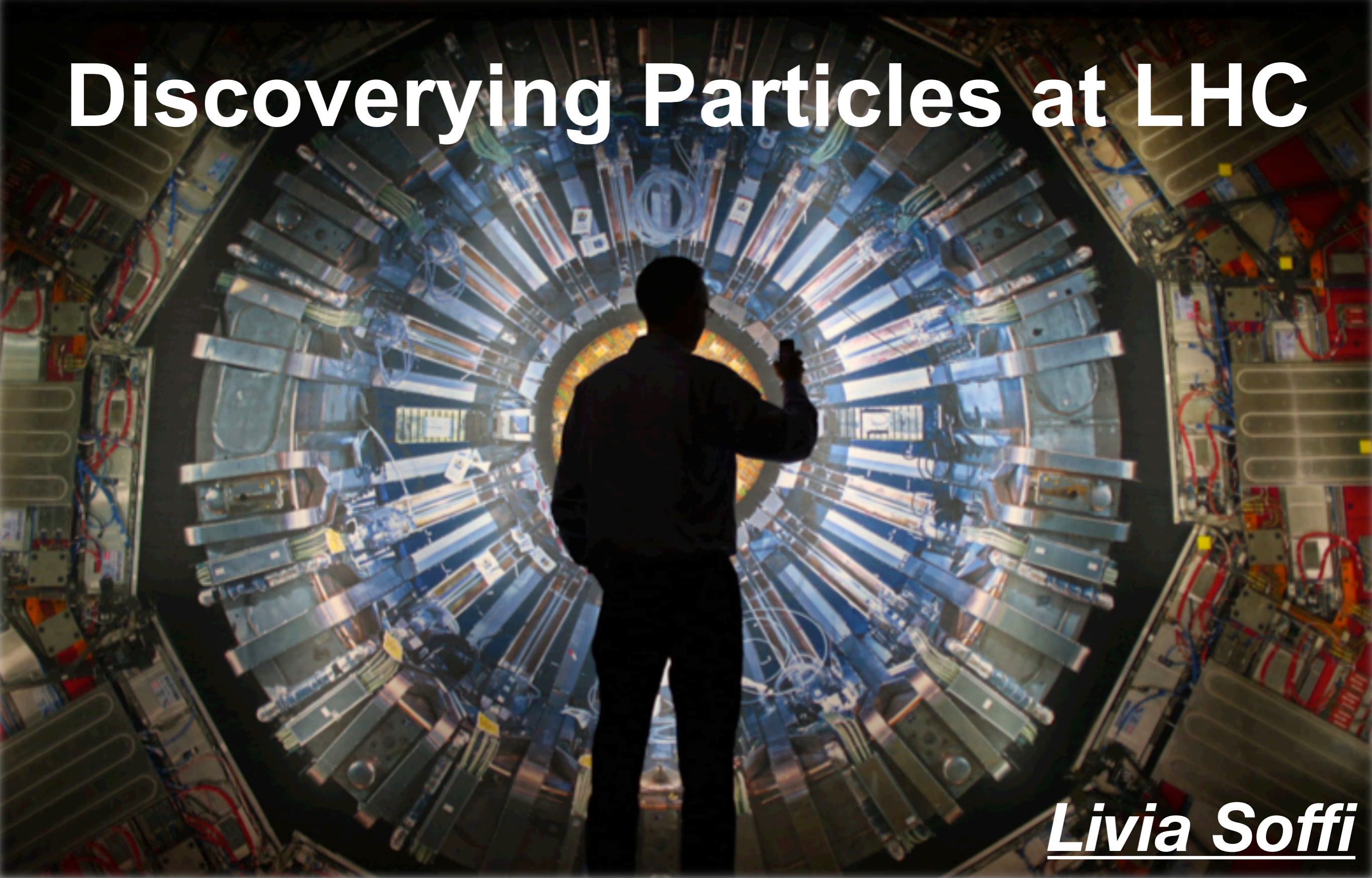


Discovering Particles at LHC



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Sezione di Roma



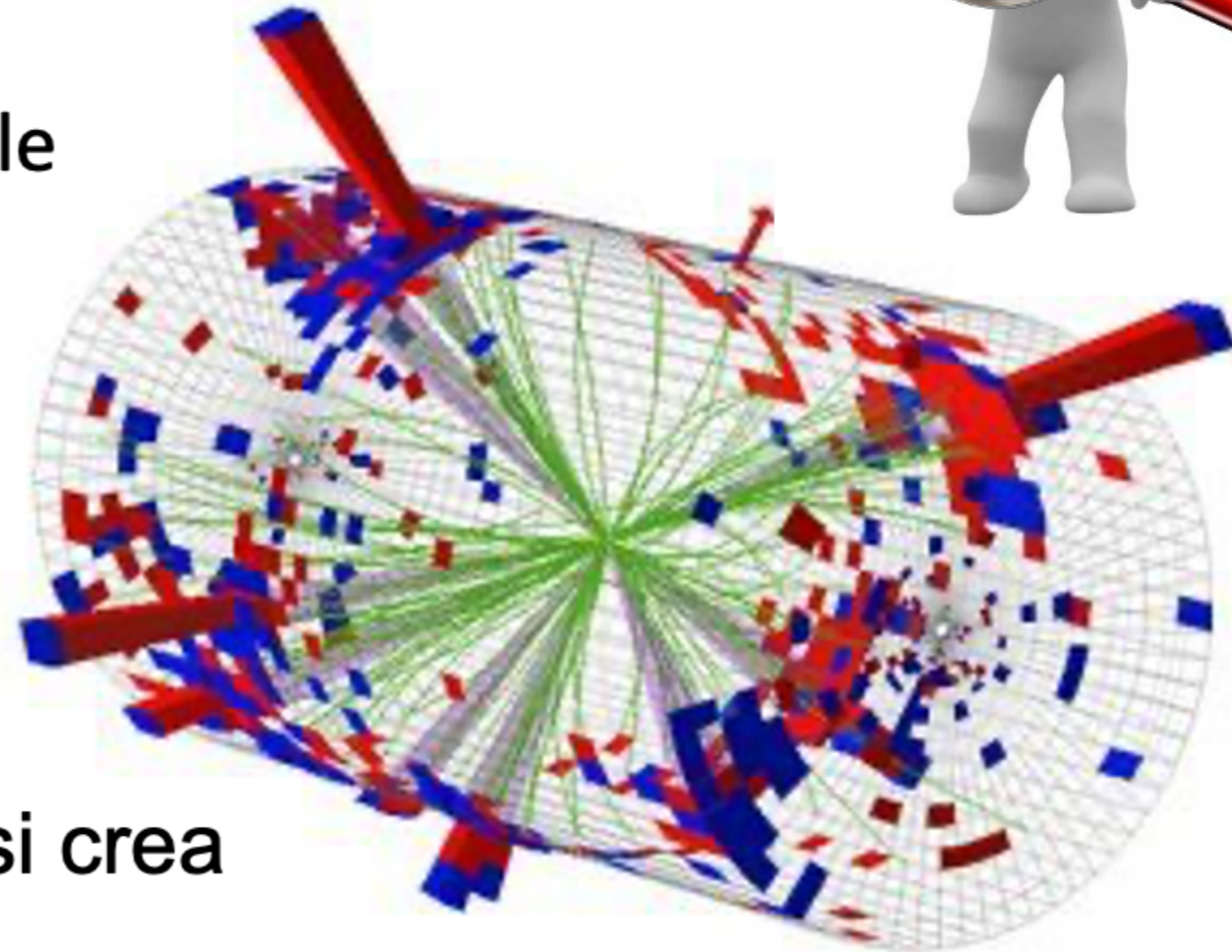
Particle identikit

Nelle collisioni si producono
diversi tipi di particelle

Ogni particella lascia un segnale
caratteristico diverso

Per ciascuna particella che si crea
vogliamo misurare:

- La direzione
- L'energia
- La carica elettrica
- Sapere che particella è



CMS Experiment at LHC, CERN
Data recorded: Mon May 23 21:46:26 2011 EDT
Run/Event: 165567 / 347495624
Lumi section: 280
Orbit/Crossing: 73256853 / 3161



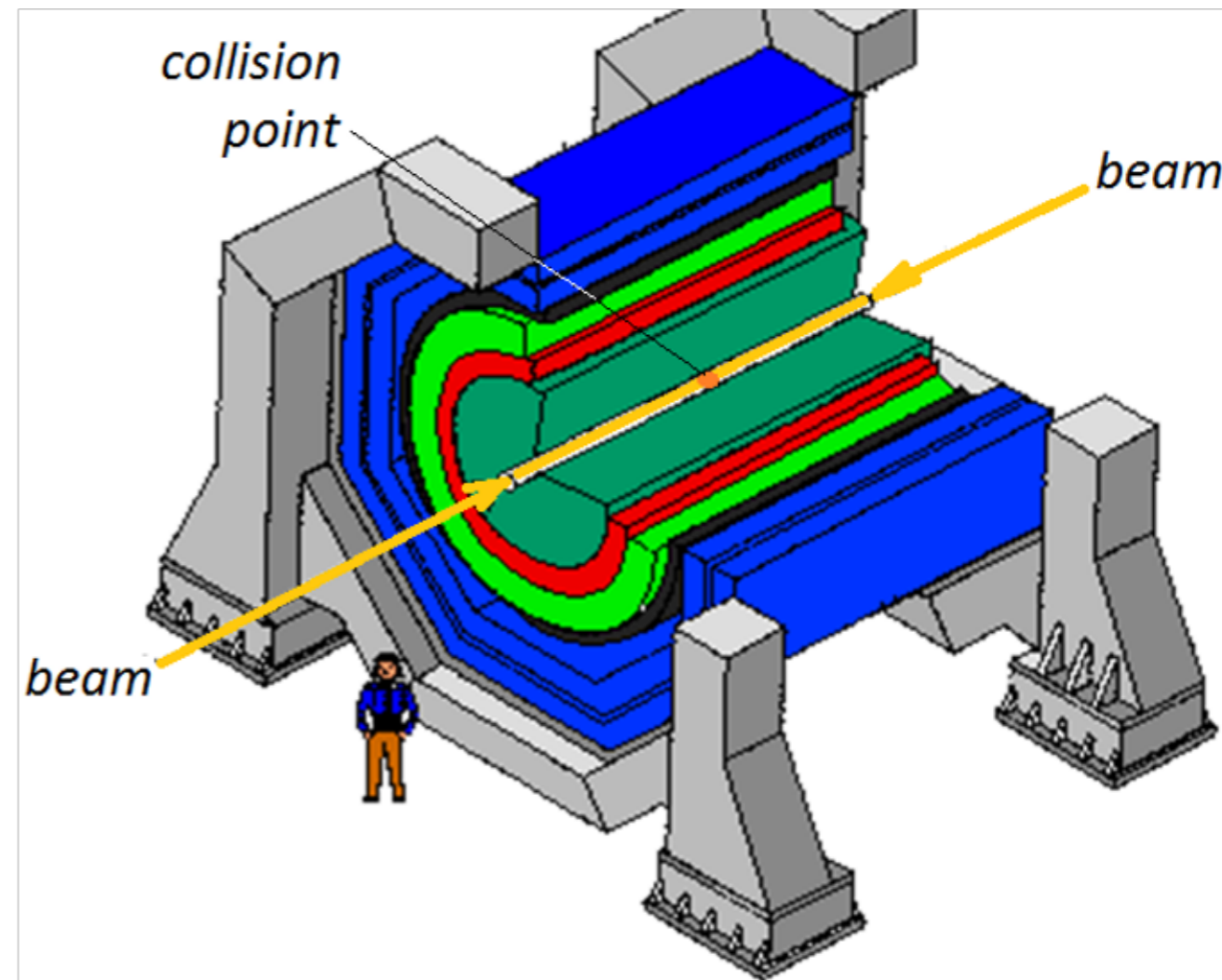
Come e' fatto un esperimento all'LHC

Un disegno generico di Atlas o CMS e' fatto cosi`:

→ Forma cilindrica attorno al tubo del fascio

dall'interno verso l'esterno:

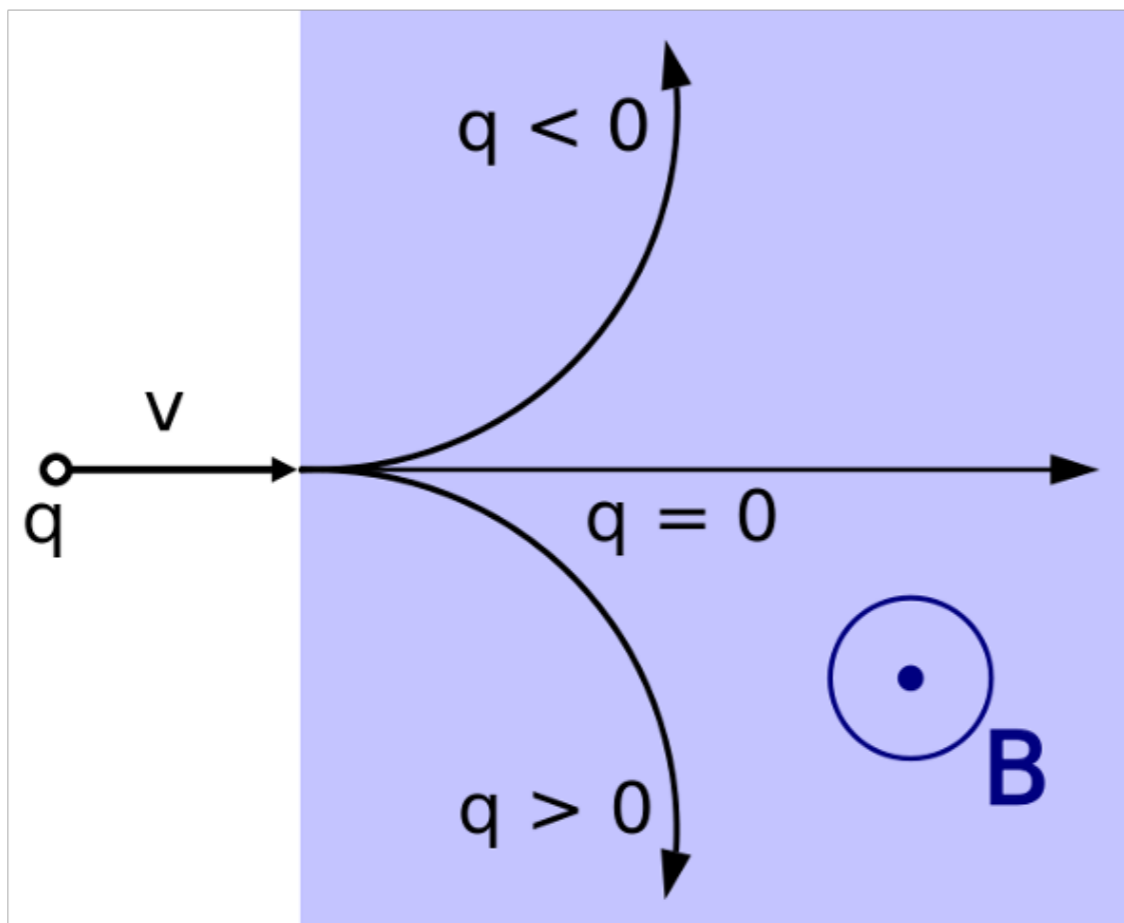
- Tracciatore
- Calorimetro elettromagnetico
- Calorimetro adronico
- Magnete
- Camere per muoni



Magnete

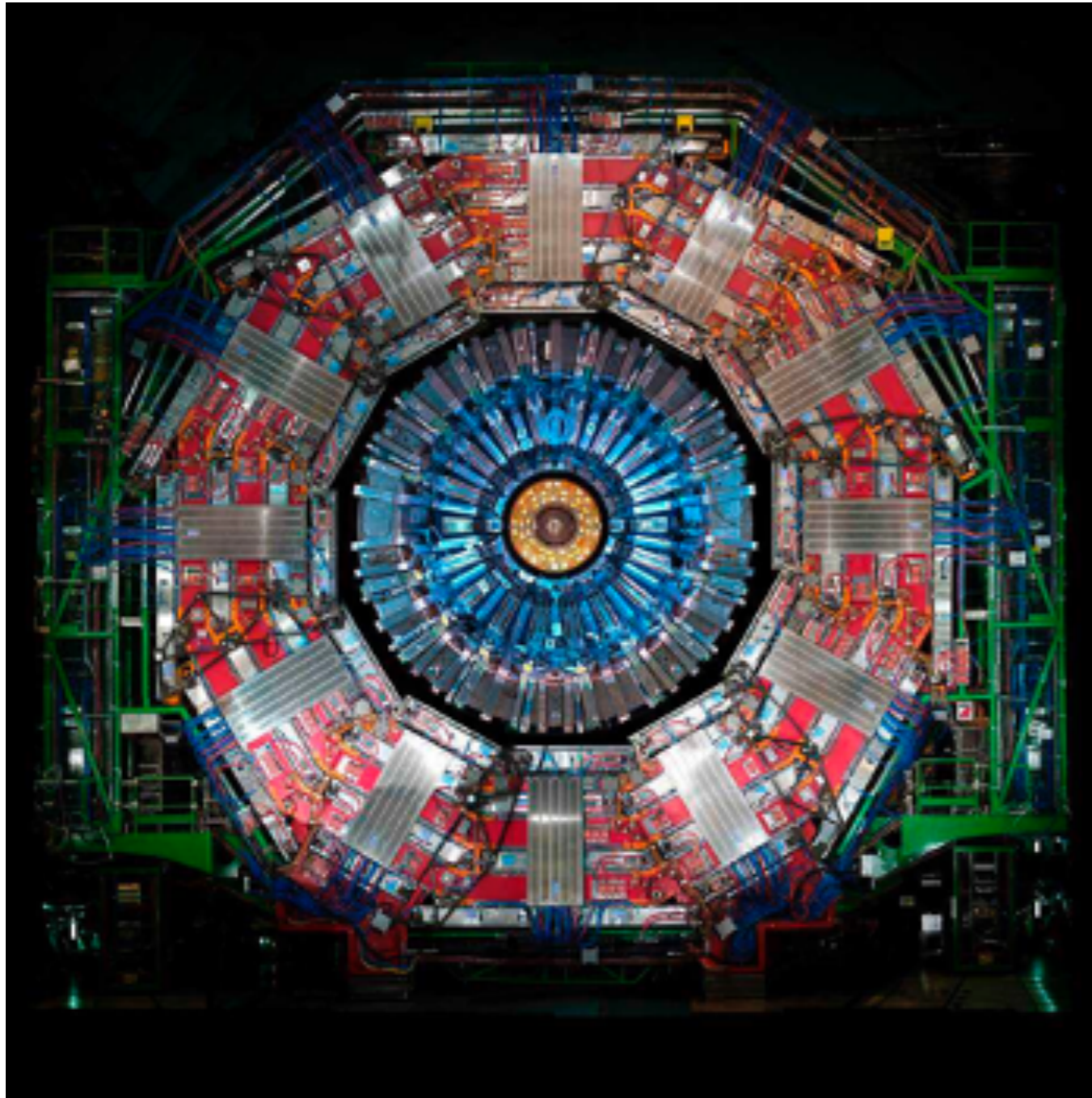
Il tracciatore e' immerso in un campo magnetico.

Usando la Forza di Lorentz: $\vec{F} = q\vec{v} \times \vec{B}$

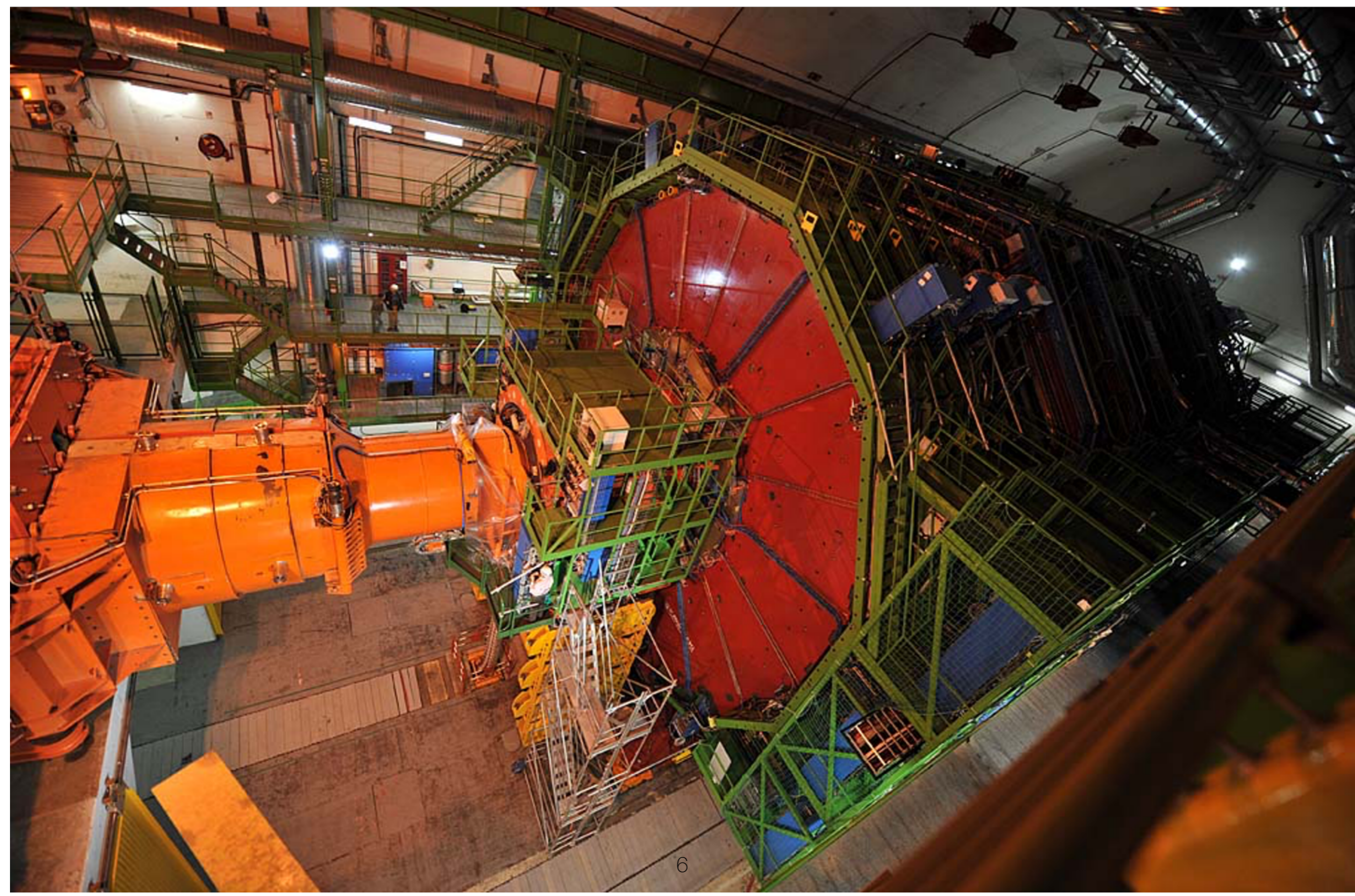


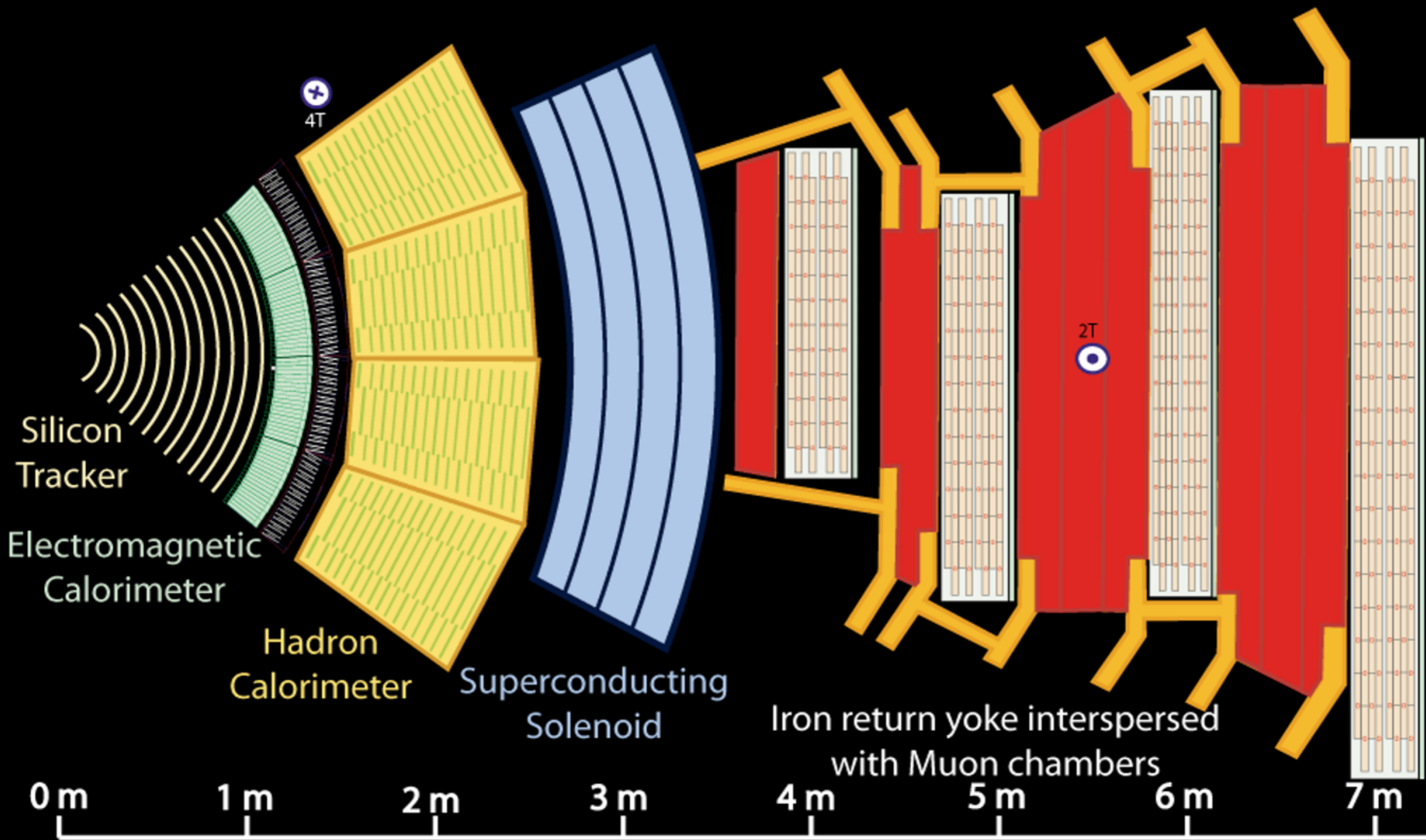
possiamo misurare la
carica delle particelle

CMS: Our beautiful experiment



La caverna di CMS (Settembre 2008)





Key:

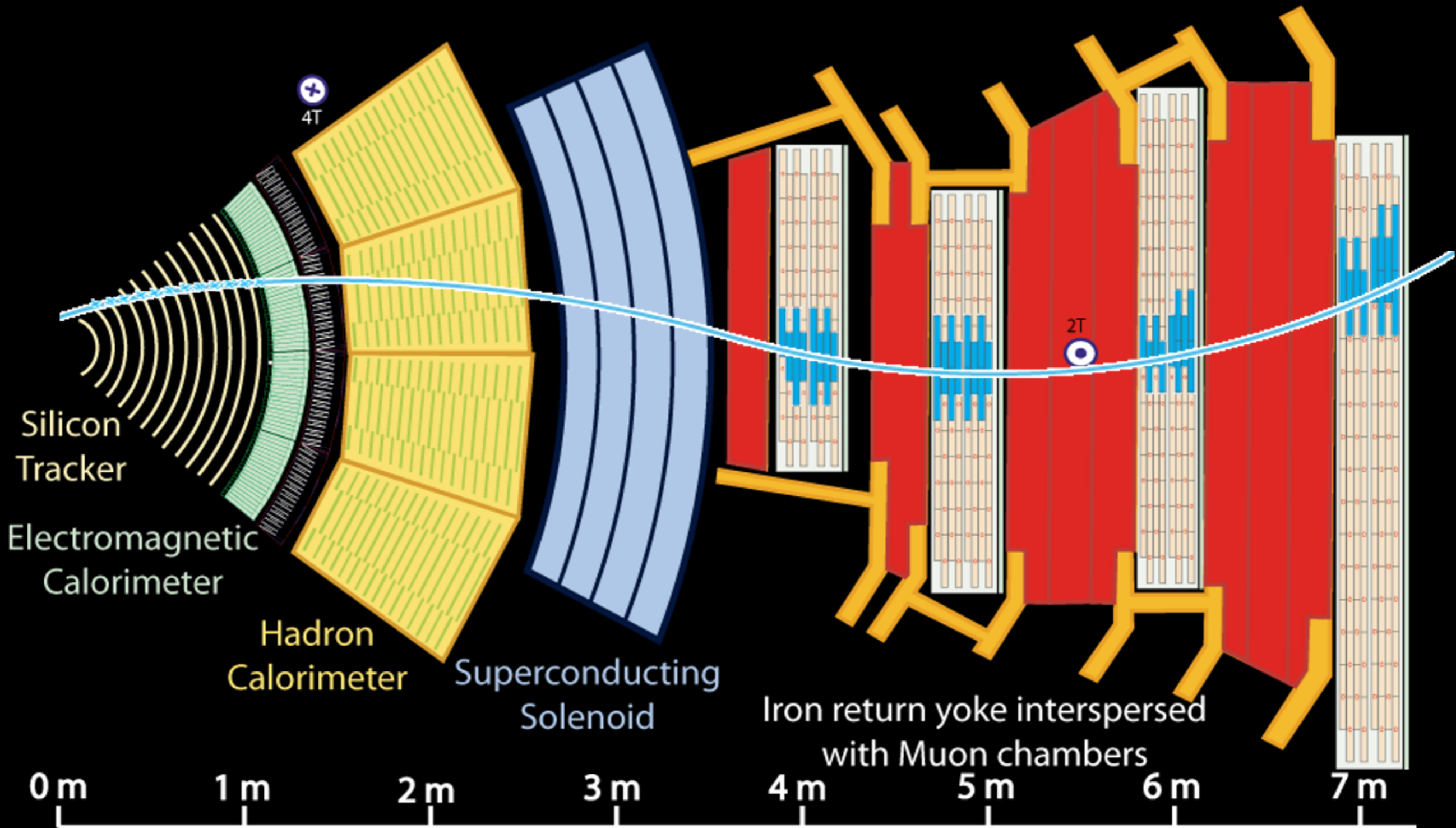
— Muon

— Electron

— Charged Hadron (e.g. Pion)

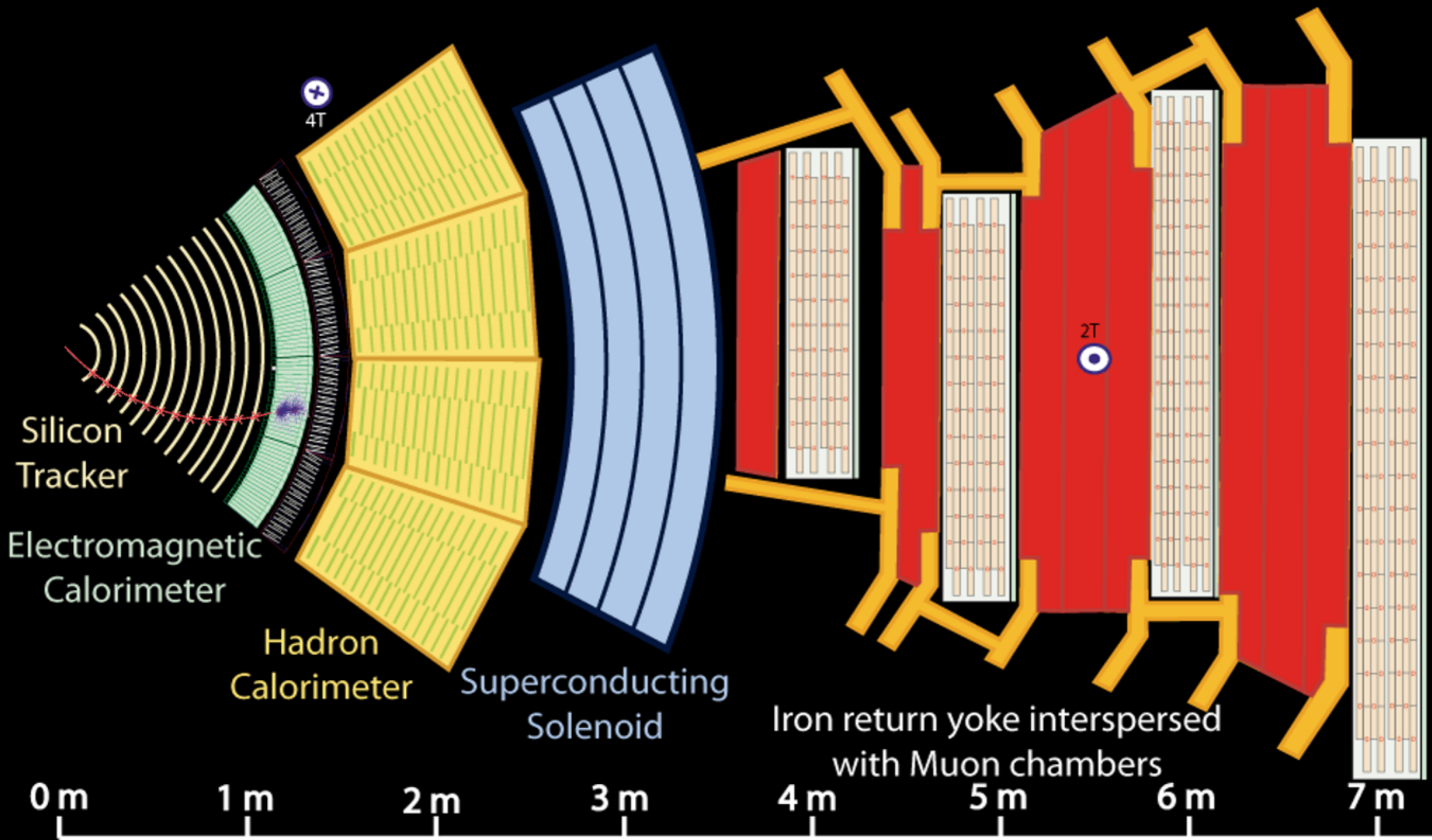
- - - Neutral Hadron (e.g. Neutron)

- - - Photon



0 m 1 m 2 m 3 m 4 m 5 m 6 m 7 m

- Muon
- Electron
- Charged Hadron (e.g. Pion)
- - - Muon
- - - Photon
- - - Neutral Hadron (e.g. Neutron)



Key:

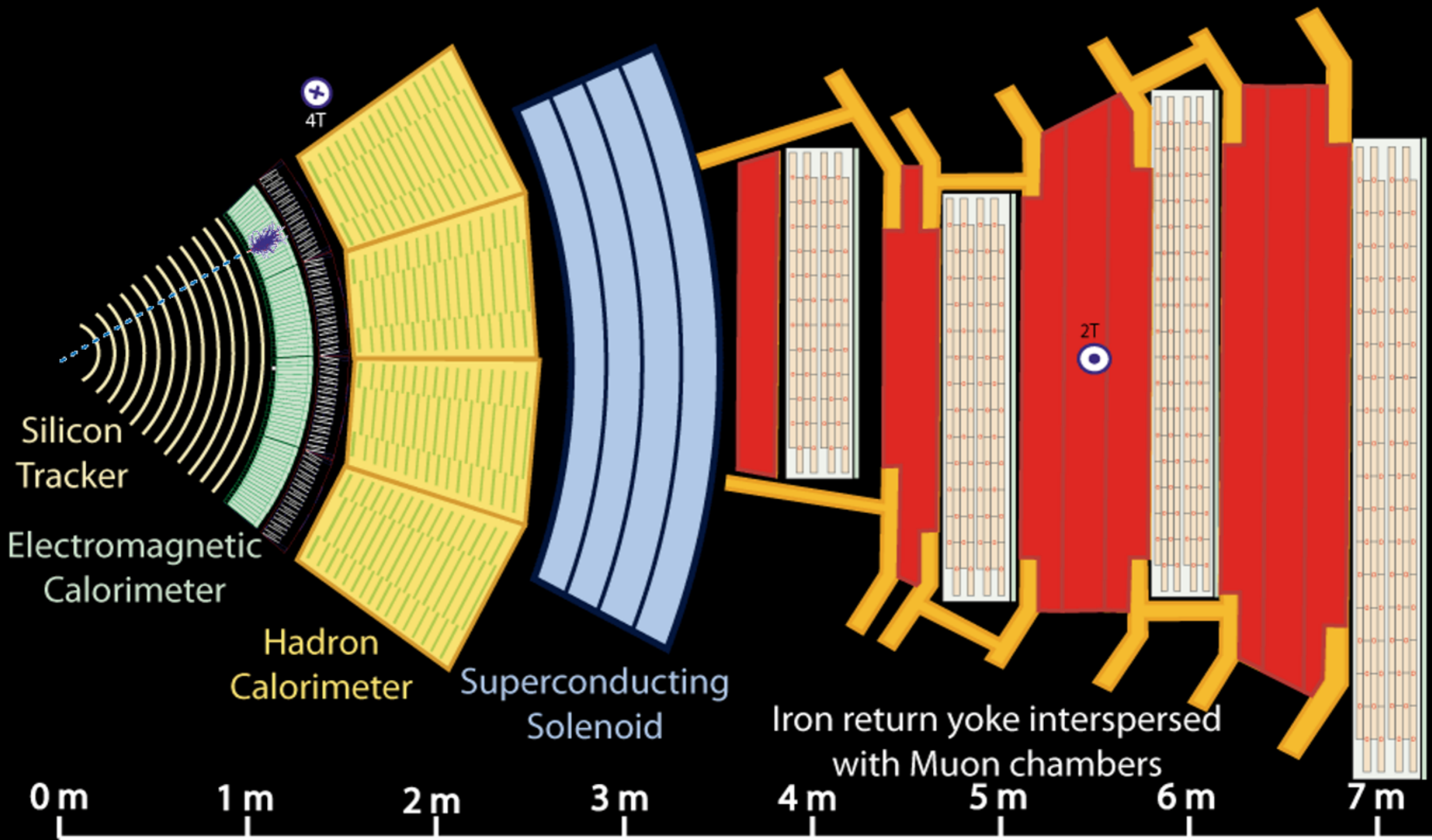
— Muon

— Electron

— Charged Hadron (e.g. Pion)

- - - Neutral Hadron (e.g. Neutron)

- - - Photon



Key:

— Muon

— Electron

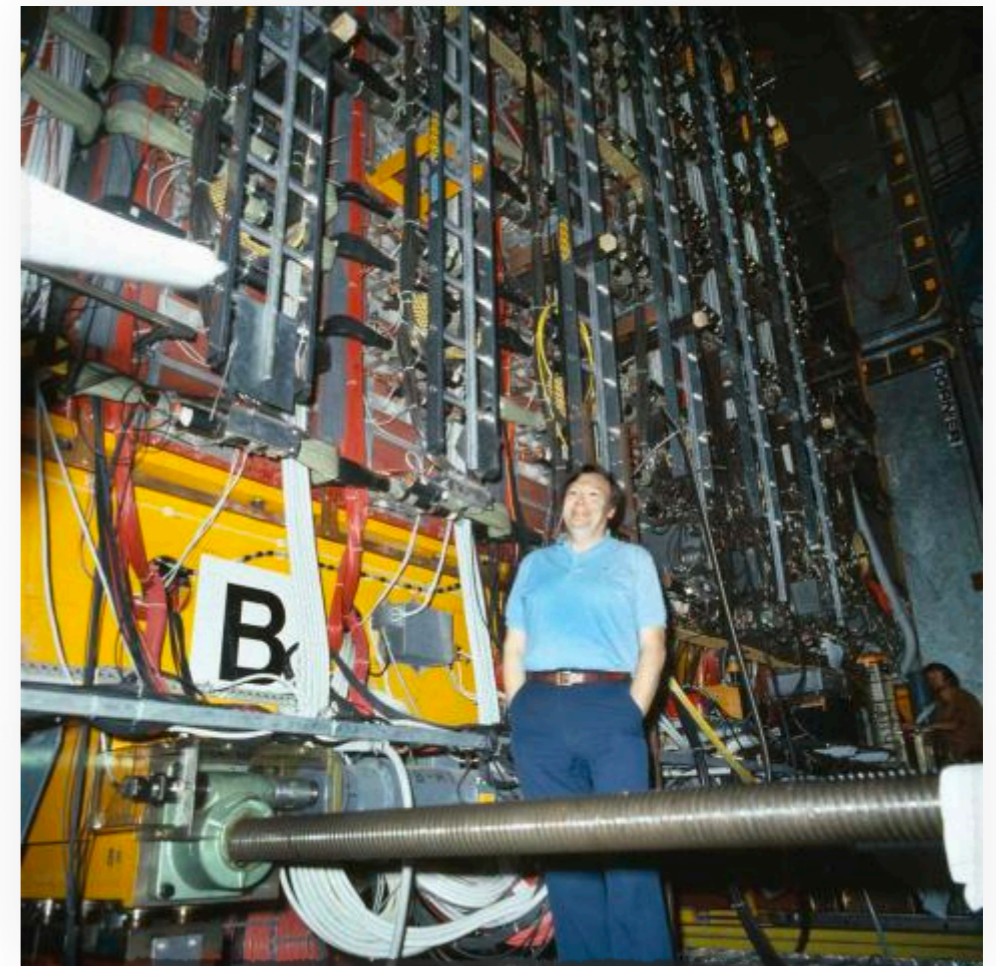
— Charged Hadron (e.g. Pion)

- - - Neutral Hadron (e.g. Neutron)

- - - Photon

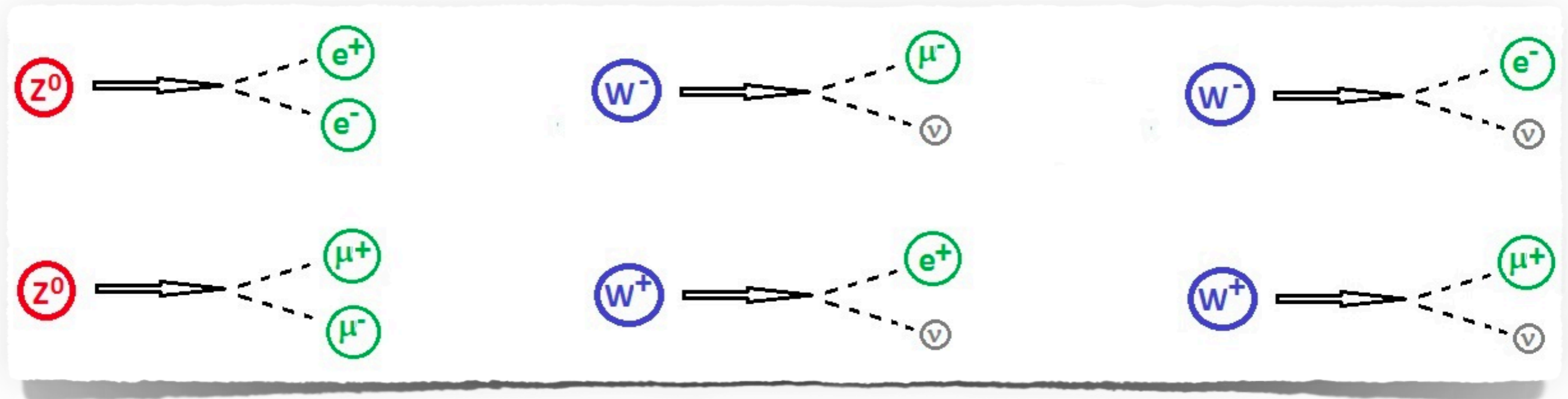
The W and Z bosons

- W and Z bosons are the particles mediator of the weak force
- They have been **predicted in the 1960`s** to explain the “beta” decays observed well before by Fermi.
- Theory predicted **W and Z masses around 100 GeV** and physicists at CERN built in early 1980`s the first most powerful collider able to reach such high energies: the SpPpS



Discovery of a new particle

- The **Z and W bosons** produced at LHC do not live long, but **decay immediately to other elementary particles that can be measured by the CMS and ATLAS detectors**



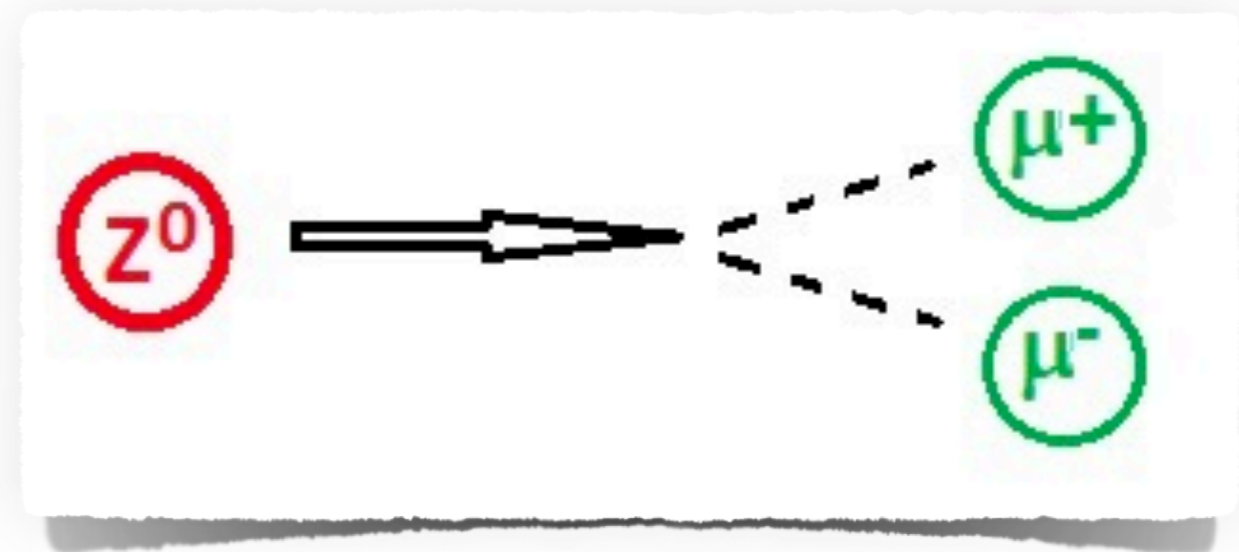
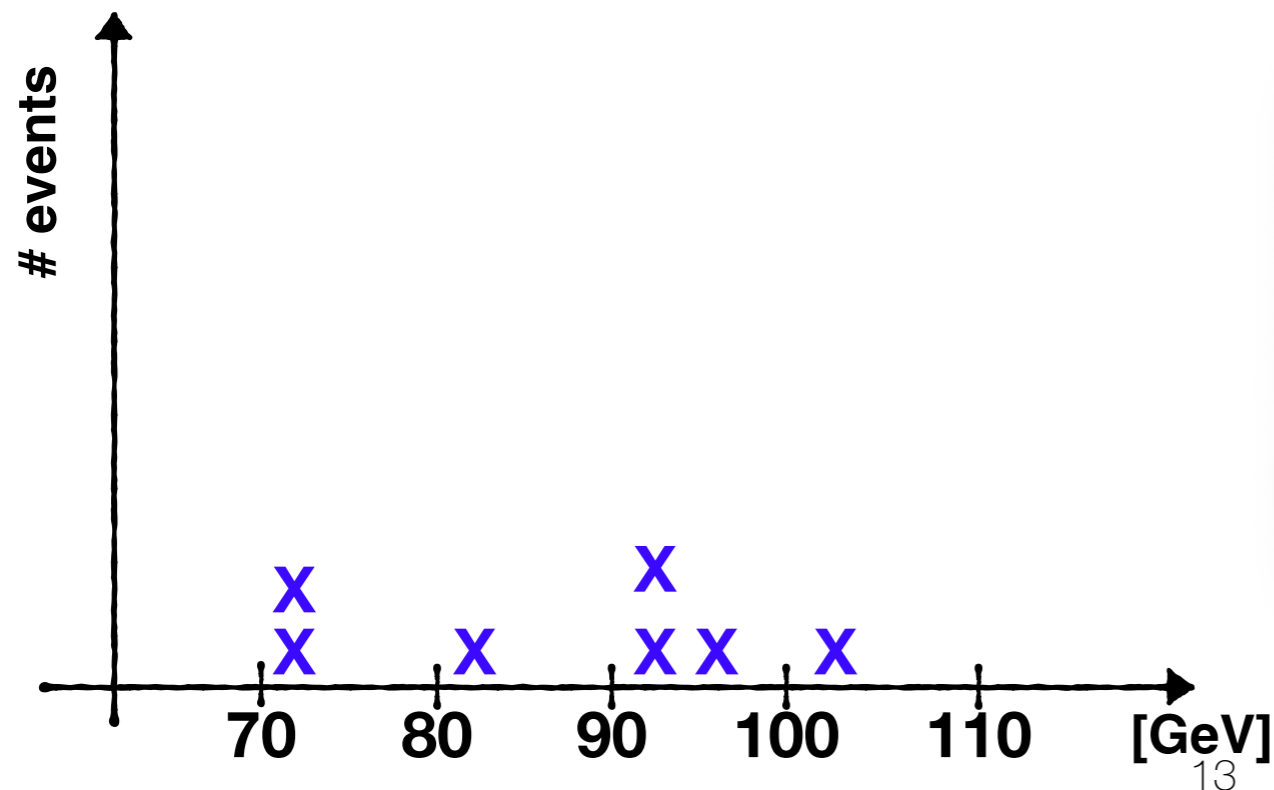
- So when in an LHC collision we produce a Z or W particle, **what we detect in the our experiments are only electrons and muons!**

The Z boson mass reconstruction

- Measuring the **energies** and the **direction of production** of the two electrons or muons, we can compute the mass of the particle that have produced them in its decays:

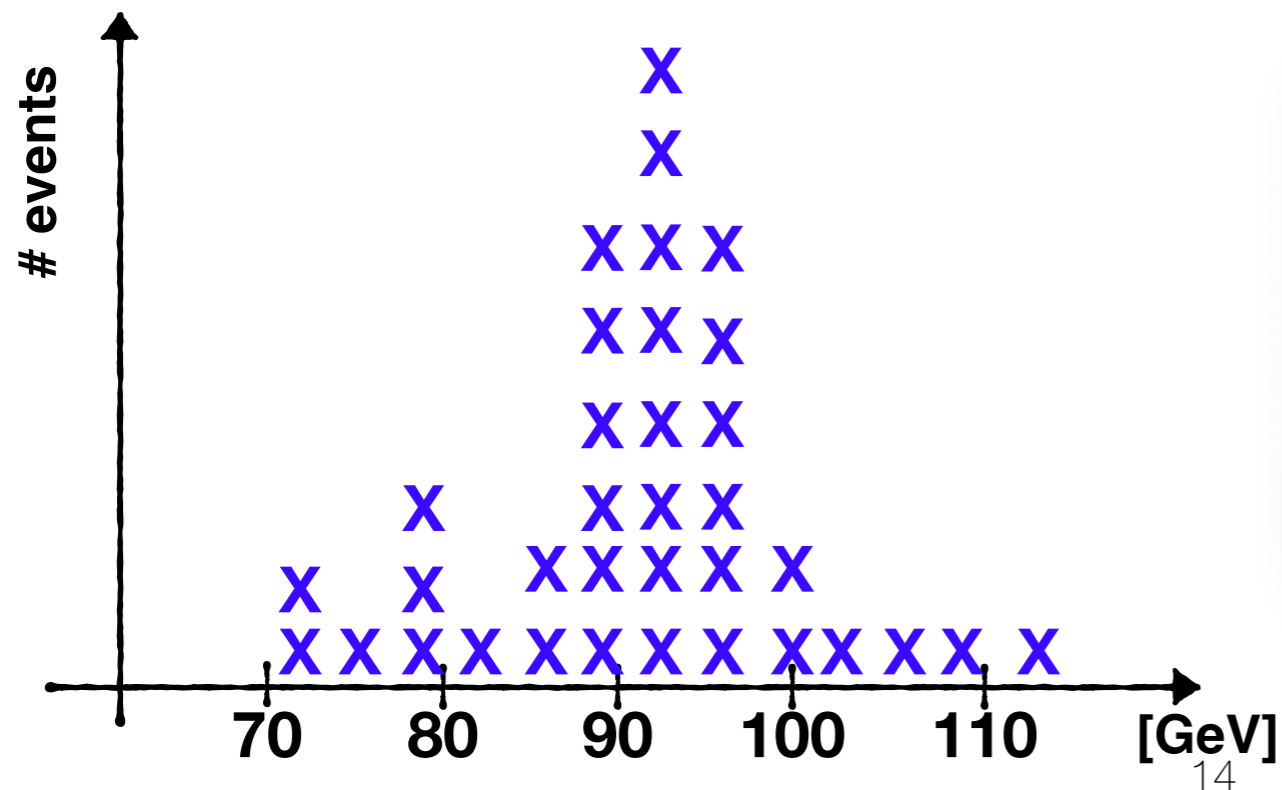
$$m_X = \sqrt{2E_1E_2(1 - \cos\theta)}$$

- In each **event** where we have two electrons/or muons we compute the Z mass with this formula and we fill an histogram of events:



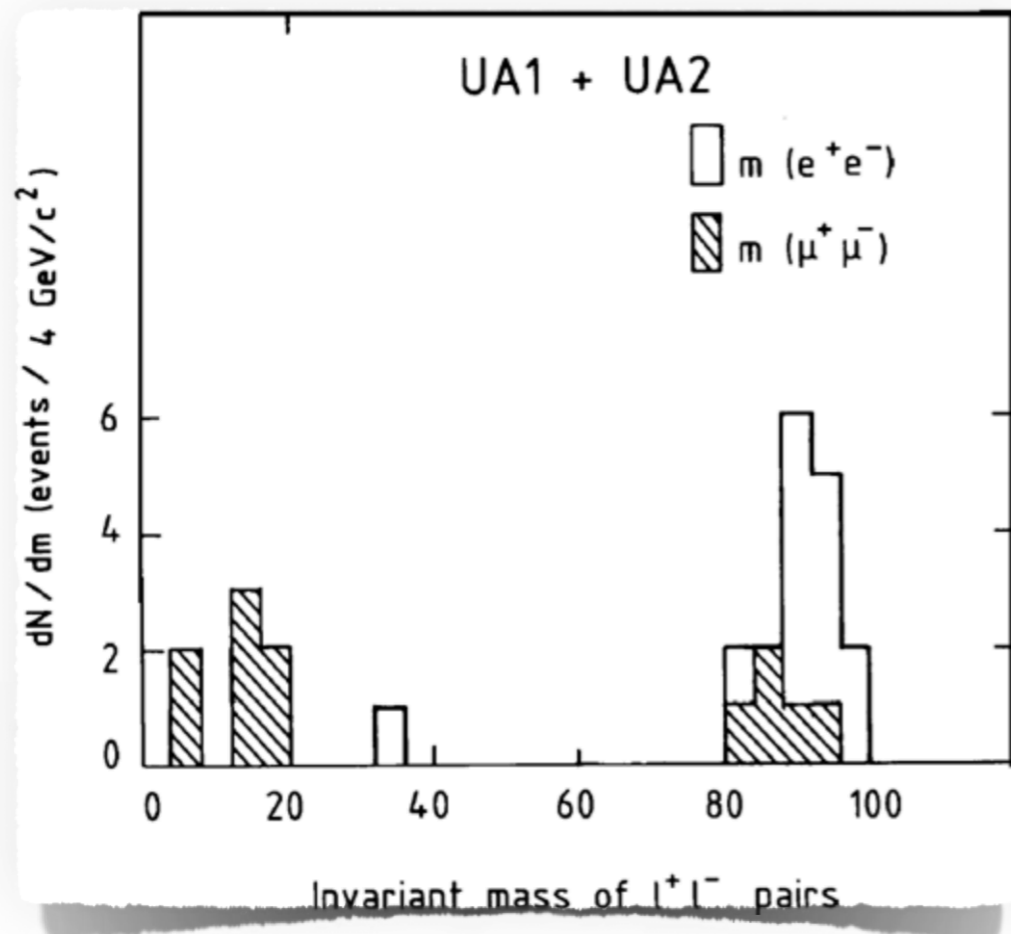
The Z boson mass reconstruction

- A peak of events will appear close to the true value of the mass of the Z boson if the Z exists
- If the “**excess**” of events is significantly big.. we discovered a new particle”



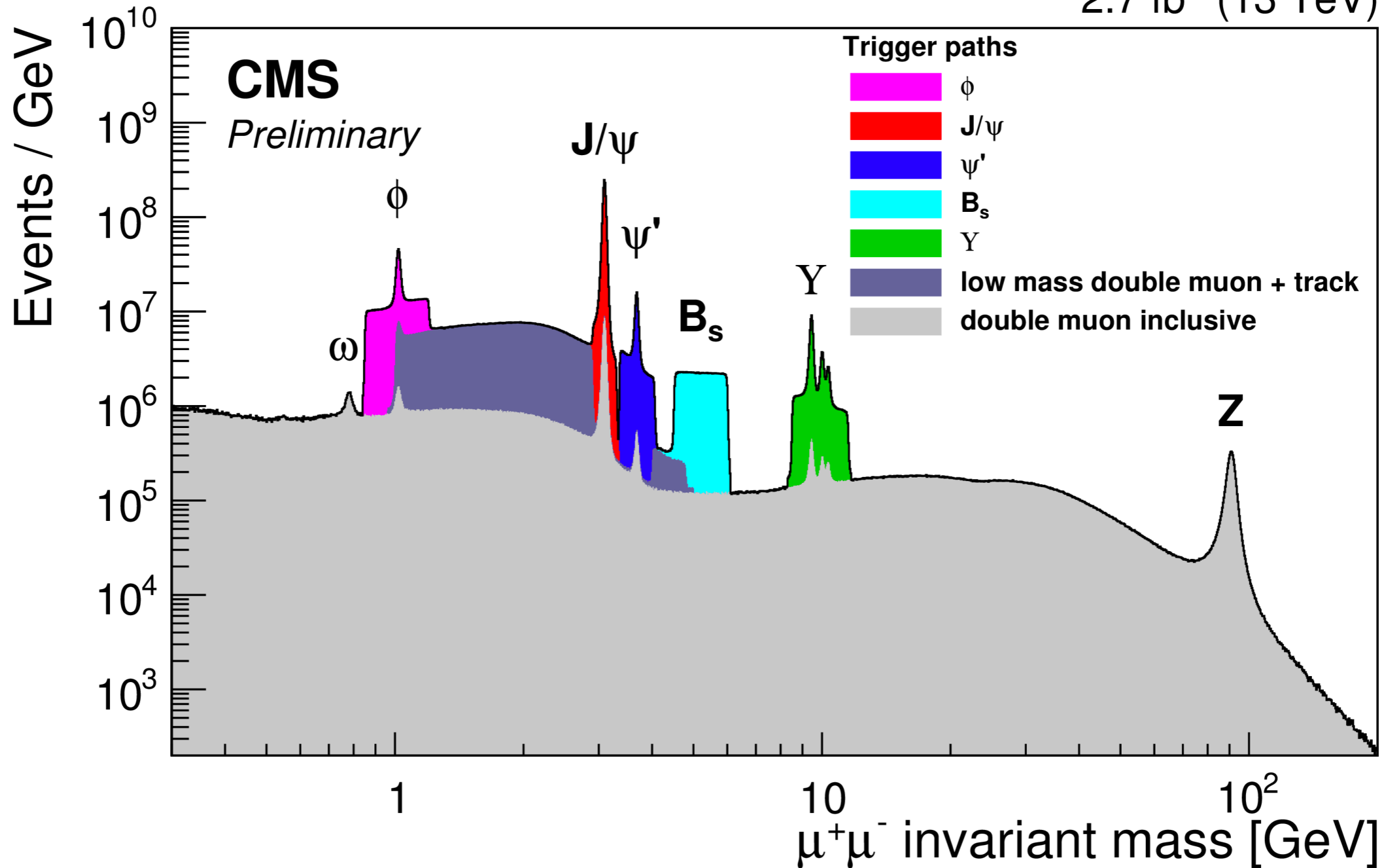
The Z boson Nobel Prize

- A peak of events will appear close to the true value of the mass of the Z boson if the Z exists
- If the “**excess**” of events is significantly big.. we discovered a new particle”
- In 1983 The UA1 and UA2 experiments at CERN: discovery of the W and Z boson



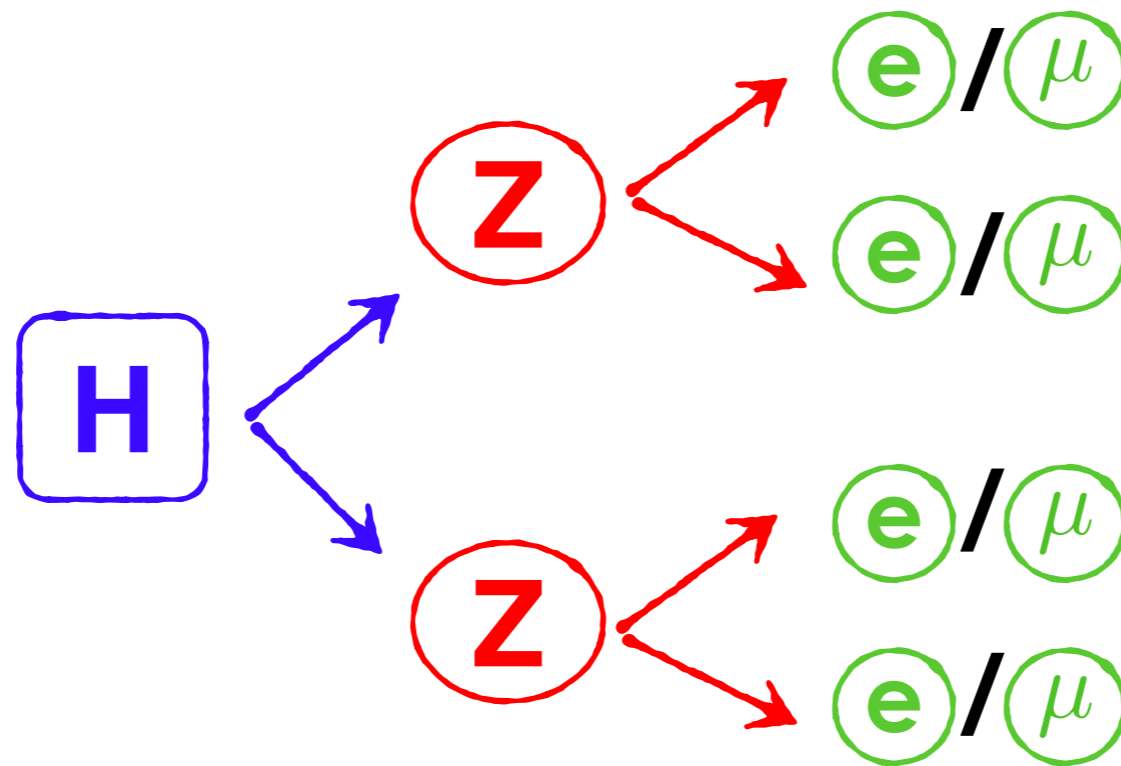
Many Resonances around!!

2.7 fb⁻¹ (13 TeV)



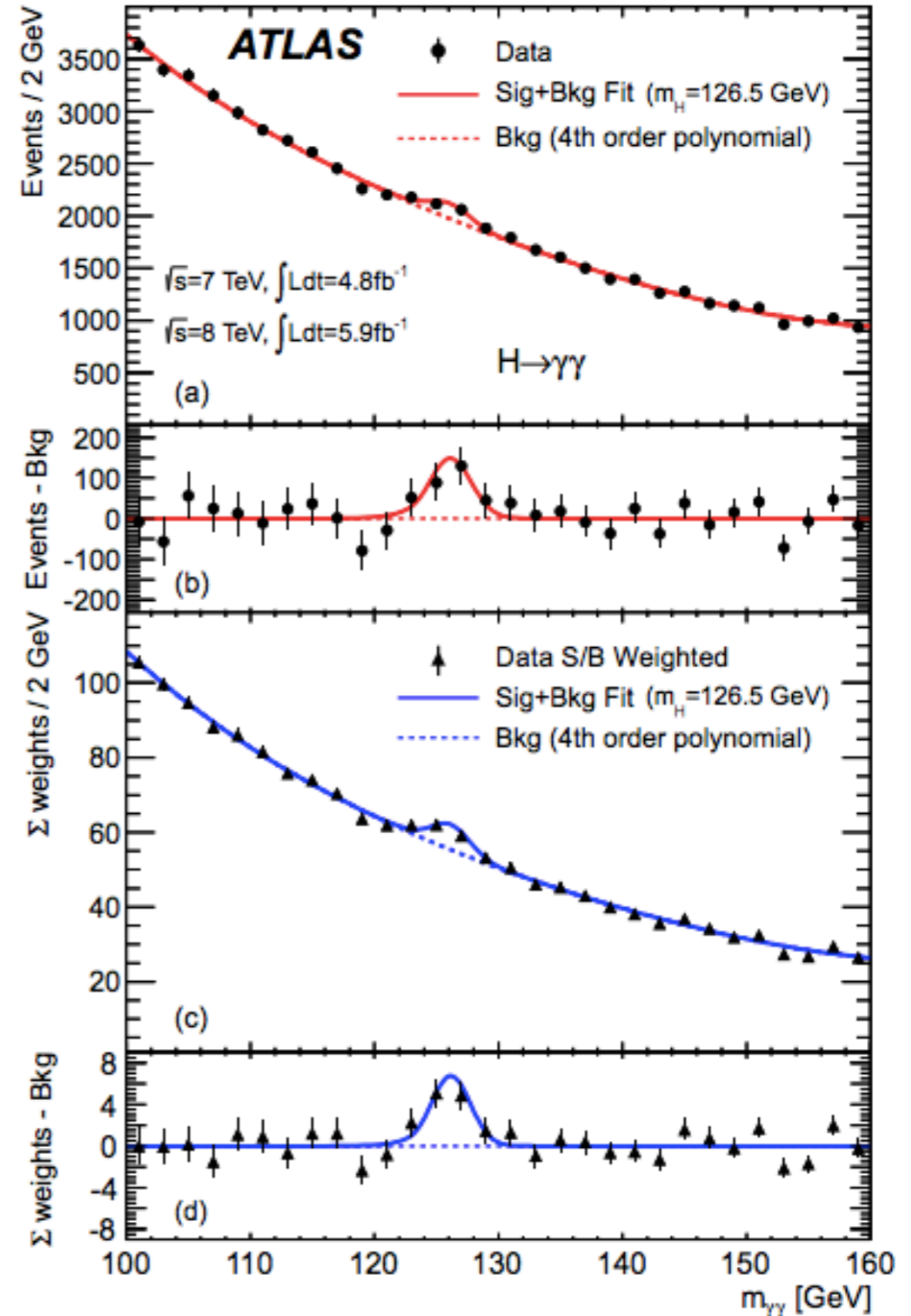
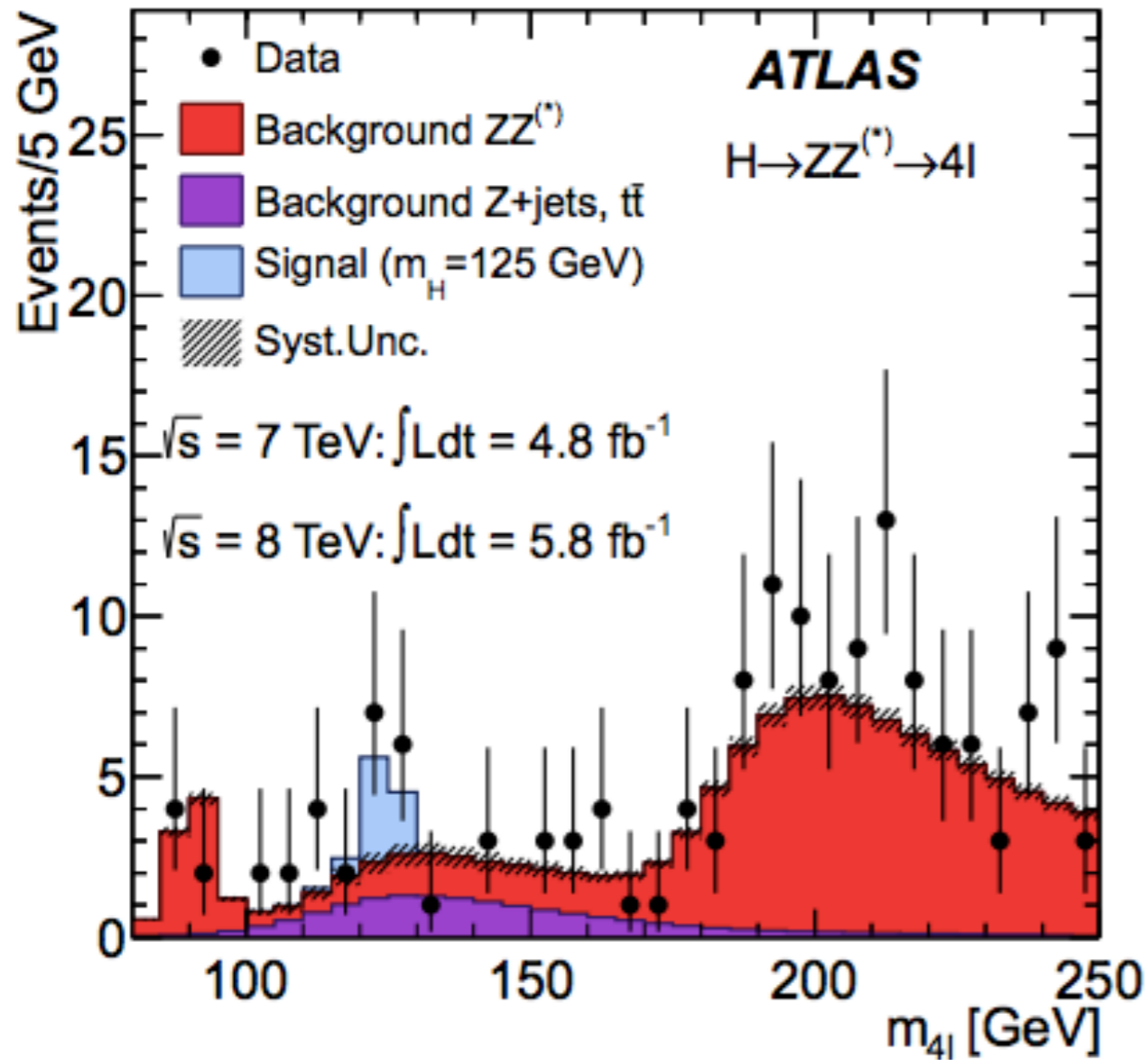
The Z boson and the Higgs discovery

- The discovery of the Z boson opened the opportunity to “use” the recently discovered particle for the quest of the Higgs boson:



- Either decays of the **Z** to **electrons or muons** are considered

The Higgs Discovery



Now it`s your turn!!

- **Today we will look at the REAL DATA collected by CMS at LHC and we will try to “RE-DISCOVER” the Z and the W bosons.**
- **We will learn how to work in team in data analysis and how to present our own results like in a major physics conference!**

iSpy tool - CMS events

Different planes views



The screenshot shows the iSpy tool interface for a CMS event. The top toolbar contains navigation and view control icons. On the left, a sidebar lists detector components with checkboxes and status icons. The main area displays a 3D visualization of the CMS detector with particle tracks. A 3D coordinate system is visible in the bottom left of the main area. The text 'Event display' is on the right. At the bottom, a table shows physics objects.

Detector components list:

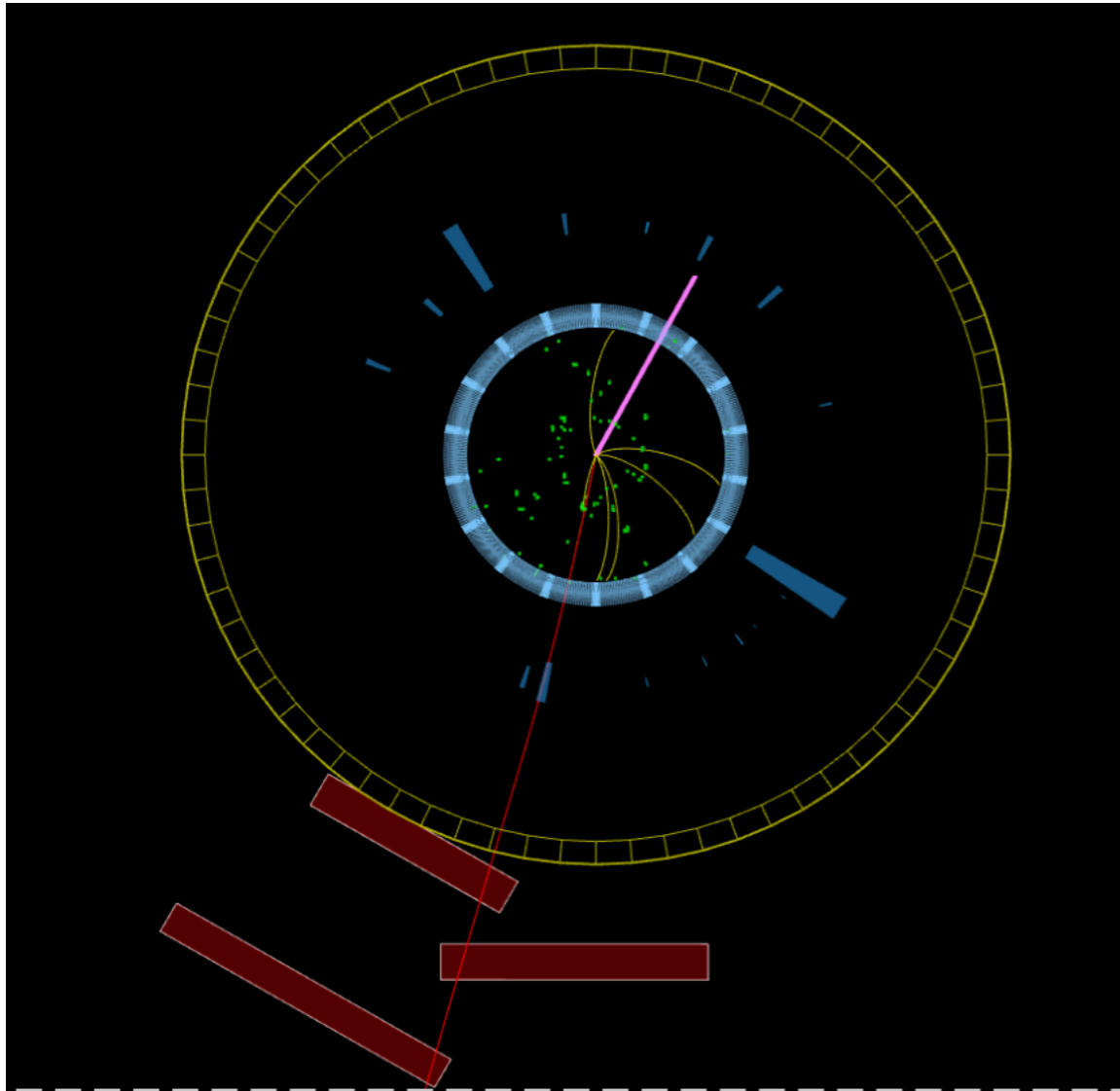
- Detector [Info]
- Imported [Info]
- Provenance [Info]
- Event [Checked]
- Tracking [Info]
- Tracks (reco.) [179] [Checked]
- ECAL [Info]
 - Barrel Rec. Hits [530] [Checked]
 - Preshower Rec. Hits [18] [Unchecked]
 - Endcap Rec. Hits [389] [Checked]
 - SuperClusters [7] [Unchecked]
- HCAL [Info]
 - Barrel Rec. Hits [50] [Checked]

Physics: Global Muons (Reco)

pt	charge	rp	phi	eta	calo_energy
17.226		0.000687702,0.00069938,-0.100233	0.344044	0.205445	0
126.97		0.000703579,0.000671055,-0.100225	2.0224	-0.887451	0

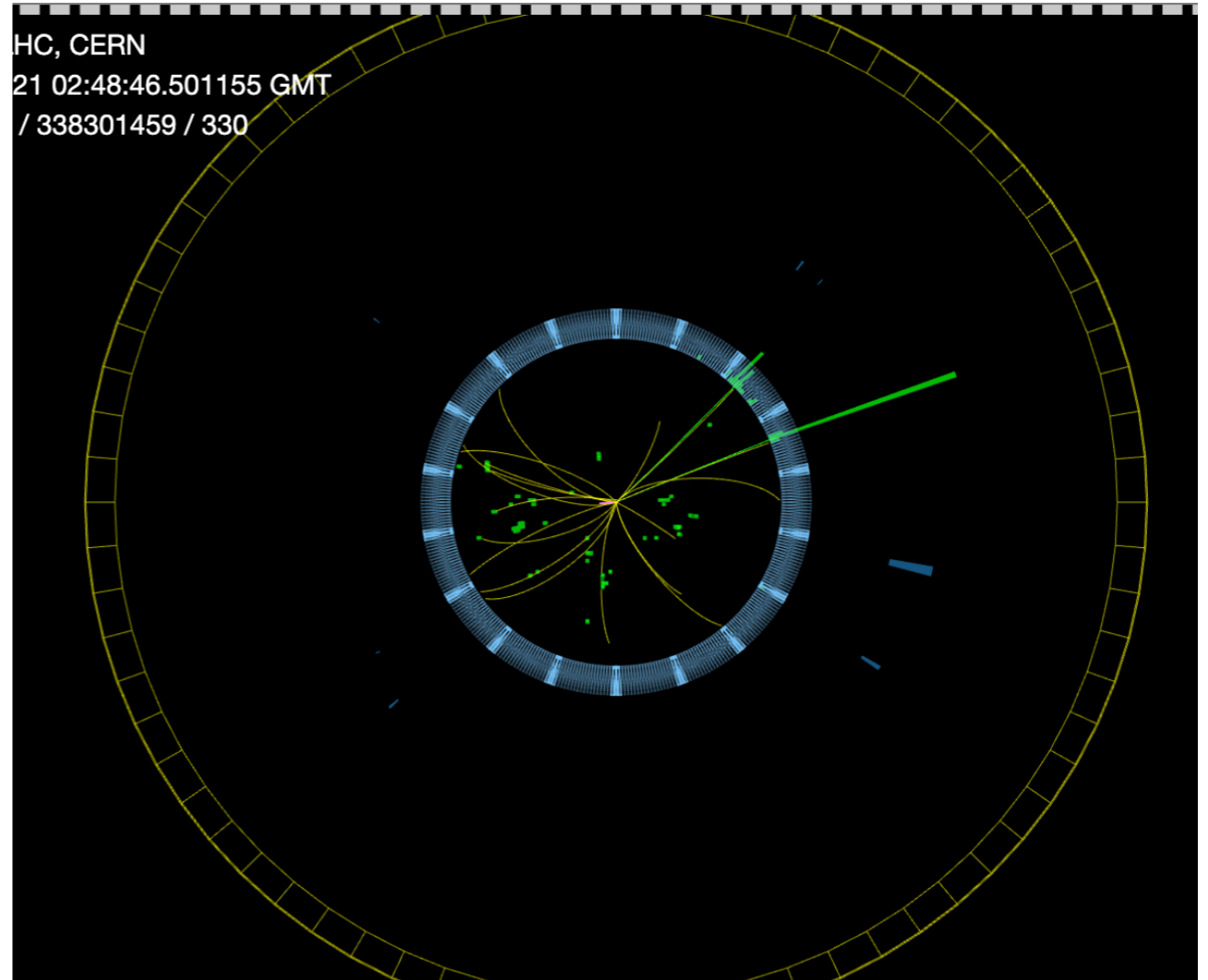
Subdetectors and physics objects visualization

Particles Identification



Muon

Neutrino



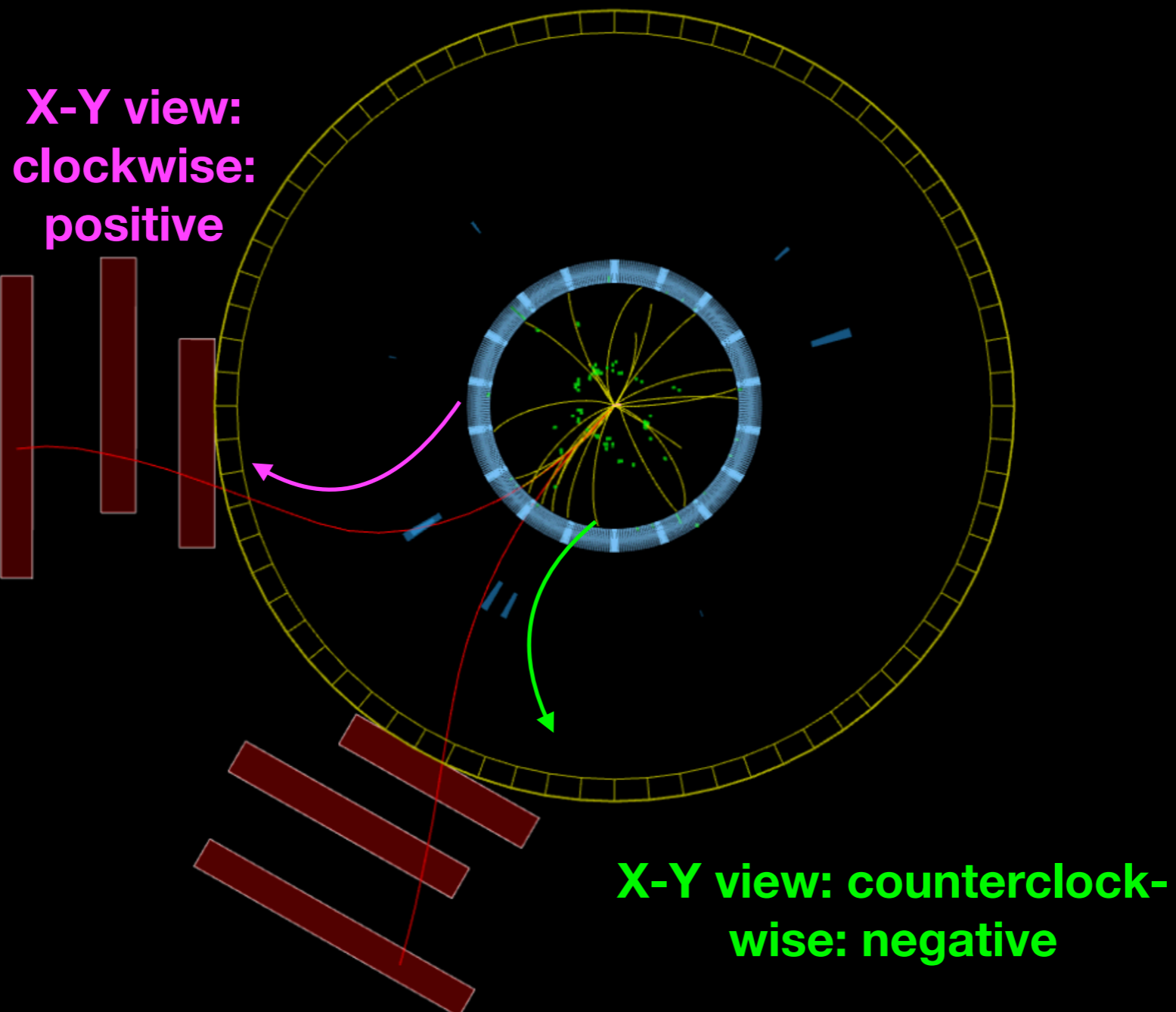
Electron

Charge Identification

the LHC, CERN

Apr-16 15:56:32.353841 GMT

909 / 39626565 / 93

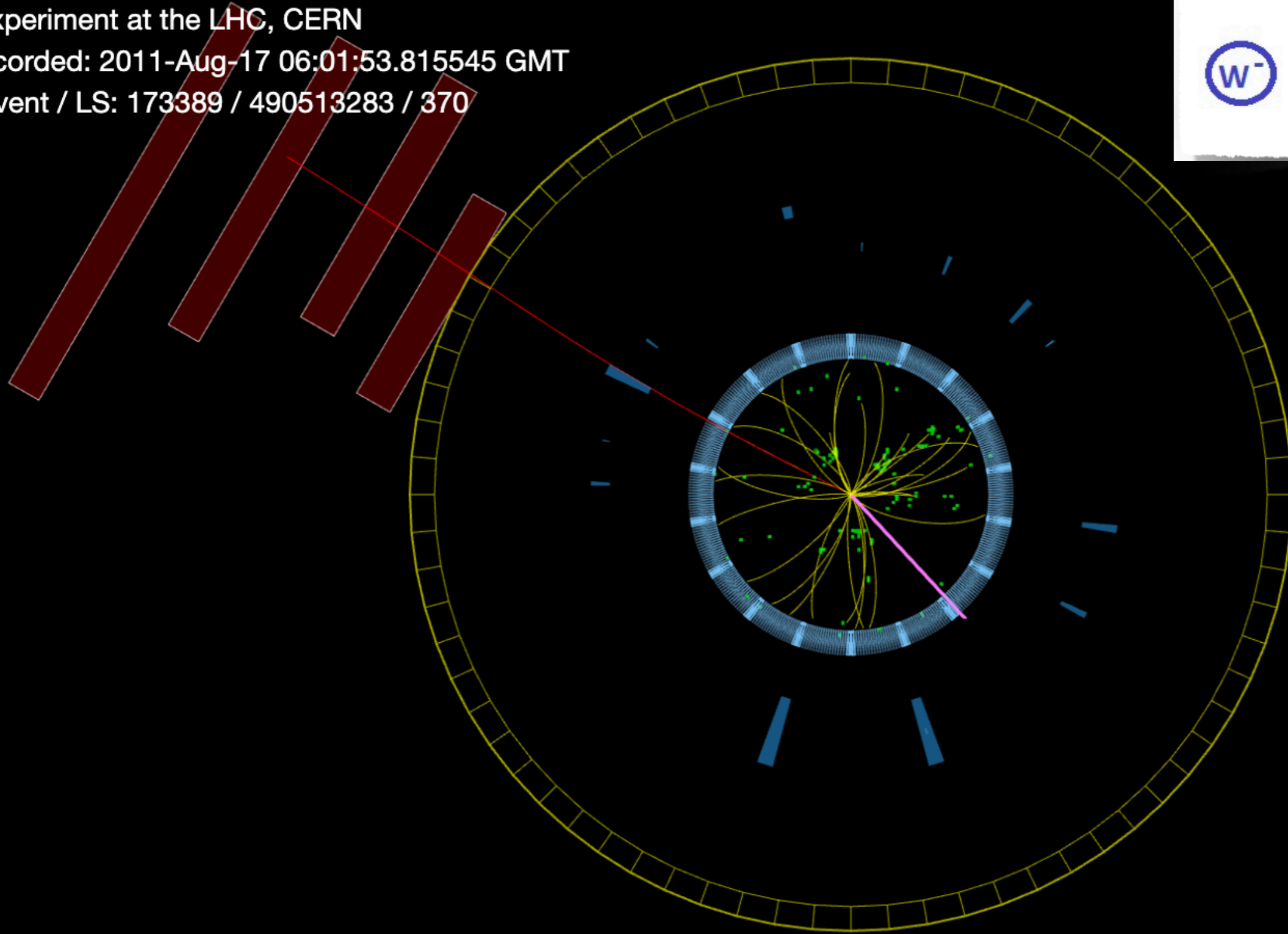
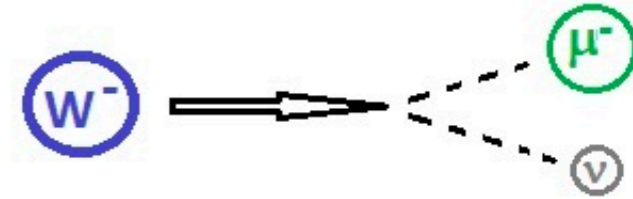


$W^- \rightarrow \mu^- + \nu$

Experiment at the LHC, CERN

Recorded: 2011-Aug-17 06:01:53.815545 GMT

Event / LS: 173389 / 490513283 / 370

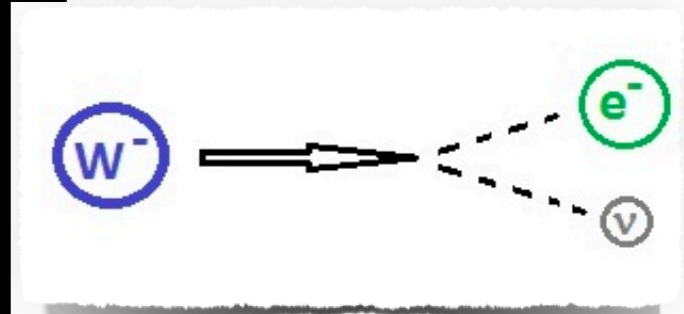
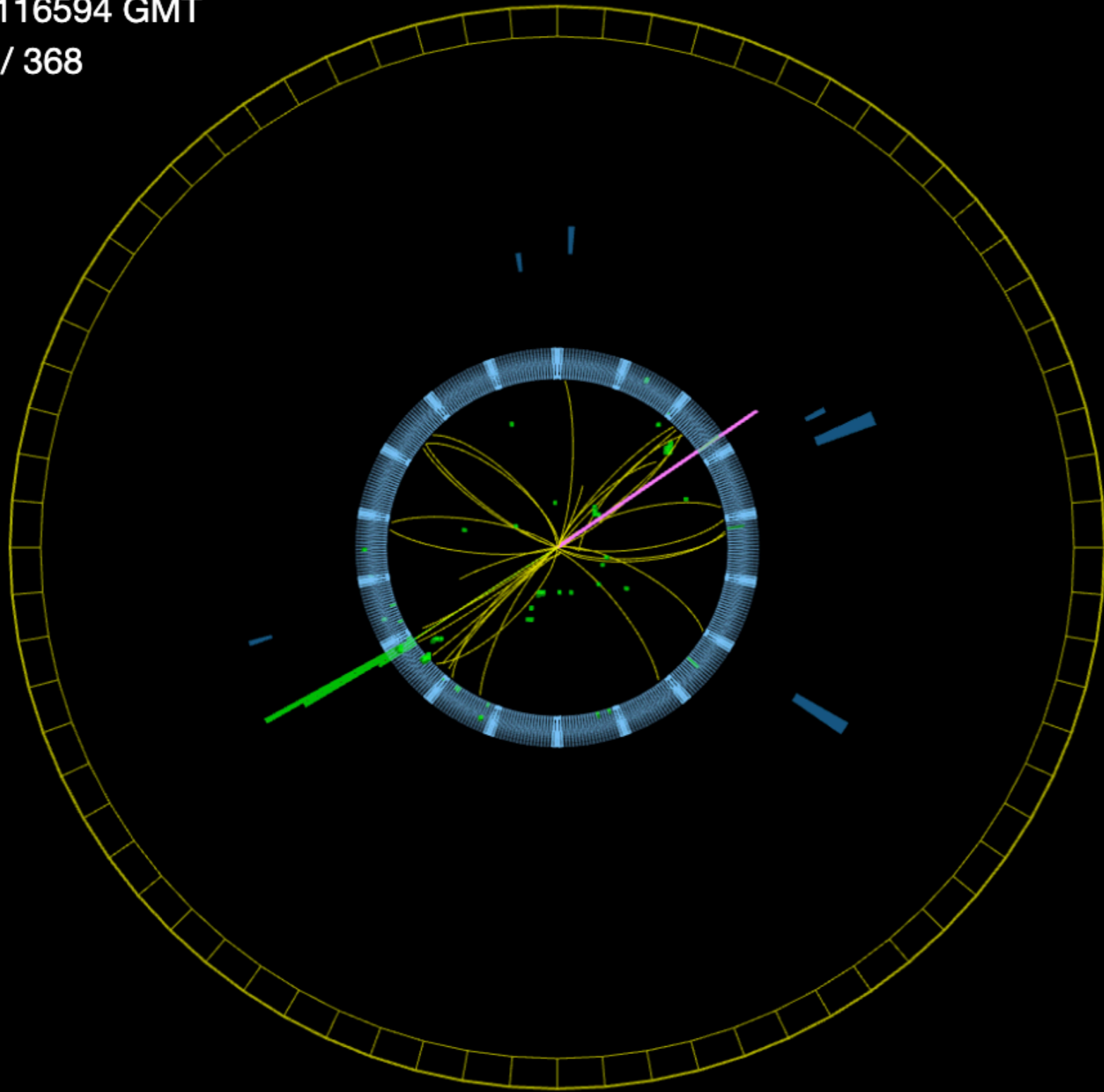


$W^- \rightarrow \text{elettrone} + \text{neutrino}$

N

:17.116594 GMT

602 / 368

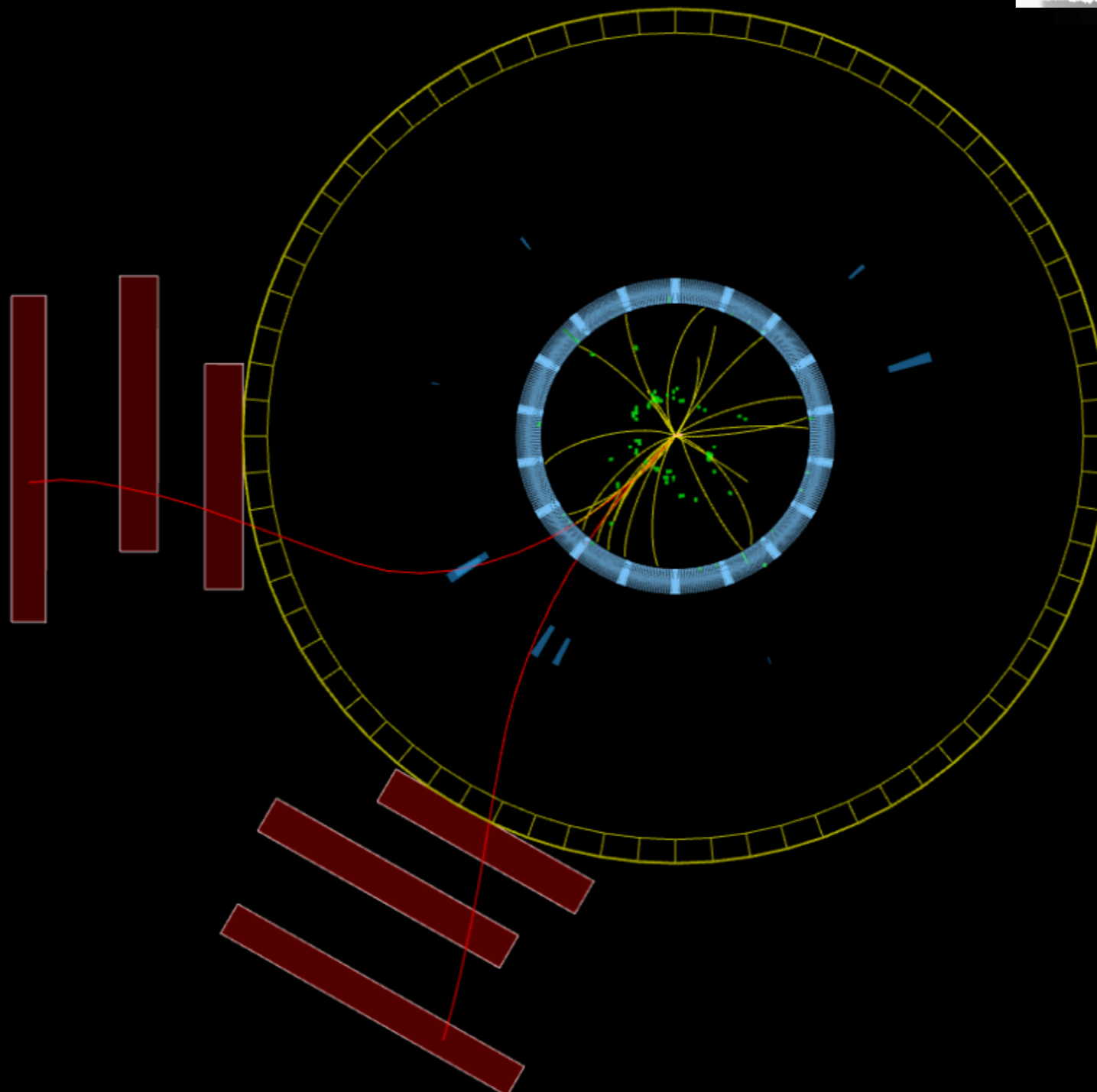
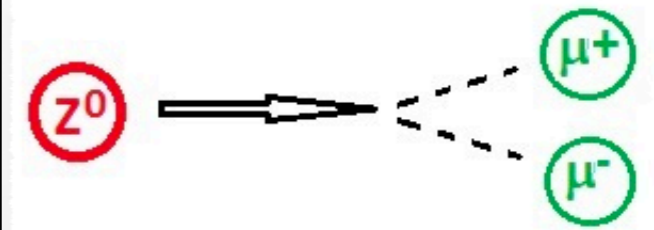


Z → muone + muone

the LHC, CERN

Apr-16 15:56:32.353841 GMT

909 / 39626565 / 93



Z → e⁺e⁻

C, CERN

02:48:46.501155 GMT

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