The Compact Muon Solenoid Detector

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CALTECH/CERN

Compact Muon Solenoid

In three parts:

1. What is it
2. How it works
3. How it was built

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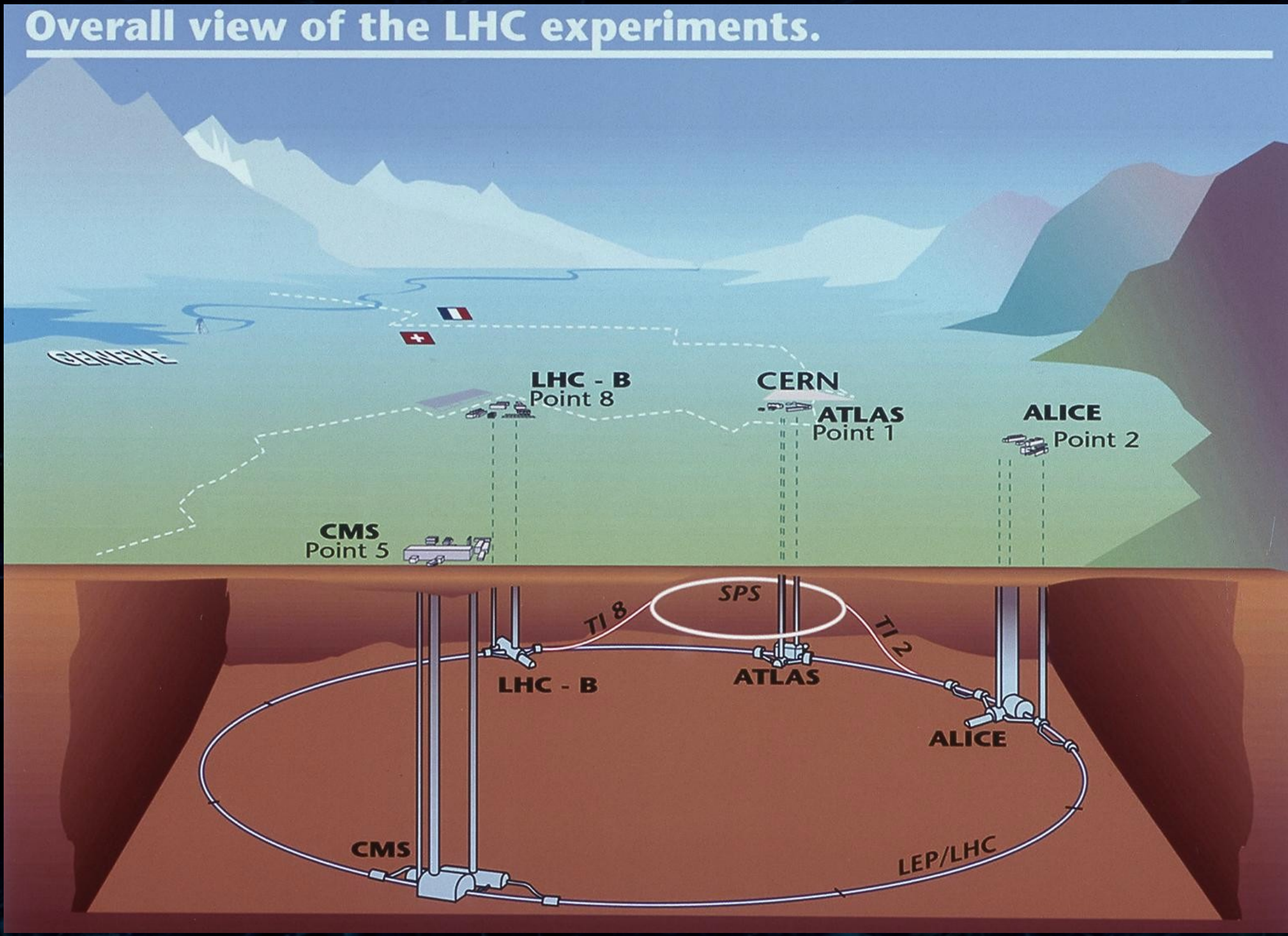
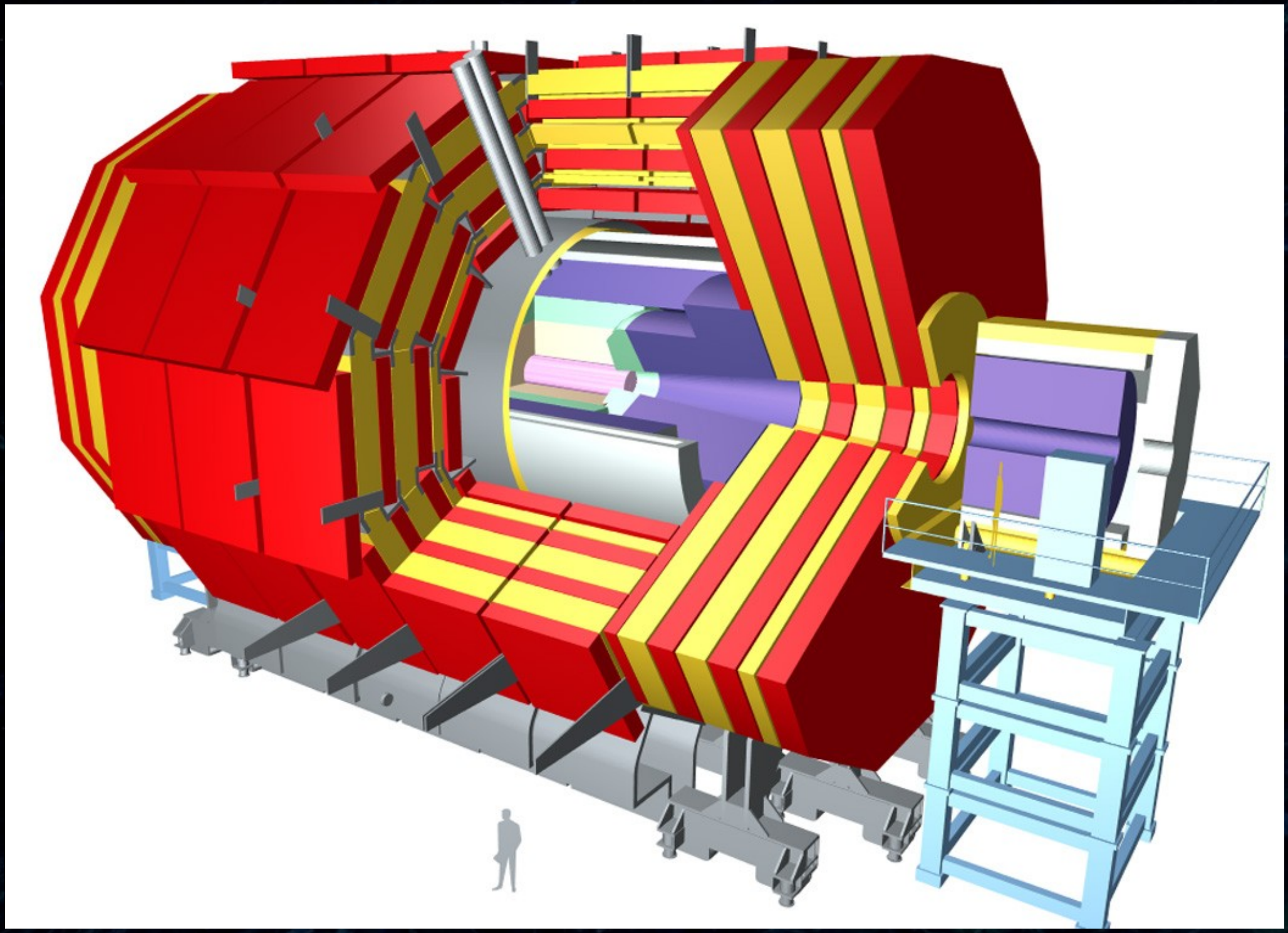
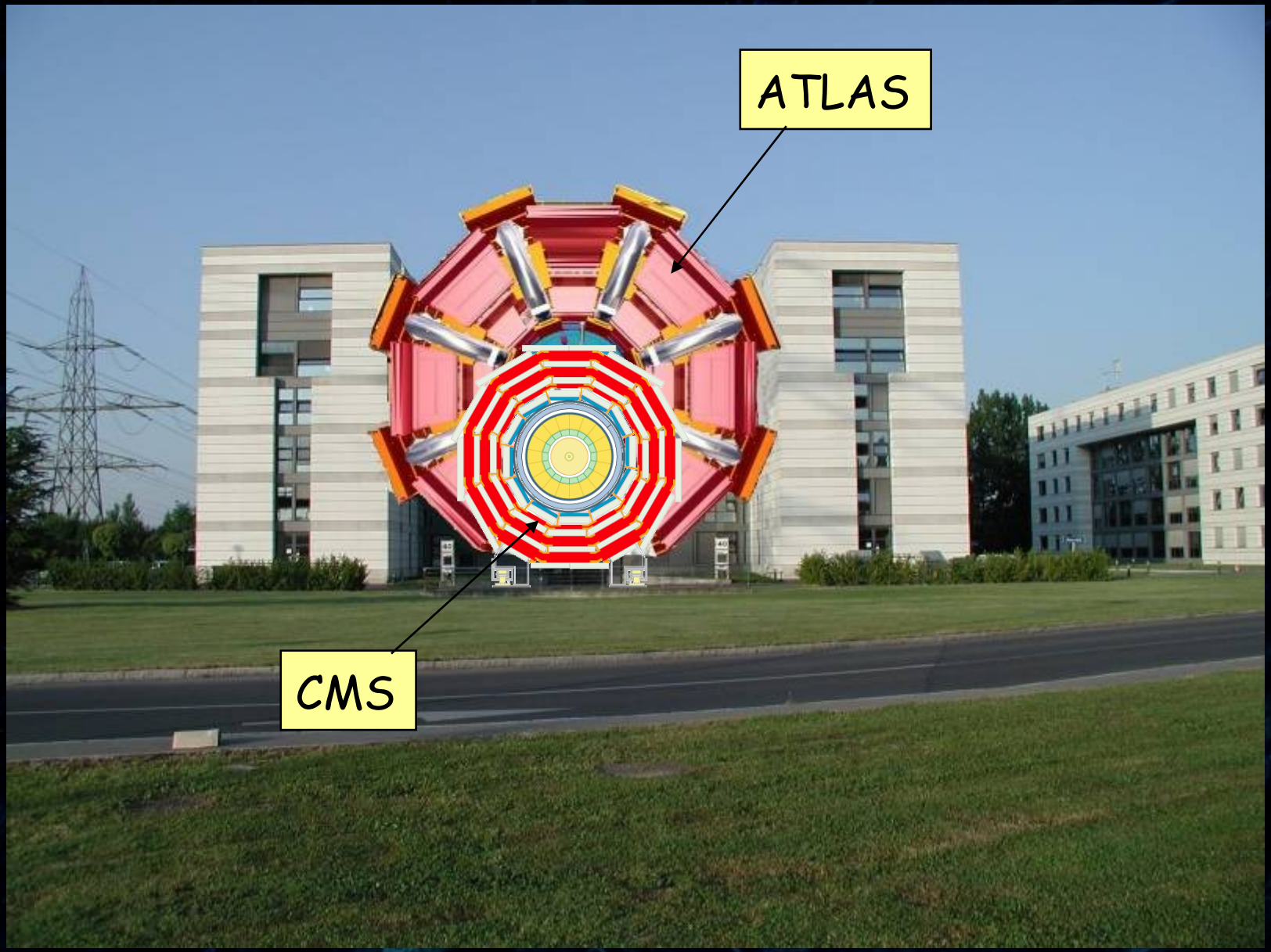
Overall view of the LHC experiments.





Compact

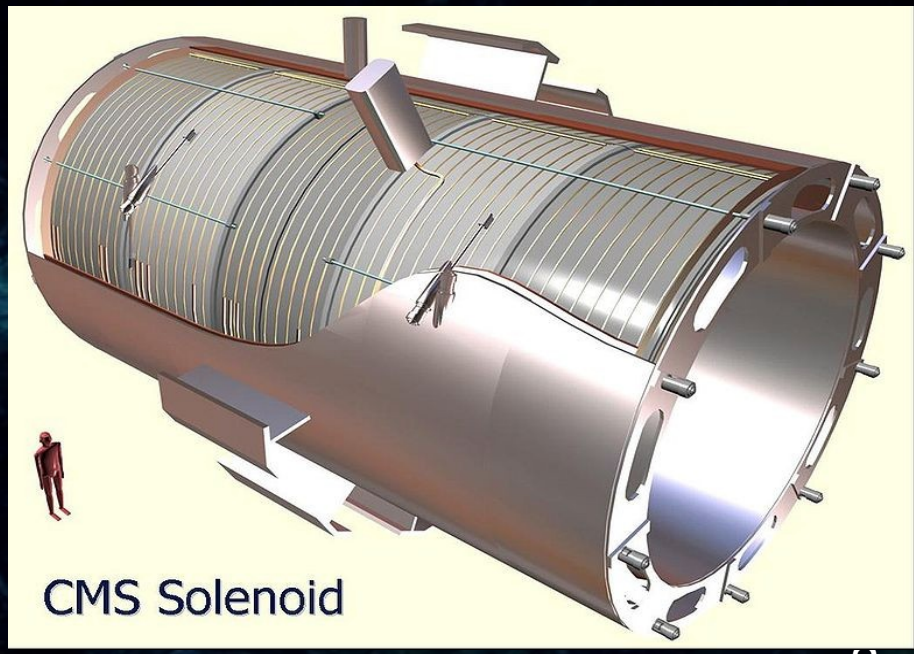


Muon

- The CMS detector was designed to provide optimal measurement of muons
- Muons give a relatively „clean" signal
- They appear as decay products of other particles in many of the processes we want to study

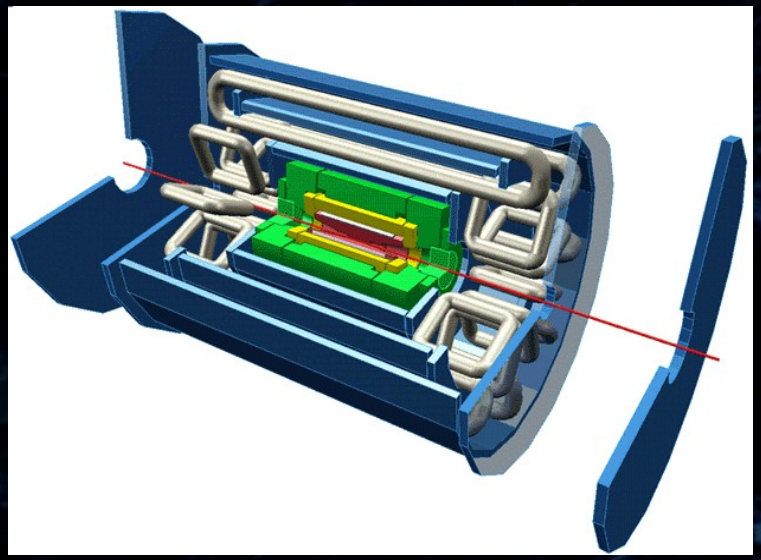
Solenoid

- CMS is built around a superconducting solenoid generating a magnetic field of 4 Tesla
- The current necessary for this – 20 kA…
- Superconducting NbTi wire cooled to ~4K
- 13m length, 6m inner diameter – enough to fit the tracker and calorimeters inside
- (cost ~80 MCHF)

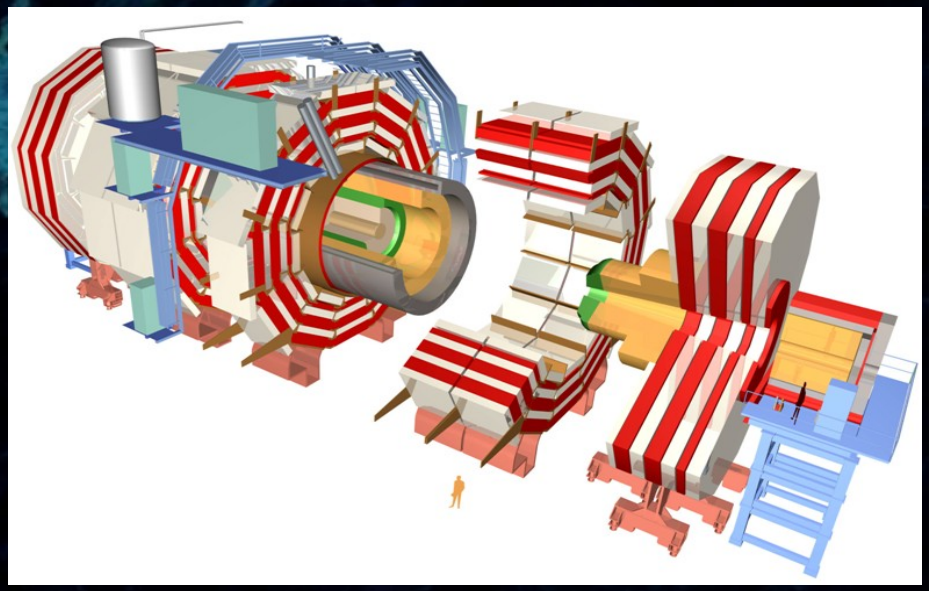


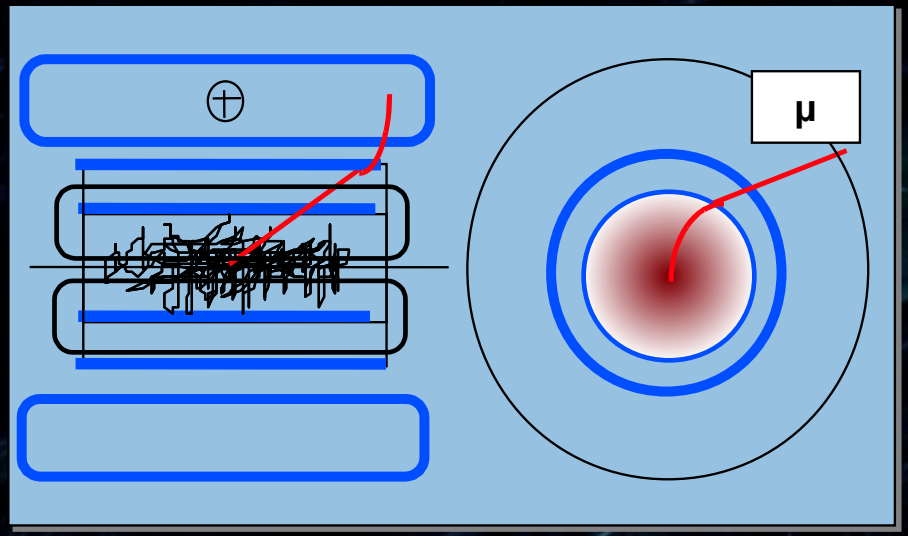
Magnets in particle detectors

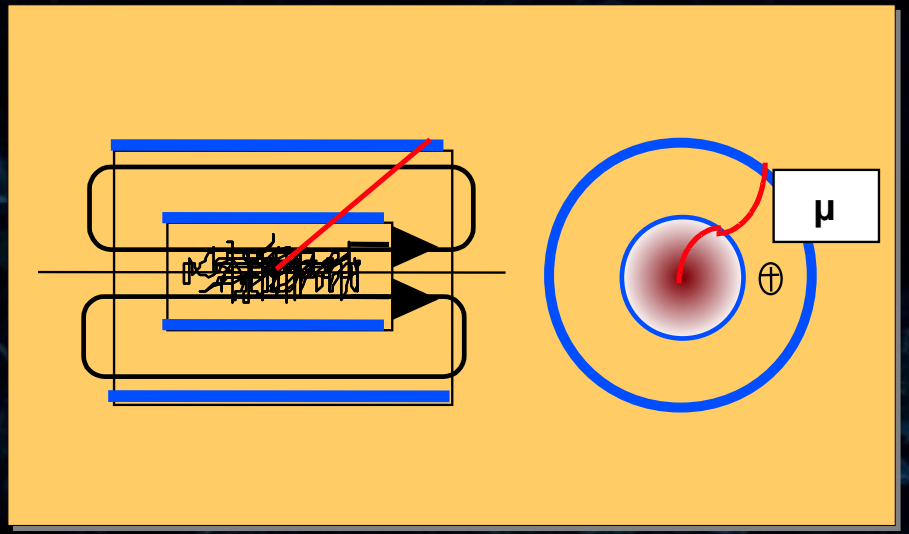
ATLAS A Toroidal LHC Apparatus



CMS Compact Muon Solenoid

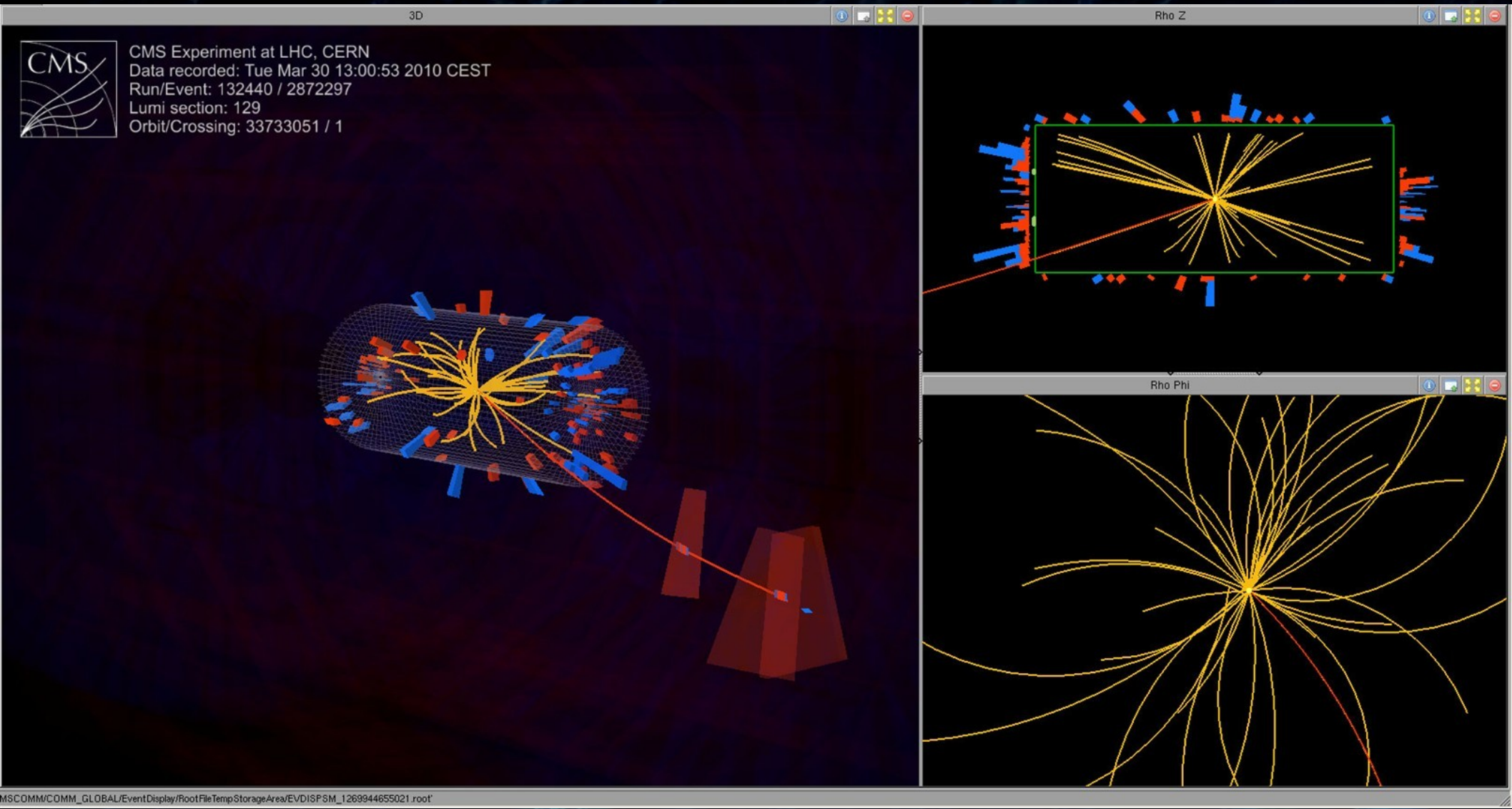




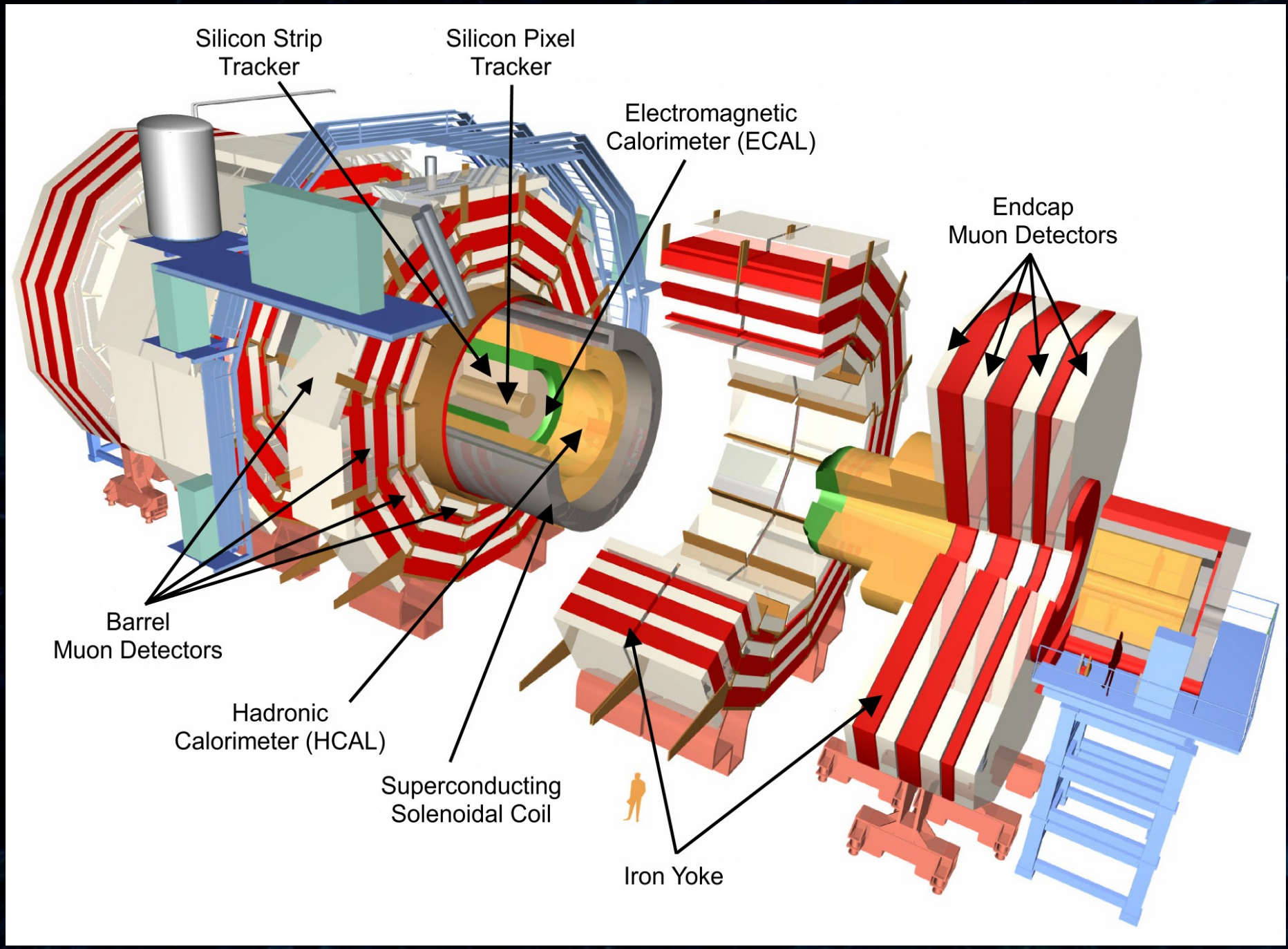


A proton-proton collision

as seen by CMS



CMS detector overview



Compact Muon Solenoid

In three parts:

1. What is it
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Two ways to detect a particle

(in CMS)

Two ways to detect a particle

(in CMS)

See the track

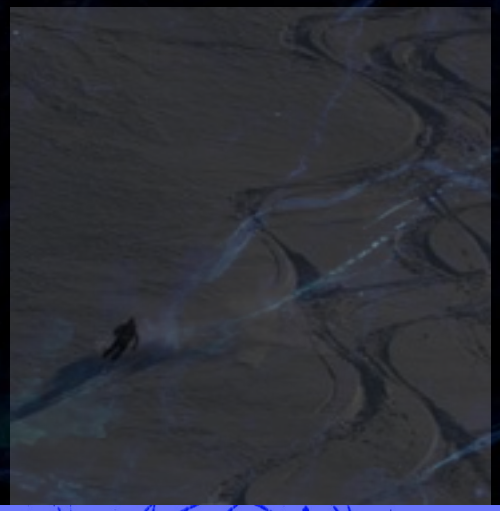
Or

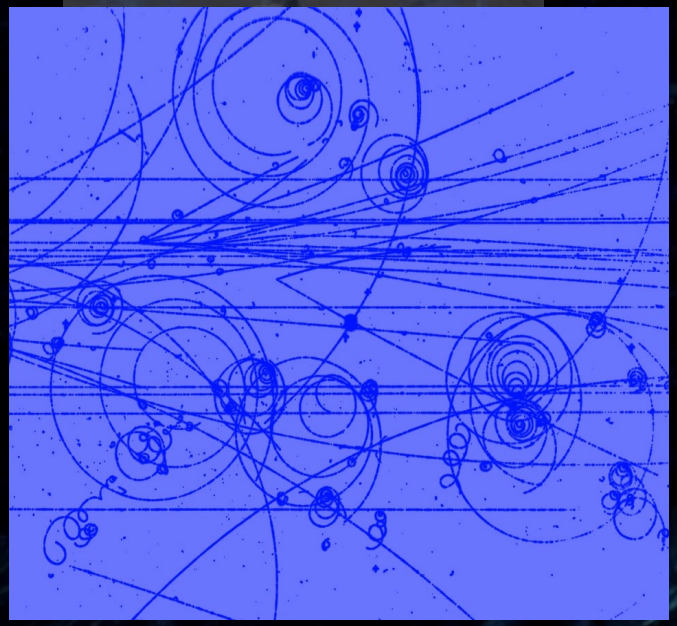
Catch

Two ways to detect a particle

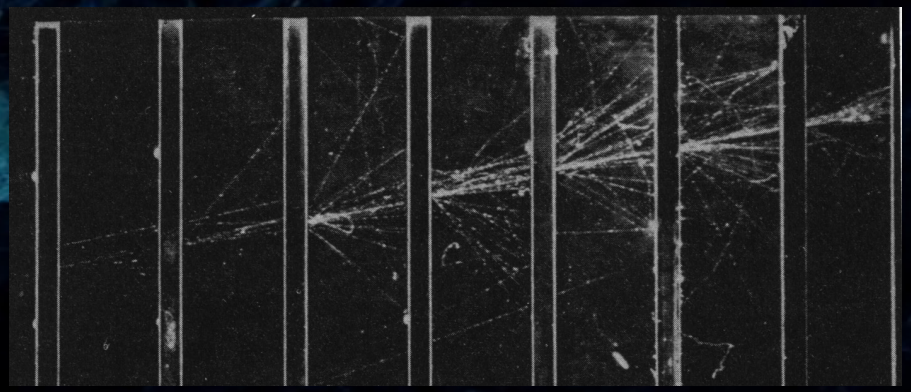
(in CMS)

Tracking detector



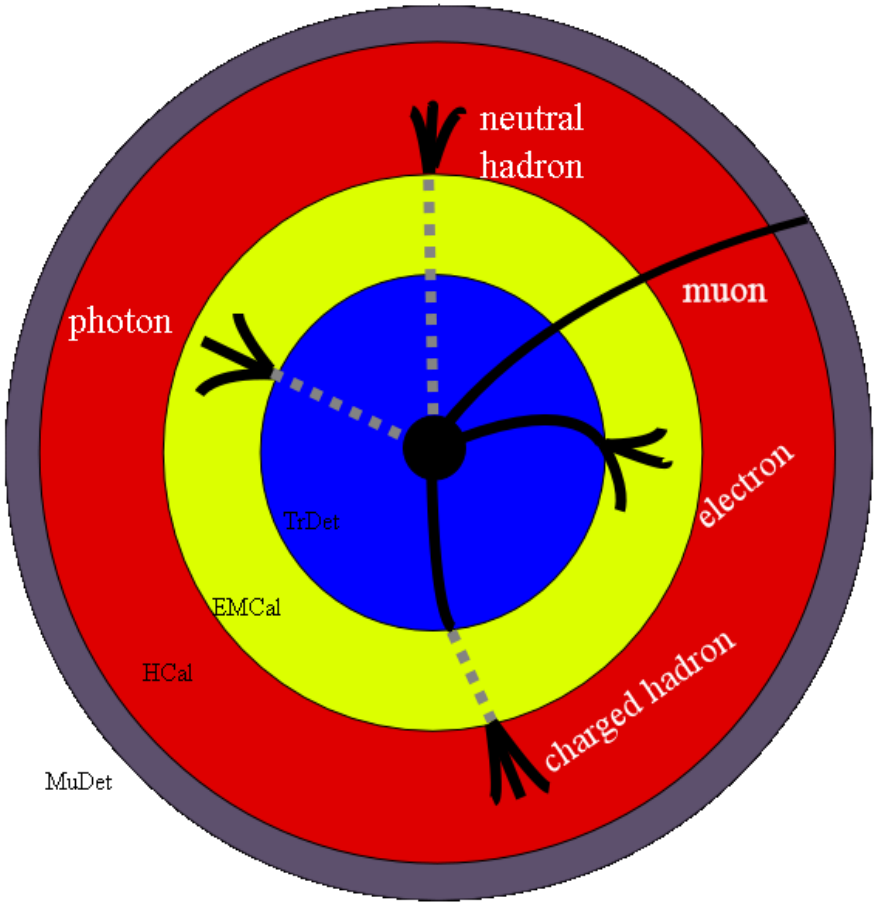


Or



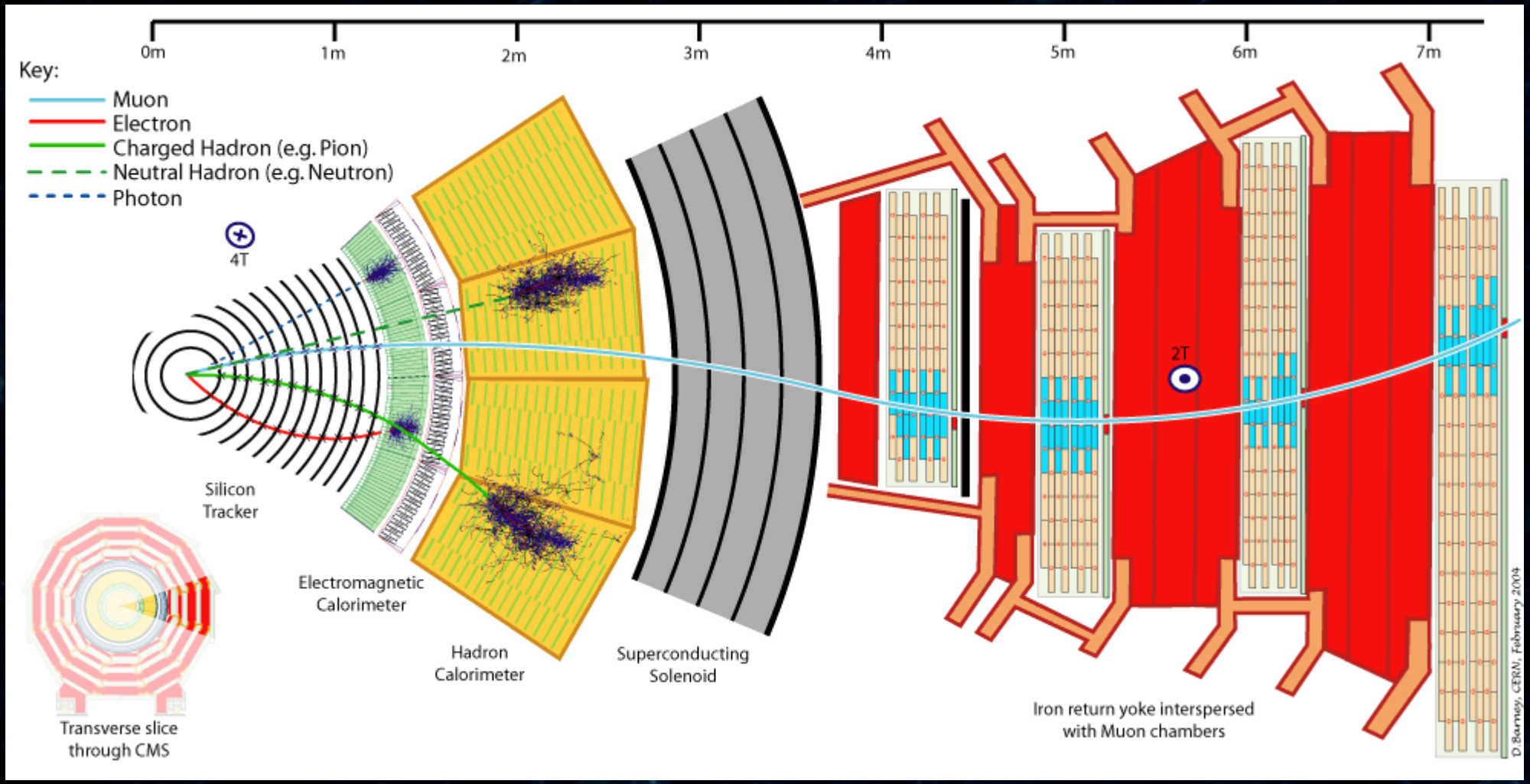
Calorimeter

Particle detectors are like...



MuDet: muon detectors
TrDet: trace detector + vertex detector
EMCal: elekcromagnetic caloriméter
HCal: hadron caloriméter

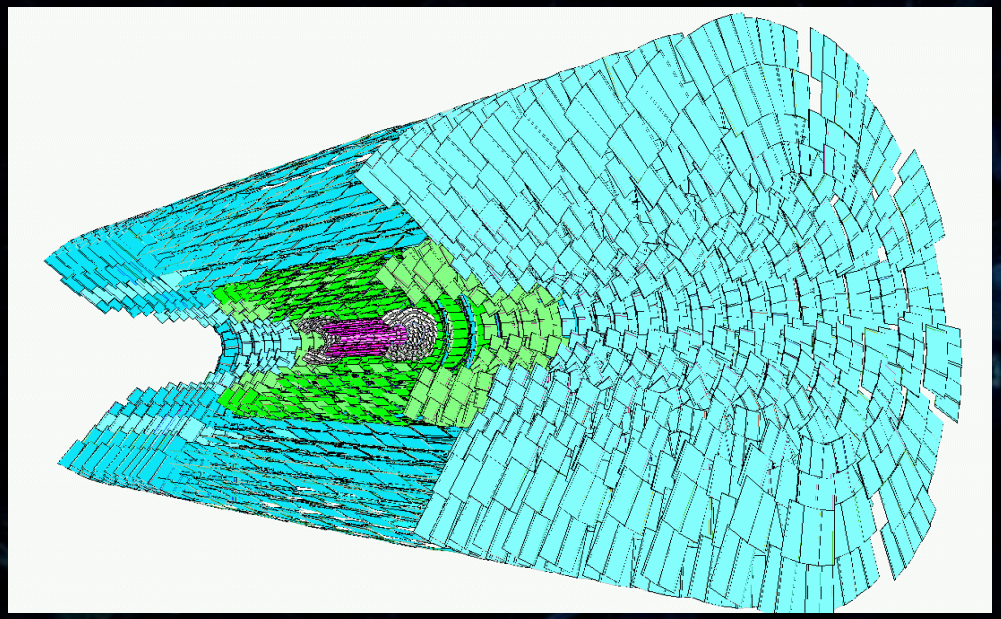
Particle identification in CMS

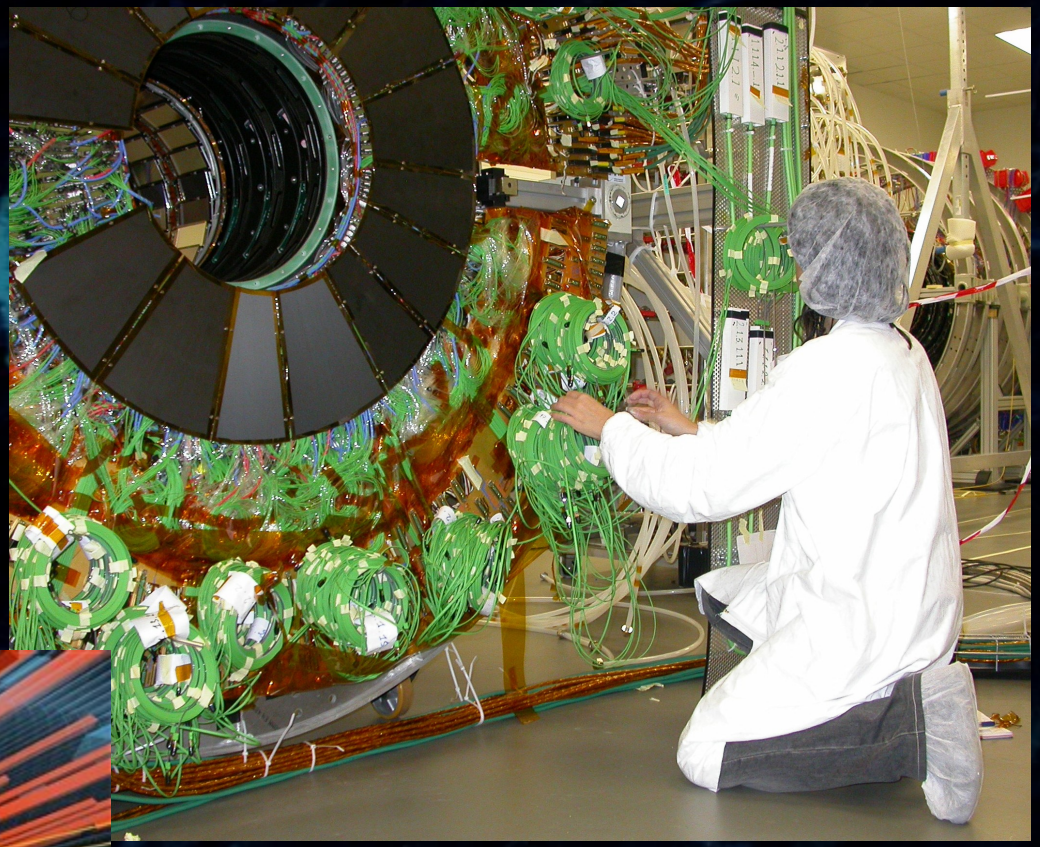


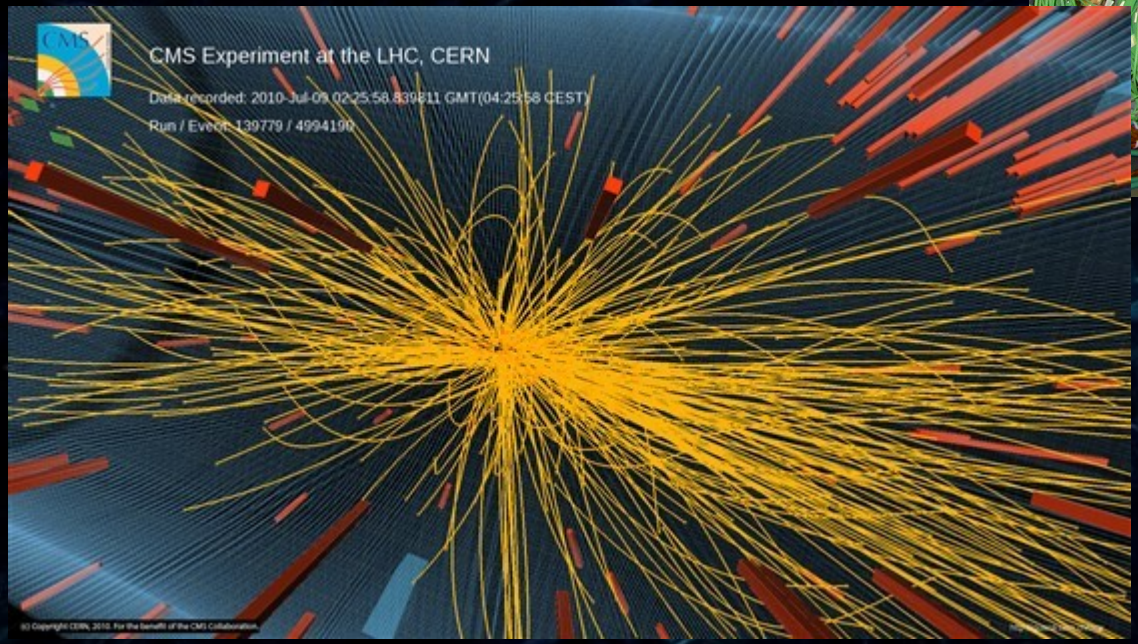
The Tracker

- Measures the trajectories of charged particles, result – momentum measurement and secondary vertex finding
- The biggest silicon detector in history
- Over 220m^2 of silicon
- 75 milions of read-out channels
- Inner part – 3 layers of pixel detectors, outside part 10-11 layers of silicon microstrips

Tracker

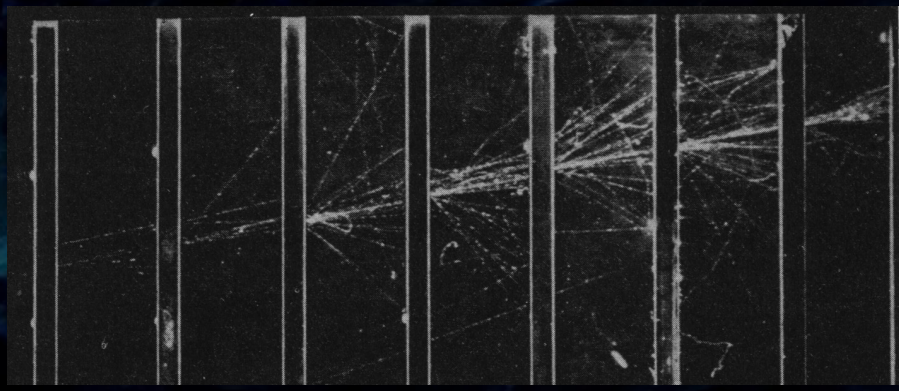




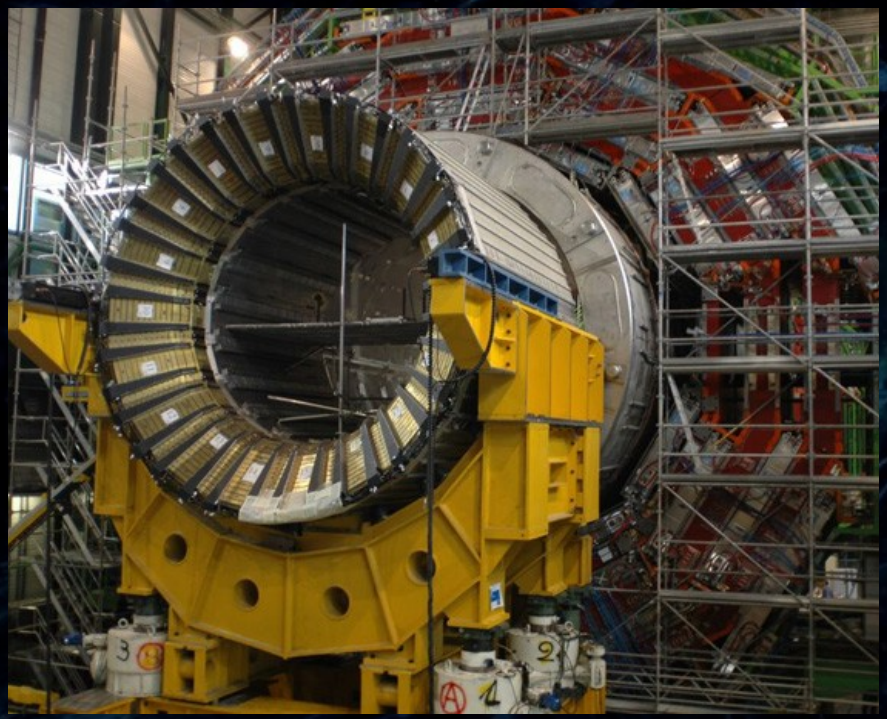

CMS Experiment at the LHC, CERN
Data recorded: 2010-Jul-09 02:25:58.839811 GMT(04:25:58 CEST)
Run / Event: 139779 / 4994190

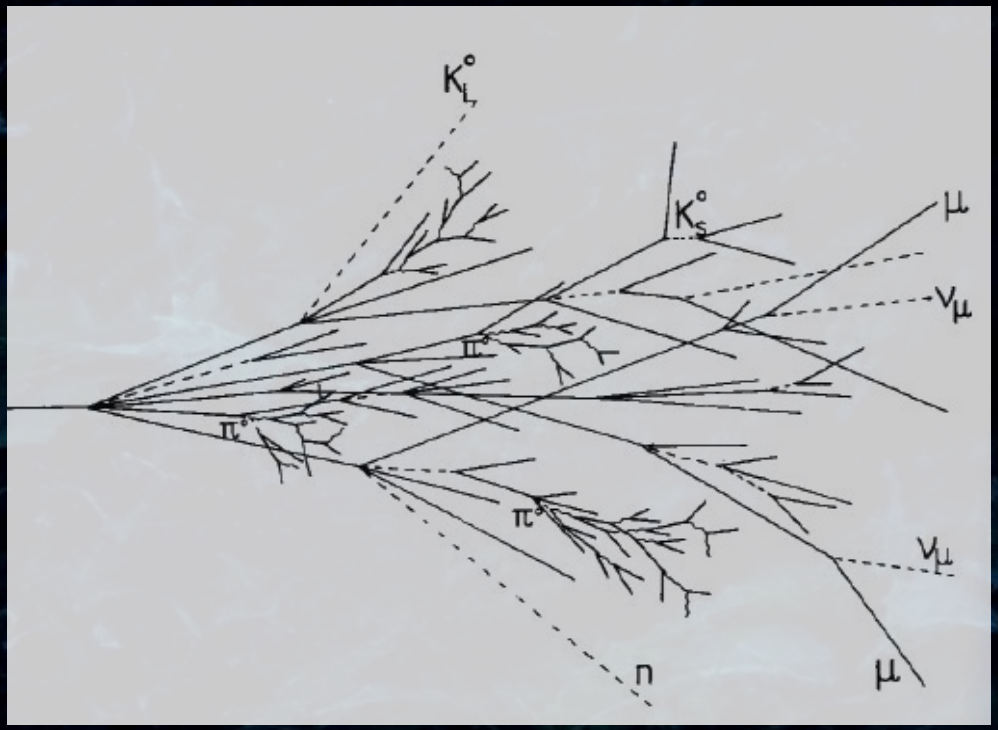
Hadron Calorimeter

(swap order)



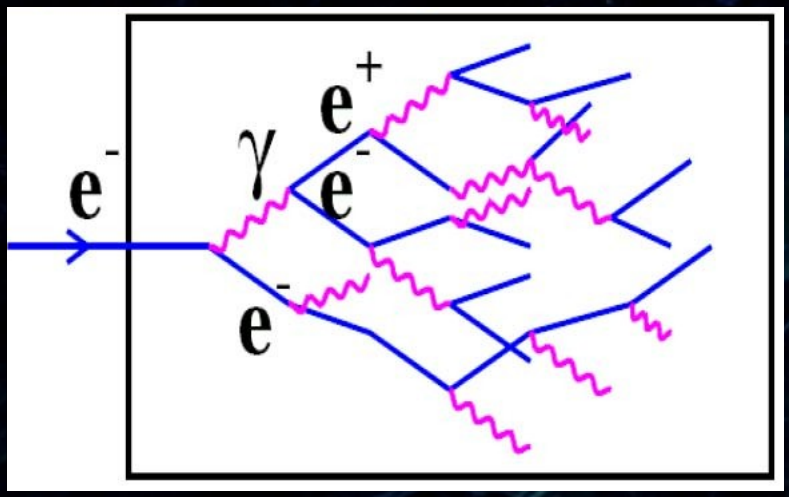
- Jet energy measurement
- Brass absorber interleaved with scintillator layers
- Steel blocks with embedded quartz fibers in the „forward" part

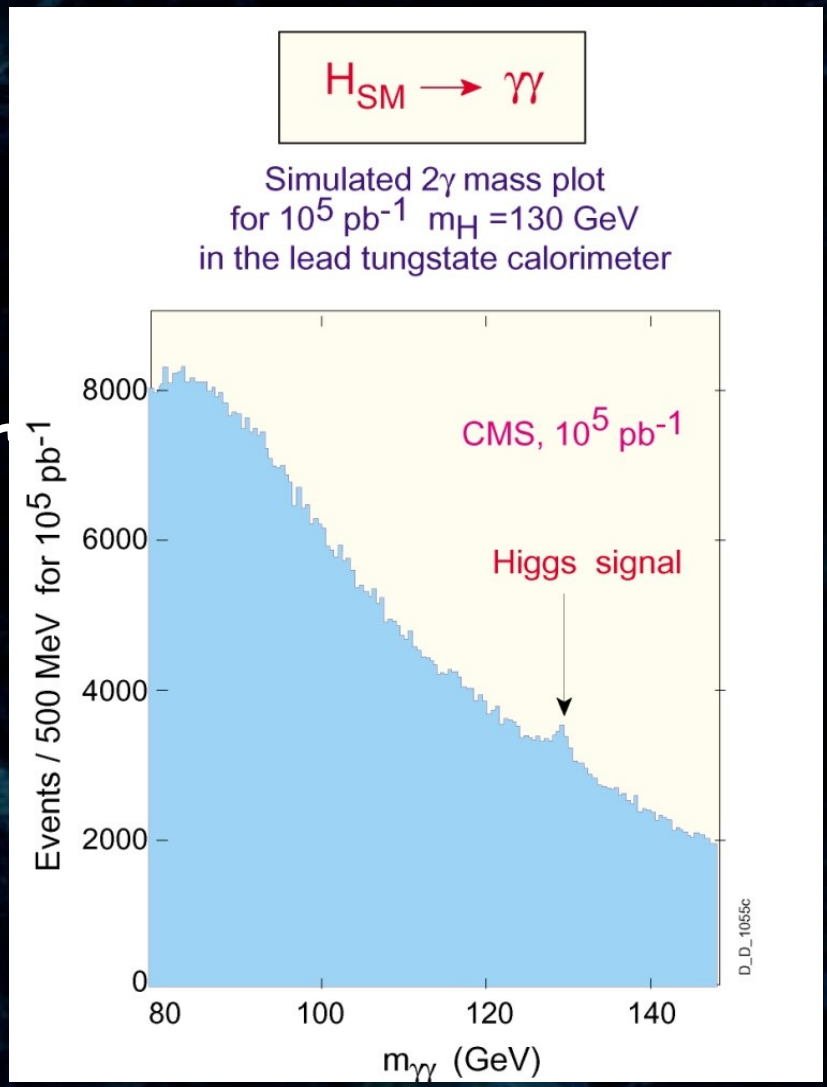


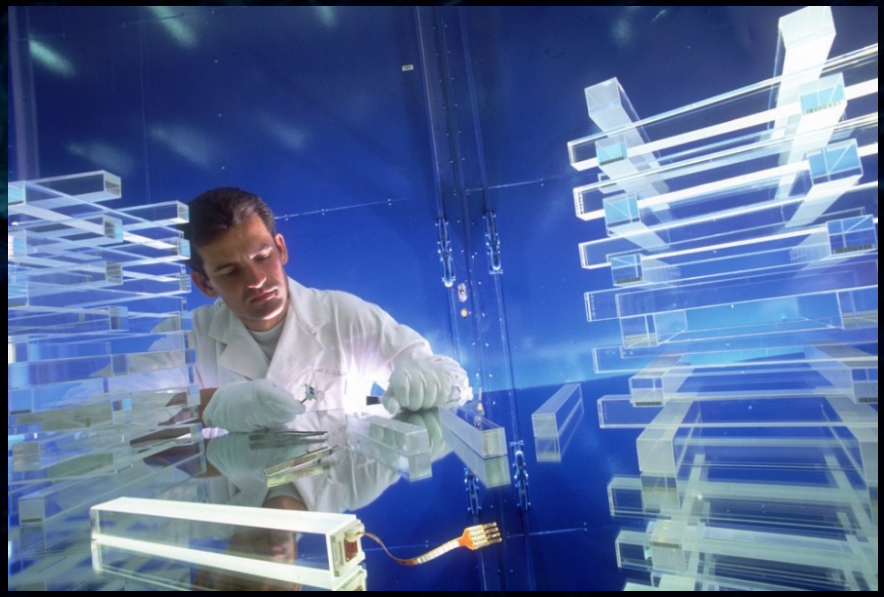


Electromagnetic Calorimeter

- Electron and photon energy measurement
- ~80 000 $PbWO_4$ crystals
- Homogeneous detector - crystals act as both the absorber and the scintillator
- Very good energy resolution







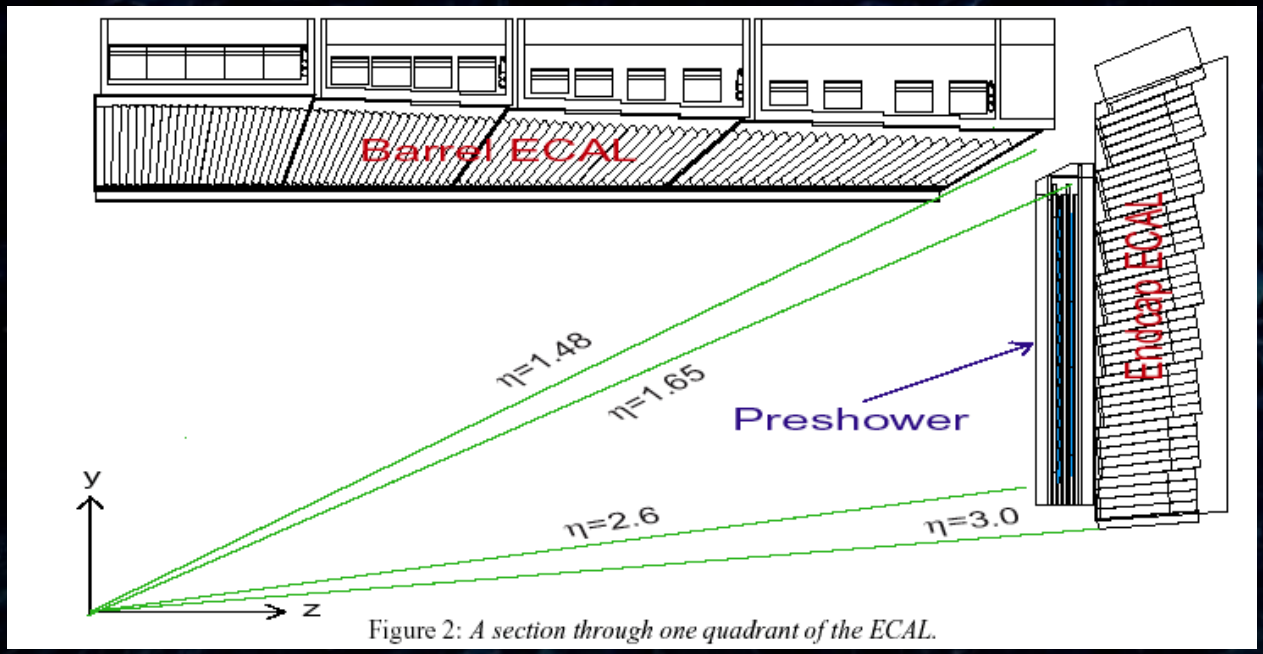
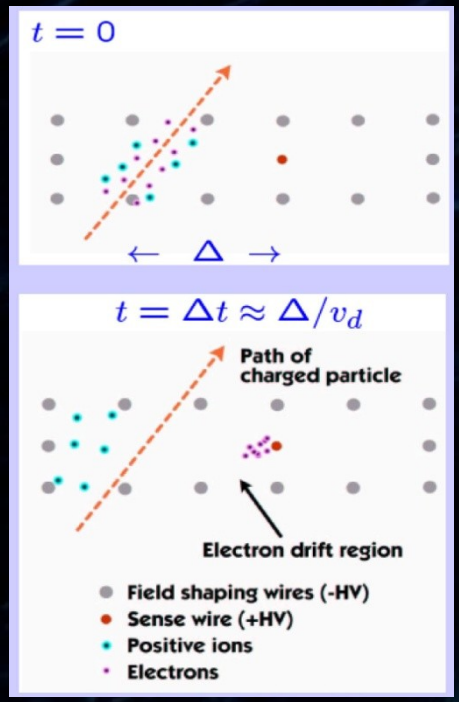
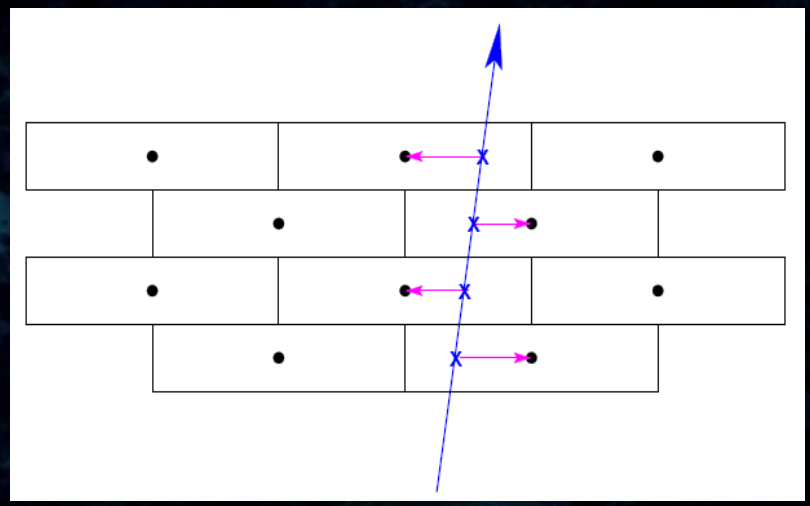


Figure 2: *A section through one quadrant of the ECAL.*

The Muon System - Drift Tubes

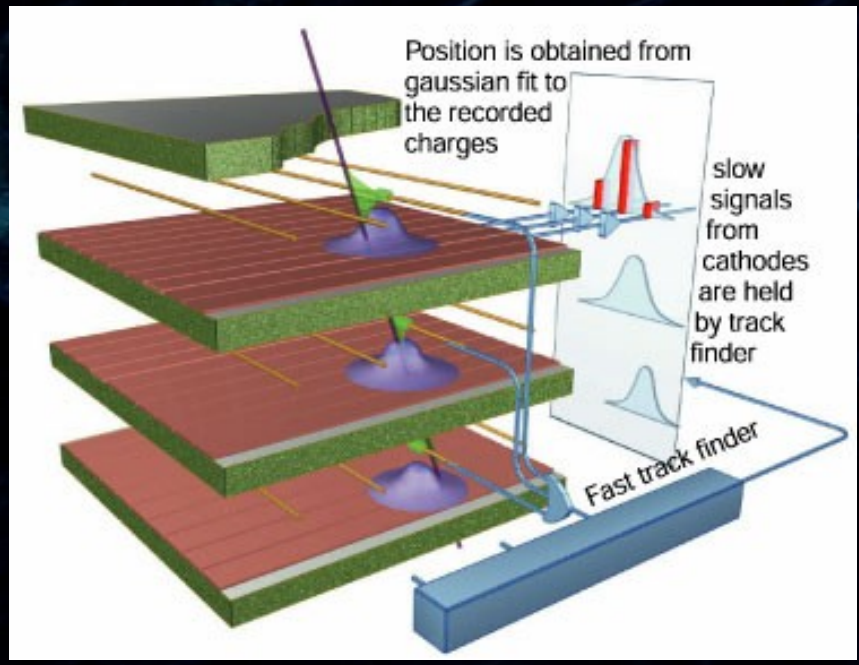
- Muon trajectory measurement (barrel)
- Measured quantity - drift time of electrons produced by the passing muon
- Known drift velocity → distance measurement (~50-200μm precision)
- Alignment very important



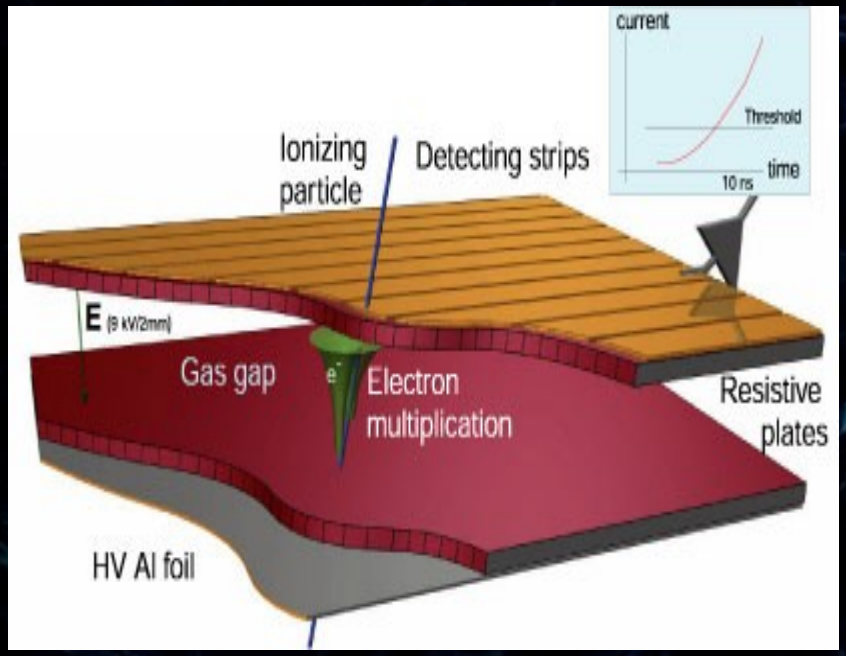


Cathode Strip Chambers (CSC)

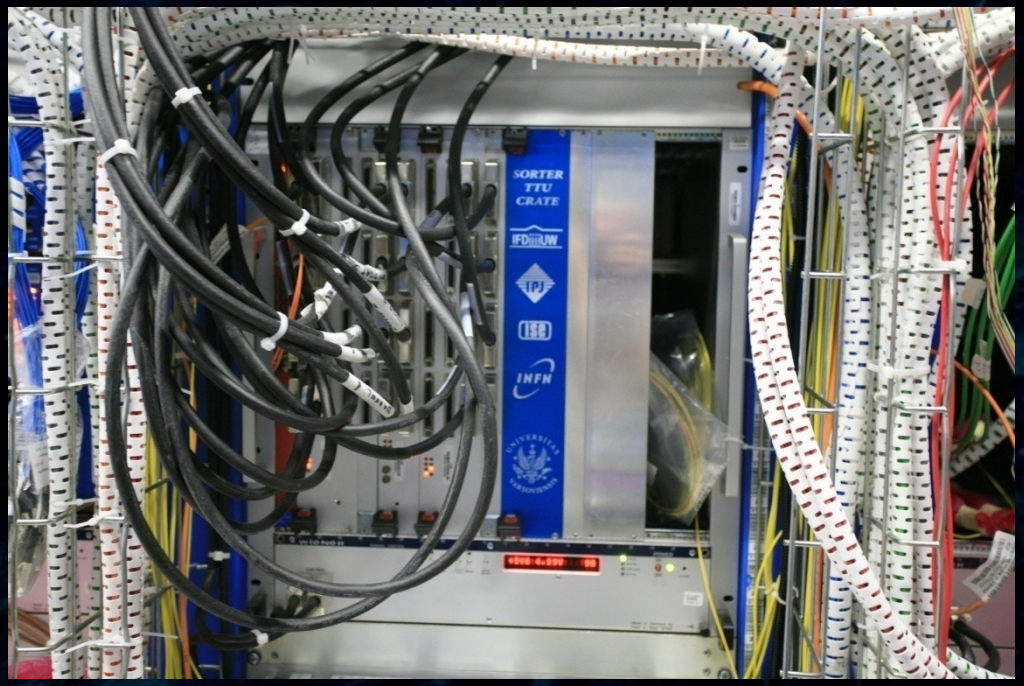
- Muon trajectory measurement in the endcaps
- Gaseous detector with layers of anode wires and cathode strips

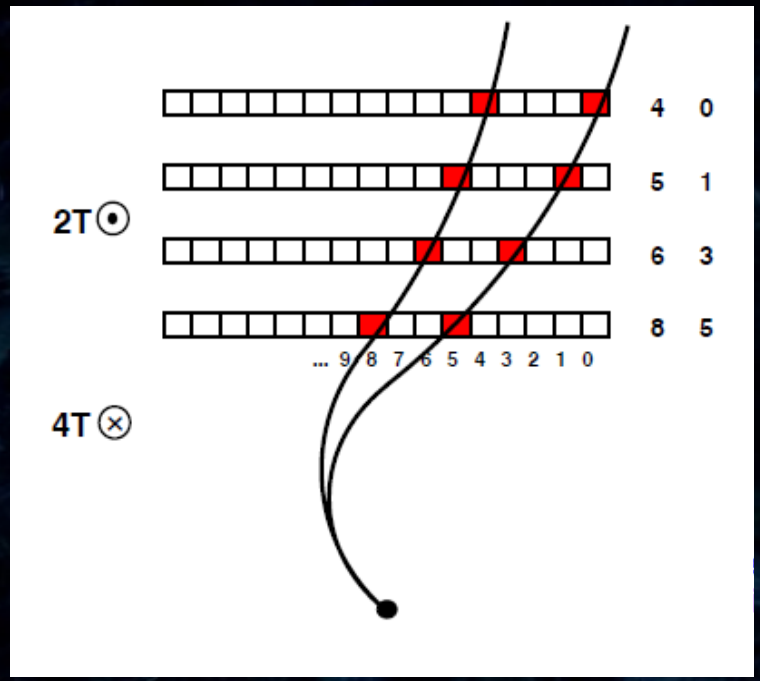


Resistive Plate Chambers (RPC)

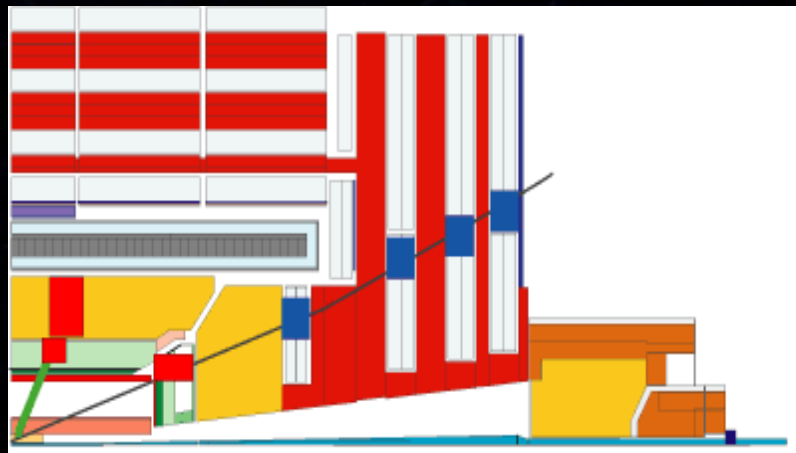


- Aim – fast estimation of muon momentum for the trigger system
- Logic - predefined pattern comparation



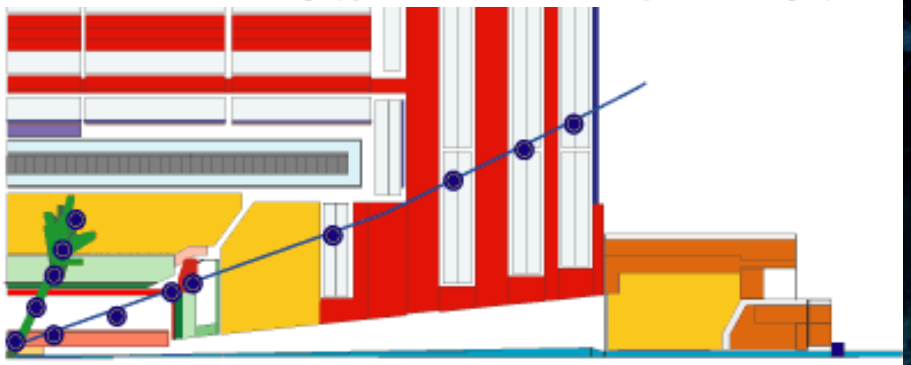


Trigger



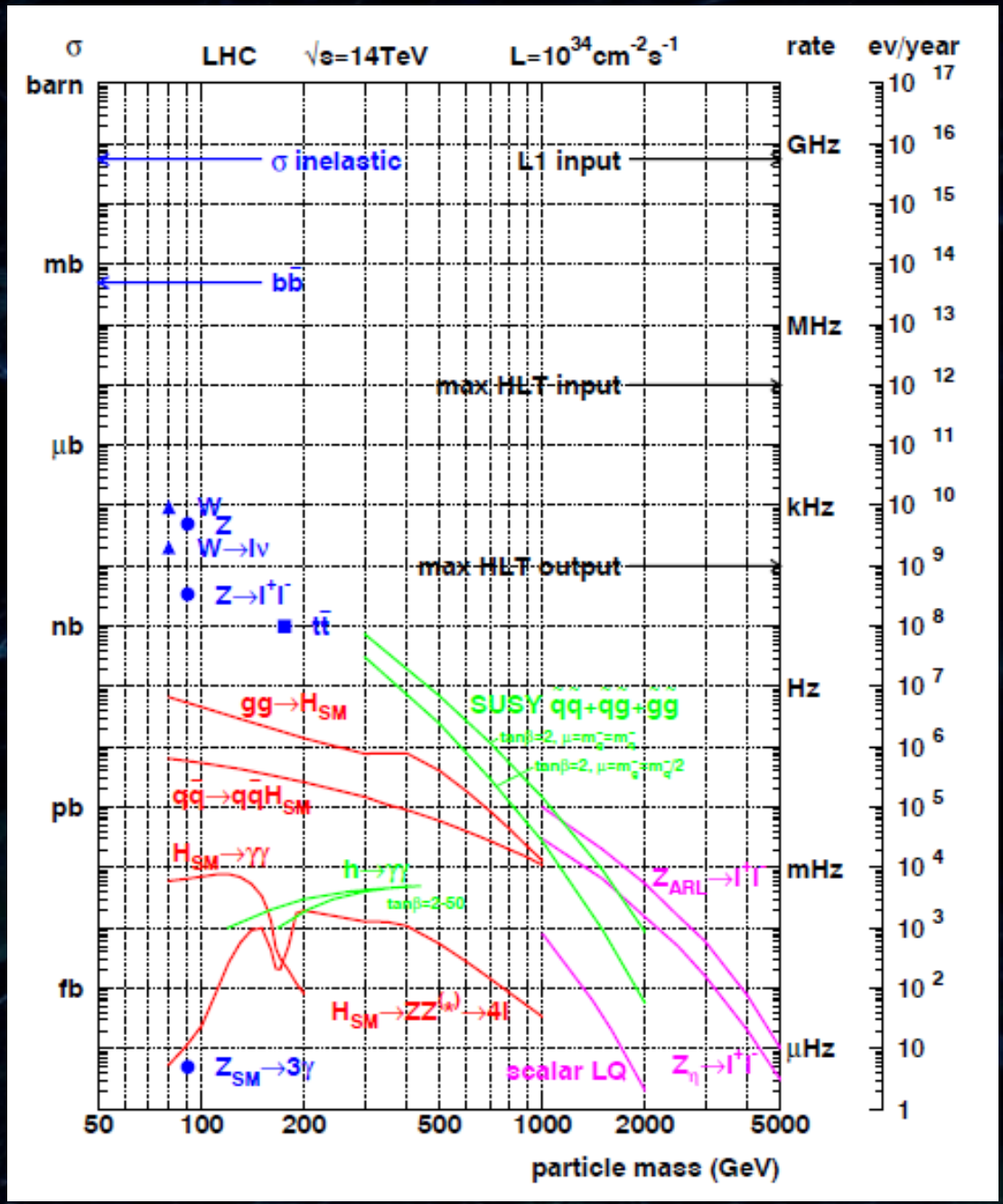
Level-1 trigger. 40 MHz input :

- Specialized processors (25 ns pipelined, latency < 1 s
- Local pattern recognition and energy evaluation on prompt macro-granular information from calorimeter and muon detectors
- Particle identification: high p_t electron, photon, muon, jets, missing E_T



High trigger levels (>1). 100 kHz input :

- Large network of processor farms
- Clean particle signature. All detector data
- Finer granularity precise measurement
- Effective mass cuts and event topology
- Track reconstruction and detector matching
- Event reconstruction and analysis



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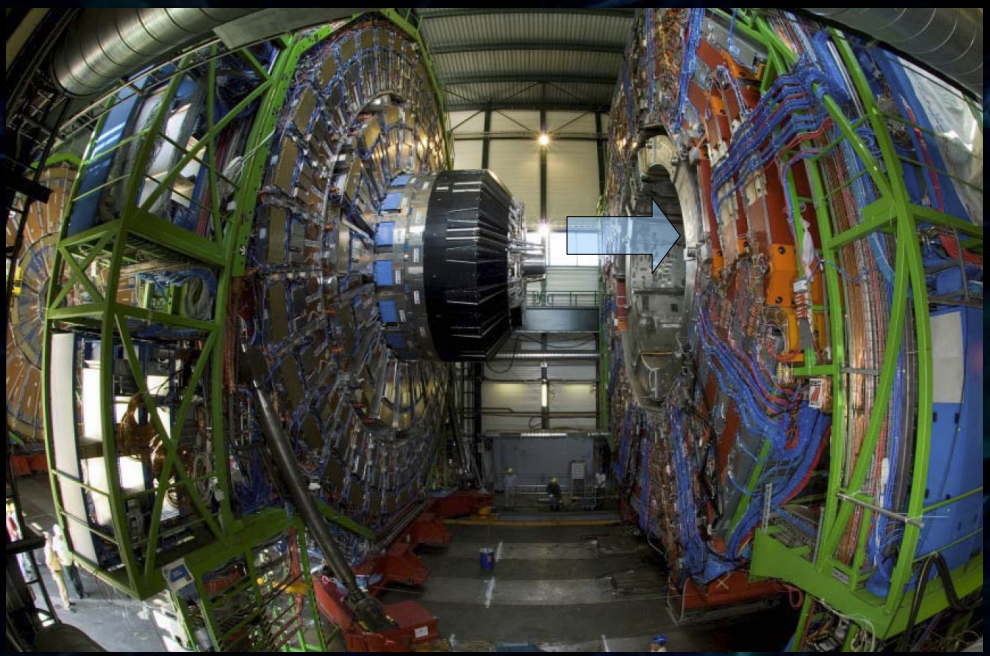
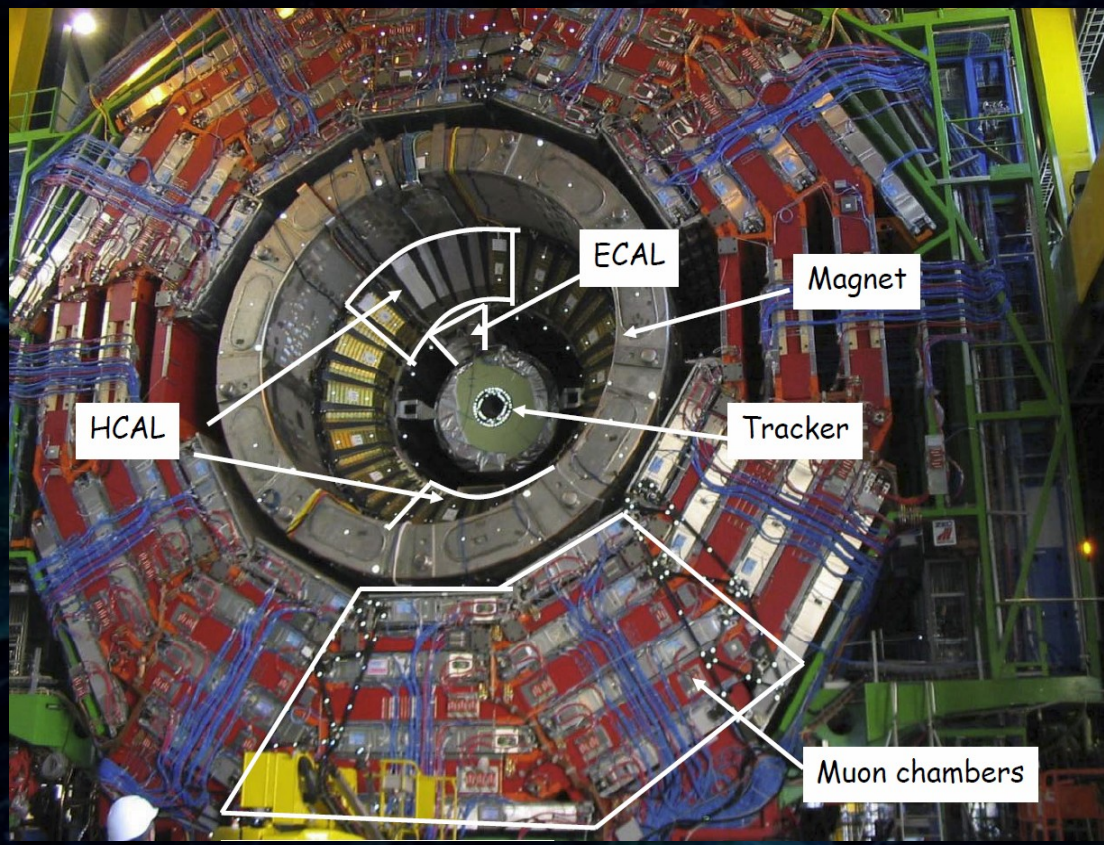
1998

2000

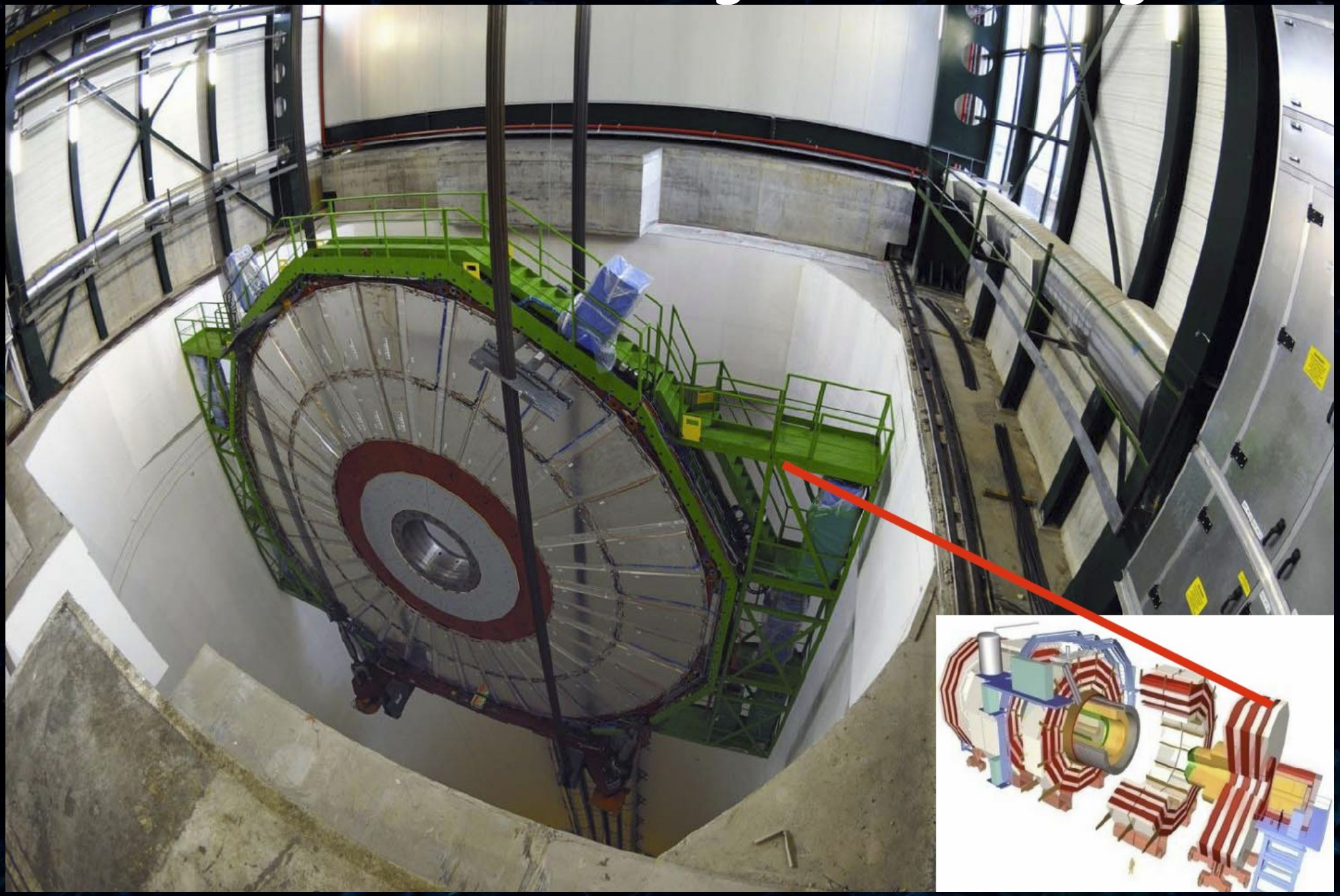
2006

- The detector was assembled and operated still in the surface hall
- MTCC – Magnet Test and Cosmic Challenge

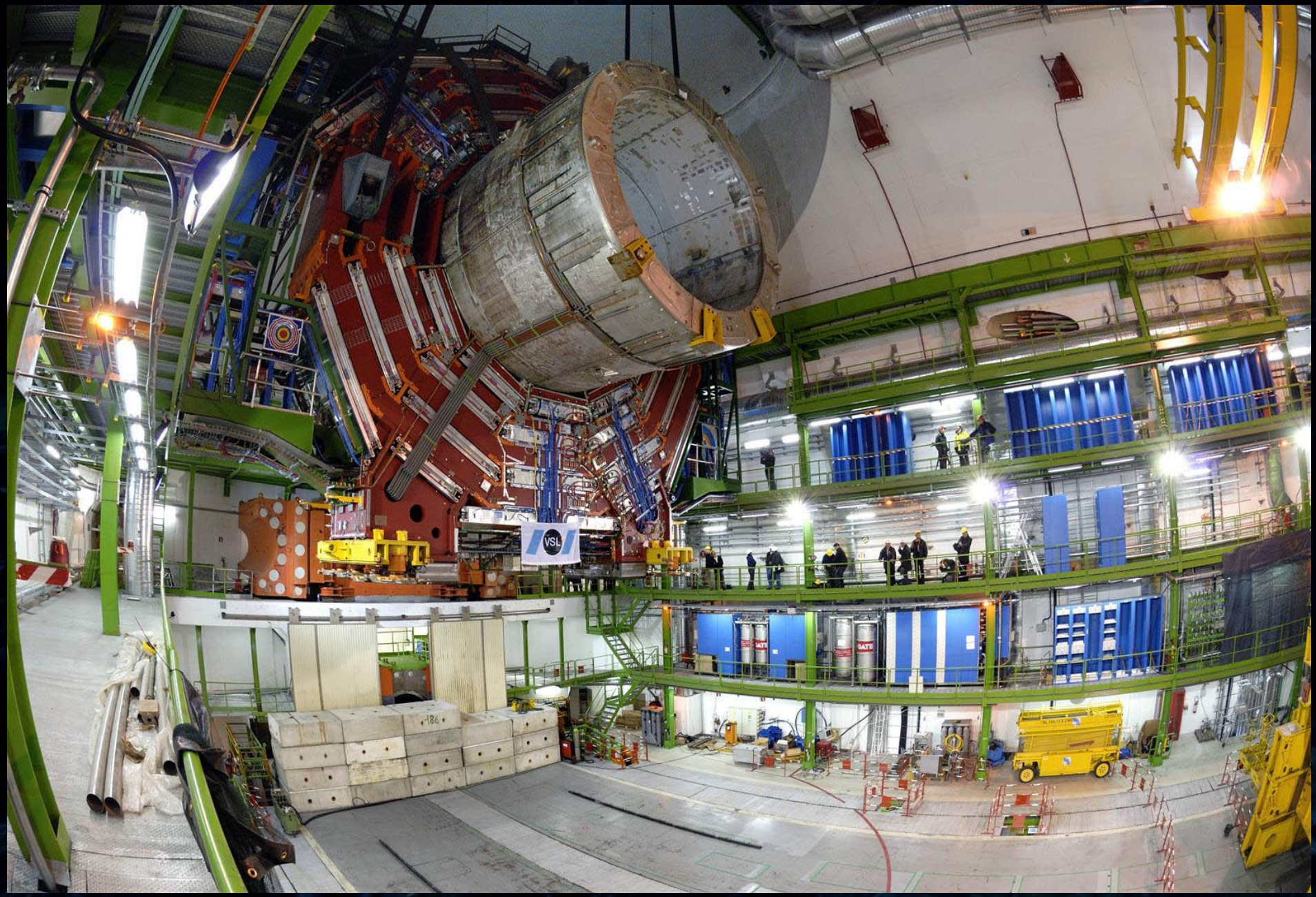




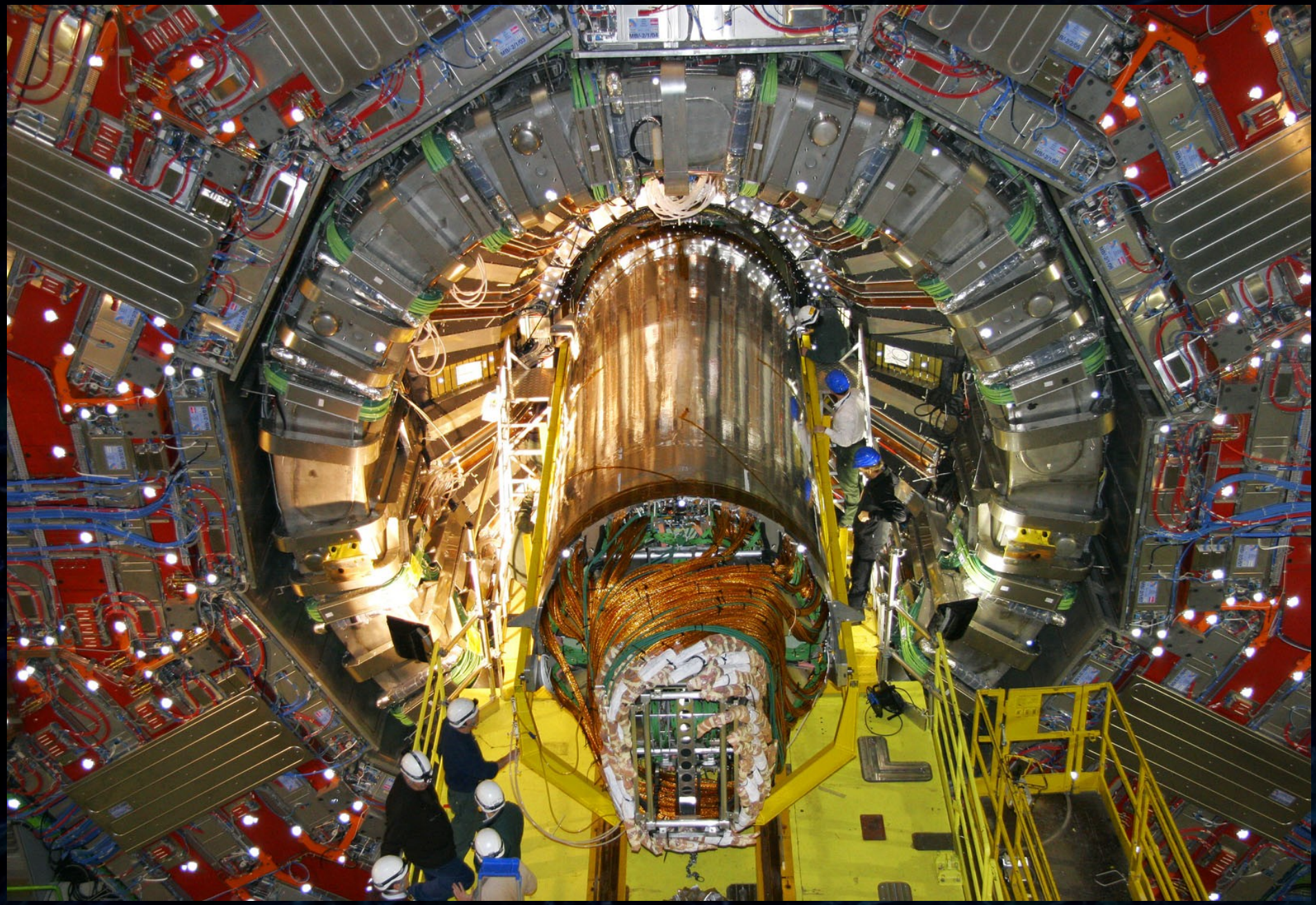
End of 2006 – lowering 100m underground



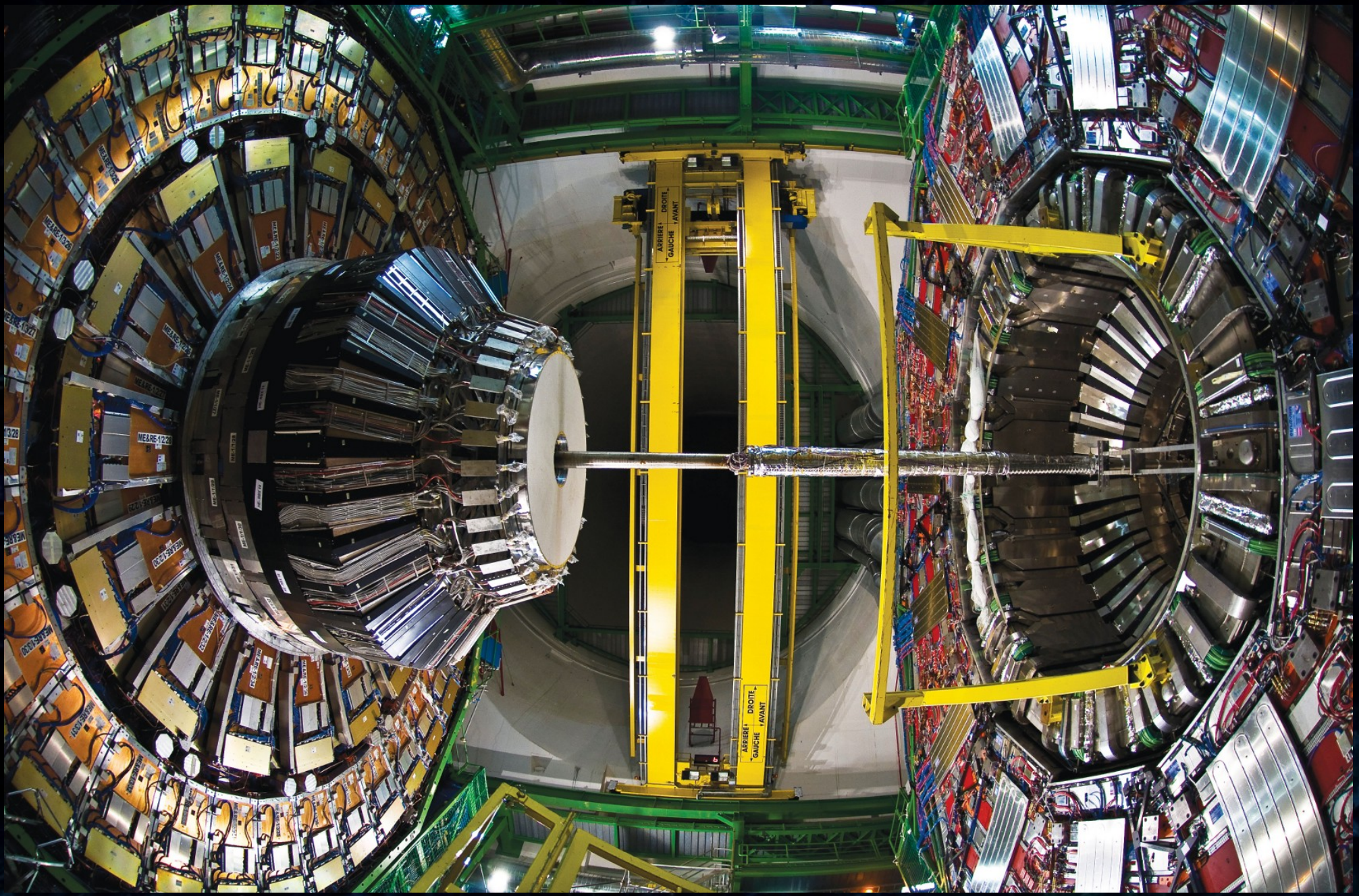
Feb 2007 – lowering the central wheel



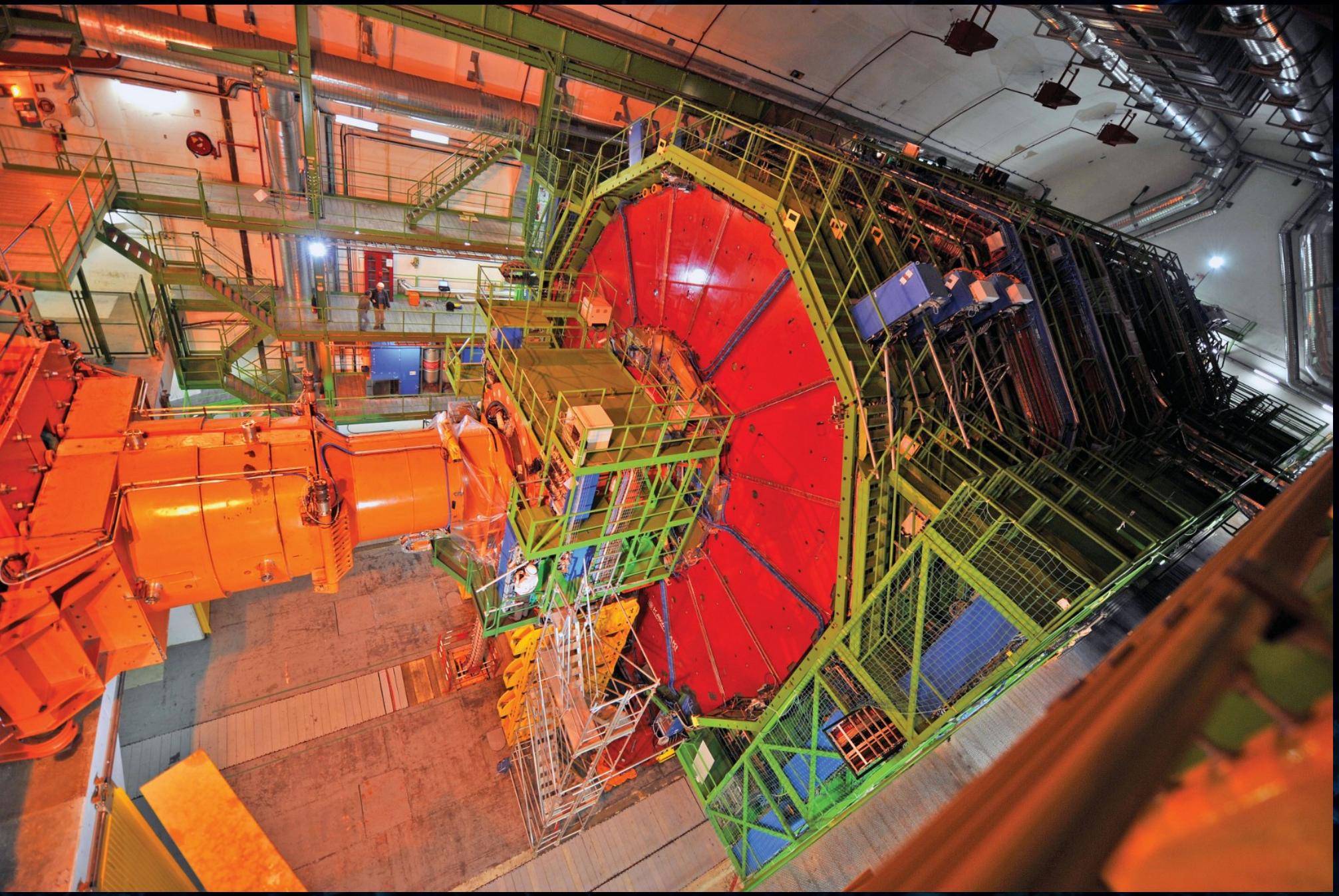
March 2008 – inserting the Tracker



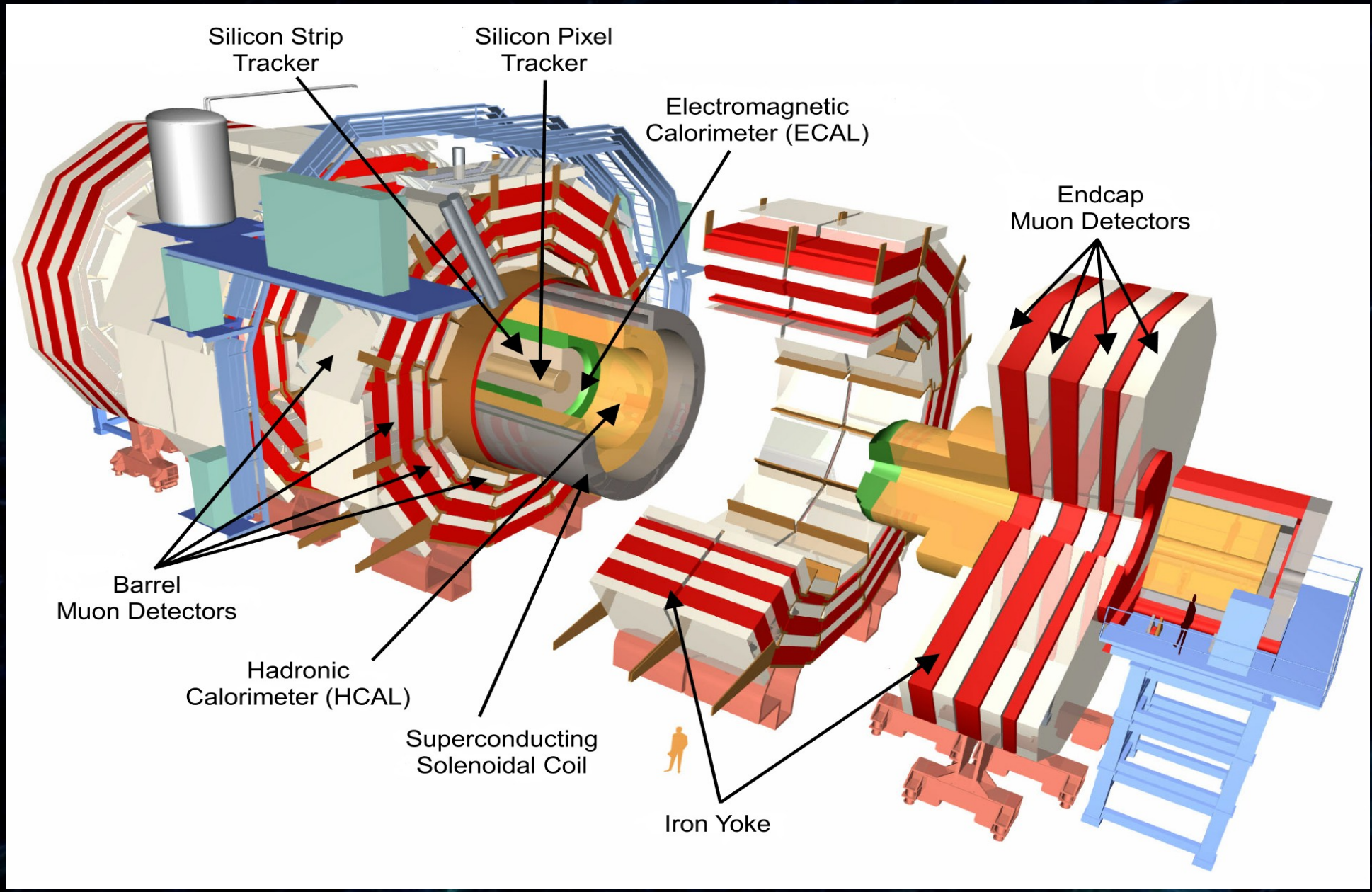
June 2008 – installation of the beam pipe



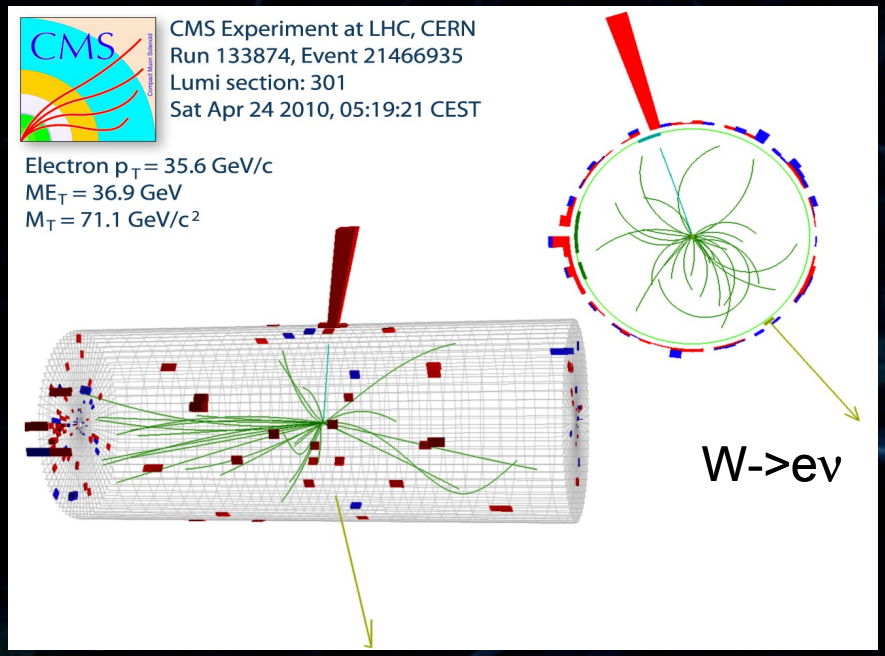
Sept 3rd, 2008 - Final closure

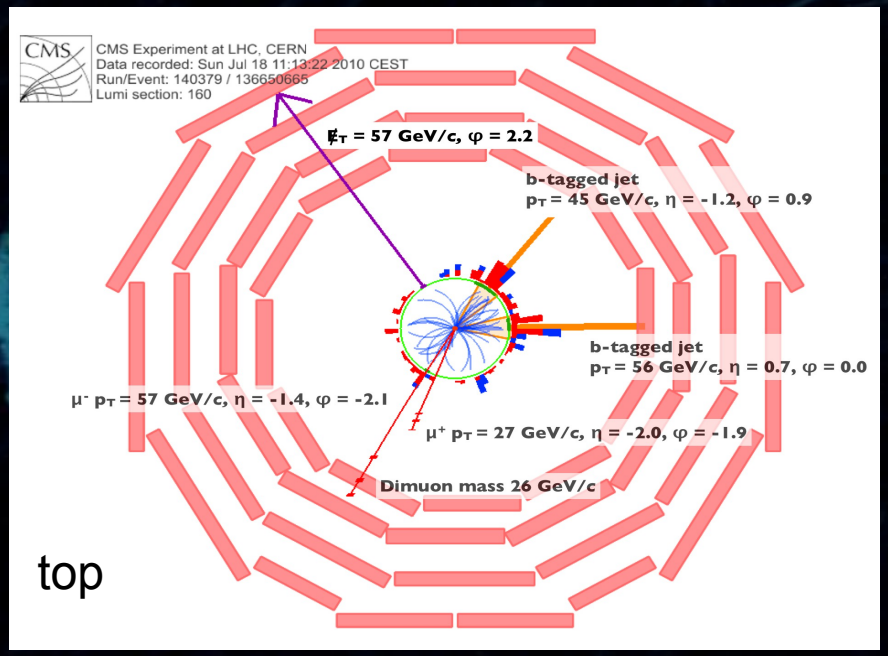


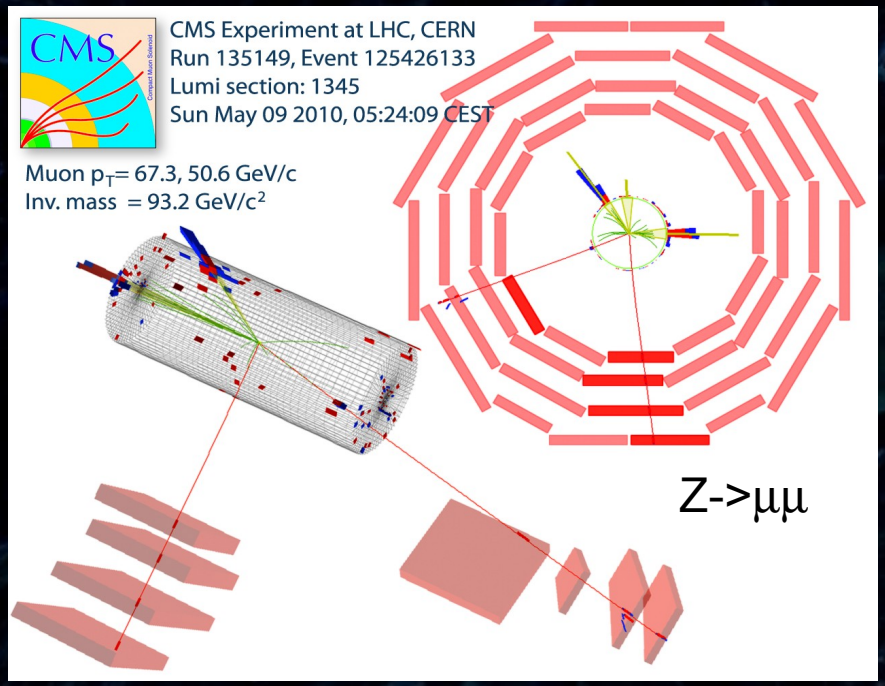
Once more:

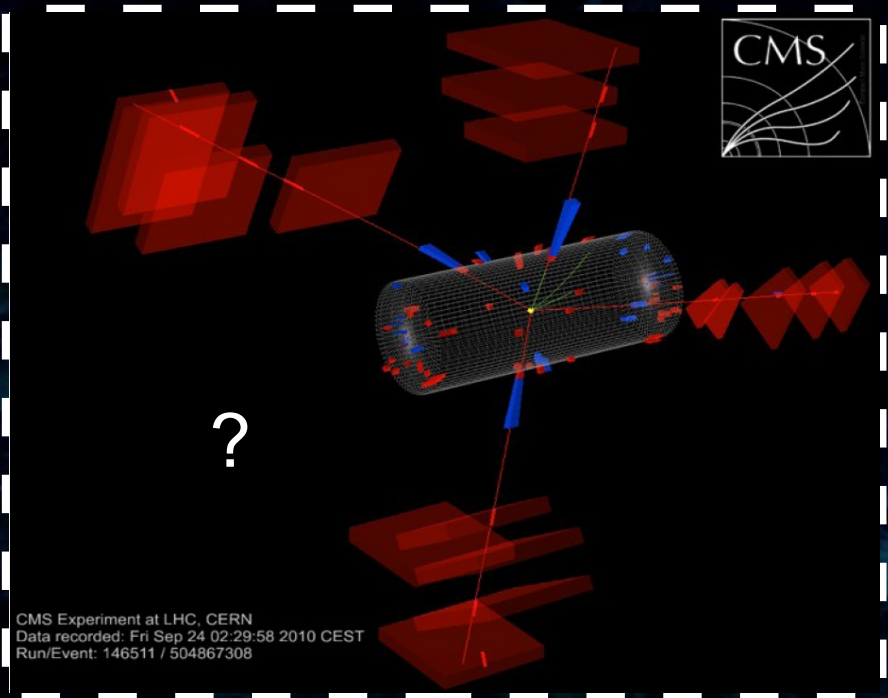

Silicon Strip Tracker
Silicon Pixel Tracker
Electromagnetic Calorimeter (ECAL)
Endcap Muon Detectors
Barrel Muon Detectors
Hadronic Calorimeter (HCAL)
Superconducting Solenoidal Coil
Iron Yoke

The End


CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST
Electron p_T = 35.6 GeV/c
ME_T = 36.9 GeV
M_T = 71.1 GeV/c²
W->eν


CMS Experiment at LHC, CERN
Data recorded: Sun Jul 18 11:13:22 2010 CEST
Run/Event: 140379 / 136650665
Lumi section: 160
$\not{E}_T$ = 57 GeV/c, φ = 2.2
b-tagged jet
p_T = 45 GeV/c, η = -1.2, φ = 0.9
b-tagged jet
p_T = 56 GeV/c, η = 0.7, φ = 0.0
μ^- p_T = 57 GeV/c, η = -1.4, φ = -2.1
μ^+ p_T = 27 GeV/c, η = -2.0, φ = -1.9
Dimuon mass 26 GeV/c
top


CMS Experiment at LHC, CERN
Run 135149, Event 125426133
Lumi section: 1345
Sun May 09 2010, 05:24:09 CEST
Muon p_T= 67.3, 50.6 GeV/c
Inv. mass = 93.2 GeV/c²
Z->μμ


?
CMS Experiment at LHC, CERN
Data recorded: Fri Sep 24 02:29:58 2010 CEST
Run/Event: 146511 / 504867308