

CMS at LHC

# LHC





# LHC

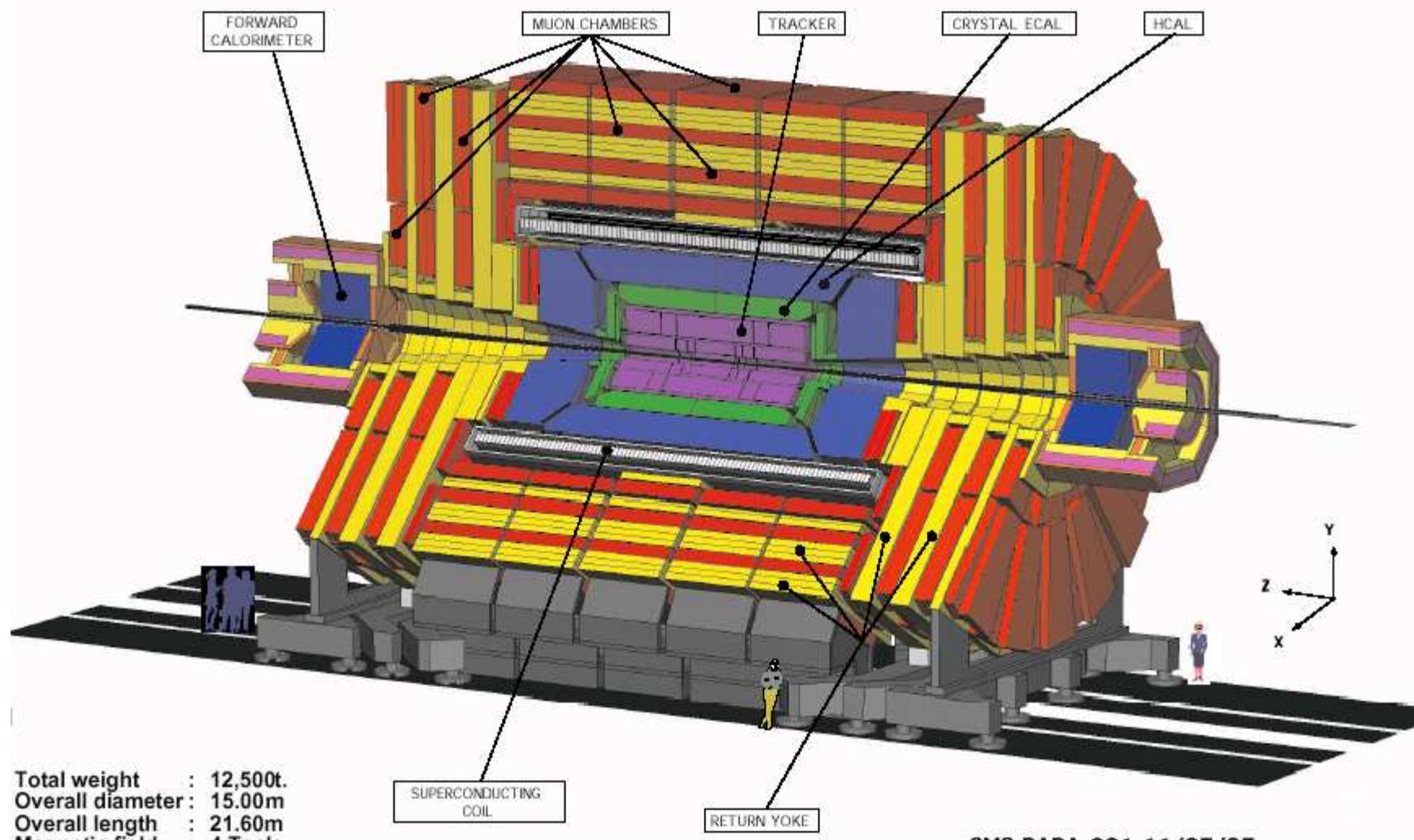
- 27 km in circumference, 100 m underground
- pp collisions
- 14 TeV center of mass energy
- $10^{34} \text{ cm}^{-2}\text{s}^{-1}$  luminosity
  - proton bunches collide every 25 ns
  - 20 pp collisions per bunch crossing
- beam energy 0.4 GJ
- energy stored in dipole magnets 10 GJ

# Underground hall for CMS

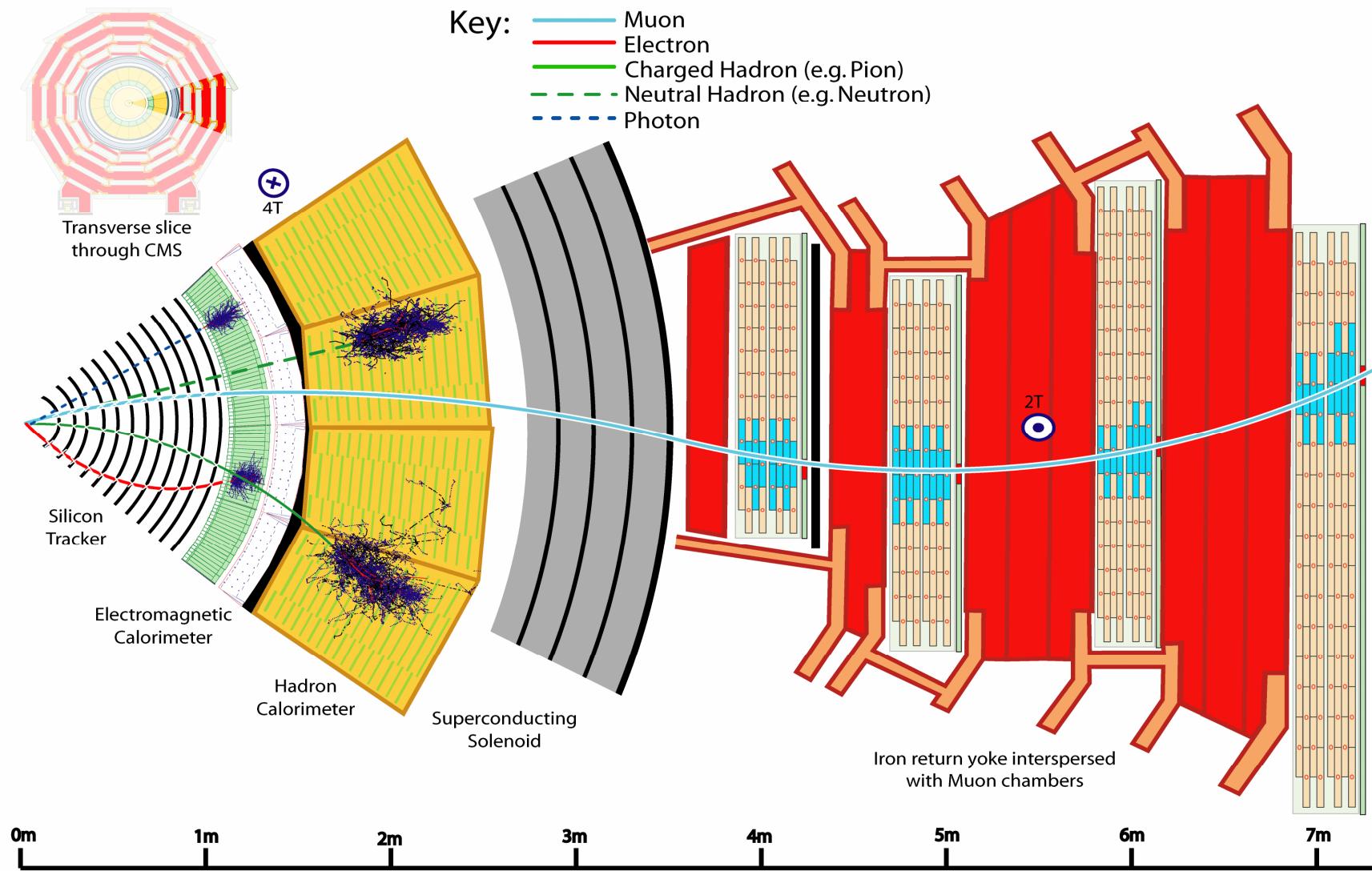


# CMS Overview

## CMS A Compact Solenoidal Detector for LHC

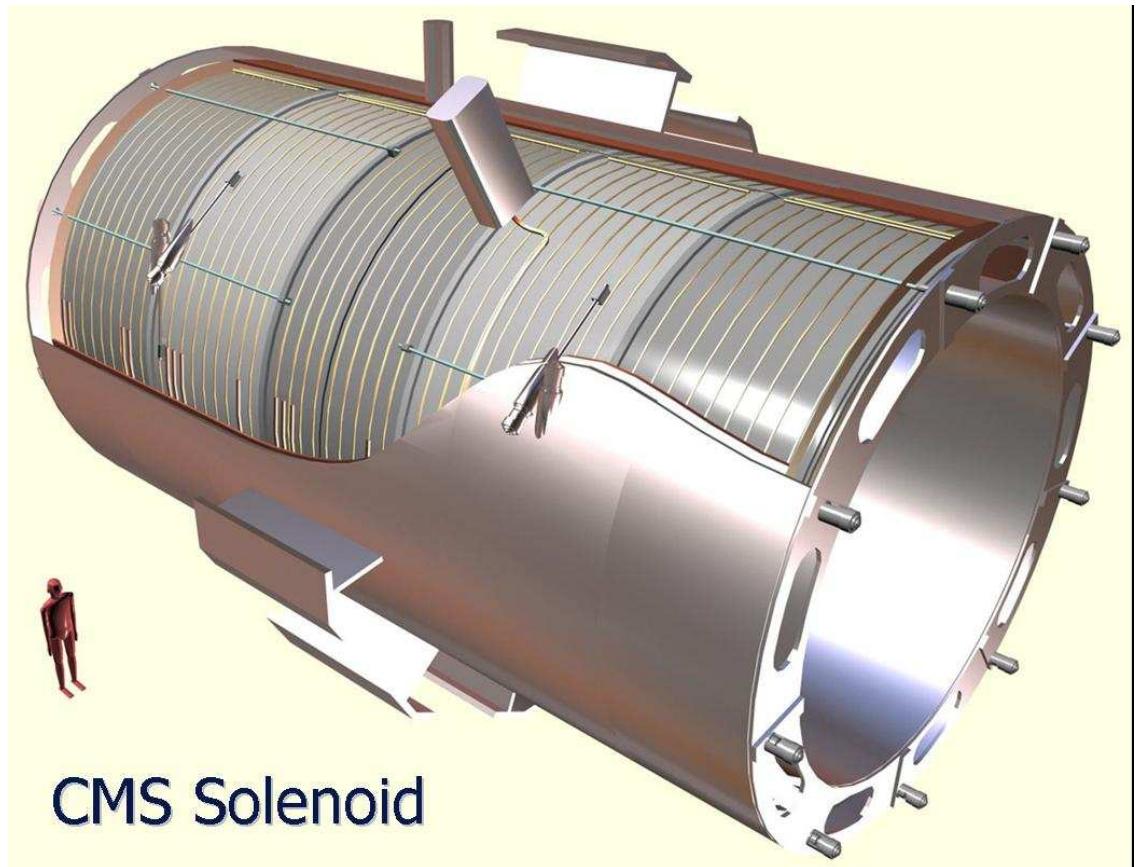


# Conceptual Design

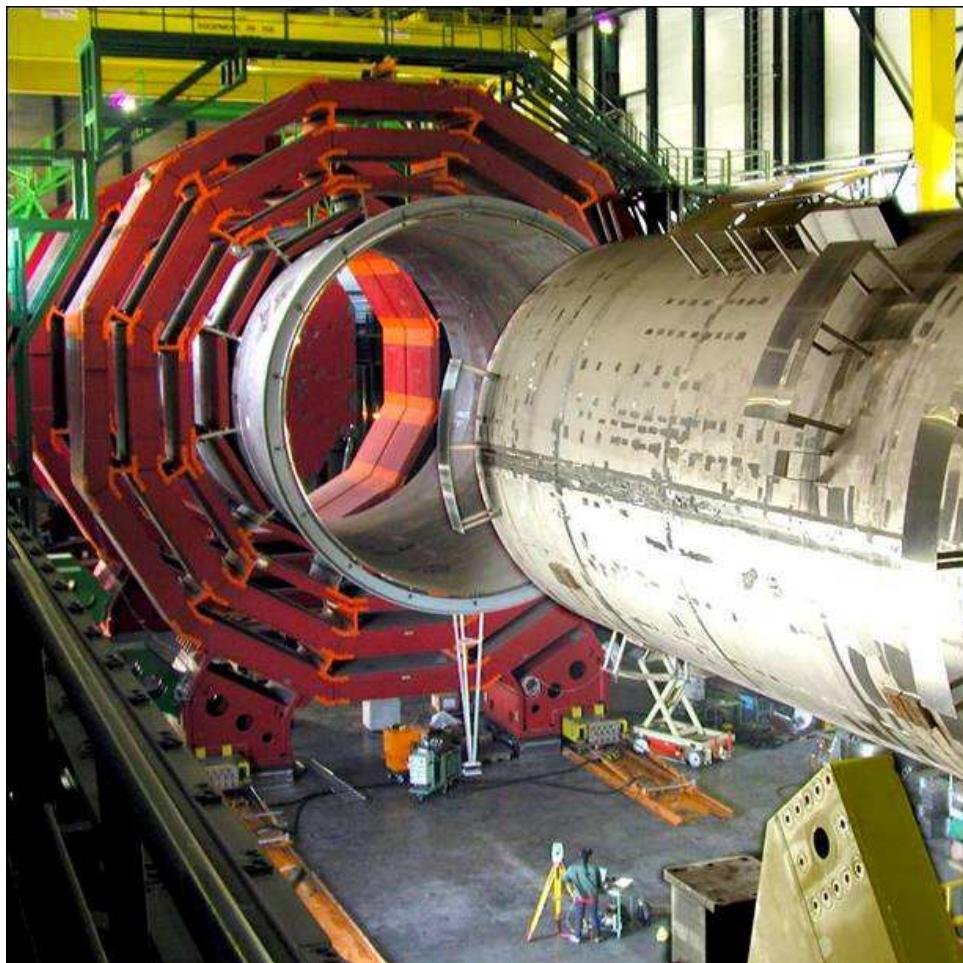


# Solenoid

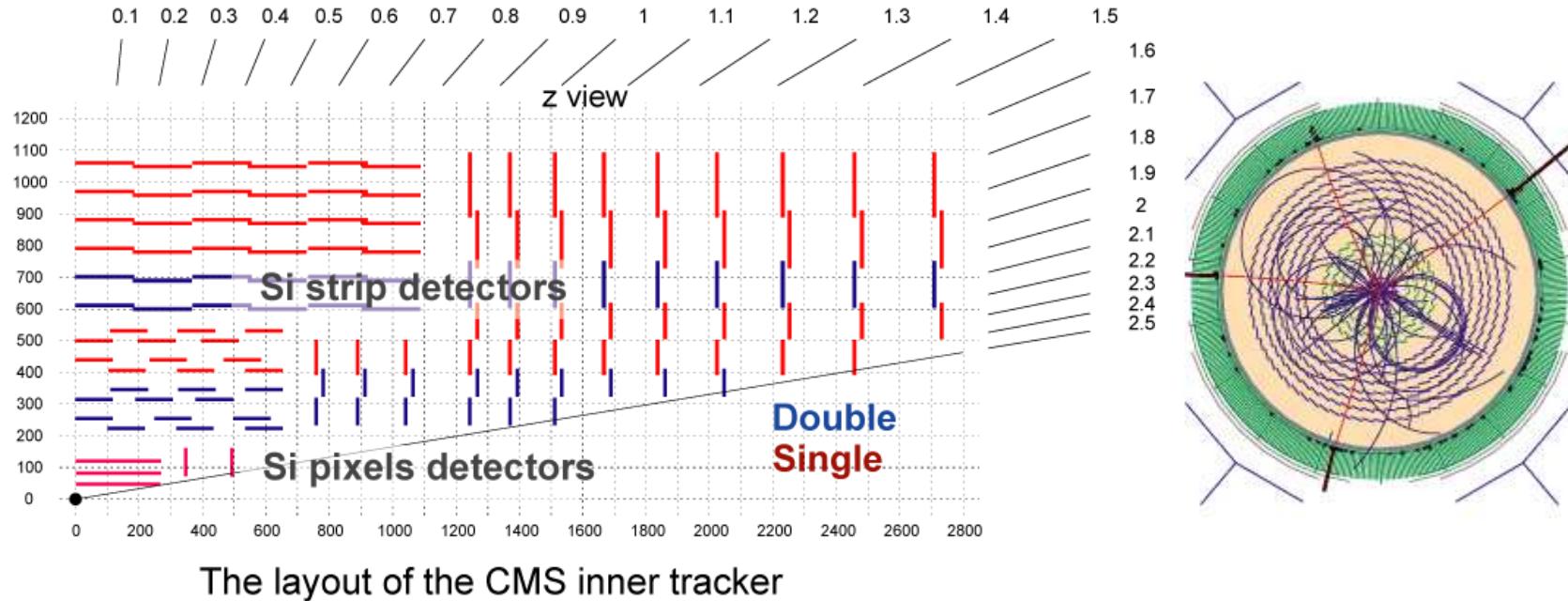
- 4 T field
- 8 m in diameter
- 12 m long
- 3 GJ stored energy  
(1500 cars on a highway)



# Solenoid

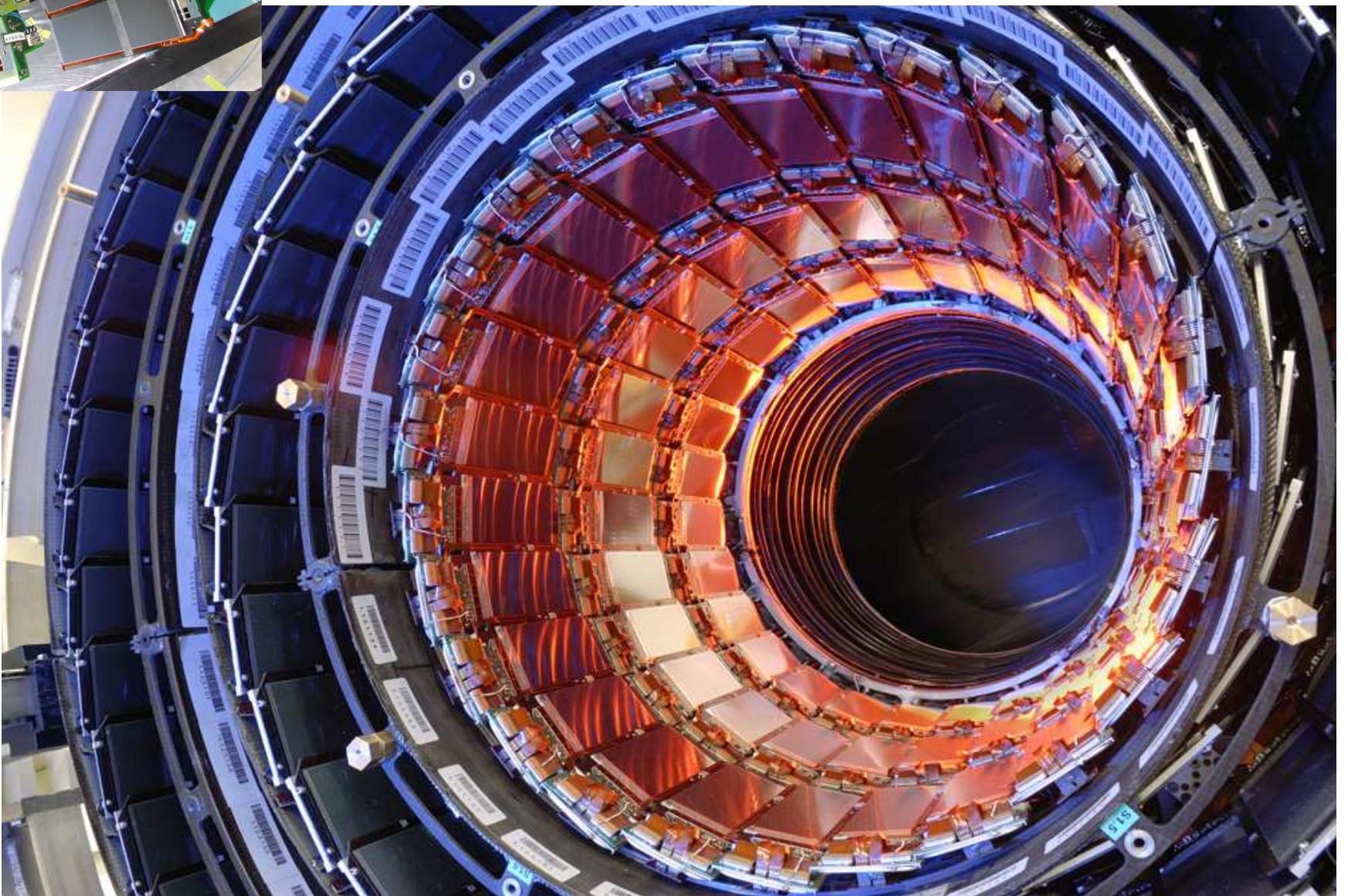
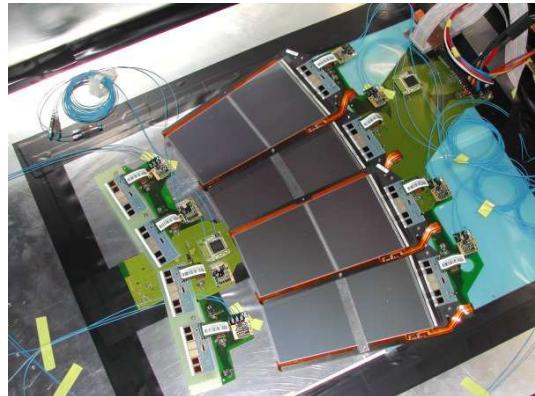


# Si Tracker

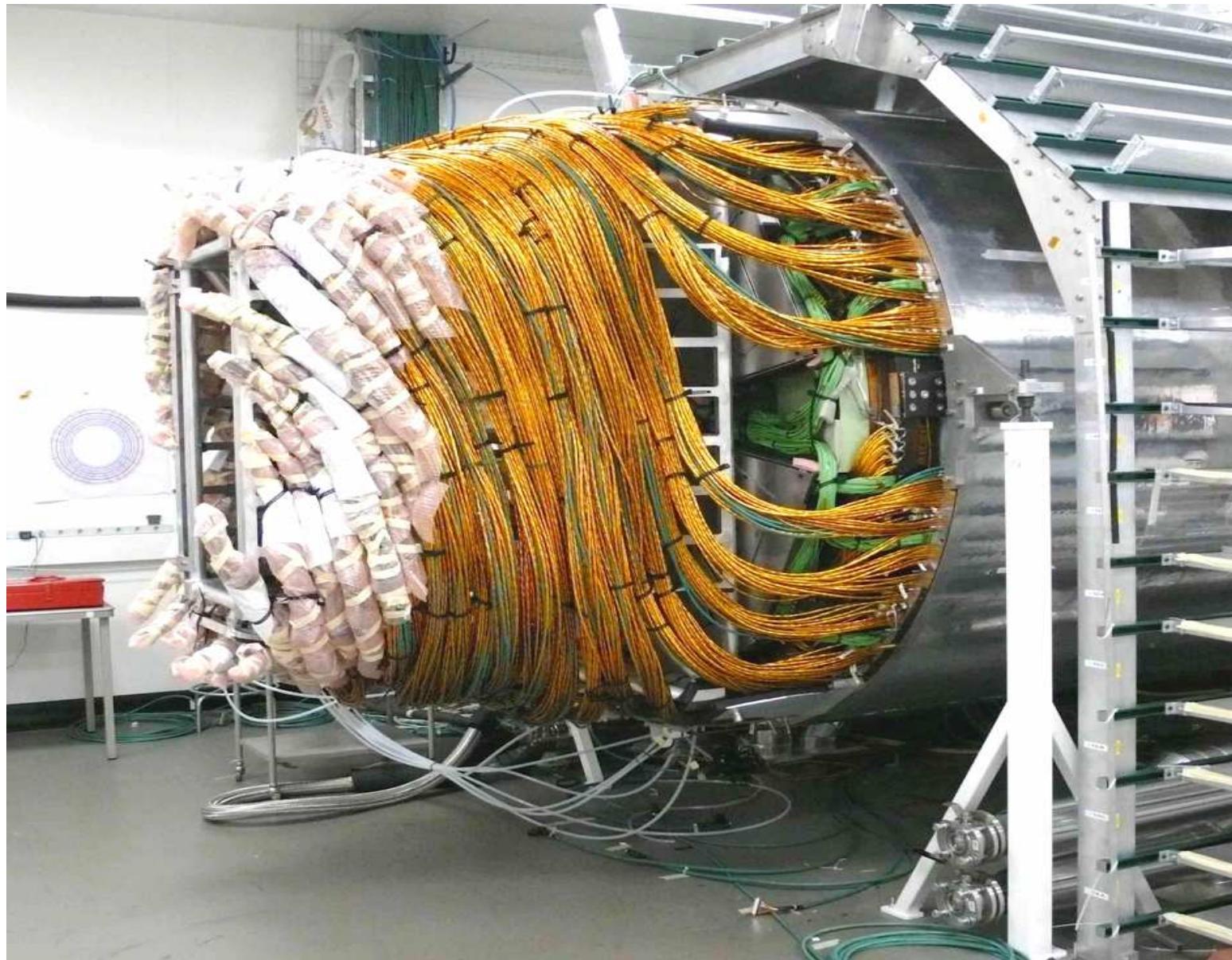


- Largest silicon-sensor system ever made
- 2.2 m diameter, 6 m long, operates at  $-15^{\circ}\text{C}$
- more than  $220 \text{ m}^2$  of sensors
- more than 60 million electronics channels (pixels and microstrips)

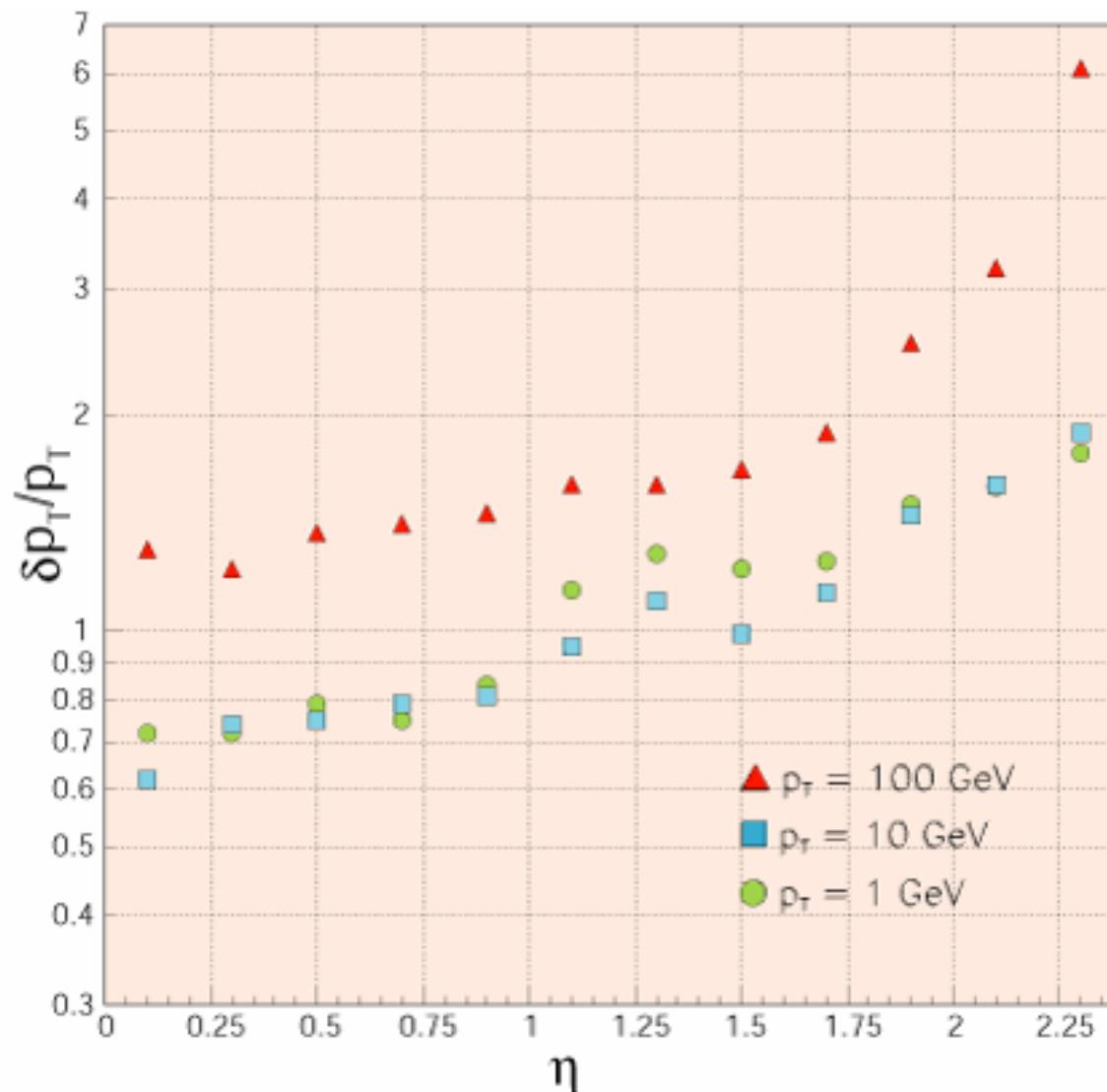
# Si Tracker



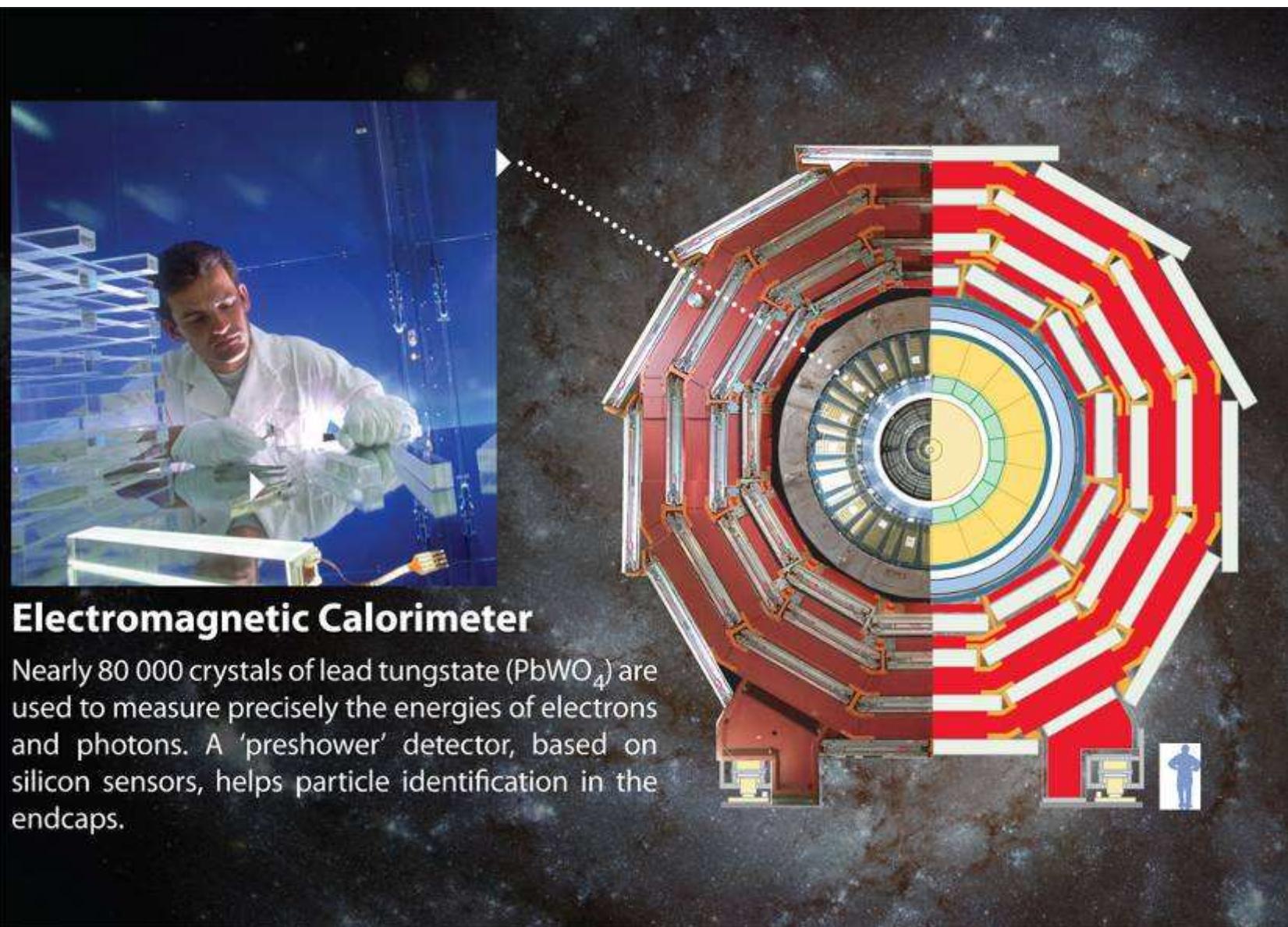
# Si Tracker



# Tracker Performance



# EM Calorimeter

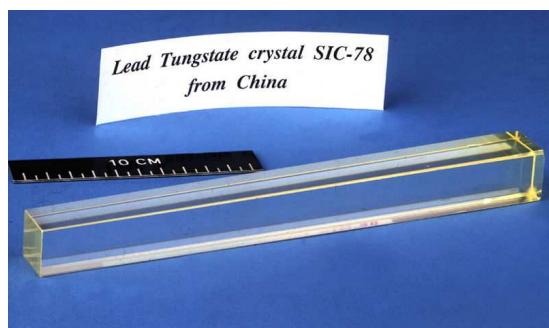


The image is a composite of two parts. On the left, a photograph shows a scientist in a white lab coat and gloves working on a large, rectangular detector module, likely a lead tungstate crystal, with a white cable attached. The background is a dark blue, possibly a liquid nitrogen dewar. On the right, a detailed cutaway diagram of the ATLAS experiment's detector is shown against a dark, star-filled background. The diagram highlights the central interaction region and the surrounding concentric layers of the calorimeter, which are represented by red and yellow segments. A small blue silhouette of a person stands next to the detector for scale.

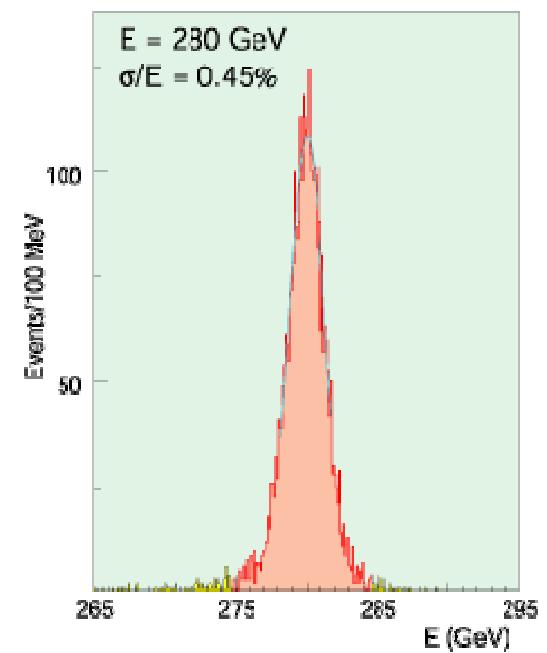
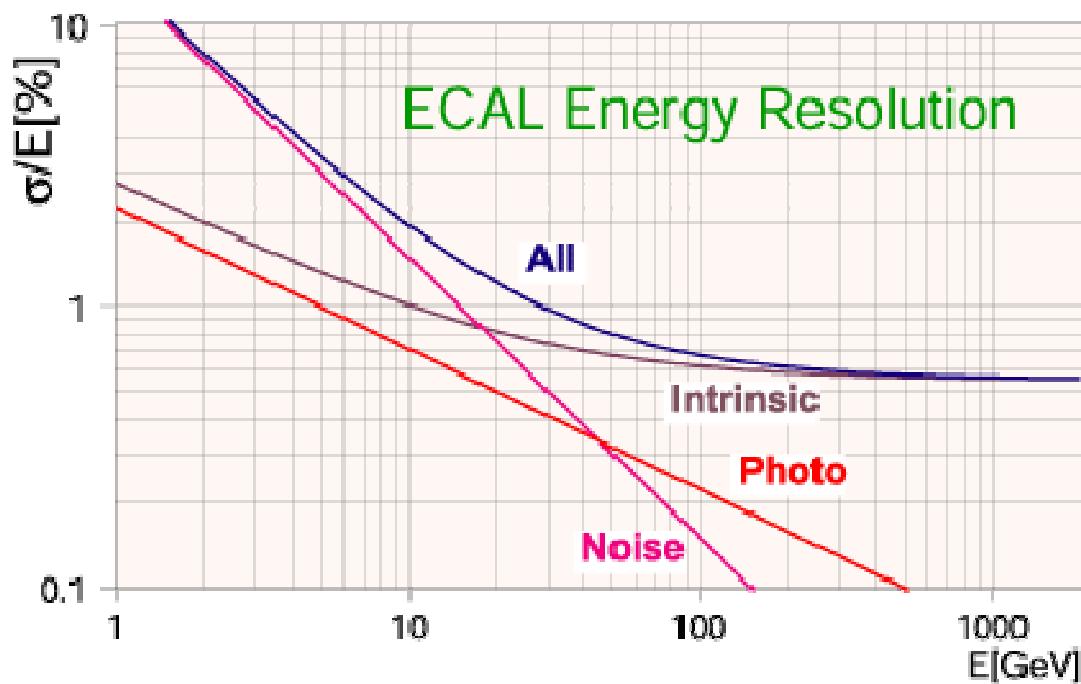
**Electromagnetic Calorimeter**

Nearly 80 000 crystals of lead tungstate ( $\text{PbWO}_4$ ) are used to measure precisely the energies of electrons and photons. A 'preshower' detector, based on silicon sensors, helps particle identification in the endcaps.

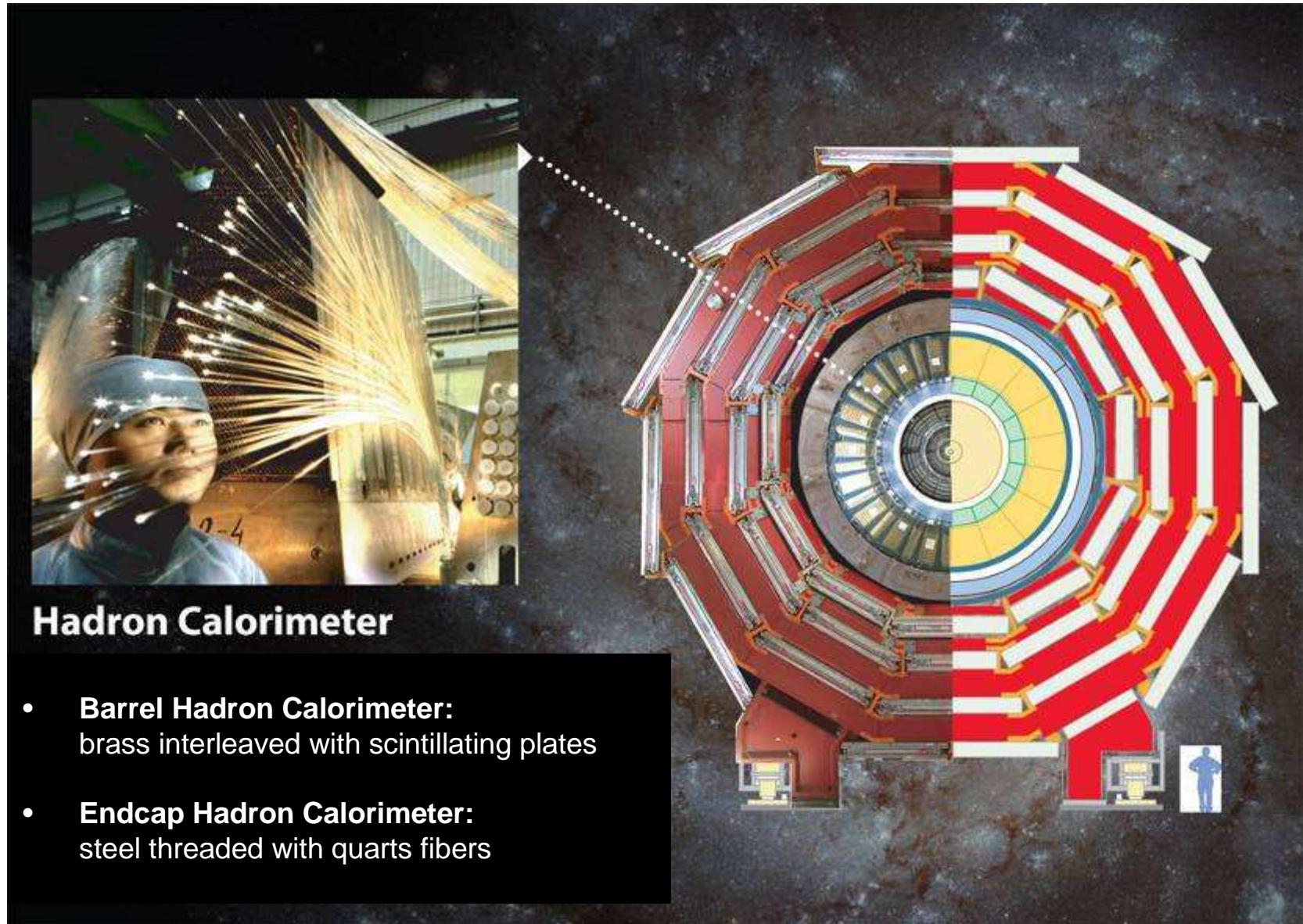
# EM Calorimeter



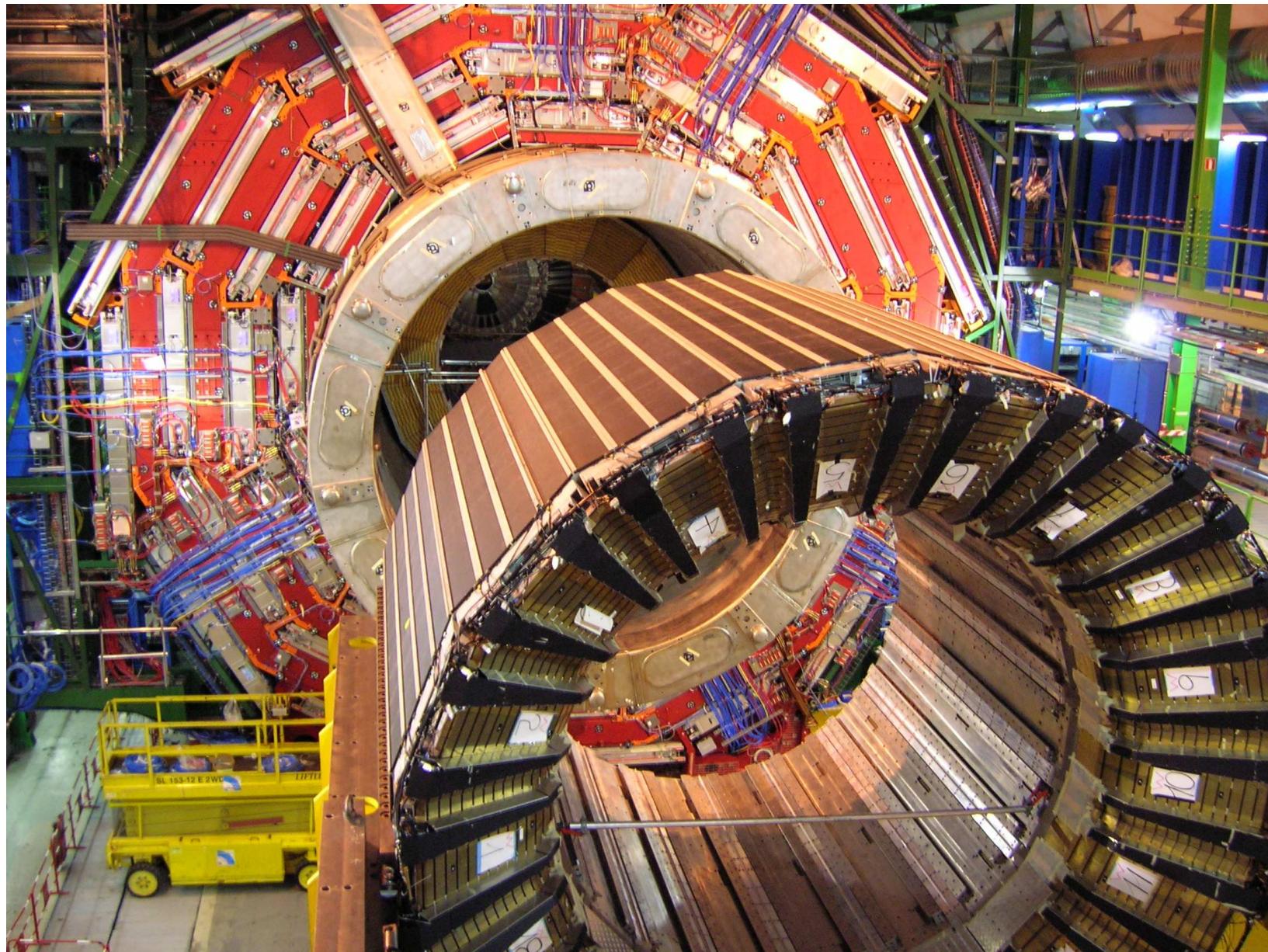
# EM Calorimeter Performance



# Hadronic Calorimeter



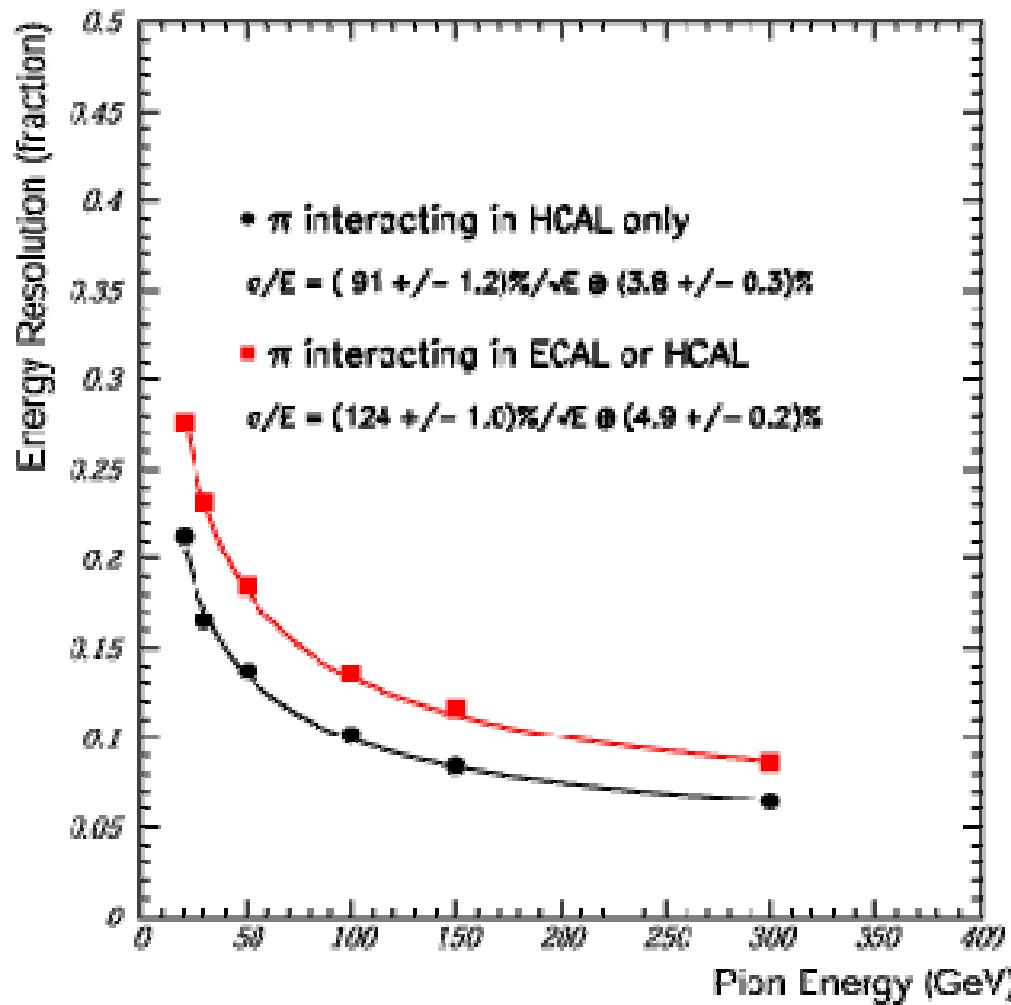
# Barrel Hadron Calorimeter



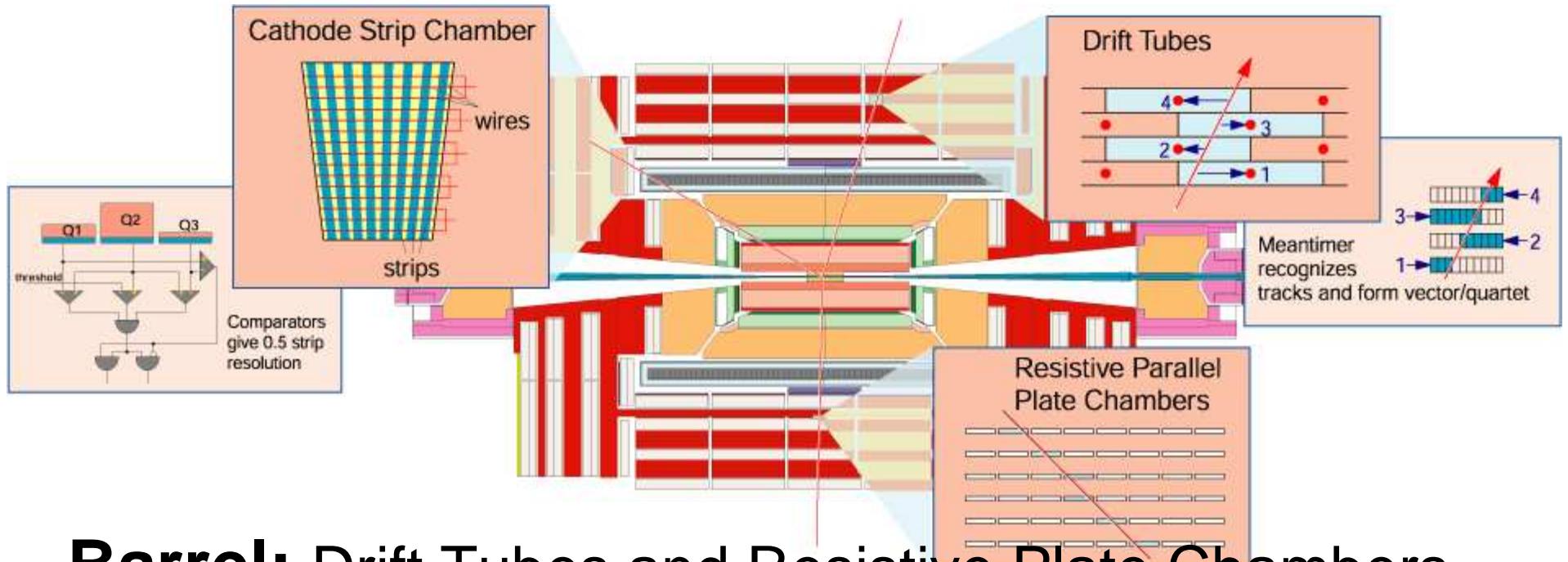
# Endcap Hadron Calorimeter



# Hadron Calorimeter Performance



# Muon System

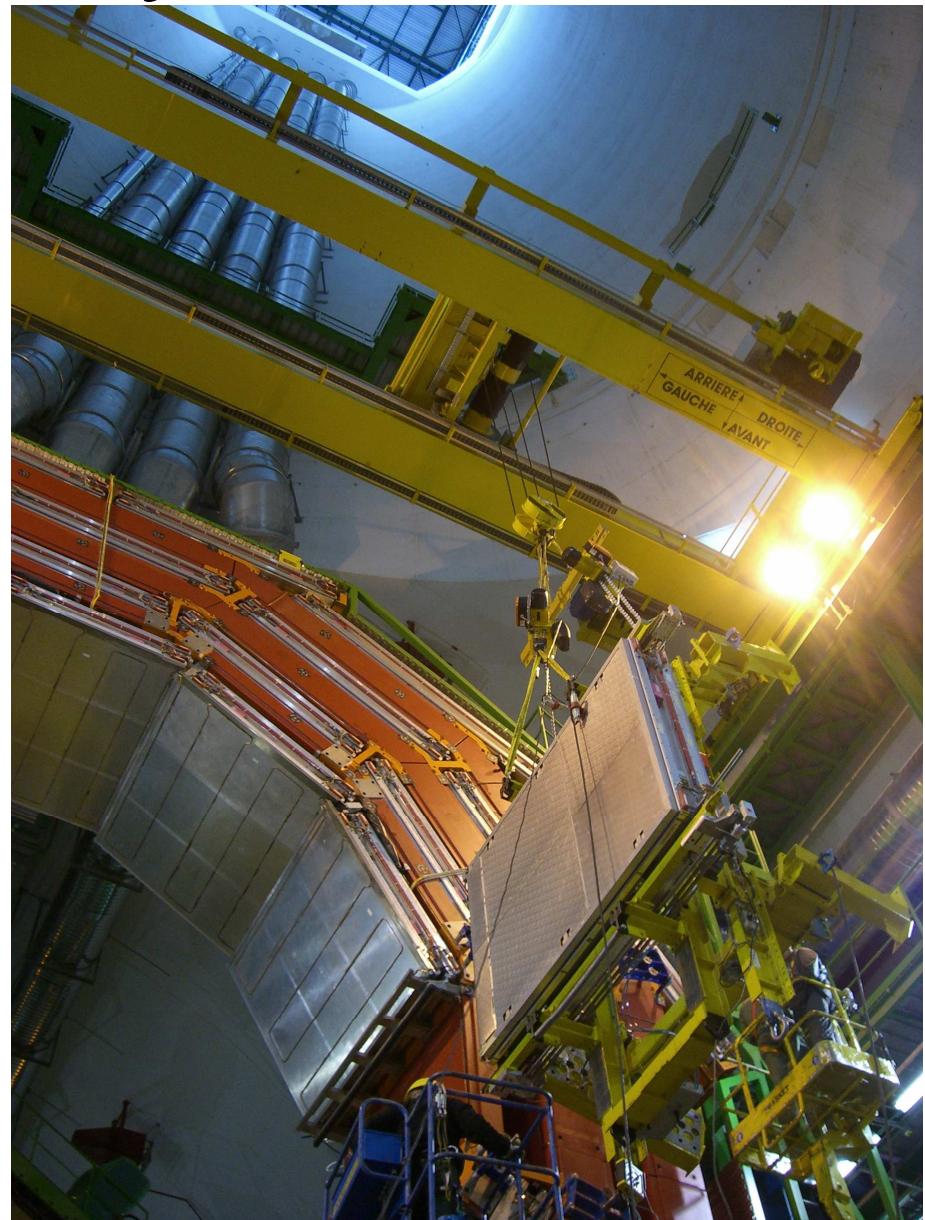
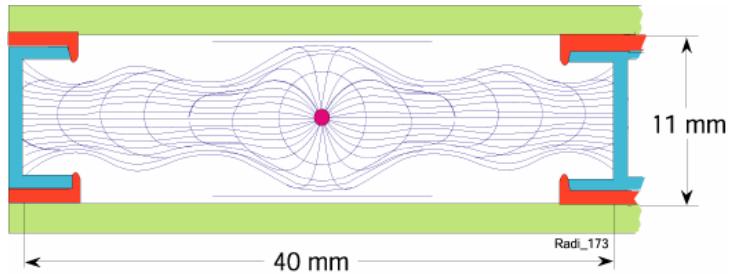


**Barrel:** Drift Tubes and Resistive Plate Chambers

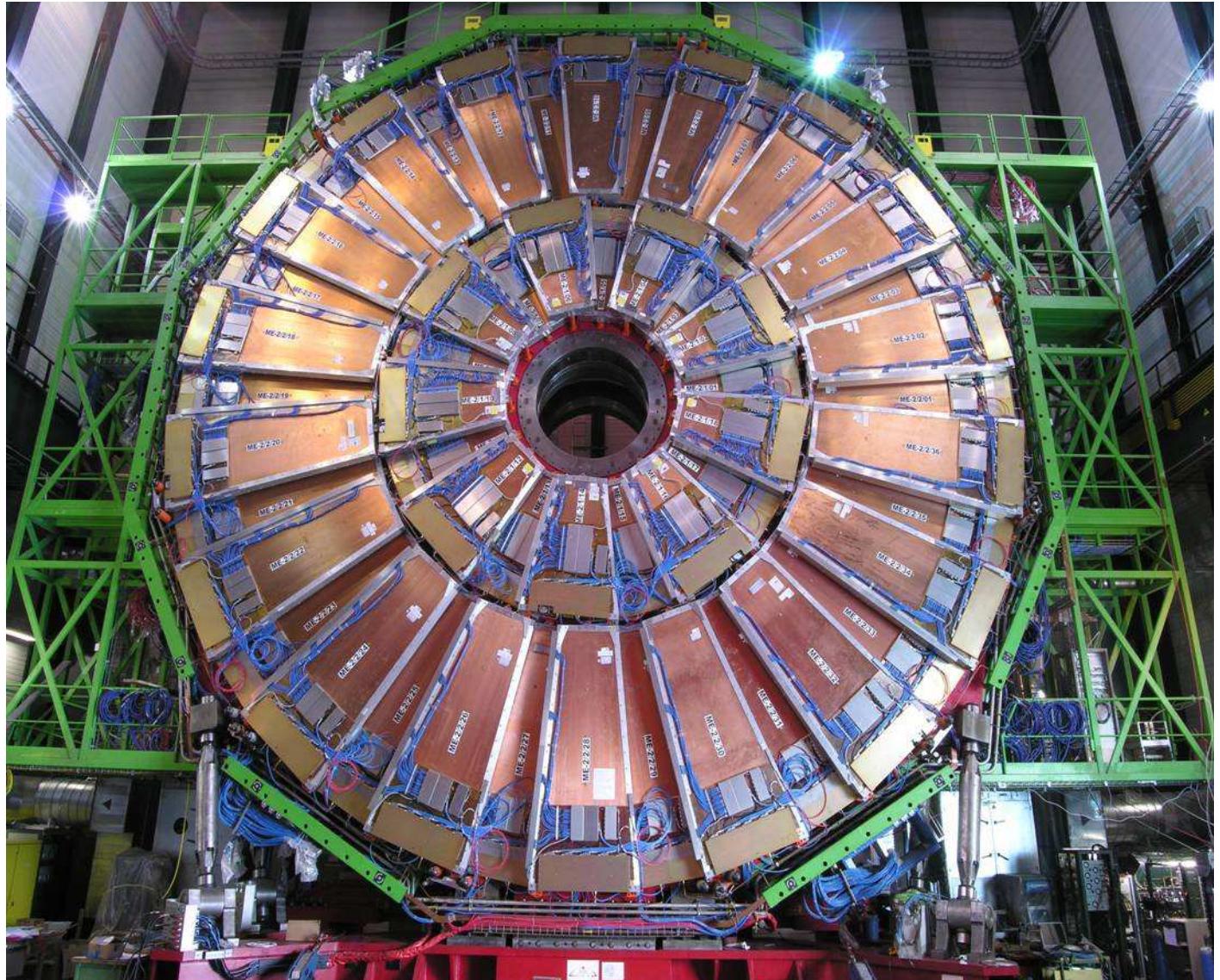
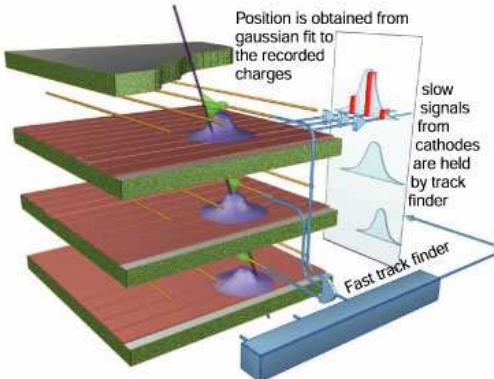
**Endcaps:**

Cathode Strip Chambers and Resistive Plate Chambers

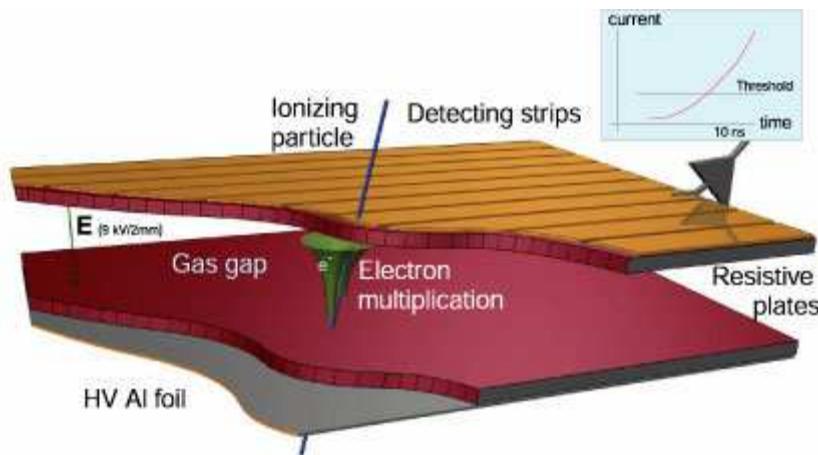
# Barrel Muon System DTs



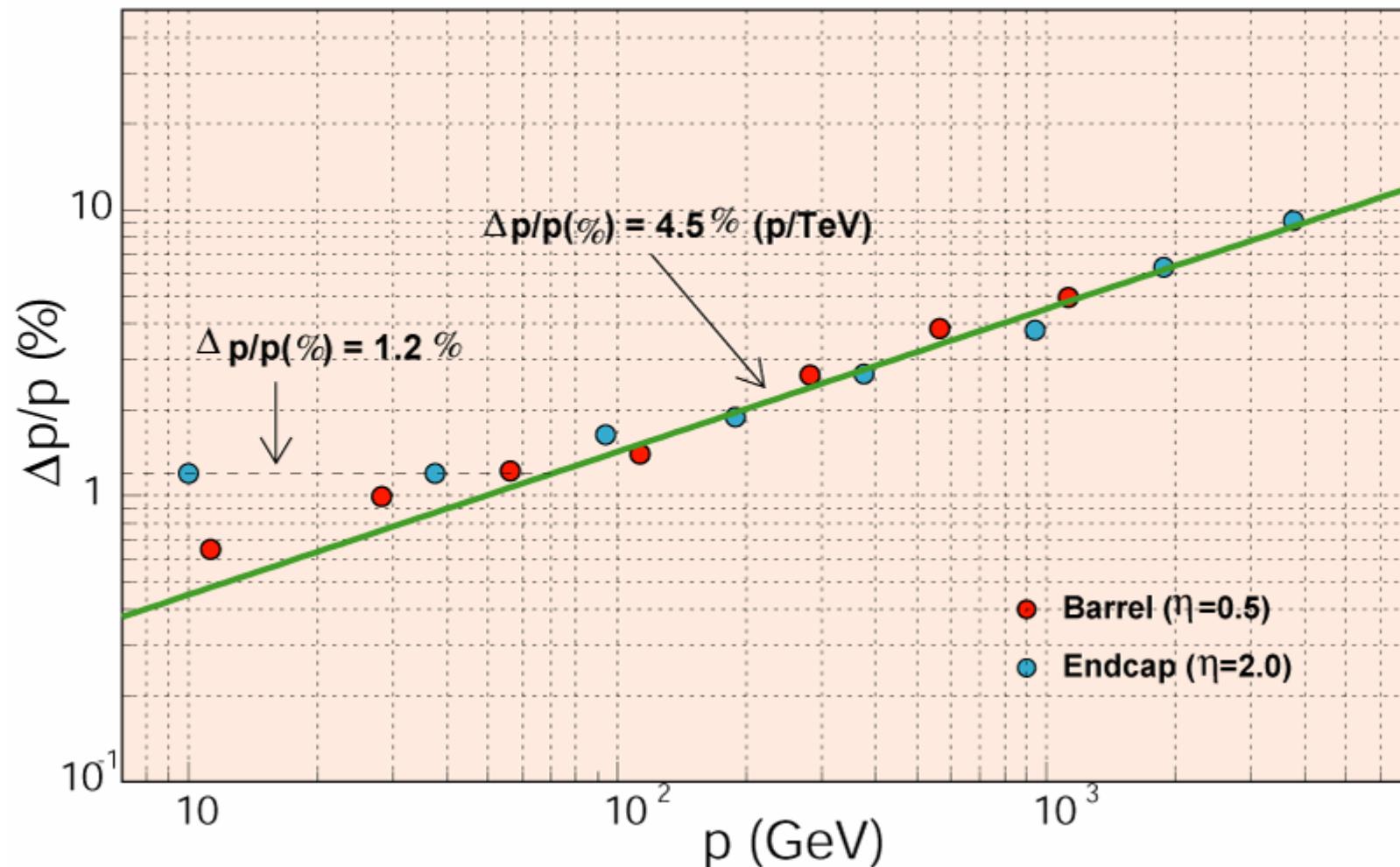
# Endcap Muon System CSCs



# Muon System RPCs

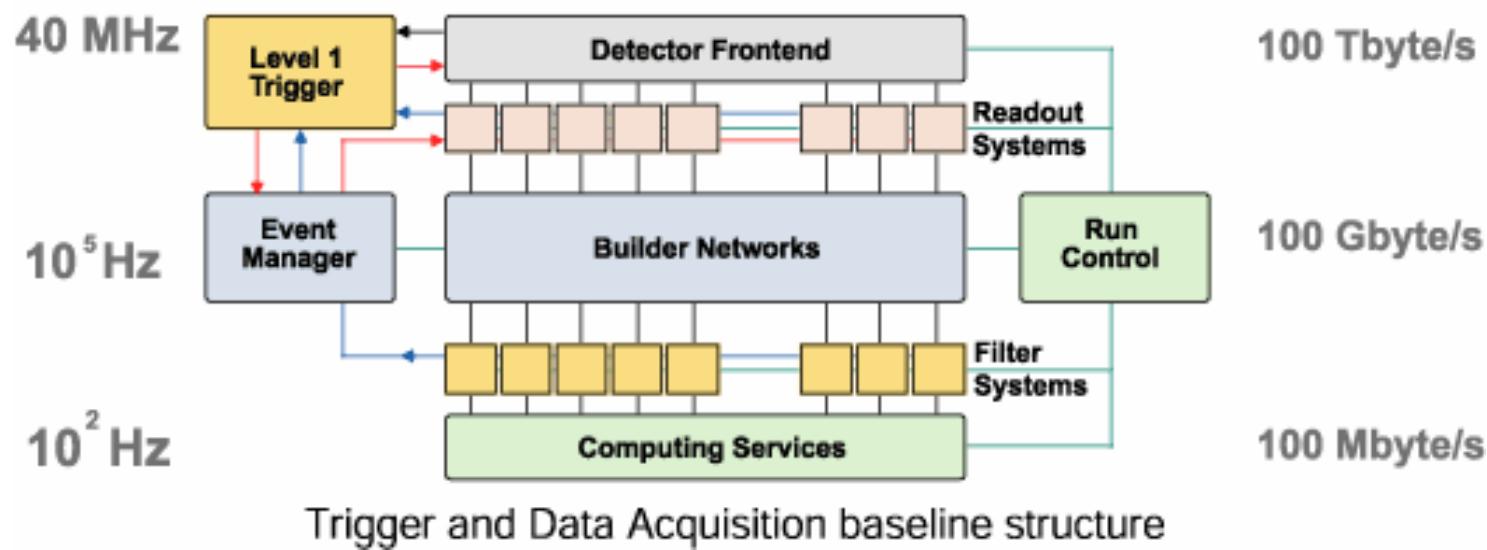


# Muon System Performance

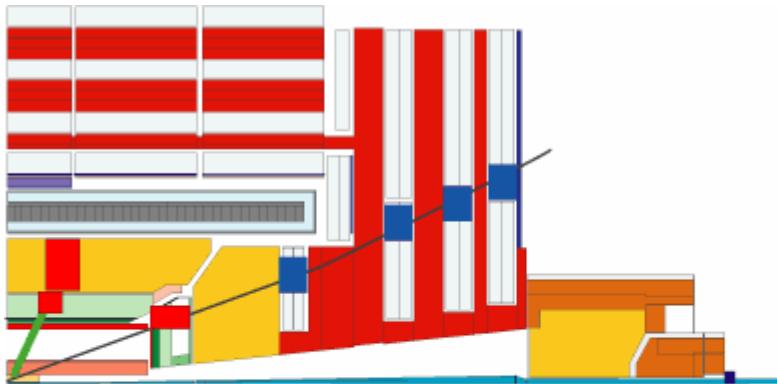


# Trigger and Data Acquisition

Data Acquisition Main Parameters	
Collision rate	40 MHz
Level-1 Maximum trigger rate	100 kHz
Average event size	1 Mbyte
No. of electronics boards	10000
No. of readout crates	250
No. of In-Out units (200-5000 byte/event)	1000
Event builder (1000 port switch) bandwidth	1 Terabit/s
Event filter computing power	5 $10^6$ MIPS
Data production	Tbyte/day

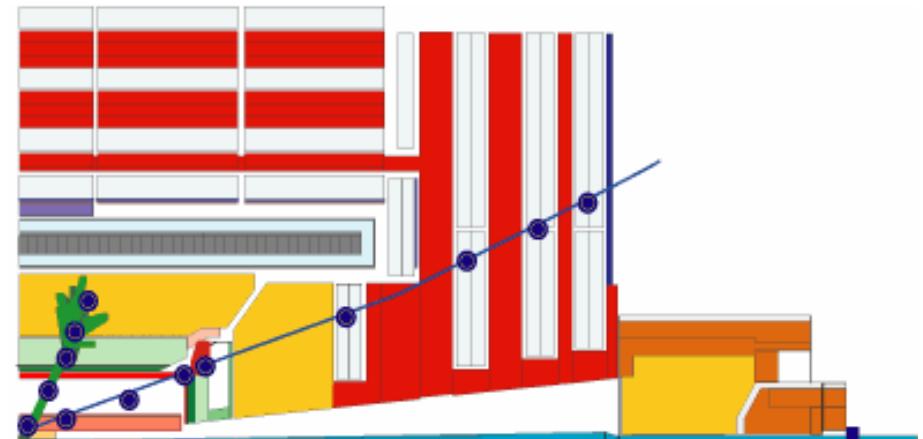


# What is in Trigger?



## 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

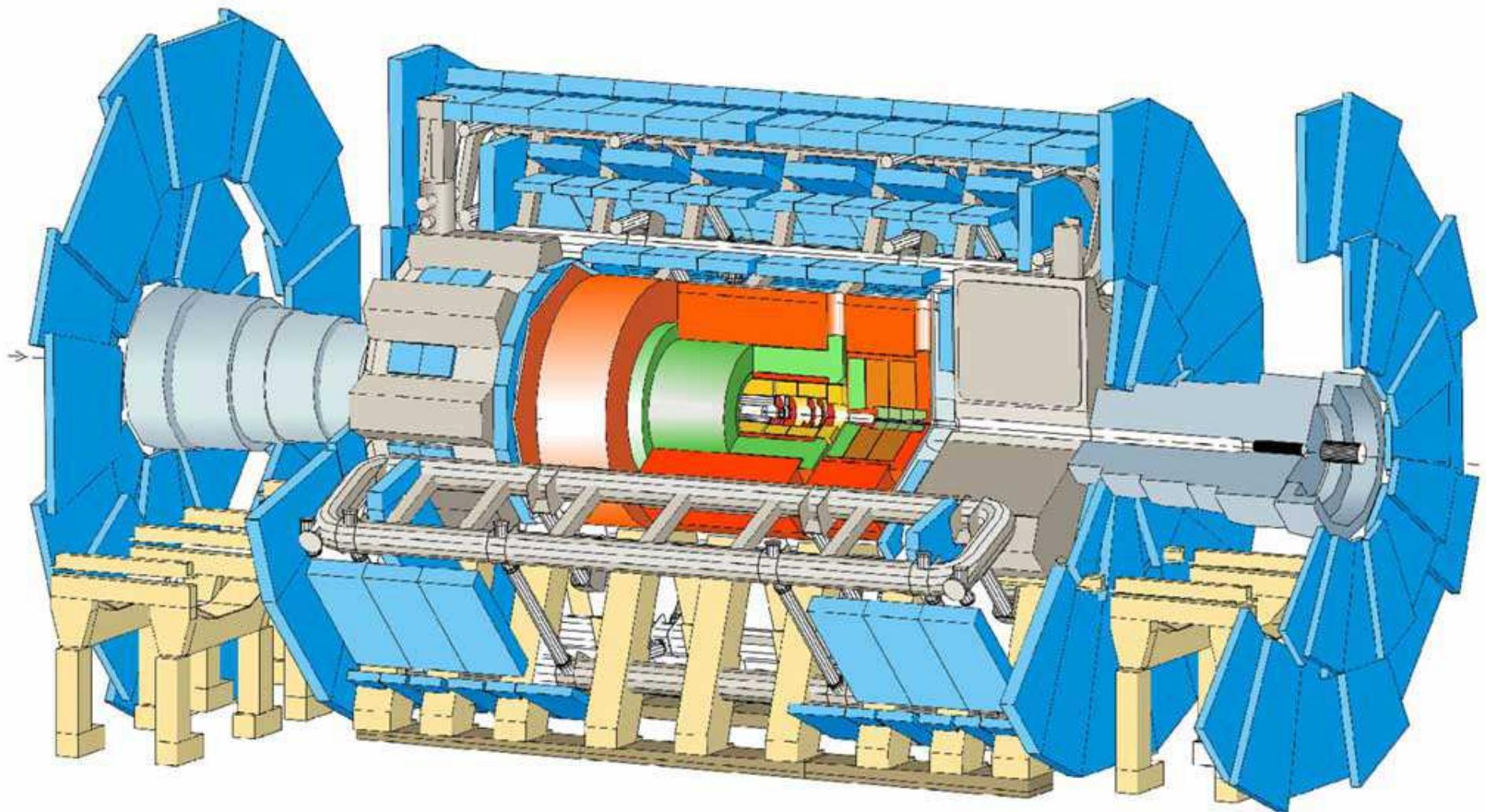
# CMS on surface



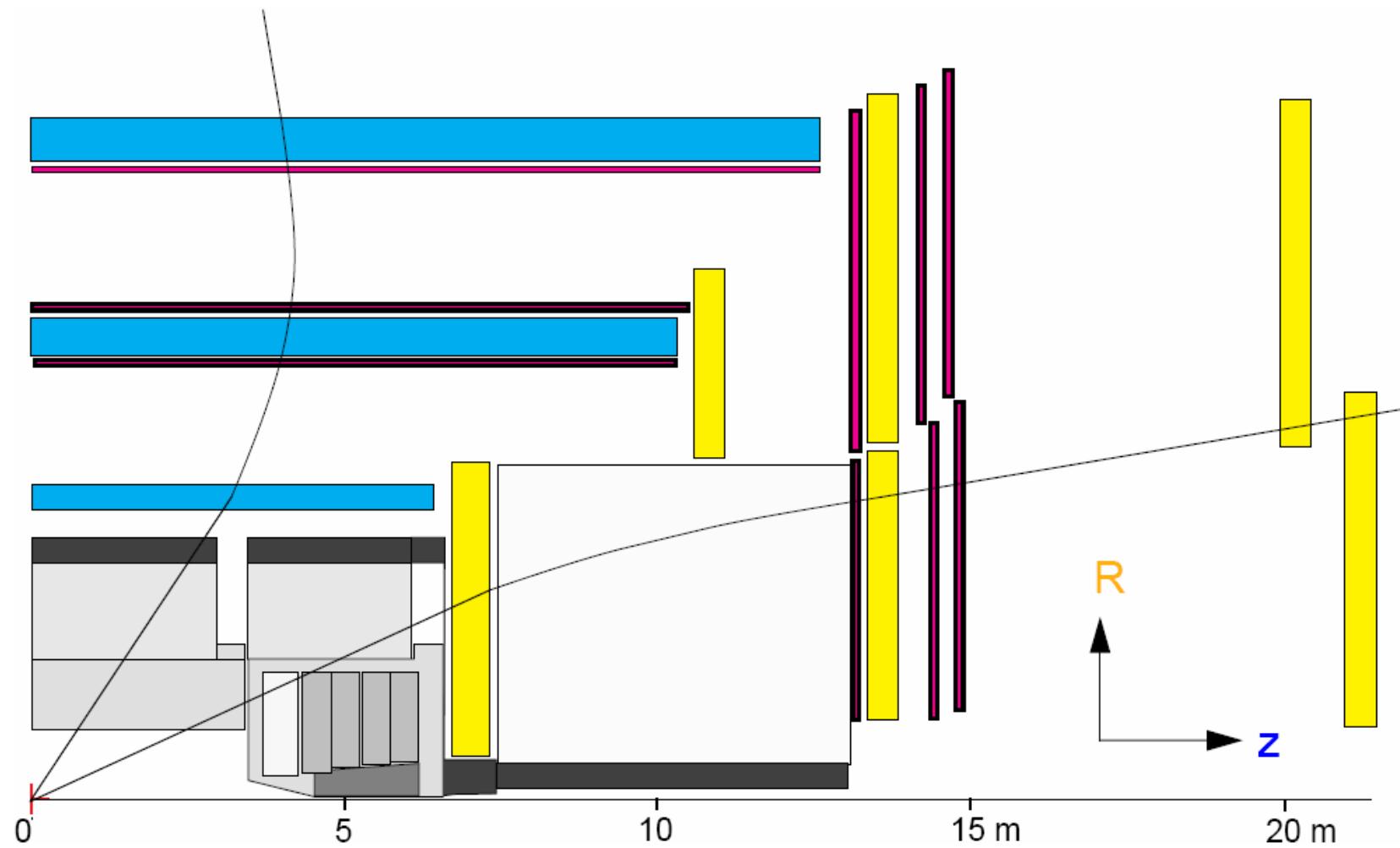
# CMS now (underground)



# ATLAS (for comparison)

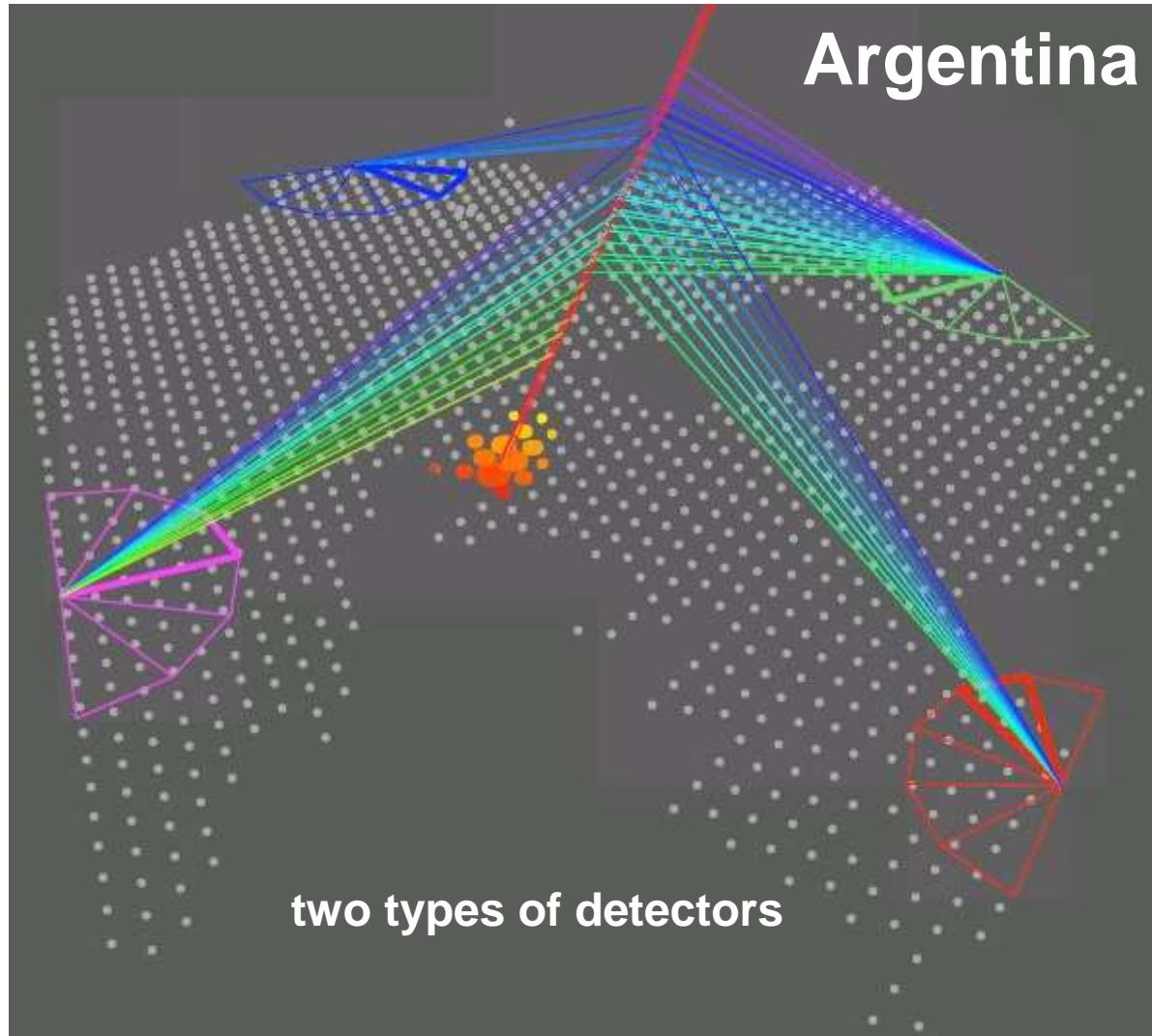


# ATLAS concept (cf CMS)

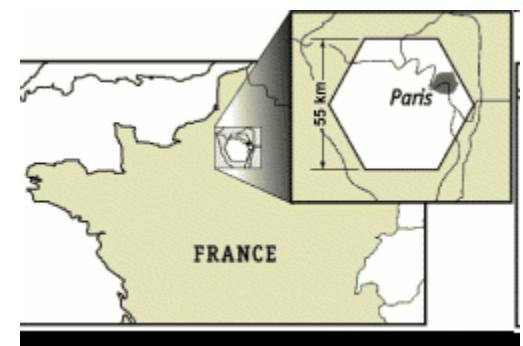


Pierre Auger Observatory  
(largest cosmic ray shower detector)

# Pierre Auger Observatory



size of the detector site  
compared to Paris

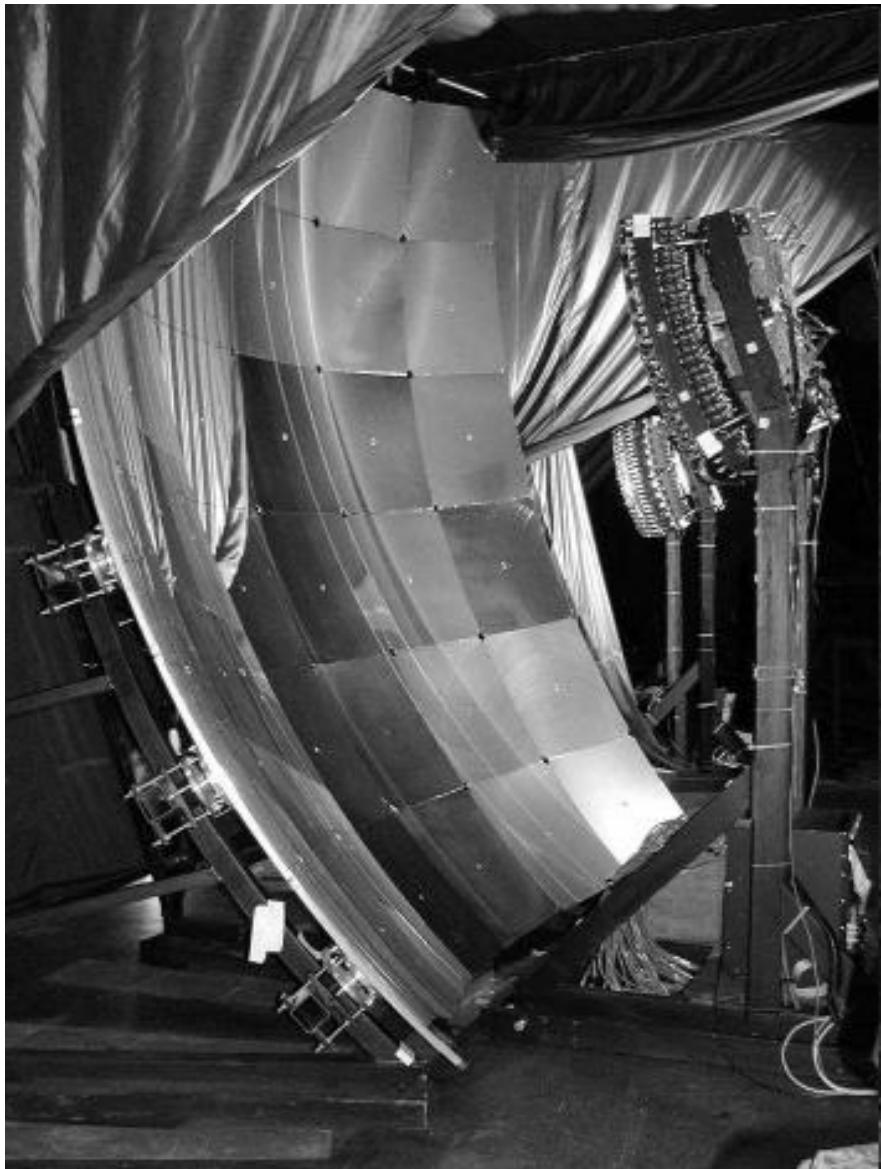


# Water Tanks

Cherenkov light  
from muons reaching  
the earth surface



# Fluorescence Light Detector



Telescopes recording the development of cosmic ray showers (em and hadronic) in the upper layers of atmosphere via fluorescence light detection