Autocalibration of ATLAS MDT Chambers

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Since in ATLAS no external reference system will be available for the calibration of the space-time relationship $r(t)$ of the drift tubes, the chambers' own data will have to be used.

Several techniques of standalone calibration have been developed. We will report about a new algorithm with particularly fast convergence.

1. Autocalibration with a Matrix Algorithm

Iterative autocalibration starts with a first-order r-t relationship obtained by simulation or from the drift-time spectrum [1]. Usually these start relationships have an rms precision of 50 - 150 μm, whereas we aim for calibrating better than 20 μm. Using this start r-t relationship the measured drift times in a multilayer (3 layers) of tubes are converted into hit radii to which a straight track is fitted. The fitted track can be used to obtain a better estimate for the r-t relationship.

The start r-t relationship deviates from the true one by a function $\varepsilon(t)$:

$$r_{\text{start}}(t) = r_{\text{true}}(t) + \varepsilon(t) \tag{1}$$

Consequently the distance of the fitted track from the wire i will deviate from the hit radius $r_{\text{start}}(t_i)$ by a so-called "residual" Δ_i:

$$\Delta_i = r_{\text{start}}(t_i) - r_{i,\text{fit}} \tag{2}$$

Since the fit is determined by the hit radii in all tubes crossed by the track, the residual Δ_i in a tube i depends on the deviations $\varepsilon(t_k)$ in all n_{hits} tubes. We can write this dependence as a matrix equation:

$$\Delta_i = \sum_{k=1}^{n_{\text{hits}}} M_{i\,k}\,\varepsilon(t_k) \quad , \tag{3}$$

where the matrix $M_{i\,k}$ depends on the track angle. The aim of autocalibration is to determine the deviation $\varepsilon(t)$. Unfortunately we cannot do this by inverting (3) because M is singular. Its rank is $\text{rg}(M) = \dim(M)$ - 2. However, if the drift times t_k of several hits on a track are identical, the dimension of (3) is reduced. In the special case where this dimension can be reduced by at least 2, there exist certain drift times t for which $\varepsilon(t)$ is uniquely determined. Only very few track angles provide such unique points of the r-t relationship. But already the reduction of the equation's dimension by 1 gives some constraint on the possible solutions $\varepsilon(t)$. In practice autocalibration can yield a unique result if enough track angles contribute their individual constraints. Technically we merge the information from many different tracks by arranging their individual matrix equations in one global matrix equation

$$N_{\text{tot}}\ \text{rows} \left\{ \underbrace{\left(\begin{array}{c} \\ M_{\text{global}} \\ \\ \end{array} \right)}_{\text{50timebins}} \right. \begin{pmatrix} \varepsilon(t_1) \\ \vdots \\ \varepsilon(t_{50}) \end{pmatrix} = \begin{pmatrix} \Delta_1 \\ \vdots \\ \Delta_{N_{\text{tot}}} \end{pmatrix} \tag{4}$$

Our calibration requires $\varepsilon(t)$ in typically 50 time bins. Therefore the vector $\vec{\varepsilon}$ has 50 components; consequently the global matrix has 50 columns while the number N_{tot} of rows is given by the number of tracks. The 50 components of $\vec{\varepsilon}$ are determined by fitting the model (4) to the measured residual vector $\vec{\Delta}$. Subtracting this $\varepsilon(t)$ from $r_{\text{start}}(t)$ one obtains an improved estimate for the r-t relationship. After a second iteration using the new $r(t)$ for the track fits the algorithm has converged (see fig. 1).

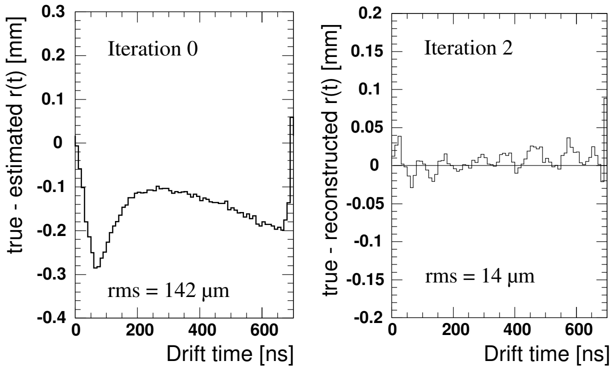

Fig. 1: Difference between (a) true and simulated start r(t), (b) true and reconstructed r(t) after the second iteration.

An older technique needs 11 iterations for the same precision. That method uses directly the measured residual $\Delta(t)$ as correction to $r_{\text{start}}(t)$, which corresponds to replacing the matrix M in (3) by the unit matrix. Doing so, one does not take advantage of all the available information. Therefore the convergence is slower and in the case of a low spread in the incidence angle the precision is worse.

2. Monte-Carlo Study of Autocalibration for ATLAS MDT Chambers

We applied the autocalibration technique explained above to simulated muon tracks through the ATLAS drift chambers using the real ATLAS geometry and magnetic field map. The muon momenta were distributed according to the expected inclusive muon cross-section. As result we obtained that 95 % of the ATLAS chambers can be autocalibrated with an rms precision better than 20 μm, the exceptions being those chambers which have typical track incidence angles around 30° where almost no constraints on ε exist. In the latter cases the obtained precision is about 50 μm.

A common r-t relationship can only be used within a zone of a chamber where the magnetic field variations entail variations smaller than 20 μm in $r(t)$. For each of these zones the calibration requires about 10000 events. To gather enough statistics, ATLAS will have to take data for about 30 hours. Since autocalibration will use normal physics data, no specific calibration runs will be needed.

References

[1] M. Deile, N.P. Hessey: Obtaining the Space-Time Relationship of Drift Tubes from the Drift-Time Spectrum, ATLAS Note ATL-MUON-99-002, CERN 1999