Cluster Error of the FOPI TPC*

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In past experiments, Time Projection Chambers (TPCs) have been equipped with a gating structure to prevent the migration of avalanche ions created during gas amplification – traditionally realized with Multi Wire Proportional Chambers (MWPCs) – in order to maintain drift field homogeneity. This, however, limited the application of TPCs to experiments with trigger rates smaller than $\mathcal{O}(10^3\,\mathrm{Hz})$. To overcome this limitation a TPC with GEM (Gas Electron Multiplier) foils [1] exploiting their intrinsic ion backflow suppression, has been built [2]. This GEM-TPC has a drift length of 728 mm, an inner radius of 50 mm and an outer radius of 155 mm. For the readout a padplane with hexagonal shaped pads with 1.5 mm radius was used.

For tests with cosmic tracks and different heavy ion beams as well as for a physics experiment with an pion beam the GEM-TPC was employed inside the FOPI spectrometer [3].

To reduce the data rate and to introduce the possibility of an early noise suppression, pad hits are collected in entities called clusters which are defined by an amplitude, a position and a corresponding error. This is done by a full 3D local minima search which is independent of the pad shape or pad plane geometry. The clusters are then passed to the pattern recognition algorithm performing track finding employing a conformal mapping method [4]. Finally, a track can be fitted to these clusters. For this the Kalman Filter implementation provided by the GENFIT [5] framework is used.

For track fitting it is mandatory to have a precise knowledge of the error on the cluster position. By calculating the error for the three spacial directions without taking correlations between them into account one introduces strong dependencies of the track topology. This dependency can be seen in Fig. 1 where the RMS of the cluster error distribution in X direction is plotted for tracks with different azimuth angles but fixed polar angles as a function of the drift length. In this case the error is calculated by:

$Var_i = \frac{1}{A_{\mathrm{Cl}}} \cdot \Sigma A_{\mathrm{Padhit}} \cdot (\mathbf{X}_{\mathrm{Padhit},i} - \mathbf{X}_{\mathrm{Cluster},i})^2$,

and $\sigma_i = \sqrt{\frac{Var_i}{A_{\mathrm{Cl}}}}$.

To eliminate these dependencies a different way to calculate the cluster position errors was introduced. The errors are calculated by first creating the shape matrix:

$\mathbf{M} = \frac{1}{A_{\mathrm{Cluster}}} \Sigma A_{\mathrm{Padhit}} \cdot (\mathbf{X}_{\mathrm{Padhit}} - \mathbf{X}_{\mathrm{Cluster}}) \otimes (\mathbf{X}_{\mathrm{Padhit}} - \mathbf{X}_{\mathrm{Cluster}})$.

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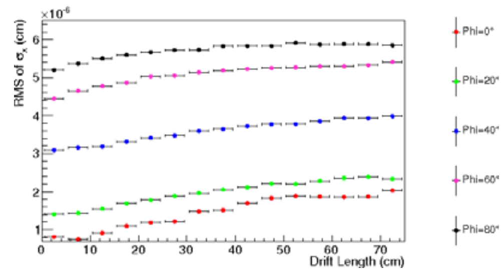

Figure 1: RMS of the standard cluster error distribution for different track topologies (see text) as a function of the drift length.

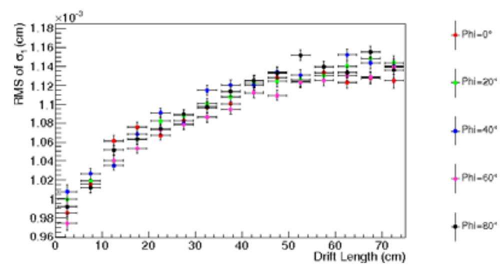

Figure 2: RMS of the matrix cluster error distribution for different track topologies (see text) as a function of the drift length.

This matrix can be seen as an ellipsoid with its three main axes representing the cluster position error. The eigenvectors of the shape matrix describe the direction of the error and the eigenvalues the magnitude. This way, the correlations between the three spacial coordinates can be taken into account. Figure 2 shows the RMS of the magnitude distribution of the first eigenvalue. One can see that the influence of the track topology can now be completely neglected.

References

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