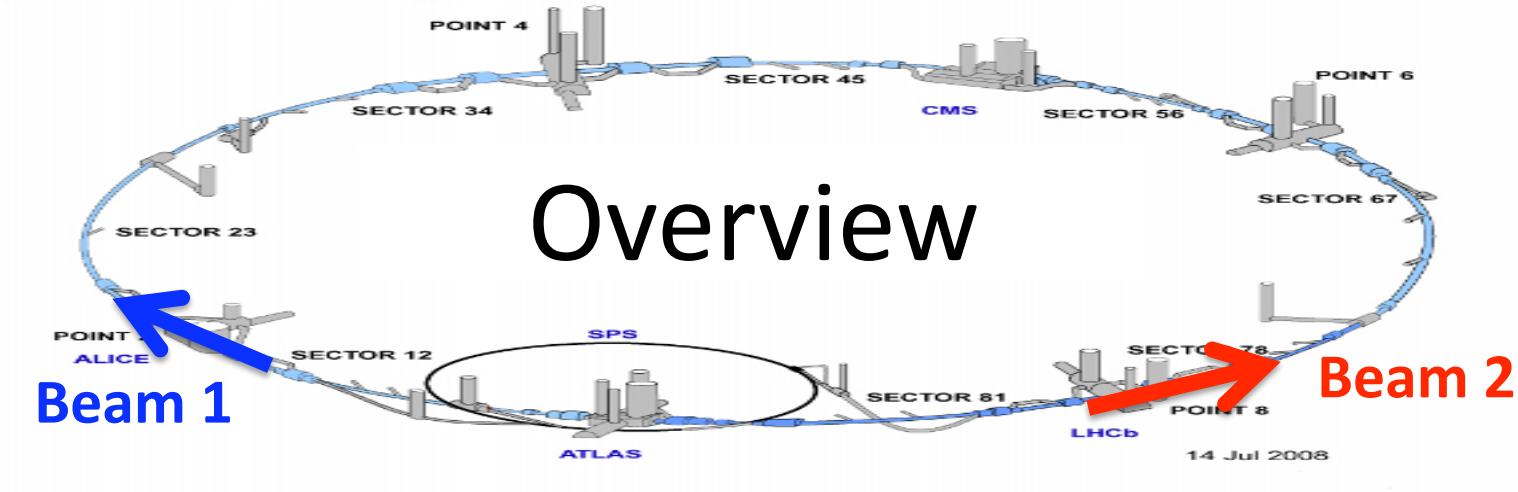
Readiness of the ATLAS Experiment for First Data

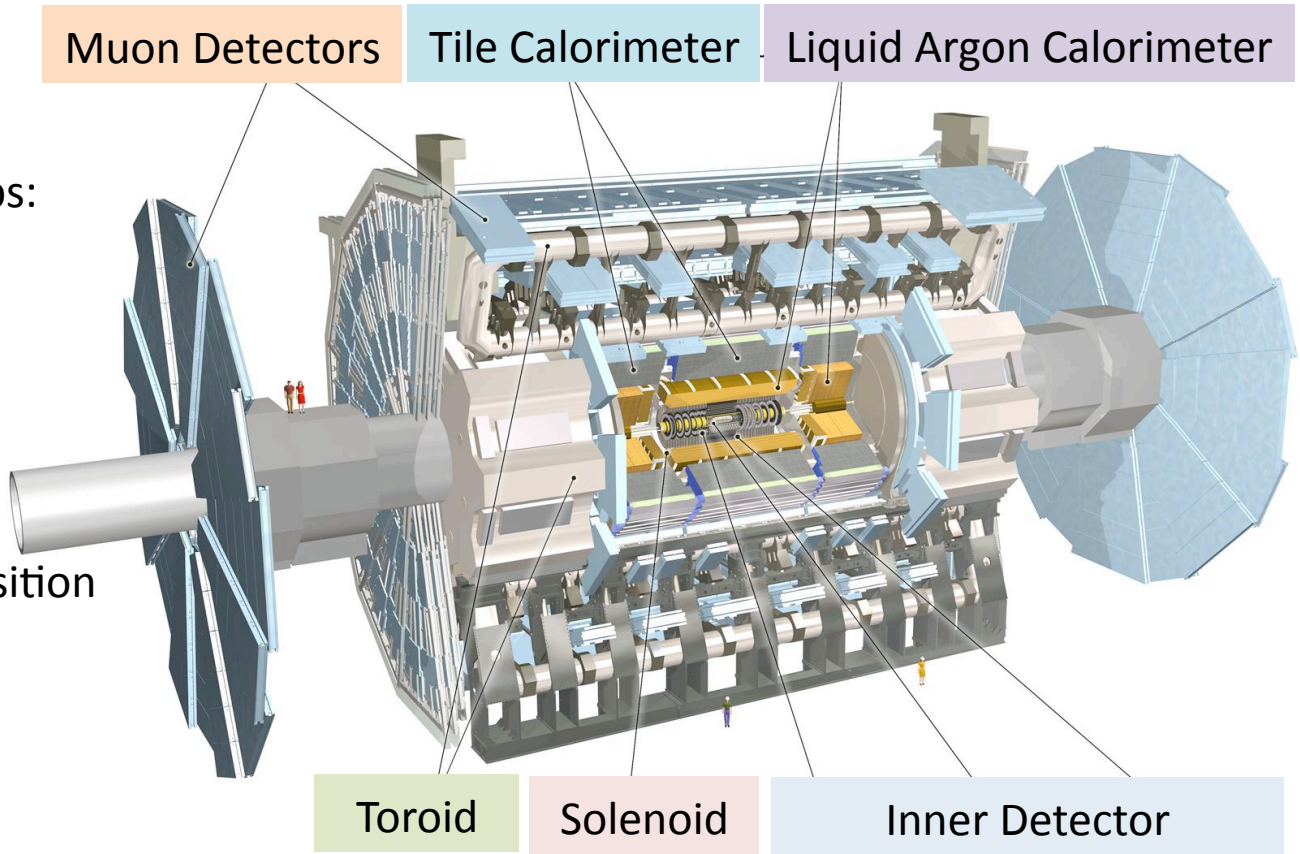
Thilo Pauly (CERN)
on behalf of the ATLAS Collaboration

Rencontres de Moriond EW 2009
7-14 March 2009, La Thuile, Italy

Overview



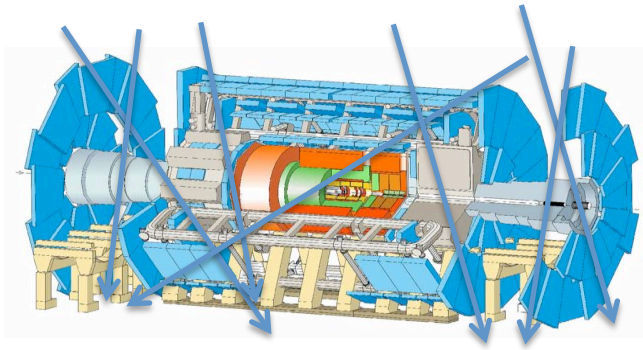
- Commissioning setups:
  - Cosmics
  - Single beams
- Magnet system
- Inner detector
- Calorimeters
- Muon Spectrometer
- Trigger & Data Acquisition
- Conclusions



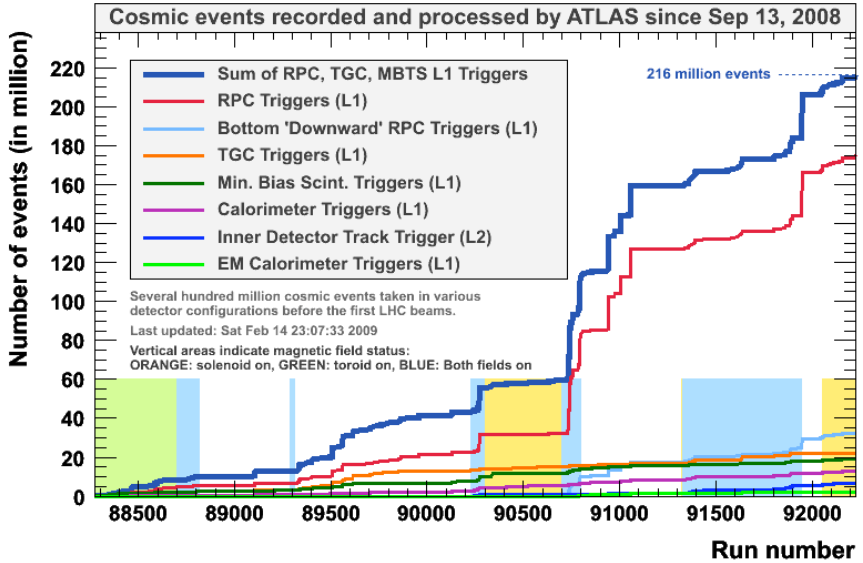
Commissioning with cosmics

Commissioning started in 2005 in parallel with the detector installation

- Test channel mapping and timing
- Determine dead and noisy channels
- Verify stability of hardware components during operation
- Gain experience in detector operation and control, data acquisition and analysis chain
- Understand and improve detector performance
  - Detector alignment
  - First calibrations

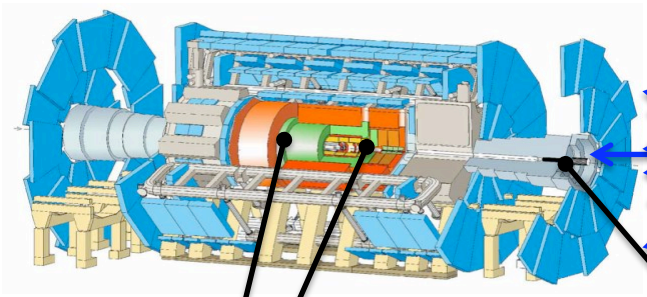


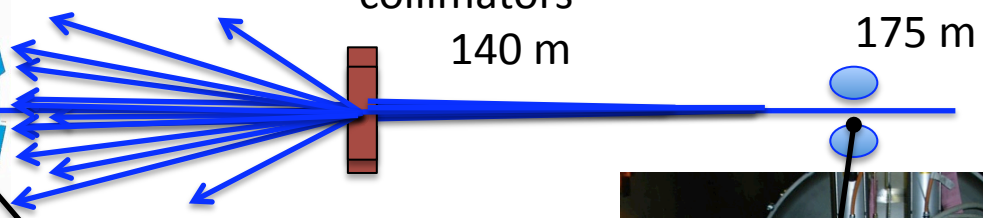
- Most of cosmics data taken in the autumn 2008

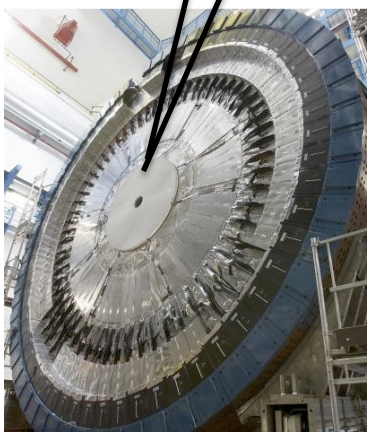


Commissioning with beam

Sept 2008

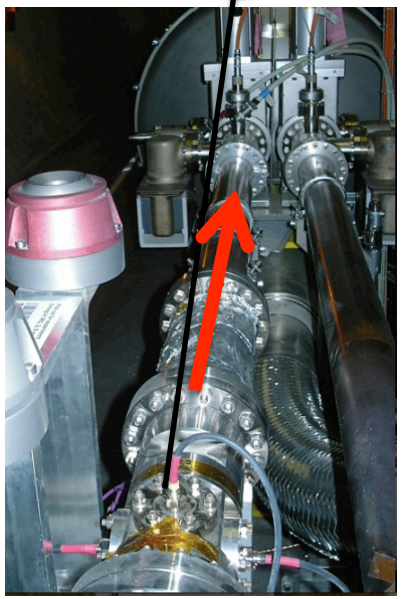






Minimum Bias Trigger Scintillator (MBTS)

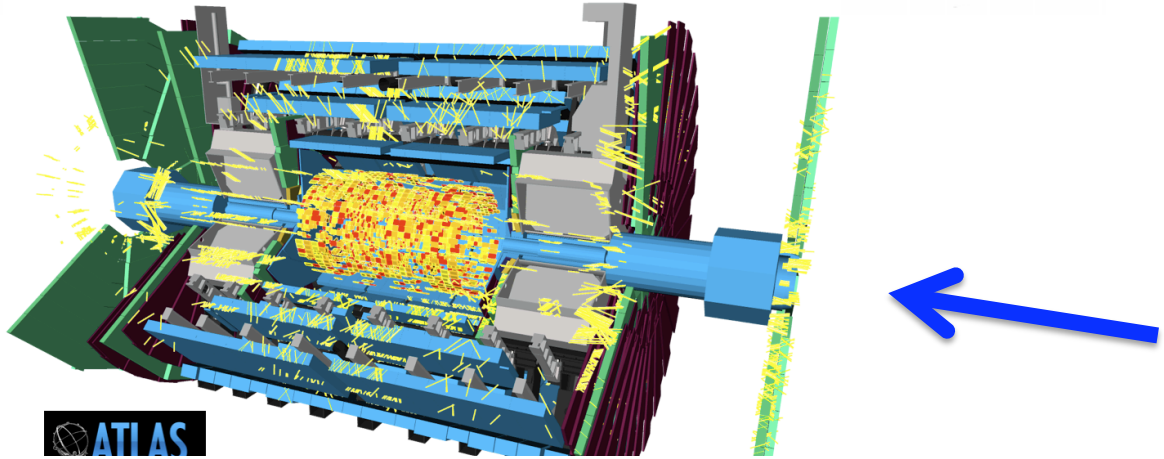
LUCID: Cherenkov tubes for luminosity measurement



Beam Timing Pick-ups (BPTX)

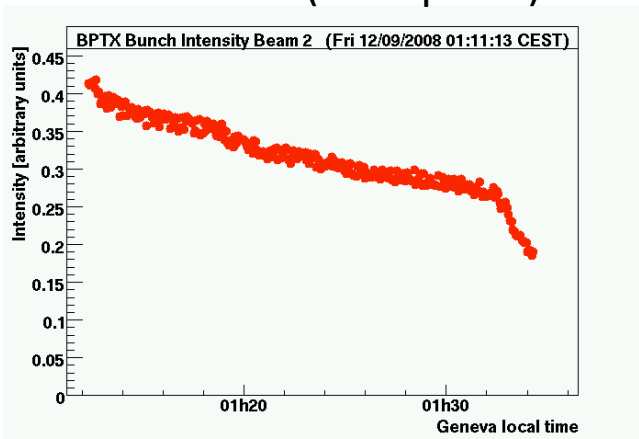
Commissioning with beam

Splash
(collimator closed)



Few turns (collimator open, no RF)

Circulation (RF capture)



Magnet system

Solenoid (1 coil)

- 2 T field (at 7.73 kA)
- Thickness: 0.66 X_0

Barrel Toroid (8 coils)

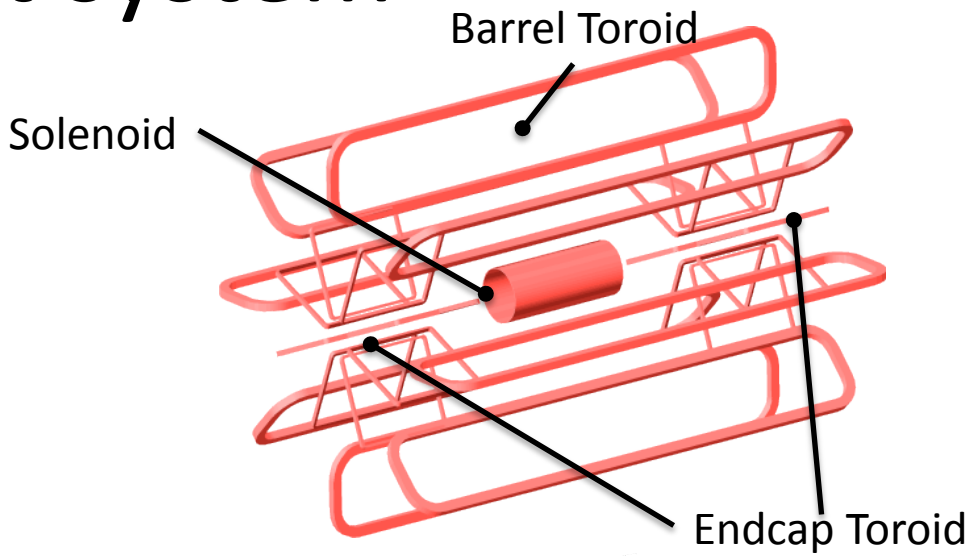
- 0.2-2.5 T field (at 20.5 kA)

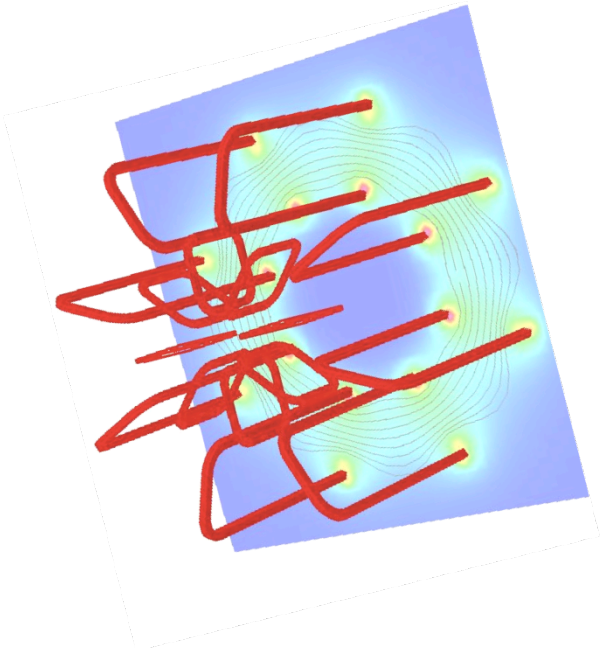
Two end-cap toroids (2 x 8 coils)

- 0.2-3.5 T (at 20.5 kA)

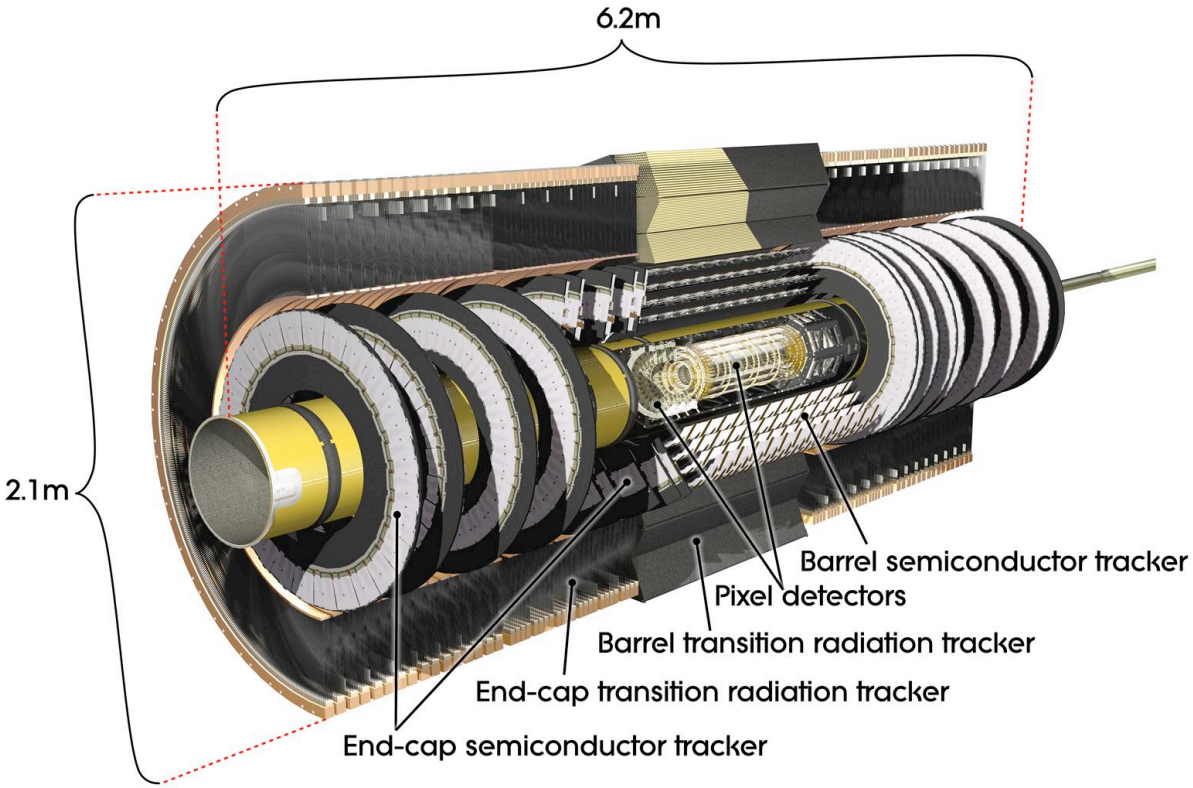
Status

- Stable continuous operation at nominal field
- Stress and heat distributions during fast quench are safe
- Geometrical distortions of barrel toroid with field on as expected

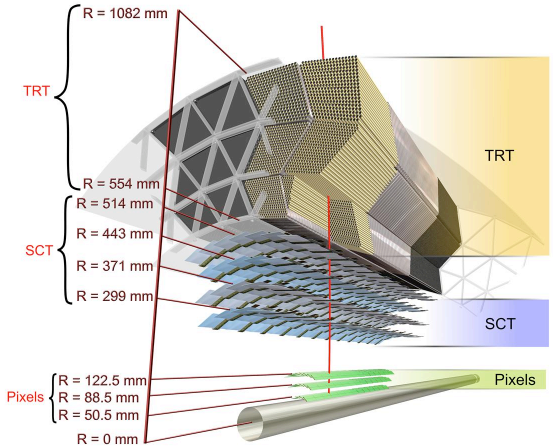




Inner Detector



Inner Detector - Status



Transition Radiation Tracker (TRT)

- combined straw tracker and transition radiation detector
- 4mm diameter straw tubes with 35µm anode wires
  - 73 layers in barrel region with axial straws
  - 2x160 (20 disks each) with radial straws in forward region
- e-π identification: 0.5 GeV < E < 150 GeV
- 98% of channels operational

Pixel Detector

- 3 layers in barrel and end-cap
- Resolution: 10µm x 110µm
- Pixel size 50µm x 400µm
- 80 million channels
- >95% of modules operational
- Noise occupancy: 5×10^{-9}
- Hit efficiency > 98%

Operated inside a 2 Tesla field, coverage

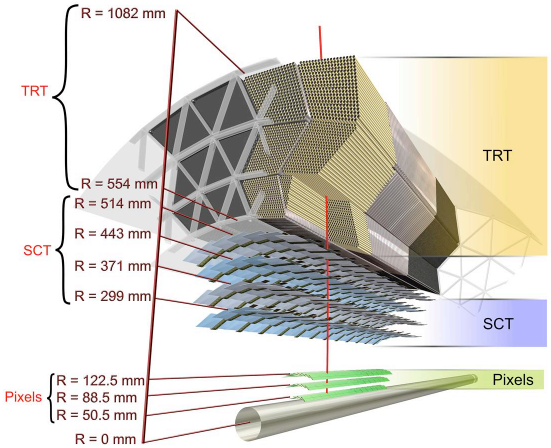
$\eta < 2.5$ (TRT $\eta < 2.0$)

$\sigma/p_T = 0.05\% \, p_T + 1\%$

Semiconductor Tracker (SCT)

- 4 double layers of strips in barrel and 9 in end-caps
- 4088 modules with 80µm strips
- 6 million channels
- Resolution: 17µm x 580µm
- > 99% of barrel and > 97% of end-cap modules operational
- Noise occupancy: 4.4×10^{-5} (barrel), 5×10^{-5} (end-cap)
- Hit efficiency > 99%

Inner Detector - Status



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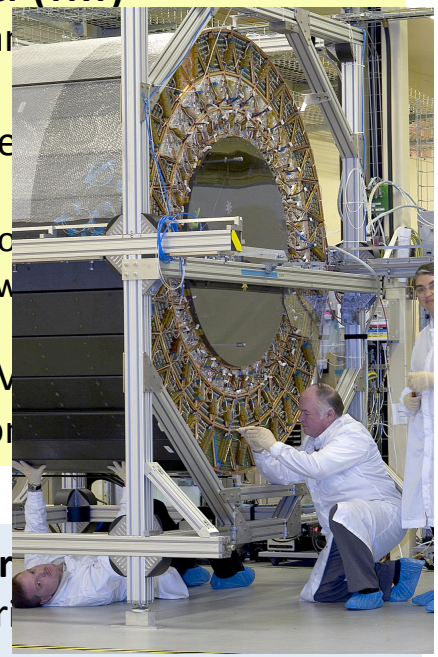
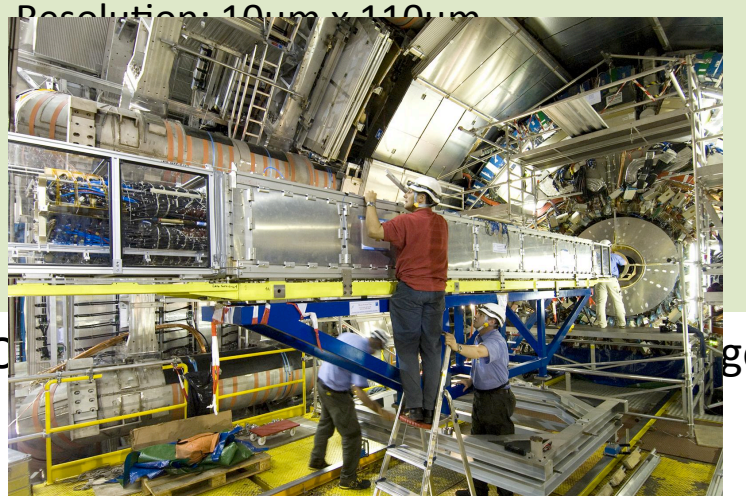


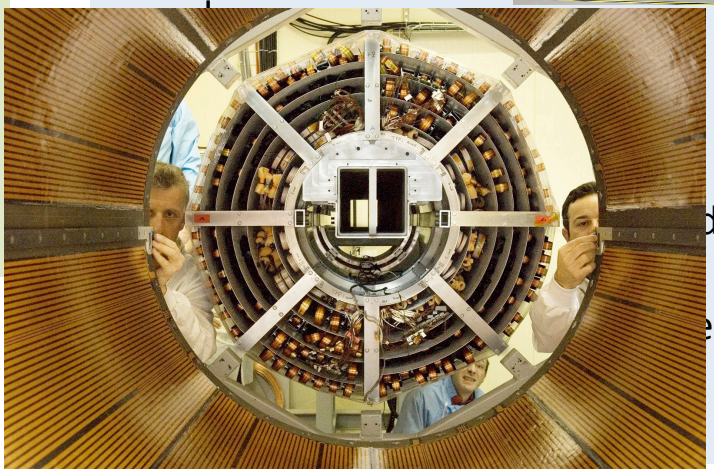
Pixel Detector

- 3 layers in barrel and end-cap
- Resolution: 10μm x 110μm



Semiconductor Tracker

- 4 double layers of str

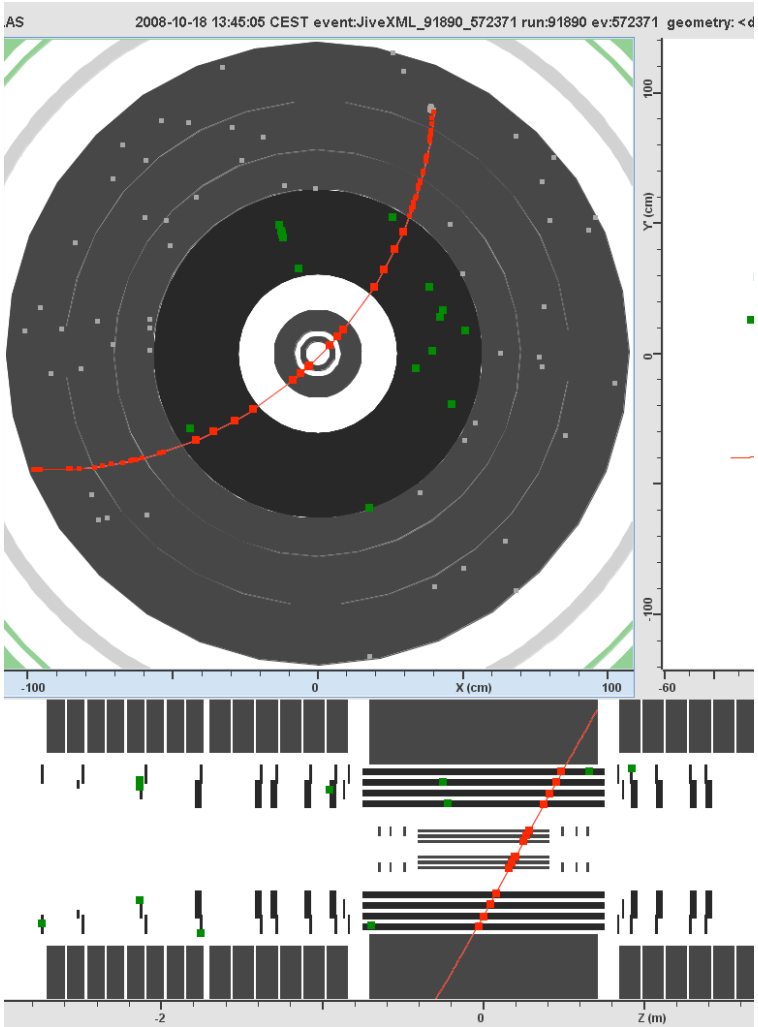


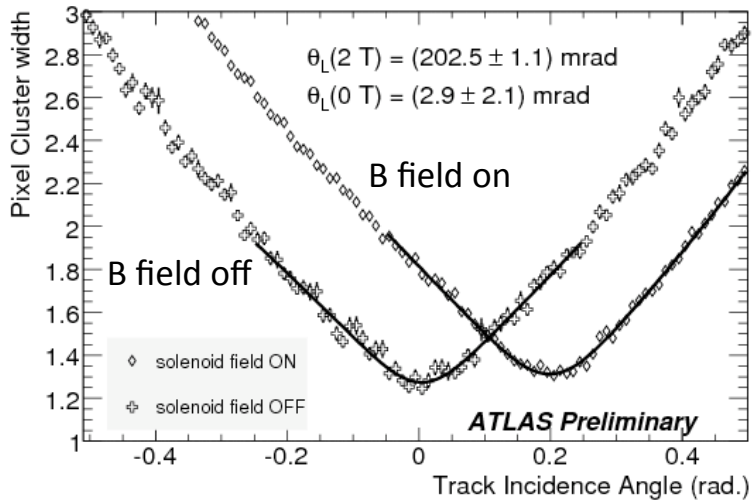
d-cap

C ge

el), $5x10^{-5}$

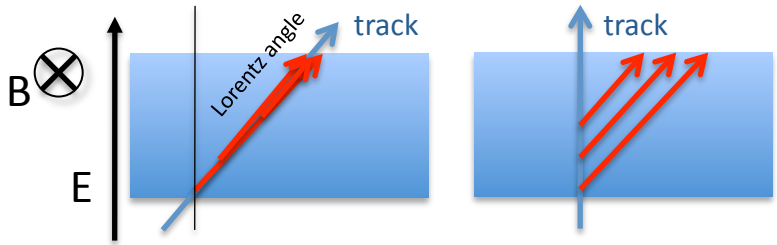
Inner Detector - Results





Measurement of cluster width in Pixels

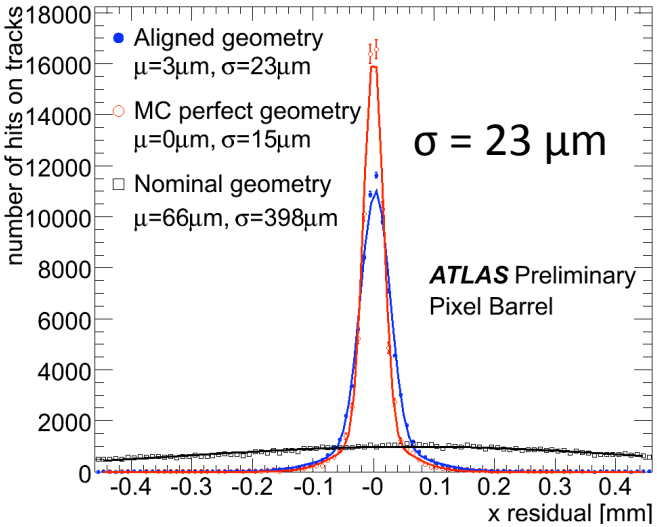
Determination of Lorentz angle, essential for reaching final spatial resolution (MC prediction: 224 mrad)

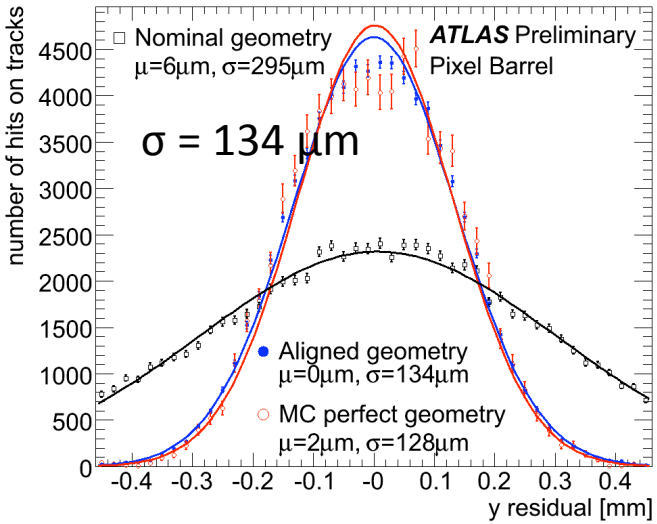


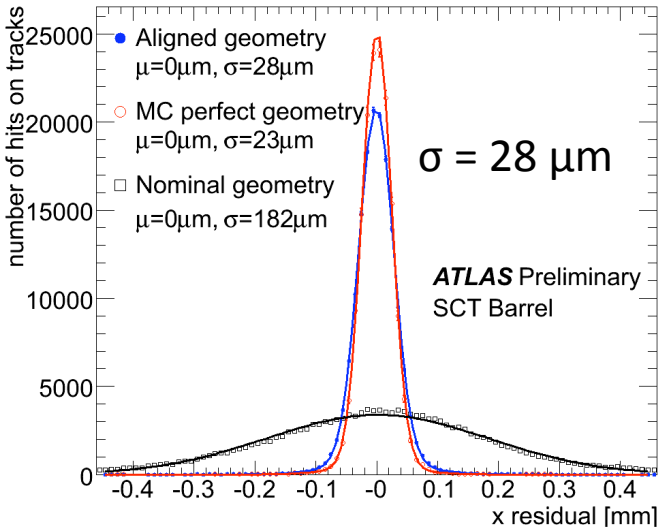
Inner detector - Results

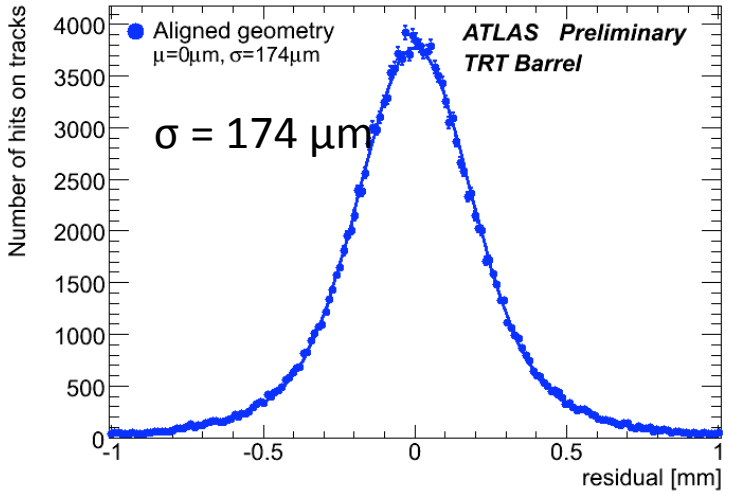
Alignment with tracks

- Track residuals close to perfect geometry for barrel region
- Limited statistics for end-caps



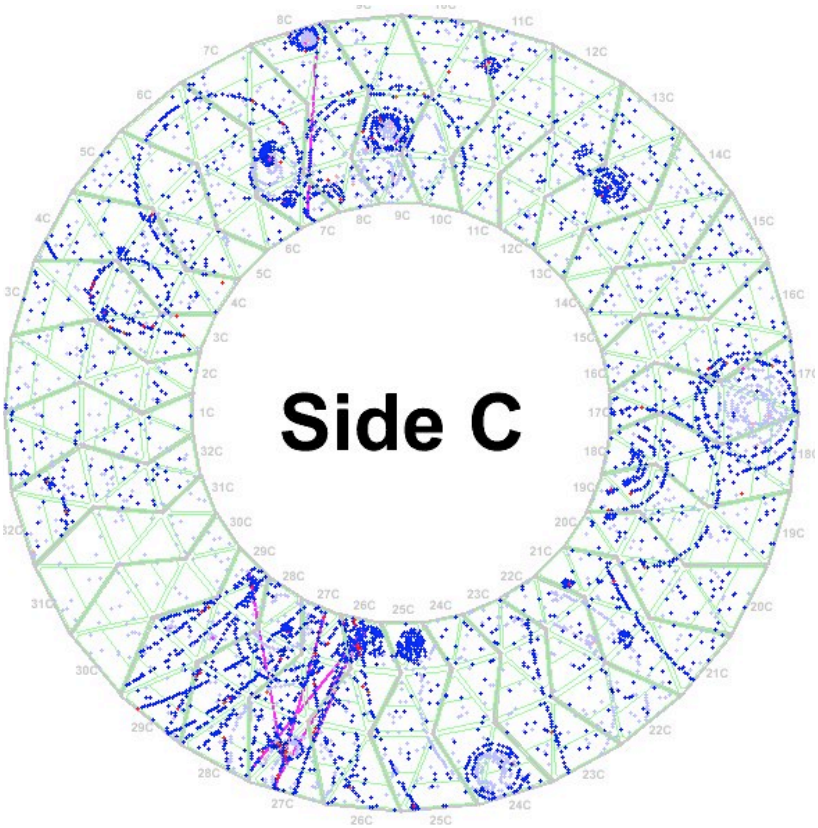




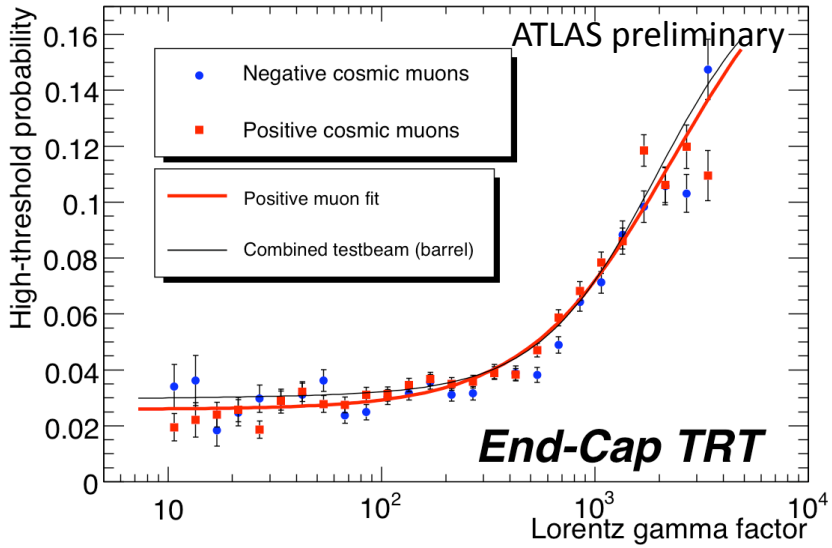


Inner Detector - Results

Cosmics in Transition Radiation Tracker



Transition Radiation Tracker

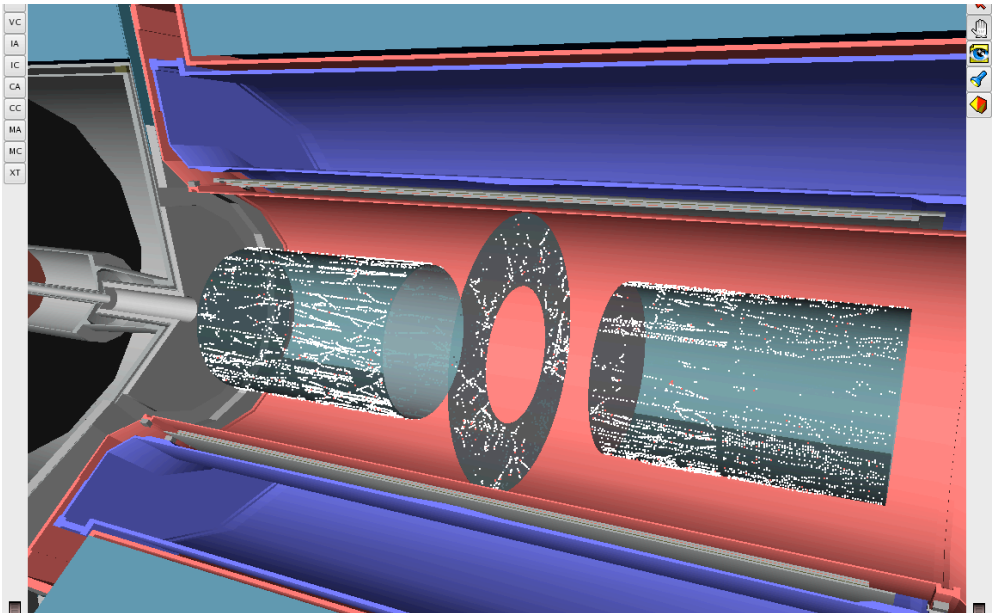


Measurement of the probability of transition radiation

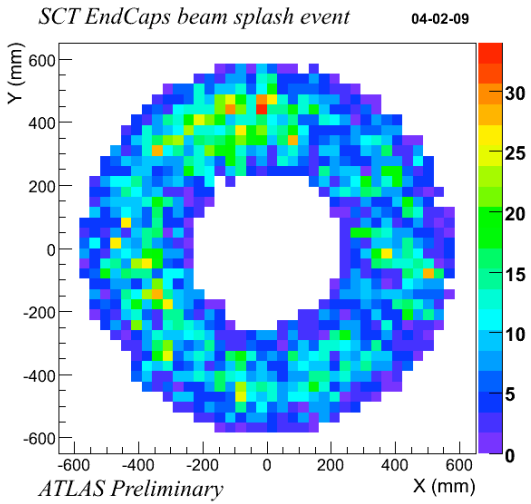
Good agreement with test beam data

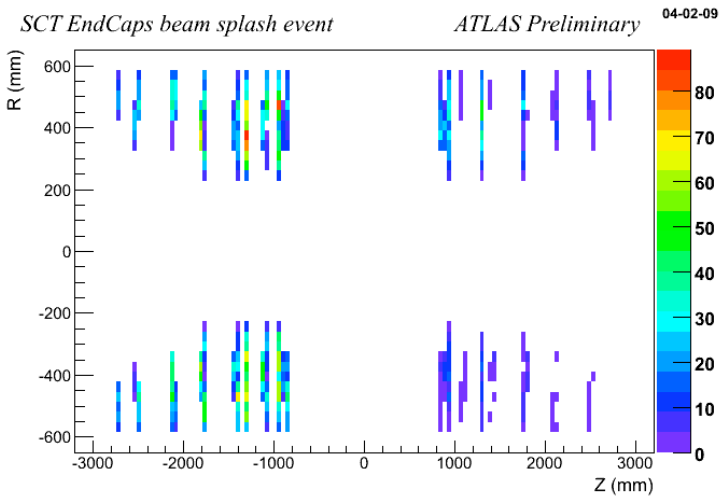
Inner Detector - Results

Transition Radiation Tracker during beam

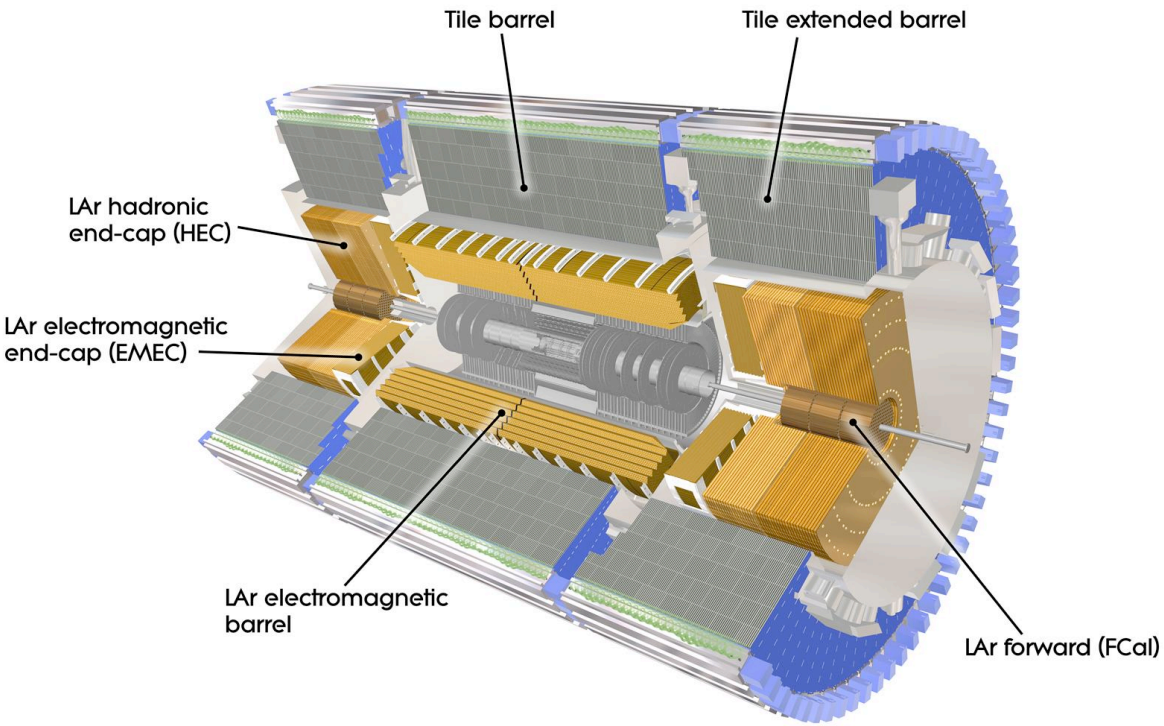


SCT End-cap occupancy during beam 'splash'





Calorimeters

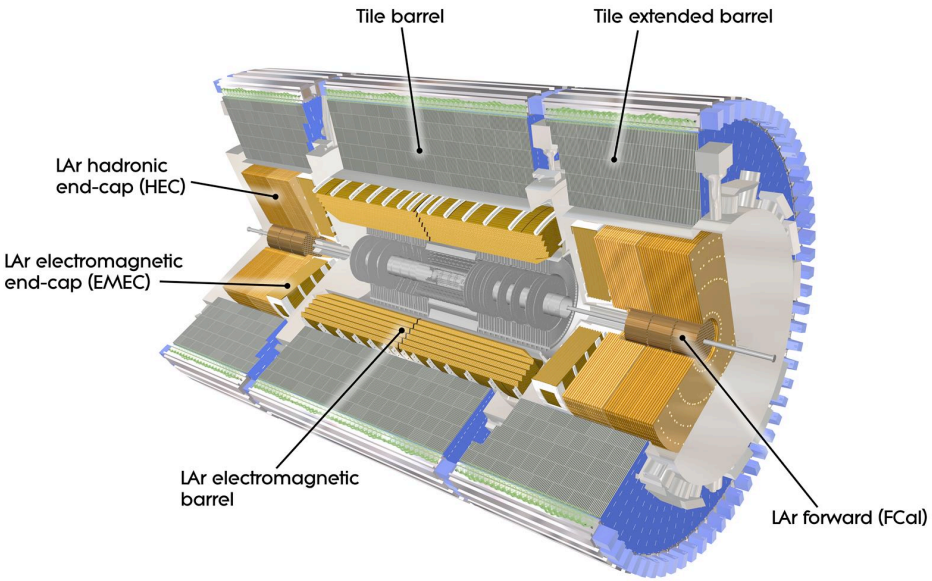


Calorimeters - Status

Liquid Argon Calorimeter

- Electromagnetic (barrel+endcap)
  - Pb-LAr accordion geometry
  - 3 longitudinal samples η < 2.5
  - Pre-shower detector η < 1.8
- Endcap/forward hadronic
  - Cu/W-LAr
  - 4/3 longitudinal samples
- Dead channels: 0.02% (+0.9% recoverable in shutdown)
- Noisy channels: 0.003%, bad calibration: <0.2%
- Electronic calibration procedure operational (calibration constants used online)

Complete azimuthal symmetry, coverage η < 4.9



Tile Calorimeter (barrel hadronic)

- Iron scintillator tiles (3 longitudinal samples)
- Dead channels: < 1.4% to be repaired during shutdown
- Calibration system operational (Cs source, Laser, charge injection)

Electromagnetic energy resolution:

$$\sigma(E)/E = 10\%/\sqrt{E} \oplus 0.7\%$$

Hadronic energy resolution:

$$\sigma(E)/E = 50\%/\sqrt{E} \oplus 3\% \quad (\eta < 3.2)$$

$$\sigma(E)/E = 100\%/\sqrt{E} \oplus 10\% \quad (\eta > 3.1)$$

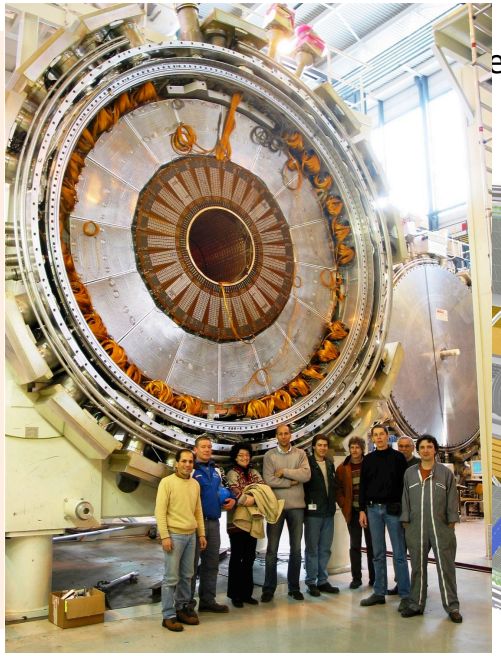
Level-1 calorimeter trigger (e/γ, jets, τ, missing E_T, energy sums)

- Dead channels: < 0.4% (+0.3% recoverable in shutdown) of 7200 analogue channels
- Channel-to-channel noise suppression allows E_T=1 GeV cut (aim: 0.5 GeV)

Calorimeters - Status

Liquid Argon Calorimeter

- Electromagnetic (barrel+endcap)
-
-
-
-



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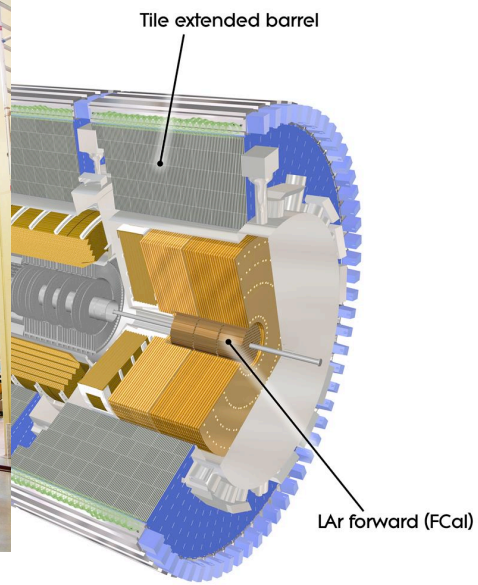
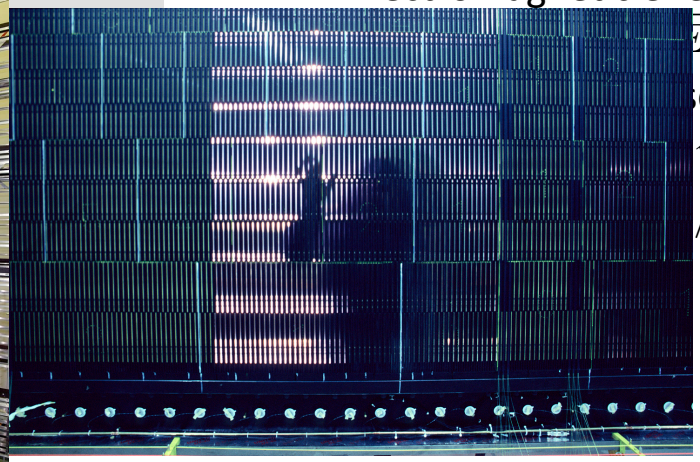


Tile Calorimeter (barrel hadronic)



Electromagnetic energy resolution:

$\oplus 0.7\%$

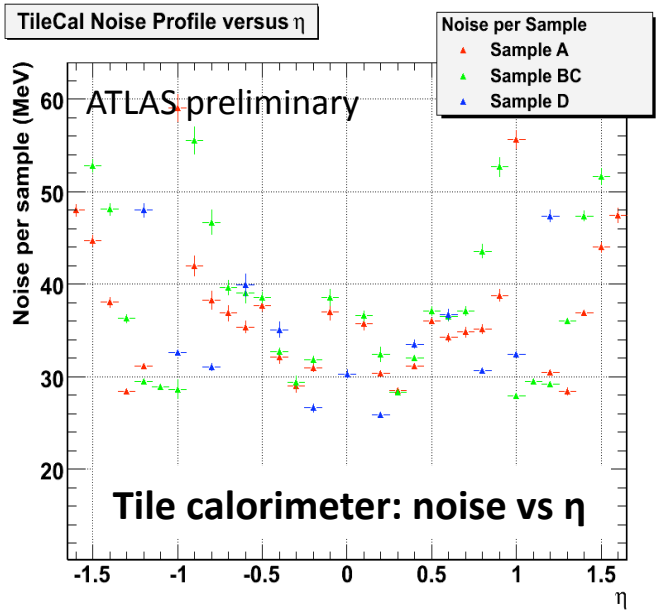
olution:

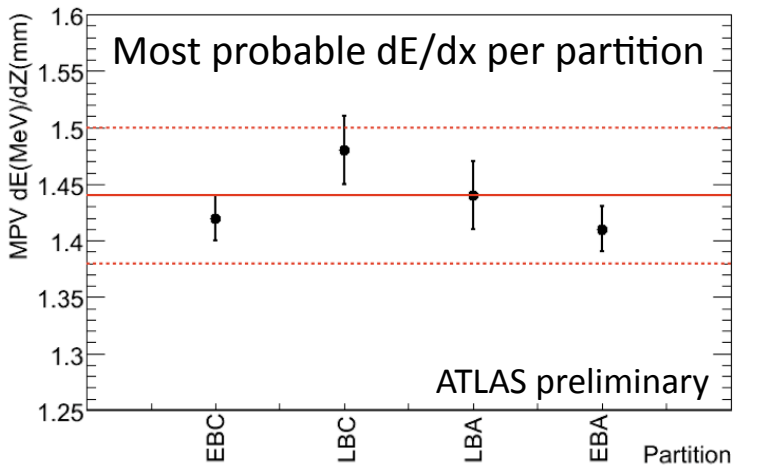
$\sqrt{E} \oplus 3\% \quad (\eta < 3.2)$

$/\sqrt{E} \oplus 10\% \quad (\eta > 3.1)$

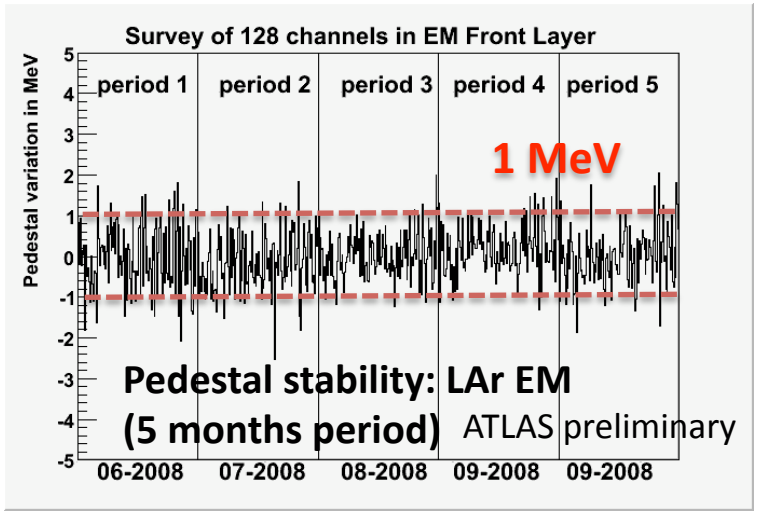
Calorimeters - Results

Tile calorimeter

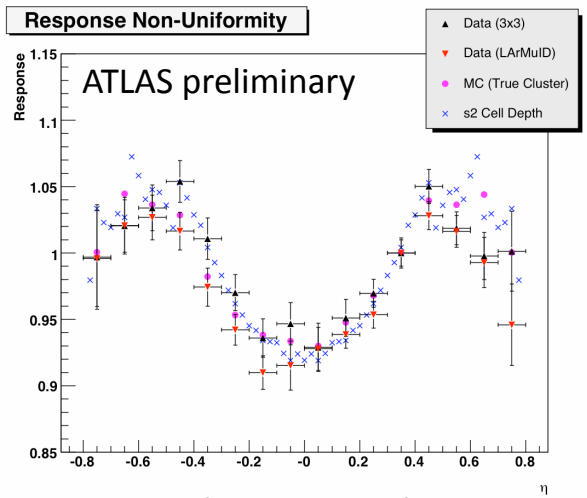




Liquid Argon calorimeter

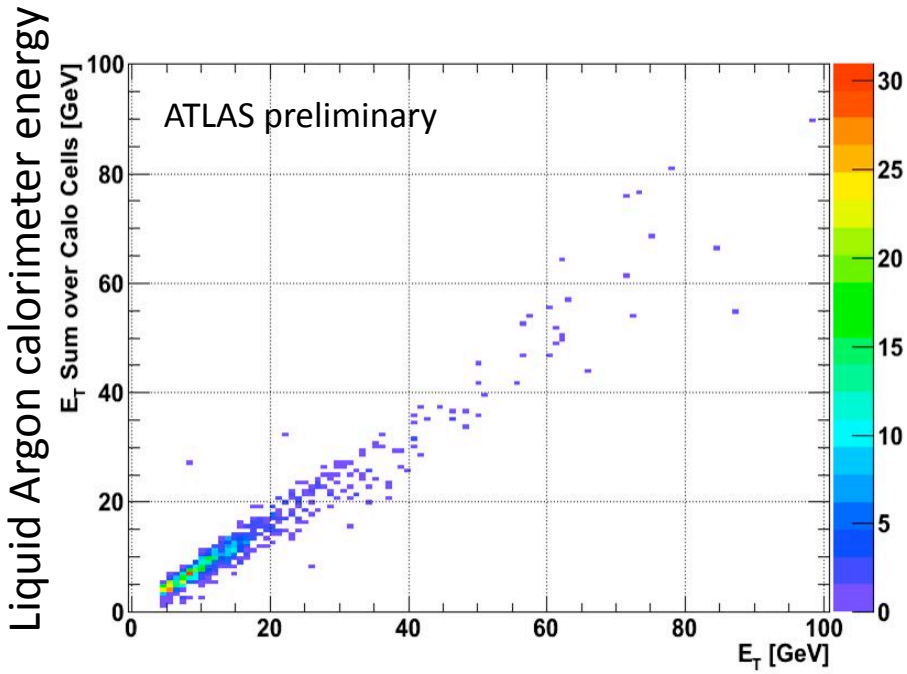


Uniformity

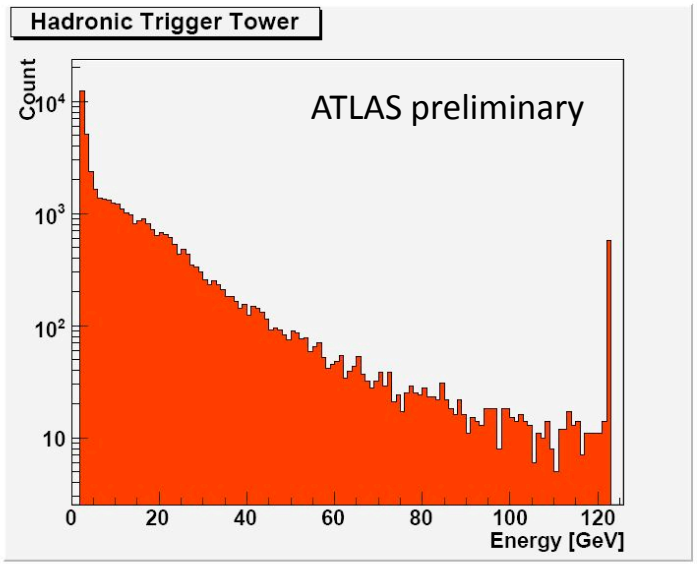


Calorimeters - Results

Level-1 Calorimeter Trigger



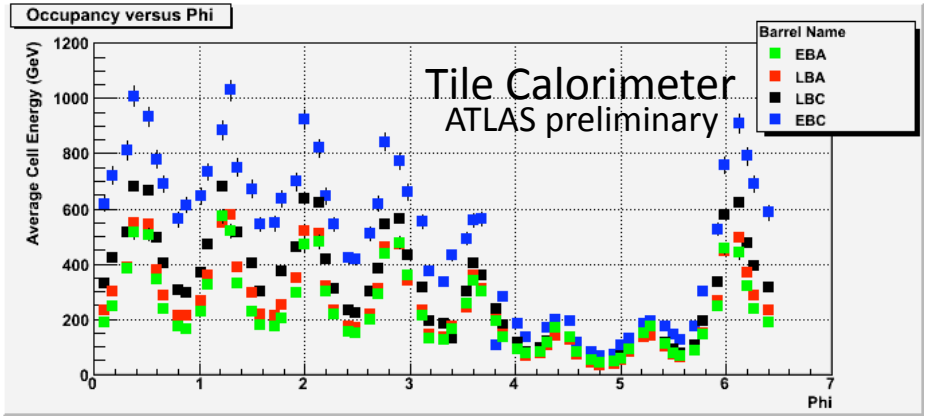
Level-1 calorimeter trigger energy



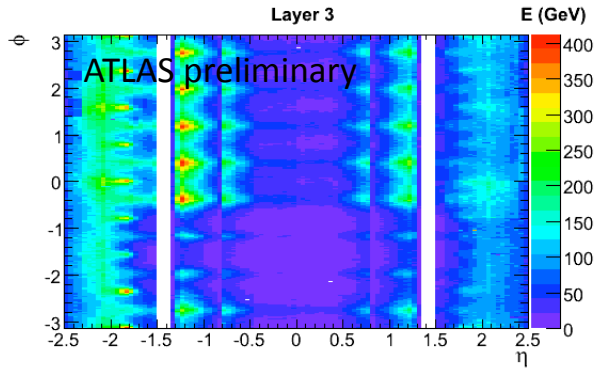
Cosmics: hadronic energy spectrum

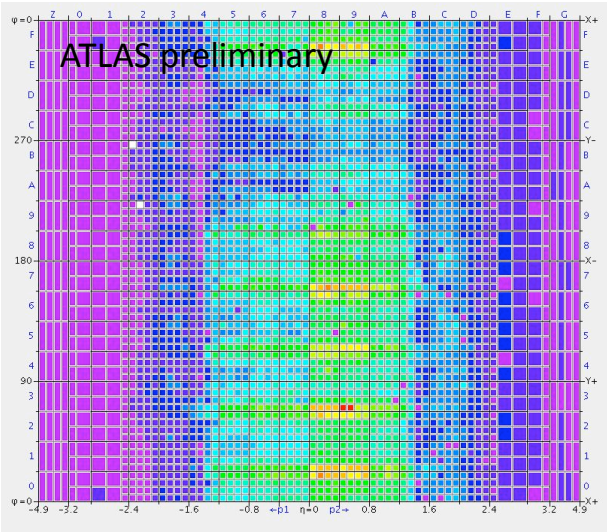
Calorimeters - Results

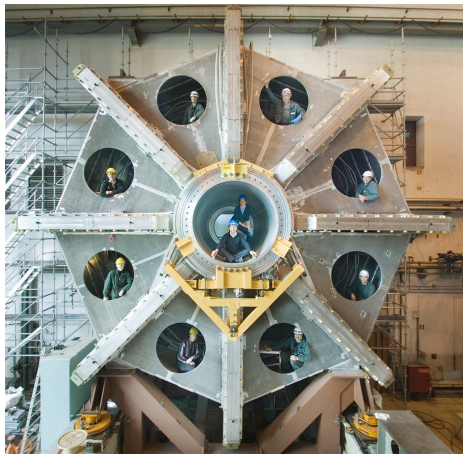
Beam splashes: toroid magnet structure visable in the calorimeter energy spectra

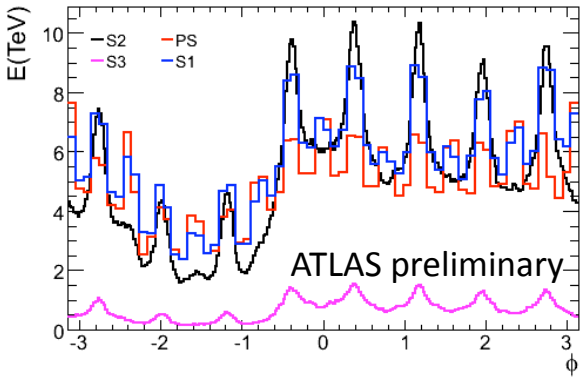


Liquid argon calorimeter



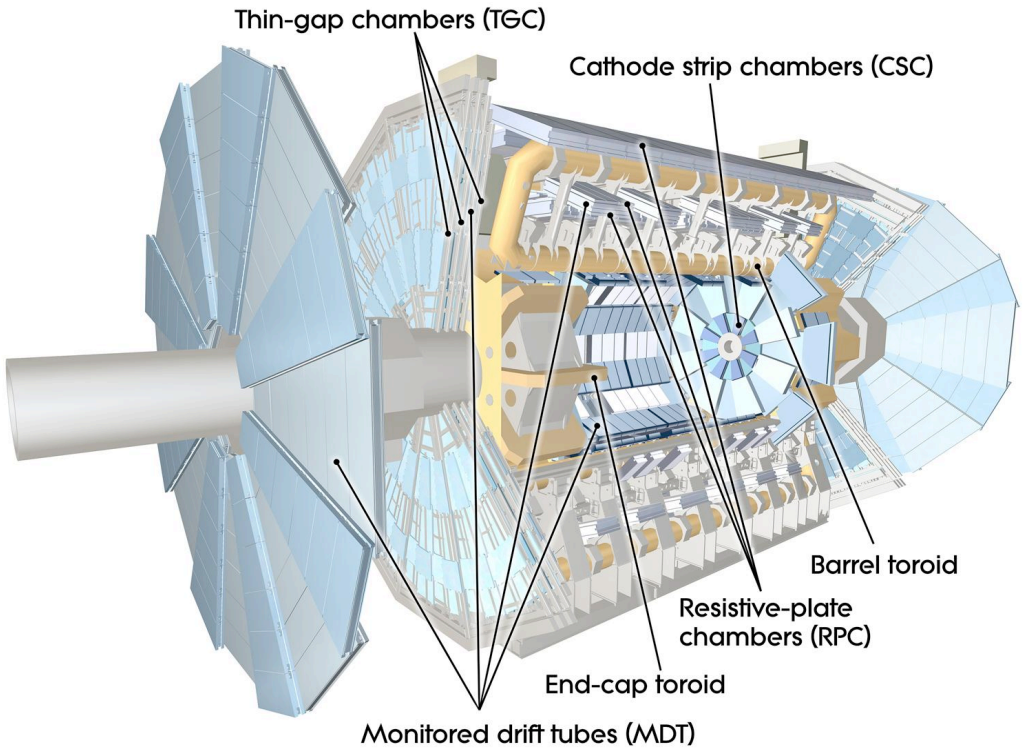




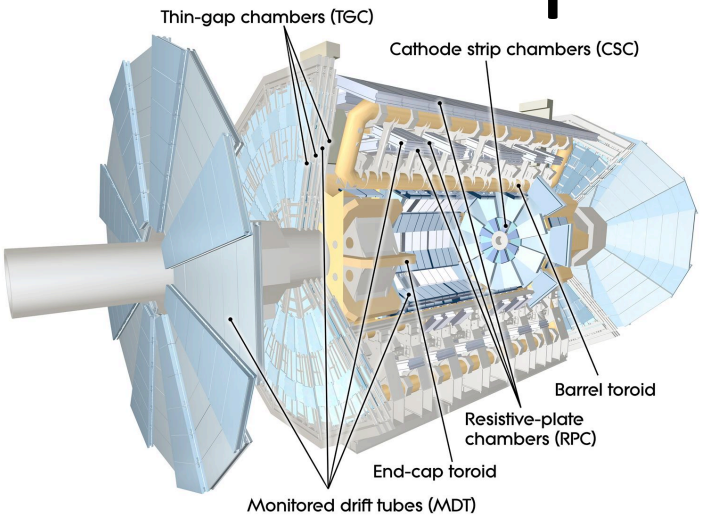


Level-1 Calorimeter trigger

Muon Spectrometer



Muon Spectrometer - Status



Coverage: $\eta < 2.5$ (trigger $\eta < 2.4$)

Air-core toroid magnet system
1.5-5.5 Tm ($\eta < 1.4$)
1-7.5 Tm ($\eta > 1.6$)

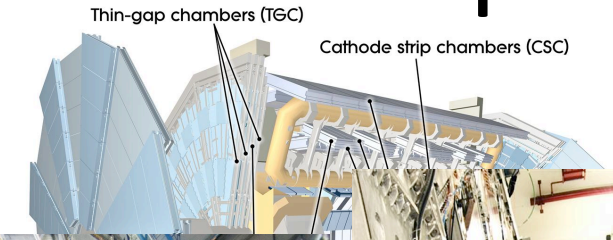
Stand-alone momentum resolution:
$\Delta p_T/p_T < 10\%$ up to 1 TeV

- **Barrel trigger: Resistive-Plate Chambers (RPC)**
  - 544 chambers with 359k channels
  - 70% of chambers operational (goal 2009: 95.5%)
  - Dead strips < 2%
  - Hot strips/spots < 1%
- **End-cap trigger: Thin-Gap Chambers (TGC)**
  - 3588 chambers with 318k channels
  - 99.8% of chambers operational
  - Dead channels < 0.01%
  - Noisy channels <0.02% with >5% occupancy
- 2-dimensional readout
- Time resolution < 10 ns
- Spatial resolution: 5-10 mm

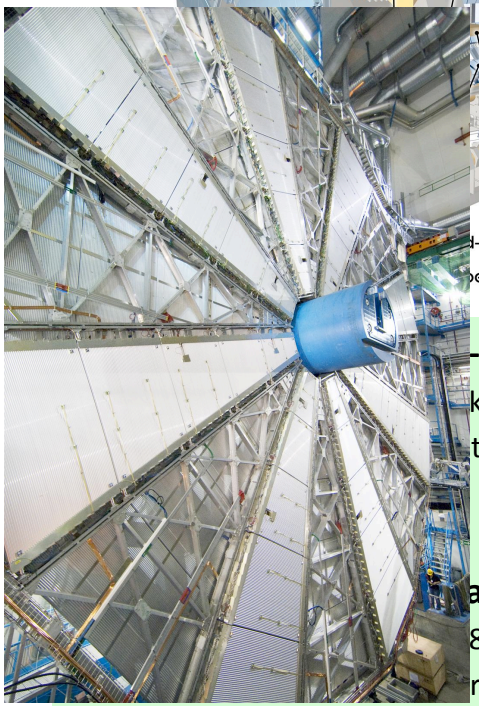
Precision chambers:

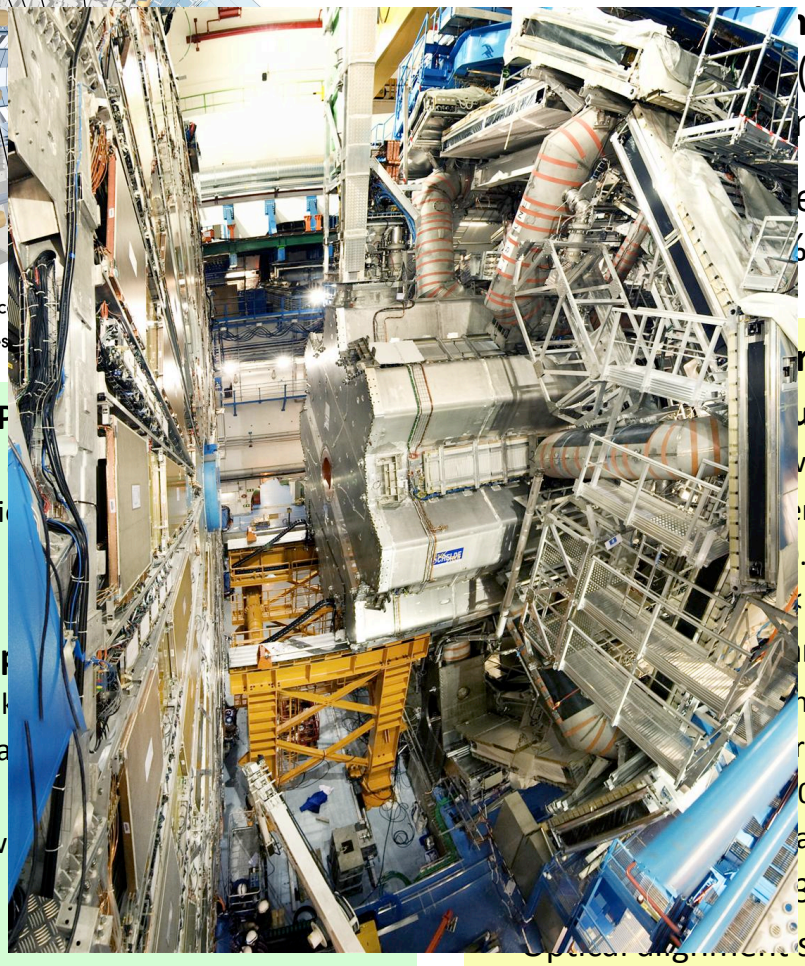
- **Monitored Drift Tubes (MDT)**
  - 1088 chambers with 339k channels
  - 99.8% of chambers operational
  - Dead channels: 0.1 % (+ 1% recoverable)
  - Noisy channels: < 0.2 % with 5% occupancy
- **Cathode-Strip Chambers (CSC)**
  - 32 chambers with 31k channels
  - 100% of chambers operational
  - Dead channels < 0.1 %
  - 2-dimensional readout
- Spatial resolution 35-40µm
- Optical alignment system: 12232 sensors
  - 99.7% (barrel), 99% (end-cap) operational

Muon Spectrometer - Status



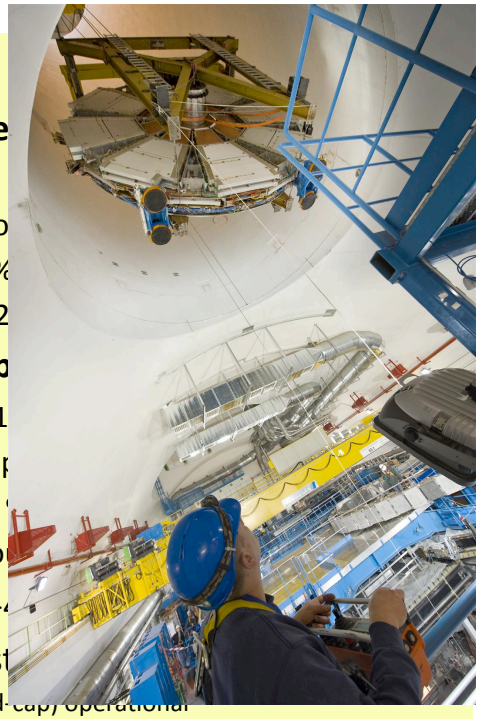
Coverage: η < 2.5 (trigger η < 2.4)





agnet system
(η < 1.4)
η > 1.6)

entum resolution:
% up to 1 TeV



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– 99.7% (barrel), 99% (end-cap) operational

– Dead channels < 0.01%
– Noisy channels <0.02% w

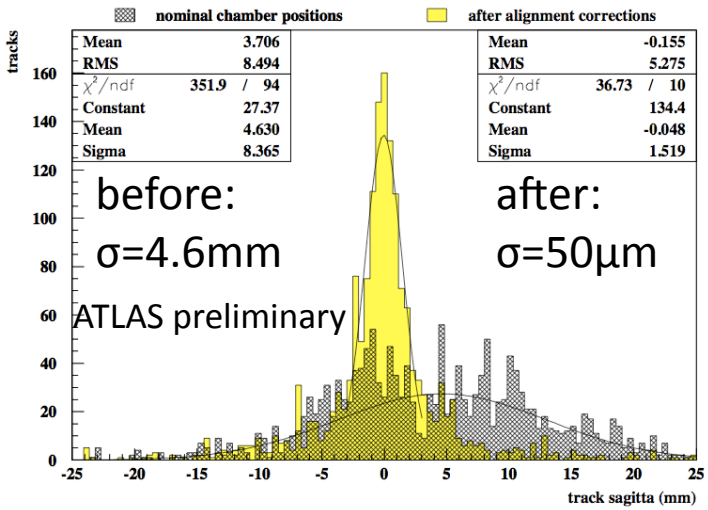
- 2-dimensional readout
- Time resolution < 10 ns
- Spatial resolution: 5-10 mm

Muon Spectrometer - Results

Monitored Drift Tube Alignment

Current precision:

- Endcap: 50-100 µm
- Barrel: 100-200 µm
  (up to 1000 µm in small sectors)

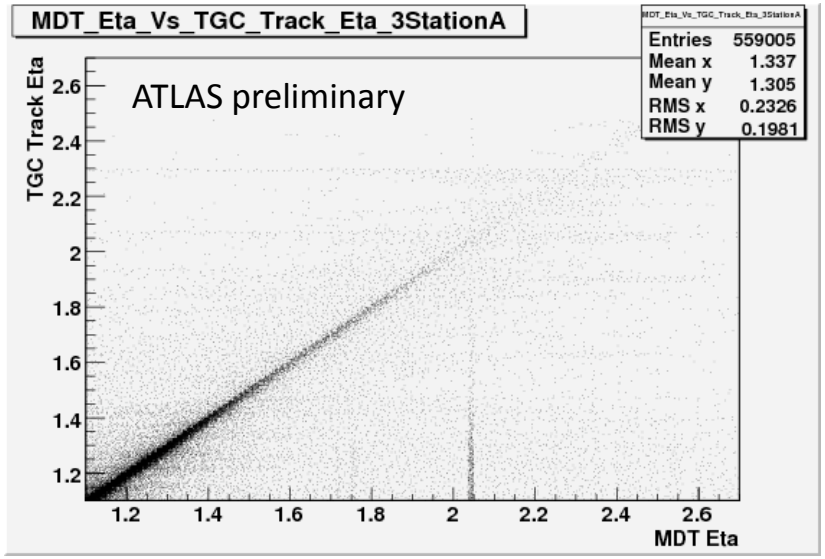


Track sagitta distribution without and with MDT chamber alignment (endcap)

Thin-gap chambers

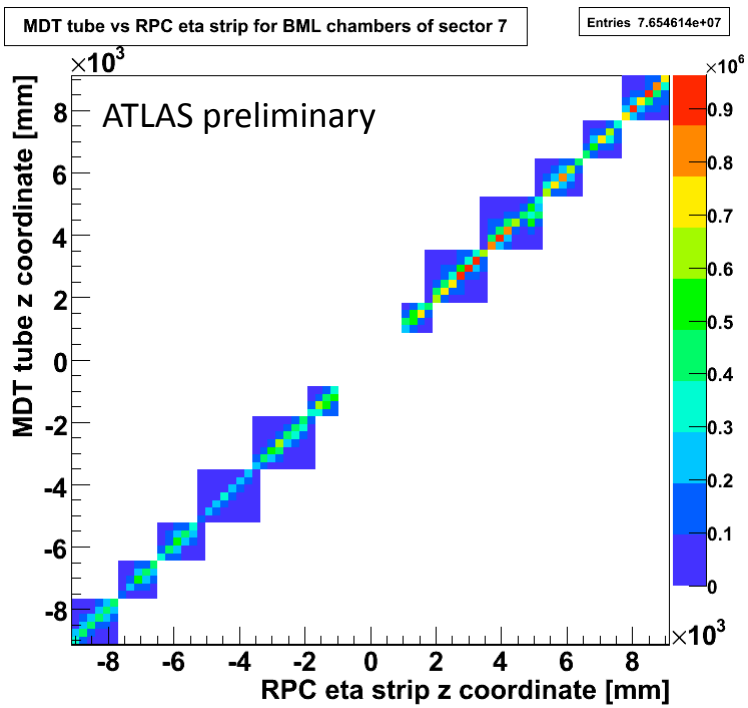
wire efficiency ~85%

strip efficiency ~87%

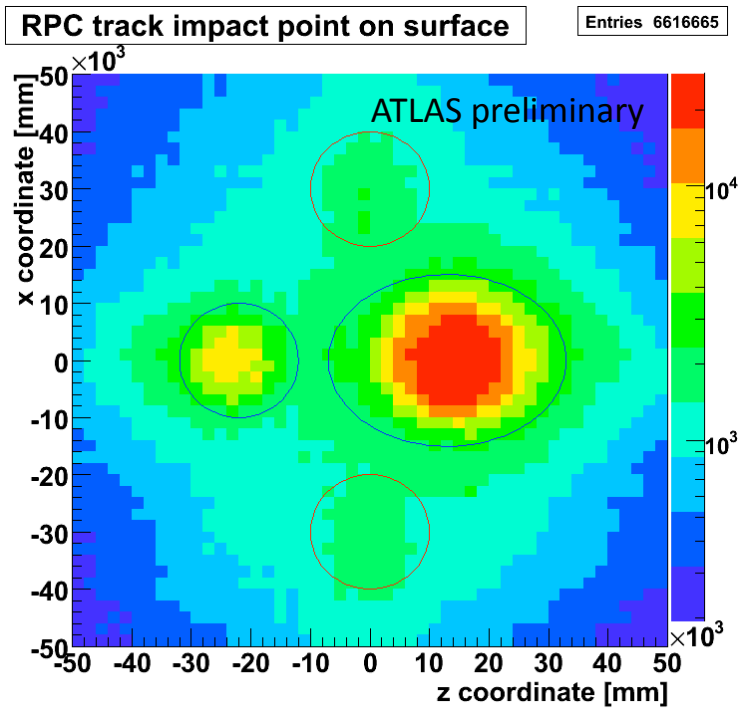


Correlation between tracks from the endcap trigger (TGC) and the precision chambers (MDT)

Muon Spectrometer - Results



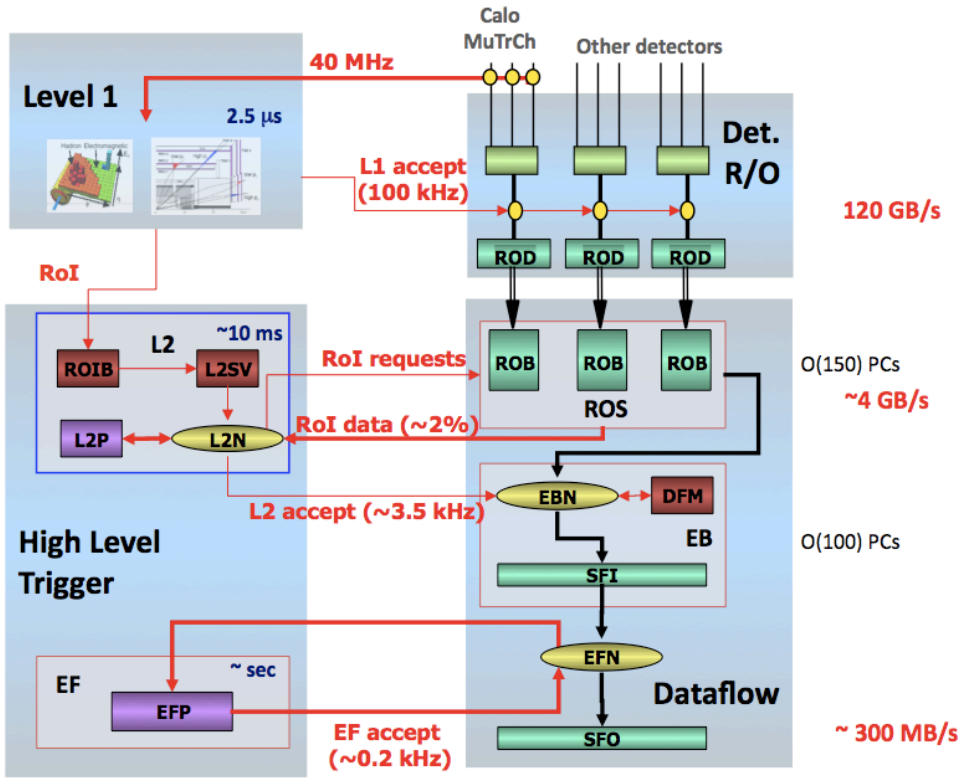
Hit correlation between barrel trigger (RPC) and precision chambers (MDT)



RPC cosmics tracks projected onto cavern surface:

- access and lift shafts visible

Trigger and DAQ



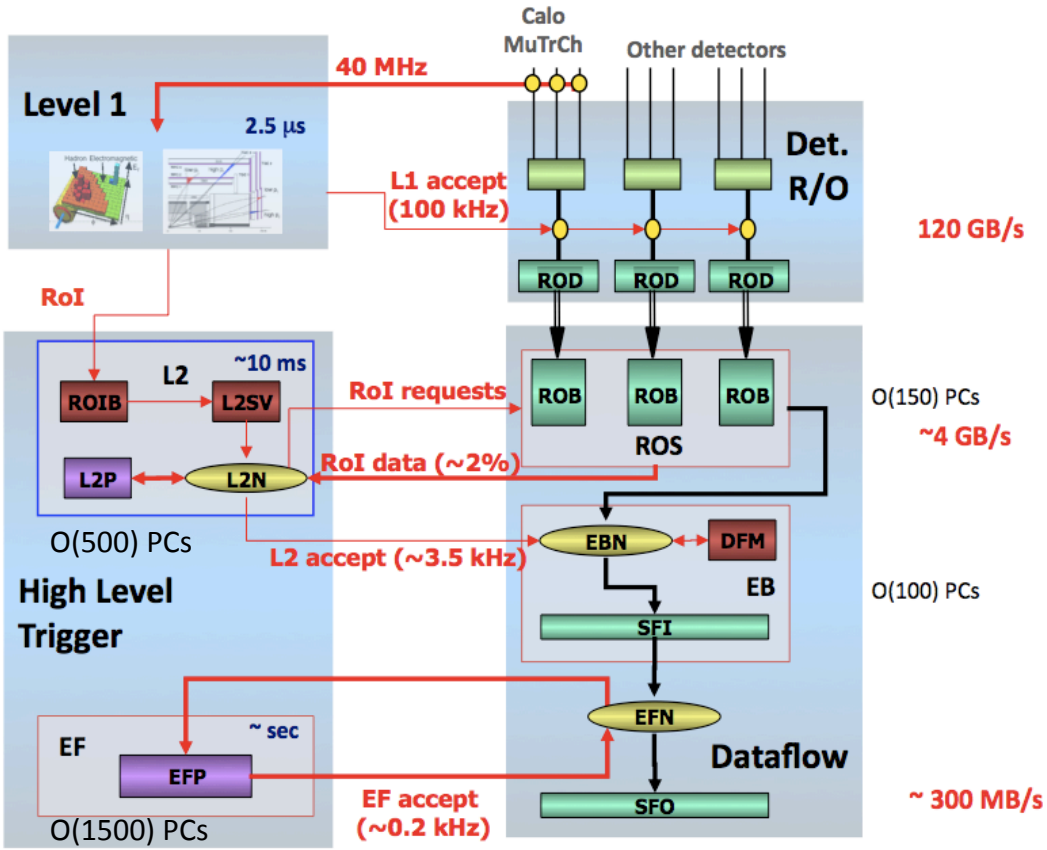
Trigger and Data Acquisition

Level-1 Trigger

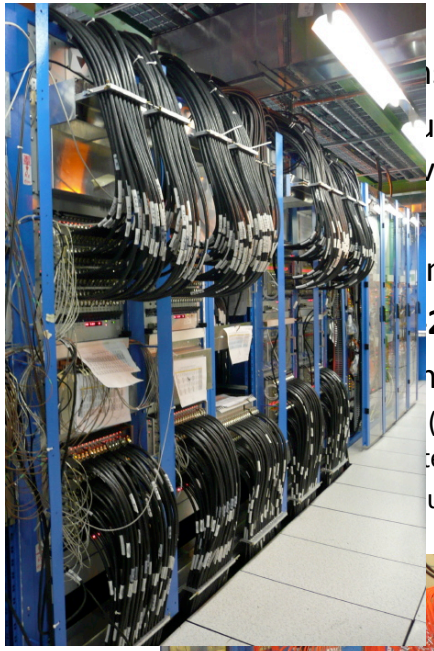
- System completely installed
- Rate test successful up to 40 kHz (random trigger), to be improved to nominal rate of 75 kHz this year
- Timing of triggers is in progress

High-Level Trigger (Level-2 and Event Filter)

- Current configuration
  - 850 PCs in 27 racks (can either be used as Level-2 or Event Filter)
  - Capable of 60 kHz sustained rate
- Final configuration
  - 500 PCs for Level-2, 1800 PCs for Event Filter (PC: 8 cores, 2.5 GHz with 2 GB RAM per core)
  - 17 Level-2 racks, 67 Event Filter racks (28 racks configurable)
  - Finalisation of system will be luminosity driven
- High-level trigger (e.g. tracking algorithms) used to enrich cosmics samples for inner detector studies



Trigger and Data Acquisition



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2 and Event Filte

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(can either be used a

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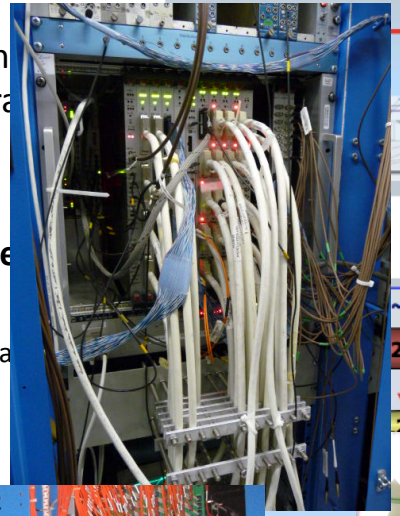
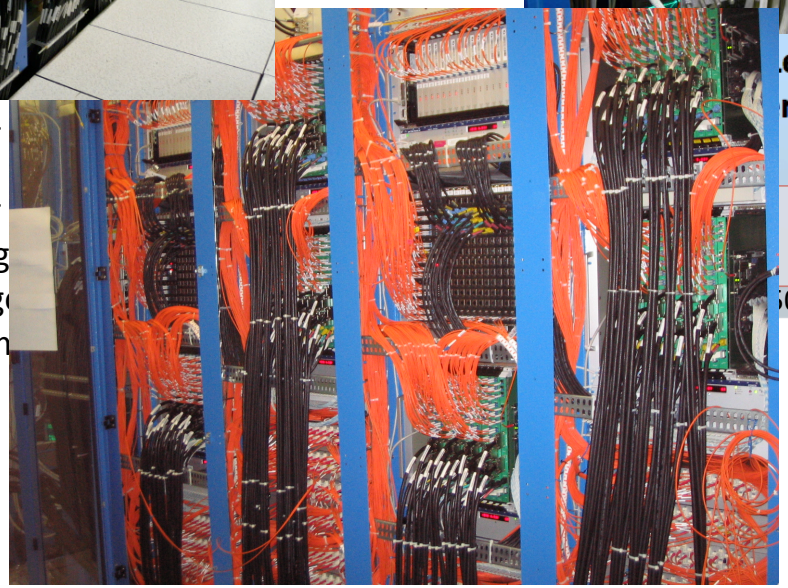
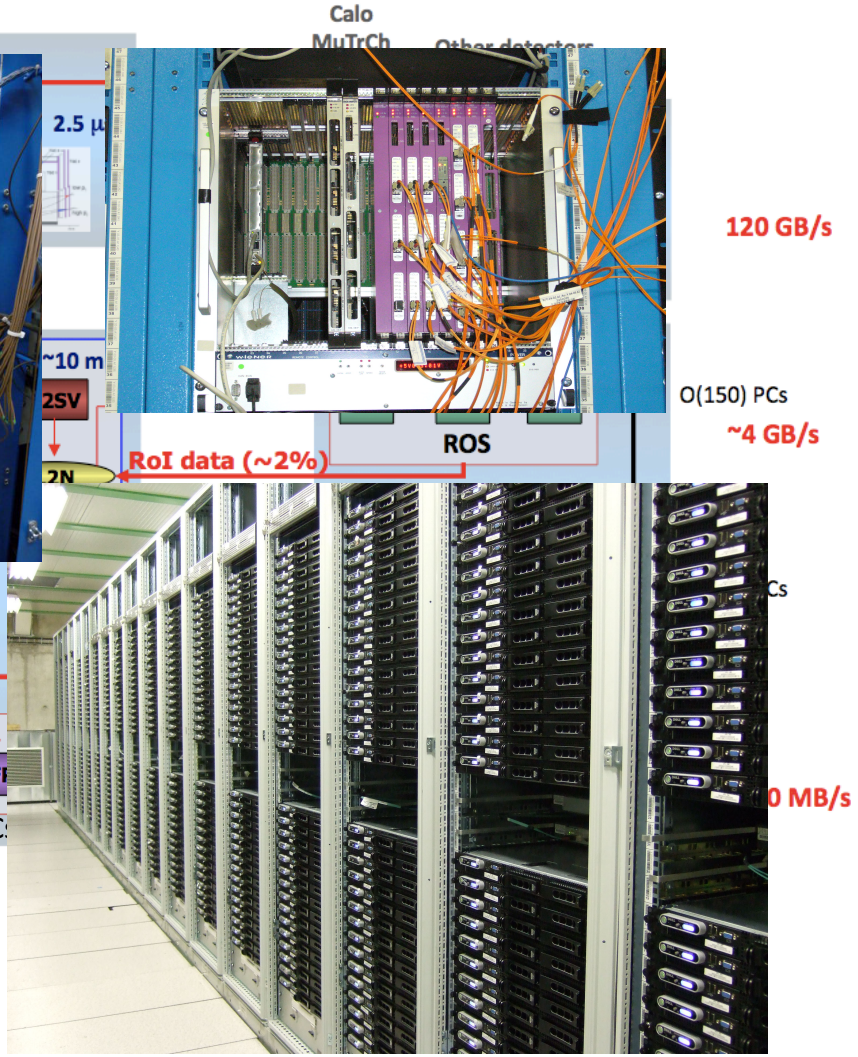
ustained rate







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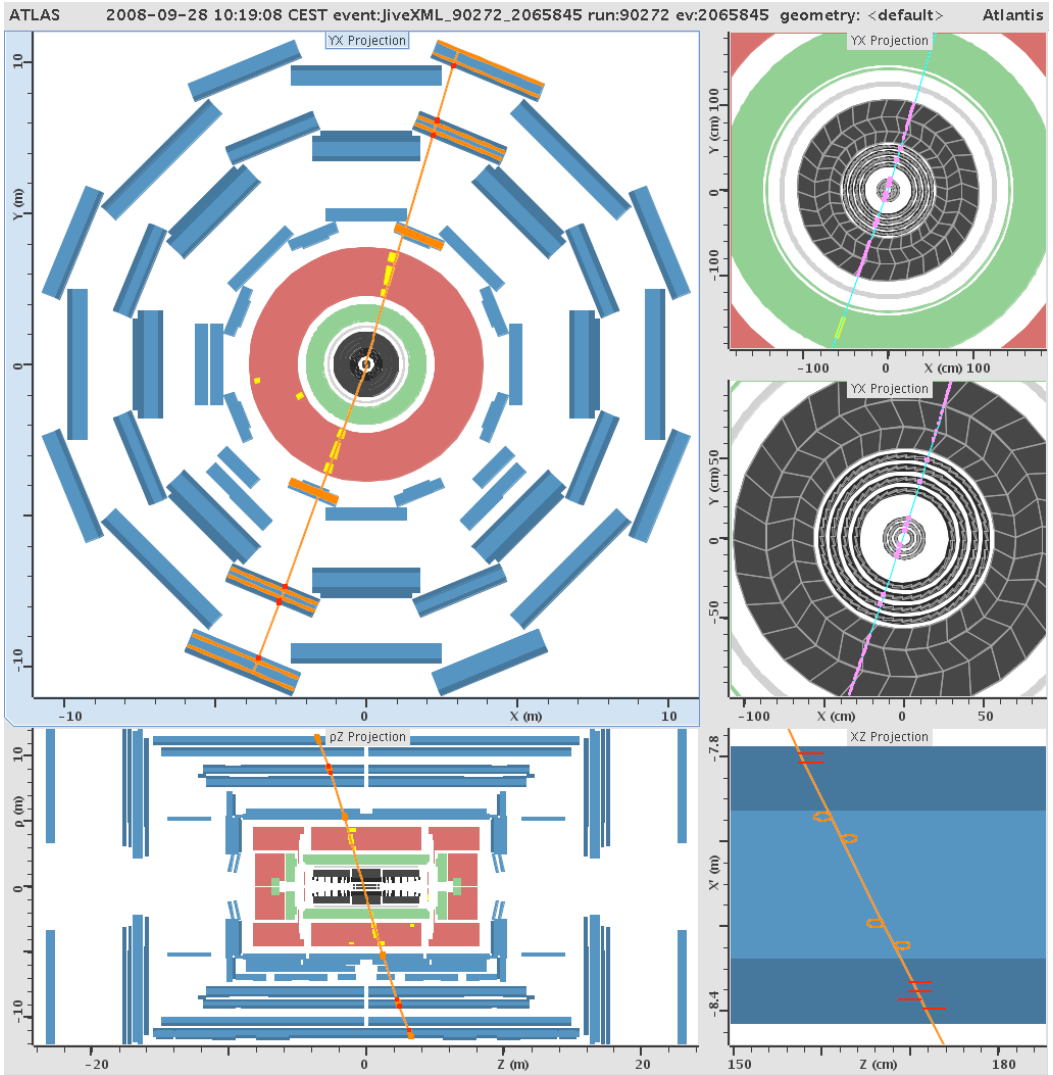
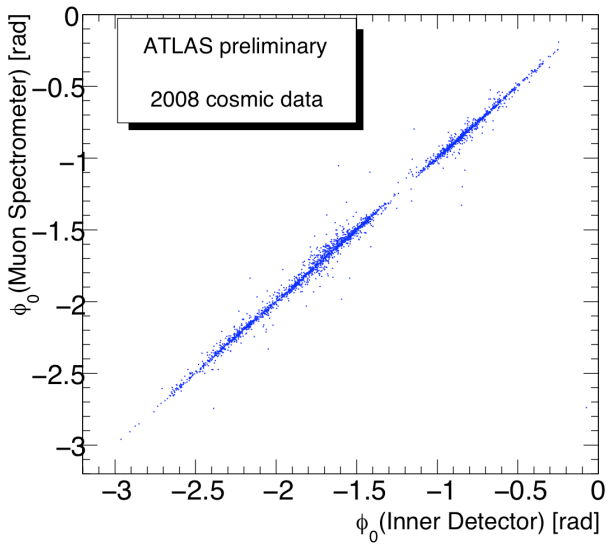
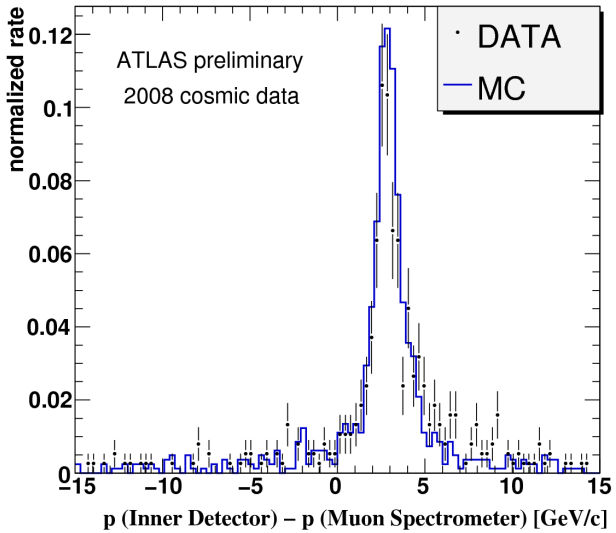
Combined results







Summary

- Commissioning of the ATLAS detector started more than 3 years ago
- Large amounts of cosmics with all sub-detectors included taken in 2008
- ATLAS successfully took beam data in September 2008
- Cosmics and beam data very useful for commissioning, detector calibration and alignment
- ATLAS will emerge from current shutdown in better shape ready again for beam collisions in the autumn this year