X-ray fluorescence and imaging using triple GEM detectors

Results of measurements at CERN with the SRS

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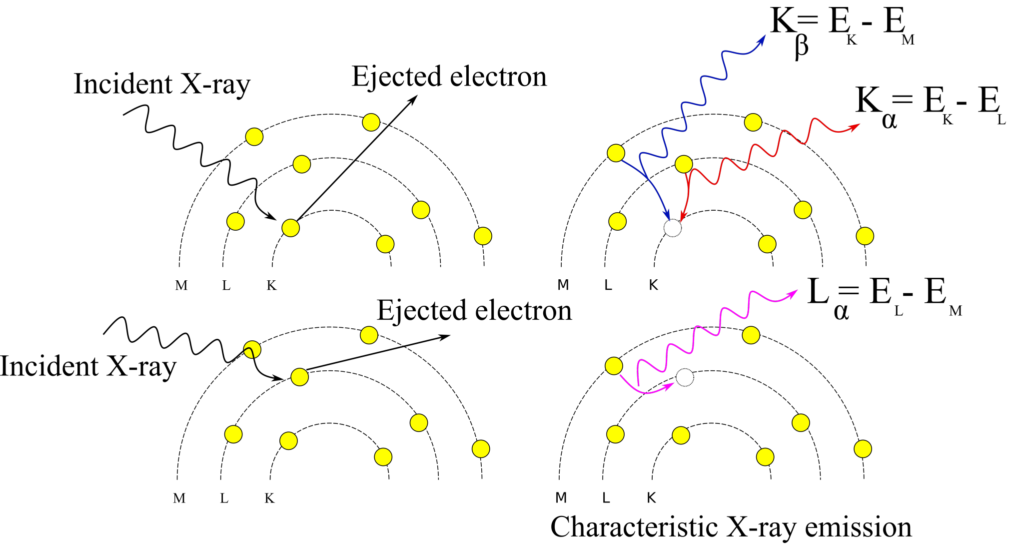
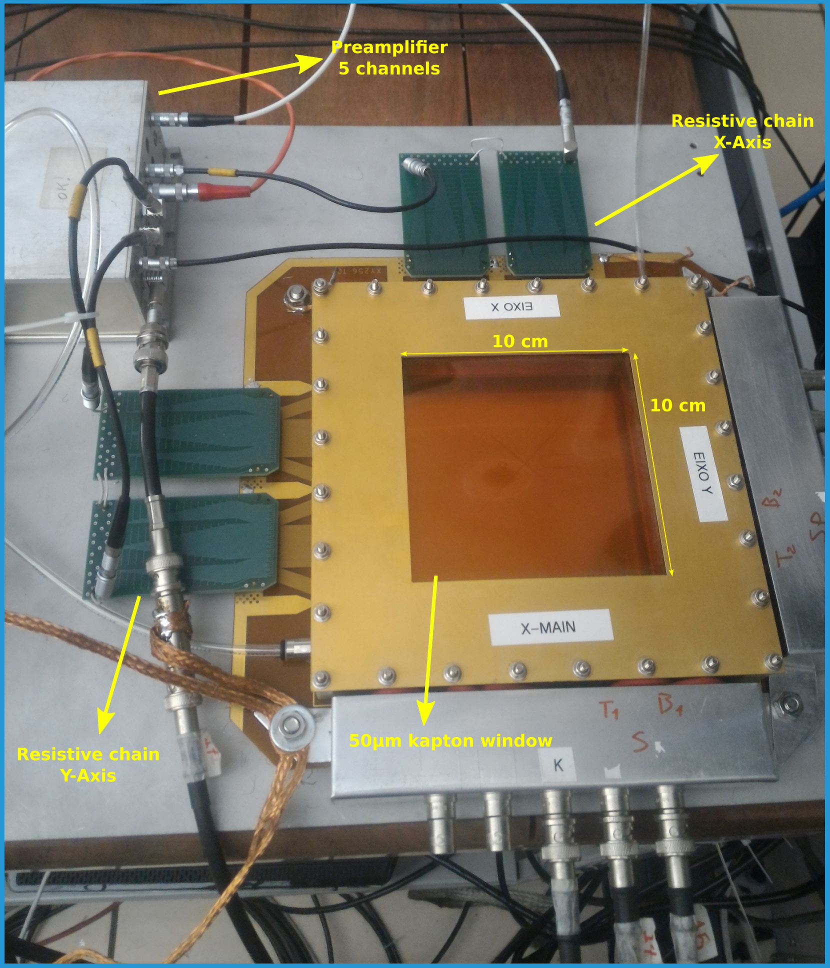
HEPIC
USP



Main goal: Create an X-ray fluorescence imaging system using GEM detectors

- Large sensitive area
- Applicable to cultural heritage studies
- Portable (future work)



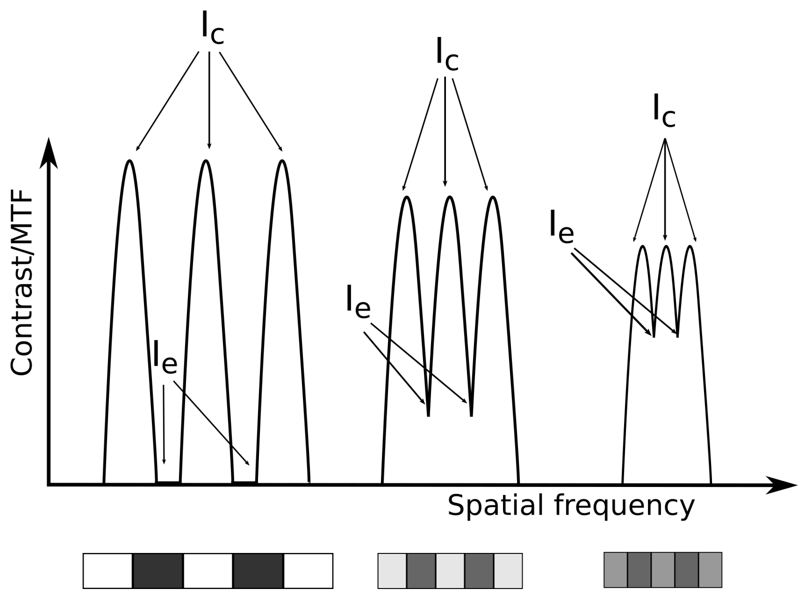
First triple GEM detector

- 4 electronic channels to determine position and 1 for energy (charge collected at the bottom of the last GEM)
- Strip readout in X and Y - resistive charge division
- 'Center of mass' determination of position
- Operating at atmospheric pressure with Ar/CO_2 (90/10)

Detector was first characterized in transmission mode

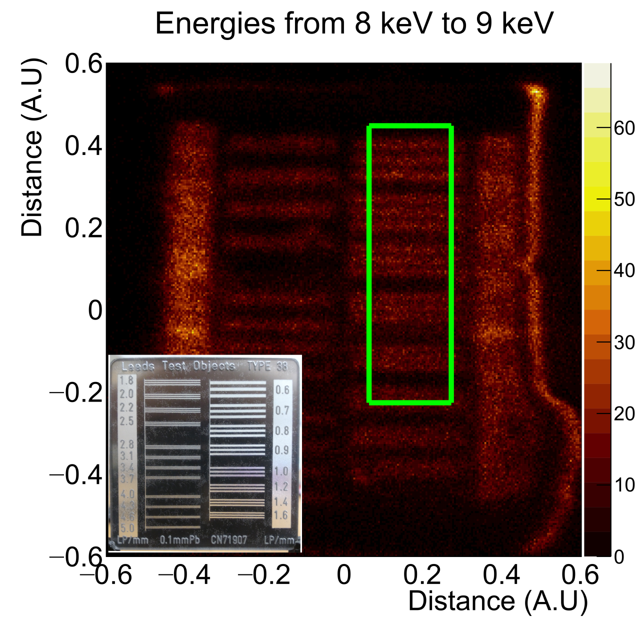
Results from São Paulo
Resistive charge division.

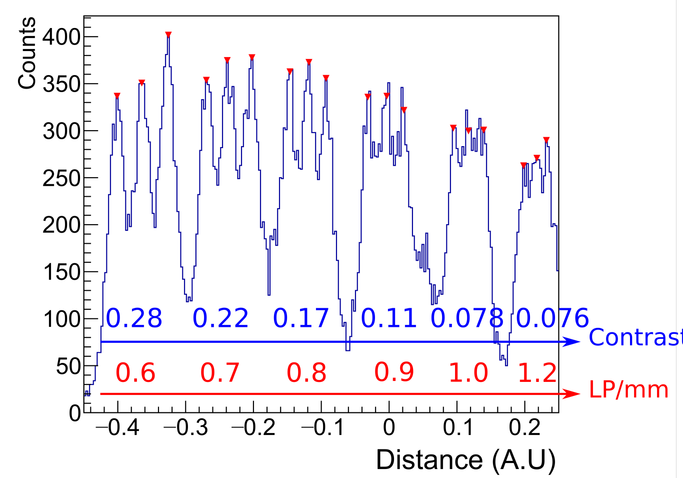
Determination of the modulation transfer function (MTF) from periodic objects



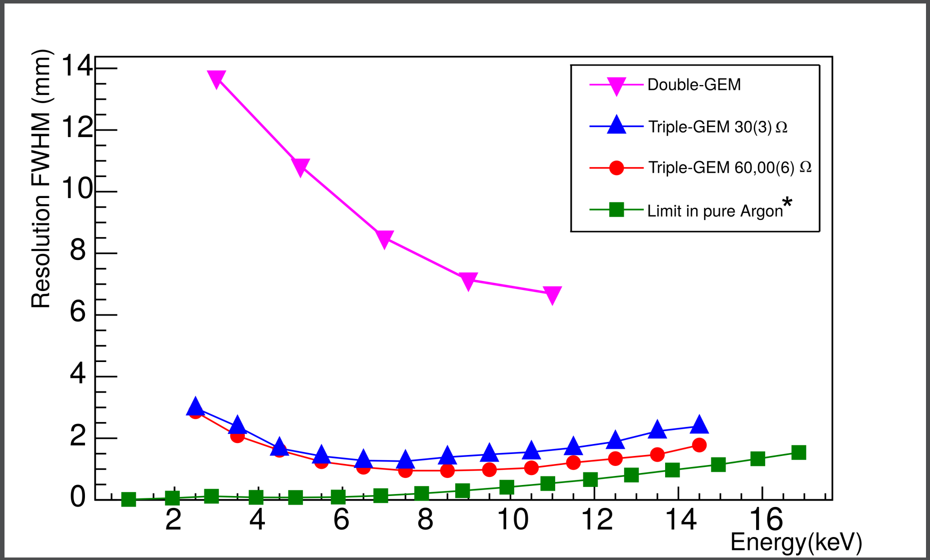
$$\text{Contrast} = \frac{I_c - I_e}{I_c + I_e}$$

$$\text{Resolution} \approx Contrast(10\%)$$





Results from São Paulo
Resistive charge division.



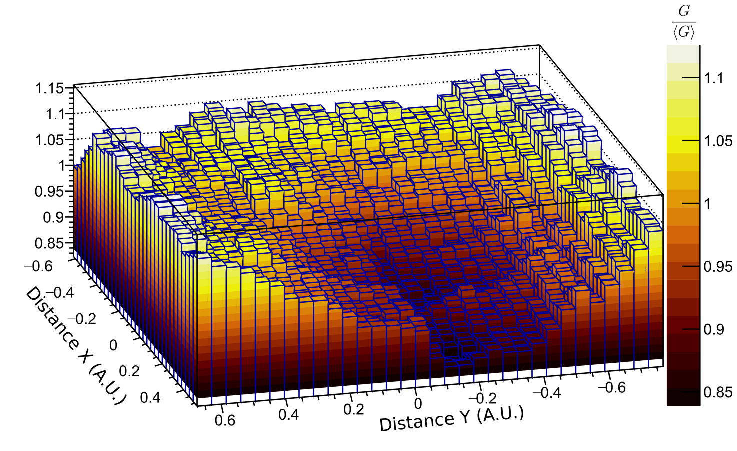
* C.D.R. Azevedo et al., Phys. Let. B 741 (2015), 272-275

Spatial resolution results

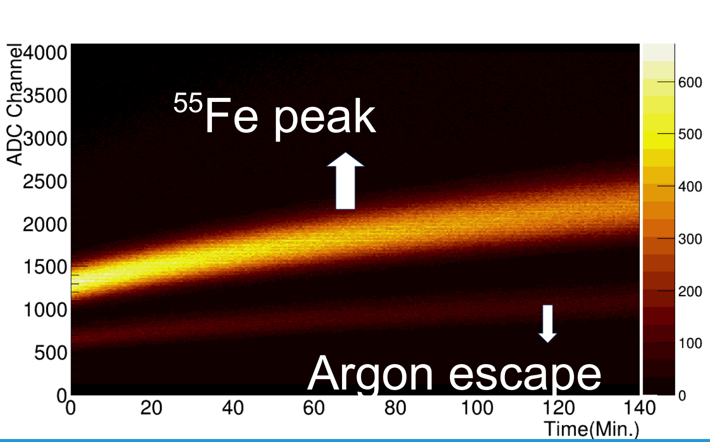
- For lower energies signal-to-noise ratio is dominant
- For higher energies photon electron range increases
- Optimal spatial resolution for the triple GEM using resistive charge division is 1.2 mm (8 to 9 keV).

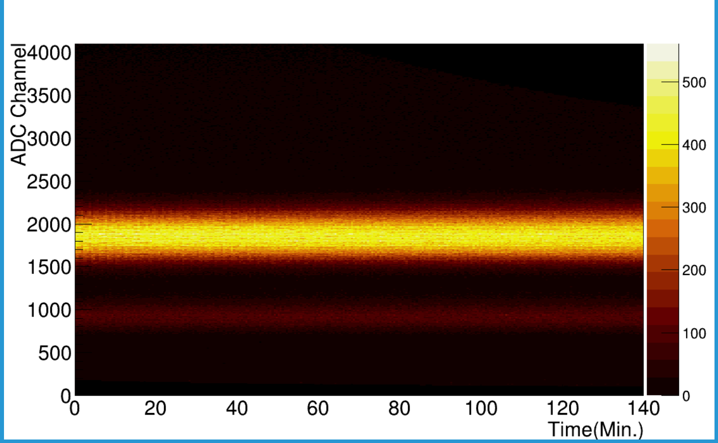
Energy resolution and gain corrections

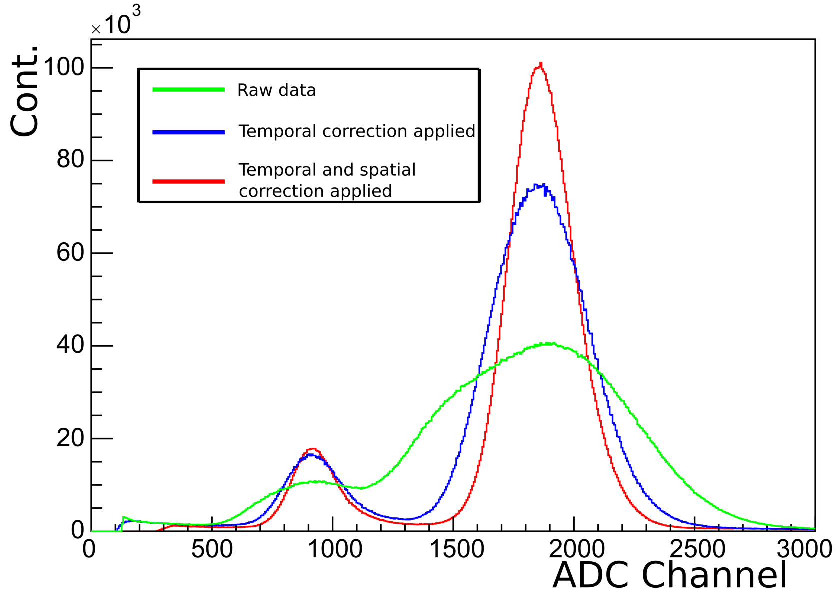
- Gain corrections across the detector

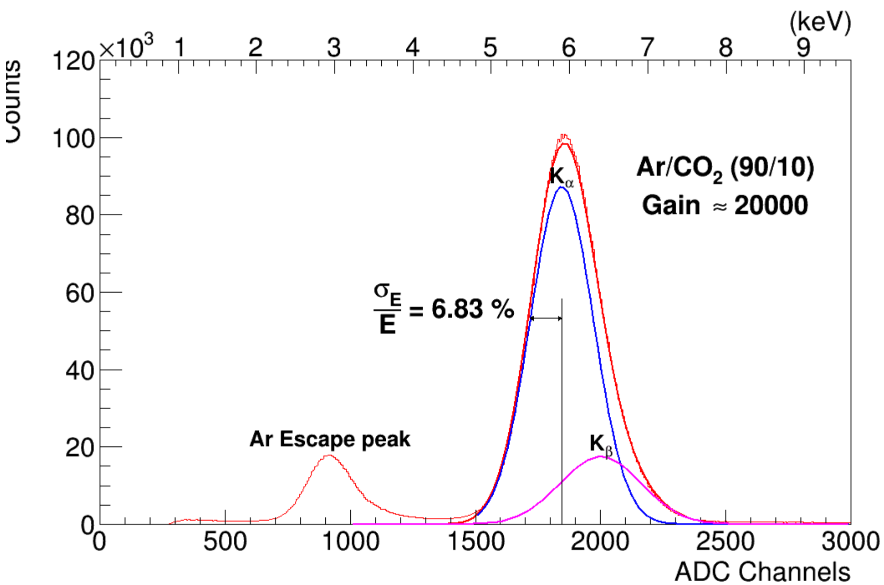


Temporal corrections – gain difference caused by temperatures changes in the detector's room









Corrections fully reconstructed the energy spectrum

- 6.8% energy resolution
- Detector's gain close to 20000
- Ar/CO_2(90/10)

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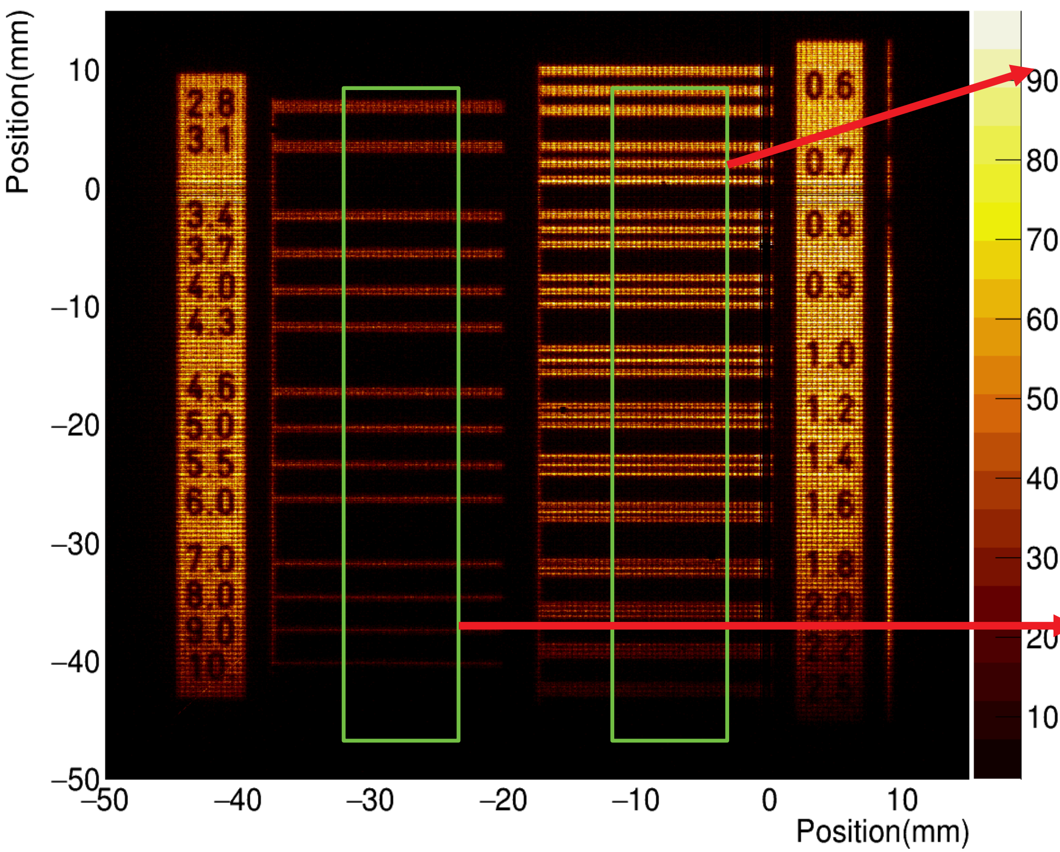
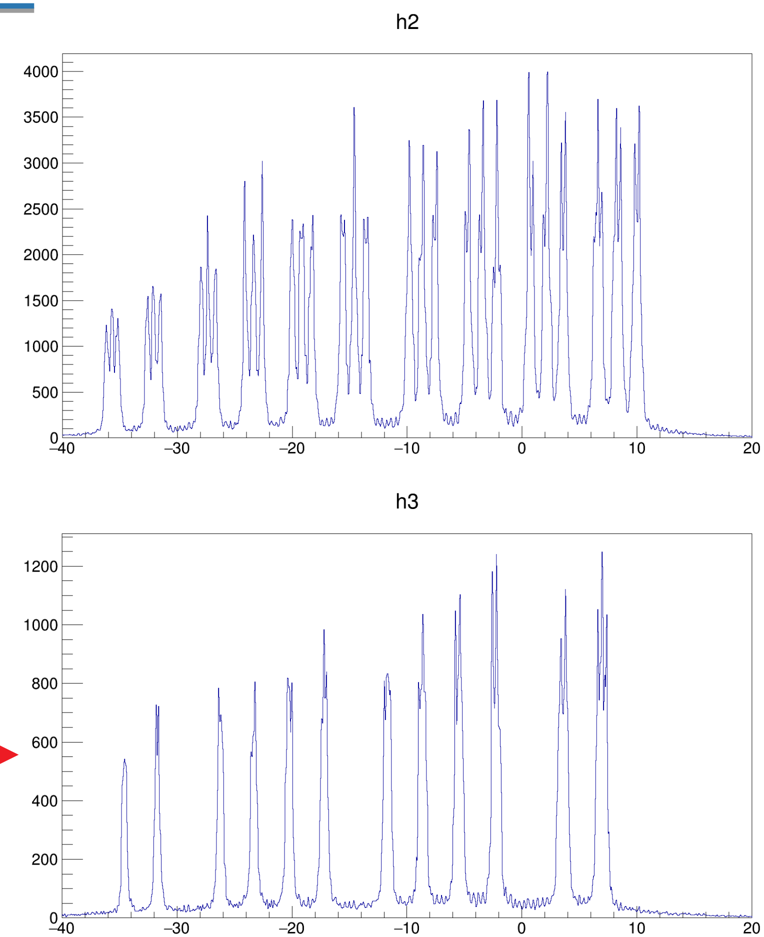
Test with SRS at CERN during November

Another triple GEM detector

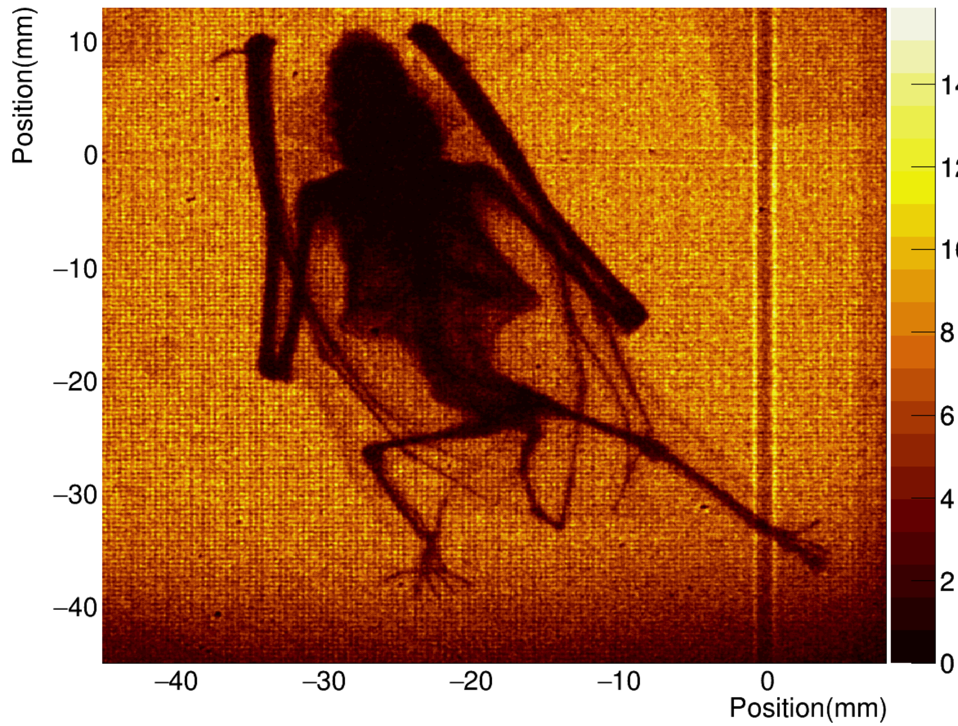




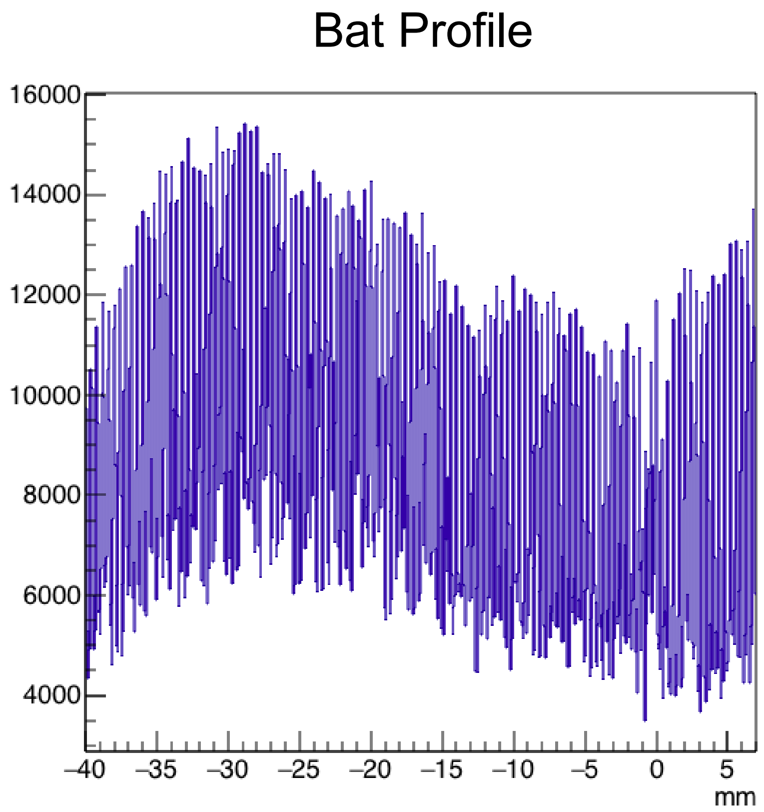
- Transmission mode ~ 2h30 hrs acquisition
- 1.2 kHz acquisition rate
- APV25

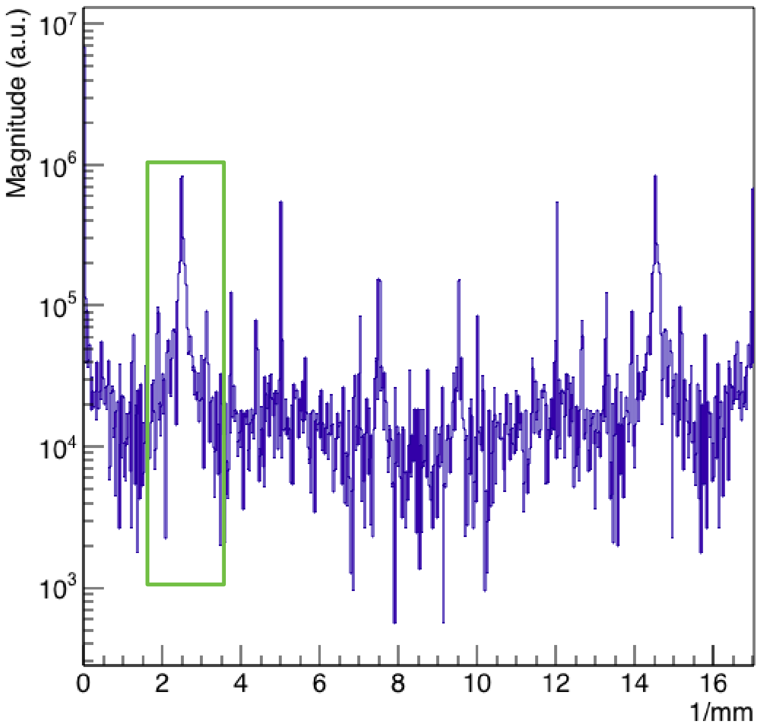
Able to distinguish contrast till 2.8 lp/mm ≈ 350μm

Test with SRS at CERN during November



Fourier analysis

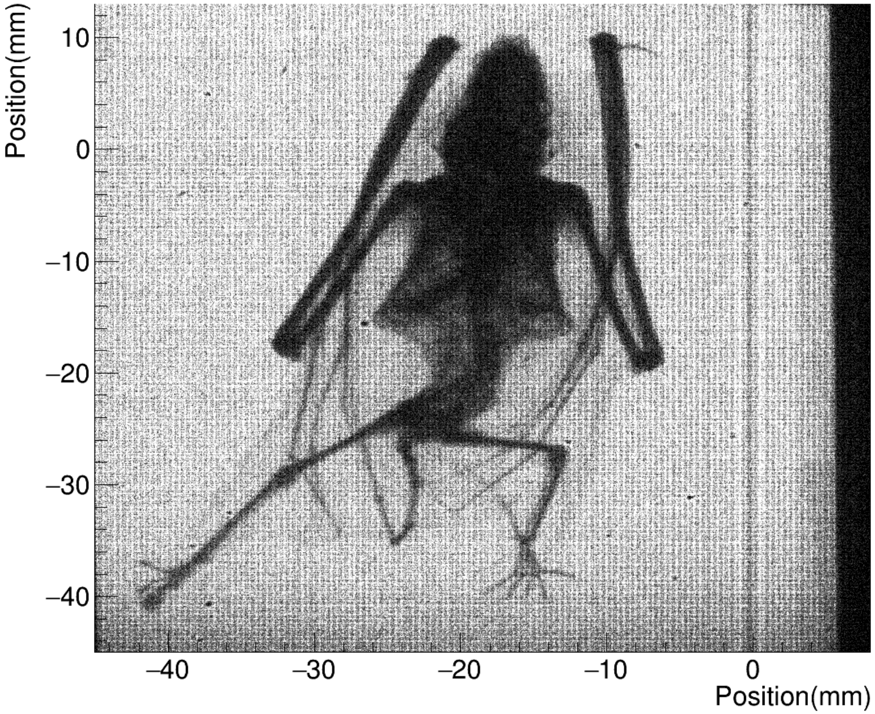




Peak at 2.5 mm^{-1}, corresponding to 400 µm, pitch of the readout strips

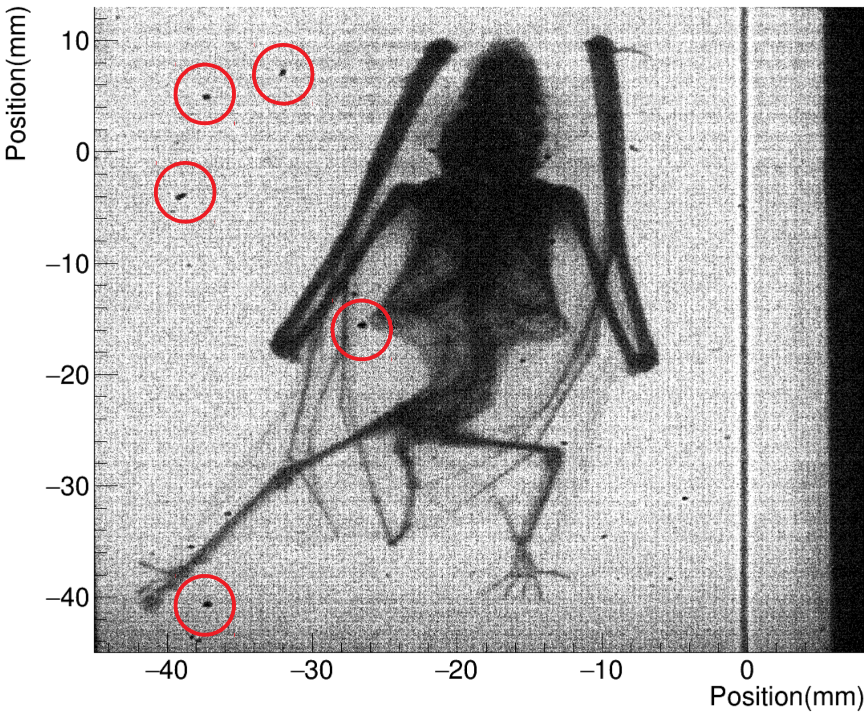
Reconstruction of the cluster

Using the normal 'center of mass'



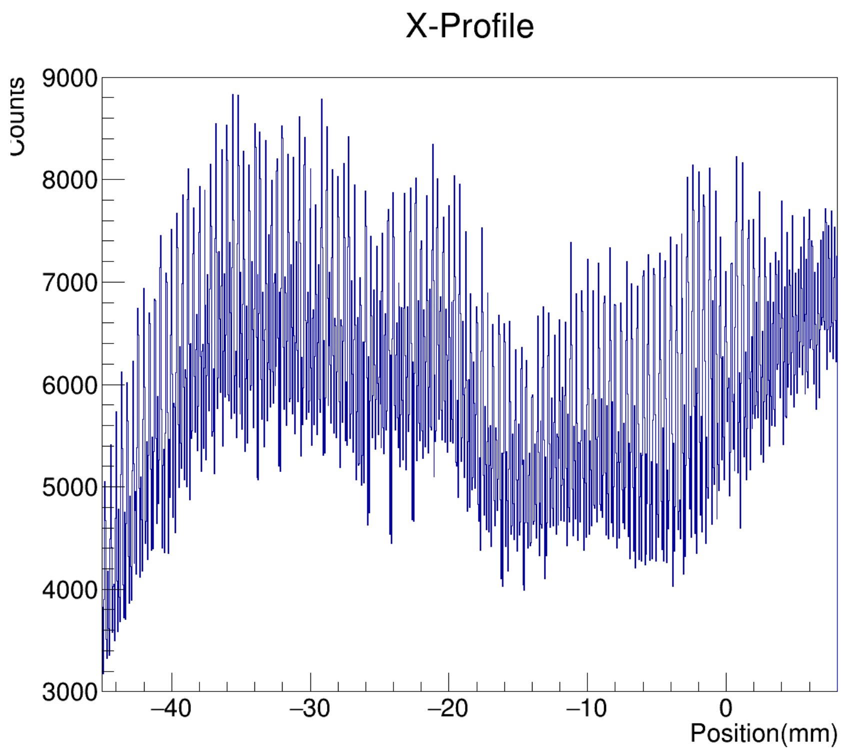
Using the changes made by Heikki Pulkkinen
Weight = (strip_charge)²;
Centroid = sum(Weight.*strip_position)/sum(Weight);

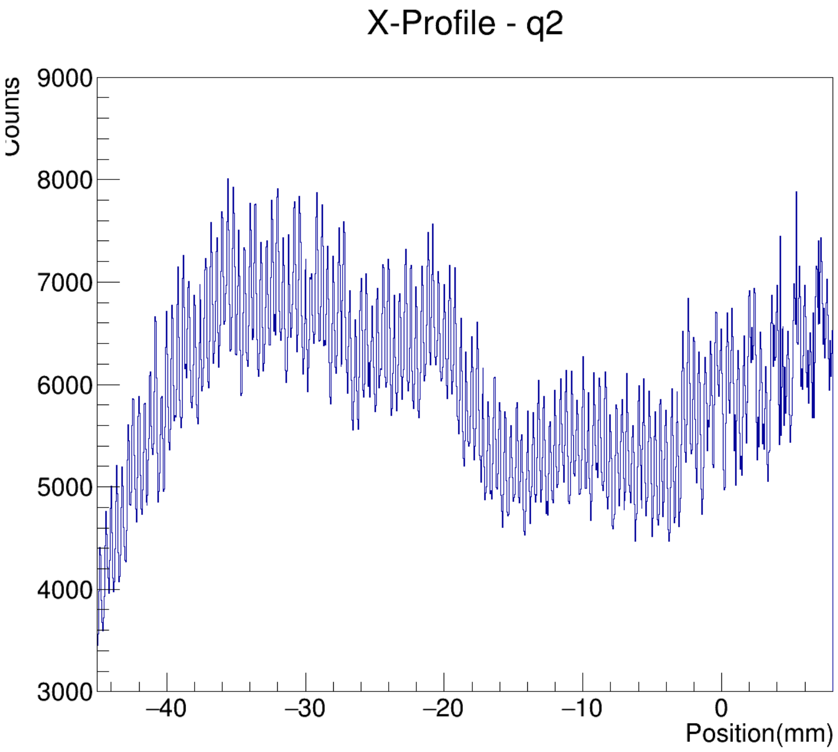
Using the square of the charge (q^2)



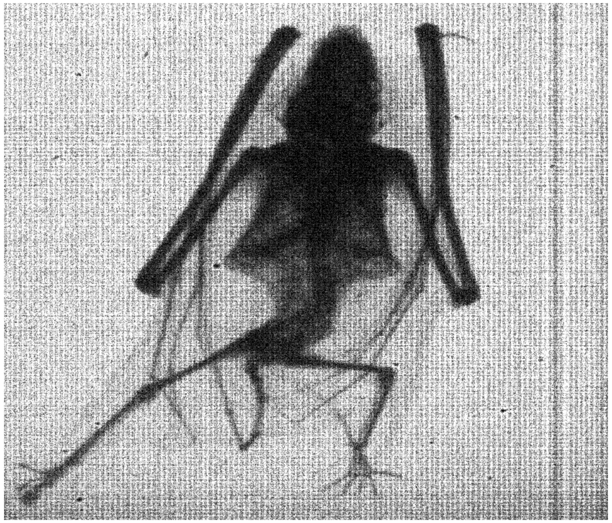
- Reduction of the readout artifact
- Enhancement of some other artifacts

Profile analysis

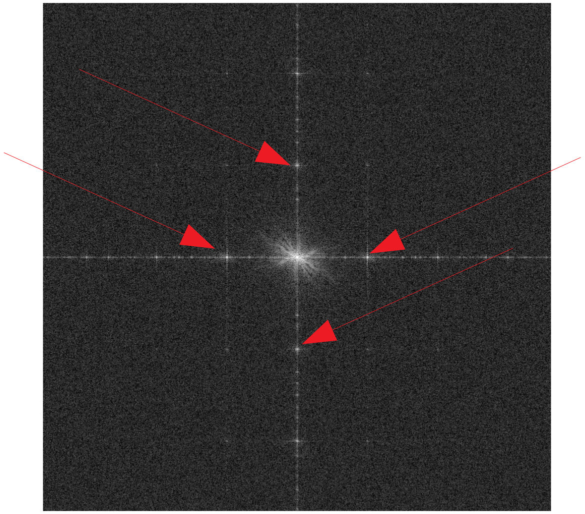




Playing with 2D Fourier analysis – work in progress

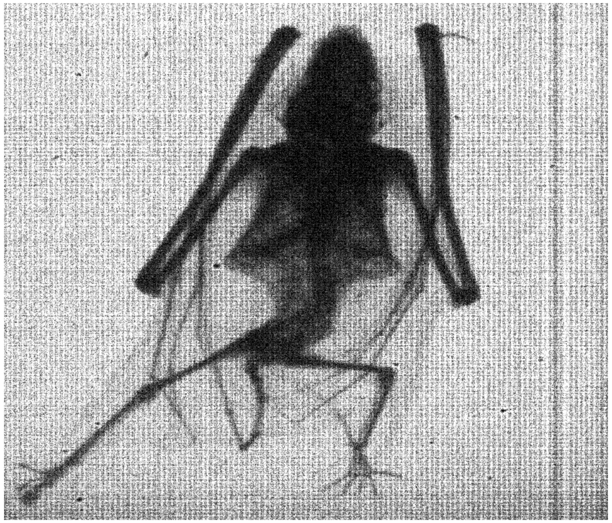


FFT

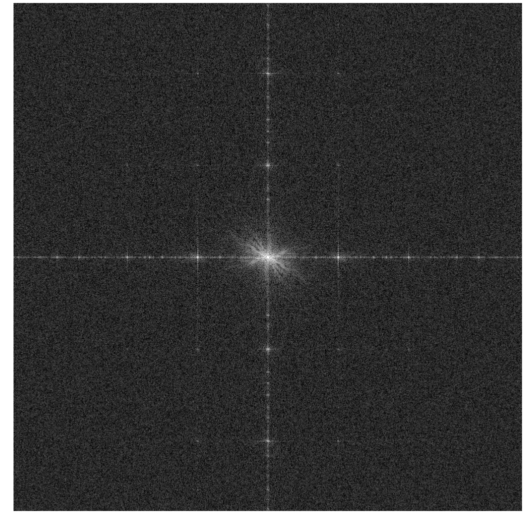


Remove some frequencies

Playing with 2D Fourier analysis – work in progress



FFT



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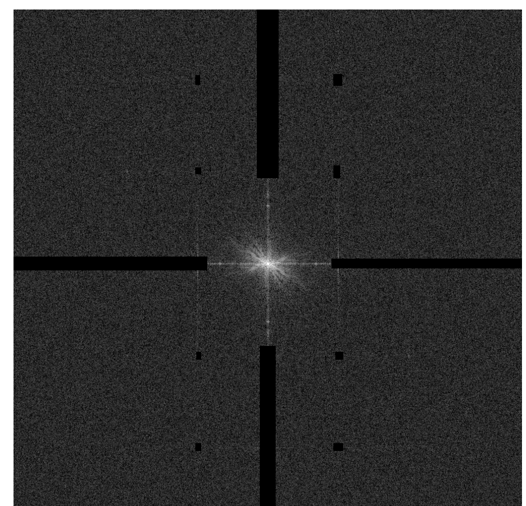
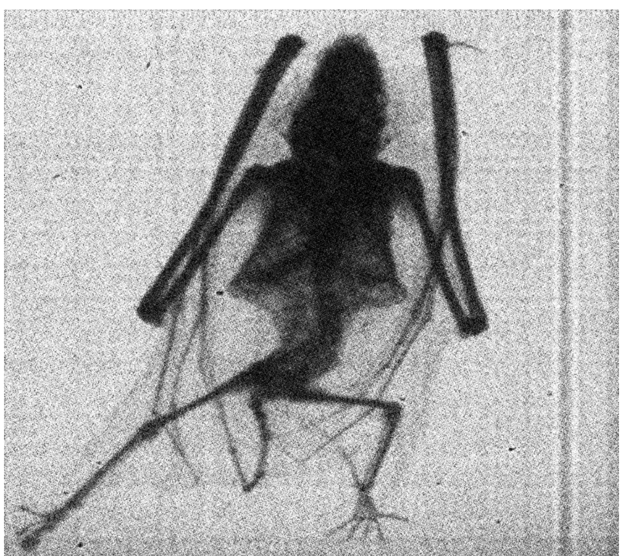


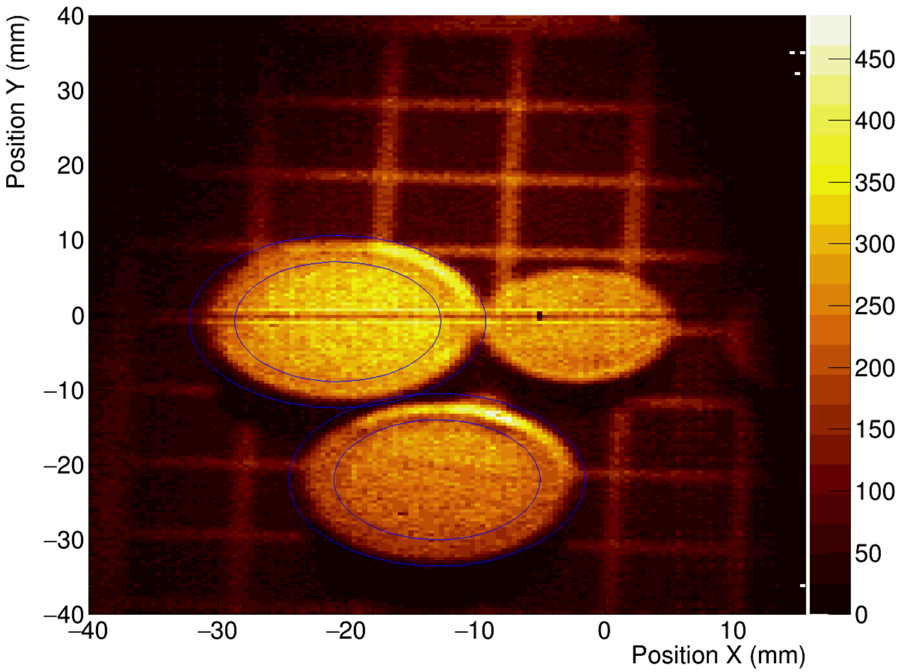
FFT^{-1}

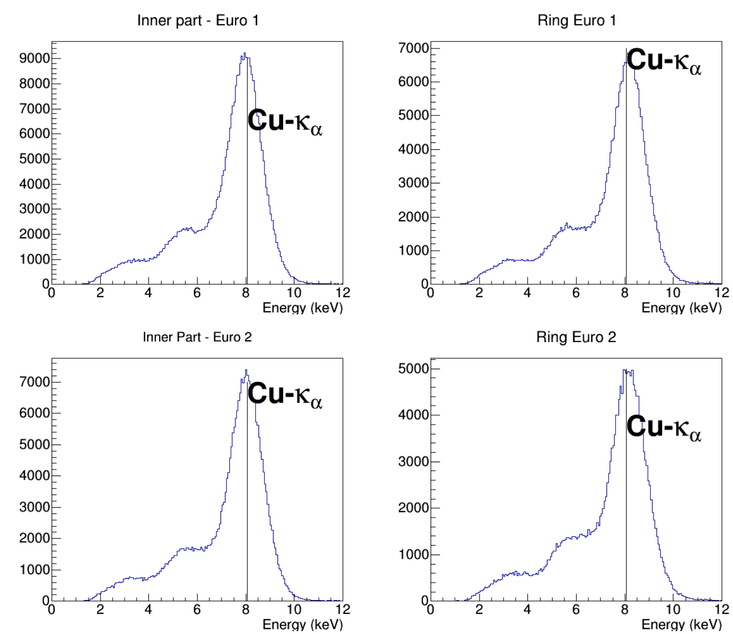


X-ray fluorescence using SRS

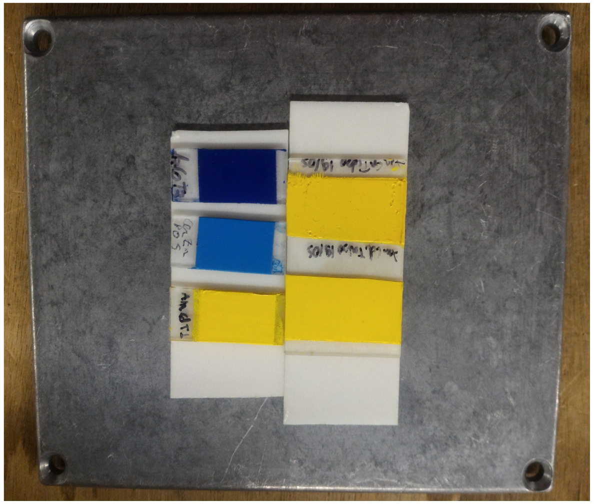
- X-ray tube 20 keV – 40mA – Cu target
- 1 mm Tantalum pinhole
- ~600Hz acquisition rate

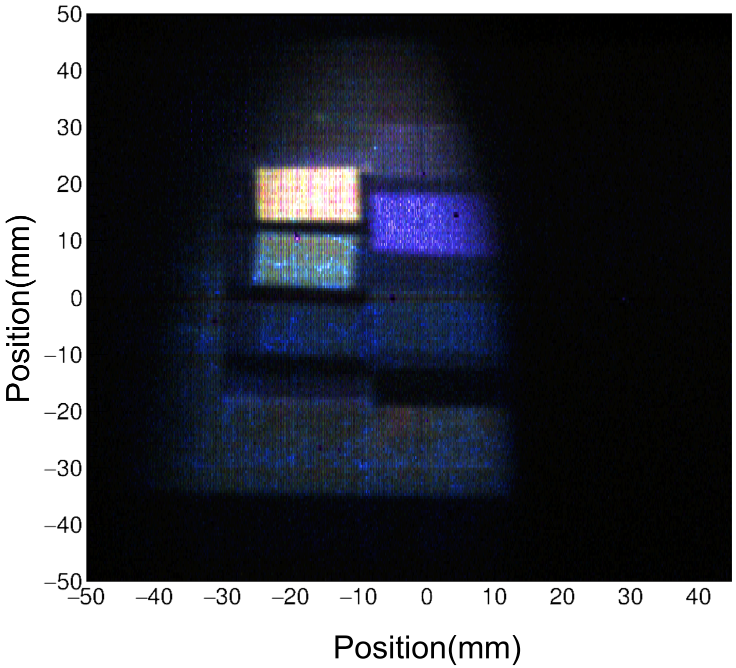
Fluorescence Image





X-ray fluorescence using SRS





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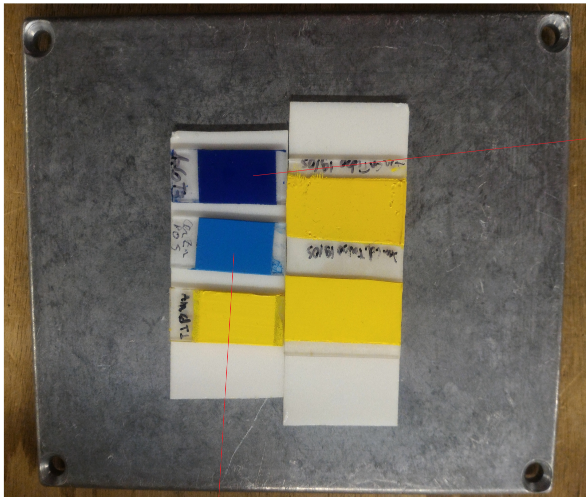

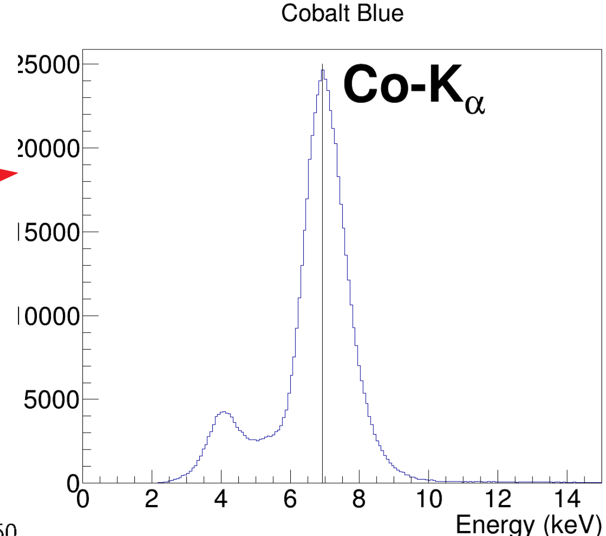

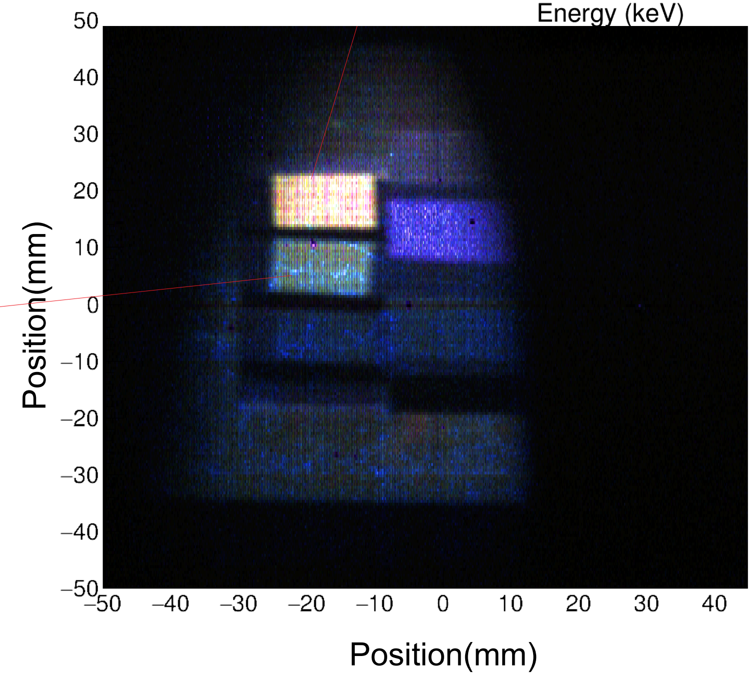

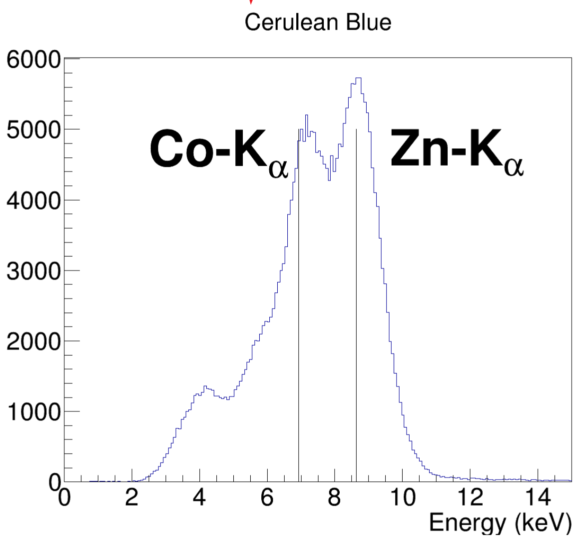

Thank you to the whole GDD lab for the great hospitality, dedication and fun!

Thank you Natasha Aguero for the pigment samples!