ガス飛跡検出機を用いた ガンマ線コンプトンイメージング検出器の開発

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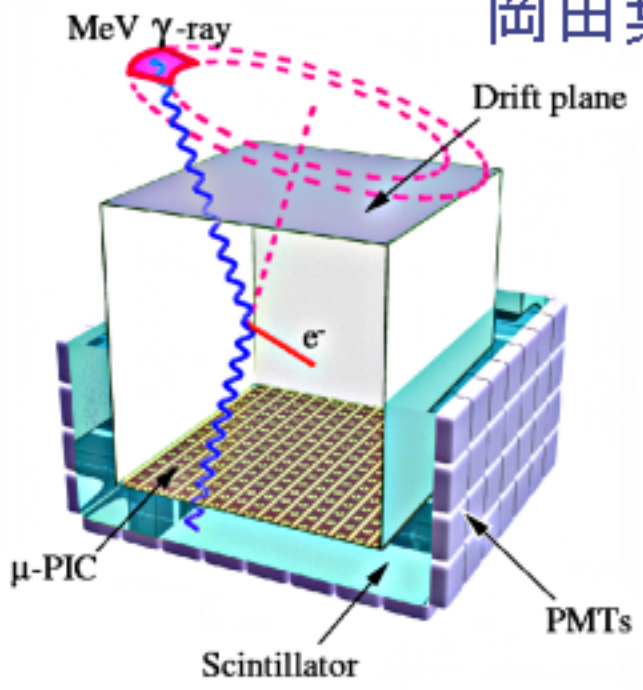
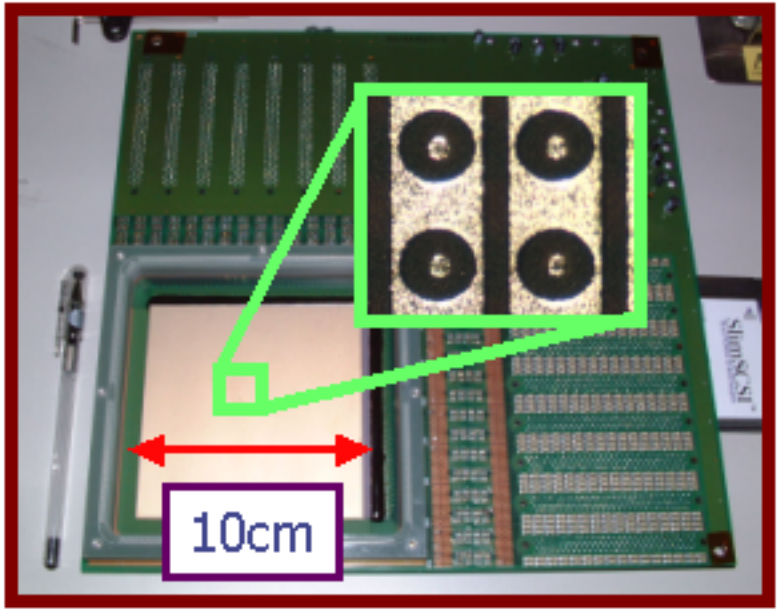
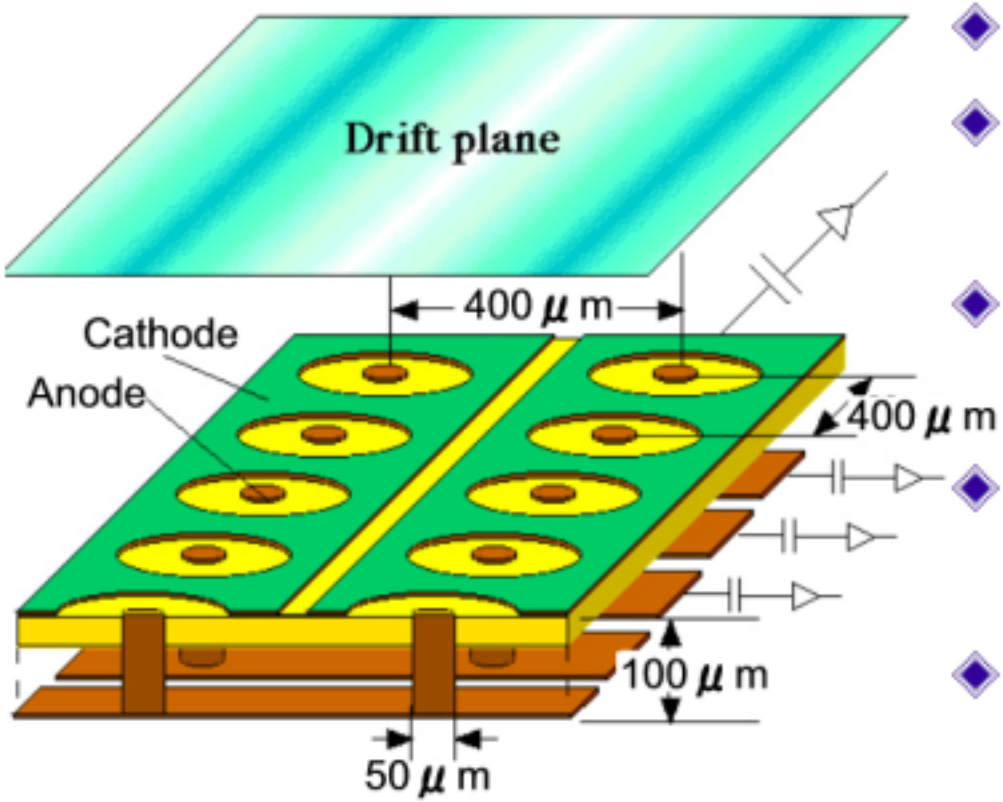


- ガス検出器 μ-PIC
  & 飛跡検出器 micro-TPC
- プロトタイプ性能評価
- まとめ

The character and structure of μ-PIC

- 2次元読出し (~65000pixels)
- 大面積 (10cm×10cm)
- プリント基板の技術により製作



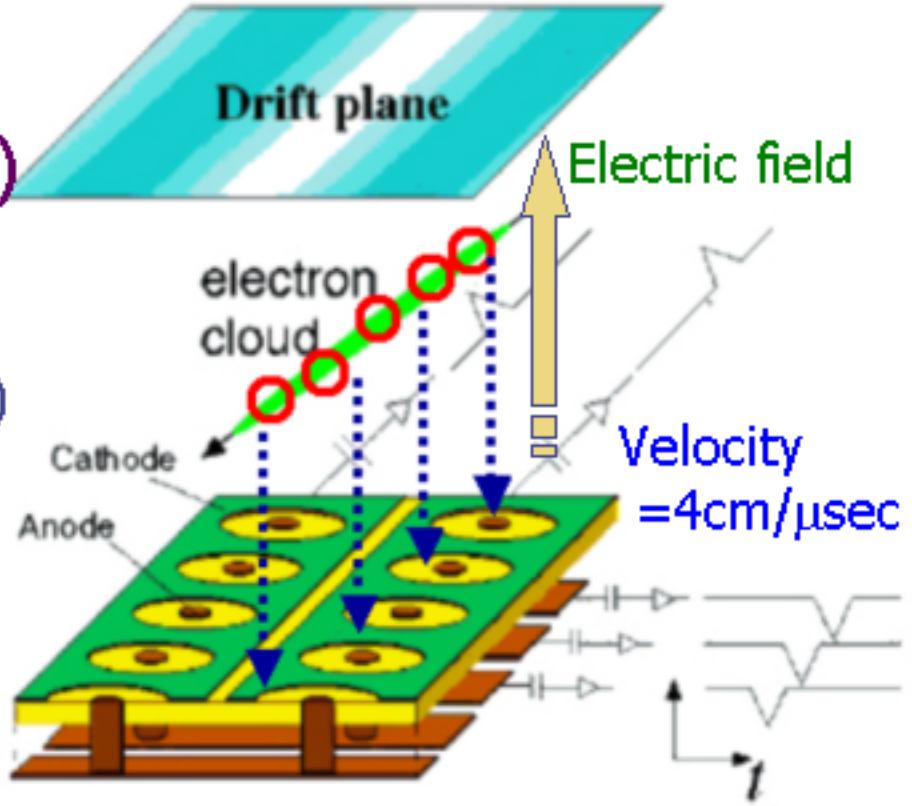


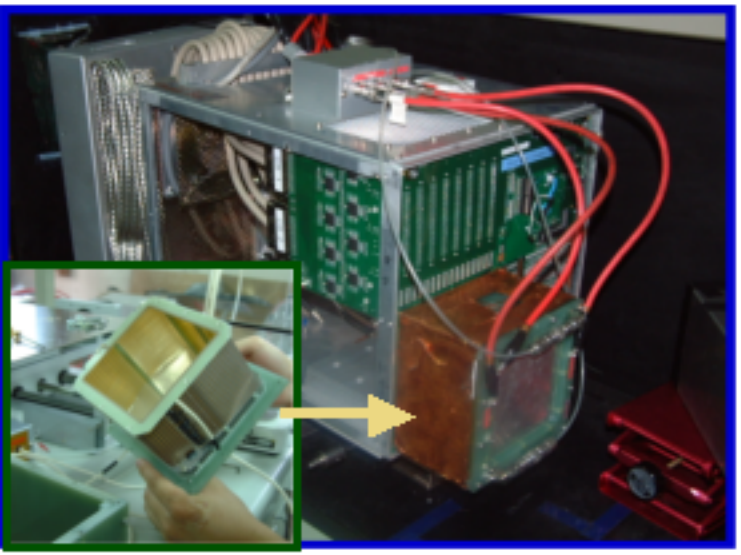
- max gas gain ~16000
- エネルギー分解能
  30% @ 5.9keV (100cm^2)
- 1000時間以上の安定動作
  @ gas gain ~6000
- 一様なgas gain
  4.5% @ 100cm^2
- 高い位置分解能
  (~120μm)

micro-TPC
(Time Projection Chamber)

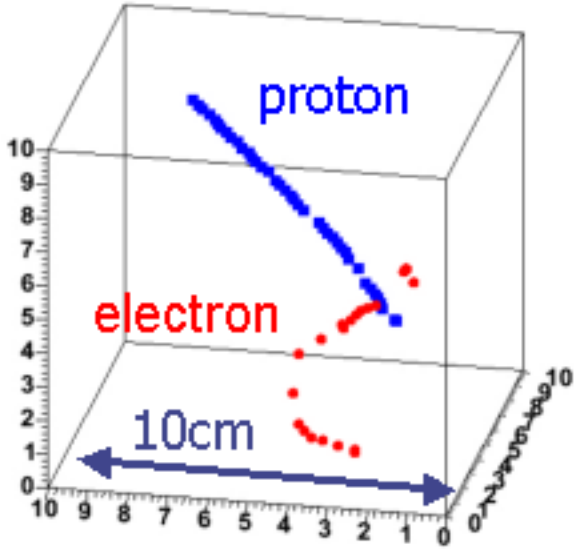
- ✓ 10cm×10cm μ-PIC
  ⇒ 2次元情報
- ✓ 8cm drift cage (E=0.4kV/cm)
  ⇒ drift time

micro-TPC
⇒ 3次元位置情報

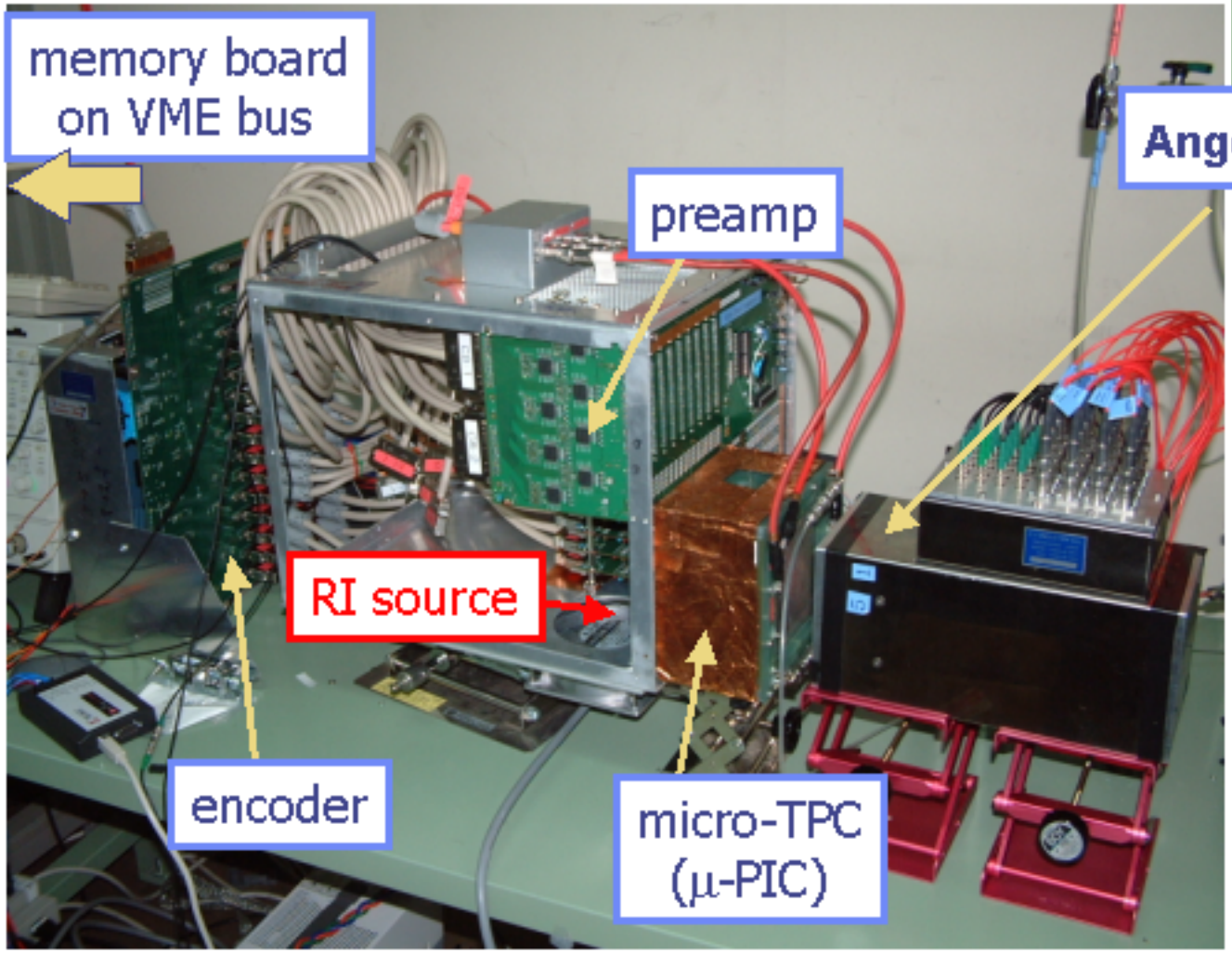


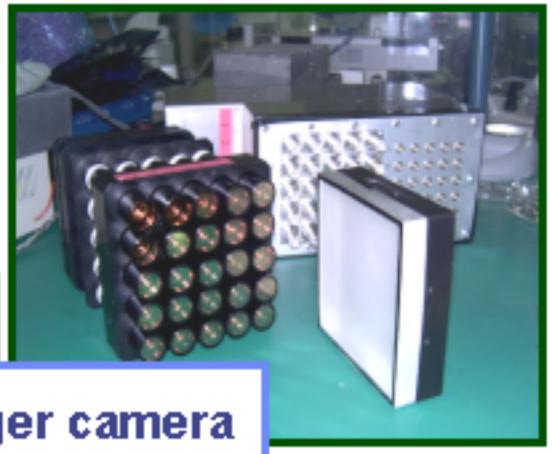


Typical tracks
Ar 90% C_2H_6 10%
gas gain ~5000
proton
E ~1MeV
electron
E ~500keV



Prototype Compton camera





micro TPC
10×10×8 cm^3
Ar +C_2H_6 (9:1)
NaI(Tl) Anger
4″×4″×1″ 25 PMTs
position resolution
~4.5mm (RMS)
energy resolution
~9%
(662keV, FWHM)

No Veto or Shield !

Typical event

uPIC8/20031017/per1 Cs137
track 648-65

E_γ : 566.25 keV
K_e : 126.60 keV
E_0 : 692.85 keV

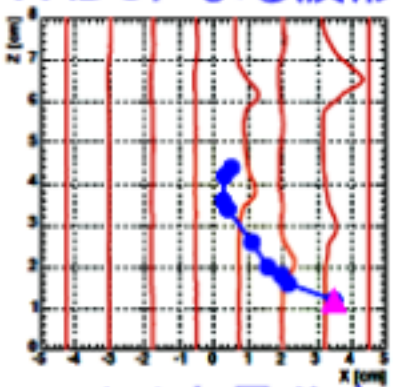
α_{geo} = 91.18°
α_{kin} = 88.14°
ϕ = 33.37°
ψ = 54.77°

$L_e \leq 1.18 \times 10^{-3} K_e^{2.2} + 1$
$\alpha_{geo} \geq \alpha_{kin} - 5°$
χ^2_{track} = 0.03
$|\alpha_{geo} - \alpha_{kin}|$ = 3.04°

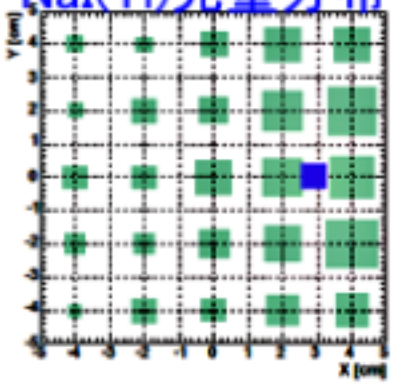
θ = 13.09°
$\Delta\phi$ = -3.11°
$\Delta\delta$ = -21.81°

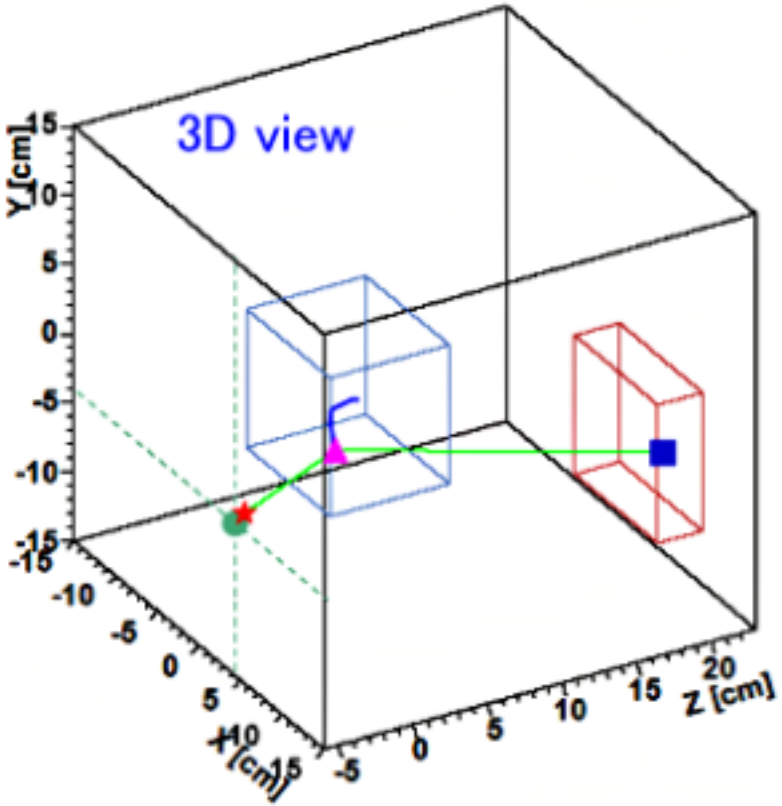
● : source position
★ : reconstruted
▲ : Compton point
■ : NaI hit

FADCによる波形

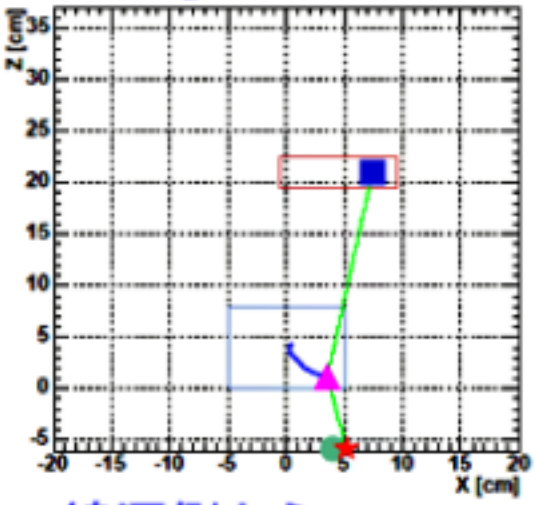


NaI(TI)光量分布

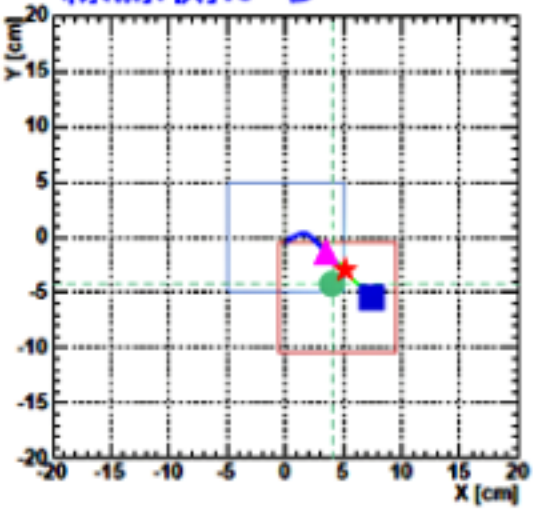




上から



線源側から



Gamma-ray imaging

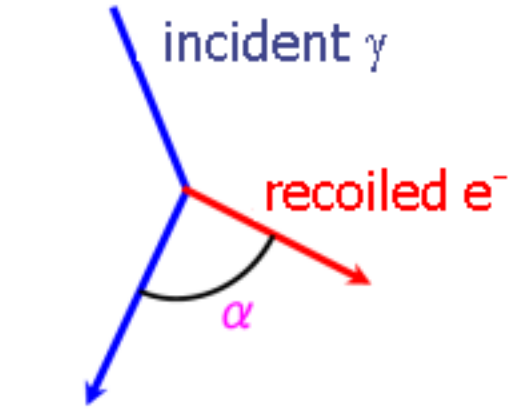
反跳電子の飛跡
散乱γ線の方向・エネルギー
入射γ線のエネルギー（既知）

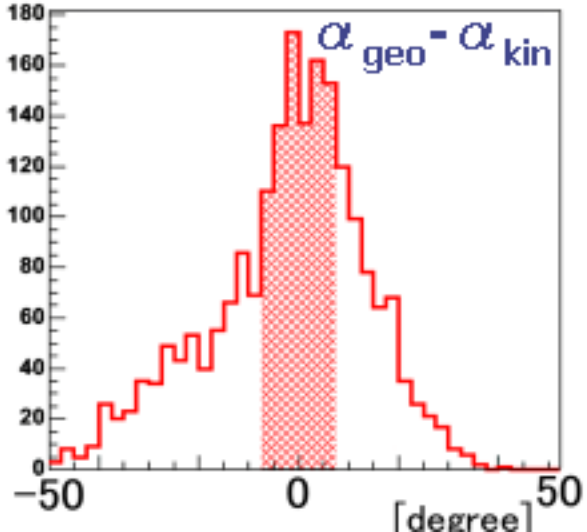
入射方向の再構成

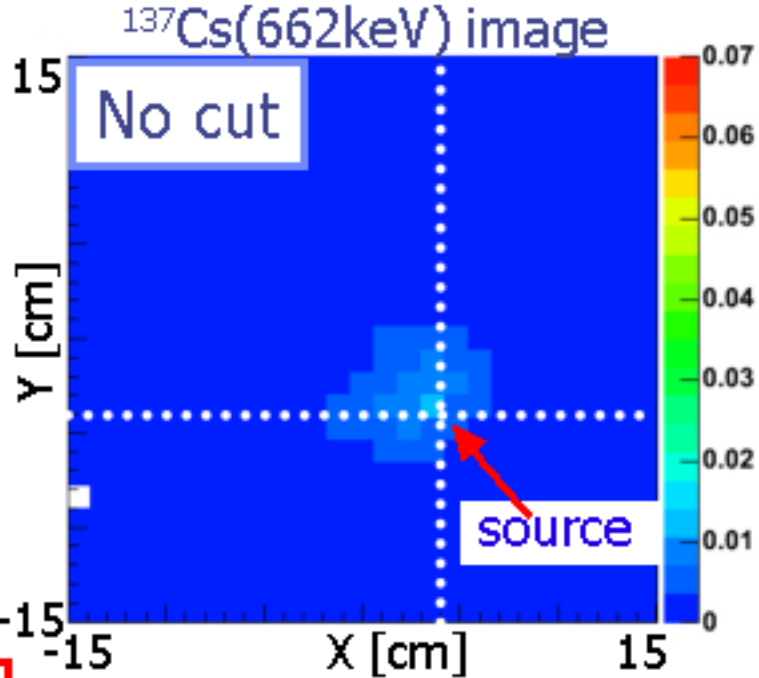
- Background除去

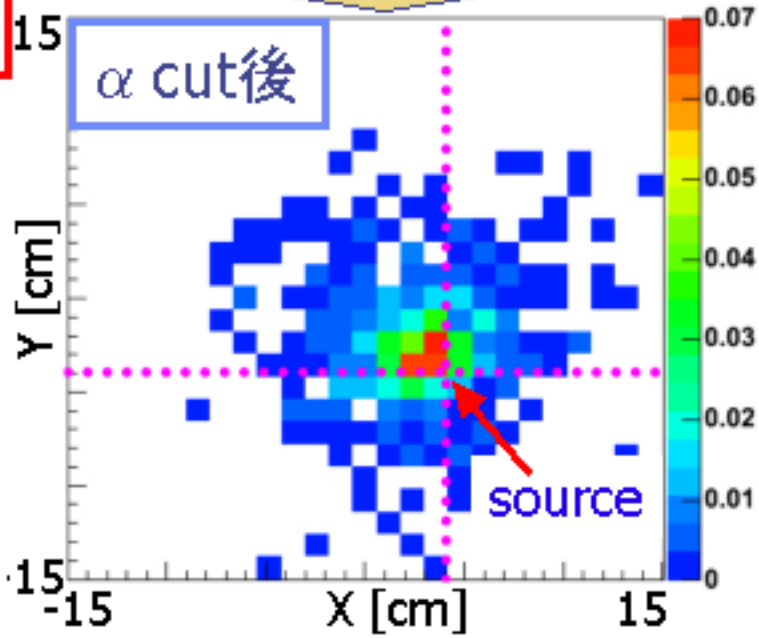
α_{geo}：幾何的な測定によるα
α_{kin}：運動学的な計算による

α cut
$\alpha_{geo} \sim \alpha_{kin}$







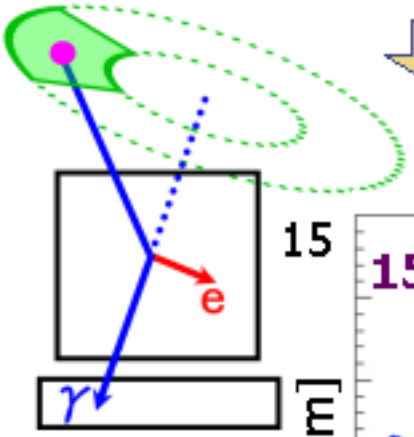


従来のコンプトン法との比較

Advanced Compton Meth.

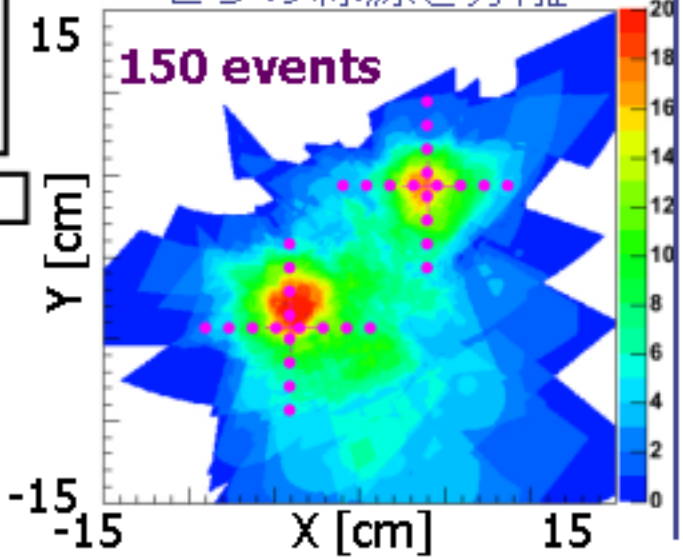
電子の反跳方向を測定

- 到来方向を一意に決定
- 誤差範囲は扇形



Simply overlay

少ないevent数で
2つの線源を分離

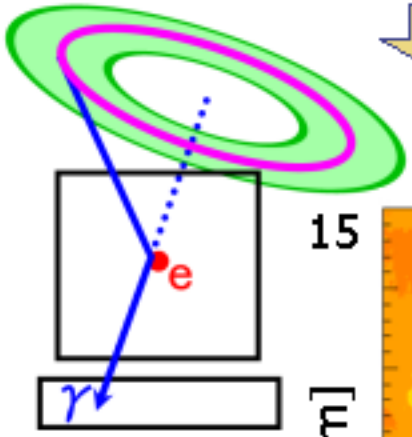


^{137}Cs(1MBq)×2, Advanced Compton

Classical Compton Meth.

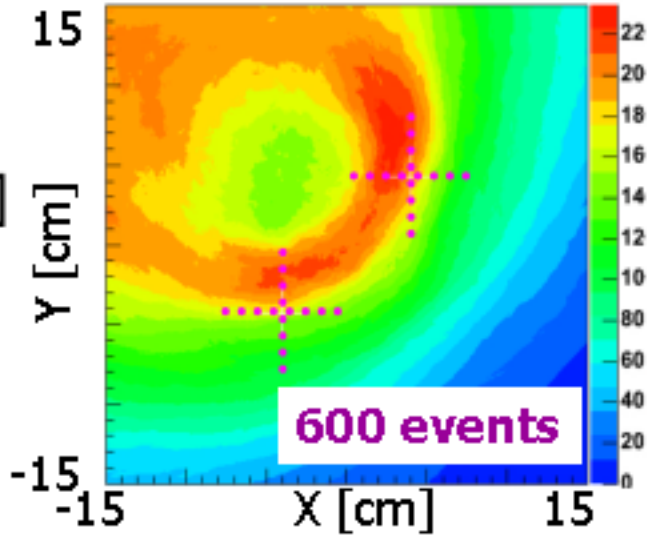
電子の反跳方向を破棄

- 到来方向を円形に制限
- 誤差範囲はドーナツ型



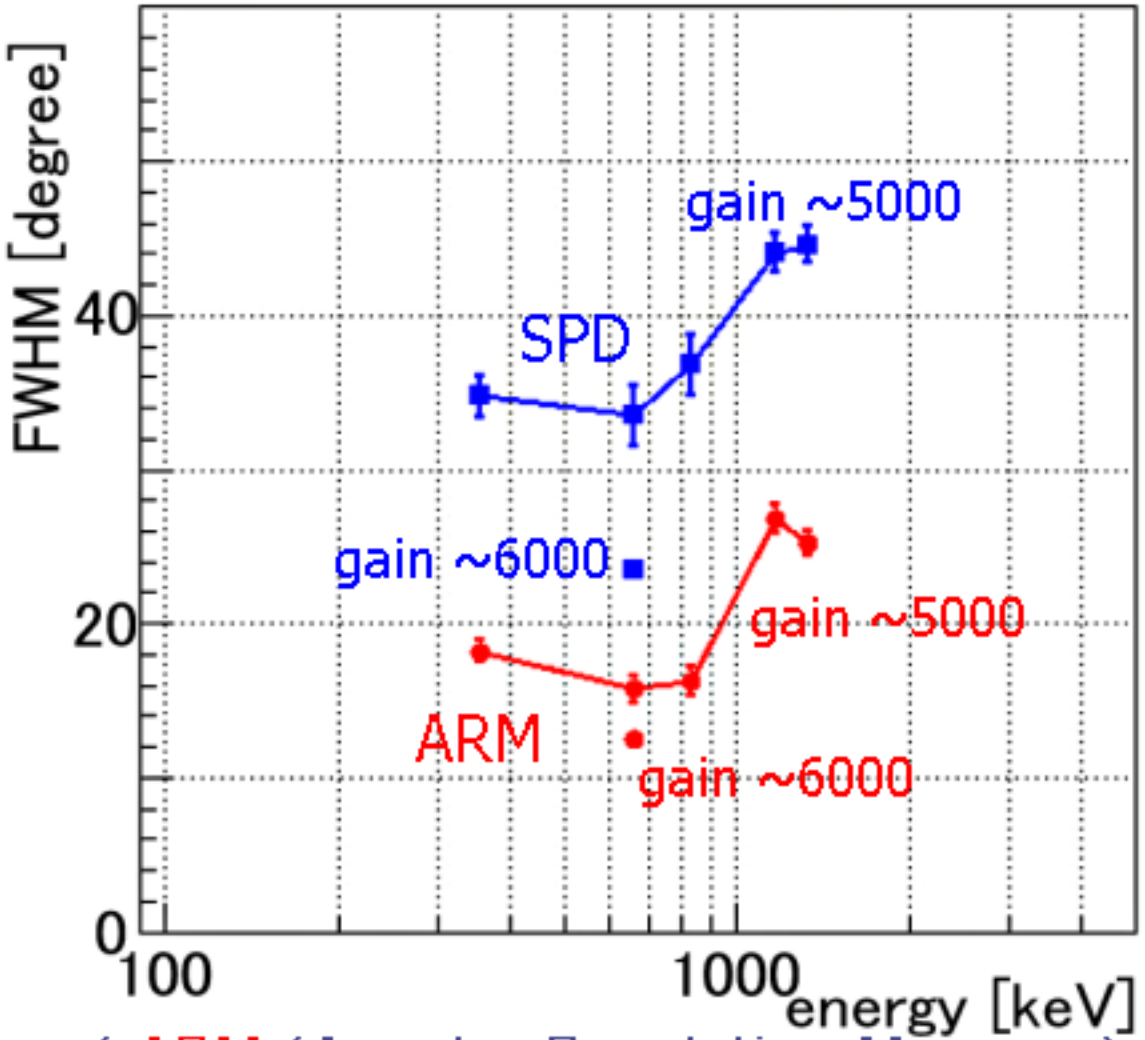
Simply overlay

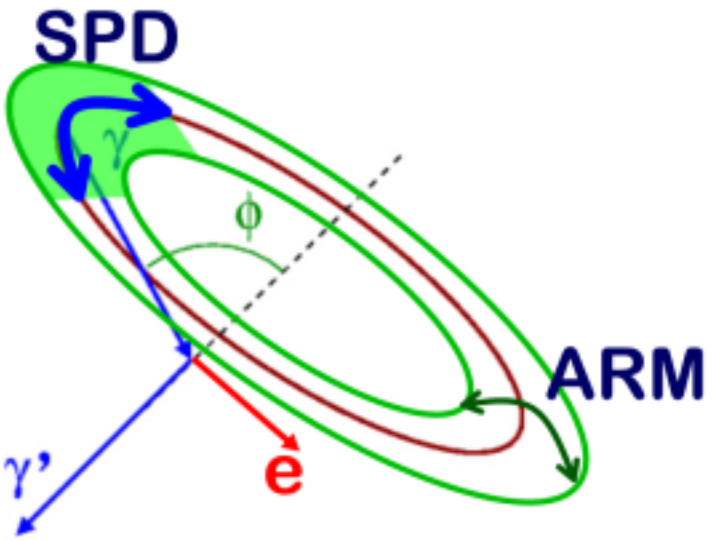
2つの線源を
分離しきれていない



^{137}Cs(1MBq)×2, Classical Compton

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 Trans. Nucl. Sci. in press

✓ ARM (Angular Resolution Measure) 16° @ 662keV FWHM

✓ SPD (Scatter Plane Deviation) 34° @ 662keV FWHM

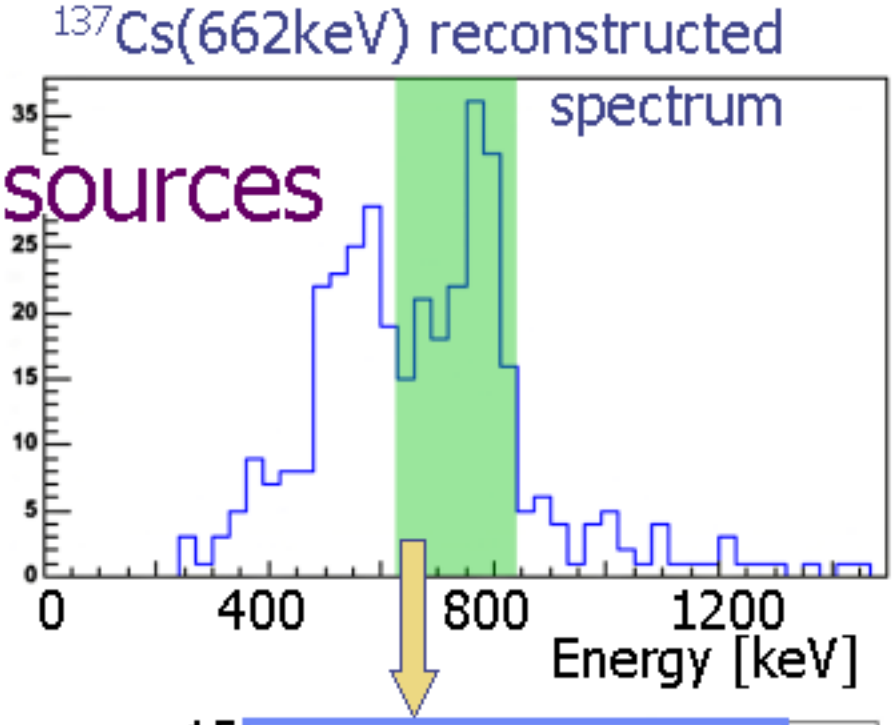
for each gamma-ray

Gamma-ray imaging for unknown energy sources

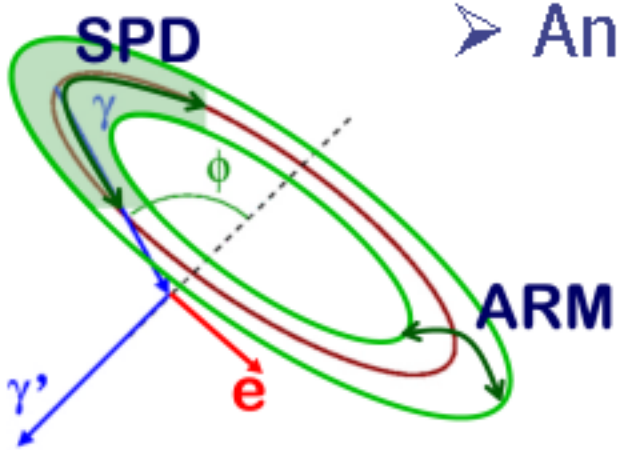
from

scattered γ's energy & direction

recoiled e^-'s energy & direction



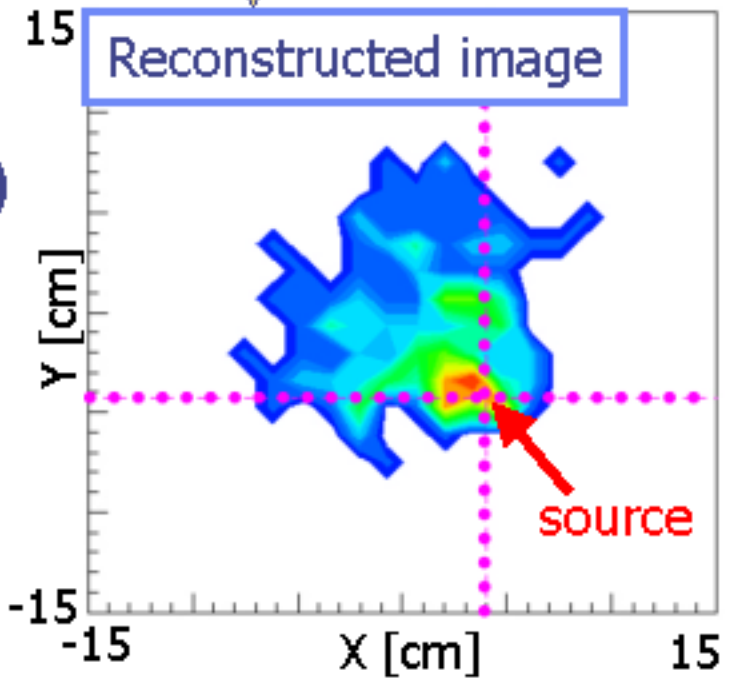
➡ **Full reconstruction** of incident γ



➢ Angular res. (RMS)

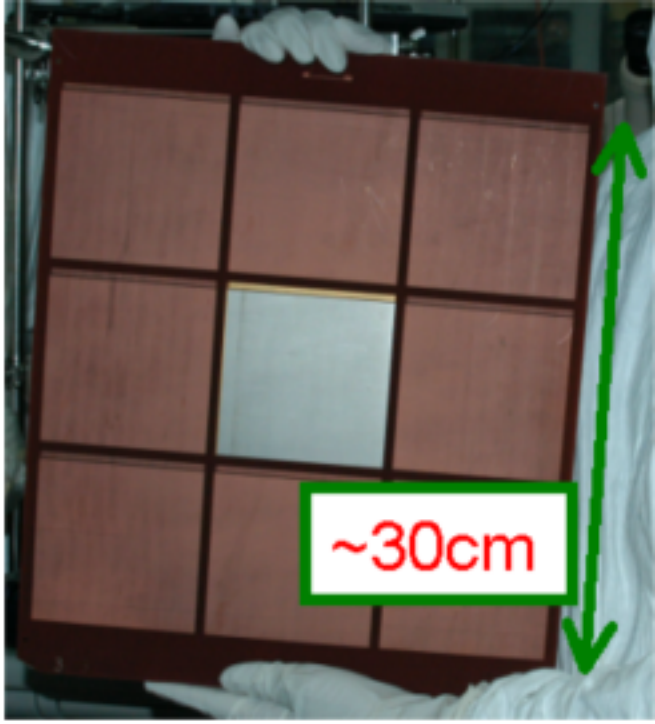
ARM ~15°

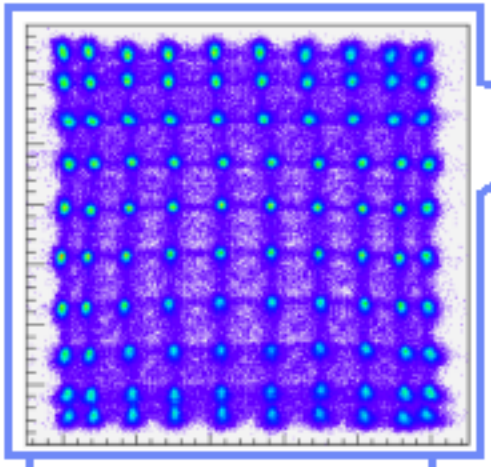
SPD ~35°



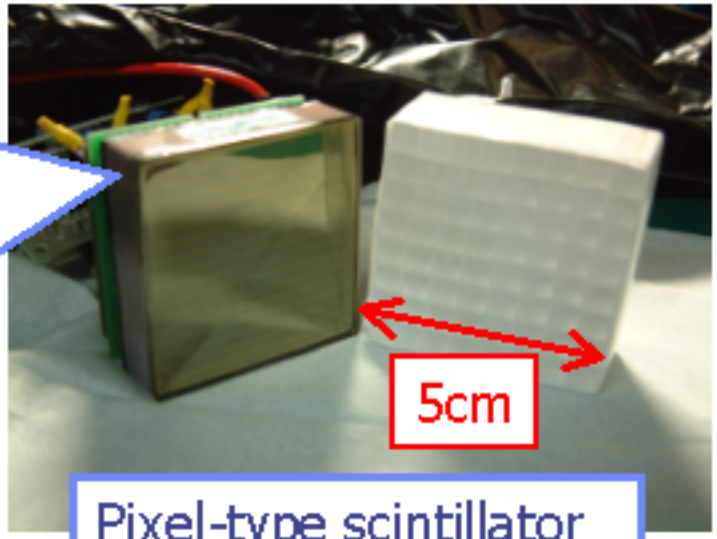
Prospects

- Scintillator
  - ：ピクセル化(multi-anode PMT),
    大面積化
  - ⇒ 位置分解能・検出効率の向上
- micro-TPC : 10cm cube ⇒ 30cm cube
  - ⇒ 反跳電子のエネルギーも捕らえる
    検出効率の向上
- Gas study

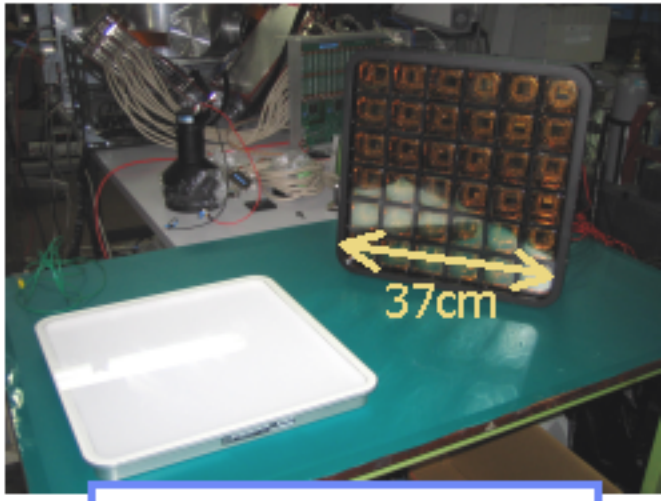




Flat panel PMT
による位置読出し



Pixel-type scintillator
+ Flat panel PMT



37cm角 NaI(Tl)
Anger camera

Summary

- ✓ 光子毎の到来方向の再構成に成功
  - ⇒ 検出原理が実証された
- ✓ 高いbackground除去能力
  - ⇒ COMPTELよりも高いSN比が実現可
- ✓ Prototype performance (for 662keV)
  - ARM(FWHM) 16°
  - SPD(FWHM) 34°

Goal 500keV(FWHM) ARM ~7° SPD ~20°

1MeV(FWHM) ARM ~5° SPD ~10°