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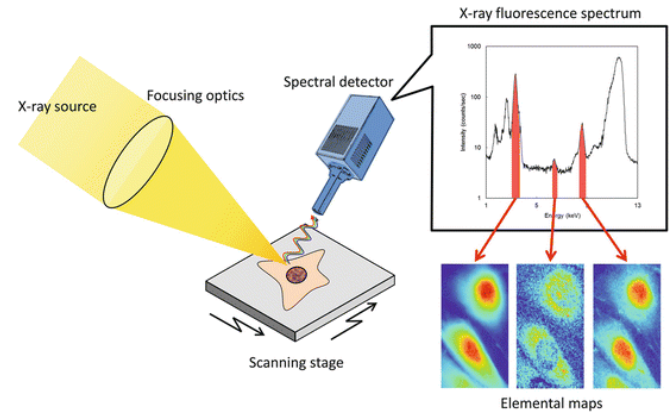


Capillary Collimated XRF-imaging with Timepix 3

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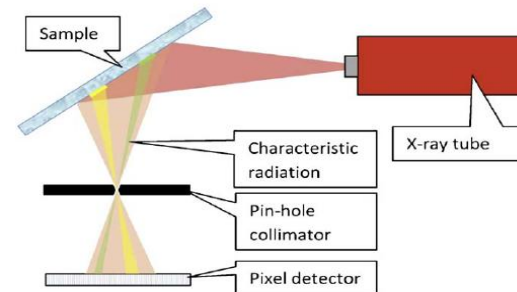
X-ray fluorescence image

Single pad detector } X-ray fluorescence scan



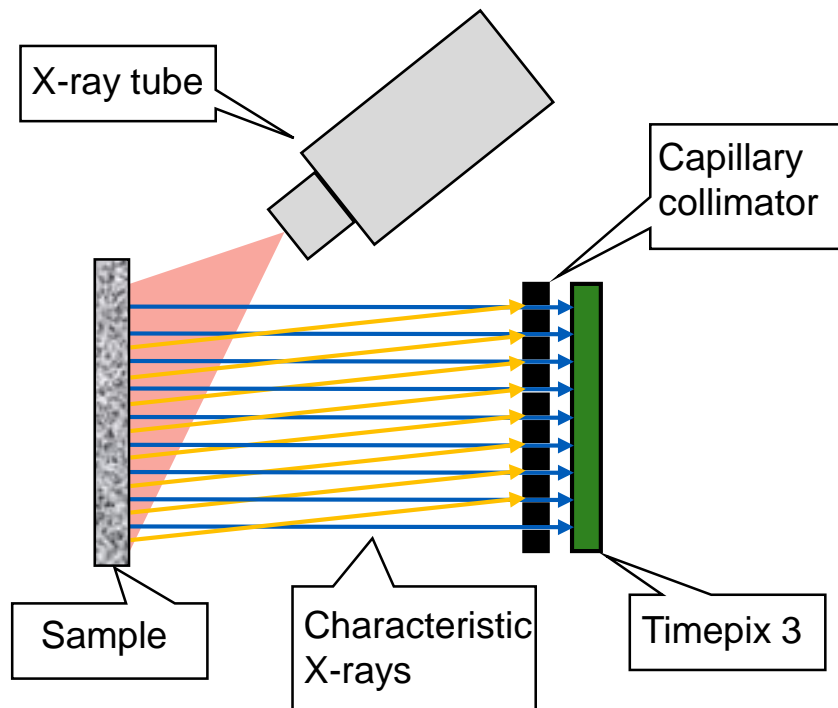
Reference: Shimura M., Szyrwiel L., Matsuyama S., Yamauchi K. (2017) Visualization of Intracellular Elements Using Scanning X-Ray Fluorescence Microscopy.

Pixel detector } Pinhole Camera
Capillary collimator



Reference: Žemlička, J., Jakůbek, J., Kroupa, M., & Tichý, V. (2009). Energy- and position-sensitive pixel detector Timepix for X-ray fluorescence imaging.

Measurement setup

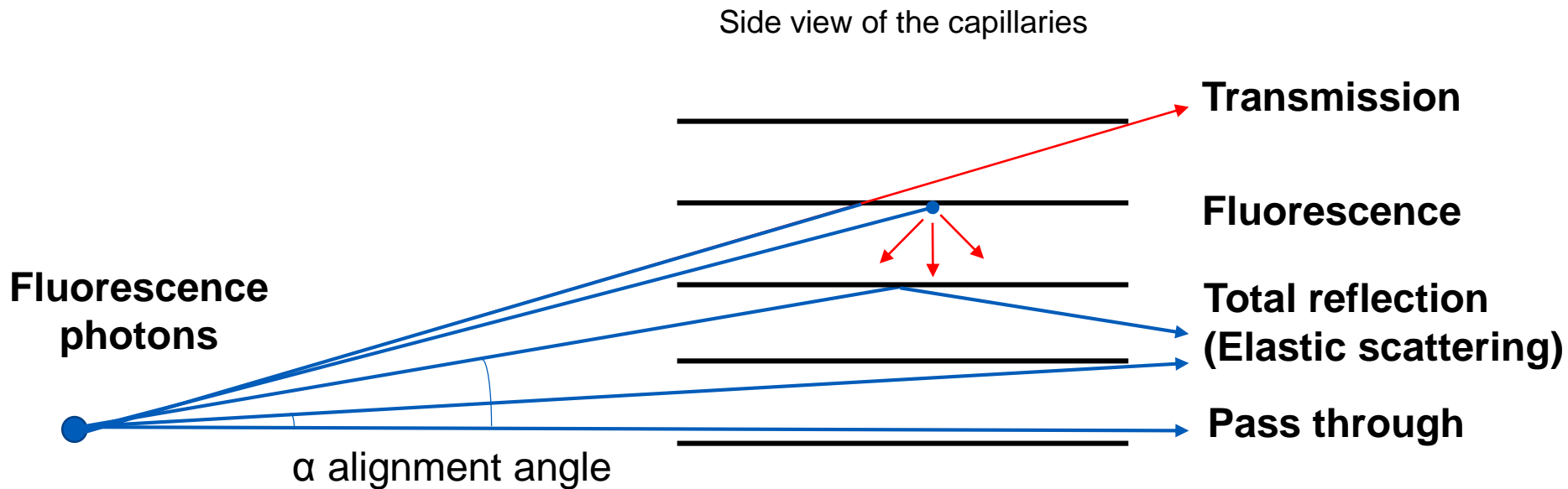


Capillary collimated setup for X-ray fluorescence imaging

- Timepix3 mounted on CERN PCB
- 300 μm p-on-n Silicon sensor
- Compact SPIDR Readout
- Cu X-ray pipe + X-ray tube (MOXTEK)
- PHOTONIS capillary collimator (lead glass, 1 mm thickness, 10 μm pore size)



Polycapillary X-ray optical effects

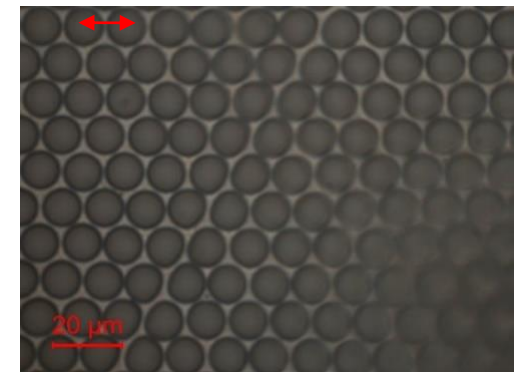
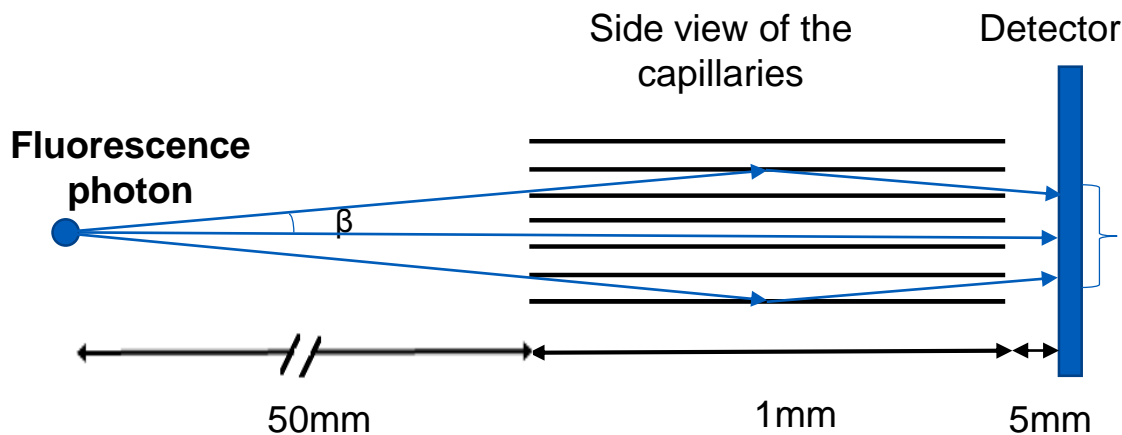


Aligned pass through for $\alpha = 0.011^\circ$

Total internal reflection spread

- Critical angle β is 0.25° for Gold L-line (9.7 keV)
- Ideal point
- The resolution is $480 \mu\text{m}$ (~ 9 pixels)

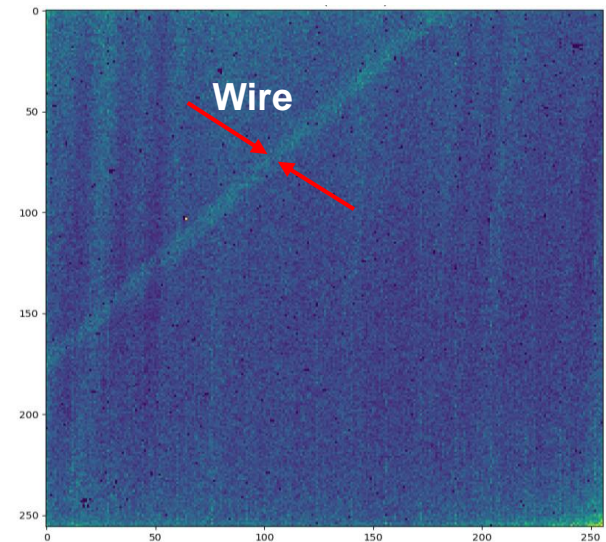
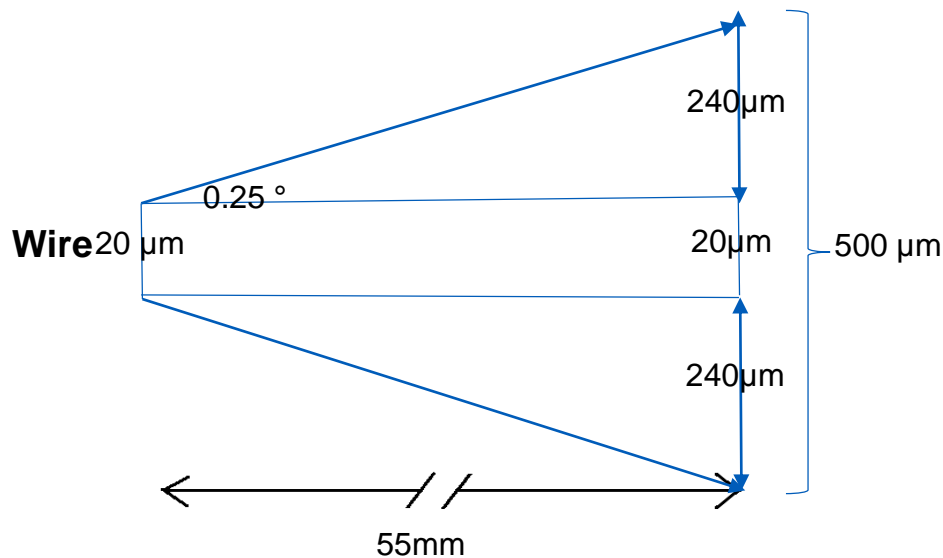
$$Res. \approx 55\text{mm} * \tan \beta * 2, \quad \beta_{deg.} \approx \frac{1.17\sqrt{\rho(g/cm^3)}}{E(keV)}$$



Microscopy image of capillary collimator at 100x, Pitch $12\mu\text{m}$

Images of gold wire

- Wire diameter $20\ \mu\text{m}$
- Calculated resolved wire size due to total reflection is $500\ \mu\text{m}$
- Real size on image is $466 - 544\ \mu\text{m}$ (6 - 7 diagonal pixels)



Edge spread function and line spread function

- Edge spread function: what the line scan looks like-gradual transition
- Line spread function: how the sharp edge of the original image is spread out

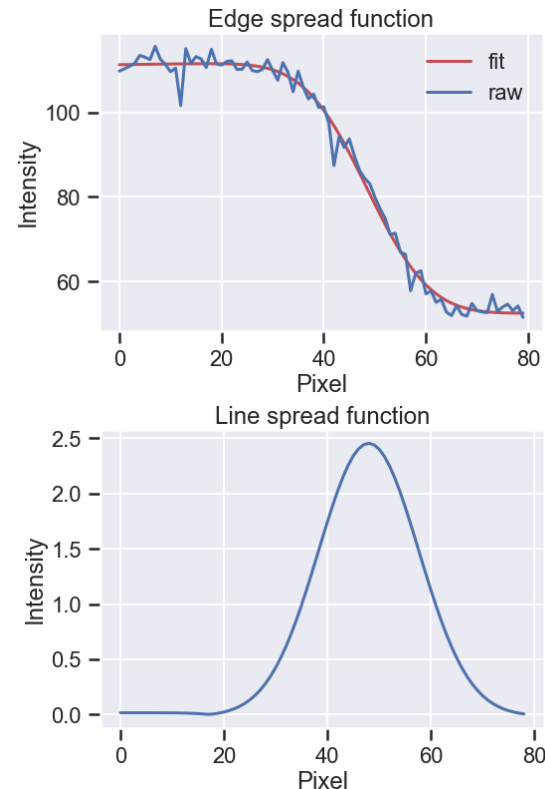
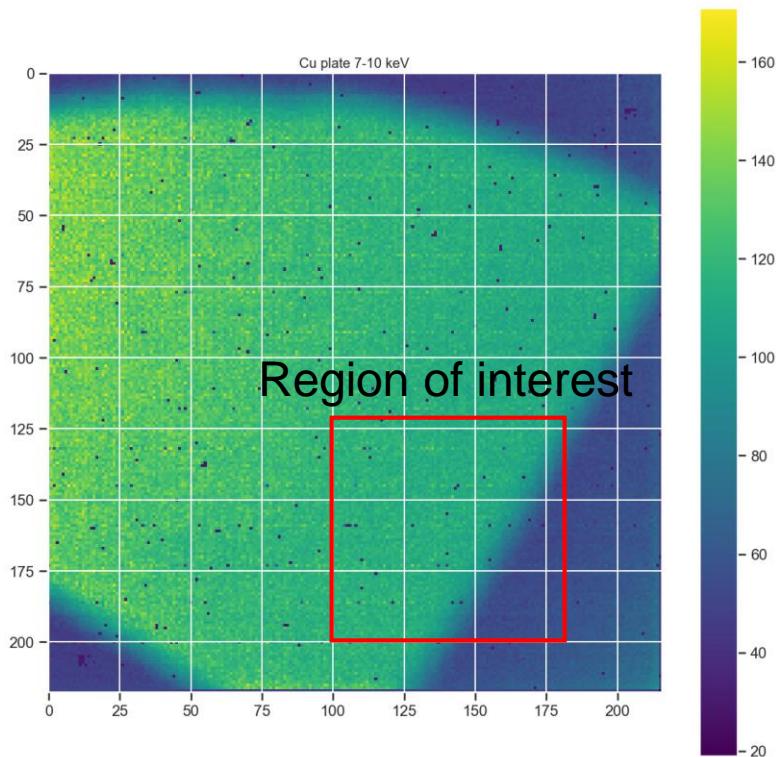


Image of Euro coin

- Blur “gold” ring in wide energy range image;
- Uneven surface gives a shadow in the image;
- Clear “gold” ring in excluded Ni image;



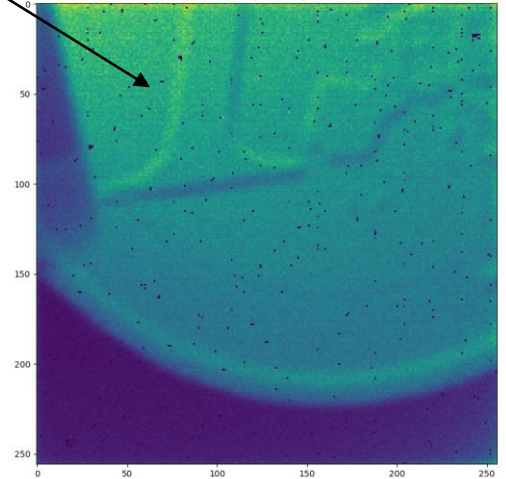
75% copper (Cu)
20% zinc (Zn)
5% nickel (Ni)

75% copper (Cu)
25% nickel (Ni)

Element	K α	K β
Ni	7.48 keV	8.27 keV
Cu	8.04 keV	8.9 keV
Zn	8.64 keV	9.57 keV

Table: X-ray emission line

X-ray



8.5 - 12 keV

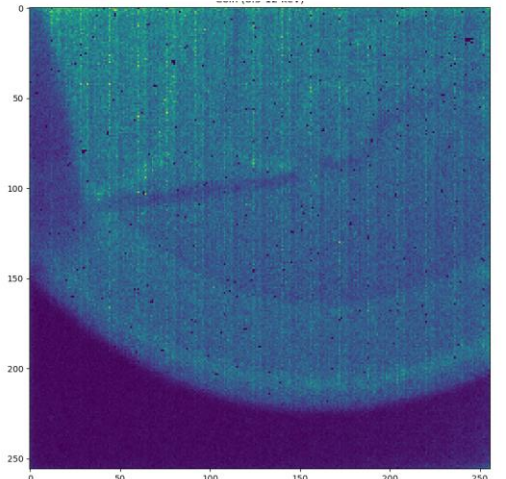
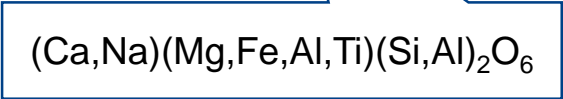
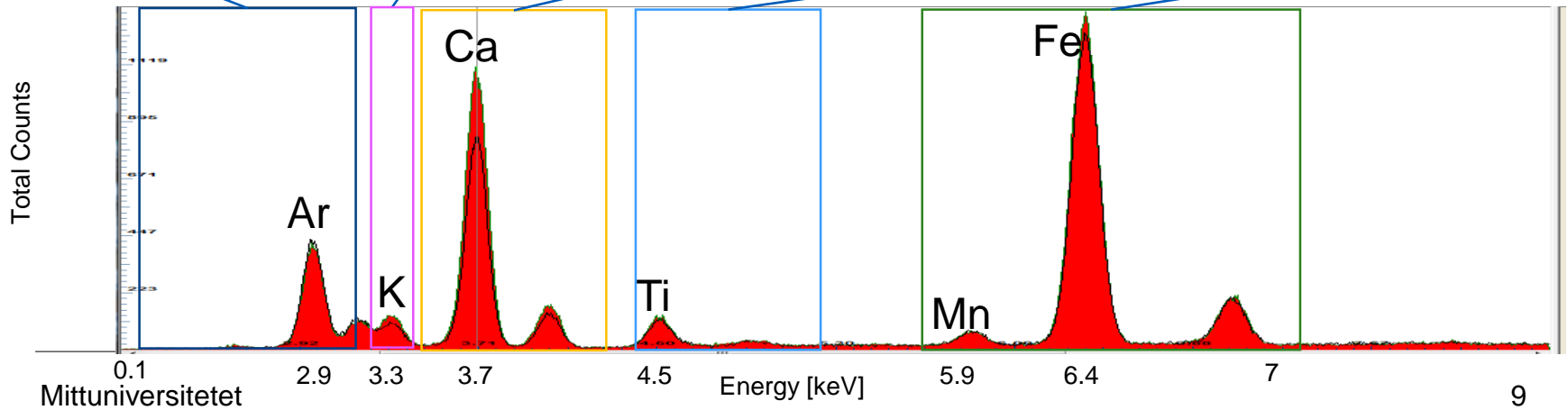
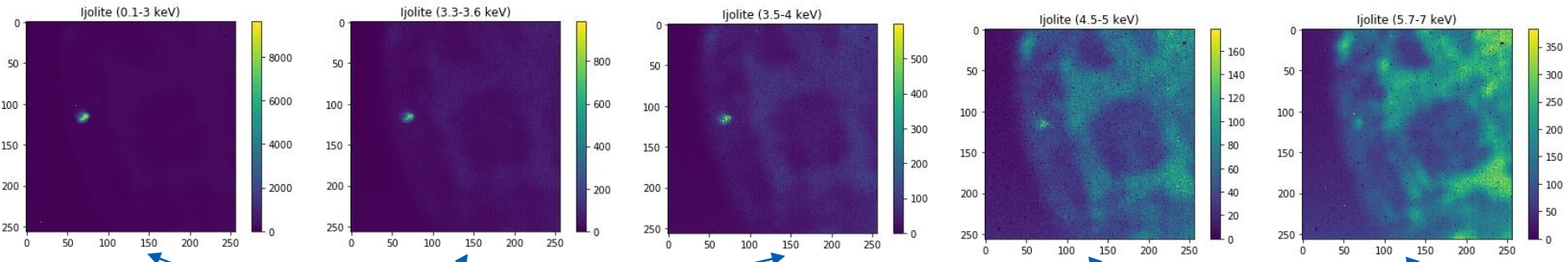


Image of mineral (Ijolite rock)

- Amptek Silicon drift detector
- Air absorption for light elements

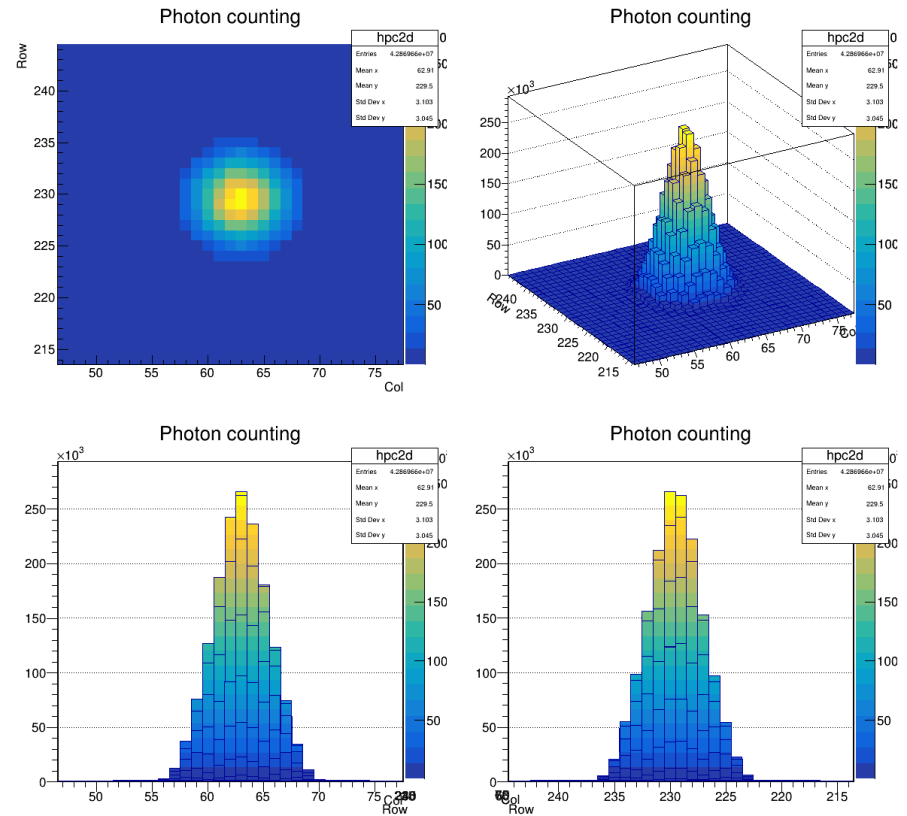


X-ray diffraction?



Focal point measurement

- Distance between tube and detector is 2.5 cm
- Critical angle is 0.123° for 20 keV
- For an ideal point source, the calculated resolution is $108 \mu\text{m}$ (2 pixels)
- Full width at half maximum (FWHM) in the measurement is $330 \mu\text{m}$
- Fluorescence of lead and transmission decrease the resolution.

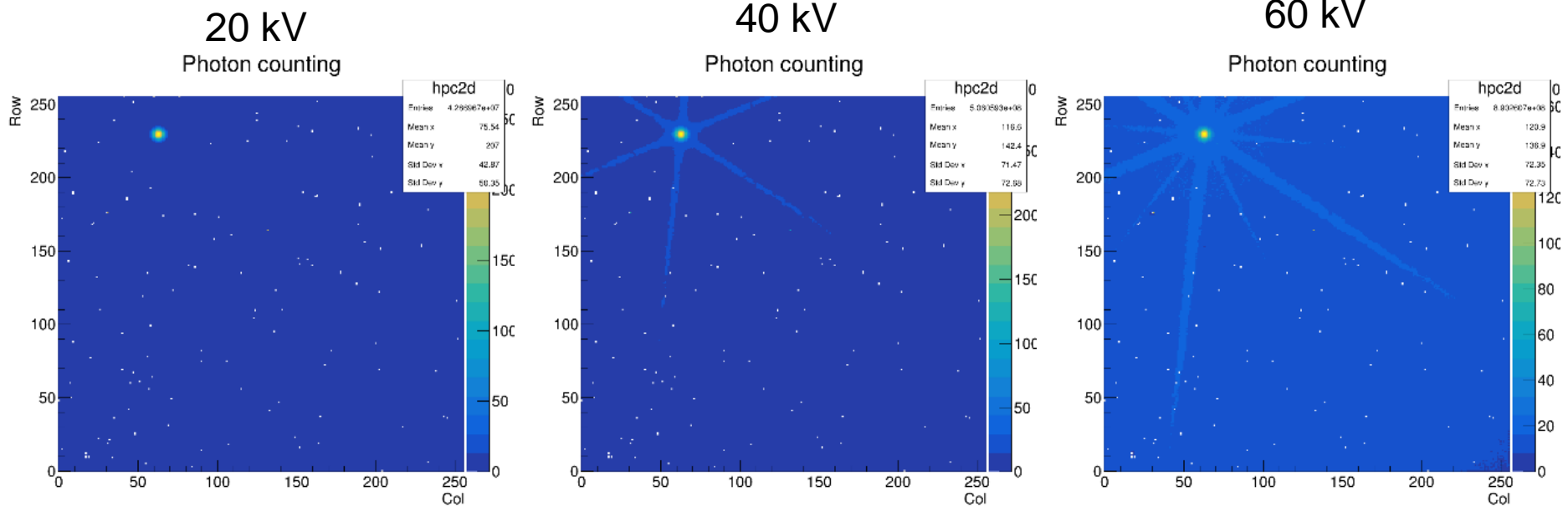


Micro-focus X-ray tube (Comet FXE-160.51) with Ag filter, 20 kV



Focal point measurement

- X-ray starts to transmit through the capillary walls at 40 kV
- Star pattern





Conclusions

- Capillary Collimated XRF-imaging with Timepix 3 is achieved
- The image resolution in our setup is about 500 μm for 10 keV photon
 - Depends on fluorescence energy, capillary material and setup geometry.
- When analyse the sample with various elements, the matrix effect should be considered
- Critical filtering of energy would be required in order to analyze various samples with higher resolution