International Masterclasses 06.03.17

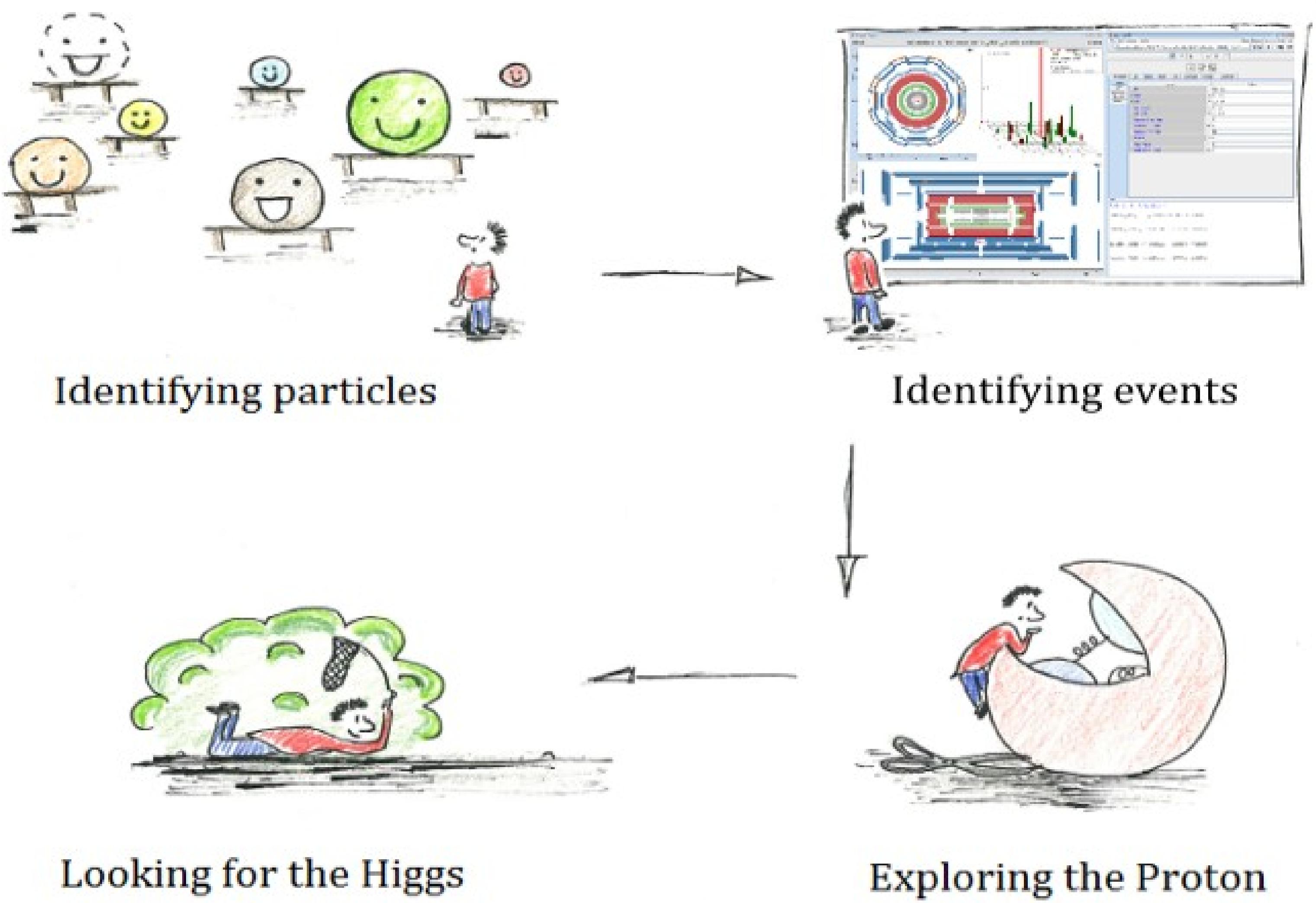
ATLAS experiment:

W – path

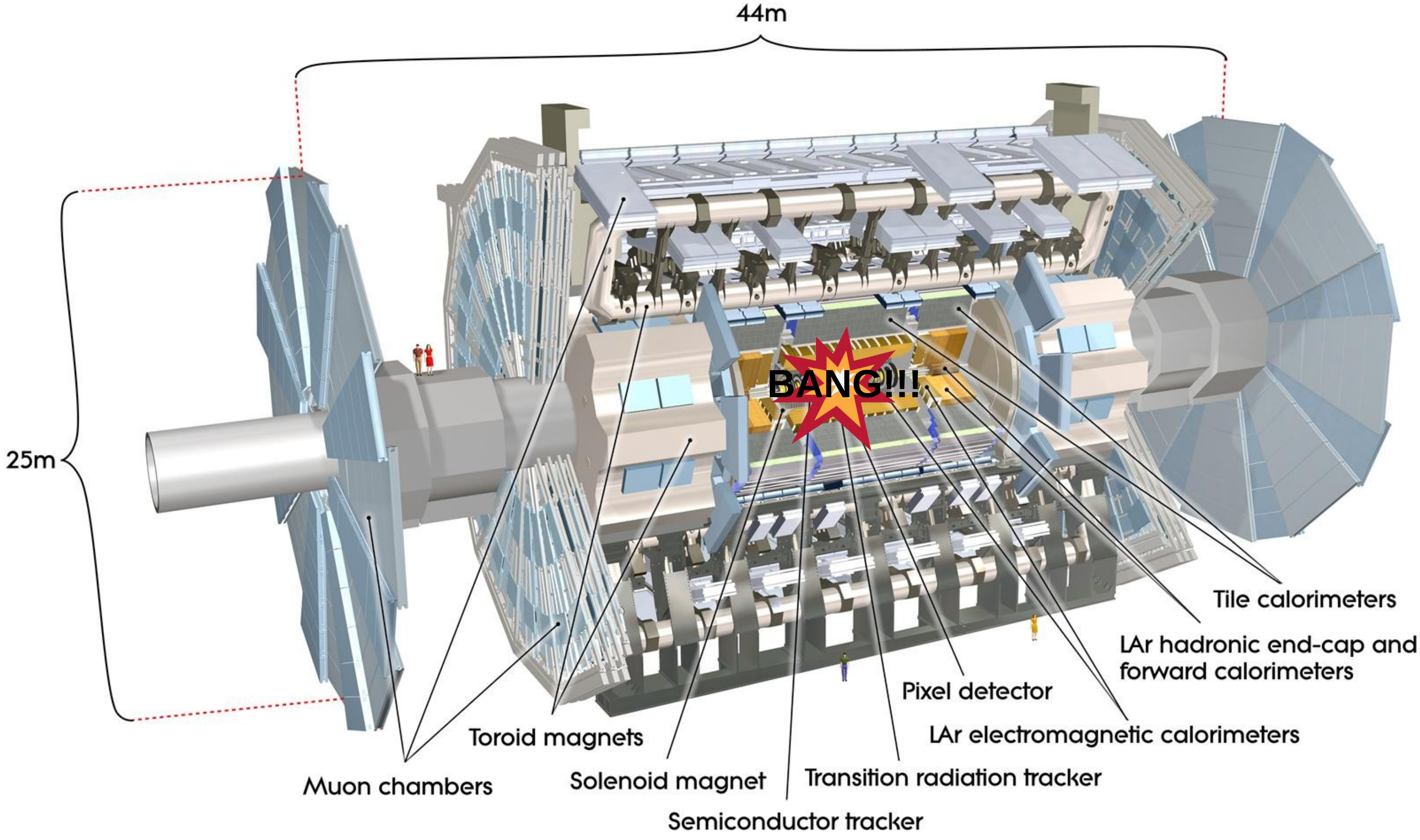
Tamar Zakareishvili

(HEPI TSU)

Our aims/tasks

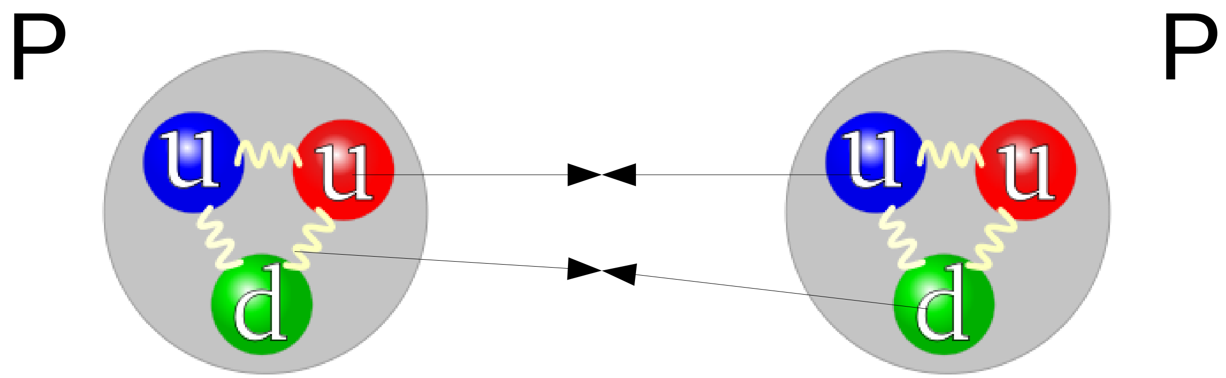


CERN ATLAS detector



https://www.youtube.com/watch?v=xaEGgKDbfnA

Proton - proton collision



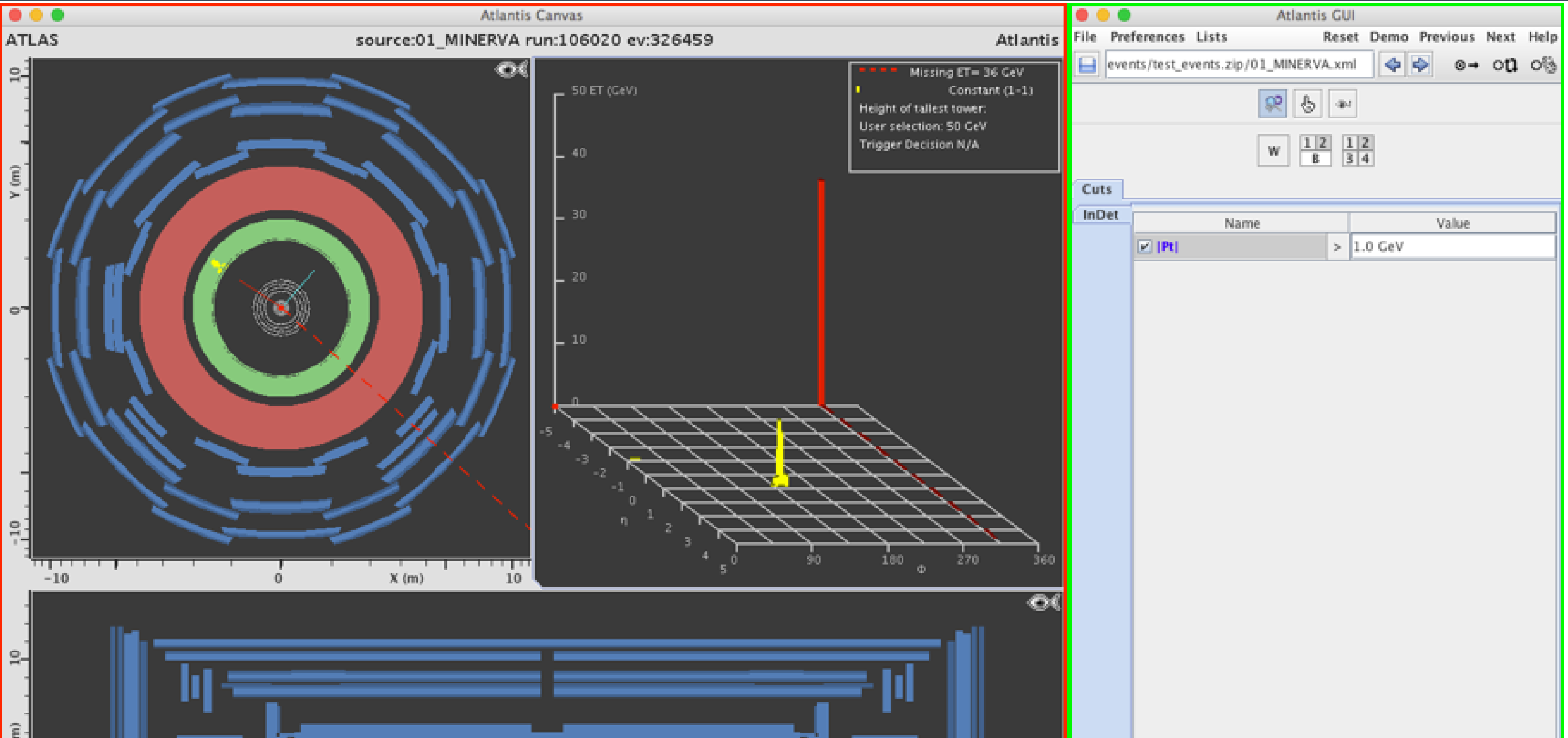
- Which objects interact during a proton-proton-collision?

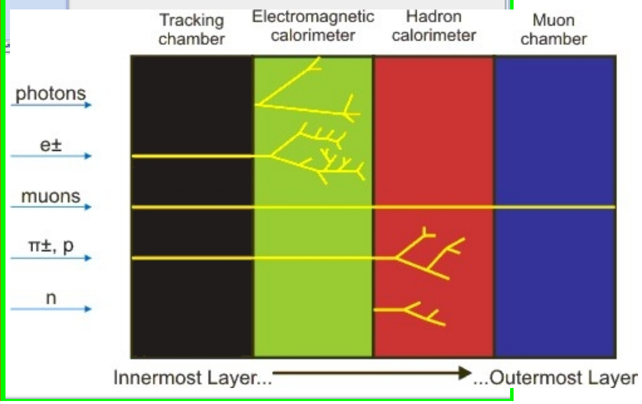
The constituents of the protons (gluons and/or quarks).

- Why did we build LHC - the biggest and most powerful particle accelerator in the world?

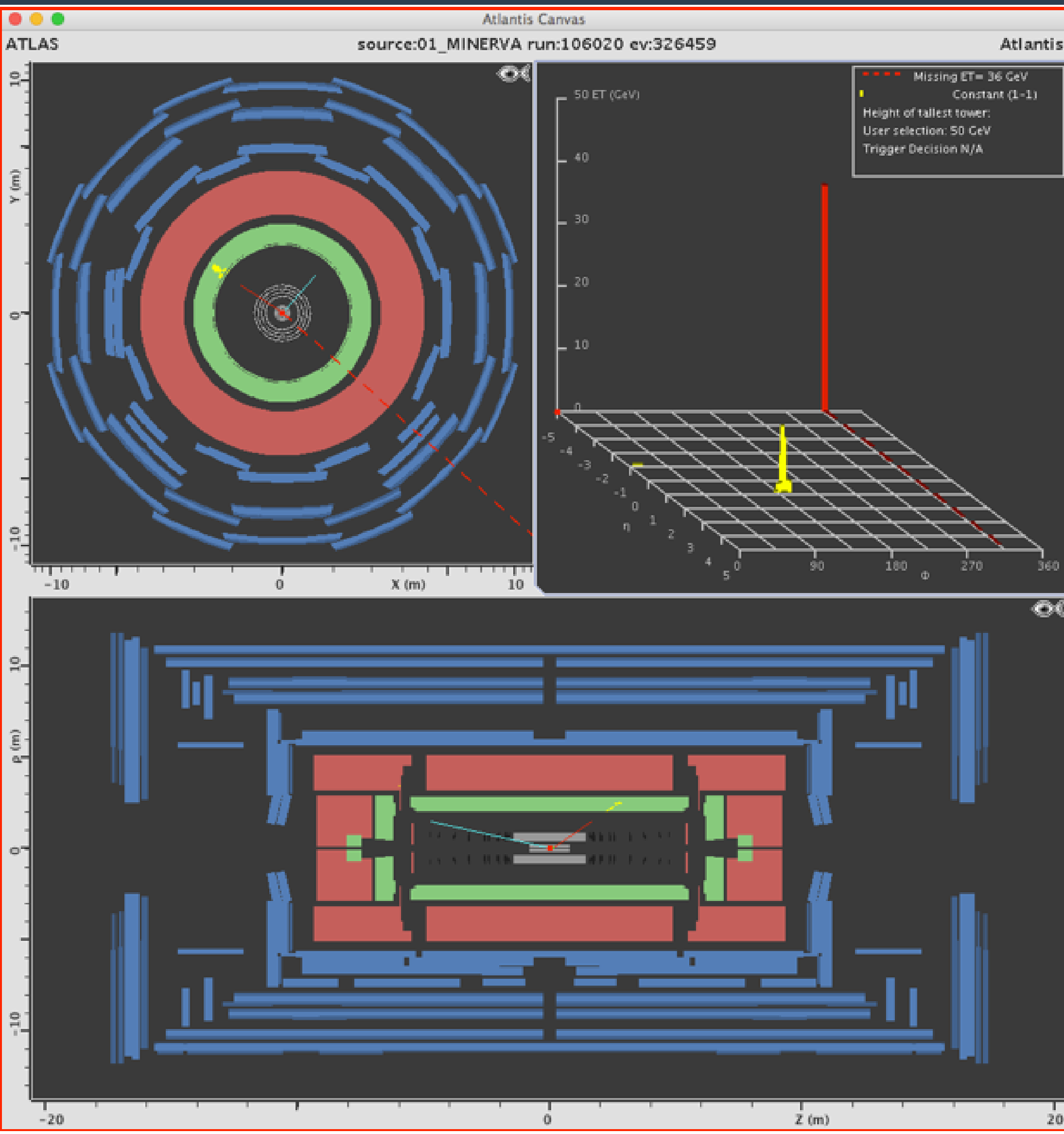
We hope it will provide answers to some open questions like how particles get their masses or why the universe has more matter than antimatter.

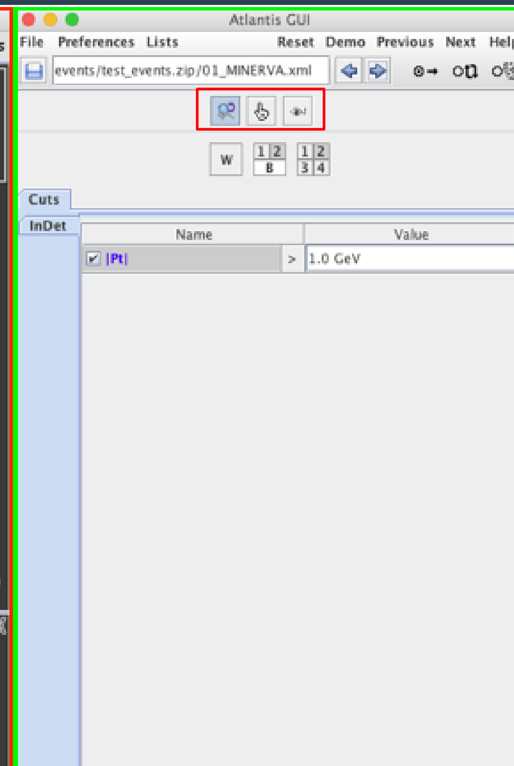
The Event Display MINERVA

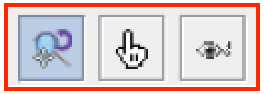




The Event Display MINERVA

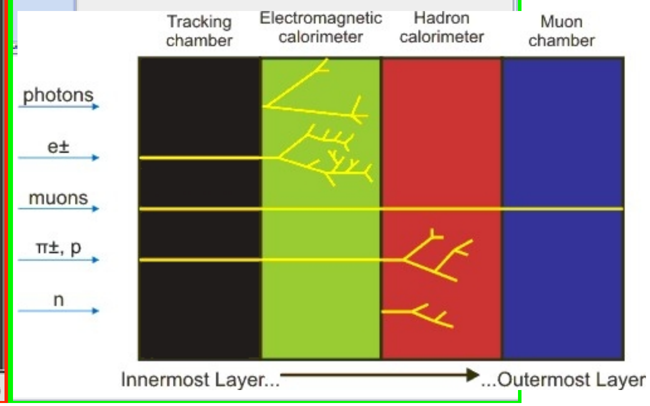




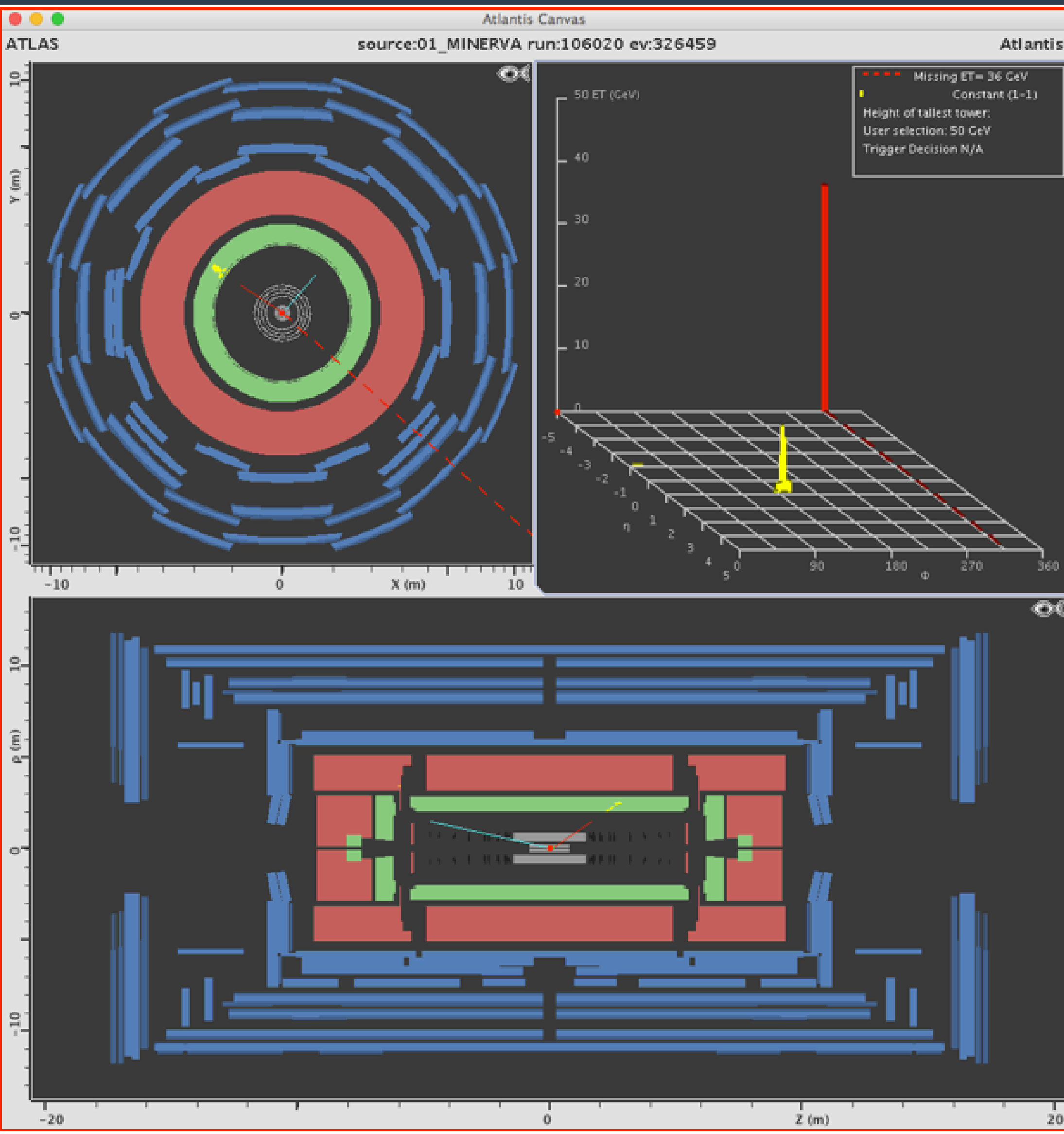


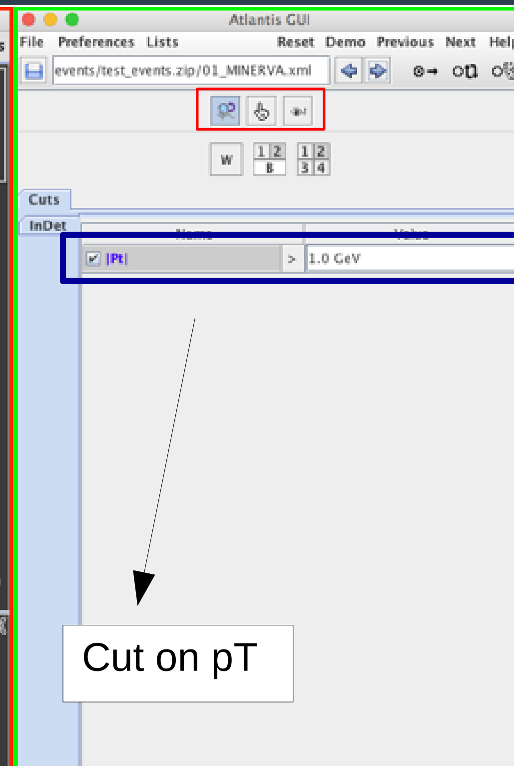
ZOOM

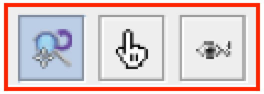
Choosing particle's track



The Event Display MINERVA



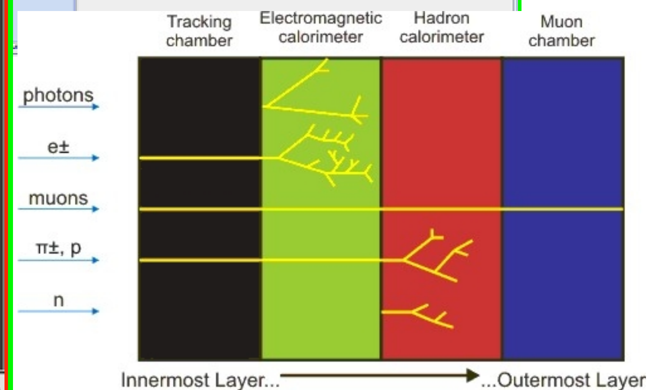




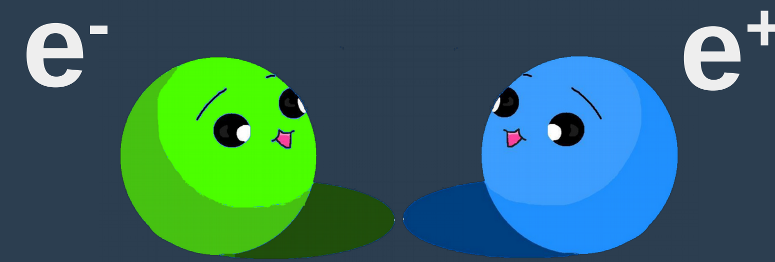
ZOOM

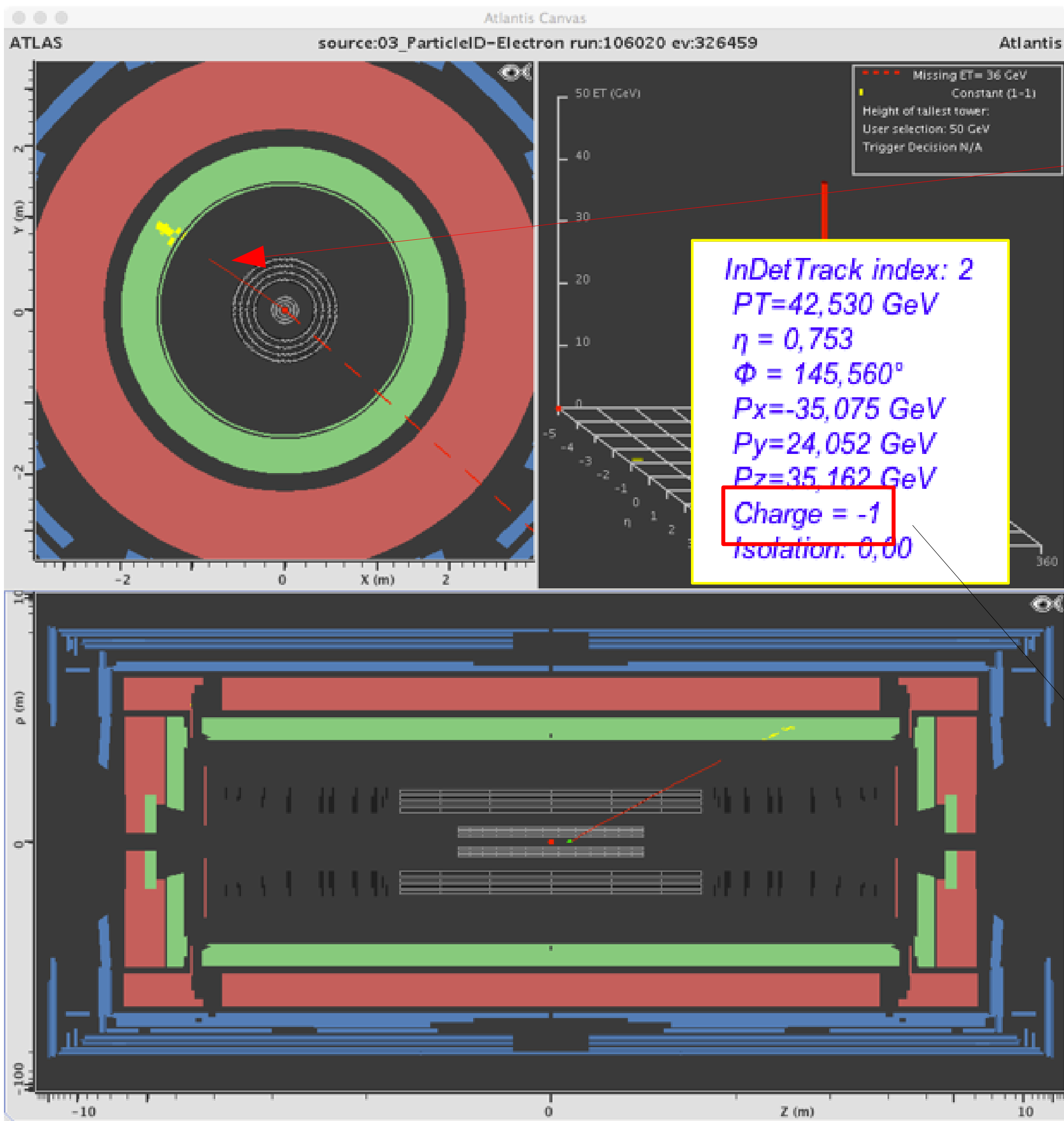
Choosing particle's track

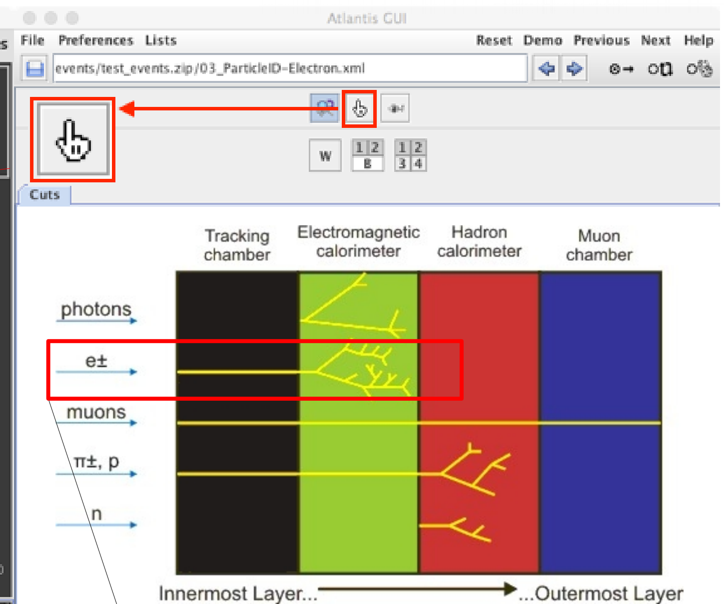
Cut on pT



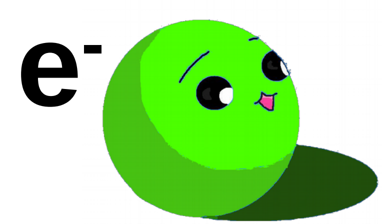
Identifying electrons



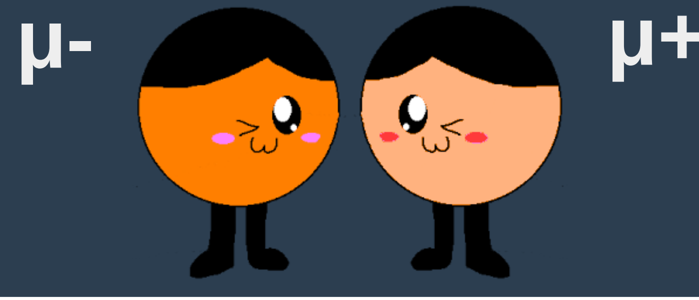


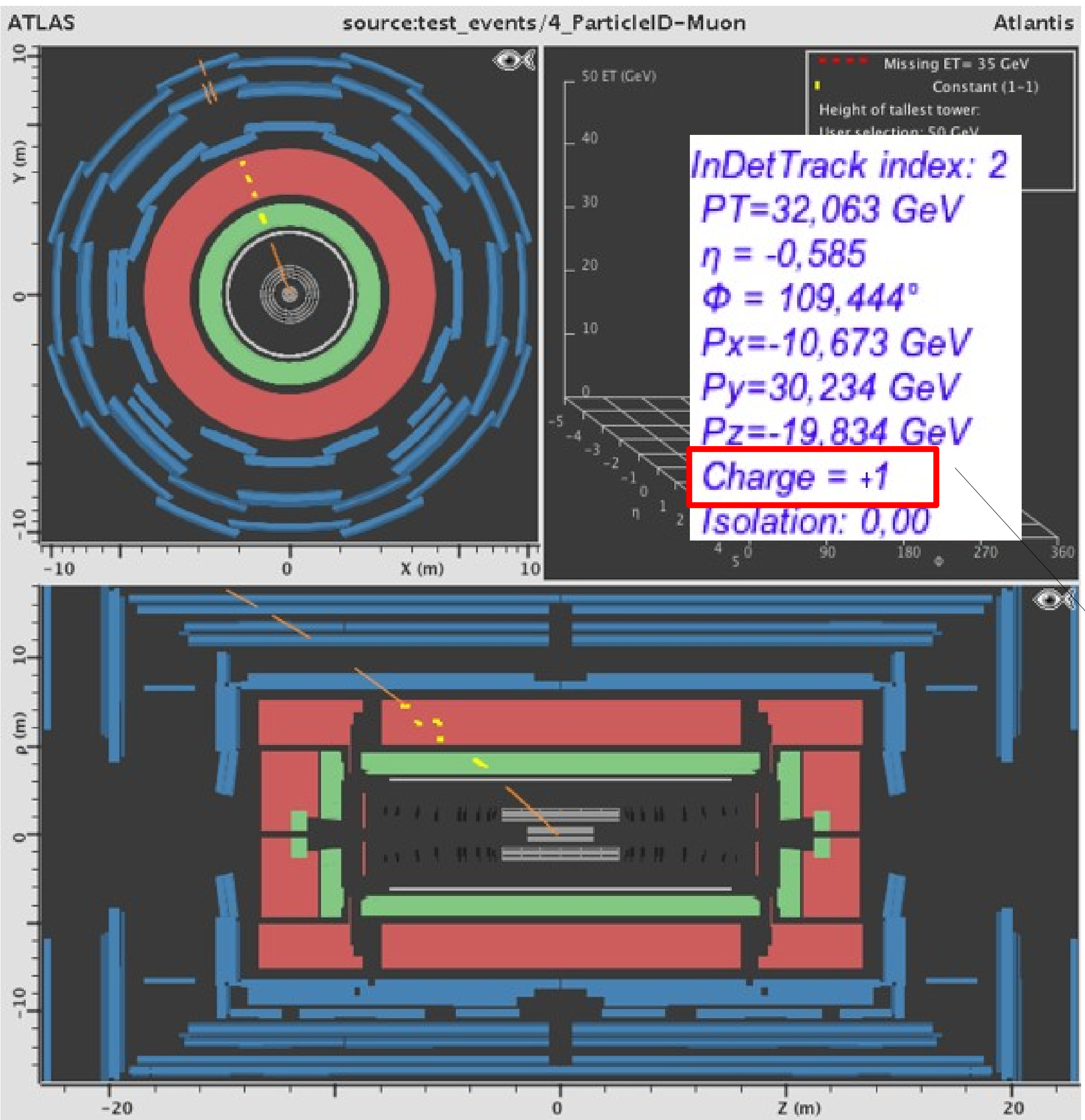


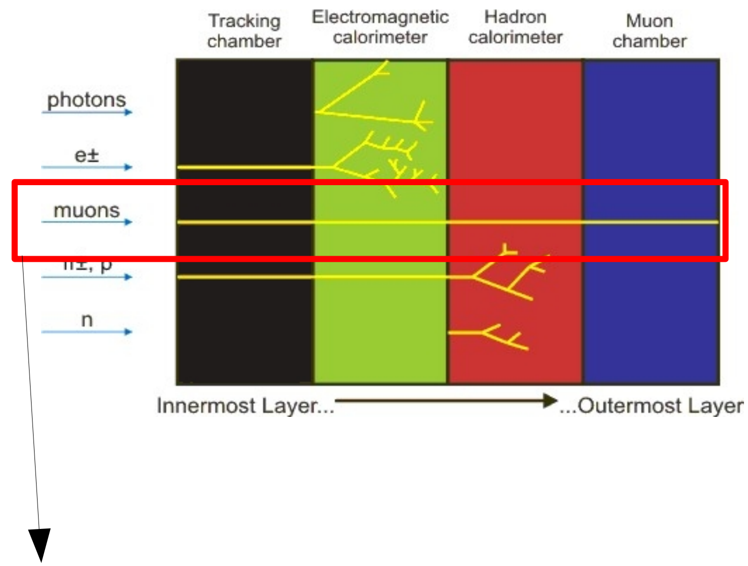
Track in detector's two parts.
(Tracking chamber, El.mag. calorimeter).
Charge: -1
That means we've found electron!



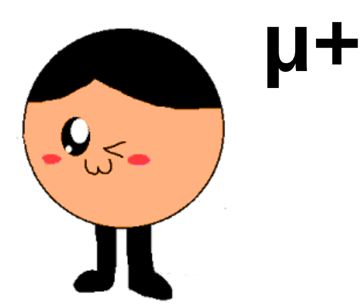
Identifying muons







Path in every part of the detector.
Charge: +1
That means we've found anti-muon!



Identifying neutrinos

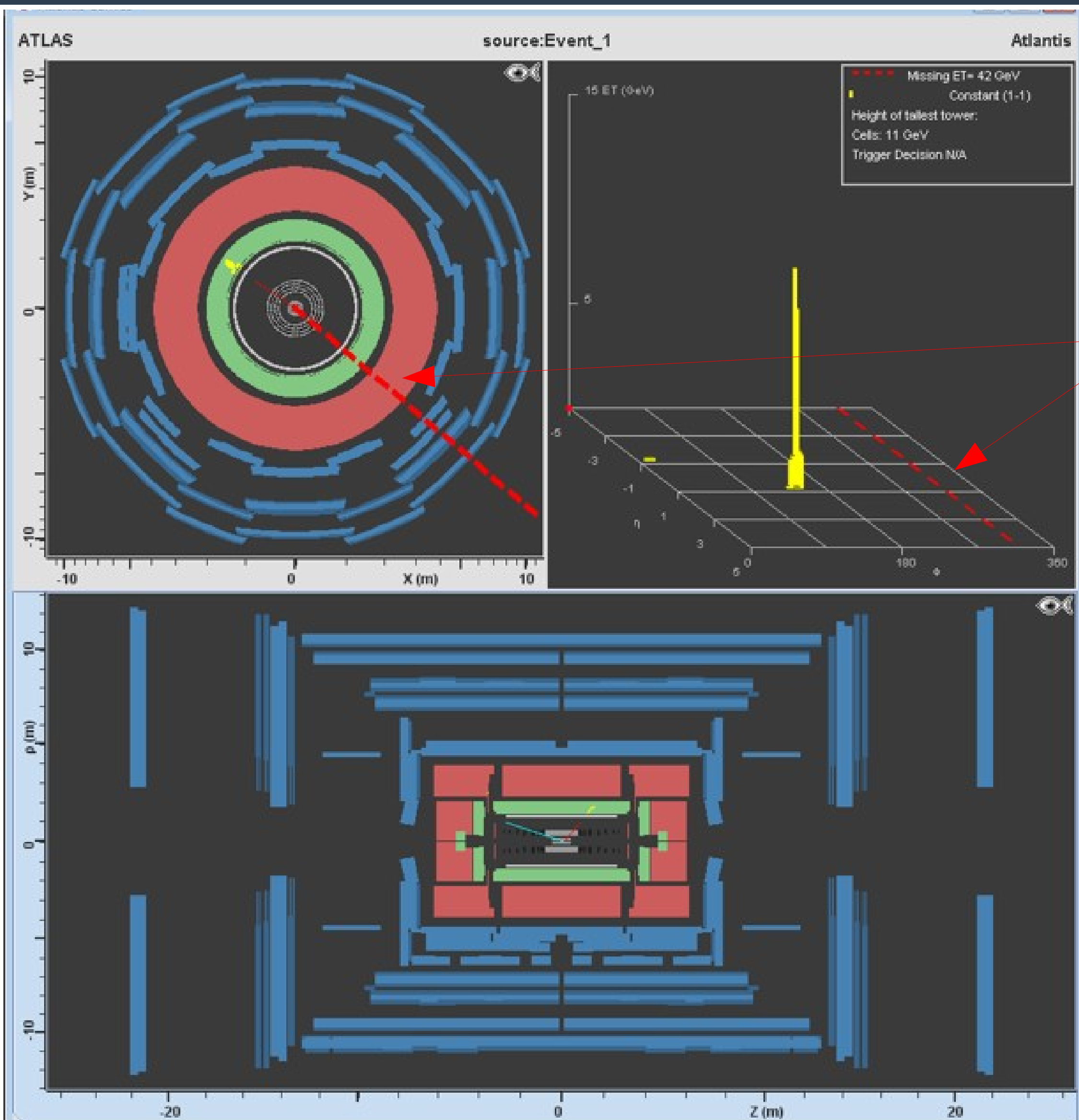
Neutrinos don't interact with even a single component of the ATLAS detector!

So how are we going to find them?

Momentum conservation law
will help us!

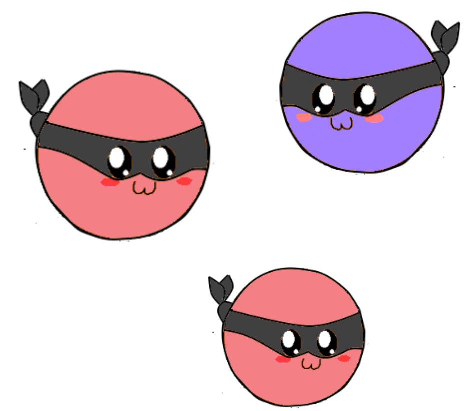
Since all quarks and gluons move along the beam axis before the proton-proton collision all of their velocity components at right angles to the beam (perpendicular) and therefore the so called total transverse momentum is zero. The total transverse momentum has to be zero after the collision as well. If the measurements contradict this, it is assumed that particles carrying transverse momentum leave ATLAS without being detected.

Identifying neutrinos

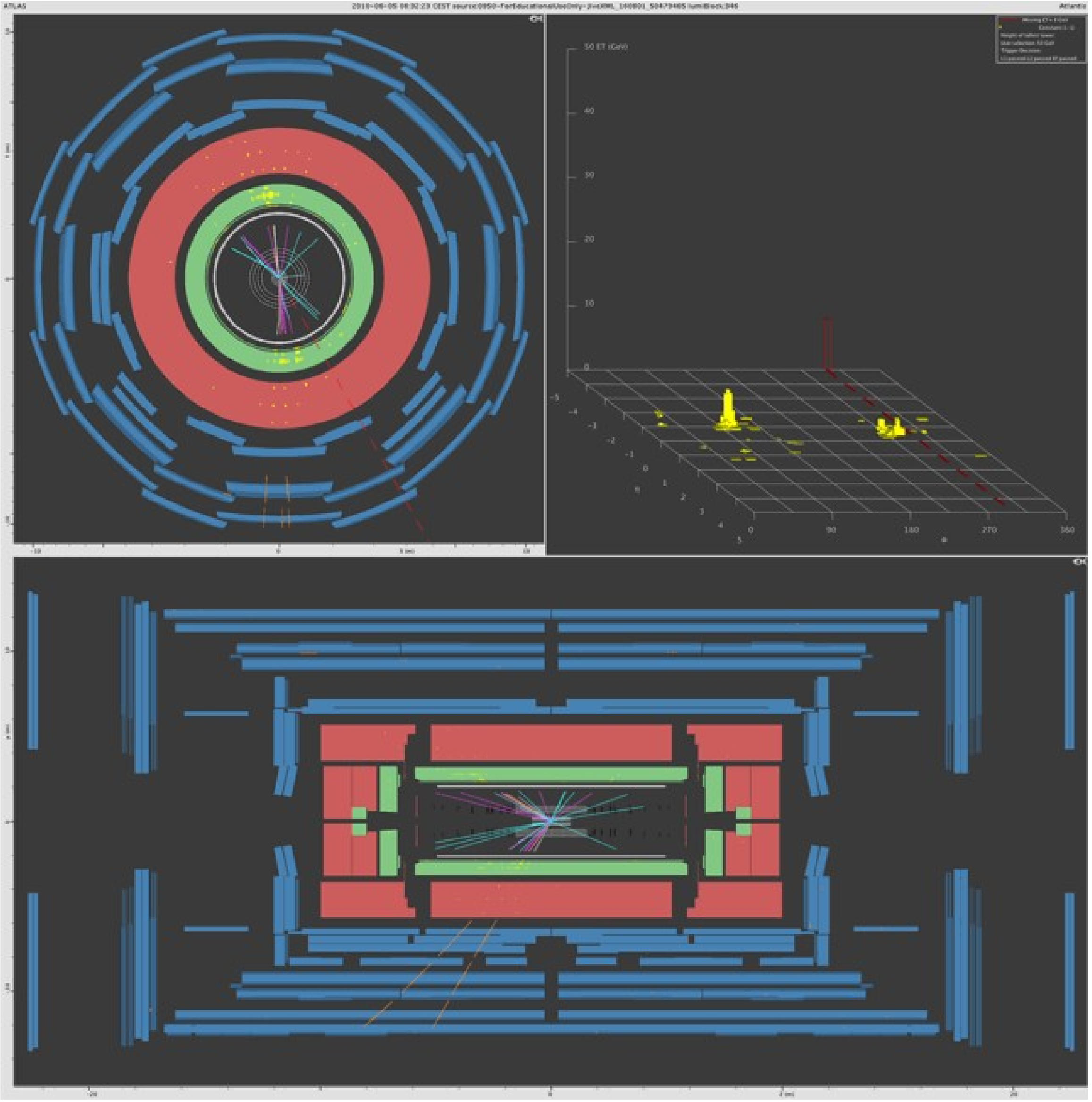


With the help of MINERVA, how should we identify neutrinos?

Red dashed line in the transverse plane of the detector shows us that we have a missing particle (pT) in the event.



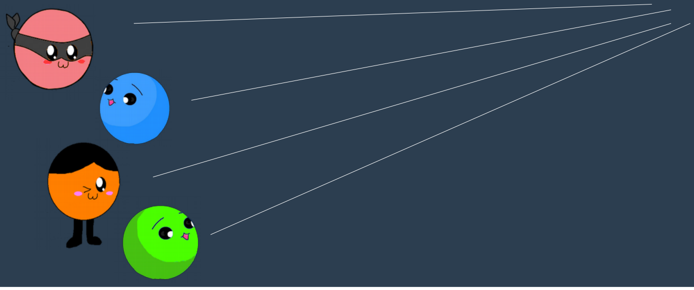
Identifying jets

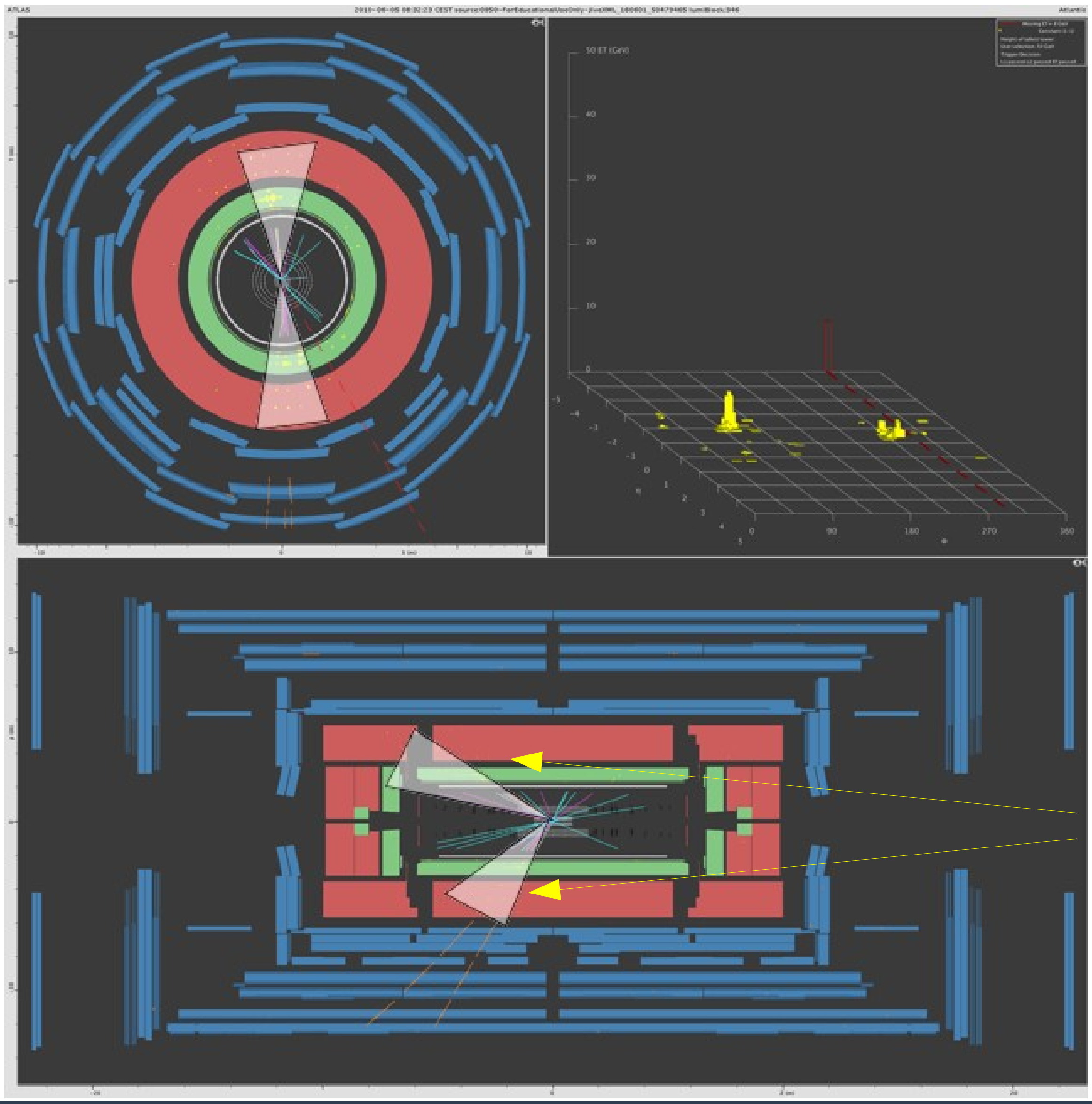


jets – a narrow cone of several particles .

- Particles that make up jets, leave it's energy in every part of the detector.
- By having a close look at their tracks we will see that they make up a cone.

Identifying jets





jets – a narrow cone of several particles .

- Particles that make up jets, leave it's energy in every part of the detector.
- By having a close look at their tracks we will see that they make up a cone.

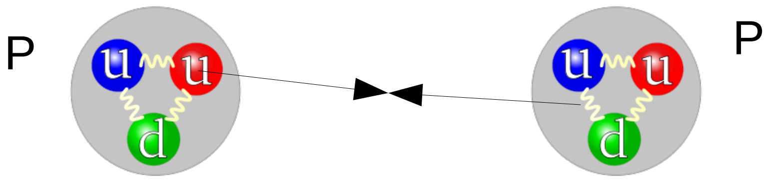
Two jets in this event!

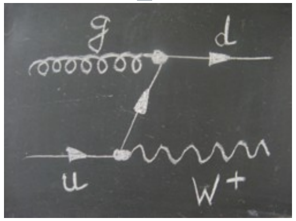
Identifying particles: exercise #1

- http://atlas.physicsmasterclasses.org/en/wpath_exercise1.htm

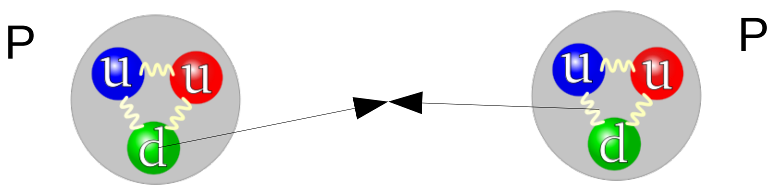
W particle

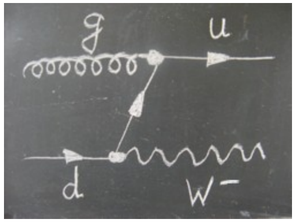
- **How are W particles created during proton-proton collision?**



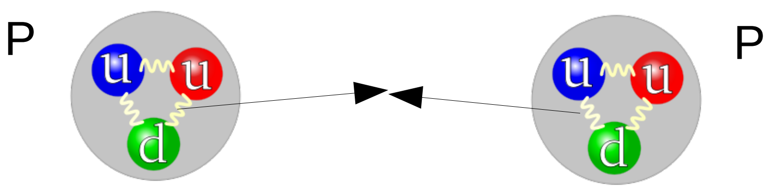


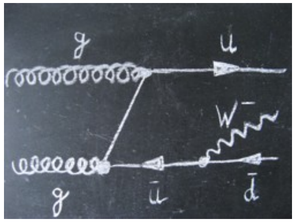
When gluon interacts with u quark W^+ particle is created

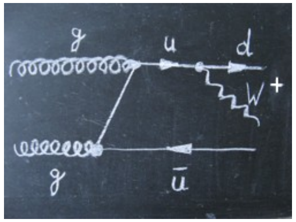




When gluon interacts with d quark W^- particle is created



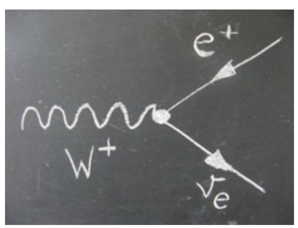


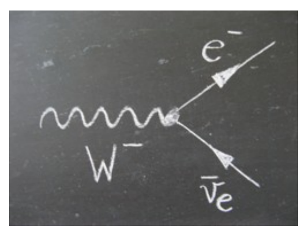


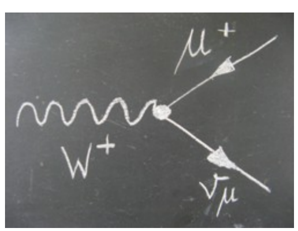
When gluon interacts with gluon W^+ or W^- particle is created

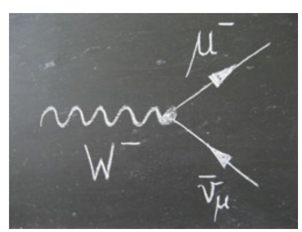
W particle

- In one third of the W-decays, a lepton and a neutrino are produced.
- In these cases, the leptons can be an electron, a muon, or a tau with equal probability.
- Before the tau can be detected in the detector, it decays as well. In our events, we will only look at decays of W particles into electrons (or positrons) or muons (or anti-muons).





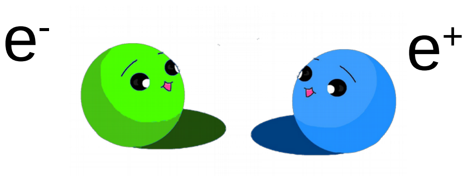




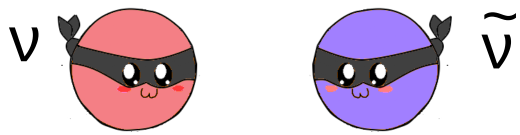
- We regard these events as signal events!

W particle

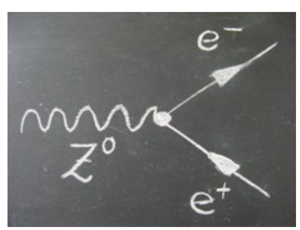
- So in detector we are searching for electrons and muons.

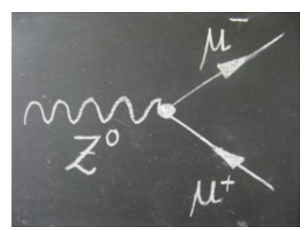


- And neutrinos as well, which we can not see, but can identify anyways!



- But during proton-proton collision not only W particles are produced, but for example Z particles as well, which decay into electrons and muons.





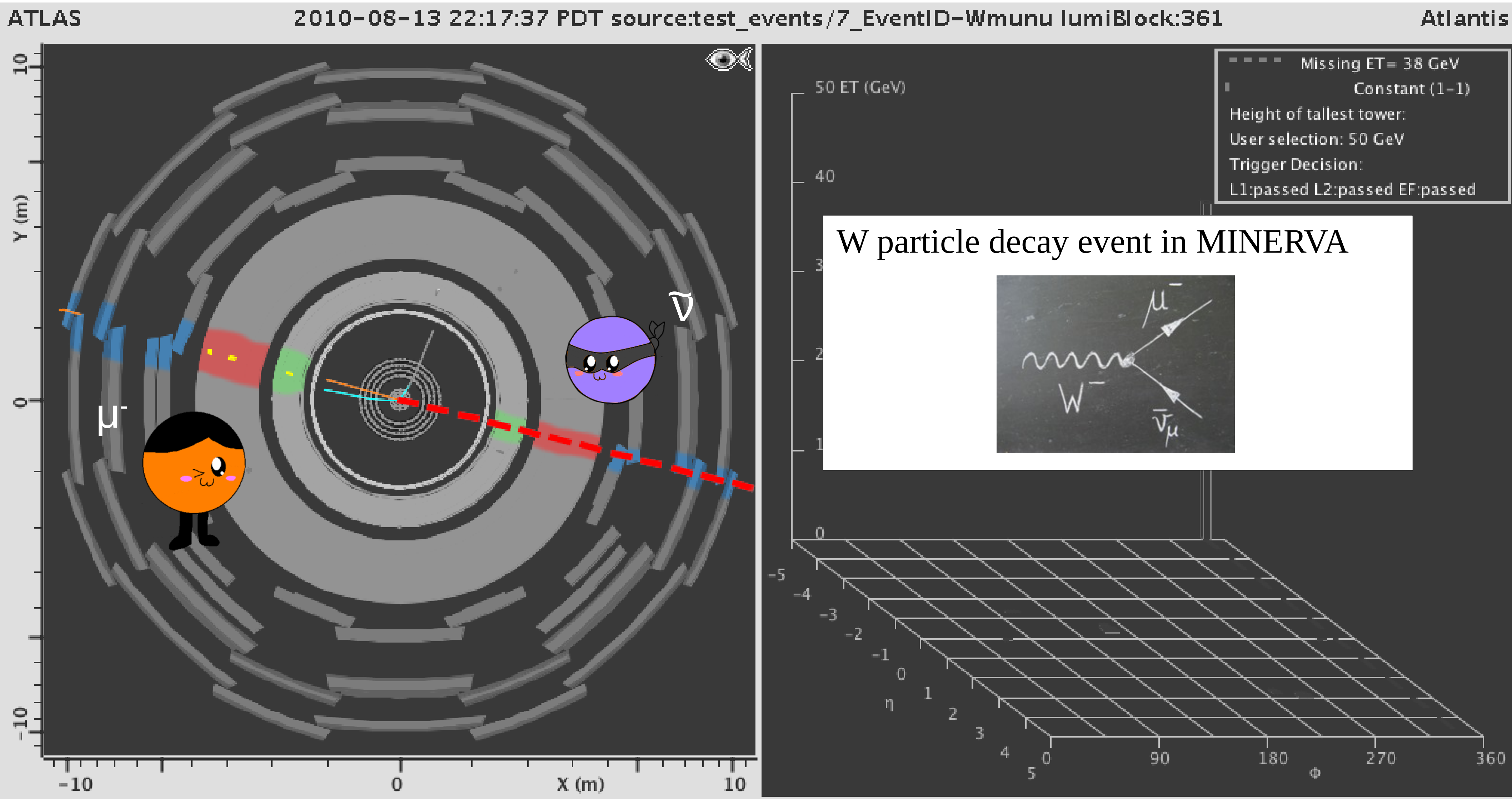
- Events like that are called **Background** events – events that give us same final particles after decay.

We are looking at final particles in the detector, how are we going to find out they came from W or Z particle?

With the help of neutrinos!

- In the background events we don’t have neutrinos.
- After identifying neutrinos (MINERVA will help us), with electrons or neutrinos, we can celebrate finding of W particle!

W particle


ATLAS
2010-08-13 22:17:37 PDT source:test_events/7_EventID-Wmunu lumiBlock:361
Atlantis
Y (m)
X (m)
μ-
ν̃
Missing ET= 38 GeV
Constant (1-1)
Height of tallest tower:
User selection: 50 GeV
Trigger Decision:
L1:passed L2:passed EF:passed
50 ET (GeV)
η
φ
W particle decay event in MINERVA
μ-
W-
ν̄μ

Higgs particle

- Higgs particles are quite heavy, so they decay really fast into another particles, that we see in the detector.
- Higgs can decay in many ways, but we are interested in the following:

$$\mathbf{H \rightarrow WW \rightarrow l\nu l\nu}$$

- Where l could be electron, anti-electron, muon or anti-muon, and ν is neutrino.

And we know how to identify all of these particles!

Higgs particle

- But if Higgs decays like this:

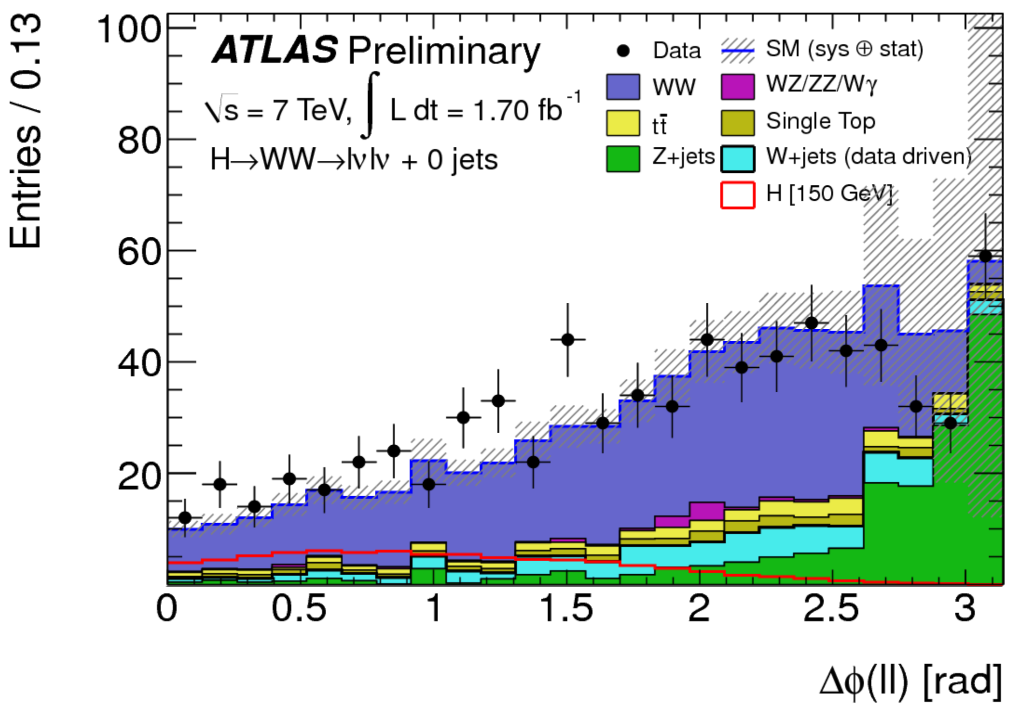
$$H \rightarrow WW \rightarrow l\nu l\nu$$

- Can we say that when we find two W particles in the event that they came from Higgs?

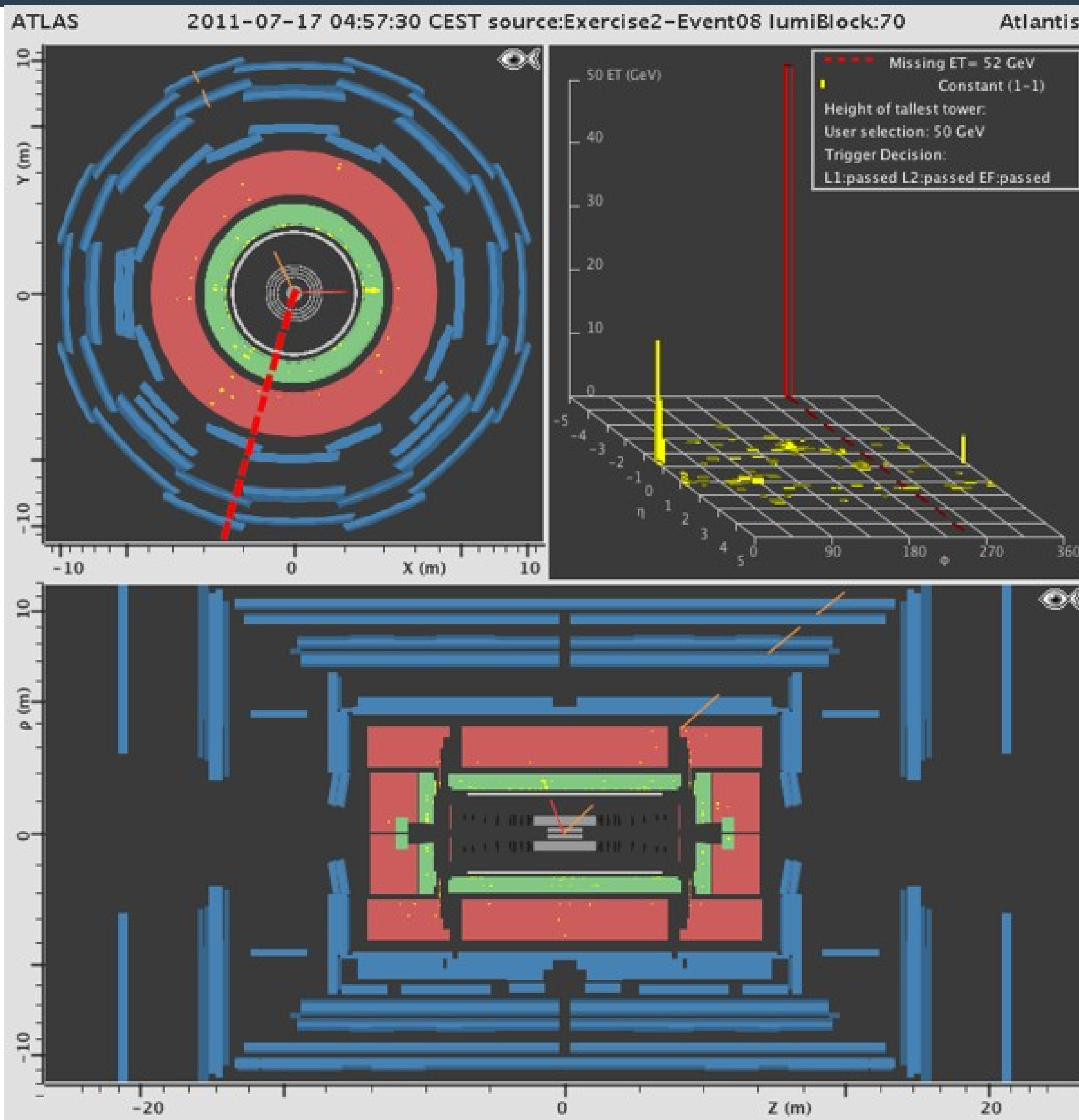
No!

Higgs particle

- We can't tell apart Higgs from WW particles, until we have a look at the angle ($\Delta\Phi_{ll}$) betweetn leptons(e, μ, τ) in transverse plane in the detector.
- When leptons come from Higgs $\Delta\varphi_{ll}$ is mostly less than 90°.
- And when leptons come from other processes, $\Delta\varphi_{ll}$ is mostly more than 90°.



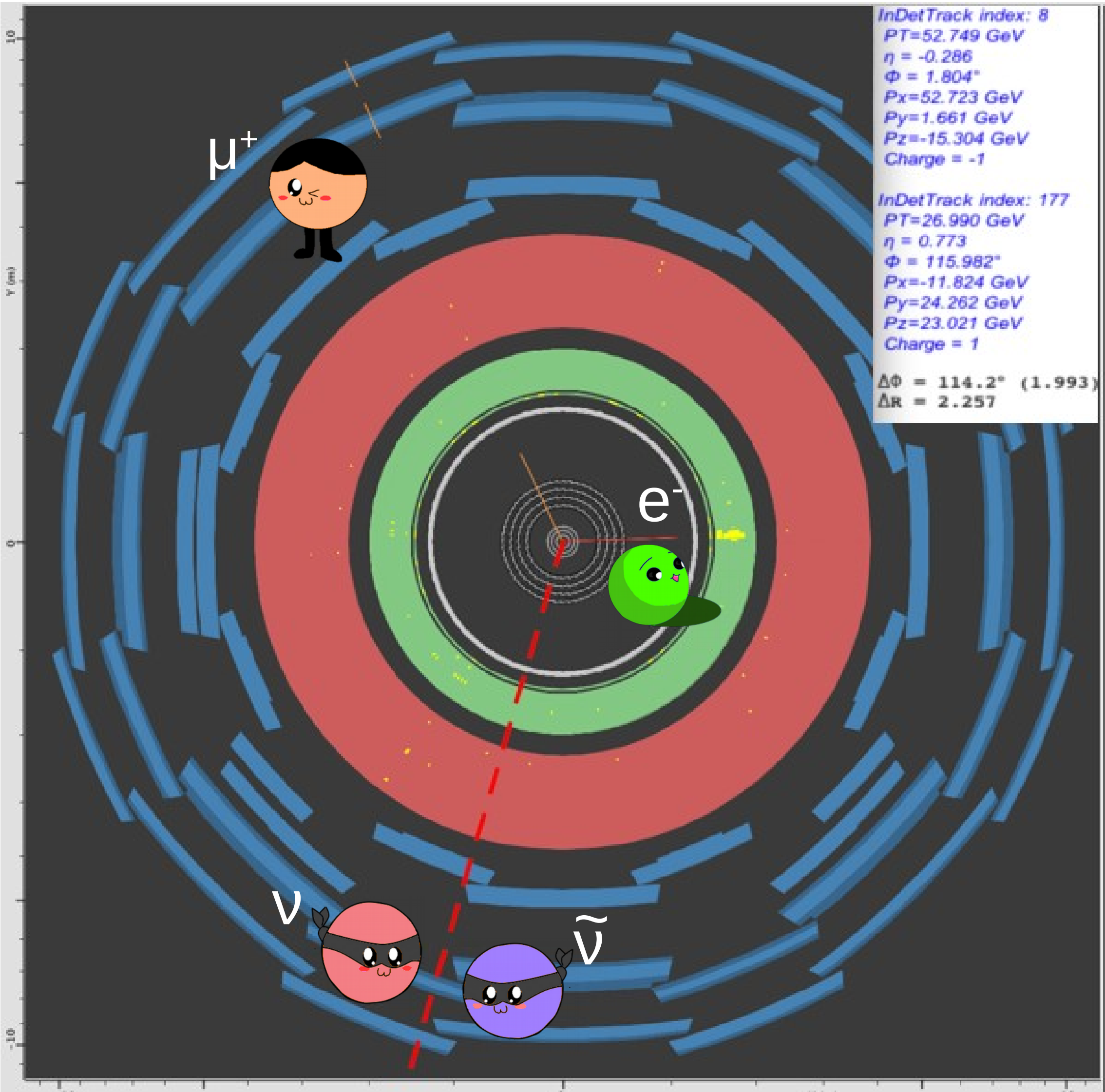
Example of Higgs particle candidate event



Event:

$$H \rightarrow WW \rightarrow e^{-} + \tilde{\nu} + \mu^{+} + \nu$$

Example of Higgs particle candidate event



Event:

$$H \rightarrow WW \rightarrow e^- + \tilde{\nu} + \mu^+ + \nu$$

Identifying events: exercise #2

- http://atlas.physicsmasterclasses.org/en/wpath_exercise2.htm

Exploring structure of the proton!

- Identify events with W particle in it.
- Identify charge of W particle (Charge conservation law).
- And now let's find ratio of number of W^+ and W^- particles:

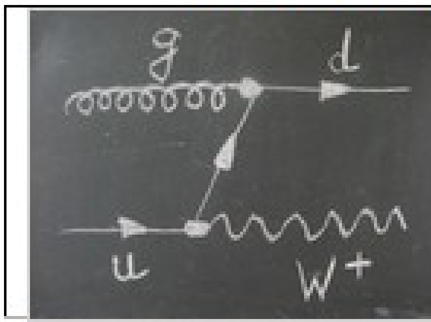
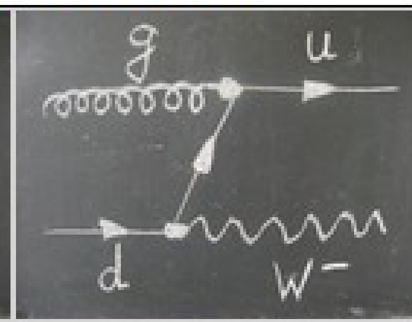
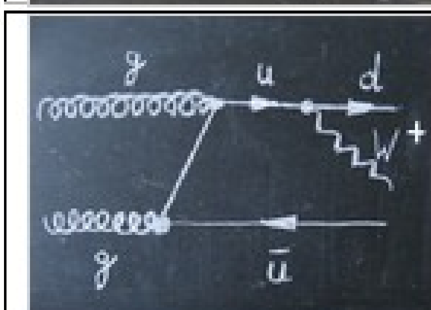
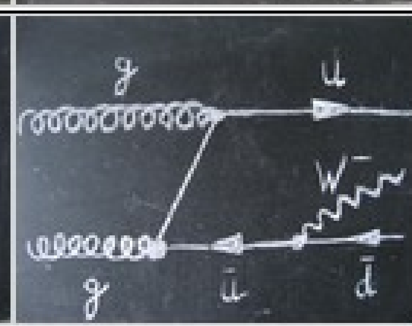
$$R\pm = N_{W+}/N_{W-}$$

Exploring structure of the proton!

- And how will it help us to explore structure of the proton when we find the ratio:

$$R\pm = N_{W+}/N_{W-} \ ???$$

- Lets remember how W^+ and W^- particles are produced:

process	Feynman diagram		proportion
gluon quark interaction			66%
gluon gluon interaction			34%

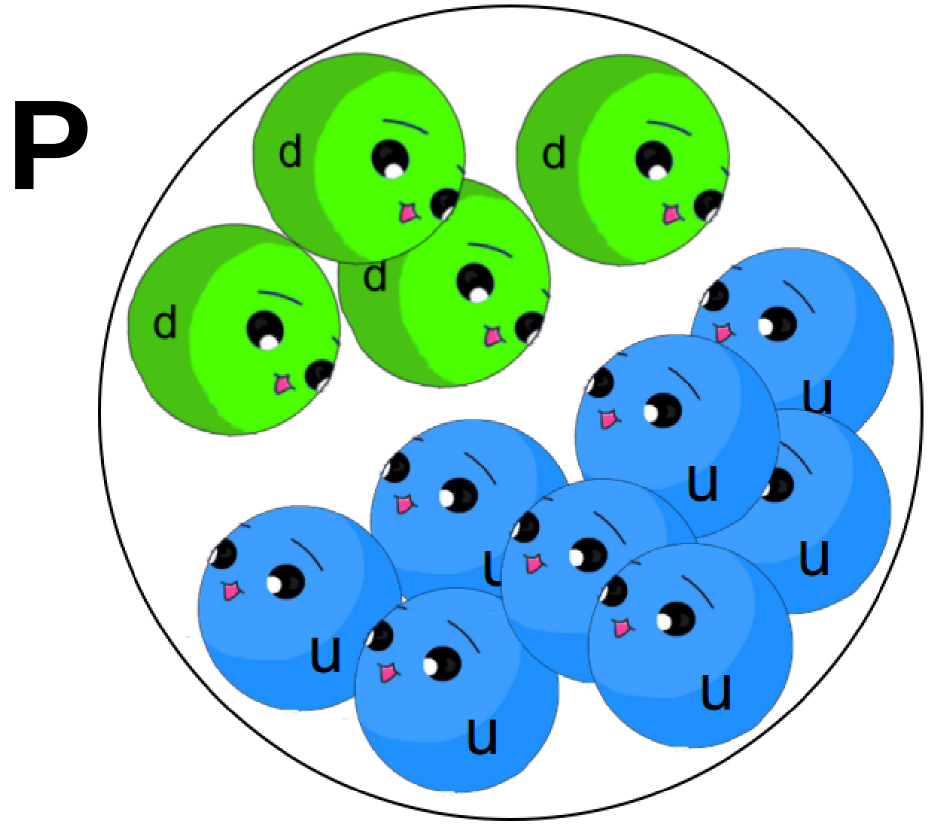
Exploring structure of the proton!

- We will calculate the ratio $R\pm = N_{W+}/N_{W-}$ for both processes (gluon quark interaction, gluon gluon interaction).
- If we calculate this ratio for just gluon quark interaction we can make some assumptions about structure of the proton.
- More precisely when gluon interacts with u quark W^+ is produced.
- And when gluon interacts with d quark W^- is produced.

$R\pm = N_{W+}/N_{W-}$, what can we learn from this ratio?

Exploring structure of the proton!

If there are more u quarks than d quarks in the proton!



What’s next?

- Every 2 of you will analyze 50 events.
- You must identify if you have a W particle in an event, two W particles with opposite charge or background event.
- In case of WW events write down the angle between leptons and number of the event.
- Calculate $R\pm = N_{W+}/N_{W-}$.
- **In the end we will discuss meaning of analysis results!**