In-pixel electronics calibration studies

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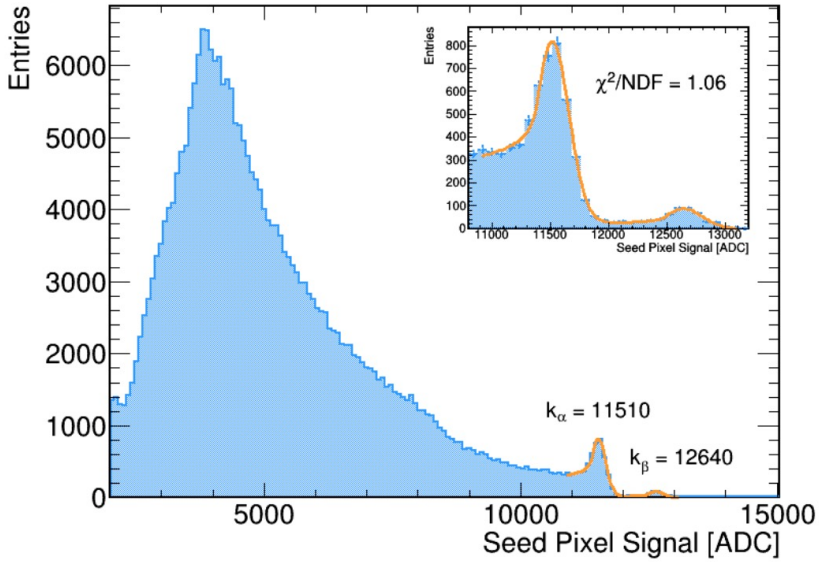
Outline

- Motivations and Backgrounds
- Test setup and Devices
- Offline data processing and results
- Summary and Discussions

Motivations

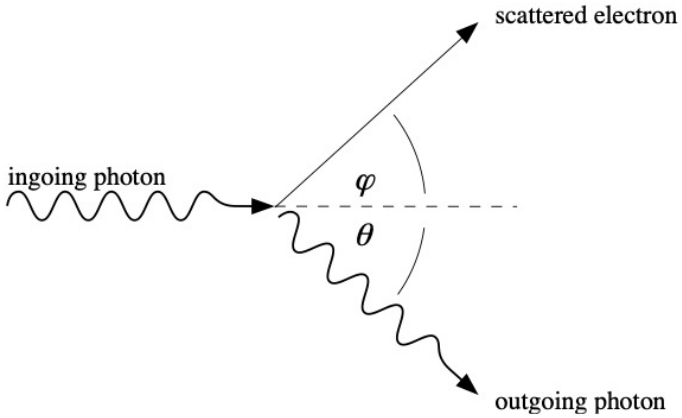
- Calibration: one of the critical steps in all kind of sensors' performance study
- Using one/several signal source with known amount of charge deposited in the sensor to validate and accurate the response
- Historically:
  - Low energy X-ray peaks from radioisotope sources
  - X-ray absorption from fluorescence



- Hard/expensive to adequate below 6 keV
- Lower energy source <1 keV is required for the high gain circuit (TaichuPix, JadePix-2/3, ATLASPix3 ToT) studies

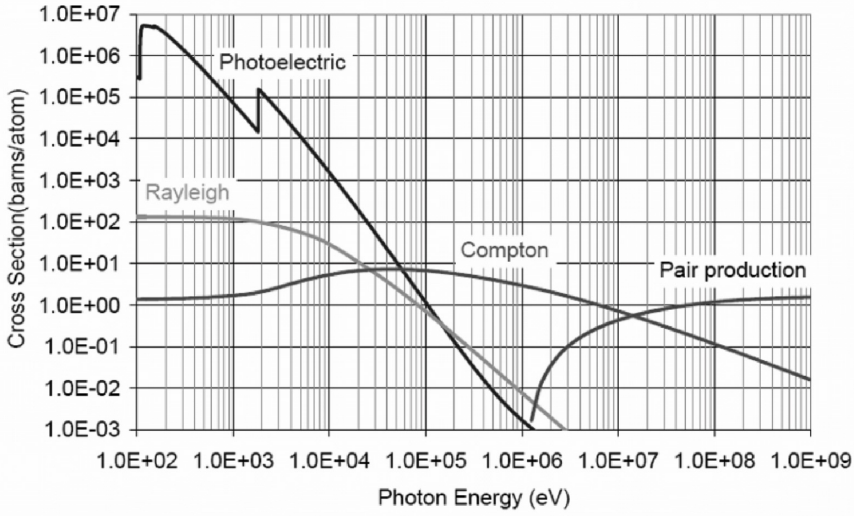
Compton scattering for calibration

- Photon's interaction with the electrons and transfer part of its energy
- Energy of the photon after scattering ($E_{\gamma'}$) was determined by the Scattering angle (θ) of the photon:



$$E_{\gamma'} = \frac{E_\gamma}{1 + (E_\gamma / m_e c^2)(1 - cos\theta)}$$

$$E_e = E_\gamma - E_{\gamma'}$$



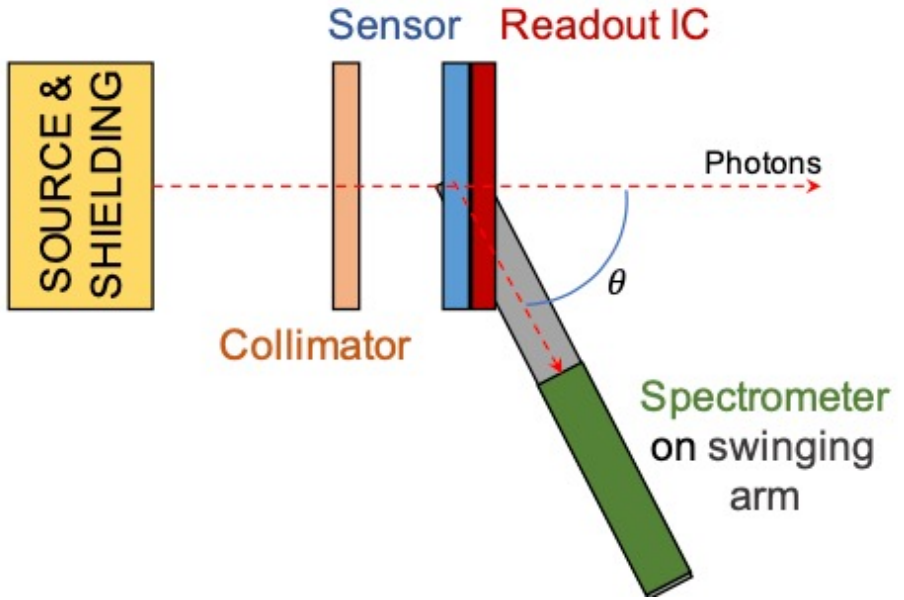
- Provide access to low energy (selectable) electrons to be promptly reabsorbed as a localized energy deposit

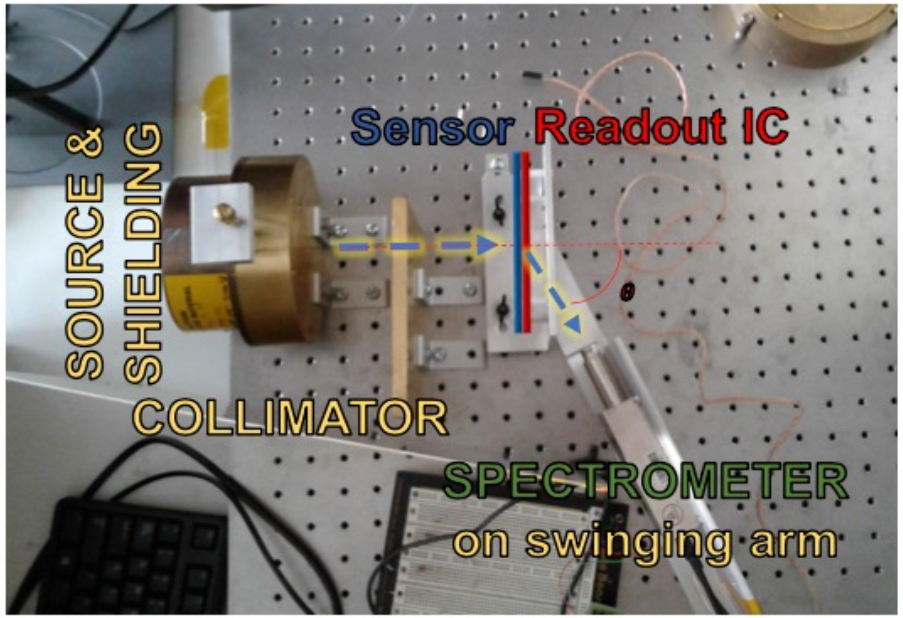
-> Goal for this study: validate the feasibility of using the scattered electrons in calibration

Inspired by LBNL setup

Setup and Devices:

- ^{241}Am
- Hybrid pixel detector
  - 150 μm silicon sensor manufactured by MPG-HLL
  - Pixel size: 100 x 25 μm
  - Total active size of the chip: 6.8 mm x 9.2 mm
- Spectrometer: Amptek X-123 x-ray spectrometer with a 5 mm diameter CdTe detector element (FWHM: 550 eV)





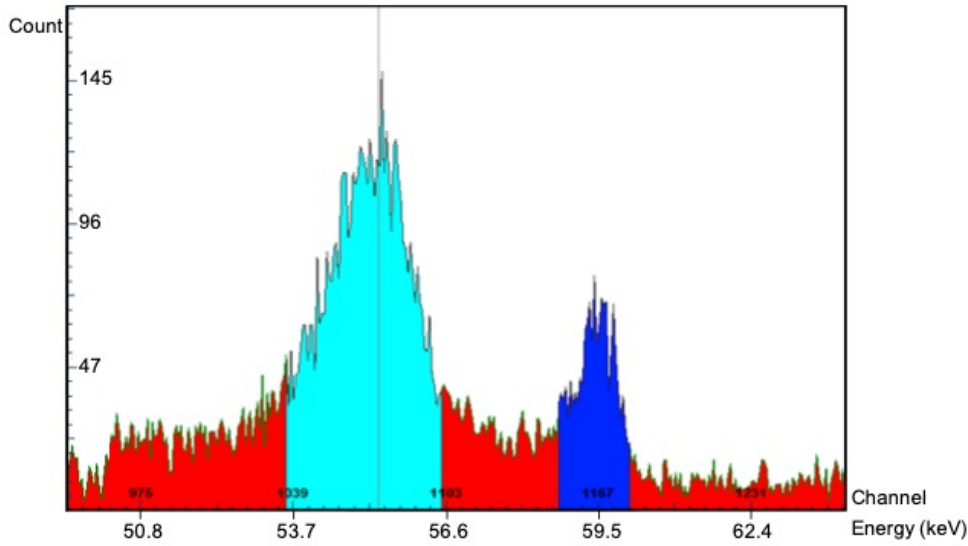
Paper: arXiv:2008.11860v1

Submitted on 26 Aug 2020

Inspired by LBNL setup

- 4 scattering angles were tried:
  - 51°, 56°, 63°, 67° (517 hours in total)
- Certain range of Photon spectrum for Compton scattering photons -> produce triggers for the sensor

-> A linear trend found



Observations:

- Time-consuming: 5 Compton-scattering hits observed per hour (700 hours needed to expect 50% of pixels to be hit)
- Hard to reach < 1 keV

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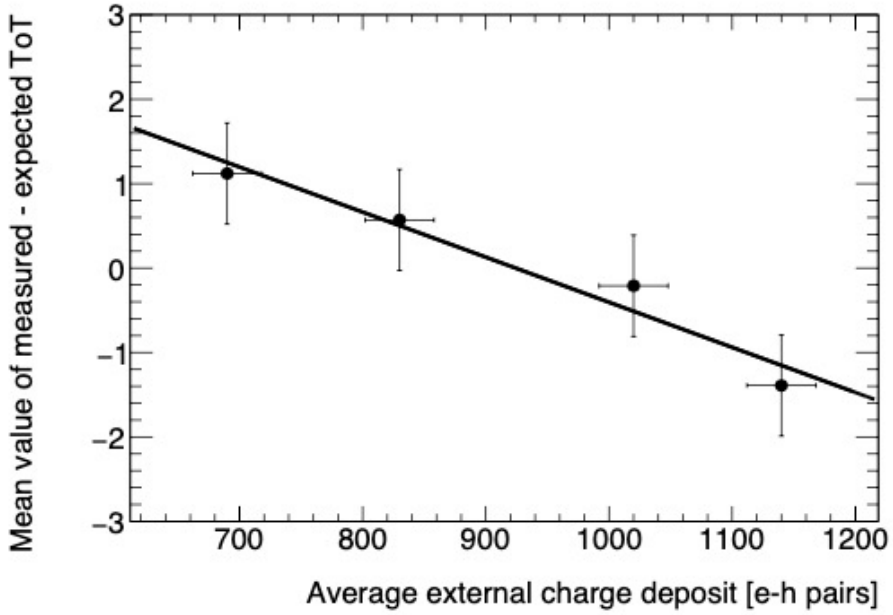
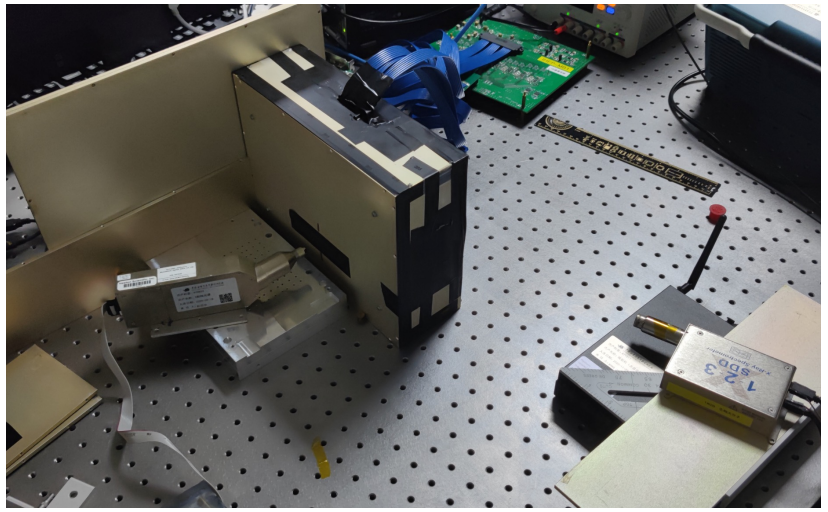


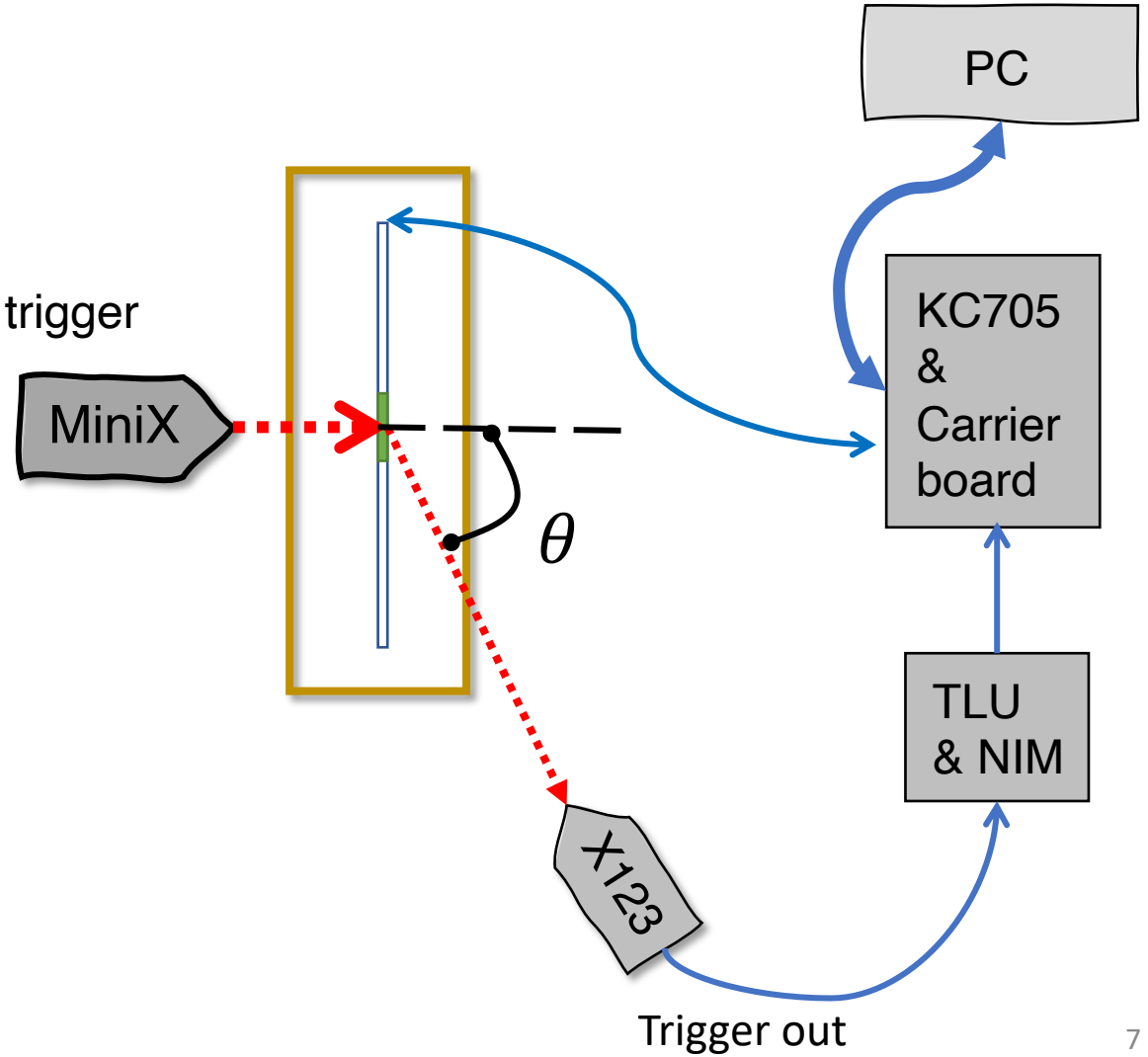
TestSetup at IHEP

- Attempt to reach energy deposit < 1 keV

Setup and DAQ

- MiniX, X123, JadePix-1, Shielding box …
- Jadepix-1 DAQ system: 5 frame saved for 1 trigger
- MiniX control and X123 DAQ software

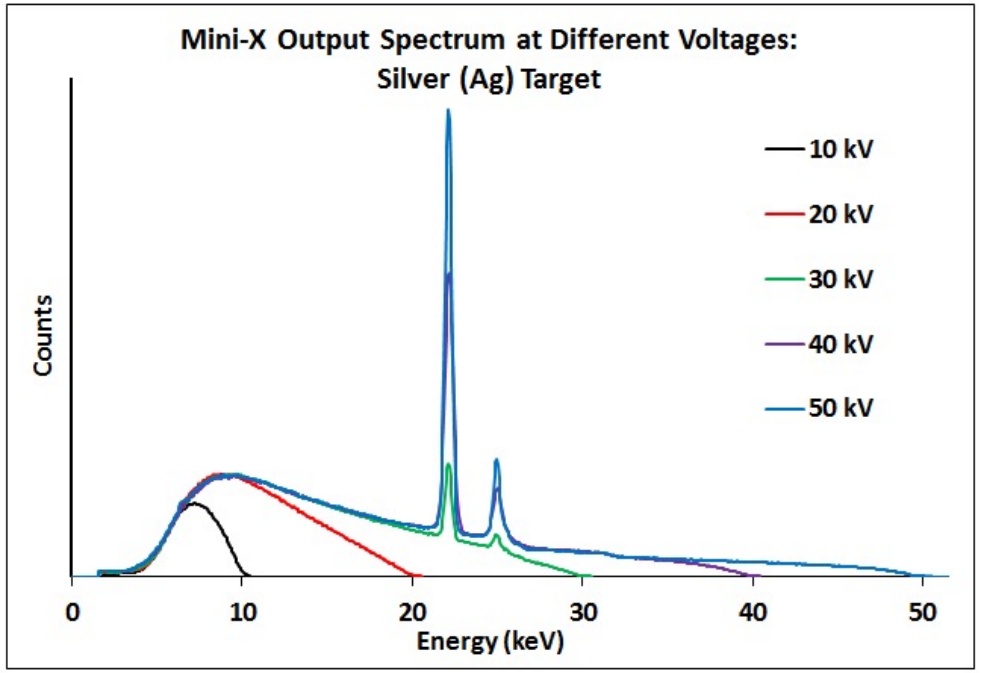




Devices

Mini-X2: X-Ray Tube System

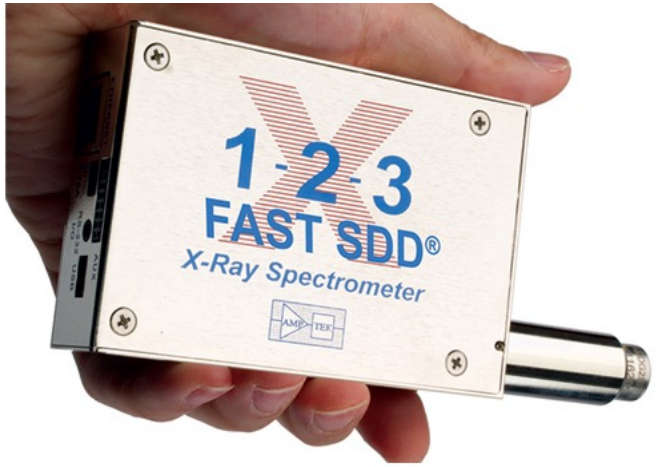
- Device and control software
- Collimator, different filters
- https://www.amptek.com/products/x-ray-sources/mini-x2-ray-tube

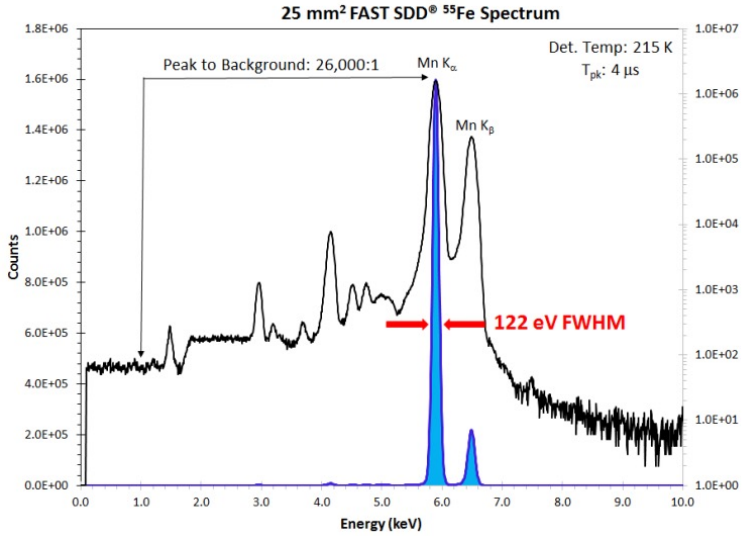


Devices

X123:

- X-ray detector
- Control and DAQ software
- FWHM for 5.9 keV: ~ 122 eV





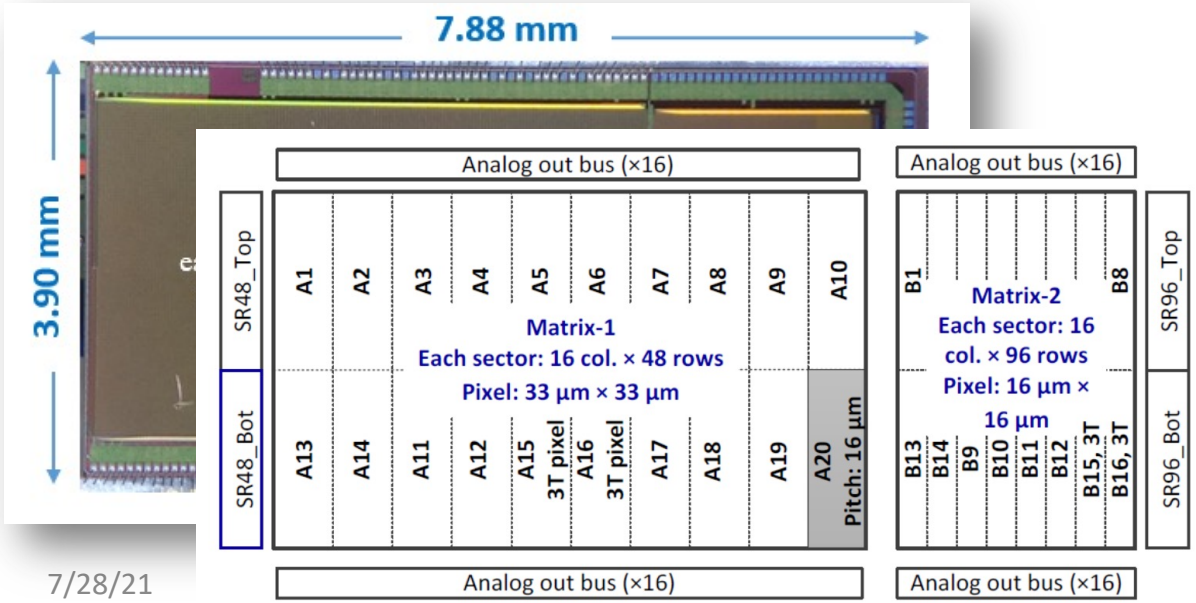
- https://www.amptek.com/products/x-ray-detectors/fastsdd-x-ray-detectors-for-xrf-eds/fastsdd-silicon-drift-detector

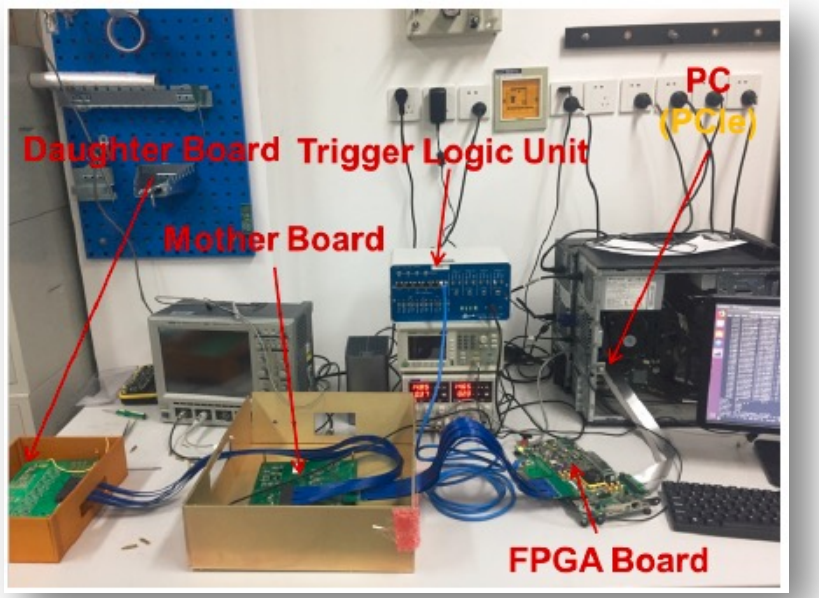
Devices

JadePix-1

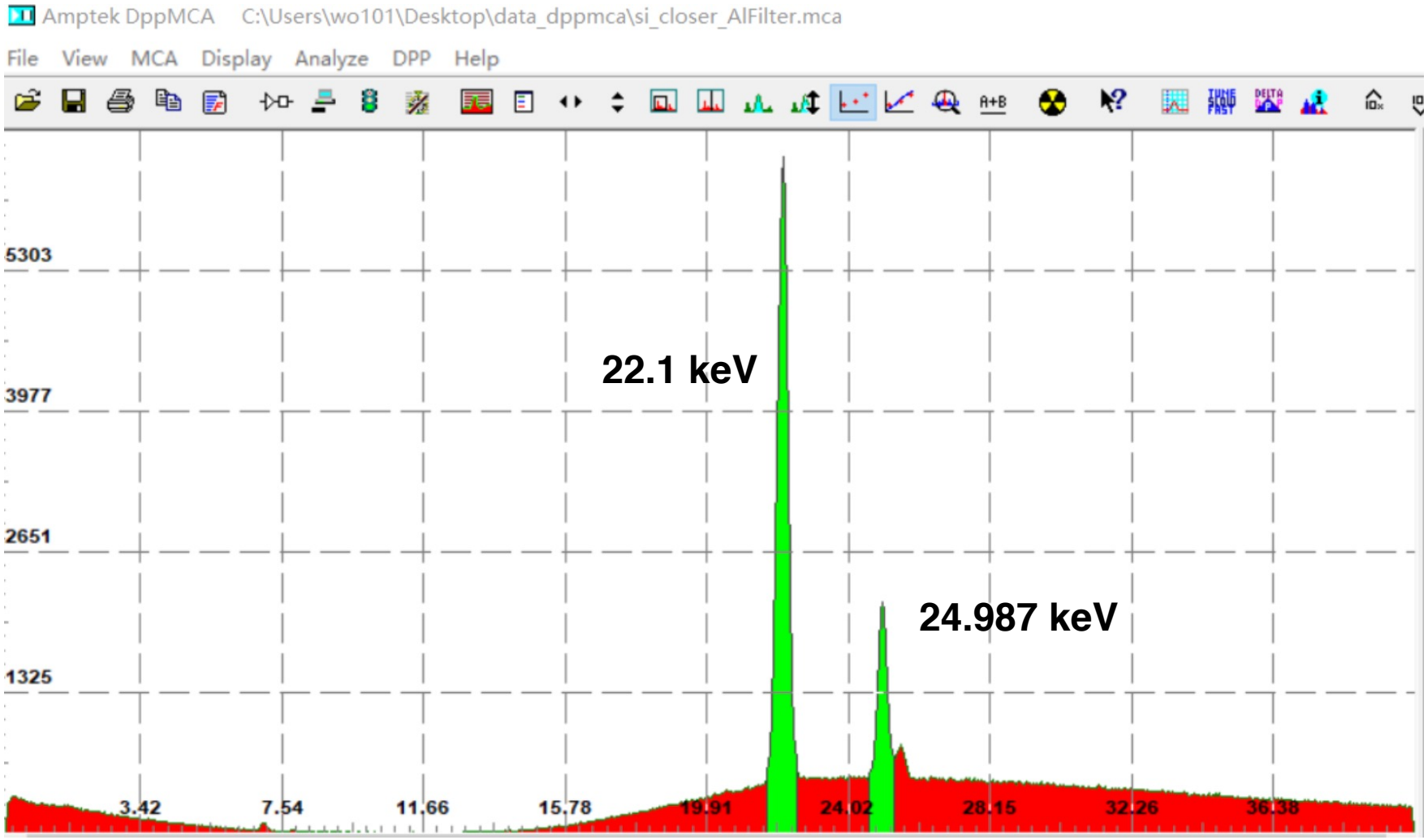
- 1st generation of CMOS pixel sensor for CEPC vectex detector
- To study the pixel structure's impacts on the performance
- Successfully tested with radioactive source (Fe55, Sr90) and Test Beam(@DESY)

- Sector A3: 1.584 x 0.768 mm

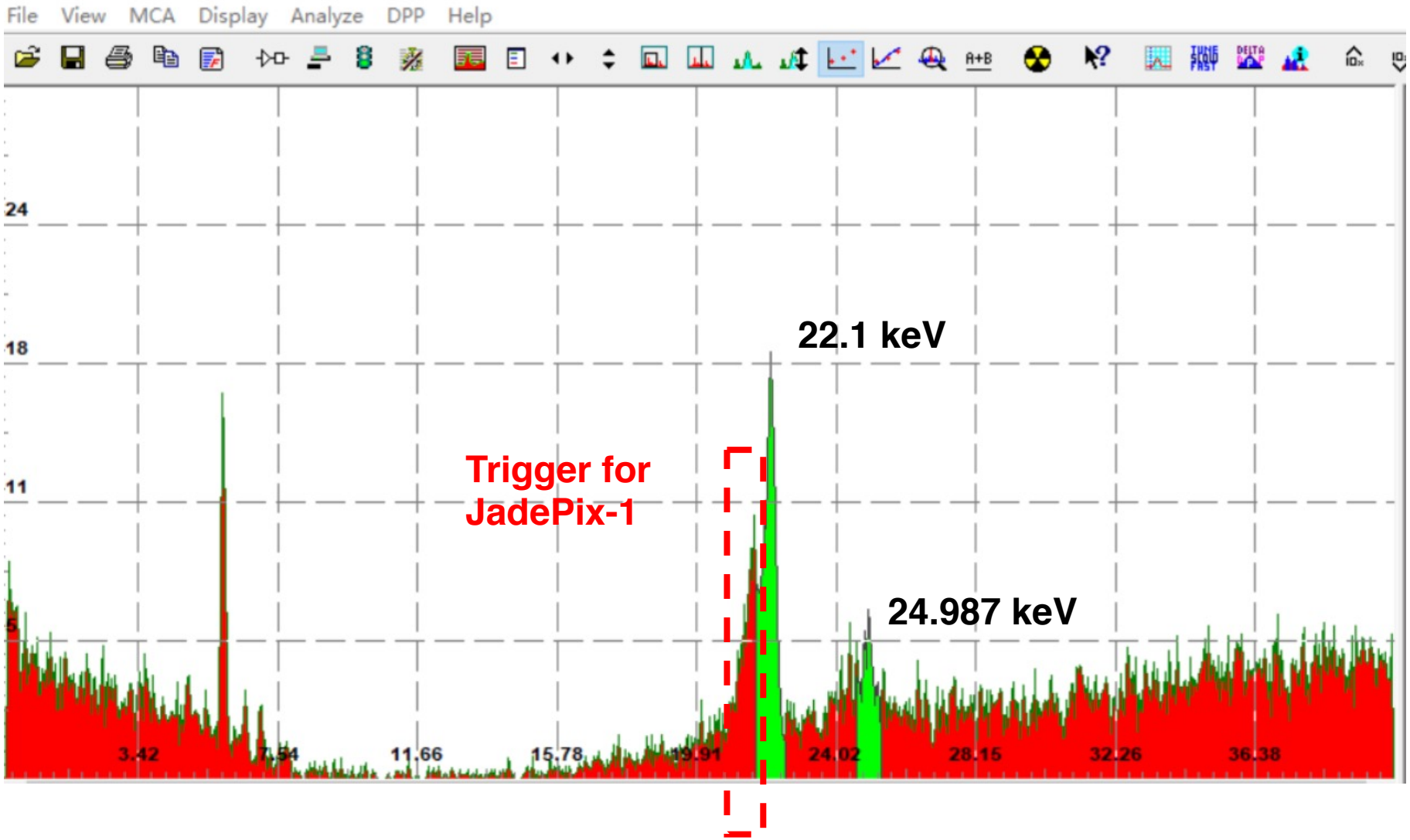




Spectrum of the silver target

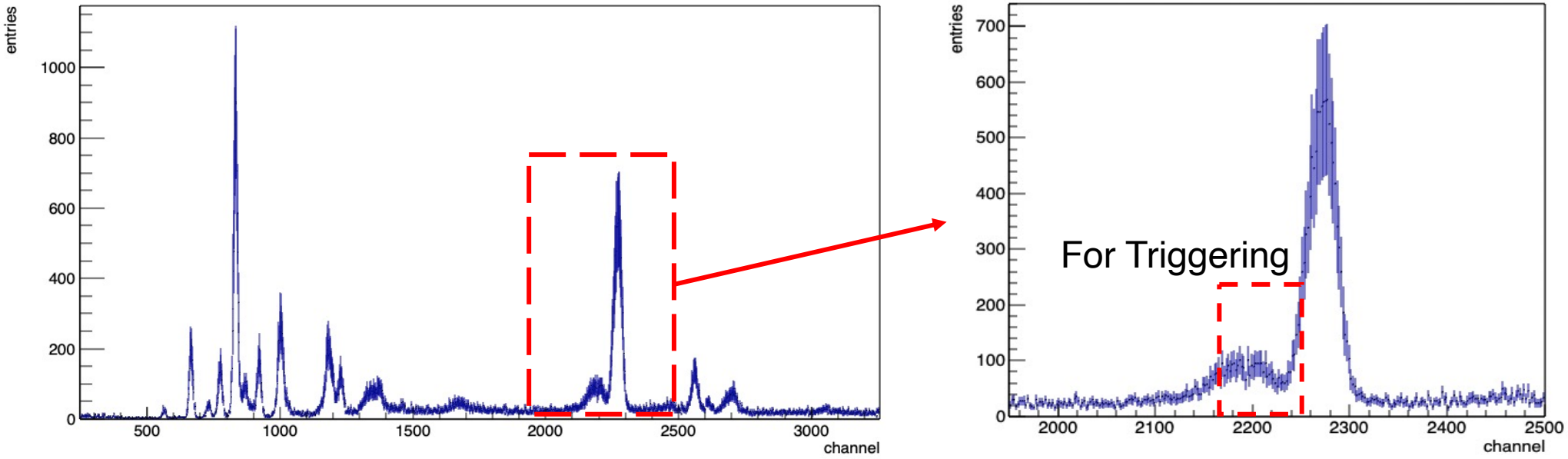


Spectrum at another position



Tests performed

- Angle : ~71 deg (0.64 eV for scattering electrons)
- 22 hours running
  - 7503 triggers in total from X123
  - JadePix-1: Noise + random selsction of the MiniX spectrum + Compton Scattering event



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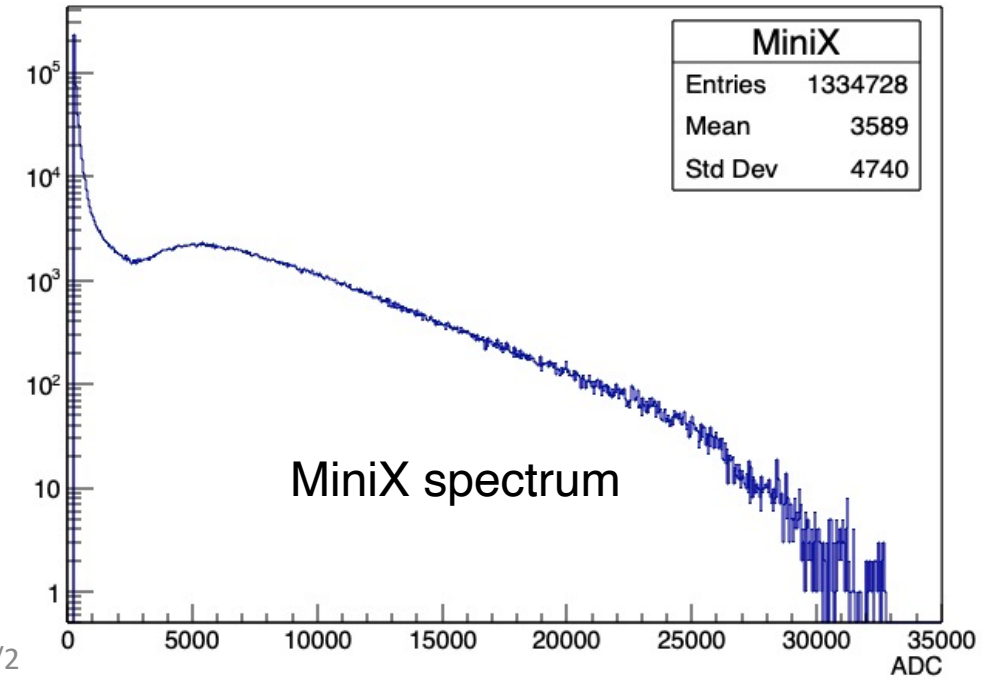
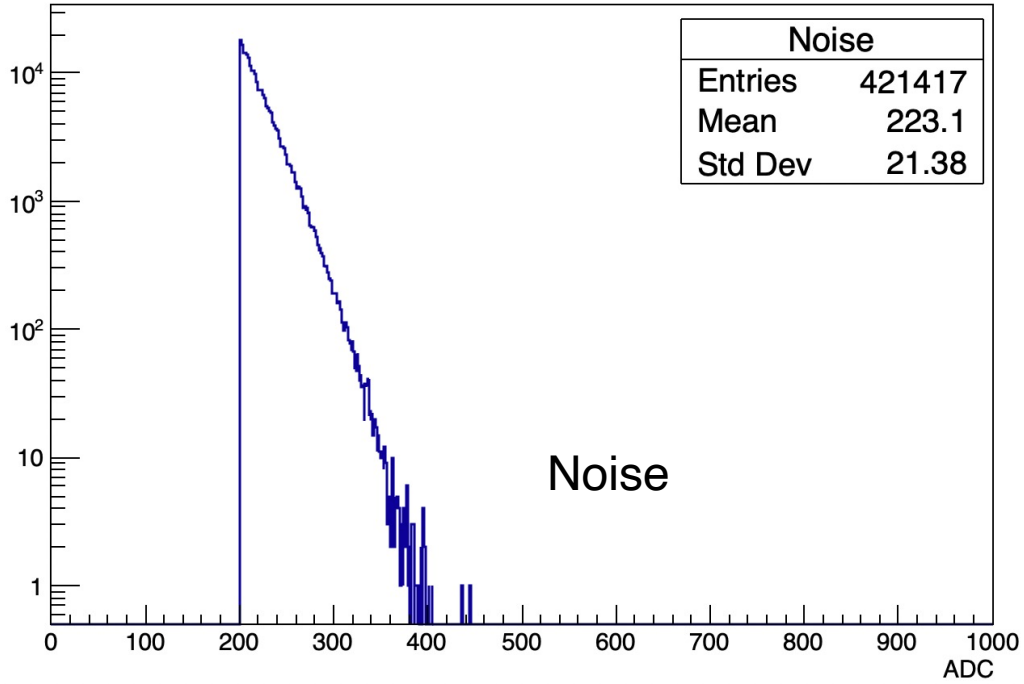
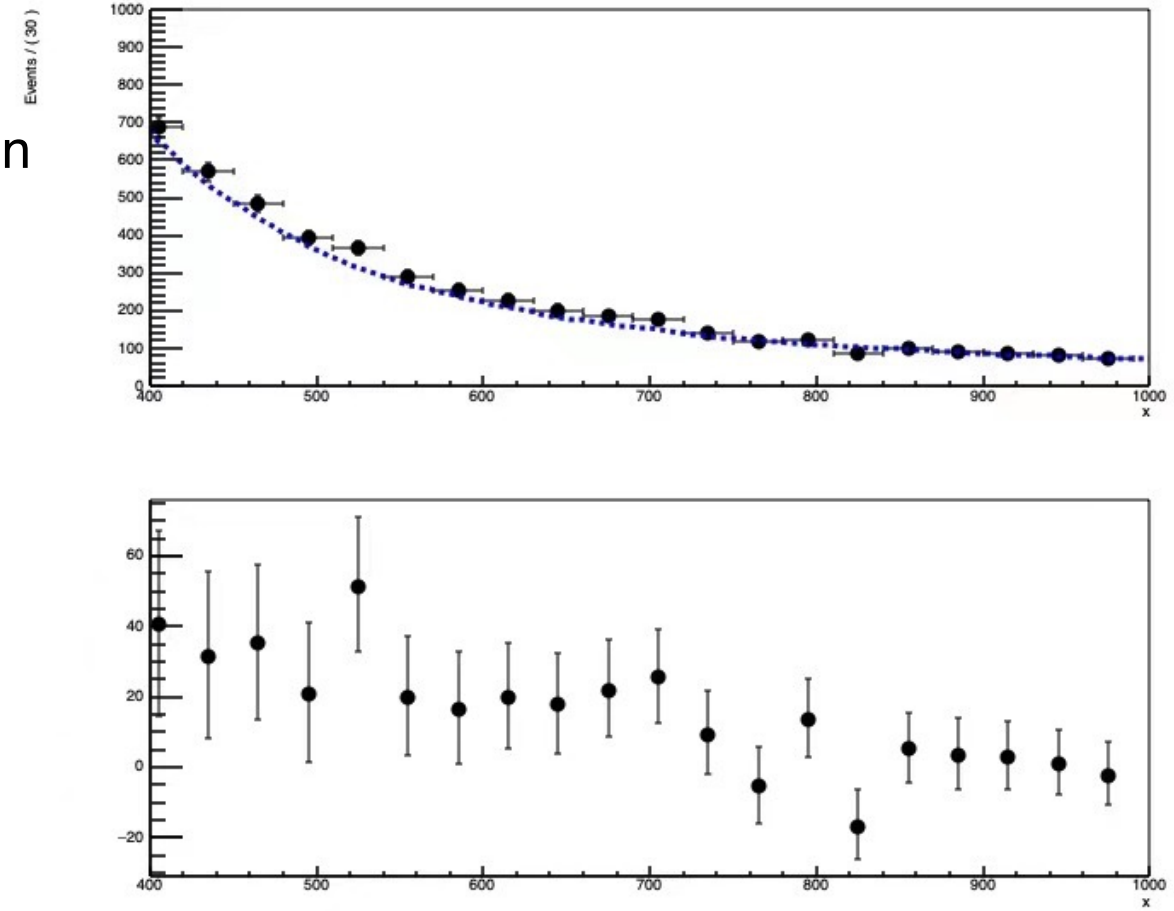




Results

- Estimation of signal events:
  - Effective region of Jadepix-1 should be taken into account
  - $N_{trigger\_total}$ x $F_{effective\_epi\_layer}$ x $F_{effective\_area}$
  - $7503 \times \frac{18}{250} \times \frac{33\mu m \times 33\mu m \times 42 \times 14}{\pi \times 750\mu m \times 750\ \mu m} \sim O(100)$



- Hard to see the expected signals
  - Much lower data taking efficiency than the LBNL setup

Summary and Discussion

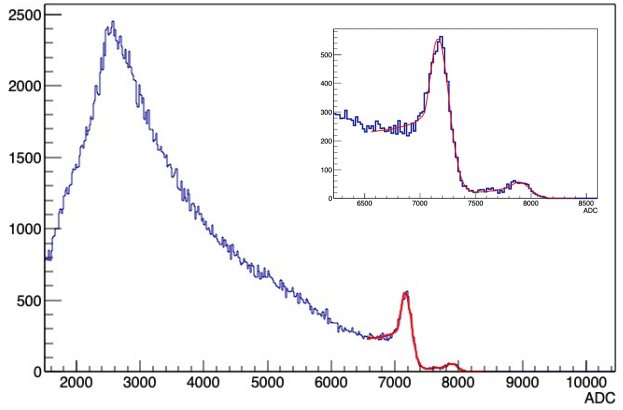
- Tests about using the compton Scattering for calibration have been done
- Hard to see any sign of signals because of the low statistic

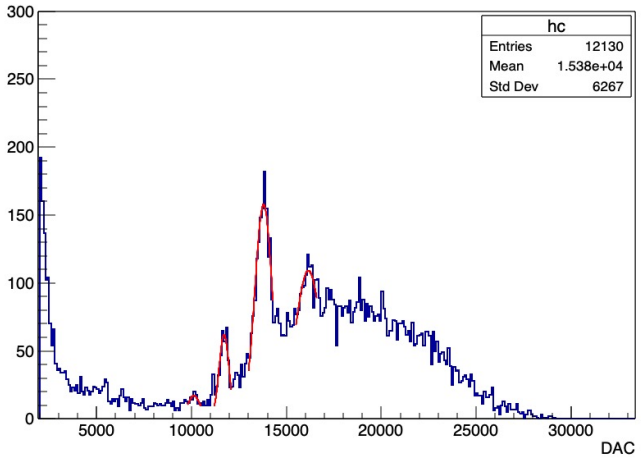
Potential reason:

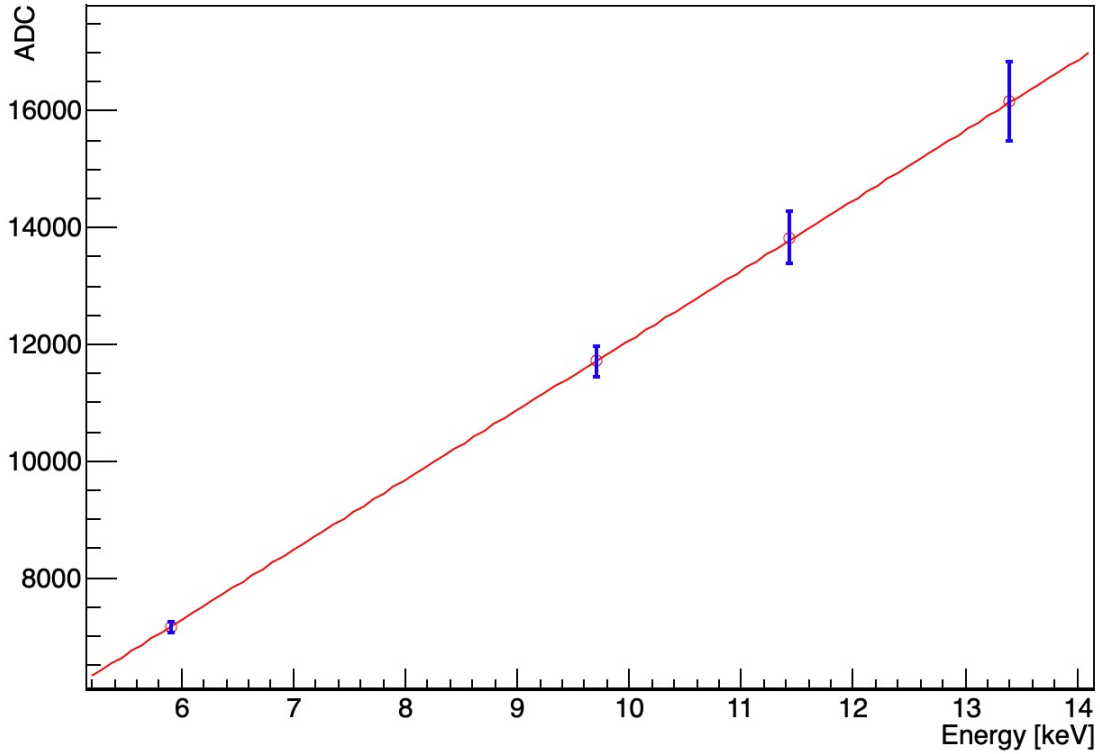
- Low statistic: thin epitaxial-layer (18 um out of 250 um)
- Complicated component of the MiniX output spectrum and processes undergoing to be further understood

For the future study about this method, we may still need to go back to the radioactive source for cleaner background

Backup: Calibration with Fe55 and MiniX (Au target)





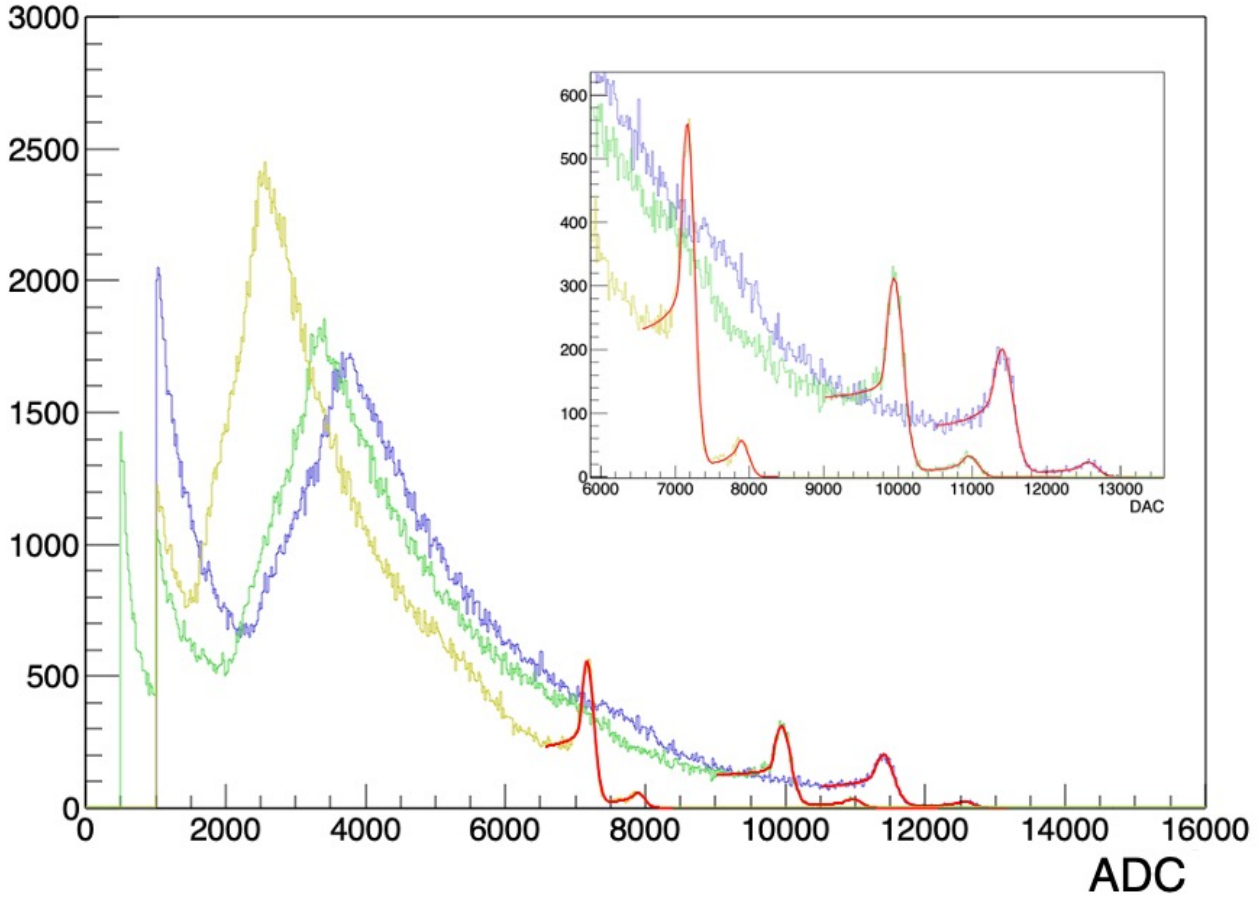


$p0 = 99 \pm 341.5$

$p1 = 1196 \pm 49.6$

Good linearity in higher energy range

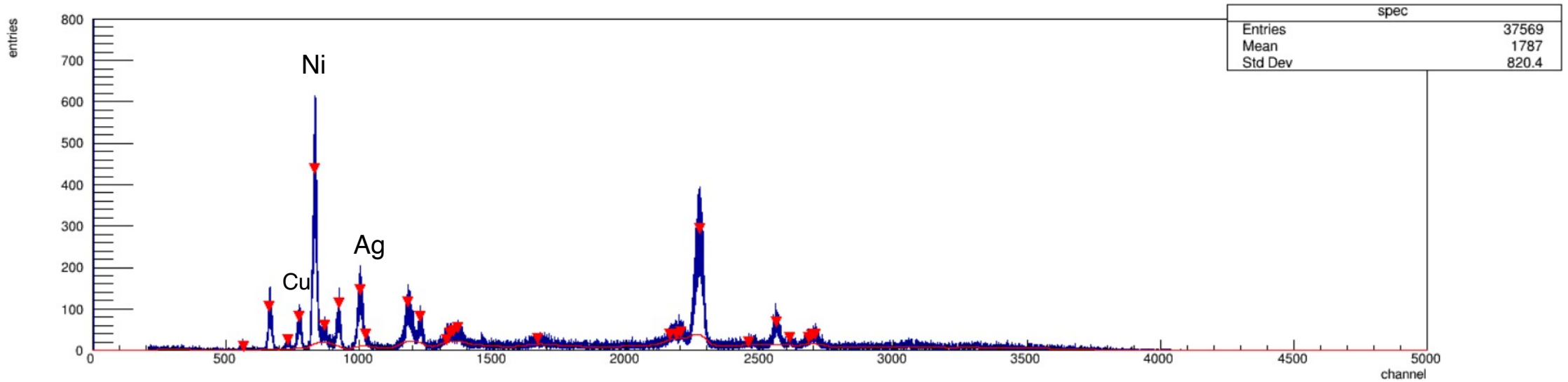
Backup



Calibration with Fe55

Backup: Simulation

- Simulation using Geant4 to estimite the ratio
- To preliminary understand what should be expected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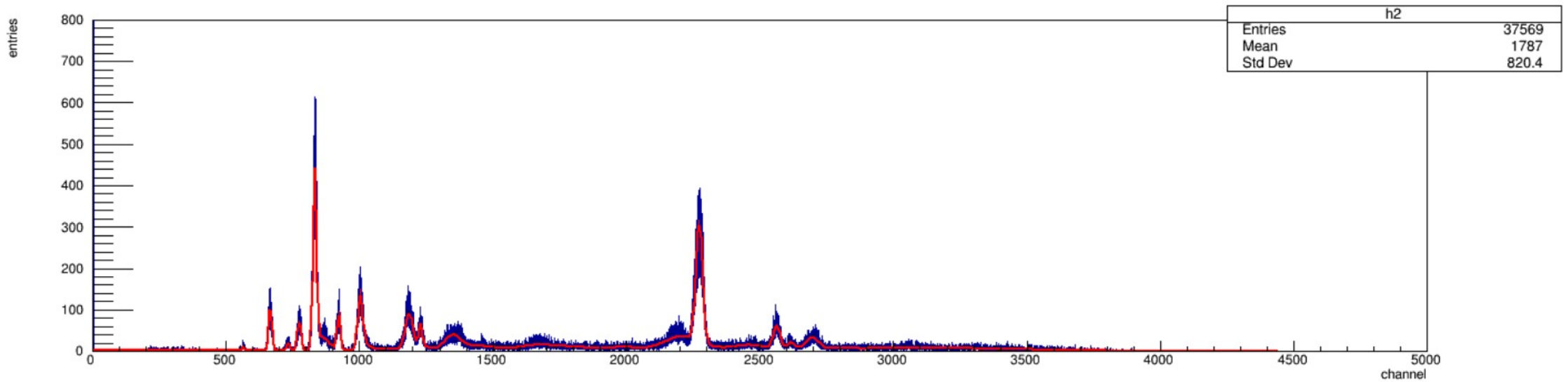
Mean 1787
Std Dev 820.4
Ni
Ag
Cu
entries
channel


h2
Entries 37569
Mean 1787
Std Dev 820.4
entries
channel