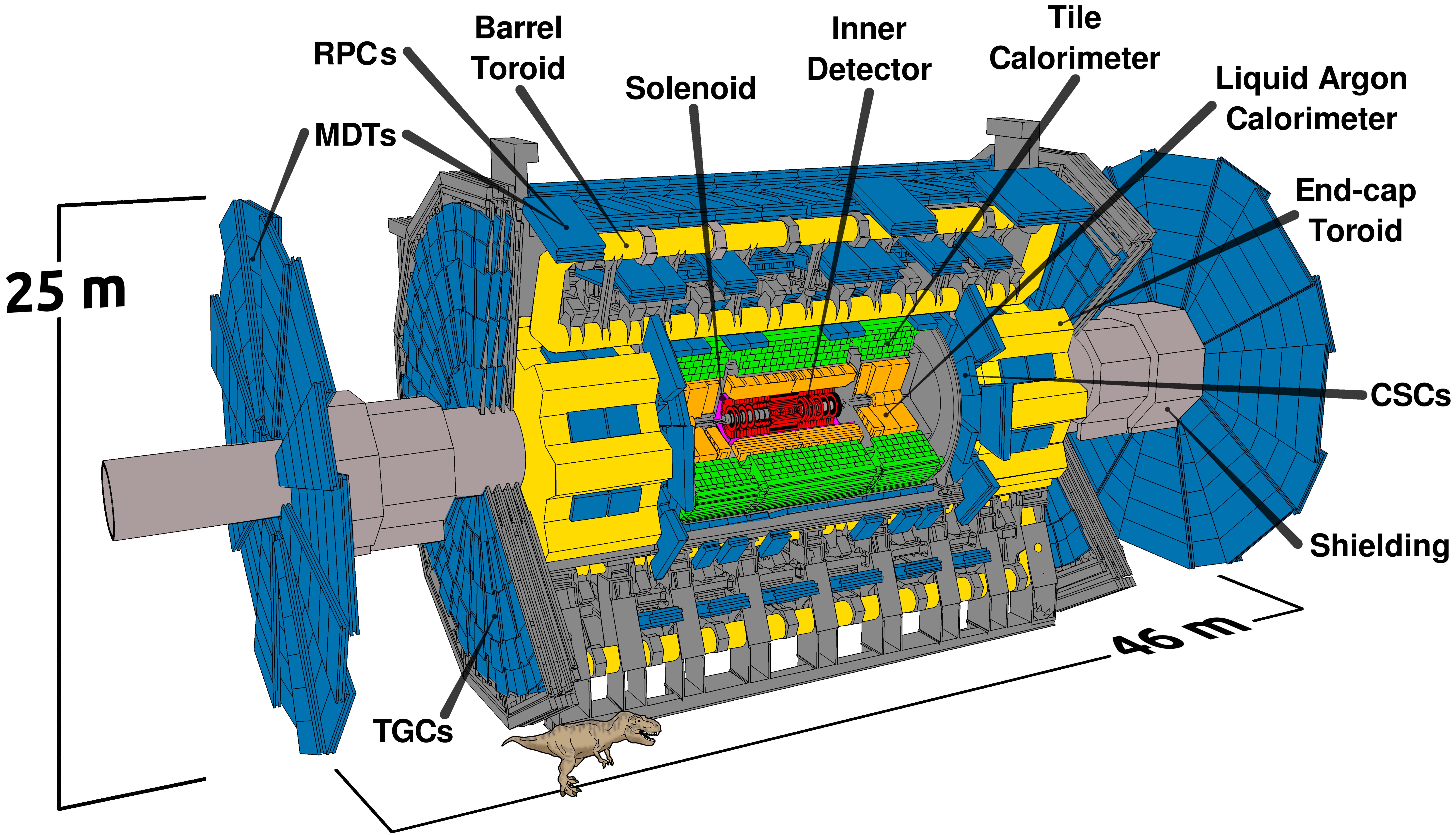
PARTICLE PHYSICS MASTERCLASS

ATLAS EXPERIMENT



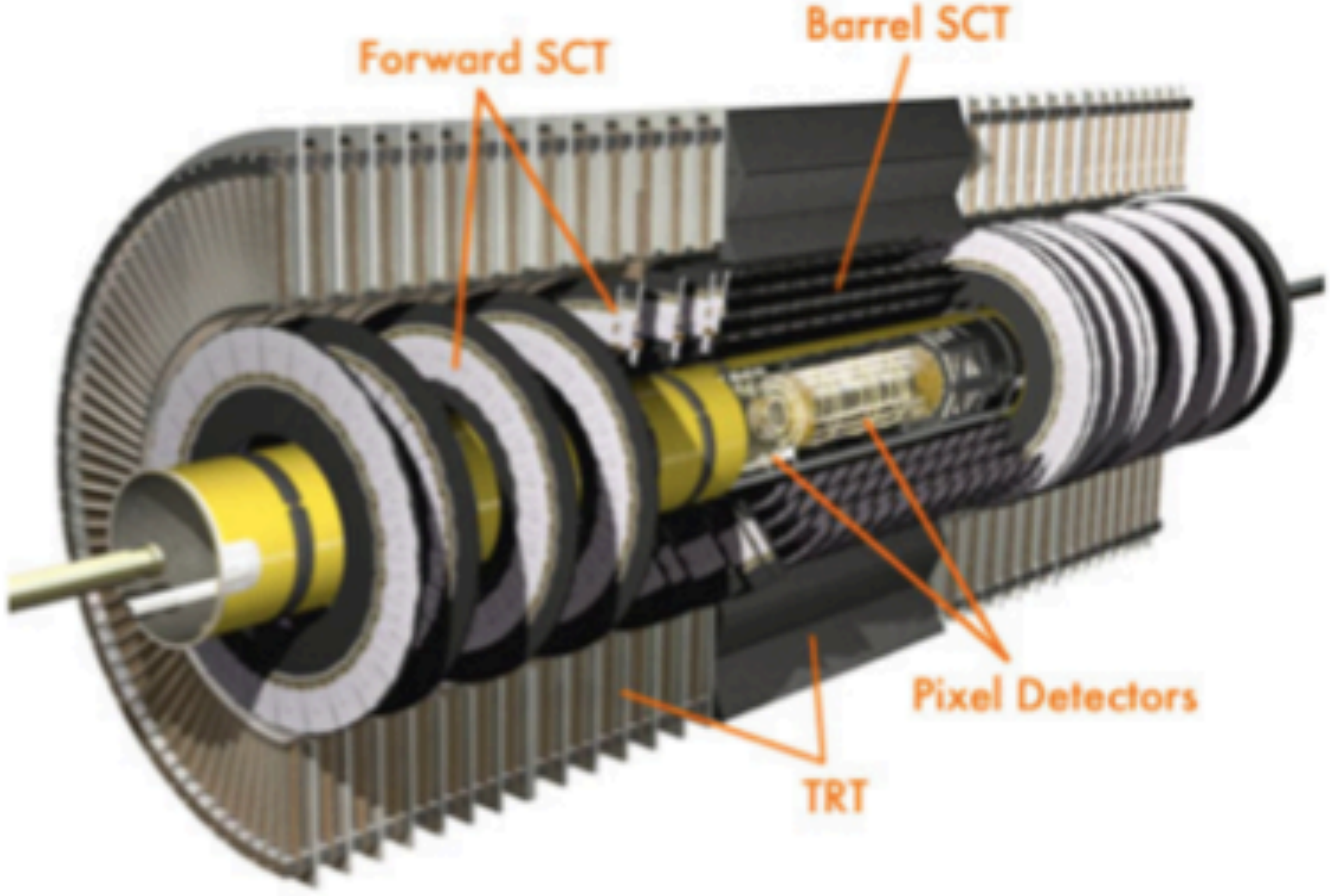
RPCs
Barrel Toroid
Solenoid
Inner Detector
Tile Calorimeter
Liquid Argon Calorimeter
MDTs
End-cap Toroid
25 m
CSCs
Shielding
TGCs
46 m


up
charm
top
gluon
Higgs
down
strange
bottom
photon
electron
muon
tau
Z
electron neutrino
muon neutrino
tau neutrino
W

ATLAS

Inner Detector

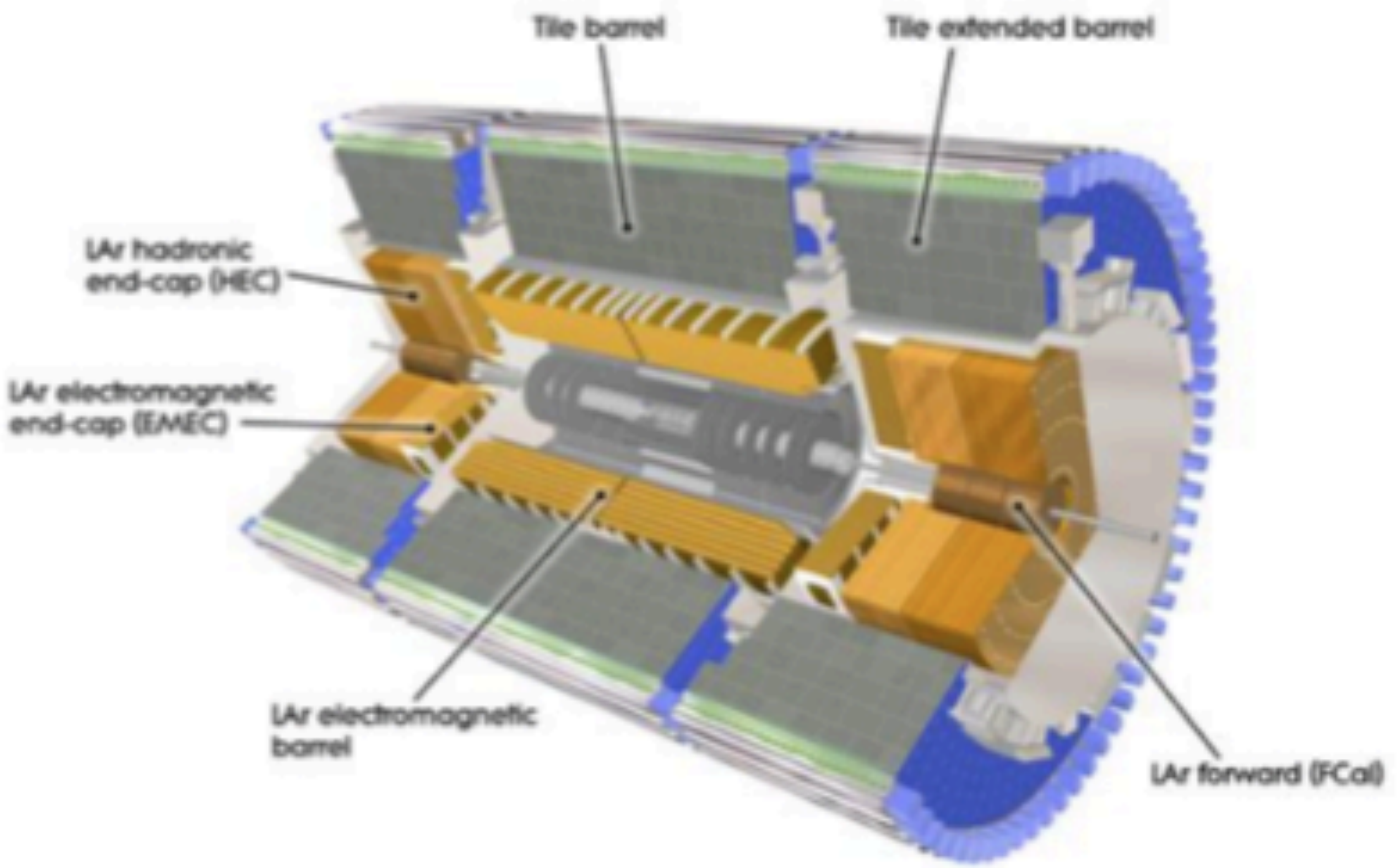
- The inner most part of ATLAS.
- Contained in solenoid magnetic field of 2T.
- Mainly from silicon.
- Determine the trajectory of charged particles.
- Magnetic field curves the track of charged particles.
- This helps to measure the momentum.



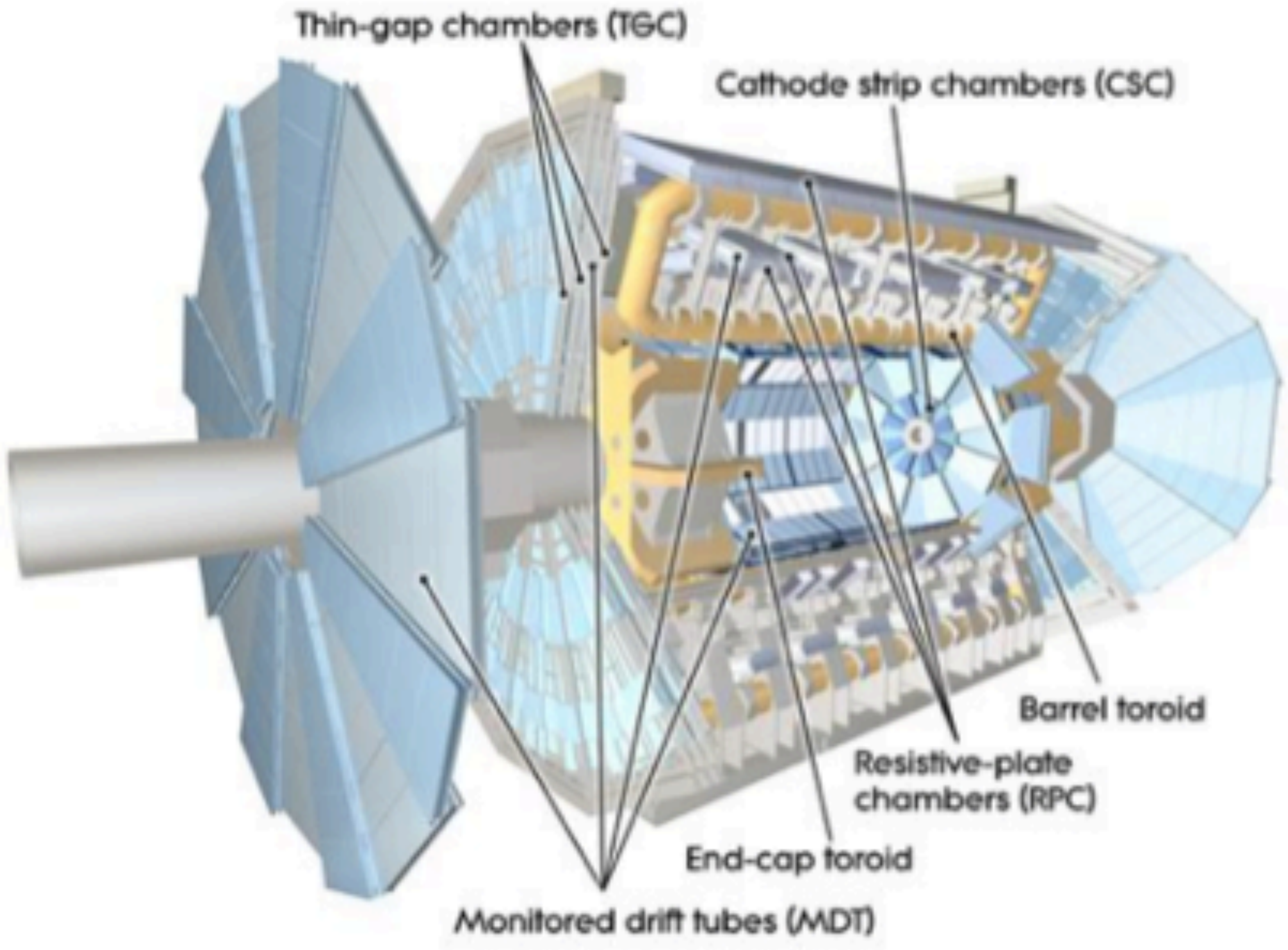
ATLAS

Calorimeter

- Absorb the particle to measures its energy.
- EM identifies electrons and photons.
- Hadronic calorimeter measures jets (hadrons).
- Muons do not stop in the calorimeter but leave a track.
- The missing transverse energy is determined ➔ neutrino



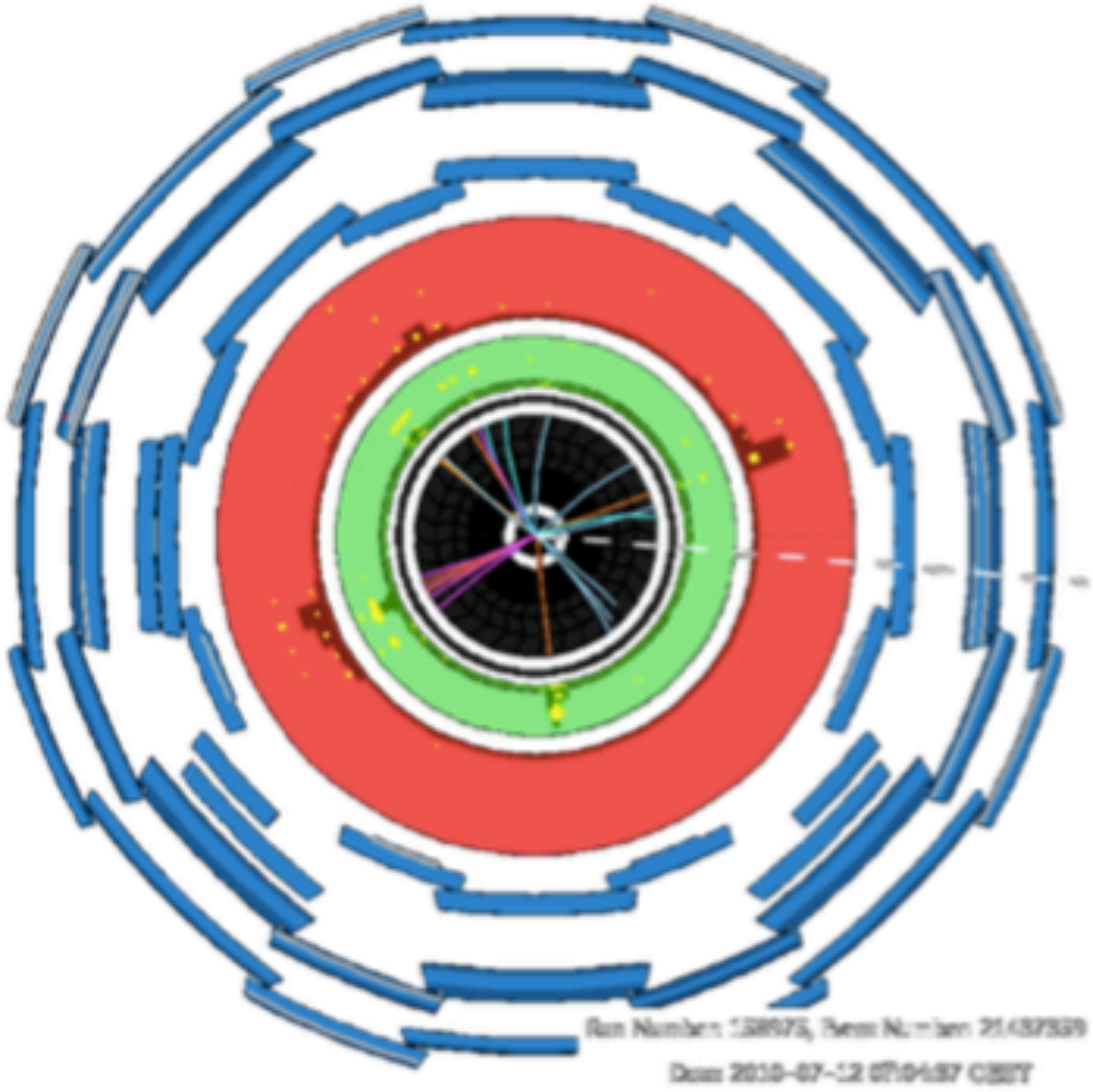
Muon Spectrometer



- The outer part of ATLAS.
- Toroidal magnets.
- 0.5 T in the barrel and 1 T in the end-cap.
- Identify muons.

ATLAS

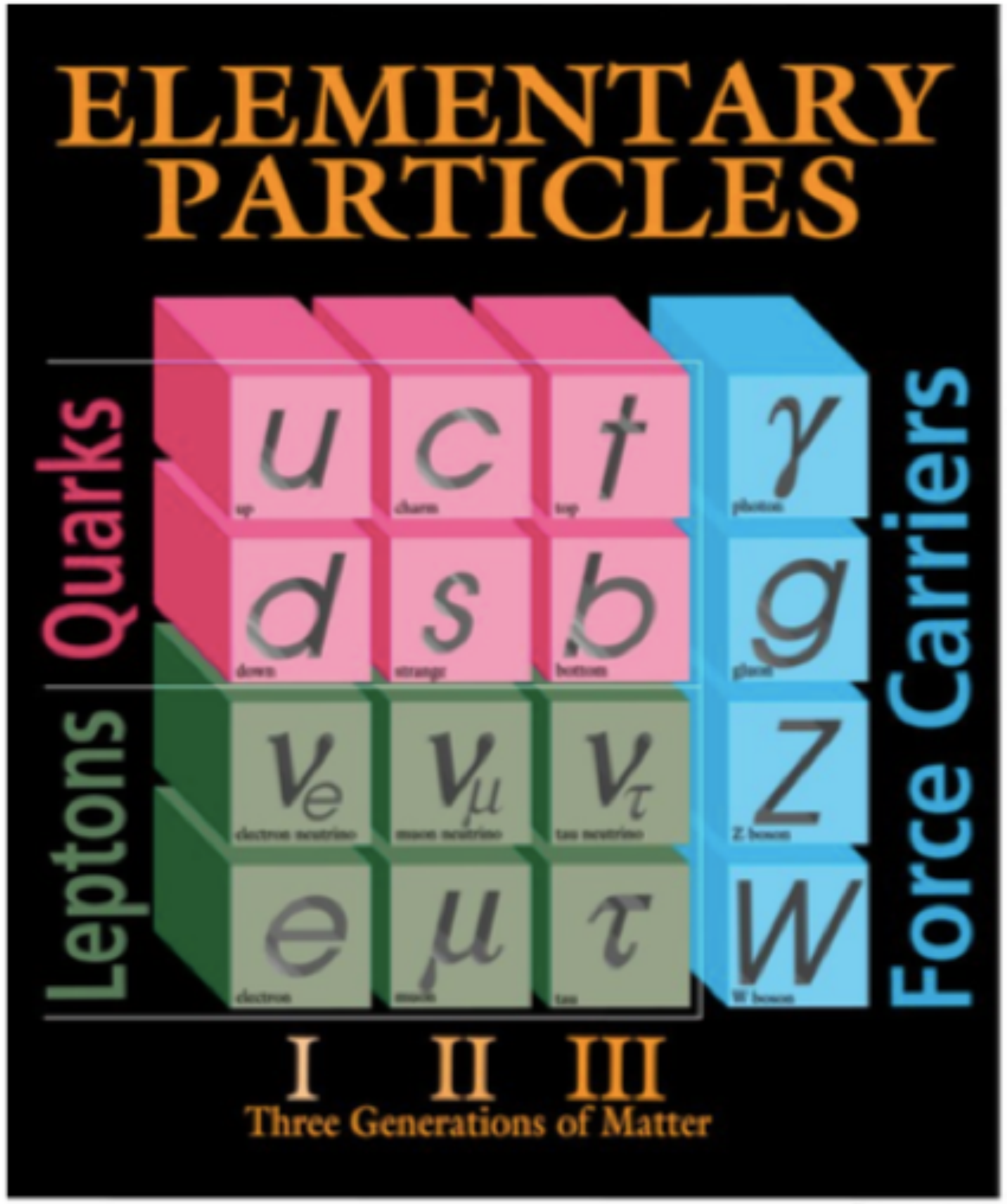
Reconstruction of Particles



- **Inner Detector:**
  - Tracks the path of charged particles.
  - Magnetic field bends the path of charged particles.
- **Electromagnetic Calorimeter:**
  - Particles that interact with the electromagnetic force leave energy deposits.
  - Absorbs Electrons and Photons.
- **Hadronic Calorimeter:**
  - Jets (from quarks) are absorbed.
- **Muon Spectrometer:**
  - Tracks the path of Muons.
  - Magnetic field bends the path of Muons.

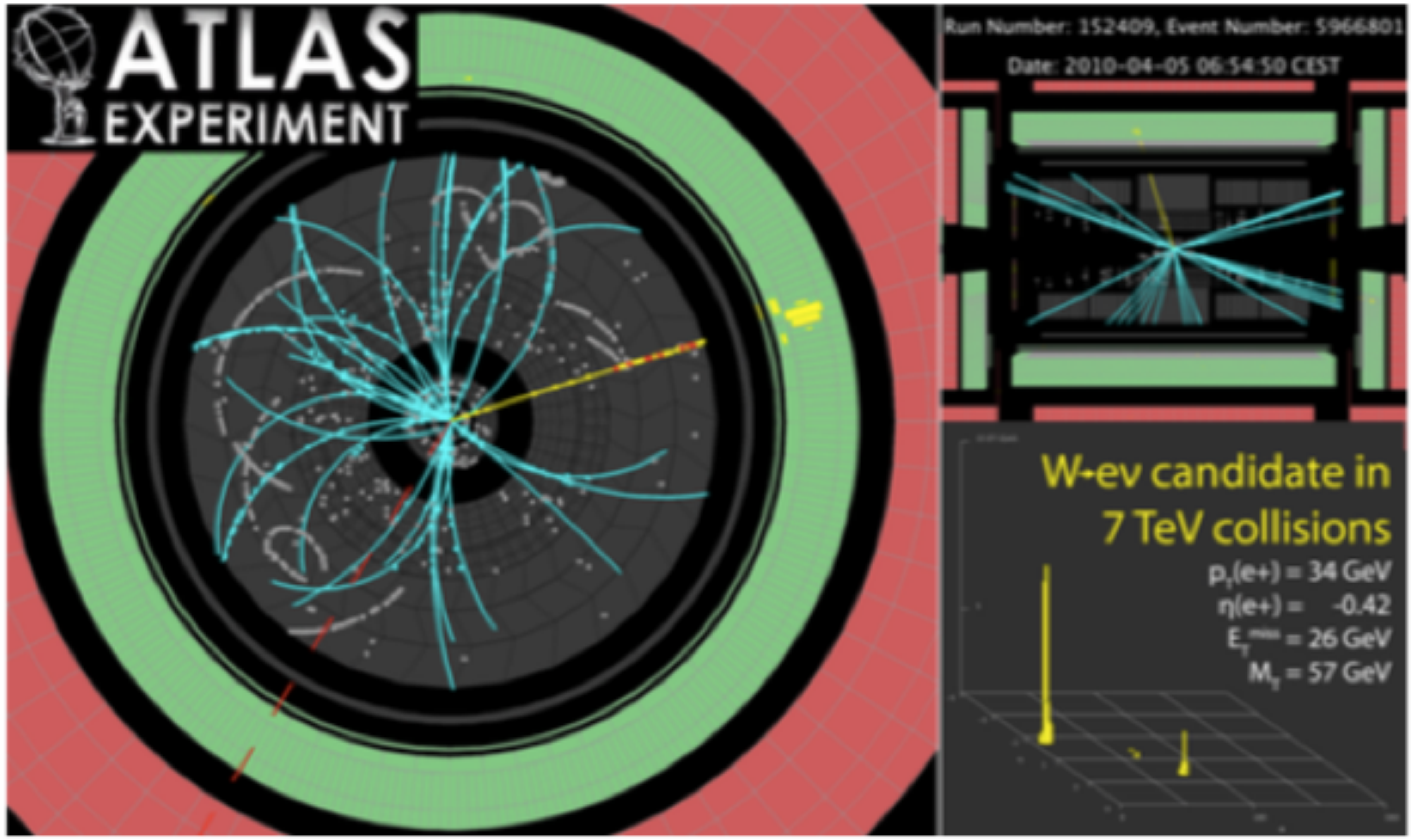
Detecting of Leptons

- Charged Leptons:
  - Electrons are stable and can be detected.
  - Muons are unstable but their lifetime is long enough to be detected.
  - Tau is unstable and decay very fast.
- Neutrino:
  - Leave the detector without leaving a signature.



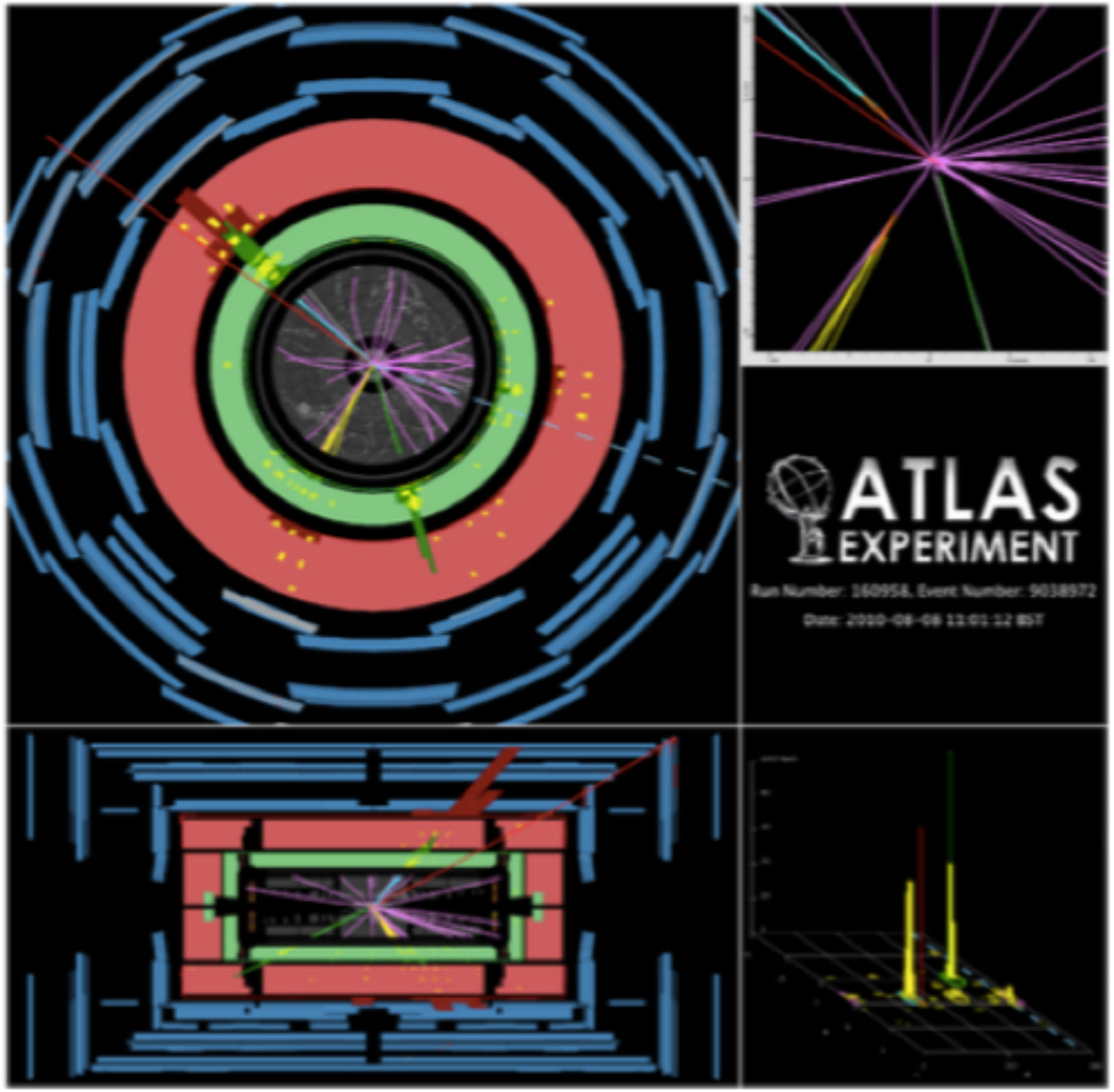
Detecting of Electrons

- e^- and e^+ are charged.
- Curve in opposite direction.
- Leave track in the inner detector.
- Absorbed in the electromagnetic calorimeter.



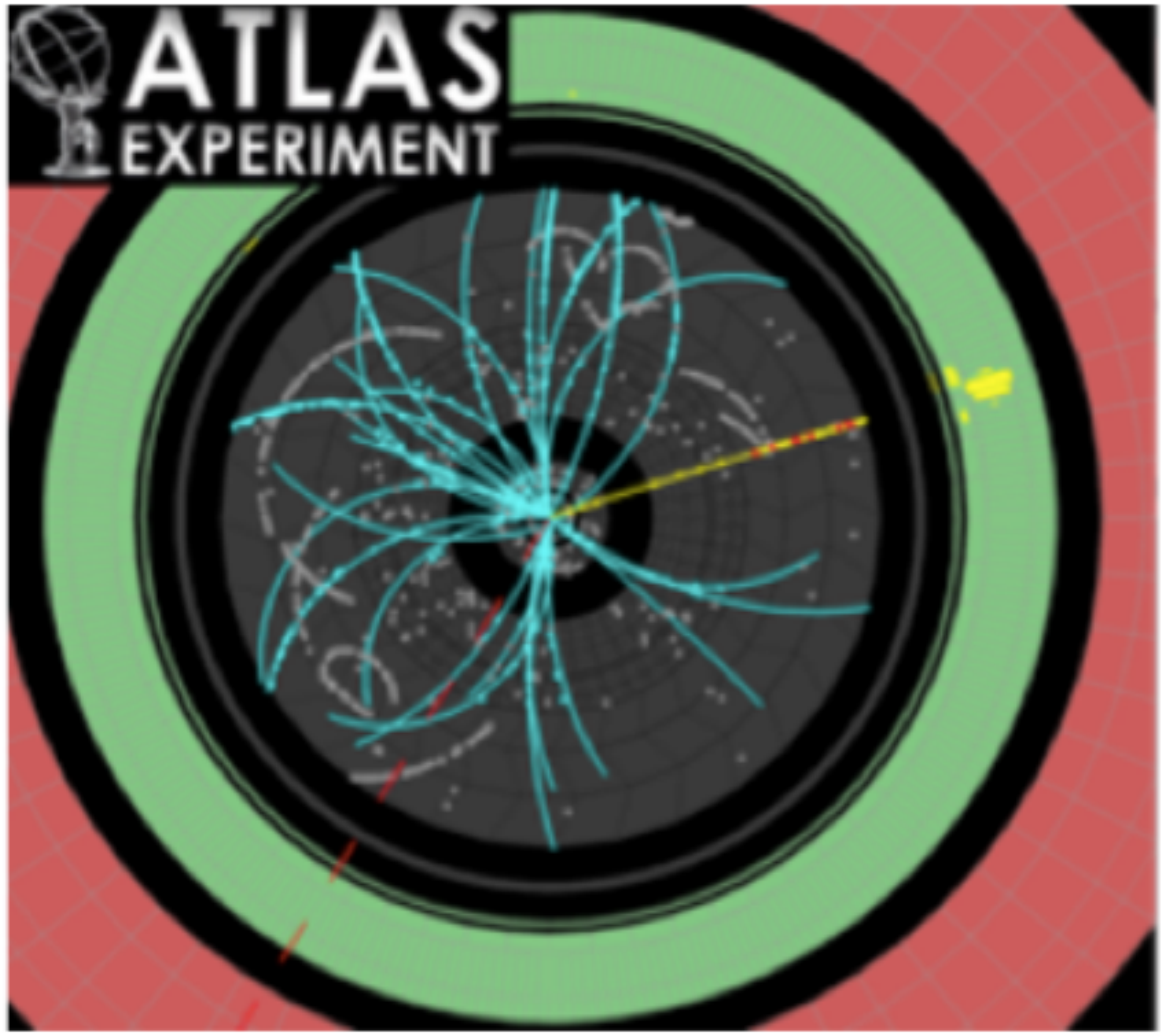
Detecting of Muons

- μ^- and μ^+ are charged.
- Leave track in the inner detector.
- Escape the detector without being stopped.
- Detected in the muon spectrometer.



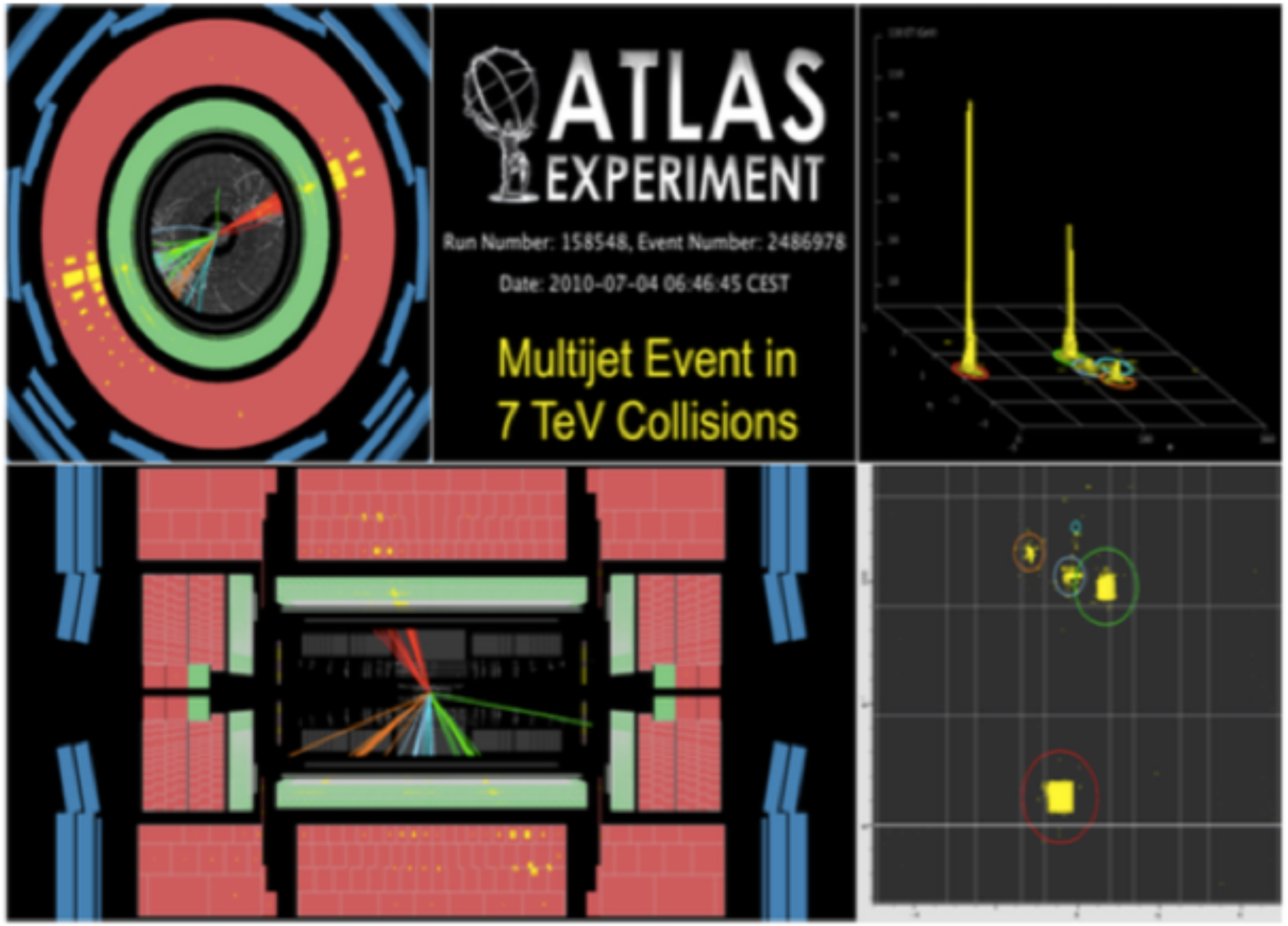
Neutrino

- The detector cannot detect neutrinos.
- We know they are produced by the conservation of momentum.
- All the transverse momenta of particles are added up, there will be missing energy that the neutrino took away.
- Called the missing transverse energy.



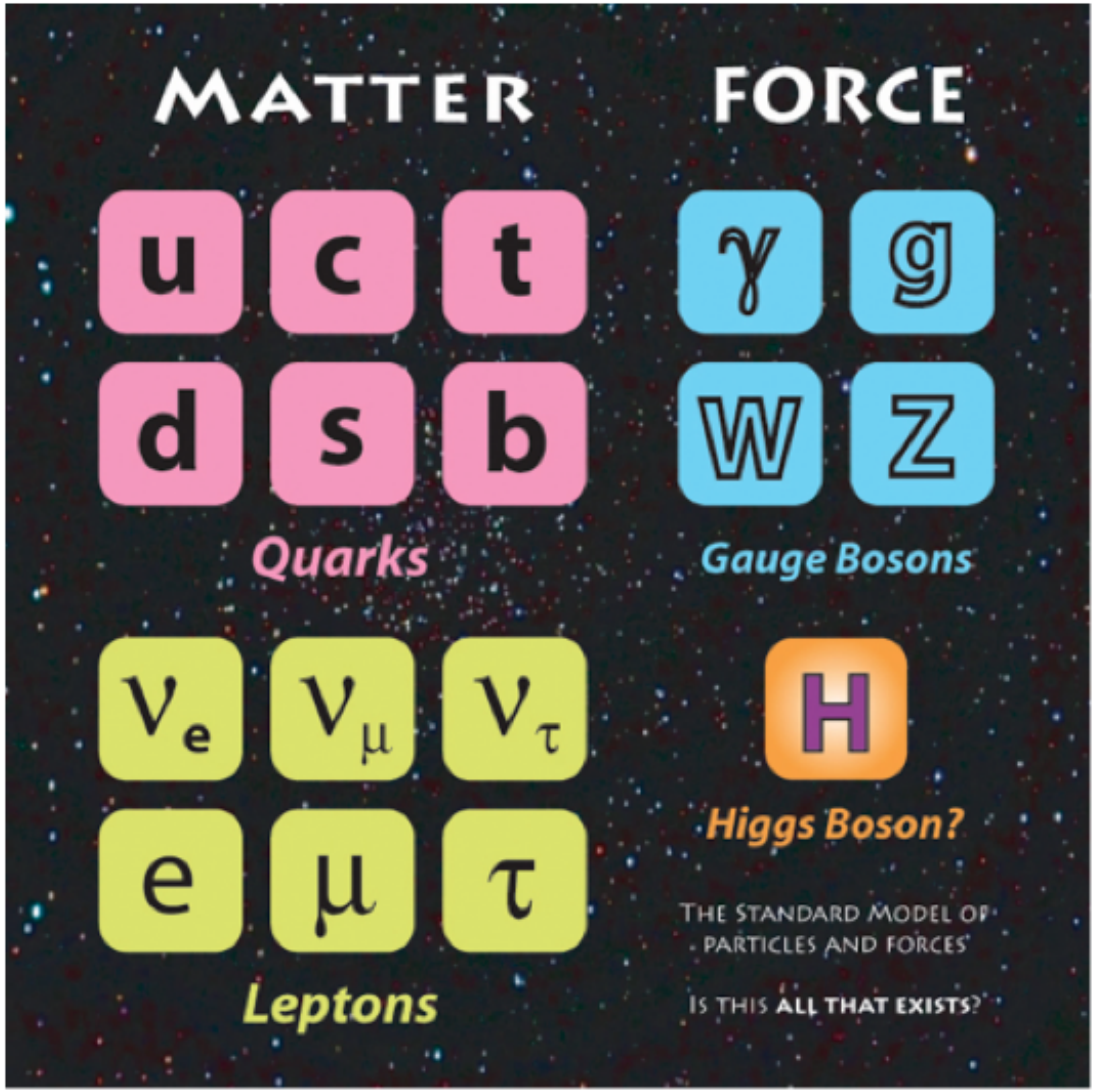
Detecting of Quarks

- Quarks are charged.
- Leave track in the inner detector.
- Interact with the electromagnetic force.
- Leave some energy deposit in the electromagnetic calorimeter.
- Absorbed in the hadronic calorimeter.



Detecting of Bosons

- Photons:
  - Do not leave track in the inner detector.
  - Stopped in the electromagnetic calorimeter.
- gluons:
  - Hadronise like quarks.
  - Many tracks in the inner detector.
  - Absorbed in the hadronic calorimeter.
- W and Z:
  - Decay very fast into other particles which are detected.



Photons

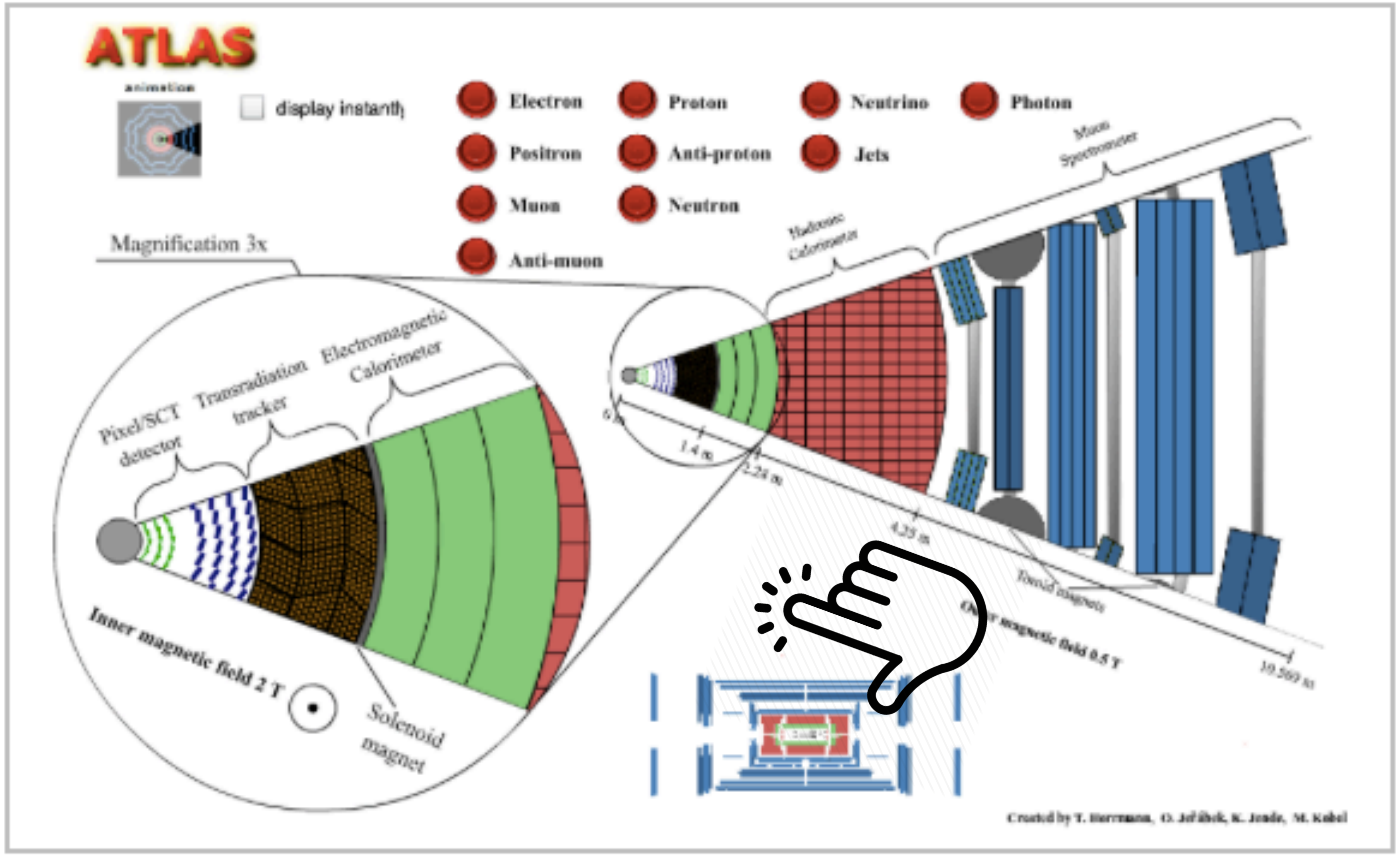
photons


Muon
Jet
Jet
Electron
Missing ET
mass
charge
spin
u
up
c
charm
t
top
g
gluon
H
Higgs boson
d
down
s
strange
b
bottom
γ
photon
e
electron
μ
muon
τ
tau
Z
Z boson
νe
electron neutrino
νμ
muon neutrino
ντ
tau neutrino
W
W boson
QUARKS
LEPTONS
GAUGE BOSONS

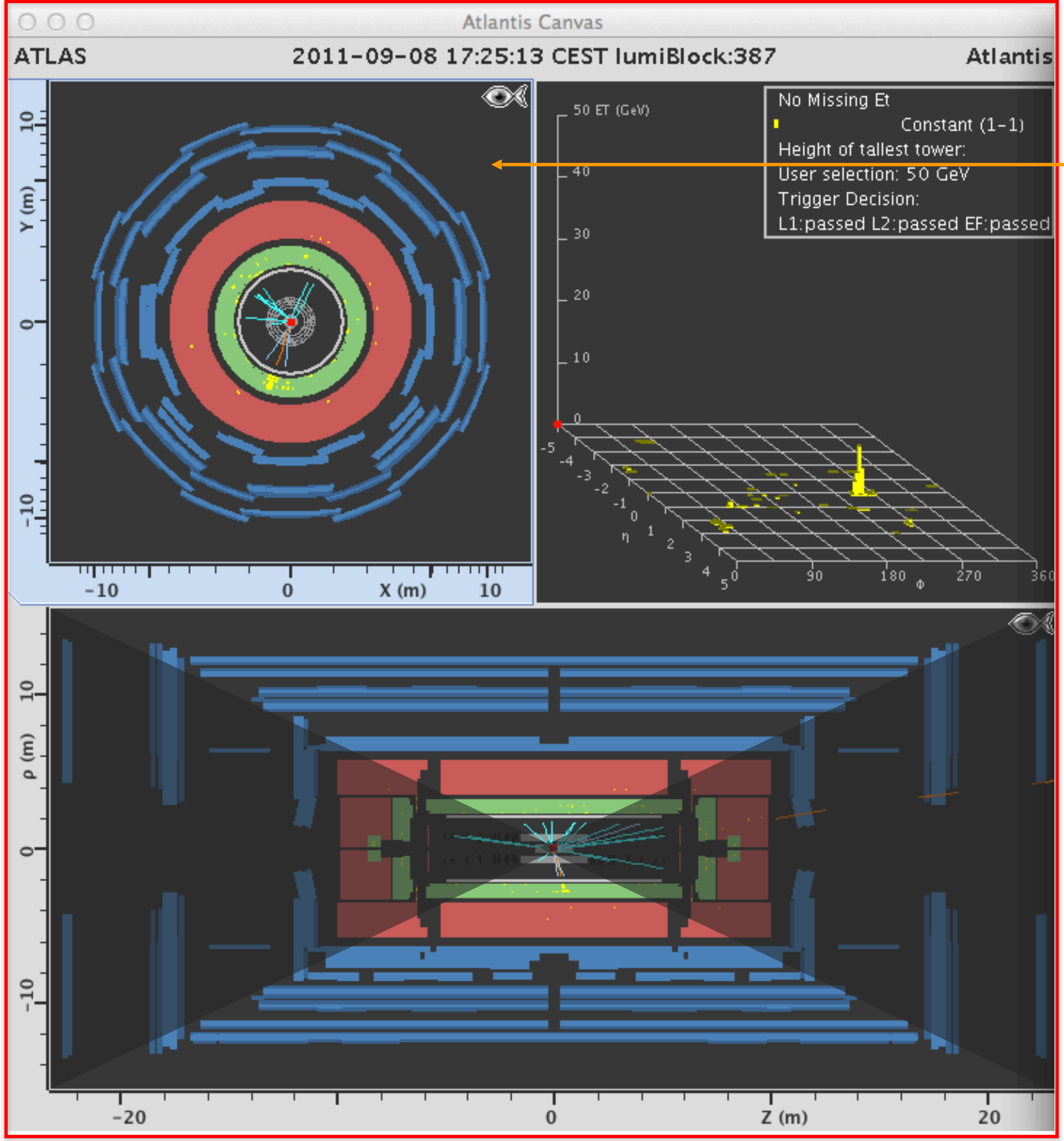
5 minutes

Play!

It is now time for active playing! Investigate the footprints left in the detector by elementary particles with the help of the interactive animation of the ATLAS detector. For this, click on the name of a specific particle in the upper menu and follow its way through the detector.



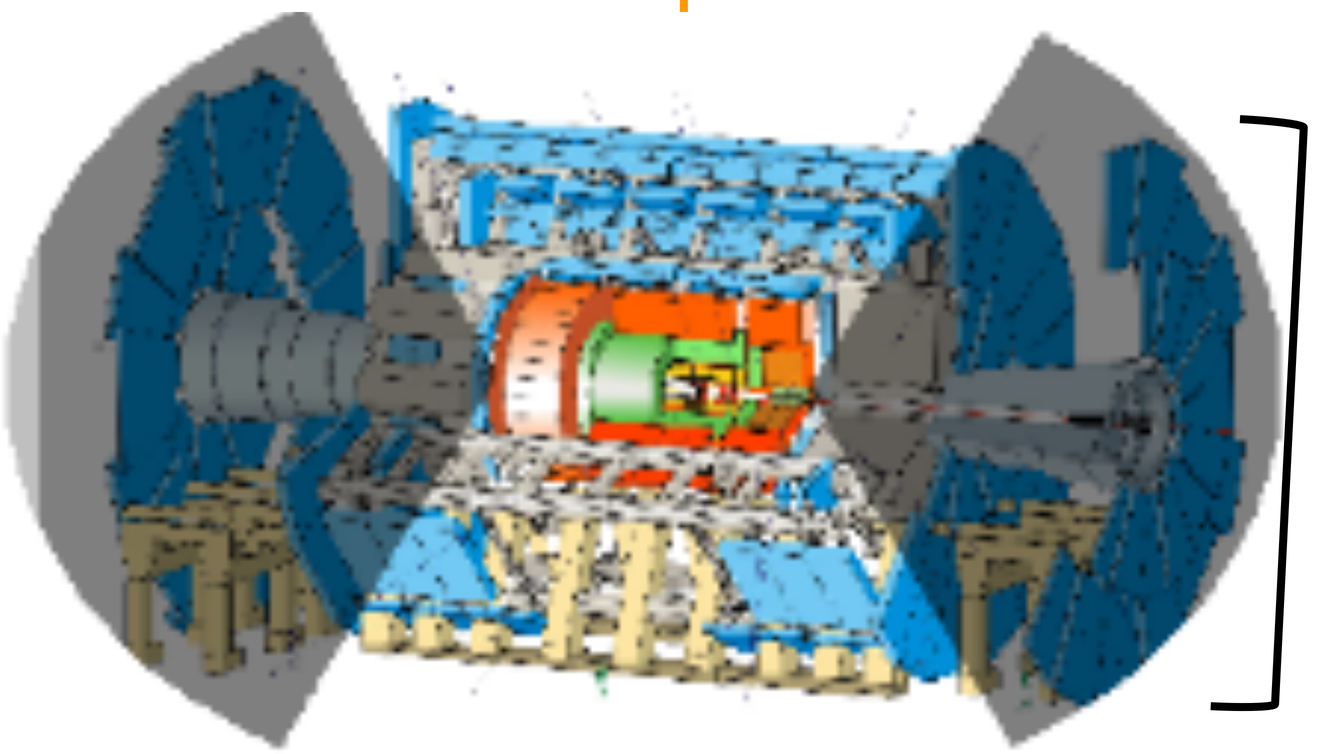
Z-Path

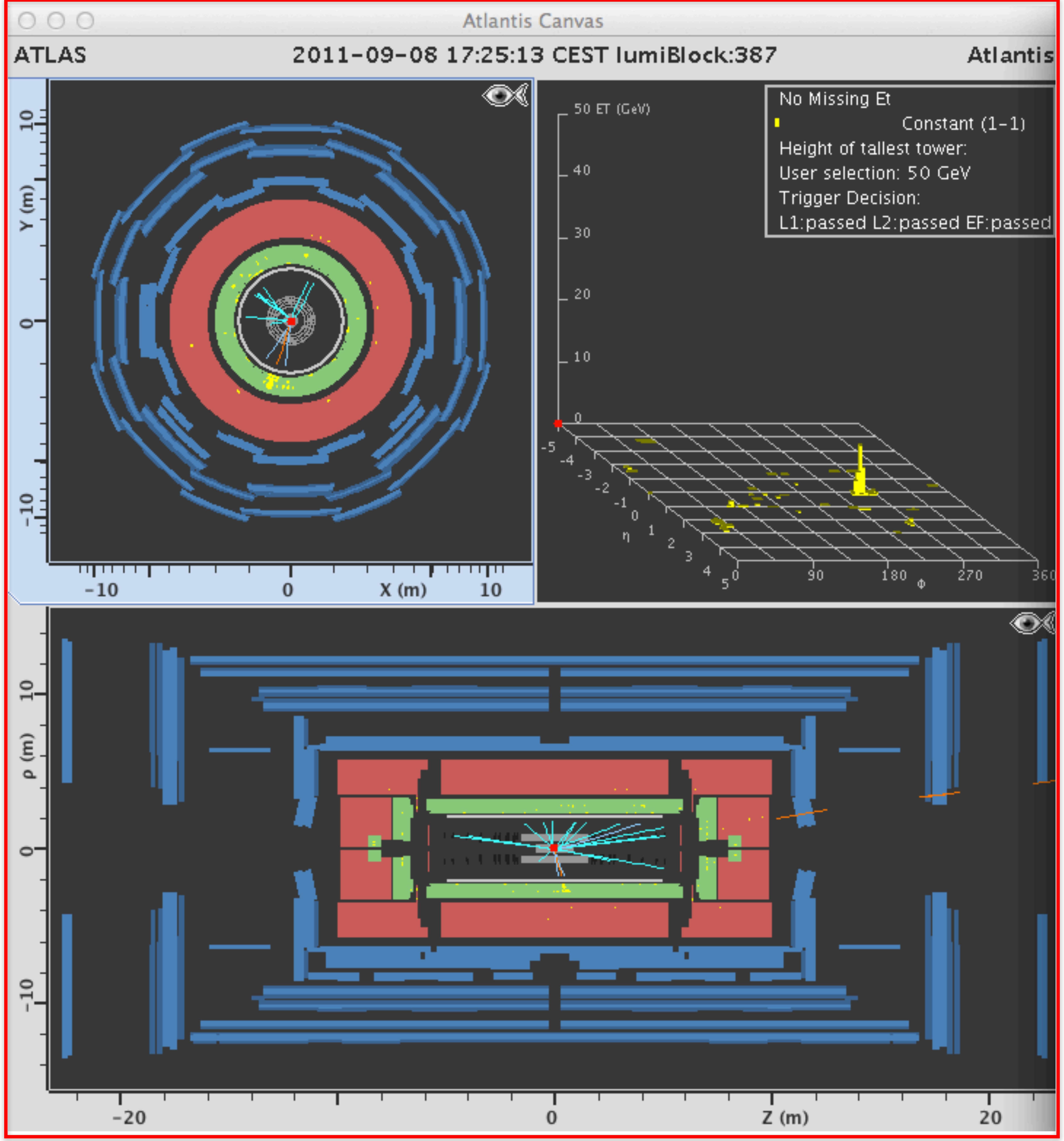


Top left

End-on view of the detector (*x-y* projection)

Warning: Only particles reconstructed in central region shown here (otherwise the particles in the forward would cover the view)!





Tracking detector

Electromagnetic calorimeter

Hadronic calorimeter

Muon detectors

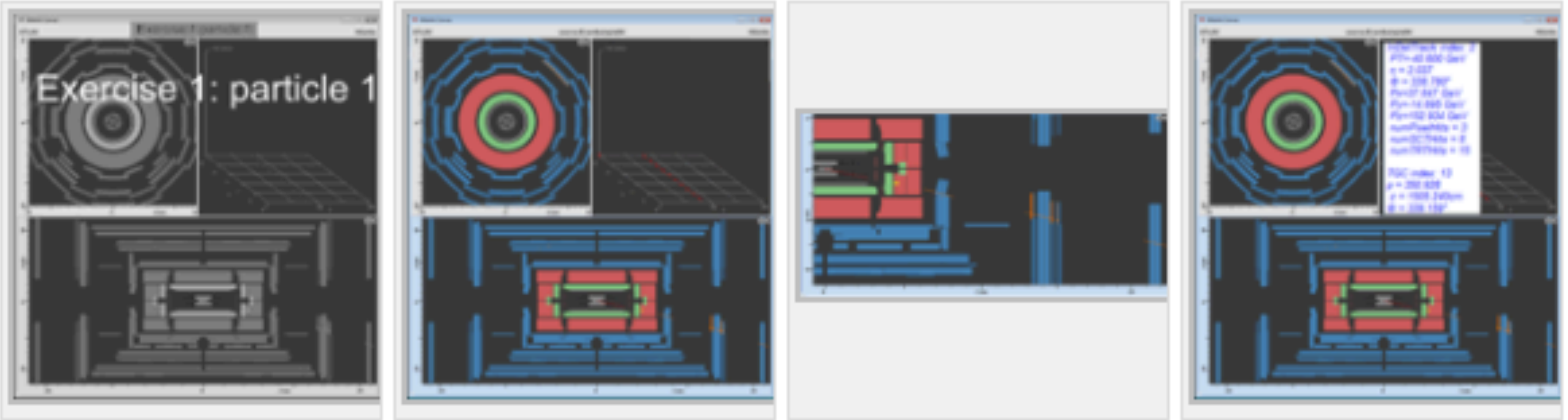
Practice Identifying Particles

One can often see tracks of several different particles in each event.

You will do some detective work in this first exercise. Make use of the event display features to find all electrons, muons, photons, neutrinos, and jets in each displayed event.

Use the checkboxes below each exercise to record the type of particles you have just observed by clicking on 'Check'. The 'Hint' button helps you along the way! The 'Correct' button shows the right answer.

Good luck!

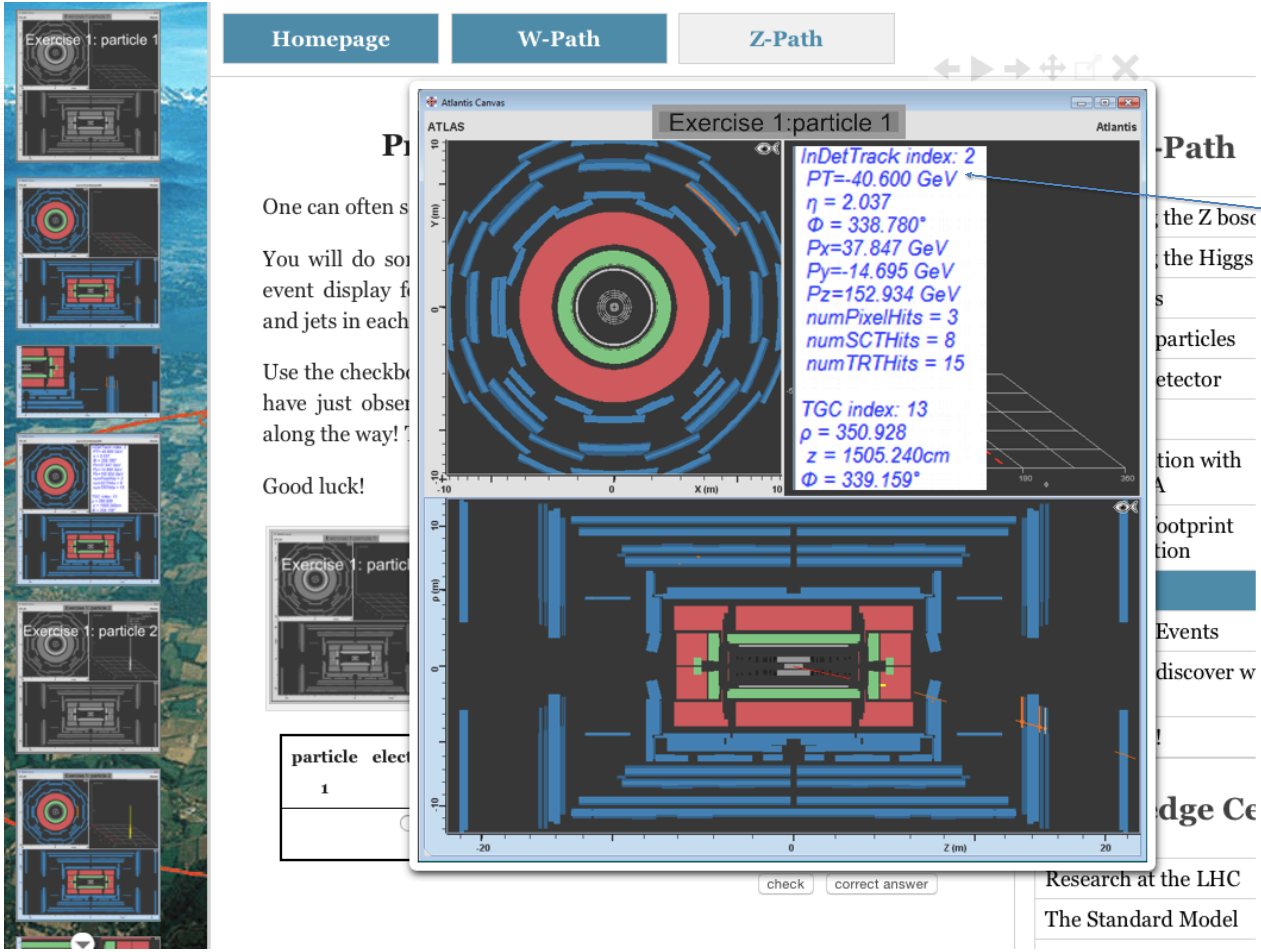


particle 1	electron	positron	muon	anti-muon	photon	neutrino-antineutrino	jet
	○	○	○	○	○	○	○

check   correct answer

Z-Path

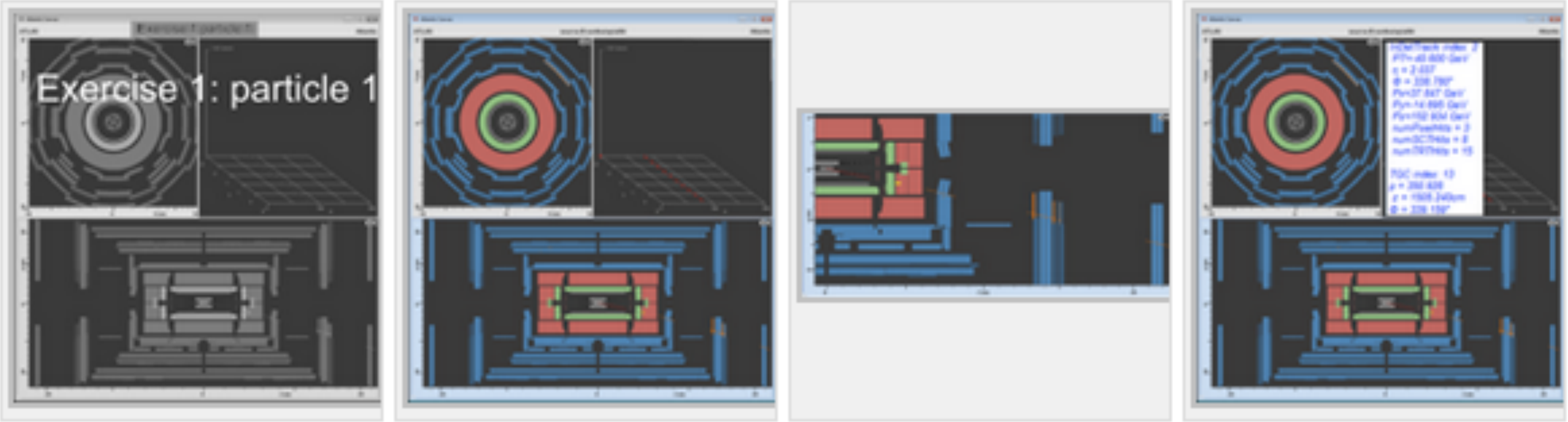
Knowledge Center



Pt = -40 GeV

Click the three pictures

What particle is it?



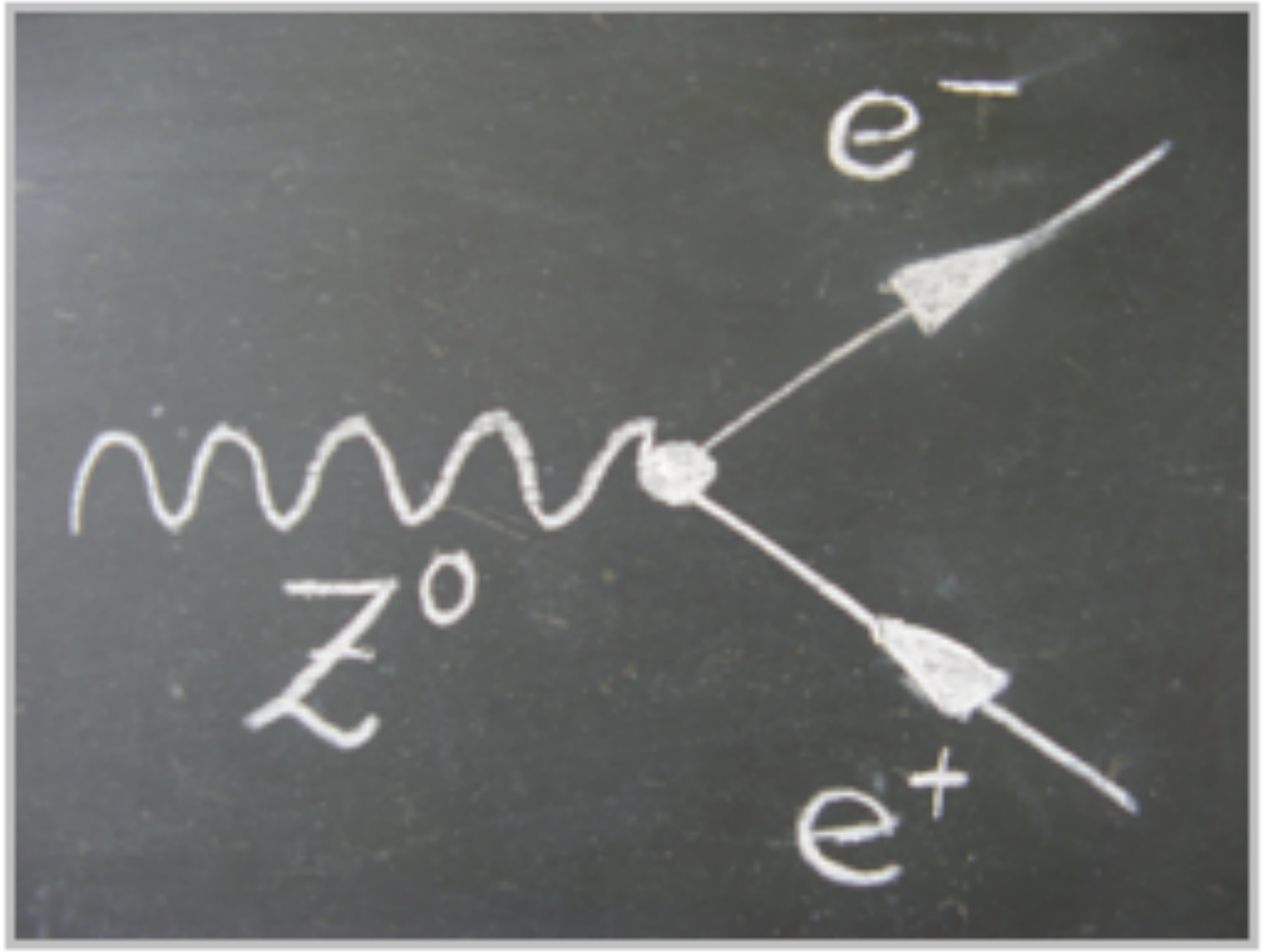
particle 1	electron	positron	muon	anti-muon	photon	neutrino-antineutrino	jet
	○	○	●	○	○	○	○

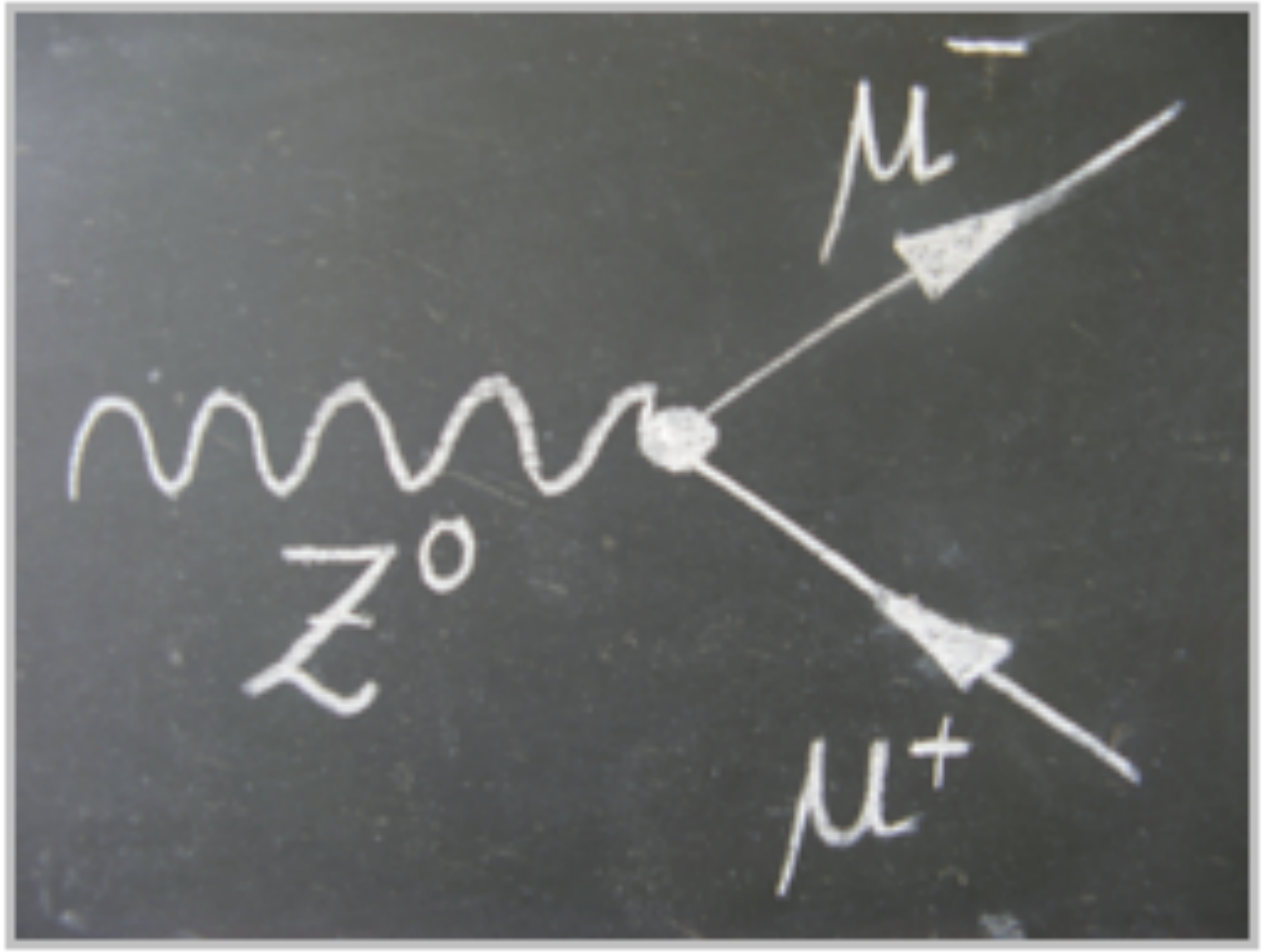
check

~~correct answer~~

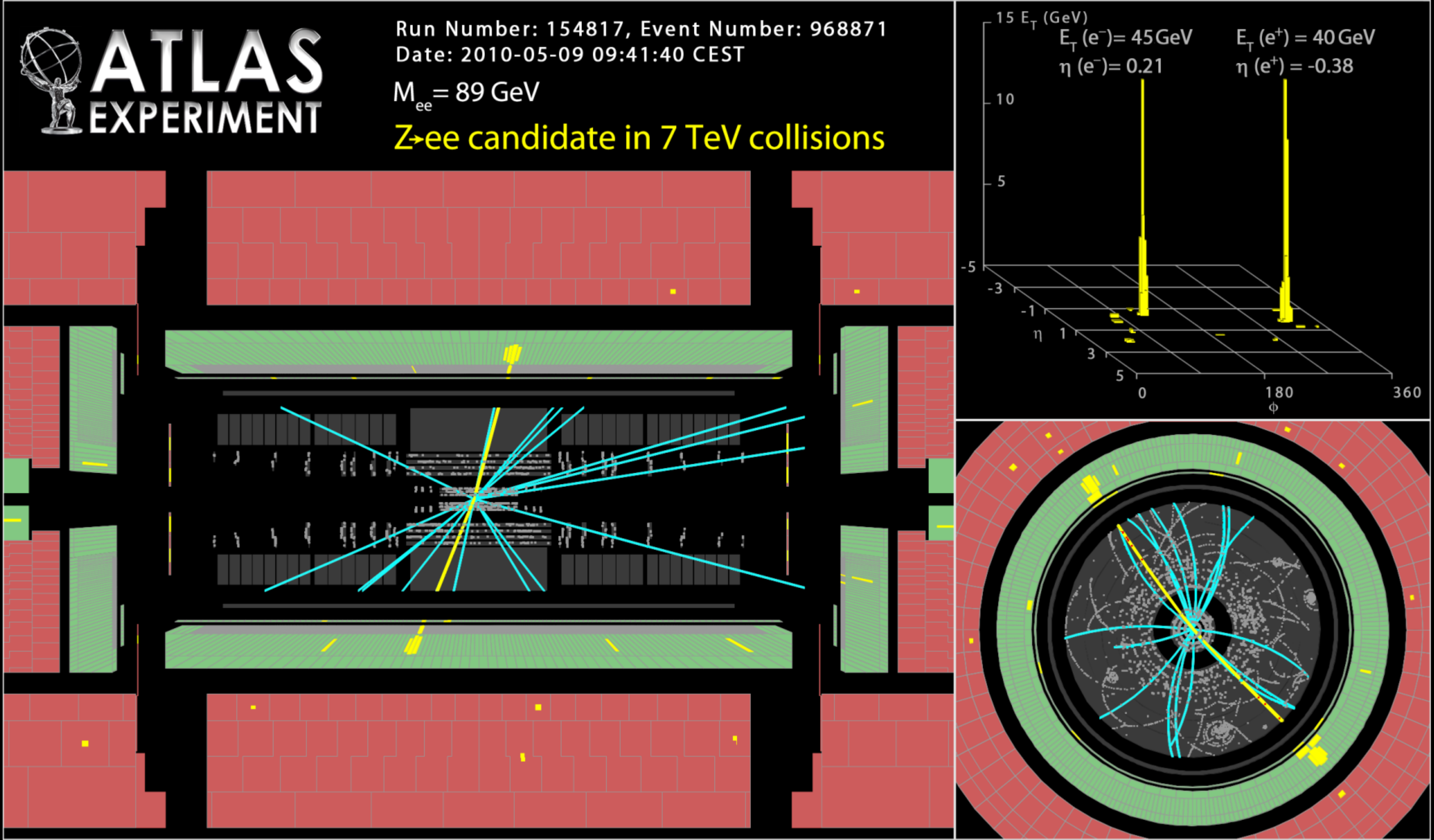
Searching for the Z-boson

Since Z is neutral the sum of the charges of its decay products must be **zero**



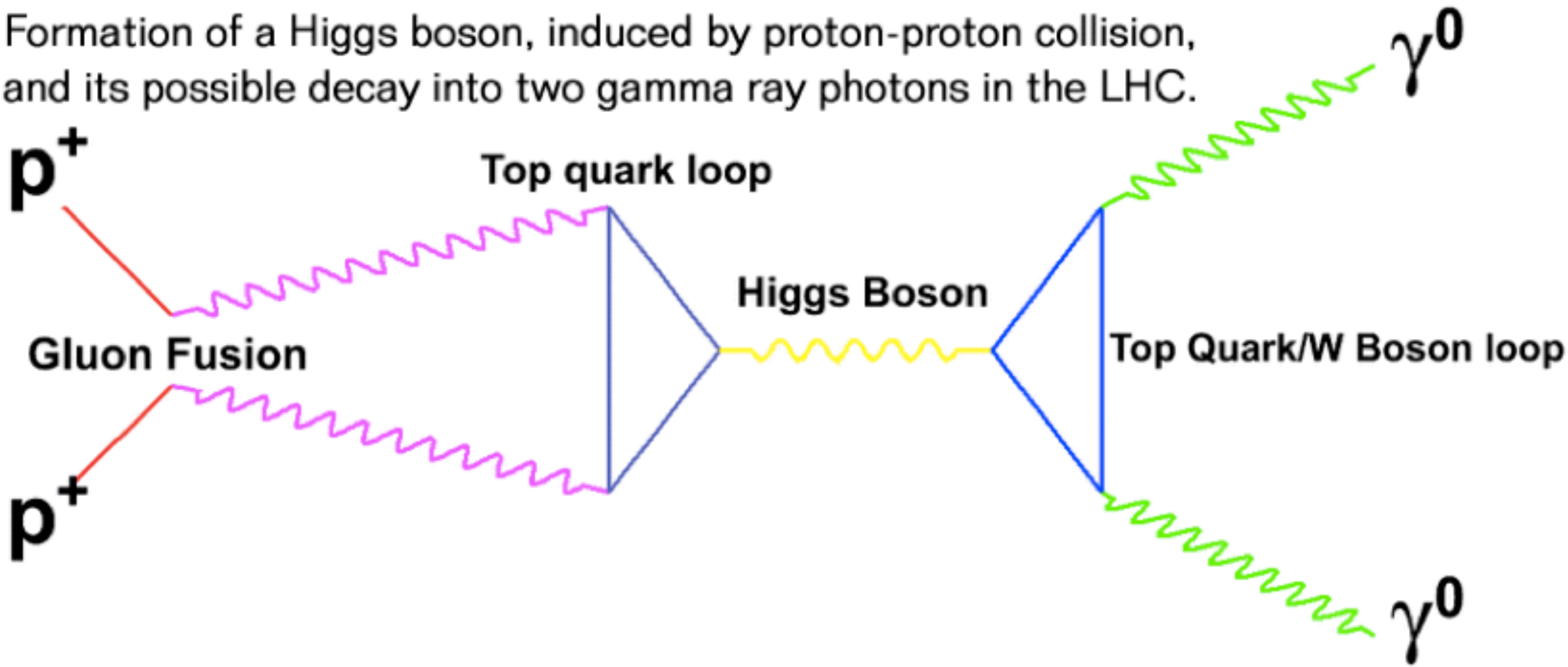


ATLAS EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST
$p_T(\mu^-) = 27$ GeV $\eta(\mu^-) = 0.7$
$p_T(\mu^+) = 45$ GeV $\eta(\mu^+) = 2.2$
$M_{\mu\mu} = 87$ GeV
Z→μμ candidate
in 7 TeV collisions

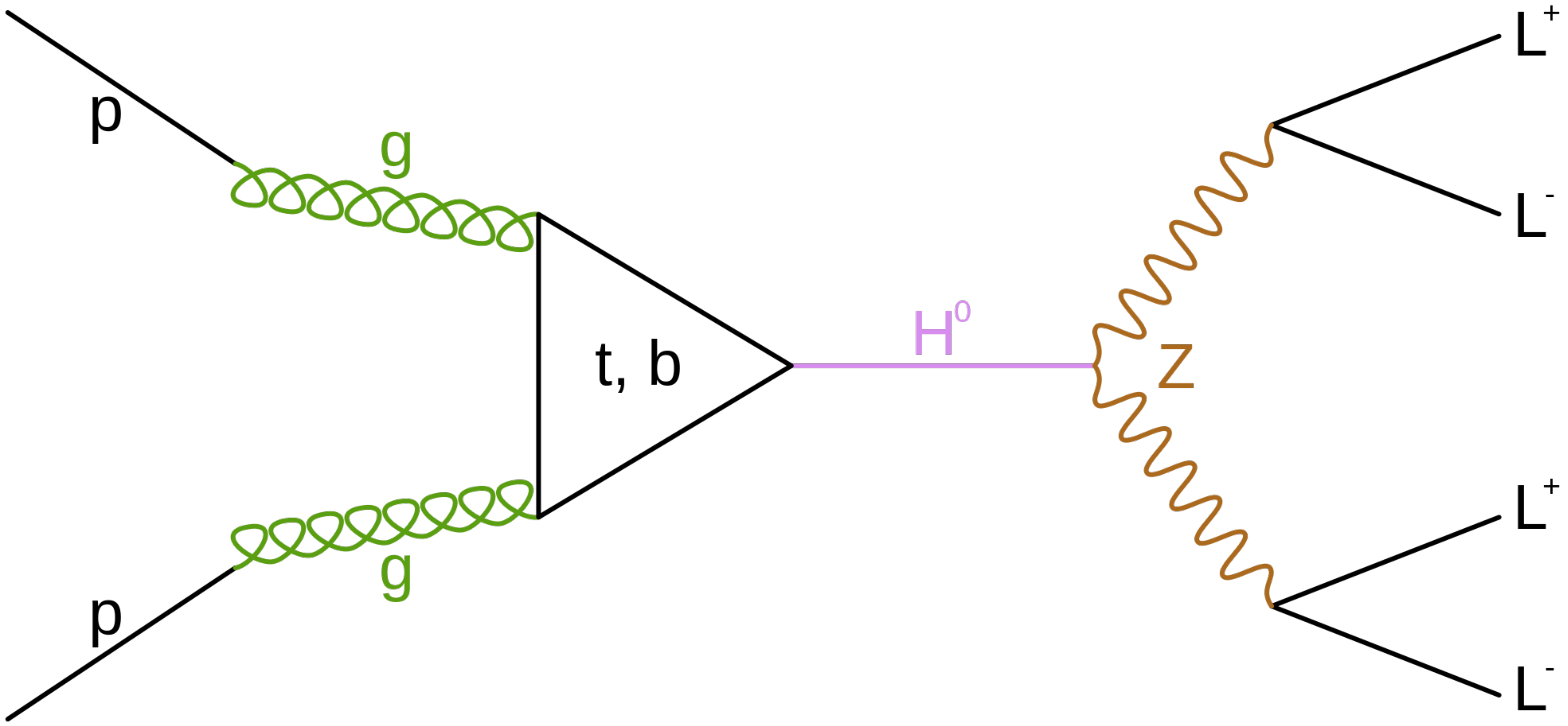

ATLAS EXPERIMENT
Run Number: 154817, Event Number: 968871
Date: 2010-05-09 09:41:40 CEST
M_ee = 89 GeV
Z→ee candidate in 7 TeV collisions
15 E_T (GeV)
E_T (e⁻)= 45GeV
η (e⁻)= 0.21
E_T (e⁺) = 40GeV
η (e⁺) = -0.38
10
5
-5
-3
-1
η
1
3
5
0
180
360
φ

Higgs production at the LHC

Formation of a Higgs boson, induced by proton-proton collision, and its possible decay into two gamma ray photons in the LHC.



Higgs production at the LHC



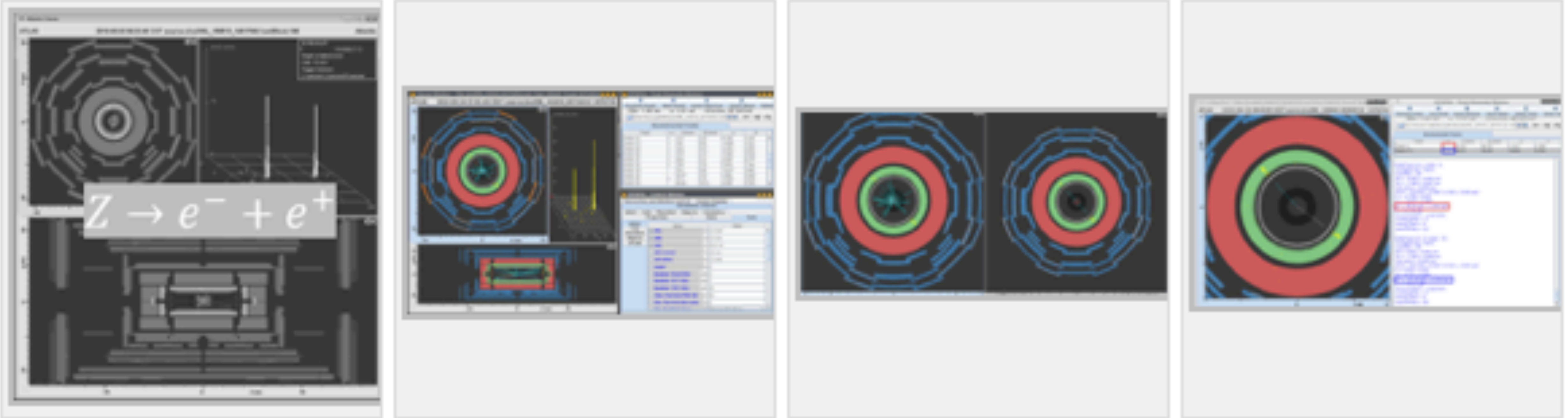
Visualizing events in HYPATIA

It is time to see how the events we have talked about look in the event display HYPATIA. You will use your newly acquired knowledge on characterizing events and identifying elementary particles. You will learn to select signal events and to distinguish them from the background events. The picture gallery will guide you through this task.

Di-lepton and 4-lepton events (electrons and muons) are, in general, easy to identify. Di-photon events are sometimes trickier, especially when tracks point to the energy cluster deposited in the electromagnetic calorimeter (ECAL).

The picture gallery will guide you through this task.

signal processes



Z-Path

- Introducing the Z boson
- Introducing the Higgs boson
- New Physics
- Identifying particles
- Identifying Events
  - When protons collide
  - Z events
  - Higgs events
  - Background events
  - Visualization
  - Practice!
- Search and discover with mass
- Get to work!

Knowledge Center

THANK YOU!

ATLAS
EXPERIMENT