Development of a large area VUV sensitive gas PMT with GEM/uPIC

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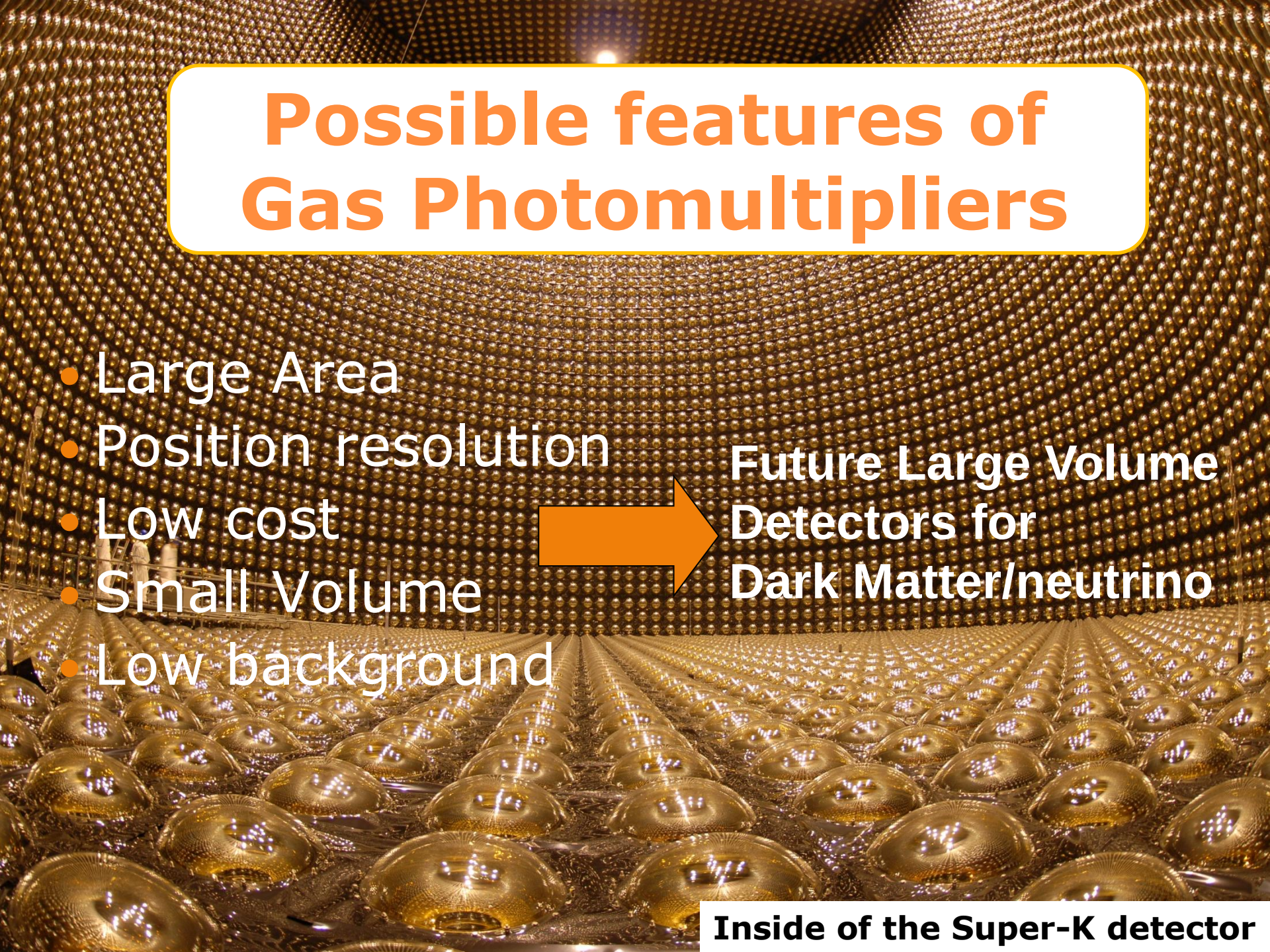
Contents

- Motivation
- VUV light source
- Setups of the detector
- Analog property
  - 1p.e. level pulse mode operation
- Digital property
  - Operation as a novel imaging detector
- Summary

Possible features of Gas Photomultipliers

- Large Area
- Position resolution
- Low cost
- Small Volume
- Low background

Future Large Volume Detectors for Dark Matter/neutrino



Inside of the Super-K detector

Feedback Problems in photon detection

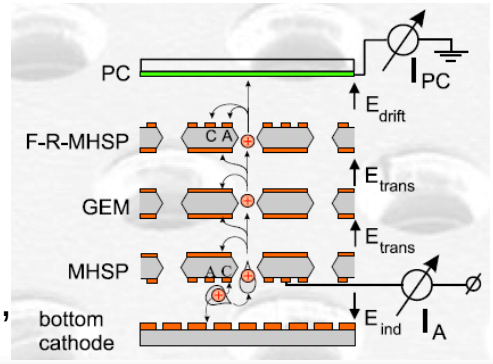
A.Breskin TIPP09@Tsukuba

- Ion and photon feedbacks

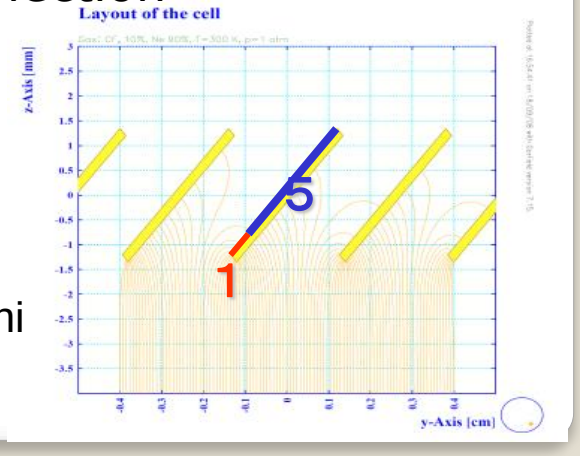
⇩

Limit the stable high gain operation

- Many activities to overcome the feedbacks.
  - Gating
  - Ion defocusing by MHSP/COBRA
  - Blind reflection

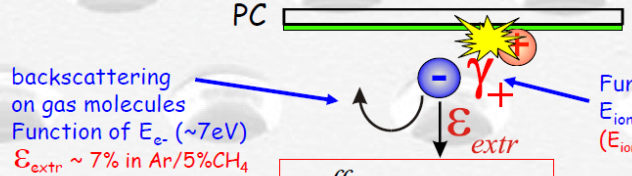


A. Breskin et al.,



T. Sumiyoshi et al.,

IBF depends on effective ion-induced electron emission from PCs



$$\gamma_+^{eff} = \gamma_+ \cdot \varepsilon_{extr}$$

PC	K-Cs-Sb	Na-K-Sb
Ion	CH_4^+	CH_4^+
γ_+^{eff} (experimental)	0.03±0.01	0.02±0.006
γ_+^{eff} (theory)	0.027	0. 029

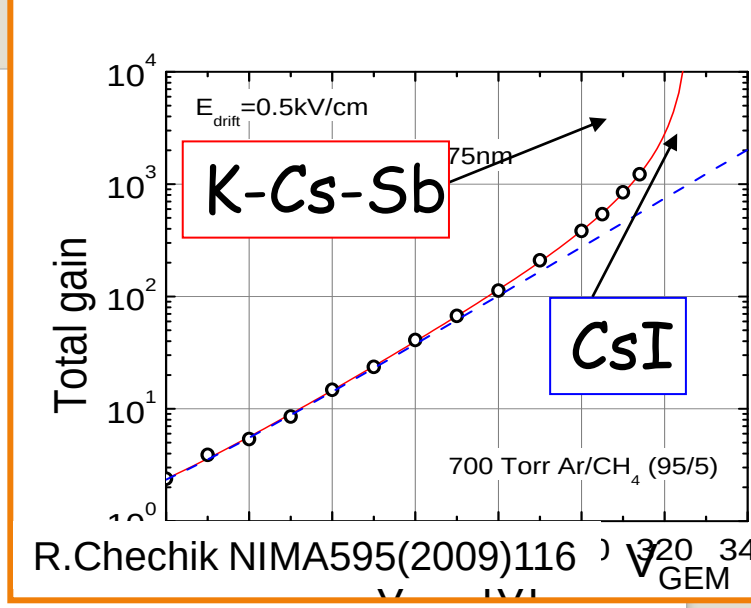
if $\gamma_+^{eff} \cdot IBF \cdot G < 1$ ➔ stable operation of visible sensitive GPM

Ar/CH_4 (95/5), γ^{eff}_+~0.03, Gain ~ 10^5 ➔ IBF < $3.3*10^{-4}$

Lyashenko et al, in preparation

TIPP09 Tsukuba VISIBLE-SENSITIVE GAS-PMs A. Breskin

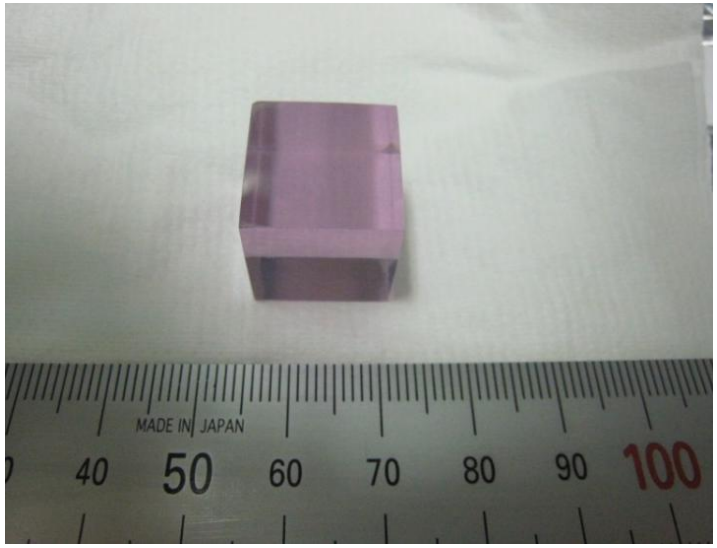
CsI photocathode



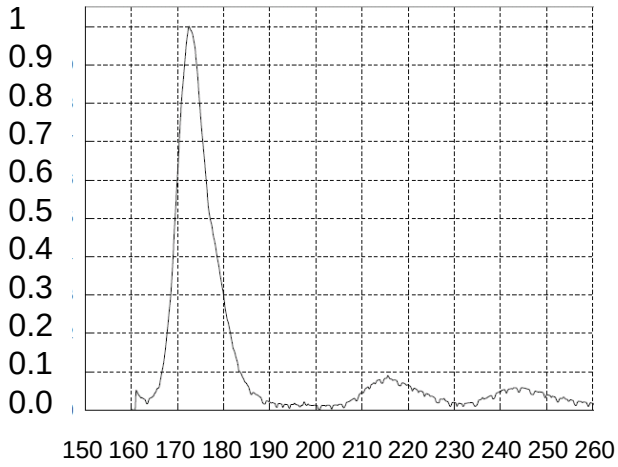
- So far, easier than bialkari.
  - Low Ion/visible photon induced electron emission probability
  - Stable in dry air.
- Many possible applications(our targets)
  - Liq. Xe/Ar scintillators (λ<180nm)
    - Single phase detector (XMASS)
      - Tube type
    - Double phase detector
      - Both charge & photon detection
  - VUV Crystal scintillators
    - Like visible scintillators + PMT
      - PET
      - Color X-ray CT
      - Gamma Camera

UV scintillator

- We are developing Nd^{3+} doped fluoride crystals which emit VUV photons through 5d-4f transition.
- This time, we focused on $LaF_3(Nd)$ as a low intensity light source to test the detector for 1p.e. level.
- λ =172nm, τ = 6ns

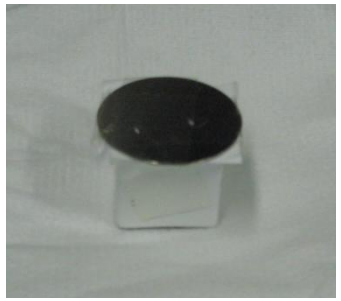


X-ray induced luminescence spectrum

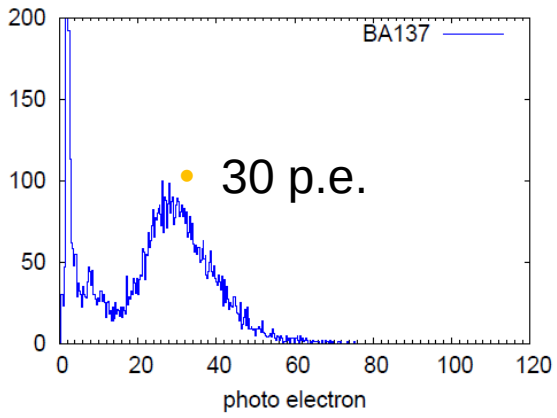


$LaF_3(Nd)$ + α = light source

- 2cm size crystal covered with Teflon + 3kBq α from ^{241}Am



- Light Yields were measured with VUV sensitive PMT R8778 (HAMAMATSU)

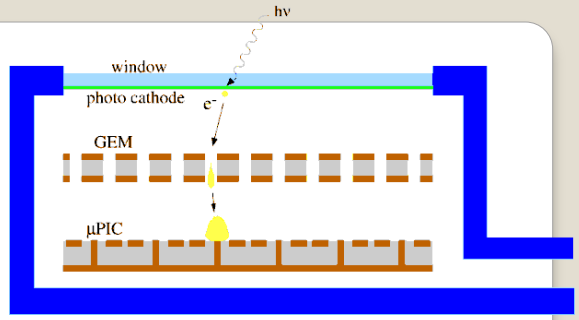


- Developed for XMASS
- Quartz window
- UV enhanced bialkali

Quantum efficiency 30%@172nm

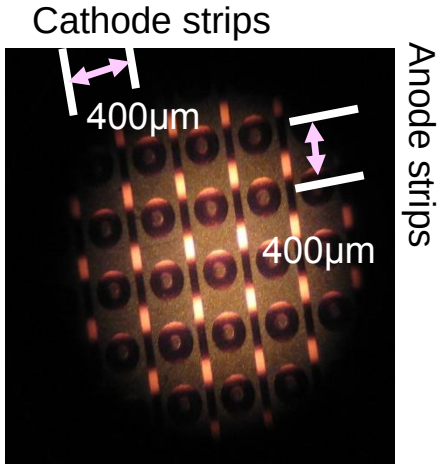
→ **LY 100 photons/5.5MeV α**

μPIC + GEMs



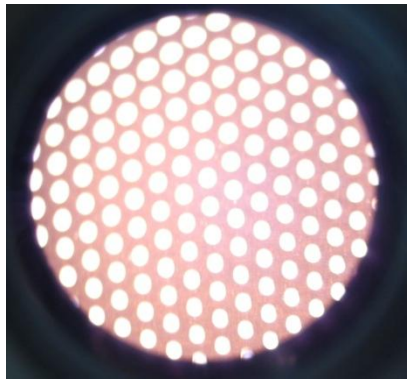
- Many R&D efforts on CsI+MPGDs.
  - Cascade GEM / MHSP/ THGEM w/ rim and so on
    ex) NIM A 595(2008) 116 and its refs
- Our strategy is plasma-etched GEMs+μPIC
  - GEMs for ion blocking
  - μPIC for high gain / position resolution

μPIC See A.Ochi's talk



- **Advanced MSGC**
- **400μm pitch strips**
- **Kyoto/DNP**

GEM/SMASH See S.Uno's talk

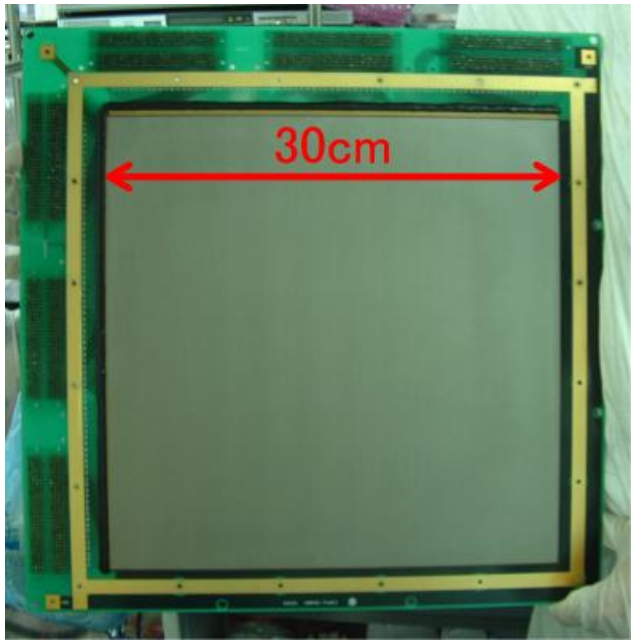


- **Laser etched.**
- **100um LCP / 50um Capton**
- **140um pitch 70umΦ**
- **RIKEN/SciEnergy**

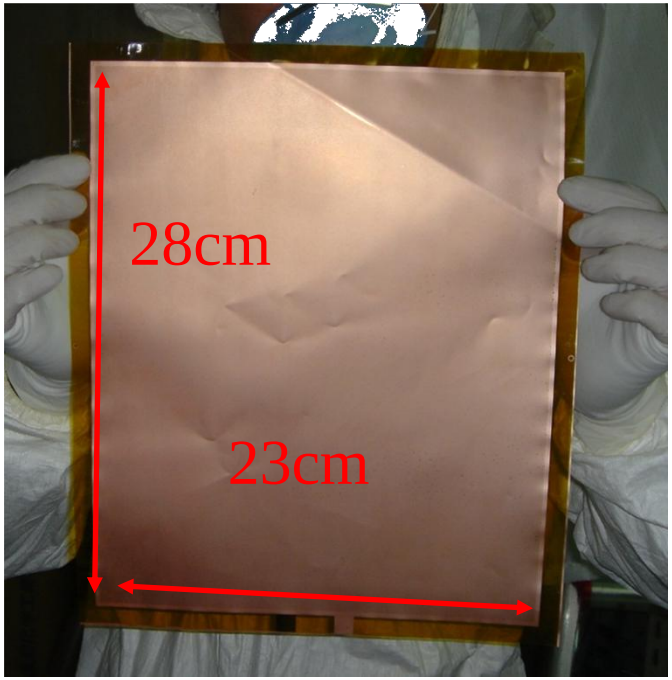
Large Area μPIC & GEM

- Large Area MPGDs are already used in many applications. ex. Medical, Dark Matter search(NEWAGE)

30cmμ-PIC



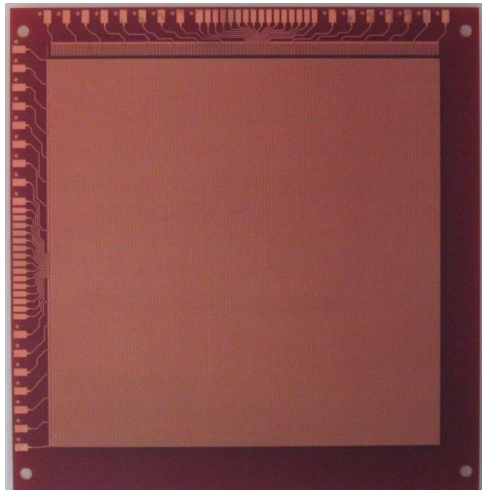
28cmGEM



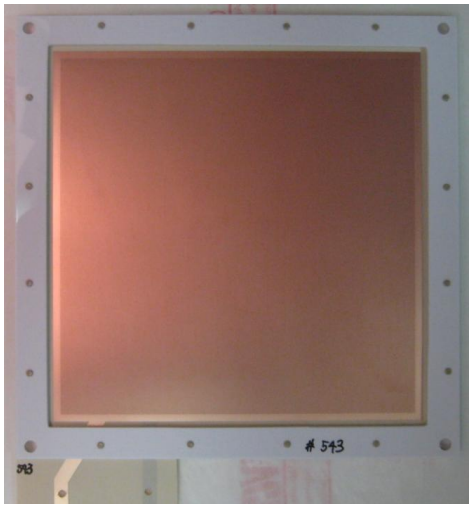
μPIC & GEM

- For the prototype detector, we adopted 10cm size MPGDs.

10cm μ-PIC



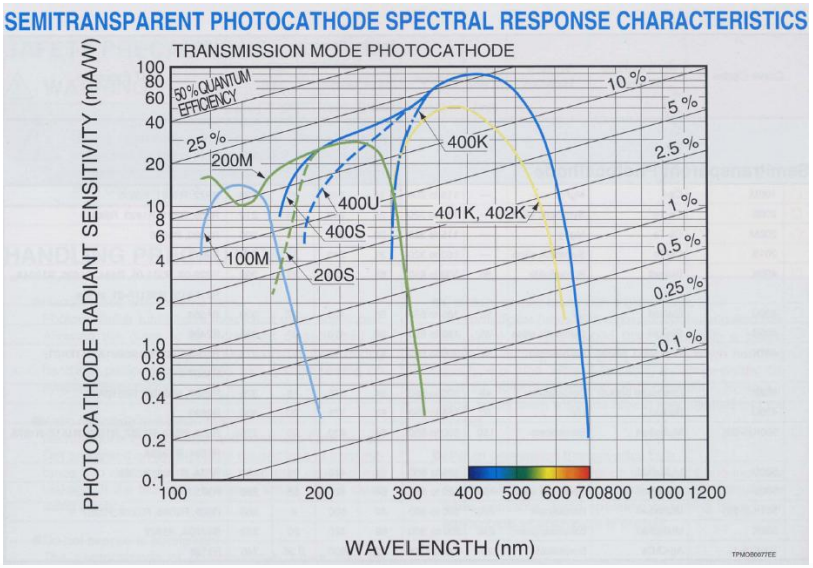
10cm GEM

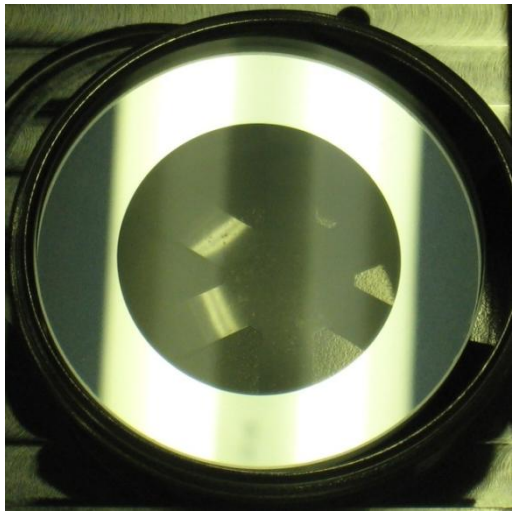


Semitransparent Photocathode

- 5t MgF_2 window
- Al vapor deposition on
  10mm edge.
- 34mmΦ　CsI vapor deposition

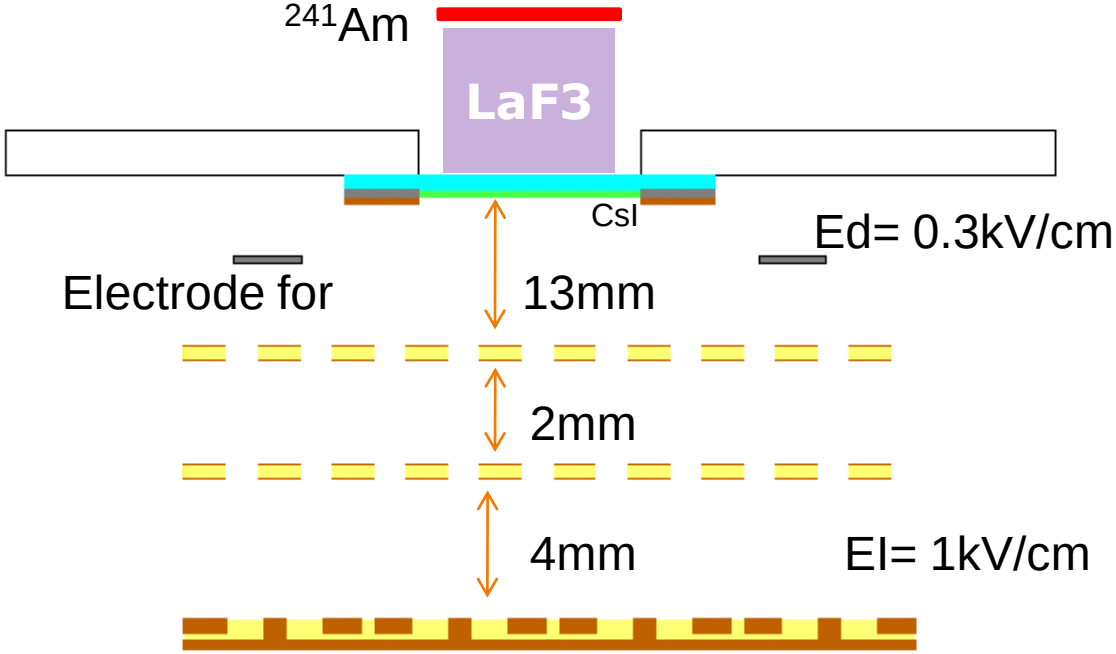
  "The thickness is same as
  that of CsI PMTs" by Hamamatsu

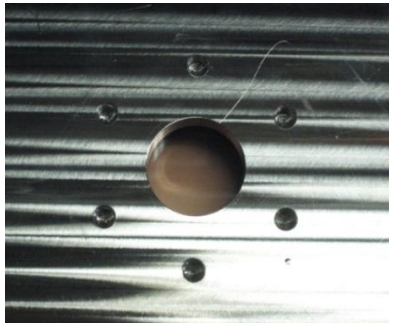




Set up for analog properties

- 2 100μm-GEMs+μPIC with CsI photocathode
- $Ar+C_2H_6$（90：10）1atm

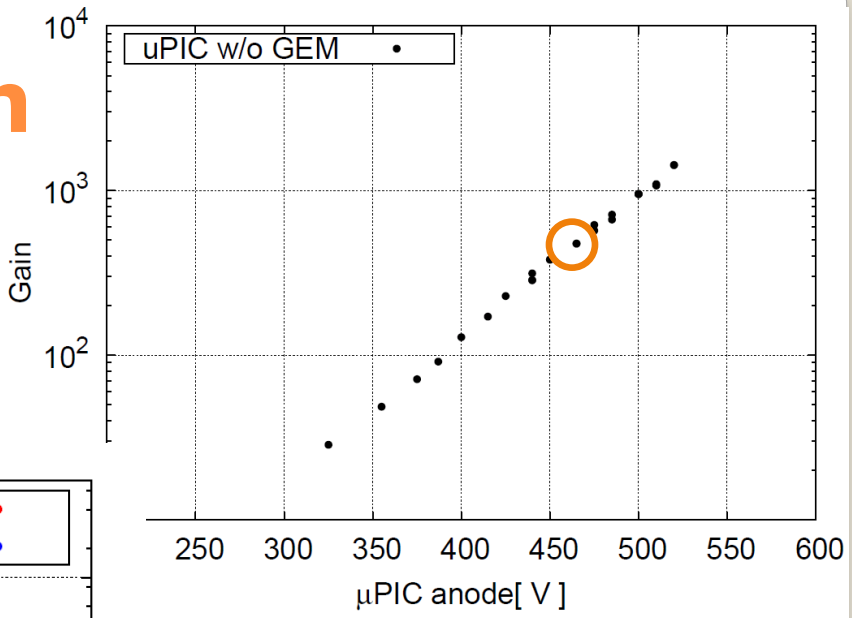


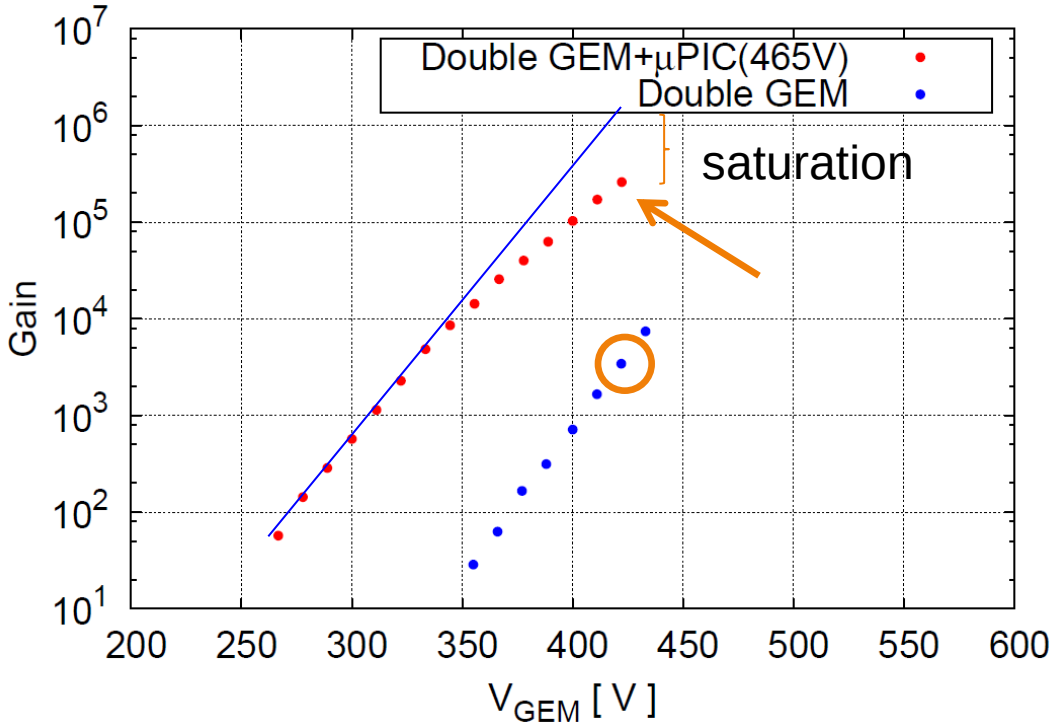


Operation Gas gain

- μPIC 465V
- GEMs 422V

→ 2.6 x 10^5

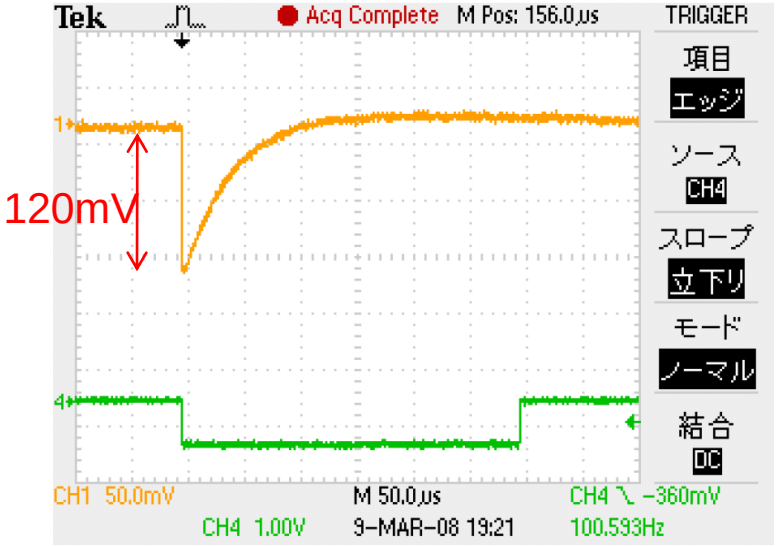




- μPIC only gain
  x GEMs only gain > 10^6
- Induction field (btw GEM & uPIC) should have been tuned.
  EI > 1kV/cm

Photon Signal

- Readout: μPIC 64 strips summed
- Amplified with CP581 preamp (1V/pC) Clearpluse co., ltd.



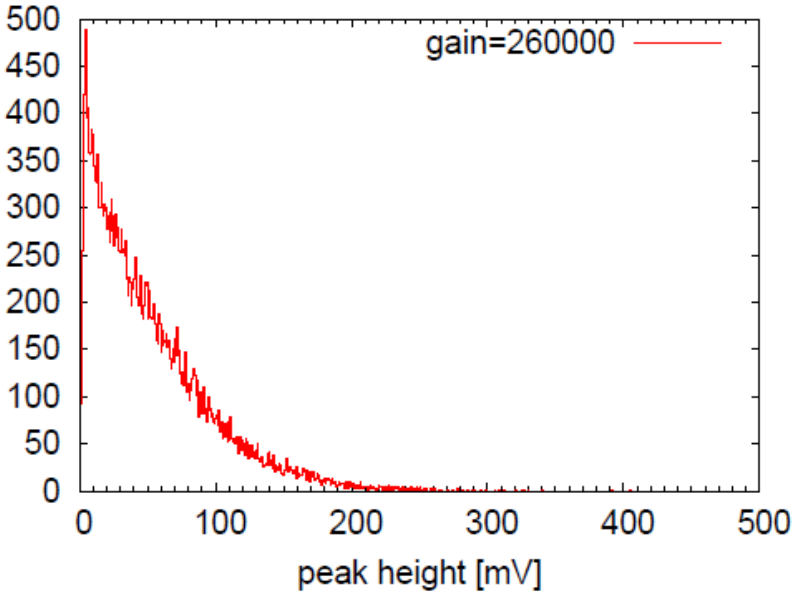
The gas gain 2.6×10^5

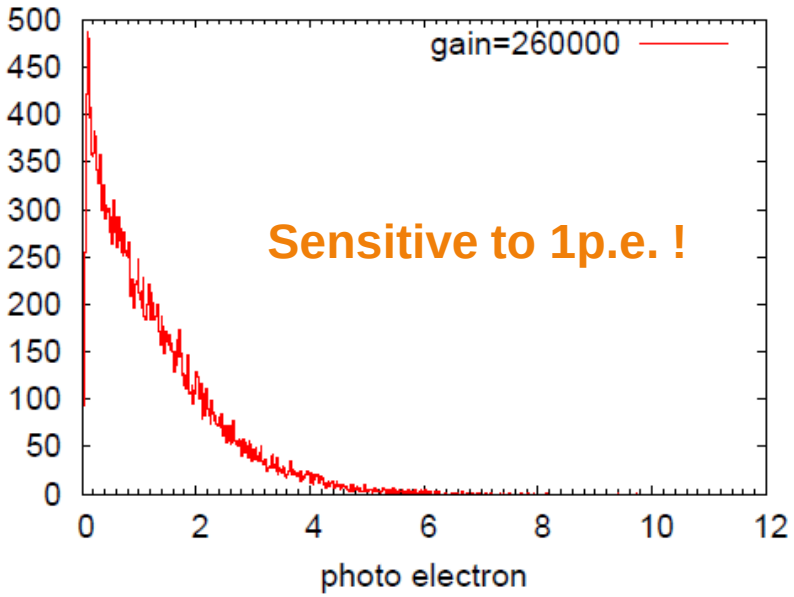
Detected number of photoelectrons

$120\text{mV}/1\text{V} \times 1\text{pC}/(1.602 \times 10^{-19})/\ 2.6 \times 10^5 = 2.9$ p.e.

Spectrum

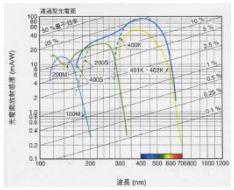
- 10MHz sampling ADC

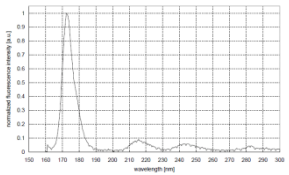




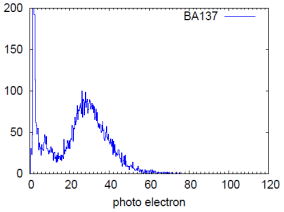
- Source intensity 100 photon → QE ~ 1-2 %

$$= \int \; \times \; d\lambda$$





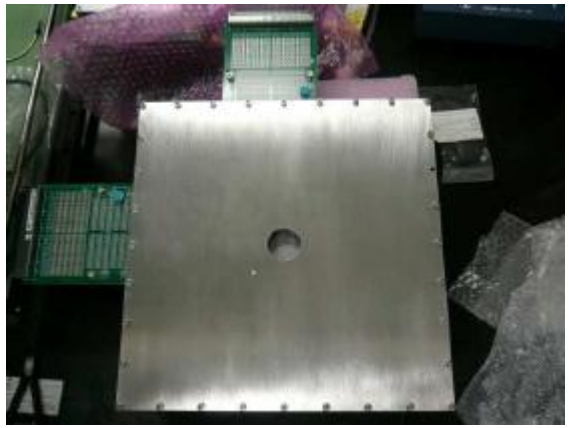
Reference PMT

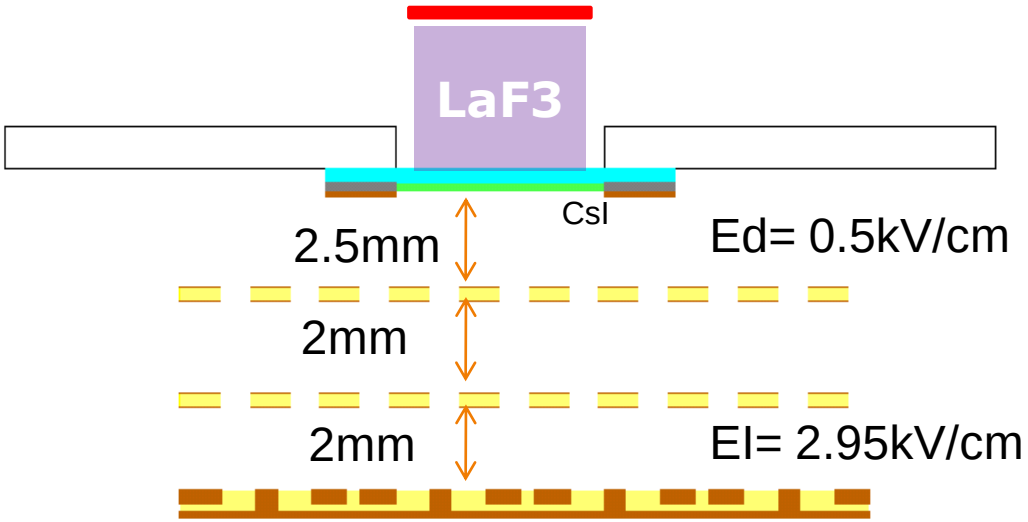


Agrees with QE curve and the luminescence spectrum

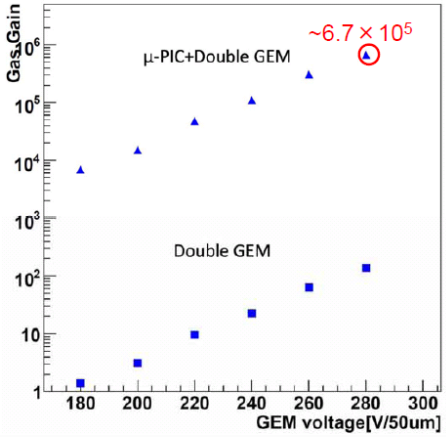
Set up for imaging properties

- 2 50μm-GEMs+μPIC with CsI photocathode
- $Ar+C_2H_6$ (90 : 10) 1atm
- 256ch x 256ch readouts
- 2.6MBq ^{241}Am for high rate test



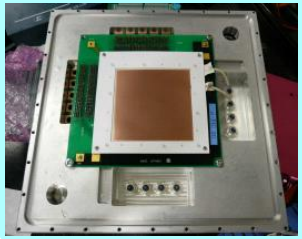


- μPIC 490V
- GEMs 280V → 6.7 x 10^5

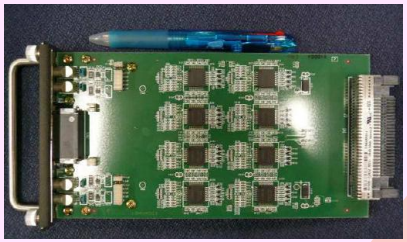


NIMA 513(2003) 94

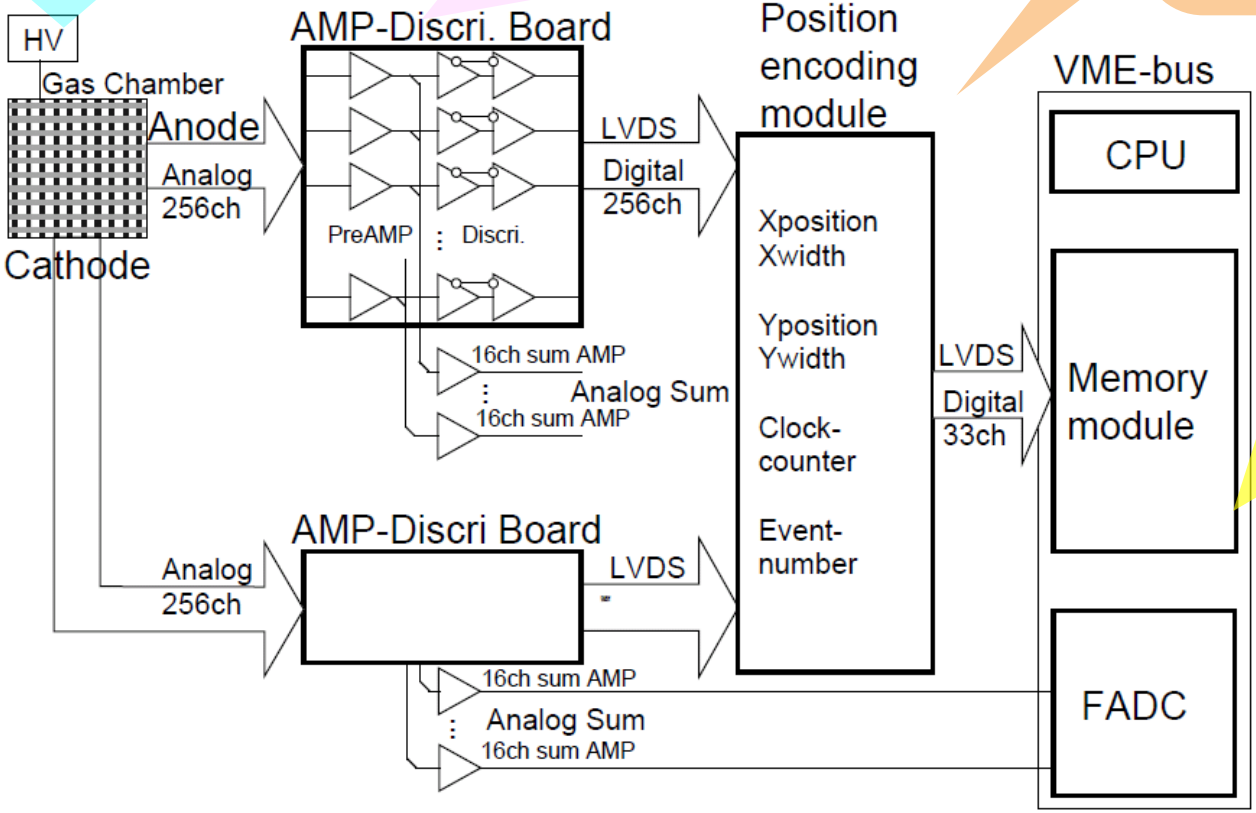
Readout system



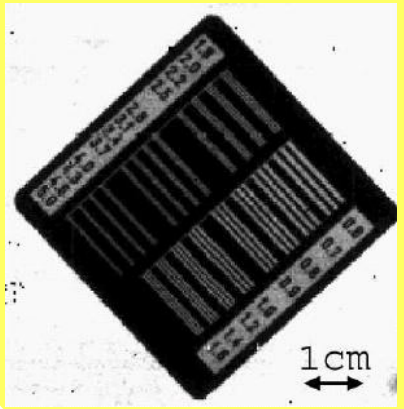
ASD chip
for ATLAS TGC
0.8V/pC



Position Encoder
FPGA x 3
100MHz clock



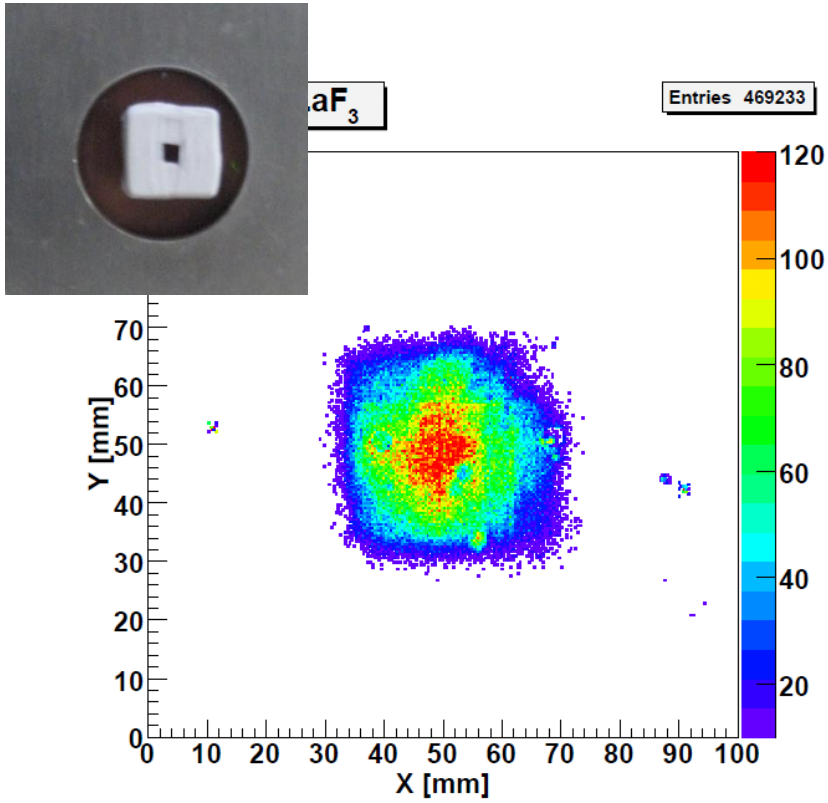
Obtained image



Crystal Shape Reconstruction

- 18x21x20mm^3 LaF_3(Nd) + 2.6MBq ^{241}Am
- High rate capability was confirmed.

Parallel composition



Diagonal composition

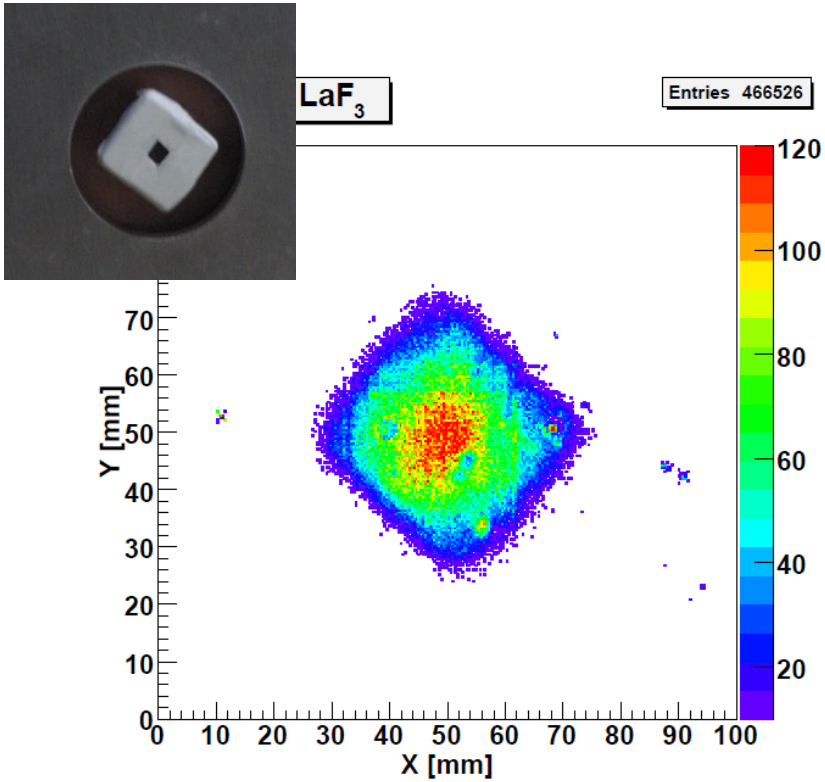
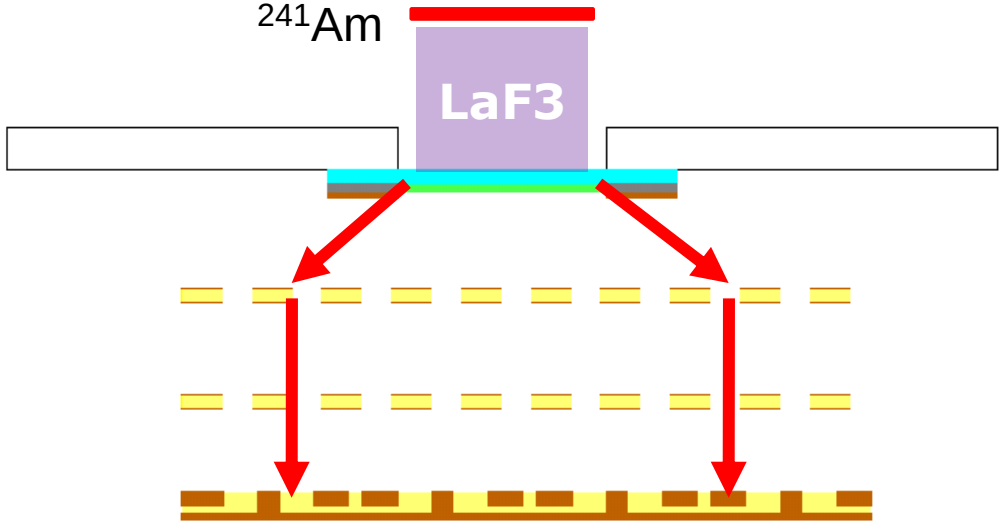
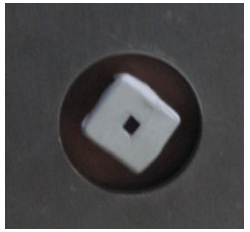


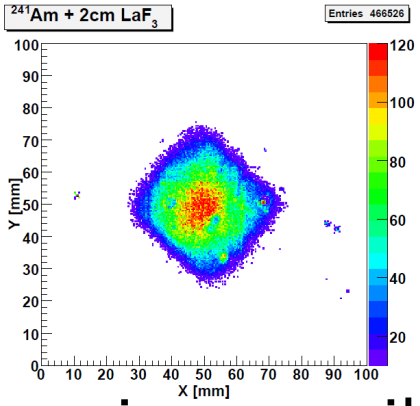
Image Expansion by Electric Fields

- Lens Effect between the PC and the 1st GEM





X 1.6 expansion

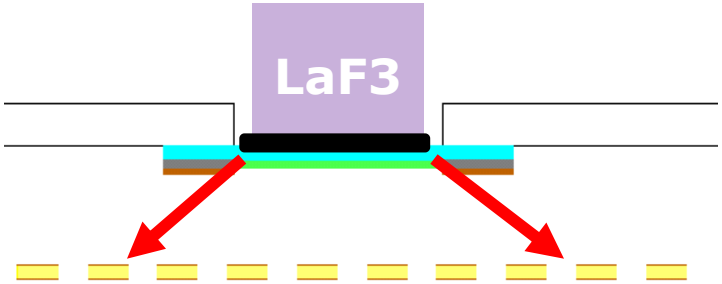


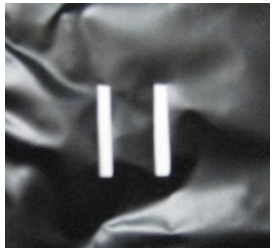
- Large area MPGDs make the expansion possible and this effect may enhance the position resolution of Gas PMTs against the diffusion.

Evaluation of the magnification

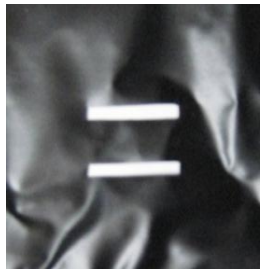
- 0.1t PVC sheets inserted

10mm distance Slits
2mm x 15mm



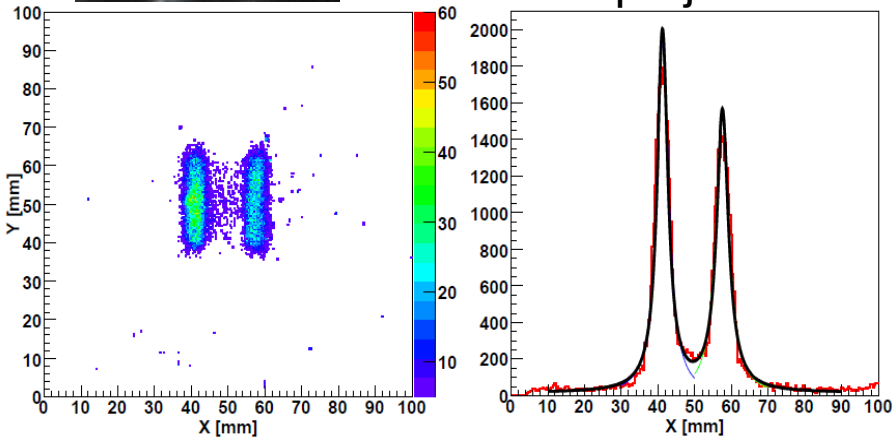


Vertical composition

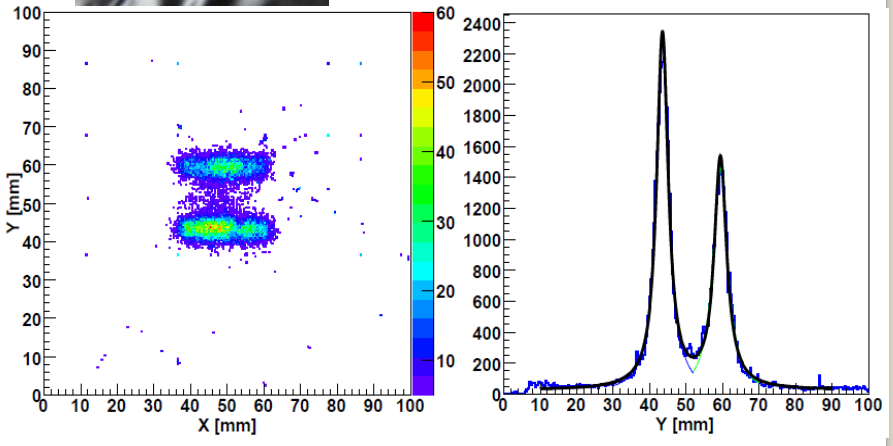


horizontal composition

X projection



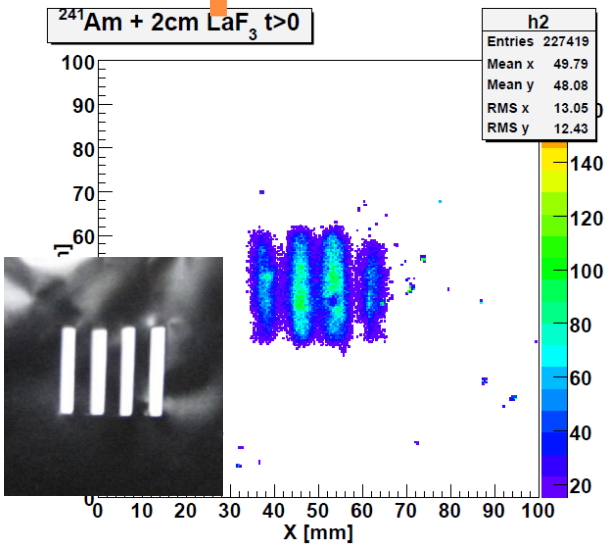
Y projection

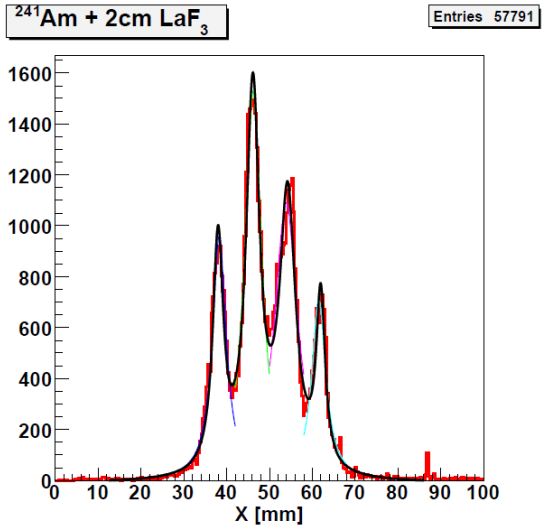


→ Uniformly x1.6 expanded

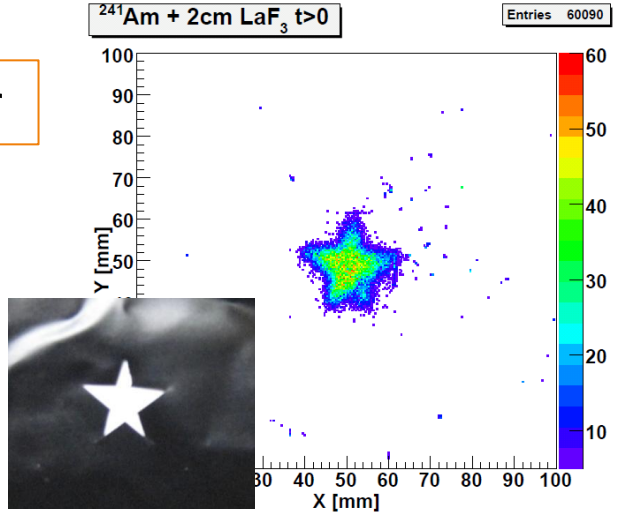
More Examples

5mm distance Slits
2mm x 15mm

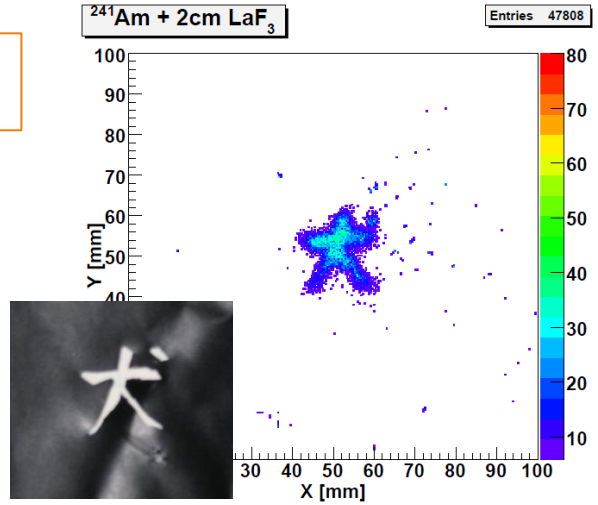




Star



犬

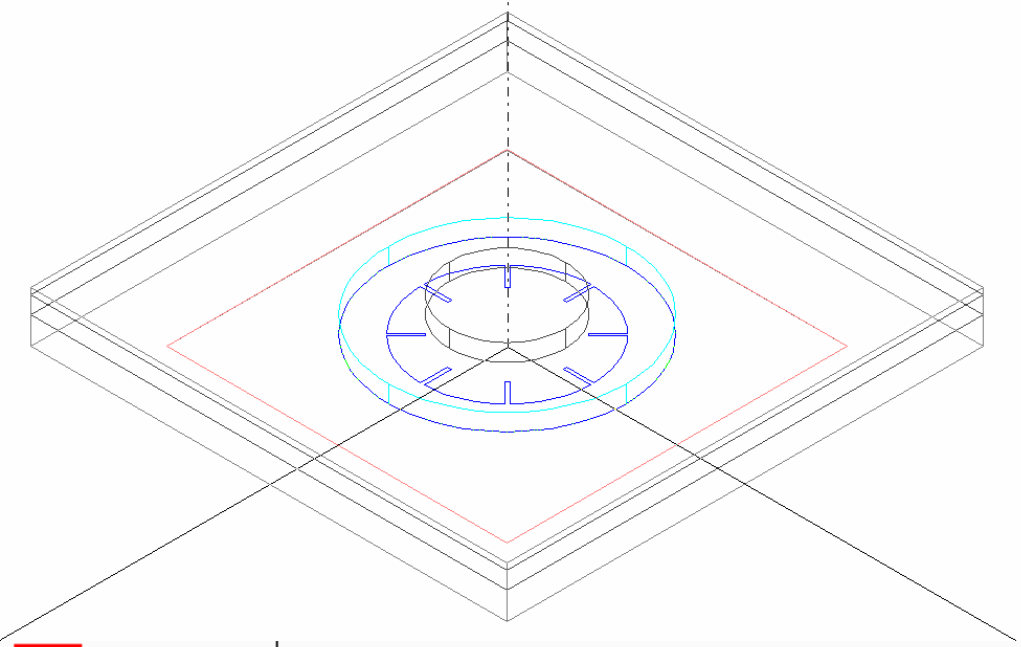


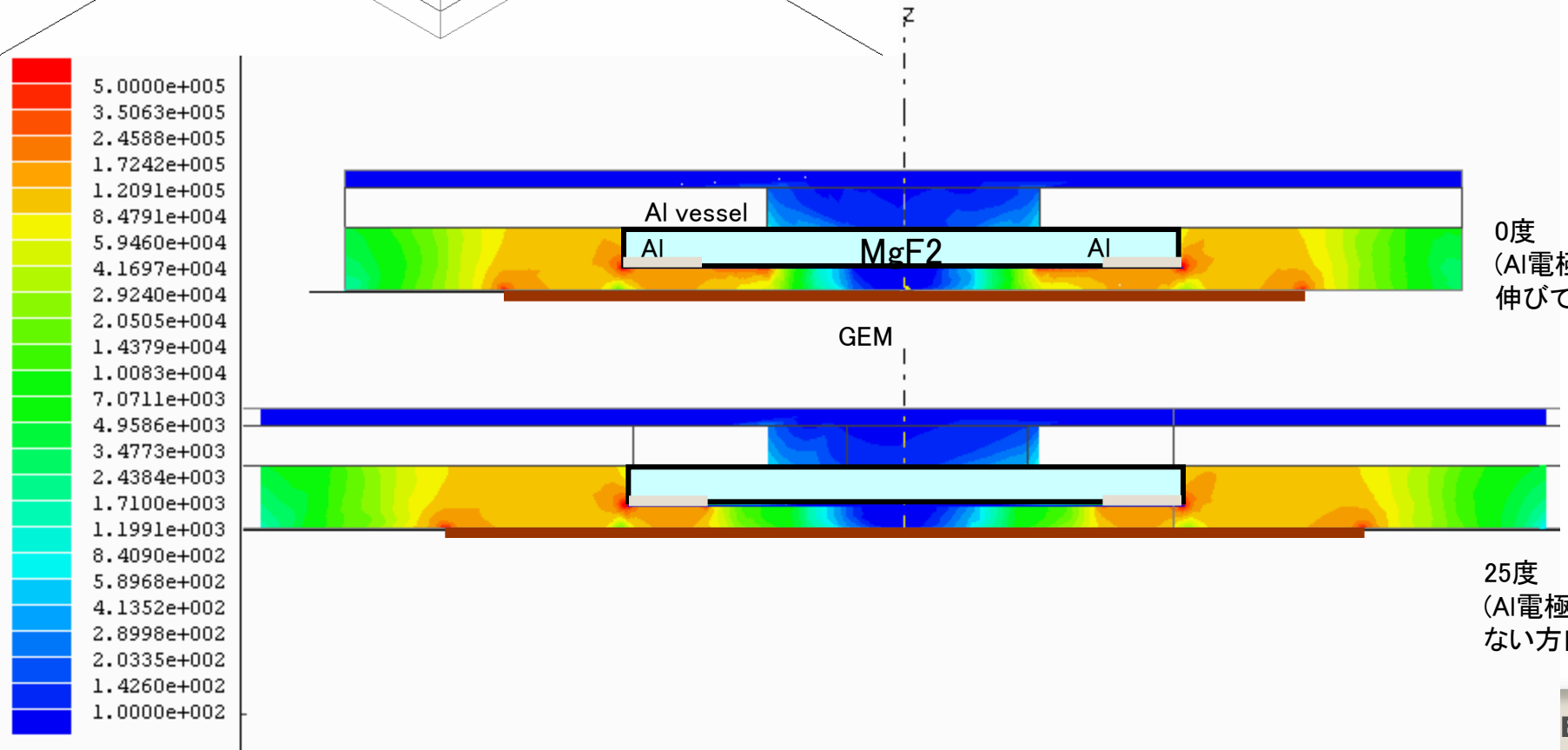
Summary

- A new VUV gas PMT with GEM/μPIC is being developed.
- Although the QE is still limited, 1 p.e. level signal is clearly detected.
- We also are developing VUV scintillators for new radiation imaging sensors which compensate the low detection efficiency of the gas detectors.
- With LaF_3(Nd), the imaging capability of the gas PMT was tested. It might have sub 1mm position resolution.
- Electric lens effect (expansion) was demonstrated thanks to the large area MPGDs.

Electric Fields

Geometry
Vessel(GND)
MgF2 Window
CsI Photocathode
Al electrode 1um -1300V)
1st GEM -910V)





0度
（Al電極の
伸びてる方向）

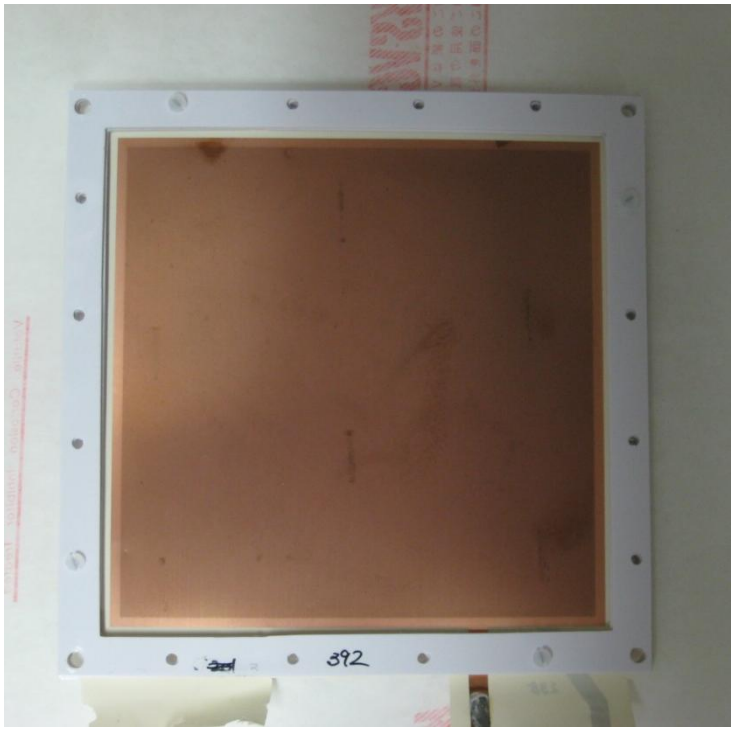
25度
（Al電極の
ない方向）

ECE

金メッキGEM

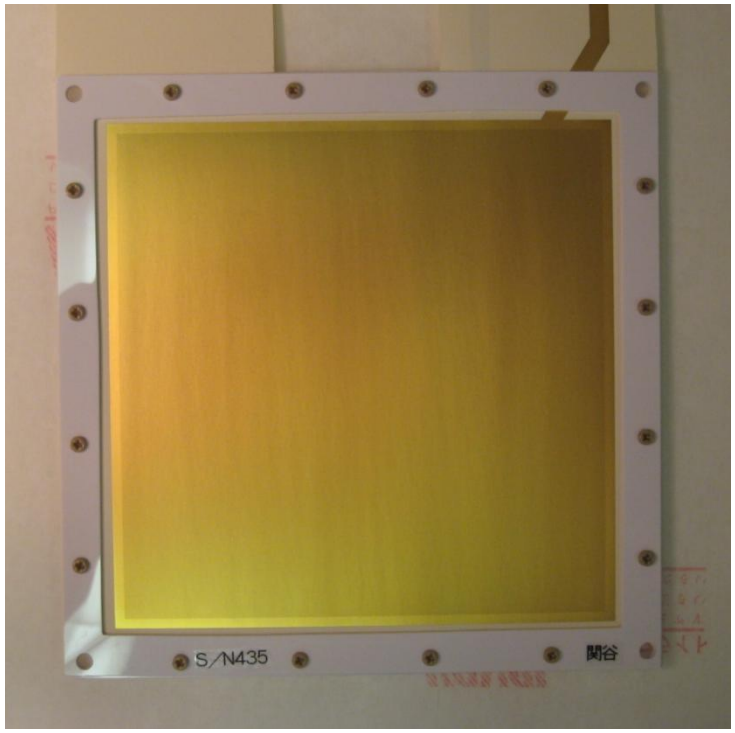
- 両面Auメッキ

100μmLCP-GEM/SMASH



窒素中　耐圧　～700V

Auメッキ後

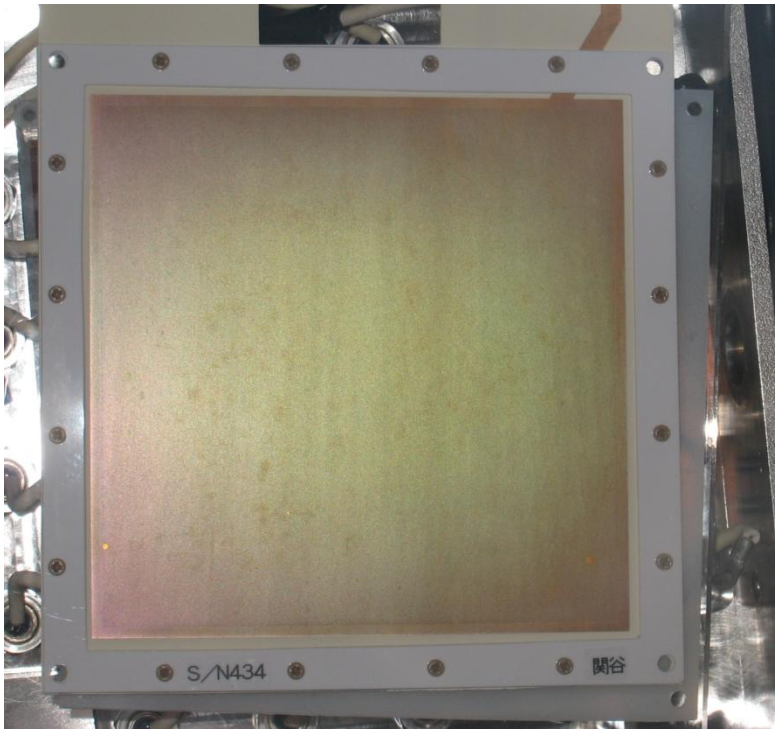


窒素中　耐圧　～650V
放電頻発

CsI蒸着　GEM

- 片面　200nm?

CsI蒸着後　（Au剥？）



注　アクリル越しの写真

窒素中　耐圧　～650V

Auメッキのときと同じ