

# Optical readout: a versatile and intuitive readout for a triple GEM detector

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# Introduction

Several groups exploit optical readout of gas-based detectors

Readout: SiPMs, PMTs, and cameras

Amplification: wires, parallel meshes, and MPGDs

Visible scintillation of  $\text{CF}_4$  mixtures

Typically R&D for specific applications

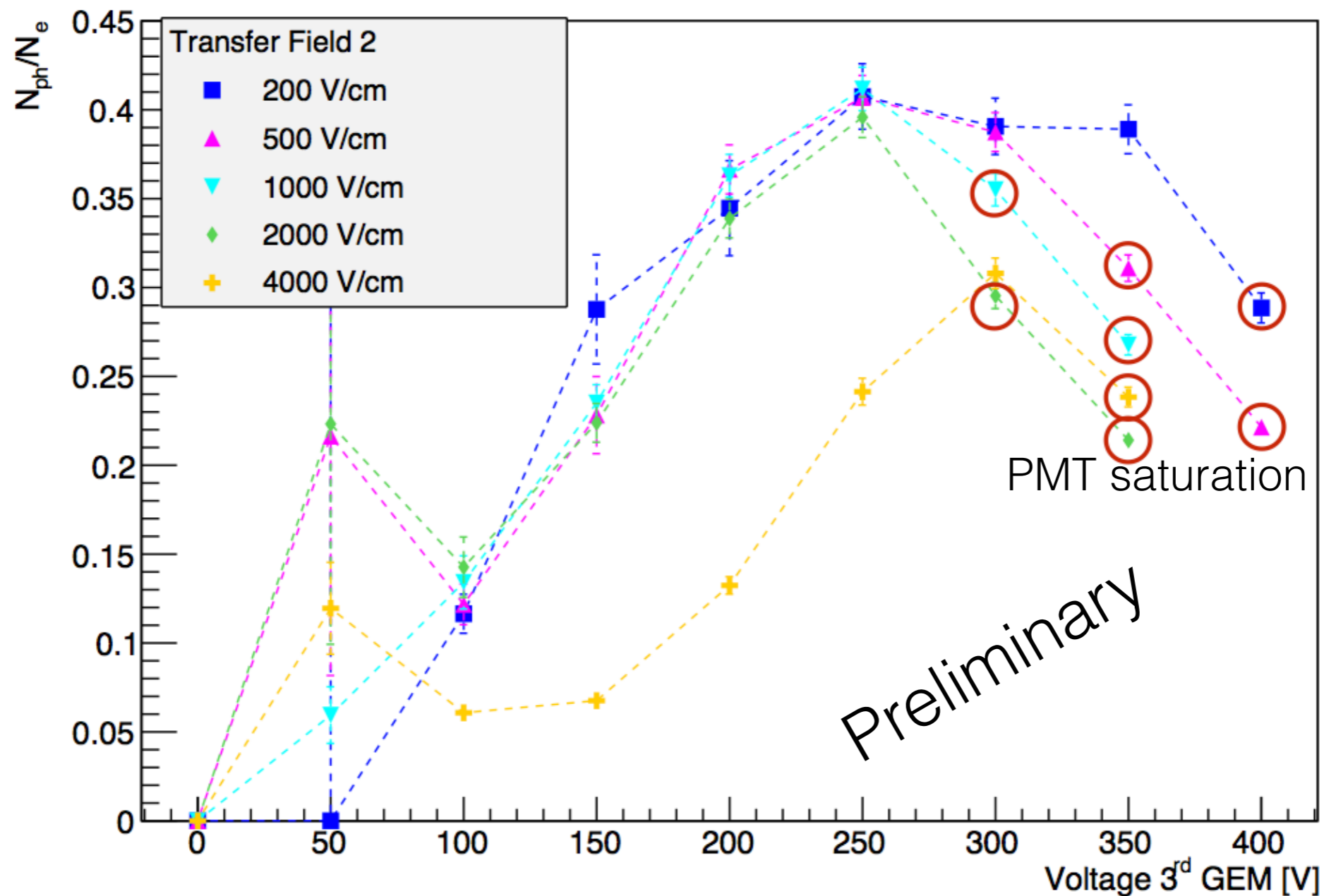


# Light yield

Same setup with a PMT instead of the camera

0.3-0.4 ph/e- in the visible

Ar-CF<sub>4</sub> 80-20



# Camera and lens



QImaging Retiga R6  
CCD: 2688x2200 4.54x4.54um pixels  
ADC: 14bit  
rate: 6.9fps (20fps with binning)  
read noise: 5.7e<sup>-</sup> RMS  
dark current: 0.0002e<sup>-</sup>/p/s @ -20°C  
trigger: external bulb + others



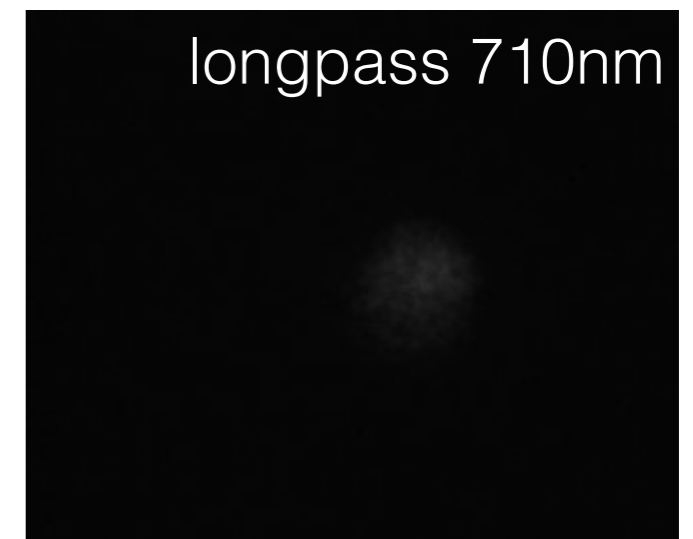
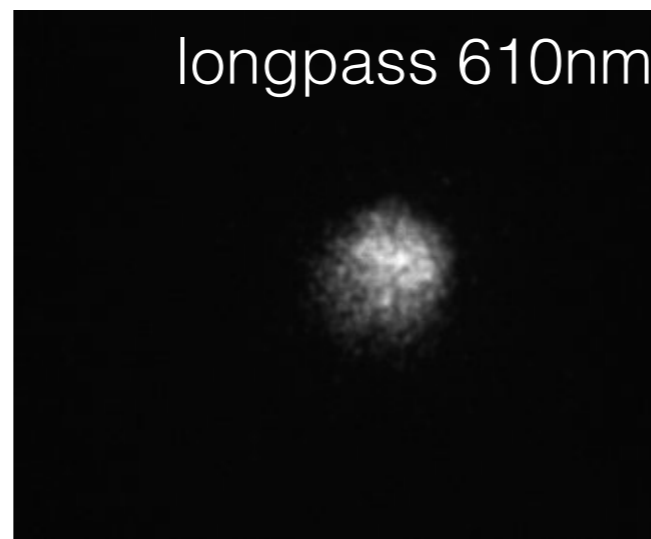
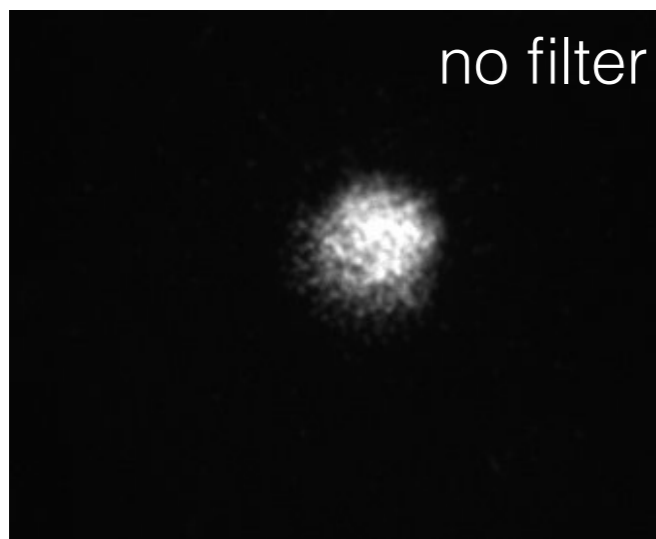
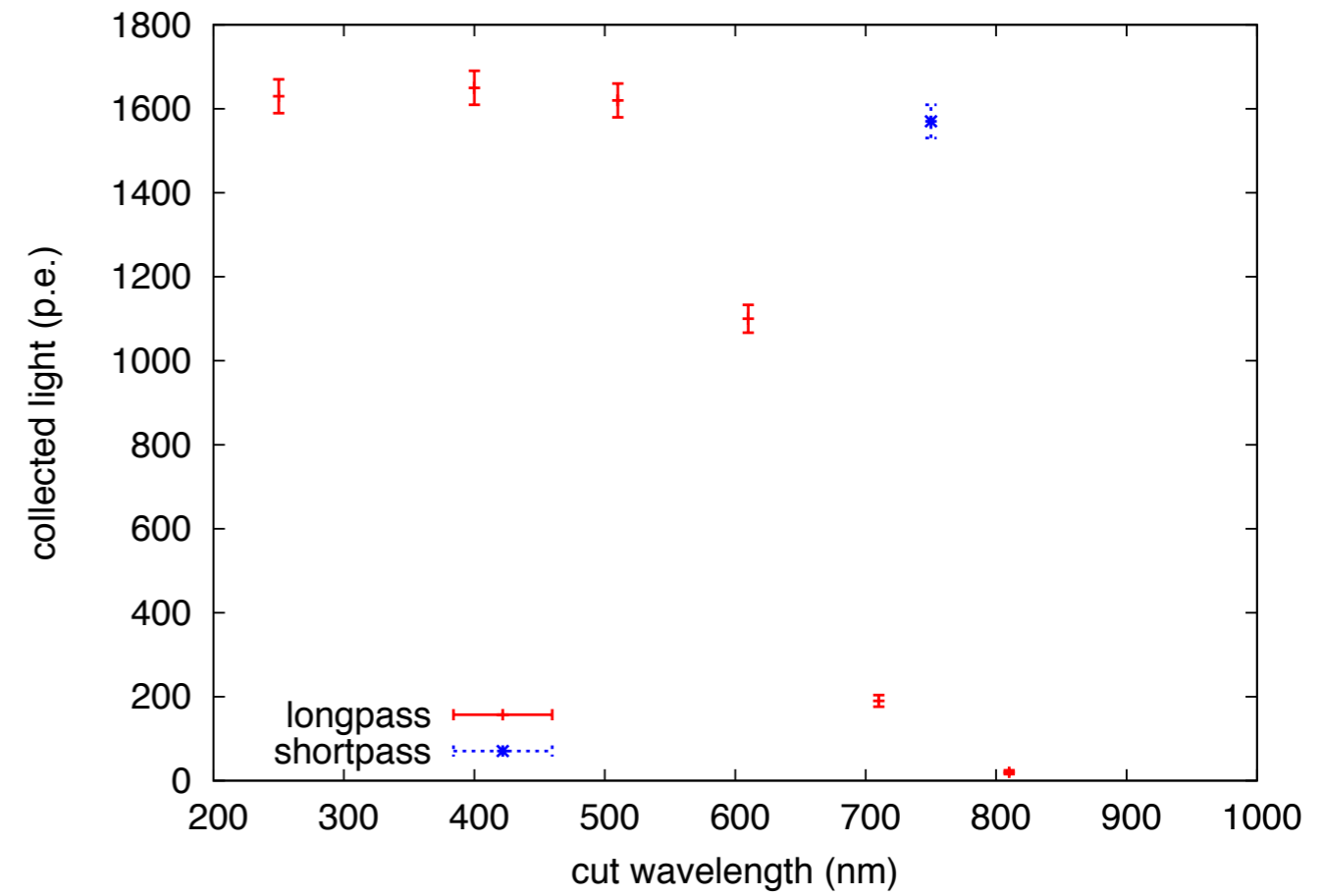
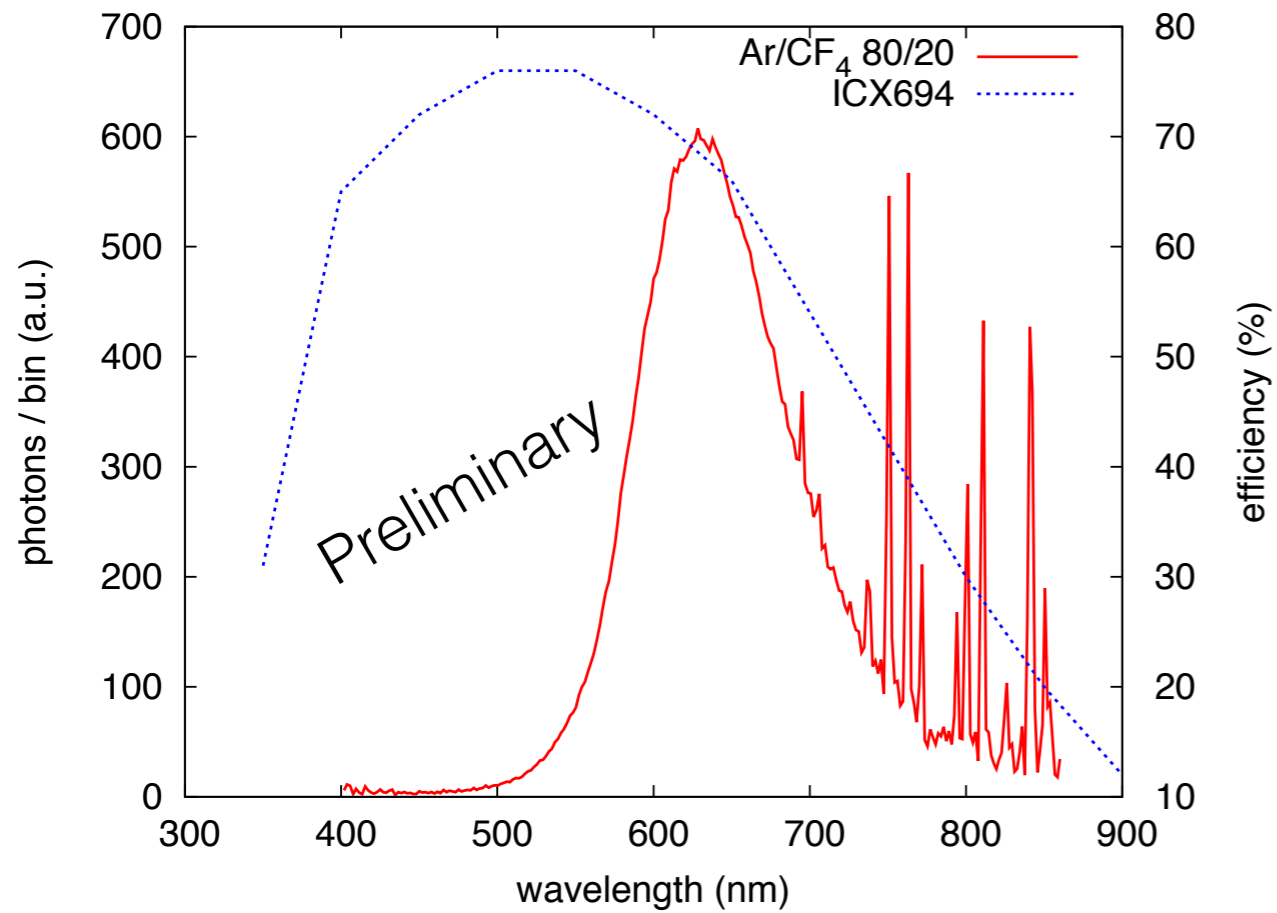
Shelyak Alpy 600  
Sensitivity: from ~365nm to ~830nm  
Resolution: ~1nm at 600nm



Navitar  
focal length: 25mm  
aperture: f/0.95  
Mount: C-Mount  
Sensor type: 1" format

# Scintillation

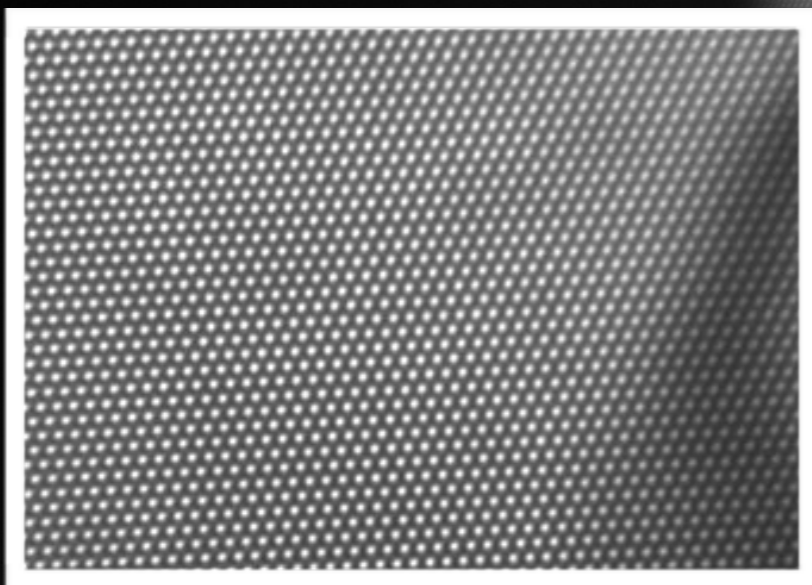
Plexiglass and lenses cut at around 400nm



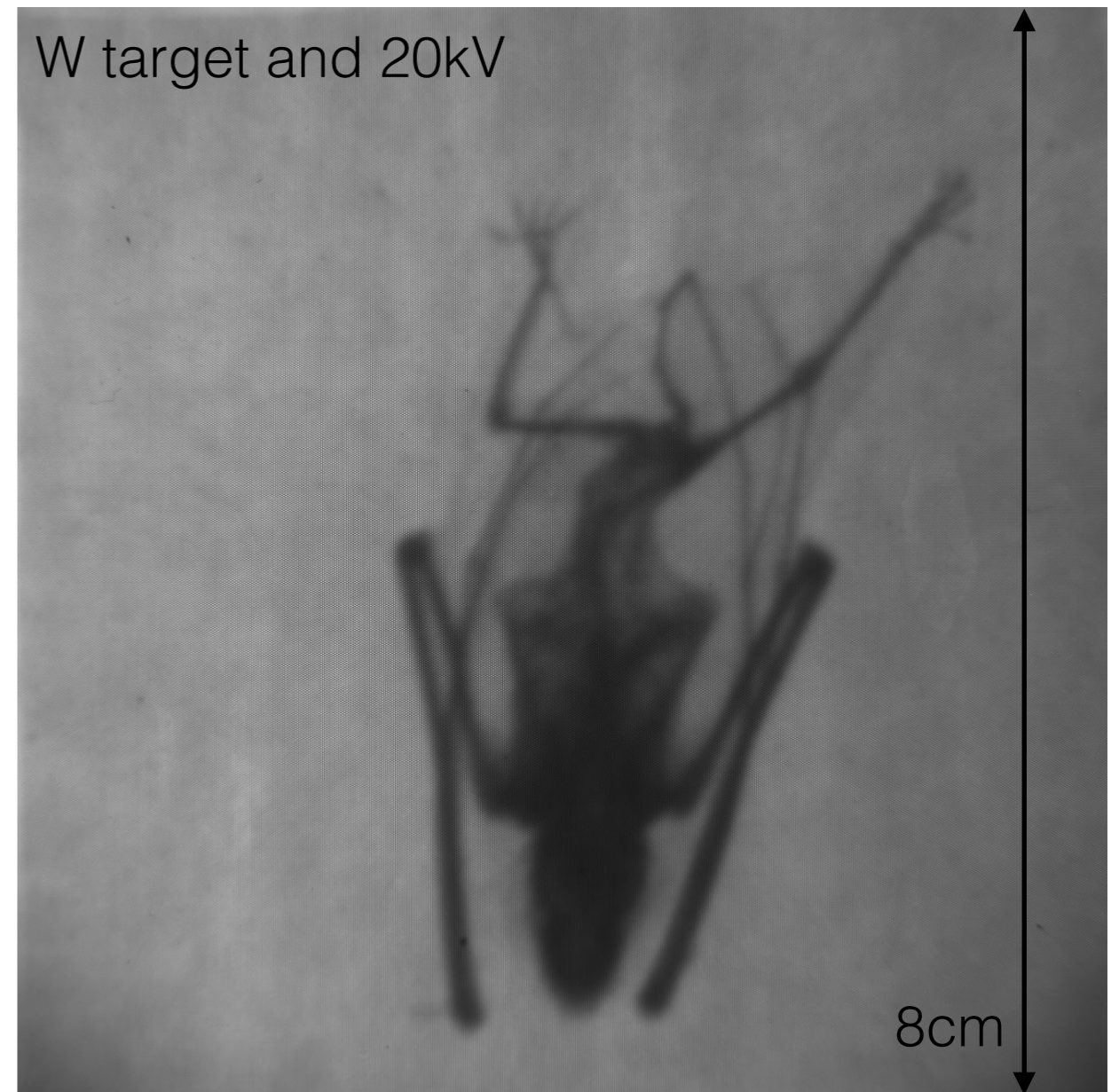
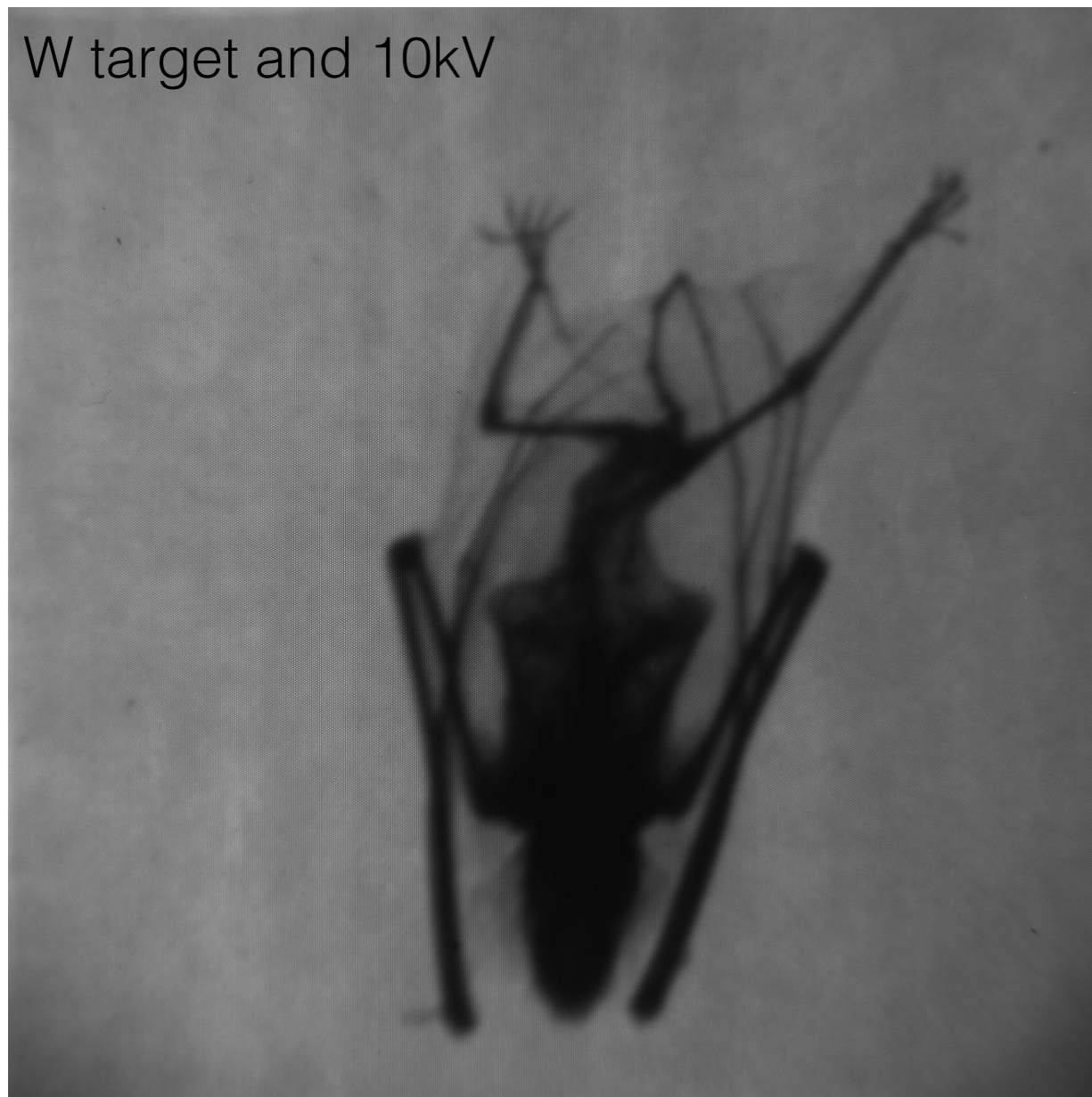
# $^{55}\text{Fe}$ X-ray imaging

4.4cm

One of the first images



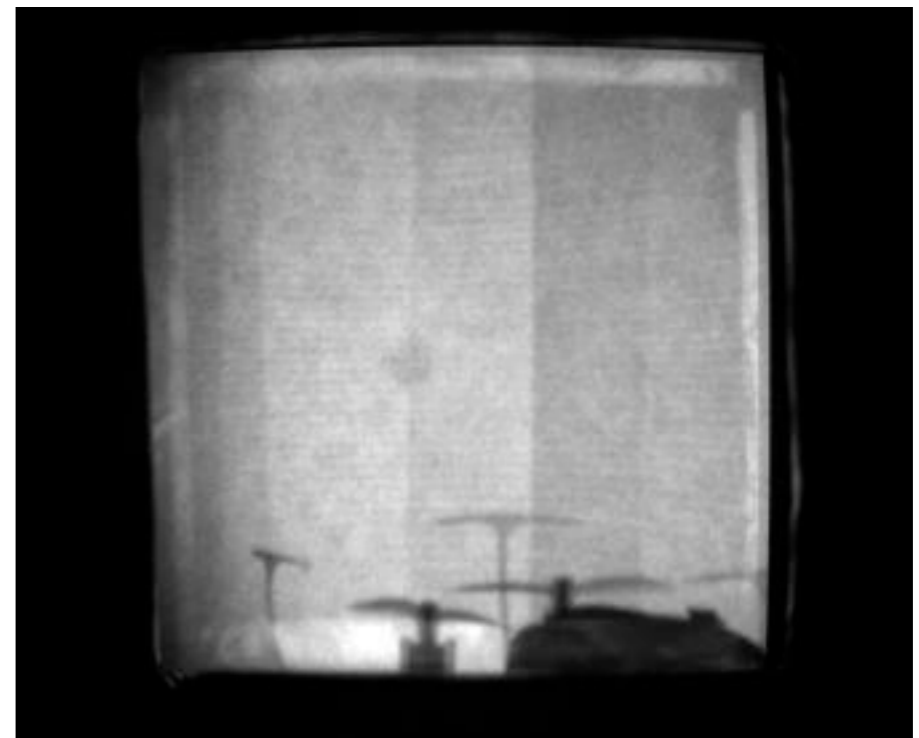
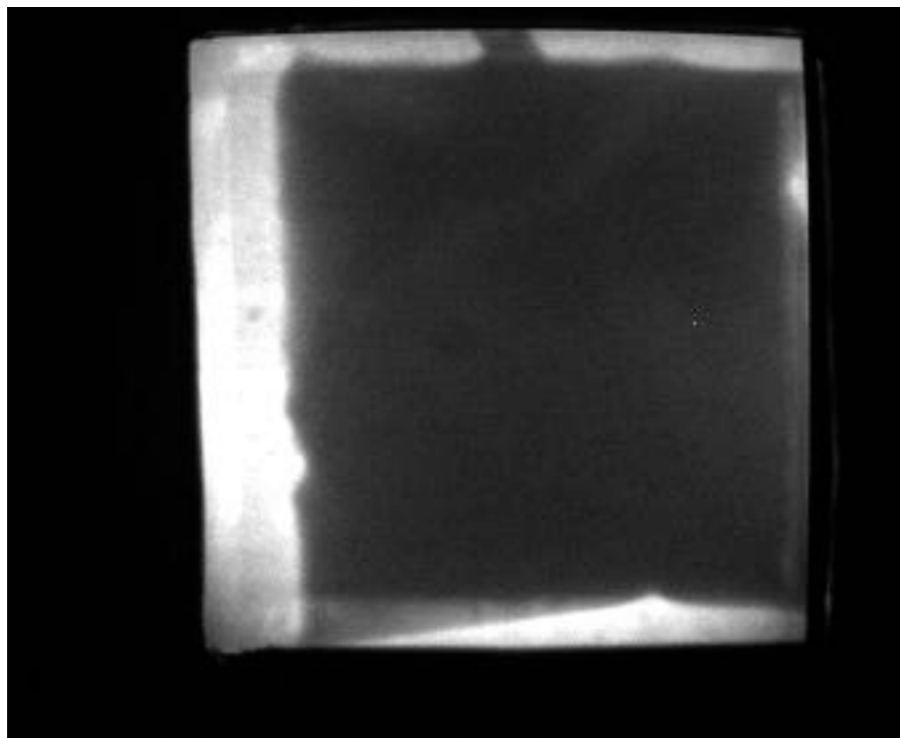
# X-ray images



Raw data: very fast acquisition and no processing time



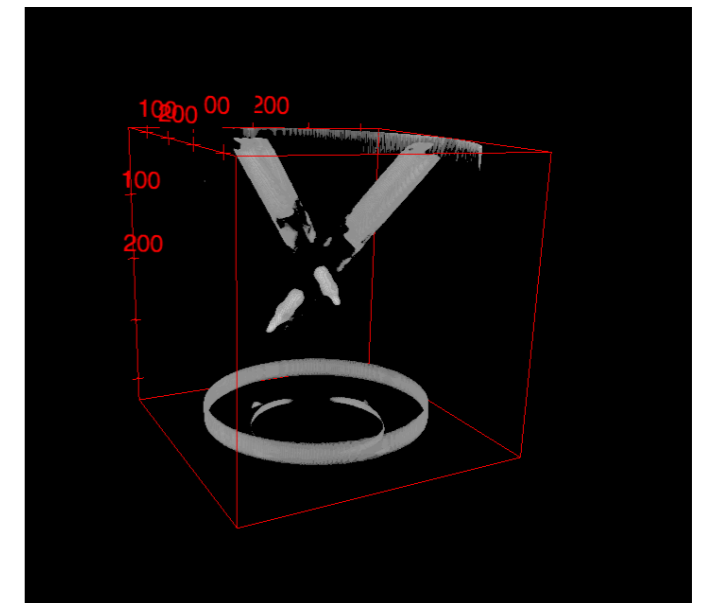
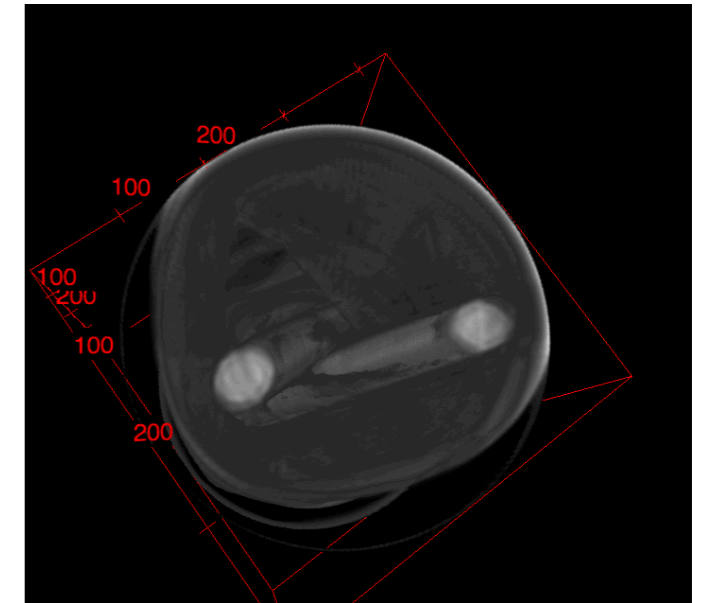
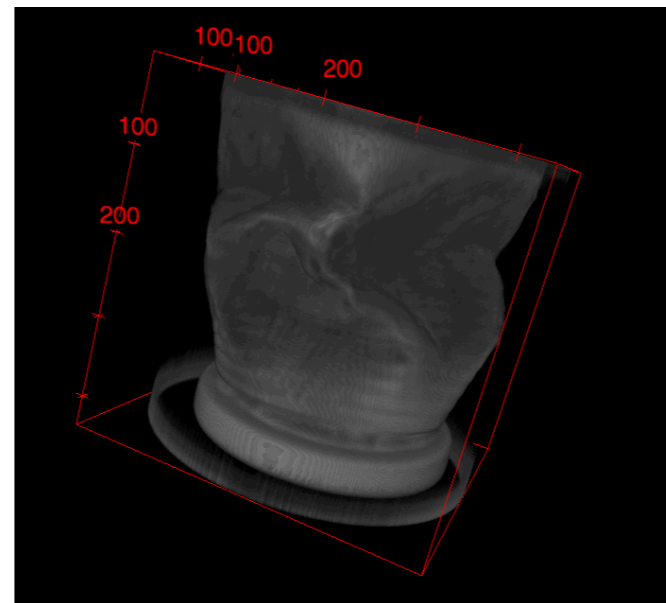
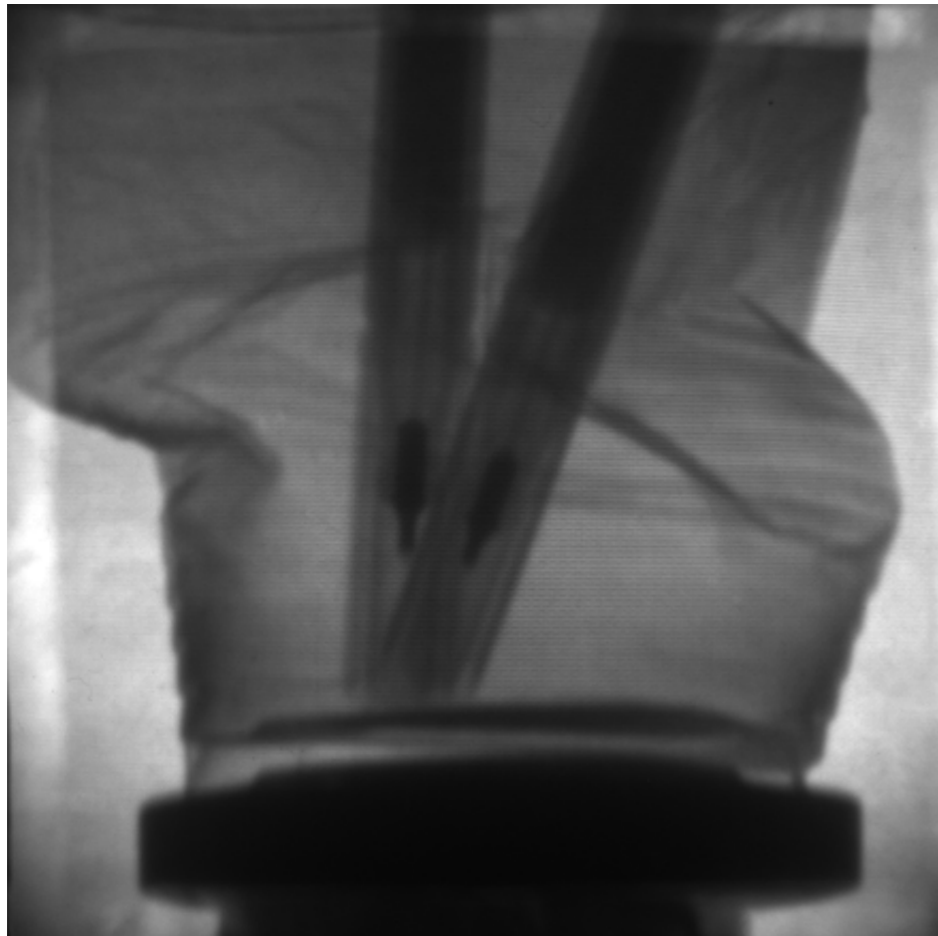
# Fluoroscopy



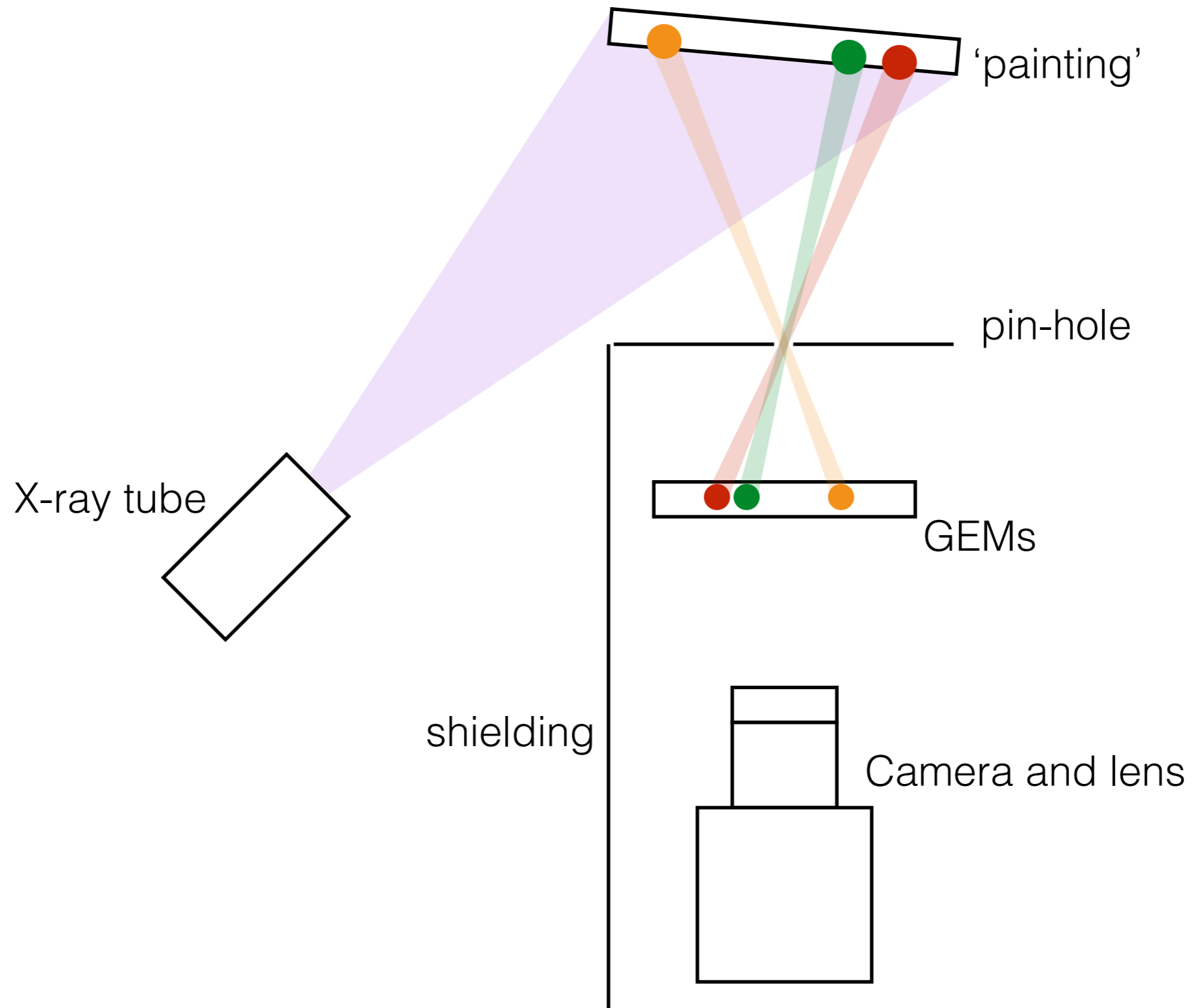
~10Hz acquisition

# CT and 3D imaging

Image -> Sinograms -> Filtered Back Projection -> 3D image



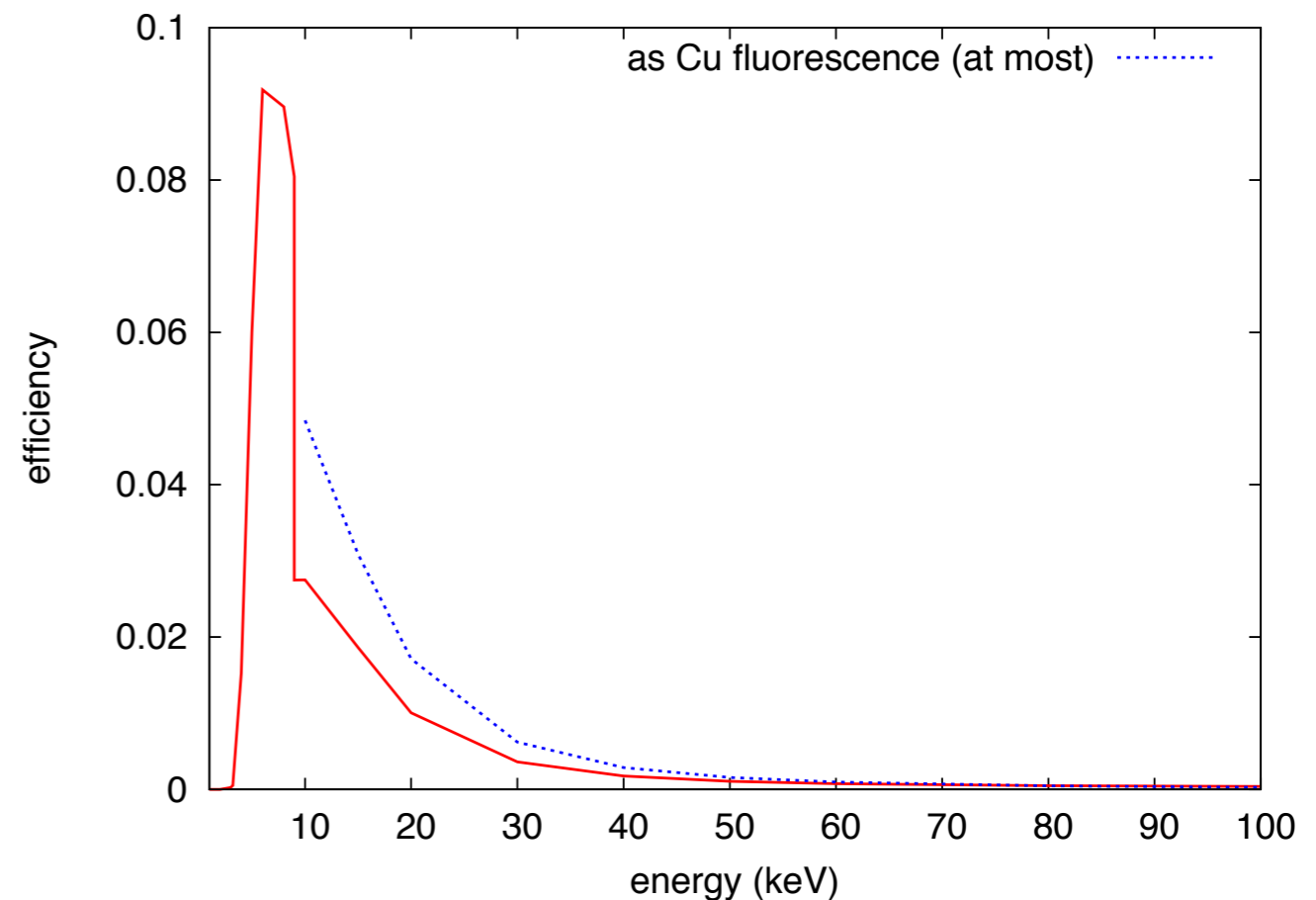
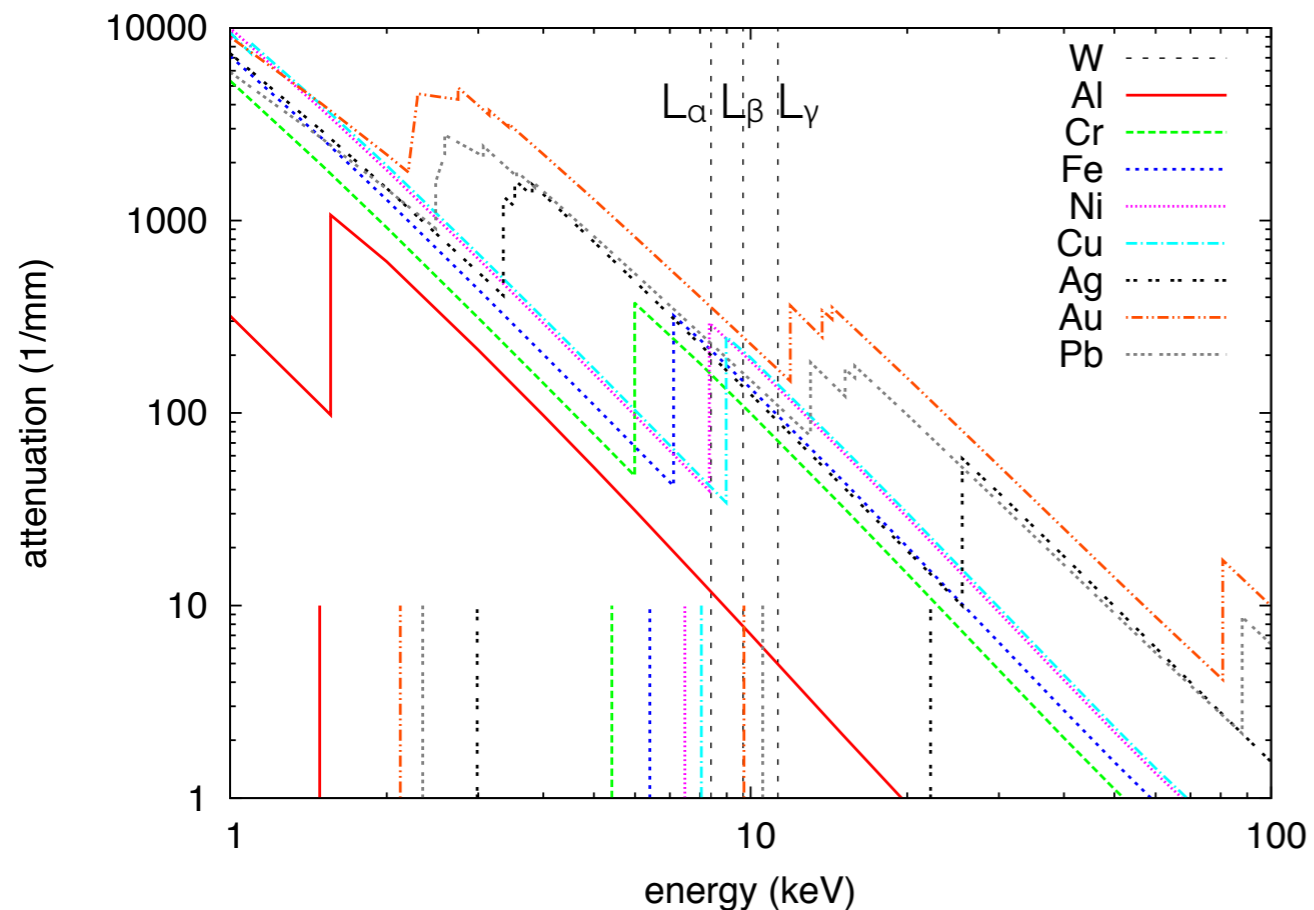
# Fluorescence



# What should be expected

W target:  
bremsstrahlung +  
characteristic lines

Limiting factor:  
low energy -> window and cathode  
high energy -> gas

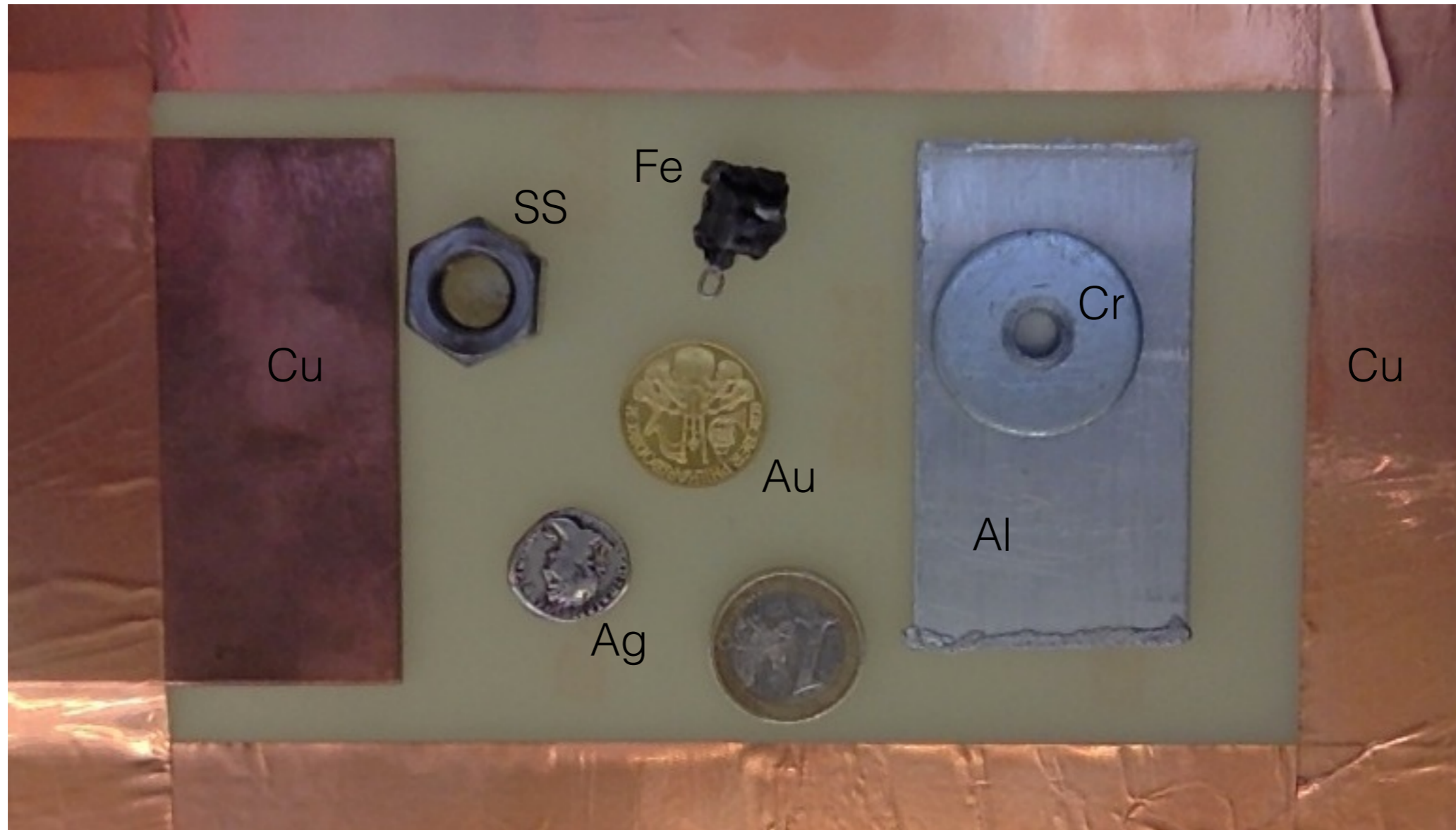


feasible:  
Cr, Fe, Ni, Cu

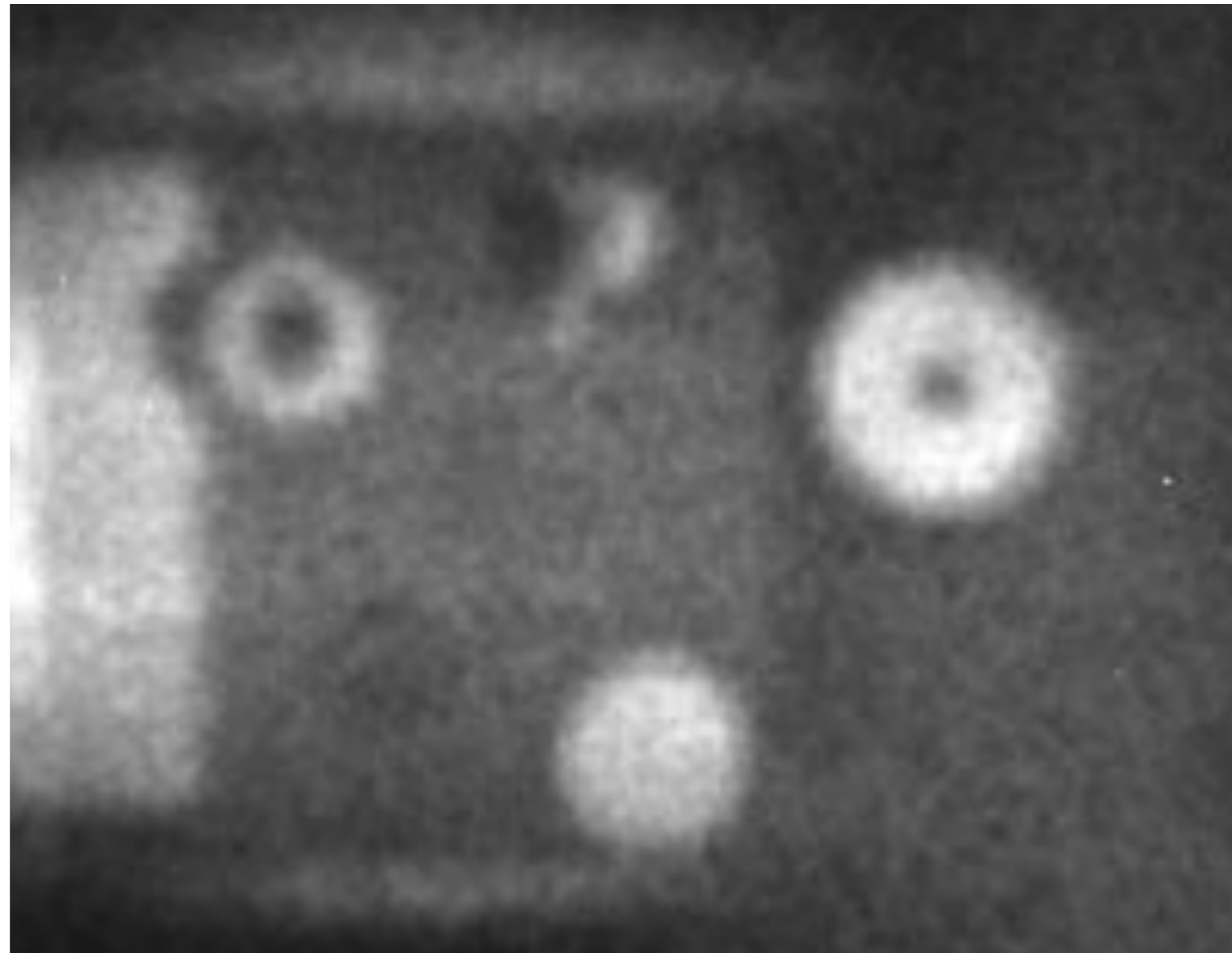
difficult:  
Au, Pb

more difficult:  
Al, Ag

# The painting (visible)



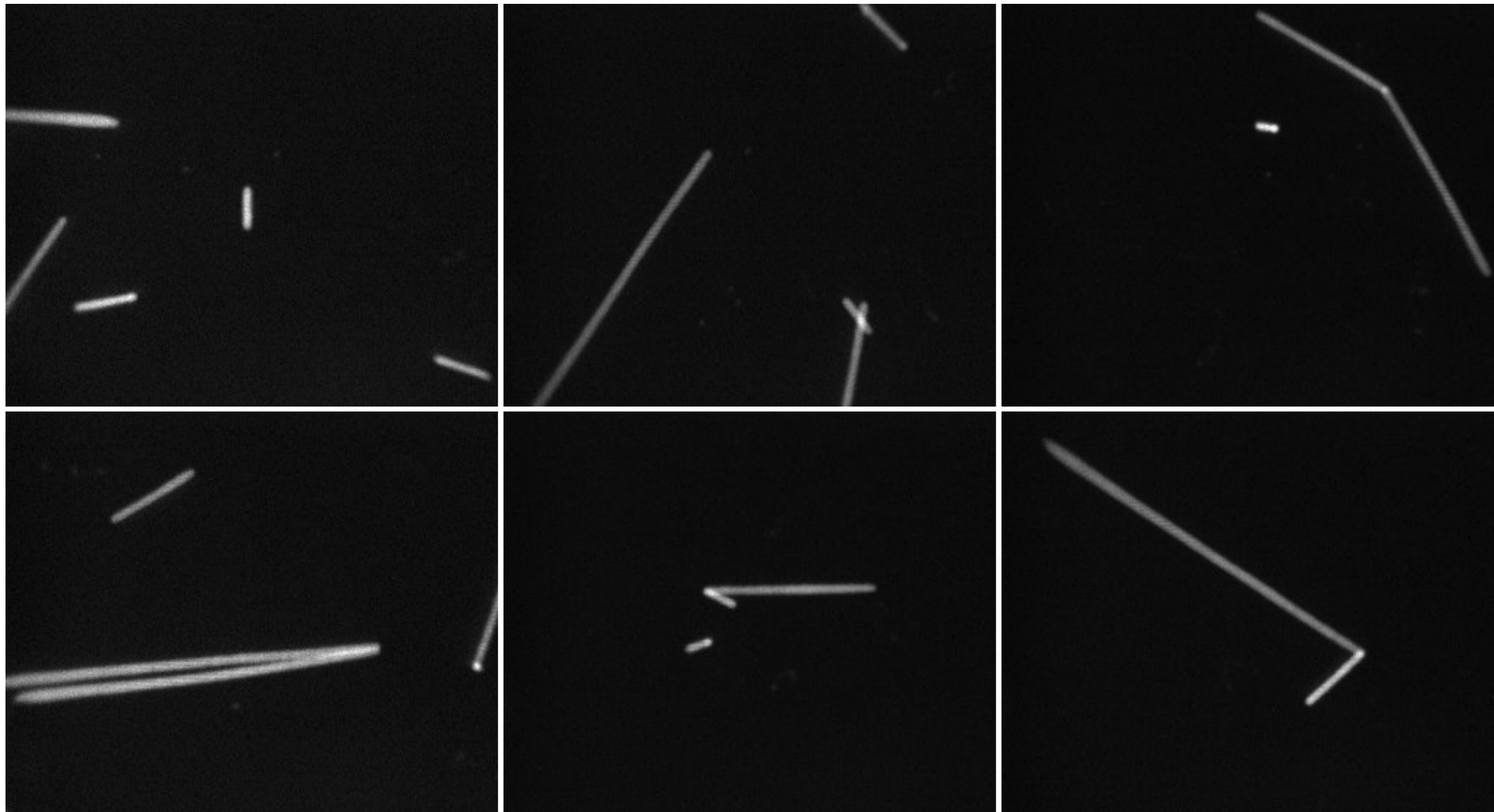
# The painting (X-rays)



$O(10\text{kHz})$  in 100s exposure

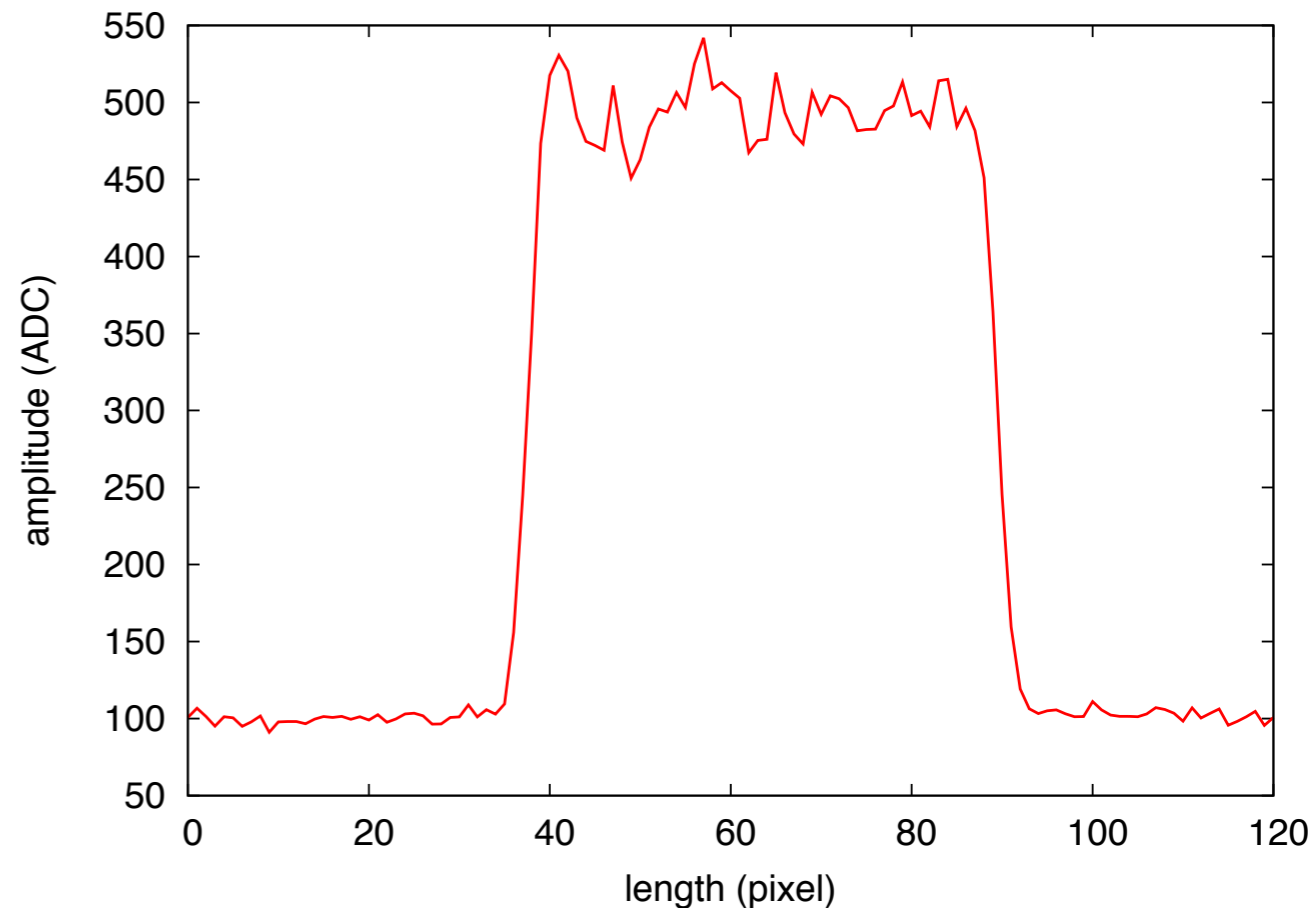
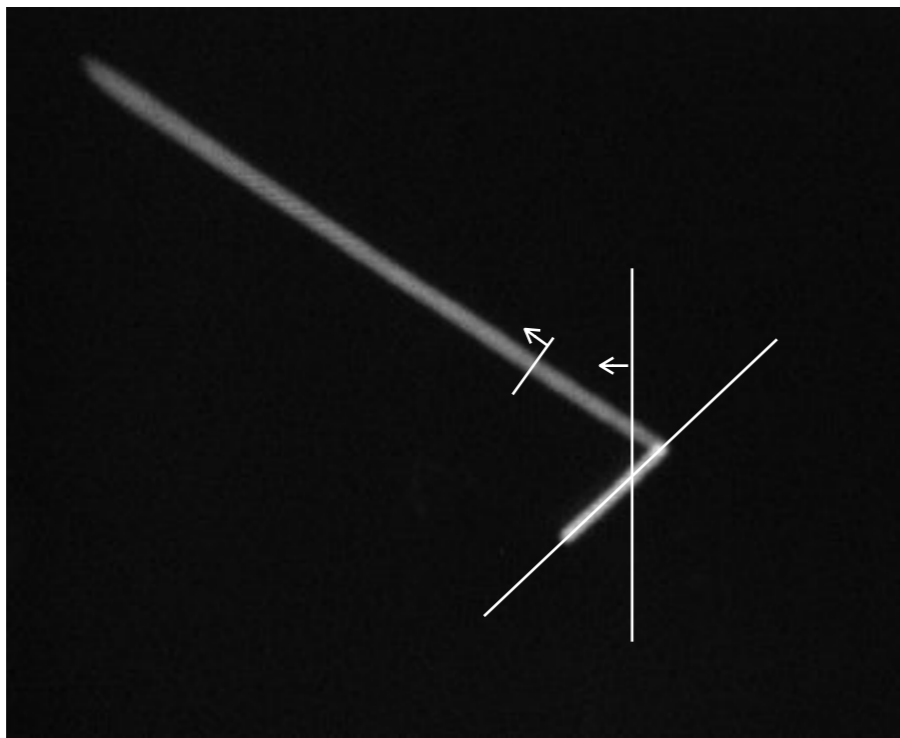
# Event by event: alphas

Settable GEM gain: increasing it

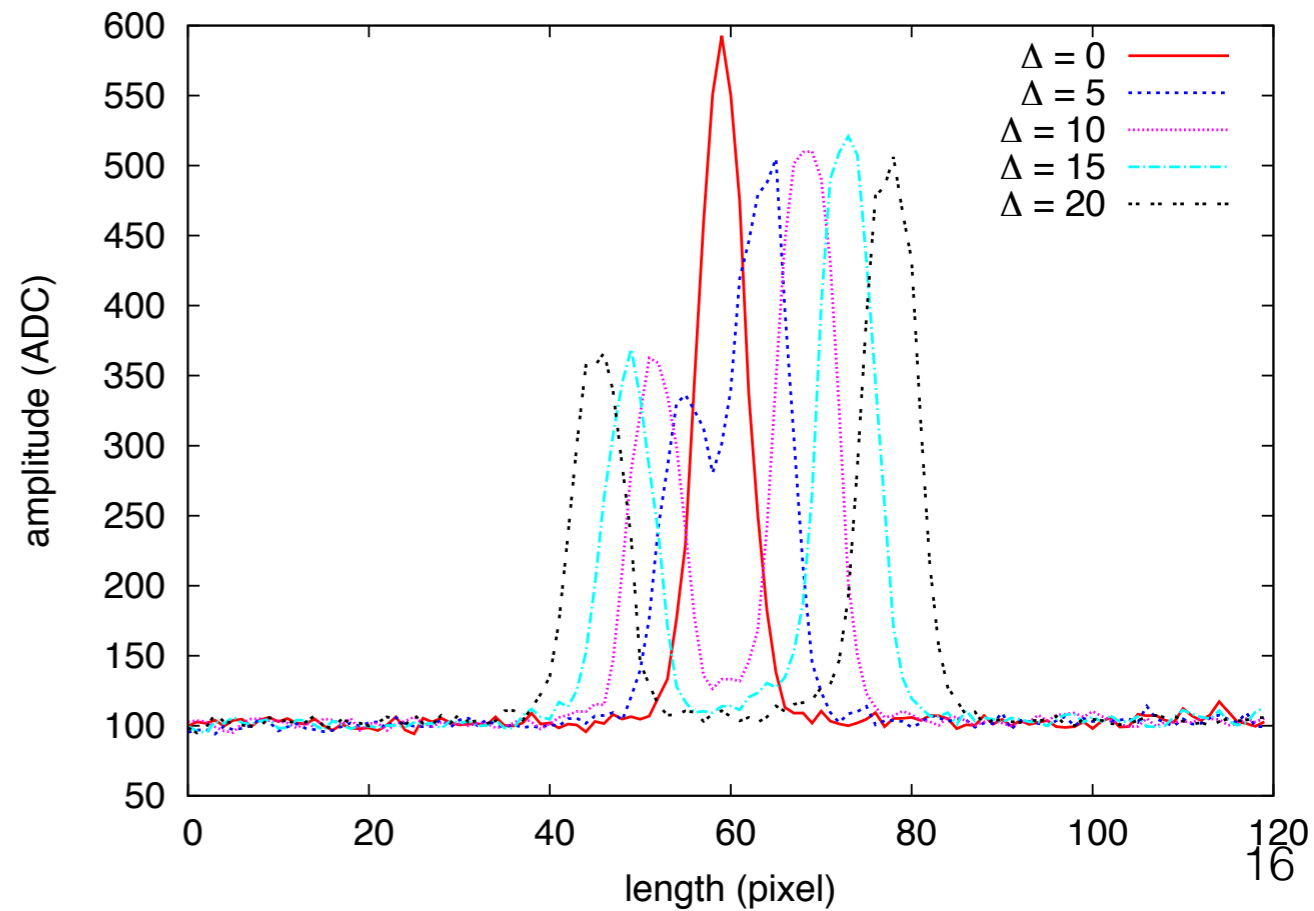
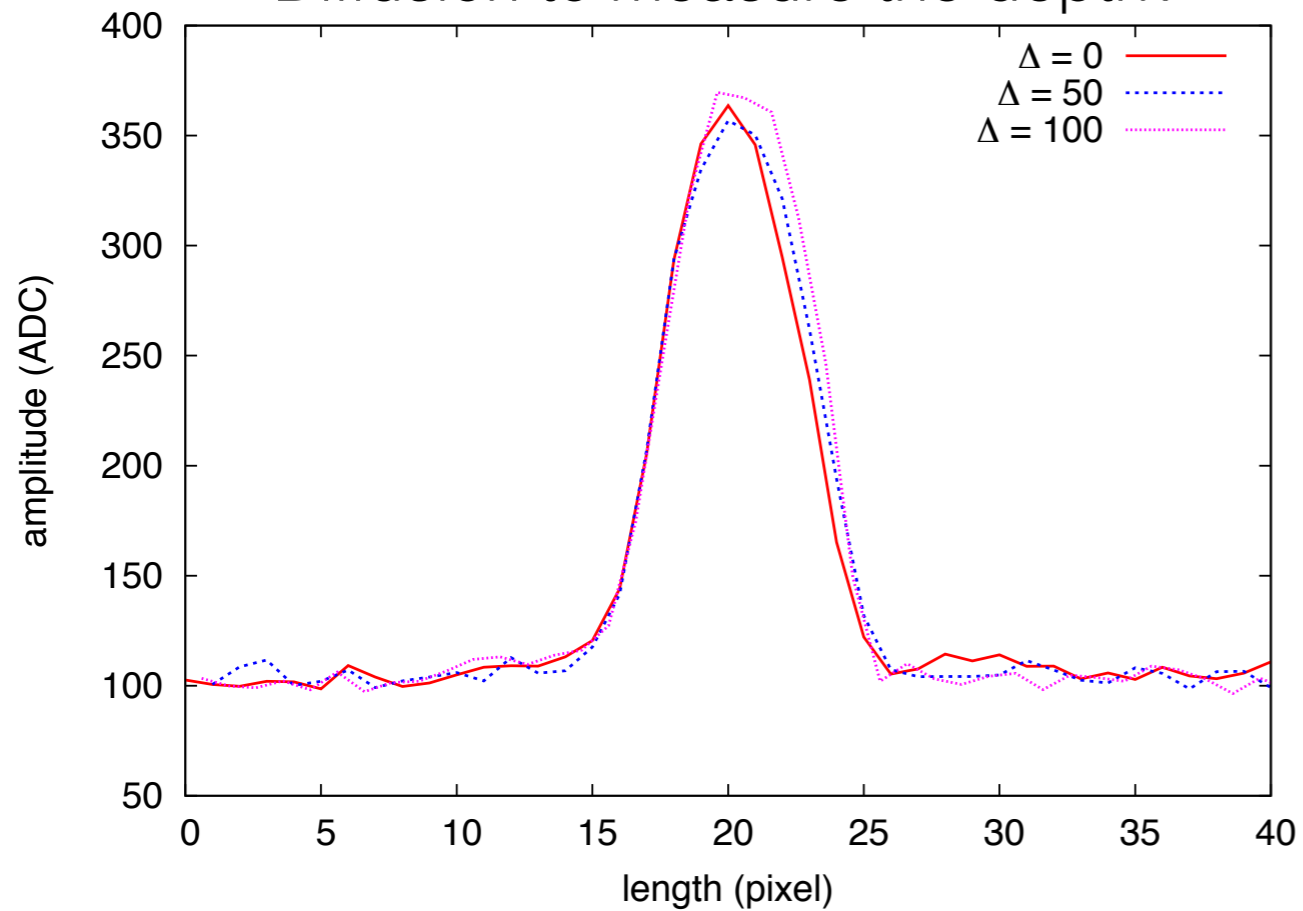


$^{220}\text{Rn}$  &  $^{216}\text{Po}$

# Possible alpha analysis



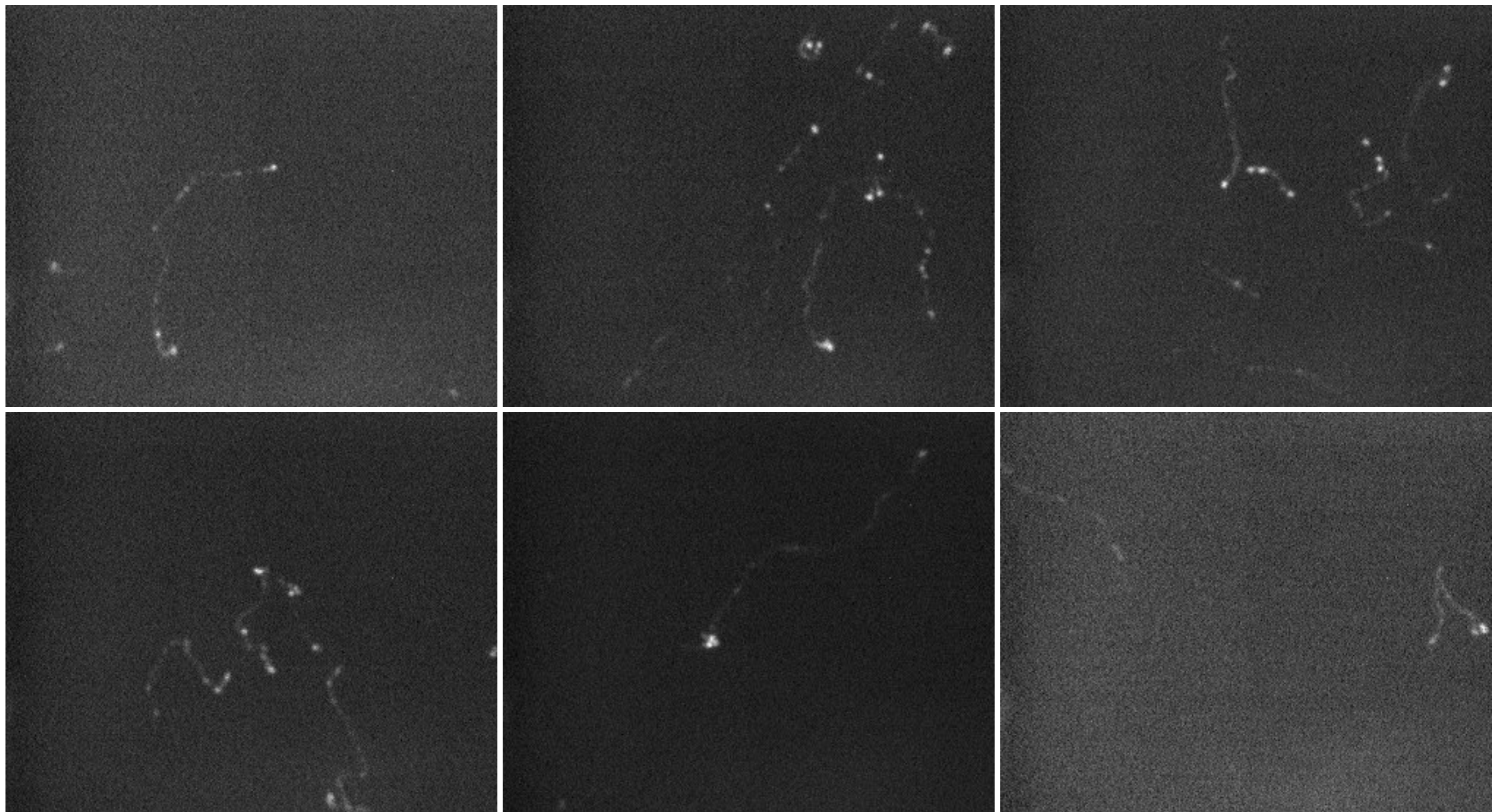
Diffusion to measure the depth?





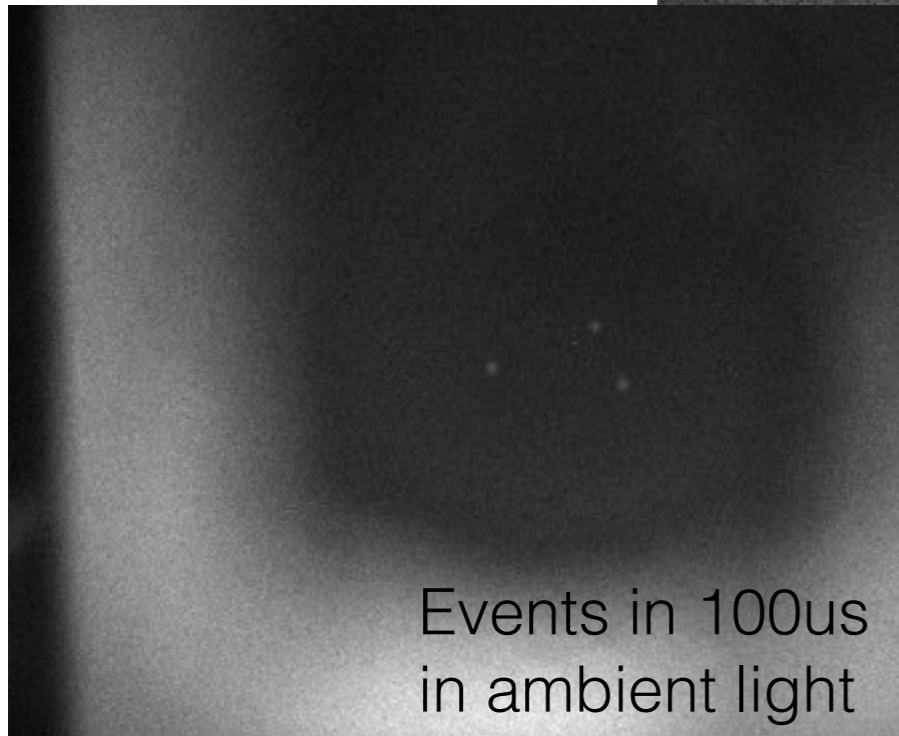
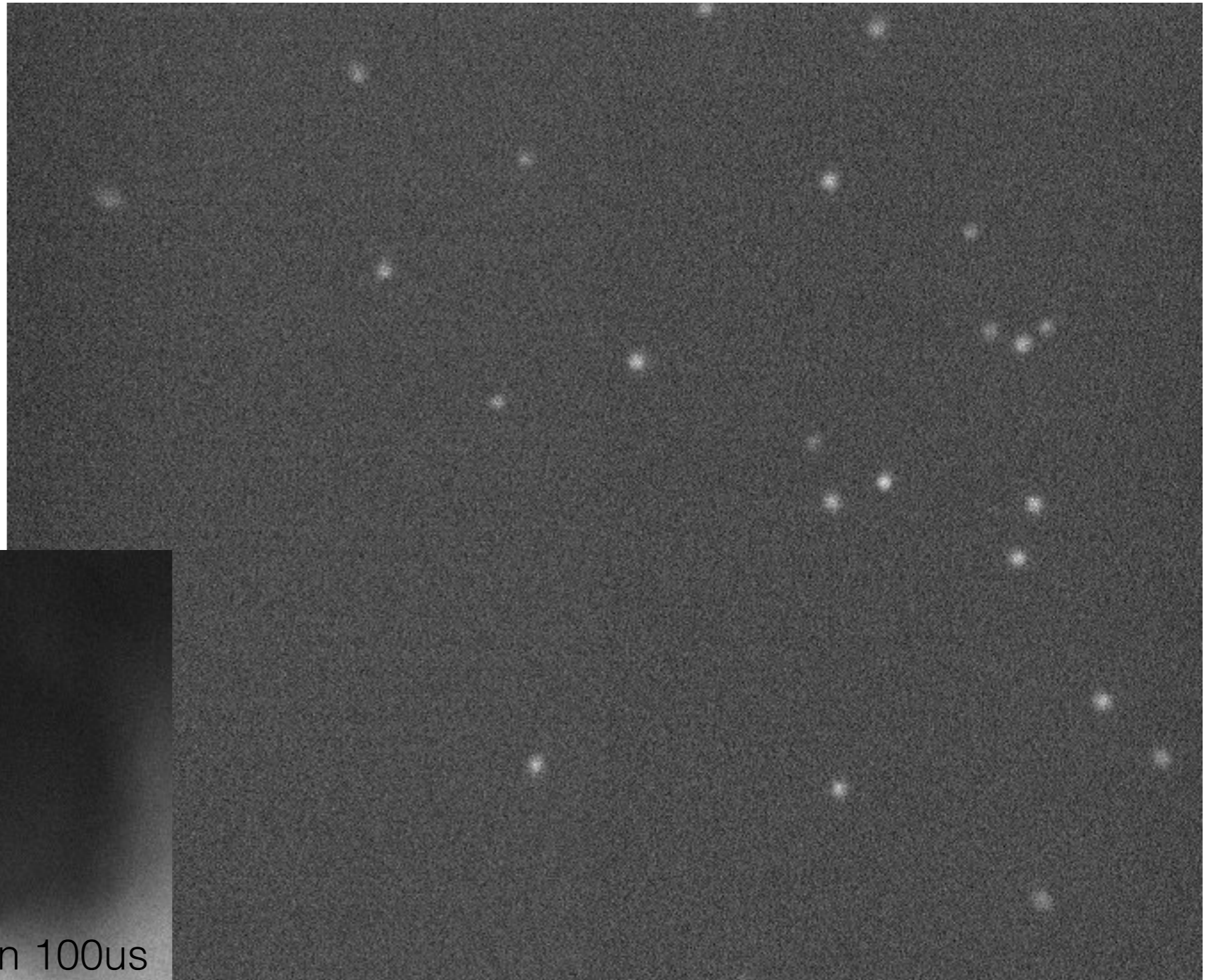
# Event by event: electrons

Settable GEM gain: increasing it more



Electrons from 125keV  $\gamma$ -rays from  $^{55}\text{Fe}$

# Event by event: X-rays



Events in 100us  
in ambient light

5.9keV X-rays from  $^{55}\text{Fe}$

# ImageJ

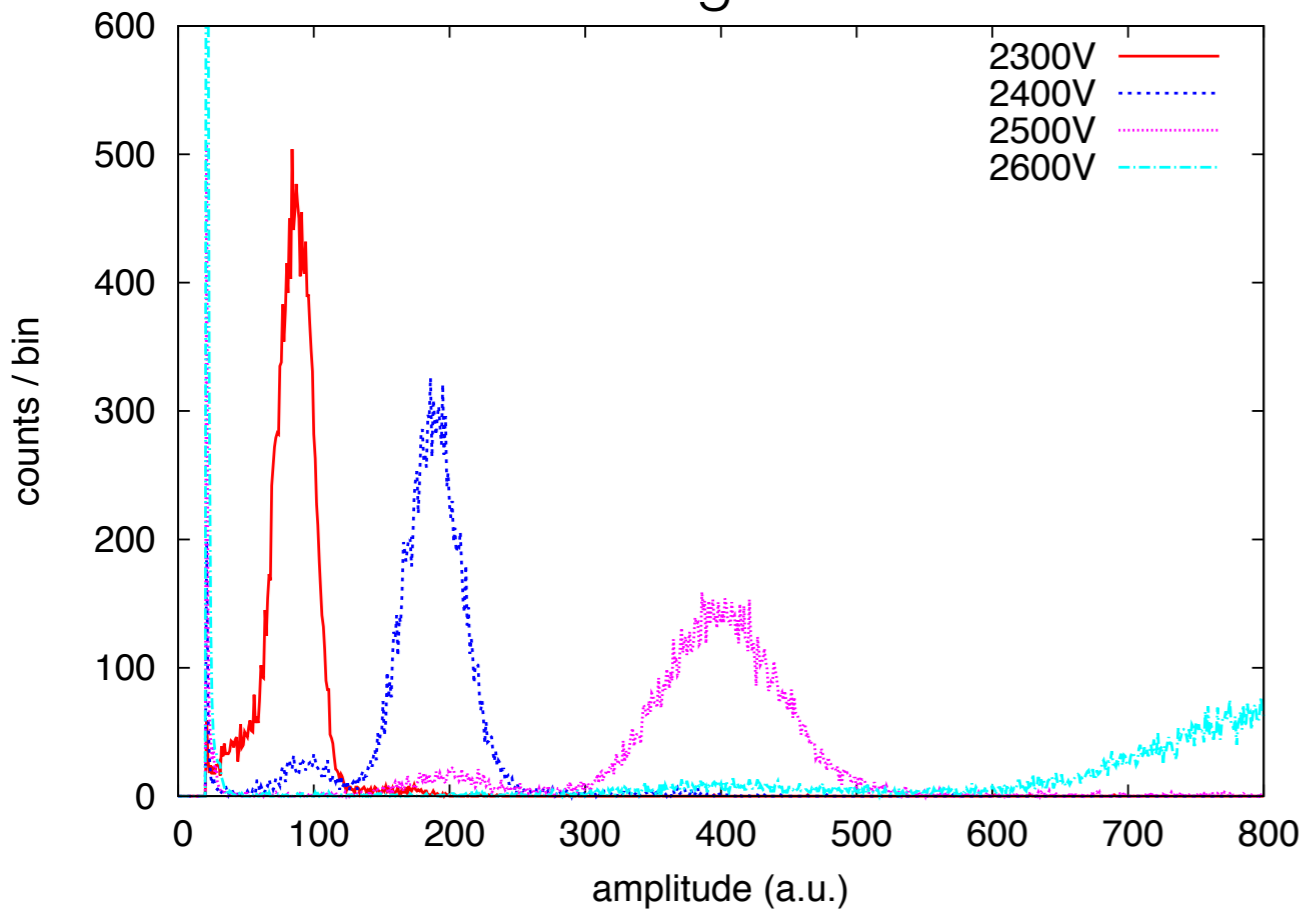
The screenshot displays the ImageJ interface with four windows:

- target.tif**: 336x275 pixels; 16-bit; 180K. Shows a dark image with three bright spots.
- tmp.tif**: 336x275 pixels; 8-bit (inverting LUT); 90K. Shows the same image as target.tif but with an inverted grayscale and added noise.
- Results**: A table with the following data:

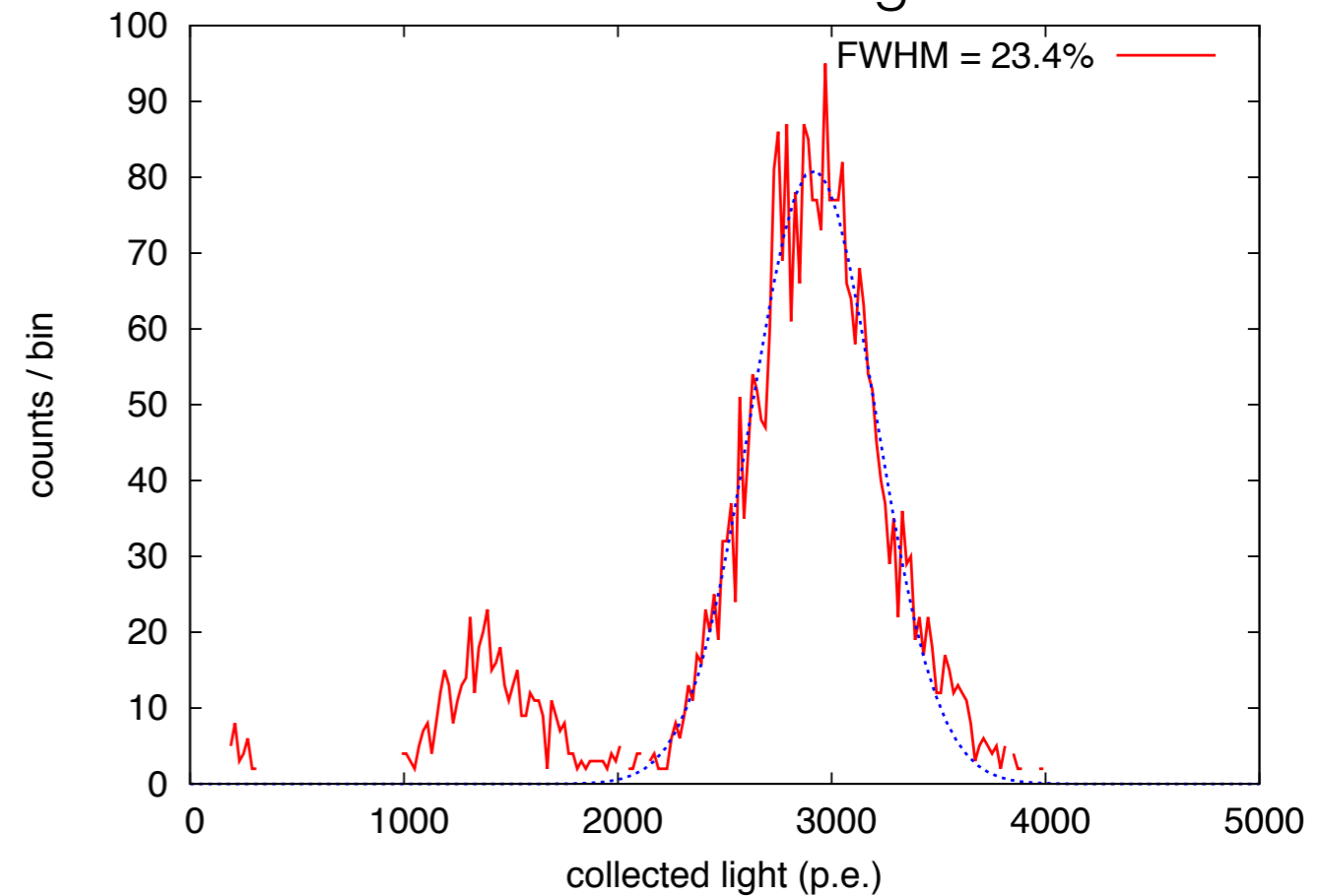
	Area	Mean	StdDev	Mode	Min	Max
1	41	135.317	31.898	107	103	225
2	25	122.400	18.108	104	103	175
3	51	134.020	32.192	103	102	215
4	43	146.535	45.997	105	103	255
- Drawing of tmp.tif**: 336x275 pixels; 8-bit; 90K. Shows the original image with the three spots highlighted by red and white bounding boxes.

# The spectrum

from charge readout



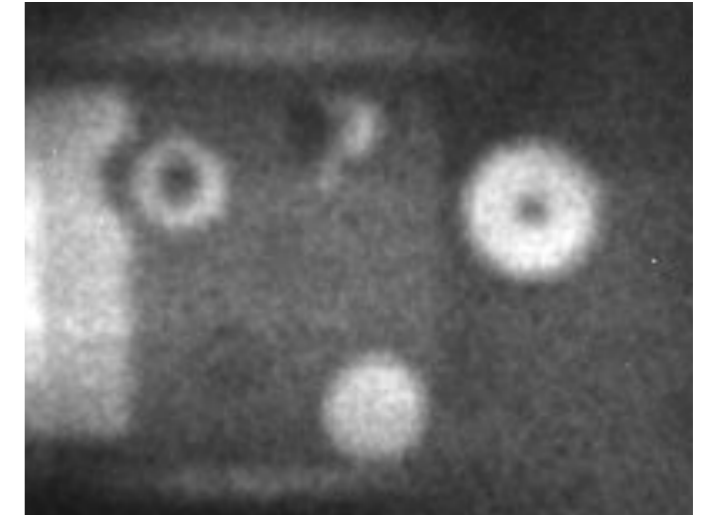
from CCD images



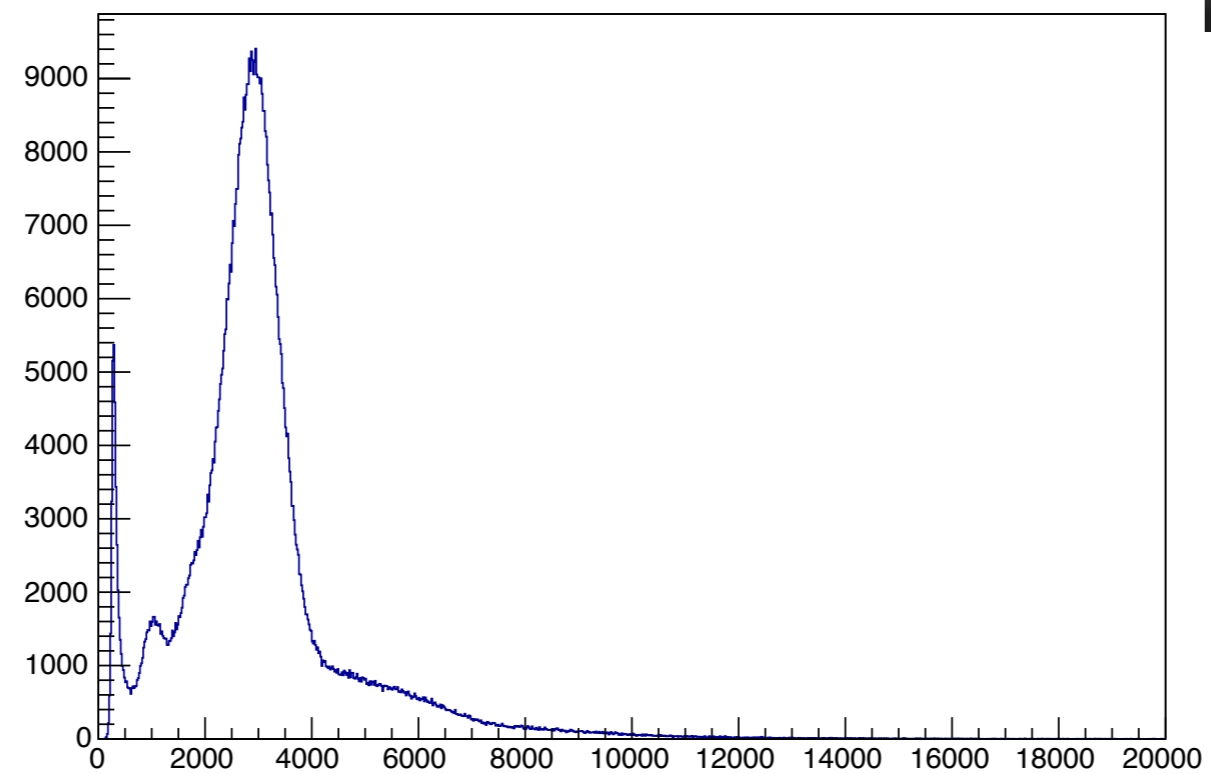
With respect to the charge mode, the escape peak in the light mode is more abundant:  
'Escape' X-ray interact in the volume, but it's a distinct event

# Event by event

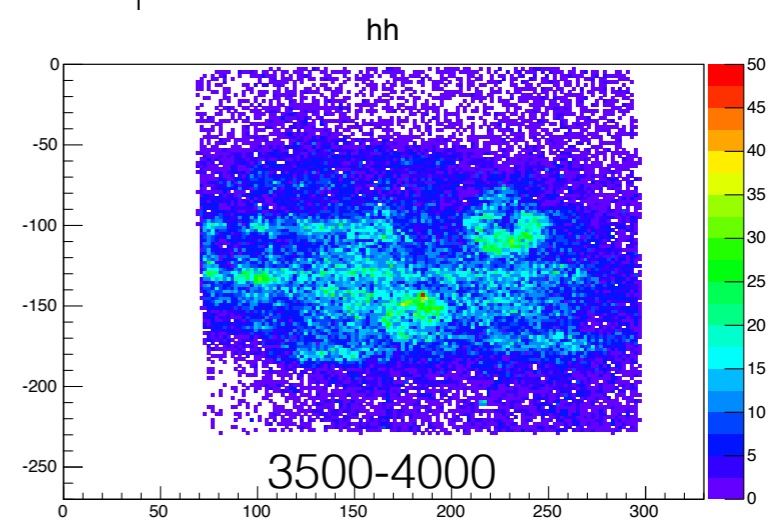
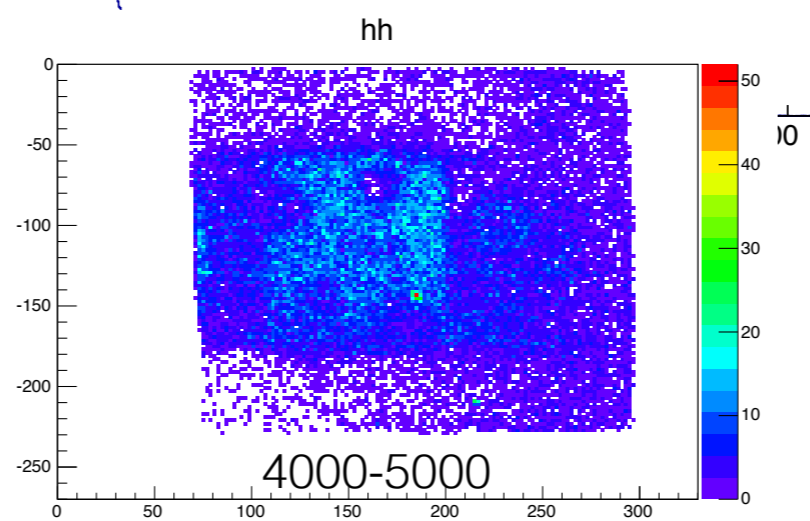
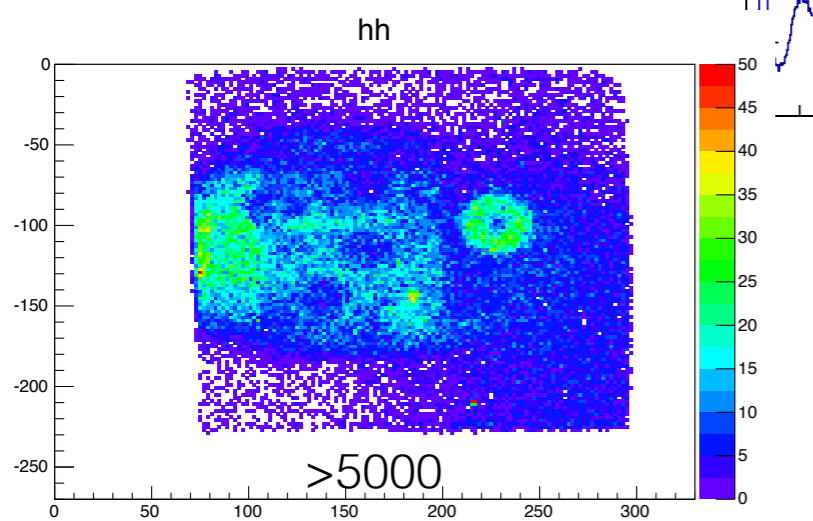
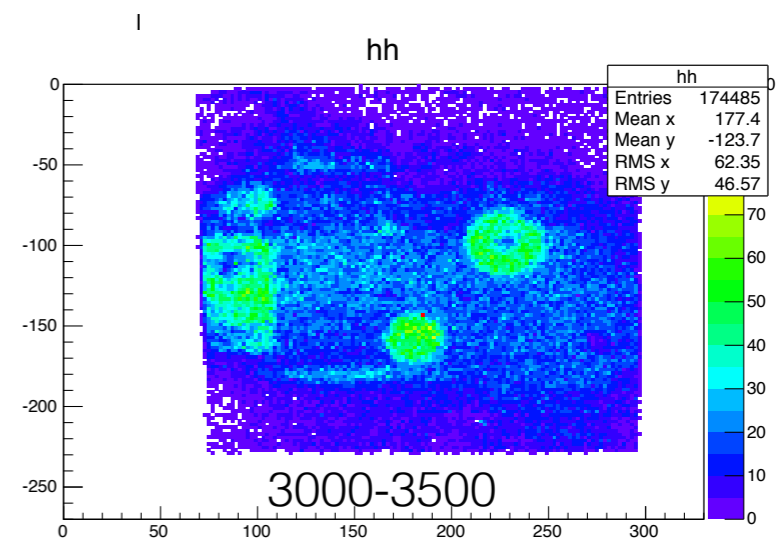
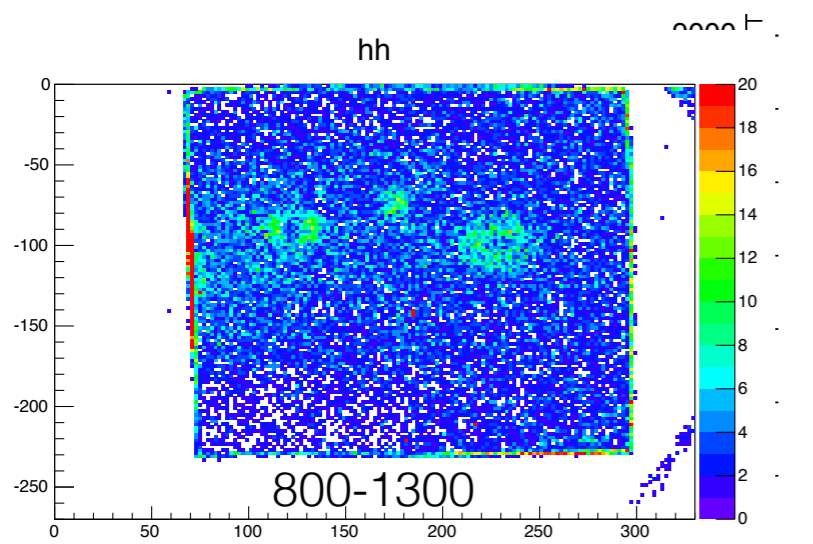
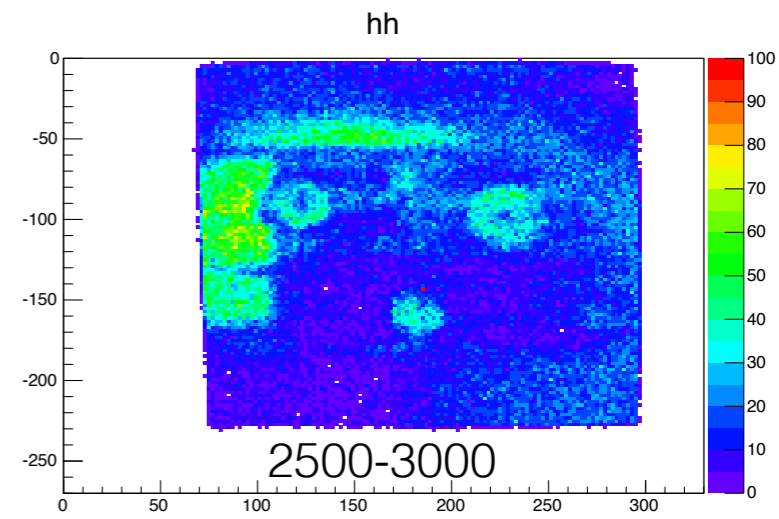
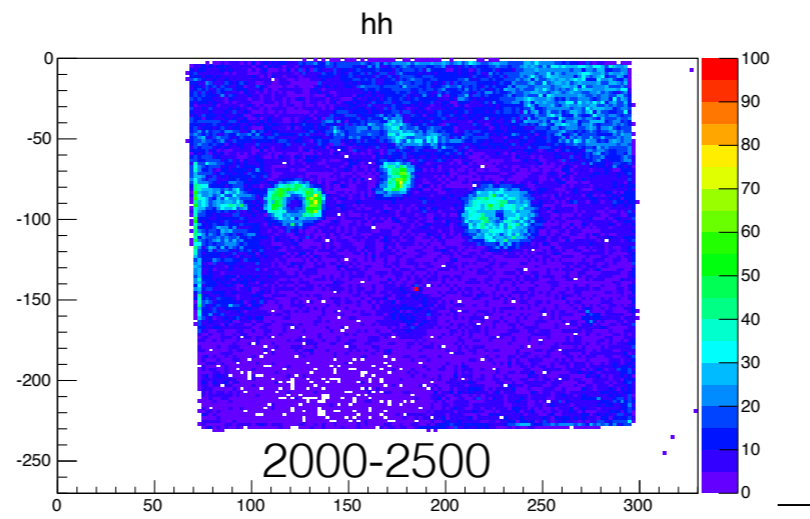
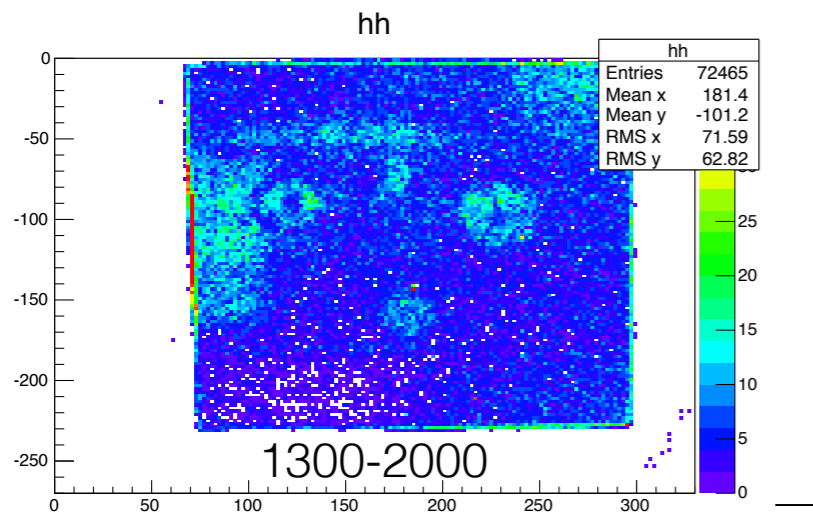
An application



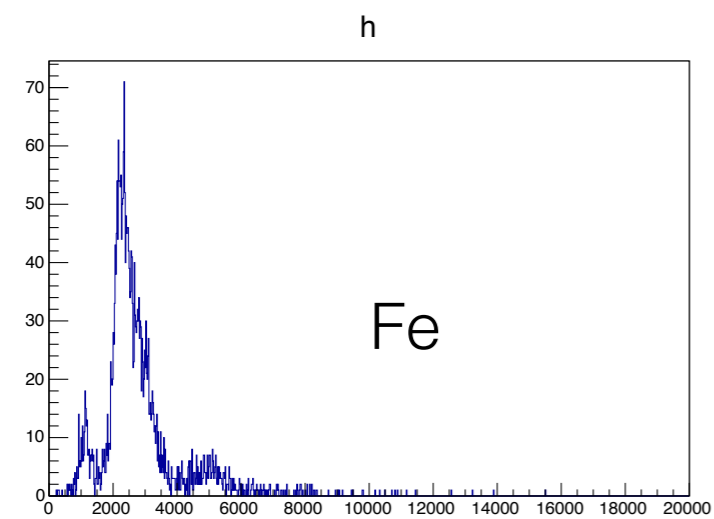
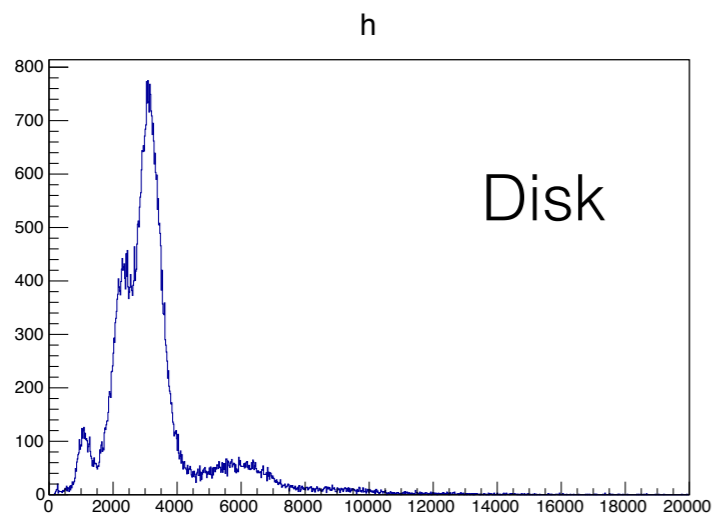
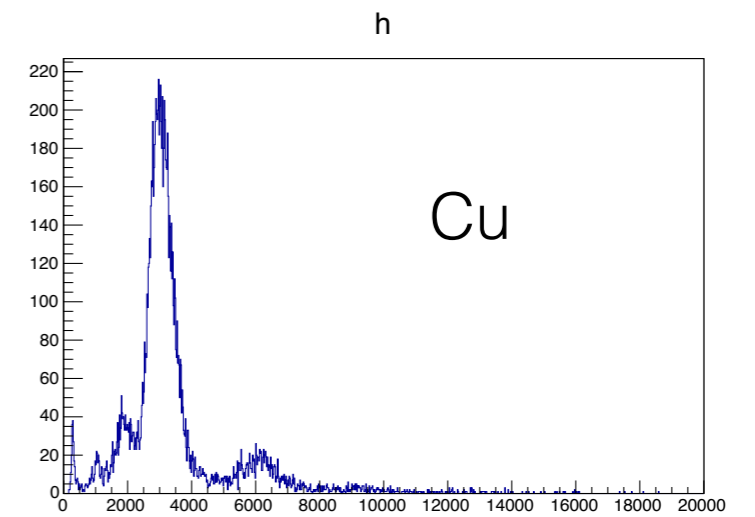
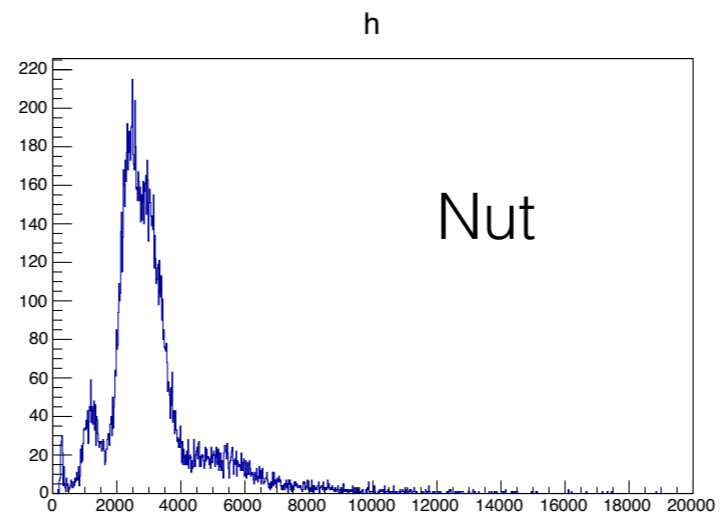
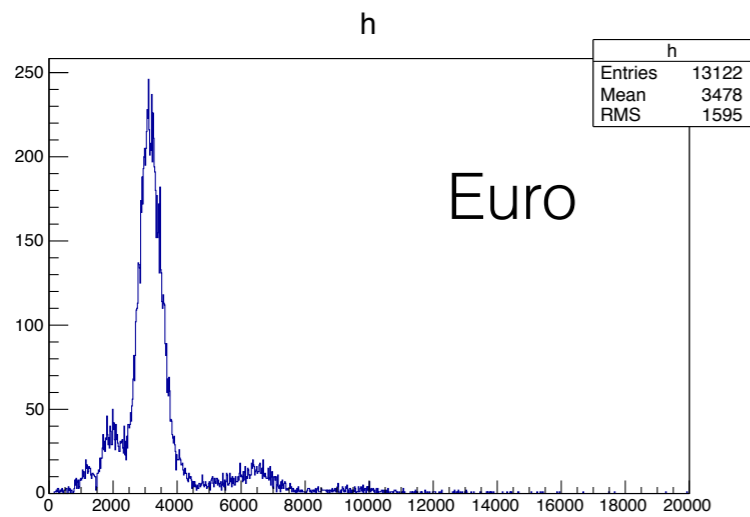
h



# Energy cuts



# Position cuts



# Advantages

Simplicity: like taking a picture

Robustness: as a device off-the-shelf

Versatility: several uses and environments



# What it does

Single events down to MIPs

Radiography - imaging and energy resolved

CT and 3D imaging

Fluoroscopy

Fluorescence - imaging and energy resolved

# Possibly what else?

Crystallography - imaging and energy resolved

UV imaging

Neutron imaging

Gamma imaging

...

# Possible applications

Nuclear Physics experiments with TPCs

Space resolved X-ray fluorescence

X-ray crystallography

Medical imaging

Educational purposes

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