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Chapter 1

Detector Description and Operation

1.1 GEM Preamplifiers

The GEM preamplifier, as described previously, amplifies the signal amplitude of the ionization chamber. When an ionizing particle intersects with an ionization chamber that has a 90/10 Ar/CO2 gas, the ionizing particle primarily liberates electrons in the detector's drift region. Consequently, drift electric field accelerates the electrons towards the GEM preamplifiers to mutiply the electrons; after that, the gain is toned by a high voltage divider circuit that helps to establish the electric field for each preamplifier. By the end, electron avalanches move toward a segmented charge collector.

As described in section 2.7, a single GEM preamplifier can increase the number of liberated electrons by three orders of magnitude via electron multiplication.[11] Using three preamplifiers increases the signal amplitude, making it measurable for ionizing particles, so the voltages on each GEM preamplifiers are toned depending the charge produced by ionization in the drift region.

The structure and the number of preamplifiers of GEM detector changes depending on the applications. GEM based detector differs in structure for different applications. for instance, in medical imaging, increasing the charge that is collected by each channel in a segmented readout is important to sharpen the image when only few ionization events occur the drift region; however, the primary charge in the drift region is multiplied by a high gain from GEM preamplifiers. Also, the same case is for low ionizing particles when their measurable signal is observed.

Highly ionizing particles need the gain of order of $10^3 - 10^4$. In case of highly charged particles like heavy ions, the ionization charge in the drift region is of order of $10^4 - 10^6$ electron, a gain of order of $10^3 - 10^4$ will increase the ionization amplitude to a measurable level, so a single or double GEM is sufficient to achieve the gain. If the aim is to avoid the discharge effect, a triple GEM system can be used and is toned at a low voltage.

1.2 Detector Structure

The triple GEM detector is composed of three GEM preamplifiers, a cathode and an anode. A GEM preamplifier is a 50 micron thick kapton foil clad on both sides with 5 microns of copper. A staggered pattern of 50 micron diameter holes, equally spaced by distances comparable to the hole diameter, is chemically etched into the copper clad foil of a 140 um pitch distance over an area of 10x10cm. [1] The detector contains three GEM preamplifiers mounted on square plastic frames separated by a vertical distance of 2.8 mm and placed parallel to the cathode.

The cathode is a square copper plate that is 10x10cm and is 3.5 mm away from the top of the first GEM card. This cathode design is capable to hold potential voltage of 5 kV (in the air) between the top and bottom side without any discharge. The charge collector (readout anode) is constructed of 50-80 micron wide strips, which are insulated to determine the location of the collected electrons. The strips are arranged in way to allow equal charge sharing on the upper (x coordinate) and lower (y coordinate) charge collector layers. [20]

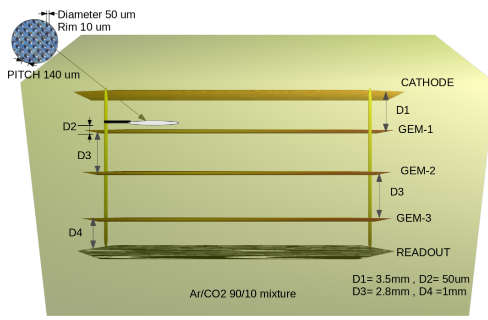

Figure 1.1: Fig.1 shows the original GEM detector design.

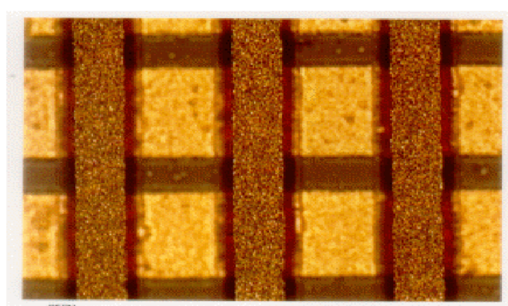

Figure 1.2: Fig. shows the charge collector dimensions and arrangement.

All the detector components exist in a sealed chamber that consists of two ertalyte plastic sheets as shown in figure x. They are bolted together by M3 plastic screws located around the detector window to form a well-enclosed cavity. Also, the chamber has a 13x13cm kapton window to reduce the energy loss of incident particles entering the chamber. The figure z,y, and x respectively below show top, bottom, and side views of the detector's chamber design.

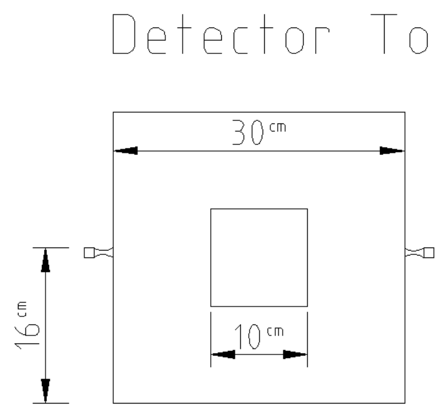

Figure 1.3

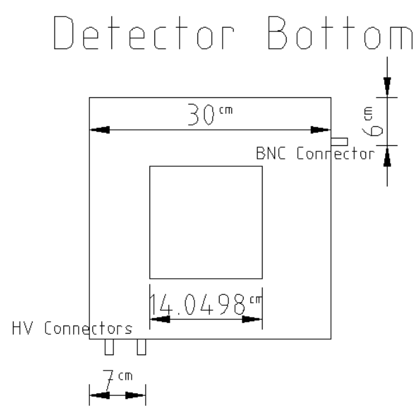

Figure 1.4

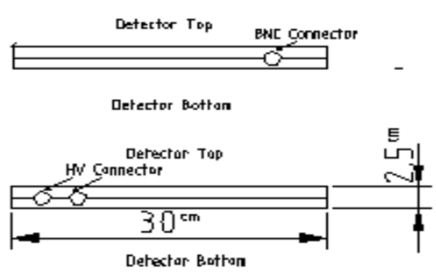

Figure 1.5

1.3 Modifying the GEM Detector as Neutron Sensitive Detector

U-233 coating becomes a part of the cathode to make the GEM detector sensitive to neutron flux. As stated previously in Section 2.2.1, U-233 is installed inside the chamber to directly detect neutrons by fission interaction. U-233 coating is a circular thin film of 2.5 cm diameter of a thickness of 30-40 um , the coating is carried by a circular metal plate of 8 cm diameter. Figure xx shows how the cathode and U-233 coating plate are combined with U-233 coating directly exposed to the drift region of the detector.

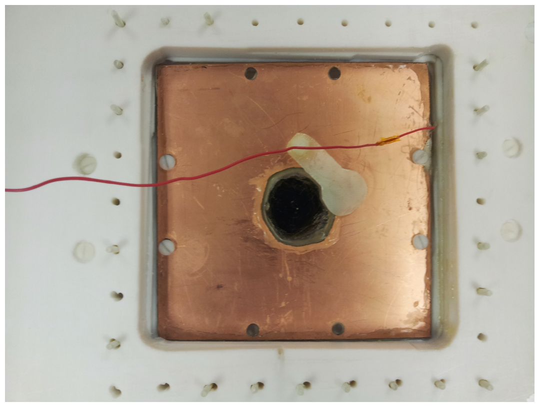

Figure 1.6: Detector's shutter is open.

An FR4 shutter takes place in the drift region and can completely cover U-233 coating. Figure XX shows the FR4 shutter, which is 1 mm thick, and can cover the U-233 coating, the FR4 shutter location is in the drift region with a distance of 2 mm from the cathode. A control rod extends from the end of the shutter to the outside the kapton window to manually open and close the shutter from outside the chamber. Hence, the shutter can cover U-233 coating when it is closed, and when the shutter is open, it exposes U-233 to the drift region.

The shutter has the ability to stop alpha particles and fission fragments that are emitted from U-233 coating. Having the U-233 coating inside the chamber as a source for alpha particles, has assisted in testing the shutter ability to stop alpha particles. Since the fission fragments are heavier in mass than the alpha particles, after a fission event, the shutter is expected to stop those fragments when it is closed.

The kapton window cavity has been modified to increase the space for the new modifcations inside the chamber. The detector cavity has been increased by increasing the height of the kapton window for about 3 mm; resulting in a larger cavity that has a place to install the shutter in the drift region with a rod controller. In addition, it accommodates an increase in the height of the drift region to become 1.1 cm .(instead of 3.5 mm in the original design).

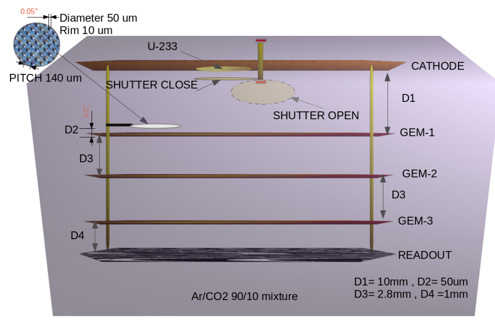

Figure 1.7: Adding modifications to GEM design.

1.4 High Voltage Divider Circuit

A high voltage divider circuit is used to apply negeative potentials on both sides of each GEM preamplifier. To operate the GEM detector, figure xx shows an electric circuit that divides the negative potentials for each GEM preamplifier. Depending on the resistors, the first GEM preamplifier encountered has the highest voltage difference between its sides; on the other hand, the last GEM preamplifier has the least voltage between its sides.

Additionally, the high voltage circuit provides potentials to create transfer electric field between successive GEM preamplfiers. GEM preamplifiers provide three stages of multiplication, after each stage a transfer electric guides the electrons to the next stage of preamplification until the electrons reach to the charge collector. A high voltage divider circuit was designed for these purposes as shown in the figure xx [? ? ?], and table XX shows the measurements of the potential between both sides, the one each GEM side.

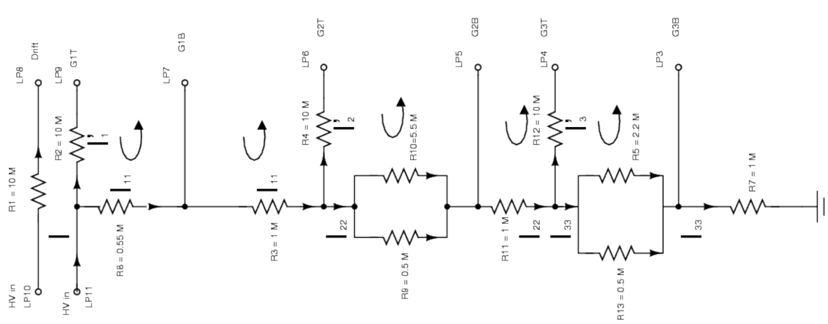

Figure 1.8: Figure shows the HV-divider circuit.

The circuit also provides a trigger signal after passing through a high-pass filter. One of the ways to get the detector signal is by a high pass filter that allows signal from the bottom side of the third GEM premplifier pass though; as the electron stream leaves the

$V_{source} \pm 1$	2550	2600	2650	2700	2750	2800
$V_{G1T} \pm 1$	2579	2630	2680	2731	2781	2832
$V_{G1B} \pm 1$	2259	2303	2348	2393	2373	2482
$\Delta V_1 \pm 1$	304	310	316	322	328	332
$V_{G2T} \pm 1$	1671	1704	1737	1770	1803	1836
$V_{G2B} \pm 1$	1394	1421	1449	1476	1503	1530
$\Delta V_2 \pm 1$	279	285	290	296	302	307
$V_{G3T} \pm 1$	818	834	850	866	882	898
$V_{G3B} \pm 1$	570	581	592	603	614	625
$\Delta V_3 \pm 1$	245	250	255	260	264	269

Table 1.1: HV-potential divider circuit

last GEM preamplifier toward the charge collector, it creates a positive current that passes through the high pass filter. The job of the high pass filter is to block low frequencies and passes only the high frequency pulses that can clearly be observed by a 50 ohm terminated oscilloscope.

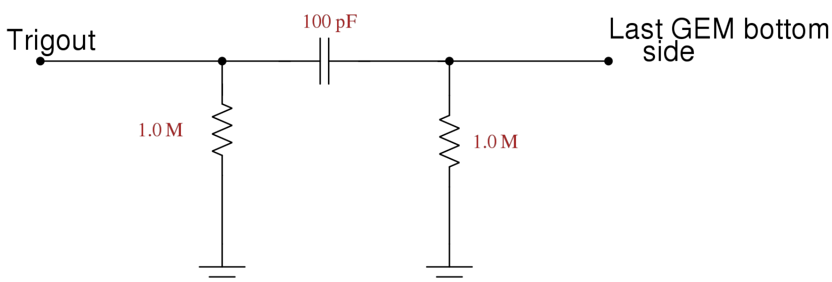

Figure 1.9: Figure shows the HV-divider circuit.

1.5 Detector operation

GEM detector operation is limited to a maximum voltage for the triple GEM preamplifiers. GEM-based detectors may contain one preamplifier or more. Operating a GEM detector mainly depends on the detector structure. The applied voltage on preamplifier's sides determines its multiplication, which is a direct proportion to the potential difference. However, there is a limit for the applied potential difference on each preamplifier to avoid the discharge, which may physically damage the GEM. In order to avoid the discharge effect, the detector should have an appropriate number of GEM preamplifiers to avoid increasing the potential difference to a discharge limit.

GEM preamplifier's characteristics change to adopt to any application. GEM preamplifiers production has been increased lately due to their various applications. Each application demands a specific area, shape, and number of GEM preamplifiers. In our case, the detector's structure is based on triple standard GEM preamplifiers, which allows the maximum potential difference to reach to 350 V on each of them, as demonstrated in Figure yy.

A four-channel digital power supply ,CAEN N470, empowers the high voltage divider circuit. CAEN N740 power supply provides the high voltage circuit with a negative potential; as result, the potential difference on the first GEM preamplifier does not exceed 350 V. Then the voltage gradually decreases to be the least on the third GEM preamplifier to reach 265V. Two HV-channels are used, one provides a voltage up to 2.8 kV for the GEM preamplfiers, and the other controls the voltage on the cathode. When the cathode voltage is 3.5 kV and 2.8 kV on the preamplifiers, it creates a drift electric field of 700V/cm in the drift region.

Furthermore, the power supply is connected to a discharge protection circuit to avoid any discharge effect. CAEN N470 has a signal Lemo 00 input to activate a 'kill' option, it automatically turns off the voltage. The 'kill' input is connected to the detector charge collector output, thus if a discharge happens and its signal is wider than 15 us, the 'kill' option state turns true to trip all the power supply channels.

The main purpose of using GEM Detector either for counting,imaging, or both simultaneously. Previously stated in section xx, GEM detector's High voltage circuit is equipped by a high-pass filter that is connected to the bottom of the last GEM preamplifier, which receives a positive current while the electron stream proceeds toward a wire-segmented charge collector. When the detector is used for counting, the electronics setup receives either a positive pulse from the high-pass filter, or a negative pulse from the charge collector; both type of pulses will help in counting the events that are created by the incident particles by the DAQ system, which is performed by Nimbin traditional electronics' modules. On the other hand, operating the detector for imaging, or measuring the electron intensity on each pixel on the wire-segmented charge collector requires a sophisticated VME based electronics; for instance, QDC(CAEN V792), and CAEN V1495 (multipurpose programmable module). They are usually supported by (VFAT) circuit boards, gum sticks, and an I2C controller to manage the signal transfer from each pixel on the wire segmented charge collector to CPU. [21] In this research, the scope is to operate in a counting mode by using the signal from the trigger connection. By high pass filter's output, the detector's positive pulse ejected into a post- amplifier to evaluate its charge by the QDC through a DAQ system.

1.5.1 Data Acquisition (DAQ) Circuit

DAQ (data acquisition) circuit is used to measure a charge spectrum for the detector output. An electronic circuit contains a number of Nimbin modules used to set the DAQ to measure the charge by CAEN V792 QDC (VME module) as shown in figure zz. The circuit will provide the CPU unit with digital pulses through the VME bus. The CPU unit has a CODA 2.6.1 software package which is responsible for collecting the data in a file. After that, a script uses the file as an input to generate an n-tuple root file, and use a root package to view and analyze the data for the collected charge spectrum.

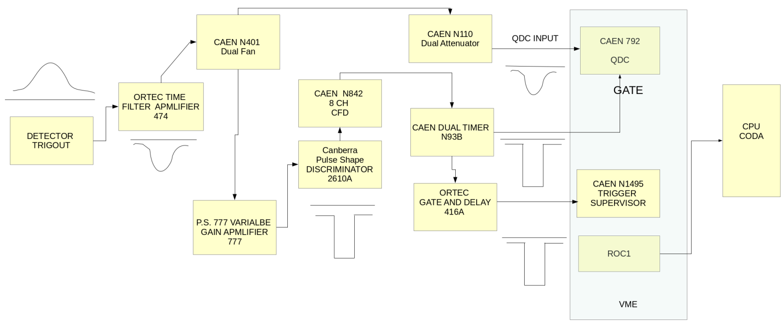

Figure 1.10: Figure shows the HV-divider circuit.

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