Imaging Polarimeter for a Sub-MeV gamma-rays using an Electron tracking Compton Camera

This presentation is based on arXiv:1703.07600v1 22 Mar. 2017 Komura, S. et al. which will be soon published to ApJ.

Contents

13/Apr./2017 @ MeV TPC.

S. Komura[1], A. Takada[1], Y. Mizumura[1,2], S. Miyamoto[1], T. Takemura[1], T. Kishimoto[1], H. Kubo[1], S. Kurosawa[3], Y. Matsuoka[1],K. Miuchi[4], T. Mizumoto[1], Y. Nakamasu[1], K. Nakamura[1], M. Oda[1], J. D. Parker[1], T. Sawano[5], S. Sonoda[1], T. Tanimori[1,2],D. Tomono[1], and K. Yoshikawa[1]

Graduate School of Science, Kyoto University, Sakyo, Kyoto

2 Unit of Synergetic Studies for Space, Kyoto University,

3 Tohoku University, 4 Department of Physics, Kobe University, 5 Kanazawa University

Next Generation of Hard-X and Gamma Polarimetry

Polarization data above hard X-rays

Instruments	Energy band	Pol.	Traget
INTEGRAL / **SPI**	100-1000 keV	46±10	Crab Nebula
INTEGRAL / **IBIS**	200-800 keV	47^{+19}_{-13}	Crab Nebula
INTEGRAL / **IBIS**	400-2000 keV	67±30	Cygnus X-1
IKAROS / **GAP**	70-300 keV	27±11 他2例	GRB100826A 他2例

$$MDP[\%] = \frac{429}{\mu_{100} R_S} \sqrt{\frac{R_S + R_B}{T}}$$

No highly reliable data with >5sigma

As discussed by Weisskopf group, both statistical fluctuation and systematics always cause a positive value of MDF for non-polarized data.

⇒ Low background by sharp well-defined PSF (ability of Imaging with large FoV)

⇒ and low systematics (treatment of off axis)

Approach of ETCC to Polarimetry

For medium and weak sources

R_S	Signal flux
R_B	Noise flux
T	Obs. Time

	Persistent	Transient
Mirror +Pol.	◎	×
Wide-FoV (non-imaging)	×	○
CC	×	◎
ETCC	○	◎

- W-FoV : but intense background and off-axis correction
- Mirror : Imaging -> low background

ETCC: imaging + W-FoV

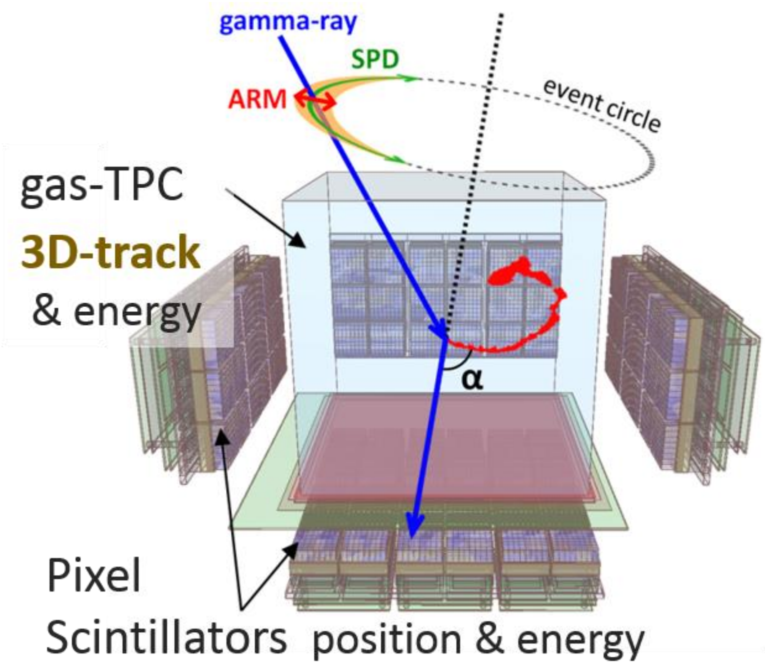
$$MDP[\%] = \frac{429}{\mu_{100} R_S}\sqrt{\frac{R_S + R_B}{T}}$$

Persistent sources

$$R_b \gg Rs \Rightarrow MPD \propto \frac{\sqrt{R_B}}{\mu_{100} R_S} \propto \frac{\sqrt{PSF}}{\mu_{100} R_S}$$

Sharp PSF is needed

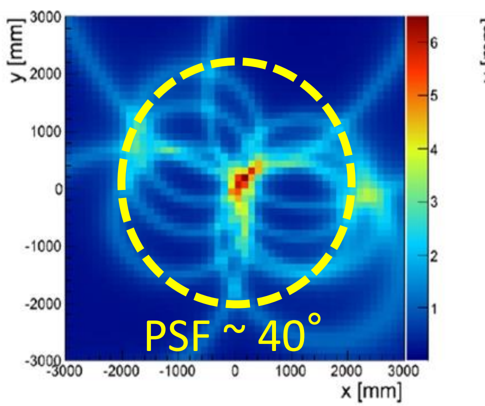
Feature of ETCC for Polarimetry



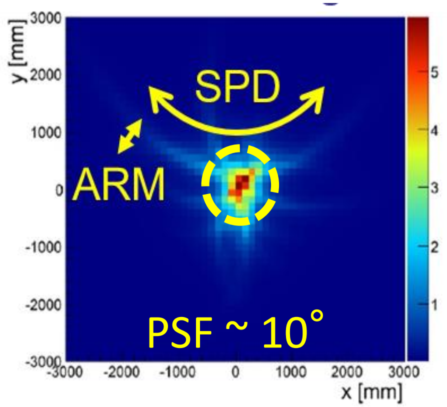
- Ture Imaging (sharp 2D-PSF)
  - Good rejection of BG γ
- dE/dx of paticles in TPCC
  - Complete rejection for neutron and cosmic-rays
- Wide-FoV >4 str

T.Tanimori et al., ApJ, 810 (2015), 28

CC imaging (662keV)



ETCC imaging



Power of PSF

Contamination of BG γ

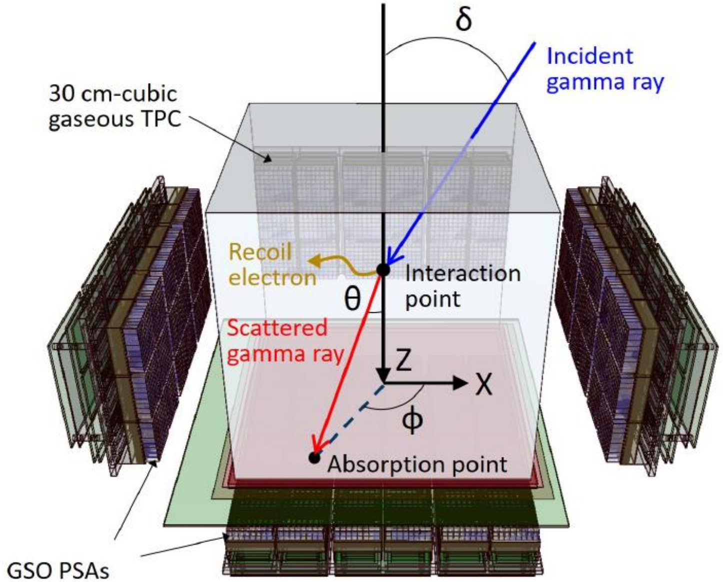
$\propto \Delta\Omega \propto \theta^2$ θ: PSF

⇨ :1/100 of CC

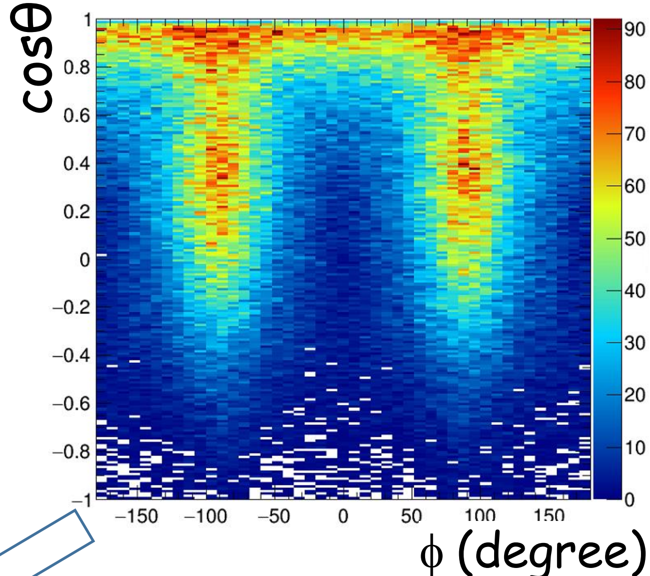
⇨ MDP: x10 improved

But not used in this time

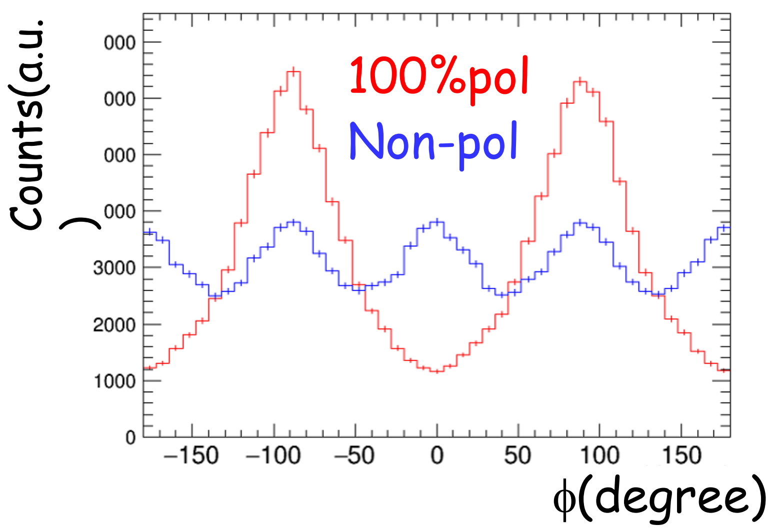
Polarimetry in ETCC for 200keV γ (Geant4 Simulation)



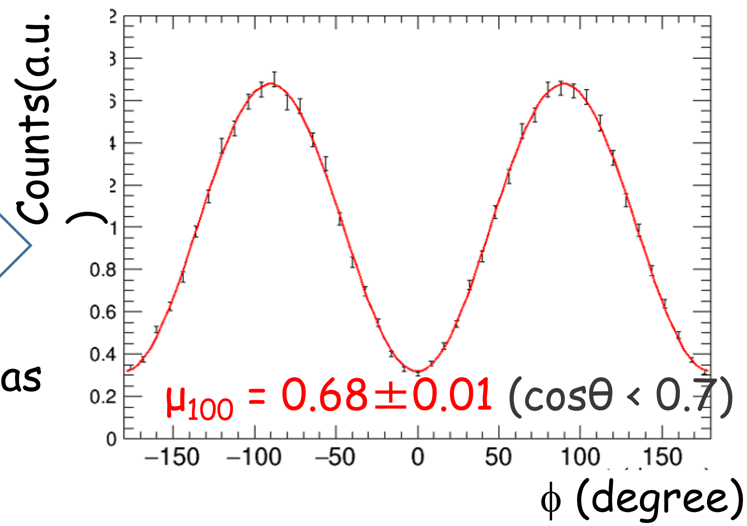
100%pol-g On-axis
Directions of Scattered g (cosθ, φ)



Projection to φ
(cosθ < 0.7)

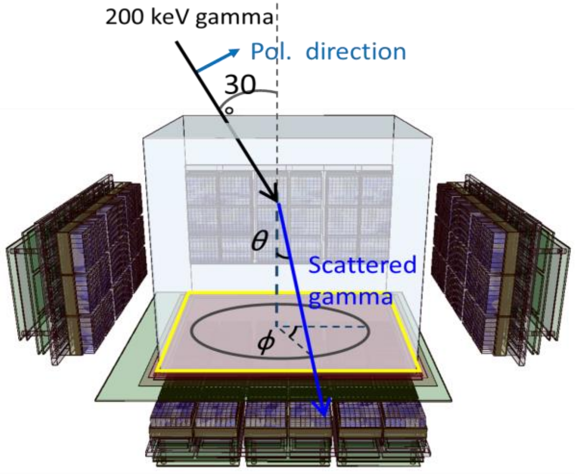


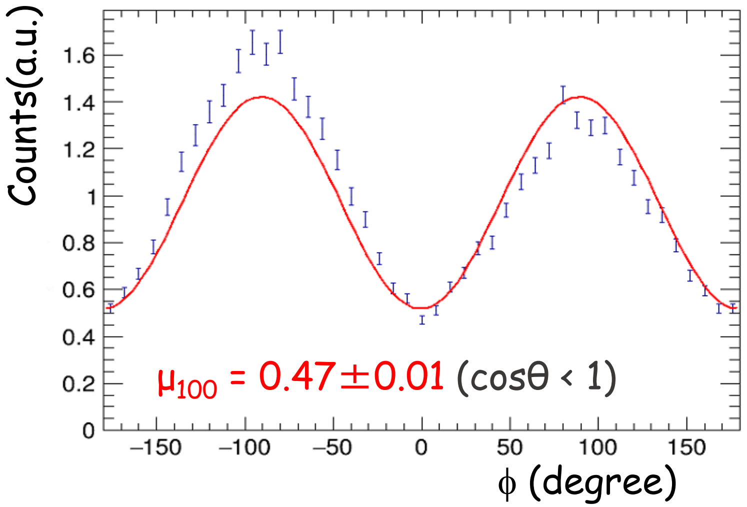
Correction of geometrical bias of detector



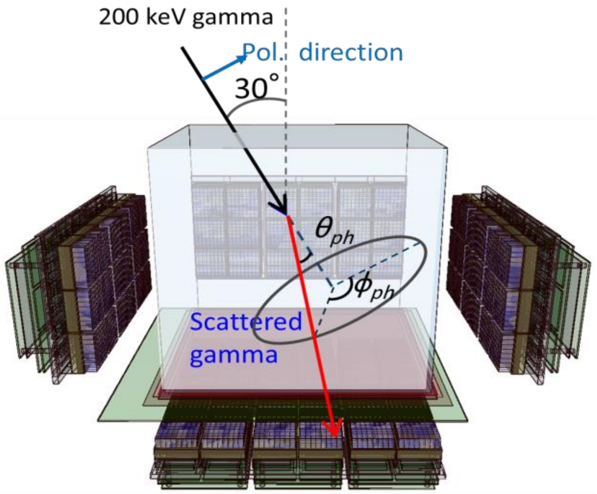
Off-axis Correction (Simulation)

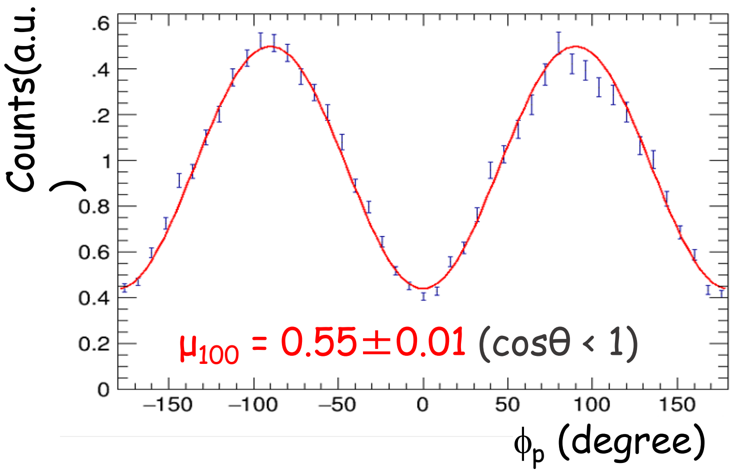
Detector coordinates
(θ, φ)





Incident g coordinates
(θ_p, φ_p)



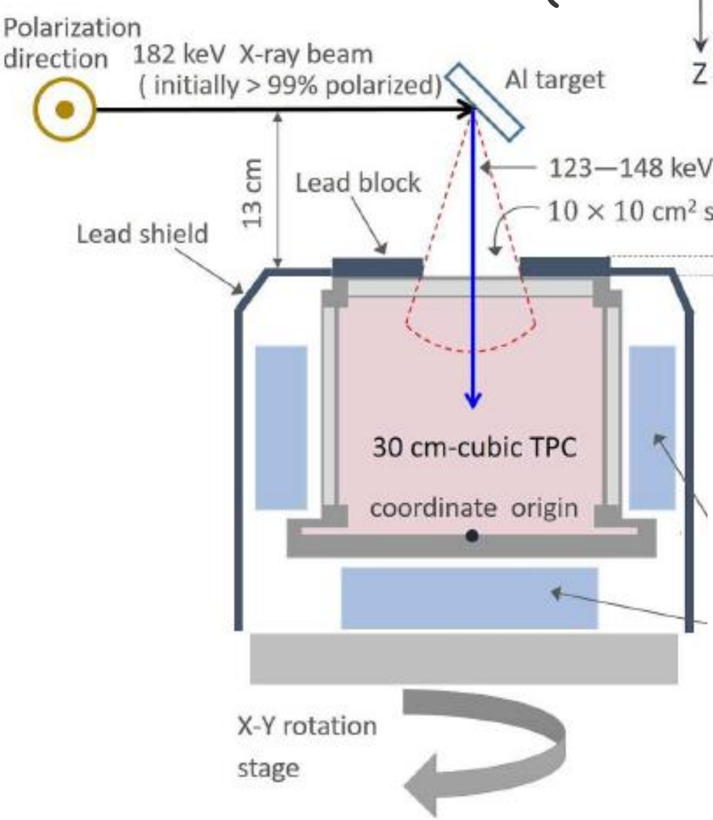


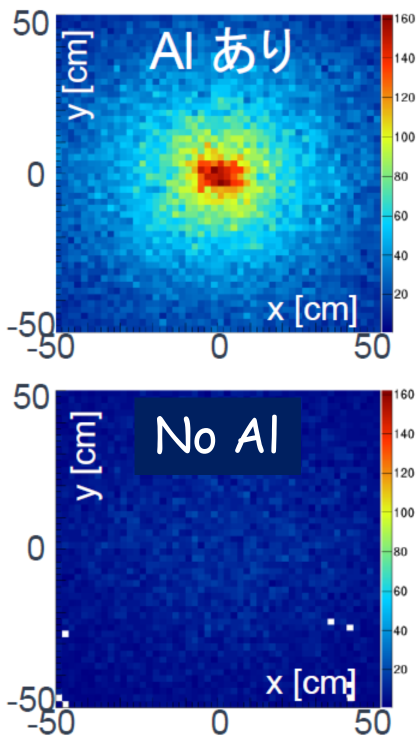
For Off-axis correction, both 3D direction of scattered gammas and incident direction of gammas are necessary

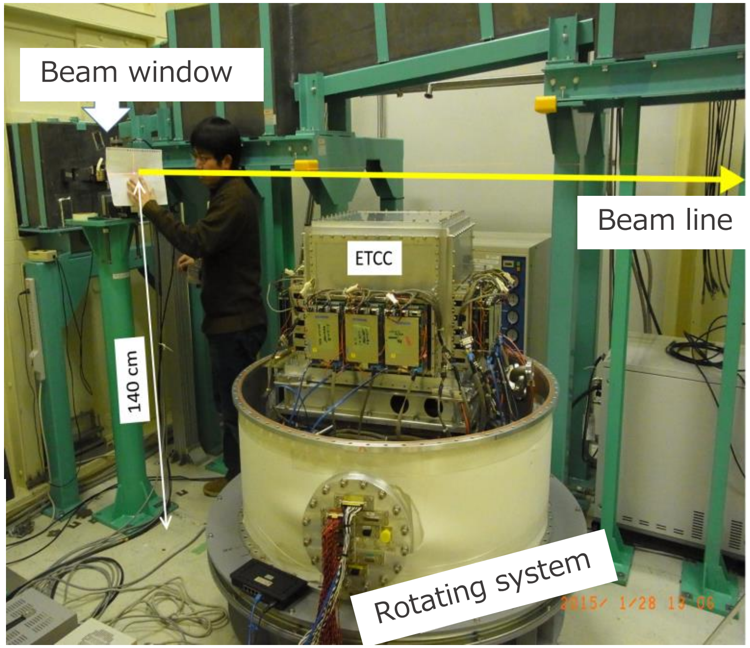
⇒ Only Compton Camera can do it and keep μ_{100} in wide -FoV

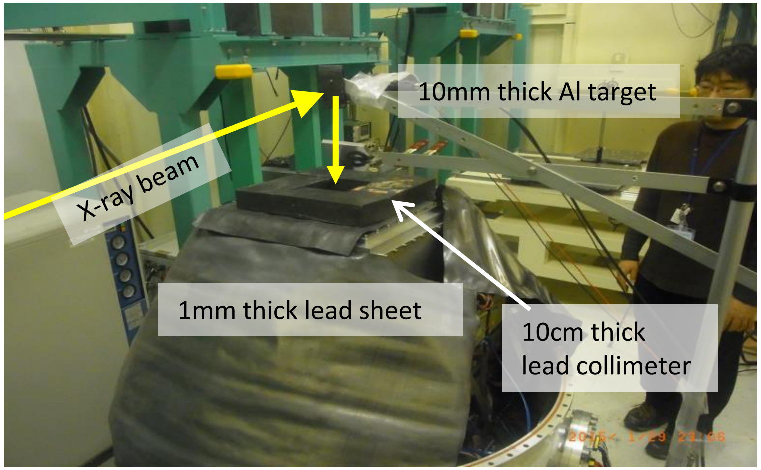
Experiment@SPring-8

BL08W: ~100%linear Polarized Xray beam (100-300 keV)



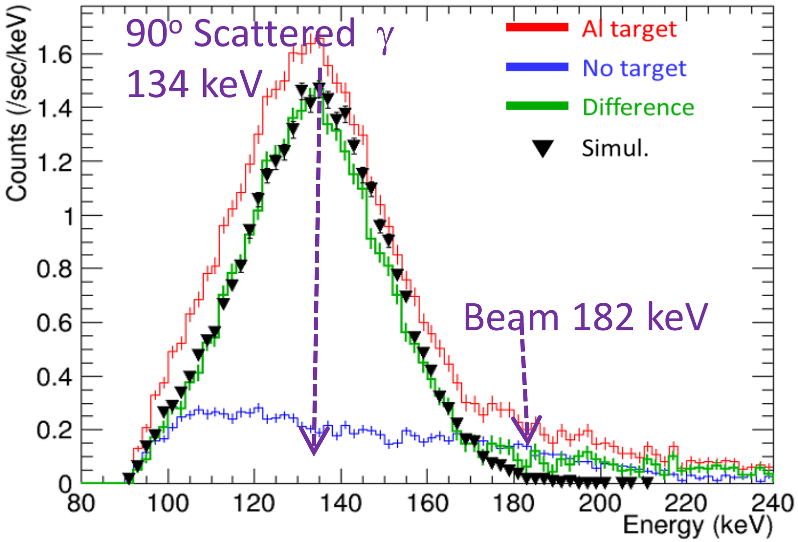


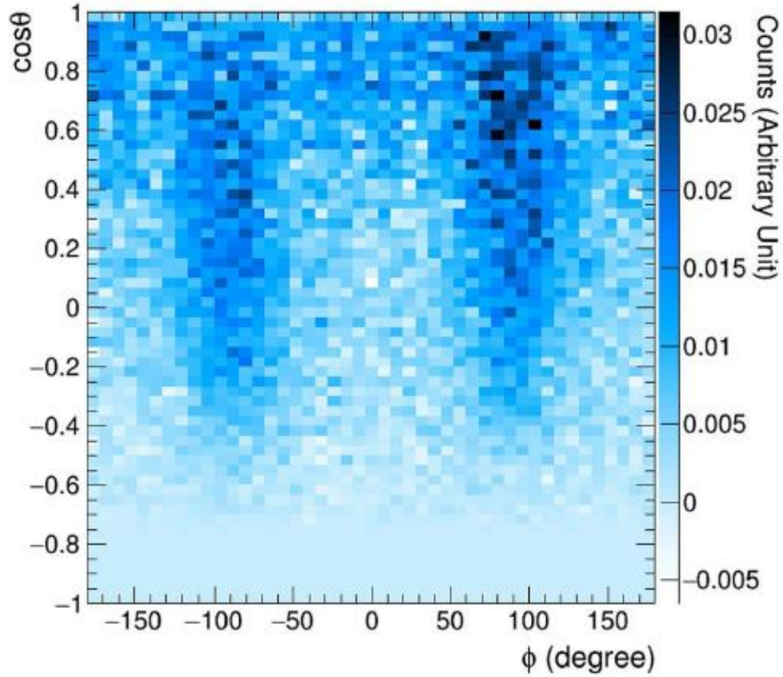




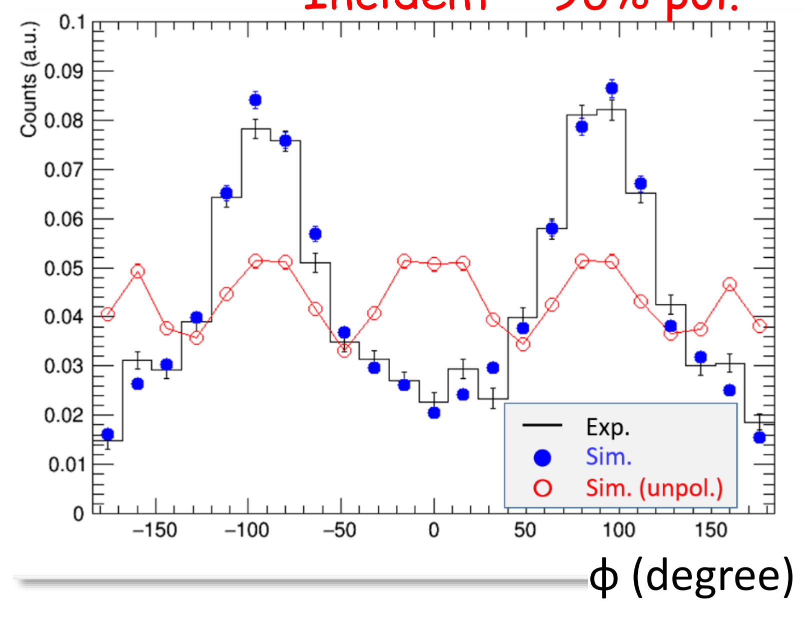
- Dispersive beam >~50°
- High Count rate >300Hz x3 of Balloon Experiment

On-axis Analysis





Incident ~ 96% pol.



- Dispersive incident angle, energy and polarization factor
- Intense low energy gammas by scatted beam in the air (dramatically increasing accidental rate)

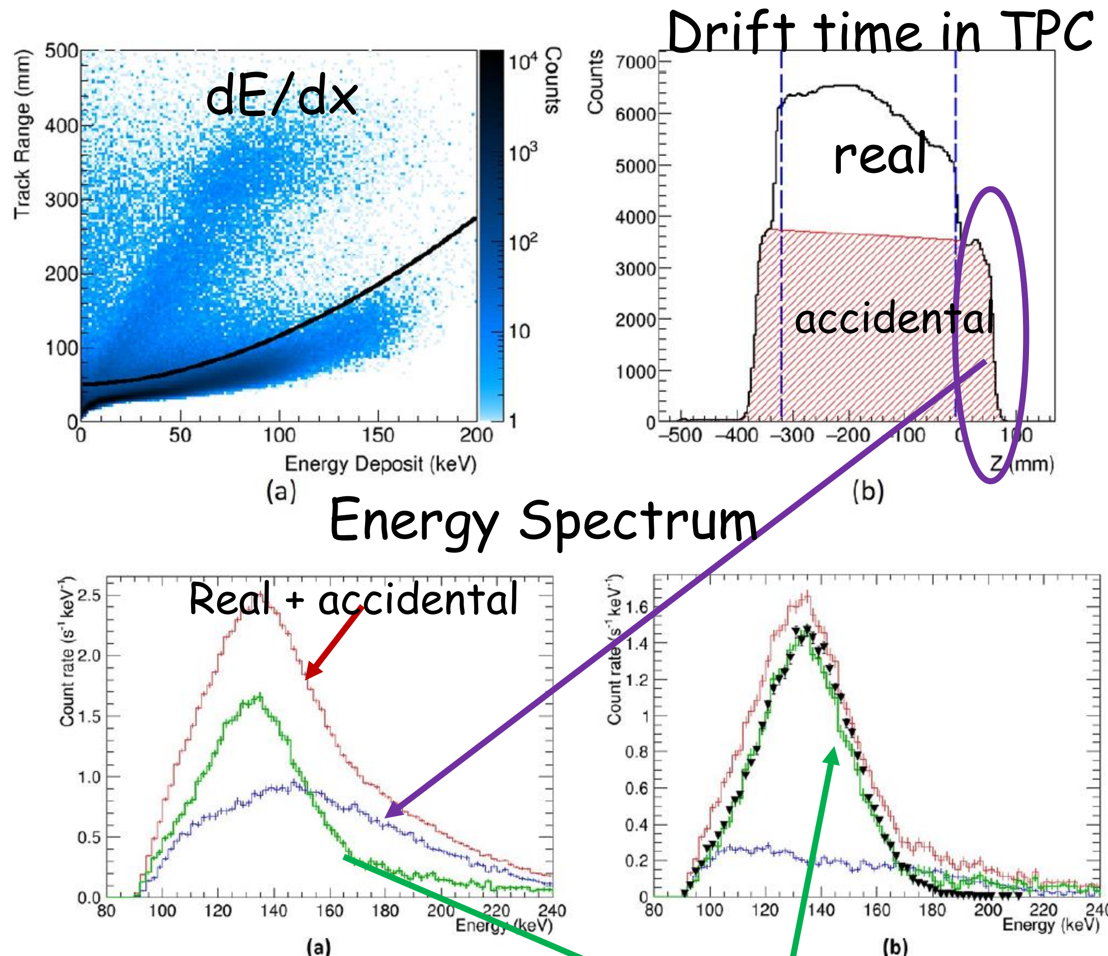
Good consistency with Simulation < 8%

Background rejection

For low enery <200keV
PSF is worse ~30°
=>PSF cut was not used.
& main BG=> low energy scattered γ

Then accidental events exceeded real events even after dE/dx cut .

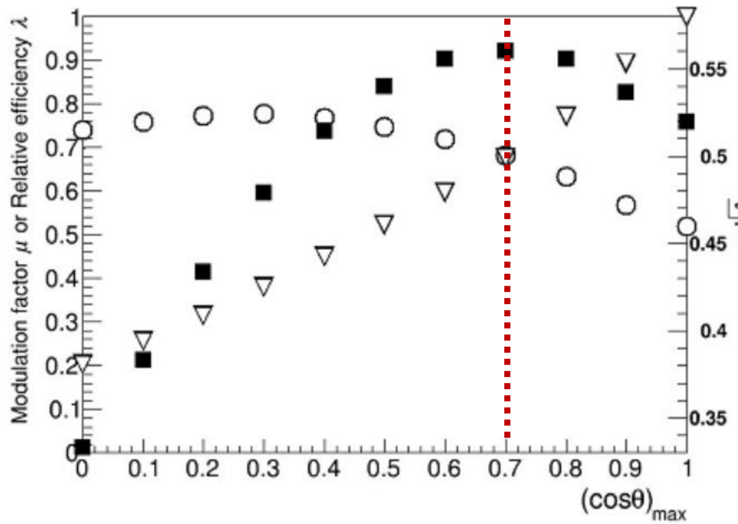
Systematics by BG was estimated from TPC drift time distribution.



Residual is well matched to Sim.

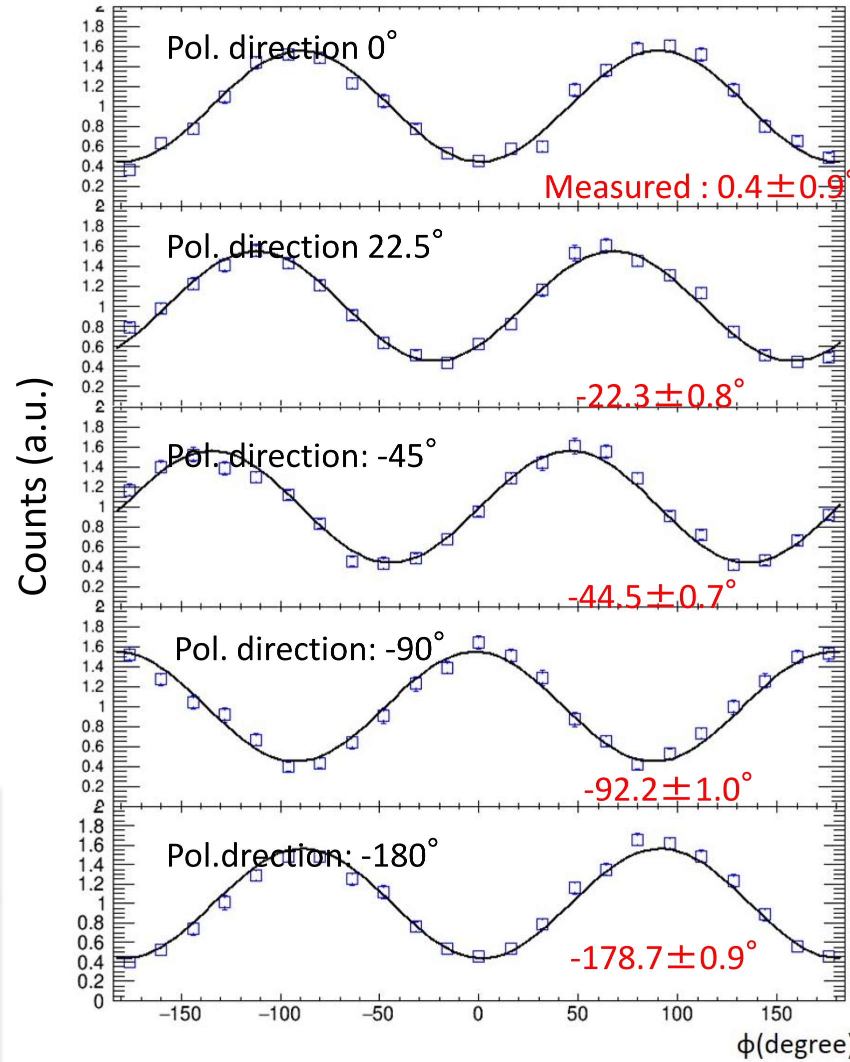
If good tracking were possible, Kinematical test and good Gas could remove almost all the accidentals.

On-axis result



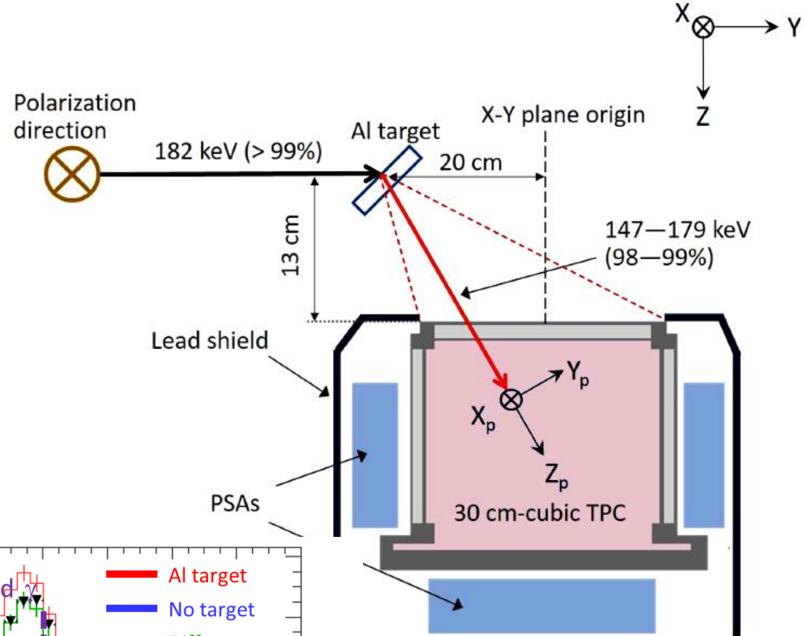
Dependences of the modulation factor μ (open circles) on to θ_{max}, the relative detection efficiency λ(open triangles), and **the figure of merits** $\lambda\sqrt{\mu}$ (filled squares) on the integration region from 0 to θ_{max}.

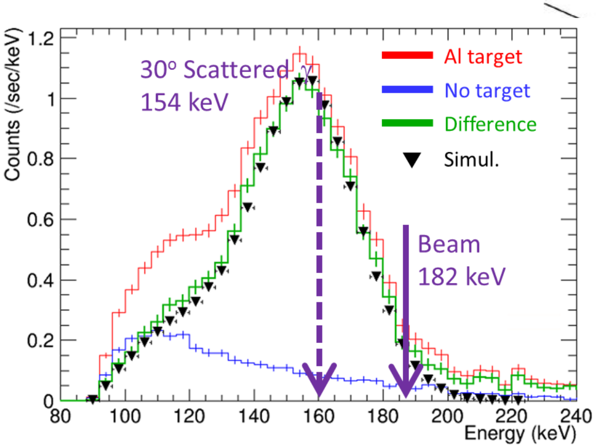
Polarization direction	μ_{100} (Exp.)	μ_{100} (Sim.)
0	0.58±0.02	0.63±0.01
-22.5	0.58±0.02	0.63±0.01
-45	0.58±0.02	0.62±0.01
-90	0.57±0.02	0.60±0.01
-180	0.59±0.03	0.61±0.01

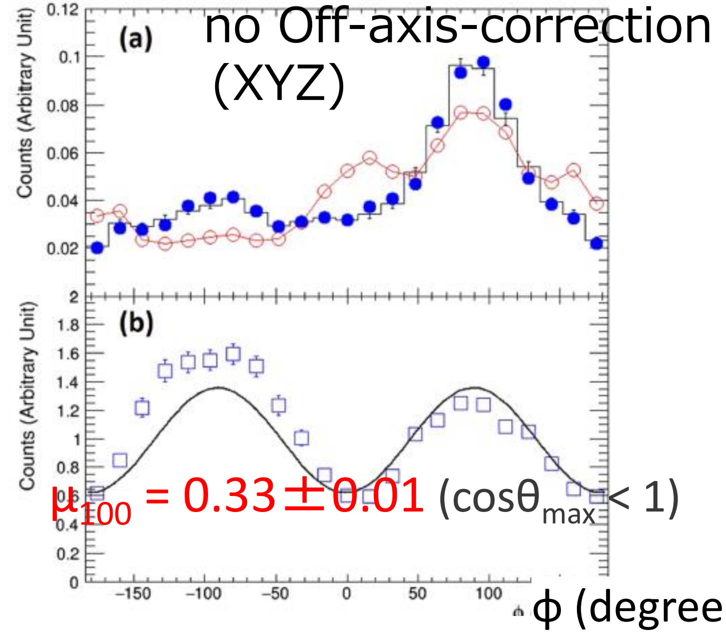


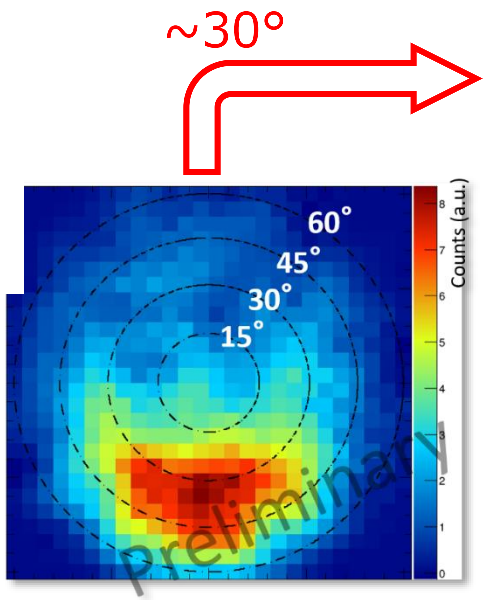
μ_{100}~ 0.58@134 keV

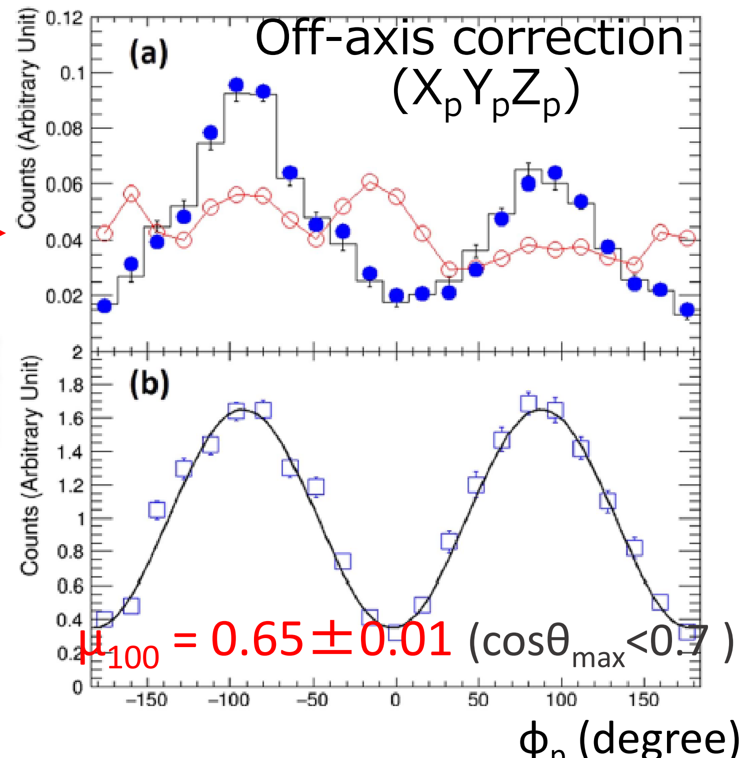
OFF-axis Analysis



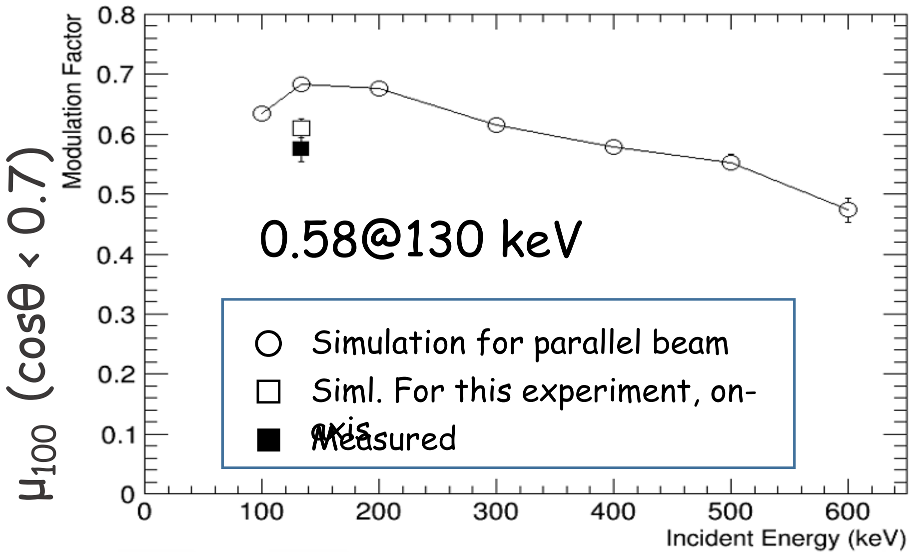


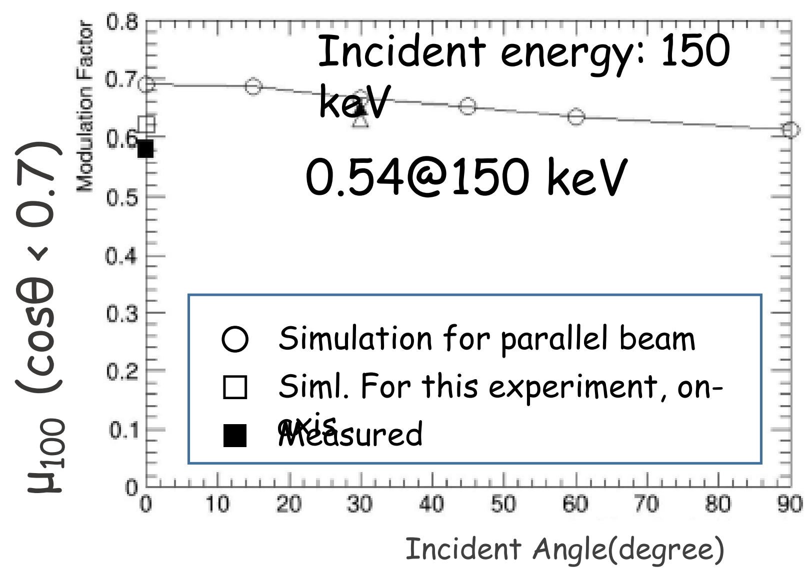






Summary result





Eff. Area SMILE-III ETCC ~30 cm^2 @200keV

- MDF:

  Crab nebula ~ 12%, Cyg. X-1 ~ 16% @10hrs Observation

  Possible for reconfirmation of INTEGRAL Results

  GRB with >10^{-5} erg/cm^2 ~ 21% (several GRBs /month)

  ⇒ similar to POLAR ~10%, (~10 GRBs/year)

Conclusion

- ❑ Imaging polarimetry in sub-MeV &MeV has been possible.
- ❑ Beam test@SPring-8
  - ➢ In intense background, imaging polarimetry is succeeded!
  - ➢ On-axis MPD =0.58@130 keV
  - ➢ Off-axis measurement ,and good MPD is obtained

⇨ These results open a new approach of polarimetry in hard Xray and MeV gammas satisfied simultaneously with wide FoV, background rejection, and Imaging.
Both transient and persistent objects would be simultaneously observed.

- ❑ Balloon (SMILE-III ETCC ~30 cm^2 @200 keV)
  - ➢ Crab nebula ~ 12 %, Cyg. X-1 ~ 16 % (10hrs)
  - ➢ GRBs ~ 21% for 10^{-5} erg/cm^2 (2-3 GRBs/month)
- ❑ Satellite-ETCC (~200 cm^2, 10^6sec)
  - ➢ ~13mCrab MPD ~10% in 10^7sec
  - ➢ GRBs (>$6x10^{-6}cm^{-2}$ MDP 10% =20GRBs /year