

Compton Gamma-ray Imager Using Electron Tracking Gaseous TPC and Scintillation Camera

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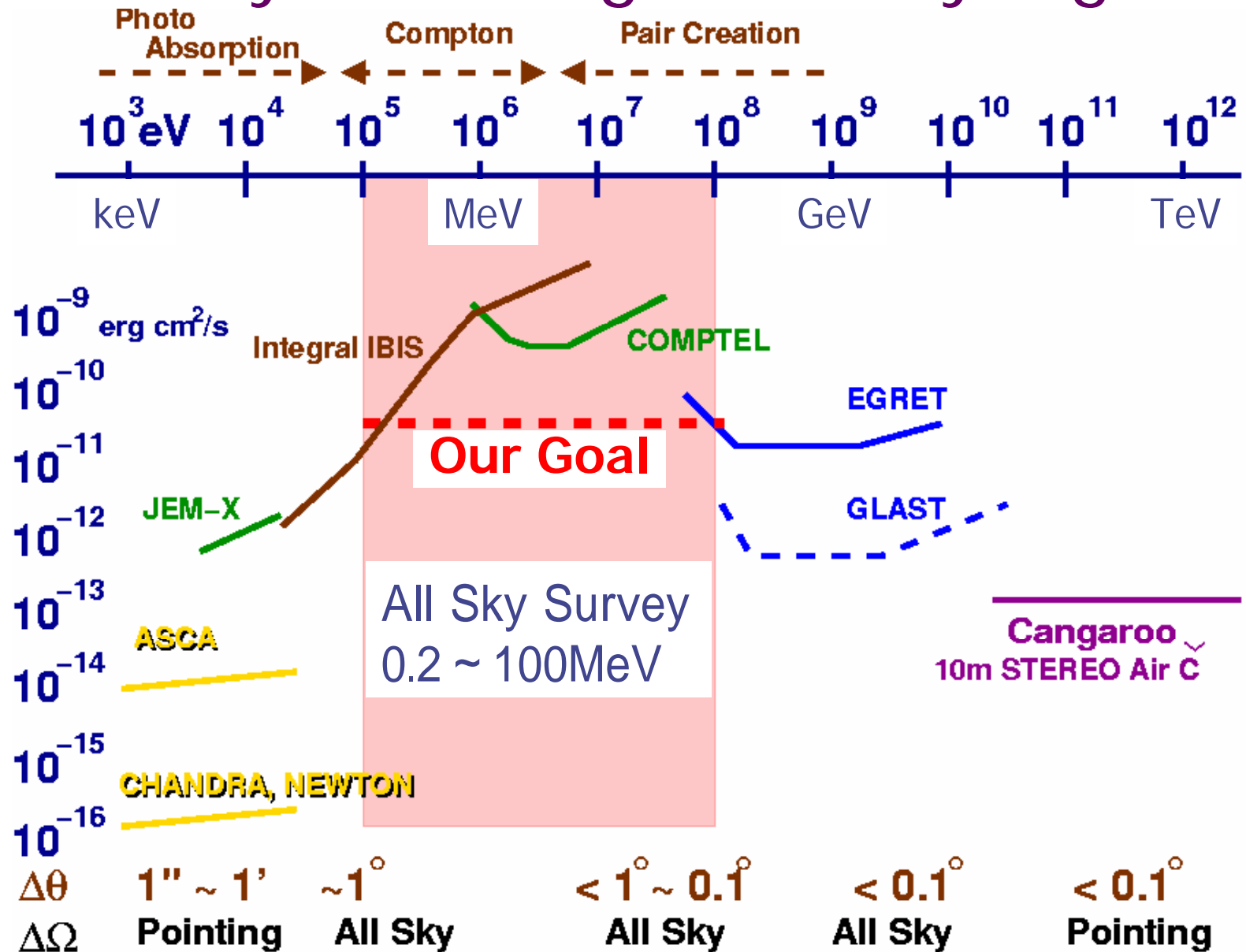
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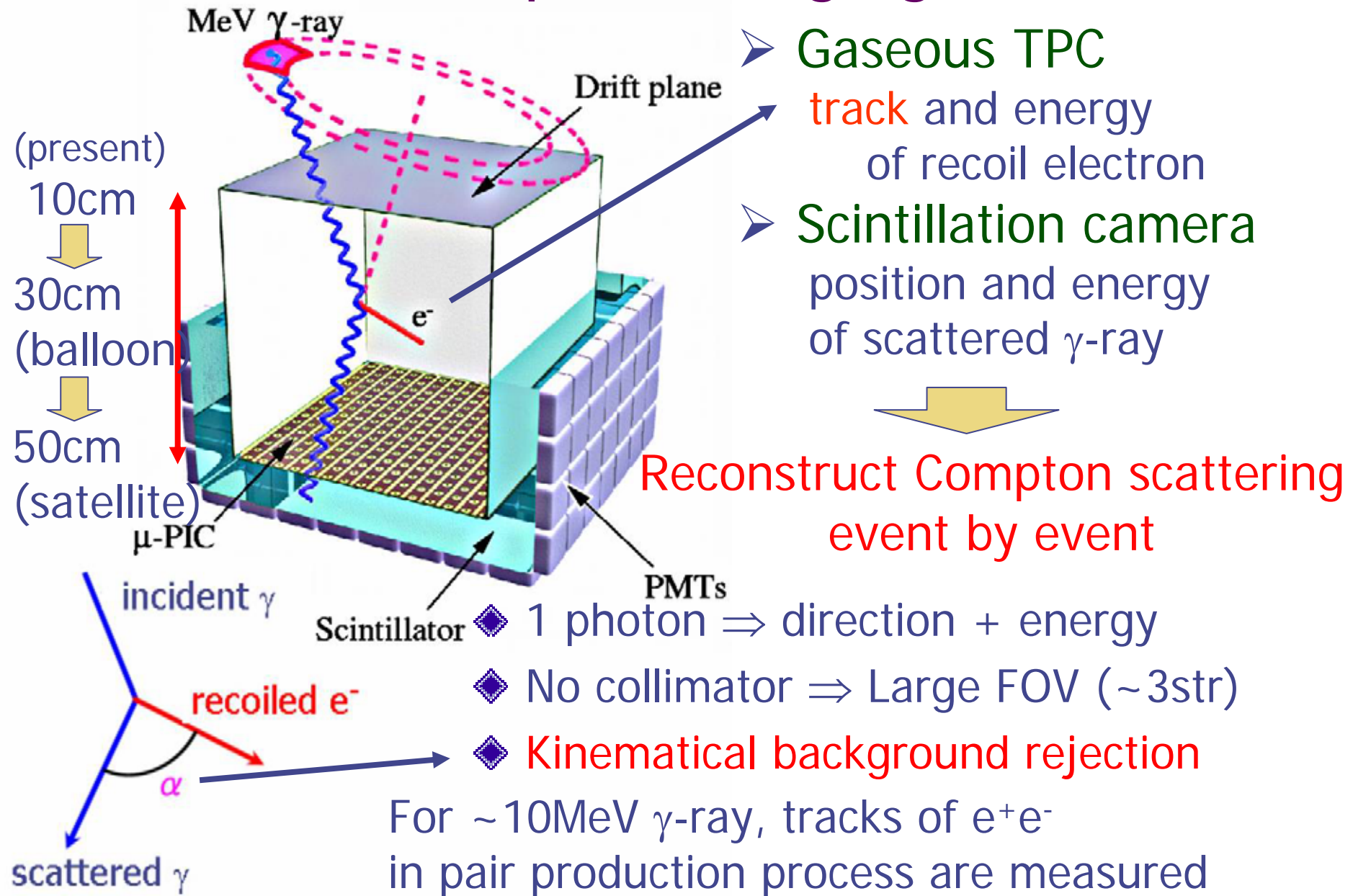
- Advanced Compton gamma-ray imaging method
- Performance of prototype camera
- Improvement
- Summary



Sensitivity in the X/gamma-ray region

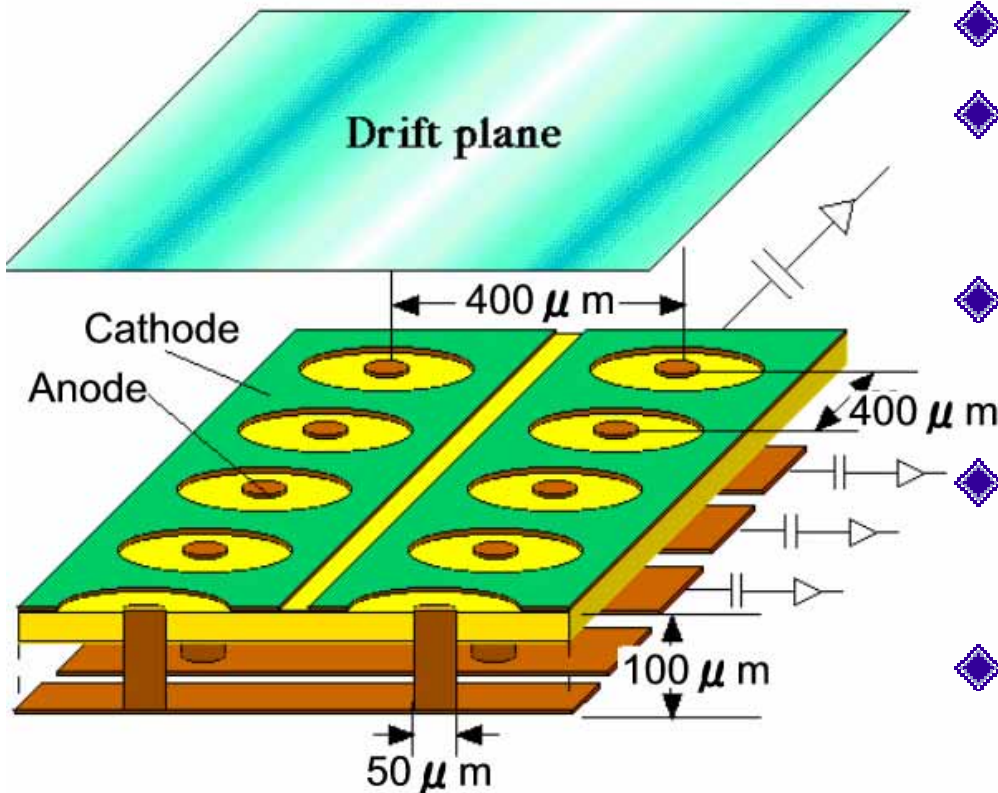
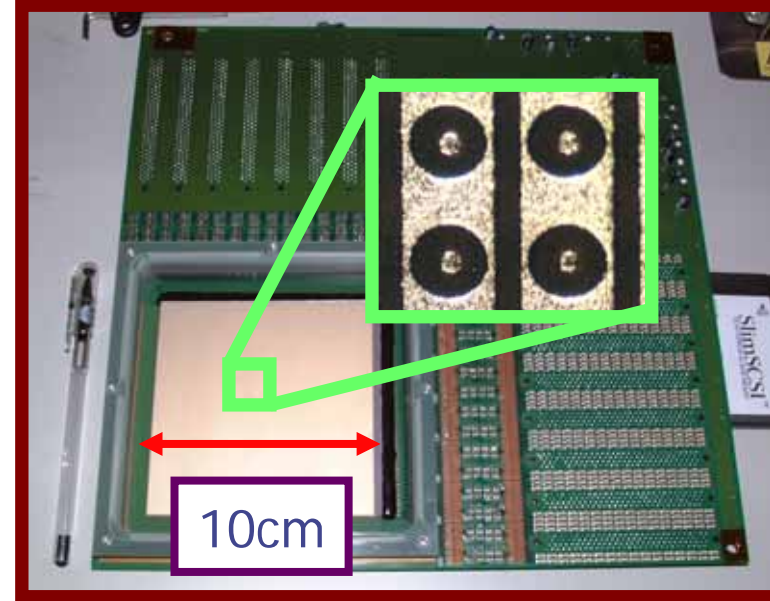


Advanced Compton Imaging



Readout of gaseous TPC (μ -PIC)

- ◆ Micro pattern gas chamber
- ◆ 2D readout (256x256pixels)
- ◆ Large detection area (10cm×10cm)
- ◆ Print Circuit Board technology



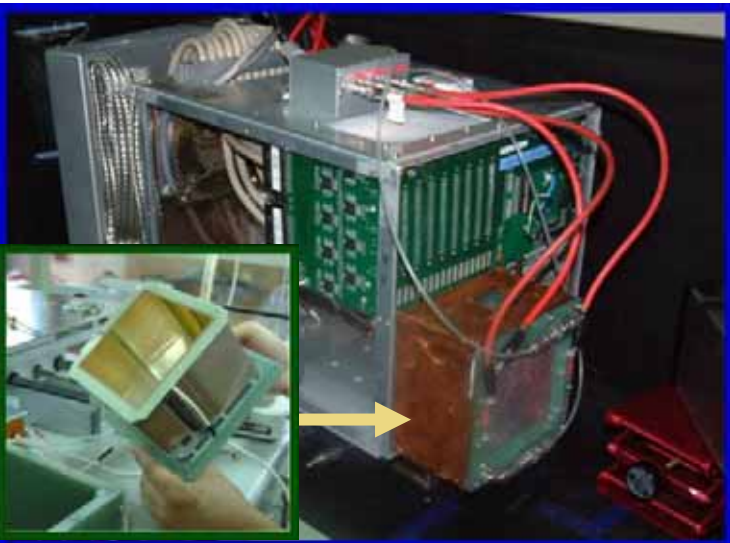
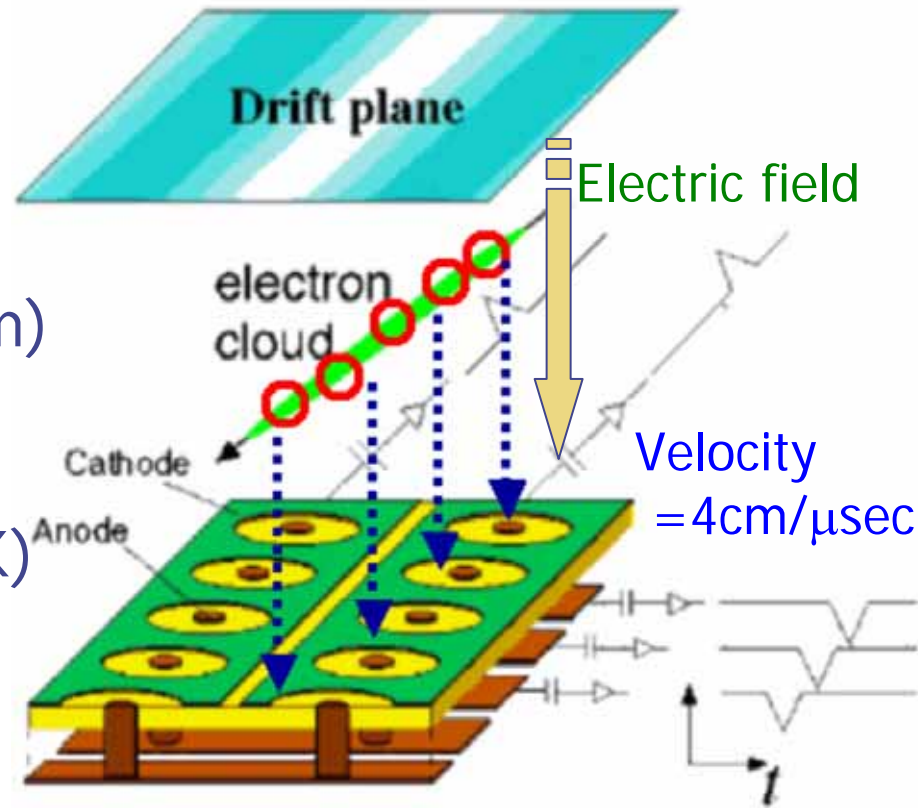
- ◆ max gas gain ~16000
- ◆ energy resolution
30% @ 5.9keV (100cm²)
- ◆ stable operation for 1000h
@ gas gain ~6000
- ◆ good gas gain uniformity
4.5% @ 100cm²
- ◆ fine position resolution
(~120μm)

Gaseous-TPC (μ -TPC)

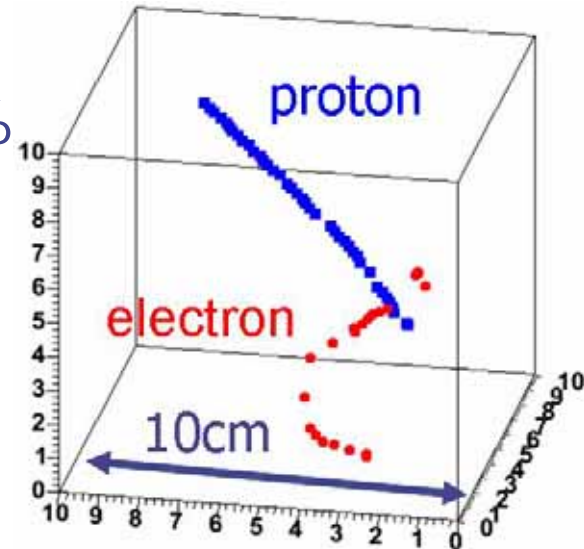
- ✓ 10cm \times 10cm μ -PIC
⇒ 2D hit position ($\Delta=120\mu\text{m}$)
- ✓ 8cm drift cage
⇒ drift time \Rightarrow Z position
($\Delta=800\mu\text{m}/\text{FPGA CLK}$)



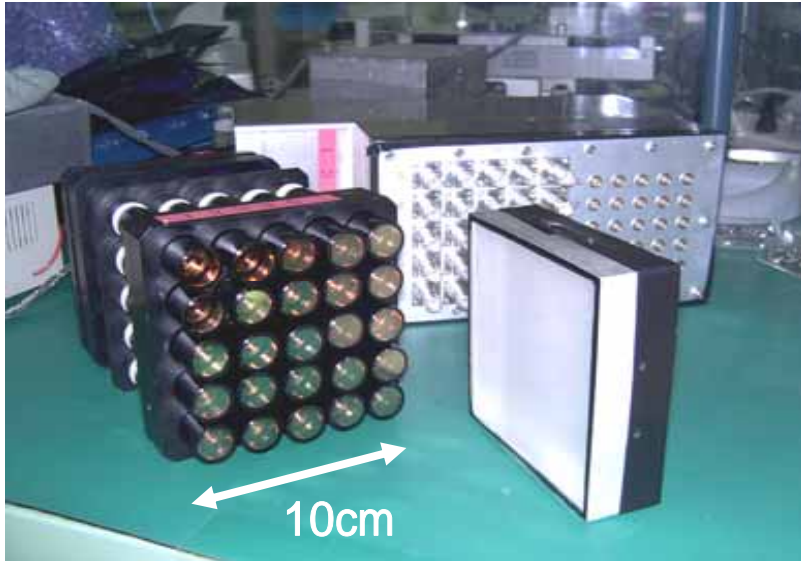
3D track of a charged particle
is measured



Typical tracks
Ar 90% C₂H₆ 10%
gas gain \sim 5000
proton
E \sim 1MeV
electron
E \sim 500keV



Scintillation Camera



Classical Anger camera

4" × 4" × 1" NaI(Tl) scintillator

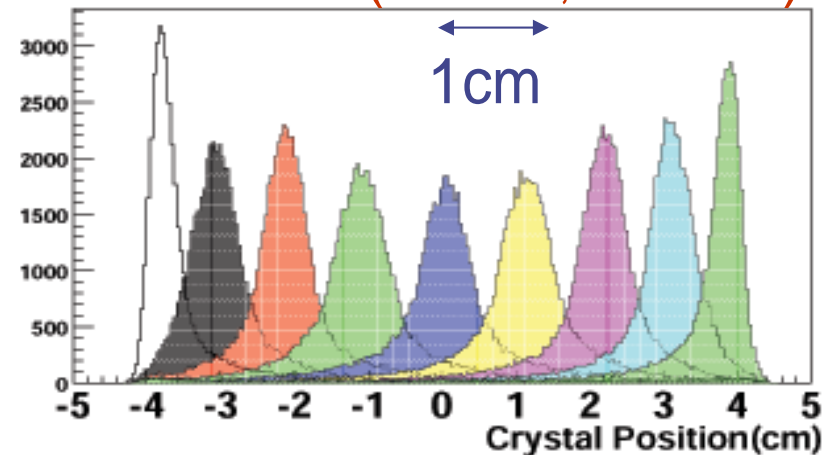
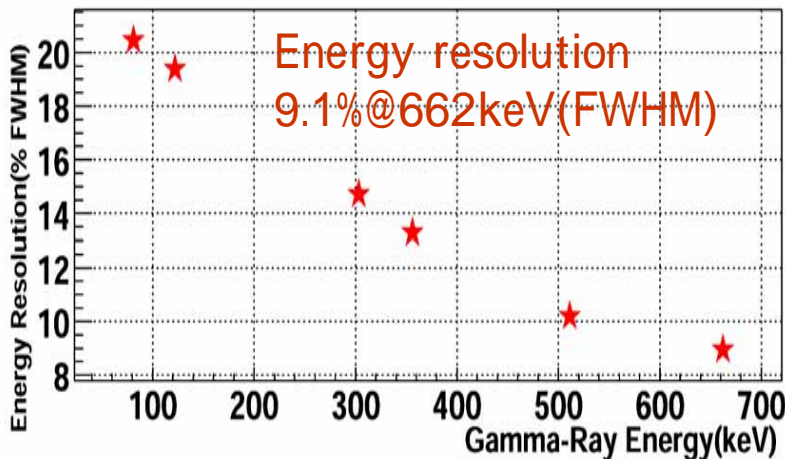
5 × 5 Hamamatsu $\frac{3}{4}$ " R1166 PMTs

Photocathodes cover 40% area

No DOI measurement

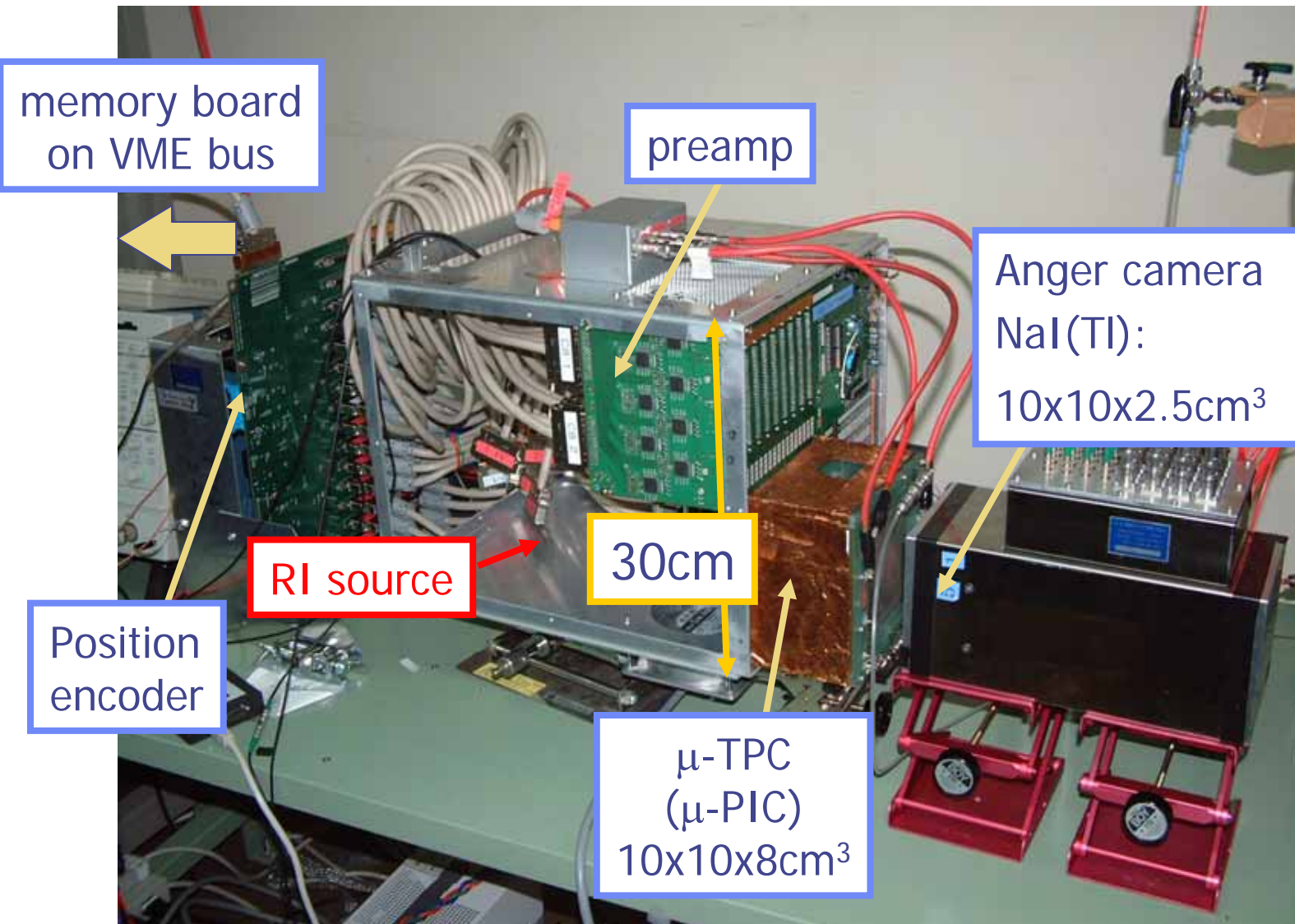
2D Position resolution

~ 7.5mm(FWHM,662keV)



Prototype Compton camera

No Veto or Shield !



Result of γ -ray imaging with prototype camera

Measure 3D track of Compton recoil e^- & energy and direction of scattered γ
energy of incident γ is known parameter

reconstruction of incident γ -ray

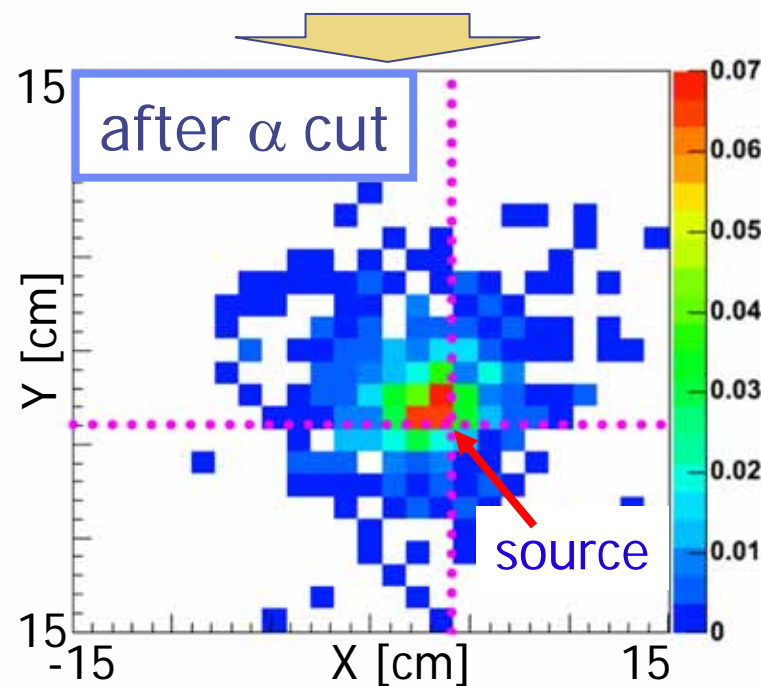
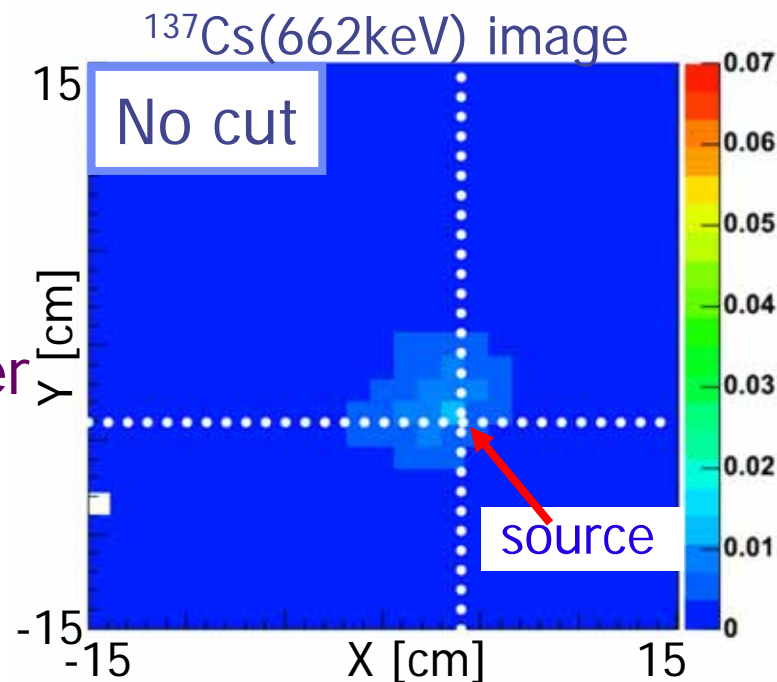
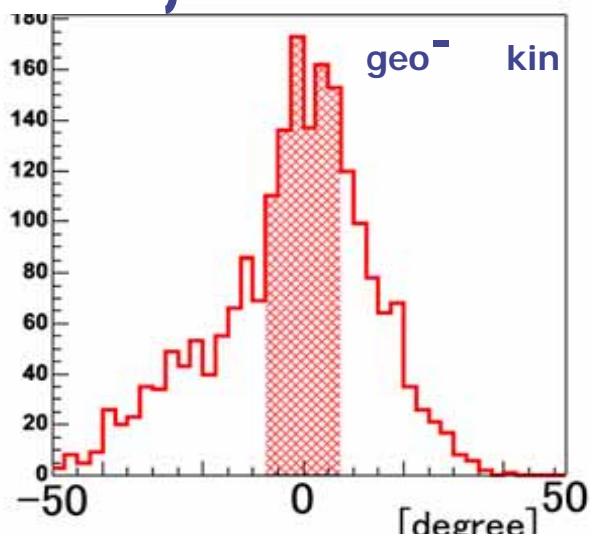
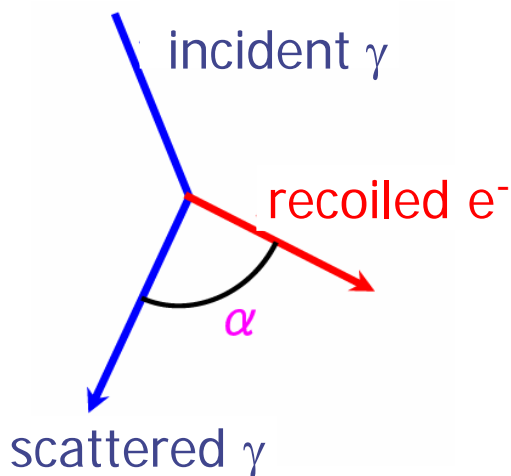
◆ Background rejection

α_{geo} : measured α

α_{kin} : calculated α from energy information

α cut

$\alpha_{\text{geo}} \sim \alpha_{\text{kin}}$



Comparison with the classical Compton method

Advanced Compton Method

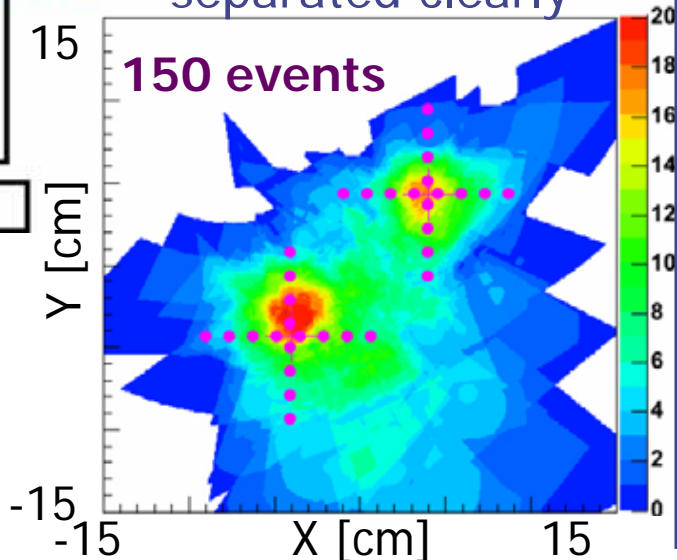
Using the electron tracks

- error region of direction is

in **sector form**

Simply overlay
2 sources were
separated clearly

150 events



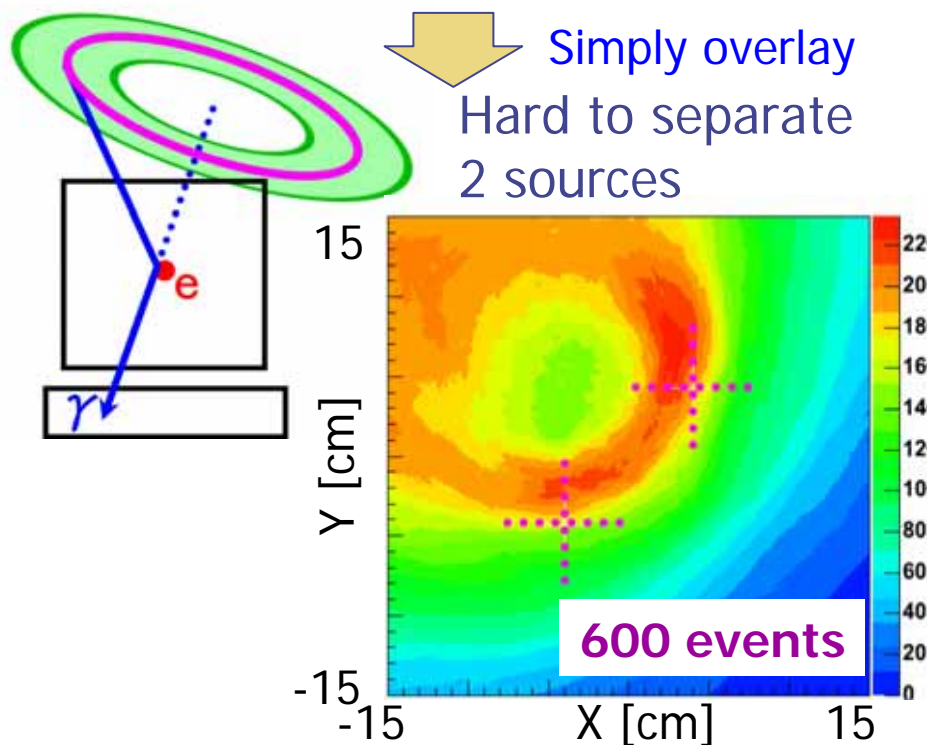
$^{137}\text{Cs}(1\text{MBq})\times 2$

Classical Compton Method

Not using the electron tracks

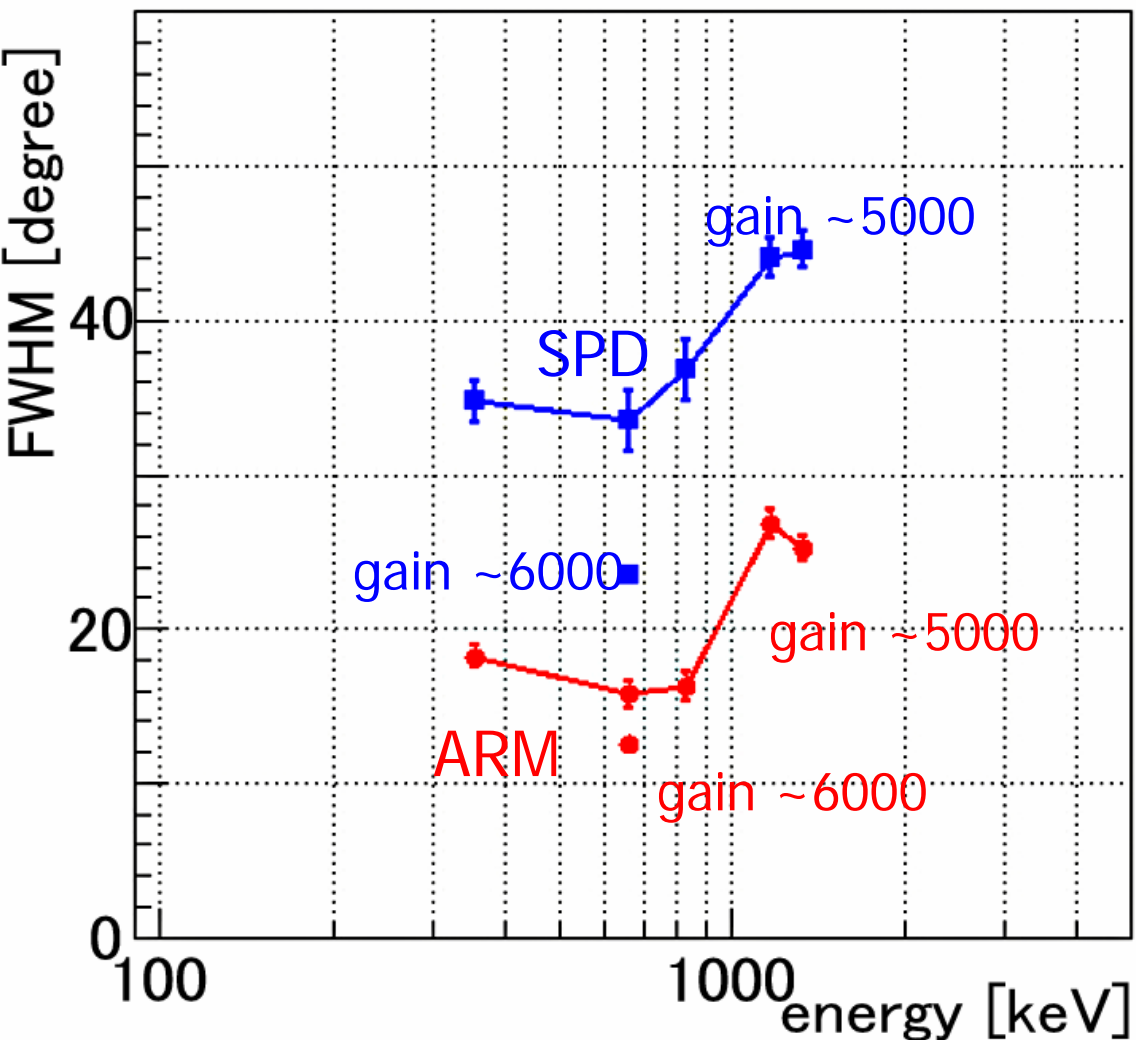
in **ring form**

Simply overlay
Hard to separate
2 sources

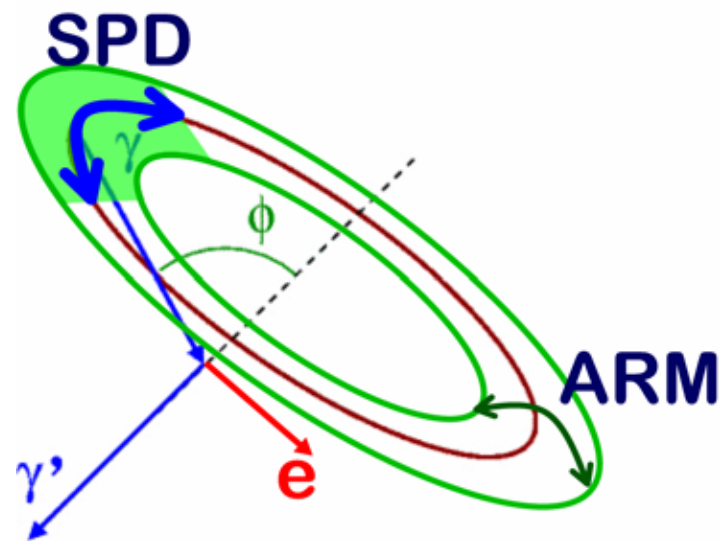


$^{137}\text{Cs}(1\text{MBq})\times 2$

Angular resolution



- ✓ SPD (Scatter Plane Deviation)
- ✓ ARM (Angular Resolution Measure)



cf.
MEGA

Si tracker + CsI(Tl)

- ARM 13.4 ° (2MeV, FWHM)
- SPD 84 ° (1.8MeV, FWHM)

A.Zoglauer, et. al.

IEEE Trans. Nucl. Sci. in press

34 ° @ 662keV FWHM

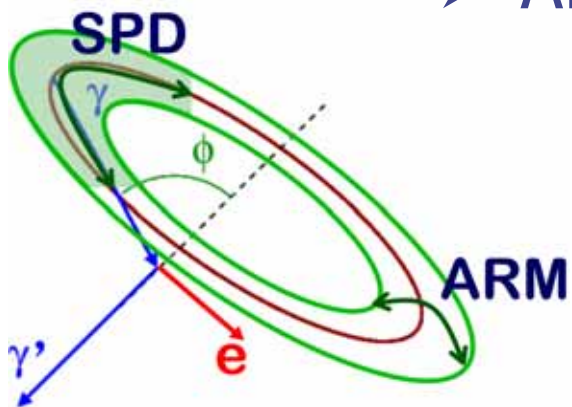
16 ° @ 662keV FWHM

for each gamma-ray

Gamma-ray imaging for unknown energy sources

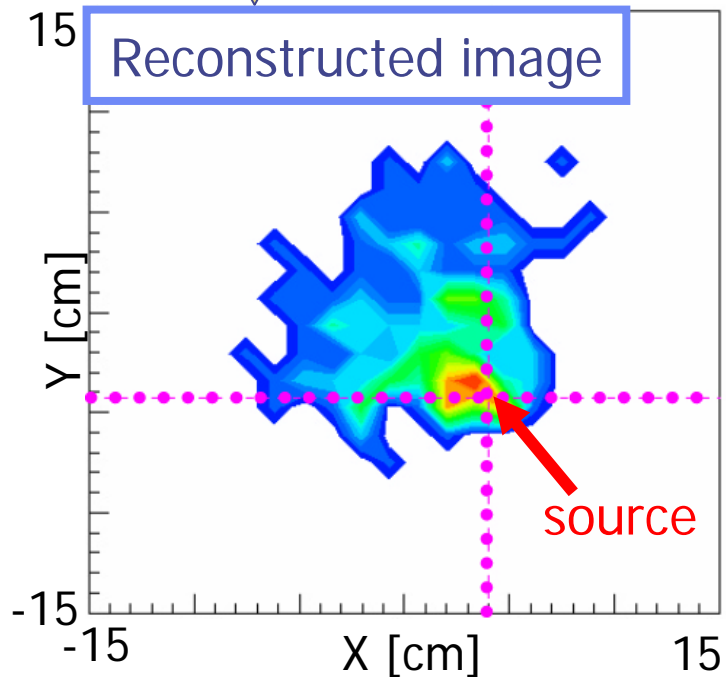
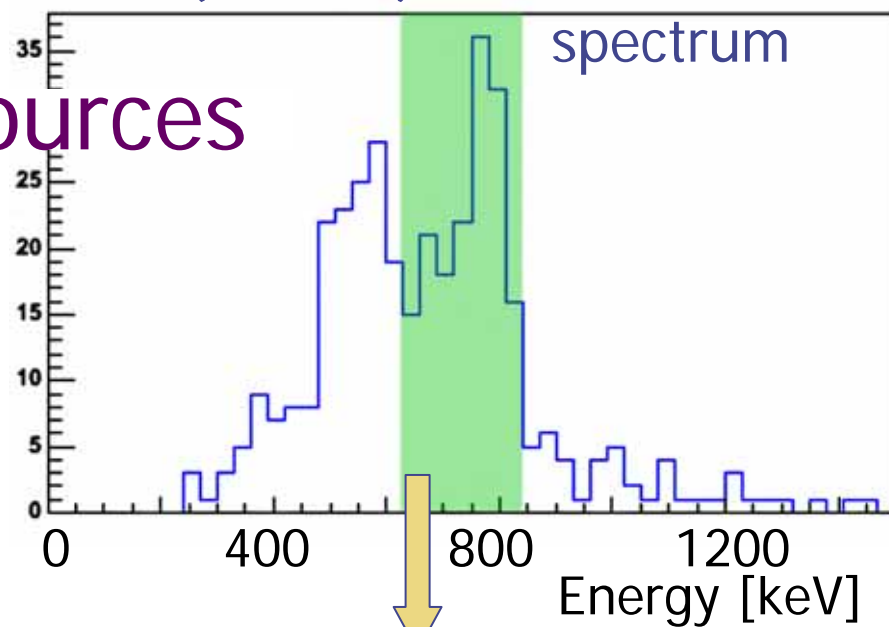
Measure scattered γ 's **energy** & **direction**
recoiled e^- 's **energy** & **direction**

➔ **Full reconstruction** of incident γ



➤ Angular res. (RMS)
ARM $\sim 15^\circ$
SPD $\sim 35^\circ$

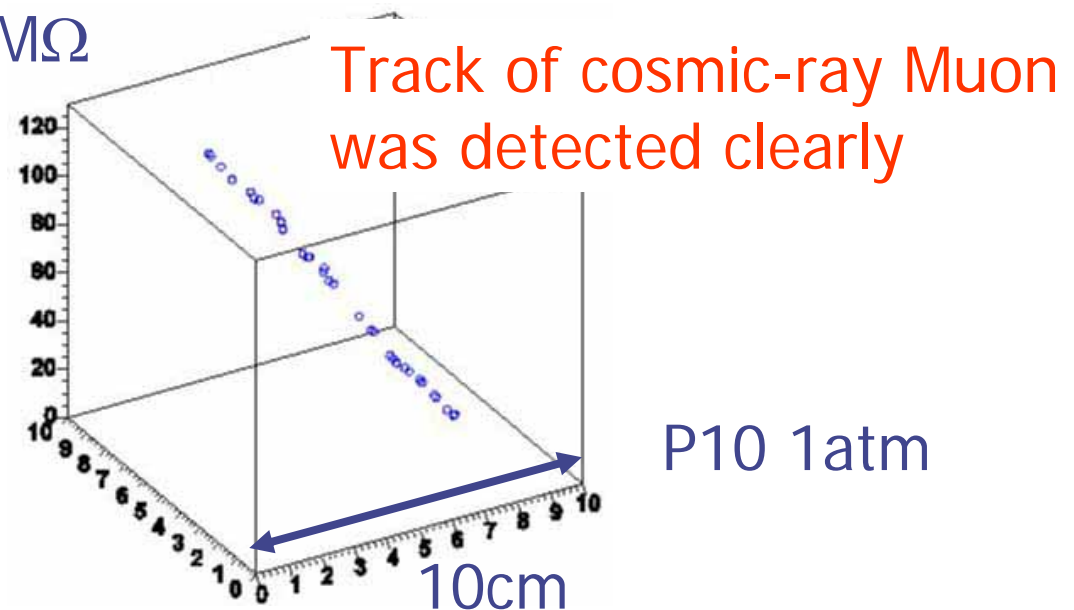
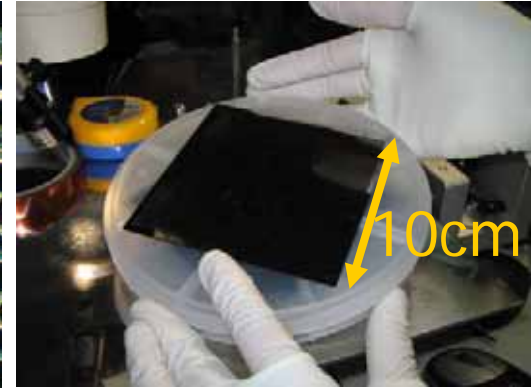
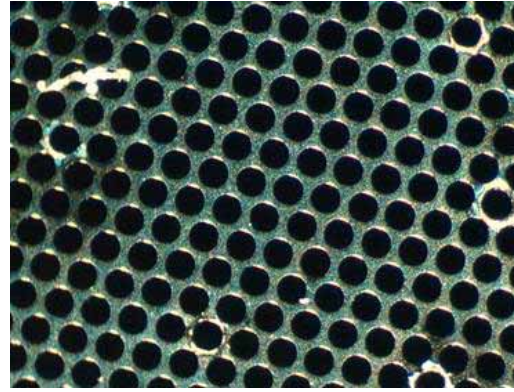
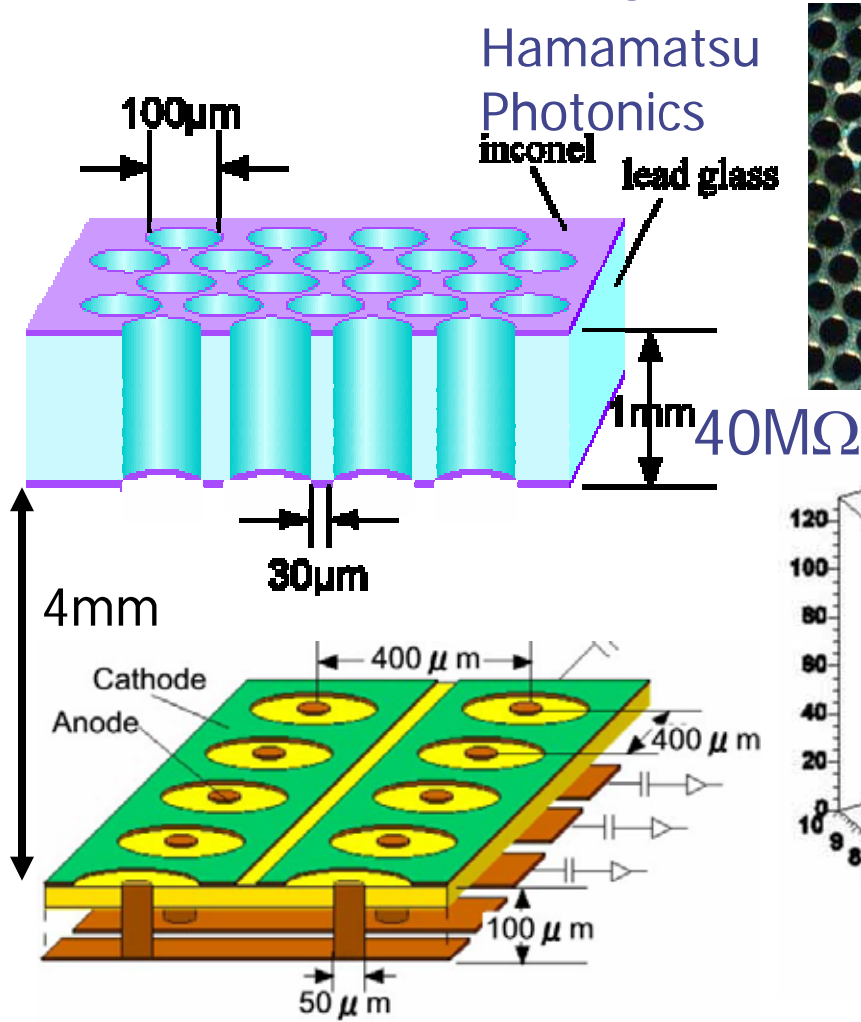
^{137}Cs (662keV) reconstructed spectrum



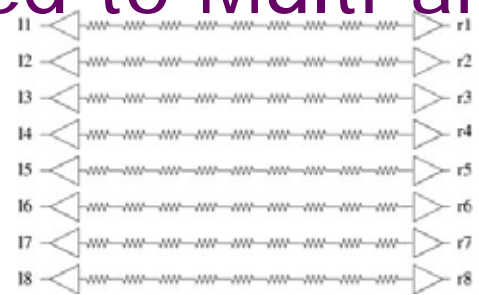
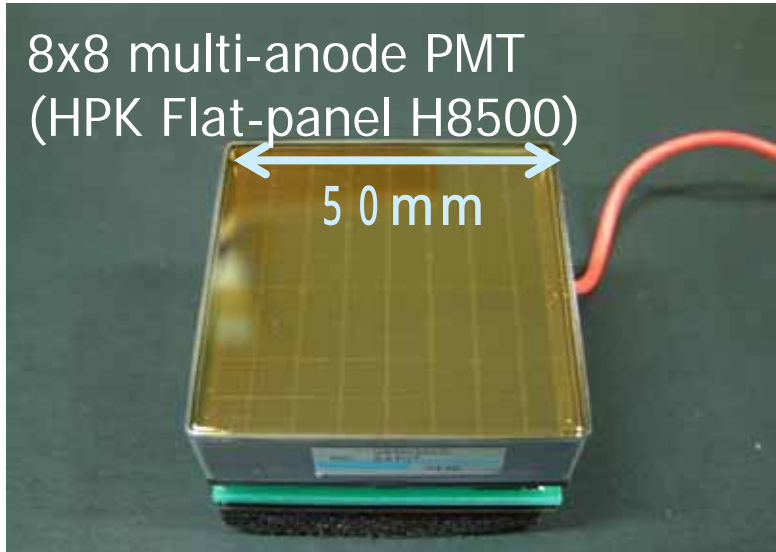
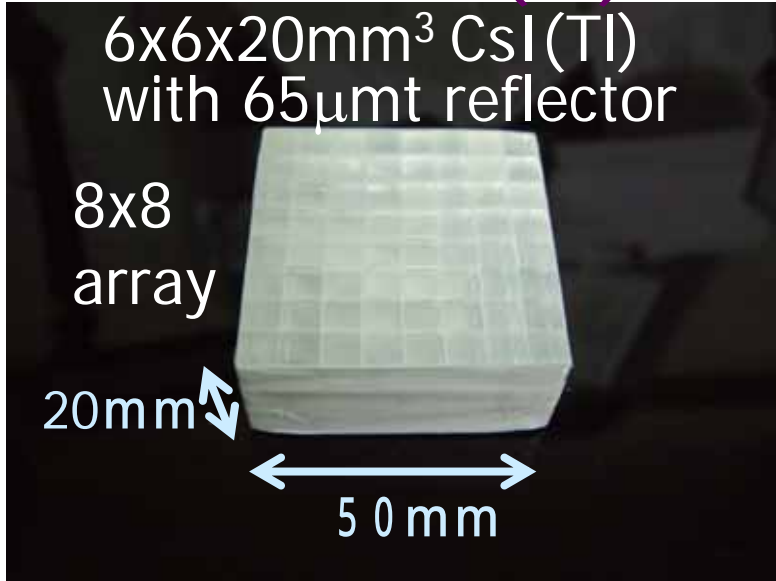
Improvement of gaseous TPC: μ -TPC with conductive capillary plate

stable gas gain of μ -PIC ~ 6000 : **not enough for MIP**

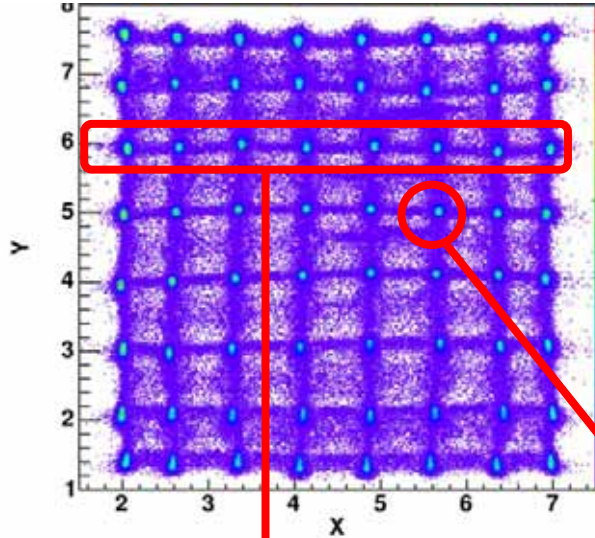
\Rightarrow Intermediate gas multiplier(X10) **Capillary Plate** is used



Improvement of scintillation camera: Pixellated CsI(Tl) coupled to Multi-anode PMT



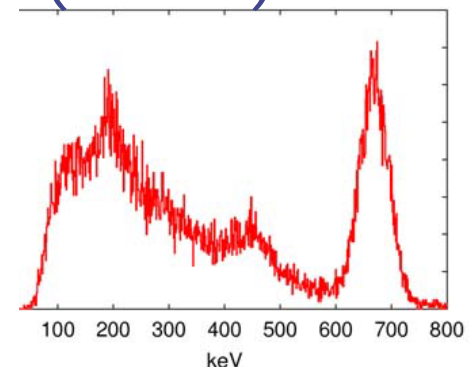
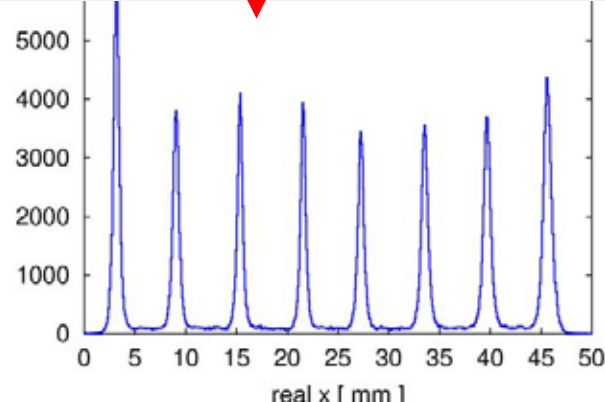
Charge division
readout with
resistor chain



Reconstructed
γ-ray image

Energy
Resolution

9.0% @ 662keV
(FWHM)



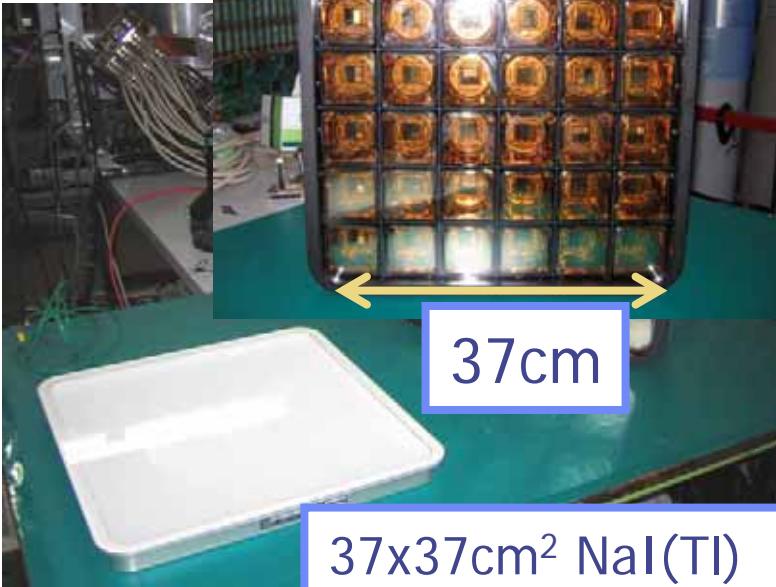
Other improvements

- Scintillation camera
 - NaI(Tl) Anger camera $10 \times 10 \text{cm}^2 \Rightarrow 37 \times 37 \text{cm}^2$
 - Pixel array: CsI(Tl) 20mm \Rightarrow GSO(Ce) 13mm (1 rad. length) to reduce DOI error
 - Readout with low power ASIC (IDE VA32_hdr11/TA32cg)
- μ -TPC : $10 \times 10 \times 8 \text{cm}^3 \Rightarrow 30 \times 30 \times 30 \text{cm}^3$



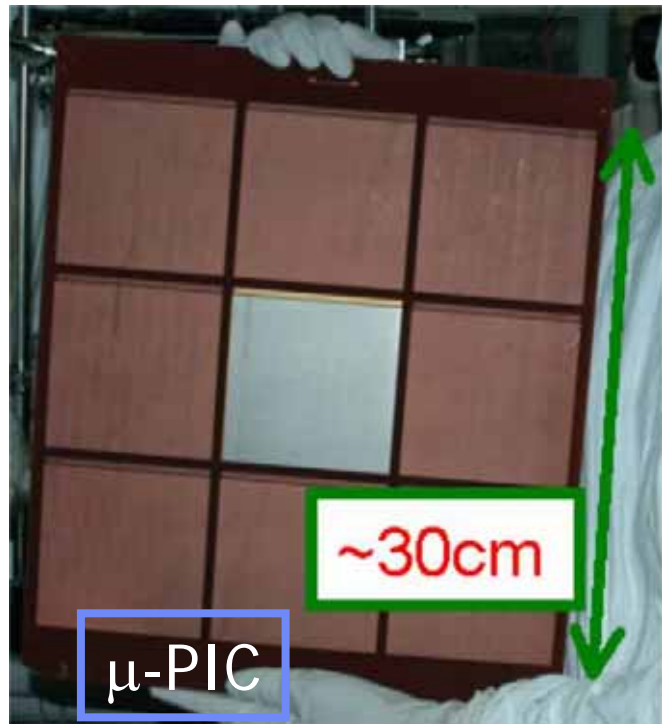
49mm

GSO(Ce)
8x8 array



37cm

37x37cm² NaI(Tl)
Anger camera



~30cm

μ -PIC

Summary

- ✓ We developed Compton gamma-ray imager using electron tracking gaseous TPC and scintillation camera
- ✓ Event by event reconstruction was successful
- ✓ Good background rejection capability
 - ⇒ higher S/N than that of classical Compton Meth.
- ✓ Prototype performance for 662keV gamma-ray
 - ARM(FWHM) 16 ° SPD(FWHM) 34 °



Goal: All sky survey in sub-MeV and MeV region with better sensitivity by order of mag. than COMPTEL

500keV(FWHM) ARM ~7 ° SPD ~20 °

1MeV(FWHM) ARM ~5 ° SPD ~15 °