Development of a High-Rate GEM-Based TPC for PANDA ◇

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1. Introduction

High-precision spectroscopy of hadrons in the strange and charm sector, as envisaged in the PANDA experiment [1], requires an excellent charged particle tracking system with a very low material budget in order not to spoil the energy and mass resolution of the apparatus. One option for the central tracker is a time projection chamber (TPC), located inside the 2 T solenoid magnetic field between the microvertex detector and the electromagnetic calorimeter. In addition to its excellent tracking properties, a TPC would strongly contribute to particle identification (PID) in the sub-GeV region, which is otherwise not covered by any other detector in PANDA. Owing to the beam properties at the High Energy Storage Ring (HESR), the TPC has to operate at interaction rates up to $2 \cdot 10^7$ in a continuous mode. The use of GEM (Gas Electron Multiplier) foils as amplification stage [2] opens the possibility to bypass the necessity of gating, as the backdrift of ions into the drift volume is suppressed due to the asymmetric field configuration.

2. Ion Backflow and Space Charge Build-up

To study this suppression, a $10 \times 10\,\mathrm{cm}^2$ dedicated triple-GEM test detector has been built, which allows an easy exchange of the GEM foils and an independent setting of all voltages. The currents on all electrodes under irradiation with Cu X-rays were measured with custom-made high-voltage current meters with a resolution of a few tens of pA. All measurements were carried out without magnetic field and in an Ar/CO_2 (70/30) gas mixture. A minimum ion backflow (ion current on the cathode divided by electron current on the anode) of 0.8% has been achieved.

In order to study the build-up of space charge in the PANDA TPC and the resulting distortions to the drift of electrons, Monte-Carlo simulations of $\bar{p}p$ annihilation events at a rate of $2 \cdot 10^7/\mathrm{s}$ were carried out, assuming an ion backflow of 0.25%, which seems feasible taking into account the presence of a magnetic field in PANDA. The resulting charge distribution was translated into a 3-D electrical field map using a finite element program. Taking into account both the electric and realistic magnetic fields, radial displacements of up to 6 mm are observed, depending on the rz start position of the electrons (Fig. 1). Such displacements have already been corrected for in other experiments like ALEPH and STAR.

3. Measurements with a GEM-TPC

First measurements with cosmic muons have been carried out using a triple-GEM TPC with 7.7 cm drift length and $10 \times 10\,\mathrm{cm}^2$ active area. The ALICE TPC front-end electronics was used to read 128 of the $1 \times 6\,\mathrm{mm}^2$ pads. The focus during these measurements was on the detection of tracks crossing the TPC almost perpendicularly to the pad plane. The resolution of the TPC was estimated from the residual distribution of clusters from reconstructed tracks. Figure 2 shows the r.m.s. width of the residuals in the y coordinate (1 mm pad width) as a function of the drift distance z. The resolution is limited in this case both by the finite pad width and the noise of the ALICE electronics, which has not been optimized for GEM detectors.

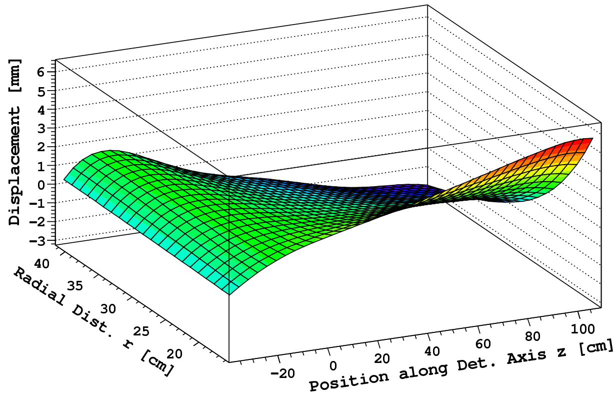

Fig. 1: Radial displacement of drifting electrons in realistic electric and magnetic fields, depending on their rz start position. The GEM stack is located at $z = -40$ cm.

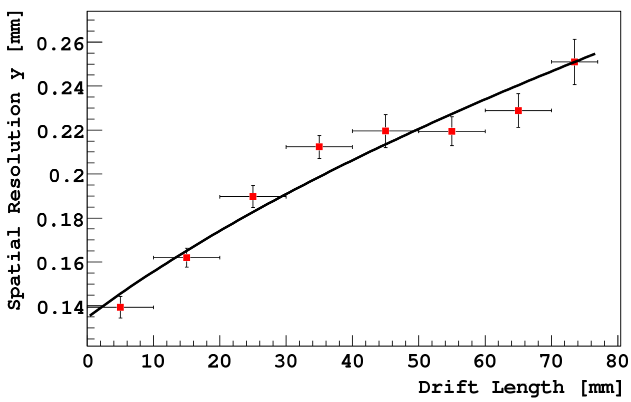

Fig. 2: Residual width in y vs. drift distance z. The black curve is the result of a fit taking into account the diffusion.

References

[1] PANDA, M. Kotulla, *et al.*, Technical progress report for PANDA: Strong interaction studies with antiprotons, FAIR-ESAC/Pbar/Technical Progress Report (February 2005).

[2] F. Sauli, Nucl. Instr. Meth. **A 386** (1997) 531

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