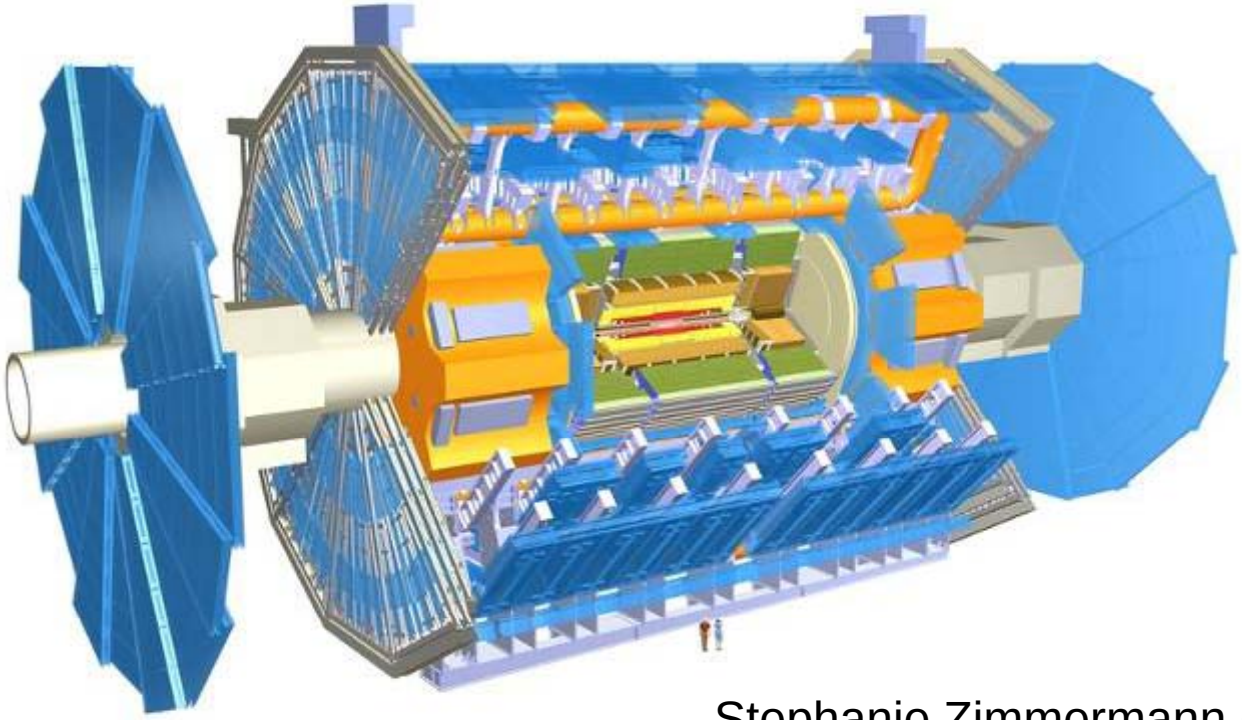
Status of ATLAS detector commissioning

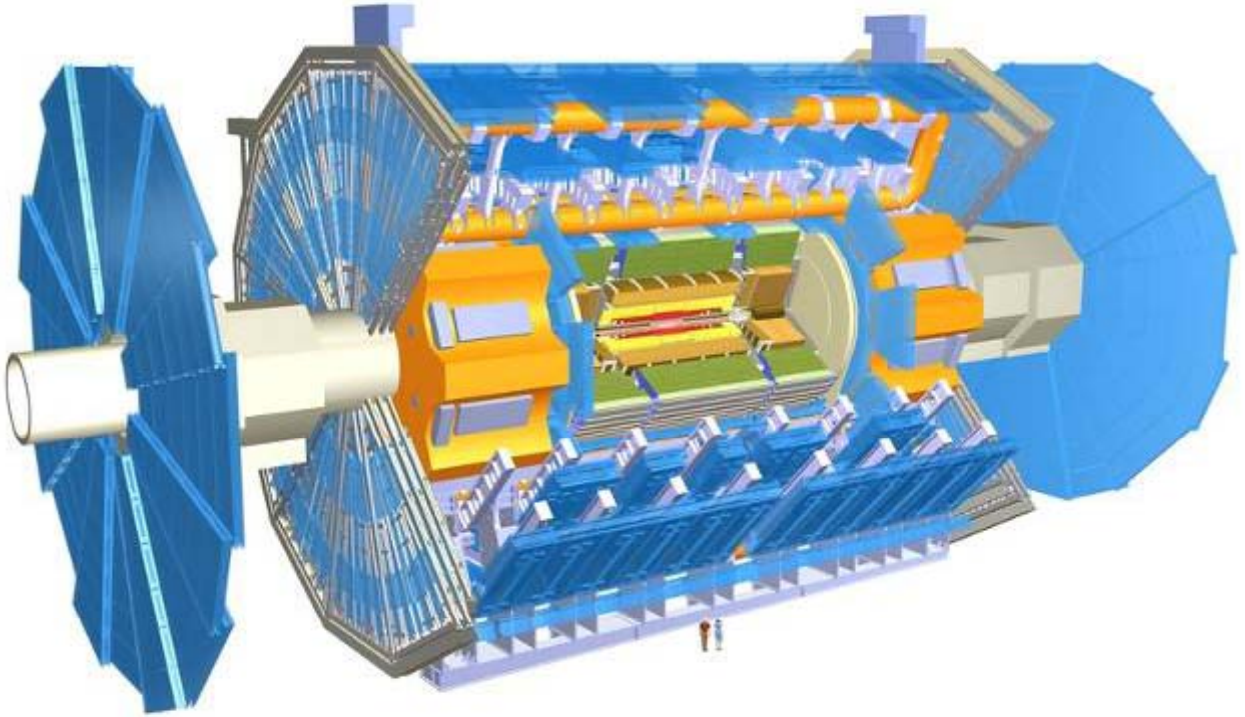


Stephanie Zimmermann (Freiburg)

for the ATLAS collaboration

HS-07, Modra-Harmonia,
Slovakia, September 3-7, 2007

Outline ….



- Introduction to ATLAS
- Overview of detector components
- Status of individual sub-detectors
- Global commissioning effort
- Summary and conclusions

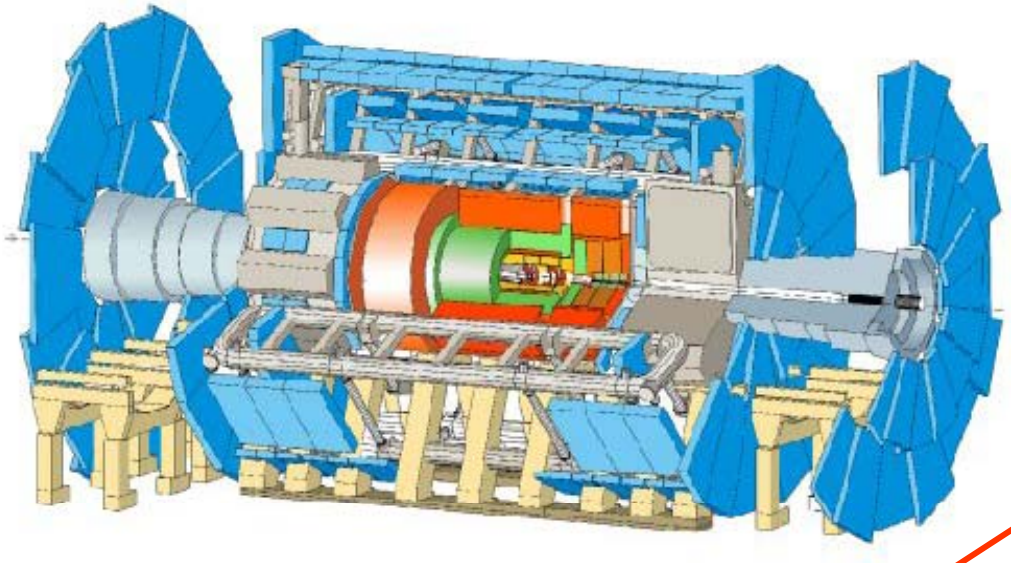
The ATLAS collaboration …

- 1 Experiment
- 35 Countries (with collaborating institutes, many more where collaborators are from…)
- 165 Institutes (as of July 2007, still becoming more …)
- 1900 scientific authors

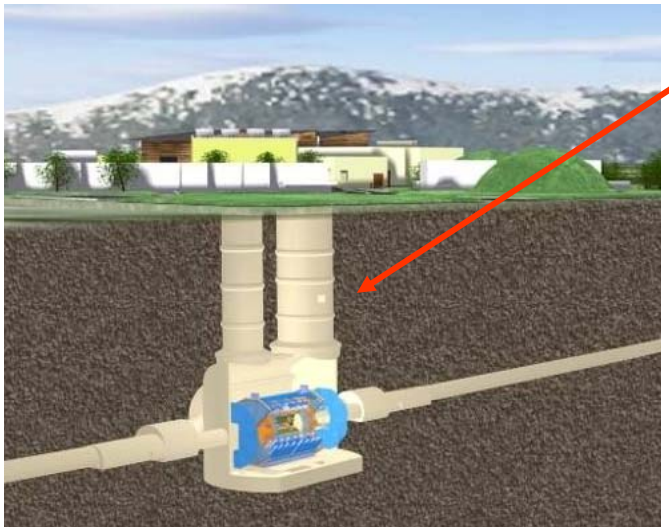
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, 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, Goetingen, 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, Rome I, 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

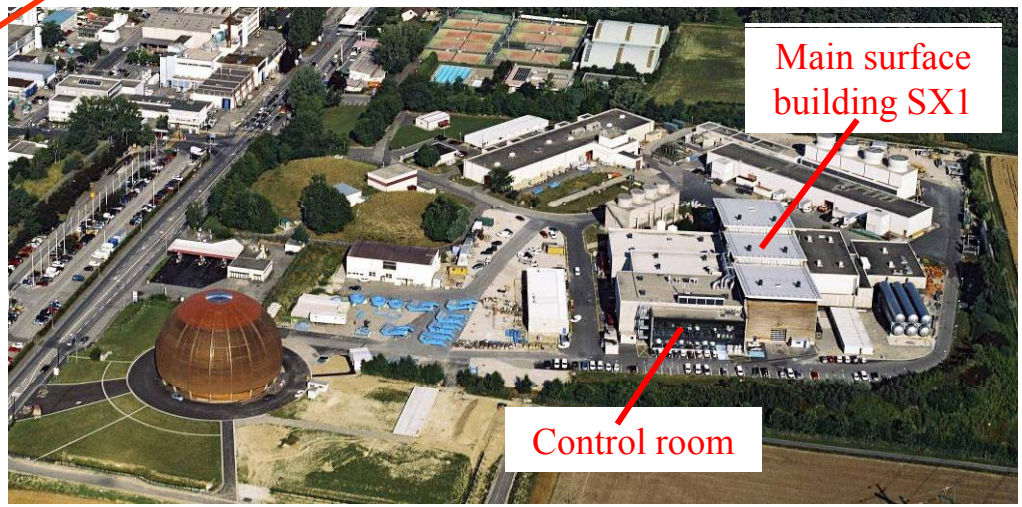
The detector …

The largest ever built



- 25m diameter
- 46m total length
- 7000t weight
- installed just across the CERN main site, 92 meters below ground
- ATLAS cavern: 55m long, 32m wide, 35m high: just large enough for the detector – ‘ship in a bottle’, but have to assemble in situ





Detector components …

Where ATLAS got its name from: **A** **T**oroidal **L**HC **A**pparatu**s**

4 super-conducting magnets: solenoid + 3 toroids

Solenoid field 2T in inner detector region

toroid field peak strength 4T

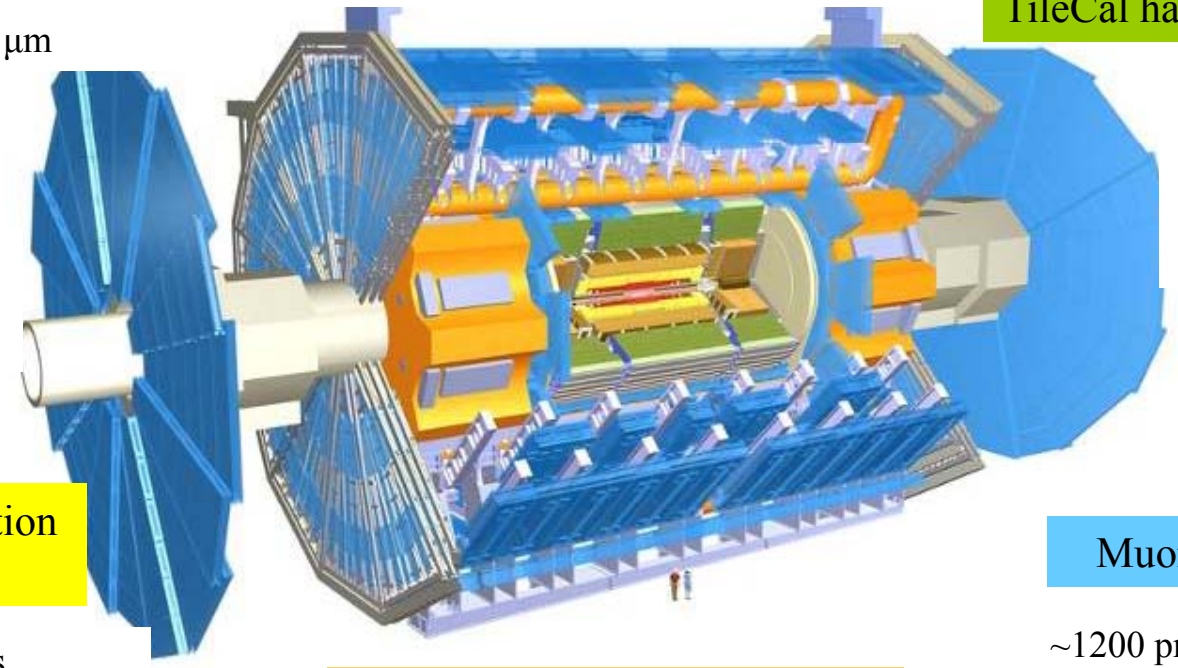
Silicon Pixel detector

$1.4 \cdot 10^8$ channels, intrinsic resolution 10 x 110 µm

Silicon tracker

~ $6 \cdot 10^6$ channels

80µm wide strips



TileCal hadronic calorimeter

Sandwich structure: iron absorber + scintillator tiles

~ 10000 channels

Transition Radiation Tracker

Xe field straw tubes, interleafed with PP/PE foil

Electron - pion separation

~ 35 hits/track for track reconstruction

LAr calorimeters (EMC, HC)

~ 160000 + 10000 channels (EMC,HC)

50%/√E energy resolution for e,γ

Trigger for electrons, photons and jets

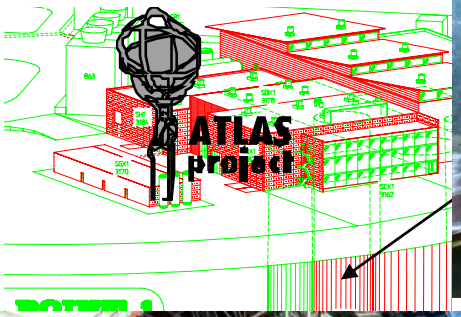
Muon spectrometer

~1200 precision chambers for track reconstruction

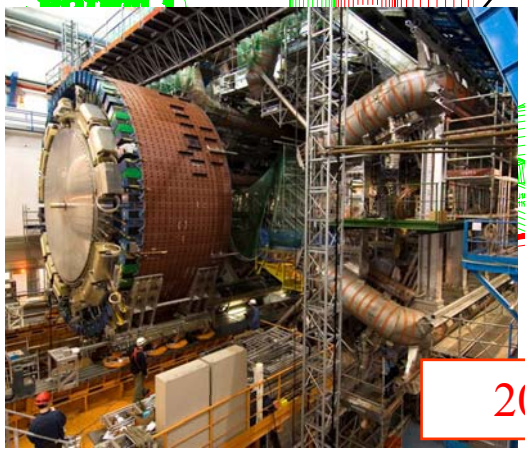
~600 RPC and ~3600 TGC trigger chambers

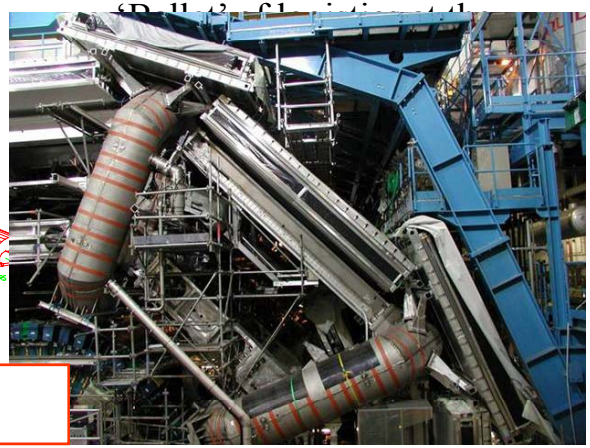
Stand-alone momentum resolution $\Delta pt/pt < 10\%$ up to 1 TeV

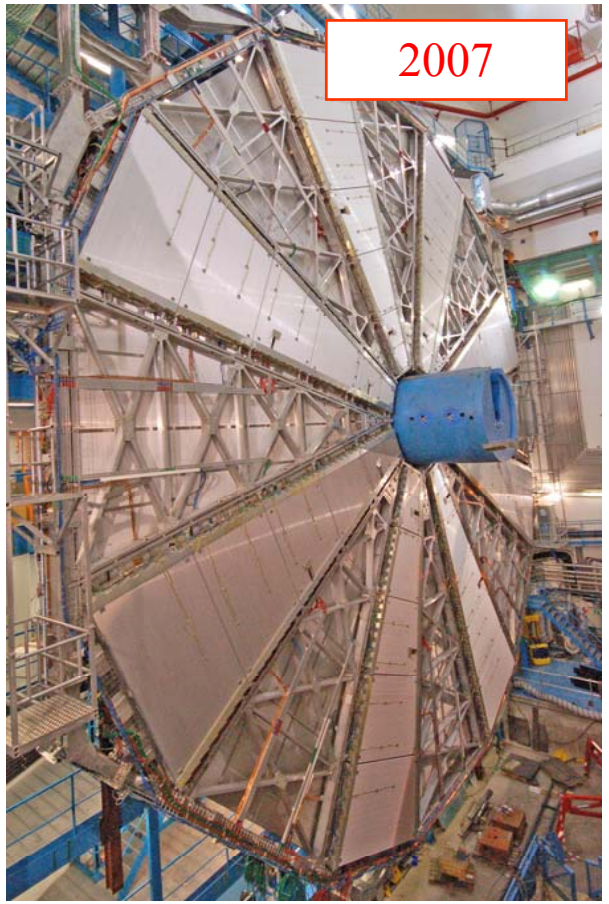
Installation – the years 2003 to 2007 …




Jun 2007

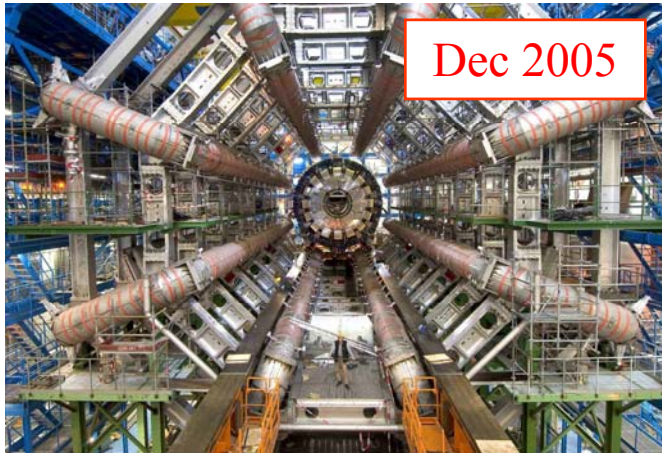

2006




2007


Aug. 2003


Dec. 2004


Dec 2005

Status: Magnet System – Central Solenoid

• Initial cool-down May 17 -23 2006, cold since then,

• First field May 25 to June 3 2006, current limited to 1kA due to cavern not yet cleared from magnetic material,

• Run at full current (7.6kA) in August 2006, detailed field mapping to 0.5 mT accuracy using a dedicated apparatus:

→ relative error on track sagitta from field uncertainties $6.3 \cdot 10^{-4}$, essentially meeting the requirement of $\Delta(\int Bdl)/\int Bdl < 0.05\%$ (driven by m_W determination)

→ Field map produced as input to offline reconstruction

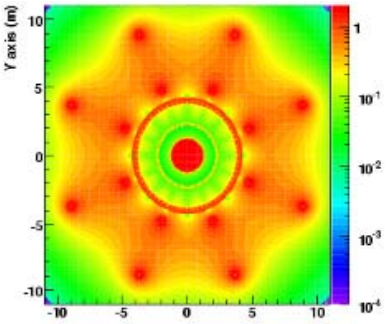
(ATLAS Athena software)

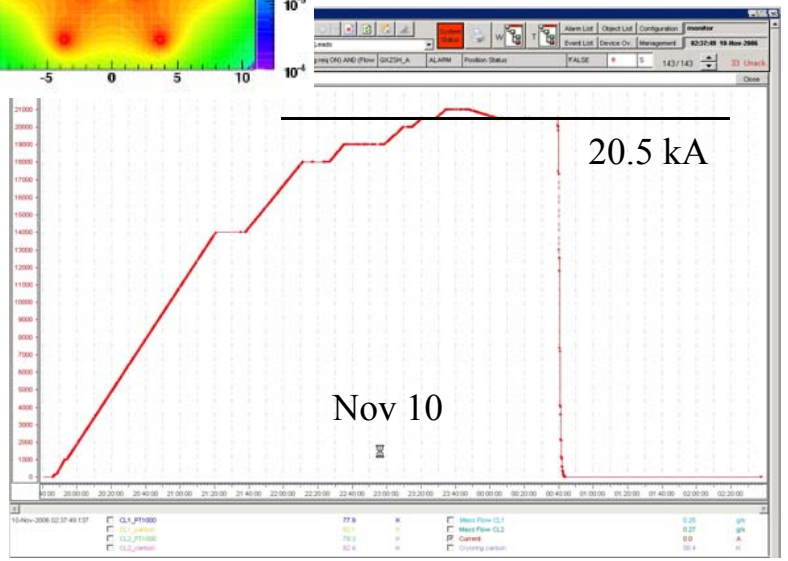
• 48 hall probes, 1 NMR probe on two rotating arms (90 degree angle) on carriage movable in z-direction

• measurements allow realistic field description including effects from e.g. the helical shape of the conductor, shape deformations due to the cool down, contribution of magnetic material,..

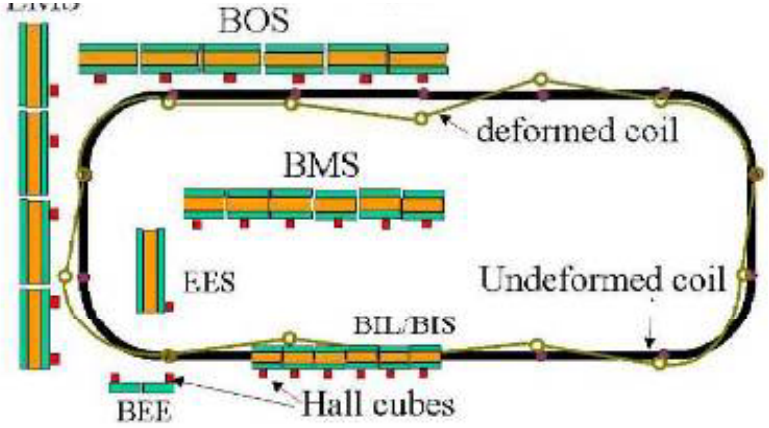
Status: Magnet System – Barrel Toroid

- Initial cool down in July 2006,
- Field tests up to nom. current in Nov. 2006,
  - reached operational current on the first try (no training),
  - slow and fast dump procedures validated
  - first reconstruction of bent cosmics track in the muon spectrometer !
- since November: (understanding the) field reconstruction





- Due to toroidal field no mapping possible:
- Measure field with 1789 3D hall probes (mainly on muon chambers),
- 'Fit' shape of the coils such that calculated field according to Biot-Savart + iron contribution agrees best with measurements
- Goal: ~ 1 mT (!!), current reconstruction of Nov. data: 2mT for BM, BO and 7 mT for BI.



Status: Magnet System – Endcap Toroids

• Endcap toroids installed in the ATLAS cavern in May and July this year,

15 m high, 5 m wide, 240 tons weight

Special installation procedure:

Lower into shaft by 5m on special supports, only then pick up by crane and lower to cavern

Next steps:

• Finish cryogenics and power connections, start cool down process

• Test ECT-A and ECT-C separately from mid October,

• Final validation together with the Barrel Toroid end of November.

Status: Calorimeters -- TileCal

• scintillating tiles + iron absorbers, $\Delta E/E = 45\%/\sqrt{E} \oplus 2\%$

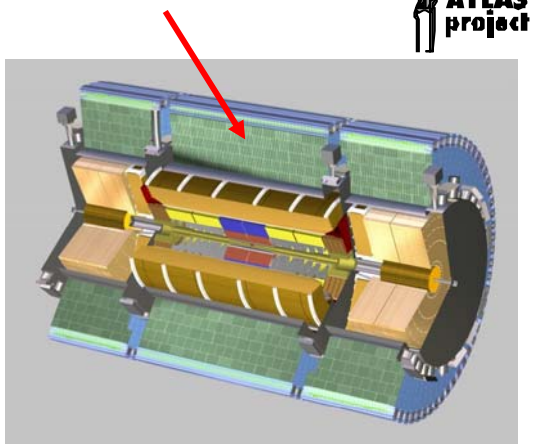
• barrel Tile calorimeter one of the first components installed in ATLAS → Commissioning well advanced:

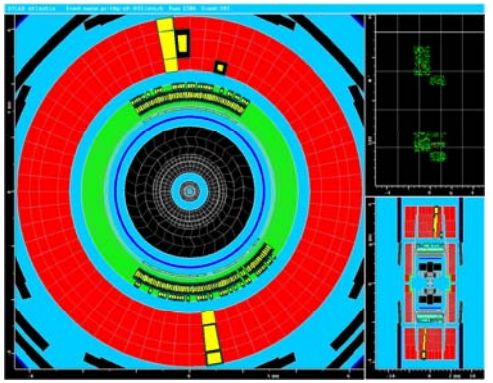
  • All services completed,

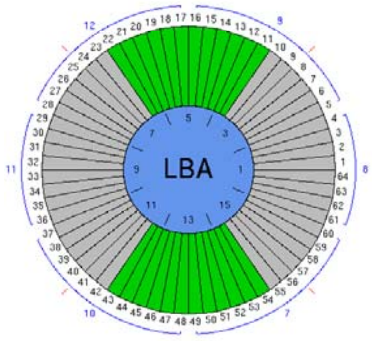
  • 80% of the modules regularly powered,

  • Need for intervention on the FE electronics of all 256 super drawers discovered (unacceptably ΔV in on-board voltage), in progress

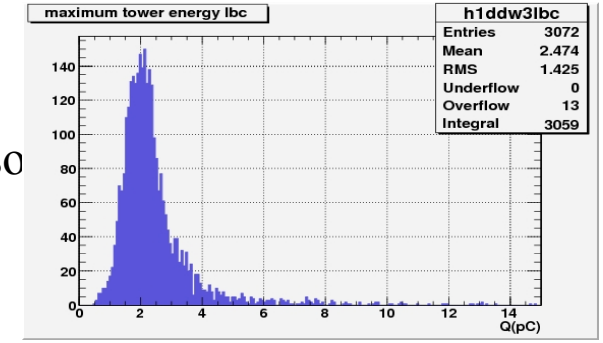
  • Online event display, detector control system and readout thru ATLAS RODs (ReadOut Drivers) fully set up,





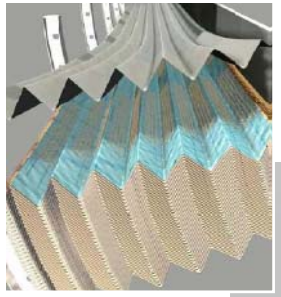


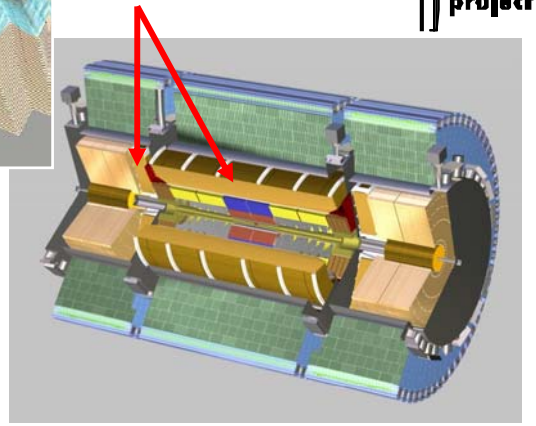
• cosmics data taking both stand alone and together with the remainder of ATLAS in the joined milestone runs since many months, also providing cosmics trigger



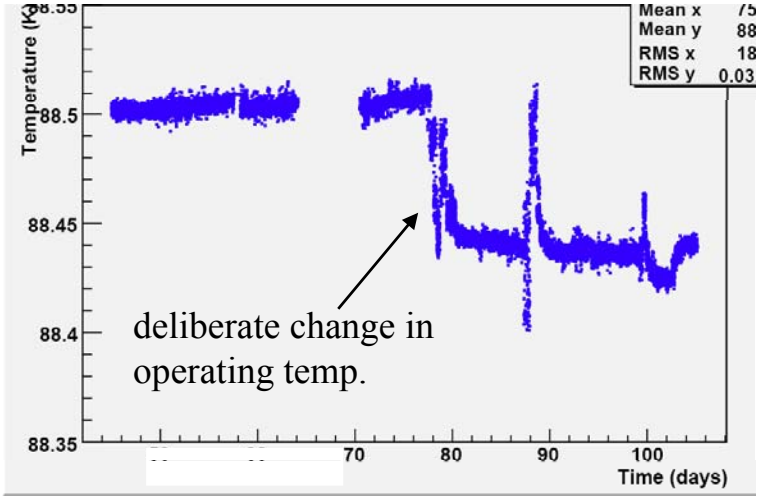
Energy in most energetic tower

Status: Calorimeters – LAr ECAL

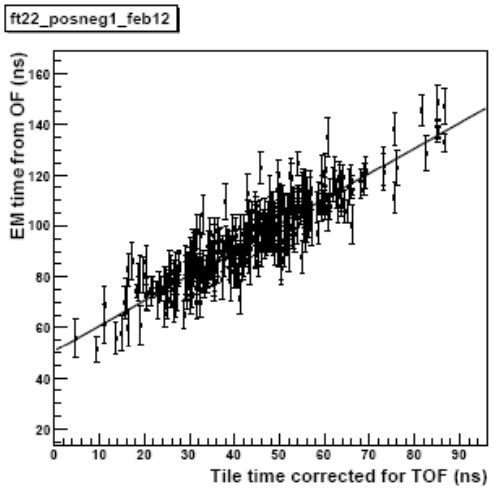




- Uses accordion-shaped electrodes and lead absorbers,
- Barrel: Installation in 2004/05, final cool down in April 2006,
- Endcap: Installation in 2005, final cool down Dec ’06/ spring ’07 (side A/C)
- cold since then, excellent temperature and Ar purity stability



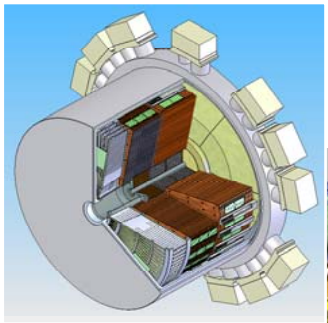
- Regular data taking with cosmics, calibration: aim is for 100 events/cell:
  - relative timing to < 1 ns level,

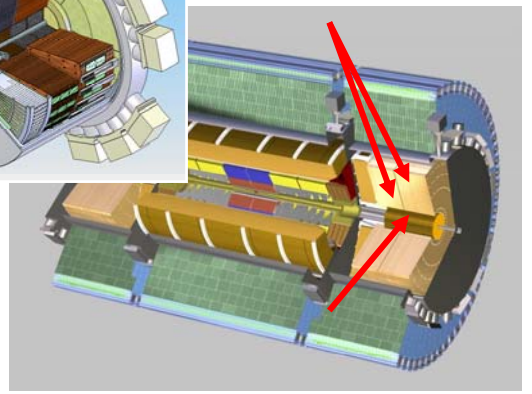


- position w.r.t. other detectors to < 1mm,
- uniformity of the response to < 0.5%

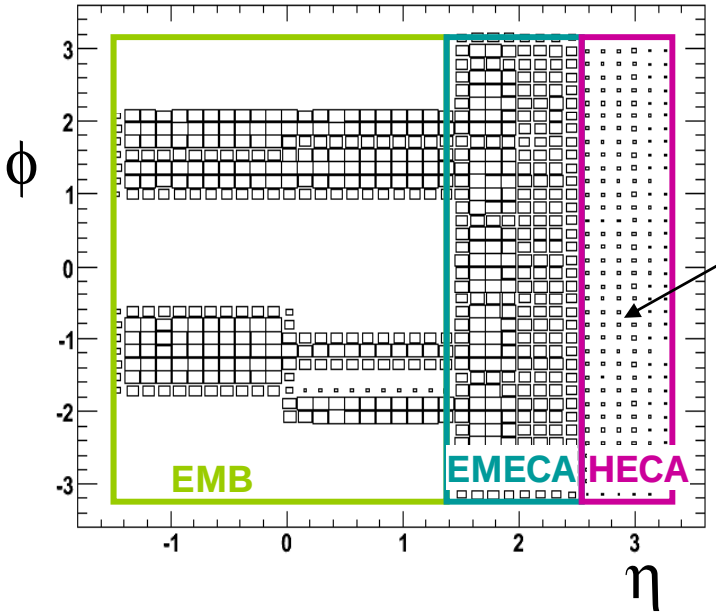
Current main activity: Understanding pulse shape of all individual cell, obtain initial set of calibration constants

Status: Calorimeters --- LAr Hadronic Endcap



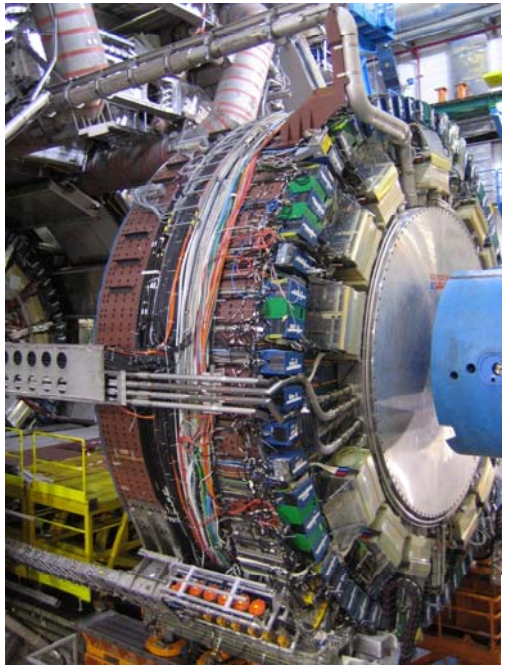


- Copper absorbers (HEC)/ tube electrodes in a tungsten
- alloy (FCAL)
- Installed together with endcap ECAL, cold since Dec. ’06/spring 07,
- Operation under nominal HV for side A since April ’07, side C imminent
- data taking with cosmics ongoing, similar goals as for EM calo

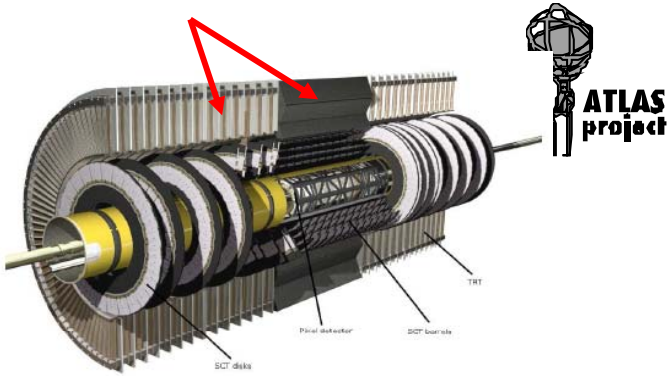


‘cosmics’ occupancy during June combined run …

Endcap calorimeter in the extended position, outside the barrel toroid



Status: Inner Detector -- TRT

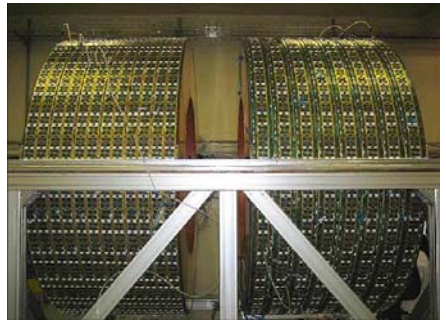


• 4 mm straw tubes, arranged in 2·160 disks and 73 layers, interleafed with stacks of PE/PP foil ;

• operated with Xe:CO_2:O_2 = 70 : 27 : 3%

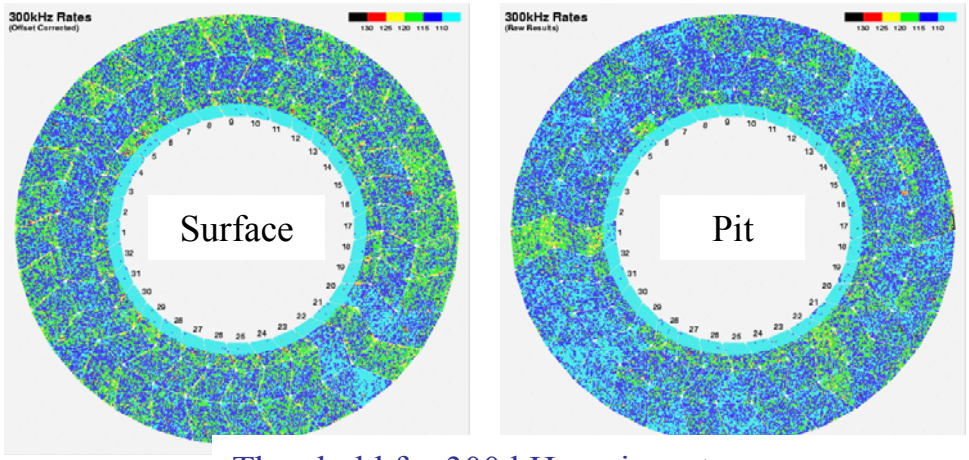
• Double purpose: Enhanced pion-electron separation (TR γ's convert into e's in Xe) , track reconstruction/momentum determination (average 35 hits/track, single tub res. 130 μm))

• Installed in ATLAS Sept. '06 (barrel), May/June '07 (endcaps),

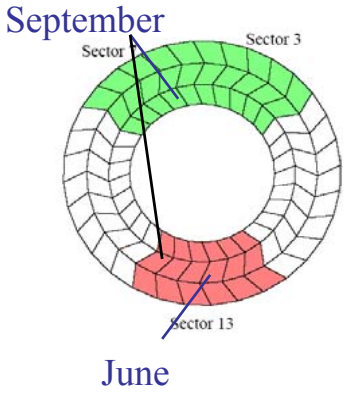


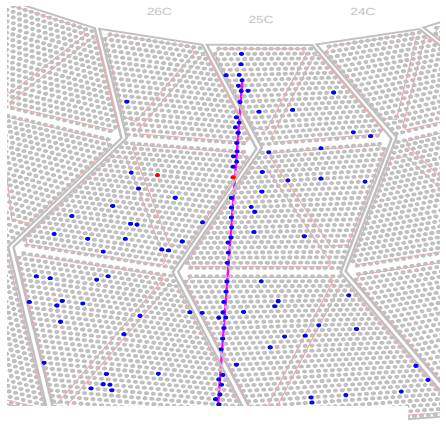
• Exhaustive data taking with cosmics both on surface and after installation (barrel), first data taking with endcap in the pit NOW

• data monitoring, detector control and DAQ well advanced



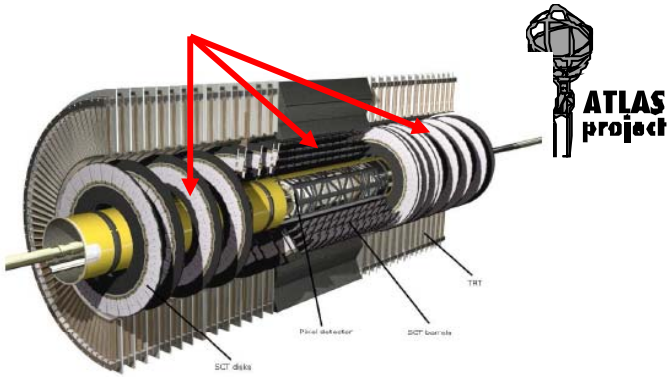
Threshold for 300 kHz noise rate



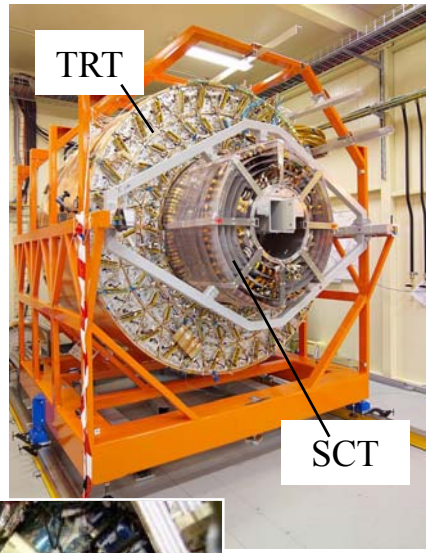


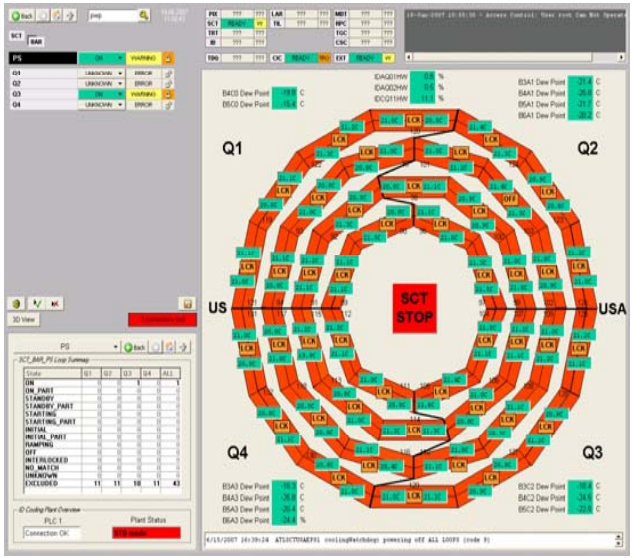
Cosmic track re-construction in the pit

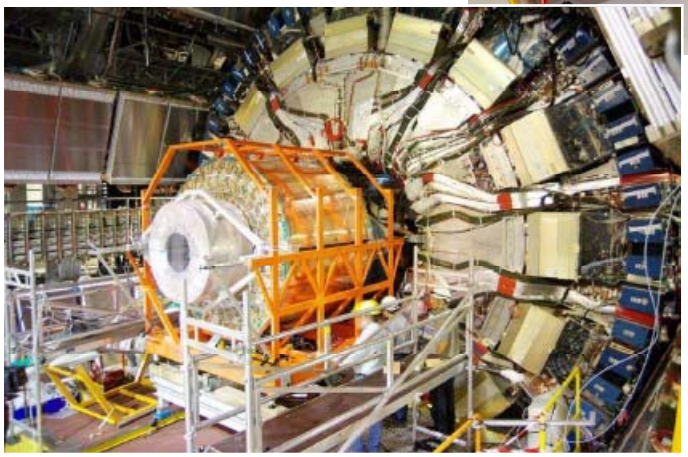
Status: Inner Detector --- SCT



- 4 cylindrical layers (barrel) + 2·9 disks of silicon strip, 80μm pitch, aligned with slight angle of 20mrad
- Installed together with the TRT (one module),
- Service/cable installation (~ 40000 individ. cable bundles together with TRT, equivalent to 800 man months) completed
- Integration into detector control system, including environmental control, and DAQ advanced
- Barrel fully signed off, < 0.3% dead channels (out of $6 \cdot 10^6$)

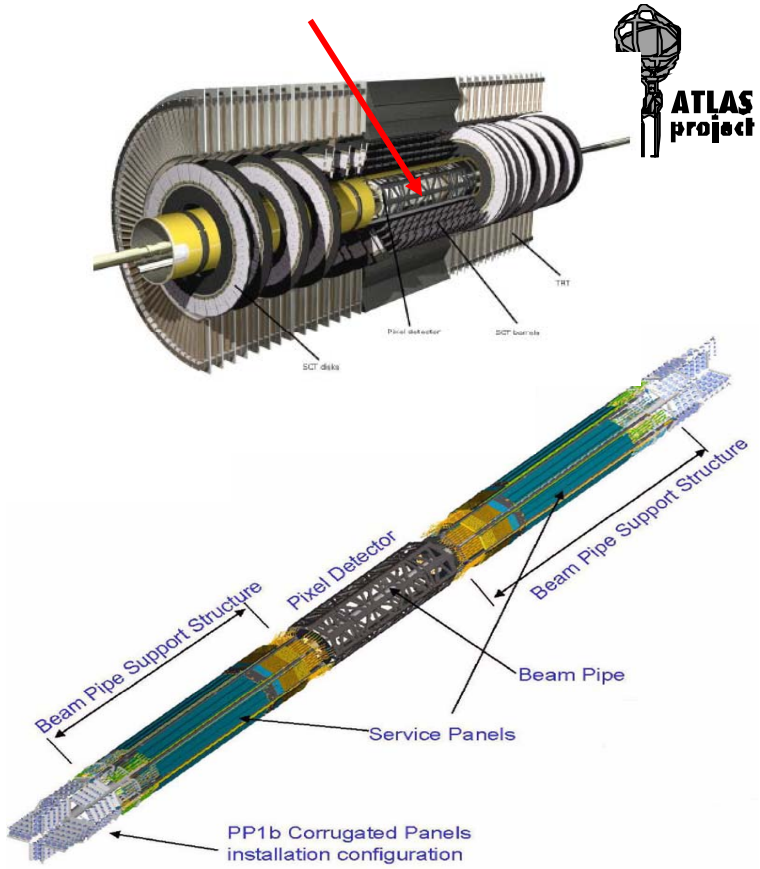


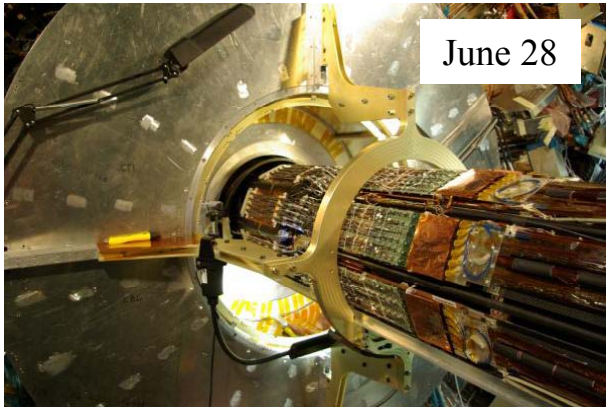




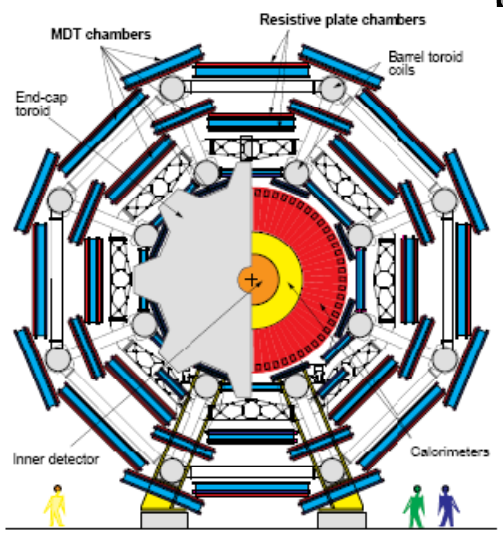
Status: Inner Detector --- Pixel

- $> 10^8$ channels (pixels), intrinsic resolution 10 x 110 μm
- Installed June 25, completing the Inner Detector
- Pre-integrated with beam pipe and connectivity panels in clean room at surface lab, test of all connections
- First data readout in the cavern expected for October this year



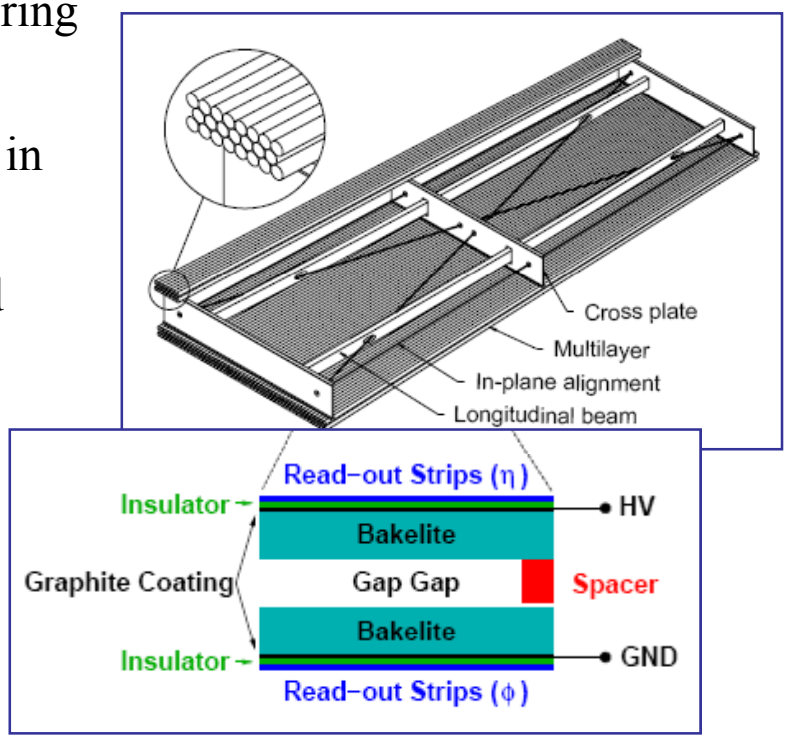


Status: Muon Spectrometer -- Barrel

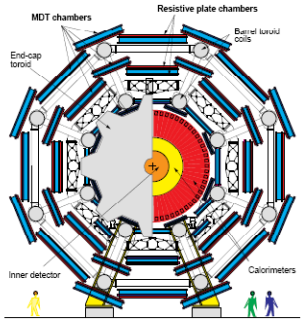


- Muon barrel has ~ 650 individual stations, arranged in 3 concentric circles. Dual purpose: track reconstruction (resolution 50μm/station → $\Delta p_t/p_t < 10\%$ up to 1 TeV) and (level-1) trigger
- Barrel stations consist of
  - a Monitored Drift Chamber (MDT), built from 3 cm drift tubes, and equipped with a optical monitoring system to reconstruct chamber deformations
  - RPCs in the middle and outer layer, operated in proportional mode for triggering
- Installation mainly in 2006, one-by-one, completed except for 4 stations (left out for better access)

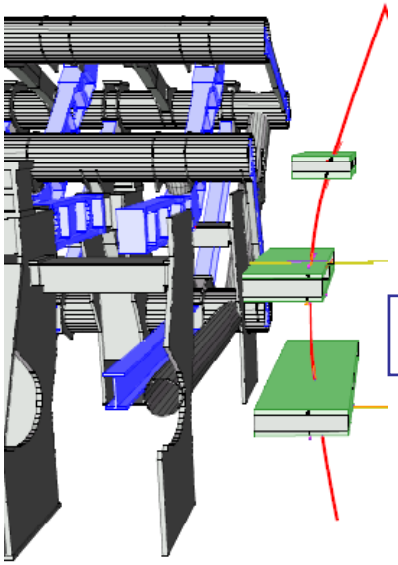
- Finishing up service connection, in parallel to commissioning



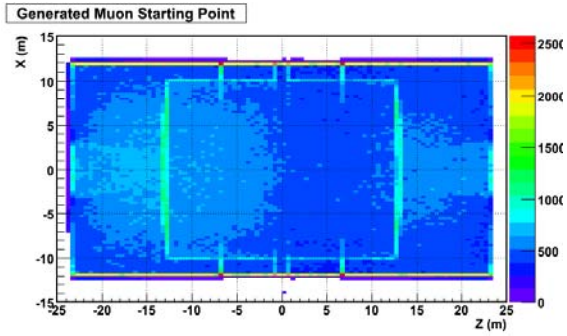
Status: Muon Spectrometer -- Barrel



- Individual testing of chambers after installation (gas leak, HV, …) and chamber positioning ~ essentially completed,
- Current activity (since April ’07): Commissioning sector by sector including DAQ, DB, DCS, 2 sectors completed (MDTs generally further ahead than RPCs)
- Dedicated data taking with cosmics (RPC+MDT) in Nov ’06 with magnetic field, in Feb/ Jun/Sept. ’07: One sector each (more for MDT)

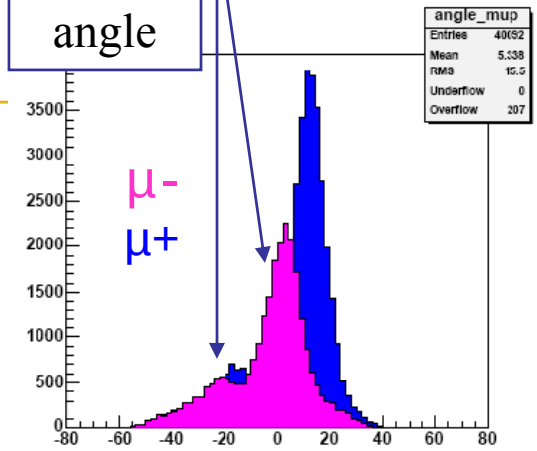


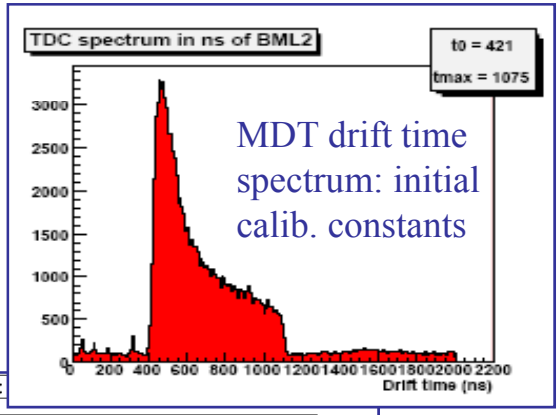
Feb. 2007

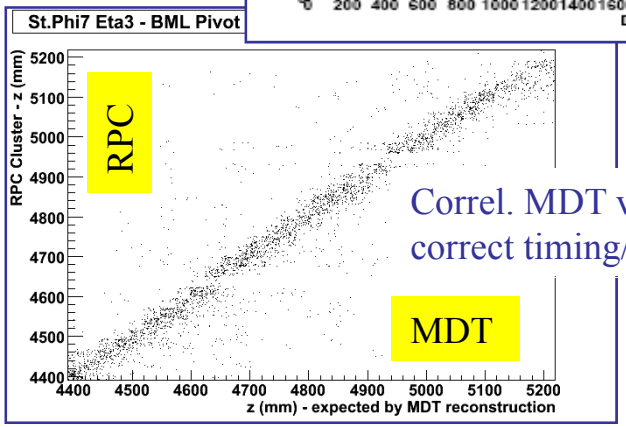


Double peak: access shafts

angle

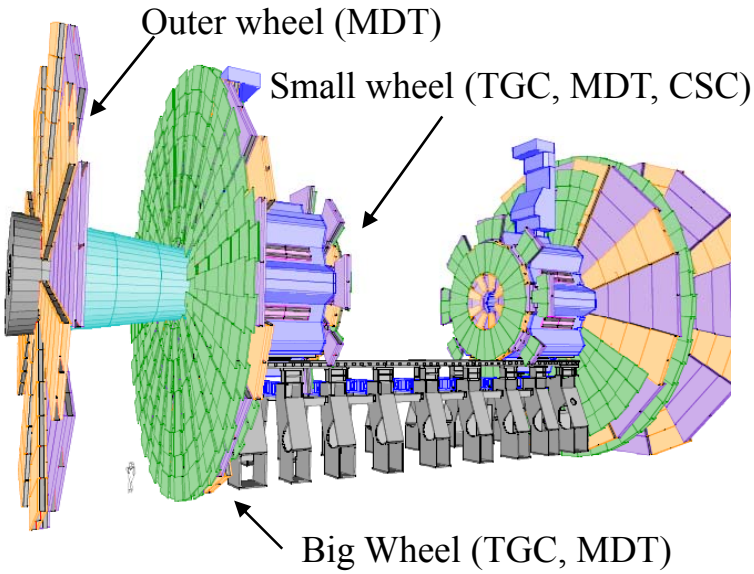




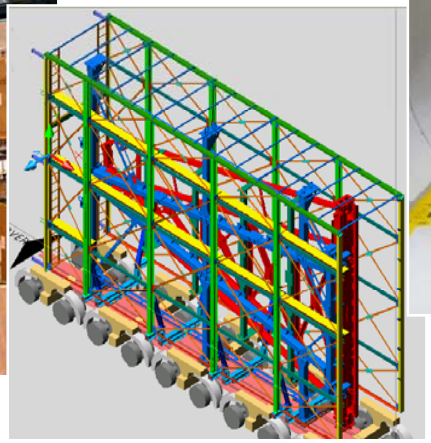


Correl. MDT vs. RPC correct timing/ mapping

Status: Muon Spectrometer -- Endcap

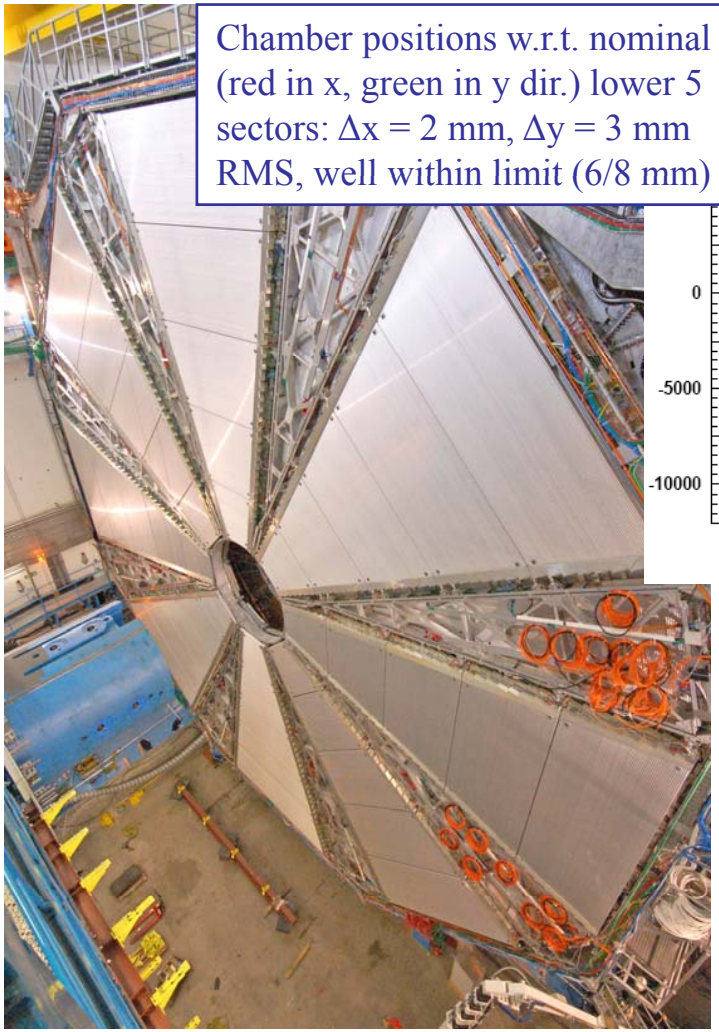


- ~600 MDT and 64 CSC (cathode strip) precision chambers for tracking
- 1578 Thin Gap Chambers (TGCs) as trigger: multi-wire proportional chambers, wire spacing 1.8 mm, operated with n-pentane/CO_2 mixture
- Geometry: 2 Small (movable), 2x4 Big (movable) and 2 Outer Wheels, interconnected by optical alignment system
- Strategy: Big wheel installation after Barrel Muon Spectrometer had been ~ completed
- Pre-assembly of 'wedge-shaped' sectors on surface including services (gas, HV, LV,..), extensive testing

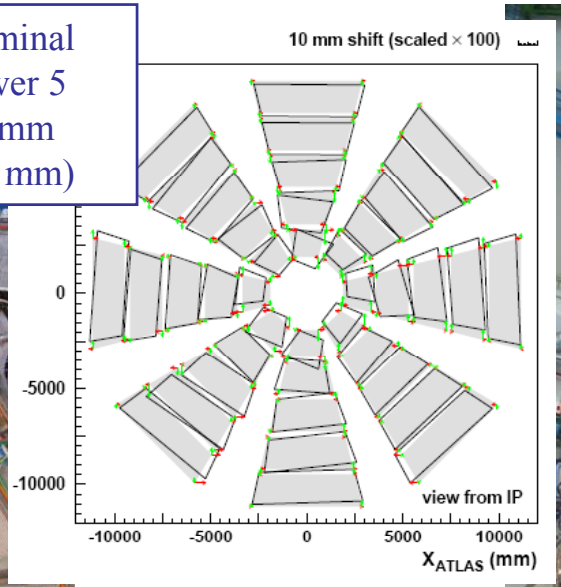


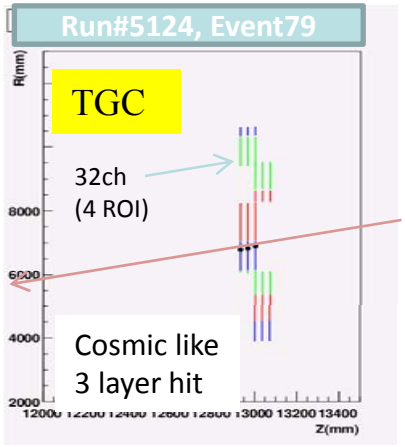
Status: Muon Spectrometer -- Endcap

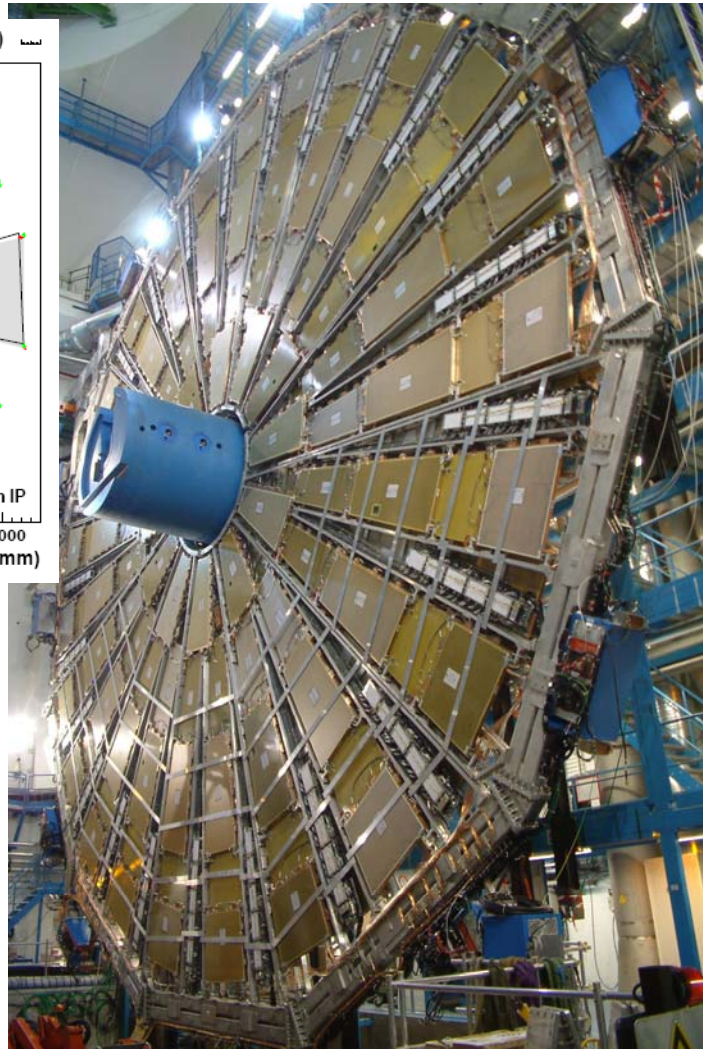
- MDT Big Wheels completed, TGC BWs completed for side C, side A by ~ October
- Cosmics data taking in June ’07 (1 TGC, 2 MDT sectors), Sept. ’07 (all side C BW), Nov. ’07 with magnet (ECT) ON



Chamber positions w.r.t. nominal (red in x, green in y dir.) lower 5 sectors: $\Delta x = 2$ mm, $\Delta y = 3$ mm RMS, well within limit (6/8 mm)



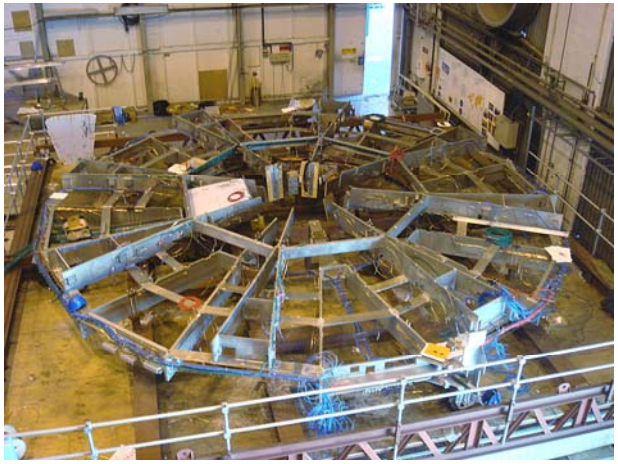


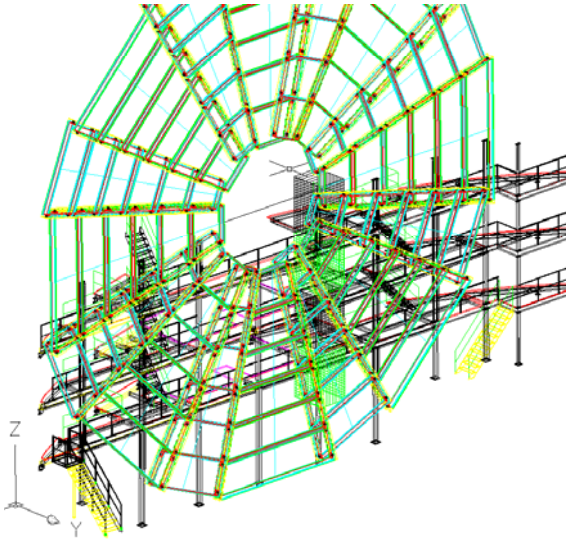


Detector Status: Installation not yet completed …

Detector components still missing:

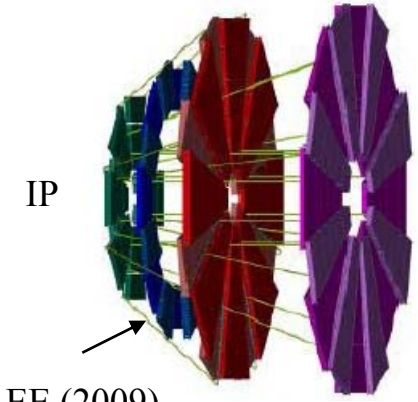
• Endcap Muon Spectrometer: 2 Outer and 2 Small Wheels, EE chamber (only in 2009)





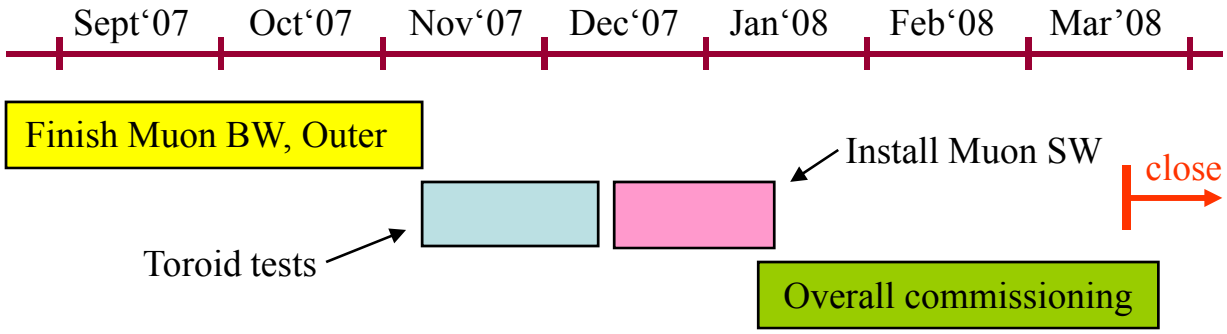
• SW under assembly on surface, all muon chambers ready, first MDT/CSC installed last week

• Outer wheel: Chamber prep. well advanced, to be installed individually in the cavern, preparation of support structure started side C → on the critical path (for side A)



• (Radiation) shielding: Install together with Small Wheel

• Closure of the beam pipe



Bringing it all together: Global commissioning

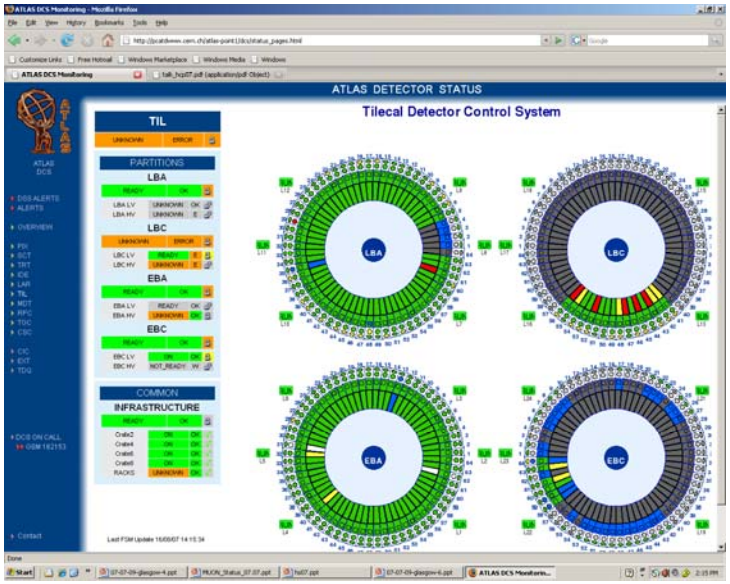
Commissioning organized in distinct phases:

- Phase 0: Pre-Installation tests and preparation on surface — DONE
- Phase 1: Individual sub-detectors/sub-detector components after installation in the cavern — NOW
- Phase 2: System integration, merging sub-detectors into one single "ATLAS" detector — NOW
- Phase 3: Global commissioning with cosmics and beam halo — March

Milestone weeks: Dedicated combined data taking every ~ 2 months

- Converge towards standard operations,
- Common tools for Run Control, Data Quality Monitoring, ….

- Status overview pages on the WEB, remote access/ maintenance for the experts



Bringing it all together: Milestone weeks/runs

M1 – Dec ’06	Barrel calorimeters, calorimeter trigger, part of barrel muon spectrometer standalone	Muon reconstruction with magnetic field
M2 – Mar ’07	New: Barrel muon (part of 1 sector), endcap calorimeters, calorimeter and muon trigger	Combined runs
M3 – Jun ’07	New: Barrel SCT, TRT, muon Big Wheel side C (part); final DAQ and event building infrastructure/ computer farms (part)	Combined runs; event display; final line for data storage; first data streaming tier-0 → tier-1 centers
M4 – Aug ’07	New: Muon Big Wheel side C, 3 additional sectors Muon Barrel Full level-1 trigger system (calo-rimeter, muon RPC (barrel) and TGC (end cap))	**Data quality monitoring** High level trigger algorithms (vertical slice) **Data streaming** to external calibration centers DAQ to DCS (slow control) communication
M5 – Oct ’07	New: TRT endcap, Pixel (readout),	
M6 – Nov/Dec ’07	New: End cap magnets	Run with magnetic field

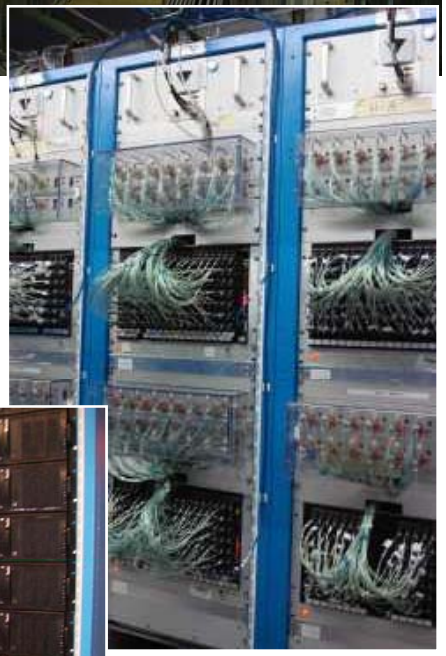
DAQ, run control, ….

M3 run (June) -- examples:

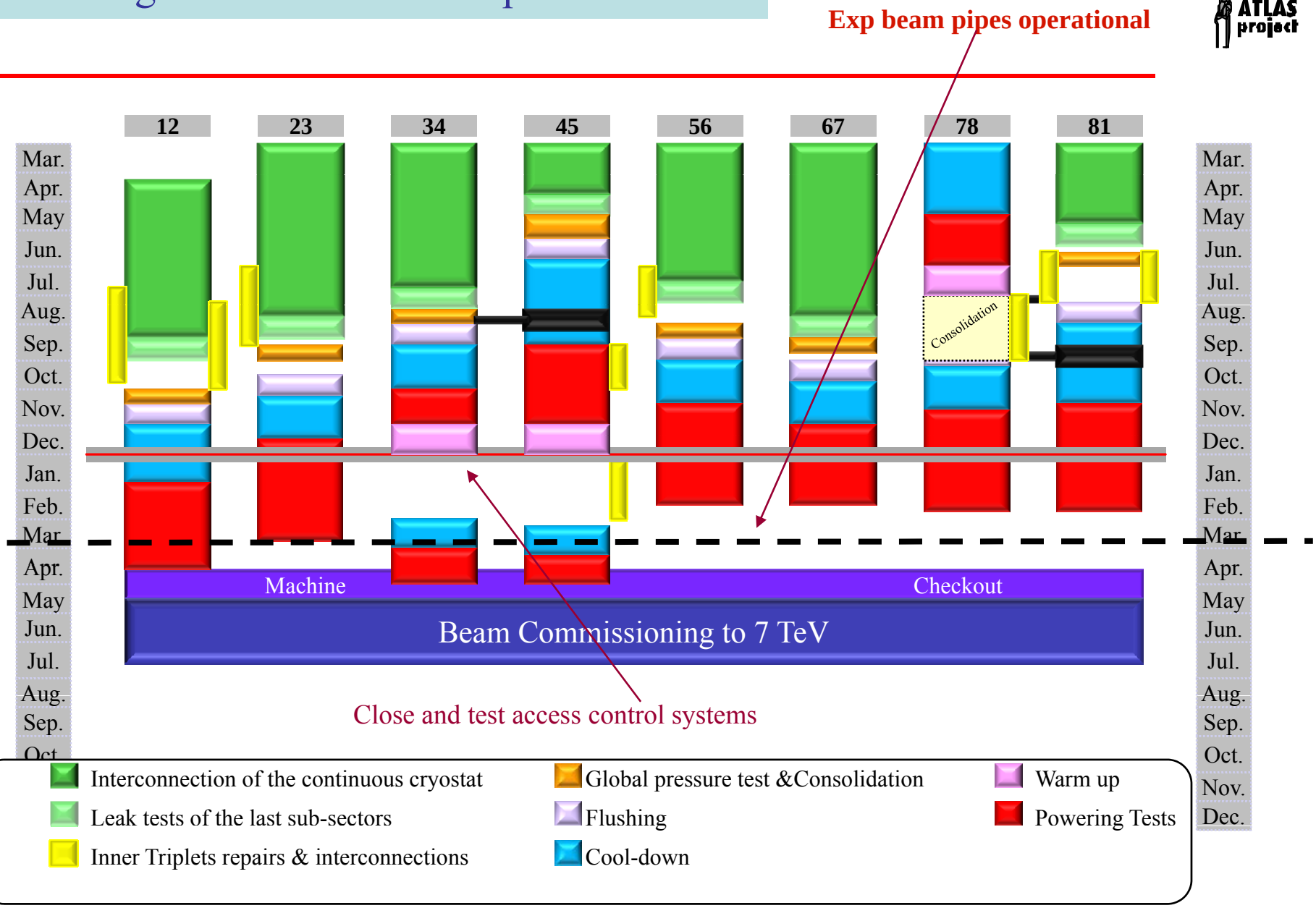
- all control room, half of online nodes ready,
- ~ 40% of readout system ready,
- ~ 15% of monitoring nodes ready,
- ~ 10% (of ~100 PCs) of event builder nodes ready,
- < 1% (of 1900 PCs) of event filter nodes ready,
- ~ 10% of high level trigger nodes purchased
- For July 2008: ~50% of final configuration planned, both event builders and high level trigger !

PC acquisition as late as possible to profit from ever increasing performance – Moore's law

DAQ surface building June



The end-game: Machine startup schedule



Conclusions …

• Detector installation has largely been completed, last components to be installed by March next year,

• Commissioning is well underway, with individual sub-detectors largely in an advanced state,

• Concentrate more and more on system integration and combined data taking,

• Gradual transition to standard ATLAS operations conditions

ATLAS physicists are eagerly awaiting first collisions, with 2008 expected to be a very intense and rewarding year …..

Thanks to my colleagues and collaborators for material and input to this talk !