Position Sensitive Scintillation Detector for Gamma Spectroscopy

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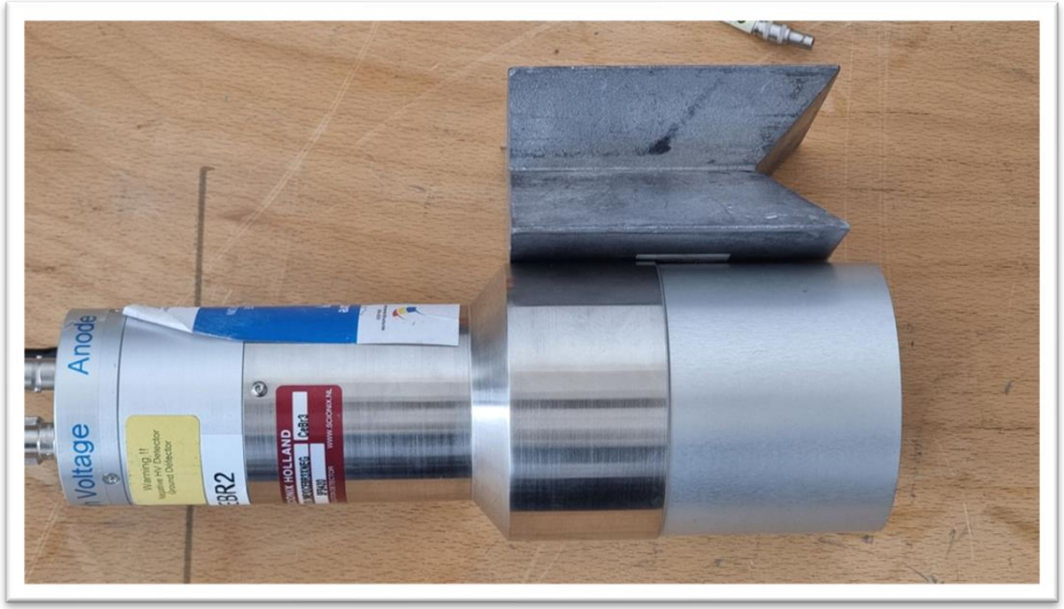
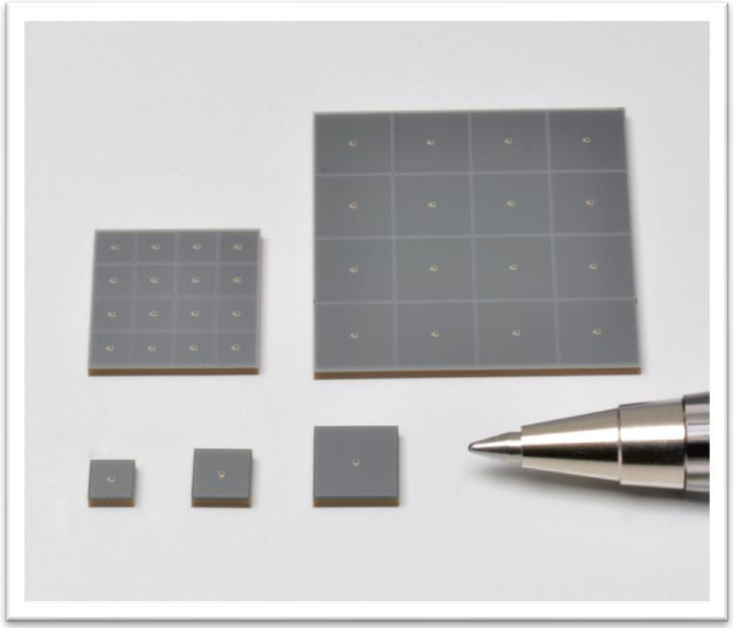
Main idea and Motivation

- Scintillation detectors - scintillation crystal paired with a photomultiplier
- Information about gamma counts, energy and timing but not interaction location
- Too large setups for positioning with regular photomultiplier tubes

- Use of Silicon Photomultipliers (SiPM) to reduce scale of setups
- Use of SiPMs to determine particle interaction location
- SiPMs – small size, low operating voltage, less sensitive to magnetic interference



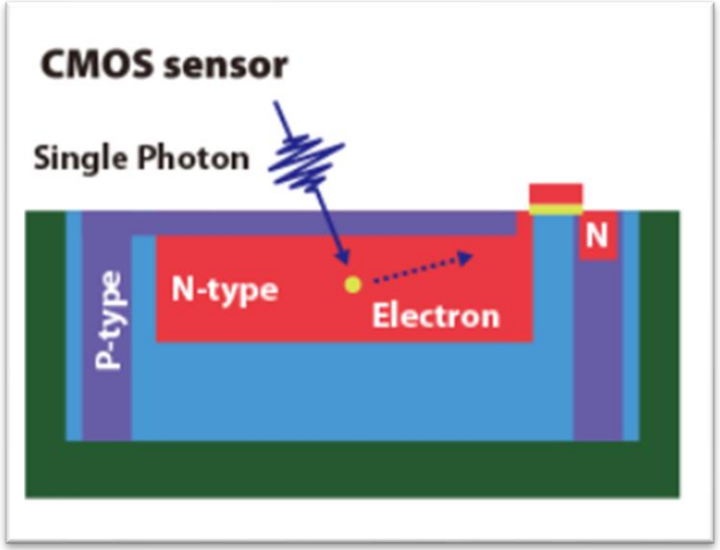
$CeBr_3$ scintillation detector, PMT a few cm across

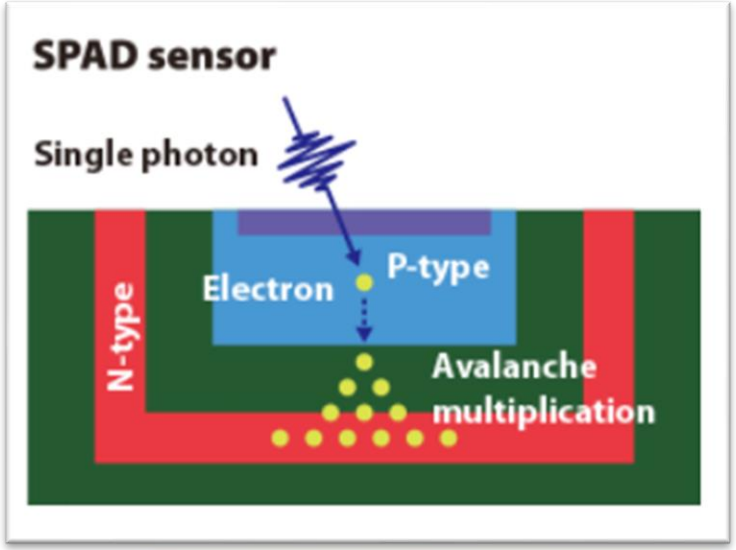


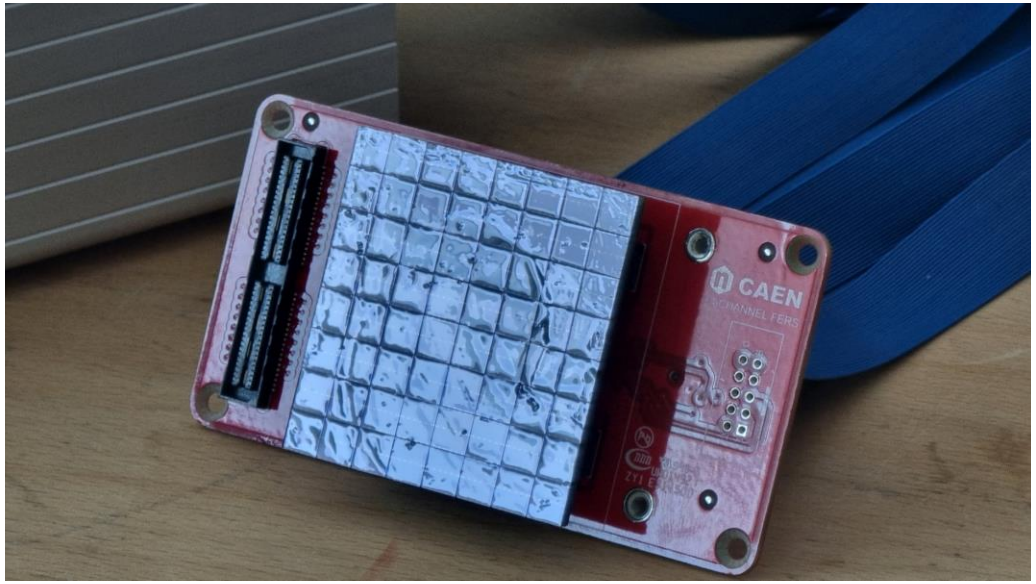
Multiple size SiPMs, a few mm^2 in area

How do SiPMs work?

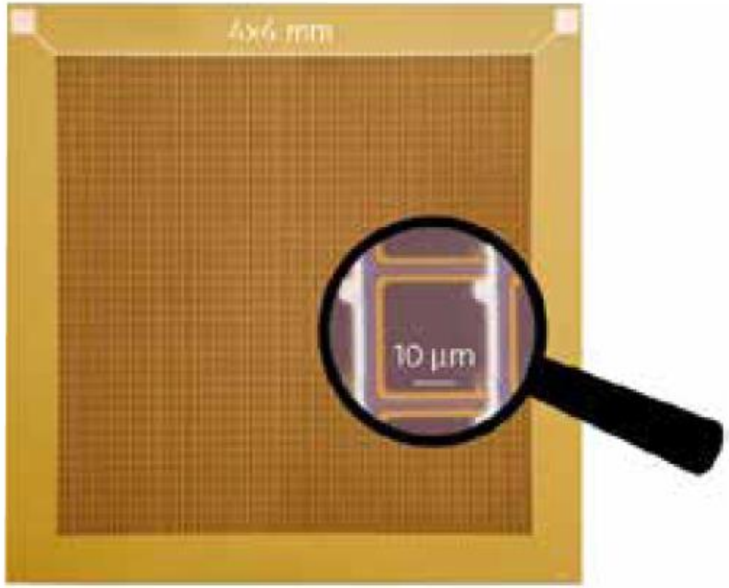
- Made of many SPADs (Single-Photon Avalanche Diodes).
- SPADs allow photon counting
- Similar to a regular photography camera







The 8x8 matrix of SiPMs used



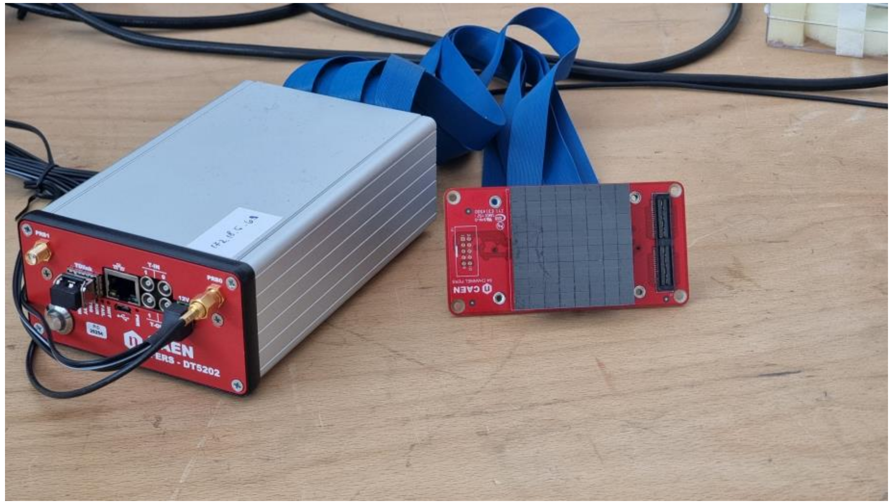
4x4mm SiPM made of many 10µm SPADs

Construct and characterize a position-sensitive detector using an 8x8 SiPM array and a thin, flat CsI crystal

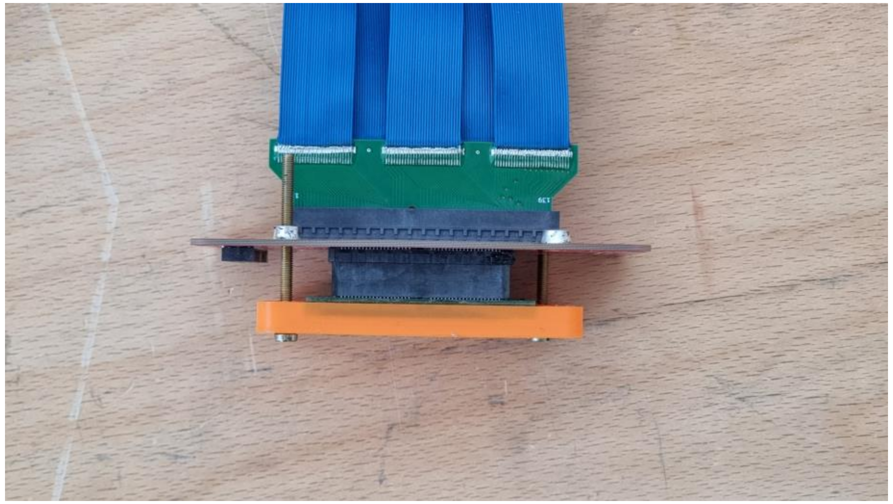
Detector construction

- CsI scintillator paired with an 8x8 SiPM array
- Encasing for stray photon prevention
- Electronic module to collect data from each SiPM

Cylindrical and flat scintillation crystals



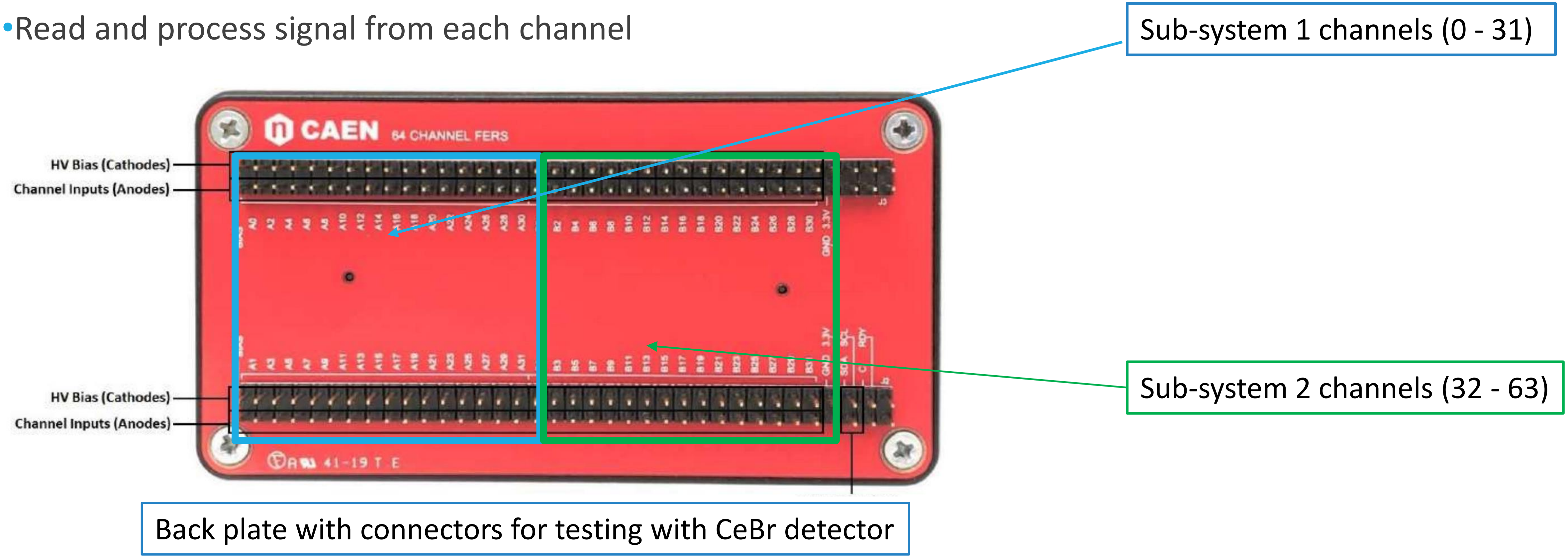
Connected 8x8 SiPM array



The flat scintillator installed

Detection assembly

- Electronic module with two sub-systems, each handling 32 channels
- Control the voltage applied to each channel (SiPM)
- Read and process signal from each channel



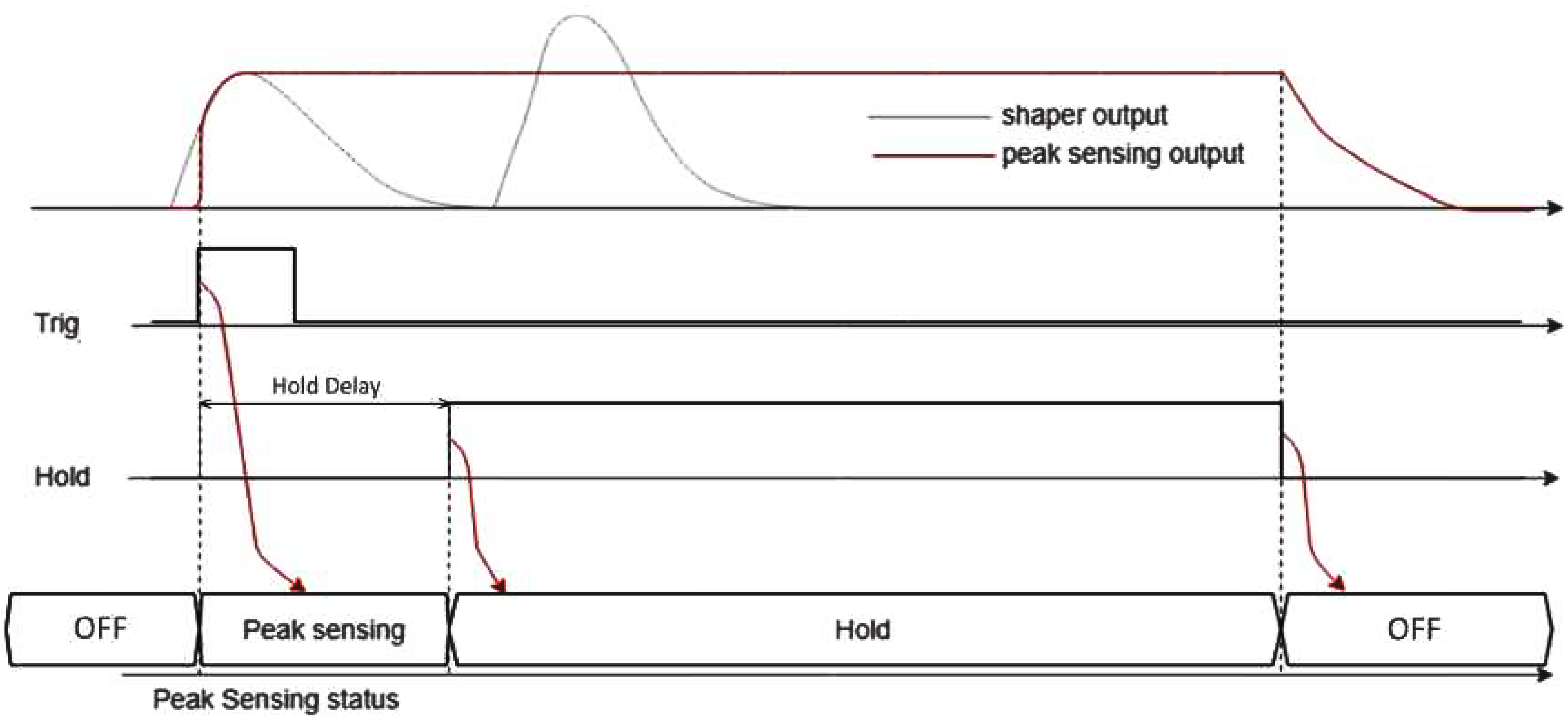
- SiPM signal = number of incident photons -> use of algorithms suitable to reconstruct interaction position

Peak sensing

Two parameters control the processing of signals from SiPMs:

- Shaping time: controls time constant of the input signal
- Hold delay: time interval between the trigger start and hold signal

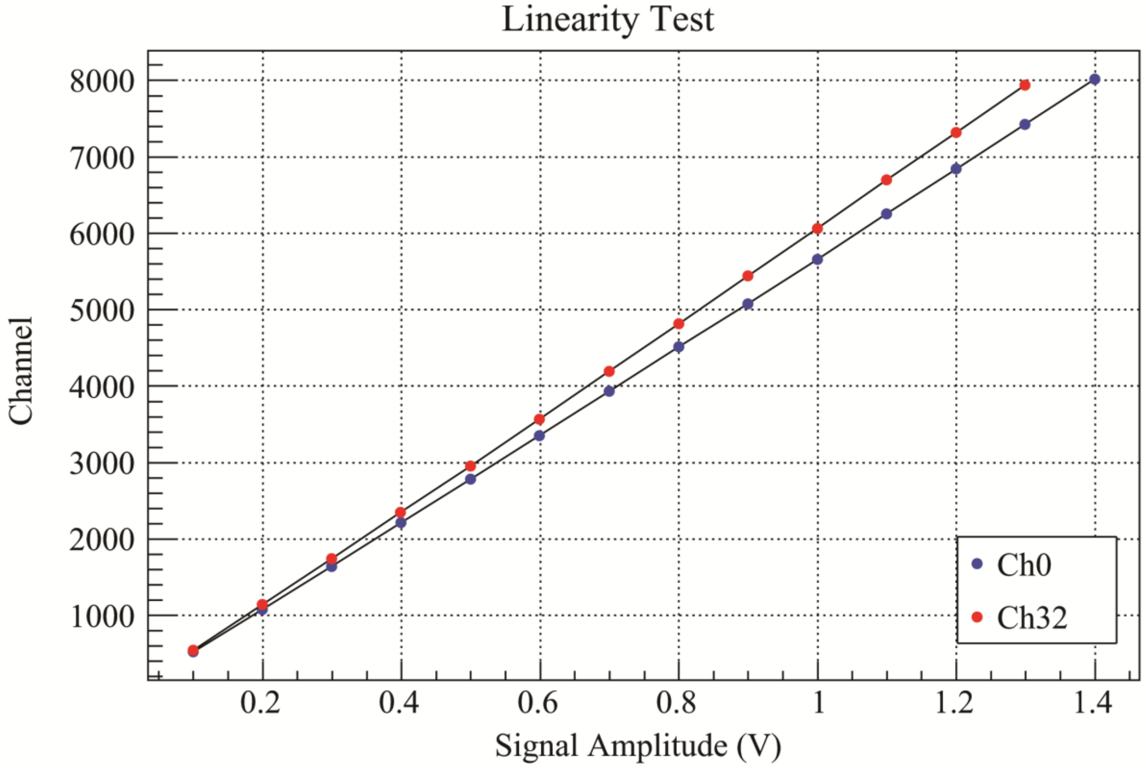
- Off phase: peak detector is off
- Peak sensing phase: when the trigger arrives, the peak detector holds the amplitude
- Hold phase: no other input signal is detected, the peak detector is disconnected from the input source

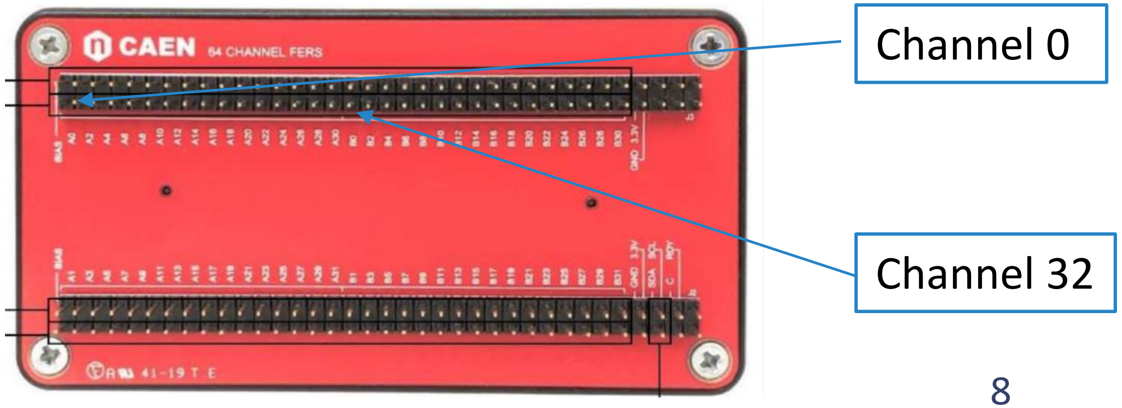


Initial Tests

- <u>Linearity of channels</u>
- Hold delay optimization
- Addback optimization

- Linearity test
- Pulse generator for signals with varying amplitudes (0.1V to 1.5V)





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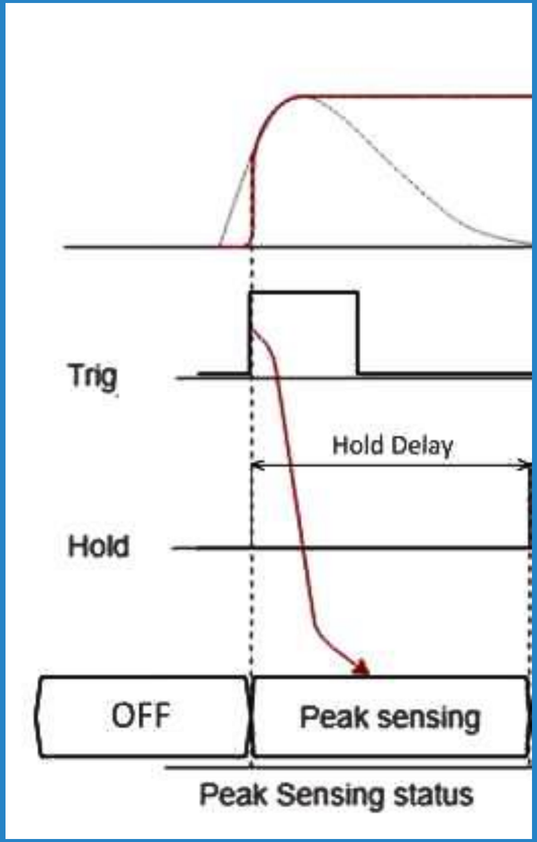
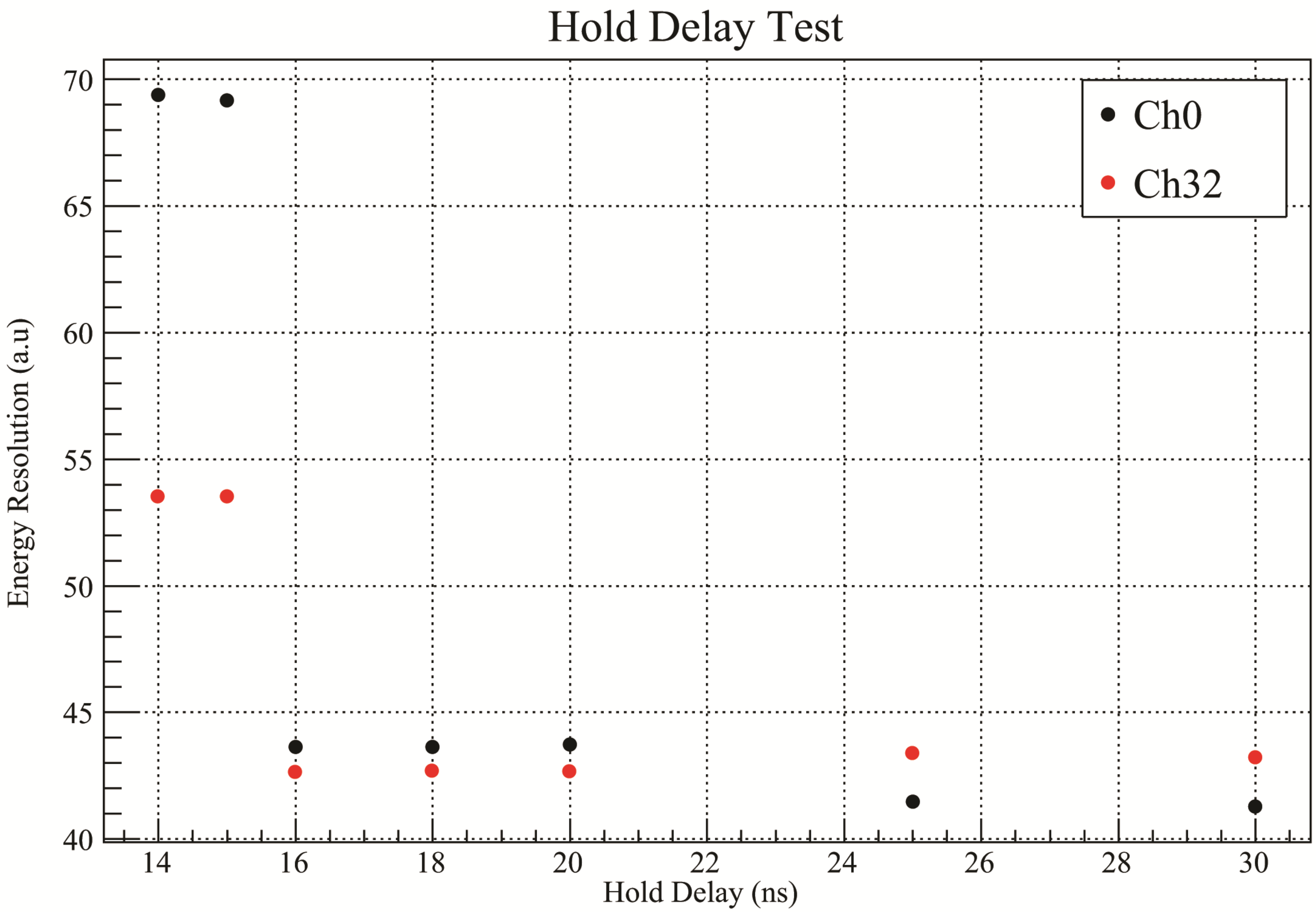


- Hold Delay influence on energy resolution for each sub-system

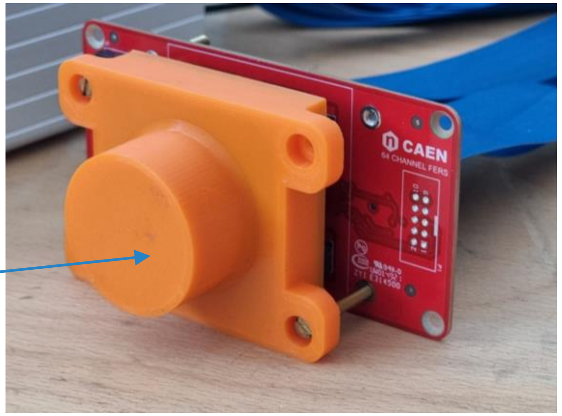


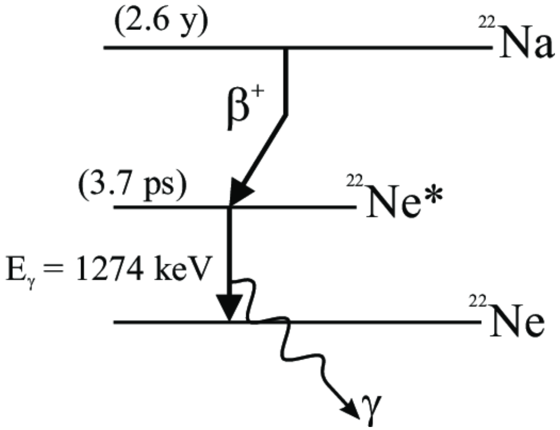
Initial Tests

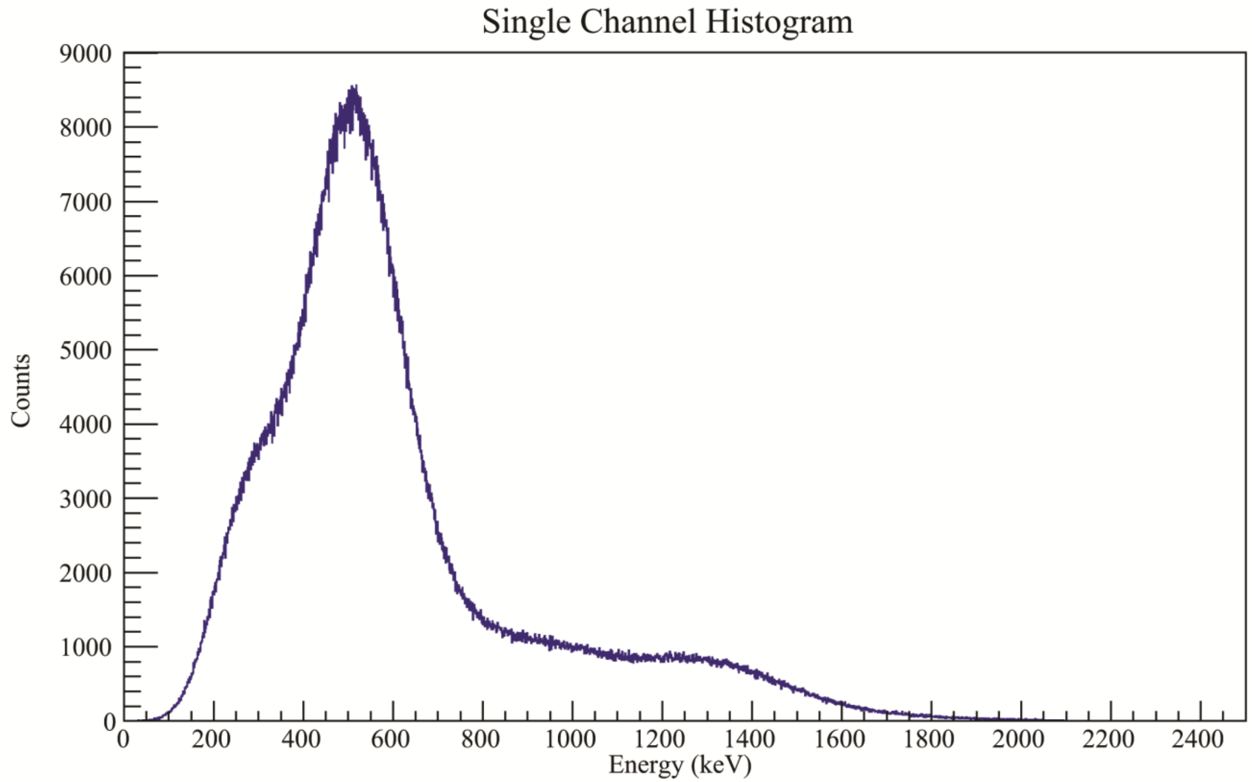
- Linearity of channels
- Hold delay optimization
- Addback optimization

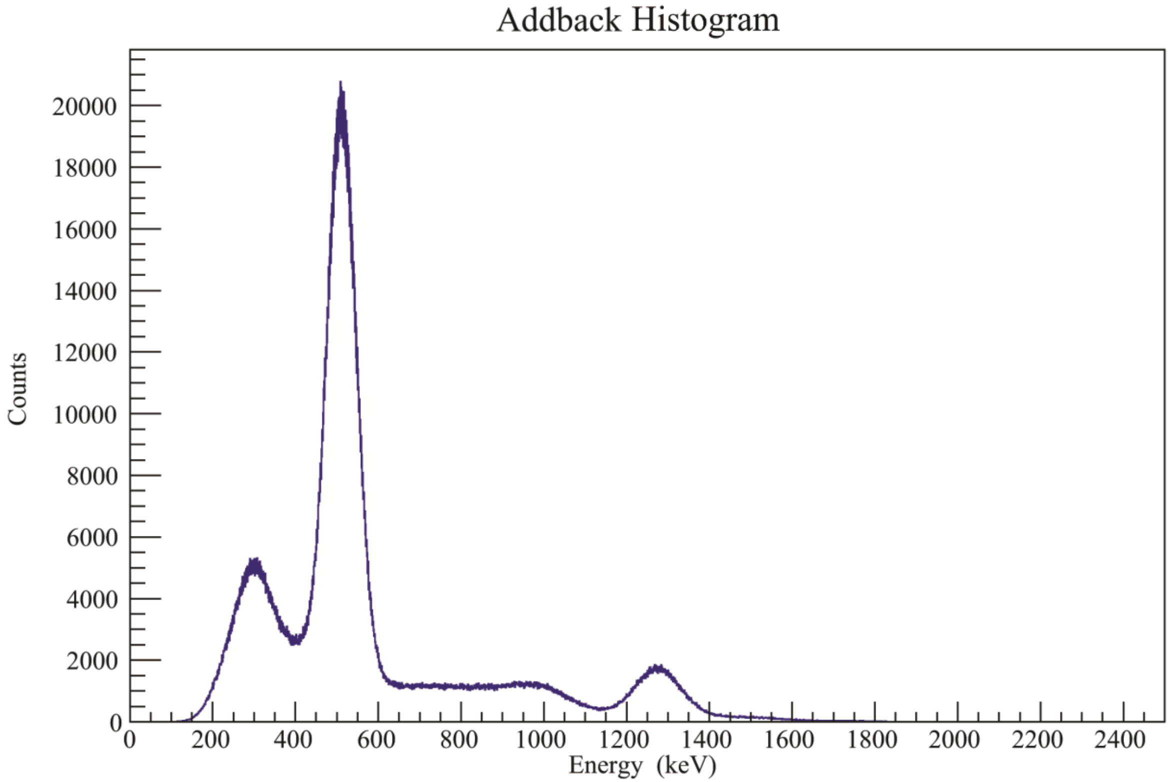
- Addback – sum data from multiple channels
- $^{54}Mn(834\ keV), ^{22}Na(511\ keV)\ and\ ^{137}Cs(661\ keV)$, for calibration
- Addback on ^{22}Na to reveal 1274 keV gamma peak

Scintillator covers 16/64 channels







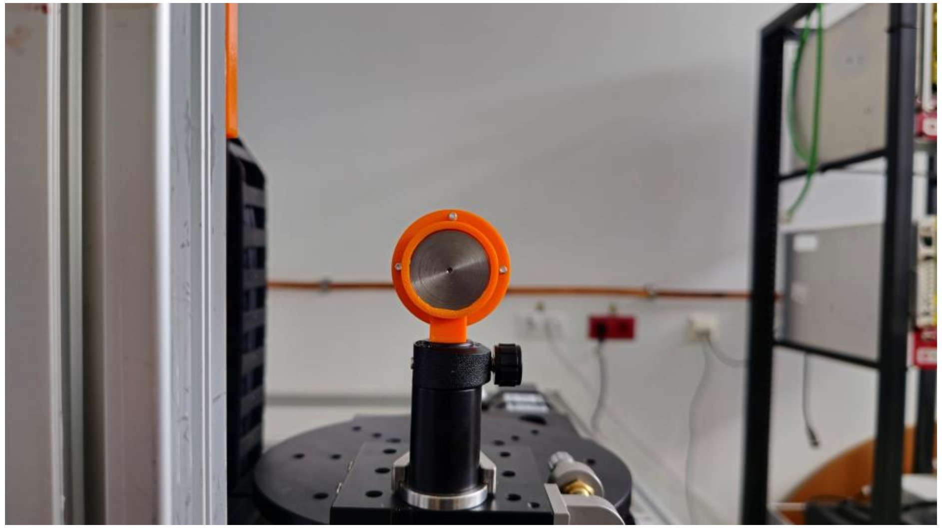


Interaction position measurements

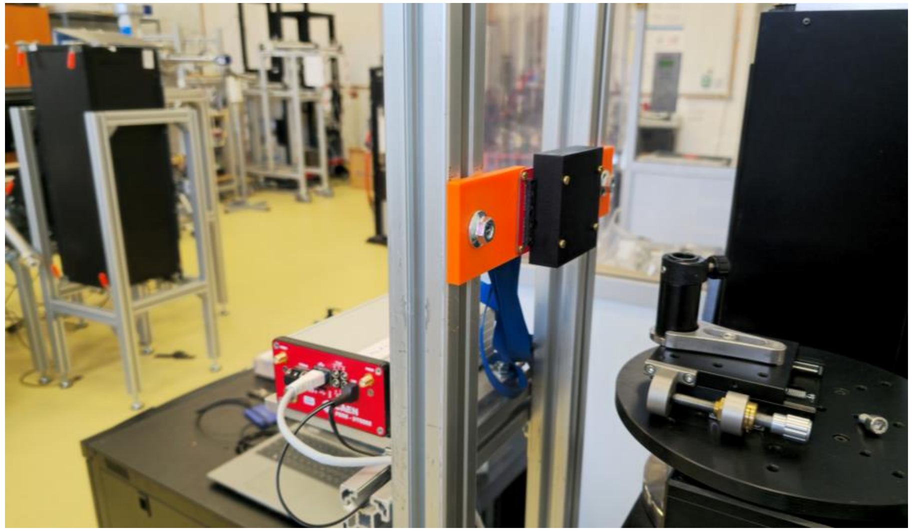
- Measurements setup
- Data processing

Detection assembly

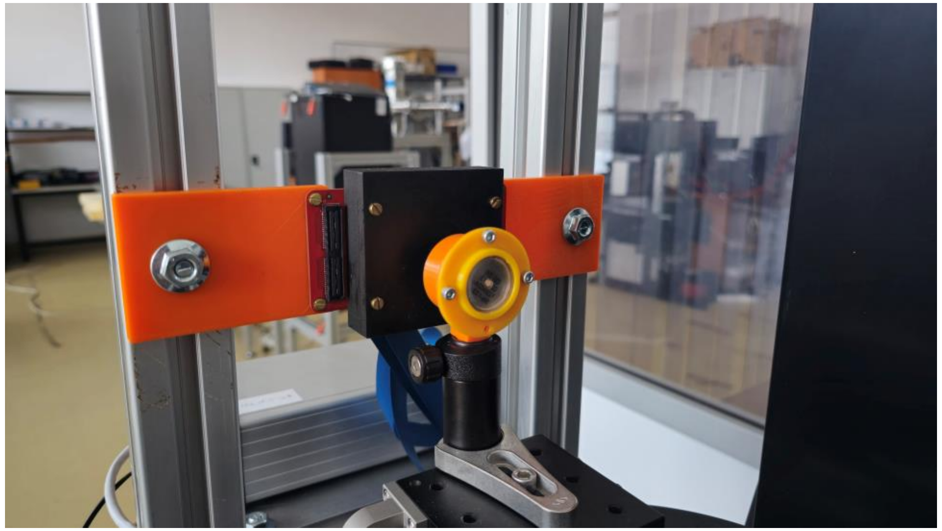
General overview of the setup



Densimet collimator with ^{241}Am source



Scintillator (2mm thick) and SiPM package



Example of interaction position measurement

Interaction position measurements

- Measurements setup
- Data processing

1.Measure point on matrix

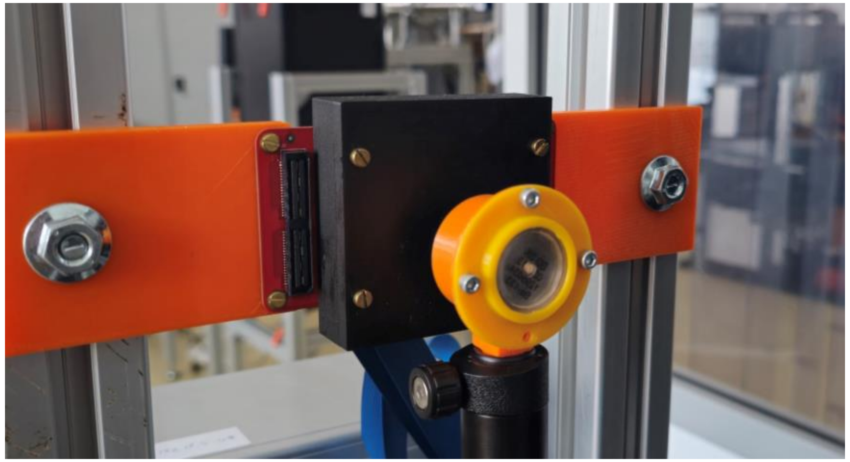
↓

2.Record individual gamma events

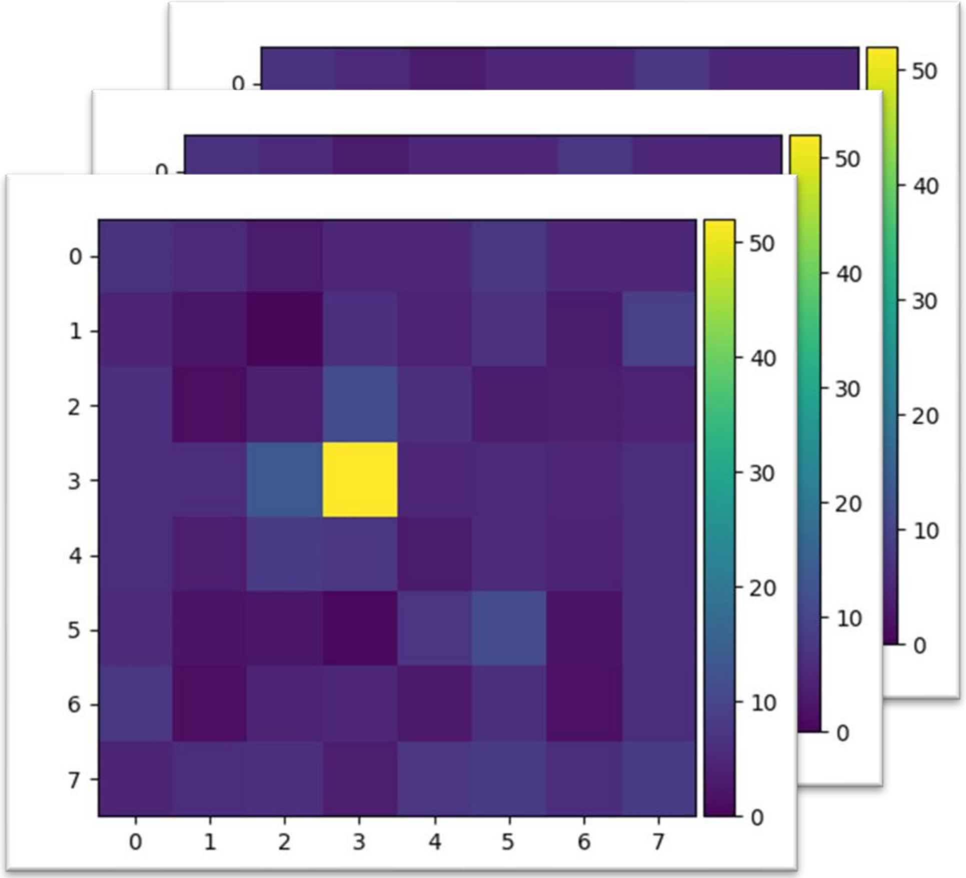
↓

3.Construct individual intensity maps

- An 8 x 8 matrix of points measured on the detector
- One measured point -> many single gamma events recorded
- Higher energy gamma -> more scintillation light -> higher intensity recorded



Individual point measurement



Single gamma events

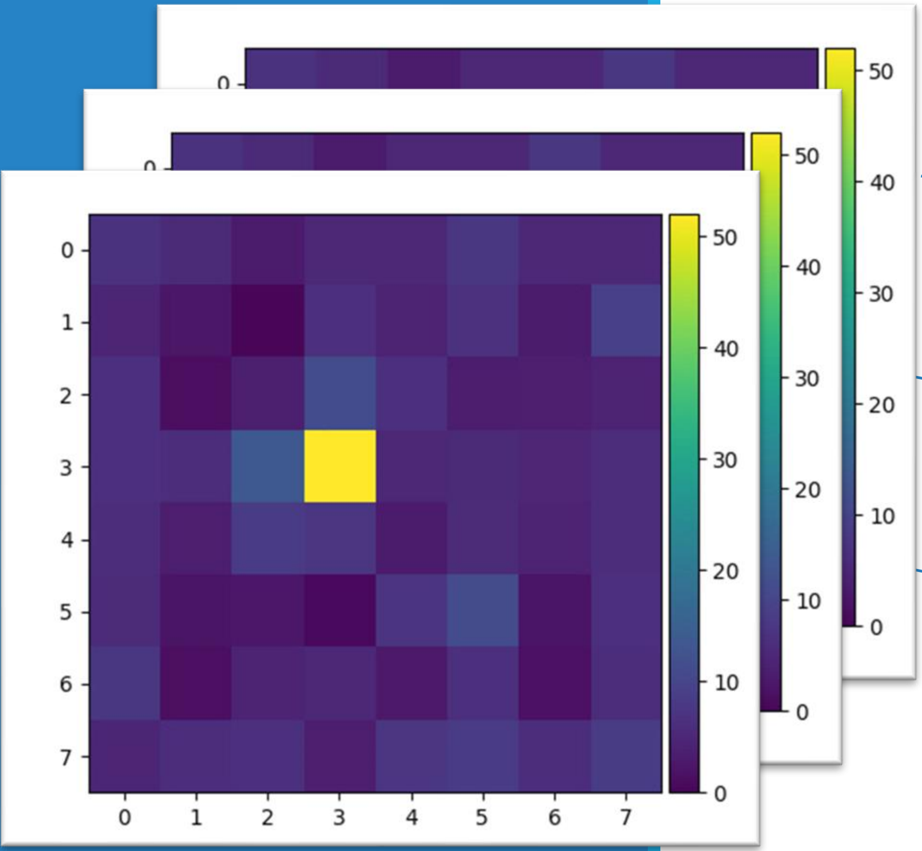
Interaction position measurements

- Measurements setup
- Data processing

- Single events processed using Centre of Gravity algorithm (CoG):

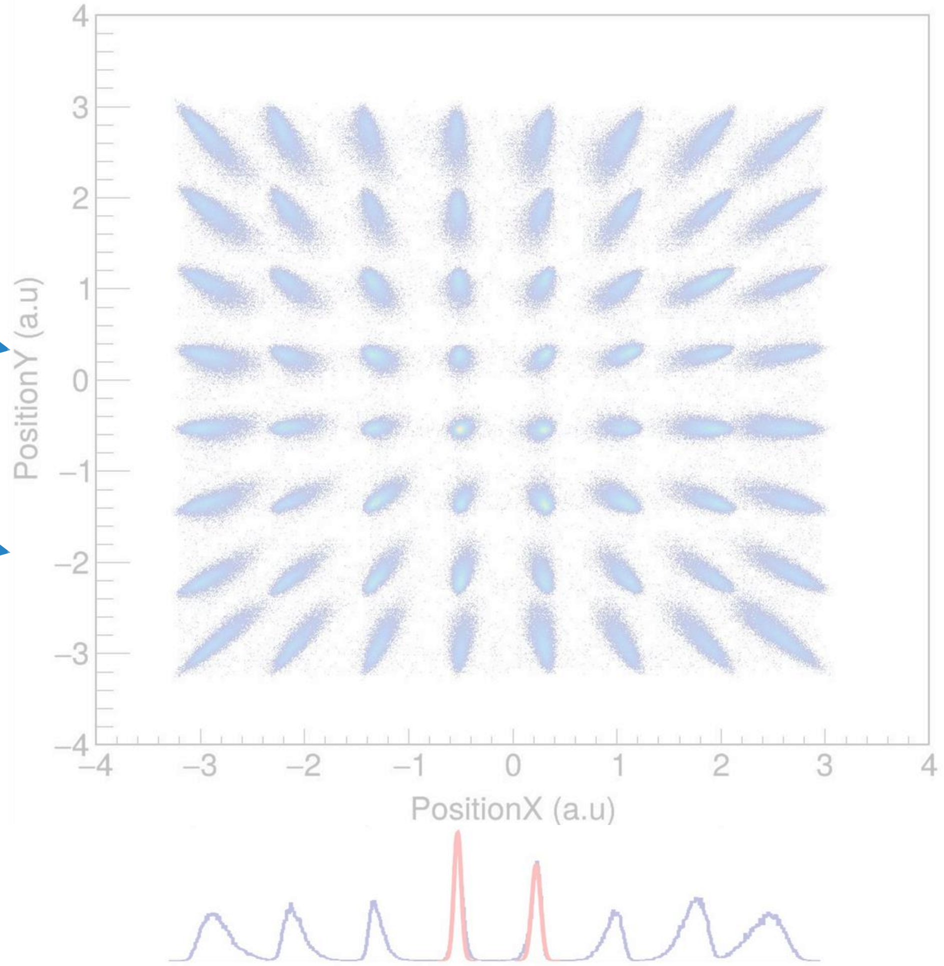
$$x_{int} = \frac{\sum_{i=1}^{64} q_i^2 \cdot x_i}{\sum_{i=1}^{64} q_i^2}$$

$$y_{int} = \frac{\sum_{i=1}^{64} q_i^2 \cdot y_i}{\sum_{i=1}^{64} q_i^2}$$



Single gamma event

1. Subtract background
2. Apply CoG
3. Add to histogram



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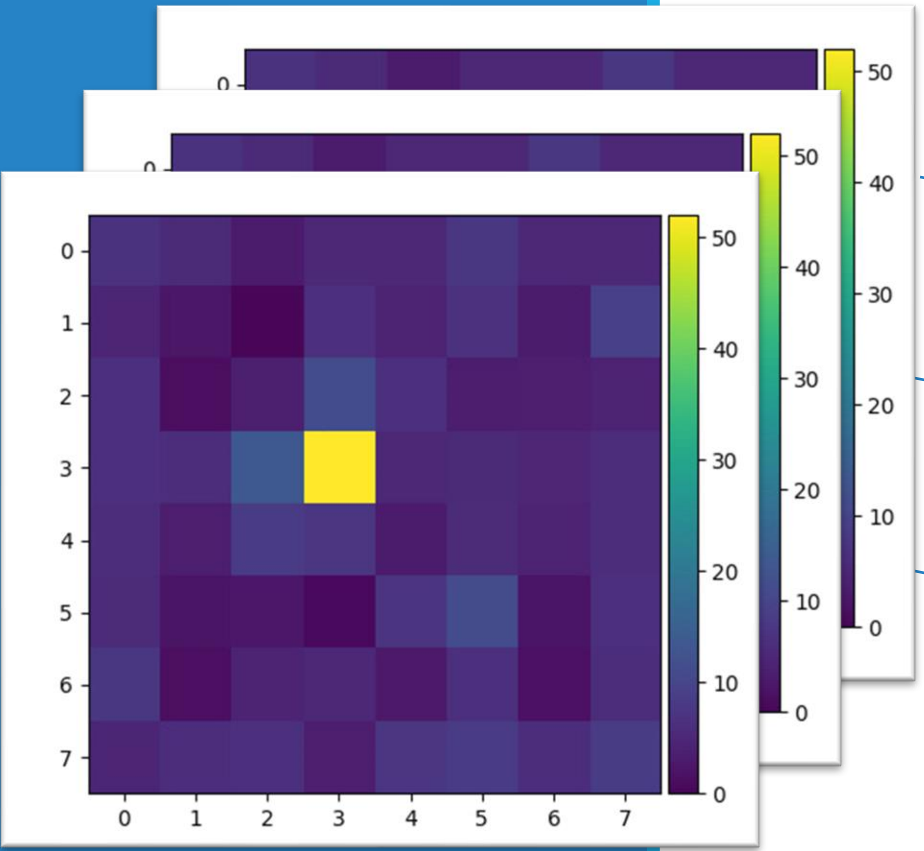

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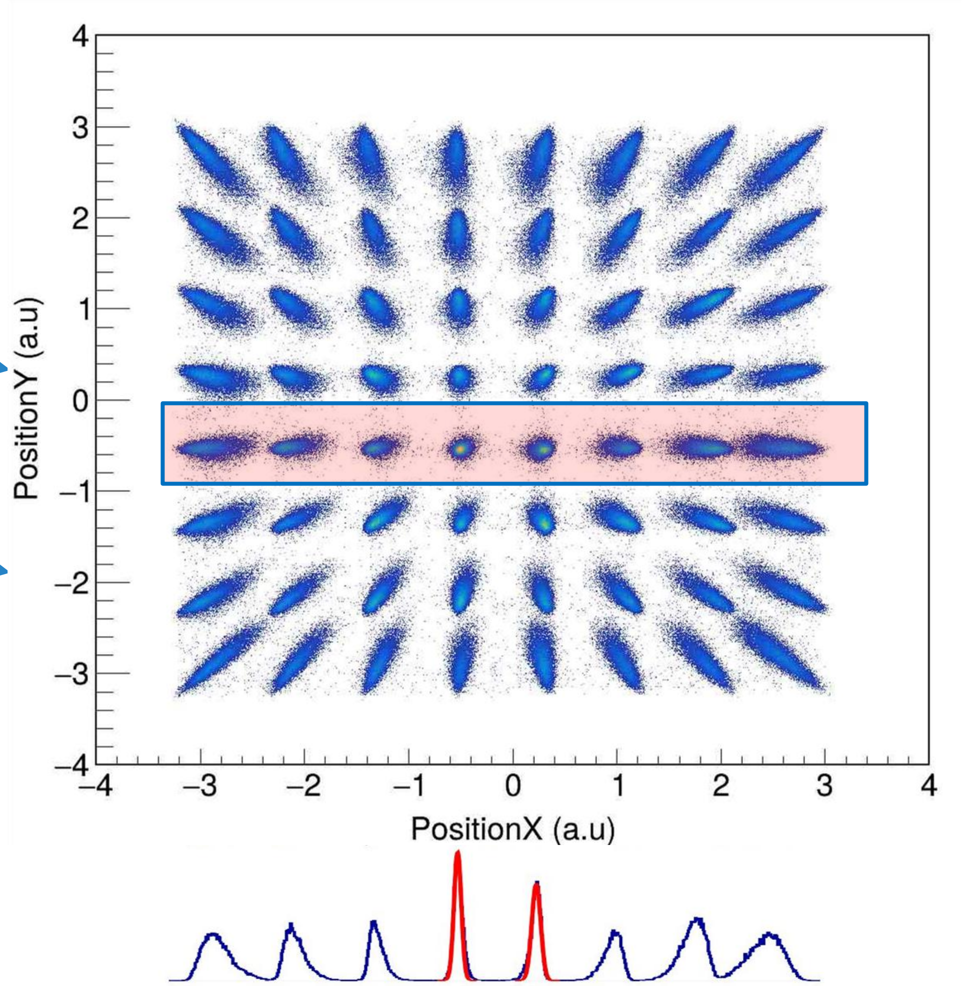
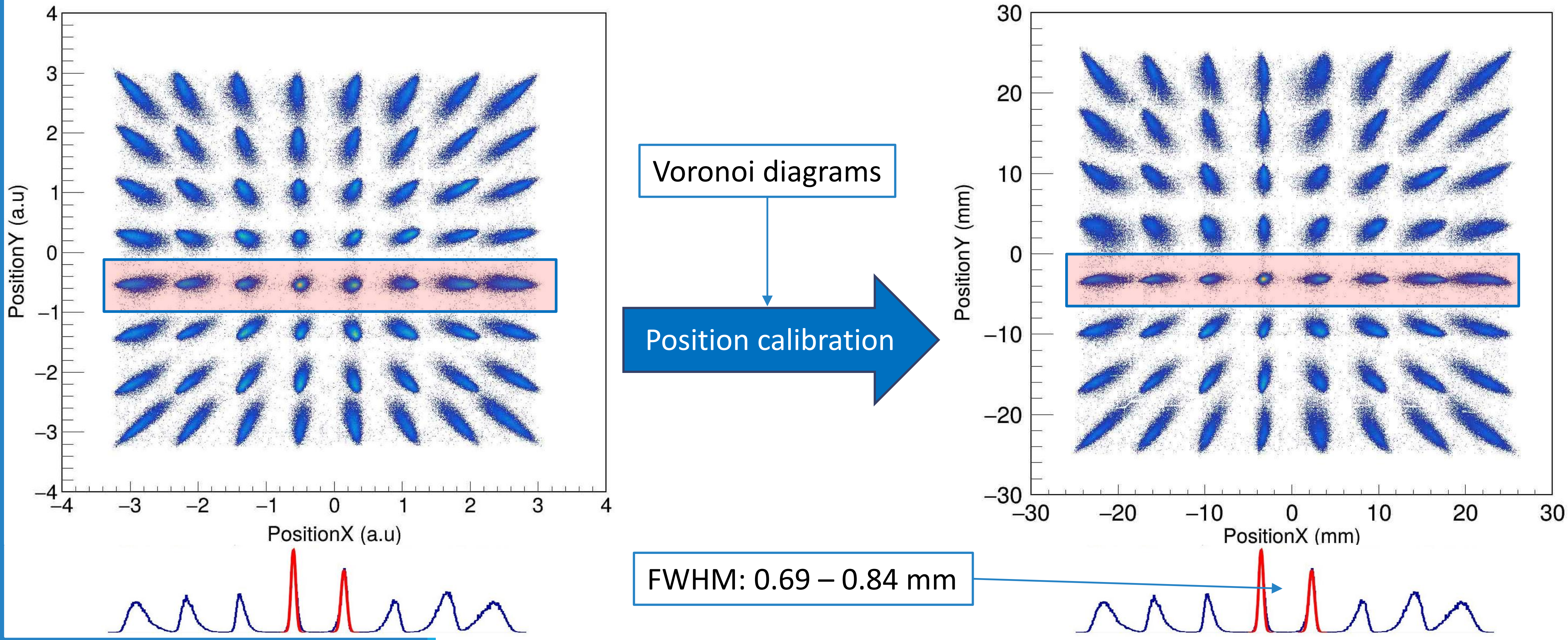


Interaction position measurements

- Measurements setup
- Data processing

- Voronoi diagrams used for position calibration
- Centre of pixels calculated with experimental data correlated to physical coordinates on the detector



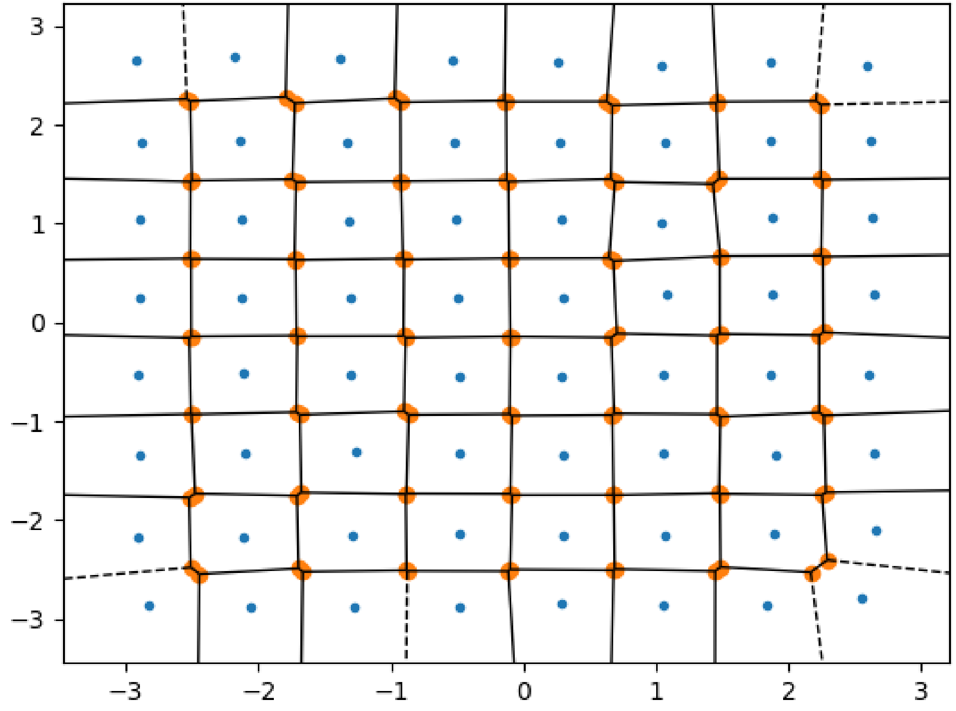
Conclusions and Future plans

- Initial tests run succesfully
- Addback procedure works effectively
- Potential to be used as position sensitive detector
- Future plans
  - Develop algorithms to correct the skewness of spots on the positioning histogram
  - Further development to accomodate larger scintillators

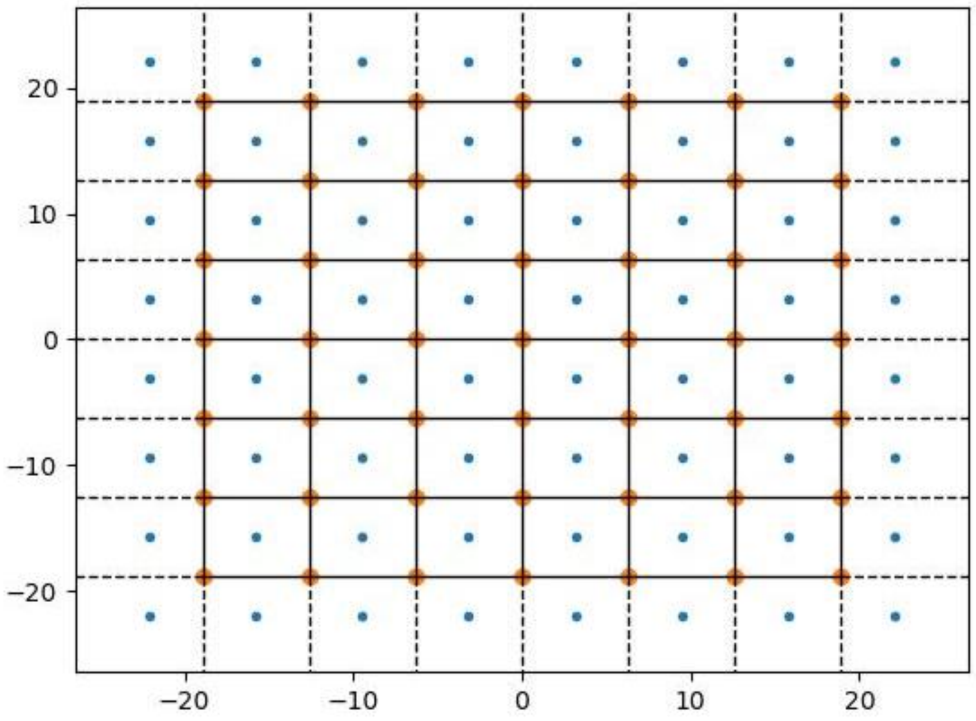
Thank you for your attention!

Voronoi Diagrams

- Region of Interest (ROI) -> points closest to one site (pixel centre) -> one site generates one ROI



Voronoi diagram constructed with experimental data



Voronoi diagram constructed with physical coordinates