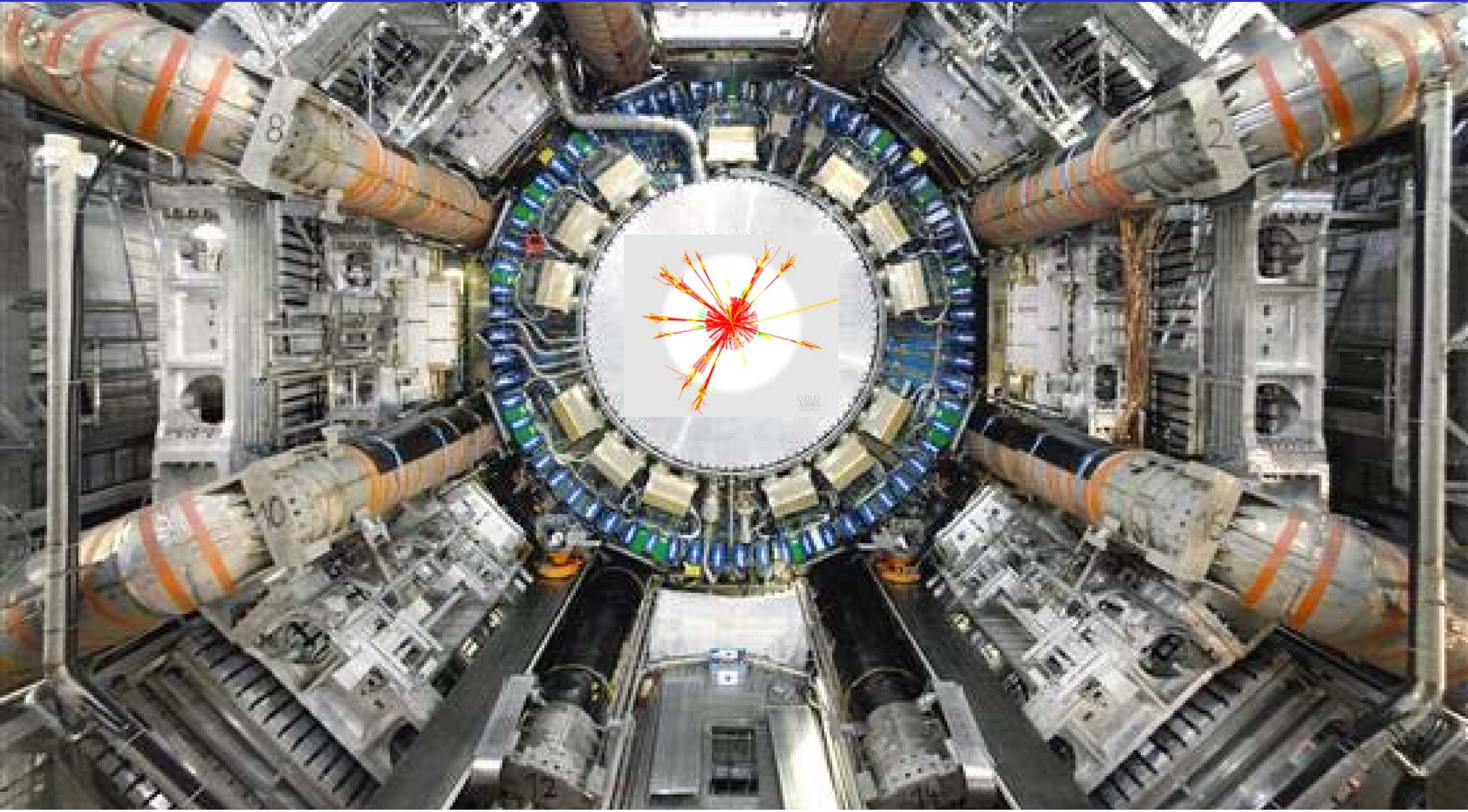
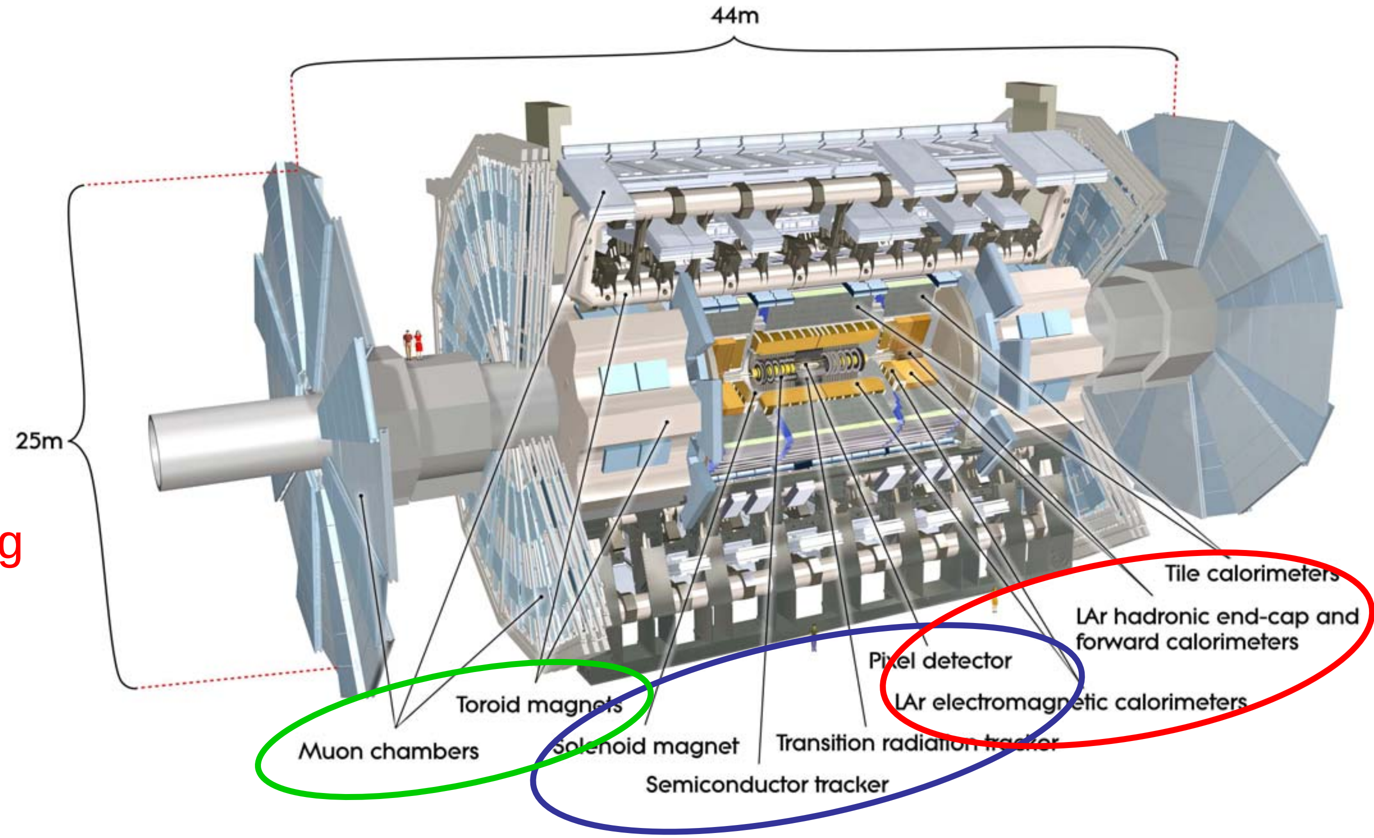
The ATLAS experiment: from calibrations & cosmics to first beams

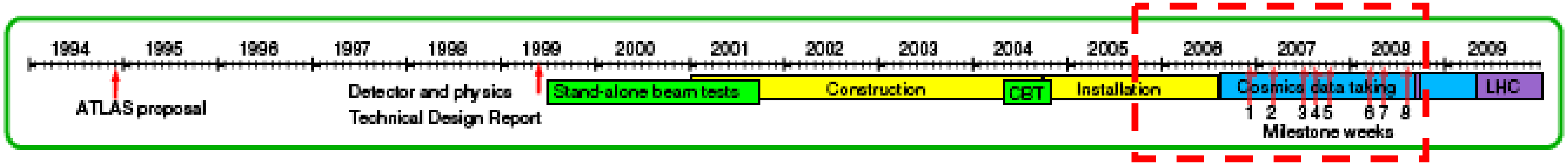


Manuella G. Vincter (Carleton University)
on behalf of the ATLAS Collaboration

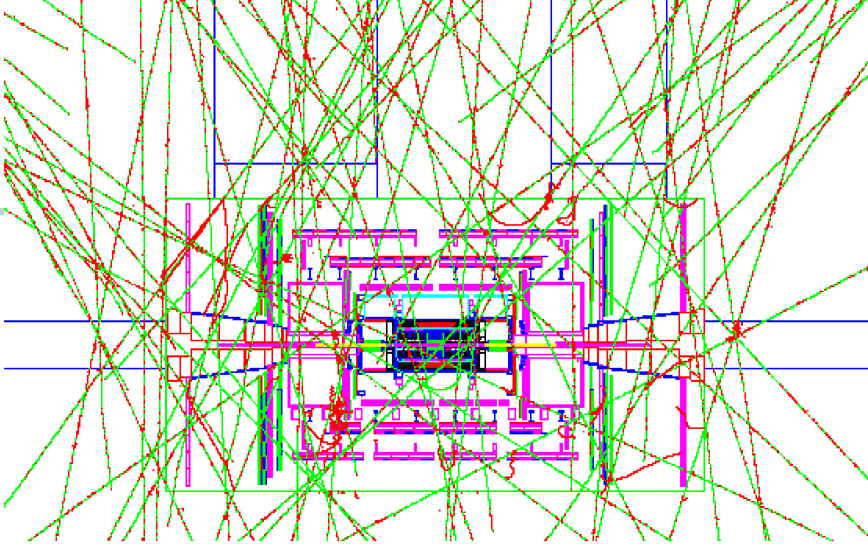
Commissioning of the ATLAS experiment

- ATLAS detector commissioning
- Subsystems and their performance
  - Trigger
  - Inner detector
  - Calorimeters
  - Muon system
- In-situ commissioning since 2005



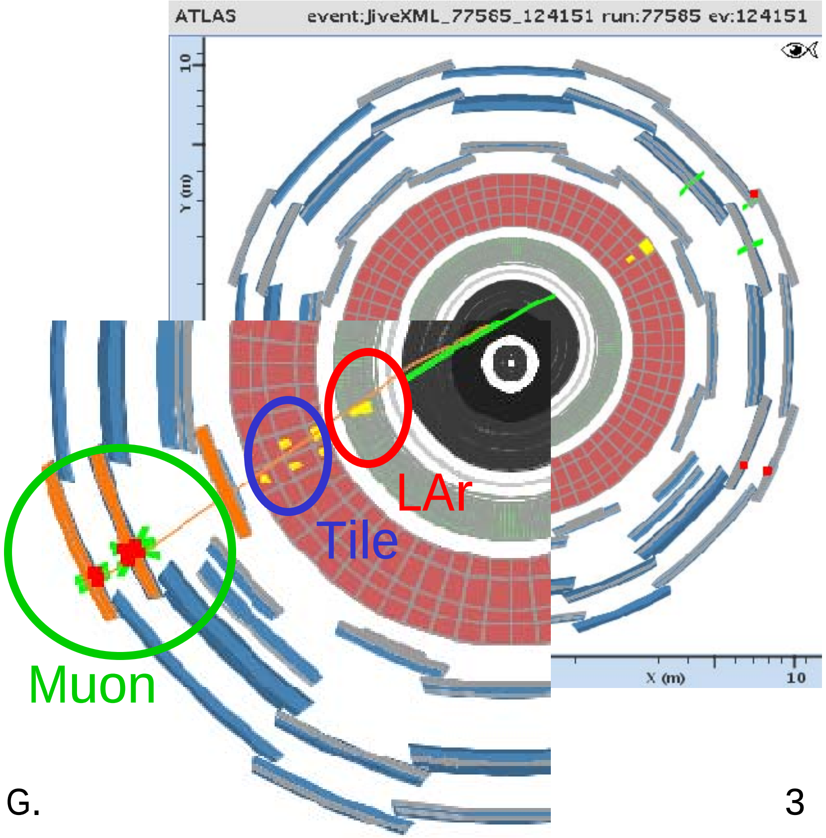


Commissioning runs



In-situ detector commissioning

- System-specific stand-alone calibration runs
  - Noise measurements
  - Calibration pulses
- Stand-alone cosmics runs
- Combined cosmics runs
  - Trigger at Level 1 with:
    - Calorimeters (LAr&Tile)
    - Muon system (RPC&TGC)
    - Minimum bias scintillators
  - Detector subsystems have joined combined runs as they came online



Trigger

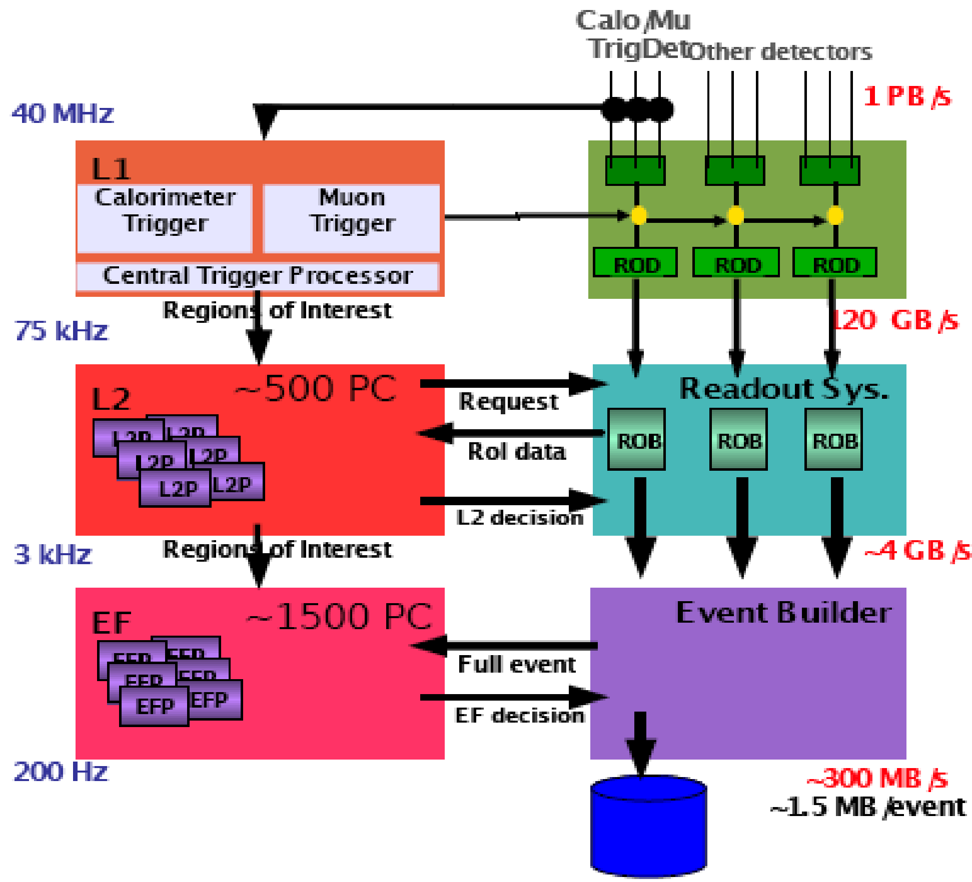
Level-1

- Custom-made electronics
- Reduced granularity info from calorimeter and muon systems
- Signatures from high p_T muons, γ/e, jets, τ, events with large E_T^{miss}

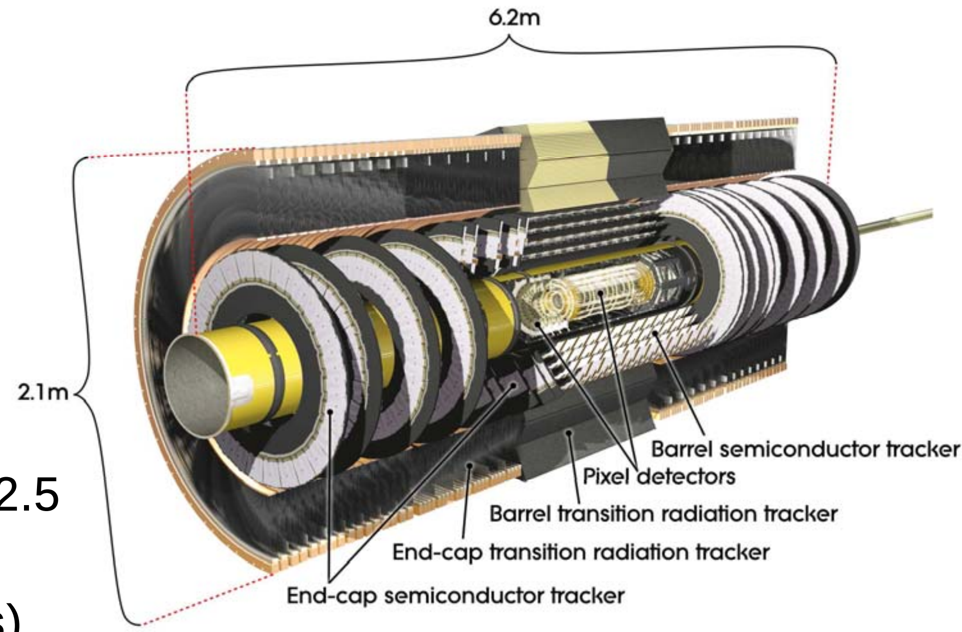
High-Level Trigger

- Software and mainly commercially available equipment
- Level-2: seeded by Regions of Interest (RoI) provided by Level-1, full detector granularity in RoI (tracking information used)
- Event Filter: uses offline analysis procedures to further select events, potential full access to event

Event rate reduced 40MHz ⇨200Hz



Inner detector



Inner detector system: 87 million readout channels

- Silicon pixel
  - Discrete space points, 3 layers, $|\eta|<2.5$
- Silicon microstrip (SCT)
  - Stereo pairs, 8 layers (4 space points), $|\eta|<2.5$
- Straw tube transition radiation tracker (TRT)
  - Typically 36 hits per track, $|\eta|<2.0$

Goals:

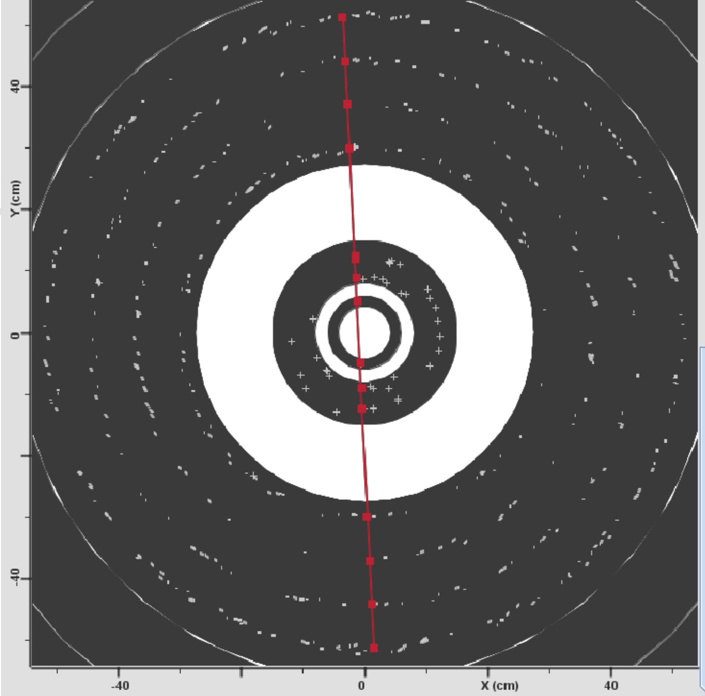
Instrinsic accuracy	**R- ϕ**	**R or z**
Pixel	10 μm	115 μm
SCT	17 μm	580 μm
TRT	130 μm	

- $\sigma/p_T \sim 0.05\%\ p_T \oplus 1\%$

2008 commissioning:

- 2.5% lost due to cooling leaks and heater problems in endcap (much can be recovered in shutdown)

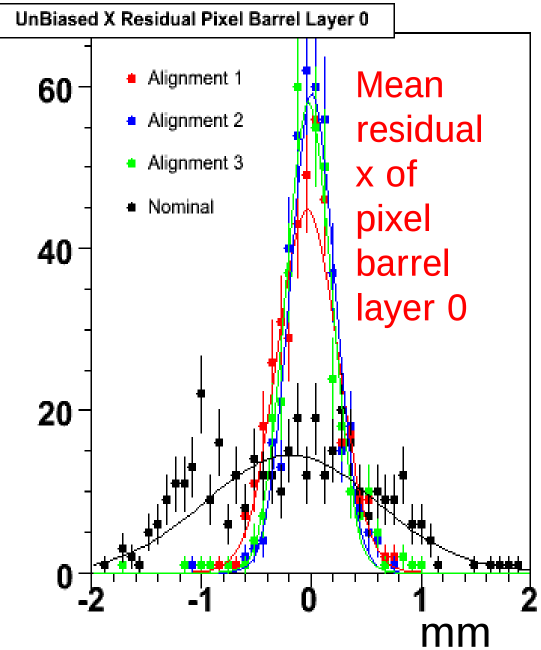
Silicon ID with cosmics events

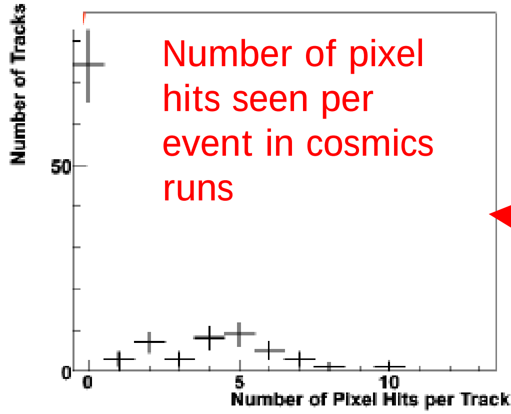


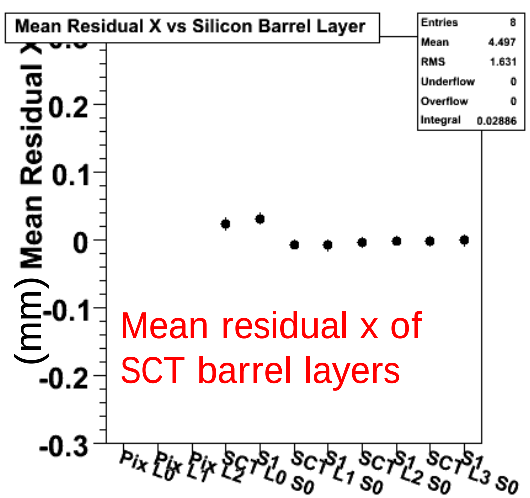
First cosmic runs with pixels: mid-September!

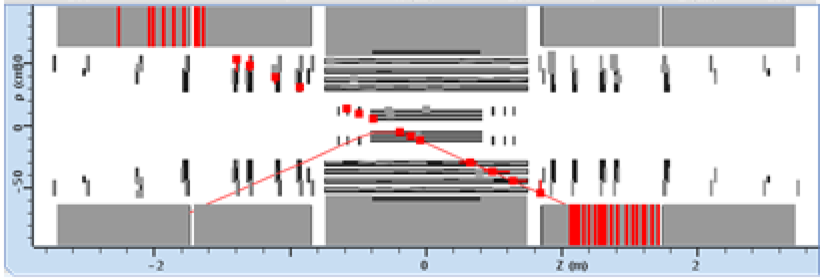
- 7 pixel hits and 16 SCT hits: one hit in every layer!

Initial alignment of SCT and pixel with cosmics:







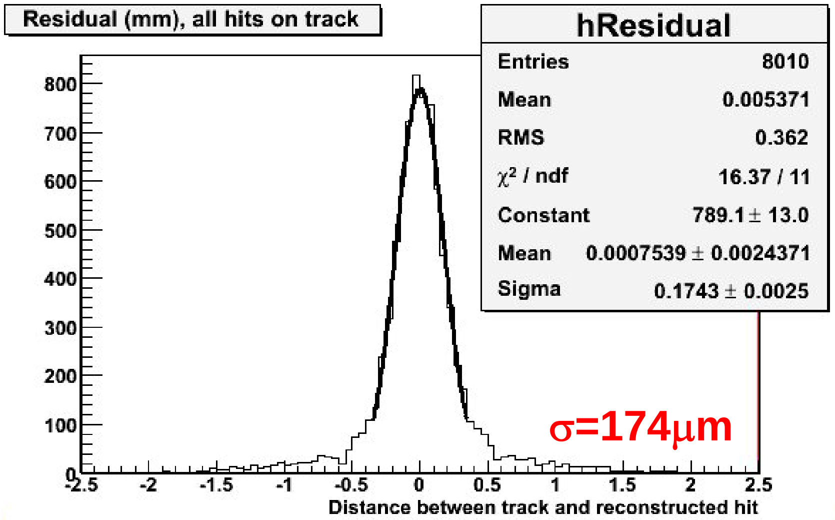


Cosmic track crossing TRT endcap, SCT and pixel barrel+endcap

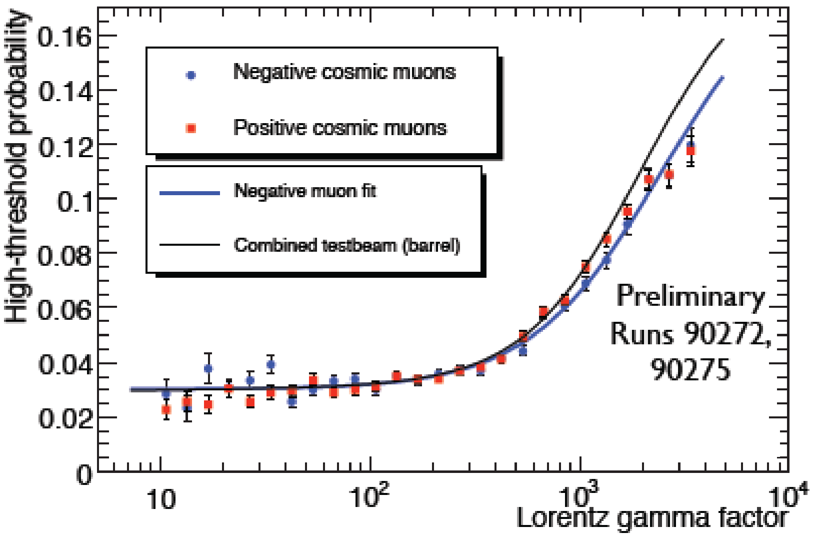
- Important for alignment

TRT with cosmic events

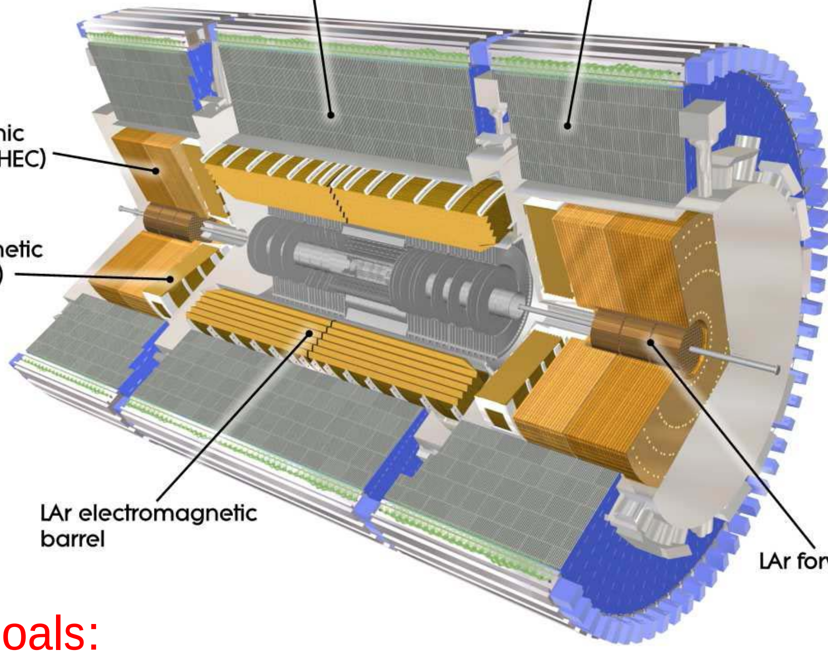
- TRT hit resolution already close to design requirements (130μm)



- In September, TRT switched to Xenon gas mixture
- First in-situ transition radiation probability curve with cosmic muons
  - Track p_T 1-400 GeV
  - Comparison with barrel TB results



Sampling calorimetry



~200k readout channels

Electromagnetic:

- 3 sampling depths in precision region $|\eta|<2.5$
- Presampler $|\eta|<1.8$

Hadronic:

- Barrel: $|\eta|<1.7$, 3 sampling depths
- Endcaps: $1.5<|\eta|<3.2$, 4 sampling depths

Forward: $3.1<|\eta|<4.9$

- 3 sampling depths (1 for electromagnetic and 2 for hadronic measurements)

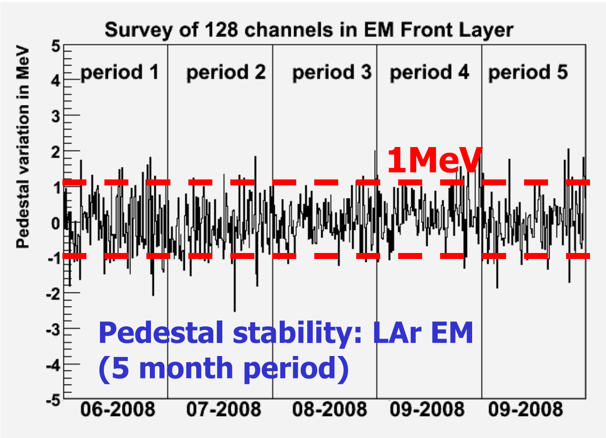
Goals:

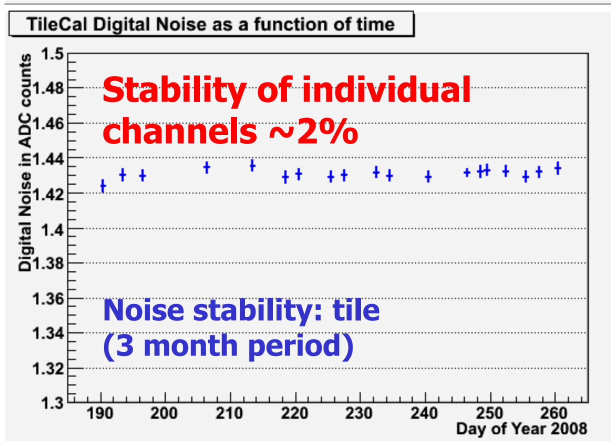
- fine granularity in overlap region with inner detector for precision measurements of e/γ
  - $\sigma/E \sim 10\%/\sqrt{E} \oplus 0.7\%$
  - Linearity to ~0.1%
- Coarser granularity in the other regions sufficient for jet reconstruction and E_T^{miss} measurements
  - $\sigma/E \sim 50\%/\sqrt{E} \oplus 3\%$ (barrel/endcap)
  - $\sigma/E \sim 100\%/\sqrt{E} \oplus 10\%$ (forward)

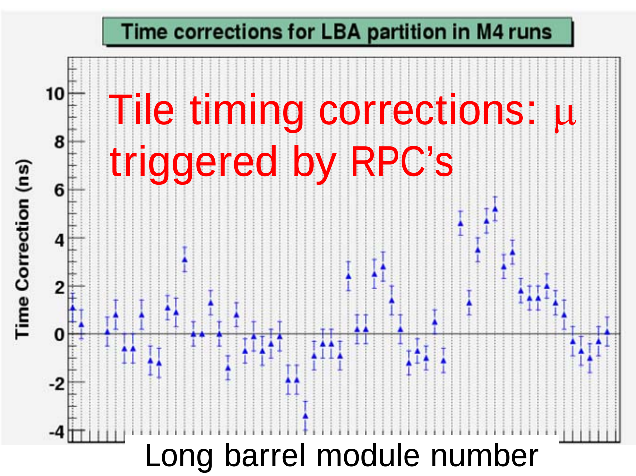
Calorimeter performance

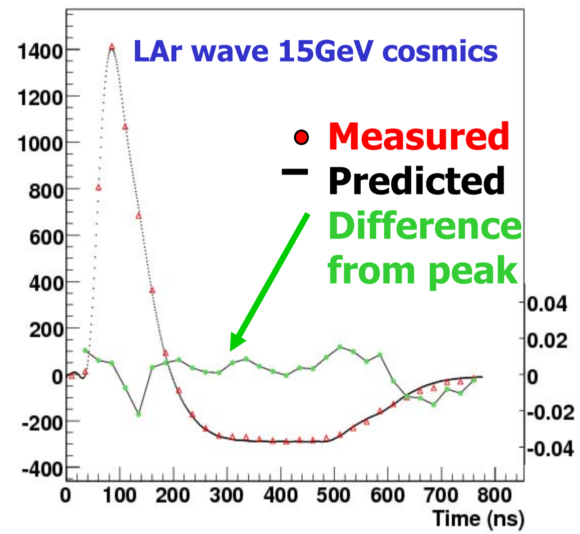
Calorimeter commissioning

- “Dead” channels:
  - EM: ~0.01% (+0.5%, most can be recovered at next shutdown via frontend board replacement)
  - HEC: ~0.1% (+LVPS impacting ¼ of an endcap, to be resolved next shutdown)
  - FCal: none
  - Tile: ~1.5% (all should be recoverable next shutdown!)
- LAr: Some channels require special corrections e.g. high voltage
- Tile: Cs source used to set HV and equalise PMT gains to <1%
- Tile timing corrections: can intercalibrate to 0.5ns
- Effort is now more focused on performance
  - Long term stability
  - Prediction of the signal
  - Calibration constants



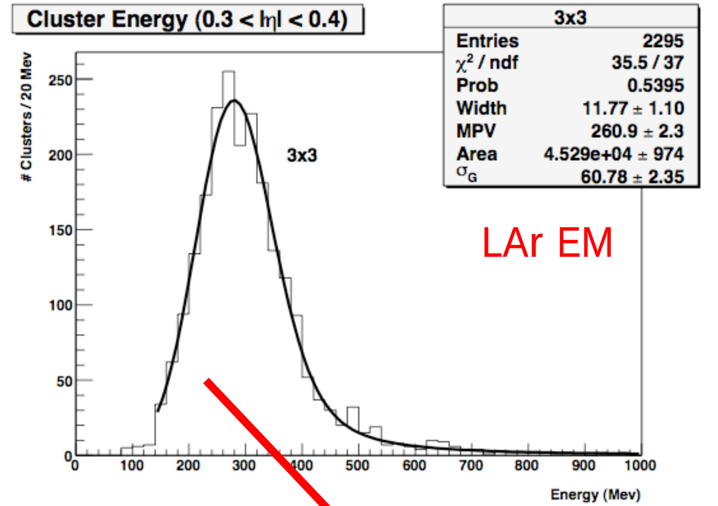


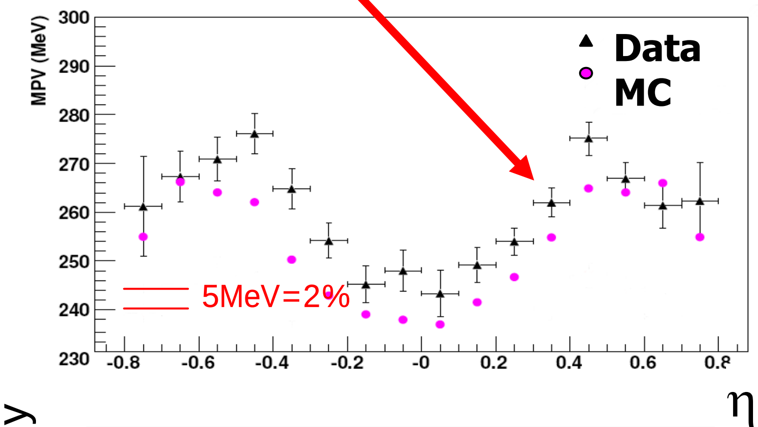


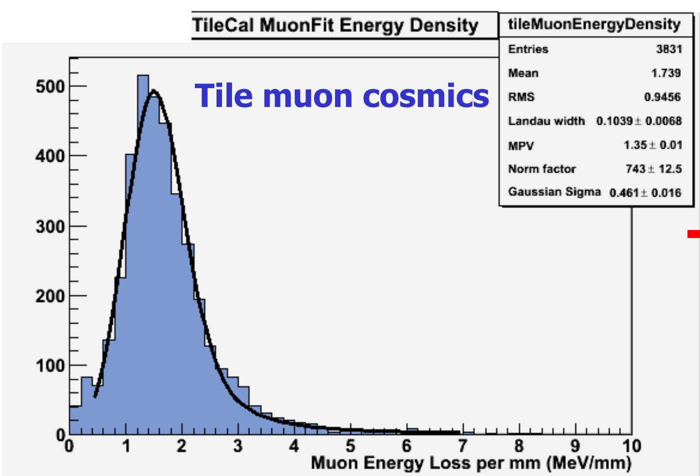


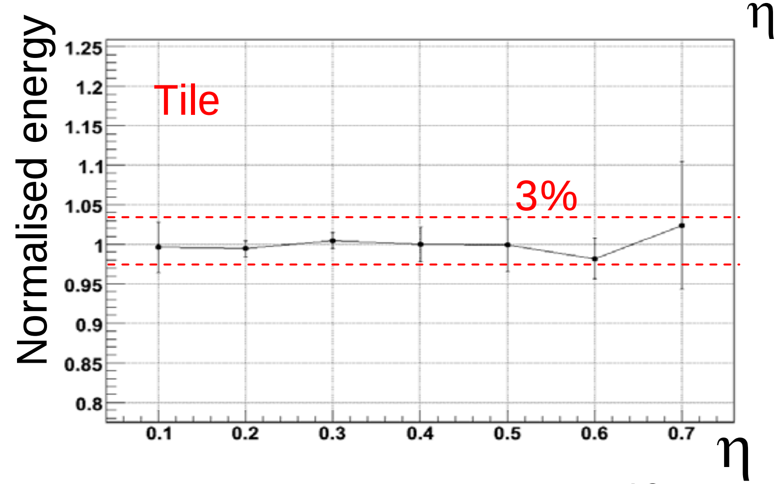
Calorimeter performance

- Energy reconstruction
  - LAr EM: Reconstruct E with 3x3 calorimeter cells, comparison to Landau
    - energy η dependence agreement, though there is a 5% systematic uncertainty on the MC prediction
  - Tile: energy deposited by μ vs. η, normalised by distance traveled in tile
    - energy scale&uniformity tested to 2-3%



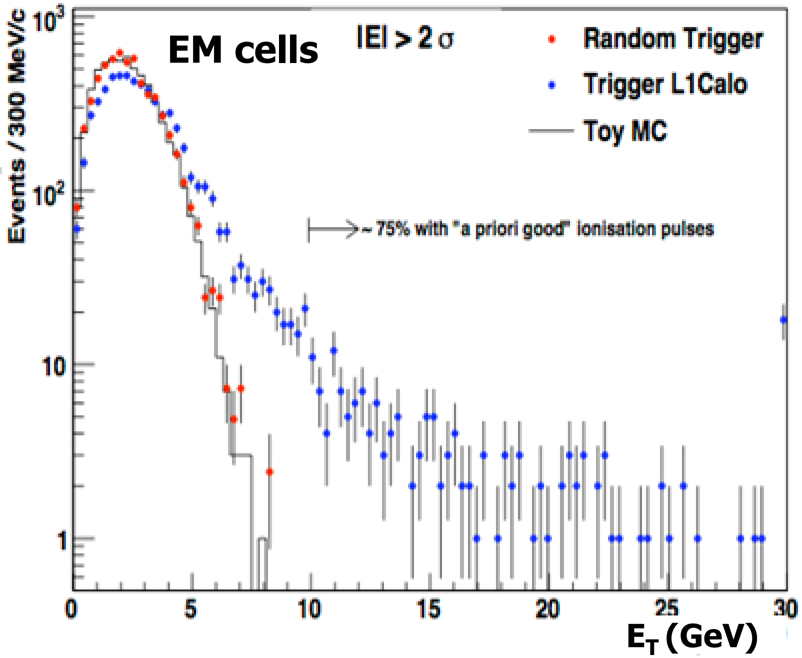




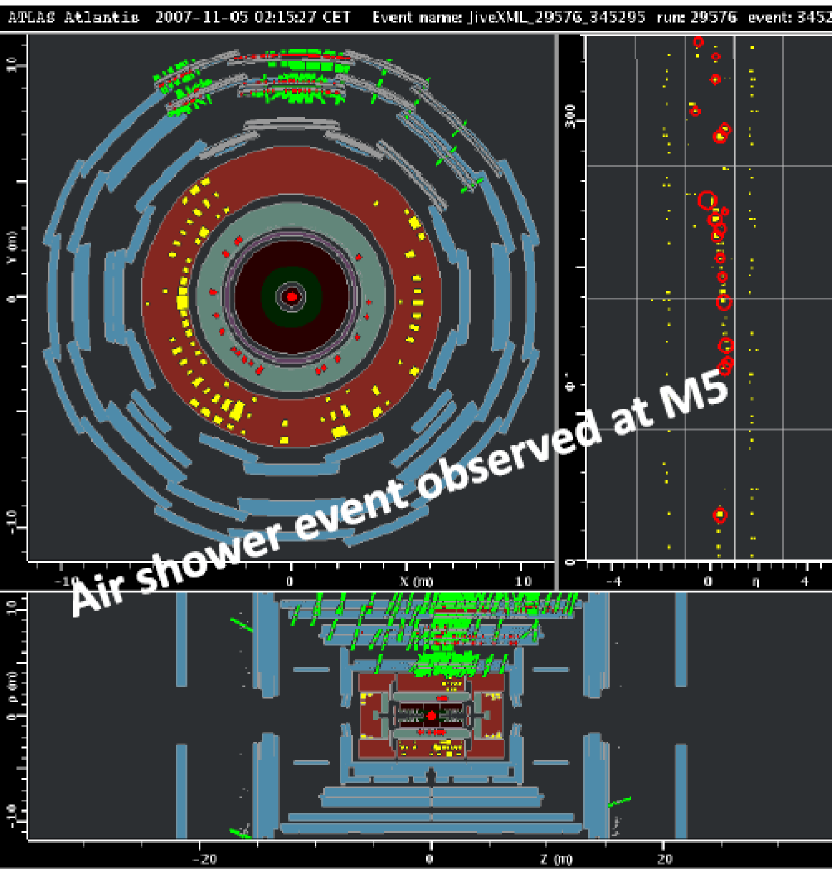


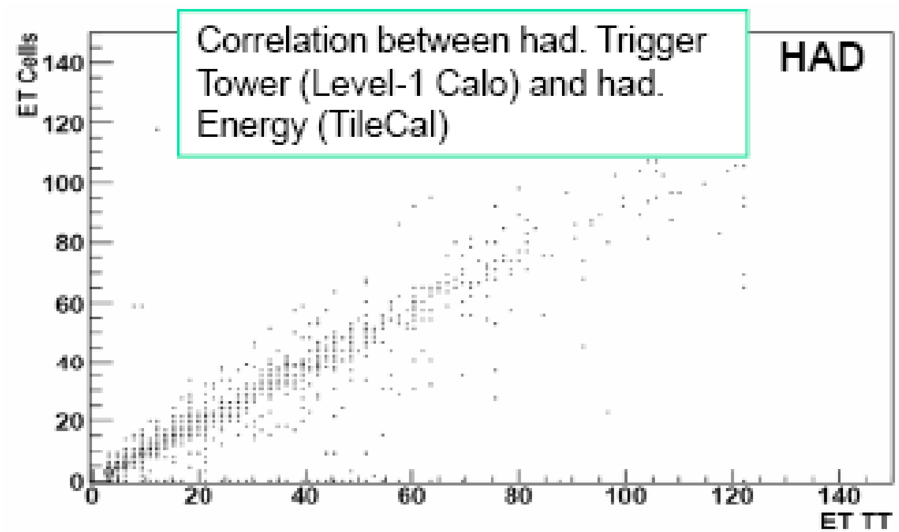
Calo/trigger performance

- Correlation between energy as measured in calorimeter and as seen in L1 trigger
- Impact of air showers as sources of non-IP jets: reduced though timing cuts

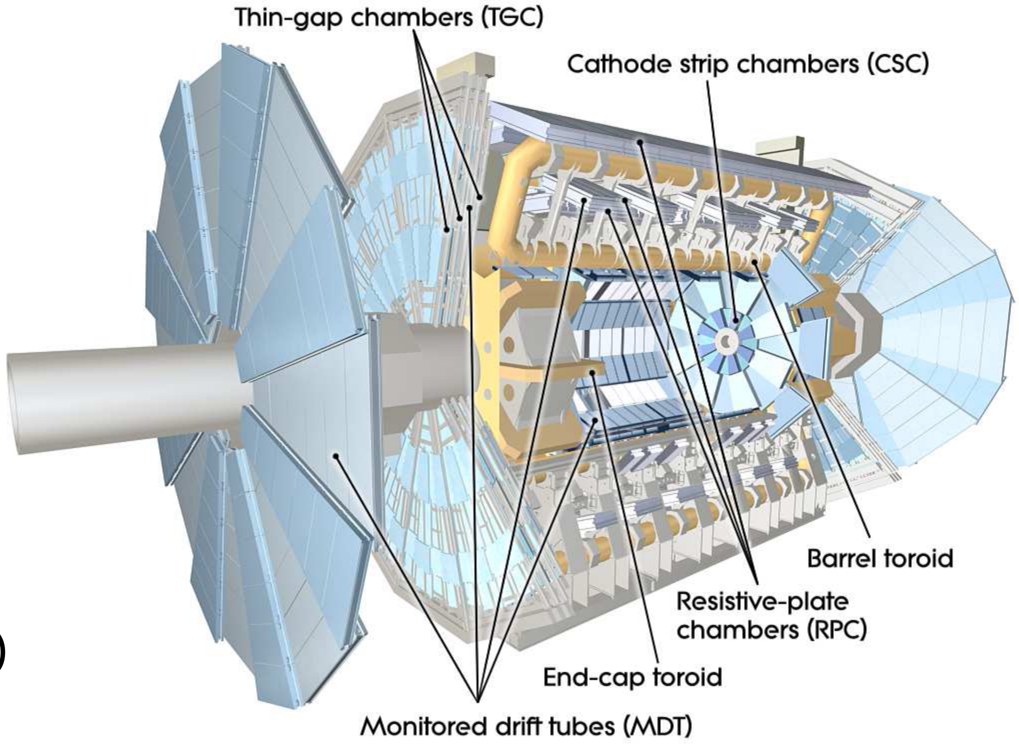


$E_T=\sqrt{(\Sigma E_{T,x}^2+\Sigma E_{T,y}^2)}$





Muon spectrometer



Air-core toroid magnet system

Precision tracking chambers

- 3 barrel layers, 3 endcap wheels
- ~370k readout channels
- Monitored Drift Tubes (MDT)
  - $|\eta|<2.7$ (innermost layer $|\eta|<2.0$)
- Cathode Strip Chambers (CSC)
  - innermost layer $2.0<|\eta|<2.7$

2008 commissioning: MDT

- 99.8% of chambers readout
  - 2 endcap chambers with no access
- 1.5% of channels dead (should be reduced to 0.2% after shutdown)

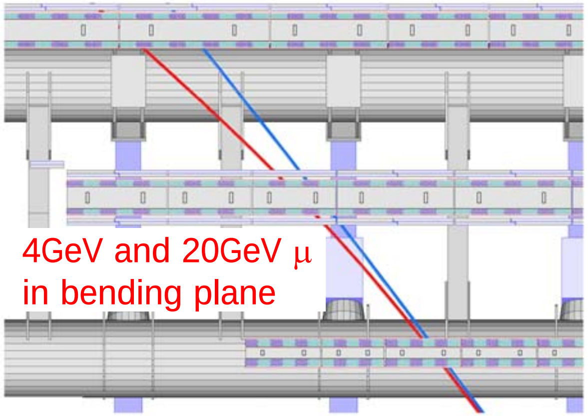
2008 commissioning: CSC

- All chambers operational
- <0.1% dead channels

Trigger chambers

- ~680k readout channels
- Resistive Plate Chambers (RPC)
  - $|\eta|<1.05$
  - 3 double layers
- Thin Gap Chambers (TGC)
  - $1.05<|\eta|<2.7$ (2.4 for triggering)
  - 4 wheels

Muon status and performance



Goal: stand-alone p_T resolution ~10% for 1TeV tracks

- sagitta along the beam axis of ~500μm for 5m track, to be measured with resolution of 50μm

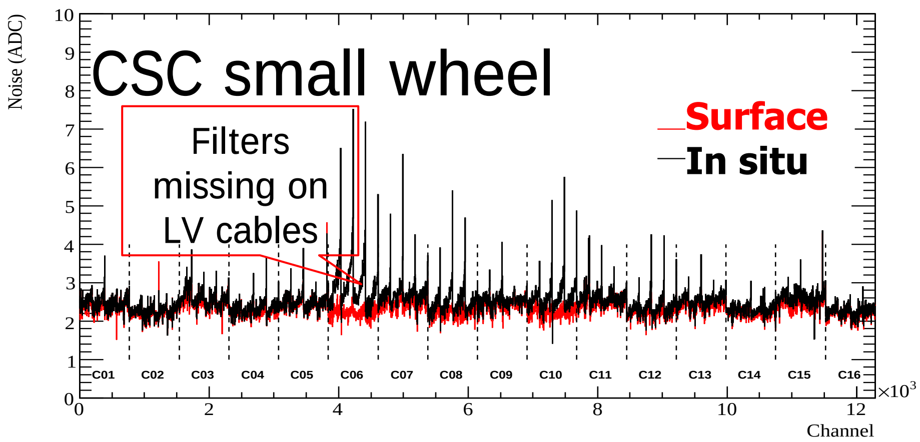
Chamber resolution	z/R	ϕ	time
MDT	35 μm (z)	--	--
CSC	40 μm (R)	5 mm	7 ns
RPC	10 mm (z)	10 mm	1.5 ns
TGC	2-6 mm (R)	3-7 mm	4 ns

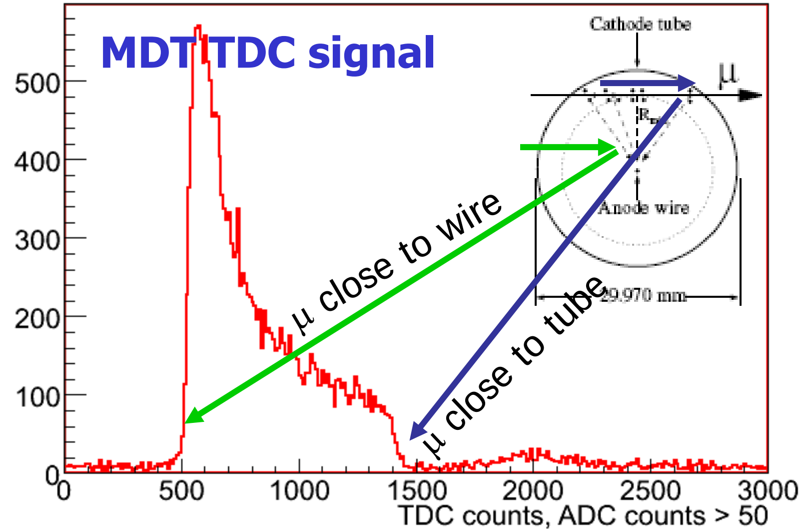
Status: All chambers installed&services connected

Noise rates are under control

Integrated into the DAQ

- MDT tested to 100kHz, TGC and RPC to 40kHz
- CSC: rate issues related to programming of FPGA
  - Under investigation

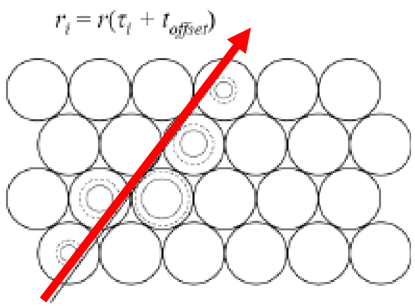


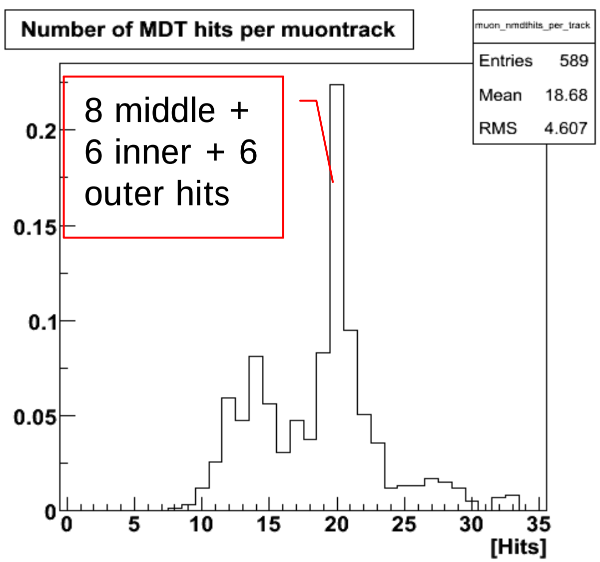


Muon performance with cosmics

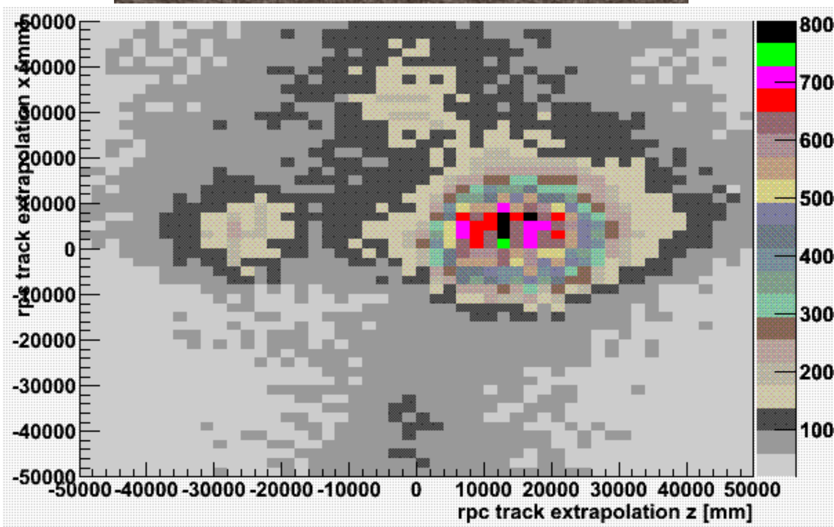
MDT sees cosmic muon tracks very well!

- ~6 hits per layer per track

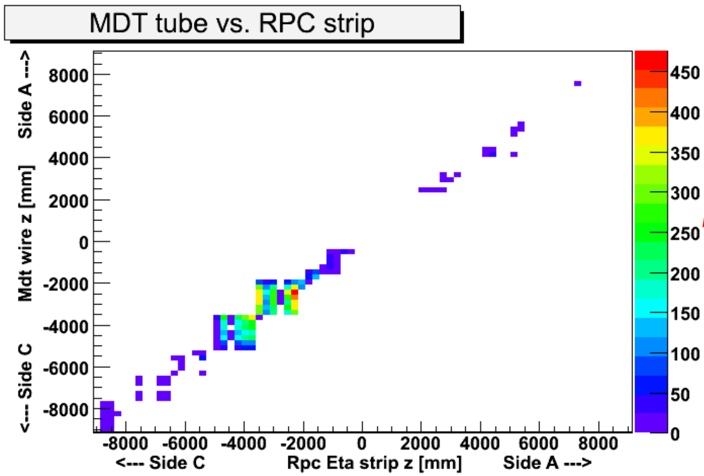




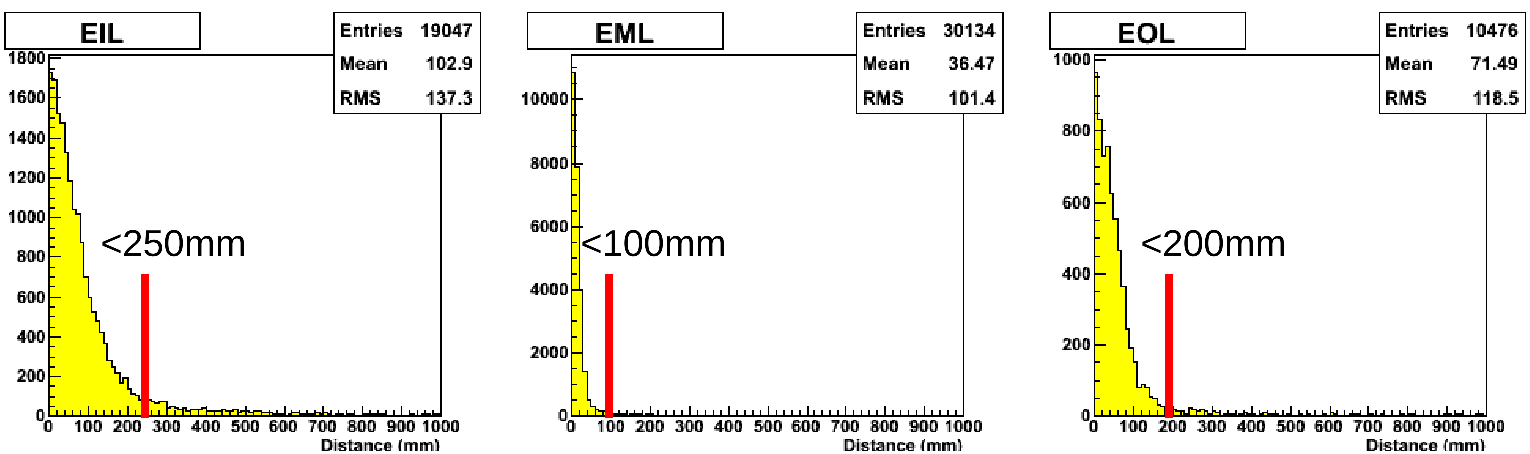
RPC's can see footprint of access shafts



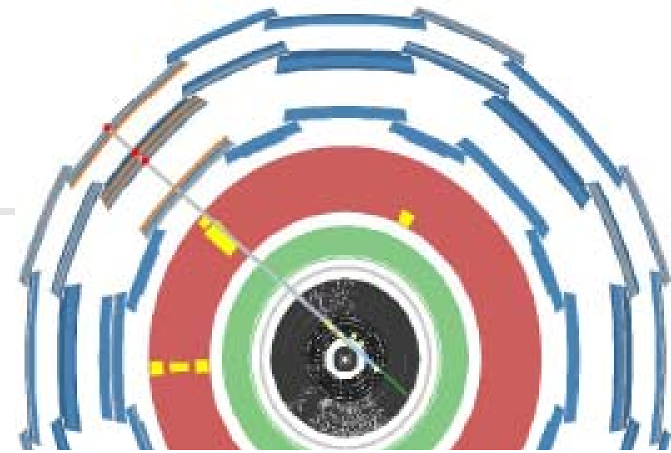
Muon performance with cosmics



- Good correlation between MDT and RPC
- Distance between MDT centre & projection by TGC (inner,middle,outer layers)



Joint ID-muon performance

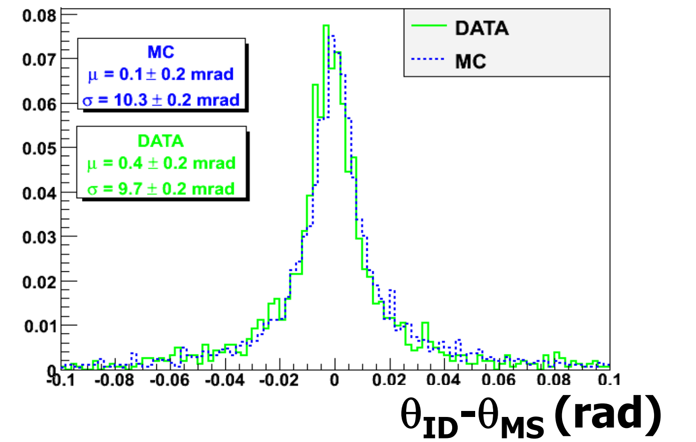


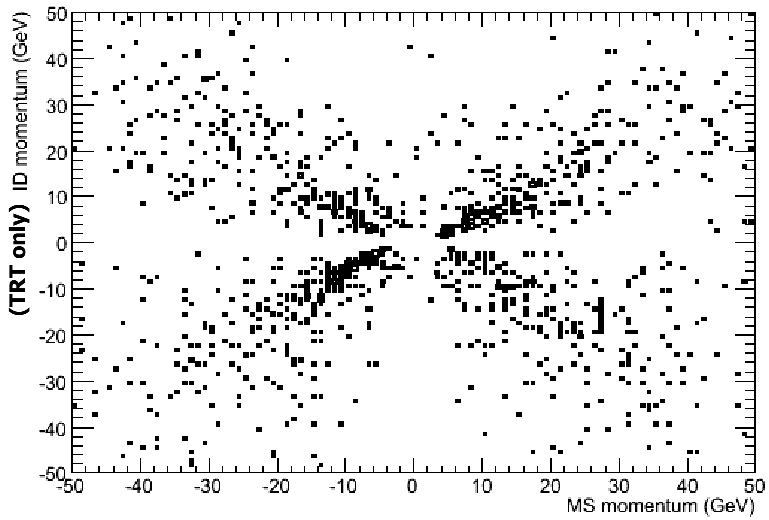
Early cosmic rays for ID in March 2008:

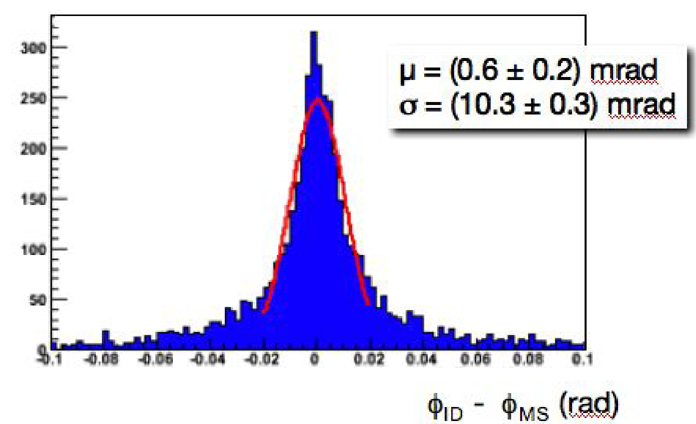
- difference in track (θ,φ) using ID (SCT+TRT) and muon (MDT) hits
- Resolution at the 10mrad level in θ,φ

August 2008 cosmics run with magnetic field “on”:

- Correlation between momentum in ID (TRT only) and muon spectrometer
- Note: muon charge wrong for downward tracks in upper detector

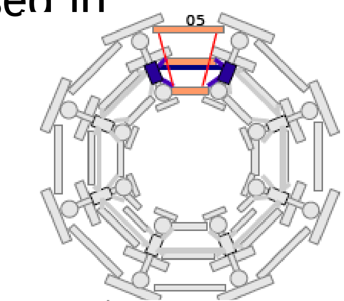




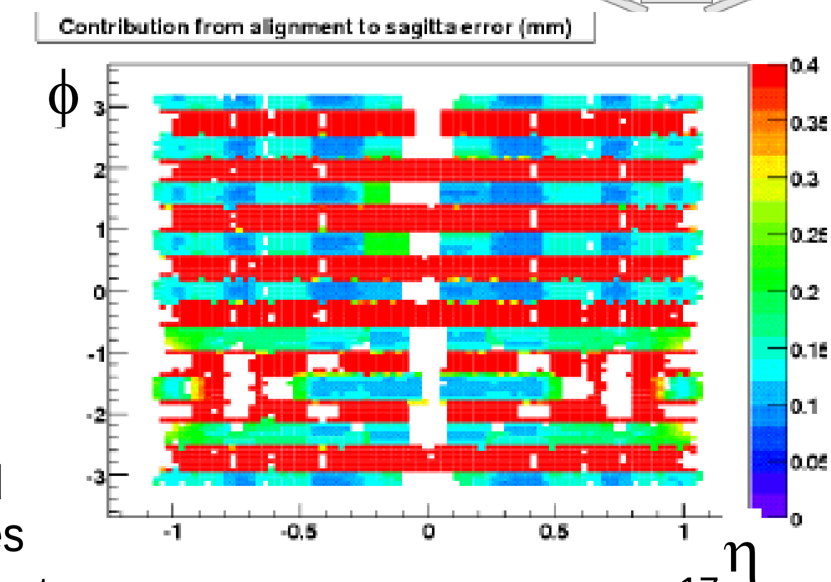


Muon alignment

- **Goal:** 10% accuracy for a 1TeV muon track requires a resolution on the reconstructed sagitta of 50μm. Intrinsic resolution of the muon chambers: ~35μm
  - relative alignment of the 3 chambers per towers should be known to 30μm
  - For needed sagitta accuracy: track-based alignment algorithms used in combination with optical system (~12000 optical sensors)

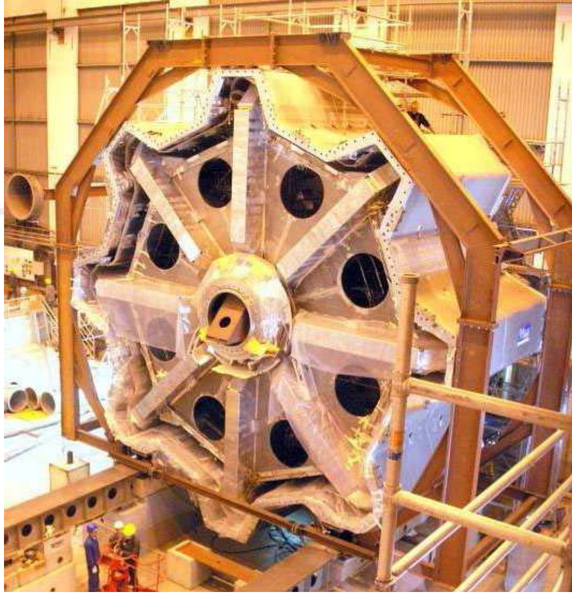


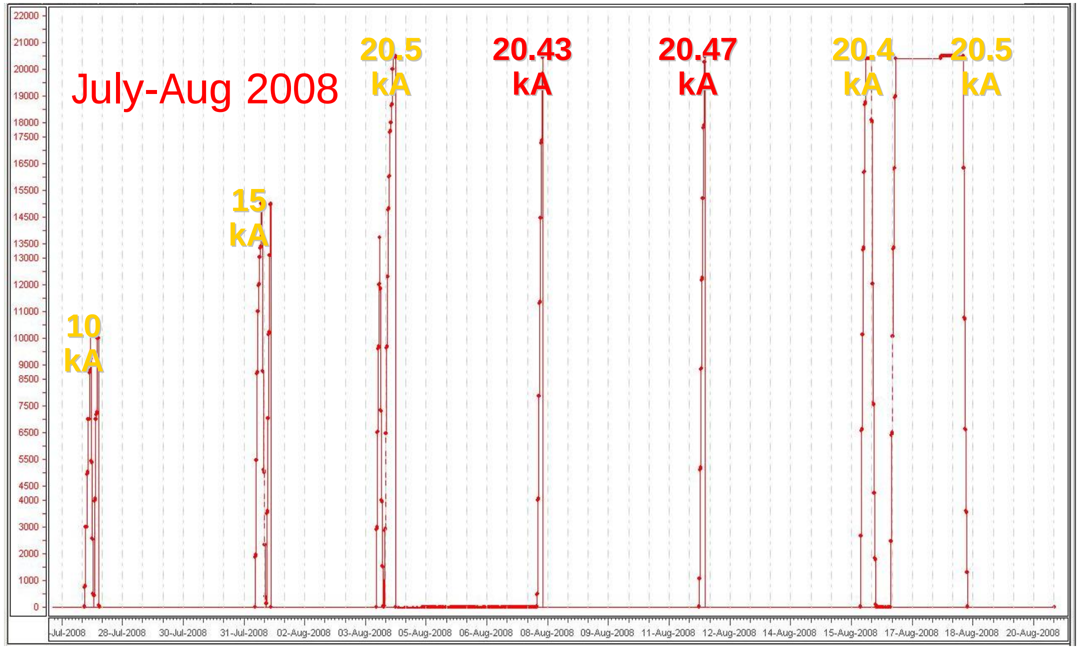
- Geometer survey: positioning accuracy of the 1100 MDT chambers: ~5mm
- Barrel alignment fit in sector 5: precision of 200-300μm (absolute mode, without straight tracks)
  - best that could be achieved is 100-200μm
- Monte Carlo of optical alignment only where e.g. sector 5 alignment error is propagated to muon sagitta
  - 50μm in the odd sectors
  - 400μm in the even ones
  - Track alignment with curved tracks needed to connect the even sectors to the odd ones



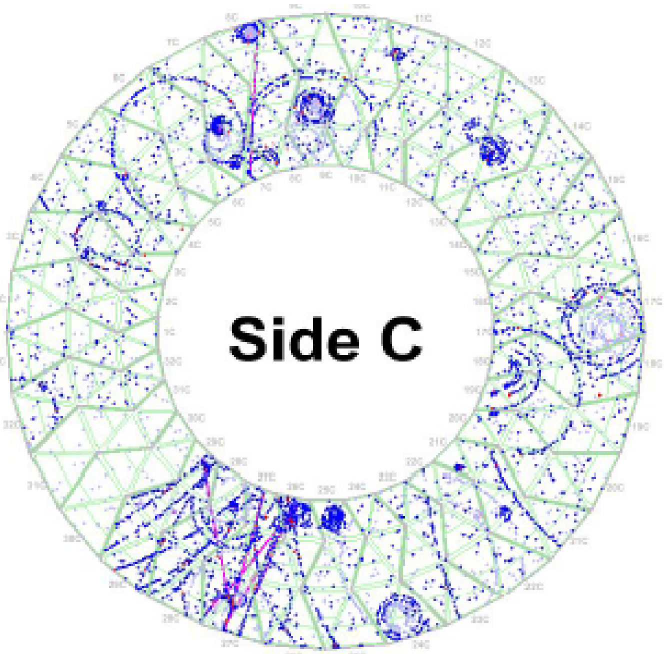
Magnet runs

- Barrel and endcap toroid magnets (4T, 20.5kA) have been run at full current, in combination with the solenoid magnet (2T, 7.7kA)
- Impact of barrel toroid field on endcap calorimeter low voltage power supplies solved with extra shielding





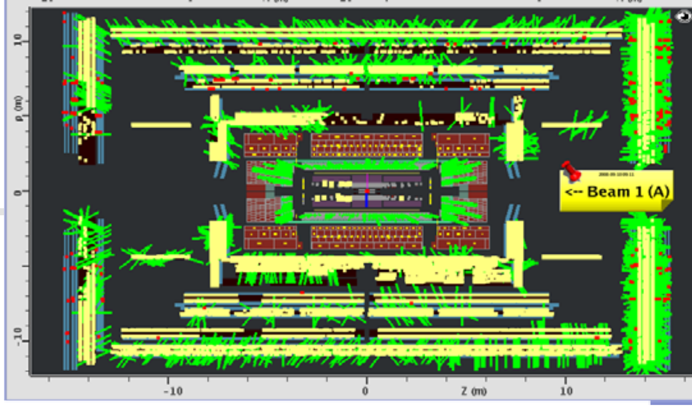
3 weeks

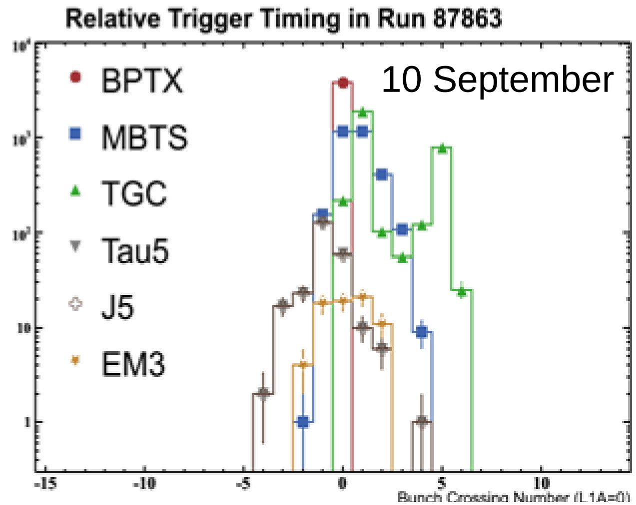


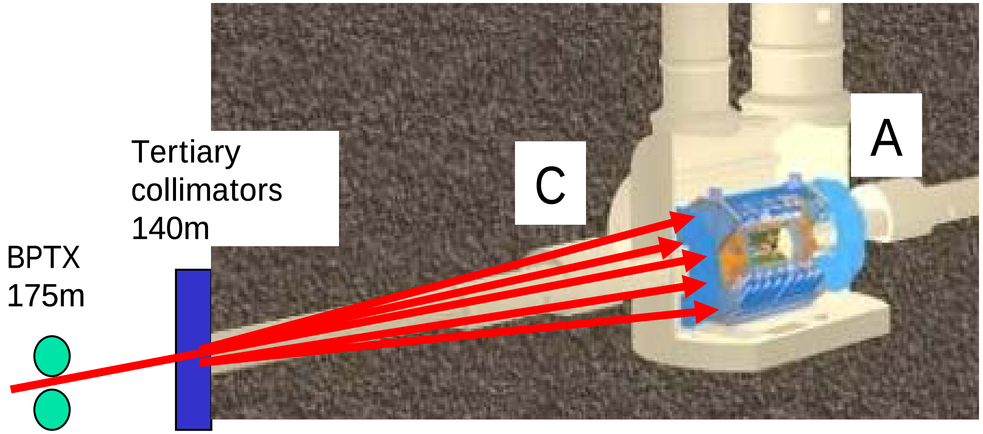
First TRT cosmic events with solenoid "on"

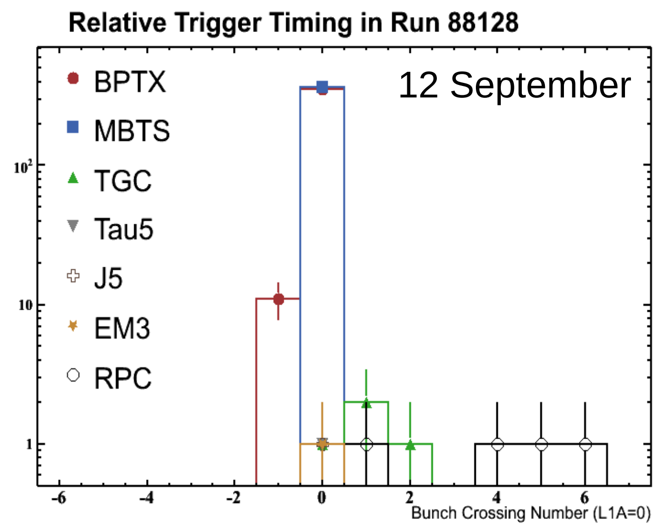
First beams in LHC!

- Sept 10, 2008! First LHC beams went sector by sector: stop beams on collimators, realigning beam and move to next sector
- Beam splash events depositing TeV's of energy in the detector
- Beam pick-ups (BPTX) at 175m used as reference for timing-in of experiment
  - Timing evolved quickly!



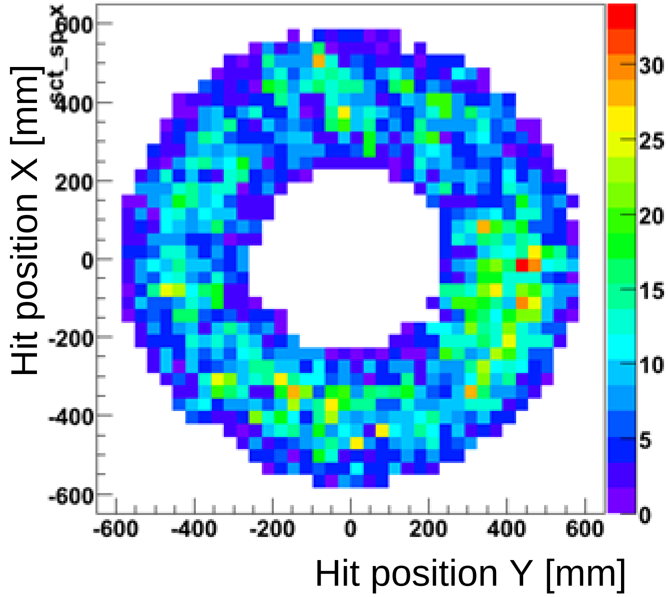


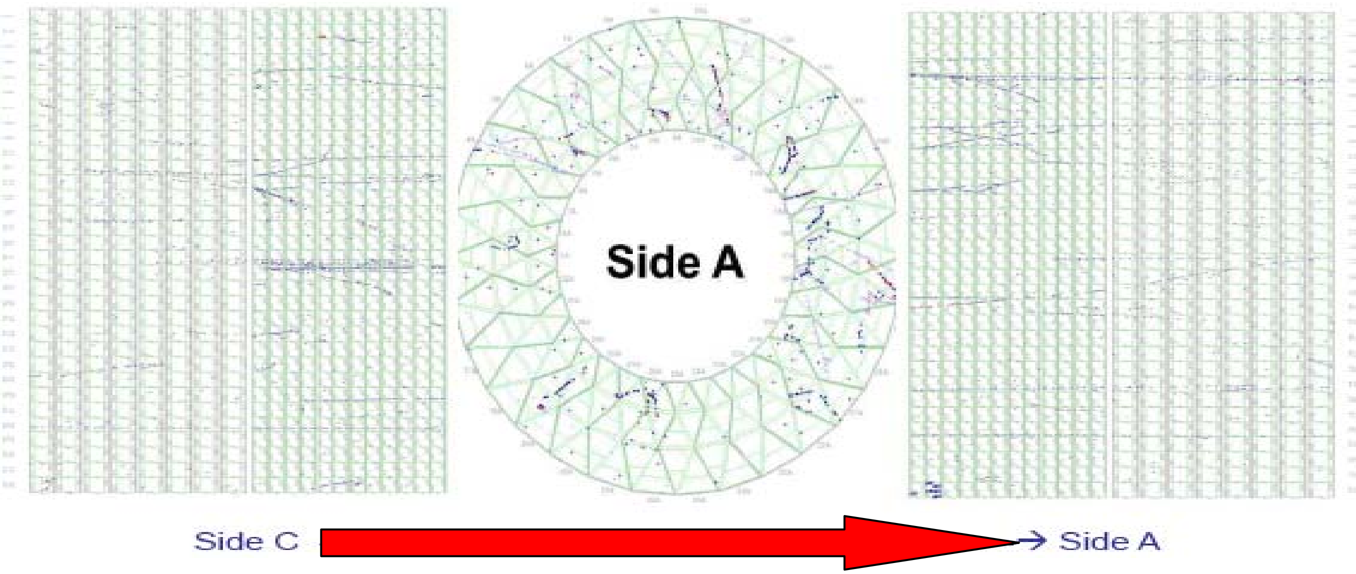




First LHC beam: inner detector

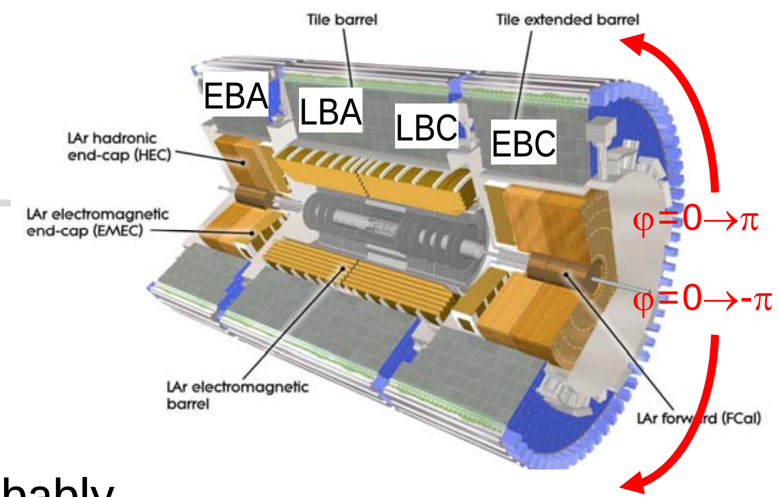
- Distribution of SCT space-points
  - SCT endcaps at 20V during first beam
- Beam halo event in TRT
  - Magnet off
  - Beam from left to right
  - Hits in barrel and endcap!

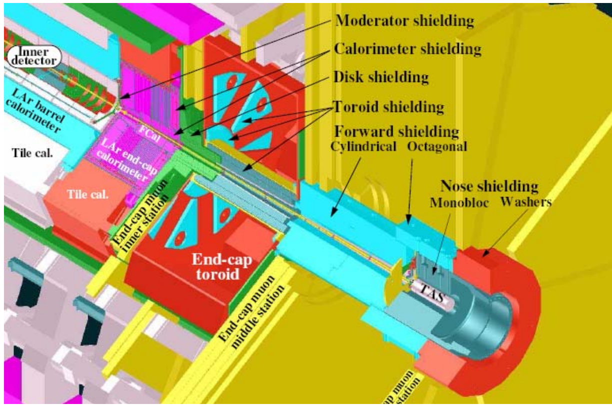


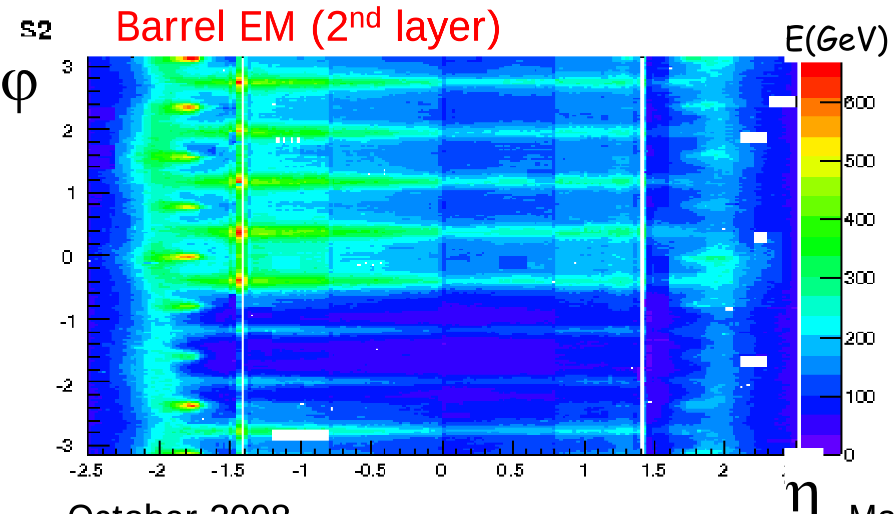


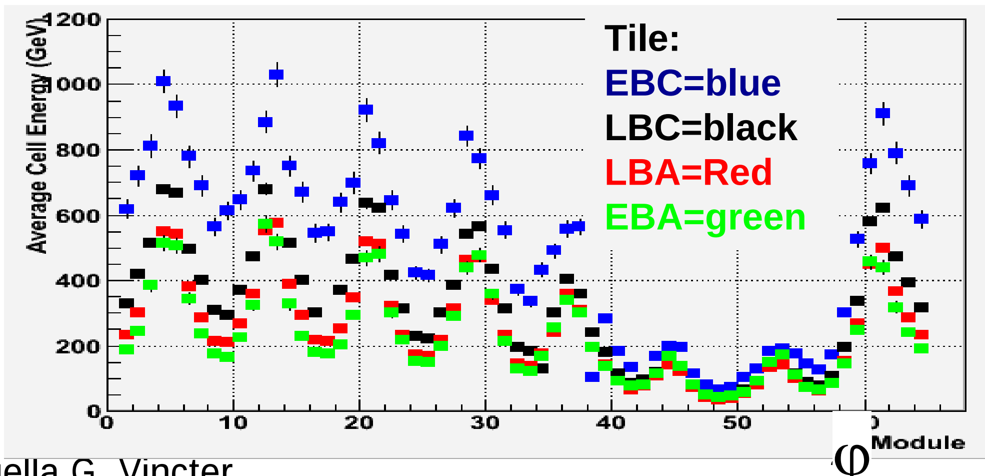
Through the calorimeters…

- Beam 2 (C-side) in the calorimeters
- Flow of π,μ running through the experiment
- Can observe
  - Lower energy deposit at ϕ~-π/4 to -3π/4 (probably protected by supports of upstream infrastructure?)
  - 8/16-fold structure due to the endcap toroids and forward shielding
  - Pions attenuated as they go through experiment?
    - Attenuation of C-side vs A-side?









ATLAS commissioning and first beam: summary

- Already 3 years of in-situ commissioning!
  - Essentially the entire detector has been fully tested (in some cases, multiple times!) with calibration runs
  - Most subsystems have joined the ATLAS combined cosmics runs, with the pixels joining just over a month ago!
  - Have a good overview of the status of the subsystems for early running
    - Some intervention required during 2008-9 winter shutdown, which will give us back most of the ailing channels (e.g. some of those due to cooling leaks, LVPS, frontend readout problems)
    - Inaccessible problems at a very low level
  - Establish the initial calibration constants for early running
    - Have already some preliminary alignments, energy scale calibrations, timing from cosmics (but nothing beats real collision data!)
  - ATLAS saw first beams!
    - Did wonders for timing-in the detector
    - Can see detector geometry through energy deposit and attenuation
- Near future activities centre on further commissioning the detector with cosmics and winter shut-down activities in preparation for first collisions next spring!