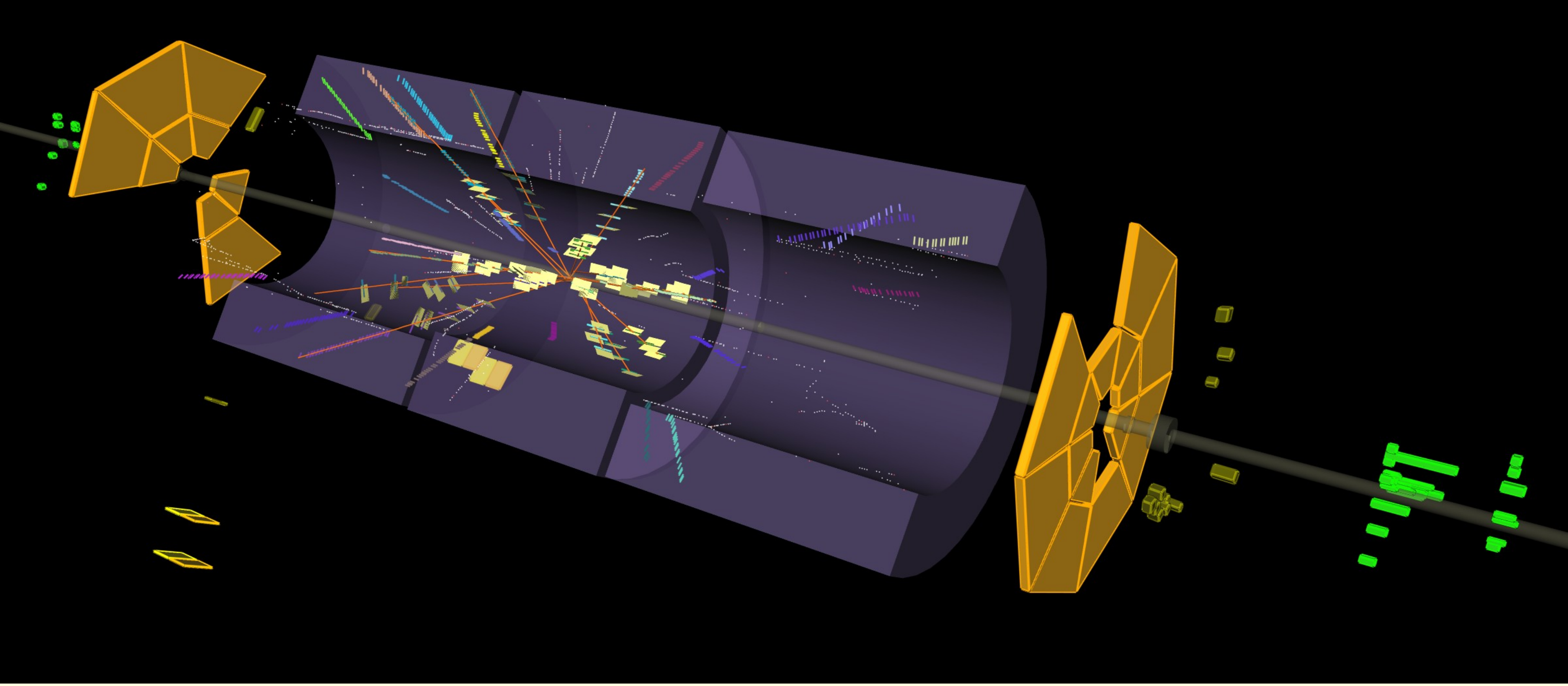
ATLAS ID performance with the LHC

ATLAS EXPERIMENT

2009-11-23, 14:22 CET

Run 140541, Event 171897



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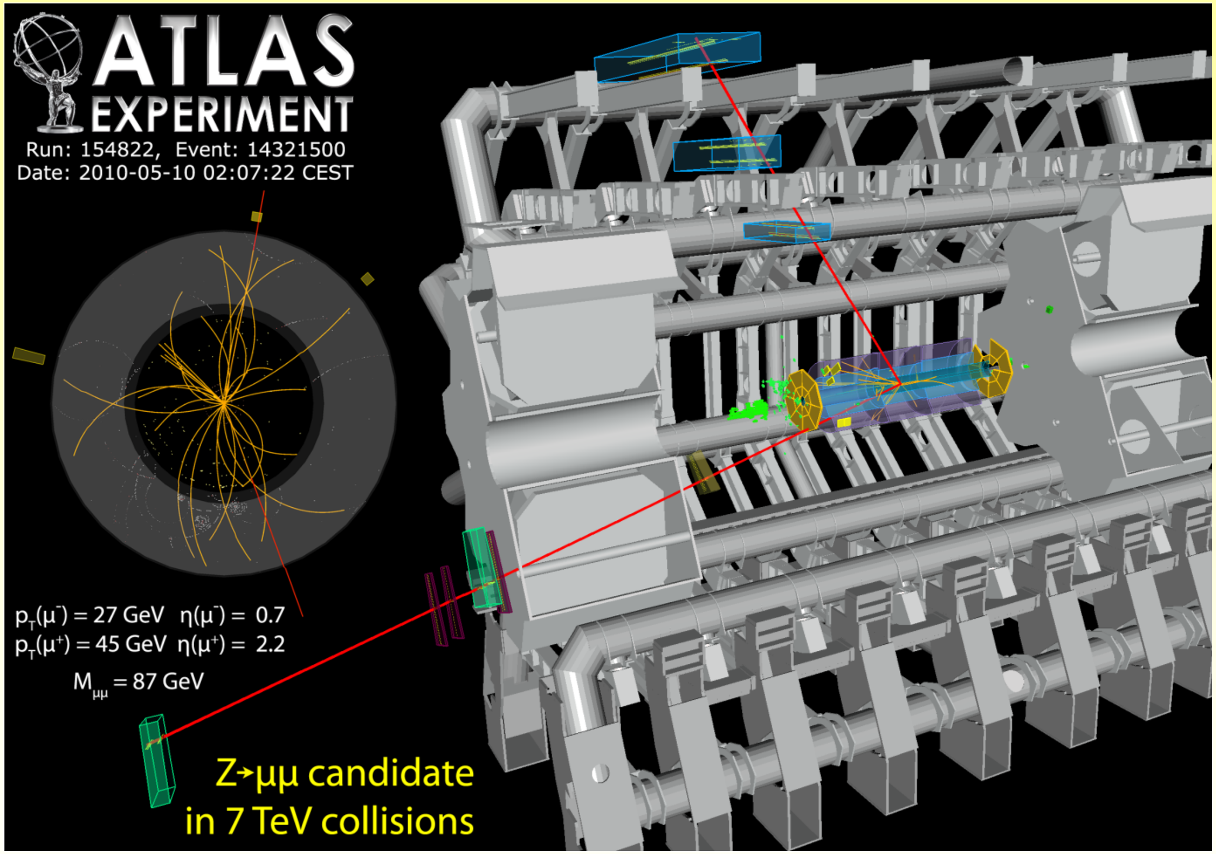
On behalf of the ATLAS collaboration

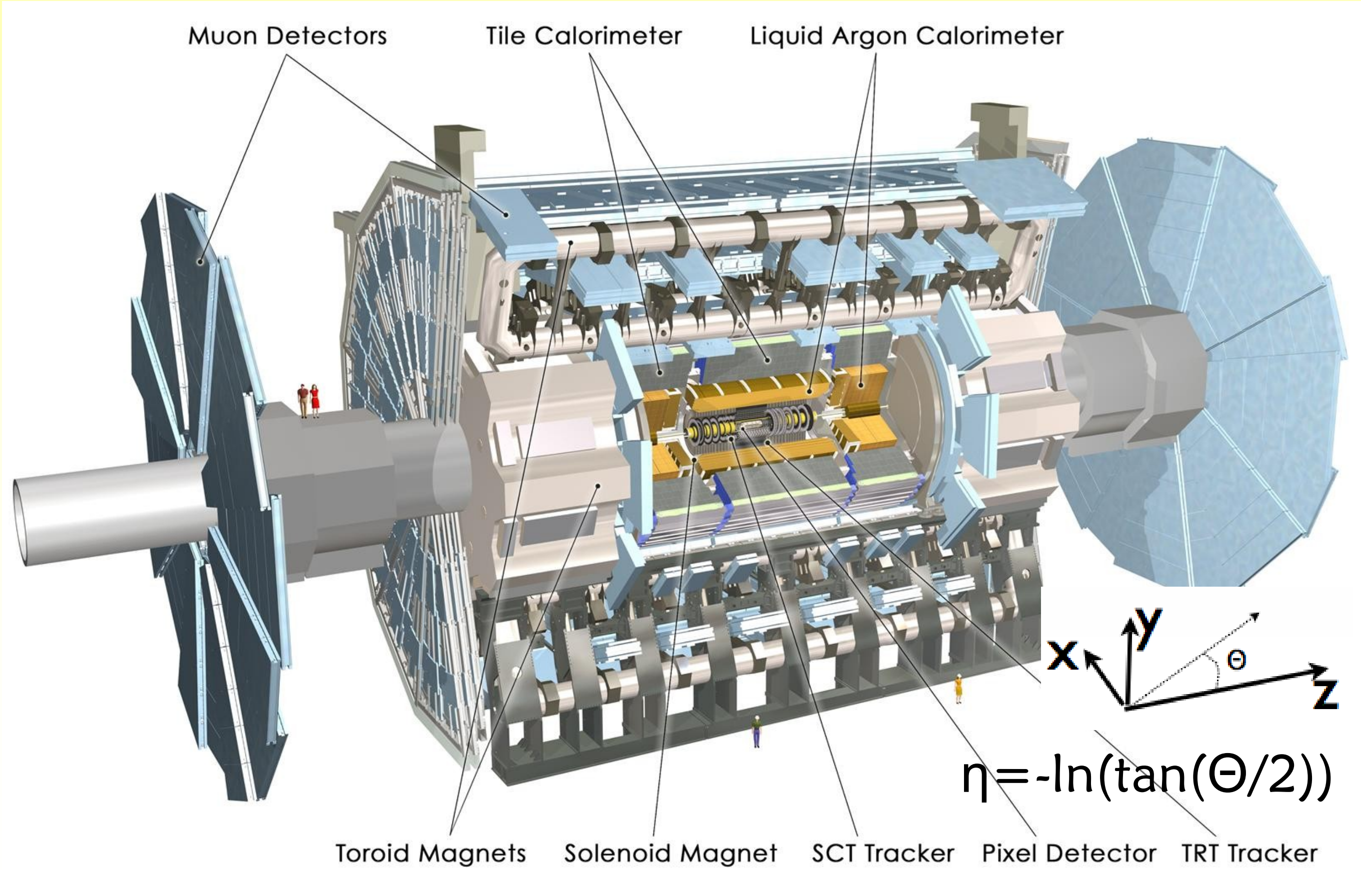
Outline

- The ATLAS inner detector
- Alignment, subdetector performance
- Tracking/vertexing performance
- Particle identification
- Material budget

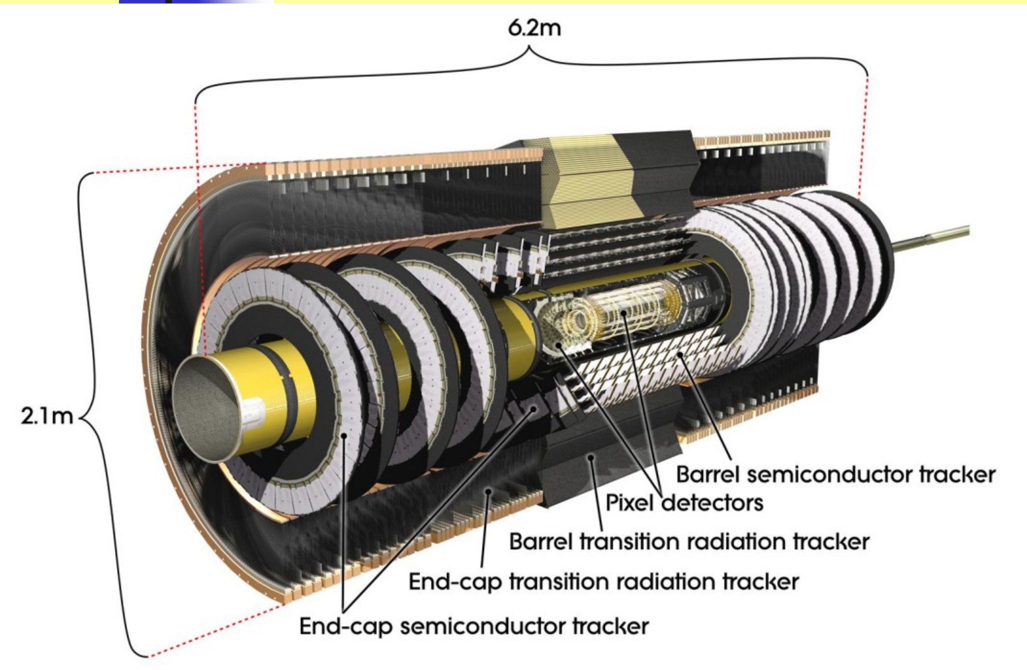


The ATLAS experiment

- A Toroidal LHC ApparatuS: multi-purpose detector designed to cover large range of physics measurements
- mass ~ 7000 tons
- height 25m
- length 46m
- ~100 million channels (90% in the inner tracker)

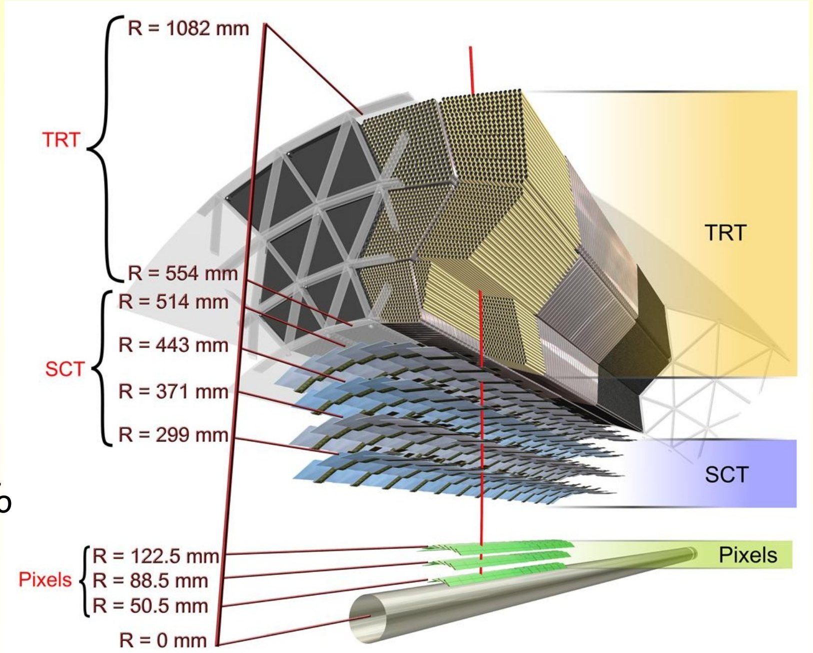


The Inner Detector (or inner tracker)



Immersed in a solenoid field of 2 Tesla measures the trajectories of charged particles.

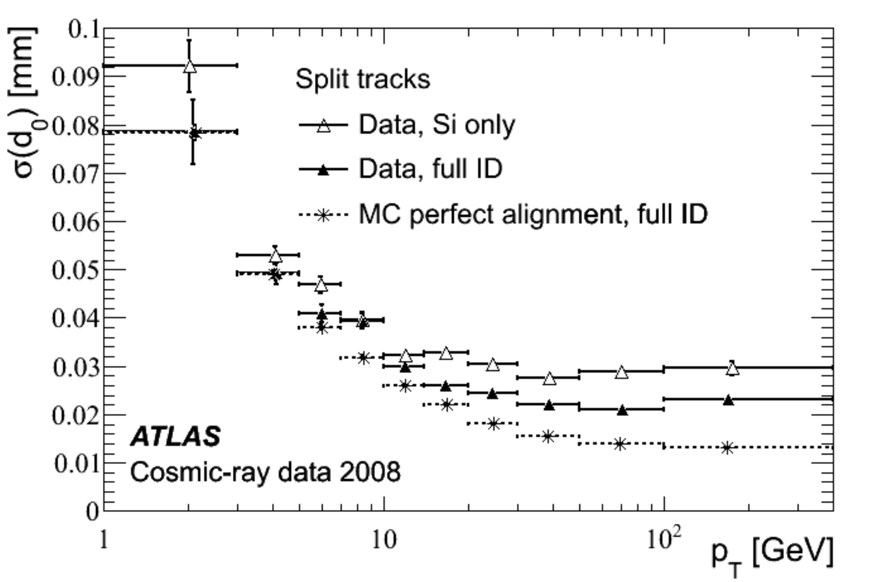
The ID comprises 3 sub-detectors: (resolution)
Pixel : 10/115 μm in Rϕ/z
Silicon strip (SCT): 17/580 μm
Transition radiation tracker (TRT): 130 μm in Rϕ

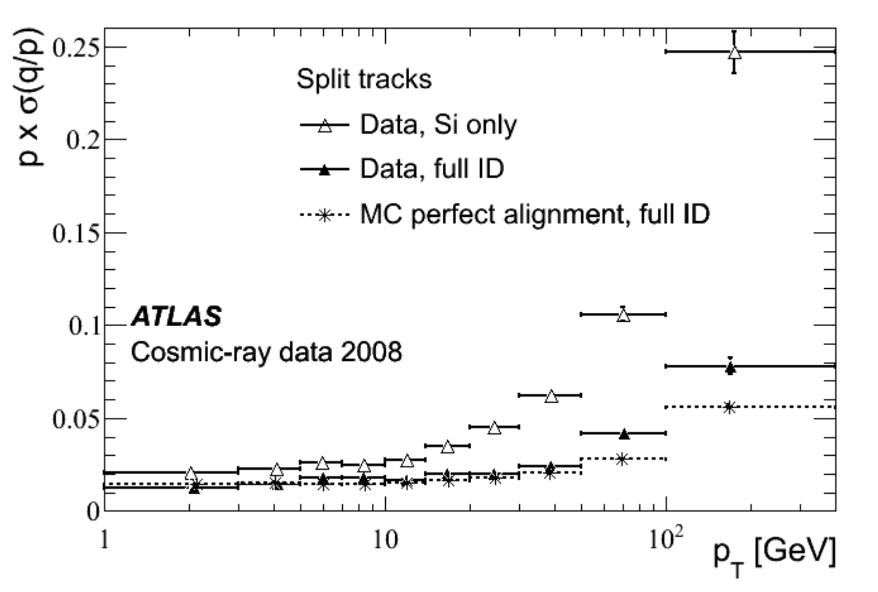


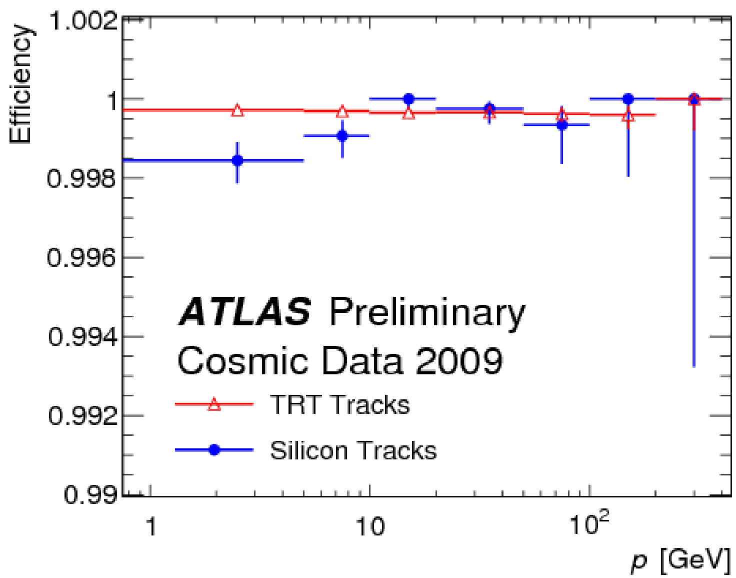
The ID covers : $|\eta| < 2.5$ (2.0 for TRT) with 3 Pixel measurements, 8 SCT and ~30 TRT.

Designed for tracking efficiency >90% (π) and 99% (μ) , momentum measurement with $\sigma_{pT} / p_T = 0.05\%\ p_T \oplus 1\%$ and impact parameter (at high p) = 10 μm

Inner detector cosmics studies

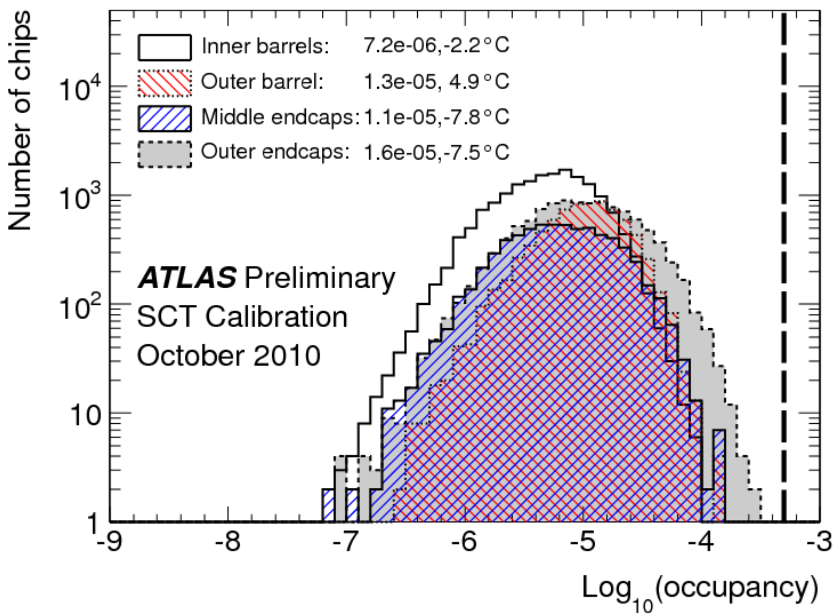


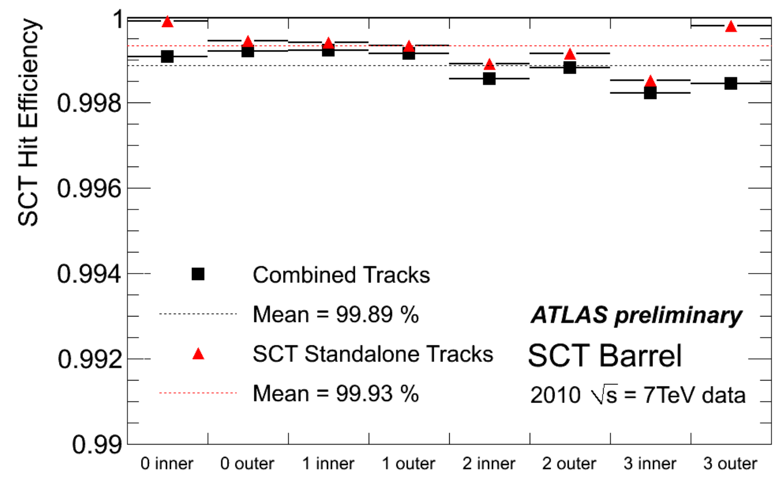




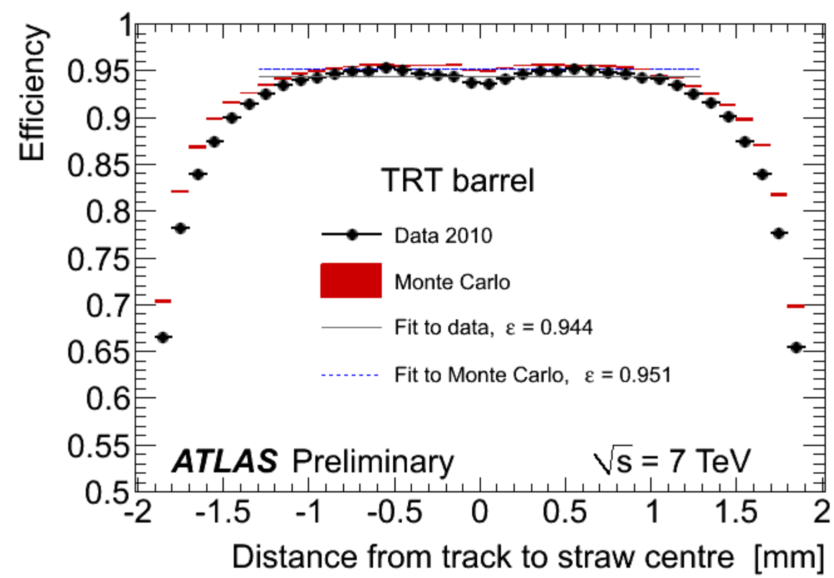
- Track parameter resolution studied by splitting cosmic track into upper and lower half, and comparing the parameters
- Tracking efficiencies very high, as expected (muons)
- Cosmics probe mainly barrel region, statistics in endcaps much lower

Efficiencies, noise levels

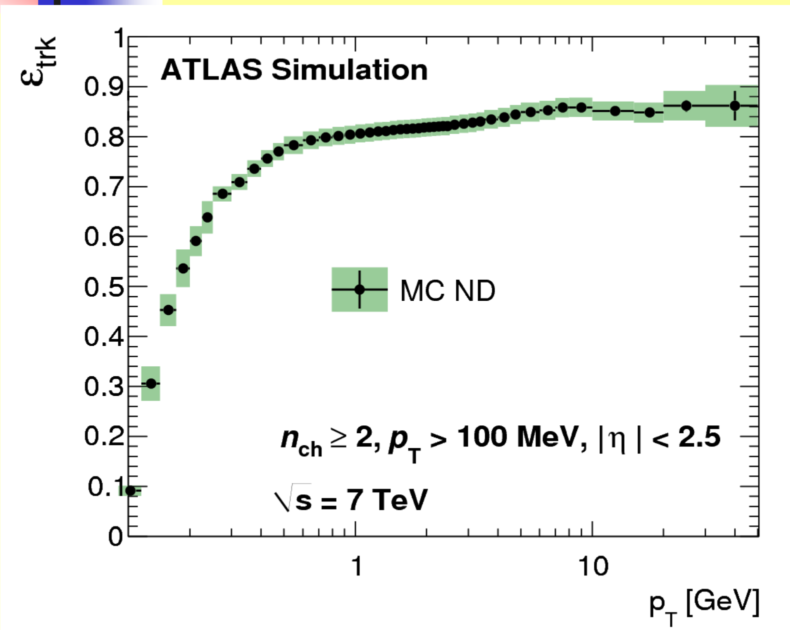


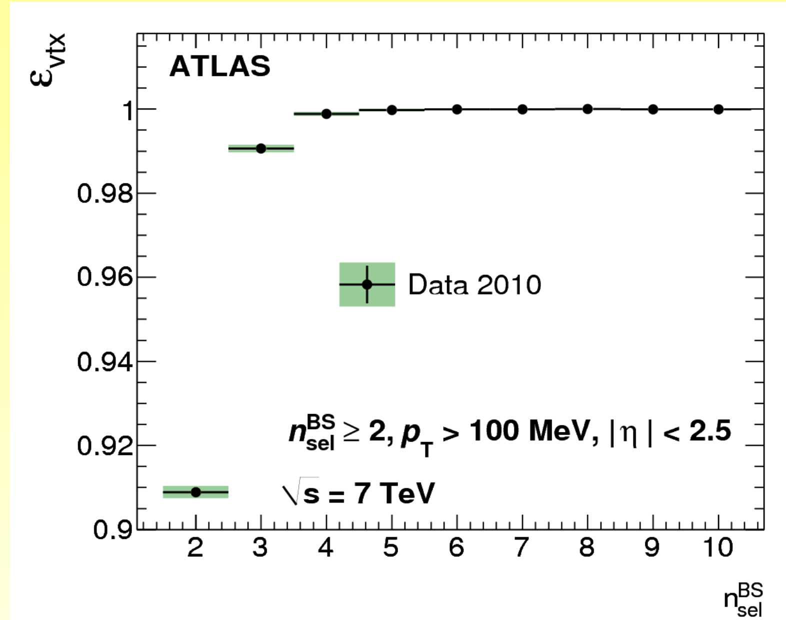


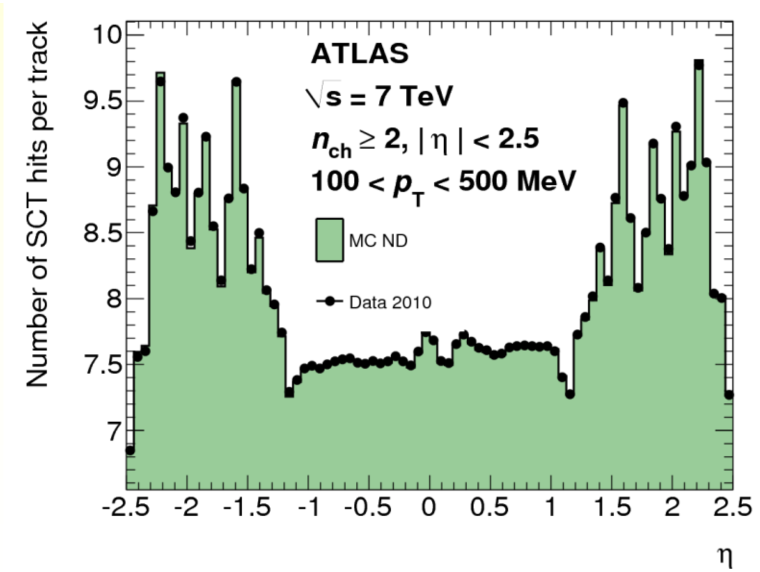
- Hit efficiencies: nearly 100% for pixel & SCT, ~95% for TRT
- Noise levels: ~10^{-8} for pixel, <10^{-3} for SCT, ~2% for TRT
  - Occupancies anyway dominated by real hits



Tracking with minimum bias events



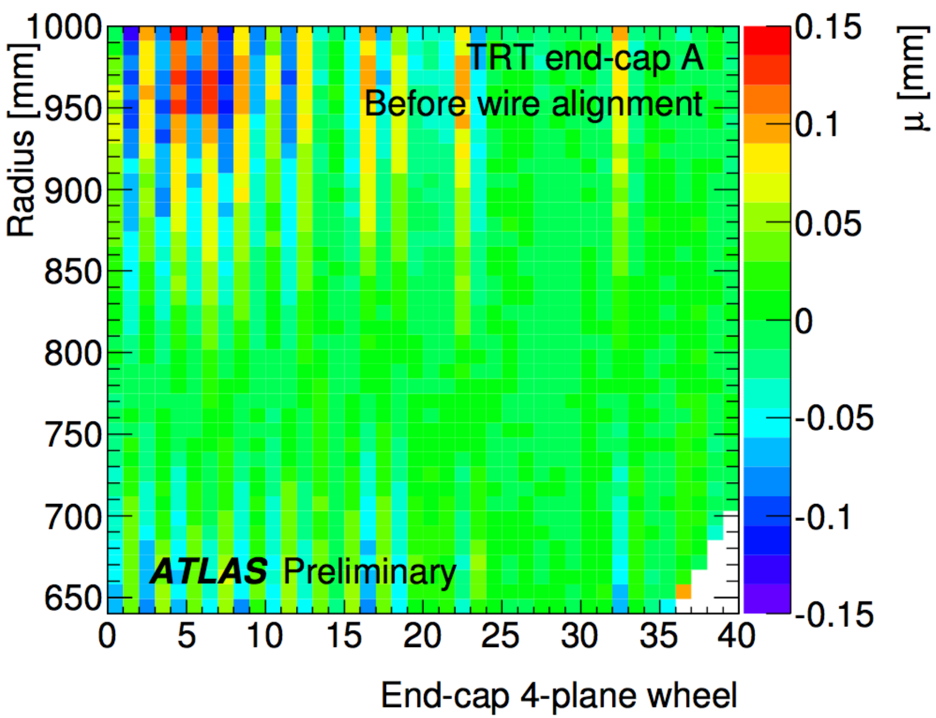


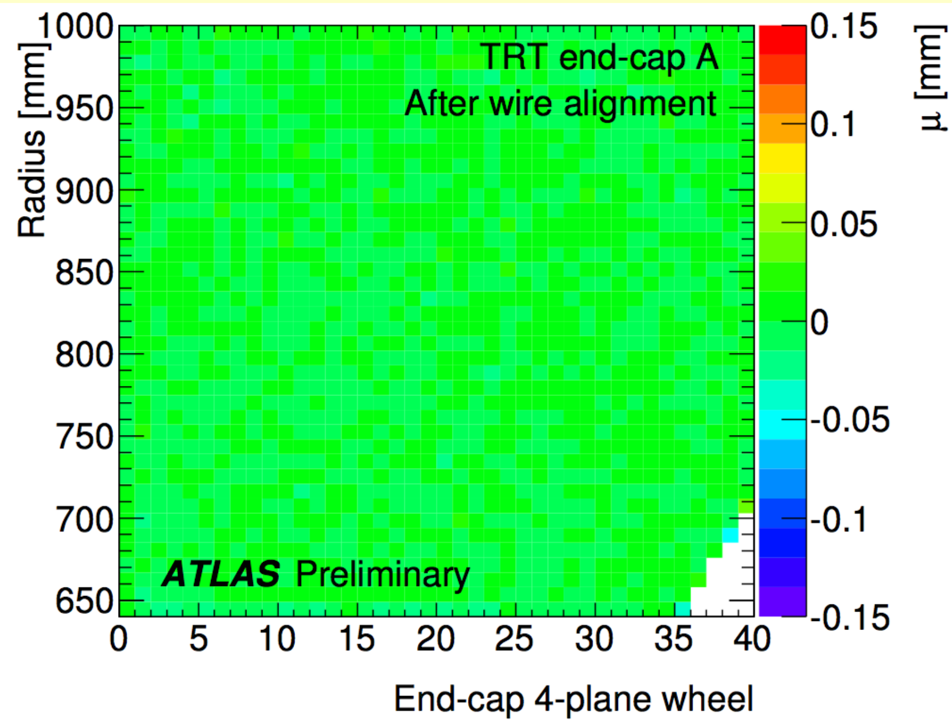


- Tracking efficiency for minimum bias analysis taken from simulation
- Systematics taken from data/MC discrepancies
  - Data/MC agreement generally very good, e.g. #hits on track (left plot)
- Efficiency highest for high-pT, central tracks
- Vertexing efficiency nearly 100% for ≥3 tracks

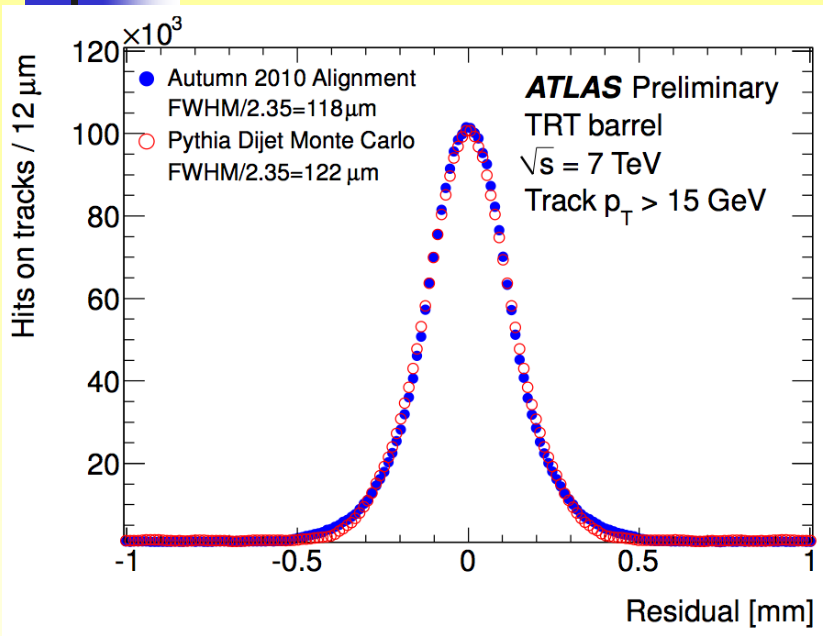
Alignment

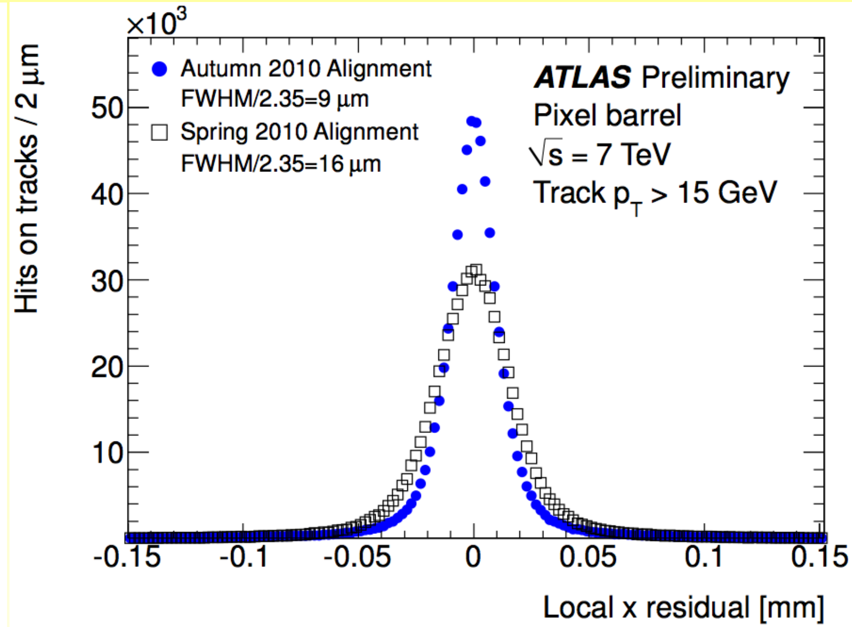
- Initial alignment based on cosmic data
  - Low statistics especially in endcaps
  - Could only align large structures (e.g. disks)
- Collision data eventually allowed alignment of individual sensors (pixel & SCT) and wires (TRT)
  - E.g. removed biases in TRT residuals (see plots)





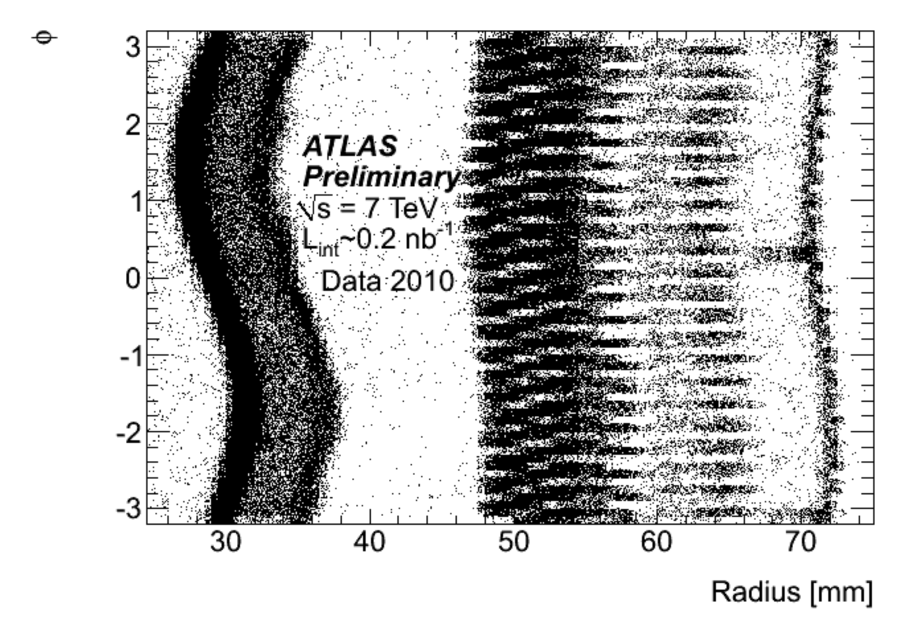
Hit resolution

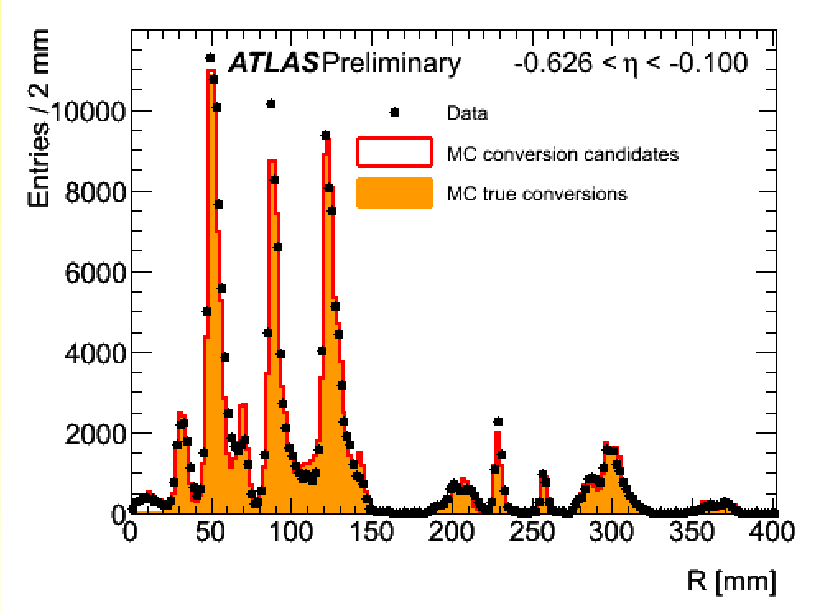




- ‘Spring 2010’ alignment based on cosmics and 900 GeV run
  - Low statistics, very few high-pT tracks
- Residual widths significantly improved in Autumn reprocessing which used updated alignment
- Pixel hit resolution also benefitted from corrections for module distortions (enabled in Autumn reprocessing)

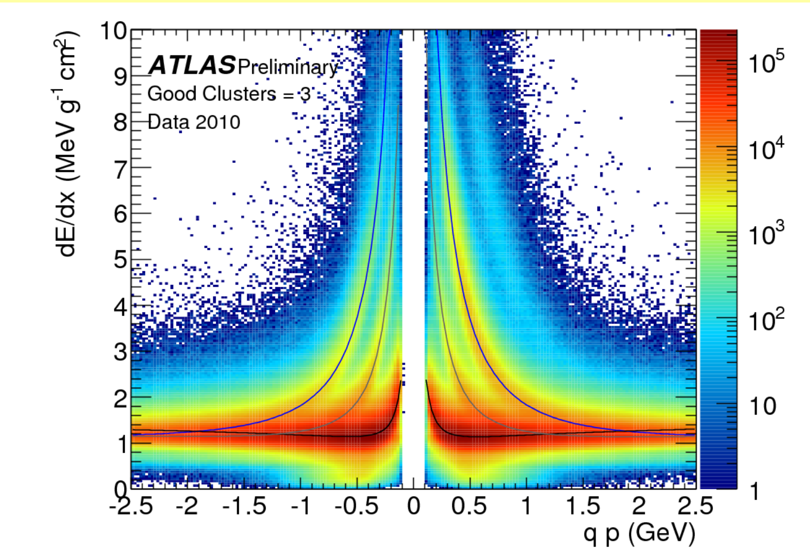
Material interactions

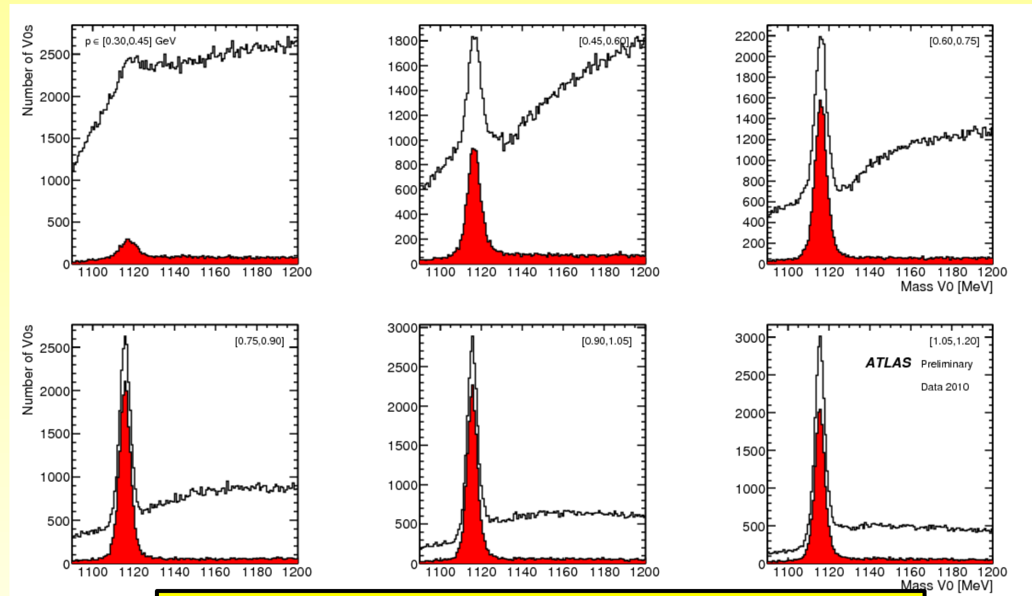




- Reconstruction of hadronic vertices probes interaction length of detector material (left plot)
  - Clearly shows that beampipe is shifted w.r.t. nominal beamline
- Reconstruction of photon conversions probes radiation length of detector material (right plot)
  - TRT crucial for detecting conversions (separates electrons from pions)
- Most data/MC discrepancies already addressed with updates for detector description

Particle identification

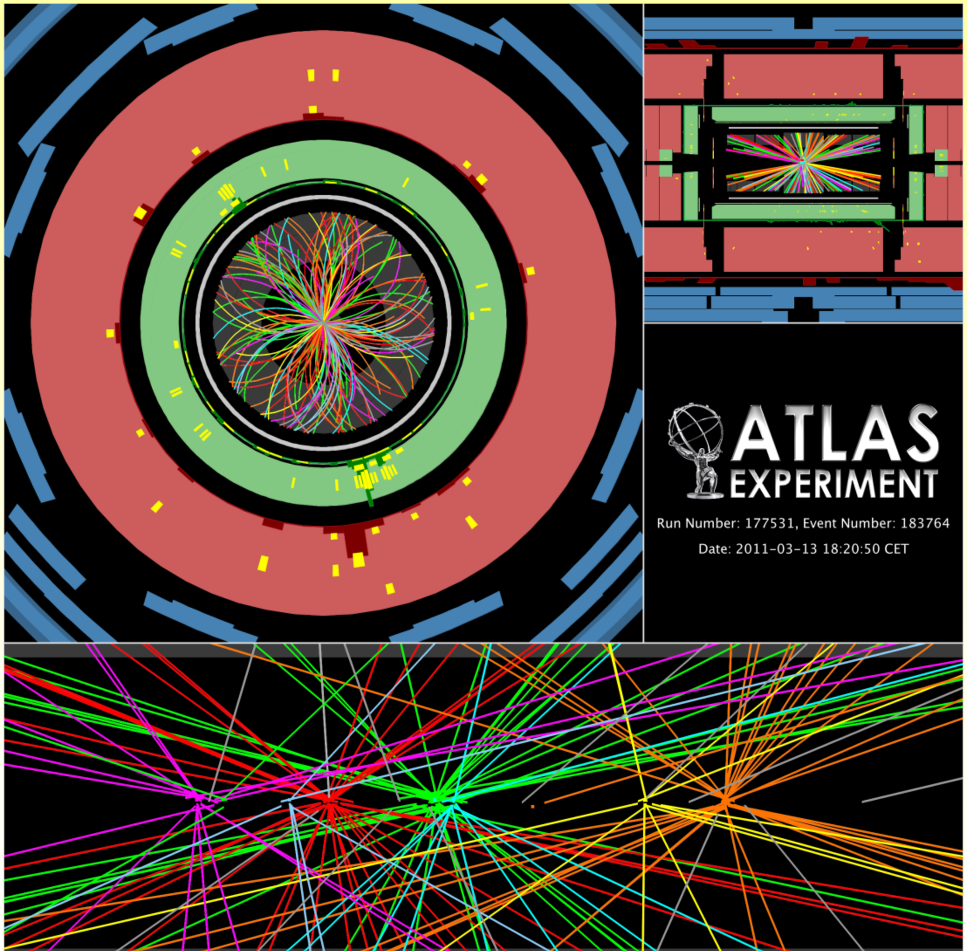




$\Lambda \rightarrow p^{+} \pi^{-}$ before/after tagging

- Pixel and TRT detectors measure charge deposit, can be used to identify particle type
- Can select e.g. $\phi \rightarrow K^{+} K^{-}$ and $\Lambda \rightarrow p^{+} \pi^{-}$ decays by tagging kaons and protons
- Also used to search for highly ionizing massive particles in SuSy models (R-hadrons)
- Performance of electron identification (based on TRT) covered by A. Bingul (link)

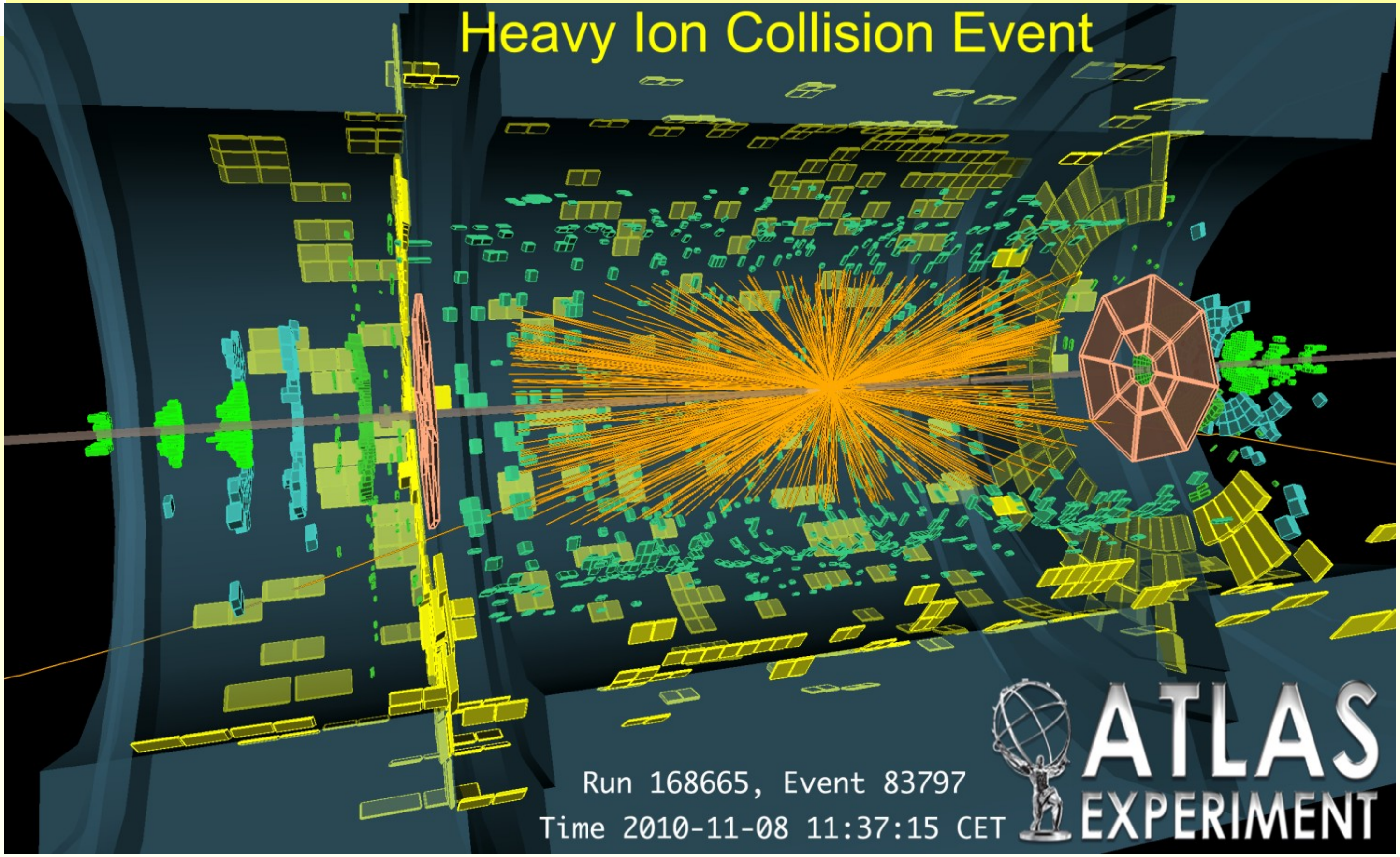
Tracking with pileup



2010:
Peak luminosity:**$2.1 \times 10^{32} cm^{-2}s^{-1}$**
Recorded**: 45 pb^{-1}**
2011:
Peak luminosity:**$1.26 \times 10^{33} cm^{-2}s^{-1}$**
Already recorded**: 1.01 fb^{-1}**

- Significantly more pileup in 2011 run
  - Up to ~15 interactions per crossing
  - 50 ns bunch spacing makes ID sensitive to out of time pileup
- ID copes well with the pileup after several measures put in place:
  - Enable out of time pileup suppression (keep only in-time hits)
  - Raise tracking pT cut from 100 MeV to 400 MeV

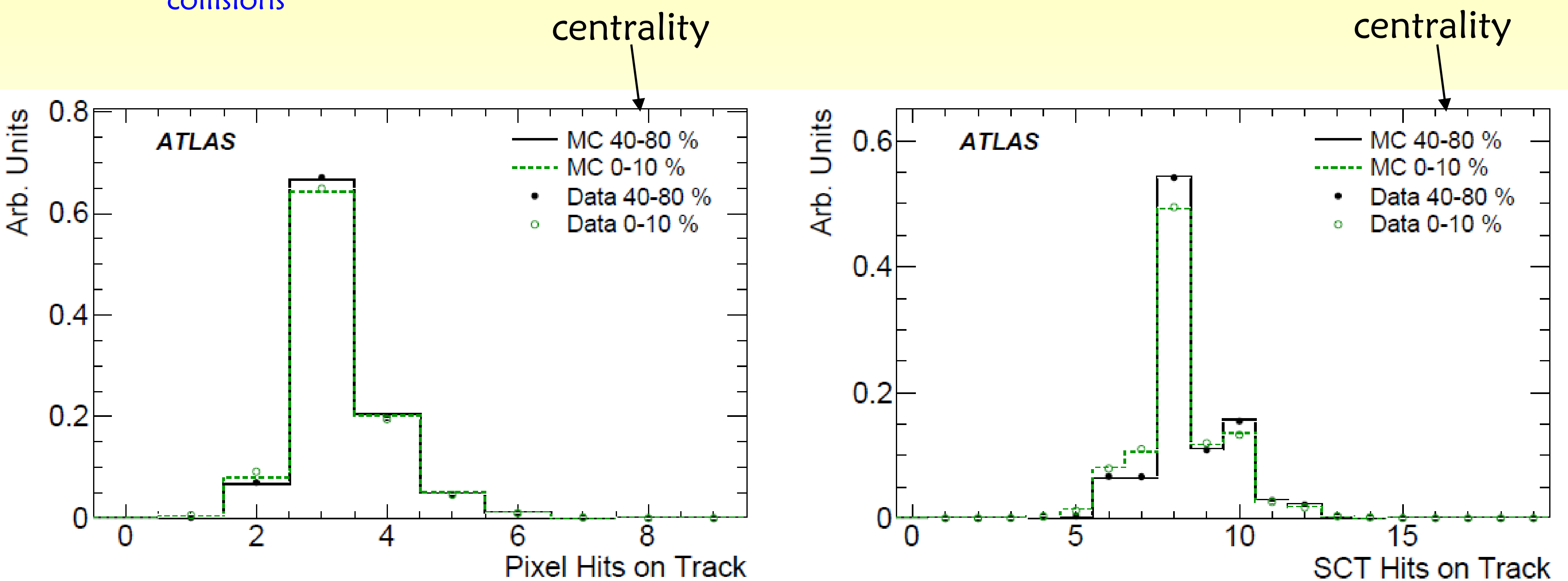
Tracking with heavy ion collisions



- Up to several thousand tracks per event with heavy ions. Required tightening of cuts in tracking to reduce combinatorics:
  - ≥9 silicon hits (instead of ≥7) per track, vertex constraint in pattern recognition, no TRT-seeded tracking
  - Tracking performance only slightly degraded: efficiency for muons ~96% in most central events (compared to ~100% in proton collisions)

Tracking with heavy ion collisions

- Excellent data-MC agreement concerning number of hits on track, both in peripheral and central collisions
- Track quality in central collisions slightly reduced compared to peripheral (less hits), but effect remains small
  - Main effect is on TRT (fewer extensions, fewer precision hits per successful extension), but TRT continues to improve momentum resolution compared to silicon tracks, even in most central collisions



Conclusions

- The ATLAS inner detector has performed extremely well since the beginning of data taking
- Robust performance under ever increasing luminosity (6 orders of magnitude since April 2010!)
- Very good data-MC agreement, remaining issues being followed up
- ATLAS inner tracker will continue to play a key role in many analyses

Backup

State of ATLAS for 2011 run

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	96.9%
SCT Silicon Strips	6.3 M	99.1%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.5%
Tile calorimeter	9800	97.9%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.5%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.8%
CSC Cathode Strip Chambers	31 k	98.5%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	98.4%

Muon EE chambers ($|\eta|\sim1.2$) not yet installed