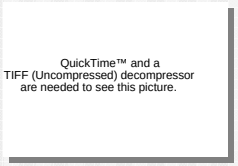
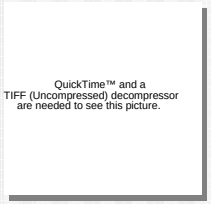
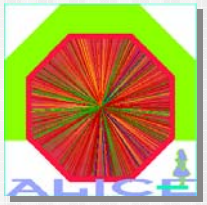
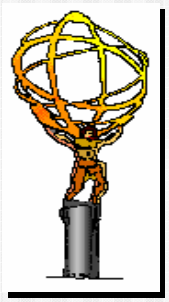
LHC Experiments: Detector Status Report









Günther Dissertori
ETH Zürich

WLCG Collaboration Workshop
CERN
23.1.2007

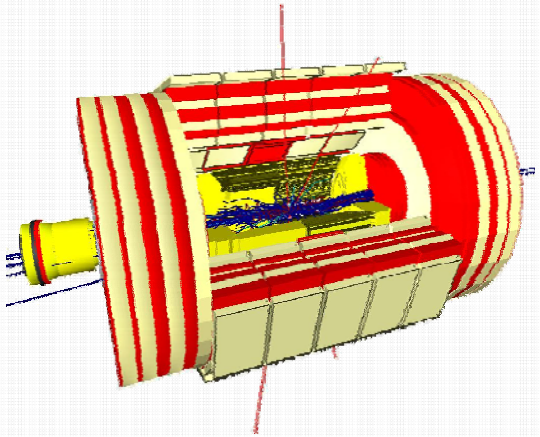
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Outline

ETH Institute for Particle Physics

- Introduction

- What is measured, why and how?
- Detector Status Overview :
  - LHCb
  - ATLAS
  - ALICE
  - CMS

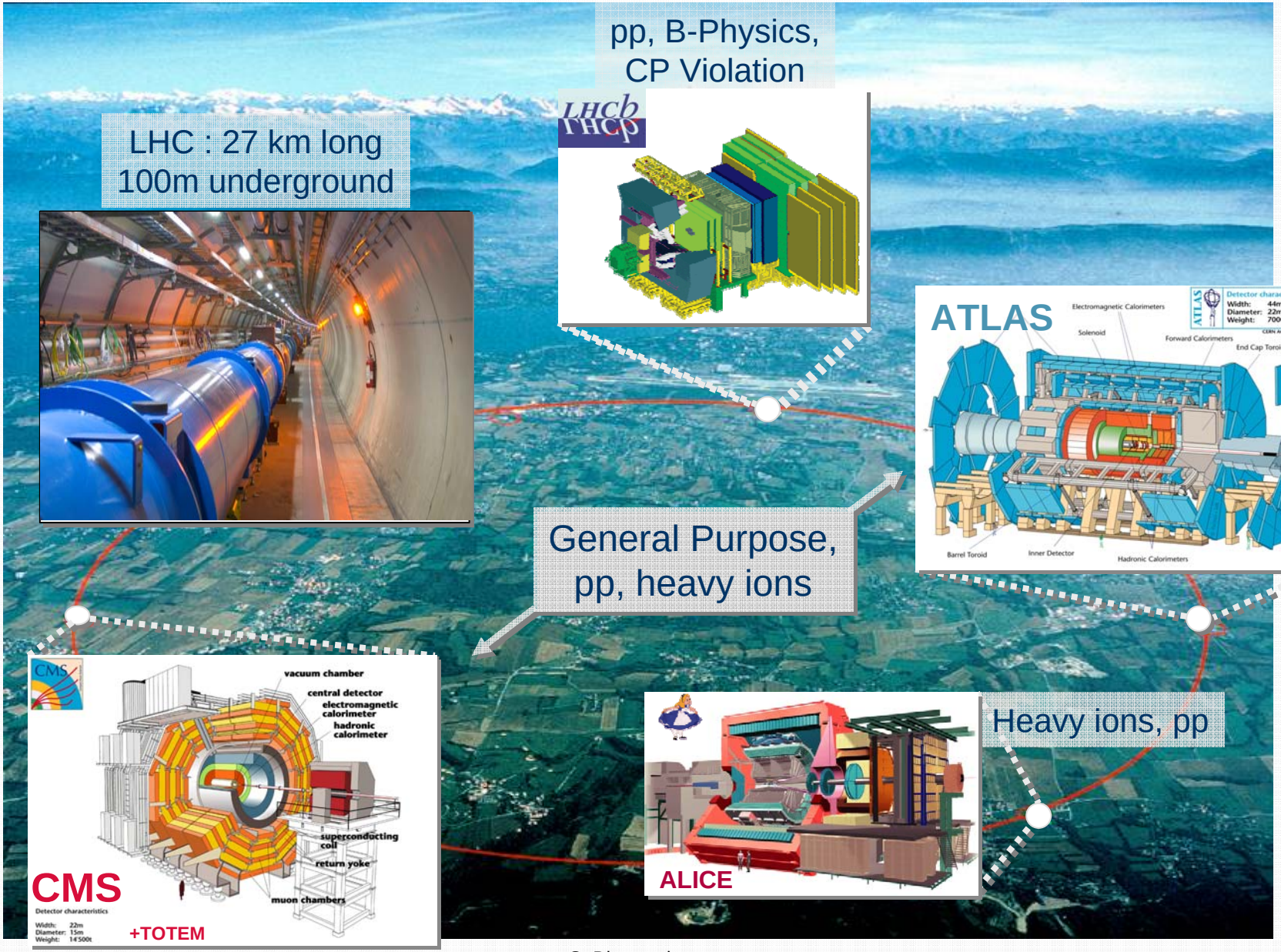


- Conclusions
- I will NOT talk about
  - Physics reach
  - Detailed detector technologies and numbers, DAQ and computing

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Our future play ground

ETH Institute for Particle Physics



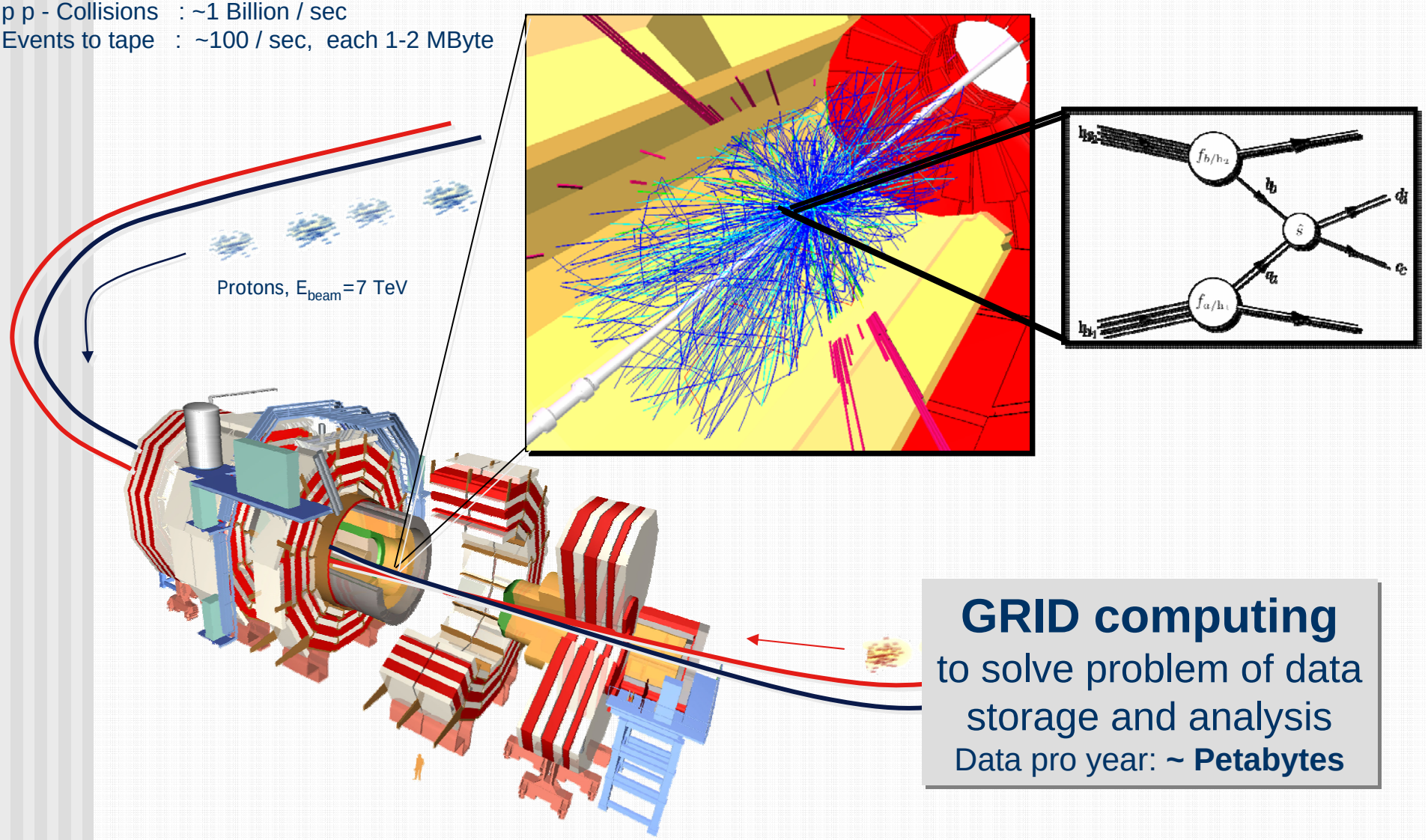
What is measured, why and how?

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Physics at the LHC

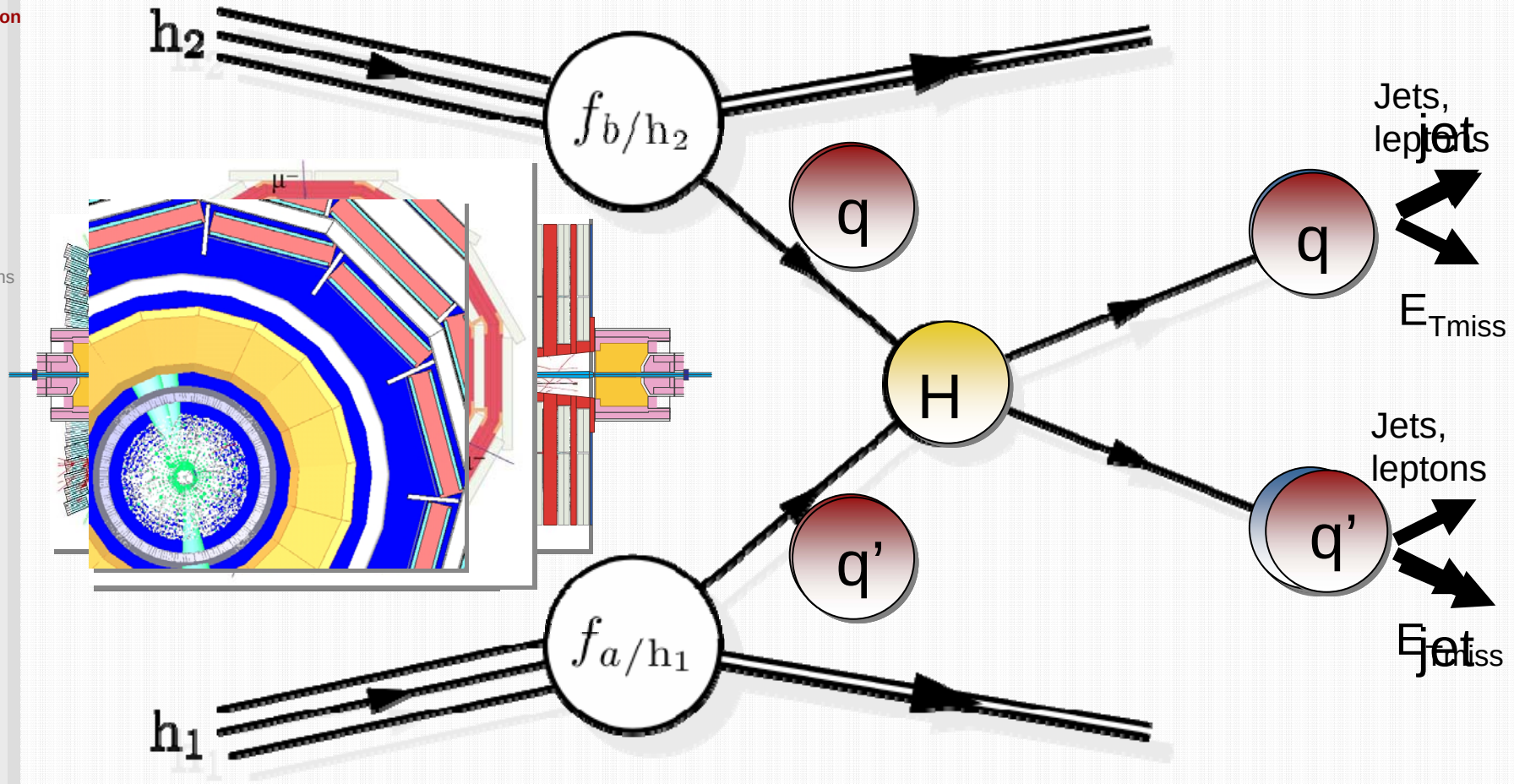
ETH Institute for Particle Physics

Centre-of-Mass Energy = 14 TeV
Beam crossings : 40 Million / sec
p p - Collisions : ~1 Billion / sec
Events to tape : ~100 / sec, each 1-2 MByte



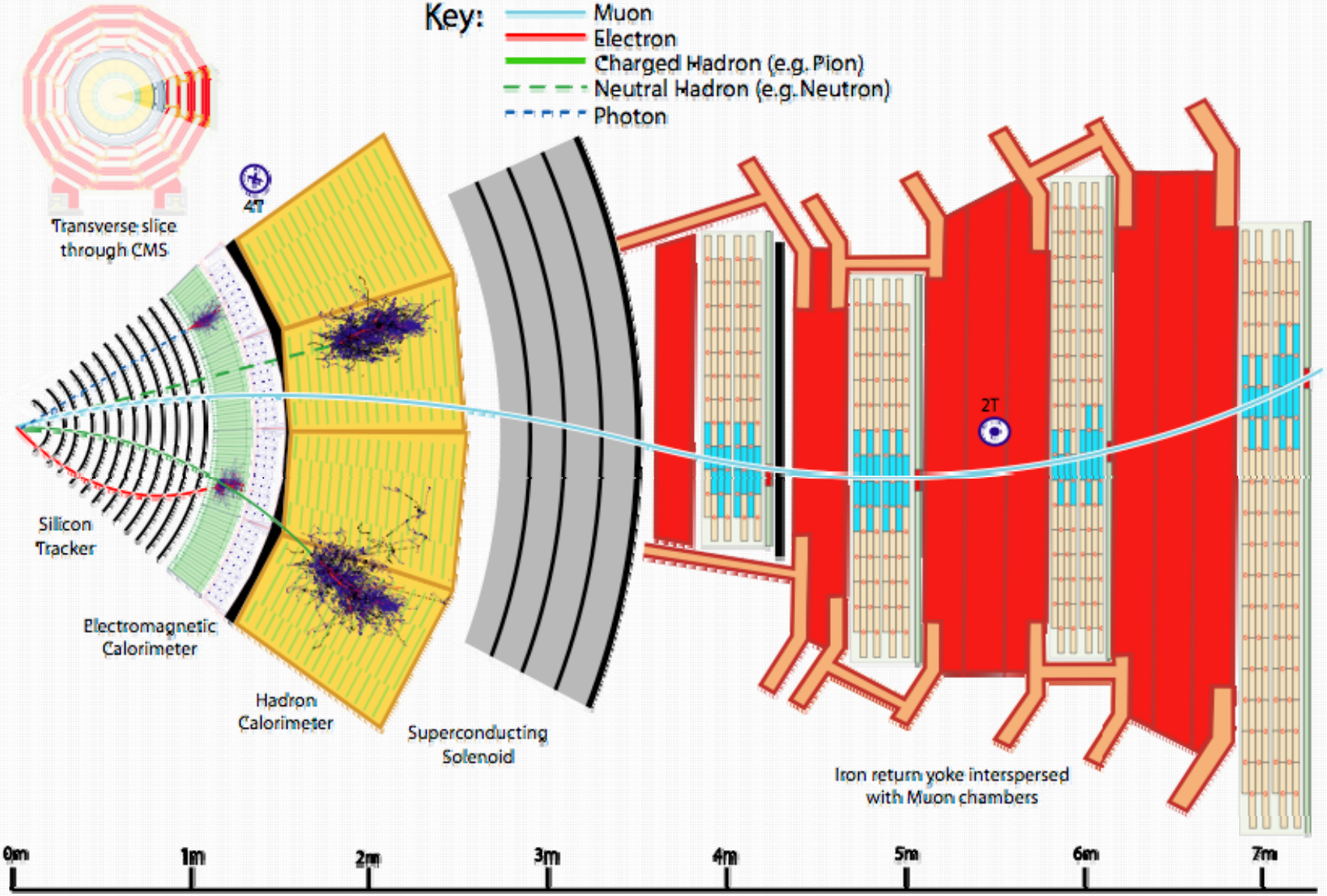
GRID computing
to solve problem of data storage and analysis
Data pro year: **~ Petabytes**

Basic processes

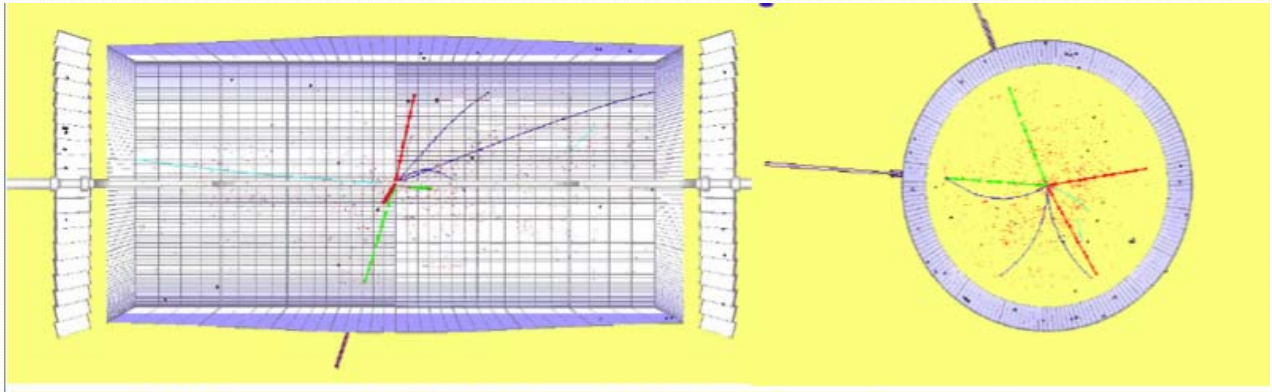


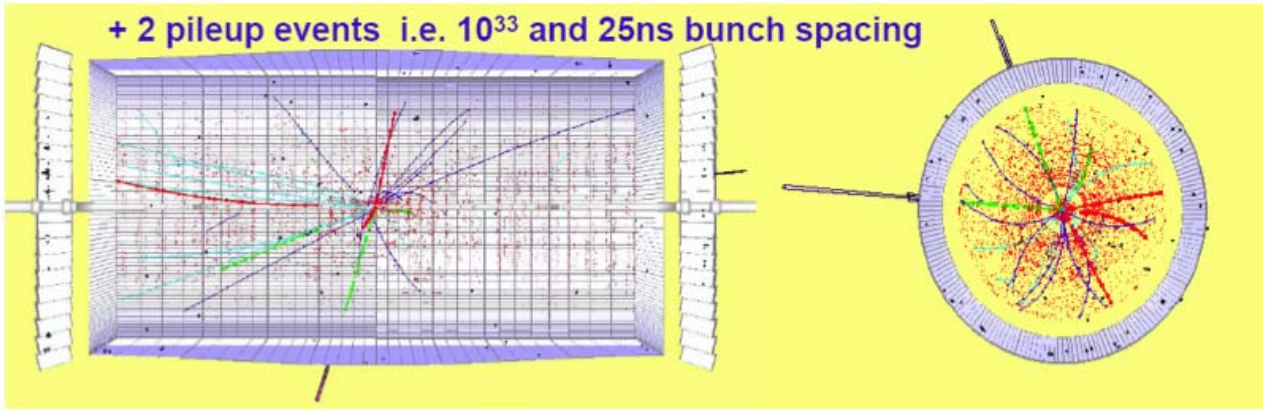
$$d\sigma(h_1 h_2 \to cd) = \int_0^1 dx_1 dx_2 \sum_{a,b} f_{a/h_1}(x_1, \mu_F^2) f_{b/h_2}(x_2, \mu_F^2) d\hat{\sigma}^{(ab \to cd)}(Q^2, \mu_F^2)$$

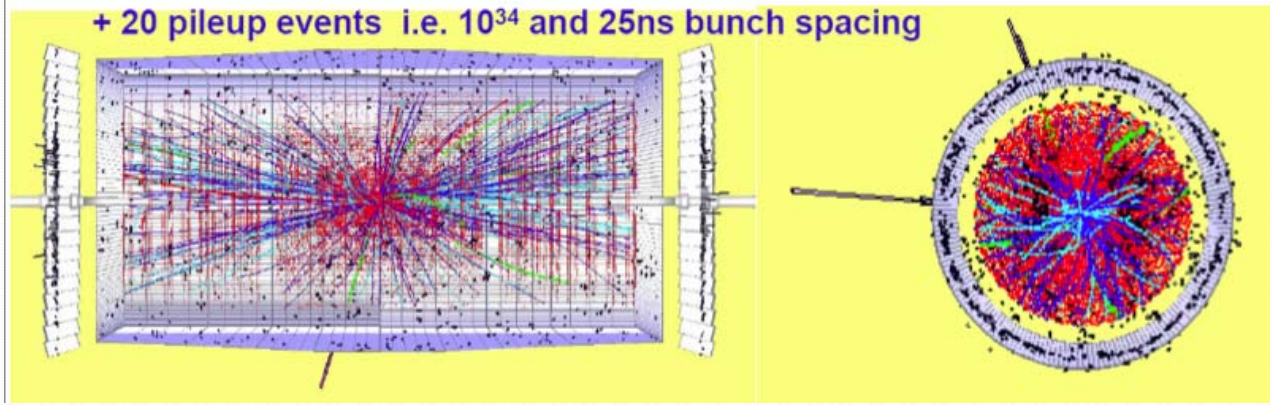
General Detector Layout



Challenge : Pile-up events





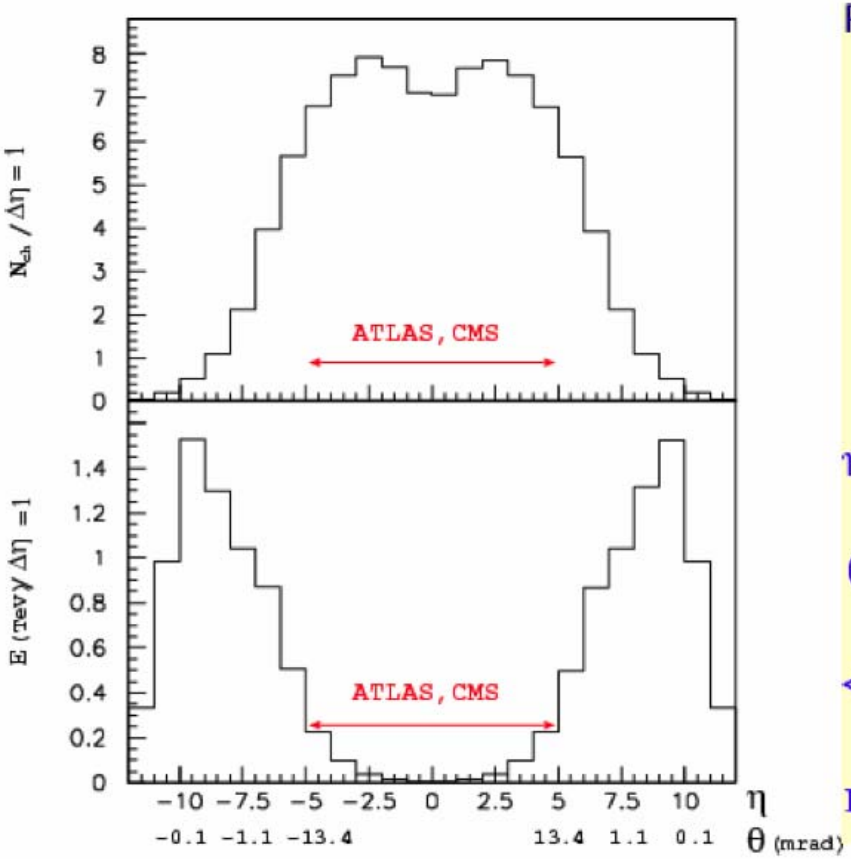


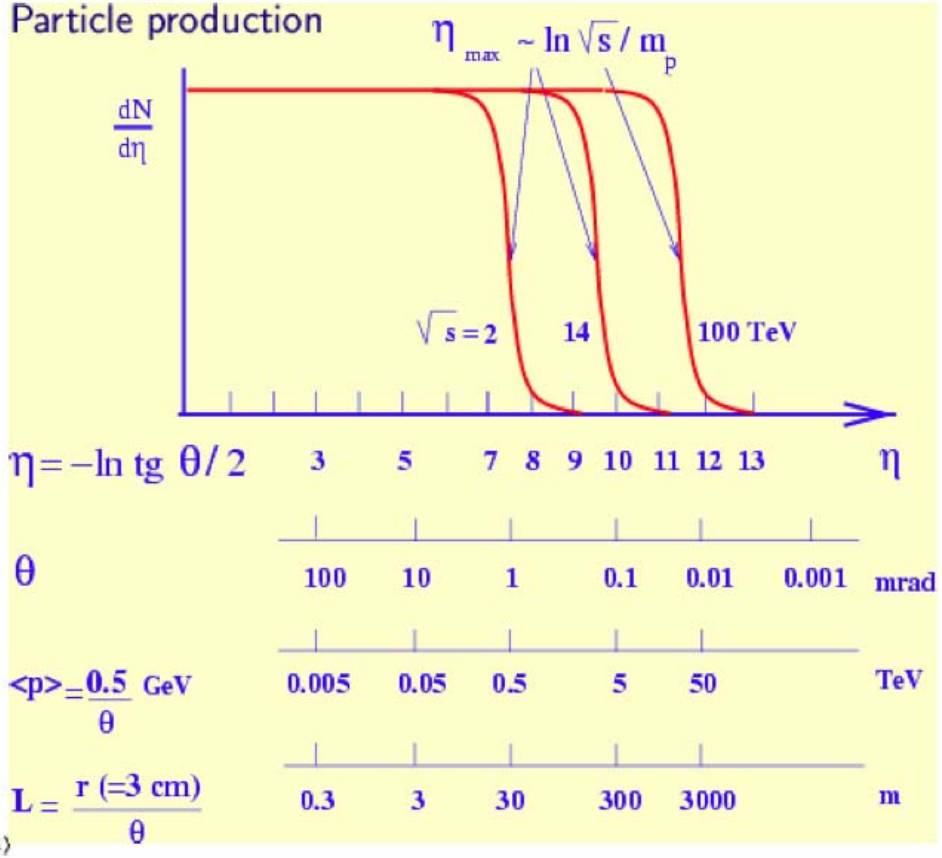
- Example of golden Higgs channel $H \rightarrow ZZ \rightarrow 2e2\mu$
- Large magnetic field and high granularity helps
- Need to understand detector first before able to exploit full lumi…

Large coverage / hermeticity

ETH Institute for Particle Physics

S. Tapprogge, Nov06



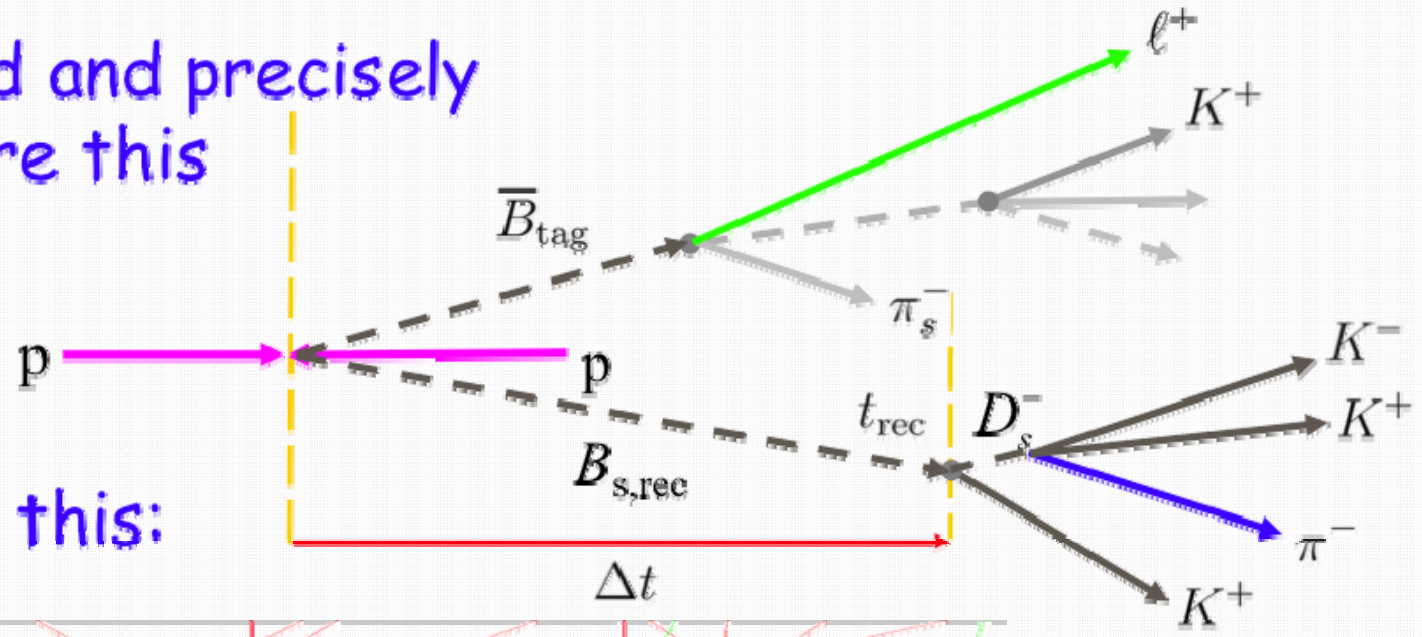


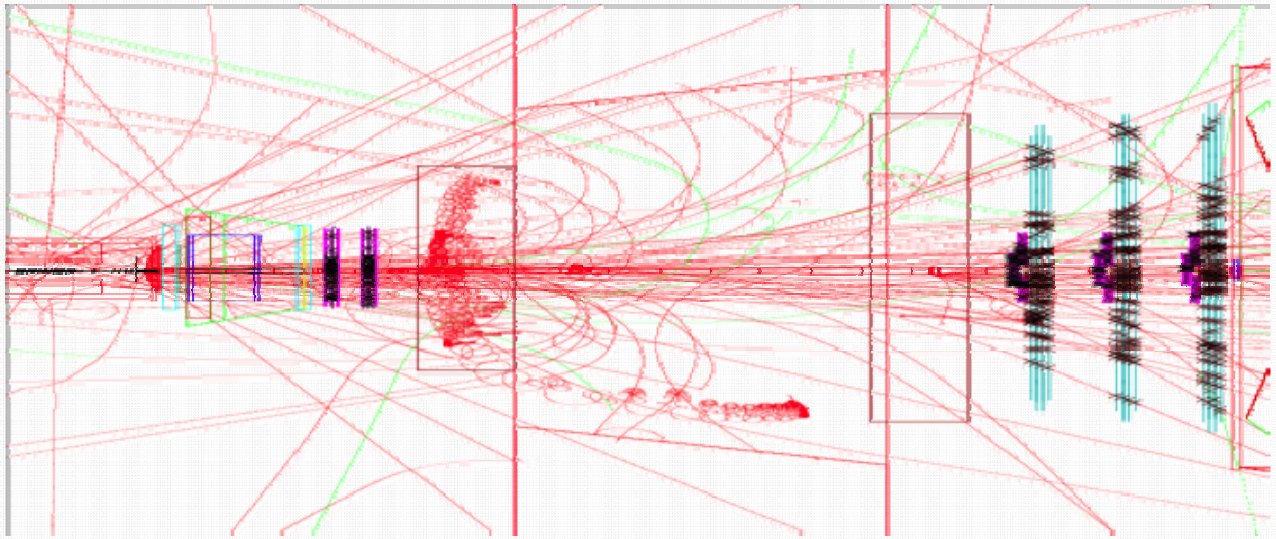
- Forward direction (|η| > 5)
  - Fewer particles produced, however with large energies

Status of the Detectors: LHCb

The LHCb challenge

- To find and precisely measure this
- Inside this:



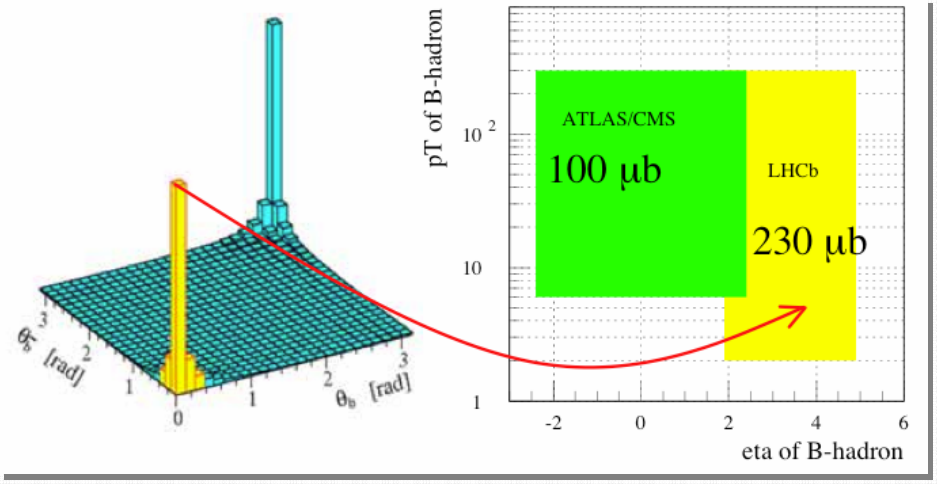


S. Tapprogge, Nov06

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Only look “forward”…

ETH Institute for Particle Physics



- Cross section for b-quark production: Very forward peaked!

$L \sim 2x10^{32} cm^{-2} s^{-1}$

$2x10^{12}$ b-hadrons/year, Br for interesting events $<10^{-5}$

Essential : Trigger

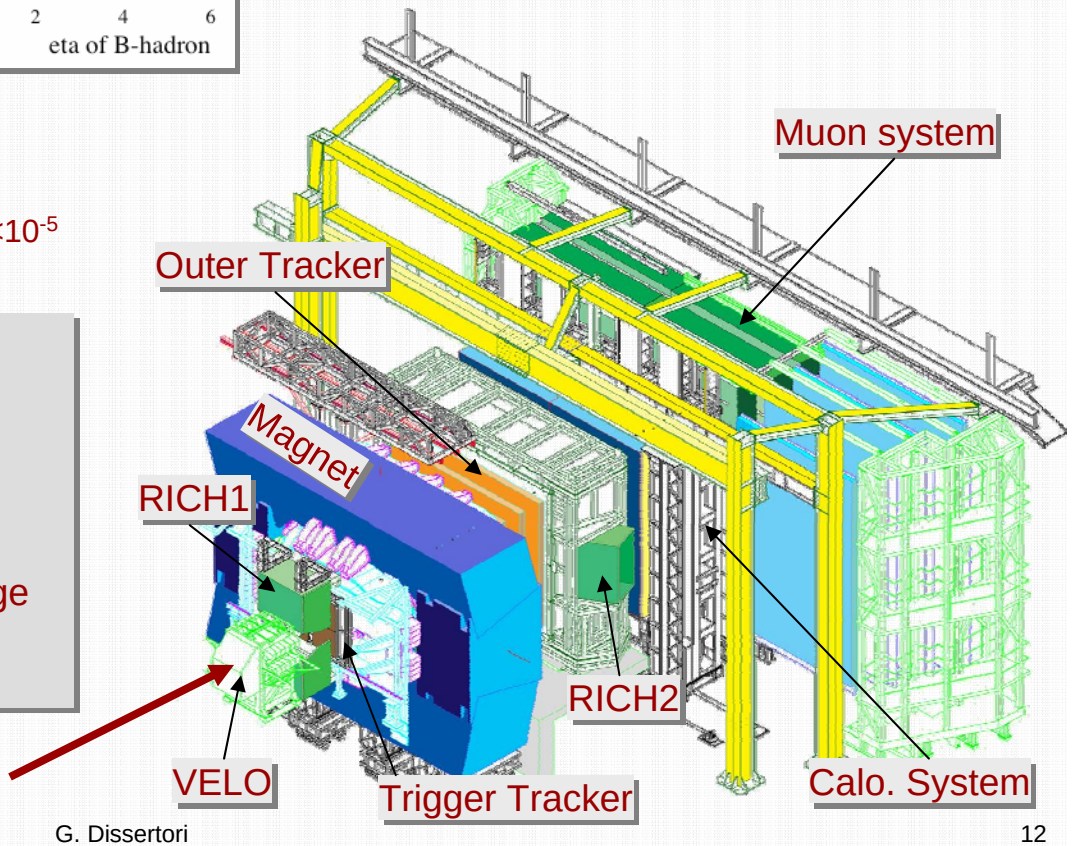
PT Level-0 : 40 MHz ➔ 1 MHz

Level 1 : 1 MHz ➔ 40 KHz

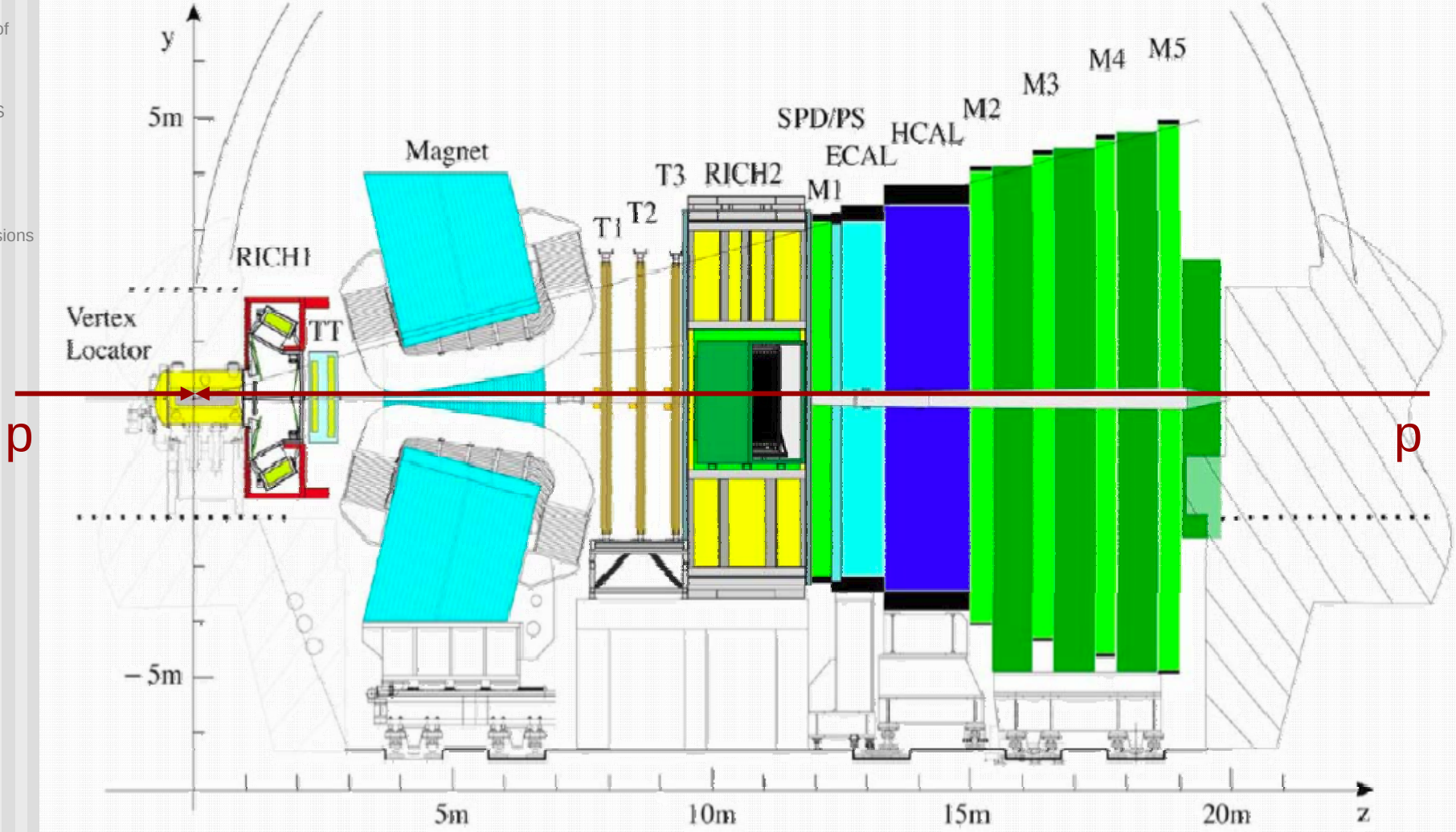
HLT (all data) : 40 kHz ➔ 2000 Hz to storage

Level-1 and HLT on PC-Farm!

10^{9}-10^{10} B-hadrons/year



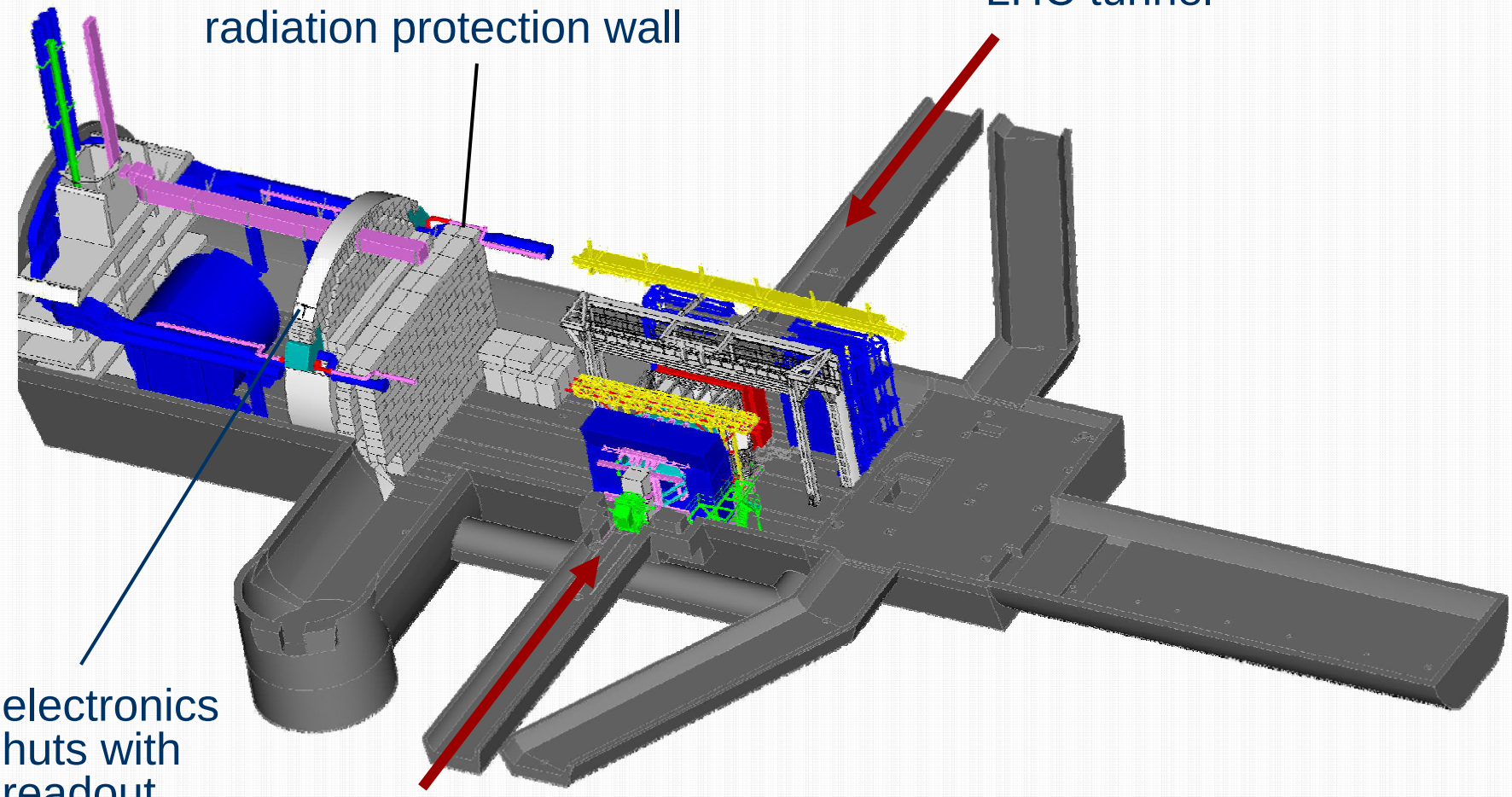
Only look “forward”…



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

LHCb in the former DELPHI cavern

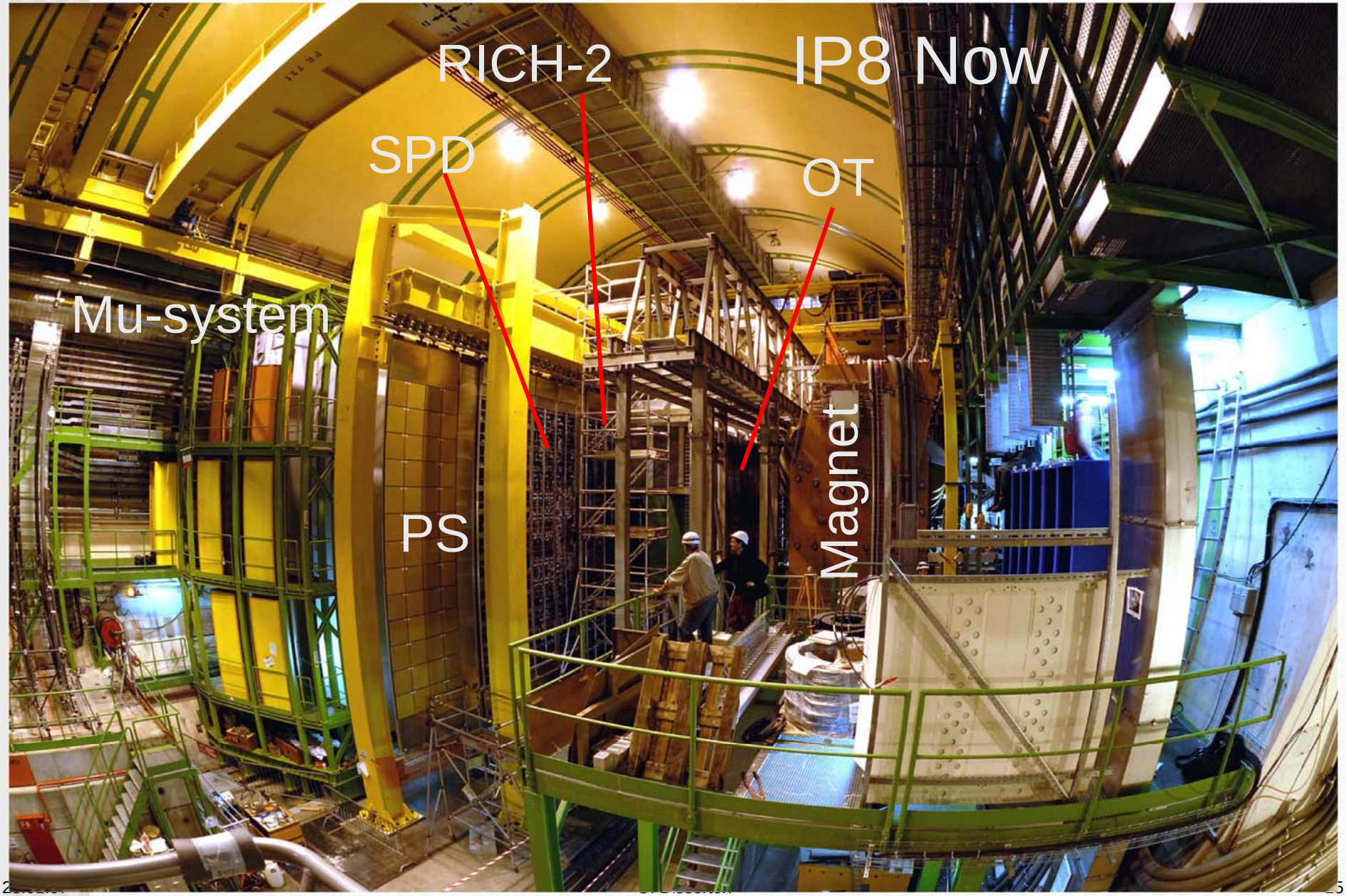
ETH Institute for Particle Physics



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

LHCb in the cavern…

ETH Institute for Particle Physics

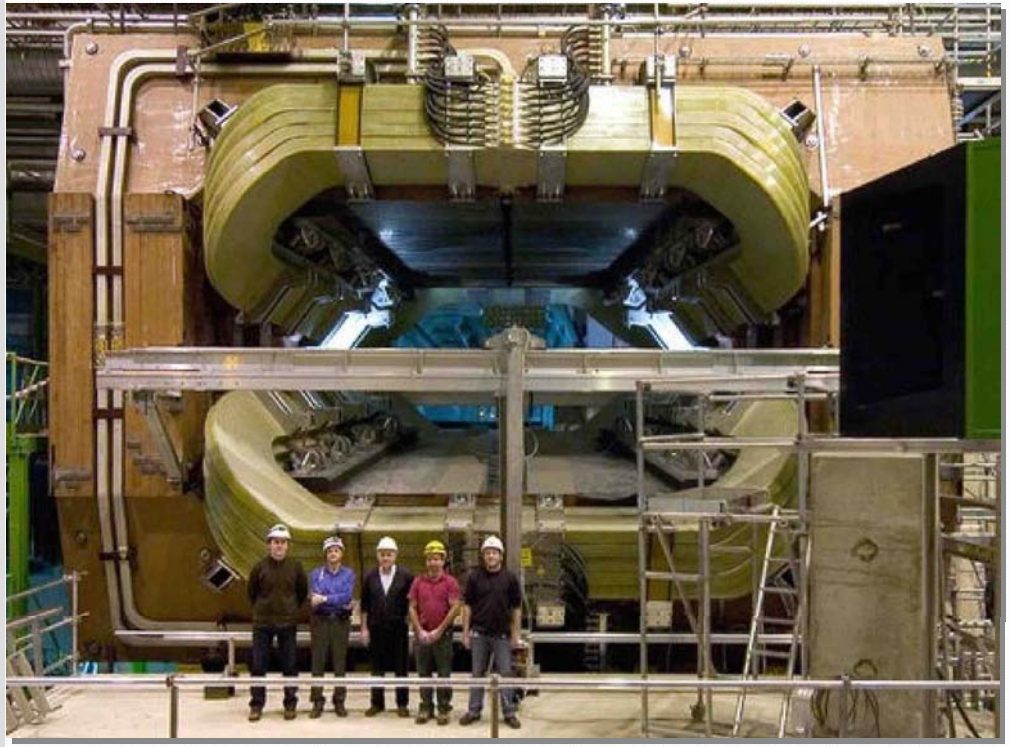


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

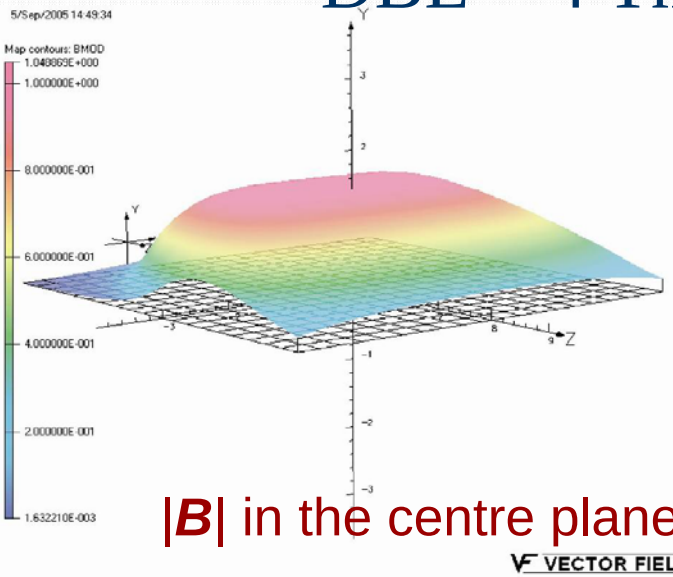
Magnet

ETH Institute for Particle Physics

Fully commissioned and B field measured for both polarities



DBL = 4 Tm



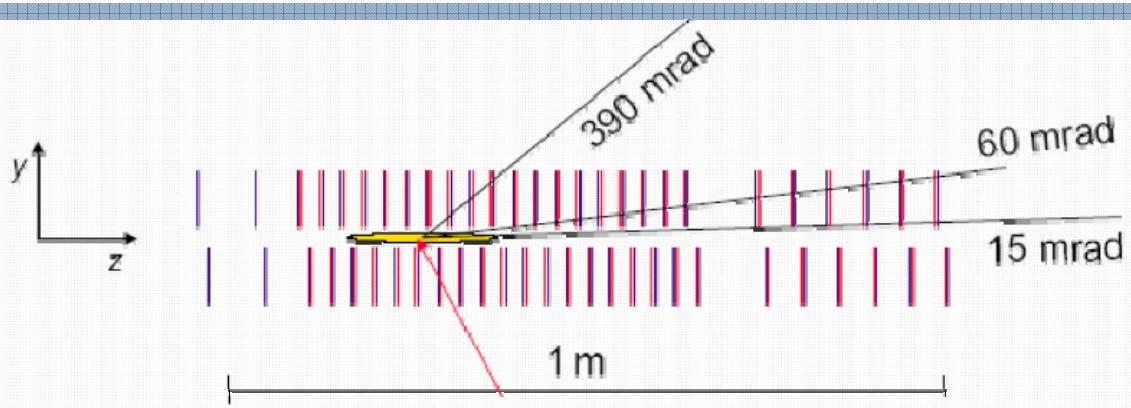
|***B***| in the centre plane

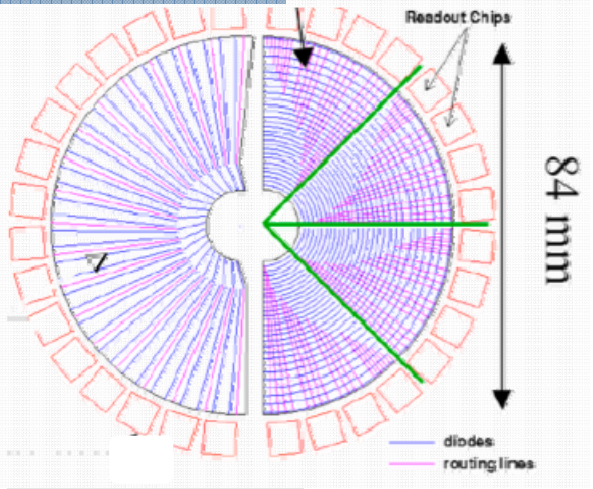
VECTOR FIELDS

Analysis is in progress for incorporating the measurements into the software

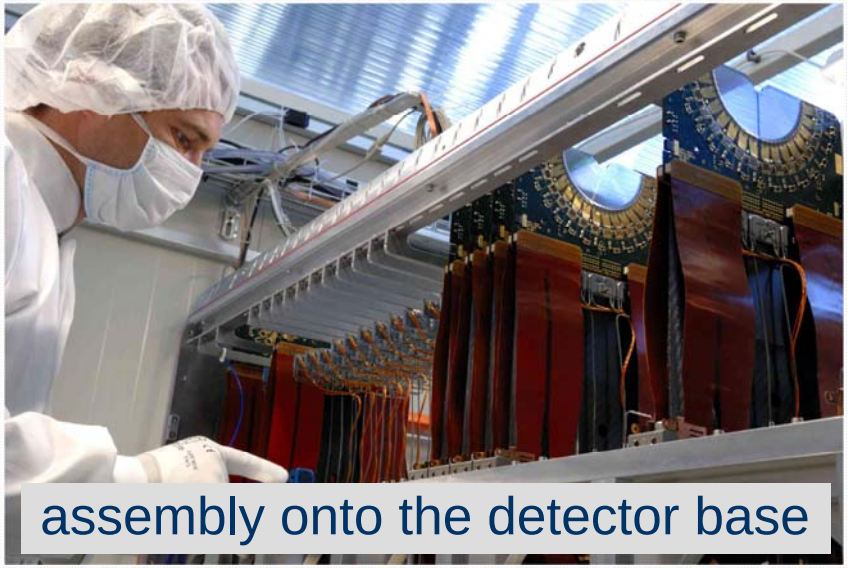
Vertex Locator : VELO

ETH Institute for Particle Physics

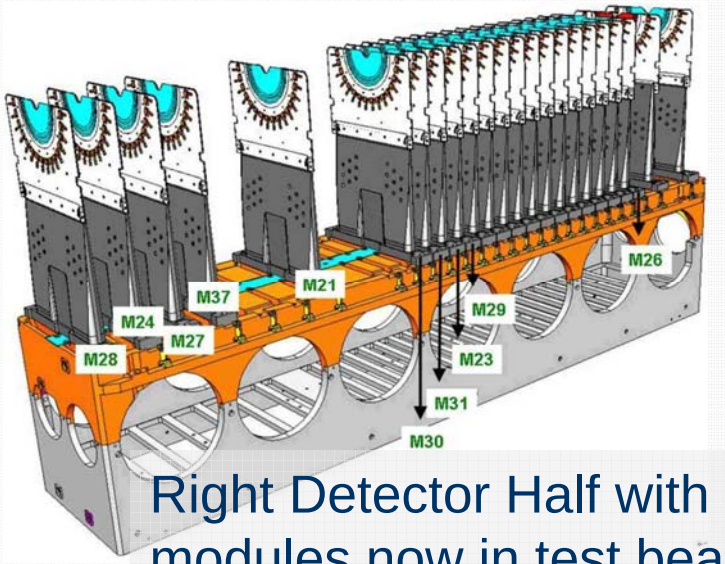




- VELO tank and vacuum system installed at IP8; vacuum leak tested
- Production of sensor modules : ongoing, finish by March 07



assembly onto the detector base



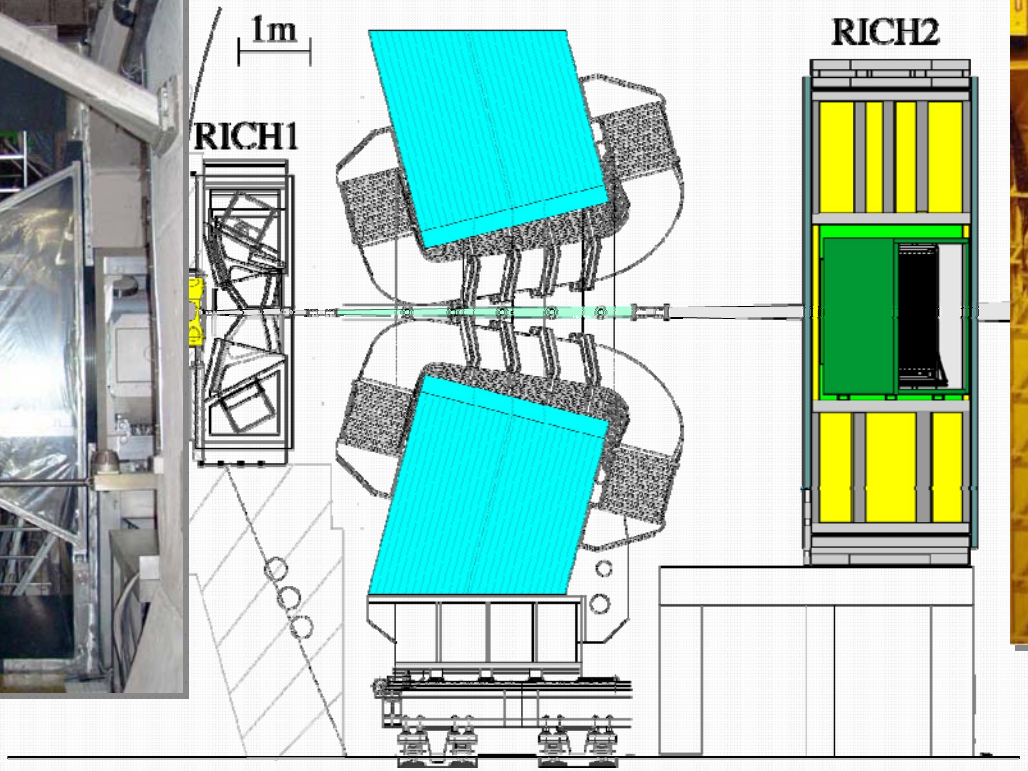
Right Detector Half with 10 modules now in test beam

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Ring Imaging CHerenkov det.

ETH Institute for Particle Physics

- RICH-2 : in place, waiting for the photon detectors
- RICH-1 : magnet. shielding box, gas enclosure in place
- HPDs : ~70% delivered, very good quality.

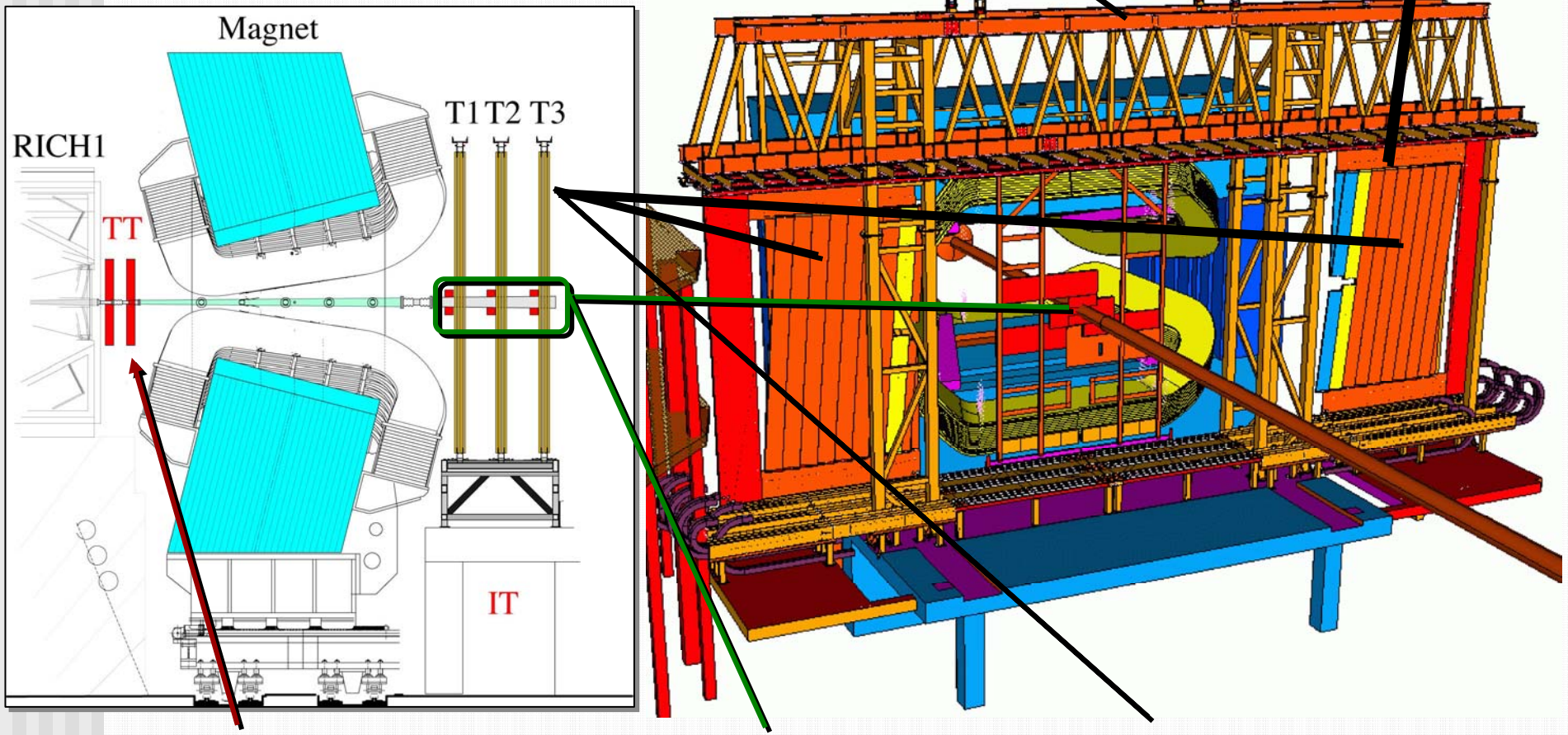


RICH-2
PD columns

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Tracker

ETH Institute for Particle Physics



Silicon Tracker

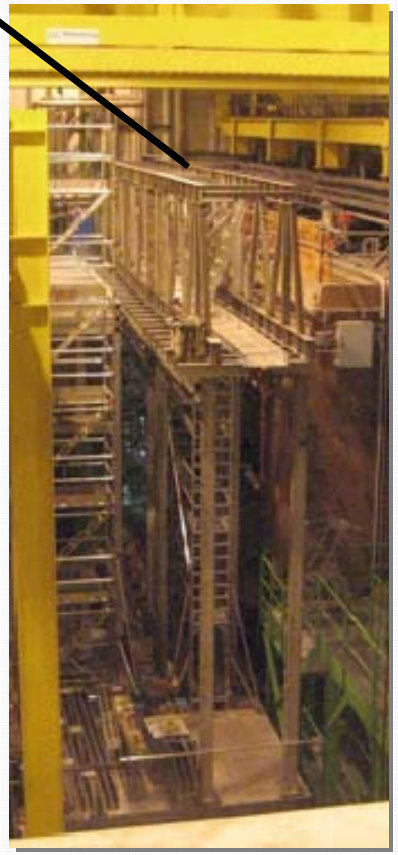
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

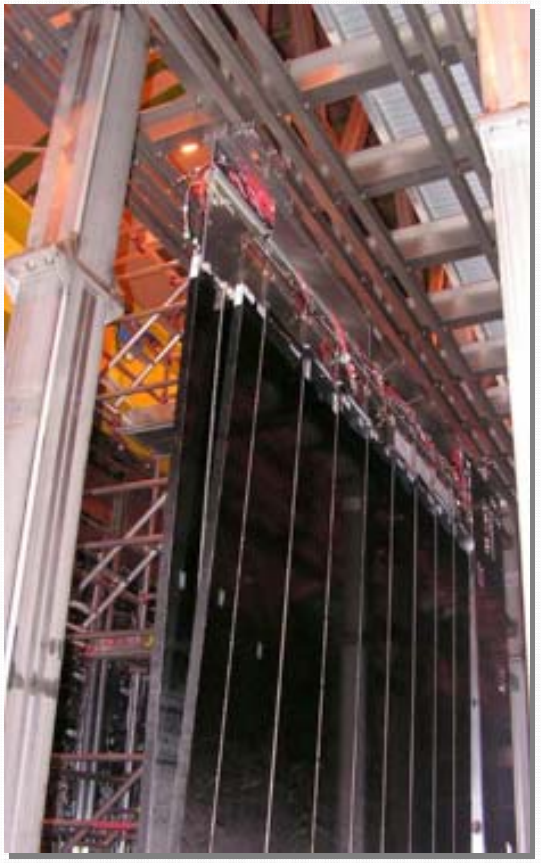
Tracker

ETH Institute for Particle Physics

OT/IT support bridge assembled

After testing, loaded C-frames are inserted to the bridge





C-frames being loaded

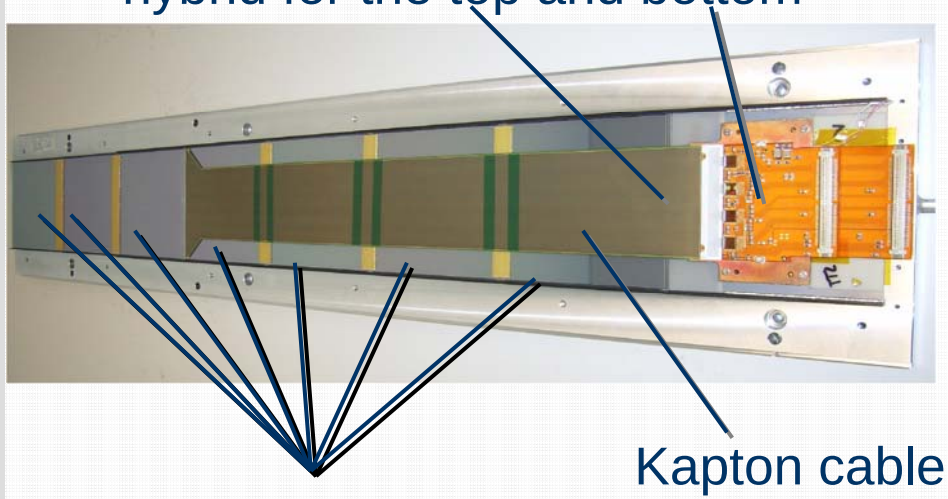
4/12 of C-frames inserted

Silicon Tracker

Trigger Tracker

Ladder production completed

hybrid for the top and bottom



Kapton cable

sensors (500μm)

Inner Tracker

…almost completed

two sensor (410 μm) ladder

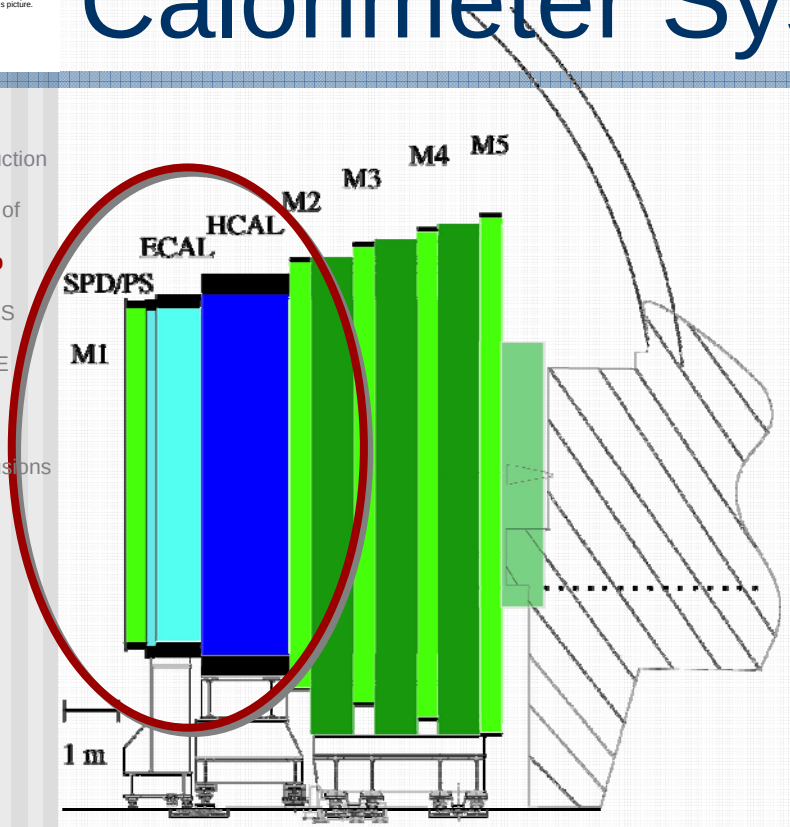
one sensor (320 μm) ladder

Tests are still ongoing…

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

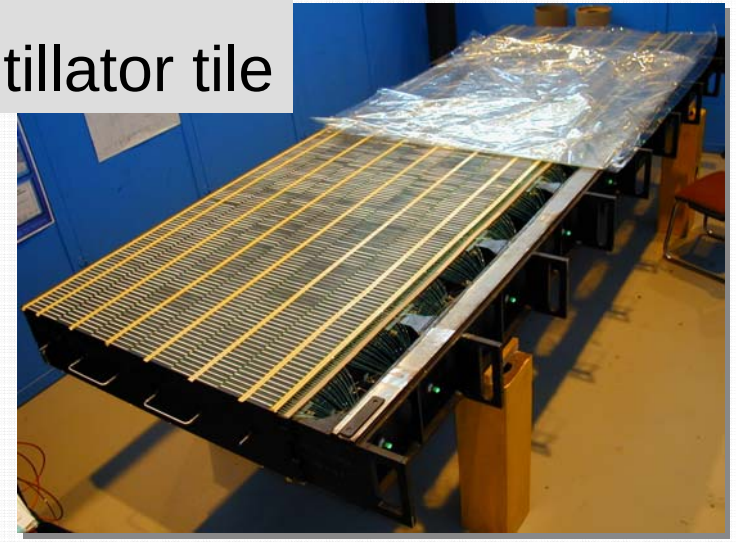
Calorimeter System

ETH Institute for Particle Physics

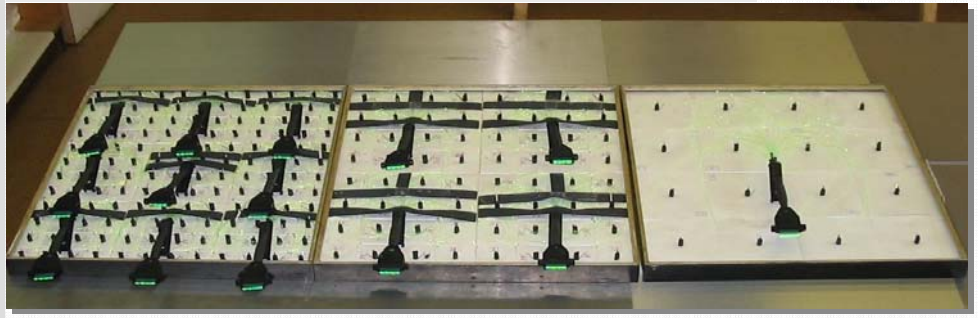


Ecal
Shashlik

Hcal
Fe-Scintillator tile



SPD/PS
Scintillator-Pb-Scintillator



Production and installation completed

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Calorimeter System

ETH Institute for Particle Physics

Scintillator Pad Detector/Preshower (recently), E-cal and H-cal all installed

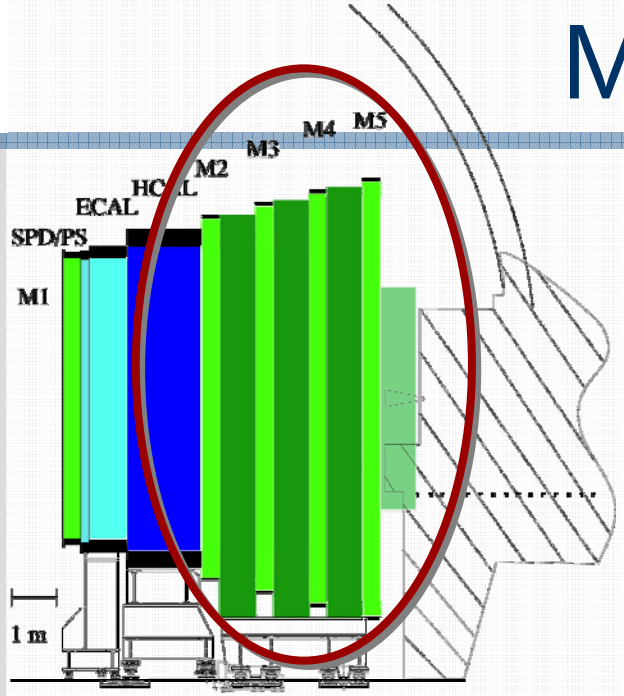
E-cal

H-cal

SPD/PS

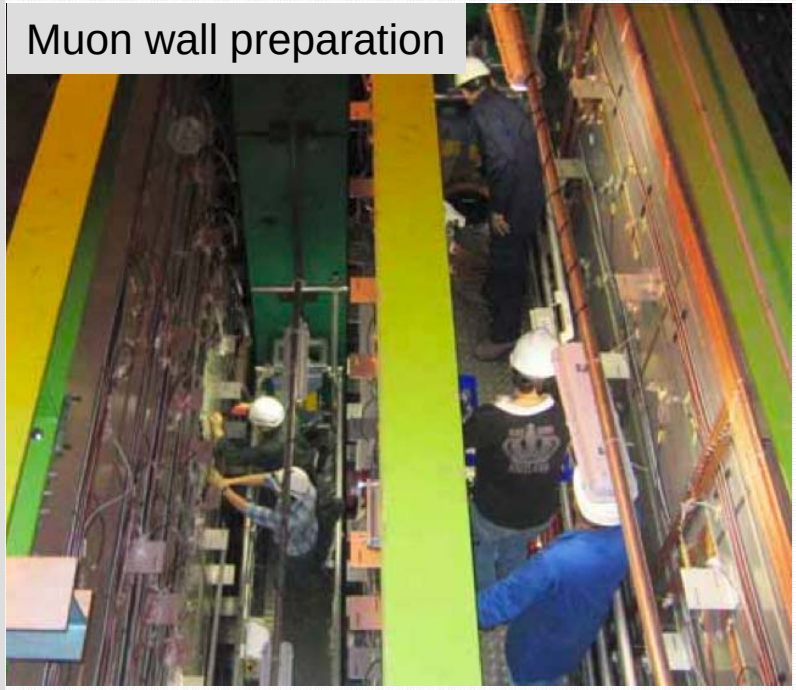
Muon System

ETH Institute for Particle Physics



- Chamber support wall for M2-M5 assembled, infrastructure being installed
- Chamber installation for M5 started

Muon wall preparation



MWPC installation for M5

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

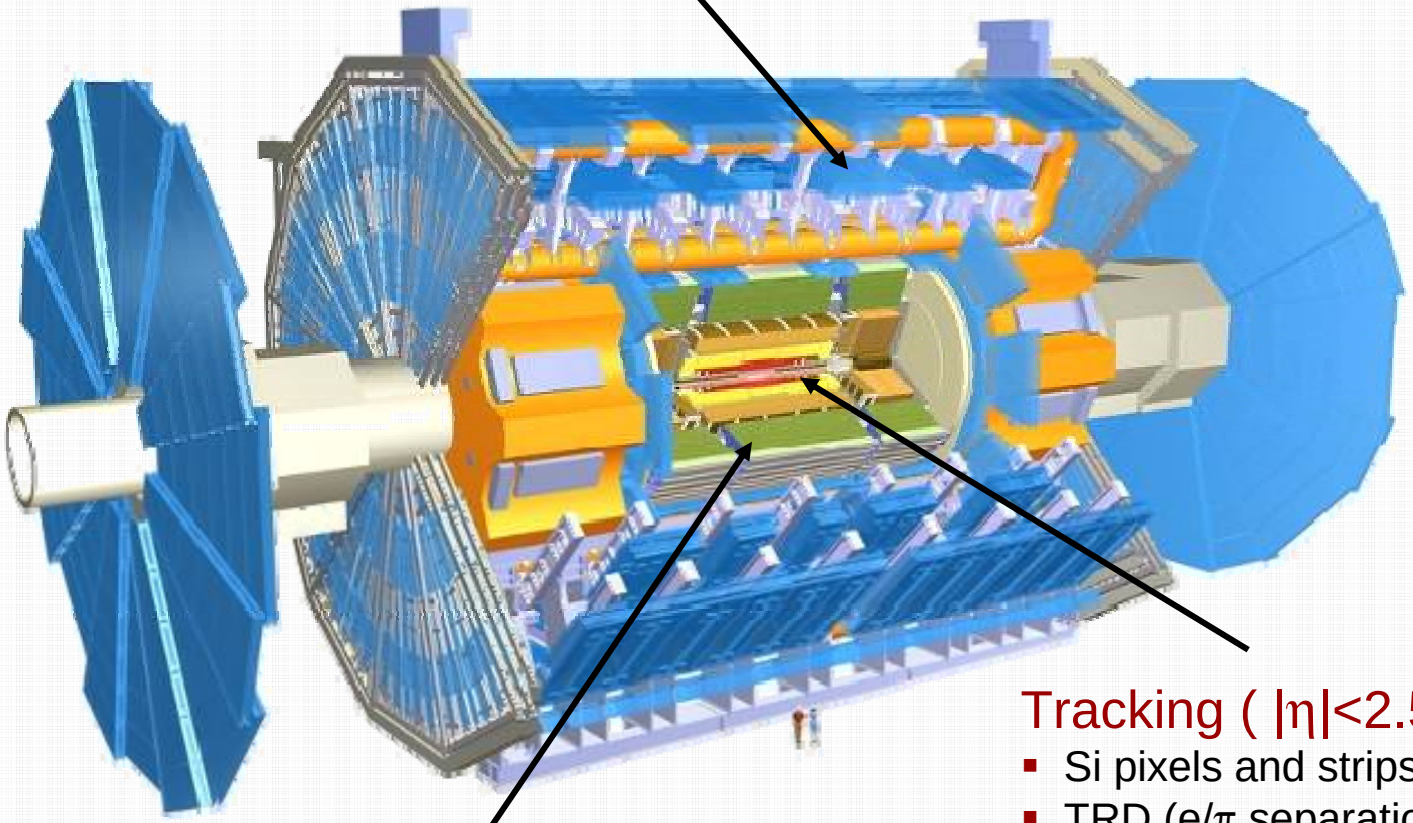
ETH Institute for Particle Physics

ATLAS

ATLAS

Muon Spectrometer (|η|<2.7)

- air-core toroids with muon chambers



Tracking (|η|<2.5, B=2T)

- Si pixels and strips
- TRD (e/π separation)

Calorimetry (|η|<5)

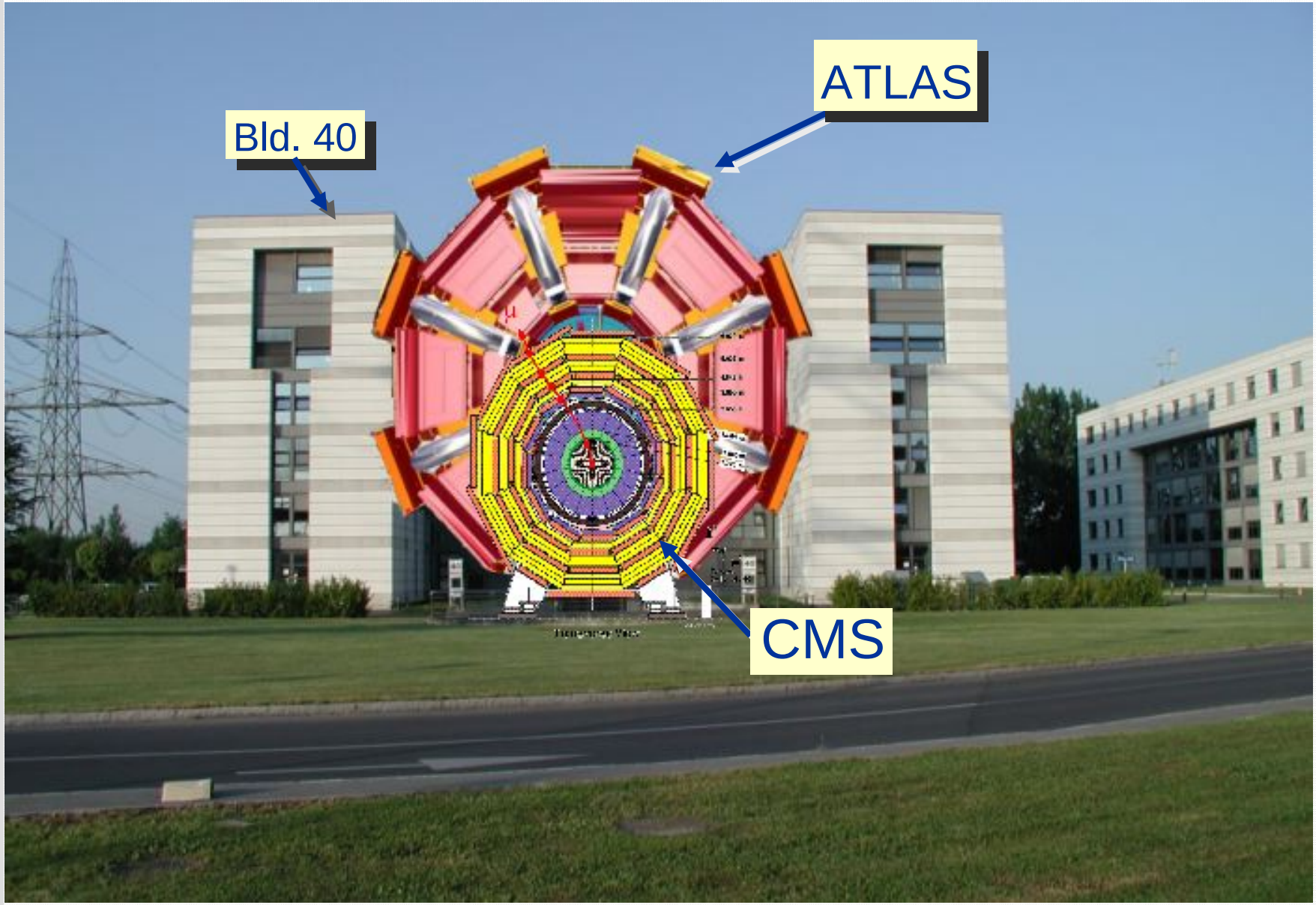
- EM : Pb-LAr
- HAD : Fe/scintillator (central), Cu/W-Lar (fwd)

Diameter	25 m
Barrel toroid length	26 m
End-cap end-wall chamber span	46 m
Overall weight	7000 tons

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Dimensions…

ETH Institute for Particle Physics

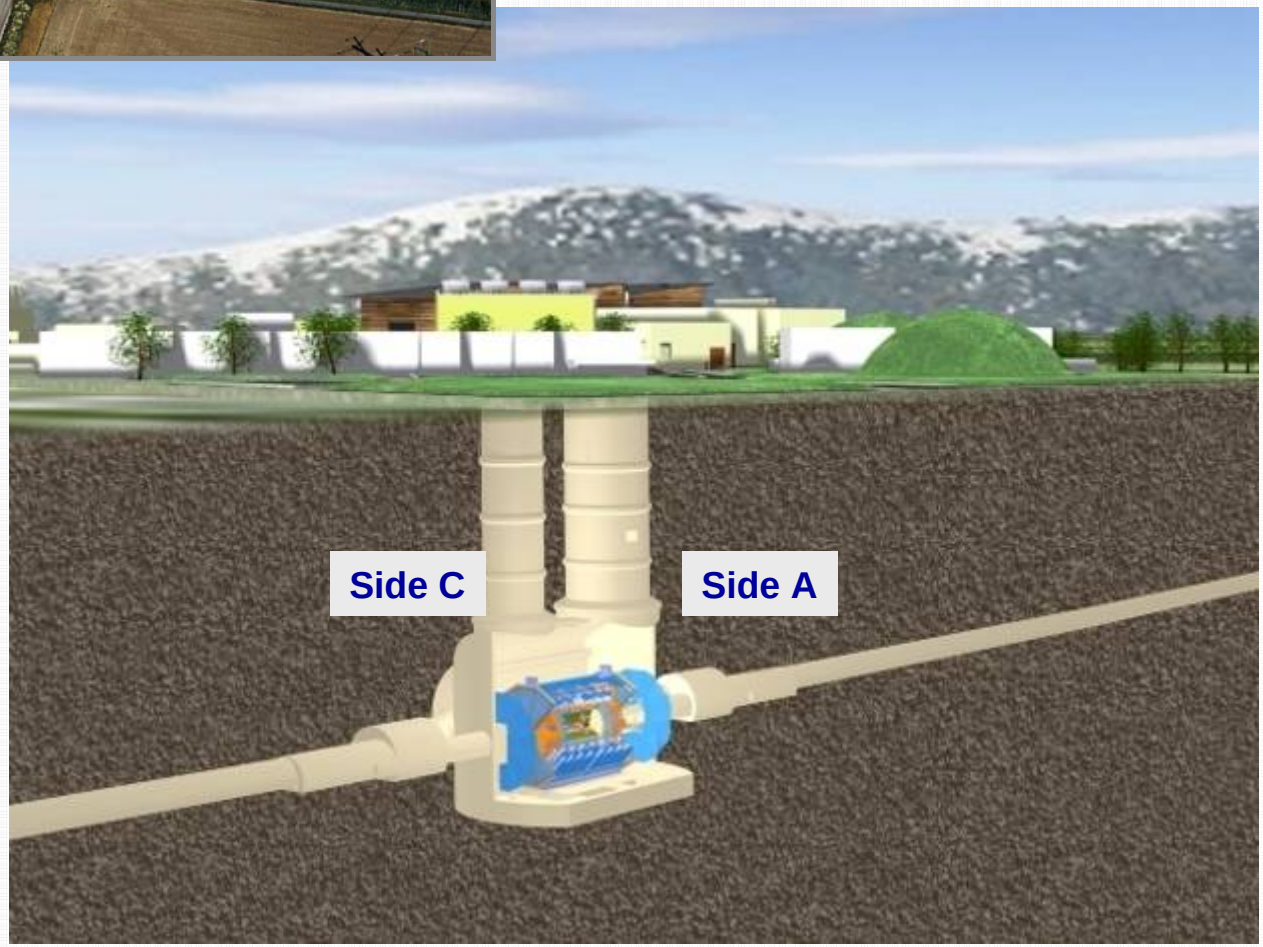


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

ETH Institute for Particle Physics

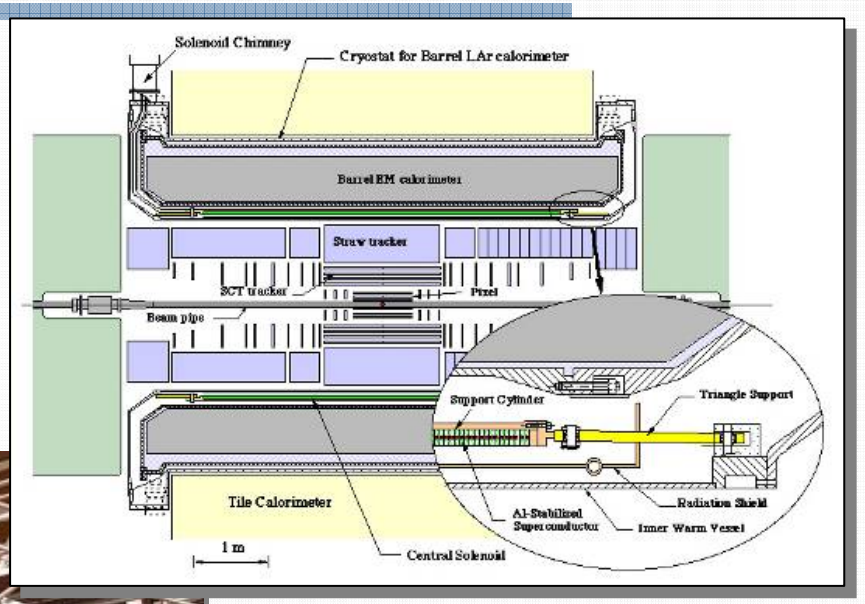
The Underground Cavern at Pit-1 for the ATLAS Detector

Length = 55 m
Width = 32 m
Height = 35 m

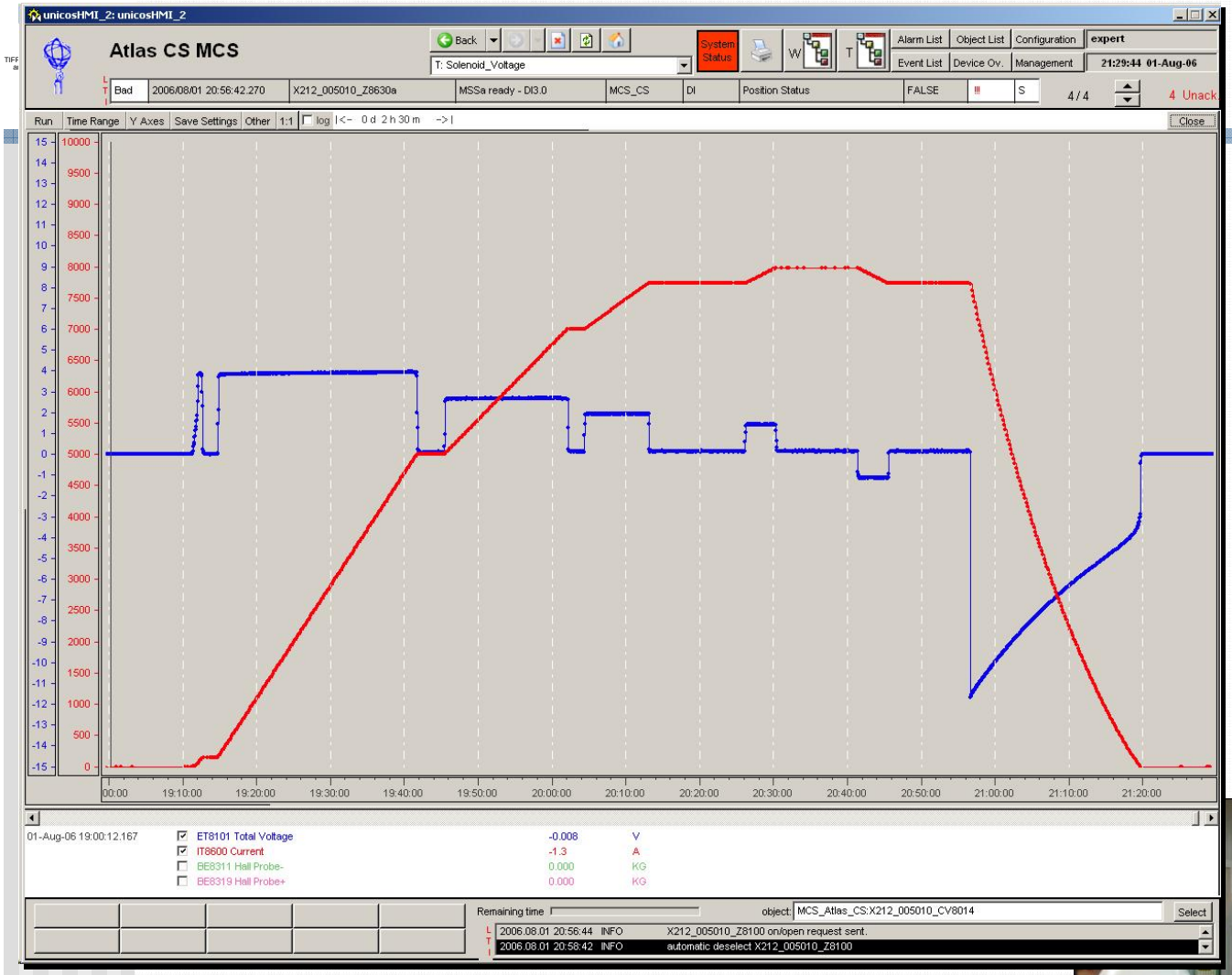


Magnet System : Central Solenoid

- 2T field with a stored energy of 38 MJ
- Integrated design within the barrel LAr cryostat



- Solenoid has been inserted into the Lar cryostat end Feb 04 and tested at full current (8 kA) during July 04



Solenoid

ETH Institute for Particle Physics

July – August 2006:

The solenoid has been fully commissioned *in-situ* up to 8.0 kA

The operation current is 7.73 kA for a field of 2.0 T

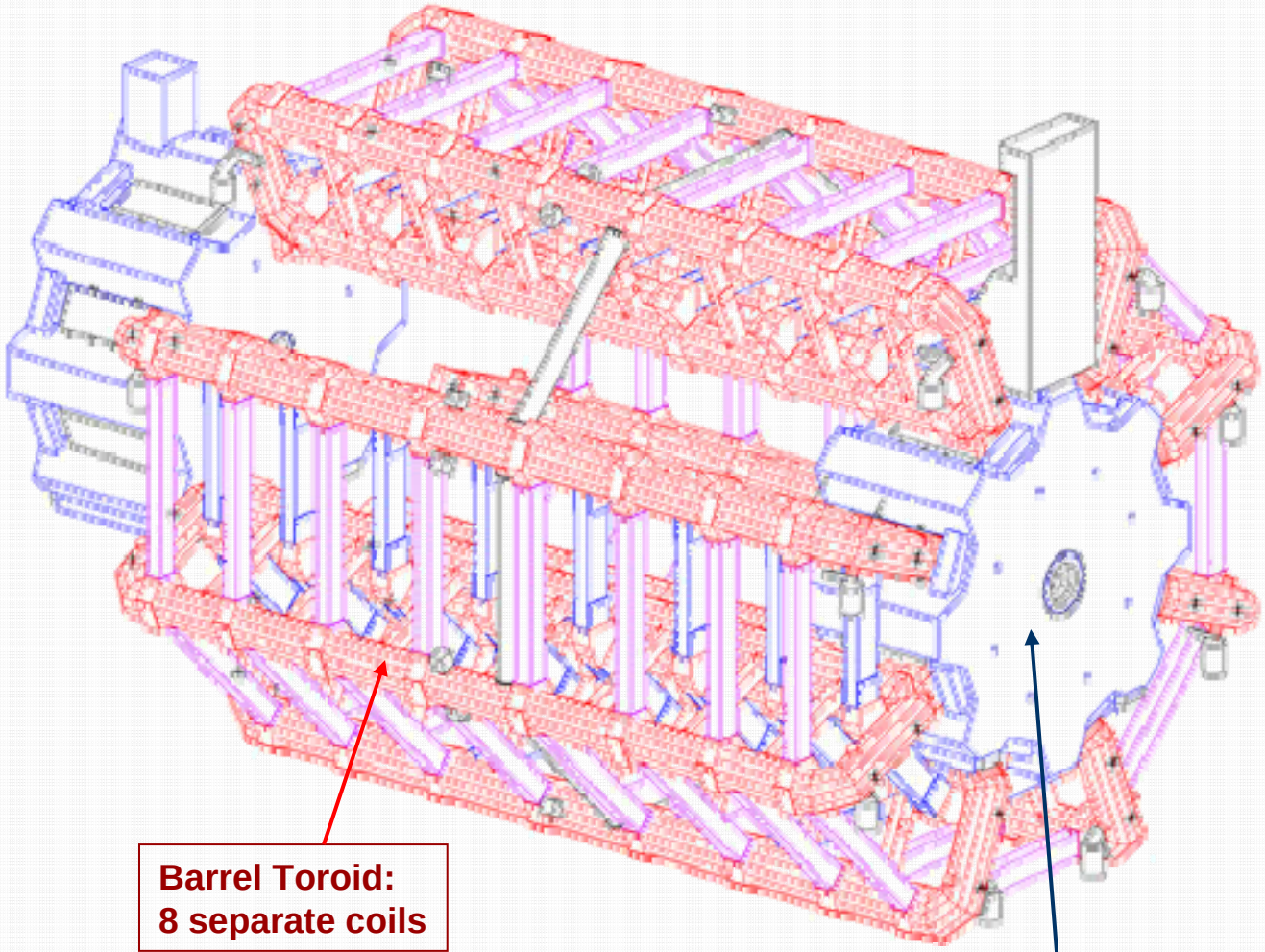
Successful accurate field mapping

1st August 2006: the solenoid is fully operational

Magnets : Toroid System

Barrel Toroid parameters

25.3 m length
20.1 m outer diameter
8 coils
1.08 GJ stored energy
370 tons cold mass
830 tons weight
4 T on superconductor
56 km Al/NbTi/Cu conductor
20.5 kA nominal current
4.7 K working point



Barrel Toroid:
8 separate coils

End-Cap Toroid:
8 coils in a common cryostat

End-Cap Toroid parameters

5.0 m axial length
10.7 m outer diameter
2x8 coils
2x0.25 GJ stored energy
2x160 tons cold mass
2x240 tons weight
4 T on superconductor
2x13 km Al/NbTi/Cu conductor
20.5 kA nominal current
4.7 K working point

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

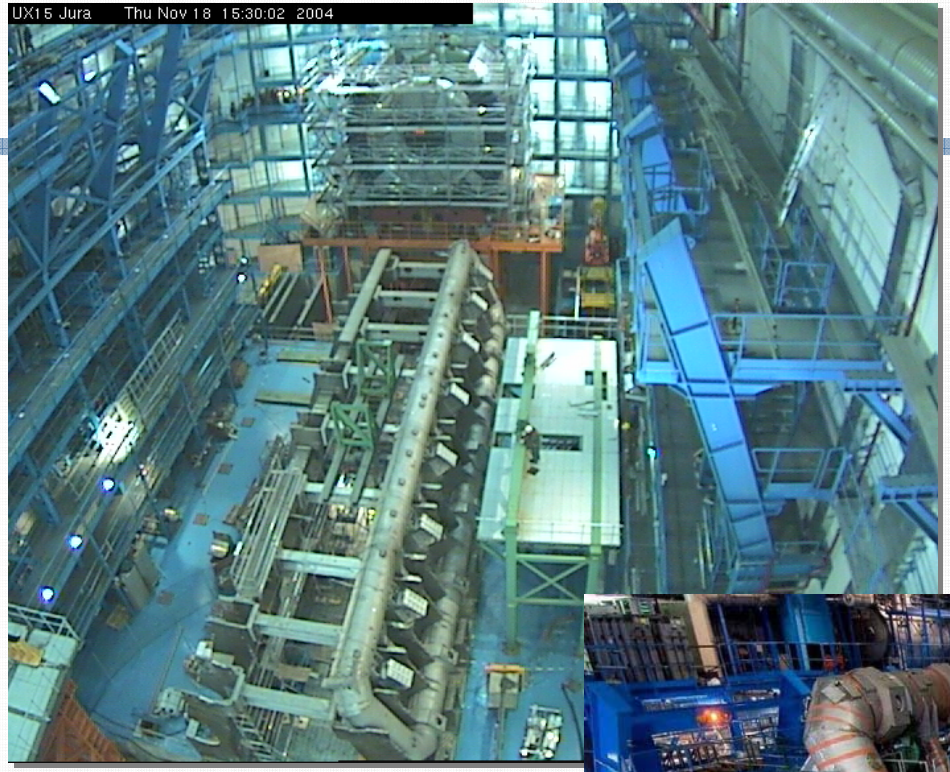
Barrel Toroid coil transport…

ETH Institute for Particle Physics

…and lowering into the underground cavern

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

ETH Institute for Particle Physics



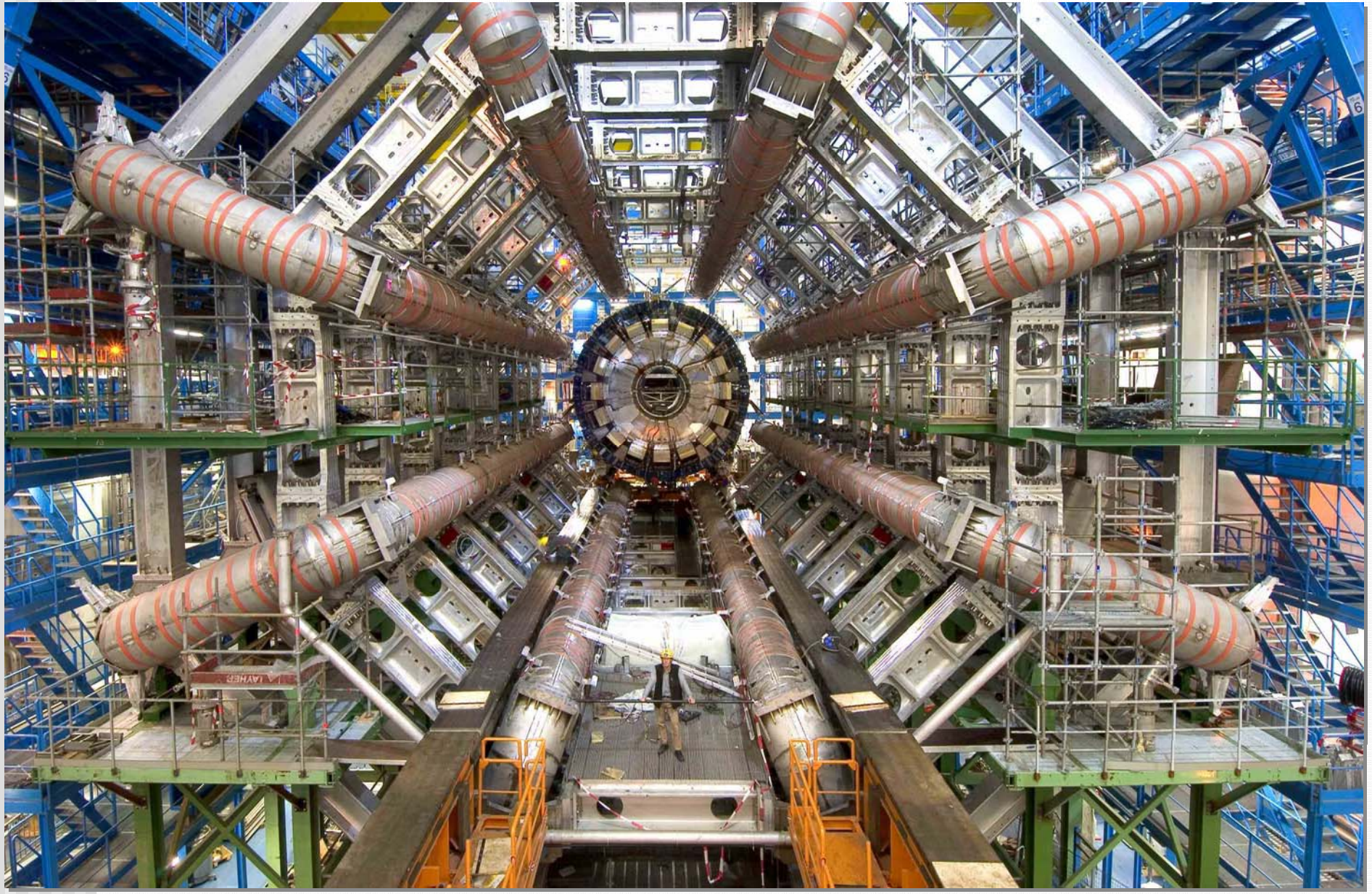
The first coil was installed in October 2004

The last coil was moved into position on 25th August 2005

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Toroids in full beauty…

ETH Institute for Particle Physics

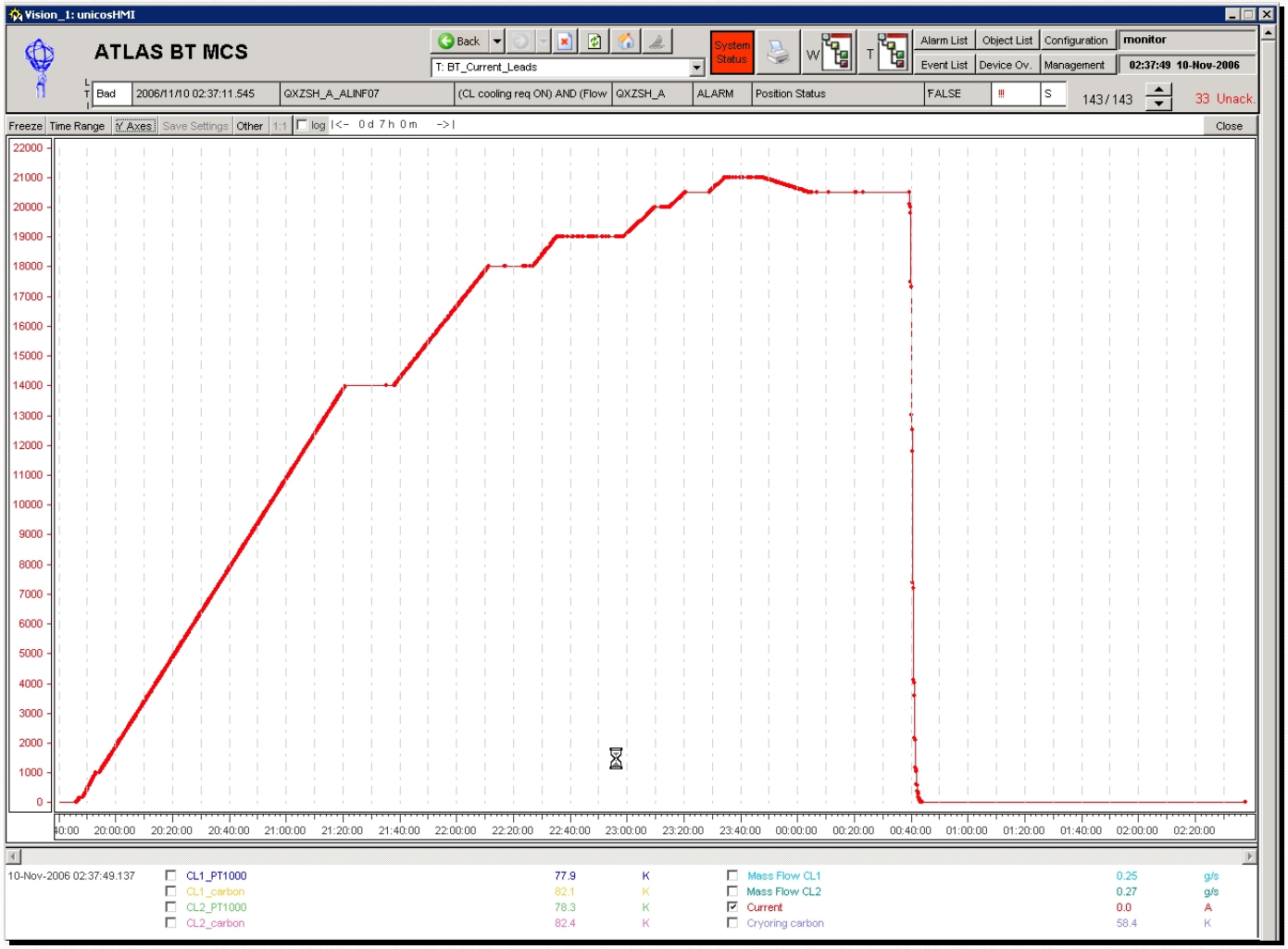


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

… and tested!

ETH Institute for Particle Physics

9 November 2006

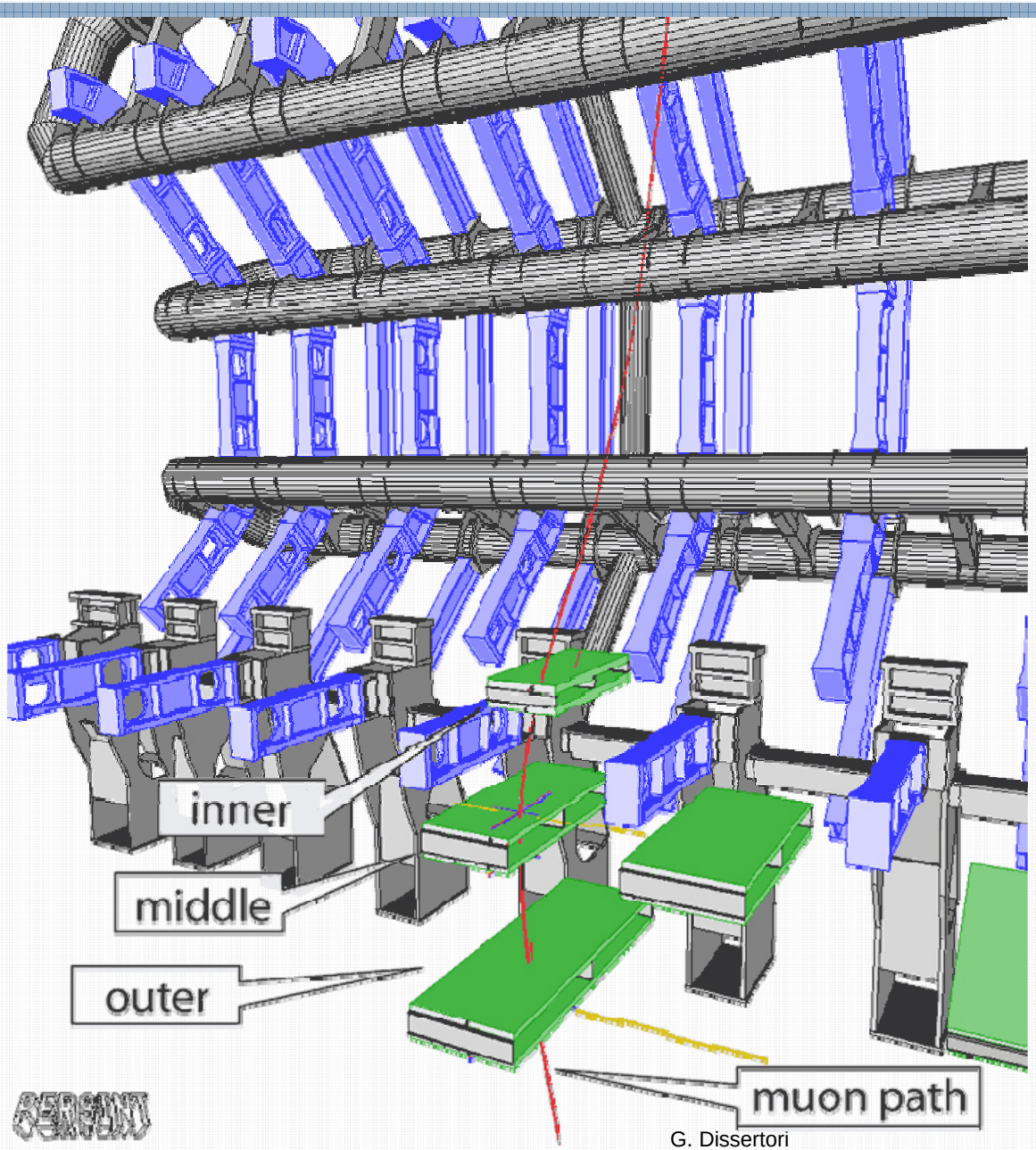


In steps to 20.5 kA nominal current, to 21kA to prove margin, back to 20.5 kA, provoke quench, fast dump, very safe operation demonstrated!

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

First bent muons seen!

ETH Institute for Particle Physics

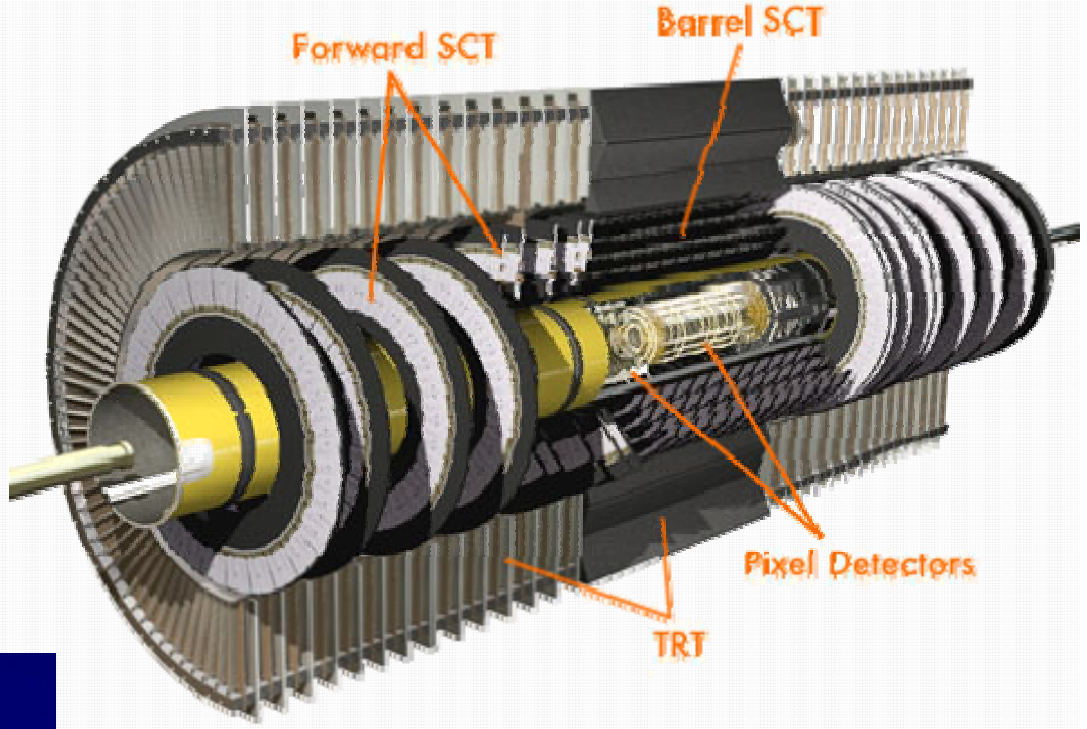


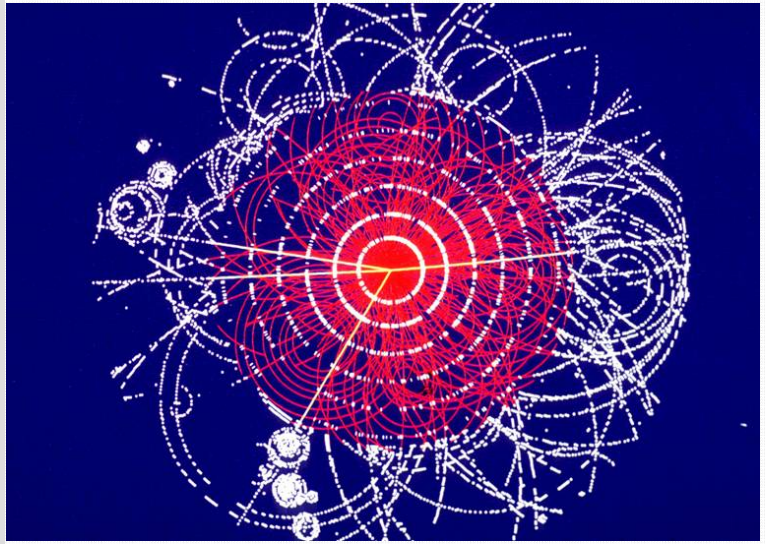
During stability test of the barrel toroid 18-19 Nov 06

7m

Inner Detector

- The Inner Detector (ID) is organized into four sub-systems:

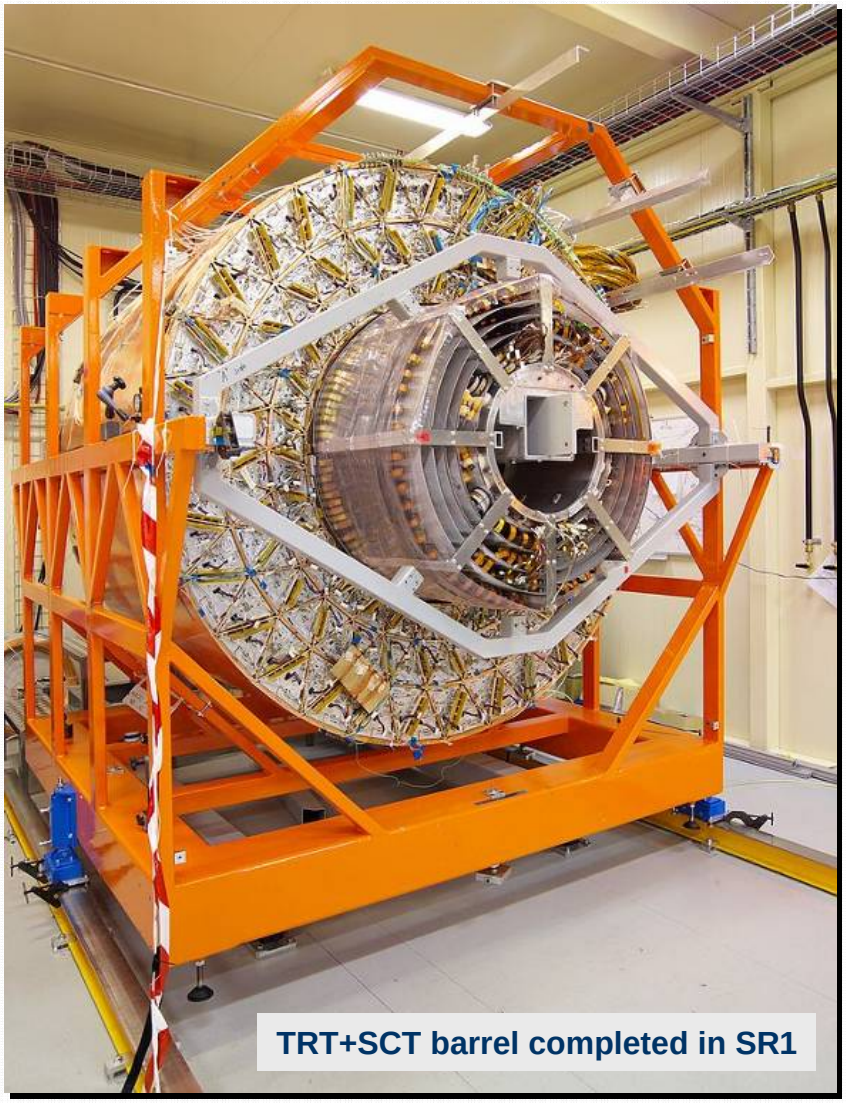




- Pixels (0.8 10^8 channels)
- Silicon Tracker (SCT) (6 10^6 channels)
- Transition Radiation Tracker (TRT) (4 10^5 channels)
- Common ID items

ID : progress report

- Pixels
  - Barrel layers 2 and 1 integrated, both end-caps finished
- Barrel
  - SCT and TRT barrel integrated on the surface.
  - Tested with cosmics (no x-talk observed).
  - Installed in the pit.
- Endcap
  - SCT ECC integrated recently with TRT ECC.
  - SCT ECA was integrated with TRT recently.
- The schedule for the Inner Detector remains very tight, without any float left (critical path: Installation and “sign-off” in the pit)



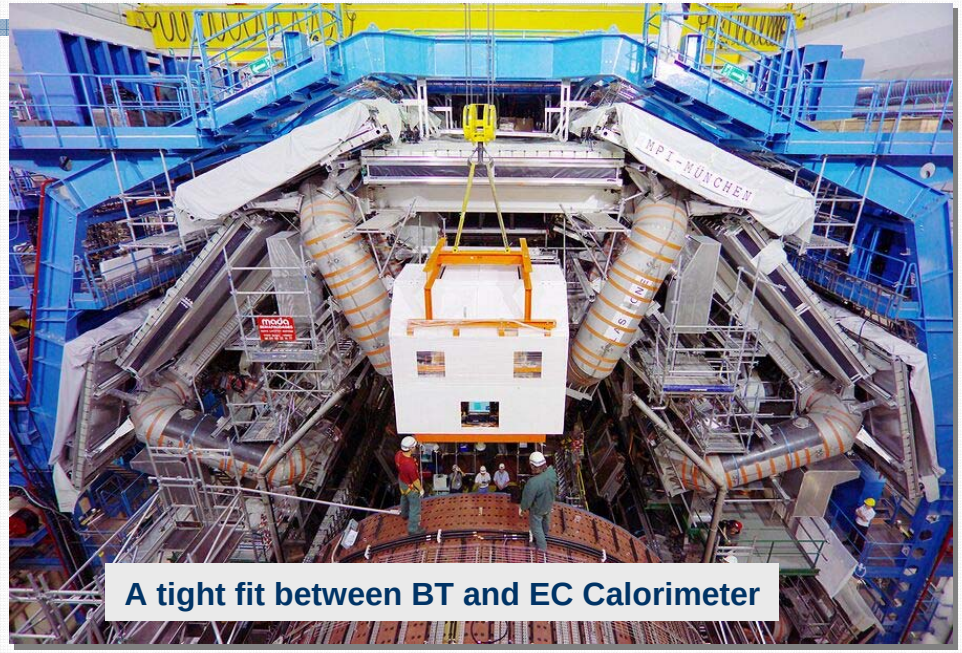
TRT+SCT barrel completed in SR1

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

TRT+SCT barrel traveled to the pit, 24th Aug 2006

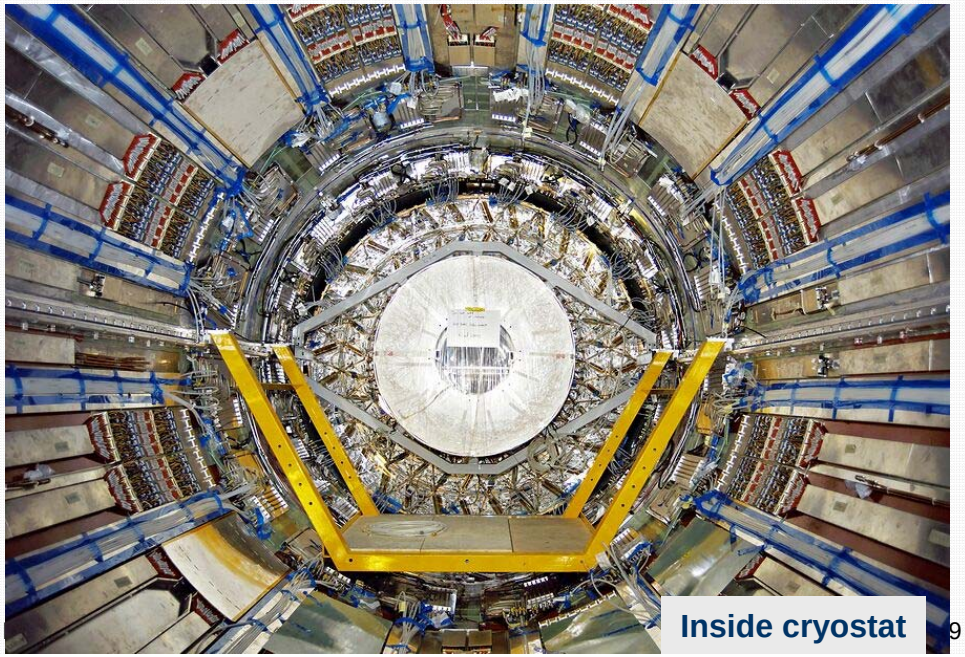
ETH Institute for Particle Physics

Through the parking area



A tight fit between BT and EC Calorimeter

From the trolley to the support rails

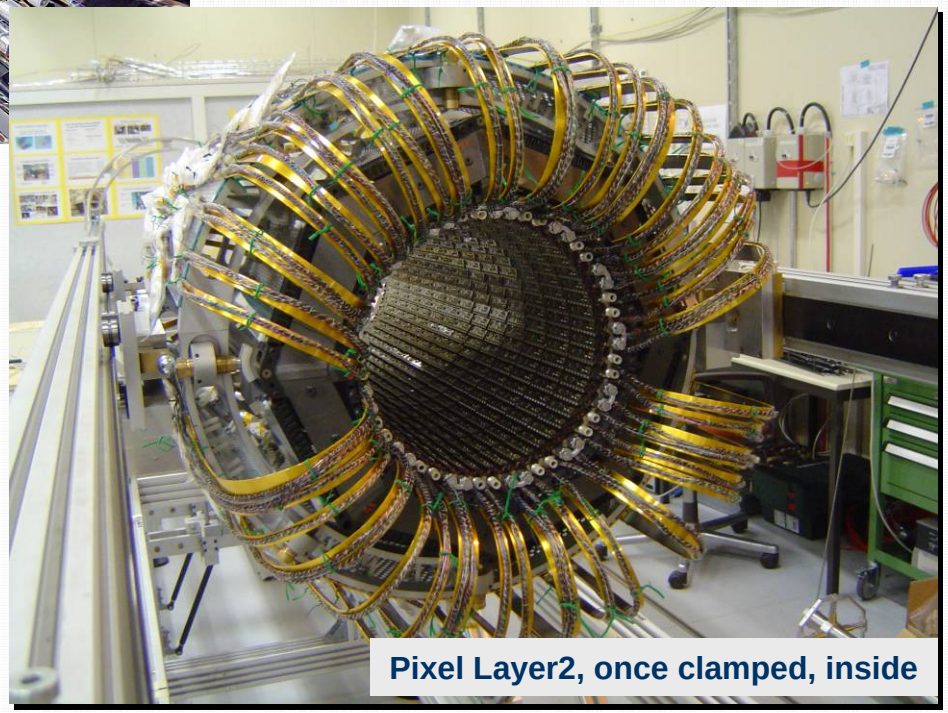


Inside cryostat

Pixel Detector

Pixel Layer-2 – half shell

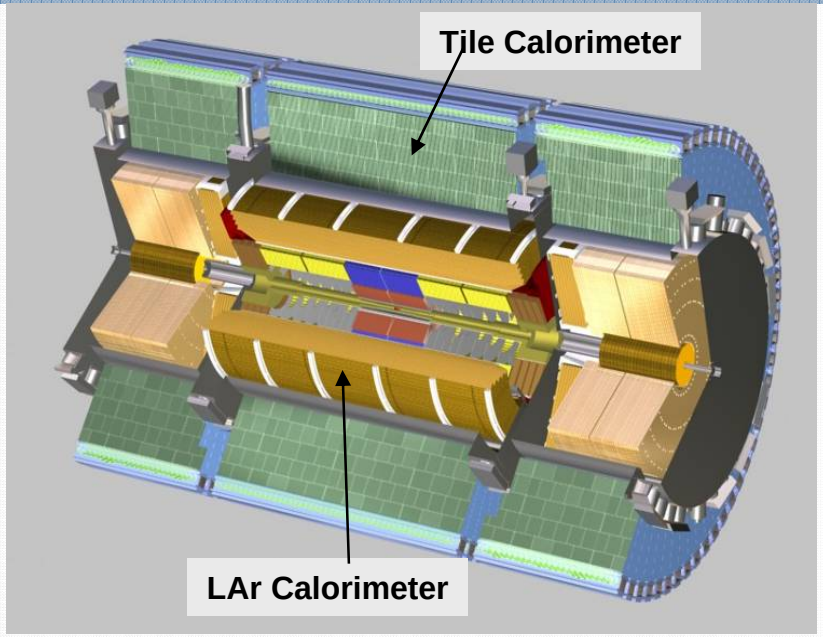
- All modules delivered with good yield
- Both EC integrated
- All barrel cylinders integrated, ready for final tests before underground installation



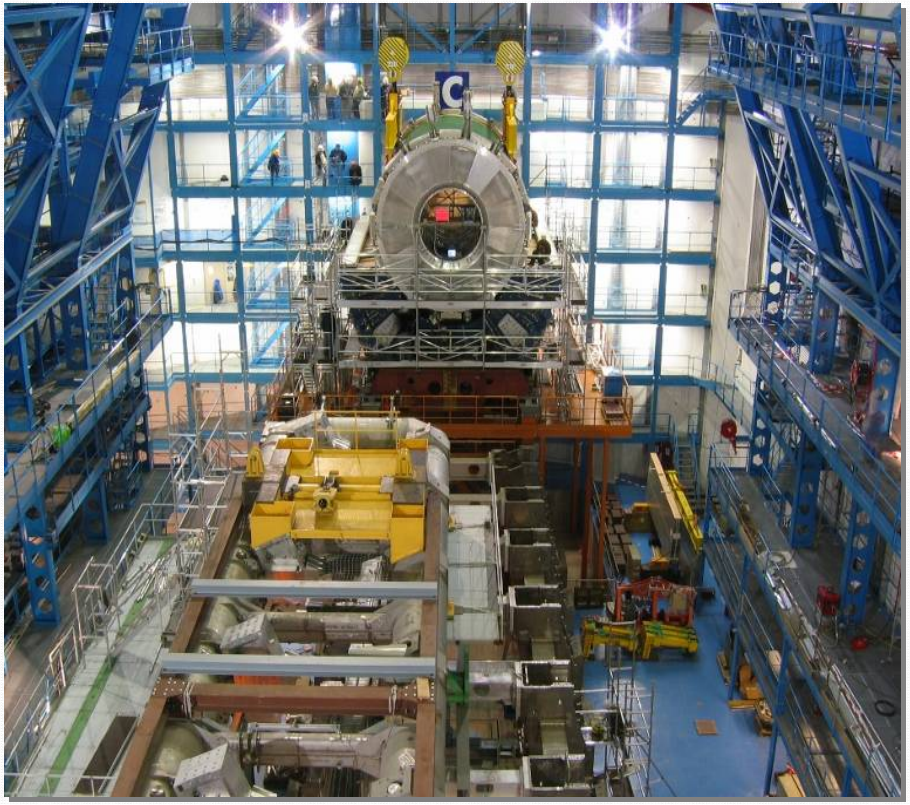
Pixel Layer2, once clamped, inside

Ready for installation date is 1st April 2007

LAr and Tile Calorimeters



- Oct 2004 : Barrel cryostat transported to the pit and lowered…

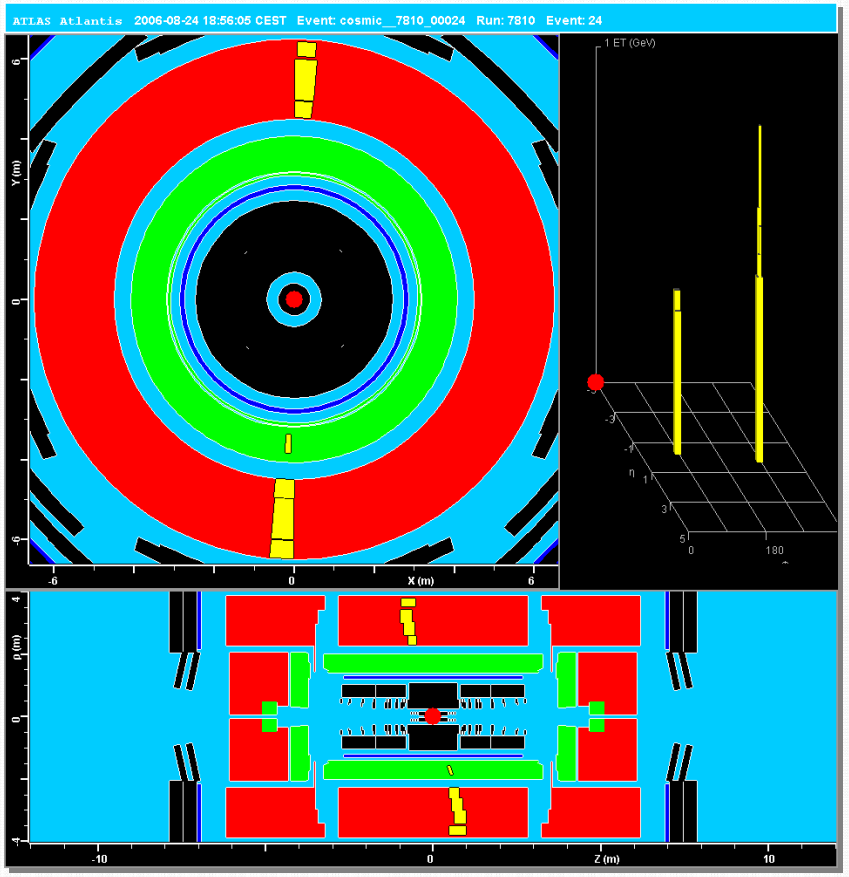


Barrel LAr and Tile Calorimeters

The barrel calorimeters are in their final position at the centre of the detector since November 2005

The final cool-down of the LAr cryostat took place over April and May 2006

Calorimeter barrel after its move into the center of the detector (4^{th} November 2005)

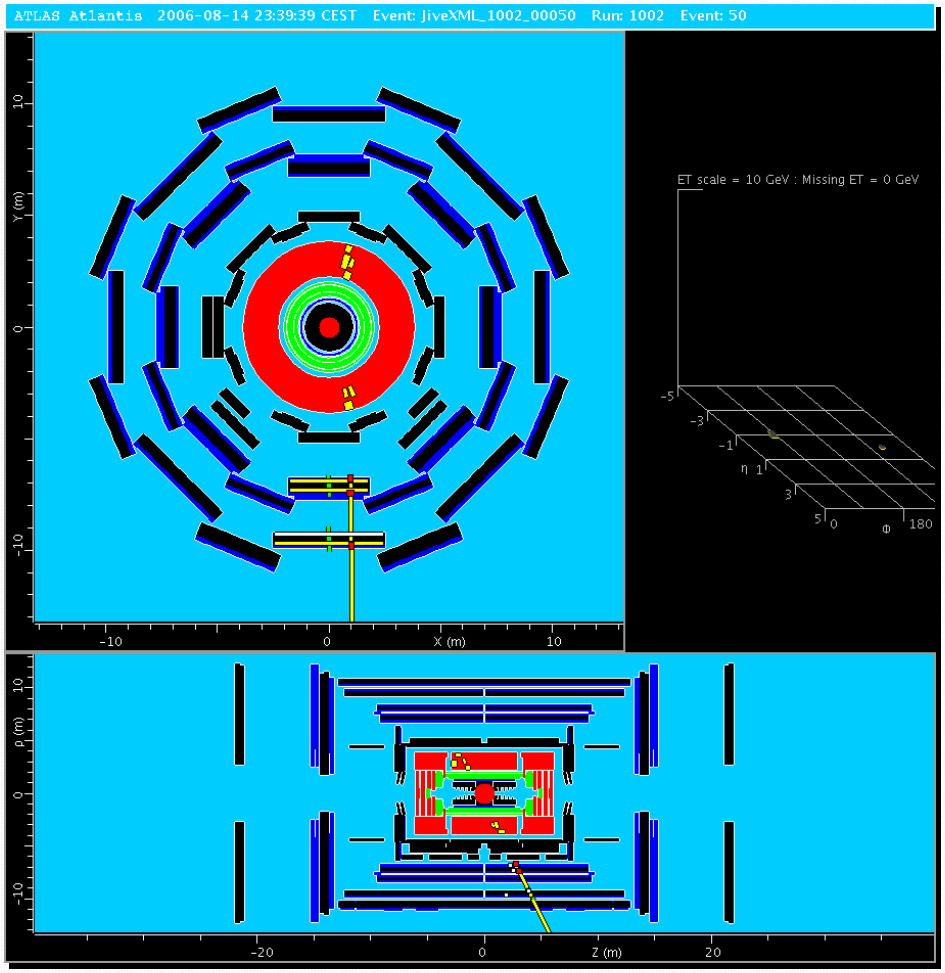


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Muon Stations : Barrel

ETH Institute for Particle Physics

Installation of barrel muon station (40% done)



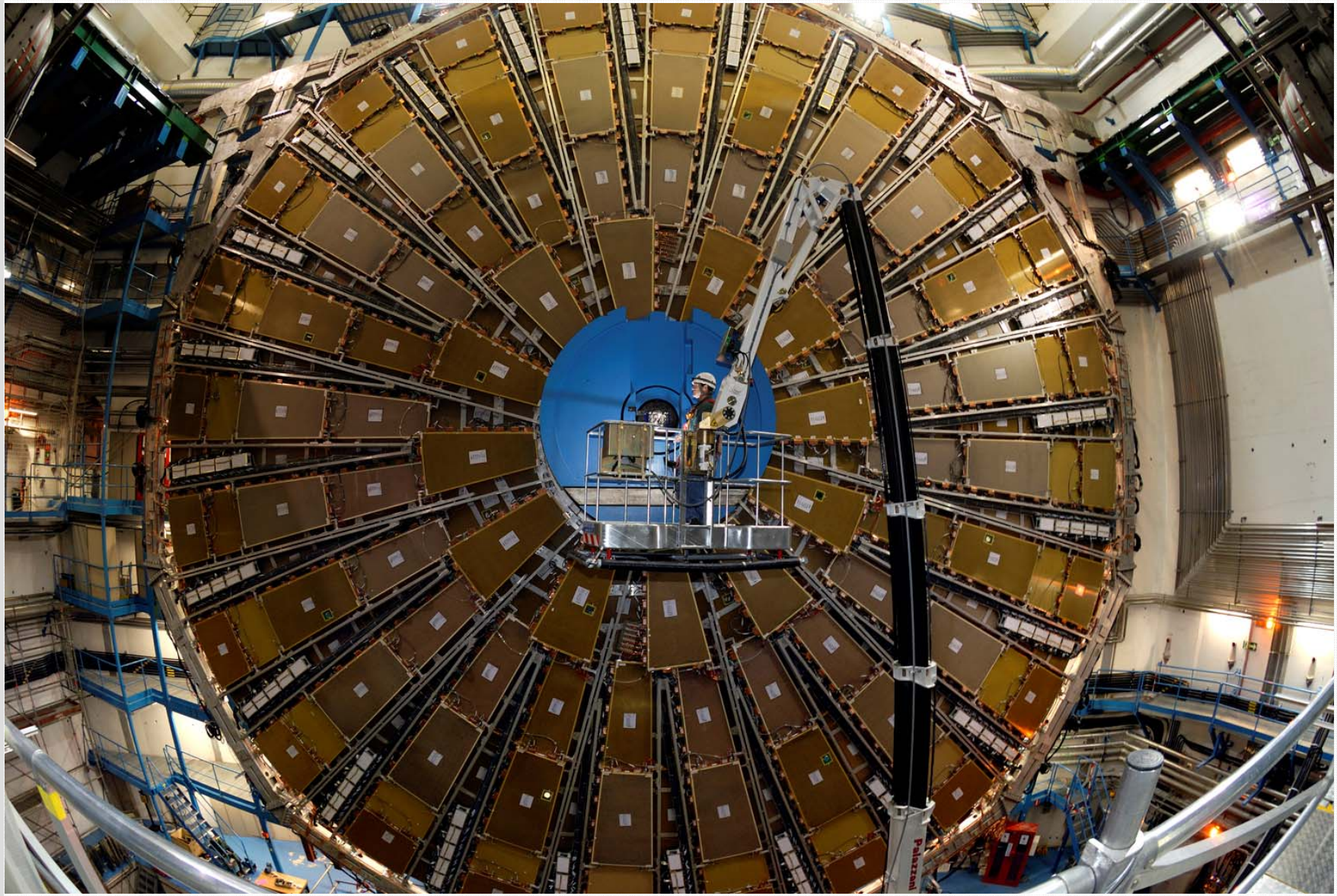
August 2006 :
first combined MDT + RPC + Tile Calorimeter cosmic ray muon run

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Muon Stations : Endcaps

ETH Institute for Particle Physics

First TGC 'Big-Wheel' assembled in the cavern early September 2006

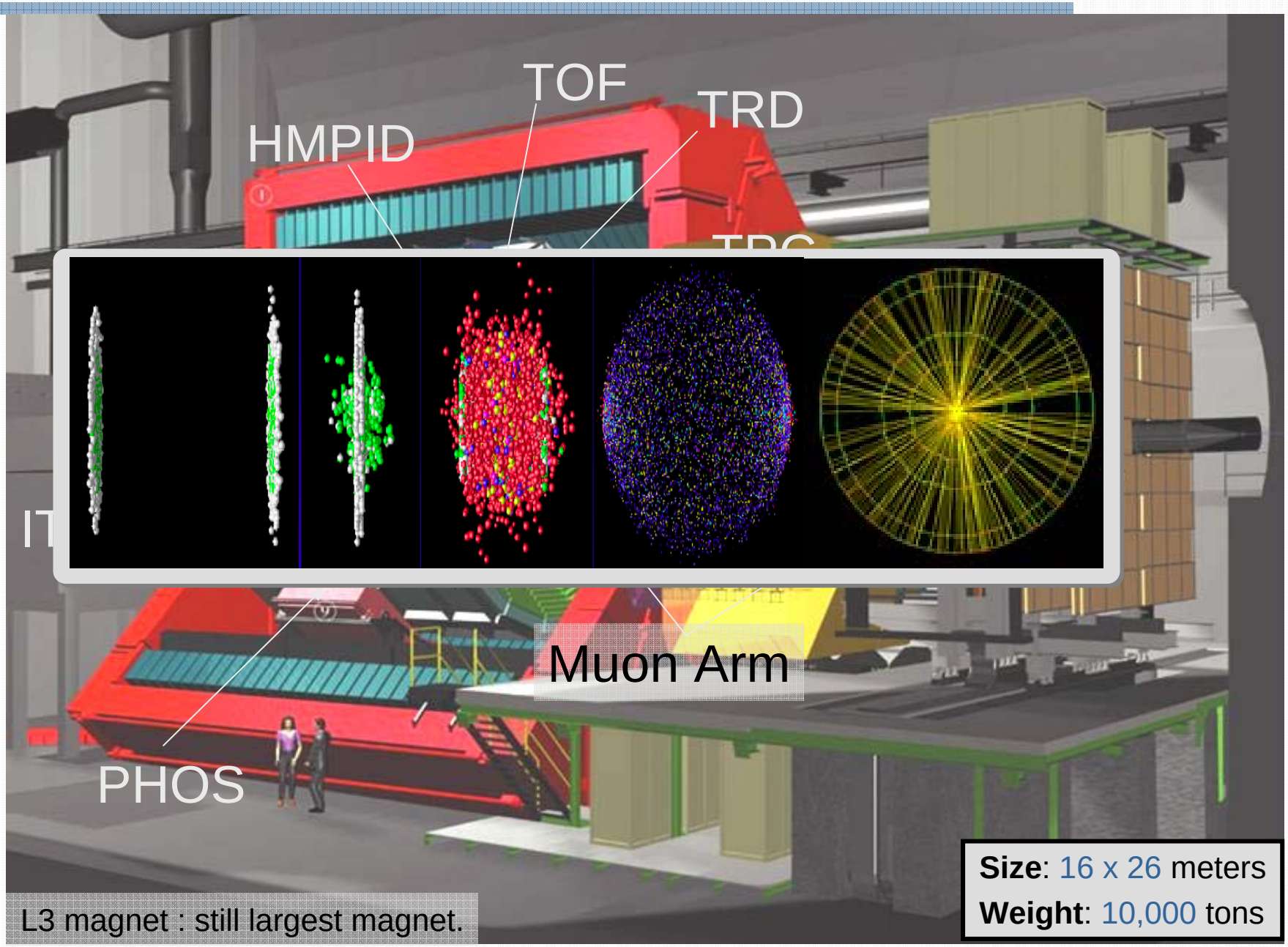


ALICE

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

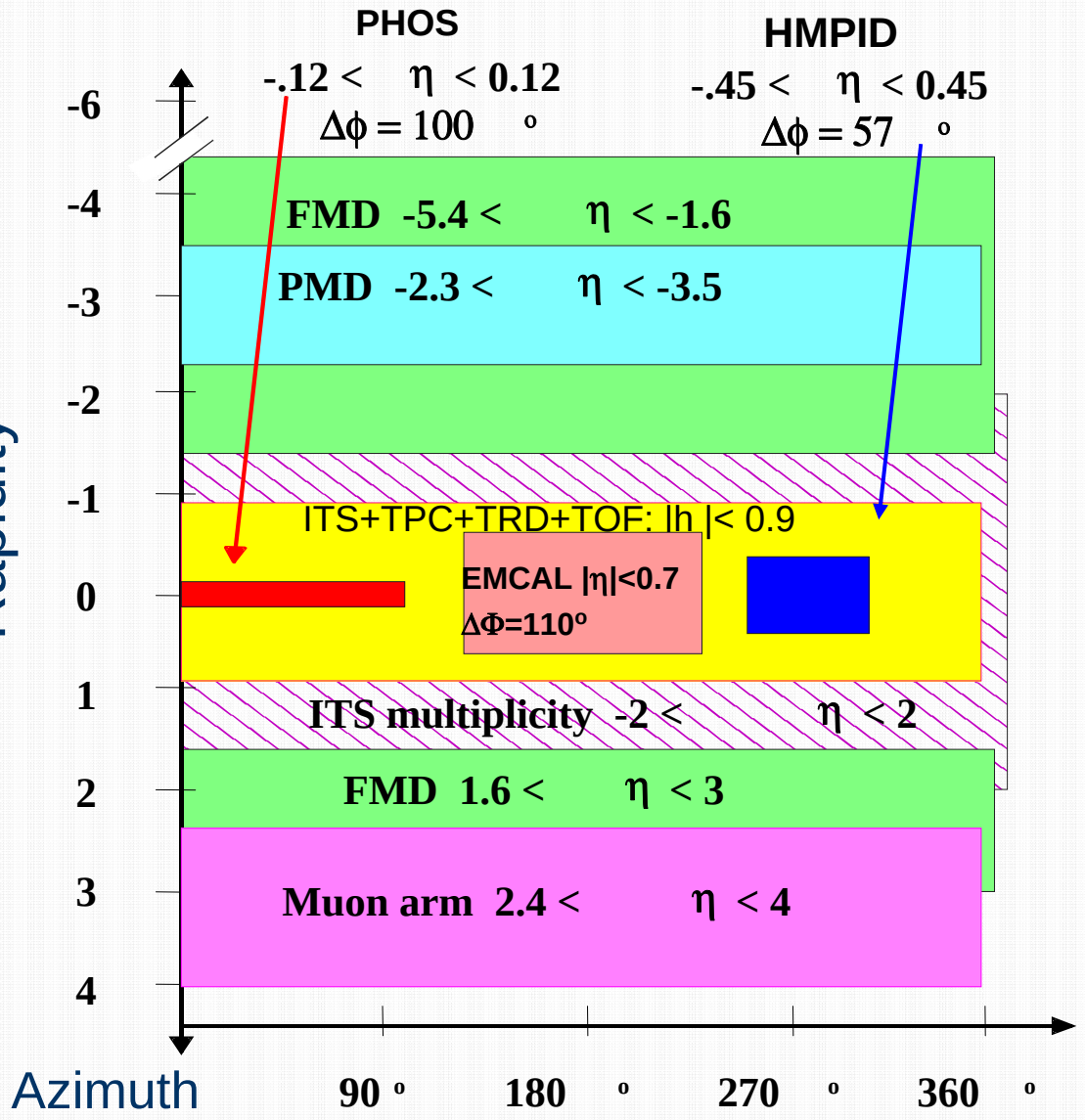
ALICE

ETH Institute for Particle Physics



ALICE Acceptance

- central barrel -0.9 < η < 0.9
  - 2 π tracking, PID
  - single arm **RICH** (HMPID)
  - single arm **em. calo** (PHOS)
  - jet calorimeter (proposed)
- forward muon arm 2.4 < η < 4
  - absorber, 3 Tm dipole magnet
    10 tracking + 4 trigger chambers
- multiplicity -5.4 < η < 3
  - including photon counting in **PMD**
- trigger & timing dets
  - 6 **Zero Degree Calorimeters**
  - **T0:** ring of quartz window PMT's
  - **V0:** ring of scint. Paddles



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

The ALICE Magnet (2002)

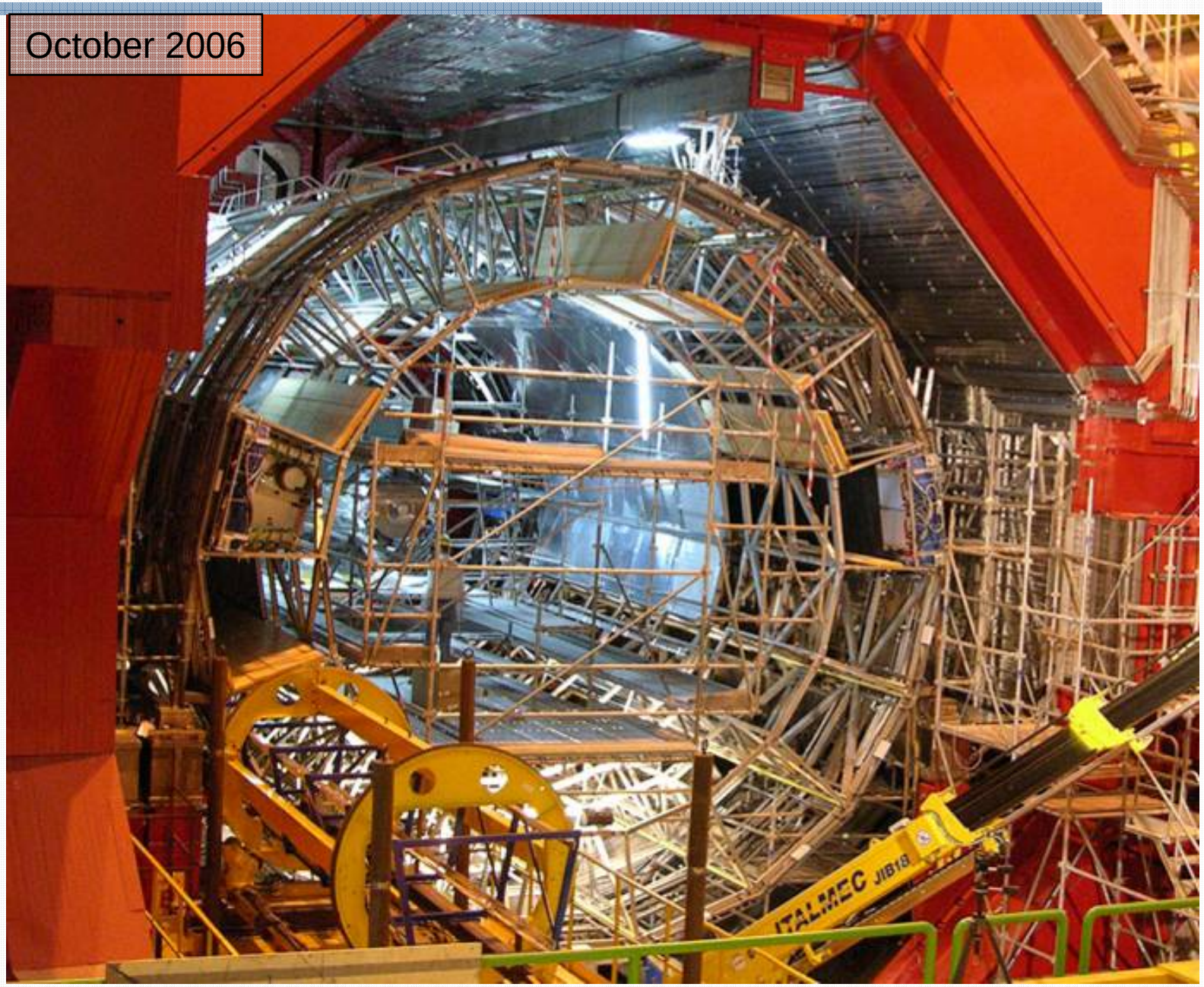
ETH Institute for Particle Physics

ready for the experiment to move in!

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Magnet and Space Frame

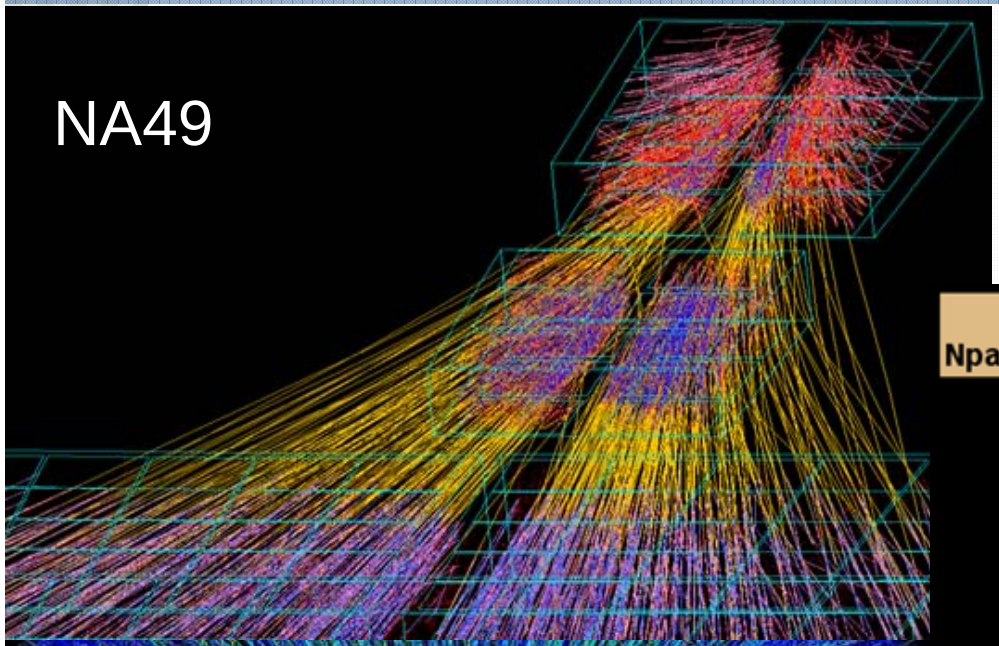
ETH Institute for Particle Physics

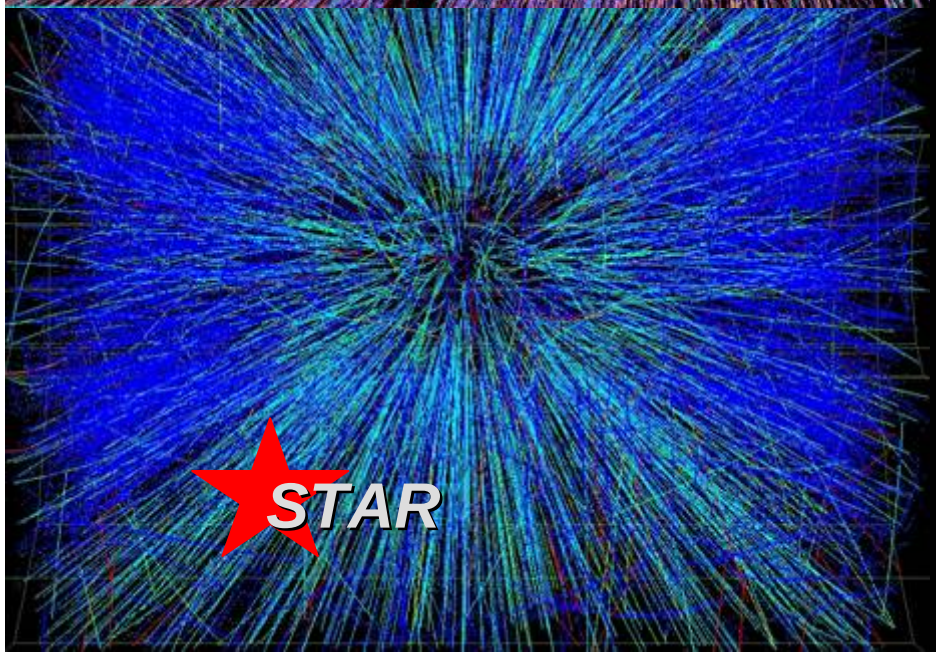


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Tracking Challenge

ETH Institute for Particle Physics

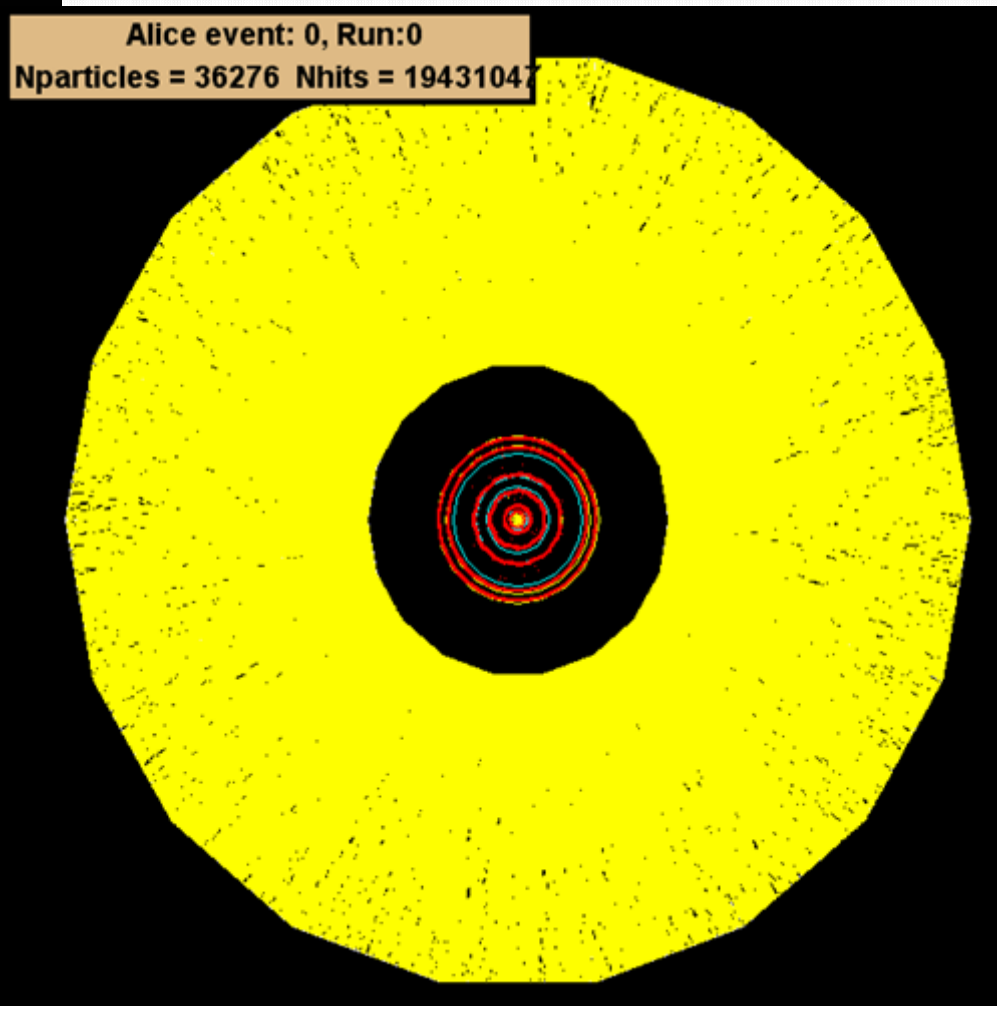




LHC: $dN_{ch}/dy = 2000 - 4000$

ALICE 'worst case' scenario:

$dN_{ch}/dy = 8000$

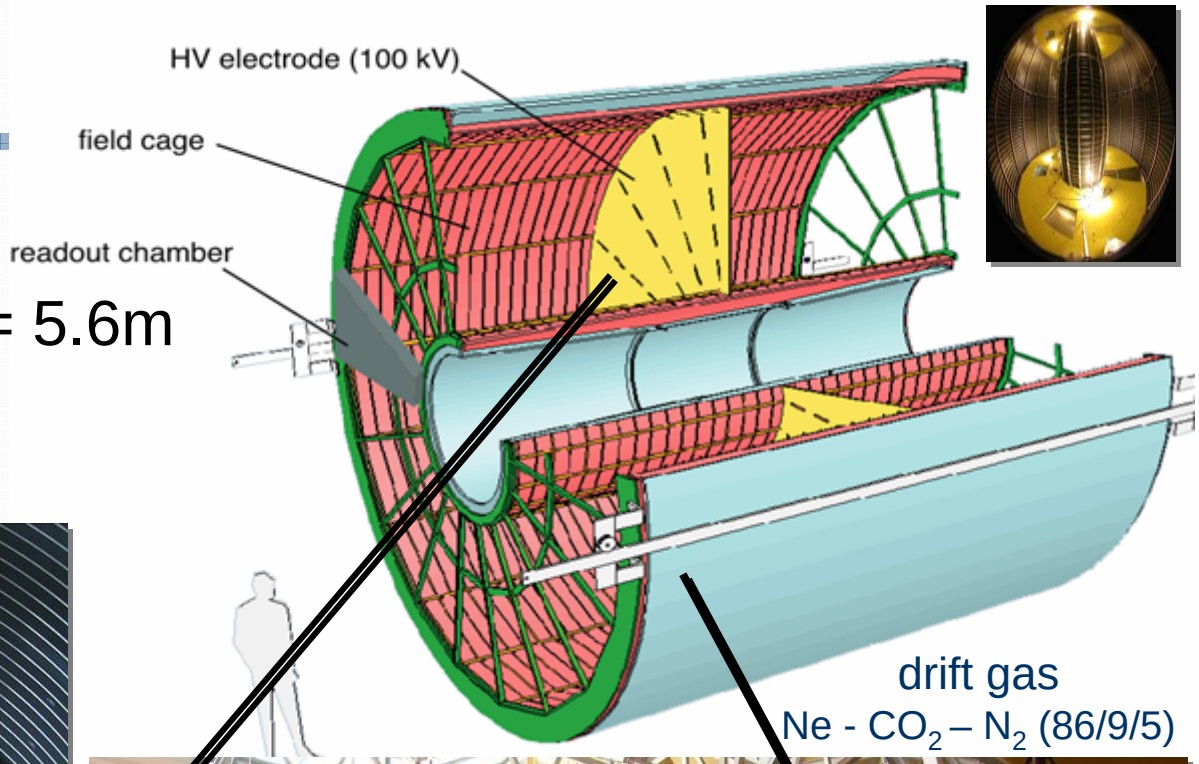


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

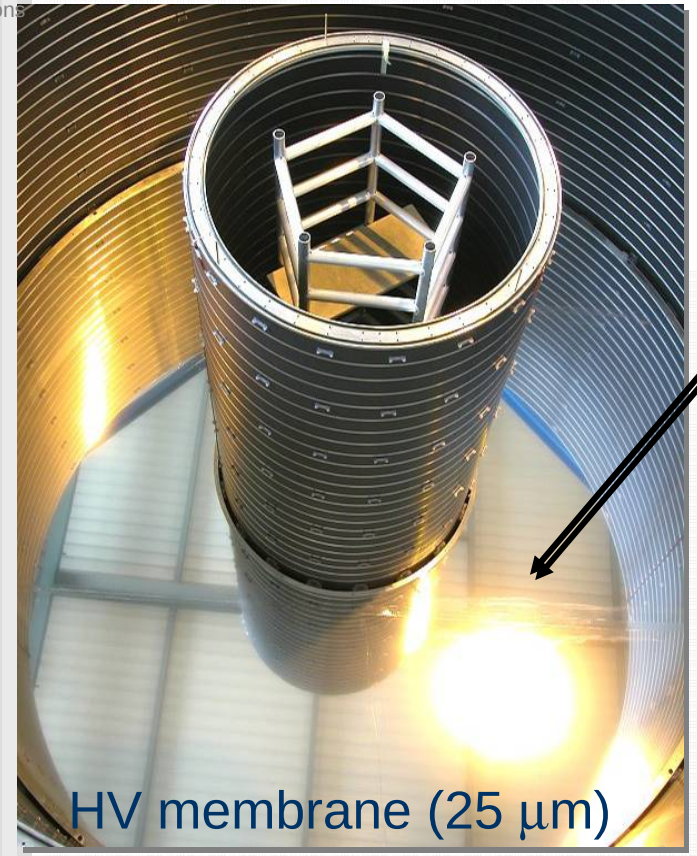
TPC

Largest ever

- 88 m^3, l = 5 m, d = 5.6m
  570 k channels



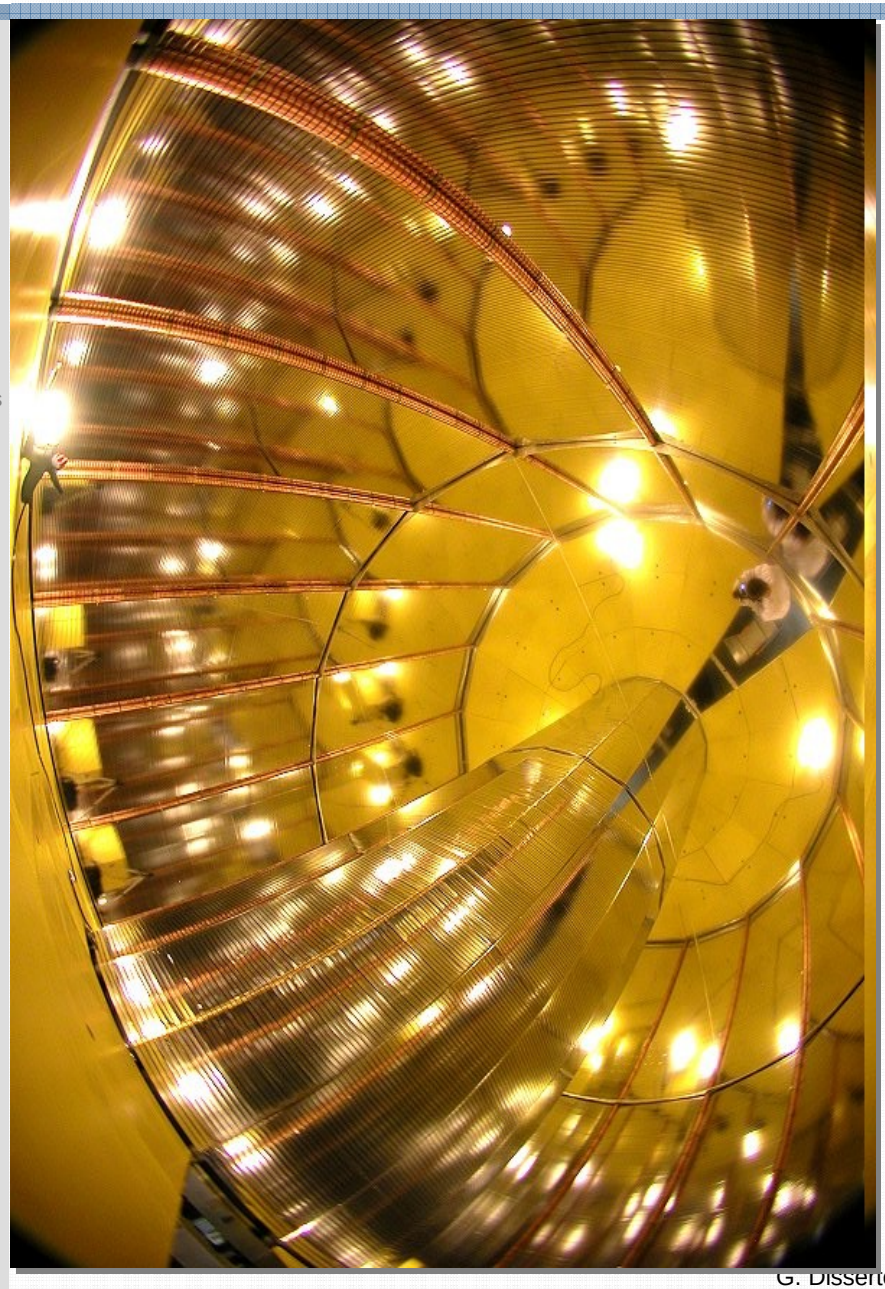
drift gas
Ne - CO_2 – N_2 (86/9/5)



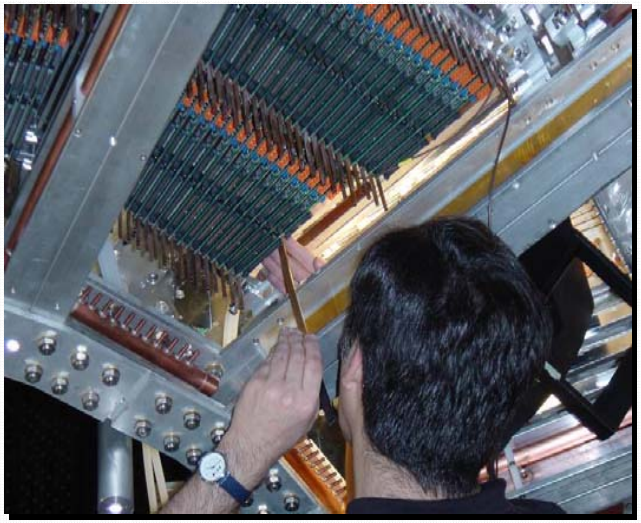
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

ALICE TPC

ETH Institute for Particle Physics

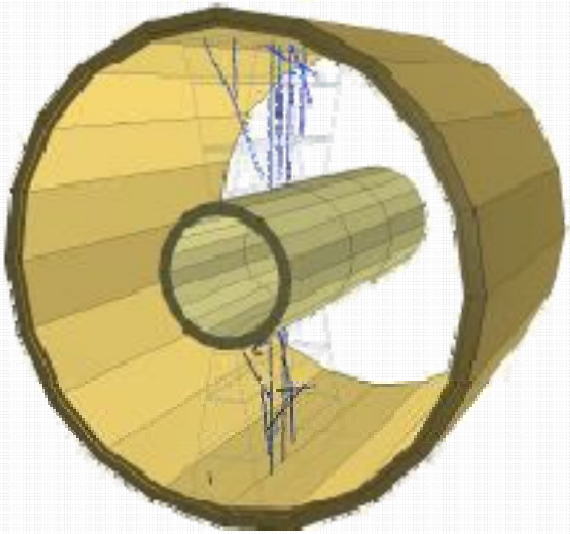


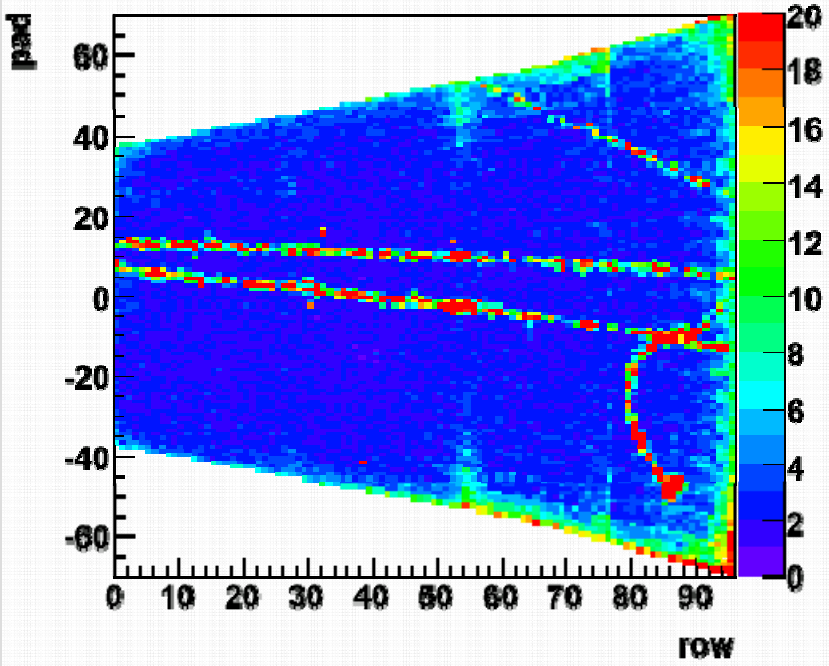
FEE installation

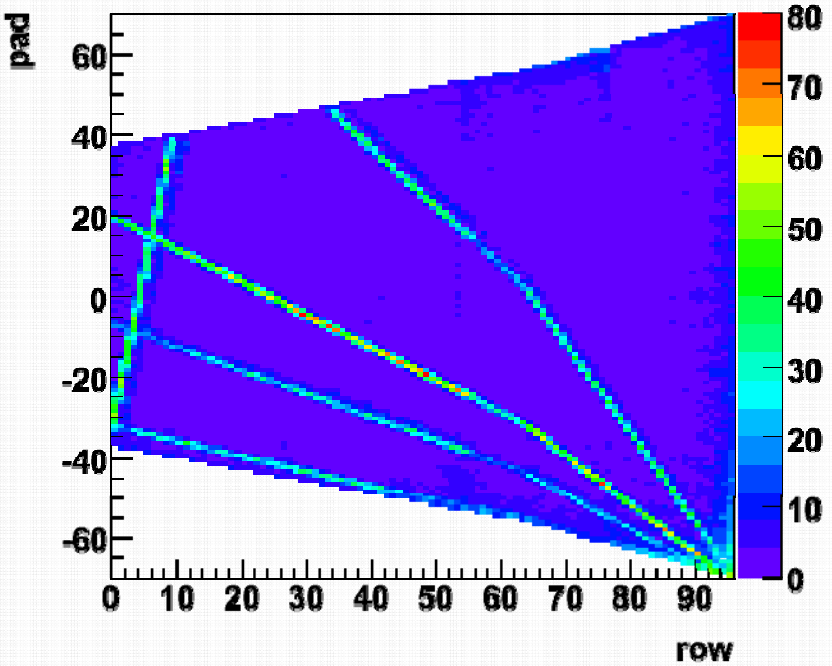


First TPC tracks

- first cosmic & laser tracks on 16 May 2006
  - first round of testing all chambers & FEE completed
    - resolution according to specifications
  - HLT connected and being commissioned
  - 2nd round ('endurance tests') ongoing







QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

TPC lowering…

ETH Institute for Particle Physics

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Subdetector installation

ETH Institute for Particle Physics

In the pit: installing first TOF SuperModule

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Subdetector installation

ETH Institute for Particle Physics

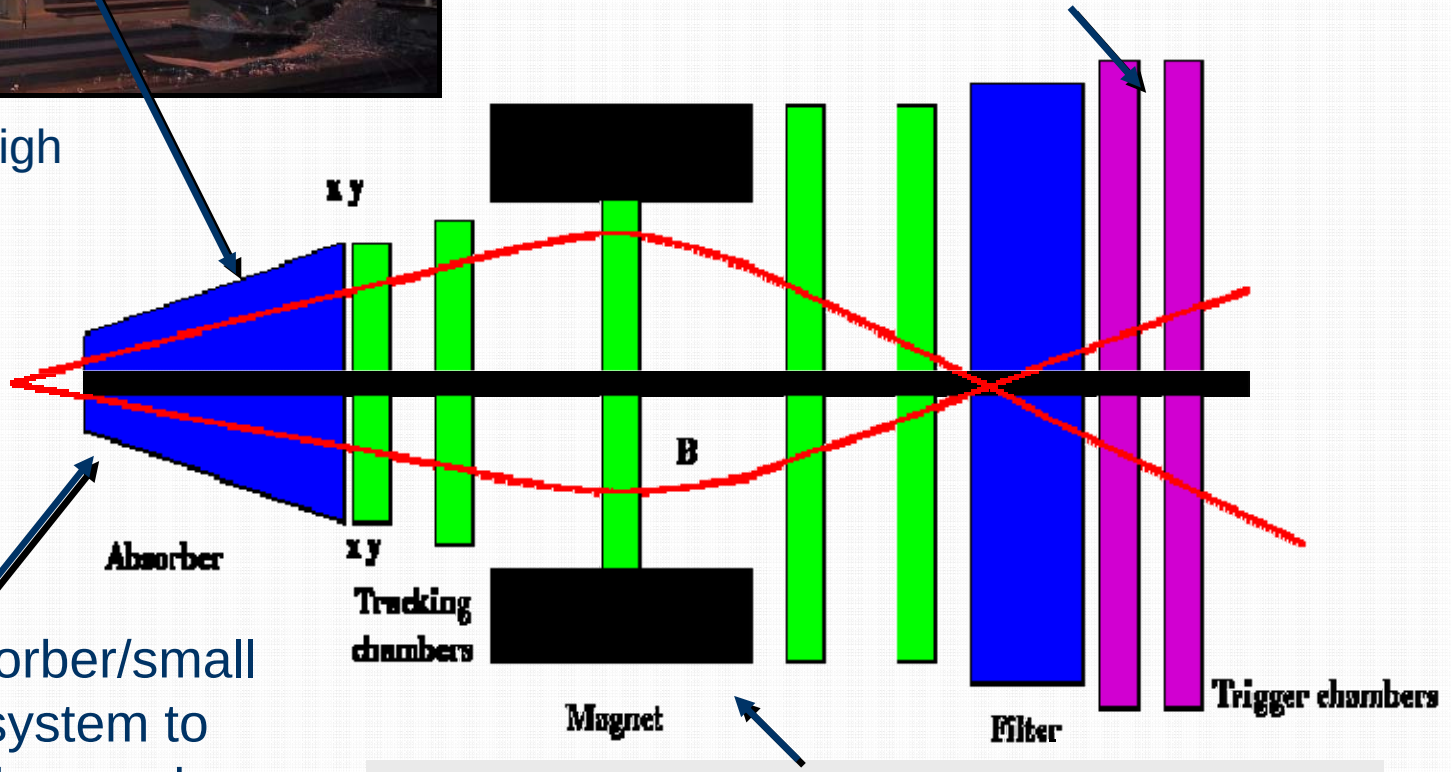
TRD module during installation

Dimuon Spectrometer

- Study the production of the **J/Ψ, Ψ', Υ, Υ', Υ''** decaying in 2 muons, $2.4 < \eta < 4$

4 RPC Trigger Chambers

10 planes of high granularity pad tracking chambers, over 800k channels



Complex absorber/small angle shield system to minimize background (90 cm from vertex)

Dipole Magnet: bending power 3Tm

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Muon Spectrometer

ETH Institute for Particle Physics

CMS

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

CMS

ETH Institute for Particle Physics

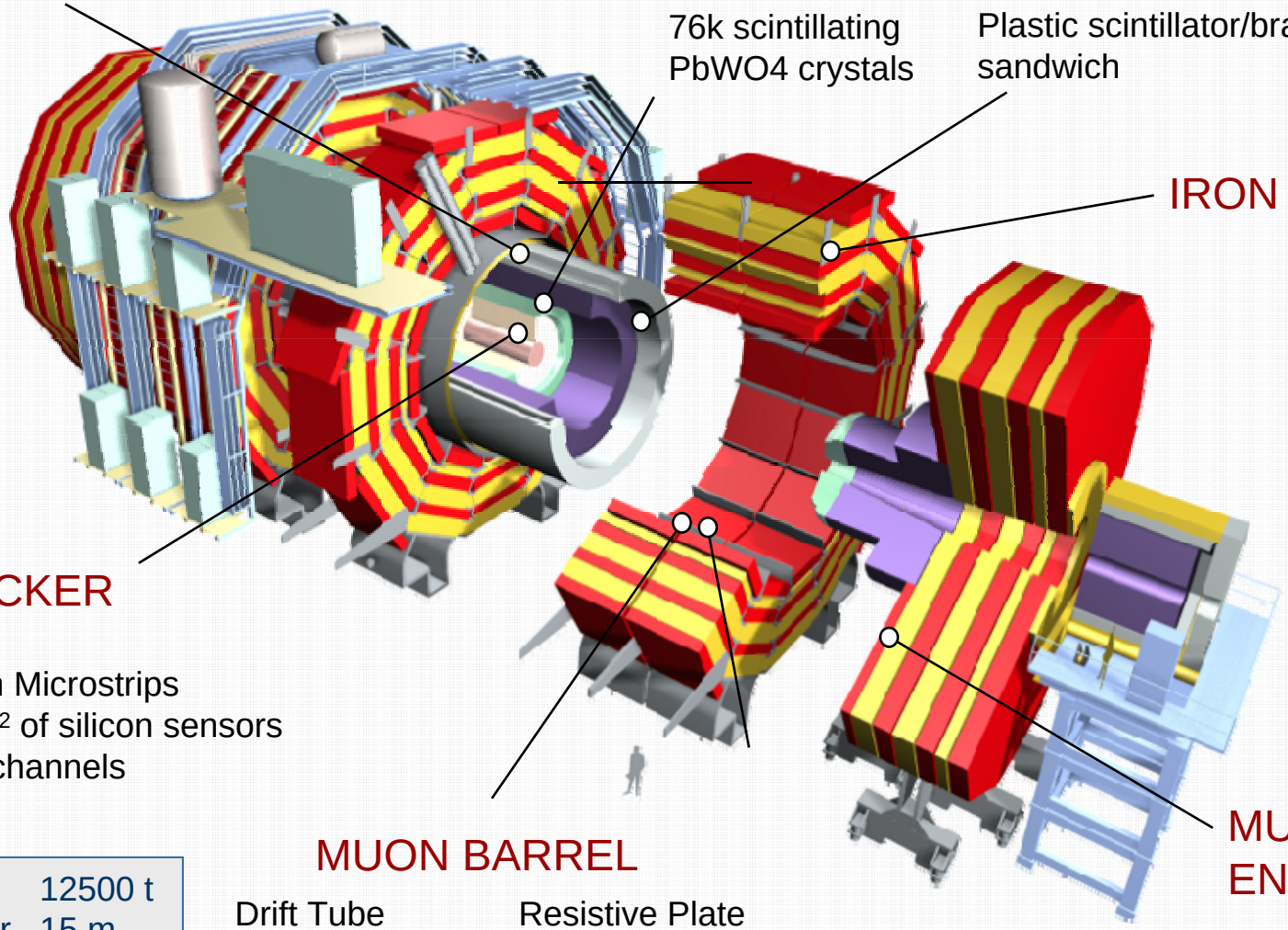
Superconducting Coil, 4 Tesla

CALORIMETERS

ECAL
76k scintillating PbWO4 crystals

HCAL
Plastic scintillator/brass sandwich

IRON YOKE



TRACKER
Pixels
Silicon Microstrips
210 m^2 of silicon sensors
9.6M channels

MUON BARREL
Drift Tube Chambers (**DT**)
Resistive Plate Chambers (**RPC**)

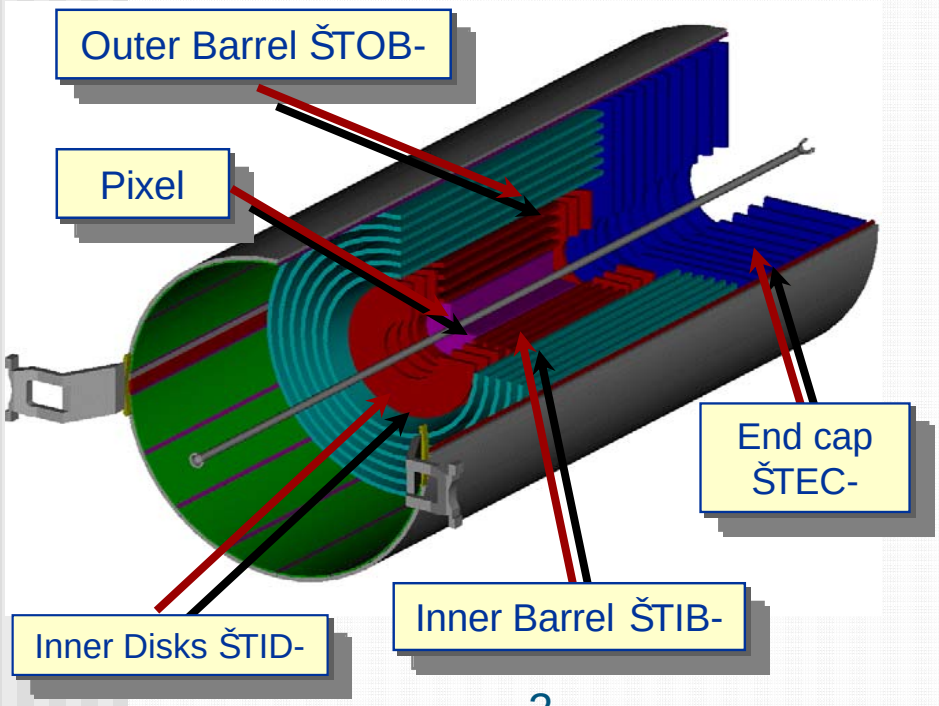
MUON ENDCAPS
Cathode Strip Chambers (**CSC**)
Resistive Plate Chambers (**RPC**)

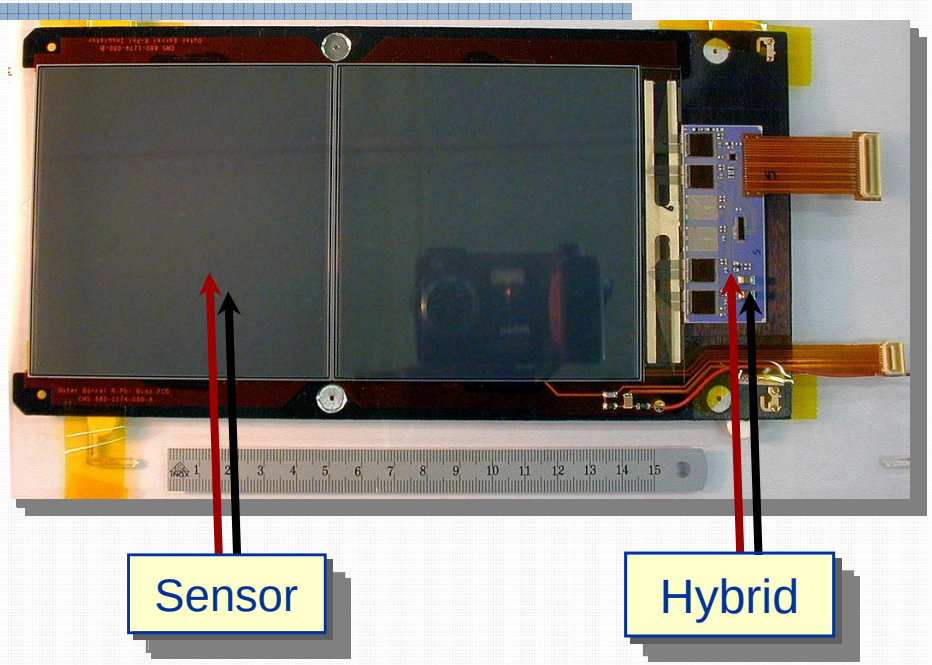
Total weight	12500 t
Overall diameter	15 m
Overall length	21.6 m

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Tracker

ETH Institute for Particle Physics



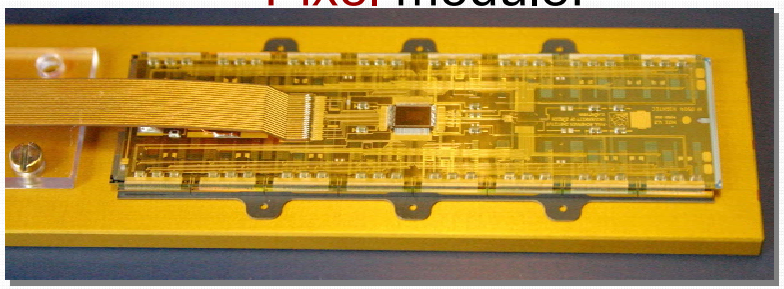


210 m^2 of silicon sensors

9,648,128 electronics channels

- All-Silicon Tracking
- Pixel : module production and testing under way. Full pixel will be installed in 2008.
- SI : all sensors produced, now integration in support tube, soon commissioning, installation in CMS mid-2007

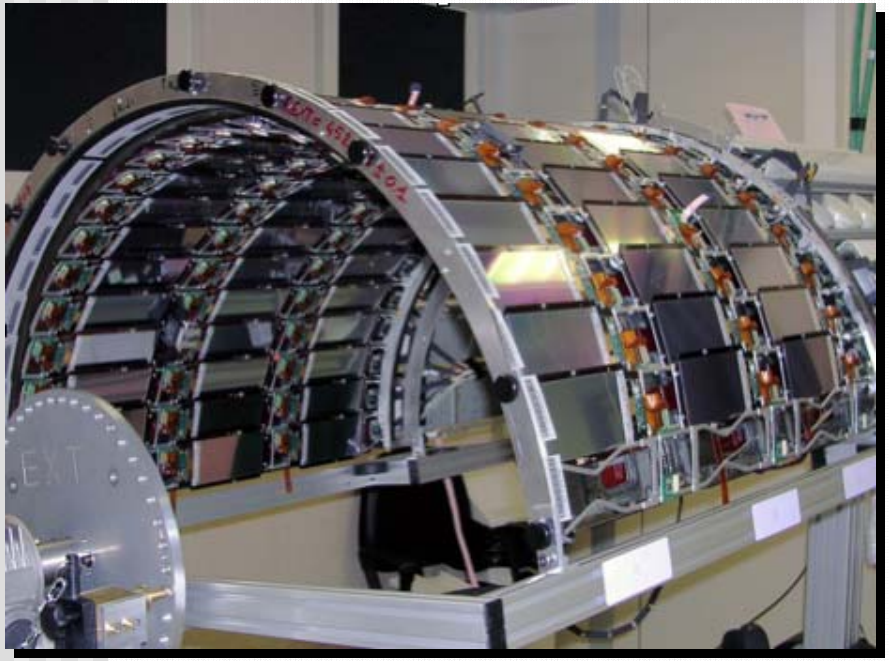
Pixel module:



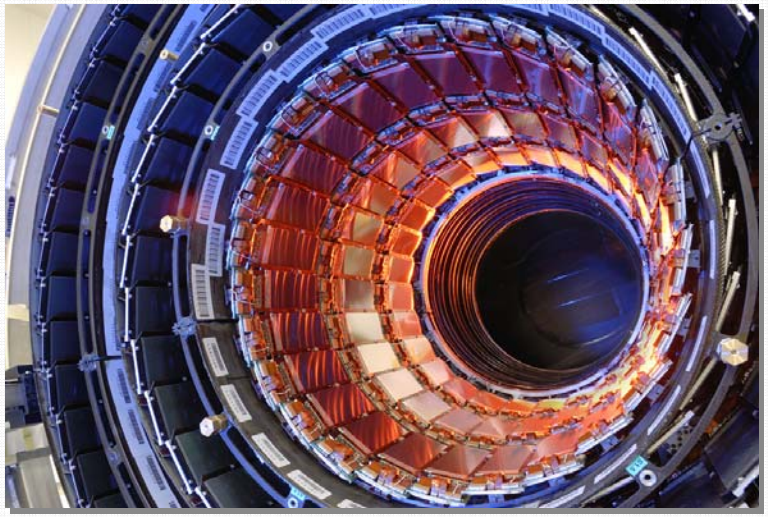
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Tracker production

ETH Institute for Particle Physics



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

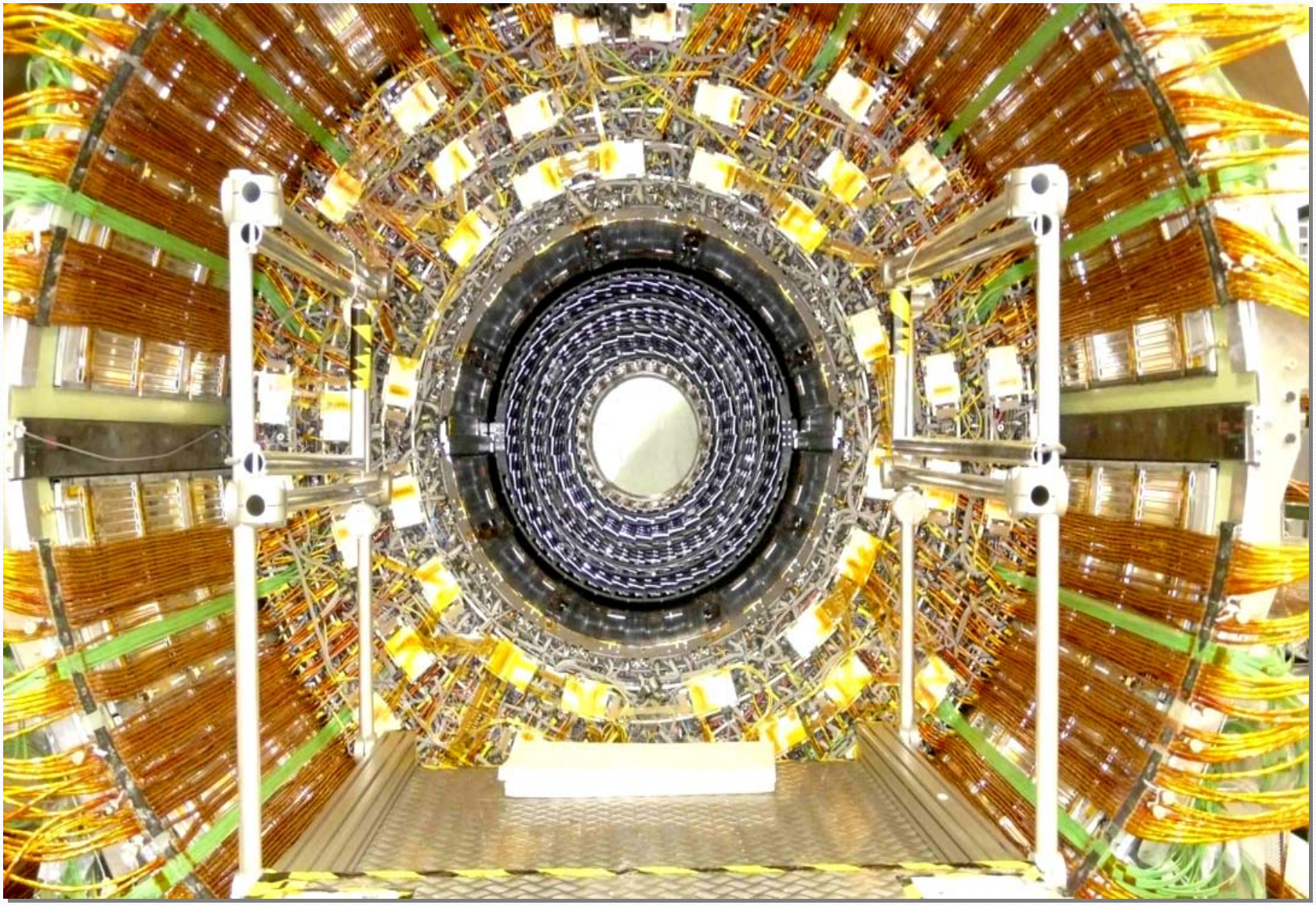


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Tracker in CERN Tracker Integration Facility

ETH Institute for Particle Physics

View of the Inner and Outer Barrel in the Tracker Support Tube



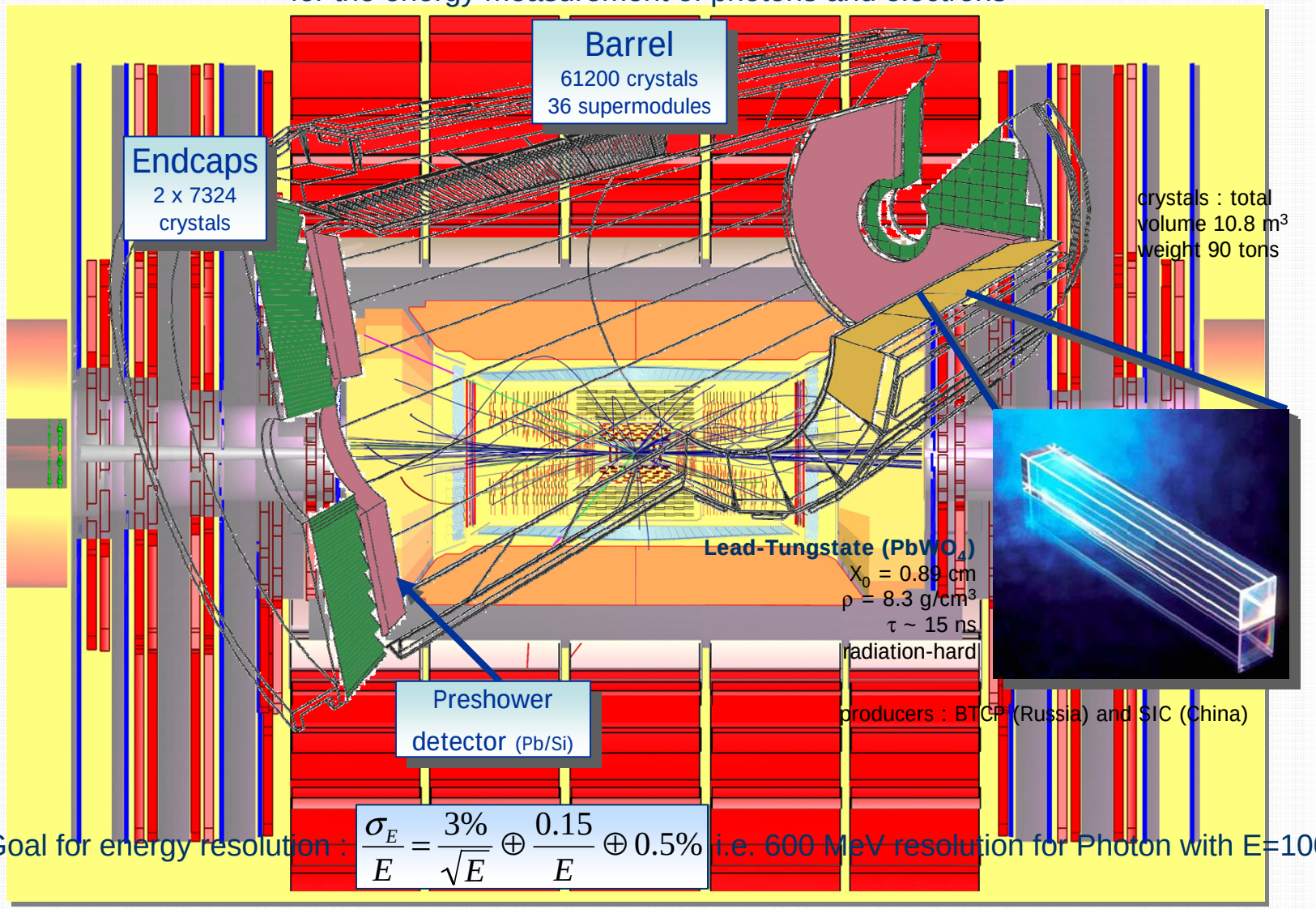
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

The CMS Crystal Calorimeter

ETH Institute for Particle Physics

Goal : Attain best possible precision

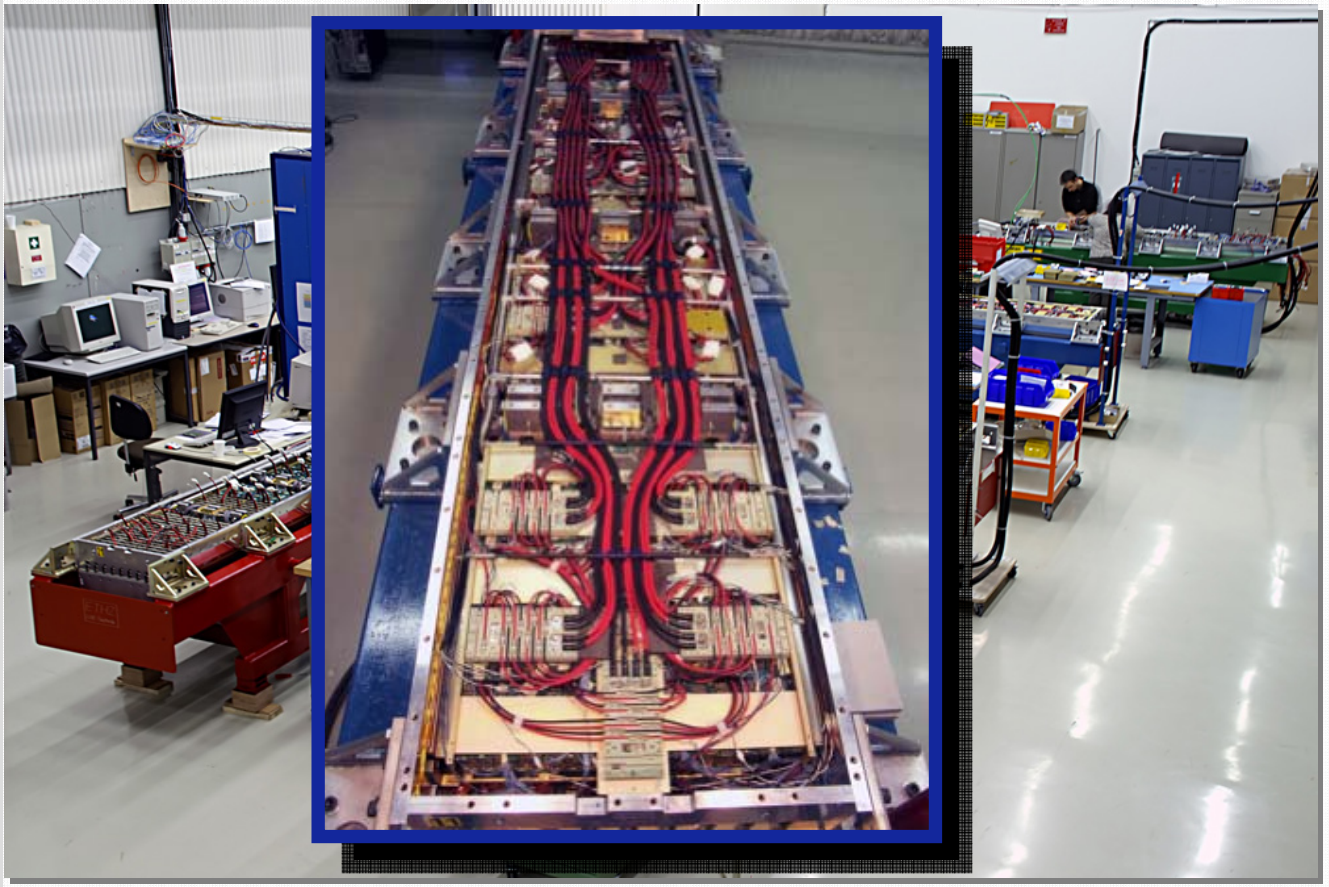
for the energy measurement of photons and electrons

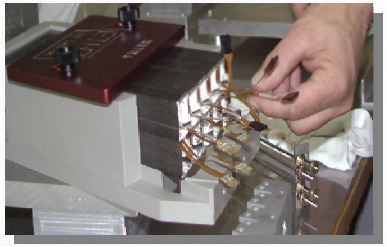


Goal for energy resolution : $\frac{\sigma_E}{E} = \frac{3\%}{\sqrt{E}} \oplus \frac{0.15}{E} \oplus 0.5\%$ i.e. 600 MeV resolution for Photon with E=100 GeV

ECAL : Construction

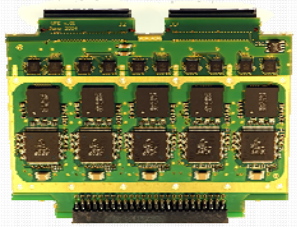
ECAL electronics integration centre:

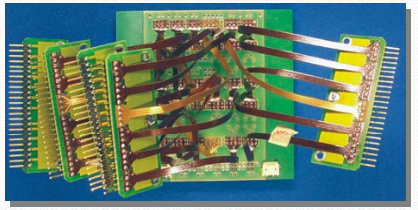




Supermodules will be installed into CMS starting in spring 07

Barrel crystal prod. will be finished in March 07;
Endcaps early 2008.

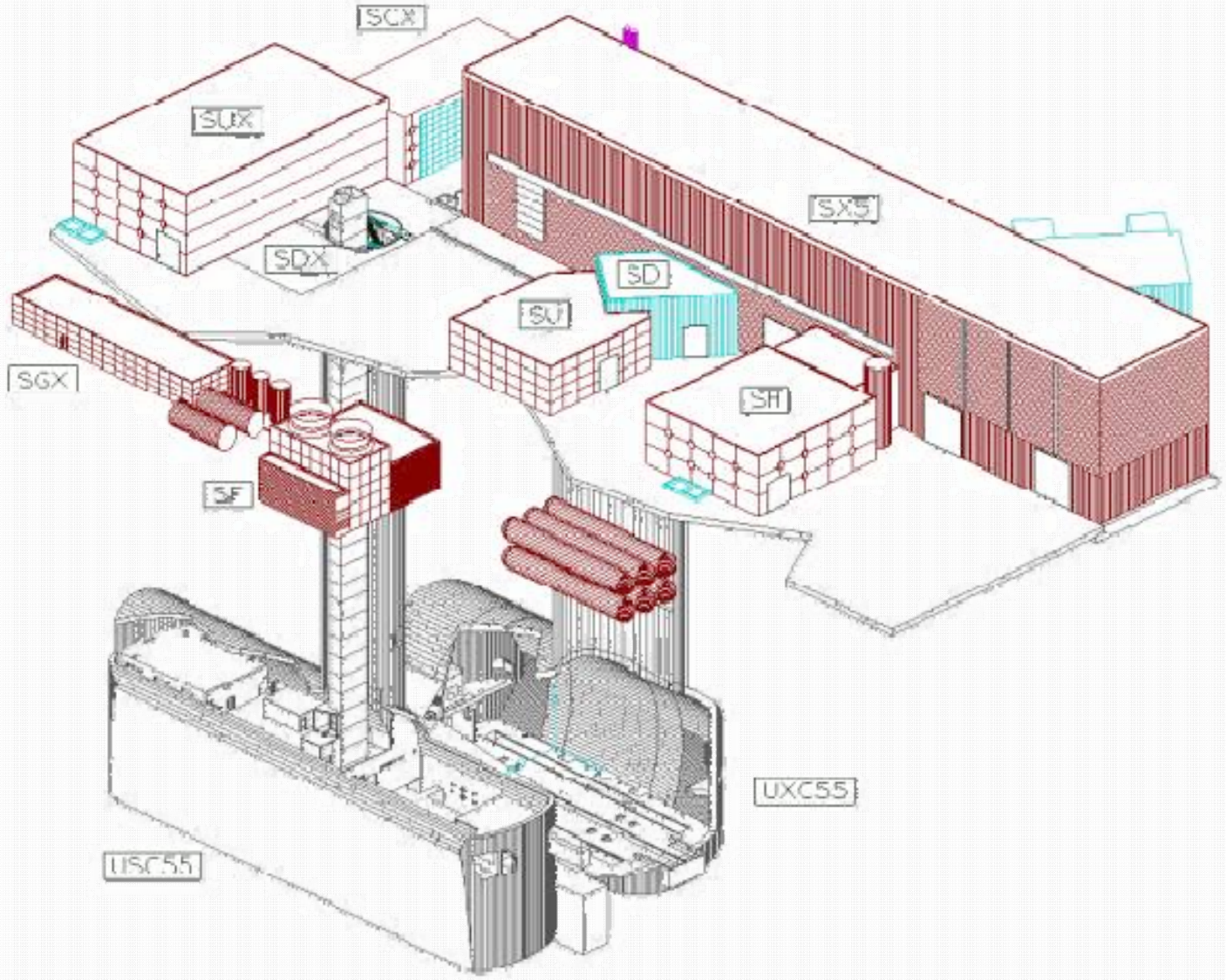




QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Experimental area : Point 5

ETH Institute for Particle Physics

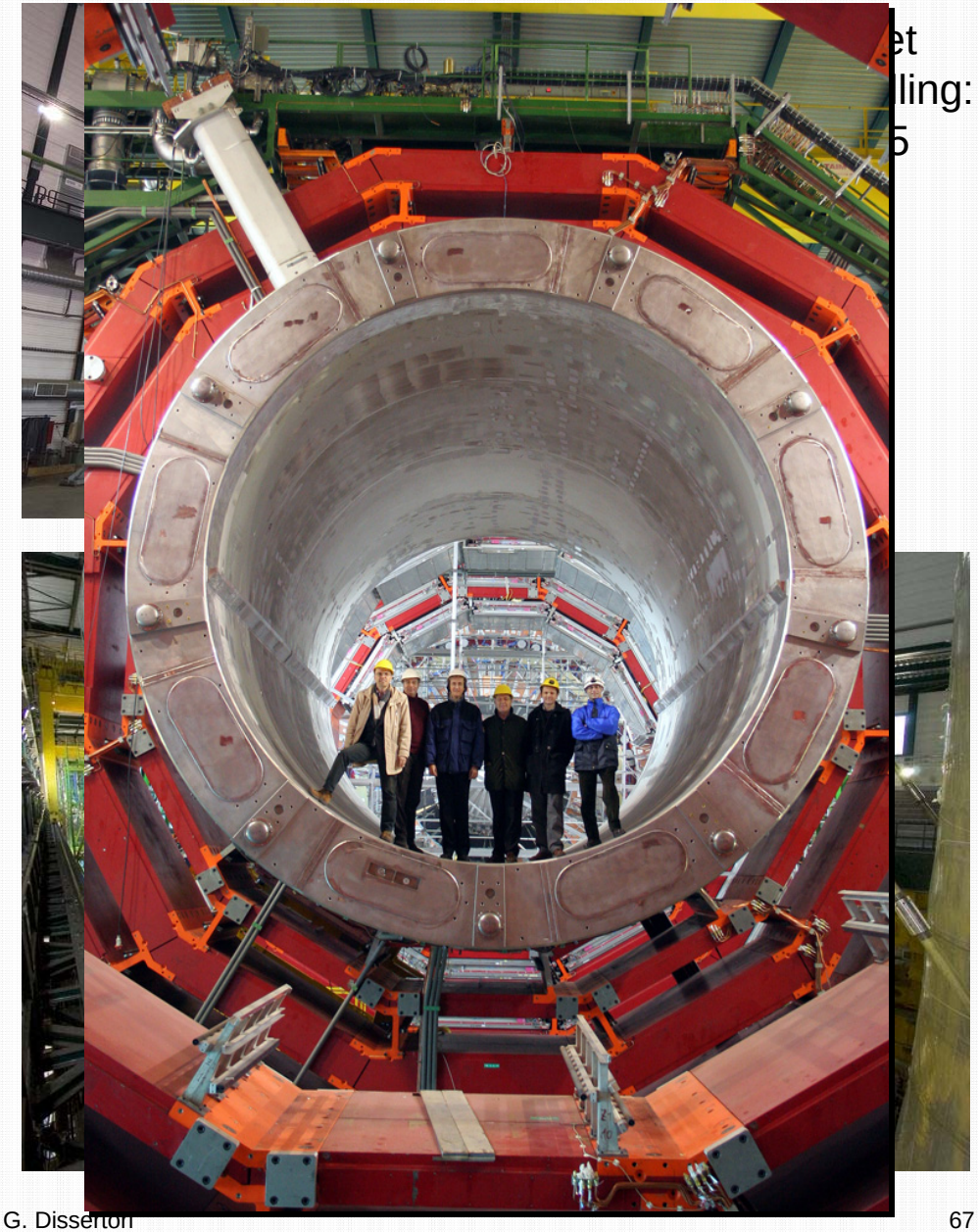


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

CMS : Magnet

ETH Institute for Particle Physics

Magnet has been built out of 5 modules, connected and leak-tested.

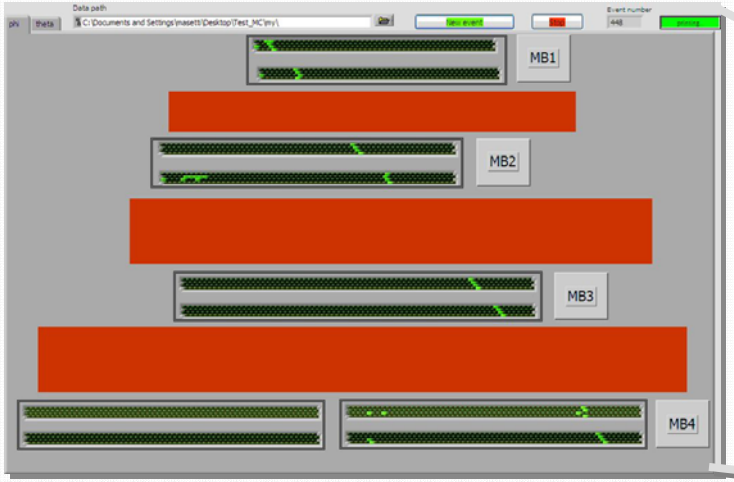


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

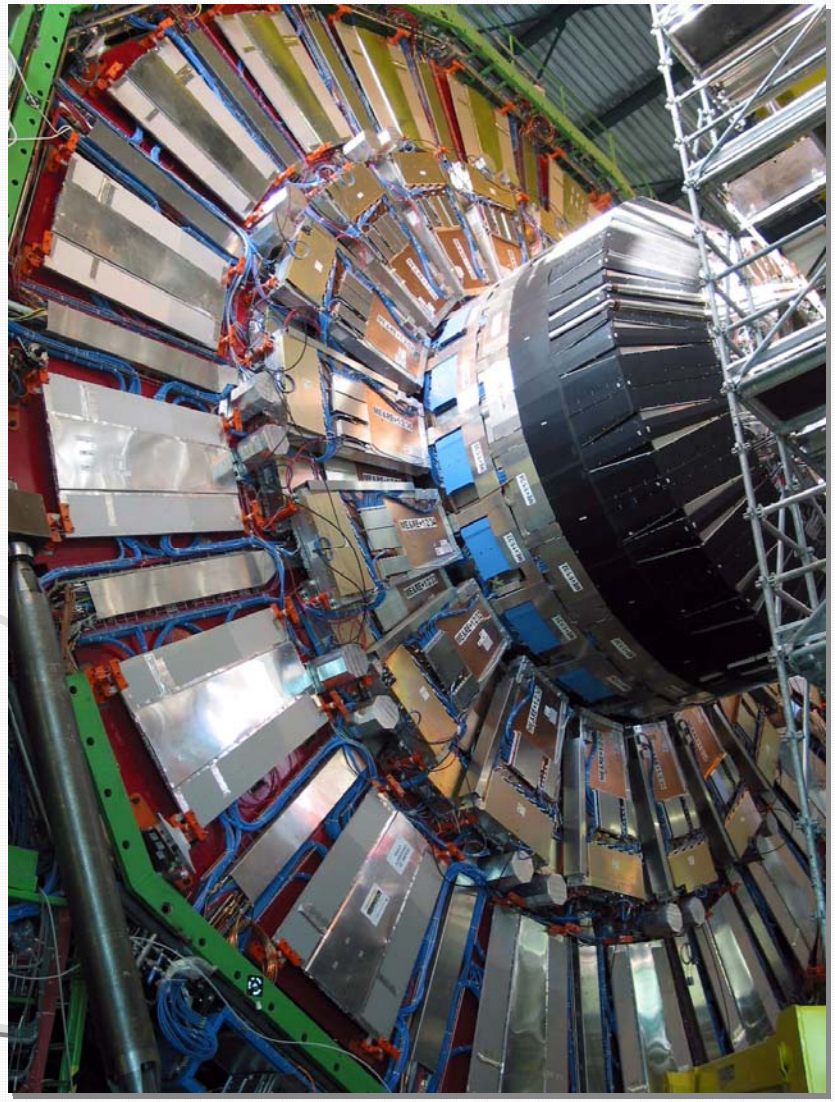
CMS : Muon chambers

ETH Institute for Particle Physics

Barrel Muon System



Endcap Disk

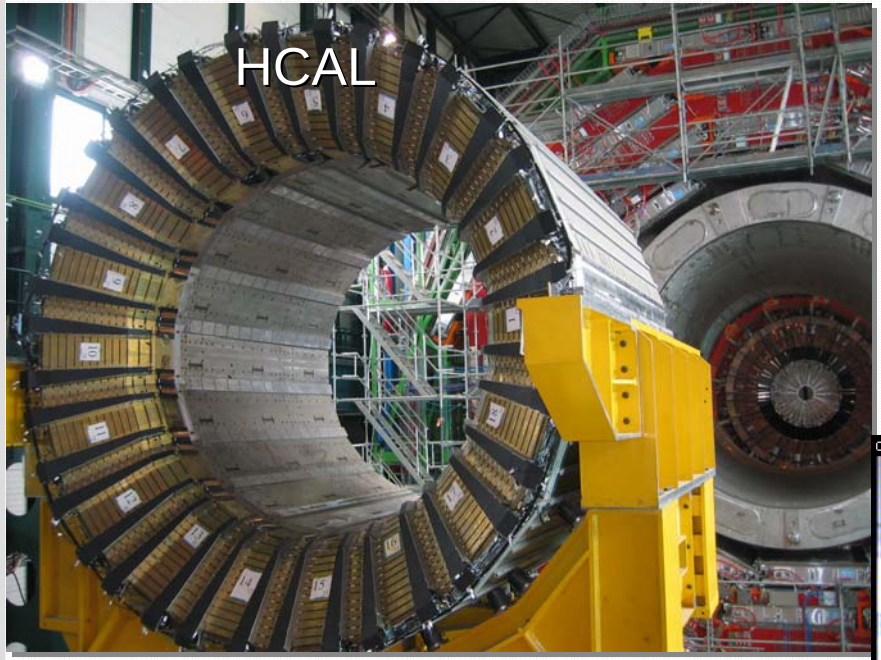


Barrel muon chamber installation complete.

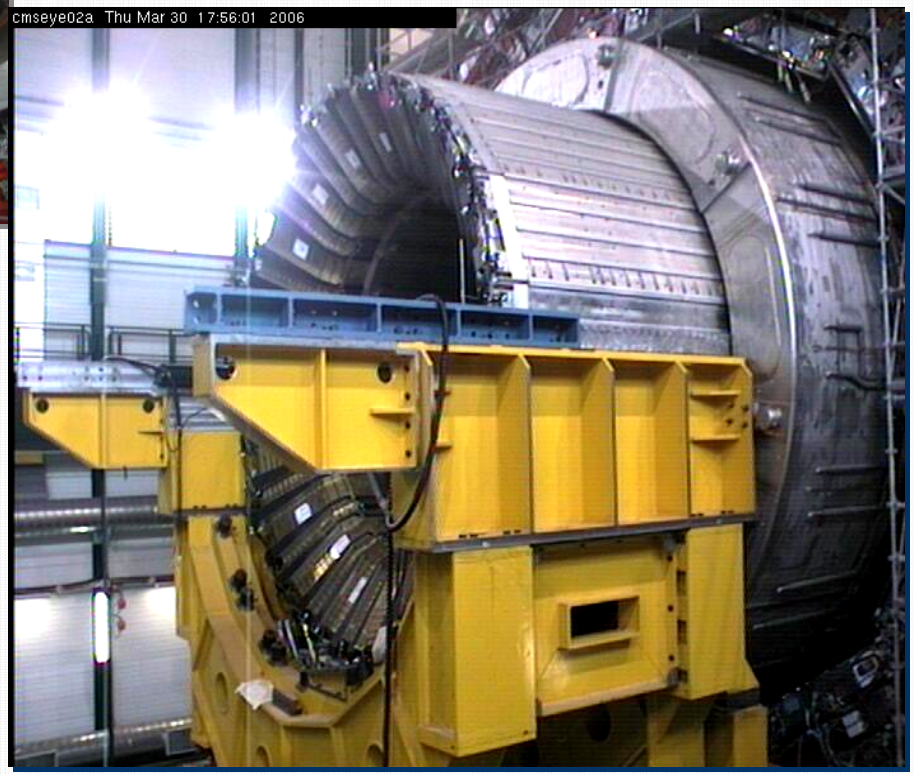
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

CMS : HCAL

ETH Institute for Particle Physics



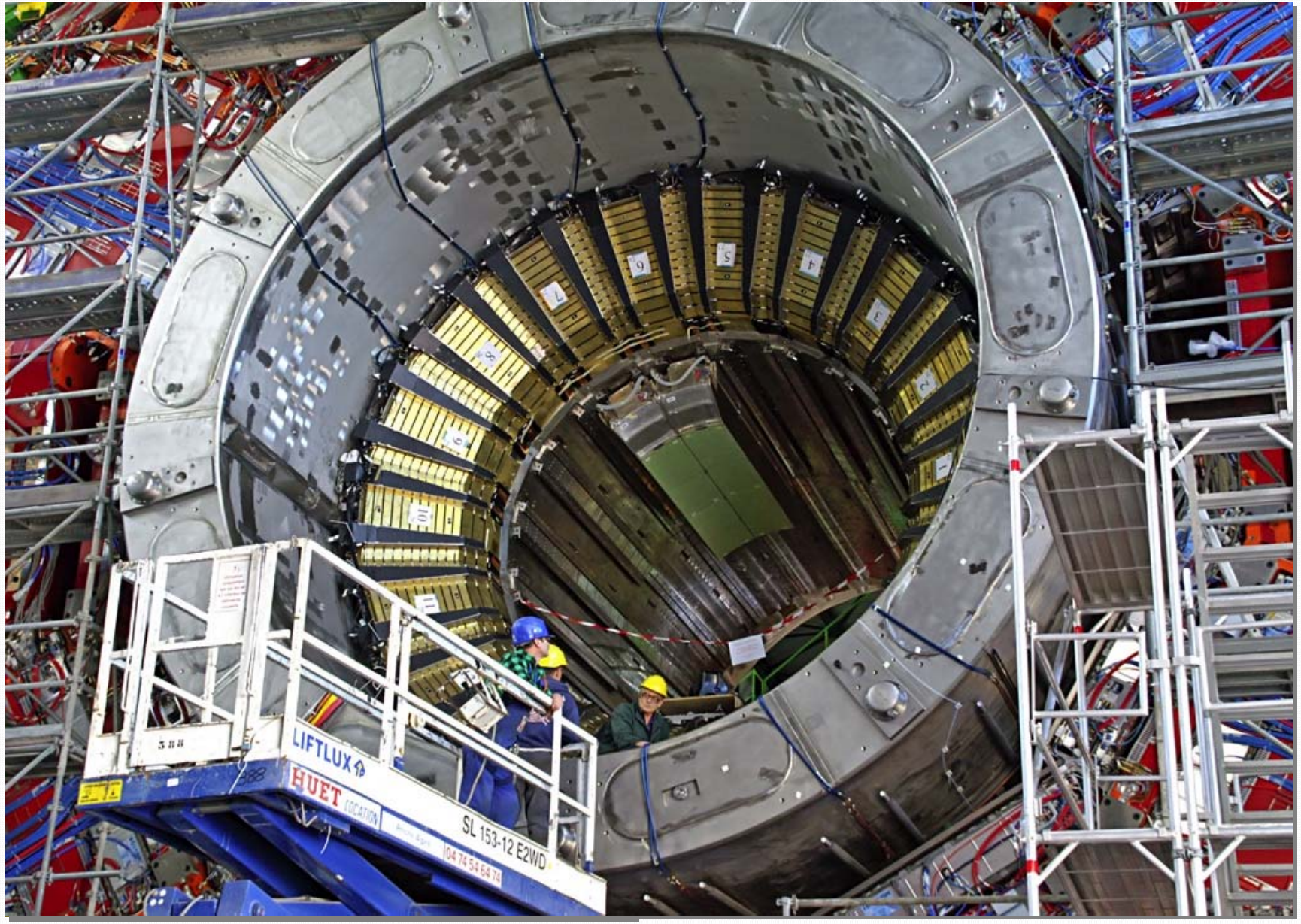
HCAL construction complete. Forward calorimeter already lowered into cavern.



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Insertion of 2 ECAL Supermodules

ETH Institute for Particle Physics

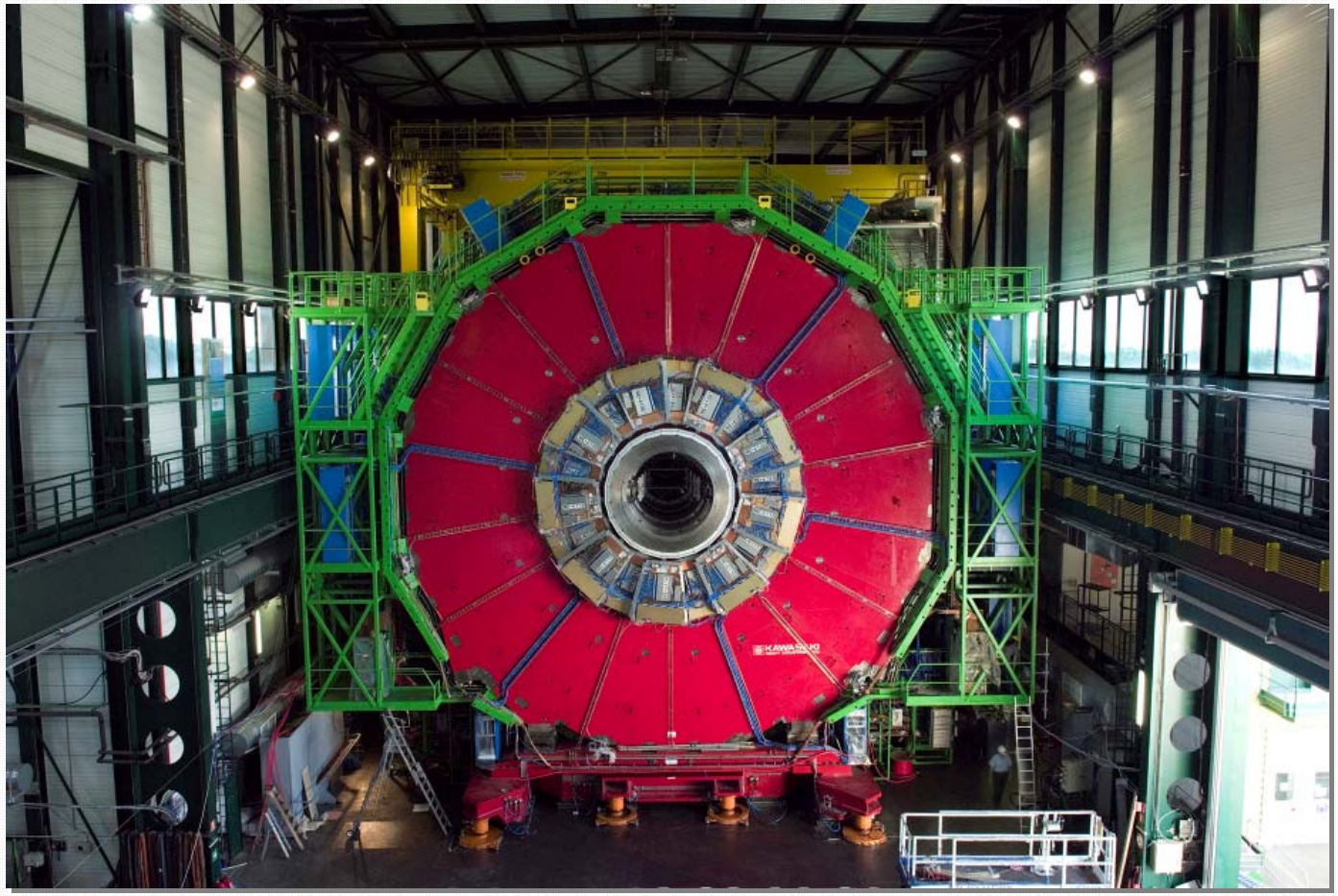


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Closing CMS for the first time in July 2006

ETH Institute for Particle Physics

Magnet Test and Cosmic Challenge (MTCC)



SC Magnet: 4 Tesla, l = 13 m, Ø = 6 m, weight > 10’000 tons

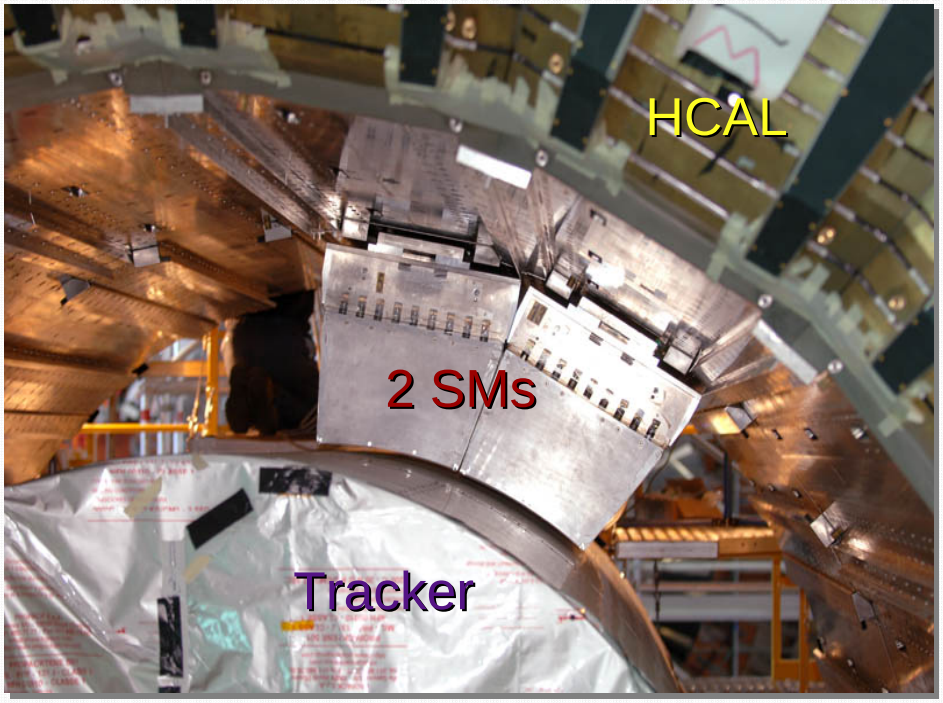
Magnet Test and Cosmic Challenge (MTCC)

ETH Institute for Particle Physics

August 28: Stable magnet operation at 4 Tesla !

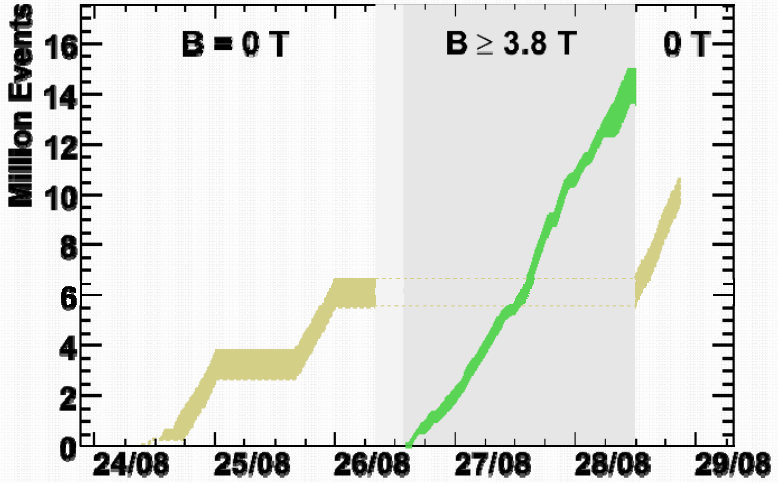
19.14 kA, 2.5 GJ stored energy, sufficient to melt 18 tonnes of gold

Muon system, HCAL, 2 ECAL SMs and part of tracker installed



Final DAQ for cosmic muon triggers:

~ 25 Million events



A big success !

Field mapping done in October

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

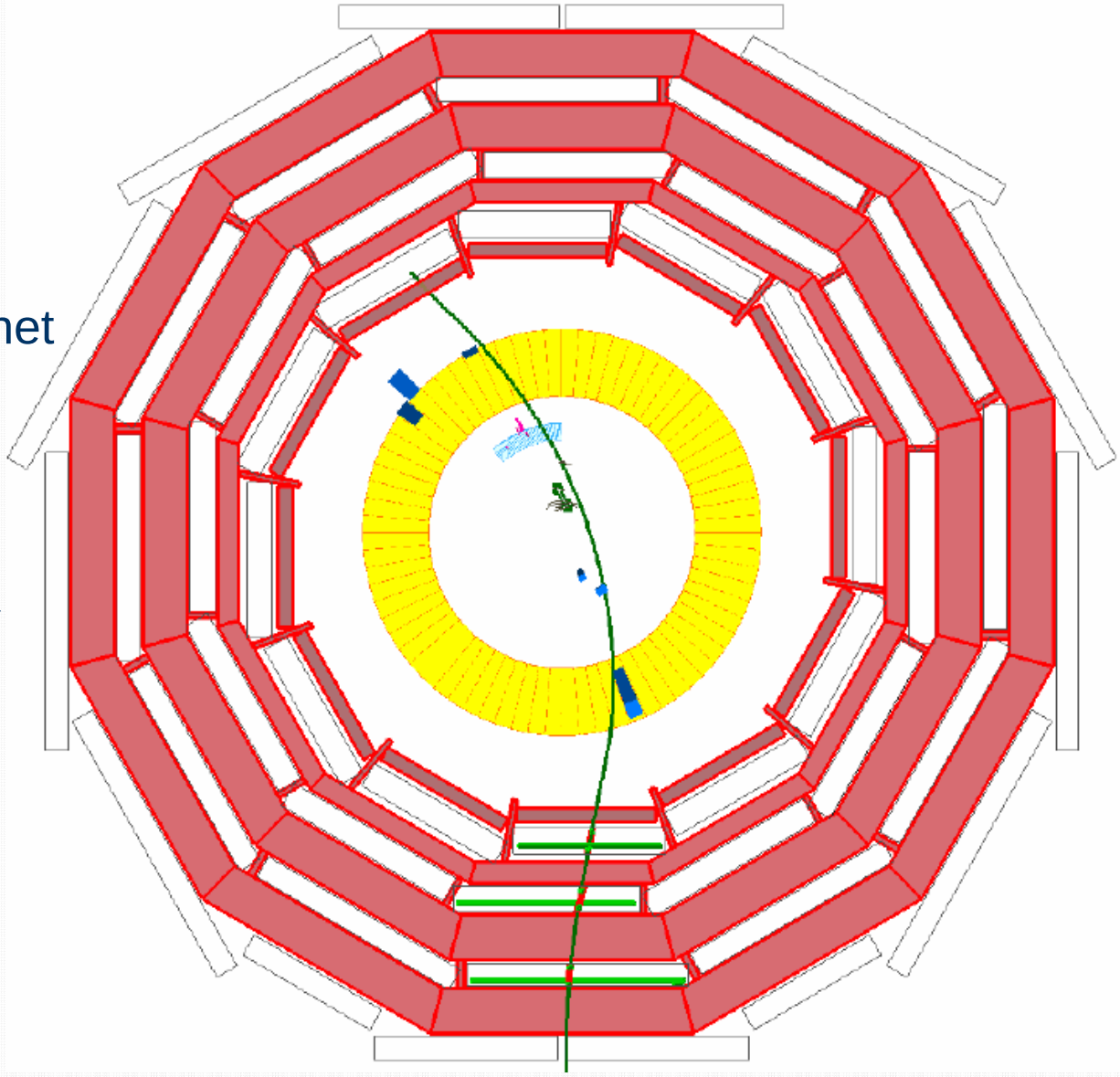
Run 2605 / Event 3981/ B 3.8 T/27.08.06

ETH Institute for Particle Physics

CERN PRESS RELEASE
13 September 2006

Mammoth CMS magnet reaches full-field at CERN

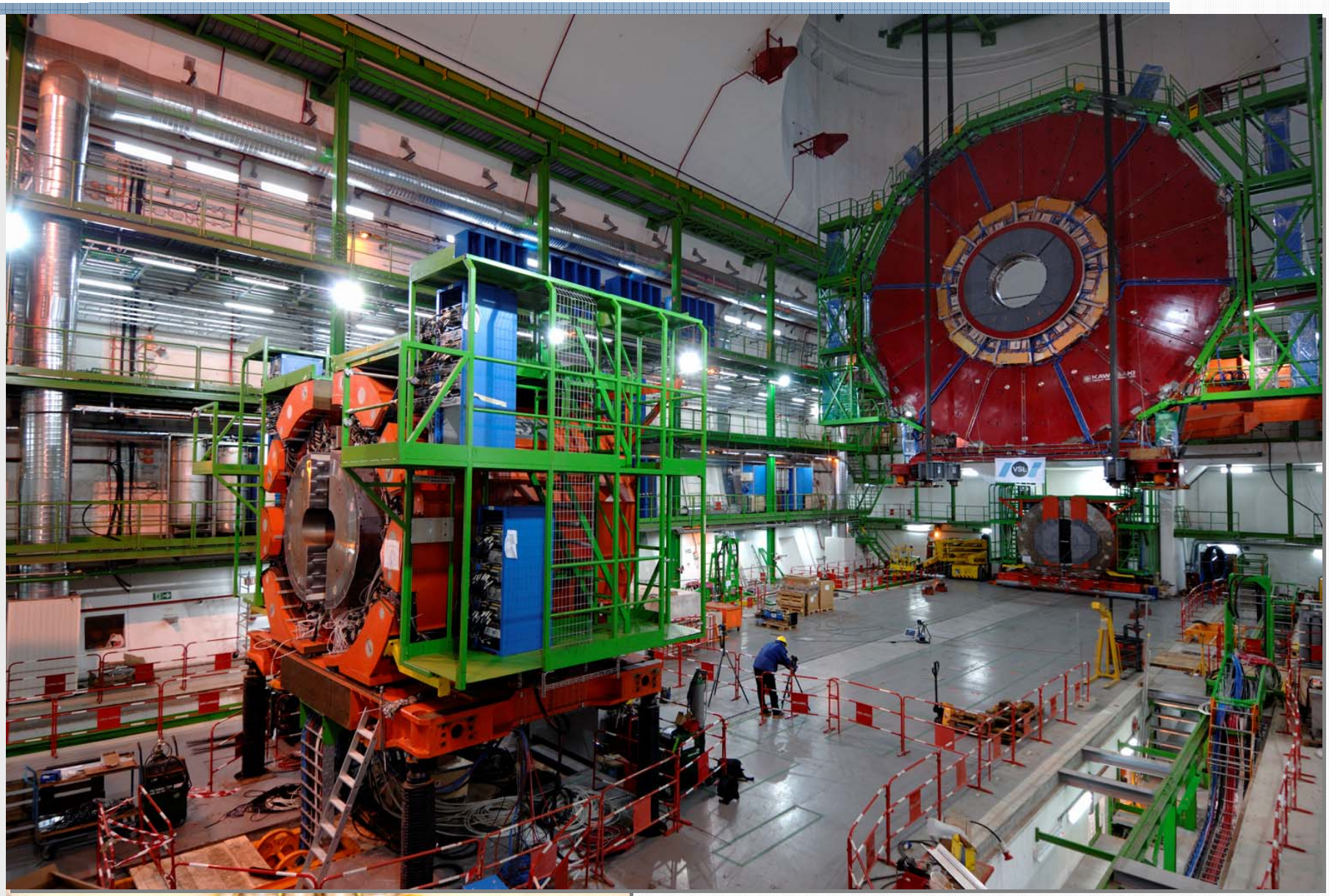
Tests show CMS detector will be ready for data



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Heavy Lowering started!

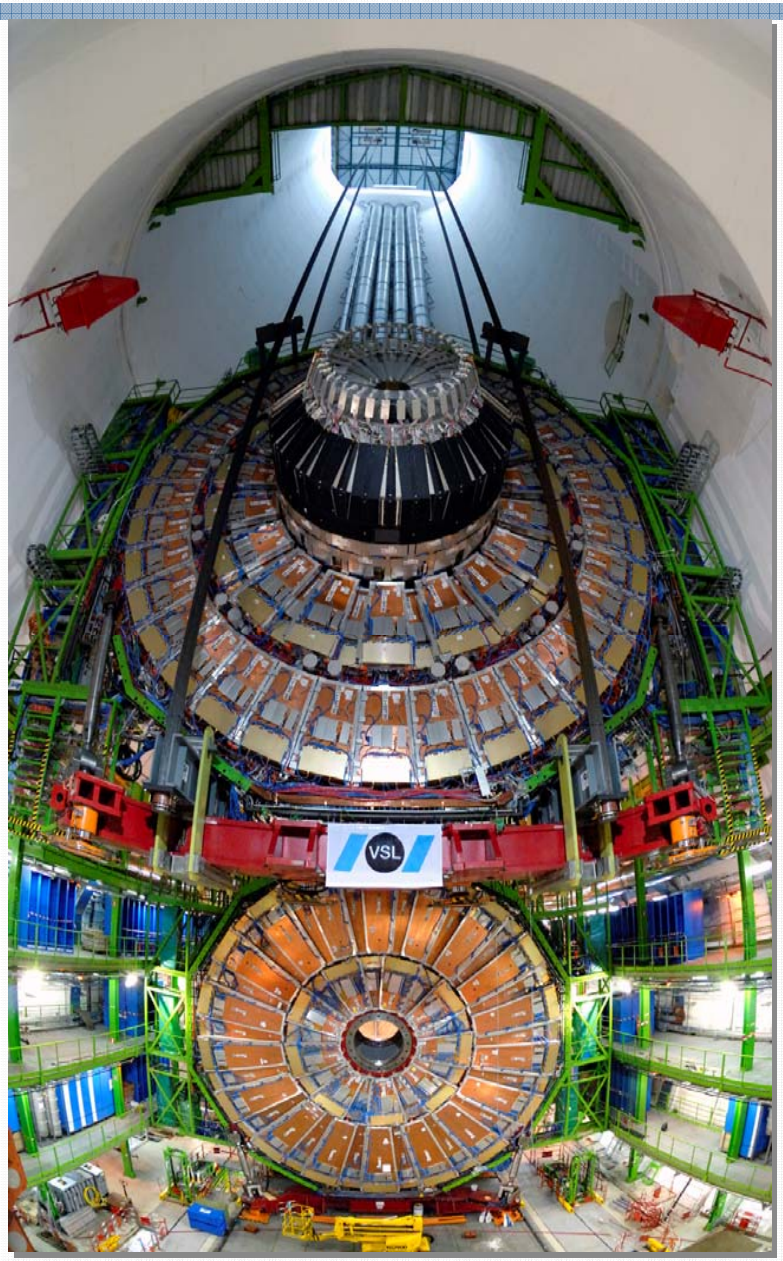
ETH Institute for Particle Physics

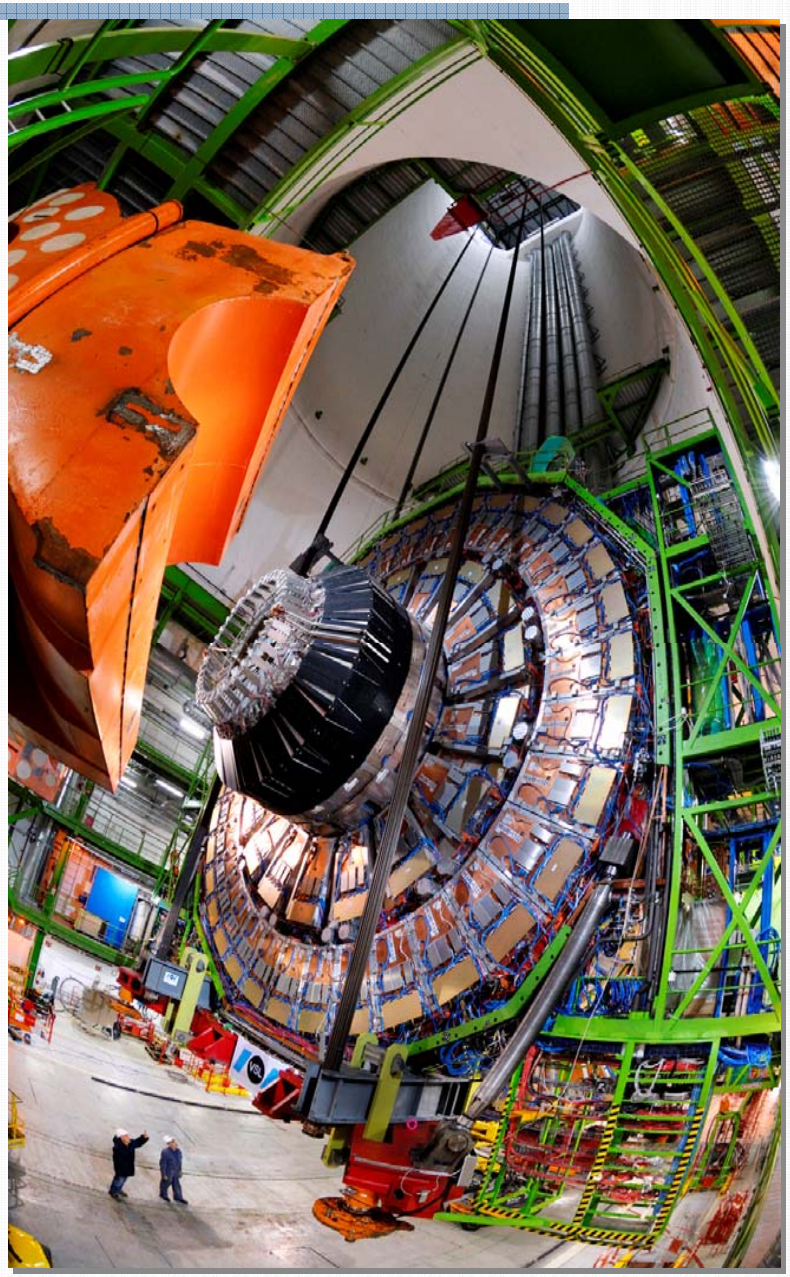


QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

First half of endcap discs downstairs

ETH Institute for Particle Physics





QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Conclusions

ETH Institute for Particle Physics

We see light at the end of the tunnel….

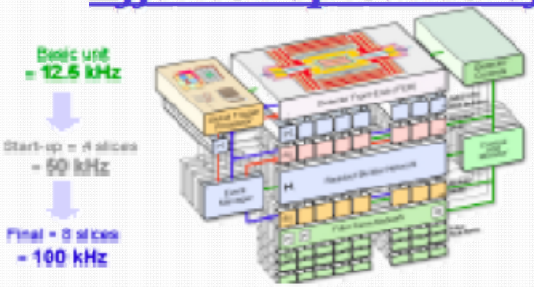
… and it’s not a train coming towards us…

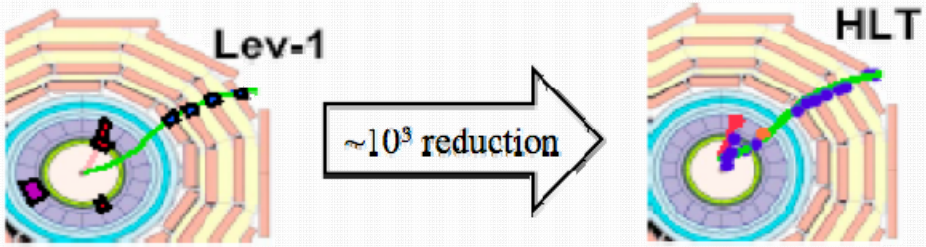
Acknowledgements

- Many thanks to the spokespersons of the four experiments:
  - P. Jenni
  - T. Nakada
  - J. Schuhkraft
  - J. Virdee

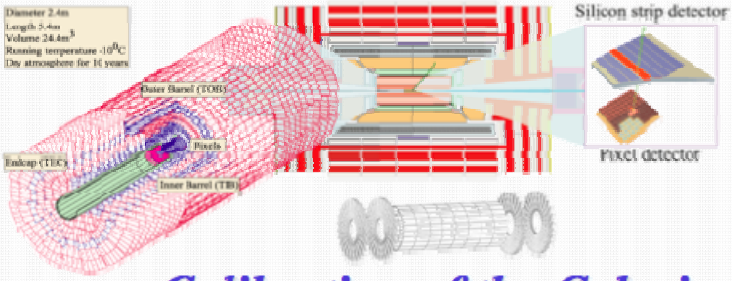
Detector Commissioning

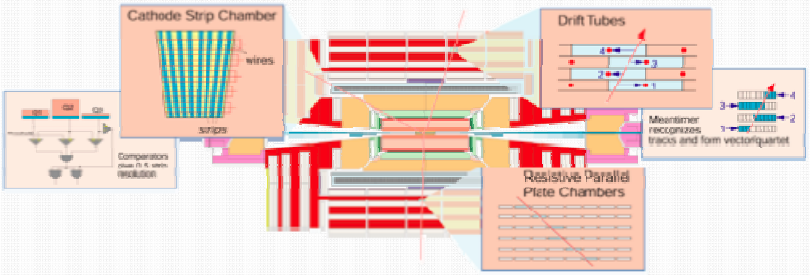
Efficient operation of Trigger (Level1/HLT) and DAQ System



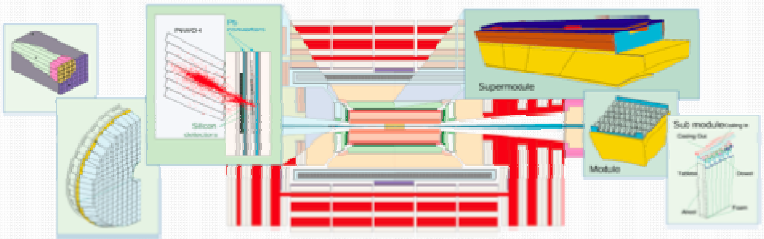


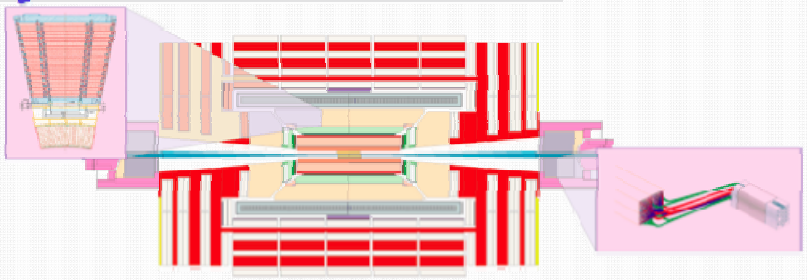
Alignment of the tracking devices Tracker(PIXEL,Strip) and Muon System





Calibration of the Calorimeter Systems ECAL and HCAL

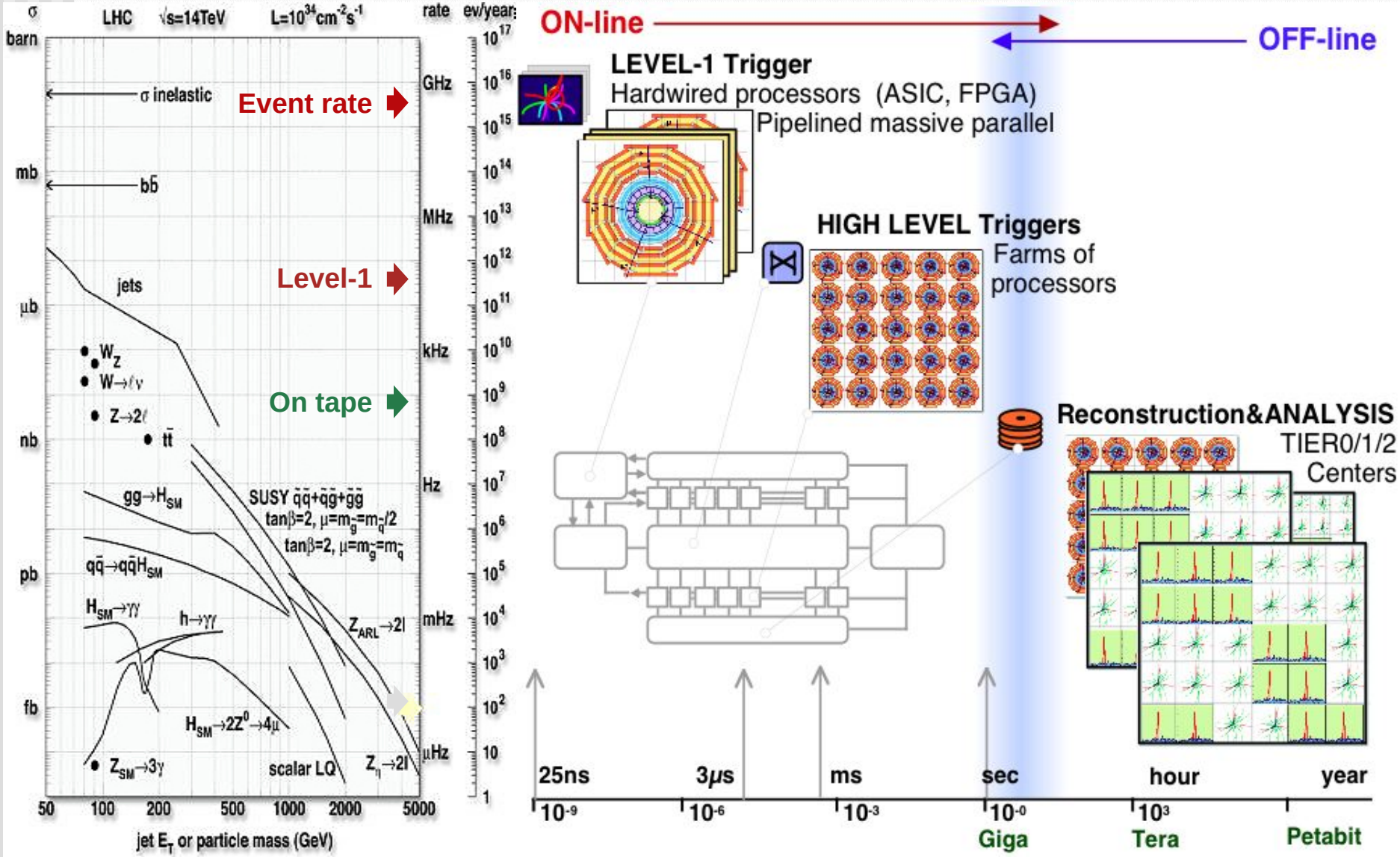




QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

CMS : Trigger/DAQ

ETH Institute for Particle Physics



QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

$H \rightarrow ZZ \rightarrow 4\ell$ (CMS)

ETH Institute for Particle Physics