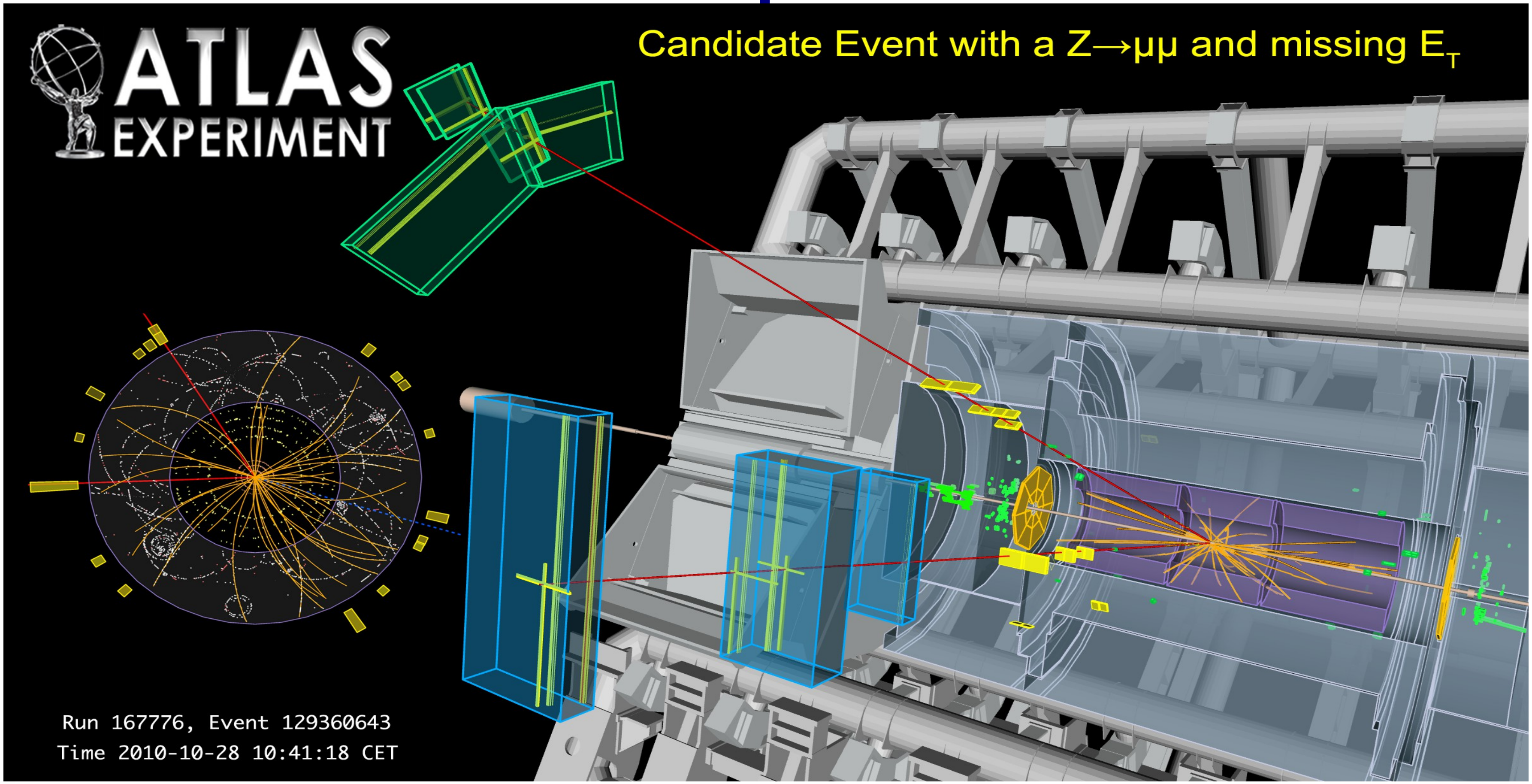
Calibration and Performance of the precision chambers of the ATLAS Muon Spectrometer



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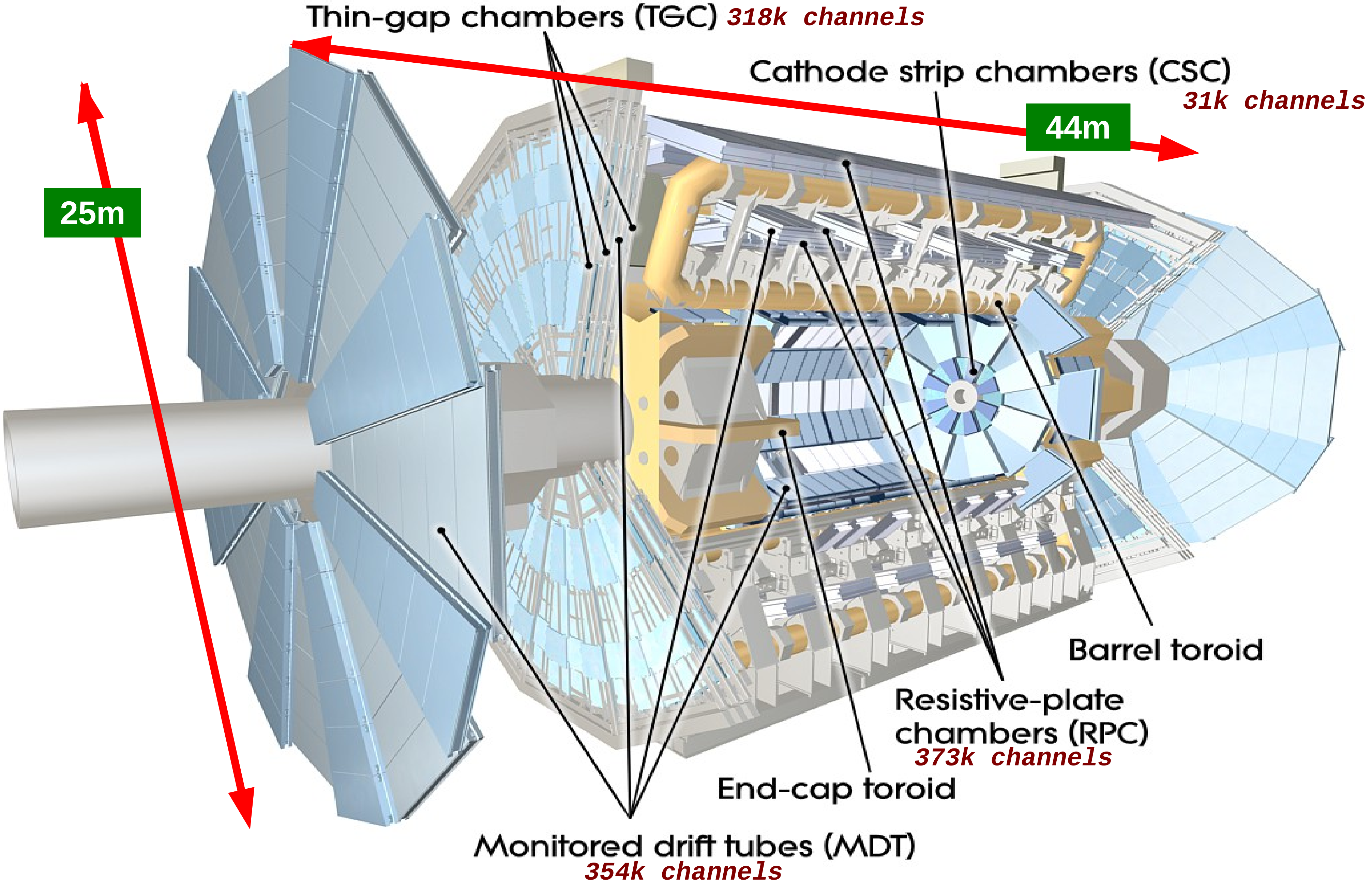
On behalf of the ATLAS Muon collaboration

ATLAS Muon Spectrometer



Spectrometer Overview

- Designed to trigger on and measure muons with $p_T \gtrsim 3$ GeV with resolution 3% < 250 GeV to 10% @ 1 TeV.
- Magnetic field from air-core toroids: barrel (∼3T·m) + 2 endcap (∼5T·m)
- Precision detectors (Δx≃60-70μm)
  - $0<\eta<2.7$ Monitored Drift Chambers (MDT)
  - *Monitored* ⇨Positions monitored by an alignment system
  - $2.0<\eta<2.7$ Cathode Strip Chambers (CSC)
- Trigger detectors (trigger + 2rd coordinate measurement Δx≃2 cm)
  - $0<\eta<1.0$ (Barrel) Resistive Plate Chambers (RPC)
  - $1.0<\eta<2.4$ (Endcap) Thin Gap Chambers (TGC)
- Alignment system – determine chamber positions to ~50 μm
  - Separate optical alignment systems for barrel & endcap complemented by alignment with tracks. See Aefsky TIPP2011 https://indico.cern.ch/contributionDisplay.pysessionId=12&contribId=123&confId=102998
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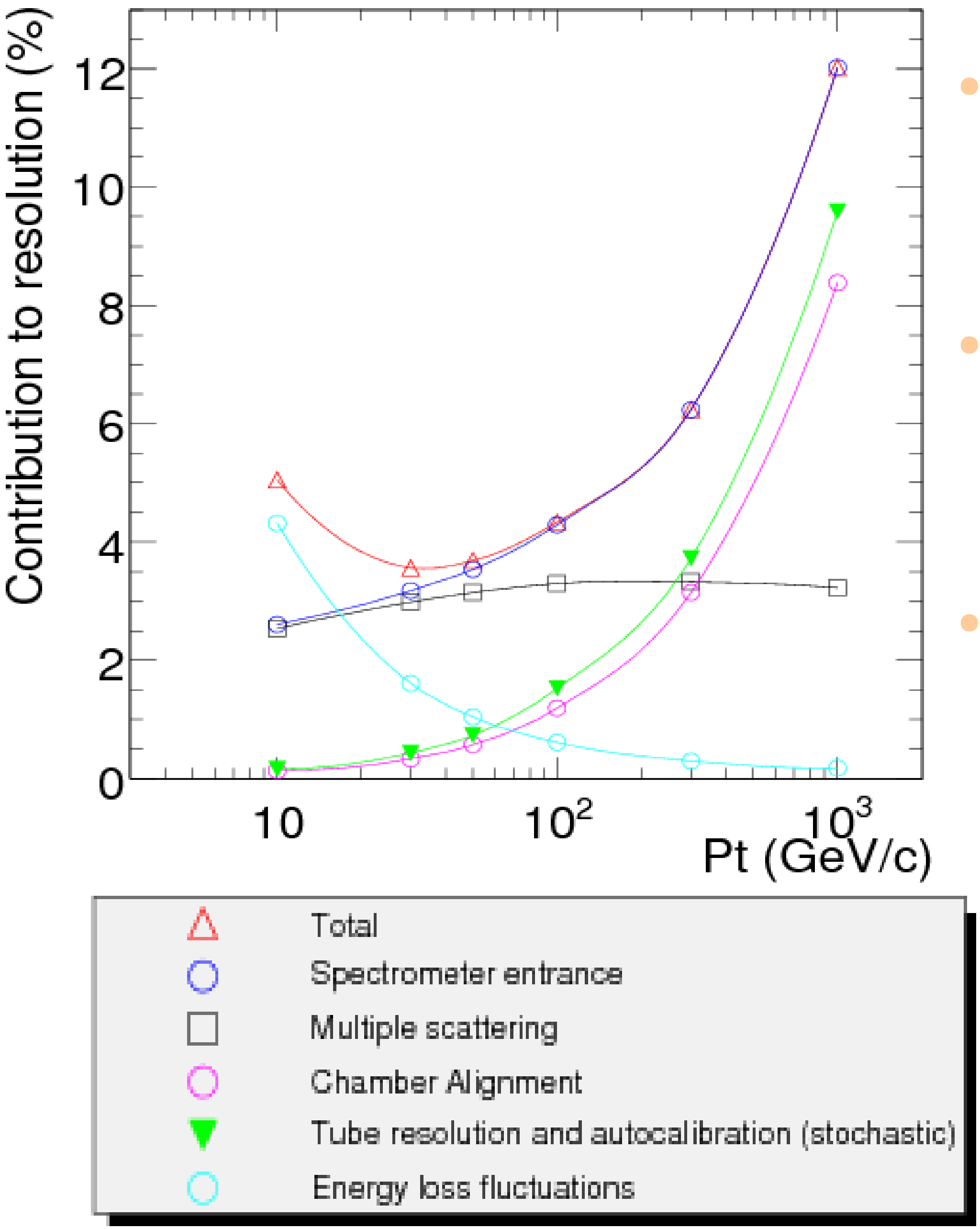
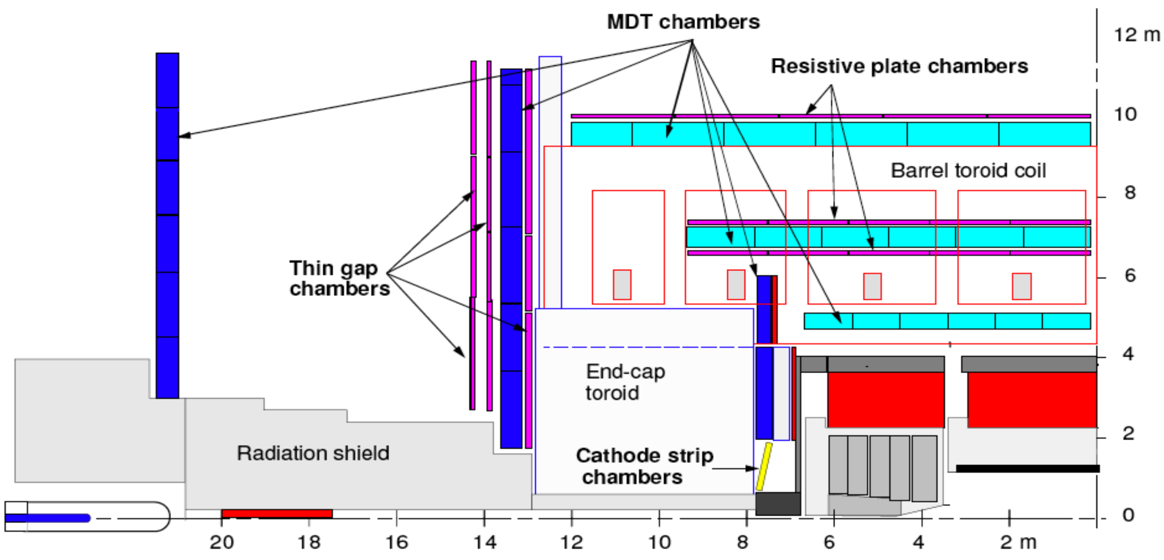
Spectrometer Resolution

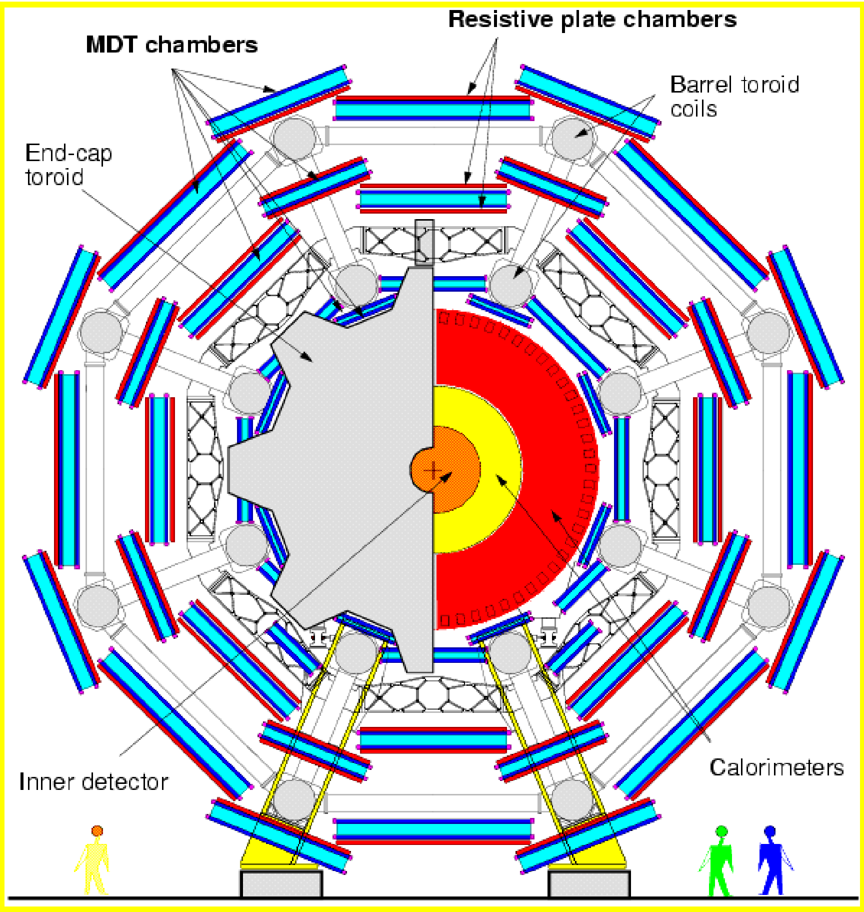


- Momentum resolution is affected by several factors as show on plot on left,.
- Calibration of the precision detectors become significant the for p_T >100 GeV/c.
- Good calibrations are necessary for ATLAS for the measurements of high p_T muons from possible high-mass resonances which is one of the main physics goals of ATLAS.

Spectrometer Layout

Endcap cross-section

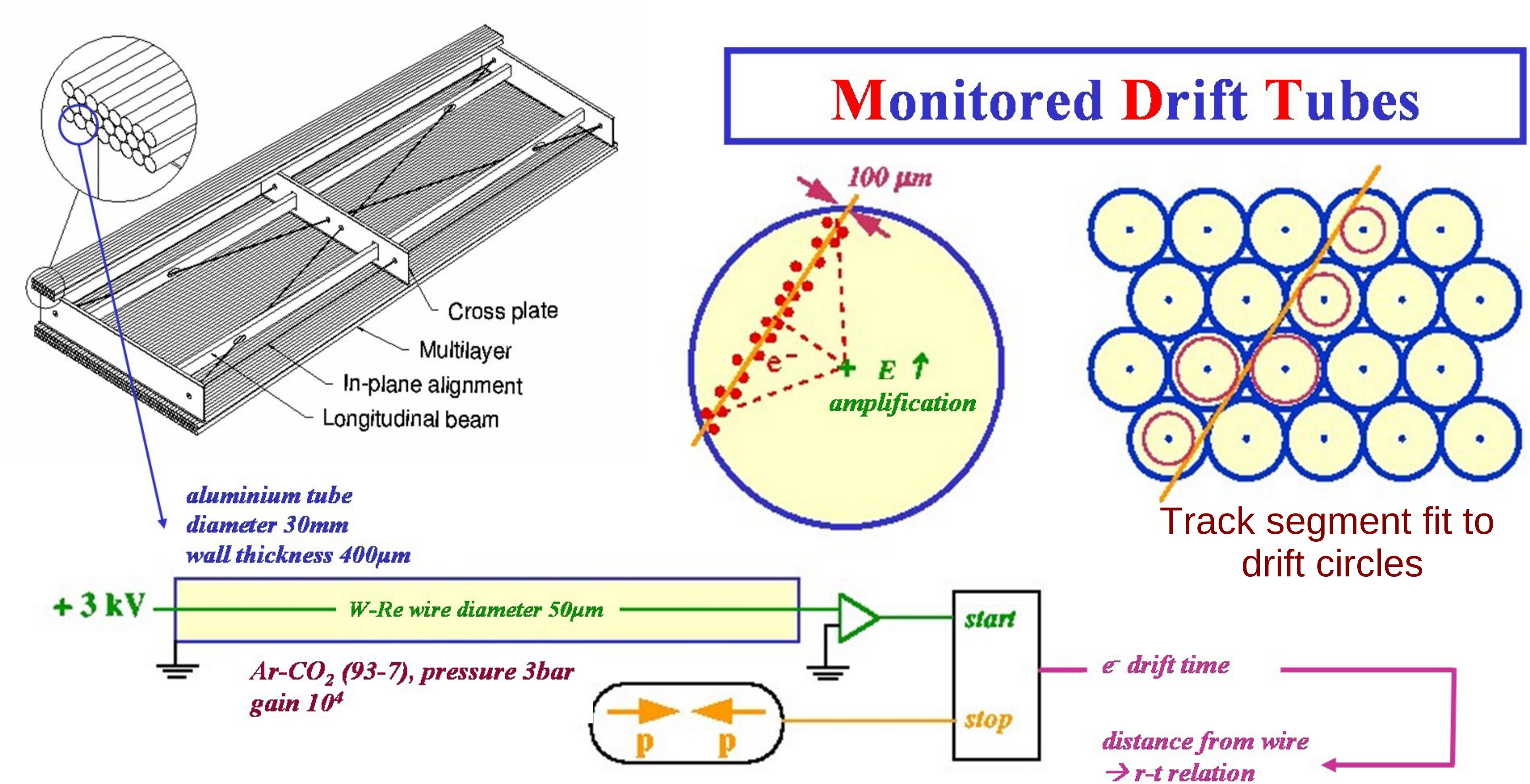




Barrel Cross-section

- Muons cross 3 stations of precision chambers for sagitta measurement
- Trigger chambers are placed on both sides of middle MDT station and the outer MDT station.

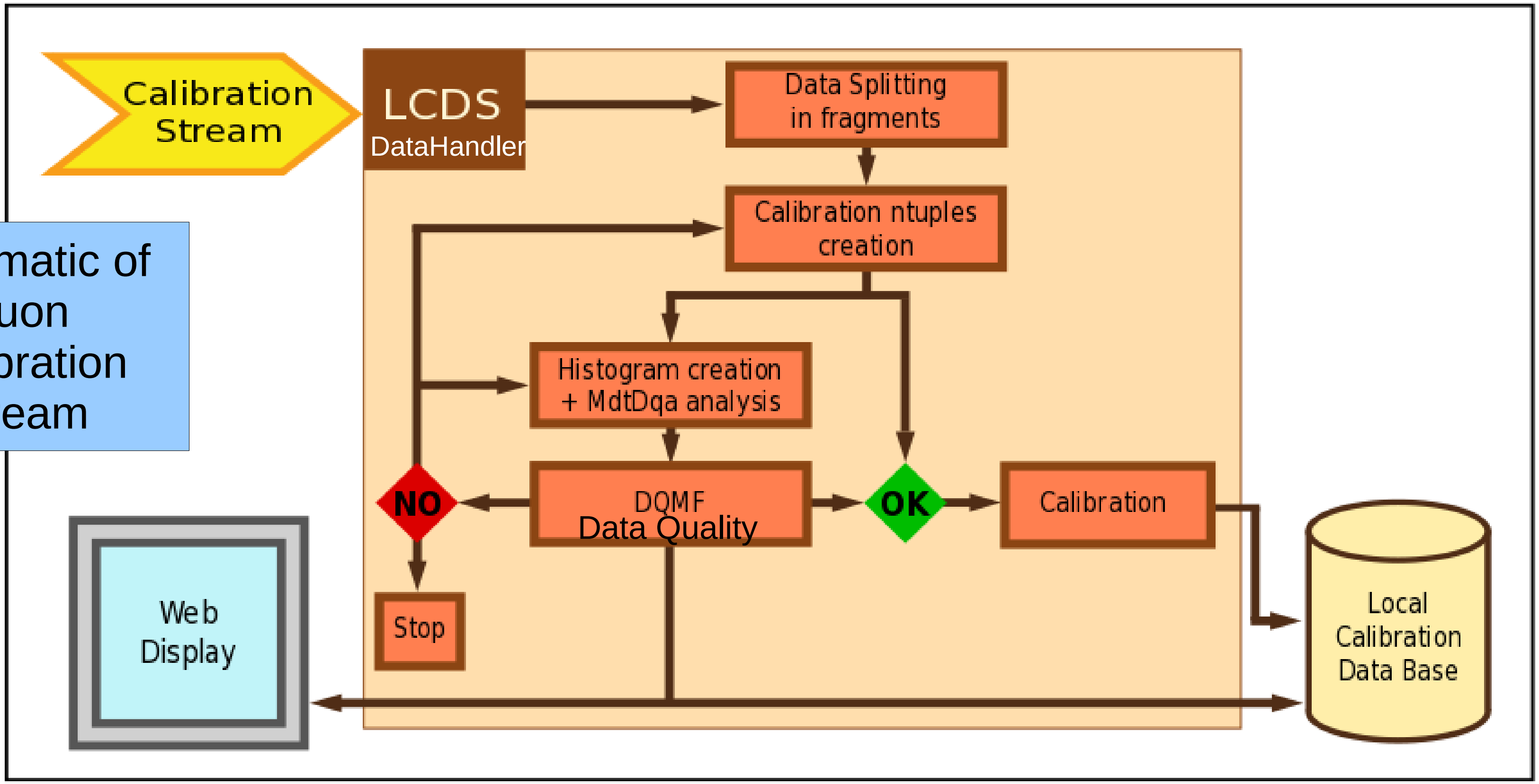
Monitored Drift Tubes



- Monitored drift tube chambers consist of two 3 or 4 layer “multilayers” glued to both sides of a support frame.
- Chamber range in size from 1 to 6m length, and 16-72 tubes wide.
- Chambers have an internal alignment system to monitor deformations as well as sensors monitoring position relative to other chambers.

Muon Calibration Stream

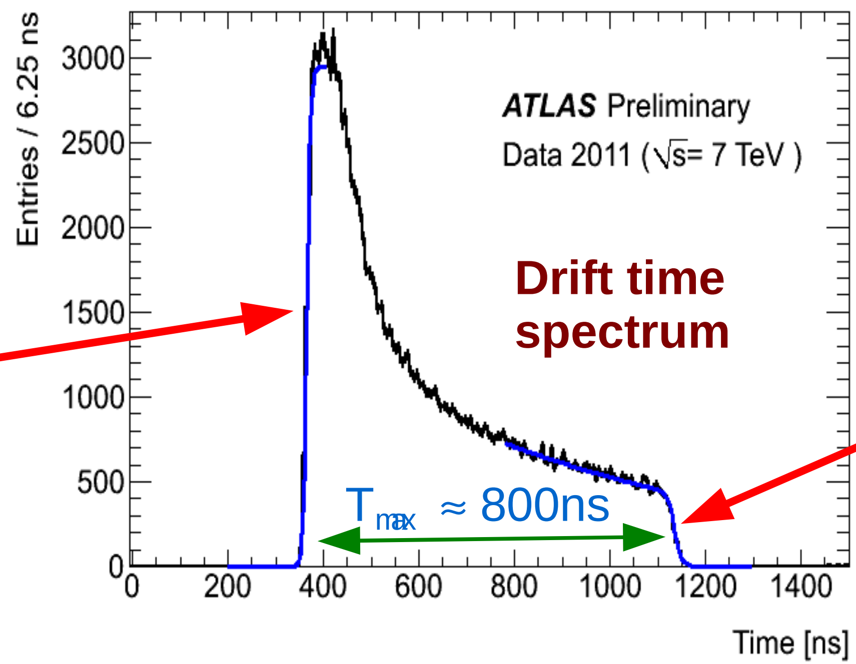
- To obtain high statistics for MDT calibrations a dedicated stream of single muon events is extracted from the level-2 trigger processors and sent to calibration centers at Michigan, Rome, and Munich.
- The calibration stream provides 100x times the statistics as the ordinary data stream allowing daily calibration updates.
- Also used for data quality assessment



Schematic of Muon Calibration stream

Monitored Drift Tube (MDT) T_o Calibration

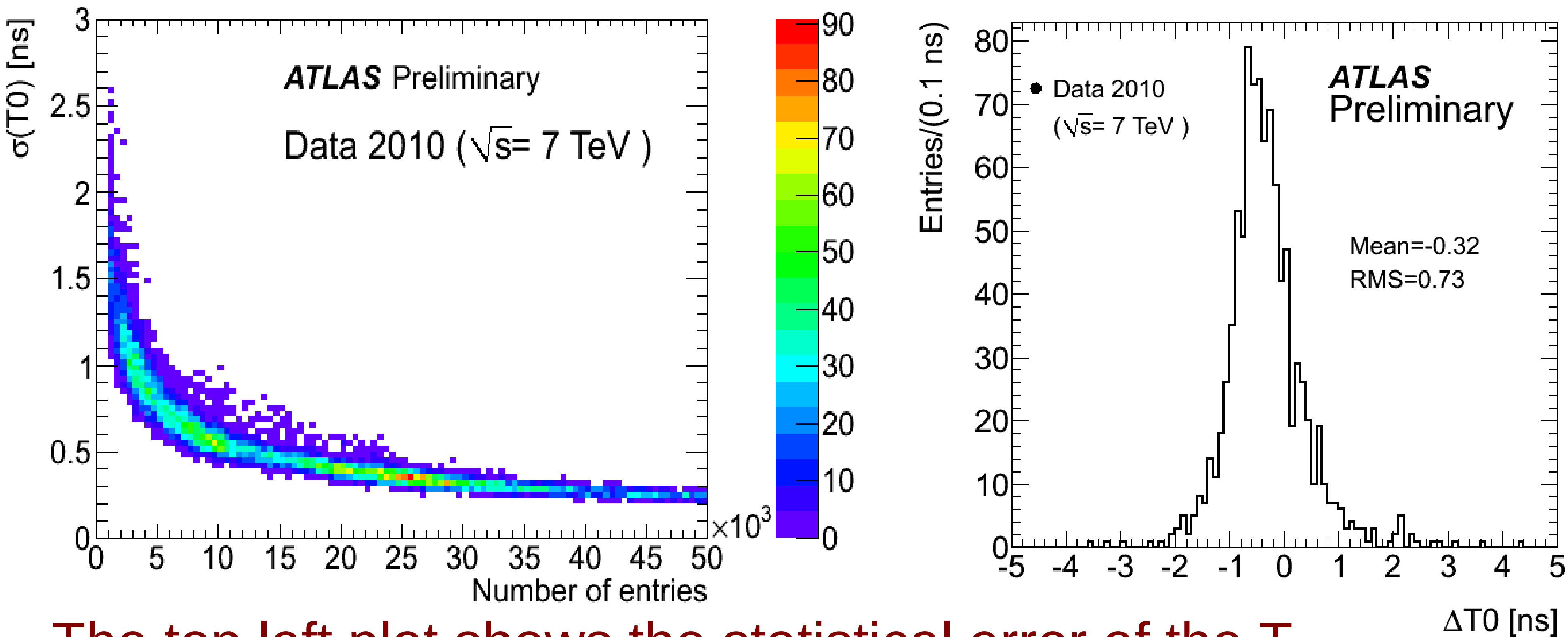
Rising edge represents muons passing near wire.
T_o fit is shown In blue



Falling edge represents muons passing near tube wall

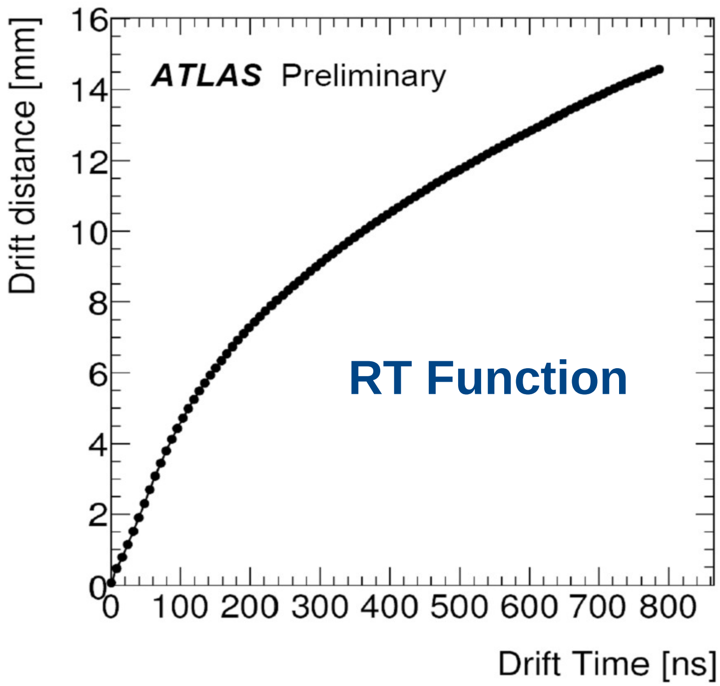
- ***Timing offset (T_o)*** – from fit to leading edge of drift-time spectrum with a step function. The T_o is defined as the half-way point of the rising edge.
- Fits are done at different levels of granularity, depending on the amount of data available: chamber level (240 to 400 tubes), multilayer (120 to 200 tubes), “mezzcard” (24 tubes, grouping in electronic readout cards), or tube.
- Calibration stream statistics permits daily mezzcard calibrations and weekly tube-level calibrations.

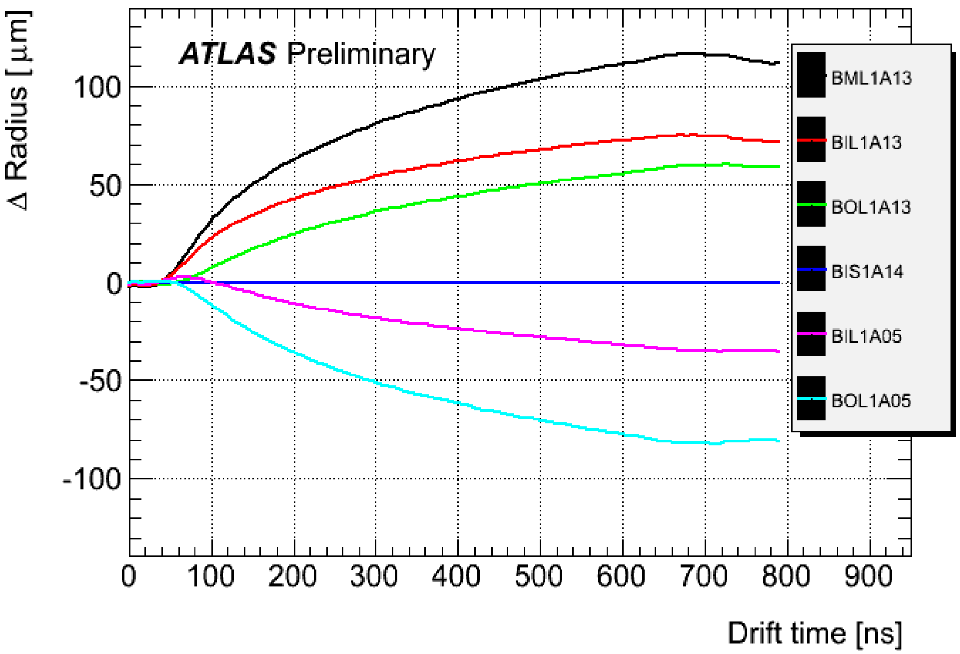
T_o Precision and Stability



- The top left plot shows the statistical error of the T_o measurement versus number of entries in the time. 10k hits are needed to achieve a 0.5 ns precision (1ns≃20μm).
- The right plot shows the change in T_o over a 2 month period in 2010 for 1118 MDT chambers. The variations are within the statistical error of the measurement showing that the T_o values are stable.

MDT Time-to-space (RT) function

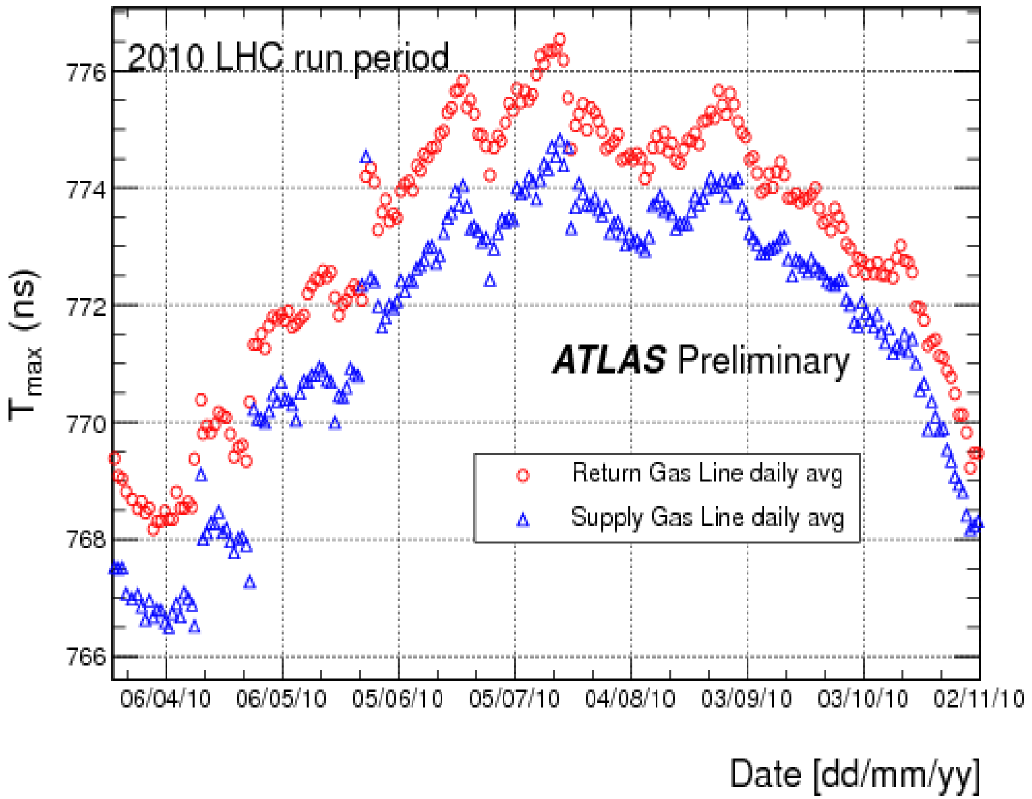


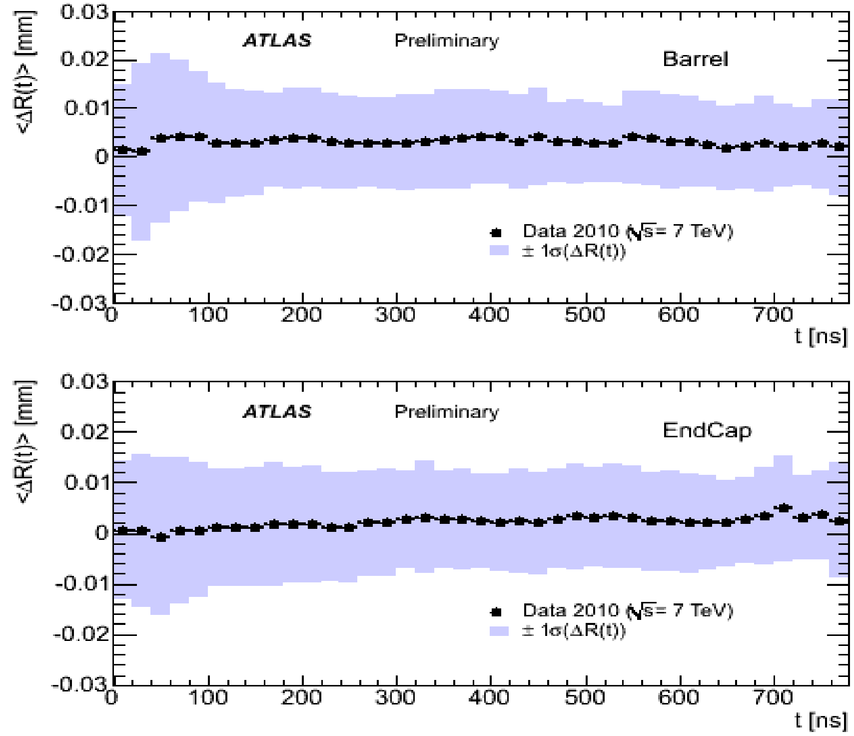


Differences in RT functions between several barrel chambers

- The ***time-to-space function*** is used to convert a drift time to drift distance. The time-to-space function is determined by an iterative procedure minimizing the tracking residuals of track segments formed in a single MDT chamber, typically comprising 6-8 tube hits.
- The right plot shows the differences in RT functions for several barrel MDT chambers. The differences are due to both variations in local magnetic field and the temperature gradient (≈20 °C) in the ATLAS cavern

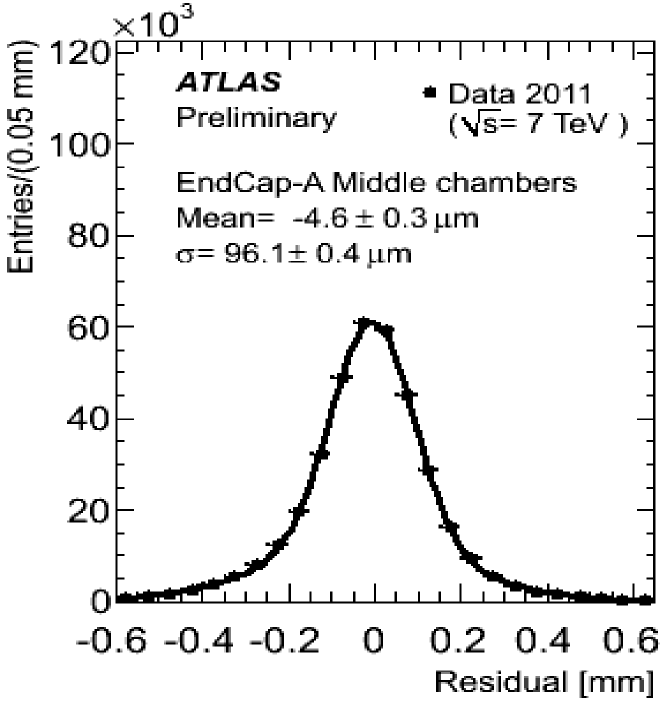
Stability of RT Functions

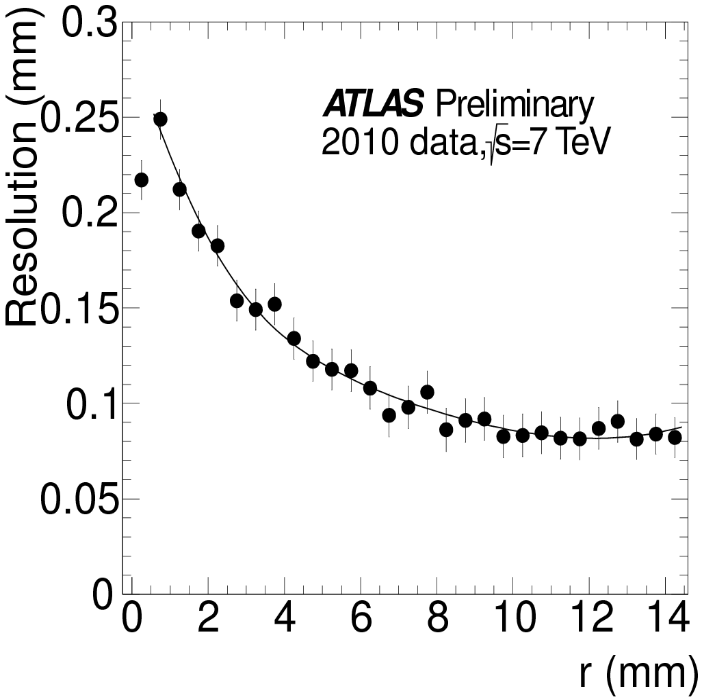




- The top left plot shows the variation in maximum drift time in 2010 as measured by a surface MDT test chamber. The supply and return of MDT gas are measured hourly. RT functions are updated if maximum drift time changes by 1 ns.
- The right plot shows the variation of RT function between successive calibrations. The points show the difference in means and purple band shows the 1σ variation which is less than 10 µm over the entire detector.

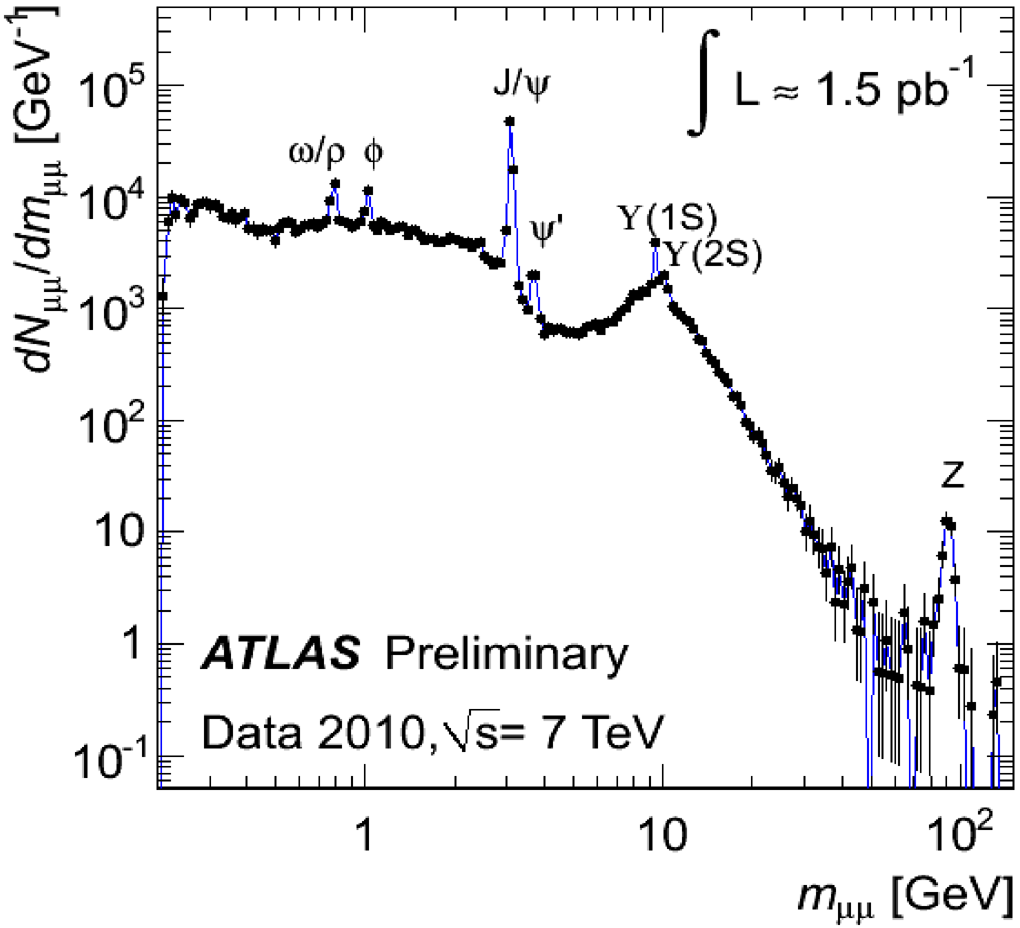
MDT Tracking Resolution





- The left plot shows tracking residuals for the middle layer of endcap chambers which are ~95μm. Such residuals result in a single chamber resolution of better than 40 μm (typically 6-8 hits per chamber). The design goal is a single-tube resolution of 80 μm which can be achieved by single-tube T0s.
- The right plot shows single-tube tracking resolution for a barrel chamber. Resolution improves at large drift radii due to the non-linear gas used in ATLAS drift tubes.

Conclusions



ATLAS Di-muon mass spectrum

ATLAS Muon spectrometer calibrations are performed daily with a high statistics muon calibration stream extracted from the level-2 trigger.

The timing offset and RT function calibrations provide allow track reconstruction with a 95 µm single tube resolution permitting the spectrometer to meet its design goals.