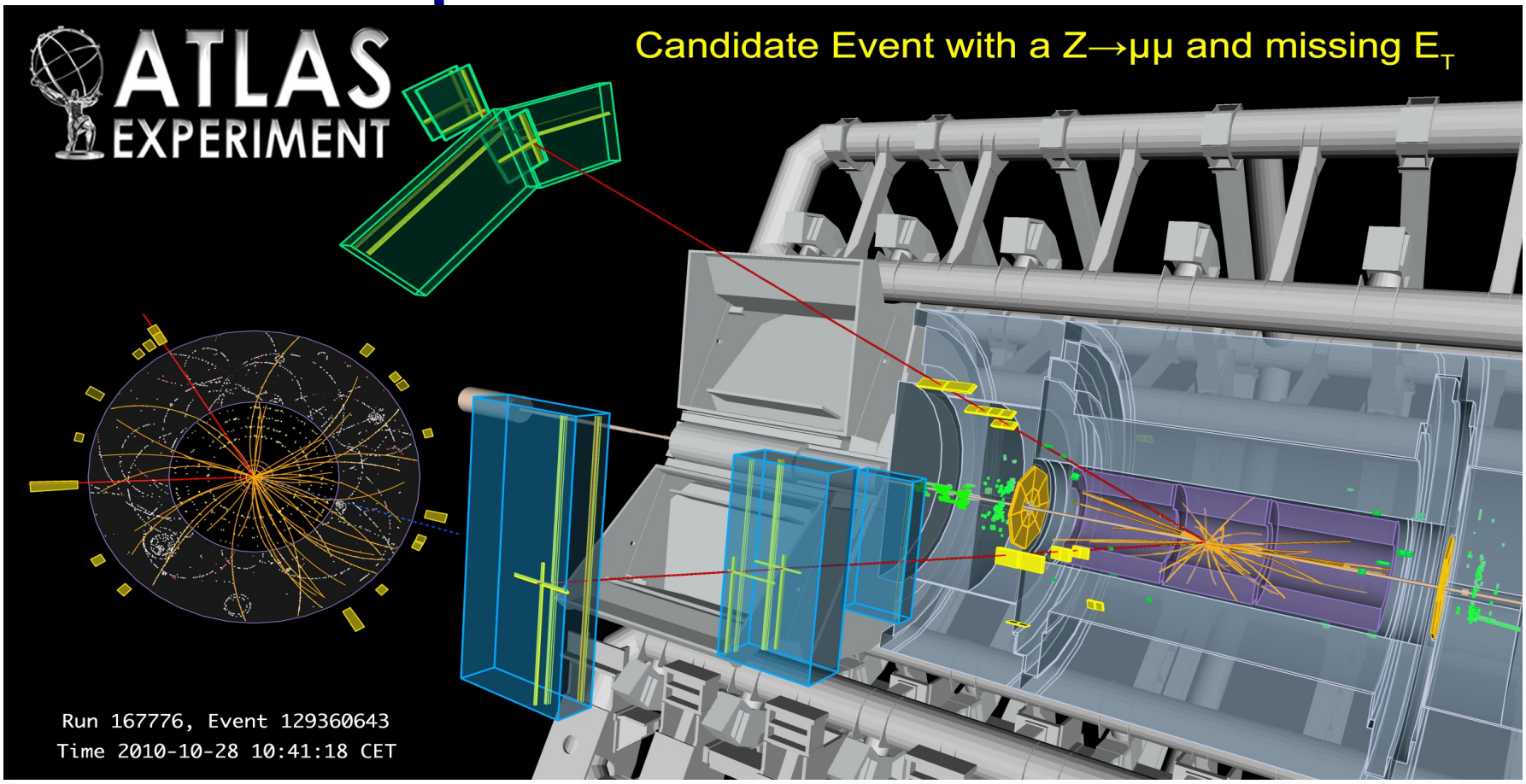
Calibration and Performance of the of the ATLAS Muon Spectrometer



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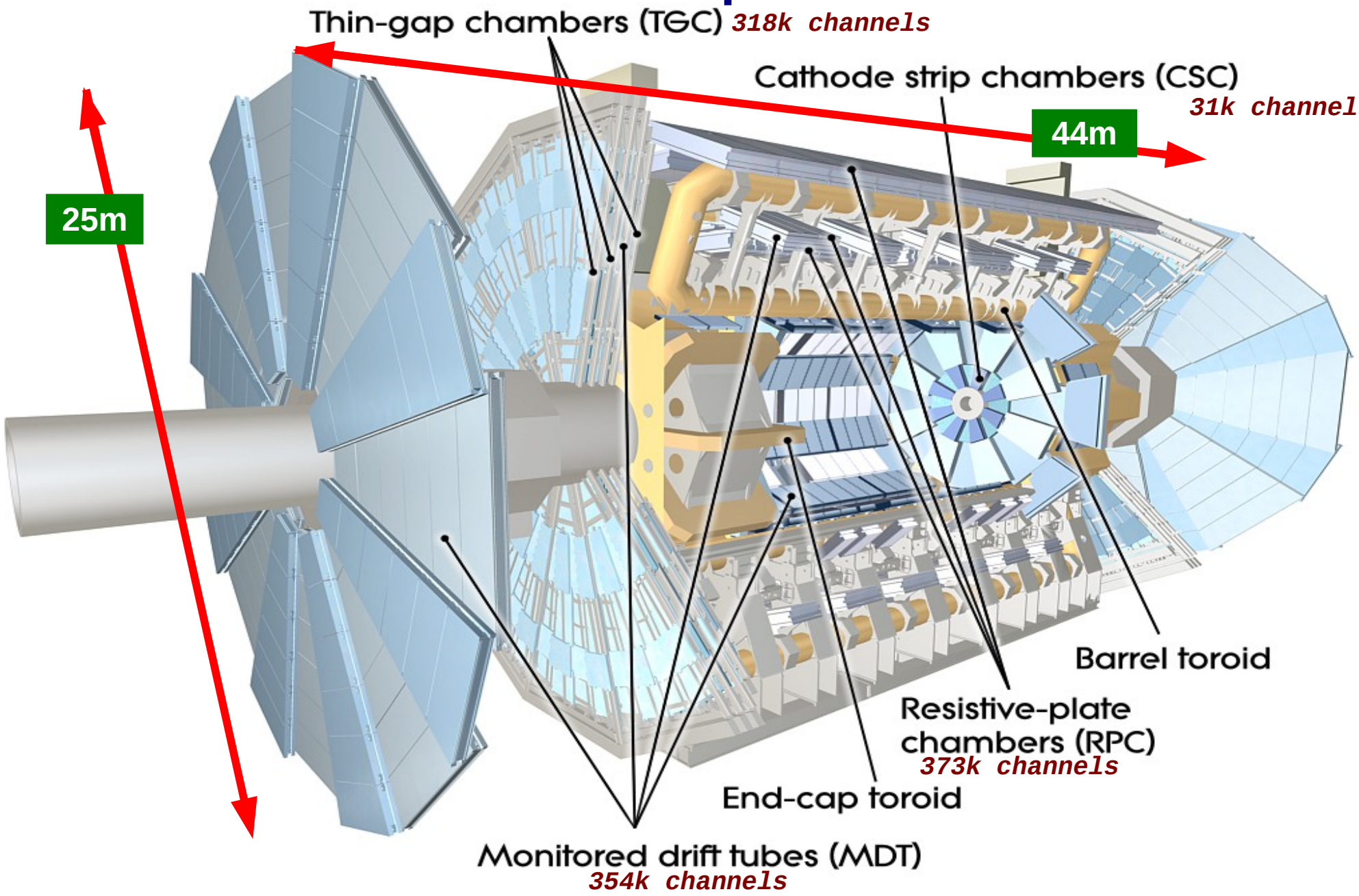
On behalf of the ATLAS Muon collaboration

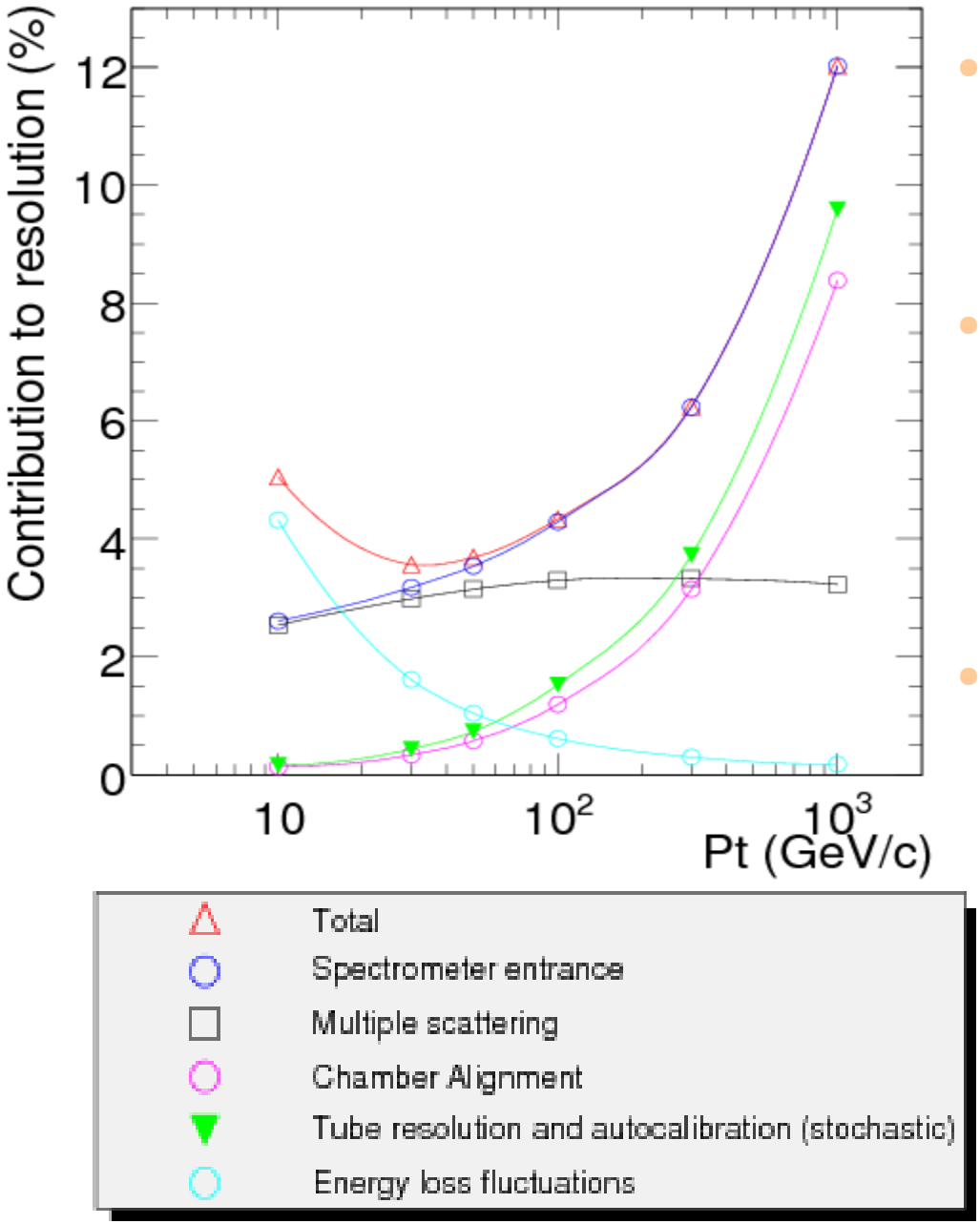
ATLAS Muon Spectrometer



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 (~80μm single tube resolution)
  - 0<η<2.7 Monitored Drift Chambers (MDT)
  - *Monitored* ⇨Positions monitored by an alignment system
  - 2.0<η<2.7 (inner layer only) Cathode Strip Chambers (CSC)
  - Arranged in 3 layers (inner, middle, outer)
- Trigger detectors (trigger + 2nd coordinate measurement to ~2 cm resolution)
  - 0<η<1.05 (Barrel) Resistive Plate Chambers (RPC)
  - 1.05<η<2.4 (Endcap) Thin Gap Chambers (TGC)
  - 2/3 (barrel/endcap) layers mounted on middle MDTs + 1 (barrel) layer on outer MDTs
- Alignment system – measure chamber positions and deformations to ~40 μm
  - Performed with optical alignment systems and alignment with tracks.

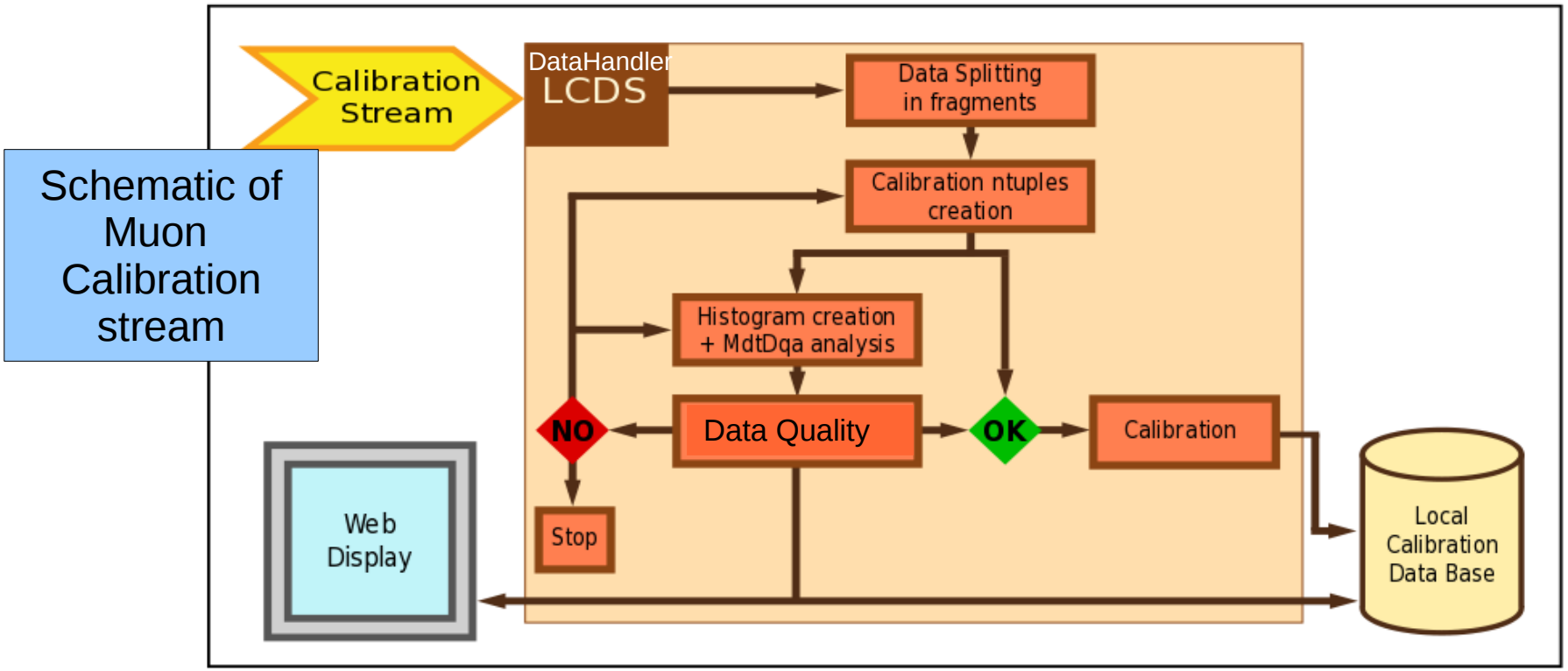
Spectrometer Expected Resolution



- Momentum resolution is affected by several factors as show on plot on left.
- Calibration and alignment of the precision detectors become significant the for p_T >100 GeV/c.
- Good MDT calibration and alignment corrections are need to reach the full physics potential of to measure high p_T muons with high precision.

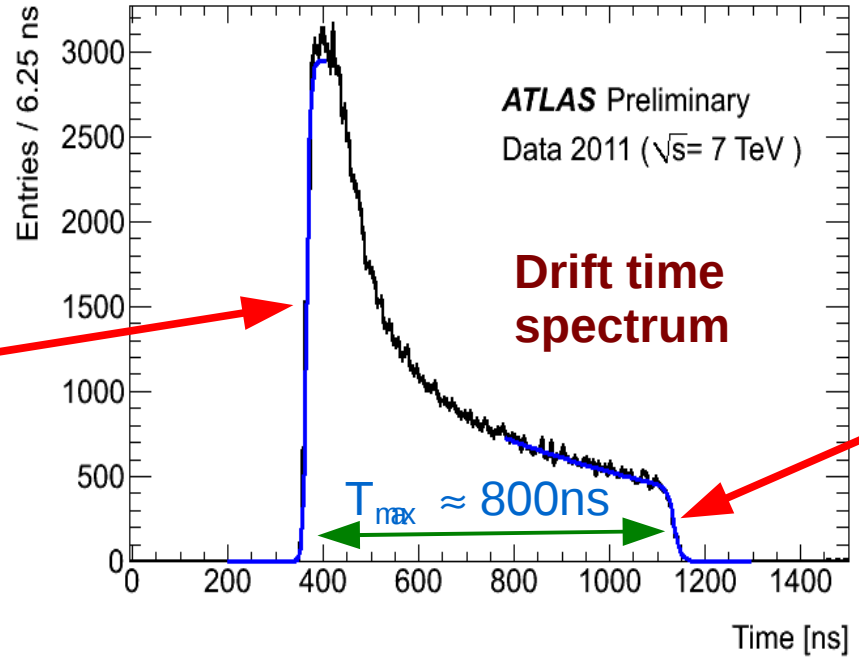
Monitored Drift Tube (MDT) Calibrations

- Daily calibrations of timing offsets (T0s) and time-to-space (RT) functions are performed using 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



MDT Timing Offsets (T_0) Calibration

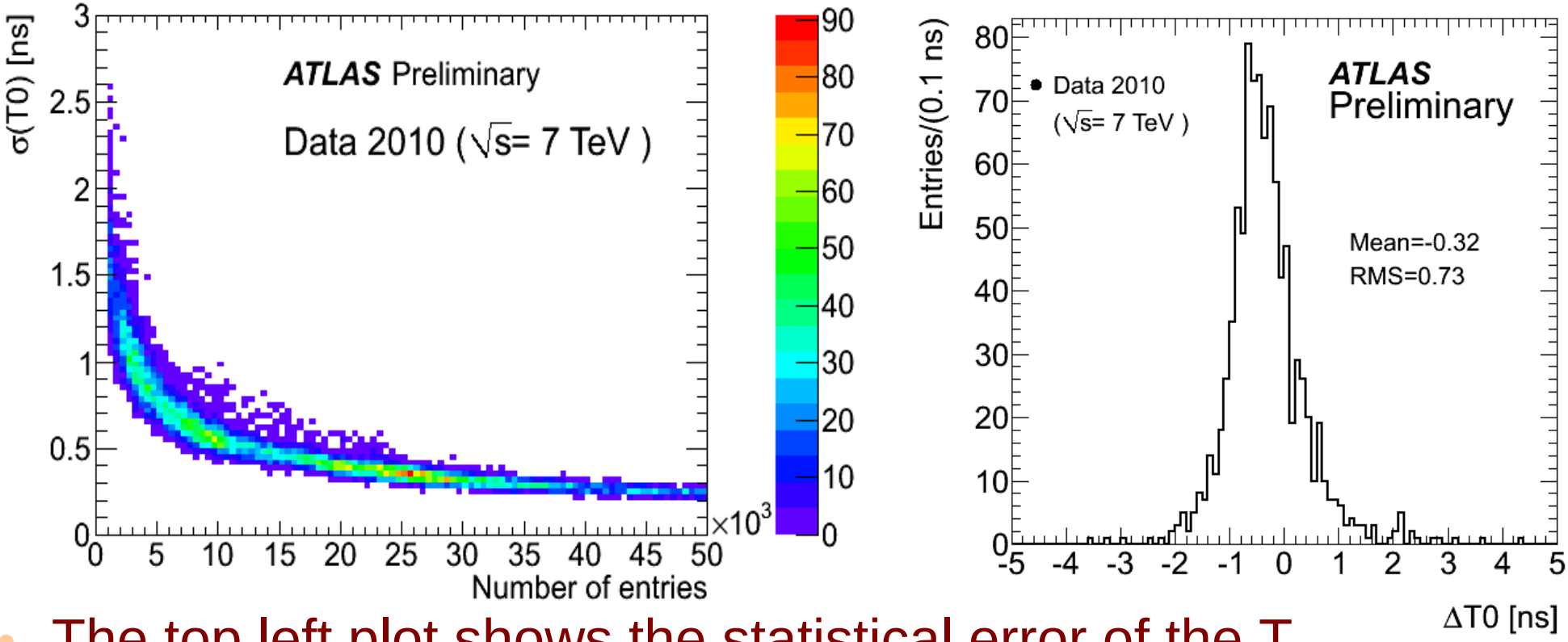
Rising edge represents muons passing near wire.
T_0 fit is shown In blue



Falling edge represents muons passing near tube wall

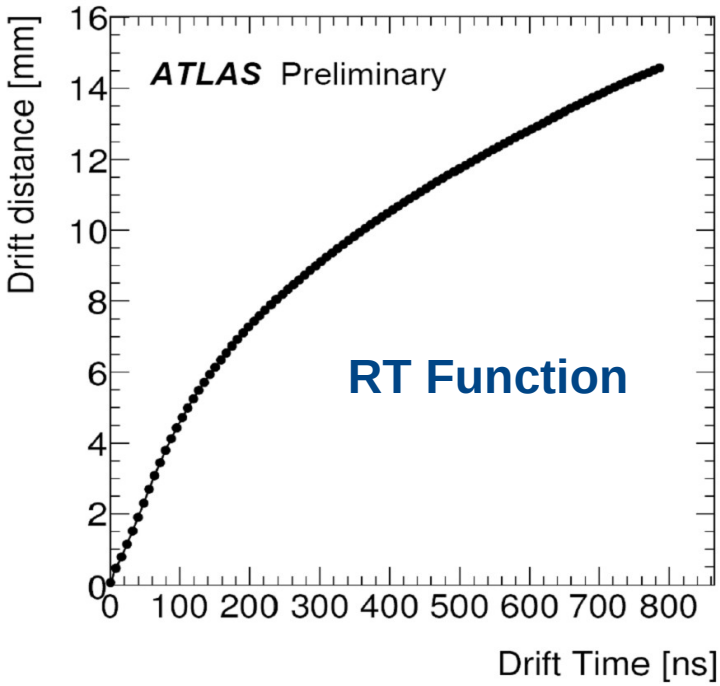
- ***Timing offset (T_0)*** – from fit to leading edge of drift-time spectrum with a step function. The T_0 is defined as the half-way point of the rising edge.
- Fits are done at different levels of granularity, depending on the amount of data available: chamber level (240 to 400 tubes), multilayer (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.

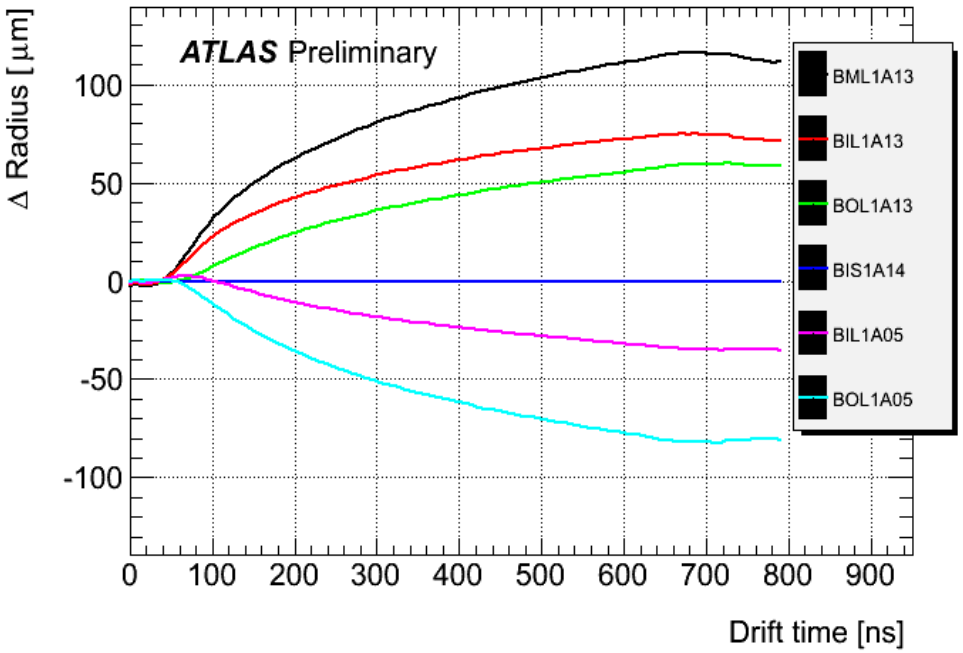
T_o Precision and Stability



- 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 small, showing that the T_o values are stable.

MDT Time-to-space (RT) functions



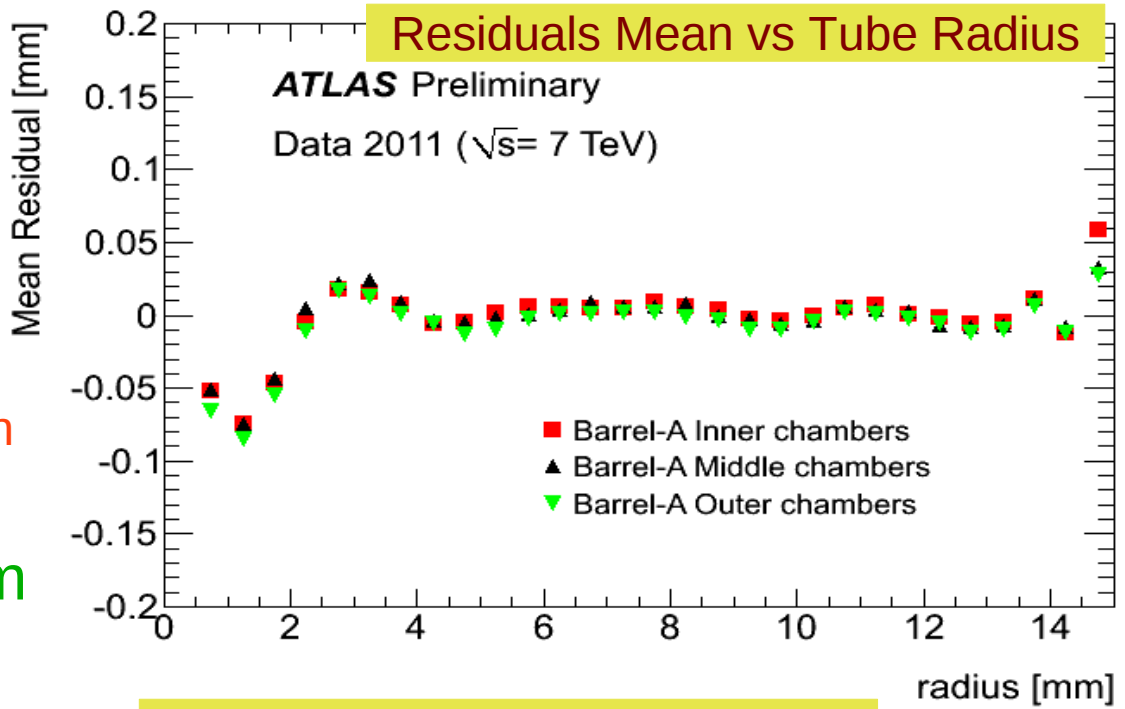


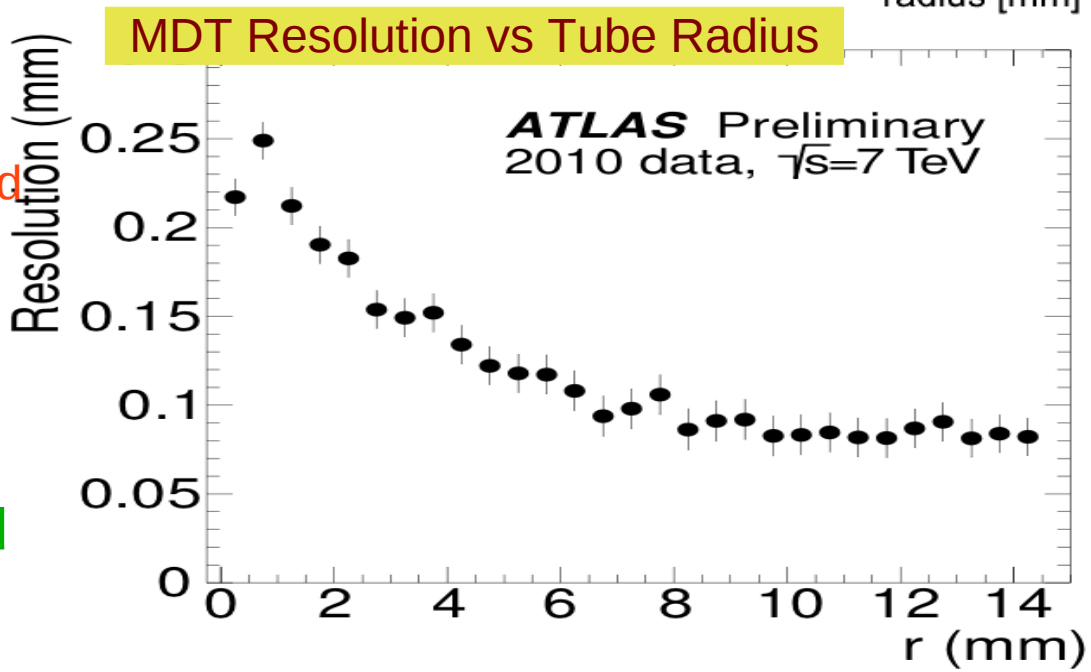
Differences in RT functions between several barrel chambers

- 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 ^{o}C) in the ATLAS cavern

RT Precision and MDT resolution

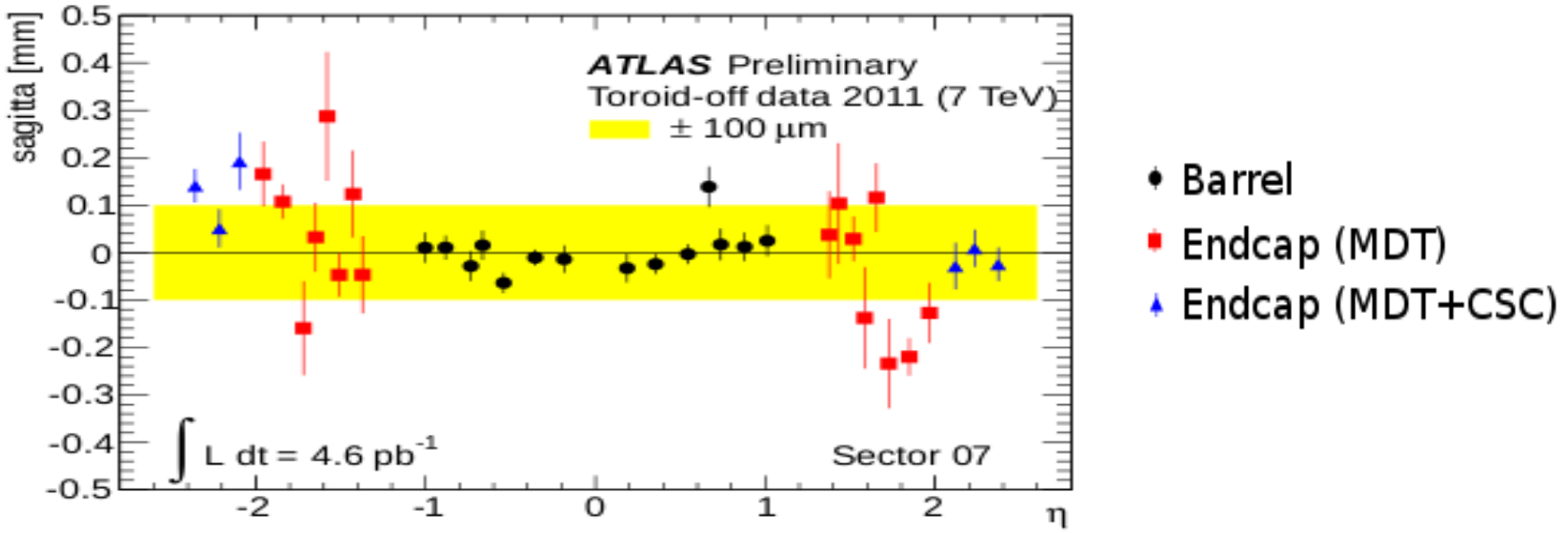
- $R_{drift} - R_{track}$ track residuals show the RT precision.
  - Deviations for r<1mm and r>14 are due to wire and tube wall, respectively
  - For r > 2mm the RT precision is < 20 μm
- Resolution is determined from tracking residuals with fit errors removed.
  - Resolution degrades at small radii due to faster drift speed and fewer drift electrons.
  - At large radii resolution approaches design specs
- Improvements expected by employing hit-level magnetic field corrections and tube-level T0s.



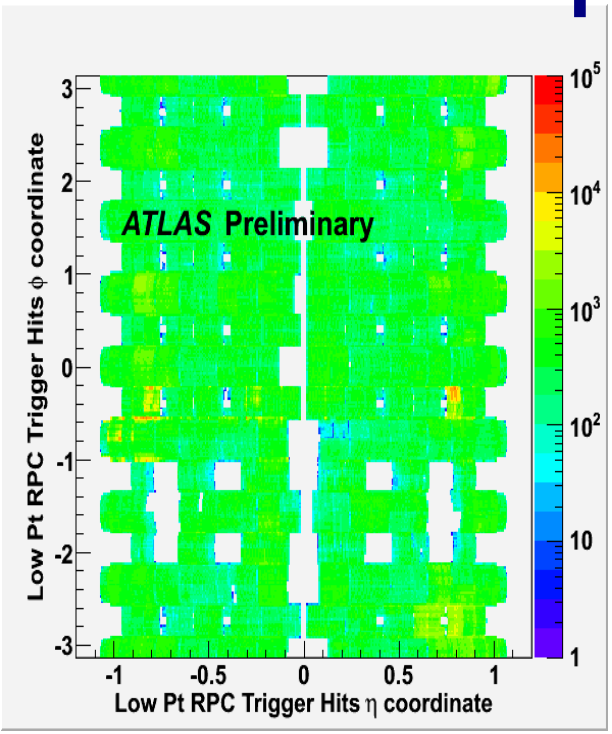


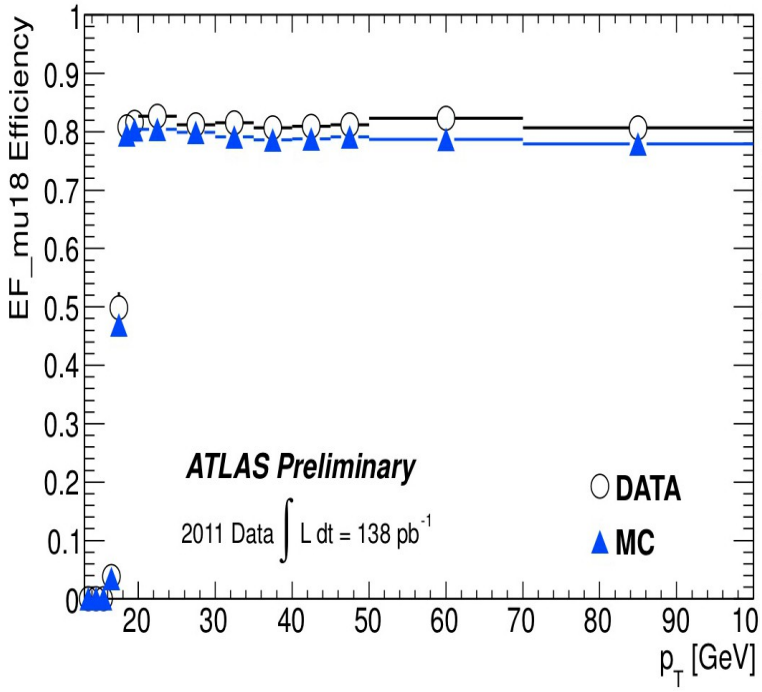
Alignment System

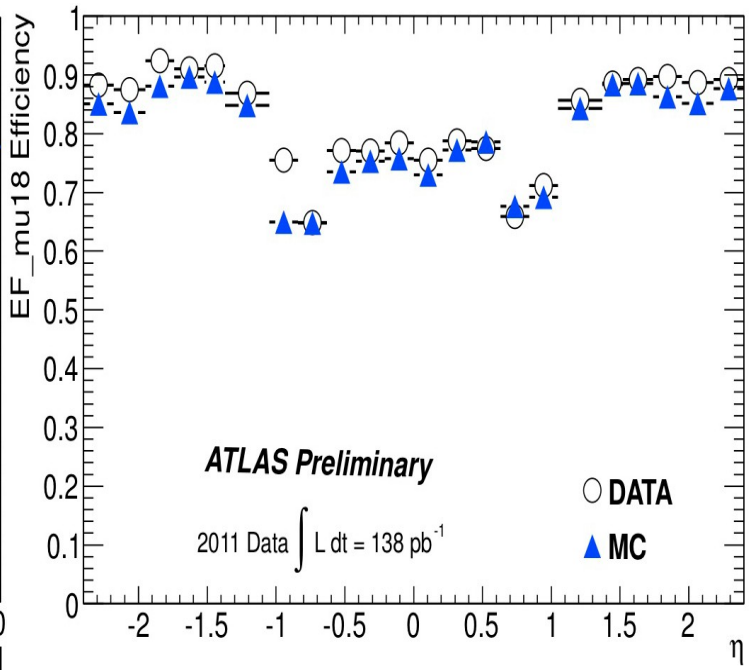
- The goal of the alignment system is to monitor the precision chambers with a precision of 40 μm.
- Barrel and endcap use separate optical systems which are validated by studies with straight tracks.
- The plot below shows the mean values of the “false” sagitta measured for straight tracks (no magnetic field) from a 2011 test run. The mean sagitta values found are: 50±4μm (barrel) and 113±10μm (endcap)



Trigger Efficiency

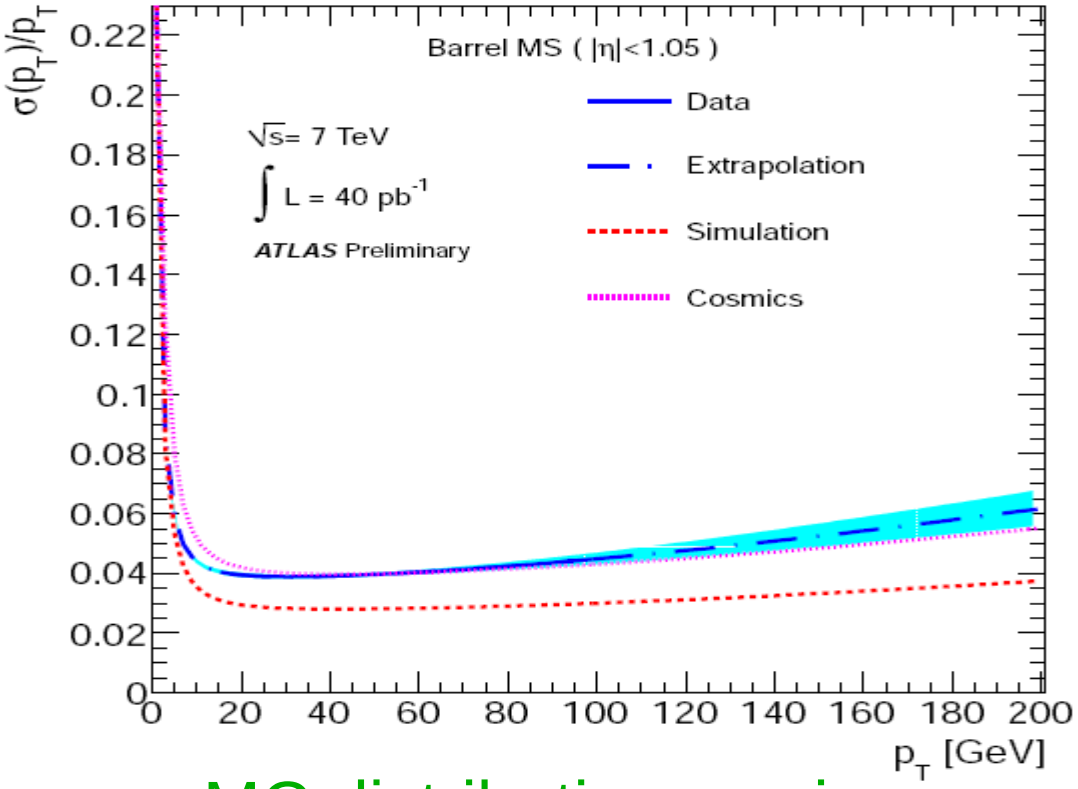






- The top left plot shows RPC occupancy from collisions showing excellent coverage except for feet regions. Geometric acceptance is about 80%.
- Center and right plots show trigger efficiency vs p_T and η, respectively. The efficiencies were determined by a tag & probe method using Z→μμ events. The overall efficiency is 0.8125±0.0016. Data efficiency is about 2% higher than MC due to reconstruction improvements not yet included in the MC.

Momentum Resolution



Contributions to momentum resolution

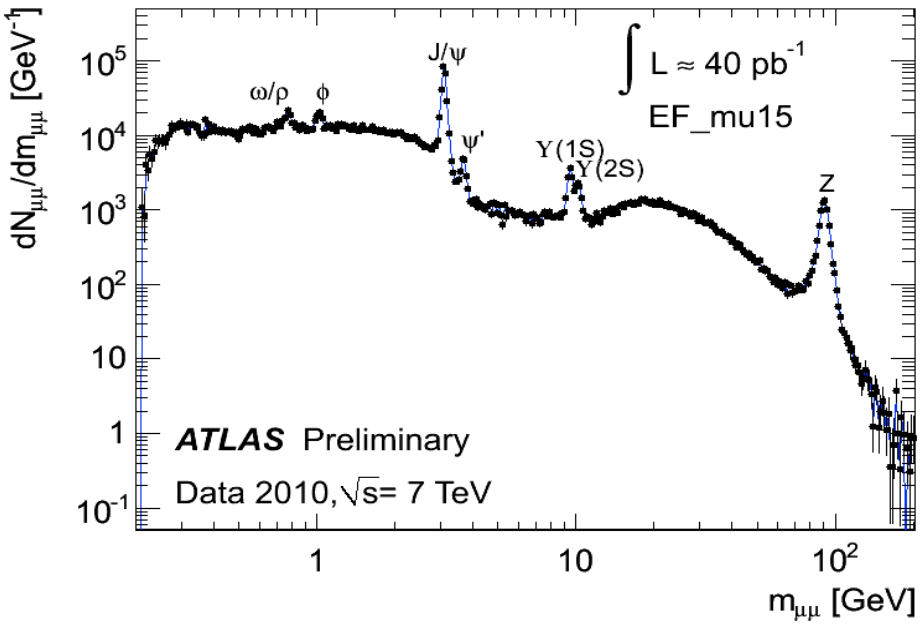
p_0 (TeV) Energy losses in calorimeters	p_1 (%) Multiple Scattering	p_2 (TeV^{-1}) Intrinsic Resolution
0.23 ± 0.01	3.75 ± 0.01	0.23 ± 0.01

$$\frac{\sigma(p)}{p} = \frac{p_0^{MS}}{p_T} \oplus p_1^{MS} \oplus p_2^{MS} p_T$$

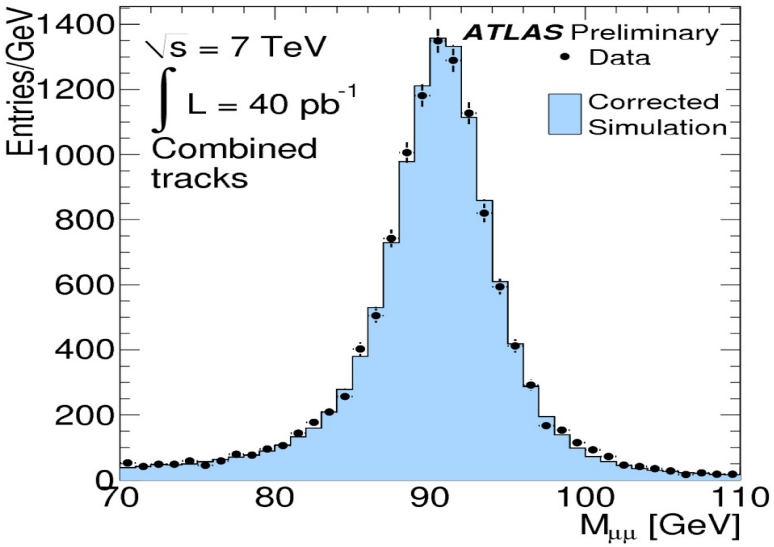
- MC distributions, using smeared reconstructed momenta, are used in a fit to the data distributions.
- Data are from dimuons from Z bosons and single muons from W/Z reconstructed in both inner detector and MS.
- Use constraints on MS alignment from straight tracks.
- Obtain resolution parameters and smearing function.

Conclusions

ATLAS Di-muon mass spectrum



ATLAS Zμμ mass spectrum



- ATLAS Muon spectrometer is working well with high trigger efficiency and tracking resolution near design specs.
- Drift tube calibrations are performed daily with a high statistics muon calibration stream extracted from the level-2 trigger.
- Alignment system is working well tracking chamber positions to ~50/100 μm (barrel/endcap)
- Momentum resolution is close to design specifications