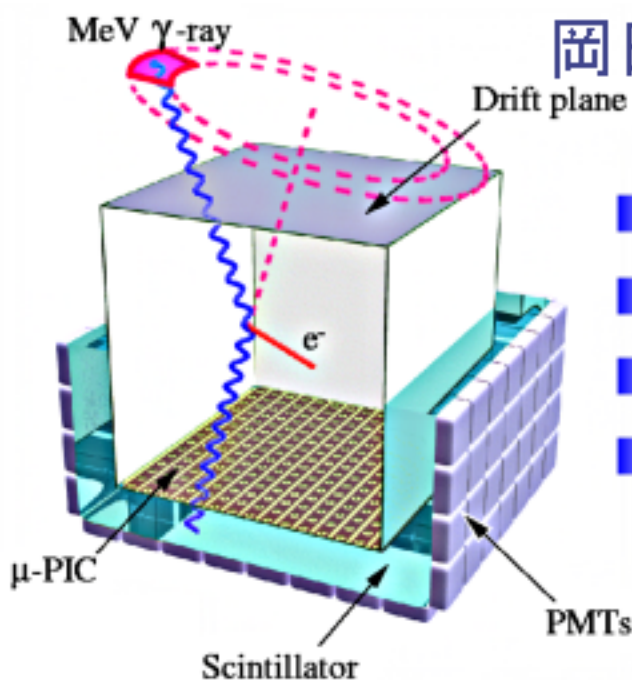




# $\mu$ -PICを用いた MeV- $\gamma$ 線カメラの開発

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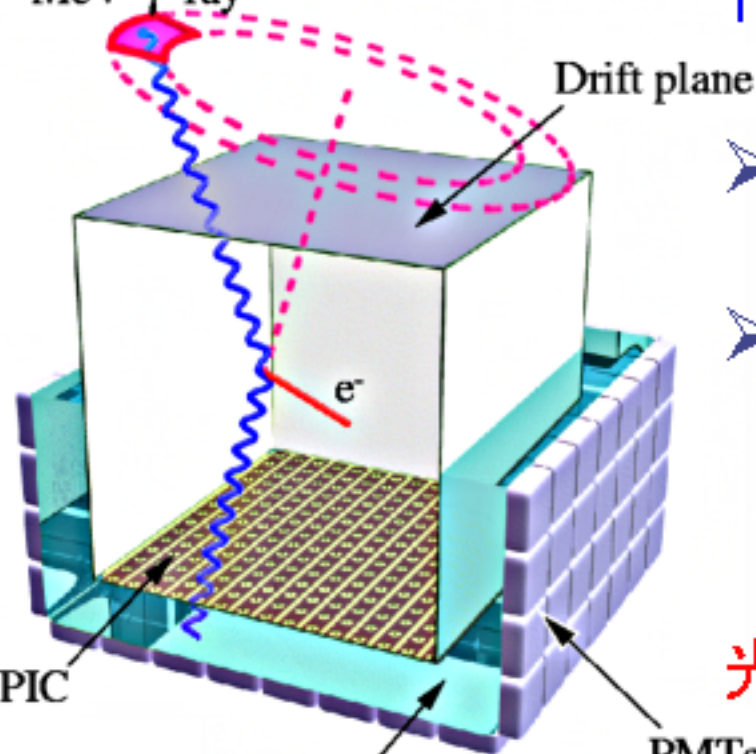


- MeV gamma-ray imaging
- プロトタイプの性能評価
- 大型化への道
- まとめ



# Advanced Compton Imaging

MeV  $\gamma$ -ray



Target: sub MeV~MeVの $\gamma$ 線  
 $\Rightarrow$  MeV- $\gamma$ 線天文学・医学など

➤ micro-TPC ( $\mu$ -PIC)

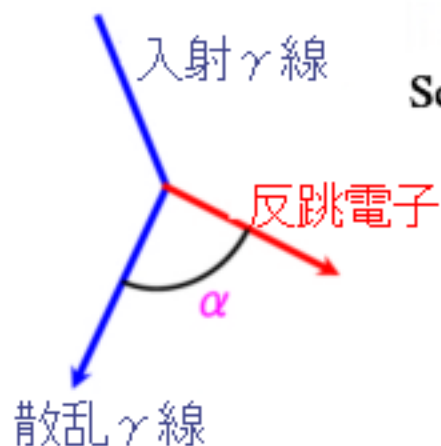
反跳電子の飛跡とenergy

➤ Scintillator

散乱 $\gamma$ 線の吸収点の位置  
とenergy



光子毎にCompton散乱を再現



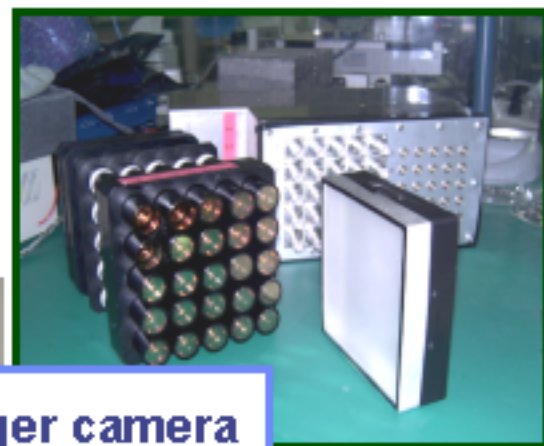
◆ 1光子  $\Rightarrow$  到来方向 + energy

◆ 大きな視野 ( $\sim 3\text{str}$ )

◆ 強力なbackground除去能力

$$\cos \alpha_{\text{geo}} = \vec{g} \cdot \vec{e} \iff \cos \alpha_{\text{kin}} = \left(1 - \frac{m_e c^2}{E_\gamma}\right) \sqrt{\frac{K_e}{K_e + 2m_e c^2}}$$

# Prototype Compton camera



Anger camera

micro TPC  
 $10 \times 10 \times 8 \text{ cm}^3$   
Ar + C<sub>2</sub>H<sub>6</sub> (9:1)  
NaI(Tl) Anger  
4"×4"×1" 25 PMTs  
位置分解能  
~4.5mm (RMS)  
energy分解能  
~9%  
(662keV, FWHM)

memory board  
on VME bus

preamp

RI source

encoder

micro-TPC  
( $\mu$ -PIC)

**No Veto or Shield !**

# Typical event

uPIC8/20031017/per1 Cs137  
track 648-65

$E_\gamma$  : 566.25 keV  
 $K_\theta$  : 126.60 keV  
 $E_0$  : 692.85 keV

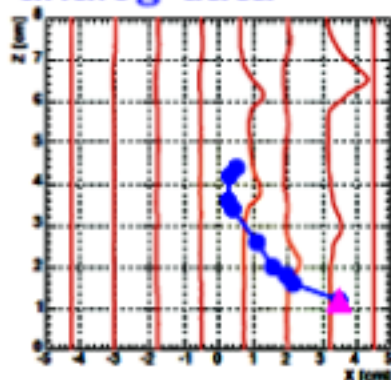
$\alpha_{\text{geo}} = 91.18^\circ$   
 $\alpha_{\text{kin}} = 88.14^\circ$   
 $\phi = 33.37^\circ$   
 $\psi = 54.77^\circ$

$L_e \leq 1.18 \times 10^{-3} K_e^{2.2} + 1$   
 $\alpha_{\text{geo}} \geq \alpha_{\text{kin}} - 5^\circ$   
 $\chi_{\text{track}} = 0.03$   
 $|\alpha_{\text{geo}} - \alpha_{\text{kin}}| = 3.04^\circ$

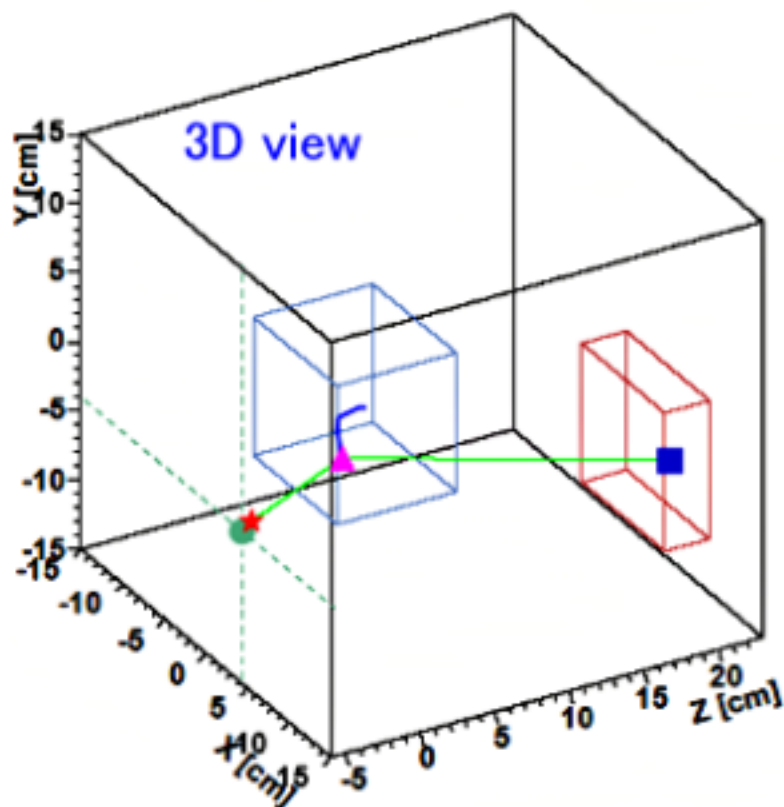
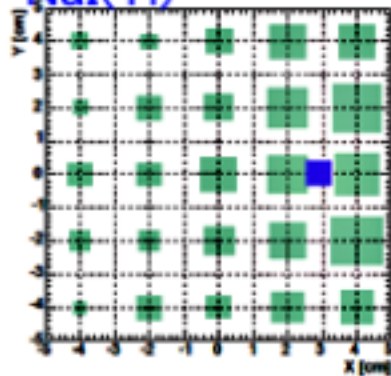
$\theta = 13.09^\circ$   
 $\Delta\phi = -3.11^\circ$   
 $\Delta\delta = -21.81^\circ$

- : source position
- ★ : reconstructed
- ▲ : Compton point
- : NaI hit

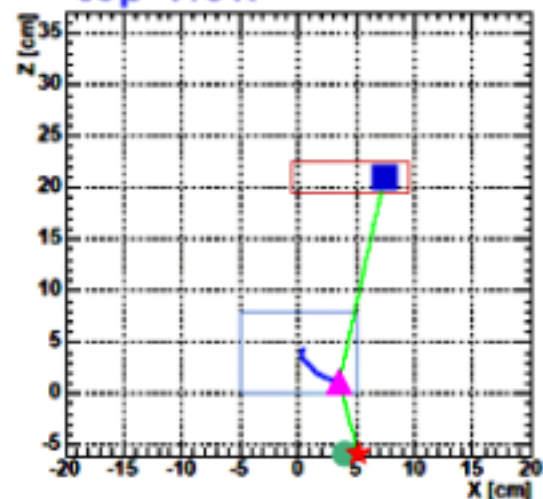
analog data



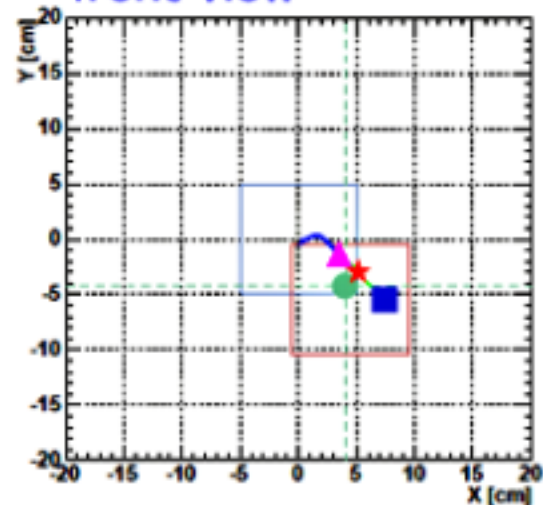
NaI(Tl)



top view



front view



# Gamma-ray imaging

反跳電子のtrack

散乱  $\gamma$  線の方向とenergy

入射  $\gamma$  線のenergy : 既知のパラメータ



入射  $\gamma$  線の到来方向を再構成

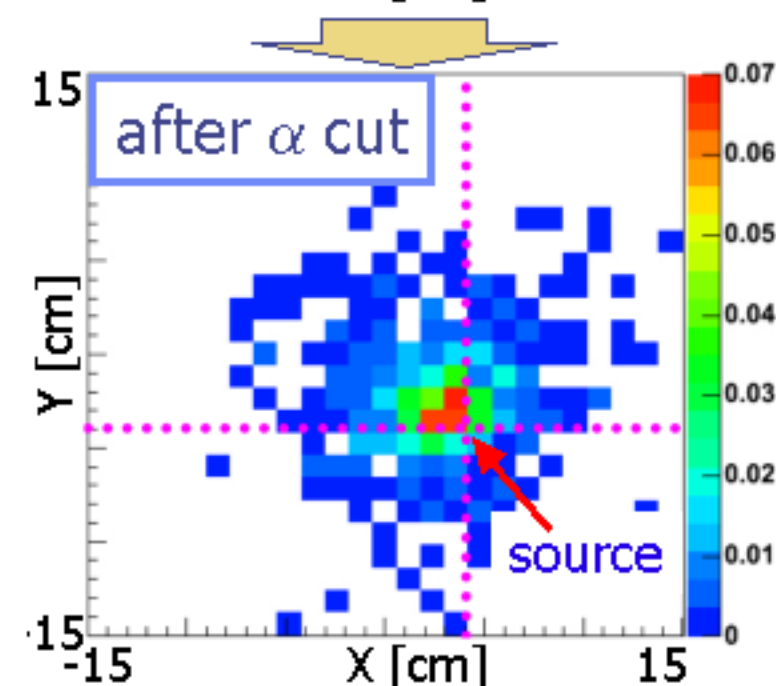
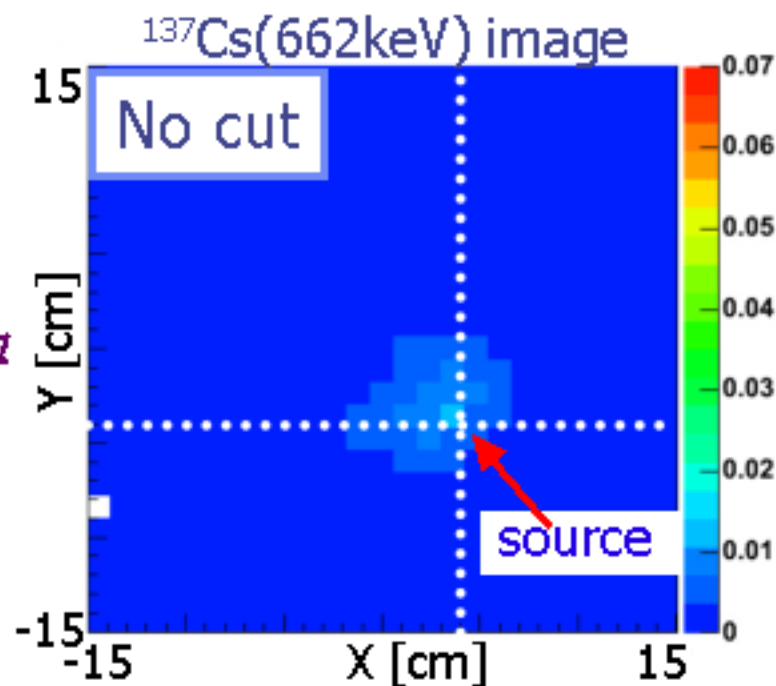
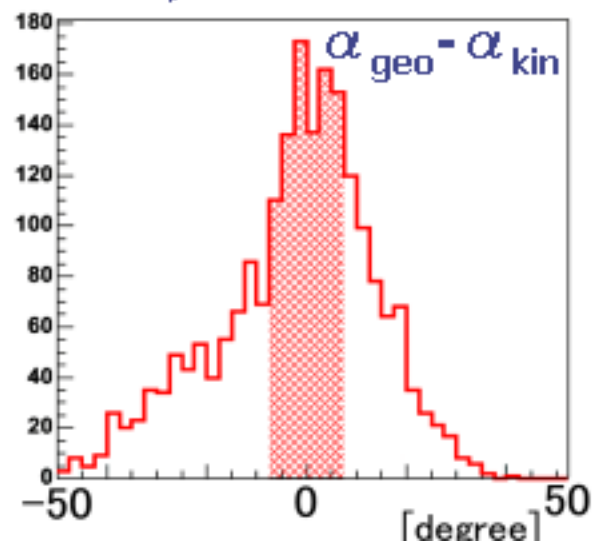
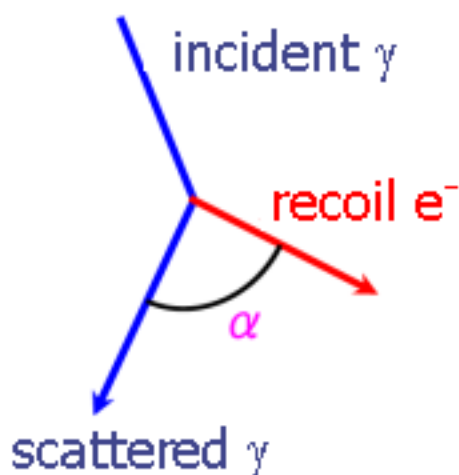
## ◆ Background rejection

$\alpha_{\text{geo}}$  : 幾何学的な $\alpha$

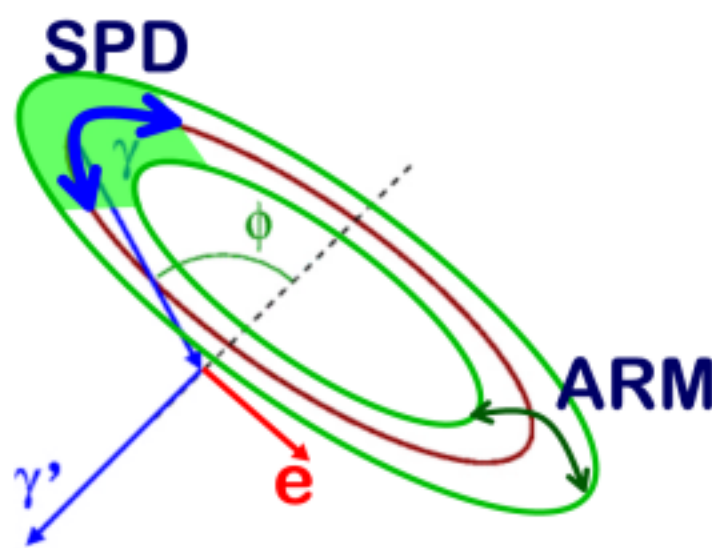
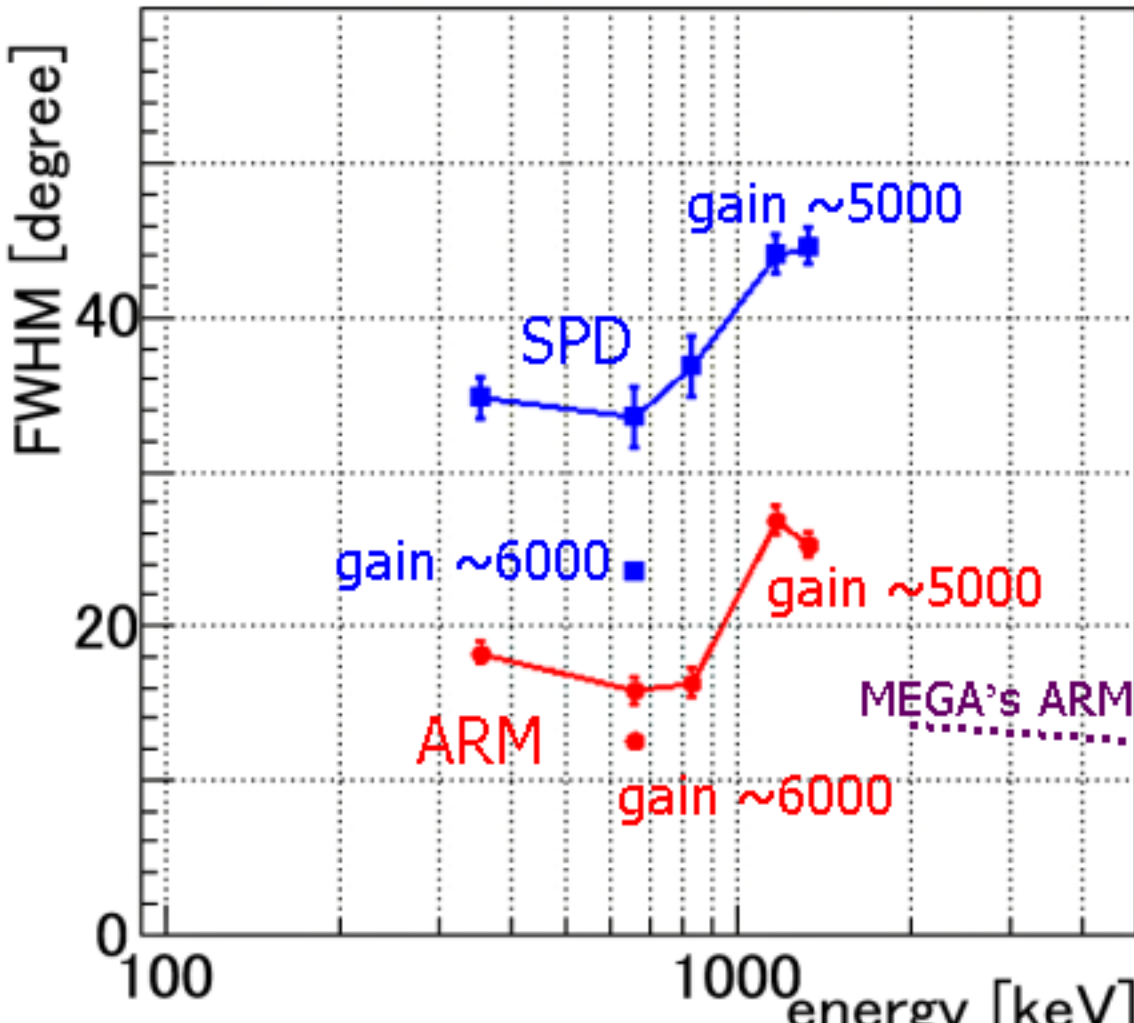
$\alpha_{\text{kin}}$  : 運動学からの $\alpha$

$\alpha$  cut

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



# 角度分解能



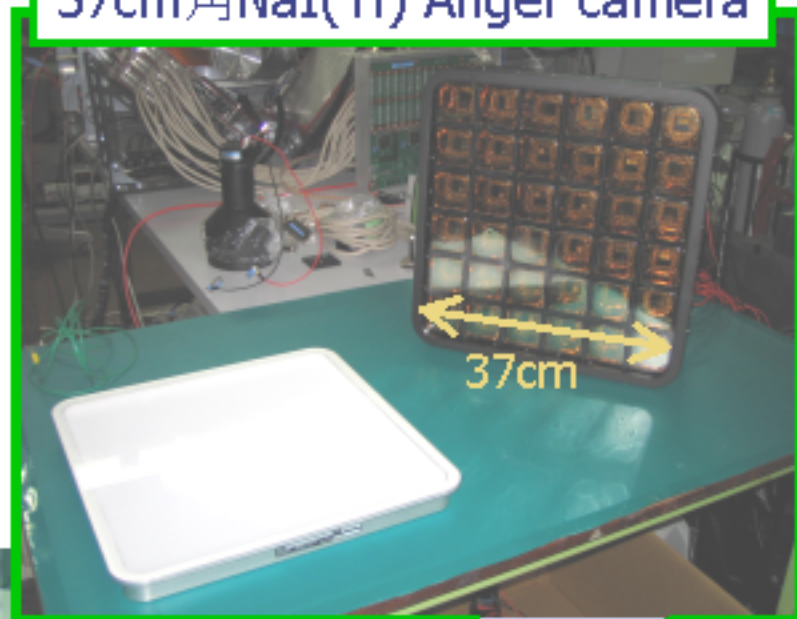
MEGA  
 Si tracker + CsIシンチ

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

A.Zoglauer, et al.  
 IEEE Nucl. Sci. Sym. Conf. 2003

- ✓ ARM (Angular Resolution Measure) 16° @ 662keV FWHM
- ✓ SPD (Scatter Plane Deviation) 34° @ 662keV FWHM

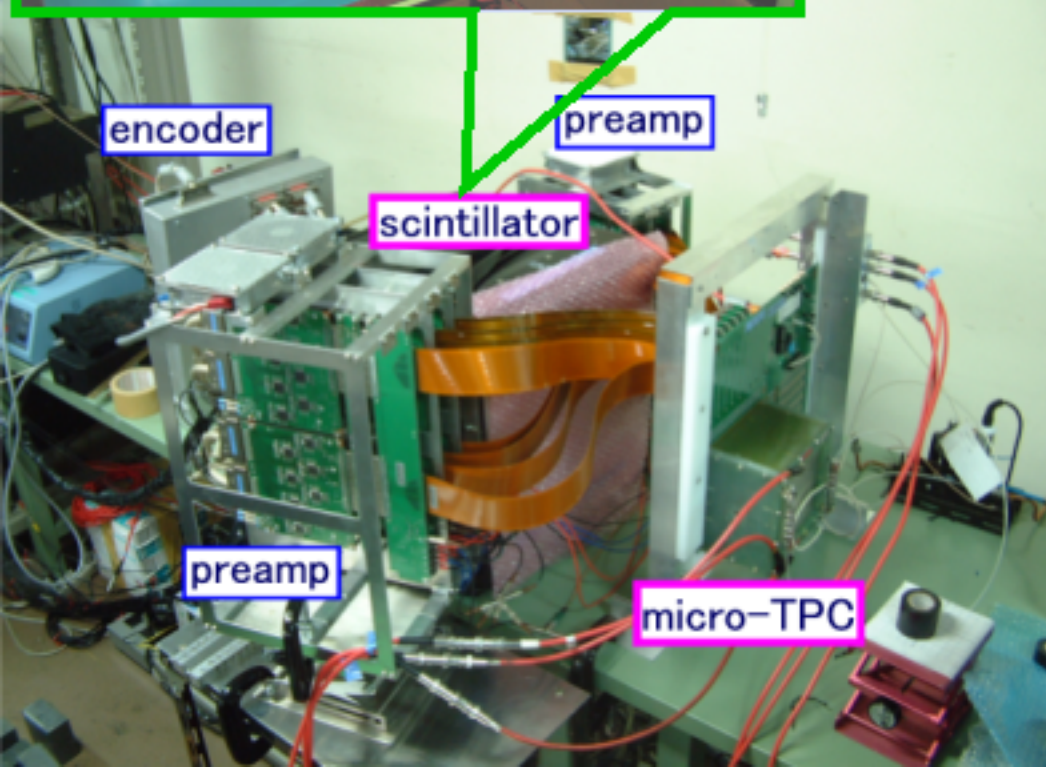
37cm角NaI(Tl) Anger camera



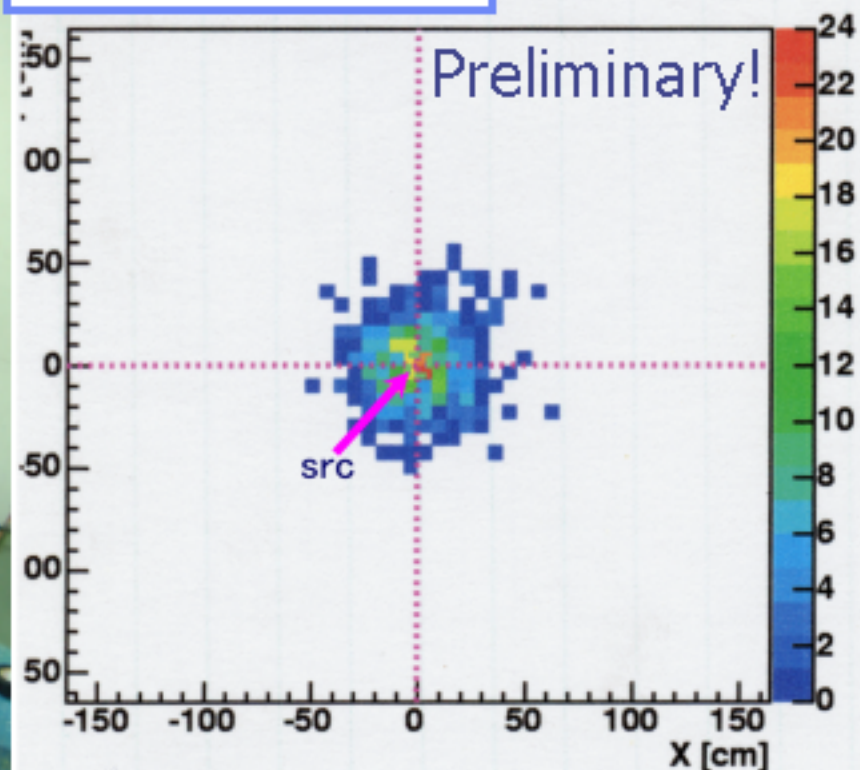
## カメラの大型化へ

$10 \times 10 \times 8\text{cm}^3$  micro-TPC  
+ 37cm角NaI(Tl) Anger camera

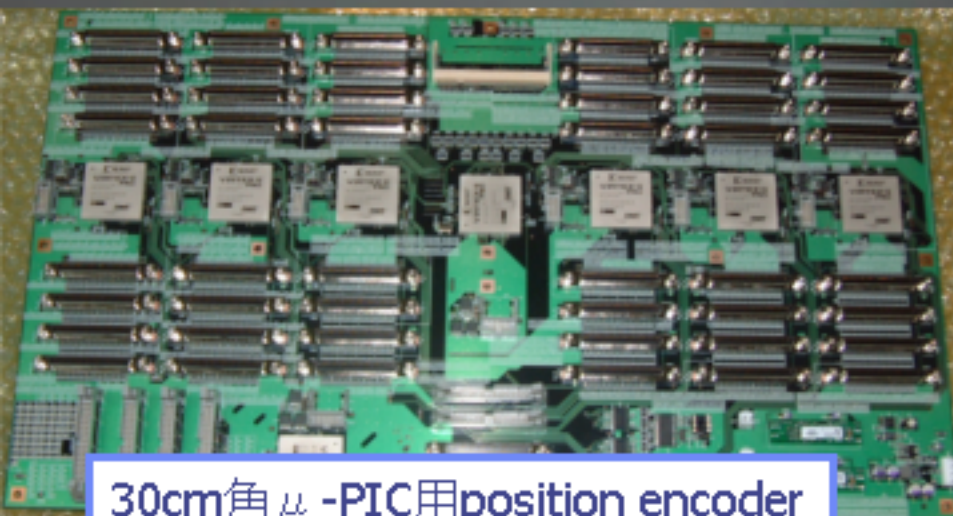
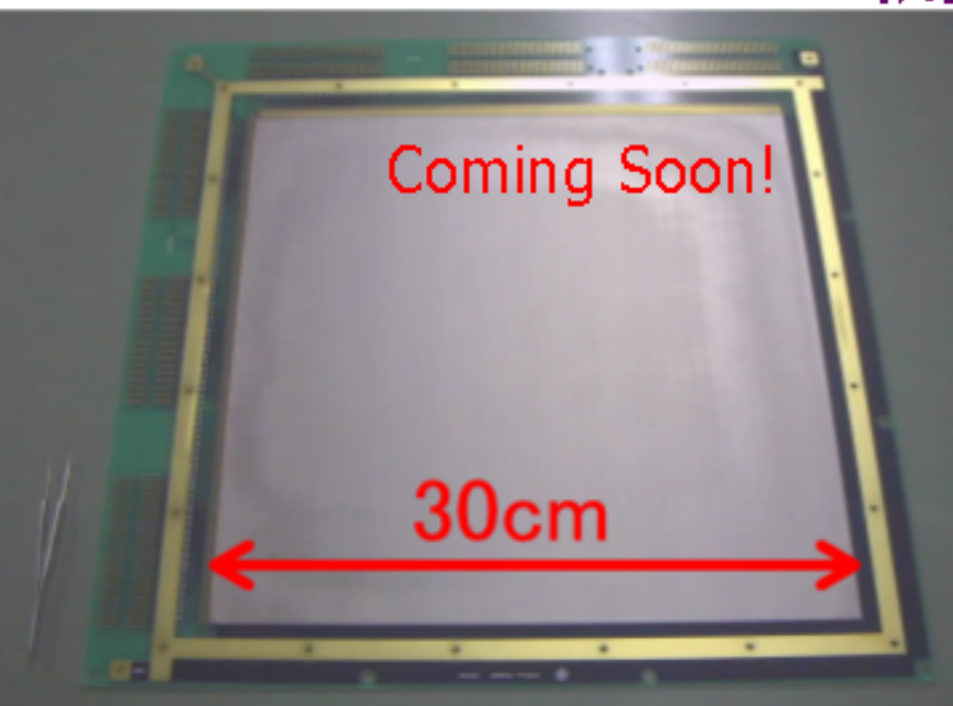
⇒ 実験室にて動作中!!



$^{133}\text{Ba}$  (356 keV)



# 30cm cube TPCの開発



## 10cm cube TPC

- $>60\text{keV}$ の電子はescape  
⇒ energyを捕らえきれない
- Compton確率 小



TPCの体積拡大!!

## 30cm cube TPC

- $\sim 200\text{keV}$ の電子まで
  - Compton確率  $\sim 30$ 倍
- ⇒ {
- 入射 $\gamma$ 線のenergyも
  - 検出効率の向上



## まとめ

- Compton imagingにおいて反跳電子の情報は重要
- ガスTPCを用いた  
Advanced Compton Imagingは  $\mu$ -PICにより実証済
- 反跳電子を捕らえるには  
半導体のstackよりもガスTPC



- ◆ 30cm cube TPCの開発
- ◆ simulationを用いた  $\mu$ -PICのpixel改良



検出効率・角度分解能の向上  
入射  $\gamma$  線のenergyの同定も可能に