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Development of a Tunable Monochromatic X-ray Source for Pixelated Semiconductor Detector Calibration

Speaker: Truong Hoai Bao Phi[a,b]

[a] Institute of Physics, Vietnam Academy of Science and Technology, Hanoi
[b] Dzhelepov Laboratory of Nuclear Problems, JINR, Dubna
baophinuclear@gmail.com

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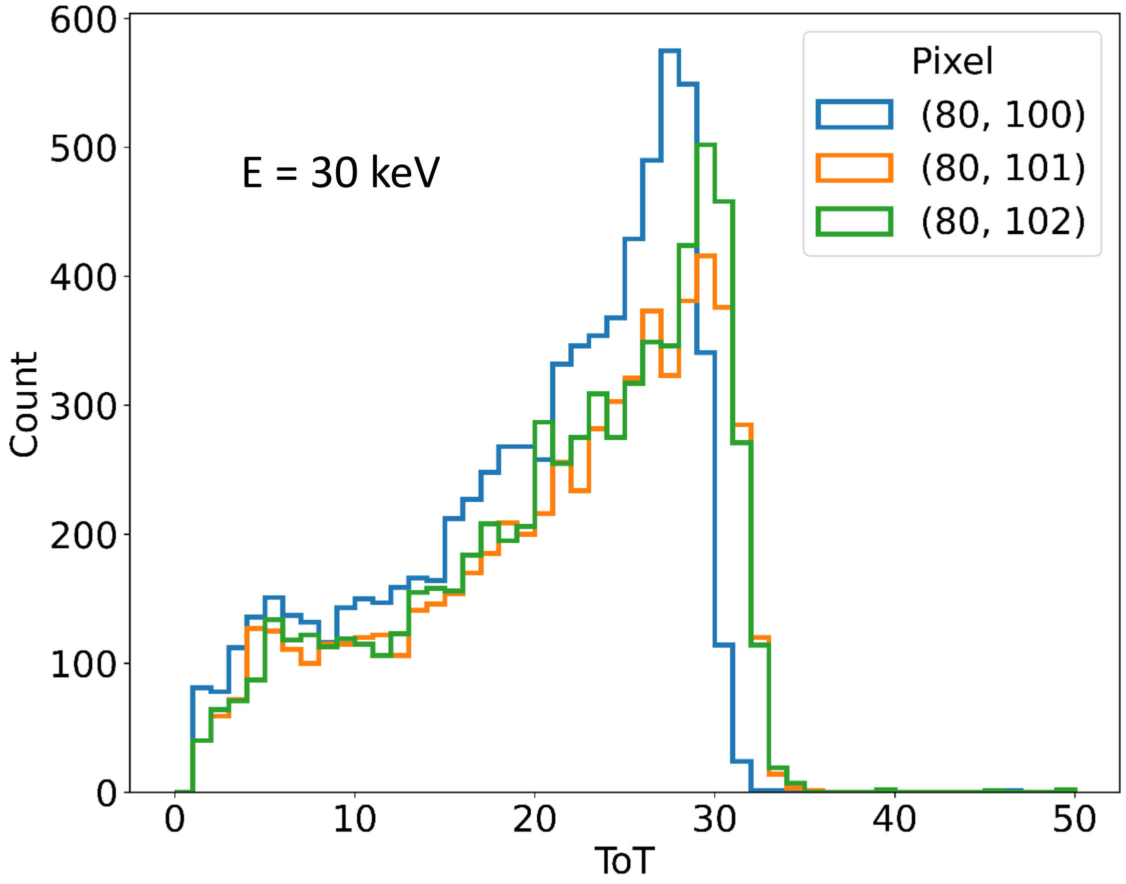
Introduction



Energy spectra of 3 pixels with the same quanta energy

- Pixel response non-uniformity degrades the performance of pixelated semiconductor detectors, particularly in energy-resolving applications.

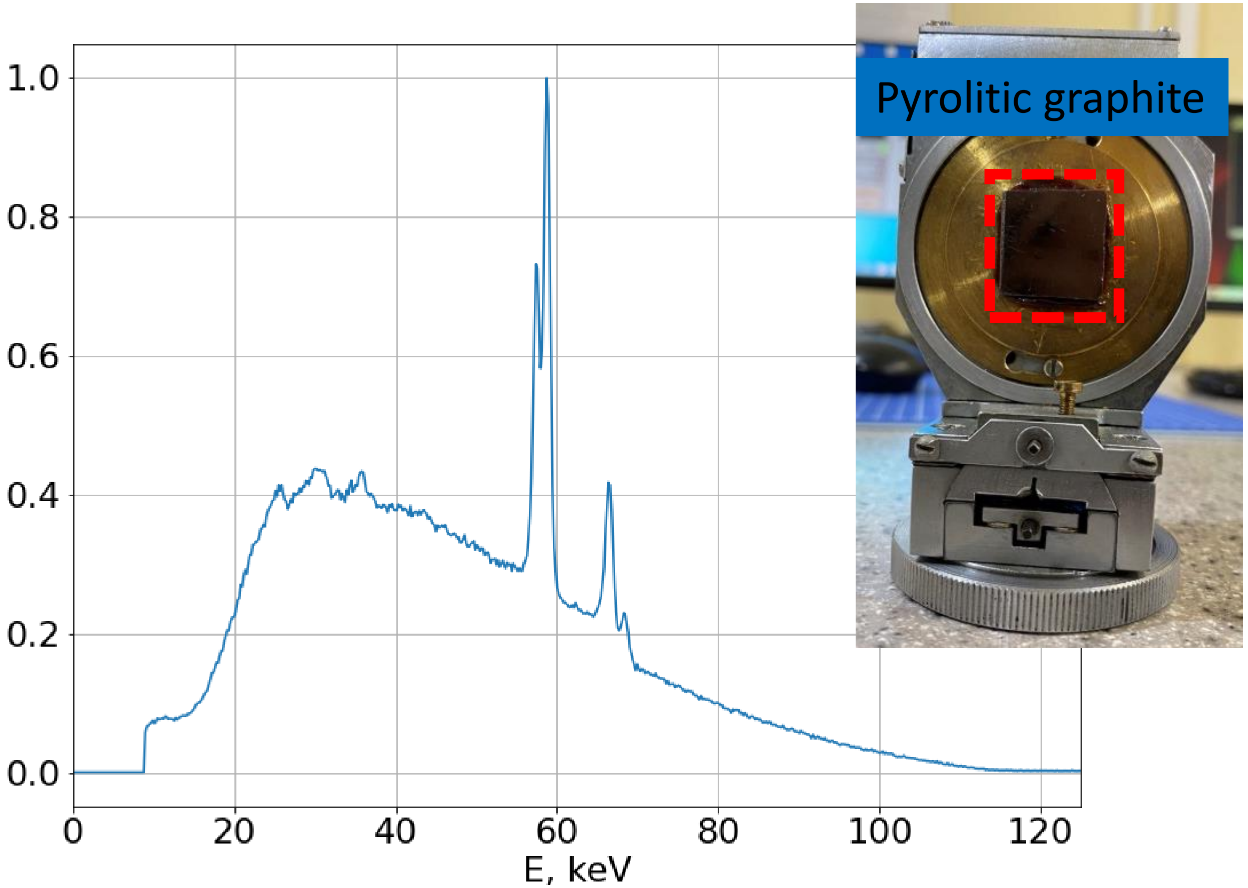
  Solution: Per-pixel energy calibration.

  Sources: isotopes, fluorescence

- In medical applications, we focus on detecting quanta with energies below 100 keV.

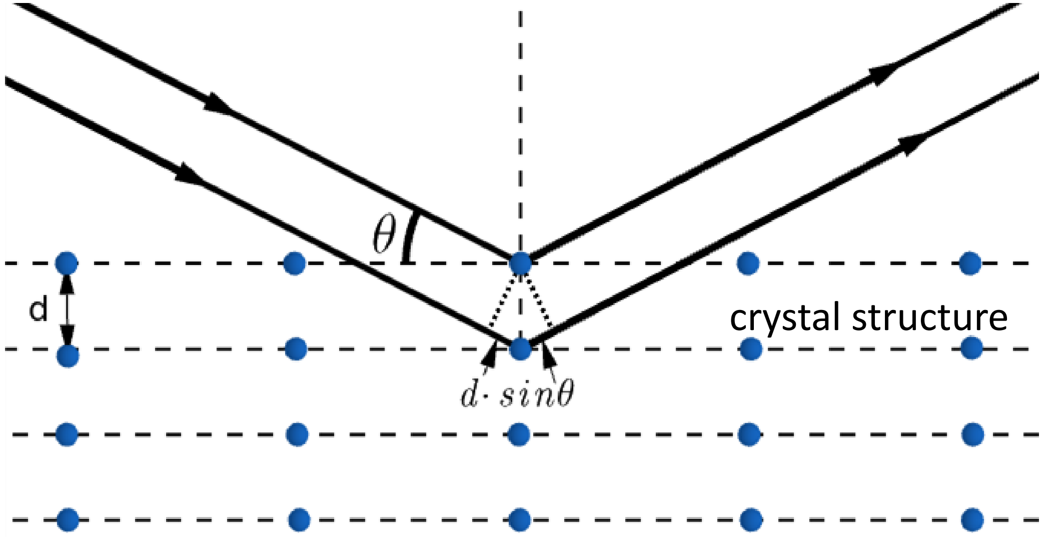
➢ This study aims to develop a tunable device capable of generating a monoenergetic quanta beam at a user-defined energy.

Operating principle



Typical continuous spectrum of a X-ray tube

Bragg's law



$$n \cdot \lambda = 2d \cdot \sin\theta$$

$$E = \frac{n \cdot h \cdot c}{2 \cdot d \cdot sin\theta} \quad (1)$$

Structural components

1. X-ray tube

(anode: W, U=60-120kV, I=10-350uA)

2. Primary slit

(3-6mm)

3. Primary collimator

(copper tube: d = 30mm, D = 36mm, L = 56cm)

4. Secondary slit

(0-2mm horizontal, 0-3mm vertical)

5. Crystal

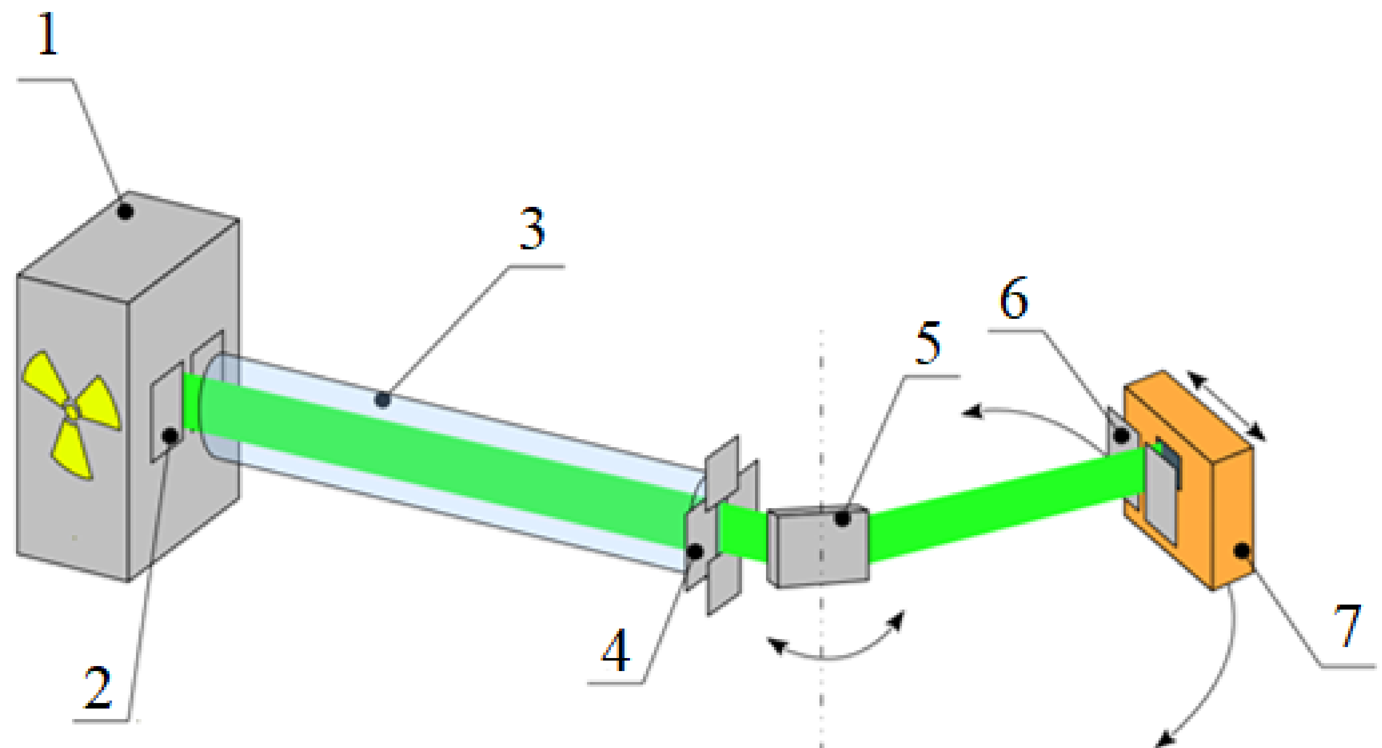
(graphite lattice)

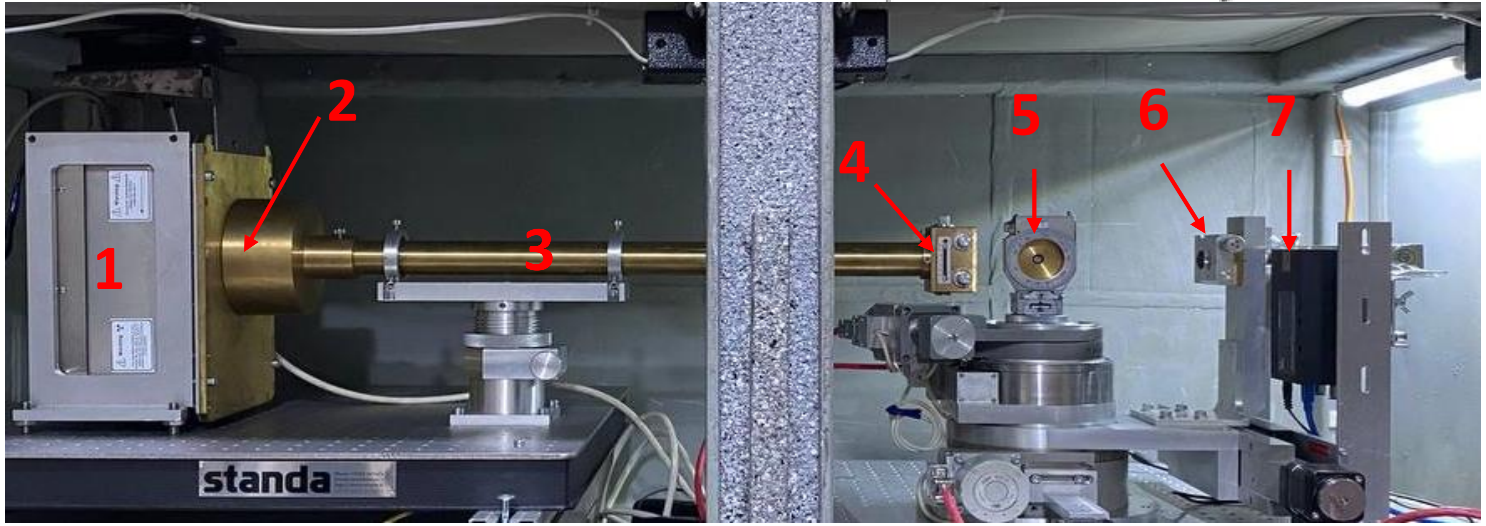
6. Secondary collimator

(0-5mm horizontal)

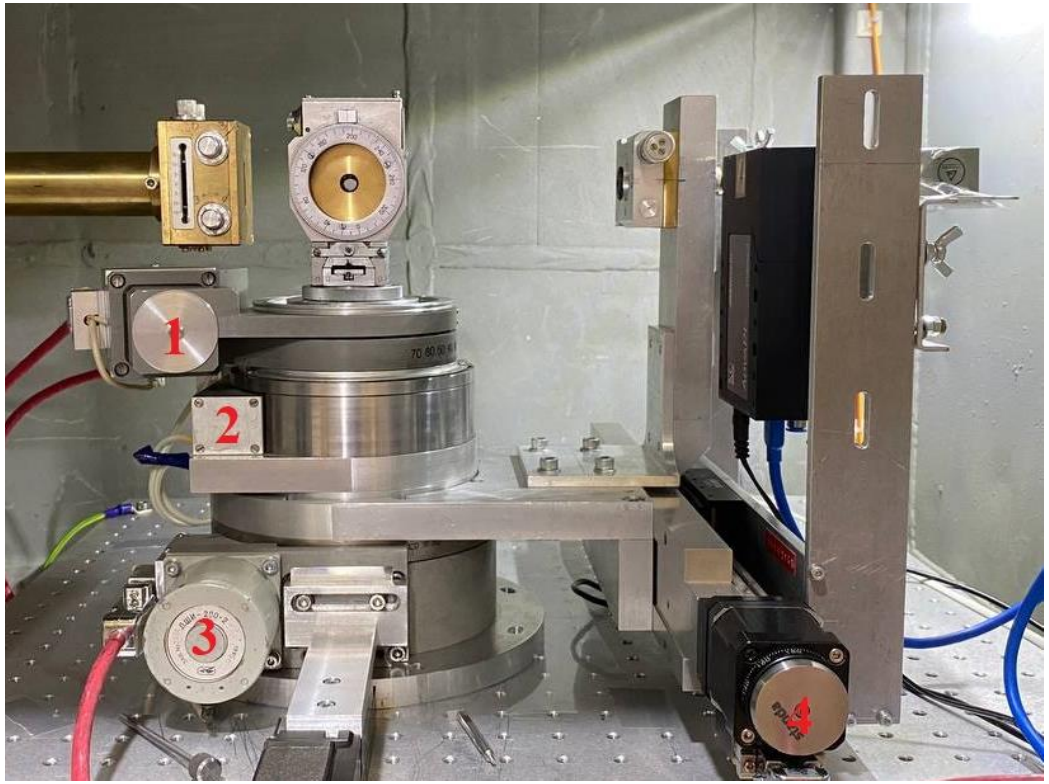
7. Detector

(any portable detectors)



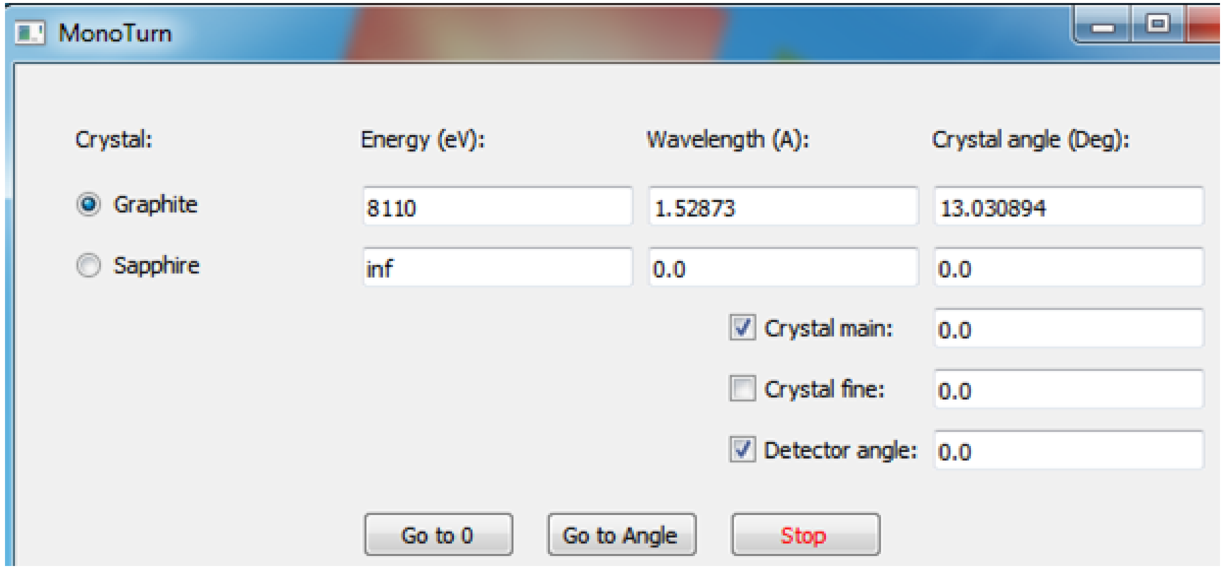


Control system



4 motors for:

1. Rotational motion of the crystal
   (1^0 = 4710 steps)
2. Precise rotational motion of the crystal
   (1^0 = 55940 steps)
3. Rotational motion of the detector
   (1^0 = 431 steps)
4. Translational motion of the detector
   (1mm = 400 steps)



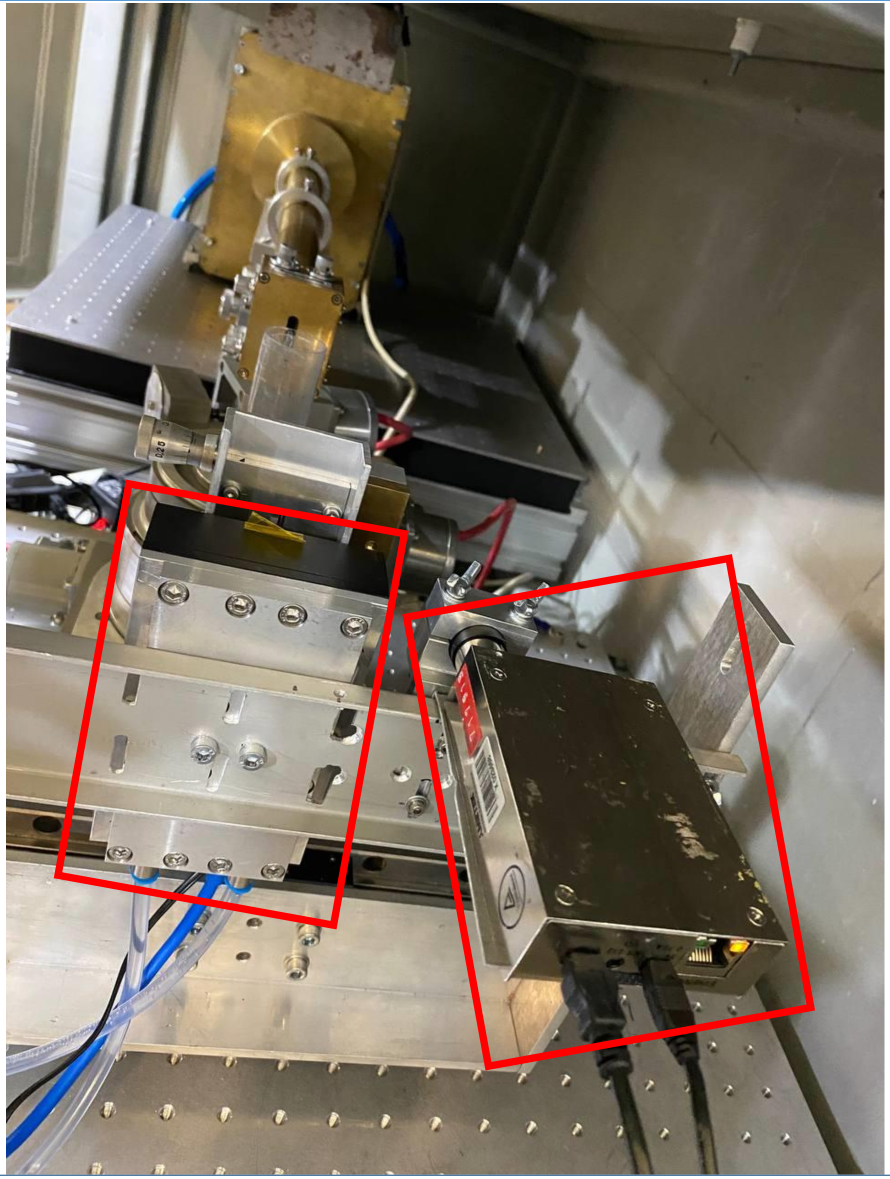
Control software:

- Input: one of 3 parameters: energy (eV), wavelength (Å) of the expected output beam, crystal rotation angle (deg).
- Runs motors to rotate crystal and detector to needed angles

Performance measurements

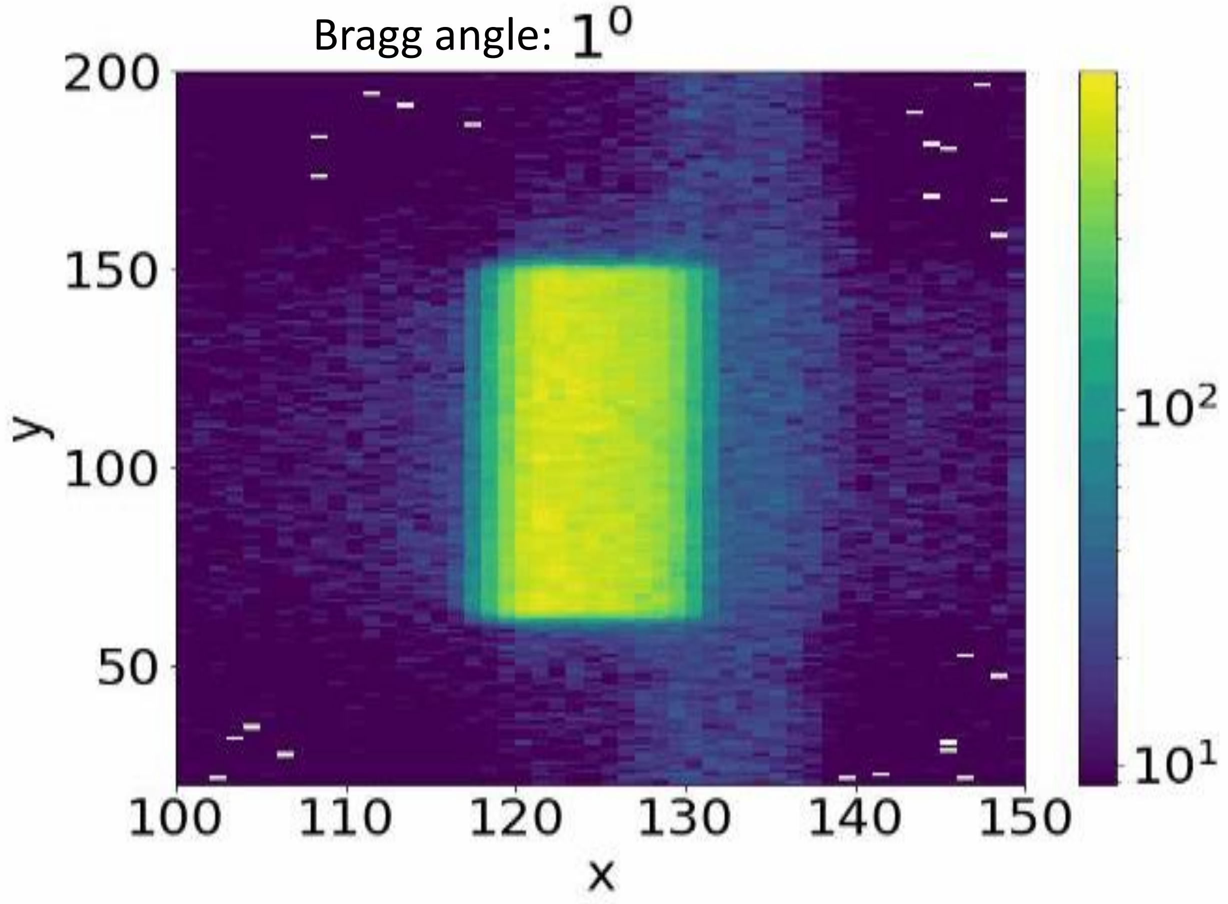
Detectors:

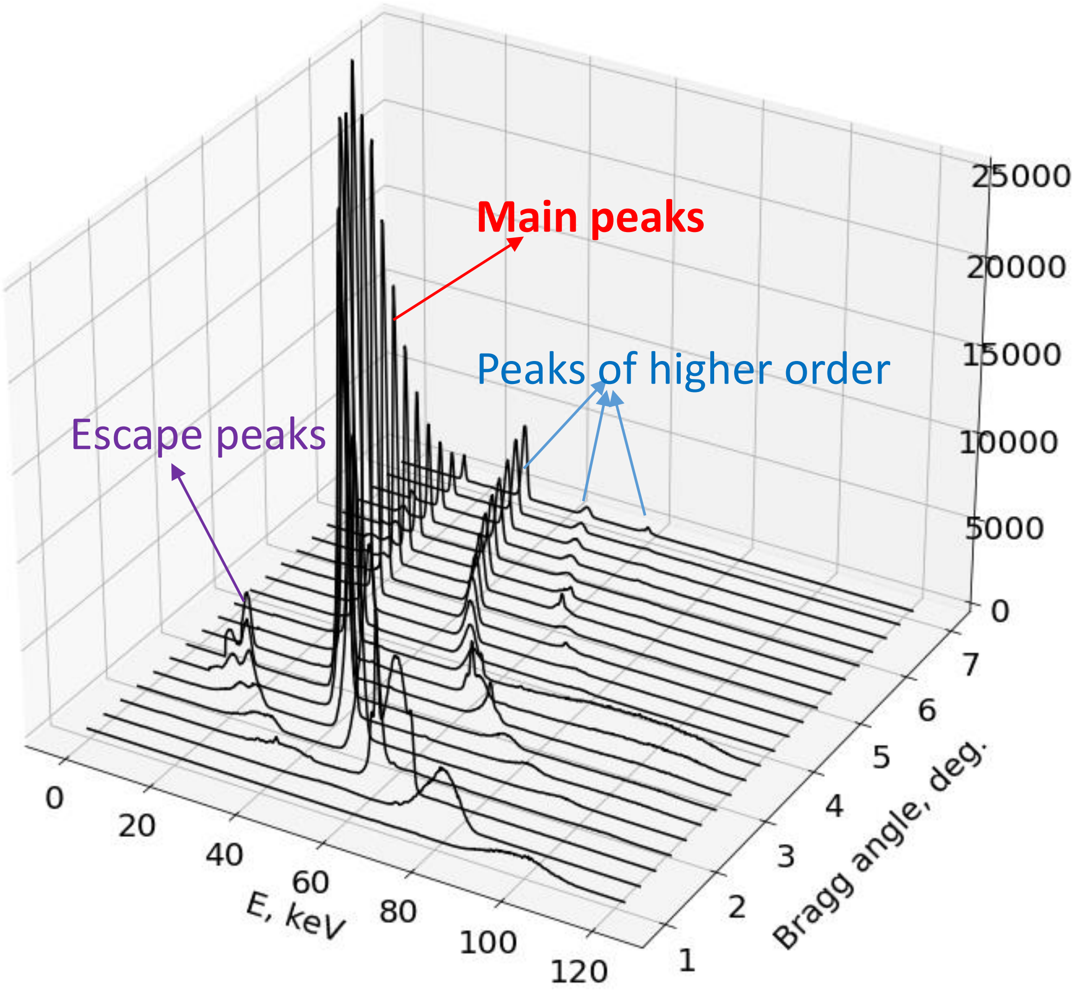
Timepix3 GaAs:Cr – beam profile



X-123CdTe Spectrometer

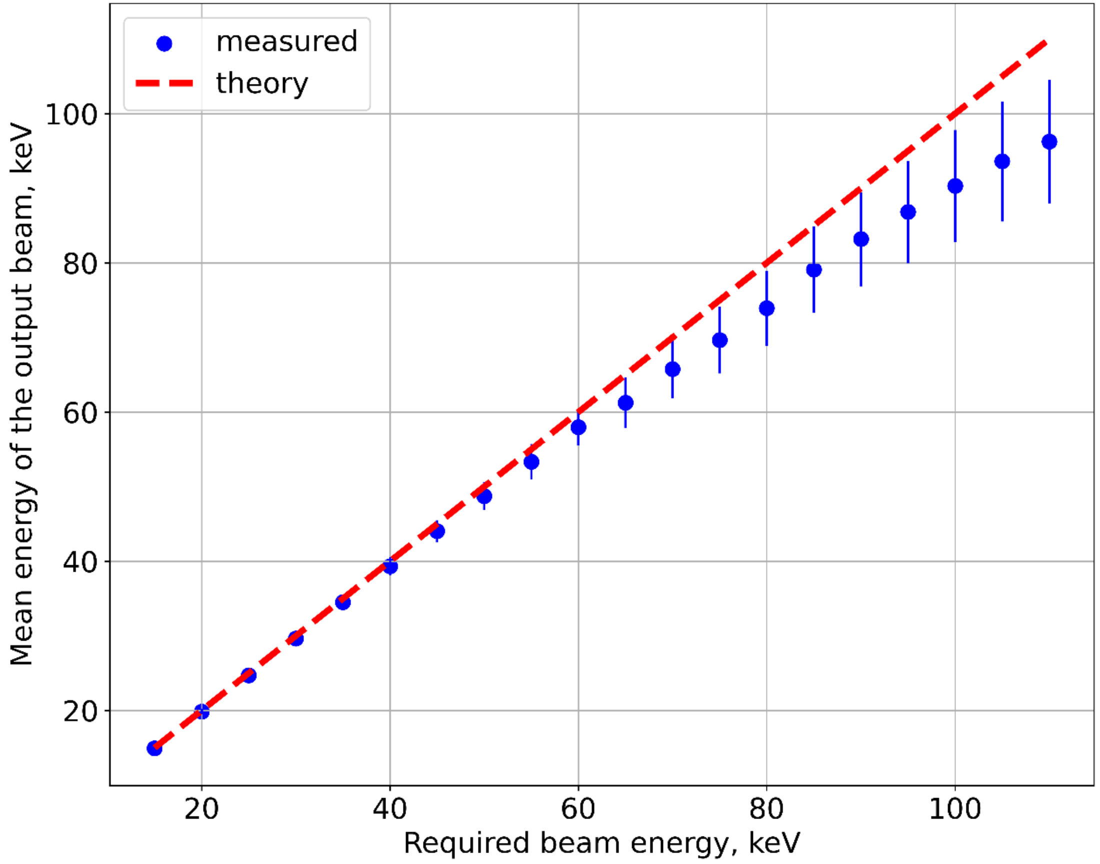
Performance measurements



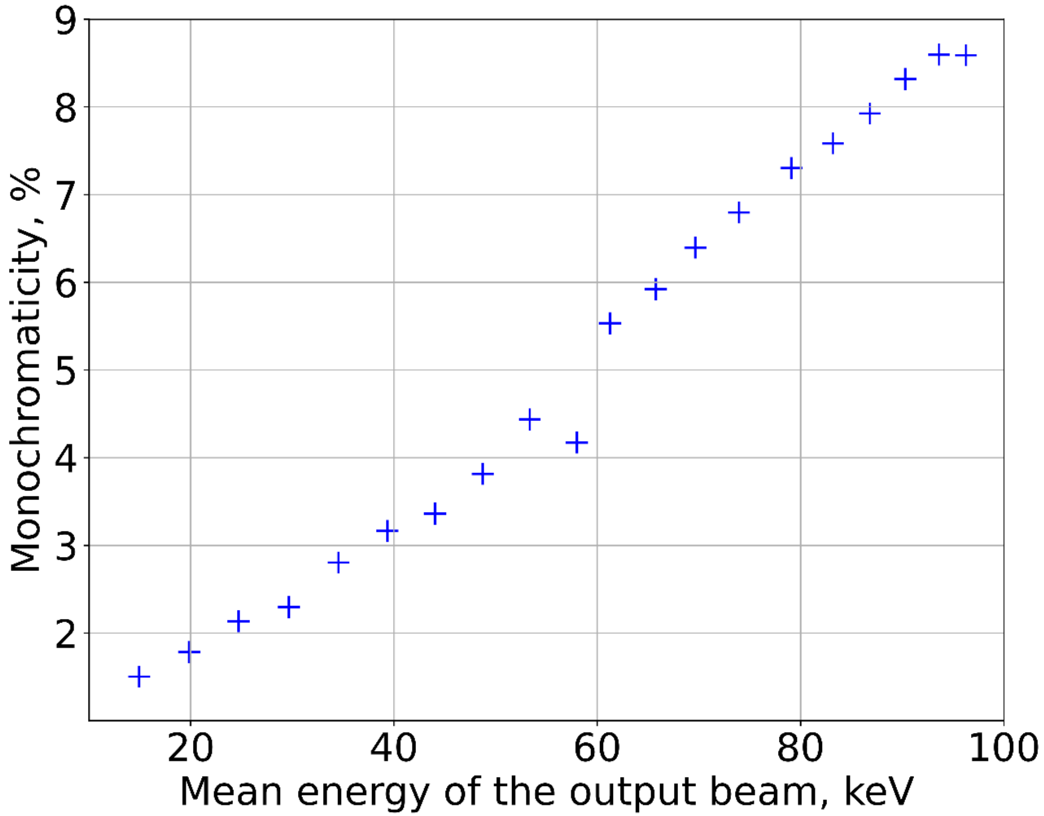


Beam profile (left) and energy spectra (right) of the output beam obtained at Bragg angles from 1 to 7 degrees
(X-ray tube voltage 120 kV, current 50 μA, exposure time 100 s)

Performance measurements

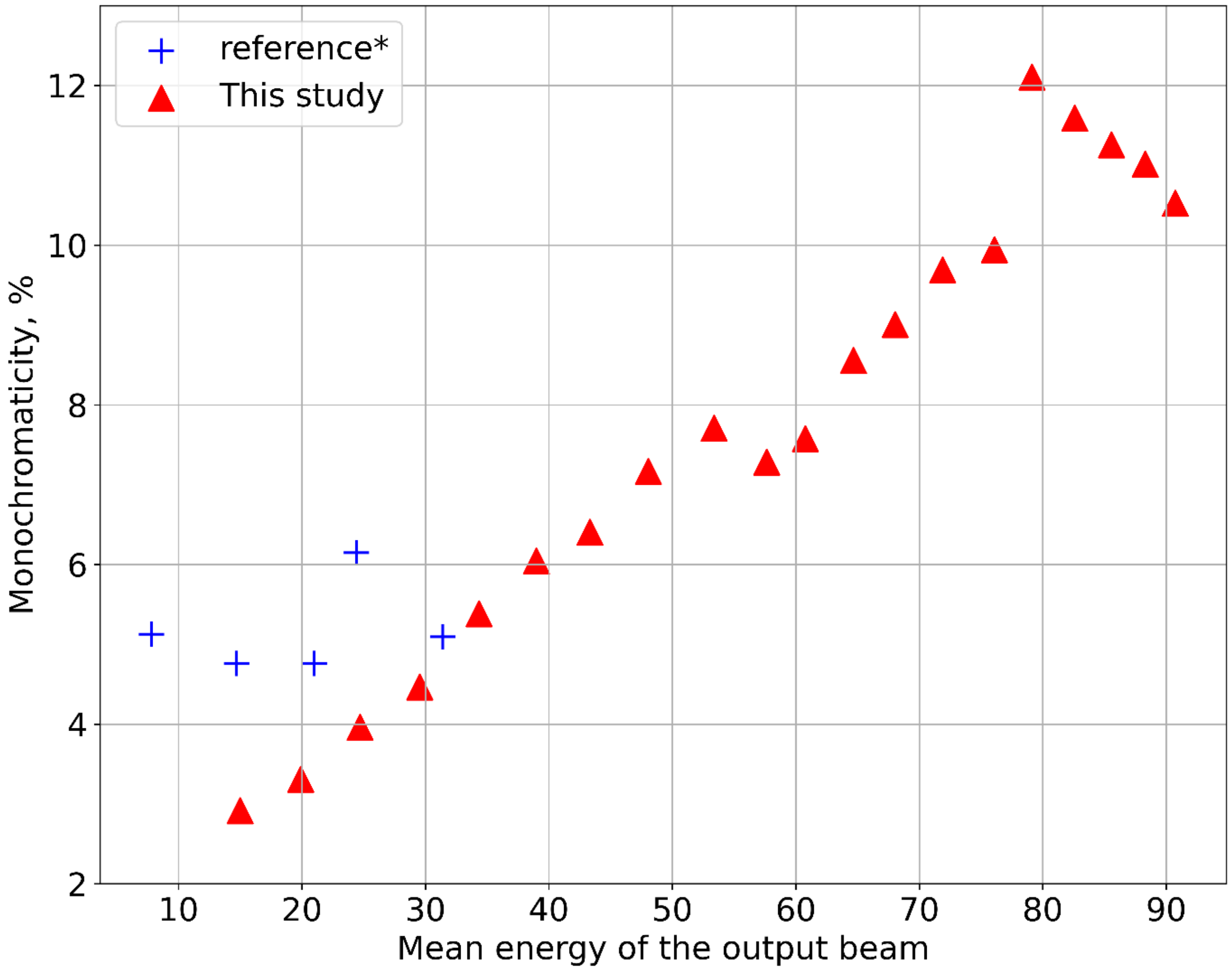


$$\frac{\Delta E}{E} = \frac{\sqrt{\sigma^2 - \sigma_{det}^2}}{E_{mean}}$$



Performance measurements

Comparison with a similar source*:



**S. Velardita et al 2025 JINST 20 T05003*

Beam profile 3x3mm^2

Conclusions

- A tunable monochromatic X-rays source was developed, covering soft to hard X-ray energies: 15–100 keV, with monochromaticity 1.5–9%.
- The resulting monochromatic beam enables precise energy calibration of pixelated semiconductor detectors.
- As an institutional X-ray platform, this facility can be used for calibration of gamma spectrometers and energy-resolved imaging - particularly valuable for materials science and biomedical studies.

Thanks for your attention!