Development of a Novel Position-Sensitive Radiation Detector Using a Gaseous Photomultiplier and a Vacuum Ultraviolet Scintillator

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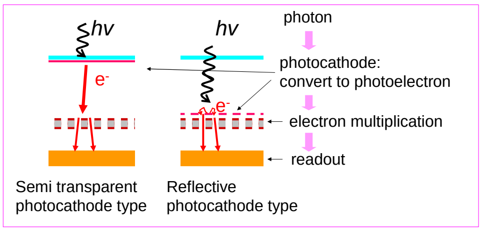
1. Introduction

➢Photomultiplier Tube (PMT) vs. Gaseous Photomultiplier (GPM)

	PMT	GPM
flat-and-large effective area	difficult to construct	easy to construct (≥1,000cm²)
use in magnetic field	difficult	easy
position resolution	≥ a few mm	~ sub mm
time resolution	good	bad

•GPMs have been applied to Ring Imaging Cherenkov counters (RICHs) [1].
•GPMs can operate without vacuum and have good points (upper table) therefore they are better suited to large-scale high energy experiments such as dark matter / neutrino searches, and medical imaging.

➢Operating Principle of GPM

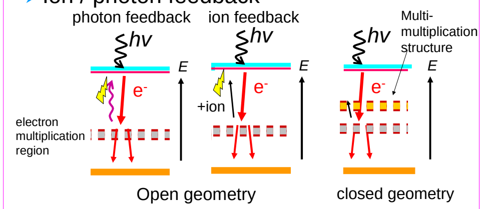


Reflective type has a higher QE than semi transparent, however reflective type is more difficult to handle than semi transparent

➢Photocathode [2]
- Bialkali [3]
  - •Visible light sensitivity
  - •Extreme chemical reaction
  - •Ion and photon feedback is more serious than CsI [4]
- CsI
  - •UV sensitivity
  - •Easy to handle

⇨ We have developed GPMs with a Semi transparent and Reflective CsI photocathode

➢Ion / photon feedback



•Photocathode degradation by photon or ion from multiplication region
•Disturbance of electric field at drift region due to the Ion feedback

➜ limit of the gas gain
Open geometry is worse than closed one

Some groups developed RICH detectors with open geometry and a Multi Wire Proportional Chamber (MWPC) [1]

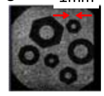
➜ limit of the gas gain and sensitivity due to the feedback effect [5]

➢GPMs with CsI photocathode and MPGD (Micro Pattern Gas Detector) [6]

MPGD: GEM(gas electron multiplier) [7, 8],
MICROMEGAS [9, 3]
μ-PIC(micro pixel chamber)[10, 11] and so on.

•Reduce the Feedback probrem [12]
•Better position resolution than MWPC

Imaging [13]



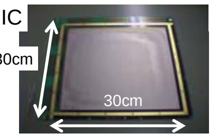
Shadow image with UV lamp

Semi transparent Photocathode (CsI) +GEM +CMOS

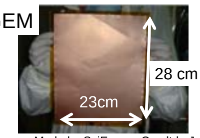
CMOS Effective area:15 mm x 15 mm → Small size Compared to other GPMs

We have already operated the 30 cm size MPGD stably for a Compton camera and an X-ray imaging detector [14]

μ-PIC

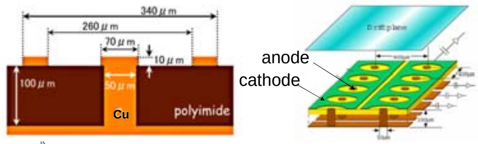


GEM



Made by SciEnergy Co., ltd., Japan

➢μ-PIC:2-D position sensitive gaseous detector



⇨ We used a μ-PIC and GEMs for our GPM

2. VUV scintillator + GPM

Vacuum Ultraviolet (VUV) scintillating crystals + our GPM

⇨ hard X-ray imaging device which compensates for the low detection efficiency of gaseous detectors.

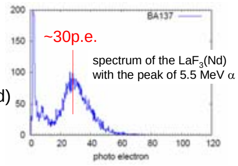
⇨ We used a LaF_3(Nd) scintillator as a VUV light source

➢LaF_3(Nd) [15, 16]
Maximum emission: at 172 nm
Light yield: 410±80 ph / MeV @1.5mol% of Nd
Decay time: 6 nsec
Density : 5.9 g / cc

Photo of LaF_3(Nd)

Decay time is shorter than visible scintillator, and it is possible to develop a high rate counter.

➢LaF_3(Nd) light output
We measured a 15 mm x 15 mm x 15 mm-sized LaF_3(Nd) irradiated with 5.5MeV α particles from a 3 kBq ^{241}Am source using a VUV sensitive PMT (Hamamatsu R8778)



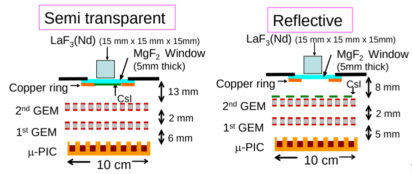
➡ ~30p.e. / 0.33(QE of PMT at 175 nm) = 100 photons

3. Photon counting

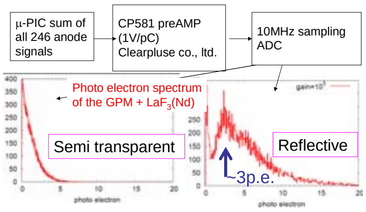
GEMs:10 cm x 10 cm size , 100 μm thick LCP
140 μm pitch, φ 70 μm hole
μ-PIC:10 cm x 10 cm size, 256 x 256 pixels
Gas : Ar (90%) + C_2H_6 (10%), 1atm (sealed)

•Semi transparent type
Gas gain: 2.6 × 10^5
GEMs: 420V/100 μm, μ-PIC: 465V
•Reflective type
Gas gain: 1.0 × 10^5
GEMs: 410V/100 μm, μ -PIC: 465V

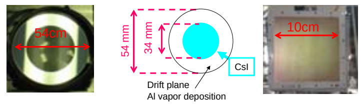
➢Setup
We have developed the semi transparent- and reflective-prototype GPM + LaF_3(Nd).



We counted photons using our detectors irradiated with 5.5MeV α particles from a 3 kBq ^{241}Am source.



➢photocathode

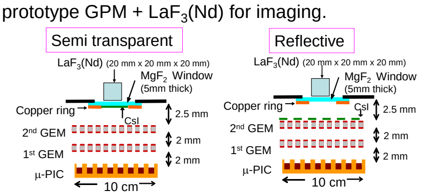


CsI was evaporated and deposited on the MgF_2 window (Semi transparent) and GEM (Reflective type) by Hamamatsu Photonics

➡ Reflective type had higher QE of a few % compared to semi transparent type.

4. Imaging

➢Setup
We have developed semi transparent- and reflective-prototype GPM + LaF_3(Nd) for imaging.



GEMs:10 cm x 10 cm size ,
140 μm pitch, φ 70 μm hole
μ-PIC:10 cm x 10 cm size, 256 x 256 pixels
Gas : Ar (90%) + C_2H_6 (10%), 1atm (sealed)

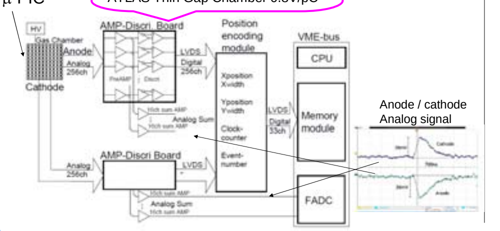
•Semi transparent type
GEMs: 50 μm thickness, PI
Gas gain: 6.7 × 10^5
GEMs: 280 V/50 μm, μ-PIC: 490V

•Reflective type
1st GEM: 100 μm thickness, LCP
2nd GEM: 50 μm thickness, PI
Gas gain: 1.0 × 10^5
GEMs: Δ300V, μ -PIC: 340V

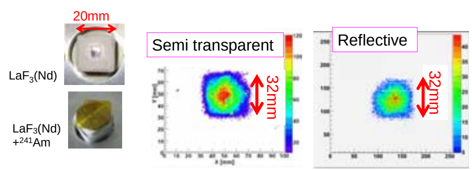
➢Imaging method
We obtained the (x, y) position from signals from Anode / cathode strips

AMP-Discri. Board
Based on a chip for ATLAS Thin Gap Chamber 0.8V/pC

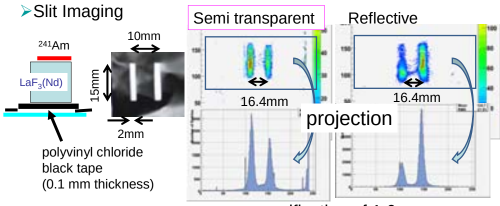
μ-PIC



➢Imaging
Images were obtained with our detectors irradiated with 5.5MeV α particles from a 3 kBq ^{241}Am source.



➢Slit Imaging



magnification of 1.6

5. Summary

•We have developed novel radiation detectors
–We have Gaseous UV detector : semi transparent and reflective CsI photocathode
2 GEMs, μ-PIC (10 cm x 10 cm)
–VUV scintillator : LaF_3(Nd)
•Reflective type had higher QE than semi transparent type
•We obtained images
–With a magnification of 1.6

Future works
•Test of large-area window
•Development of large-area LaF_3(Nd) / new crystals

References

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