ComPol
A Compton Polarimeter in a Nano Satellite

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HLL: Peter Lechner

TOPICS

- Scientific motivation

- Detector system

- Working principle

- Sensitivity study

- Hardware status

Scientific motivation

Cygnus X-1

Some facts:

- Black hole binary
  - Black hole (16 $M_\odot$)
  - Blue supergiant star (27 $M_\odot$)
- Distance: 1.8 kpc
- Strong X-ray source

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Scientific motivation

Different emission states of Cygnus X-1
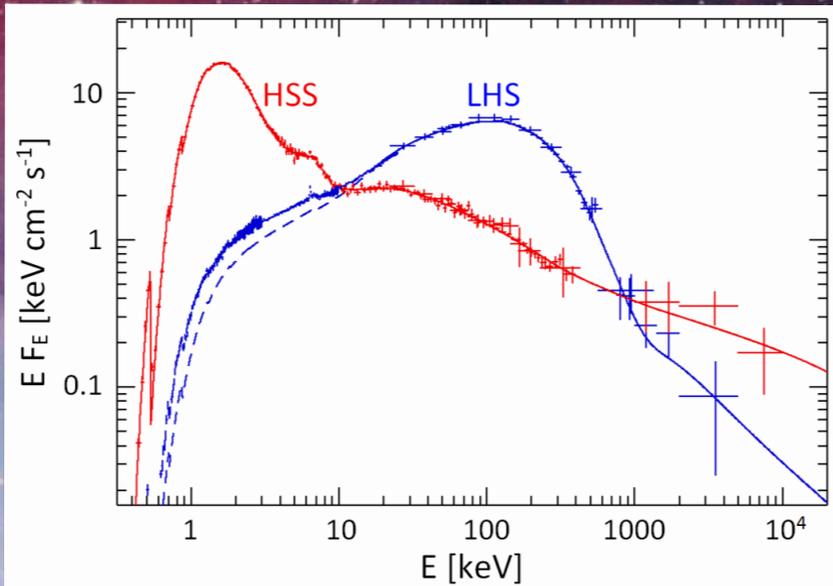
Paredes, Josep M. et al. "Gamma Rays from Compact Binary Systems." AIP Conference Proceedings (2008)
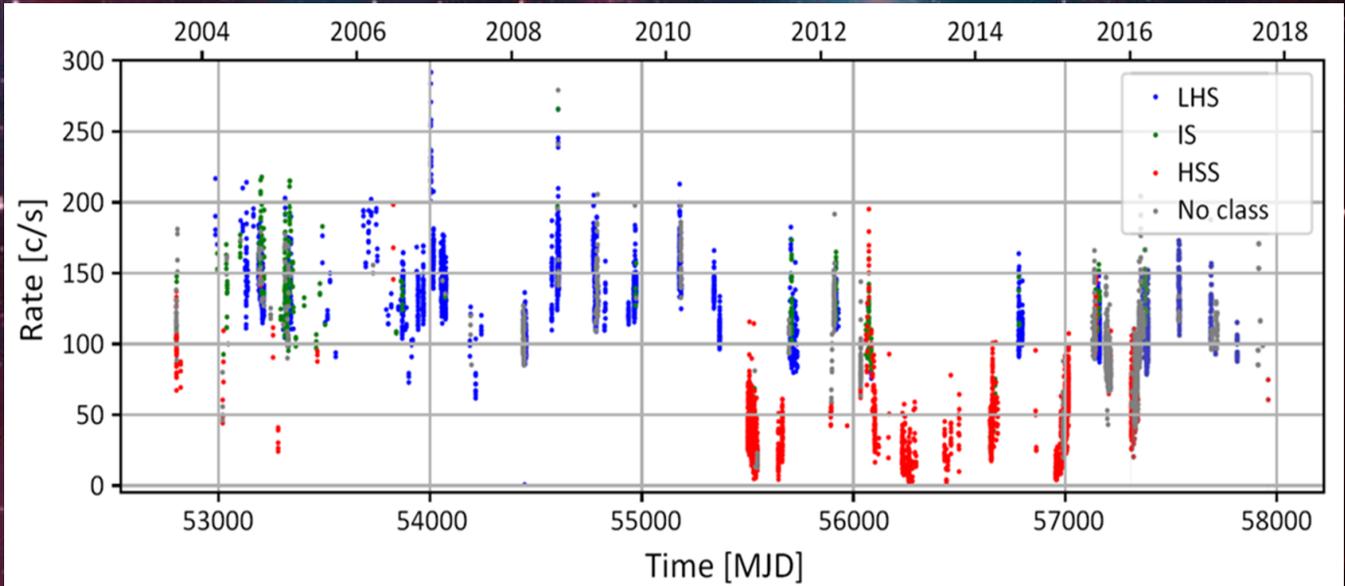
F. Cangemi et al., "High energy spectral study of the black hole Cygnus X-1 with INTEGRAL", SF2A, 2018

→ Continuous observation necessary

# Scientific motivation

Origins of hard X-rays?

- Inverse Compton in Corona

- Synchrotron radiation (in disk/jets)

→ Polarimetry!
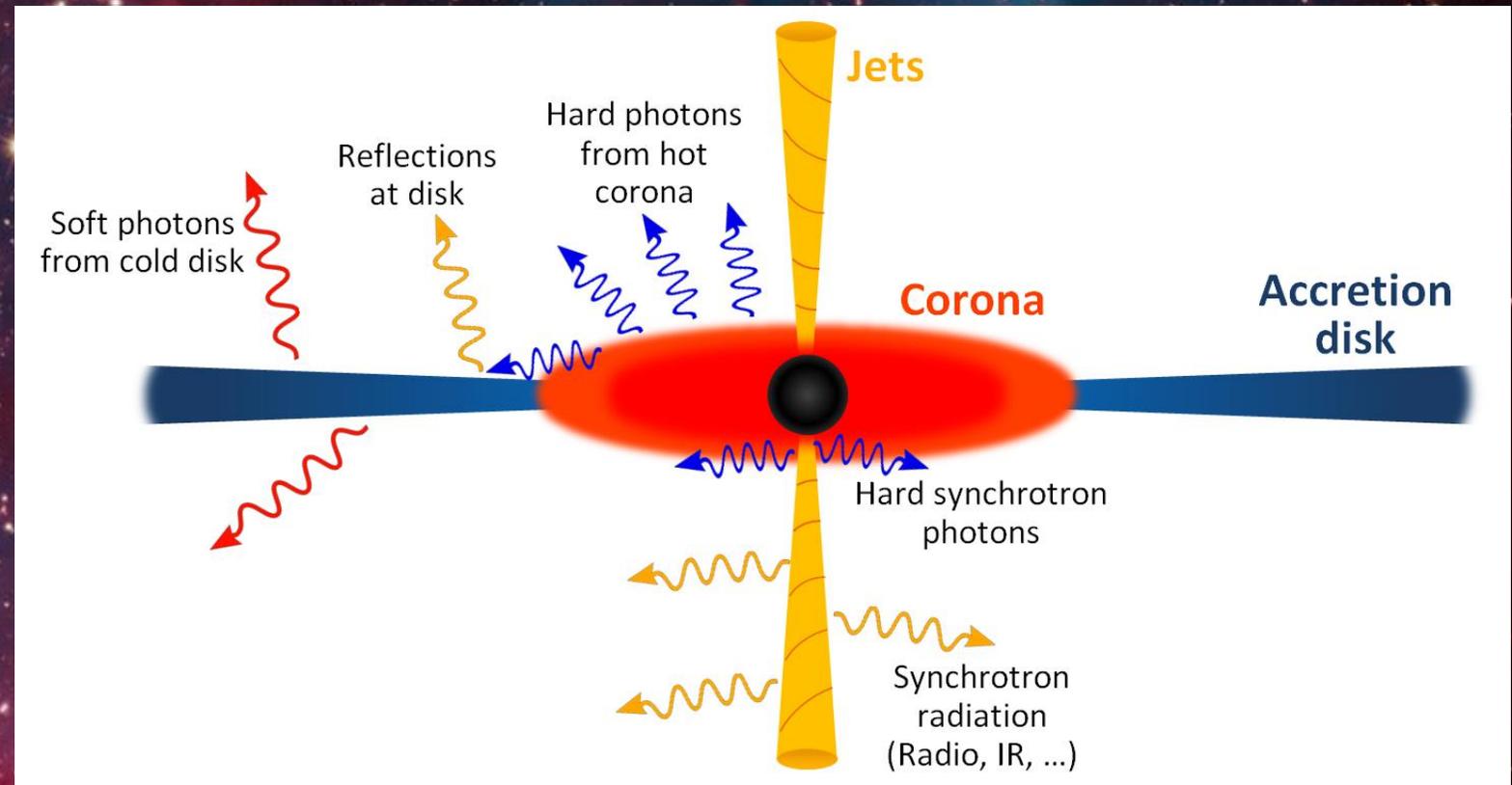
ComPol project (**Com**pton **Pol**arimeter)

- ## CubeSat mission
  3U (10x10x34 cm^3)

- ## Energy range 20 – 200 keV
  largely unexplored

- ## Continuous, long-term pointing at Cygnus X-1
  1 year

- ## Part of the ORIGINS LRSM
 Laboratory for Rapid Space Missions
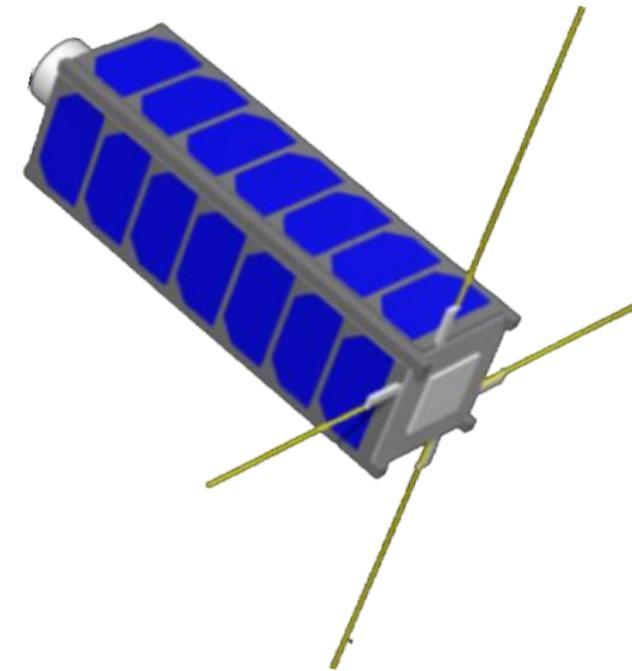
Detector system
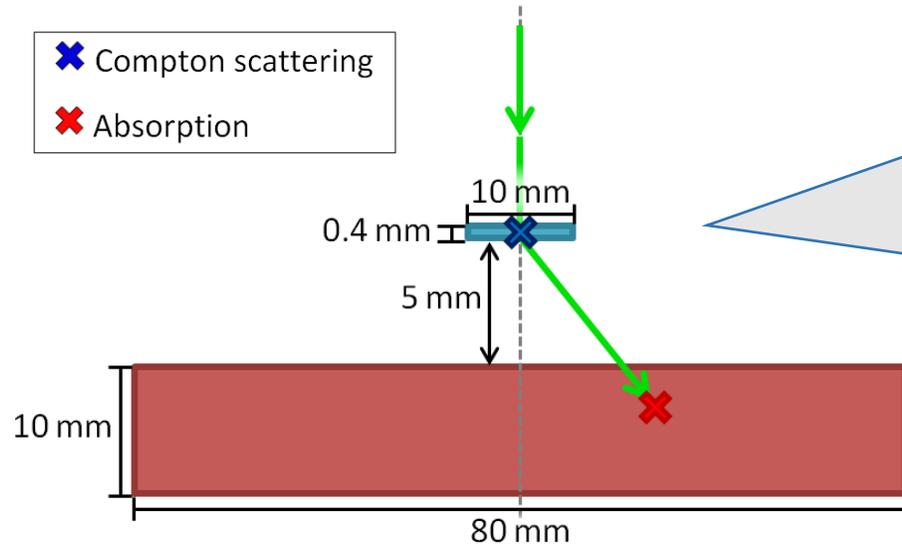
Compton scattering
Absorption

Silicon Drift Detector (SDD)
- Used for KATRIN/**TRISTAN**
(Neutrino mass experiment)
- Excellent energy resolution
(300 eV @ 20 keV)

10 mm
0.4 mm
5 mm
10 mm
80 mm

12.7 mm
10.0 mm
2.0 mm
1.15 mm
2.31 mm

31	8	20
30	19	9	21
18	2	10
29	7	3	22
17	1	11
28	6	4	23
16	5	12
27	15	13	24
26	14	25

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POLITECNICO MILANO 1863

MPG HLL
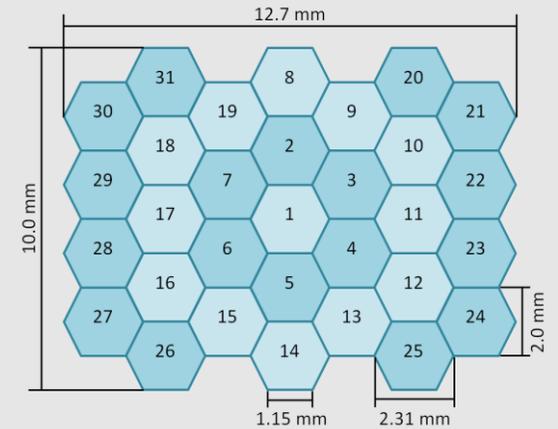
Calorimeter
- Scintillating crystal: $CeBr_3$
- Silicon photomultiplier matrix on the backside

cea

Incoming photon
Scintillation light
Silicon photomultiplier matrix

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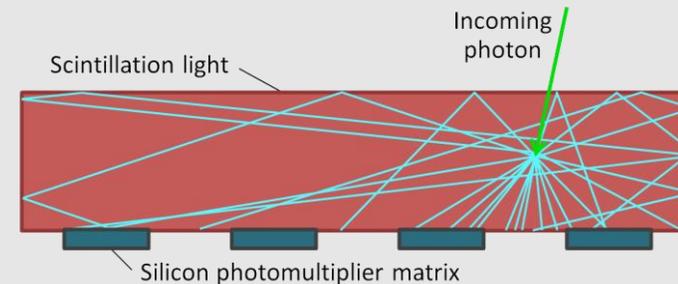
Working principle

Scatter plot in second
detector plane
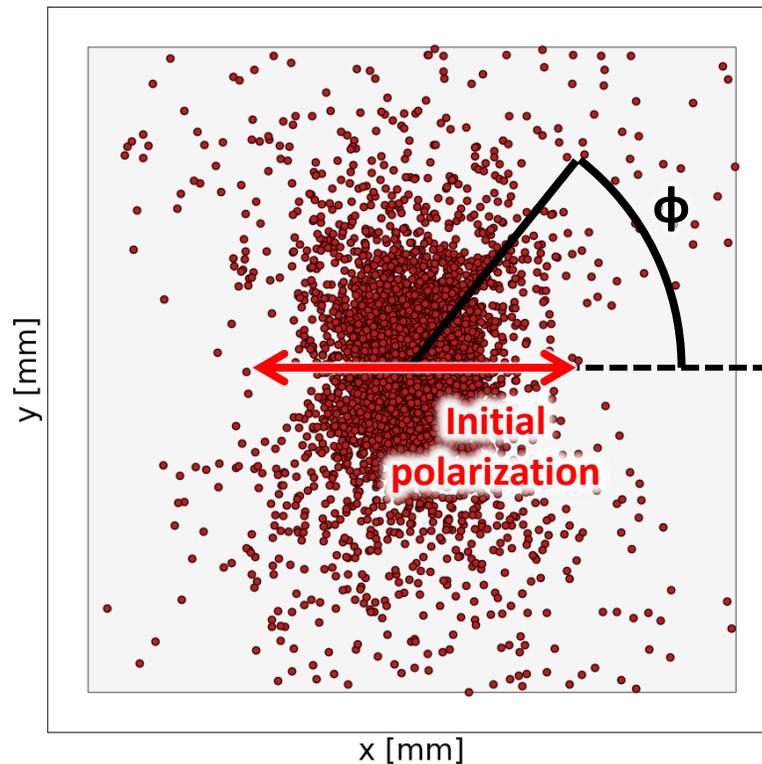
Histogram of the azimuthal
scatter angle φ
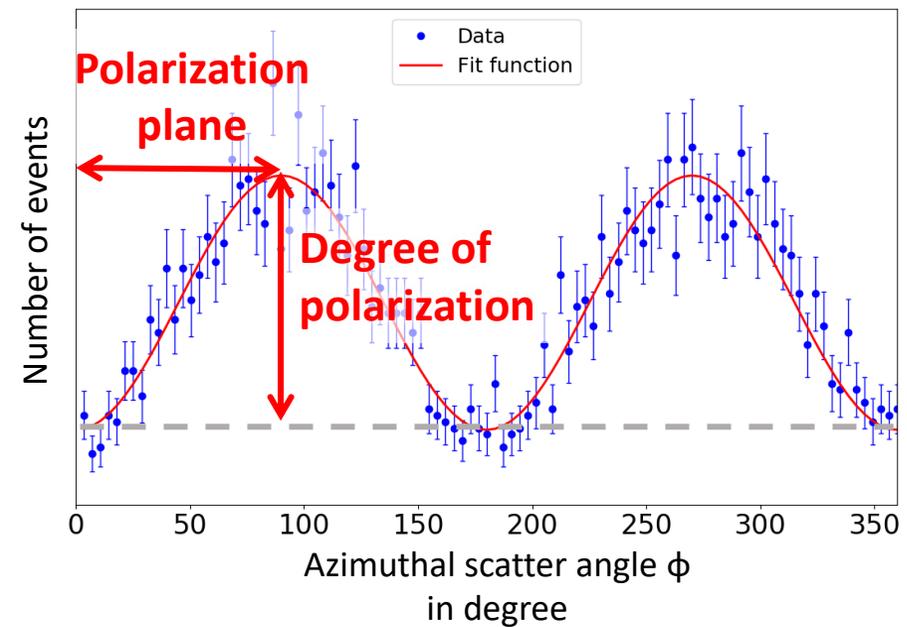
Event reconstruction

Two ways to determine the scatter angle Θ

1) via interaction points
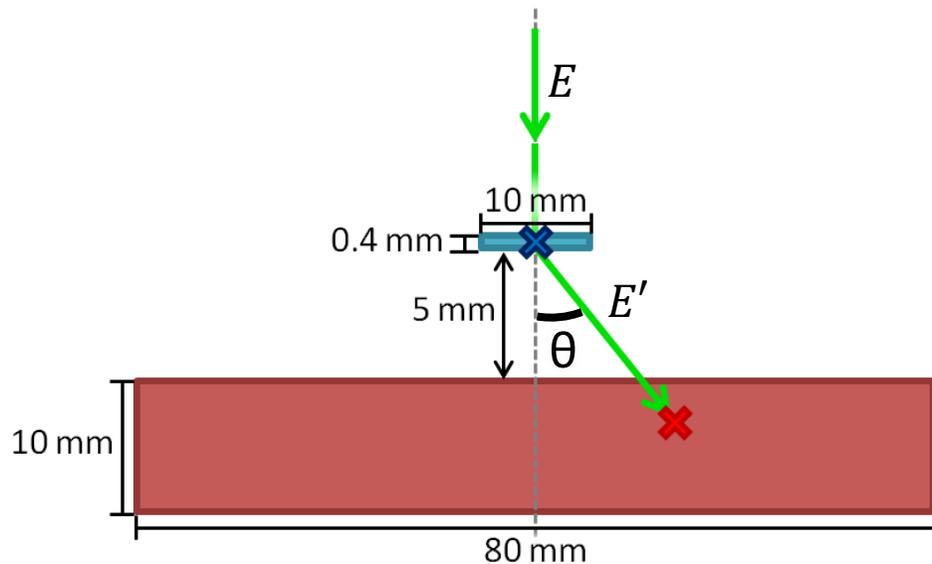
2) via energy deposits

$$\Delta\lambda = \lambda' - \lambda = \frac{h}{m_e c}(1 - cos\theta)$$

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow cos\theta = 1 - m_e c^2 \left(\frac{1}{E'} - \frac{1}{E}\right)$$

energy after
scattering
$E' = E_{Cal}$

initial energy
$E = E_{Si} + E_{Cal}$

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Event selection

Two ways to determine the scatter angle Θ

1) via interaction points

2) via energy deposits

Difference between Θ_E and Θ_{Pos}
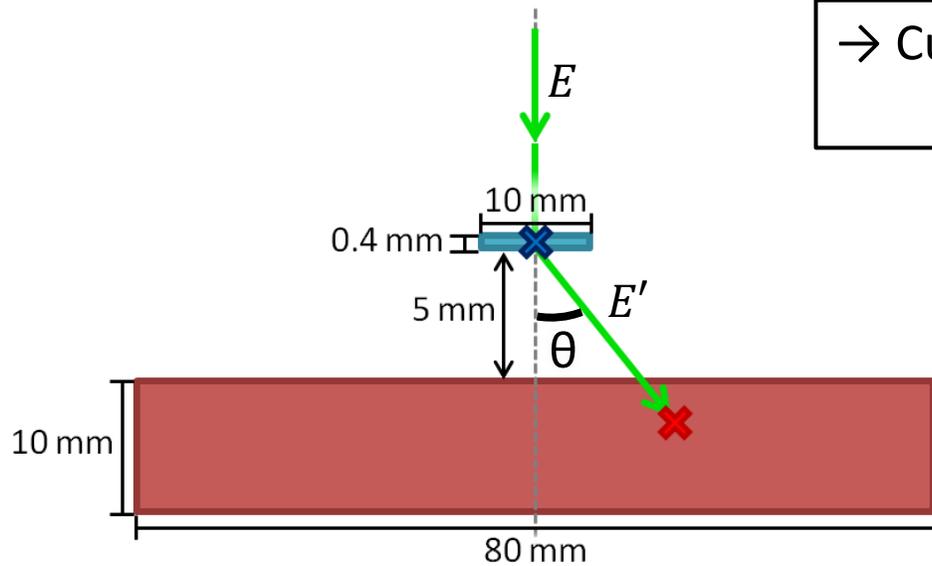
→ Cut on the difference
$\Delta\Theta = \Theta_{Pos} - \Theta_E$
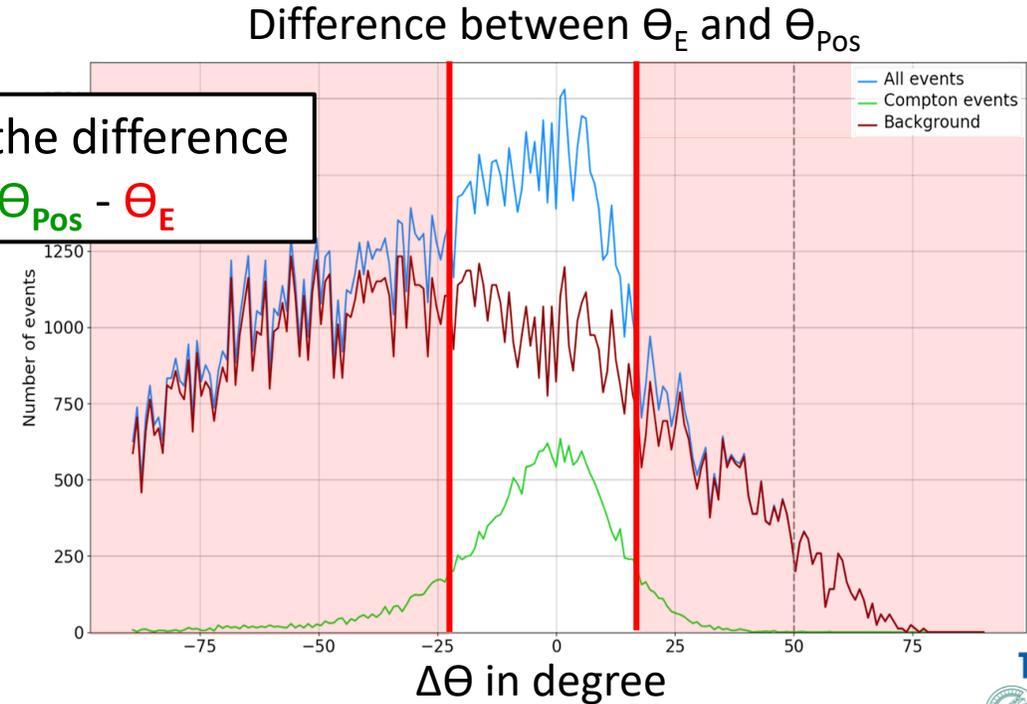
Sensitivity studies with Geant4

Simulated effects:

- Real spectra
  - Cygnus X-1
  - Background:
    γ, e^-, e^+, n, p^+, α
    + Cosmogenic activation
- Whole detector system
+ Surrounding materials
- Detector effects:
  - Position resolution
 - Energy resolution
  - Energy thresholds

Sensitive to 15% polarization after 6 month
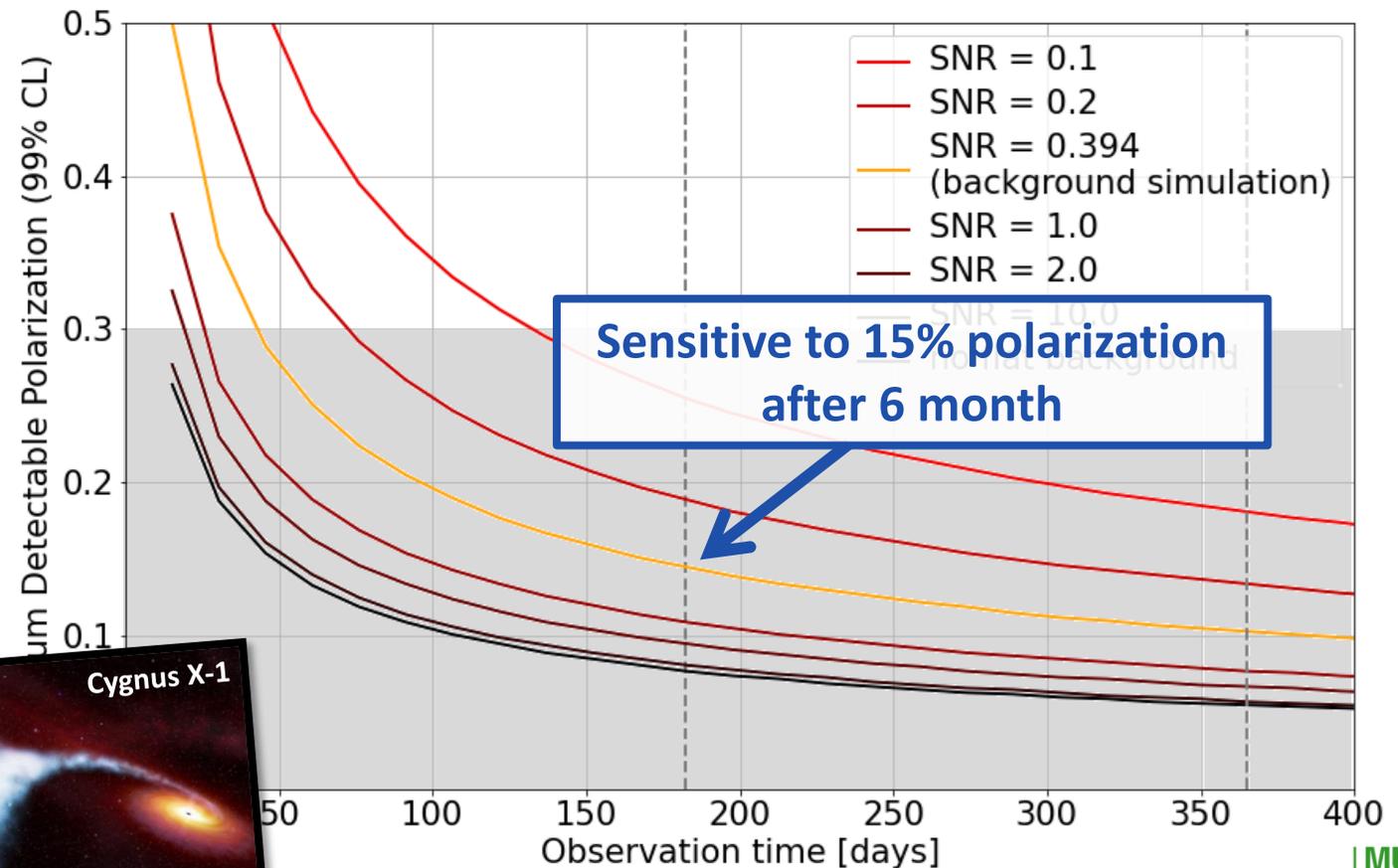
Background study

Shielding strategy and Cosmogenic Activation

South Atlantic Anomaly
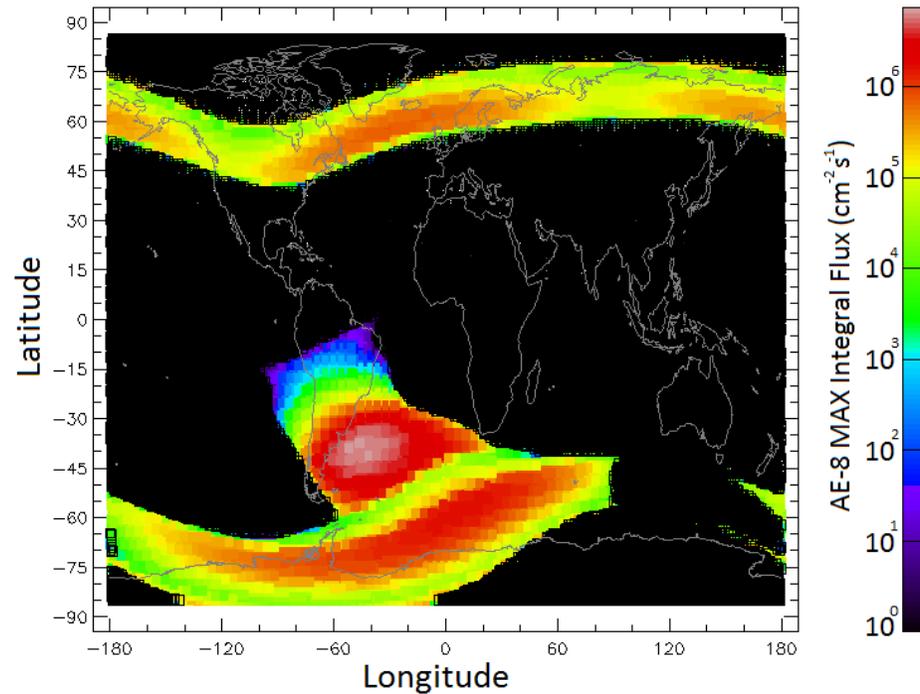
SAA Influence over time

Project schedule

01/2022   07/2022   01/2023   07/2023

In Orbit Verification (ISS) ... **CubeSat Version**

Cygnus X-1

Launch

Finish subsystems

Merging of subsystems

Characterization / testing

Measurement

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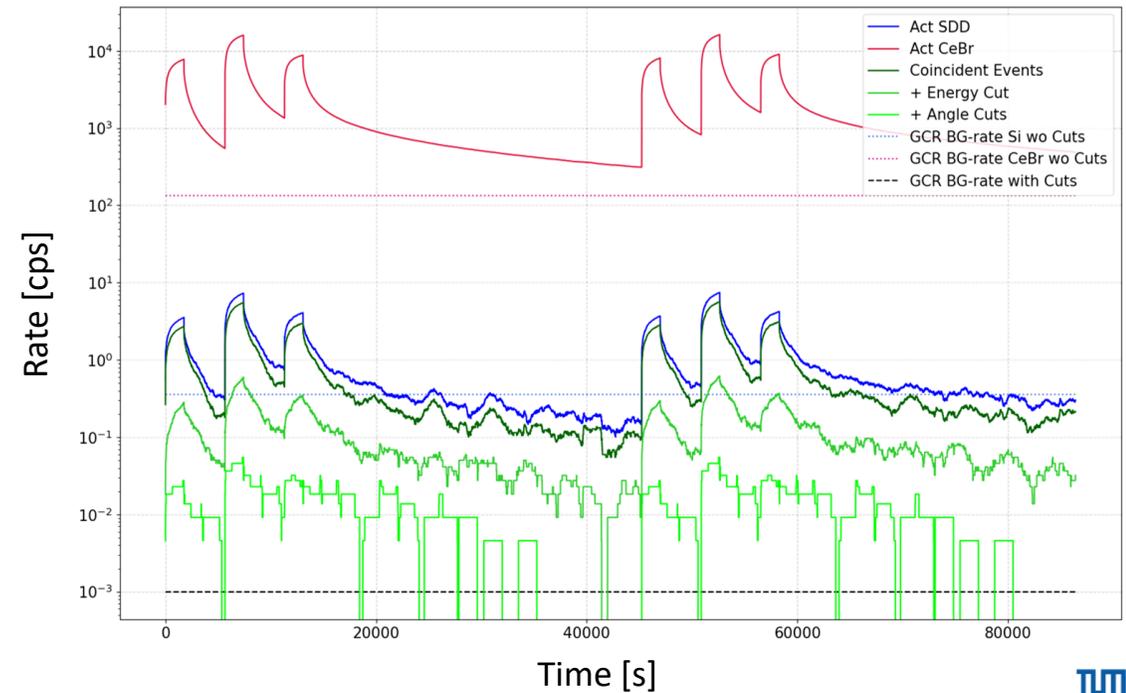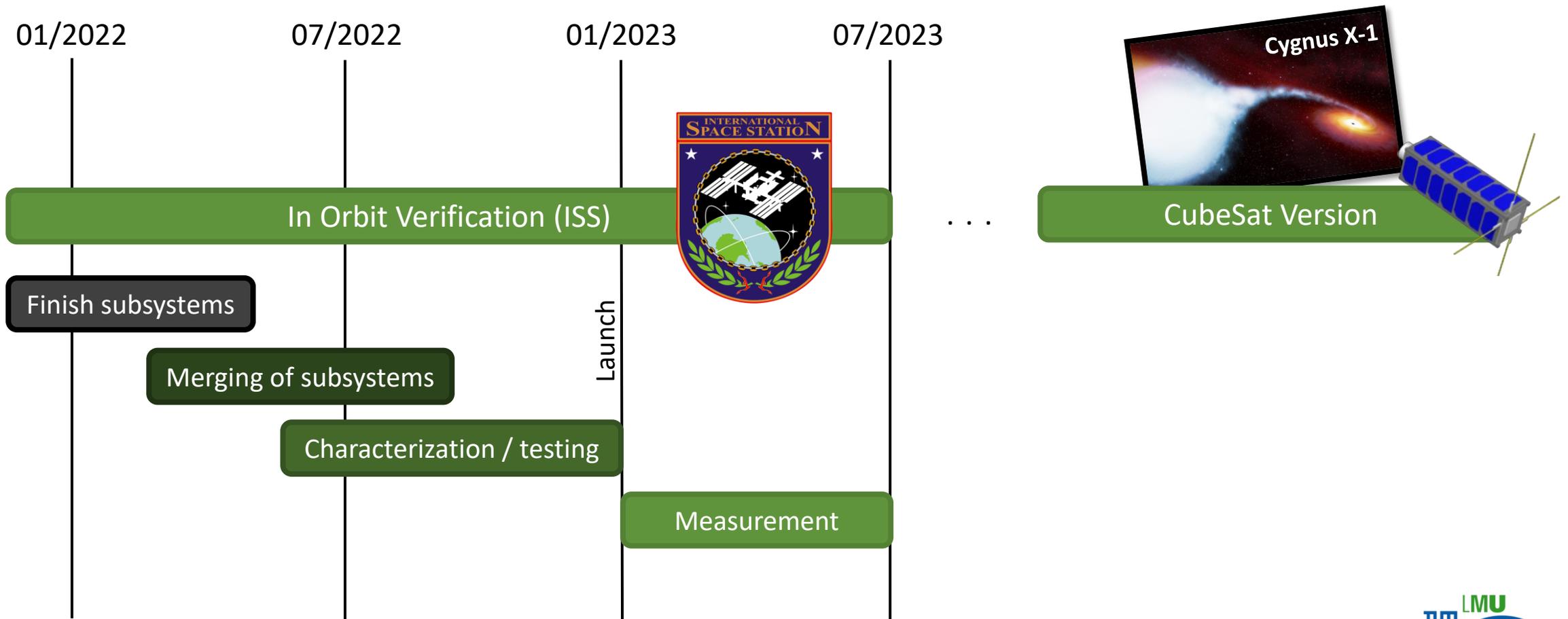
Hardware ISS version

See talk by
K. Geigenberger

SDDs

CeBr$_3$
Scintillator

Light
shielding

- Readout
- Payload
  computer
- Power
  supply

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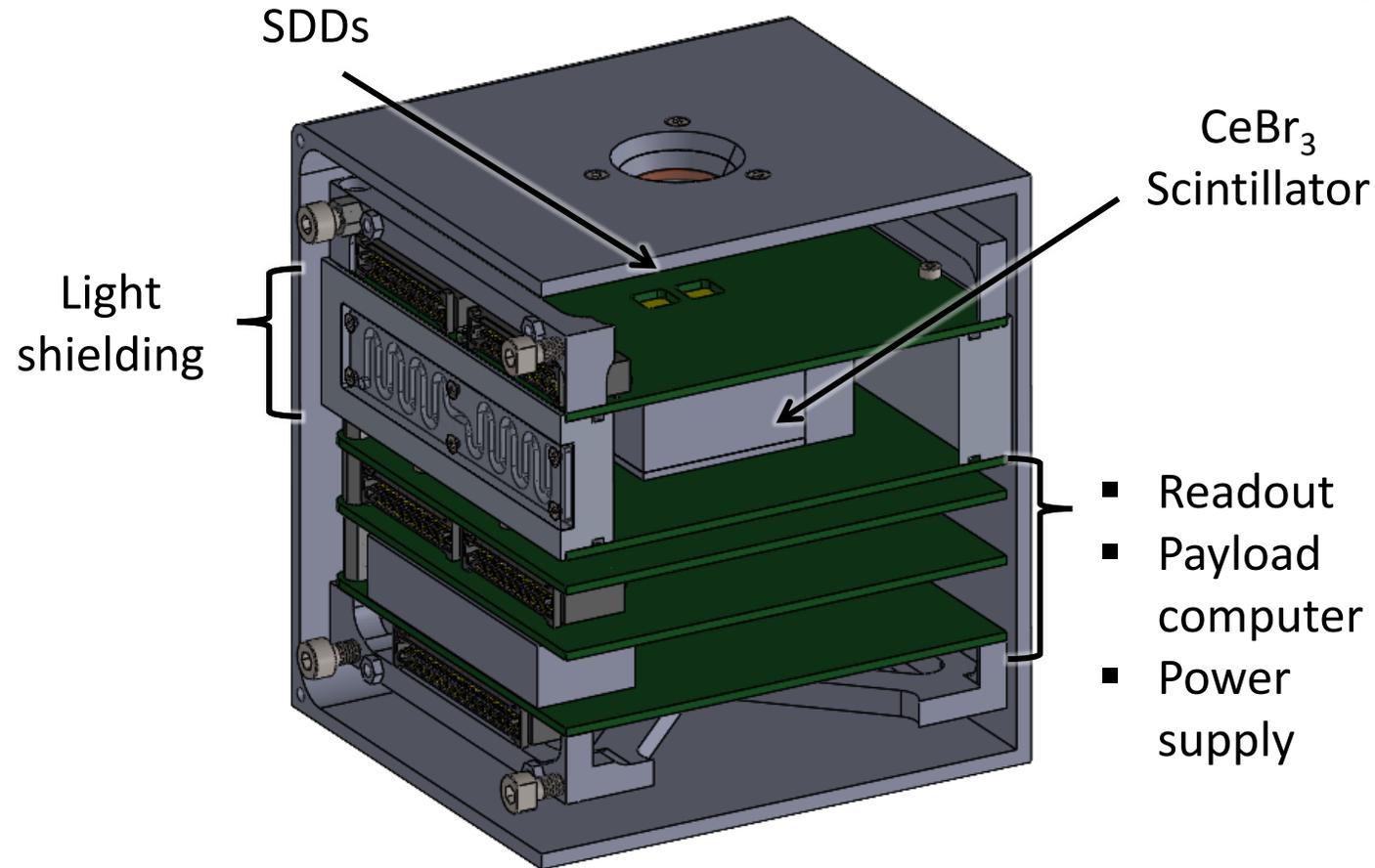
Hardware ISS version

First prototype boards are ready!

Achieved:

- First operation of HLL SDD with SFERA ASIC
- Good performance verified

Iron-55
152eV FWHM
@ 5.9 keV

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lrz
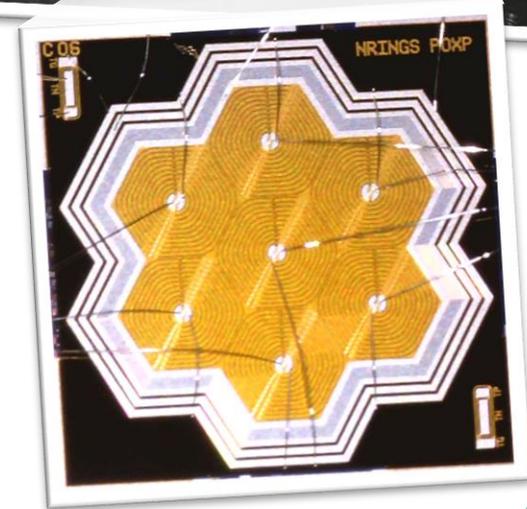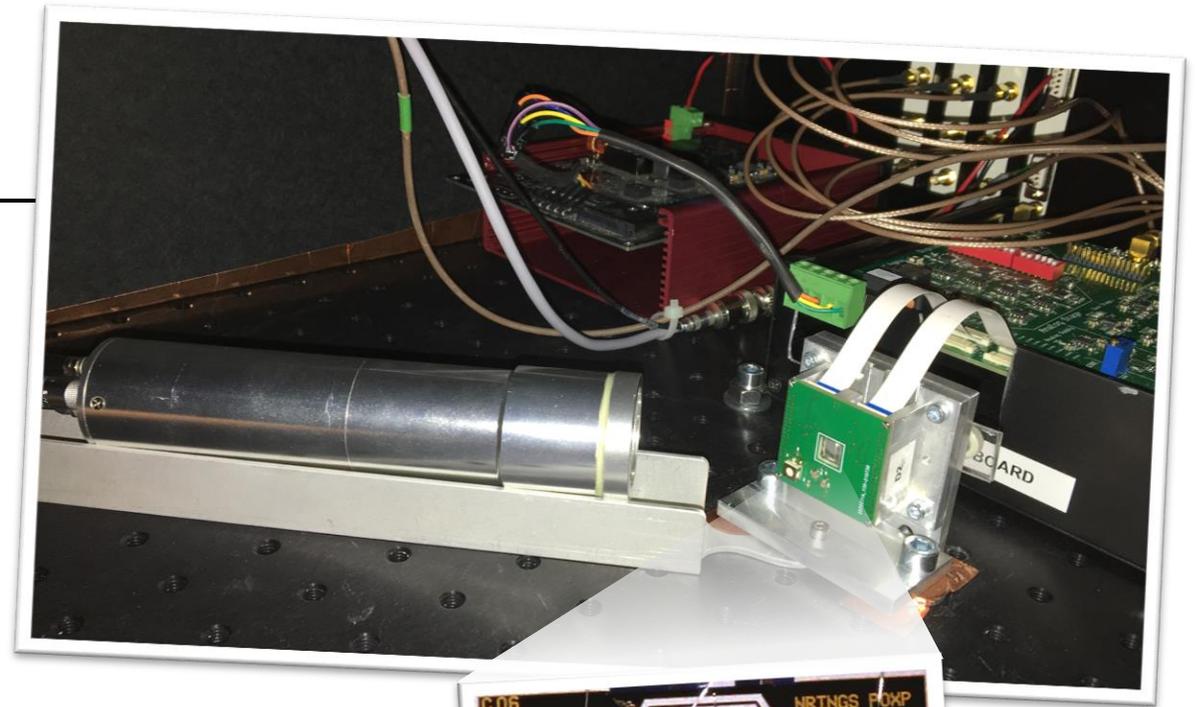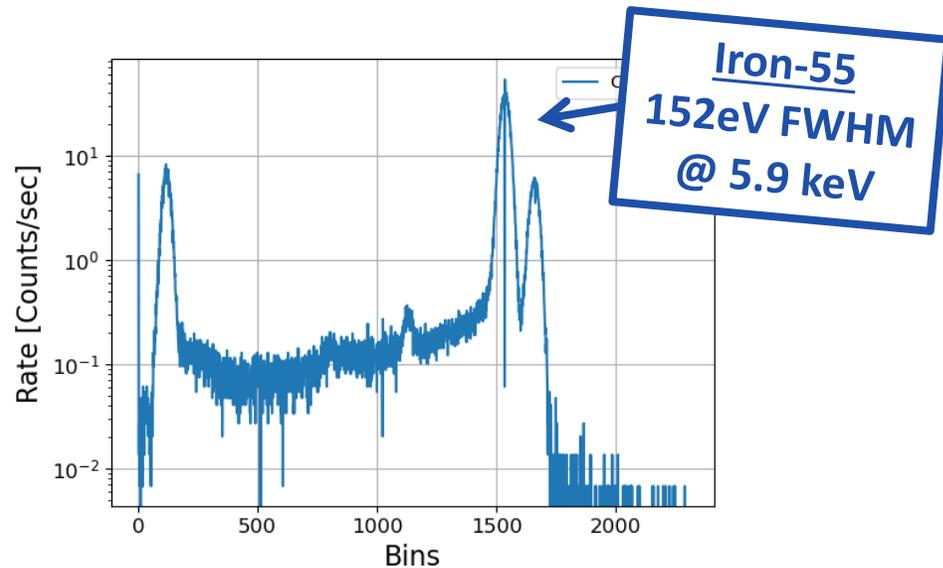
ComPol project (Compton Polarimeter)

CubeSat mission

- 3U CubeSat → (10x10x34 cm^3)
- IOV mission: 2023
- CubeSat Launch >2023

Cygnus X-1

Observe Cygnus X-1

- 20 keV – 2 MeV
- Continuous for >1year
- Spectrum & polarization

Detector system

- Compton telescope
- Stacked detector system

SDD

CeBr$_3$
Scintillator

10 mm

0.4 mm

d

10 mm

80 mm
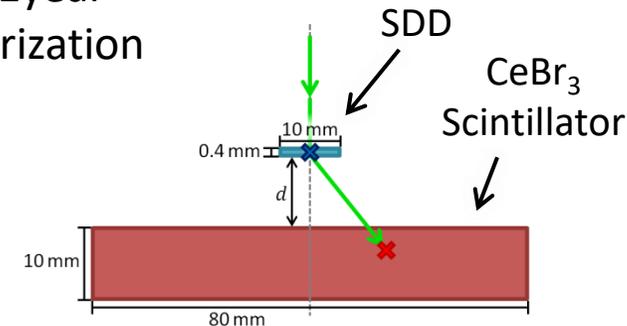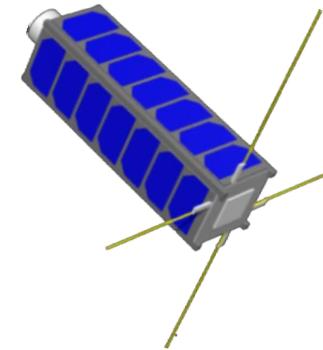
→ **Minimum Detectable Degree of Polarization ≤15%**

Thank you for your attention!