Track Reconstruction near Anode Wires of ATLAS Drift Tubes

M. Deile, S. Chouridou, N. P. Hessey, D. Schaile, A. Staude , R. Ströhmer, and T. Trefzger

To reconstruct muon tracks through chambers with several layers of drift tubes, straight lines have to be fitted to the impact circles defined by the drift times of those ionization electrons which arrive earliest at the tubes' anode wires. Traditionally this is done by minimization of

$$\chi^2 = \sum_{i=1}^{4} \frac{(r_{\text{hit}}^{(i)} - r_{\text{MDTtrack}}^{(i)})^2}{\sigma_i^2} \quad , \tag{1}$$

where the hit radii $r_{\text{hit}}^{(i)}$ are calculated from the r-t relationship and $r_{\text{MDTtrack}}^{(i)}$ is the shortest distance between the reconstructed track and the ith wire. σ_i is the resolution of the ith tube at the radius $r_{\text{MDTtrack}}^{(i)}$. This approach however is only valid if the drift time distributions for given radii are gaussian, which is correct far from the wire (fig. 1 right). For impact distances r smaller than about 2 mm however the gaussian approximation doesn't hold (fig. 1 left).

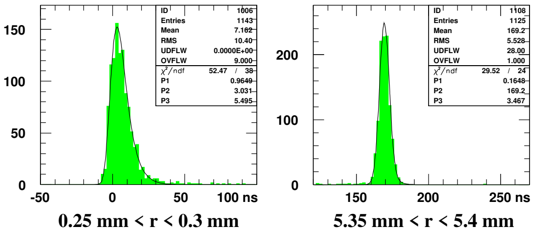

Fig. 1: Drift time distributions in 50 μm wide radial bins. The left distribution (near the wire) is asymmetric, the right one (far from the wire) gaussian

The reasons for the asymmetric time distributions near the wire are the statistical distribution of the ionization electron clusters along the muon track and the cluster size distribution: In ATLAS drift tubes the time measurement is triggered when the 25th ionization electron arrives at the wire. For big track radii many ionization clusters arrive almost at the same time. Therefore the charge distribution along the track has no significant impact on the trigger time. For tracks near the wire however the arrival times of the different clusters have a big spread. Most frequently the cluster containing the 25th electron has been created far away from the wire. Thus the measured time distribution peaks at $t > 0$ and gets a big tail at long drift times.

Conventional methods used to "squeeze" a Gauss function over the central part of an asymmetric distribution like in fig. 1 (left). Consequently both the peak position and width of the distribution are badly determined by the fit. If then all events in the tails of the residual distributions $r_{\text{MDTtrack}} - r_{\text{hit}}$ are discarded by applying a 3σ cut, the reconstruction efficiency will be low. Furthermore it is not very helpful to define a functional dependence $t(r)$ near $r = 0$. If for example the maximum of the measured time distribution at $r = 0$ is taken as $t_0 = t(0)$, times $t < t_0$ have to be artificially set to t_0 in order to avoid non-physical "negative drift times". By doing so however we lose most of the information contained in the measured time.

To avoid these problems, instead of defining a function $r(t)$ with gaussian errors we use the full information contained in the time distributions for given r. For this purpose we measured the shape of the r-t distribution in a test beam using a Silicon microstrip beam telescope as external reference system. Then we parametrized the conditional time distribution $P(t|r)$ for small radial slices. Maximization of the likelihood function

$$L = \prod_{i=1}^{4} P(t_i | r_i(m, c)) \tag{2}$$

by adjusting the track slope m and offset c then replaced the usual least χ^2 method for track fitting.

Fig. 2 demonstrates the improvements in tracking performance passing from conventional χ^2 tracking (upper plot) to maximum likelihood tracking (lower plot) for a chamber with 4 layers of drift tubes. It shows the track offset difference $\Delta c = c_{\text{MDTtrack}} - c_{\text{Silitrack}}$ as a function of $c_{\text{Silitrack}}$ of the reference track obtained from the silicon microstrip hodoscope.

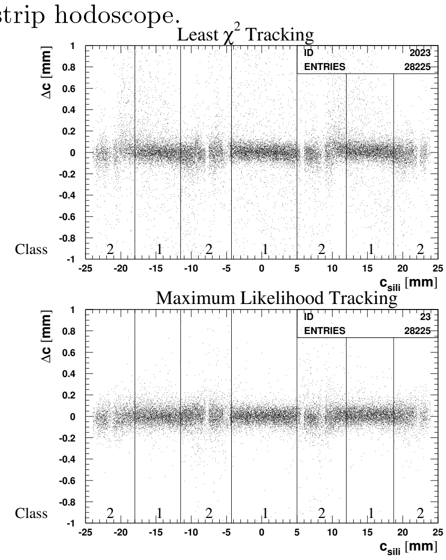

Fig. 2: Offset difference Δc versus the reference offset c_{ref}. Class 1 tracks pass all wires with a distance > 2 mm, whereas class 2 events have at least one radius < 2 mm.

Apparently the least squares method (upper plot) has difficulties with tracks passing near a wire (class 2): There are steps (evidence for biases) and big tails in the band pattern. For the maximum likelihood method (lower plot) these problems are much reduced. Even events with delta rays, which in χ^2 tracking are always badly reconstructed (background events in the upper plot), are correctly included into the likelihood fit by giving their hits the correct probabilities.

A more quantitative evaluation shows that for tracks near the wire the maximum likelihood technique reduces tails in the track offset deviation Δc by a factor 4 and improves the reconstruction precision by about 5 μm. The fraction of events where the fit completely fails is also reduced by a factor 4.

References

[1] M. Deile, N. P. Hessey, and A. Staude: MDT Track fitting with the Maximum Likelihood Method, ATLAS Muon Note 240, CERN 1998