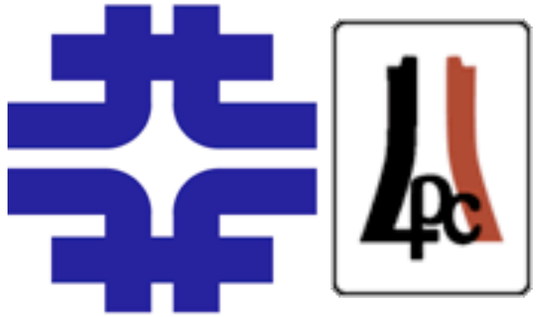
CMS and the Higgs boson

Jim Hirschauer
Fermilab



TRAC meeting
25 June 2015

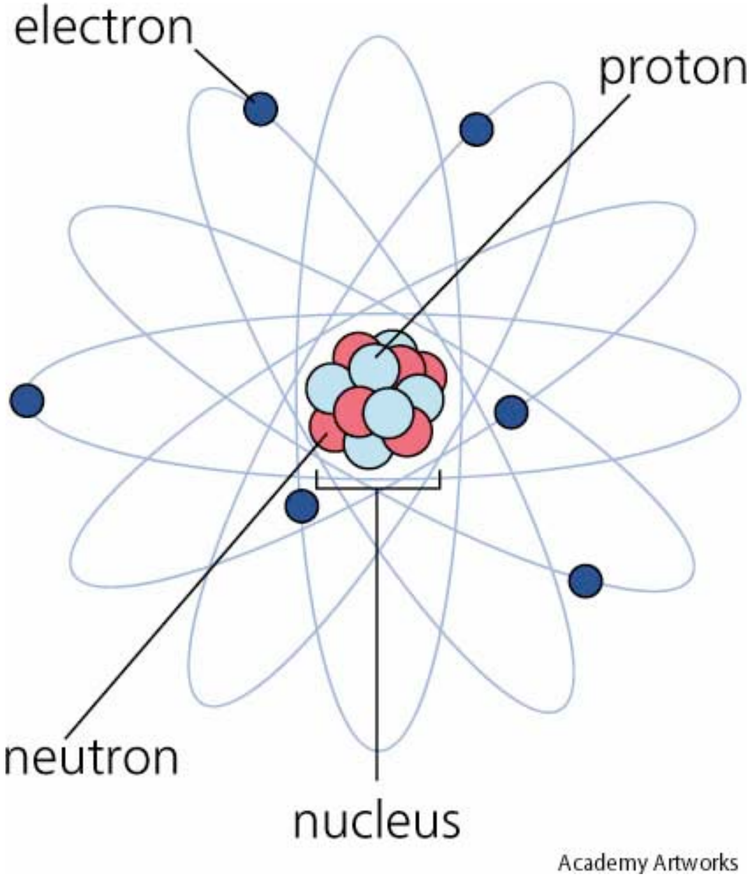
What are particles?

Electrons, **protons**, and **neutrons** make up the matter we experience daily.

Protons and **neutrons** are made up of smaller particles called **quarks**.

Our current theories describe **particles** as excitations of a corresponding **“field”**.

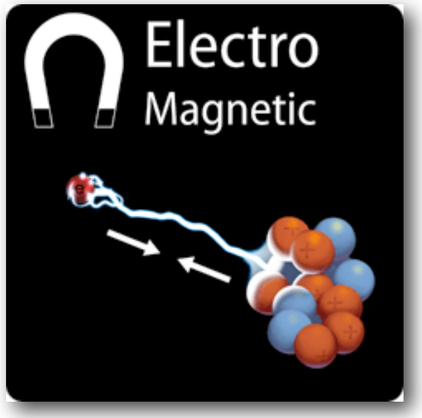
Carbon Atom



What are the four forces?

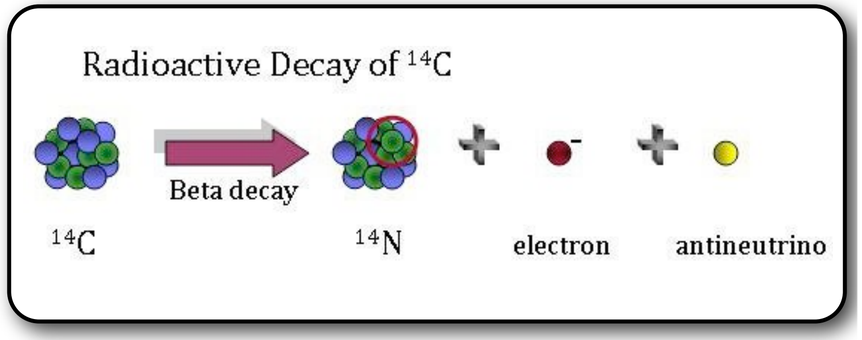
1) **Electromagnetic force** binds electron+nucleus.

Exchange of **photons** -- particles of light.



2) **Weak nuclear force** causes nuclear decay.

Exchange of **W bosons**.



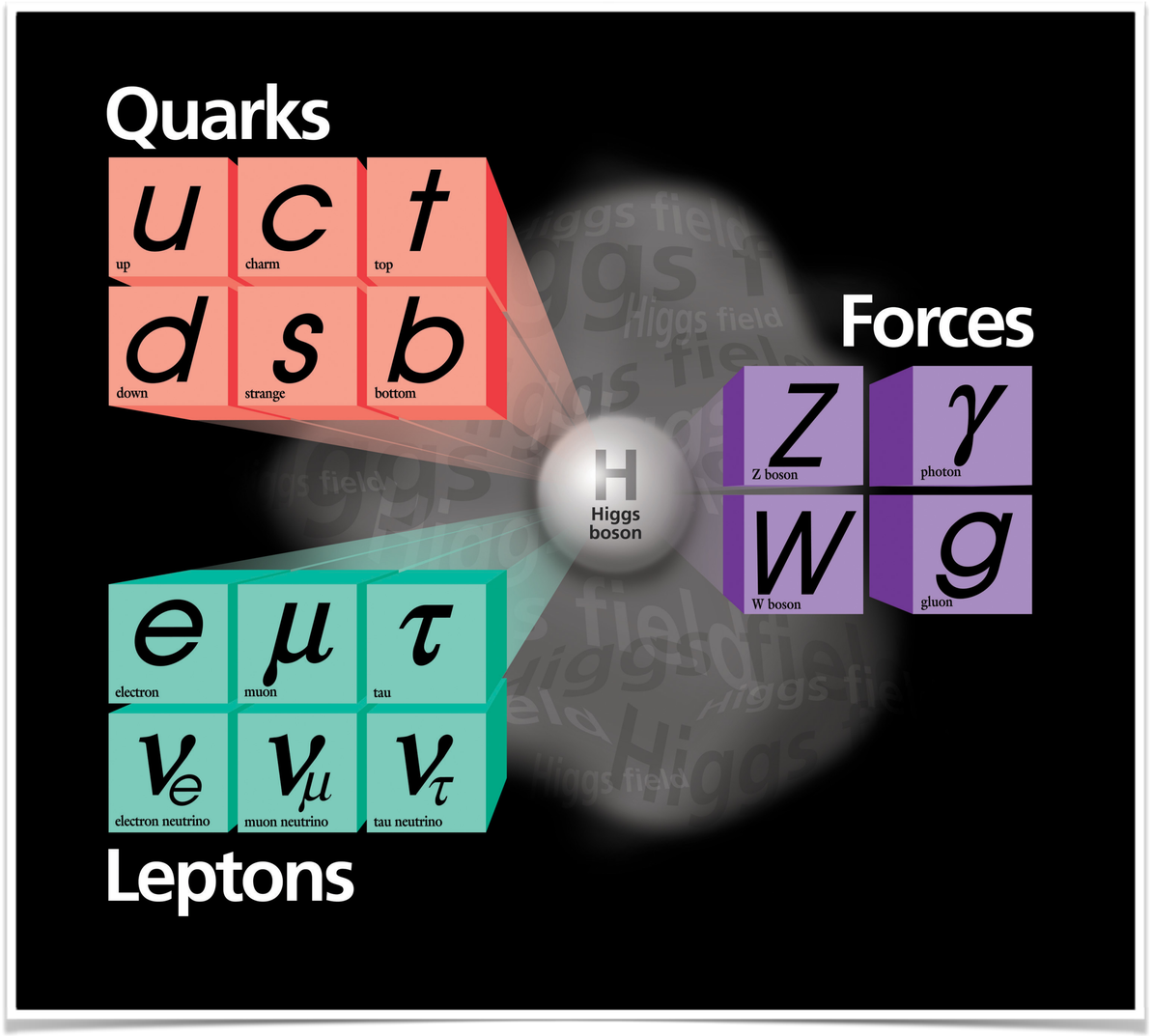
3) **Strong nuclear force** binds quarks in the nucleus.

4) **Gravitation** binds planets, stars, galaxies, etc.

All the particles we know about

- **Up** and **down** quarks make up protons and neutrons.

- **electron** surrounds the nucleus.
- **muon** is heavy “cousin” of electron.



- **W and Z** both “carry” weak force
- **gluon** carries strong force

Particle mass

Mass of **W boson** = Mass of **80 protons** = Mass of **15,000 electrons**

The **photon** and the **W boson** both “carry” forces.

Why is the **W boson** very heavy and the **photon** massless?

Mass of **photon = 0**

(It zips around at the speed of light, and won’t even sit in the scale!)

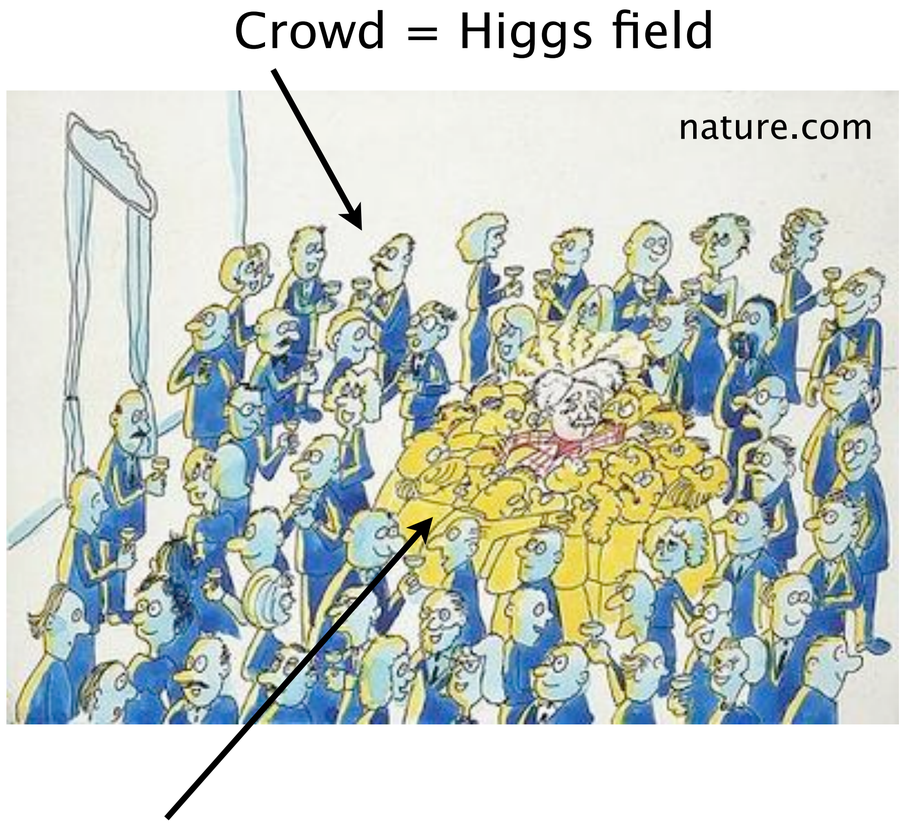
The Higgs field gives mass to particles.

The universe is filled with the **Higgs field**.

Heavy particles (W) interact strongly with the Higgs field.

Light particles (e) interact weakly with the Higgs field.

Massless particles (**photon**, **γ**) do NOT interact with the Higgs field.



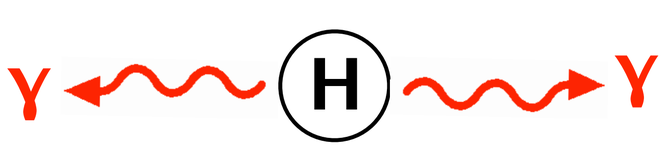
The **Higgs boson** is a vibration of the **Higgs field**.

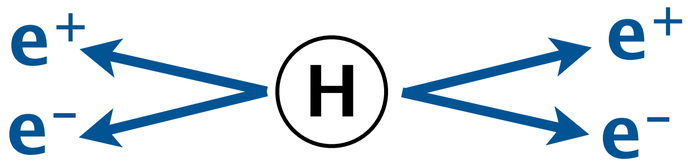
How do we “see” the Higgs boson?

Higgs bosons are created in **proton collisions** – only 1 Higgs boson every several billion collisions.

The Higgs boson is unstable and **immediately decays** to other particles.

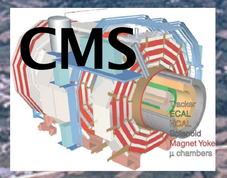
Sometimes the Higgs boson decays to **2 photons**, other times it decays to **4 electrons**.





We look at ALL the **2-photon** and **4-electron** combinations in our data to see if anything looks interesting.

Large Hadron Collider



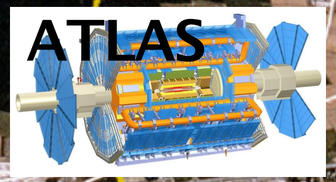
Lake Geneva

LHC

SPS

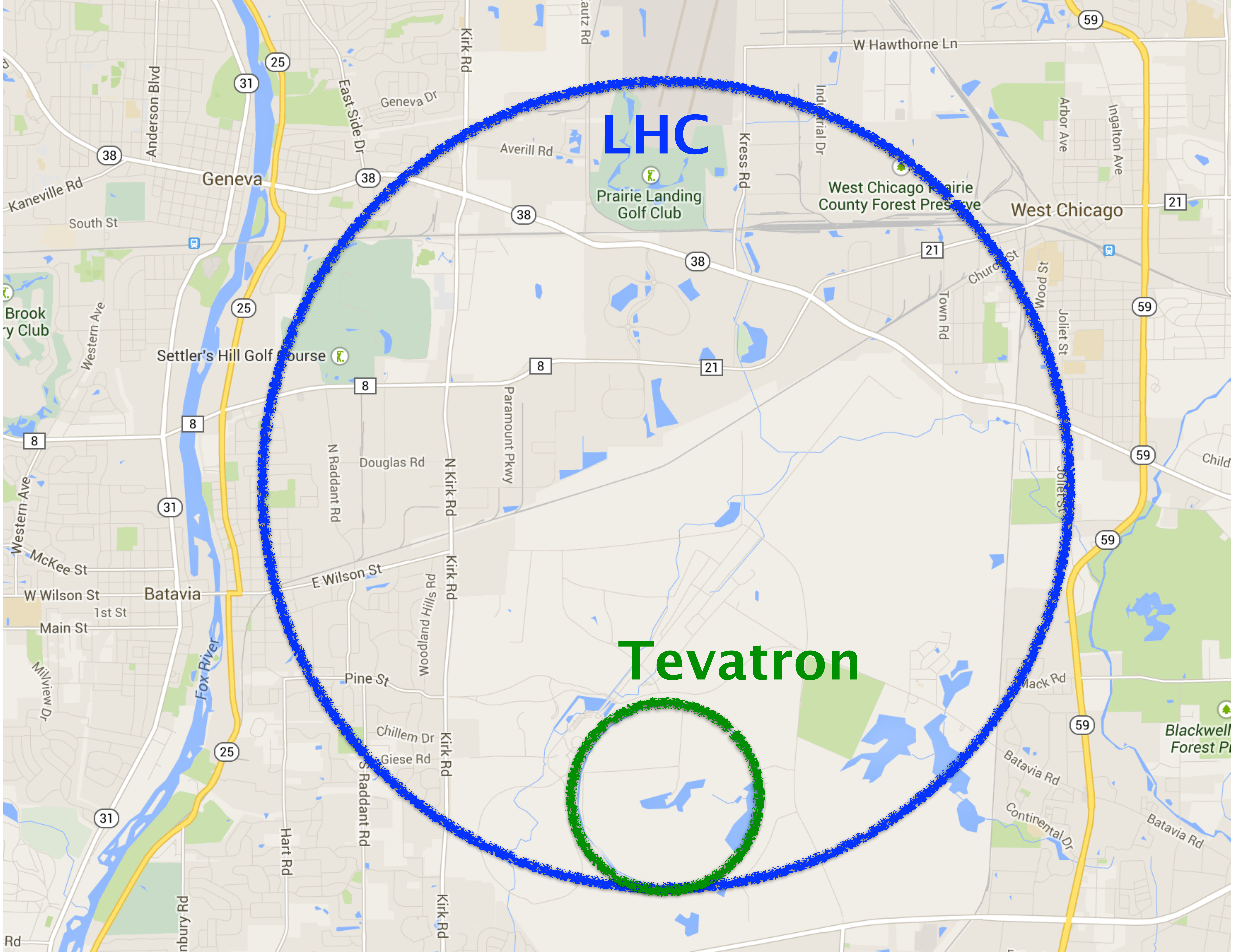
LHCb

ALICE



Center-of-mass energy	7-14 TeV
Proton bunches / beam	~3500
Protons / bunch	~1.5 x 10^{11}
Bunch crossing frequency	40 MHz
Proton collisions / bunch crossing	~40

Particle	Rate
Top quark	600/minute
Higgs boson	30/minute
Dark matter	?


LHC
Tevatron
Geneva
Batavia
West Chicago
Prairie Landing Golf Club
West Chicago Prairie County Forest Preserve
Settler's Hill Golf Course
Fox River
Kaneville Rd
South St
Anderson Blvd
East Side Dr
Geneva Dr
Kirk Rd
N Kirk Rd
Averill Rd
Kress Rd
W Hawthorne Ln
Arbor Ave
Ingalton Ave
Church St
Wood St
Town Rd
Joliet St
Western Ave
Douglas Rd
N Raddant Rd
S Raddant Rd
Paramount Pkwy
E Wilson St
W Wilson St
McKee St
1st St
Main St
Woodland Hills Rd
Pine St
Chillem Dr
Giese Rd
Hart Rd
Mack Rd
Batavia Rd
Continental Dr
Blackwell Forest Pr
Brook
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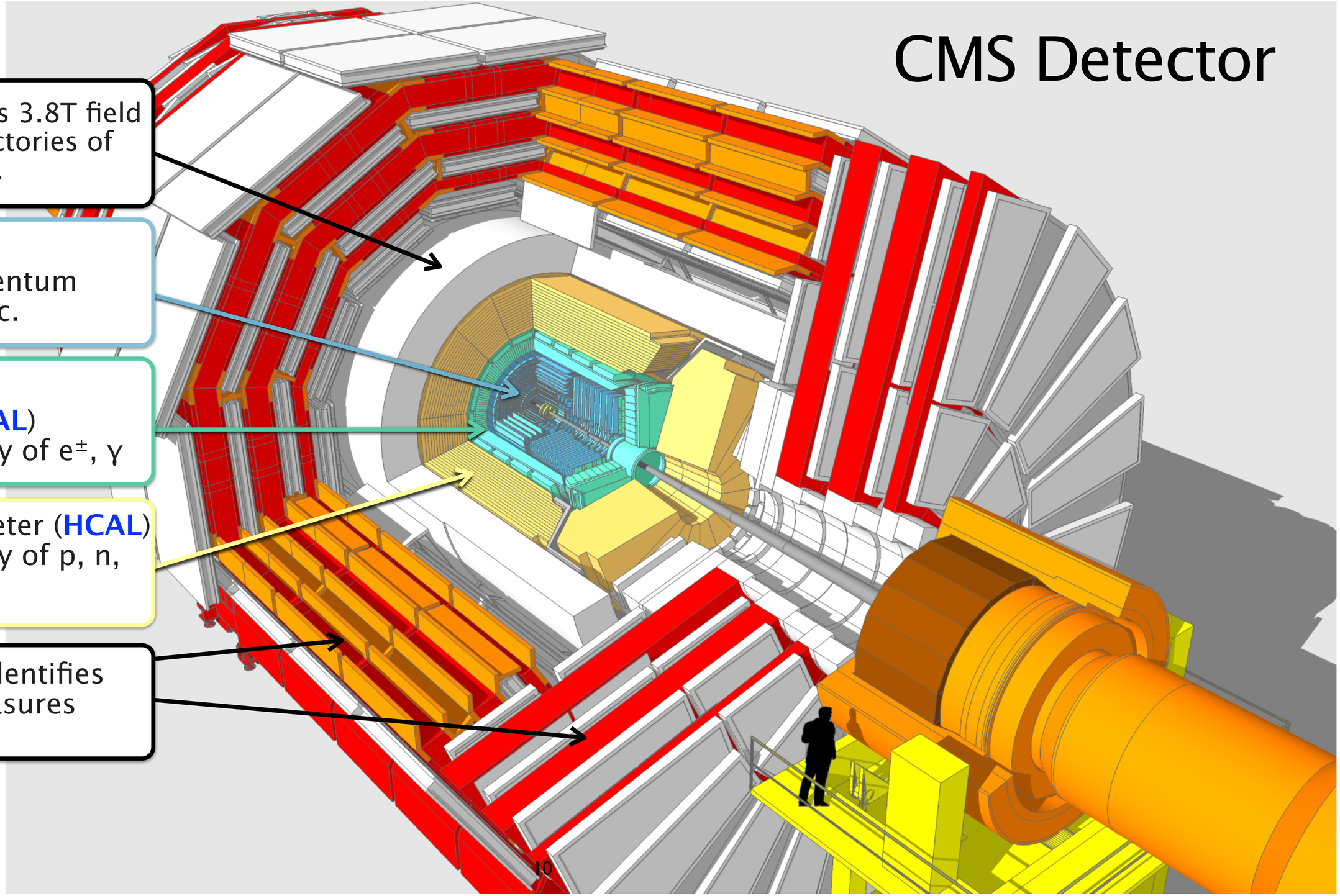
Child
Millview Dr
25
31
38
8
21
59

CMS Detector



Solenoid provides 3.8T field for bending trajectories of charged particles.

Silicon **tracker** measures momentum of $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, etc.

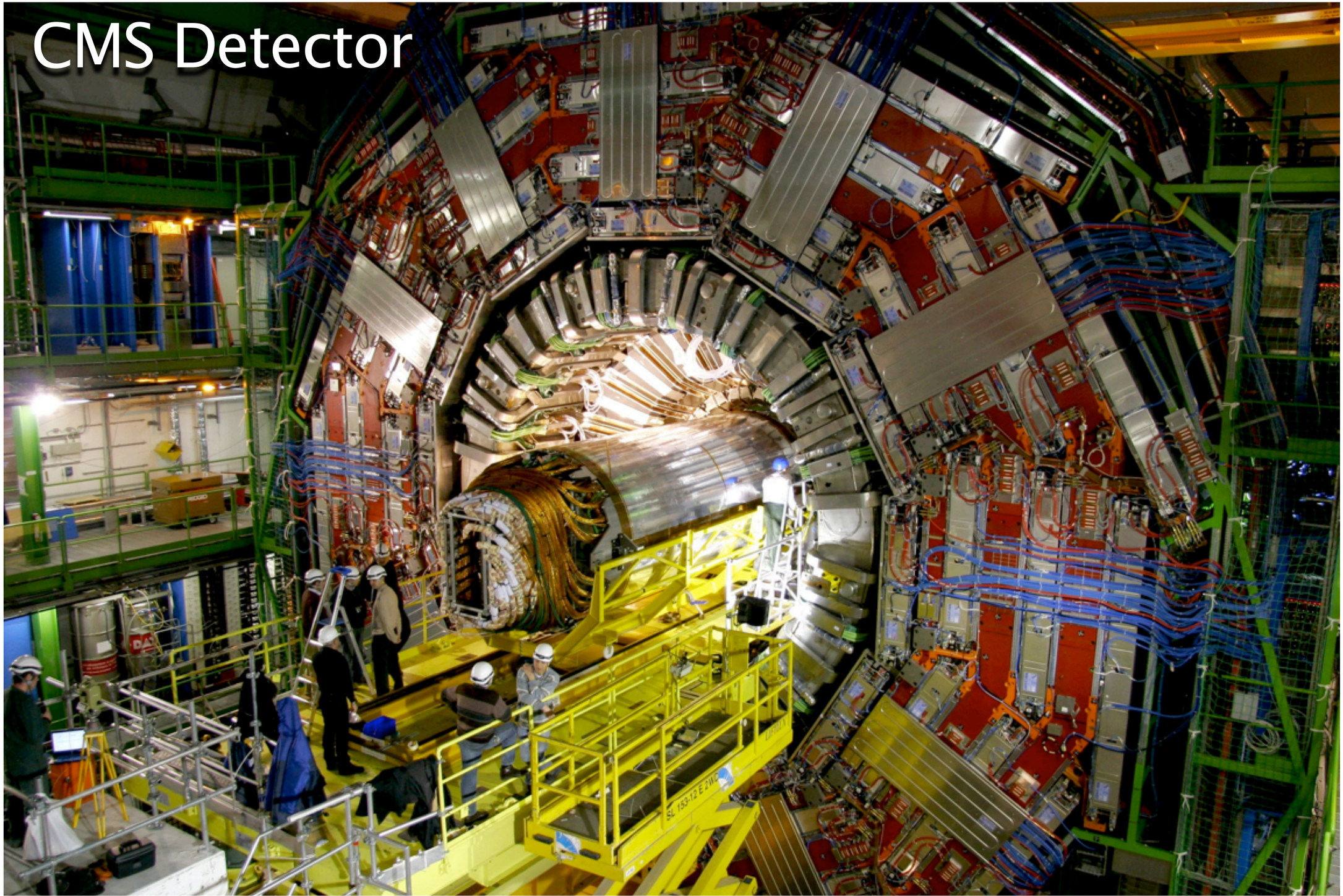
Electromagnetic calorimeter (**ECAL**) measures energy of $e^{\pm}$, γ

Hadron calorimeter (**HCAL**) measures energy of p, n, π, etc.

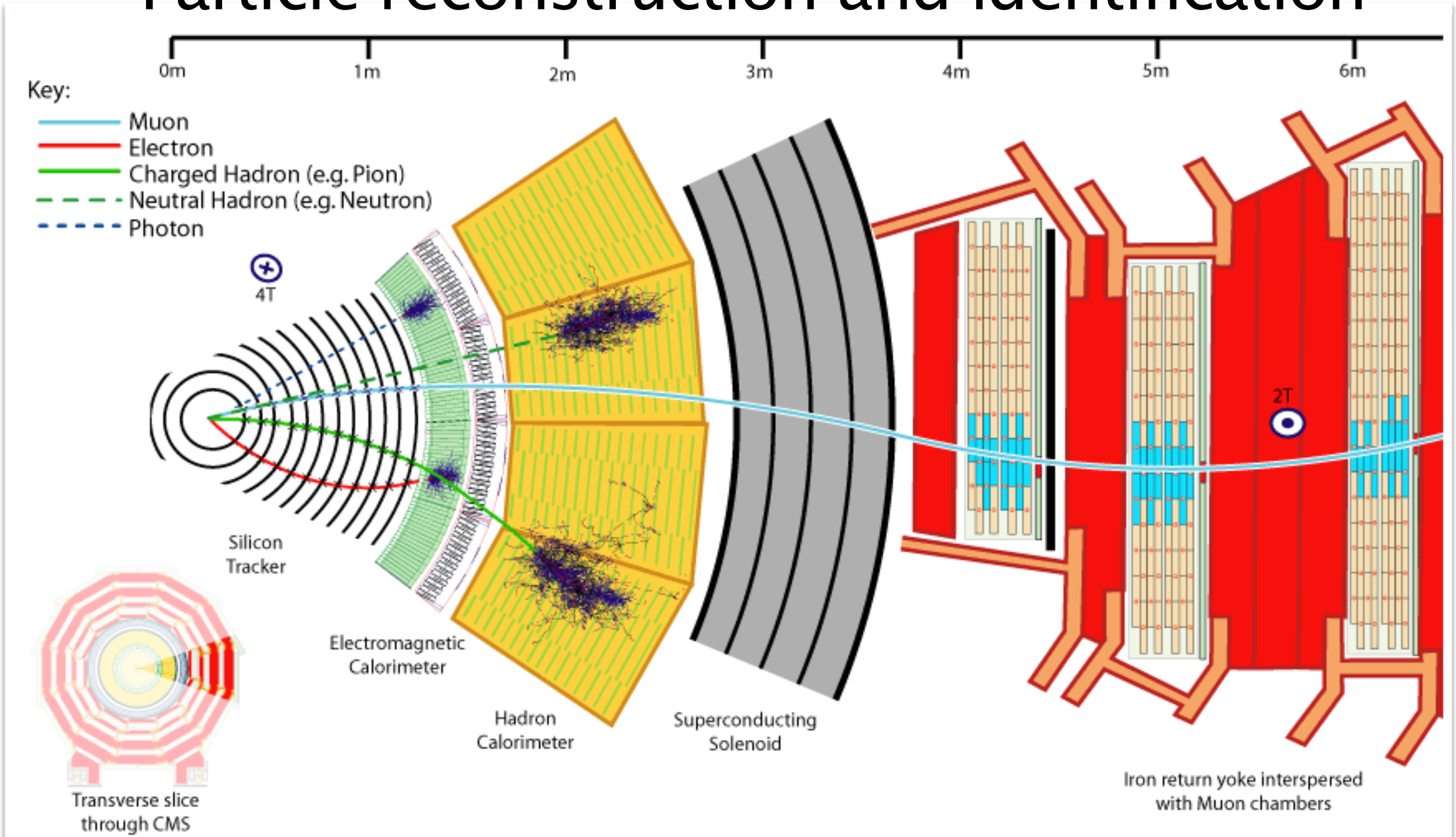
Muon system identifies muons and measures their momenta.


CMS Detector

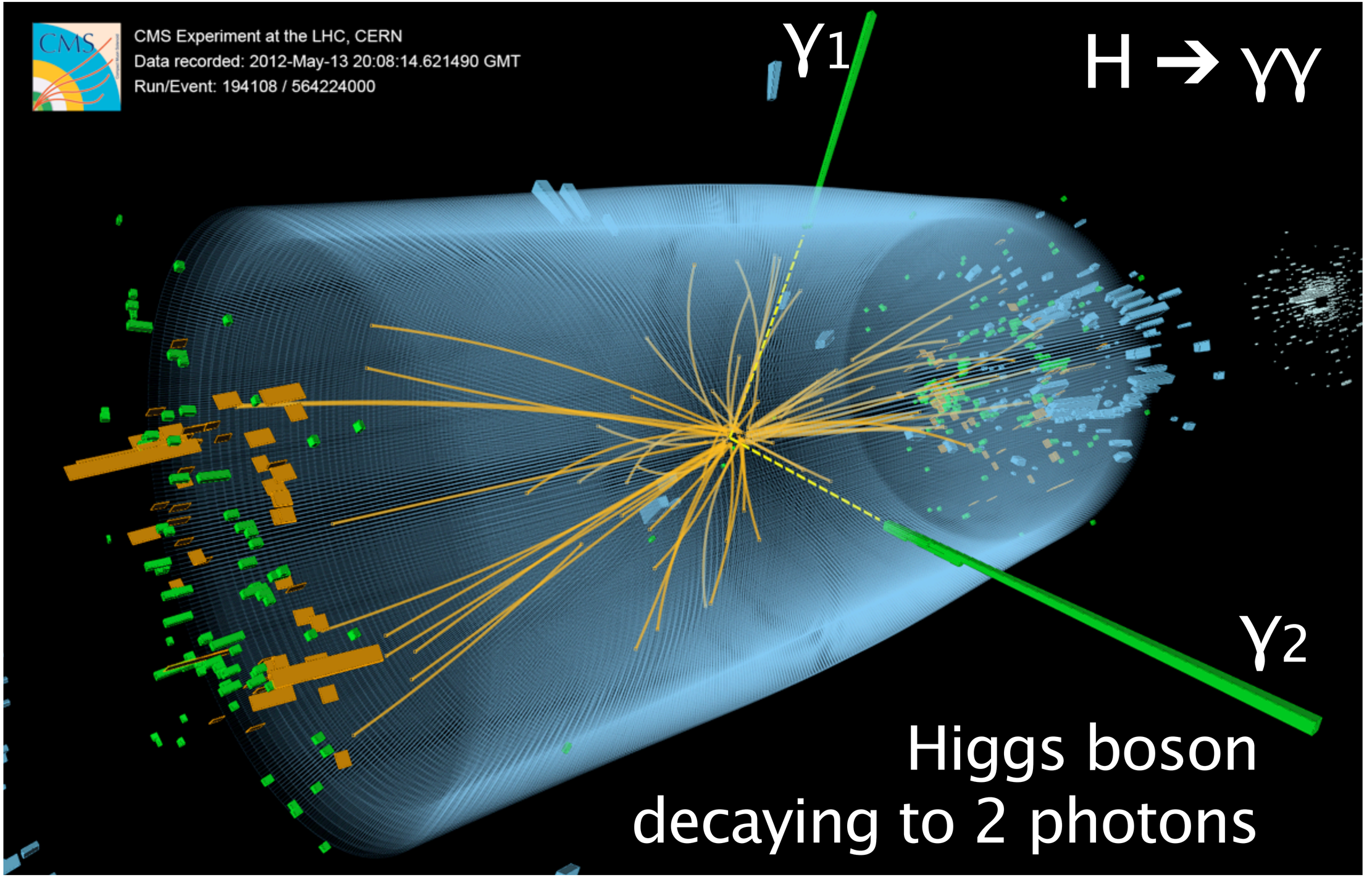
CMS Detector



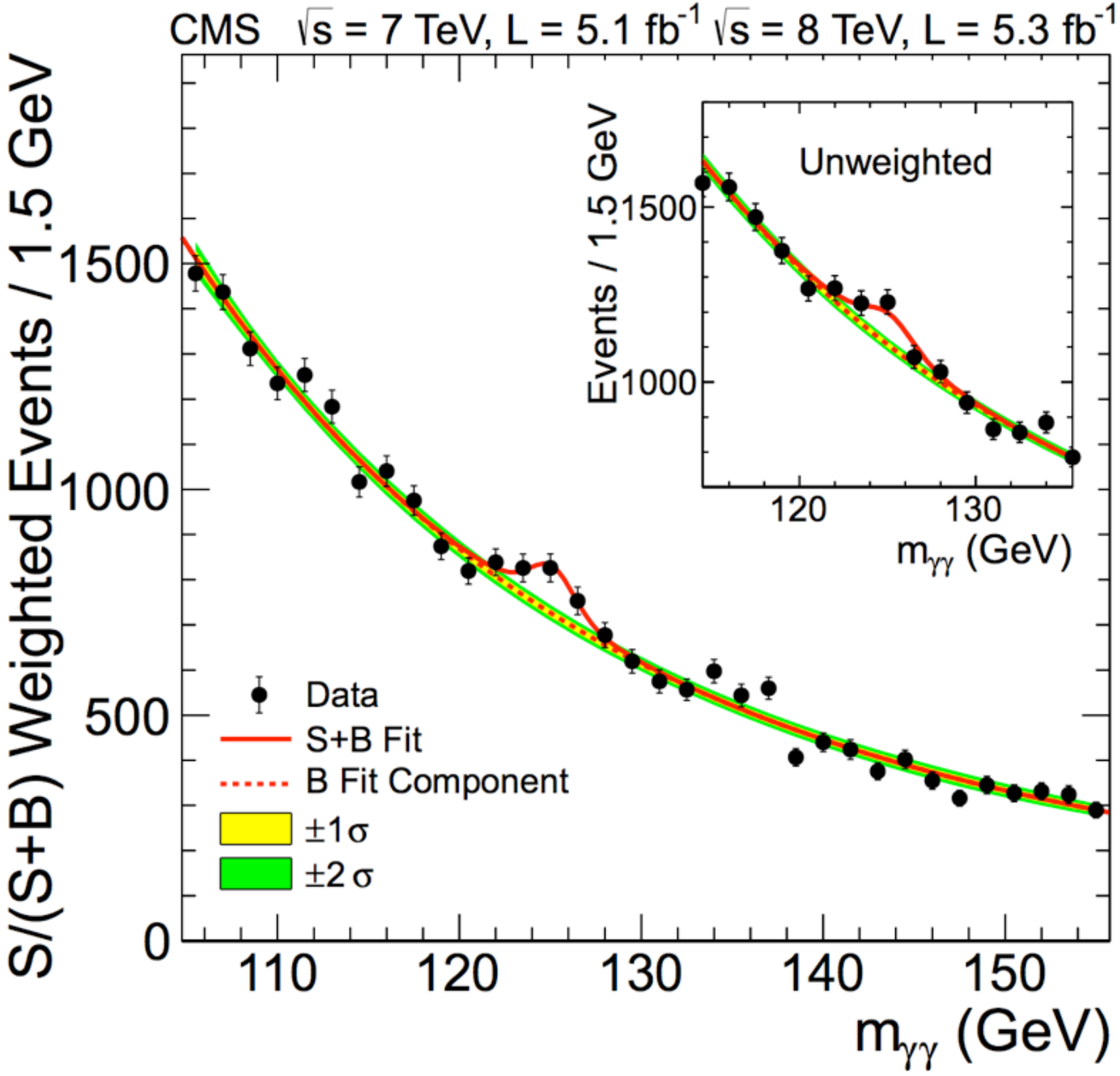
Particle reconstruction and identification



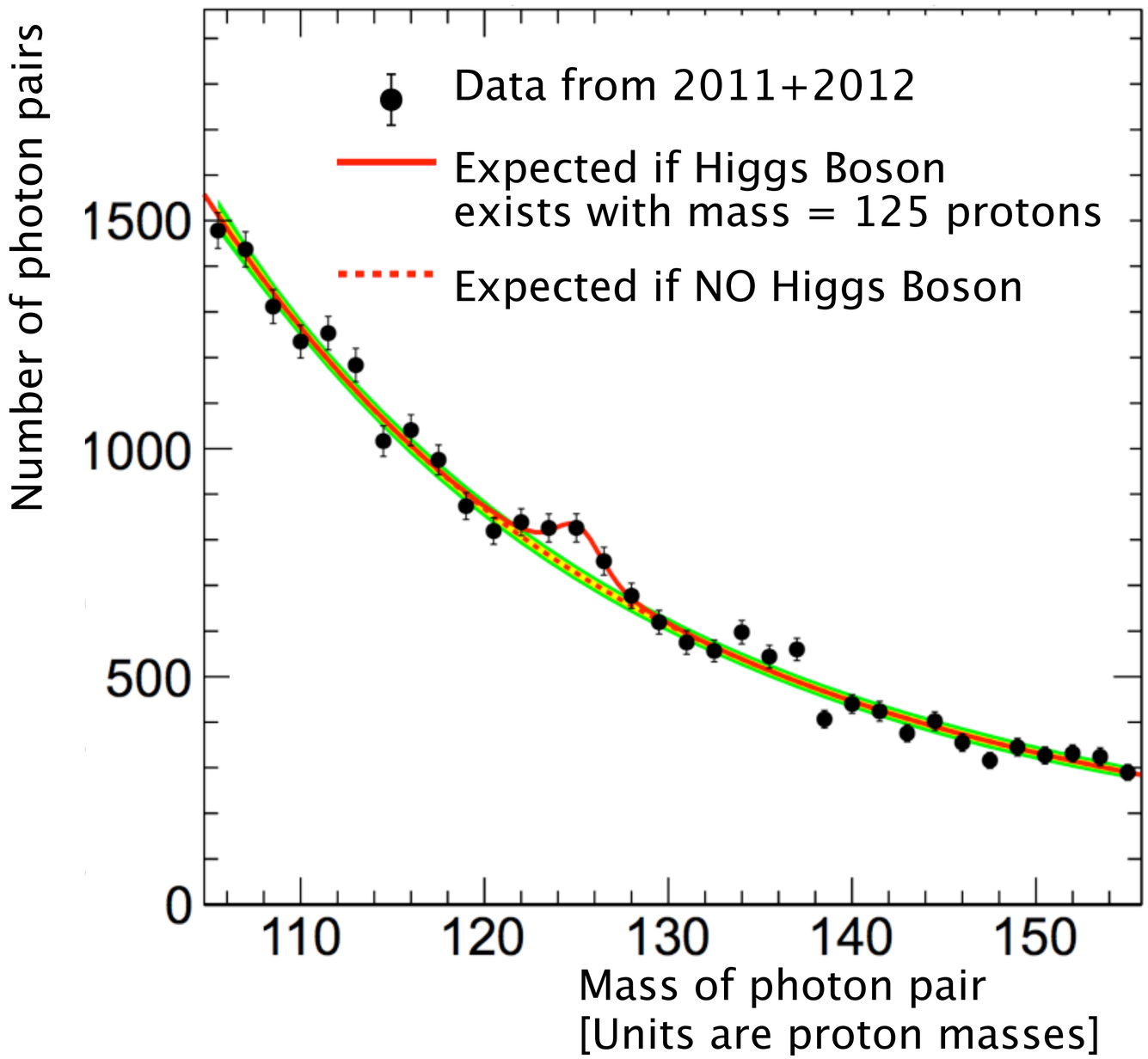

CMS
E
CMS Experiment at LHC, CERN
Data recorded: Mon May 28 01:16:20 2012 CEST
Run/Event: 195099 / 35488125
Lumi section: 65
Orbit/Crossing: 16992111 / 2295
Pile–up


CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
γ1
H → γγ
γ2
Higgs boson
decaying to 2 photons

Masses of all pairs of photons in data



Masses of all pairs of photons in data



Masses of all 4-electron groups