Testing ATLAS Inner Detector with Cosmic Muons

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2008

Contents

Cosmic Muons Simulation

Used Athena Packages

SW Versions:	**Geant4** in Athena **13.0.10**
Generator:	Generators/CosmicGenerator-00-00-24
Simulator:	Simulation/G4Atlas/G4AtlasApps-00-02-15 LArCalorimeter/LArG4/LArG4HitManagement-00-00-25
User Actions:	Simulation/G4UserActions-00-00-15 (modified)
Reconstruction:	InnerDetector/InDetExample/InDetRecExample-00-03-62

$$SimFlags.WriteTR = time\_output;\ JiveXML = true$$

Results from Summer 2007

Muons generated	Muons accepted	Pixels hits	ID hits	Real time
6 907 433 412	11 575 728	220	59 333	259.6 s

Table: Calculation of muon rates from the simulation. Only muons that were detected by three of more layers have been considered in the rate calculation.

Pixels rate	ID rate
0.85 Hz	229 Hz

Primary Vertex Positions

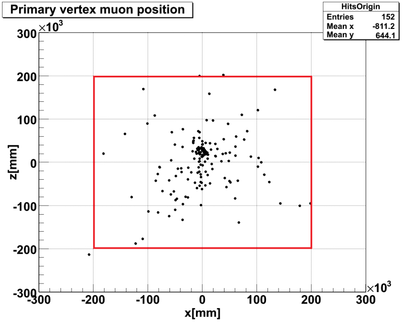


Figure: Initial XZ positions of muons eventually hitting the detector. Generated from 600×600 m surface.

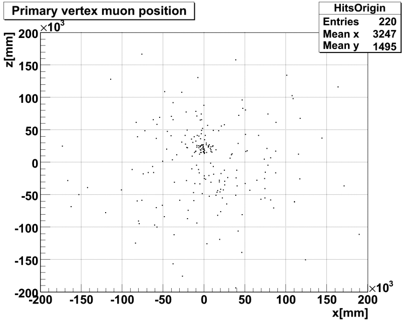


Figure: Initial XZ positions of muons eventually hitting the detector. Generated from 400×400 m surface.

- Virtually no hits outside the 400×400 m plane

$\Rightarrow$ it is totally satisfactory

Scattering

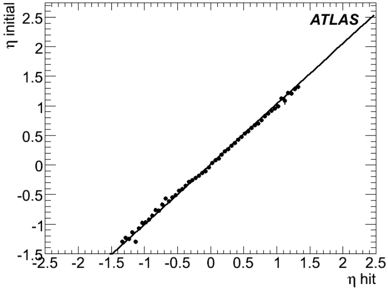


Figure: Correlation between initial and final pseudorapidity η. Fit parameters: $y = 1.002x - 0.003$.

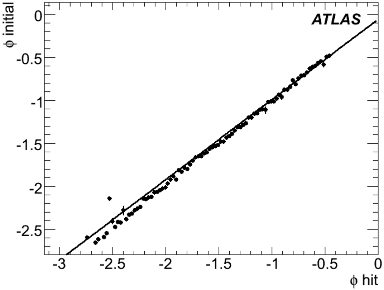


Figure: Correlation between initial and final angular angle ϕ. Fit parameters: $y = 0.933x - 0.057$.

- η and ϕ of particles on the surface and those hitting the detector is practically **the same** $\Rightarrow$ minimal scattering

Hit Distributions for η and ϕ in the Pixel Detector

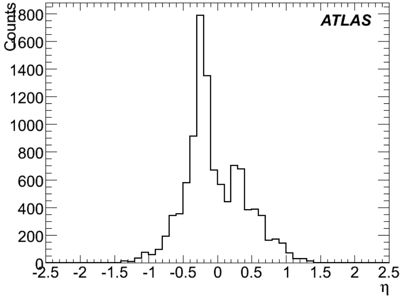


Figure: η hits distribution in the Pixel Detector. Maximum hits in: $\eta \in (-0.30; -0.05)$.

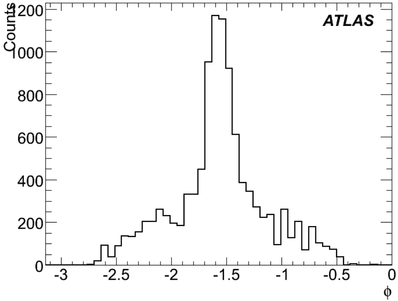
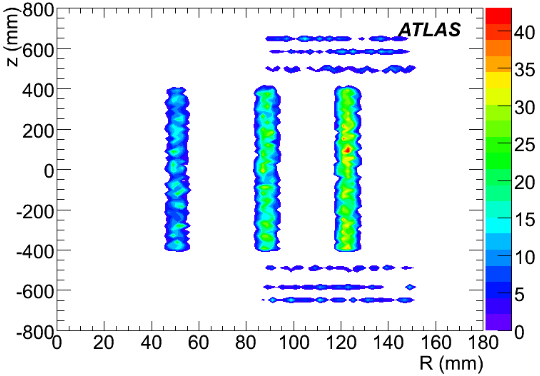


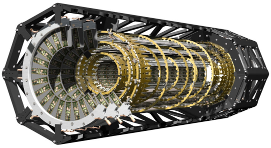
Figure: ϕ hits distribution in the Pixel Detector. Maximum hits in: $\phi = \frac{\pi}{2}$

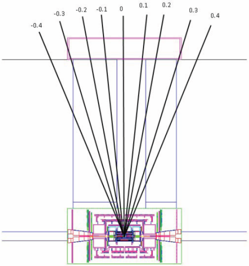
- η histogram shows the effect of PX14 shaft.

Rz Hit Distribution in the Pixel Detector

Figure: Hits distribution in the Pixel Detector







Total hit count:	10 574
B0 / **B1** / **B2**	4404 / 3209 / 1874
Endcap **A** / **C**	577 / 510
Real Time	207 s

Primary Hits in the Pixel Detector

Figure: Primary hits in the Pixel

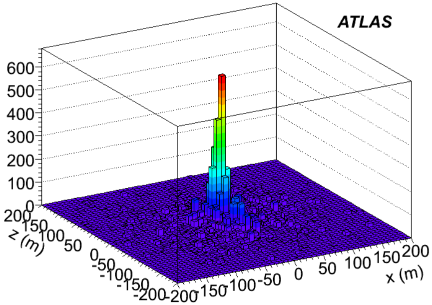
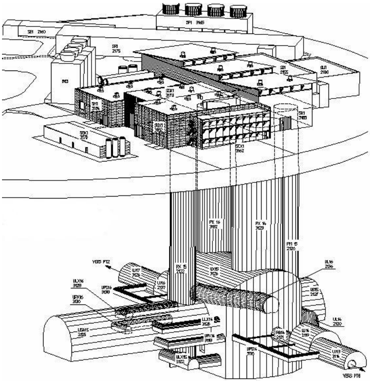


Figure: ATLAS Cavern Schematic



- Main peak is within the main PX14 shaft.
- PX16 has a minor effect on the hit distribution (the second maximum).

Energy Distributions

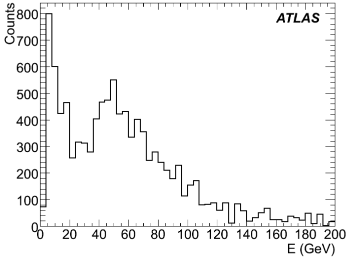


Figure: Primary energy distribution (before entering the cavern) of muons that eventually hit the pixel detector.

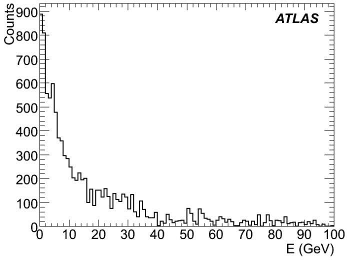


Figure: Energy distribution of muons that hit the Pixel Detector.

- Low-energy muons ($E \approx 10$ GeV at the surface) arrive through shafts
- High-energy muons ($E \approx 50$ GeV at the surface) pass the rock $\Rightarrow$ Substantial drop from the energies on the surface.

Rz Distribution of Deposited Energy (Integral)

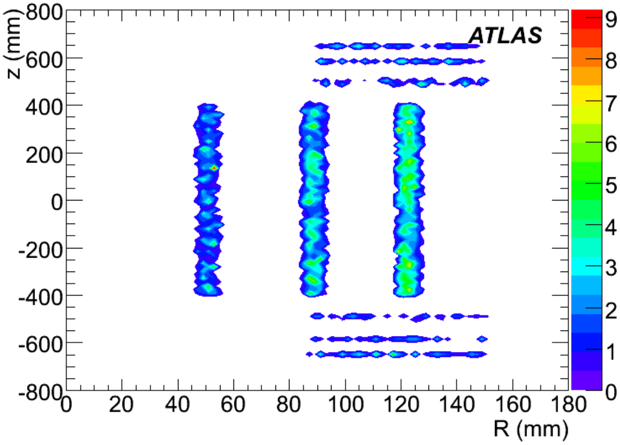


Figure: Deposited energy E_{dep} distribution in the Pixel Detector. Almost all muons leave a deposit of $E_{\mathrm{dep}} \approx 0.1$ MeV
Most energy is deposited in the outermost layer B2.

SCT Barrel Hitmaps

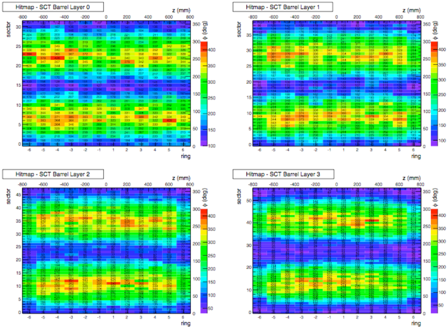


Figure: Hit occupancy of the SCT layers. **Simulated** data.

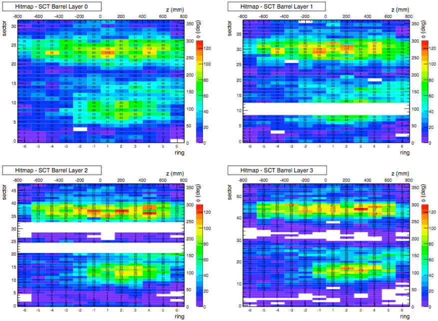


Figure: Hit occupancy of the SCT layers obtained from cosmic runs during **M6 week**.

- **M6**: Numerous breakdowns and cooling loops

Figures from Regina Moles - Alignment using Cosmic Ray Data from the M6

Simulated Pixel Hitmap for B2 Barrel

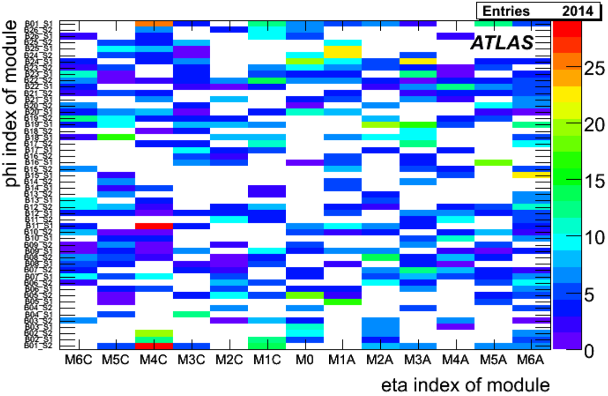


Figure: Simulated hit occupancy of the outermost Pixel layer (B2).

- Every rectangle represents one real module.
- Simulates cca 1 hour of real time data taking.

Module Hit Occupancy Over All Modules

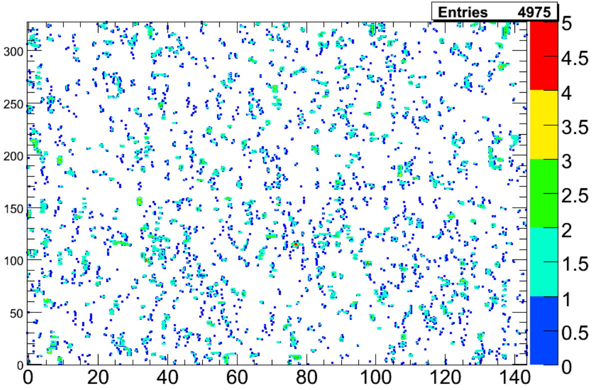


Figure: Hit occupancy integrated over all modules.

- Some areas have been hit even five times (red).
- Simulates cca 1 hour of real time data taking.

Example of a Reconstructed Track in the Pixel Detector

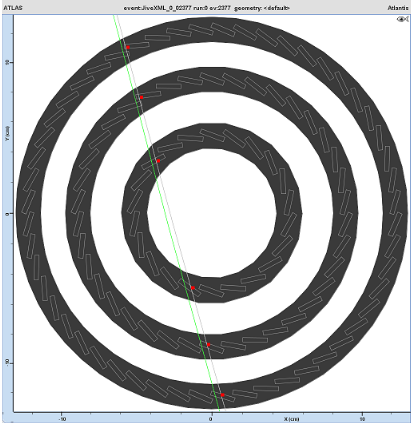


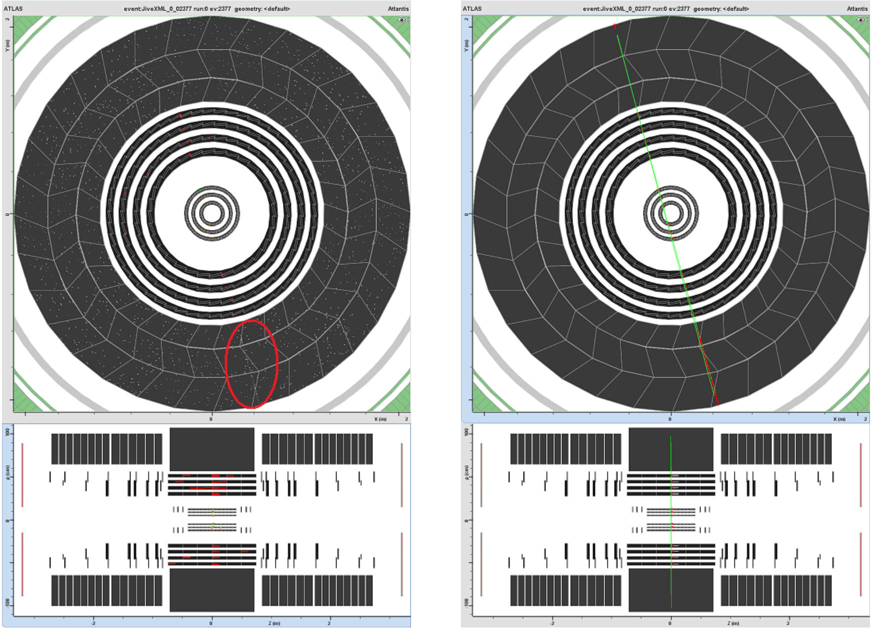
Figure: Example of a cosmic track with hits in all barrel layers of the Pixel Detector

Event display

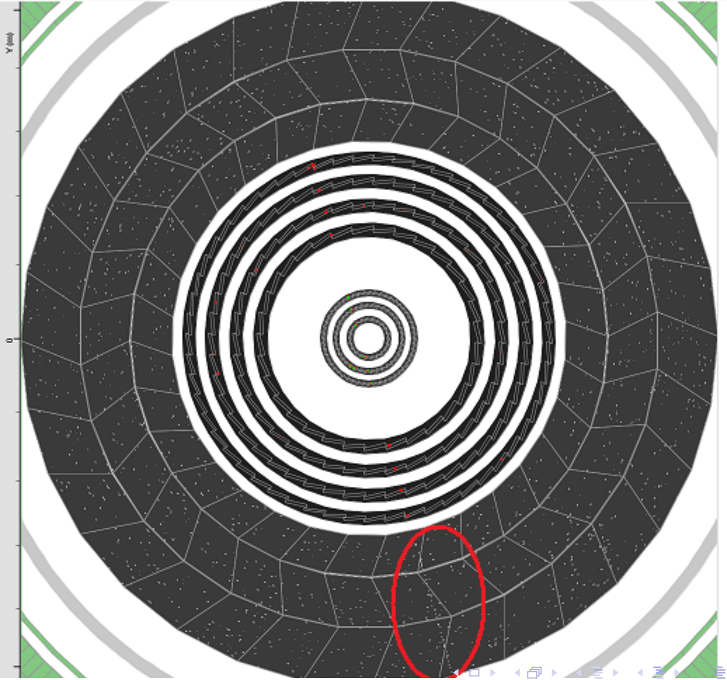
reconstructed track in JiveXML
$\Longrightarrow$ **Atlantis**

- Visualisations in $R\phi$, Rz and other perspectives
- Display/hide endcaps
- Two reconstruction algorithms (green and grey segment)
- Different cuts (with or without noise)

Example of a Reconstructed Track in the Inner Detector



Example of a Reconstructed Track in the Inner Detector



Example of a Reconstruction Failure

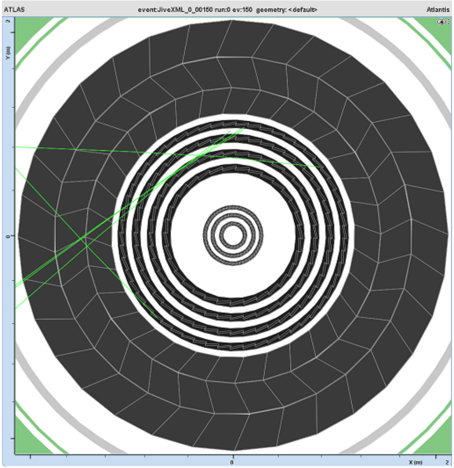


Figure: Event display of a reconstruction algorithm failure giving wrong solutions. No hits anywhere (good cut), just the track segments.

Real and Simulated Tracks

Figure: Ten reconstructed simulated tracks

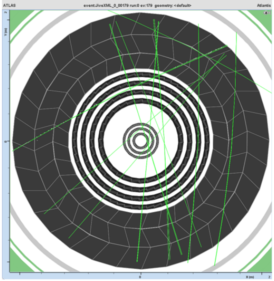


Figure: Real data from M4 week cosmic runs

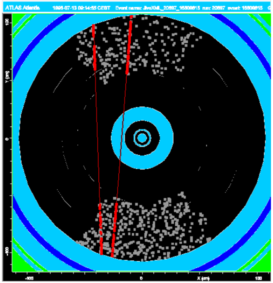
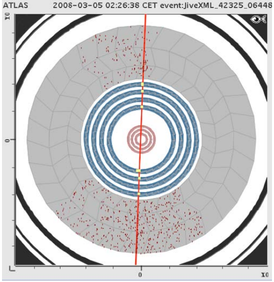


Figure: Real data from M6 week cosmic runs



M4 & M6 figures from Thijs Cornelissen - Overview of Cosmics Reconstruction

Conclusions

1. Pixel Detector rate 0.85 Hz $\Longleftrightarrow$ $\approx$ 3000 hits per hour (should keep the trigger happy).
2. Muon distribution in the cavern is mainly affected by the main access shaft PX14: $\eta_{\max} \in (-0.30; -0.05)$
3. The reconstruction algorithms do not always give correct results for cosmics (because they do not originate in the centre of the detector). The real data reconstruction uses the same algorithm.
4. Simulated monitoring works for Pixel Detector as well as for the SCT. No real Pixel Hitmaps available so far.
5. Cosmic *simulation* in Athena 13.0.10, *reconstruction* in Athena 14.0.10 and Atlantis visualisation all give meaningful results and thus they can be used for analysis of cosmic runs.

- Great exercise in using the ATLAS software and understanding of detector geometry.