First Results from the 2024 Flight of the XL-Calibur Hard X-ray Polarimetry Mission

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on behalf of the XL-Calibur Collaboration

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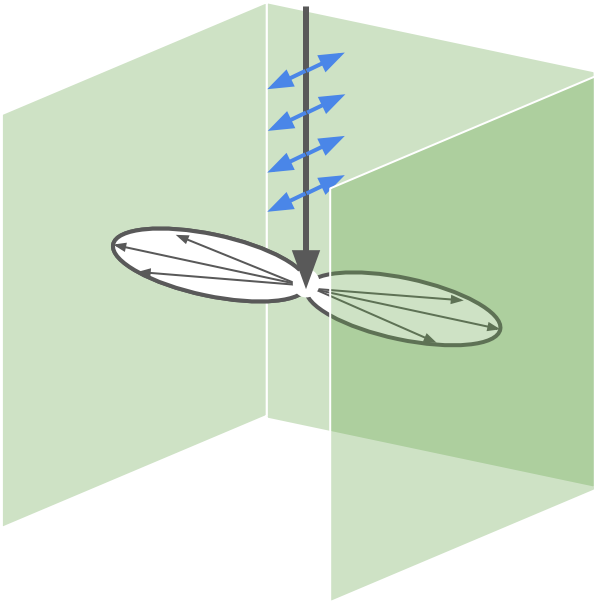
11th International Fermi Symposium, College Park, MD

X-Ray Polarimetry with Compton Scattering

- Klein–Nishina formula:

$$\frac{d\sigma}{d\Omega} = \frac{r_0^2}{2}\left(\frac{\omega'}{\omega}\right)^2\left(\frac{\omega'}{\omega} + \frac{\omega}{\omega'} - 2\sin^2\theta\cos^2\psi\right)$$

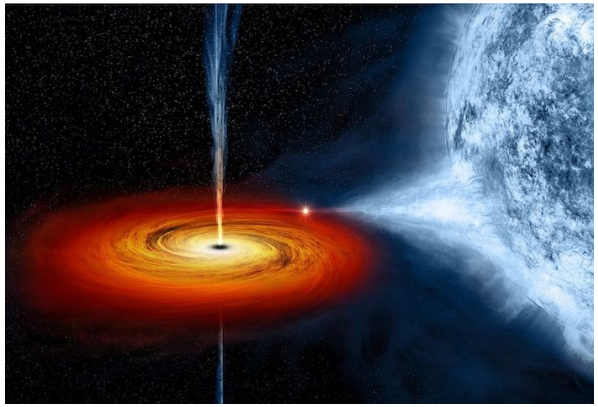


- Photon distribution:

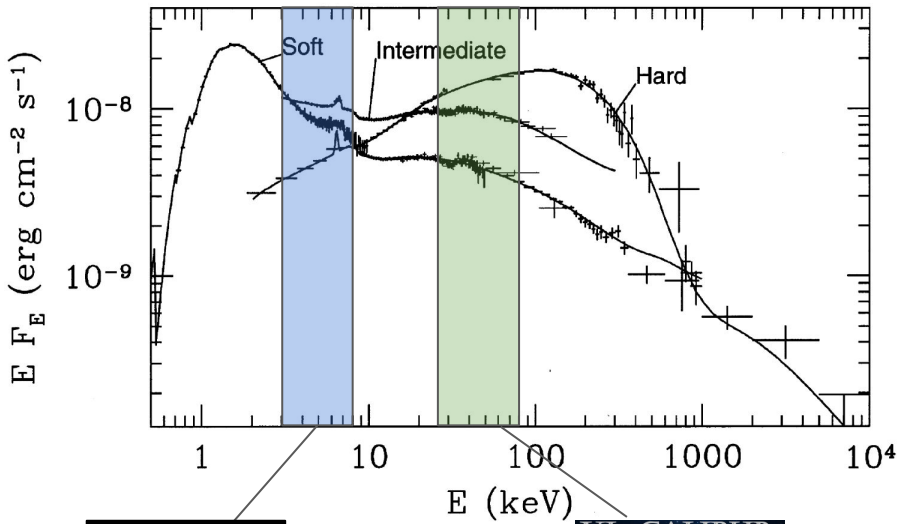
$$\frac{dN}{d\psi} = \frac{1}{2\pi}\left[1 + \mu\, p_0\, \cos\left(2(\psi - \psi_0 - \pi/2)\right)\right]$$

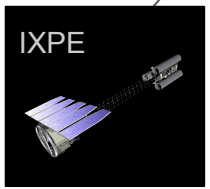
Modulation factor

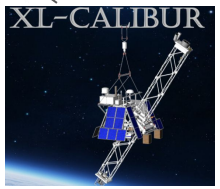
X-Ray Polarimetry



Gierliński et al. 1999







XL-Calibur extends the polarization measurement to hard X-ray!

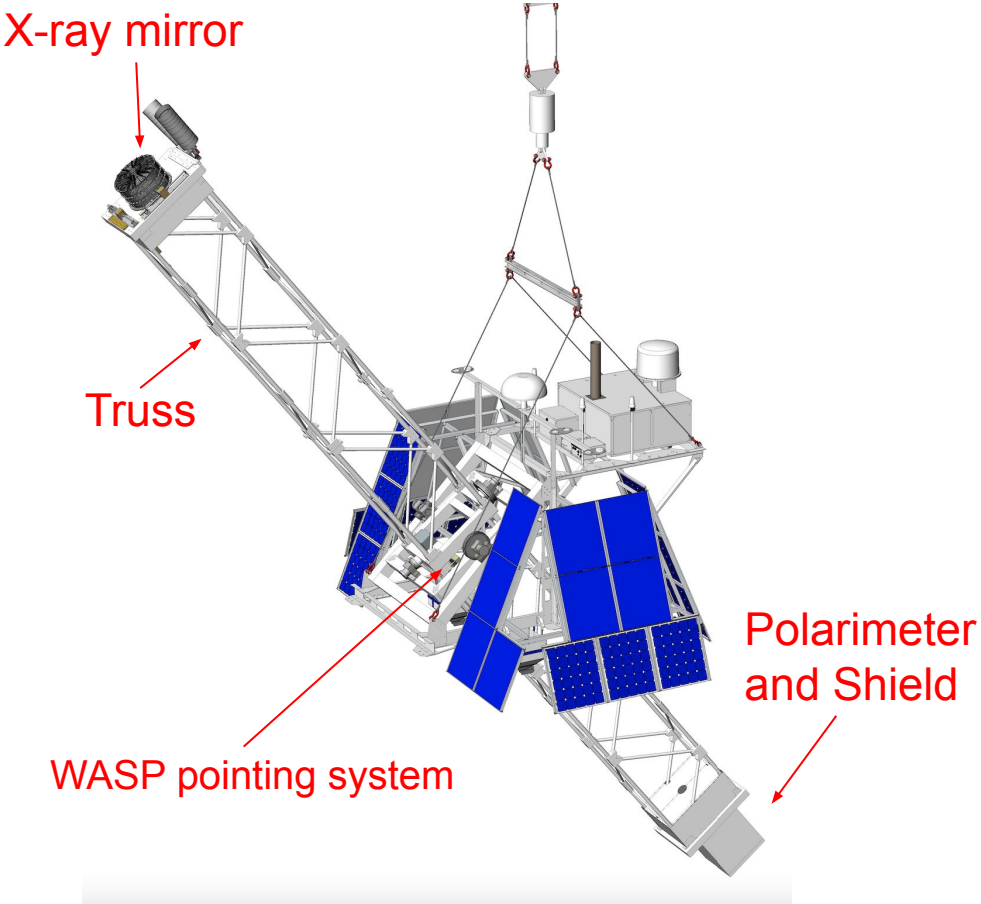
		Lindsey	Lisalda
Mio	Aoyagi	Yoshitomo	Maeda
Hisamitsu	Awaki	Hiroto	Matake
Richard	Bose	Hironori	Matsumoto
Dana	Braun	Gakuto	Matsumoto
Sohee	Chun	Asuka	Miyamoto
Gianluigi	de Geronimo	Takuya	Miyazawa
Teruaki	Enoto	Tsunefumi	Mizuno
Manel	Errando	Takashi	Okajima
Yasushi	Fukazawa	Mark	Pearce
Akihiro	Furusawa	Zachary	Peterson
Thomas	Gadson	Mehrnossh	Rahbardar Mojave
Ephraim	Gau	Brian	Rauch
Victor	Guarino	Nicole	Rodriguez Cavero
Shuichi	Gunji	Felix	Ryde
Tomohiro	Hakamata	Yoshitaka	Saito
Scott	Heatwole	Natsuki	Sakamoto
Arman	Hossen	Kohei	Shima
Kun	Hu	Kentaro	Shirahama
Ryuta	Imamura	Garry	Simburger
Ryo	Imazawa	Sean	Spooner
Kazunori	Ishibashi	Theodor-Adrian	Stana
Manabu	Ishida	David	Stuchlik
Kota	Ishiwata	Hiromitsu	Takahashi
Nirmal Kumar	Iyer	Mai	Takeo
Keon	Harmon	Toru	Tamagawa
Wataru	Kamogawa	Hiroshi	Tsunemi
Fabian	Kislat	Nagomi	Uchida
Mózsi	Kiss	Yuusuke	Uchida
Takao	Kitaguchi	Andrew	West
Kassi	Klepper	Wulf	Eric A.
Henric	Krawczynski	Marina	Yoshimoto
Haruki	Kuramoto		

XL-Calibur Collaboration

Brookhaven National Laboratory

Design of XL-Calibur

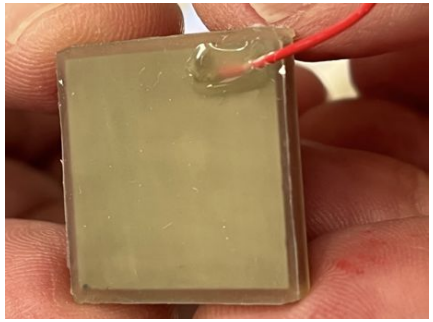
- Be scattering CZT polarimeter
- Anticoincidence shield
- X-ray mirror
- WASP pointing system
- 12m carbon fibre truss

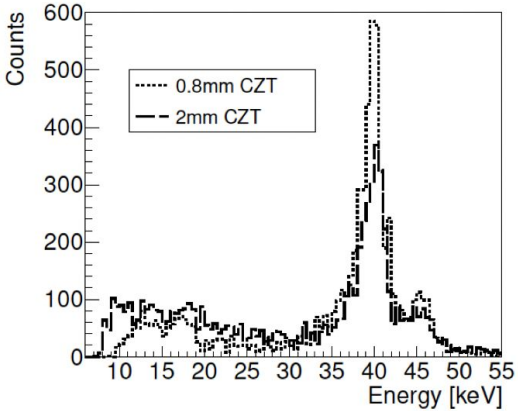


Scattering Polarimeter

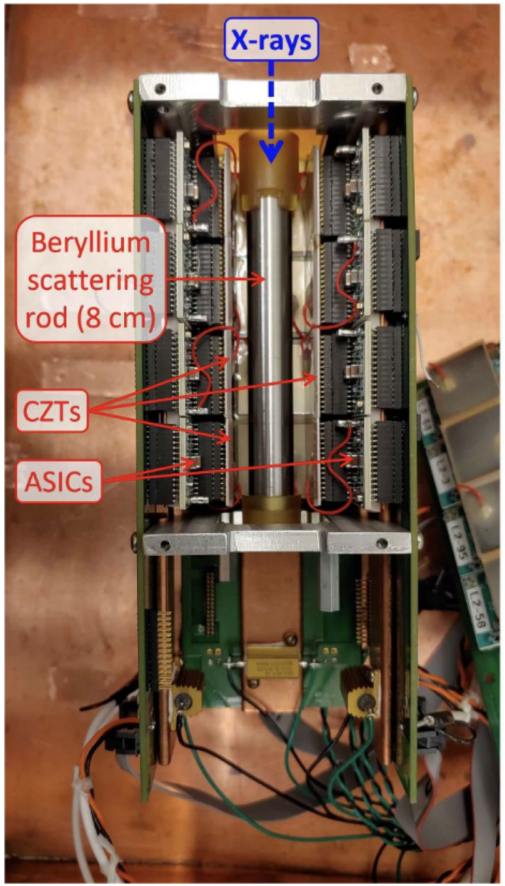
- 17 CZT detector × 64 pixels
  - 16 polarimeter detector + 1 imaging detector
  - Resolution FWHM = 5.9 keV @ 40 keV

- Polarimeter energy range: 15 keV - 80 keV



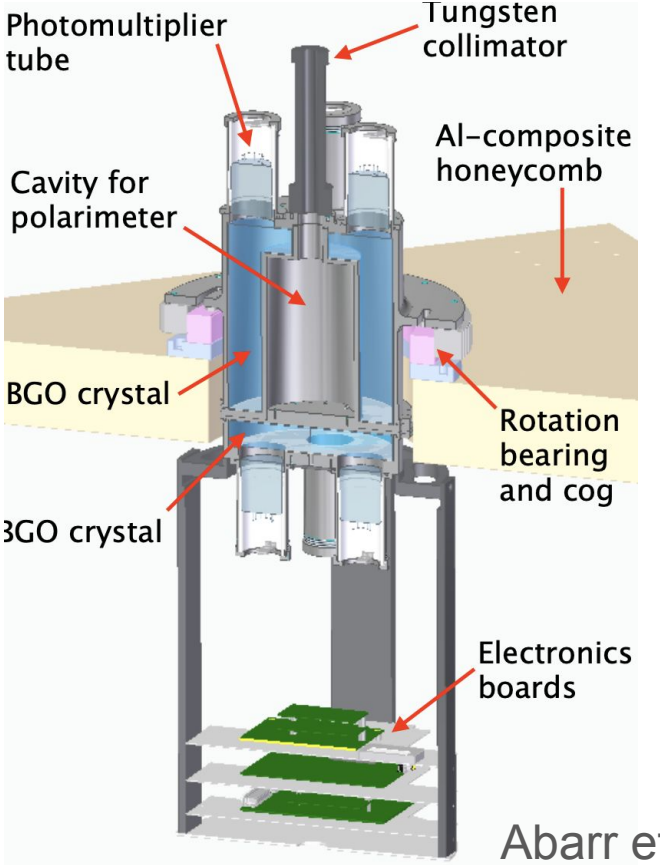


Abarr et al. 2020



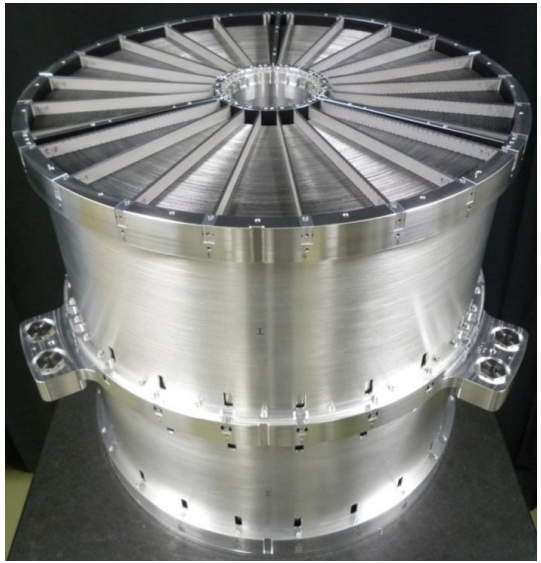
Anticoincidence Shield

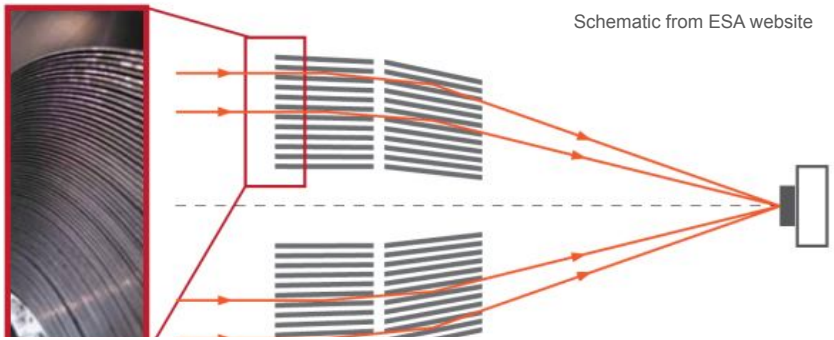
- Veto signal for the background
- Mounted on the honeycomb panel with a motor

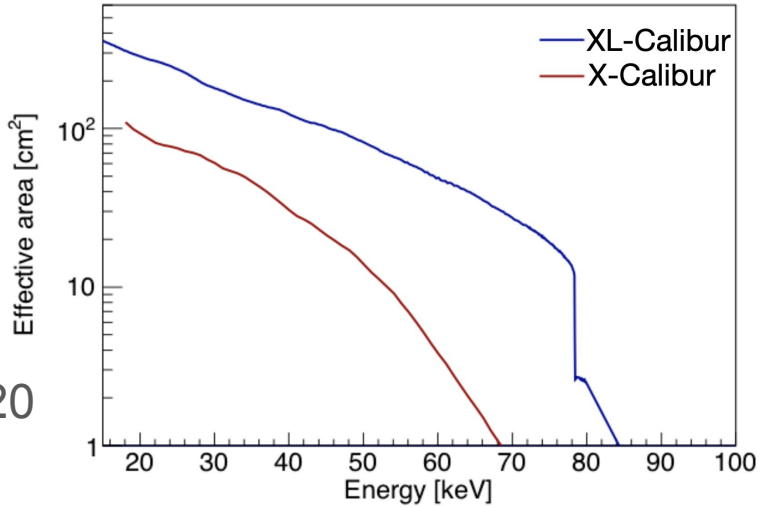


Abarr et al. 2020

X-Ray Mirror





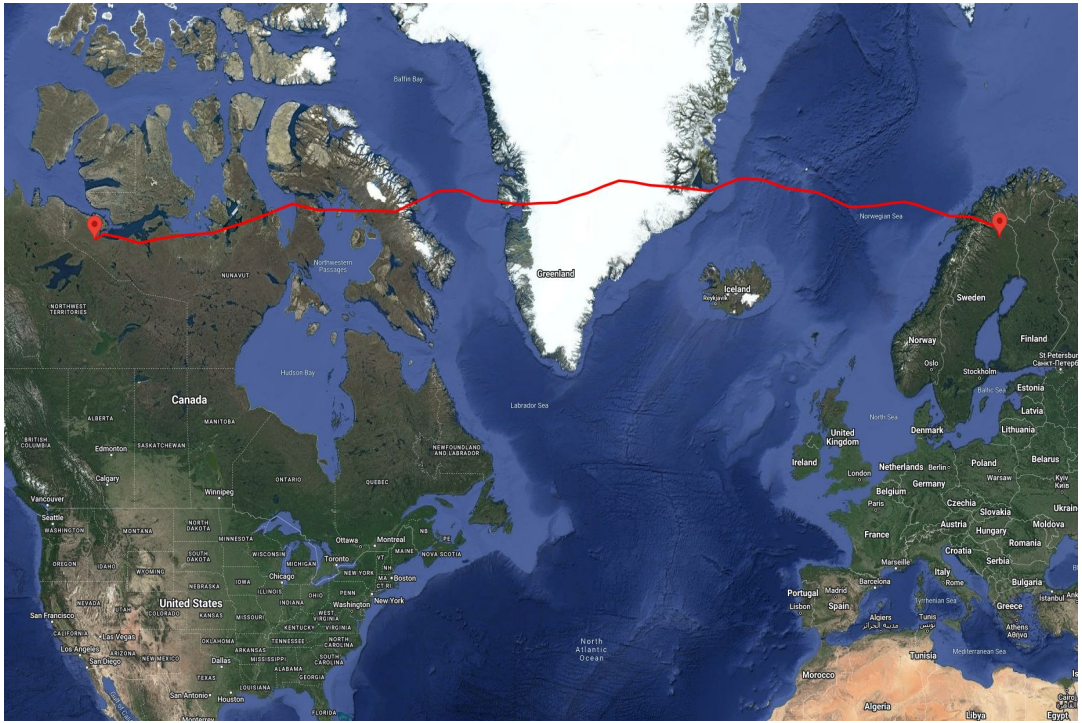


Abarr et al. 2020

2024 Esrange Flight

- Launch: 2024-07-09
- Time at float: 5 days, 15 hours, 49 minutes
- Float time with WASP pointing: 4 days, 16 hours, 51 minutes

2024 Esrange Flight



- Time at float:
  5 days, 15 hours, 49 minutes
- Float time with WASP pointing:
  4 days, 16 hours, 51 minutes
- Usable Crab observations: 4
- Usable Cyg X-1 observations: 4

Observations – Cyg X-1

Cyg X-1 (hard state):

On source: 83ks, 58k events

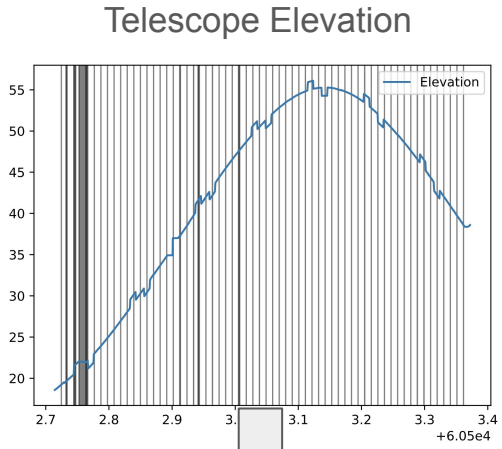
Off source: 50ks, 13k events

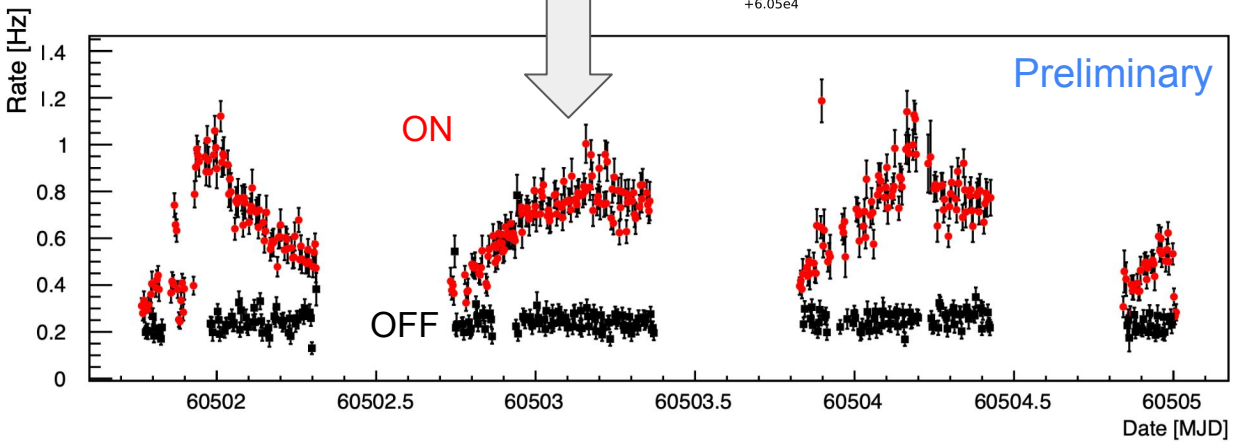
MDP99～ 5%

$$\mathrm{MDP} = \frac{4.29}{\mu R_{\mathrm{S}}} \sqrt{\frac{R_{\mathrm{BG}} + f_{\mathrm{off}} R_{\mathrm{S}}}{(1 - f_{\mathrm{off}}) f_{\mathrm{off}} T}}$$

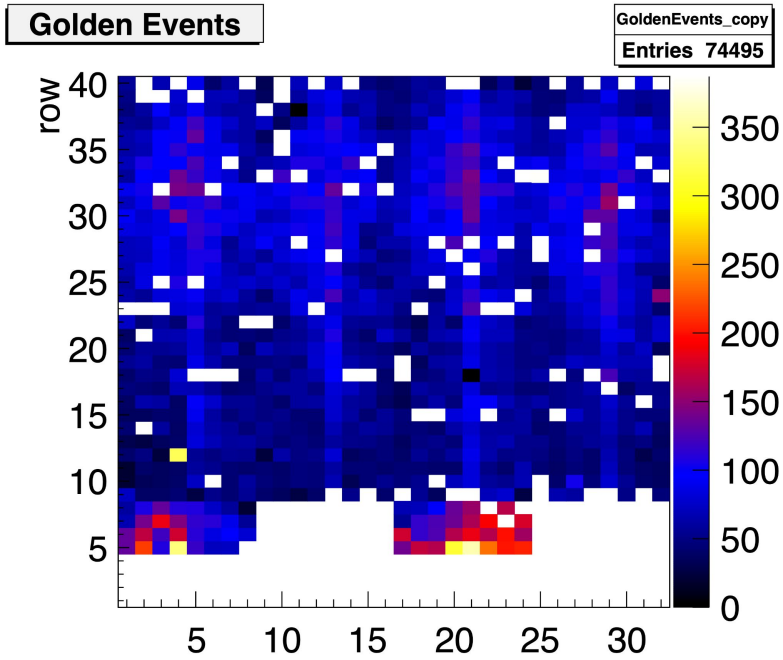
Modulation factor μ ~ 0.43

Aoyagi et al. 2024

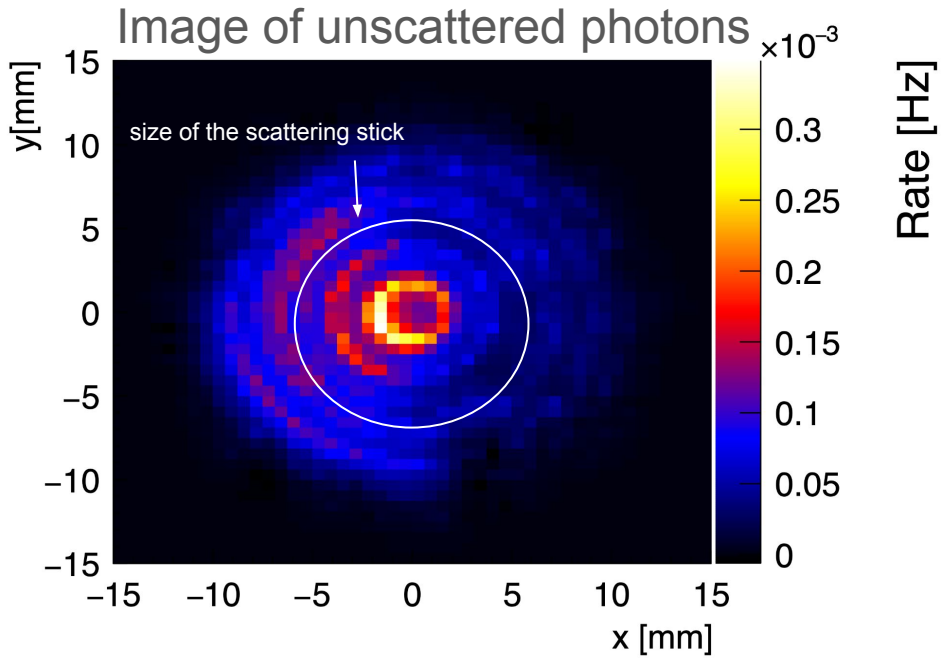




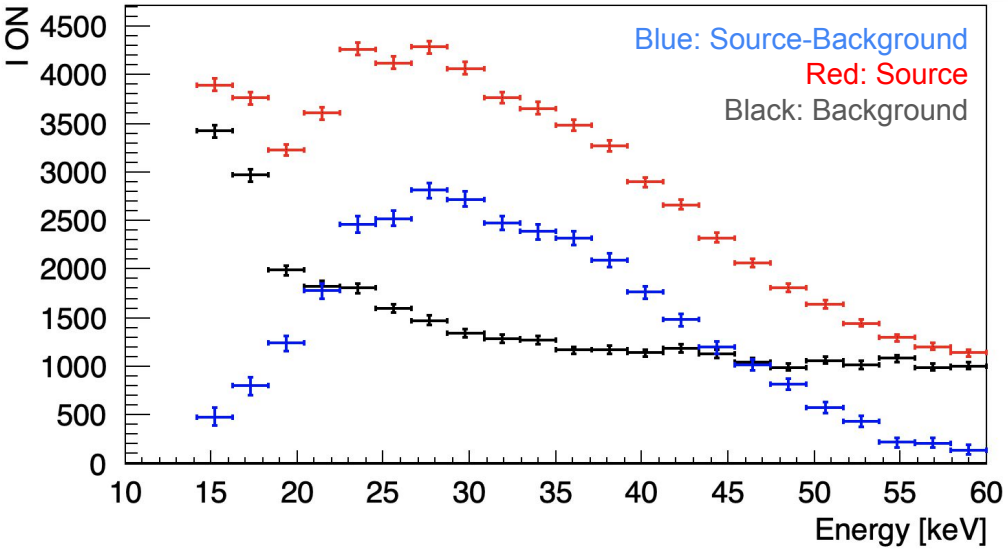
Cyg X-1 Hitmap and Image

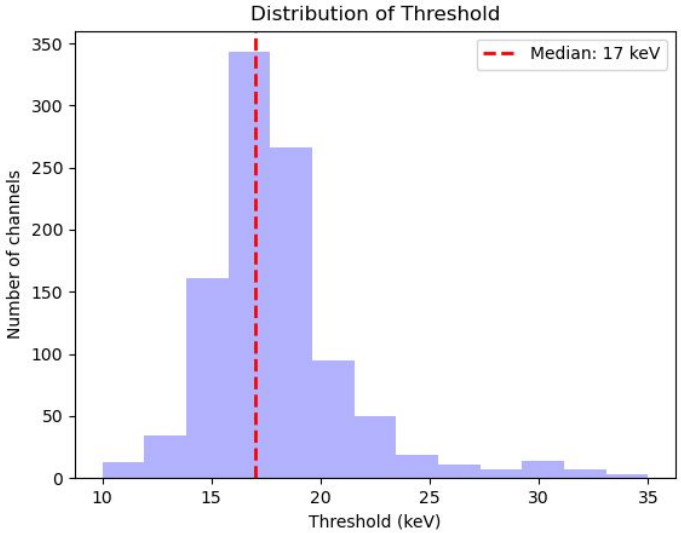


Unwrapped 4-sides of the detector walls



Cyg X-1 Spectrum





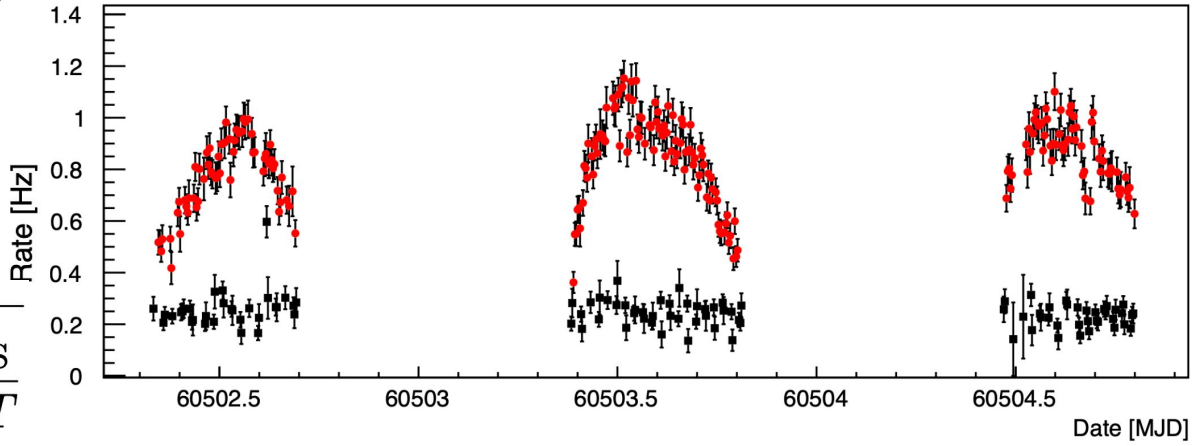
Observations – Crab

Crab:

On source: 64ks, 48k events

Off source: 17ks, 4k events

MDP99 ~ 9%

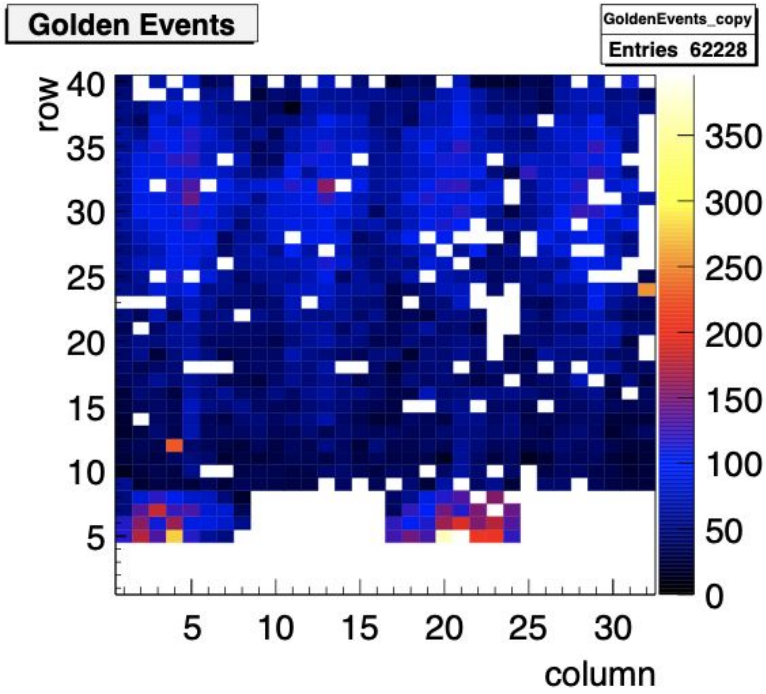


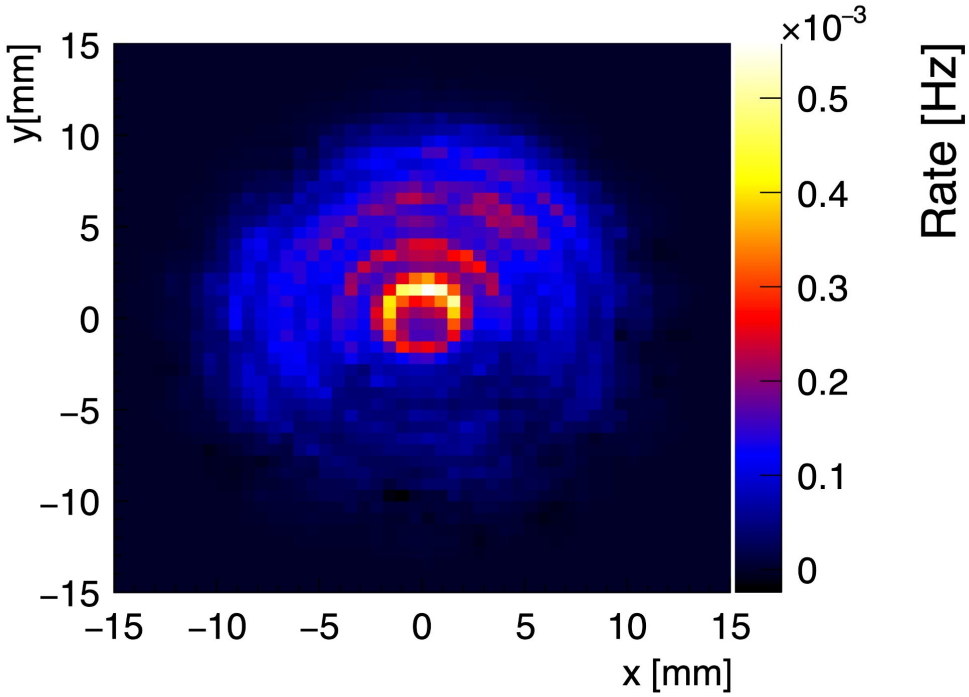
$$\mathrm{MDP} = \frac{4.29}{\mu R_{\mathrm{S}}} \sqrt{\frac{R_{\mathrm{BG}} + f_{\mathrm{off}} R_{\mathrm{S}}}{(1 - f_{\mathrm{off}}) f_{\mathrm{off}} T}}$$

Modulation factor μ ~ 0.43

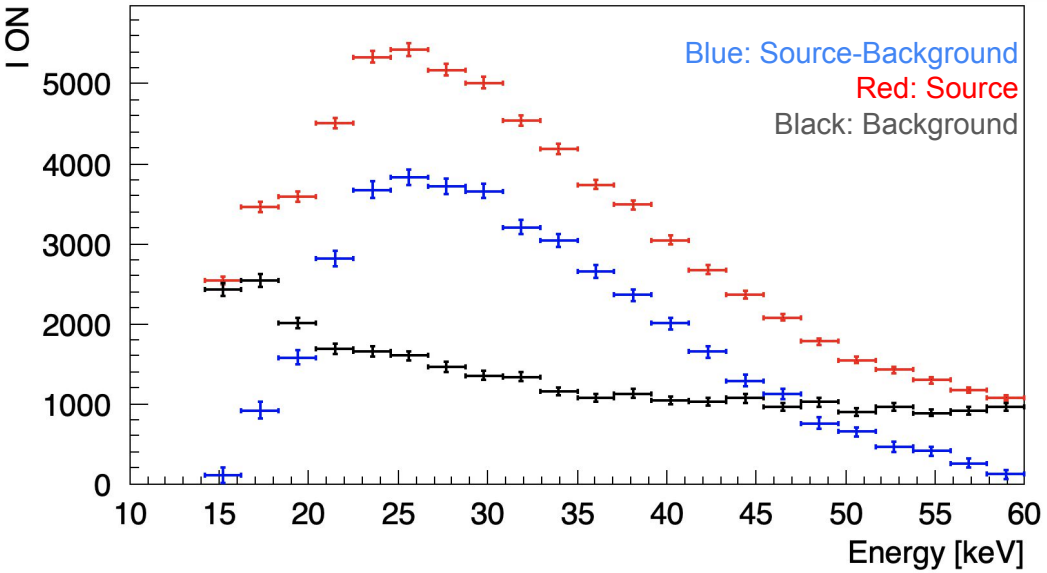
Aoyagi et al. 2024

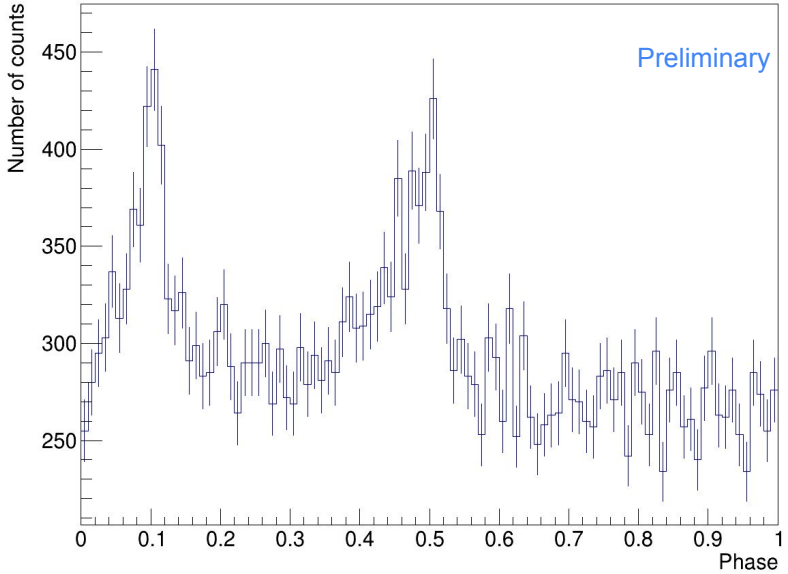
Crab Hitmap and Image





Crab Spectrum and Pulse Profile



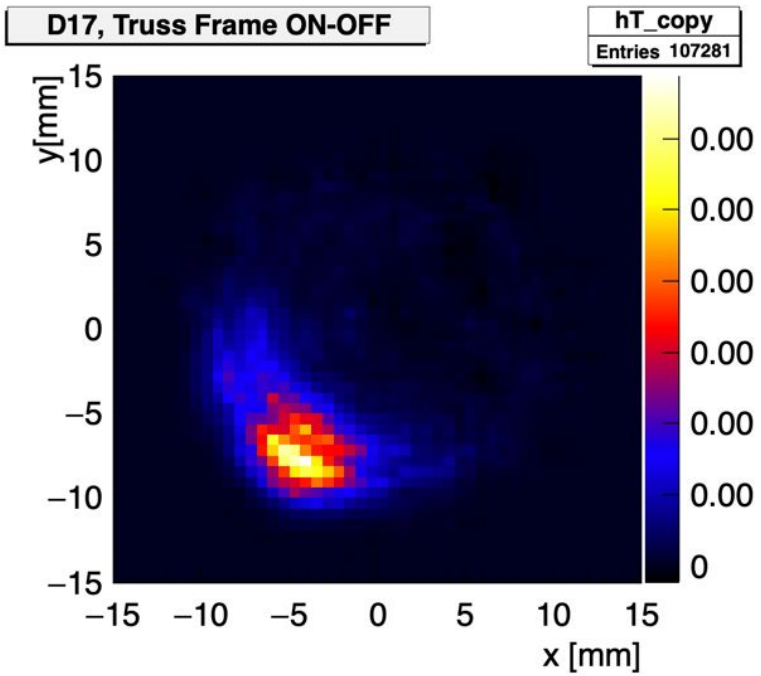


Current Status

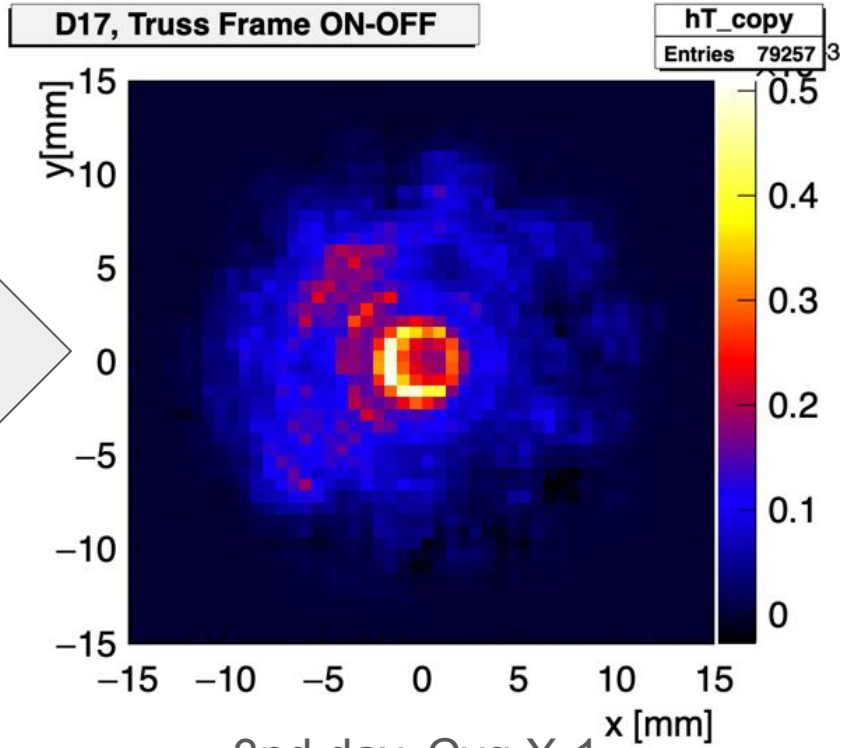
- Polarization analysis
- Multiwavelength analysis (with IXPE, NICER, NuSTAR…)
- Data releasing

…

Pointing Correction



1st day, Cyg X-1



3nd day, Cyg X-1