Cluster anslysis of data from the Silicon On Insulator detector

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Index

The detector

What is it?

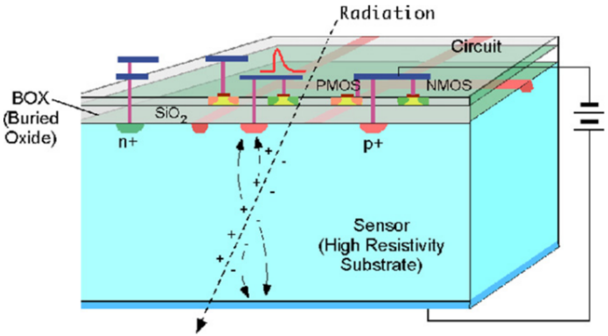

Figure: S.O.I. Pixel schematics[1]

The detector

What is it?

- Pixel detectors
  - Tracking detectors with precise hit position information.

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  - Less multiple scattering

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What is it?

- Pixel detectors
  - Tracking detectors with precise hit position information.
- Monolithic
  - Single crystal: small, thin pixels, with good boundaries, produced with commercially available technology
  - Less multiple scattering
- Complementary Metal Oxide Semiconductor (CMOS)
  - Circuitry isolated from the rest of the detector

Advantages and disadvantages

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- Pixel size
- Energy resolution (for a pixel detector)
- Production method (cost)

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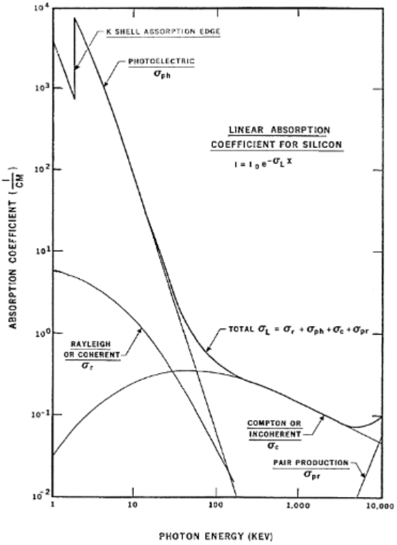
Disadvantages

- Pixel size
- Signal accumulation time
- Radiation damage
- Coupling to the main board

Absorption coefficient[2]



Americium decay

- Americium half-life: 432 years.
- Decay chain: ${}^{241}_{95}$ Am $\xrightarrow{432y.}$ ${}^{237}_{93}$Np $\xrightarrow{2.4e+6y.}$ ${}^{233}_{91}$Pa $+ \ldots$ (Neptunium cascade)
- Most important: ${}^{241}_{95}$ Am $\rightarrow$ ${}^{237}_{93}$Np $+ \alpha + \gamma$ 59.5 keV
- A typical americium spectra contain this 59.5 keV peak, as well as peaks near 14 keV, 18 keV, 21 keV and 26 keV from less likely Am decays and from the Neptunium decay.[3]

Americium 241 spectra

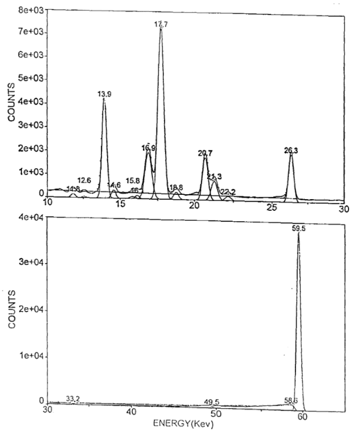


Figure: Americium 241 decay spectra.[3]

Data processing

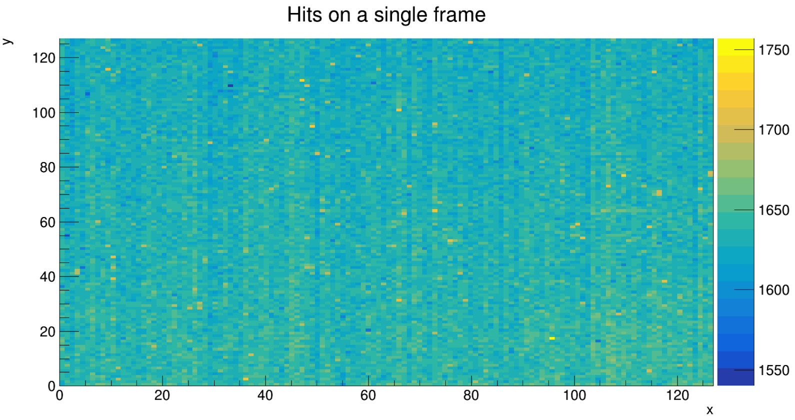


Figure: Data from a single frame, before processing it

Pedestal

- Pedestal: DC component of the signal (main factor)

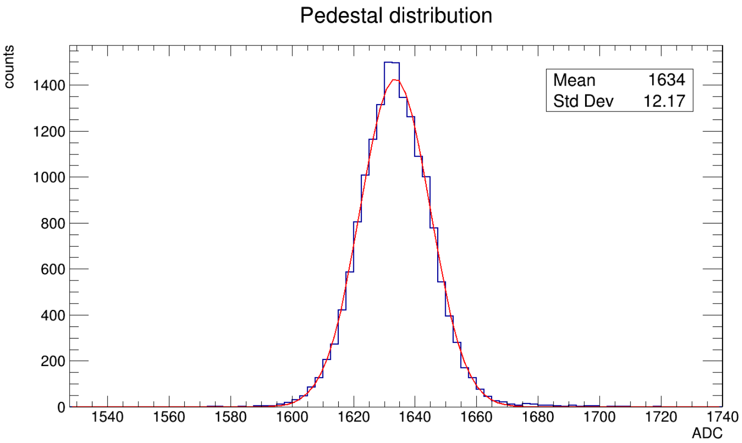


Figure: Pedestal: Pedestal distribution over each pixel

Common mode

- Common mode: Oscillations due to electrical noise from the surroundings.

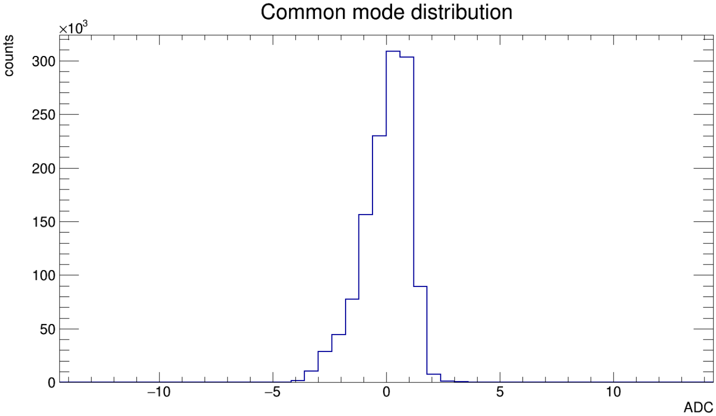


Figure: Common mode: Distribution of common mode over each frame

Data processing

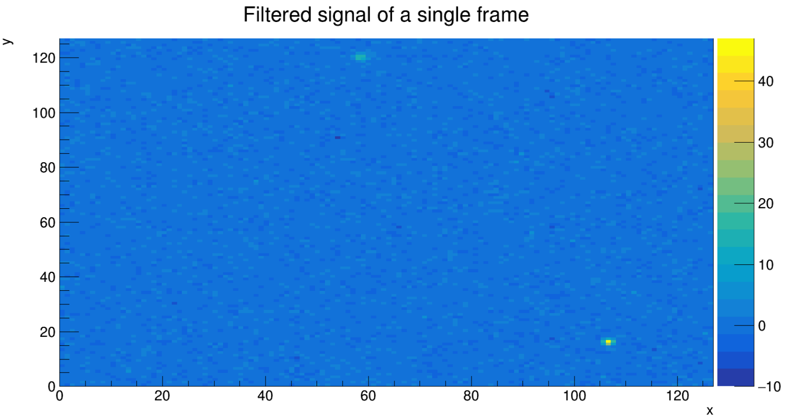
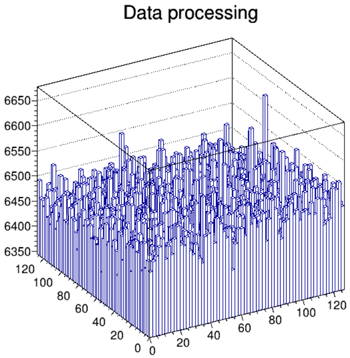
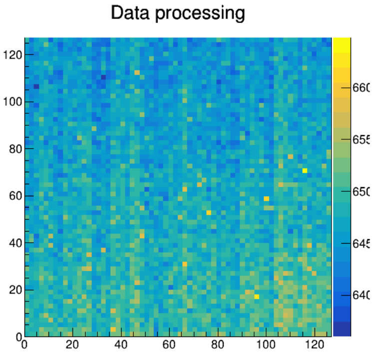


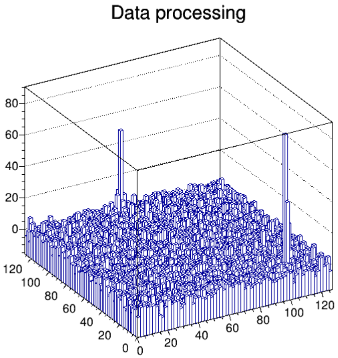
Figure: Data processing: signal after removal of pedestal and common mode

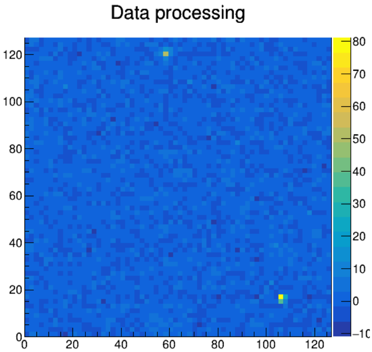
Data processing



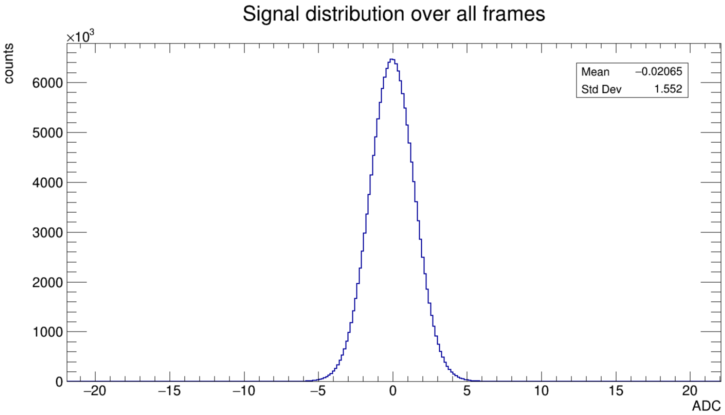


Data processing





Data processing



Clustering

- Particles going through the detector create electron and hole pairs, which can spread out to more than one pixel. The signal from those pixels needs to be added in a cluster.
- The higher is the energy of the particle, the larger is the cluster.

Clustering

- K-Means and DBSCAN algorithms are not optimised for cluster for a pixel grid (pixels in a cluster must be neighbours).
- “Brute forcing” would not be easily optimised.
- a middle ground solution was applied.

Clustering

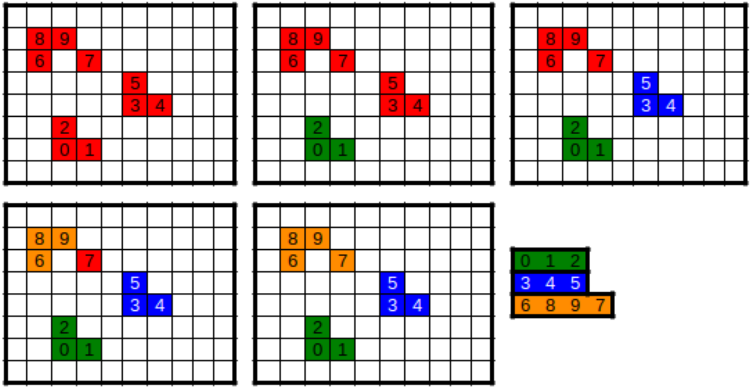


Figure: Illustrative clustering scheme

Clustering

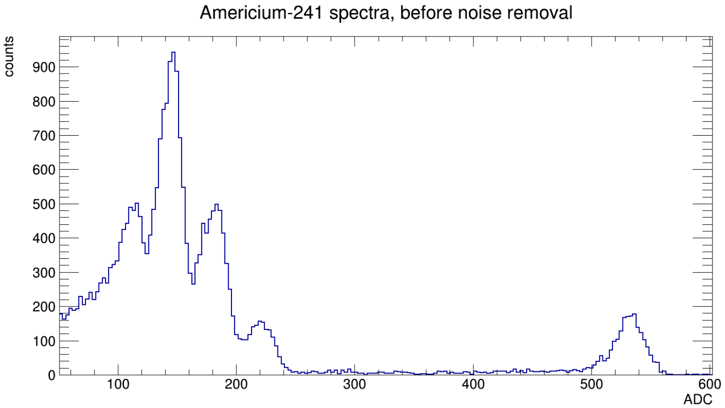


Figure: Energy spectra in clusters (spectra before removing background)

Americium 241 spectra

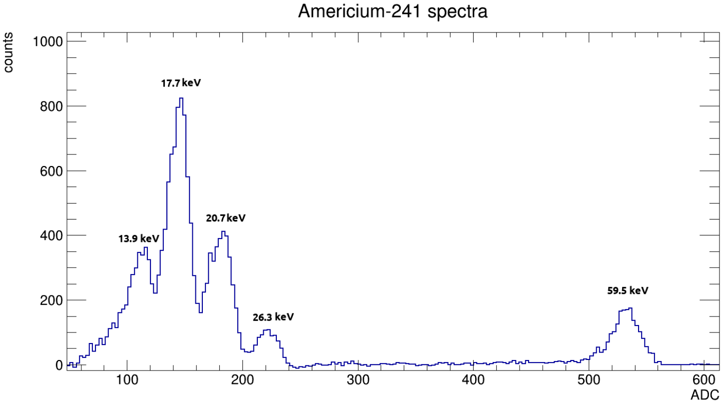


Figure: Americium spectra after removing background (SNIPS algorithm). The peaks are clearly visible, but their width encompasses several possible peaks from the americium spectra.

Energy calibration

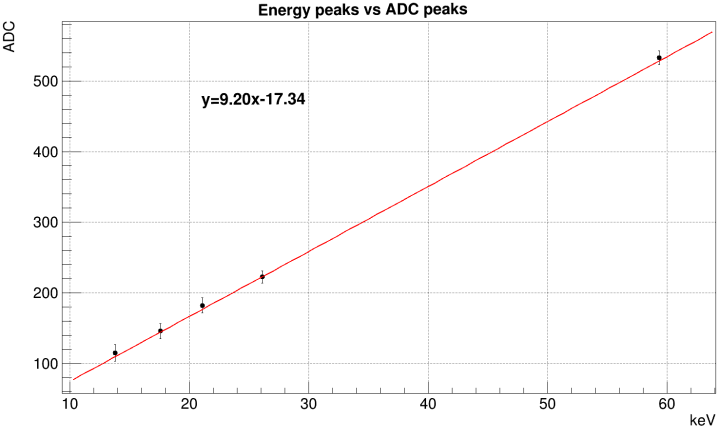


Figure: The energy from the peaks is plotted versus the ADC value measured by the detector to obtain a linear relation between both of them.

Detector parameters

$$\text{Slope} = 9.20 \pm 0.18 \ {}^{\text{ADC}}/_{\text{keV}}$$

$$\frac{\text{ADC}}{\text{eV}} = 0.0092 \pm 0.00018 \ {}^{\text{ADC}}/_{\text{eV}}$$

$$\frac{\text{ADC}}{\text{e}} = 0.030 \pm 0.001 \ {}^{\text{ADC}}/_{\text{e}}$$

$$\text{ENC} = 45.28 \pm 0.89 \ \text{e}$$

Future work

- Data acquisition: presorting
- Full ROOT integration
- Laser testing: Evaluation of depletion layer
- ...
- `https://github.com/sucunza/Pixel-Detector`

References

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- 5. Occurrence of the $(4n + 1)$ series in nature. Peppard, D.F.; Mason, G.W.; Gray, P.R.; Mech, J.F (1952). Journal of the American Chemical Society. 1952.