Detectors at the Large Hadron Collider

a review and a status report

the countdown has started

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Outline

- Detector Design Considerations
- Technical Implementations
- Status & Commissioning Results

Detector Design Considerations

The ‘general purpose’ LHC detectors are radically different from their predecessors at the SppS collider, LEP, SLC, HERA, Tevatron, etc.

They are designed for a **luminosity of 10^{34} $cm^{-2}s^{-1}$** for pp collisions at an **energy of 14 TeV**

Detectors need to be fast, radiation hard (also the electronics) and big

Large Hadron Collider

Luminosity L:
collision rate normalized to cross section 10^{34} cm^{-2}s^{-1}

$$L = \frac{N^2 k_b f \gamma}{4\pi \varepsilon_n \beta^*} F$$

$k_b f$ = 40 MHz: bunch crossing frequency,
i.e. **25 ns between bunches**

Detector Design Considerations

The Large Hadron Collider - experiments

Two 'general purpose' 4π detectors are in preparation

$$\int_0^{2\pi} d\phi \int_{-1}^{1} d\cos\theta = 4\pi$$

pp collisions at high L; some capabilities for PbPb
ATLAS and CMS

One dedicated PbPb detector with some capabilities for pp
ALICE

One dedicated detector for studying B mesons (CP violation; rare decays), prolifically produced in the forward (backward) hemisphere
LHCb

$$\sigma_{b\bar{b}} \approx 500\mu b$$

$$gg \rightarrow b\bar{b}$$

Detector Design Considerations

The Large Hadron Collider - experiments

Furthermore:

precision (1%) measurement of total cross section (and more)
TOTEM (σ_{tot}~100 mb)

$$\sigma_{tot} = \frac{16\pi}{1+\rho^2} \times \frac{(dN/dt)|_{t=0}}{N_{el} + N_{inel}}$$

study of forward production of π^0 s
LHCf (LHC energy equivalent to 10^{17} eV beam on fixed target – cf cosmic rays)

search for magnetic monopoles
Moedal

Detector Design Considerations

Experimental Challenge

High Interaction Rate: $N = L\sigma = 10^{34} \times 100 \times 10^{-27} = 10^9$ Hz

data for only ~100 out of the 40 million crossings can be recorded per sec

Level-1 trigger decision will take ~2-3 μs

⇨ electronics need to store data locally (pipelining)

Large Particle Multiplicity

~ <20> superposed events in each crossing

~ 1000 tracks stream into the detector every 25 ns

need highly granular detectors with good time resolution for low occupancy

⇨ large number of channels

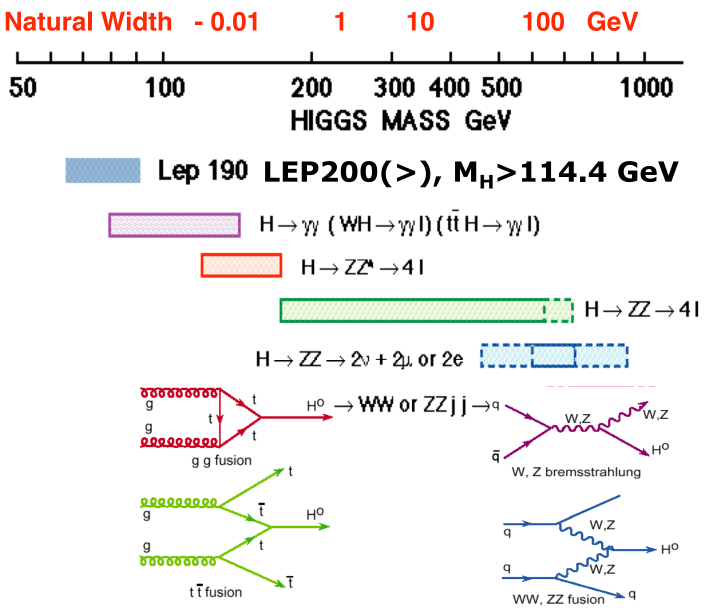
High Radiation Levels

⇨ radiation hard (tolerant) detectors and electronics

Detector Design Considerations

Physics Requirements

At the LHC the SM Higgs provides a good benchmark to test the performance of a detector



Detector Design Considerations

Physics Requirements

Very good muon identification and momentum measurement
trigger efficiently and measure sign of a few TeV muons
momentum resolution 10% at 1 TeV

High energy resolution electromagnetic calorimertry
~ 0.5% @ E_T~50 GeV

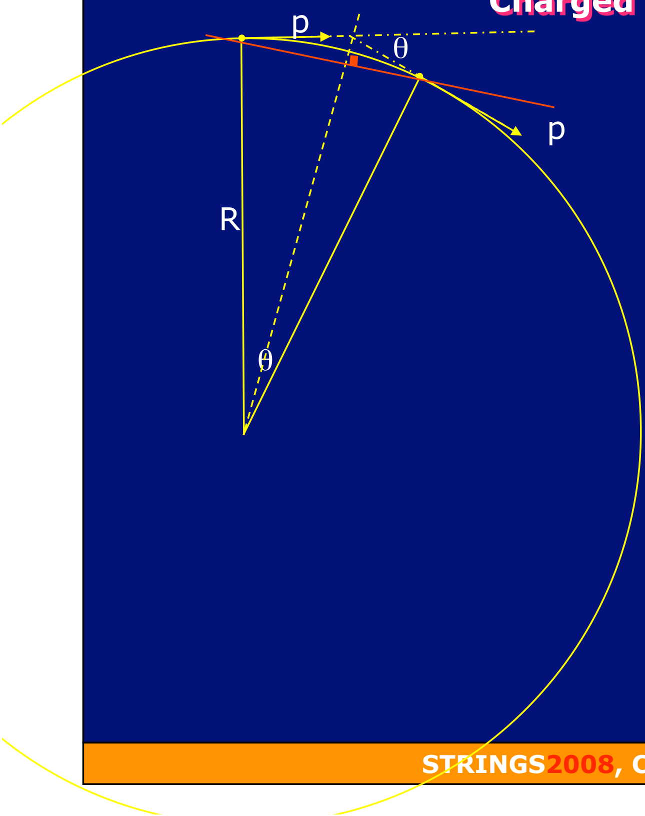
Powerful inner tracking systems
factor 10 better momentum resolution than at LEP

Hermetic calorimetry
good missing E_T resolution

(Affordable detector)

Detector Design Considerations

Charged particle moving in magnetic field B



- Sagitta s

$$s = R - R\cos\frac{\theta}{2} \approx R\theta^2/8$$

$$p = 0.3BR$$

$$L = R\theta$$

$$s = \frac{0.3BL^2}{8p}$$

Units: Tesla, meter, GeV

Detector Design Considerations

Charged particle moving in magnetic field B

Resolution on *s* determines resolution on *p*

$$dp/p = (p/F)ds$$

$$F = 0.3BL^2/8$$

ds depends on resolution tracking devices (technology!)
10 μ (Si) – 100 μ (Drift)

F is also determined by state of the art technology:
large magnets with high fields (superconducting)
1 – 4 Tesla

Large *L* better than high *B*, but the volume of the detector grows as L^3
1 – few Meters

Multiple Scattering

Multiple Coulomb scattering adds an apparent deflection angle, i.e. apparent sagitta

$$\theta_{mlt} = \frac{13.6[\mathrm{MeV}]}{\beta p c} Z \sqrt{\frac{L}{X_0}}$$

$$\left(\frac{dp}{p}\right)_{mlt} \approx 0.05 \frac{1}{B\sqrt{LX_0}}$$

Use light material in trackers

Calorimetry

Energy and position measurement of
- photons, electrons, positrons – electromagnetic calorimetry
  e.m. showers thru Bremsstrahlung, pair creation, etc.
  Energy E ~ N charged 'ionizing' (or generating scintillation, Cerenkov) light.

$$\Delta E / E = k / \sqrt{E} \oplus \ldots$$

k smaller for more samplings (cf. homogeneous calorimeters)

Calorimeter depth determined by radiation length. Approximately:

$$X_0 = \frac{716.4A}{Z(Z+1)\ln(287/\sqrt{Z})}$$

[g cm^{-2}]

Granularity determined by Molière radius (lateral shower size)

$$\rho_M = 21.2 X_0 / \varepsilon_c$$

Calorimetry

- hadrons

Energy resolution scales as for e.m. calorimetry but with *k* typically larger
Calorimeter depth determined by interaction length $\lambda_{\text{int}} \propto 1/\sigma$
Courser granularity than e.m.

- jets

Some examples of materials:

	X_0 [cm]	λ_{int} [cm]
Fe	1.76	16.8
Pb	0.56	17.0
$PbWO_4$	0.89	18.0

Electromagnetic Calorimetry at LHC

In several scenarios moderate mass narrow states decaying into photons or electrons are expected:

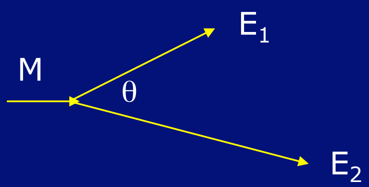
SM : intermediate mass H → γγ, H → Z Z* → 4e
MSSM: h → γγ, H → γγ, H → Z Z* → 4e

In all cases the observed width (cf. signal over background) will be determined by the instrumental mass resolution. Need :

- good e.m. energy resolution
- good photon angular resolution
- good two-shower separation capability

$$M^2 = 2E_1E_2(1-\cos\theta)$$
$$dM/M \propto d\cos\theta/\cos\theta$$
$$dM/M \propto dE/E$$

$$tg(\theta_{min}/2) = M/2(E_1+E_2)$$



Detector Design Considerations

Hadronic Calorimetry at LHC

- **Jet energy resolution**
  - Limited by jet algorithm, fragmentation, magnetic field and energy pileup at high luminosity
  - Can use the width of jet-jet mass distribution as a figure of merit
    - Low p_t jets: W, Z → Jet-Jet, e.g. in top decays
    - High p_t jets: W', Z' → Jet-Jet
  - Fine lateral granularity (≤ 0.1) high p_t W's, Z's
- **Missing transverse energy resolution**
  - Gluino and squark production
    - Forward coverage up to $|\eta| = 5$
    - Hermeticity - minimize cracks and dead areas
    - Absence of tails in the energy distribution is more important than a low value for the stochastic term
  - Good forward coverage is also required to tag processes initiated vector boson fusion

Detector Design Considerations

‘Granularity’, size of read-out ‘cells’

Convenient variable: ‘one particle phase space is uniform in rapidity’

inelastic particle production shows a ‘rapidity plateau’ (from ~-3 to +3 at LHC)

rapidity has a geometrical interpretation → detector ‘granularity’ corresponding to fixed rapidity intervals (and similarly for ϕ, azimuthal angle, intervals) (cf. calorimeter cell size)

$$\mathrm{d}^4 P \delta(E^2 - P^2 - m^2) = \mathrm{d}\vec{P} / E = P_T \mathrm{d}P_T \mathrm{d}\phi \mathrm{d}y$$

$$\mathrm{d}y = \mathrm{d}P_{//} / E$$

→

$$y = \frac{1}{2} \ln \frac{E + p_{//}}{E - p_{//}}$$

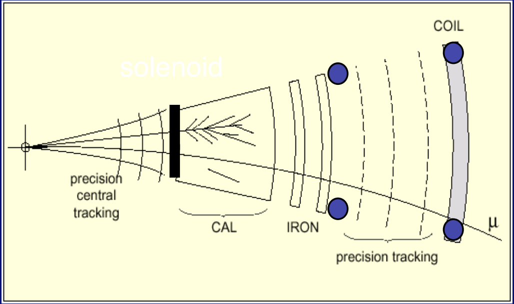
For *E*>>*m* : $y \approx \eta = -\ln \tan\theta / 2$

Detector Design Considerations

Muon spectrometers

1 TeV muon to be measured with 10% resolution

Complementary Conception

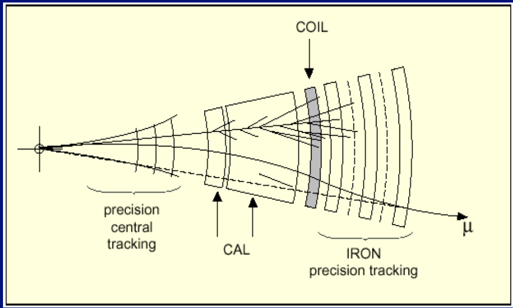


ATLAS

Standalone μ momentum measurement; safe for high multiplicities;

Air-core toroid

Property: σ_p flat with η



CMS

Measurement of momentum in tracker and B return flux;

Solenoid with Fe flux return

Property: muon tracks point back to vertex

Tracking at LHC

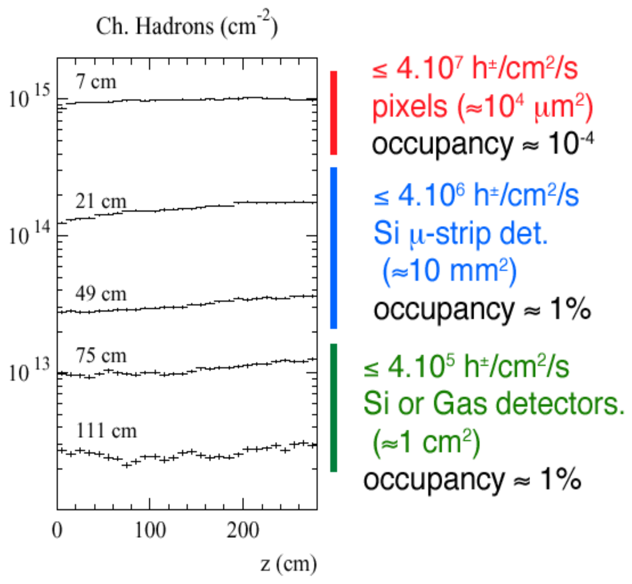
Factors that determine performance

Track finding efficiency – occupancy

Momentum resolution

Secondary vertex reconstruction

Fluence over 10 years



Detector Implementations

Very recently published in Journal of Instrumentation (JINST):

The CERN Large Hadron Collider: Accelerator and Experiments

LHC Machine
Lyndon Evans and Philip Bryant (editors)
2008 JINST 3 S08001

The ALICE experiment at the CERN LHC
The ALICE Collaboration, K Aamodt *et al*
2008 JINST 3 S08002

The ATLAS Experiment at the CERN Large Hadron Collider
The ATLAS Collaboration, G Aad *et al*
2008 JINST 3 S08003

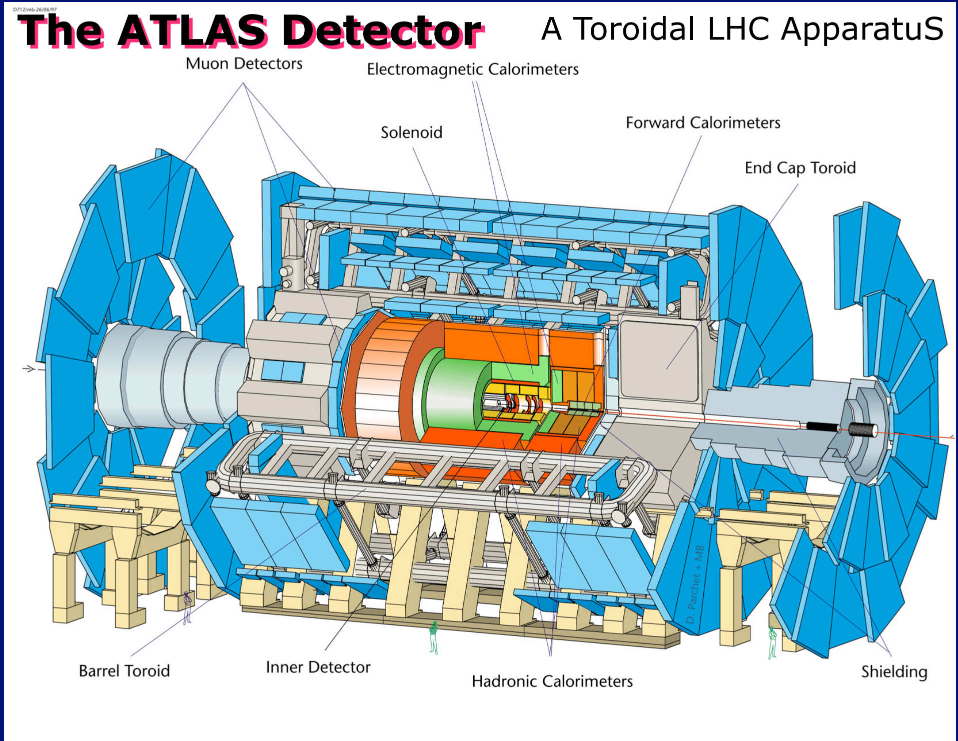
The CMS experiment at the CERN LHC
The CMS Collaboration, S Chatrchyan *et al*
2008 JINST 3 S08004

The LHCb Detector at the LHC
The LHCb Collaboration, A Augusto Alves Jr *et al*
2008 JINST 3 S08005

The LHCf detector at the CERN Large Hadron Collider
The LHCf Collaboration, O Adriani *et al*
2008 JINST 3 S08006

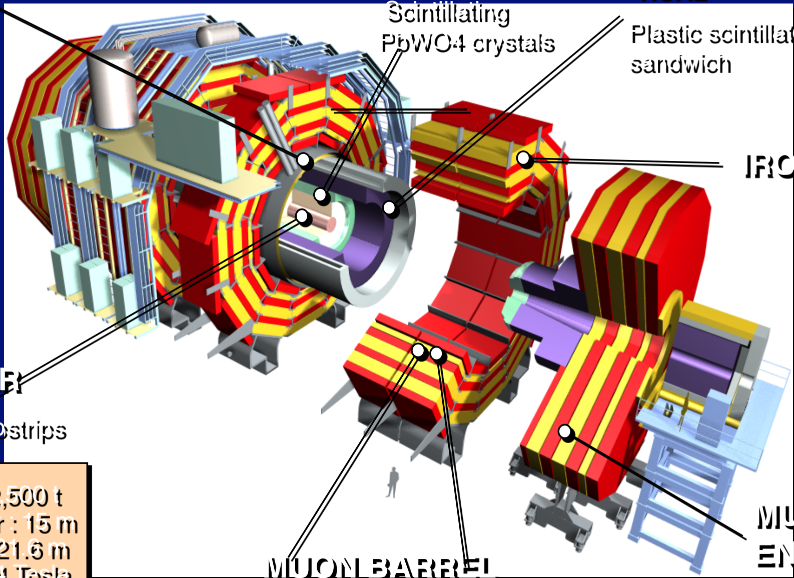
The TOTEM Experiment at the CERN Large Hadron Collider
The TOTEM Collaboration, G Anelli *et al*
2008 JINST 3 S08007

Detector Implementations



Detector Implementations

The CMS Detector



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

Detector Implementations

ATLAS

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

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

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

CMS

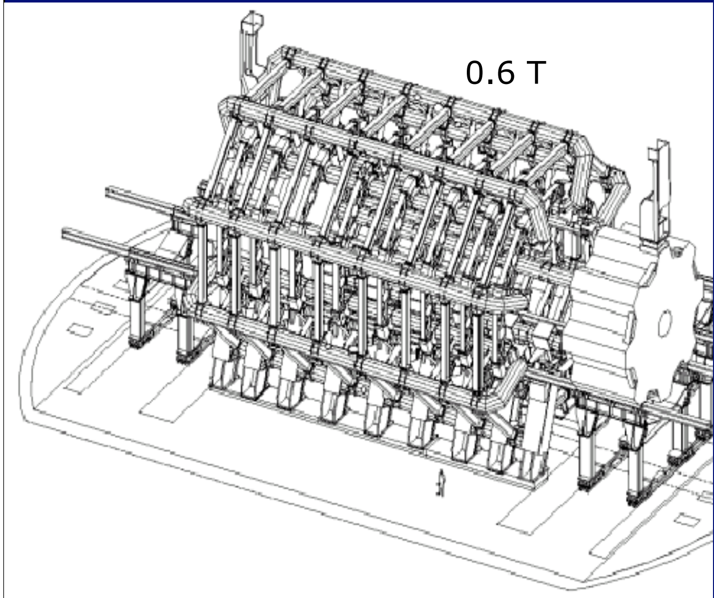
Tracking ($|\eta|<2.5$, B=4T) : Si pixels and strips

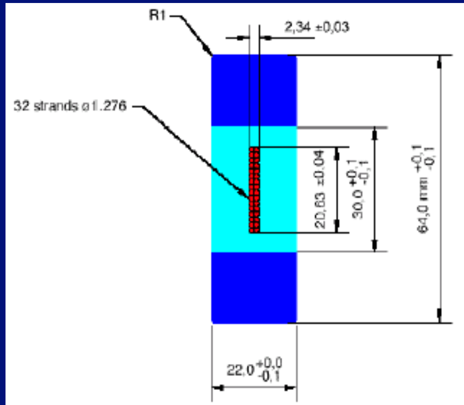
Calorimetry ($|\eta|<5$) :
- -- EM : PbWO4 crystals
- -- HAD: brass-scintillator (central+ end-cap), Fe-Quartz (fwd)

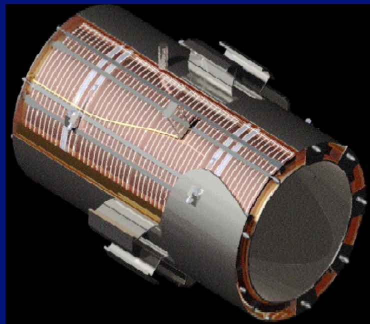
Muon Spectrometer ($|\eta|<2.5$) : return yoke of solenoid instrumented with muon chambers

Magnets 20 kA s.c.; GJ's stored energy

ATLAS unique objects!







CMS

4 T

Status - Commissioning

From talks at ICHEP2008 by

Martine Bosman (ATLAS)

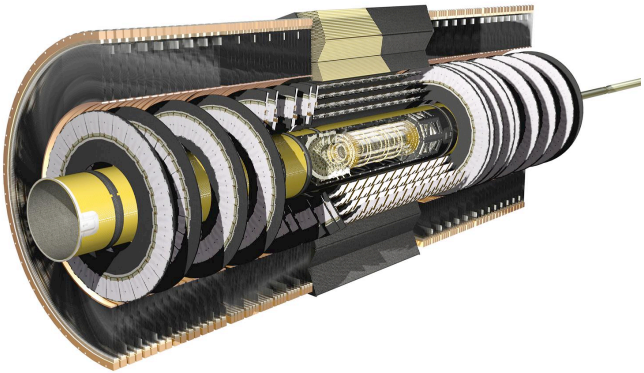
and

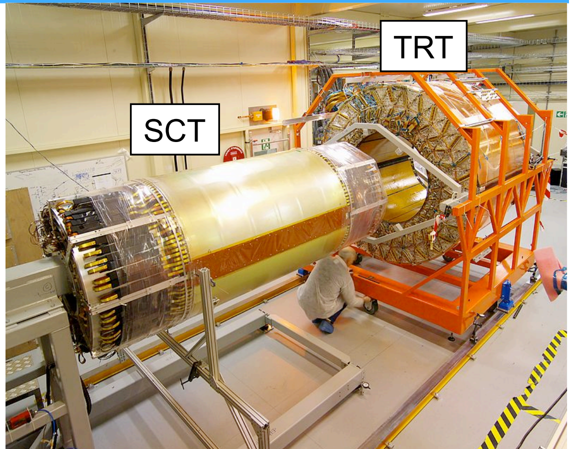
Austin Ball (CMS)

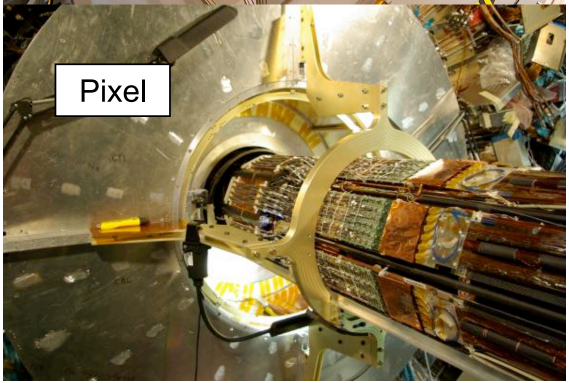
I have made a selection, impossible to be even nearly complete in finite amount of time; even after selection I may have to skip some of the material 'on the fly'

Inner Detector

Tracking **|η|<2.5** **B=2T**





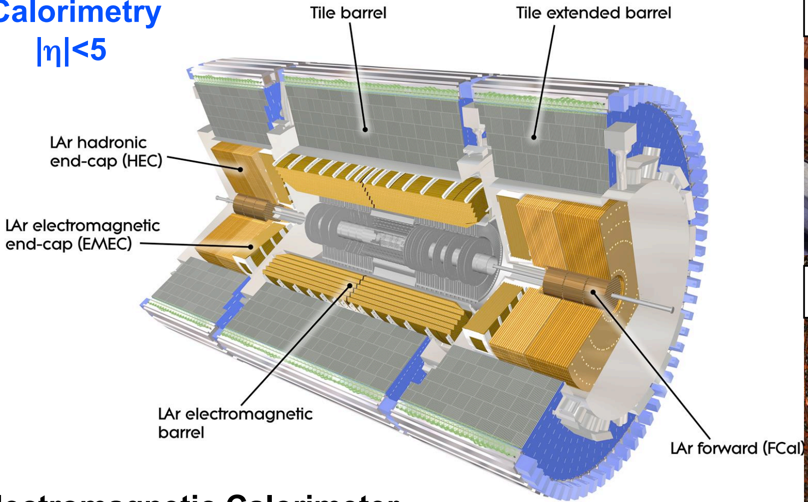


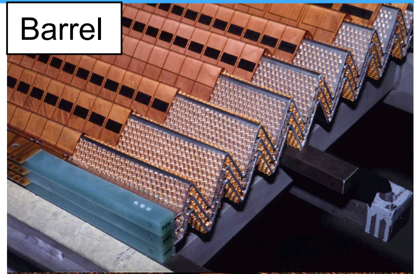
Silicon pixels (**Pixel**): 0.8 10^8 channels
Silicon strips (**SCT**) : 6 10^6 channels
Transition Radiation Tracker (**TRT**) :
straw tubes (Xe), 4 10^5 channels
e/π separation

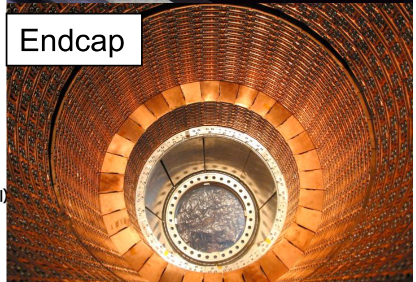
$$\sigma/p_T \sim 5\times10^{-4}\, p_T \oplus 0.01$$

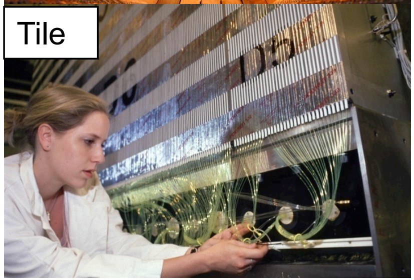
Calorimetry

Calorimetry
|η|<5





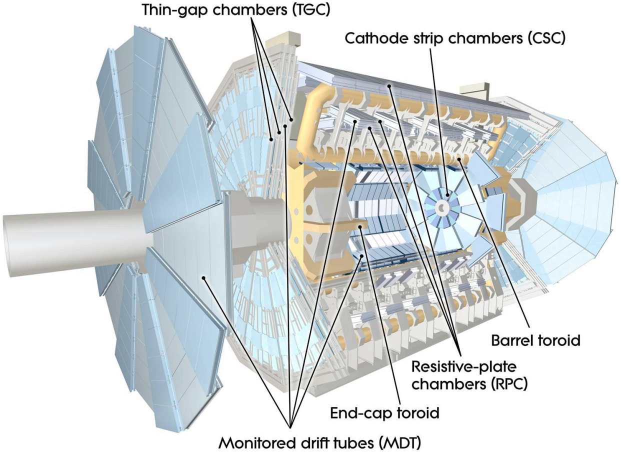




Electromagnetic Calorimeter
barrel,endcap: Pb-LAr
~10%/√E energy resolution e/γ
180000 channels: longitudinal segmentation
Hadron Calorimeter
barrel Iron-Tile EC/Fwd Cu/W-LAr (~20000 channels)
$\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$ pion (10 λ)

Trigger for **e/γ** , **jets, Missing E_T**

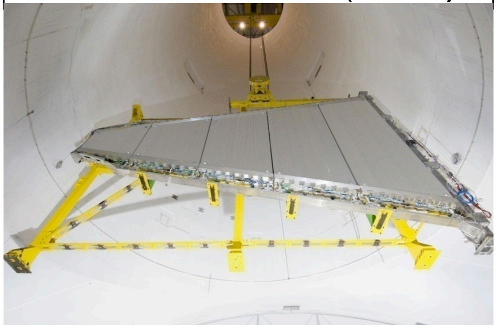
Muon System

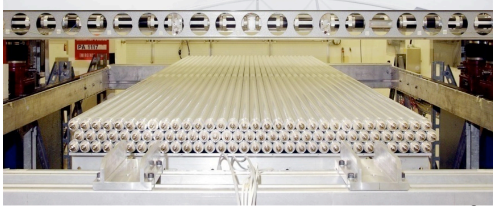


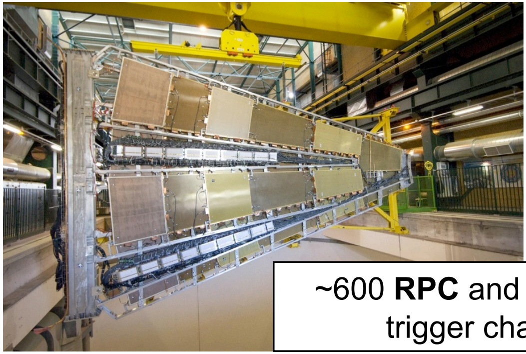
Stand-alone momentum resolution
Δpt/pt < 10% up to 1 TeV

2-6 Tm |η|<1.3   4-8 Tm 1.6<|η|<2.7

~1200 **MDT** precision chambers for track reconstruction (+ **CSC)**

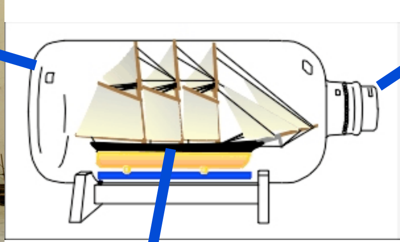






~600 **RPC** and ~3600 **TGC** trigger chambers

short history of the construction & installation

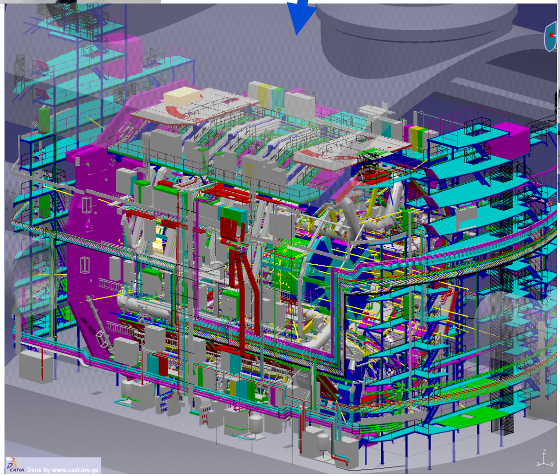


JUNE 2003

Cavern

92m underground

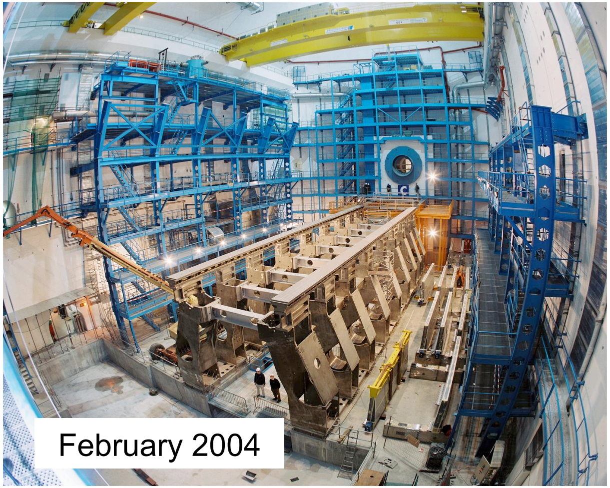
55m long
32m wide
35m high

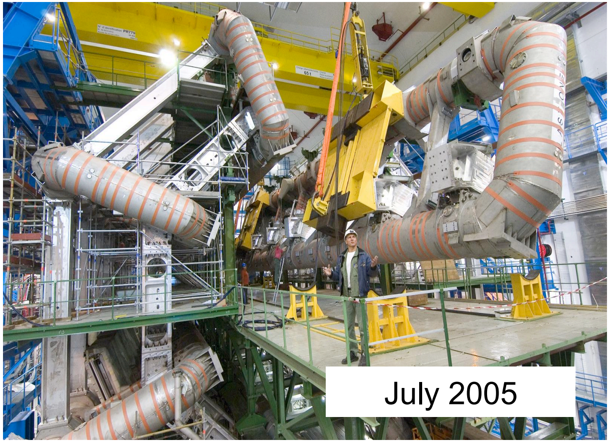


Today

ATLAS

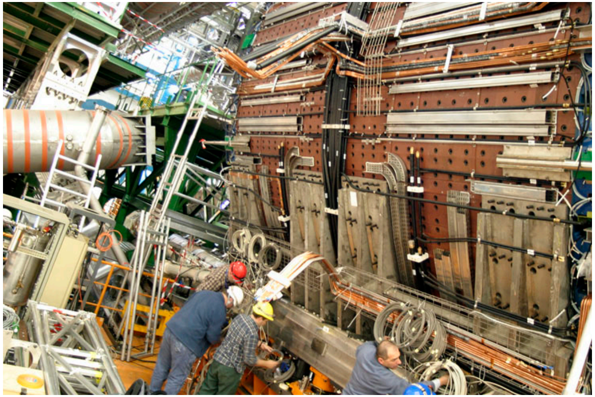
is built


February 2004

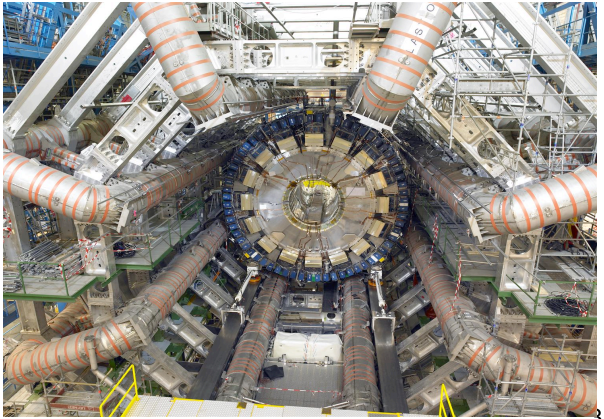

July 2005

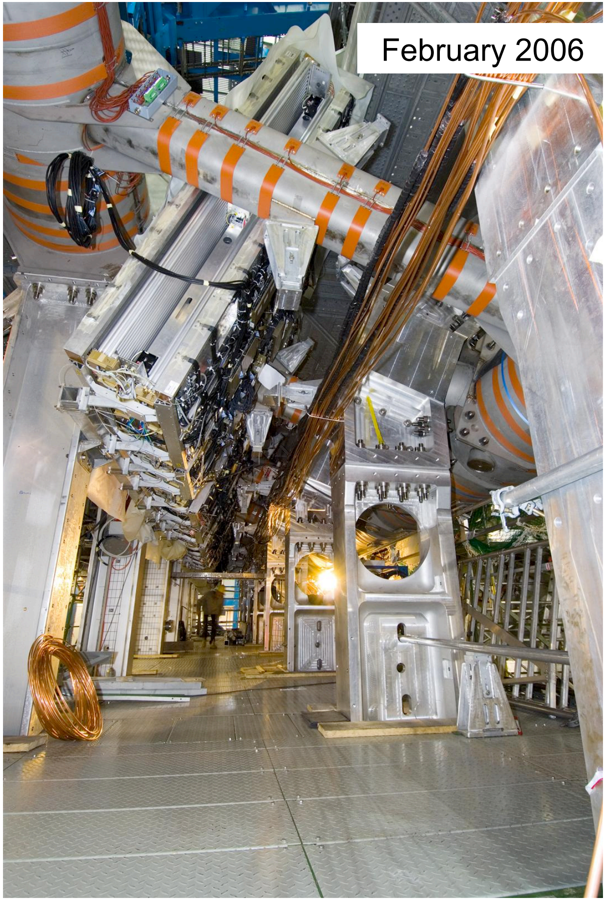

October 2004

October 2004

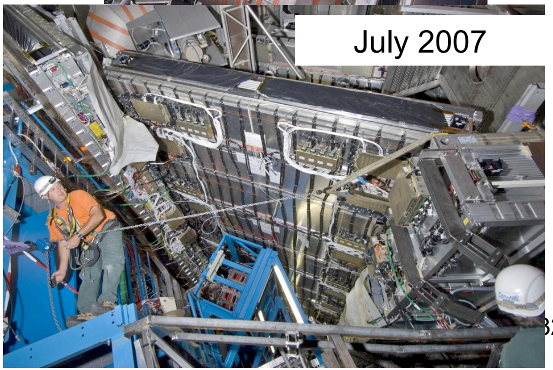


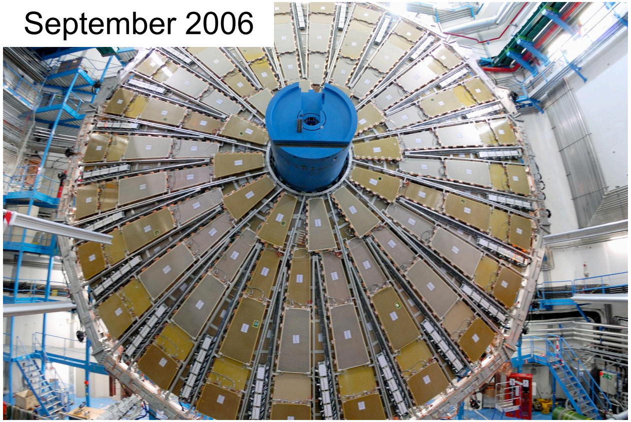
November 2005




February 2006


October 2006


July 2007


September 2006


February 2008


September 2007

A historical moment

Closure of the LHC beam pipe ring on 16th June (the last piece was the one shown here in ATLAS)

Hardware Readiness

- All hardware is essentially ready and installed – very few dead channels – some refurbishment was necessary
- Beam pipe baked out
- Magnet system tested (central solenoid – 8 barrel toroids – 2 x 8 end-cap toroids

Trigger / DAQ

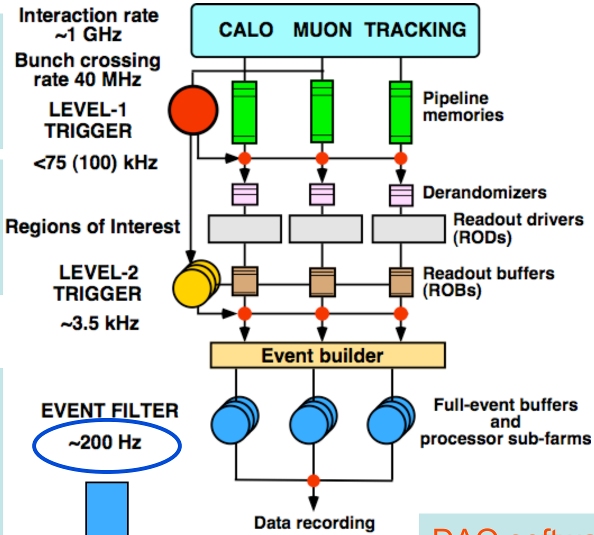
Custom Hardware

Level-1 Trigger
Calorimeter
Muon System

Region of Interest Builder
e/γ, μ, jet, ..

PC Farms

High-Level Trigger
850 nodes farms
High bandwidth
Data Network



300 MByte/s
to Computer Center
.. Pbytes stored / year

Detector

Front End Electronics

Readout Drivers

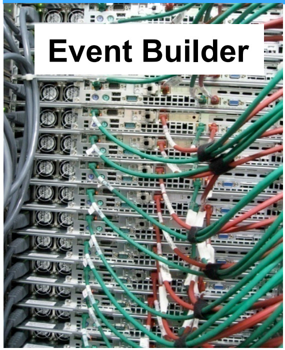
PC Farms

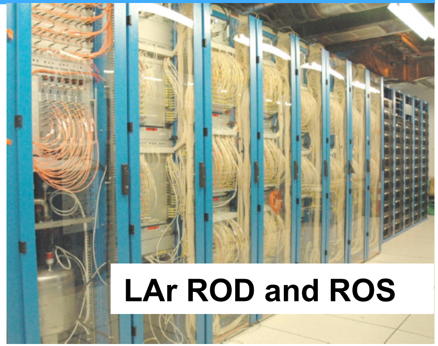
Readout System
Custom built buffers
in PC farm

Event Building
More PC farms
on Data Network

DAQ software
Control, configuration, monitoring
on Control Network

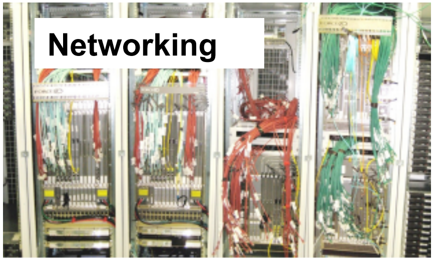
Trigger / DAQ / Control



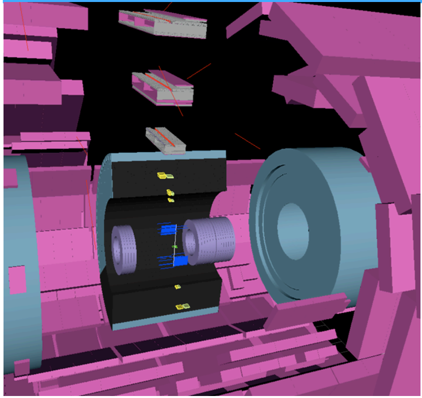


Full Online system being exercised since ~2 years

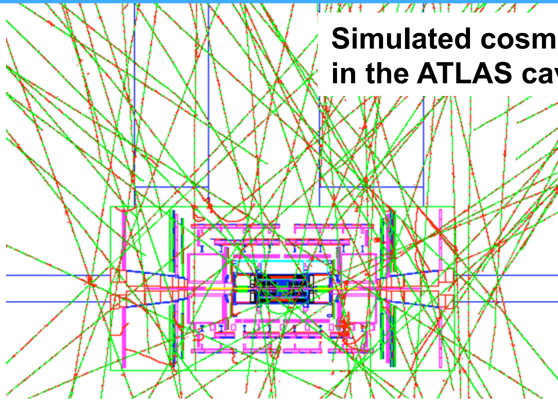
H/w now being completed - Ready for data-taking



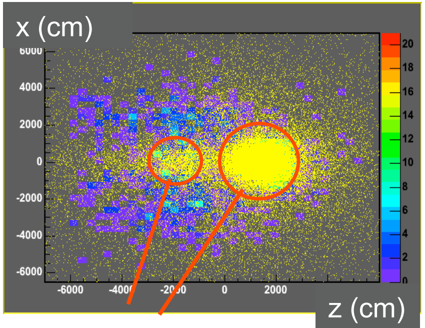
Towards data-taking: Cosmic Muons



Real Cosmic Event



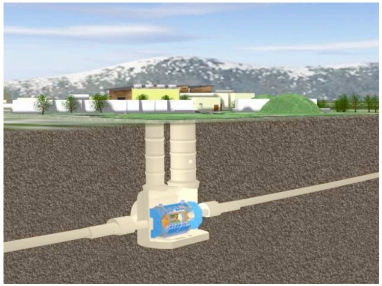
Simulated cosmics flux in the ATLAS cavern



ATLAS shafts

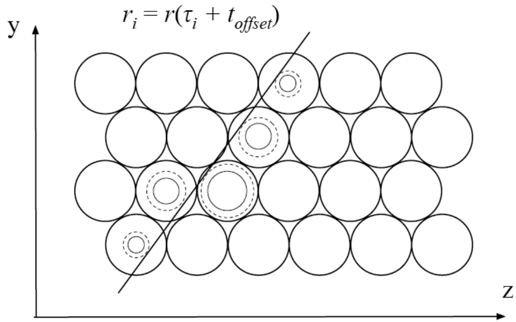
Muon impact points extrapolated to surface as measured by Muon Trigger chambers (RPC)

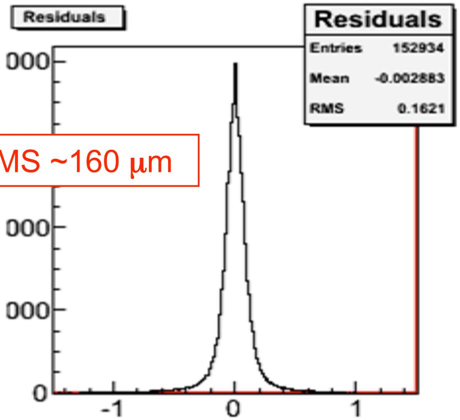
(Calorimeter trigger also available)



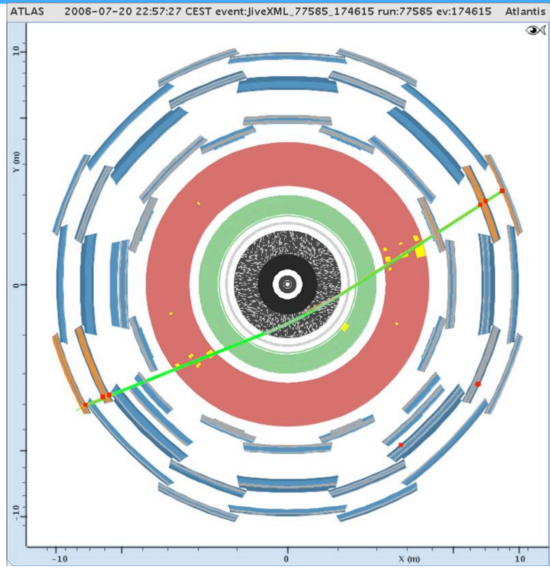
Rate ~100 m below ground: ~ O(15 Hz) crossing Inner Detector

Commissioning with Cosmics





RMS ~160 μm



Measure t0 and (r,t) relation

Alignement of chambers

To reach 40 μm will need large samples

of tracks B field ON and OFF

Conclusion

- ATLAS is built and installed
- Cavern in restricted access mode since 24th July
- Intense on-going commissioning activities
- Will continue with single beam

Ready for collisions !

- Proceed with detector calibration
- Study SM processes

and start searching for new physics

CMS Assembly Sequence

SURFACE : *independent of underground Civil Engineering*

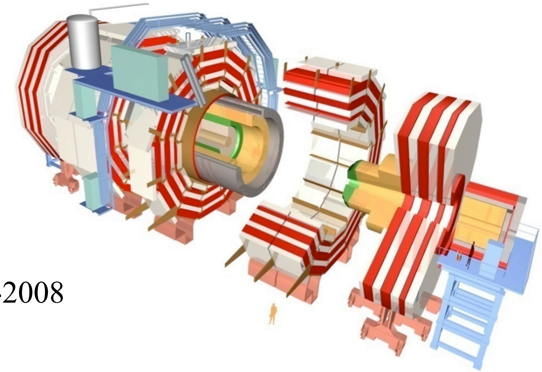
*construct magnet barrel yoke & pre-cable
* prepare solenoid vac tanks
* construct endcap yoke & pre-cable
* assemble hadron calorimeters
* install muon chambers (barrel+ec) in yoke
* assemble coil & insert in vac tank
* insert HCAL inside coil
• **Test magnet + parts of all subsystems**
*separate elements and lower sequentially

2000-2007

UNDERGROUND:

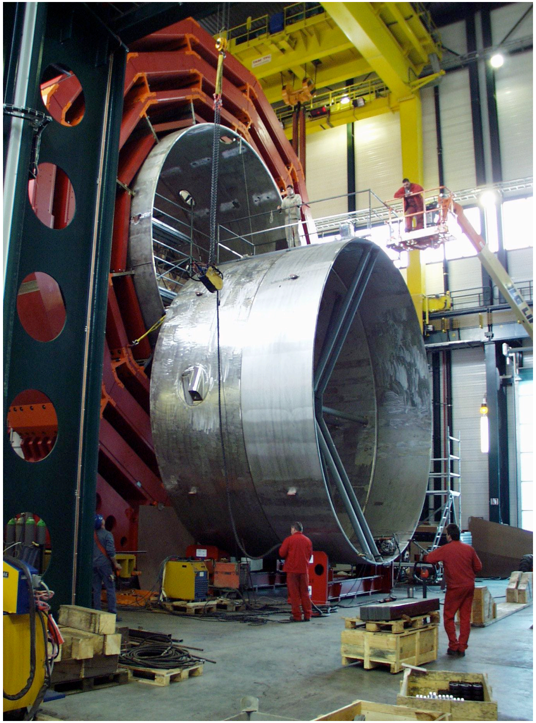
* re-install HCAL
* install ECAL barrel & cable central wheel
* install Tracker & cable
* install beampipe & bake-out
* install ECAL endcaps
* close & finish commissioning

2006-2008

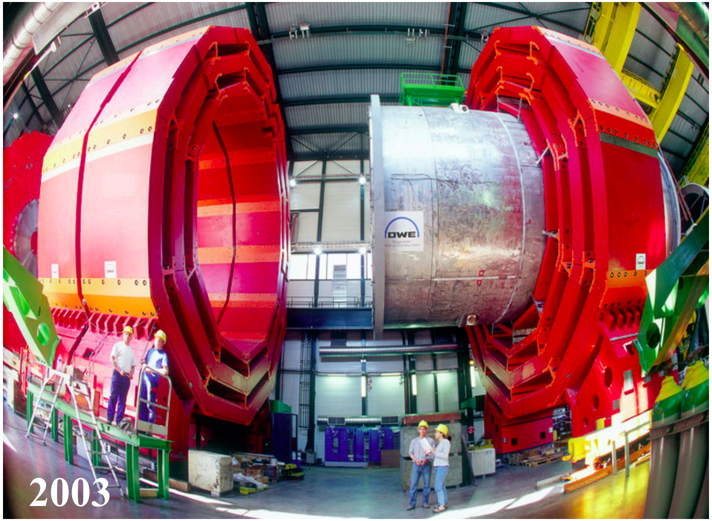


modular : ease of surface pre-assembly
: lowering as 15 large modules
: rapid access for maintenance

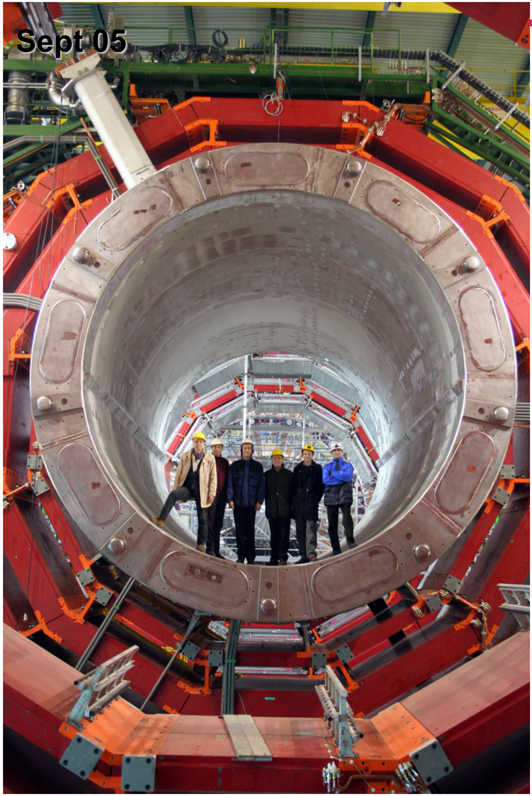
Surface & Underground 2001-2

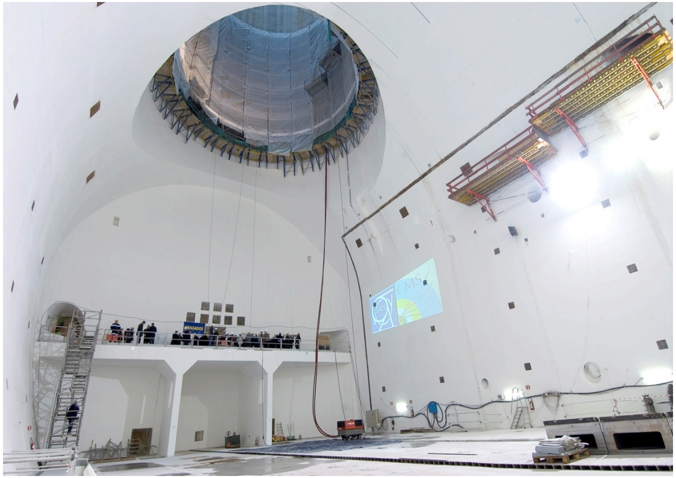


Surface & Underground 2003-4



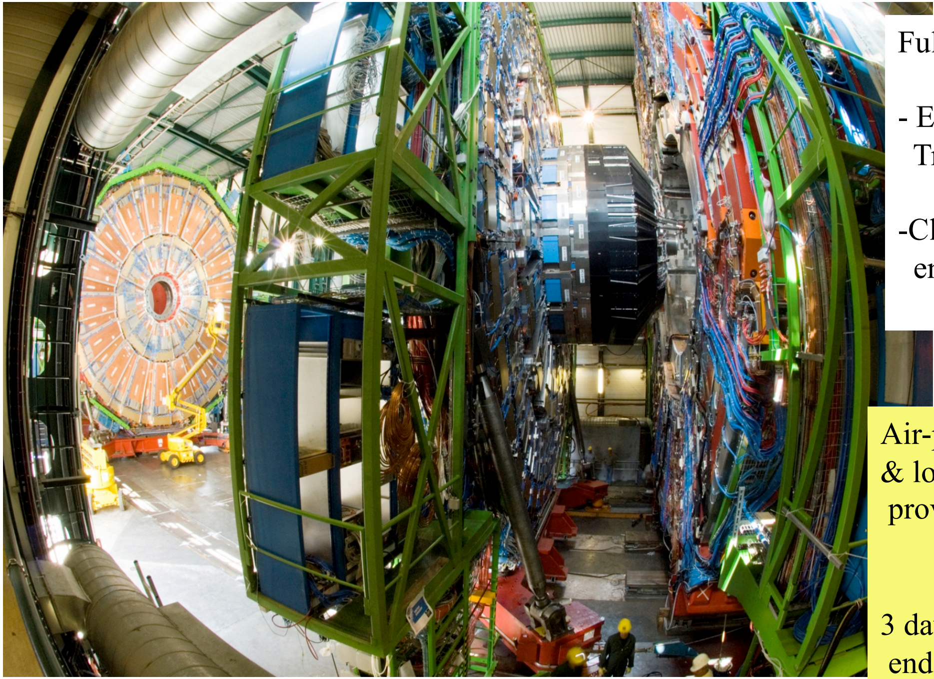
Surface & Underground 2004-5





First Closure of CMS (2006)

In preparation for surface testing and field mapping of the 4T solenoid magnet



Full rehearsal of:

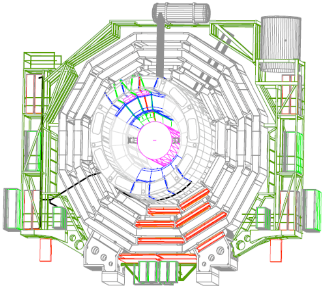
- ECAL, HCAL & Tracker installation.
- Closure of barrel and endcaps

Air-pads, grease pads & locking jacks proven to work

3 days to open or close endcap

Magnet Test & "Cosmic Challenge" 2006

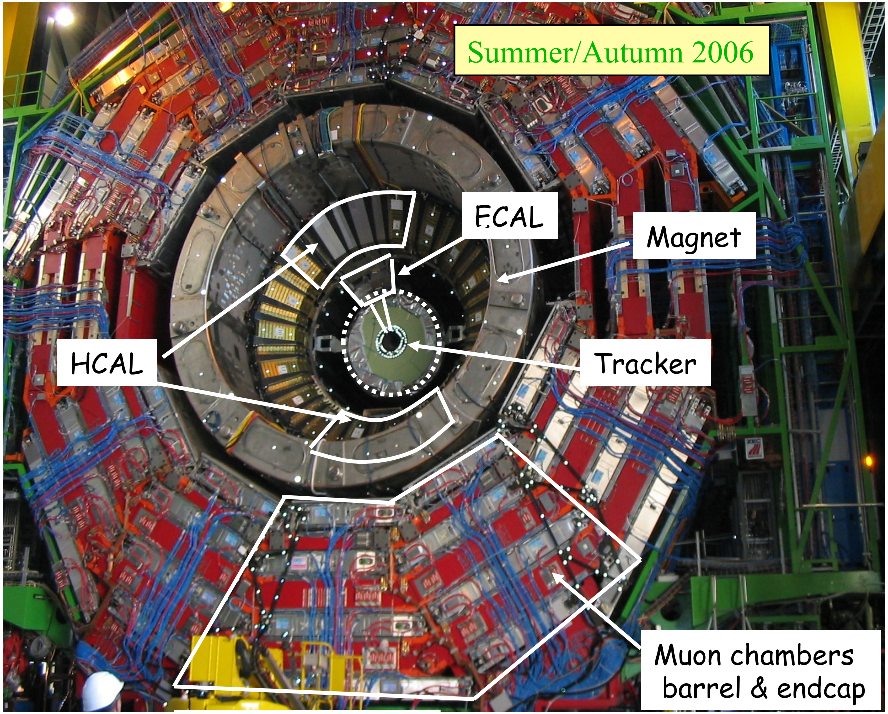
1'st CMS system test



Surface testing and field-mapping of magnet

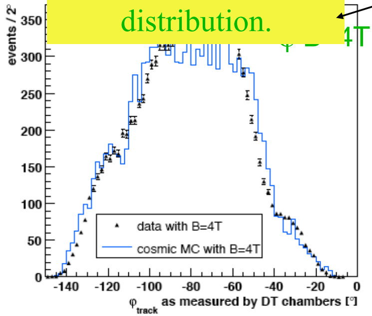
Parasitic system test, with elements of all subsystems plus central trigger & DAQ at nominal field

(Investment in surface infrastructure, DAQ, rack & control rooms)



"Cosmic Challenge" 2006

Azimuthal distribution.

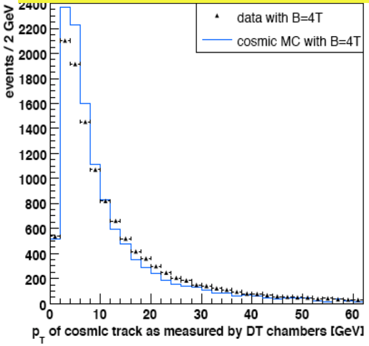


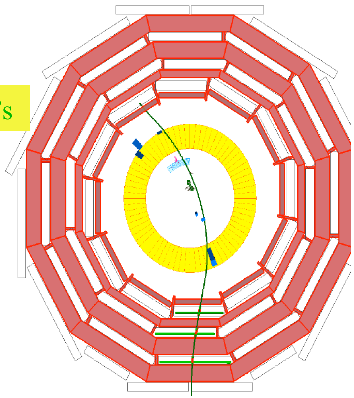
Cosmic muon data normalised to Monte Carlo simulation

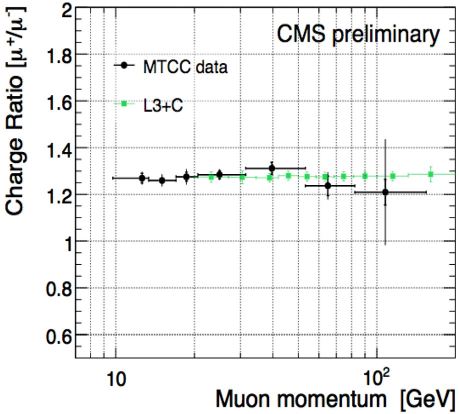
Reasonable agreement between data and simulation.

Tested nearly all aspects of final CMS from detector through DAQ, controls & DQM to the software framework and gave the first "physics" result

p_T distribution measured by DT's

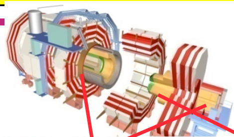






Cosmic in TK, ECAL, HCAL, Mu

Heavy Lowering Nov 2006-Jan 2008



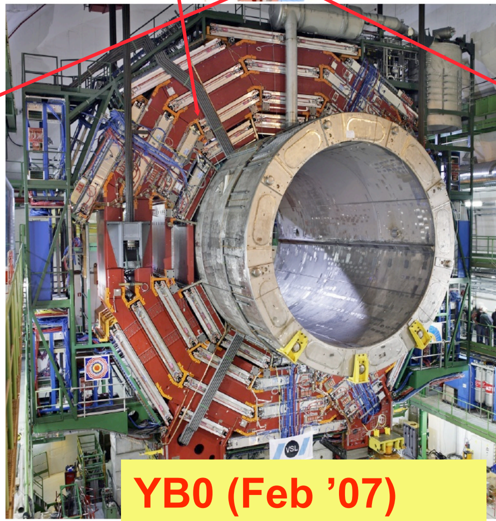
15 objects in total: 350-2000 t each

#1

HF- (Nov'06)

Connected to pre-installed cable chains

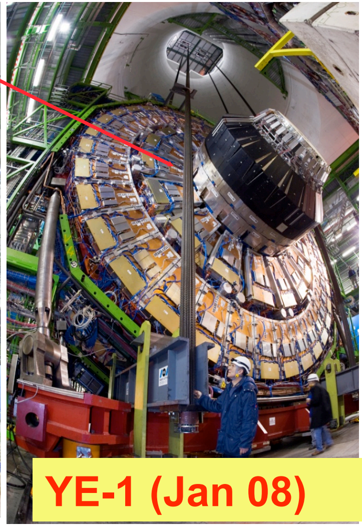
#9



YB0 (Feb '07)

Surveyed & aligned: few x 0.1mm
few x 0.1 m rad

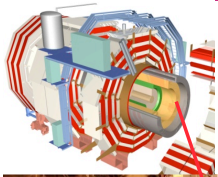
#15



YE-1 (Jan 08)

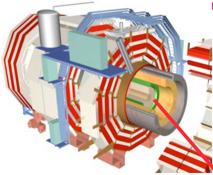
Connected to pre-installed cable chains

Underground installation: barrel calorimeters

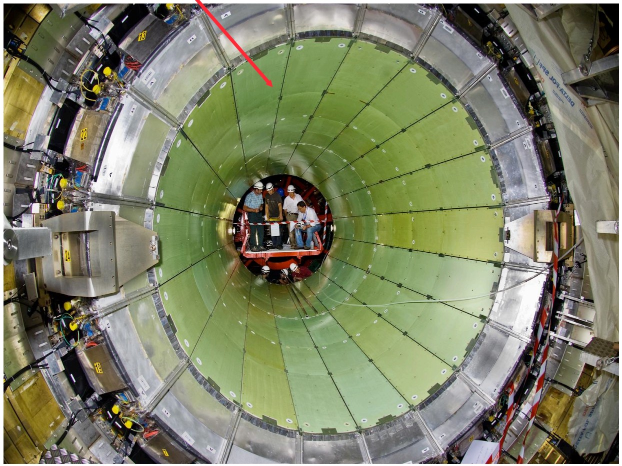


HCAL

Two ½ barrels (removed for heavy lowering, following surface test).
(weight restrictions on central section)



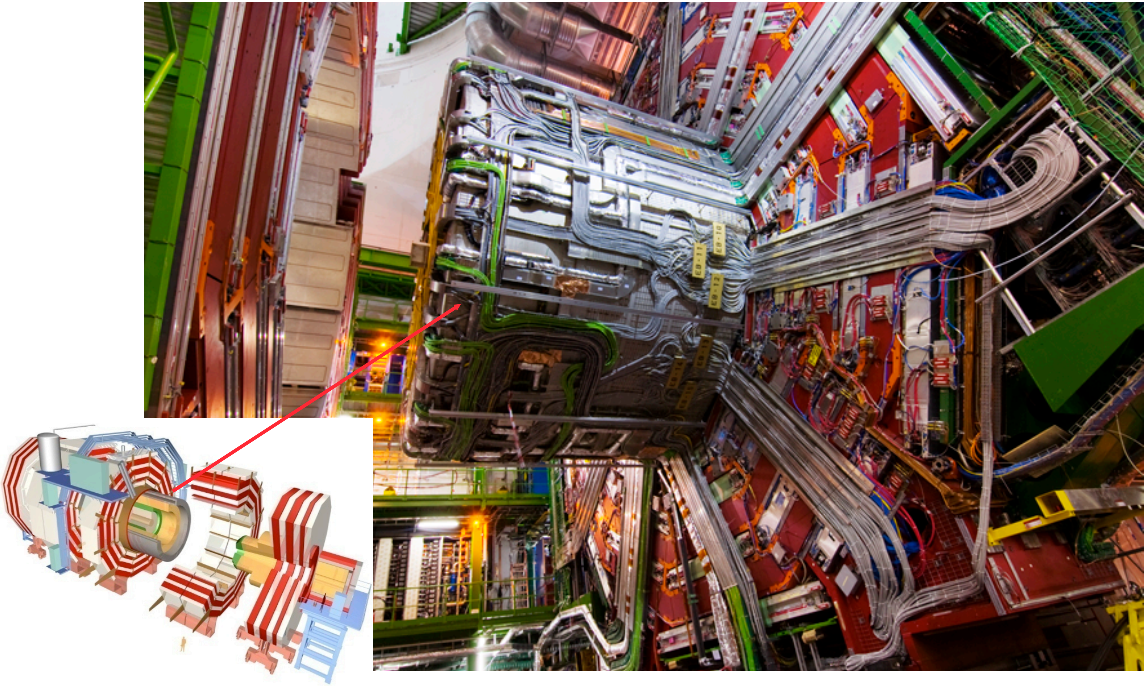
ECAL



Two ½ barrels, each installed as 18 pre-tested supermodules (~1800 crystals each)

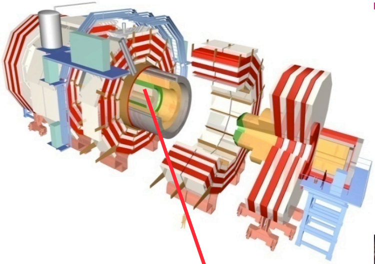
Central wheel (YB0) services May-Dec 07

Estimated ~50,000 man-hours of work on critical path!!



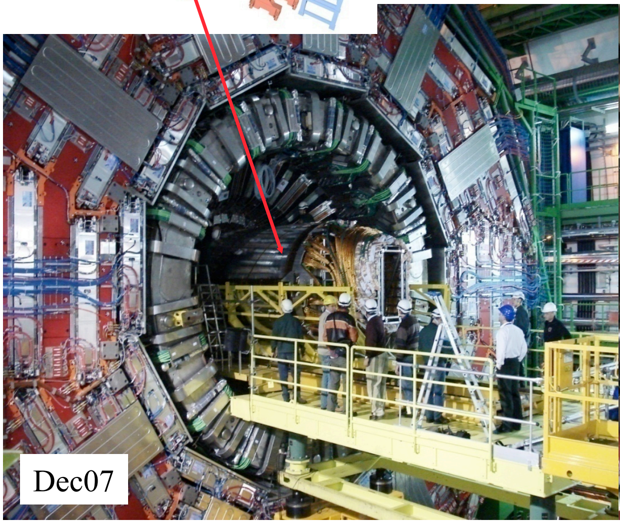
Completion triggered Tracker installation, then beampipe installation →

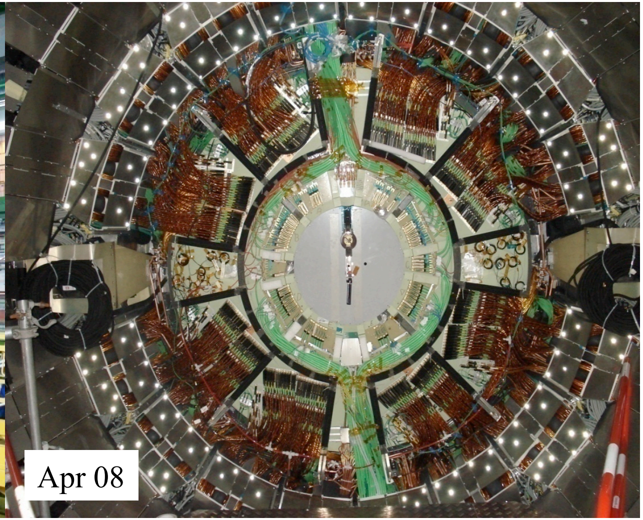
Tracker Installation & Connection



Pre-cabling of services to patch panels inside the solenoid vacuum tank simultaneous with Si-strip Tracker surface pre-commissioning.

Speeded up the final connections, completed in 4 months



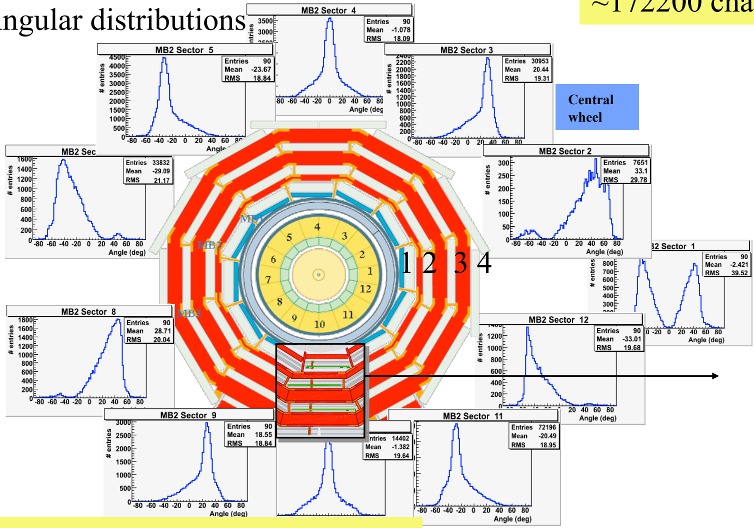


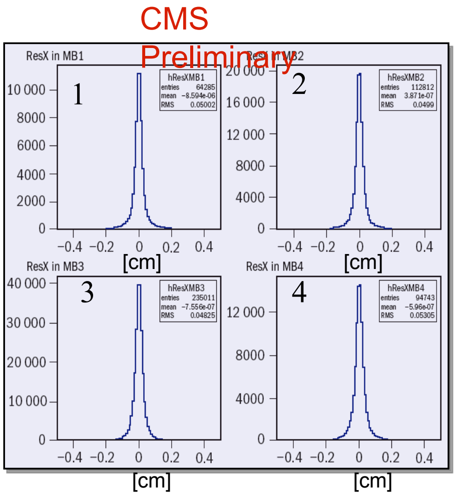
Muon System: Barrel Drift Tubes

Underground re-commissioning

250 chambers in 5 wheels of 12 sectors each
~172200 channels (0.2% inoperative)

Angular distributions

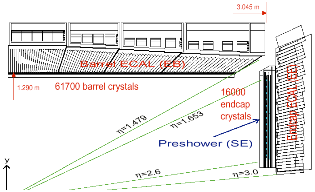




Residual distributions
in the 4 layers of a sector

DAQ & trigger fully integrated
providing reliable “trigger service”
for ECAL/HCAL/Tracker
Total rate stable at ~200Hz

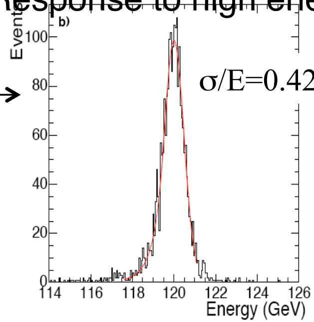
Single hit resolution ≤ 250μm as anticipated



Electromagnetic Calorimeter, ECAL

Surface: 36/36 barrel supermodules calibrated using cosmics ~1.5% crystal intercalibration
9/36 also beam calibrated.

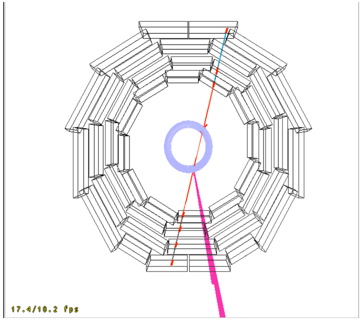
Response to high energy e-



σ/E=0.42±0.01%

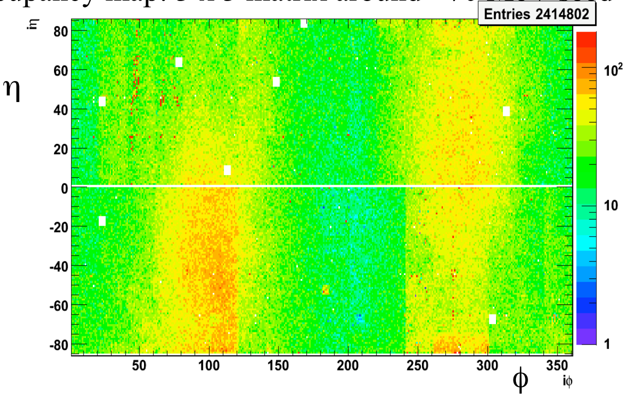
Underground: All 36 barrel supermodules readout
84/61200 (0.14%) masked channels
Commissioning with cosmics
(typically 250MeV mip deposit)

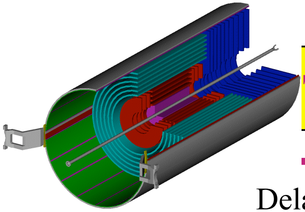
Track-cluster association



μ trigger : 288GeV cluster!

Occupancy map: 3 x 3 matrix around >70 MeV seed





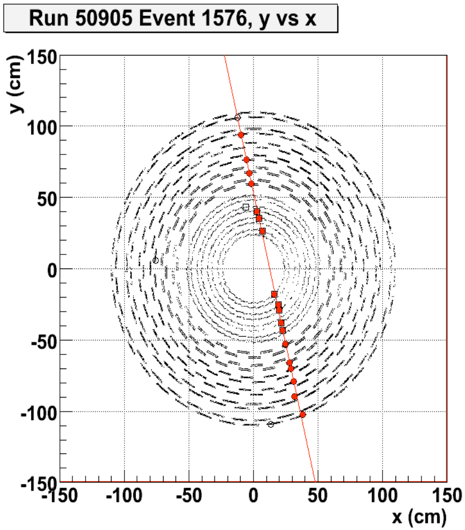
Tracker: underground recommissioning

Delayed 2-3 months due to failures & subsequent repairs of cooling plant

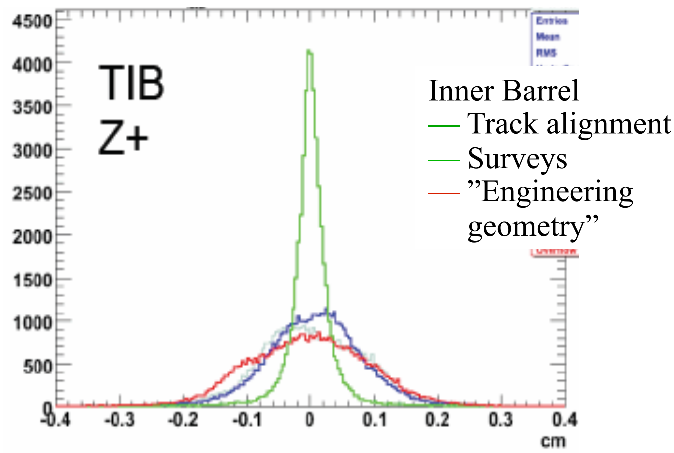
Noise and S/N performance from surface confirmed as typical

~95% of ~29k optical readout channels worked first try

DAQ fully integrated

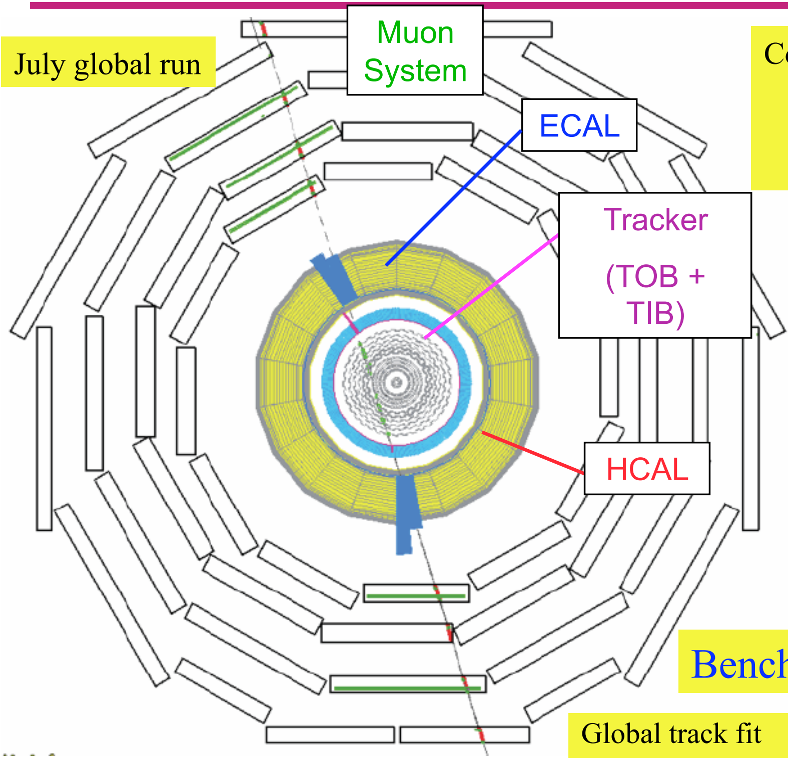


Using ~90k cosmic tracks



System Integration: global cosmic runs

July global run



Cosmic Trigger
≥ 2 layers in top and bottom sectors of muon wheel

Pre-requisites:
infrastructure, detectors, μ-trigger, DAQ integration,
r/o synchronization,
μ-calibration,
track reconstruction
…

Benchmark of detector readiness

Global track fit

Programme for remainder of 2008: I

Prior to beam: the last few moves …..

Complete cabling & tests of recently installed detectors (pixel, EE)

Close magnet yoke

Continue local & global detector commissioning with cosmics (in parallel)

Re-confirm magnet operation up to 4T

Configure forward detectors & shielding for beam

Magnet

Cryogenics :

Cooldown complete.

Stable at operating temperature

Mechanical Tests: all OK.

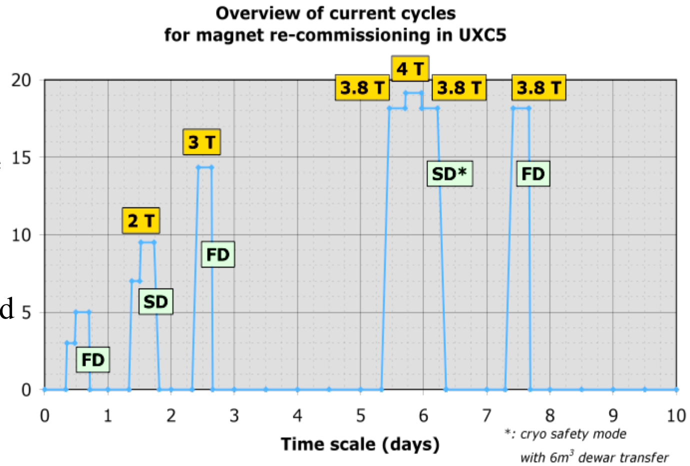
Electrical System:

All connections made and tested

Power converter tested.

Control and safety systems:

Tested & working



Programme for remainder of 2008: II

From first beam up to 10pb^{-1}, p-p collisions at (900GeV) & 10 TeV :

Commission beam radiation monitoring system including abort

Tune operating procedures for beam operation

Establish (lack of) effect of solenoid field on beams

Synchronize detectors using beam timing

Commission beam trigger, start "physics commissioning":

Align and calibrate with beam-halo events, min-bias events,etc

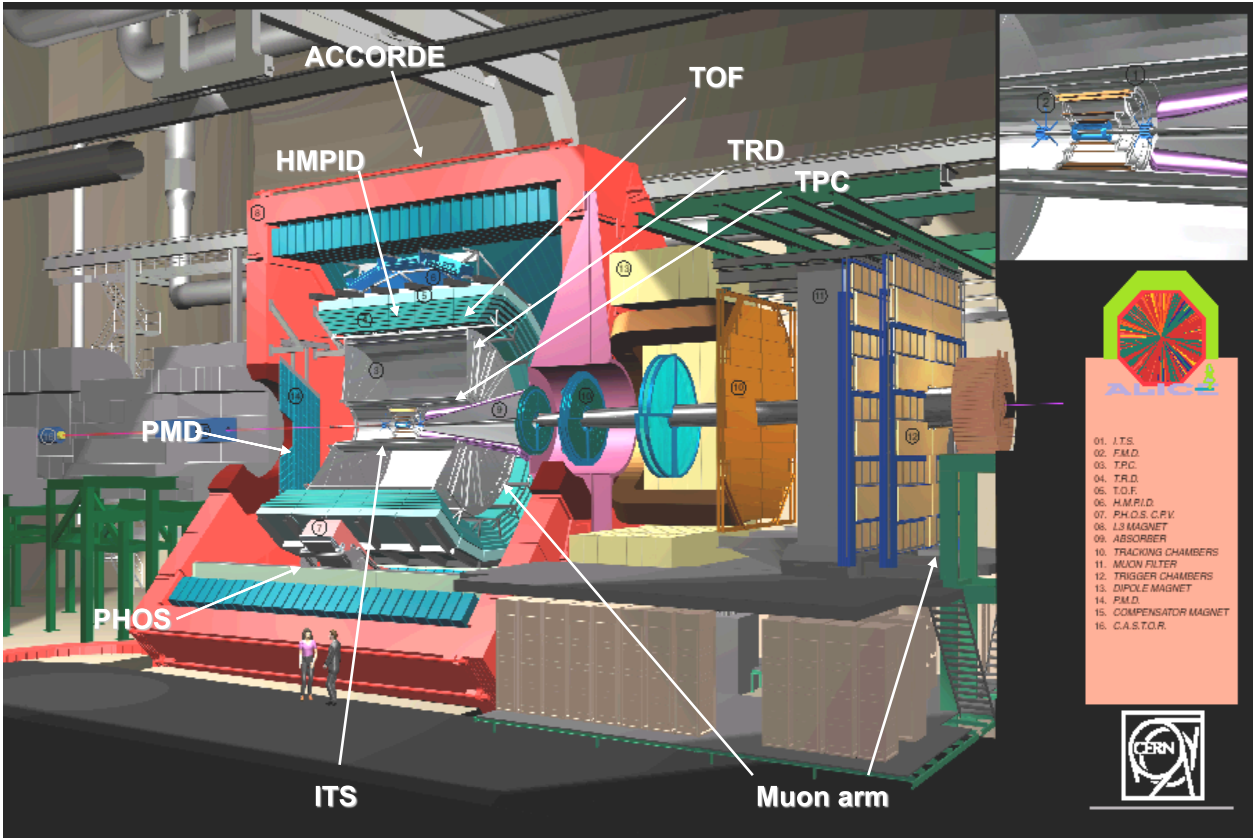
Measure jet and lepton rates; observe W, Z, top

First look for possible extraordinary signatures…

Conclusion

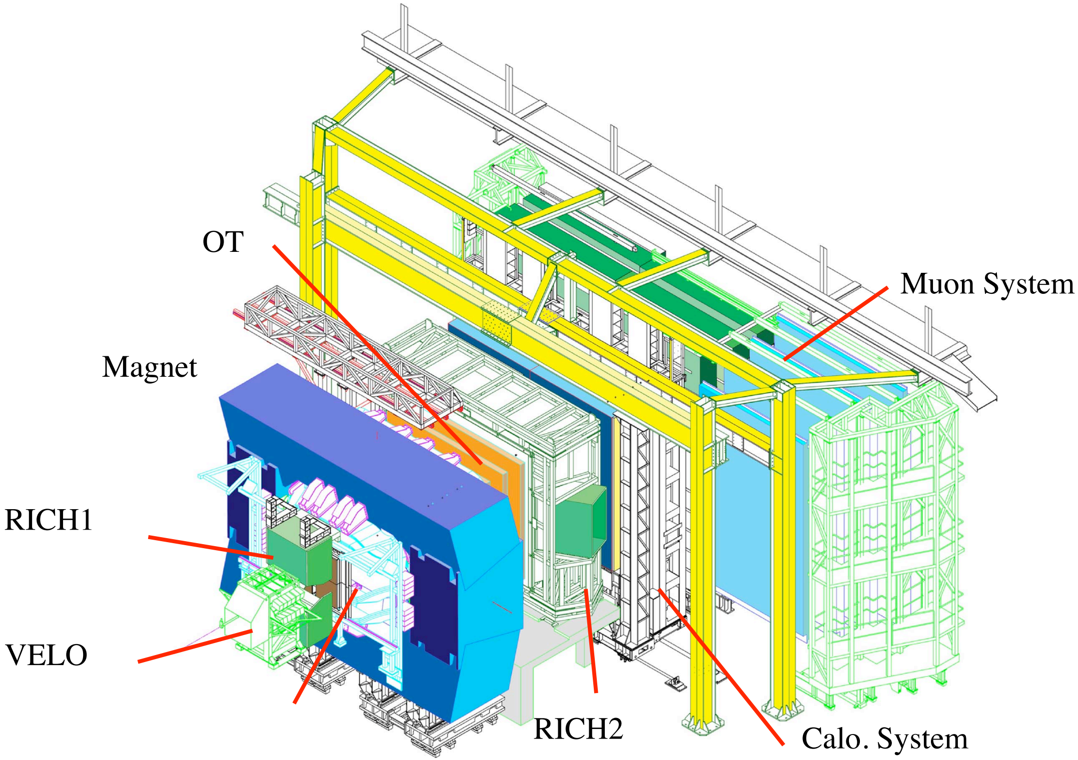
- Construction of the CMS experiment is almost completed.
- Commissioning work already carried out gives confidence that CMS detectors will operate with the expected performance.
- Integrated operation of subdetectors and central systems using cosmic triggers is routine with near-final complexity and functionality.
- Challenges conducted around the clock @ 100% of 2008 load show that Computing, Software & Analysis tools are ready for early data.
- Preparations for the rapid extraction of physics are being made.

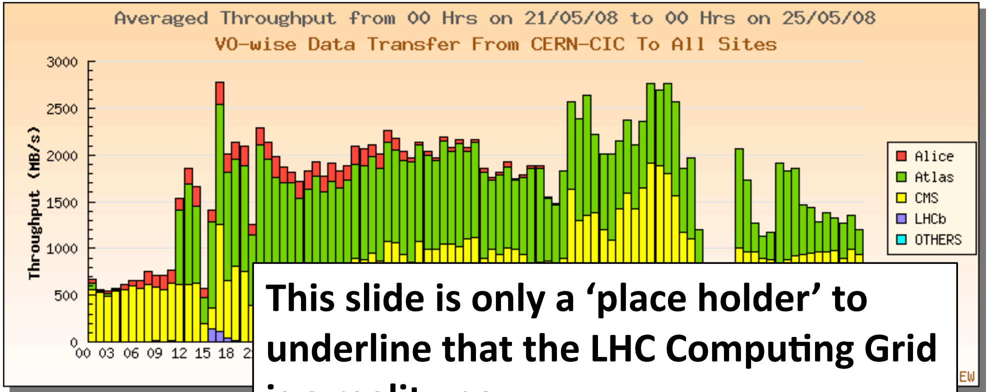
- Later this month, CMS will be closed with magnetic field on, taking cosmic data, in (eager!) anticipation of beam.



ALICE Detector

LHCb Spectrometer



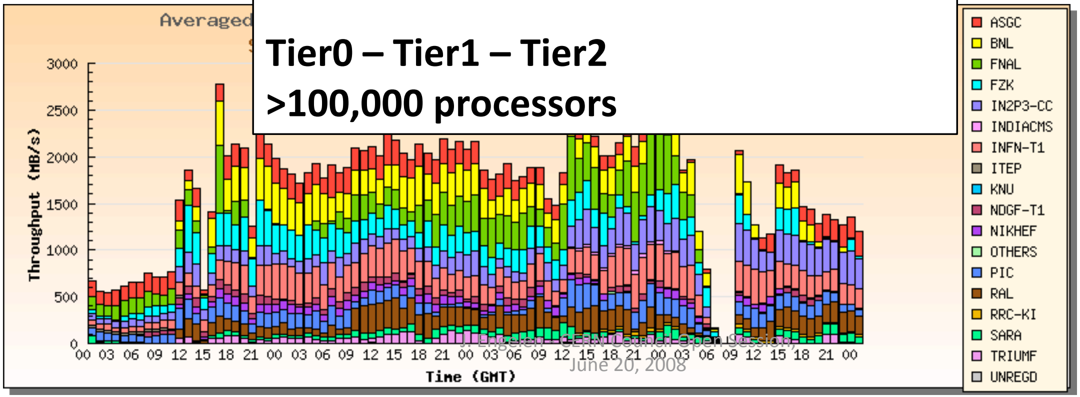


This slide is only a 'place holder' to underline that the LHC Computing Grid is a reality now.

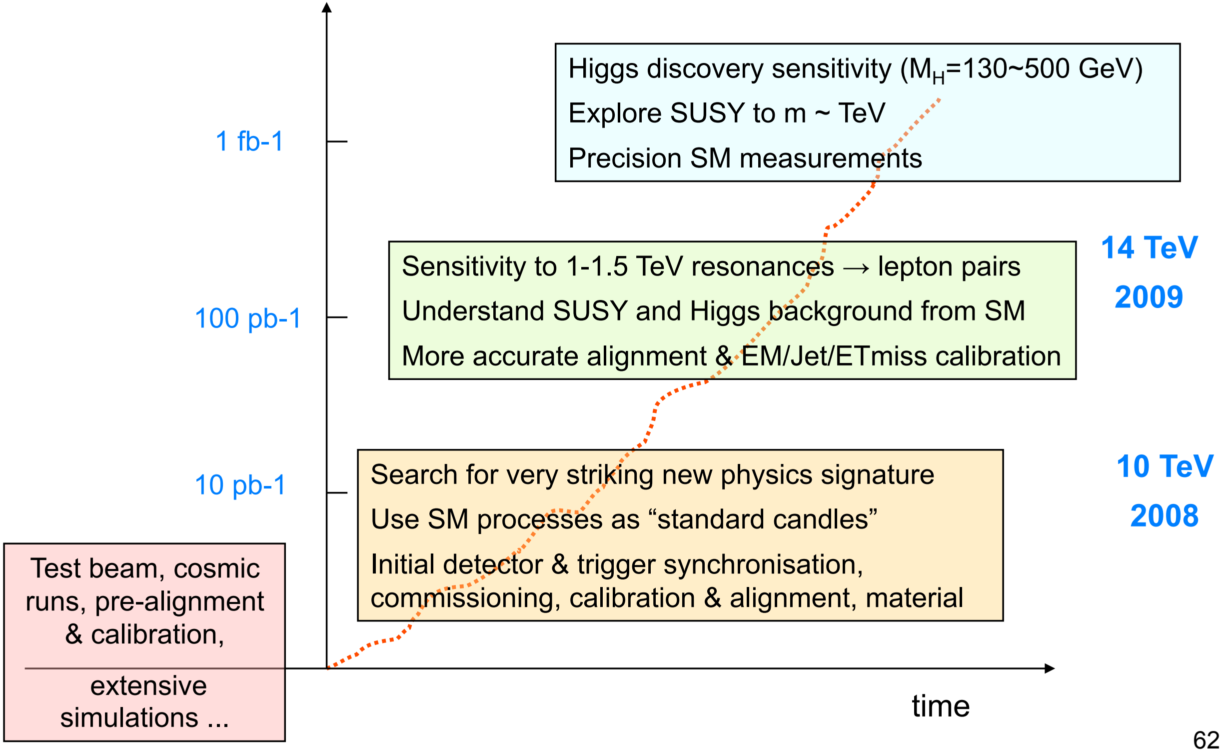
15 10^{15} Bytes per year

Tier0 – Tier1 – Tier2
>100,000 processors

Data transfe ... elow by Tier 1
Target aggre



Collisions: a physics Roadmap

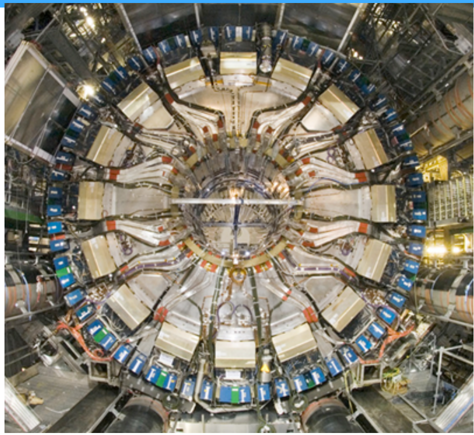


Residual / Back up

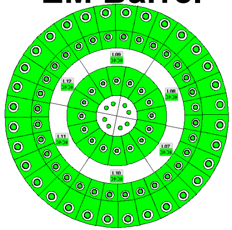
Hardware Readiness Liquid Argon Calorimeters

Installation in the cavern
Barrel in October 2004,
End-caps by 2006

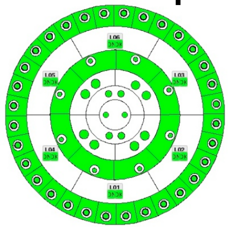
Electronics equipment completed
Back-End May 2007
Front-End April 2008
(some refurbishment was needed)



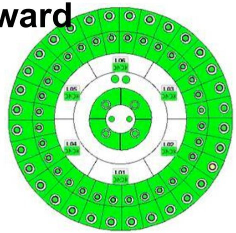
EM Barrel



EM EndCap



Had. EndCap & Forward



Since May 2008

full calorimeter up, integrated in DAQ, slow control

in steady running mode

~190.000 channels read-out

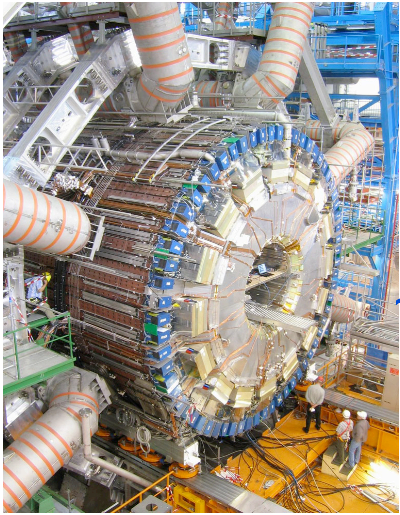
~0.02% dead (isolated) channels
+ ~1.5% (½ barrel module - power supply control lost)
will be repaired during shutdown

Commissioning on-going

Hardware Readiness Tile Calorimeter

Installation in the cavern

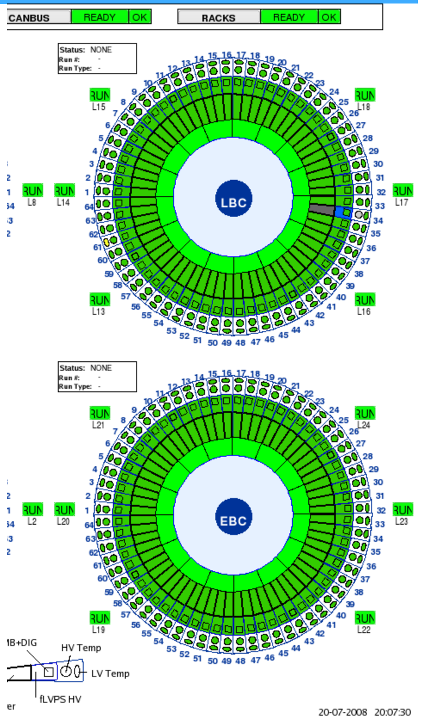
Ext. Barrel C December 2004
Barrel October 2005
Ext. Barrel A May 2006



full calorimeter up and running, integrated in DAQ

~10000 PMTs → 5000 cells

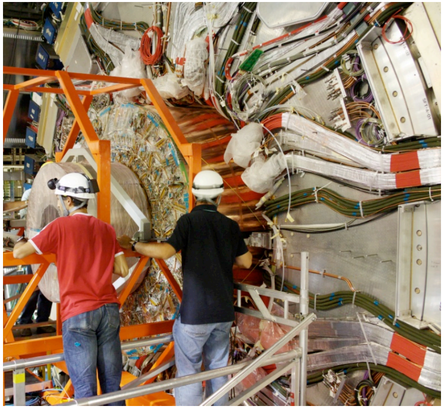
~0.2% dead (isolated) cells
~0.2% 1ext.barrel – power supply problem
will be repaired during shutdown



Electronics equipment completed May 2008
(some refurbishment was needed)

Hardware Readiness: Inner detector

TRT/SCT installed Aug 2006



Pixel installed June 2007

TRT operational
and in test mode

SCT sign-off tests
(with cooling)

Only few weeks of running
Barrel: May 07, Apr 08
Endcap A: Jan08
Endcap C Feb 08

6 days Pixel sign-off
test

end April 2008

interrupted by cooling
plant incident

April/May 2008

ID volume sealed
complex End-Plate with 1000
feed-throughs
needed to achieve closing
ATLAS by end of June

Hardware Readiness: Inner Detector

- **Solenoid field:** mapping done with precision ~10^{-4}
- **Pixel** ~0.6% dead/problematic channels
  except EndCap wheel A: ~4.2% (+ 8.3% if cooling loop inoperable)
- **SCT** barrel ~0.35%, end-caps ~0.26% dead/problematic channels
  except EndCap wheel C: ~1.6% (1.3% due to cooling loop failure)
- **TRT** : dead channels 1.2-2.0%,
  delivery of some readout elements being completed
  run with Xenon or not – to be decided

Cooling plant repair completed on 23rd July

→on time for beam pipe bake-out (done succesfully 29-31 July)

- Pixel resumes commissioning:
  ~4 weeks standalone commissioning before joining common ATLAS running
- SCT will join for limited periods and depending on the overall tune-in progress
- TRT commissioning proceeds steadily

Hardware Readiness: Muon system

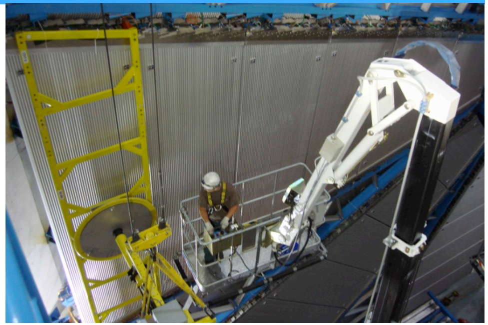
Chamber Installed
February 2005

All chambers installed
(few chambers staged 09)

All wheels in final position.

Most alignment rays are operational
Good results: ~200 μm

Magnetic field measurement
< 5% of probes lost
expect ΔB/B=1.5% at day-1



Last Muon Chamber
Installed July 1rst 08

Very few bad channels
Few chambers with problem
(gas leak, overpressure accident,...)
Some loss of redundancy but
no acceptance hole

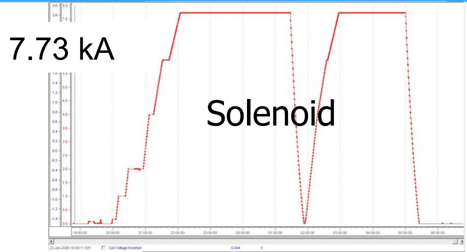
Finishing up connections in barrel RPC
and final alignment of a few chambers
TGC: now running with n-Pentane

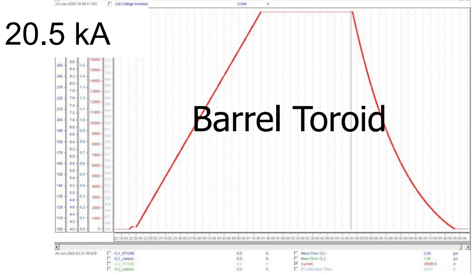
Toroids & Solenoid Magnet System

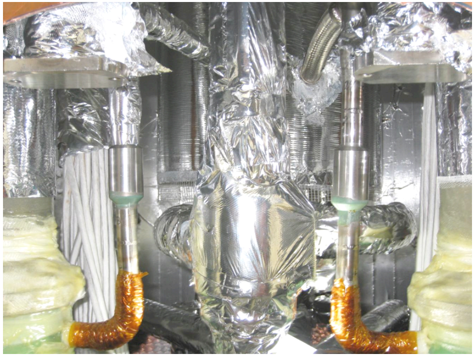
- Central Solenoid up to full field at 7.73 kA nominal in Aug 06
- Barrel Toroid up to full field at 20.5 kA nominal in Nov 06

Combined test June 08 OK

- EndCap-C Toroid up to full field at 20.5 kA nominal in June 08
- EndCap-A Toroid







Leak in electrical pipe isolators - 23rd May

Toroid warmed-up/repaired/cooled - 20th July

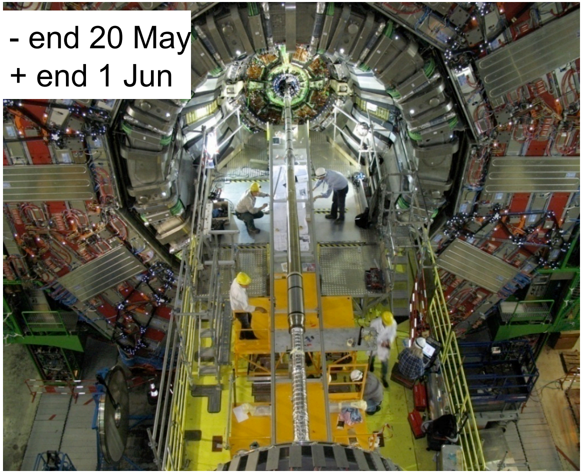
EndCap-A tested up to 21kA – 23rd July

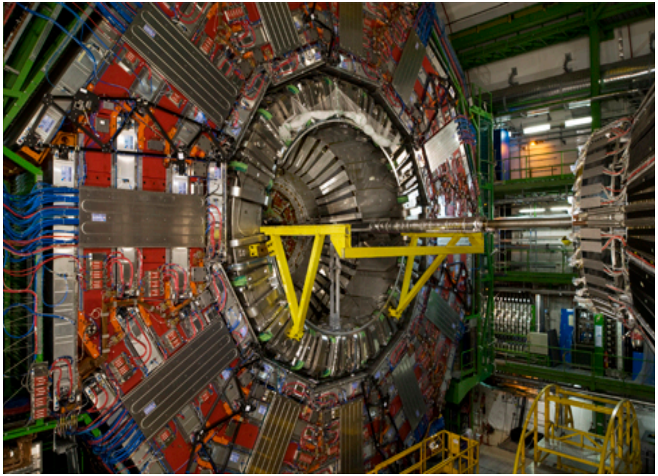
Combined test of 3 magnets at 15kA - 31rst July

Beampipe insertion & bake-out

Endcap disks closed along beampipe for bakeout
bakeout complete 25 Jun

- end 20 May
+ end 1 Jun

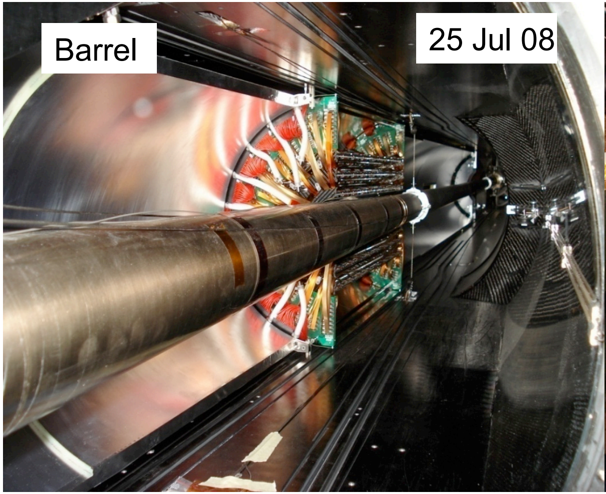


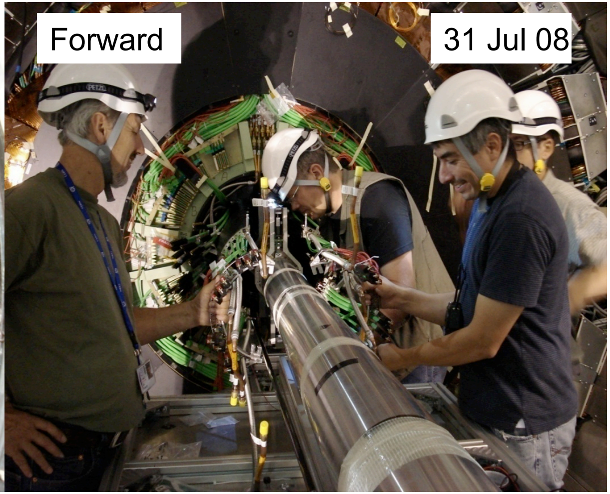


4m long Be central section braised to stainless steel cones connecting to endcap cones

Pixel Tracker installation

ATLA proje





3 cylindrical layers at 4,7,11 cm
mounted on 2 half-shells

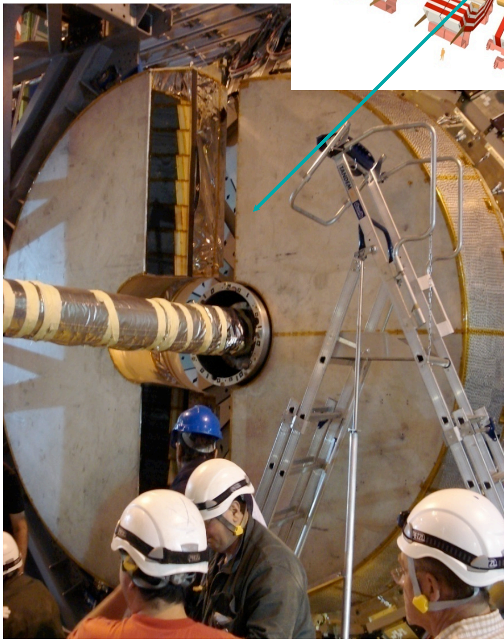
At each end, 2 disks of over-lapping blades
Mounted on two half-shells

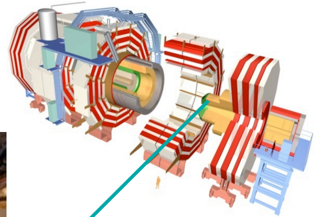
66 mega pixels!!

ECAL Endcap Installation

24 Jul 08

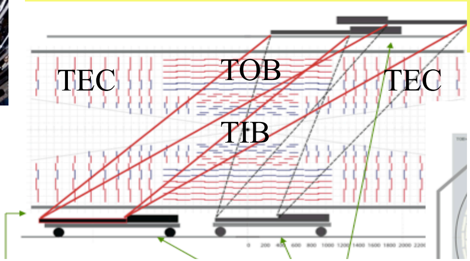
31 Jul 08



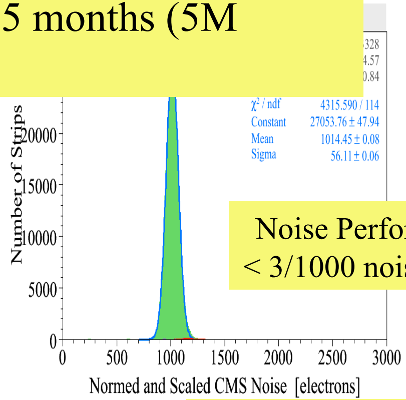


Tracker: surface commissioning

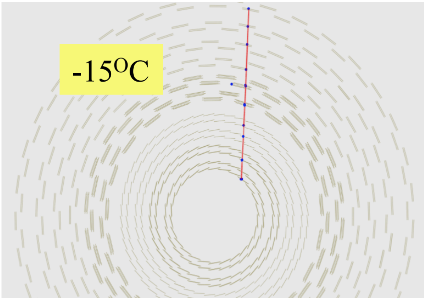
20% section tested over 5 months (5M



Signal/Noise > 25/1 in “Peak” Readout Mode

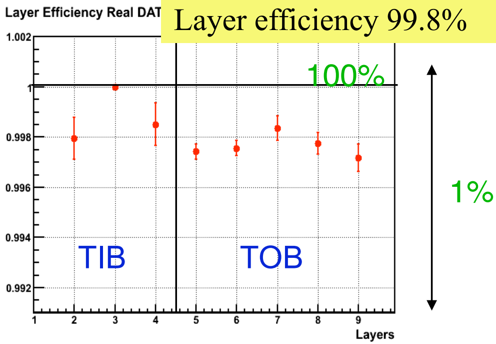


Noise Performance
< 3/1000 noisy strips



-15^{O}C

Performance check at -15^{O}C



Layer efficiency 99.8%