Commissioning of the MuonSpectrometer with Cosmics

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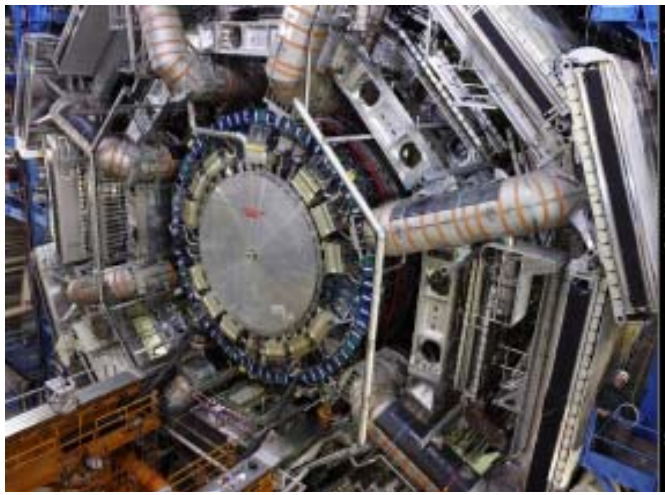
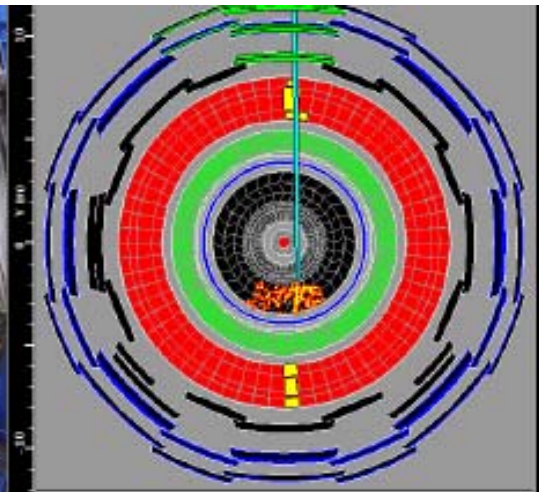
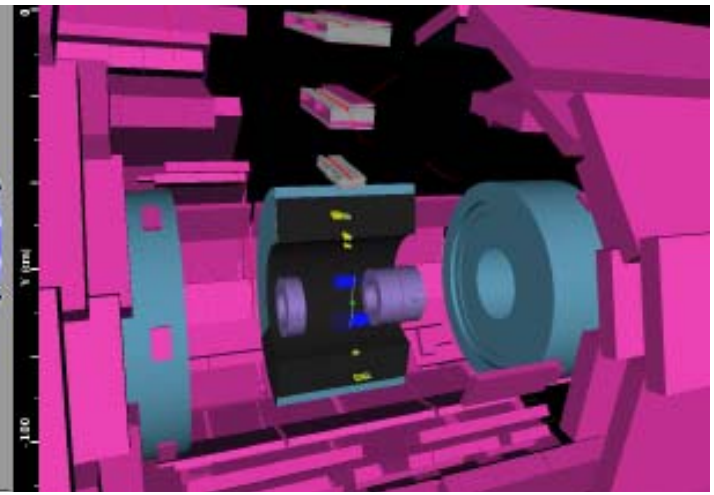




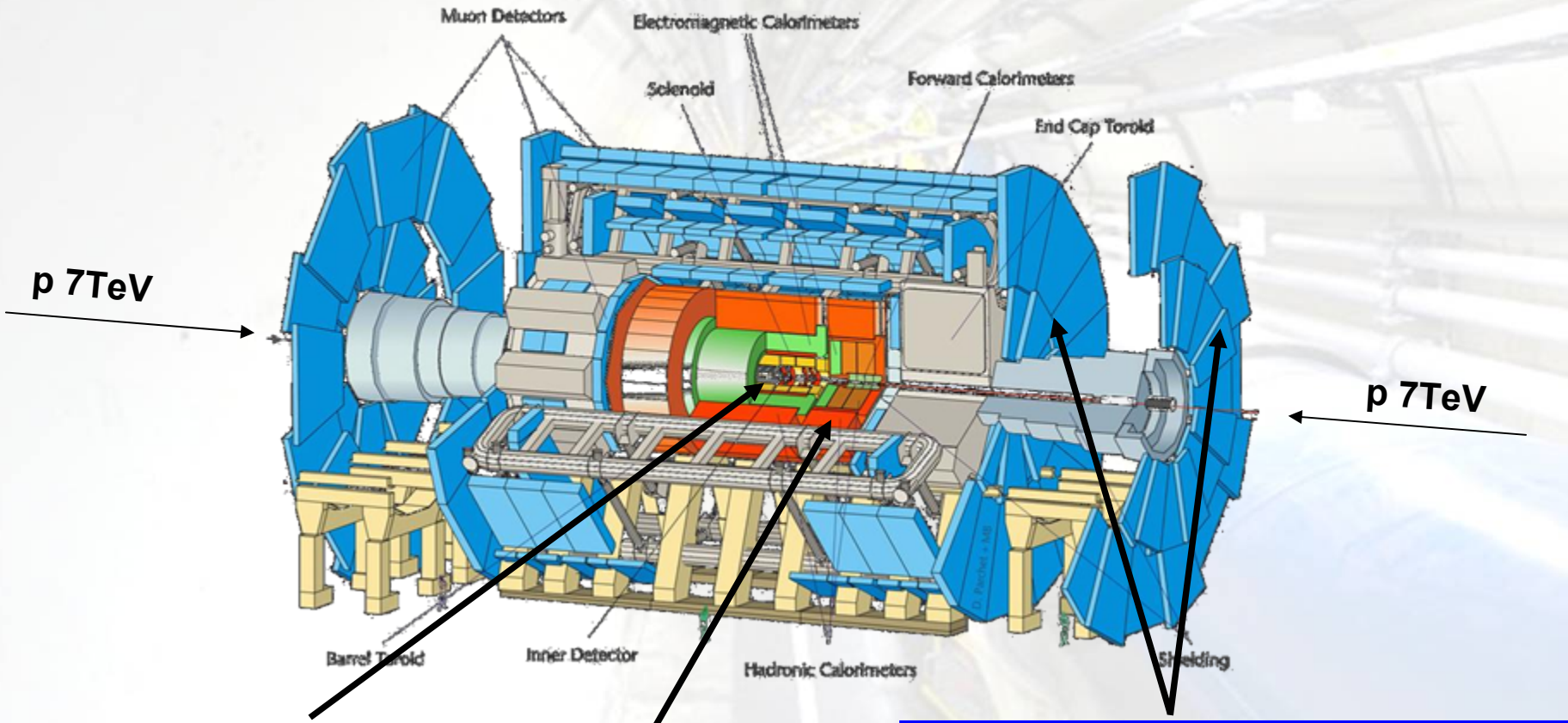


General purpose particle detector

(coverage up to $|\eta|=5$, $L=10^{34}\ cm^{-2}s^{-1}$)

ATLAS Basics

25m diameter, 46m long, weighing 7000T, with 3000km of cables and 10^8 channels



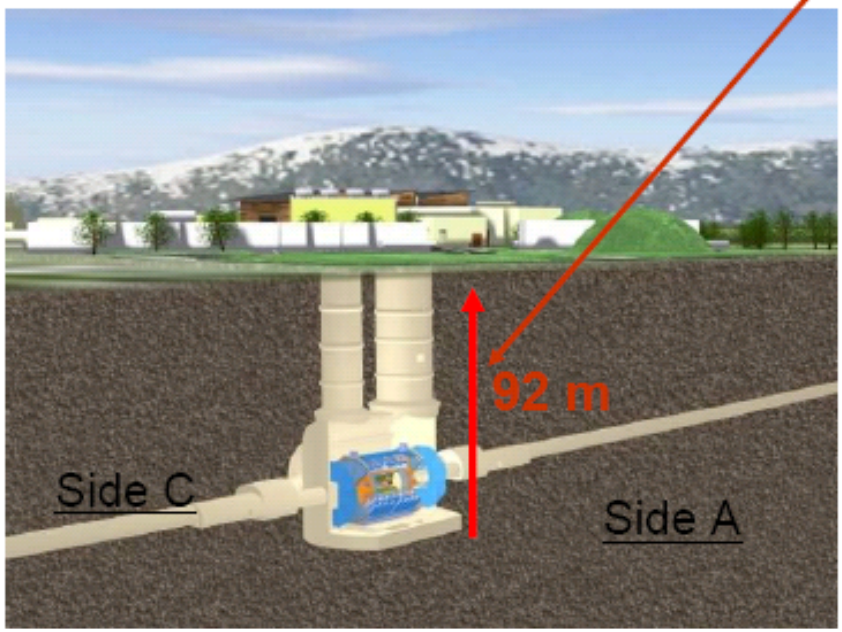
Tracking ($|\eta|<2.5$, B=2T):
- Silicon pixels and strips
- Transition Radiation Tracker

Calorimetry ($|\eta|<5$)
EM : Pb-LAr **($|\eta|<3.2$)**
HAD: Fe/scintillator **($|\eta|<5$)** (central), Cu/W-LAr (fwd)

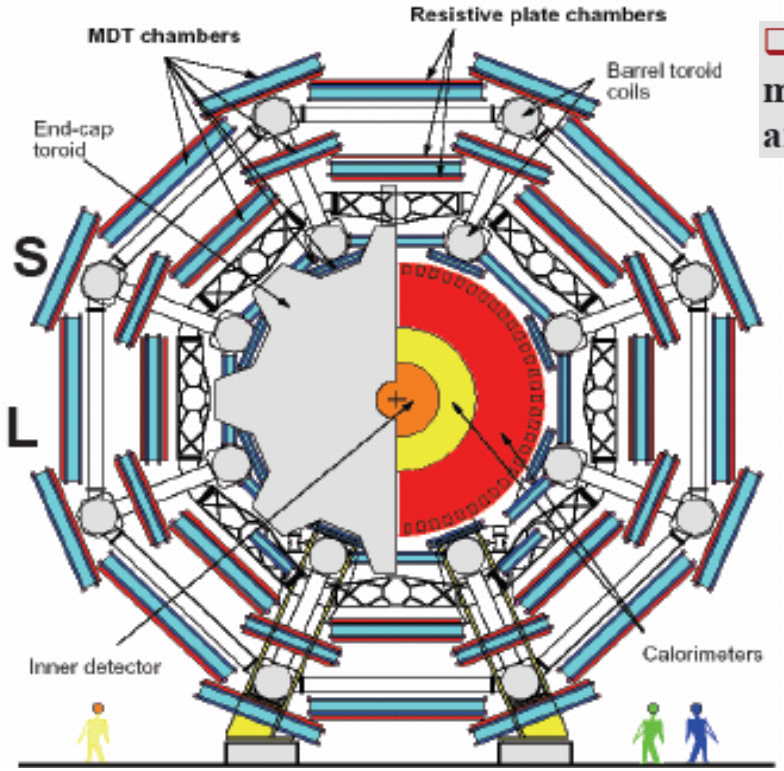
Muon spectrometer ($|\eta|<2.7$, B=4T max)
Toroid magnet system with precision and trigger chambers

Size of ATLAS

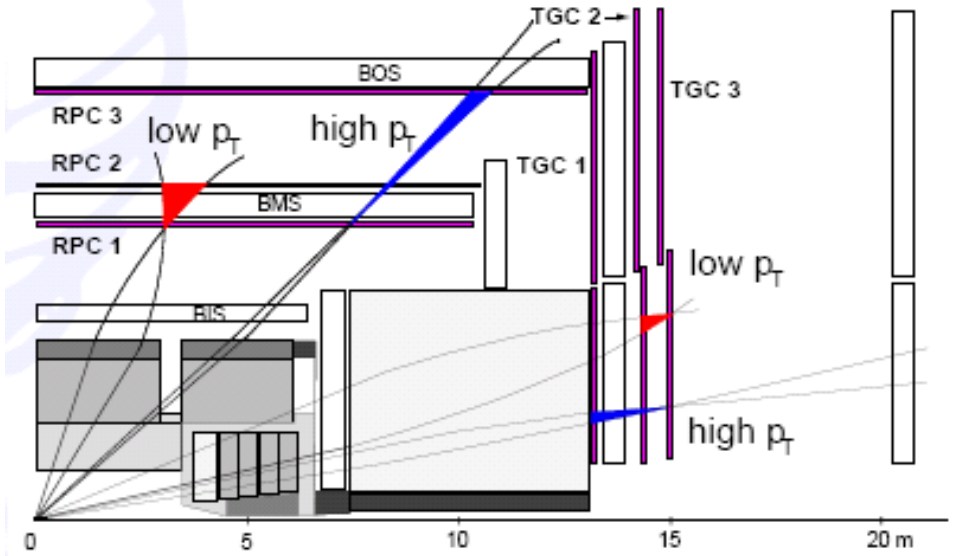
- ATLAS superimposed to the 6 floors of building 40
- ATLAS assembled 92 m under ground at CERN



MuonSpectrometer



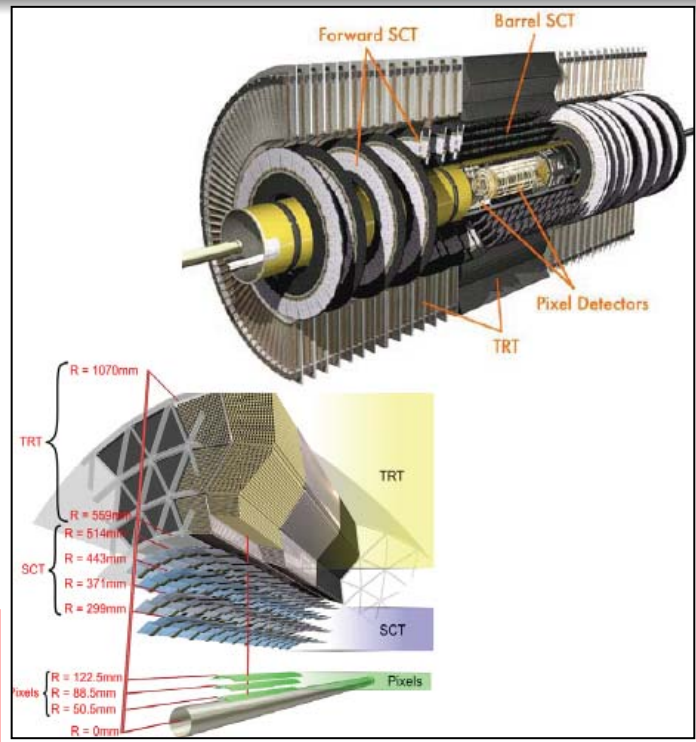
❑ **The final aim is to reach the highest efficiency with standalone momentum resolution of a few % level at 10-100 GeV/c and ~10% at 1 TeV/c**



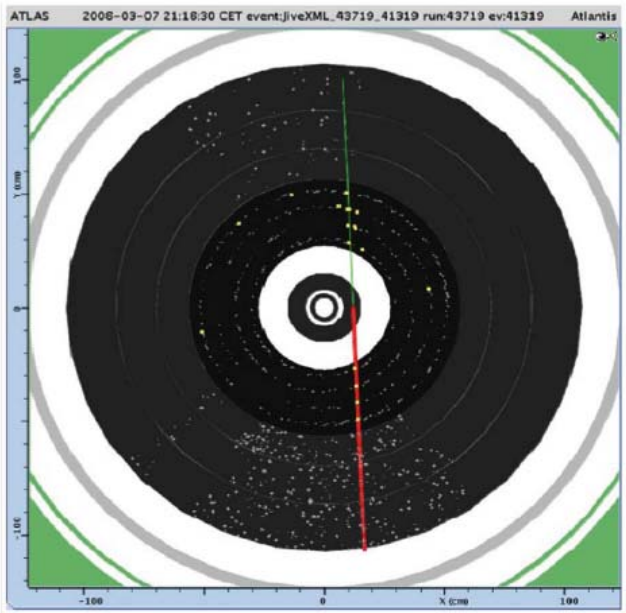
- 3 superconducting air-core toroid magnets
- 1100 precision chambers
  - 1050 MDT chambers
  - 32 CSC in forward endcap region
- 2200 fast trigger chambers
  - 592 RPC in barrel
  - 1578 TGC in endcap
- 12000 optical alignment sensors

Inner Detector Commissioning Status

- All detector components installed
  - Barrel SCT & TRT
  - Both EndCaps for forward SCT & TRT
  - Full Pixel detector & Be beam pipe
- SCT & TRT fully connected and signed off
- Final work on Pixel ongoing
  - Optical & electronic connections validated
  - Cooling issues

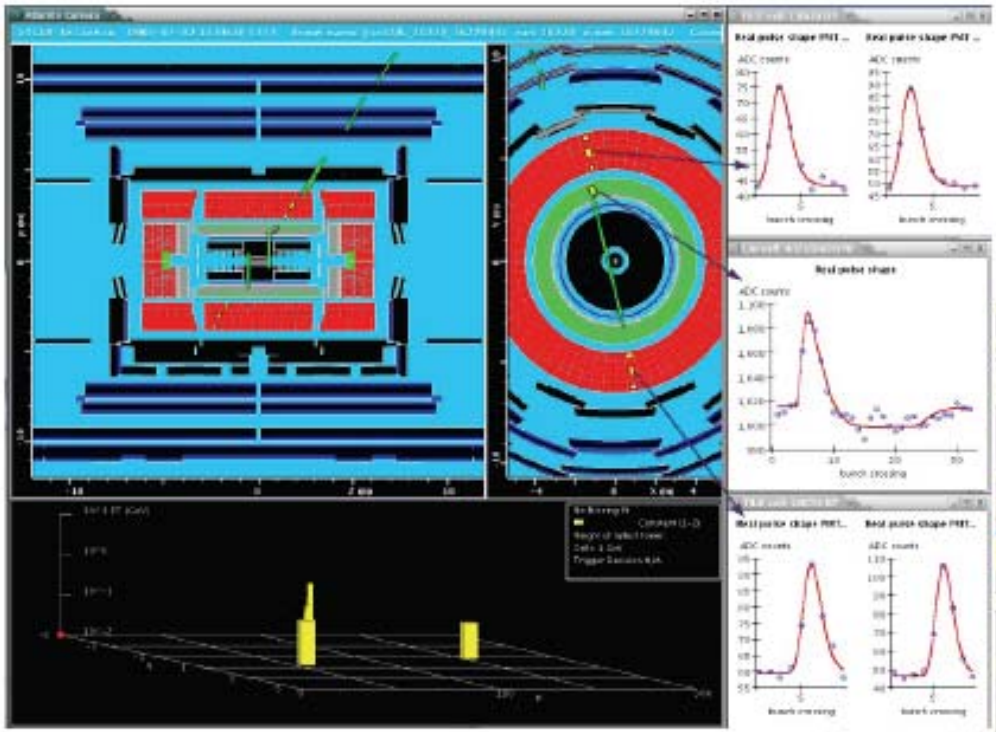


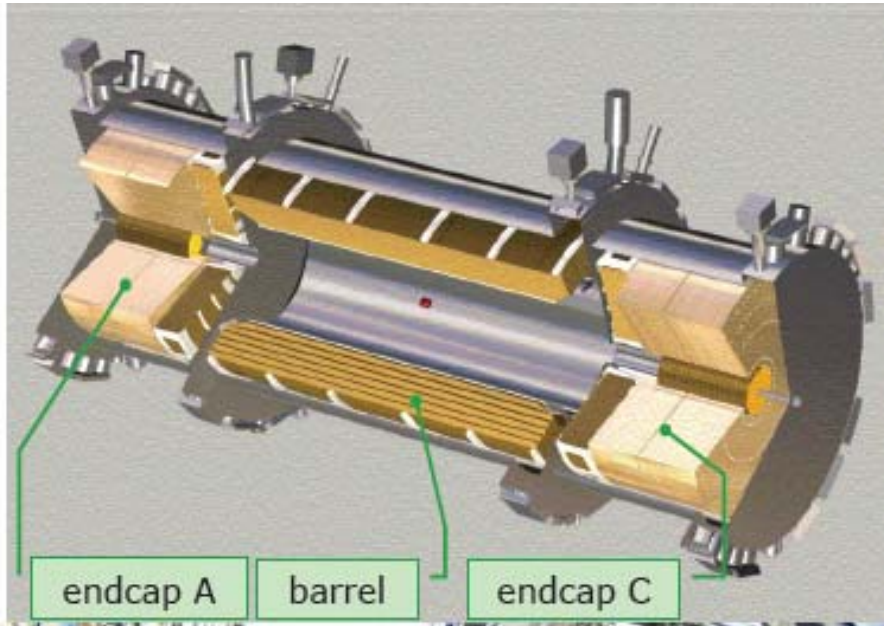
- Milestone Run 6 (M6) in March 2008:
  - Successfully took cosmics data with SCT & TRT sectors
  - Only part of TRT was turned on, clearly visible from noise hits
  - Timing & alignment checks successful

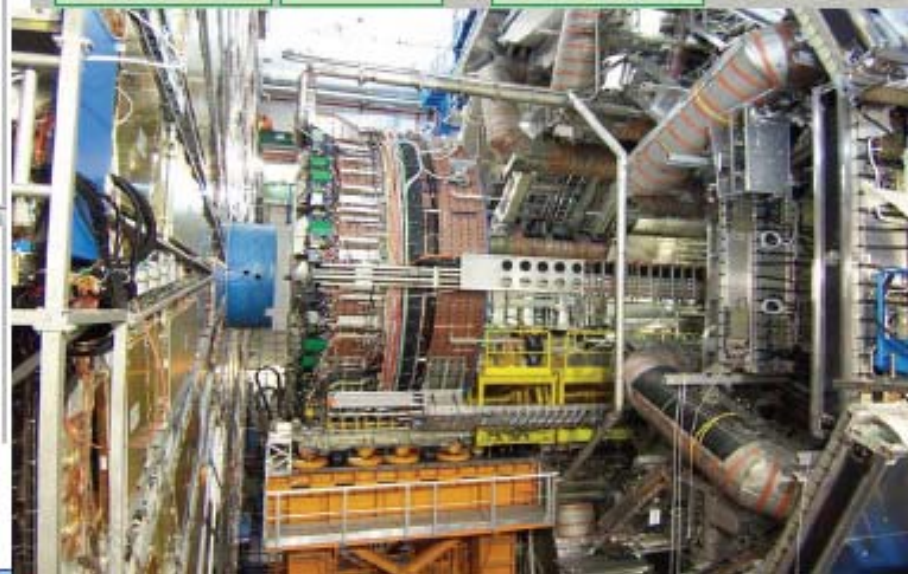


LAr Calorimeters Commissioning Status

- Complete LAr detector switched on, participating at MCalo data taking (HV, LV, …)

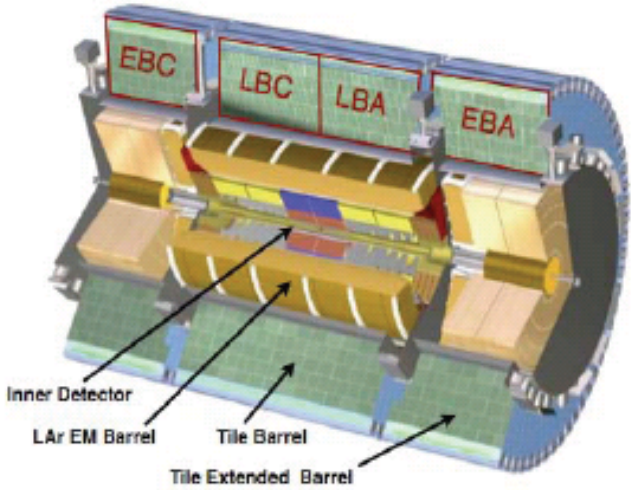


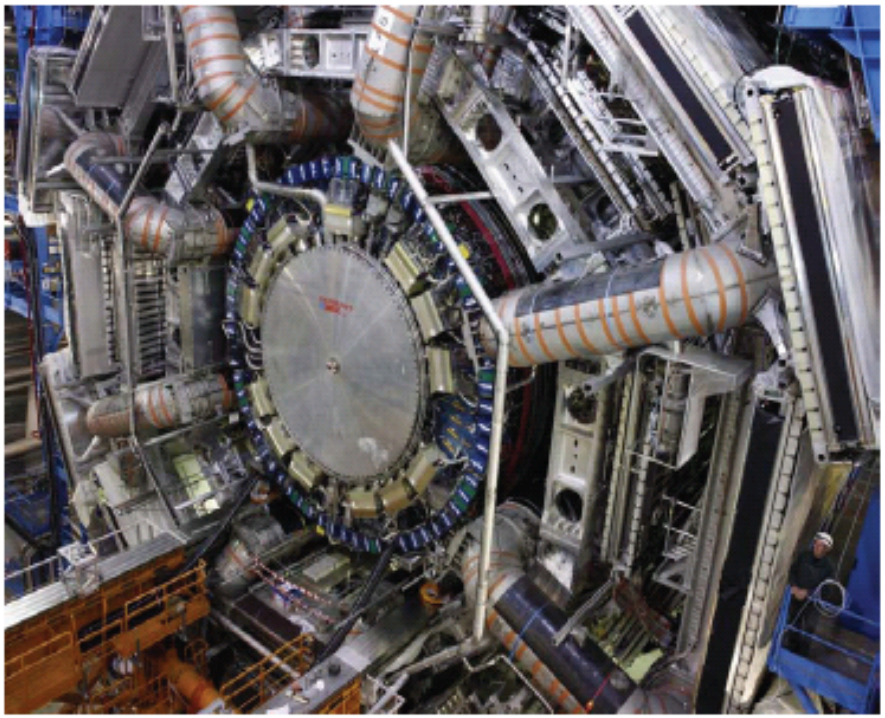


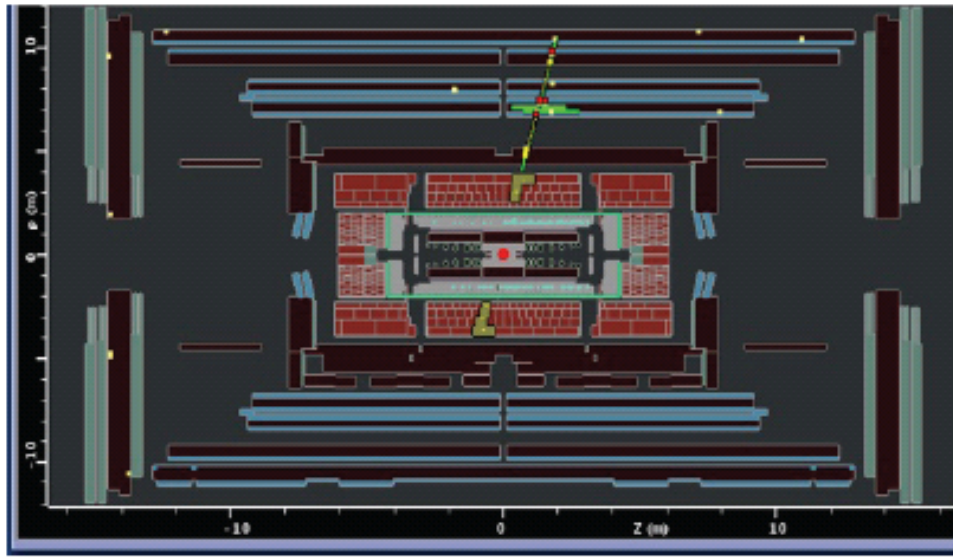


TileCal Hadron Calorimeters Commissioning Status

- Detector fully installed and operational since several months
  - including a set of dedicated minimum bias scintillators



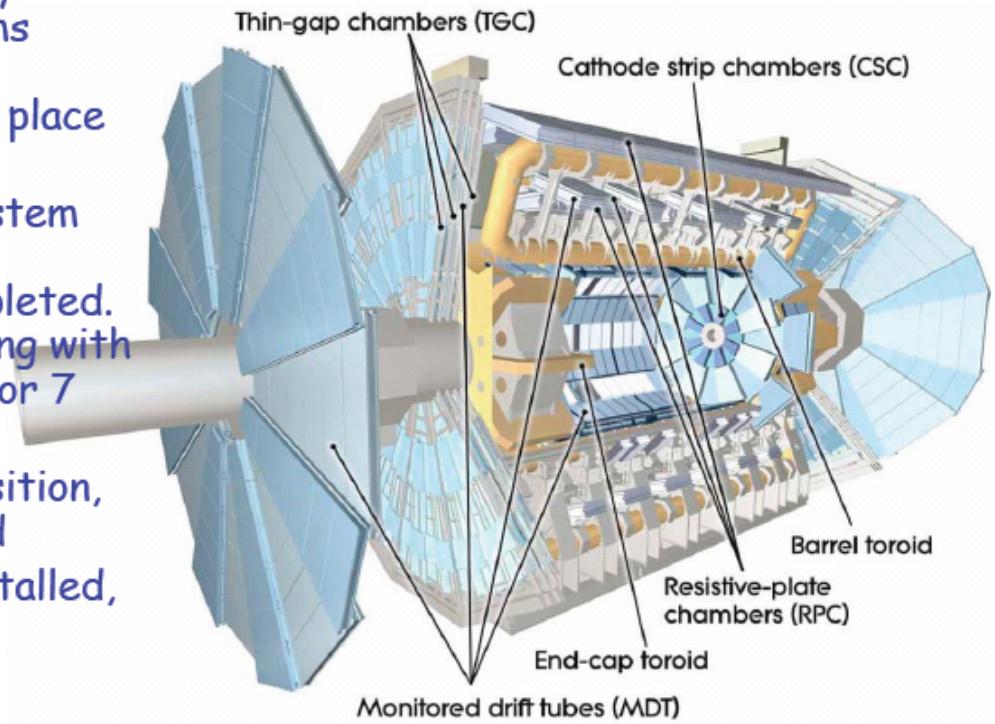




MuonSpectrometer Commissioning Status (I)

- **Barrel MDT:** Installation of all services, cables, pipes, gas, cooling systems and access platforms complete.
  All chambers are in place and are serviced.
- **Barrel RPC:** gas system test completed, cabling almost completed. Sector commissioning with cosmic rays (done for 7 out of 16 sectors)
- **"Big wheels":** in position, installed, connected
- **"Small wheels":** installed, connection ongoing

✓**Cabling almost finished for all subsystems**



Gas Systems

✓MDT/CSC gas system operational
✓RPC gas system in recirculation mode tested
✘TGC gas system not tested with final gas mixture

Cosmic Ray Commissioning

✓11 of 16 barrel MDT sectors, 2 EOS sectors all 16 BW and SW sectors on both sides tested with cosmics
✓10 of 16 RPC sectors tested with cosmics
✓13 of 24 TGC sectors tested with cosmics

MuonSpectrometer Commissioning Status (II)

All subdetector will be almost 100% operational

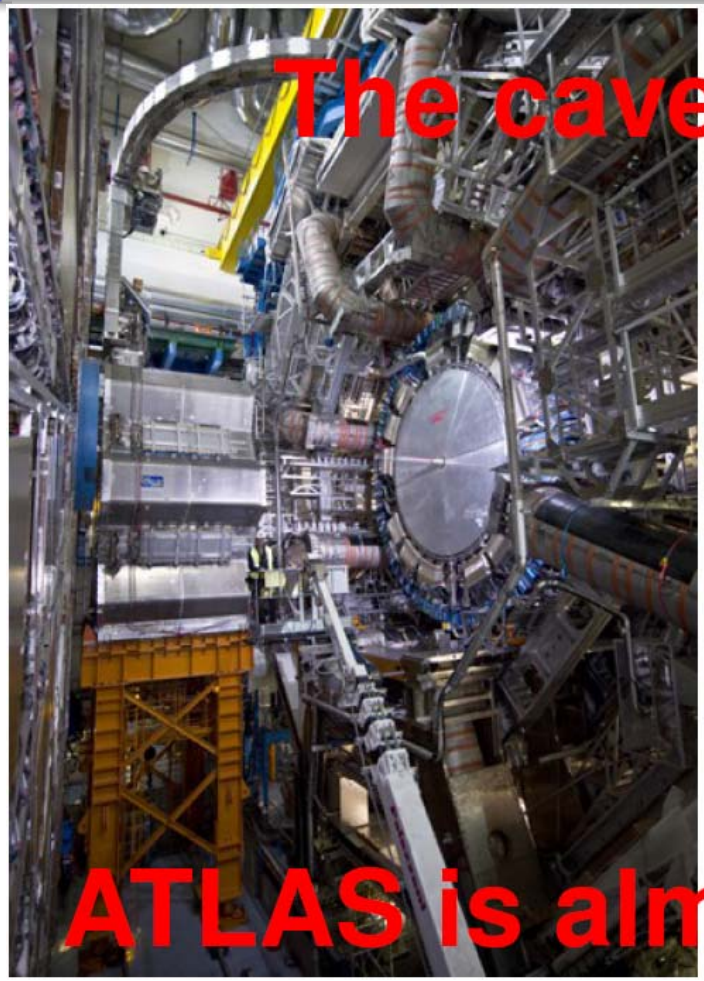
Open issues:

- All 62 EE MDT missing (staged)
- Some EOL MDT may be missing due to services
- Few MDT multilayer may be missing due to gas leaks
- 40 RPC single gas gaps will be missing
- RPC trigger acceptance reduced by 1% (inverted RPCs)
- TGC Small Wheel A and EIL4A might have reduced efficiency

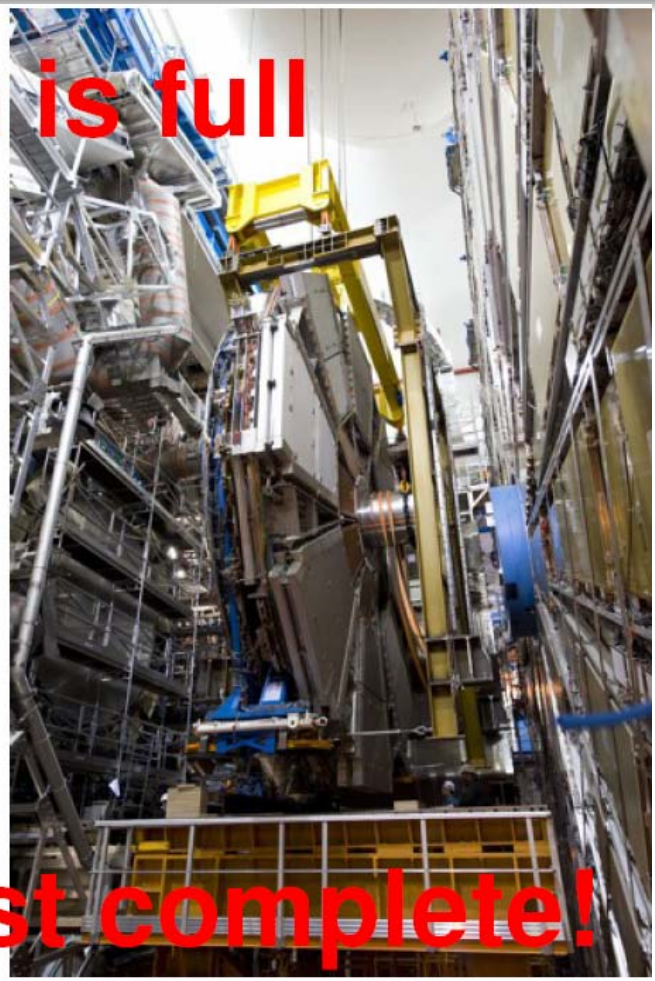
Open issues will have no major impact on performance

- ✘ TGC gas system untested with final mixture so far
- ✘ High failure rate of CAEN power supplies could be problematic

Detector Status



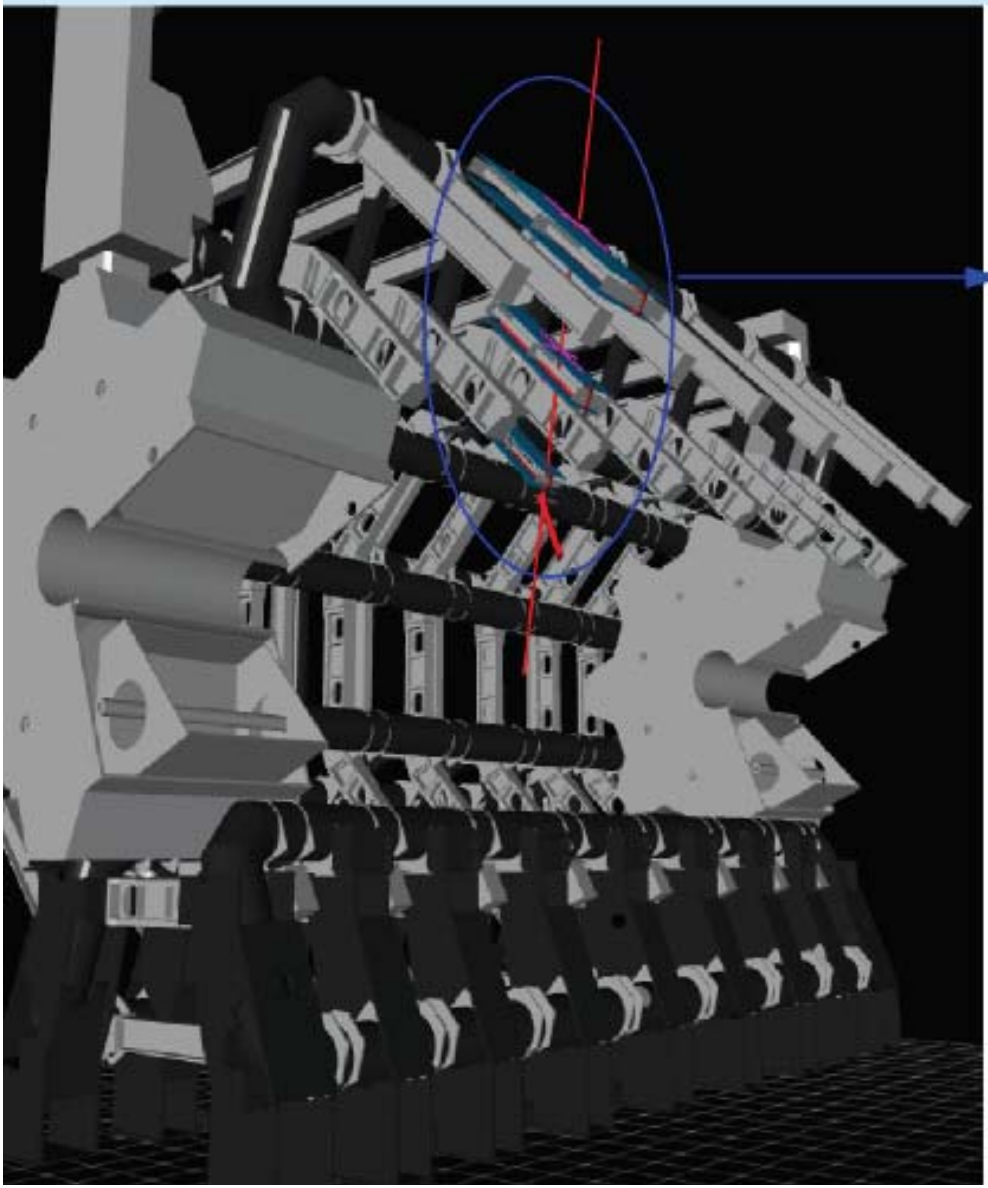
The cavern is full

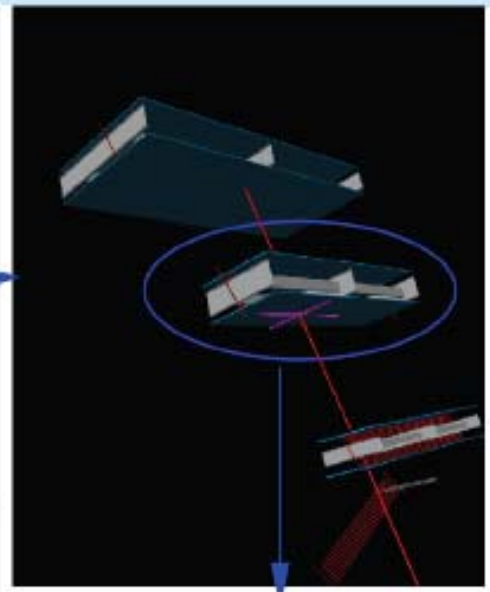


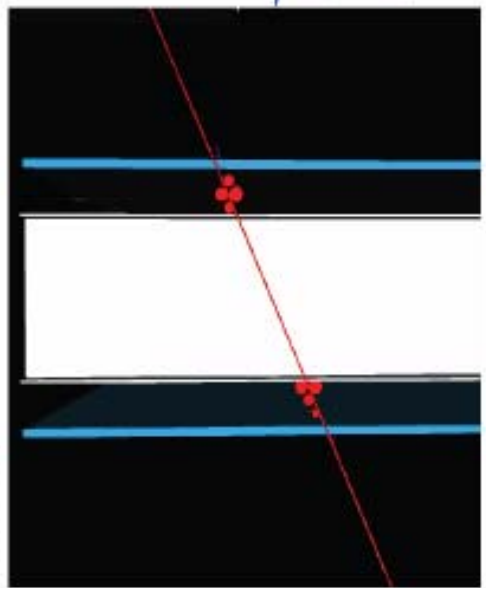
ATLAS is almost complete!

Detector Construction	: Completed
Installation in the underground cavern	: Almost completed
Commissioning with cosmics	: Ongoing

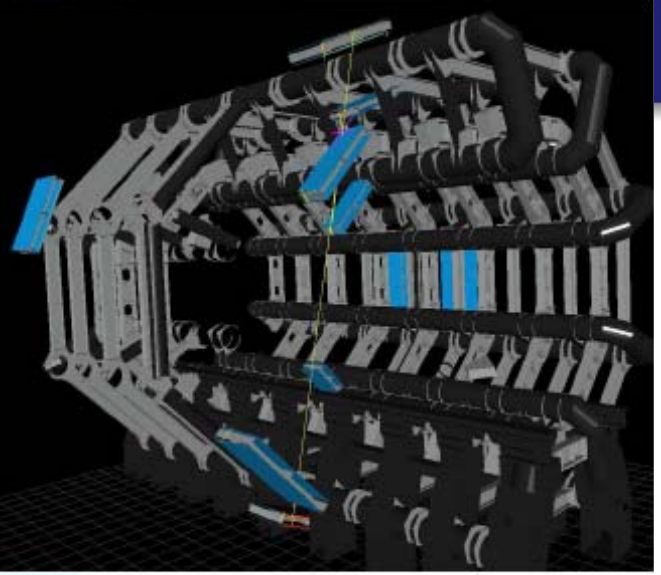
Cosmic Hits in Muon Barrel

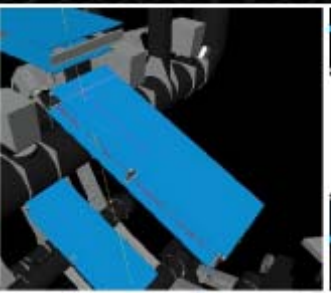






- Purple crosses: RPC trigger hits
- Red dots : MDT precision measurement
- Barrel Muon system largely operational

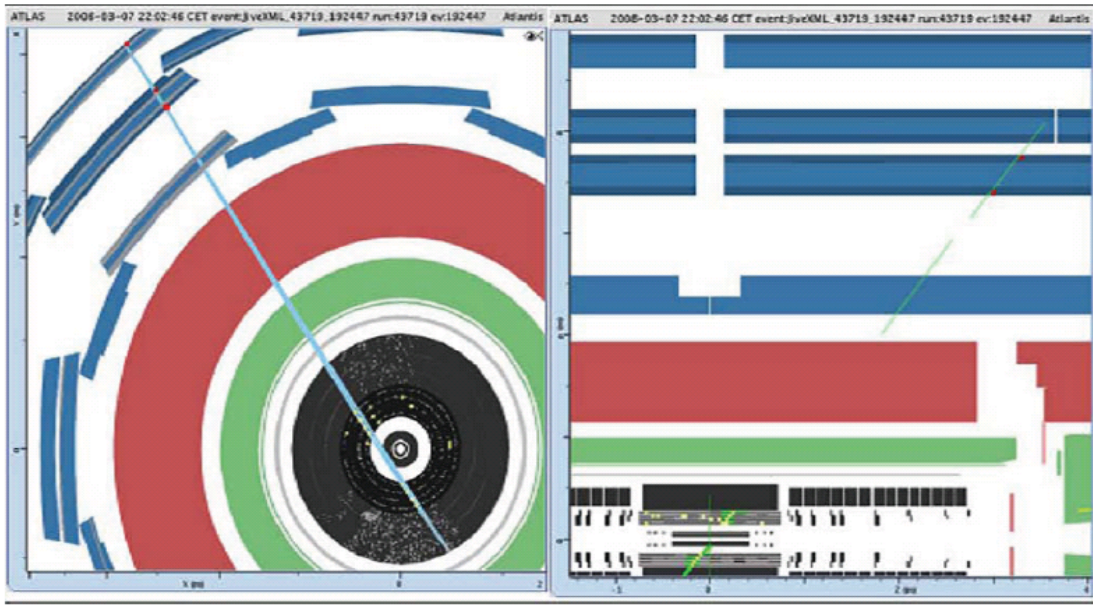




Combined Data Taking

Successful P5/M7 runs

- ✓All muon subsystems participating
  - ✓RPC trigger — 4(6)/16 sectors, 100 Hz
  - ✓TGC trigger — 13/24 sectors, 5 Hz
  - ✓MDT chambers: 90% in read-out
    - ✓(65% with HV)
- ✓All subsystem working with new DAQ version
  - ✓CSC with some problems
- ✓Stable runs over several hours
- ✓6.5 million events collected
- ✓Many failures due to damage in bottom MDT barrel sectors fixed

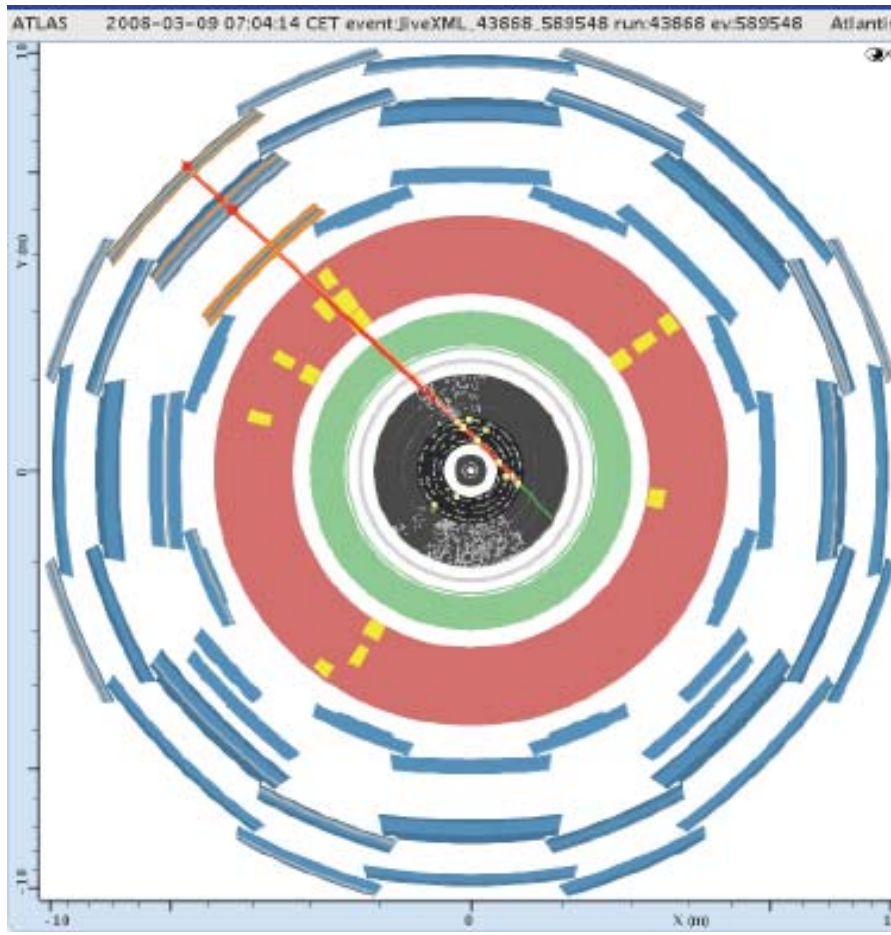


- Joint data taking with SCT, TRT and Muons during M6

Motivation to analyze cosmic data

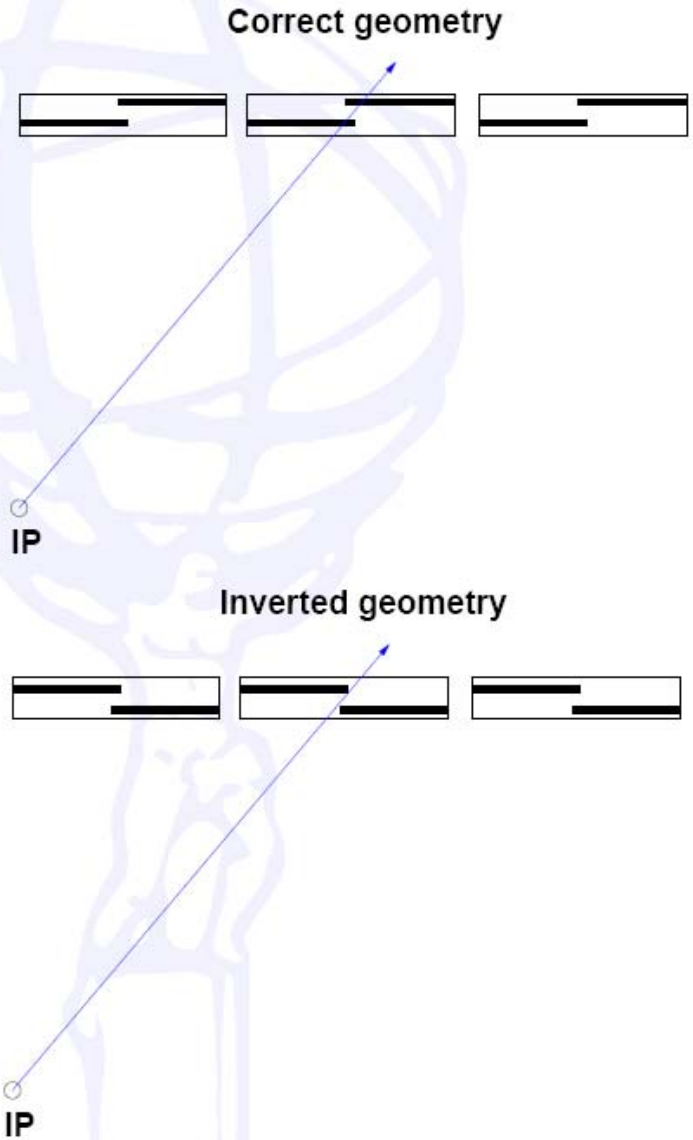
- **Study the performance of:**
  - Detector
  - Do debugging, identifying non-working channels/chambers
  - Calibration & alignment
  - Non-pointing cosmics are useful for alignment studies
  - Reconstruction algorithms
    - (offline & HLT)
    - (standalone & combined muon
  - Monitoring algorithms
  - Simulation (through data/MC comparisons)

- First step towards achieving physics requirements



See example- next slide

RPC — Inverted Chambers

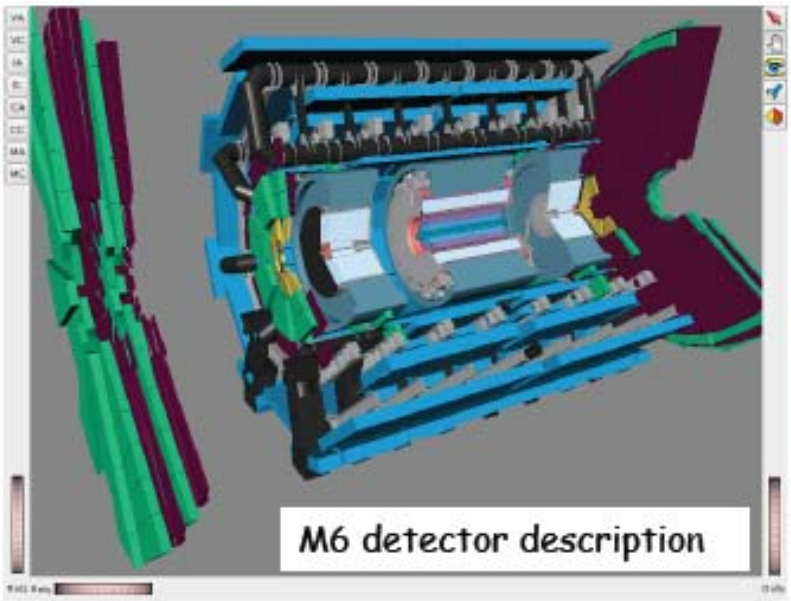


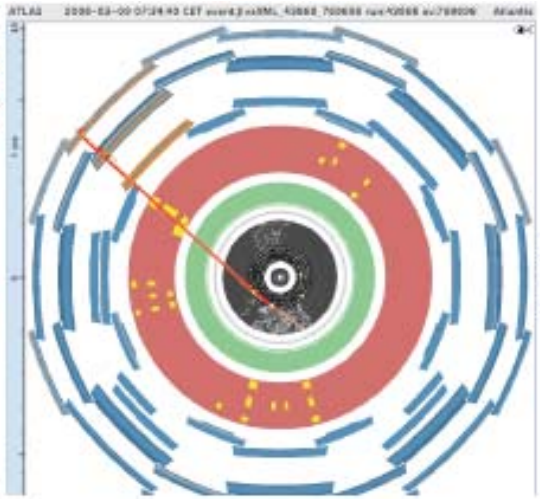
- Most RPC in small sectors (BMS, BOS) inverted
- Some RPC in large sectors (BML4/5) inverted
- Overlap region not aligned with IP
- AMDB updated in next release
- Acceptance loss needs to be simulated

Est. Loss of acceptance: 1%

Commissioning Data : Not exactly pp LHC data

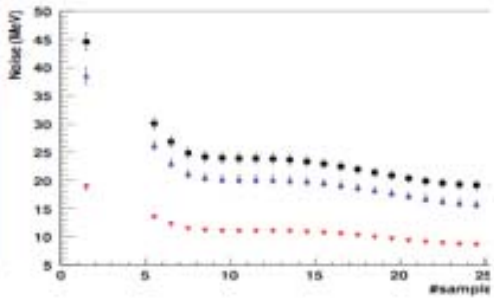
- Detector not in nominal position and conditions
- Not synchronized with the 40MHz readout clock
- No primary vertex
- Not the best particles for LAr performance studies





No PV constraints for tracking
TRT standalone tracking

Noise reduction vs number of samples used in LAr



Requires some adaptations of the reconstruction algorithms and specific detector description and simulation samples

ATLAS Commissioning Activities

“Online”

1. Commissioning of individual subsystems in pit (almost finished)
2. Integration of subsystems into ATLAS trigger and DAQ system (on-going)

Several global commissioning runs using cosmic rays in 2007-2008:

- operate the whole experiment
- achieve stable running for long periods
- exercise Trigger and DAQ (data flow, run control, configuration)
- operate control room as if data taking

Should not forget “Offline”

- Full Dress Rehearsal (FDR):
  a “stress test” of the full data processing and analysis chain from point-1 to the end user

What is FDR?

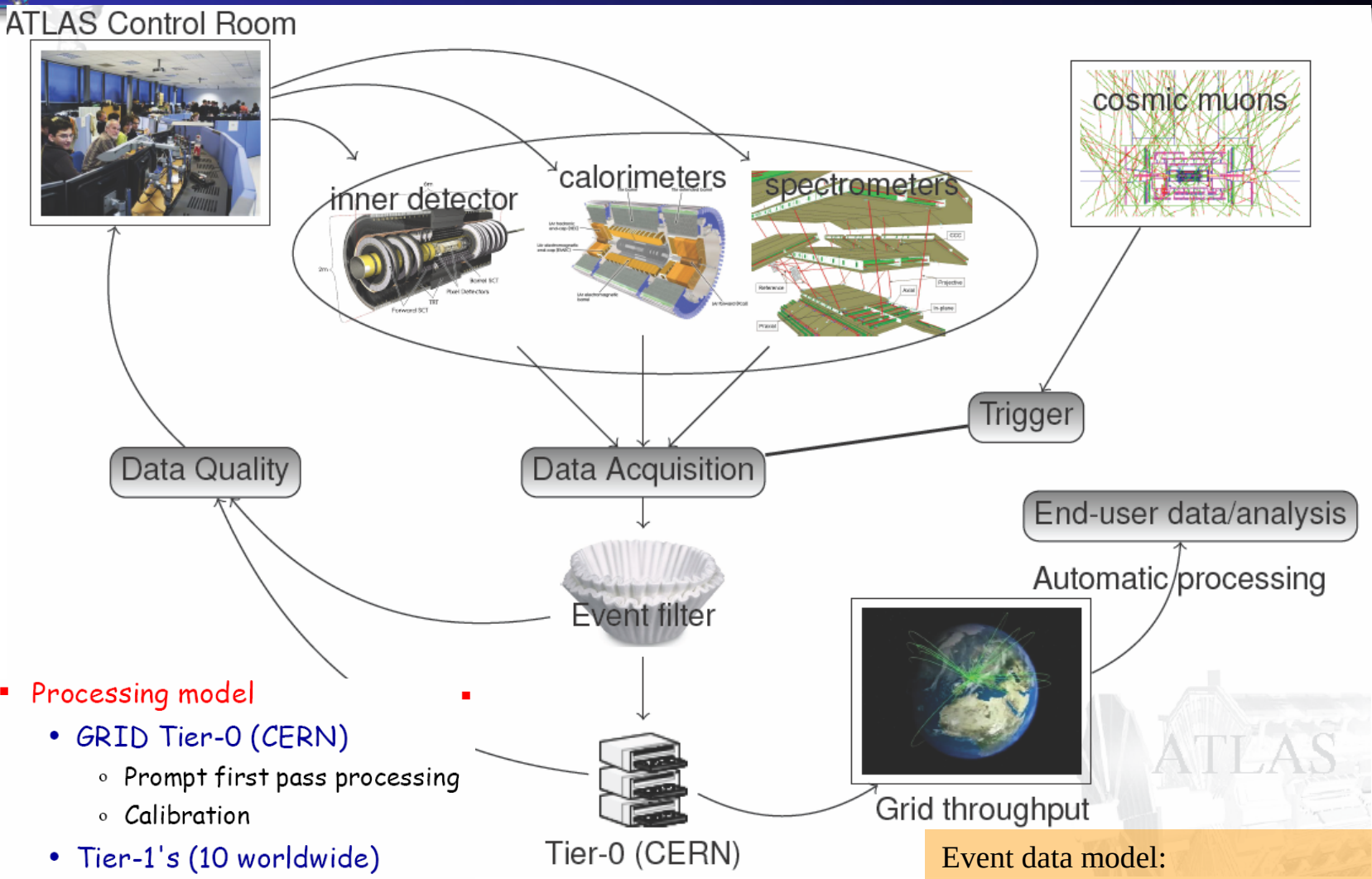
Real-time (stress) test of entire offline data processing chain:
- from TDAQ (SFO) to user analysis (AOD/DPD) – Offline Analysis
- mix of events according to luminosity ⊗ trigger menu

Main steps:
- prepare a "raw data" sample and transfer to point-1

synchronised as for data-taking

- make this "appear" at point-1 as real data
- copy raw data to Tier-0, and also out to Tier-1s
- run calibration and data quality procedures, mainly at Tier-0
  except for Muons
- process bulk physics events as planned for data
- distribute reconstructed events (ESD) and analysis objects (AOD) to Tier-1s, and on to Tier-2s for AODs
- make TAG event database and derived physics data (DPD)

- reprocess data at Tier-1s after a certain time (~month)
- in parallel, continue normal Monte Carlo production at the Tier sites

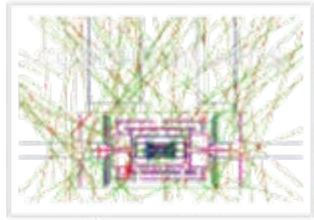


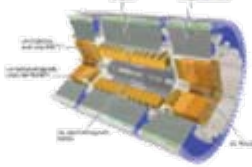
- Processing model
  - GRID Tier-0 (CERN)
    - Prompt first pass processing
    - Calibration
  - Tier-1's (10 worldwide)
    - Process 1-2 months later with better calibrations
  - Tier-2's (30+ worldwide)
    - Analysis, simulation

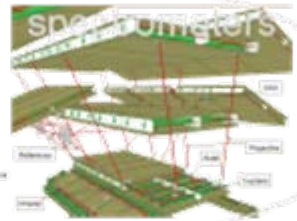
Event data model:
- ✓Raw Data Object (1.6 MB/ev)
- ✓Event Summary Data (0.5 MB/ev)
  - ✓Reco output, calibration
- ✓Analysis Object Data (0.1 MB/ev)
  - ✓Physics-oriented objects

Integration

Detector Control System (DCS) operational

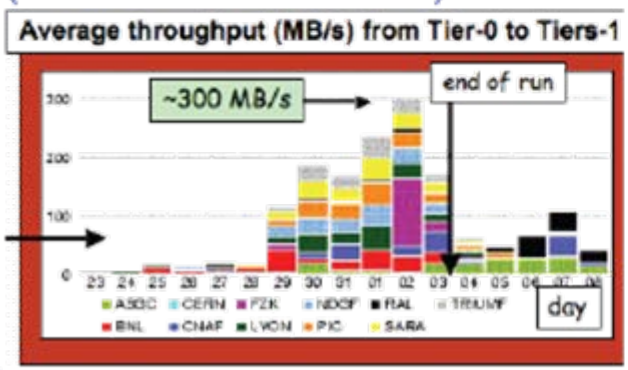






Monitoring tools developed

Load tests with cosmics
(200MB/s vs 1GB/s at LHC)



Full Dress Rehearsal (FDR):
stress test of the full data processing and analysis chain

Major s/w activities in the Commissioning Phase

- Event decoding
  - BS conversion
  - cabling maps
- Calibration
- Alignment
  - Optical alignment
  - Alignment with tracks
- Database issues
  - Store and retrieve from the database all the necessary quantities needed in the reconstruction
- Monitoring
  - Standalone in the muon spectrometer
  - Combined with ID and calos
  - Event displays
- Reconstruction
  - Adapt existing algorithms to reconstruct cosmics
  - Implement and test the use of several features (dead, noisy channels)
  - Combined reconstruction with all the sub-detectors
- Simulation
  - Provide the right detector description for simulation of cosmics with the various setups of (Mx/Px Runs)

Schematic Overview of ATLAS Offline Commissioning Software

Detector description

Changing often during commissioning

Simulation

- Cosmic generator
- GEANT4
- Digitization and trigger emulation

REAL RAW DATA!

Reconstruction

- Integrate reconstruction of different subsystems
- Combined reconstruction algorithms

CONDITIONS DATA FROM DB

Try to identify and flag faults related to hardware performance

Monitoring

- Integrate monitoring of different subsystems
- Combined monitoring
- Online event display

Evaluation and labelling of data

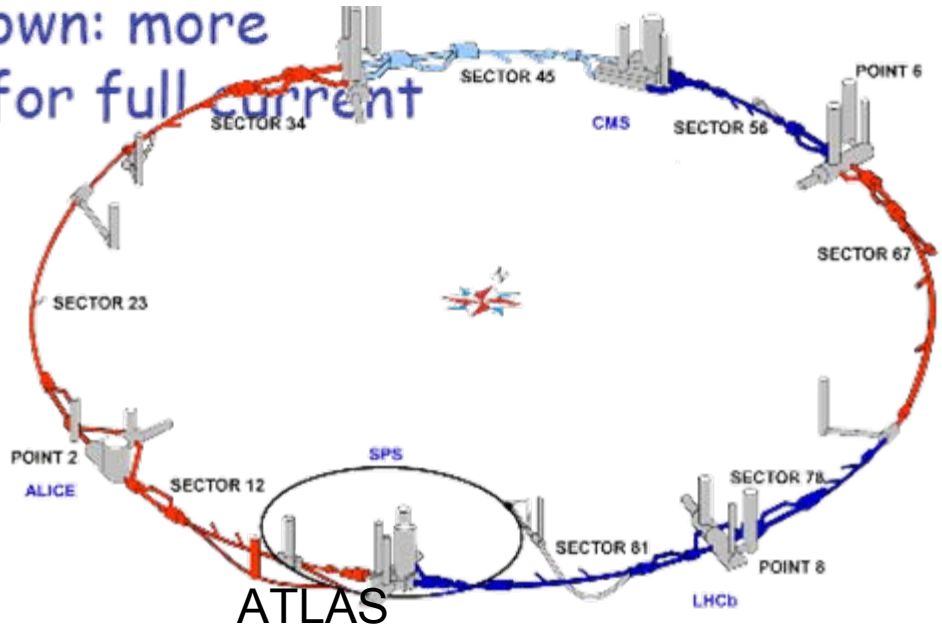
Analysis

- Subsystem commissioning
- ID/muon alignment
- Energy/time calorimeter correlations

Collaboration with detector experts is essential

LHC Start-Up Schedule

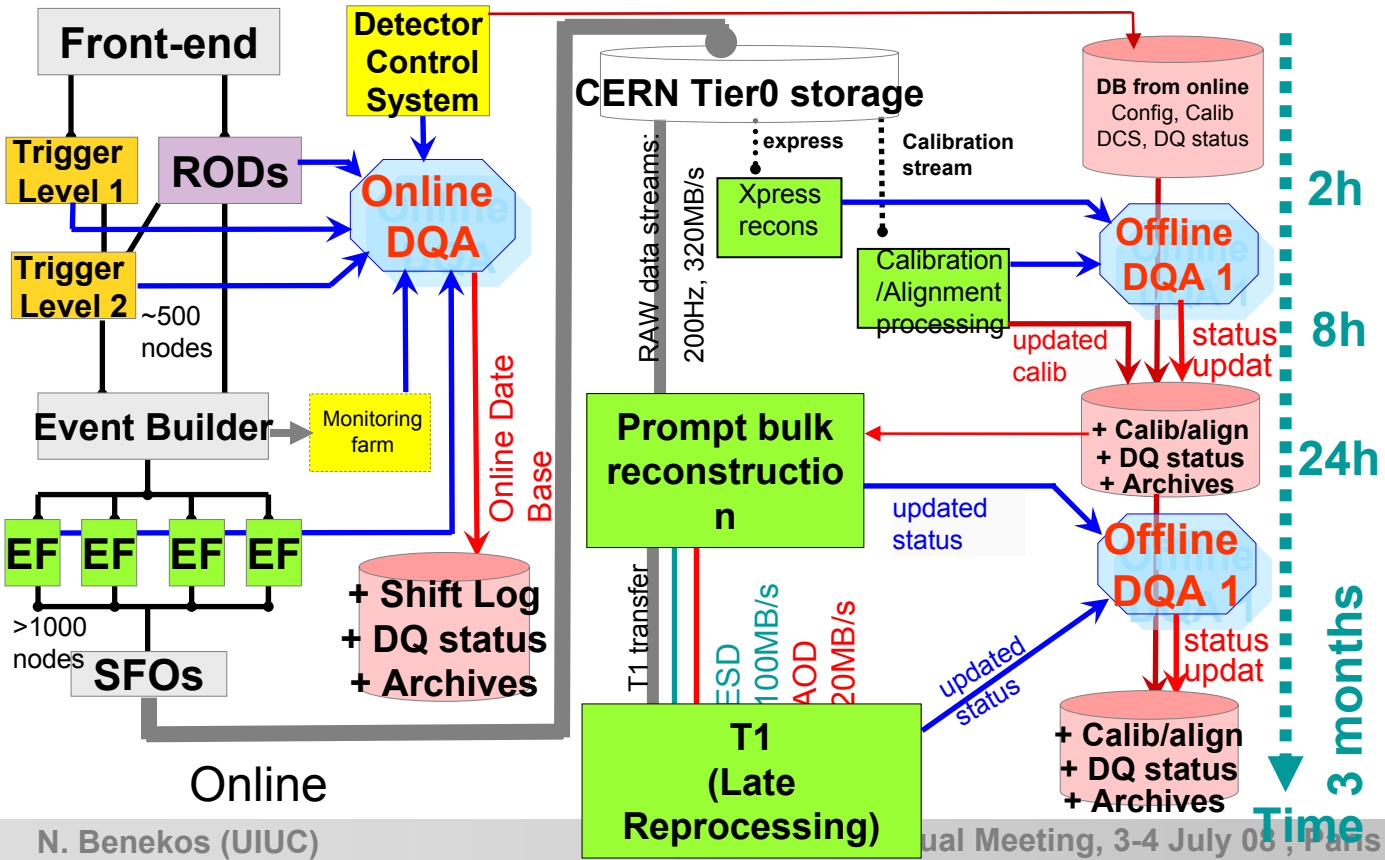
- Up-to-date schedule from DG/LHC meeting 6 May
- End June: LHC cold
- End July: first LHC beam
  - Commissioning with beam (~2 months)
- Then first collisions at 10 TeV
  - Stick to 10TeV for 2008
    ["The machine considers this to be a safe setting to optimize up-time of the machine until the winter shut-down (starting likely around end of November). Therefore, simulations can now start for 10 TeV. „]
- December: Winter LHC shutdown: more commissioning, train magnets for full current
- 2009: Run at 14TeV



ATLAS μDQA

- Official ATLAS μDQA has 4 parts
  - Online (in the ATLAS control room)
  - Offline (on Tier0)
  - Calibration centers (at Rome, Munich & Michigan)
  - Combined μDQA

Each has a specific, complementary, role



Monitoring timelines

- Online DQA (GNAM/DQMF)
  - Latency: 10s of seconds

- Offline Express Stream DQA (DQMF)
  - Latency: 1–2 hours;
  - Full detector
  - Old calibration constants.
  - Repeat w/ latency 1 day with new calib constants

→All important parameters are monitored
→ Focus is quick turn-around (<24hrs), runs in "real time" on Express Stream at Tier0.
→ Validation prior to 1st full reconstruction on Tier0 & feedback to shift crew.
→ Not optimal for fine-grained checks that require lots of stats.

- Calibration Stream (LVL2 stream)
  - Latency: 1–2 days;
  - Highest statistics
  - Muons only

See Elektra's talk

Offline DQA

- Monitoring done at 3 Different levels :
  - Low Level offline (hit level quantities)
    - MuonRawDataMonitoring
  - occupancies, correlations,…
    - Primarily to test readout-chain from online->offline
    - Backup for online (very useful during Px/Mx)
  - Mid Level offline (reconstructed quantities)
    - MuonSegmMonitoring , MuonTrackMonitoring
    - Occupancies on tracks, residuals,…
    - Check calib constants, chamber efficiencies, alignment
  - High Level offline (physics quantities)
    - MuonPhysicsMonitoring
    - Cross sections, mass peaks,…
    - Check calib constants, long-term stability, tracking eff.
- All are limited by event rate at Tier0

Tier-0 Monitoring WebDisplay

Commissioning and physics with first data

Step #1

- Understand / calibrate detector & trigger in situ using well-known processes
  - Z(ee,μμ) calibration/alignment for tracker, Calorimeters, MuonSystem, detector efficiency, trigger performance, detector momentum scale, uncertainties on the magnetic filed (distorded B Filed)
- "Rediscover" Standard Model at 14TeV

→ use well modeled "standard candles": W, Z, top:

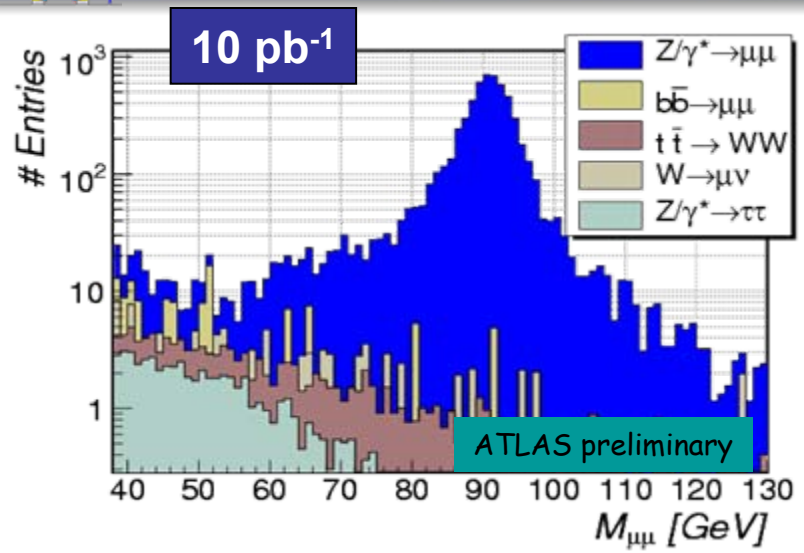
Channel	Events/ $100pb^{-1}$	Total Events from LEP/Tevatron	Leads to understanding of…
Z →ee, μμ	**~10^4**	**~10^6 LEP ~10^5 Tevatron**	**ECAL energy scale and uniformity Tracking alignment**
W→eν, μν	**~10^5**	**~10^4 LEP ~10^6 Tevatron**	**ECAL energy scale Tracking alignment Constrain PDFs**
tt→WbWb→μν+X	**~10^2**	**~10^4 Tevatron**	**Jet scale from W→jj B tagging performance**

Step #2

Understand backgrounds to New Physics,
e.g. tt and W/Z+ jets (omnipresent…)

Step #3

Look for New Physics potentially accessible in first year(s),
e.g. Z' → ee/μμ, SUSY, Higgs…?



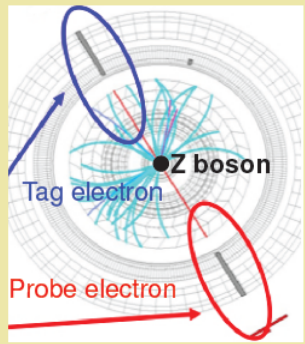
After all cuts expect ~600 Z→μμ/ee events per pb^{-1}, per channel

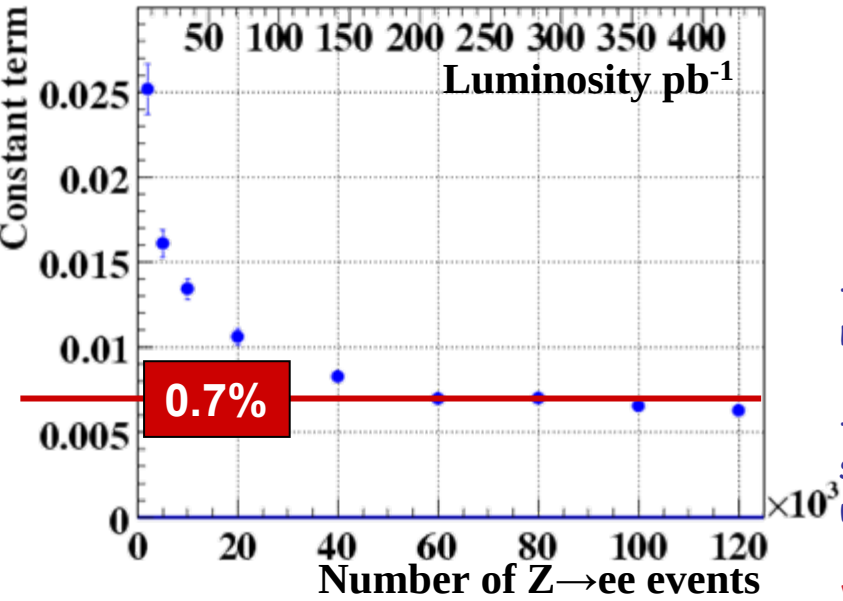
Muon channel used for alignment of muon spectrometer and ID tracker, plus trigger and reconstruction efficiencies

Electron channel used to calibrate the lepton energy scale, using the Z mass constraint, measure trigger and reconstruction efficiencies and calibrate the ECAL uniformity:

Tag&Probe method

- well identified electron on one side: **tag** electron
- simple object on the other side (track or EM cluster): **probe** electron
- determine the efficiency with the number of events in the mass window: $M_{inv}=M_Z \pm 20GeV$





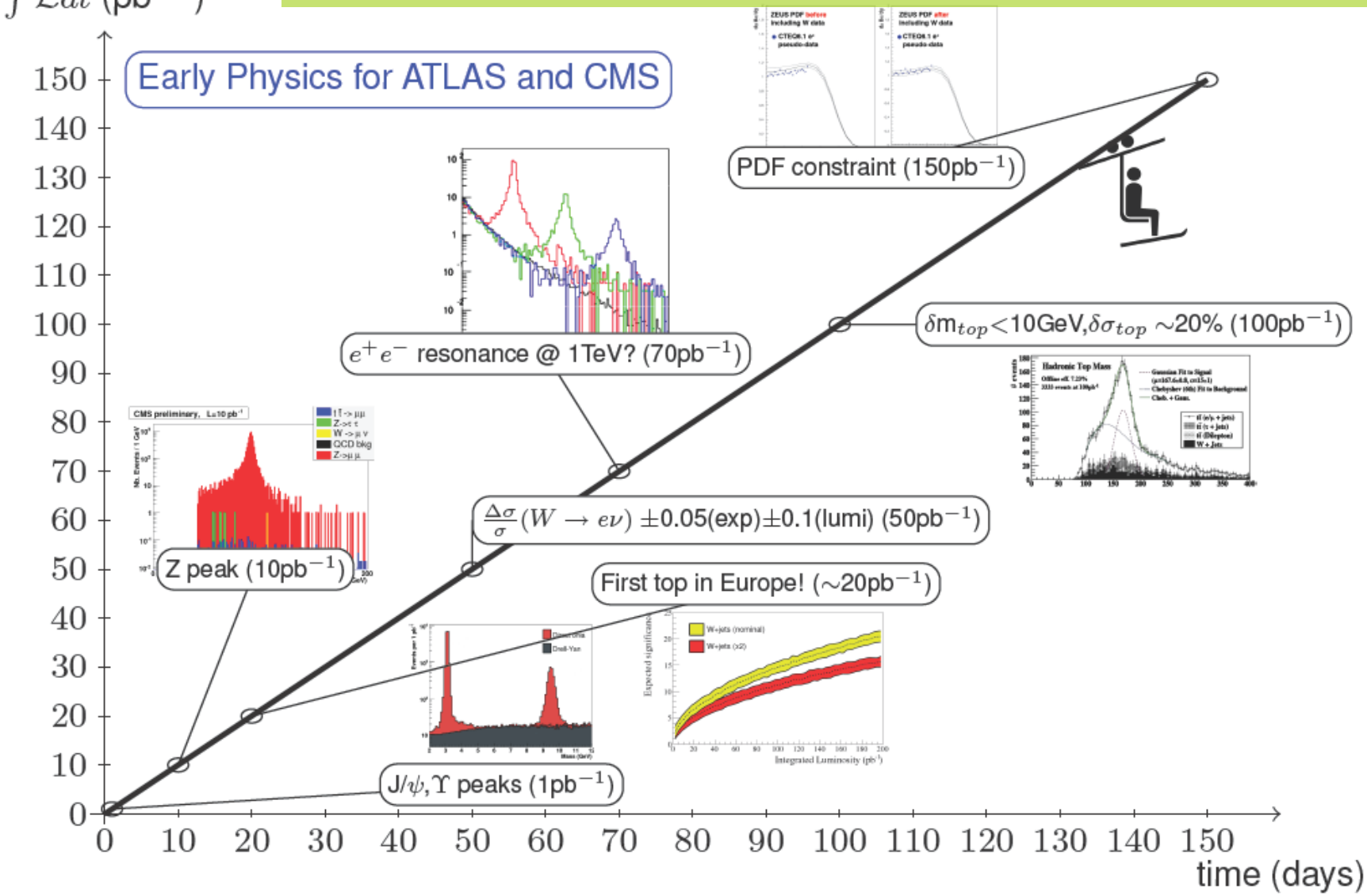
-Expect initial, residual long range non-uniformities at level of 1-2%

- Around 10^5 Z→ee events should be sufficient to reach the goal response uniformity of ~ 0.7%

With 100pb^{-1} the Z cross section should be measured to around 10%, dominated by the uncertainty on the luminosity

Conclusions

ATLAS is getting ready to collect data by recording already cosmic ray particles and is eagerly awaiting the first LHC collisions this summer...



Outlook

ATLAS readiness:

✓ATLAS is ~100% installed in the cavern and integration into global TDAQ is progressing well

✓Commissioning with cosmics ongoing

✓The ATLAS offline software is being commissioned with cosmic rays

- ✓Ironing out bugs, exercising subsystem integration
- ✓Develop/debug combined algorithms

✓ATLAS is ready to take first data this summer

✓We are on the road to an exciting physics program, starting with SM channels for calibration purposes, and moving on to hopefully numerous discoveries

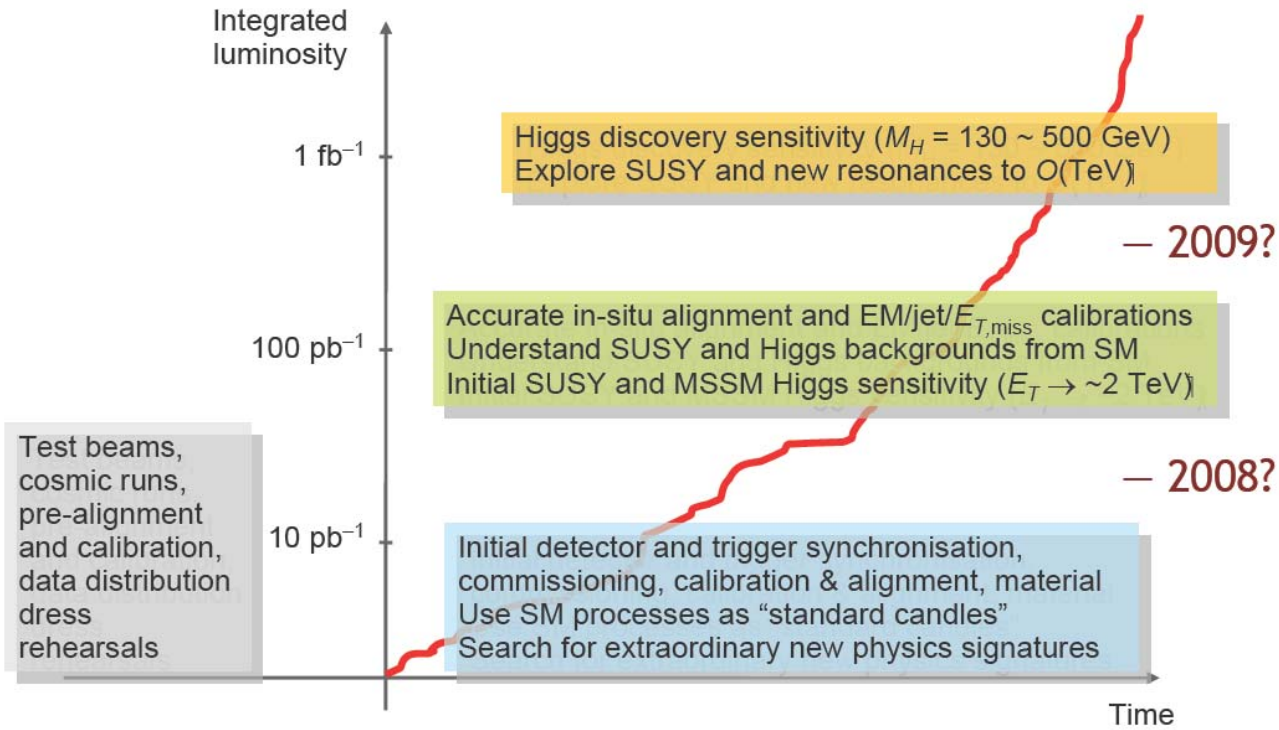
✓Prime goal remains to shed light on the mechanism of EW symmetry breaking. The LHC is set to find the Higgs if it is there (from the LEP limit to ~1TeV)

- ✓as for Artemis-RTN

✓ ***The first steps on the road to discovery in 2008***

Thanks for the invitation !

A Physics Road-Map



Much work to be done before physics, building on:

- test-beam
- calibration and alignment systems
- cosmics (have been accumulated for a while)

	Initial	Ultimate	Samples
e/γ E scale	~2%	0.1%	Z→ee, J/ψ, π^0
e/γ uniformity	1-2%	0.5%	Z-ee
jet E scale	5-10%	~1%	W→jj in tt, γ/Z+jets
tracking alignment	10-50μm	<10μm	tracks, Z→μμ
muon alignment	100-200μm	30μm	inclusive μ, Z→μμ

Expected Status at 1st Beam

Muon spectrometer will be almost 100% operational

- **MDT**
  - All chambers fully commissioned with cosmics
- **RPC**
  - 12(13) of 16 sectors fully commissioned with cosmics
  - 4(3) sectors fully cabled and powered, but not debugged
  - Chamber trigger efficiency: 90–95% (without optimizing working point)
- **TGC**
  - All sectors fully commissioned with cosmics
  - Chamber trigger efficiency: 99% (estimated)