Development of a UV/X-ray imaging device based on large area gas photo-multipliers

TIPP2011 Jun 11 2011

Hiroyuki Sekiya
Kamioka, ICRR/IPMU, University of Tokyo

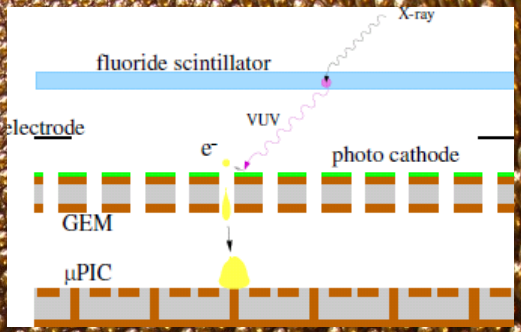
K.Taniue,H.Kubo,T.Tanimori
Dep. of Physics, Kyoto University
A.Yoshikawa,T.Yanagida,Y.Yokota,S.Kurosawa
IMRAM, Tohoku University
K.Fukuda,S.Ishizu,N.Kawaguchi,T.Suyama
Tokuyama Coporation

Contents

- Gas Photomultiplier
  - Large Area μPIC+GEM
- UV sensitive CsI photocathode
  - Combination with crystalline scintillators
- Imaging properties of the detector
- New hybrid imaging senser
  - Gas PMT with scintillating window
- Summary

Gas Photomultipliers

Photocathode
+ Micro Pattern Gaseous Detector



Possible features

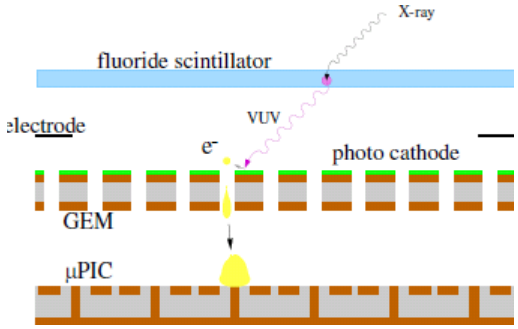
- **Large Area**
- **Position resolution**
- **Low cost**
- **Small Volume**
- **Low background**

Future Large Volume Detectors for Astroparticle physics (Dark Matter/neutrino)

Inside of the Super-K detector

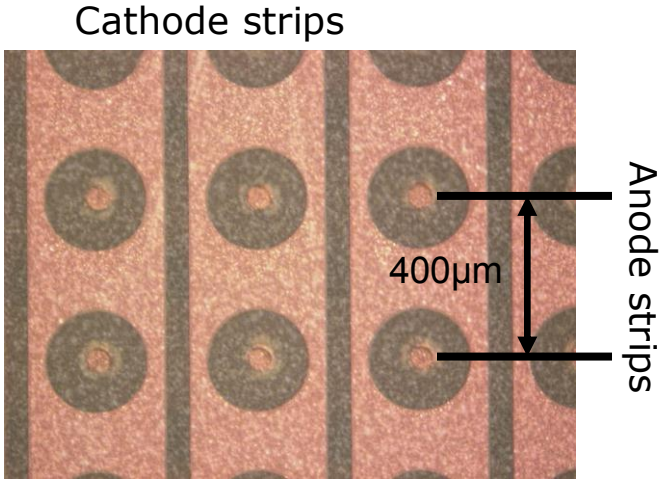
μPIC & GEMs: electron multiplier

- Many MPGDs have been applied for GPM.
  - Cascade GEM/MHSP/THGEM/post process bulk micromegas and so on.
- Our strategy/choice is GEMs+μPIC
  - GEMs for ion feedback blocking
  - μPIC for high gain / position resolution



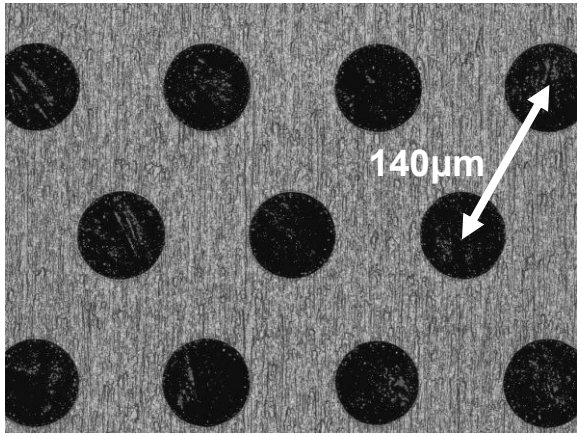
μPIC

- **Pillar-Anode MSGC**



GEM/SMASH

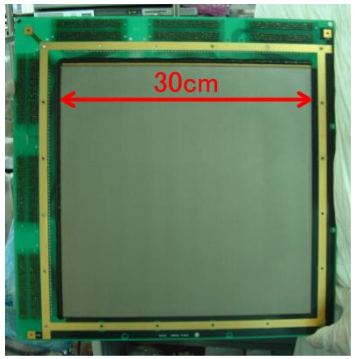
- **Laser etched 100μm thick LCP**



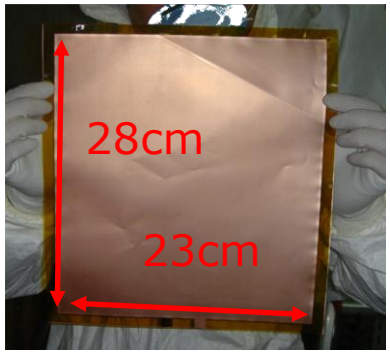
Large Area μPIC & GEM

- 30cm size Area MPGDs are already used in many applications.

30cm μ-PIC

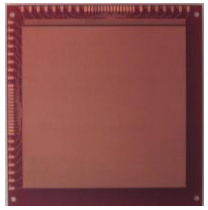


28cm GEM

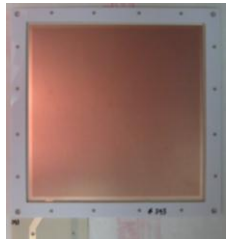


- For the prototype detector (partly because the window size is limited for the moment)
  we adopted 10cm size MPGDs.

10cm μ-PIC



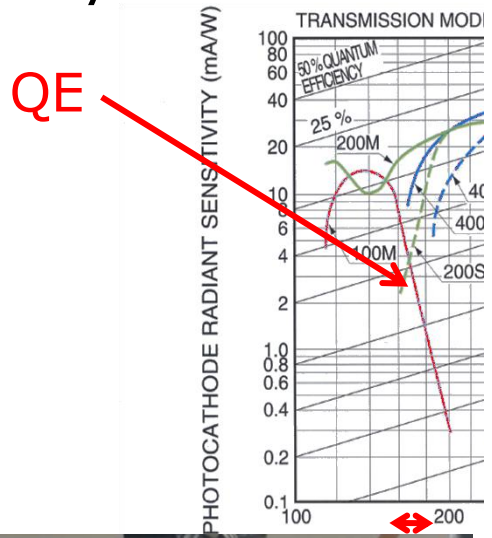
10cm GEM



CsI photocathode for GPM

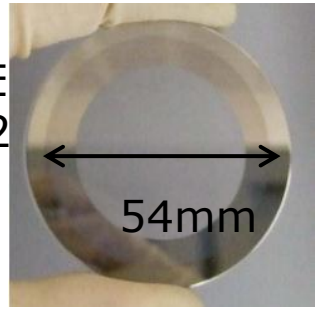
- Although only sensitive to <200nm, easy to handle (⇔ Bialkali PC)
  - Strong for ion feedback flow: Low Ion induced electron emission probability
  - Stable in dry air.
  - Many R&D has been conducted.

c.f. TIPP09 A. Breskin et al.

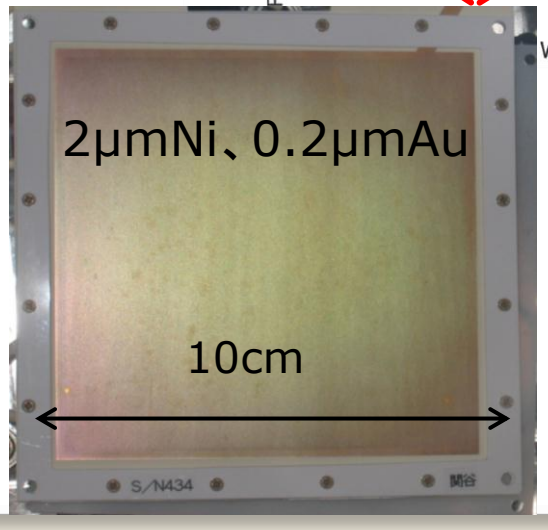


- Both transmissive and reflective types are tested.
  (CsI deposition by Hamamatsu)

TRANSMISSIVE CsI PC on MgF2 window



REFLECTIVE CsI PC on Au coated LCP-GEM

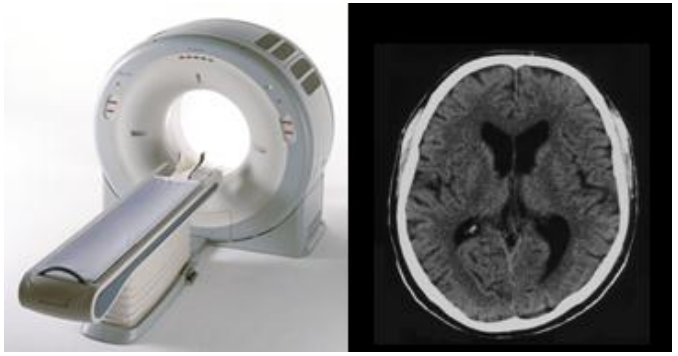


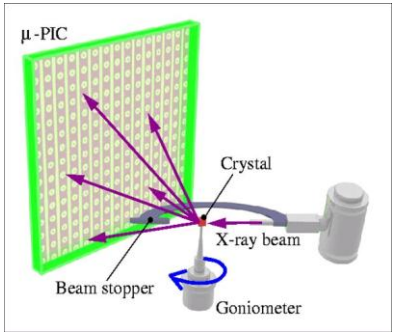
Combine with UV Scintillators

- Like visible light scintillator+MAPMT/APD array system

Possible application

- Hard X-ray imager
  - Color X-ray CT
  - Material structure analysis
  - None destructive inspection
  - Security check
- PET/gamma camera
- Radiation monitors etc..



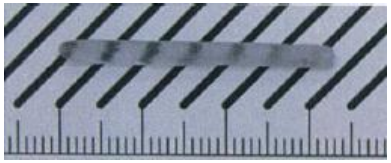


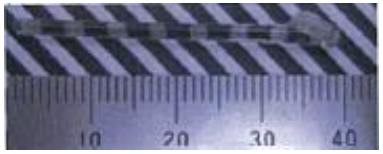
- These might be realized in cheaper way.
- In principle, UV scintillations show rapid decays.

Crystalline UV scintillators

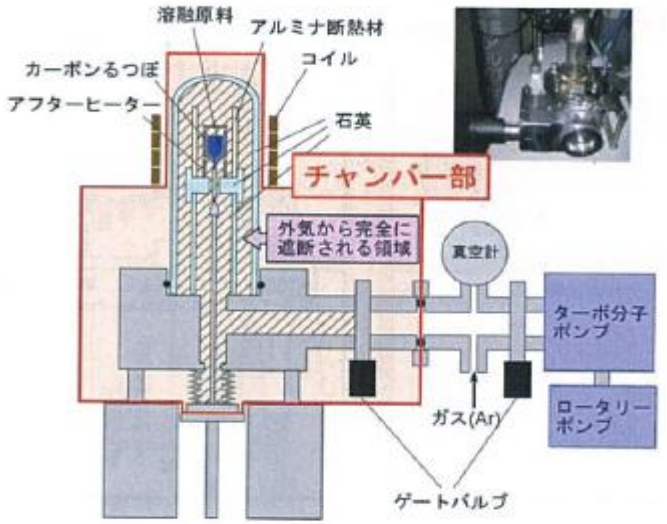
- We are developing Nd^{3+} doped fluoride crystals which emit VUV photons through 5d-4f transition.
- Special μPD system was developed to grow various kinds of crystals effectively.

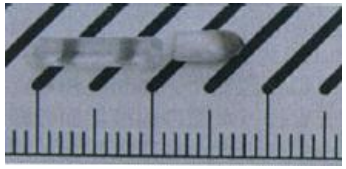
Nd:CaF 

Nd:LiKF 

Nd:NaLuF 

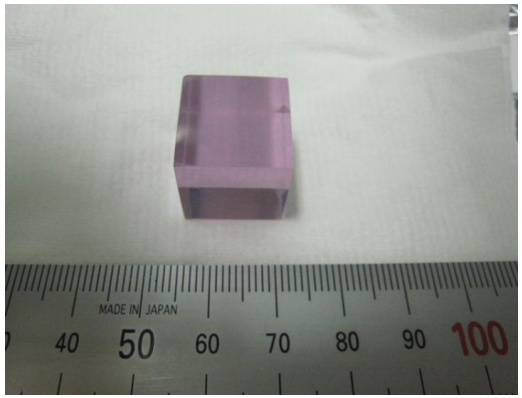
Nd:GaLiF 



Nd:BaYLuF 

Nd:LaF_3 as a light source

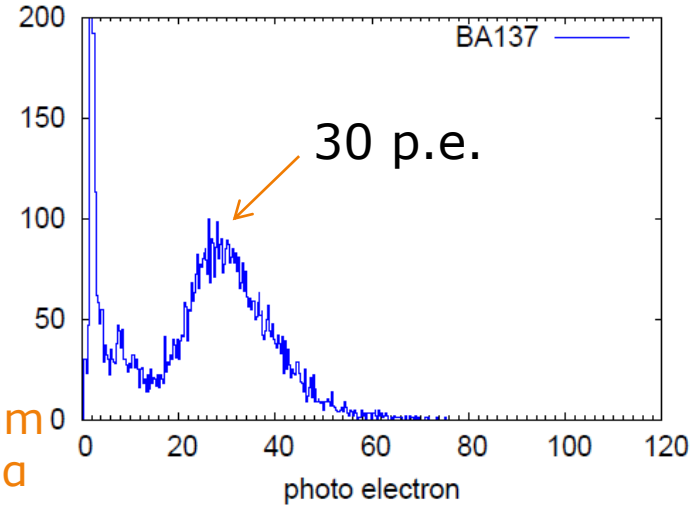
- For the first step, we focused on LaF_3(Nd) as a low intensity light source in order to test the detector for 1p.e. level.
- λ =173nm, τ = 7ns
- Light Yields were measured with VUV sensitive PMT Hamamatsu R8778



5.5MeV α from ^{241}Am irradiated to 2cm size crystal covered with Teflon

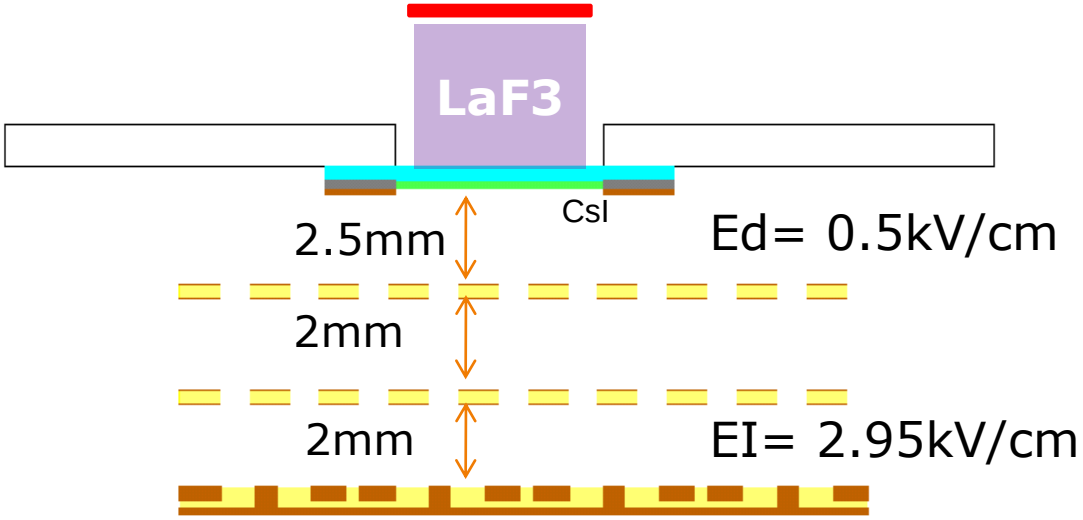
- Prototype PMT of XMASS
- Quartz window
- UV enhanced bialkali

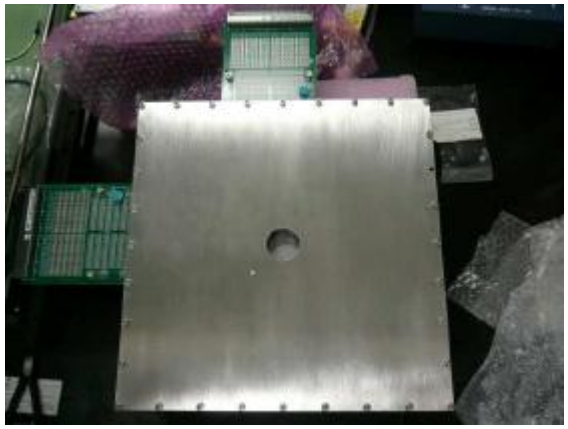
Quantum efficiency 30%@172nm
→ **LY 100 photons/5.5MeV** α



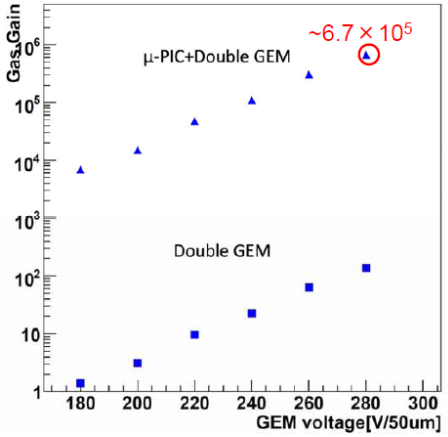
Setup

- 2x50μm-GEMs+μPIC with CsI photocathode
- $Ar+C_2H_6$ (90 : 10) 1atm
- 256ch x 256ch readouts
- 2.6MBq ^{241}Am for high rate test



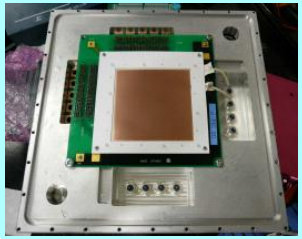


- μPIC 490V
- GEMs 280V → Gas gain 6.7×10^5

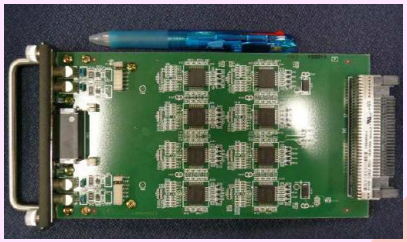


NIMA 513(2003) 94

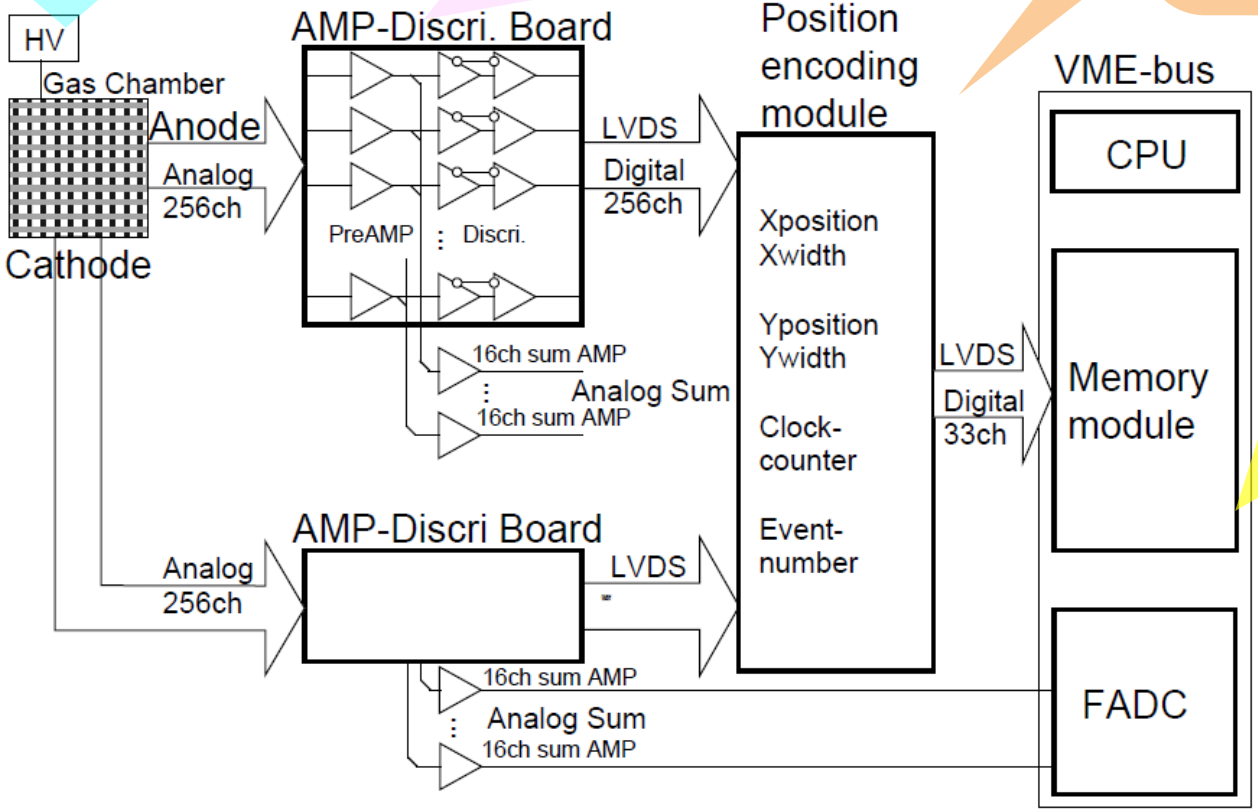
Readout system



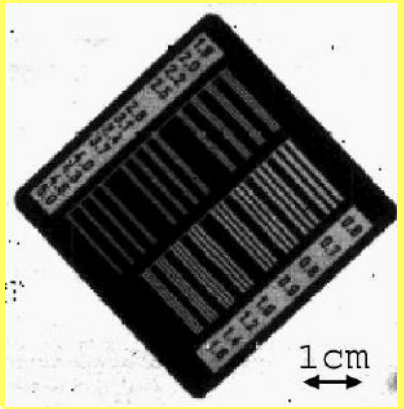
ASD chip
for ATLAS TGC
0.8V/pC



Position Encoder
FPGA x 3
100MHz clock



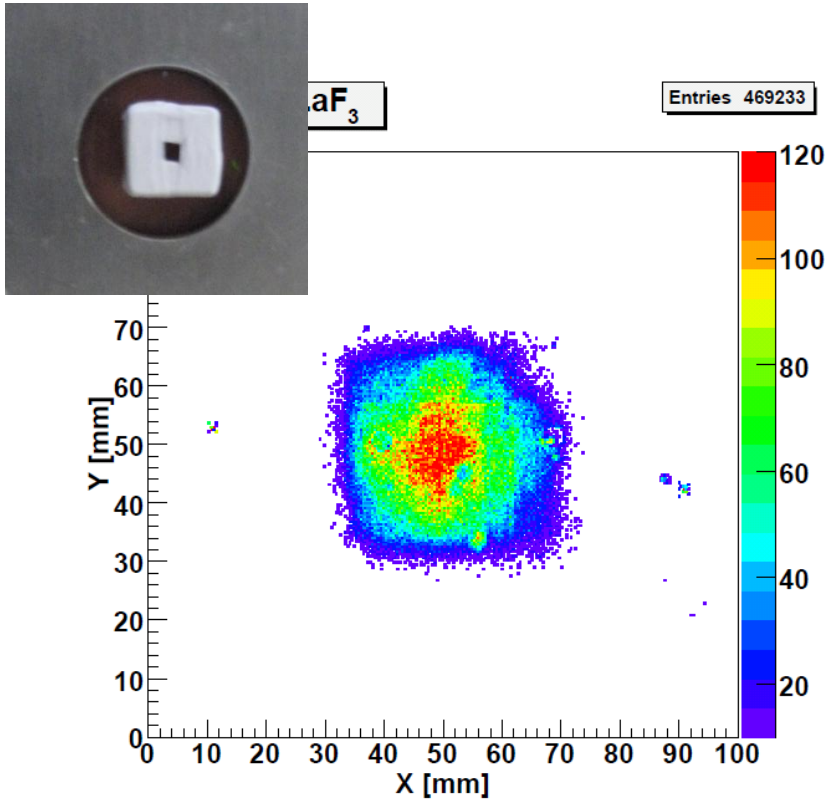
Obtained image



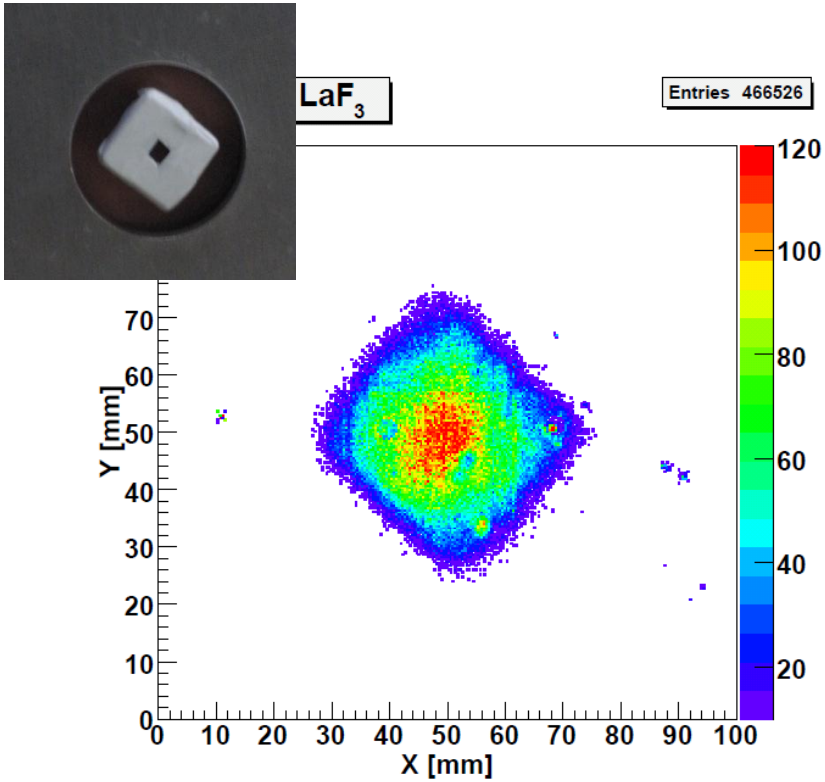
Crystal Shape Reconstruction

- 18x21x20mm^3 LaF_3(Nd) + 5.5MeV α

Parallel composition

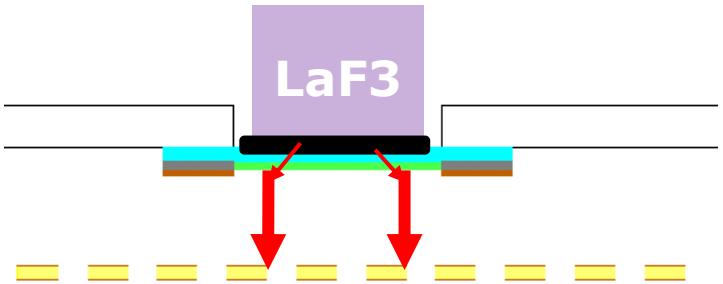


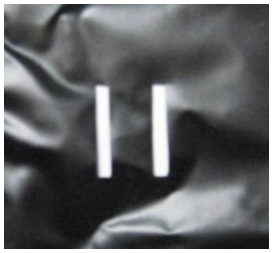
Diagonal composition



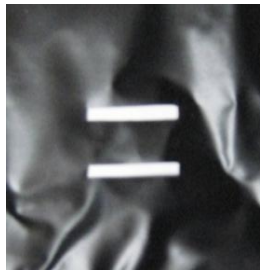
Evaluation of the position sensitivity

- 0.1t PVC sheets inserted
  - 10mm distance Slits
  - 2mm x 15mm



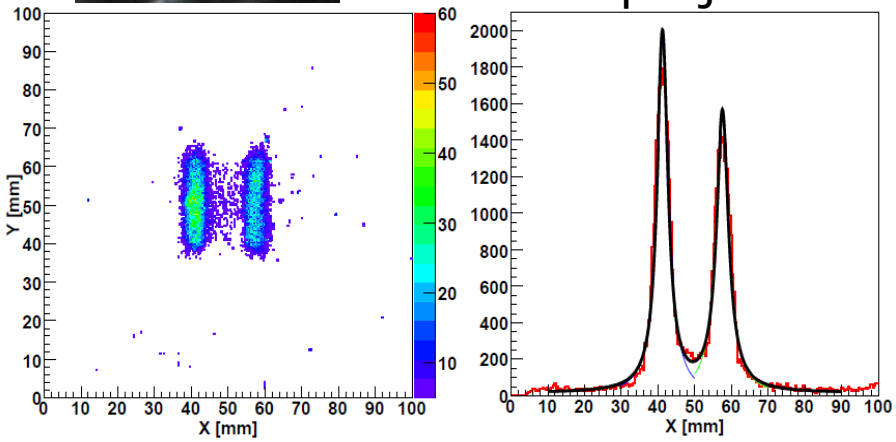


Vertical composition

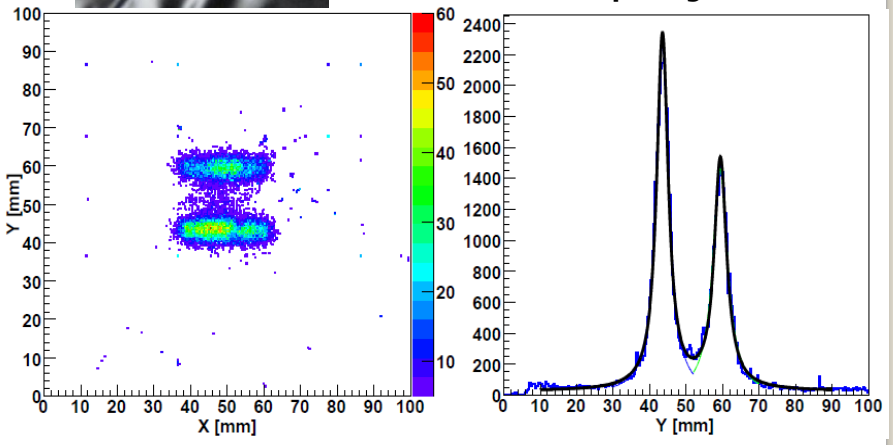


horizontal composition

X projection



Y projection



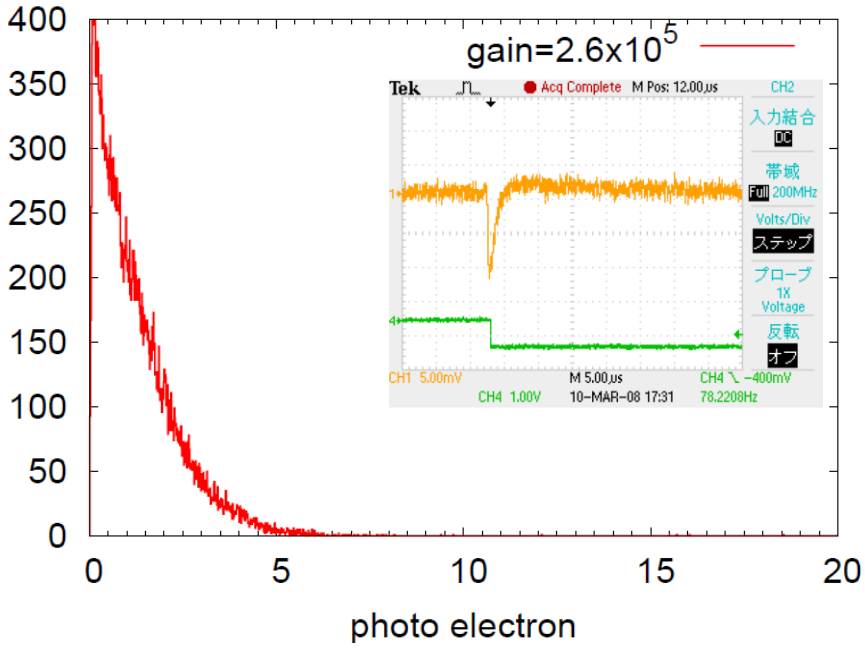
Uniformly x1.6 expanded

MgF_2 refractive index 1.45@180nm

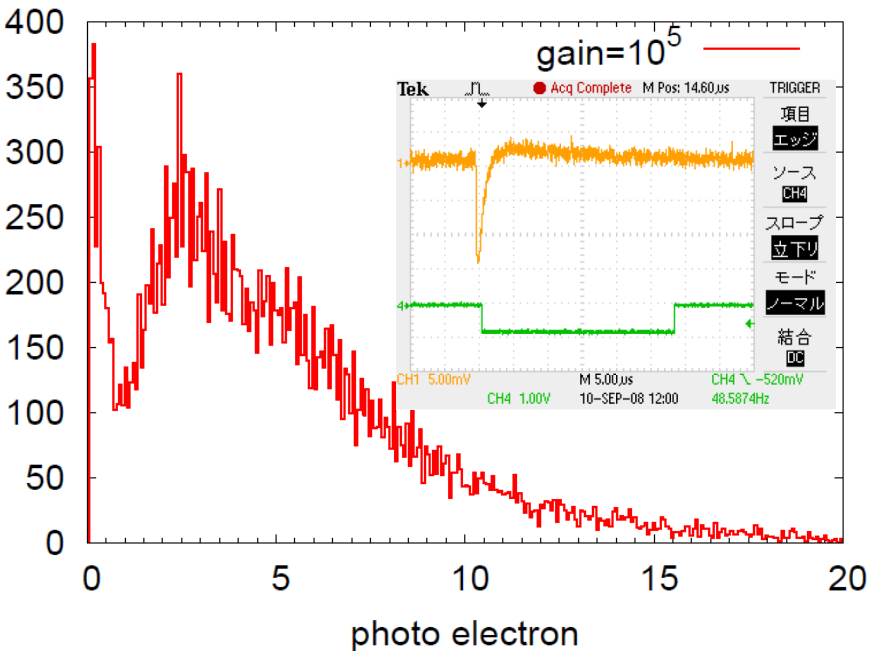
Analog properties

5.5MeV α
64 strips summed signal
amplified with0.1V/pC

Transmissive PC



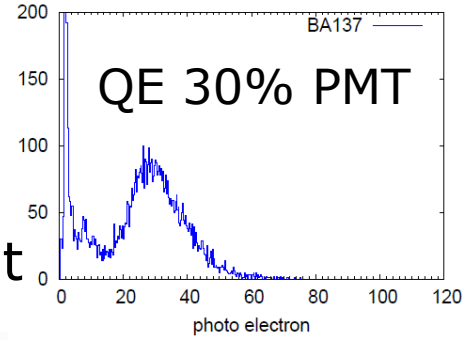
Reflective PC



Quantum efficiency

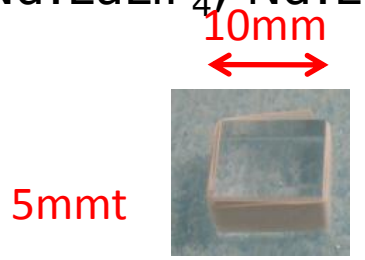
- Transmissive PC ~1%
- Reflective PC ~3%+

- Efforts to increase QE are required…but

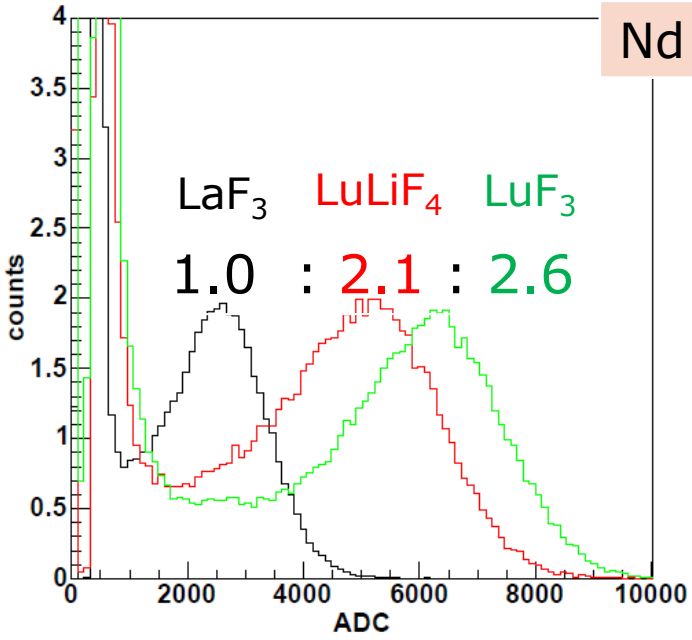


Development of higher light yields scintillators

Good candidates:
$Nd:LuLiF_4$, $Nd:LuF_3$



Crystal	Z	Density [g/cm³]	Wave length [nm]	Decay time [ns]
$Nd:LaF_3$	53	5.9	173	7
$Nd:LuLiF_4$	64	6.2	183	12
$Nd:LuF_3$	66	8.3	178	10

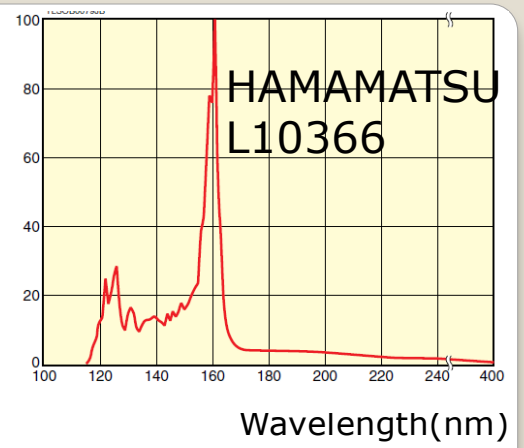


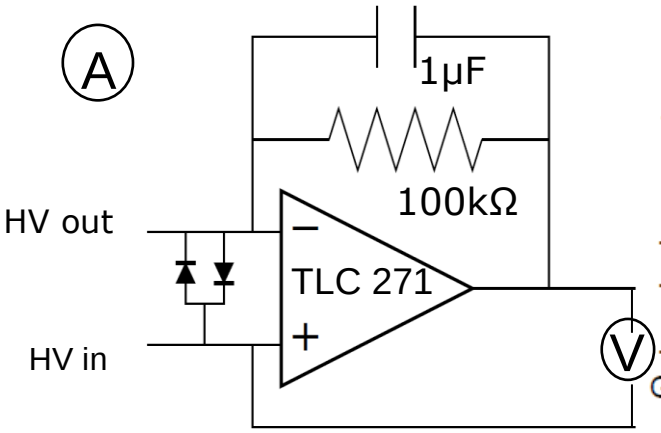
5.5MeV α(^{241}Am)
measured by PMT R8778

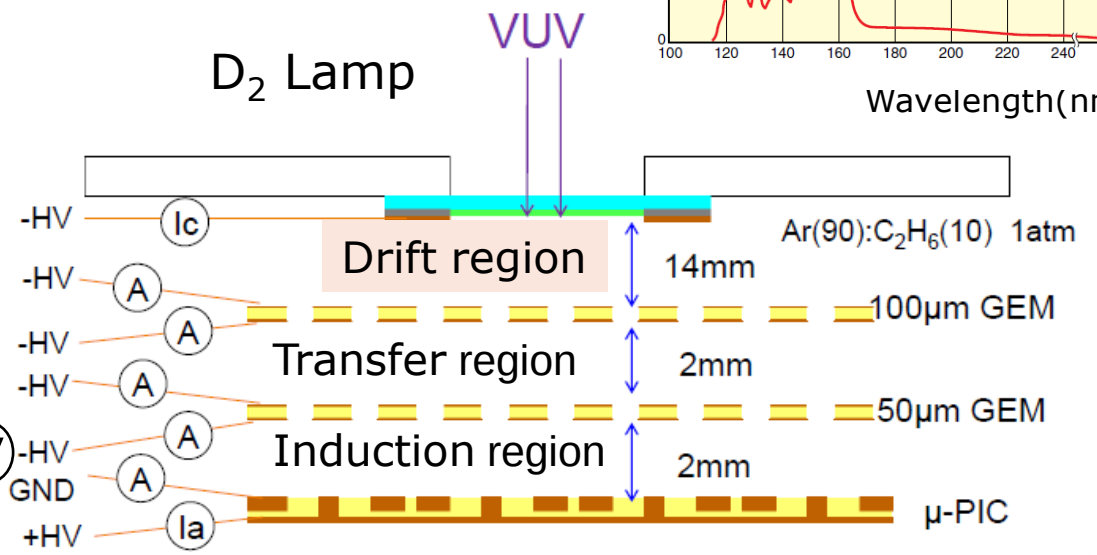
→$LuLiF_4$ is 2.1 times,
LuF_3 is 2.6 times brighter
than LaF_3

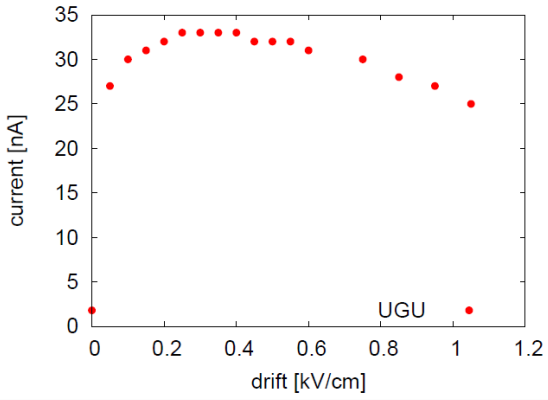
Tuning of the Fields

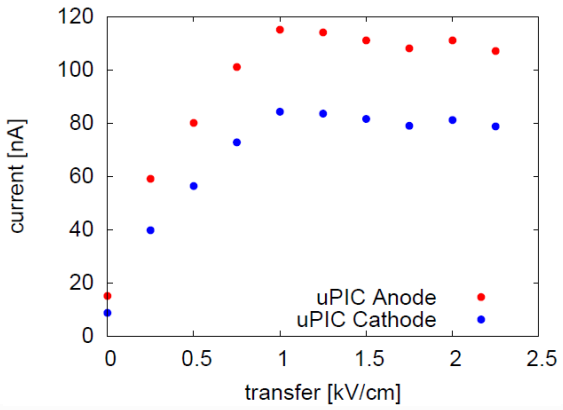
- By measuring currents of all the stages









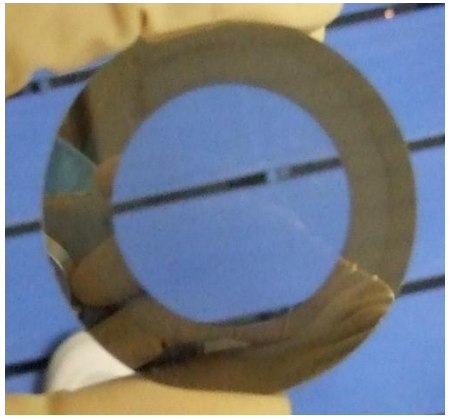


Best tuned fields for Transmissive PC

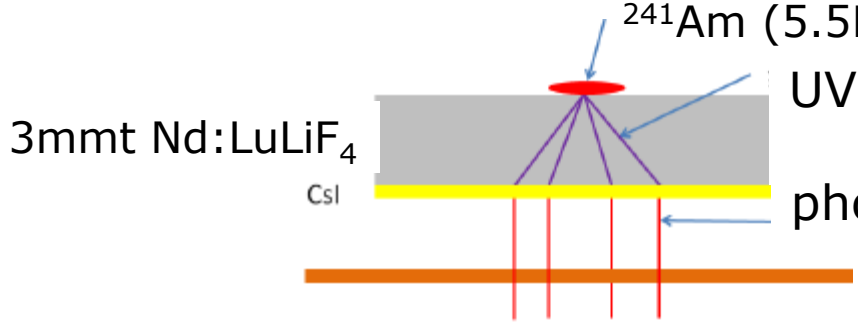
Drift	0.25kV/cm
Transfer	1 kV/cm
Induction	4.2kV/cm ↑

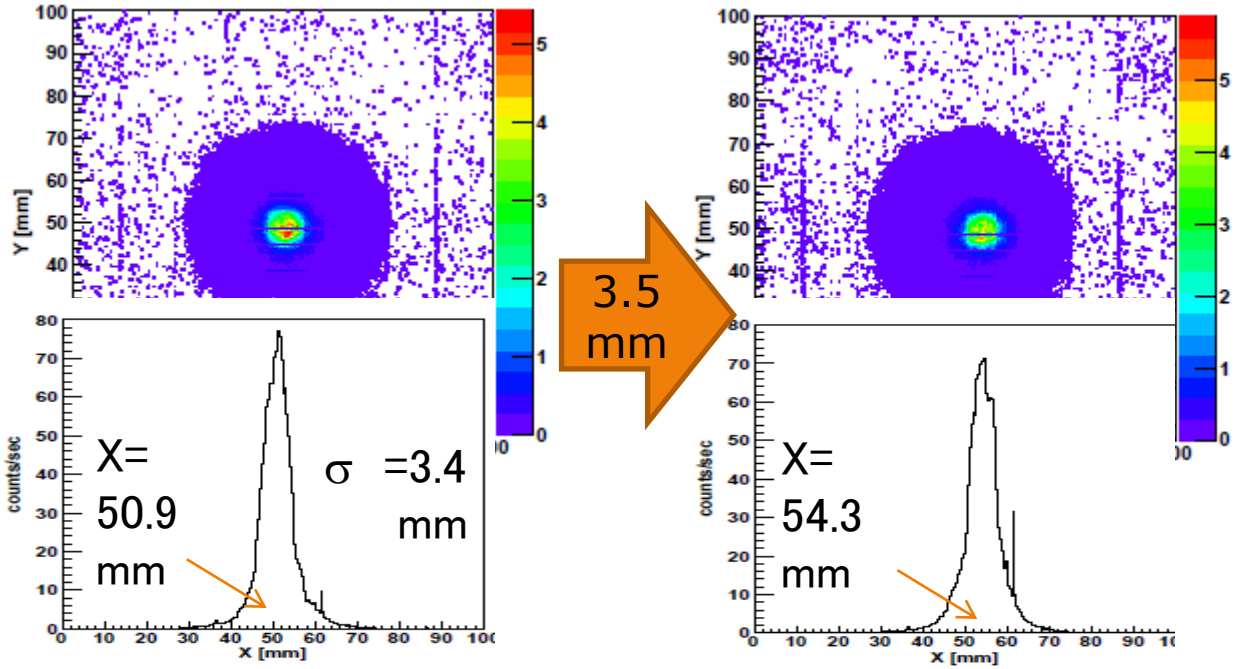
New hybrid imaging device

- Scintillator itself is the window



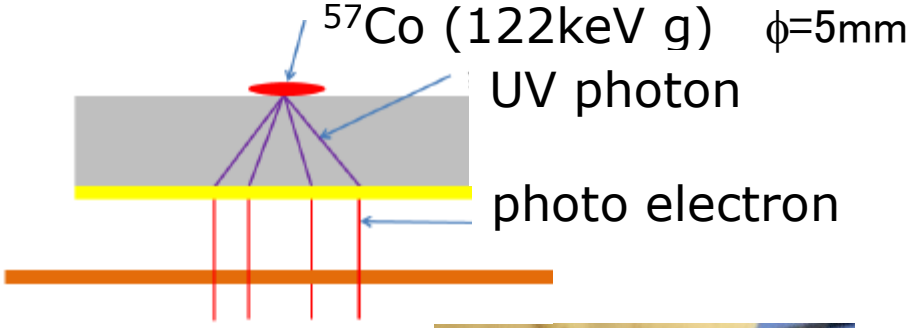
ϕ54mm
Ni contact
CsI active area
ϕ34mm

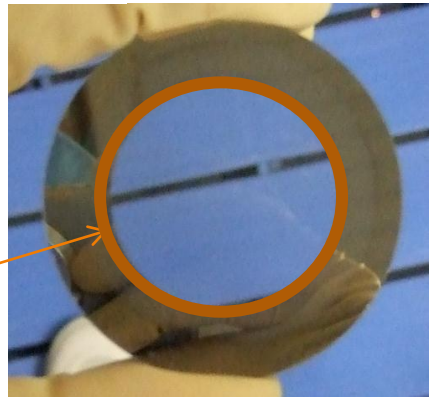


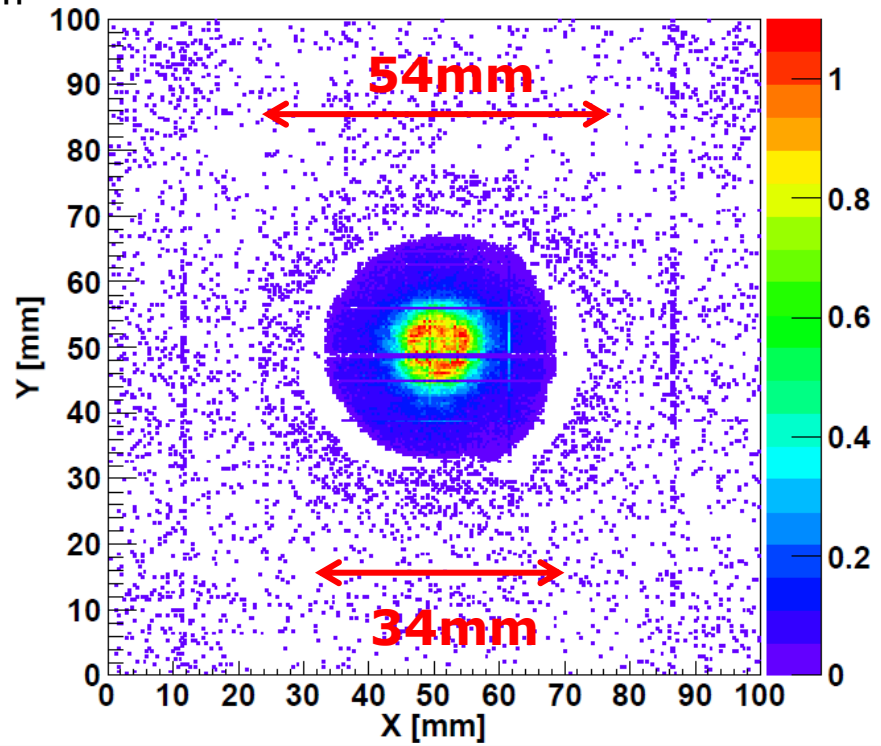


Imaging with ^{57}Co 122keV γ

- First step for X-ray imaging…
  - Although QE is still low, the detection efficiency is much higher than that of gaseous detectors.







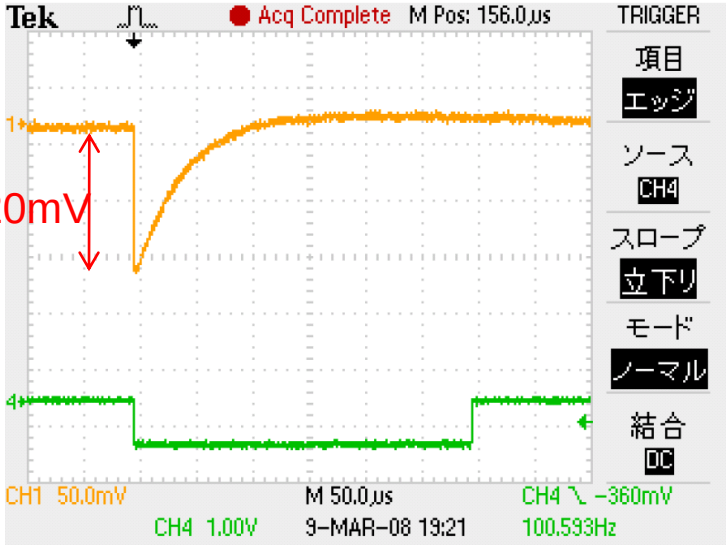
Summary

- A UV sensitive imaging gas PMT is being developed.
- Although the QE is still limited, 1 p.e. level signal was clearly detected.
- With newly developed UV scintillators, the imaging capability of the detector was tested. It should have sub 1mm position resolution.
- Adopting the UV scintillator itself as the UV-transparent window, a new hybrid imaging device is also developed and γ/X-ray pictures were successfully obtained.
- In order to increase QE, tuning of PCs and gas (Ne base) are in progress.

Extras

Photon Signal

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

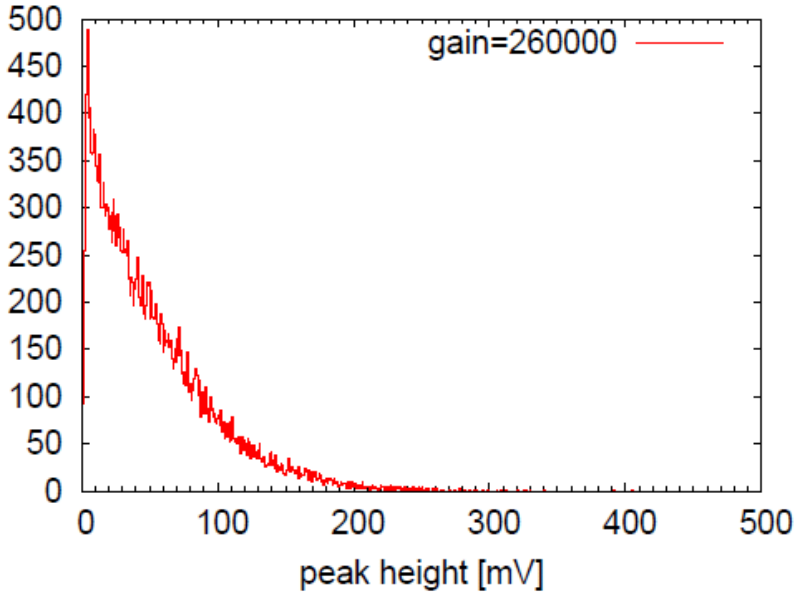


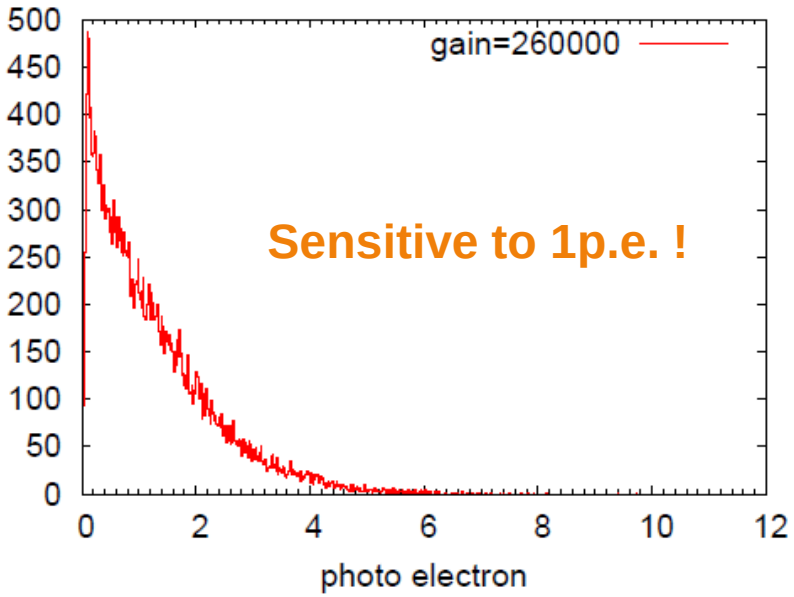
The gas gain 2.6×10^5

Detected number of photoelectrons

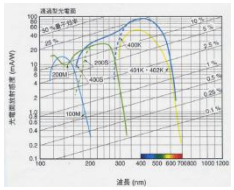
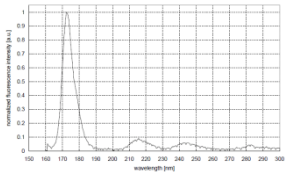
$120\text{mV}/1\text{V} \times 1\text{pC}/(1.602 \times 10^{-19})/\ 2.6 \times 10^5 = 2.9$ p.e.

Spectrum





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

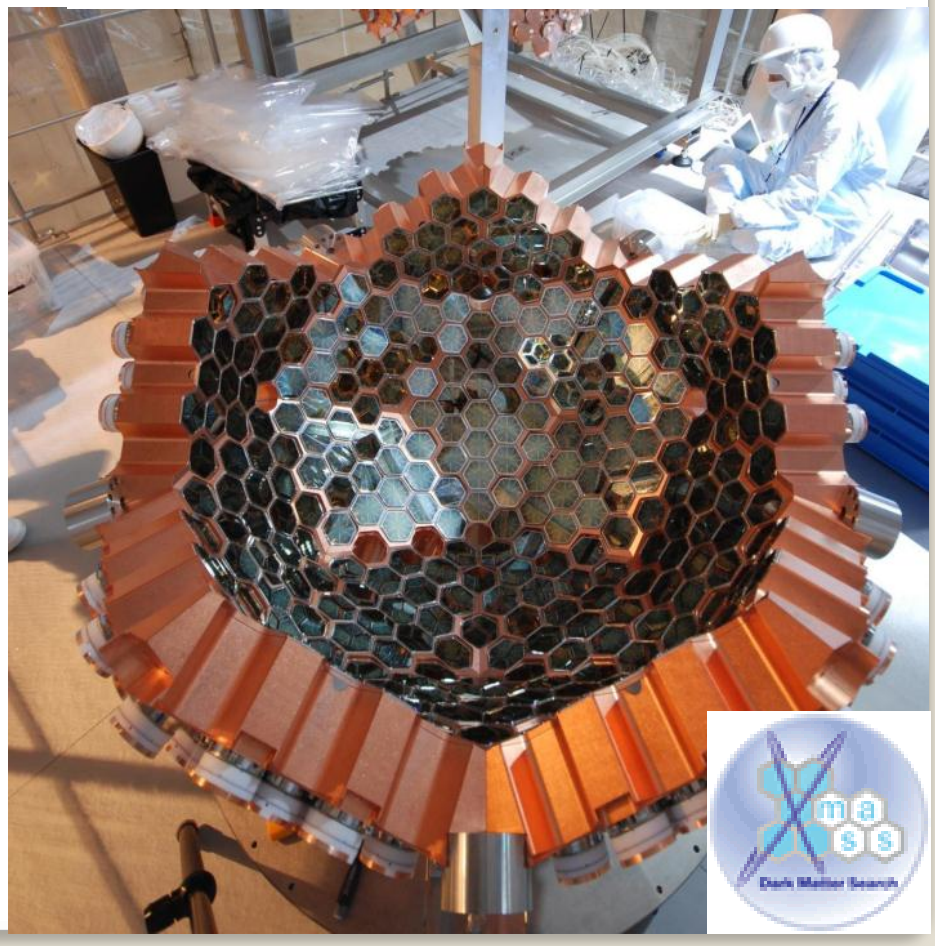
$$= \int$$  $$\times$$  $$d\lambda$$

Agrees with QE curve and the luminescence spectrum

CsI photocathode for GPM

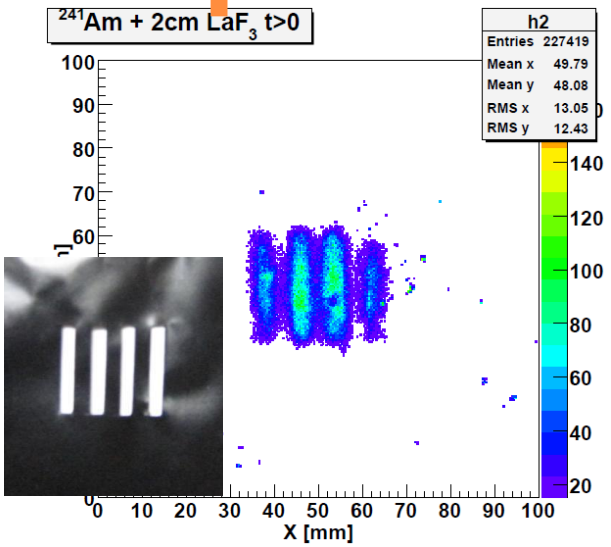
- Although only sensitive to <200nm, easy to handle (⇔ Bialkali PC)
  - Strong for ion feedback flow: Low Ion induced electron emission probability
  - Stable in dry air.
  - Many R&D（Micromegas）
- With UV scintillators
  - Liq. Xe/Ar scintillators (λ<180nm)
    - Single phase detector
    - Double phase detector
      - Both charge & photon detection

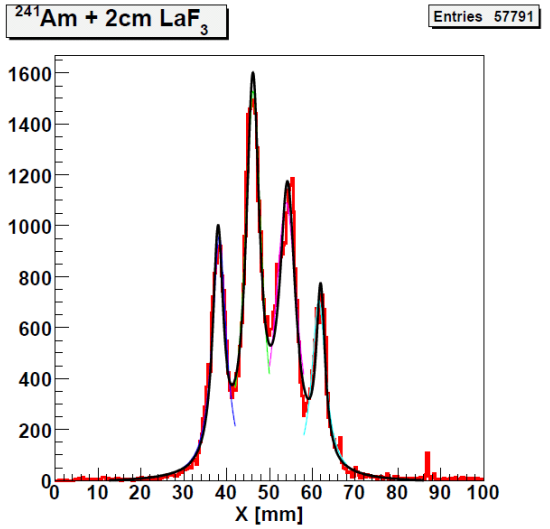
Inside of the XMASS detector



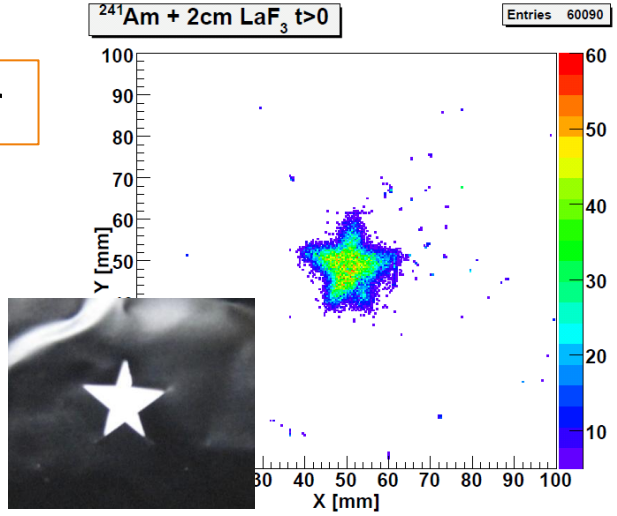
More Examples

5mm distance Slits
2mm x 15mm





Star



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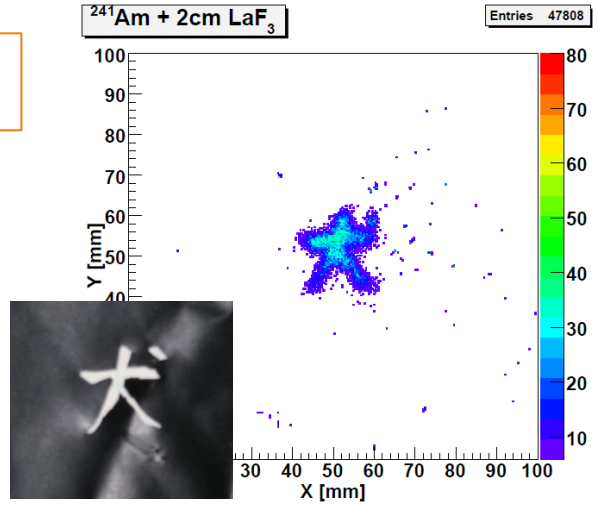

Set up for testing analog properties

- 2 100μm-GEMs+μPIC with CsI photocathode
- $Ar+C_2H_6$ (90 : 10) 1atm
- Gas gain 2.6 x 10^5 | μPIC 465V | GEMs 422V