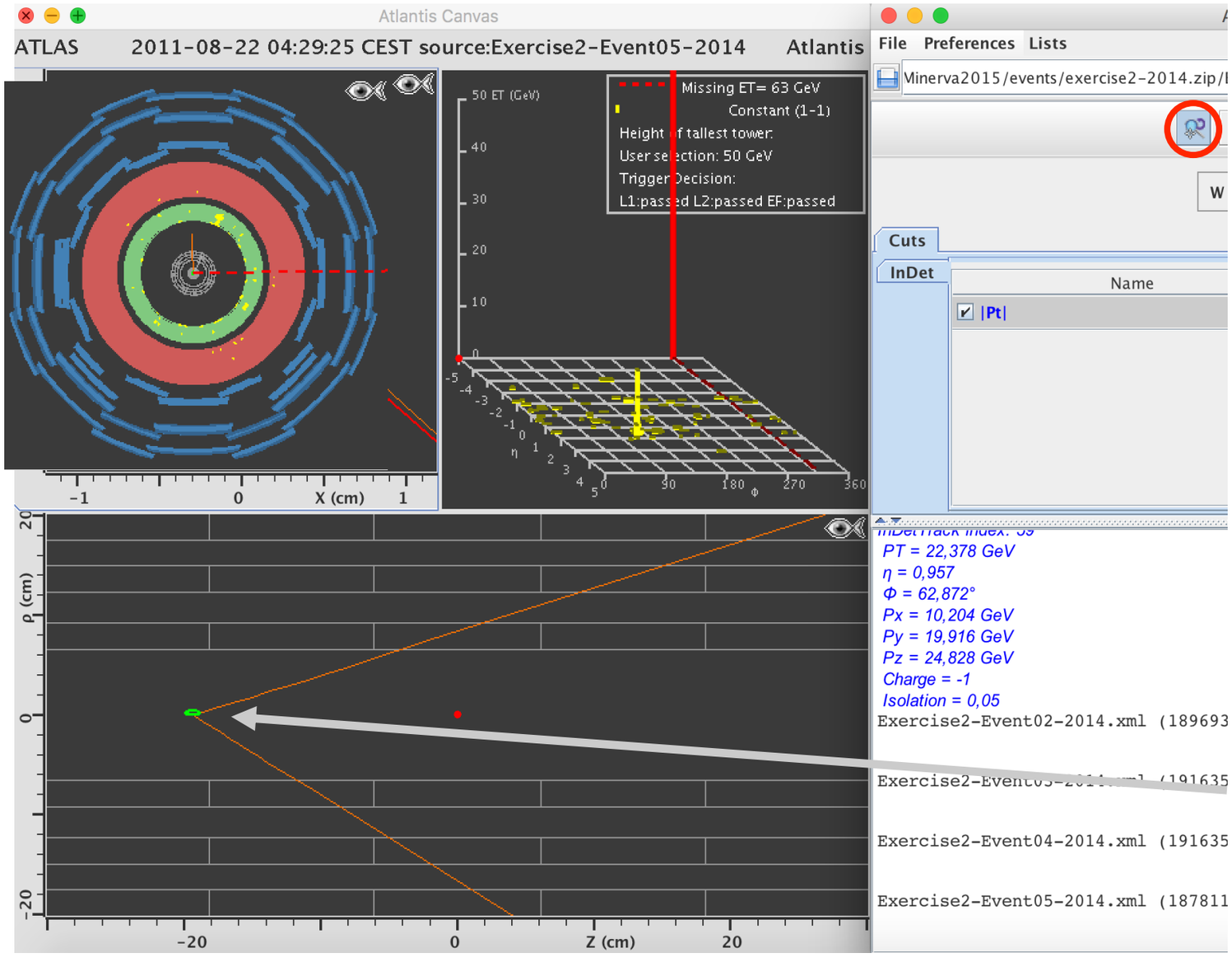
1. Select hand
2. Click on track
3. Information is displayed at the bottom right.

Track isolated

⇔

Isolation < 0.2

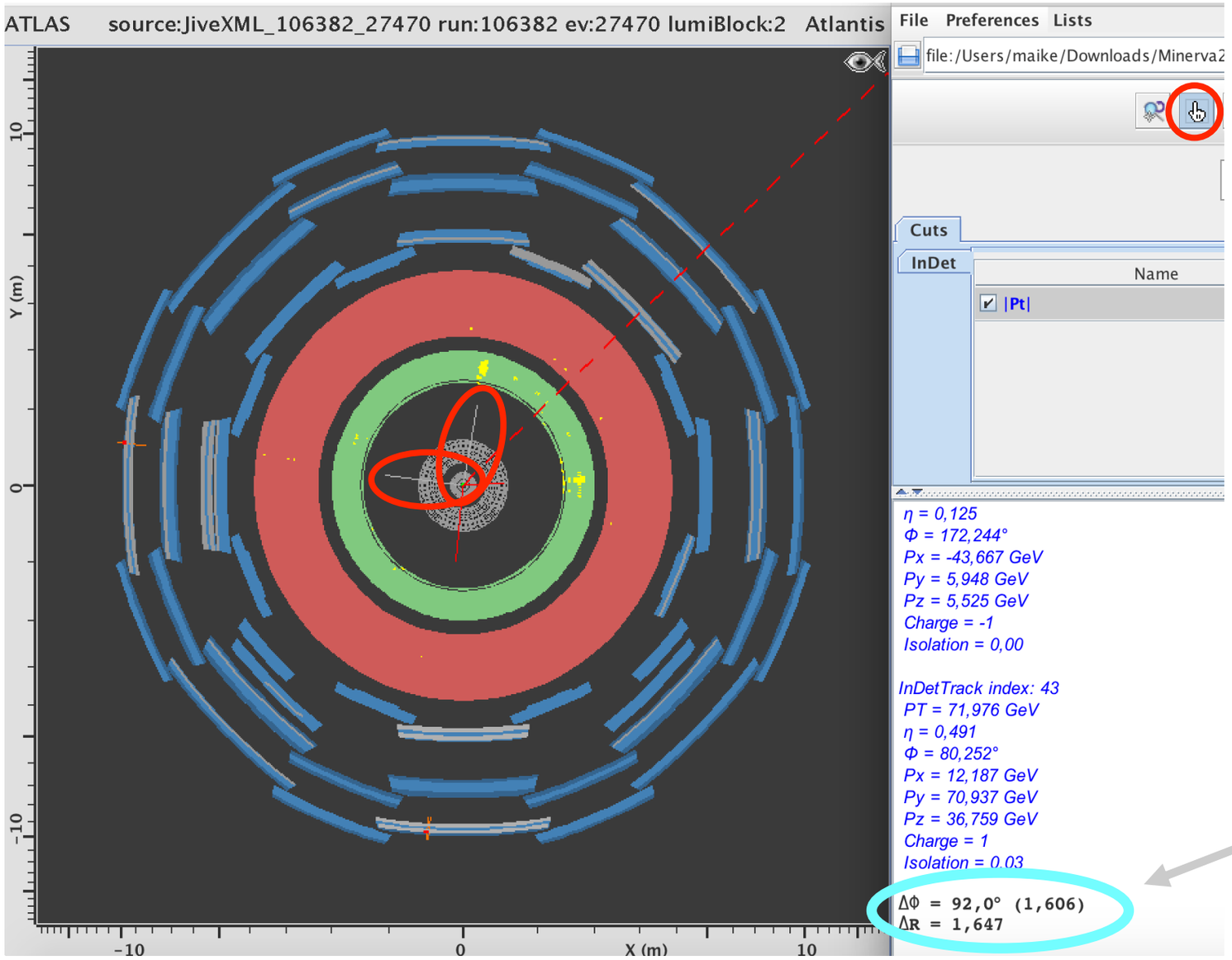
TOOLS: VERTEX



1. Select magnifying glass
2. Move cursor from center of the image outwards

Everything in the green circle belongs to the vertex & must be considered.

TOOLS: ANGLE



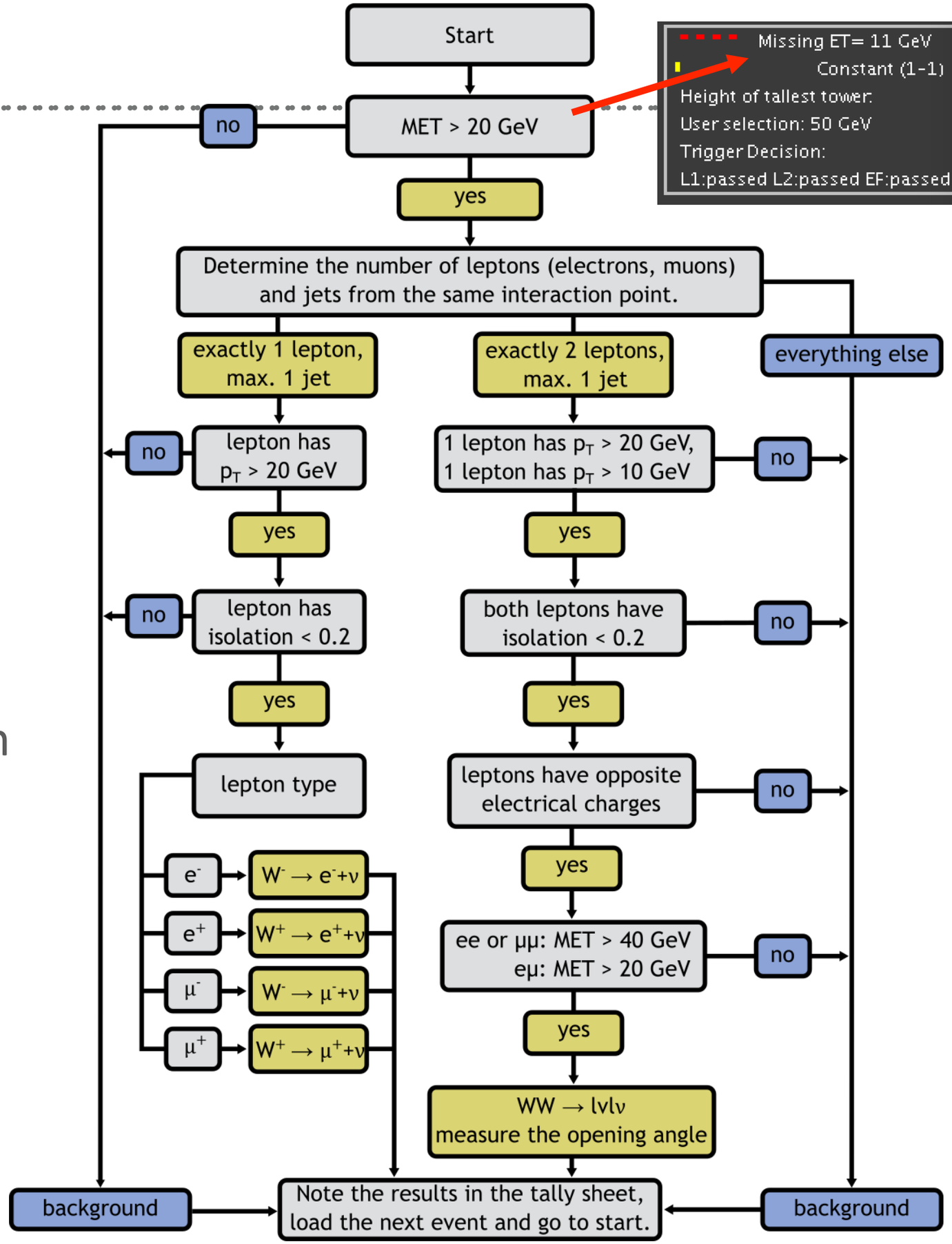
1. Select hand
2. Hold down P key
3. Click on the two tracks one after the other

You will find the angle $\Delta\phi$ displayed at the bottom right.

EVENT SELECTION

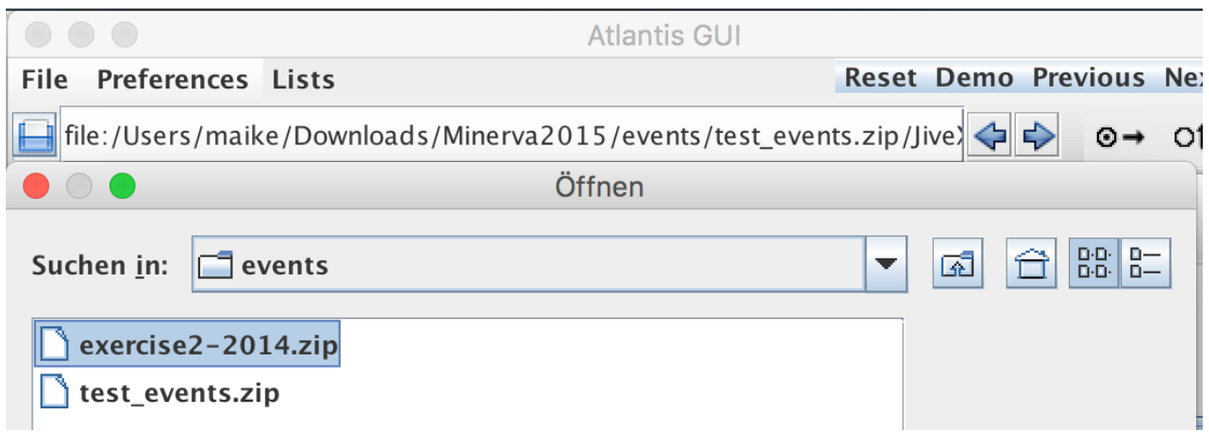
1. Start at the top
2. Follow the flowchart
3. Classify the event

- MET= missing transverse energy
- lepton = electron or muon here
- jet = several tracks in same direction



IT‘S YOUR TURN!

- https://atlas.physicsmasterclasses.org/en/wpath.htm
- Click on identifying events and perform exercise 2
  - Open Minerva and load events for exercise 2
  - Classify events
- Enter the results into the table on the website & check



IT‘S YOUR TURN!

- https://atlas.physicsmasterclasses.org/en/wpath.htm
- Open Minerva and analyze one of the data sets
- Load your own data set (A/B/…)
- Mark each event in the table
- At the end: Add up events and tell us!
  - We enter the results into a table.