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Development of a large area gas photomultiplier with GEM/μPIC

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We are developing a new photon detector with gas amplification devices. We combined the CsI photocathode with GEM/uPIC for the first prototype which is aimed at the application to the large liquid Xe detectors. We assembled 10cm×10cm μPIC+GEMs and a 5cmϕ MgF_2 window with a transmissive CsI photocathode into a prototype detector.
Using Ar+10%C_2H_6 gas, we achieved the gas gain of 10^5 which is enough to detect single photoelectron. We, then, irradiate UV photons with the Excimer Xe lamp to the prototype detector and we successfully detected the UV photons.

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1. Introduction

In the last two decades, many gaseous photomultipliers with CsI photocathodes operated in both flushed gas mode and sealed gas mode have been developed and tested[1, 2, 3, 4, 5]. Moreover, recently, large area micro pattern gaseous detectors with avalanche multiplication structures, such as Micromegas[6], GEM[7], and μPIC[8] have been developed and successfully operated. These devices with photocathodes can realize a low cost large area photon detector with position sensitivity and can be applied to large astroparticle detectors. In particular, the quantum efficiency of the CsI photocathode matches the Liquid Xe scintillator, thus dark matter search experiments are the first targets of this photon detector[9, 10, 11].

In this work, for the first step, we investigated the feasibility of manufacturing large size gaseous photon detectors with CsI photocathode and evaluated their performances.

2. The prototype detector

The configuration of the prototype detector is shown schematically in Fig. 1. We use 2 GEMs and a μPIC for the charge amplification, which allows to suppress the avalanche-induced photon and ion feedback and provide the high gain operation and the long lifetime of the detector.

The GEM is SMASH® LCP SPECIAL manufactured by SciEnergy Co., Ltd. The size is 10cm×10cm with 70μmϕ holes of 140μm pitch[12], and the insulator is 100μm thick Liquid Crystal Polymer. The μPIC is the standard type of 10cm×10cm with 256 anode strips and 256 cathode strips developed by Kyoto University[8]. Although μPIC has the very fine position sensitivity, for this time, all the cathode strips and anode strips were summed to reduce readout circuit.

The size of the MgF_2 window is 54mmϕ and the thickness is 5mm. The CsI photocathode is evaporated to the window by Hamamatsu Photonics and the effective area is 34mmϕ. In order to apply high voltage (-HV) to the photocathode, at the edge of the MgF_2 window, an Al electrode is also evaporated. The -HV is supplied to the electrode via contact Cu ring. Between the photocatode and the GEM1, we place a guard ring in order to make a uniform electric field and to drift photoelectrons to the GEM1.

These devices are put in a stainless steal chamber with a gas/vacuum port, therefore, when the gas spoils, we can replace the gas and we can also exchange the other components. 1 atm of Ar+10%C_2H_6 mixture gas was loaded to the chamber during this measurement.

All the components given above are assembled in a nitrogen-sealed glove box to avoid the deliquencence of the CsI photocathode.

3. Gas gain measurement

In the beginning, we examined the gas gain of the detector. For this measurement, instead of the MgF_2 window in Fig. 1, we sealed the chamber with Mylar® tape of 25μm thickness, then, we irradiated 5.9keV X-ray of ^{55}Fe from the Mylar® window. The charge outputs from the GEM2 and μPIC were amplified by charge amplifiers (Clear Pulse 581 for GEM, Clear Pulse 515-1 for μPIC) and the signals were monitored by a digital oscilloscope (Tektronix, DPO4032). Thus, the gas gain can be calculated from the pulse height of the signal of the 5.9keV X-ray.

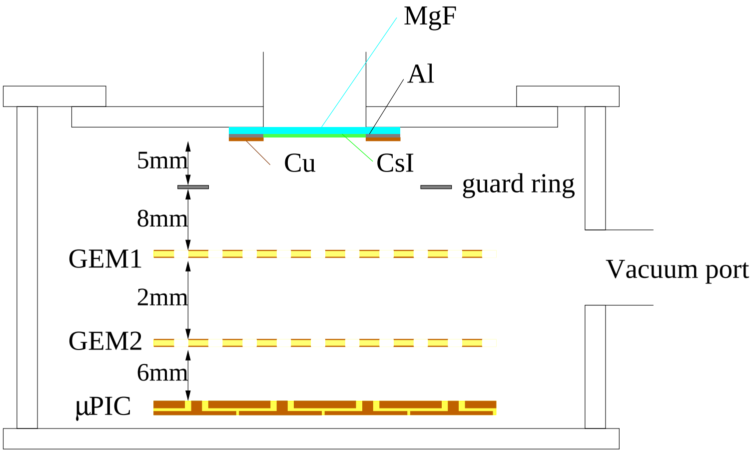

Figure 1: Schematic drawing of the prototype detector. The size of GEMs and µPIC is 10cm×10cm, while the diameter of the window is 54mm and the diameter of the effective area of the CsI photocathode is 30mm.

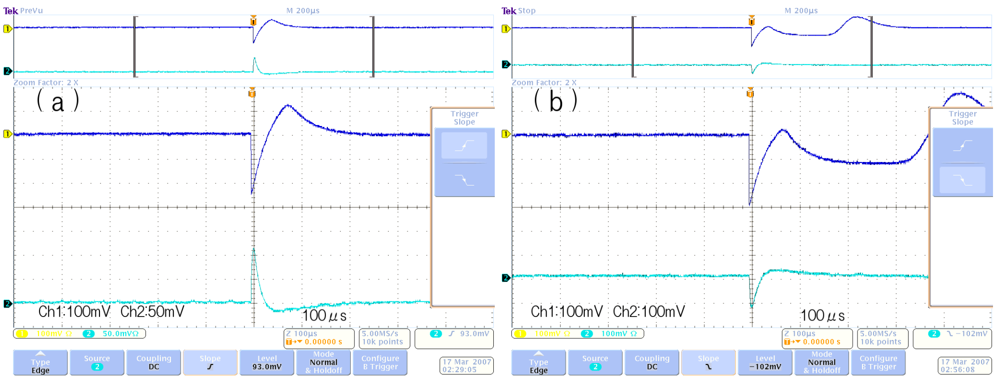

Figure 2: Typical signals. (a) µPIC=0V, (b) µPIC=170V. Ch1(blue): output of the GEM2. Ch2(cyan): output of the sum of the cathode strips of the µPIC. The voltage of the GEMs were 400V.

At first, we did not applied any HV to the µPIC. Fig.2 shows the typical signals when we applied 0.3kV/cm at drift region and between GEM1 and GEM2. The applied voltage to both GEMs was 400V.

Next, we turned on the HV to the µPIC. As shown in Fig.2, when we applied +170V to the anode of µPIC, the signal polarity turned over and the undershoot of the GEM signal became large due to the ion feedback flow. This result indicate that the operation threshold of the voltage of µPIC in Ar+10%C_2H_6 gas is +170V, and the ion feedback flow is intercepted by the GEM2. However, the obtained gas gain without µPIC was sufficient enough. Consequently, from then on, we did not apply HV to µPIC for this measurement although it is effective to achieve the higher gas gain.

The obtained gain curves as a function of the applied voltage to both GEMs are shown in Fig. 3. As the outputs of the amplifiers were saturated (because CP581 and CP515-1 are for semiconductor detectors.), the results over 435V are not plotted. While we successfully apply 470V to GEMs without any discharges; this shows we have achieved the stable amplification with

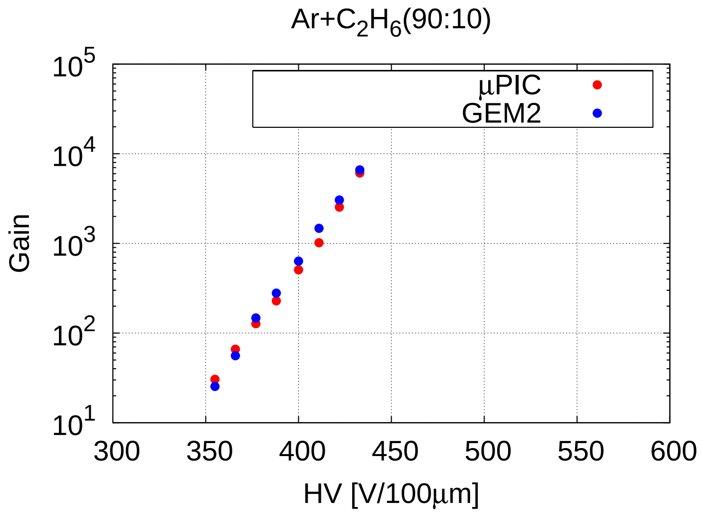

Figure 3: Obtained gas gain. The results from both signals of µPIC cathode and GEM2 are plotted.

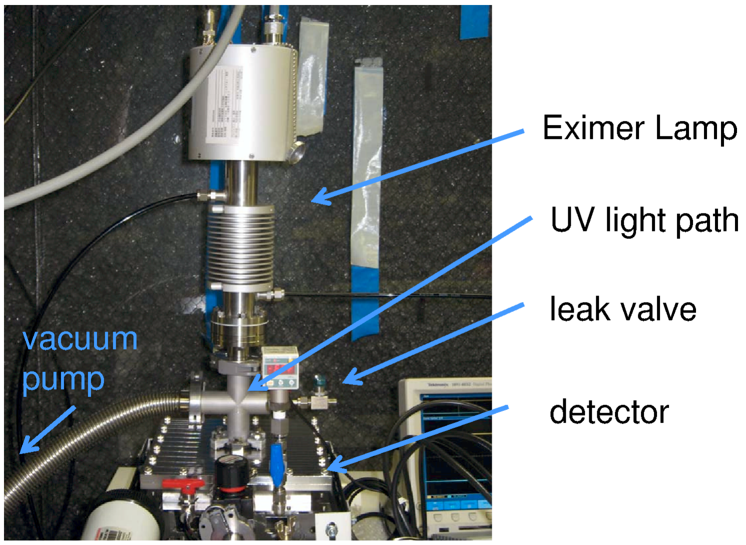

Figure 4: The setup for the UV light test

the gain of 10^5.

4. Light detection

The picture of the setup for the UV light test is shown in Fig.4. The UV light source is a Xe_{2*} Eximer Lamp (Usio H0016) which emits λ_{mean} =172nm UV lights, therefore the quantum efficiency of the CsI photocathode is well matched for this light source.

The MgF_2 window of the photon detector and the UV light source is connected with typical DN 25 ISO-KF (NW25) coupling components. The cross piece is used as the light path which also

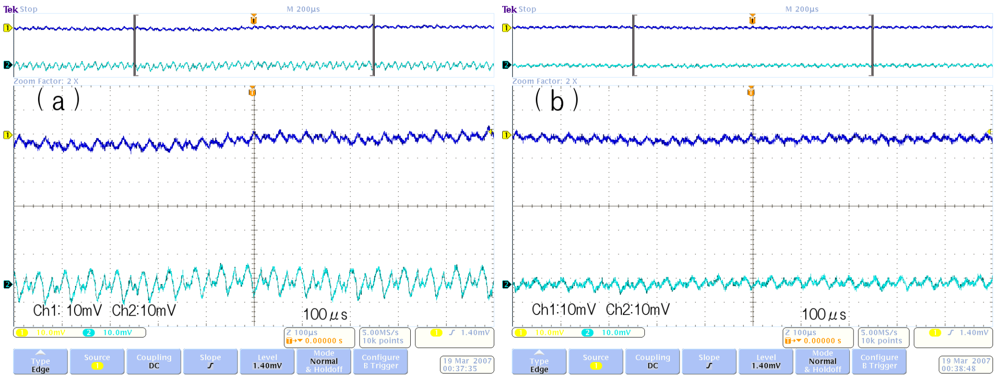

Figure 5: UV light signals (a)when the path was vacuumed, (b) when the path was filled with air. Ch1(blue): output of the GEM2. Ch2(cyan): output of the sum of the cathode strips of the μPIC. The voltage of the GEMs were 400V.

has a vacuum port and a air leak valve. The light intensity is 50mW from the 35.5mmϕ window of the light source, and it is too strong for this test. As a consequence, we introduced 1mmϕ collimator as a KF center ring, and removed the charge amplifiers from the readout circuit. Both GEM1 and GEM2 were operated at 400V which corresponded to the gas gain of 600 in total.The charge outputs of GEM2 and μPIC are fed directly to the oscilloscope through 100pF capacitors.

After vacuuming the light path by 1Pa, the Eximer lamp was on, then the 18kHz oscillation signal was observed as shown in Fig.5 (a). Since the frequency of the AC power supply to the Eximer lamp is 18kHz, and at this rate, Xe gas is excited and the UV photons are emitted, Fig.5 (a) shows clearly that we successfully detected the UV light from the Eximer lamp.

In addition, when we opened the leak valve, the amplitude of the signal became about 1/4 as shown in Fig.5 (b). This shows that the UV light was attenuated in the air and it is correctly monitored by this photon detector.

Incidentally, after this test, the detector was disassembled and the photocatode was preserved in a desiccator, then two days later, it was assembled again and another light test was conducted. The amplitude of the output signal was same as that of before, therefore, reusability of this detector is confirmed for the first step. The reusability is the main feature of this detector in contrast with the usual tube type detectors.

5. Conclusion

A UV photon detector based a CsI photocathode combined with large area GEMs and a μPIC has been reported. The obtained results demonstrated not only the UV detection but the possibility of the detection of 1 photoelectron with the gain of 10^5 with the suppression of ion feedback flow.

Clearly, many additional tests are required with regard to the uniformity, the long time stability, the detection efficiency, the operation in low temperature, and so on. For all that, this is a milestone in the realization of 10cm size gas photomultiplies. We are now developing the photon detector with a 10cm×10cm photocathode for the next step.

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