



# Experimental Characterization of a Fast X-Ray Spectroscopic Imager Module for Real-Time Contaminants Detection

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# Technology transfer collaboration



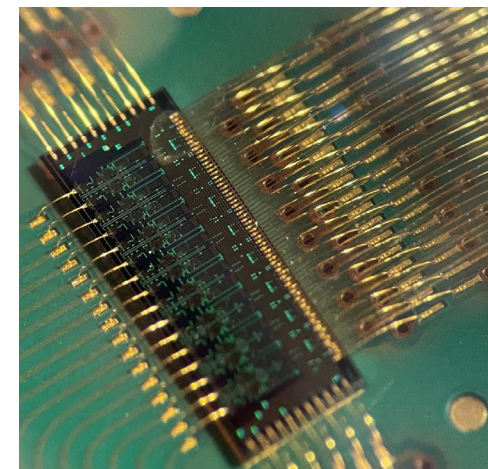
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- Knowledge-intensive high-tech SME based in Milan
- XSpectra® inspection technology for high and low-density contaminants:
  - Real-time analysis
  - X-ray imager + computer vision neural networks

<https://www.xspectra.eu/>

<https://x-next.com/>

- Goal: custom **detector** + **electronic read-out** solutions for XSpectra®
- Task: **New read-out ASIC** design and testing



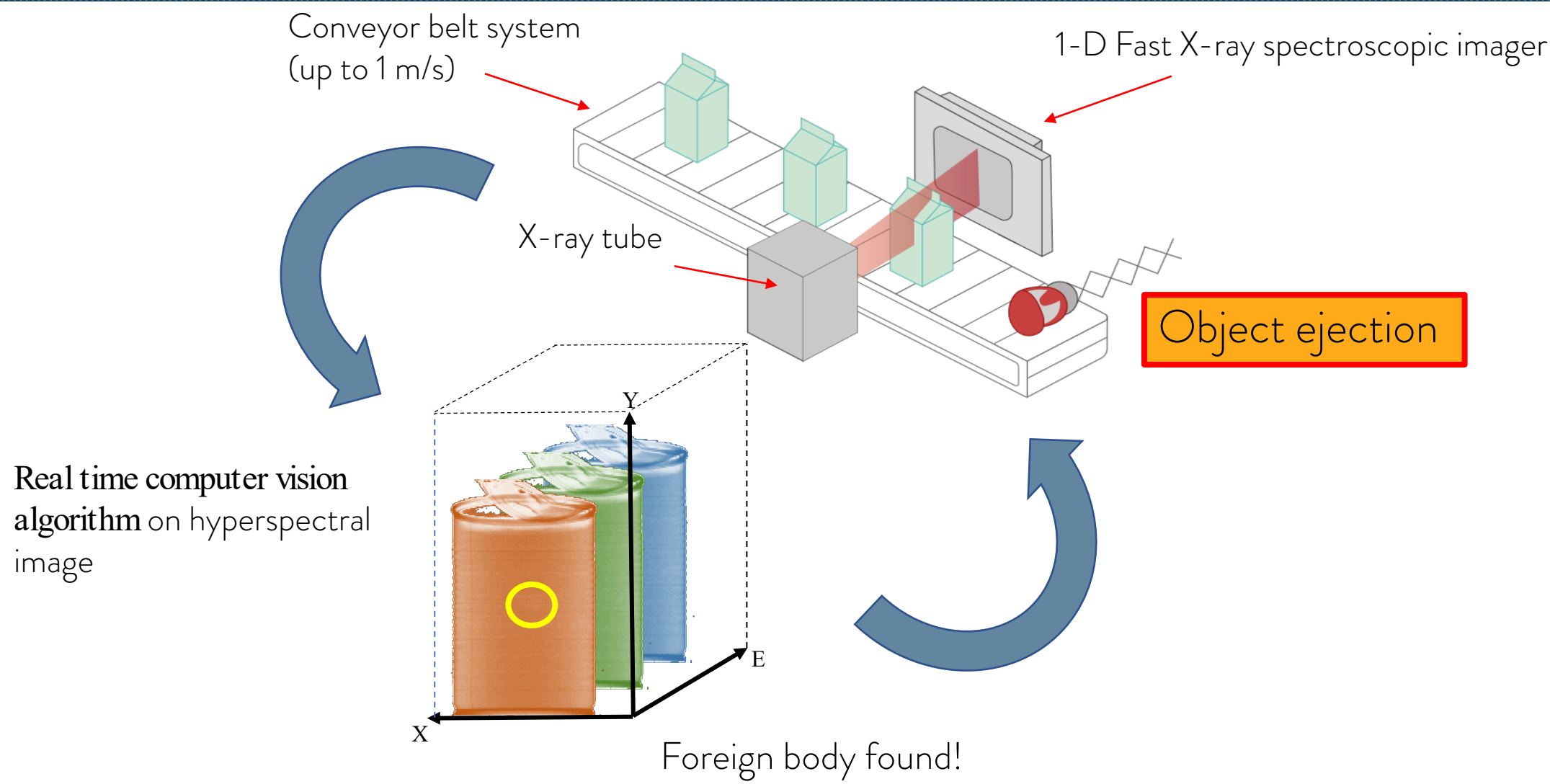
- XSpectra® hardware overview and application requirements
- Experimental results
  - Low-rate spectroscopic characterization
  - High-rate tube test
  - Test case: thin plastic fragments in yogurt cups



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# Principle of operation



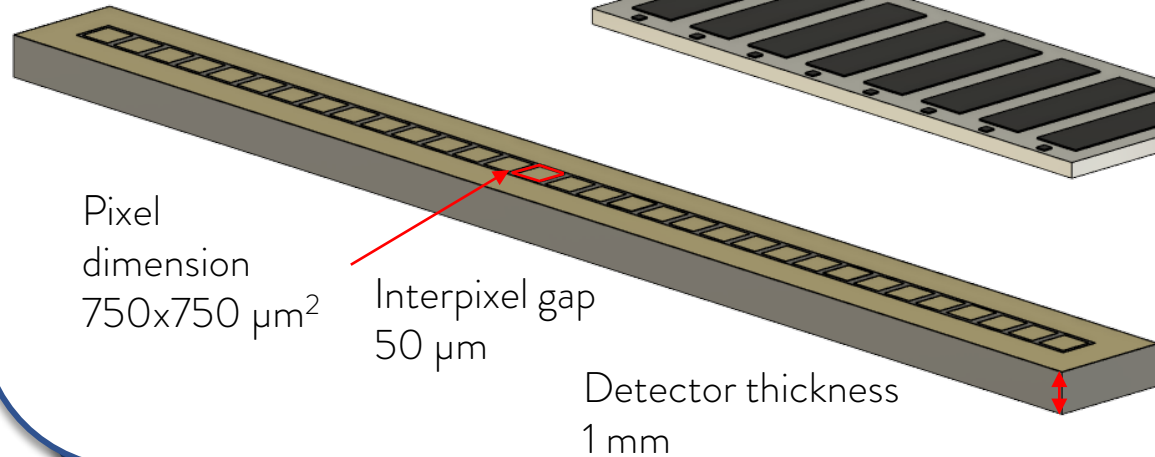
# Hardware overview

## CORE MODULE

**X4**  
8-channel analog read-out  
CMOS ASIC

Off chip ADC + Full Custom DSP  
(pulse shaping, pile-up logic, PHA)

32-pixel linear CdTe array



**4 modules under test  
(128 pixel in total)**



## Application Requirements

- Energy-resolved photon counting (ERPC) capability with energy 1024 bins.
- Wide energy dynamic range for both low and high-density foreign body detection.
- High-speed spectra acquisition (few ms/frame).

## Read-out ASIC

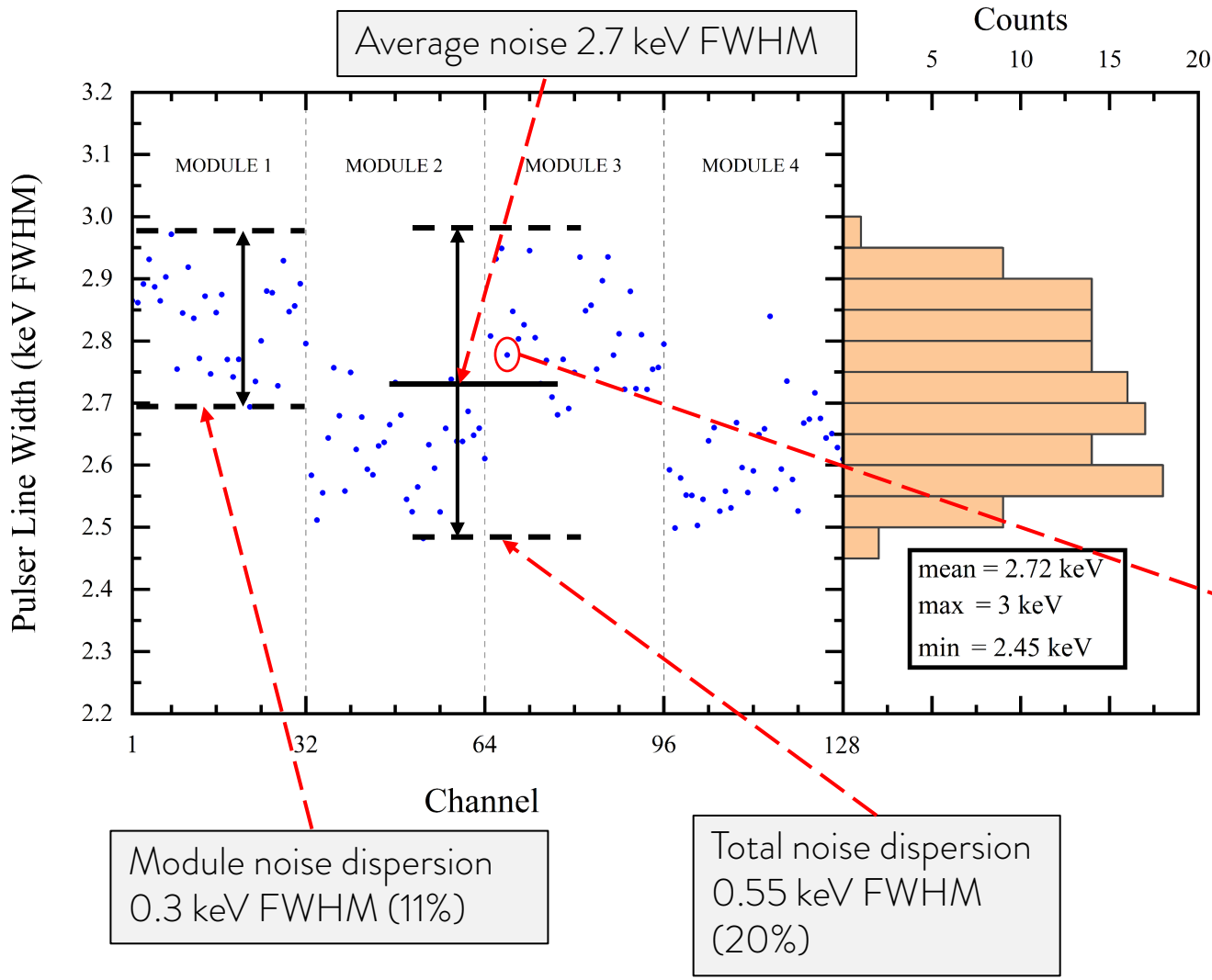
Parameter	Specification (at system level)
Input Capacitance (detector+connection)	$\cong 1 \text{ pF}$
Energy range	5-200 keV
Equivalent Noise Charge	< 290 el. r.m.s. (3 keV FWHM on CdTe)
Peaking time	< 100 ns
Analog signal rise time	30 ns
Linearity error	< $\pm 1\%$
Power Consumption	< 20 mW/channel

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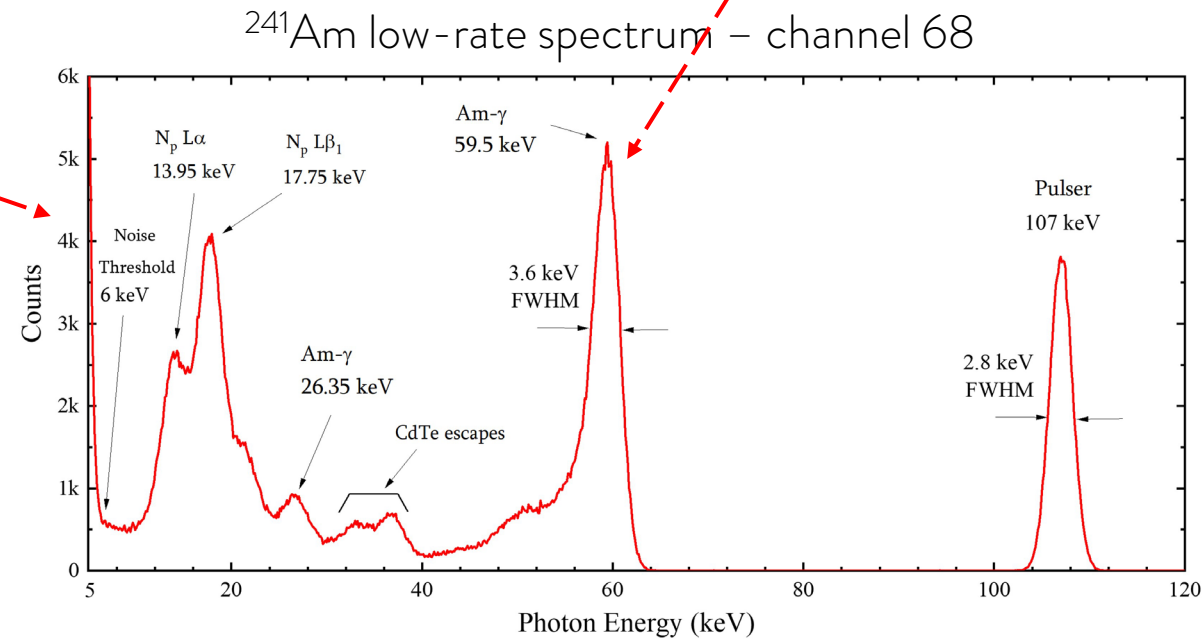


# Energy resolution



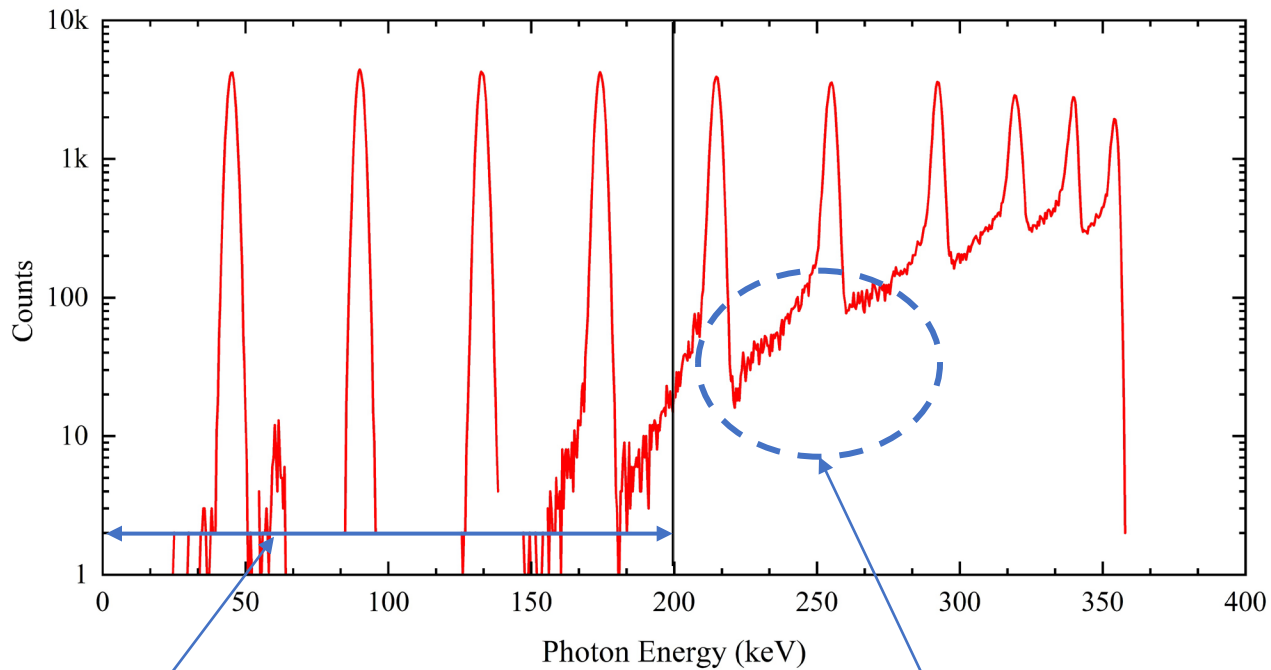
Test condition:  
 $T = +30\text{ }^{\circ}\text{C}$   
 $\tau_{\text{peak}} = 60\text{ ns}$

6% Relative FWHM  
 @ 59.5 keV



# Linearity

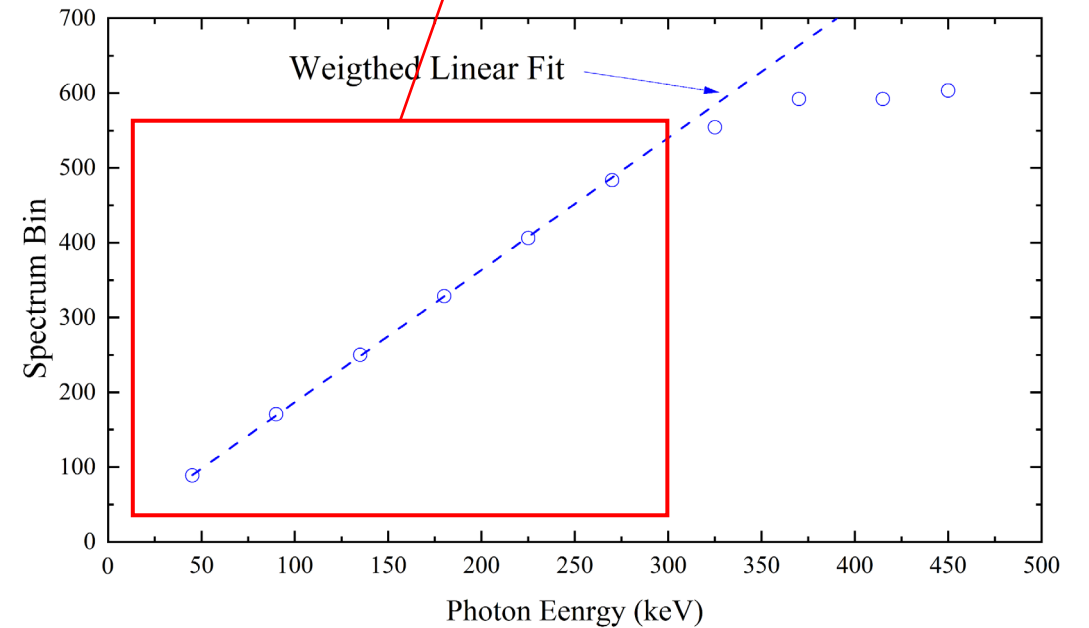
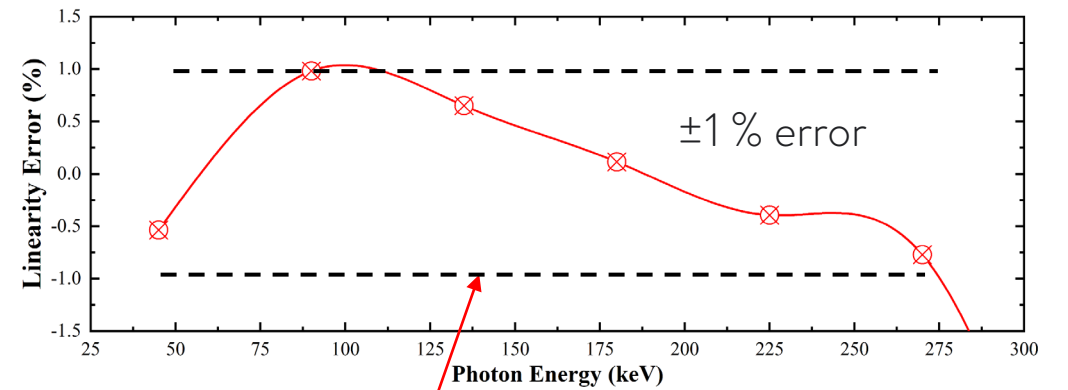
Pulsers equally spaced (45-450 keV range)



$^{241}\text{Am}$   
source

Operating range 200 keV

Random amplitude error  
associated with waveform  
sampling



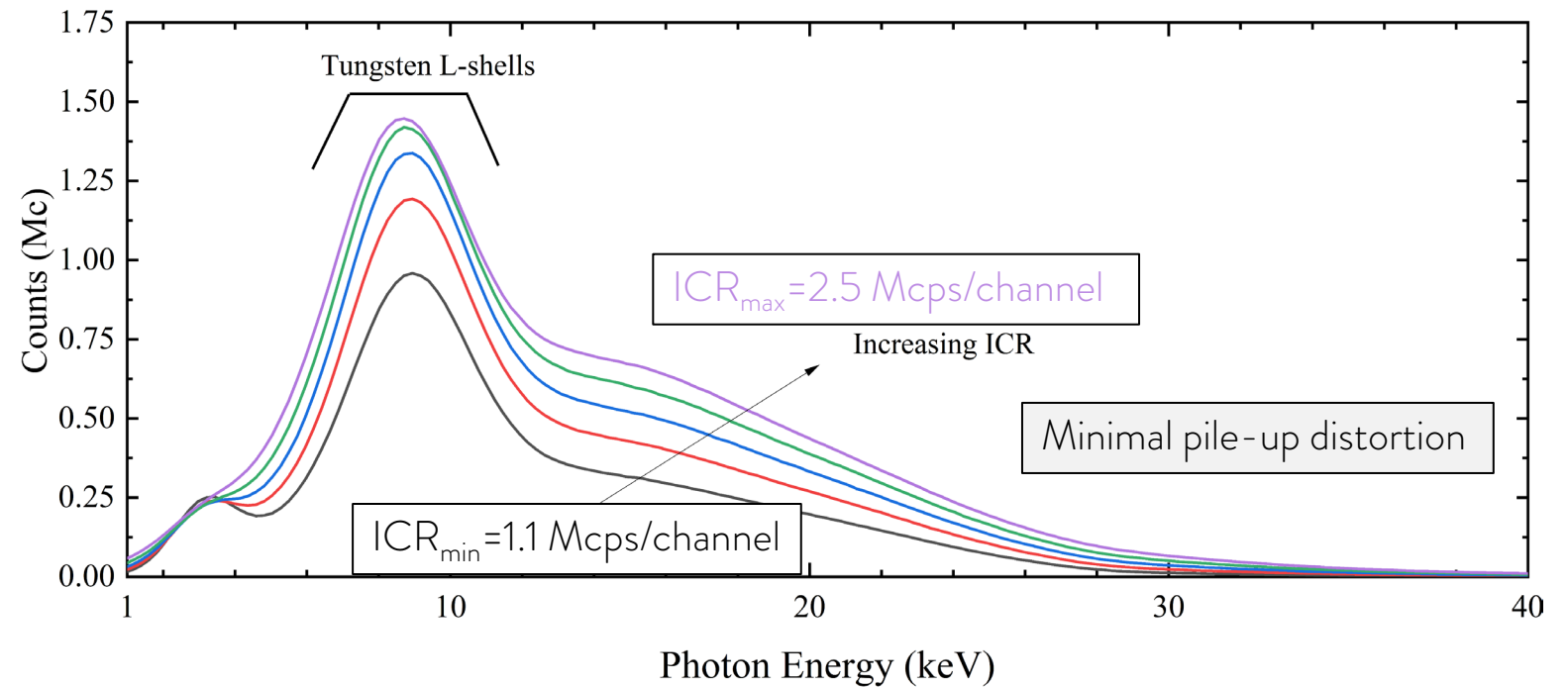
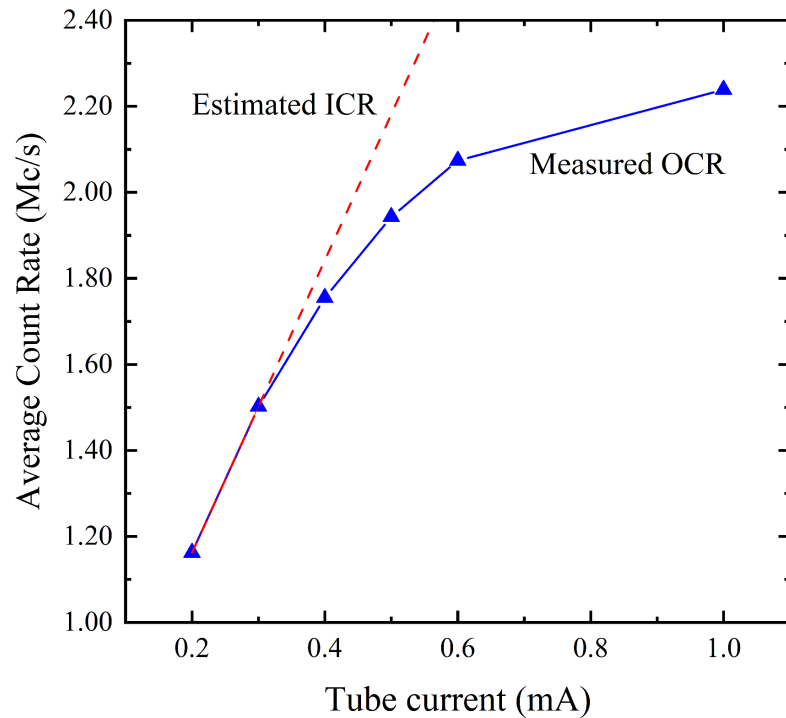
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# High-rate tests

Tungsten anode X-ray tube –  $V_{\text{tube}} = 30$  kV

X-ray tube high-rate spectra – channel 68



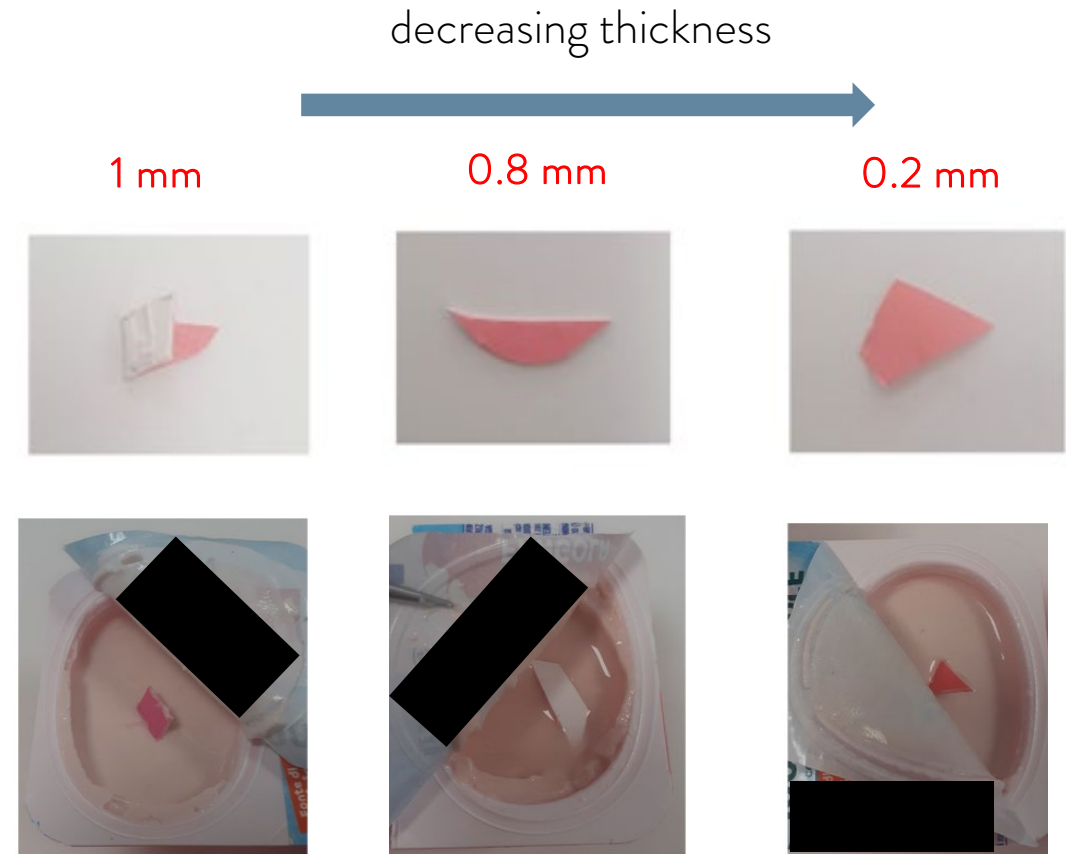
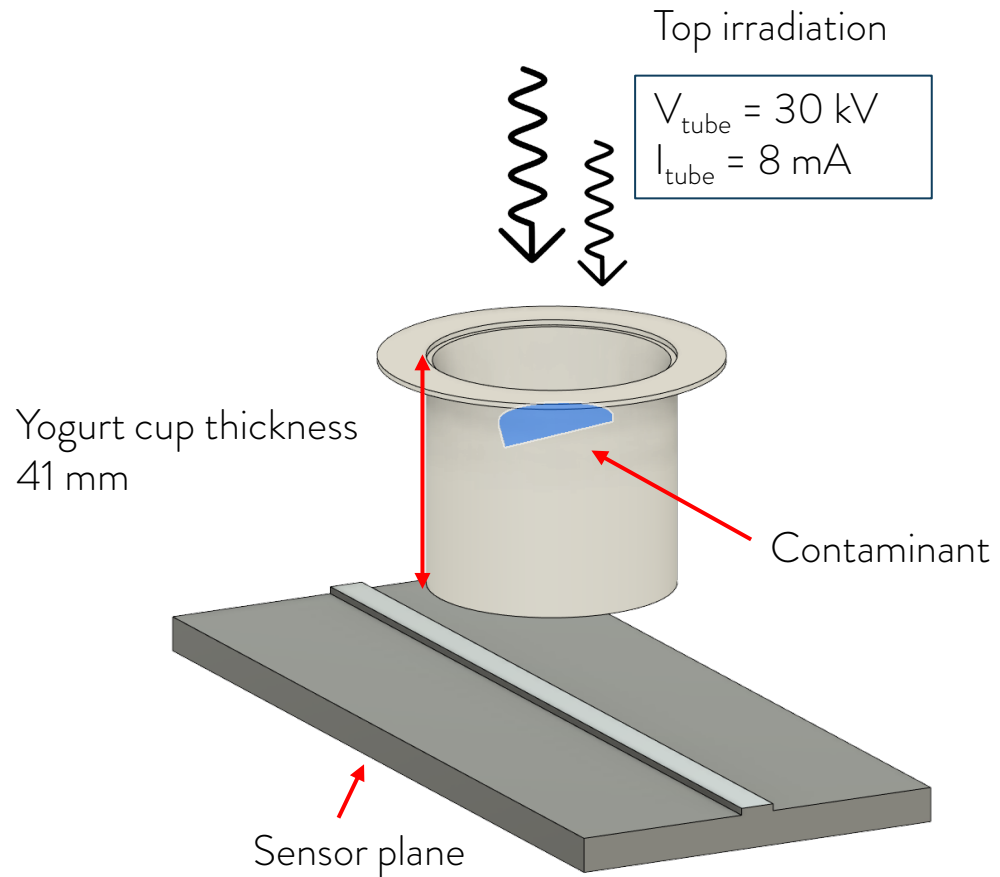
Maximum counting capability (Energy resolved) : 2.2 Mcps/channel - 3.9 Mcps/mm<sup>2</sup> - 281 Mcps for the total array



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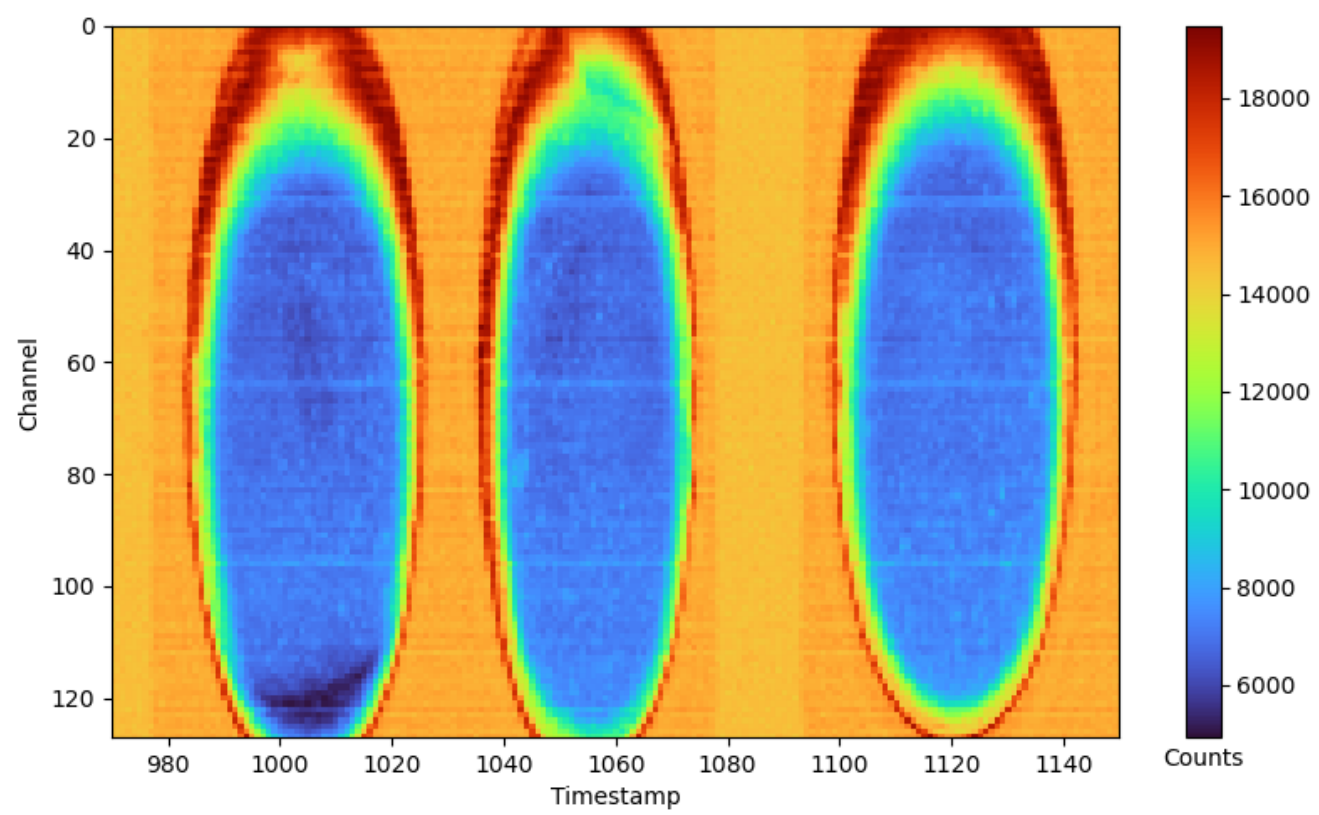


# Test case: experimental set up

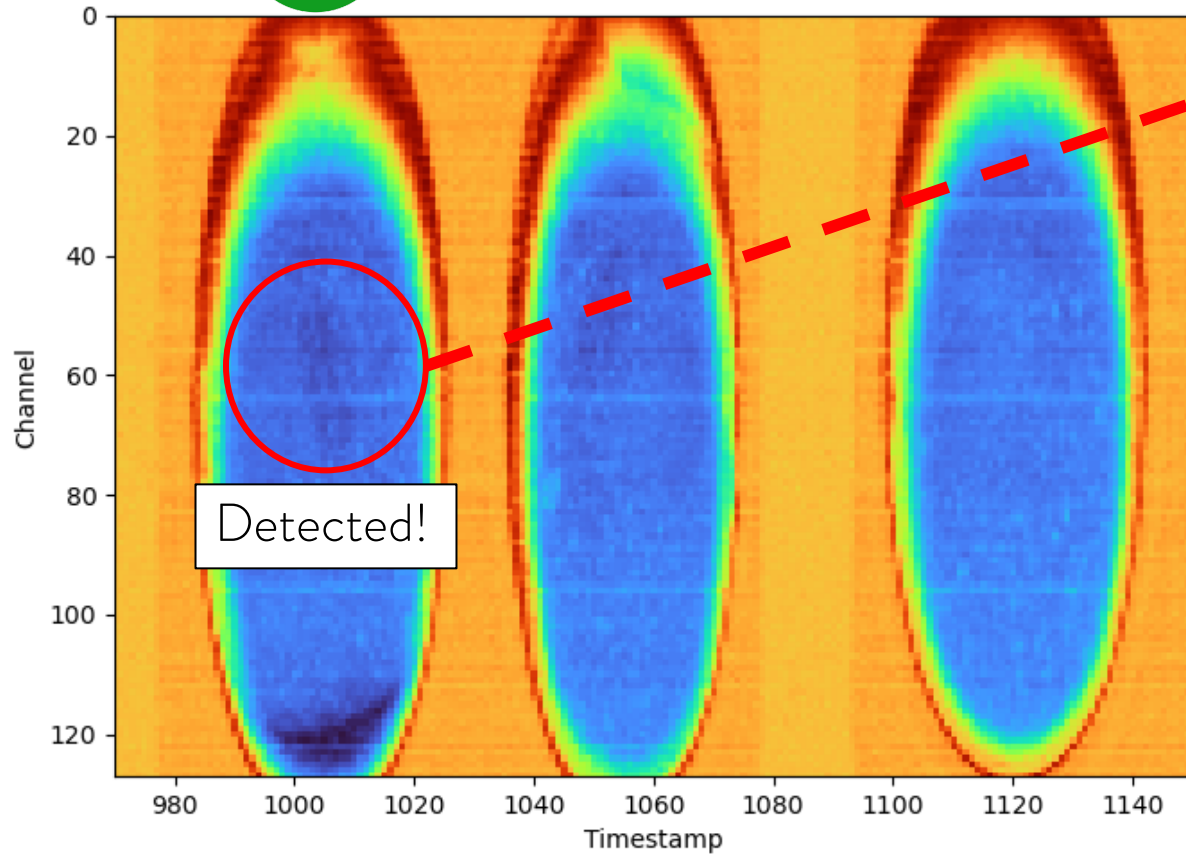


# Test case: acquired image

- Raw image (just background calibration applied)
- Exposure time 7.5 ms (equivalent conveyor belt speed 0.1 m/s)



# Test case: plastic fragments

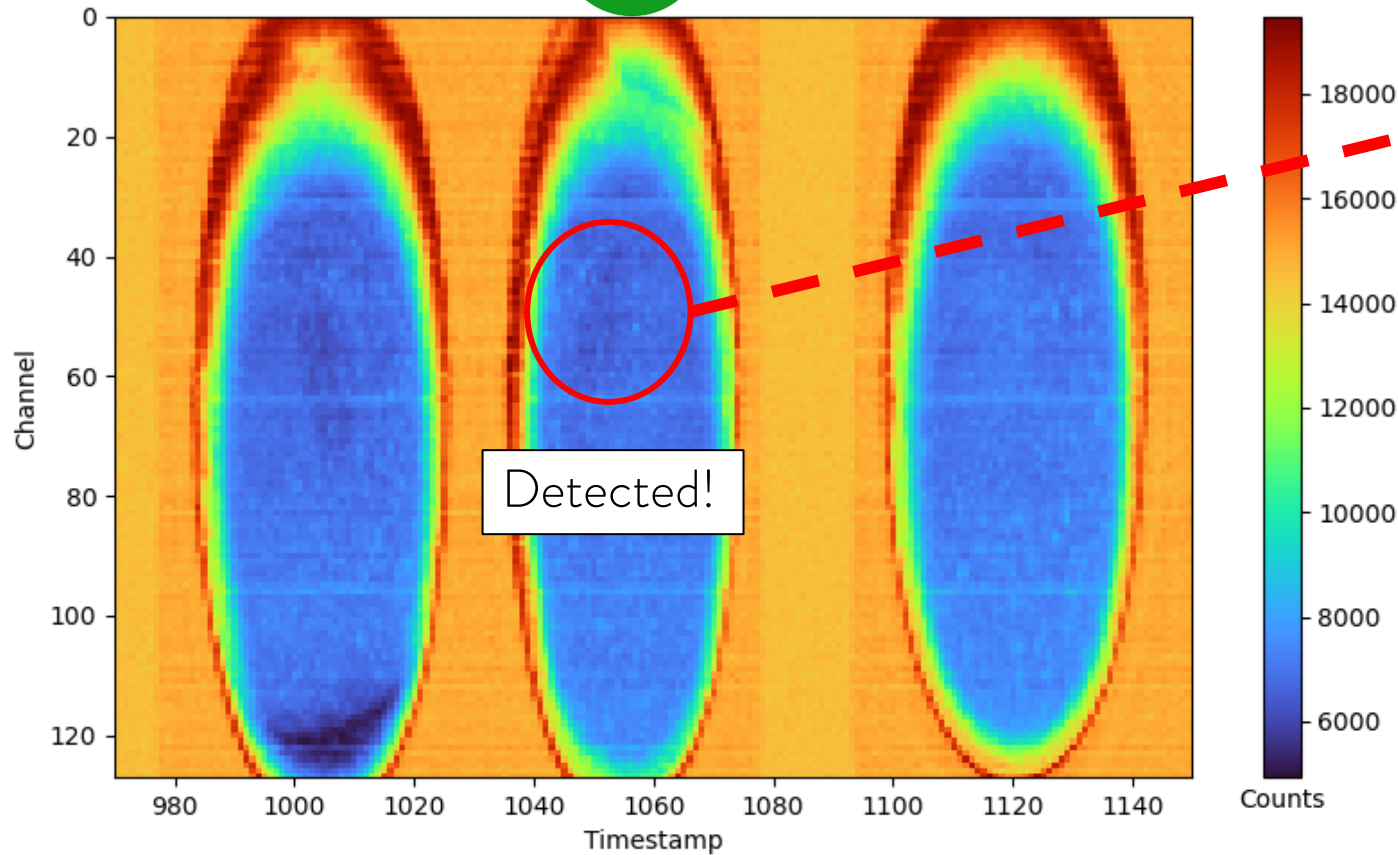


1 mm thick

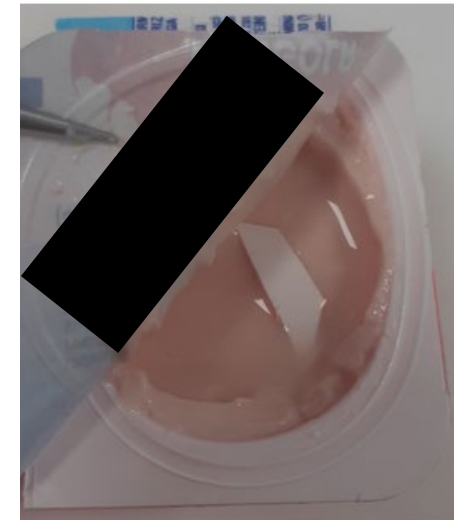




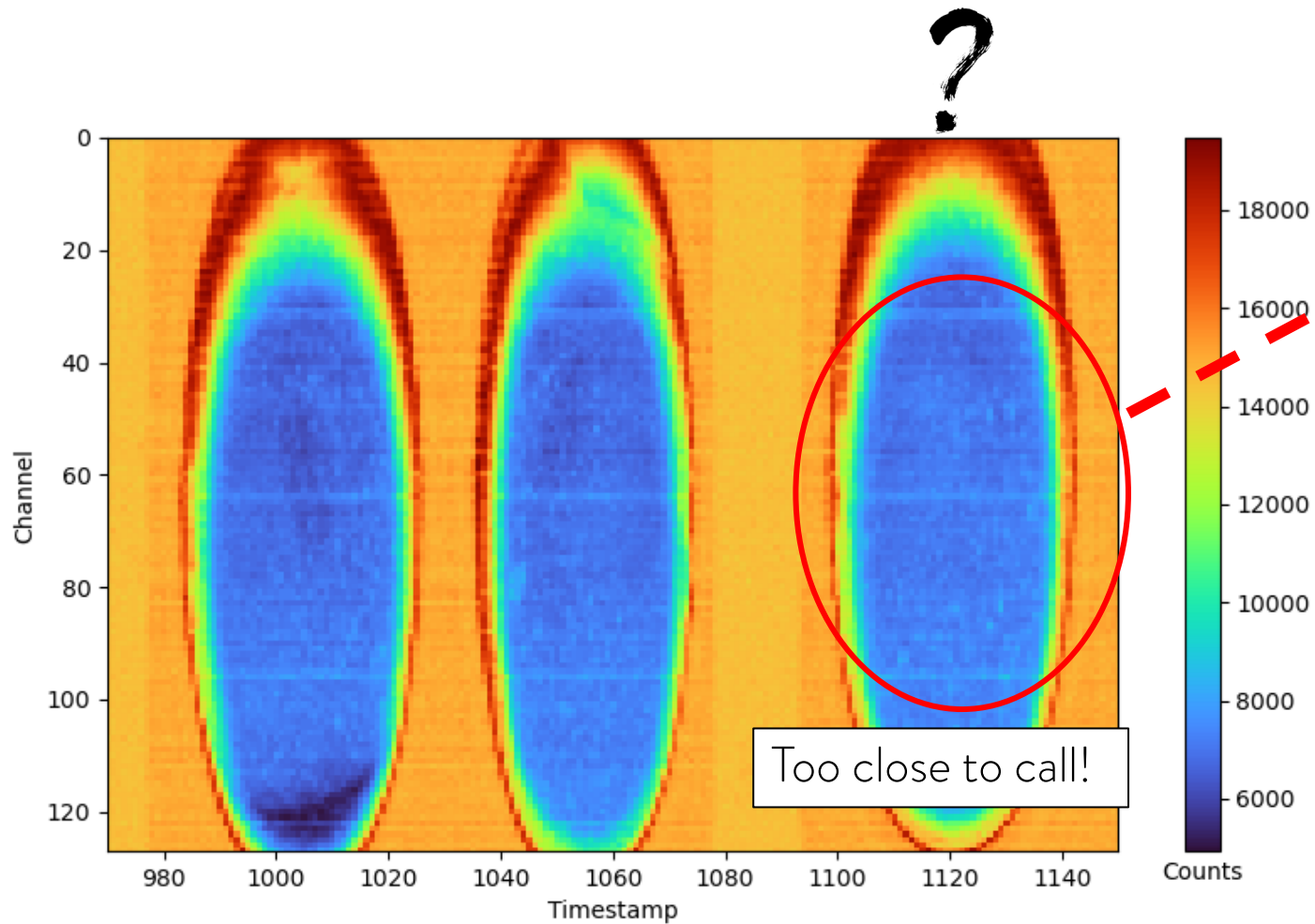
# Test case: plastic fragments



0.8 mm thick



# Test case: plastic fragments



0.2 mm thick



# Conclusion and Outlook

- X Spectra<sup>®</sup> fast X-ray spectroscopic imager for real-time contaminants detection
  - Design of new read-out ASIC
  - Testing of 4 core modules (128 channel)
- Performance summary:
  - Energy range: 6-275 keV ( $\pm 1\%$  error)
  - Electronic noise  $< 3$  keV FWHM ( $\tau_{\text{peak}} = 60$  ns) for all 128 channels
  - Counting capability up to 2.2 Mcps/channel
  - Minimal pile-up distortion up to  $\text{ICR}_{\text{max}} = 2.5$  Mcps/channel
  - Thin plastic fragments detectable on raw image (thickness  $< 1$  mm).
- Outlook:
  - 0.4 mm pitch detector
  - Increased counting capabilities

THANK YOU  
FOR YOUR ATTENTION!



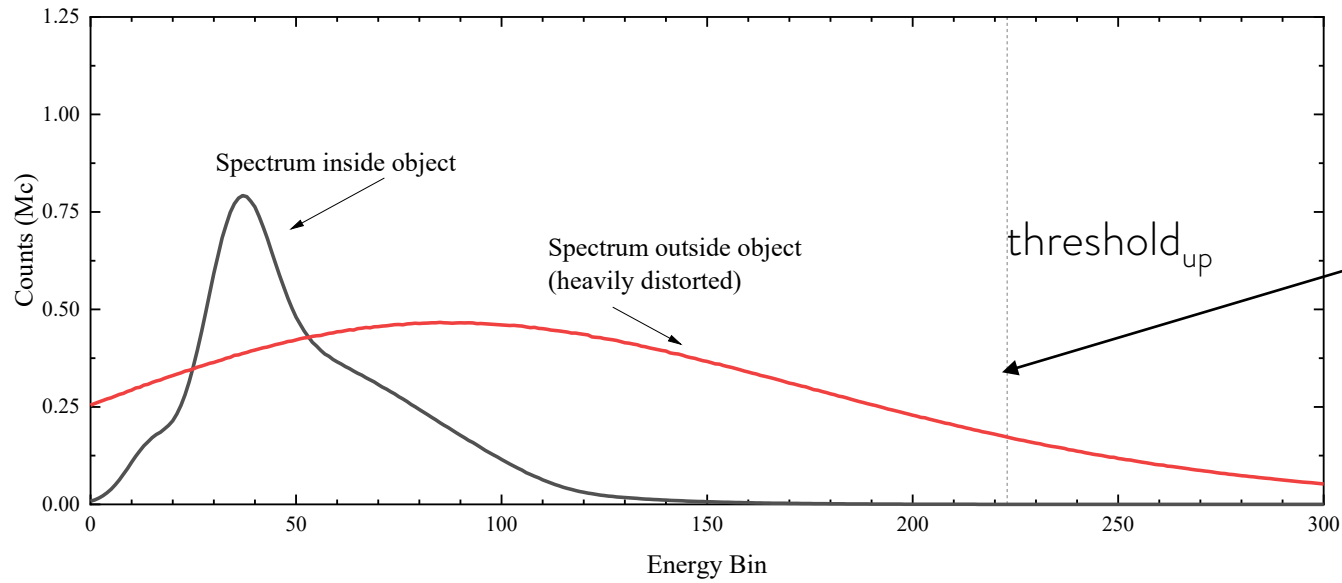
# Backup Slides



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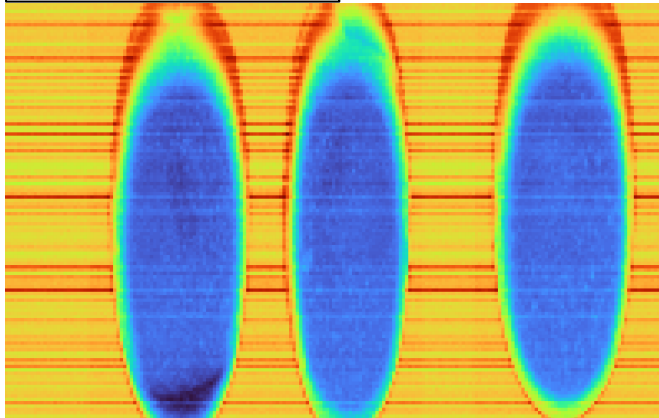
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# Correction of background non-uniformities

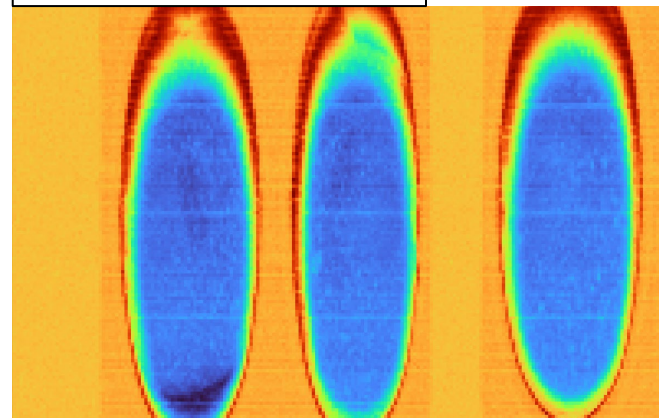


Compute upper integration threshold value for each channel to equalize counts

Fixed threshold

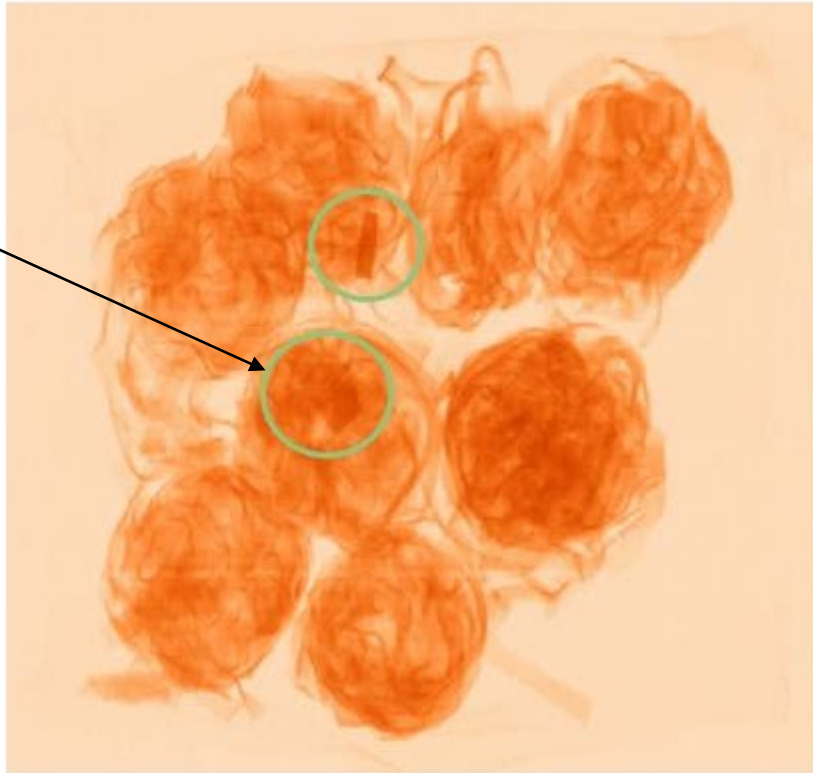


Dynamic threshold



# Additional demonstration images

Carpet fragments



Shrimp shells

