Track Resolution Studies for a MPGD TPC

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Three out of the four concepts for the ILC detector will have a Time Projection Chamber (TPC) as the central tracking device. Due to physics' specifications track parameters have to be determined to a high degree of precision. In order to achieve this precision Micro Pattern Gaseous Detectors (MPGD) have to be used as the readout structure for the TPC.
A small sized prototype TPC with a Gaseous Electron Multiplier (GEM [1]) has been used in order to perform resolution studies. The results will be presented.

1 The Small Prototype TPC

A small sized prototype of a TPC (Fig. 1), built at DESY was used for resolution studies. The gas amplification was achieved with a triple GEM structure, with both, staggered and non-staggered pad readout. The sensitive volume was $660 \times 50 \times 53\, mm^3$. The pads had a pitch of $2.2 \times 6.2\, mm^2$, distributed over 24 columns and 8 rows. Two different gas mixtures were used for the studies: TDR-gas (Ar 93%, CH_4 5%, CO_2 2%), respectively P5-gas (Ar 95%, CH_4 5%). Cosmic muons were measured and the provided tracks were investigated for determining the spatial point resolution.

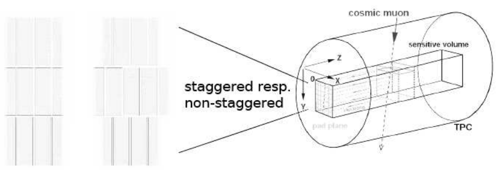

Figure 1: Small sized TPC prototype

2 The Reconstruction software

Analysis of the recorded tracks was performed with the software package "MultiFit" [2], based on C++, ROOT [3], and LCIO [4]. The reconstruction takes place in three steps:

1.) finding a cluster,

2.) finding a track,

3.) fitting the track.

Two different methods were used in order to analyze and fit the tracks.

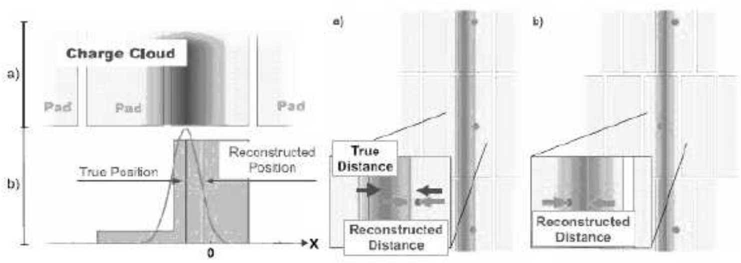

Figure 2: The effect of the pad response.

They were based on a least square, respectively a maximum-likelihood method. Both were capable to determine straight line and circular arc tracks.

The first method consisted of an adjustment of straight lines, respectively circular arcs for hits in the x-y-plane and subsequently minimizing χ^2. The second method consisted of an adjustment of straight lines for pulses in the x-y-plane and subsequently maximizing the likelihood function [5].

Using the minimization method one needs to include a Pad Response Correction (PRC). This is due to the fact that the pad size is of finite geometry. Deposited charge on these pads can be insufficiently shared between neighboring pads if the signal's size is of the order of the pad size or narrower. Such charge distribution can lead to incorrect determination of the x-position (Fig. 2), since a center of gravity calculation would tend to reconstruct the position of the signal towards the center of a pad.

The PRC corrects for this effect, using a Pad Response Function (PRF). The PRF describes the measured charge on a pad as a function of the original charge and the pad geometry [6]. The PRF is a convolution of two Θ-functions, describing the pad's geometry, and a spatial charge distribution, assumed to be Gaussian distributed. The PRF is used to simulate the pad signal of a Gaussian distributed charge cloud. From these signals the x-position of the hit is determined with the center of gravity method and are being used to correct for the pad response. The minimization procedure is applied row wise, i.e. the responding pads are considered from row to row and subsequently a least square method is applied with respect to the residuals from the track parameters and positions of the track points.

Using the maximization method the correction due to the pad response is not necessary. In this case a charge density distribution due to primary ionization and a two-dimensional charge density function due to diffusion is used to describe the response of a signal on the pads. The convolution of these two functions leads to a charge distribution on the pad plane. After determination of the distributions on the individual pads a likelihood function is applied. The likelihood function consists of terms describing the probability of the expected charge deposition on the pads. The maximum for the sum of the probabilities will determine the best track parameters. The design of this fitting procedure includes intrinsically the pad response.

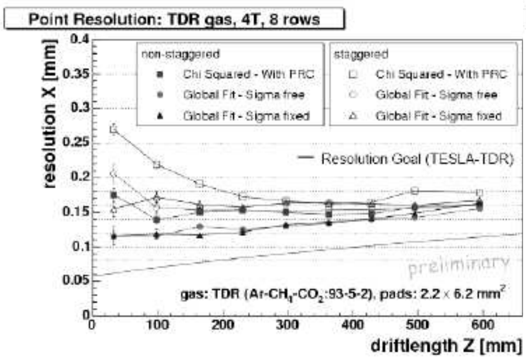

Figure 3: The track point resolution for two different gas choices and fitting methods.

3 Track Point Resolution

Both fitting methods described in Ch. 2 were applied in order to determine the track point resolution. Dependent on gas choice and pad layout the methods gave more or less similar results as a function of drift length. The results are summarized in Fig. 3. The track point resolution varied between 120 μm and 180 μm for drift distances less than 600 mm. The best results were obtained with the maximum likelihood method when the width of the distributions were used as a fixed parameter. The resolution, needed for the ILC-TPC is not yet achieved and further evaluations have to be performed, in particular with larger prototypes of a TPC, i.e. with a larger number of readout pads.

4 Summary and Outlook

The software package "MultiFit" provides tools for reliable track reconstruction. With a small prototype of a TPC a track point resolution above the desired resolution for the ILC-TPC has been found. Further studies have to be performed in order to prove the feasibility of such a TPC.

Studies are ongoing for the determination of double track resolution. Important issues are the separation distance, the reconstruction efficiencies, and the influence of two nearby tracks on the fit and single point resolution. For these studies data from the cosmic as well from a laser track setup are being analyzed. First investigations show that an applied method for the hit separation yields a more efficient way for finding double tracks as compared to a hit merge method. For the hit separation a pulse splitting was performed such that a local minimum is found and subsequently reweighing of the charge sharing. This yields to an improvement of double track recognition.

References

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