ATLAS Inner Tracker Performance
at the beginning of LHC Run 2

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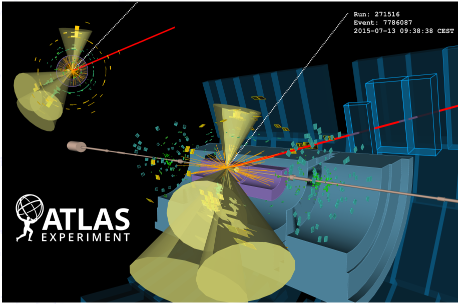
Outline

Physics requirements for precision tracking and vertexing

Most of the physics analysis in ATLAS require precise measurement of the trajectories of charged particles emerging from LHC collisions as well as precise reconstruction of secondary vertices.

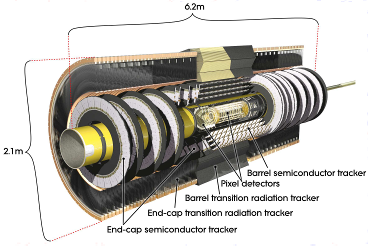
- Precision tracking at LHC luminosity over 5 units in pseudorapidity: $|\eta| < 2.5$
- Precise primary/secondary vertex reconstruction
- Excellent b-tagging in jets
- Electron, muon, tau, b- and c-hadron reconstruction

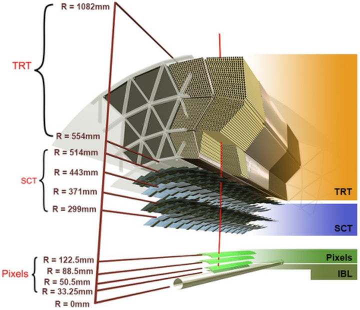


The Inner Detector overview

Immersed in 2T solenoid magnetic field:

- 80M channel Pixel Detector, resolution $10 \times 115\mu m$ + new IBL 4th Pixel layer with planar & 3D silicon sensors, resolution $8 \times 40\mu m$
- 6M channel Silicon microstrips (SCT), resolution $17 \times 580\mu m$
- 350k ch. Transition Radiation Tracker (TRT), resolution $\sim 130\mu m$

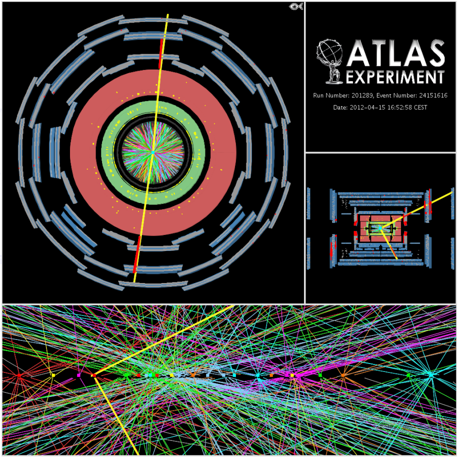




ATLAS tracking challenge in Run 2

The LHC underwent several upgrades during the long shutdown period: beam energy 7 TeV $\rightarrow$ 13 TeV, bunch crossing 50 ns $\rightarrow$ 25 ns, luminosity increase $\Rightarrow$ stress on detector hardware and software:

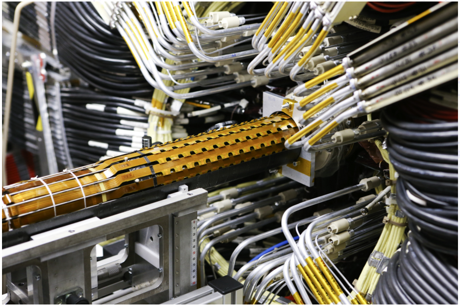
- High pile up - in Run 1 up to 40 *pp* interactions per bunch crossing.
  - High detector occupancy.
  - Non-zero rate of Single Event Upsets (SEUs)
- Optimize pattern finding and reconstruction algorithms for dense environment.
- Improvement in computing models to handle trigger rate and large event size



Inner detector upgrade during LS1: Pixel and IBL

The Pixel Detector was extracted and serviced on surface:

- Repaired all accessible failures
- On-detector services replaced and opto electronics moved to off-detector location for improved accessibility
- New optical links installed with an increase data bandwidth capability for Run 2 for L1/L2 & beyond ($3 \times 10^{34} cm^{-2} s^{-1}$)

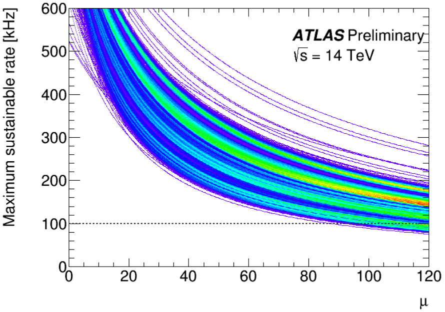


New insertable B-layer (IBL) :

- additional pixel layer at 33 mm from beam line
- IBL assures better track and vertex reconstruction performance at high luminosity expected during run 2 and mitigates the impact of radiation damage to the B-layer.

Inner detector upgrade during LS1: SCT

- Upgrade/expansion of SCT DAQ
- Installation of an additional 38 Read-Out Drivers (RODs) to remove a critical DAQ bottleneck, allow to read out the SCT up to $3 \times 10^{34} cm^{-2} s^{-1}$ (at 25ns bunch spacing)
- Installation of new TX optical engines in the Back Of Crate (BOC) cards.



- ROD firmware upgrade
  - Auto recovery of modules with non-zero errors.
  - Periodic reconfiguration to protect against the spontaneous corruption of the configuration (single event upset).
  - Stop-less reconfiguration & reintegration of RODs in case of busy.

Inner detector upgrade during LS1: TRT

- Acive gas issues:
  - Leaks of Xenon developed at the end of Run1
  - Leaks in end-cap successfully repaired
  - DCS system for leak control implemented
  - Operation scenarios prepared: parts of TRT will run with Ar-mixture
  - Performance was tested and it was demonstrated that the tracking properties are not changed.
  - TR performance is still supported with other parts of the TRT running with Xe mixture
- DAQ enhancement for high intensity and high occupancy running.
- HV PS improvements to provide protection against HV overshoot at the beam dump.
- PID improvements for high luminosity/occupancy

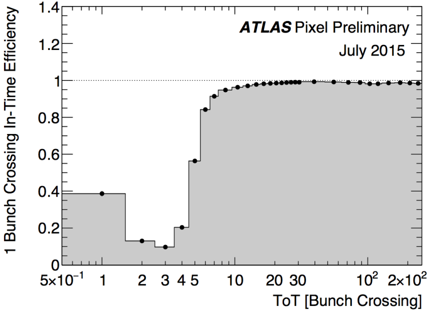
Inner Detector active coverage

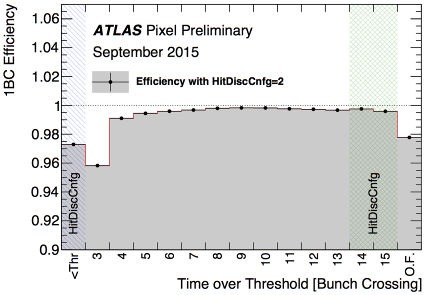
Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	98.2%
SCT Silicon Strips	6.3 M	98.6%
TRT Transition Radiation Tracker	350 k	97.3%

- For the Pixel status:
  - 3-Layers Pixel (80 M channels) - 98%
  - IBL (12 M channels) - 99.5%
- SCT expected to rise to 98.9% after including temporarily disabled modules.

Pixel and IBL Performance - Detector Timing

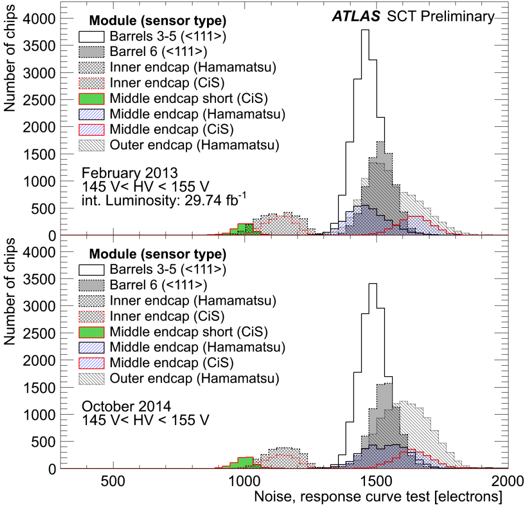
- Time-over-Threshold (ToT, length of discriminator signal); depends on deposited charge, discriminator threshold and feedback current.
- Pixel Detector re-timed in during early 50 ns runs
  - Hits with ToT ≤ 7 recovered by "hit duplication" mechanism from next BC
- IBL Maintained nearly 100% efficiency for 1 BC readout
  - For the 25 ns run, hits with TOT$\leq$2 (suffering from time-walk) recovered thanks to FE-I4 special functionalities (HitDiscCnfg).





SCT Performance - calibration

- Noise comparison between end of Run 1 and pre-Run 2 data.

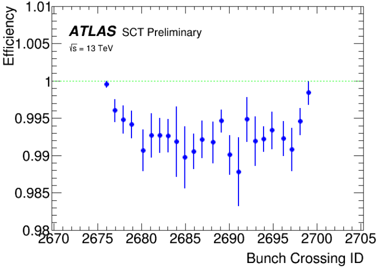


SCT Performance at 25 ns

All SCT performance metrics are comparable to Run1, except for the impact on hit efficiencies with 25ns.

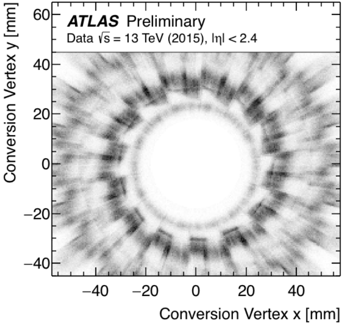
- SCT reads–out three time bins per strip: previous BC, current BC, next BC (XXX)
- Online reads–out via X1X; offline require 01X to reject ghost tracks from previous BC
- but strips, that are hit again in the current BC are lost ⇒ 0,5 % hit efficiency drop

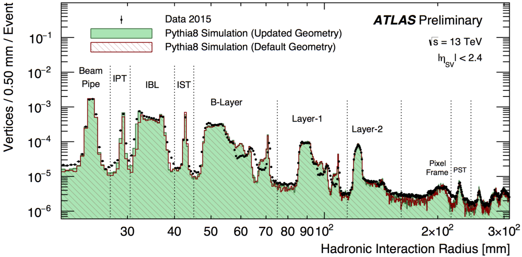
The intrinsic SCT hit efficiency can be determined using the first bunch in the train.



Combined performance - ID material studies

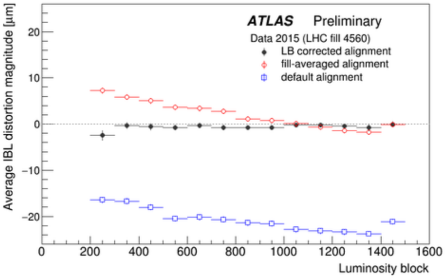
- IBL, new Beam Pipe and Services$\Rightarrow$ additional material.
- Material studies using hadronic interactions and conversions have led to a new geometry for simulations.

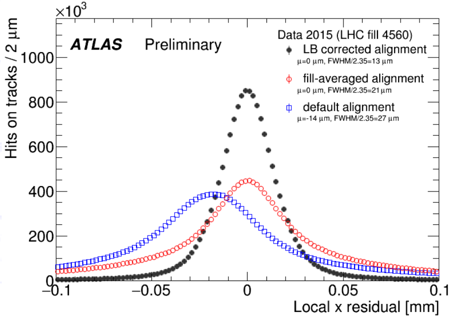




Combined performance -Alignment

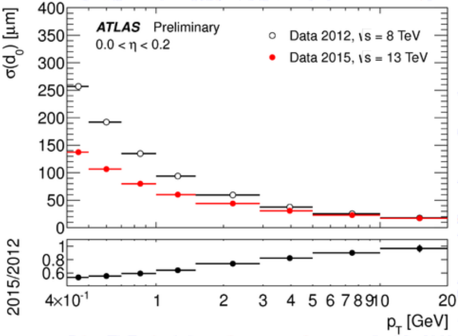
- 13 TeV *pp* collisions used to align Inner Detector with a track based algorithm. ID stable at a μm level under regular operational condition.
- Special focus on the IBL detector - observed distortion related to $\triangle T$
- Alignment corrections for fill and lumi blocks mitigate the effect of of the IBL distortion.

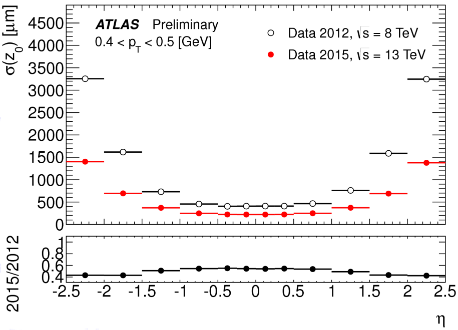




Combined performance - Track impact parameter

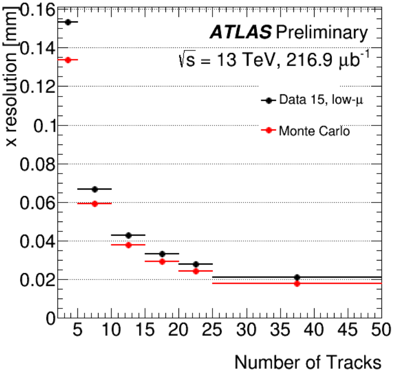
The impact parameter resolution improved with IBL.

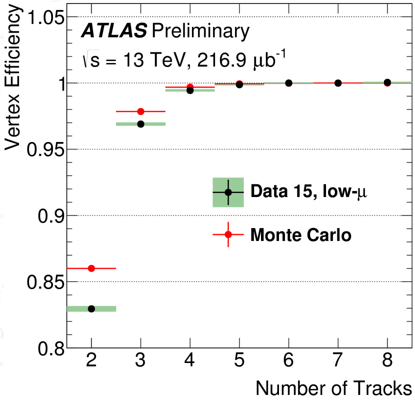




Combined performance - Vertex reconstruction

- Vertex reconstruction performance studied in 13 TeV data with low- and high- number of *pp* interactions per bunch crossing (μ).
- The simulation describes the data reasonably well





Summary and outlook

- TRT, SCT and Pixel Detector + IBL (re)commissioned after LS1 upgrades with 13 TeV data
- All subsystems proved to work reliably with 13 TeV collissions at 25 ns bunch crossing
- Combined Inner Detector tracking performance improved with respect to Run-1 thanks to IBL.
- Looking forward to more data in 2016!

Thank you for your attention!