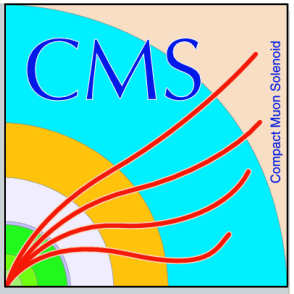

Introduction To CMS

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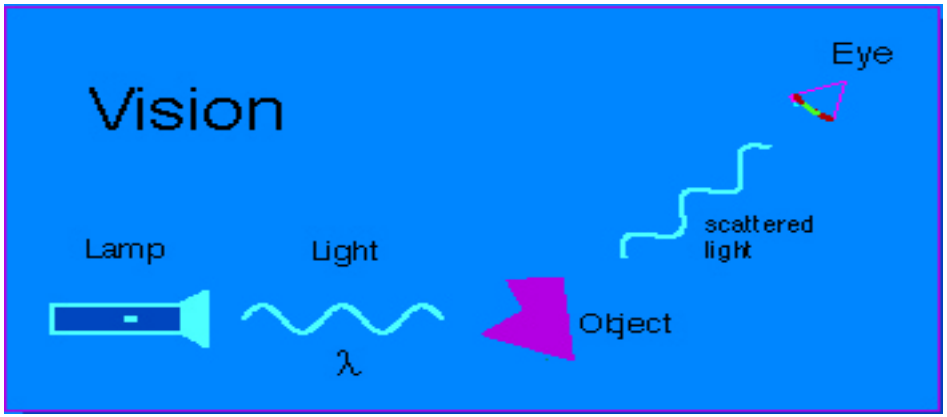
How small you can resolve?

- What limits the size of the smallest thing you can see in a microscope is diffraction
  - You cannot see things smaller than ~ half length of the light wave, about 200 nm = 0.2 micrometers



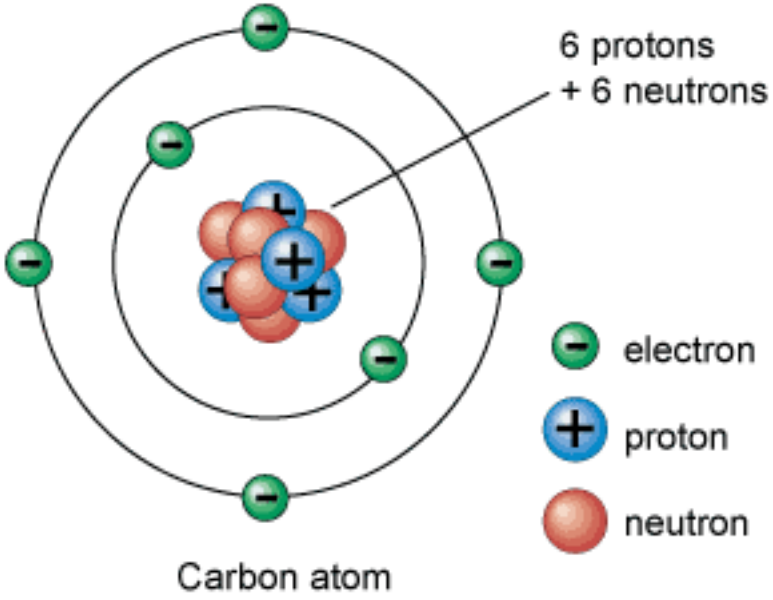
- You need different tools to probe really small things in Nature

How small you can resolve?

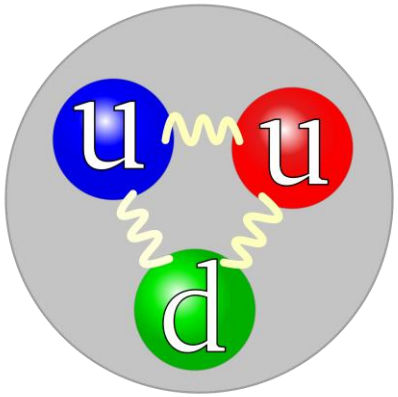
- Wait a second… instead of light we used particles to look at microscopic things!
- Quantum mechanics: all matter can exhibit wave-like behavior
  - The wavelength is inversely proportional to momentum of the particle
  - By increasing the energy of your probing beam, you can resolve the smallest things!

  - The higher the energy of the particle – the smaller the wavelength and therefore, the smaller dimensions we can explore!

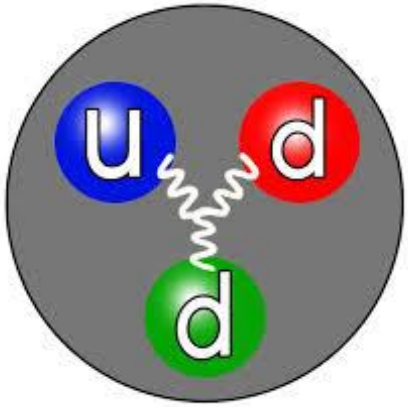
Atom



Proton

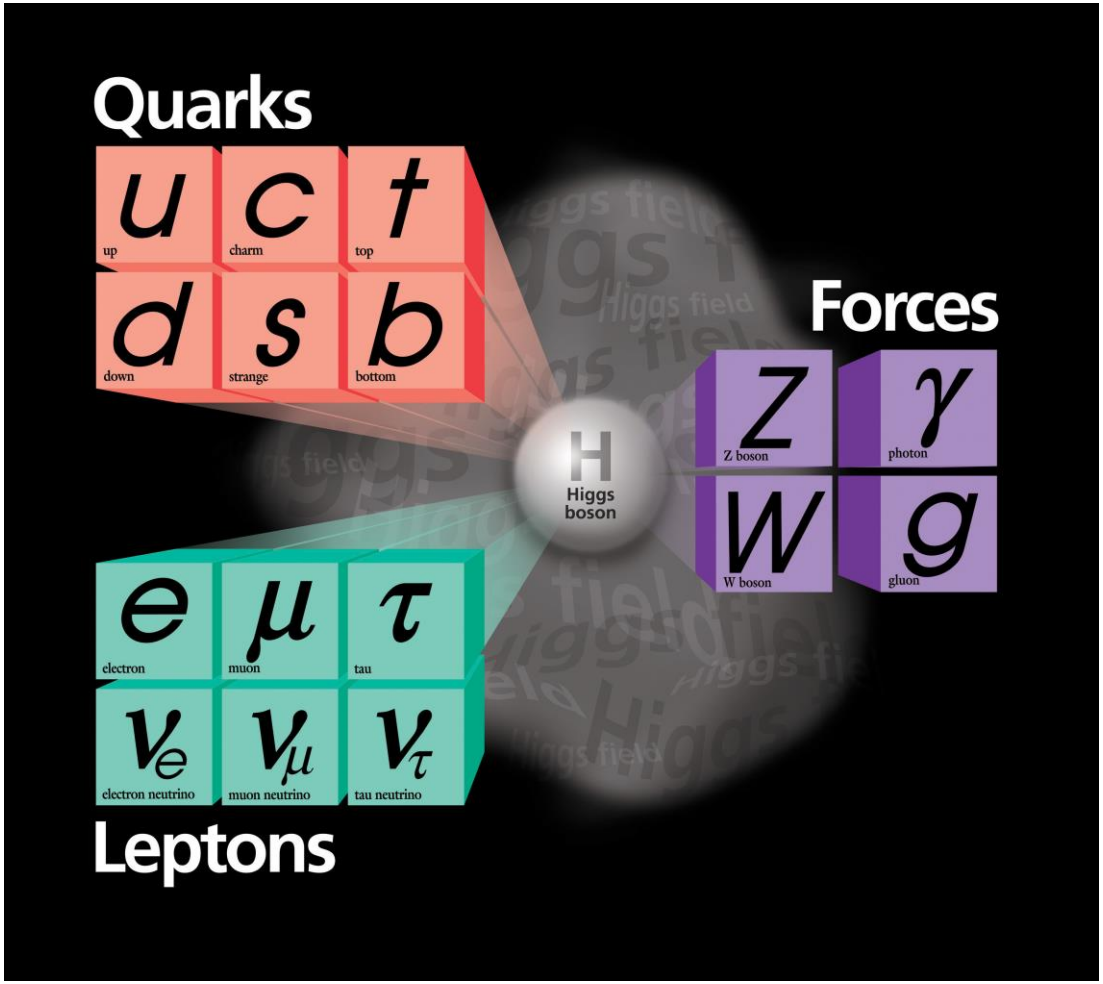


Neutron



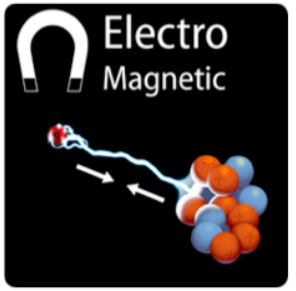
The Standard Model

- Describes elementary particles and their interactions



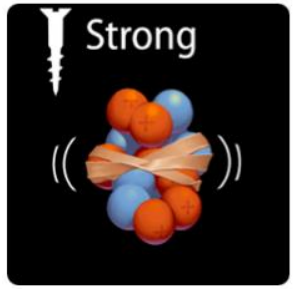
Interactions

Photon

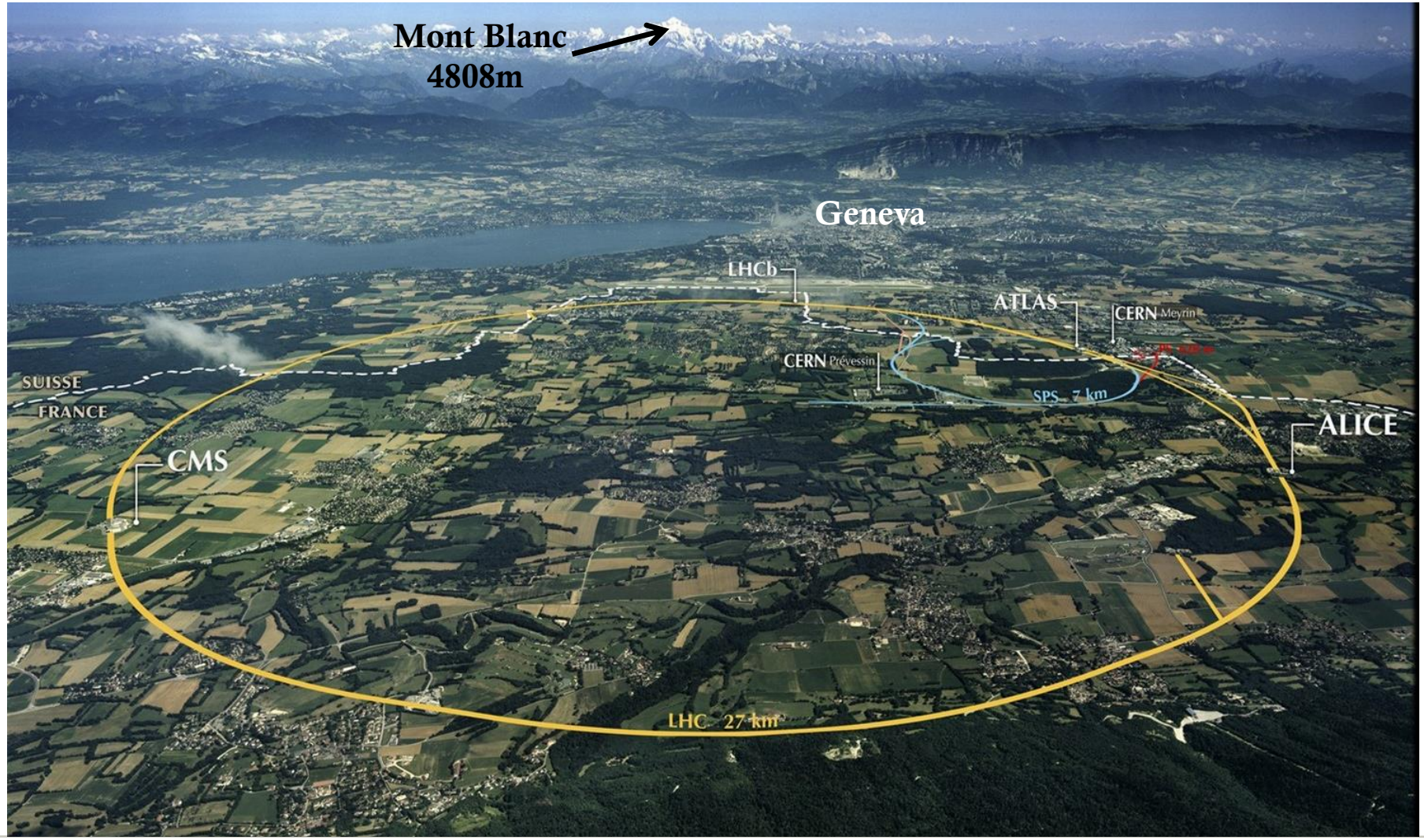


$W^{\pm}/Z^{0}$ bosons

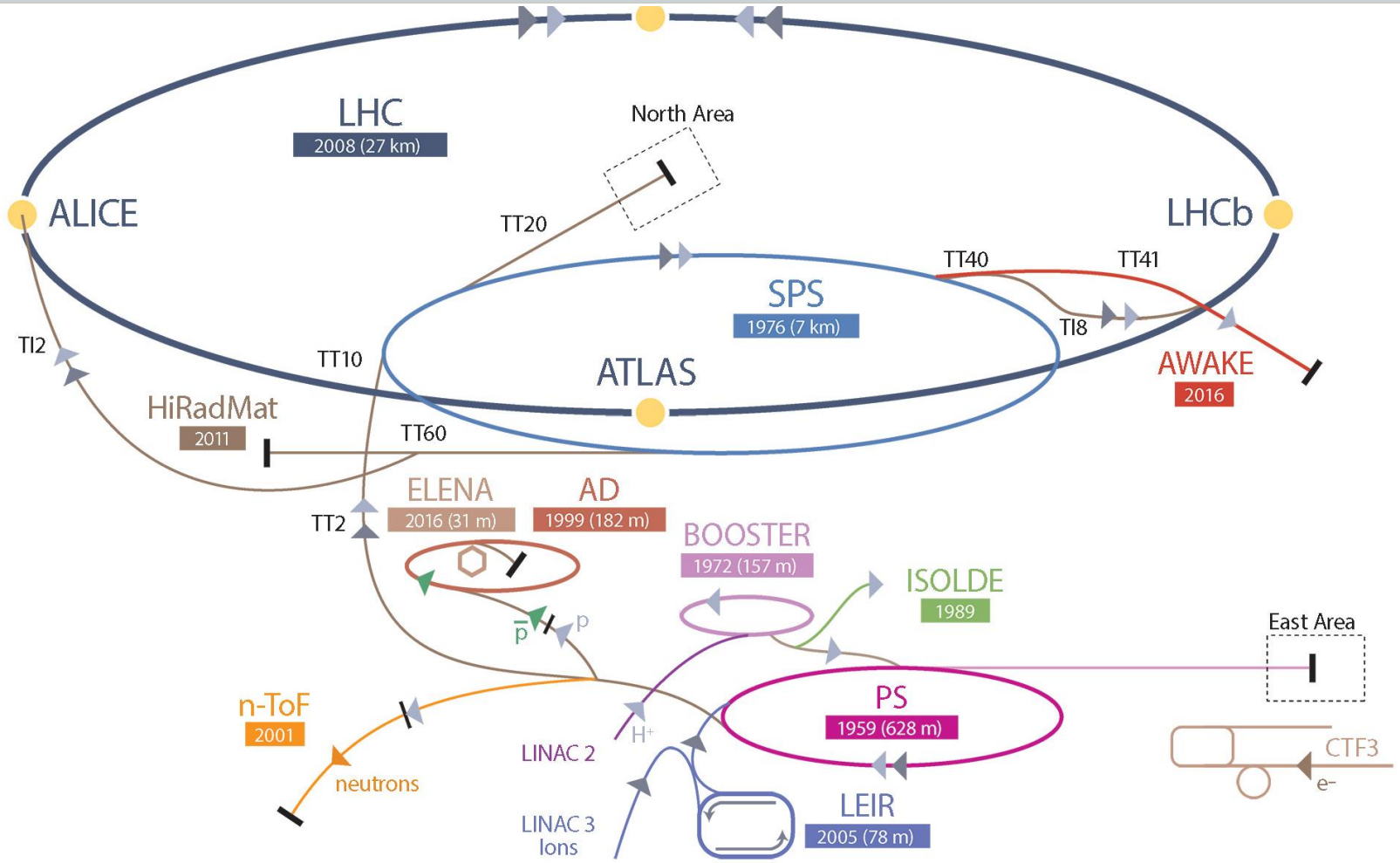
Gluon



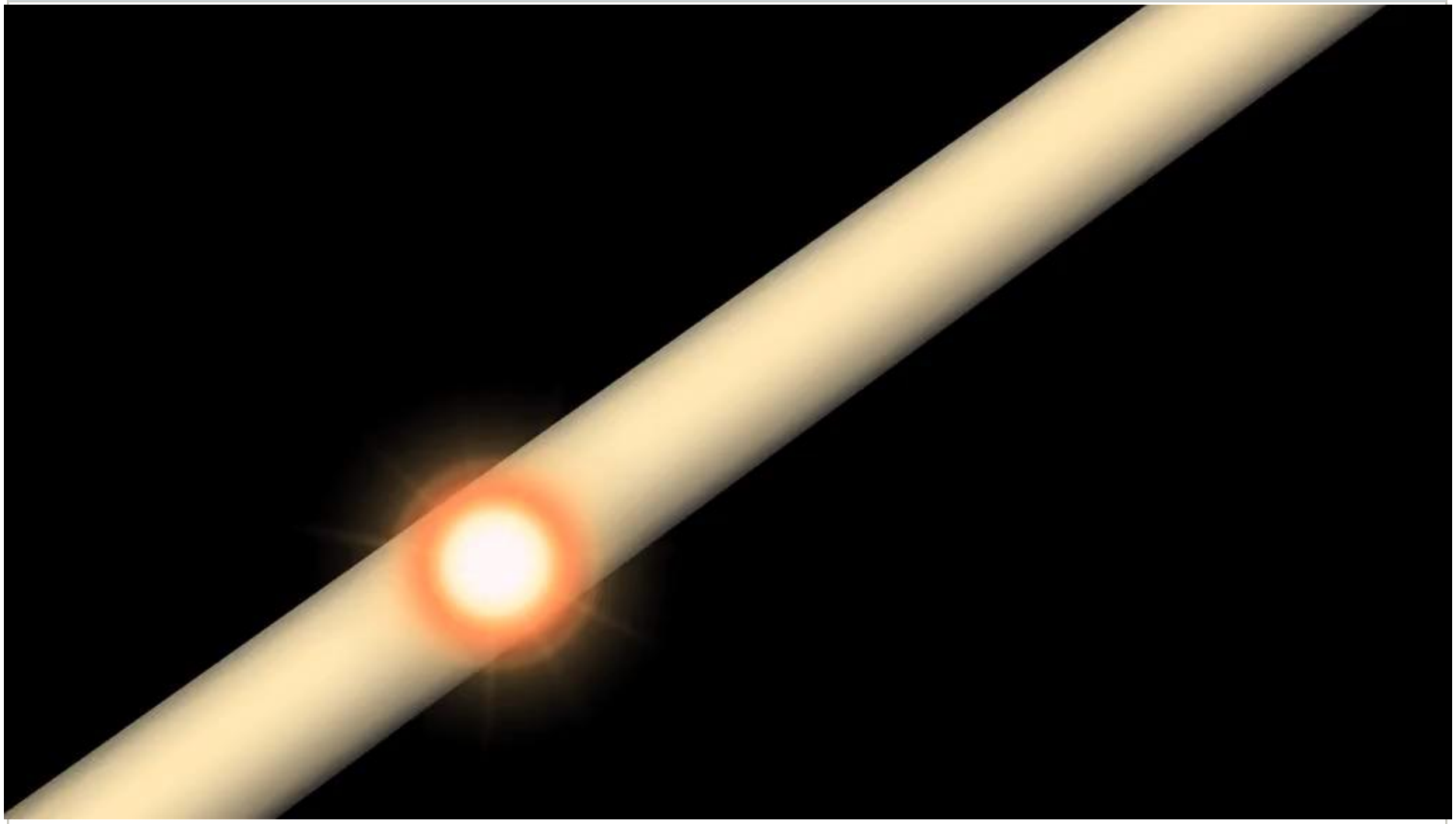
The Large Hadron Collider



Accelerator Complex

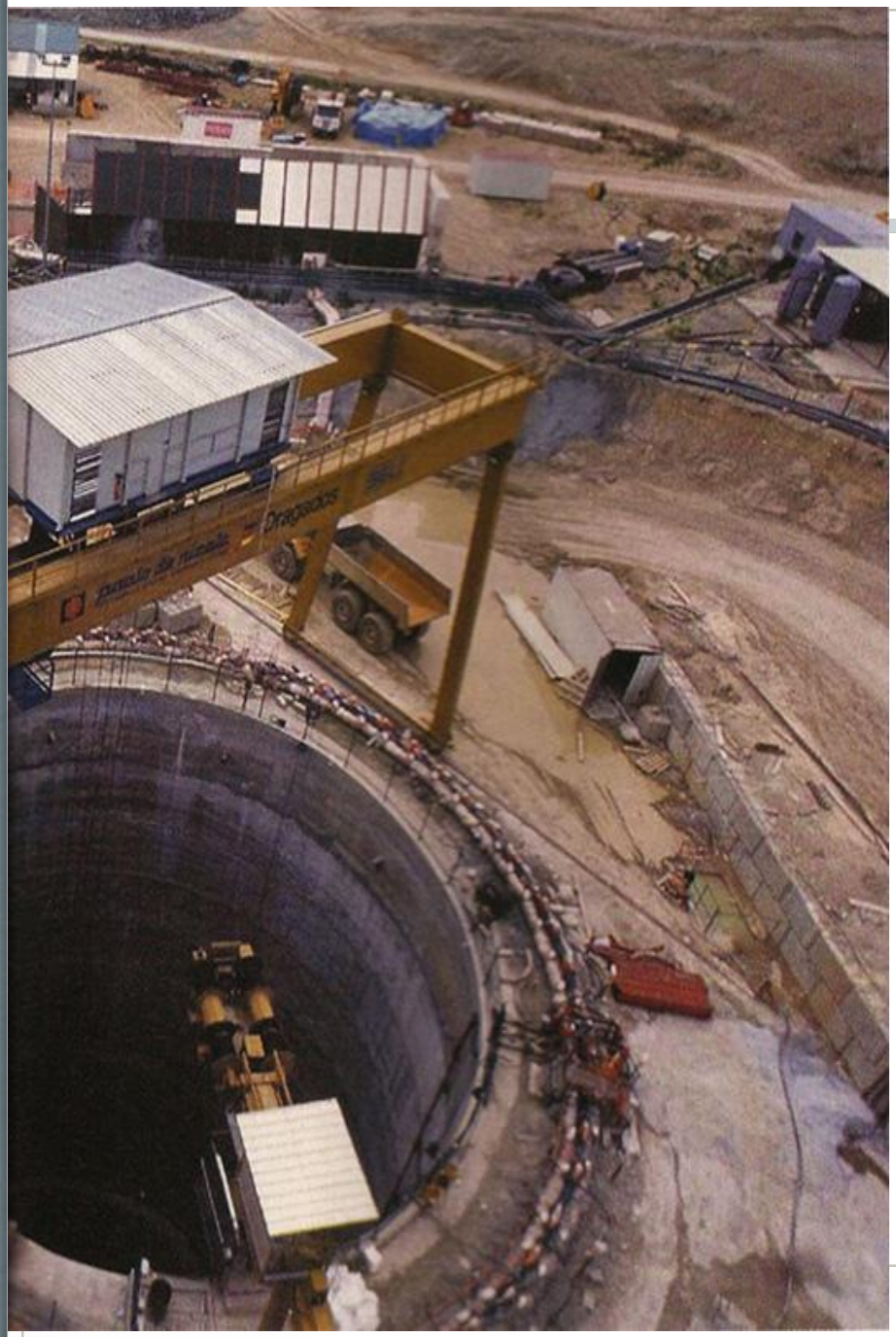


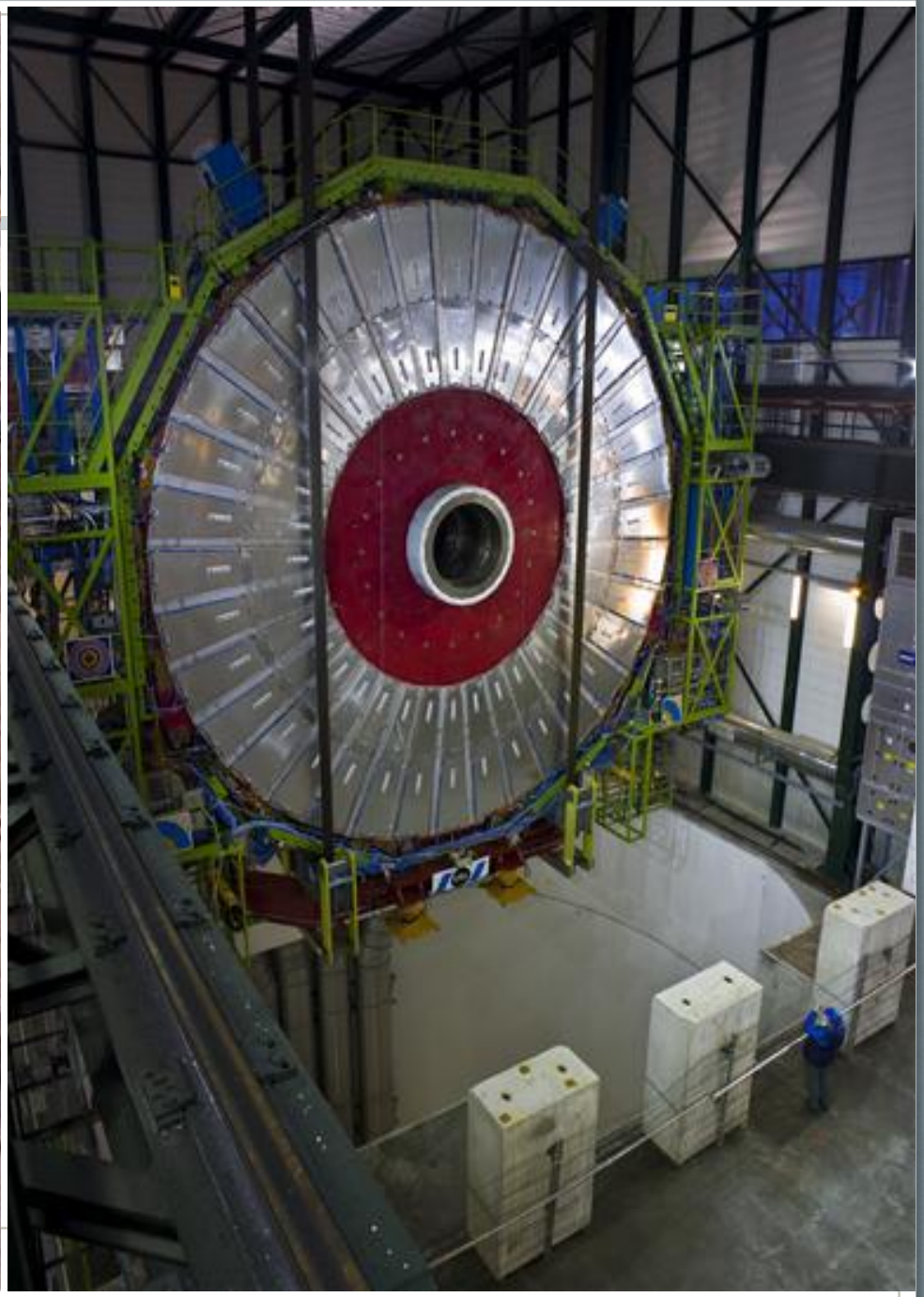
pp Collision at the LHC

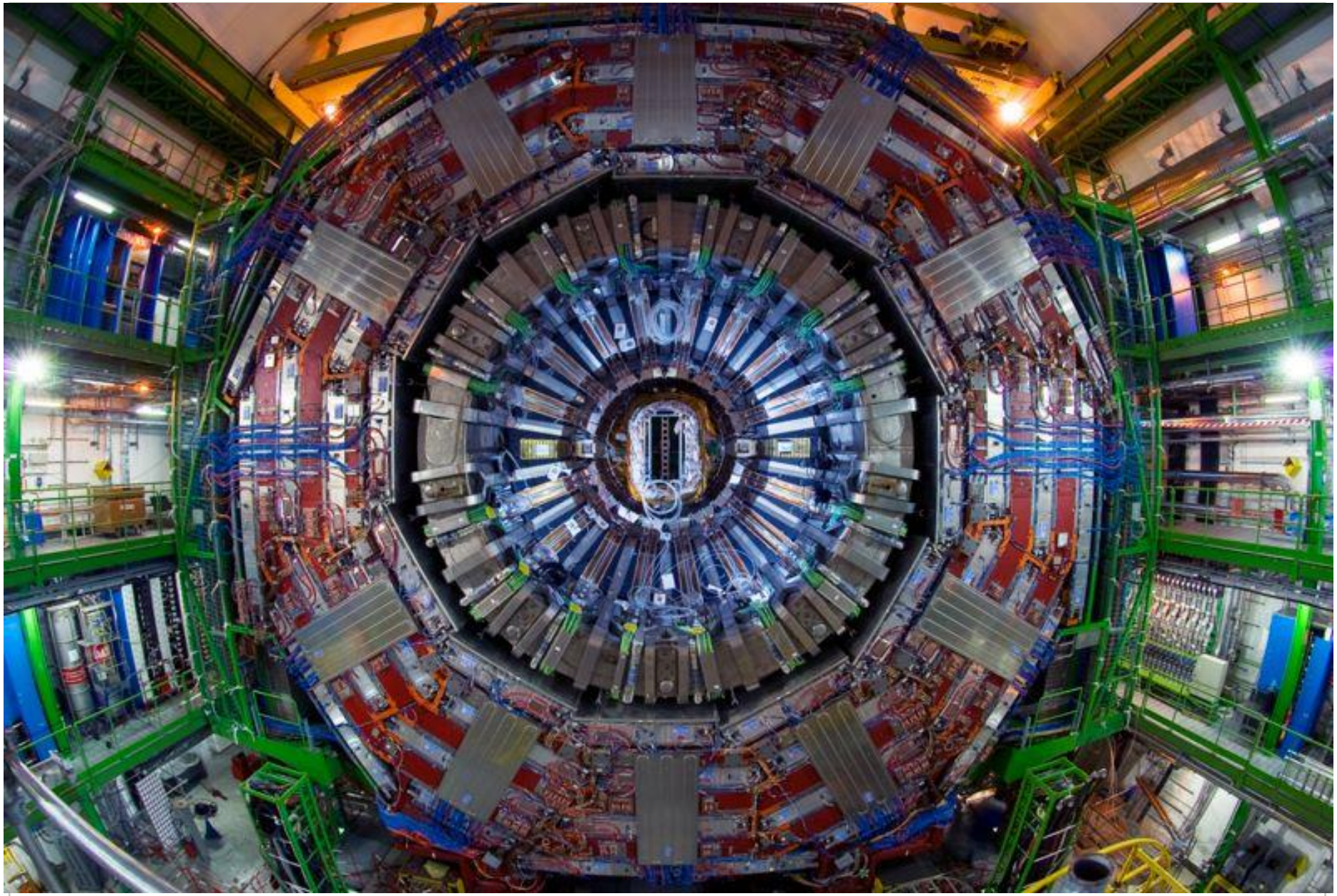


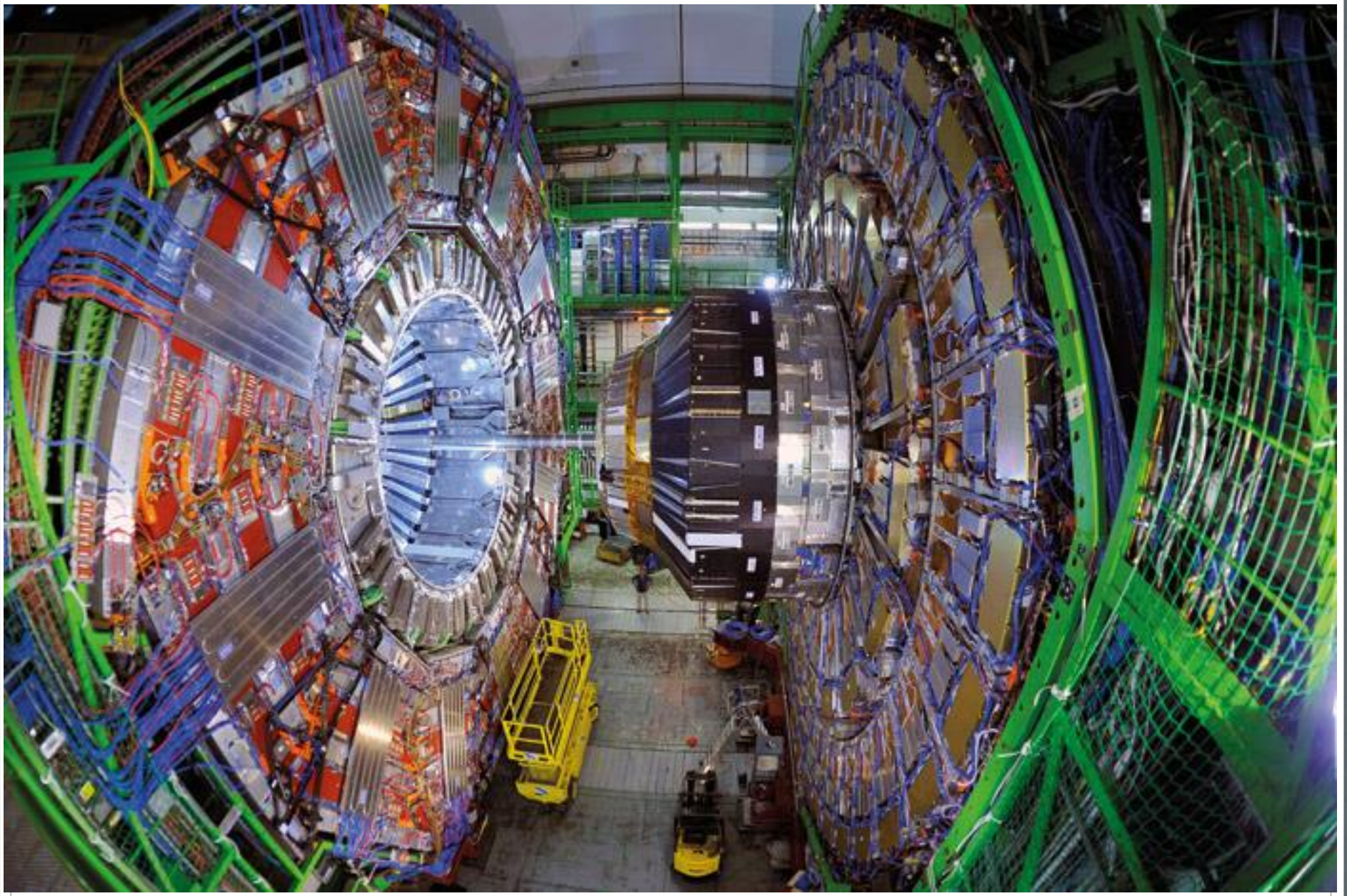
Excavation at P5 for CMS Experiment

point 5-excavation commencement of PM54 shaft — 09 Jul 1999 CERN ST-CE





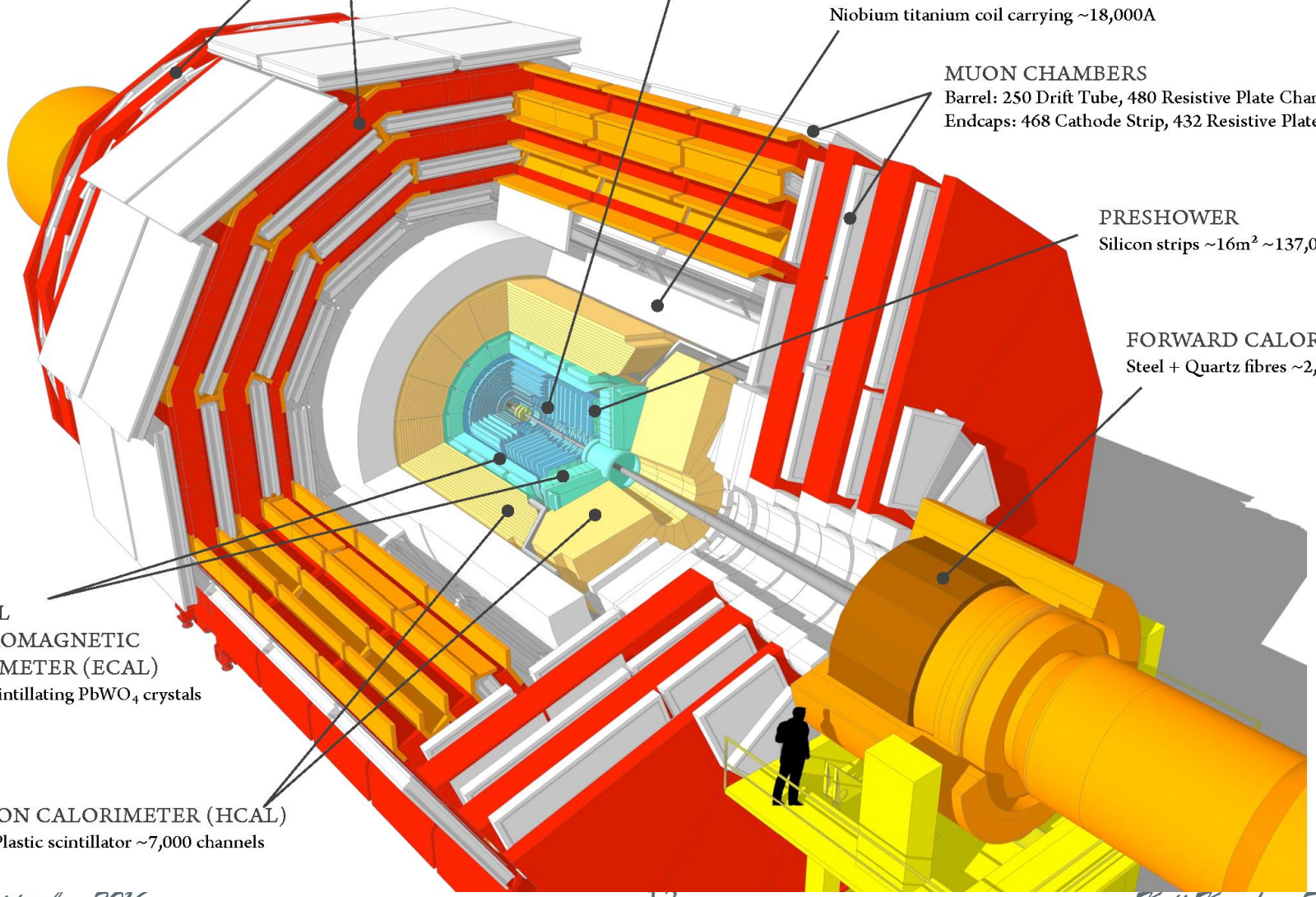




CMS Detector

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

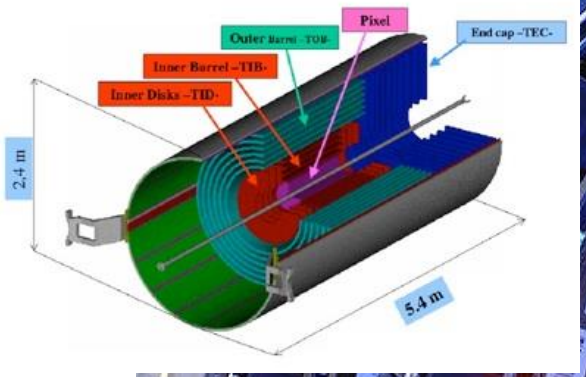
PRESHOWER
Silicon strips ~16m² ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

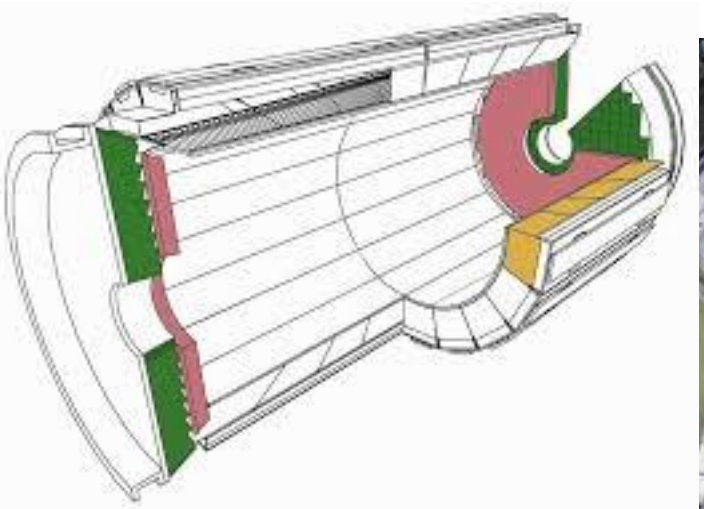
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

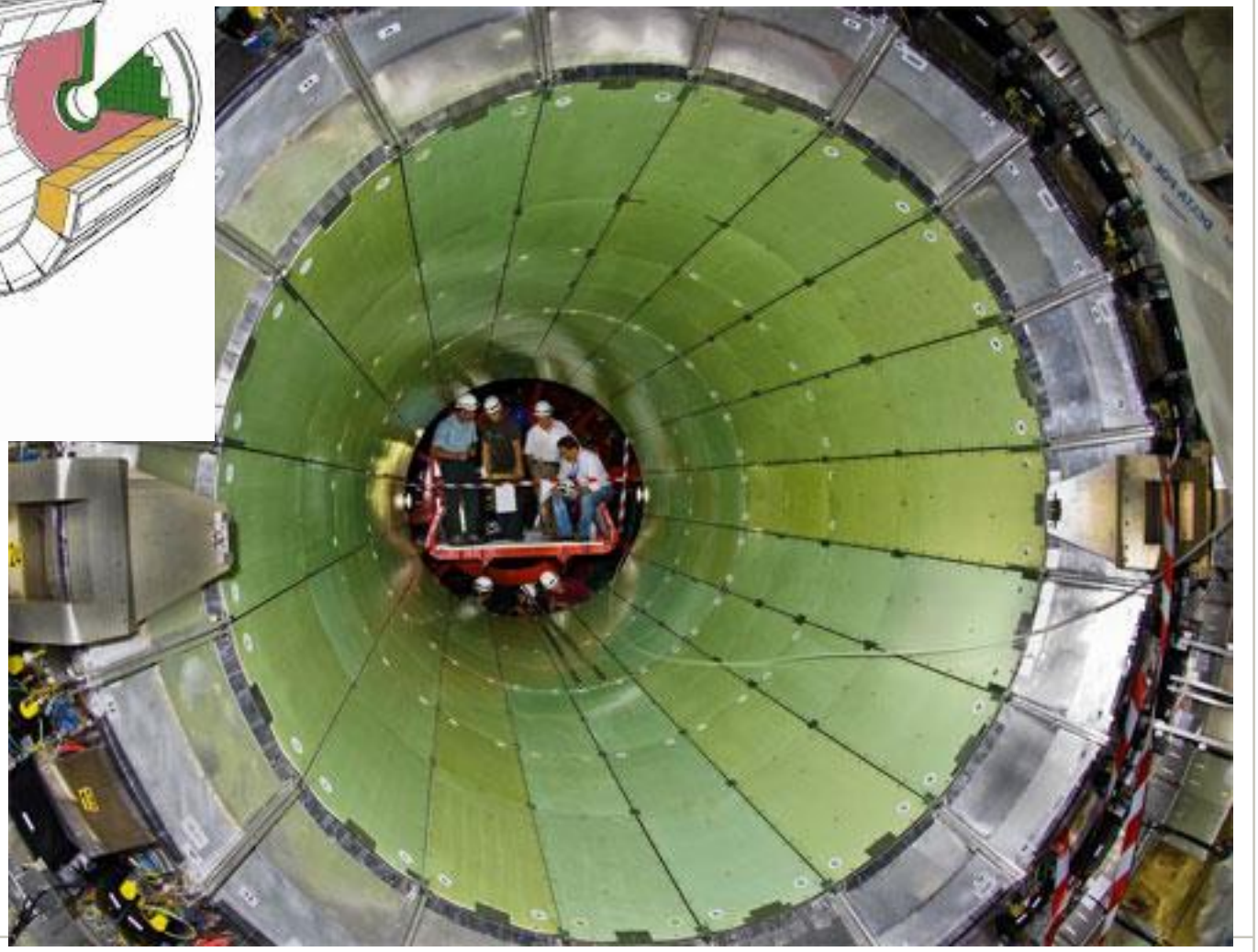
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

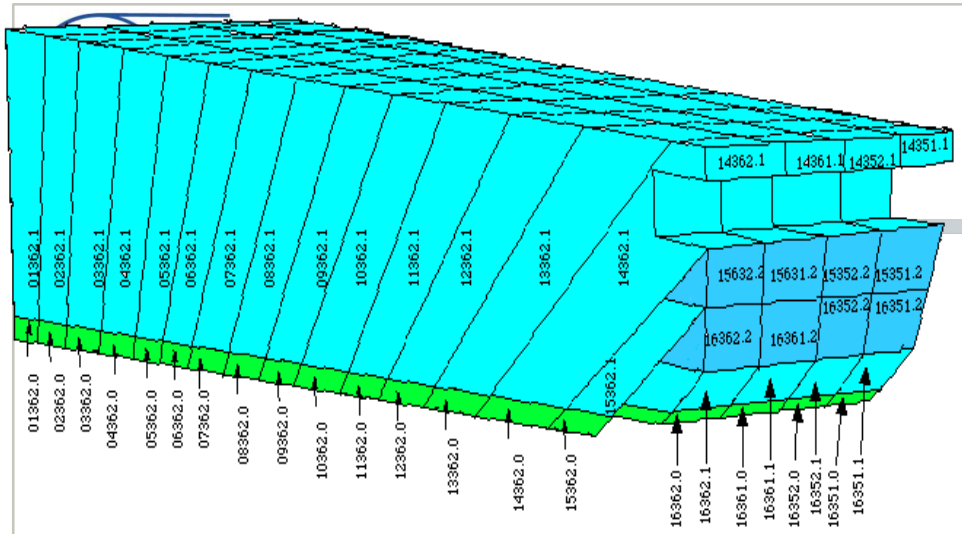
CMS Silicon Strip Tracker



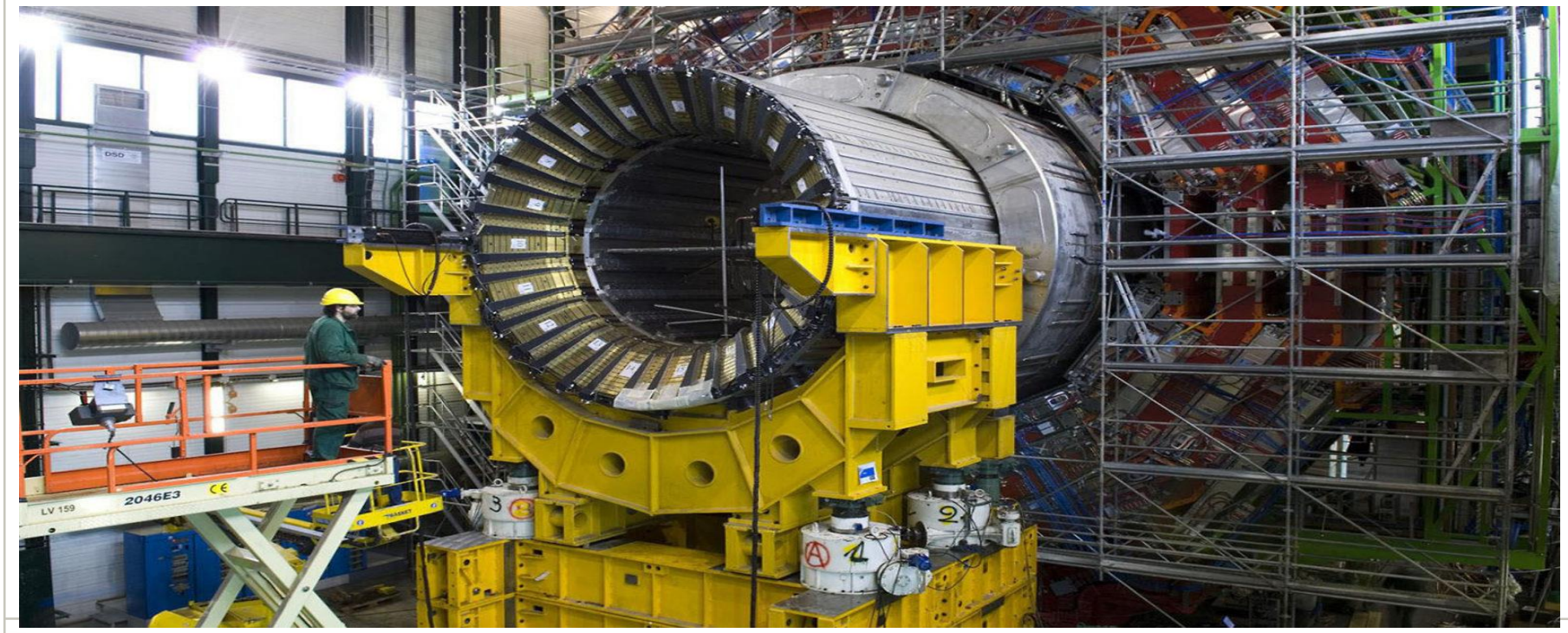
CMS Electromagnetic Calorimeter



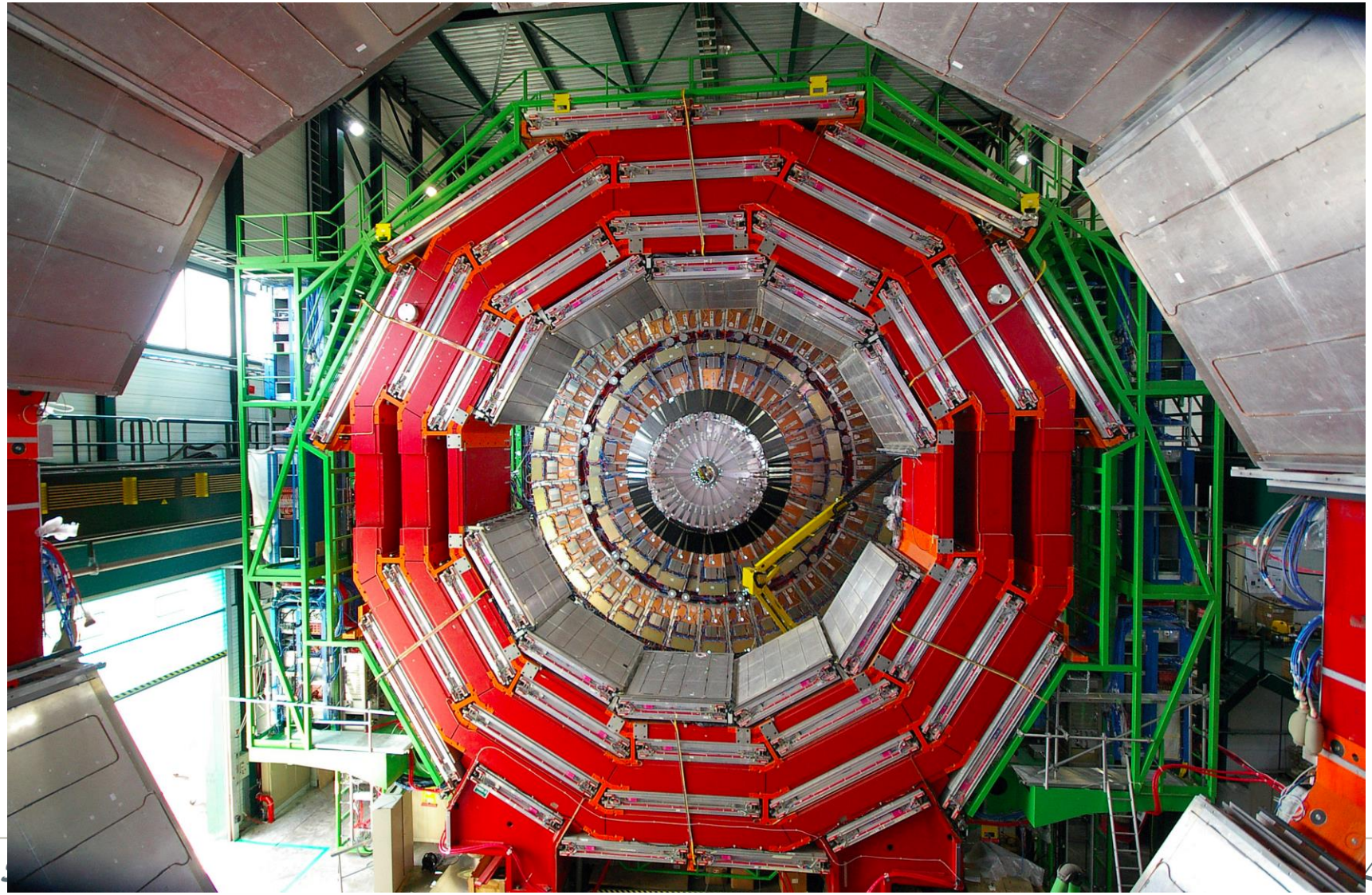


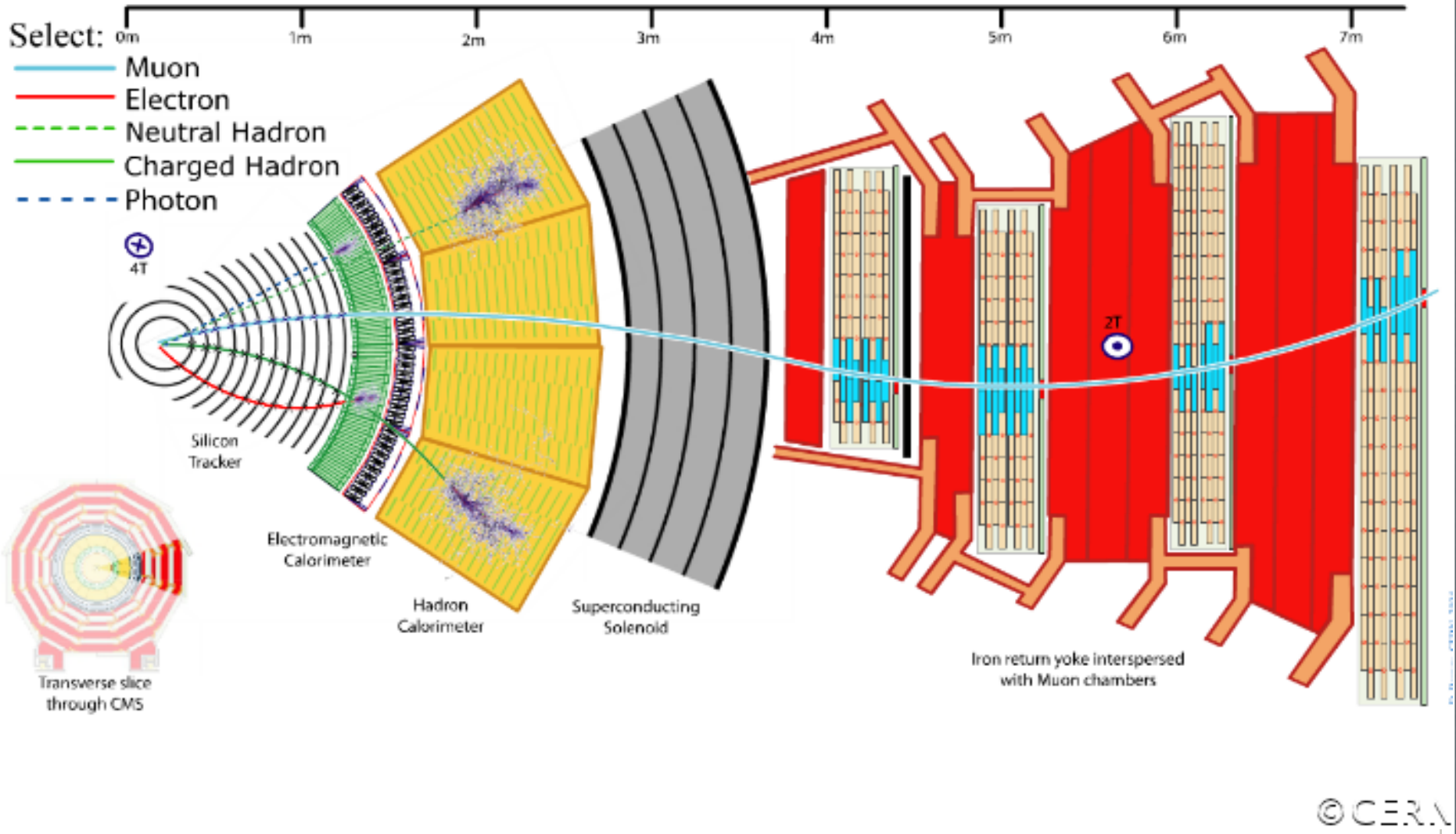


CMS Hadronic Calorimeter

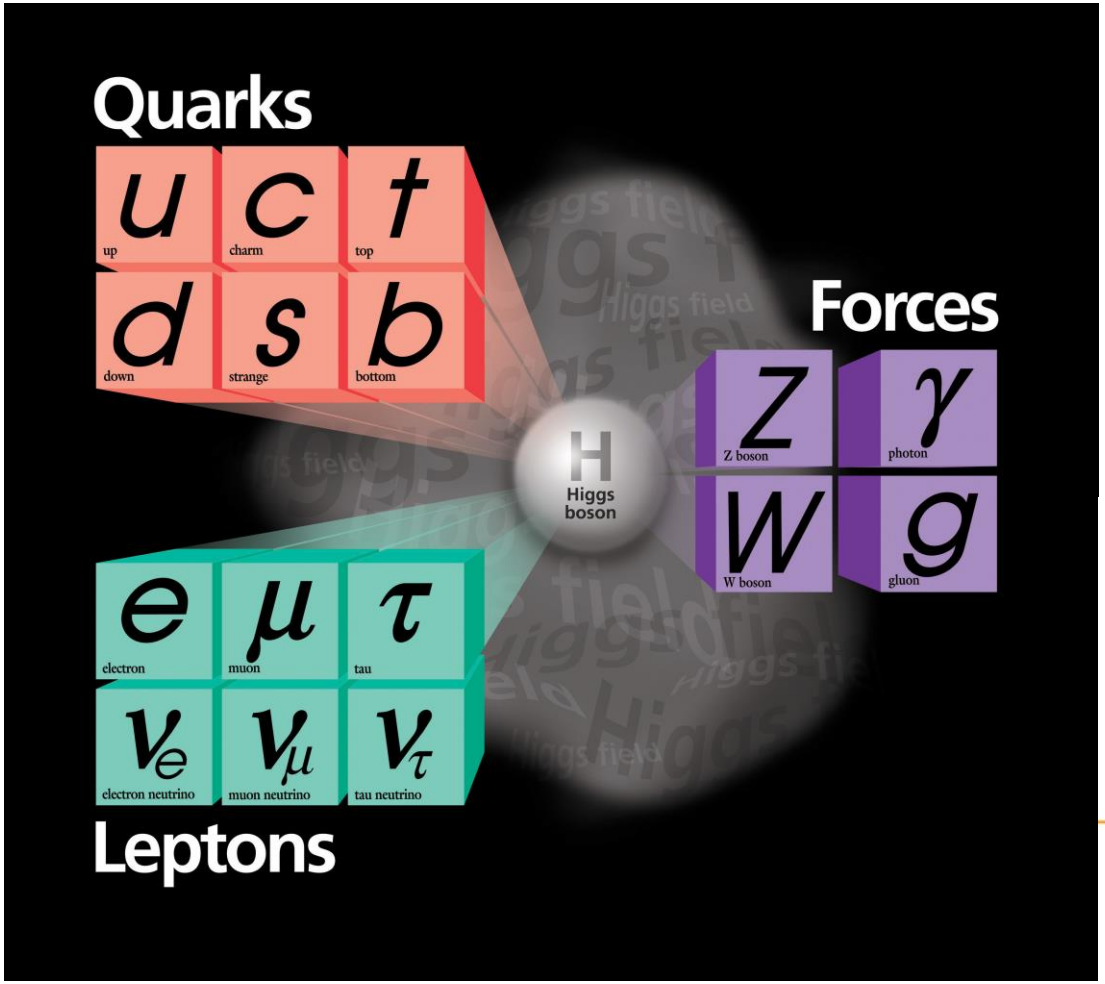


CMS Muon System




Select:
Muon
Electron
Neutral Hadron
Charged Hadron
Photon
0m
1m
2m
3m
4m
5m
6m
7m
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
©CERN

What We Detect?

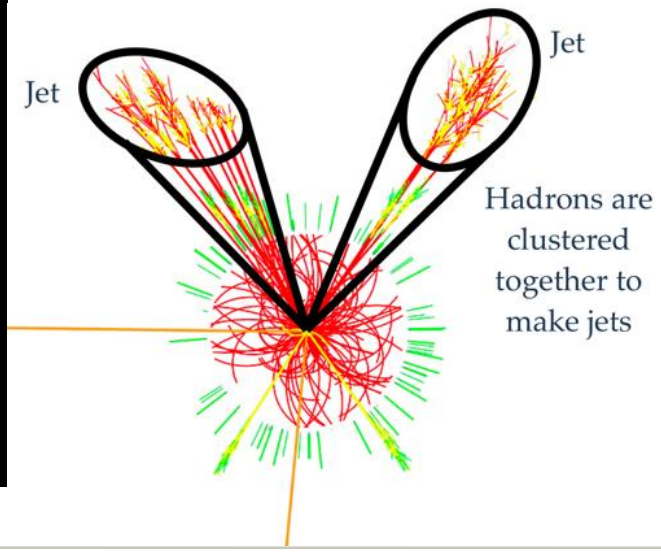


We directly detect:

- Electron
- Muon
- Photon

Using reconstruction algorithms we can also identify

- Quarks
- Gluon
- Tau



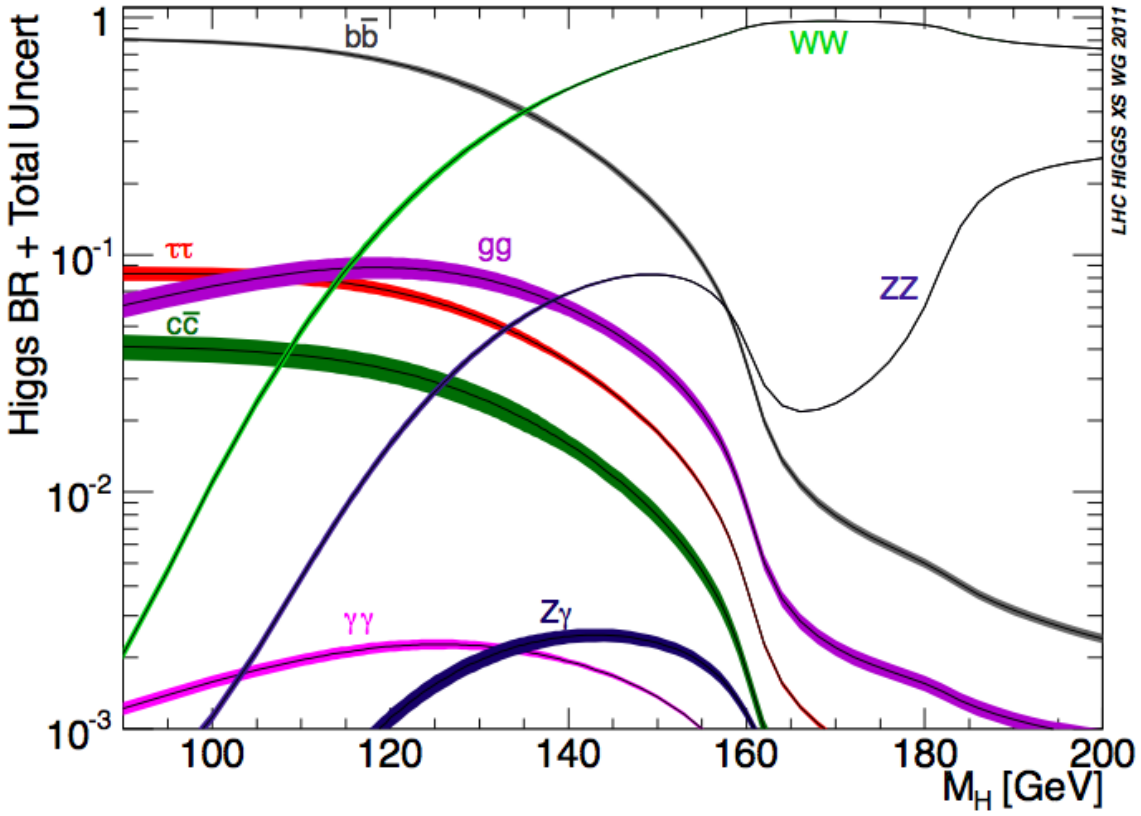
Detecting the Higgs boson

- Need to identify its decay into heaviest particles
  - In case of some decays the invariant mass of Higgs particle can be reconstructed with excellent resolution

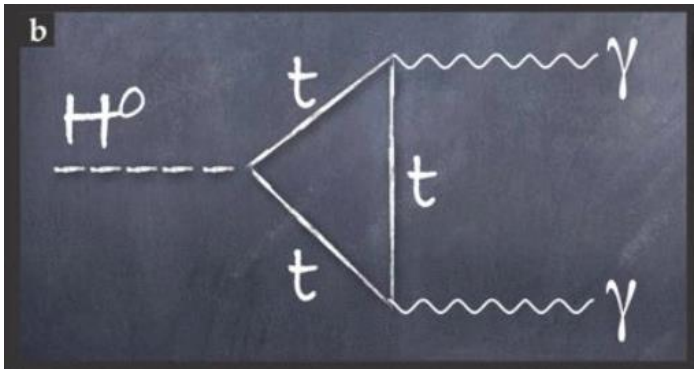
$$m^2c^4 = \left(E_1 + E_2\right)^2 - \left(\left|\vec{p}_1 + \vec{p}_2\right|\right)^2 c^2$$

$H \rightarrow \gamma\gamma$

$H \rightarrow ZZ \rightarrow l^+l^-l^+l^-$

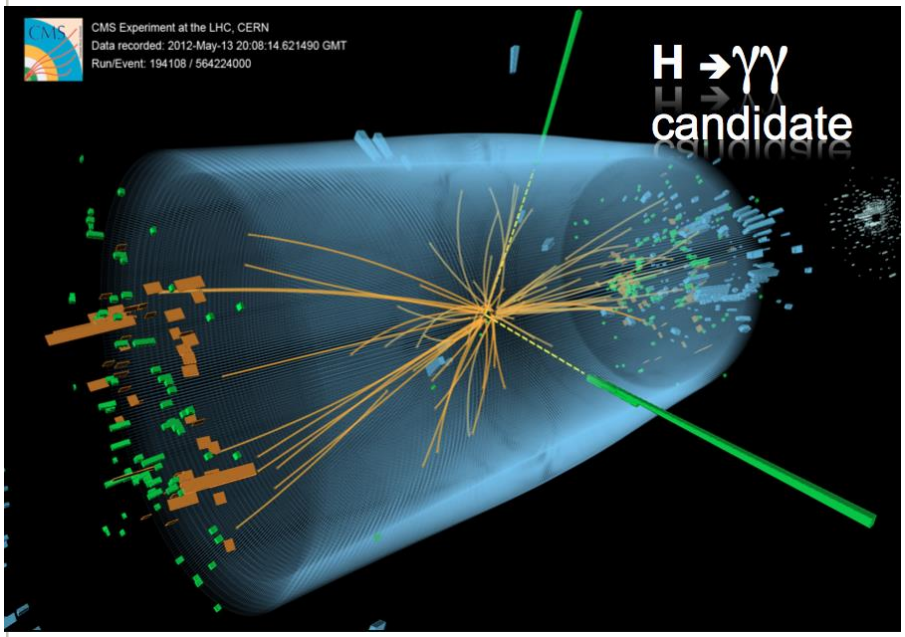


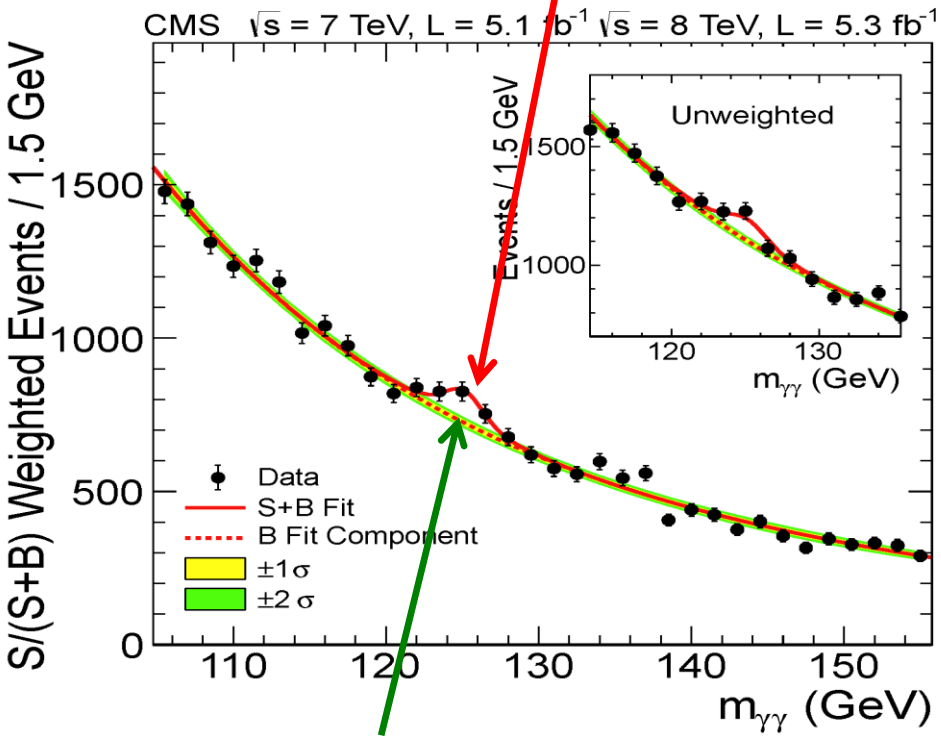
Higgs Discovery in γγ final state



Large signal rate;
Large background.

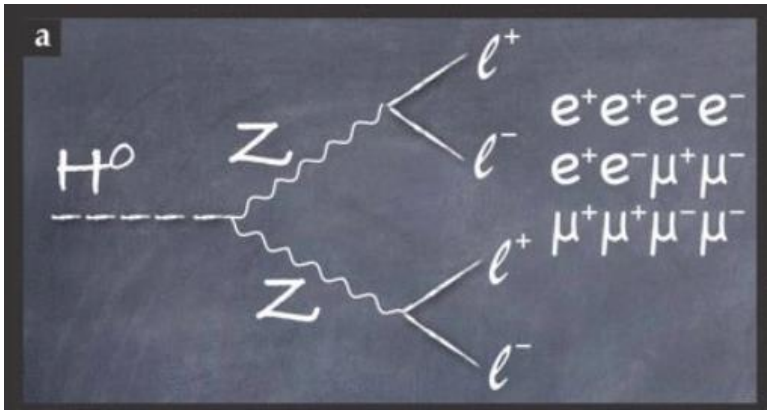
Colliding gluons fuse into Higgs boson with 125 GeV mass

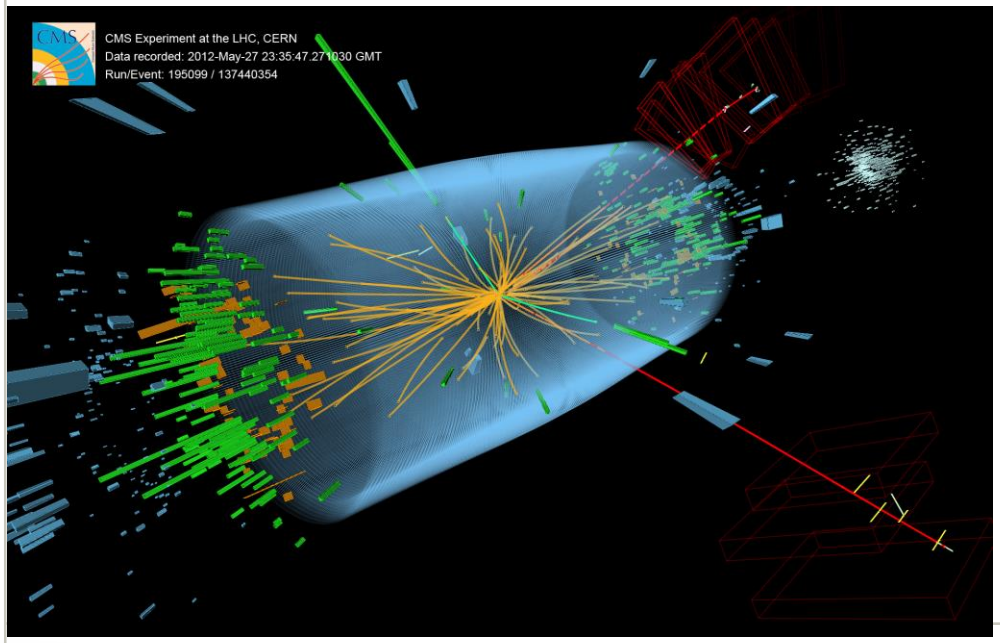




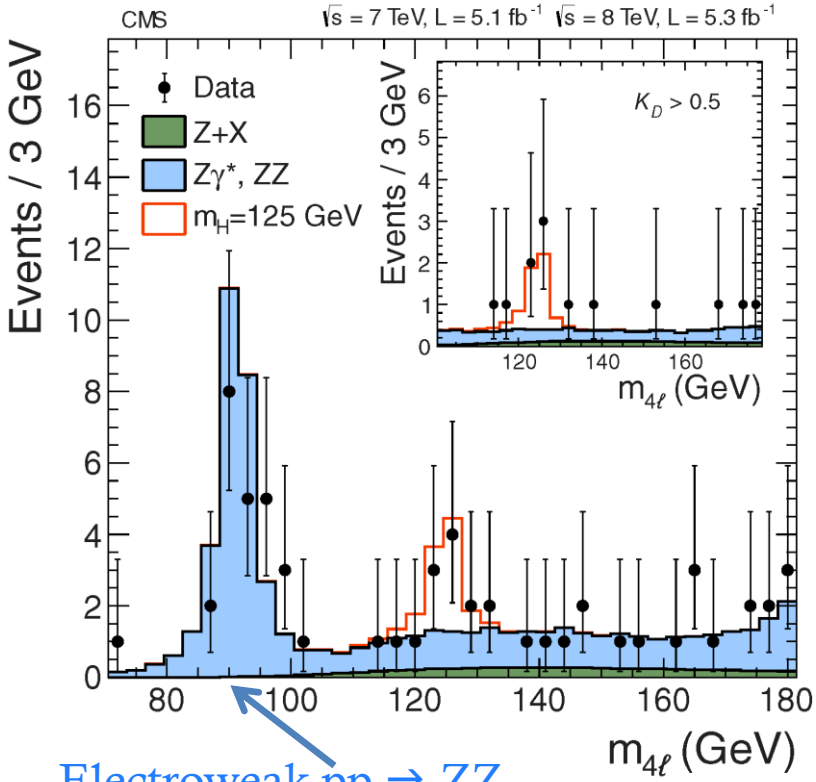
Colliding quark and anti-quark annihilate into photons

Higgs Discovery in $l^+l^-l^+l^-$ final state





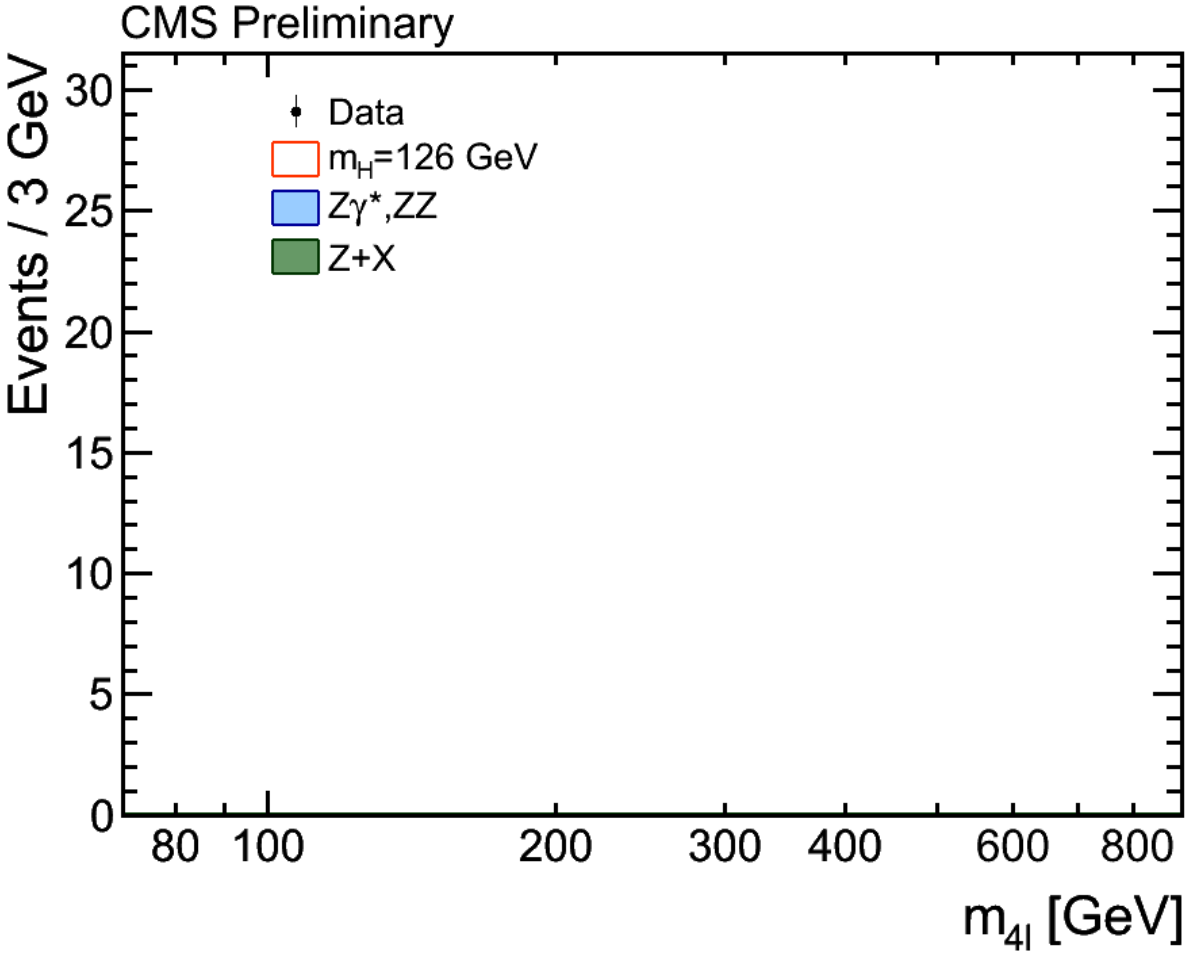
Small signal rate;
Small background



Electroweak pp → ZZ production

H→ZZ→eeee/eeμμ/μμμμ

Data by 2013



CMS Collaboration