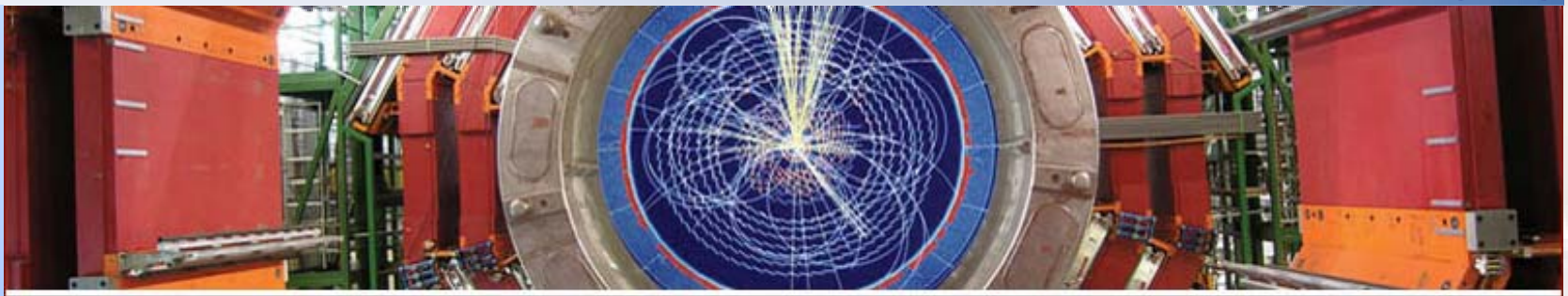
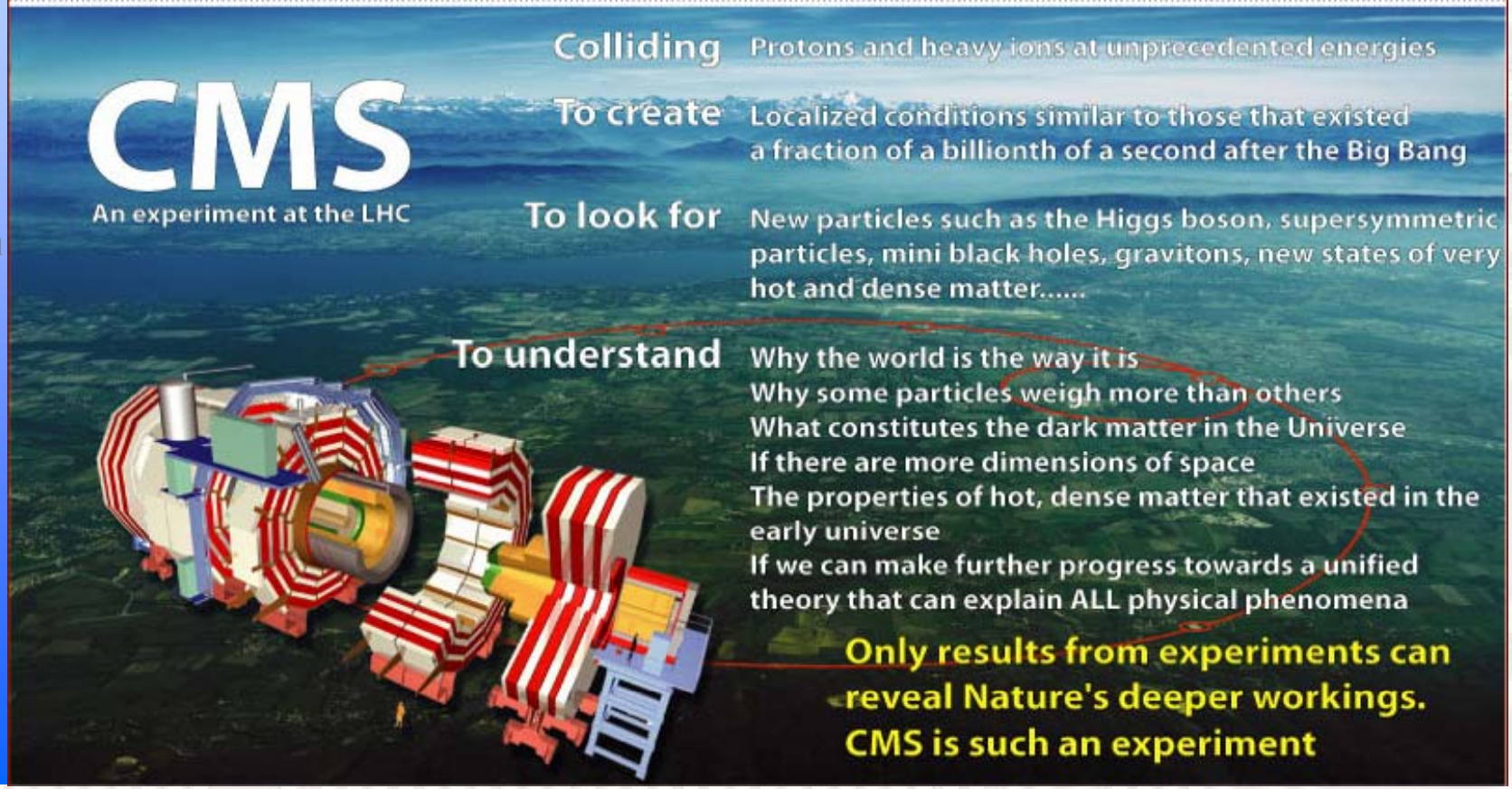
Introduction to CMS for CERN Guides

- **The physics goals of CMS**
- **CMS in 3 minutes (well, maybe 5!)**
  - Compact
    - What does this mean?
  - Muon
    - Why do we need to detect Muons?
  - Solenoid
    - What is it, what does it do, and what is so special about the CMS solenoid?
- **The CMS detector components**
  - facts and figures etc.
- **The visit to Point 5**
  - Outside the construction hall
  - Inside the construction hall
  - The visitors gallery
  - The caverns
- **Questions and, hopefully, answers!**

The physics goals of CMS

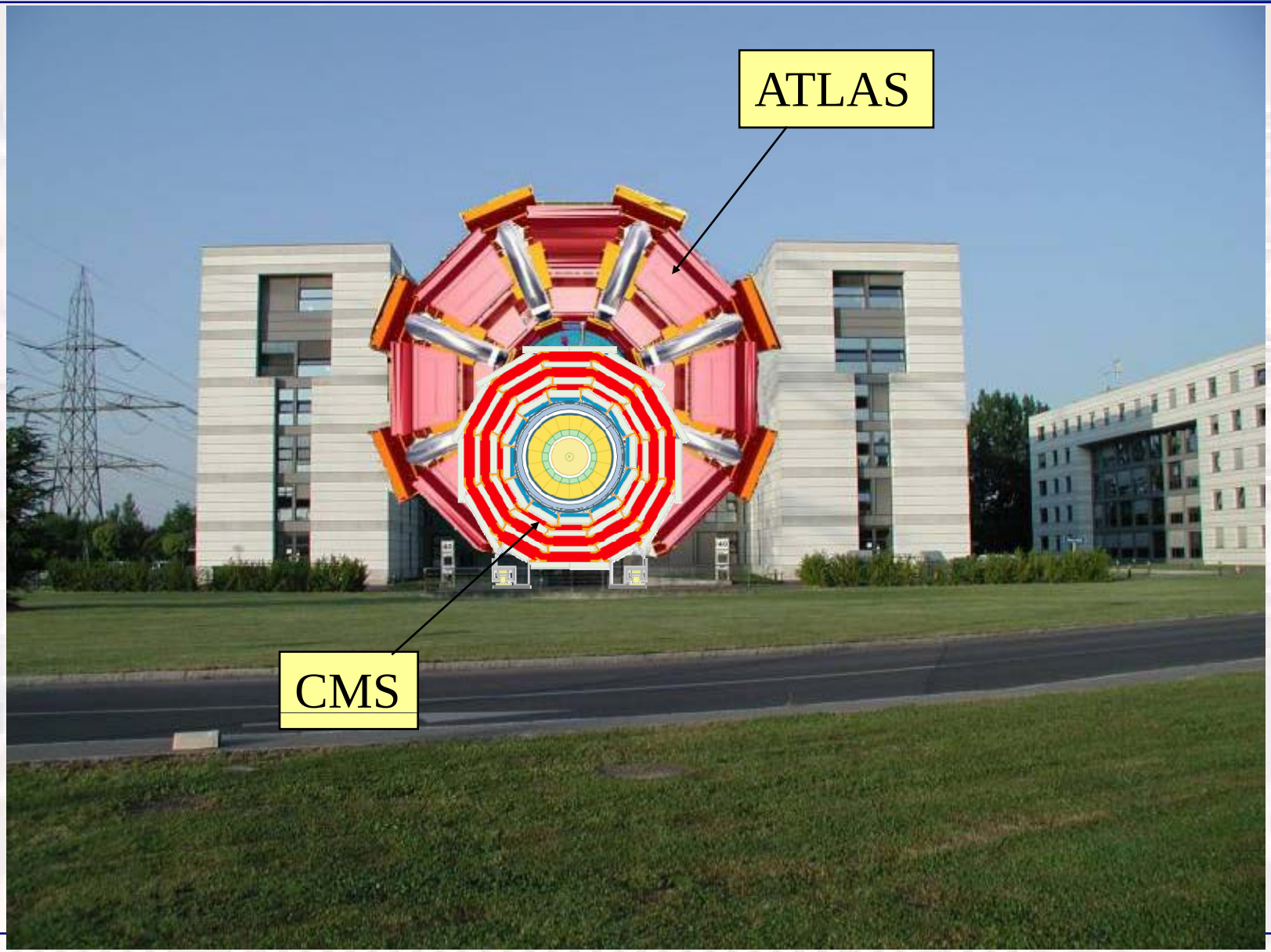




CMS in 3 mins

- First ideas back in 1990 – a few people around a table in a restaurant ("l'amphitryon" in St Genis)
- Based around a single large solenoid with all tracking and calorimetry inside
- Build major components on the surface, then lower in pieces underground
- Basic design has changed little in 17 years!
- Collaboration is now > 2000 scientists and engineers from 178 institutes in 38 countries
- Major construction started ~5 years ago
- Will start observing collisions as soon as LHC provides them (mid-2008 is current estimate)

Compact does NOT mean small!



Muons are important

- **In CMS, high energy muons can only originate from the decay of a heavier particle – something that might be potentially interesting!**
- **Muons are easy to identify (see later)**
  - Can quickly decide if we want to keep data from a collision or throw it away
- **CMS uses multiple layers of muon detectors (again, see later)**

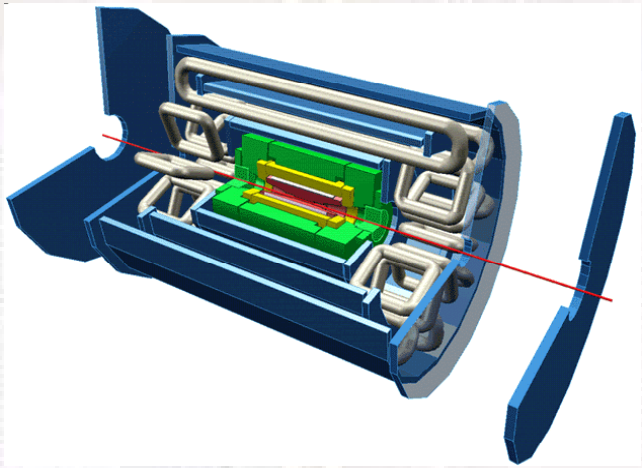
What is a Solenoid?

- 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
  - The full potential of the inner detectors can be realised
- Charged particles only bend in one projection (looking along the beam line – see next page)
  - Makes life easier for the physicist!

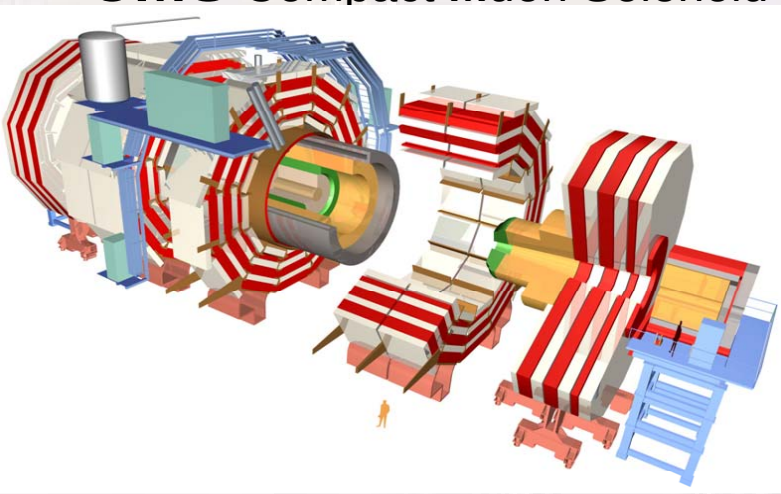
- **A large fraction of the things you see at Cessy concern the solenoid! (see later)**
- **(oh, and it costs about 80 million CHF!)**

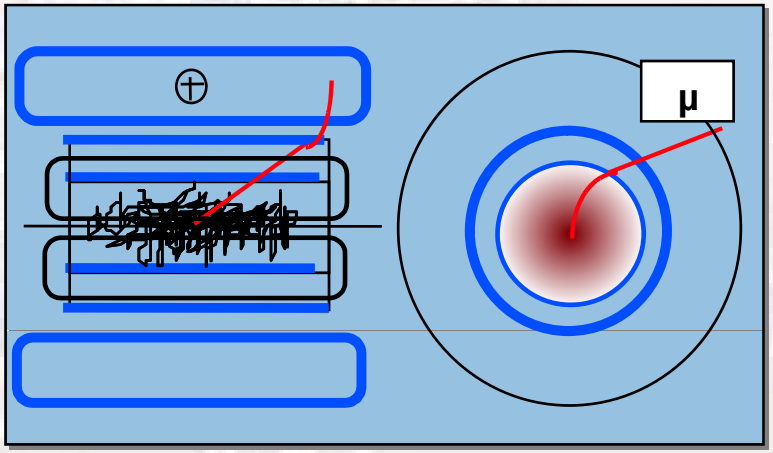
ATLAS vs CMS (the magnets!)

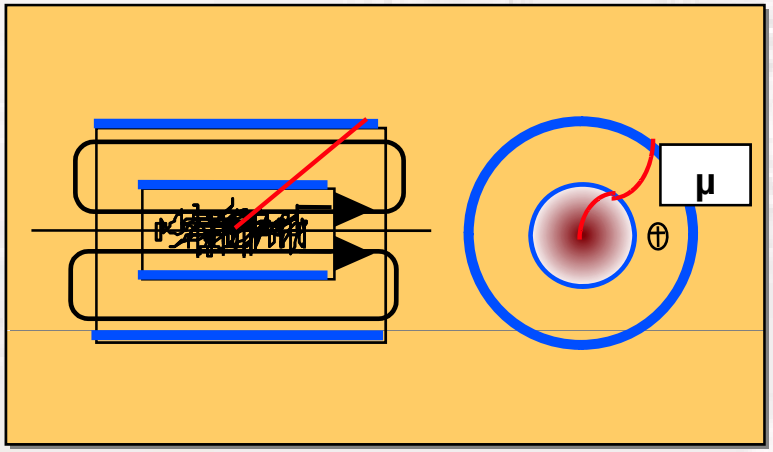
ATLAS A Toroidal LHC Apparatus



CMS Compact Muon Solenoid

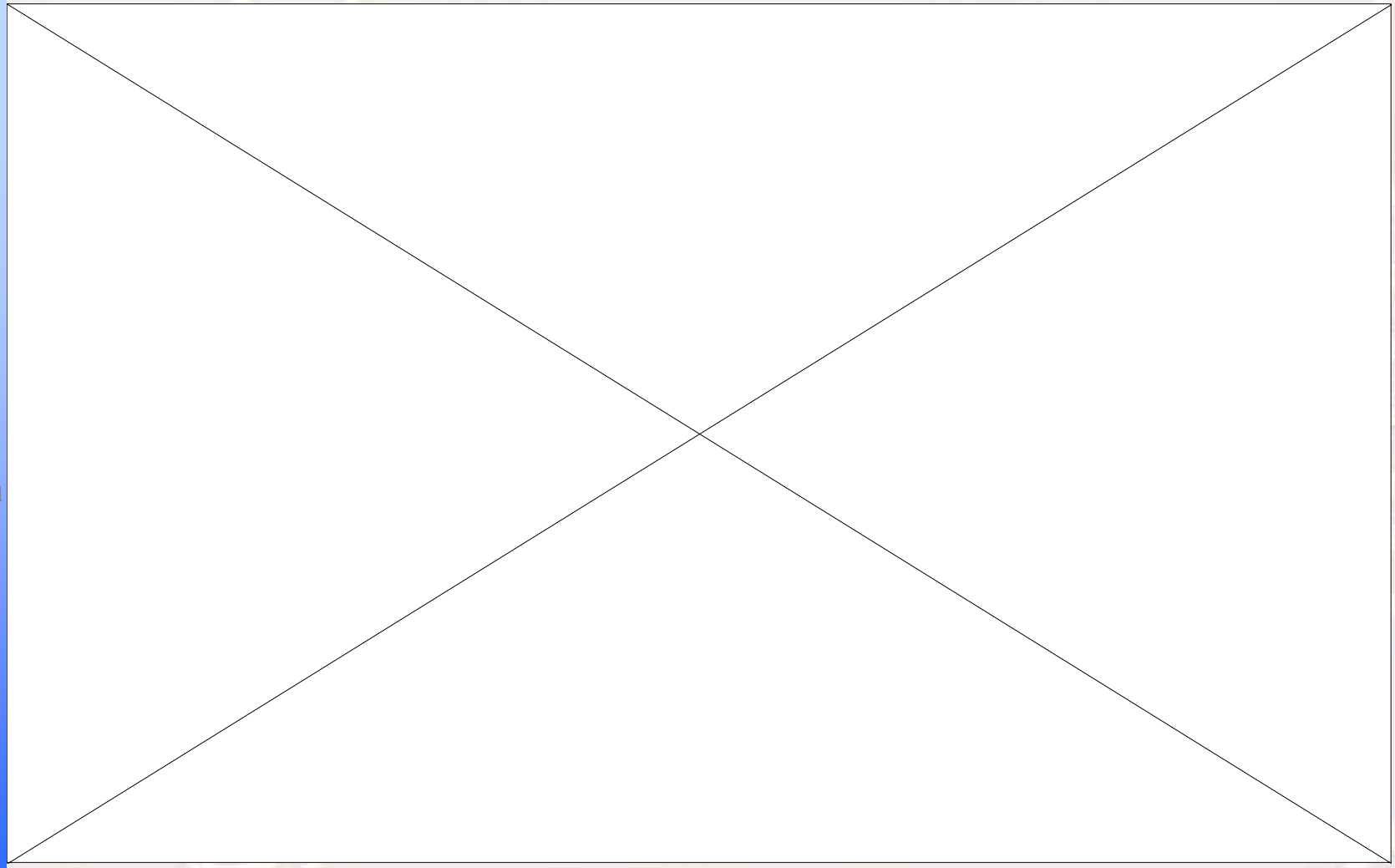






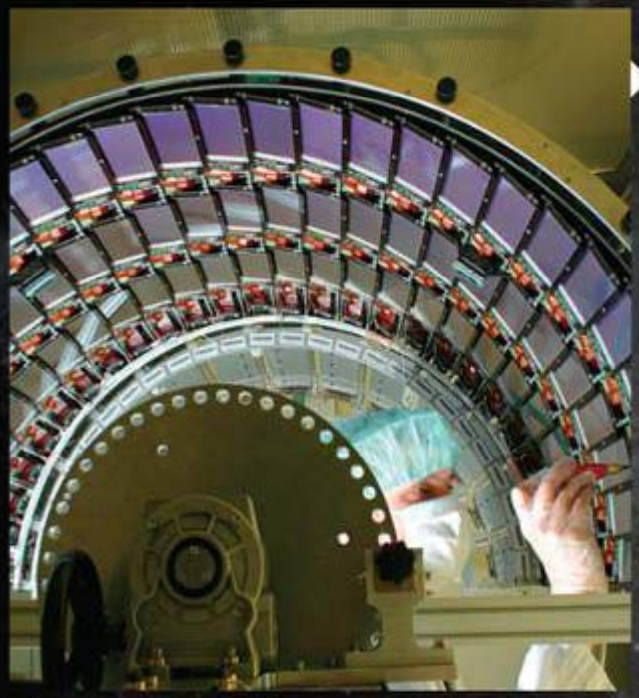
Charged particles "bend" in a magnetic field; the amount they bend tells us ~ how fast they are travelling

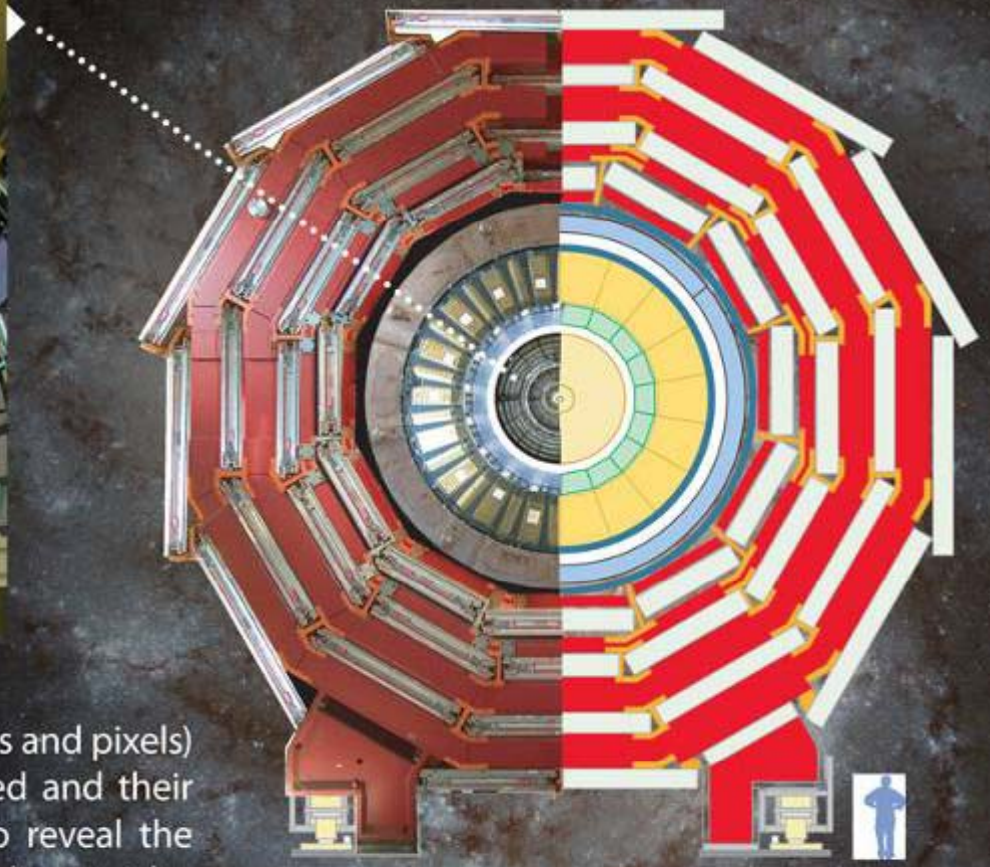
Particle Identification in CMS



Most particles are "absorbed" by CMS; a few (mainly muons, neutrinos…) escape

Components of CMS: the TRACKER





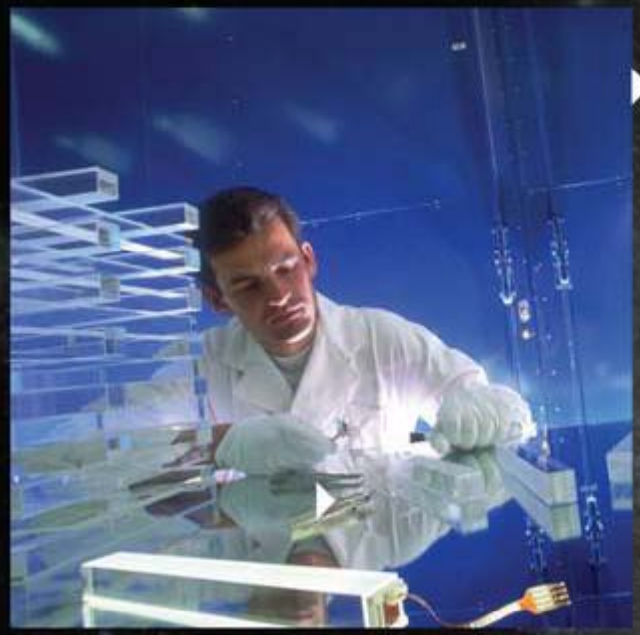
Tracker

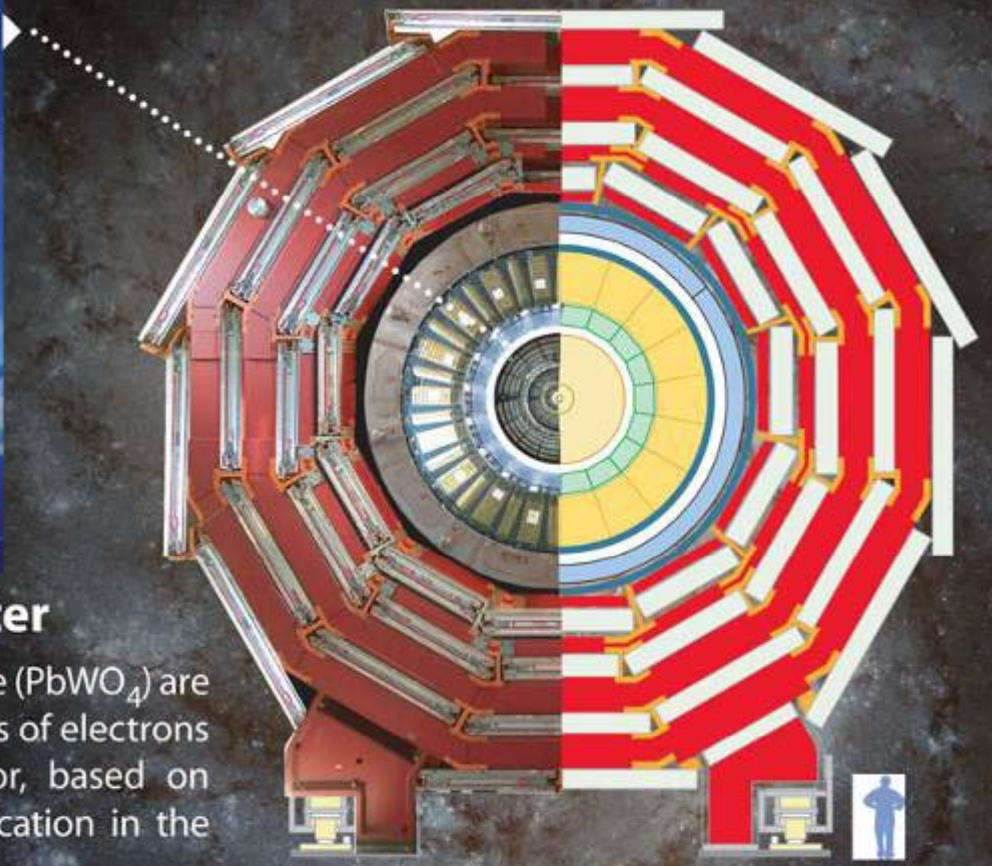
Finely segmented silicon sensors (strips and pixels) enable charged particles to be tracked and their momenta to be measured. They also reveal the positions at which long-lived unstable particles decay.

Numbers & Status: 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^{o}C
- **Status**
  - Strip tracker is completely built; being tested at low temperature now (bldg. 186); should be installed in September/October 2007
  - Pixel detectors are nearly complete; will be installed early 2008

Components of CMS: the ECAL





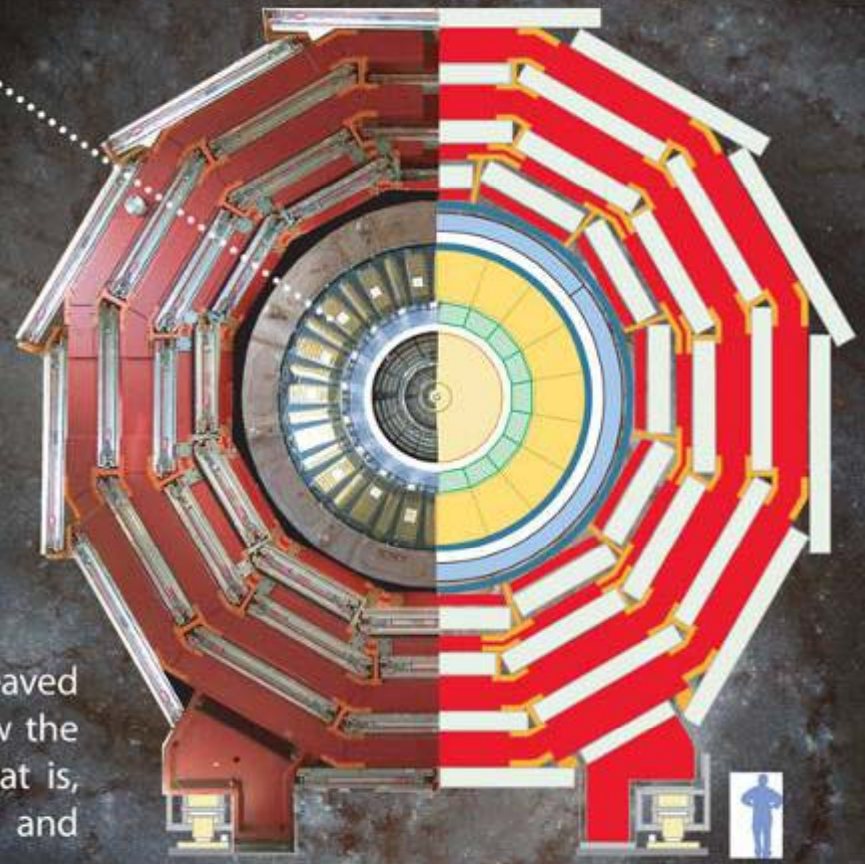
Electromagnetic Calorimeter

Nearly 80 000 crystals of lead tungstate ($PbWO_4$) are used to measure precisely the energies of electrons and photons. A 'preshower' detector, based on silicon sensors, helps particle identification in the endcaps.

Numbers & Status: ECAL

- **Homogeneous calorimeter**
  - Lead tungstate ($PbWO_4$) crystals create electromagnetic showers and produce scintillation light
  - Barrel: ~64000 crystals constructed in 36 "supermodules" (1700 crystals each); light detected by avalanche photodiodes
  - Endcaps: ~16000 crystals constructed as "supercrystals"
    - 5x5 arrays; light detected by vacuum phototriodes
- **Status**
  - All barrel supermodules assembled; 18 installed in May (all on one side); other 18 being installed this month
  - Endcaps (including the "Preshower" detector) will be installed in early-to-mid 2008

Components of CMS: the HCAL



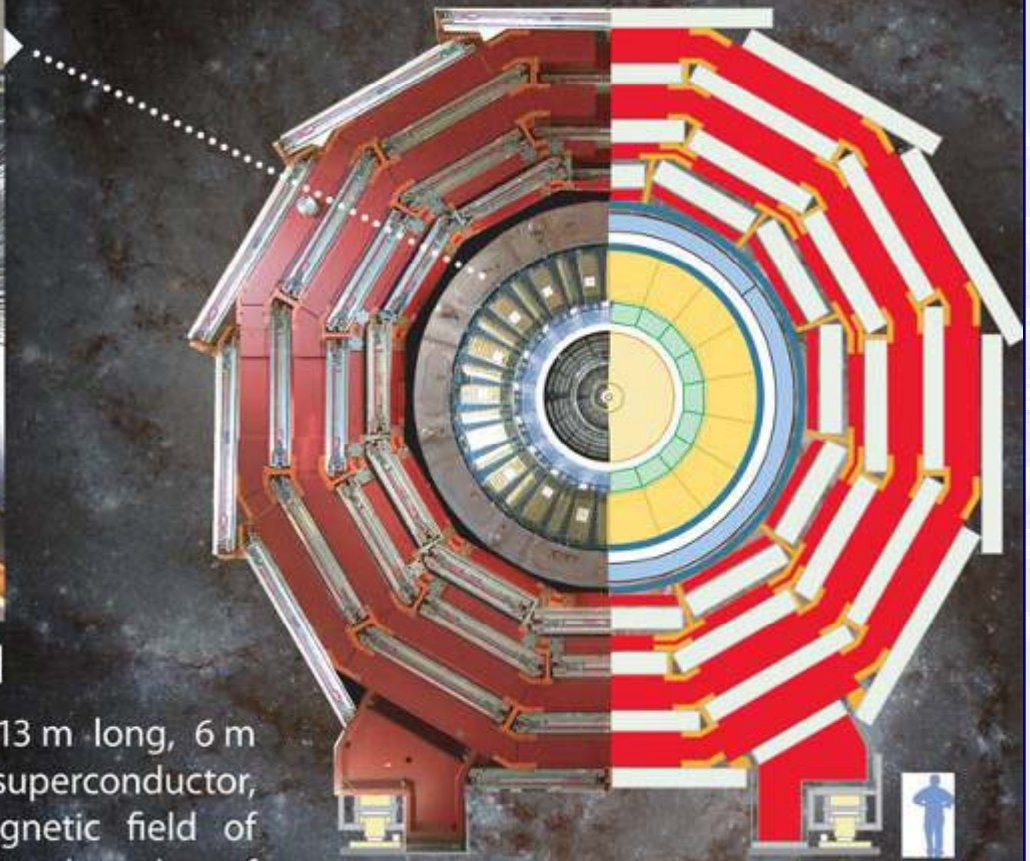
Hadron Calorimeter

Layers of dense material (brass or steel) interleaved with plastic scintillators or quartz fibres allow the determination of the energy of hadrons, that is, particles such as protons, neutrons, pions and kaons.

Numbers & Status: HCAL

- **Three parts to the puzzle**
  - 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
- **Status**
  - Barrel and Endcaps installed
  - HF first objects to be lowered into the cavern; also first parts to be commissioned with cosmic rays

Components of CMS: the SOLENOID

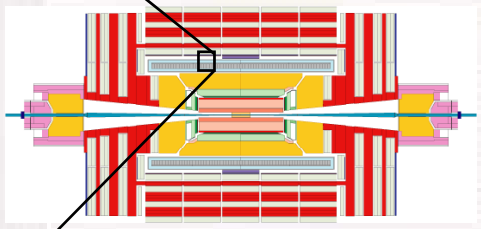


Superconducting Solenoid

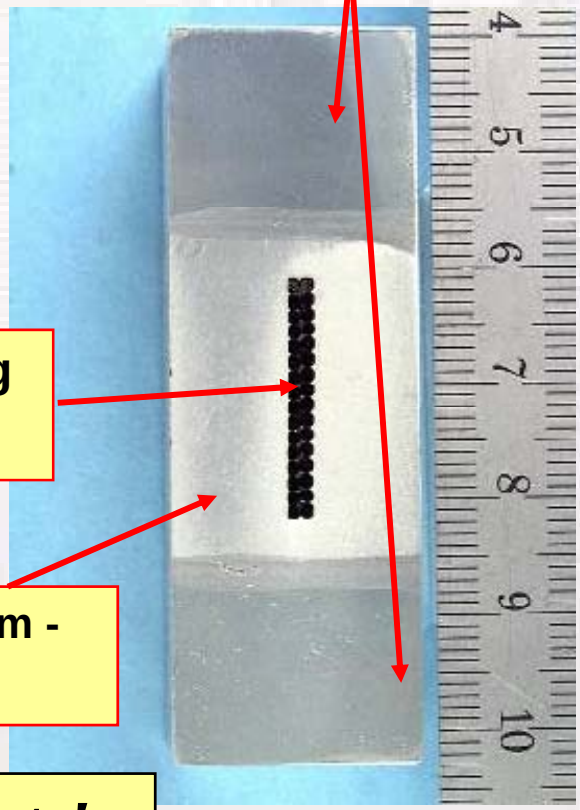
Passing 20 000 amperes through a 13 m long, 6 m diameter coil of niobium-titanium superconductor, cooled to –270°C, produces a magnetic field of 4 teslas (about 100 000 times stronger than that of the Earth). This field bends the trajectories of charged particles, allowing their separation and momenta measurements.

Numbers & Status: Solenoid (1)

Solenoid piece at Cessy



Aluminium alloy - mechanical stabilizer



Superconducting cable - NbTi

Ultra-pure Aluminium - magnetic stabilizer

Approx: 1 million km of NbTi filaments!

http://cmsinfo.cern.ch/outreach/CMSdocuments/MagnetBrochure/MagnetBrochure.pdf

Construction of the Solenoid

- **7 main parts:**
  - Outer vacuum tank: made in 3 pieces, assembled at CERN
  - Inner vacuum tank: single piece transported to CERN from ~120km away in the Jura
  - Solenoid itself: 5 coils, welded to each other
- **Also a huge "return yoke"**
  - ~10500 tonnes of solid steel pieces surround the solenoid to control the magnetic field
  - Also act as the "skeleton" of CMS
  - Yoke is divided into 5 barrel rings and 6 endcap disks (3 on each side)

Transporting and constructing the solenoid

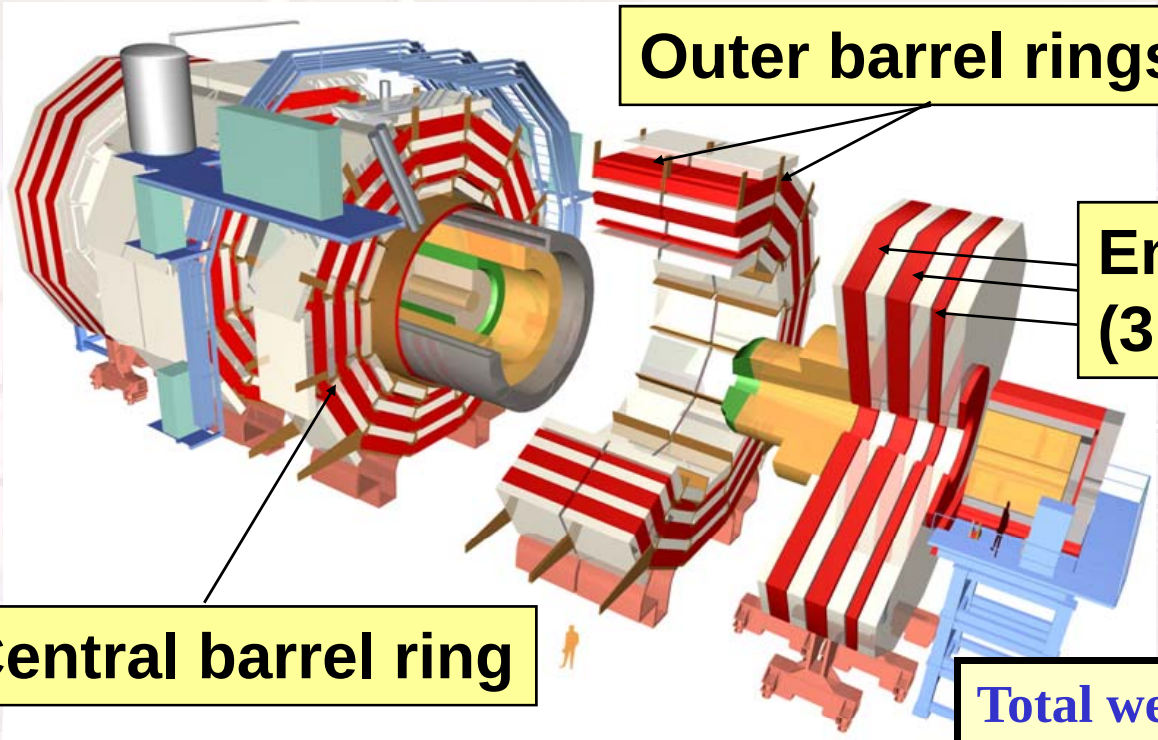
“Swivelling the coil”

Coil is constructed vertically but needs to be horizontal!

Inserting the coil

Standing in the coil – at 100K!

Numbers & Status: Solenoid (2)

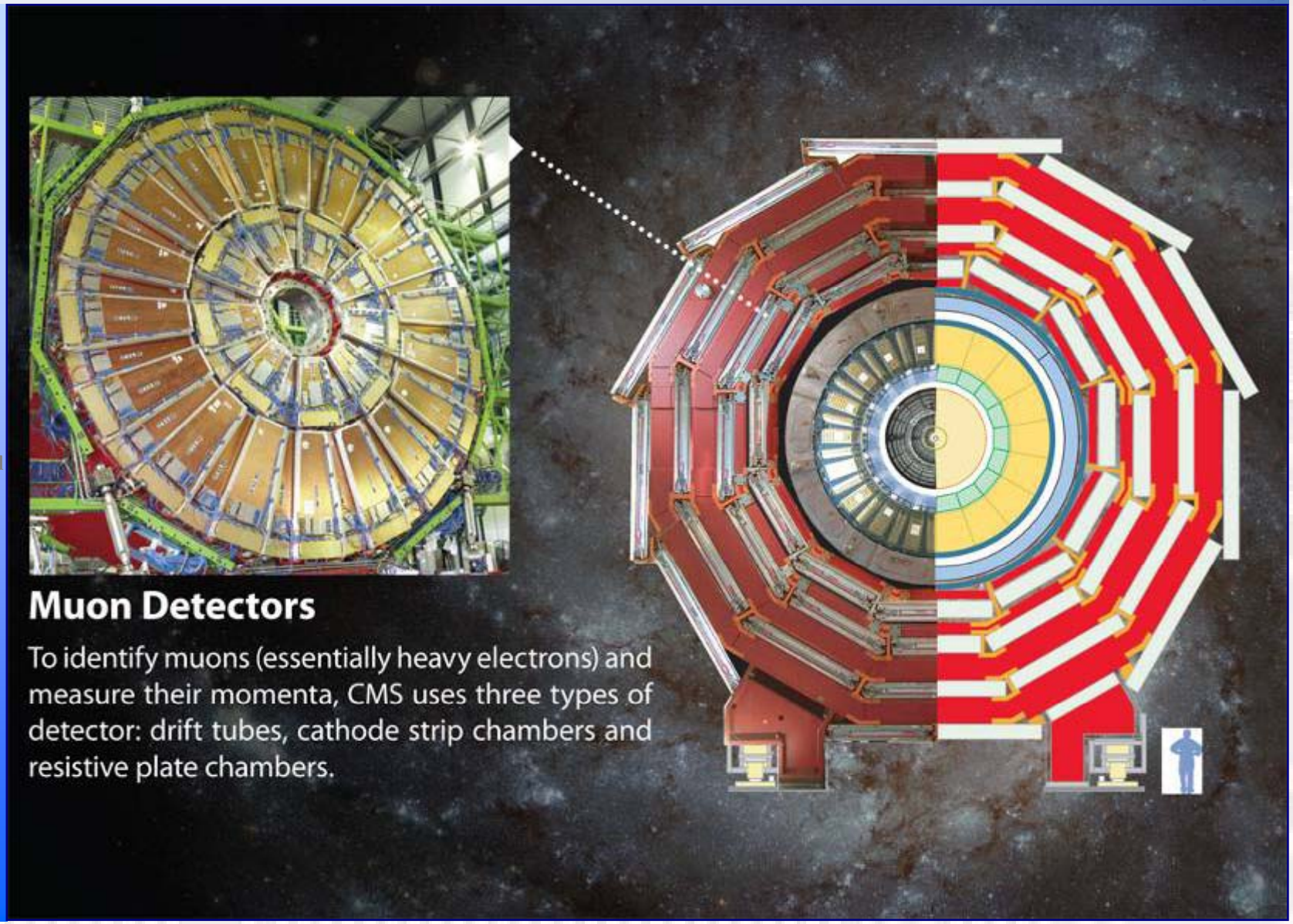


	Central Ring	*Outer Rings*
Barrel ring	1250 tonnes	1174 tonnes
Vacuum vessel	264 tonnes	-
Superconducting coil	234 tonnes	-
Support feet	72 tonnes	66 tonnes
Cabling on vacuum vessel	150 tonnes	-
Support for racks and cables	10 tonnes	10 tonnes
Total	**1980 tonnes**	**1250 tonnes**

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

Endcap disk 1 (YE1)	~730 (disk) + 90 (cart) tonnes
Endcap disk 2 (YE2)	~730 (disk) + 90 (cart) tonnes
Endcap disk 3 (YE3)	~300 (disk) + 90 (cart) tonnes

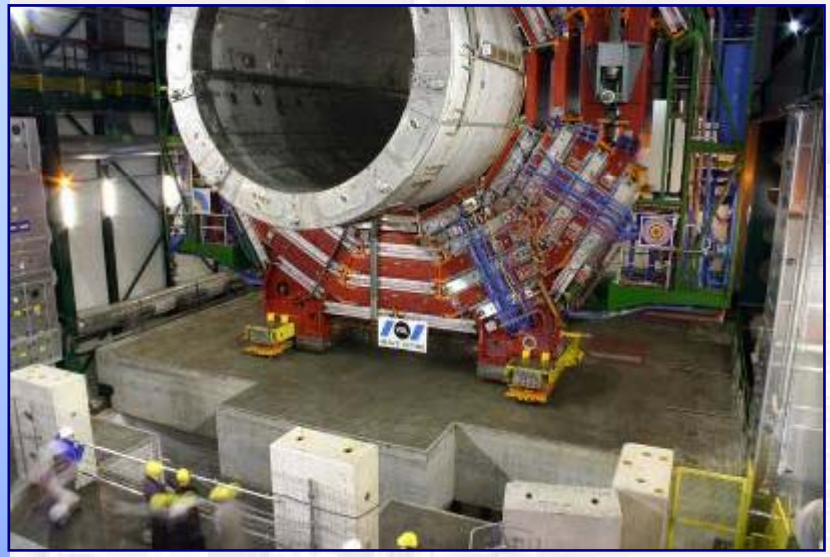
Components of CMS: the MUON system

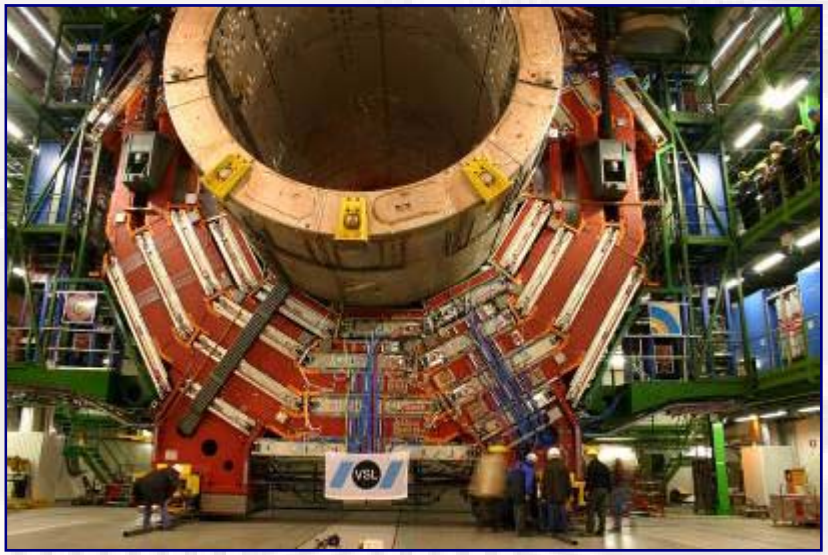


Numbers & Status: MUON system

- **Position measurement**
  - Drift Tubes (DT) in barrel
  - Cathode Strip Chambers (CSC) in endcaps
- **Trigger**
  - Resistive Plate Chambers (RPCs) in barrel and endcaps
- **Status**
  - Most muon chambers installed and commissioned with cosmic rays

Lowering parts of CMS – the central ring





Visiting Point 5

- **Outside the construction hall**
- **Inside the hall**
- **The visitors gallery**
- **Underground**
- **NOTE: things change every day!!**

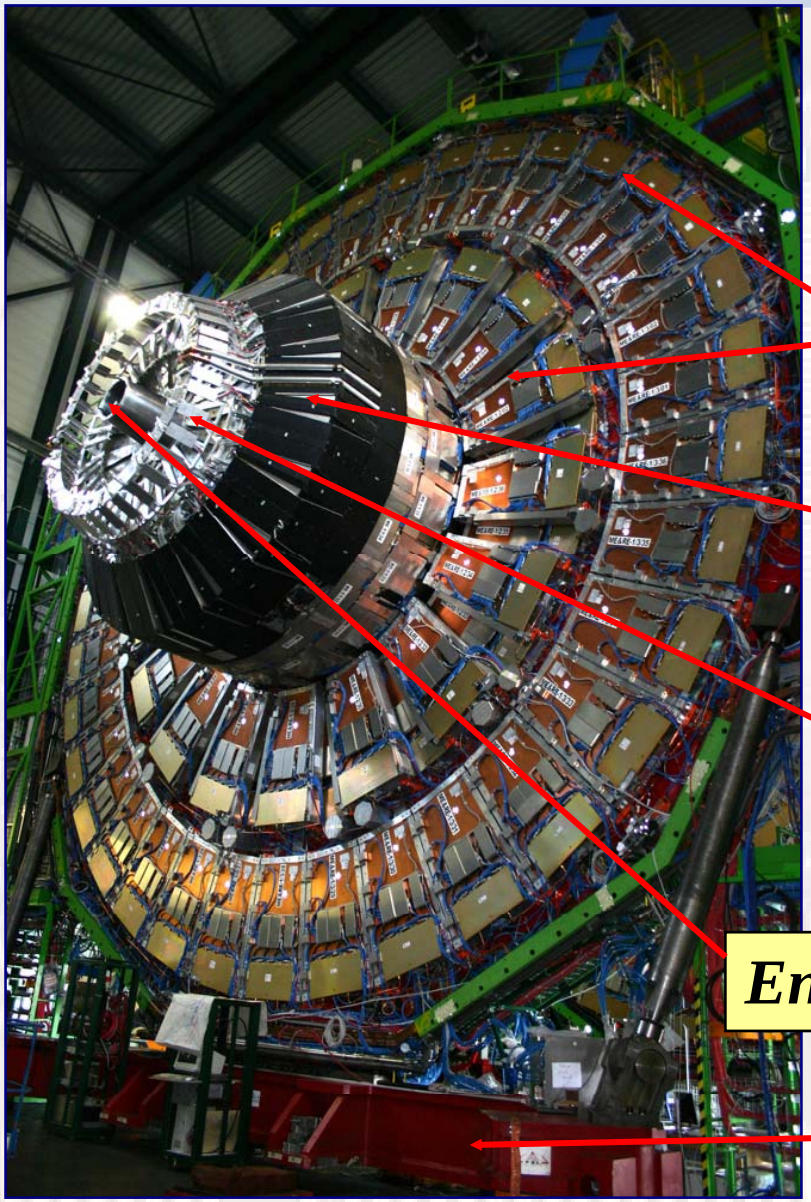
Outside the construction hall

- **Filled with Helium gas**
- **Two cylinders supply He for the CMS solenoid cryogenic system – about 5000 litres of liquid He are required**
- **The time to cool the CMS solenoid to ~4K is about 3 weeks**
- **Other 4 cylinders will supply He for the LHC cryogenic system**

Outside the construction hall

Inside the construction hall

Inside the construction hall yesterday!



- **YE-1 ("Yoke Endcap disc -1")**

Muon detectors

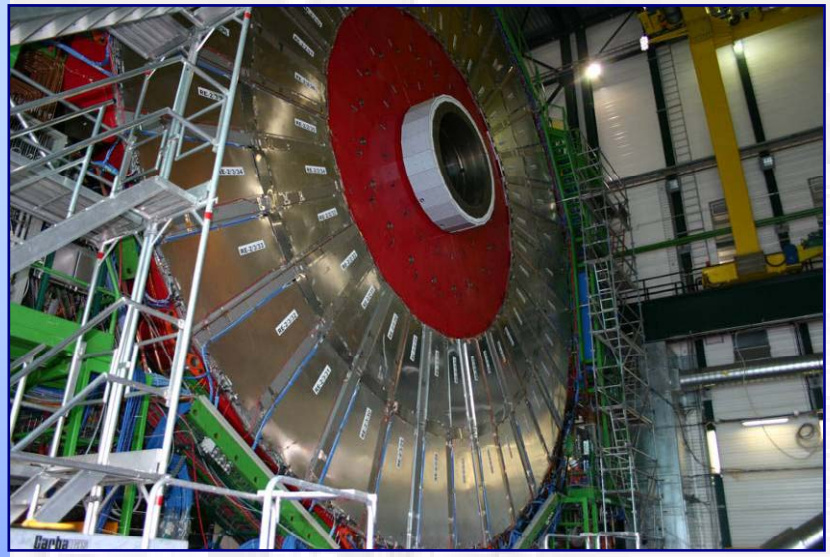
Endcap Hadron Calorimeter

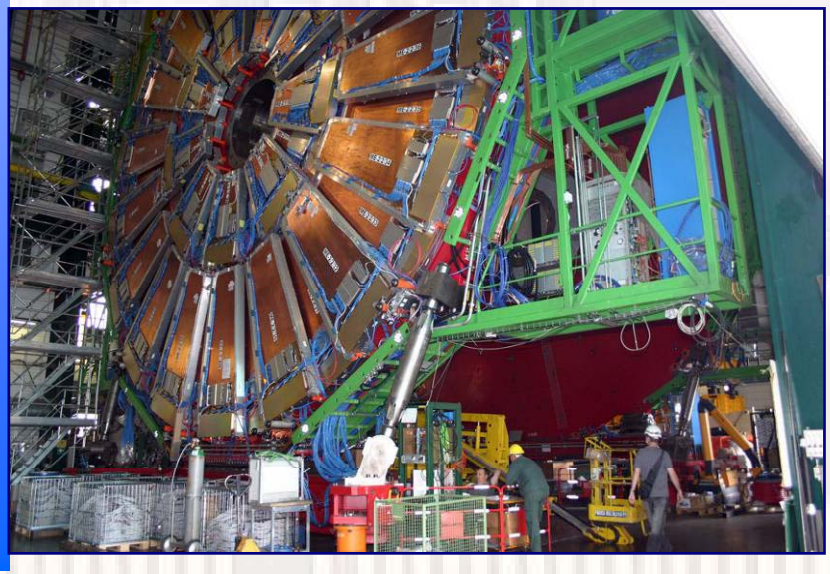
Endcap ECAL (not present)

Endcap Preshower (not present)

Support "cart"

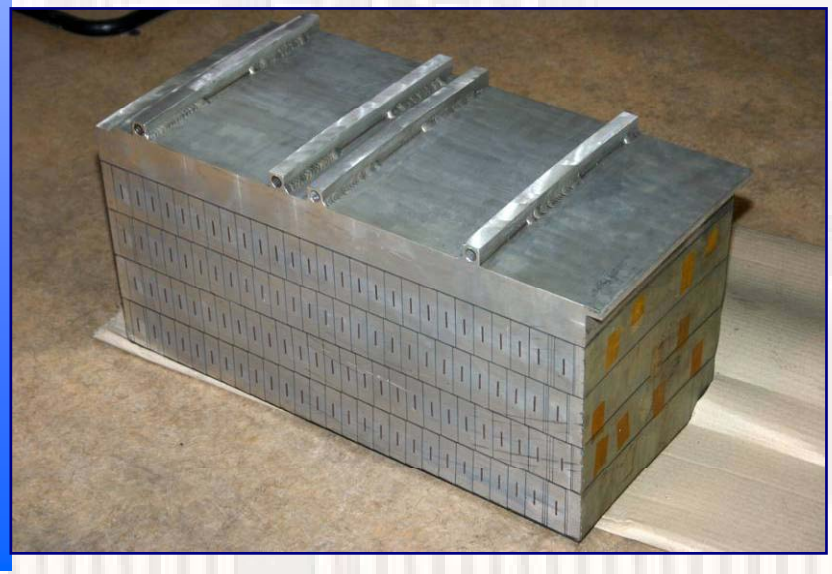
Inside the construction hall yesterday!





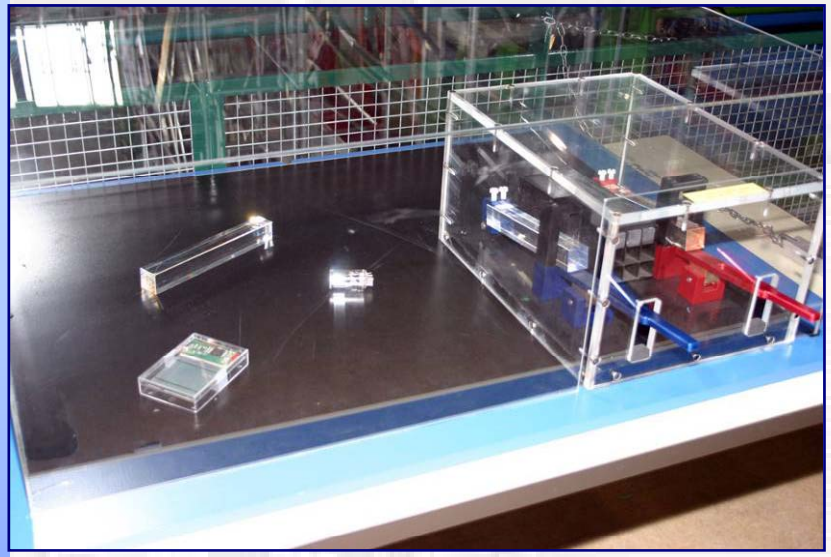
- **YE-2 and YE-3 discs**
- **Loaded with muon detectors**

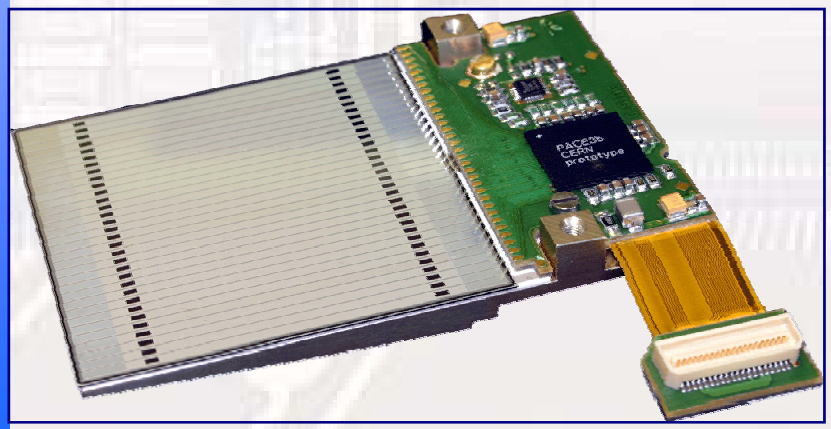
The visitors gallery



- **“opened” muon chamber (top)**
- **Piece of solenoid (bottom)**
- **Labels currently being made**
- **Searching for something to show from the HCAL…..**

The visitors gallery



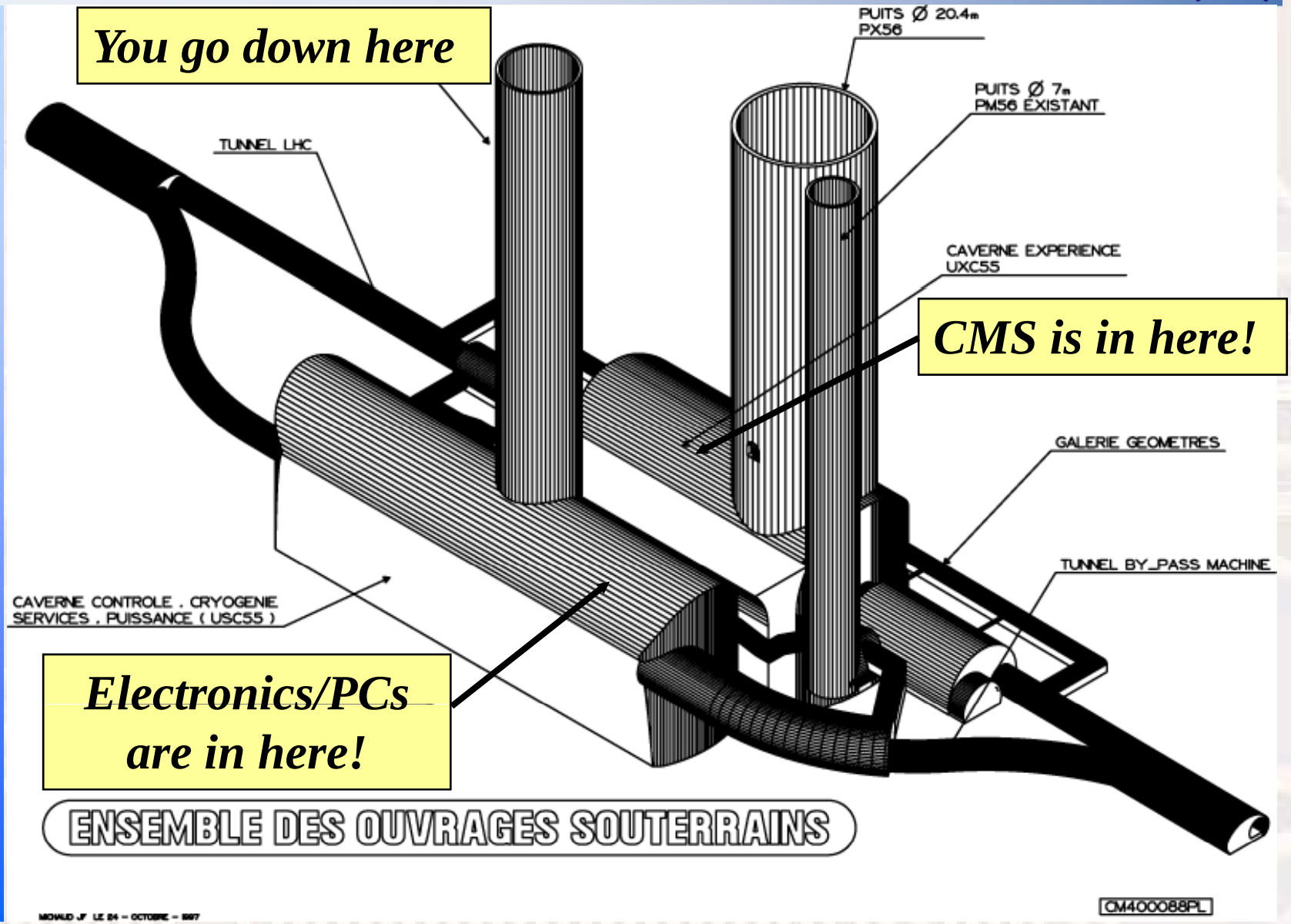


- **ECAL:**
  - PbWO4 crystal; balance (PbWO4 vs glass); vacuum phototriode;
- **Preshower module (you can see the strips on the sensor)**

The visitors gallery

- **Piece of the CMS tracker will be installed in the gallery soon**
- **Hope to have a magnifying glass to view the strips etc.**

The underground caverns



From the bottom of the elevator to the main cavern

This room mainly houses electronics for the CMS safety systems – it was the first underground area to be commissioned

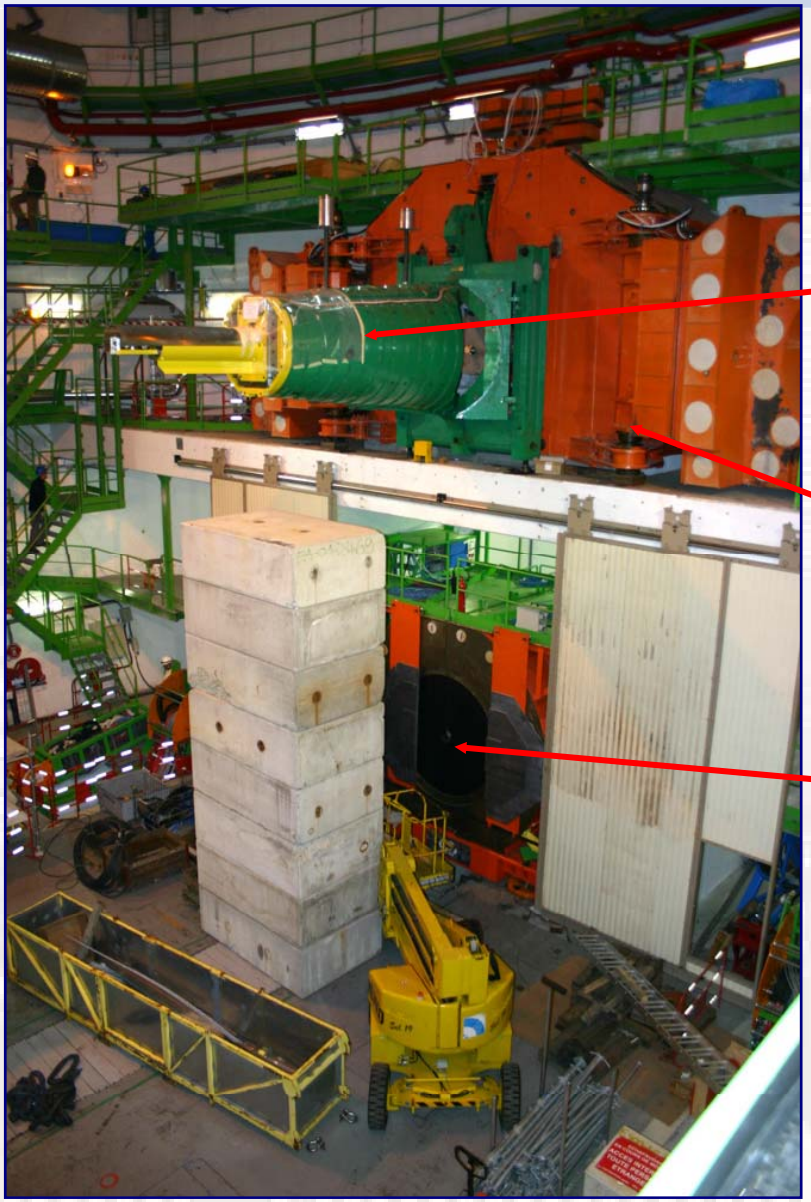
Going Underground (1)

Going underground (2)

The UXC55 cavern yesterday

- **A lot of work on the central barrel ring (YB0)**
  - Installing ECAL supermodules
  - Pre-cabling/piping etc. for the Tracker
  - Cabling/piping etc. for the ECAL
- **The fixed iron nose (green) with the beam pipe present (protected by an Al cover)**

The UXC55 cavern yesterday



Fixed iron nose

Rotating shielding (100 tonne doors!)

One of the forward Hadron calorimeters

Fire safety underground

Can fill the experimental cavern with foam in 7 minutes!

Resources for guides

- **CMS public web site (being completely redesigned now!)**
  - cmsinfo.cern.ch
- **CMS Brochure**
  - Available from secretariat etc. in English and French
  - Many other translations done or ongoing

http://cmsinfo.cern.ch/outreach/CMSdocuments/CMSbrochure/NewBrochure2006/Brochure2006.html

	Draft screen quality PDF	Final screen quality PDF	Final print quality PDF	Centre page poster PDF	Responsible for translation
English		Available	Available (30 Mbytes)	Available (20 Mbytes)	D. Barney, J. Virdee
French	Available				C. Pralavorio, P. Bloch, M.Della-Negra
Italian	Available				F. Cavallari et al
German	Available				C. Wulz et al
Dutch	Available				F. Blekman, B. Van Konigsveld
Greek	Available				P. Vichoudis, E. Petrakou, E. Symeonidou, N. Tracas
Spanish	Available				J. Puerta-Pelayo, P. Garcia
Chinese	In preparation				C.M. Kuo
Finnish	Available				J. Tuominiemi, K. Aspola
Russian	In preparation				A. Zarubin
Polish	Available				M. Lapka
Portuguese	Available				C. Lourenco
Serbian	Available				D. Lazic, P. Milenovic, D. Maletic, A. Vitlic
Turkish	Available				Erhan Gulmez et al

- German and Italian will be printed in July

Resources for guides (cont.)

- **CMS Times**
  - Weekly online newsletter – contains latest status at point 5
  - http://cmsinfo.cern.ch/outreach/CMSTimes.html
  - In particular, edition of 18th December 2006 has a lot about the history of CMS
- **Comic-book brochure**
  - Available in English and French; other languages being printed
- **This presentation! (will be on the CMS public web site next week)**

CMS Comic-Book Brochure

Some Q & A

- ***How many people are involved in building CMS ? Do they work 24 hours a day ? Do they work over Christmas ? How many man-years of effort are required to build it ?***
- **See http://cmsdoc.cern.ch/peoplestat.html**
- **At the moment there are about 2700 scientists and engineers from 184 institutes in 39 countries**
- **Also huge effort from industry**
- **Started construction about 5 years ago, but design etc. started nearly 20 years ago!**

Some Q & A

- ***How much power does it consume ?***
- **See the CMS Times this week!**
- **About 10 MegaWatts required during operation**
  - Equivalent to about 3000 average houses
- **About 1200 m^3 of water per hour for cooling**
  - The jet d'eau in Geneva pumps 1800 m^3 per hour!

Q & A

- ***Why do we have CMS and ATLAS? i.e. why 2 experiments to do the same thing?***
- **An important part of the "scientific method" is validation. We do not know the "answer" in advance. So having two detectors (built and optimized in different ways) can provide independent verification (or denial!) of discoveries**