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High Magnetic Field Performance of a GEM-TPC

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Abstract

A large volume time projection chamber (TPC) has been proposed as main tracking device for a detector at a future linear e^+e^- collider. Gas electron multipliers (GEMs) are studied as potential replacement of the conventional wire based gas amplification system of TPCs. This talk presents recent results from R&D activities with a small GEM-TPC prototype. The spatial resolution was measured for different magnetic fields up to 4 T.

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HIGH MAGNETIC FIELD PERFORMANCE OF A GEM-TPC

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A large volume time projection chamber (TPC) has been proposed as main tracking device for a detector at a future linear e^+e^- collider. Gas electron multipliers (GEMs) are studied as potential replacement of the conventional wire based gas amplification system of TPCs. This talk presents recent results from R&D activities with a small GEM-TPC prototype. The spatial resolution was measured for different magnetic fields up to 4 T.

1 Introduction

The ambitious physics program of a future linear e^+e^- collider poses stringent requirements on the precision of its tracker as part of a precise overall detector. The measurement of the Higgs properties e. g. requires excellent momentum resolution for mass reconstruction and good dE/dx accuracy for particle identification for branching ratio measurements. A large volume time projection chamber (TPC) is considered a good candidate as a tracking device for this detector. Contrary to conventional TPCs with a multiwire proportional chamber (MWPC) technique for gas amplification, future TPCs are likely to make use of micro pattern gas detectors (MPGDs). The best known representatives of such MPGDs are the gas electron multiplier (GEM) [1] and micromegas [2]. MPGDs have amplification structures of order 100 μm giving rise to only tiny $\vec{E} \times \vec{B}$ effects, they provide a fast and narrow electron signal and have intrinsic ion feedback suppression – all features making them good candidates for a gas amplification system in TPCs.

2 The DESY TPC Prototype

To study the potential of TPCs with GEM foils for gas amplification, a small TPC prototype has been built at DESY. The chamber has a length of 800 mm with a diameter of 270 mm. The diameter has been chosen such that the chamber fits into a superconducting 5 T magnet with a 280 mm aperture available for detector R&D at DESY. The chamber is equipped with $24 \times 8 = 192$ readout pads of size 2.2×6.2 mm^2. The maximal drift distance is 680 mm. Gas amplification is provided by a triple GEM structure with two 2 mm transfer gaps and a 3 mm induction gap. The readout of the chamber is based on electronics built for the ALEPH experiment at LEP.

3 Single Point Resolution in High Magnetic Fields

One of the important questions which are addressed by the present TPC R&D activities is the achievable single point resolution of a TPC with a GEM based amplification system in magnetic fields as high as 4 T as proposed in the technical design report for TESLA [3]. The single point resolution is a useful number to compare the resolutions obtained from different prototypes and to extrapolate from small prototypes to the performance of a large scale device.

To find an answer to this question a number of measurements with cosmic muons was carried out in the 5 T magnet at DESY. Data were taken at magnetic fields of 0 T, 0.75 T, 1 T and 4 T. The reconstruction of the track parameters from the data is done in three steps. First, in each of the planes spanned by a pad row and the drift direction, clusters are reconstructed from the hits of the various channels. The x coordinate, describing the position along a pad row, is obtained using a center-of-gravity method. For each pad row the vertical position of the pad center is assigned to the y coordinate. The z coordinate of a cluster, describing the drift distance, is set to the position of the inflection point of the rising edge of the corresponding cluster. In a second step the reconstructed three-dimensional points are combined into tracks using a three-dimensional track following algorithm. Finally track parameters are fitted to the points belonging to the various tracks using a χ^2 technique. The track parameters are fitted independently in the xy and the yz plane. The fitted parameters are the intersection of the track with the xz plane at $y = 0$, the slope in the xy and yz plane and the curvature in the xy plane.

To determine the single point resolution, the following procedure is used: Remove the track point in row i and re-fit the x axis intercept of the track without point i. The distance of point i to the re-fitted track is called residual for row i. The resolution is obtained from the standard deviation of the residual distribution of the four central rows for the whole track sample.

Fig. 1 shows the transverse single point resolution versus drift distance obtained with this technique for the gas mixture Ar-CH_4-CO_2 (93-5-2). For the data collected up to 1 T, an increase of the resolution with drift distance is observed. In these cases the spatial resolution is limited by the diffusion in the drift region of the TPC. At 4 T the situation is different. Up to the maximal drift distance of 680 mm the resolution is flat as a function of the drift distance. With the present preliminary analysis a resolution of ≈ 160 μm is achieved which is not yet sufficient to fulfill the TESLA technical design report specifications. This indicates that the magnetic field suppresses the diffusion in the drift region to an extent that it is not the limiting factor anymore. Possible reasons might be either an inappropriate ratio of the charge distribution width

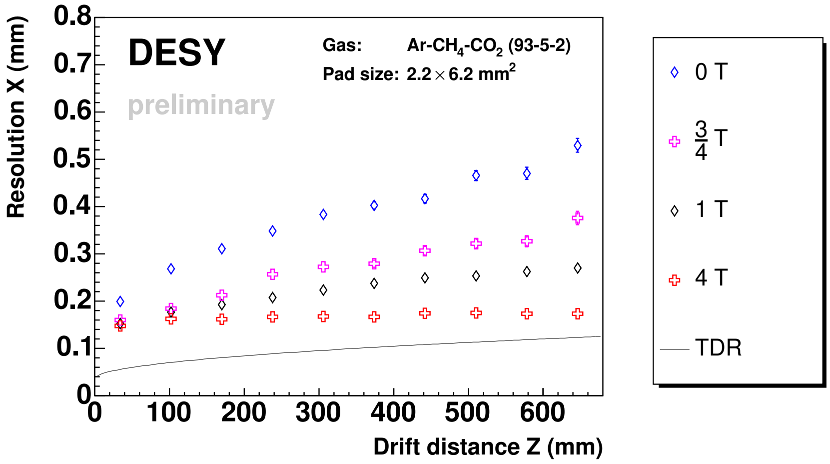

Figure 1: The single point resolution versus drift distance for different magnetic fields [4].

to the pad width or analysis systematics. Further investigations are ongoing to understand the measurements.

4 Conclusion

A small TPC prototype with GEM foils for gas amplification has been successfully built to measure the single point resolution in high magnetic fields. Cosmic muon runs were carried out in B fields up to 4 T. A transverse resolution of 160 μm has been achieved with the present preliminary analysis. Further studies are under way to understand the limiting factors and to improve the performance.

References

1. F. Sauli, *Nucl. Instrum. Methods* A, **386** (1997) 531.
2. Y. Giomataris *et. al.*, *Nucl. Instrum. Methods* A, **376** (1996) 29.
3. T. Behnke, S. Bertolucci, R.-D. Heuer, and R. Settles, TESLA Technical Design Report, DESY, Hamburg, Germany, DESY 2001-011 and ECFA 2001-209 (2001).
4. M. E. Janssen, Auflösungsstudien an einer Zeit-Projektions-Kammer mit GEM-Auslese, Diploma thesis, University of Dortmund (2004).