micro-TPCを用いたガンマ線イメージング検出器の開発 VII

京都大学　高田淳史

谷森達, 窪秀利, 身内賢太朗,
竹田敦, 永吉勉, 折戸玲子, 植野優

- MeV-γ imaging
- μ-PIC & micro-TPC
- Prototype detector
- Summary

MeV-γ imaging

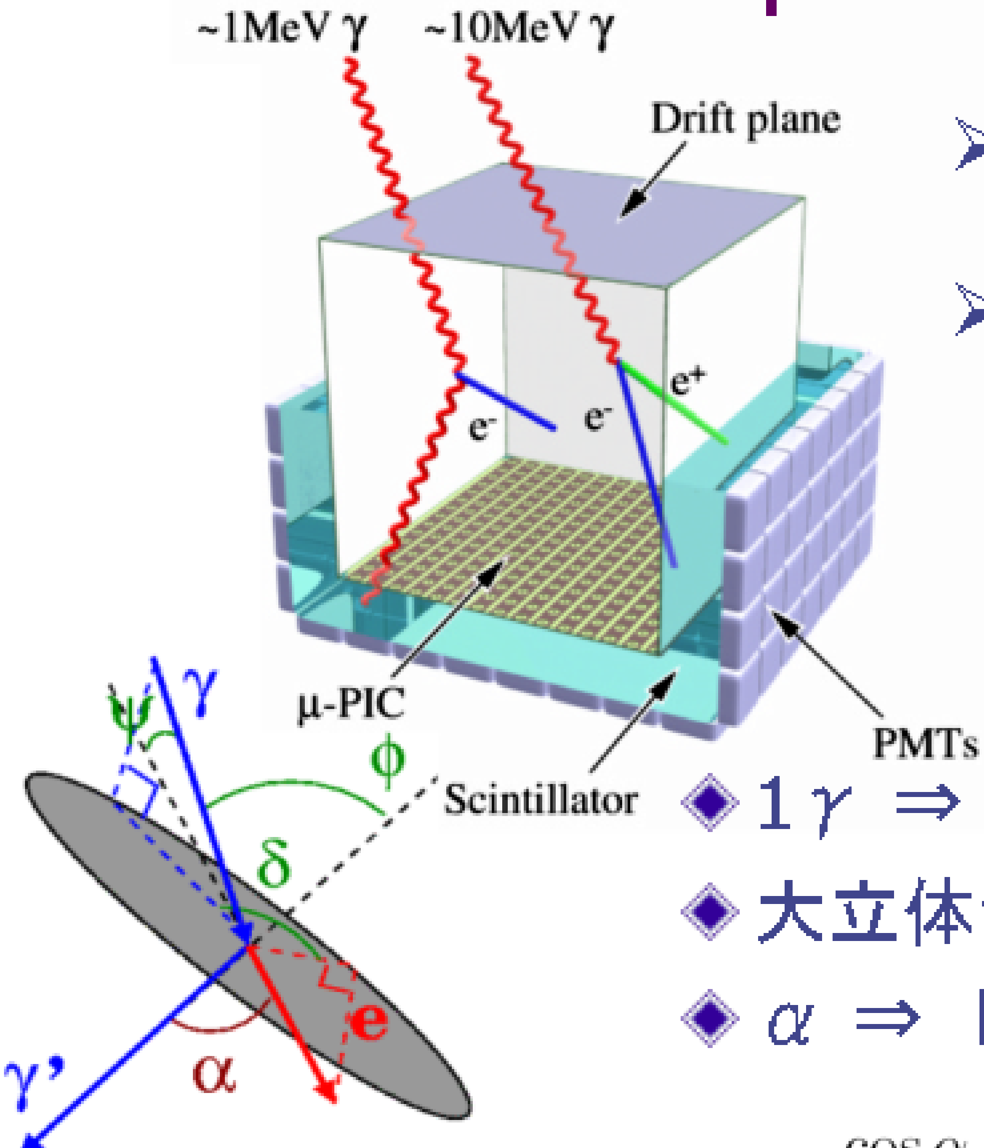
MeV領域におけるimaging

- Compton Imaging (COMPTEL)
- Coded Aperture Imaging (INTEGRAL)

Event毎の到来方向はわからない
Background除去能力は低い

⇒ 新しいimaging方法が必要

Advanced Compton Imaging



- micro-TPC (μ -PIC)
  - 反跳電子のtrack, energy
- Scintillator
  - 散乱γの位置, energy

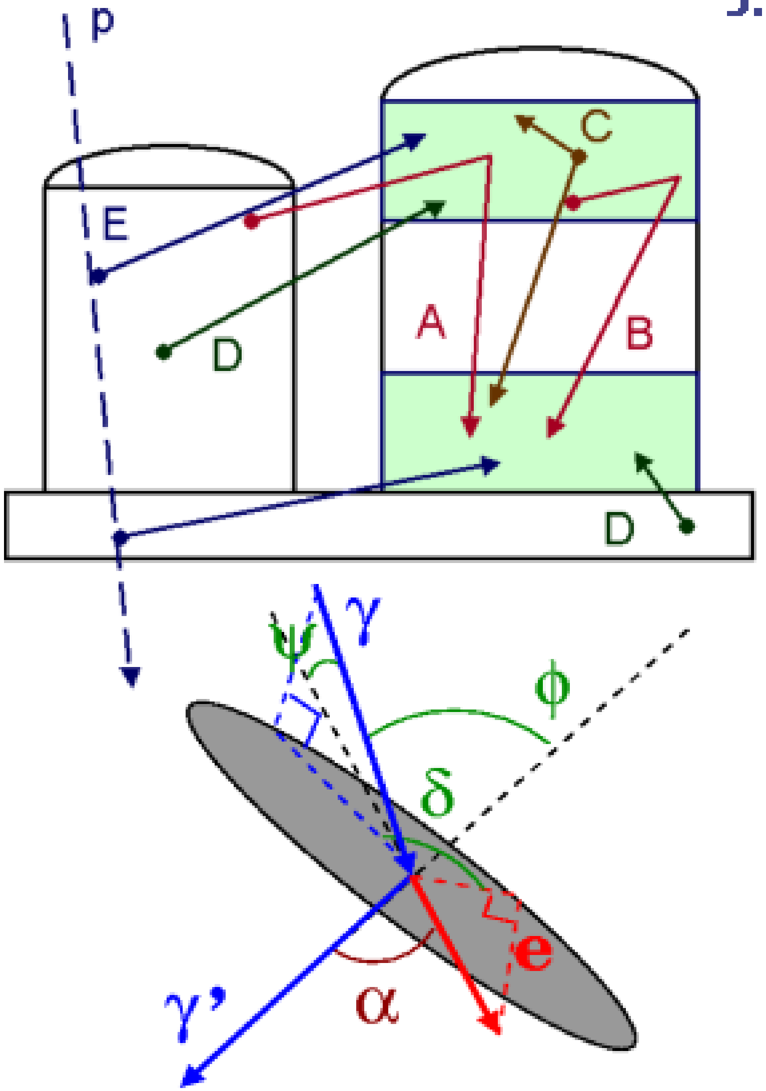
Event毎に
Compton散乱を再現

- 1γ ⇒ 到来方向＋energy
- 大立体角 (~2str)
- α ⇒ background rejection

$$\cos\alpha = \left(1 - \frac{m_e c^2}{E_g}\right)\sqrt{\frac{K_e}{K_e + 2m_e c^2}}$$

Background of COMPTEL

J.Ryan (Astronomy with radioactivities, 2003)



A, B : internal γ

C : two γ ← α でcut

D : random coincidence

← α でcut

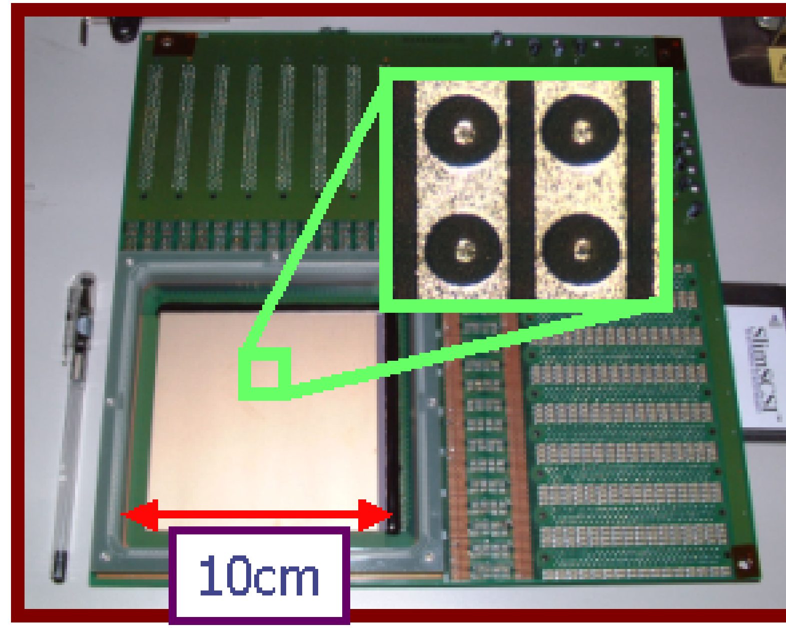
E: proton-induced γ

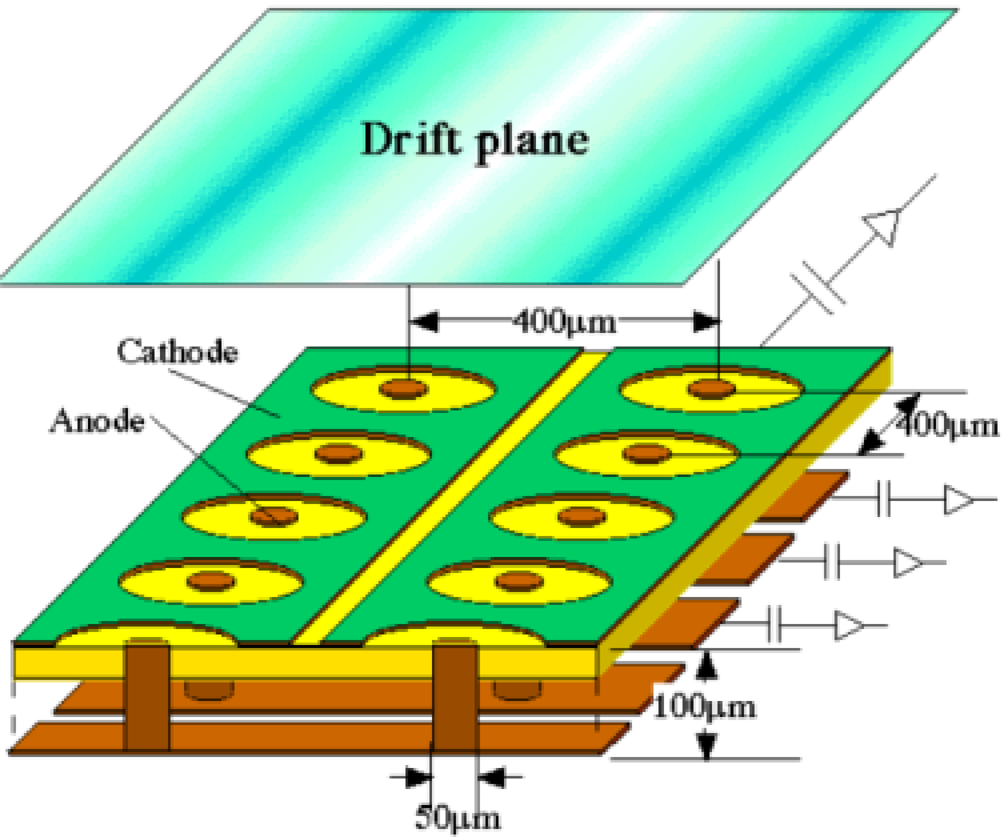
← α でcut

- Other background
  - neutron ← dE/dXでcut
  - electron ← α でcut

$$\cos\alpha = \left(1 - \frac{m_e c^2}{E_g}\right)\sqrt{\frac{K_e}{K_e + 2m_e c^2}}$$

μ-PICの構造と特徴
(Micro Pixel Chamber)





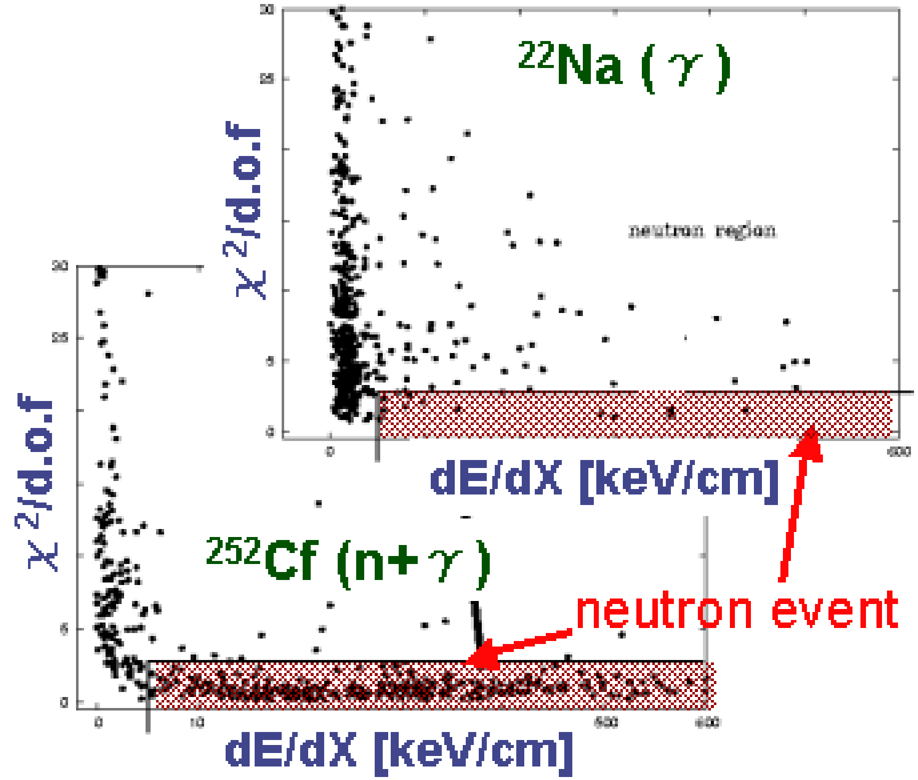
- 2次元読み出し(~6500pixels)
- **大面積** (10cm × 10cm)
- Max gain ~15000
- Energy分解能
  30% @ 5.9keV
- Gas gain~5000で
  1ヶ月以上の**安定動作**
- **高い位置分解能** (~160μm)
- 大強度入射にも耐える

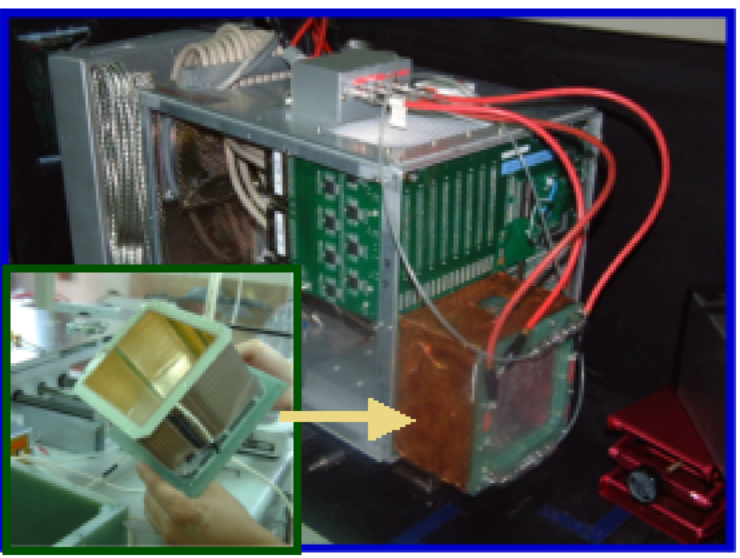
大幅な改善
→ 永吉 10aSJ-9(素粒子実験)

micro-TPC

- ✓ 10cm × 10cm μ-PIC
  - ・・・ 2次元位置情報
- ✓ 8cm drift cage (E=0.4kV/cm)
  - ・・・ drift time

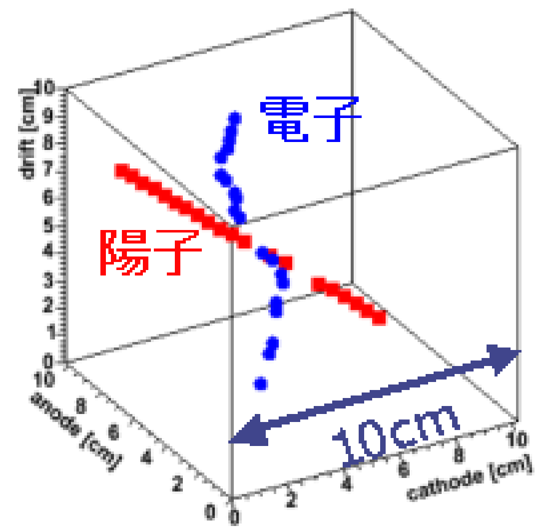
⇒ **micro-TPC**
・・・ 3次元情報



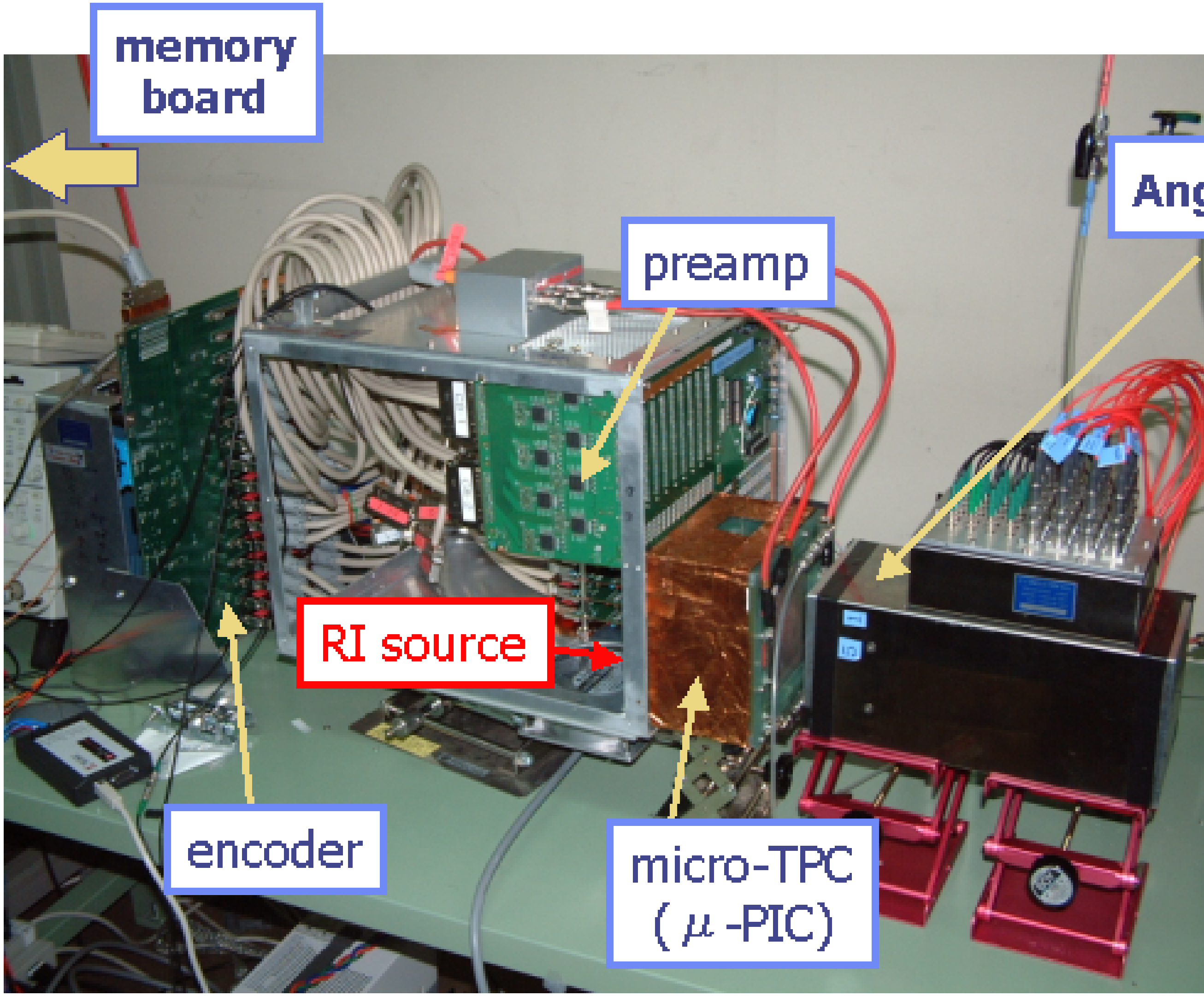


位置分解能
(Ar, 20MHz clock)

- drift方向
  ~1mm
- driftに垂直な方向
  ~200 μ m



Prototype detector



micro-TPC

$10 \times 10 \times 8$ cm^3

Ar +C_2H_6 (9:1)

NaI（Tl） Angur

4"×4"×1" 25 PMTs

position resolution

~7.5mm (FWHM)

energy resolution

~9.1%

(662keV, FWHM)

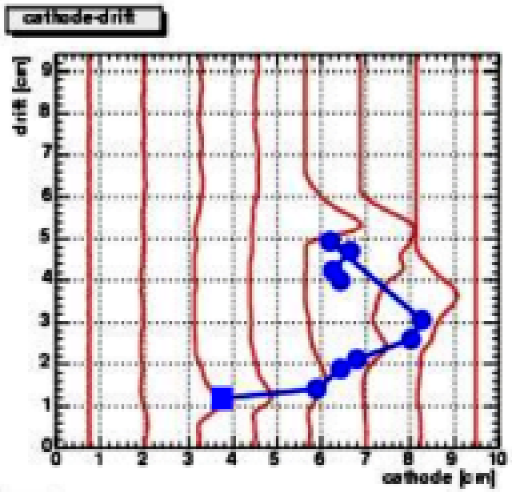
No Veto or Shield !

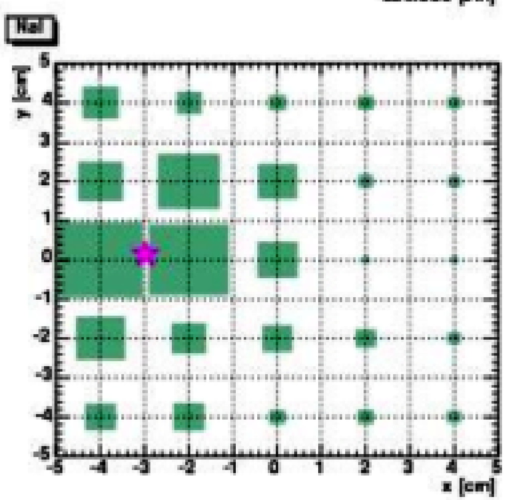
Typical event

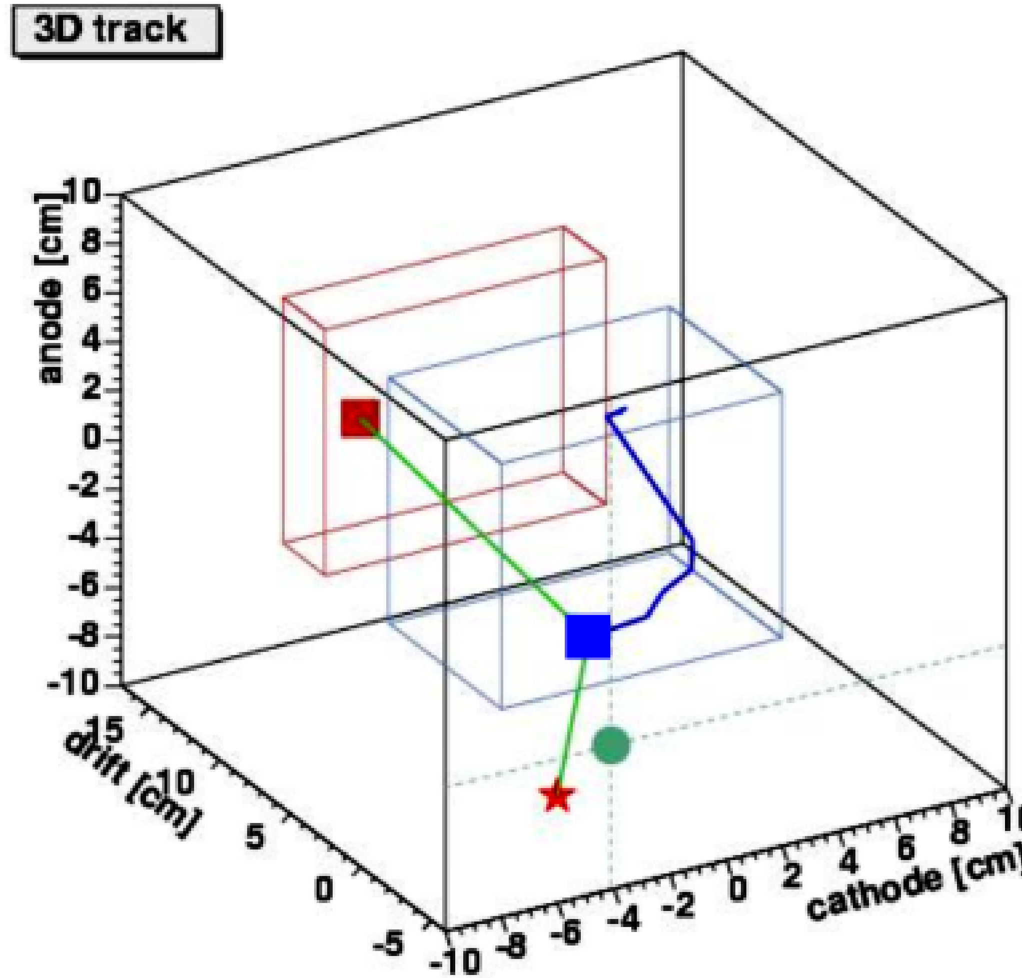
E_γ : 485.9 keV
K_e : 138.1 keV
E_0 : 624.0 keV

$\alpha = 90.78^\circ$
$\phi+\psi = 91.02^\circ$
$\phi = 39.89^\circ$
$\psi = 51.13^\circ$

●: source position
★: reconstructed
■: Compton point
■: NaI hit



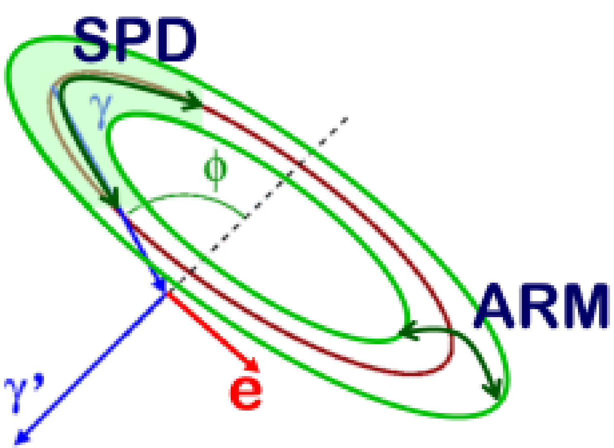


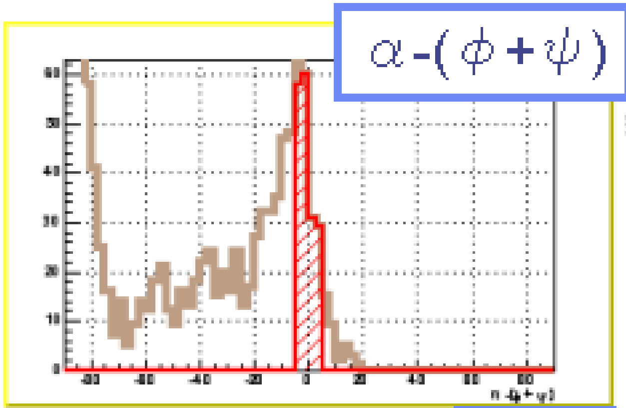


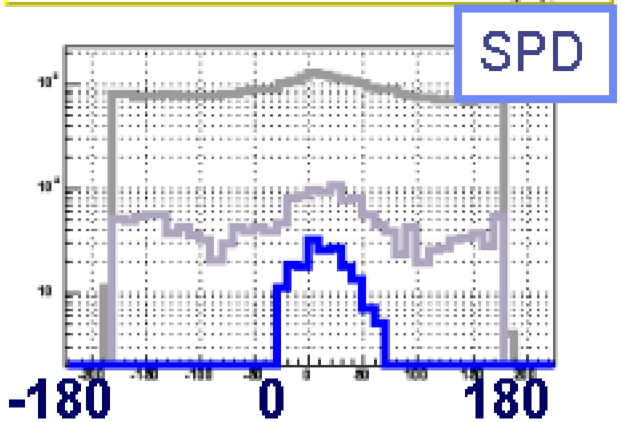
Background rejection

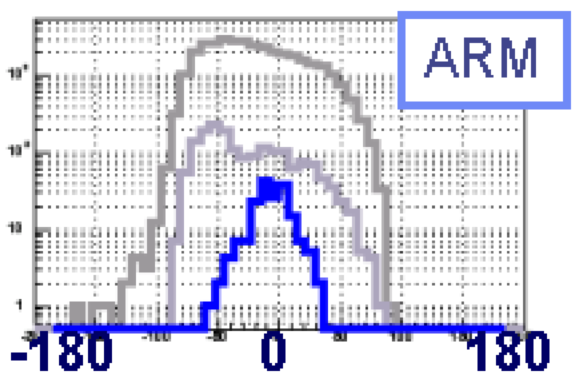
αによる
kinematical cut

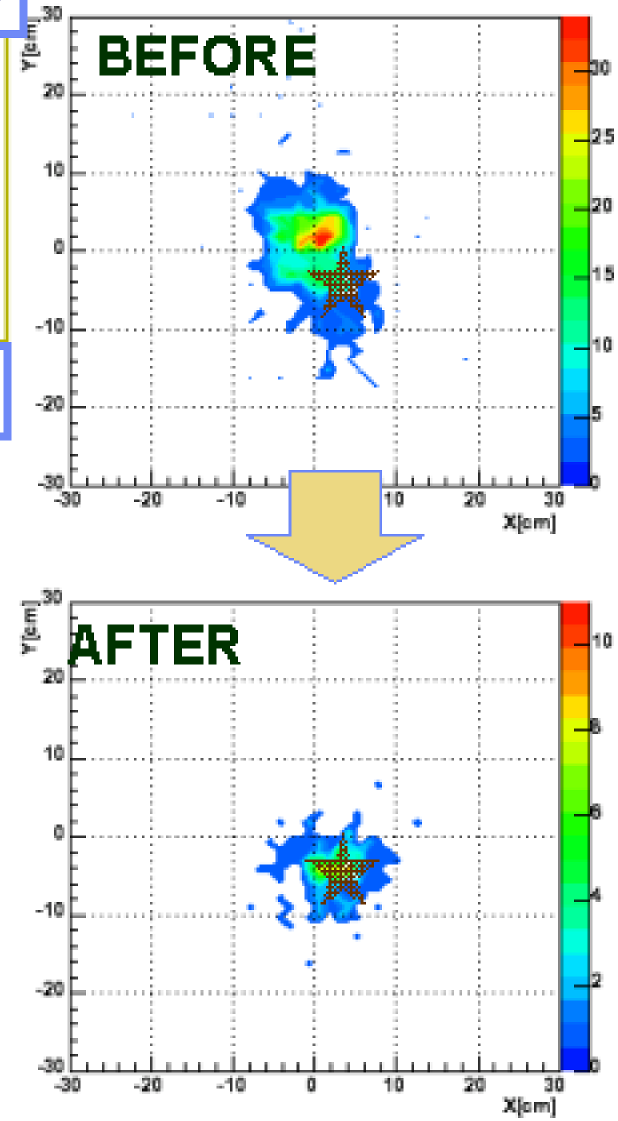
SN比は大幅に向上





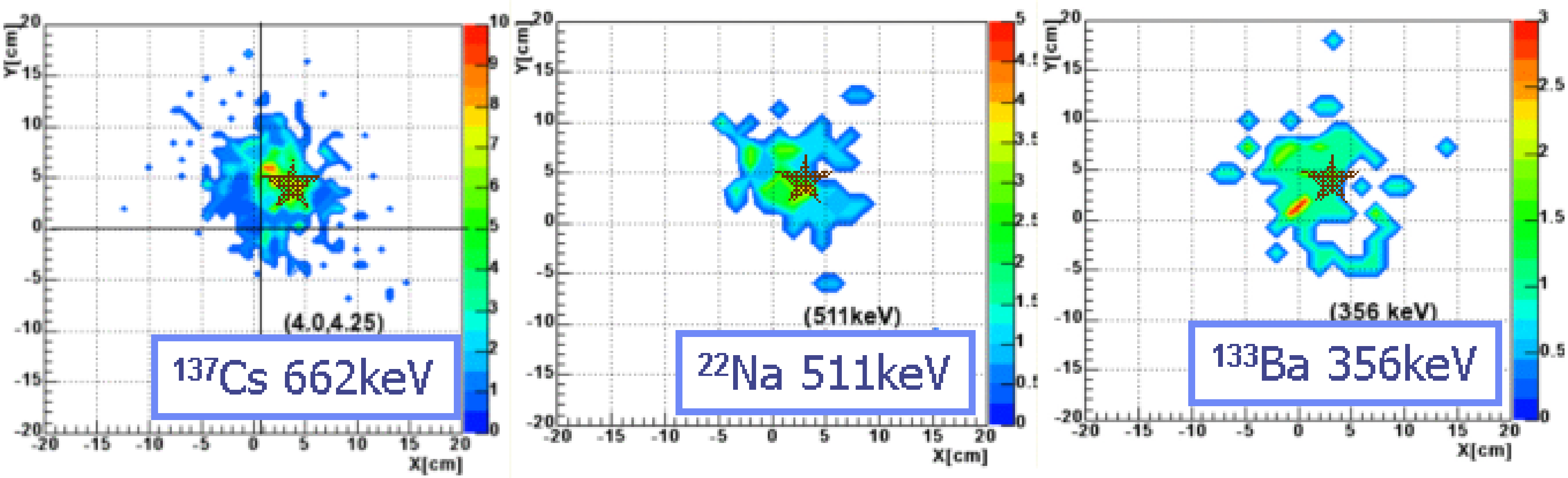






Prototype performance (1/2)

sourceのenergyは既知
反跳電子のtrack, 散乱γのenergyと散乱方向を測定 → **再構成**

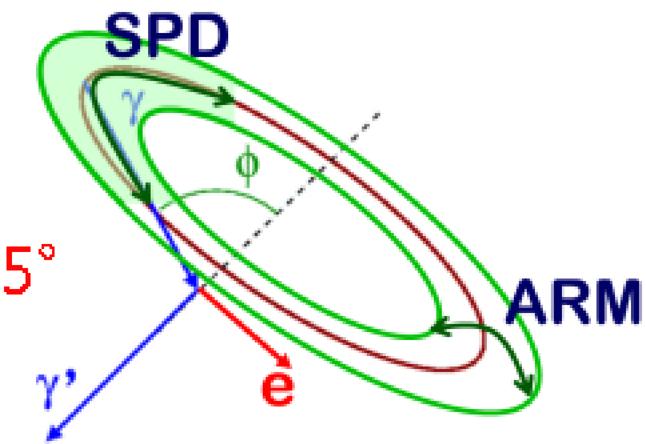


^{137}Cs 662keV
^{22}Na 511keV
^{133}Ba 356keV

低energyでもimagingが可能

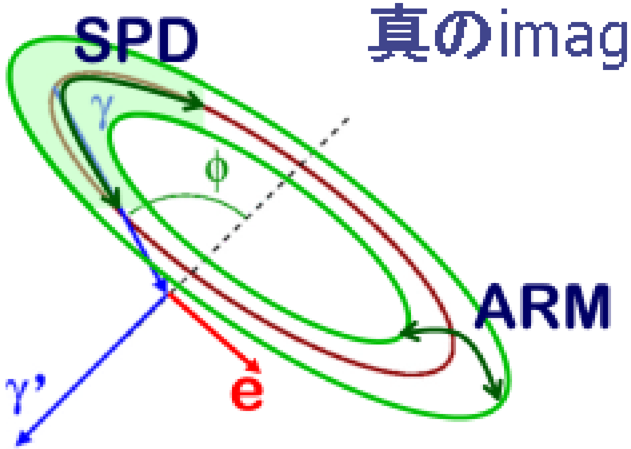
- 角度分解能(σ)

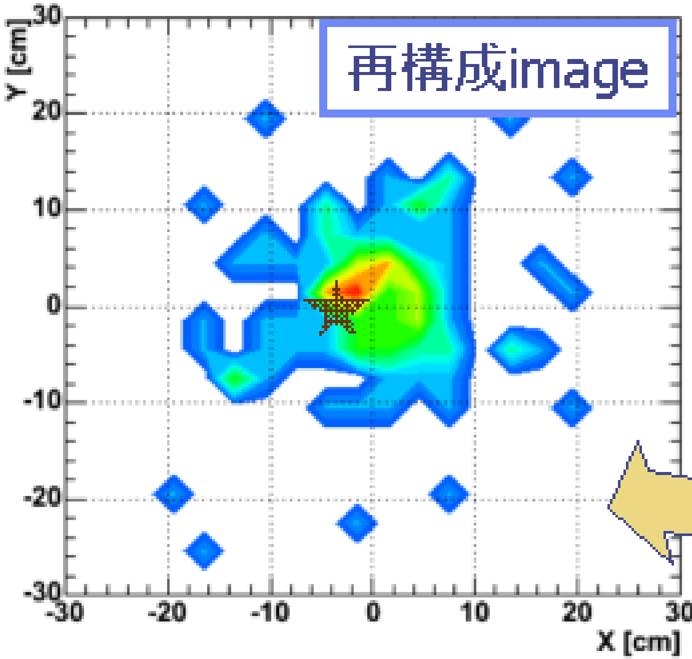
  Angular Resolution Measure(ARM) ~15°
  Scatter Plane Deviation (SPD) ~25°

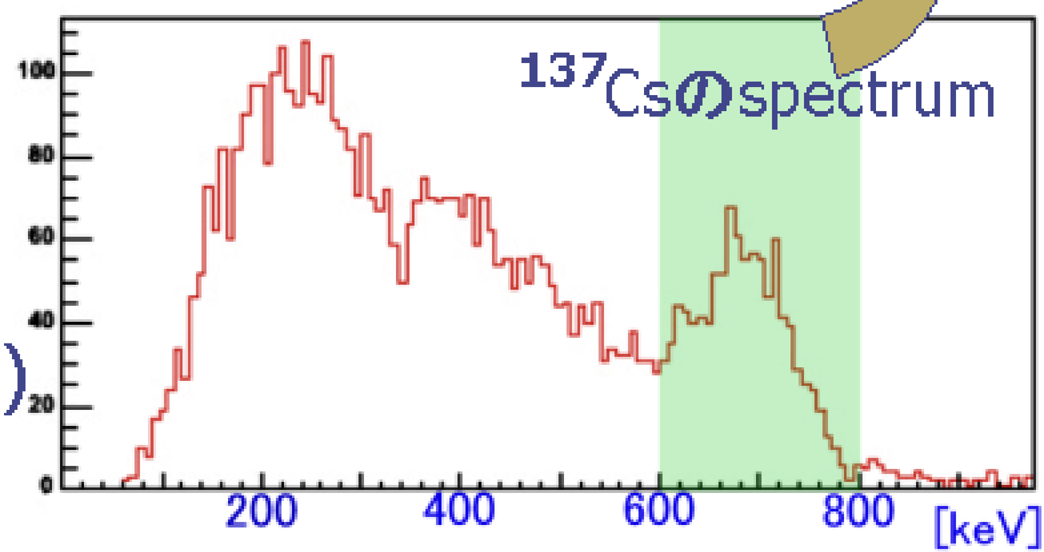


Prototype performance (2/2)

micro-TPCのcalibration
⇒ 電子のenergyも測定
⇒ energyも含めた真のimaging







- 角度分解能(σ)
  ARM ~20°
  SPD ~30°
- energy分解能(FWHM)
  ~20% @ 662keV

Summary & Future work

- ✓ event毎のγの再構成ができた
  - ⇒ continueな成分についても再構成が可能
- ✓ Prototype performance
  - ARM(σ) ~20°
  - SPD(σ) ~30°
  - energy分解能(FWHM) ~20% @ 662keV

➢ ARM（目標 σ~3°)
- micro-TPCのuniformity向上
- scintillatorのpixel化

⇒ energy分解能の向上

➢ μ-PICの改良
⇒ 永吉 (10aSJ-9)

➢ scintillatorの改良
⇒ 折戸 (10aSB-8)

➢ SPD（目標 σ~5°)
- micro-TPCのclock up
- gas study (Ar→CF_4)
- tracking algorism
- micro-TPCの大容積化

  ⇒ tracking能力の向上
- scintillatorのpixel化

  ⇒ scintillatorの位置分解能の向上