Upgrade of the ATLAS Muon Spectrometer with sMDT Chambers

Upgrade with small-diameter Muon Drift Tube (sMDT) chambers:

- Half drift-tube diameter of the "standard" MDT
- > 10 times higher rate capability
- Same resolution/efficiency

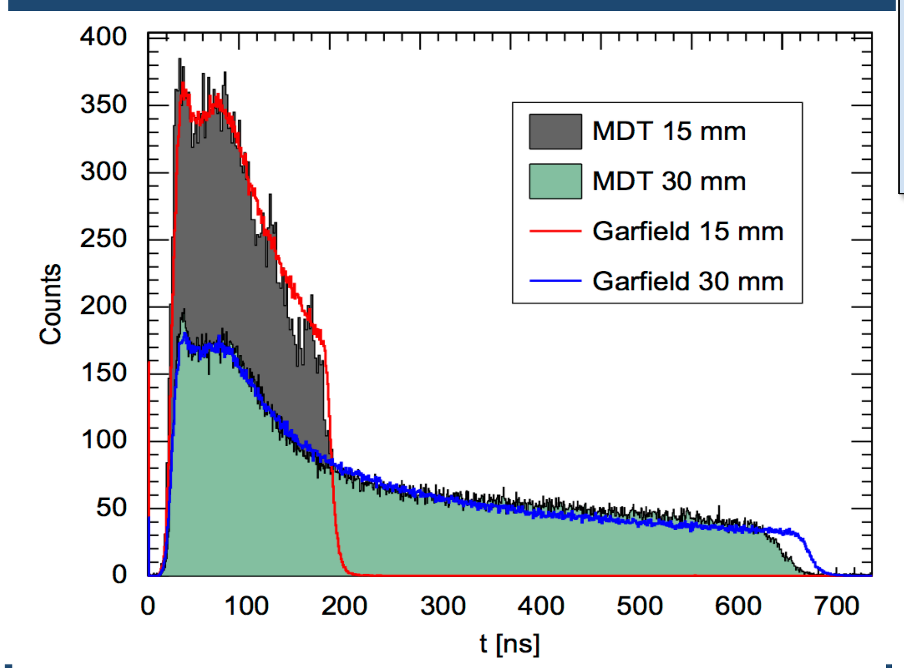
➢ **Improves rate capability in the high-background regions for Super-LHC**
➢ **Increases acceptance for precision P_T measurement & triggering**

✓ Two sMDT installed in 2014 in Muon Spectrometer barrel region
✓ Construction of 12 chambers for the feet regions underway

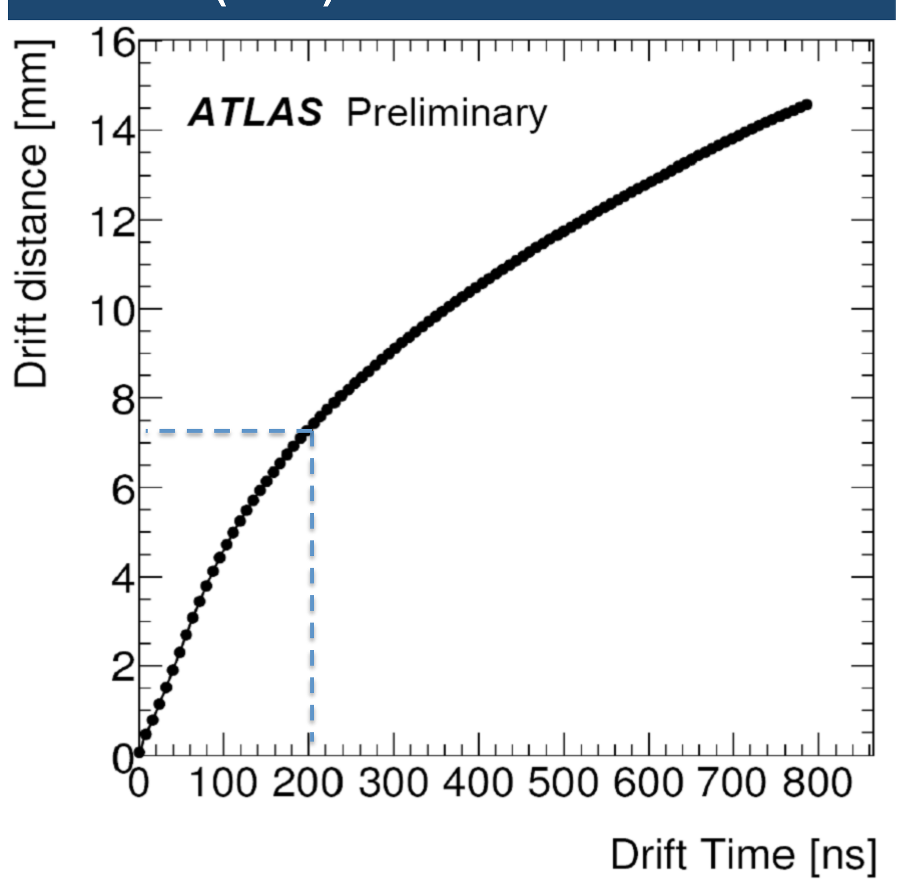
Parameters

Diameter	15 mm	30 mm
Gas	$Ar{:}CO_2$ (93:7) at 3 bar	
Wire	50 µm W-Re	
Tube Wall	400 µm	
High Voltage	2760V	3080V
Gain	$2 \cdot 10^4$	
Max Drift-Time	200 ns	750ns

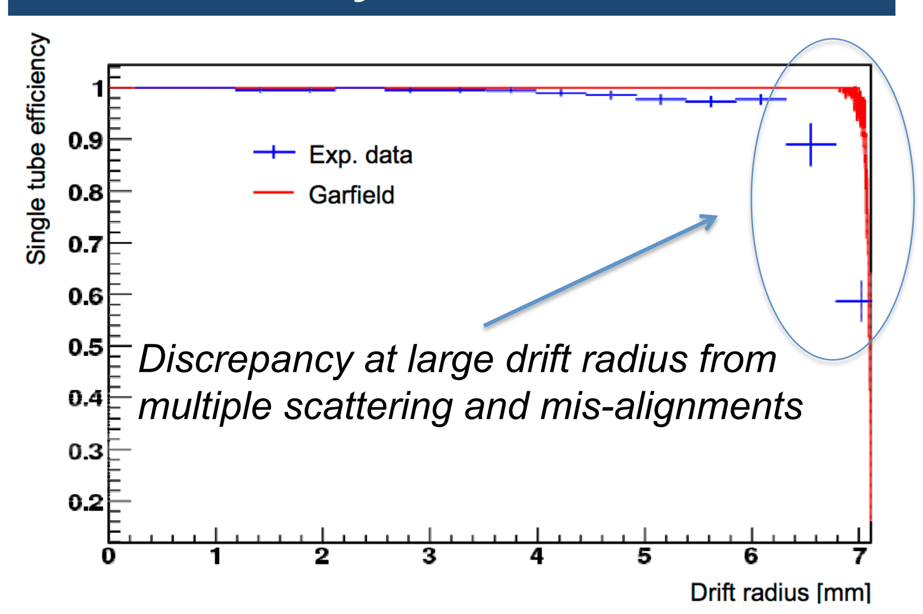
MDT and sMDT Time Spectrum



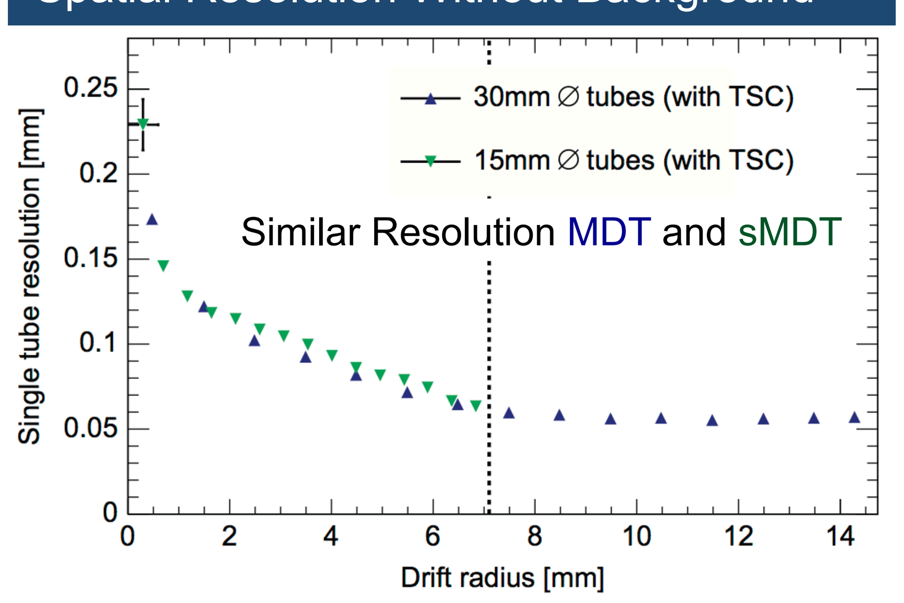
Ar:CO2 (93:7) RT-function



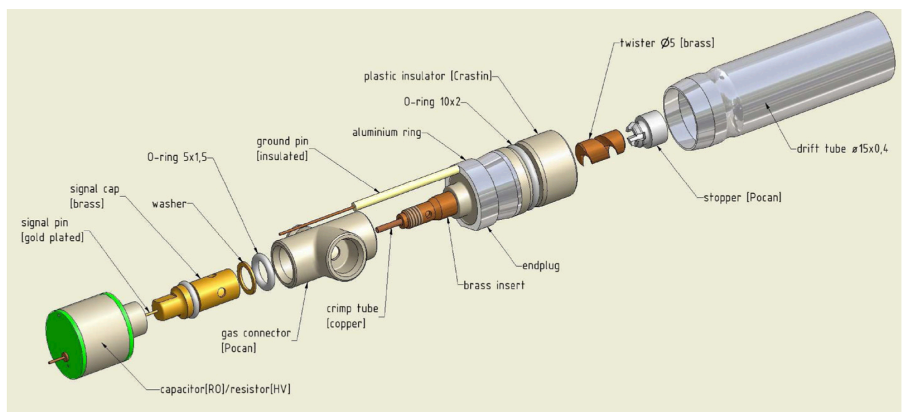
Tube Efficiency



Spatial Resolution Without Background

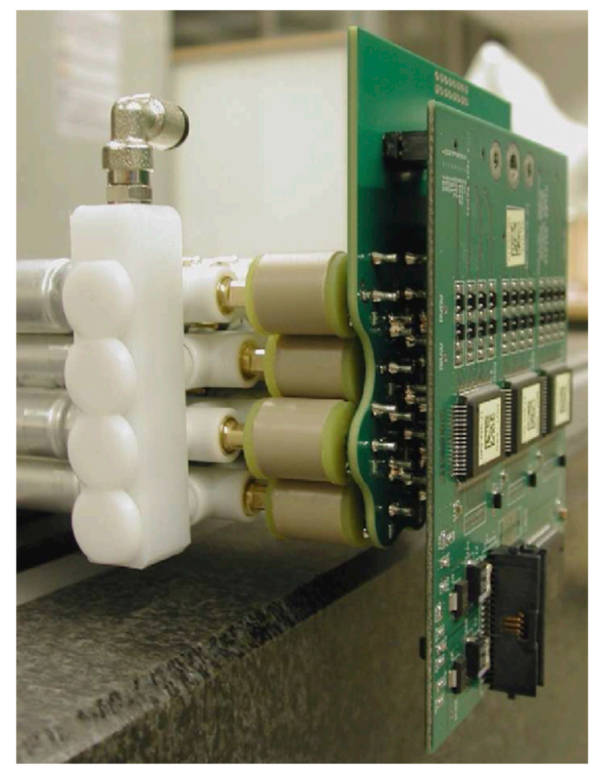


Chamber Construction



New chamber design similar to the current ATLAS MDT. Main challenge: four times denser tube gas and electrical connections → **new tube endplug** to

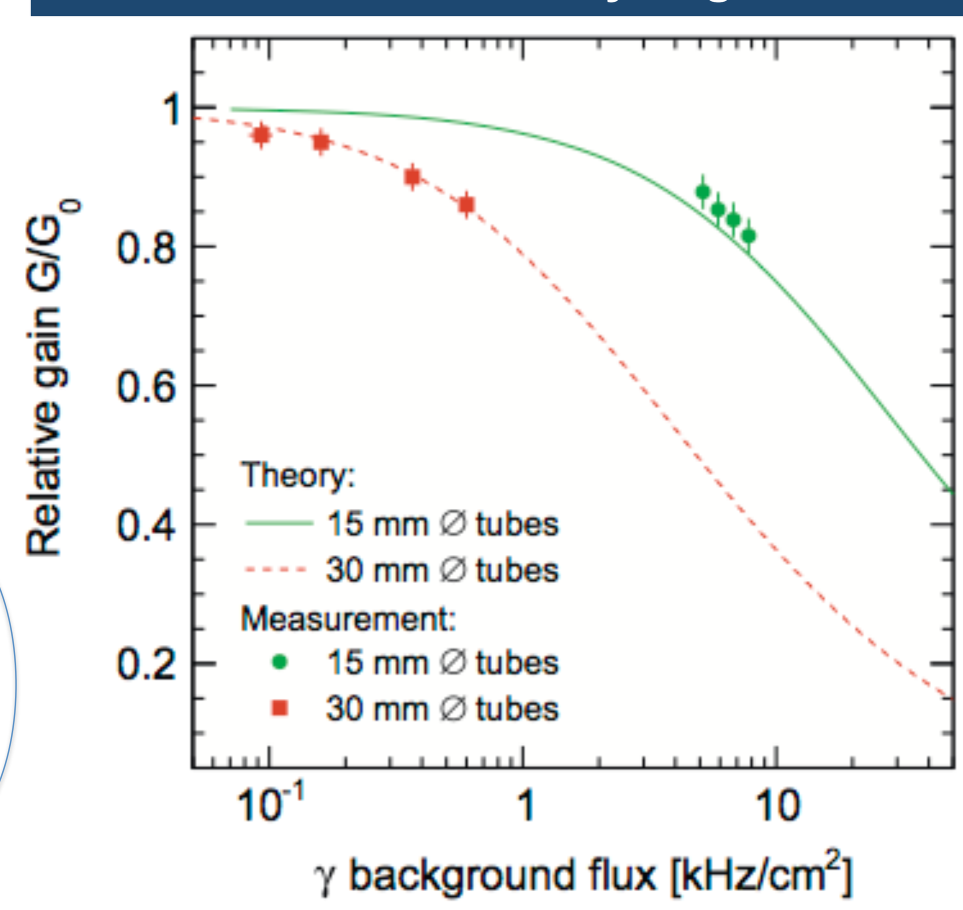
- insulate the wire from the tube wall,
- center the wire with an accuracy ~10 µm
- connect to the gas manifold (in HV-safe way)
- connect with HV and RO electronics



Tube wire tension 3.5±0.15 N; leakage current < 1 nA; gas leak rate <10^{-8} bar l/s.
Semi-automatic wiring & testing of tubes → three people can prepare 50-60 tubes/day.
A chamber of 8 layers of 78 tubes/layer glued together with high precision in just 5 days.

The 3D-survey of the two sMDT chambers (2.2 m long x 1.2 m wide) installed in the ATLAS detector has shown a construction precision of ≈ 10 µm.

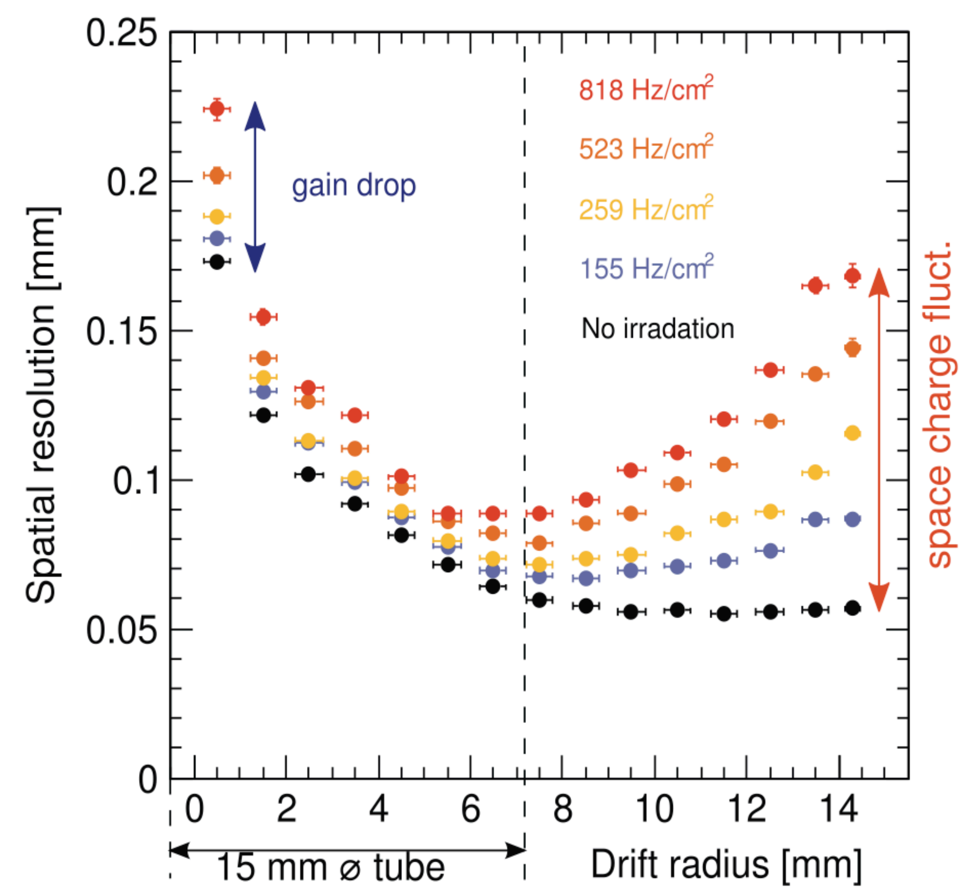
Resolution and Efficiency Degradation at High Rate Background

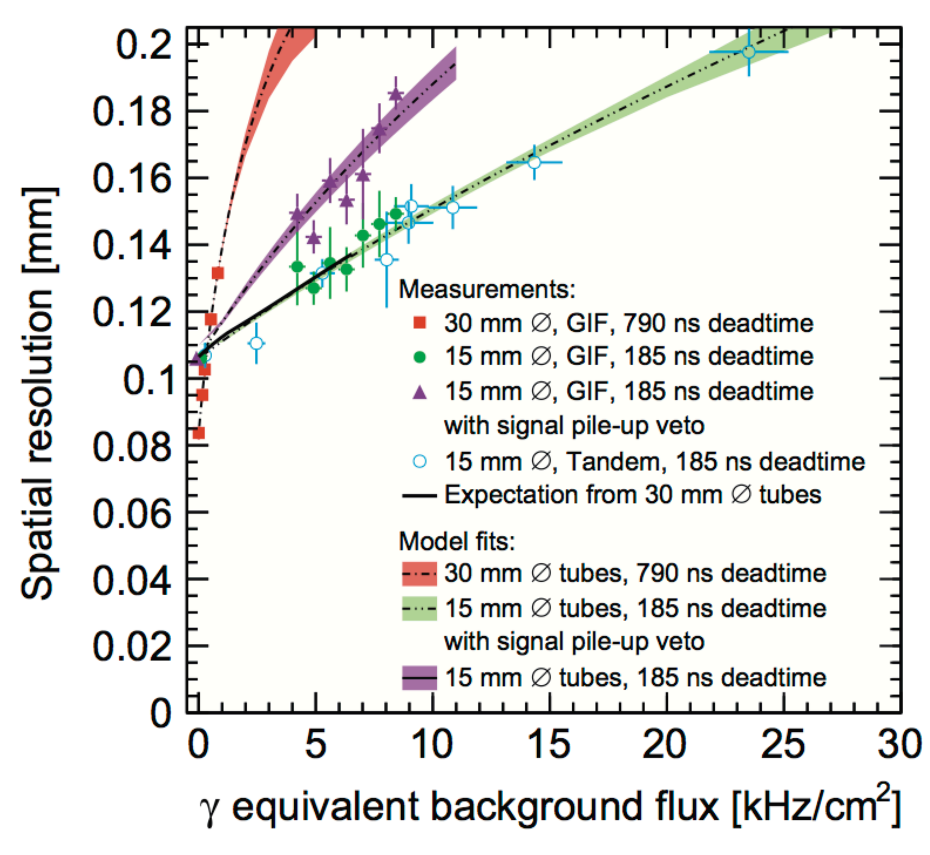


Increasing flux of background radiation (rate n/γ up to 14 kHz/cm²), degrades spatial resolution:

- at small radii: reduced gain from space charge around the wire (Gain ≈ $(r_{wire}/r_{tube})^3$ → factor 8)
- at large radii: space charge density fluctuations of ions+ modifies the E-field & v_{drift}

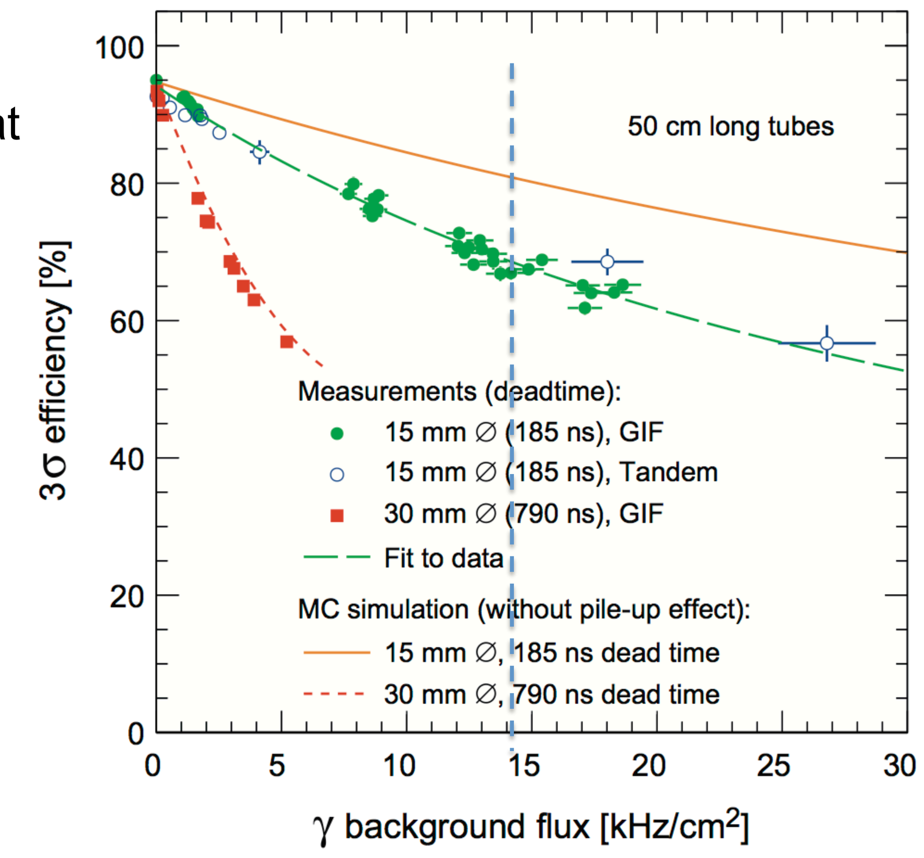
Smaller diameter → performance degradation vs radiation reduced by more than one order of magnitude





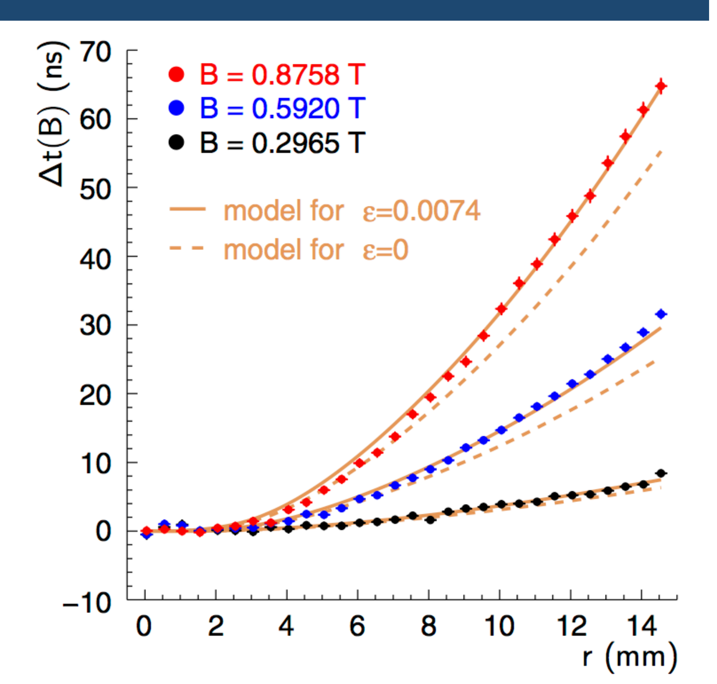
Tracking ***3σ efficiency*** = probability that muon hit distance from reconstructed track is < $3\sigma_{resolution}$

3σ efficiency ≤ 94% (δ-rays created by muon interactions in tube walls) less rapidly decreasing with background for small tube MDT ➔



Further Advantages

- Increasing tracking redundancy and efficiency by packing a double number of tubes in the same volume as a standard MDT
- Replacement of a MDT with a sandwich of sMDT and RPC to extend the trigger acceptance and reduce the trigger fake rate in regions where it is not possible to introduce any new trigger chamber (BIS7/8), without loosing tracking resolution.
- Much shorter drift time helps the project of including MDT hits information in Level 1 trigger: improved accuracy of p_T measurement of muon candidates sharpens the trigger p_T-threshold reducing the trigger rate.
- R-T function almost linear for drift radii < 7 mm: reduced sensitivity of the position measurement to gas composition and pressure, irradiation rates, temperature, magnetic field, …



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ATLAS EXPERIMENT