Determination of the Drift-Velocity in ATLAS MDT Chambers

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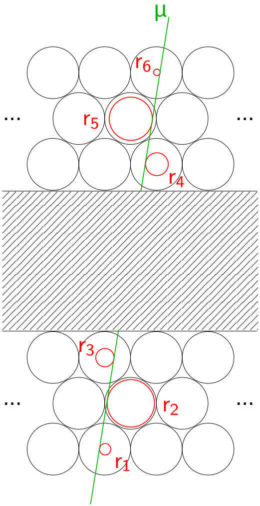
Drift Velocity and $r(t)$ Relationship



Needed for track reconstruction:

- drift radii $r_1, \ldots, r_6$.

Measured quantities:

- drift times $t_1, \ldots, t_6$.

$\longrightarrow$ Needed link:

- $r(t)$: space-time relationship or
- $\dot{r}(t)$: drift velocity.

Accuracy Requirement for $r(t)$

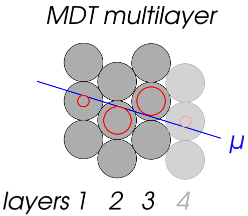
- $r(t)/\dot{r}(t)$ changes with operating conditions, mainly magnetic field and temperature.
- Influence of $r(t)$ on the magnetic field and temperature gradients inside a chambers can be corrected for.

$\longrightarrow$ Same operating conditions within a chamber.

- Goal: redetermination/check of $r(t)$ every hour.
- A priori accuracy of $r(t)$: $\sim$200 μm.
- Required accuracy: 20 μm.

$\Rightarrow$ Refinement of the initial $r(t)$ by means of the chamber's data required (so-called "autocalibration").

Residuals as a Measure of the $r(t)$ Accuracy



Definitions

- Straight tracks within a multilayer.
- d_k := track distance from the k-th anode wire hit.
- $r(t_k)$:= drift radius of the k-th hit.
- Residual $\Delta(t_k) := r(t_k) - d_k$.

Values of the residuals

$r(t) = r_{true}(t) + \epsilon(t)$ implies:

- $d_k \rightarrow d_{k,true} + \delta_k$.
- $\Delta(t_k) \rightarrow ?$ (answer on the next slide)

Residuals as a Measure of the $r(t)$ Accuracy

Dependence of $\Delta(t_k)$ on $r(t) = r_{true}(t) + \epsilon(t)$

Case 1: Large angular spread of the tracks, many hits.

- $< \delta_k > \longrightarrow 0$.

$\Rightarrow$ $< \Delta(t_k) > = < r(t_k) - d_k > \longrightarrow \epsilon(t_k)$.

$\Rightarrow$ $r_{true}(t) = r(t) - < \Delta(t) >$ (conventional approach).

Case 2: Small angular spread of the muon tracks.

- $< \delta_k > \neq 0$ usually.
- $\delta_k = \delta_k(\epsilon(t_1), \dots, \epsilon(t_n))$ (n: number of track hits).
- $\Delta(t_k) = \sum_{l=1}^{n} M_{k,l}\epsilon(t_l)$ to first order.

  $M_{k,l}$ can be calculated analytically.

The Analytic Autocalibration Approach

Problem

- $rank(M_{k,l}) = n - 2$ except for special configurations.

$\Rightarrow$ Can't solve $\Delta(t_k) = \sum_{l=1}^{n} M_{k,l}\epsilon(t_l)$ on a single track basis.

Solution

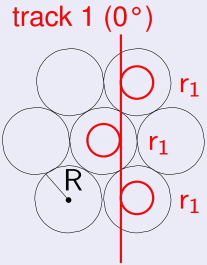
- Use a set of tracks.
- Parametrize $\epsilon(t)$ as a linear combination of base functions: $\epsilon(t) = \sum_{p=0}^{P} \alpha_p u_p(t) =: \epsilon_\alpha(t)$.
- Determine $\alpha = (\alpha_1, \ldots, \alpha_P)$ by minimizing

$$X^2 := \sum_{tracks} \frac{\left[\Delta(t_k) - \sum_{l=1}^{n} M_{k,l}\epsilon_\alpha(t_l)\right]^2}{\sigma^2(t_k)}.$$

Geometrical Constraints

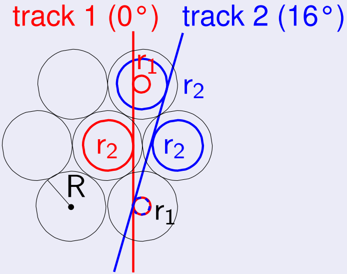
Basis of the approach: geometrical constraints.

Single-Track Constraint



$$r_1 = r_2 = r_3 = \frac{1}{2}R.$$

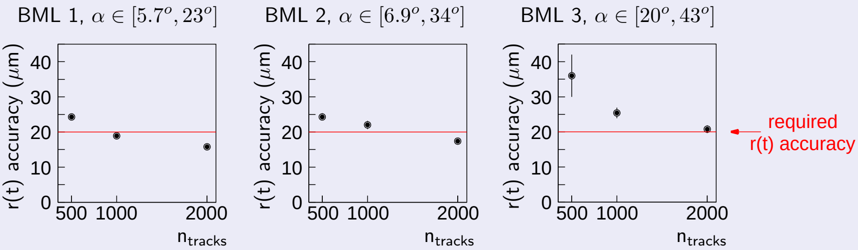
Double-Track Constraint



$$r_1 = 0.24\,R,\ r_2 = 0.72\,R.$$

Performance

Results from earlier ensemble tests outside ATHENA



Required $r(t)$ accuracy achievable with about 2000 tracks.

References

References

For further details please consult:

- M. Deile, Optimization and Calibration of the Drift-Tube Chambers for the ATLAS Muon Spectrometer, CERN-THESIS-2003-016.
- M. Deile et al., Autocalibration: The Influence of the Track Incidence Angles and a New Method, ATL-MUON-2004-02.
- O. Kortner, Performance of the Analytic Autocalibration Method, talk February 2005.

First Tests of the Algorithm in ATHENA

Status

- Algorithm working with release 12.
- Algorithm will be part of release 13.
- Features of the algorithm:
  - $\epsilon_\alpha(t)$ as a linear combination of Legendre or Chebyshev polynomial or a polygon;
  - returns a quality estimate for the final r-t relationship.

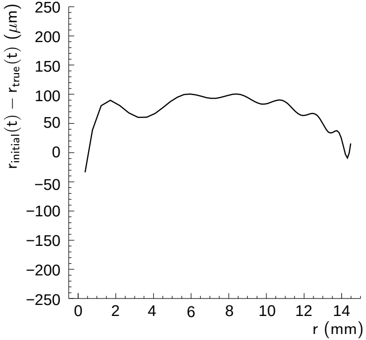
First Tests of the Algorithm in ATHENA

Data set:

- Single muons, μ^- at $p_t = 6$ GeV/c.
- ~2000 tracks per calibration region.

Correction function: Polygon with 15 equidistant r points.

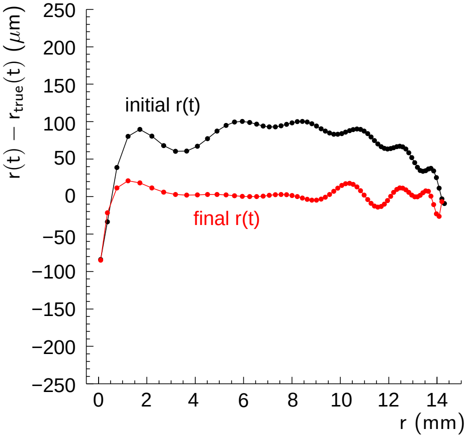
Initial $r(t)$ relationship:



- Characteristic initial $r(t)$.
- Accuracy: ~100 μm.

Results of the First Performance Test

Region with many geometrical constraints

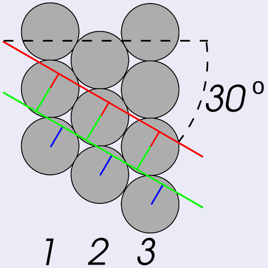


Observations

- Achieved $r(t)$ accuracies between 10 and 30 μm.
- High accuracy over a large drift-time interval.
- Optimization needed at t_{min} and t_{max}.

Results of the First Performance Test

Region with few geometrical constraints



Red track configuration:

$$r_{1,red} = r_{2,red} = r_{3,red}$$

$\Rightarrow$ no sensitivity of the residuals to a wrong $r(t)$.

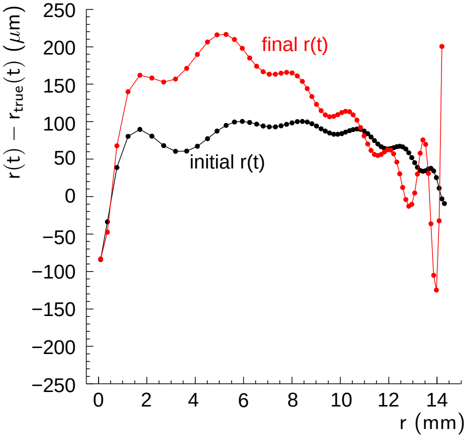
Green track configuration:

$$r_{k,green} \neq r_{k,blue},$$

$\Rightarrow$ Limited sensitivity of the residuals to a wrong $r(t)$.

Results of the First Performance Test

Region with poor geometrical constraints



Observations

- Algorithm not able to resolve the ambiguities at 30^o with a 3-layer mulitlayer.
- Optimization mandatory!

Summary and Outlook

Analytic autocalibration – status and plans

- Autocalibration part of ATHENA.
- First tests indicate proper functioning of the code.

But optimization for tracks at 30^o in 3-layer multilayers mandatory.

- Next test of the algorithm: running on DC-3 data with temperature and magnetic-field effects.