Performance studies on muon tracking reconstruction of sMDT detector for the HL upgrade of the ATLAS muon system

The sMDT muon detector

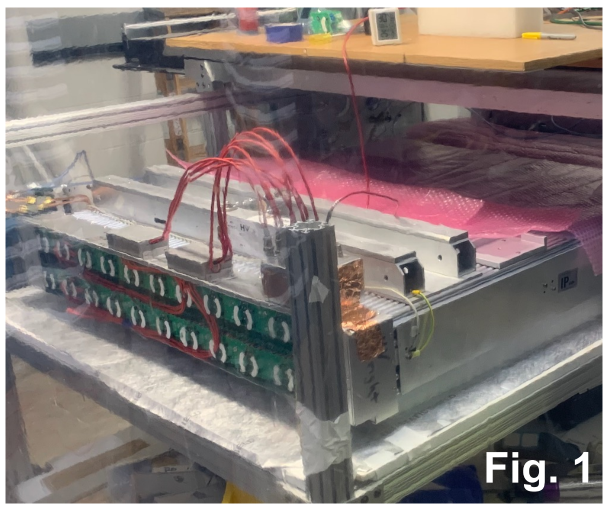

Fig. 1

- The smaller-diameter monitored drift tube (sMDT) muon detector will be built to upgrade the ATLAS Muon Spectrometer (MS) for the HL-LHC program [1]
- The detector was designed at MPI [2]. Each chamber consists of 500 tubes in 8 layers. The in-plane alignment system is assembled in the spacer-frame of the chamber. The sMDT international collaboration includes MPI, MSU, UM, Protvino, Saclay and NIKHEF
- Figure 1 shows a sMDT chamber built at Michigan in the cosmic-ray test station. DAQ is triggered by a large scintillator paddle. Figure 2 shows the typical raw TDC spectrum for each tube with time slew correction and has Fermi-Dirac fit for T0. Figure 3 shows measured cosmic-ray hits

Raw spectra

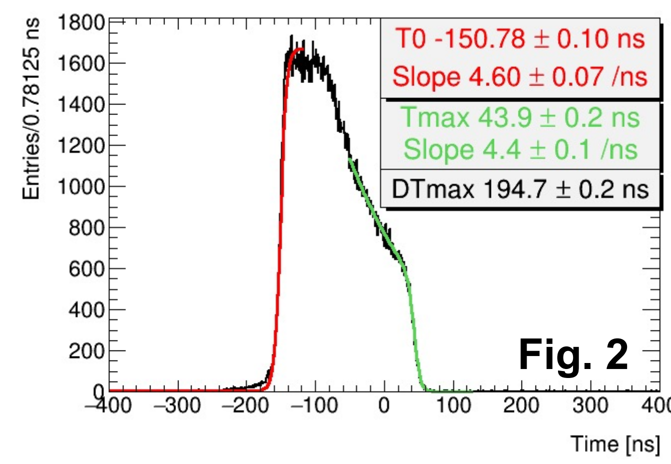

Fig. 2

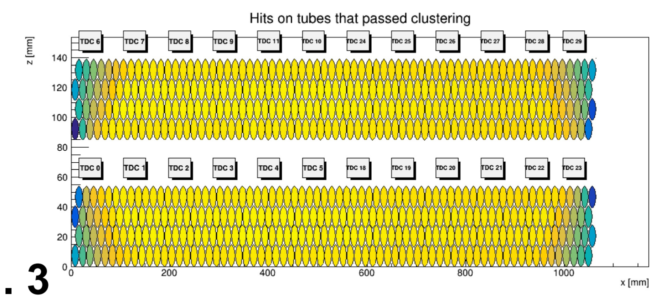

Fig. 3

Cosmic-ray muon tracking [5]

- The r(t) function is parameterized as a 10-degree Chebyshev polynomial and is derived using an autocalibration [3] routine
- The track is parameterized as a 2D straight line and event-by-event timing degree of freedom
- The residual distribution is the difference between track and r(t) radius. Figure 6 shows the biased residuals
- The mean single-hit resolution is the geometric mean of biased (all hits used) and unbiased (leave one hit out) residual distribution widths $\sigma^2=\sigma_b \times \sigma_u$

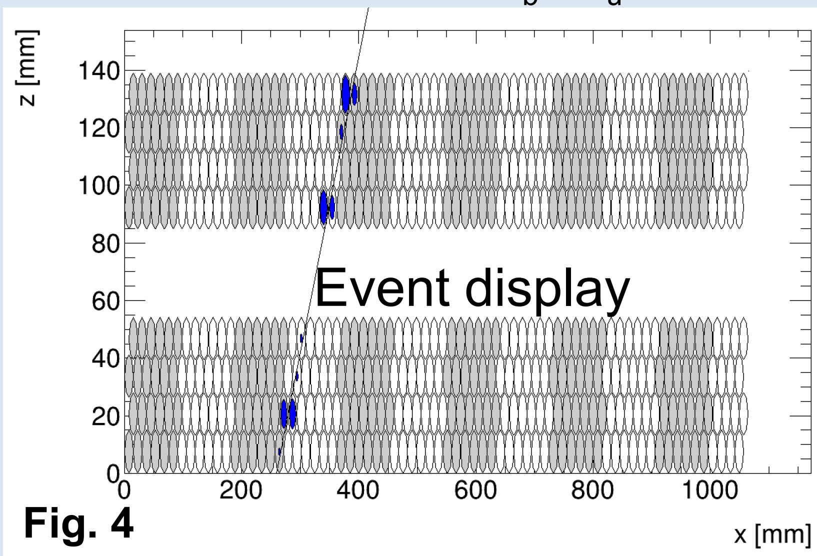

Fig. 4

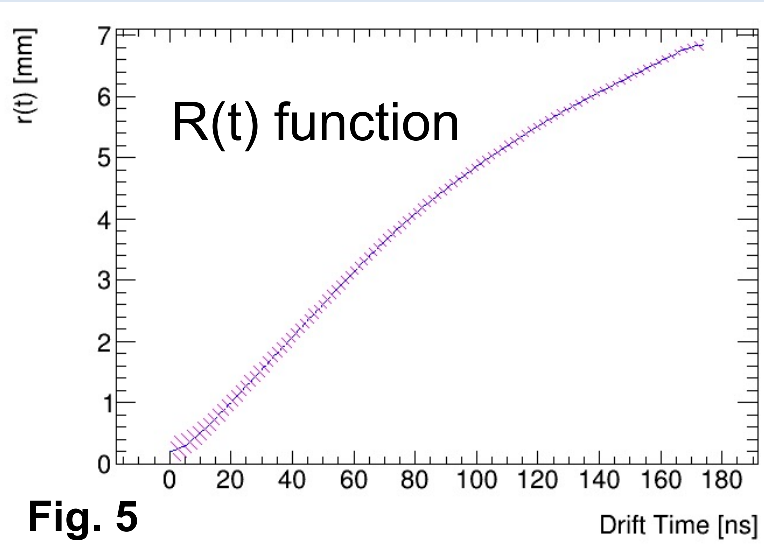

Fig. 5

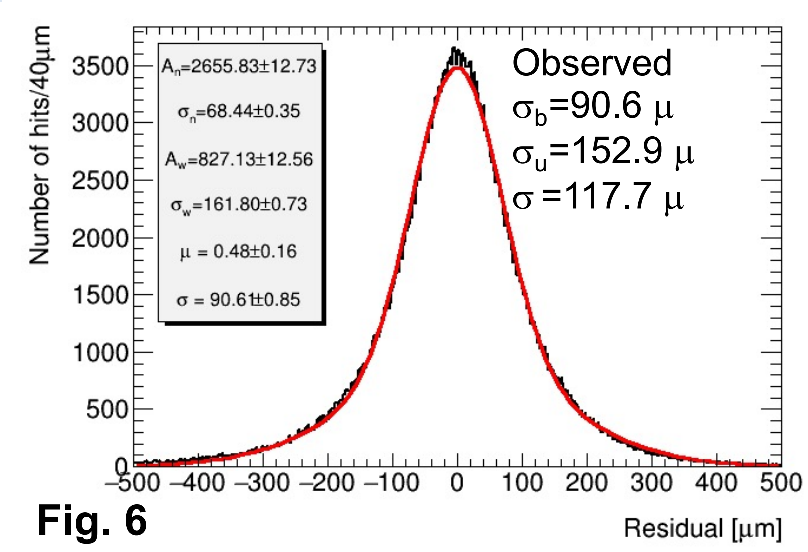

Fig. 6

Geant4 simulation [6]

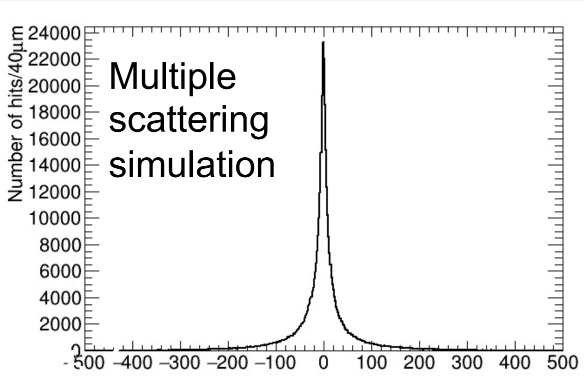

Fig. 7

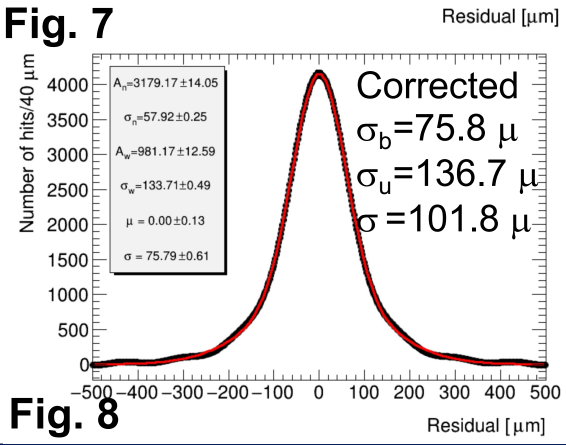

Fig. 8

- Cosmic-ray muons have an average energy 2 GeV
- We use the Geant4 simulation to estimate the expected tracking performance with a 20 GeV muon sample to compare to the ATLAS MDT resolution measurement [4]
- We deconvolute the cosmic-ray observed residuals (see fig. 6) with the Monte-Carlo truth scattering distribution for cosmic-ray muons (see fig. 7), producing figure 8
- We also convolute with the equivalent scattering distribution for 20 GeV muons
- The multiple-scattering correction for cosmic-ray muons changed resolution from 117.7 to 101.8 μm

Results

- The observed (expected) mean single-hit resolution is **101.8±7.8 μm** (106 μm) [2] (fig. 9)
- The observed (expected) layer efficiency is **0.942±0.002** (0.94)
- New, high gain readout electronics (ASD 2) improve the resolution to **90.6±7.8 μm**
- Uncertainty estimate includes systematic uncertainties for time slew, tracking parameterization, and more

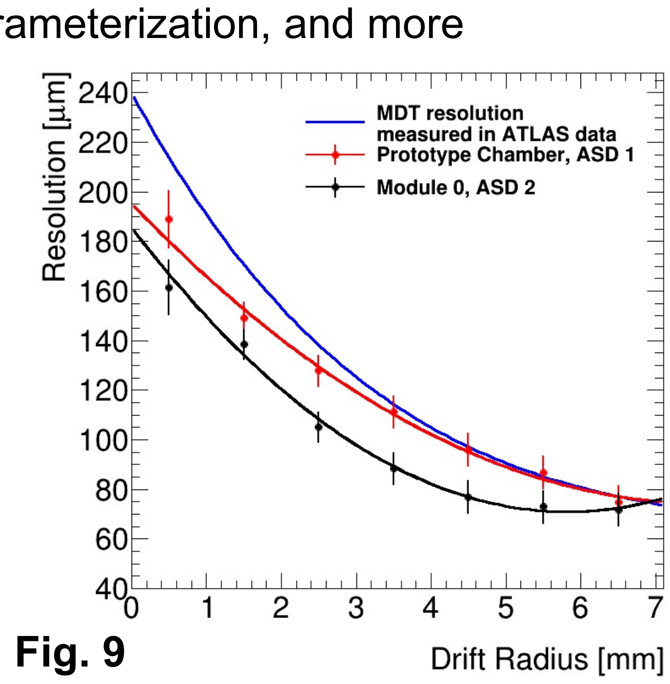

Fig. 9

References

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[5] K. Nelson, Y. Guo, D. Amidei, E. Diehl, arXiv:2105.09263
[6] The Geant4 collaboration, Nucl. Inst. Meth. A. 506 (2003) 3 p. 250-303

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EPS-HEP 2021, 26-31 July

ATLAS EXPERIMENT