Performance of the ATLAS track and vertex reconstruction in the LHC Run 2

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On behalf of ATLAS Collaboration

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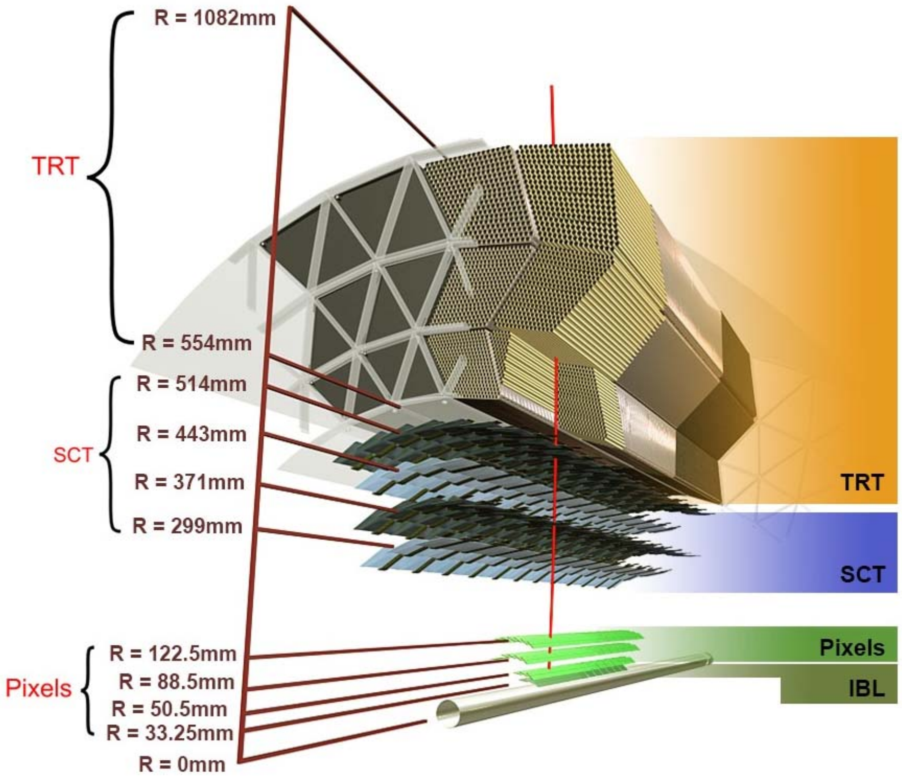
ATLAS Inner detector



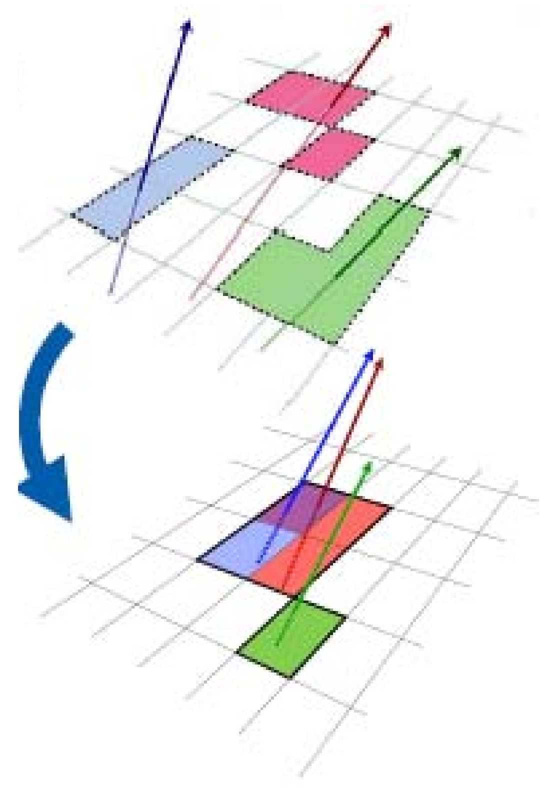
- Pixel detector
  - 4 barrel layers including a new layer (IBL) added in Run 2
    - IBL: $R_{in} = 31$ mm, $R_{out} = 40$ mm; 14 staves, total length is ~64 cm
  - 3 end-cap layers from each side
- Strip tracker (SCT)
  - 4 double sided barrel layers
  - 9 end-cap layers from each side
- Transition radiation tracker (TRT)
  - Straw tubes combined into 73 barrel and 160 end-cap planes
  - Measure track position in the plane perpendicular to the straws
  - ~30 hits per track

Challenges of tracking in Run2

- Increased luminosity and energy of collisions
  - Jets become more energetic and the track density in jets increases accordingly
  - Increased number of pile-up interactions per recorded event
- Changing conditions of the detector and accelerator
  - Mechanical instability of IBL with temperature
  - Gas leaks developed in TRT towards the end of Run1
  - Bunch spacing in LHC is decreased from 50 ns in Run 1 to 25 ns in Run 2
- These challenges require special care to achieve a similar or better tracking performance in Run 2

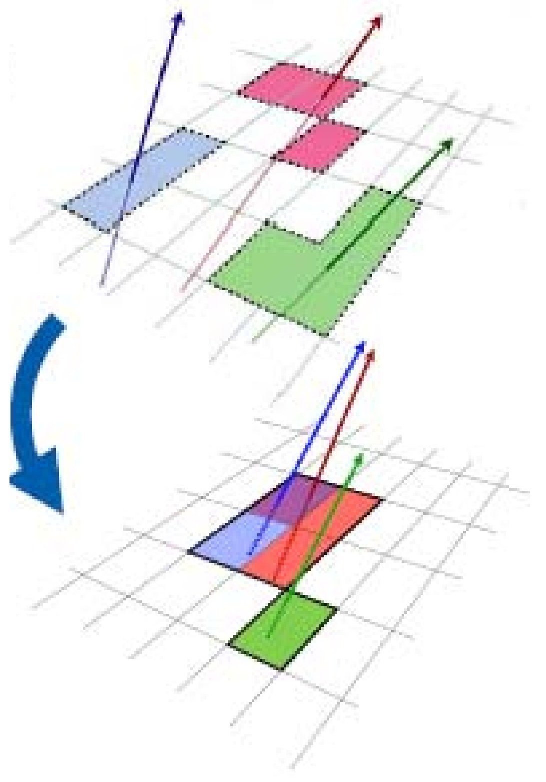
Tracking in Dense Environment (TIDE)

- For very energetic jets, spatial separation between charged particles becomes comparable with the size of sensors of tracking detectors
  - Neural Network (NN) approach to identify such clusters, determine their position and its uncertainty
- Special study of robustness of NN
  - ATLAS-PHYS-PUB-2015-052
  - NN is robust against the variations which do not change the total charge of the cluster
    - Fake rate increases by 70% when scaling up the charge in the cluster by 20%
  - Resolution of the position measurement is sensitive to subtracting charge from the cluster
    - Resolution decreases by ~10% in IBL when subtracting 400 electrons from each pixel in the cluster



Tracking in Dense Environment (TIDE)

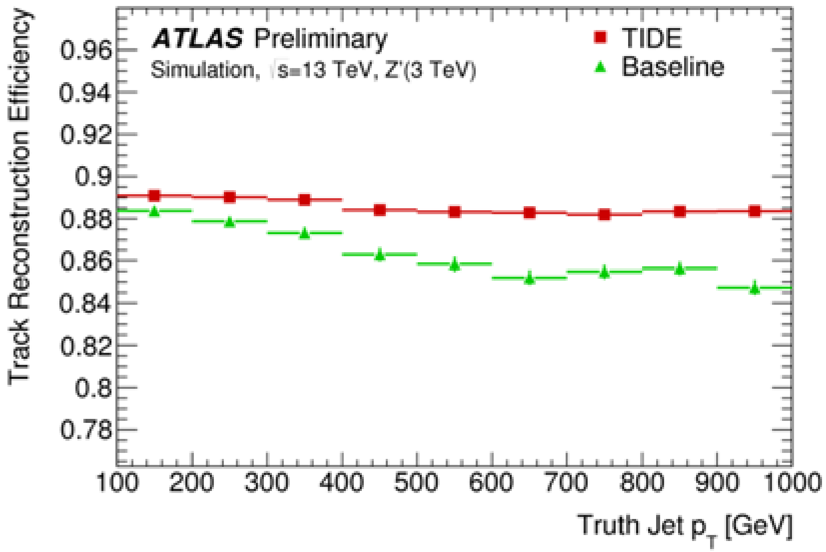
- Latest improvement: special treatment of clusters produced by multiple charged particles
  - Use NN information at the latest stage of track reconstruction (track ambiguity solver)
  - Instead of splitting such clusters, allow many tracks to share them
  - Adjustment of algorithmic thresholds to optimise the reconstruction efficiency and suppression of fake tracks
  - **ATL-PHYS-PUB-2015-006**

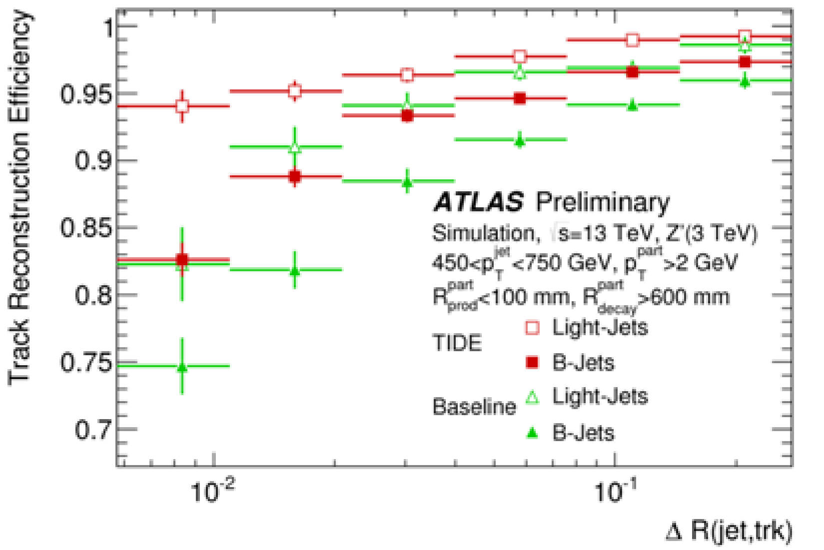


Tracking performance in jets

ATL-PHYS-PUB-2015-006

- Considerable improvement of the track reconstruction efficiency in the new approach
- Especially noticeable at large jet p_T and for dense jets (small ΔR(jet,trk))
  - ~4% gain in track reconstruction efficiency for tracks with p_T=1000 GeV
  - ~12% gain for tracks with ΔR(jet,trk) $\leq 10^{-2}$

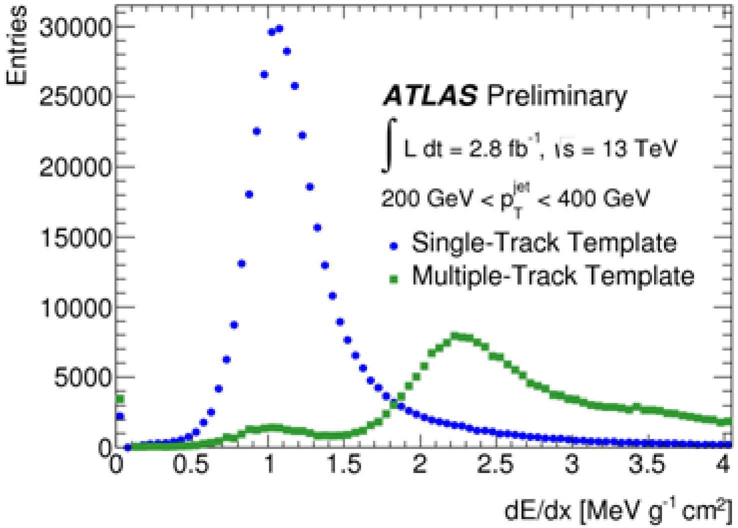


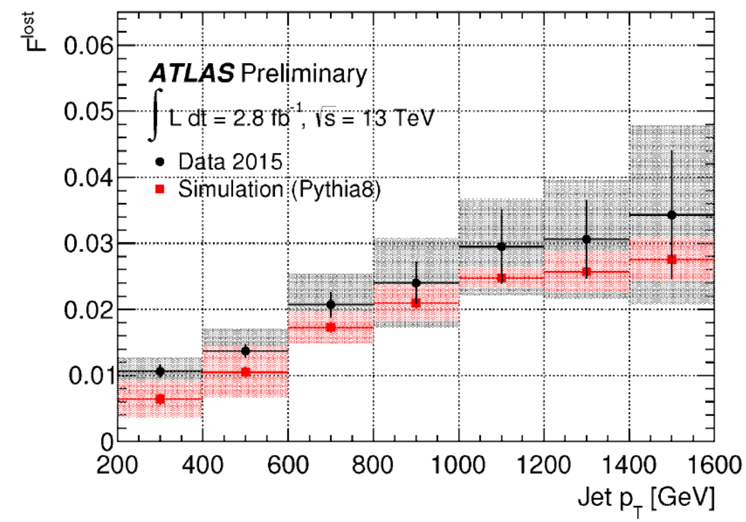


Measuring track efficiency in data

ATL-PHYS-PUB-2016-007

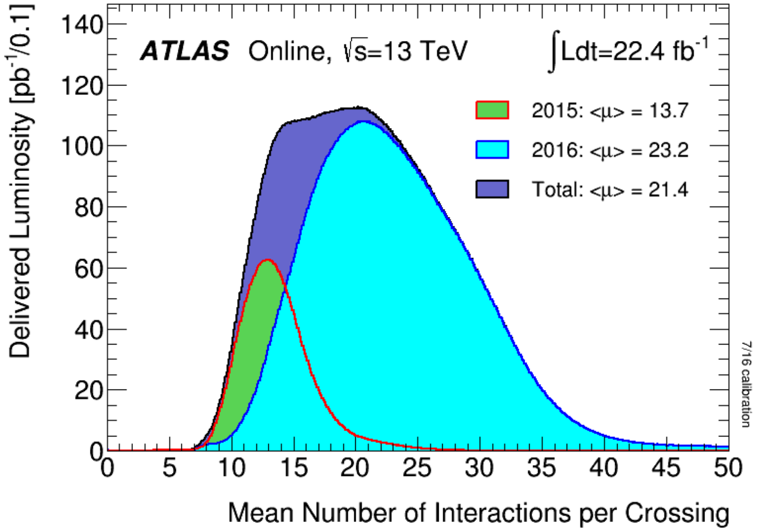
- Determine the fraction of lost tracks using *dE/dx* measured in pixel sensors
- *dE/dx* of clusters produced by a single track and by many tracks are different
- Using this difference, tracks reconstructed from a single particle and from multiple particles can be statistically separated
- From this, the fraction of lost tracks is determined in data
  - fraction of lost tracks: 1% to 5% for jet p_T between 200 and 1600 GeV
  - relative discrepancy with MC ~ 25%
  - Systematic uncertainty 15-75% depending on jet p_T

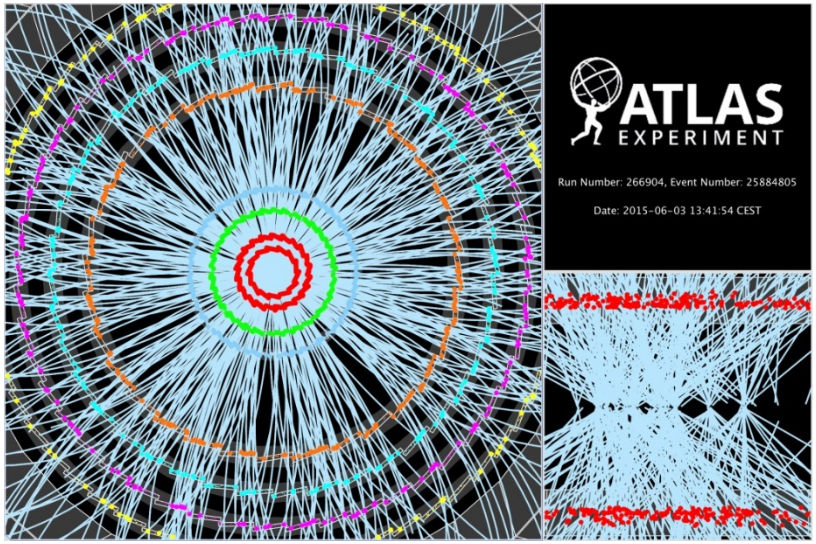




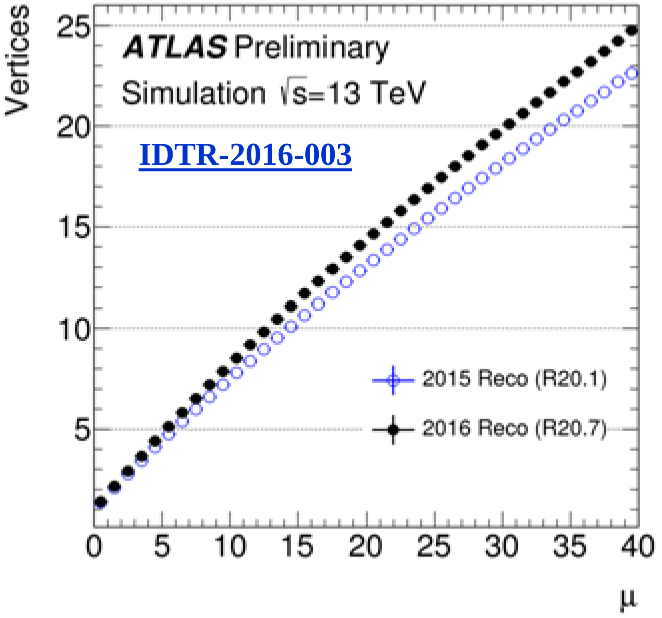
Performance of primary vertex reconstruction

- PV reconstruction – challenging task because of a large number of tracks and primary interactions (⟨μ⟩ = 23.2)
- Work is ongoing on improvements in the vertexing algorithm
  - increase efficiency of PV reconstruction



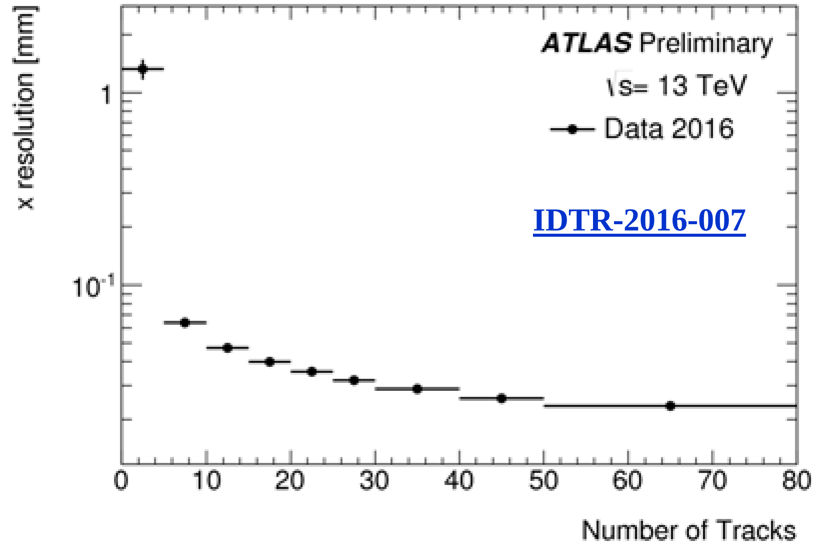


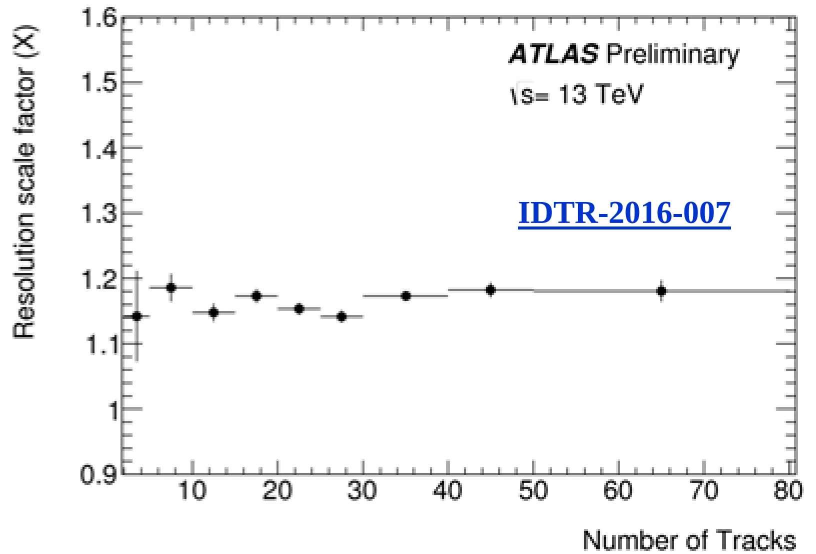
Event with 17 reconstructed vertices



Resolution of PV measurement

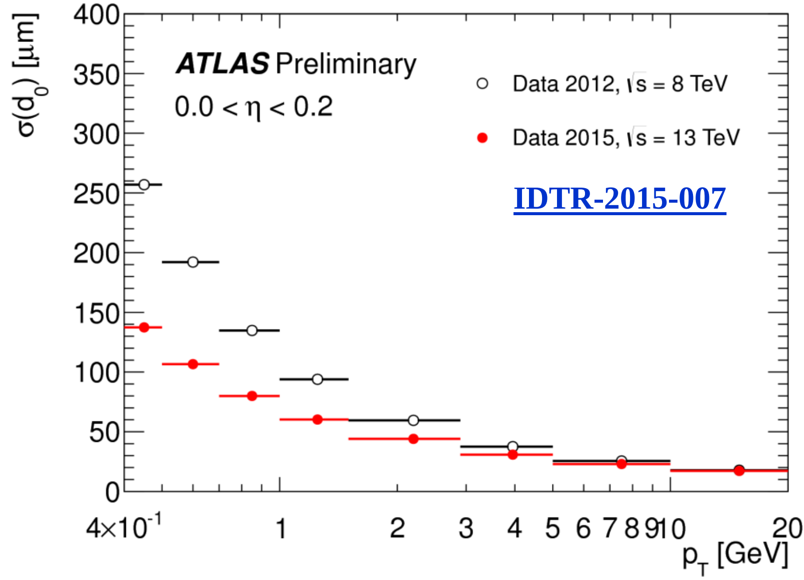
- PV resolution is measured directly in data using the split vertex method
  - All PV tracks are randomly split into 2 groups and the PV is measured independently using each group of tracks
  - Pull of the difference in the position of two PV reflects the PV resolution and can be compared with the value, obtained from the vertex fit
    - Reasonably good agreement achieved
    - Derived scale factors can be used to correct the resolution in physics analyses

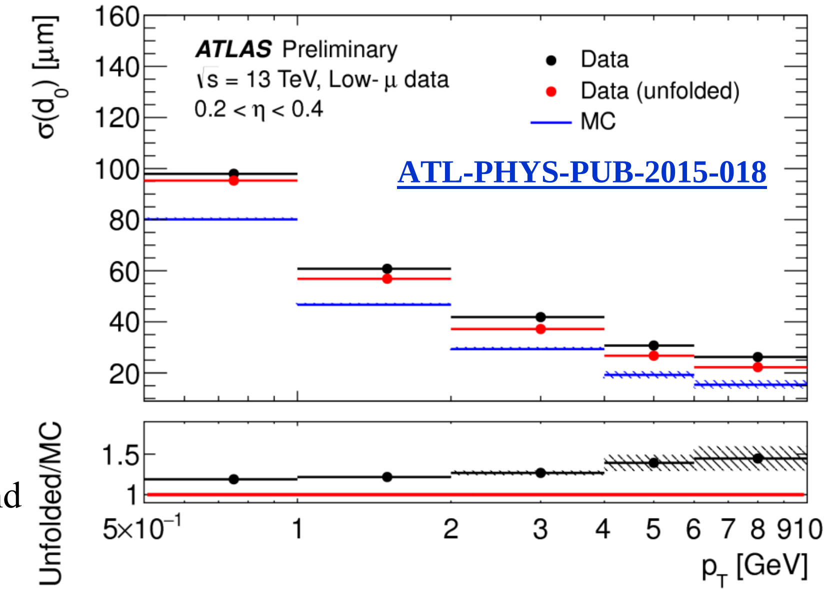




Improved precision of the track impact parameter (d_0)

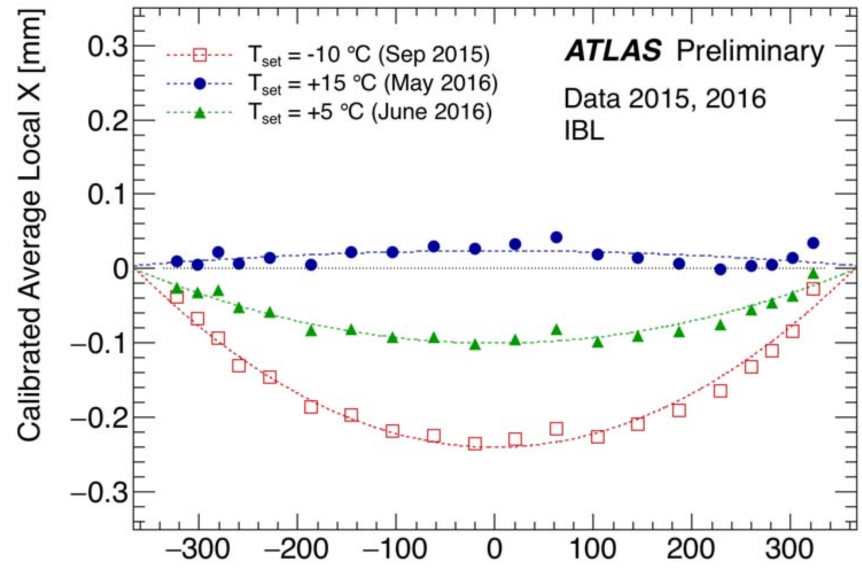
- New layer of pixel detector (IBL) is added in Run 2
- Big improvement in the d_0 resolution, especially for low p_T
  - essential for flavour tagging
- Remaining differences between data and MC in the d_0 resolution are understood to be due to
  - the material description in the detector (low p_T)
  - residual misalignment (high p_T)



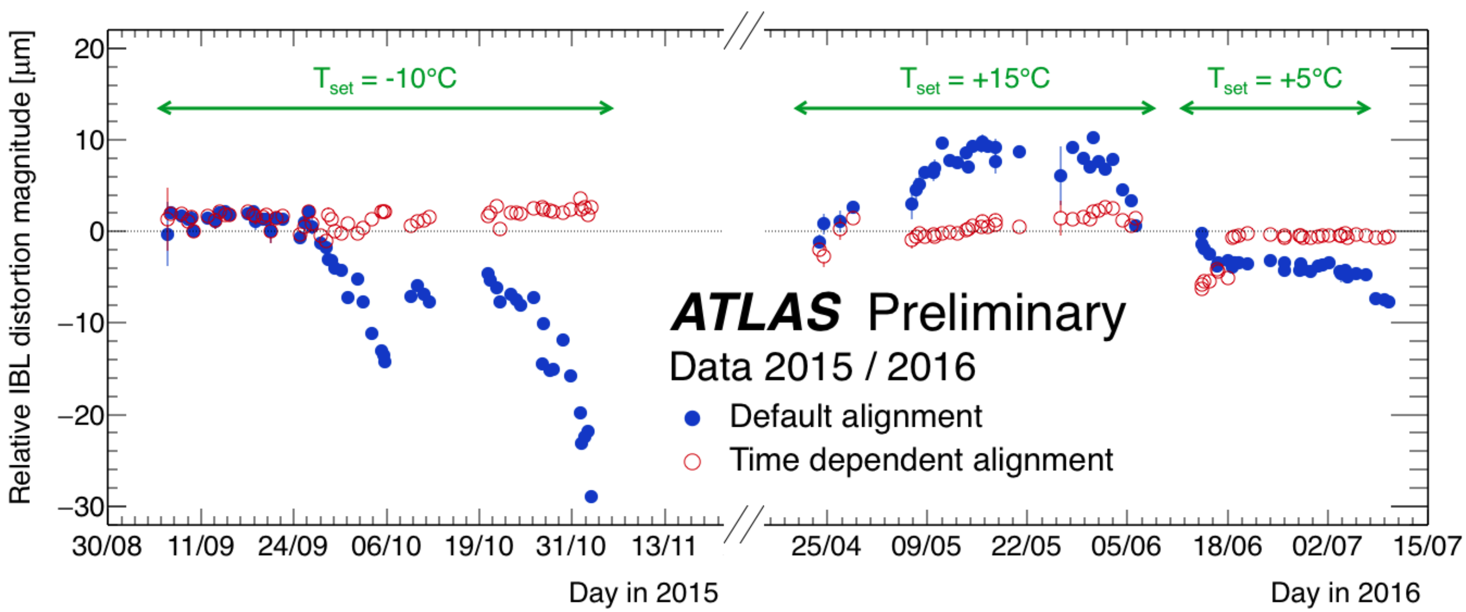


Mechanical instability of IBL

- IBL staves distort depending on the operational thermal conditions
- Time-dependent alignment is performed with IBL staves aligned every 100 minutes



IDTR-2016-005



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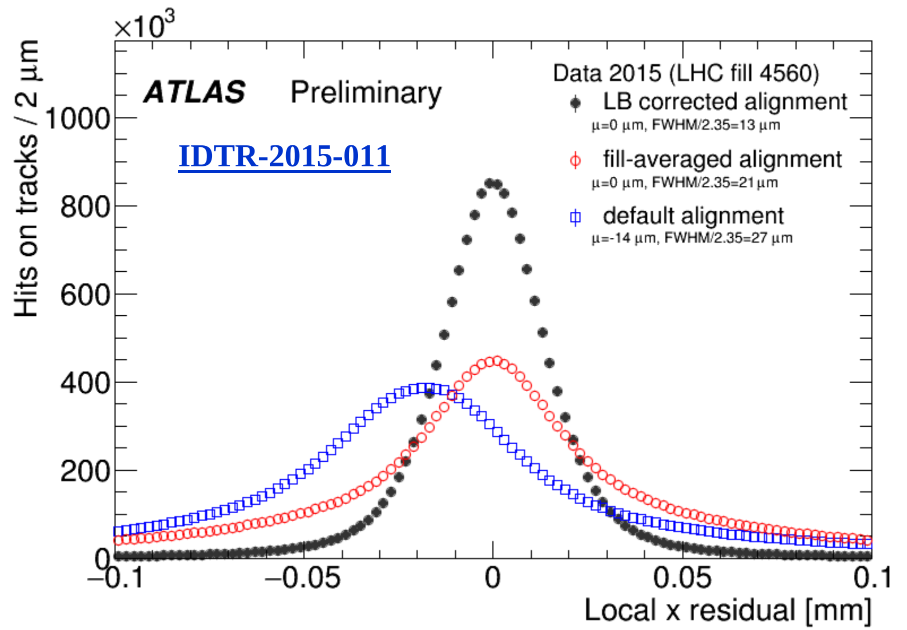
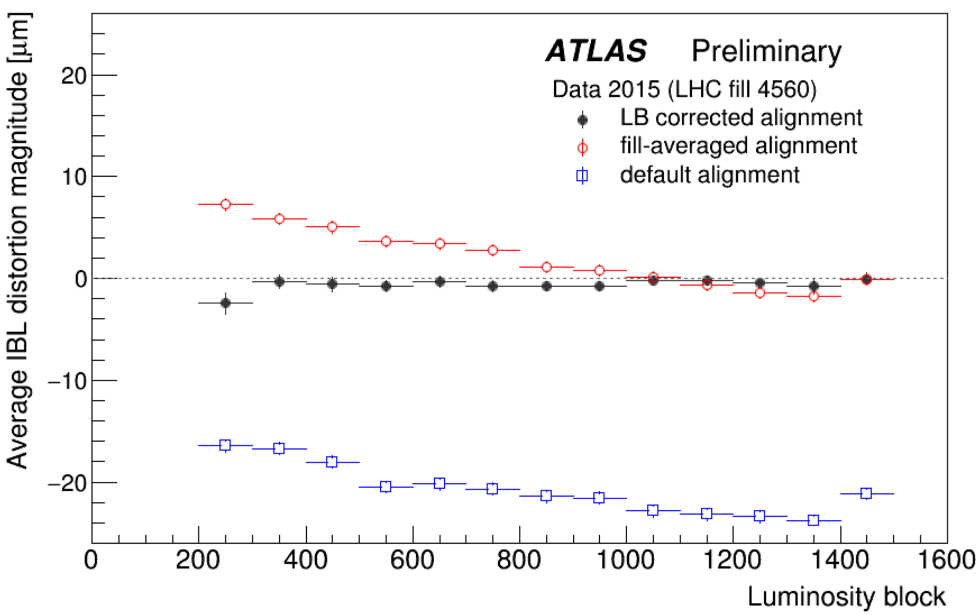
Improved precision of the track impact parameter (d_0)

- Time-dependent alignment corrects for the IBL distortions
- Achieved alignment accuracy at the same or better level compared to the end of Run 1

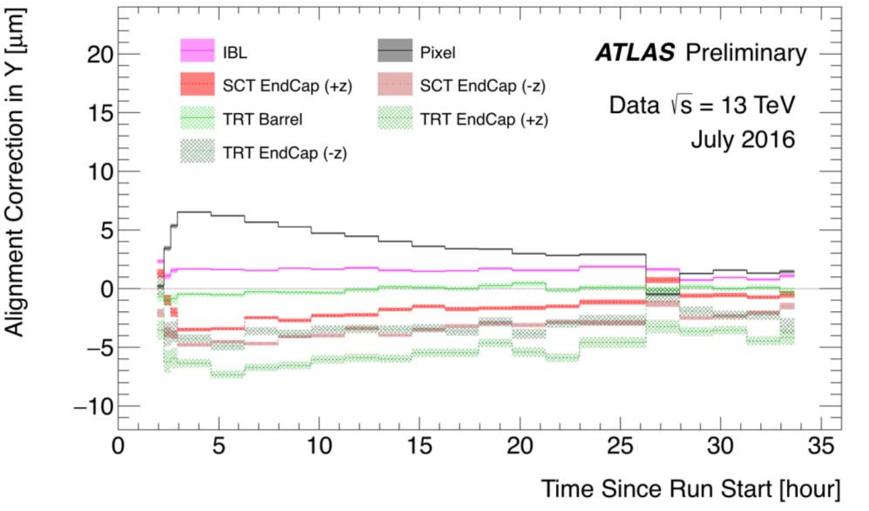


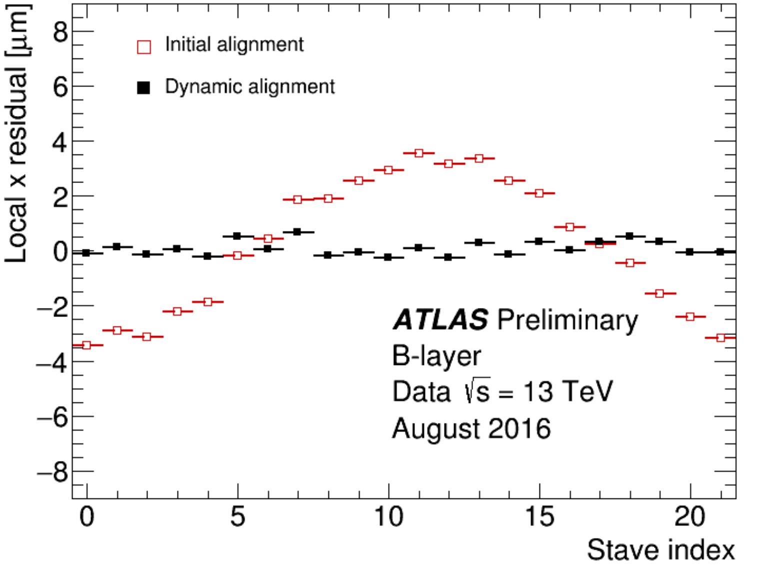


Dynamic alignment of pixel detector

IDTR-2016-009

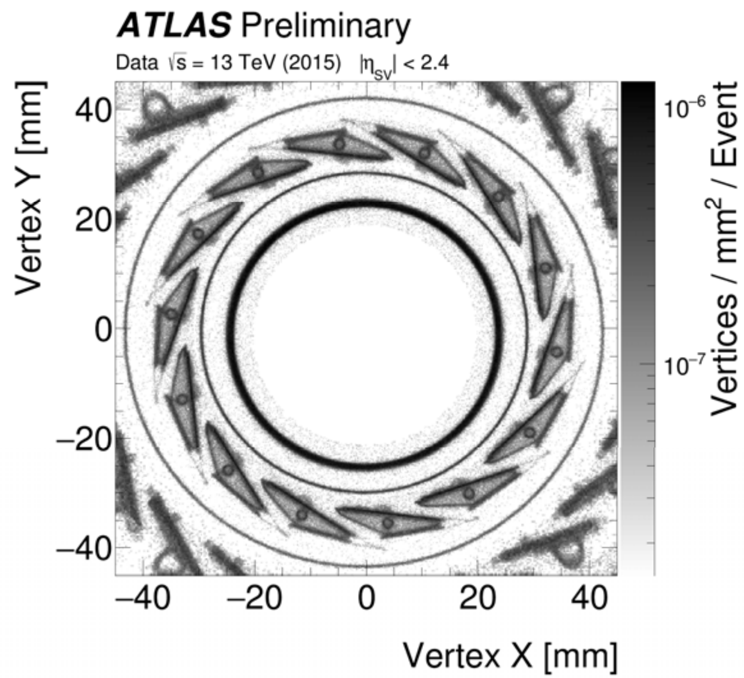
- Time-dependent alignment of pixel detector (since August 2016)
- It takes into account small vertical movement of pixel detector in the beginning of each run and a slow drift in the opposite direction afterwards
- Additional improvement of the geometry description of the ID is achieved

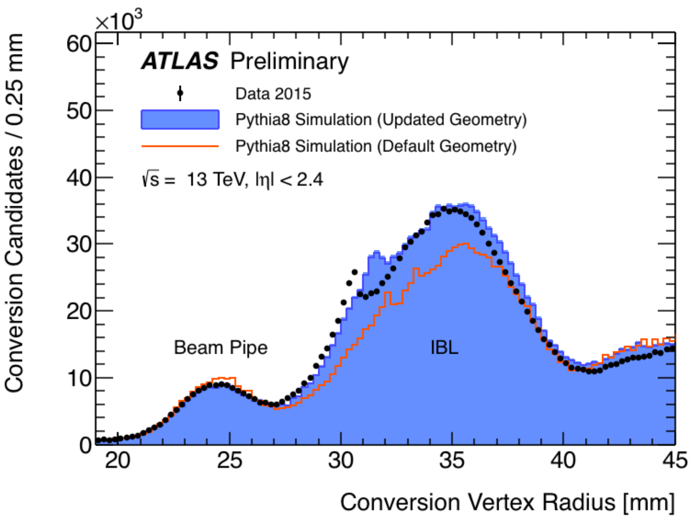




Material description

- The distribution of the material in the detector is measured using vertices of the photon conversion and hadronic interactions
- Initial amount of material in IBL is underestimated in MC
- After its correction, the agreement data/MC is improved





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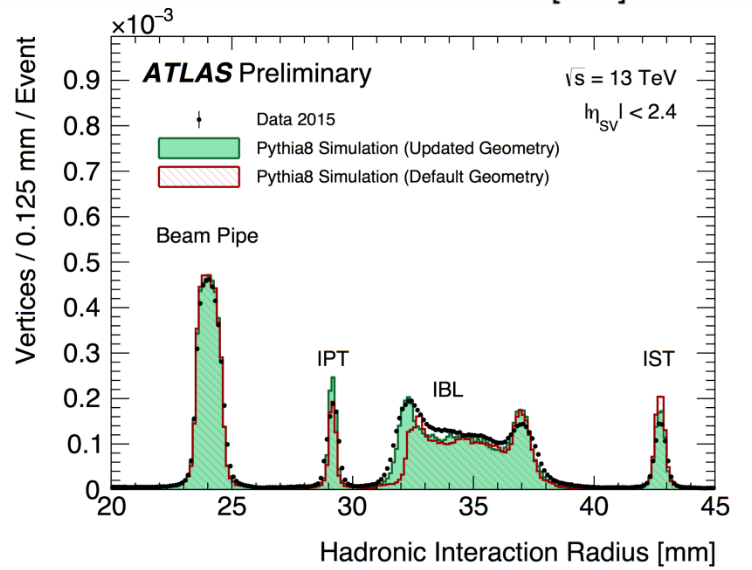
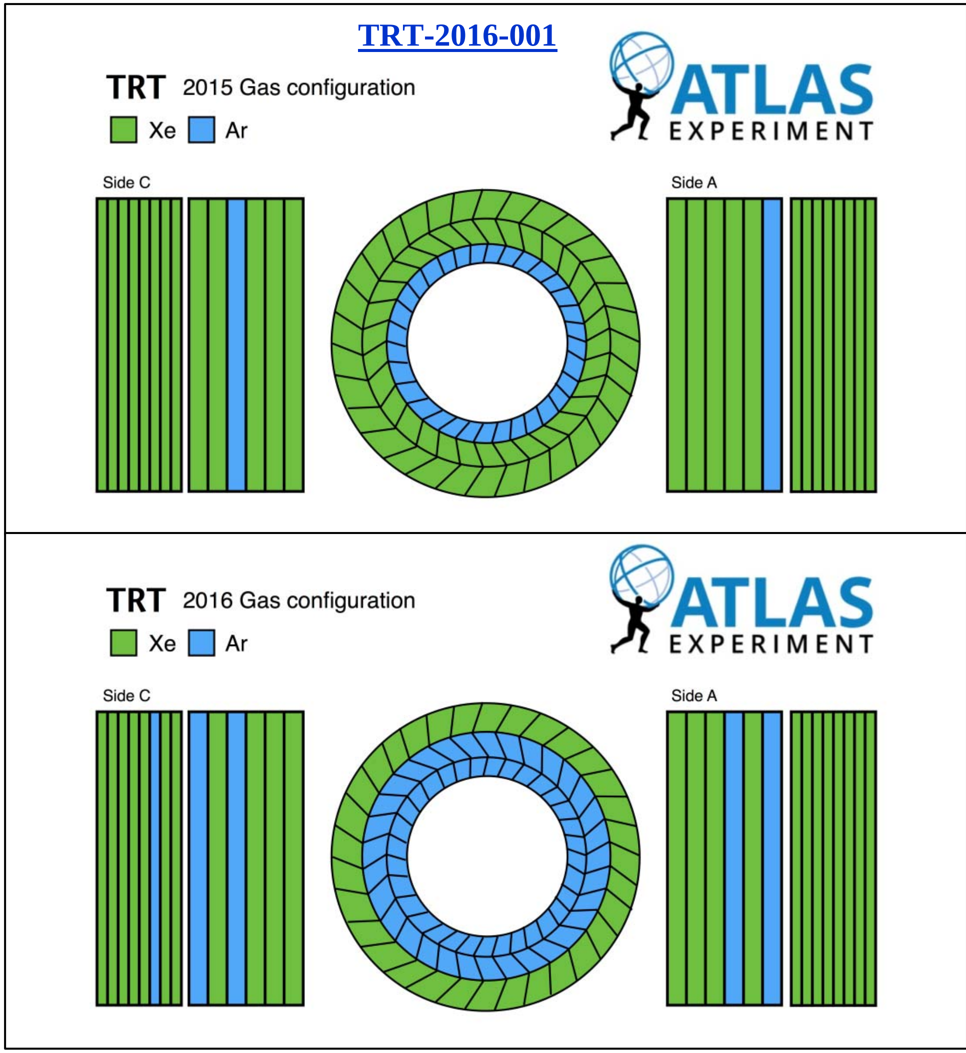


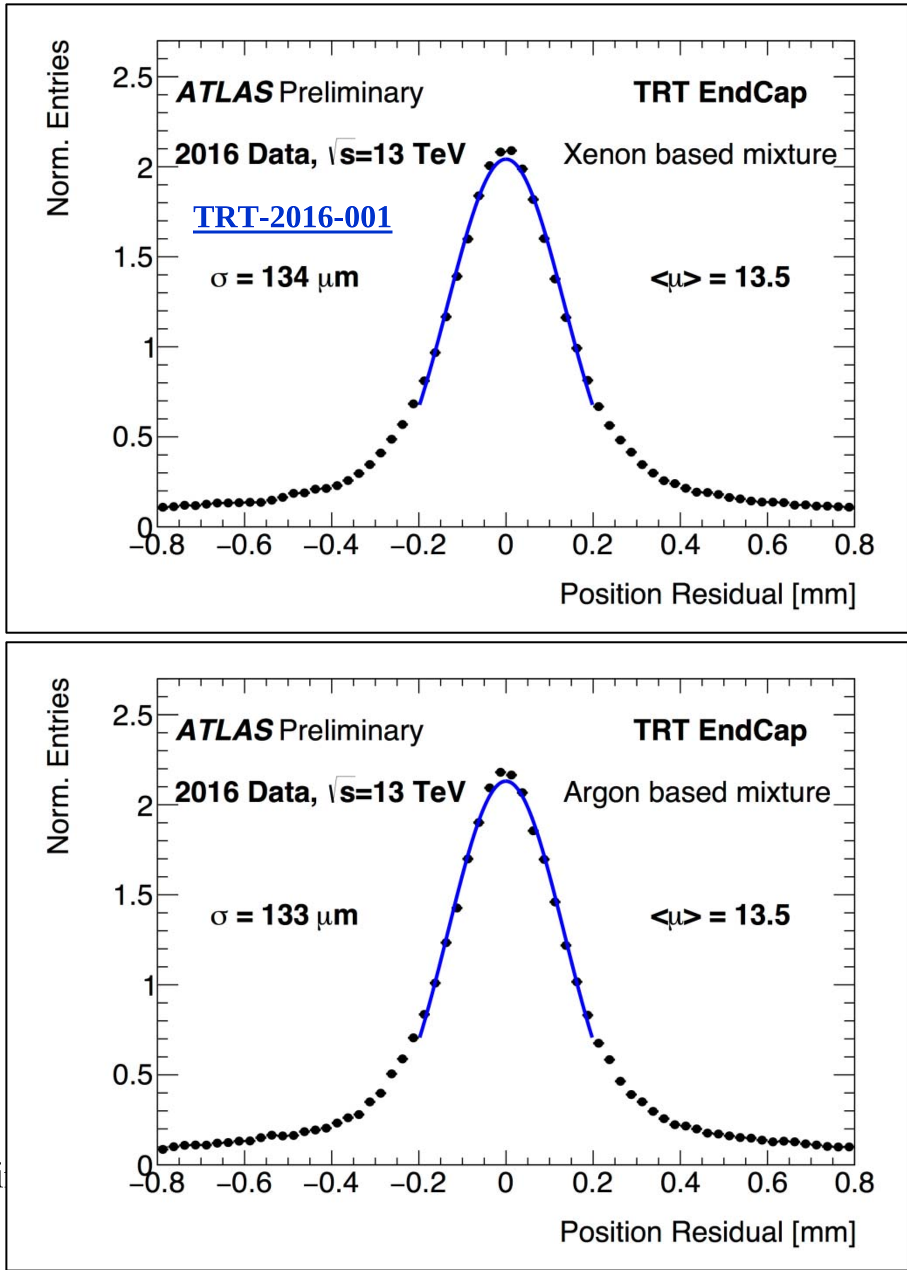
Gas leaks in TRT

- Gas leaks were detected in TRT in the end of Run 1
- TRT was repaired during LS1
- For some modules, the leaks could not be repaired
- In these modules argon is used instead of xenon



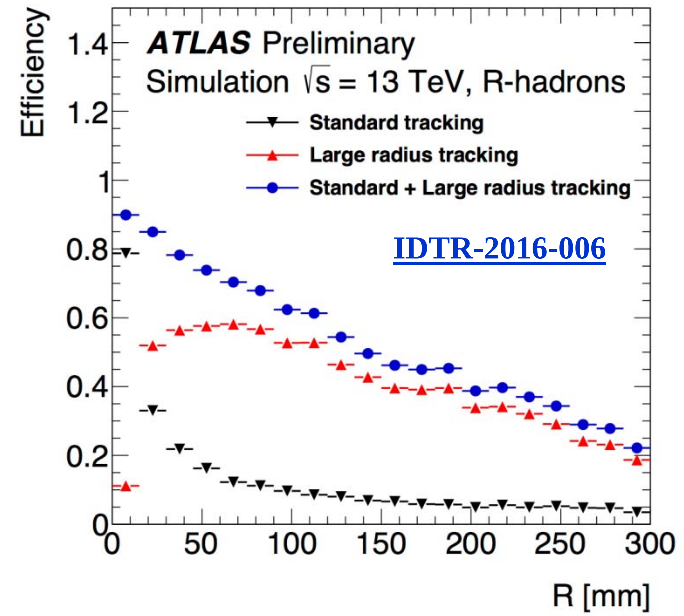
Gas leaks in TRT

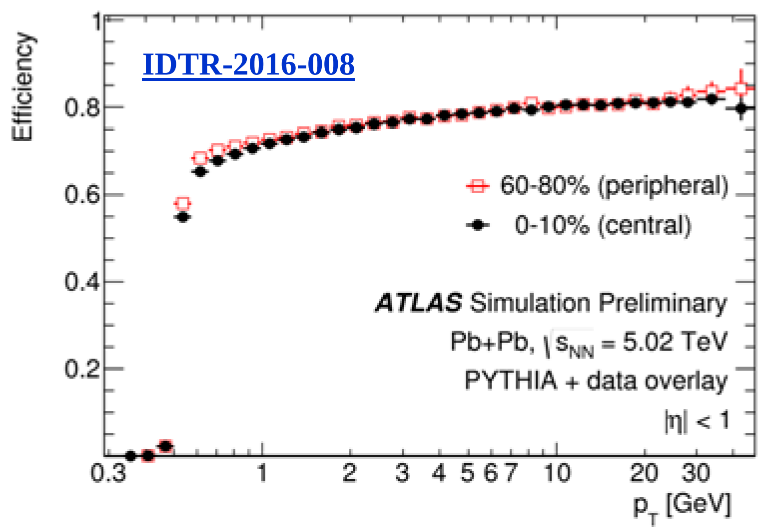
- Replacement of xenon by argon does not change significantly the precision of TRT
  - σ(residual) = 134 μm (Xe)
  - σ(residual) = 133 μm (Ar)
- Still, we want to keep the xenon as much as possible since it provides a better particle ID



Special tracking

- In addition to the standard tracking, special tracking setup is used for specific needs
  - reconstruction of tracks produced at large radius
  - heavy ion collisions: p_T threshold is ~500 MeV
  - reconstruction of short tracks (pixel-only) is done by default for $p_T > 5$ GeV





Conclusions

- Upgrade of the tracking detector (addition of IBL) improves the tracking performance
- Several methods to measure the tracking and vertexing performance directly in data are developed
- Many improvements in the tracking and vertexing algorithms to withstand the challenging conditions of Run2 and the changes in the detector
- Performance of tracking in Run 2 is at the same or better level compared to Run 1