Ion Gating in a GEM

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1. Introduction

GEM(Gas Electron Multiplier) is superior to other gas detectors because of its high counting rate, excellent spatial resolution, good imaging capability, operability in a magnetic field, and large sensitive area. One of the important features in a GEM is the strong suppression of the feedback of the positive ions, which are generated from the avalanche. GEM can be used in various application areas such as the end cap detector for a TPC(Time Projection Chamber) and the GEM photomultiplier. [1] In these cases, the ion feedback has to be reduced to reduce the field distortion in the TPC and prevent a photocathode degradation in the GEM photomultiplier.

The ion feedback in a multi GEM was measured by changing the gas mixture, the drift electric field, the effective gain, the transfer electric field, and the asymmetry of the applied voltage. A simple model is made to explain the ion feedback.

One way to reduce the ion feedback is an ion gating. That is, multi-wires are placed in the drift region, and the relative voltage is applied to the wire, which can prevent the ions from arriving at the drift plate. Electric field calculation was done to simulate the ion gating in the GEM. Also, the suppression of the ion feedback was measured with the ion gating method.

2. Experiment and Analysis

The ion feedback was measured and it was explained by a simple model. [2]

2.1 Experiment

Two GEM foils were mounted in a cascade inside a stainless-steel chamber. The GEM foils were fabricated in a CERN. The drift plate was placed above the GEM foils. The drift gap between the drift plate and the above GEM foil was 3 mm, and the gap between the GEM foils was 2 mm. 5.9 keV X-rays were beamed through a 0.5-mm thick Be window. The anode signal was measured directly through the bottom of the lower GEM foils, and the cathode current was measured from the drift plate. Highly pure Ar and CO_2 gas flew through the chamber. The effective gain was defined as the anode current divided by the primary ionization current. The ion feedback ratio was defined as the cathode current divided by the anode current.

The effect of the effective gain and the gas mixing ratio on the ion feedback was measured. The ion feedback ratio decreased with the effective gain, and it was almost independent of the gas mixture.

The effect of the drift electric field on the ion feedback was also measured. The ion feedback increases almost linearly with the drift electric field. The effect of the transfer electric field was measured. The effective gain increased with the transfer electric field, and the ion feedback decreased slowly with the transfer electric field. The effect of the asymmetry of the applied voltages, which were biased on the GEM foils, was measured. As the applied voltage on the above GEM became higher, the ion feedback got smaller.

2.2 Ion feedback Model

The ion feedback effect can be explained by the charge transfer parameters. If we set the electron collection efficiency into the GEM hole as c_i, the real gain of a GEM as g_i, the electron transfer efficiency e_i, the ion extraction efficiency from the GEM hole as f_i, the ion collection efficiency into the GEM hole as i_i. Then the effective gain, G, in the double GEM structure is

$$G = c_1 g_1 e_1 c_2 g_2 .$$

The ion feedback current to the cathode, I_D, is

$$I_D = c_1 g_1 f_1 + c_1 g_1 e_1 c_2 g_2 f_2 i_1 f_1 .$$

Then the ion feedback ratio can be expressed as

$$I_D / G = a + \frac{b}{\sqrt{G}} .$$

Here, a and b are the parameters. If we make the two parameters fit the data, we can explain the ion feedback as a function of the effective gain, G.

3. Ion Gating

The ion feedback can be reduced with an ion gating. A multi-wire is placed between the above GEM foil and the drift plate, and the relative voltage is biased on each wire. In the open gate mode, all the wires are kept at the same potential, V_{Gate}, and the electrons and ions transport freely. The gate is closed, when the potentials of the wires are changed to $V_{gate}\pm\Delta V_{gate}$ respectively.

The ion gating in a GEM was measured. The parallel wires with the thickness of 100 μm were placed between the drift plate and the above GEM. The spacing between the wires was 2 mm. We increased the ΔV_{gate} and we measured the ion feedback ratio. Figure 1 shows that the reduction of the ion feedback as ΔV_{gate} was increased.

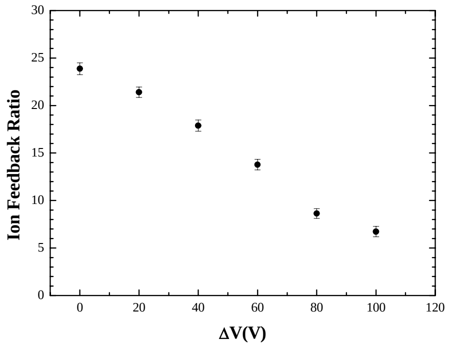

Fig. 1 The ion feedback ratio as a function of the relative bias.

4. Conclusion

The ion feedback was measured as a function of the drift field, the transfer field, the effective gain, and the asymmetry of the bias voltage. The ion feedback was explained by the model. The ion feedback was successfully reduced by placing parallel multi wires between the drift plate and the above GEM.

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