Measurement of the 2nd coordinate for drift tube chambers

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MPP ATLAS Muon Group

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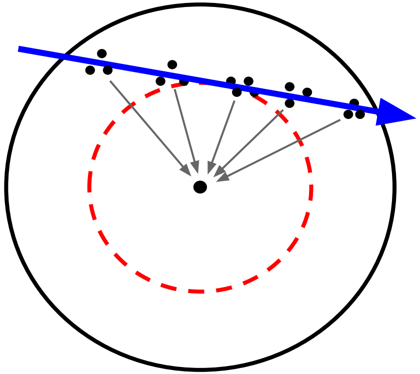
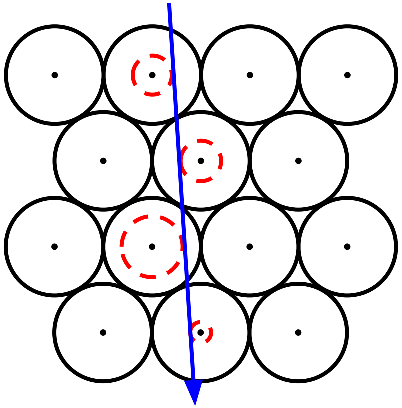
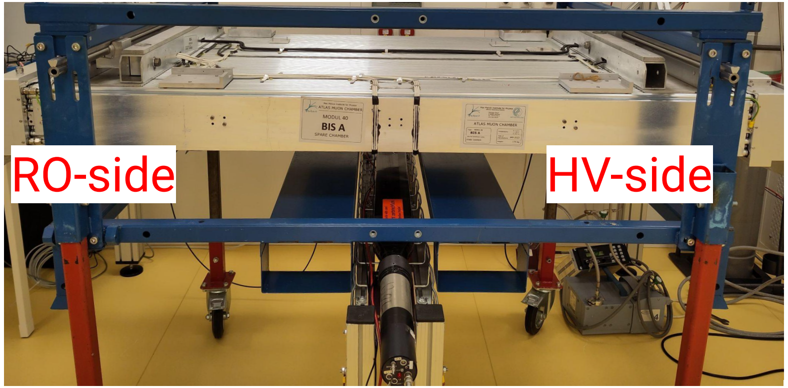
What is a drift tube chamber?

- Measurement of the track in 2D of :
  - Tube level: Obtained drift time, measuring the time electrons take to drift to the wire.
  - Chamber level: Track by using multiple layers of drift tubes.



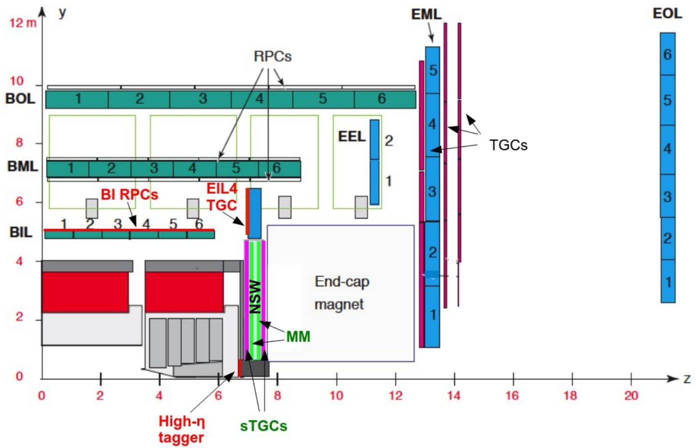


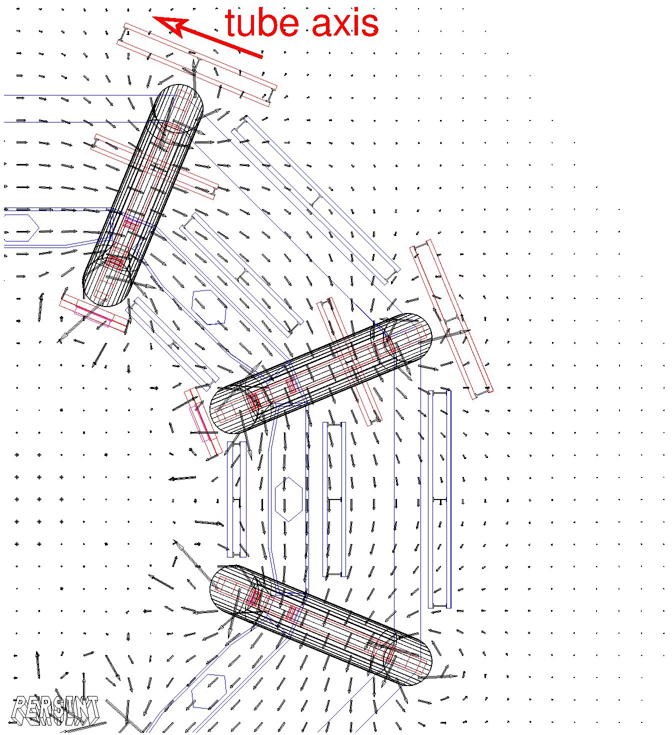


- Applying high voltage on the other side of the tubes (HV- side) and read out signals on one side of the tube (RO-side). Don't get information, where along the wire the signals are produced.
- Used in various experiments for large area coverage with high position resolution measurement:
  - ATLAS Muon Drift Tubes (MDT) and small-diameter Muon Drift Tubes (sMDT)

Why to obtain the 2nd coordinate in ATLAS for MDT's?

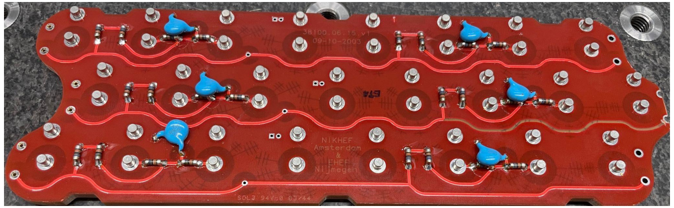
- 2nd coordinate needed to resolve inhomogeneities of magnetic field
  - Position resolution for 2nd coordinate ~20cm needed.
- Traditional Approach for Drift Tubes Chamber (relying on external sources for the 2nd coordinate)
- Back up for Legacy ATLAS RPCs in HL-LHC era
  - Designed for LHC era
  - Legacy RPCs are reduced in voltage from 9.8kV to 9.2kV
  - Remains slight risk of individual RPCs fail during HL-LHC
- During Long Shutdown 3 the outer MDT are accessible for modification

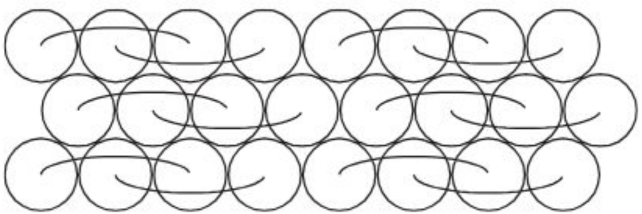


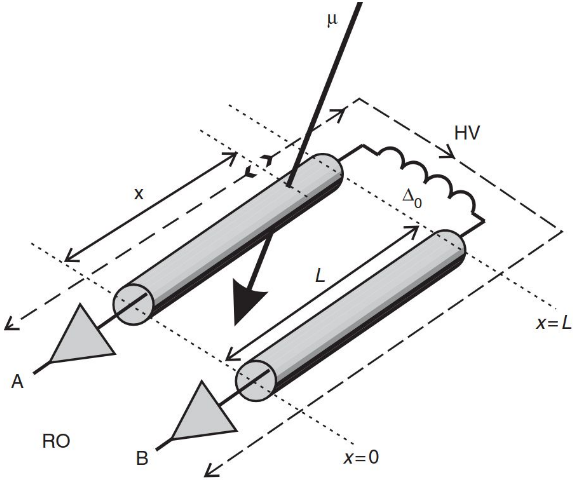


Setup of MDT

- ➢ Muon Drift Tube (MDT) prototype available with 3.77m long tubes
- ➢ HV hedgehog card with Twin Tube Concept from NIKHEF
  - ○ Connects 2 tube to each other
  - ○ Measure time difference of the signal from the readout side
  - ○ Build-in delay of 5ns to distinguish events close to the HV side
- ➢ Easy way to implement in ATLAS
  - ○ Only HV hedgehog cards needs to be exchanged to get 2nd coordinate

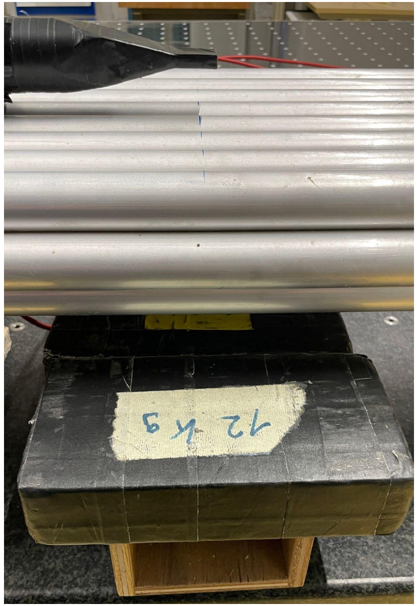






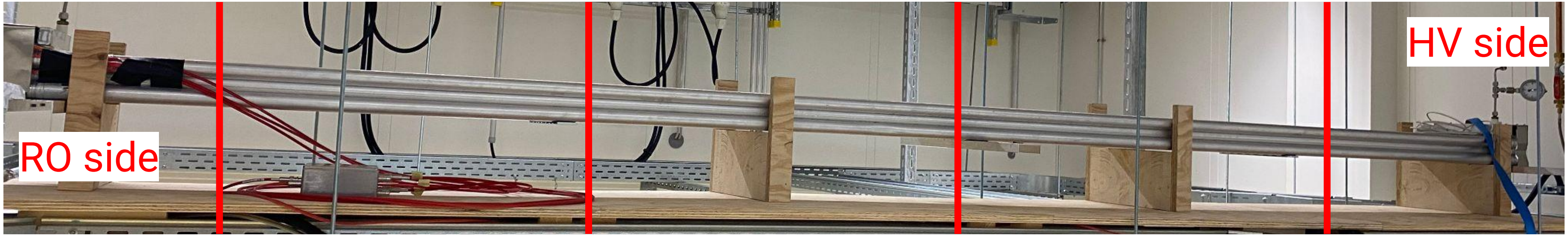
Setup of MDT

- For triggering on muons at different distances from the RO side
  - small 2.5 cm*2.5 cm scintillator on top
  - big scintillator covered with Lead as coincidence
- Readout
  - with readout board with a ATLAS TDC chip with time resolution of 0.78 ns and ATLAS ASD chip
  - measure threshold crossing time and amplitude of signals



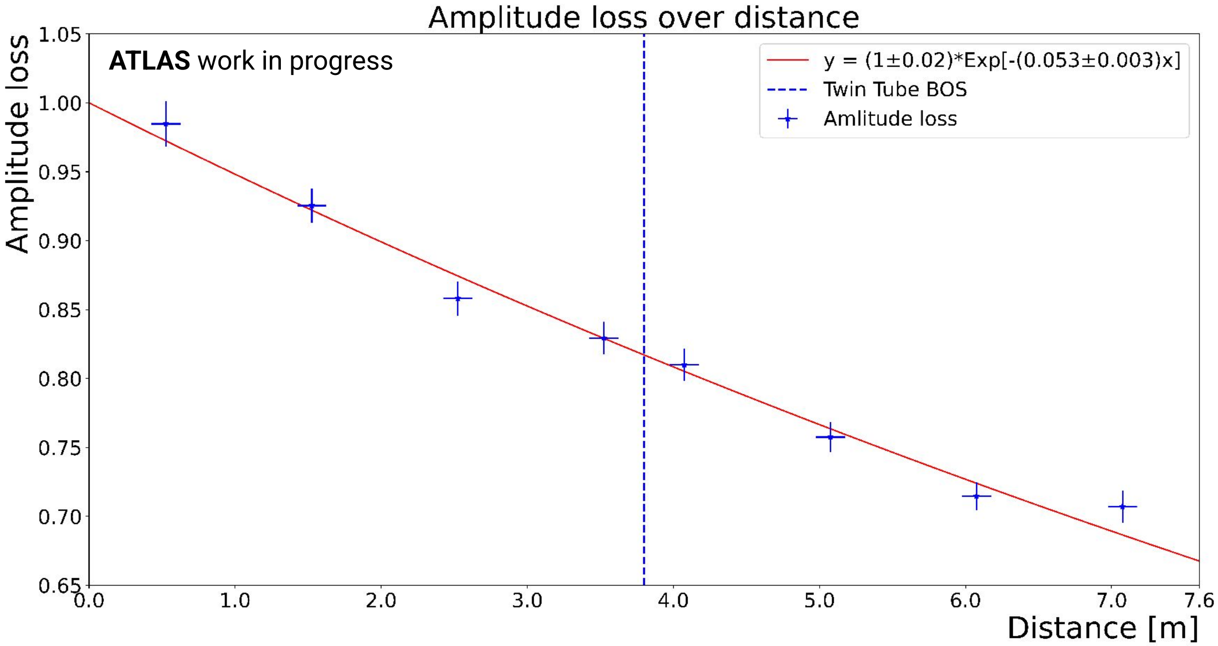
distance from readout side for the placement of scintillators

0.5m 1.5m 2.5m 3.5m



Amplitude Loss for MDT

- Amplitude loss: α = (0.053 ± 0.003) m^{-1}
- Theoretical prediction amplitude loss: α_{theory} = 0.0576 m^{-1}
- Signal differences of amplitude up to 35%

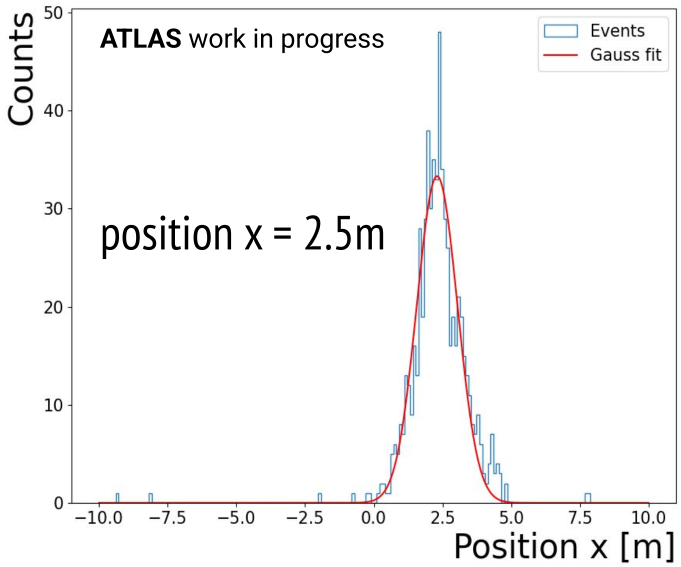


Position resolution of 2nd coordinate

- Try to calculate the position of 2nd coordinate via difference in amplitude loss was considered.
- Insufficient resolution to resolve inhomogeneities of magnetic field

$$x = L - \frac{\ln\left(\frac{\mathrm{Amp}_{twin}}{\mathrm{Amp}_{main}}\right)}{2 \cdot \alpha}$$

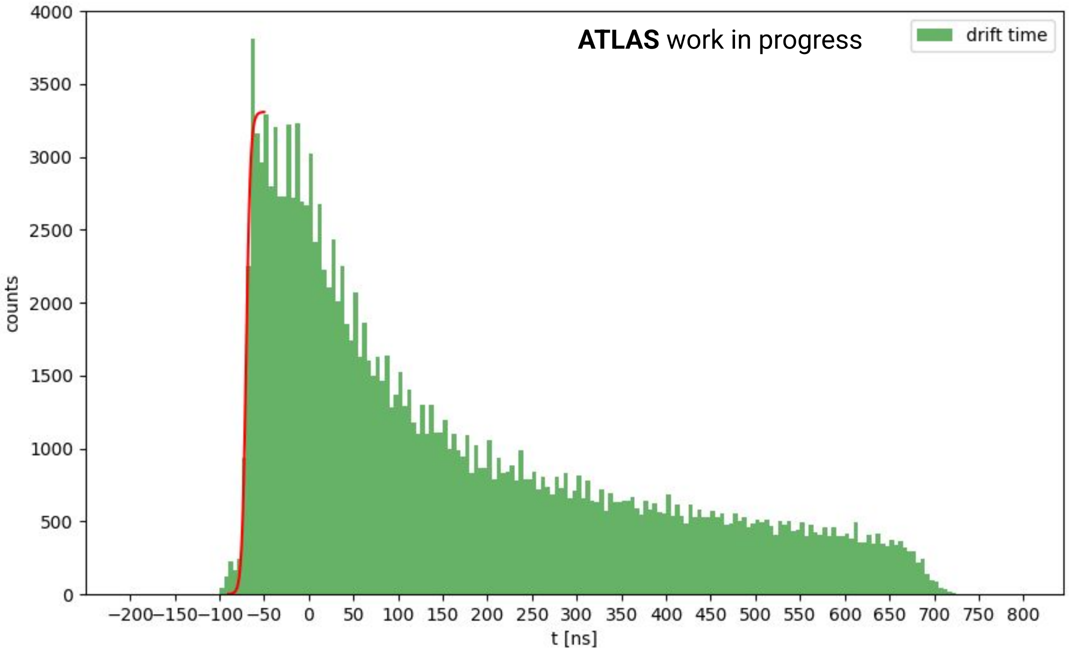
σ=(73.9+/-1.7)cm



Arrival time of signal for MDT

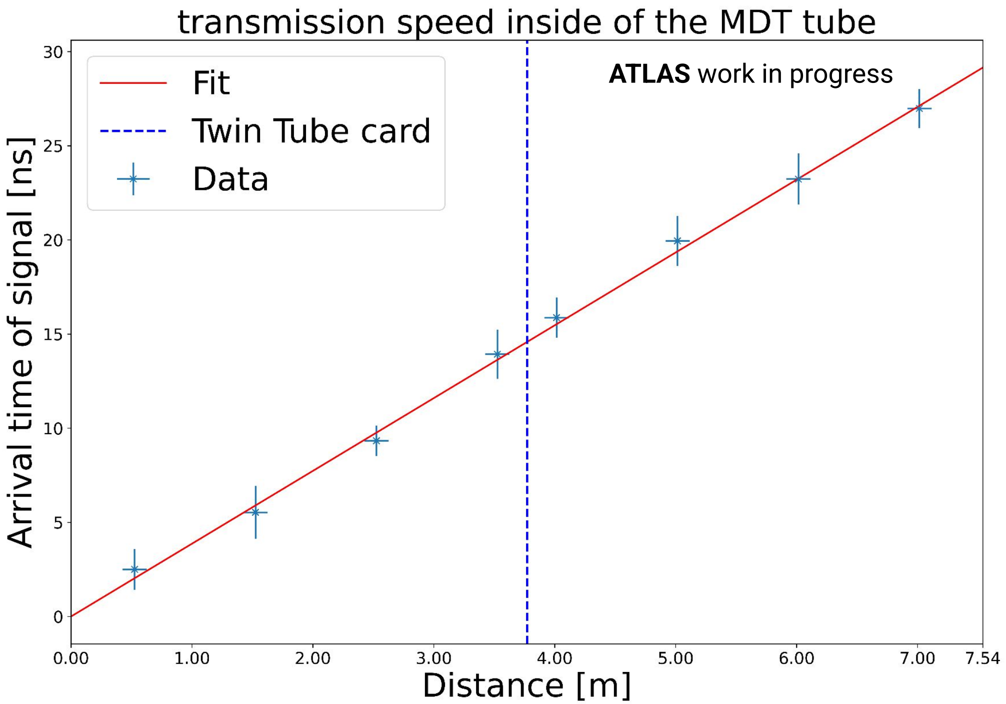
- Measurement of the starting time of the drift time spectrum t_0 (time with muon traversing closest to the wire)
- Get t_0 from performing fit Fermi function
- Perform the fit to drift time spectrum at different positions along the tube

$$G(t) = p_0 + \left[\frac{A_0}{1 + e^{-\frac{t-t_0}{T_0}}}\right]$$



Transmission speed for MDT

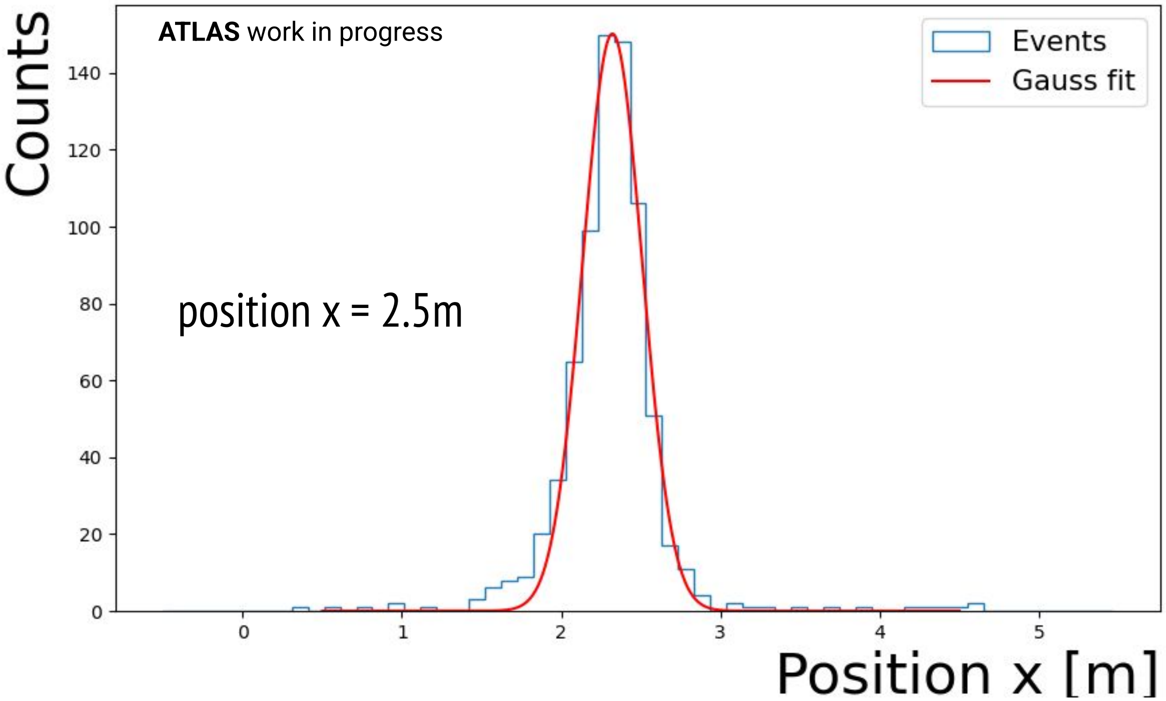
- Fitting to a transmission speed of v = (0.87 ± 0.02) × c
- ATLAS TDC resolution best position resolution achievable (20.4 ± 0.4) cm



Position resolution of 2nd coordinate

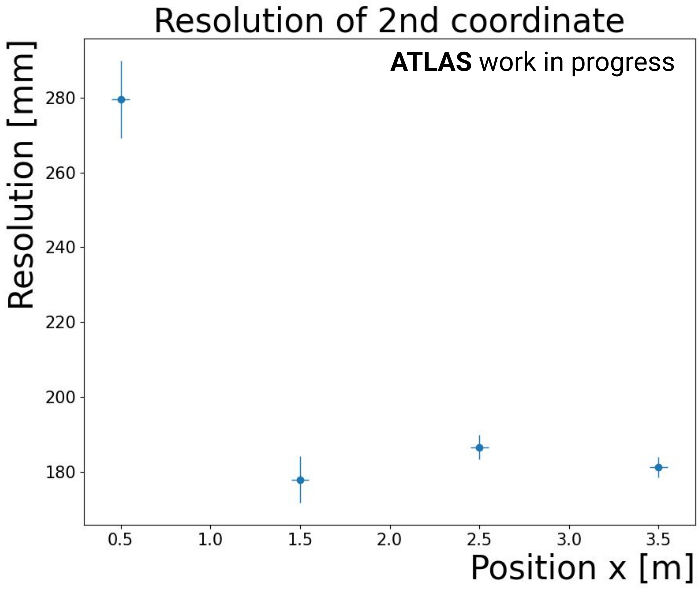
- Calculation of the position of 2nd coordinate via time difference
- Position resolution of 2nd coordinate σ = (18.7 ± 0.3) cm

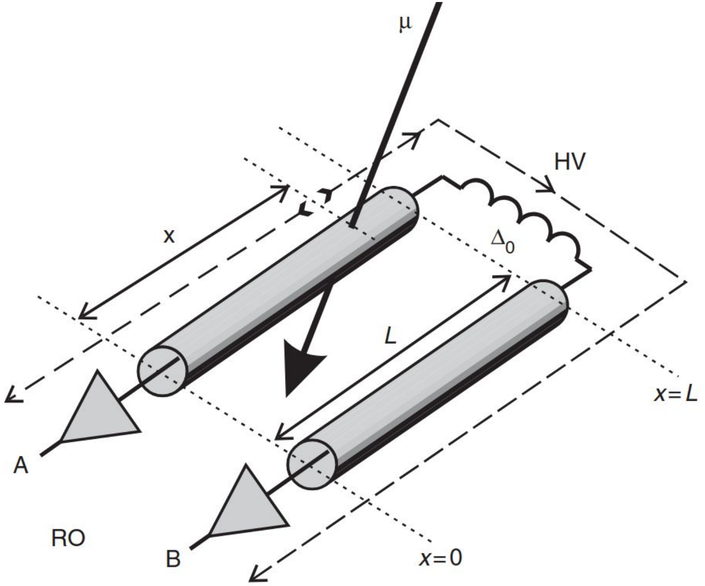
$$x = L - \frac{t_{diff} \cdot v_{trans}}{2}$$



Position resolution of 2nd coordinate

- Calculation of the position of 2nd coordinate via time difference at different positions along the tube
  - at 0.5 meters the time difference is large between the measurements due to fluctuations in the transmission results in worse resolution
- Limited by the resolution of the ATLAS TDC position resolution of (20.4 ± 0.4) cm
- Showed desired resolution and proposed to be used as a backup for the legacy RPC's

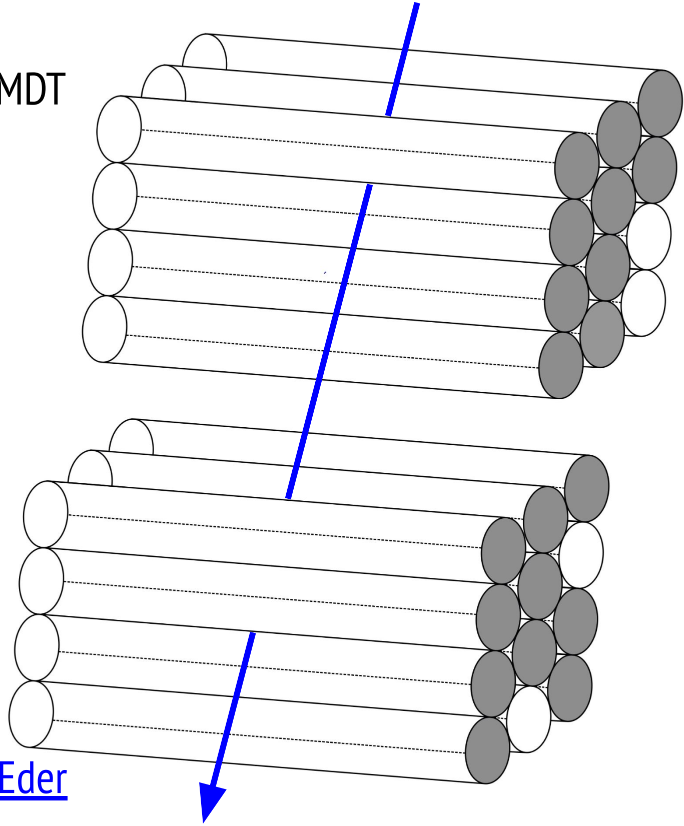




Why to obtain the 2nd coordinate sMDT?

➢ sMDTs are designed for high rate environment
  - 2x smaller tube radius and 4x smaller max. drift time compared to MDT
    ⇒ 8x lower drift tube occupancy
  - work up to drift tube chamber occupancy of 20%-30%
    - to still be able to do track reconstruction
  - to be installed in high background region of ATLAS (next talk)

➢ Having information of 2nd coordinate one:
  - Can differentiate background hits from tracks
    - Background hits are produced somewhere along the wire
    - Hits from tracks are all around the same 2nd coordinate.
  - Standalone capabilities of sMDT
    - independent of other detector reconstruct tracks in 3D
    - more about standalone MDT muon trigger for ATLAS (Stefan Eder talk T 34.8)



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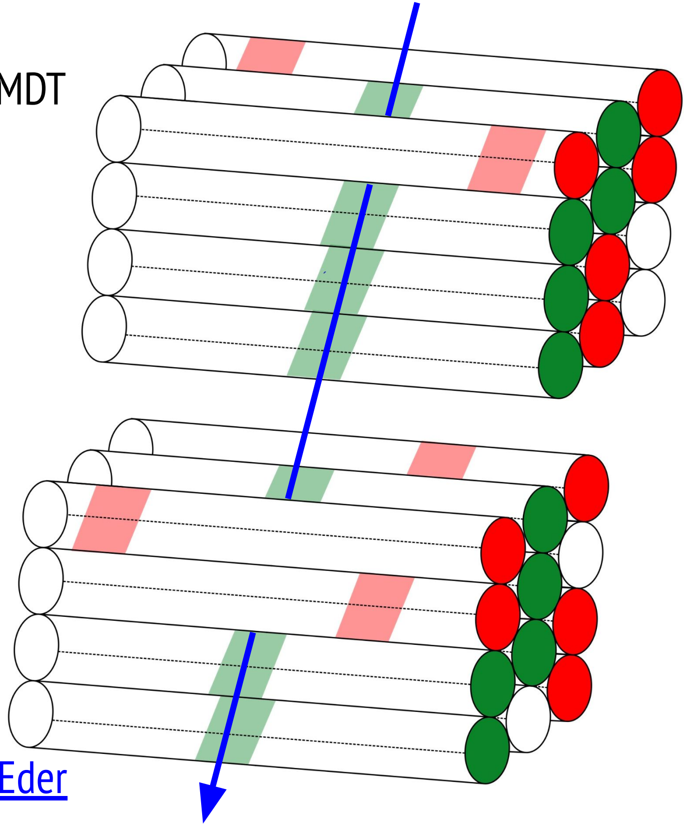

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Setup of sMDT

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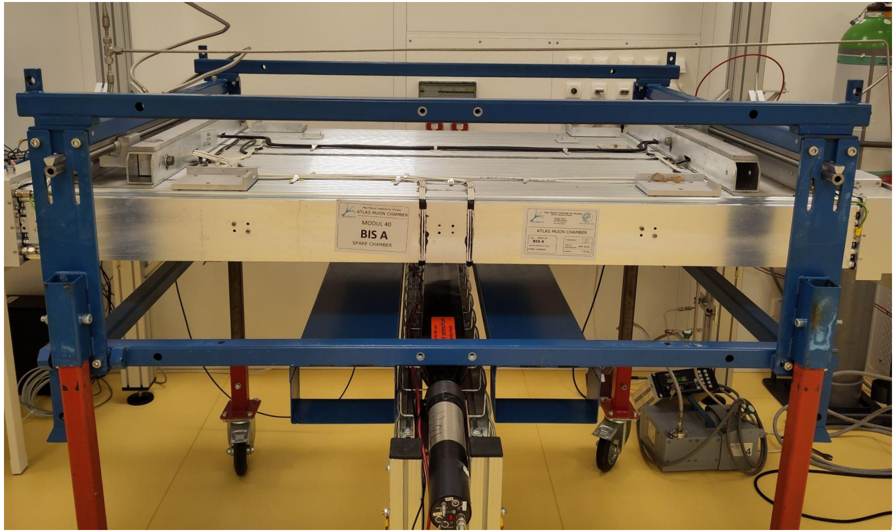
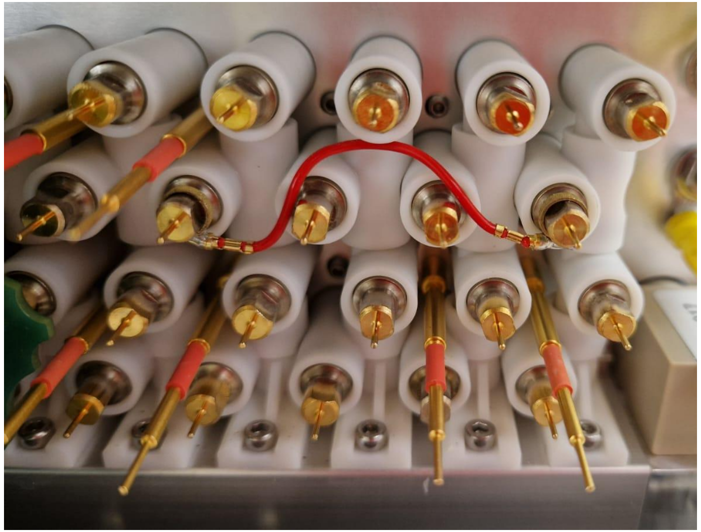
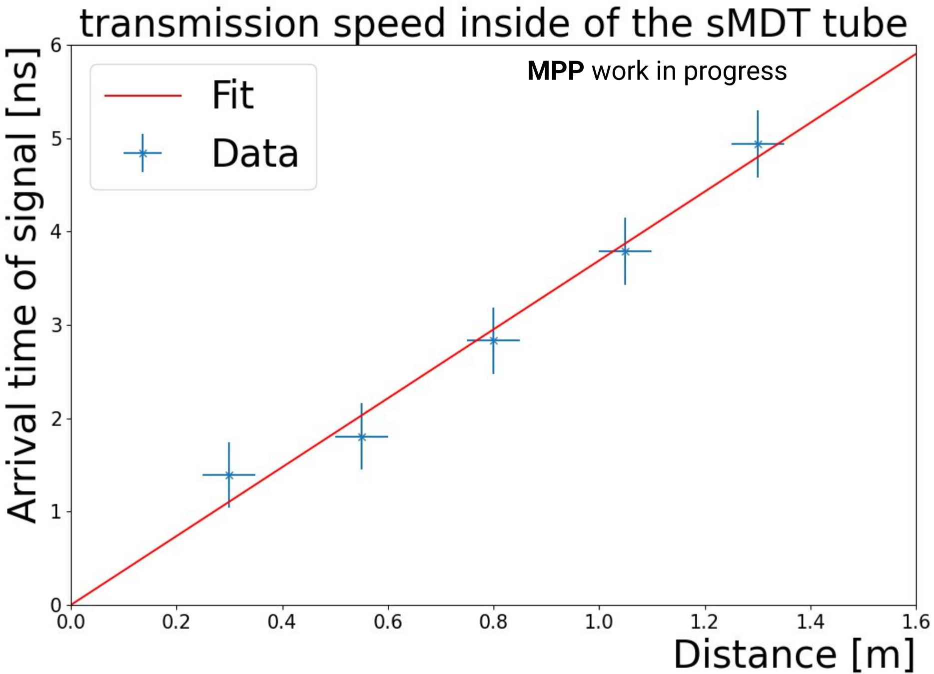
- small-diameter Muon Drift Tube (sMDT) available with 1.6m long tubes
- Tried to find an easy and fast way to have the 2nd coordinate
  - Starting with Twin Tube concept and connect two tubes with a wire
  - Down side of Twin Tube concept doubles the tube occupancy
- Did again measurements at different positions along the tube





Transmission speed for sMDT

- Doing again t_0 fit for different positions along the tube
- Leading to a transmission speed of $v_{trans;\ sMDT} = (0.90 \pm 0.08) \times c$
- Similar transmission speed to $v_{trans;\ MDT} = (0.87 \pm 0.02) \times c$



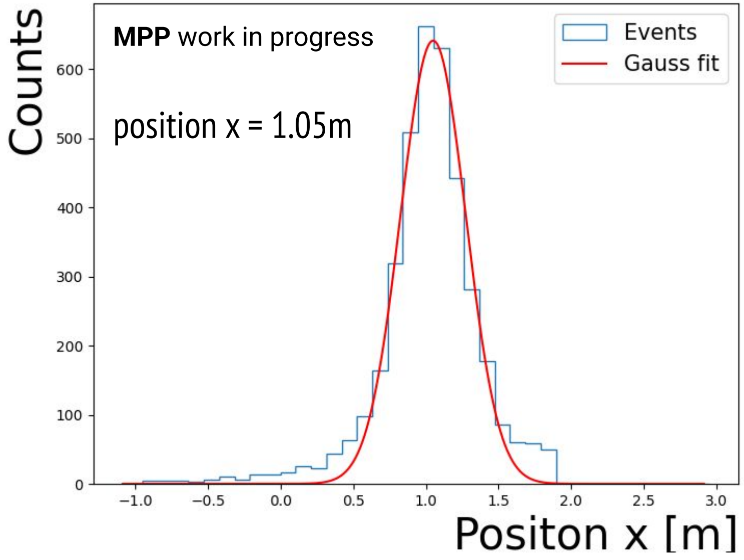
Position resolution of 2nd coordinate for sMDT

- Calculation of the position of 2nd coordinate via time difference

$$x = L - \frac{t_{diff} \cdot v_{trans}}{2}$$

- Allows to split the 1.6m long tube into 7 parts for distinguishing background events from tracks.
  - To be tested in GIF++ with test beam and gamma background source.
- To be done investigation into higher resolution TDCs (if purely limited by resolution of TDC the position resolution)
  - picoTDC with resolution of 3ps σ=(0.79+/-0.01)mm

σ=(22.4+/-0.1)cm



Summary and Outlook

- Development way to measure 2nd coordinate for drift tube chambers using Twin Tube concept.
- Demonstrated position resolution in 2nd, reducing dependence on external tracking systems.
  - Proposed to be used in the ATLAS detector in the outer layers for the HL-LHC.
- Further studies
  - Twin Tube Concept with sMDTs in a test beam with high gamma background irradiation.
    - show improved track reconstruction by knowledge of 2nd coordinate.
  - Want to implement real dual readout for sMDTs with readout electronics on both ends of the tube.

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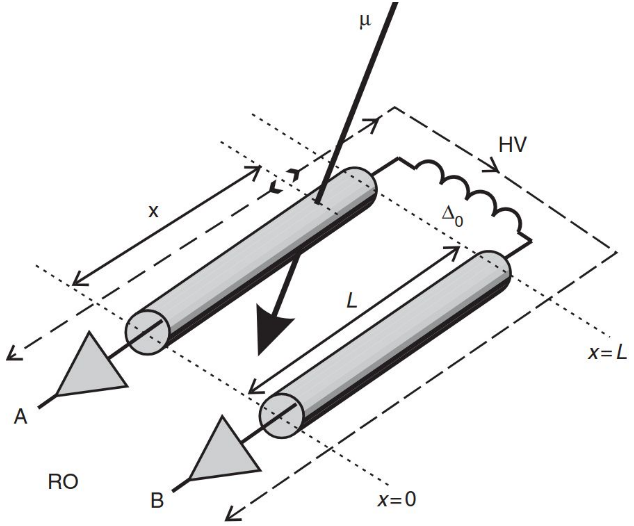
Thank you for your attention !

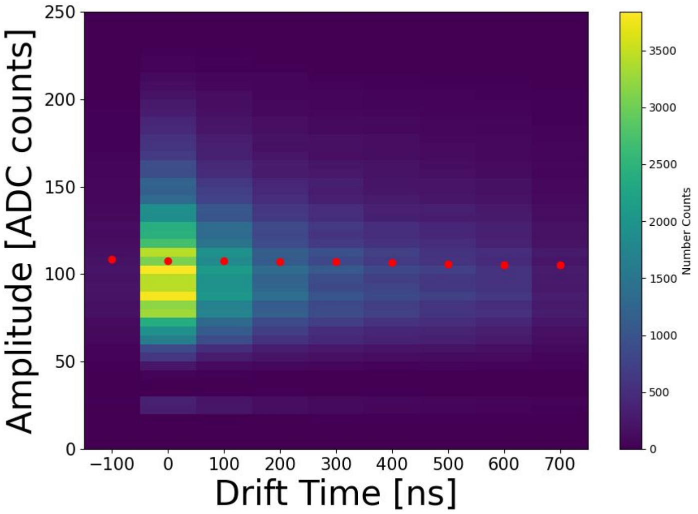
Event selection

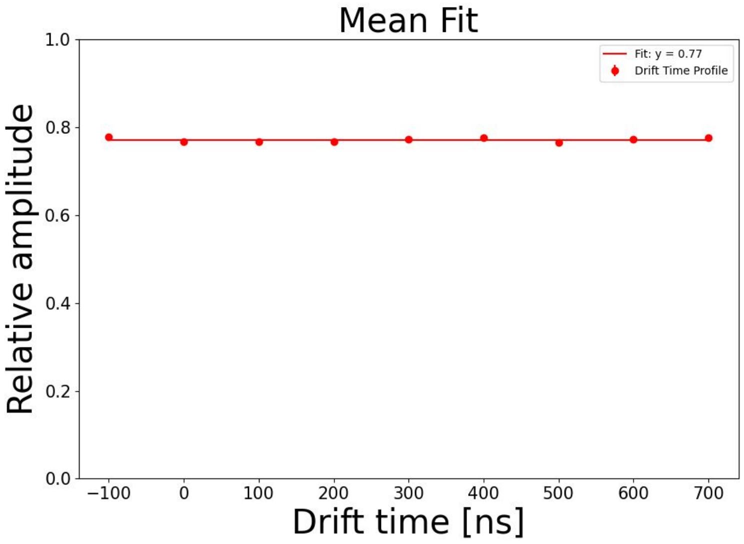
- Looking into the twin tube partners checking if both of them have a hit
- Selection in to main tube (where the muon hit tube) and twin tube partner (where only the signal was transmitted in) via the time difference. Main tube has a smaller time then the twin tube partner (due to the build in delay).



Relative amplitude loss for MDT

- For the different length plotting amplitude against the drift time in bins of 100 ns and 5 ADC counts and then get the mean amplitude in each drift time bin
- Afterward compare the mean amplitudes in the drift time bins of the lengths against one reference length with the mean amplitudes in the drift time bins (main tube at a length of 0.5m)
- From the drift time bins calculate the mean amplitude loss for each length





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