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Ion-Backflow Measurements of a Single Gas Electron Multiplier Foil

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For gaseous detectors in high energy physics experiments the Ion-Backflow (IBF) into the drift space is often an unwanted feature, especially for large Time Projection Chambers (TPC) that are used for example in the ALICE experiment at LHC or the STAR experiment at RHIC. Both use Gas Electron Multiplier (GEM) technology for their readout chambers. The IBF can be minimized using a stack of GEM foils with an optimized field setup to suppress the majority of ions from drifting back into the drift space. In case the IBF is small of around 1% and less, the distortion of the drifting electrons from primary ionization points can be corrected to maintain accurate tracking with high efficiency. However, the correction mechanism works best by assuming a homogeneous IBF over the drift space.

We present a systematic study of the IBF in a single foil GEM detector by using custom made GEM foils produced by single mask technique by TECHTRA SP. Z O.O., Poland. The GEM foils with a size of 10 x 10 cm2 are divided in four segments with different hole dimensions. The diameters vary from less than 40 µm to more than 70 µm. Differing from previous studies, the foil design allows us to compare the effects of the different hole dimensions simultaneously without the need of modifying the measurement setup.

We defined the hole dimensions from high resolution optical scans [1]. The scans were used to map the hole distributions. We have shown earlier that the relative gain of a GEM foil depends on the geometry of the holes [2,3]. Non-uniformity in the hole properties will lead to non-uniform gain behavior. This will lead to variation in IBF, which is the subject of this study.

We measured the effective gain and the IBF in a standard gas enclosure with a 2D strip readout plane. The strips were combined to 4 sectors, readout in current mode by a set of picoammeters. The isotope ^{55}Fe was used as an X-ray source and we used two different gas mixtures, Ar-CO_2 (70-30) and Ne-CO_2- N_2 (90-10-5). The irradiation was done separately for each foil segment. This allows us to compare the different hole geometries. Finally, we compared the results with simulations we made with Garfield++ toolkit.

We show that the IBF depends on the individual hole sizes and shapes of the GEM foil. Maintaining the drift field and the effective gain of a GEM foil we found that a lower IBF is possible by choosing the right hole diameter and shape. The results can help to choose for example an optimal GEM foil for the first amplification instance in a TPC readout chamber that is most responsible for letting the ions pass into the drift space.

[1] M. Kalliokoski et al., Nucl. Instrum. Meth. A 664 (2012) no.1, 223.
[2] T. Hildén et al., Nucl. Instrum. Meth. A 770 (2015) 113.
[3] E. Brücken et al., Nucl. Instrum. Meth. A 1002 (2021), 165271.

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