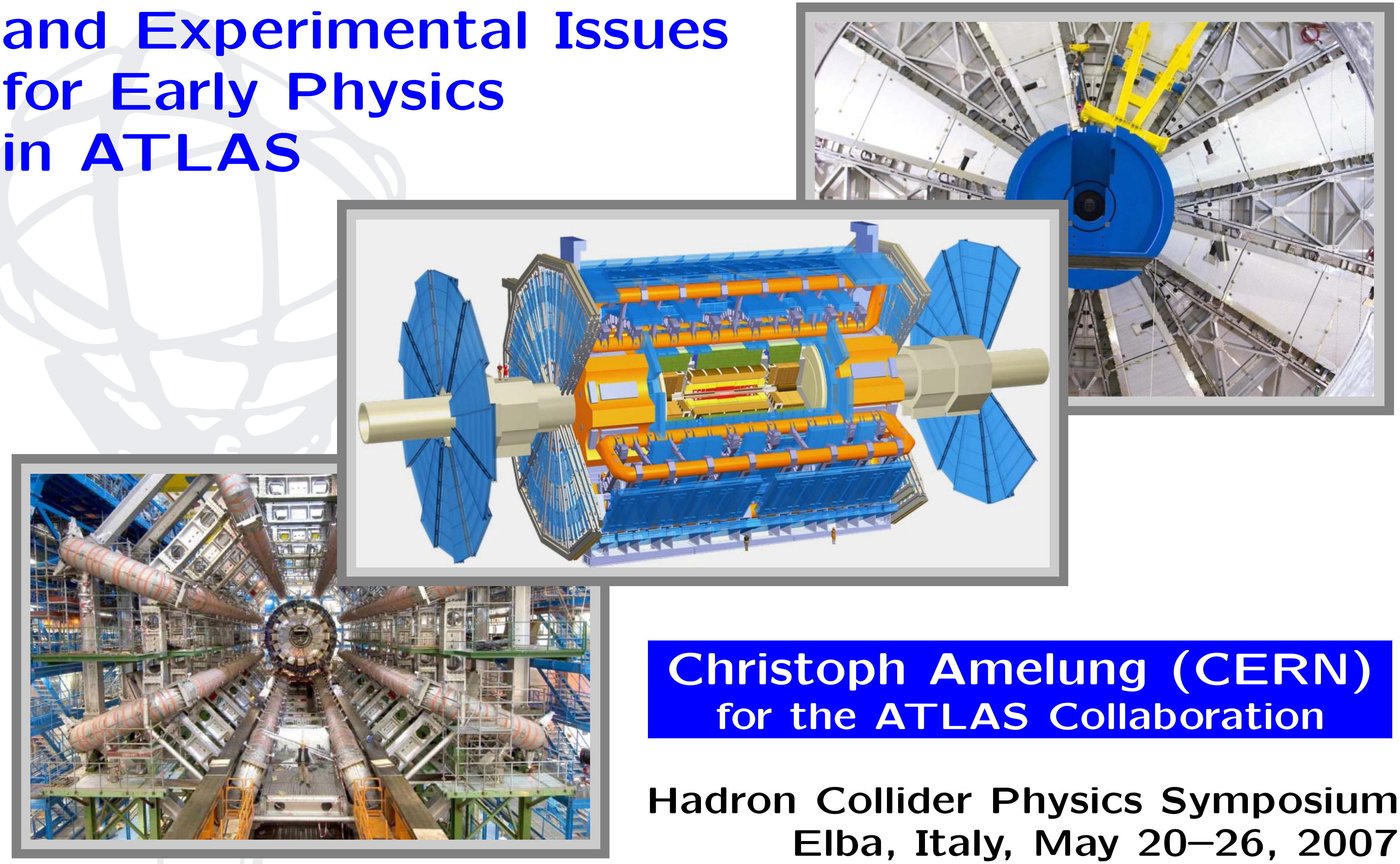
Status of Commissioning
and Experimental Issues for Early Physics in ATLAS



Christoph Amelung (CERN)
for the ATLAS Collaboration

Hadron Collider Physics Symposium
Elba, Italy, May 20–26, 2007

The ATLAS Collaboration

- **ATLAS:**

  35 countries
  164 institutions
  1800 scientific authors

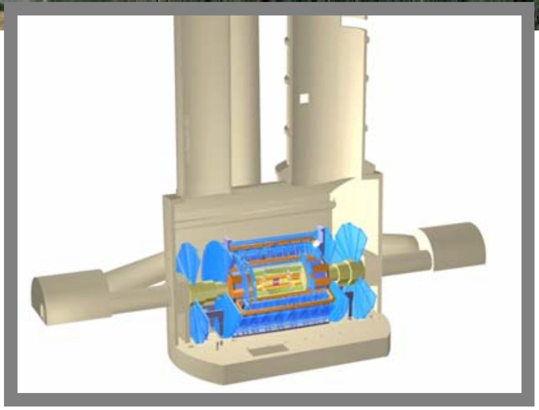
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Ritsumeikan, UFRJ Rio de Janeiro, RomeI, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Yale, Yerevan

The ATLAS Construction Site

- **ATLAS cavern:**

  92 m below ground, across the street from CERN Meyrin site

  53 m long, 35 m high, 30 m wide
  just large enough for the detector:
  building a "ship in a bottle"

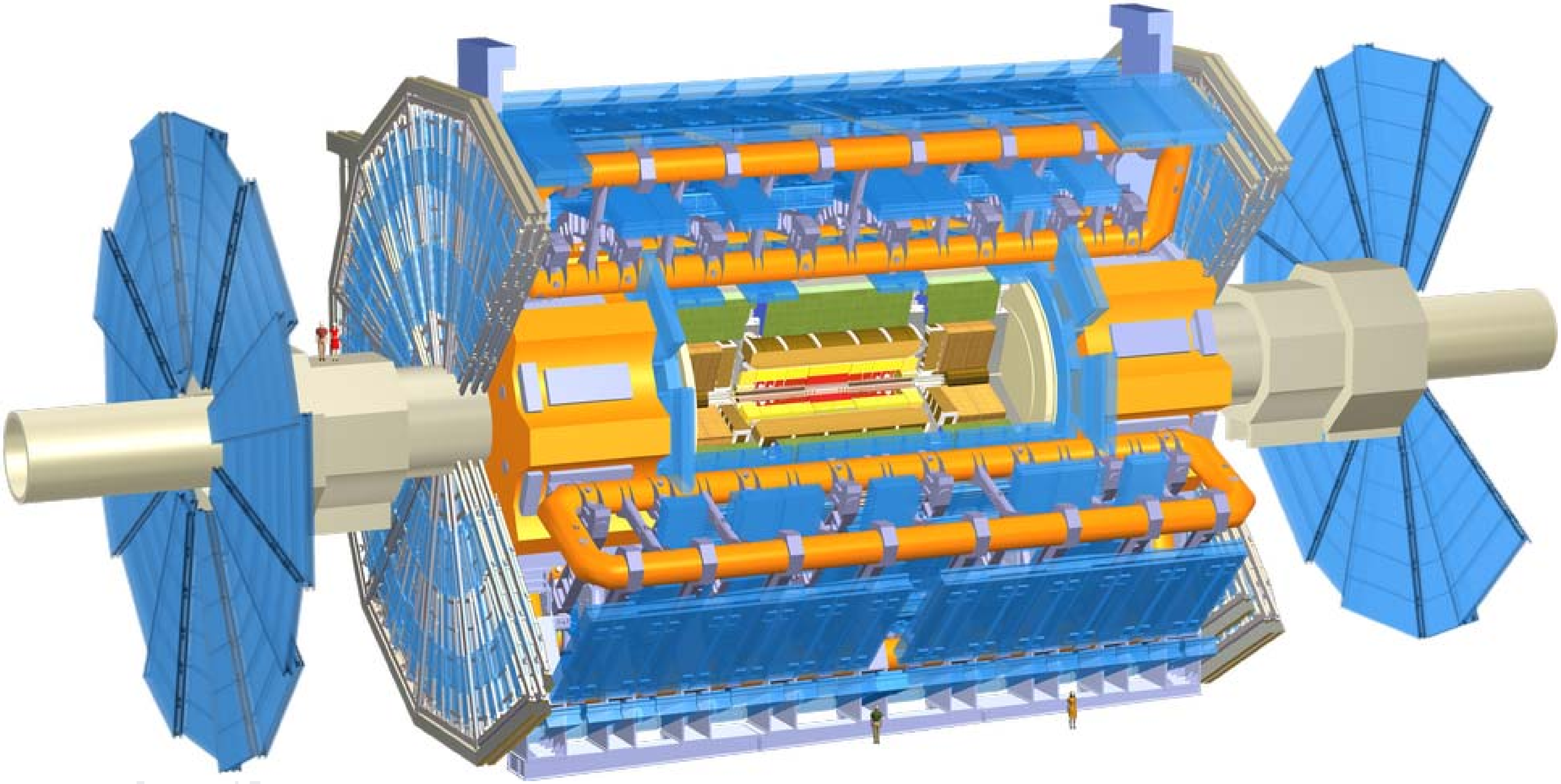


The ATLAS Detector for the LHC

- **ATLAS detector:**

  diameter 25 m, length 46 m, mass 7,000 tons, 10^8 channels, 3,000 km cables

muon spectrometer toroid magnets tile calorimeter liquid argon calorimeter



solenoid magnet transition radiation tracker silicon tracker pixel detector

ATLAS Detector Commissioning

- Many activities in parallel:

• on surface:	• in the pit:
assembly of sub-detectors	installation of sub-detectors
commissioning of components	commissioning of sub-detectors
connecting on-detector services	connecting off-detector services

ATLAS has a very tight installation schedule – first priority is sub-detector installation in the pit, all other activities must happen "in the shadow" of this – including commissioning

- Commissioning:

from "just installed" to "ready for physics"

make the detector run: from low-level (finding dead/hot channels, mapping mistakes, cabling problems) to high-level (integration of sub-detectors into global ATLAS DAQ)

understand the detector: from alignment and calibration to debugging offline reconstruction software and simulation

constrained by installation (availability of other sub-detectors, e.g. as triggers) and connection of services (e.g. to control room): many temporary ad-hoc solutions

ATLAS Commissioning Organization

- **Structure:**

ATLAS Commissioning Coordinator
(Run Coordinator after LHC start-up)

sub-dector commissioning coordinators,
subsystem sub-sub-detector coordinators

- **Commissioning phases:**
  - Phase 1: commissioning of individual sub-detectors in the pit
  - Phase 2: integrating (eventually all) sub-detectors together into ATLAS
  - Phase 3: global commissioning, ATLAS running with cosmics and halo

in addition, most sub-detectors also have one or several

  - Phase 0: commissioning of sub-detectors or components on surface

- **Milestone weeks:**

most sub-detectors now in phase 1 (typically quite advanced), interrupted sporadically by "milestone weeks", bringing together an increasing number of sub-detectors for phase 2 (eventually starting phase 3)

Detector Commissioning with Cosmics

- Cosmics are weird events:

limited angular spread – even more pronounced underground: most particles arriving in ATLAS have travelled most of the last 100 m in one of the shafts

particles do (typically) not pass through the interaction point (IP): not the type of event which detector and reconstruction software were designed for

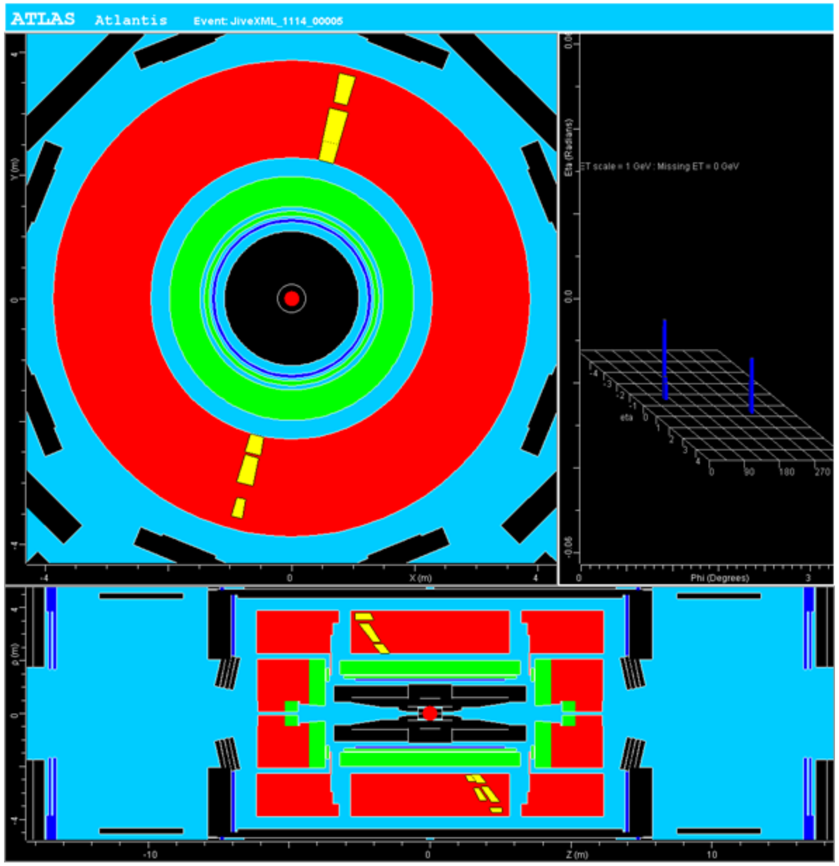
lazy approach: use only particles that do go through the IP, treat as two back-to-back particles

however timing is wrong ($t_{\text{up}} \neq t_{\text{down}}$), and event rate dramatically reduced

diligent approach: modify trigger/DAQ and reconstruction software such that they can cope with non-pointing tracks

however now you are testing and debugging a configuration and software that is not the one you wanted to test

more useful for barrel detectors than for endcaps (unless detector can be rotated)

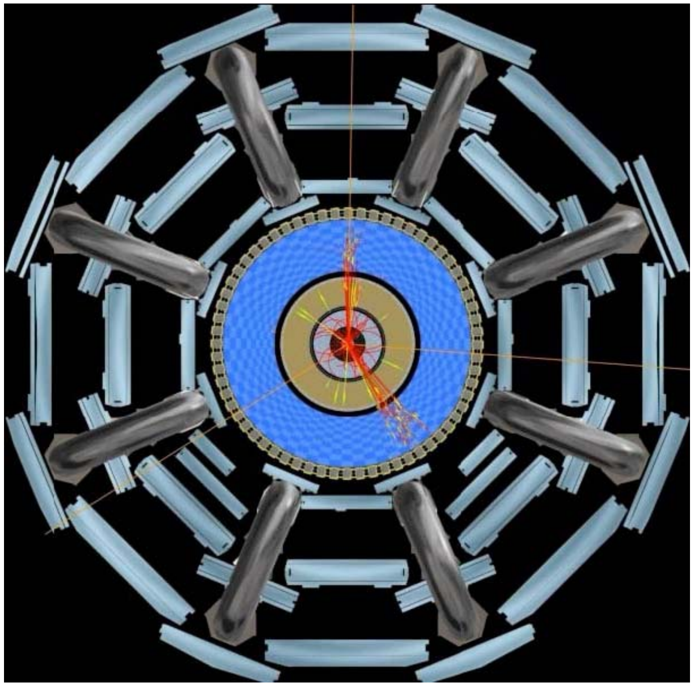


“untypical” cosmic event in calorimeters →

Muon Spectrometer

- **Muon precision chambers:**

  MDT (monitored drift tubes) for tracking (both barrel and endcap): 3 cm diameter, $4 \cdot 10^5$ channels, 80 µm resolution, chamber positions monitored by alignment system

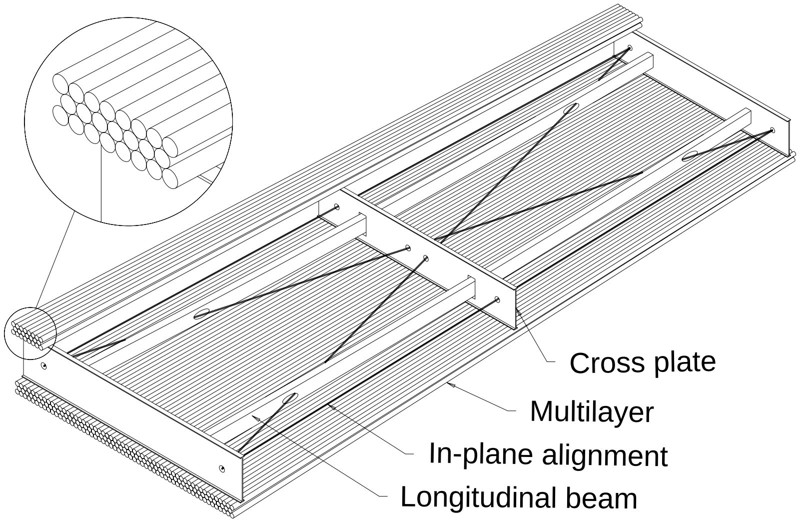


- **Barrel region:**

  RPC (resistive plate chambers) as trigger

  3 layers (BI-inner, BM-middle, BO-outer) of chambers, embedded in toroid magnet

  muon stations assembled from 1 MDT and 0/2/1 RPC chambers (BI/BM/BO)



Muon Spectrometer

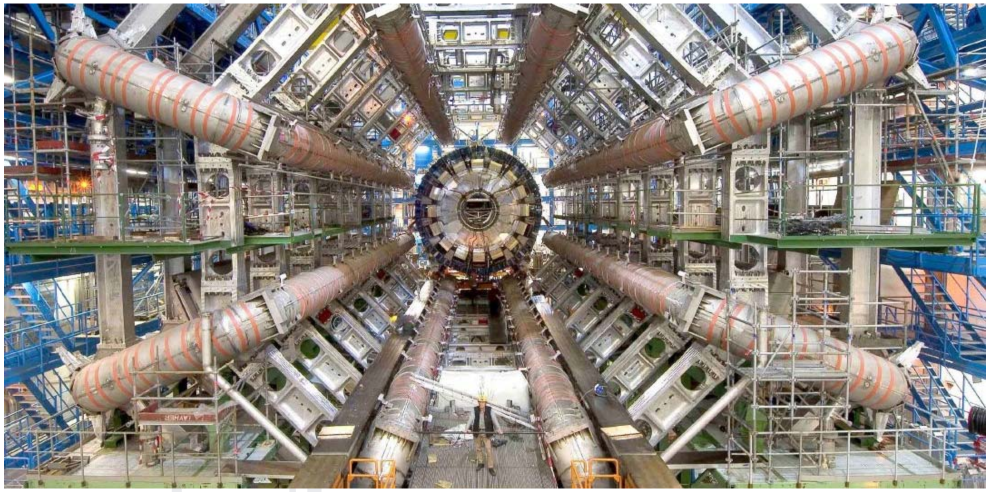
- **Barrel installation/commissioning:**

completed stations tested in assembly hall on surface with cosmics

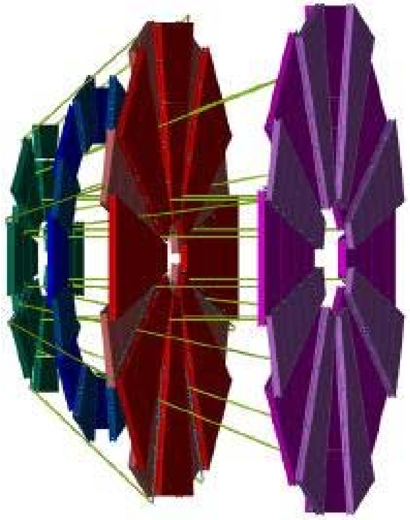
588 muon stations installed one by one in the toroid magnet (≈ 4/day), 99% complete

full commissioning directly after installation impossible as services (cables, gas) not available at that time; now catching up

many stations damaged (and repaired), due to ongoing heavy mechanical work in parallel, and extremely difficult access



Muon Spectrometer



- Endcap region:

  2×4 wheels (EI-inner, EM-middle, EO-outer, EE-extra) of chambers, in front of/behind endcap toroid magnet

  CSC (cathode strip chambers, EI wheel) replace MDT for tracking in small high-rate region around beam line

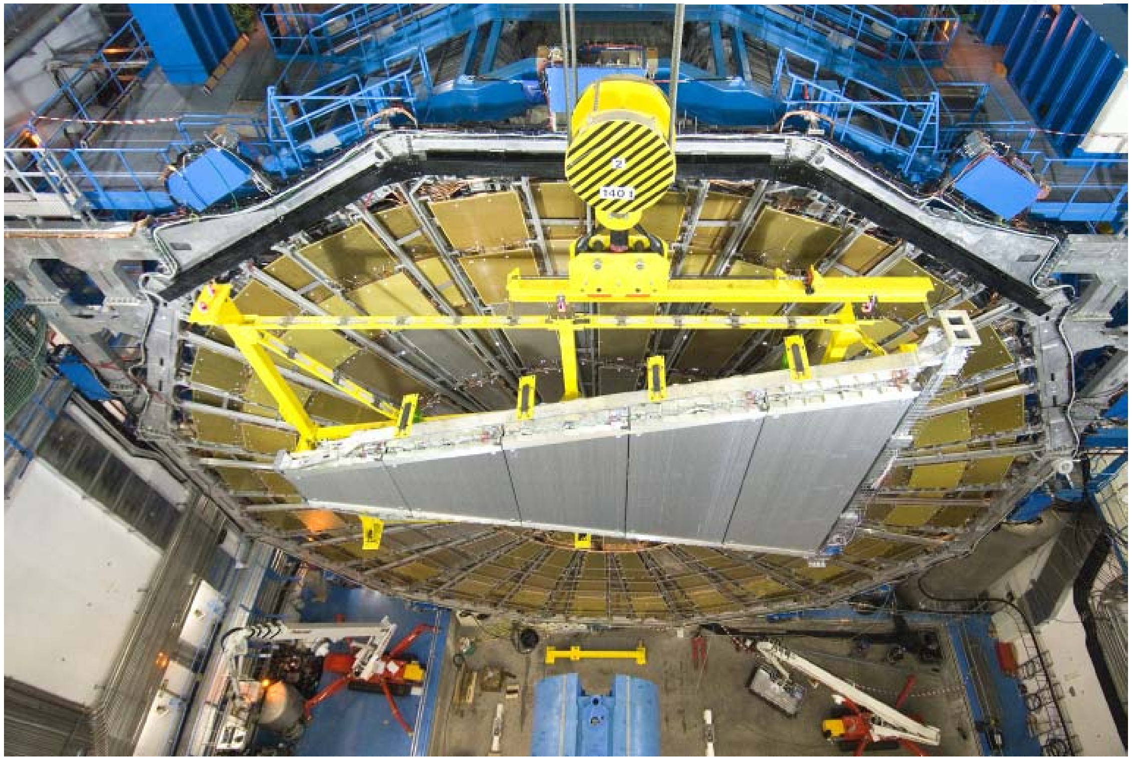
  TGC (thin gap chambers, 3 layers in EM wheel, 1 in EI) as trigger

- Endcap installation/ commissioning:

  for some wheels, chambers are pre-assembled and commissioned on surface in larger units: sectors (EM), entire wheels (EI)

  30–50% installed and being commissioned

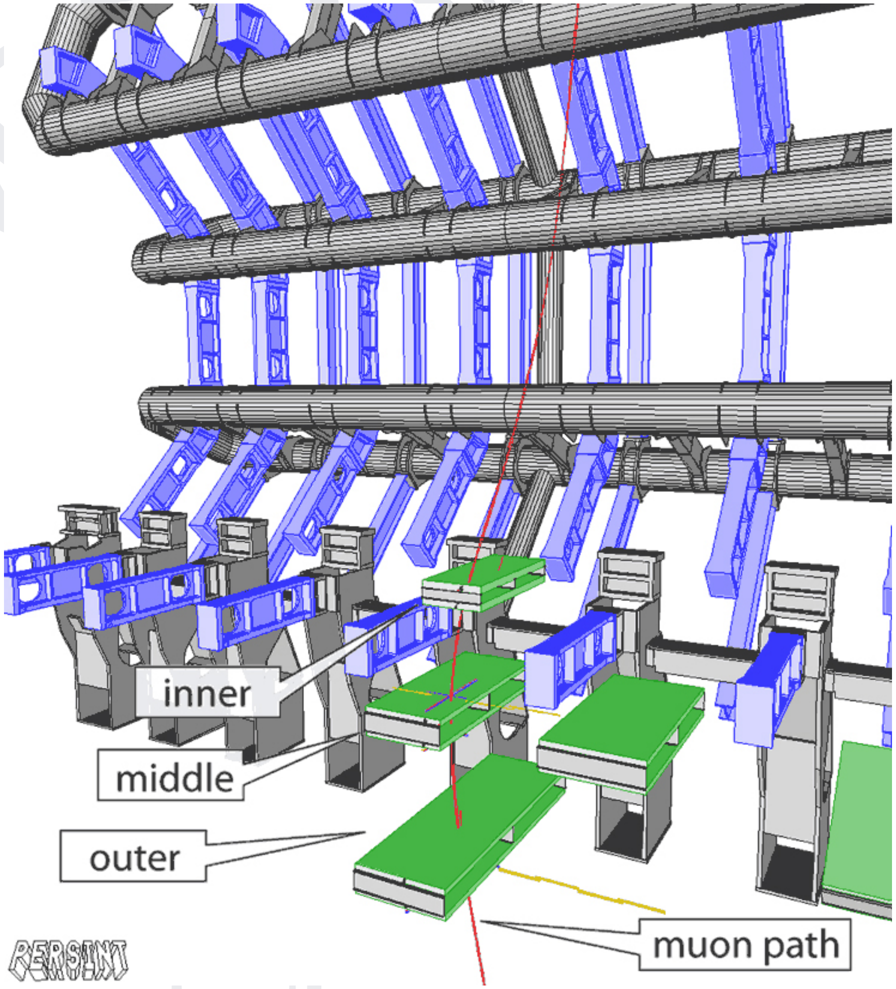
  EI/EM/EO finished by end of 2007, EE not before 2009



Muon Spectrometer

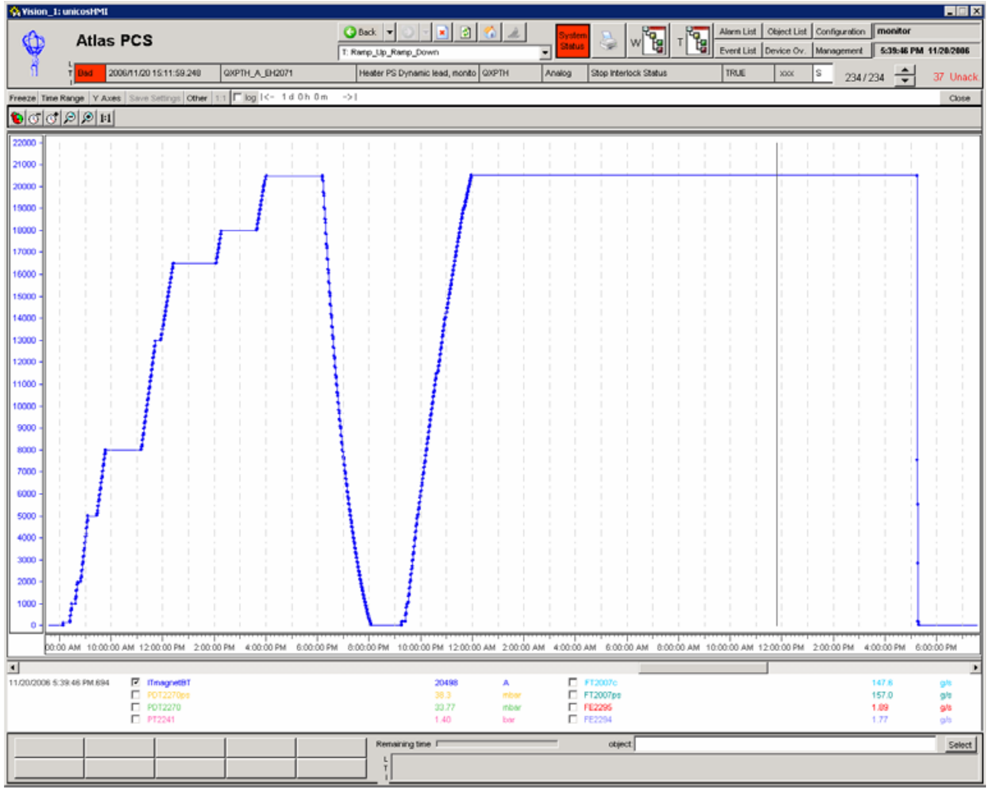
- **Muon Barrel triggers and reconstructs its first curved muons:**

muons triggered by RPC chambers, tracks reconstructed by MDTs



barrel toroid magnet ramped up to 102% of nominal field: 21 kA current

ramped up in steps, without problems (smaller maximum currents tested on the previous days), also tested dumping



T: Ramp_Up_Ramp_Down

monitor

5:39:46 PM 11/20/2006

Bad | 2006/11/20 15:11:59.248 | QXPTH_A_EH2071 | Heater PS Dynamic lead, monito | QXPTH | Analog | Stop Interlock Status | TRUE | xxx | S

234 / 234

37 Unack

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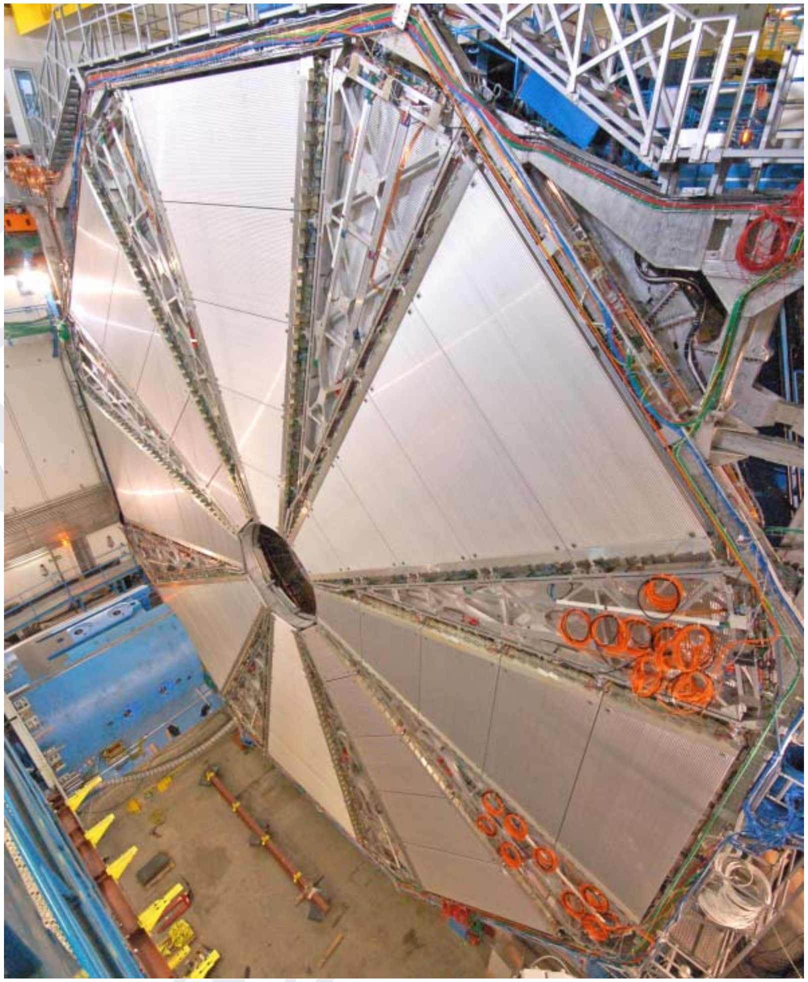
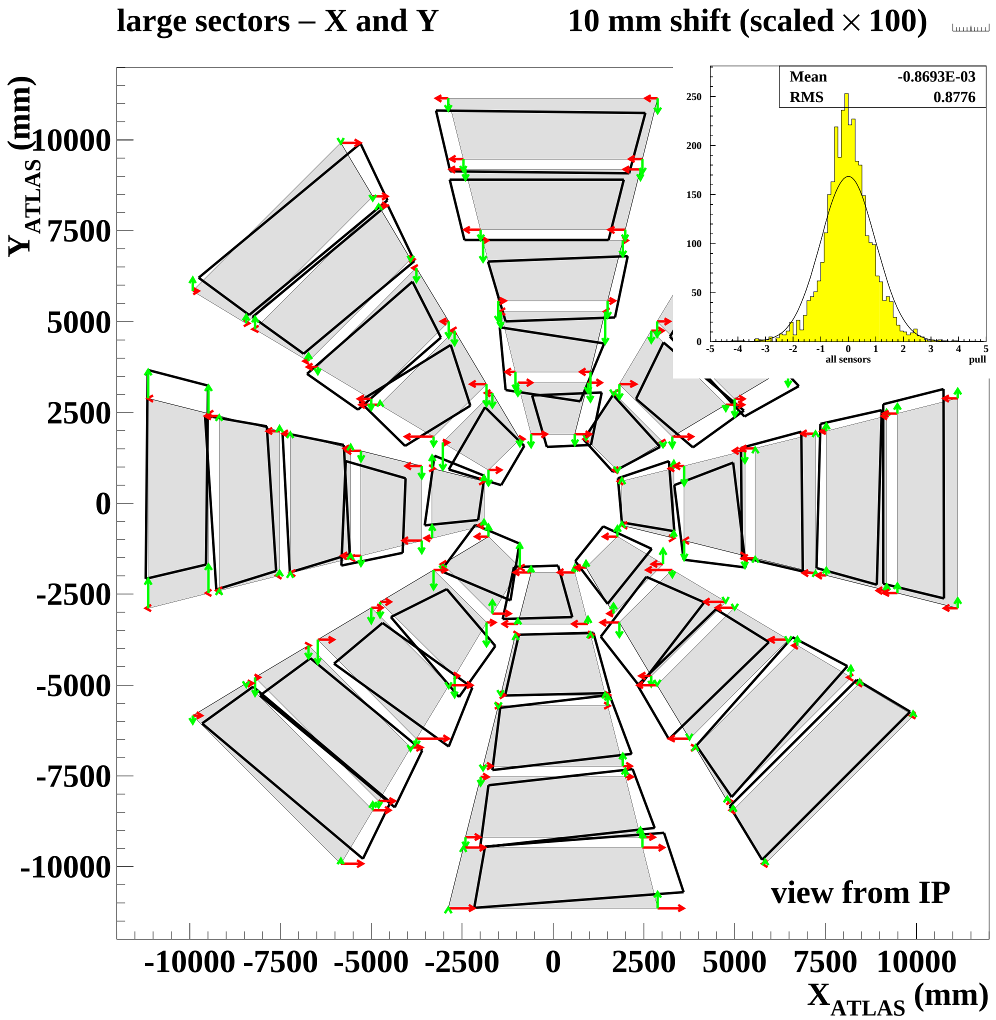
11/20/2006 5:39:46 PM.694

☑ ITmagnetBT 20498 A
☐ PDT2270ps 38.3 mbar
☐ PDT2270 33.77 mbar
☐ PT2241 1.40 bar

☐ FT2007c 147.6 g/s
☐ FT2007ps 157.0 g/s
☐ FE2295 1.89 g/s
☐ FE2294 1.77 g/s

Muon Spectrometer





- Optical alignment system:

≈ 12,000 optical sensors (cameras) to continuously monitor chamber positions (to 40 µm) while running

↑ chamber positions as reconstructed from alignment sensor measurements

check redundant sensor measurements for consistency, compare to survey

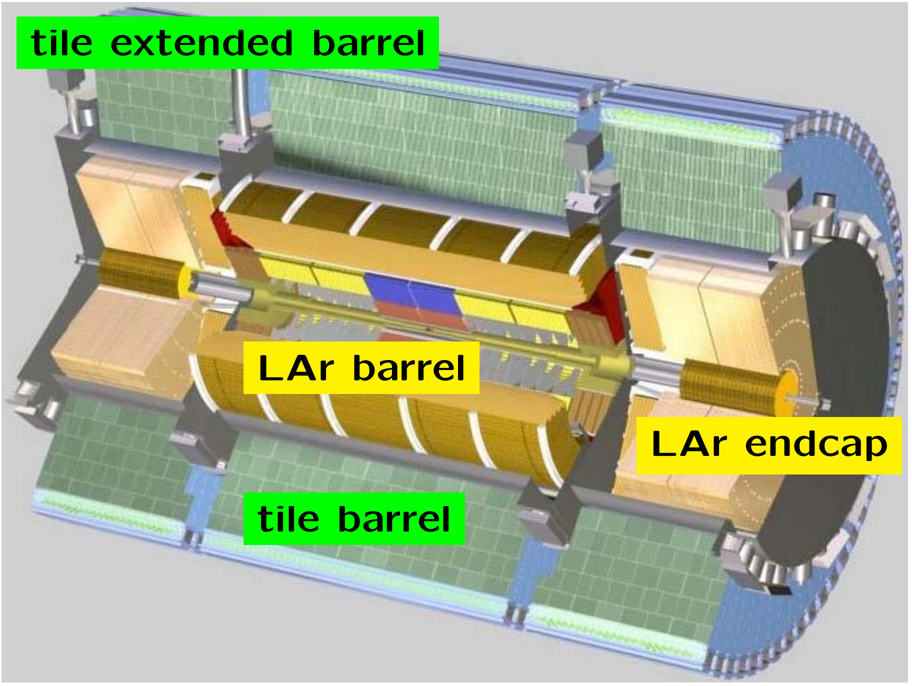
Calorimeters – LAr and Tiles

- **Electromagnetic calorimeter:**

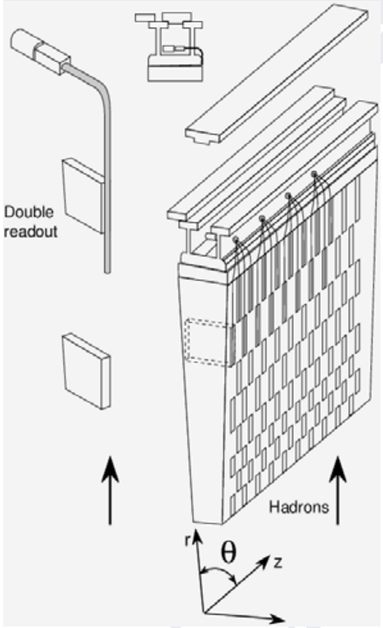
  Liquid-Argon calorimeter with presampler, $\Delta E/E = 10\%/\sqrt{E} \oplus 0.3\%$

  barrel and endcap: accordion-shaped electrodes, lead absorber plates

  forward: tube electrodes in a copper absorber matrix



Tilecal module

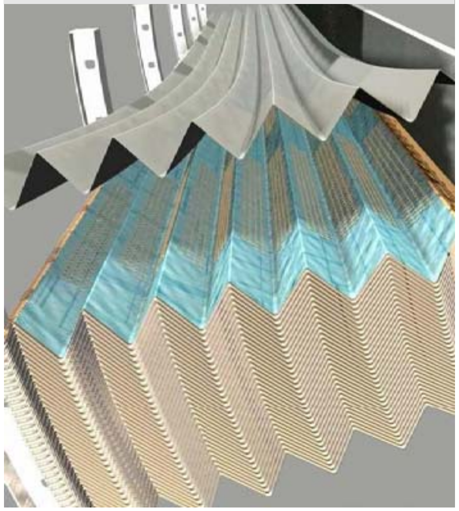


- **Hadronic calorimeter:**

  barrel and extended barrel: scintillator tile calorimeter, steel absorber plates, $\Delta E/E = 45\%/\sqrt{E} \oplus 2\%$

  endcap and forward: Liquid Argon calorimeter, flat electrodes with copper absorber plates (endcap) and tube electrodes in a tungsten alloy absorber matrix (forward)

LAr accordion shape



Calorimeters – LAr and Tiles

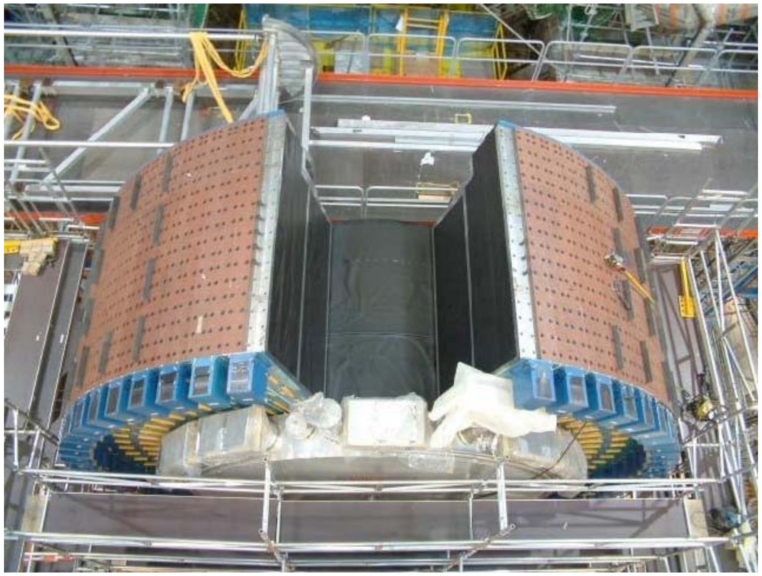
- **Installation and Commissioning:**

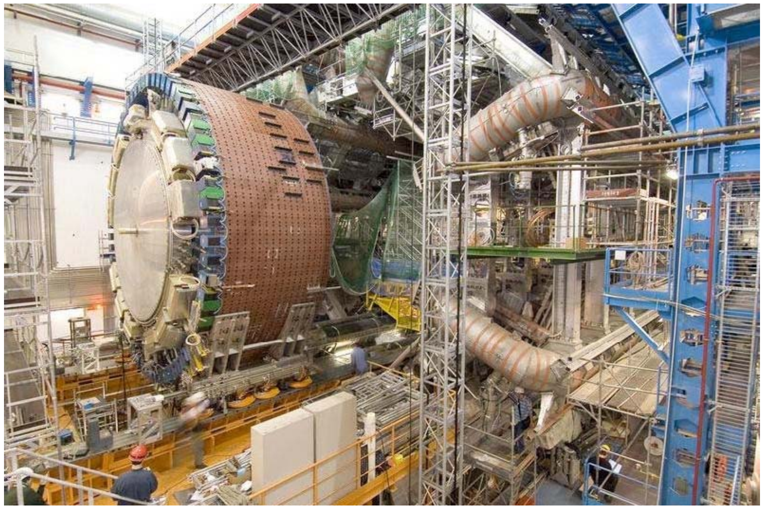
LAr barrel and two endcap calorimeters assembled on surface in cryostats (barrel sharing cryostat with solenoid magnet)

lowered into the pit, onto lower half of barrel/extended barrel tile calorimeters

uppper half of tiles assembled around cryostat, then pushed into final position (barrel) or access position (endcaps)

barrel LAr and Tile calorimeters were the first detectors in the pit, most advanced in services connection and commissioning





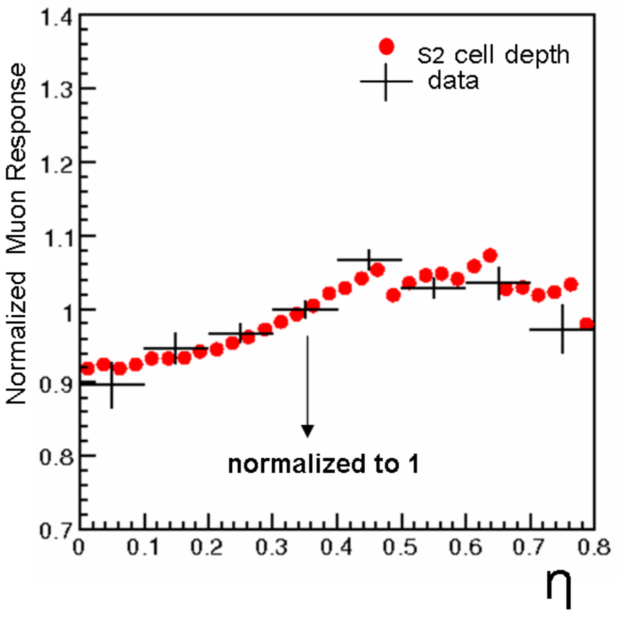
Calorimeters – LAr and Tiles

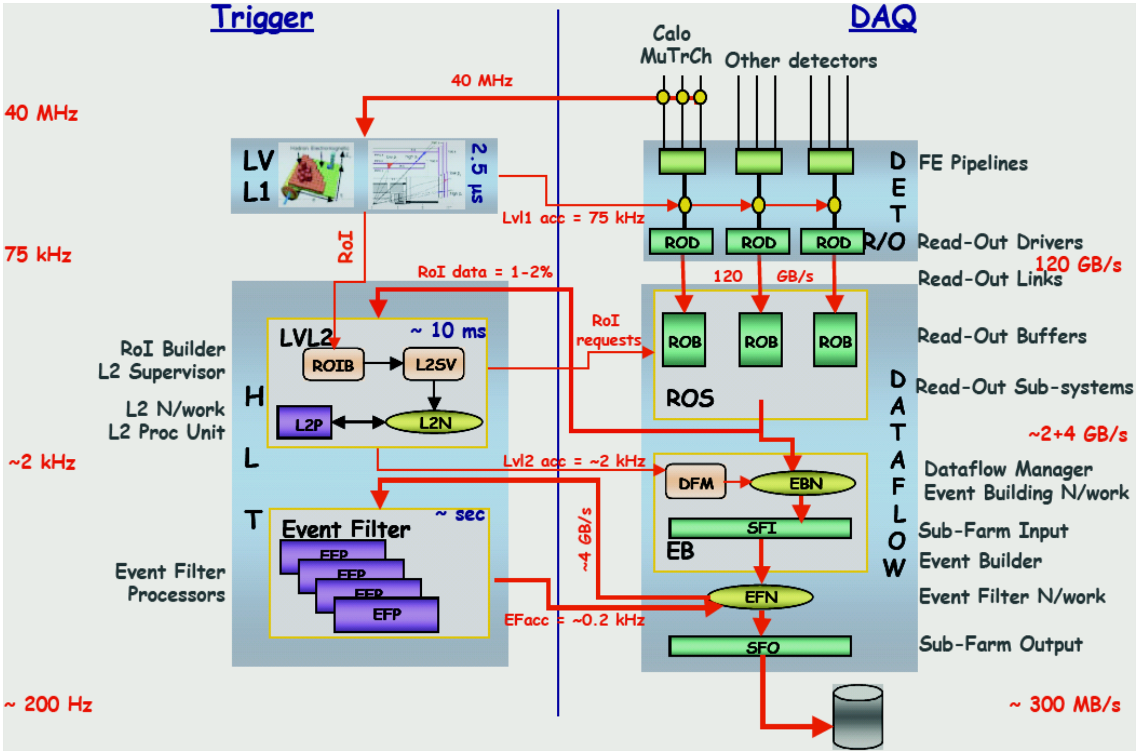
- **Barrel calorimeters most advanced in integration:**

commissioning phase 2: routinely taking cosmic data every weekend, using the trigger/DAQ system set up during the previous milestone week (M2), exercising/debugging the system and many of the final components

including data storage,
online monitoring,
online event display,
DCS, databases, . . .

not yet the final system (→), but many components of it





phase 1 work in parallel: e.g. study uniformity of LAr calorimeter response as a function of η

also studies of calibration, cross-talk, noise; adding endcaps

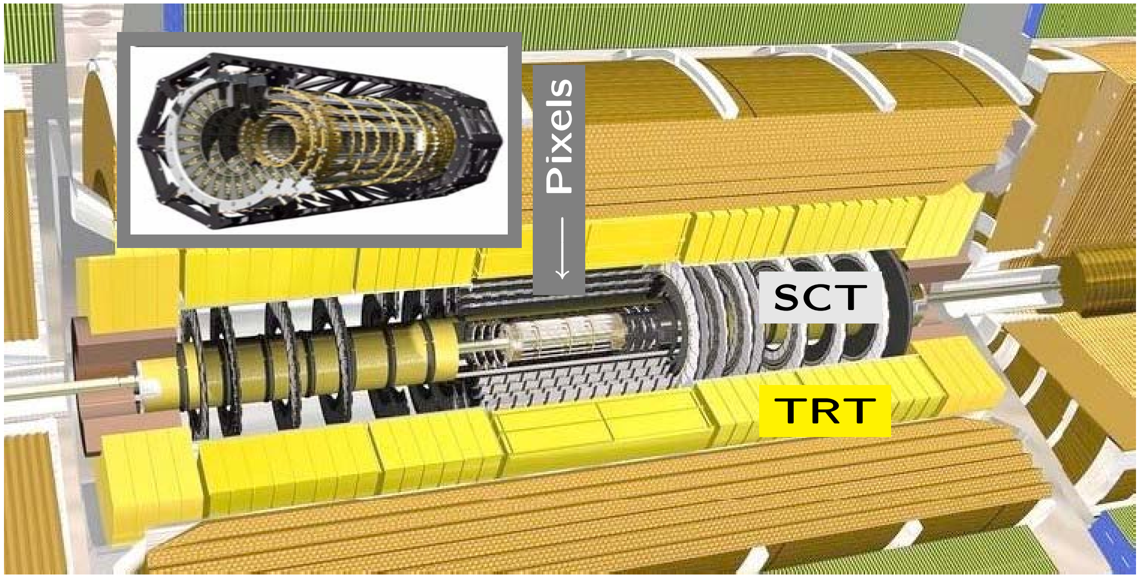
Inner Detector: Pixels, SCT, and TRT

- Pixel (vertex) detector:

  Si pixels: $400 \times 50\,\mu\mathrm{m}^2$

  3 barrel layers,
  2×3 endcap disks

  $8 \cdot 10^7$ channels



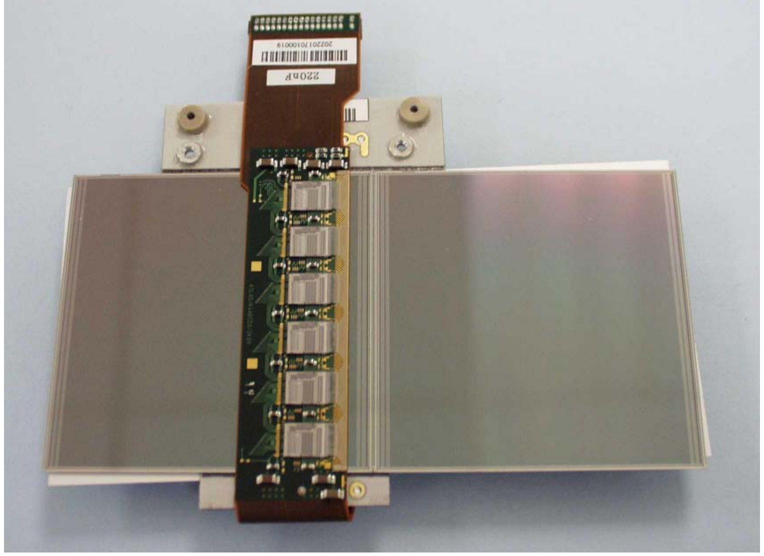
- Silicon tracker (SCT):

  Si strips: $80\,\mu\mathrm{m}$ pitch (stereo)

  4 barrel layers, 2×9 endcap disks

  $6 \cdot 10^6$ channels

SCT barrel module



- Transition radiation tracker (TRT):

  straw tubes: 4 mm diameter

  in $16\,\mathrm{m}^3$ volume, interleaved with radiator

  $4 \cdot 10^5$ channels

  ≈ 35 hits per track, $150\,\mu\mathrm{m}$ resolution

Inner Detector – SCT and TRT

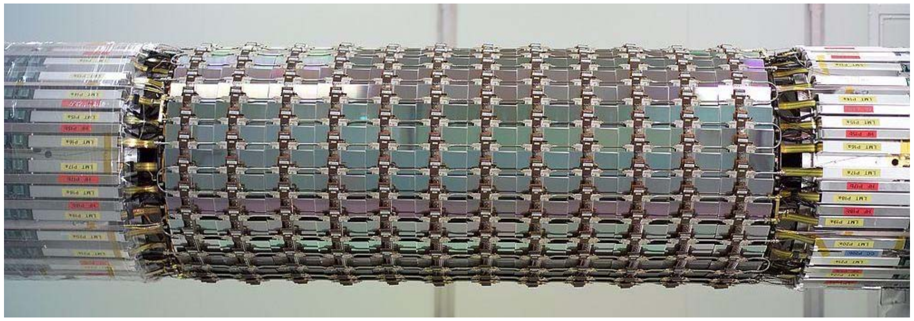
- **Installation and commissioning:**

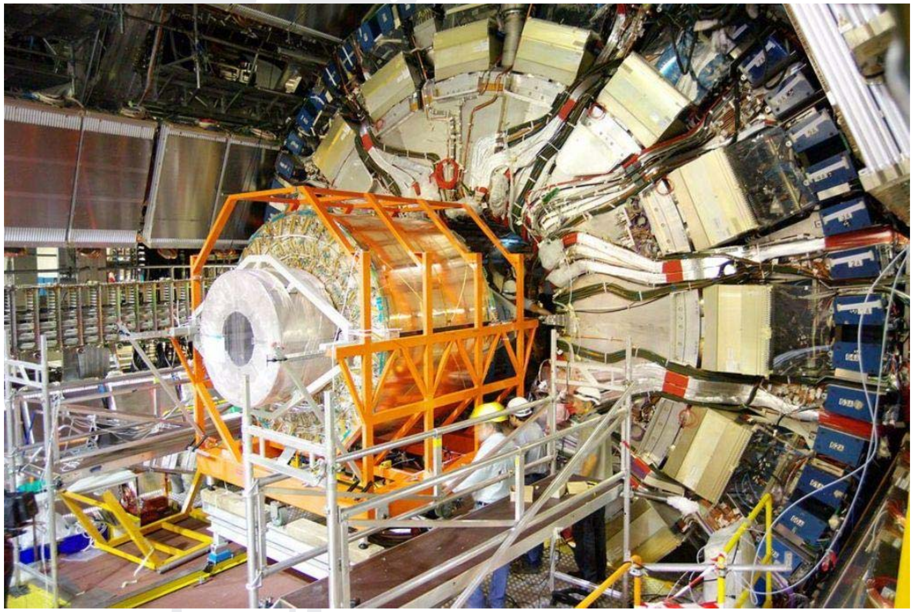
in clean room on surface: SCT cylinders (B3, B4, B5) inserted into largest one (B6), complete SCT barrel inserted into TRT barrel

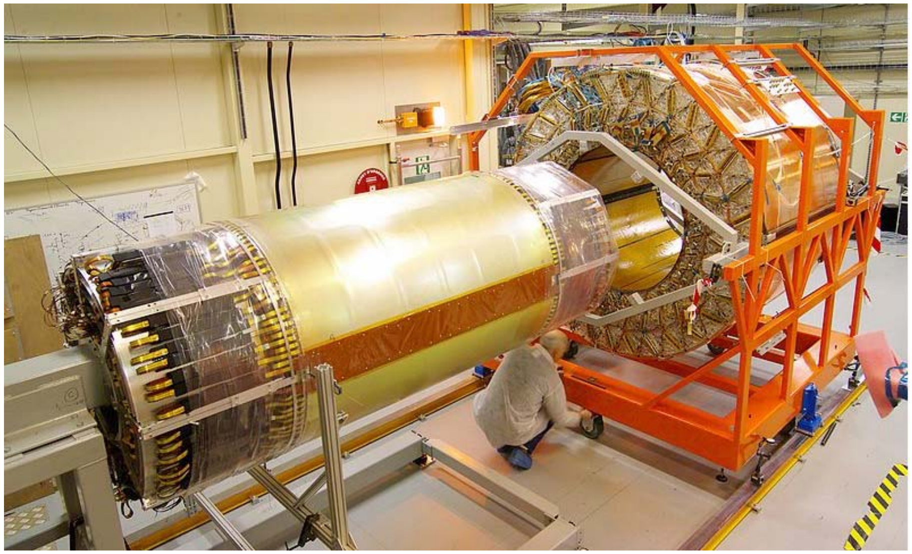
temporary connections of services, extensive commissioning on surface

SCT and TRT barrels are now installed inside ATLAS calorimeters, continuing commissioning in the pit

endcaps: SCT/TRT assembled, to be installed in ATLAS in May





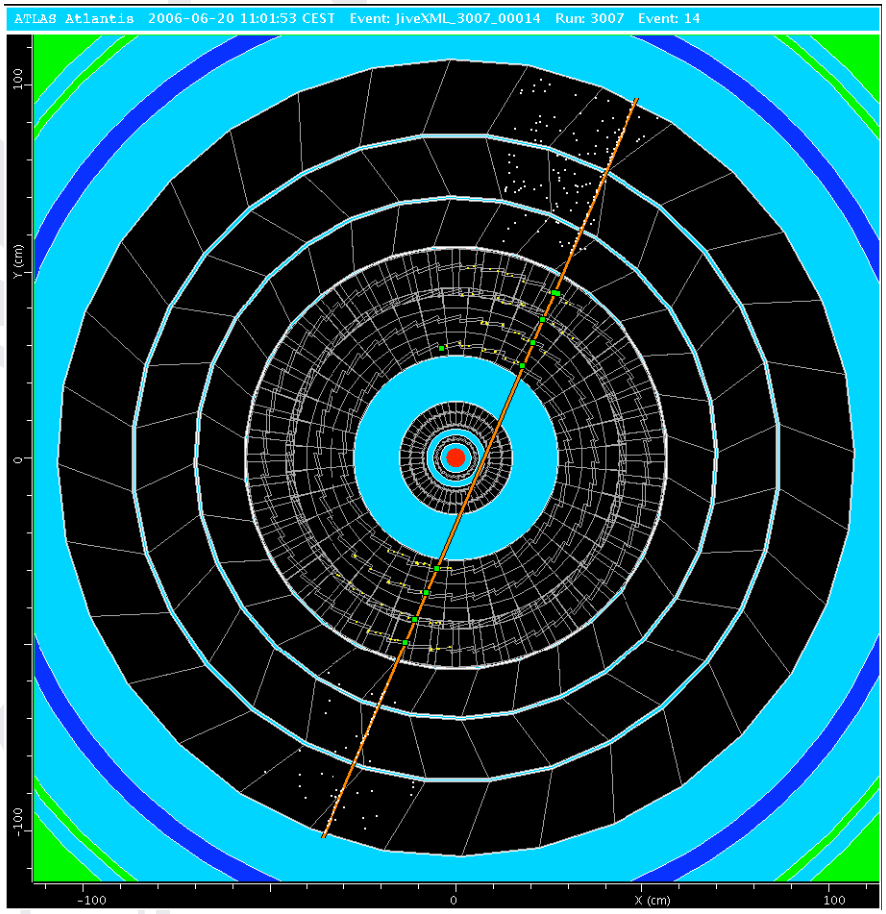


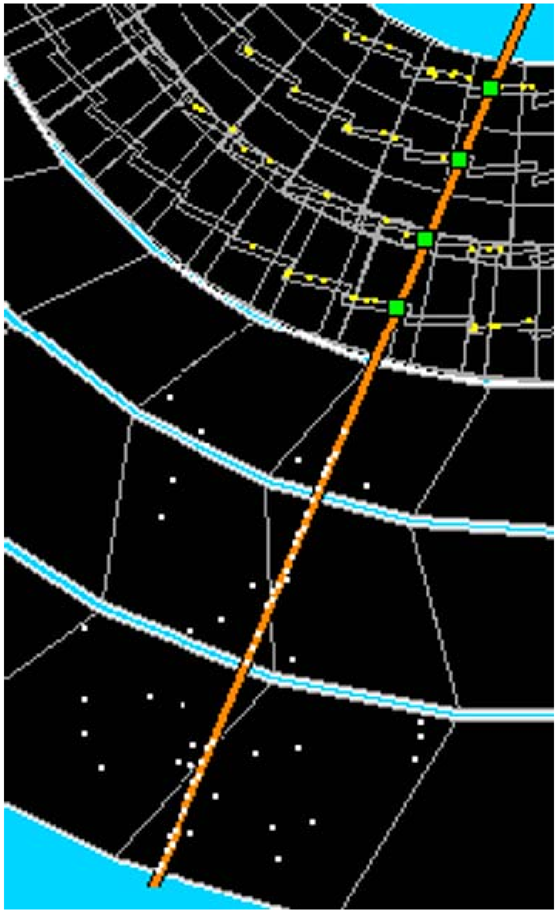
Inner Detector – SCT and TRT

- **Commissioning with cosmics:**

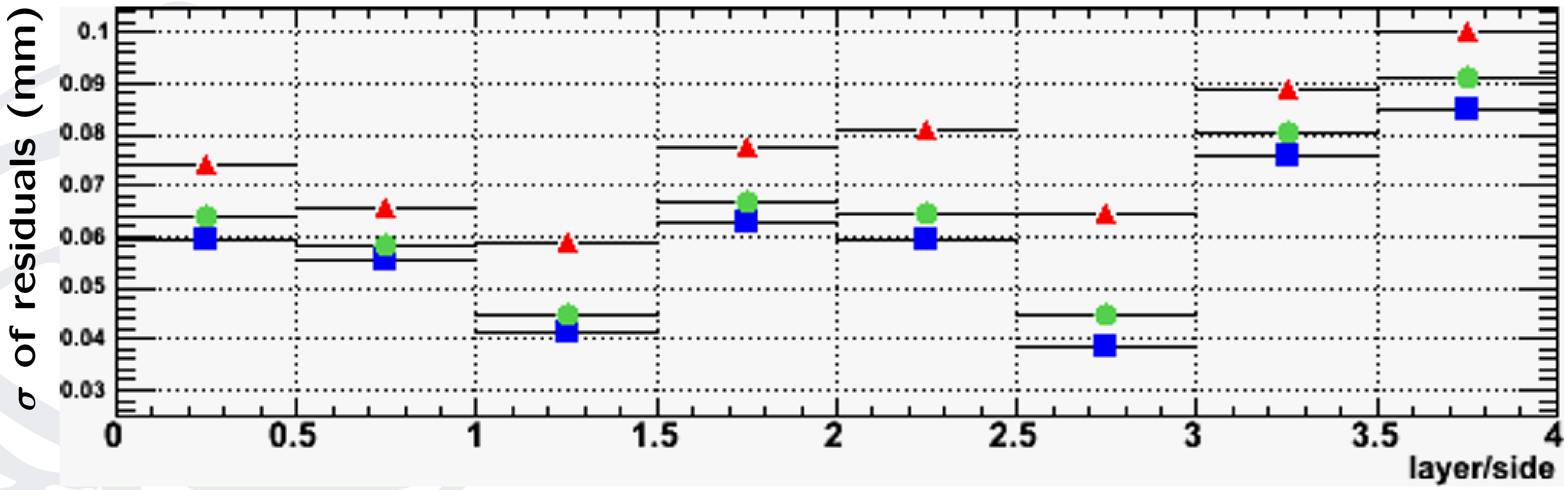
combined commissioning of SCT and TRT: online event display of cosmic track in SCT and TRT barrels
(on surface, using external scintillator trigger)

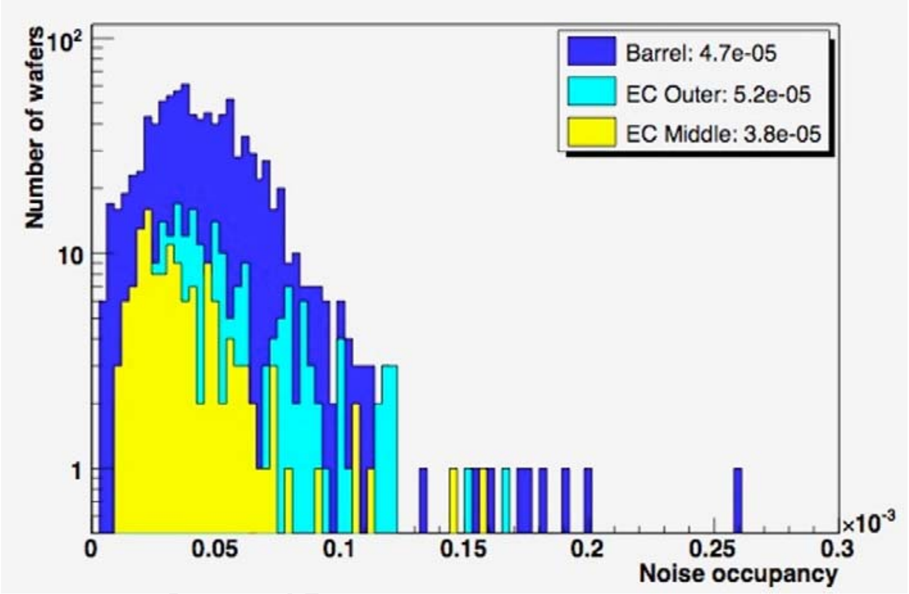
repeated in the pit with Tilecal as trigger





Inner Detector – SCT





- **Efficiency, alignment, noise:**

  look for dead/quiet/noisy channels

  determine hit efficiency

  ↑ exercise alignment algorithms, extract mean/width of track residuals, compare to MC

  ← measure noise occupancy, look for induced extra noise

  same type of studies done for TRT, Pixels

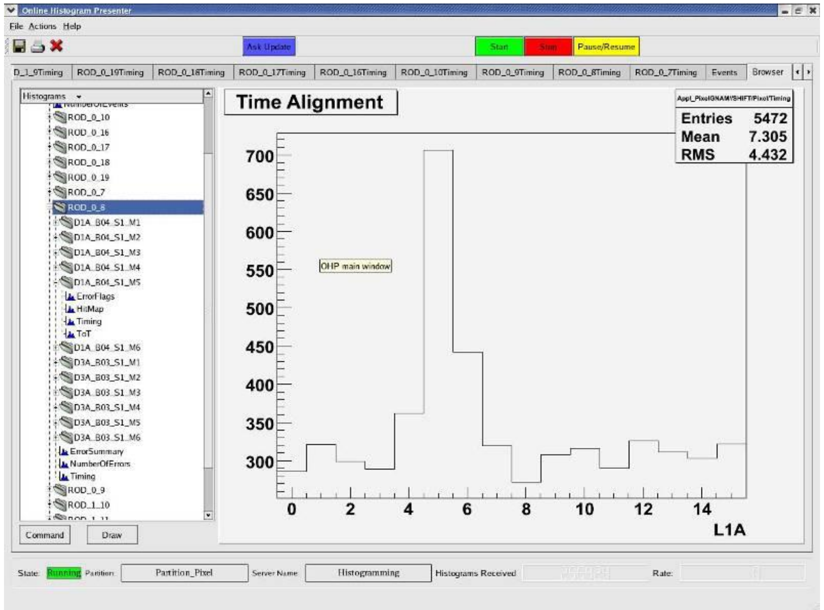
Inner Detector – Pixels

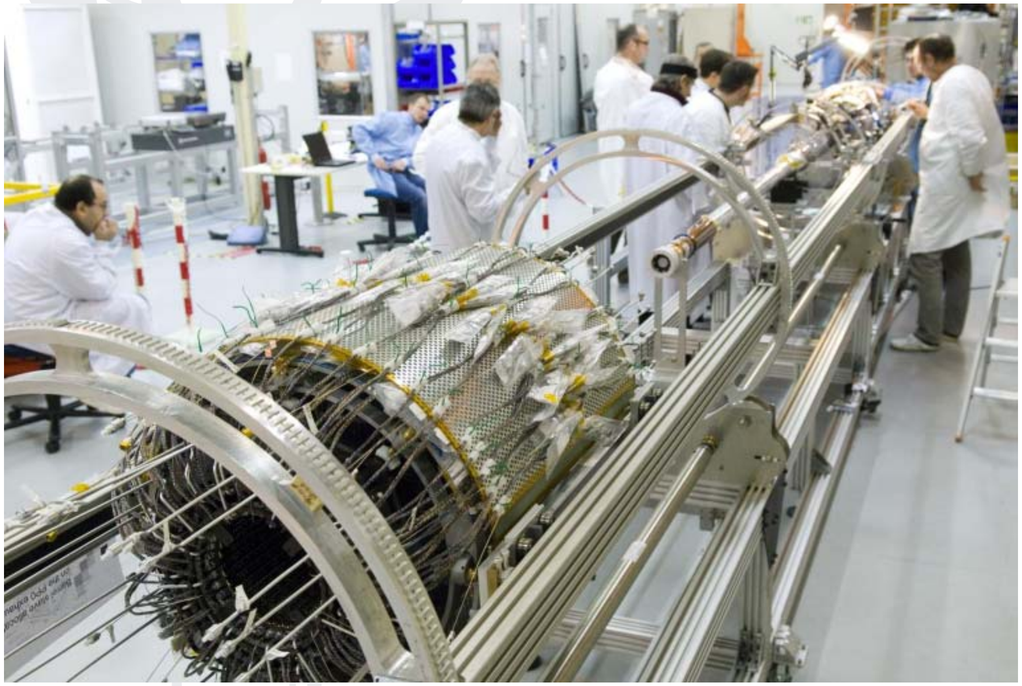
- **Installation and Commissioning:**

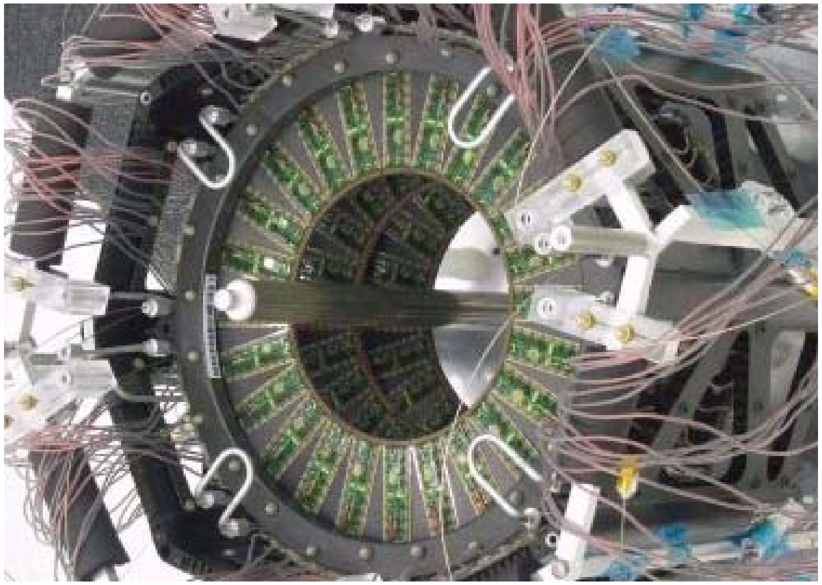
  in clean room on surface: assembly of pixel barrel and endcaps mostly done, now installing and testing services

  ready for installation in ATLAS in June

  first cosmic signal in the pixel endcaps → (time of pixel hit after scintillator trigger)







Selected Recent Problems

- **SCT evaporative cooling system:**

  SCT (operated at $-7°C$) cooling system uses heaters: to raise the temperature of the exhaust fluid above the dew point of the cavern

  a heater of the barrel system overheated in the pit, temperature rising to $\gg 200°C$, smoke coming out – not prevented by the interlocks

  could have been a major desaster if SCT endcaps already installed

  problem being investigated by experts, now modifying architecture to buy time: heaters moved outwards, so that they can be accessed/installed later

- **LAr calorimeter low-voltage power supplies:**

  passed acceptance test upon reception at CERN,
  but exhibited alarming failure rate when installed
  and running in the detector: no clear pattern observable

  complete reverse engineering revealed $\approx$ 20 different issues/problems/design flaws: retrofitting ongoing

  delivery schedule critical (require access to calorimeters)

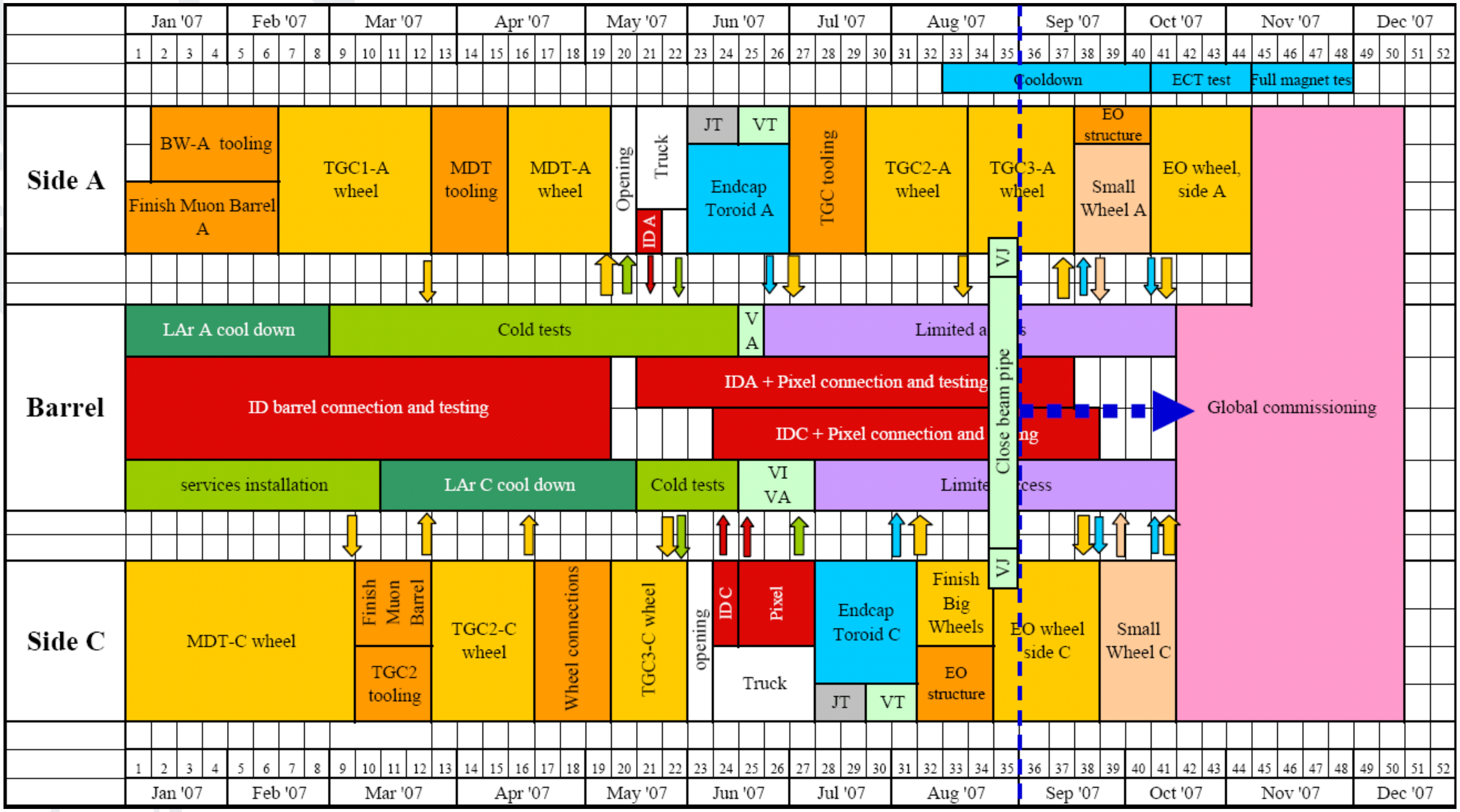
  some other sub-detectors are having (completely different) problems with power supplies, too

Endgame: Installation Schedule 2007

- **If all goes well:**

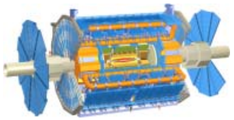
finish installing all sub-detector components before end of 2007

biggest/outermost (muon spectrometer endcaps) and smallest/innermost (pixel) detectors are last to be installed



Conclusions

- **Summary:**

  the  installation is progressing, on track to be finished in 2007

  the  commissioning is well underway, with most sub-detectors in an advanced state of their individual commissioning

  barrel detectors typically more advanced than endcaps

  one of the main themes for the rest of 2007 will be the integration of more and more sub-detectors to eventually form the  detector

  several milestone weeks upcoming: next one (M3) planned for June, integrating calorimeters (already in M1/M2), SCT/TRT barrels, muon barrels/endcaps