An introduction to LHC and CMS

21 Tir 91

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Outline

- LHC
  - What is it?
  - How it works ?
  - 2010 Startup
  - Current Status
- CMS
  - Important numbers
  - 2010 data taking

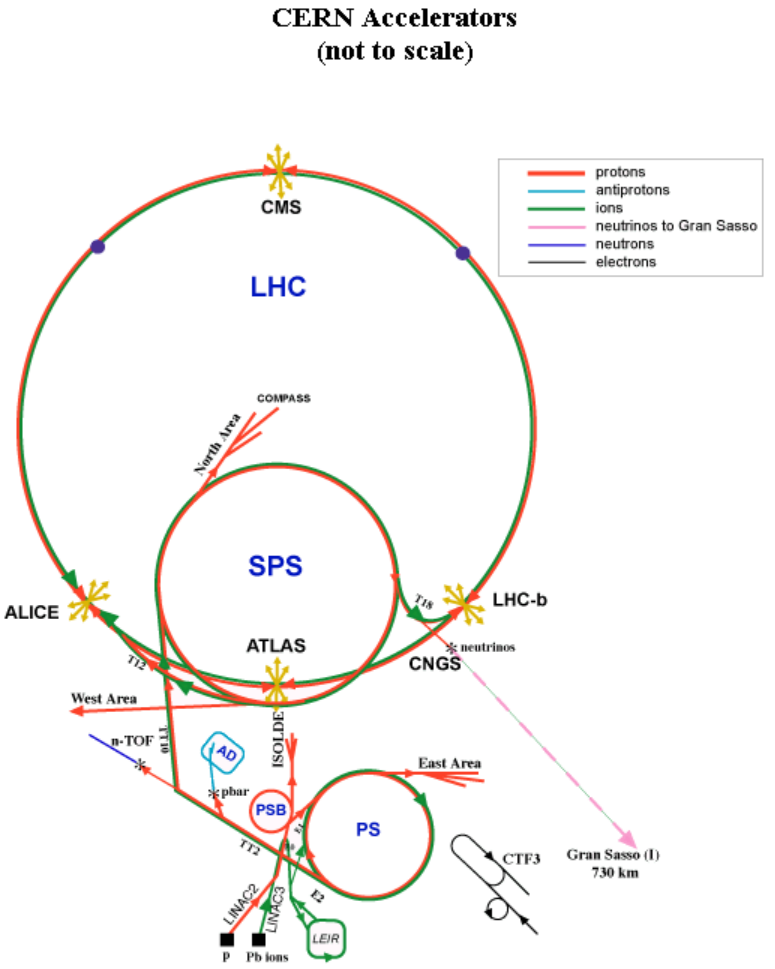
LHC - 1

- Large Hadron Collider

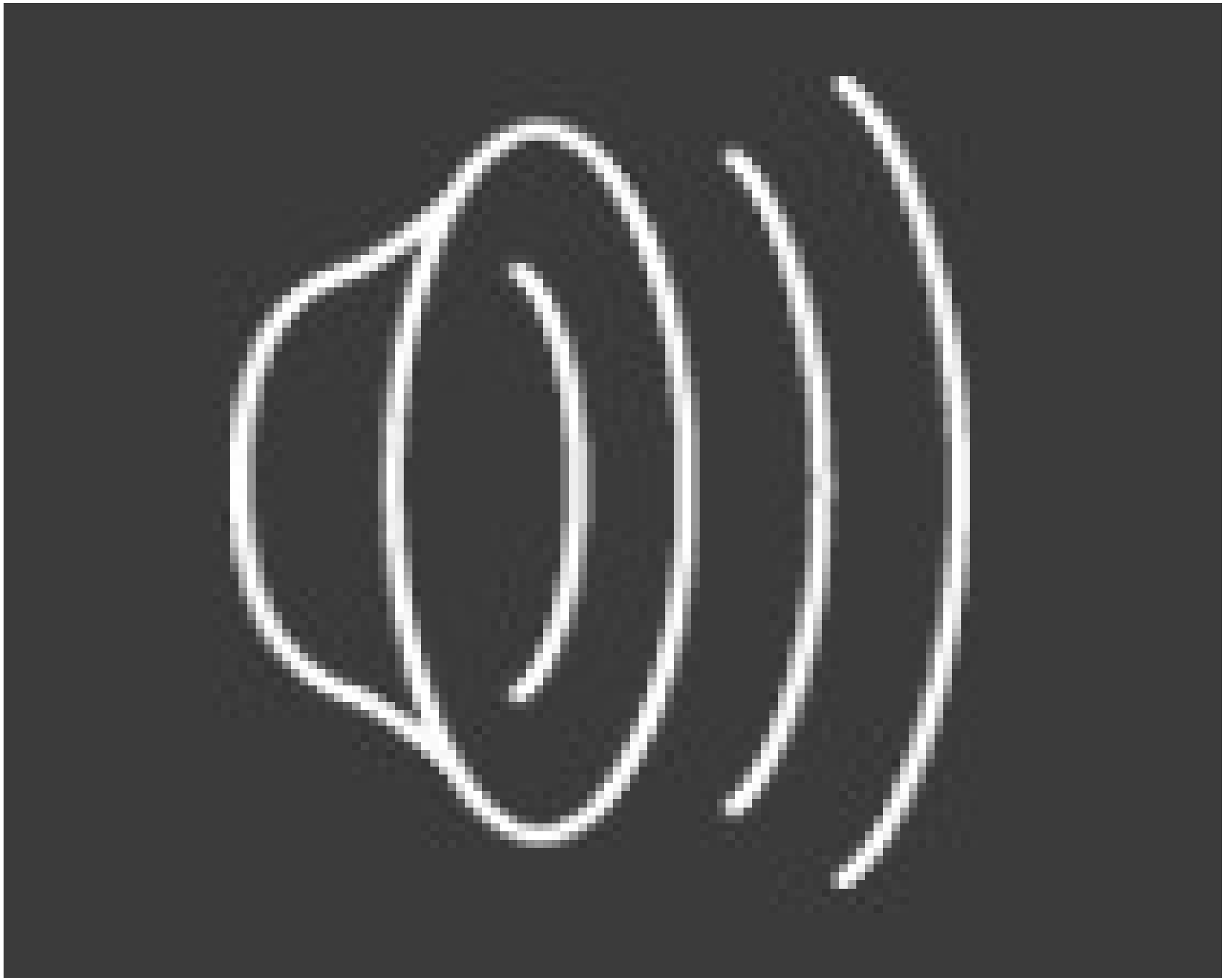
•A high vacuum is required. The pressure in some parts is over 10^{-9} Pa.
•Operating temperature: 1.9 K
•Injected beam energy: 450 GeV (protons)
•Nominal beam energy in physics: 4.0 TeV (protons)
•Revolution frequency: 11.2455 kHz.
•Magnetic field at 8 TeV: 8.35 Tesla

Beam Energy

- 1) The collisions at the LHC begin life in a bottle of hydrogen. Protons are extracted from hydrogen.
- 2) The protrons are accellerated first by the LINAC2 accellator to 50MeV
- 3) Then are boosted by the PSB to 1.4GeV
- 4) Next they head to the PS and get accellerated to 25Gev
- 5) Then on to the SPS where they really pick up speed, 450 GeV
- 6) Finally they reach the LHC and go in opposite directions where they will reach 8000GeV (8TeV) in head on collisions in the experiments, ALICE, ALTAS,CMS or LHCb
- 7) Filling time is about 4'20”. It takes 20 minutes to reach to the nominal energy of 8TeV



LHC Animation



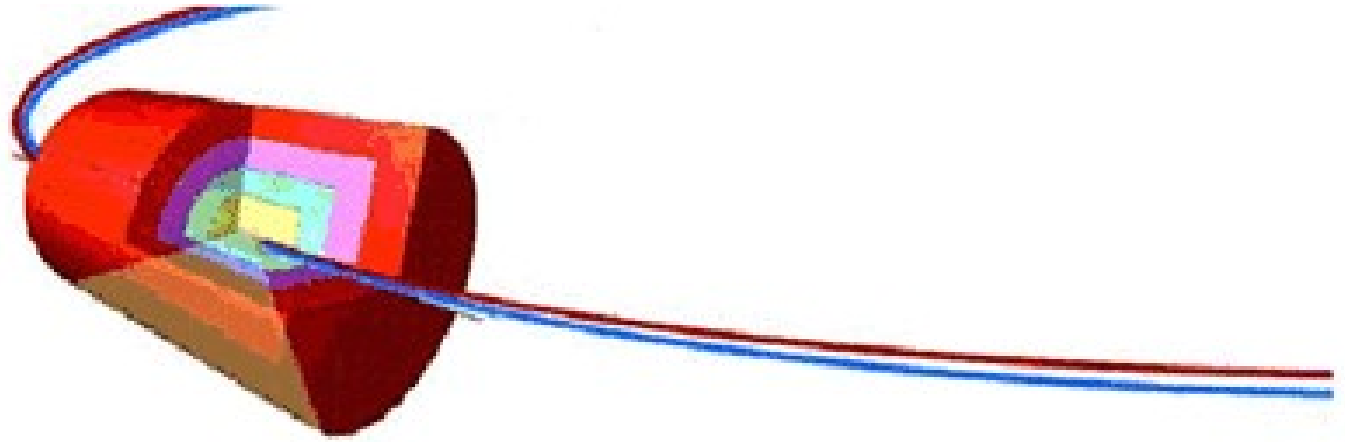
Total Energy

- Each proton beam at full intensity will consist of 2808 bunches per beam.
- Each bunch will contain 1.15×1011 protons per bunch at the start of nominal fill.

2808 bunches * 1.15 10^{11} protons @ 8 TeV each. = 2808*1.15*1^{01}1*8*^{10}12*1.602*$^{10-}$19 Joules = 415 MJ per-beam

  - Comparing to Tevatron, it's about 280 times larger
  - This energy is equivalent to the energy of 150 KG of TNT
  - It's enough to melt ~1 tonne of copper

    If it's not directed well, can damage LHC
- Total Power consumption: ~120 MW



Luminosity I

- It´s a measurement of the number of collisions that can be produced in a detector per cm^2 and per second.
- $L \sim f \cdot N^2 / (S_{eff})$
  - F is the bunches crosses frequency
  - N is Number of protons per bunch
  - S_{eff} : section effective of collision that depends on the cross section of the bunch (“effective” because the beam profile doesn’t have a sharp edge); the formula for this is given by : $S_{eff} = 4 \cdot \pi \cdot \sigma^2$
  - Luminosity is usually expressed in units of inverse barn per second :

$$1 \text{ barn} = 10^{-24} \text{ cm}^2$$

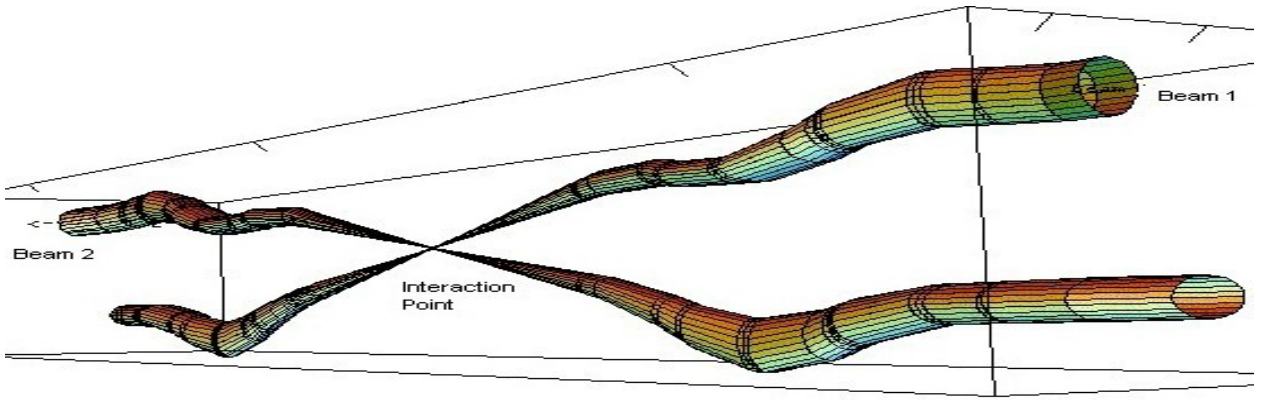
  - Total collected data is the integral of the luminosity over time :

$$L = \int L dt$$

Luminosity II

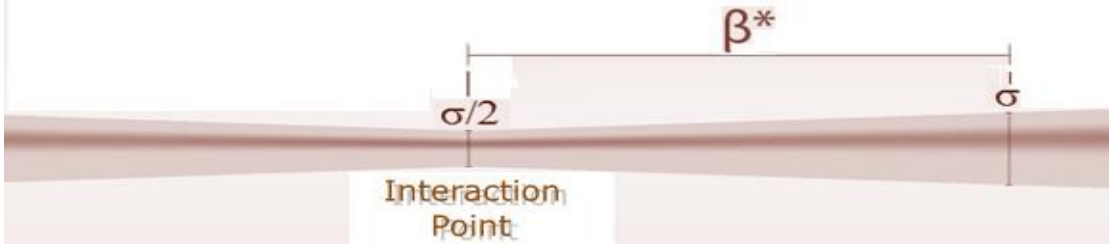
- We can also express the Luminosity in terms of ε (emittance) and βeta (amplitude function) as:

$$L = f \cdot N^2 / (4 \cdot \varepsilon \cdot \beta^*)$$



•transverse emittance, ε, is a beam quality concept reflecting the process of bunch preparation (the injector chain), extending all the way back to the source for hadrons. A low emittance particle beam is a beam where the particles are confined to a small distance and have nearly the same momentum.

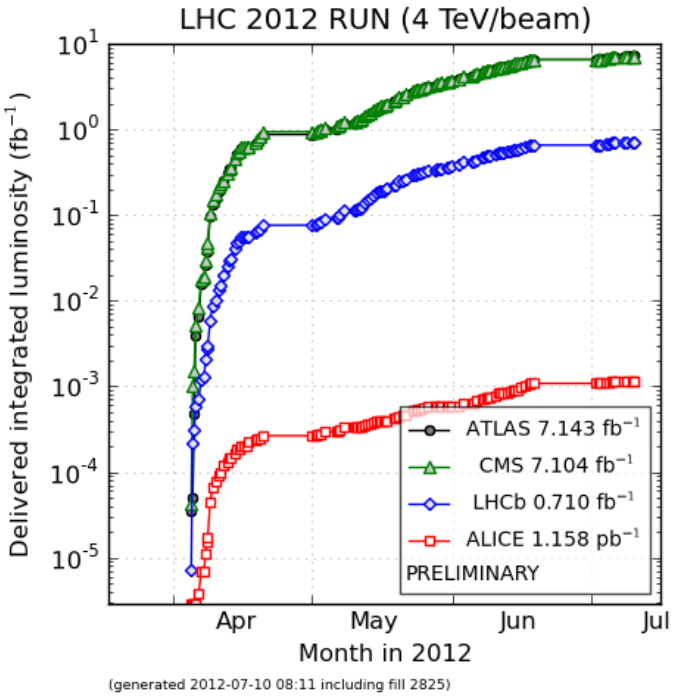
•The amplitude function, β , is determined by the accelerator magnet configuration (basically, the quadrupole magnet arrangement) and powering.



Luminosity III (Values over time)

- The energy of each beam and N Protons per bunch reached to the nominal values very soon
- Two important parameters that are still far from nominal values are N Bunches per beam and β

	Current	Nominal
β	0.6 m	0.55 m
N Bunches	1380	2808
Luminosity	7e33	1e34



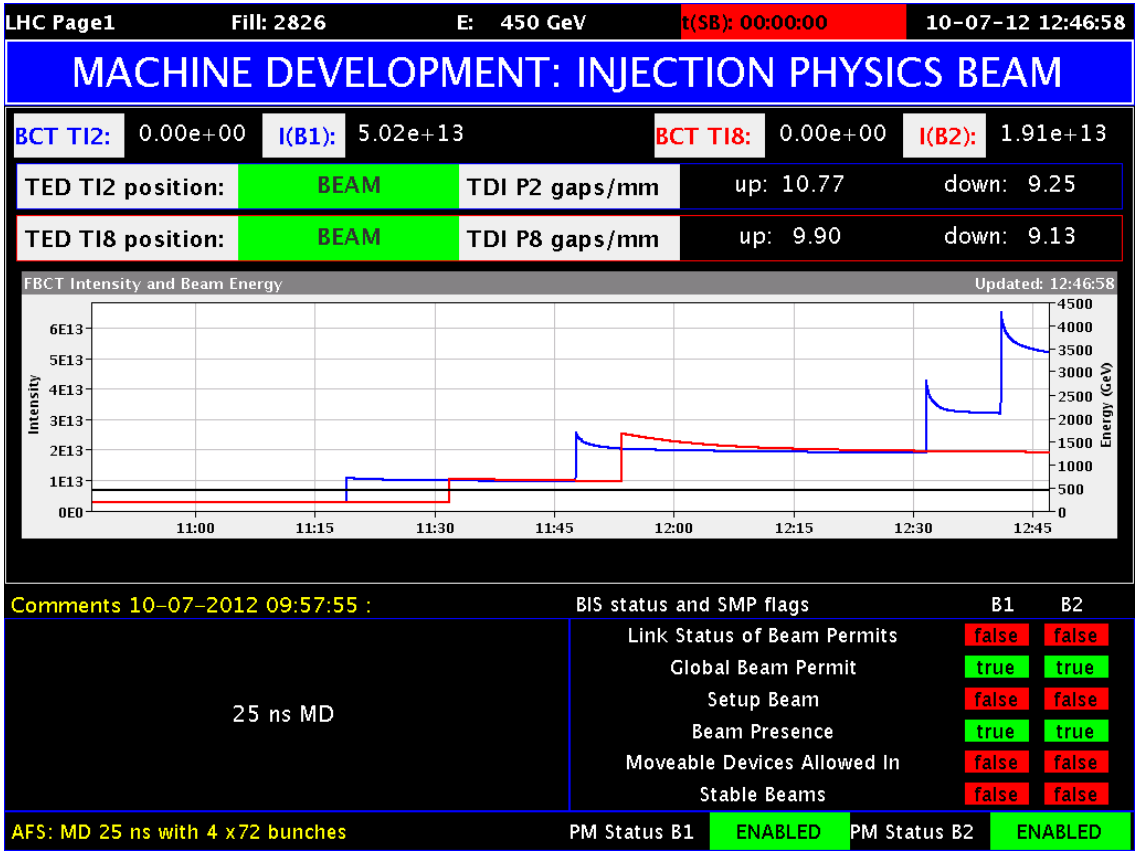
Cross sections of some physical processes :

	Xsection (pb)	Nevents so far (6 fb^{-1})
Wjets→lnu	36250	217.5 M
Z → ll	3503	21 M
TTbar	225.2	1.35 M
Higgs 125GeV	~20	12000
SUSY LM5	1.879	282

All calculations need PDF of proton as input

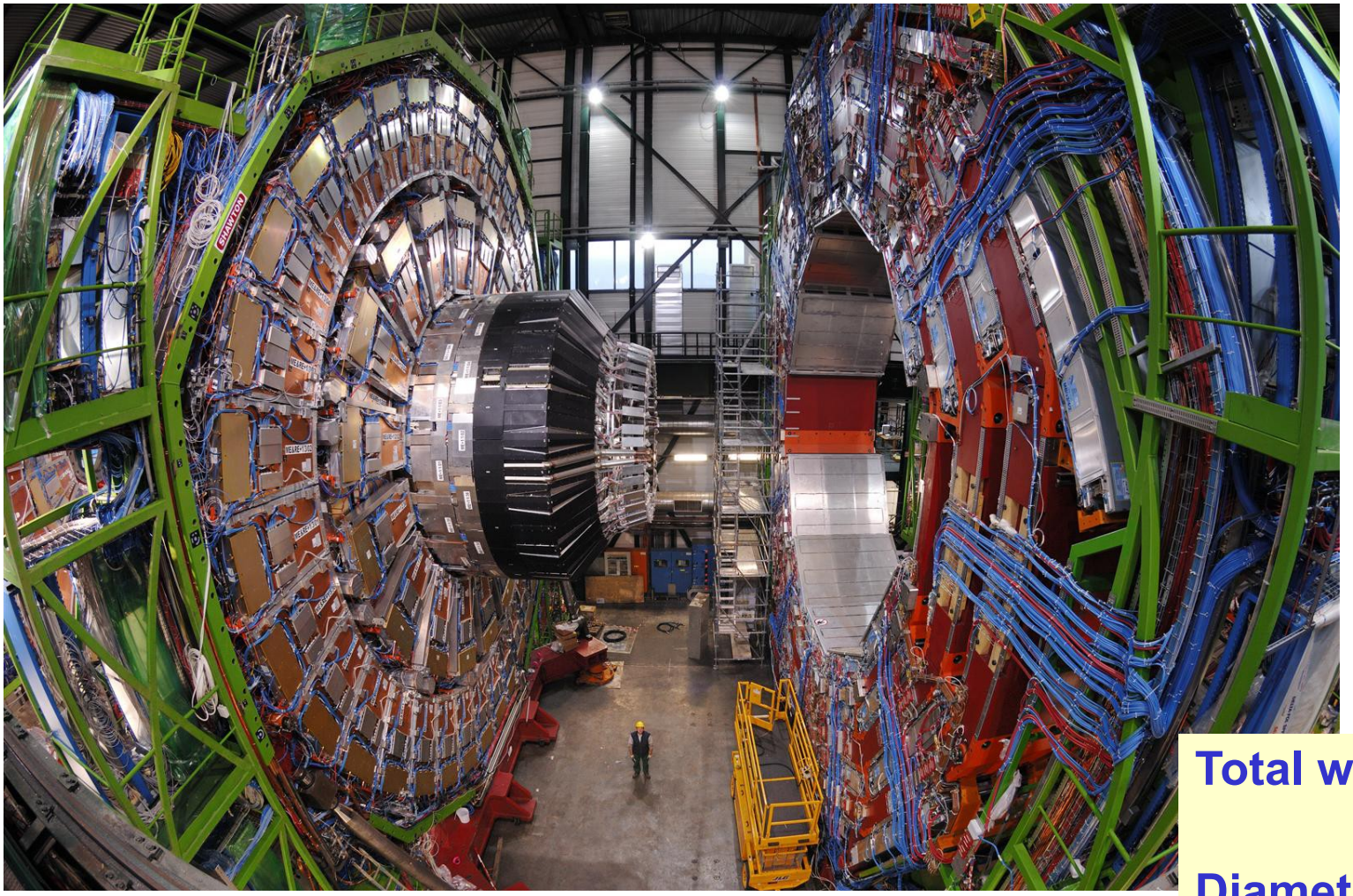
Keep updated

- To see the current status of LHC, go to :
  http://op-webtools.web.cern.ch/op-webtools/Vistar/vistars.php?usr=LHC1



When LHC sets world record beam intensity

Compact Muon Solenoid



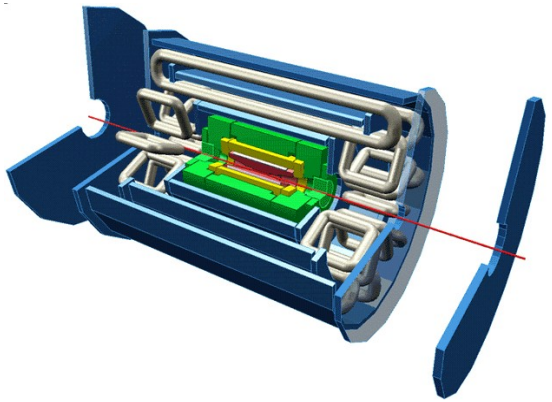
Total weight	**12500 tonnes**
Diameter	**15m**
Length	**21.6m**
Magnetic field	**4 Tesla**

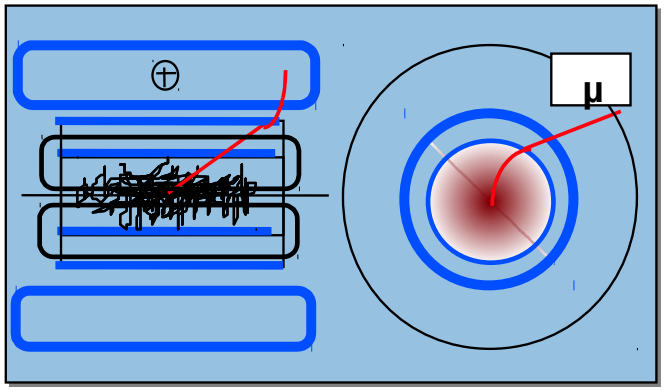
Solenoid

- A solenoid is essentially a cylinder of wire. Passing an electric current down the wire creates a magnetic field
- The CMS solenoid is designed to provide an axial magnetic field of 4 teslas – about 100000 times that of the earth
- The current required is ~20 k amperes → need to use a superconducting wire (zero resistance)
- The superconductor chosen is Niobium Titanium (NbTi) wrapped with copper – needs to be cooled to ~4K
- The CMS solenoid is 13m long with an inner diameter of 5.9m
- The solenoid is sufficiently large that the tracking and all central calorimeters can fit inside
  - Charged particles only bend in one projection (looking along the beam line)

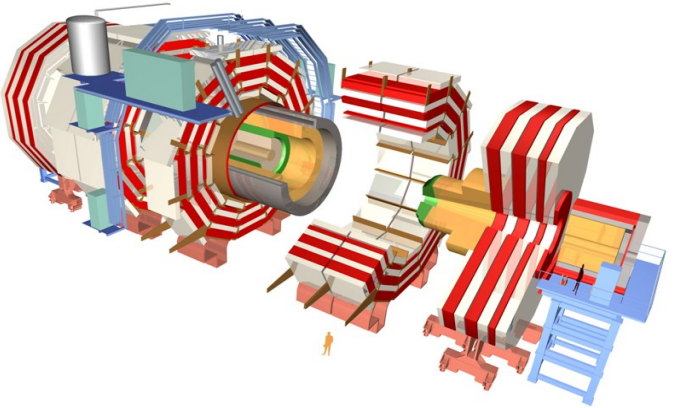
ATLAS vs. CMS

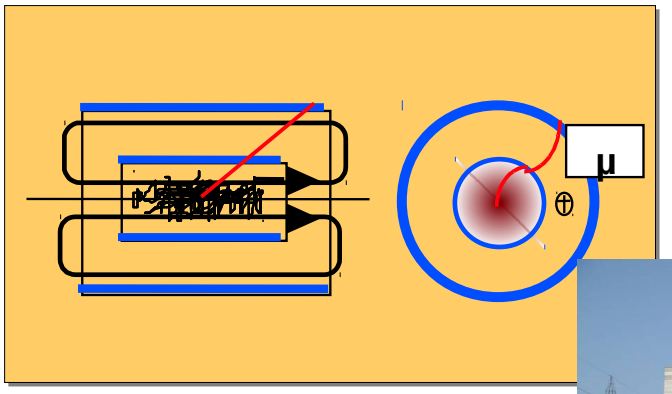
ATLAS A Toroidal LHC Apparatus

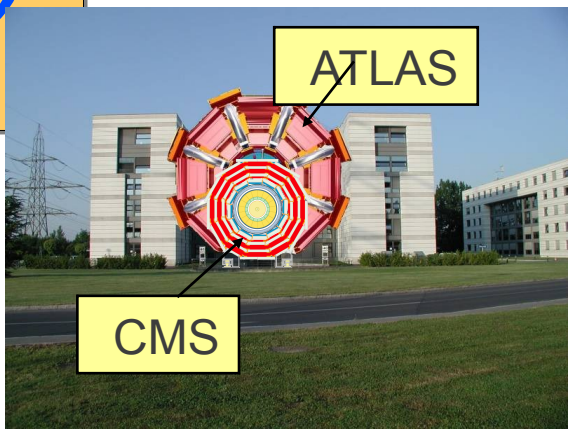




CMS Compact Muon Solenoid

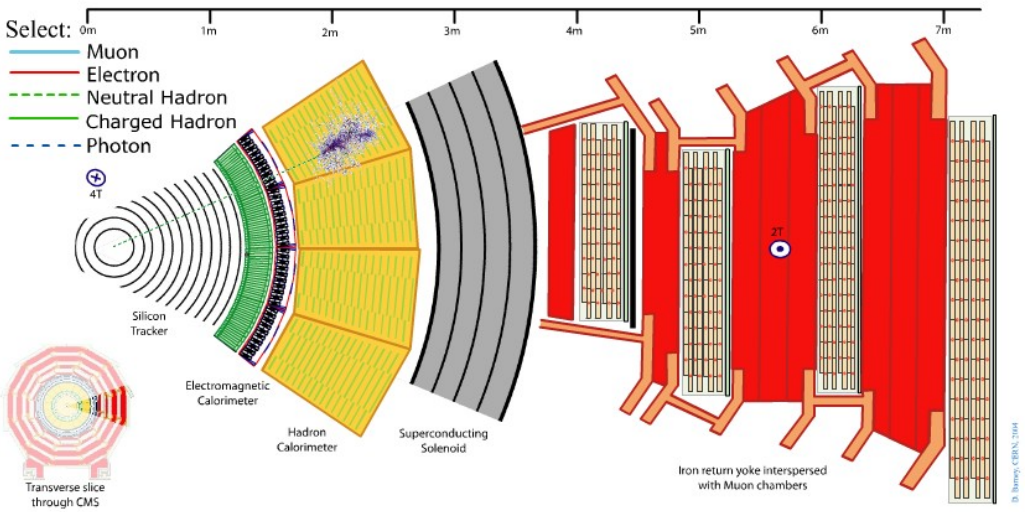






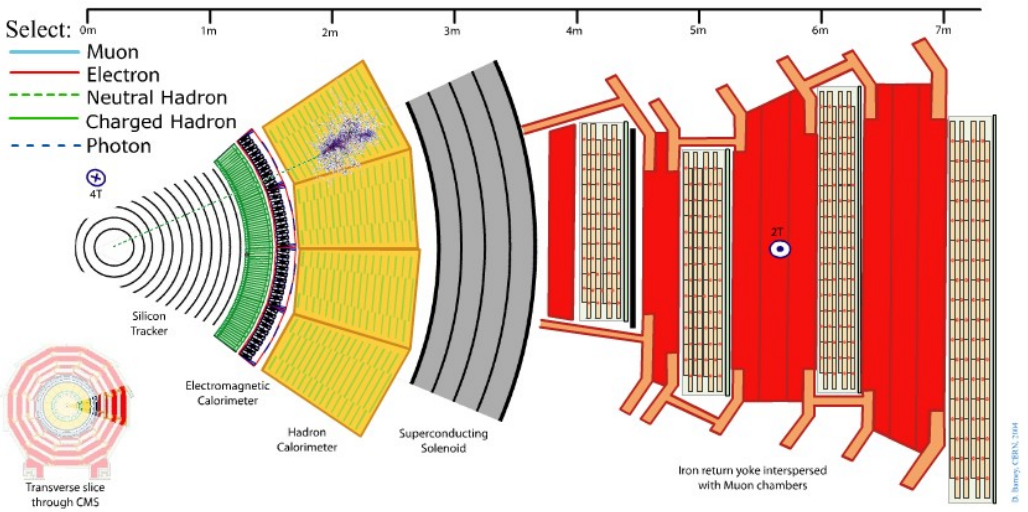
Tracker

- Largest silicon-sensor system ever made
  - More than 220m^2 of sensors
  - More than 60 million electronics channels (pixels and microstrips)
  - 6m long, ~2.2m diameter, operates at -15^{0}C



Calorimeter

- ElectroMagnetic
  - Lead tungstate ($PbWO_4$) crystals create electromagnetic showers and produce scintillation light
  - Barrel: ~64000 crystals
  - Endcaps: ~16000 crystals
- Hadron
  - Barrel HCAL made of 36 brass wedges, each of which is ~35 tonnes
  - Endcap HCAL made from brass recuperated from Russian military
  - Forward HCAL (known as HF) made from steel embedded with quartz fibres



The CMS Animation

Physics Object Reconstruction

- Electron
  - Find the hits in Ecal crystals, make the clusters
  - Find the tracks using the hits in tracker
  - If a cluster in Ecal matchs a track, it's a candidate for an electron
  - An electron from a physical process should be isolated
- Photons
  - An electron with no track (!!!)
- Muon
  - Match two tracks from Muon system and inner tracker

Reconstruction, a work in progress

- Inefficiency in reconstruction
  - Some of the objects can't be reconstructed well
- Impurities in reconstruction
  - Some objects are reconstructed by mistake
  - For example : a real electron always passes the jet reconstruction criteria and fakes as a jet
  - Taus and jets are also barely indistinguishable
- The value of these inefficiencies and impurities are important to claim a discovery ...
- The collaboration works to improve the algorithms

CMS and 2012 data taking