最遠方GRB検出のための赤外線望遠鏡とサブMeVガンマ線イメージングによる衛星探査の可能性

1. Electron Tracking Compton Camera in MeVガンマ線天文学 (SMILE-project)
2. 最遠方ガンマ線バースト検出の可能性
3. 中間赤外線望遠鏡
4. 極域での長時間気球観測
5. まとめ

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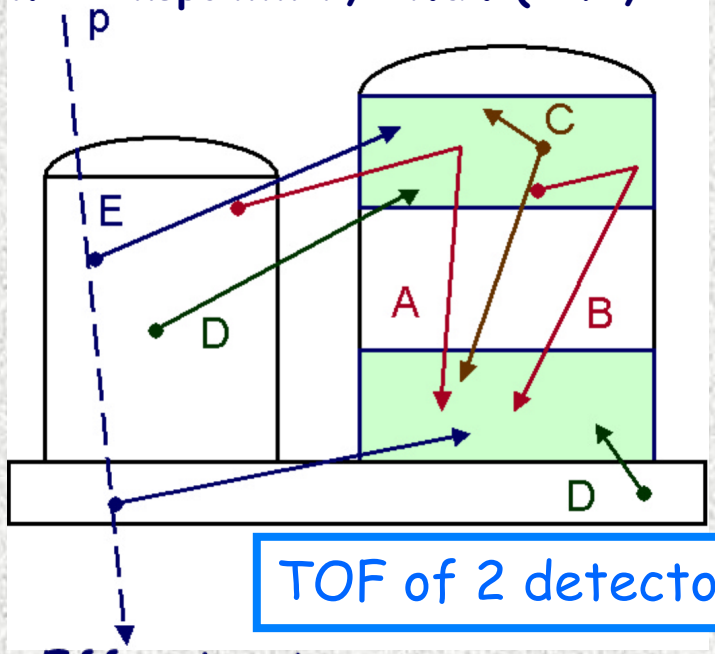
2010 Sep.17GRB-WS @CRC将来計画シンポジウム

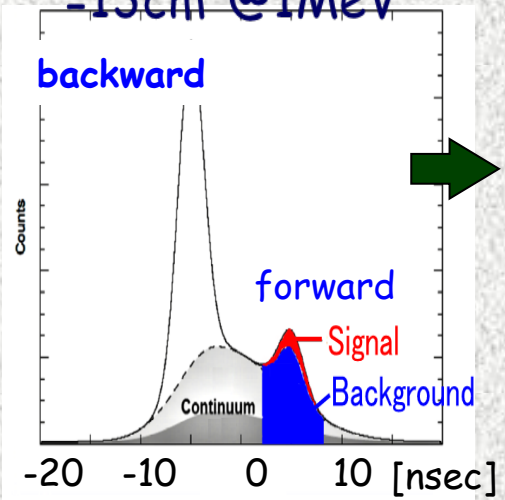
MeV Astronomy

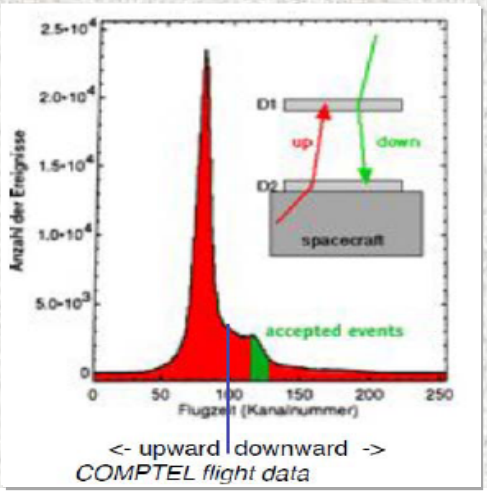
G.Weidenspointner, et.al. (A&A, 2001)

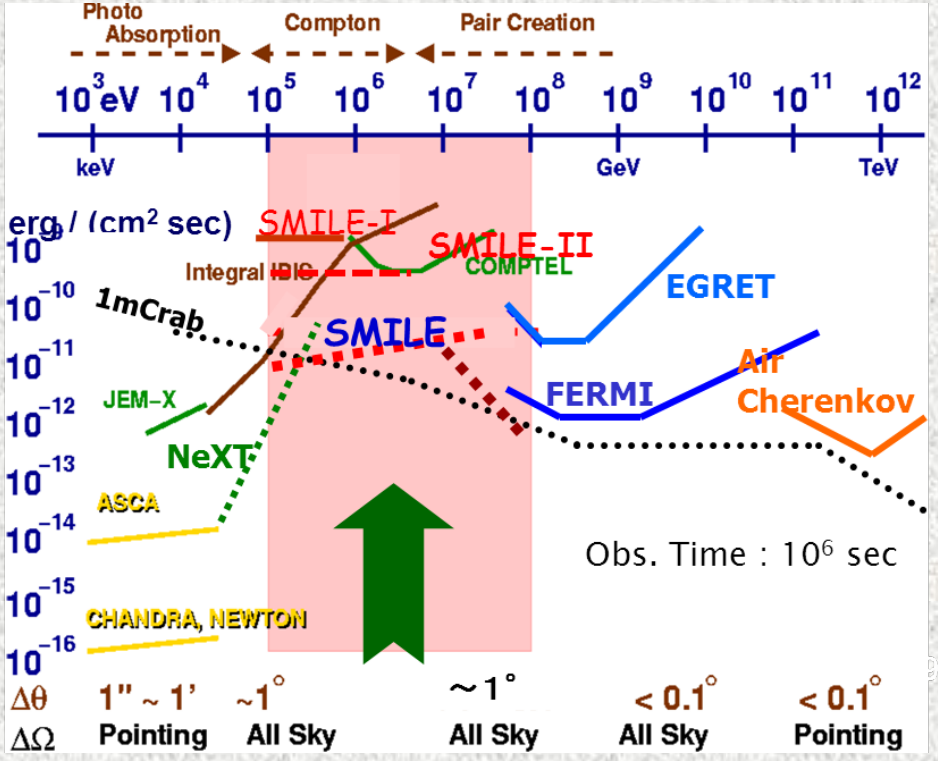


TOF of 2 detectors

Effective Area
=13cm^2@1MeV



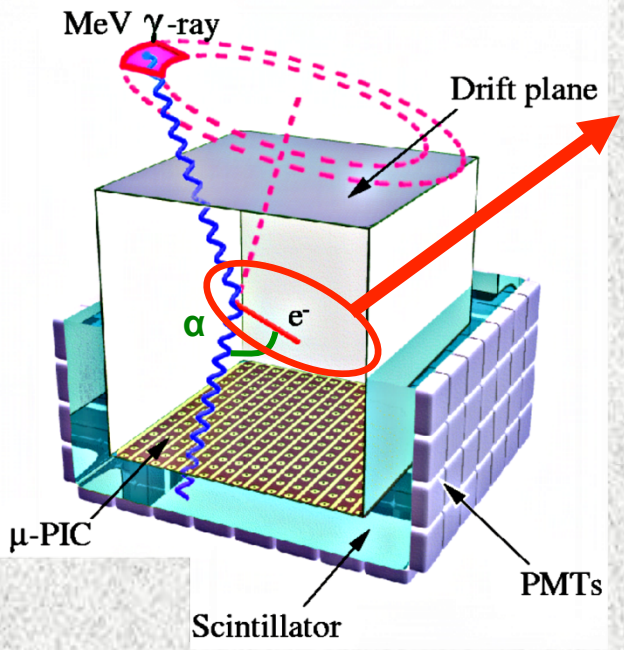




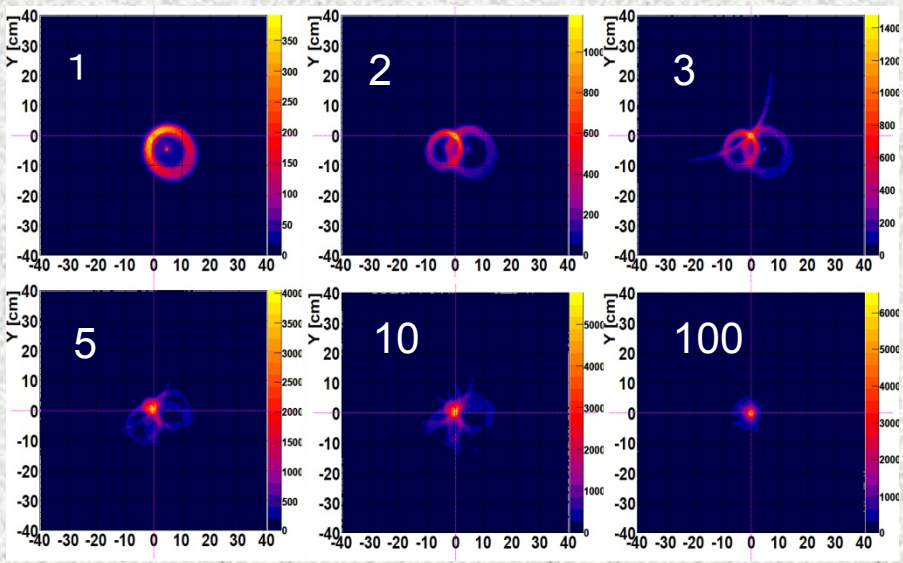
ラインガンマ線
元素合成 ^{26}Al・ 511 keV

○連続ガンマ線放射
- ブラックホール等
- 宇宙線加速 AGN, Pulsar, SNR,
- 宇宙の始まり
  ガンマ線バースト(GRB)
  + 極地方での最小バースト

Electron Tracking Compton Camera(ETCC)

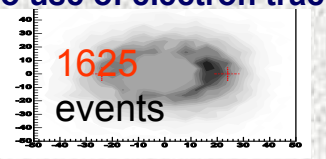


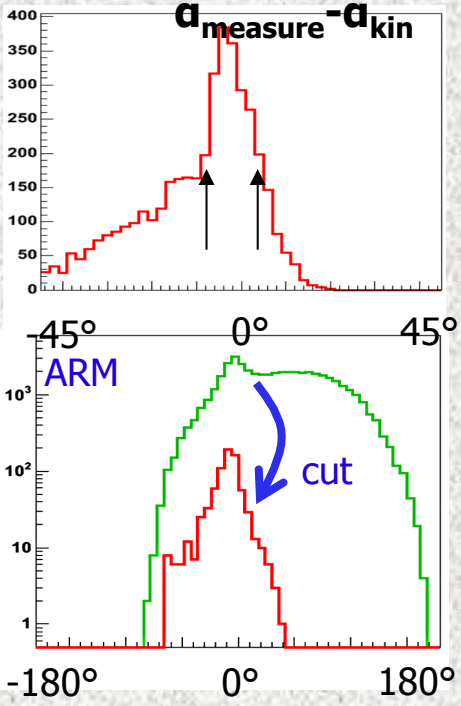
1. Determination of the direction of each gamma ray
2. Noise Reduction by Kinematics(α)
3. Large FoV. ~3str
4. For All Sky MeV-γ Survey with >10 better than COMPTEL



In use of electron track

no use of electron track

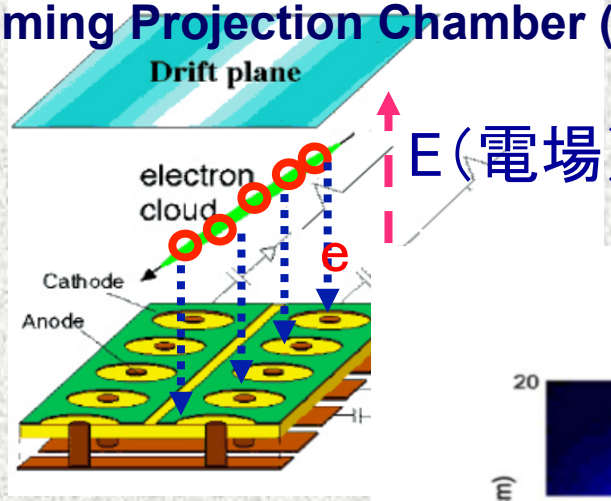




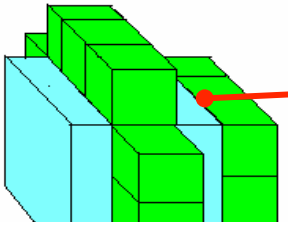
10cm-cube μ-TPC & ETCC

GSO Pixel

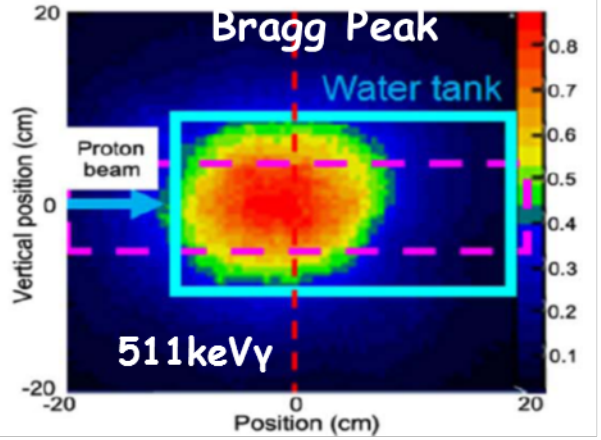
Timing Projection Chamber (TPC)

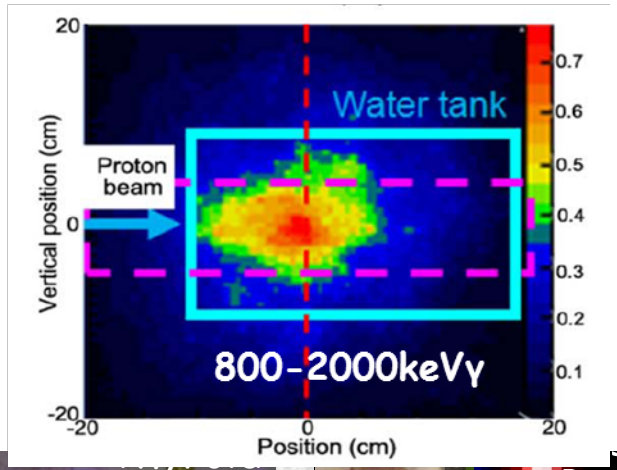


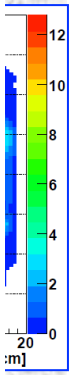
TPC

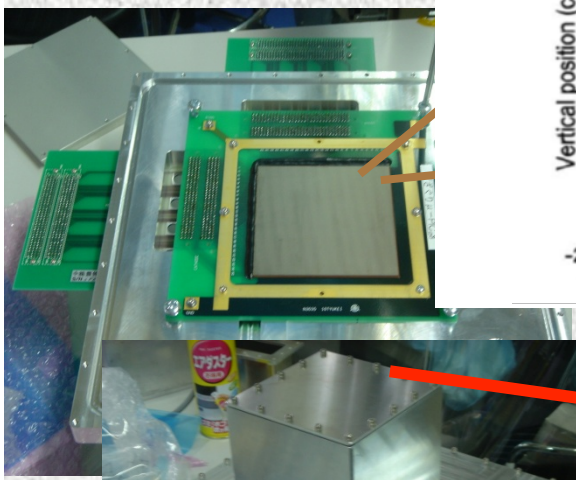


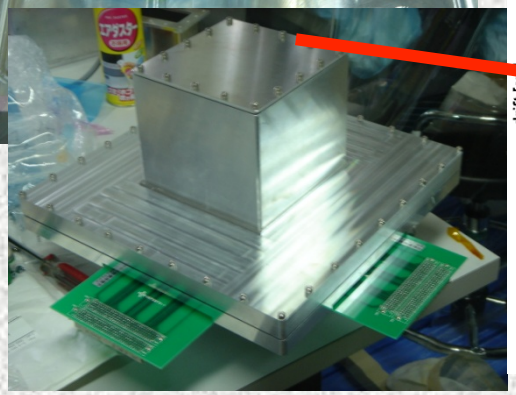
連続ガンマ線イメージング

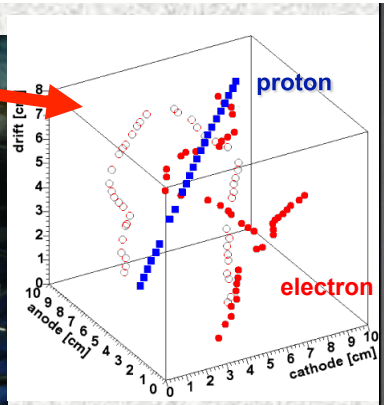


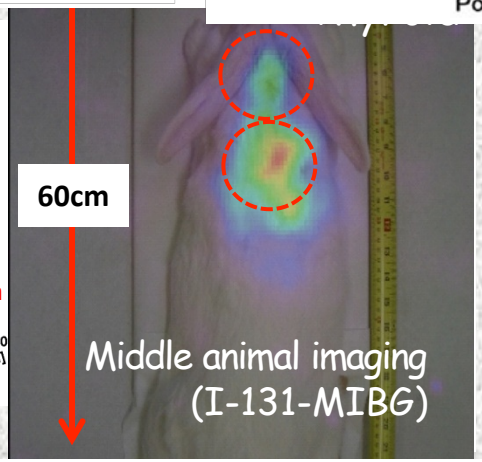


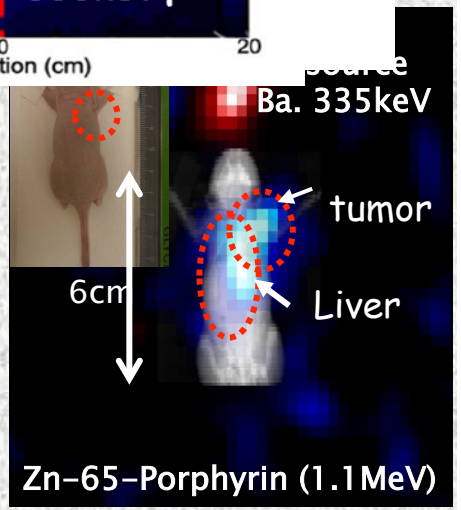




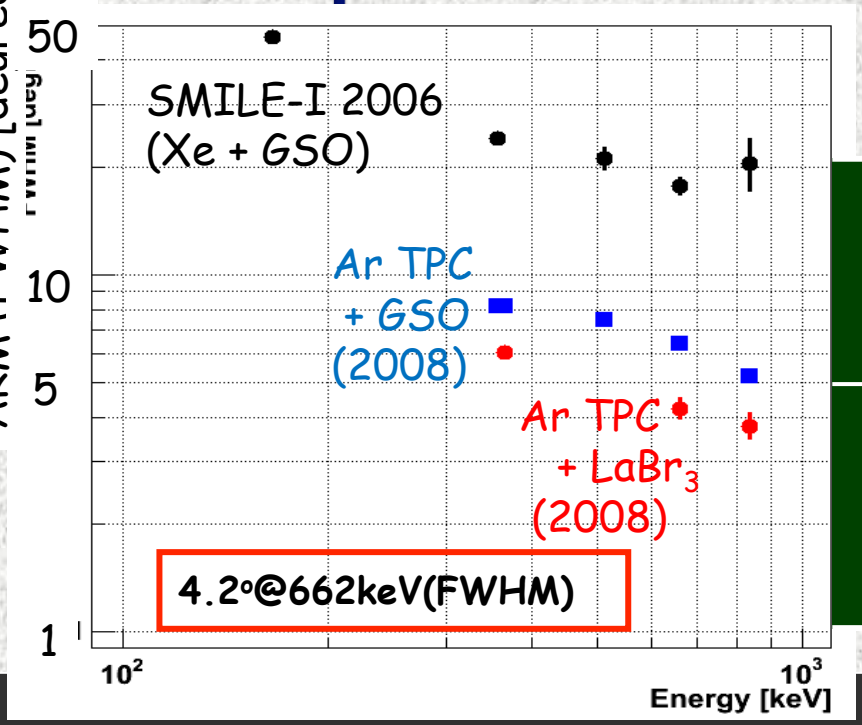




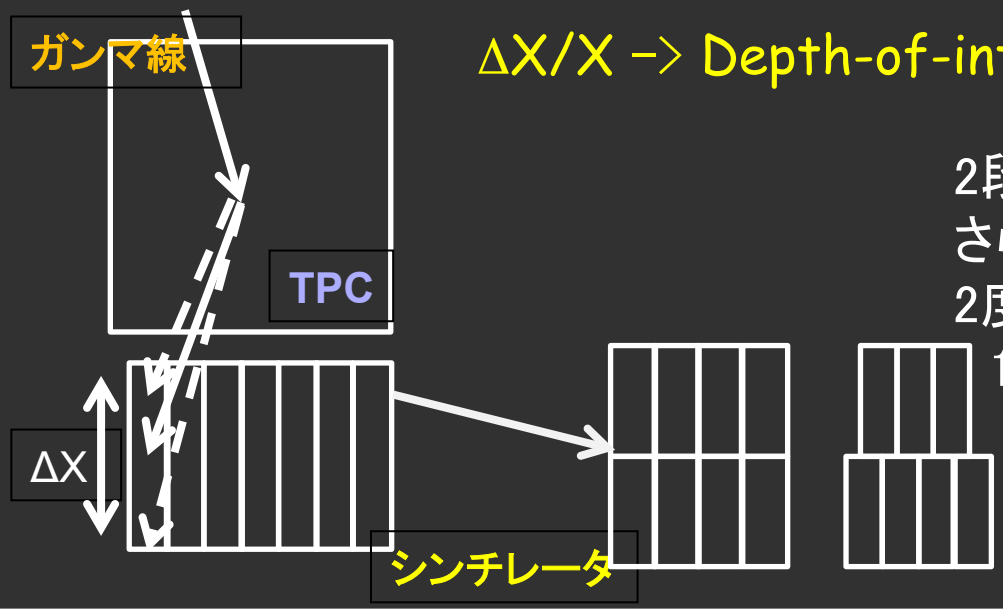




Improvement of Angular resolution



	角度分解能 実測値	角度分解能	ΔE/E	ΔX/X	Doppler
		（計算値）			
GSO	5.0 ± 0.2	5.2	4.3	2.8	0.9
$LaBr_3$	4.2 ± 0.3	4.3	2.7	3.2	0.9

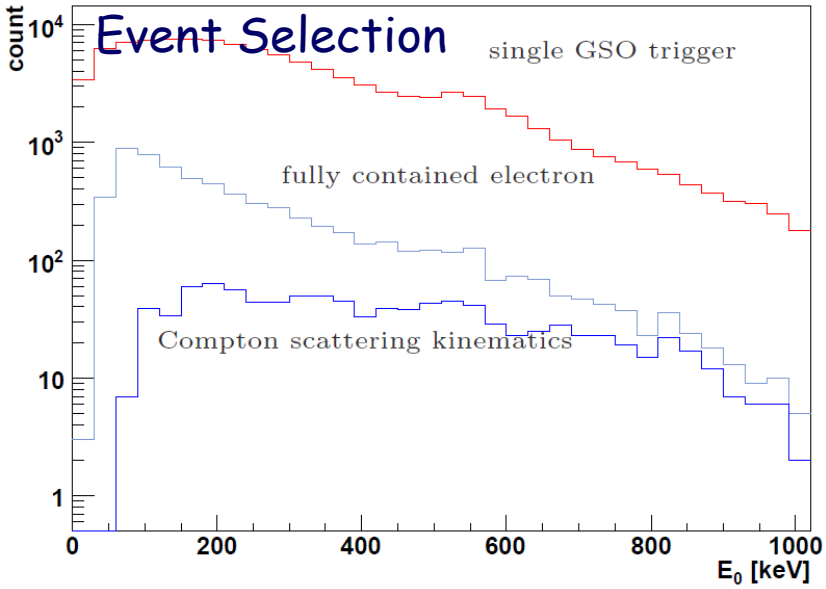


ΔX/X -> Depth-of-interaction (DOI)

2段DOIー＞3度@662keV、
さらにシンチレータ-5.8%->4%で
2度以下も可能
1MeV->1.3度（COMPTEL；4.7度）

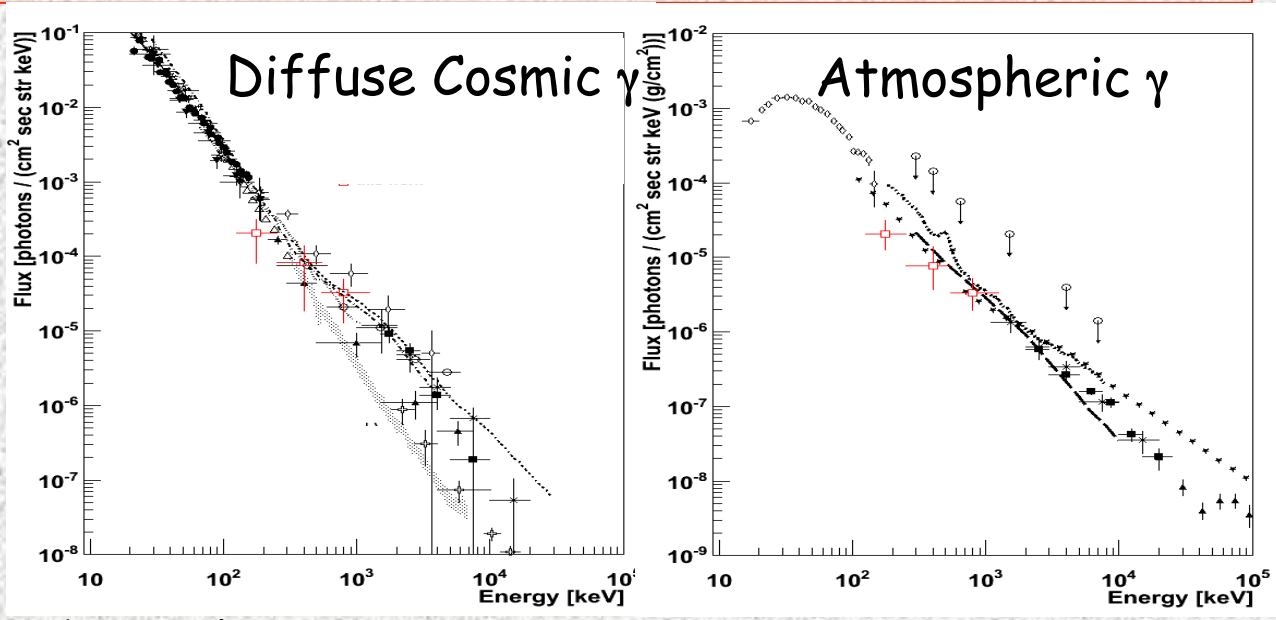
First Balloon Experiment (Smile-I)

Test flight using 10cm cube ETCC to measure
Diffuse Cosmic and
Atmospheric gamma rays in 0.1-1MeV
3hours observation @35km



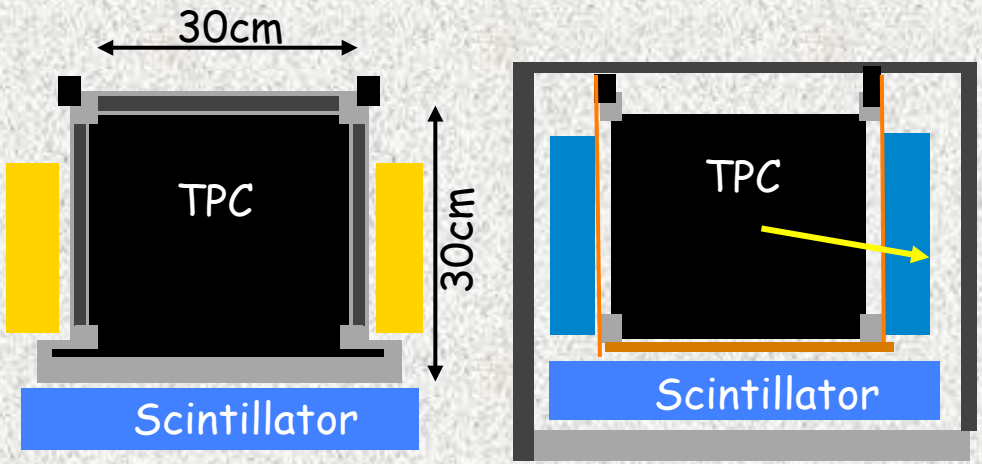
All Trigger enent 2.3×10^5 events

Signal ⇒ ~420 events Simulation ⇒ ~400events (GEANT4 base)



Takada et al., ApJ 2011

Simulation of SMILE-II flight model



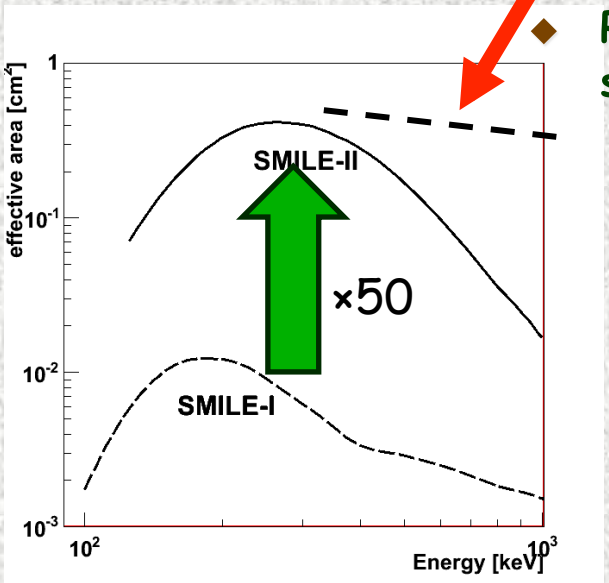
Effective area

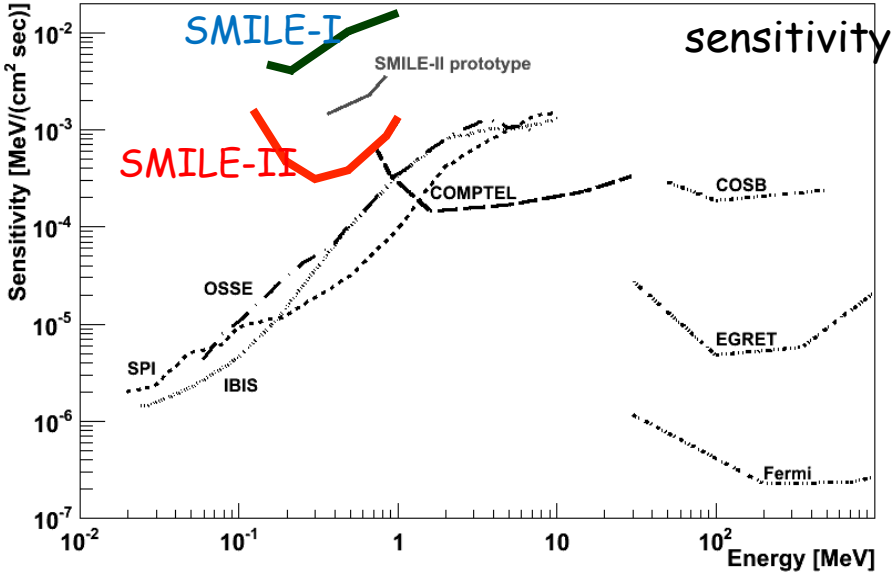
prototype
- Absorber: 36 GSO-PSAs
- Tracker gas: Ar 1atm

Flight Model
- Absorber: 216 GSO-PSAs
- Tracker gas: CF_4+Ar 1.5atm
- Azimuthal Tracking of target
- New Reconstruction method

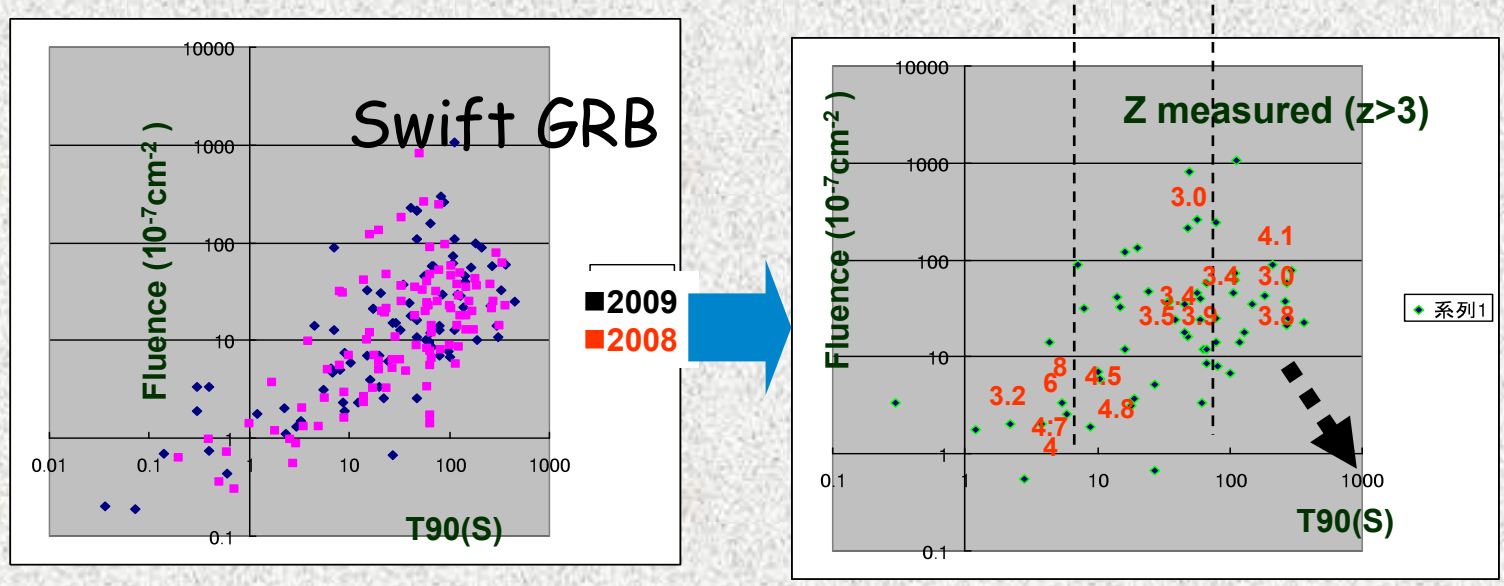
Scintillator inside

Plastic scintillator inside





GRBs detected by Swift



Sensitivity of X-ray Burst Trigger

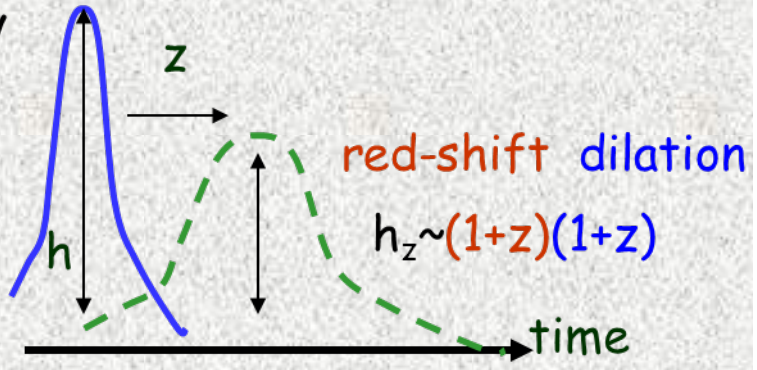
- Diffuse X-ray BG:~10ph./cm^{-2}s^{-1}str^{-1} >5keV
- Ph.$_{lim}$ $\propto$ $\sqrt{}$(A: Detection Area)

  A(10^{4}cm^2 >5kev)->10^{5}counts s-1 in A

  -> 0.20Ph./cm^{-2}s^{-1} at 8σ
- Ph.$_{lim}$ $\propto$ hz ~(1+z)^2

  z+1 $\propto$ (A)$^{1/4}$

  If z$_{lim}$(Swift)~7 -> z$_{lim}$(Swiftx10)~12

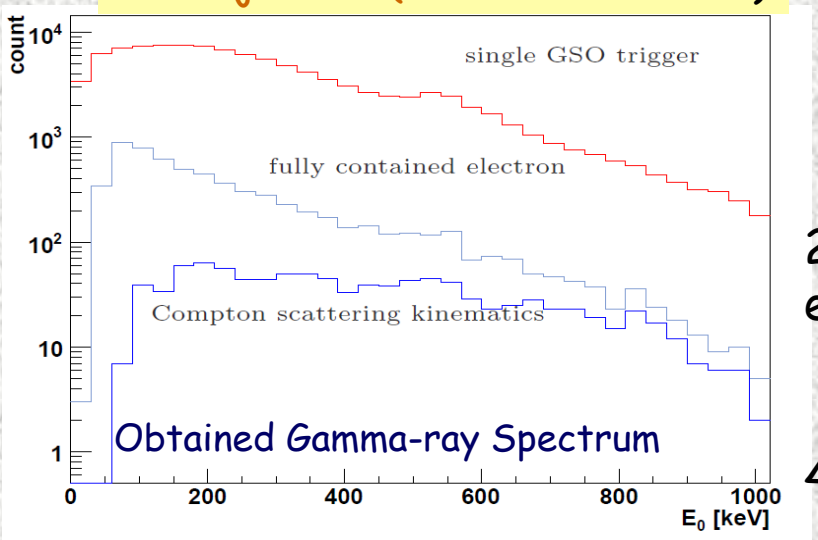


consistent to Salvaterra et al. 2008

Imaging GRB Trigger in Sub-MeV

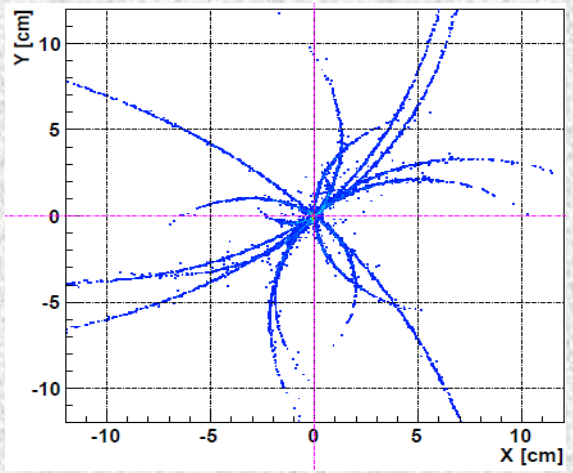
- ETCC measure the each photon direction >100keV
- Cosmic BG >100keV; ~8ph./10^2s >100keV in 4°x4° @100cm^2
- BG; several 10 x of Diffuse γ but rejected by Kinematical cut

BG Rejection (SMILE-I off-line)



2.23×10^5 events

420 γ



Several γ Mapping in Lab.

- P_{lim} ~30 ph. >100keV in 4°x4° @~100cm^2 in 10^2 sec (8σ)
- Point Accuracy for GRBs <0.2° for 300γ, 0.5° for 30γ
- With a wide field of view infra red or X-ray telescope (~0°.5)

Expected Flux >100keV for GRB@z~20

Expected Photon #(>100keV) for GRB @z=20 & $E_{iso}=10^{52}$ erg ->**1000 ph.**

Detection limit ~100ph. ->10^{51}erg @z=20 and 3str ->1 GRB@day

(Almost all GRBs in the universe would be detected !)

GRB	z	Epeak (keV)	Fluence (5- 50 keV) (erg/cm2)	Peak Flux (ph/cm2/s)
090423A	20	36 +/- 7	(2.6 +/- 0.2) x 10-7 ☑	0.3 +/- 0.1 ☑
080913	20	48 (+83, -18)	(2.1 +/- 0.2) x 10-7 ☑	0.2 +/- 0.1 ☑
050904	20	152 (+116, -52) !?	(1.7 +/- 0.1) x 10-6 ☑	0.1 +/- 0.1 ▲
060927	20	23 (+8, -3)	(0.3 +/- 0.1) x 10-6 ☑	0.3 +/- 0.1 ☑
060510B	20	27 +/- 17	(1.2 +/- 0.1) x 10-6 ☑	0.1 +/- 0.1 ▲
060223A	20	18 (+26, -3)	(1.7 +/- 0.1) x 10-7 ☑	0.1 +/- 0.1 ▲
060206	20	18 +/- 5	(2.0 +/- 0.1) x 10-7 ☑	0.2 +/- 0.1 ☑

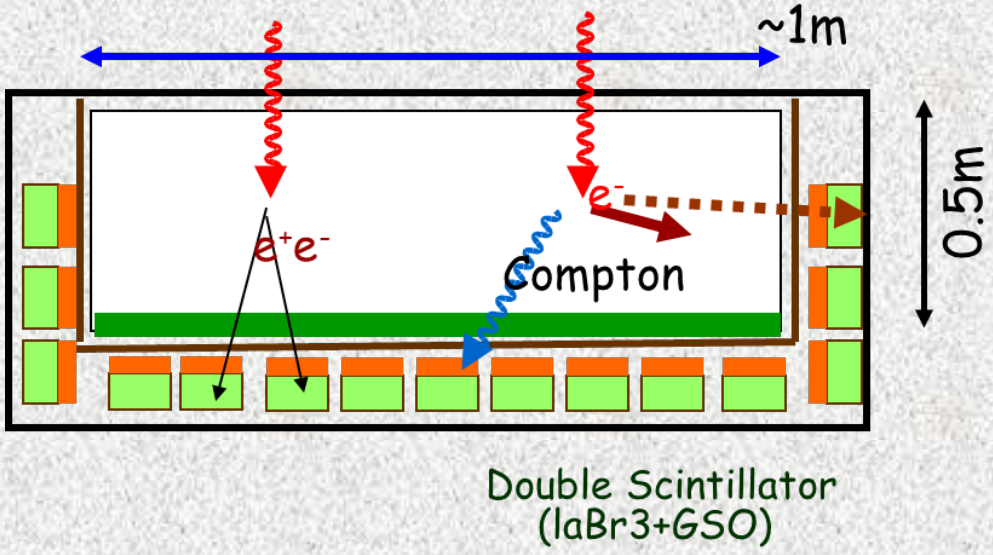
Eiso (10^{52}erg)	Expected γ (>100keV)
89	2.6×10^3
7	2×10^3
38	1.7×10^4
	3×10^3
20	1.2×10^4
3	1.7×10^3
5	2×10^3

Requirements

Detection Area 30~100cm^2
from 0.1-100MeV

Angular Res. 4°~0.3° <0.1-100MeV

-> Position Res. 0.2° for 100 photons



GUNDAM（仮称）

Gamma-ray burst for UNravelling Dark Ages Mission

PATHFINDER

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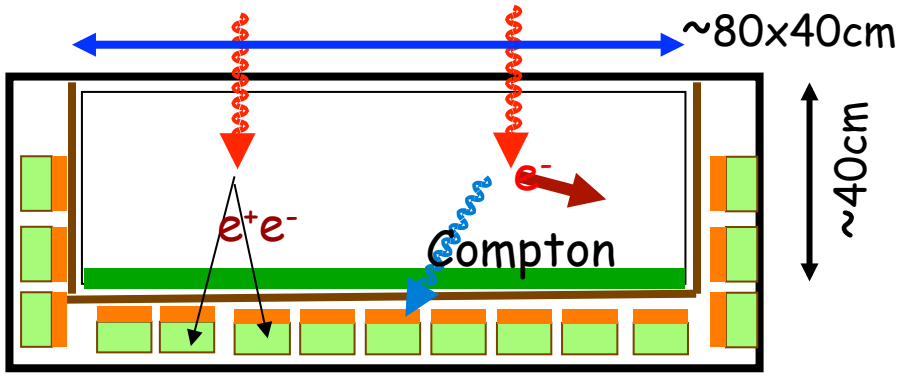
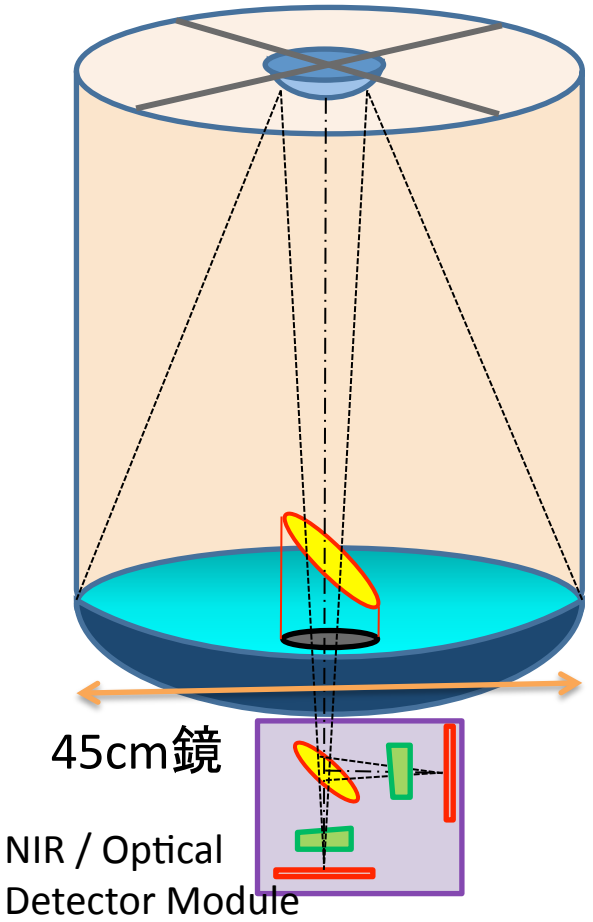
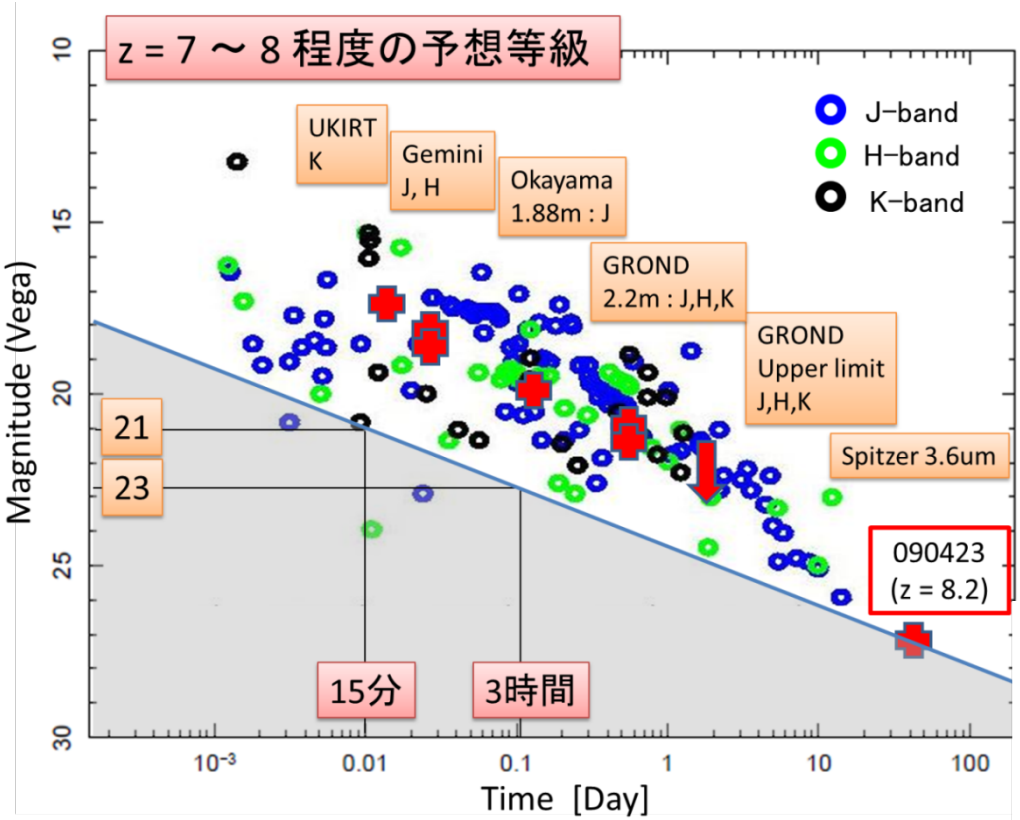
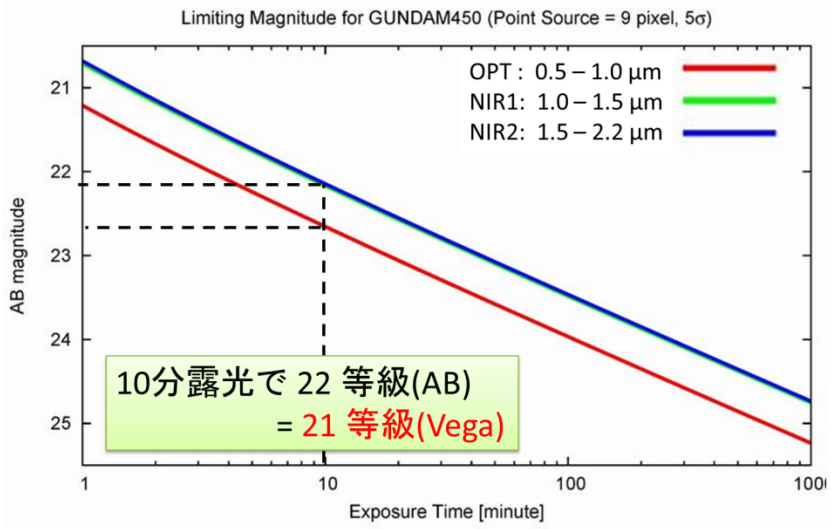
戸谷友則 (京都大学)
高橋慶太郎 (名古屋大学),
井岡邦仁，水田晃，川中宣太 (KEK)
中島正裕 (東京大学),
松浦周二，坂井真一郎 (ISAS/JAXA)



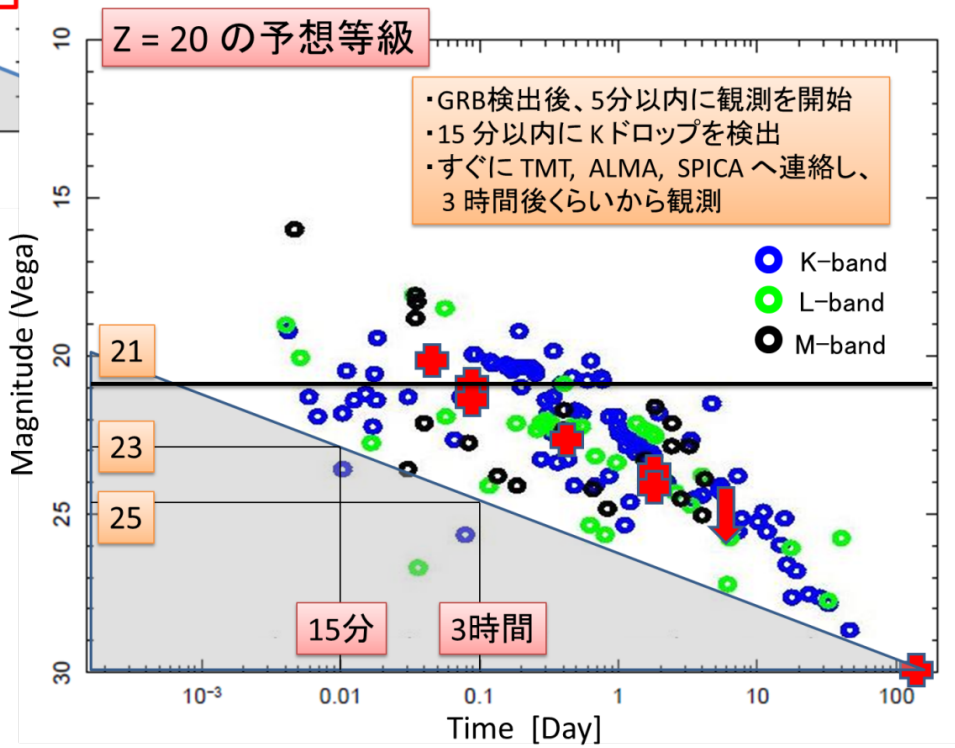






口径 45cm, HgCdTe 2k x 2k, 0.5arcsec/pixel (視野 17' x 17')

with 1m class NIR telescope



Relativistic electron Precipitation γ–burst with EISCAT& ERG

K.R.Lorentzen et al.,(2000)

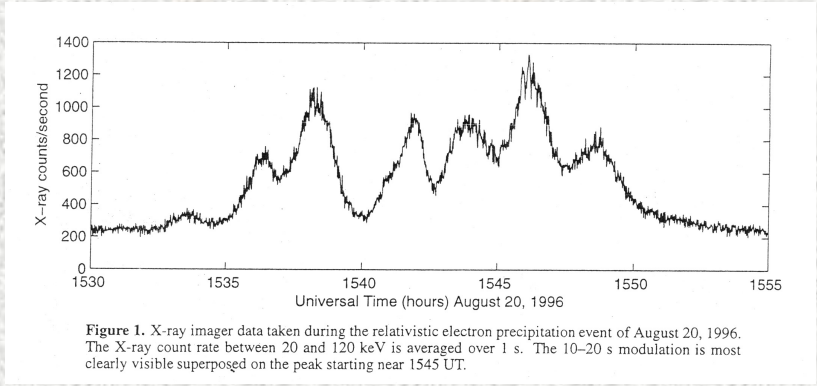
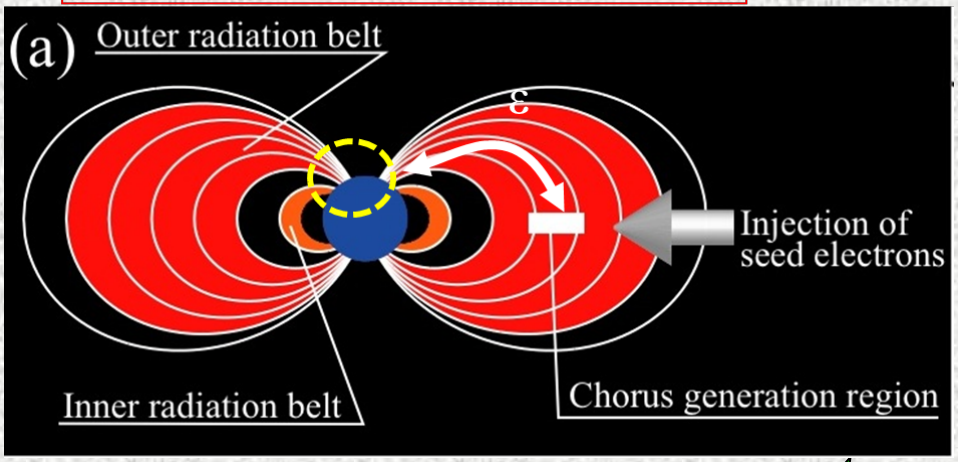


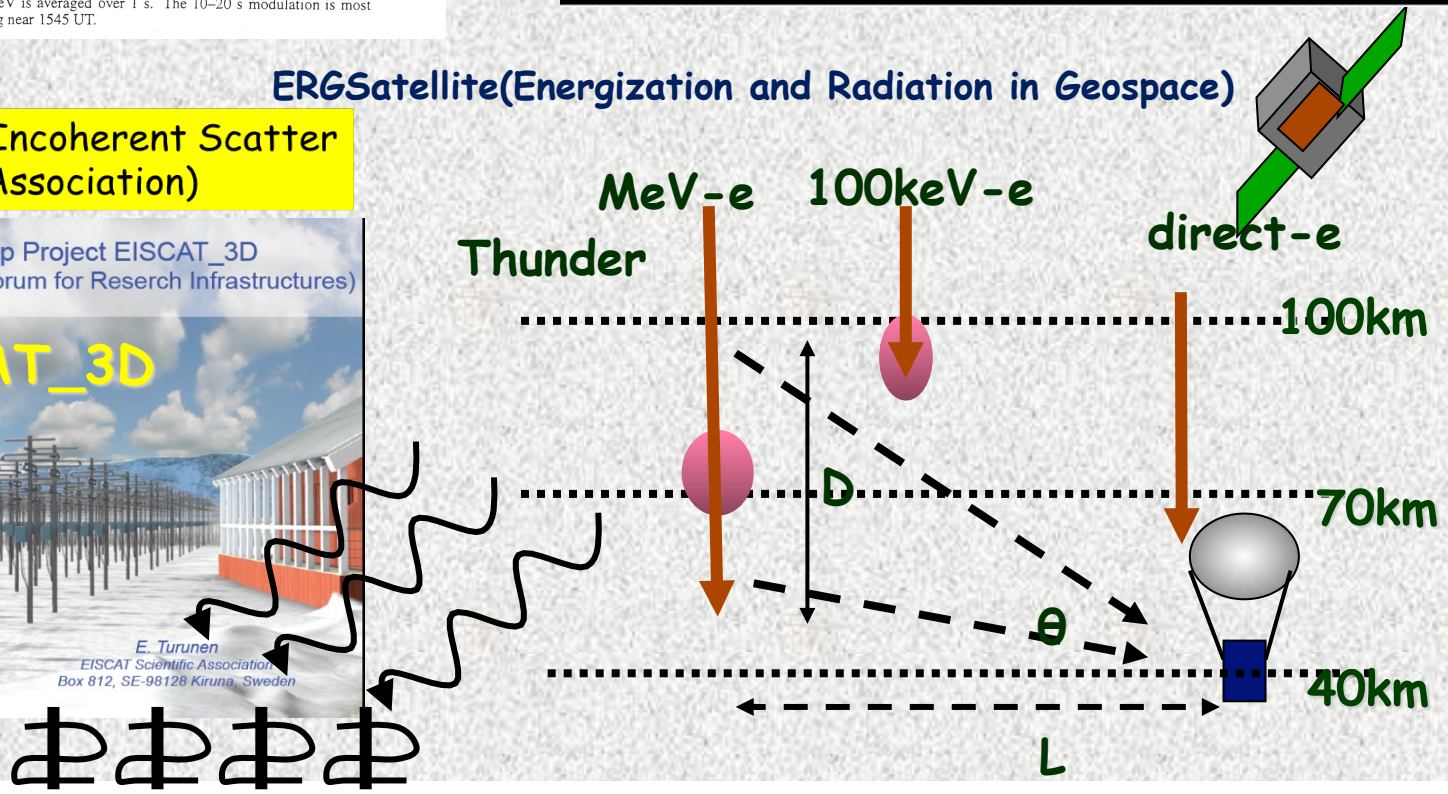
Figure 1. X-ray imager data taken during the relativistic electron precipitation event of August 20, 1996. The X-ray count rate between 20 and 120 keV is averaged over 1 s. The 10–20 s modulation is most clearly visible superposed on the peak starting near 1545 UT.

MeV electron & ion in Radiation belt

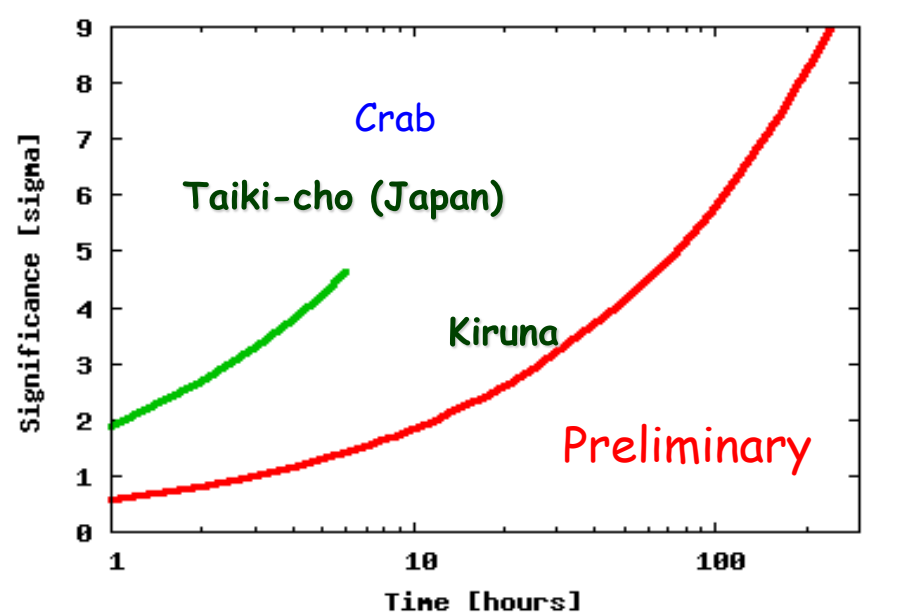


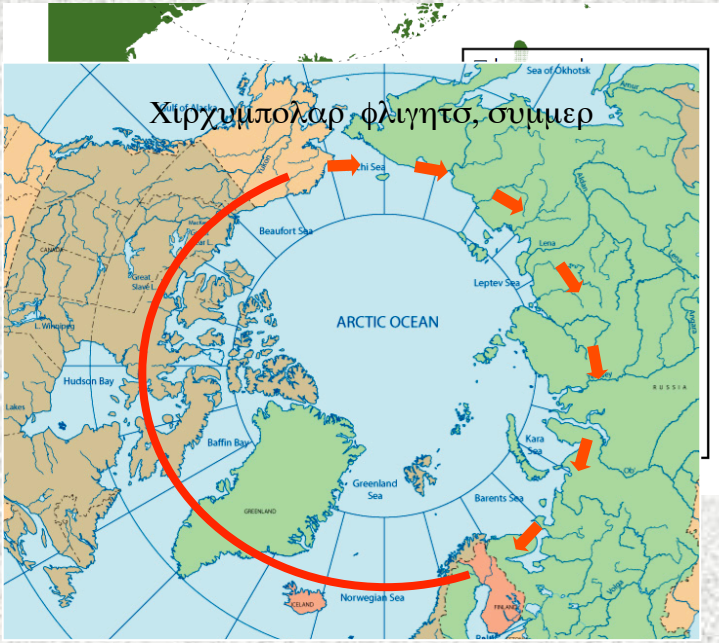
EISCAT(European Incoherent Scatter Scientific Association)

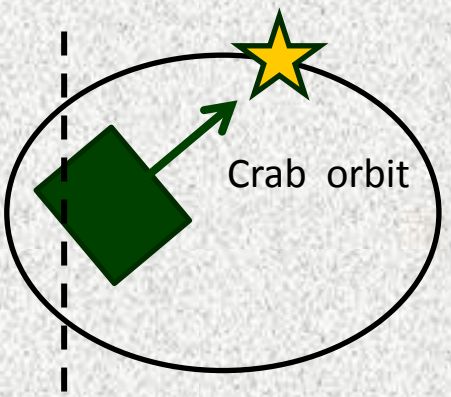
ERGSatellite(Energization and Radiation in Geospace)



Northern Polar Long Flight

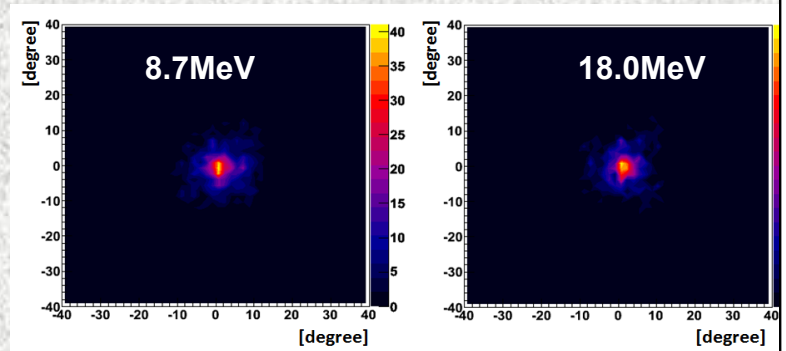


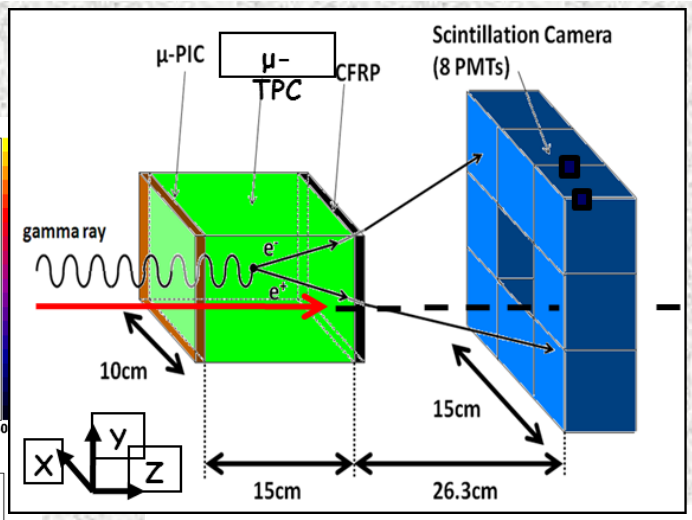


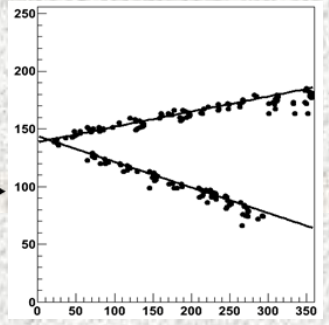


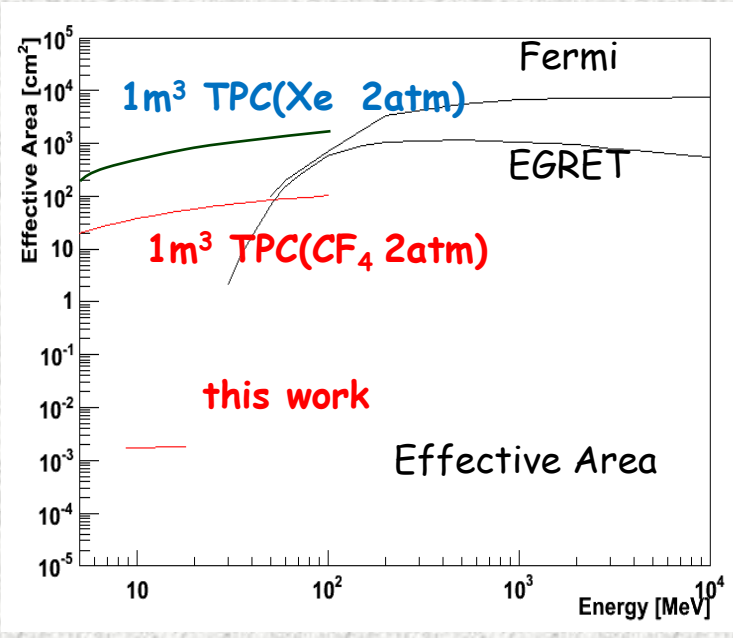
- 2012 Test Flight @ Taiki Japan
- 2013 Polar Long Flight @Kiruna—> two weeks
- Gondola 3t; Multi detectors
- ~1x1x0.5m ETCC(~100cm^2 Eff. Area)
  Observation time xEff.Area~3x10^4 cm^2 hours/year
- Small Satellite ETCC（400kg、~20cm^2、）
  Observation xEff.Area~6x10^4 cm^2・hours/years

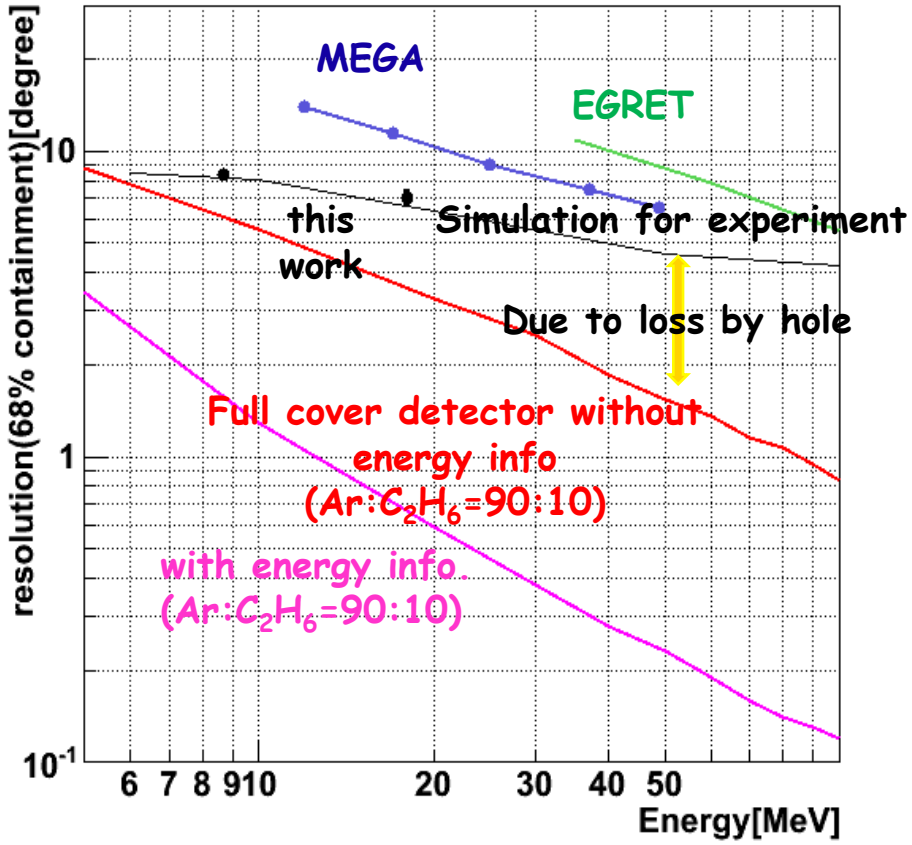
Pair creation





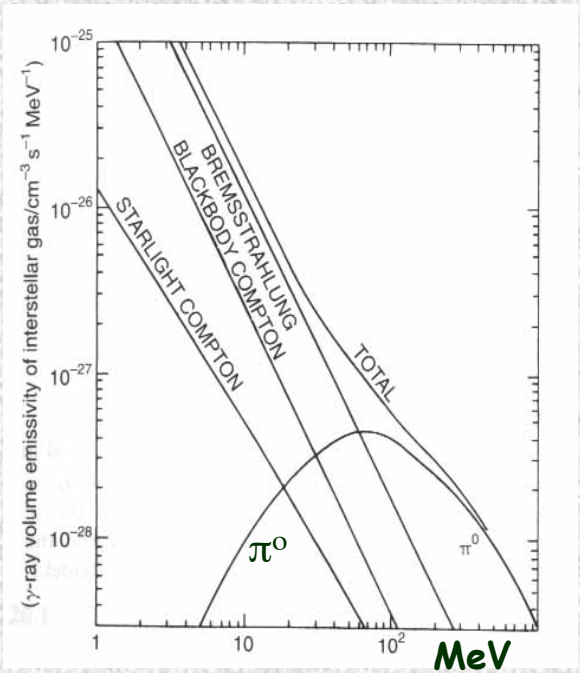


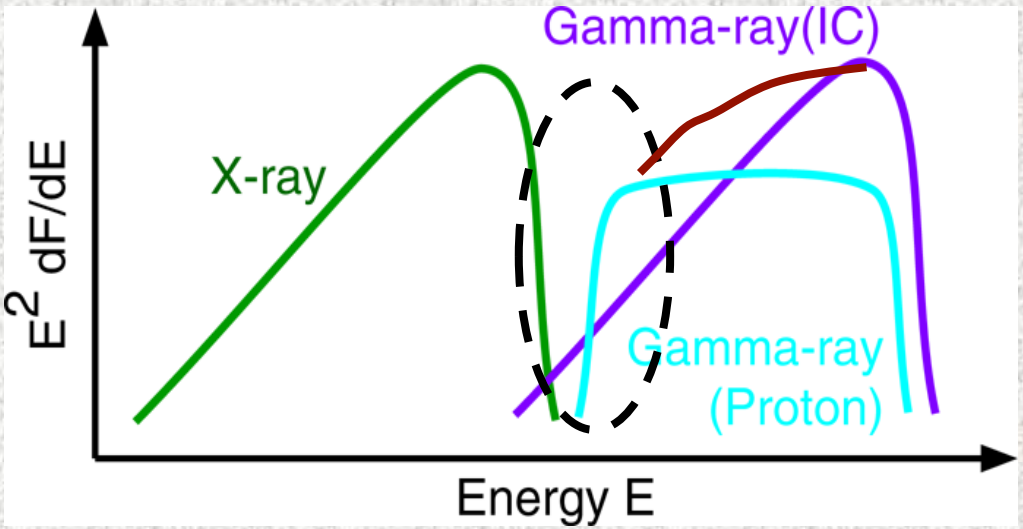




Other Astrophysics in Pair mode

- Except usual Compton Camera objects
- Good & High Statistical Images for 50-100MeV
  $\Delta\theta$ <<0.5°
- Cosmic-ray origin (Proton identification from Spectrum; 10-100MeV)



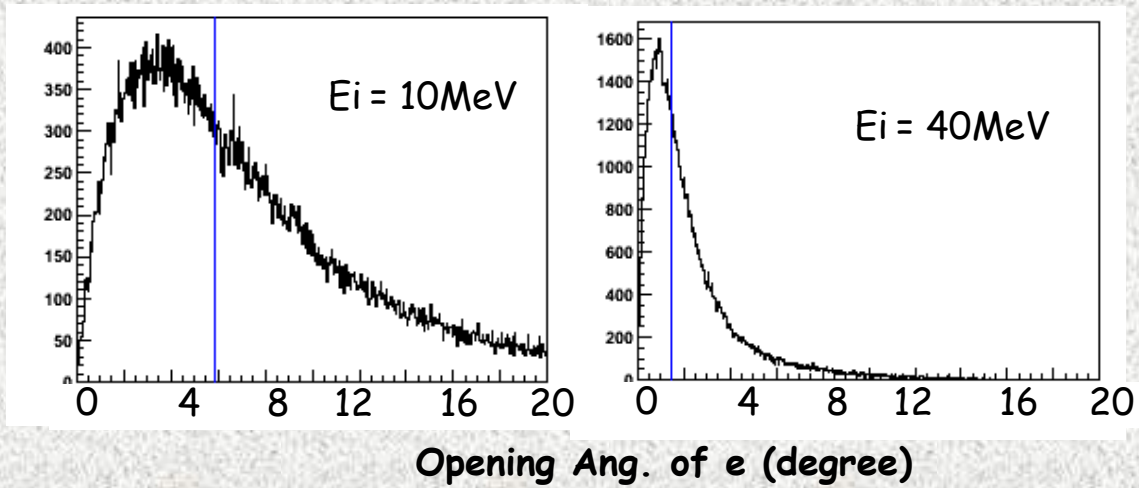


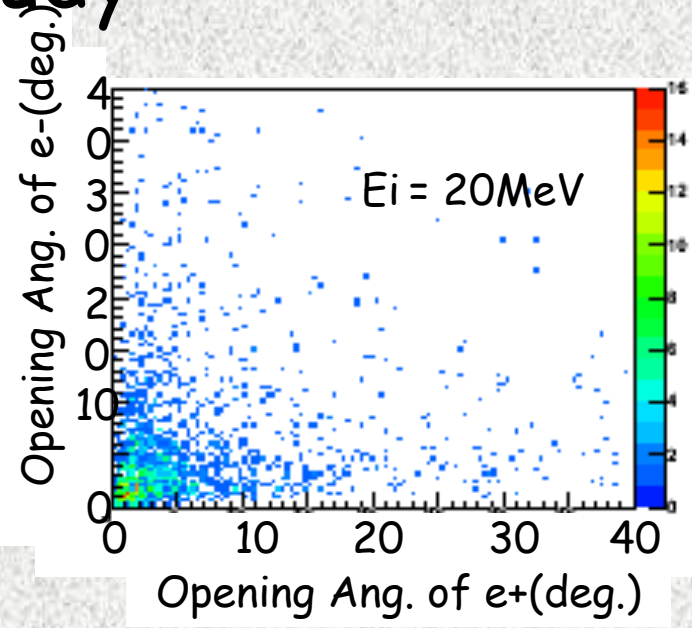
まとめ（今後）

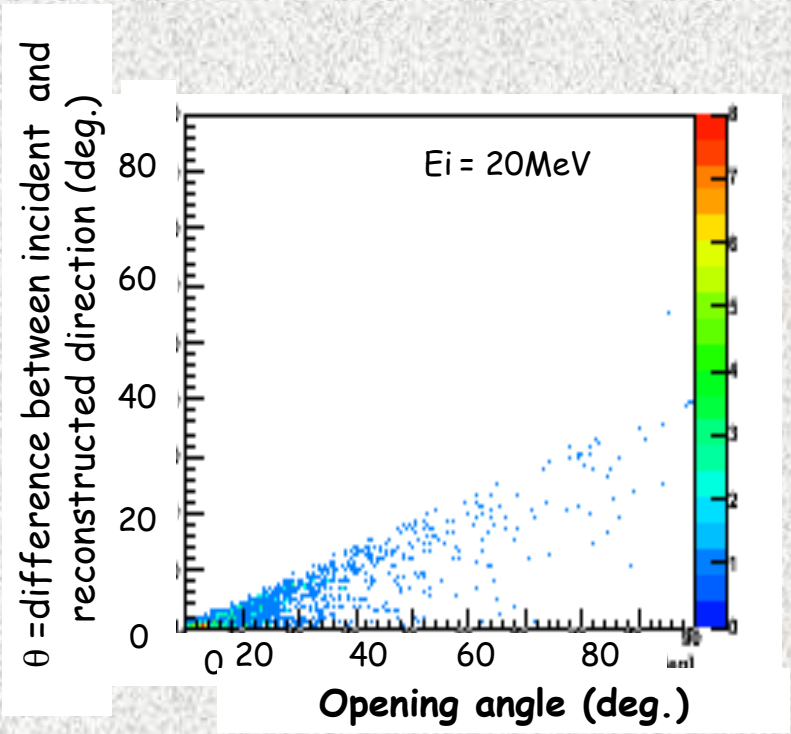
- ETCCは連続ガンマ線探査に強い
- 中型ETCC，SMILE-II　201@Taiki 試験飛行
  2013～ Kiruna　から北極周回観測へ
- 毎年200-300時間程度の観測
  地球（REP-γ、太陽中性子＋γ）　ー＞精密粒子加速機構研究、
  宇宙（コンパクト天体、AGN、GRB検出の試験）。
- 定点観測（気球の必要性）による新しい地球・宇宙観測基地へ
  30cm角ETCCから数年後50cm角ETCCレベル以上へ！

- 中間赤外望遠鏡＋ガンマ線（又はX線）イメージング装置の小型、中型遠方GRB探査衛星計画始動！

Simulation Study







Angular resolution determined by multiple scatterings of e+e- and their opening angle.

Low density material and fine Tracking are necessary for <100MeV gamma rays.

Sub-MeV gamma-ray Imaging Loaded-on-balloon Experiment (SMILE) Roadmap

10cm cube camera @ Japan (Sep. 1st 2006)

- Observation of diffuse cosmic/atmospheric γ
  ~400 photons during 3 hours (100 keV~1MeV)

30cm cube camera with Domestic balloon (@Kiruna

- Observation of Crab/Crg X-1 + **REP-γ**

40cm cube camra with long duration observation

- Galactic survy
- Test of Gamma-Ray Burst Detection

50cm or 1m cube camera with satellite

- All sky survey, detection of highest-z GRB