Alignment of muon chambers with tracks

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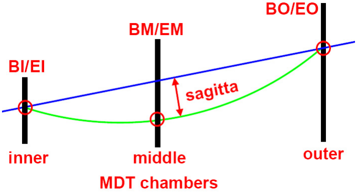
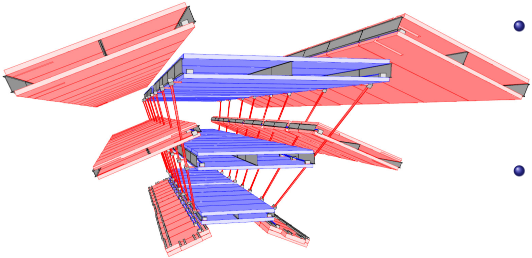
Overview of the ATLAS Muon Spectrometer alignment

- Momentum measurement design goal:
  $\delta p_t / p_t = 10\%$ for 1 TeV muons $\Rightarrow$
  sagitta of 500 μm measured with 50 μm accuracy
- Muon chambers ($\sim$ 1200 in total) are high-precision objects by construction: sense wires are placed with 20 μm precision during chamber assembly
- Single muon chamber spatial resolution is $\sim 40\mu$m $\Rightarrow$ muon chambers must be aligned to 30 μm accuracy in order to provide the required momentum resolution



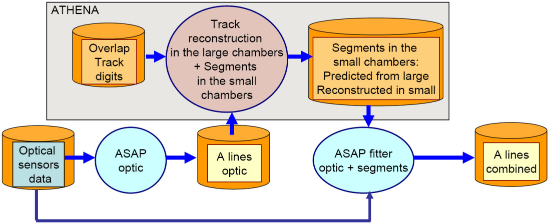
- In the first order, only the relative alignment of triplets of chambers (towers) traversed by the same muon track is important for momentum measurement
- Optical alignment system provide this tower alignment:
  - in the barrel region 3-point straightness monitors (RASNIKs) installed on the inner/middle/outer chambers form projective lines pointing to the interaction region
  - in the endcap regions projective lines are impossible because the cryostats of endcap toroid magnets block the interaction region $\Rightarrow$ the endcap alignment relies on high precision reference rulers – alignment bars which form alignment grid for the endcaps
- In principle, muon tracks can be used to align the muon spectrometer (some of these activities are being pursued by MPI MDT group)

Track based alignment of chambers without projective alignment sensors

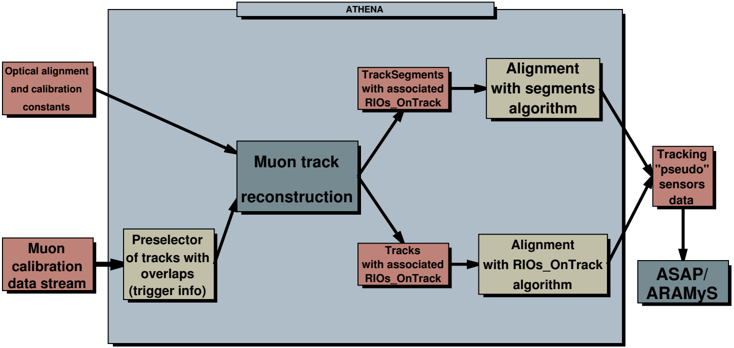


- Many muon chambers don't have projective optical alignment sensors ⇒ no correction to sagitta measurement
  - small barrel chambers
  - BEE chambers
  - BIS8 chambers
- Solution: use muon tracks passing through overlaps between these chambers and optically aligned chambers to obtain their relative positions

- Alignment of chambers without optical projective sensors is official respons-ibility of MPI MDT group and during data taking will be carried out at Munich MDT calibration and alignment center (part of Munich Tier-2)



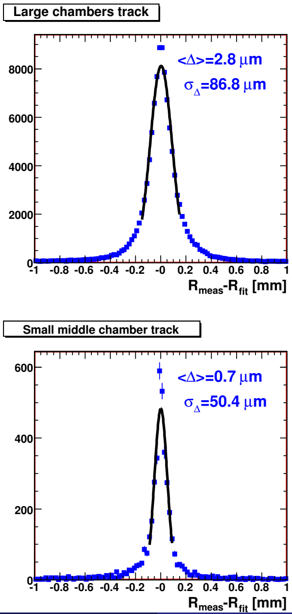
ATHENA track based alignment package



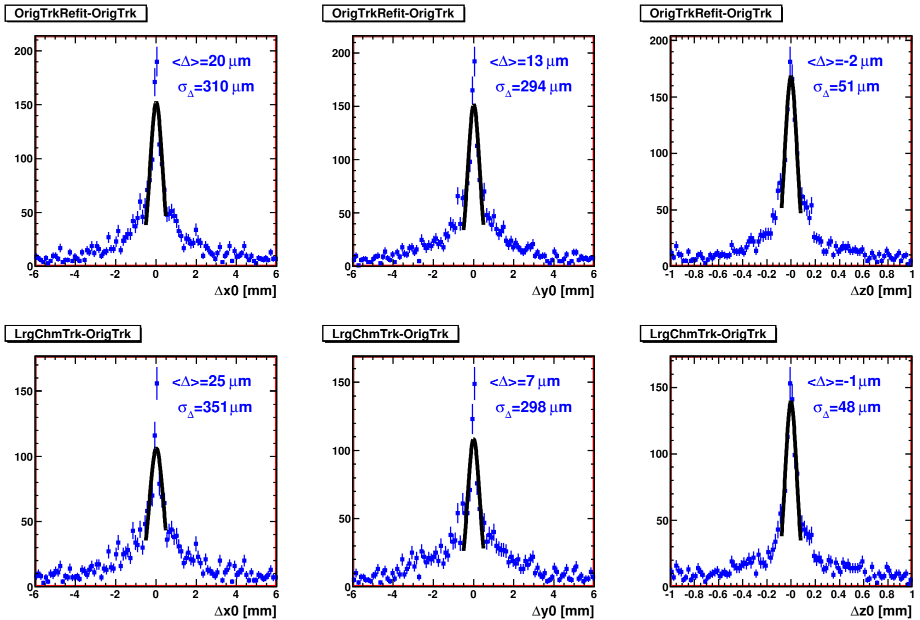
An ATHENA package MuonTrkAlign for track based alignment of the muon spectrometer is being developed by MPI MDT group

- based on new common tracking EDM (uses its data objects and tools):
  - operate with tracking EDM data objects: Tracks, TrackParameters, RIO_OnTrack
  - use TrackFitters, TrackExtrapolators and other common tracking tools
  - runs on both Mounboy and MOORe output
- current results were obtained with:
  - release 12.0.1, samples of 20 GeV and 100 GeV muons
  - perfectly aligned detector geometry
  - input track container “ConvertedMooreTracks”

Check of common tracking tools: MDT residuals for refitted 20 GeV tracks



Check of common tracking tools: position at MS entrance for refitted tracks



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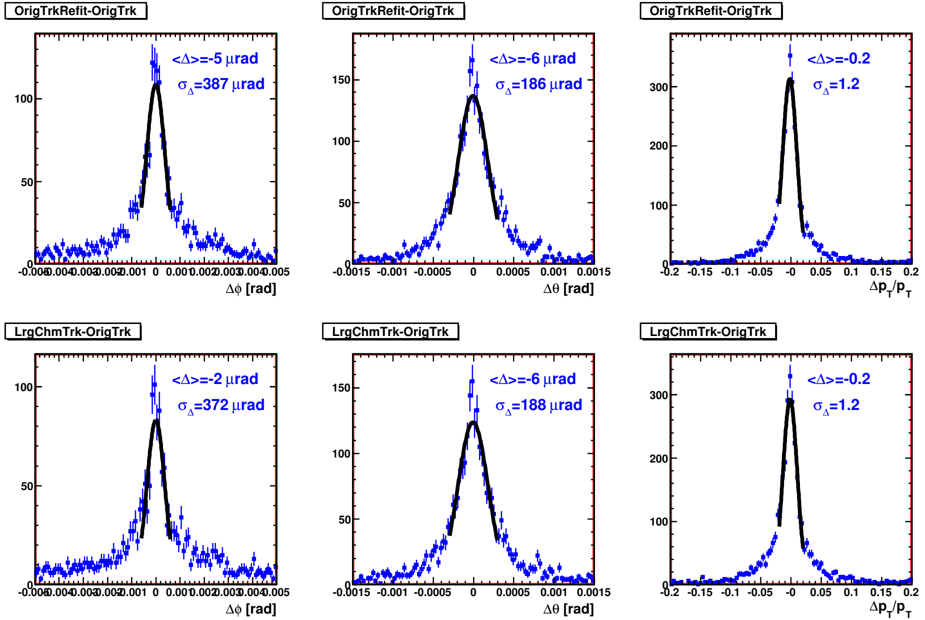
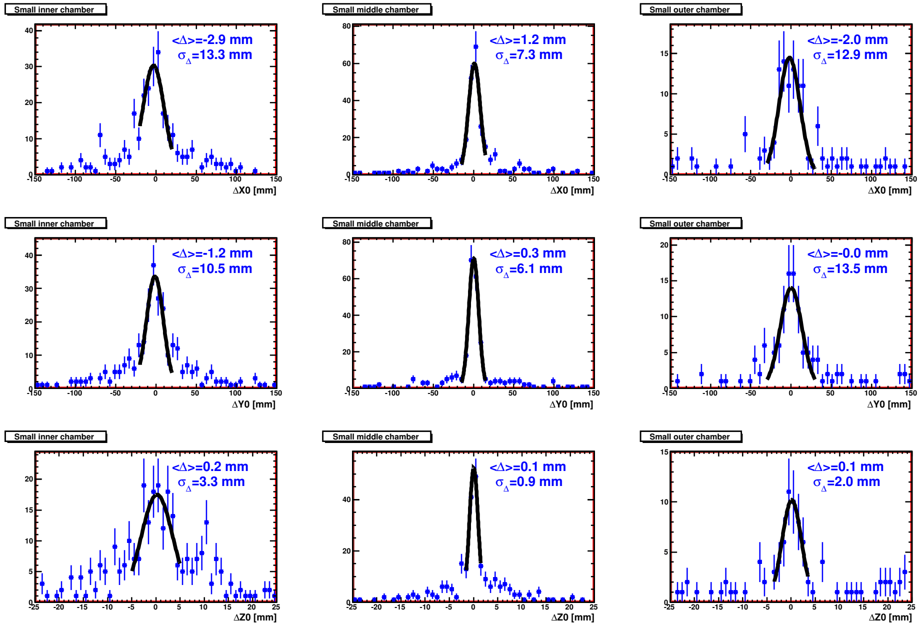
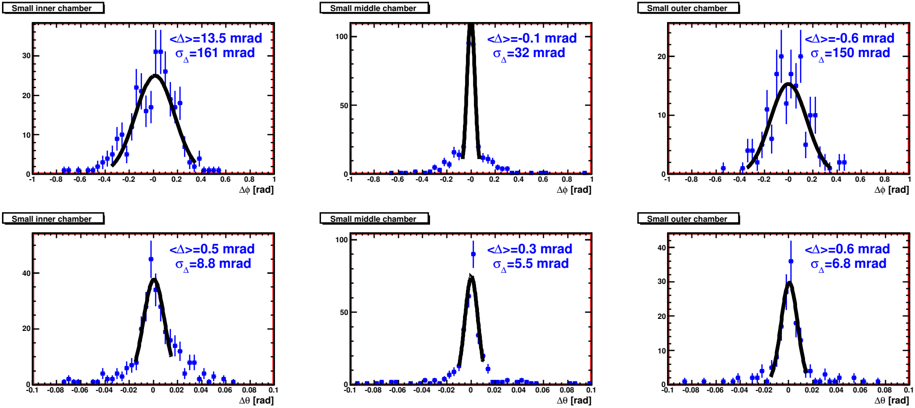


Extrapolation of large chambers track into small chambers: positions



Extrapolation of large chambers track into small chambers: angles



Problems with extrapolation of large chambers track

Refitting of muon track with new common tracking tools seems to work quite well:

- MDT fit residuals are about 50 μm which corresponds to chamber spatial resolution
- differences in track perigee parameters between original and refitted tracks at MS entrance look reasonable

But extrapolation of large chambers track into small chambers does not show expected precision:

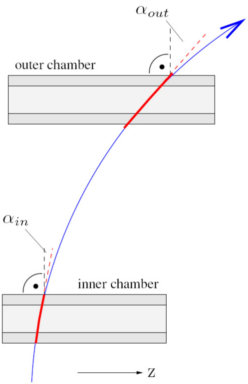
- shifts in Z-position (precision coordinate) 1-3 mm instead of expected 0.1-0.2 mm
- shifts in X- and Y-position 10-13 mm instead of $\sim$1 mm
- shifts in ϕ angle 30-150 mrad instead of $\sim$1 mrad
- shifts in θ angle 5-9 mrad instead of $\sim$0.4 mrad
- extrapolation to small middle chambers shows best results, extrapolation to small inner chambers is the worst

Possible reasons for under-performance of large chambers track extrapolation:

- common tracking tools were never tuned for use in muon system
  - different magnetic field configuration (toroidal instead of solenoidal)
  - different extrapolation step size is needed because the MS is much bigger in comparison to ID
  - considerably inhomogeneous magnetic field in many chambers (this partly explains why extrapolation into small middle chambers gives better results)
- bugs in muon spectrometer part of new common tracking code (in release 12.0.1)
  - MdtDriftCircle_OnTrack tracking class had bugs in *localToGlobal* and *associatedSurface* methods
  - there were bugs in RPC digitization code

A lot of things have to be done in order to achieve the desired performance level

First look at segment based alignment of large muon chambers



- use track segments associated with the same muon track to estimate the track momentum: $\Delta\alpha = \alpha_{out} - \alpha_{in} = \frac{q}{p_t} \int Bdl$
- start with middle chamber segment and extrapolate it to inner and outer chambers using the estimated momentum from $\Delta\alpha$ (a simple custom made segment extrapolater is used)
- calculate relative translations and rotations of the inner and outer chambers with respect to the middle chamber from discrepancies between extrapolated and measured segments
- in the first order approximation, uncertainties in momentum determination and segment extrapolation are canceled out with enough track statistics
- preliminary study gives the following number of tracks per η tower needed to achieve 100 μm accuracy of relative chamber alignment:

p_t^{μ}, GeV	N_{tracks}
6	500k
20	20k

- for muon calibration stream with rate of 2 kHz and threshold of 20 GeV it seems doable

Conclusions and plans

- Common tracking tools can be used for fitting tracks in the muon spectrometer
- An ATHENA package for track based alignment of small muon chambers has been written but needs considerable tuning to achieve the required alignment accuracy
- Feasibility studies of segment based alignment of muon chambers have been performed and show promising results
- To do list:
  - run the alignment algorithm with the upcoming release 12.3.0 which has a lot of bug fixes for muon system part of common tracking code
  - tune the TrkExtrapolater tool for use in the muon spectrometer
  - continue studies of segment based alignment method for muon chambers

Backup slides

Structure of MuonTrkAlign algorithm

Steps of the MuonTrkAlign algorithm

- select an overlap region Track with associated RIOs_OnTrack collection from standard muon reconstruction
- divide this collection into four parts: RIOs_OnTrack coming from large chambers and RIOs_OnTrack coming from small inner/middle/outer chambers
- refit the “large chambers” RIOs_OnTrack collection with TrackFitter from common tracking tools, using original track as a seed
- extrapolate this “large chambers” track into small chambers with TrackExtrapolator and get track’s extrapolated parameters
- refit inner/middle/outer small chamber RIOs_OnTrack collections with TrackFitter, using extrapolated “large chambers” track parameters as seed
- differences between the refitted inner/middle/outer small chamber tracks and the extrapolated “large chambers” track are the tracking “pseudo” sensors input for ASAP

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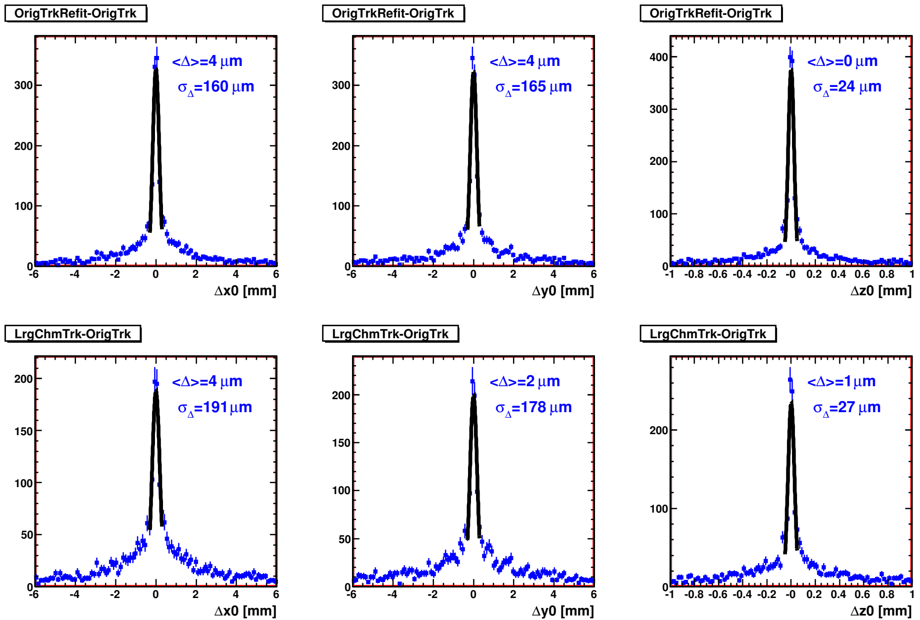

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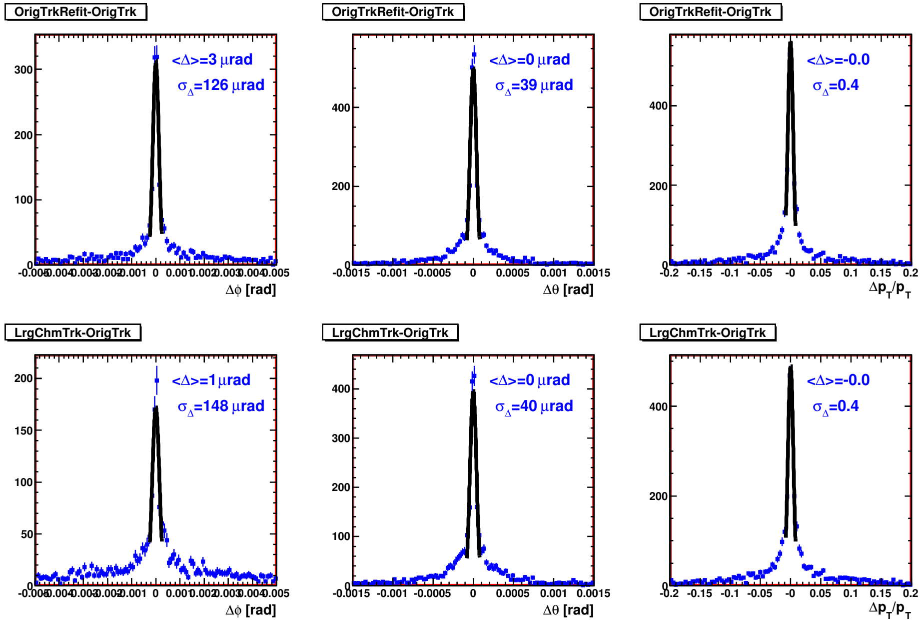

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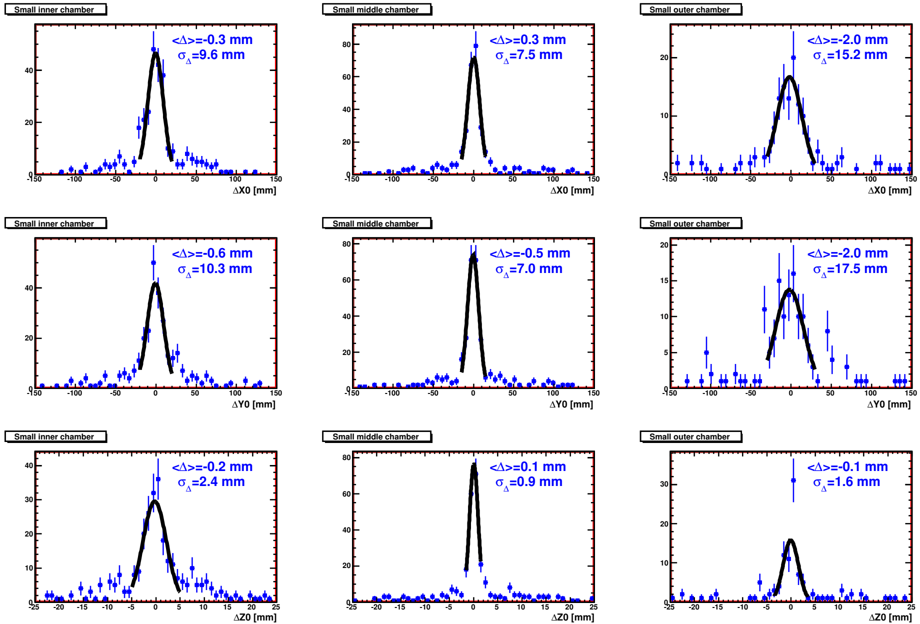

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