New developments in track reconstruction for the ATLAS experiment for Run-2 of the LHC

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*on behalf of the **ATLAS** Collaboration*

ICHEP, Chicago

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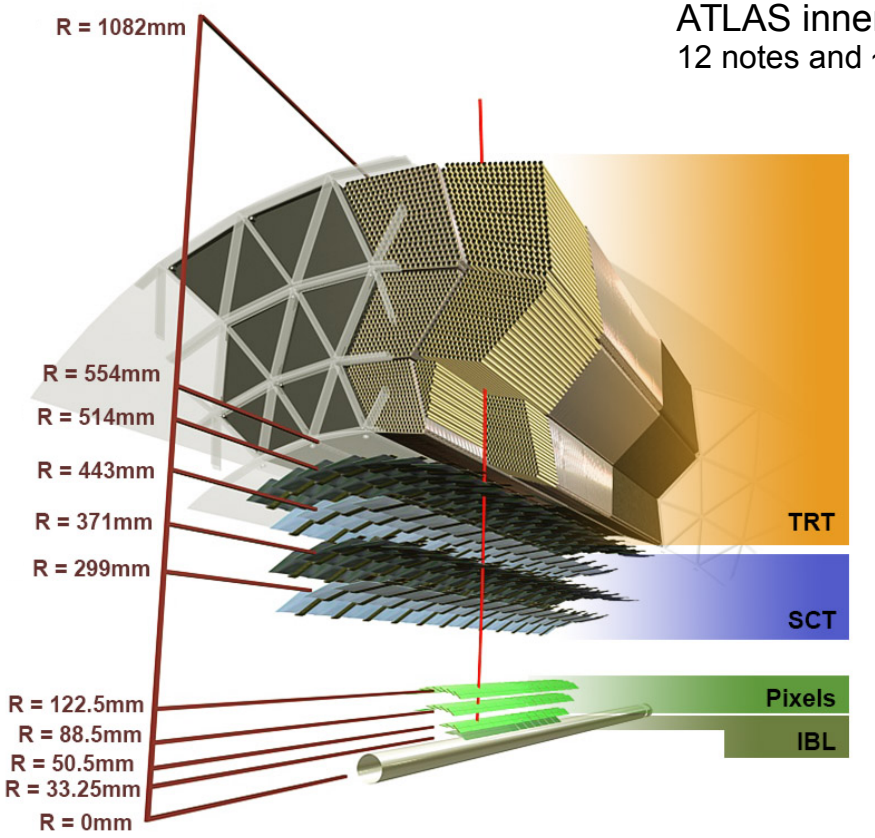
Introduction

ATLAS inner tracking results public page:
12 notes and ~20 set of plots on Run-2 data



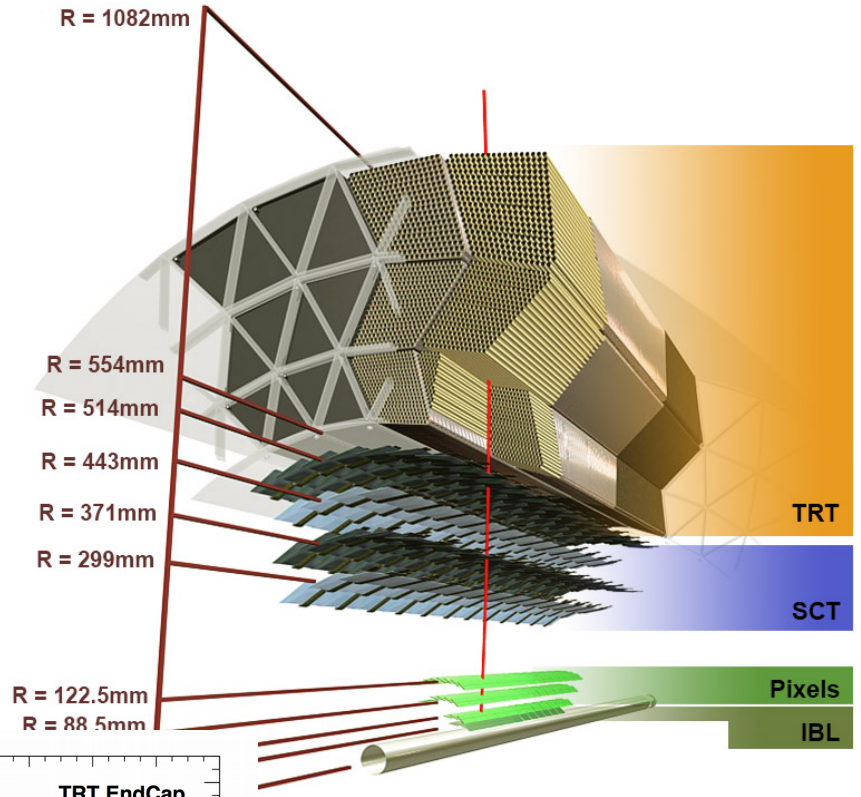
- **Improvements** over Long-Shutdown 1 (2012-2014) algorithmic and technical developments
- **Stability** against rapidly changing conditions of detector and LHC
  - data-driven measurements of key observables and comparison with simulation

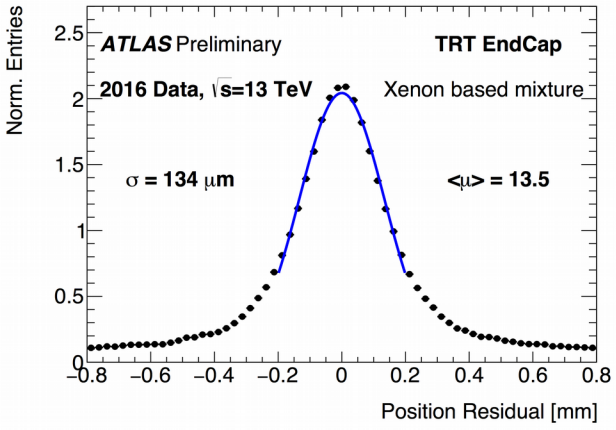
Run-2 ATLAS Inner Detector

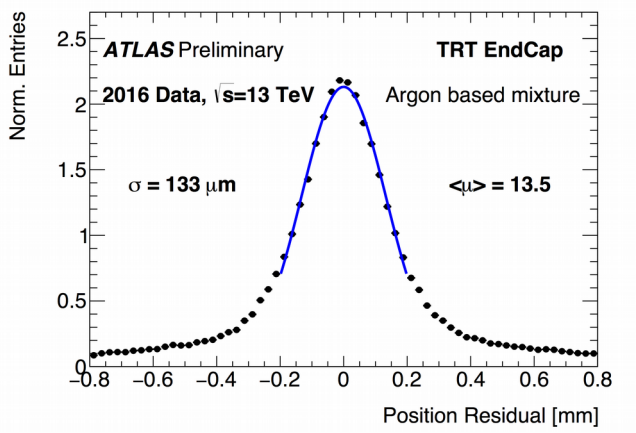
Transition radiation tracker
73 barrel and 160 end-cap planes
<hits> / track ~ 30

- Gas leaks developed ~end of Run-1
- Repair work during LS1
- Using *Ar* instead of *Xe* in regions where leaks could not be repaired

- Flexible approach to describe performance under different gas configurations





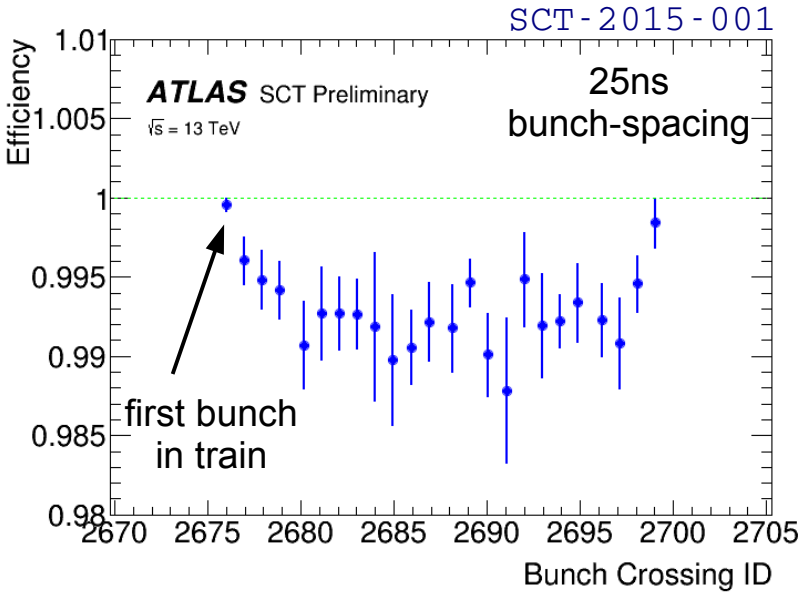


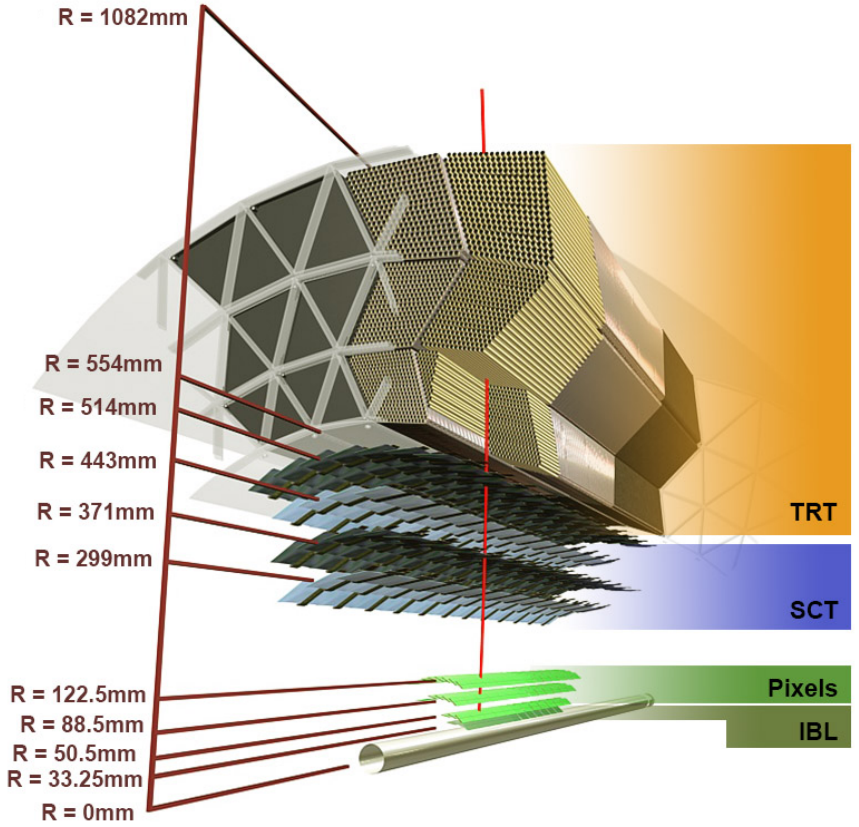
- Almost no effect on hit resolution
- Particle Identification slightly degraded

Run-2 ATLAS Inner Detector

Strip detector
4 double-sided barrel layers
and 2x9 end-caps
<hits / track> ~ 8

- 3 bunch-crossings read-out
- Veto signal in previous bunch crossing

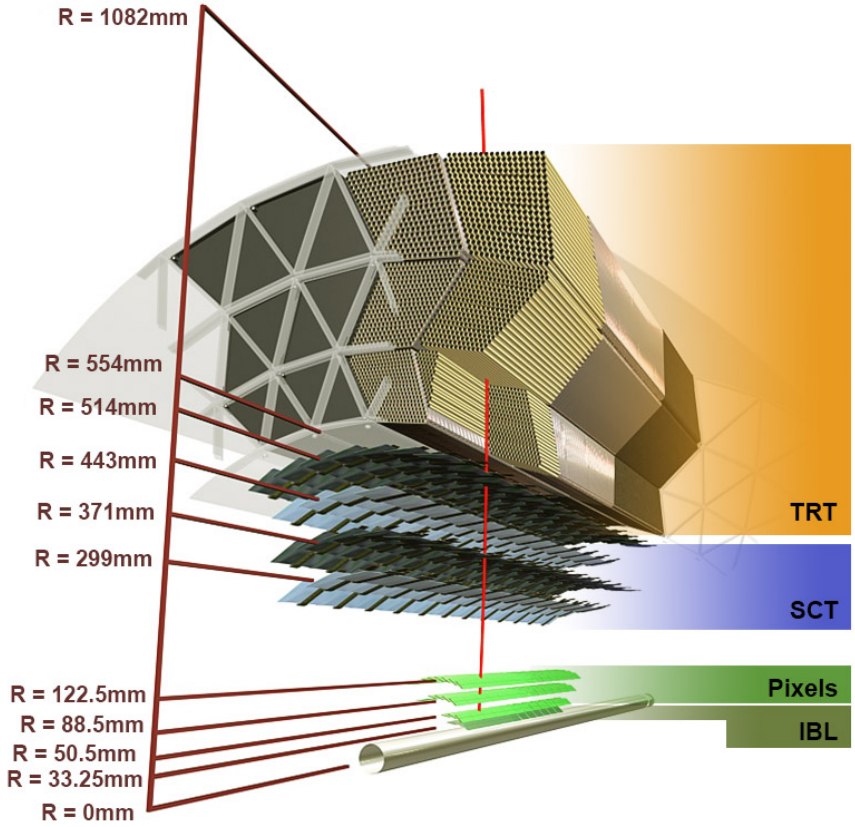




- Reduced bunch-spacing causes hit inefficiencies after the first bunch in the train
  - tiny effect on track reconstruction efficiency

Run-2 ATLAS Inner Detector

Pixel detector
4 barrel layers, 2x3 end-caps
including Insertable B-Layer (**IBL**)
<hits / track> ~ 4



- IBL mechanical instability with temperature

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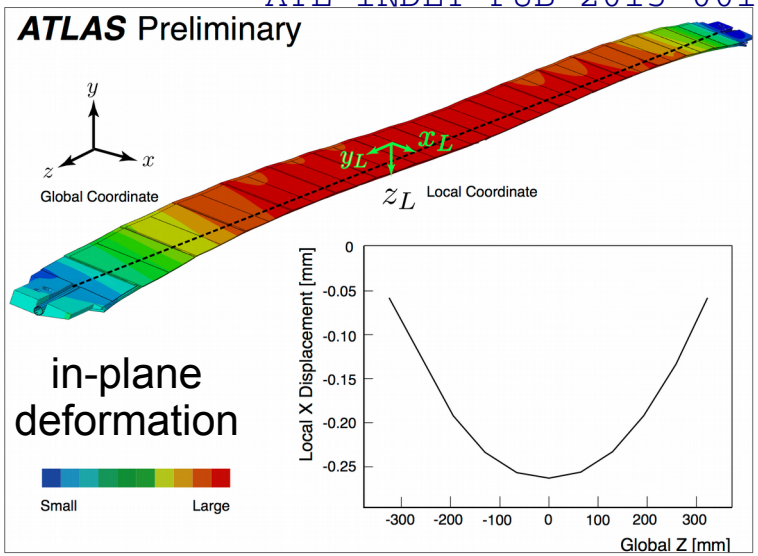
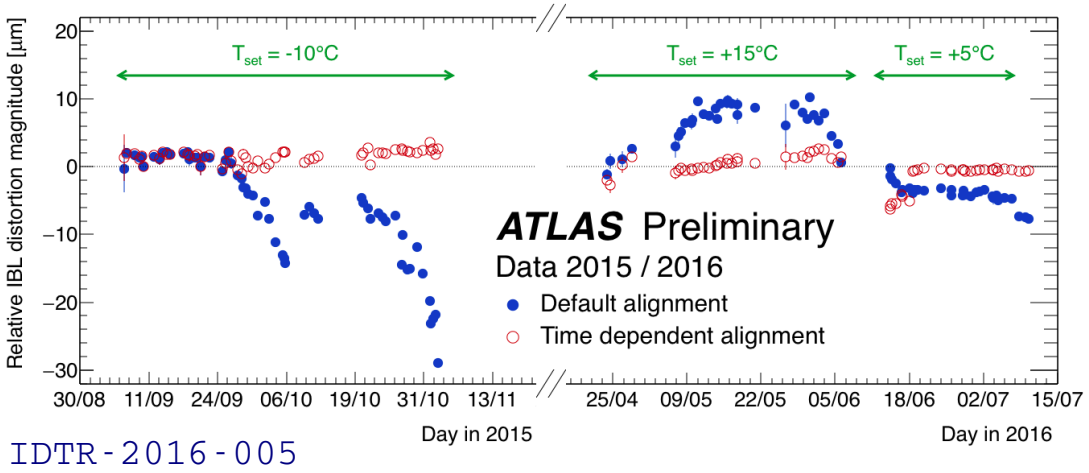


- Temperature not stable during data-taking due to radiation effects and operational constraints

Alignment

- Fit IBL distortion during “calibration loop”
  - detector re-aligned before offline processing after each run with ~1h time granularity



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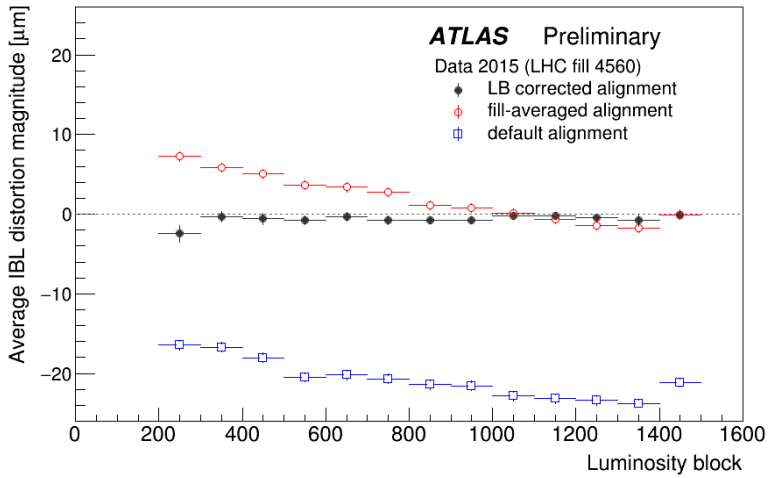
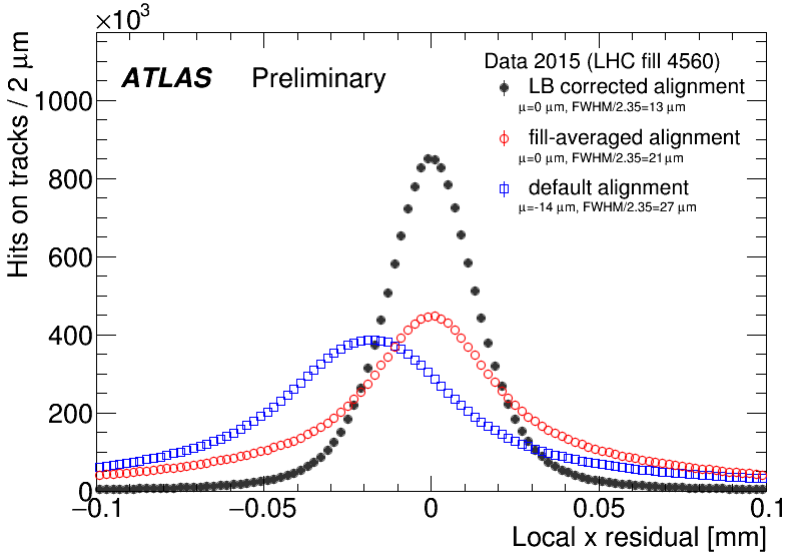
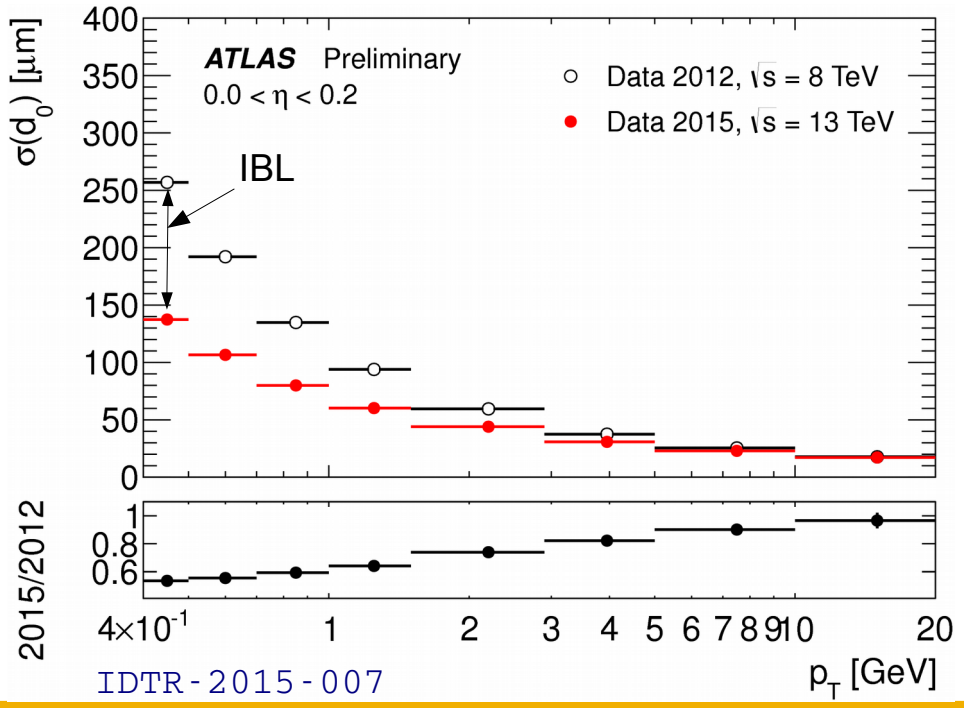


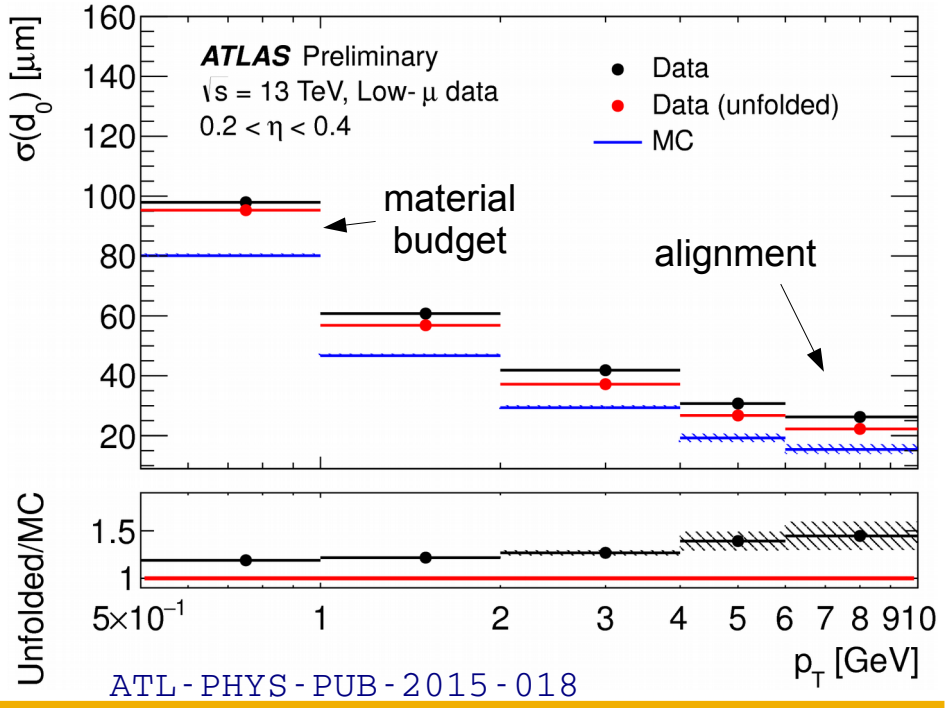


- Excellent alignment accuracy achieved
  - comparable or better to end of Run-1
  - capability of time-dependent re-alignment of full Inner Detector

Track impact parameter resolution

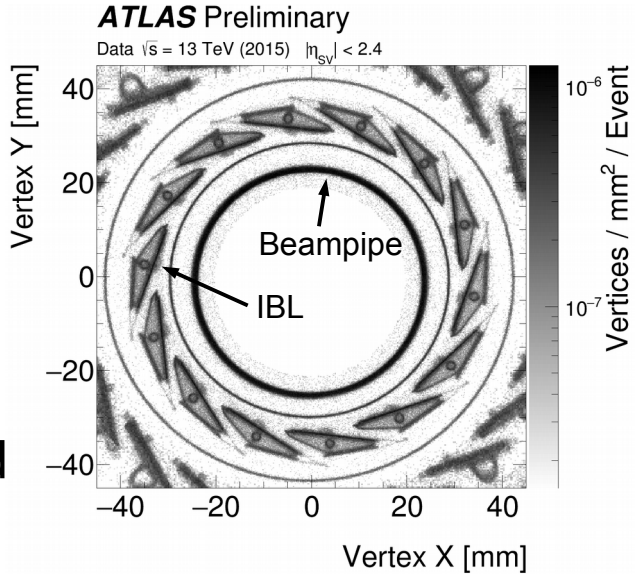
- Improved d_0 resolution in Run-2 thanks to IBL
- Measurement of d_0 resolution sensitive to
  - Alignment, intrinsic resolution at high p_T
  - Material budget at low p_T
- Material budget studied using in-situ techniques

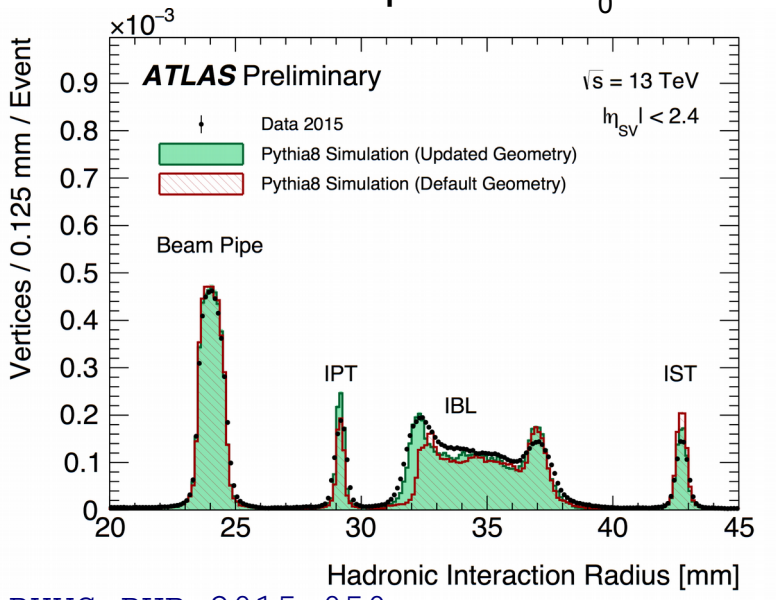


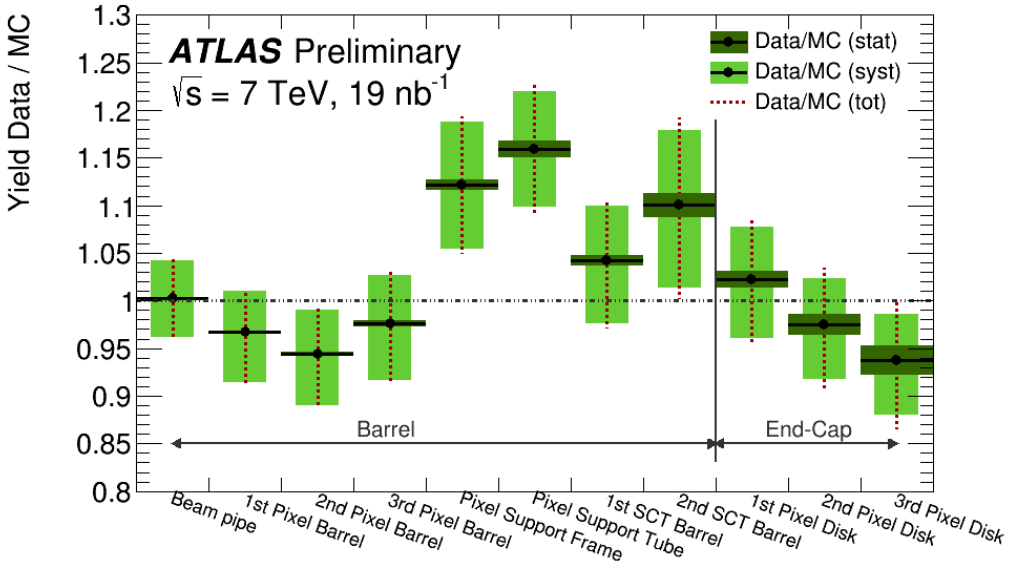


ID Material measurements

- Material budget probed using techniques complementary in systematics and coverage
  - vertices from hadronic interactions
  - photon conversions
  - pixel → SCT extension efficiency
- Initial under-estimation of IBL material corrected
  - cause of over-optimistic d_0 resolution in simulation







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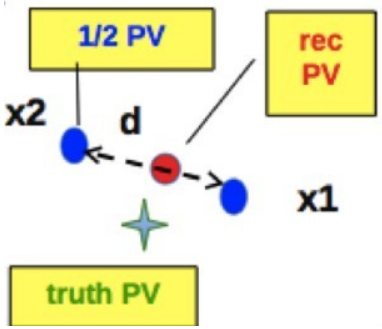
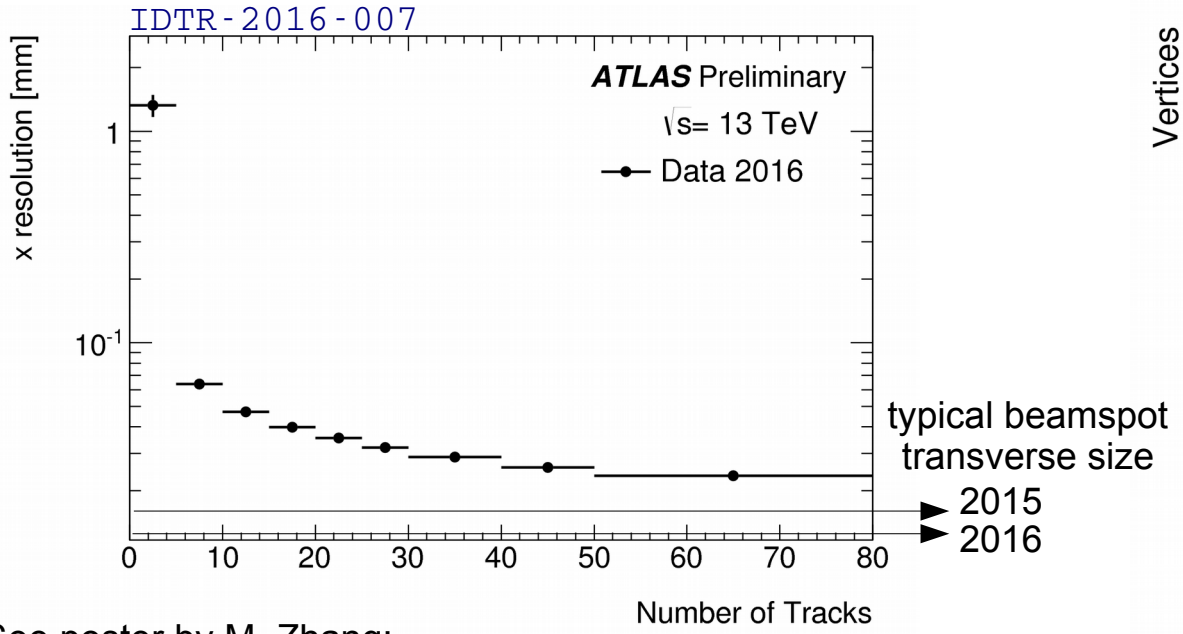
Primary Vertex reconstruction

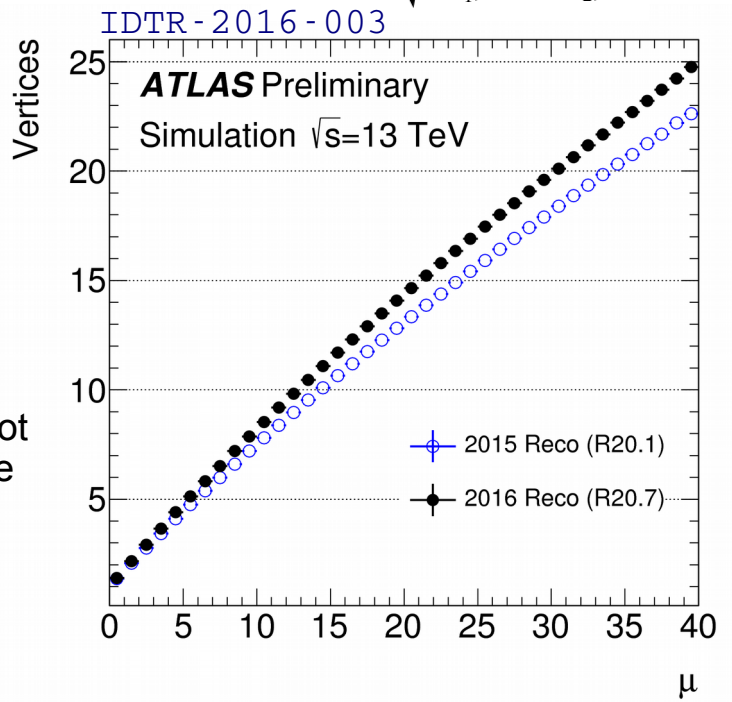
- Data-driven measurement of position resolution
  - beamspot transverse size smaller than vertex resolution!



- Algorithmic refinements for 2016 increase efficiency for high vertex densities

$$\mathrm{Pull}_x = \frac{x_{1,PV} - x_{2,PV}}{\sqrt{\sigma^2_{x_1,\mathrm{fit}} + \sigma^2_{x_2,\mathrm{fit}}}},$$

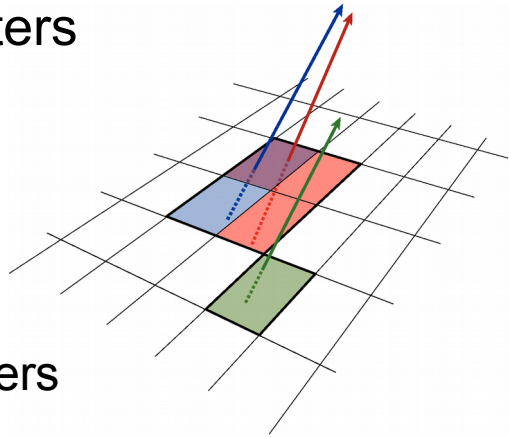




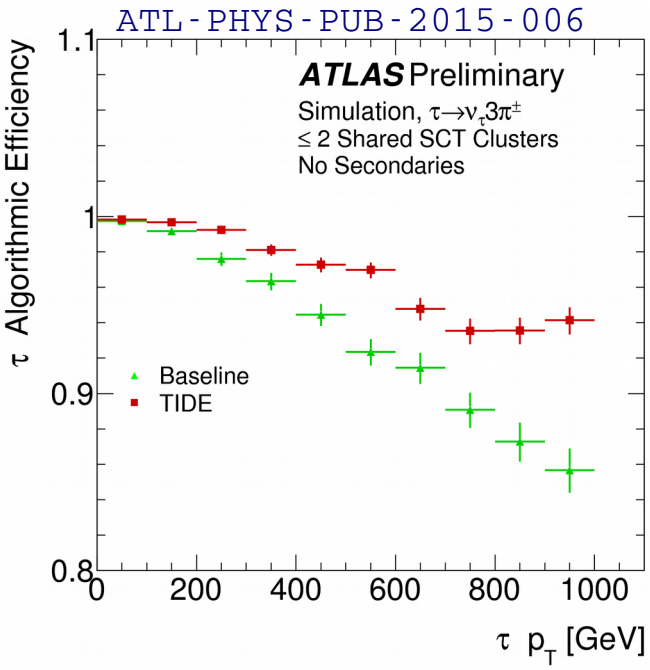
See poster by M. Zhang:
"Performance of the ATLAS primary vertex reconstruction algorithms"

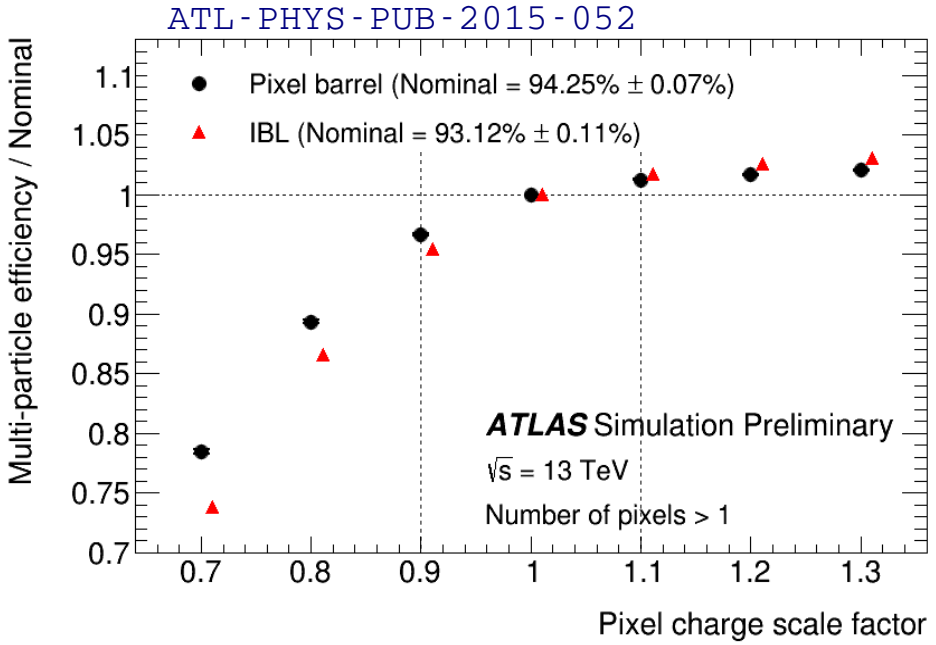
Tracking in Dense Environments (TIDE)

- Resolve close-by particles leading to merged pixel clusters without increasing fakes
  - Local approach (2012) → multivariate technique exploit information on cluster charge and shape
    - Returns # of particles, positions, errors
  - Global approach (2015) → correlate information across layers



- Verify robustness of local approach with simulation



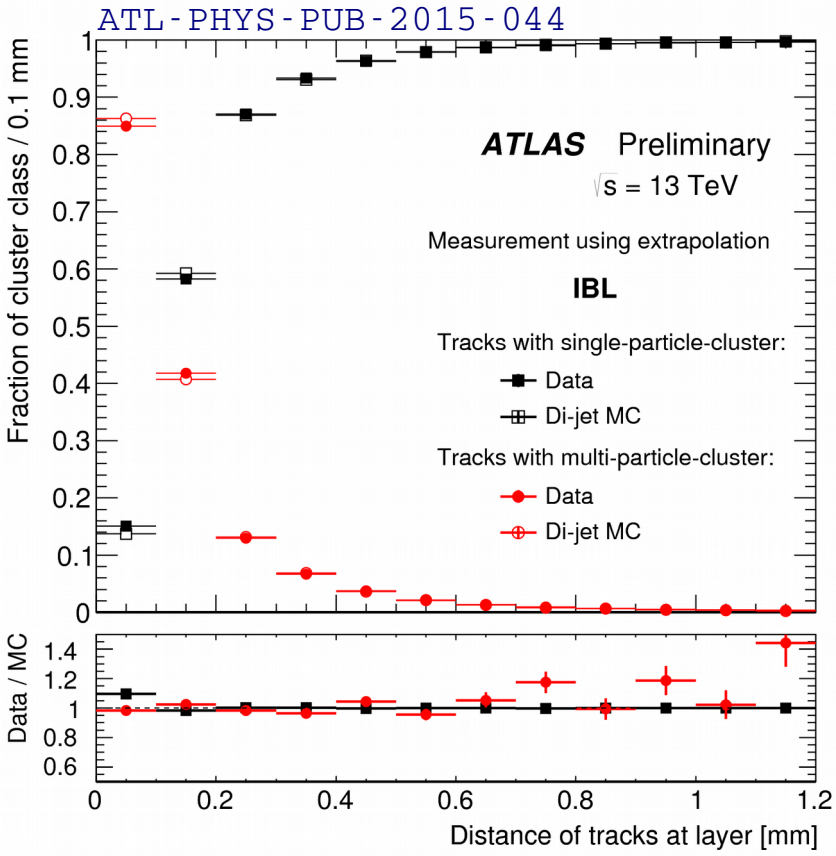


TIDE performance

- Performance measured in data with complementary techniques

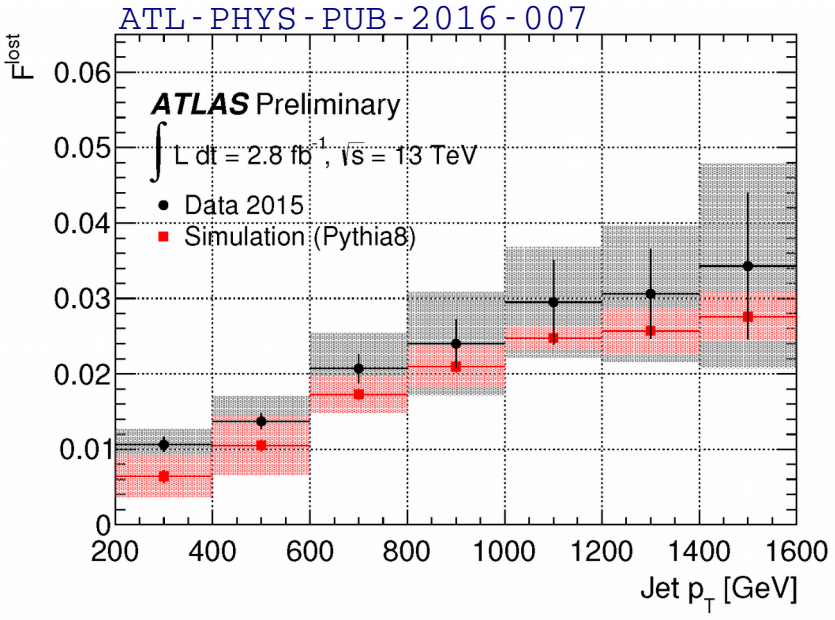
Geometrical extrapolation

- Test local approach in separating single/multiple particle clusters



Energy loss in Pixels (dE/dx)

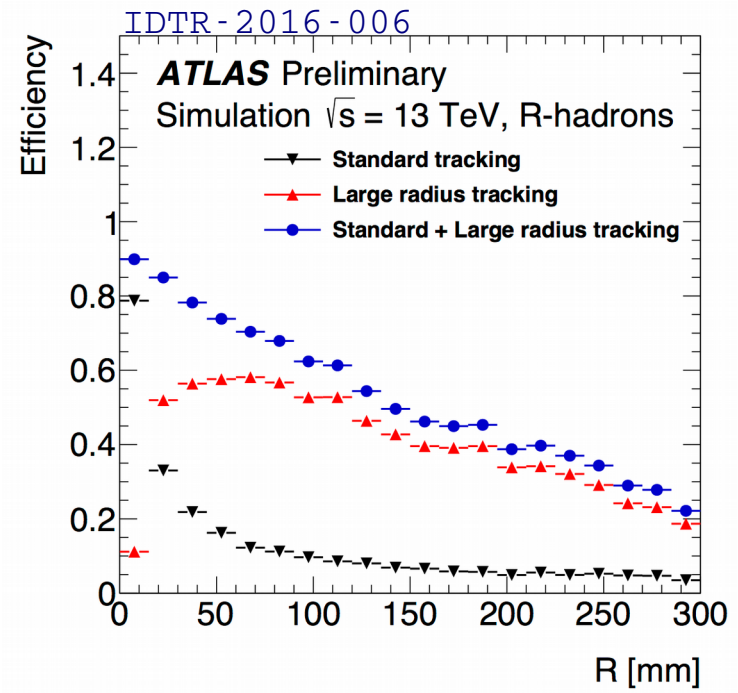
- Measure fraction of particles not reconstructed inside jets
- Statistically disentangle single/multiple particles from dE/dx in innermost layer

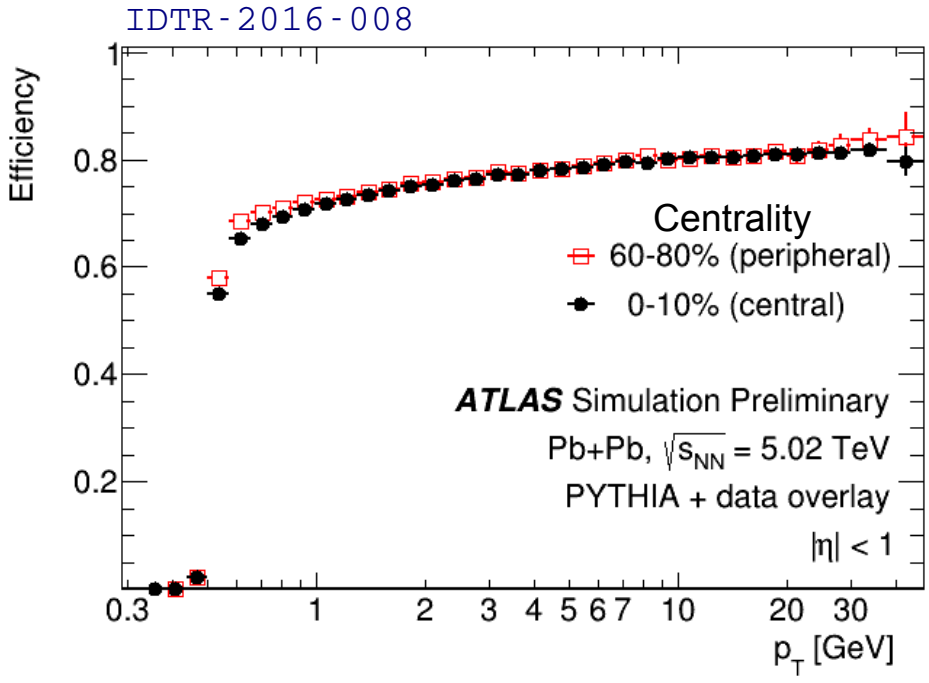


See poster by E.M. Duffield:
"Measurement of ATLAS track reconstruction inefficiency in dense jet environments using dE/dx"

"non-standard" tracking

- Dedicated tracking setup for specific needs
  - Minimum-bias → "single-interaction" mode, p_T down from 400MeV to 100MeV
  - Heavy-Ion → "high-occupancy", but p_T threshold as low as possible (300/500MeV)
  - Large-radius tracking → decay products within the whole Pixel volume (large d_0)
  - Short-tracks → pixel-only tracks. Now reconstructed by default (p_T > 5GeV)



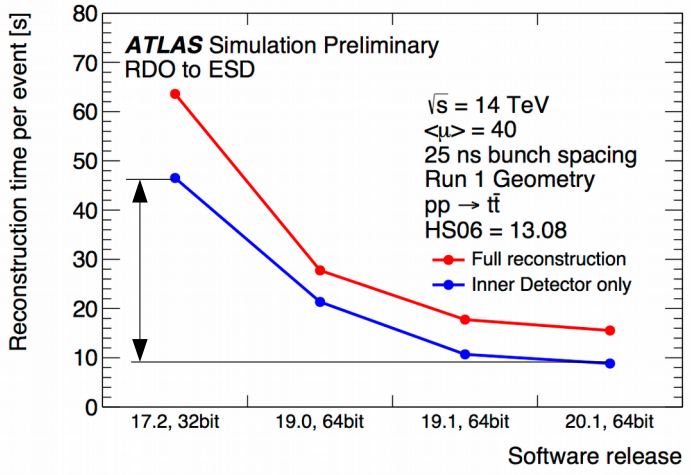


Conclusions

- Upgraded detector and rapidly changing running conditions pose new challenges to track reconstruction in Run-2

- Performed a comprehensive set of in-situ measurements of key observables

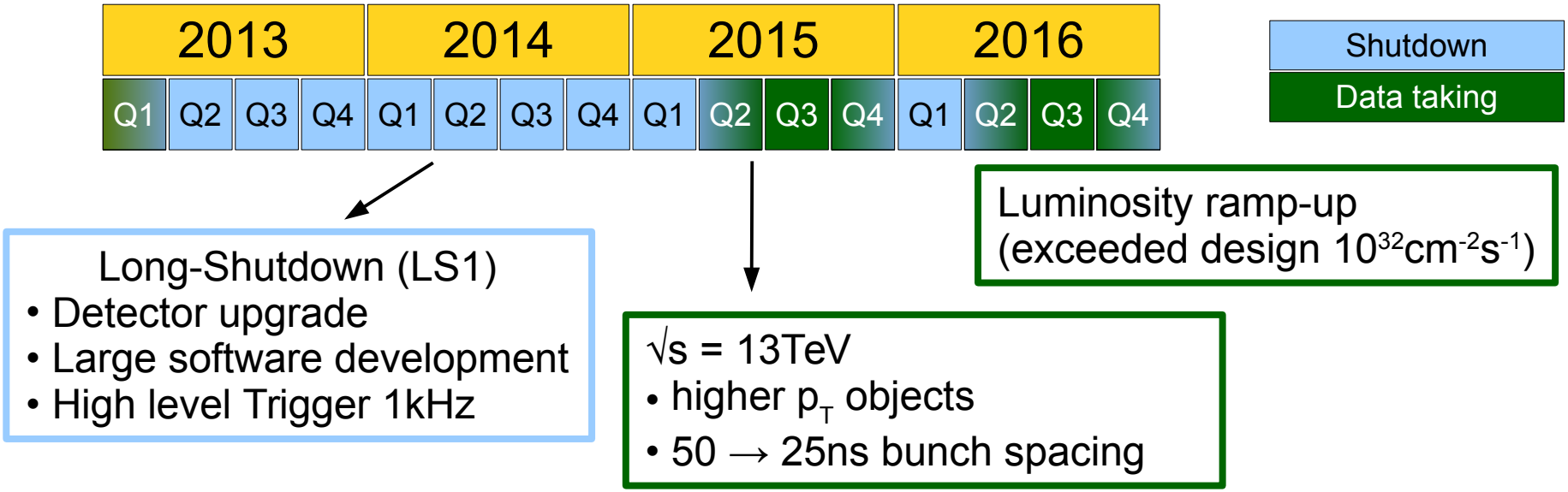
- Developed mechanisms to mitigate new problems and achieve better or similar performance than in Run-1
  - All of this reducing track reconstruction CPU timing by more than a factor of 4!



- Ready for the ongoing luminosity ramp-up to make the best use of the large dataset ahead of us

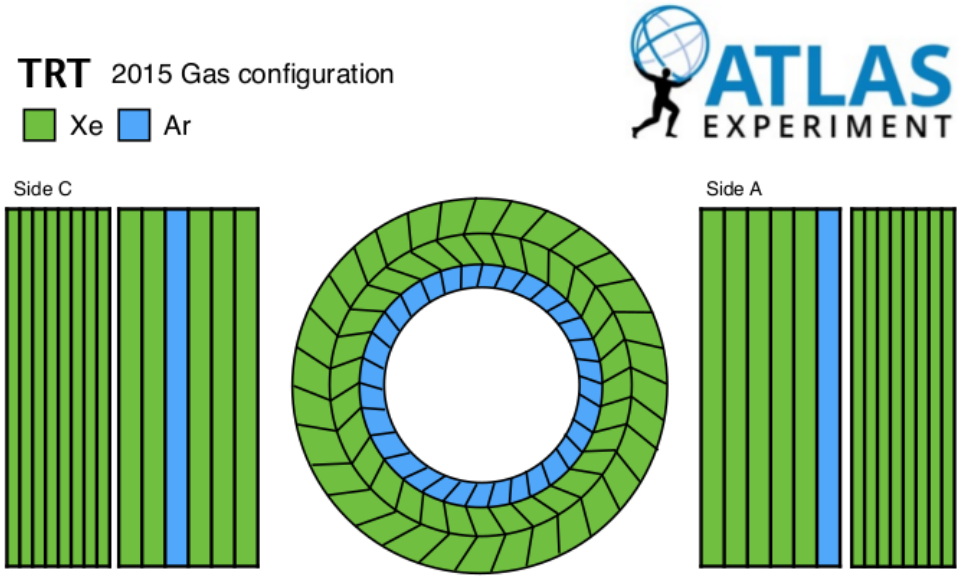
BACKUP

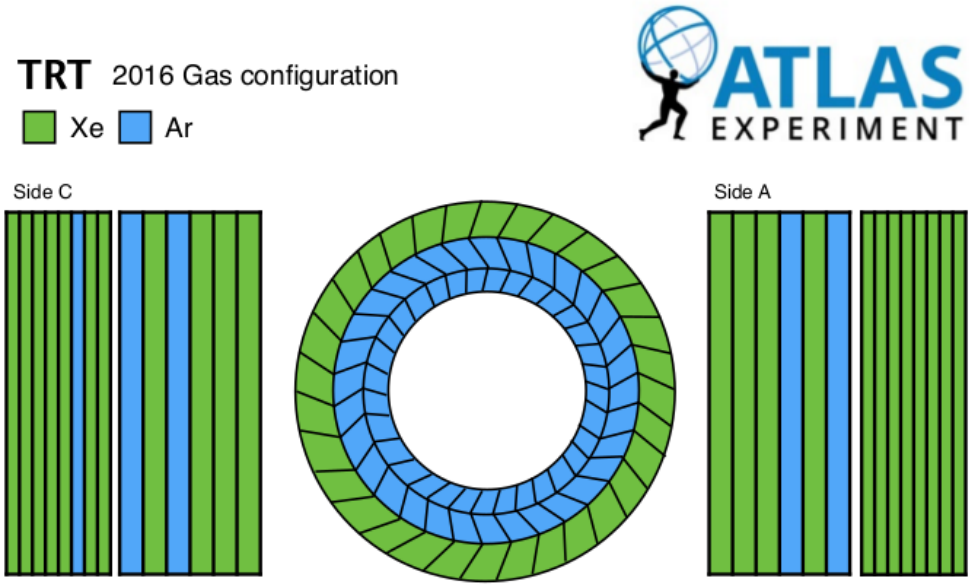
Introduction



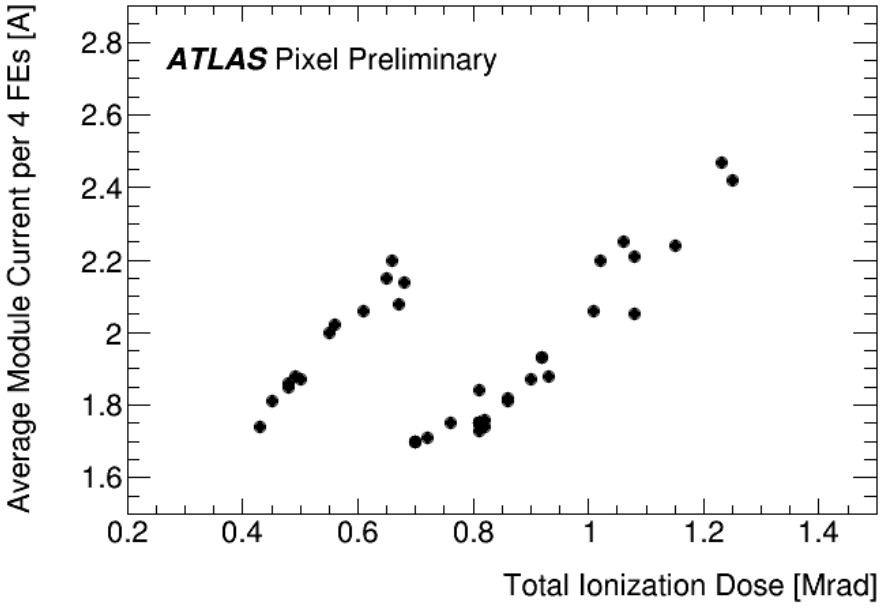
- **Improvements** over LS1 algorithmic and technical developments
- **Stability** against rapidly changing conditions of detector and LHC
  - data-driven measurements of key observables and comparison with simulation
- ATLAS inner tracking results public page:
  12 notes and 15 set of plots on Run-2 data

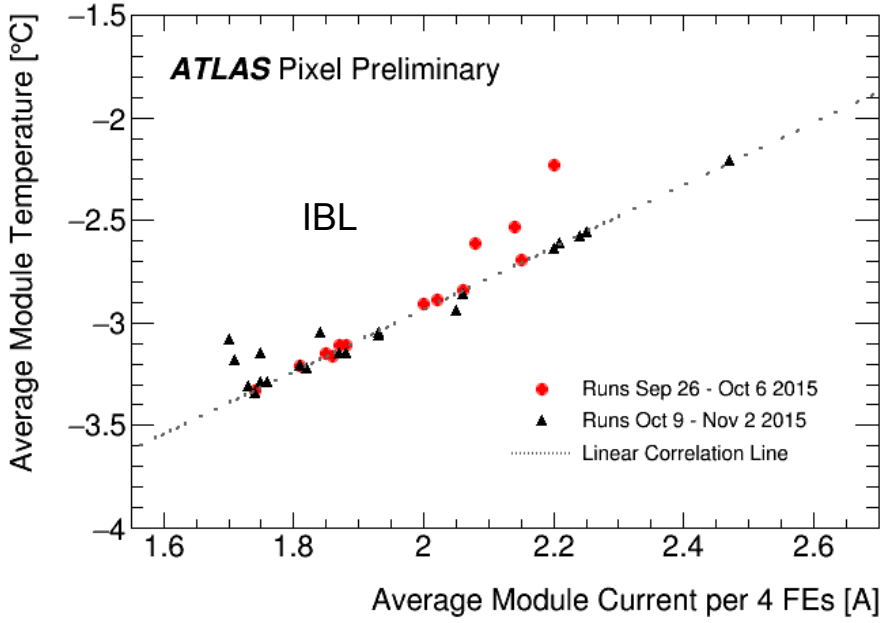
TRT gas operation





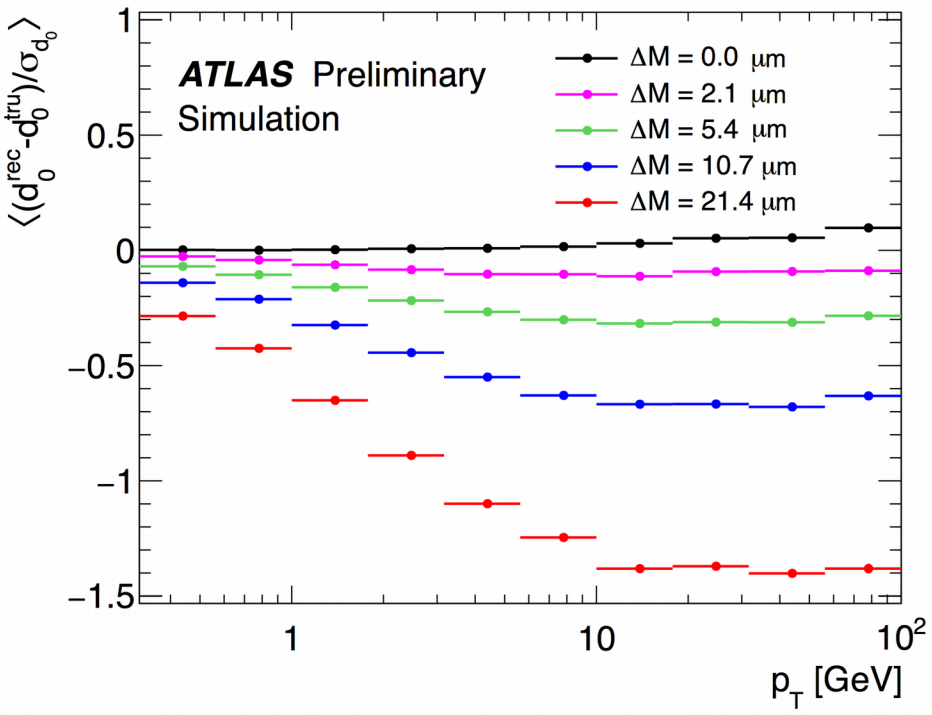
IBL LV current

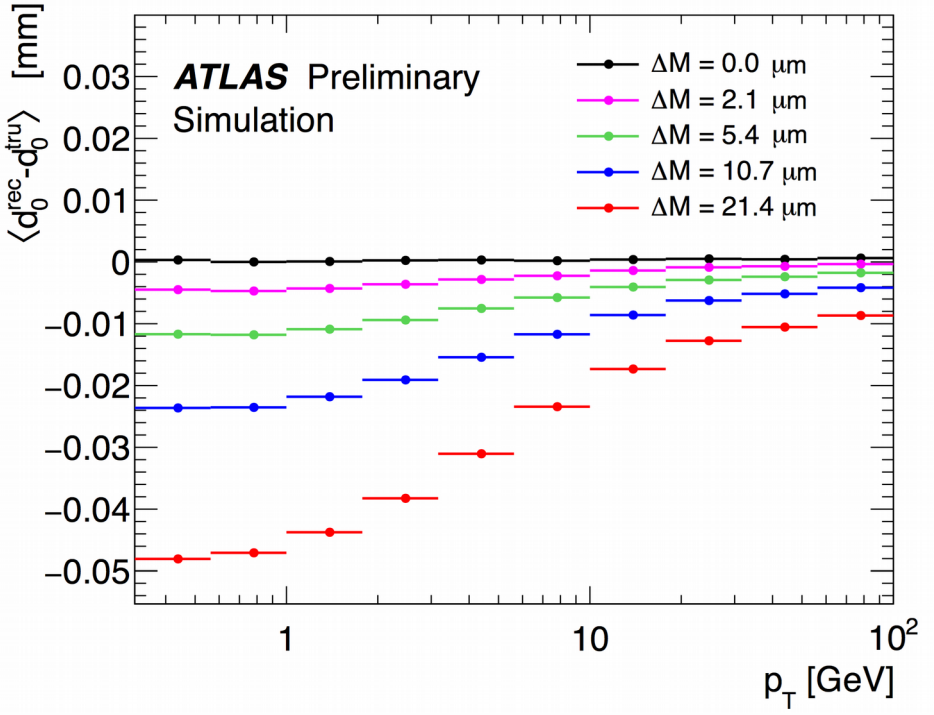




IBL distortion

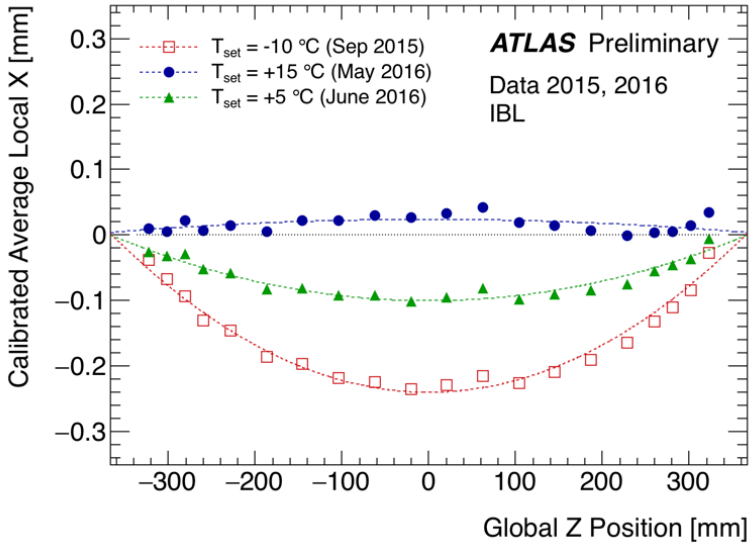
- Impact on track transverse impact parameter



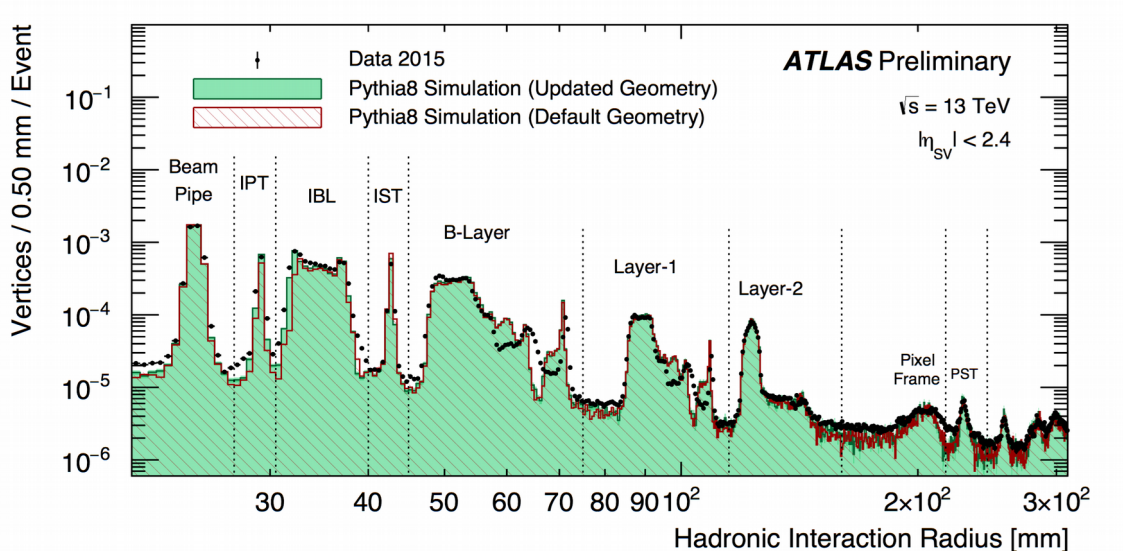


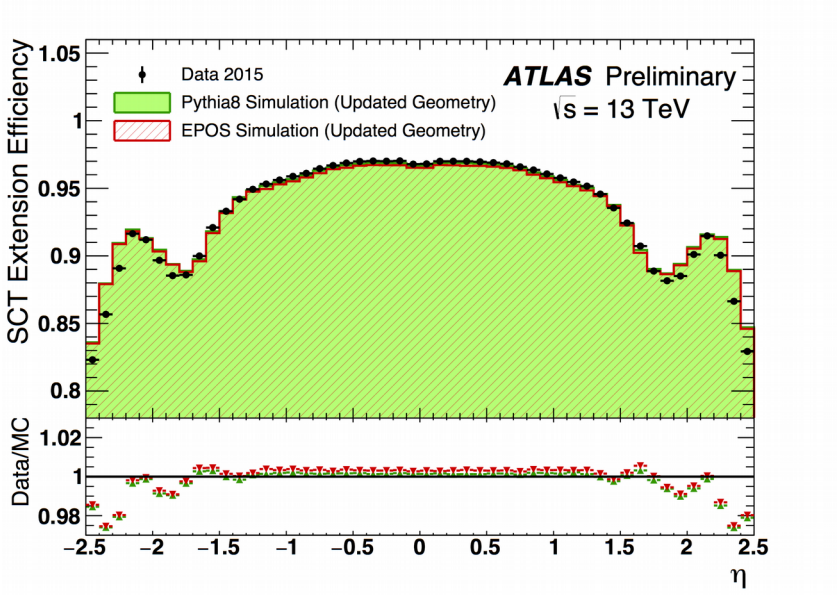
Time-dependent alignment

- IBL deformation for various operational temperatures during 2015/2016

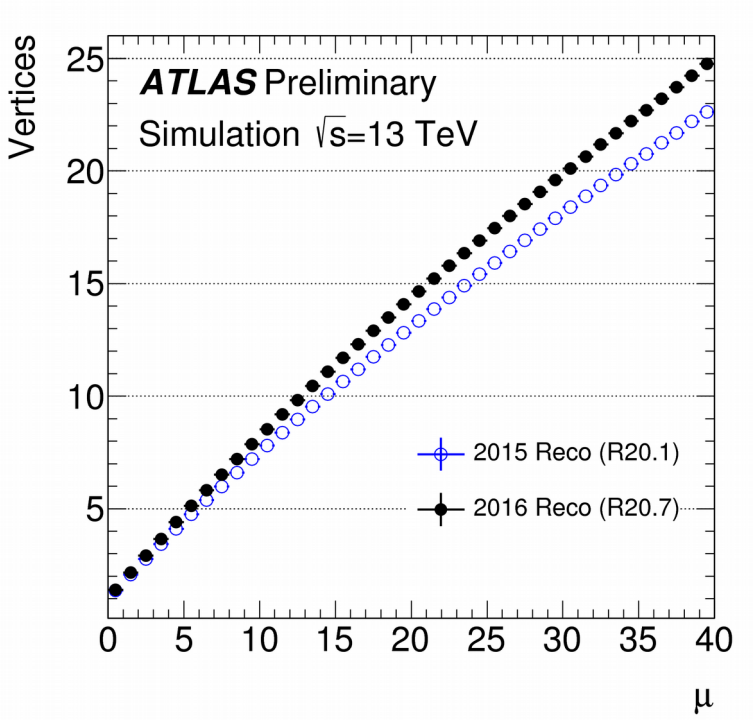


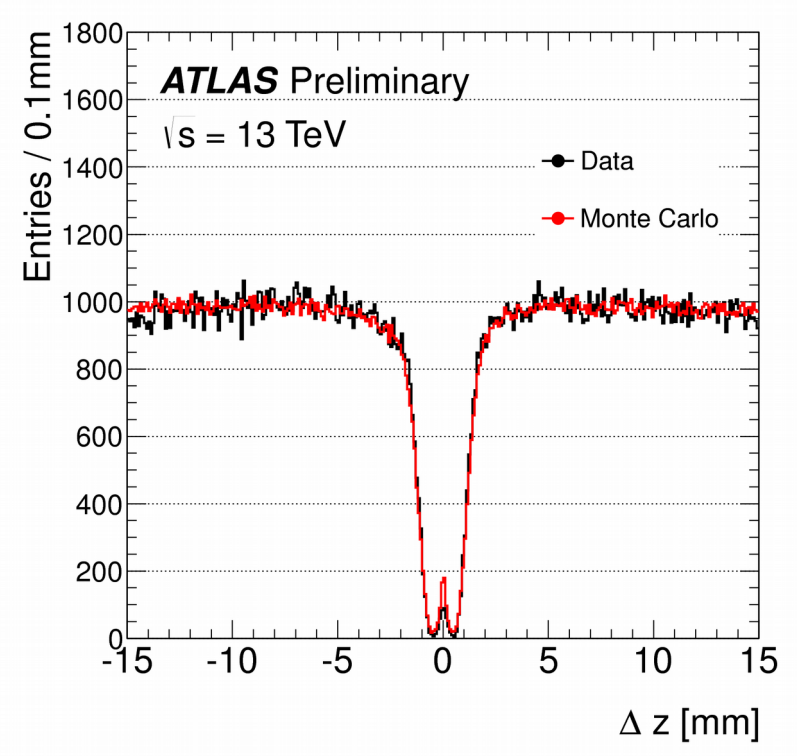
ID Material studies





Primary vertex





Primary Vertex Resolution

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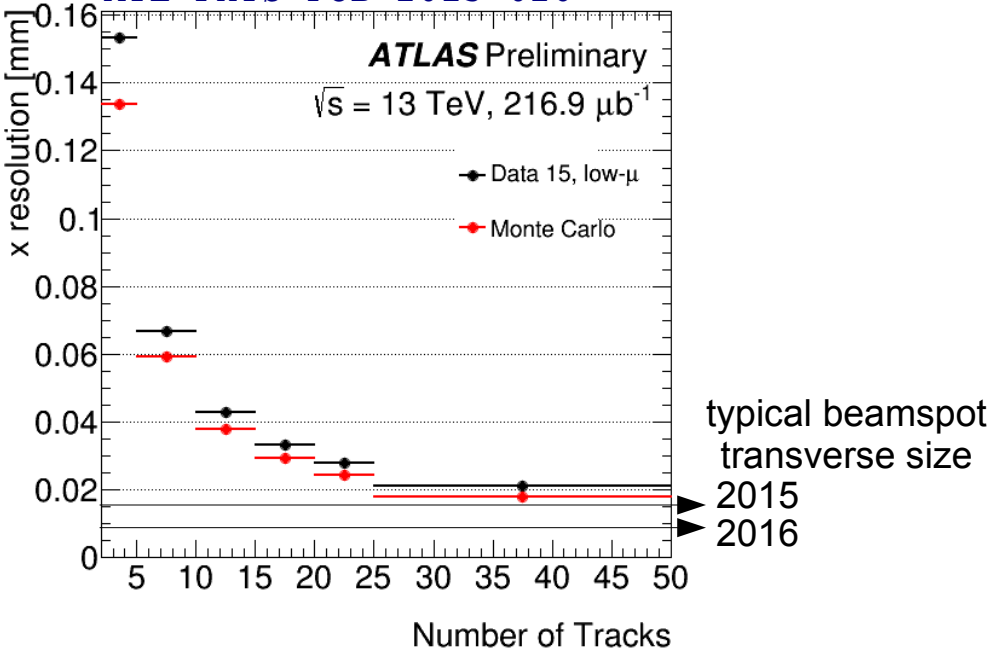
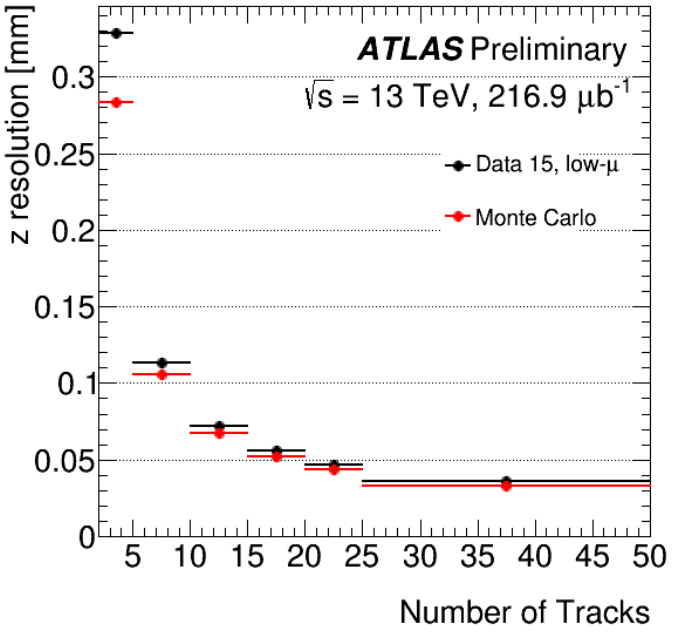
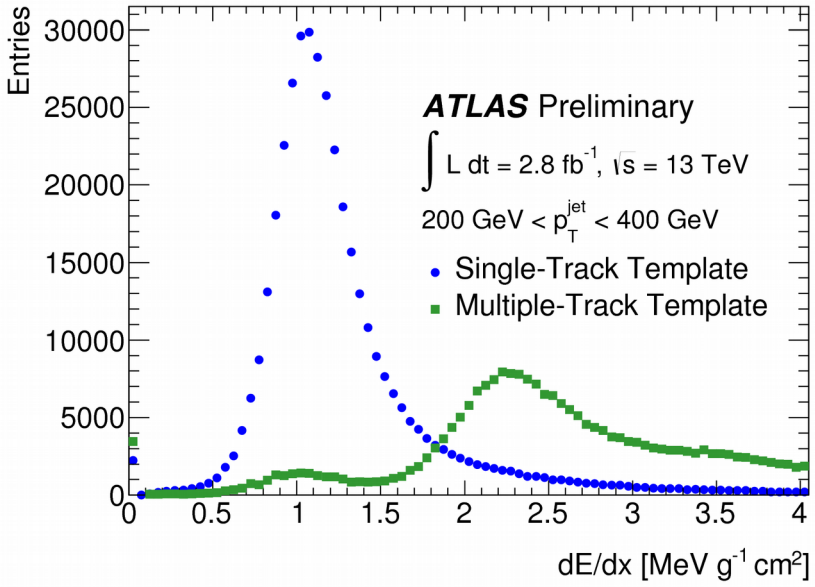
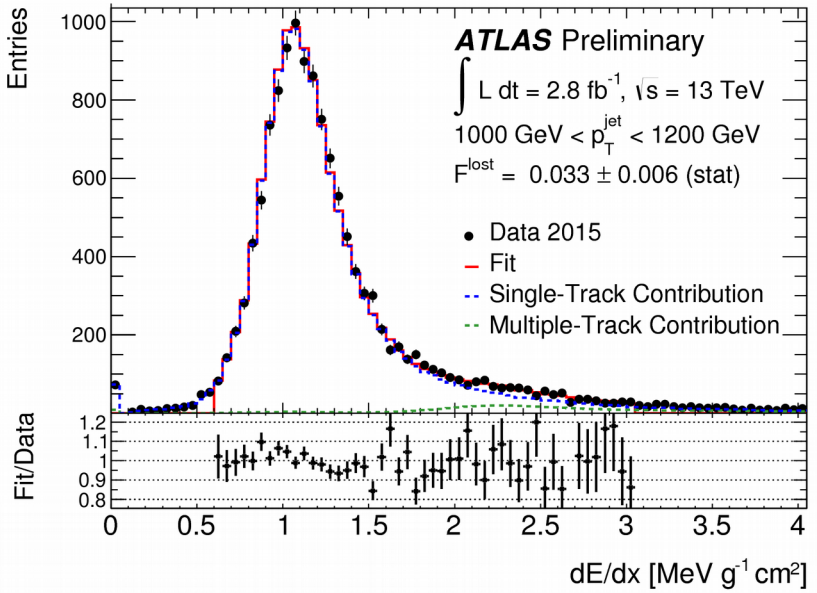
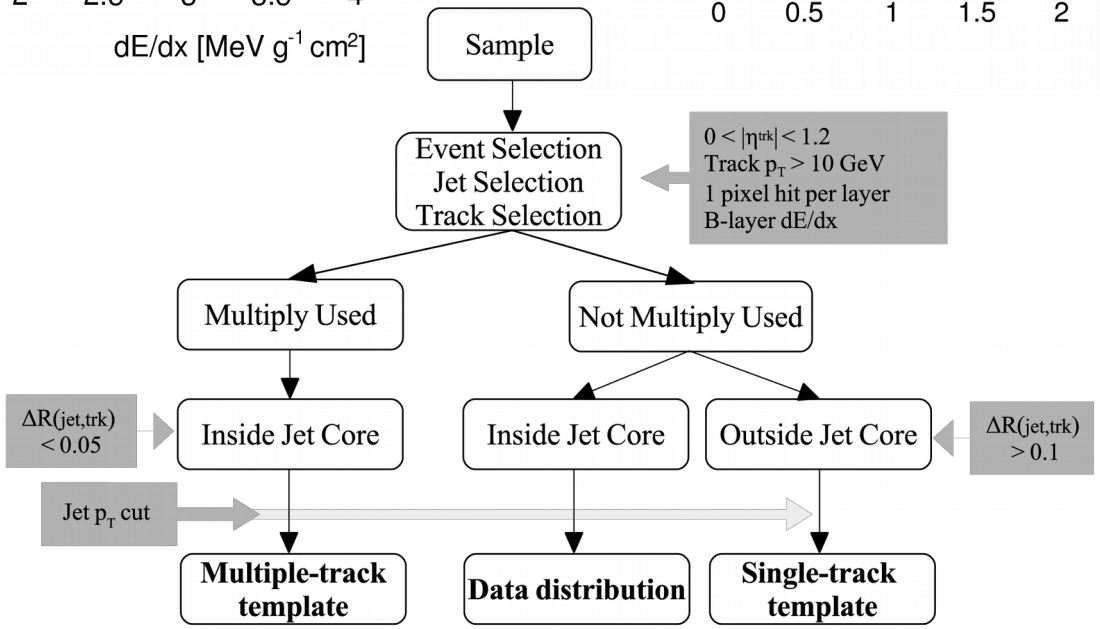




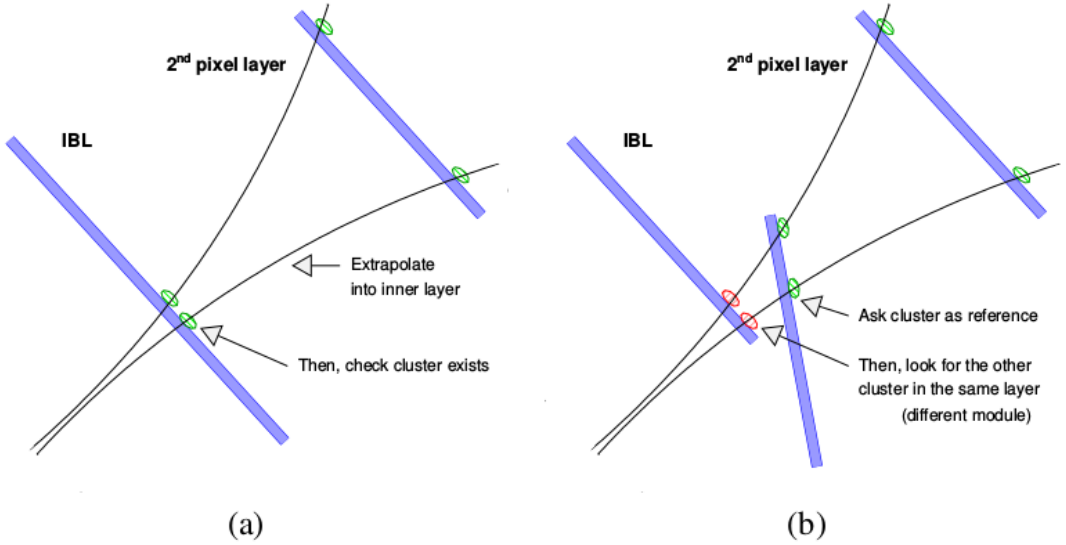
TIDE - Pixel dE/dx



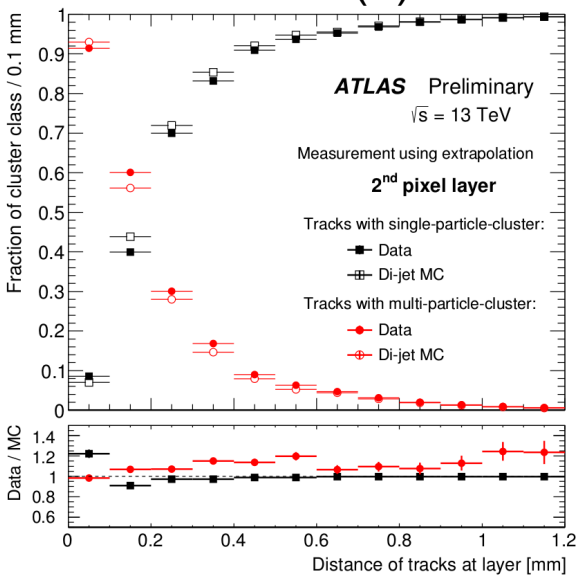




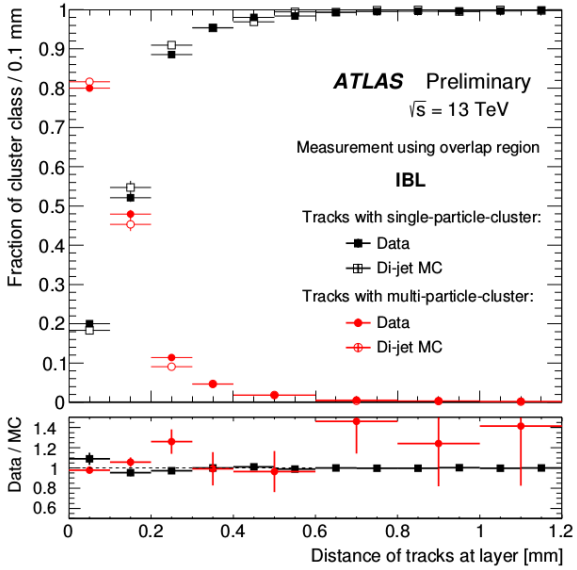
TIDE - geometrical

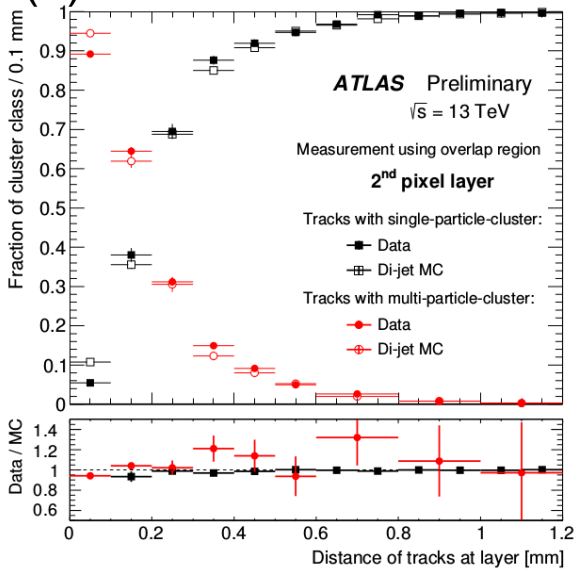


Method (a)



Method (b)





TIDE - geometrical