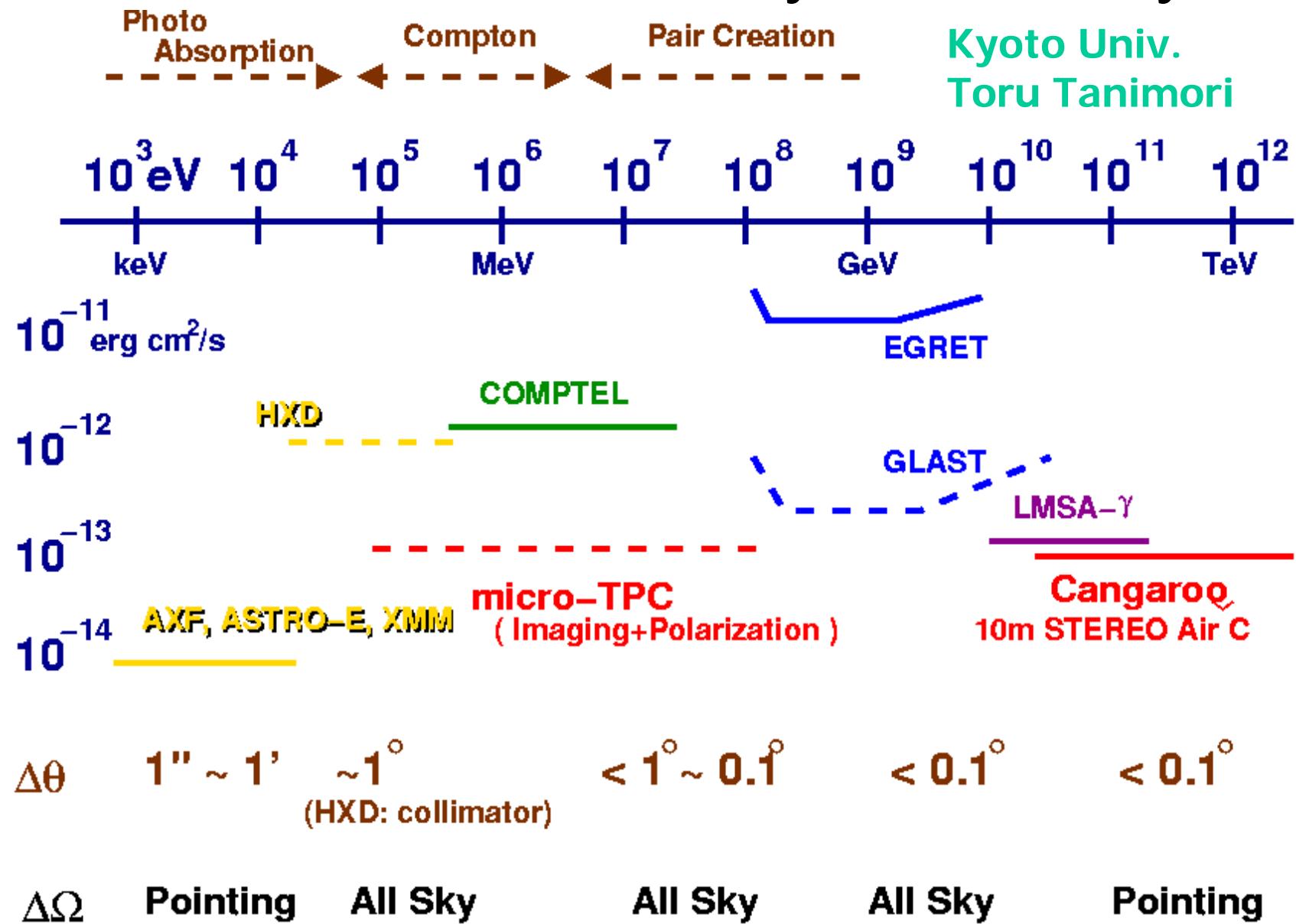


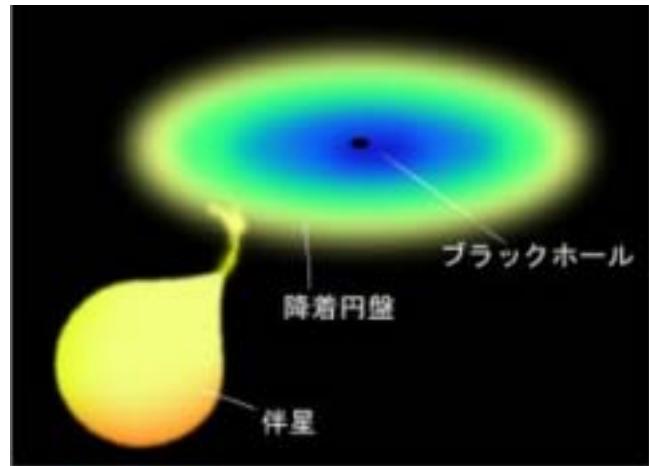
MeV Gamma-Ray Astronomy



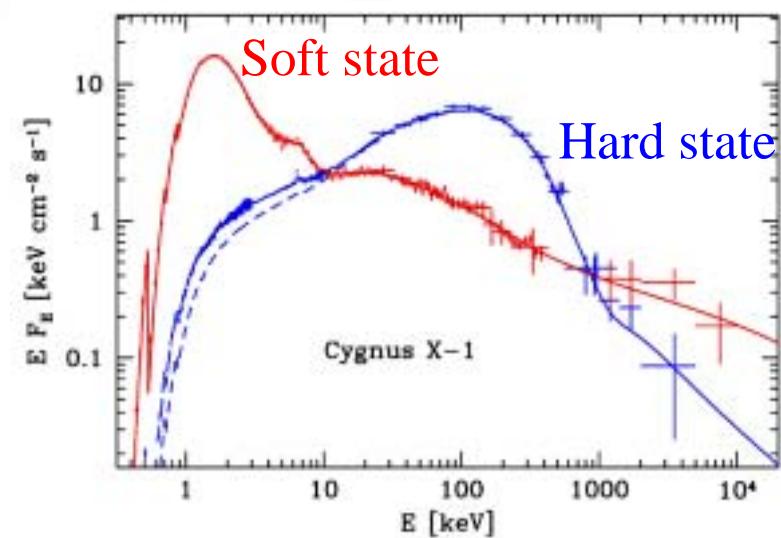
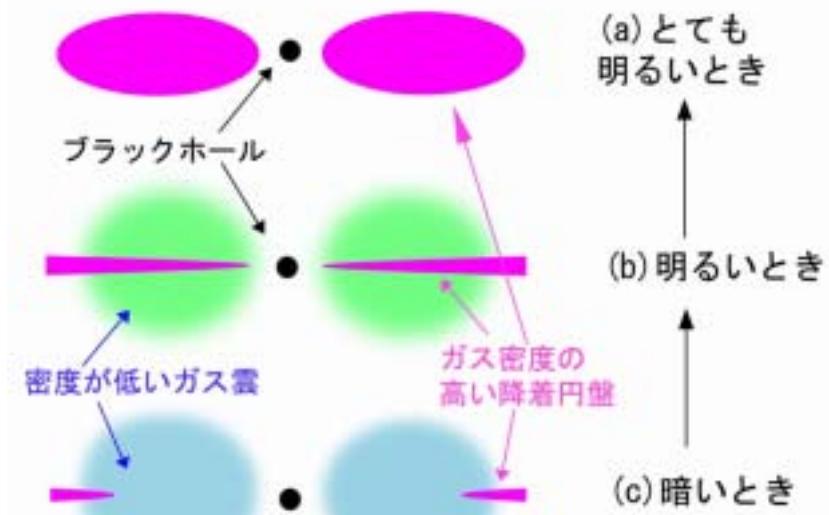
Expected Sources in MeV Region

- Black Hole; Binaries, **Galactic Center, AGNs, Primordial BH, 511keV**
- Pulsars
- AGN jets; **OVV, Blazar**
- Galaxies; **PIO peak due to Cosmic Ray**
- SNRs; **Al, Ti, Nuclear Gamma**
- Diffuse; **Extra and Galactic**
- Gamma Ray Bursts; **Polarization**

BH X-ray Binaries; Slim Disk



- Slim Disk Radiation cooling
- $T_d \sim 10^7 \text{ K}$, 10^5 K (AGN)
- Optical Thick
- Keplerian Motion



ADAF (Advection Dominated Accretion Flow)

1. Low Radiation Rate
2. High Temperature

$$T_e \sim 10^9 \text{ K}$$

$$T_{ion} \sim 10^{12} \text{ K} \quad (\geq 100 \text{ MeV})$$

$$\begin{aligned} & \sim \frac{1}{10} m_p \quad (\text{Virial velocity}) \\ & = \frac{GMm_p}{r_{sw}} \end{aligned}$$

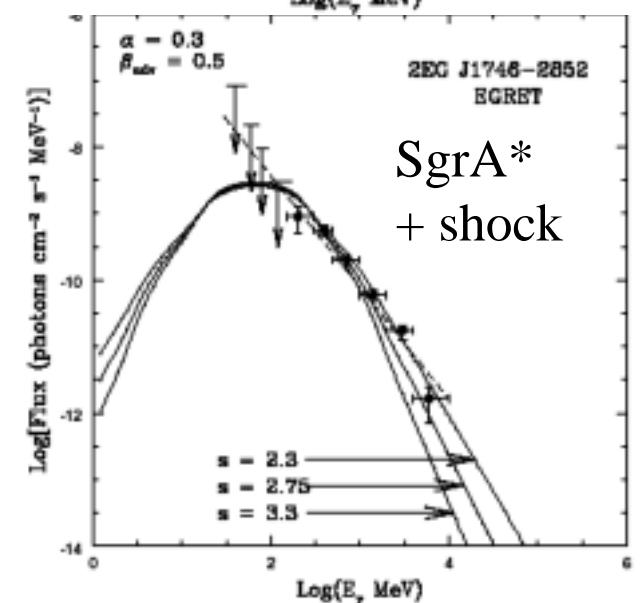
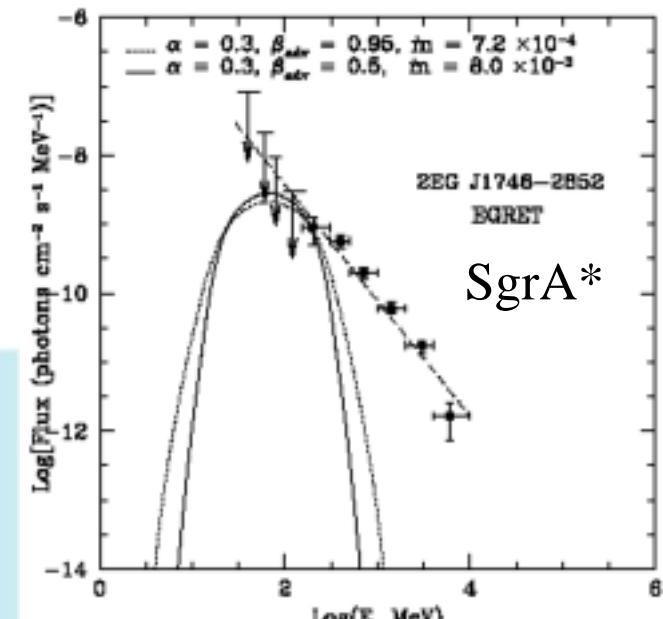
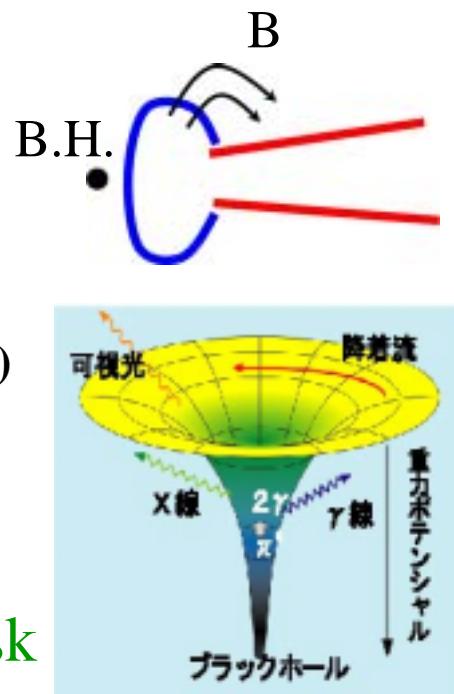
3. Expansion

Thick Disk Increase
 Slim Disk $T_{e,i} \sim 10^5 \sim 10^7 \text{ K}$ (Keplar Motion)

Example. Sgr.A*, M87

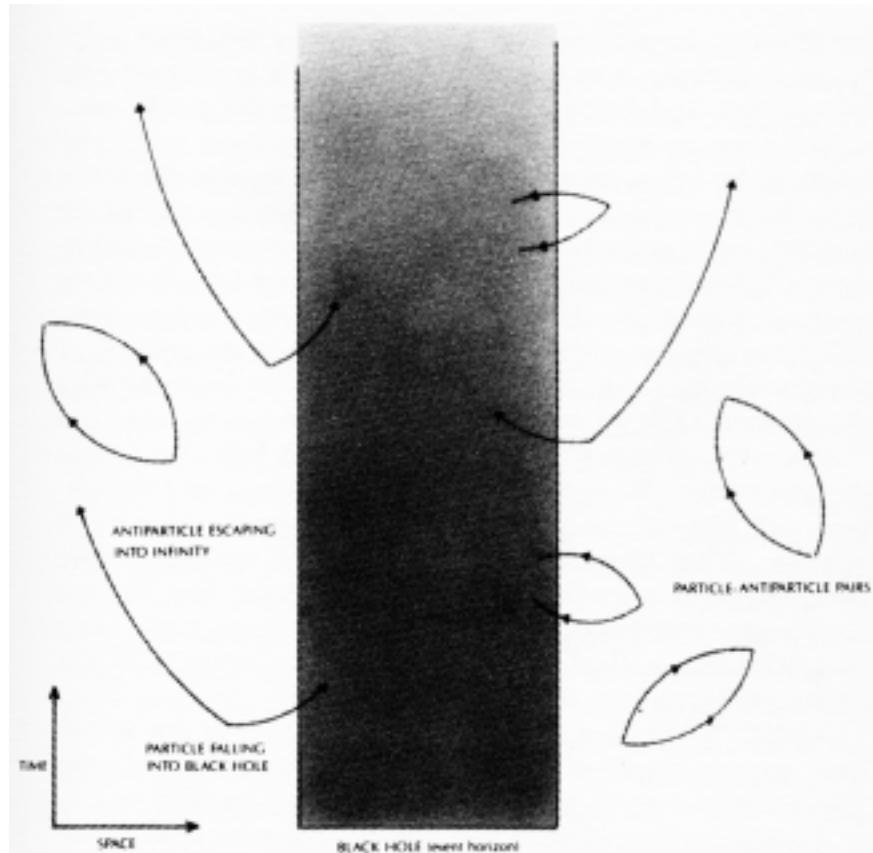
Very Low X-ray Intensity B.H.

- Thermal Expected
Corresponding to field around Event Horizon!



Mahadevan & Narayan (1997)

Particle Generation () in Universe, Primordial B.H.



Primordial B.H.

$$\tau \sim \frac{M^3}{\hbar} \sim 10^{10} \text{ yr} \left(\frac{M}{10^{15} \text{ g}} \right)^3$$

$$\frac{dE}{dt} \sim 10^{20} \text{ erg s}^{-1} \left(\frac{10^{15} \text{ g}}{M} \right)^2$$

$$\hbar\omega \sim 100 \text{ MeV} \left(\frac{10^{15} \text{ g}}{M} \right)$$

Only Thermal Gamma
Emission <100MeV

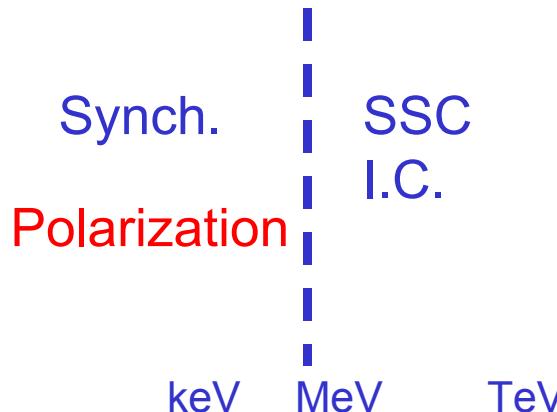
MeV AGNs (Blazars)

Emission from relativistic jet
Key factor → Polarization

BL Lacs(HBLs)

Highest synch.

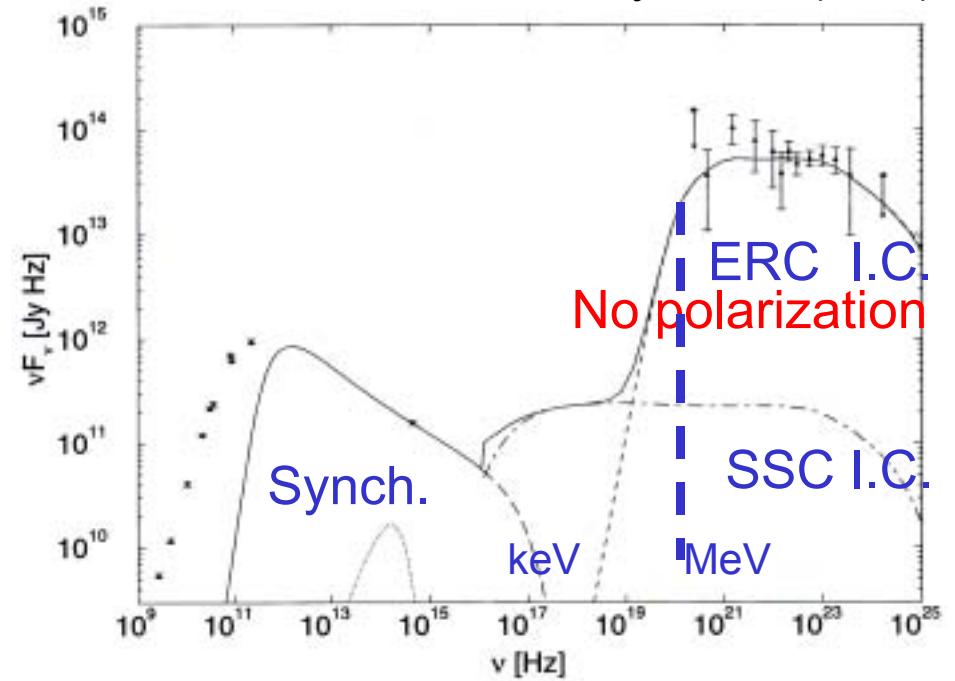
1H1426+428 Horan et al. (2002)



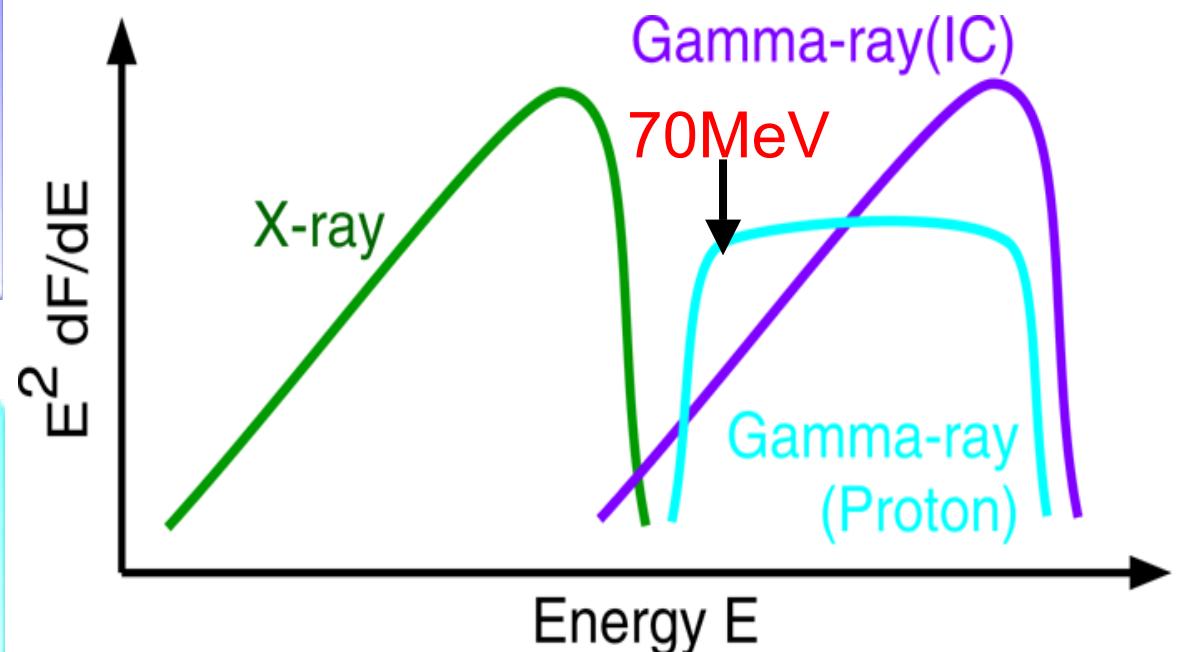
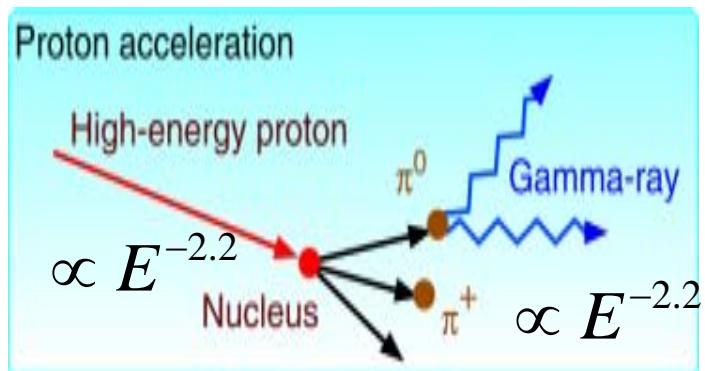
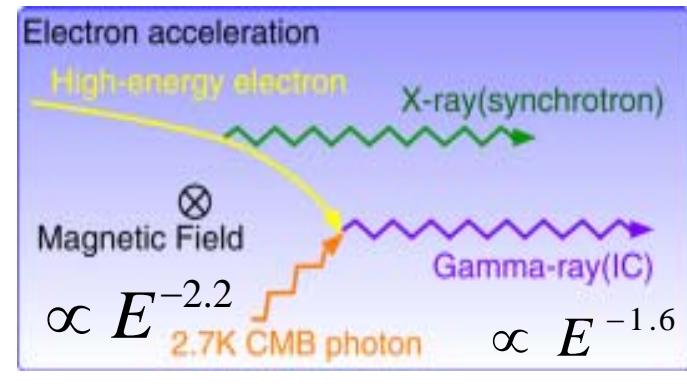
OVV QSOs(FSRQs)

Large I.C. peak

PKS0528+134 Mukherjee et al. (1999)

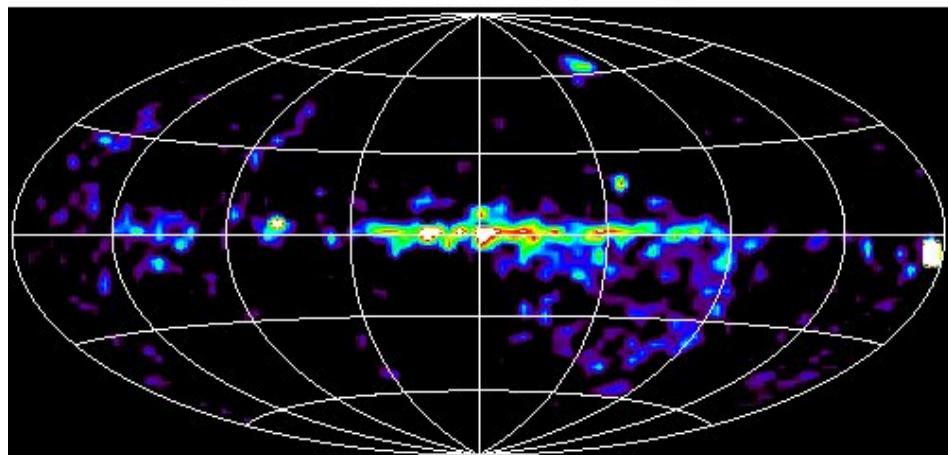


Cosmic-Ray (Proton Identification)

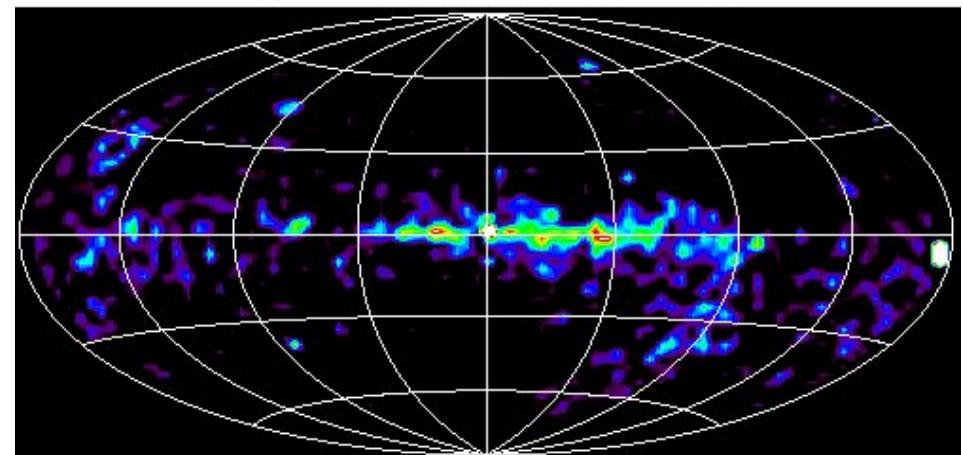


COMPTEL all sky survey

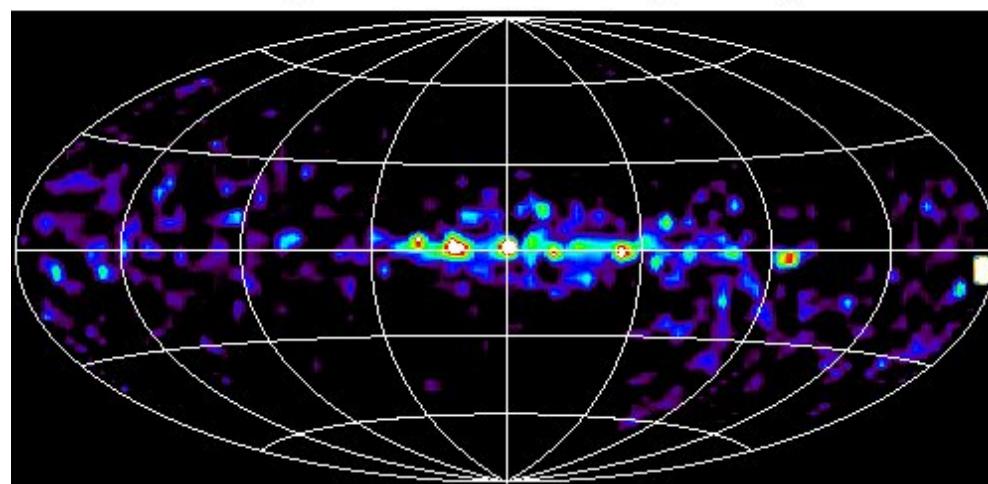
1-3 MeV Cycle 1-6 SKY MOS/Cray T3E



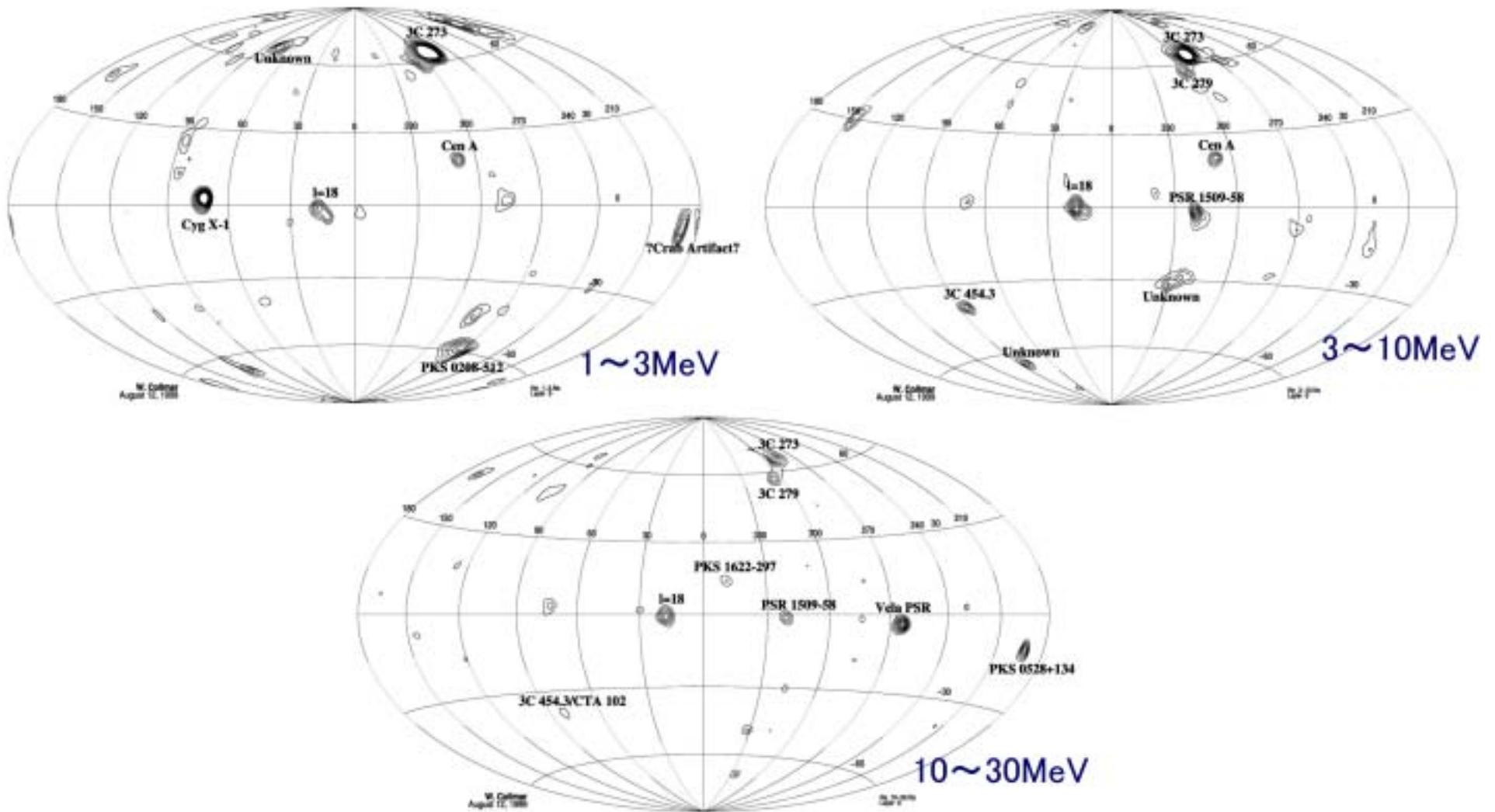
3-10 MeV Cycle 1-6 SKY MOS/ Cray T3E



10-30 MeV Cycle 1-6 SKY MOS/ Cray T3E



COMPTEL all sky survey (point source)

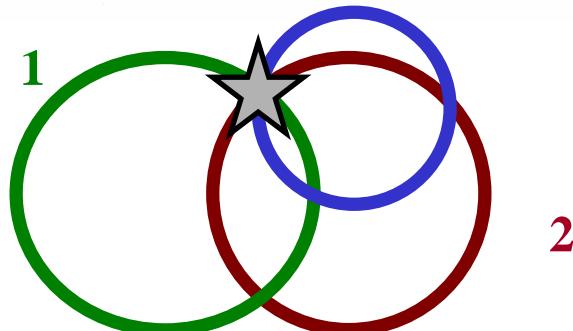
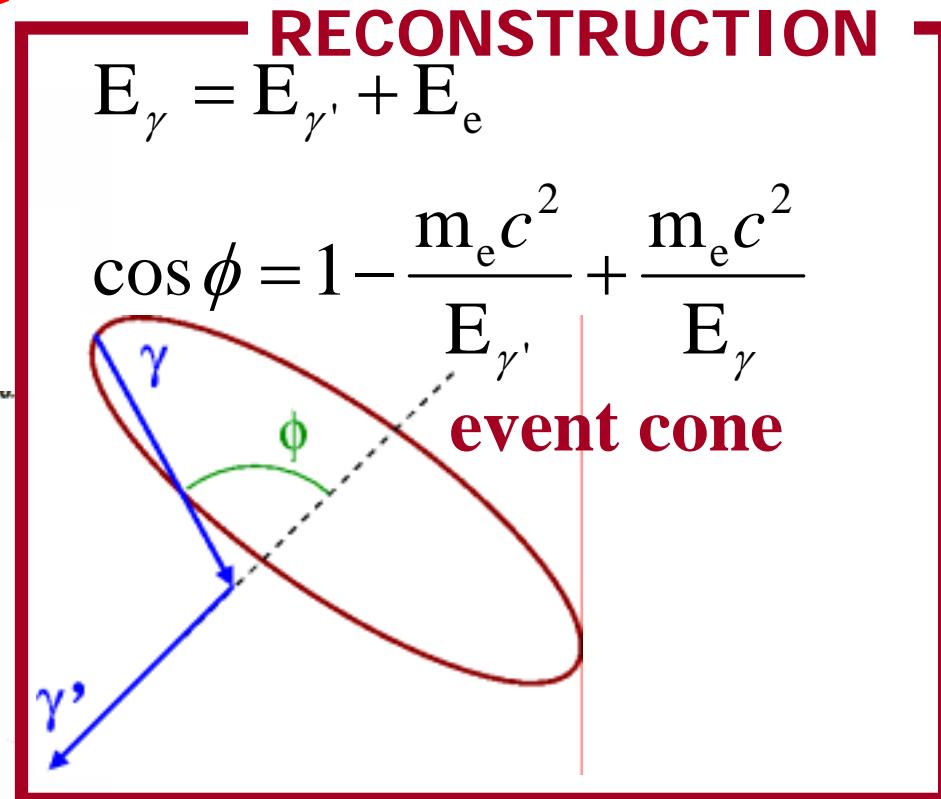
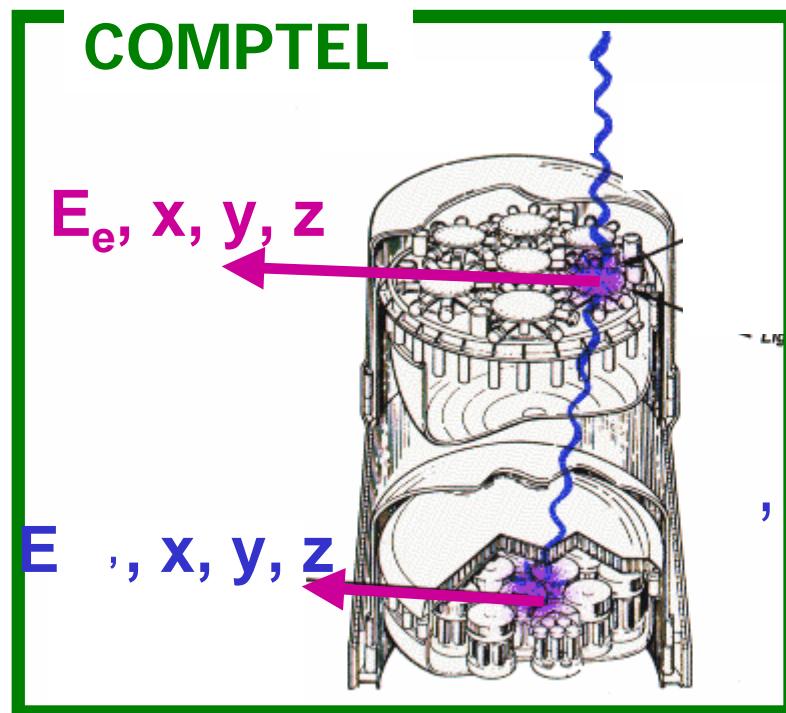


MeV γ -ray Imaging

- Collimator + Active Shield (OSSE)
- Coded Mask + Active Shield
 - Maximum Entropy Method
- Double Compton Method (COMPTEL)
- Multi Compton Method (CdTe, Ge)
- Full Tracking
 - MEGA (Si + Scintillator)
 - Micro-TPC + Scintillator
 - Fine tracking of electrons

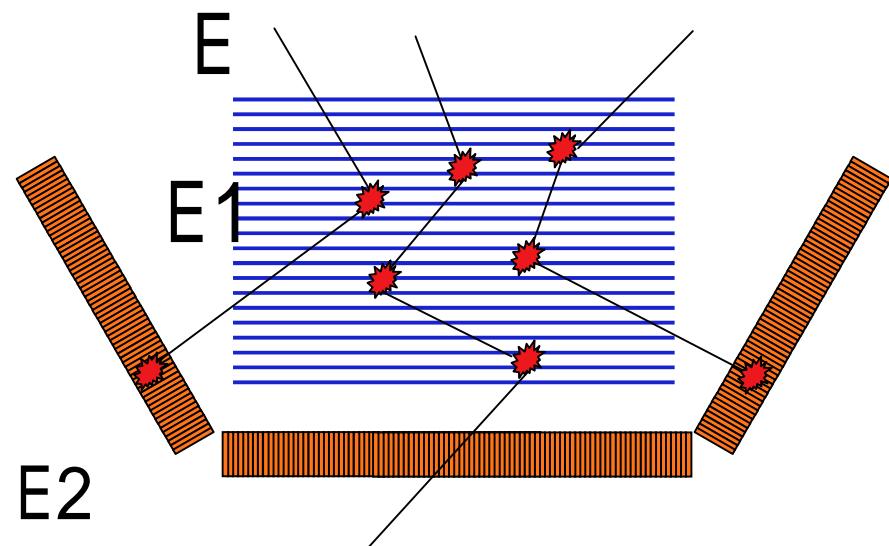
Compton -ray Imaging

- Double Compton Method

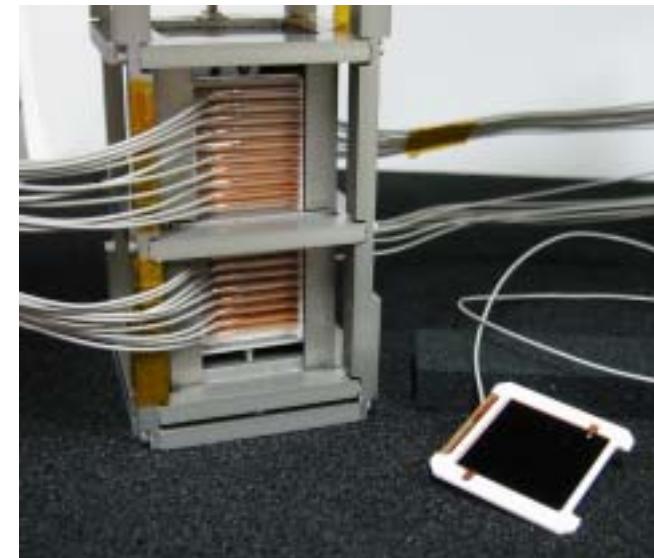


3 1 direction
No background rejection
needs TOF to know UP or DOWN

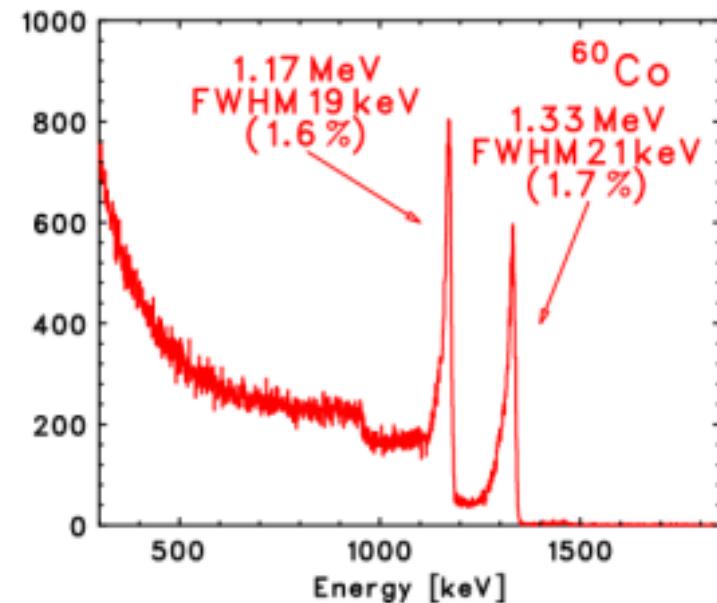
半導体多重コンプトンカメラの概念図



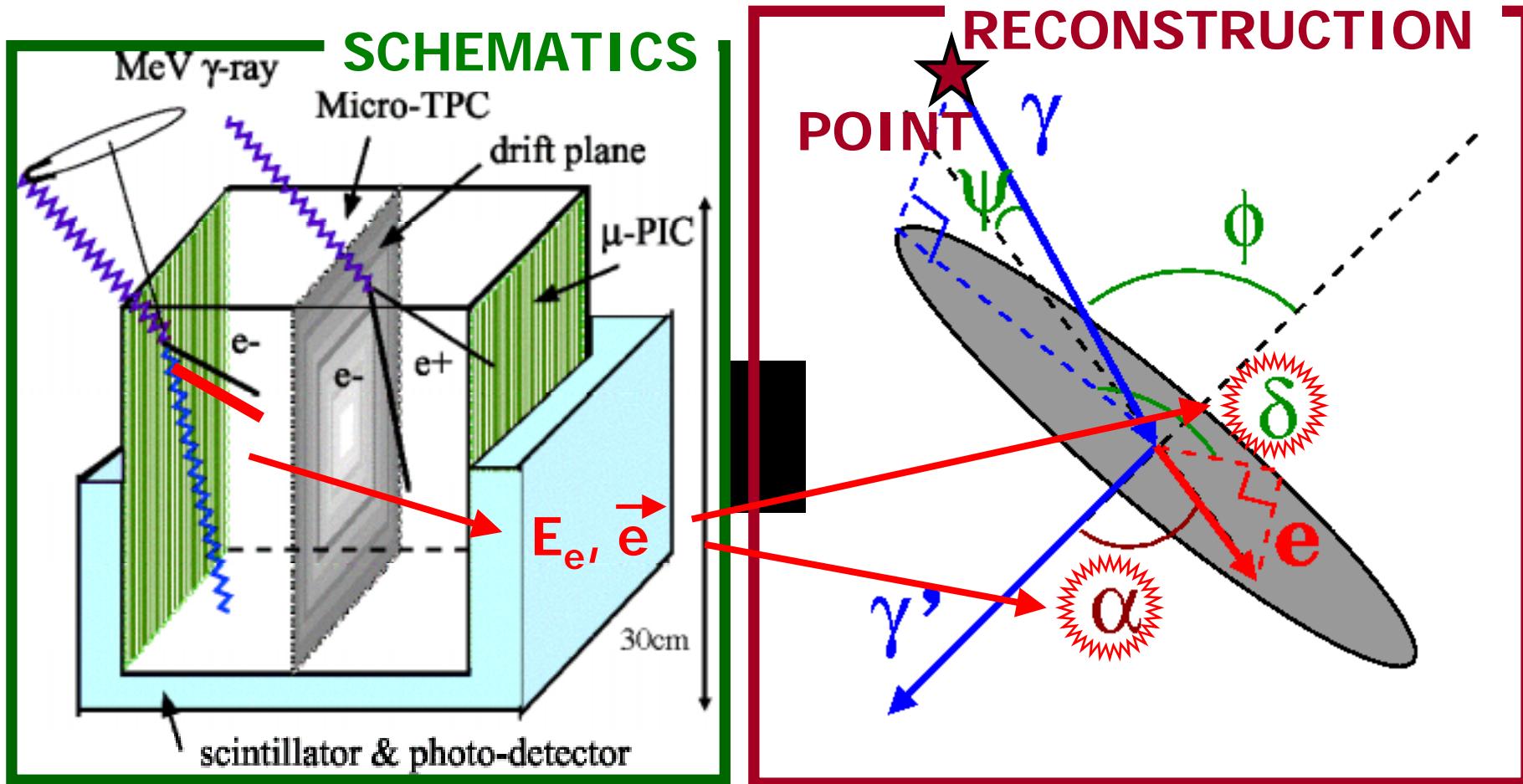
40段CdTe多層検出器の試作
(2.2cm × 2.2cm × 2cm)



上記多層検出器のスペクトル



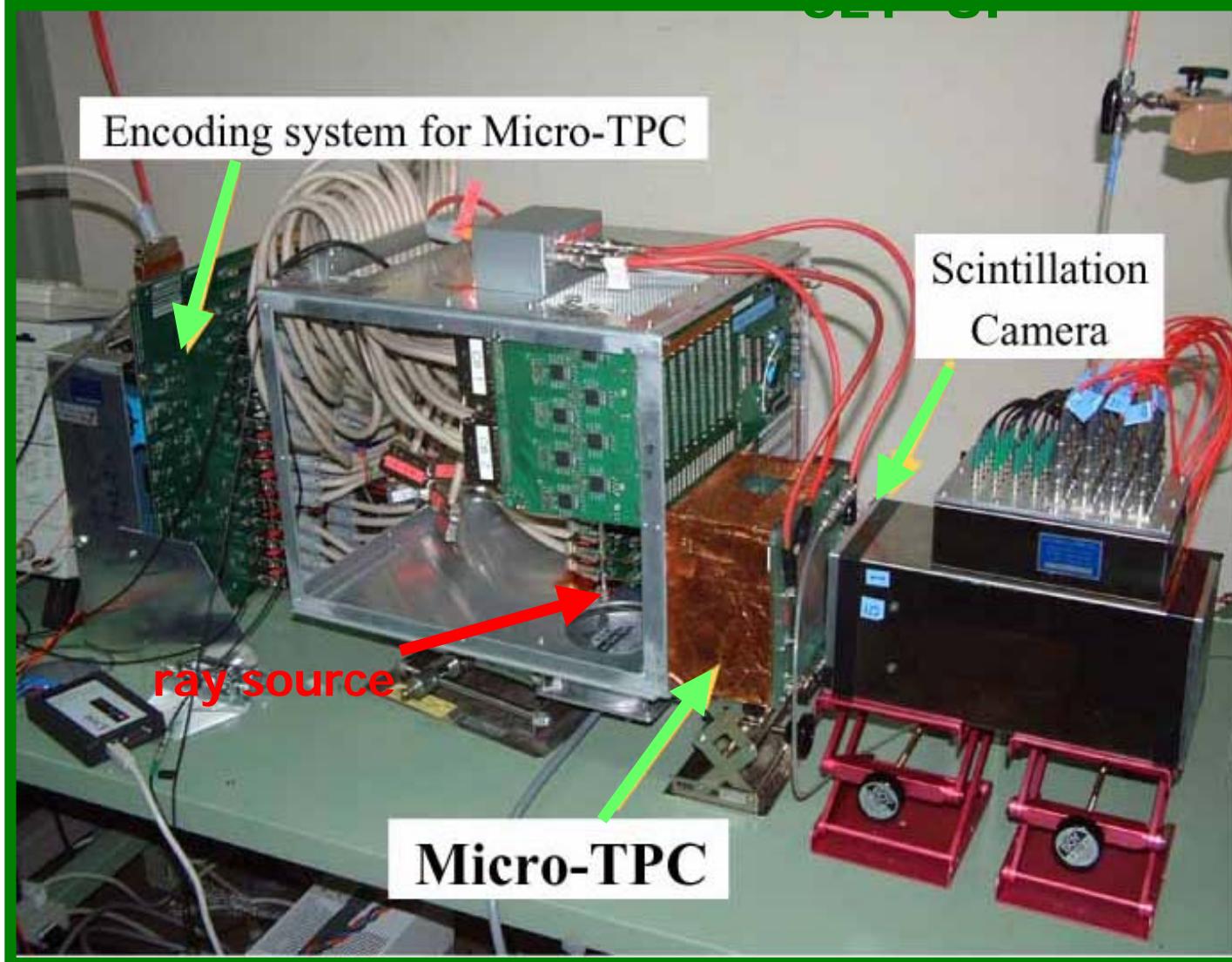
- Micro – TPC with Scintillator



- Full Imaging $\Delta\theta \sim 1^\circ$
- Wide Field of View $\sim 3\text{str}$
- Wide energy range $0.1 \sim 100\text{MeV}$
- Polarization
- Light Detector

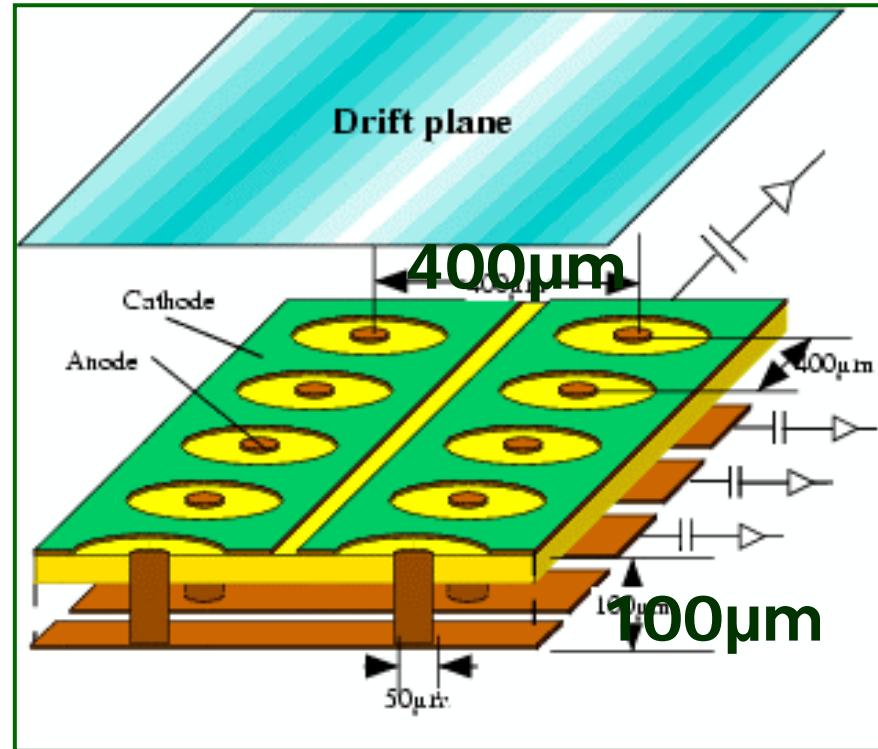
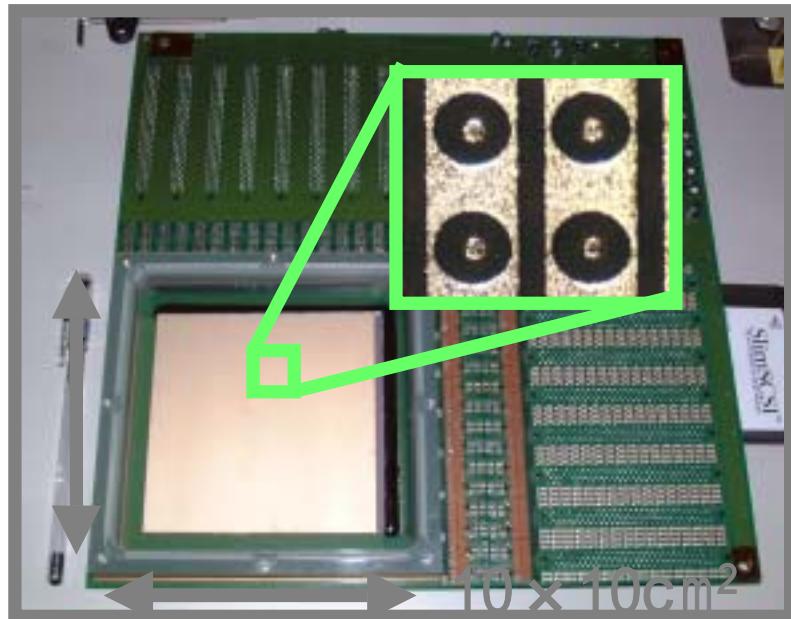
Prototype detector

SET UP



2. μ -PIC Detector

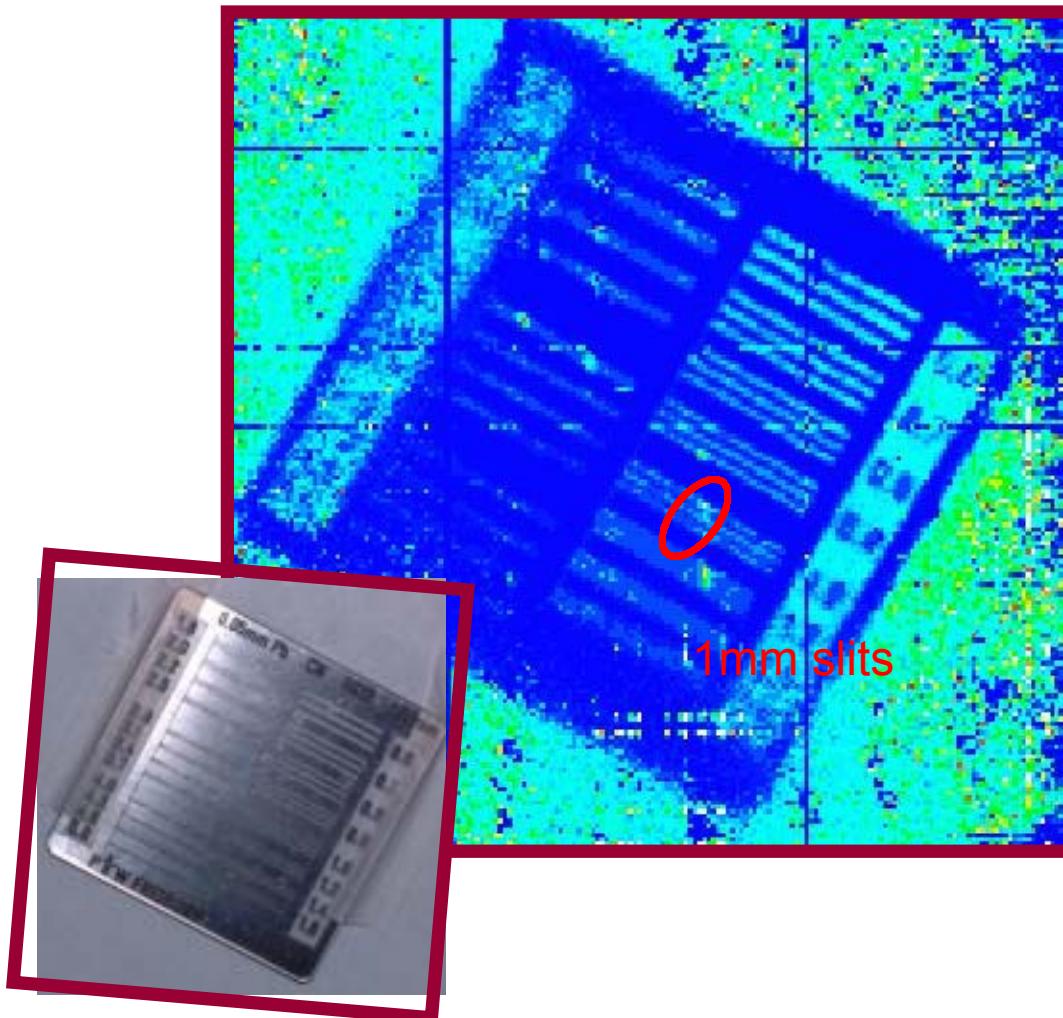
- Micro Pixel Chamber
256 anode + 256 cathode strips
- Fine position resolution
- High gain
- Discharge damage: small



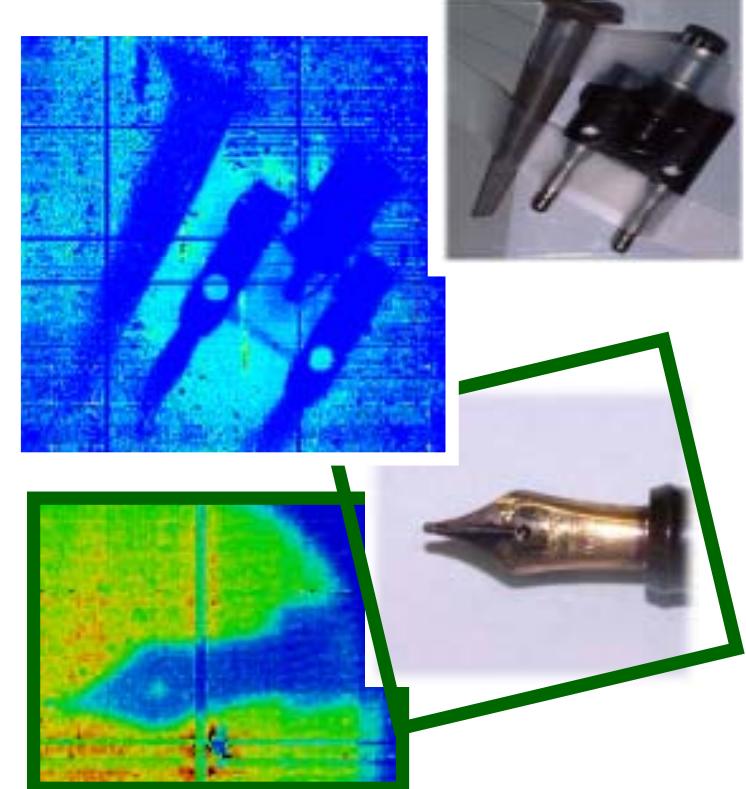
TPC
readout

μ -PIC Detector: X-ray imaging

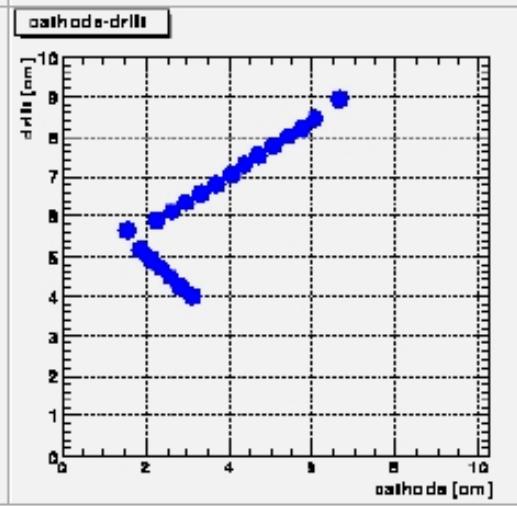
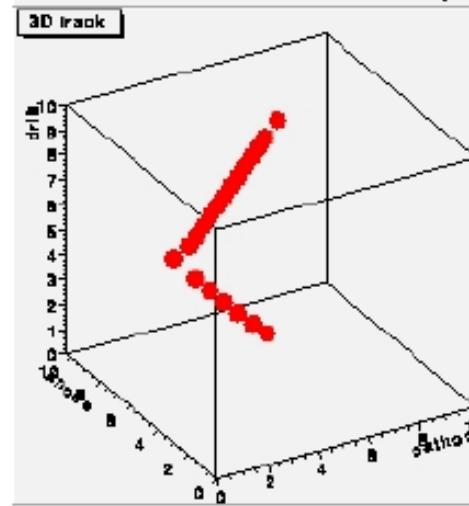
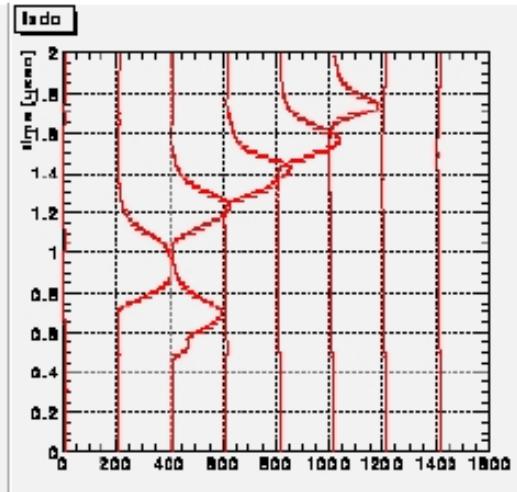
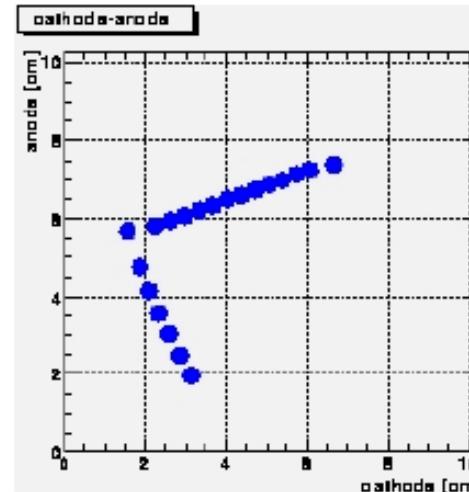
- test chart image
(Xe:C₂H₆ 7:3)



spatial resolution
knife edge test
400 μ m resolution



particle Decay Vertex



Performance

uPIC4 20030106 per10

file 765 event 534

- * Reconstructed
- * Source Position
- NaI hit
- △ Compton point

SOURCE:
 ^{137}Cs

nhit: 5

Source: 662.0 keV

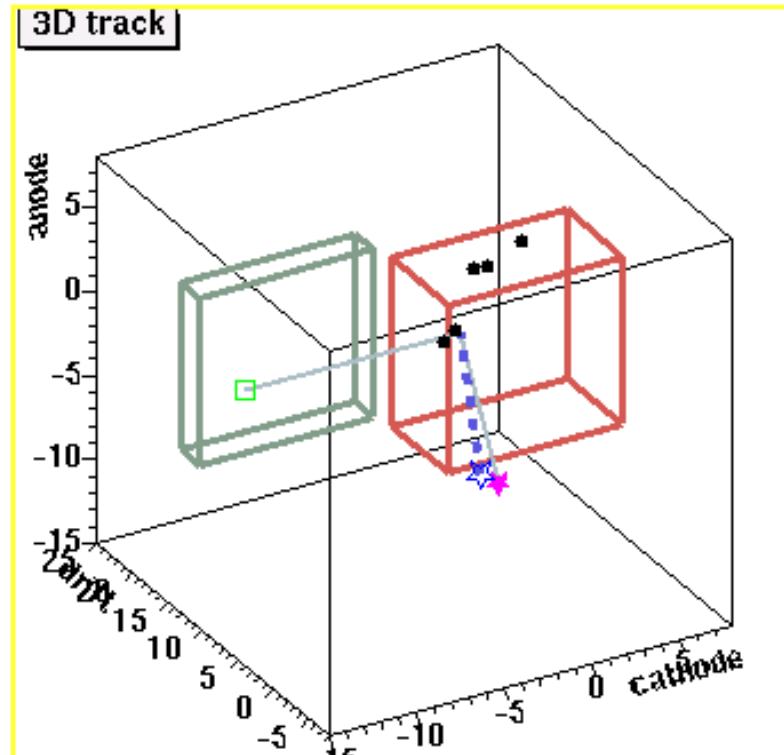
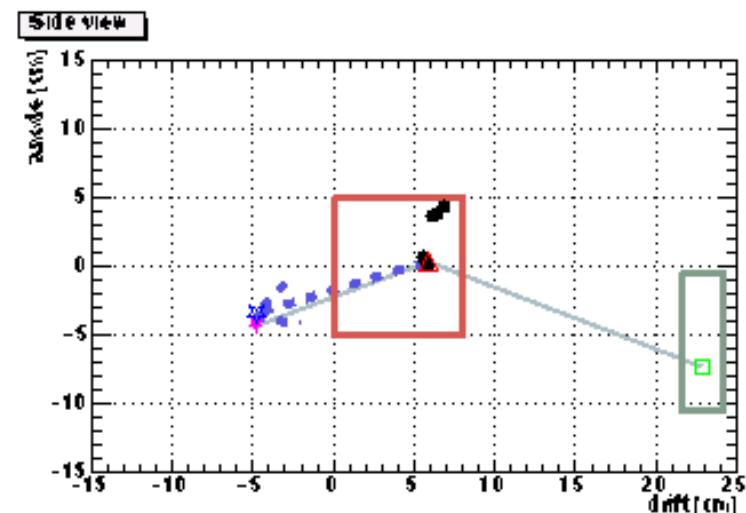
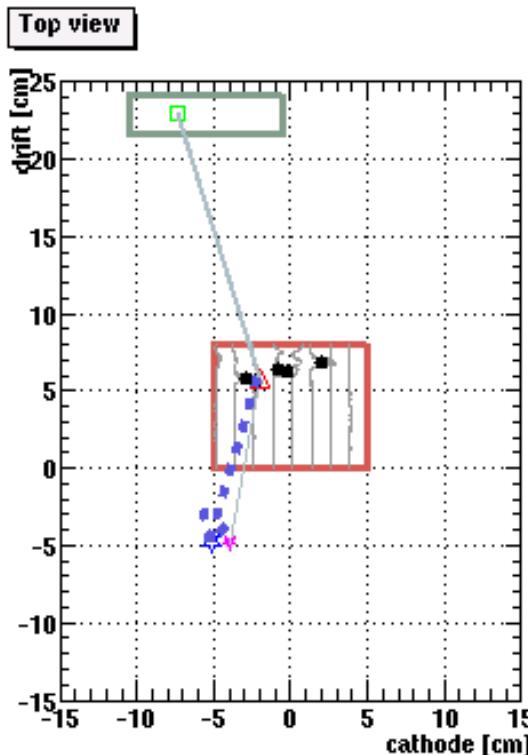
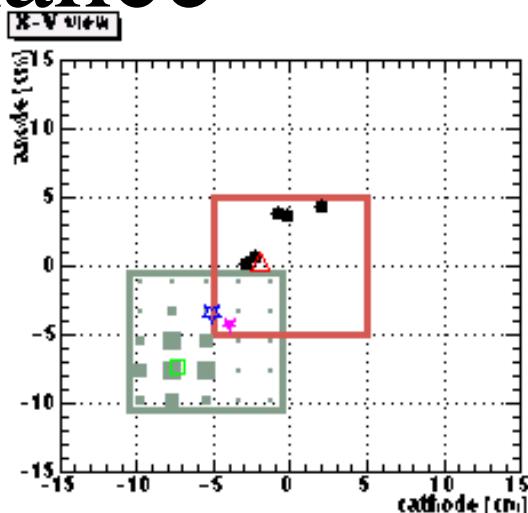
NaI: 432.8 keV

$\alpha = 112.1^\circ$

$\phi = 53.8^\circ$

$\psi = 40.7^\circ$

$\alpha/\phi+\psi = 1.19$



uPIC4 20030106 per3

file 1137 event 60

- * Reconstructed
- * Source Position
- NaI hit
- △ Compton point

SOURCE:

^{133}Ba

nhit: 5

Source: 356.0 keV

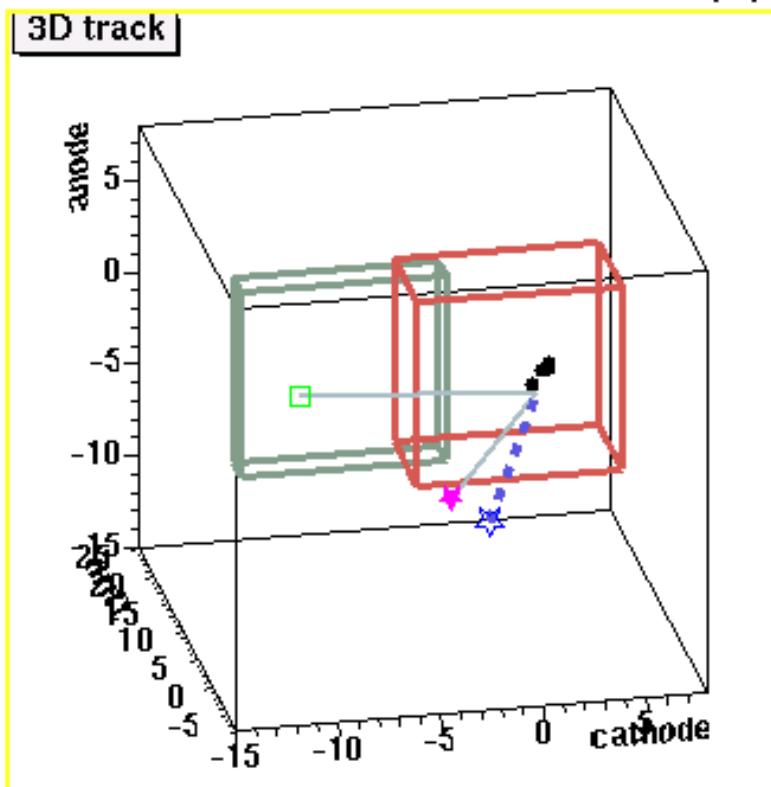
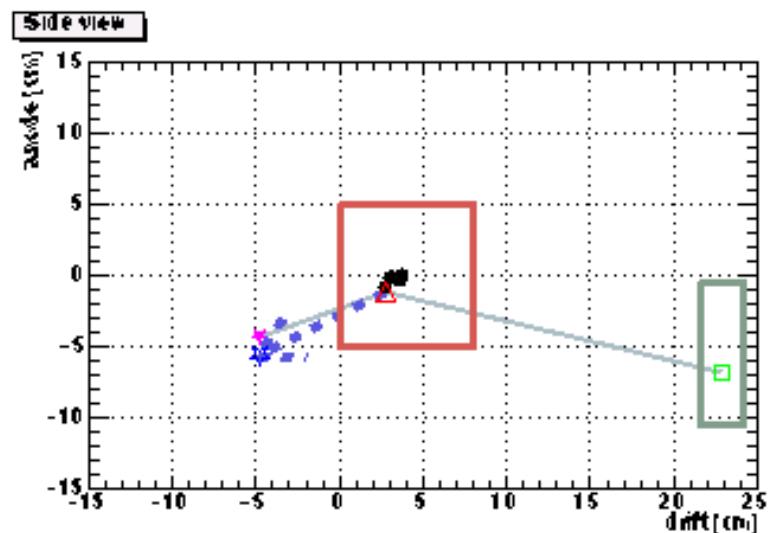
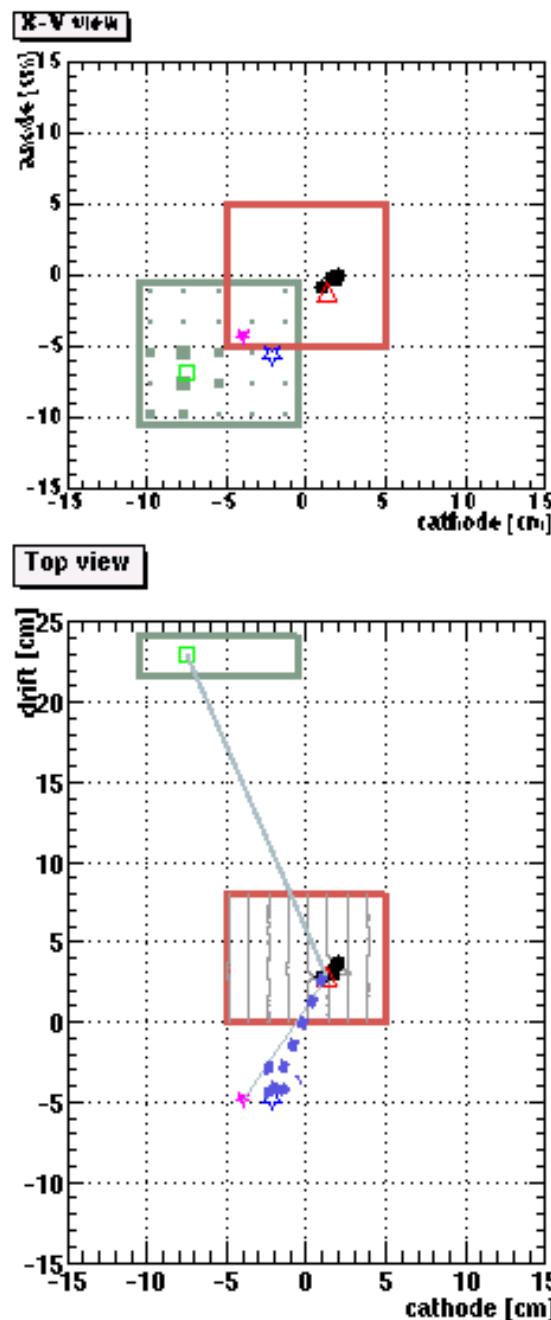
NaI: 258.4 keV

$\alpha = 100.4^\circ$

$\phi = 62.7^\circ$

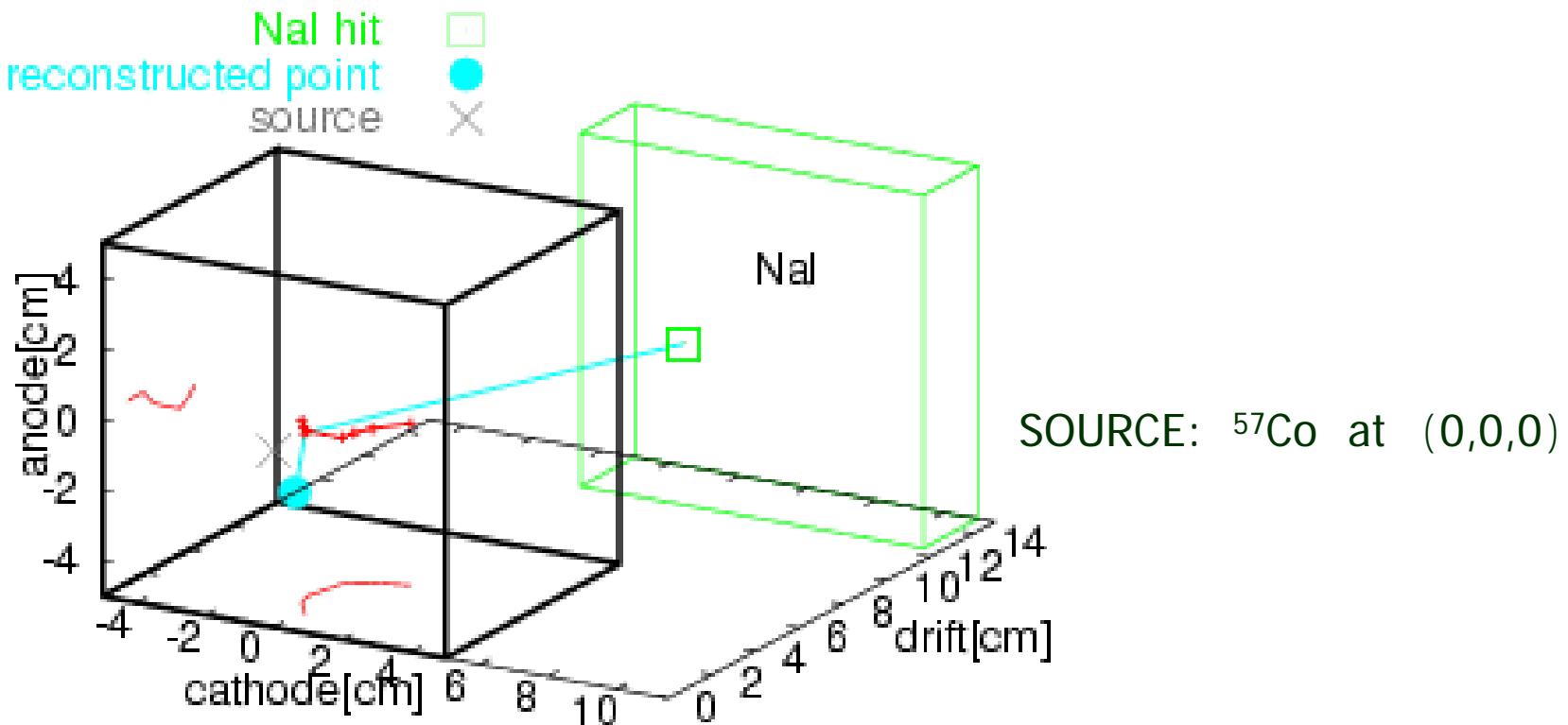
$\psi = 44.0^\circ$

$\alpha/\phi + \psi = 0.94$

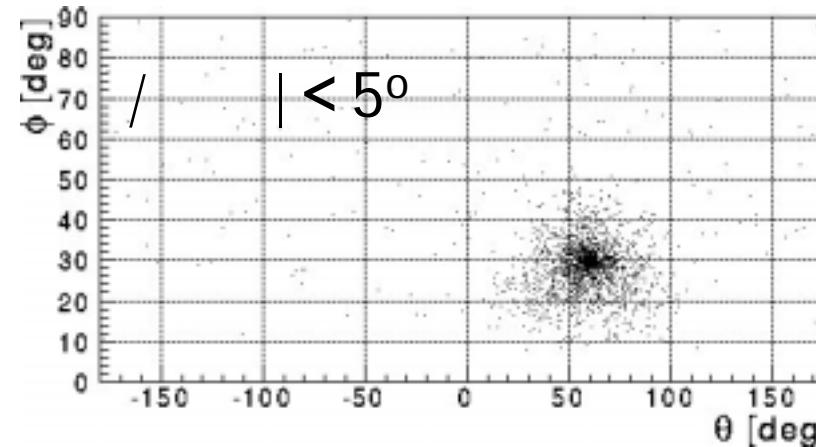
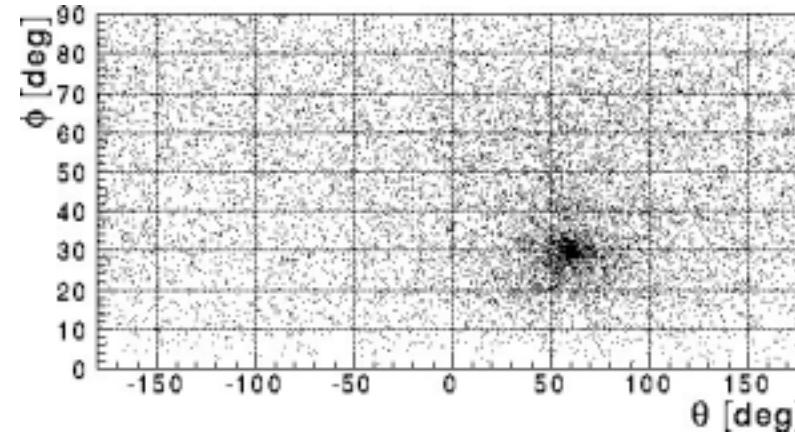
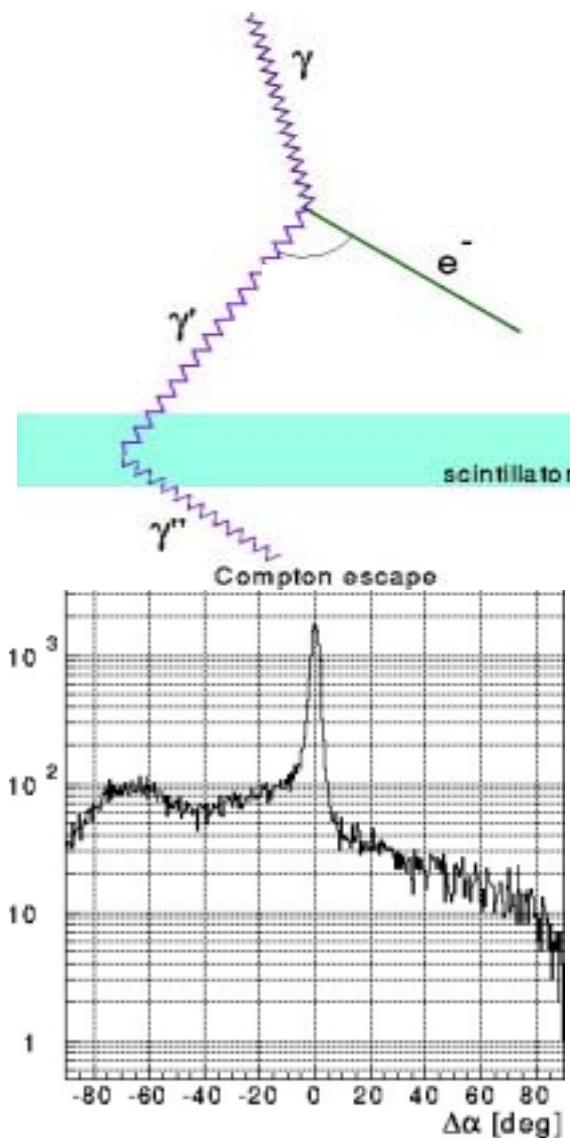


Performance

- Typical Events

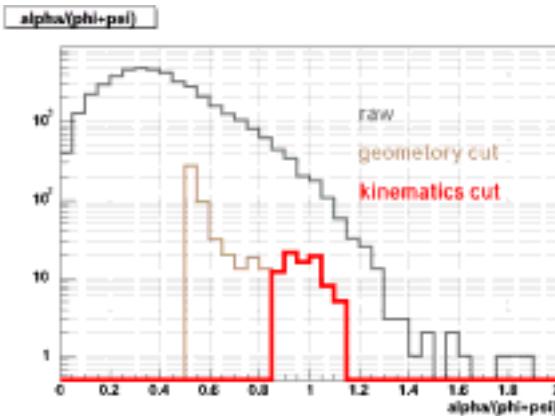


Background Self-Rejection



NO Active Shied!

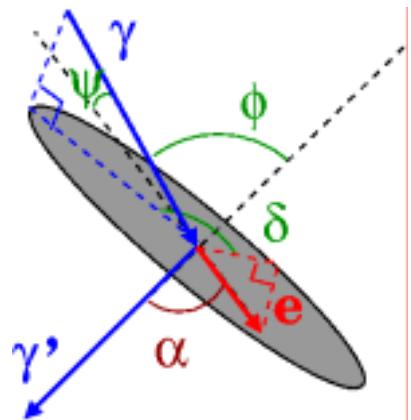
• Results



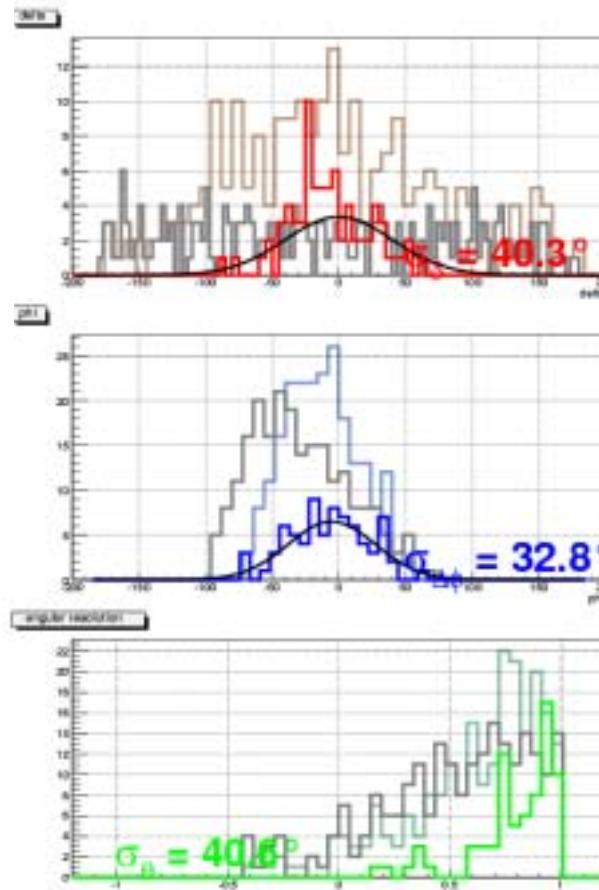
簡単なカット

+

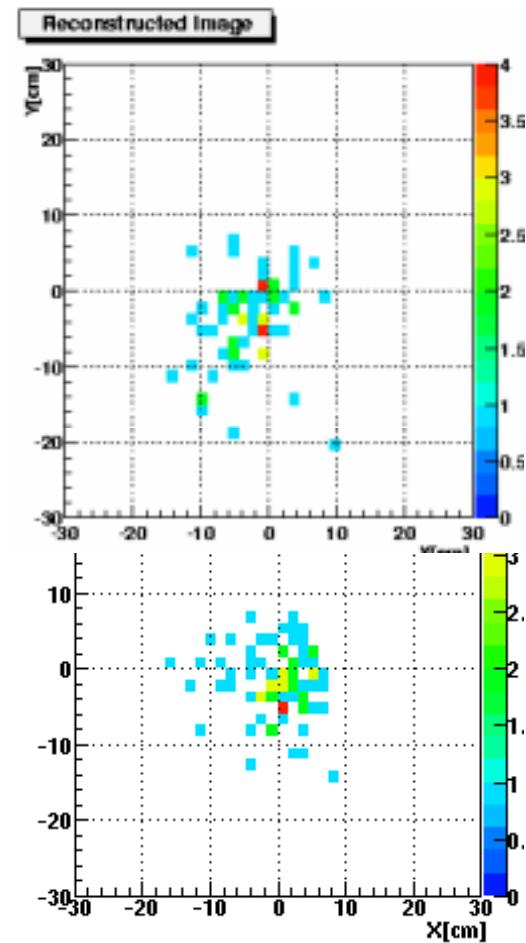
運動学を利用したカット



角度分解能

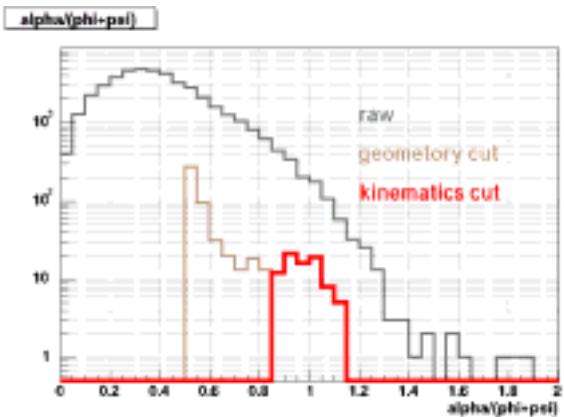


再構成されたイメージ



^{133}Ba を 5cm離した位置から照射
上 (-4.0, -4.2) と 下 (4.0, -4.2)

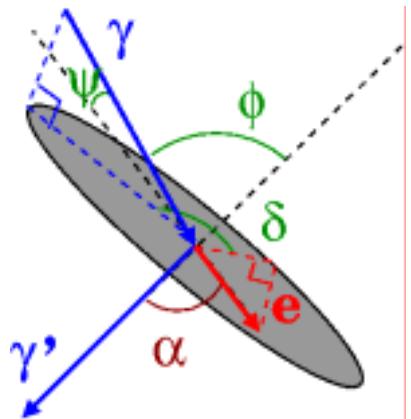
• Results



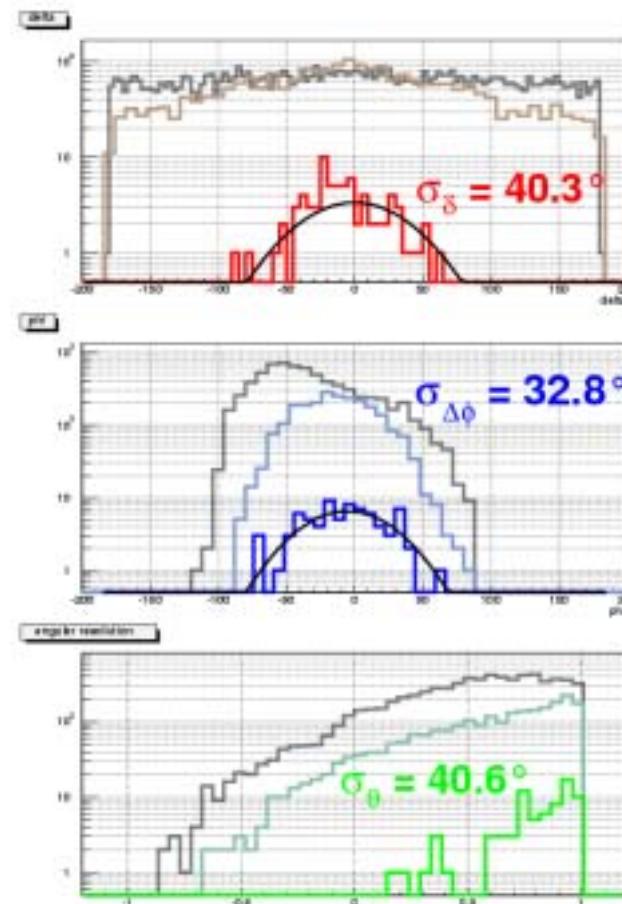
簡単なカット

+

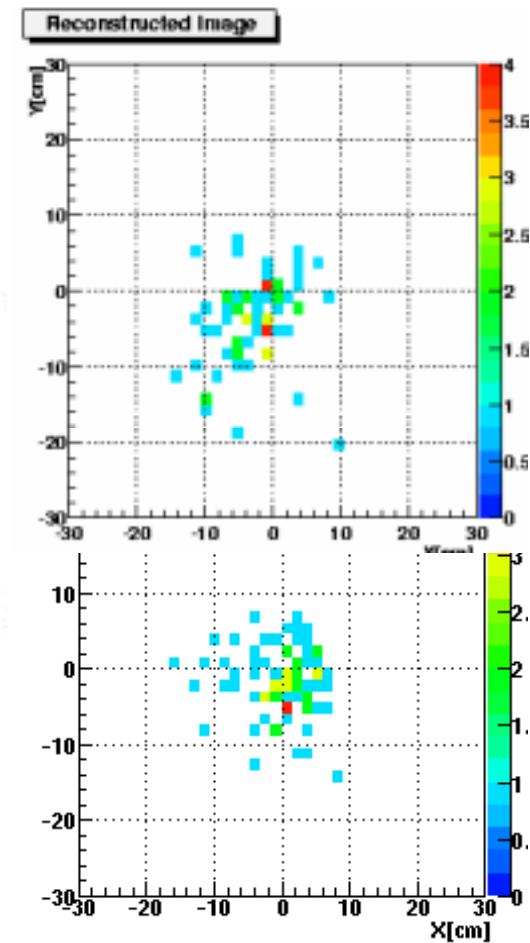
運動学を利用したカット



角度分解能



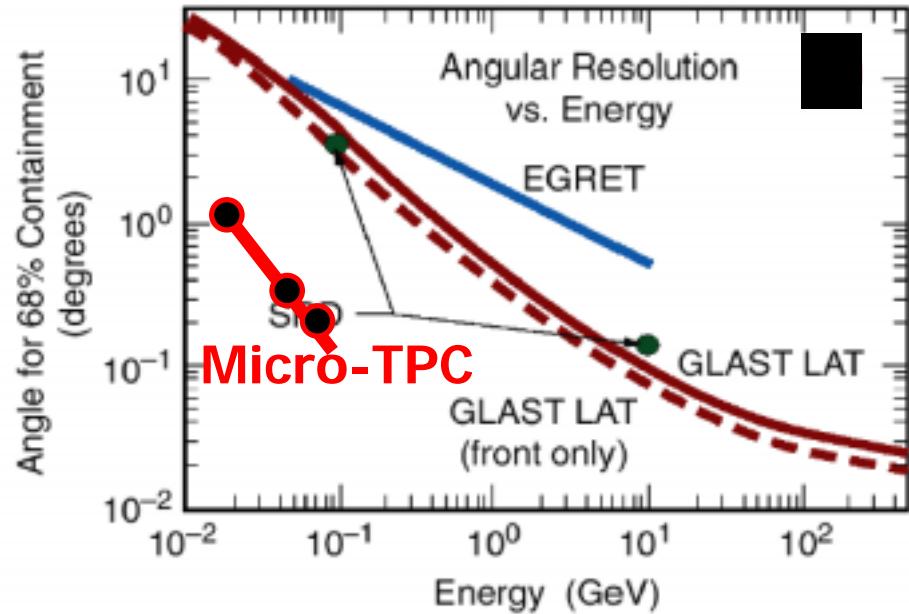
再構成されたイメージ



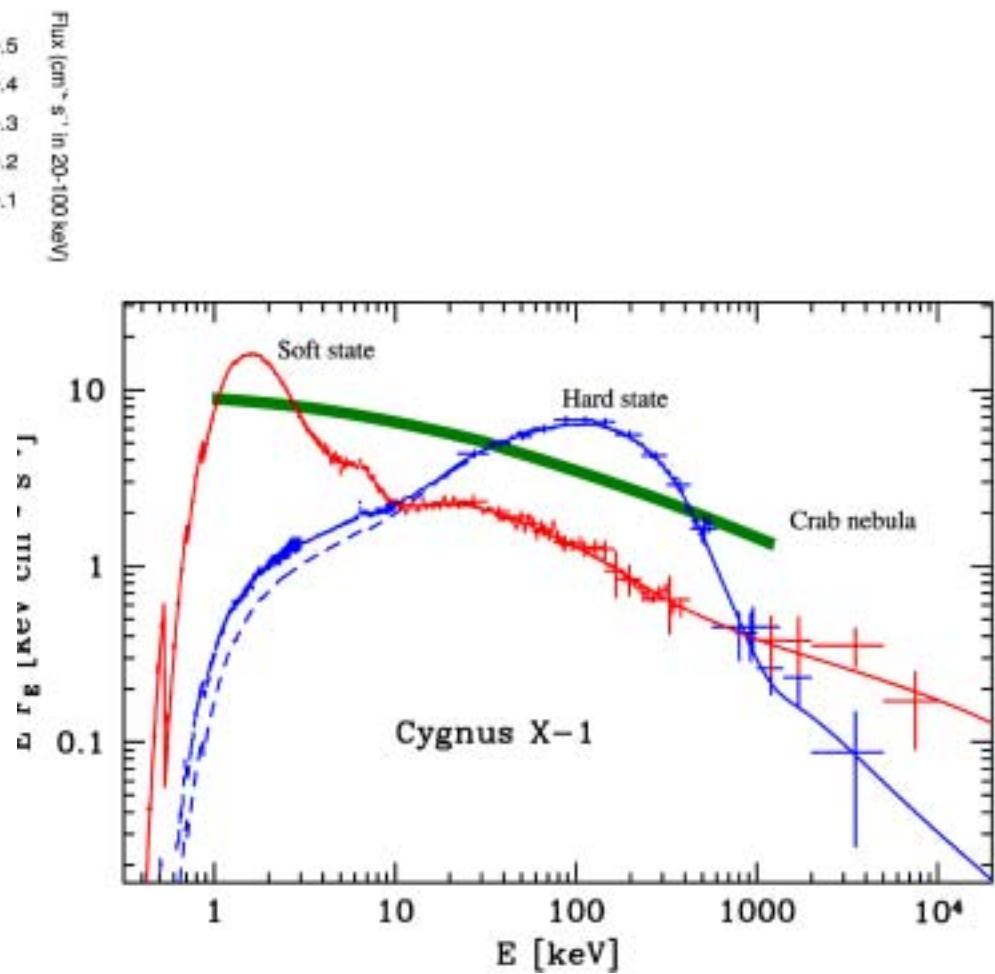
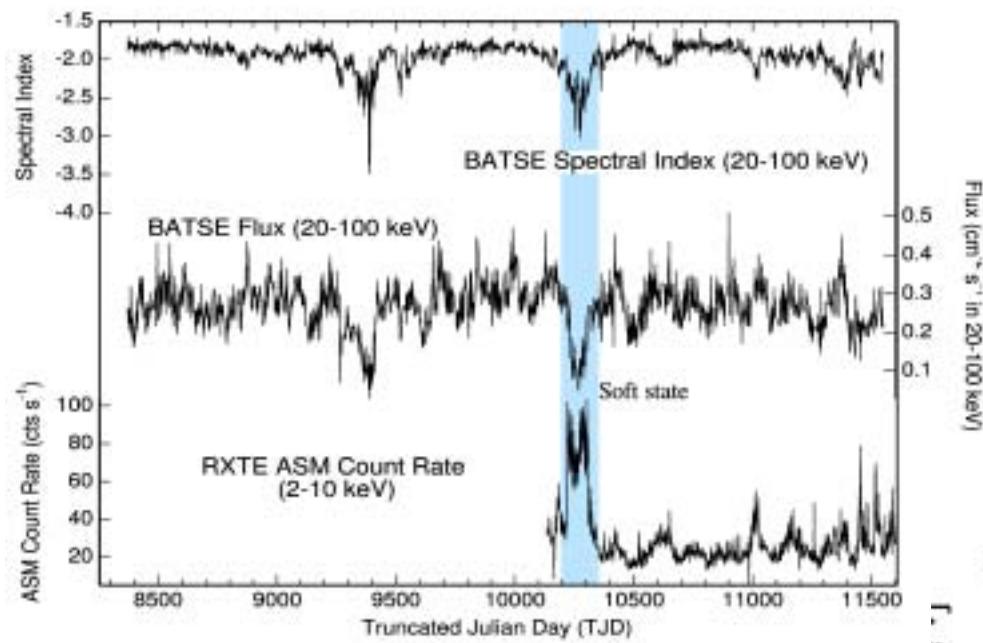
^{133}Ba を 5cm離した位置から照射
上(-4.0, 4.2) と 下(4.0, 4.2)

γ -ray camera

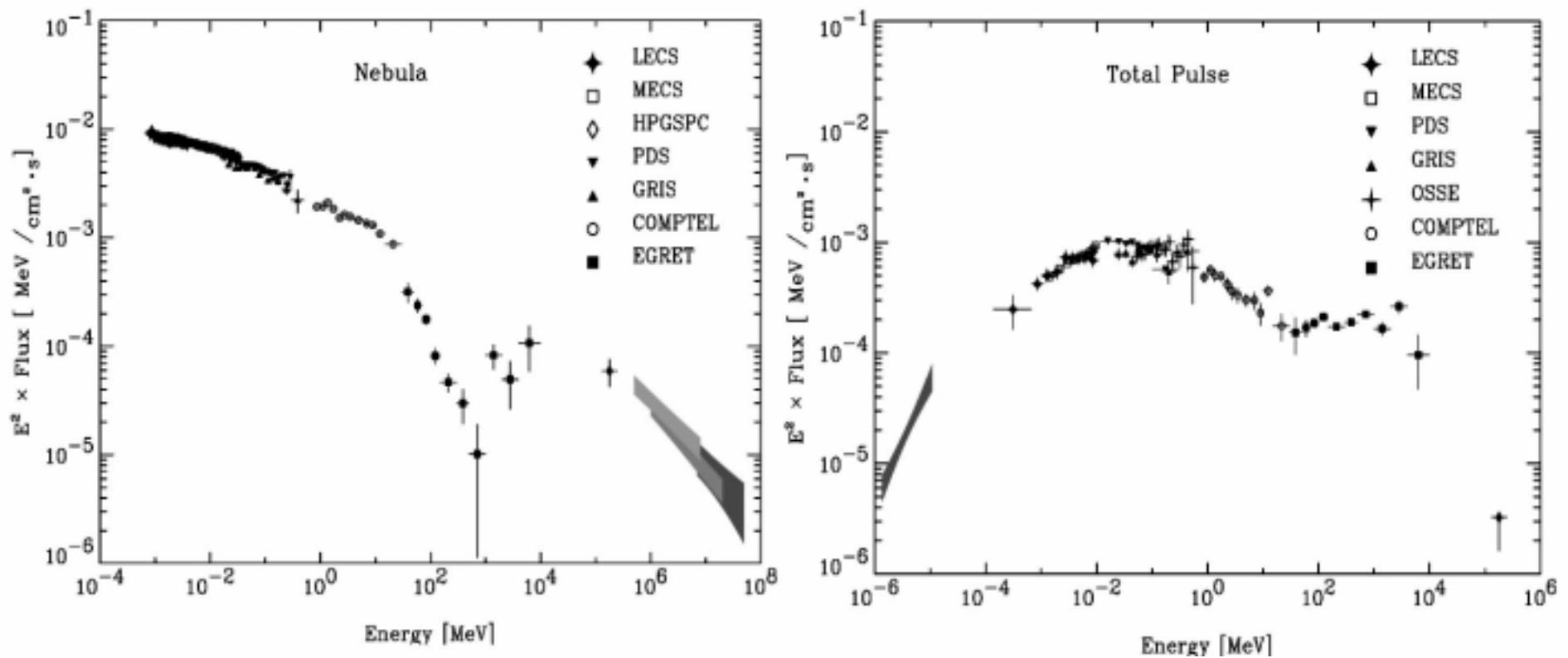
- for Astrophysics
 - point source search in all sky
 - 0.1 ~ 100 MeV
 - Imaging($<1^\circ$) + Polarization
- for Medical Imaging
 - RI tracing with low radiation exposing
 - γ -ray CT scan
- for Safety Control of Radiation
 - Rapid survey of radioactivity
 - Status monitor of reactor/accelerator



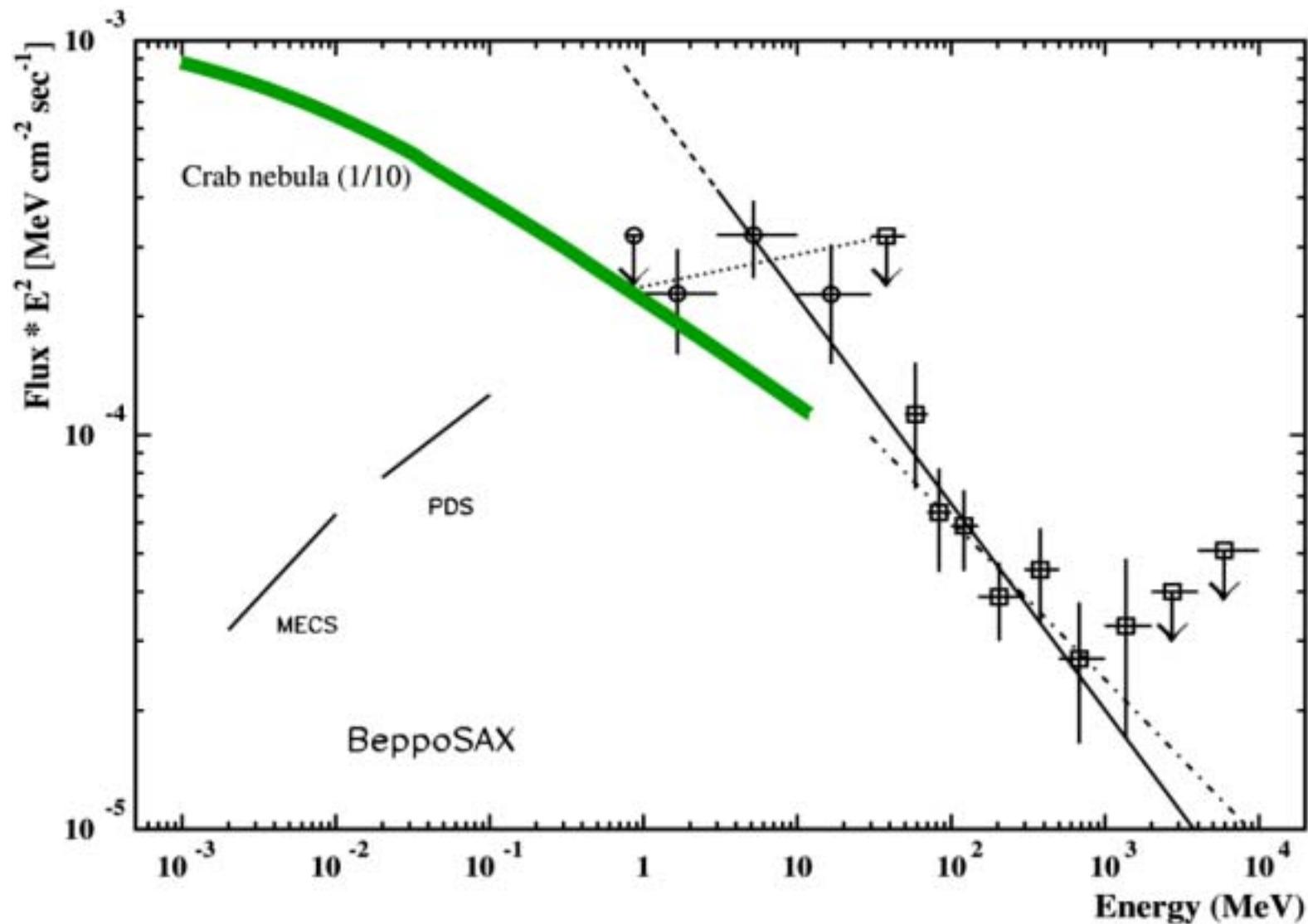
Cyg X-1 (Galactic Blackhole Candidate)

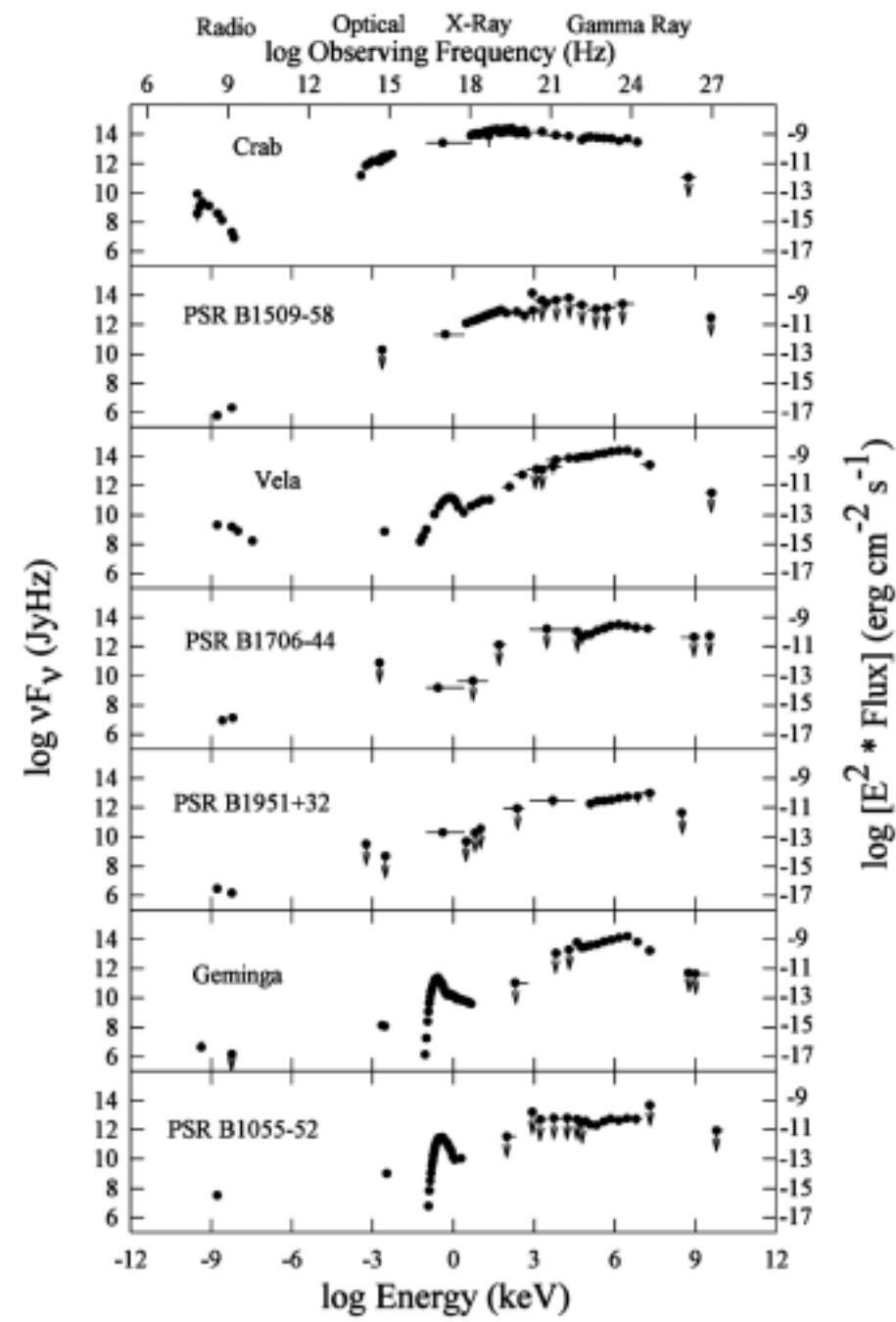
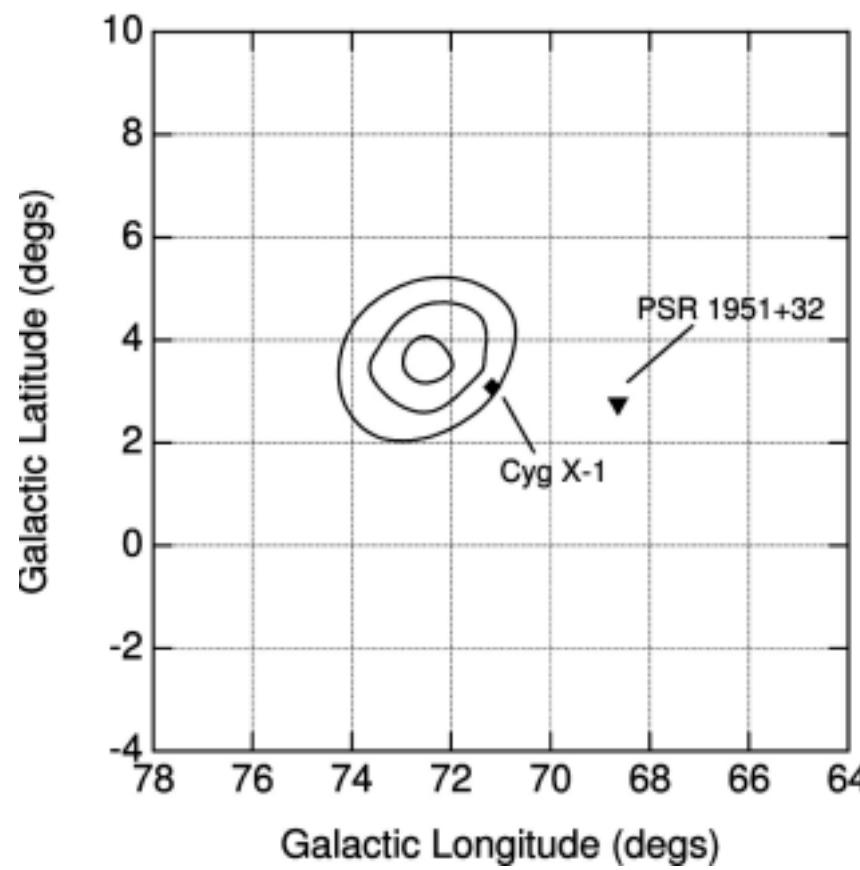


Crab pulsar, nebula



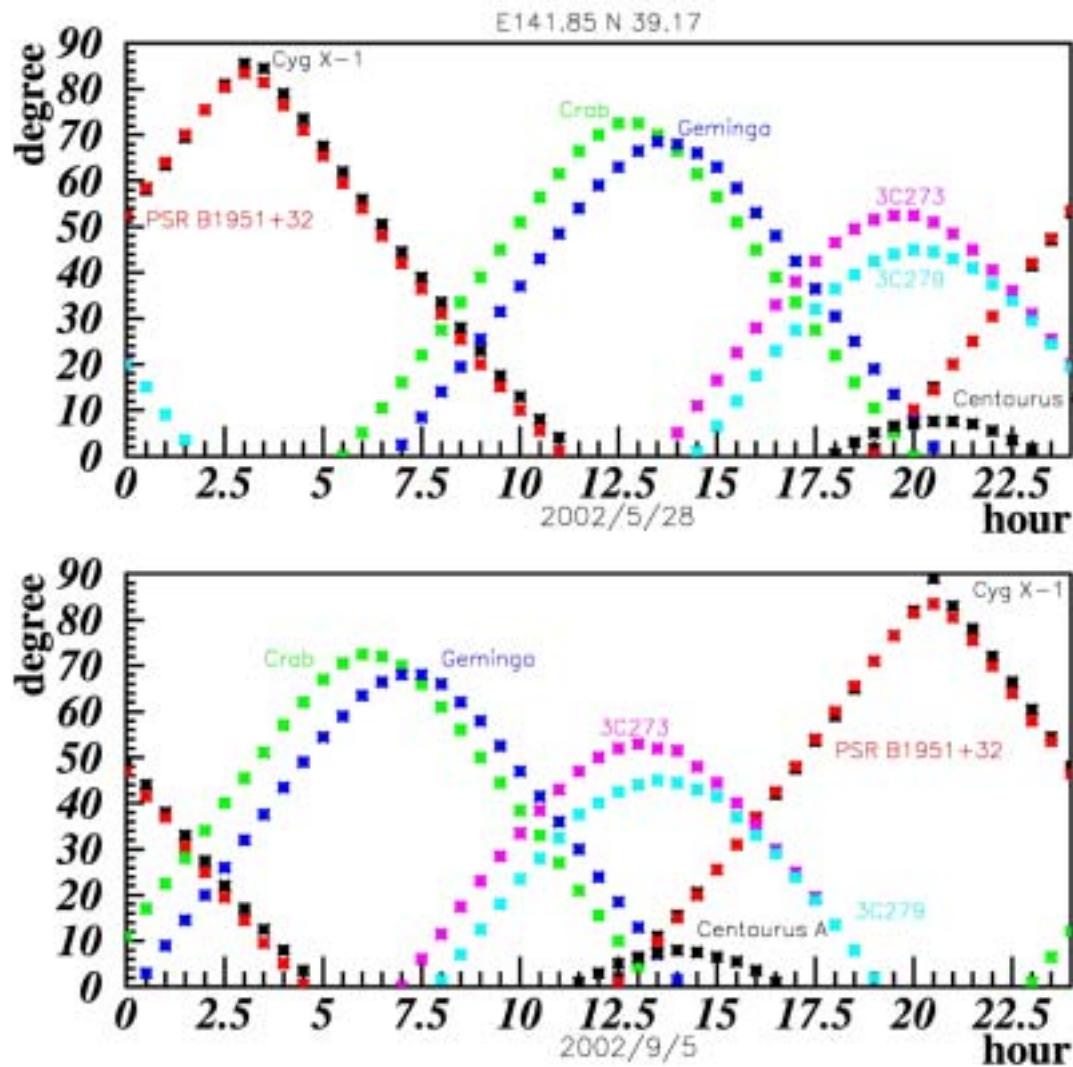
3C273 (Blazar)





Cen A (Radio galaxy)

見える天体@三陸



Summary

- MeV Region -> Final Unexploited Region in E.M. Waves in Astrophysics.
- But very fruitful ! -> In particular P.H.
- Multi-Compton, Full Tracking etc.
Lots of Studied about MeV gamma-ray Imaging are on going.
- Dark Matter (Angular Distribution Method),
- Double Beta
- Thin Flat Large Area Gas PMT
- 現在の財源 宇宙フォーラム IA, 特定領域