The exercise today, two parts

Analyse some real proton-proton collisions in CMS

- Identify particles, determine what happened
- From analysing many events, can get an insight into some fundamental physics!

Designing a detector: what do we want to look for?

- the stable particles left over from decays of unstable particles that we can create in our collisions, e.g. W^+, W^-, Z^0 (and H^0)

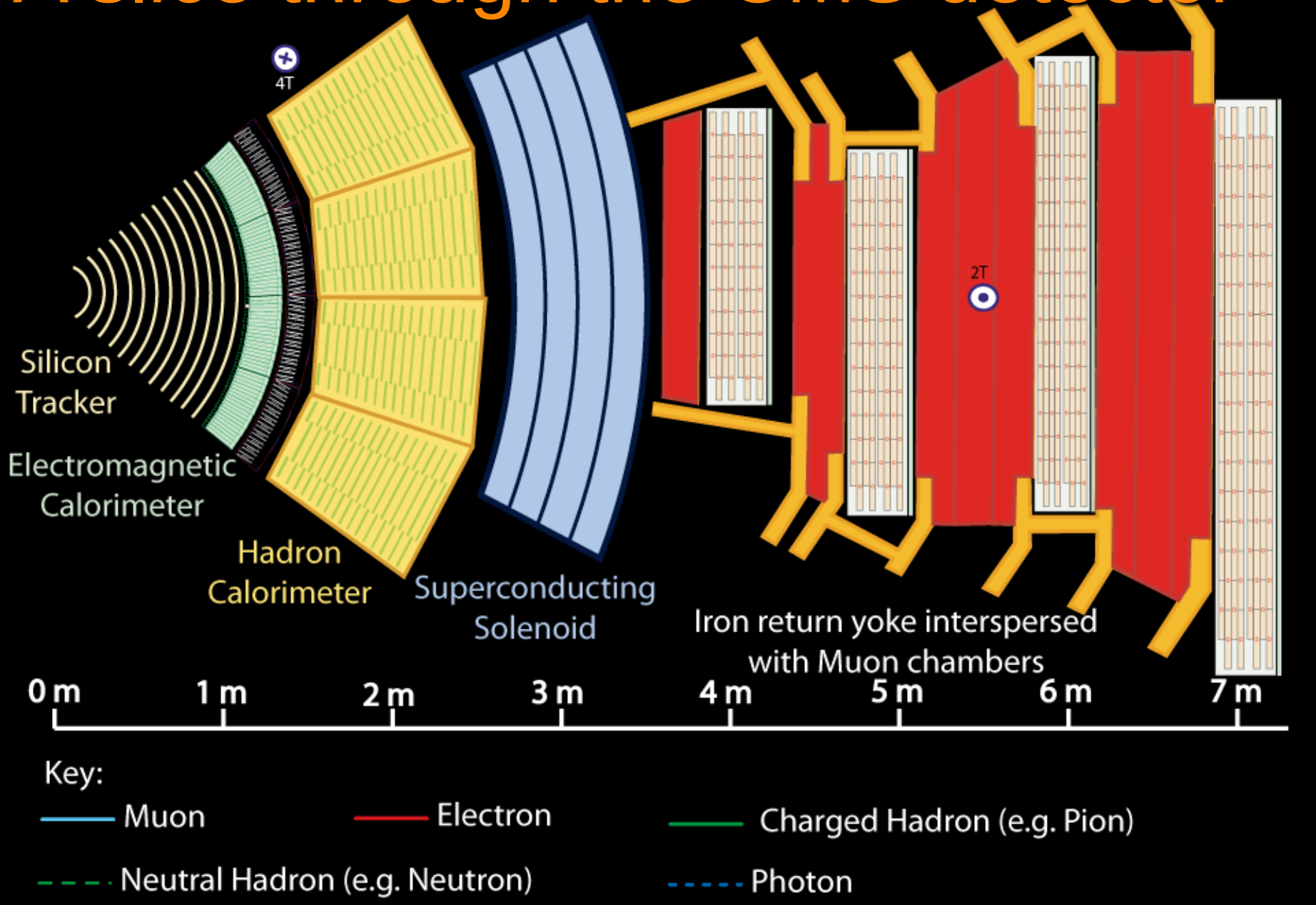
- $W^+ \rightarrow \mu^+ + \nu$
- $W^+ \rightarrow e^+ + \nu$
- $W^+ \rightarrow$ hadrons
- $W^- \rightarrow \mu^- + \nu$
- $W^- \rightarrow e^- + \nu$

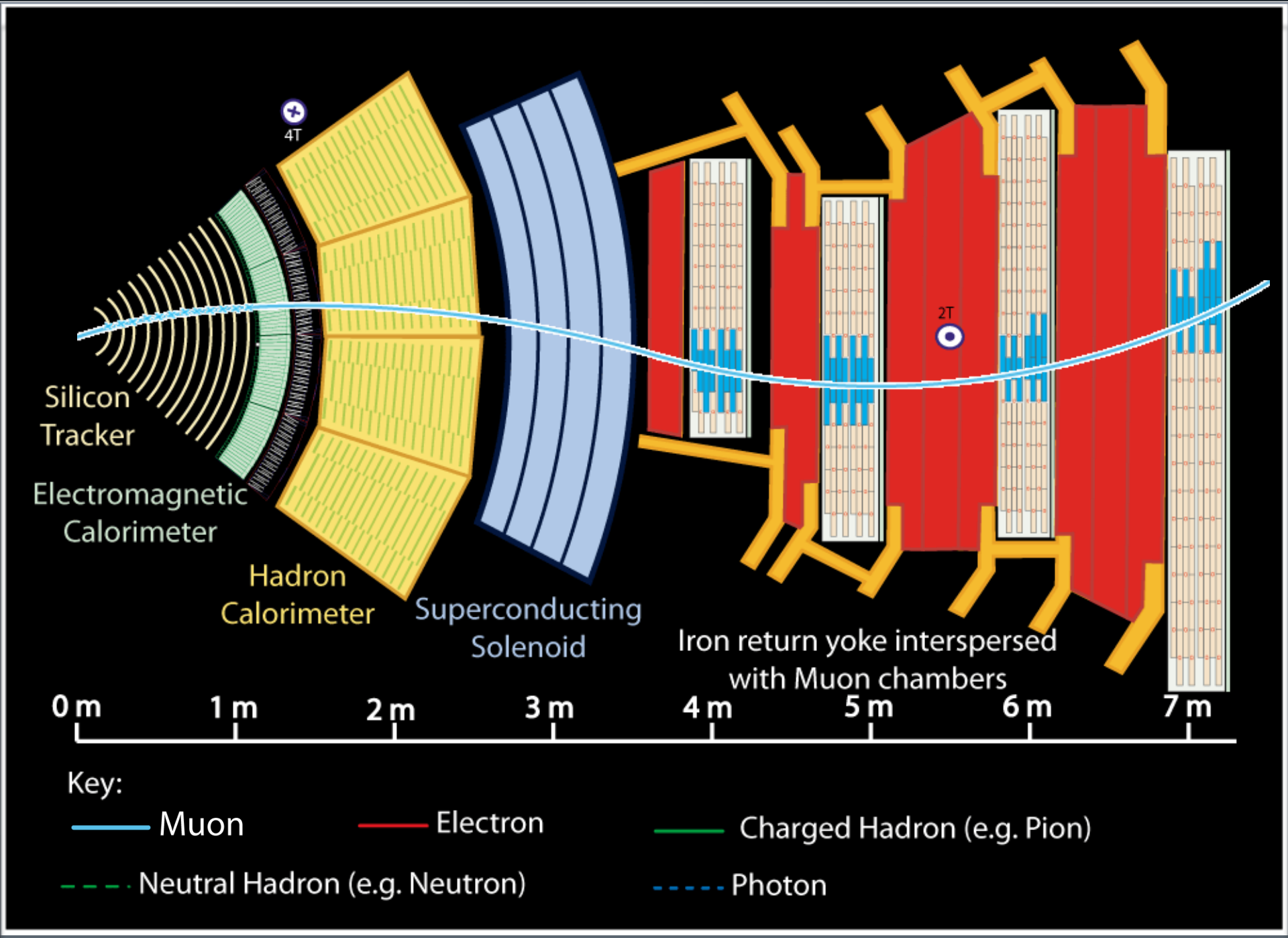
- $W^- \rightarrow$ hadrons
- $Z^0 \rightarrow e^+ + e^-$
- $Z^0 \rightarrow \mu^+ + \mu^-$
- $H^0 \rightarrow \gamma + \gamma$

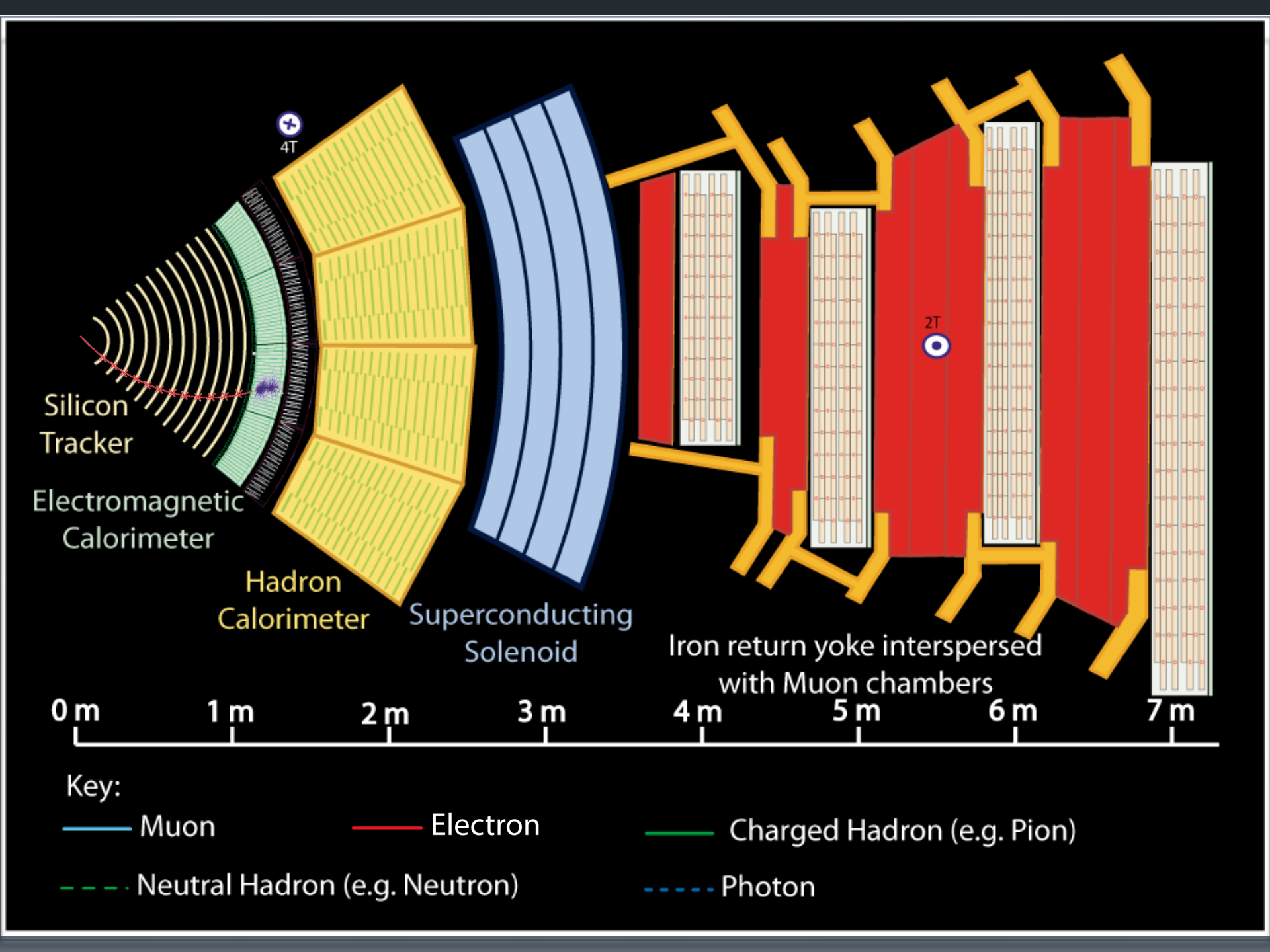
Hadrons could be:
$\pi^+, \pi^-, K^+, K^-, \Lambda$..

- A particle "*i*" will move away from the interaction point with momentum p_i and energy E_i

A slice through the CMS detector




4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
0 m
1 m
2 m
3 m
4 m
5 m
6 m
7 m
Key:
Muon
Electron
Charged Hadron (e.g. Pion)
Neutral Hadron (e.g. Neutron)
Photon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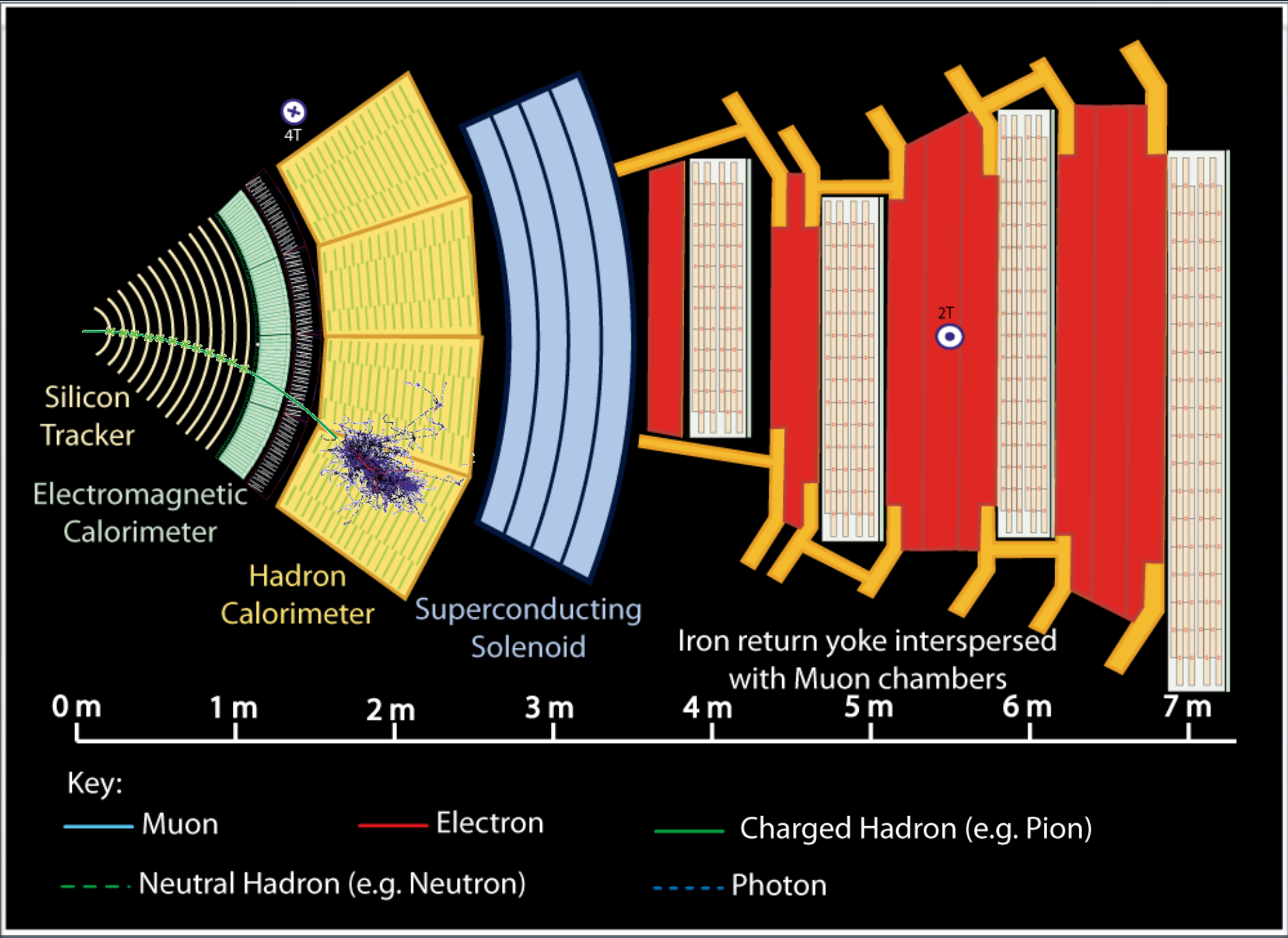
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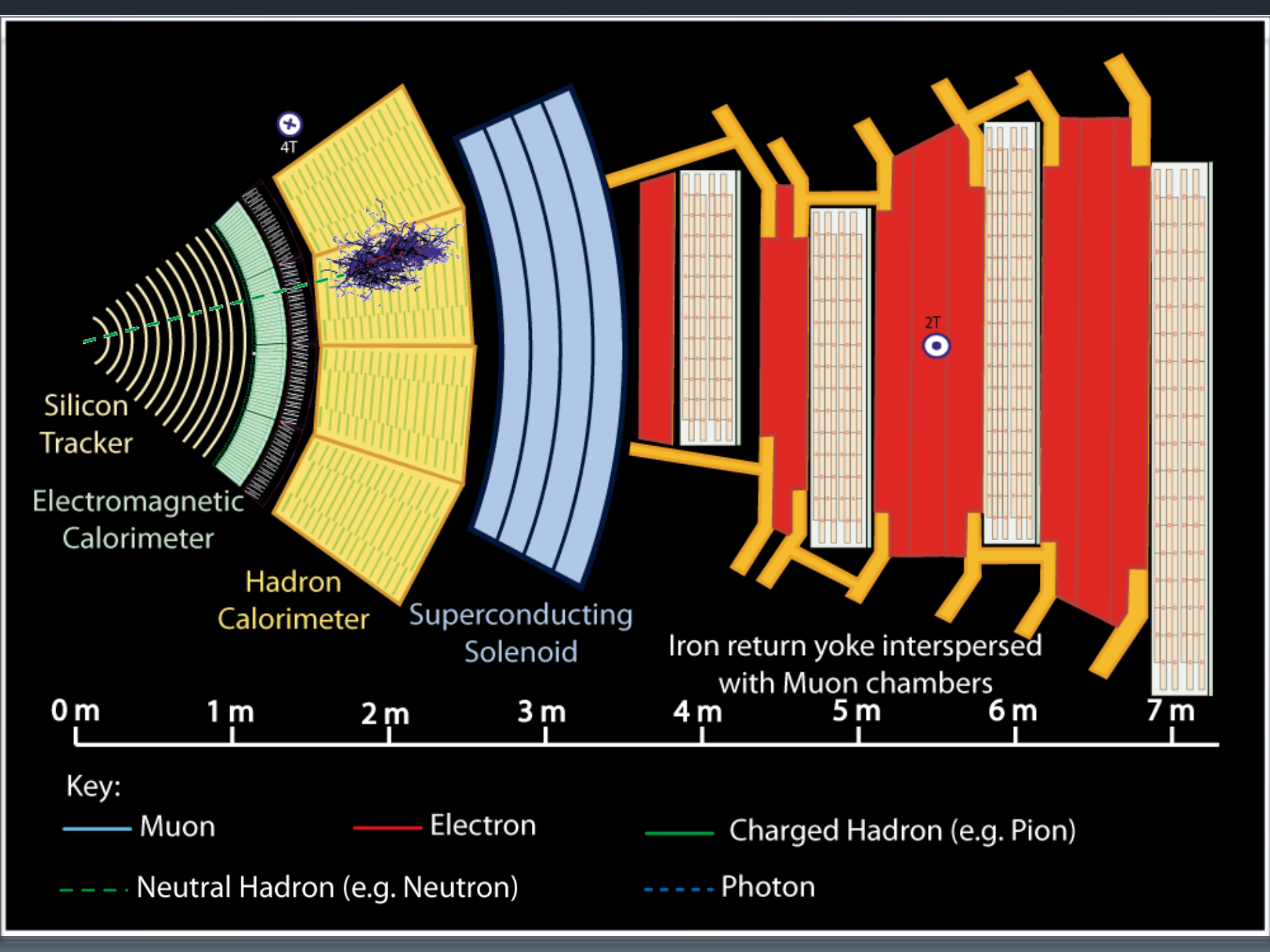
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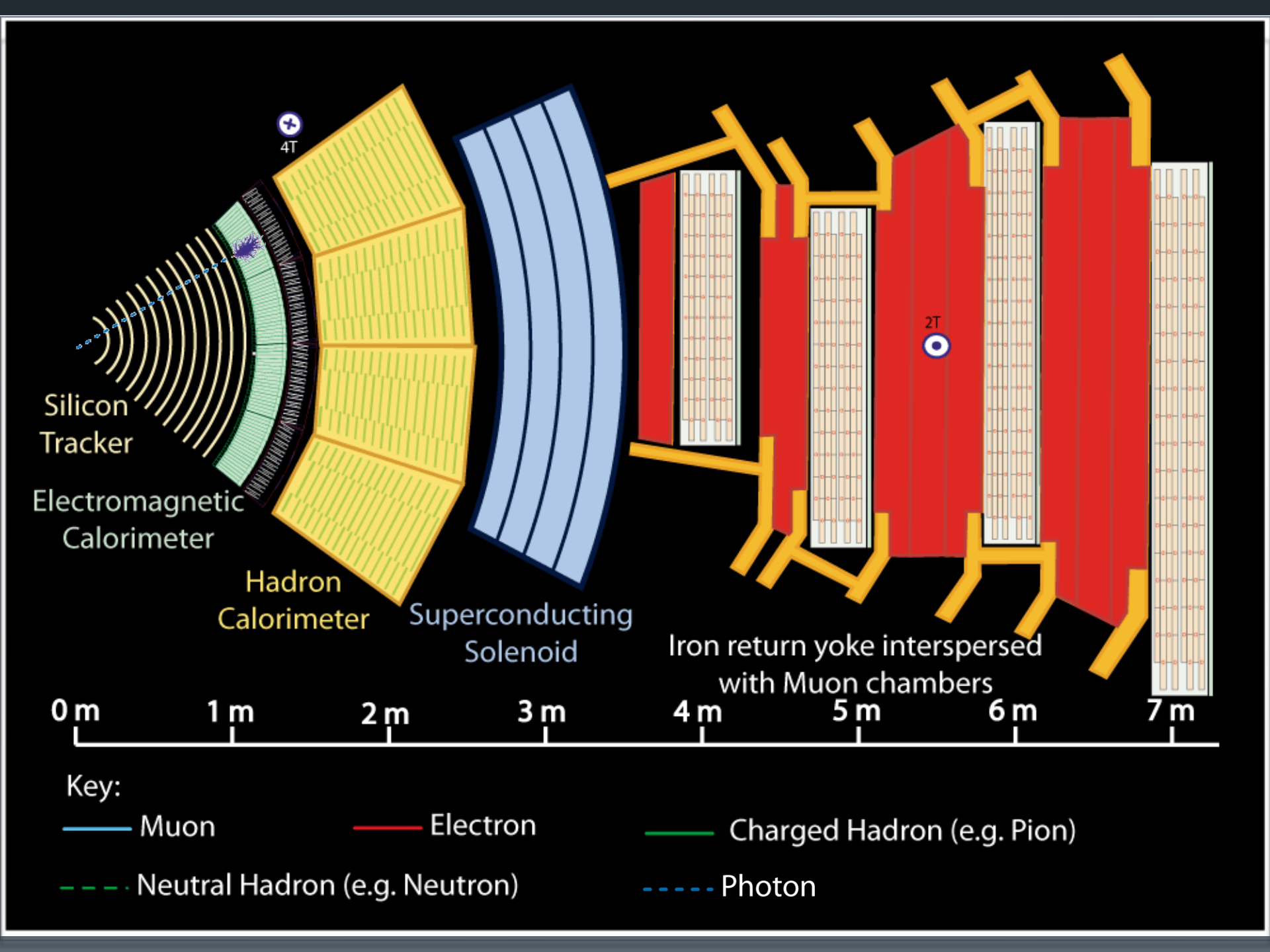
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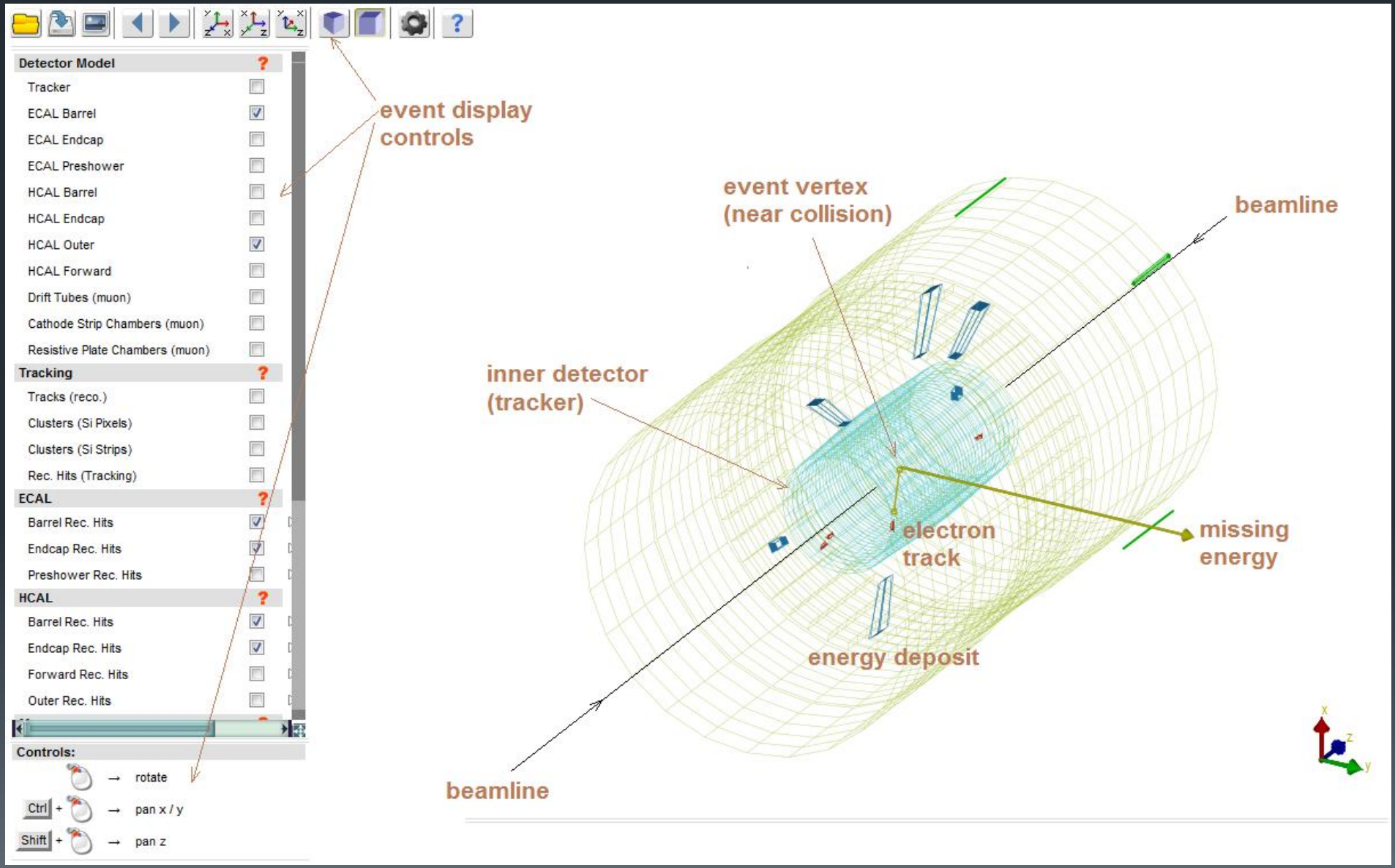
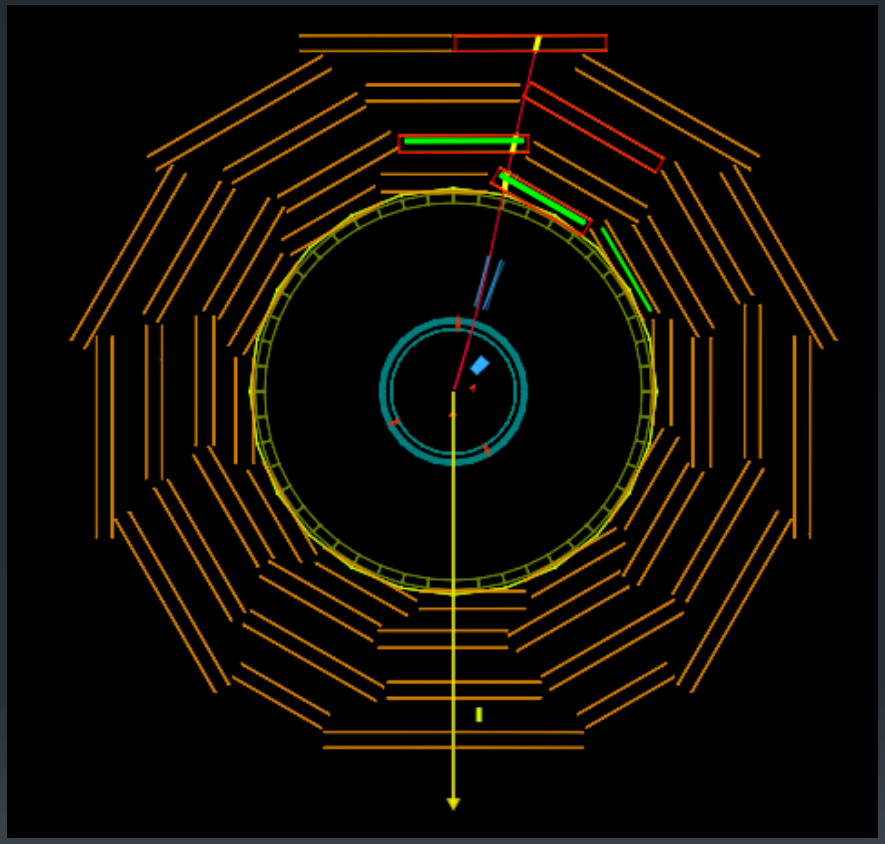
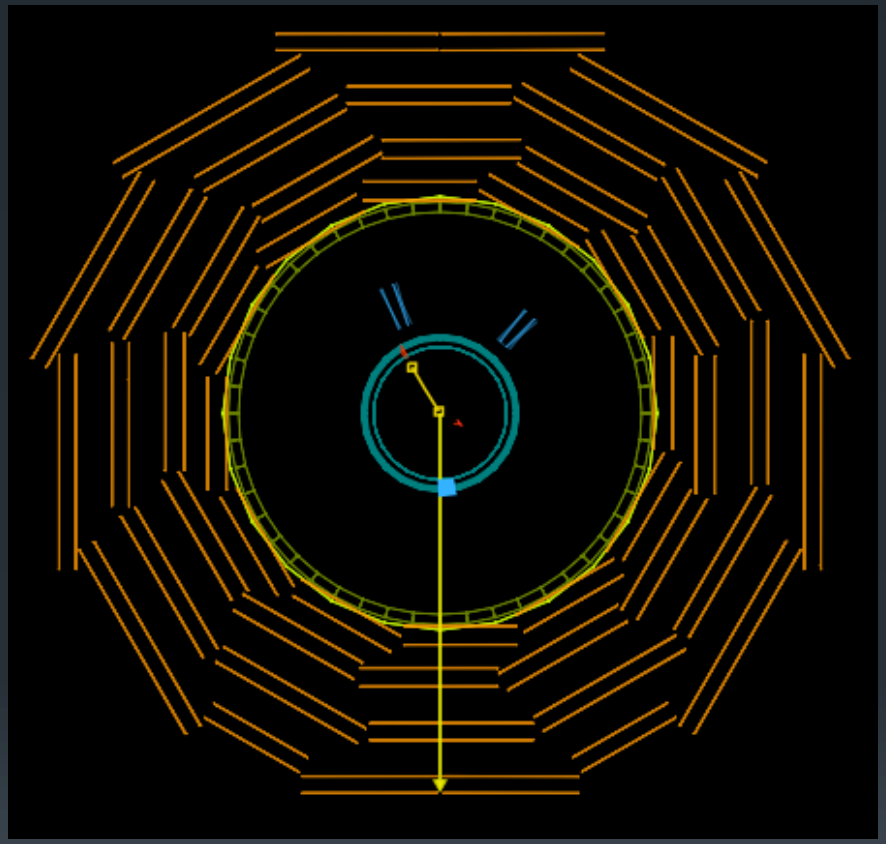
The event display software: iSpy



Particle identification in CMS

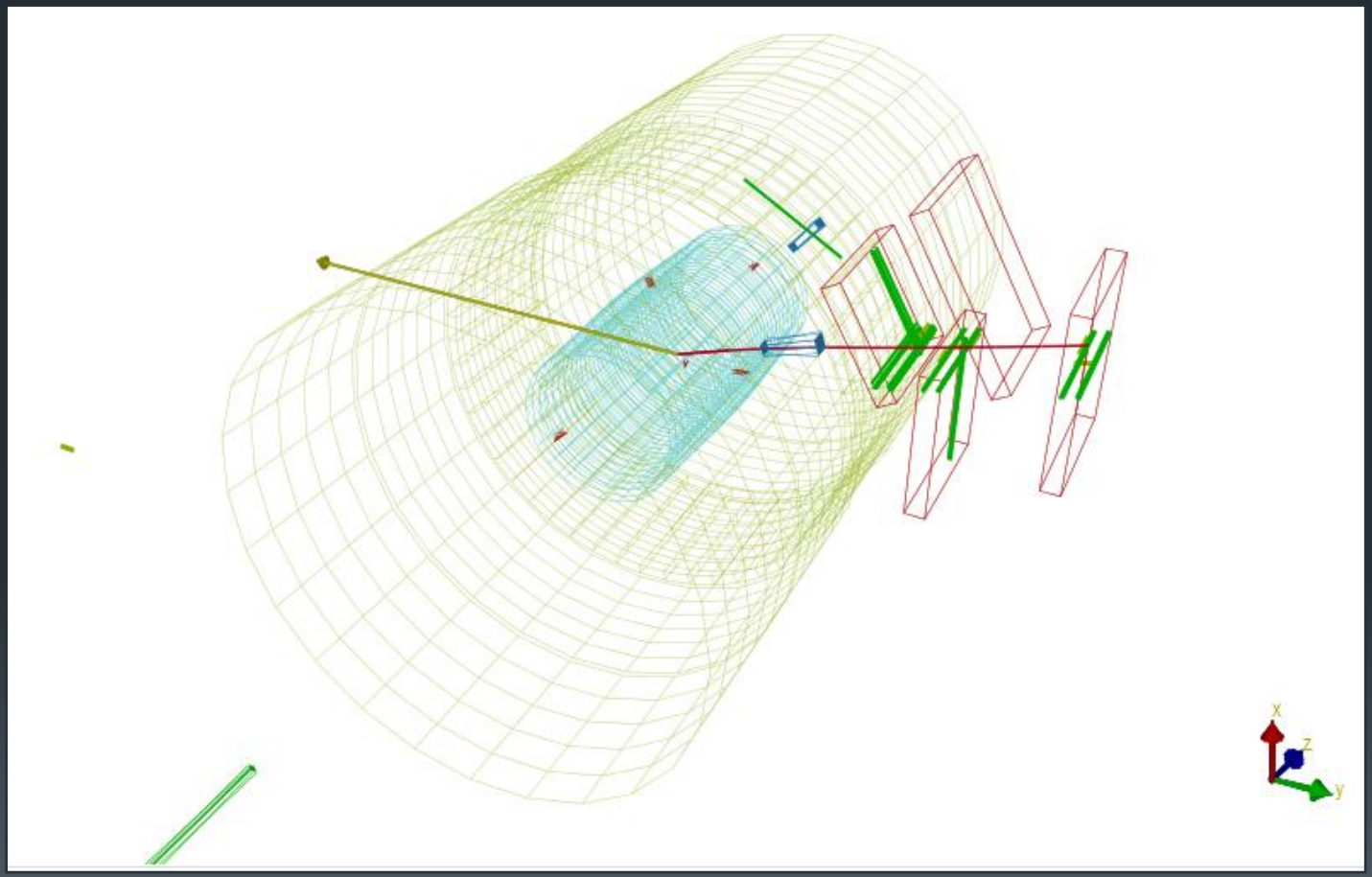


Muon (red track) traversing whole detector, leaving hits in outer layers. Missing energy represented by yellow arrow



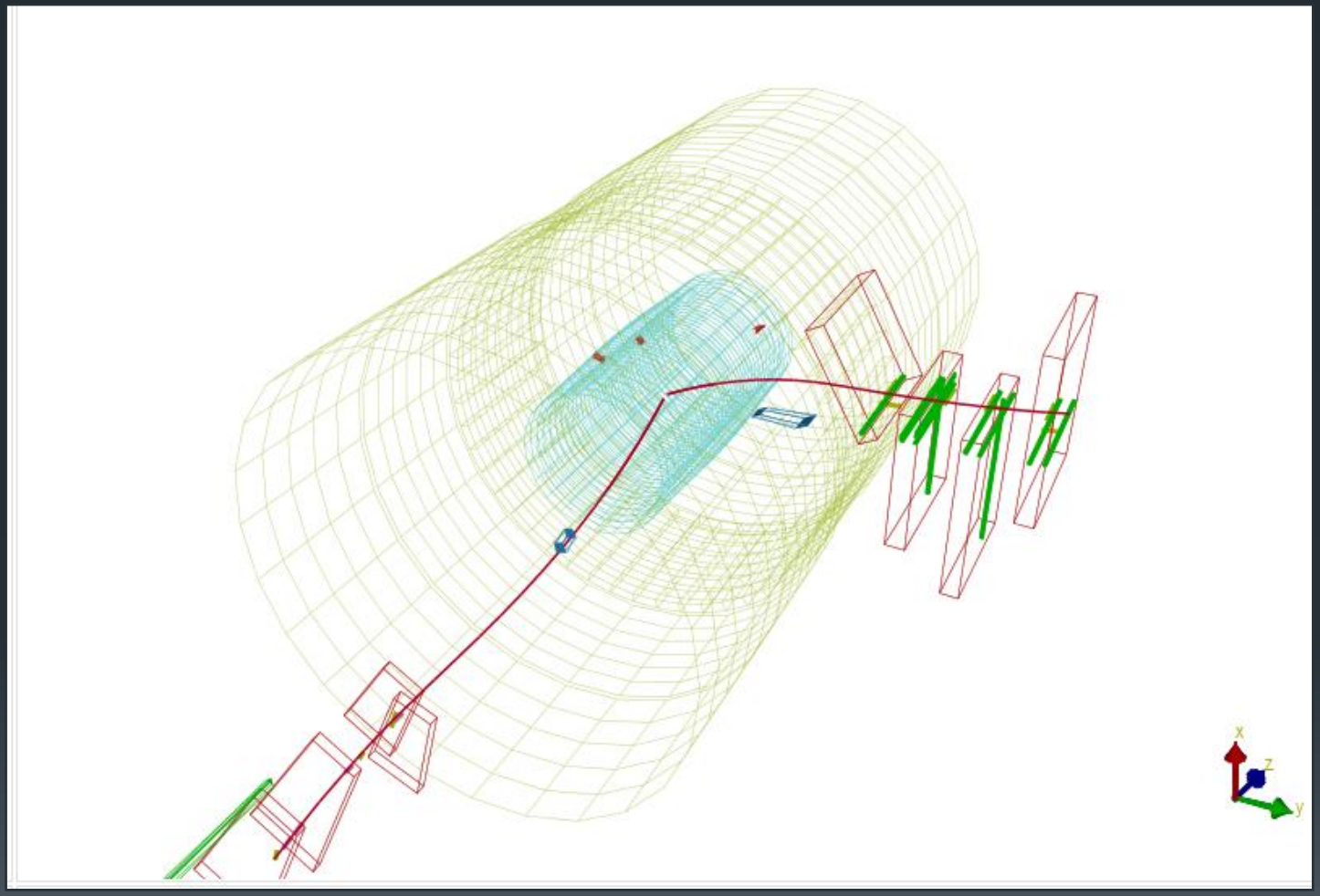
Electron (yellow track) stopping in the ECAL. Missing energy represented by yellow arrow

A W decaying to a muon and a neutrino (not seen directly)



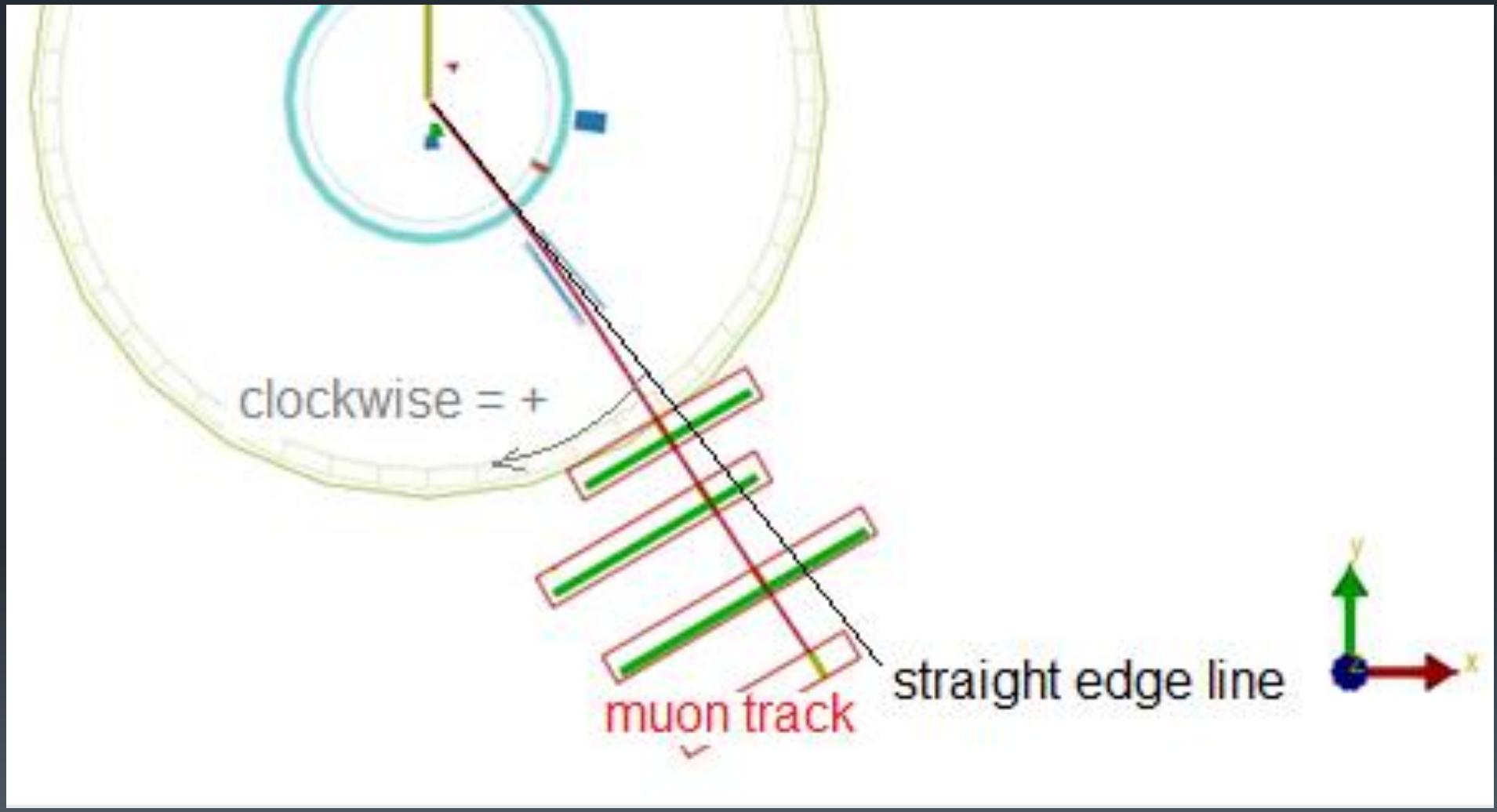
Signature: Signal in muon detectors + missing energy

A Z^0 decaying to two muons



Signature: Two signals in muon detectors

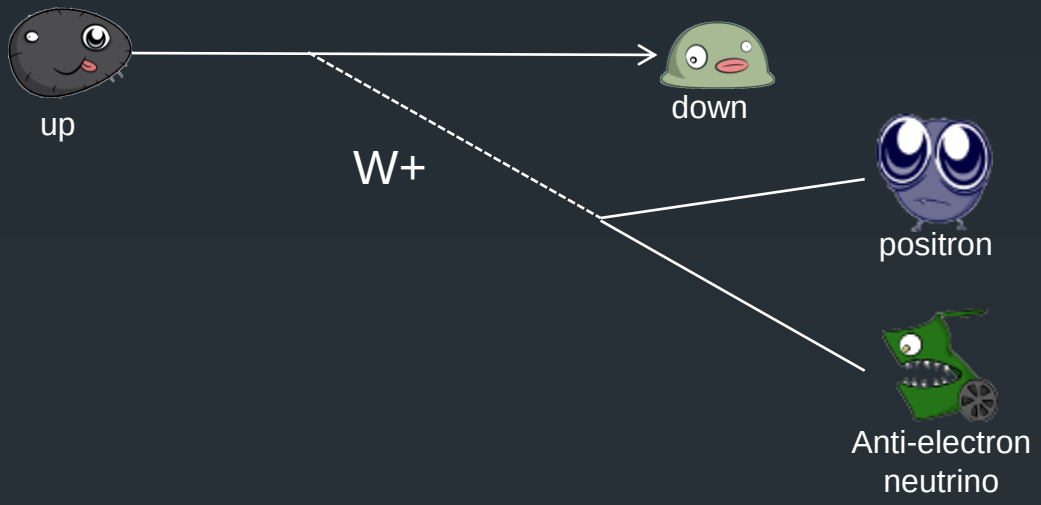
How to measure the charge



Clockwise bend = +ve charge

Today's exercise - objective

- Quarks inside a proton can be "excited" (due to the high energy collision), and transform to a different type of quark, emitting a W



- Down quark could transform to an up quark by emitting a W^-
- Today: Try to measure the ratio between the number of W^+ and W^- produced in collisions in CMS
  - Why? – see later!

Today's exercise – getting started

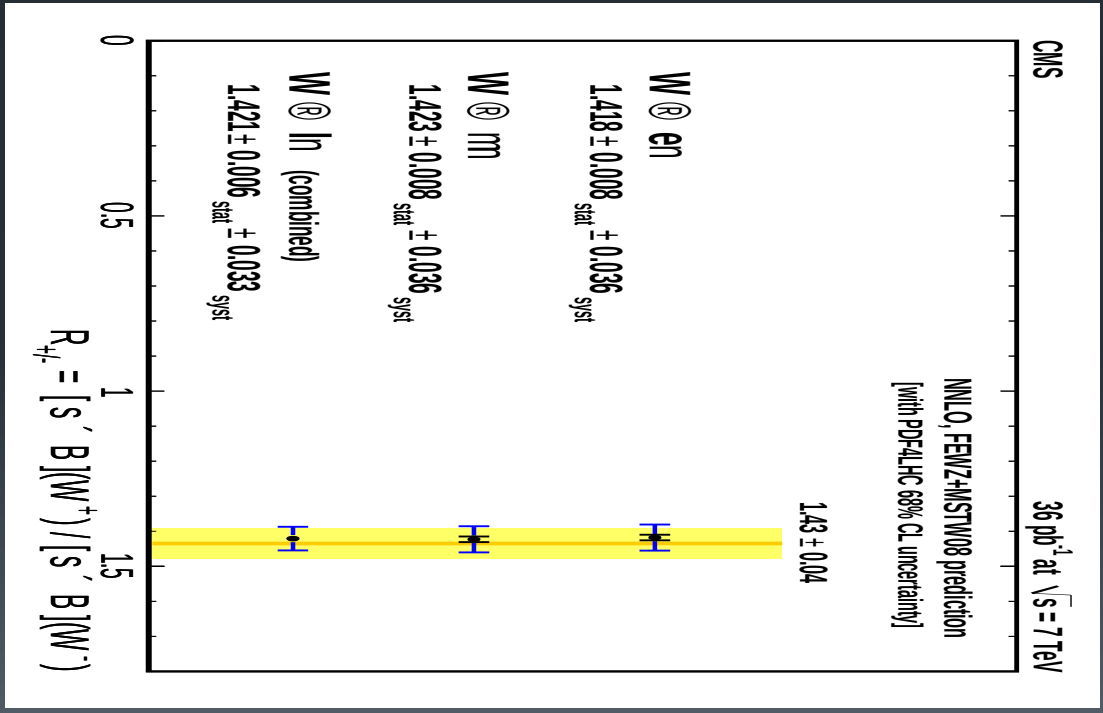
- Split into teams of two
  - Each team (numbered 1-6) will look at 50 events
  - Open your Firefox browser with two tabs
    1. Event display software
       - **http://www18.i2u2.org/elab/cms/event-display**
    2. Spreadsheet for results
       - **http://docs.google.com**
       - Username/email: CMSmasterclasses
       - Password: CMSmasterclass
       - Select the "mc_1900_events_ISEF2013" file
       - Select the tab corresponding to your group number

Event classification & particle id

- Click on the  icon to see a transverse view
- Make sure the “Drift tubes (muon)” box is checked
- Click on the file folder icon to open the folder called “masterclass-2012” and then select “mc_n.ig” where “n” is the number of your group. Finally, select the first event in the list and click the “load” button
- Make sure the “Missing Et (reco)” box is checked
- Perhaps uncheck the “Tracks (reco)” box….
- Rotate, zoom etc. to get an idea of whether you are seeing signs of a Z^0 or W^+ or W^-
- Follow the instructions in the spreadsheet
- To go to the next event, click the  icon
- Try to get through about 30 events in 45 minutes

Discussion of one result

- W^+/W^- ratio: gives an insight into the inner structure of the proton
- What did you expect to find?



What does this mean?

That the “simple” model of the proton (uud) is not quite correct……