Tracking properties of the ATLAS Transition Radiation Tracker (TRT)

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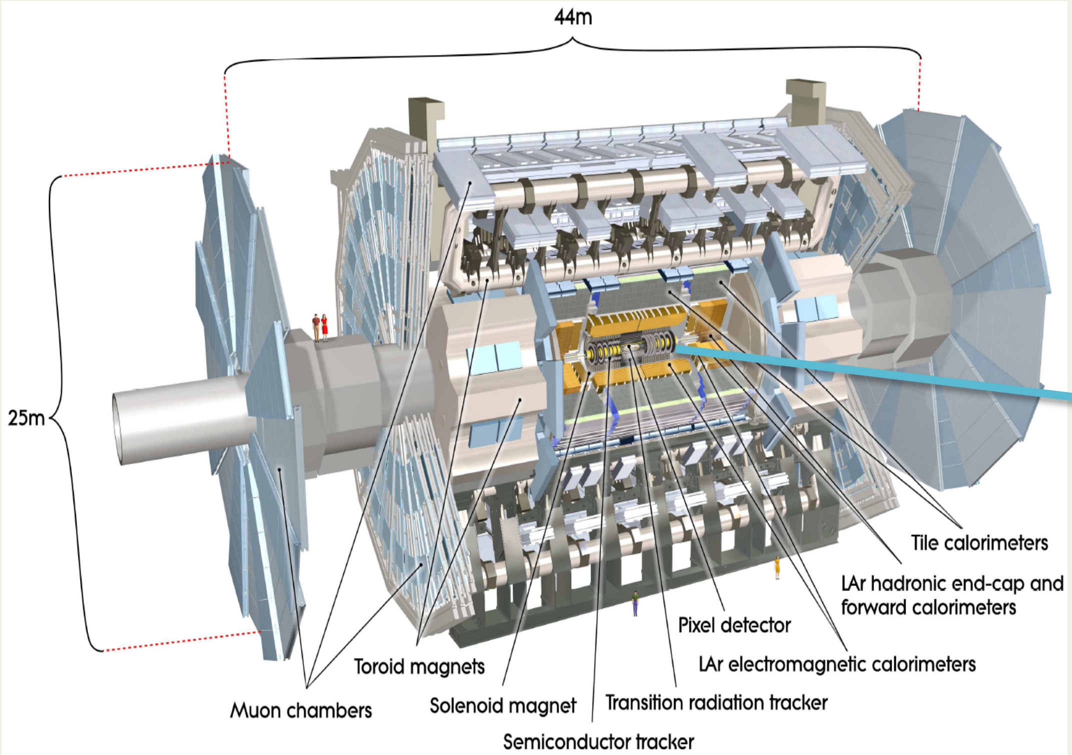
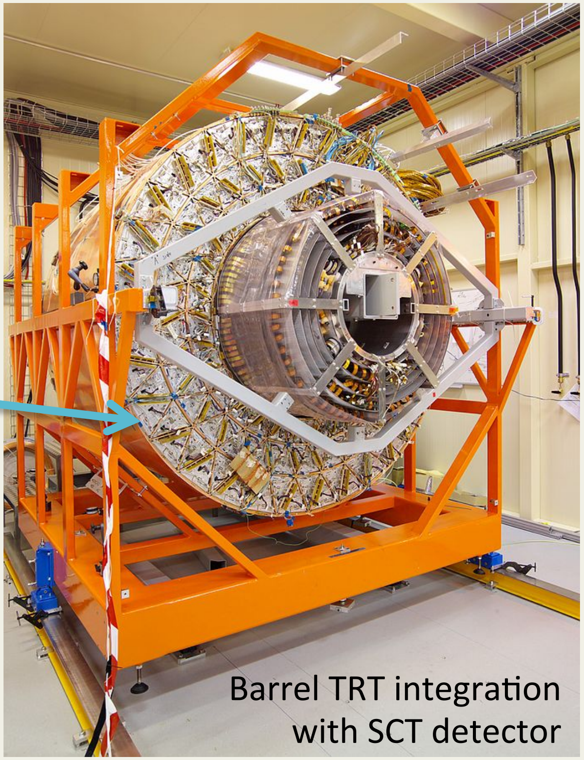
1. ATLAS EXPERIMENT
   - Transition Radiation Tracker
2. TRT TRACKING PROPERTIES
   - Low/high occupancy conditions during LHC Run 1
   - Tracking inside hadron jets during LHC Run 1
   - Recent Run 2 results

ATLAS Transition Radiation Tracker (TRT)

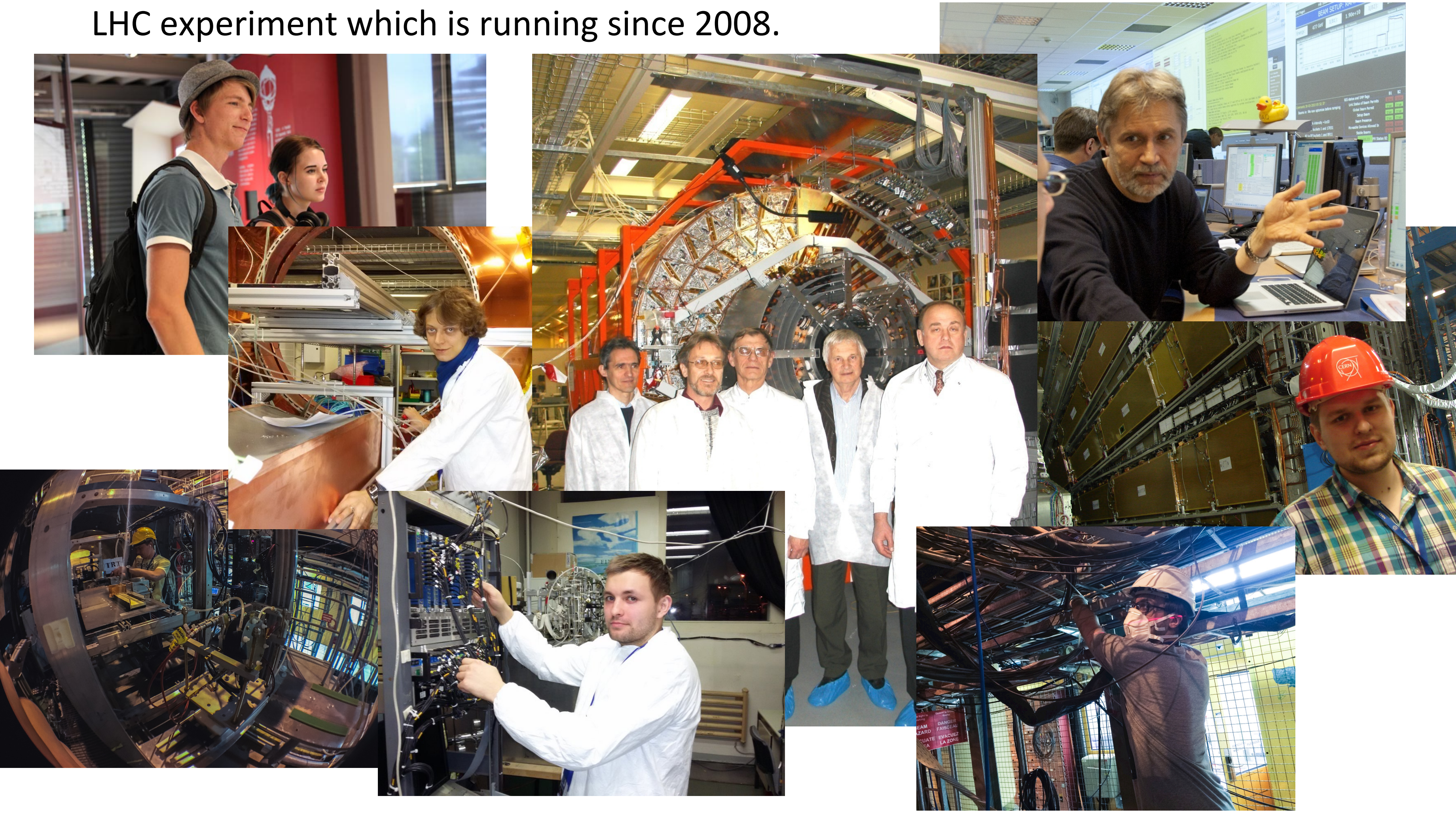




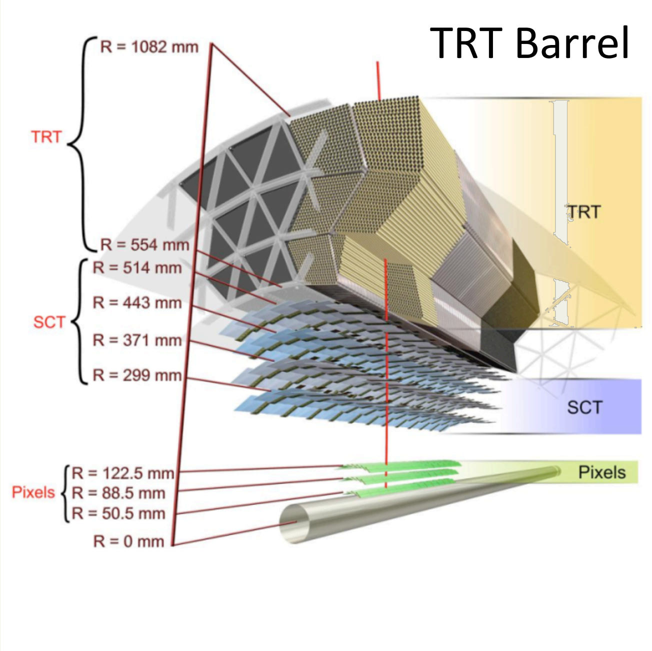
- ✓ ATLAS – general purpose experiment at Large Hadron Collider united 3000 scientists from 174 institutes in 38 countries.
- ✓ TRT is a large straw tube tracking system that is the outermost of the three subsystems of the ATLAS Inner Detector. It eases the tracks pattern recognition with its large number of close hits and contributes to particle identification and momentum resolution.
- ✓ Detector operates in Combined or Standalone modes, providing extensions for tracks registered in other subsystems and recognizing the whole electron tracks from photon conversions.

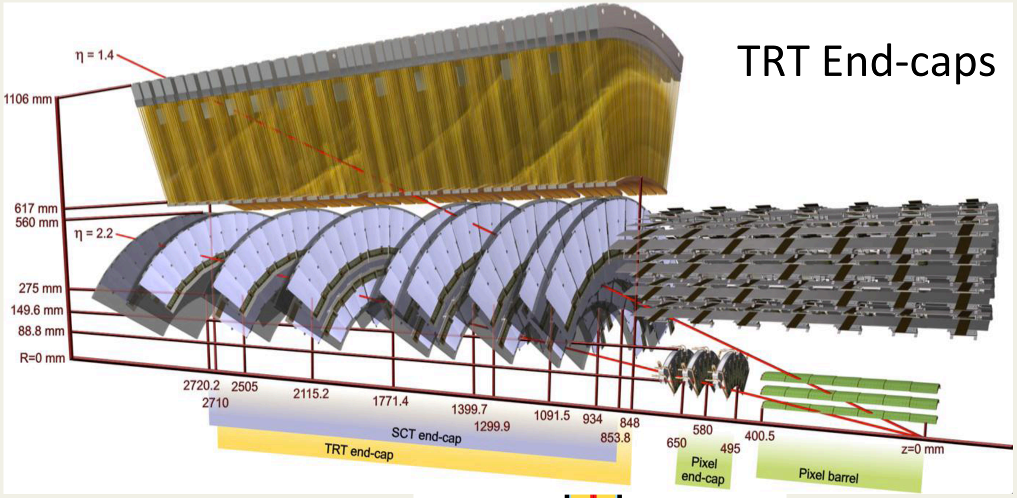
ATLAS Transition Radiation Tracker

In 1989 MEPHI group proposed a novel concept of transition radiation detector for experiments at future colliders. It has made a big contribution for development, design, production and operation of the Transition Radiation Tracker in the ATLAS at LHC experiment which is running since 2008.

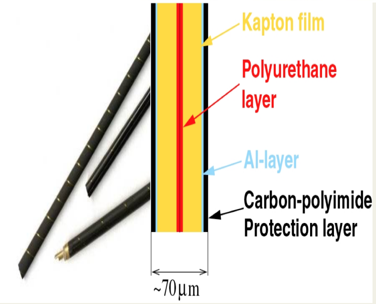


ATLAS Transition Radiation Tracker



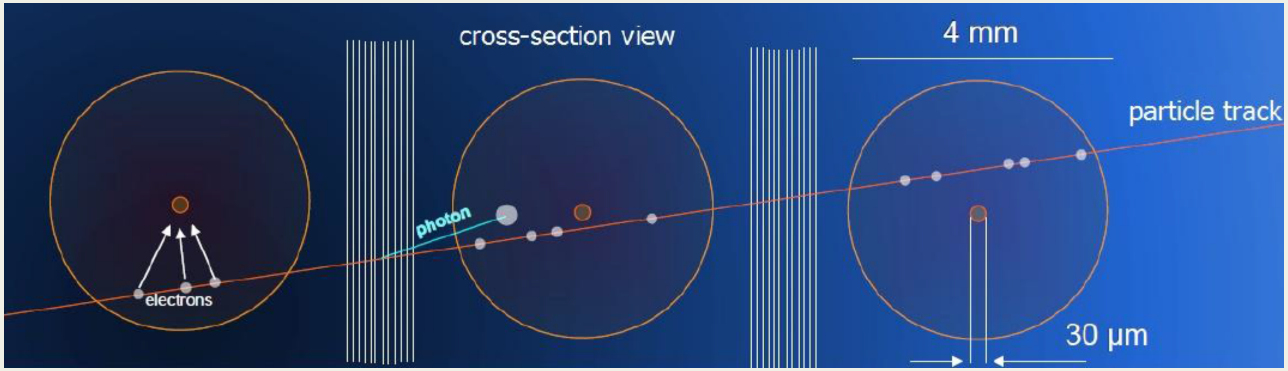


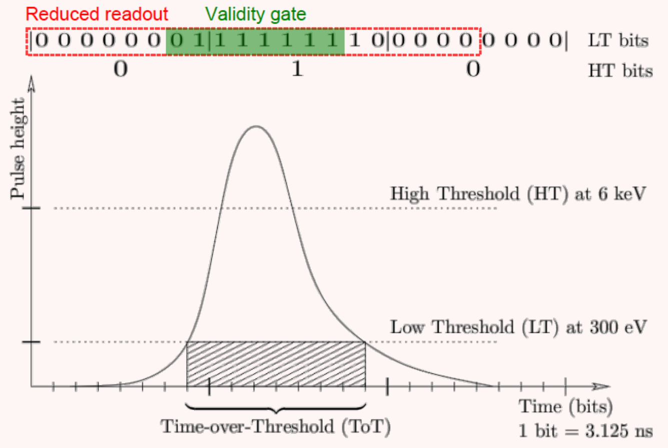
Straw filled with xenon gas mixture



- ✓ ≈ 0.4 M channels give ≈ 30 two-dimensional space-points for charged particles with $|\eta|<2$ and $p_T > 0.5$ GeV
- ✓ Single hit resolution: ≈120 μm
- ✓ Particle identification (electron-pion separation) by detection of transition radiation
- ✓ Provides accurate p_T measurements
- ✓ Works at high occupancy conditions
- ✓ Stable performance in hard radiation environment

TRT: key points





Ionization signal:

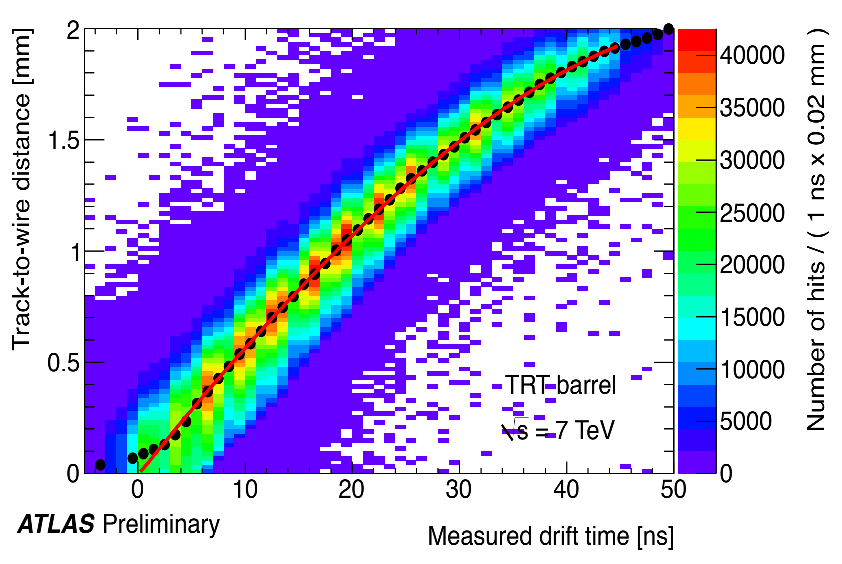
- Originates on charged particle track in gas mixture inside the straws
- Registered with low-level threshold
- Used for tracking

Transition radiation signal

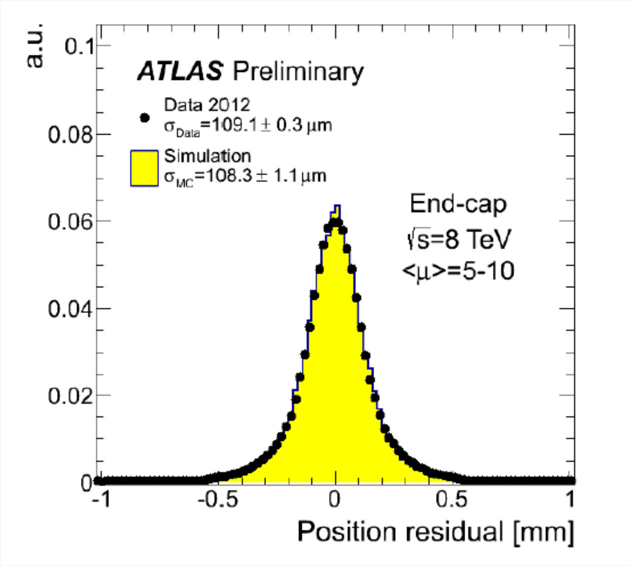
- Originates when the particle traverses through radiators with different dielectric permittivity (located outside of straws)
- Contributes to ionization signal and is registered with high-level threshold
- Used for particle identification (electron and pion separation)

TRT: key points

- Track to wire distance (r) as a function of drift time (t) (so-called r-t relation) is used to derive the spatial position of charged particle track
- The track position measurement accuracy is defined as the sigma of difference between the measured drift radius and actual track-to-wire distance distribution (position residual)



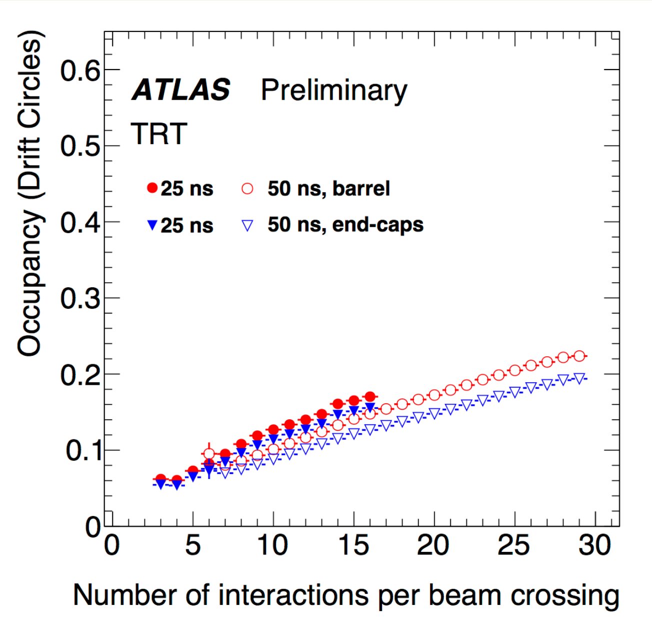
R-t relation for TRT Barrel



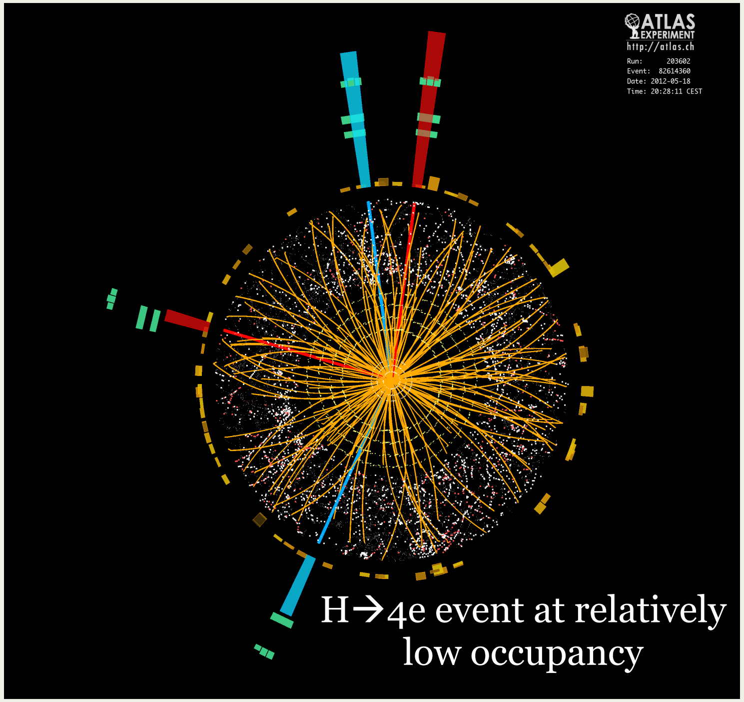
Position residual distribution for TRT End-caps

Low occupancy conditions

- Intensity of proton collision is characterized by <μ> — average number of proton interactions in single collision
- The TRT occupancy is defined as the probability to have the straw signal above a given threshold value in the TRT read-out window of 75 ns

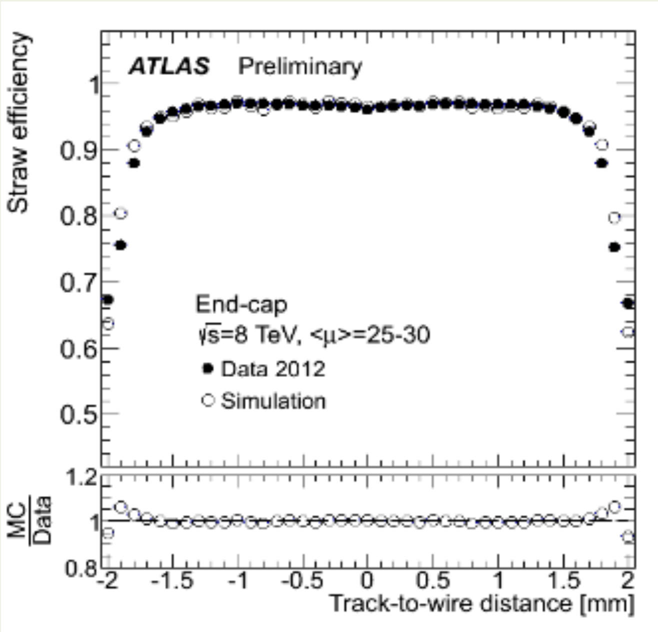


TRT occupancies in barrel and endcap parts of detector as function of <μ> for 25 and 50 ns data taking periods in 2012

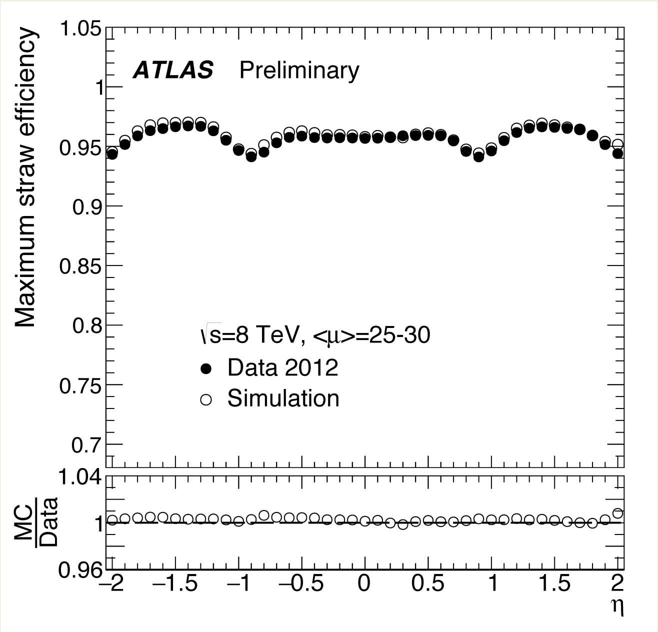


Low occupancy conditions

The probability for the straw to produce a signal above the low level threshold (straw efficiency) is about 96% for muons traversing the straw gas volume with p_T > 30 GeV



Straw efficiency as the function of track-to-wire distance in TRT End-cap

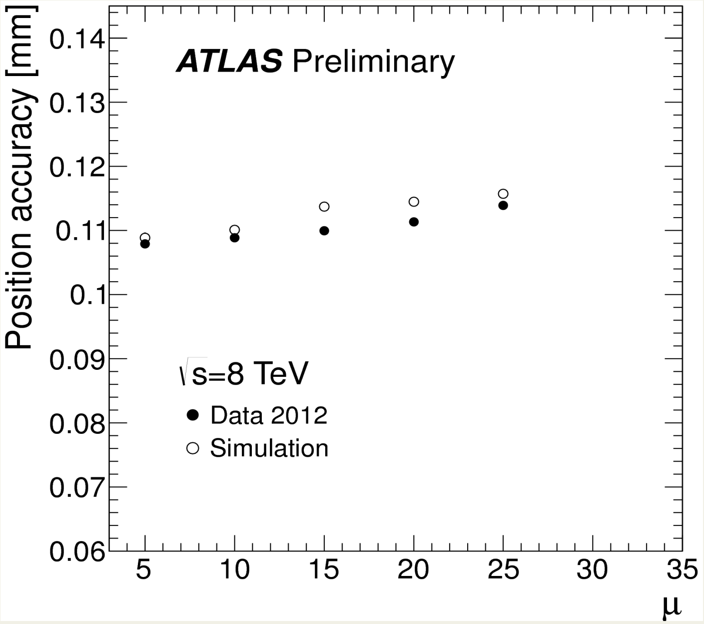


Maximum straw efficiency as the function of η

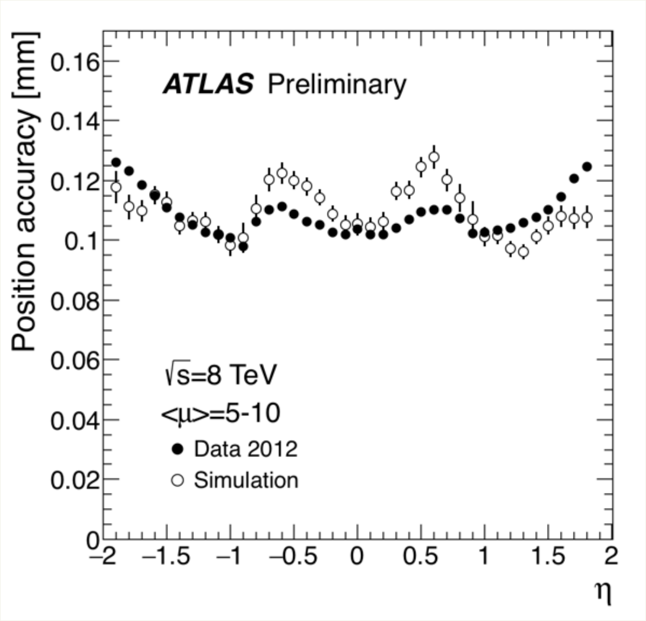
Data and simulation are in good agreement

Low occupancy conditions

- High track measurement accuracy even at the maximum number of proton interactions
- Low dependence of track measurement accuracy from <μ> and η
- Small disagreement reflects the fact that the electrical model of the straw as a signal transmission line is a rather complex function and and may not be exactly reproduced in the simulation especially for the long straws in the barrel



Track measurement accuracy as function <μ>



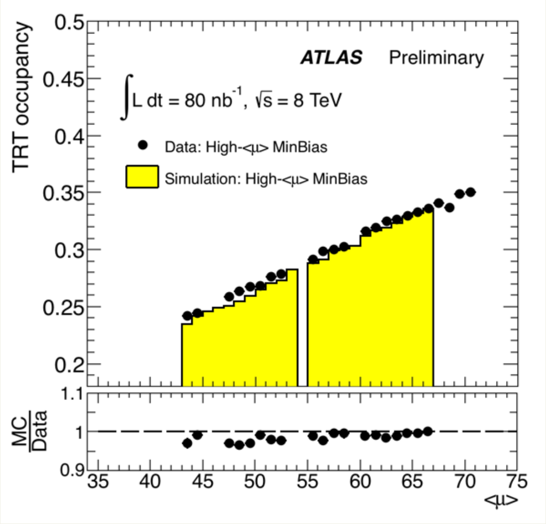
Track measurement accuracy as function η

Data and simulation are in good agreement

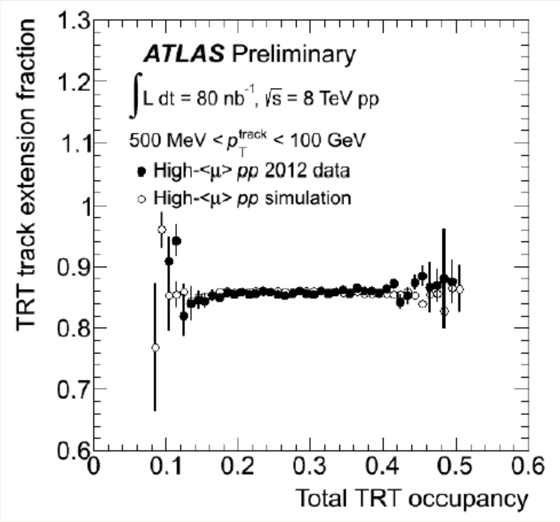
High occupancy conditions

Understanding of TRT performance at high occupancy is important for many ongoing ATLAS physics analyses. Detector performs well for occupancies up to 50% occupancy in high pile-up proton collisions:

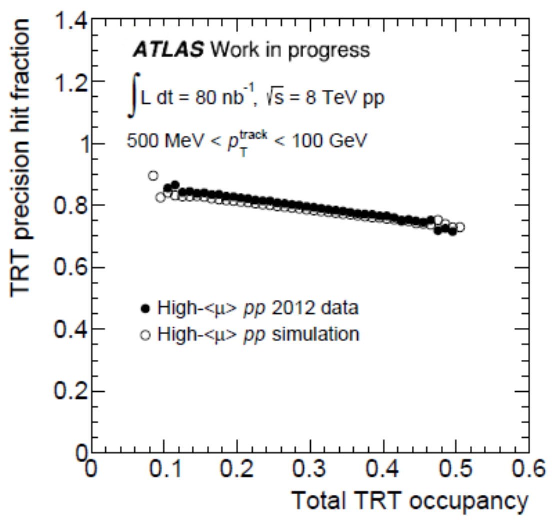
- ✓ The relative number of tracks reconstructed in the Pixel and SCT detectors that also have a continuation in the TRT (track extension fraction) almost does not change with occupancy
- ✓ The number of precision TRT hits divided by the total number of hits on the track (precision hit fraction) is decreasing linearly with increasing occupancy since the probability for a straw to be hit by two or more particles increases



TRT occupancy as a function of <μ>



Track extension fraction as a function of occupancy

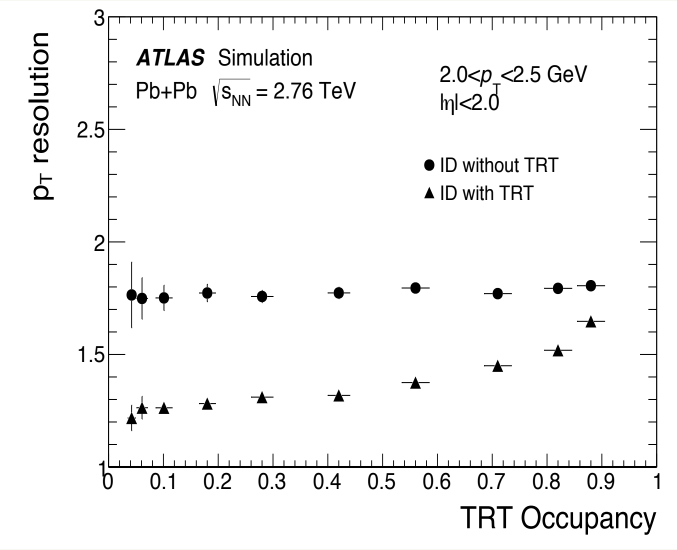


Precision hit fraction as a function of occupancy

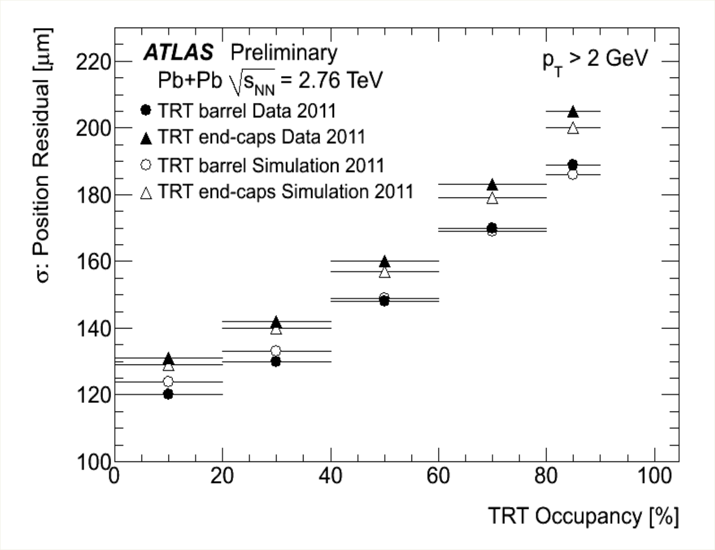
Data and simulation are in good agreement

High occupancy conditions

- ✓ The TRT contribution to the particle momentum measurement remains almost constant for occupancies up to 50% in heavy ion collisions
- ✓ Track measurement accuracy increases linearly with TRT occupancy
- ✓ The degradation of position resolution does not affect the p_T resolution much due to the large number of TRT hits on track

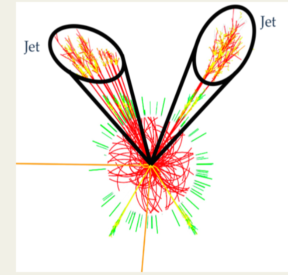


Track p_T resolution as a function of occupancy

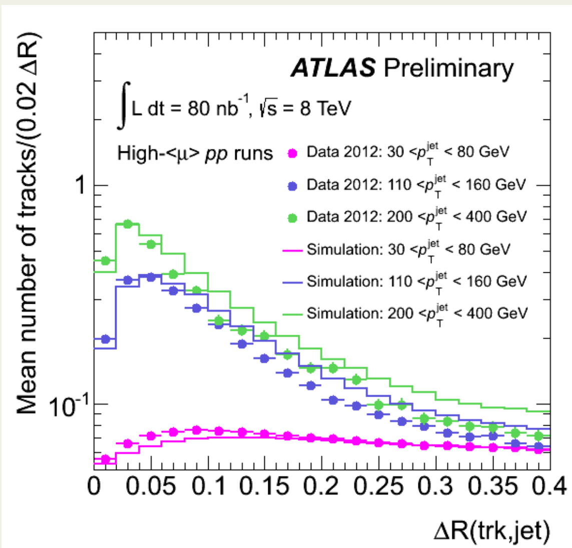


Track measurement accuracy as a function of occupancy

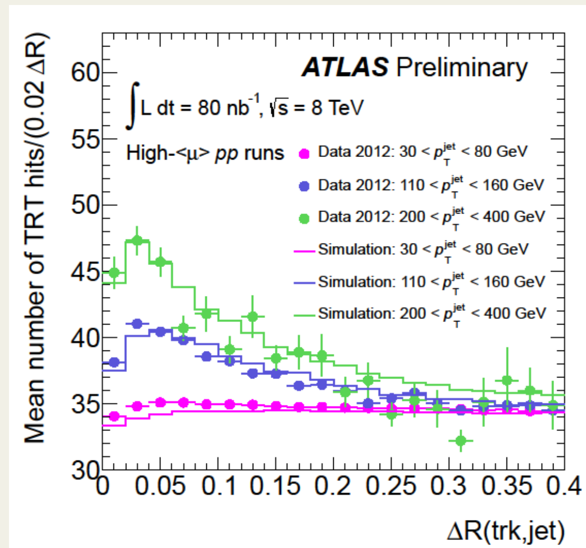
Study of TRT performance in hadron jets



- One of the most challenging tasks for any tracking detector is finding and measuring tracks in the dense environment of energetic hadron jet cores.
- Tracking inside jets in TRT were studied as a function of distance in η-φ plane ($\Delta R = \sqrt{\eta^{2+}\varphi^2}$) between track and jet core for tracks with $p_T > 2$ GeV



Number of reconstructed tracks in ATLAS as a function of ΔR

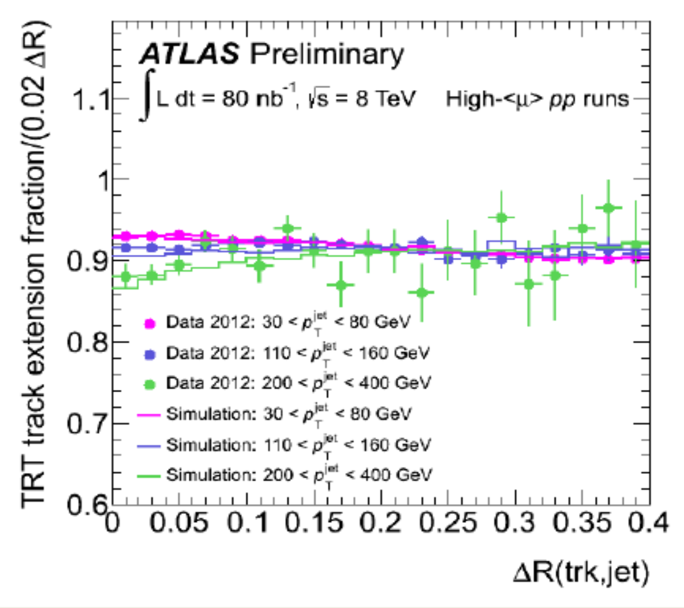


Mean number of TRT hits as a function of ΔR

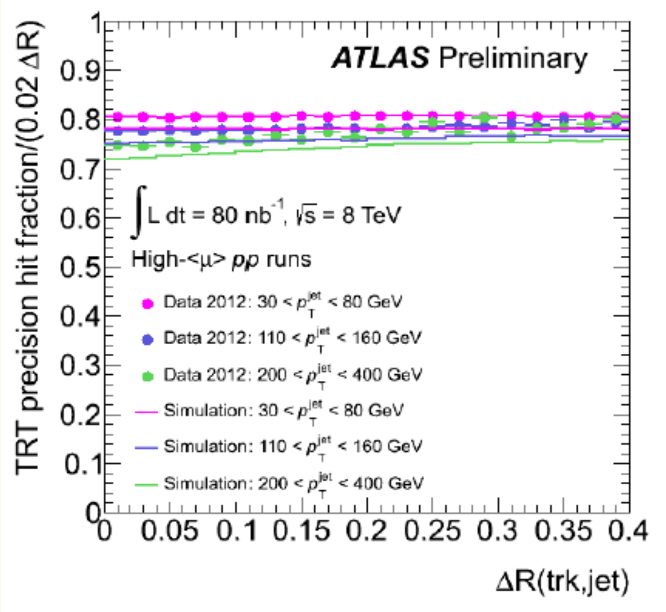
- ✓ Tracks are reconstructed correctly even near the jet cores
- ✓ Mean number of TRT hits and reconstructed tracks are increasing with increase of jet energy

Study of TRT performance in hadron jets

- ✓ Track extension fraction is practically constant even within dense core of the most energetic jets.
- ✓ Precision hit fraction in the core of most energetic jets is almost the same as that outside of jet core.



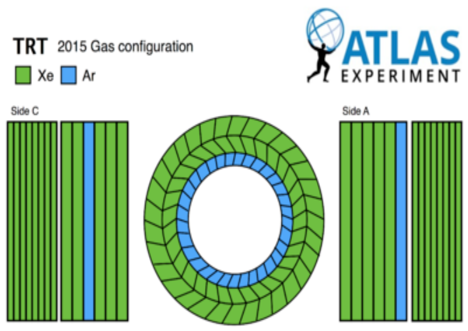
Track extension fraction as a function of ΔR



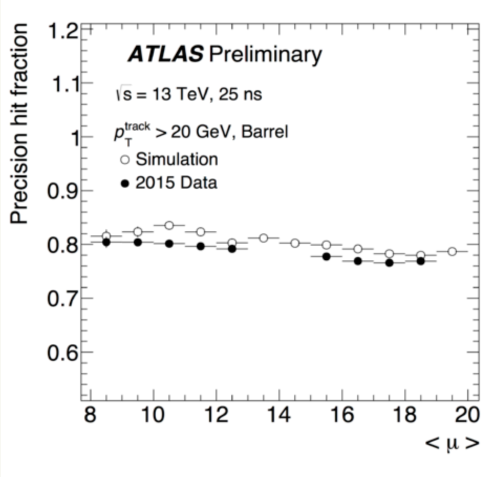
Precision hit fraction as a function of ΔR

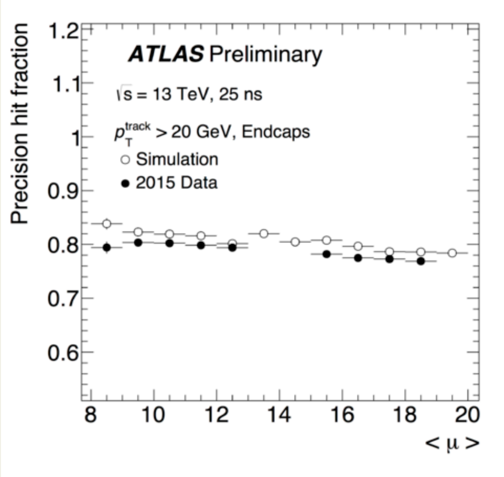
Data and simulation are in good agreement

Run 2 results 2015

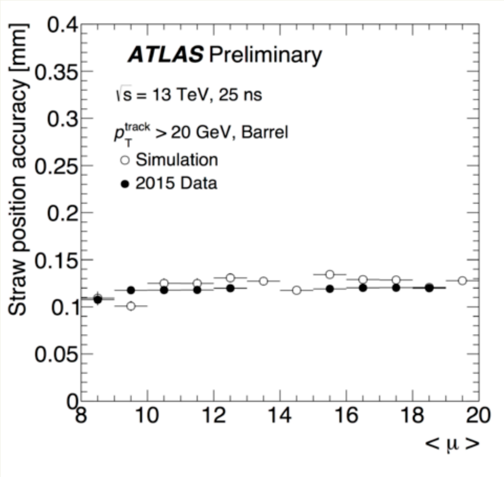


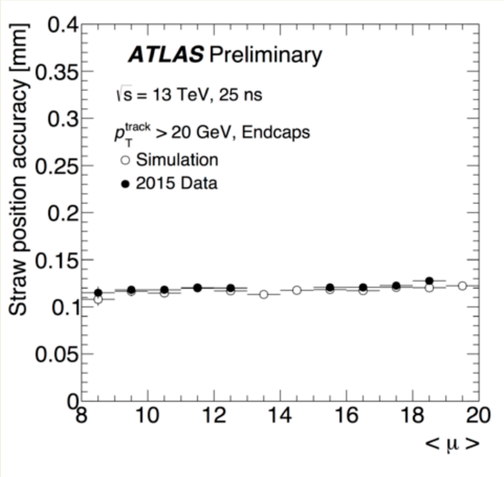
TRT gas geometry in 2015





Precision hit fraction as function <μ>





Track measurement accuracy as function <μ>

New calibration for 2015 conditions including optimization of spatial measurement uncertainties in TRT helped to achieve high level of agreement between simulation and data for new TRT gas geometry with Xenon and Argon mixtures used in Run 2.

Conclusion

- ATLAS Transition Radiation Tracker during the Run 1 of the LHC showed good performance and high precision of measurements

- Performance of TRT was studied in conditions of high occupancy which reaches the 50% for proton collisions. Quality of track reconstruction is observed to be at the same level. According to heavy ion studies the TRT contributes to the particle momentum measurement up to 90% occupancy

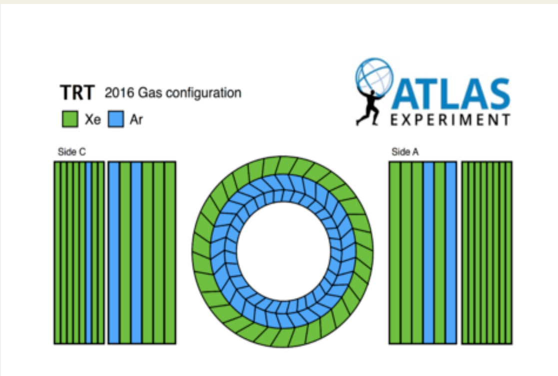
- Additional studies which include the track characteristics in hadron jets showed that even in dense jet cores TRT tracking parameters are undergoing very little degradation.

- The TRT tracking performance remains on a high level for Run 2 conditions

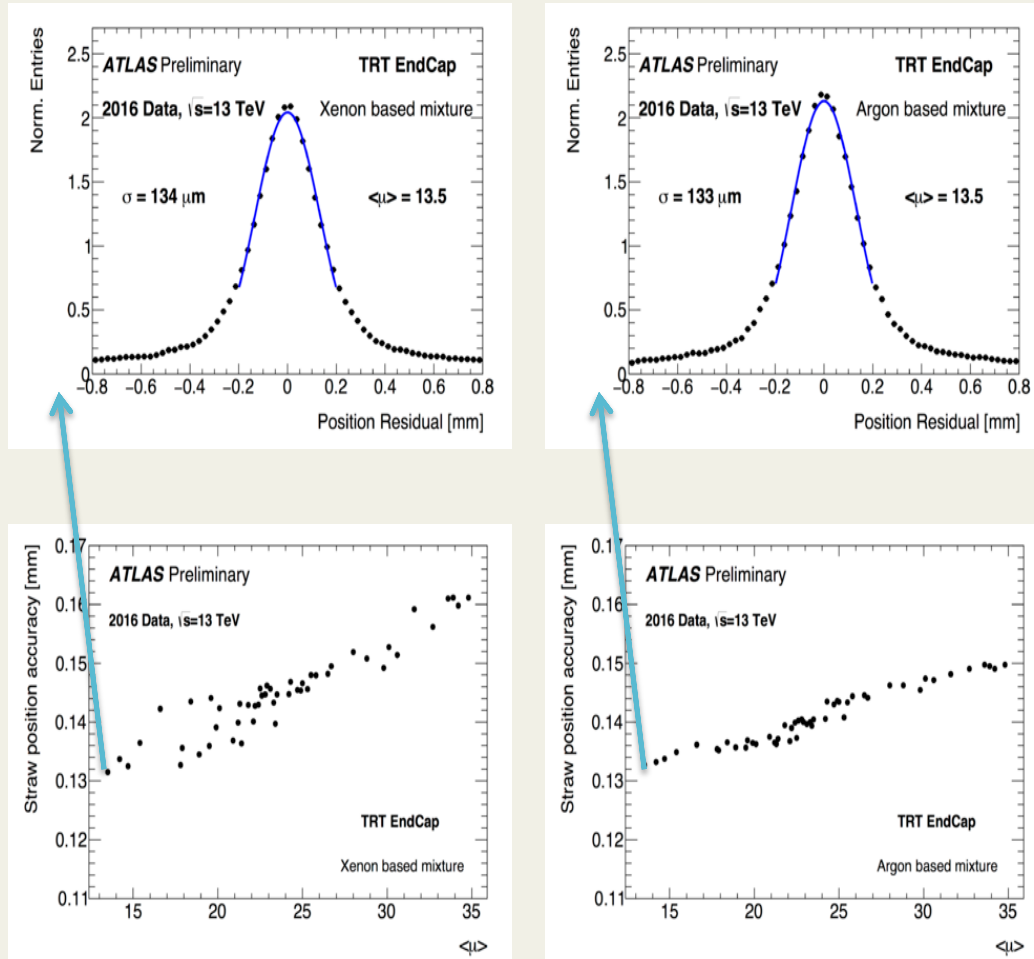
The end
Thank you

Back up

Run 2 results 2016



TRT gas geometry in 2016



Track measurement accuracy as function <μ>

Data and simulation are in good agreement