High Voltage Distribution scheme for large size GEM detector

J. Saini*, A. Kumar, A. K. Dubey, V. S. Negi and S. Chattopadhyay
High-Density, Experimental High Energy Physics Division,
Variable Energy Cyclotron Centre, Kolkata - 700064, INDIA
** email: jsaini@vecc.gov.in*

Introduction

Gas Electron Multiplier (GEM) detectors will be used for Muon tracking in the Compressed Baryonic Matter (CBM) experiment at the Facility for Anti-proton Ion Research (FAIR) at Darmstadt, Germany. The sizes of the detector modules in the Muon chambers are of the order of 1 metre x 0.5 metre. For construction of these chambers, three GEM foils are used per chamber. These foils are made by two layered 50μm thin kapton foil. Each GEM foil has millions of holes on it. In such a large scale manufacturing of the foils, even after stringent quality controls, some of the holes may still have defects or defects might develop over the time with operating conditions. These defects may result in short-circuit of the entire GEM foil. A short even in a single hole will make entire foil un-usable. To reduce such occurrences, high voltage (HV) segmentation within the foils has been introduced. These segments are powered either by individual HV supply per segment or through an active HV distribution to manage such a large number of segments across the foil. Individual supplies apart from being costly, are highly complex to implement. Additionally, CBM will have high intensity of particles bombarding on the detector causing the change of resistive chain current feeding the GEM detector with the variation in the intensity. This leads to voltage fluctuations across the foil resulting in the gain variation with the particle intensity. Hence, a low cost active HV distribution is designed to take care of the above discussed issues.

HV distribution design motivation

With the HV segmentation on the GEM-foil, HV distribution using a single channel of the power supply along with the resistive chain is a common practice to feed the GEM detector. Prototype testing results [1] with this configuration are already been reported earlier. But this method has two fold problems, 1) It does not take care of any short-circuit within the foil segment and 2) with the high intensity of particle incident on these foils, there will be rise of current leading to an appreciable voltage fluctuation across the foil which finally results in gain drop. To take care of these shorts as well as voltage stability across the GEM foil, a specialized HV distribution is required. An Active GEM Voltage Divider (G-AVD) [2], is being developed by RD51 collaboration at CERN. This has issues of bulky components and use of additional HV channels. Another option is to use newly developed 14-channel individual-source power supply from CAEN. In this case, instead of bias being supplied from resistive chain, voltage to the GEM foil is directly feed through an individual floating HV power supply channel. This is an attractive solution and theoretically deals with both the problems mentioned above. But there are two issues with this solution: 1) high cost 2) increased noise without filters. Use of external filters reduces the noise but with this configuration one can not maintain a constant voltage across the foils in case of any short, inhibiting the very purpose of using such a specialized power supply solution.

HV distribution design

We have designed a new HV distribution circuit which uses a resistive chain to feed the GEM-detector and being able to handle the basic requirement of isolation among the segments of the GEM foils as discussed above. As this circuit works with normal resistive chain and inherent filters already exist, therefore this configuration has good noise performance as well.

In this circuit, to deal with the problem of current fluctuation with high particle flux, resistive voltage divider chain was modified to increase the current through the divider network. In earlier resistive design, the chain current was approximately 500μA but for this new chain design, this current is around 1.5mA which reduces the voltage fluctuation to 3 times lower as compared to earlier design. Apart from the resister chain modification, an opto-coupler is introduced in each of the GEM foil segment as shown in Fig.1. ON/OFF of this opt-coupler is controlled by a 5V input as shown by ON/OFF control in the same figure. These control lines are pulled up by a 1K resister as shown in Fig.2 to make the circuit normally ON. With this opto-coupler setup, if there are any short across the GEM foil segment, this will raise the current of the HV-supply. We can put the alarm on certain current level so that we are informed about any short across the chamber. To debug which segment has went bad; we can cut-off opto-coupler one by one until the normal operating current is restored in the HV-supply. Once identified, we can put the bad segment permanently OFF for further operation until any physical interventions. With the above functionality, this circuit can handle any number of bad segments without interfering normal working of good segment within the foil.

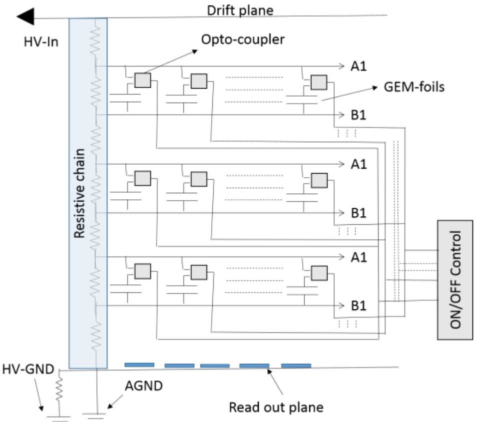

Fig. 1 Opto-coupler based HV distribution for GEM detectors

Test-Setup

This circuit is tested for its working principle using a standalone setup with opto-coupler as shown in Fig. 2. We have tested the circuit upto 4.5 kV which is the expected operating voltage of the CBM-MUCH GEM detectors. With 4.5 kV in a resistive chain, GEM foils have maximum gradient of 500V with the present configuration. Opto-coupler CPC1393 was chosen, which can withstand 600V at output with optical isolation of 5kV. This component exactly suits our present requirement. With the opto-coupler put in series with the GEM foil, there are two conditions which need to be verified. Those conditions are; 1) if the GEM foil develops any short, how does the opto-coupler behaves and 2) under normal operating condition, whether there is any significant change in operating current due to opto-coupler.

As shown in Fig. 2, we have put a switch sw1 in series with opto-coupler to simulate short-circuit in a GEM foil. With and without opto-coupler, the normal resistive chain current is 435µA. A short-circuit is introduced by switch sw1 and recovered back using via opto-coupler using switch sw2 as shown in Fig. 2. With the simulated short circuit, resistive current jumped from 435µA to 485µA. After isolating the short circuit using opto-coupler, the increased current 485µA is restored back to 435µA. The above results shows that any short-circuit across the GEM foil can be isolated using the opto-coupler and the opto-coupler has no noticeable effect on normal operation mode of the detector.

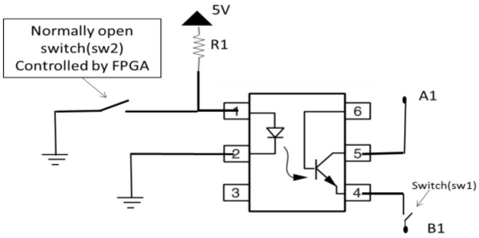

Fig. 2 HV opto-coupler test-setup

Conclusion

Hence with the above results, it has been proved that this opto-coupler based HV distribution design can handle short circuited segments in a GEM foil by isolating them properly and without hampering the normal working of other good segments with overall good noise performance of the system.

References

[1] GEM detector development for CBM experiment at FAIR, site: http://dx.doi.org/10.1016/j.nima.2012.10.043

[2] https://indico.cern.ch/event/365380/contributions/1780244/attachments/726462/996914/Project_News_GAVD_TPIC_FEMTO.pdf