X-Ray Polarimetry Detectors @ XCF (X-ray calibration facility)

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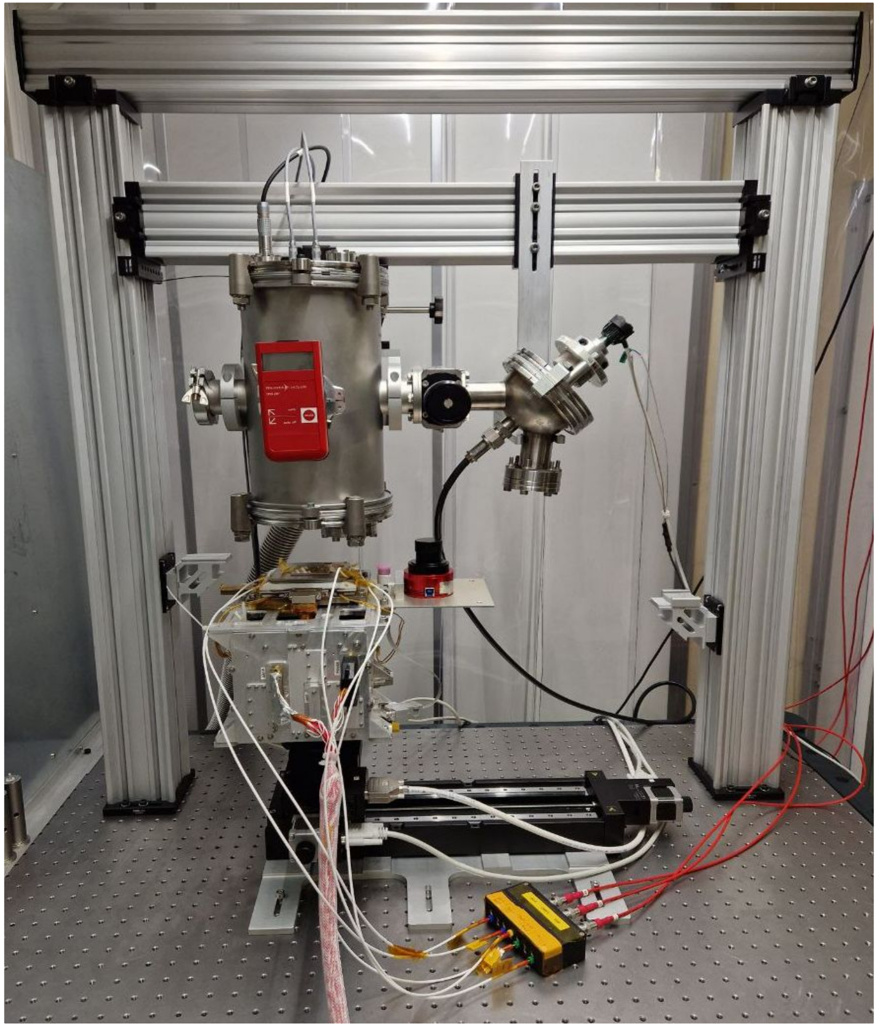
XCF: X-ray Calibration Facility @Torino

Irradiation setup in Torino, to test, characterize and qualify

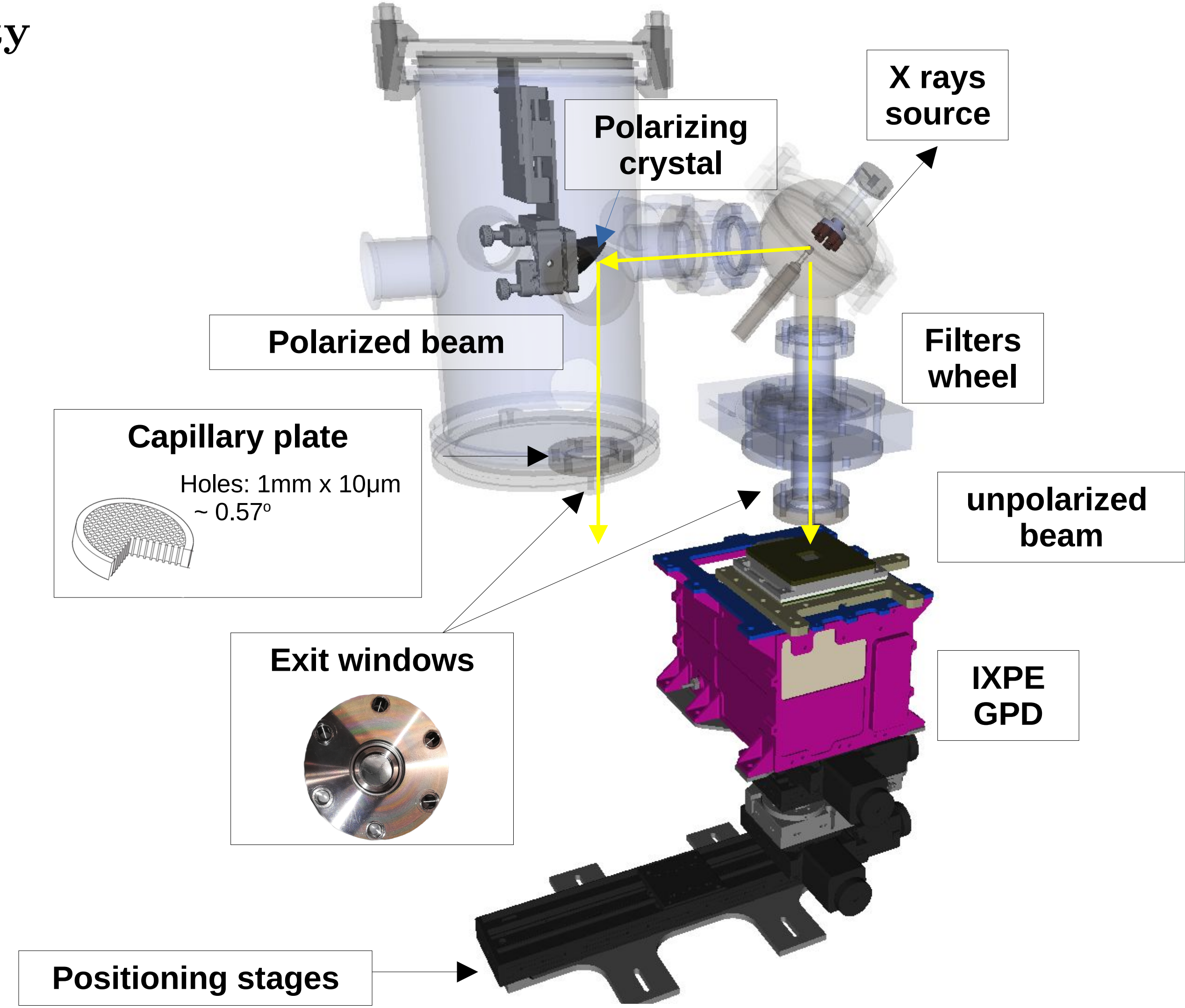
- Gas Pixel Detectors
- Position- energy- and **polarization**-sensitive X-ray detectors.



XCF: X-ray Calibration Facility

Main Characteristics:

- Multi-anode Xray source
- two output beams, one polarized
- Crystal positioning:
  - height
  - θ, φ axes
- Detector positioning:
  - Two couples x-y stages
  - One rotary stage
- Source and polarizer cylinder in vacuum (~10^{-6} hPa)



X-ray source: McPherson 462

Specifications

6 interchangeable solid anodes

Flux in bright lines: ~10^{11} photons s^{-1} sr^{-1}

Emission uniformity: Dual beam output, balanced

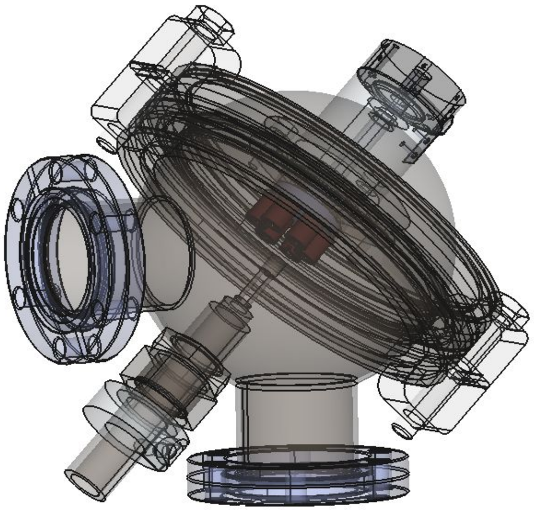
Power: 30W, 10 kV max, 3mA

Operating pressure: 10^{-6} torr range or lower

Selected anodes:

Anode	Mo	Rh	Pd	Ti	Fe	Ni
Line	Lα	Lα	Lα	Kα	Kα	Kα
E [KeV]	2.293	2.697	2.839	4.511	6.404	7.478

We control manually both voltage and anode current



Beam monitors

- Amptec fast SDD

25 mm² active area

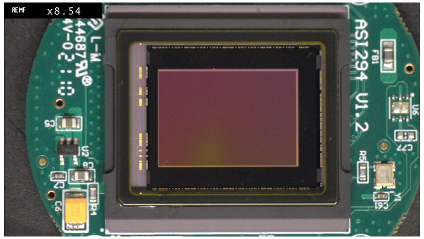
Resolution of 122 eV FWHM at 5.9 keV   ~2%

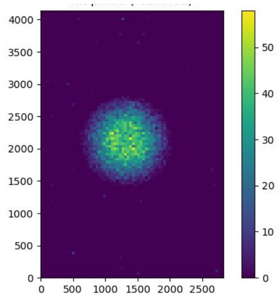
Count rates > 1,000,000 CPS

Windows: Be 12.5 µm

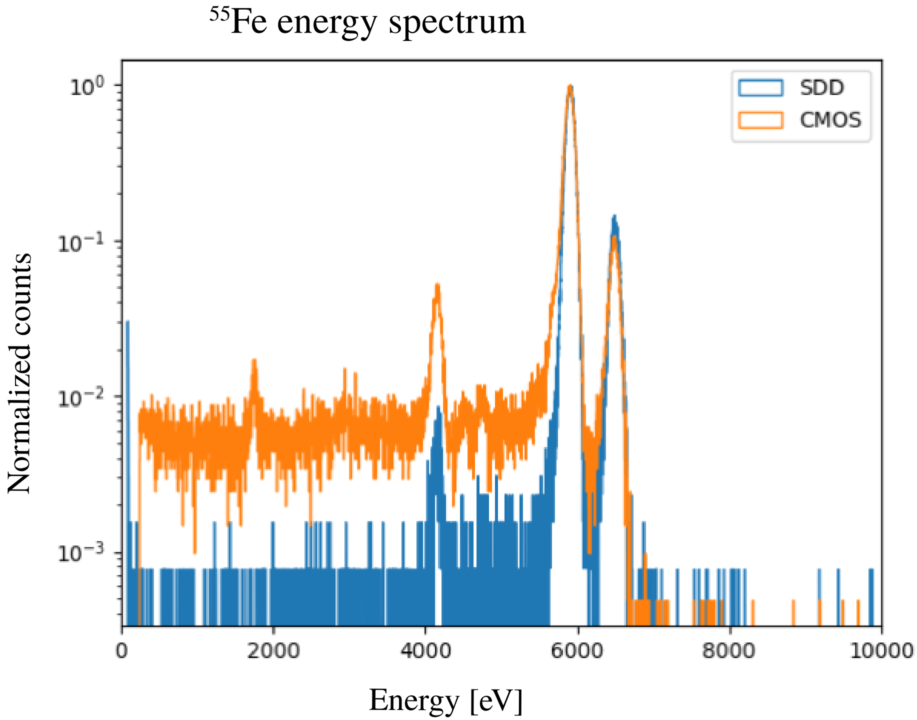
- Modified* optical sensor (sony IMX294)

*glass cover removed



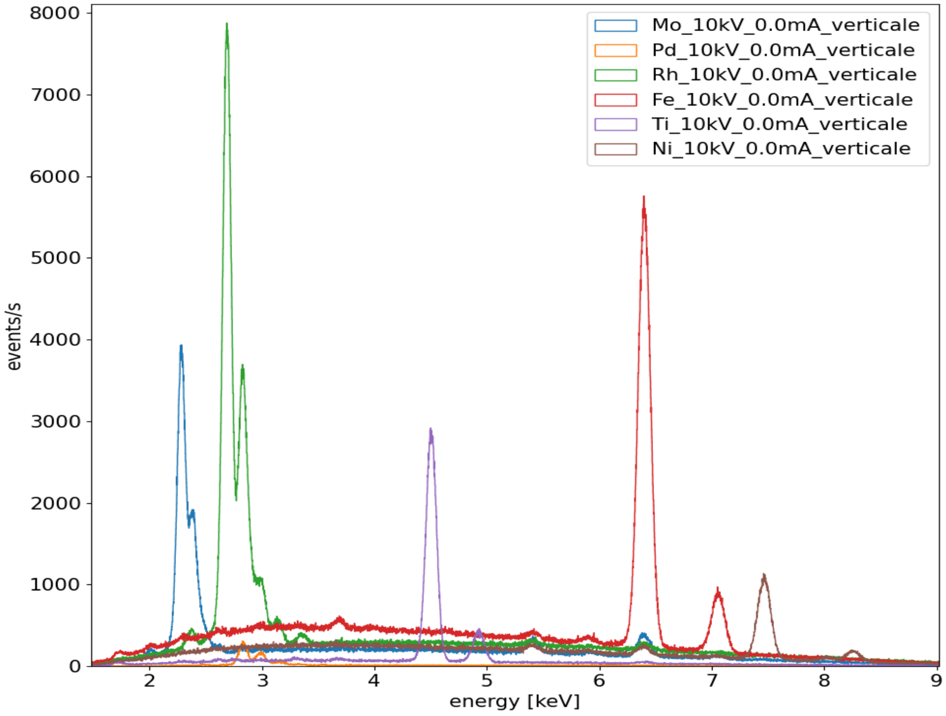


4144x2822 pixels (4.63 um)
Energy resolution (FWHM) ~2.2% @6keV
Efficiency ~10% @6keV w.r.t SDD



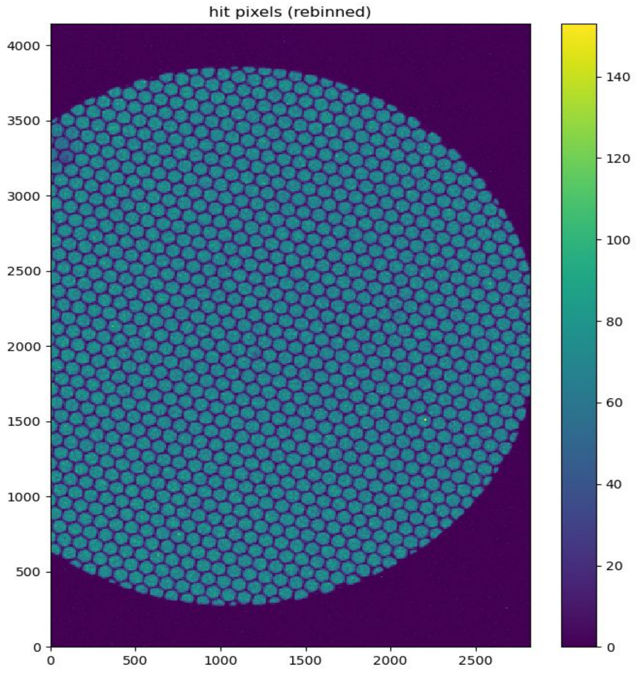
X-ray source: measured output

Energy:



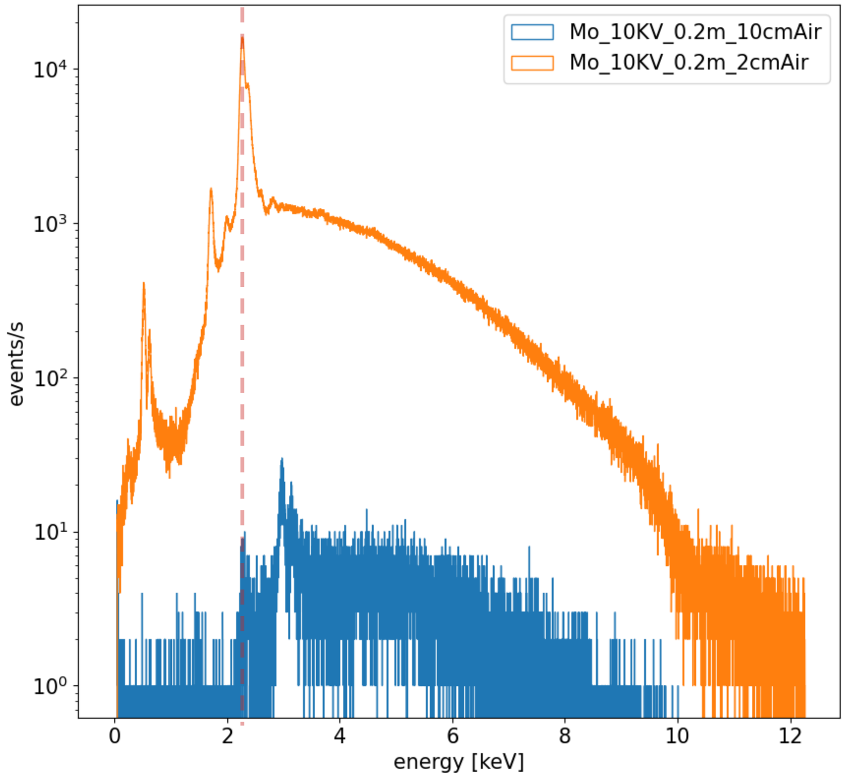
Measured with Ampek fast SDD

Spatial uniformity

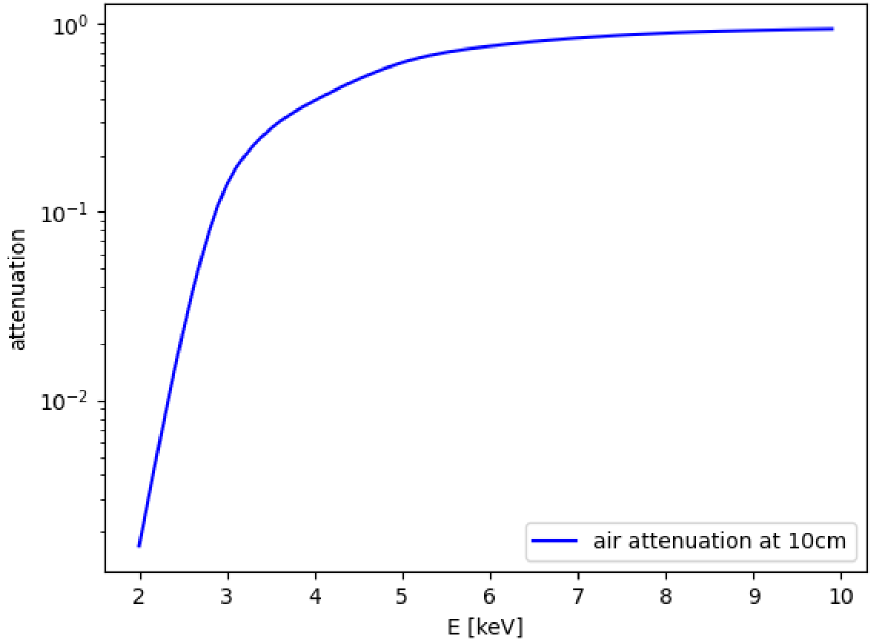


Measured with sony cmos

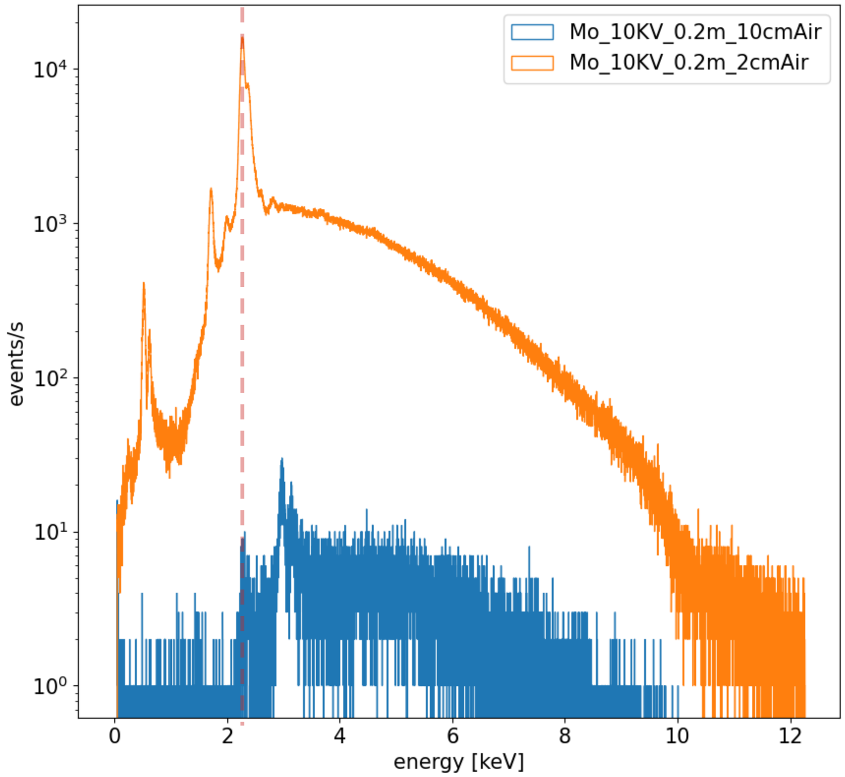
Air attenuation:



At low energy air attenuation is important!



Air attenuation:



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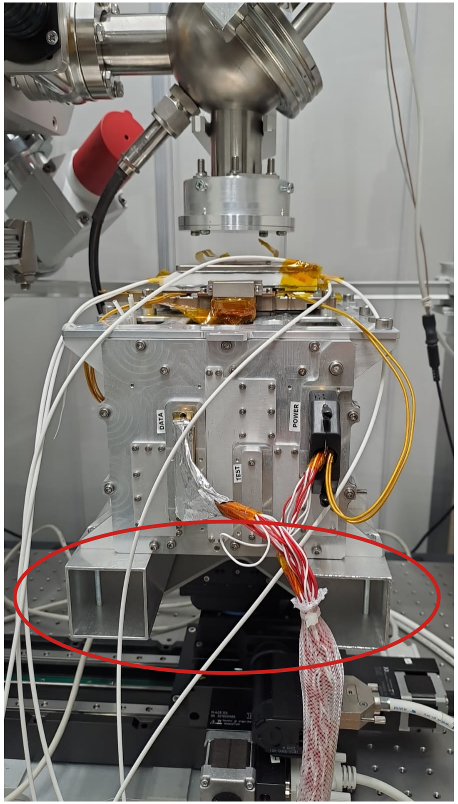
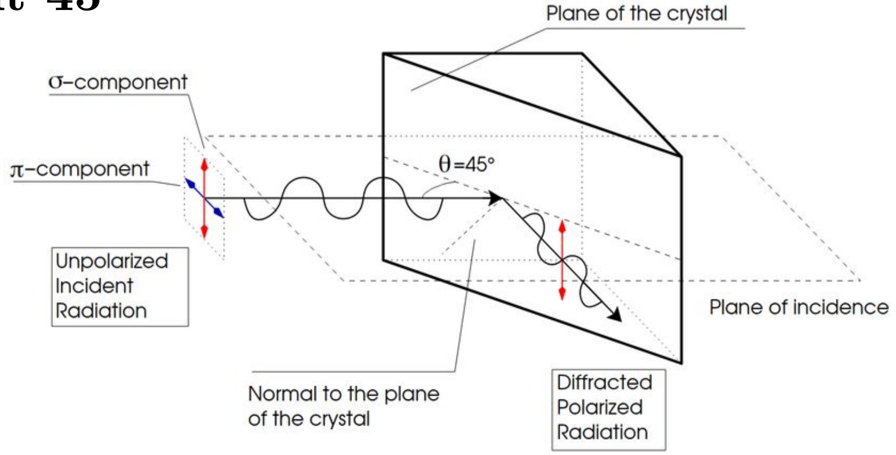


We need to keep the detctor as close as possible to the exit window

Polarization by Bragg diffraction at 45°

Bragg condition

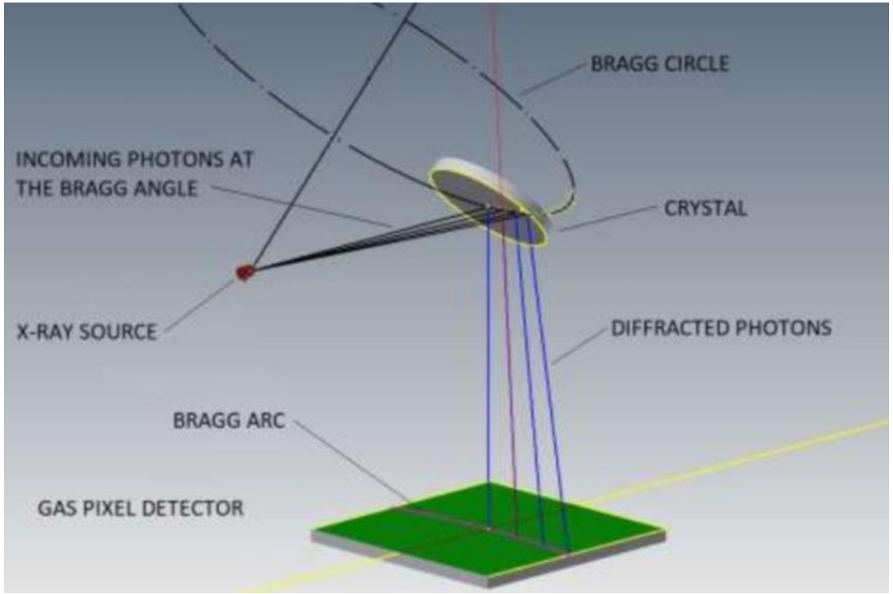
$$\sin(\theta_{Bragg}) = \frac{n h c}{2 d E}$$



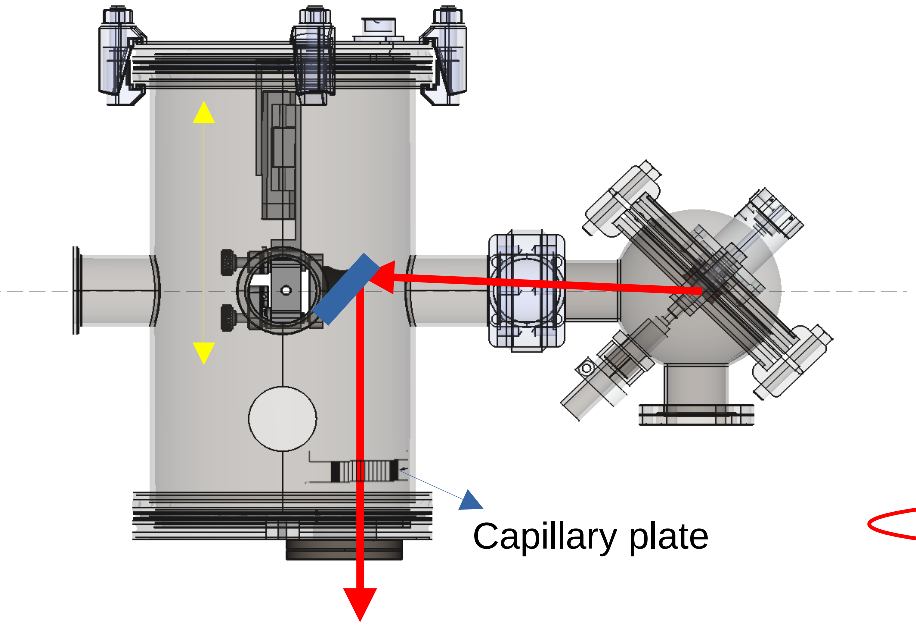
Polarization degree:

$$\mathcal{P} = \frac{1-k}{1+k}$$

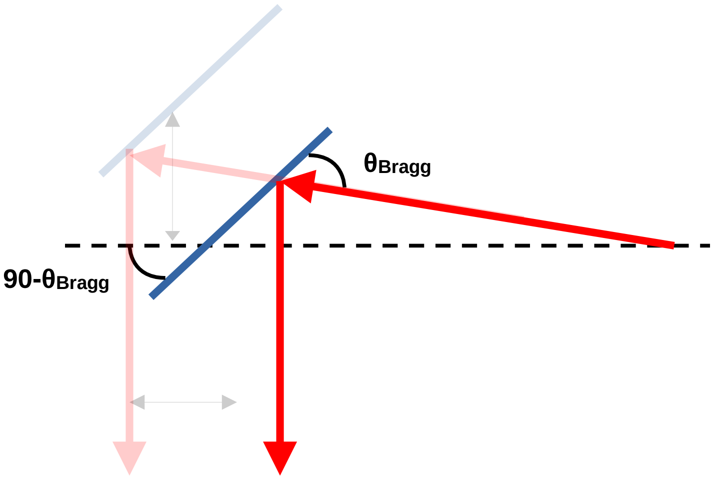
With: $k = \frac{R^{\pi}}{R^{\sigma}} \approx 0$ for $\theta_{Bragg} \approx 45^{o}$



Polarized beam

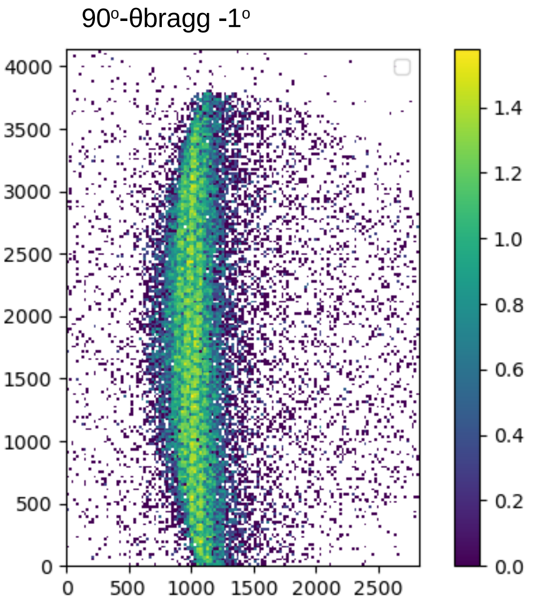


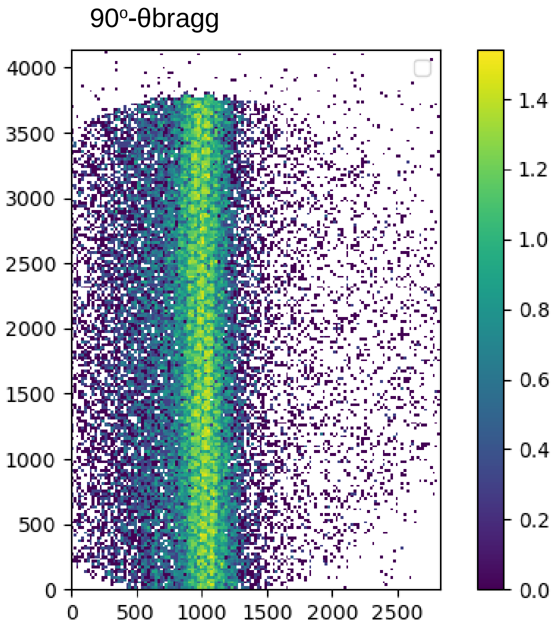
selecting vertical output with capillary plate, the geometry is fixed

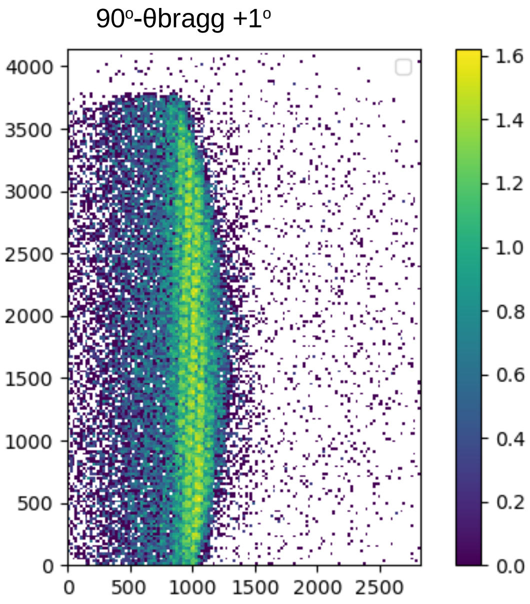


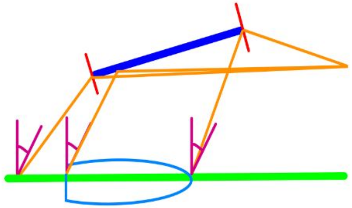
Anode line	E [KeV]	Xtal	2d (A)	θ_{Bragg}	P
Mo Lα	2.2932	InSb111	7.481	46.28	99.32%
Rh Lα	2.697	Ge111	6.532	44.87	99.28%
Pd Lα	2.839	Si111	6.271	44.12	>95.08%
Ti Kα	4.511	Si 220	3.840	45.71	99.51%
Fe Kα	6.404	Si 400	2.7142	45.5	99.7% ??
Ni kα	7.478	Ge 422	2.31	45.86	99.04%

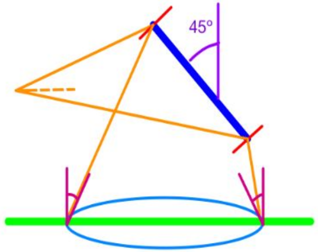
InSb111 xtal positionig: angle

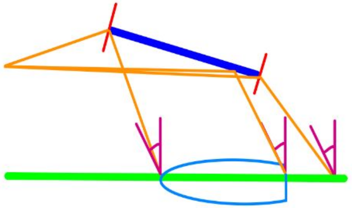






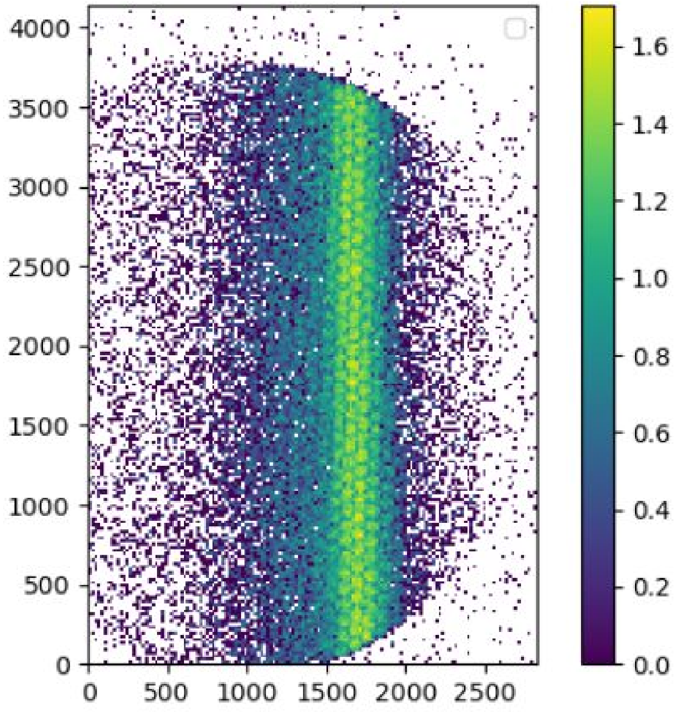




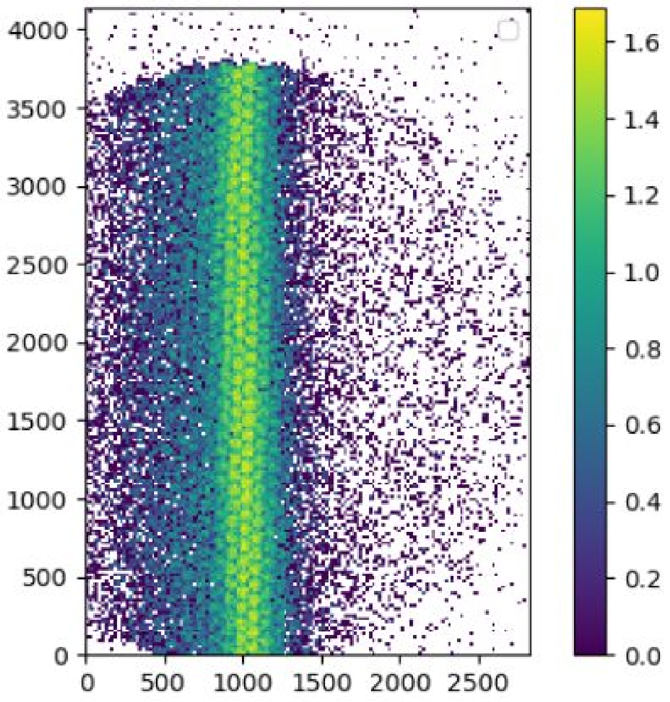


InSb111 xtal positionig: height

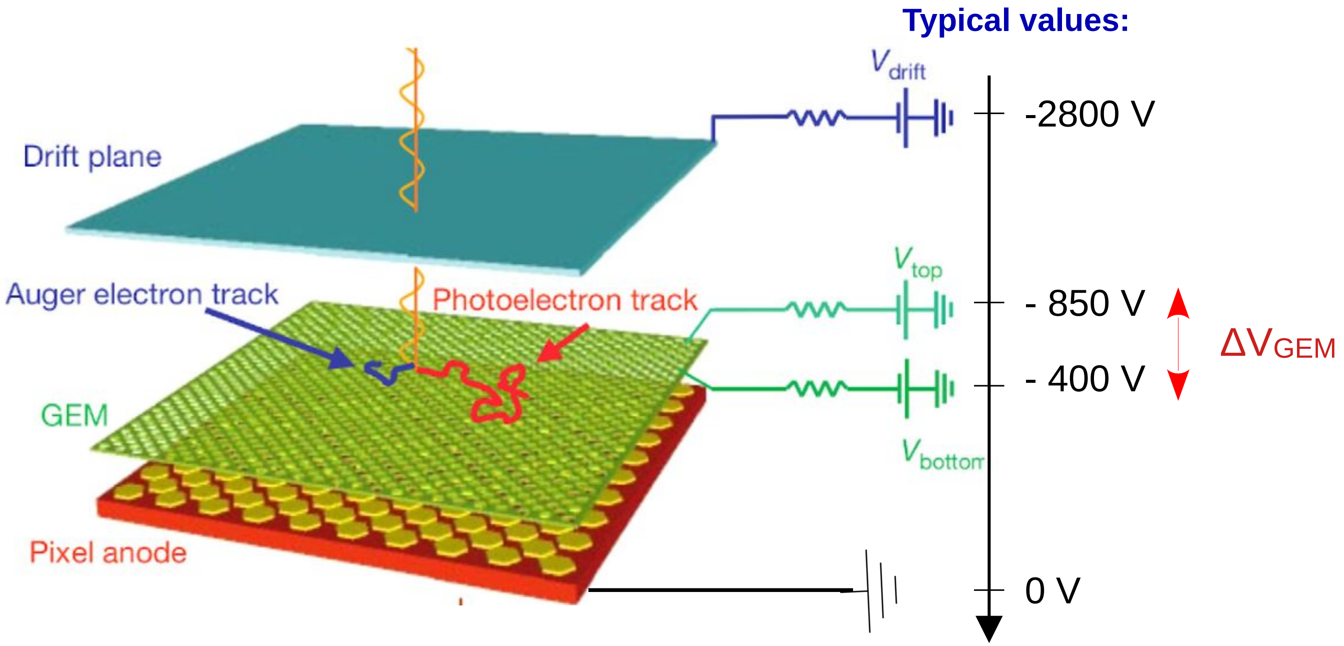
Xtal vertical = 17mm



Xtal vertical = 20mm

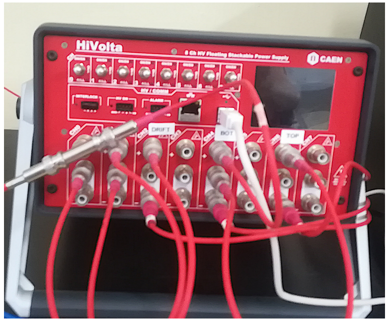


GPD: High voltages



Gem gain scales as:

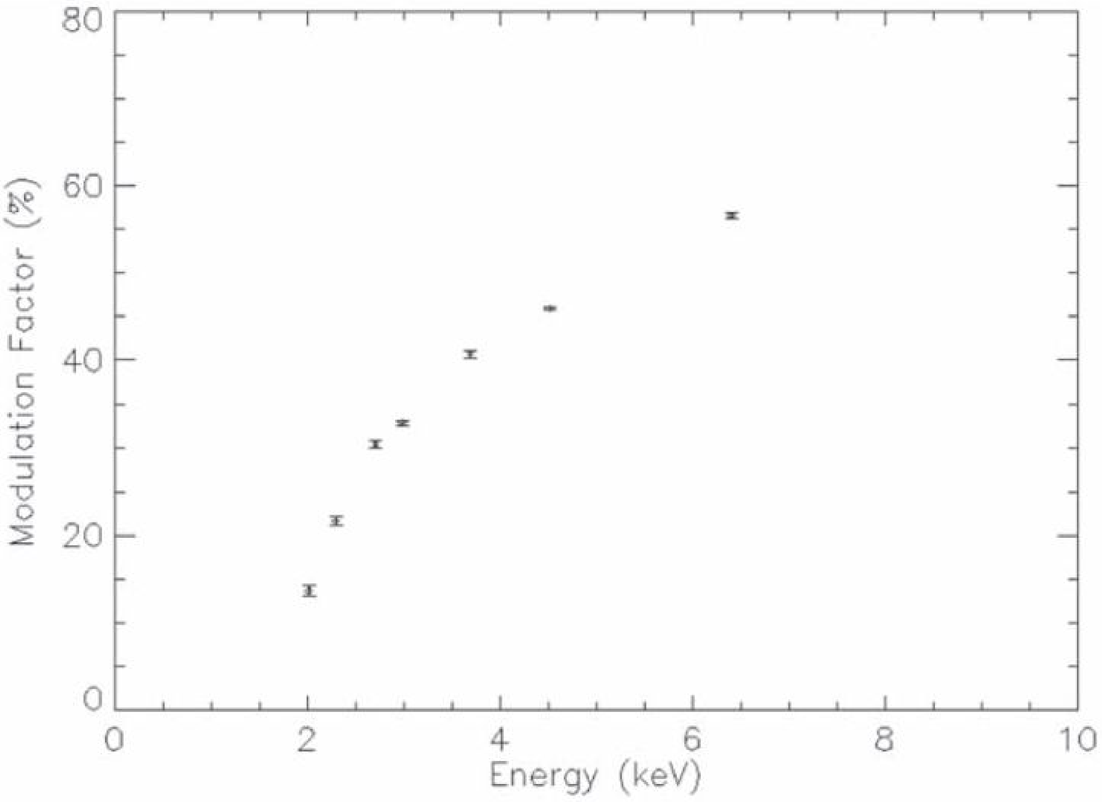
$$G(V) = G_0 e^{\gamma V}.$$

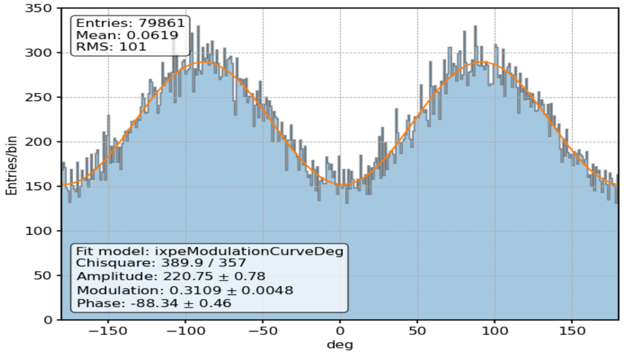


In the lab we control the GPD HV levels with an external module.

We set Vdrif , Vbottom, and ΔVgem

GPD Modulation factor

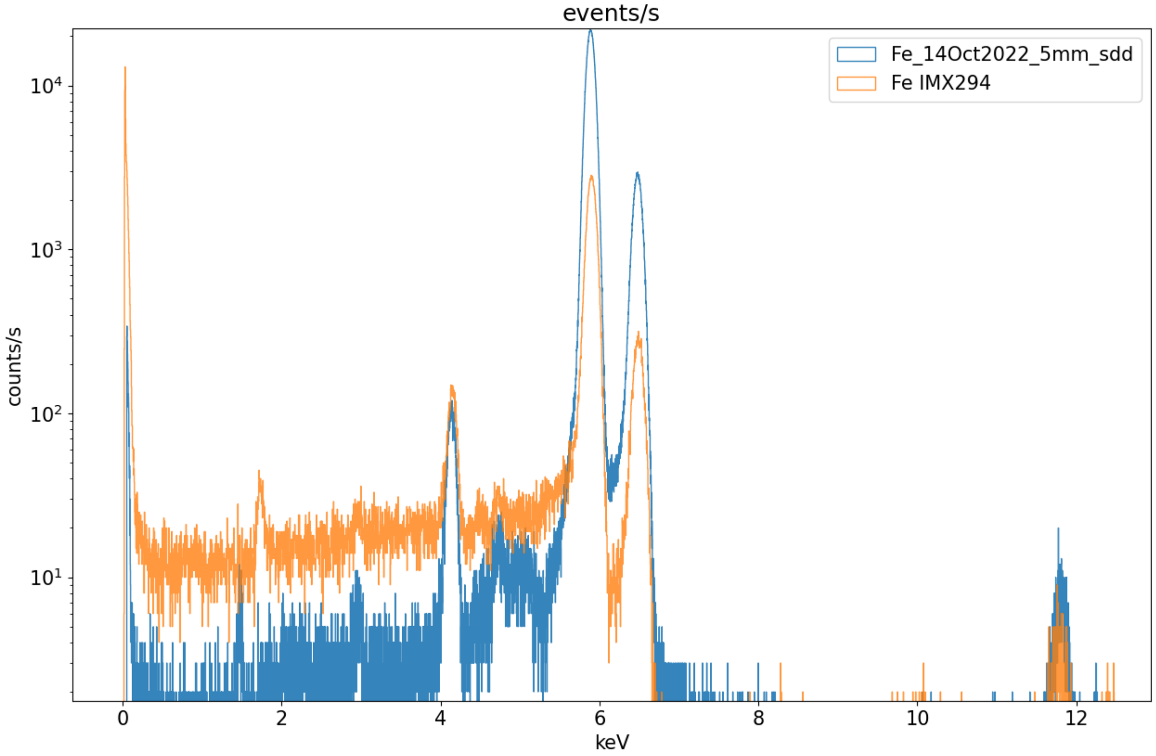




$$\mathcal{M}(\phi) = A + B\cos^2(\phi - \phi_0),$$

$$M = \frac{\mathcal{M}_{max} - \mathcal{M}_{min}}{\mathcal{M}_{max} + \mathcal{M}_{min}} = \frac{B}{2A + B}.$$

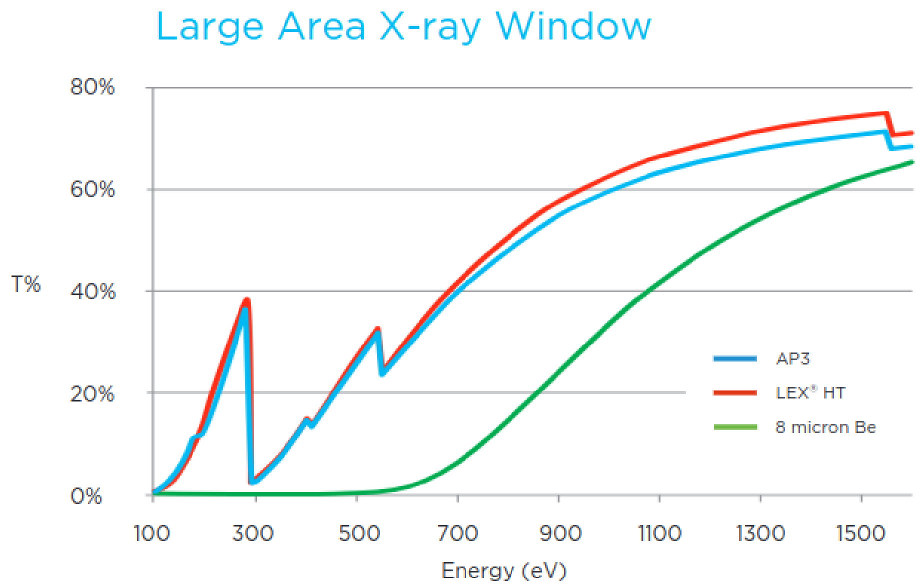
Comparison cmos SDD: rate



Efficiency with respect to SDD:

Kalpa =2830/22070~ 12%   Kbeta → 315/2929~~10%

Luxel window

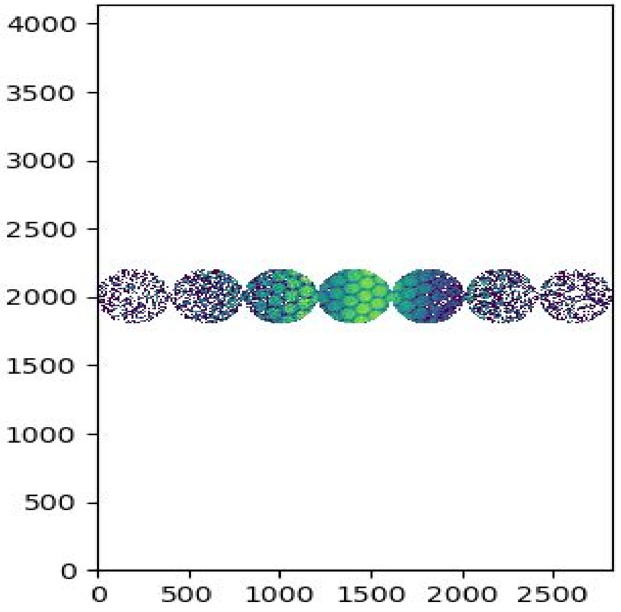


Specifications

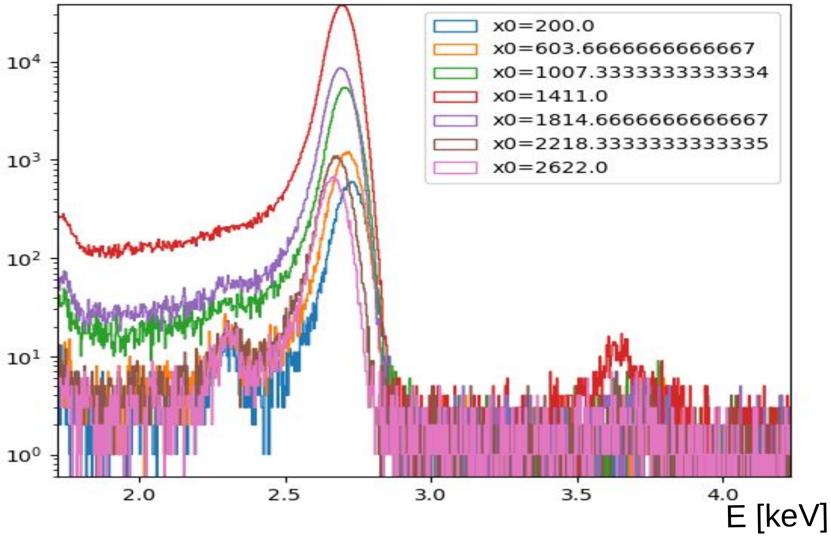
Mesh Open Area	80%
Rib Thickness	100 μm
Rib Width	30 μm
Maximum Temperature	100°C
He Leak Rate	<1E-9 mbar-L/sec
Front SidePressure Limit	1 atm
MaximumAperture	25mm

d=16mm

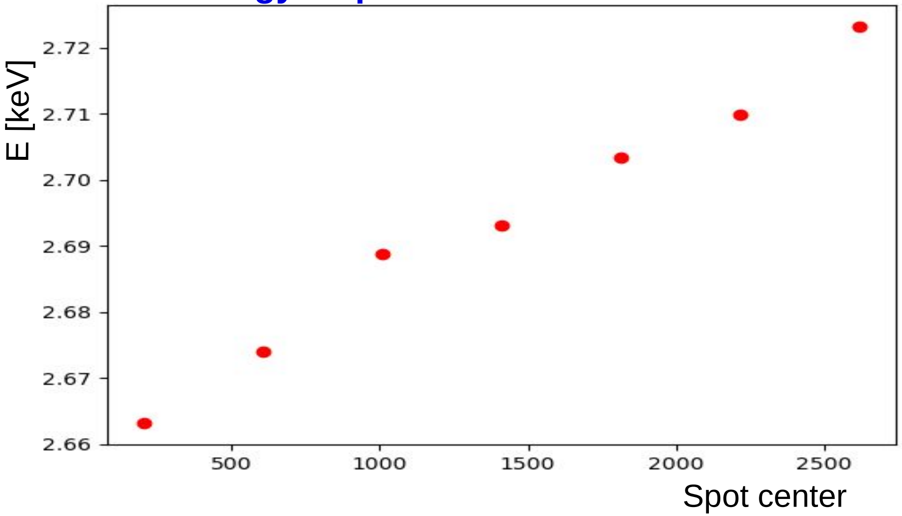
Rh-Ge111: energy-position



As expected different energies are diffracted at different angles



Peak energy vs position



Polarized beam measurements: Rh - Ge111