Alignment of the ATLAS Muon Spectrometer (MS)

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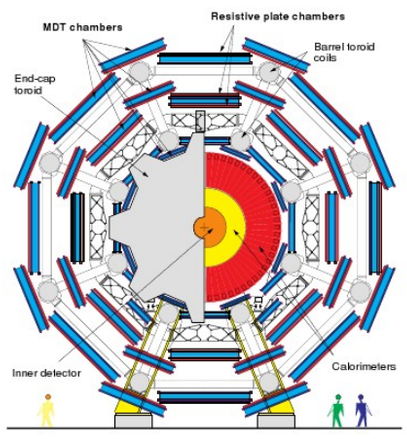
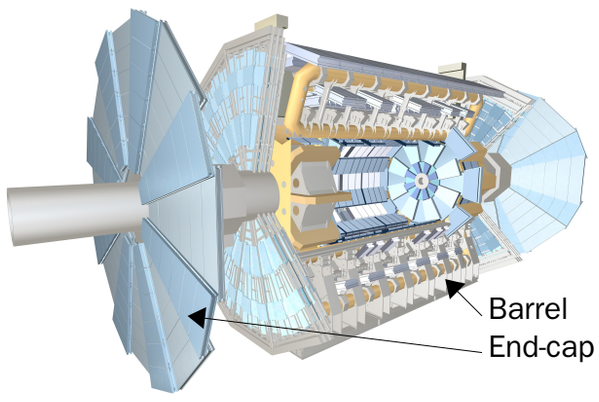
Presentation of the Spectrometer

- ~1200 drift tube chambers (MDT) and CSC chambers (in forward part) assembled in three layers.
- ~ 0.5 T inhomogeneous toroidal magnetic field produced by superconducting magnets.
- Momentum measurement through muon track curvature in magnetic field.



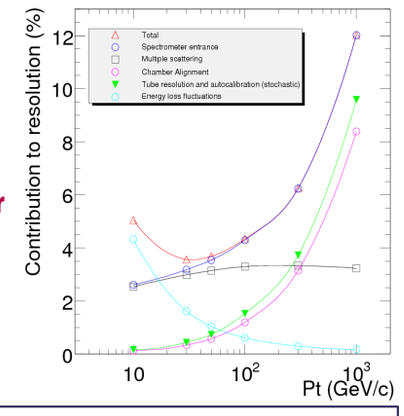


Impact of alignment on momentum resolution

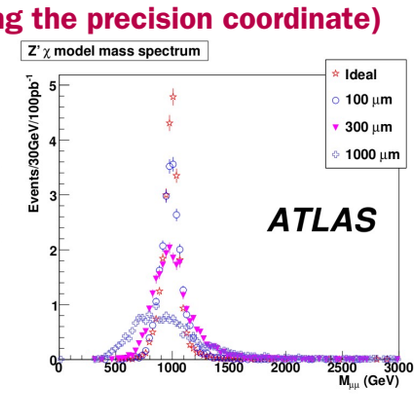
Alignment is one of the main sources of uncertainty for high momentum muons. The designed momentum resolution is **10% for 1 TeV muons** meaning 50 µm resolution on track sagitta.

Contributions to resolution at 1 TeV in barrel :

- Energy loss fluctuations (small)
- Multiple scattering in stations (10 µm)
- Tube resolution (35 µm)
- Alignment **(30 µm precision required on chamber position along the precision coordinate)**



Effect of MS alignment on mass resolution for 1 TeV Z' signal



Other sources of misalignment

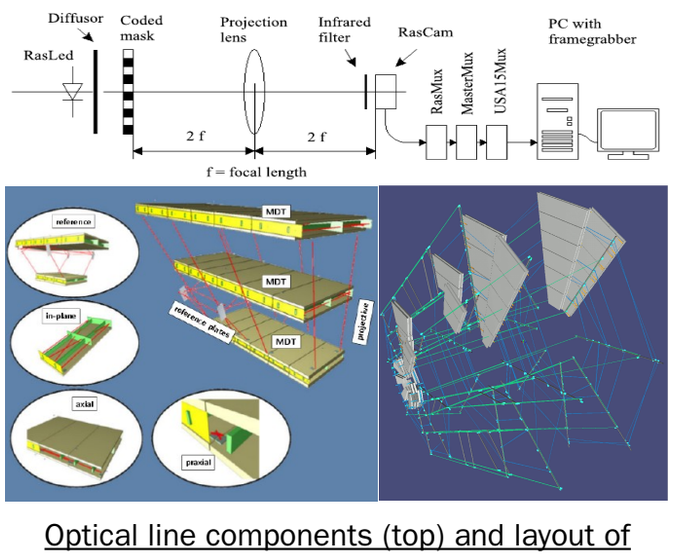
- Variations of magnetic field
- Temperature variations
- Internal deformations of chambers

Muon Spectrometer Alignment System

Survey measurements give an estimate of the alignment with a precision of a few mm.

Optical lines Signal emitted by LEDs through coded mask is collected by CMOS sensor after focalization by a lens (in barrel). Precision reached ~ 10 µm.

Track-based alignment relies on χ^2 minimization of hit residuals for straight tracks (recorded without toroid magnetic field). The free parameters are the chambers translations and rotation angles.



Optical line components (top) and layout of optical system in barrel and endcap (bottom)

Alignment in barrel

- Due to the knowledge of the positioning of the optical sensors on the chambers, the precision of the optical alignment in absolute mode is ~ 200 µm.
- Optical alignment used in relative mode to monitor the position of the chambers (precision 10 to 20 µm).
- Initial reference provided by a combination of optical and track-based alignment provided by cosmic run without toroidal field.

Alignment in endcap

- Provided by optical system for MDTs (sensors precisely positioned on alignment bars) and provided by combination of optics and tracks for CSCs.
- Absolute precision better than 100 µm due to high redundancy of measurements.

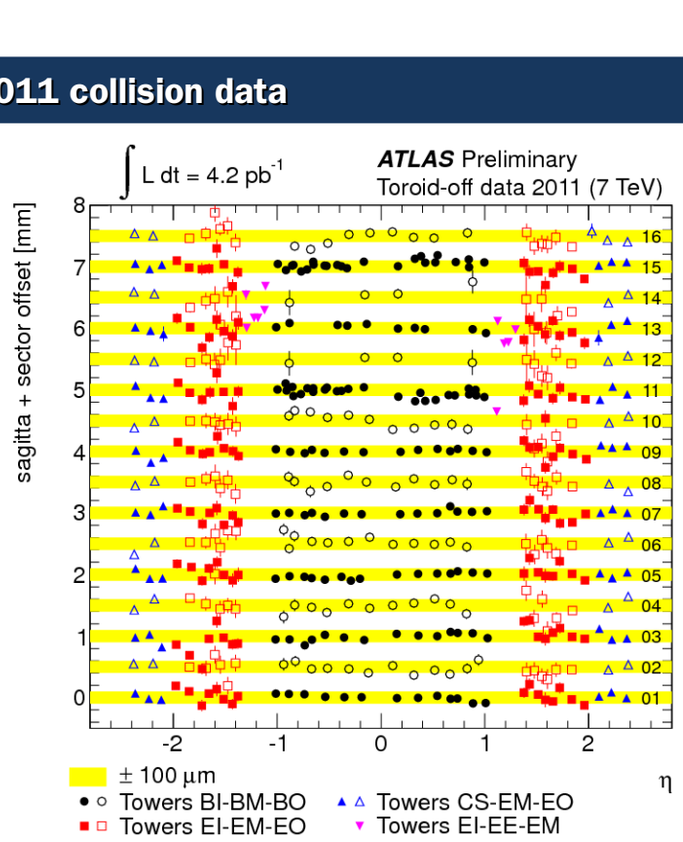
Validation of the alignment performance with 2011 collision data

Validation with straight tracks

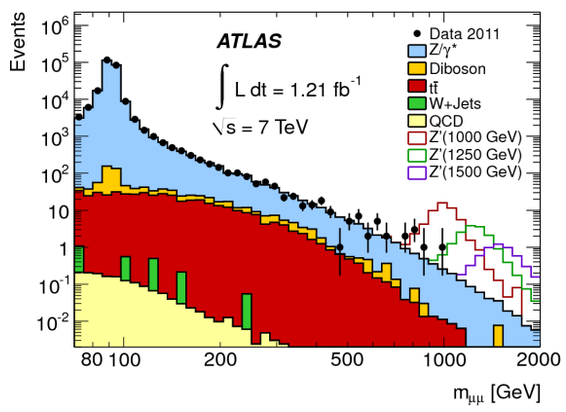
- Data taking without toroid magnetic field : straight trajectory of muon in the MS with impulsion measured by the Inner Detector. Select tracks going though 3 stations.
- The mean value of the sagitta distribution in a tower gives an estimate of its misalignment ; the width of the distribution is dominated by other contributions like multiple scattering and tube resolution.
- Sagitta resolution :
  $\sigma_{sagitta}$ = 54±4 µm in barrel,
  $\sigma_{sagitta}$ = 102±9 µm in MDT end-caps,
  $\sigma_{sagitta}$ = 59±8 µm in CSC region.
- p_T resolution obtained knowing the magnetic field intensity

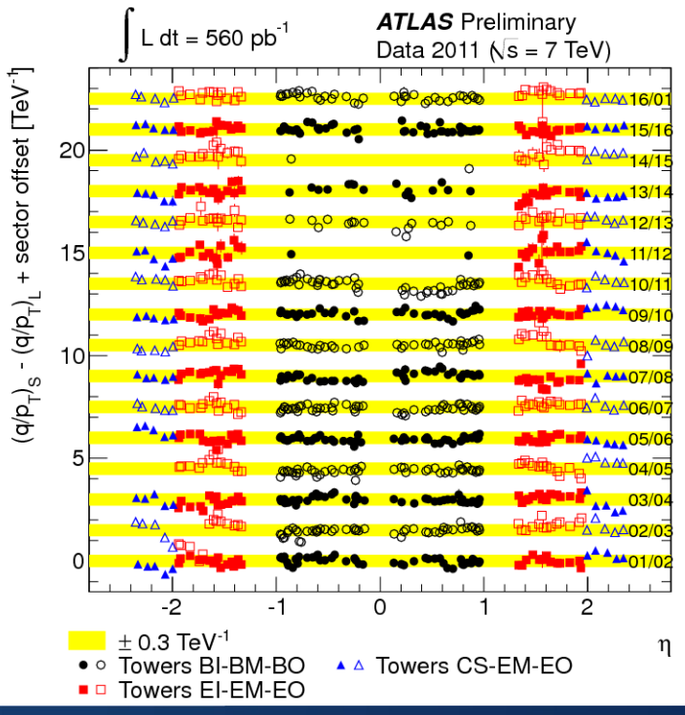
Validation with curved tracks

- Select tracks in the overlap between φ-sectors crossing 3+3 stations and refit twice with 3 large and 3 small stations.
- Mean value of $(q/pT)_L$ -$(q/pT)_S$ gives contribution of alignement to momentum resolution.
- Sensitivity to multiple scattering and B-field suppressed at first order due to use of the same track for comparison. More sensitive to internal deformation of chambers.
- Results of the two methods are combined to give global alignment performance (see table).



Detector region	σ_{ali} (TeV^{-1})
Barrel	0.130±0.005±0.050
MDT end-caps	0.174±0.008±0.050
CSC end-caps	0.146±0.009±0.050





Good performance of momentum measurement at high pT illustrated by dimuon invariant mass spectrum for 3 station tracks (Z' analysis).

Conclusion and perpectives

- Excellent alignment performance validated with data.
- Ongoing studies :
  - Global alignment of barrel with respect to end-cap ongoing. No optical lines connecting these parts so alignment with curved tracks.
  - Alignment of MS with respect to Inner Detector in order to improve muon combined resolution.
  - Implementation of alignment precision at the reconstruction lavel on a per track basis
- New chambers to be installed at the end of the year in the transition region between barrel and endcap.

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