Status of the LHC and its pp-Experiments

HERA-LHC Workshop 2007 Hamburg

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CERN & RWTH Aachen
With input from ATLAS, CMS coll., M.Lamont (LHC)

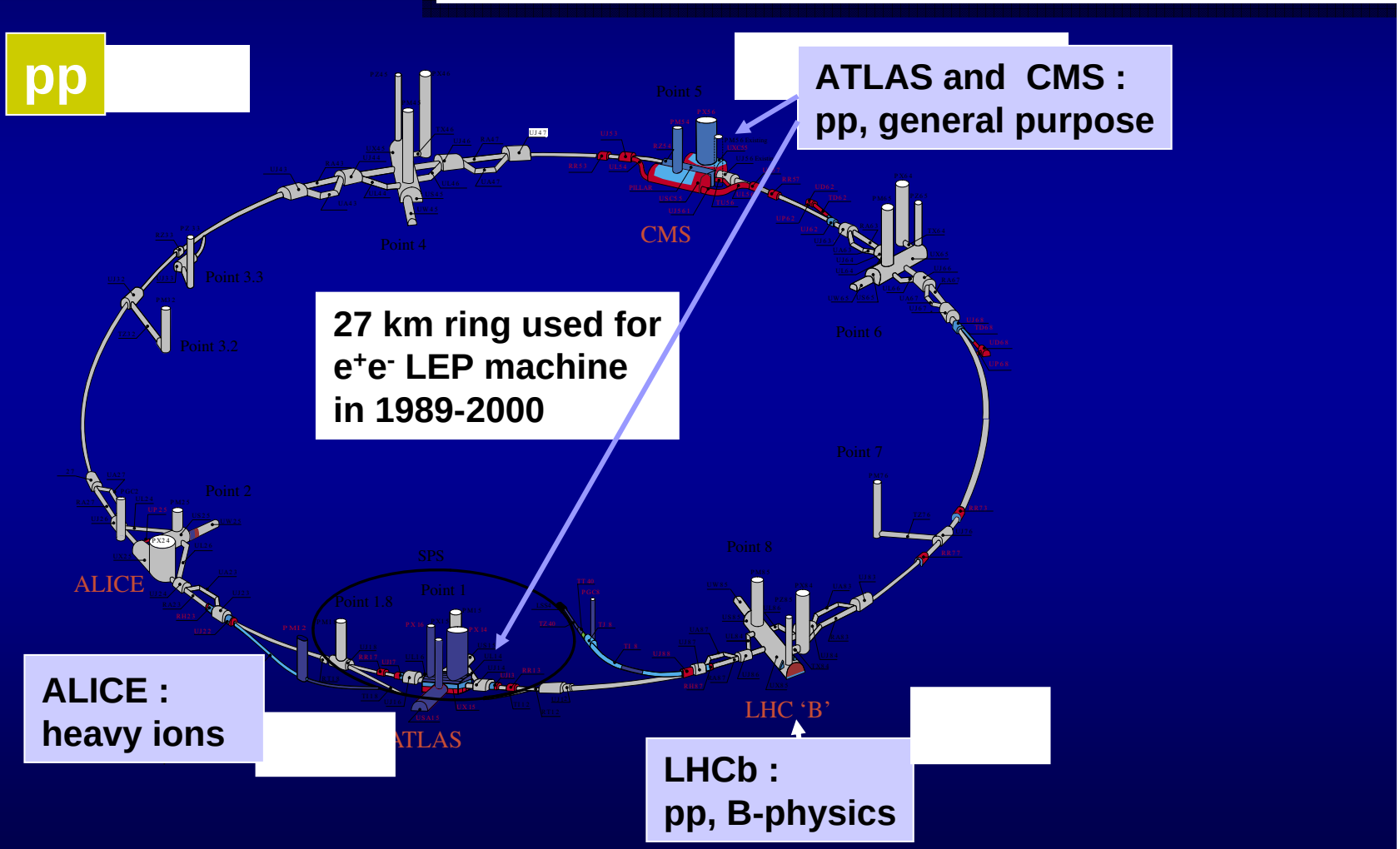
Outline:

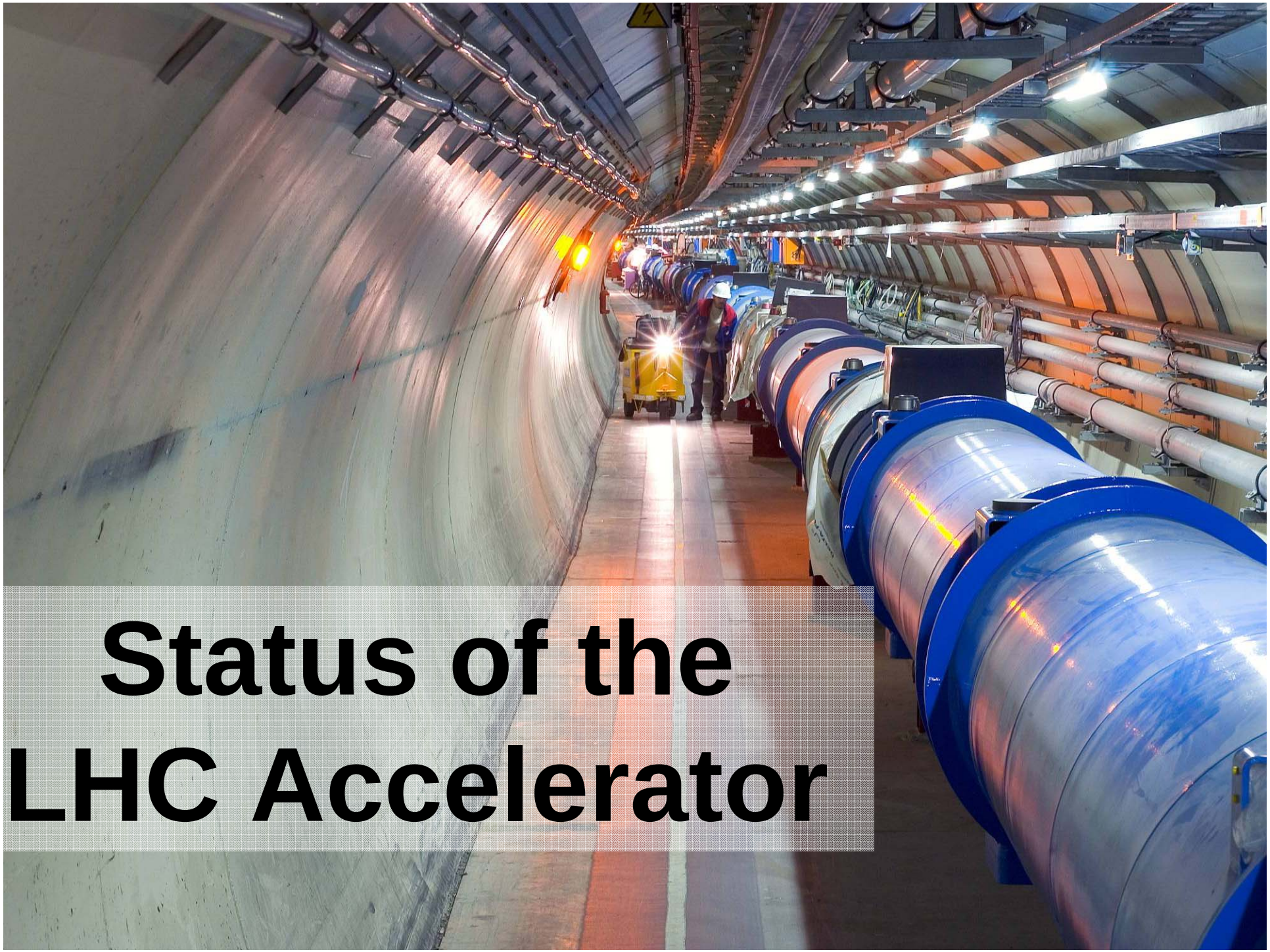
1. Present plans for the LHC start-up
2. Status and start-up plans for ATLAS
3. Status and start-up plans for CMS
4. Brief status of LHCb

The LHC & its Experiments

$\sqrt{s}$ = 14 TeV (7 times higher than Tevatron/Fermilab) s
search for new massive particles up to m ~ 5 TeV

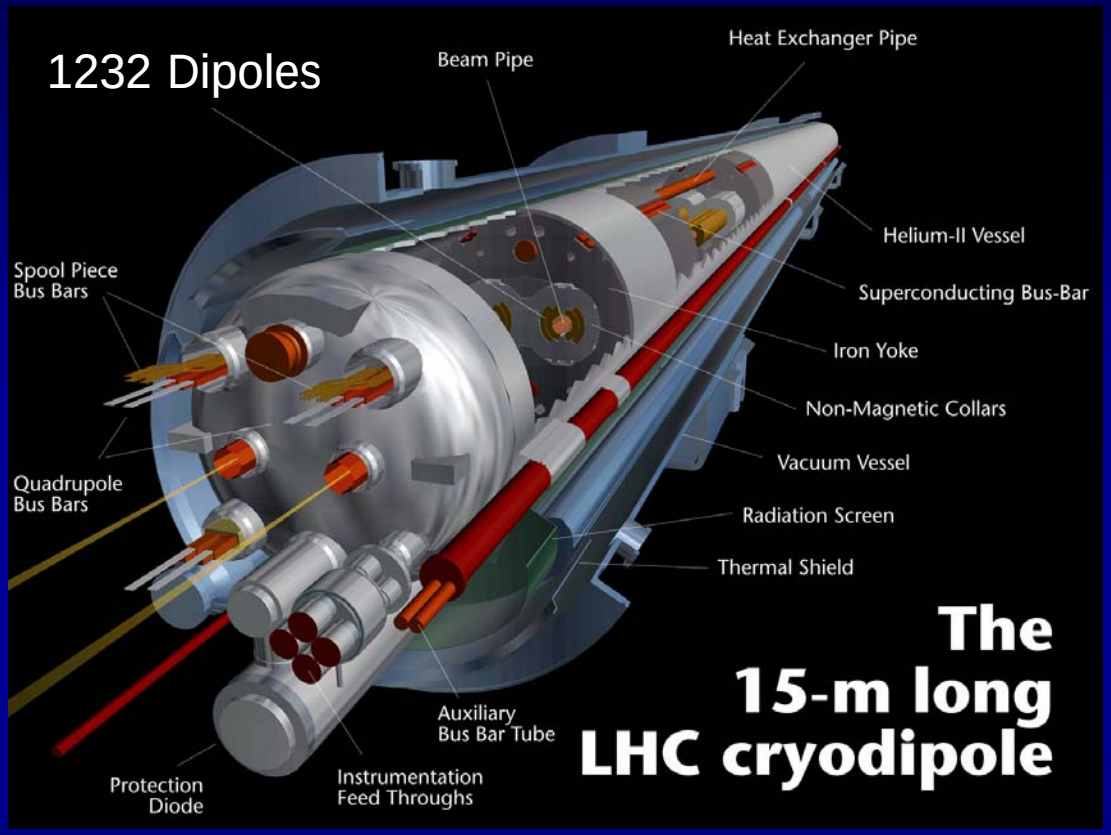
$L_{design} = 10^{34}\ cm^{-2}\ s^{-1}$ (10^2 higher than Tevatron/Fermilab)
search for rare processes with small σ ($N = L\sigma$)





Status of the LHC Accelerator

LHC Challenge: Dipoles



Magnetic Field for Dipoles p (TeV) = 0.3 B(T) R(km)
For p = 7 TeV and R = 4.3 km
⇨ B = 8.4 T
⇨ Current 12 kA

LHC magnets are cooled with pressurized superfluid helium.

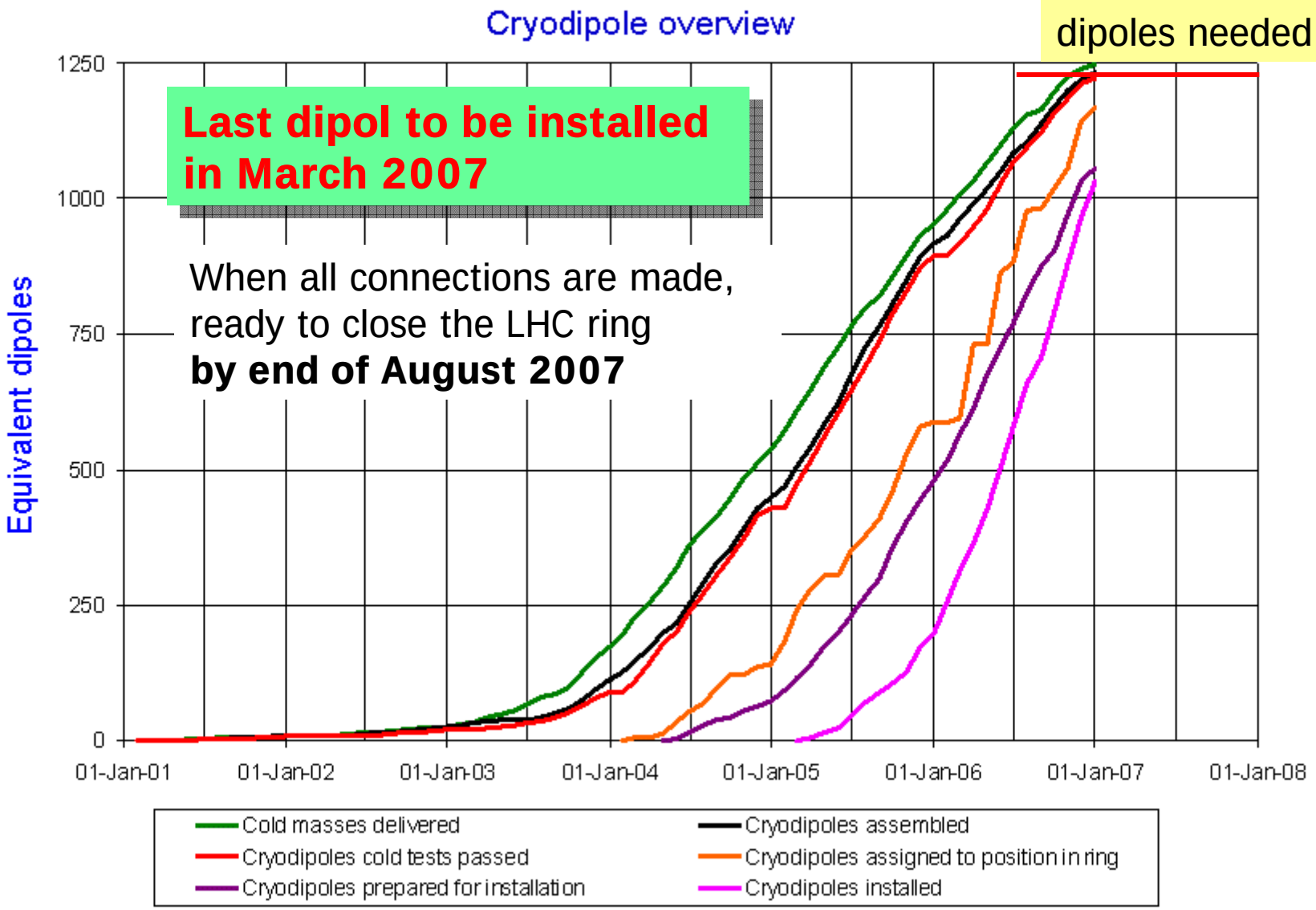
Delivery of the last dipole cold mass (before producing the spares)

(left: LHC Project Leader Lyndon Evans, right: magnet Project Leader Lucio Rossi)

LHC Progress Dashboard

Accelerator Technology Department

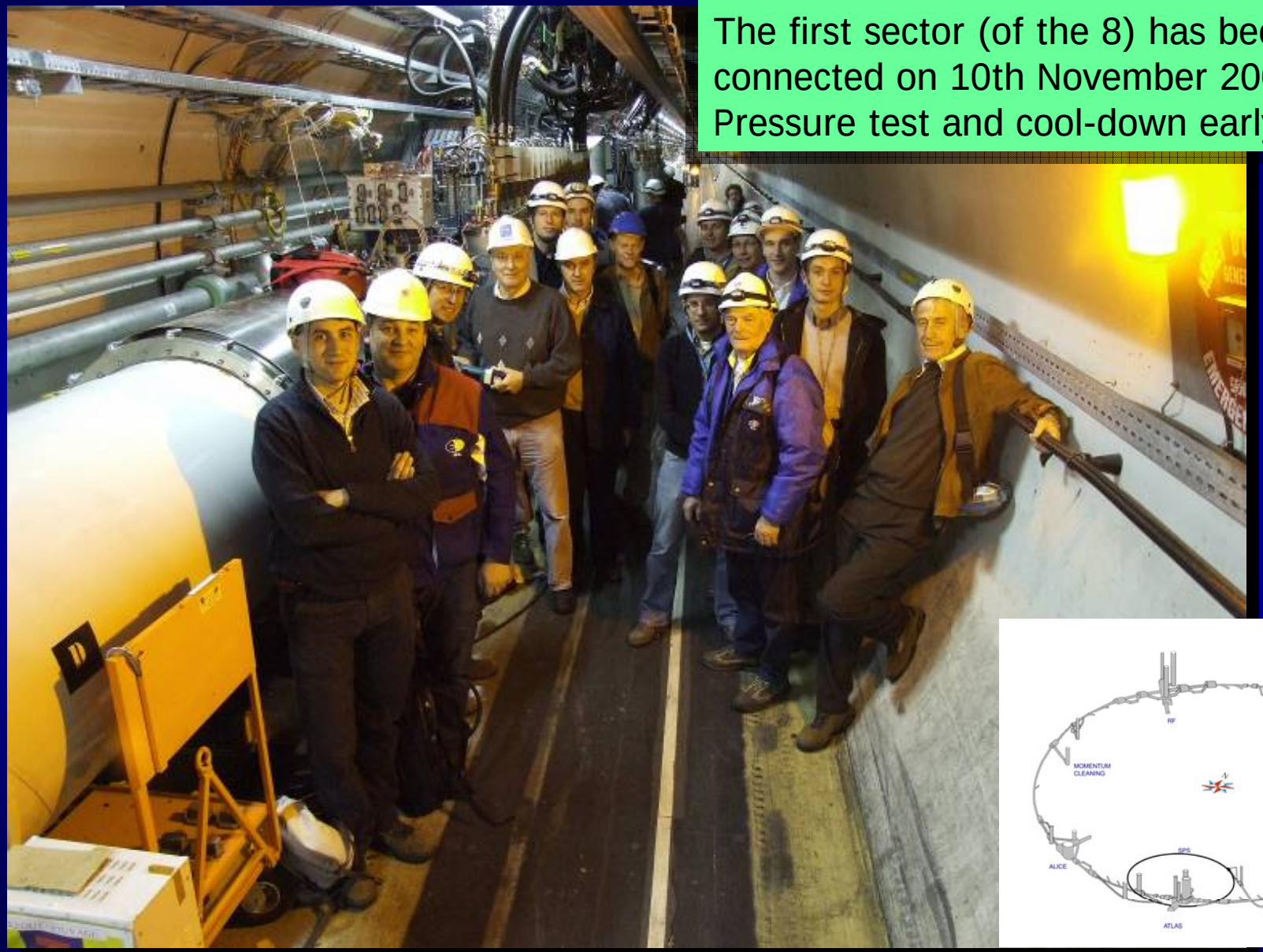
In total 1232 dipoles needed



Data provided by D. Tommasini AT-MCS, L. Bottura AT-MTM

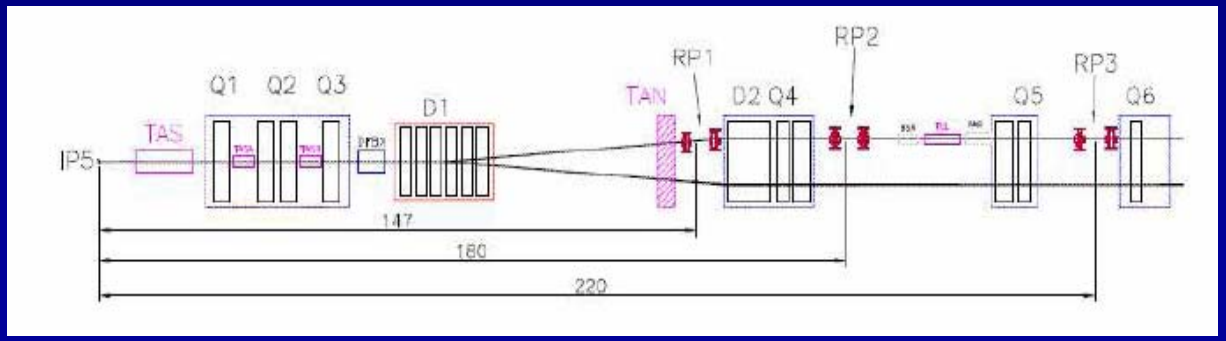
Closure of sector 7-8 on 10.11.2006

The first sector (of the 8) has been fully connected on 10th November 2006.
Pressure test and cool-down early 2007.



Pressure Test and Inner Triplets

- During the pressure test of Sector 8-1 (25th November) the heat exchanger tube in the inner triplet failed at 9 bar differential pressure



Inner Triplet Quadrupoles, installed in the LHC tunnel

- All 24 quadrupoles will be repaired (18 are already installed).
- Priority: Inner triplet quadrupoles in CMS area, 5L has started and 5R to be repaired in time for Sectors 4-5 and 5-6 cool down. Others afterwards.

- The consequences on the 2007 schedule will be evaluated once this repair has been carried out. Start-up end 2007 is still the target
- Time needed for commissioning hardware to high energy in 2008

LHC Milestones and Schedule

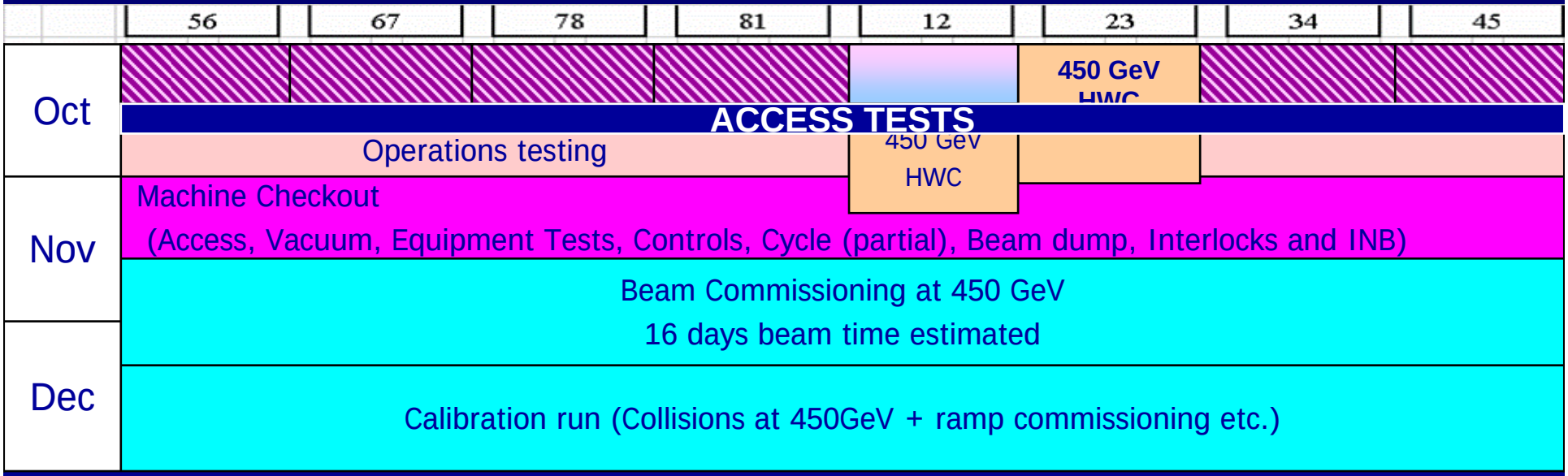
presented at the December 2006 CERN Council meeting by L Evans

The initial operation will be at 450+450 GeV cms energy (at the injection energy from the SPS) in order to debug the machine and the detectors

Last magnet delivered	**November 2006**
Last magnet tested	**January 2007**
Last magnet installed	**March 2007**
Machine closed	**August 2007**
First collisions 900 GeV	**November 2007**
First Collisions 14 TeV	**June 2008**

Beam Start-Up with 450 GeV

1) Beam Commissioning planned for END 2007, after machine checkout
~1 month beam commissioning with ~16 days estimated beam time



2) Calibration run END 2007:

- After beam commissioning ~3 weeks collisions
  - Single bunch initially, with staged increase to 156 bunches with 4 x 10^{10}
  - Luminosities: 1.3 10^{28} to 2.6 10^{29} $cm^{-2}s^{-1}$
  - Interleafed with low intensity single beam MD

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Conditions 450 GeV Beam Commissioning

	Phase	Beam time [days]	Beam
1	First turn	4	1 x Pilot
2	Establish circulating beam	3	1 x Pilot
3	450 GeV – initial	3	1 x Pilot++
4a	450 GeV - consolidation	1-2	1 x Pilot++
4b	450 GeV – system commissioning	2-3	1 x Pilot++
5a	2 beam operations	1	2 x Pilot++
5b	Collisions	1-2	2 x 1 x 10^{11} ➔
		16 days	

Pilot Beam

Single bunch, 5 - 10 x 10^{9} protons, reduced emittance

Pilot++

Single bunch 3 to 4 x 10^{10} protons

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450 GeV - Performance

			Reasonable	Maximum
k_b	43	43	156	156
i_b (10^{10})	2	4	4	10
β^* (m)	11	11	11	11
intensity per beam	$8.6\ 10^{11}$	$1.7\ 10^{12}$	$6.2\ 10^{12}$	$1.6\ 10^{13}$
beam energy (MJ)	.06	.12	.45	1.1
Luminosity ($cm^{-2}s^{-1}$)	**$2\ 10^{28}$**	**$7.2\ 10^{28}$**	**$2.6\ 10^{29}$**	**$1.6\ 10^{30}$**
event rate [1](kHz)	0.4	2.8	10.3	64
W rate [2] (per 24h)	0.5	3	11	70
Z rate [3] (per 24h)	0.05	0.3	1.1	7

Several days

1. Assuming 450GeV inelastic cross section 40 mb
2. Assuming 450GeV cross section $W \rightarrow l\nu$ 1 nb
3. Assuming 450GeV cross section $Z \rightarrow ll$ 100 pb

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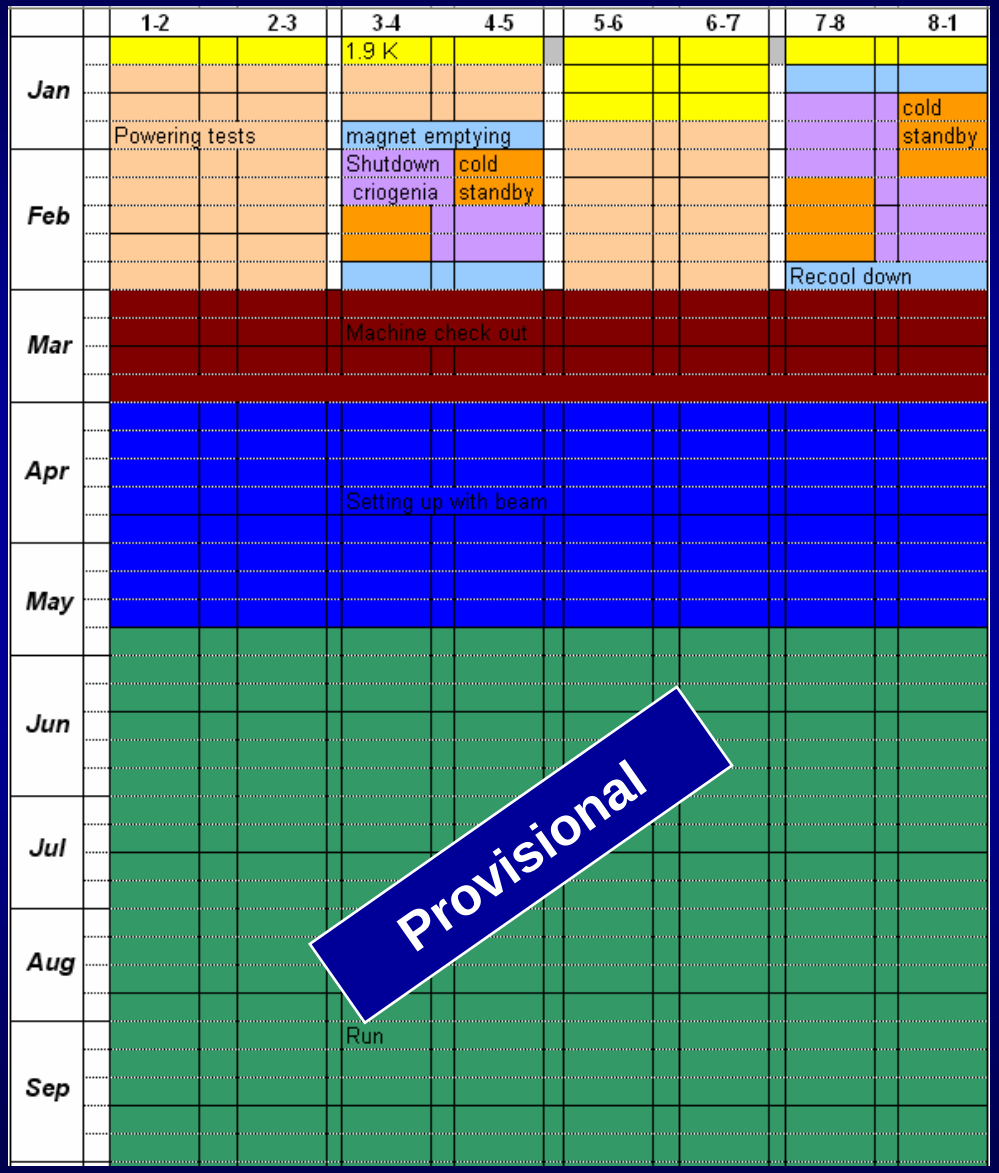
2008 Should Be Something Like…



Staged commissioning for protons @ 7 TeV

Hardware commissioning to 7 TeV

Machine Checkout ≈ 1 month

Commissioning with beam ≈ 2 months

Pilot Physics ≈ 1 month

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Pilot Run

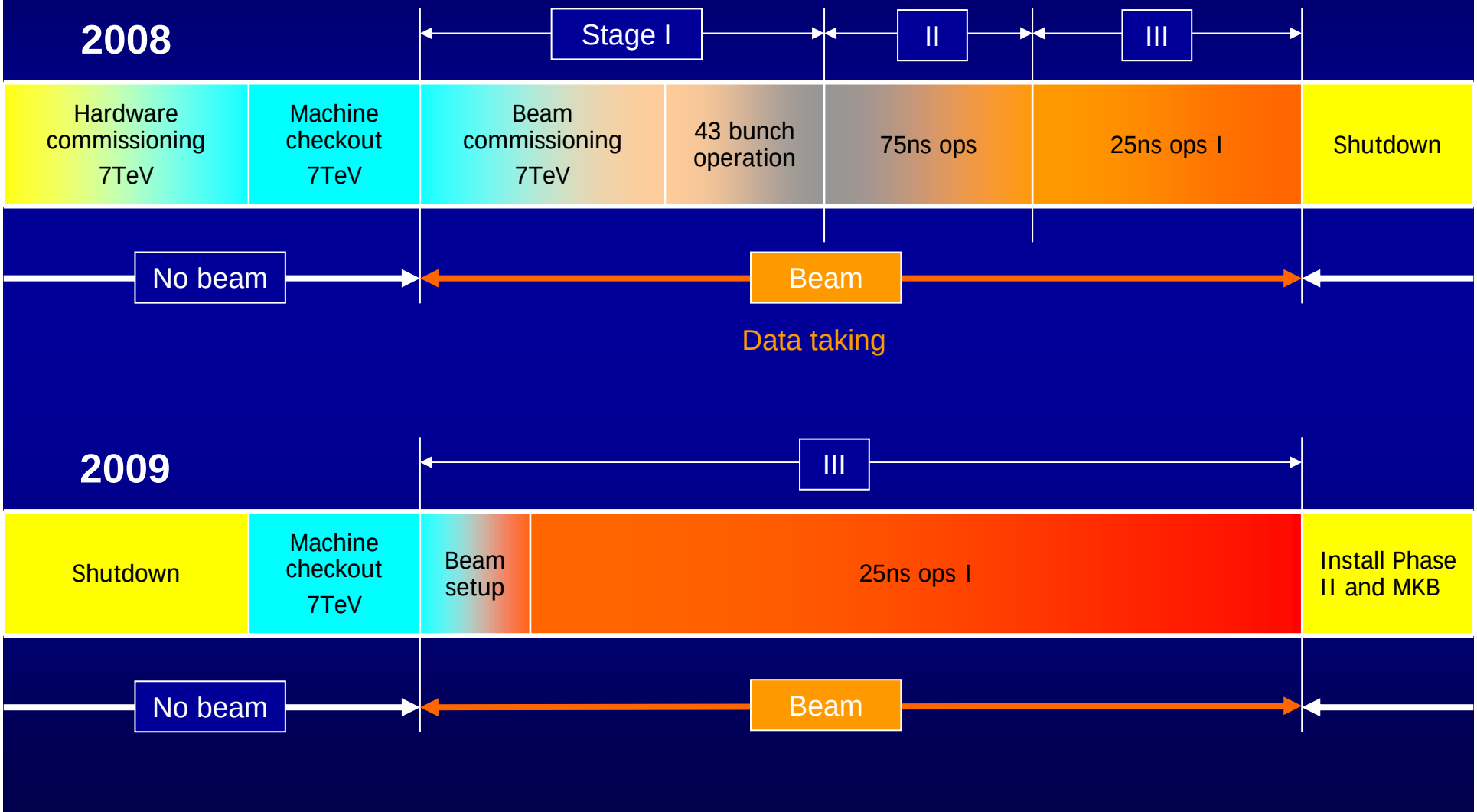
Sub-phase	Bunches	Bunch Int.	beta*	Luminosity	Time	Int lumi
First Collisions	1 x 1	4×10^{10}	17 m	1.6×10^{28}	12 hours	0.6 nb^{-1}
Repeat ramp - same conditions	-	-	-	-	2 days @ 50%	1.2 nb^{-1}
Multi-bunch at injection & through ramp - collimation	-	-	-	-	2 days	-
Physics	12 x 12	3×10^{10}	17 m	1.1×10^{29}	2 days @ 50% in physics	6 nb^{-1}
Physics	43 x 43	3×10^{10}	17 m	4.0×10^{29}	2 days @ 50% in physics	30 nb^{-1}
Commission squeeze – single beam then two beams, IR1, IR5	-	-	-	-	2 days	-
Measurements squeezed	-	-	-	-	1 day	-
Physics	43 x 43	3×10^{10}	10 m	7×10^{29}	3 days - 6 hr t.a. - 70% eff.	75 nb^{-1}
Commission squeeze to 2m collimation etc.	-	-	-	-	3 days	-
Physics	43 x 43	3×10^{10}	2 m	3.4×10^{30}	3 days - 6 hr t.a. - 70% eff.	0.36 pb^{-1}
Commission 156 x 156	-	-	-	-	1 day	
Physics	156 x 156	2×10^{10}	2 m	5.5×10^{30}	2 days - 6 hr t.a. - 70% eff.	0.39 pb^{-1}
Physics	156 x 156	3×10^{10}	2 m	1.2×10^{31}	5 days - 5 hr t.a. - 70% eff.	2.3 pb^{-1}
					28 days total	

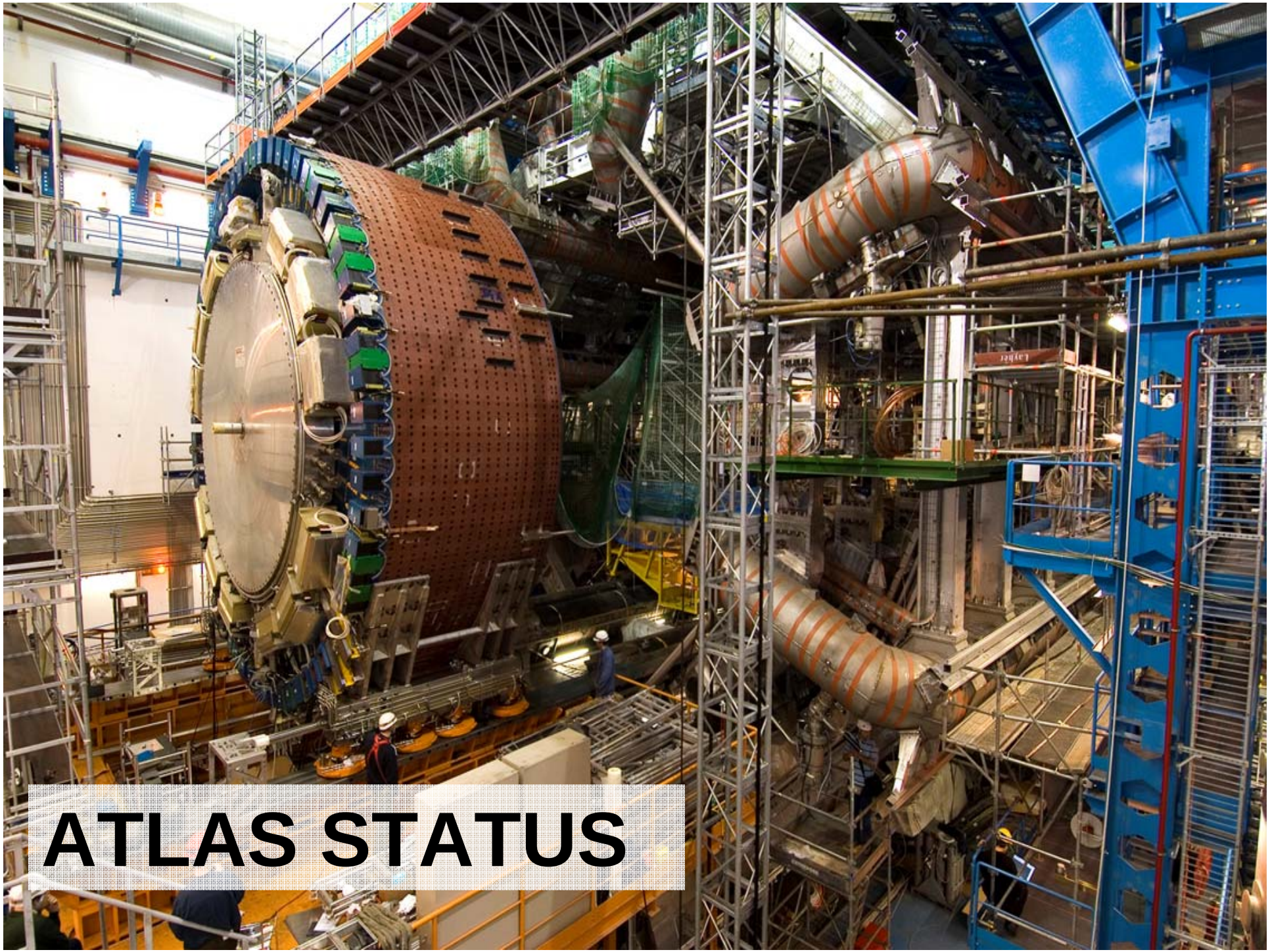
Pilot run ~1 month, ~50% physics beam

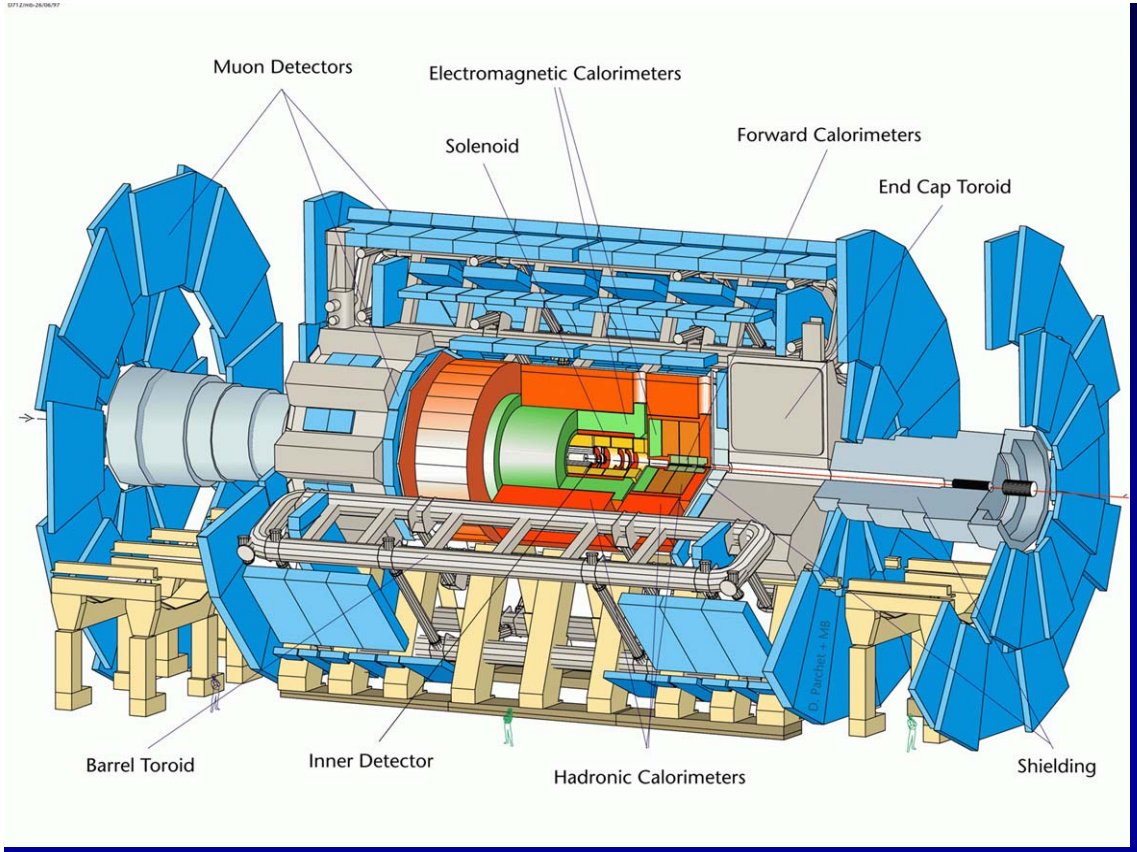
Σ int.L (pilot run) ~2.4 pb^{-1}

Staged Commissioning for Protons@7 TeV

See http://cern.ch/lhc-commissioning/




ATLAS STATUS



ATLAS

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables

- Tracking ($|\eta|<2.5$, B=2T) :
  -- Si pixels and strips
  -- Transition Radiation Detector (e/π separation)

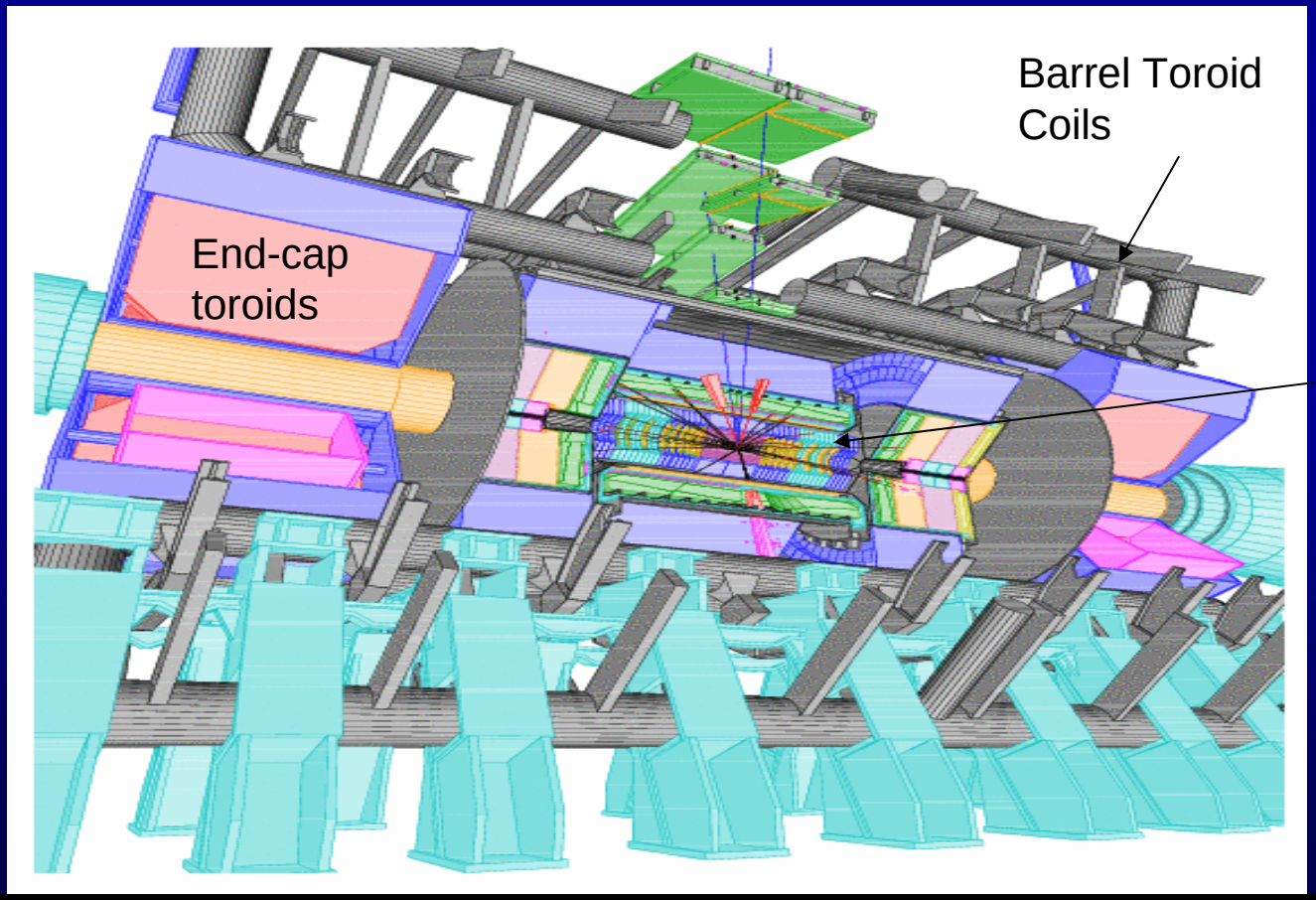
- Calorimetry ($|\eta|<5$) :
  -- EM : Pb-Liquid Argon
  -- HAD: Fe/scintillator (central), Cu/W-Liquid Argon (fwd)

- Muon Spectrometer ($|\eta|<2.7$) :
  Air-core toroids with muon chambers

ATLAS Magnets

Components:

- Solenoid 2.5 m diameter 5m long, field B=2T
- Barrel toroid 8 25 m long coils, field B=1.8T
- 2 endcap toroids 5 m long coils, field B=1.8T



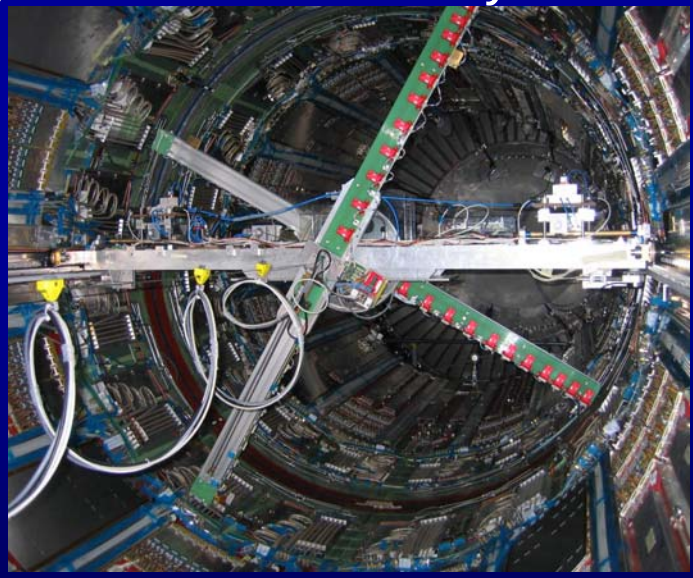
ATLAS Solenoid Magnet

Central solenoid provides B=2T field with a stored energy of 38 MJ

Status:

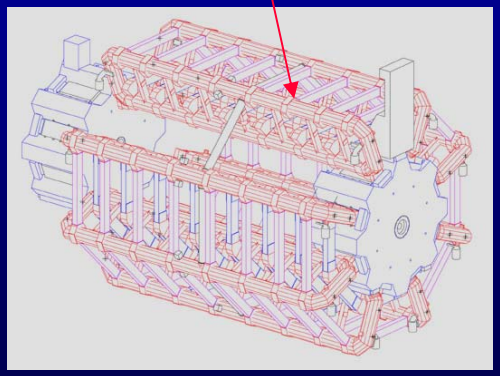
- Solenoid inserted into the LAr cryostat at the end of February 2006
- Commissioned in-situ at full current (8 kA) during July-August 2006
- The operation current is 7.73 kA for a field of 2.0 T
- Successful accurate field mapping. Goal: 10 G accuracy

Installation of the solenoid in Feb.2006



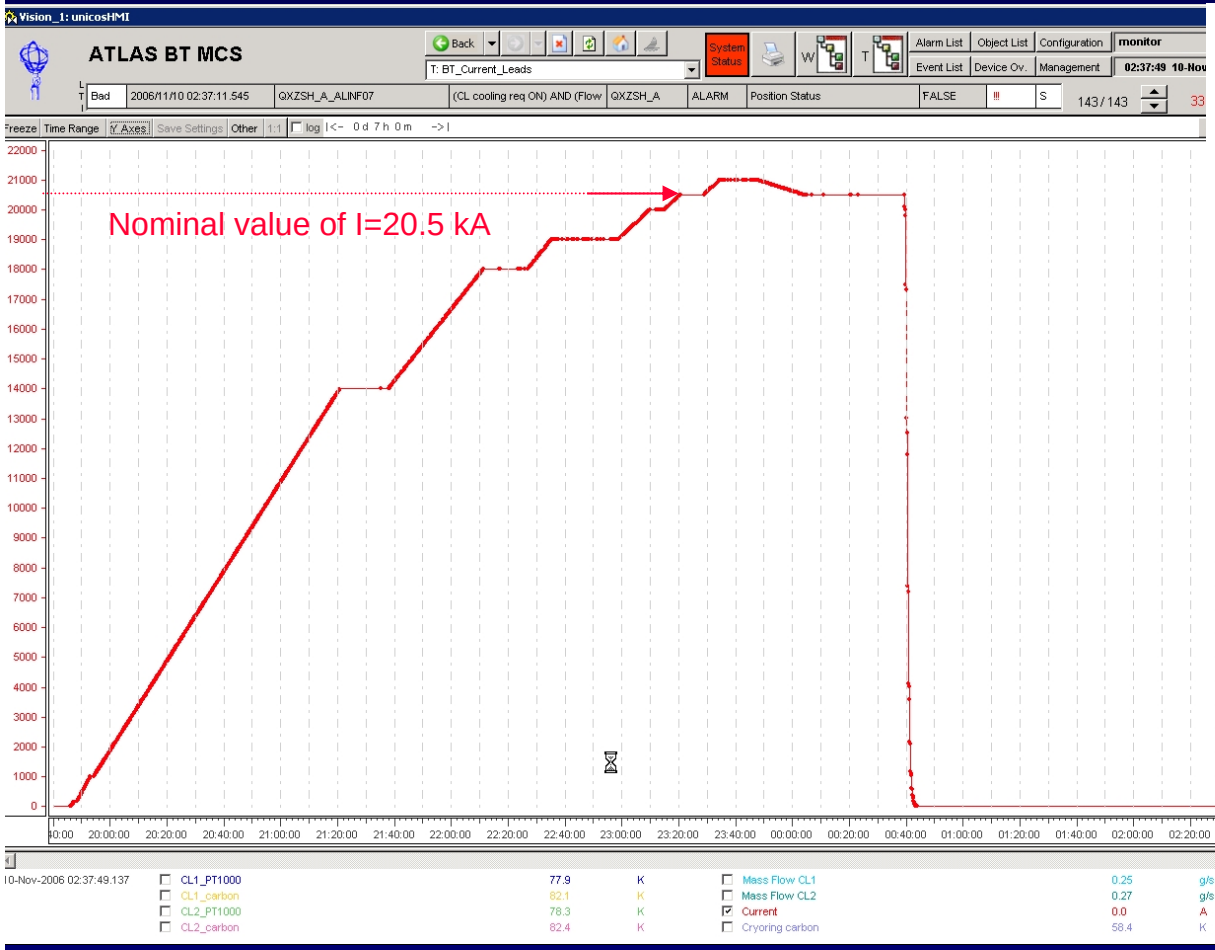
Field mapping: 48 Hall probes were read out at 181 z-positions (some overlap), and 16 phi-positions each. In total 250'000 points measured (for 4 different current values)

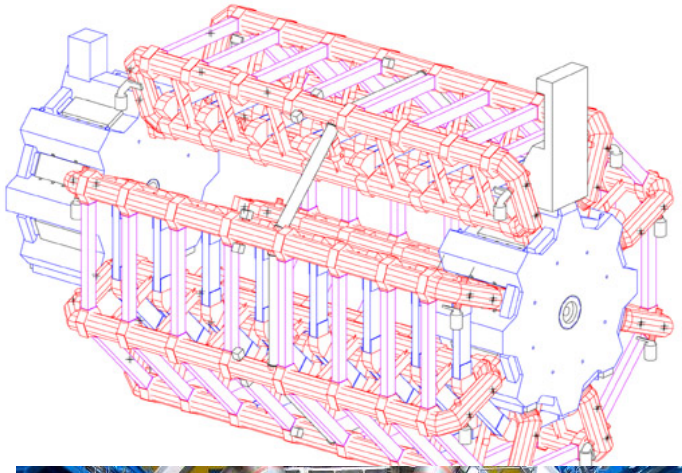
ATLAS Toroid Status

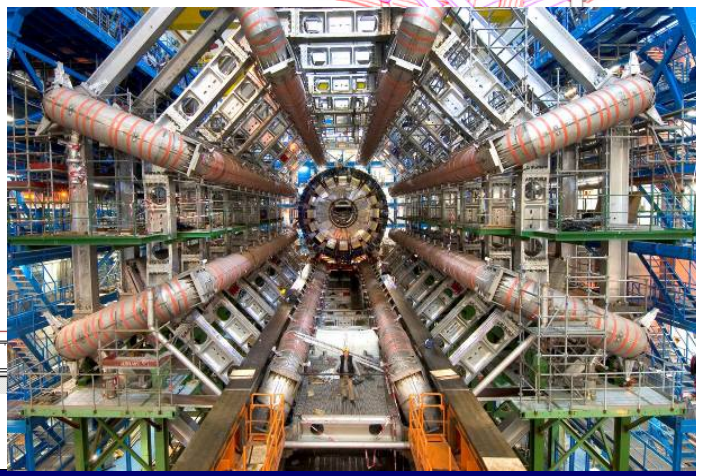


The first coil was installed in October 2004
The last one was moved into position on 25th August 2005

Toroid 21 kA Test in November 2006





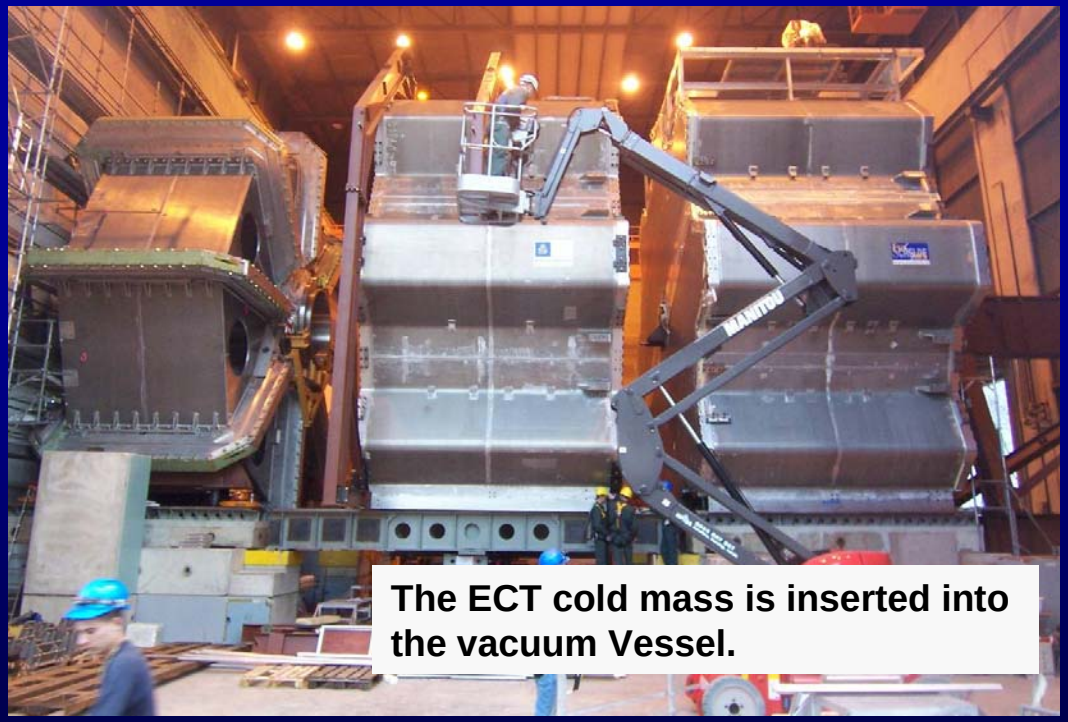


The current was ramped in steps to 20.5 kA (nominal current), then to 21kA in order to prove margin, reduced back to 20.5 kA, then provoked quench, fast dump, the cold mass heated to T_{max} = 58 K → safe operation was demonstrated!

End-cap Toroid

- All components are fabricated, assembly is ongoing at CERN
- Both end-cap toroids (ECT) will be tested at T=80 K on the surface, before installation and excitation tests in the cavern
- First End-Cap Toroid transported from Hall 191 to hall 180 for cool-down test at LN temperature (cool-down going smoothly).
- Second ECT, cold mass has already been inserted in vacuum vessel

The first ECT will move to the pit in June 2007, the second one in July 2007

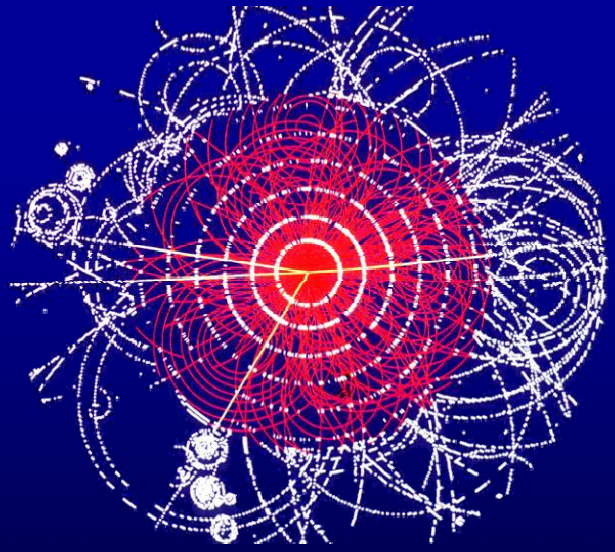


The ECT cold mass is inserted into the vacuum Vessel.

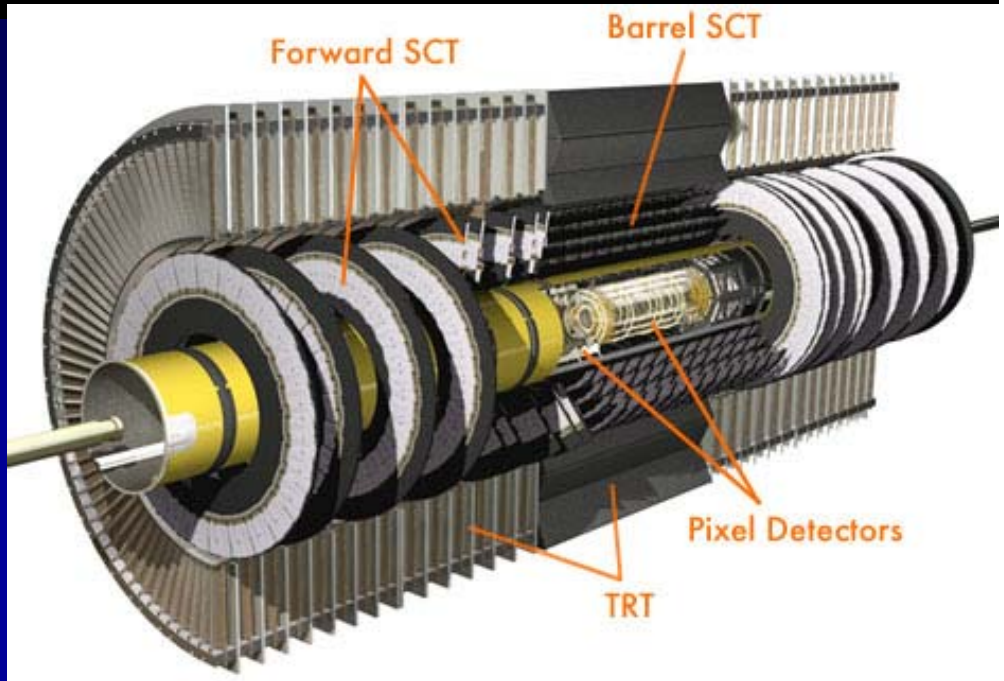
ATLAS Inner Detector

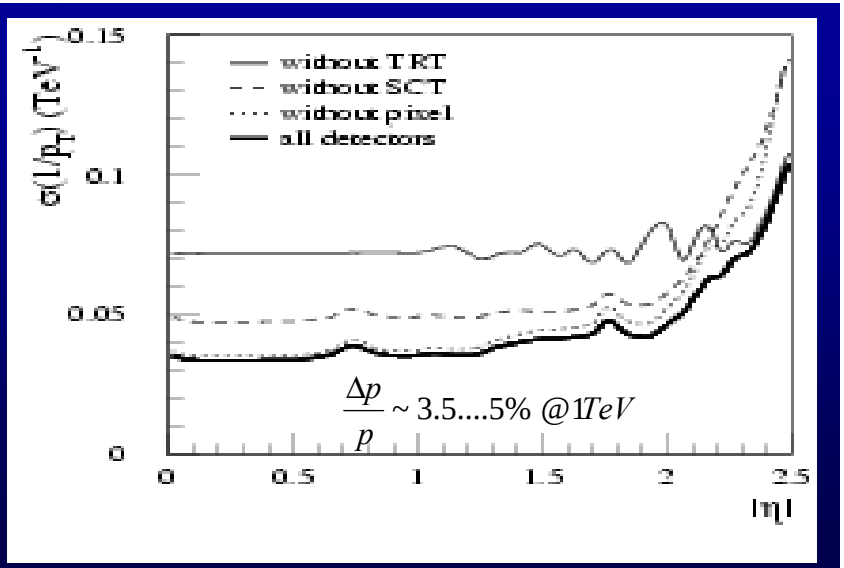
The Inner Detector (ID) is organized into three sub-systems:

- Pixels (8 x 10^7 channels) 3 layers
- Silicon Strip Tracker (SCT) 4 layers (6 x 10^6 channels)
- Transition Radiation Tracker (TRT) (4 x 10^5 channels) ~36 layers



Provides many points along the track





Inner Detector Progress Summary

All detectors are built.

Pixels: Barrel and endcap are integrated.

Barrel: SCT and TRT barrel integrated on the surface. Tested with cosmics (no x-talk observed). Installed in the pit.

End-Caps: SCT and TRT integrated and ready for installation.

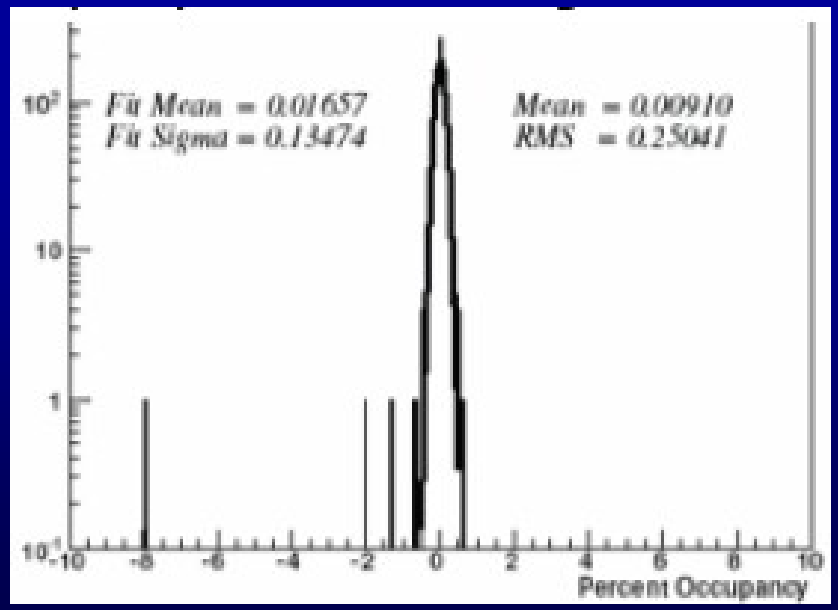
➡ The schedule for the Inner Detector remains very tight, without any float left (critical path: Installation and “sign-off” in the pit)

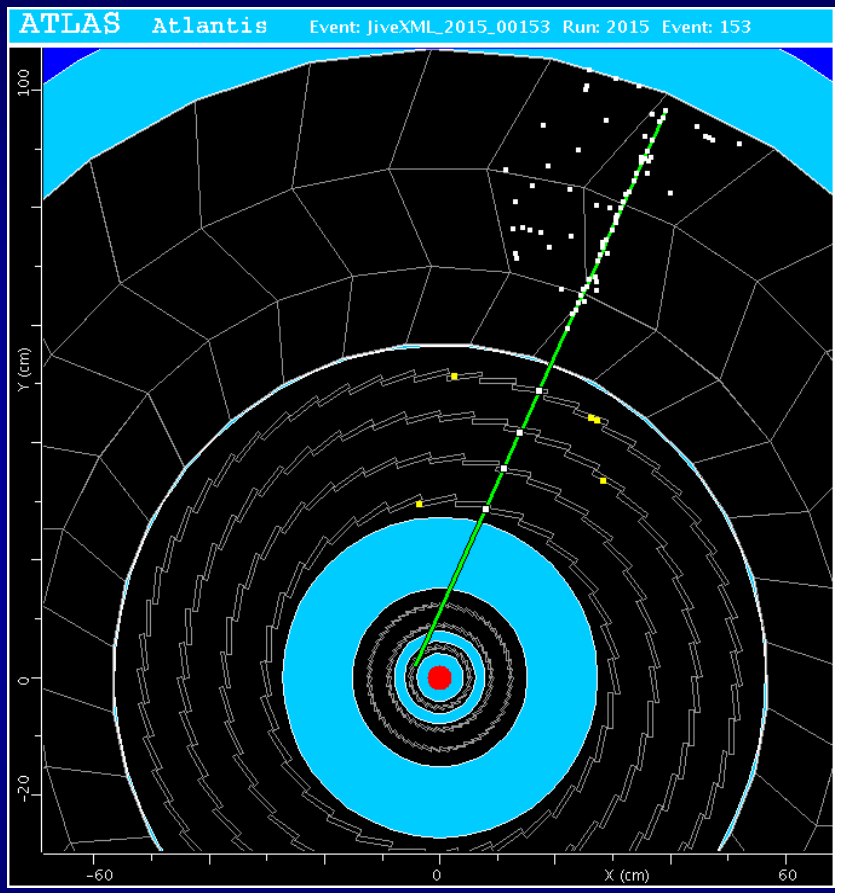
TRT+SCT barrel completed in SR1

TRT & SCT Tested with Cosmics

- Cosmic test on surface (SR1)
- 1/8 of the TRT and 1/4 of the SCT were equipped with complete readout chains
- Dead channels: 0.2% SCT, 1.5% TRT
- Noise level as for the individual parts and below specs (e.g. SCT random noise prob. is 4.5 10^{-5}, spec = 5 10^{-4})

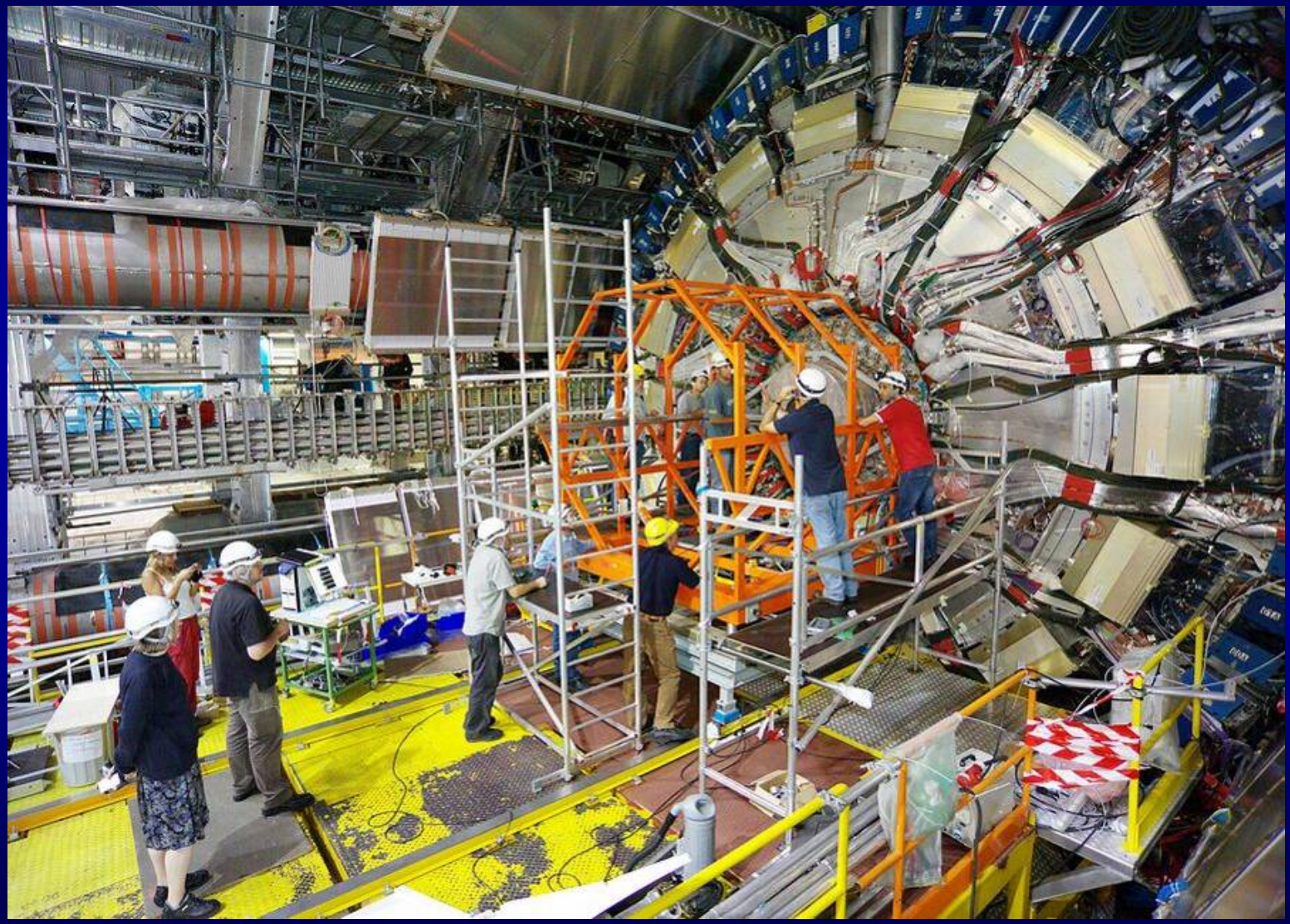
TRT % noise occupancy before-after insertion





Side view of a cosmic track trough TRT and SCT, noise is small

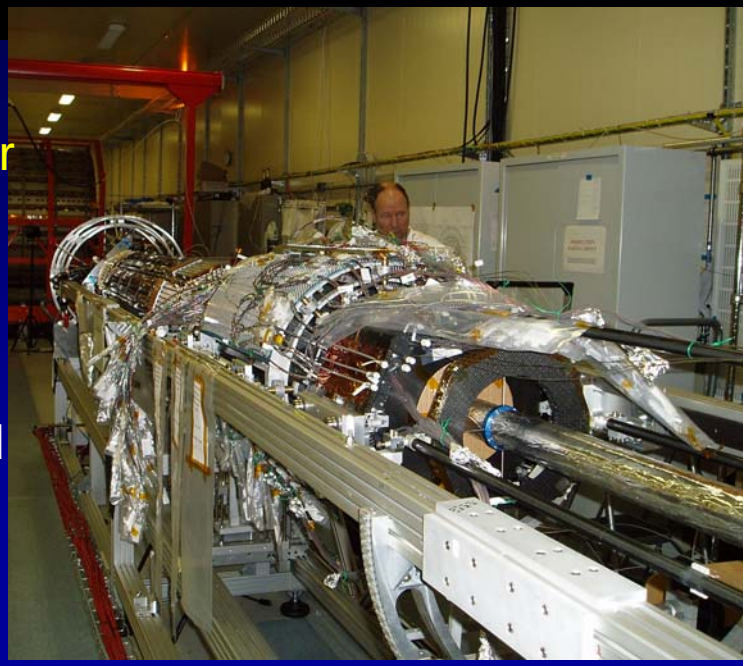
Tracker Barrel Installation 24.08.2006

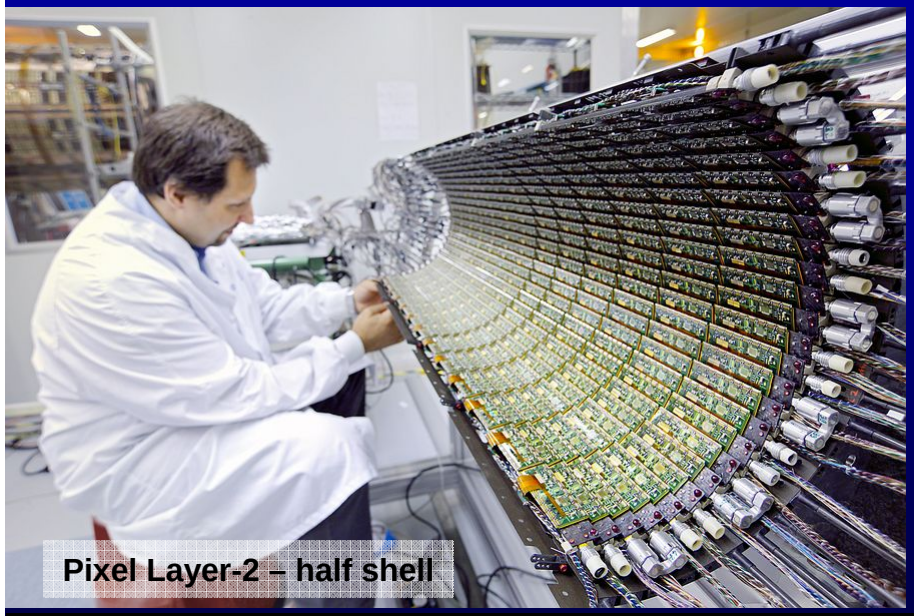


ATLAS Pixel Detector

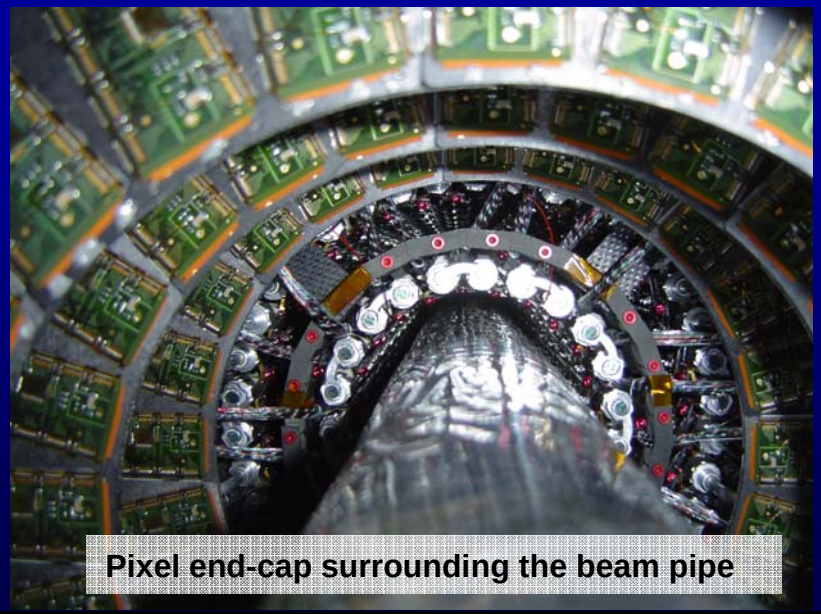
- All modules have been delivered with good yield
- Barrel stave production was finished mid September 2006 (including corrosion leak repairs)
- Both end-caps have been integrated, delivered to CERN and acceptance-tested. One end-cap has undergone cosmics tests
- Barrel and end-cap integrated. Still to be connected to services.

→ **Ready for installation May 2007**



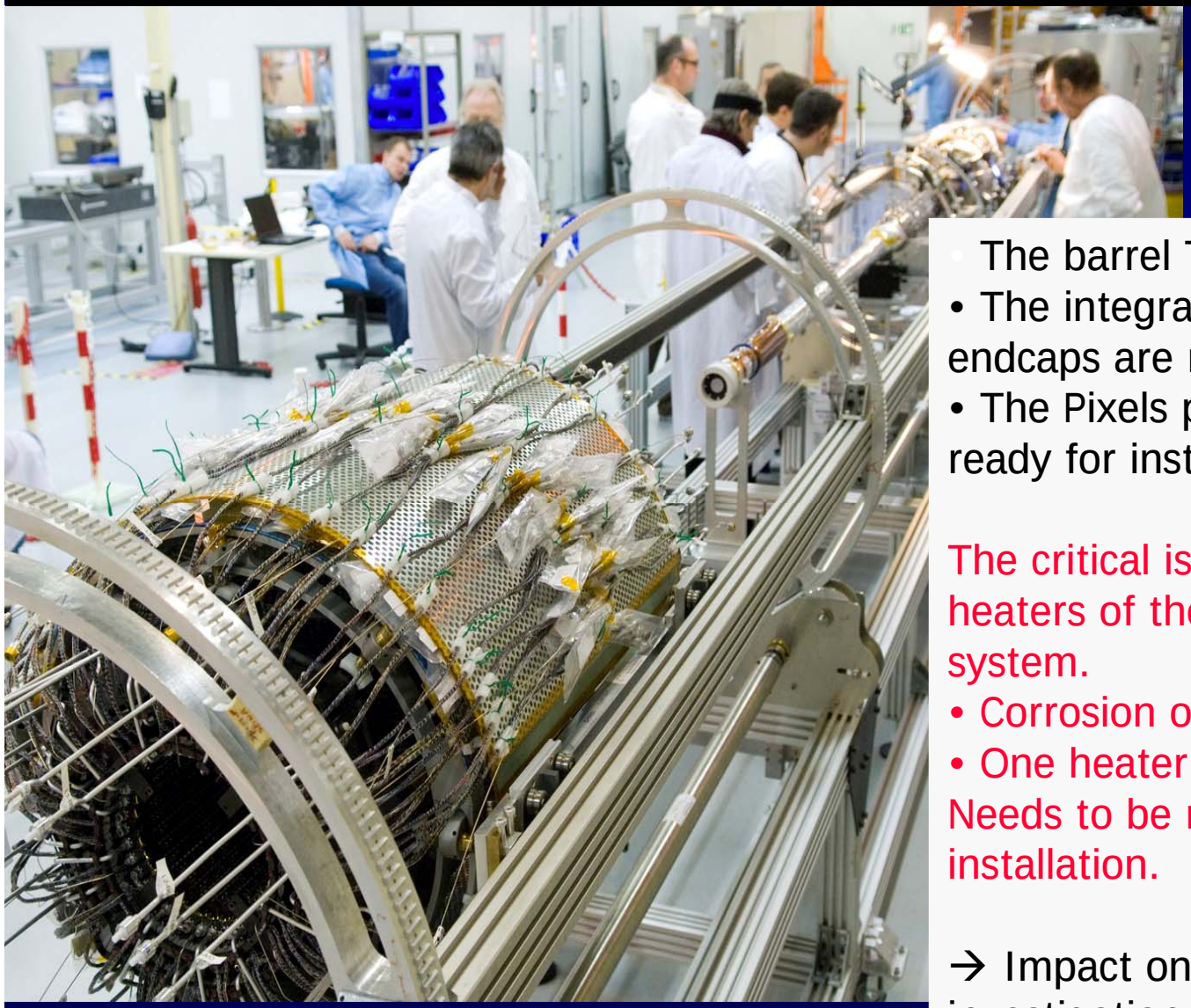


Pixel Layer-2 – half shell



Pixel end-cap surrounding the beam pipe

Latest News on Inner Detector



ATLAS Pixel detector integration

- The barrel TRT+SCT are installed
- The integrated and tested TRT+SCT endcaps are ready for installation.
- The Pixels plus beam pipe will be ready for installation in May.

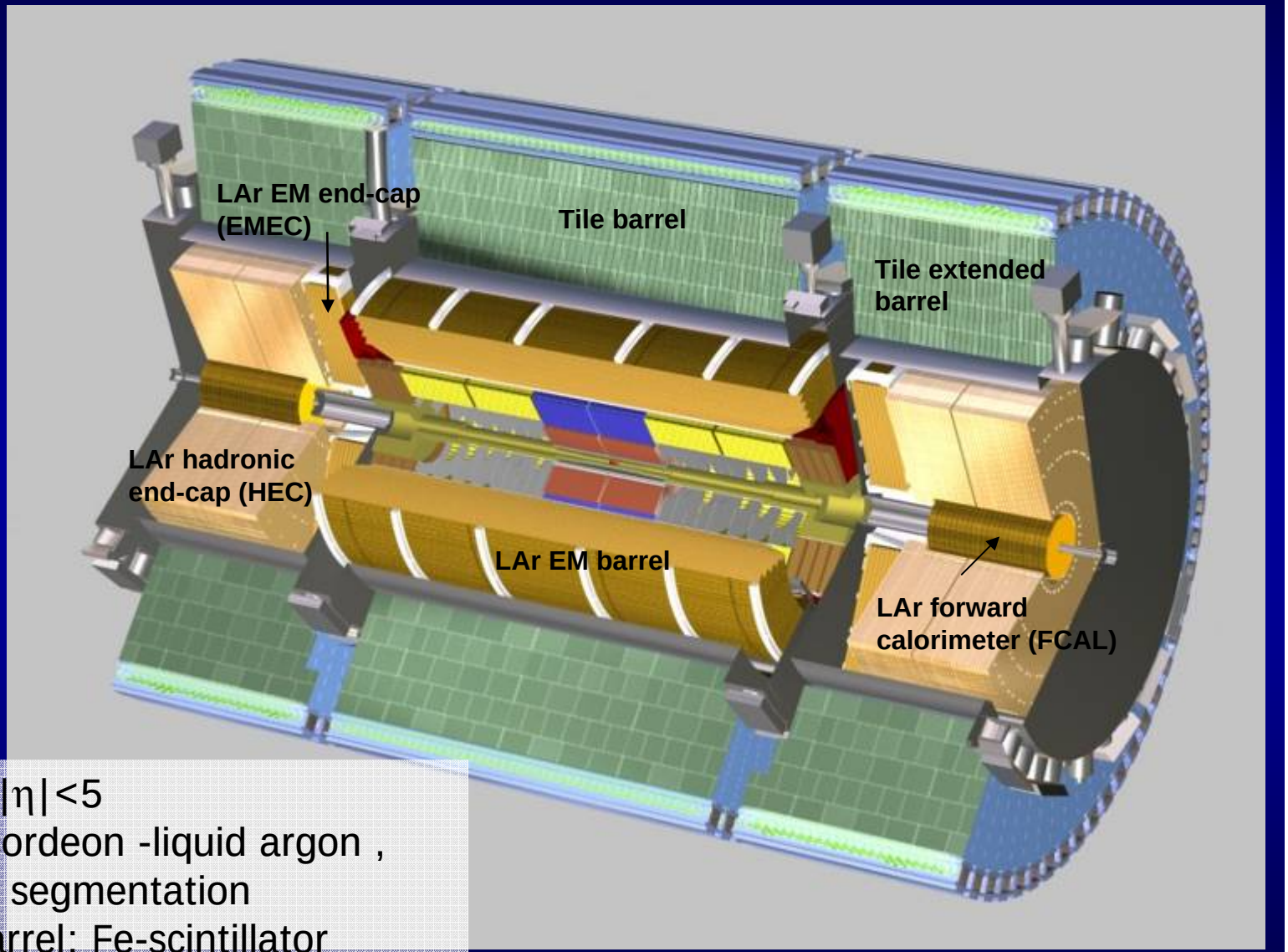
The critical issue is the repair of the heaters of the evaporative cooling system.

- Corrosion observed
- One heater burned catastrophically

Needs to be repaired before pixel installation.

→ Impact on ATLAS schedule under investigation

Liquid Argon and Tile Calorimeters



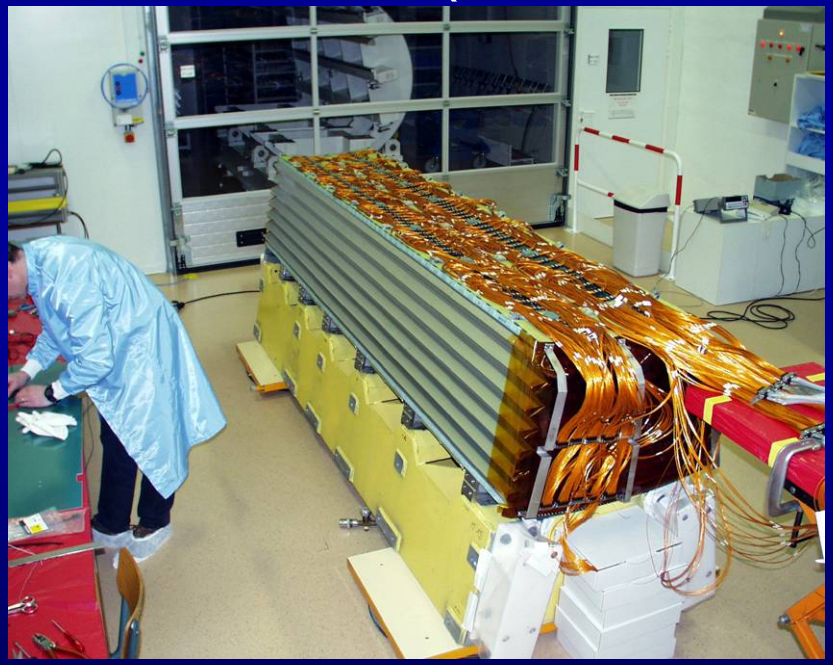
Coverage up to $|\eta|<5$

- EM: Pb accordeon -liquid argon , longitudinal segmentation
- Hadronic barrel: Fe-scintillator
- Hadronic End-cap : Cu-liquid argon

Barrel Calo Commissioning at the Surface

After many years of module constructions, the barrel EM calorimeter was installed in the cryostat. After insertion of the solenoid, the cold vessel was closed and welded early 2004

A successful complete cold test (with LAr) was made during summer 2004 in hall 180 at CERN (dead channels much below 1%)

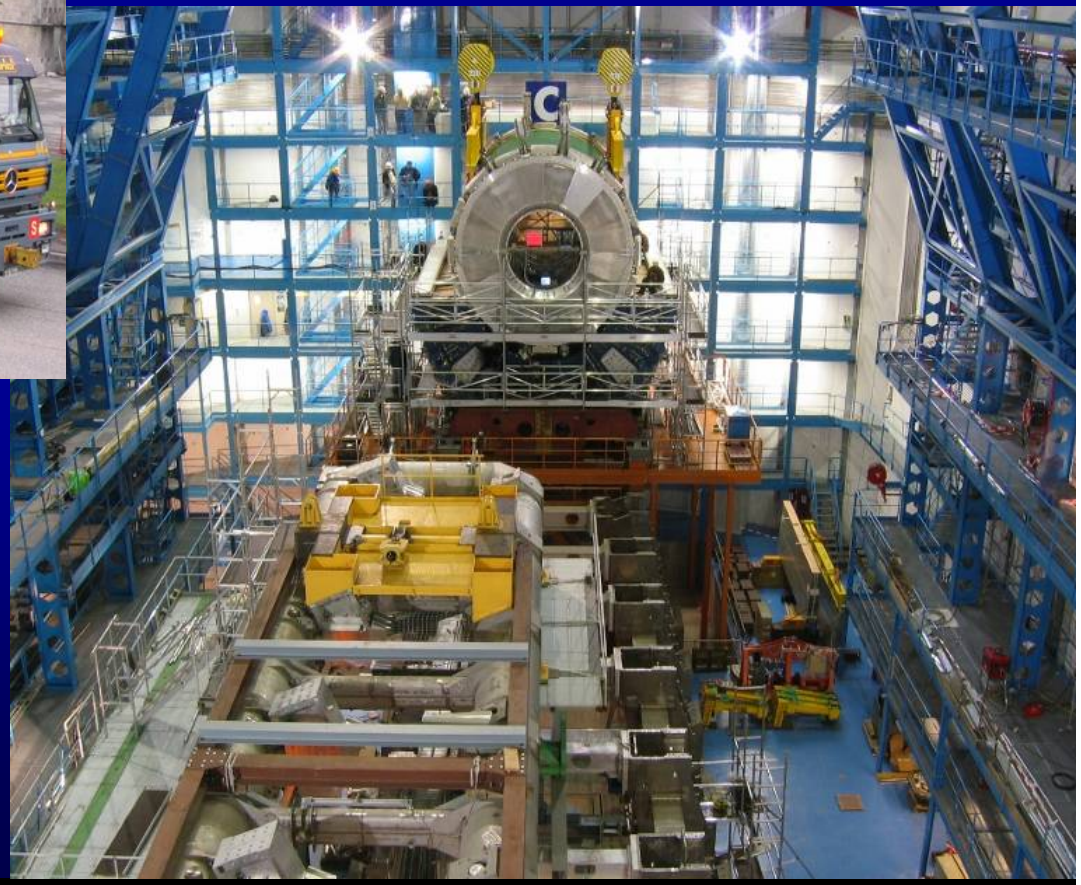


LAr barrel EM calorimeter module at one of the assembly labs

LAr barrel EM calorimeter after insertion into the cryostat

Calorimeter Installation

End of October 2004 the cryostat was transported to the pit, and lowered into the cavern



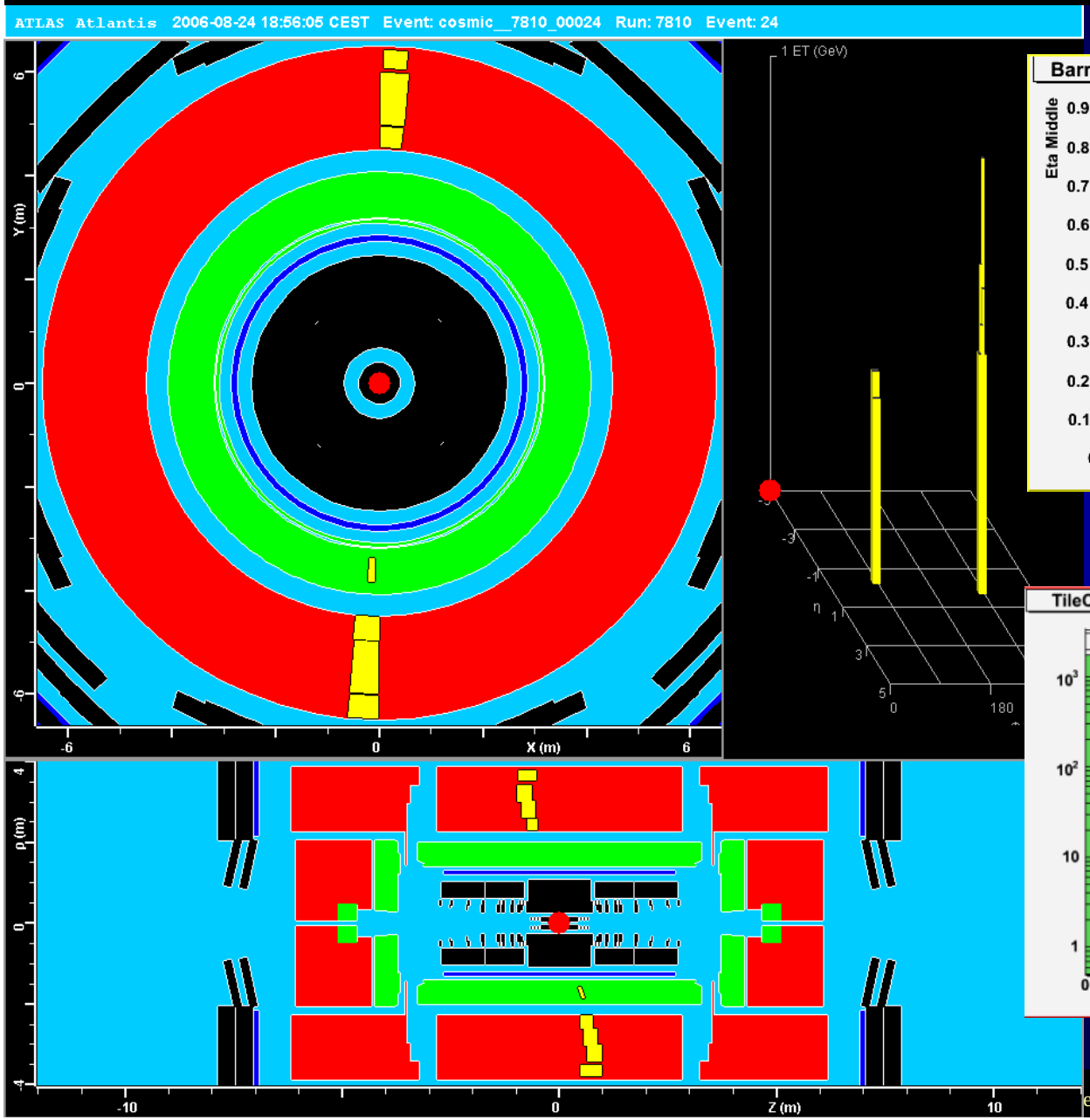
Barrel Calorimeter

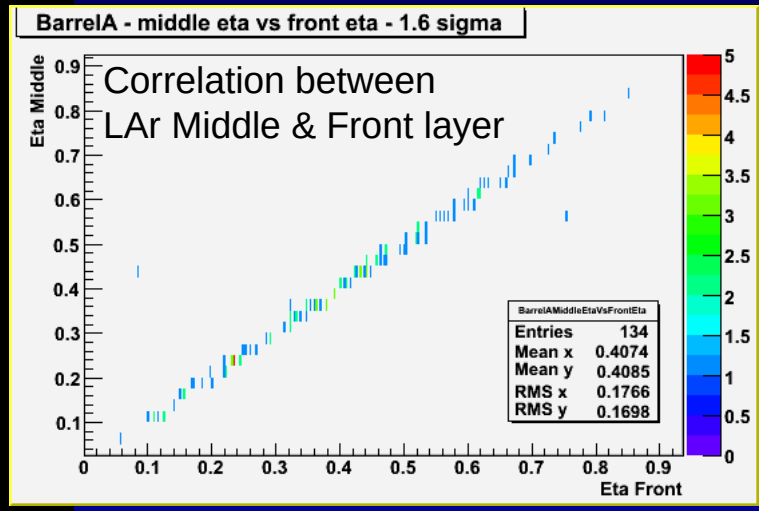
The barrel calorimeters have been in their final position at the centre of the detector since November 2005

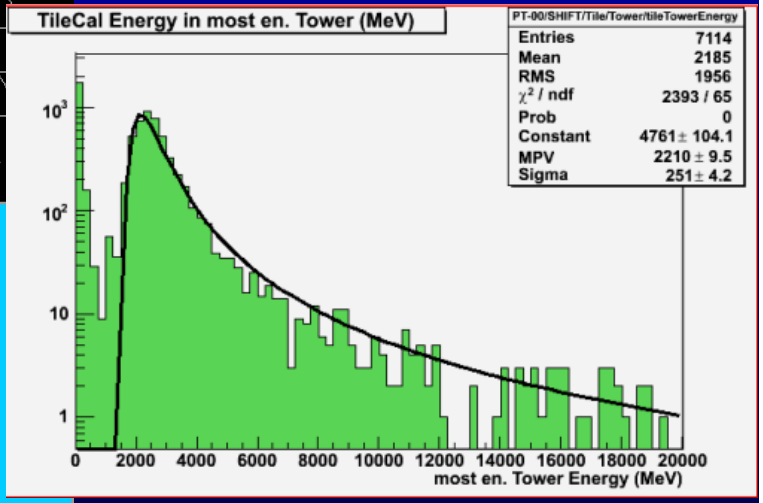
The final cool-down of the LAr cryostat took place over April and May 2006

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

Event Display From the First LAr + Tile Calorimeter Barrel Cosmics Run (Detector Commissioning Has Started !)







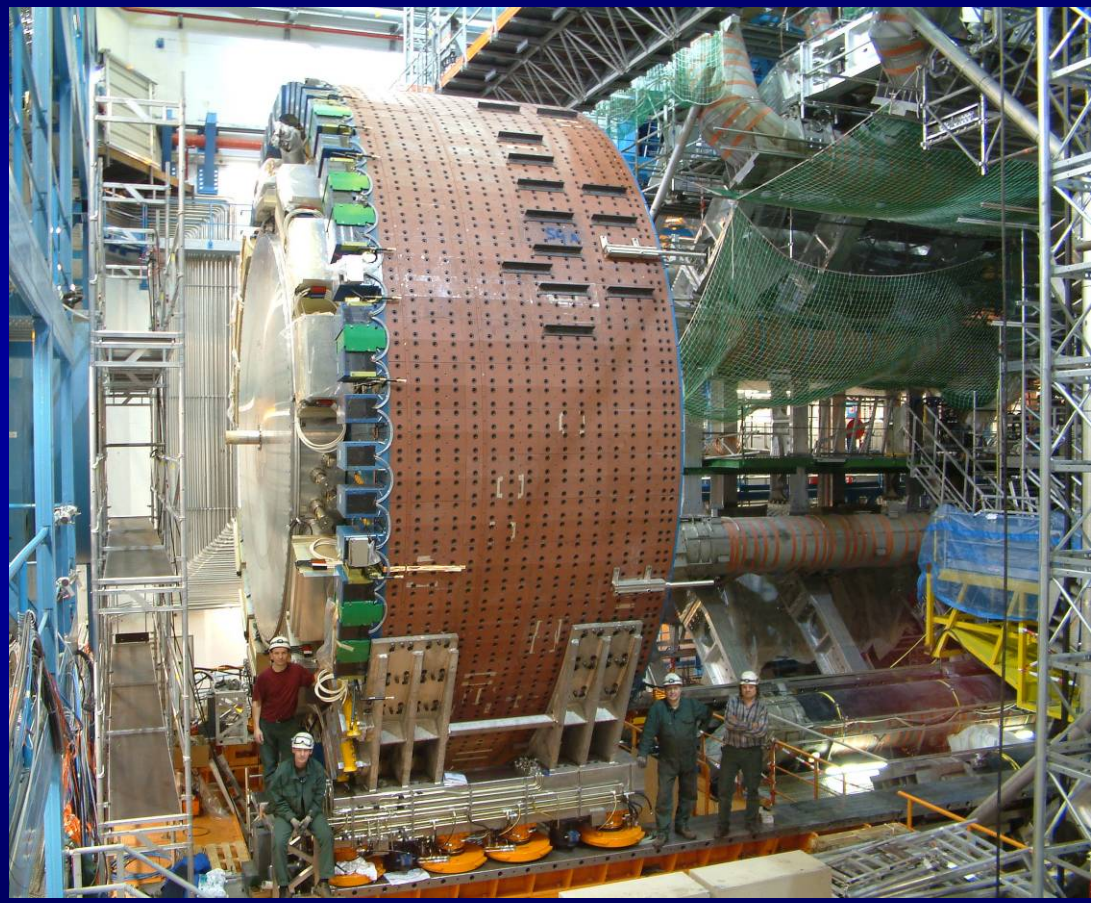
ATLAS End-Cap Calorimeters

ATLAS end-cap calorimeters use liquid Argon and Tile technology.
Side C was assembled in the cavern by end of January 2006, A-side in May 2006

Main LAr activities and plans for the end-caps

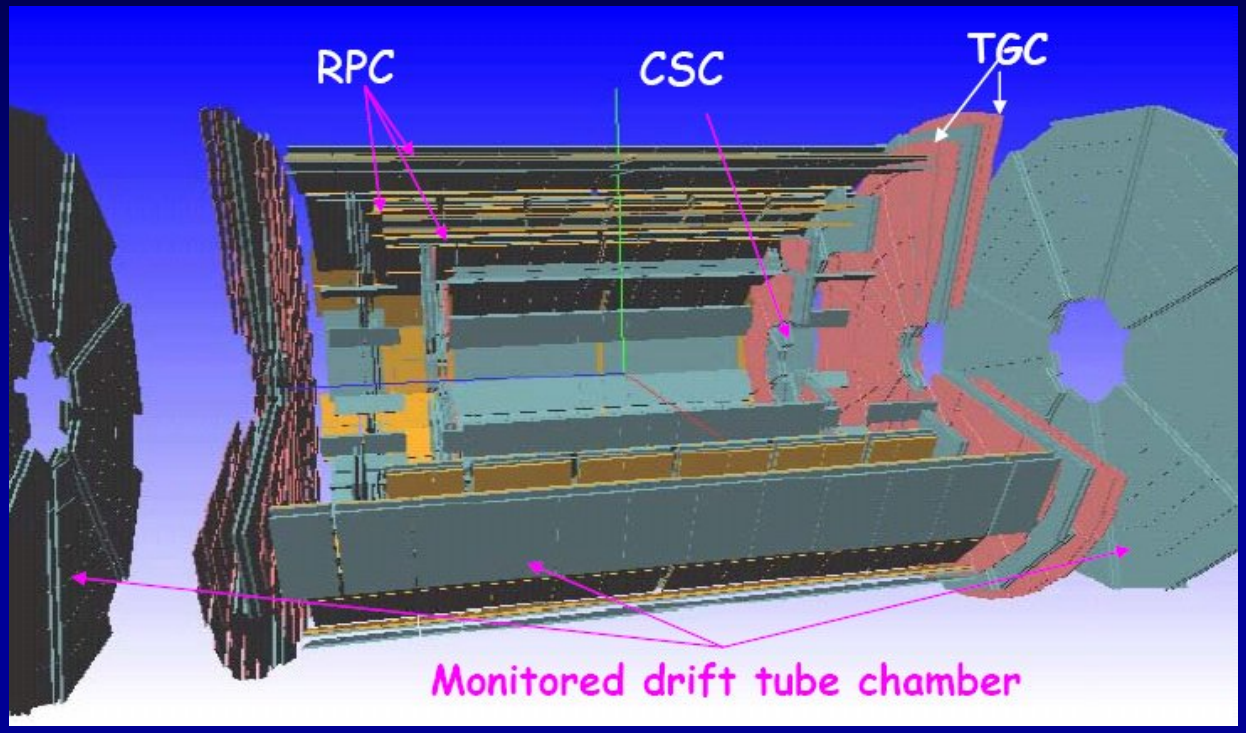
End-cap A:
- Since August '06 installation of FE electronics (no LVPS yet)
- December 2006 started cool down
- Feb.2007 started cold operation

End-cap C:
- Since April '06 installation of FE electronics, then switched to End-cap A
- March 2007 start cool down
- May 2007 start cold operation



Completed end-cap calorimeter side C, just before insertion into the detector

ATLAS Muon Spectrometer



Little multiple scattering in air-core toroids → high precision possible

Goal: $\Delta p_T/p_T$ <10% in stand-alone operation

Precision chambers + fast trigger chambers

A crucial component to reach the required accuracy is the sophisticated alignment measurement and monitoring system

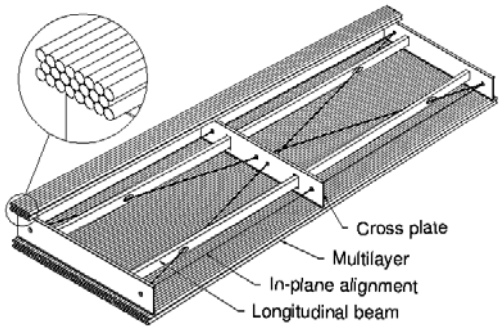
Precision chambers:
- **MDTs in the barrel and end-caps**
- **CSCs at large rapidity for the innermost end-cap stations**

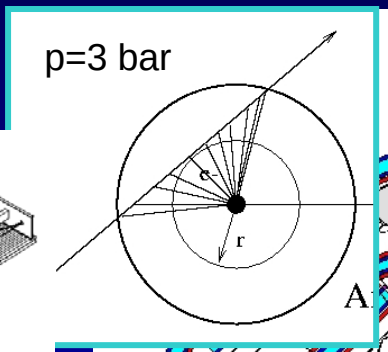
Trigger chambers:
- **RPCs in the barrel**
- **TGCs in the end-caps**

At the end of February 2006 the huge and long effort of series chamber production in many sites was completed for all chamber types

Muon Barrel Instrumentation

- 640 precision chambers (MDTs) measuring 1 r,ϕ-Coordinate





- 686 trigger chambers (RPCs)
  - 2 planes in middle MDT layer (low p_T)
  - 1 plane in outer MDT layer (high p_T)
- Precision and trigger chambers combined to simplify installation
- Precise alignment with ~50 μm

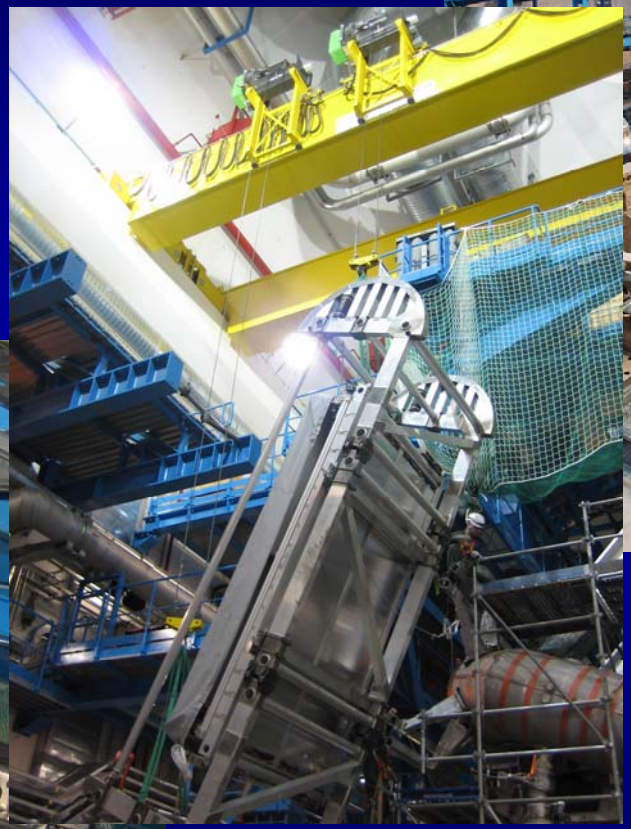
640 muon chambers, 3 stations, 16 sectors

ATLAS Muon Status

Surface station commissioning 100% complete

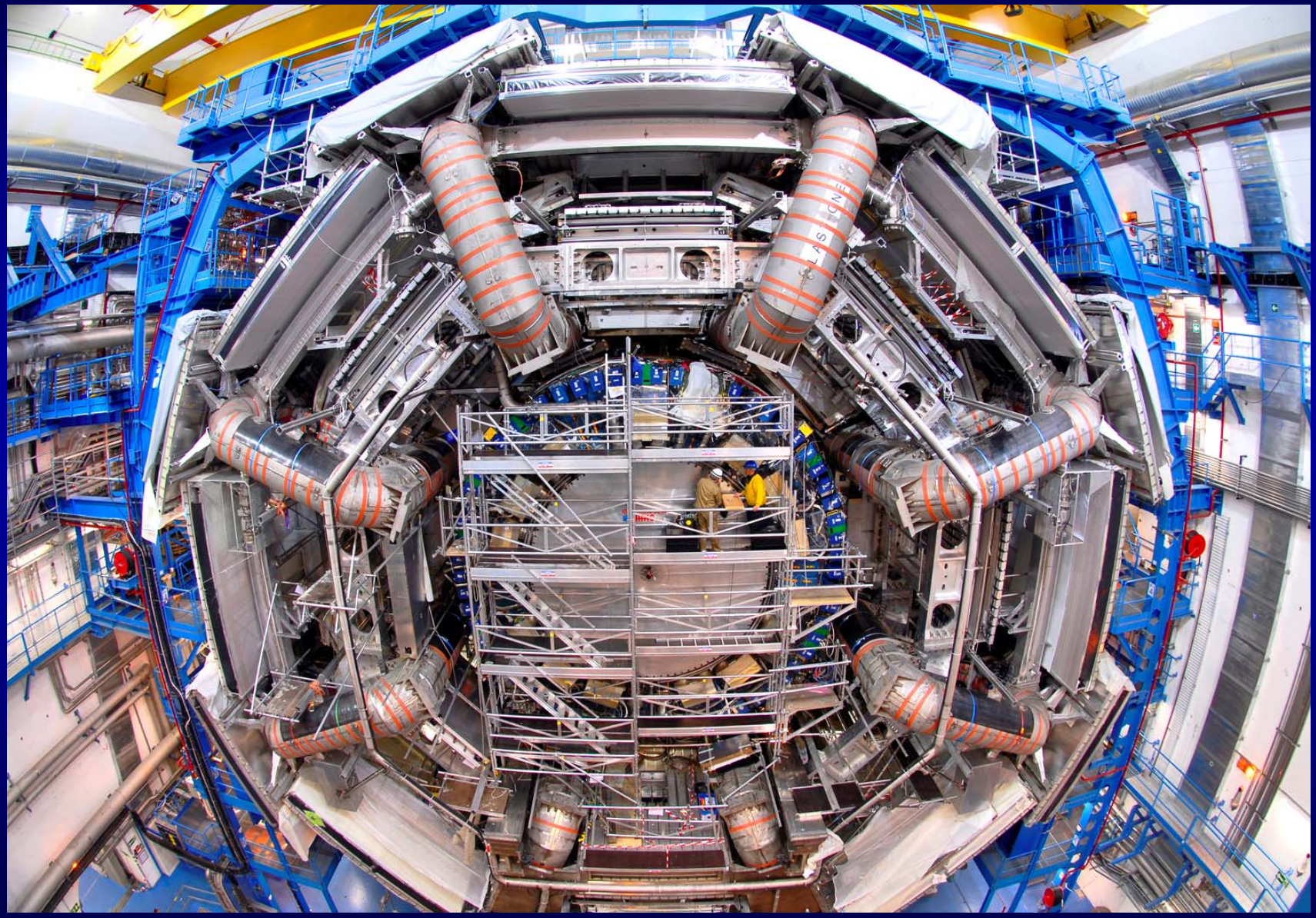
Installation 92% complete

Electronics and alignment are on schedule.

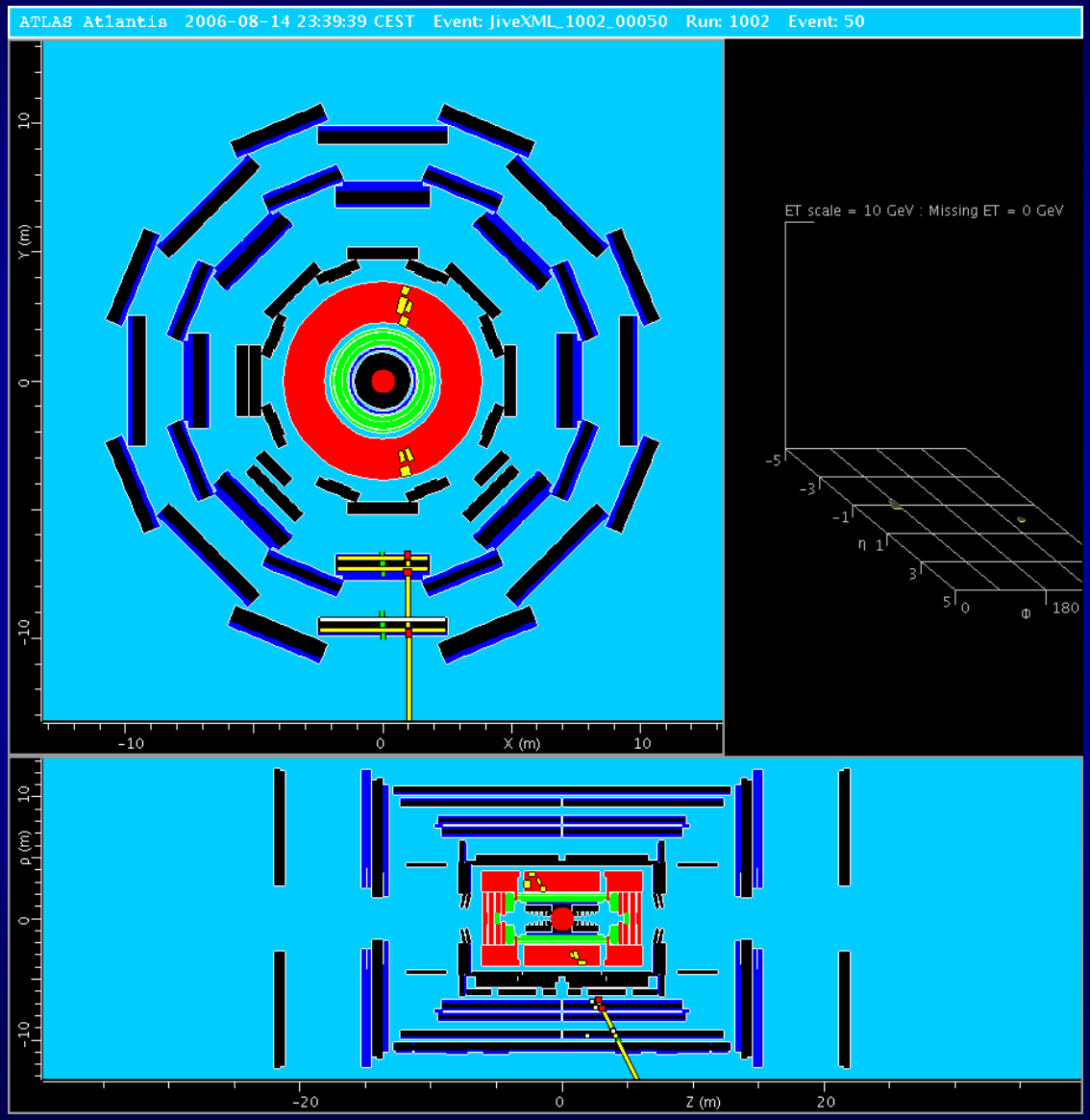


In 2004

Muon Installation Almost Completed



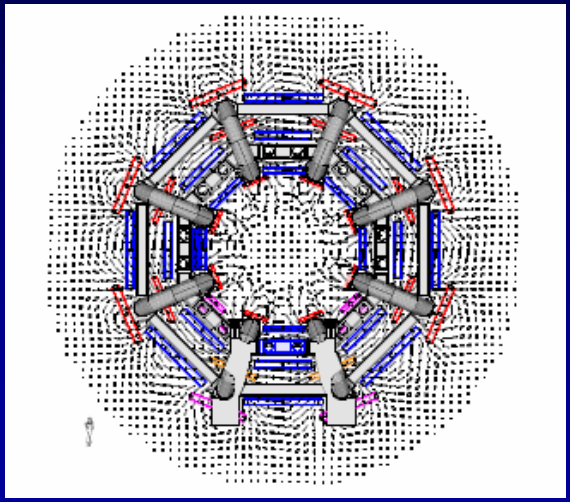
Cosmic Muons Seen in Chambers

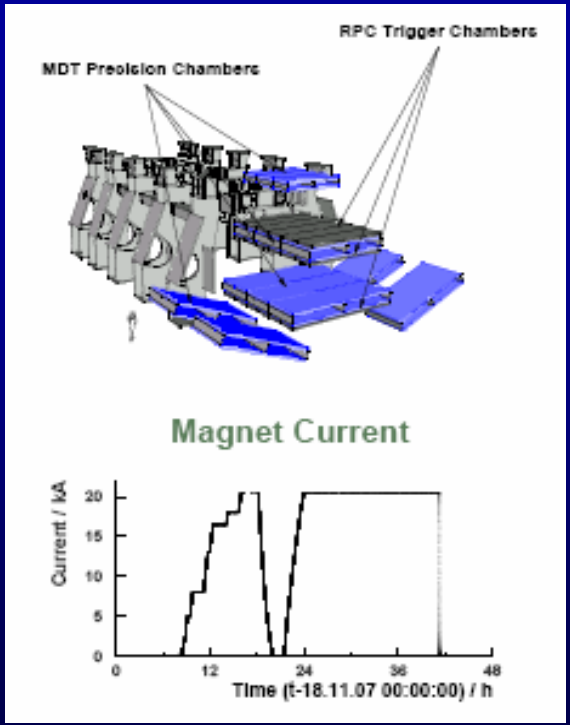


August 2006 saw the first combined MDT + RPC + Tile Calorimeter cosmic ray muon run

RPC trigger on sector-13

Barrel Cosmic Run with B-Field





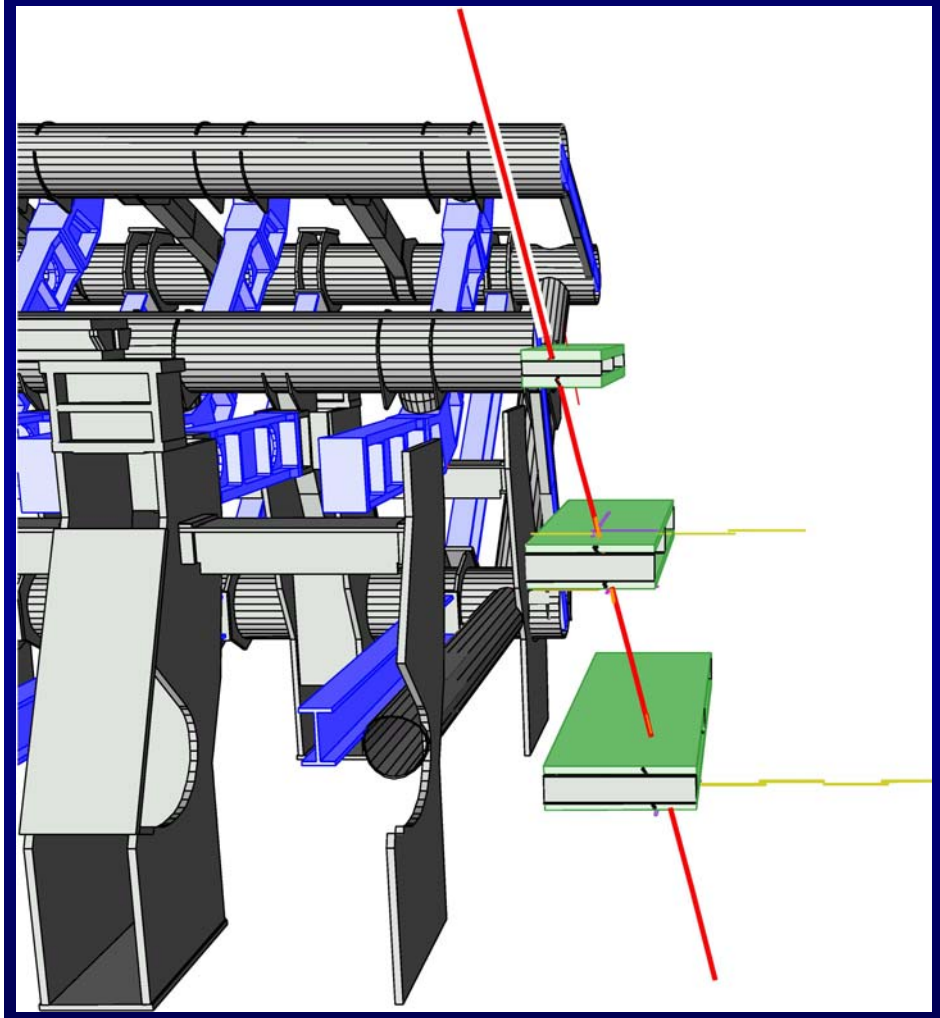
18-19th November 2006, barrel toroid at full field.
Current 20.5 kA

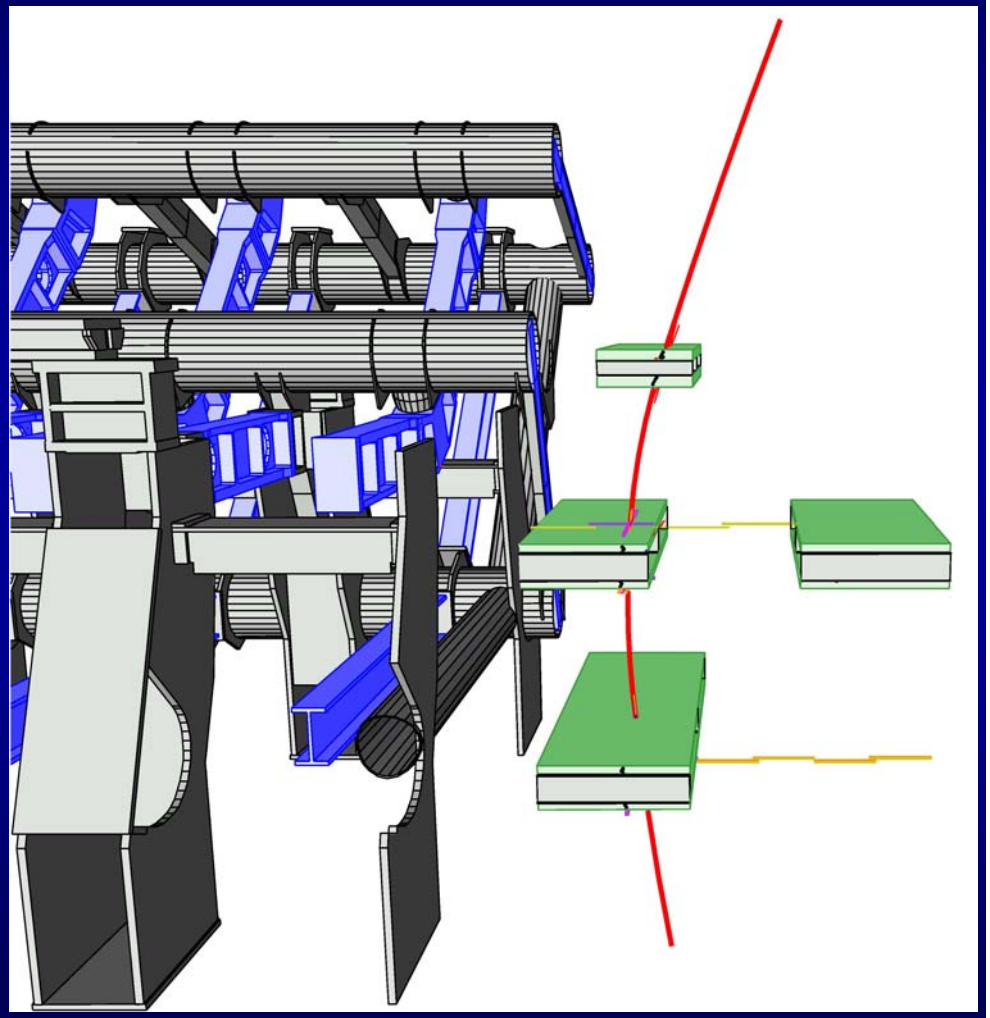
Muon Instrumentation

- 13 muon stations (2% of barrel)
  - ¼ sector
  - 2 stations in each neighbouring sector
- Low and high p_T trigger
- Muon barrel alignment (15 % of barrel)
- Use of central trigger processor

➡ First complete test of barrel spectrometer,
Up to now only components in B-field.

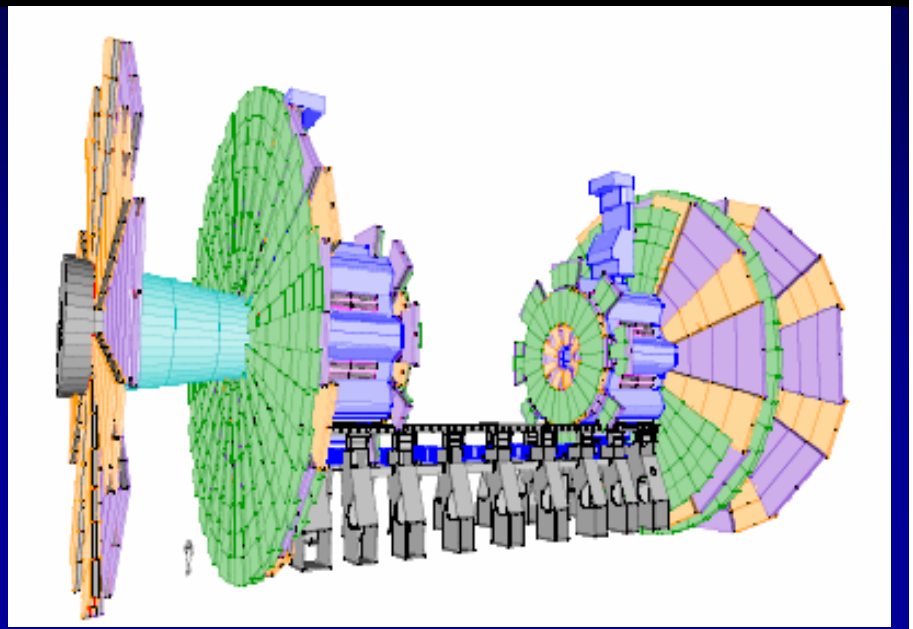
Muons from November Cosmic Test





Muon Endcap System

- 2112 muon chambers organised in 2 small and 10 big wheels
- 534 precision chambers
  - 470 Monitored DT Chambers
  - 62 CSCs
- 1578 trigger chambers (TGC)
  - 2 layer outside 1st MDT BW (low p_T)
  - 1 layer inside 1st MDT BW (high p_T)
- Coverage $1 < \eta < 2.7$



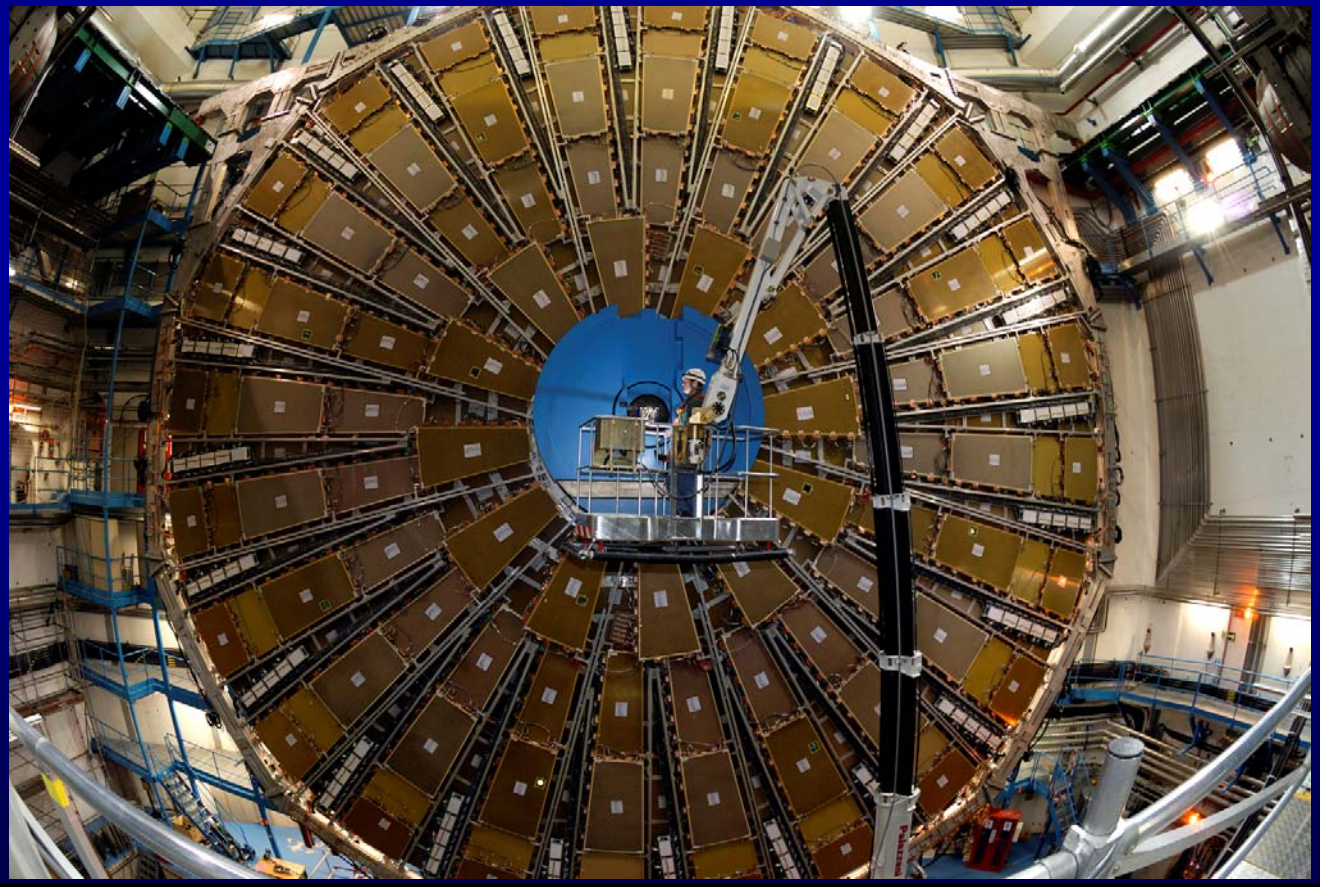
Big wheel end-cap TGC chambers in sectors

MDT chambers are pre-assembled to sectors before lowering

Endcap Muon Sector Preparations

75% of all end-cap MDT/TGC sectors are assembled from individual chambers. This work is in full swing in the Hall 180 where previously the Barrel Toroid and the LAr integration and tests were done

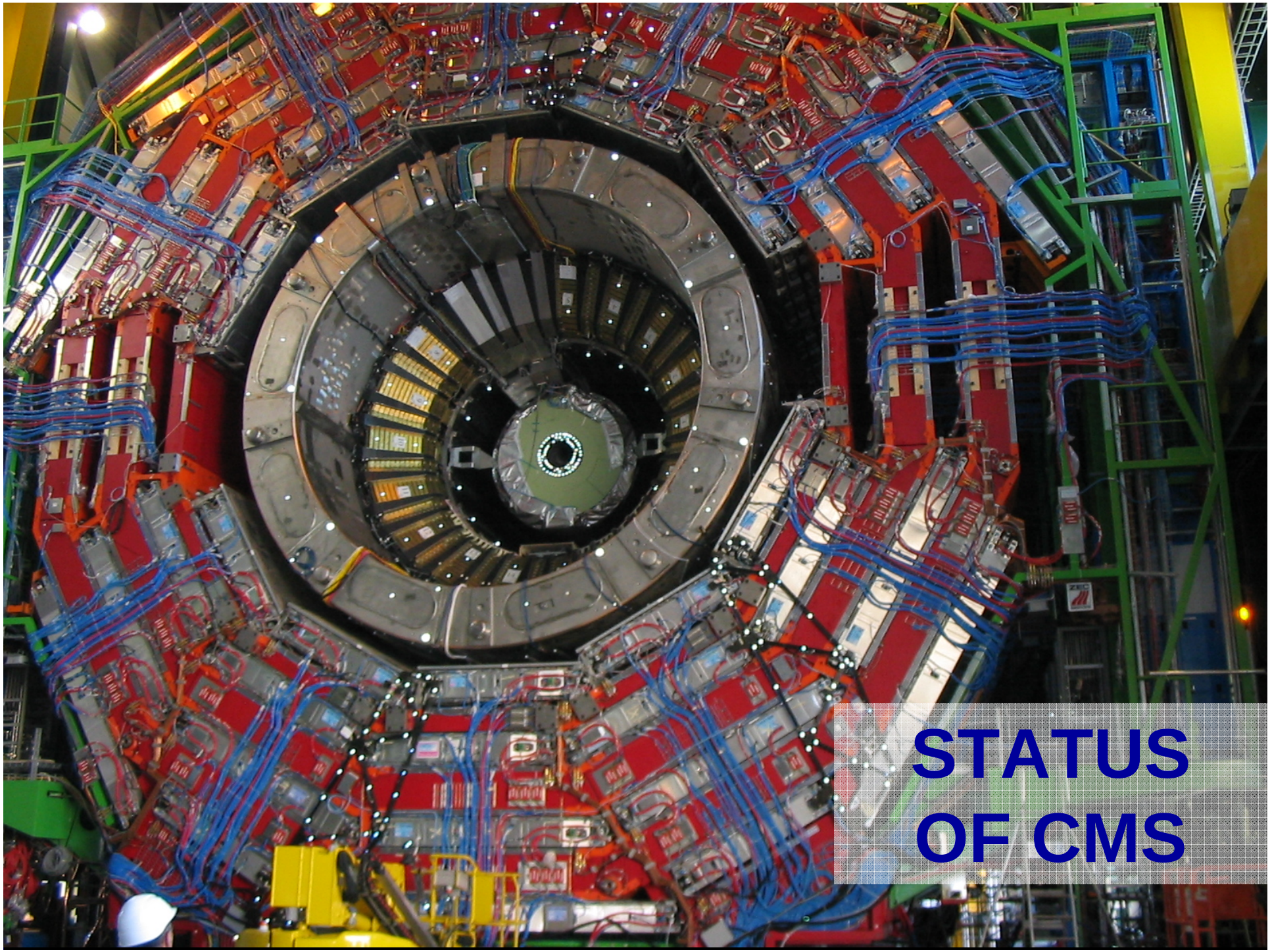
Installation of 1 MDT & 1 TGC Big Wheel completed!



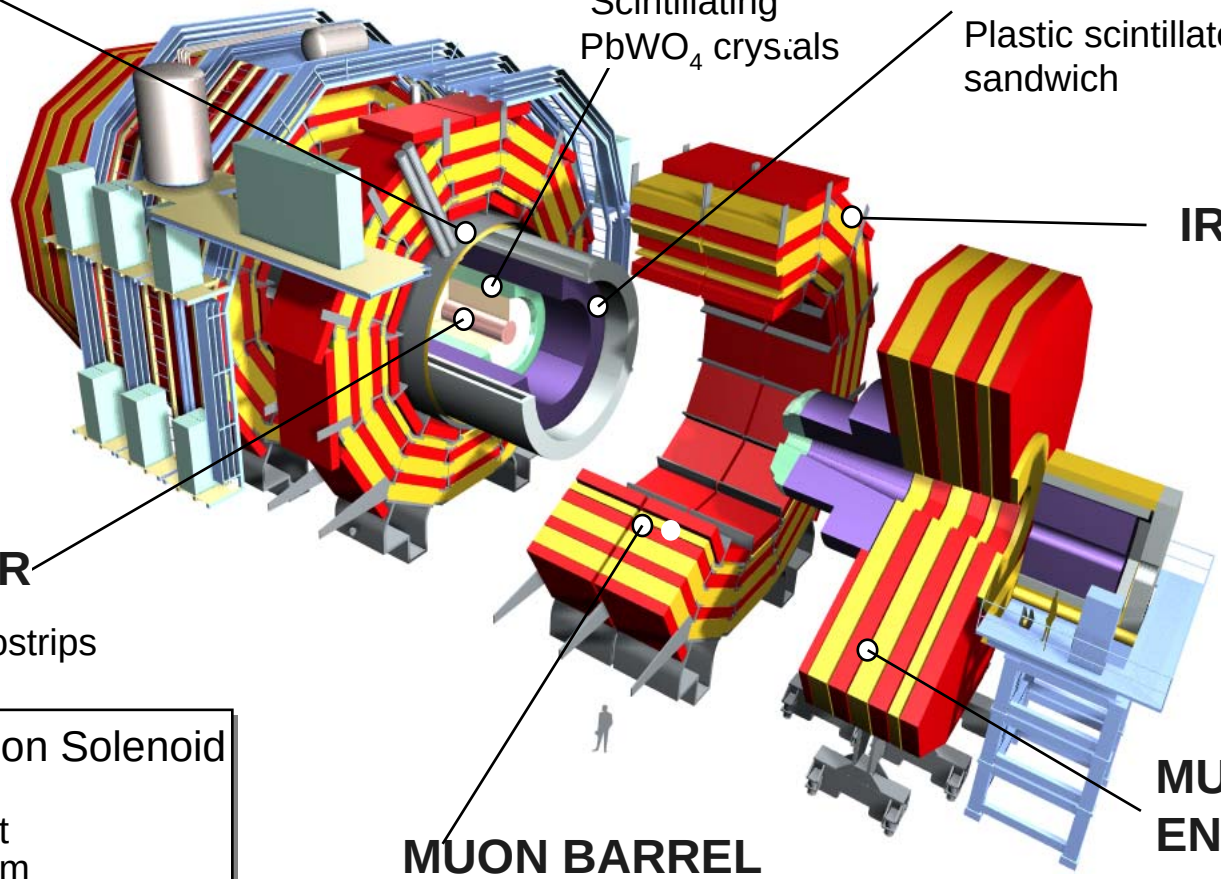
ATLAS Control Room

Control room is operational and used during the cosmic commissioning runs integrating gradually more detector components.

Cosmic ray data is collected through segments of the full final Event Building and DAQ system


STATUS
OF CMS

CMS Detector



CMS=Compact Muon Solenoid

Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

CMS Objectives

900 GeV Collisions - Nov 2007

Initial CMS detector ready to take data at 900 GeV. Use the pilot run to commission and operate the detector with beam and to prepare for data taking and analysis.

- Without ECAL Endcap, and pixels

14 TeV Collisions - Mid-2008

Low luminosity CMS detector* commissioned and ready for efficient physics data taking and analysis 14 TeV pp collisions.

* including ECAL Endcap, and pixels

Two parallel paths being followed

1. Detector Installation, Commissioning and Operation.
2. Preparation for Analysis - Computing, Offline and Physics

CMS Schedule

2007 has started well. Holding schedule to the day.

- **Key milestone: Lowering of YB0 by end-Feb'07 was held**
- **Next Key Milestone: Insertion of Tracker in CMS by end-Aug'07**

Schedule 35.3 : Initial CMS Detector Ready to Close 15 October

Beam pipe installed and baked out.
v35.3 is much more suitable for CMS than v35.2. It leads to a complete initial detector for the November run.

Schedule 35.2: schedule with beam-pipe closure on 31 Aug.

But it leads to a reduced functionality detector for the November run (EB, HB, Tracker almost fully cabled but CMS not closed).

CMS will meet with the DG/DDG in March/April to decide final pathway. The two schedules diverge in ~ May.

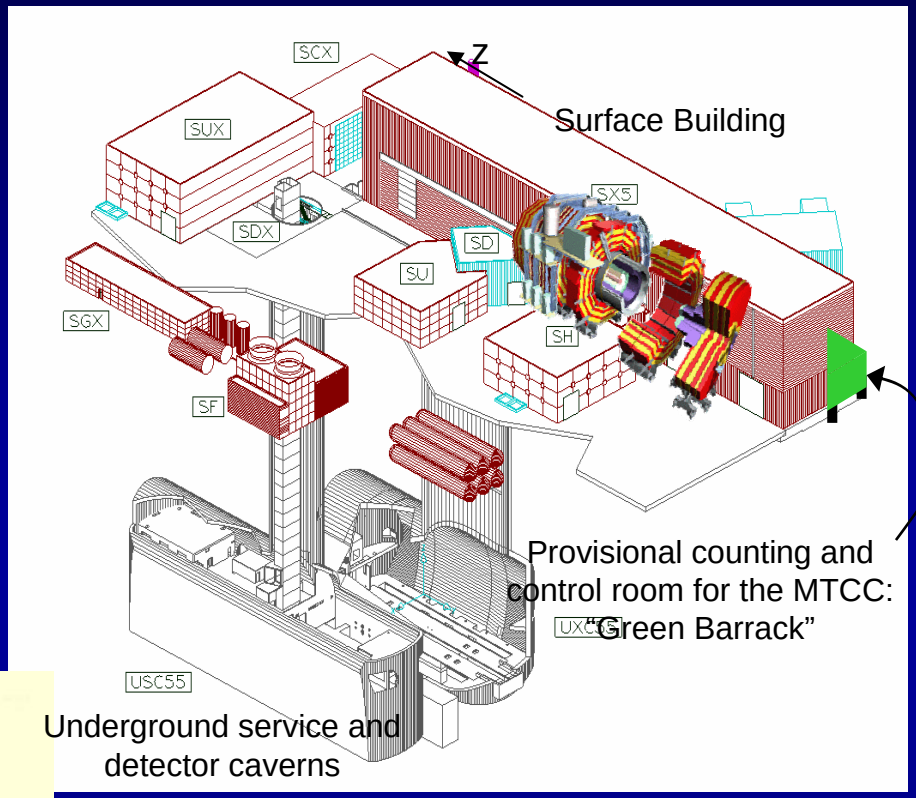
Surface Assembly and Lowering

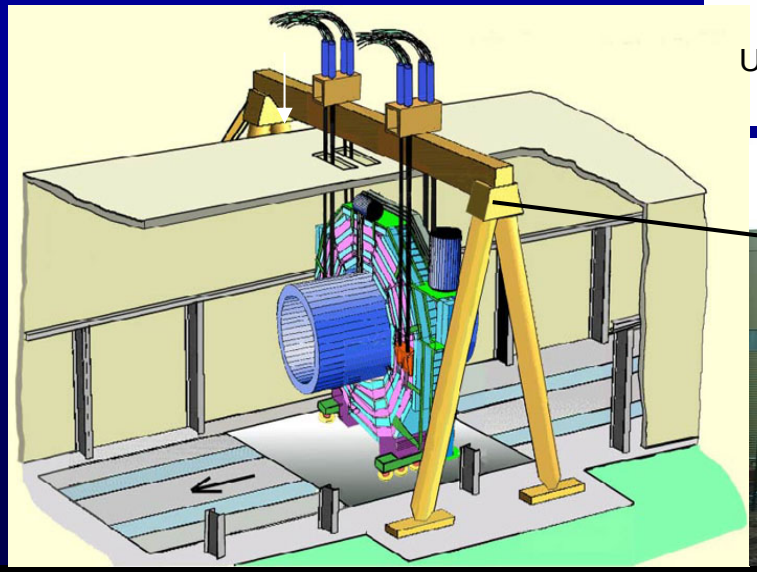
Compact and modular design → extensive pre-assembly on the surface. Lowering piece by piece underground.

Started in fall 2006, on schedule.

>50% is underground!

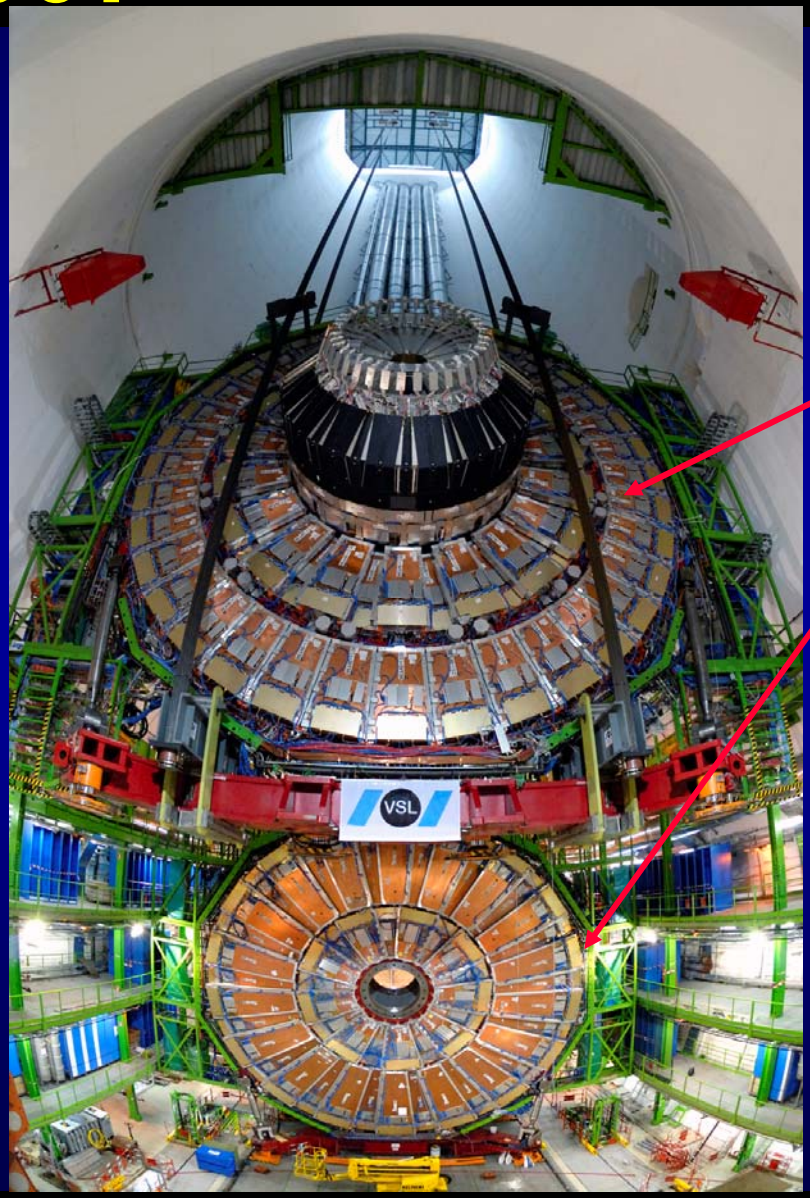
Positive CMS "half" (muon end-cap, muon barrel, HCAL)

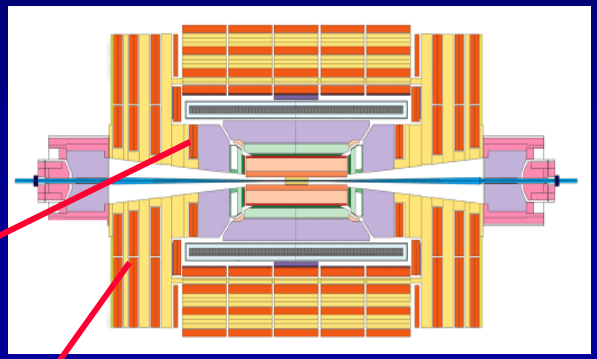




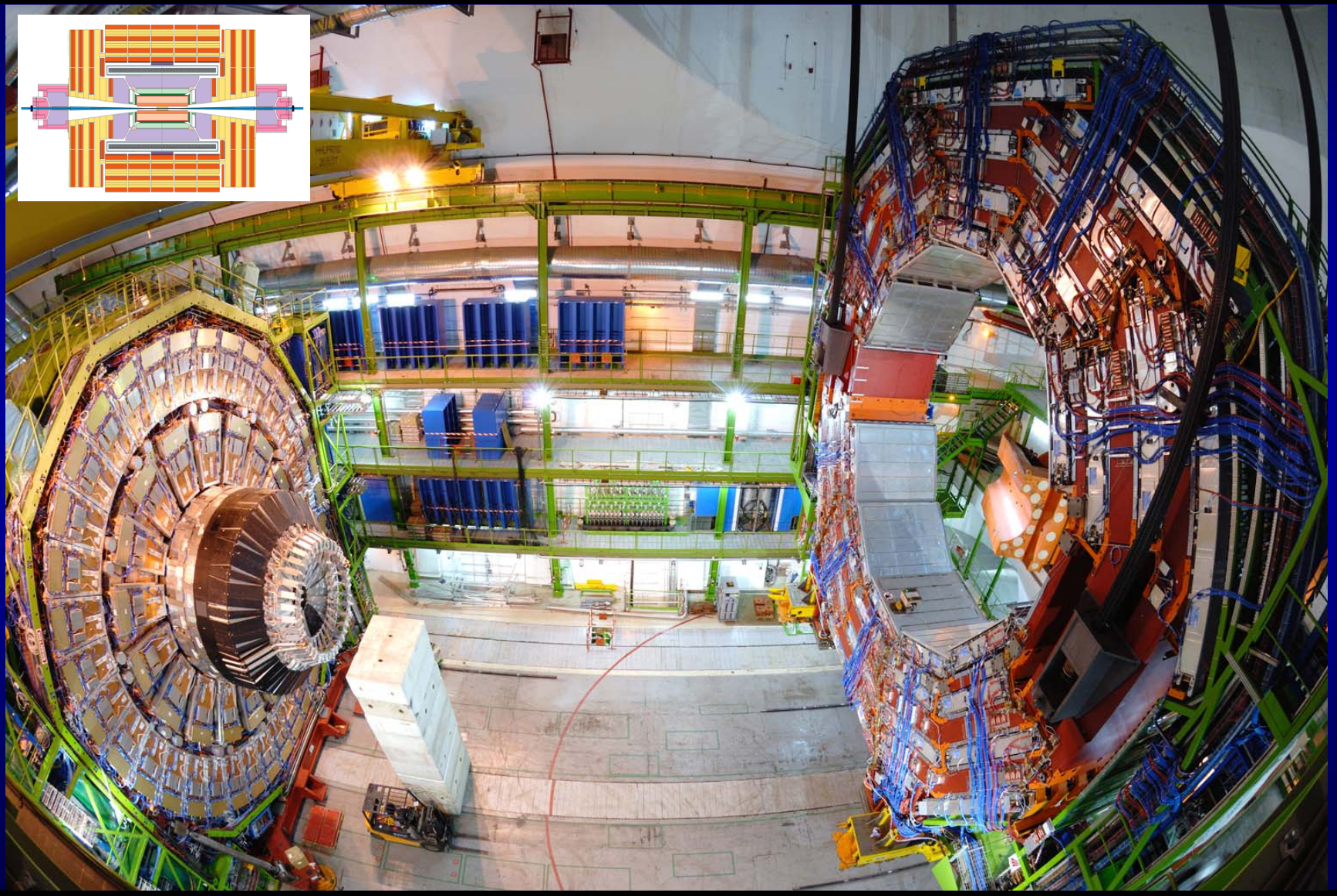
Lowering of the heaviest piece (1900t): central wheel

Muon Forward Disk (YE+1) Lowering 09.01.2007

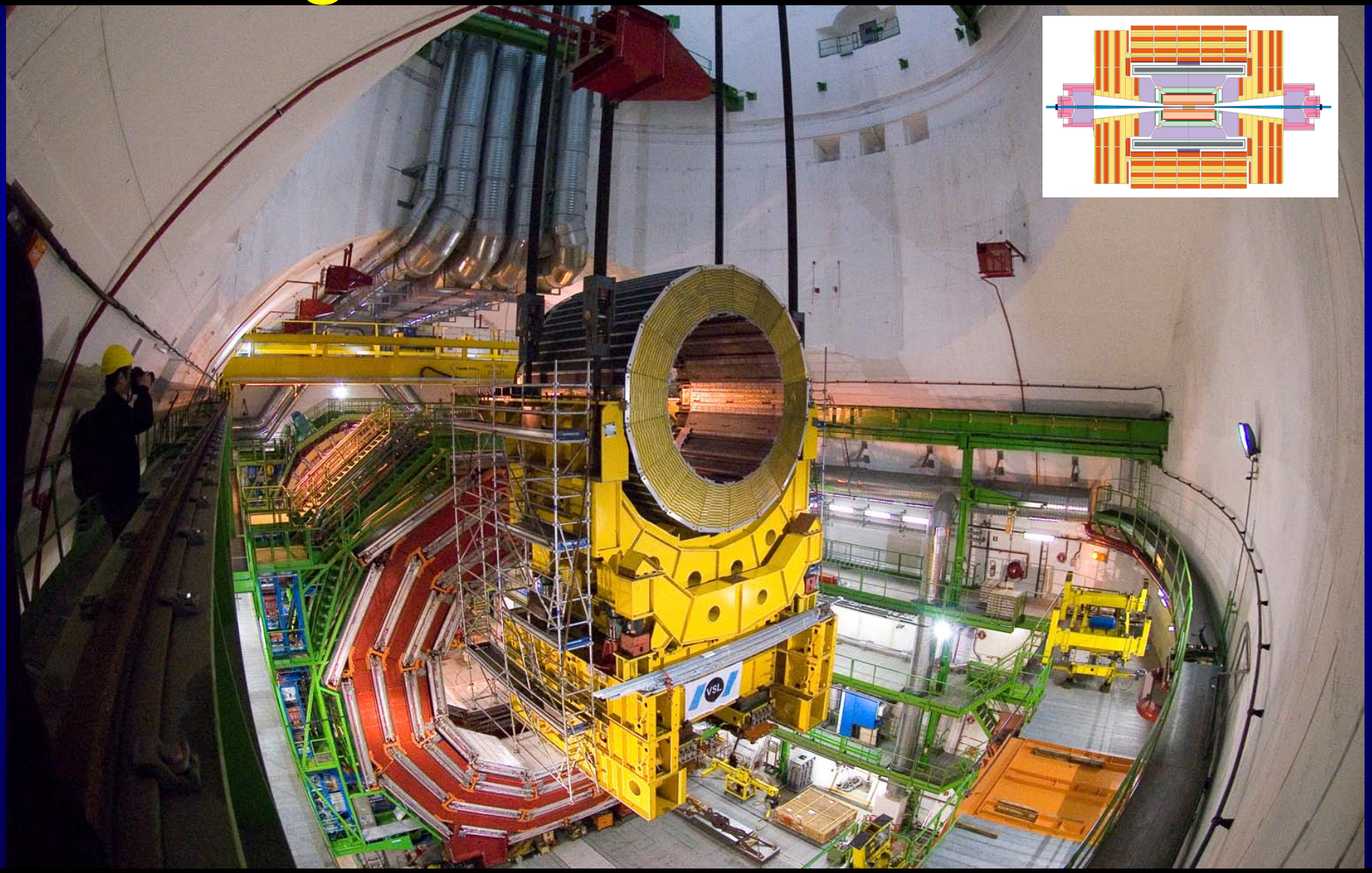




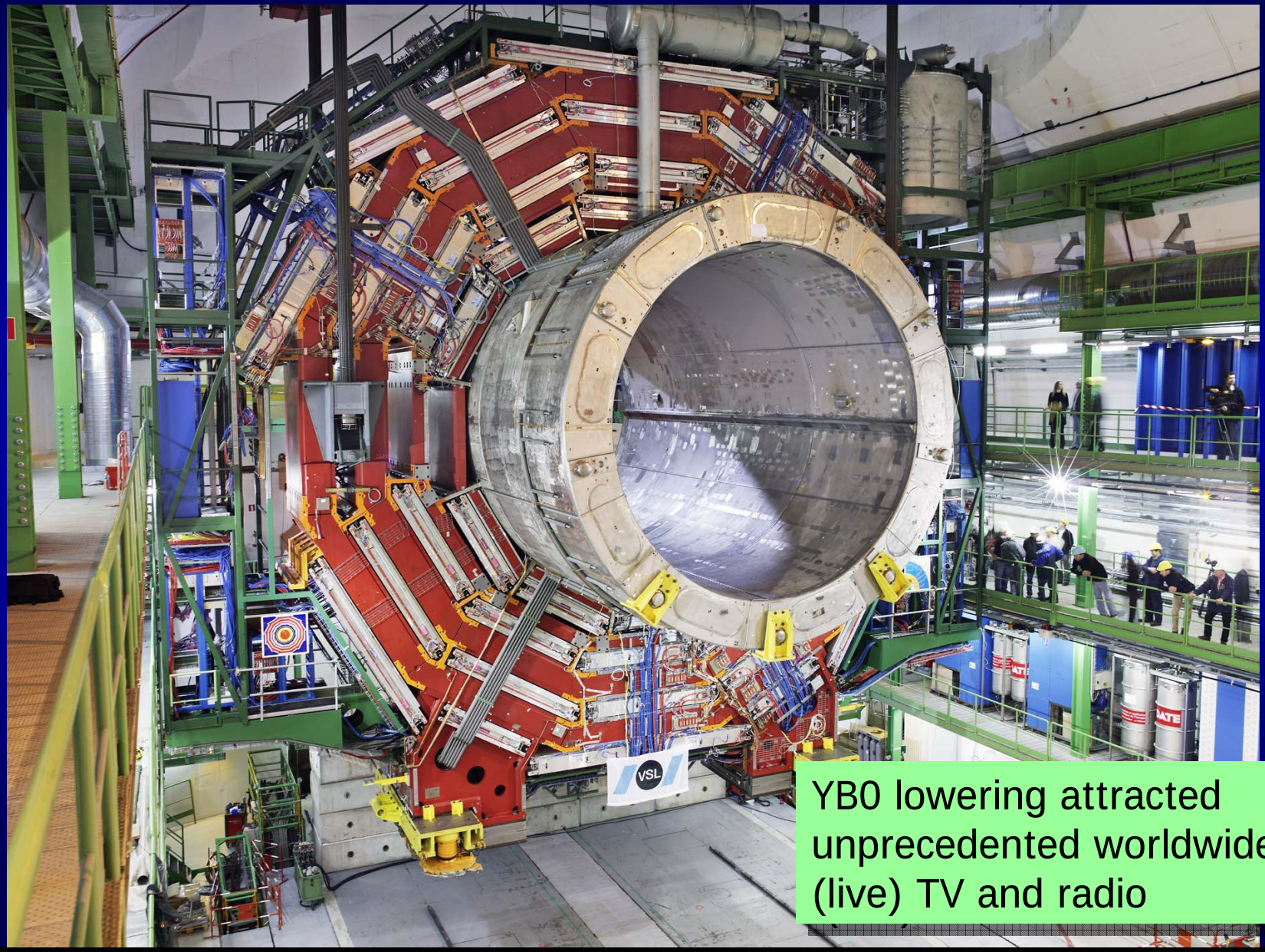
First Muon Barrel Wheel (YB+2) Lowering 19.01.2007



HCAL Barrel (Positive Half) Lowering 13.02.2007

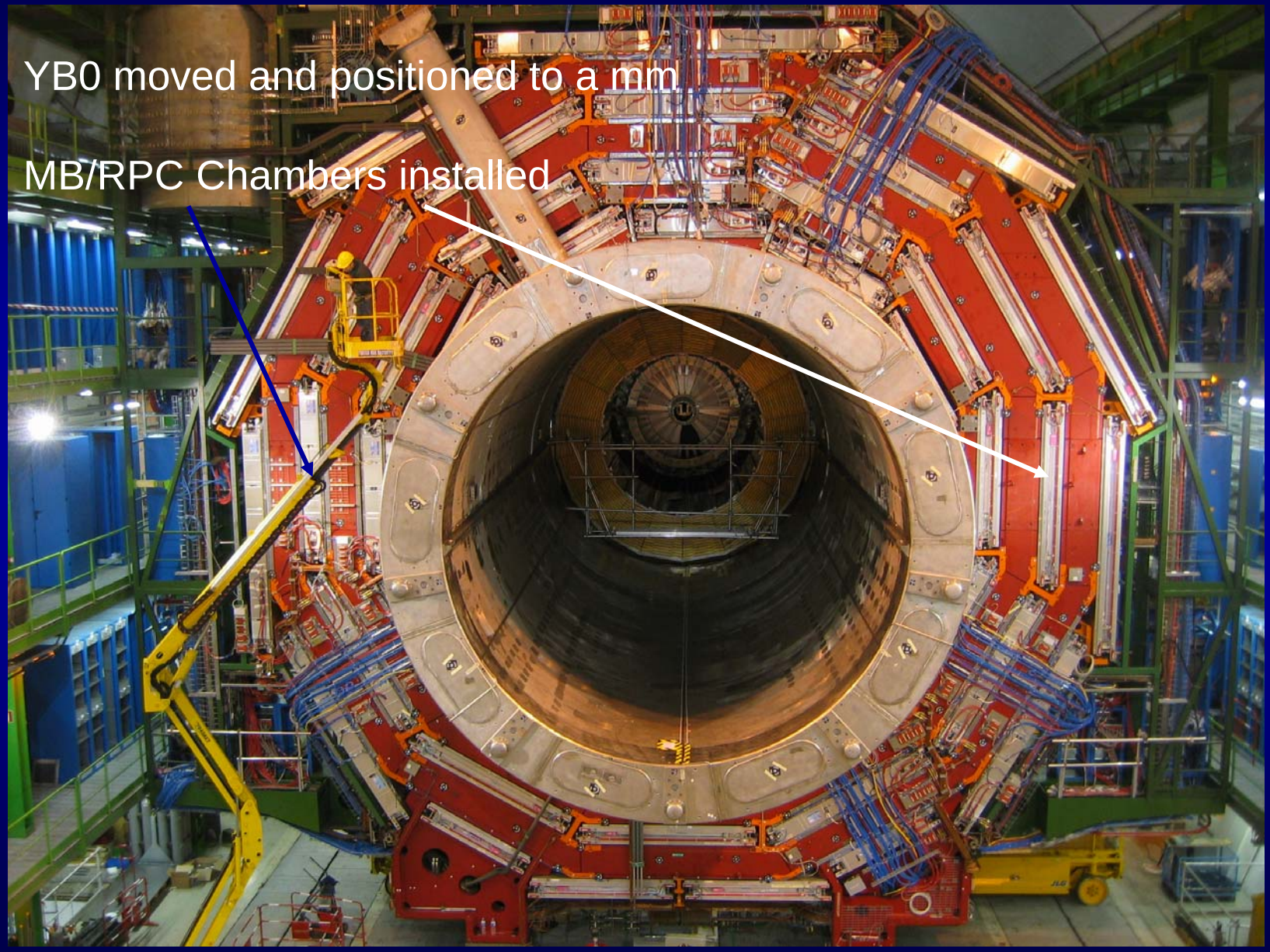


YB0 Lowering on 28.02.2007

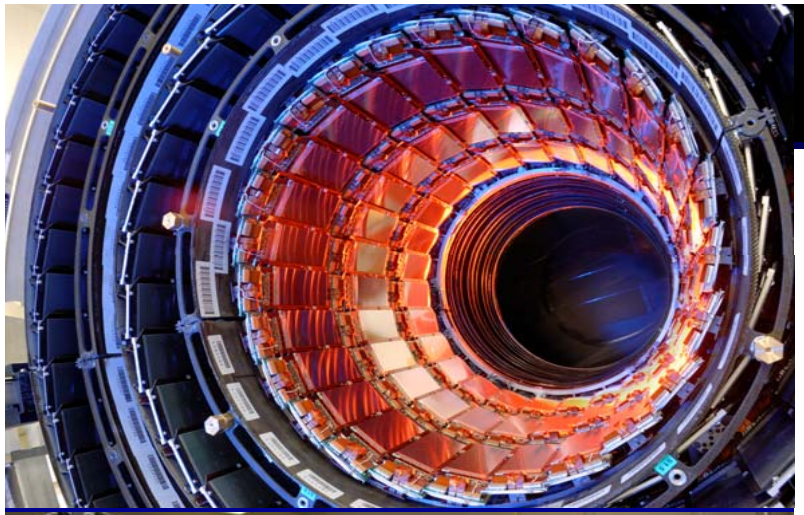


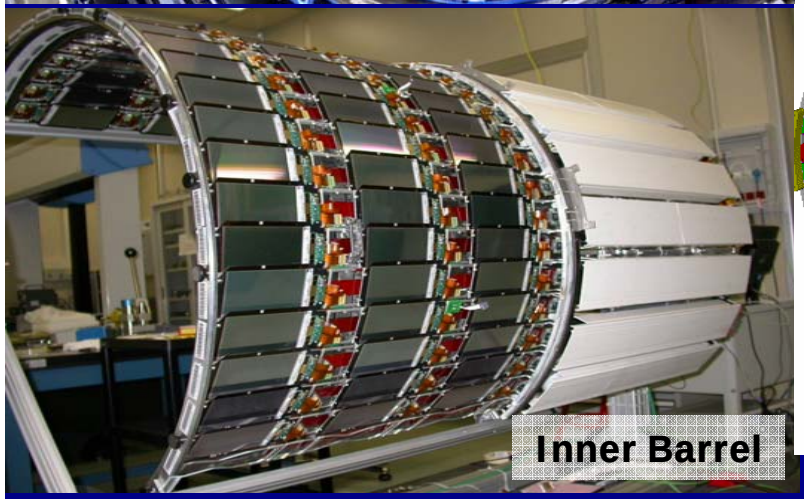
YB0 lowering attracted unprecedented worldwide (live) TV and radio

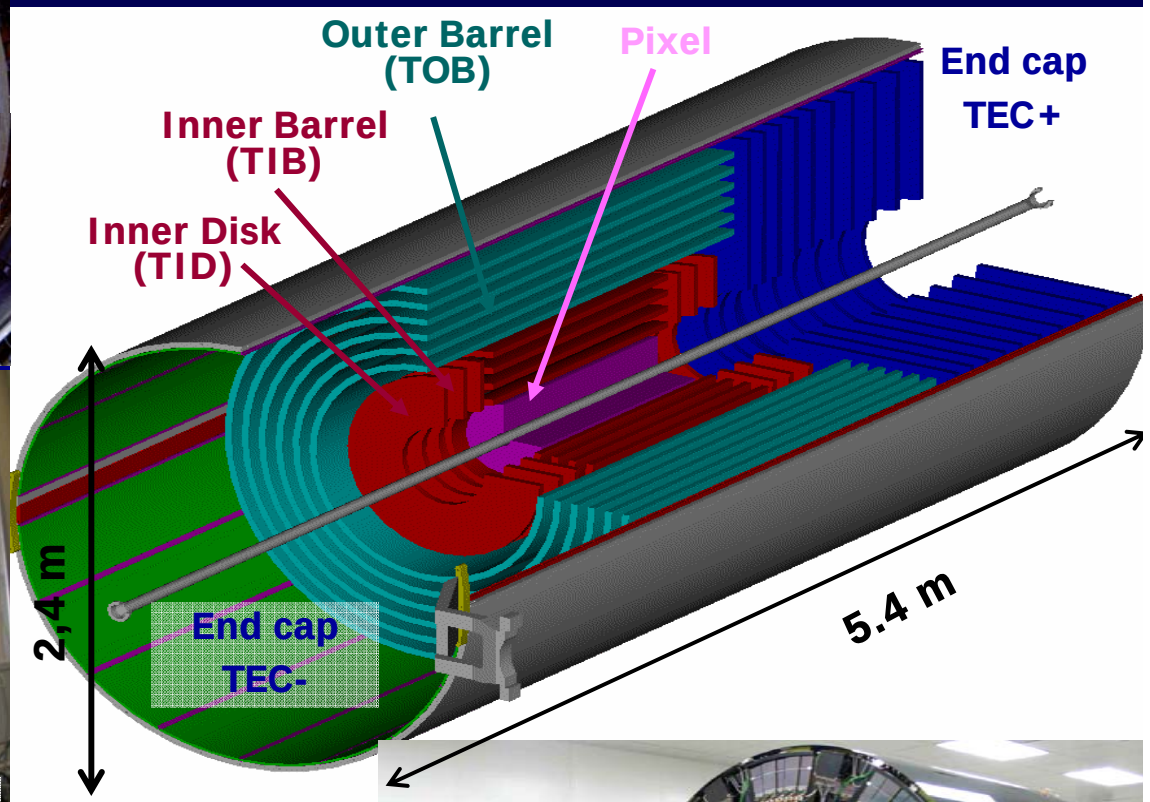
Situation in Cavern on 09.03.2007



CMS Silicon Tracker







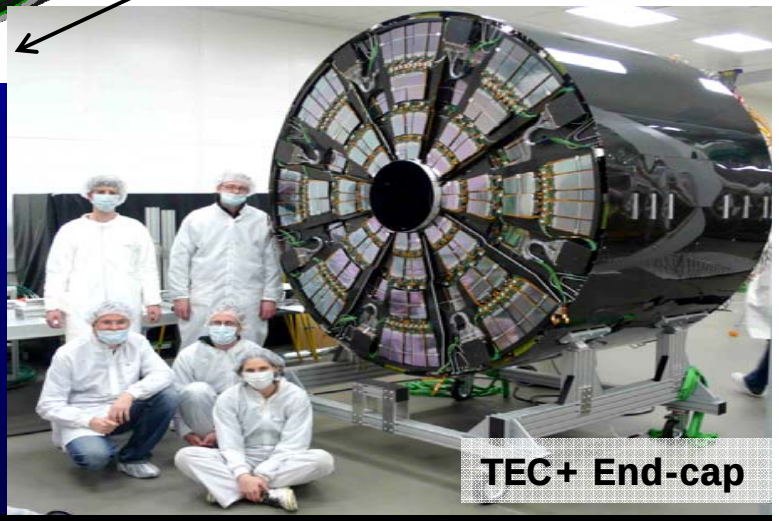
206 m^2 Silicon Sensors (158 m^2 + 48 m^2)

6136 thin + 9096 thick Silicon detectors

~10 Mill. Readout channels

~26 Mill. Bonds

Tracker operates in N_2 atmosphere, T~ -10°C



Progress in the Tracker

Integration:

• 75% of Tracker inside Support Tube (inner barrel, outer barrel, positive endcap TEC+). By end March'07 all the silicon strip tracker is integrated.

• The Pixel Support Tube has been integrated.

→ **Pictures**

Commissioning and testing

• 50% TEC +/- successfully tested at -10^0 C (operating temperature)

• Tracker commissioning and cosmic tests started in February

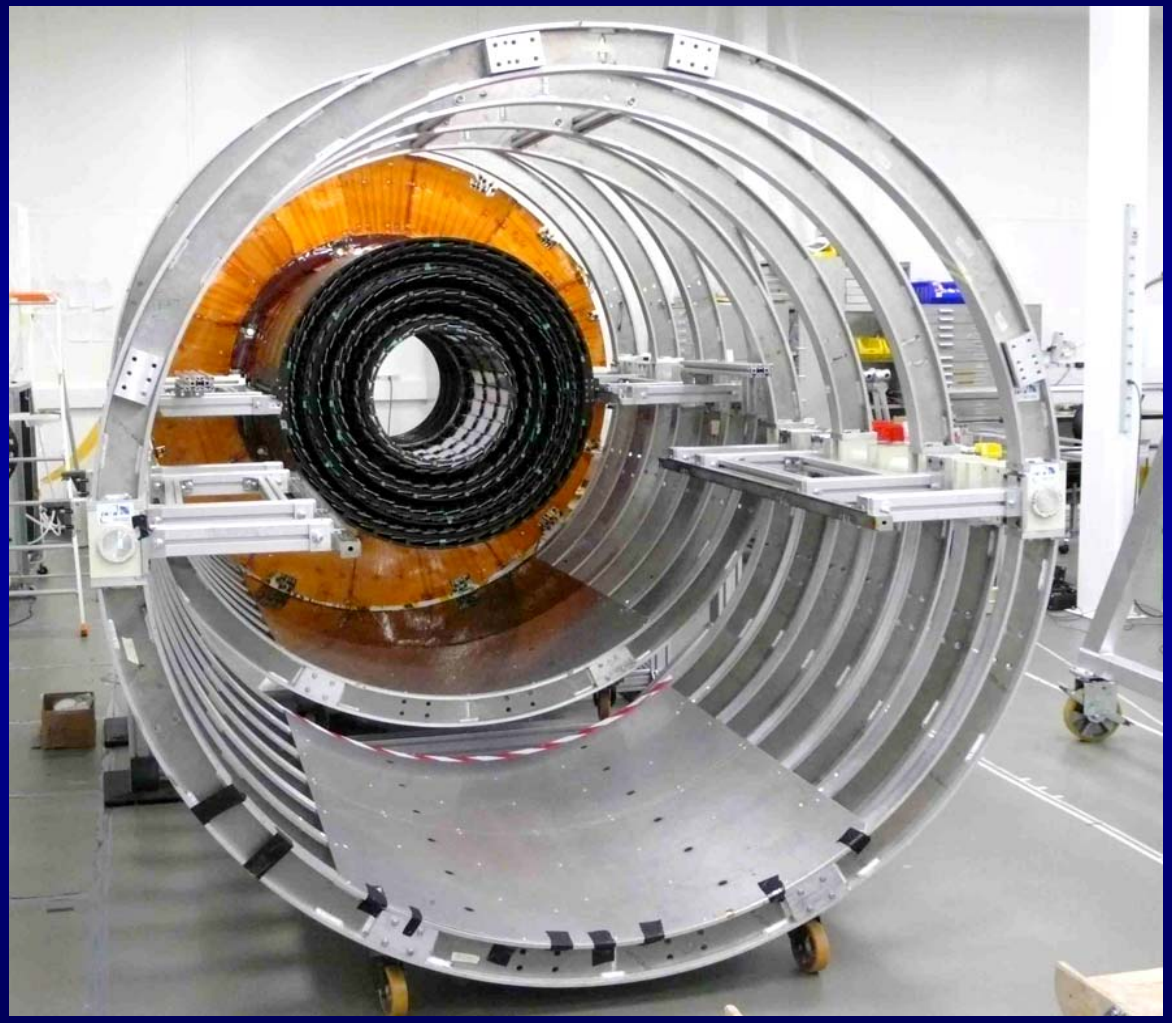
• Before Move to Point 5
  ~ 3 weeks of Cosmic Tests at Room Temperature (~ 20% of tracker)
  ~ 3 weeks of Cosmic Tests at Operating Temperature (20% of tracker)
  Start Preparation for moving ~ 8 weeks before Installation

"Ready for Installation" mid-July 2007.

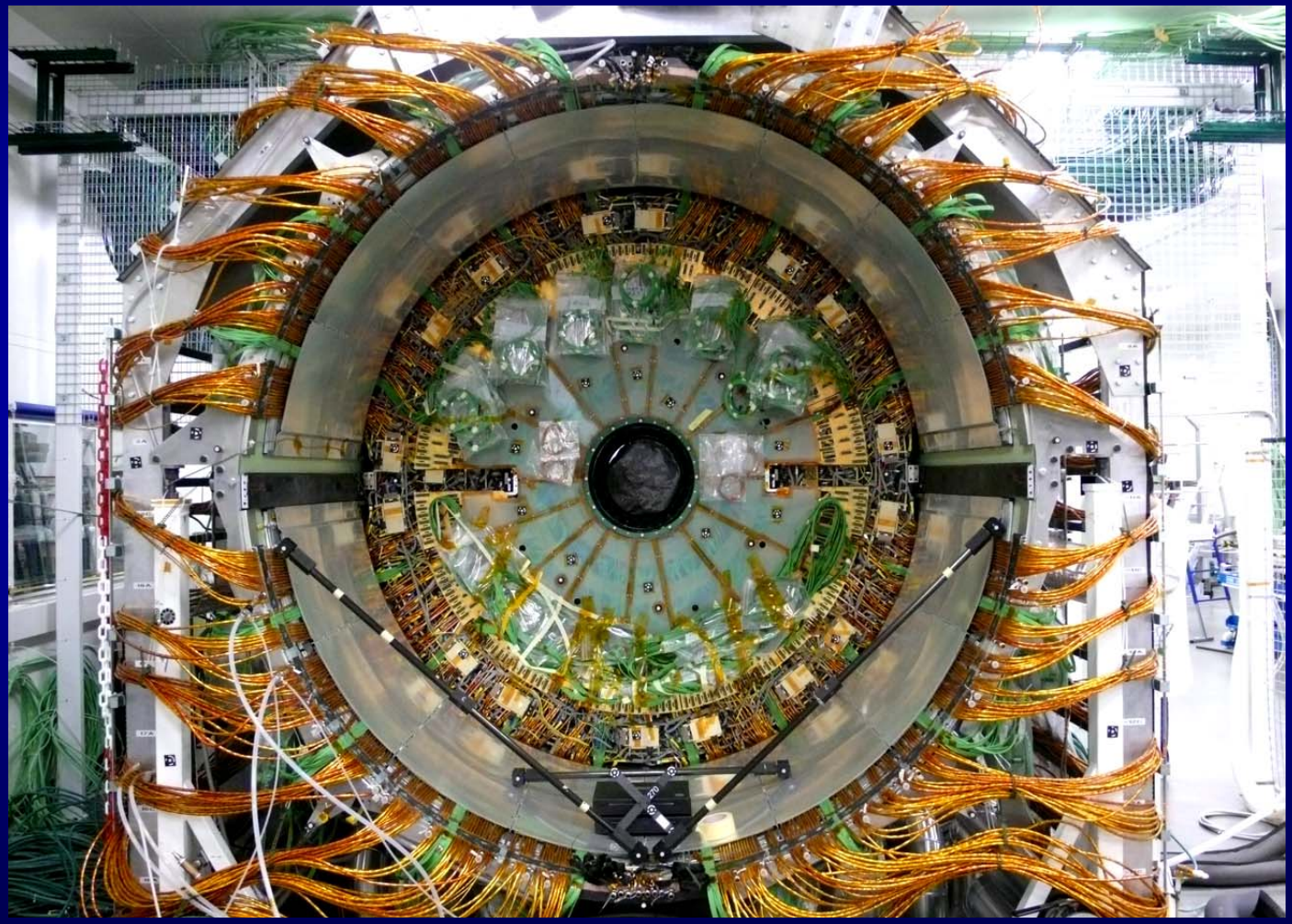
Next Key CMS Milestone: insertion of Tracker in CMS by end-August'07

Integration of Inner and Outer Barrel

Preparing TIB -
for Insertion
into TOB -

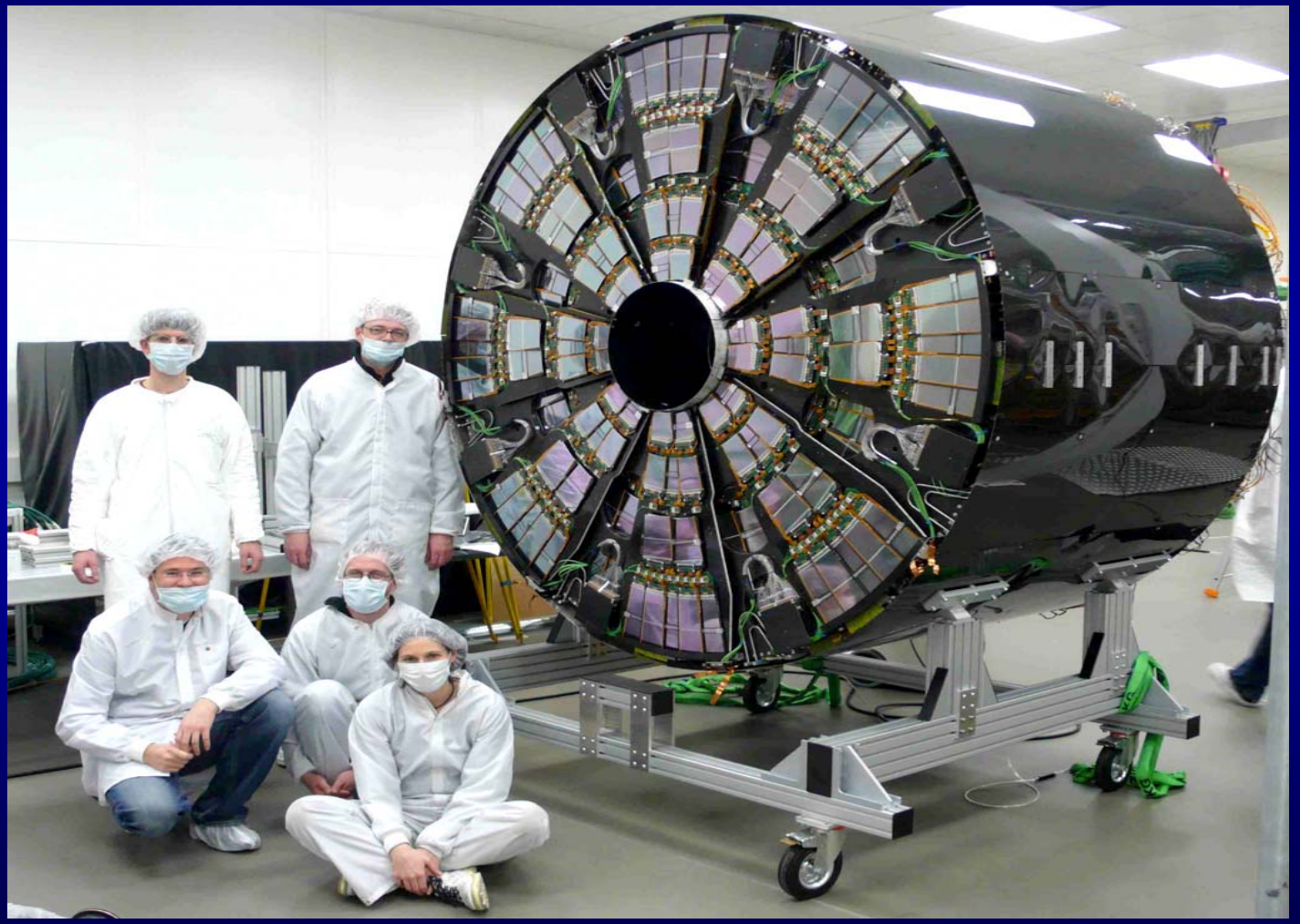


Tracker Inner Barrel - Inserted into Tracker Outer Barrel



Tracker Endcap TEC+ Ready for Insertion

The Aachen Team with TEC + End Cover Removed to show Silicon



Progress in the Tracker

Integration:

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• The Pixel Support Tube has been integrated.

Commissioning and testing

• 50% TEC +/- successfully tested at -10^0 C (operating temperature)

• Tracker commissioning and cosmic tests started in February

→ **Cosmic track**

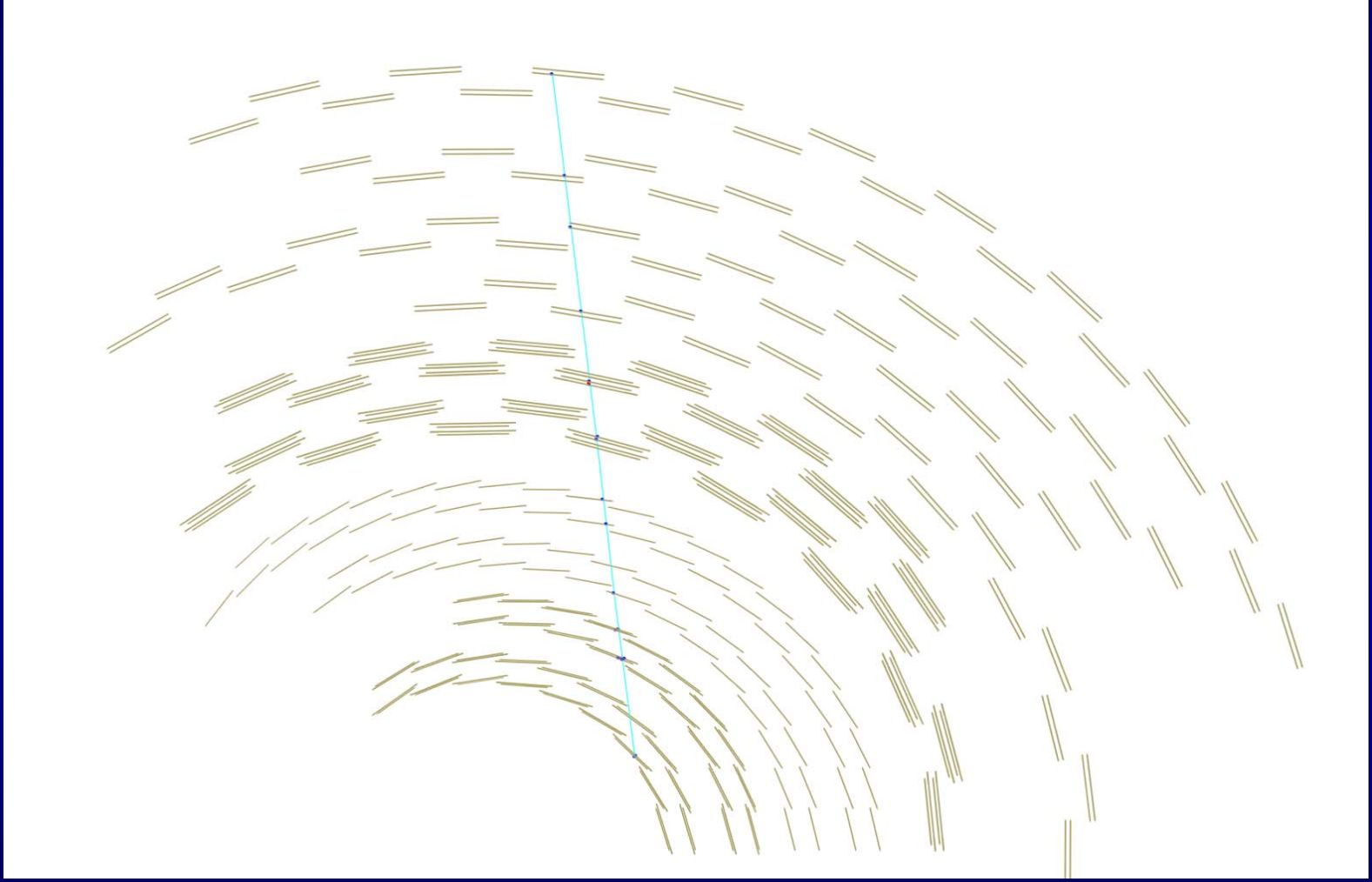
• Before Move to Point 5

~ 3 weeks of Cosmic Tests at Room Temperature (~ 20% of tracker)
~ 3 weeks of Cosmic Tests at Operating Temperature (20% of tracker)
Start Preparation for moving ~ 8 weeks before Installation

"Ready for Installation" mid-July 2007.

Next Key CMS Milestone: insertion of Tracker in CMS by end-August'07

A Cosmic Track in TOB and TIB



CMS Pixel Detector

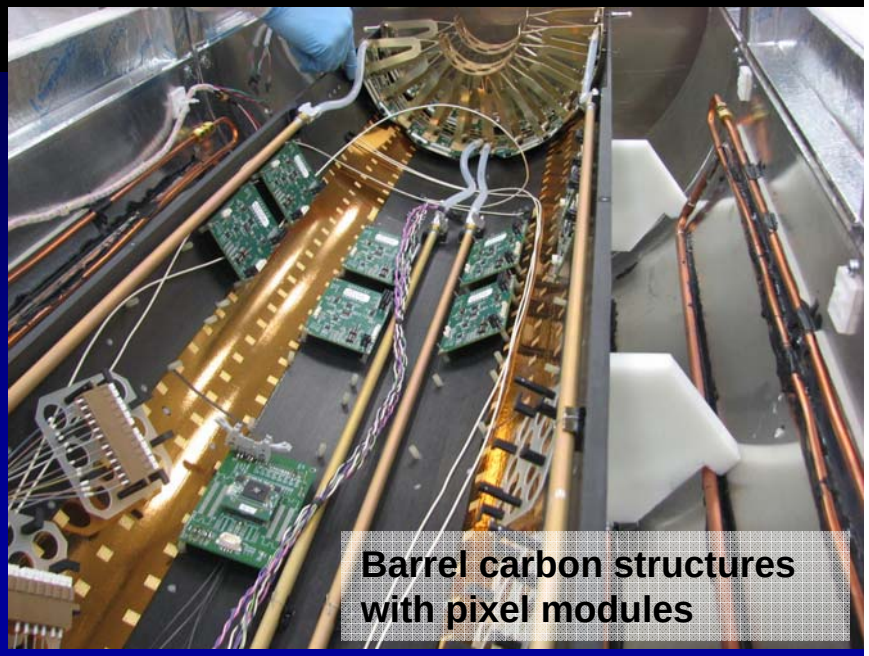
CMS pixel detector will not participate in beam commissioning.

- Module production till August 07, on track. Status for barrel modules:

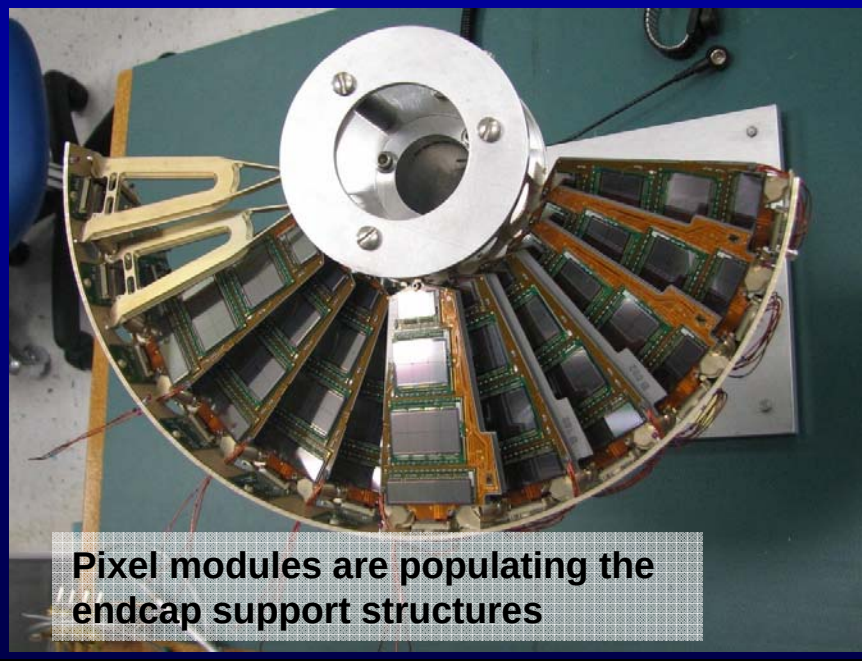
	Full Modules	Half Modules
Total needed (3 layers)	672	96 (2x48)
Needed for layer 1&2	352	64 (2x32)
Produced and graded A/B	353	49
Fraction	53%	51%

- Installation in the winter shutdown after 900 GeV run(s). CMS will open and pixel detector slides as a unit on rails into tracker.

- CMS pixels 100 μm x 150 μm
- N-implant on n-bulk. Radiation will lead to type inversion.

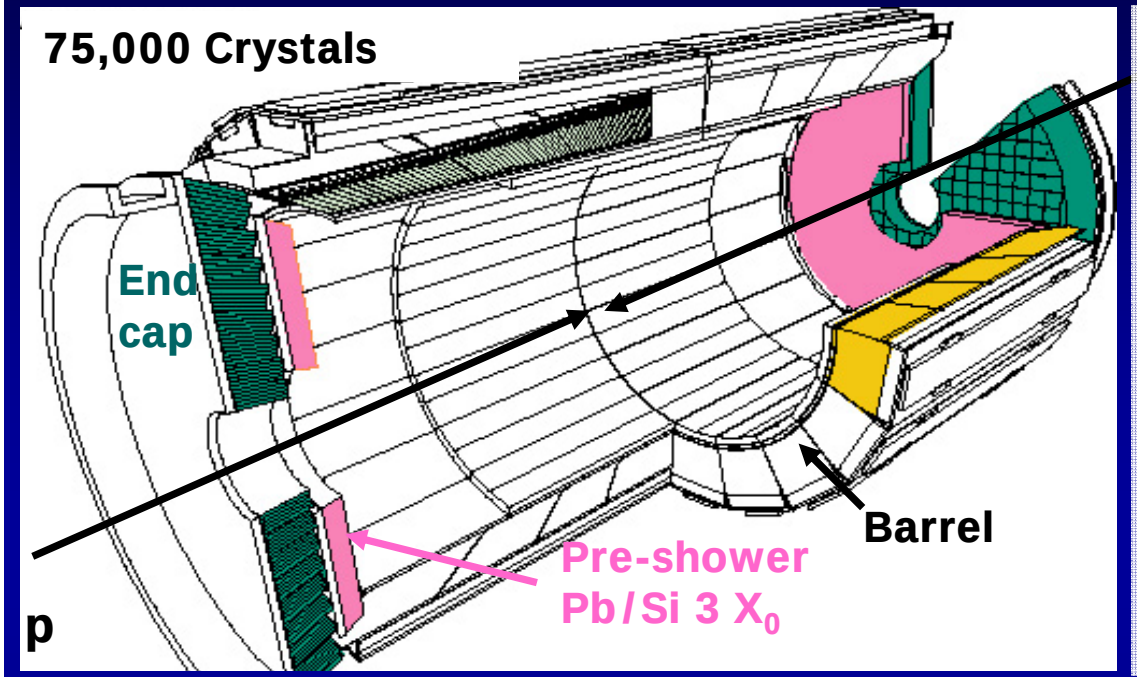


Barrel carbon structures with pixel modules



Pixel modules are populating the endcap support structures

CMS $PbWO_4$ Electromagnetic Calorimeter



Scintillating crystals $PbWO_4$

- Fast scintillation (80% in 25 ns)
- Radiation tolerant
- Moliere radius of 2.2 cm
- Radiation length of 0.89 cm

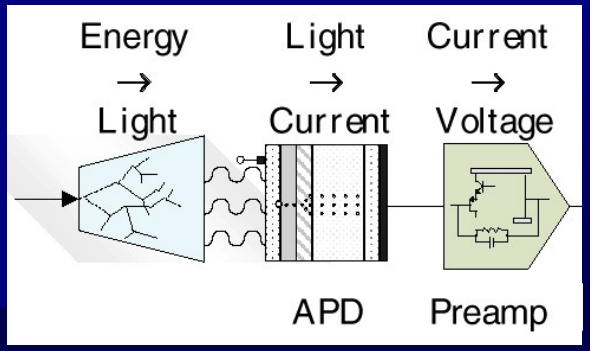
$$\frac{\Delta E}{E} \leq 1\% \quad \text{Energy resolution}$$

Operating conditions:

B=4T, $\Delta T <= 0.1K$

Parameter	Barrel	Endcaps
coverage	$\|\eta\| < 1.48$	$1.48 < \|\eta\| < 3.0$
$\Delta\eta \times \Delta\Phi$	0.0175 x 0.0175	0.021x0.021 to 0.05x0.05
depth in X_0	25.8	23
No. crystals	61200	15632
Modularity	36 Super-modules	4 Dees

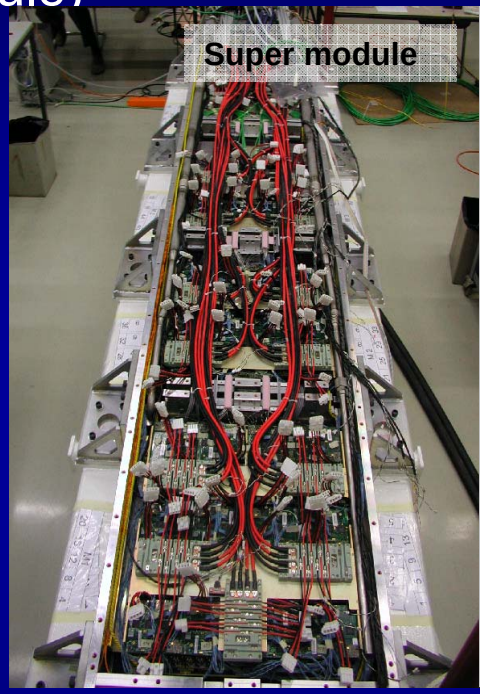
Detection of the scintillation light with B-field insensitive APDs in the barrel and VPT in the forward



CMS ECAL Progress

Crystal Production

- Last barrel crystal received last week (according to schedule)
- Endcap crystal production has started

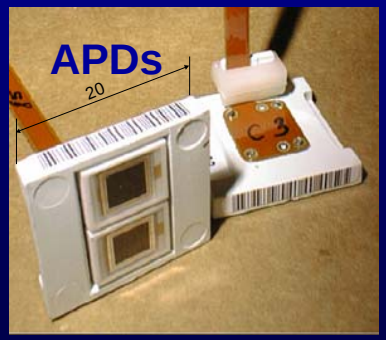


Supermodule Assembly and Integration

- Barrel supermodules integration completed by may'07
- Install last (36th) supermodule June'07
- Assembly of one (forward) Dee is progressing.
- Aim: one Dee for pilot run in 2007
- Complete endcap installation for physics run in 2008.

Readout

- All 130k APDs for barrel readout delivered
- All 15000 VPTs for forward delivered



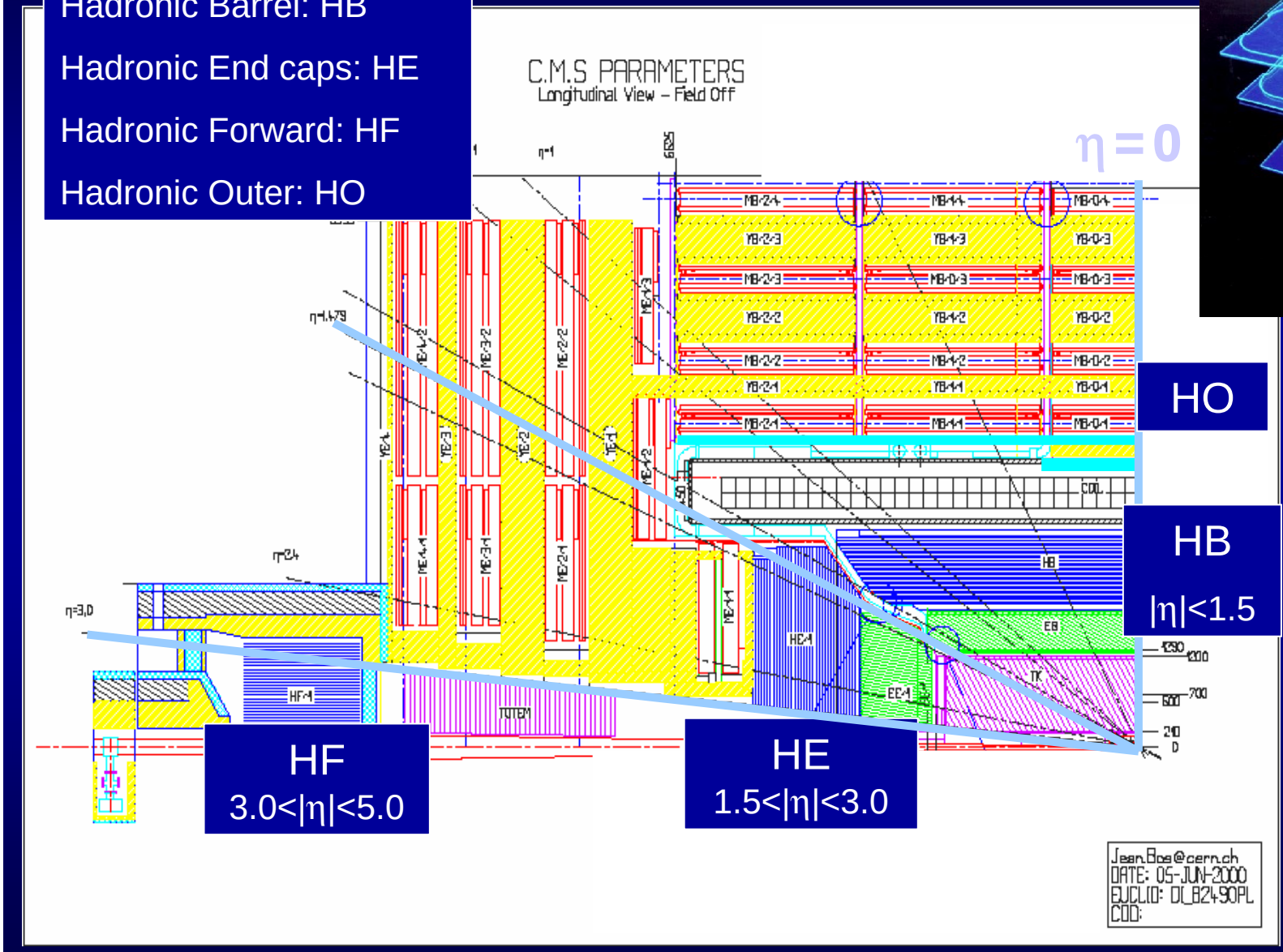
CMS HCAL Components

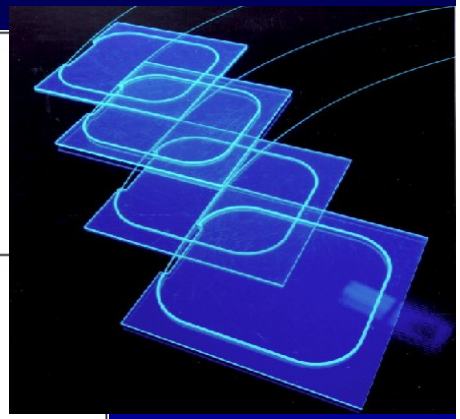
Hadronic Barrel: HB

Hadronic End caps: HE

Hadronic Forward: HF

Hadronic Outer: HO





Sampling tile calorimeter with wavelength shifting fibers

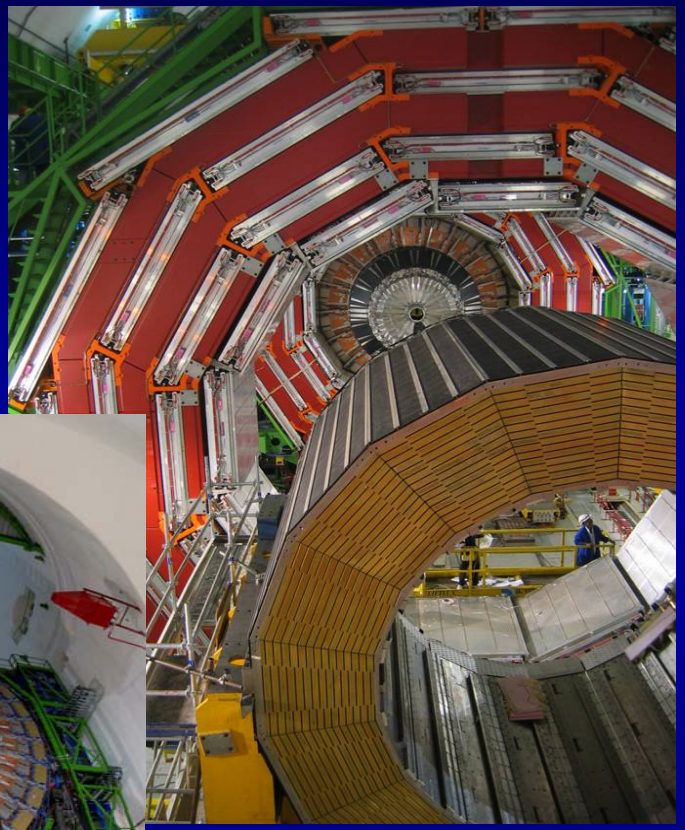
Readout with HPD

CMS HCAL Status

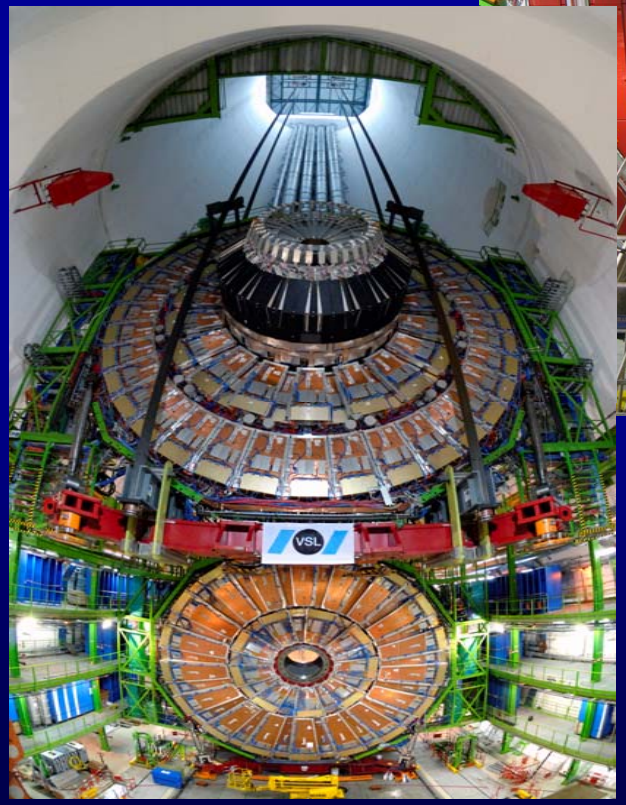
HCAL detectors are ready for many months!

Positive halfs of HCAL barrel and forward have been successfully lowered underground. Negative halfs follow in late Spring 07.

Ongoing work on installation, integration and commissioning



Positive half of the HCAL Barrel in underground cavern. Lowered on 13.02.07



Lowering of the positive HE into the cavern on 09.01.07

Towards CMS Trigger Commissioning

Installation of Trigger Hardware in USC55.

Trigger Subsystems tests (internal). Dec-Jan 07

- Interconnection tests between trigger subsystems in USC55. Mar-Apr 07
- Trigger and TTC control distribution to DAQ and FEDs in USC55. Feb-Apr 07

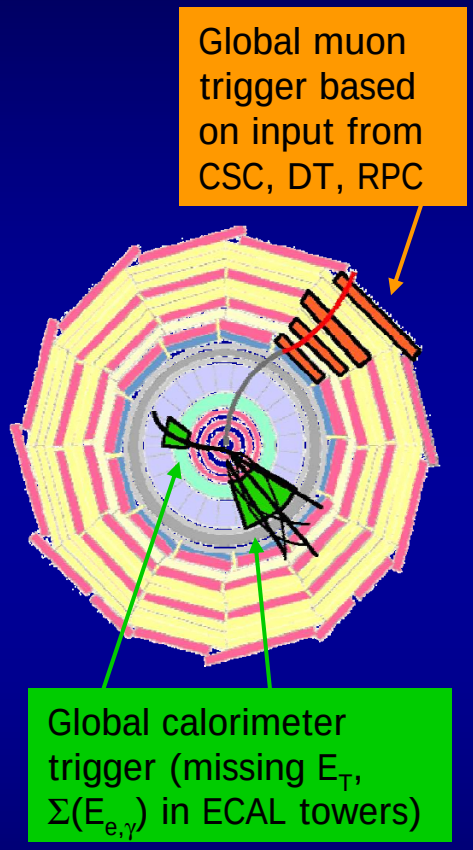
Integration with TPGs as Detectors connected to USC55.

Trigger Slice Tests with cosmics Apr-Aug 07

- Trigger Synchronization and Validation with test patterns. Full Trigger System Commissioning May-Aug 07

Ready for final CMS commissioning in August 07

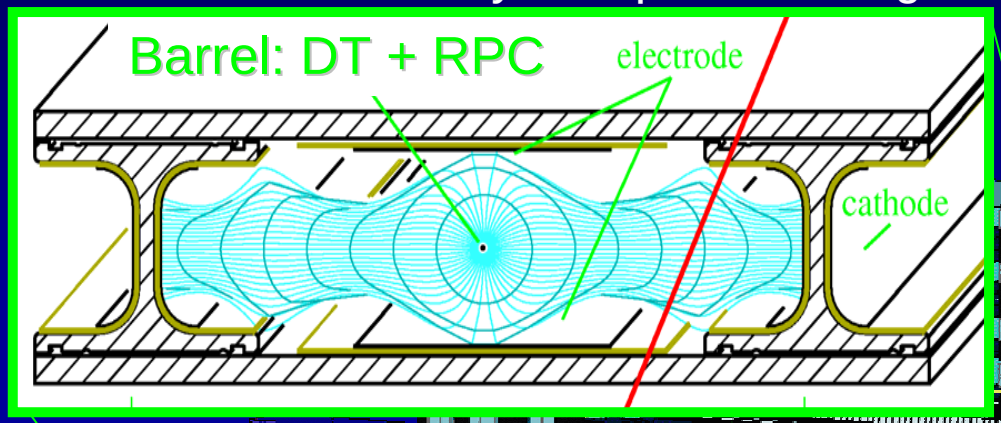
1) First level trigger

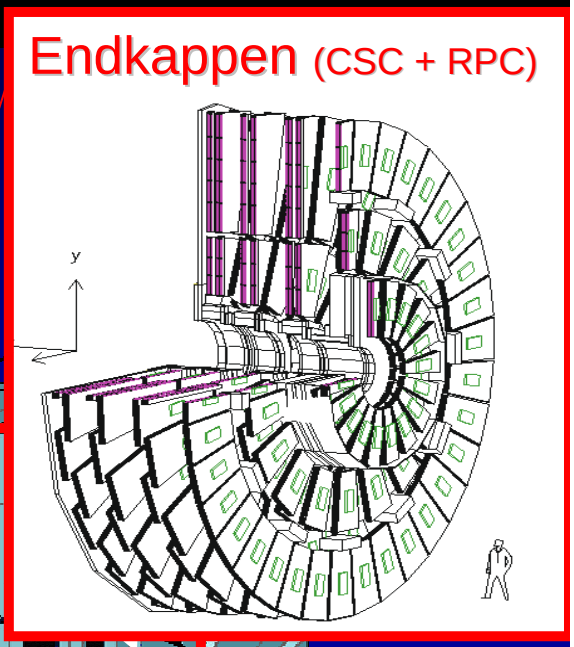


2) High level trigger (reconstruction)

CMS Myon System

- 3 detection technologies for redundancy
- Resolution limited by multiple scattering to ~100 μm

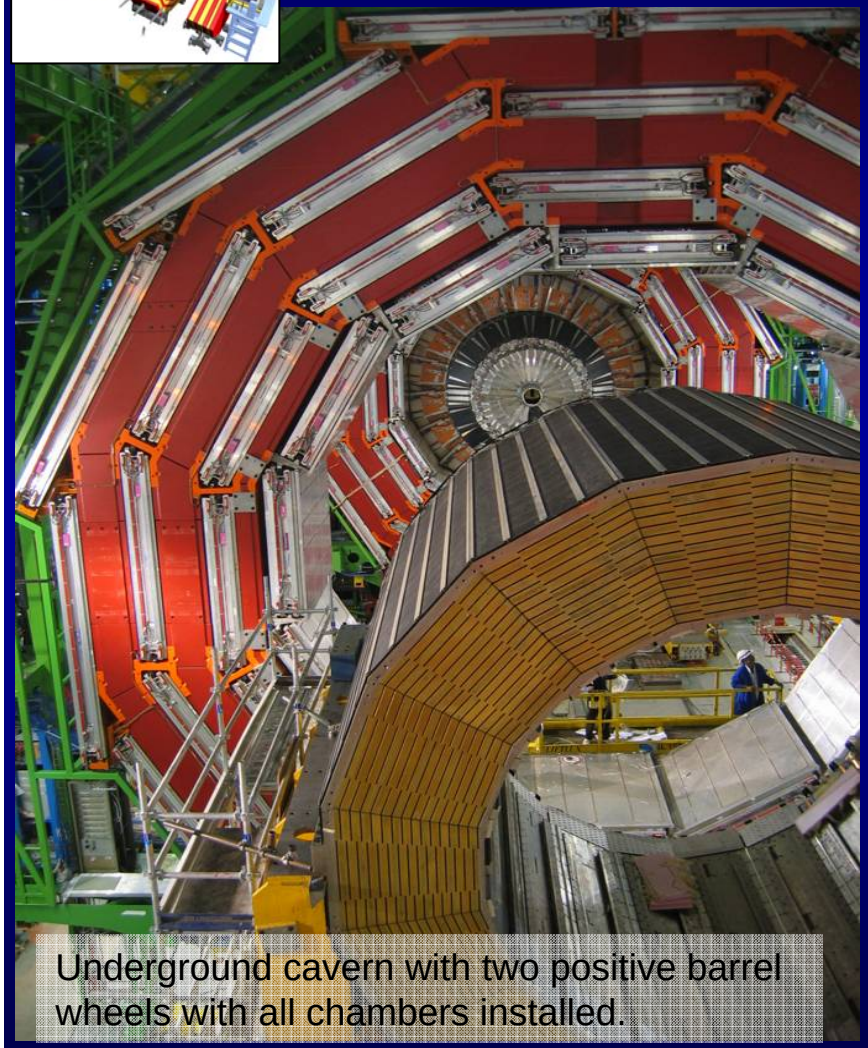




Alignment System

Doppellagige RPC

Barrel Muons: DTs + RPCs



Underground cavern with two positive barrel wheels with all chambers installed.

Installation of DT/RPC packages:

- 85% on surface → completed
- 15% underground → all but 14 chambers
  Can only be done after lowering.

Wheels YB+2,+1,0 successfully lowered

YB-1,-2 ready for lowering April 2007

After lowering:
cabling, system commissioning and integration. Ongoing for 3 underground wheels. Ready for global run May'07

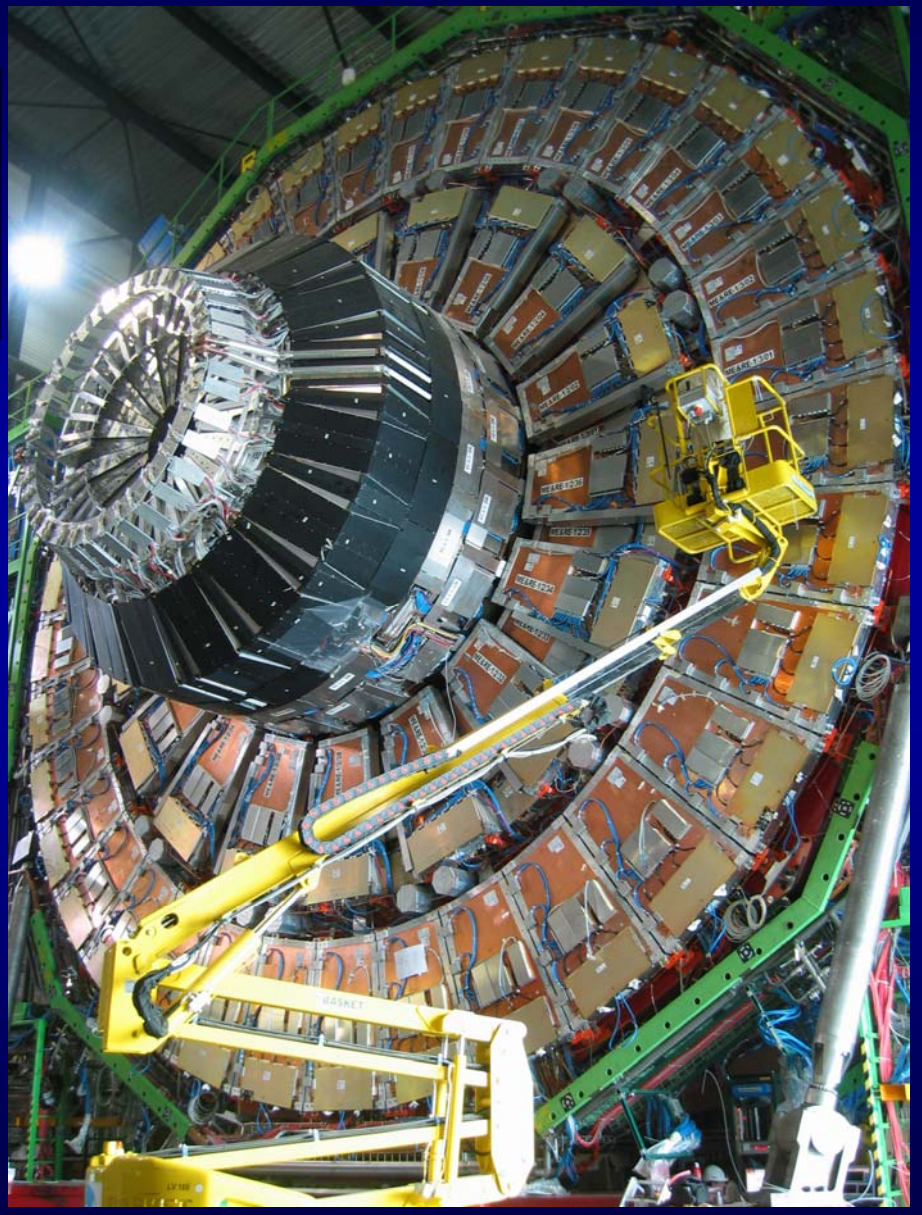
Installation Muon Endcap Chambers

All Endcap Precision Muon Chambers now installed (8 Mar).

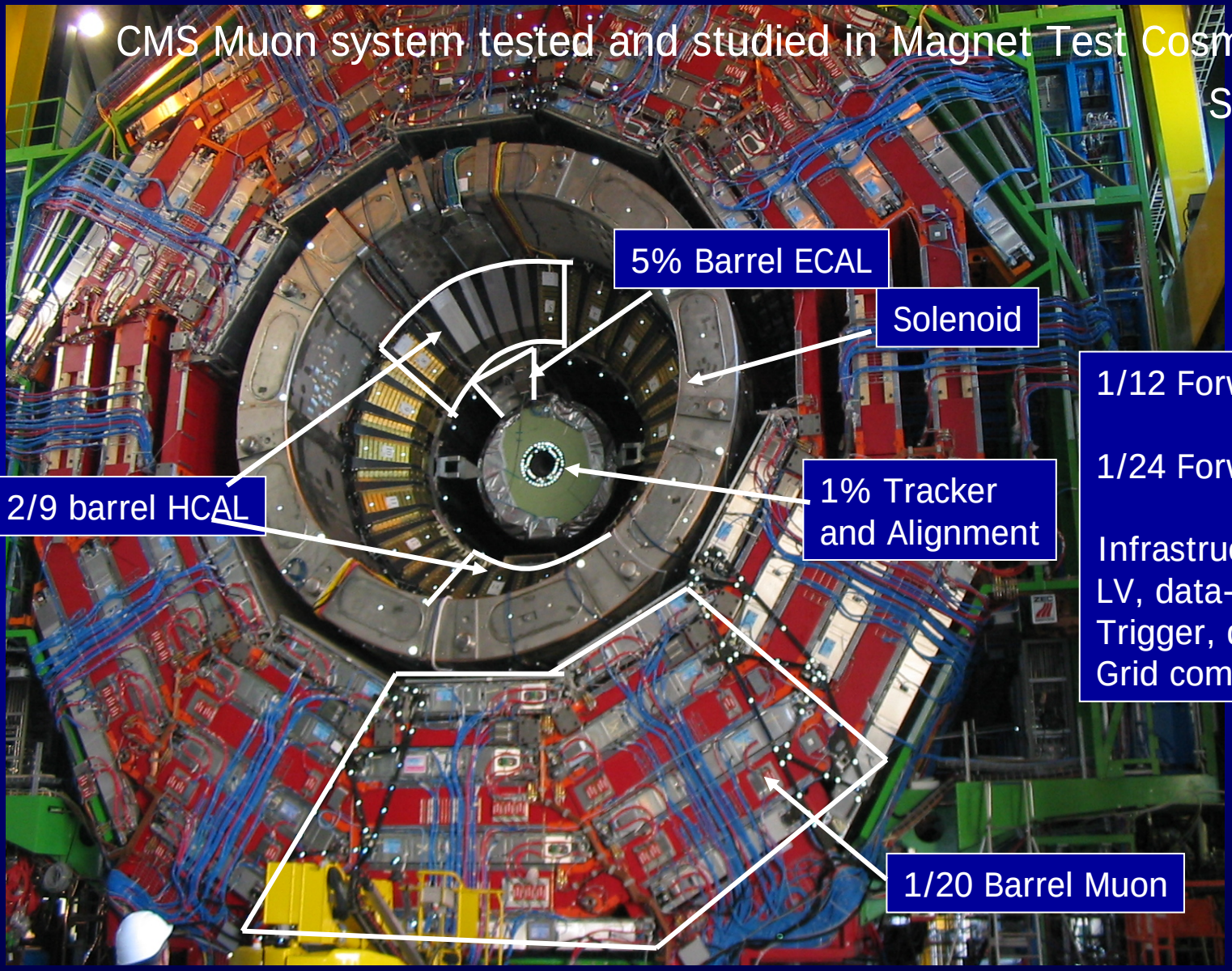
Positive half of muon endcap underground. Commissioning ongoing.

- Available for global run 30 May (YE+1)
- All stations 15 July

Negative disks:
YE-1 ready for lowering 30 June

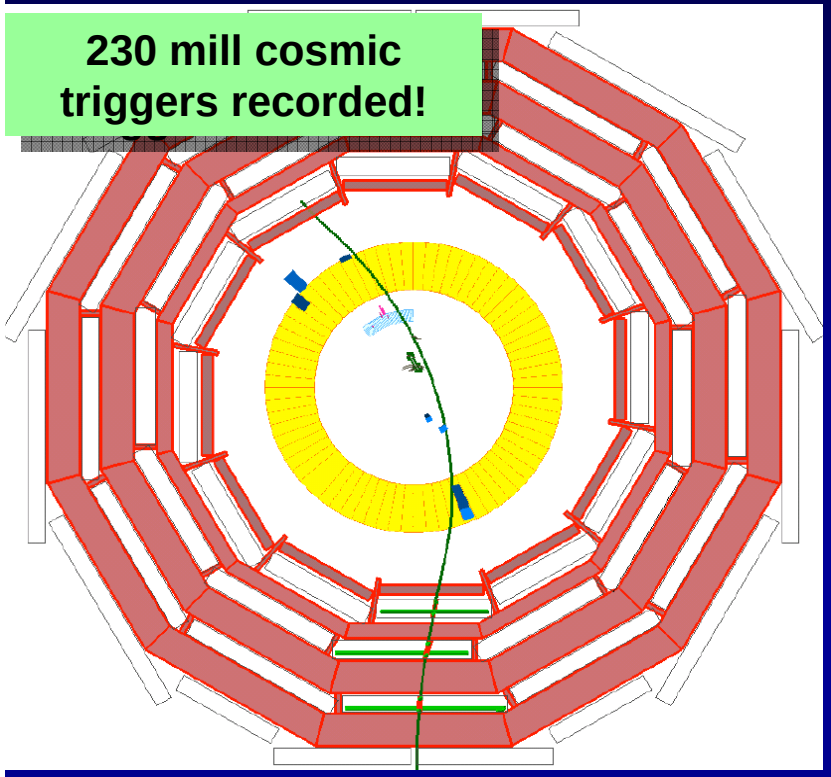


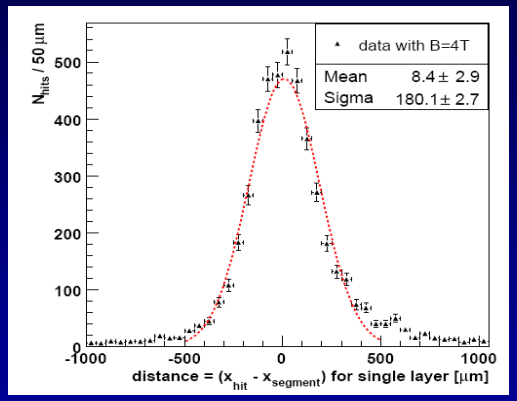
CMS Magnet Test Cosmic Challenge

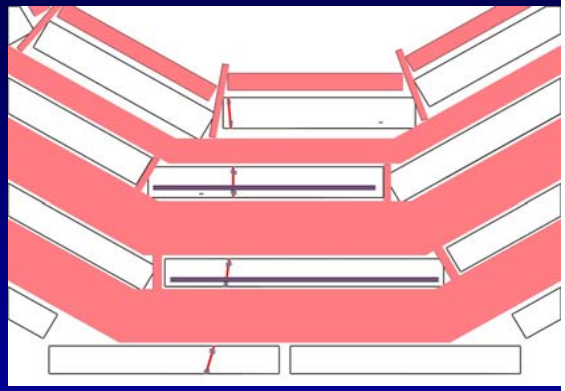


Good Performance of CMS

230 mill cosmic triggers recorded!

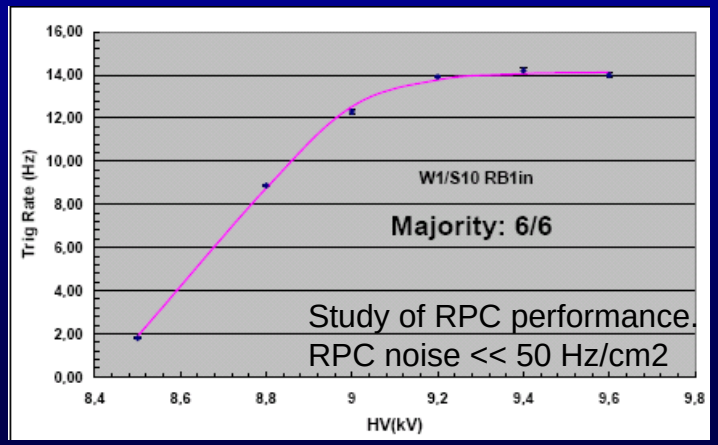




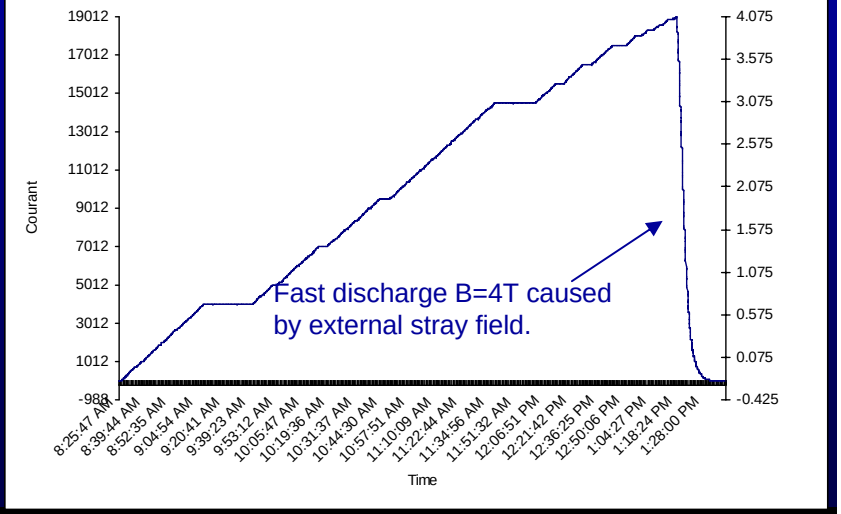


Local reconstruction with 180mum resolution after correction for cosmic timing jitter

Tracking in muon system and combining tracker and muon information works!

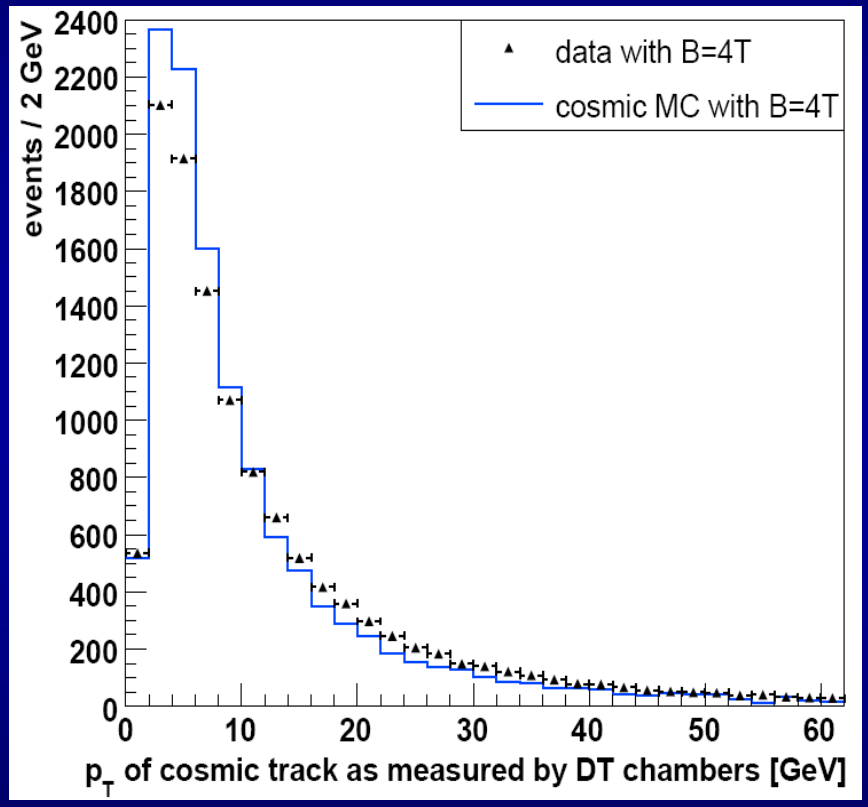


Design B-Field B=4T (on axis) reached 22 Aug. 2006

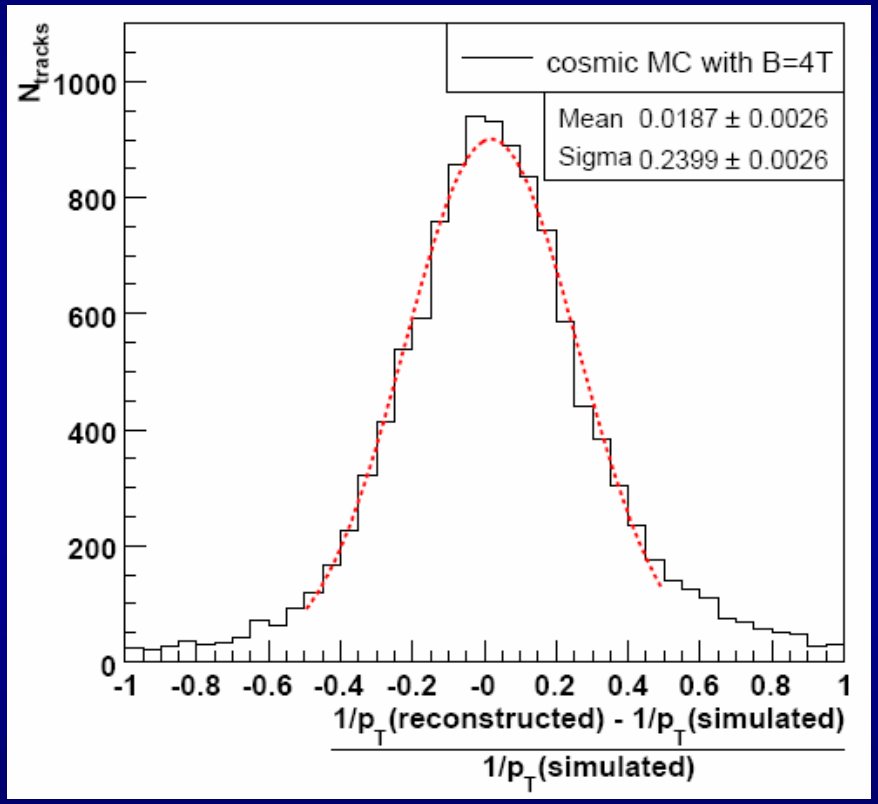


Cosmic Muon Momentum Resolution

Momentum reconstructed for cosmic muons and compared to cosmic simulation. Good agreement!

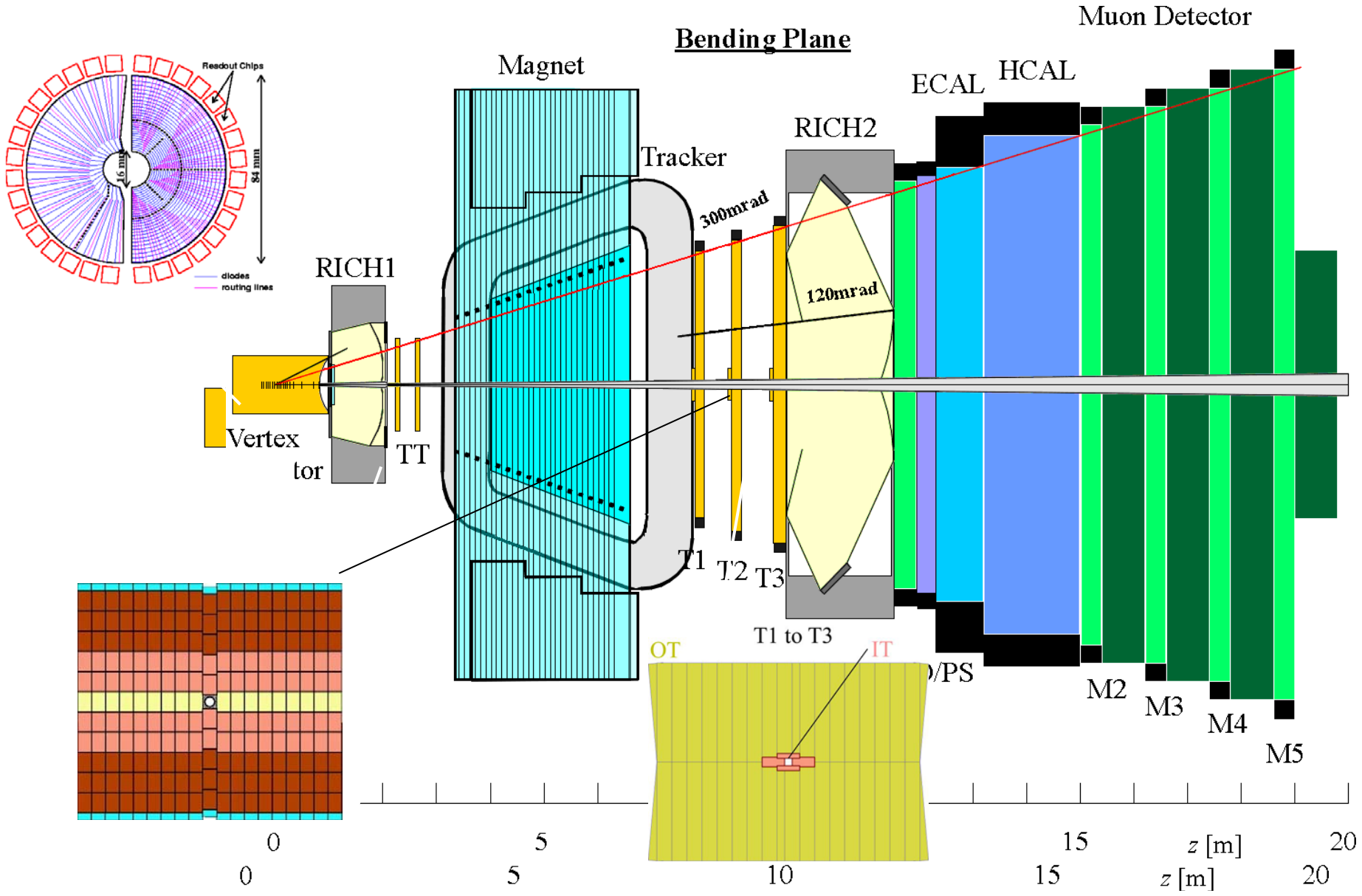


Comparison of momentum spectrum for data and simulation (E_μ>7 GeV)



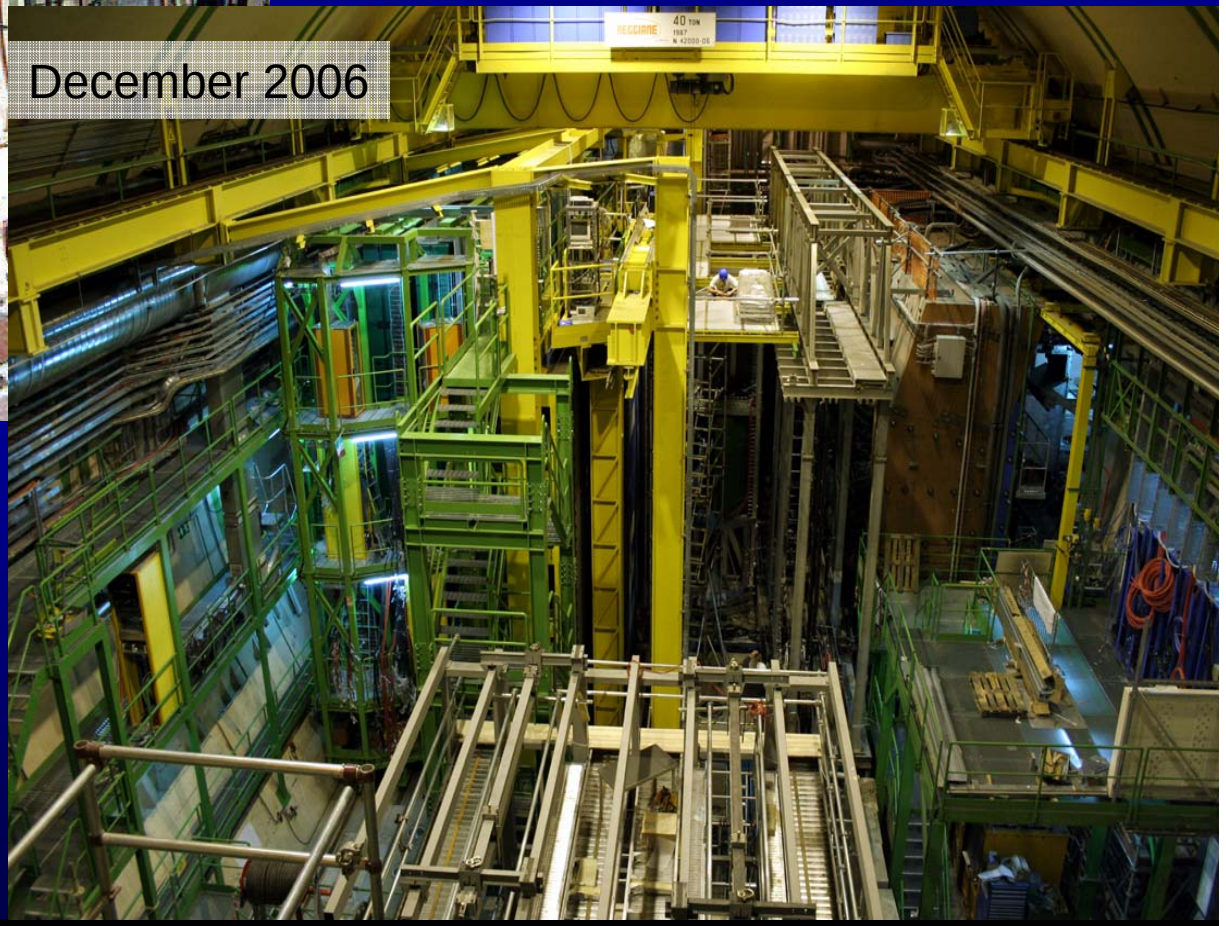
p_T resolution ~24% for cosmic muons. Expect for muons from pp collisions with vertex constraint ~10%

Status of LHCb



Status of LHCb

- Well on its way. Complete installation before machine closes in Aug'07
- Commissioning of the detector, including a 450 GeV pilot run in Nov/Dec



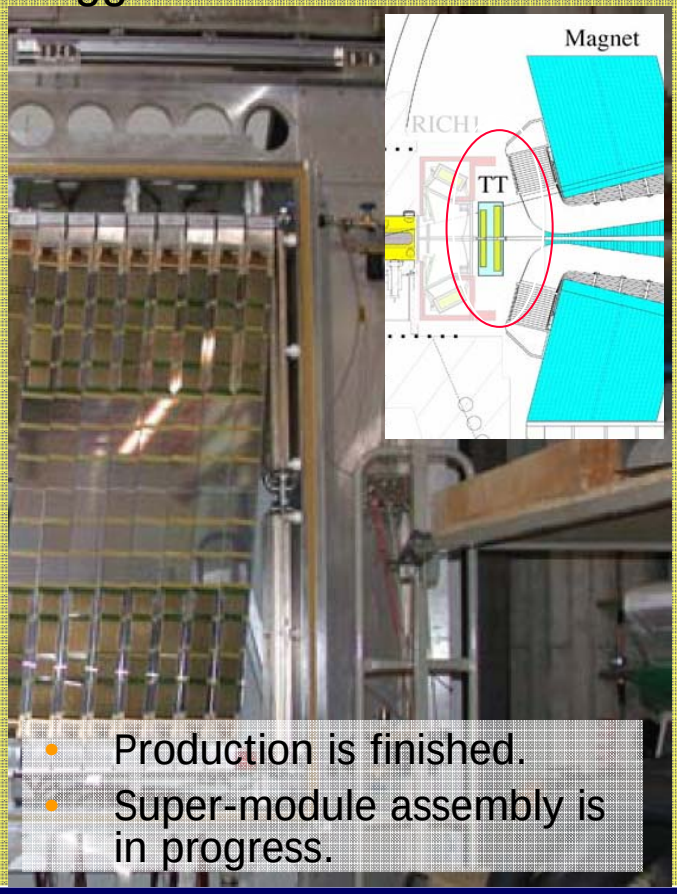
LHCb Tracking System

Production about half done.

- 21 stations, r,ϕ layer each
- 2048 strips/sensor
- Strip pitch varies from 40μm to 100μm

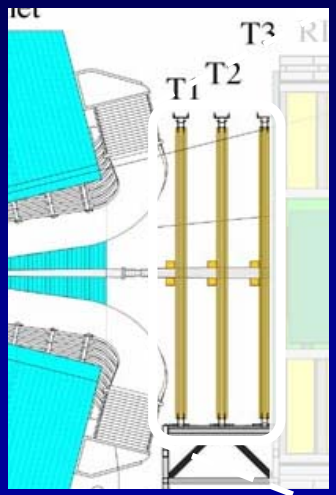
VELO

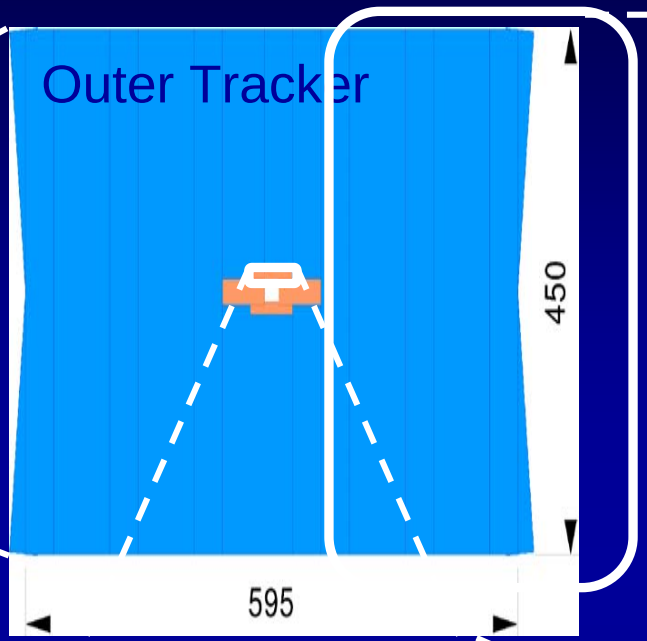
Trigger Tracker

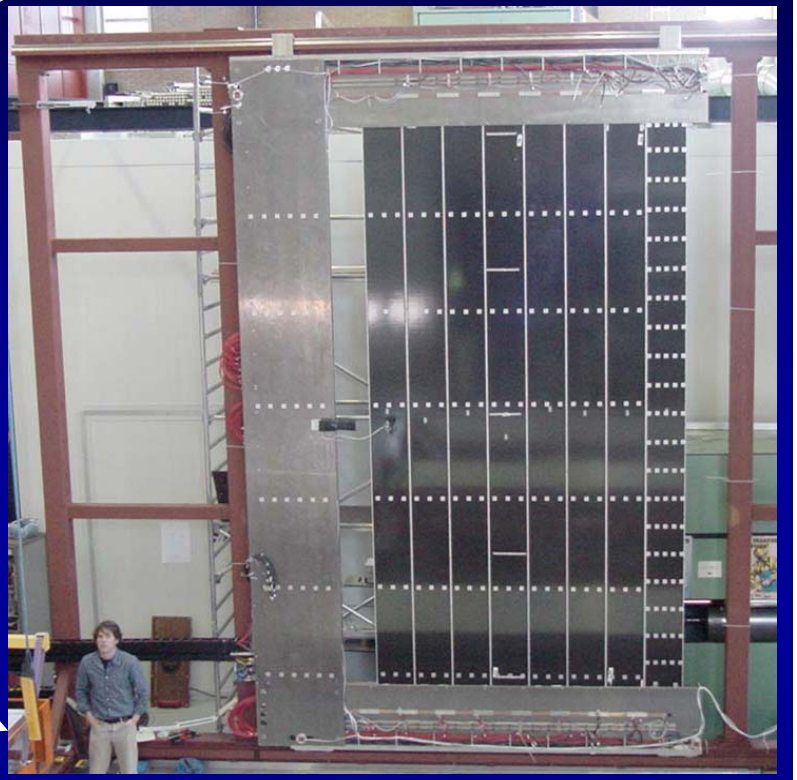


- Production is finished.
- Super-module assembly is in progress.

LHCb Main Tracker







Inner **T**racker:
2% of area
20% of tracks
Silicon strips
11cm long
200 μm pitch
320-410 μm thick

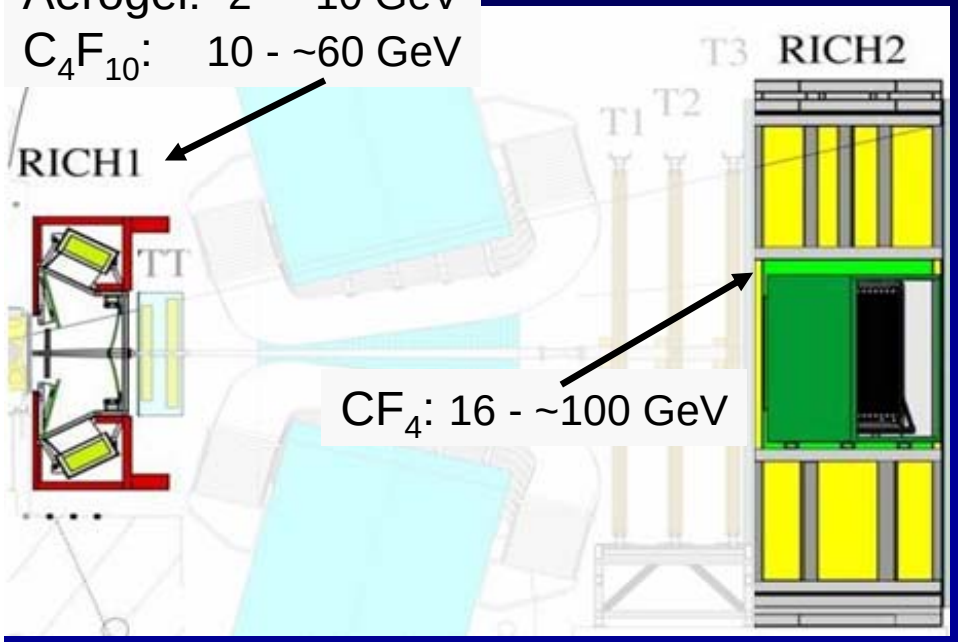
- Sensor-module production finished
- Assembly of boxes in progress

Outer **T**racker:
4 double-layers of Kapton/Al straws

- Production of modules and frames finished
- Installation in progress

LHCb RICH Detectors

Aerogel: 2 - ~10 GeV
C_4F_{10}: 10 - ~60 GeV

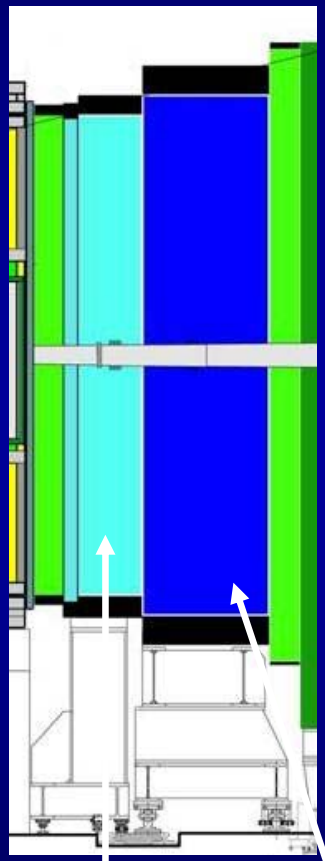


- Novel photo-detector: HPDs with built-in readout chip. Production almost complete.
- Successful test beam of full readout chain in Sept.06.
- RICH2 in place. HPDs are being installed.
- RICH1 gas enclosure installed. Flat mirrors ready.

LHCb Calorimeters

SPD/PS

Scintillating **P**ad
Detector/**P**re**S**hower
Pb/Scintillator, 2.5 X_0



ECAL

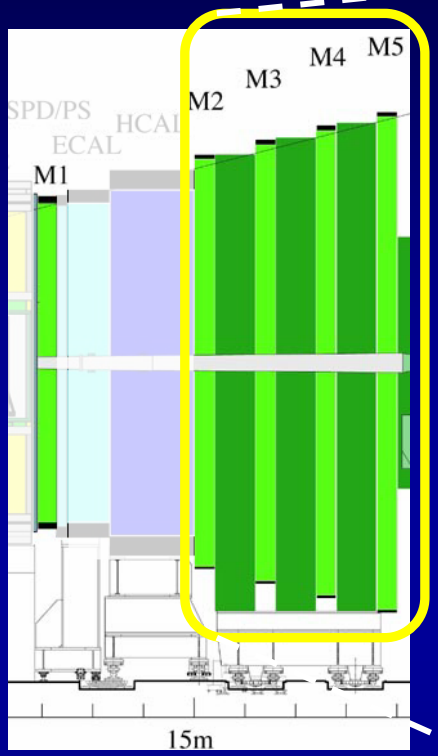
Pb-Scintillator
Shashlik, 25 X_0

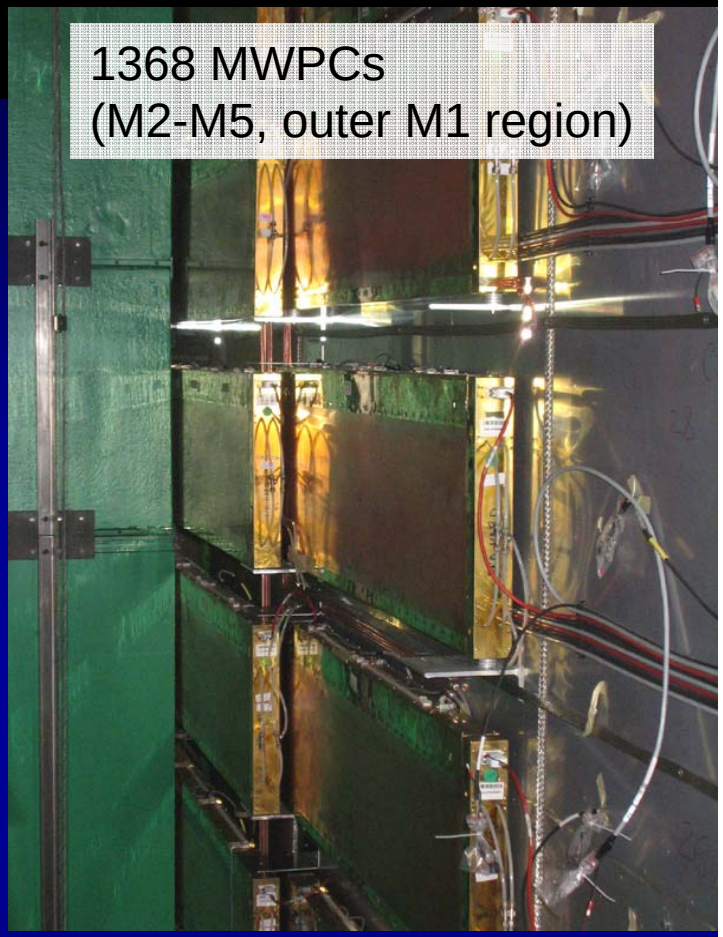
HCAL

Fe/Scintillator
tiles, 5.6 λ_0

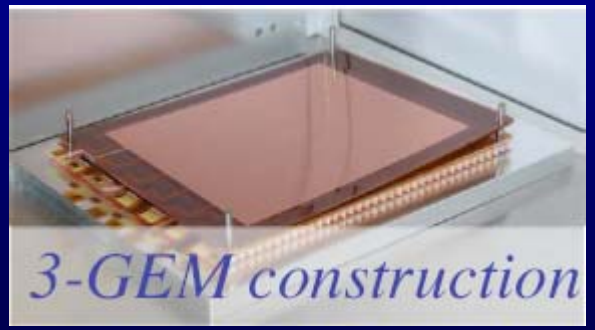
- All calorimeter modules installed (SPD/PS recently)
- Production/installation of readout electronics ongoing.

LHCb Muon system





- MWPCs and GEMs produced.
- Full readout chain with MWPCs and 3-GEMs checked at the test beam.
- Installation in progress.



24 3-GEMs (inner M1 region)

Summary

LHC Start-up Plan:

- End 2007 run with 450 + 450 GeV protons, Collisions for a few days
- In 2008 staged commissioning to reach 7 TeV beam energy
- Pilot run in 2008 for ~1 month

ATLAS

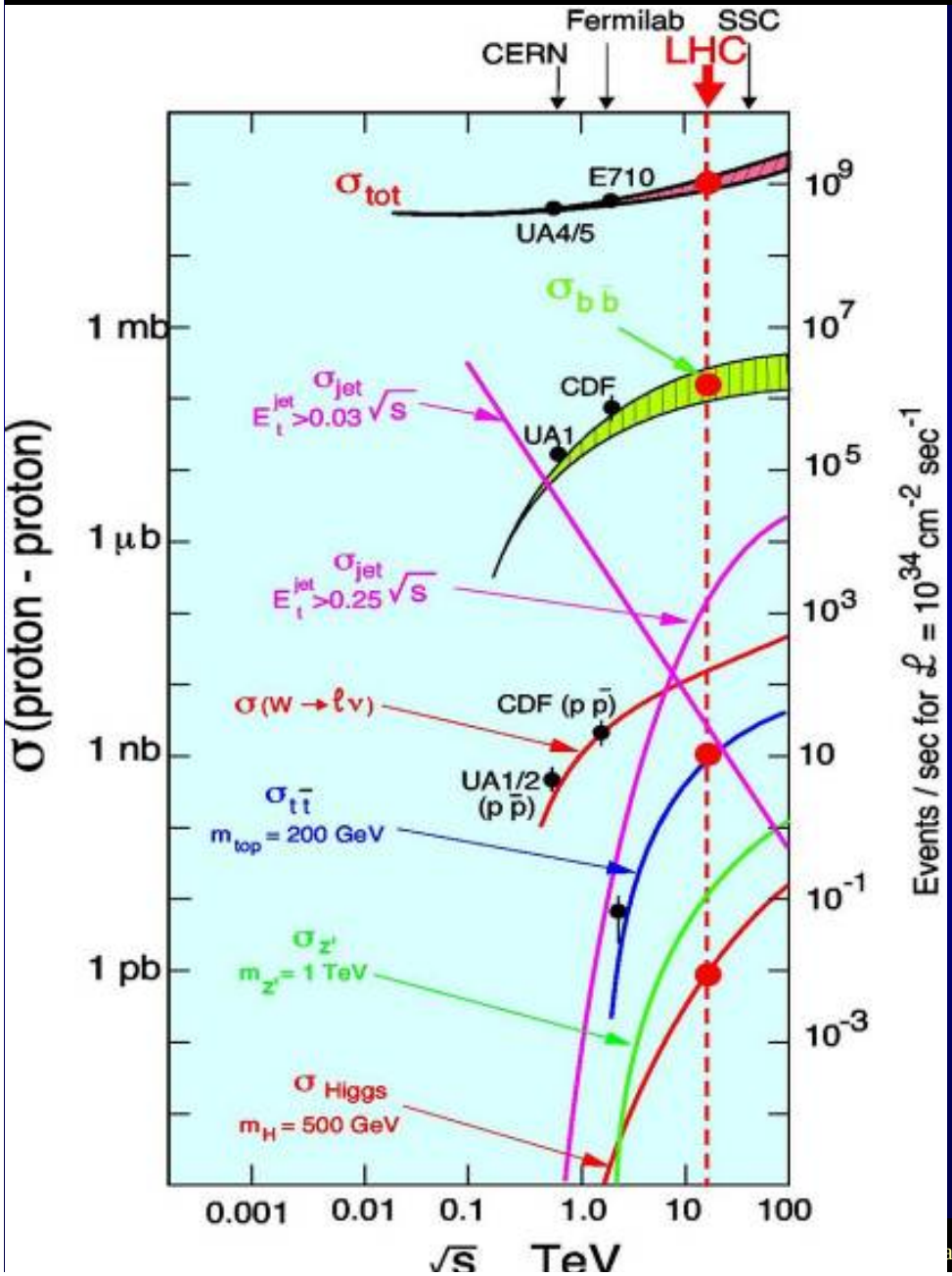
- Installation is progressing well. Start-up detector should be ready be end 2007. Many tests with cosmics progressing with integration.
- Impact of recently observed failure of evaporative cooling system on schedule is under investigation.

CMS

- Initial detector (without ECAL endcaps and pixels) should be ready for 900 GeV running
- Installation of these components in 2007/08 shutdown
- Low luminosity detector ready for 14 TeV running in summer 2008

SPARES

Cross Sections and Production Rates



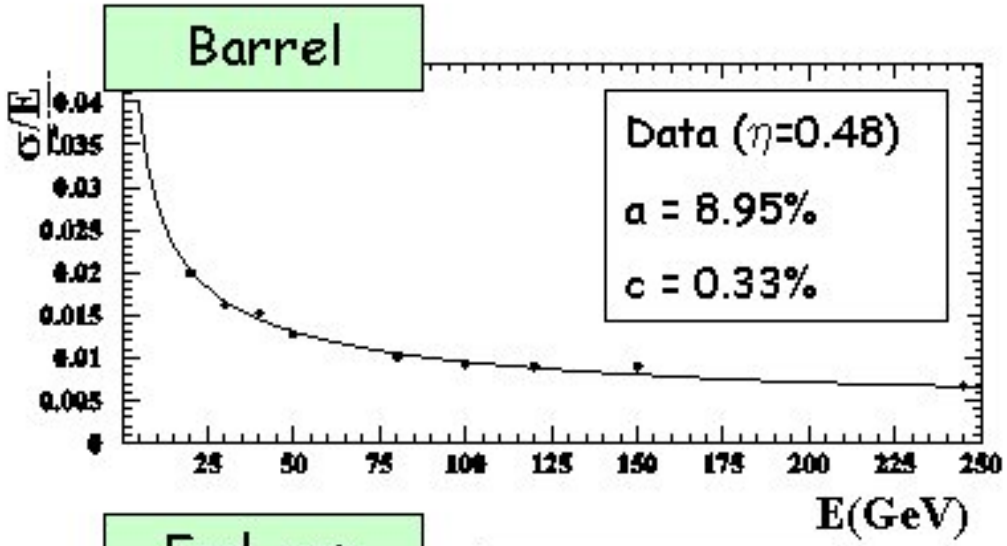
Rates for L = 10^{34} cm^{-2} s^{-1}: (LHC)

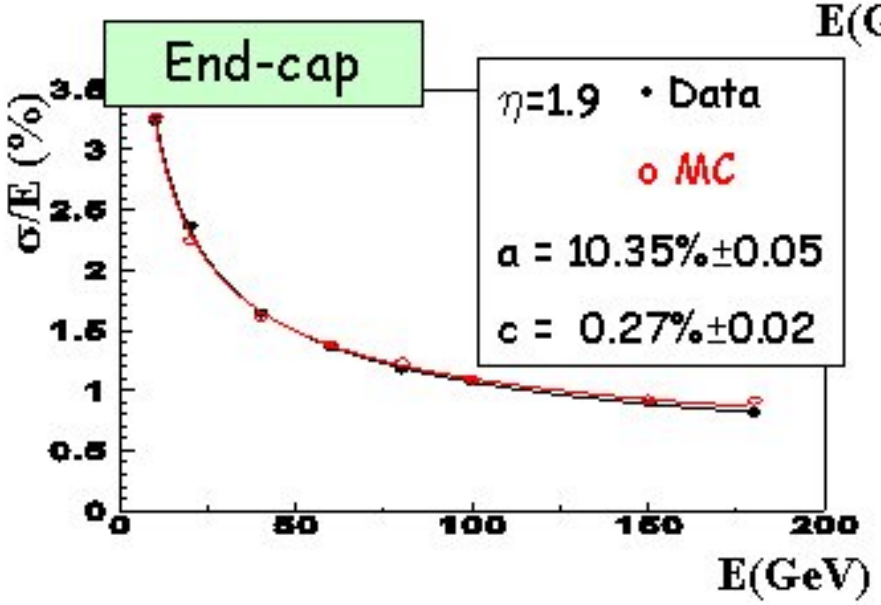
• **Inelastic proton-proton reactions:**	**10^9 / s**
• **bb pairs**	**5 10^6 / s**
• **tt pairs**	**8 / s**
• **W → e ν**	**150 / s**
• **Z → e e**	**15 / s**
• **Higgs (150 GeV)**	**0.2 / s**
• **Gluino, Squarks (1 TeV)**	**0.03 / s**

LHC is a factory for: top-quarks, b-quarks, W, Z, ... Higgs, ...

The challenge: to detect them !

EM Energy Resolution (Testbeam)





$$\sigma_E/E = a/\sqrt{E} \oplus c \oplus n/E$$

For every tested points:

Barrel	End-cap
a < 10%	a < 12.5%
c < 0.4%	c < 0.5%

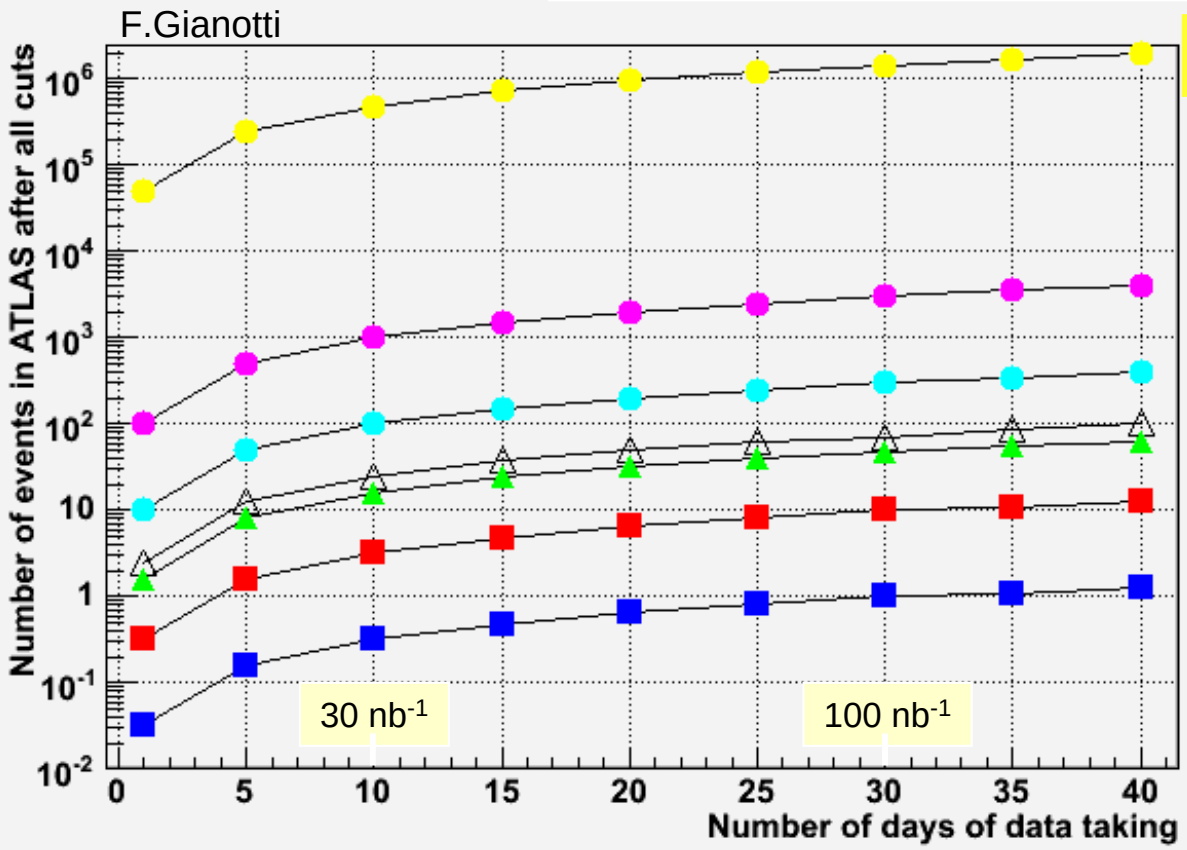
- Within specifications
- Good agreement with MC

Start-Up Data Samples

30% data taking efficiency included (machine plus detector) Trigger and analysis efficiencies included

ATLAS preliminary

$\sqrt{s}$ =900 GeV, L = 10^{29} cm^{-2} s^{-1}



Jets p_T > 15 GeV

(b-jets: ~1.5%)

Jets p_T > 50 GeV

Jets p_T > 70 GeV

$\Upsilon \rightarrow \mu\mu$

$J/\psi \rightarrow \mu\mu$

$W \rightarrow e\nu, \mu\nu$

$Z \rightarrow ee, \mu\mu$

+ 1 million minimum-bias/day

- Start to commission triggers and detectors with collision data (minimum bias, jets, ..) in real LHC environment
- Maybe first physics measurements (minimum-bias, underlying event, QCD jets, …) ?
- Observe a few $W \rightarrow l\nu$, $\Upsilon \rightarrow \mu\mu$, $J/\psi \rightarrow \mu\mu$?

ATLAS and CMS Physics Goals

Search for the Standard Model Higgs boson over ~ 115 < m_H < 1000 GeV

Search for physics beyond the SM (Supersymmetry, q/ℓ compositeness, leptoquarks, W'/Z', heavy q/ℓ, Extra-dimensions, ...) up to the TeV-range

Precise measurements :

-- W mass
-- top mass, couplings and decay properties
-- Higgs mass, spin, couplings (if Higgs found)
-- B-physics (complementing LHCb): CP violation, rare decays, B^0 oscill.
-- QCD jet cross-section and a_s
-- etc. ....

Study of phase transition at high density from hadronic matter to plasma of deconfined quarks and gluons (complementing ALICE).
Transition plasma $\rightarrow$ hadronic matter happened in universe ~ 10^{-5} s after Big Bang

Etc. etc. .....