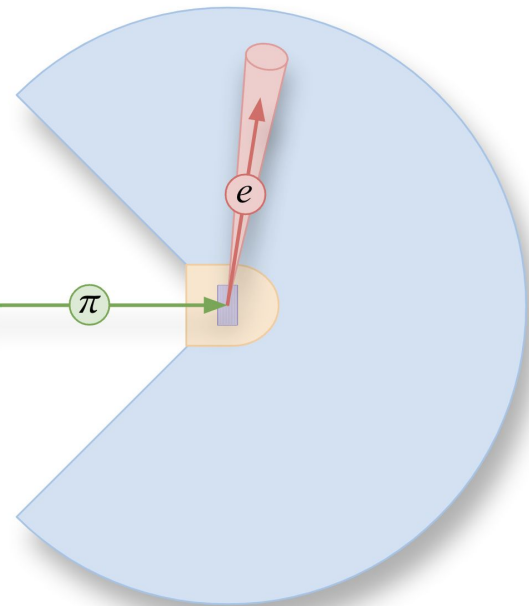


LYSO test beam

Upstream detectors and
x-scan data analysis



Entrance detectors for LYSO beamtime

Hodoscope:

- 24 x 24 mm² total area
- 2 layers (x&y)
- 12 BC 404 bars per layer
- Each 2 mm wide, 1 mm thick
- 24 SiPMs readout on alternating sides
- Signals amplified



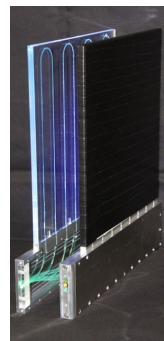
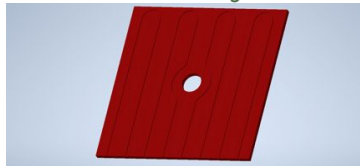
Entrance detector:

- 25 x 25 mm² area
- 1 piece of BC 404
- 1 mm thickness
- Read out by PMT

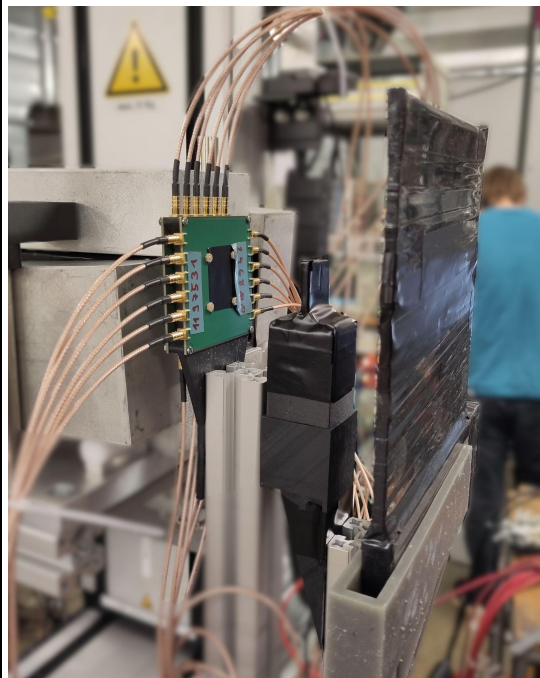


Veto detector:

- 18 x 18 cm paddle
- 11 mm radius hole
- Read out by a SiPM



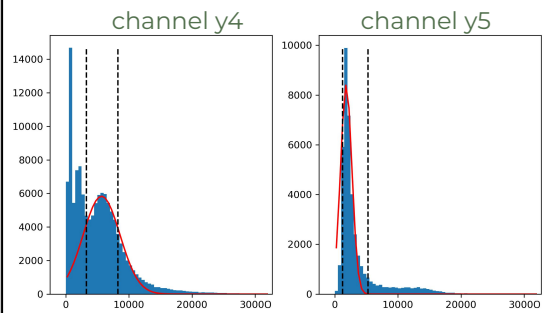
Upstream detector setup:



Hodoscope calibration

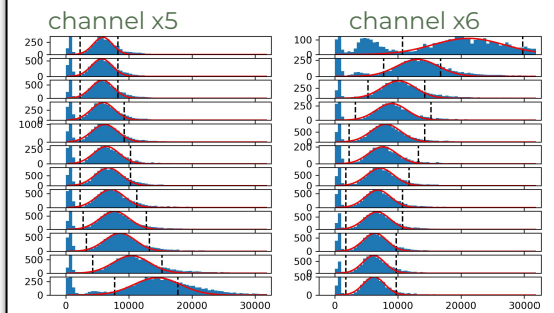
Rough calibration:

Channel dependent gain



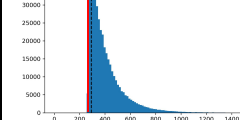
Fine calibration:

Position dependent gain

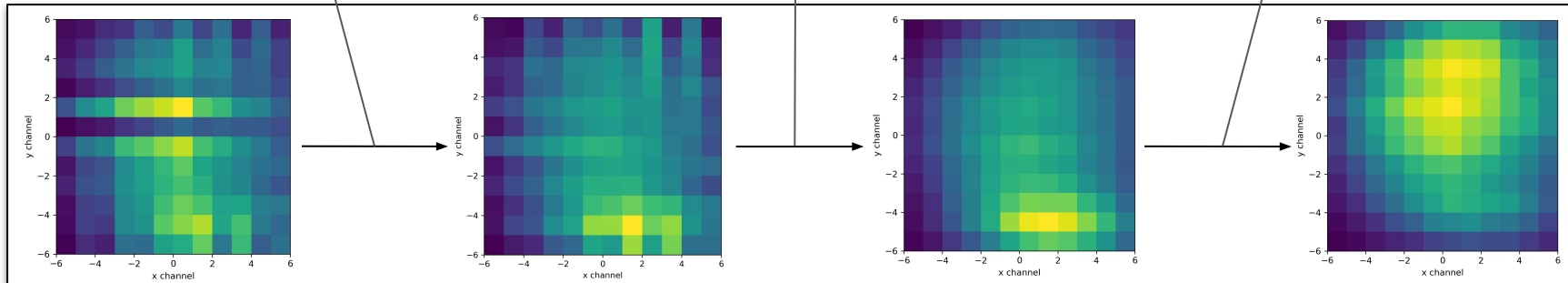
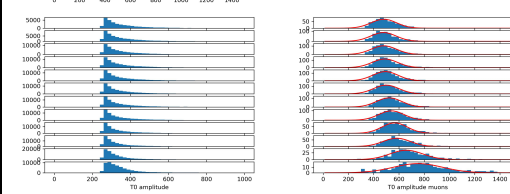
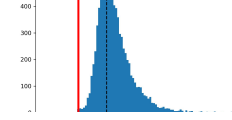


T0 cutoff:

Positrons

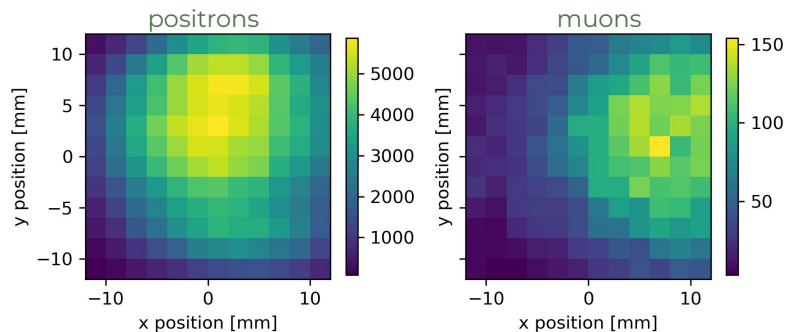


Muons



Hodoscope and beam parameters

Result:

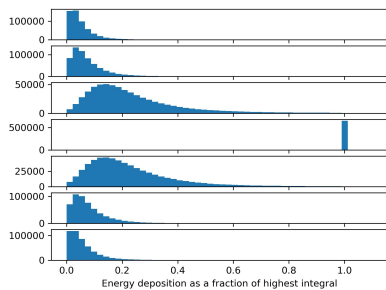


Hodoscope performance:

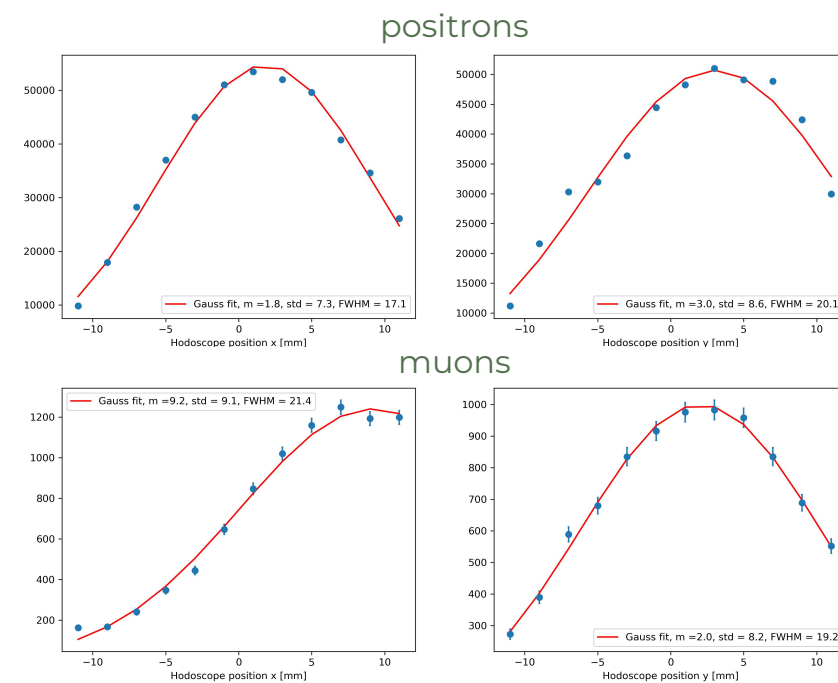
- Efficiency:
 - 69 % two hits
 - 23 % one hit
 - 8 % no hit

- Crosstalk probability:

- 50 % in x
- 45 % in y



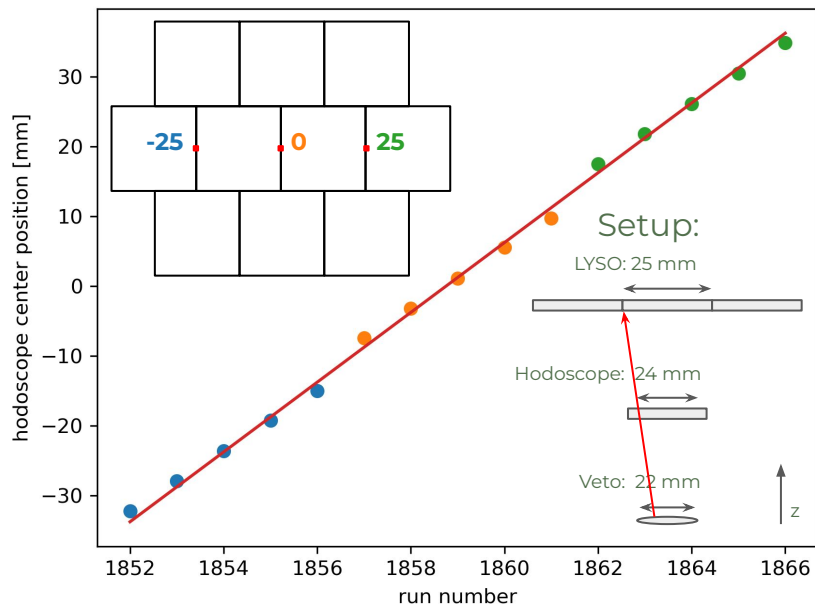
Beam profile: FWHM: ~ 20 mm



Position calibration

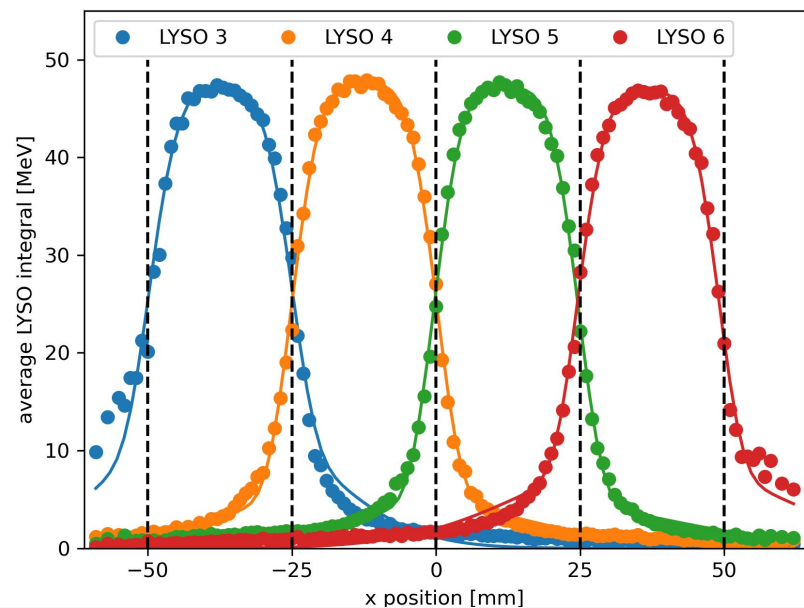
Internal calibration:

- Combining hodoscope and LYSO information
- Track position of crystal boundaries along runs



Result:

- Crystal center at $x = -1.43, y = -0.36$
- Data of all x-scan runs combined:



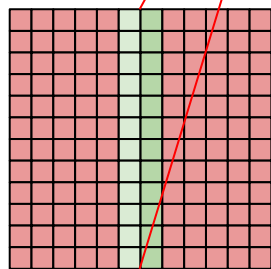
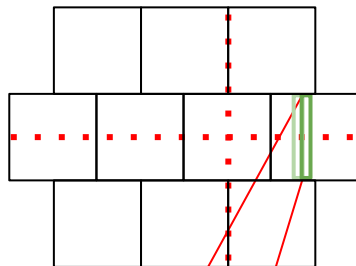
Uniformity

X - scan:

- Take data along center line in x
- check array uniformity

Procedure:

- Tag event location on event by event basis
- Bin data along x
- Apply calibration
- Add contributions of all crystals
- Fit energy distribution at each location

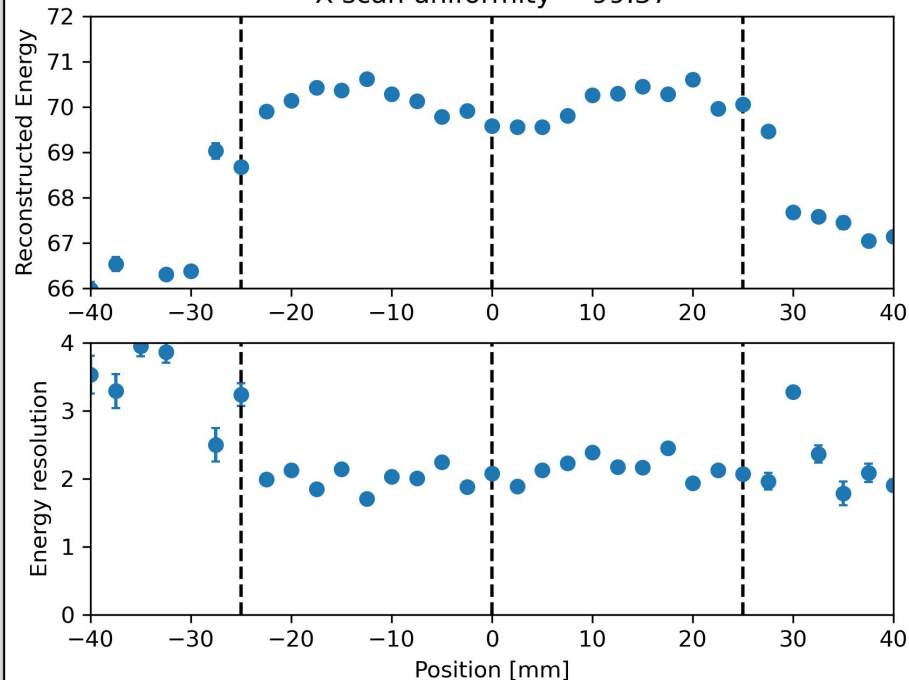


Uniformity:

$$U = \left(1 - \frac{\sigma_E}{E}\right) \cdot 100\%$$

Result:

X-scan uniformity = 99.37



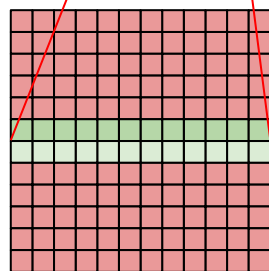
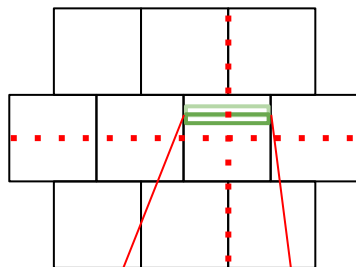
Uniformity

Y - scan:

- Take data along a line in y
- check array uniformity

Procedure:

- Tag event location on event by event basis
- Bin data along y
- Apply calibration
- Add contributions of all crystals
- Fit energy distribution at each location

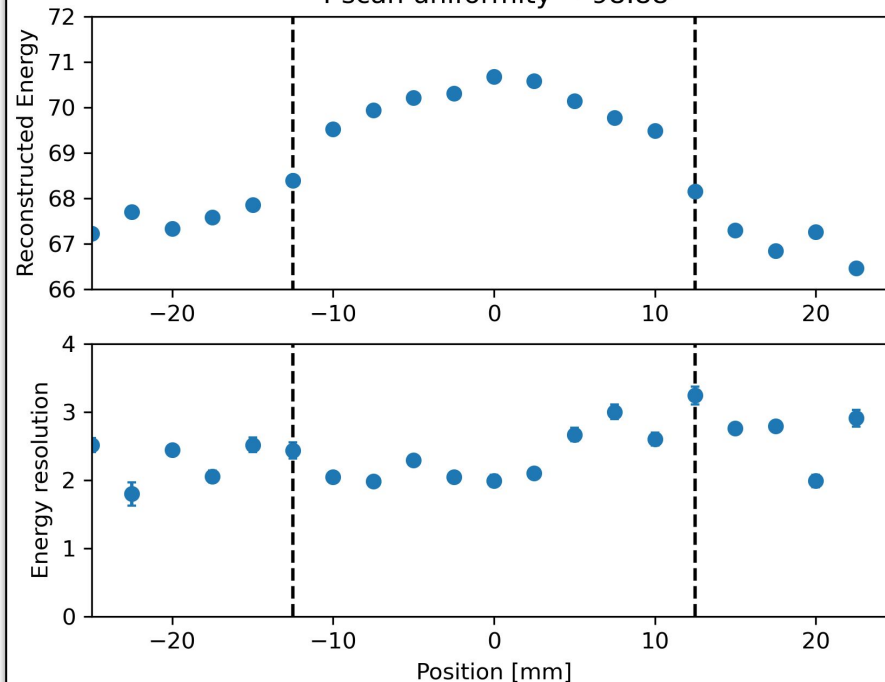


Uniformity:

$$U = \left(1 - \frac{\sigma_E}{E}\right) \cdot 100\%$$

Result:

Y-scan uniformity = 98.88



Position resolution of LYSO array

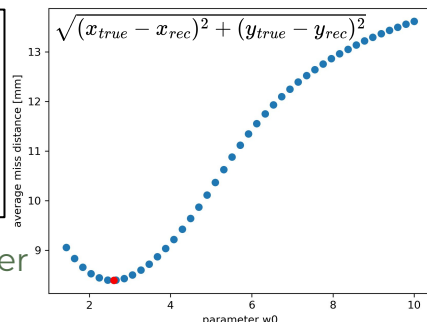
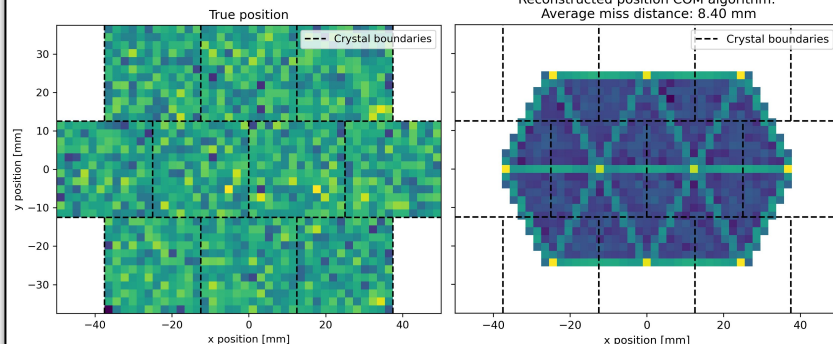
Center of mass algorithm:

$$(x, y) = \left(\frac{\sum_i w_i \cdot x_i}{\sum_i w_i}, \frac{\sum_i w_i \cdot y_i}{\sum_i w_i} \right)$$

$$w_i = \max \left\{ 0, \left(w_0 + \log \frac{E_j}{\sum_j E_j} \right) \right\}$$

- Optimize w_0 parameter

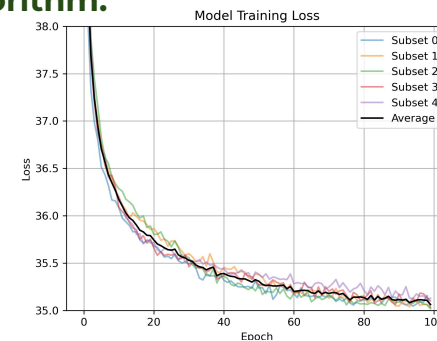
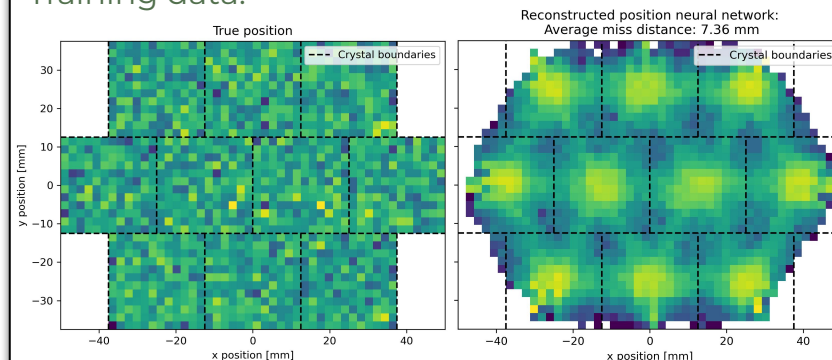
Optimization data:



Machine learning algorithm:

- Feed forward neural network
- Two hidden layers with 64 & 32 nodes
- Relu activation function

Training data:



Position resolution of LYSO array

Simulation data:

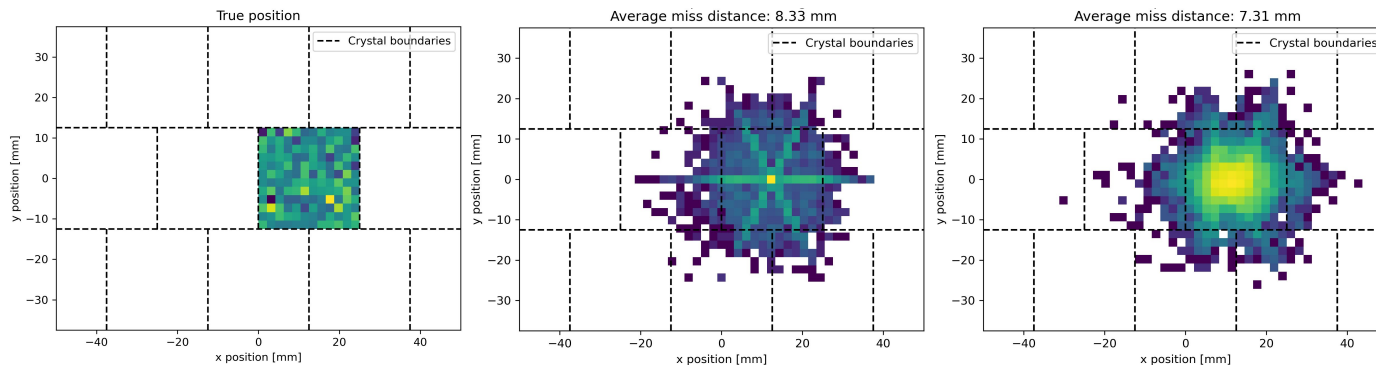
Position resolution:

COM: $\sigma_x = 6.0$ mm,

$\sigma_y = 6.2$ mm

NN: $\sigma_x = 5.5$ mm,

$\sigma_y = 5.7$ mm



X-scan data:

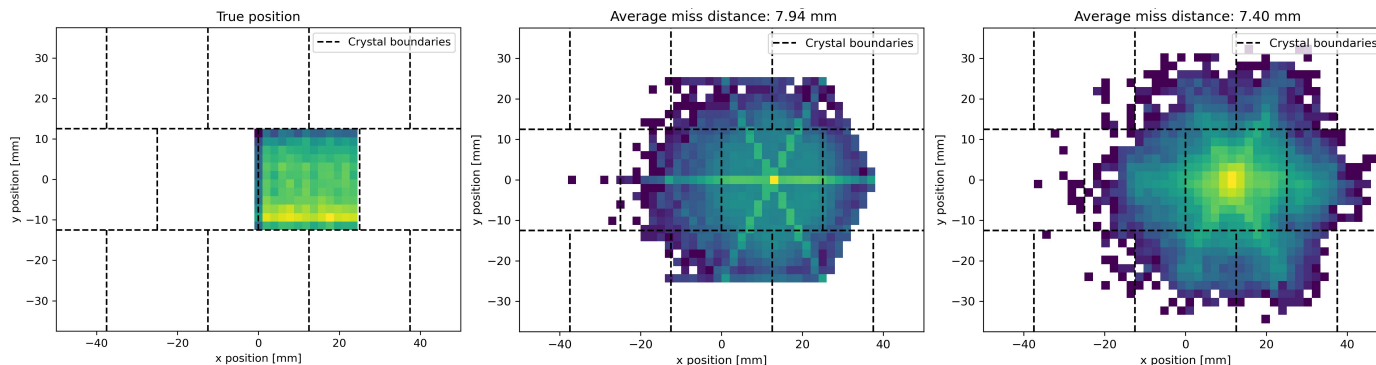
Position resolution:

COM: $\sigma_x = 6.4$ mm,

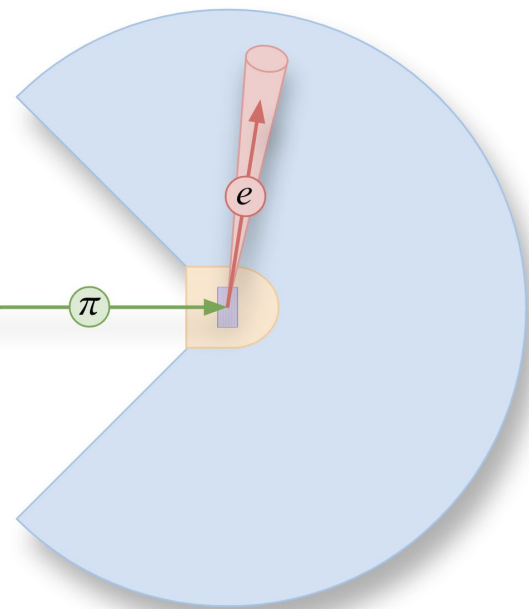
$\sigma_y = 6.3$ mm

NN: $\sigma_x = 6.1$ mm,

$\sigma_y = 5.8$ mm



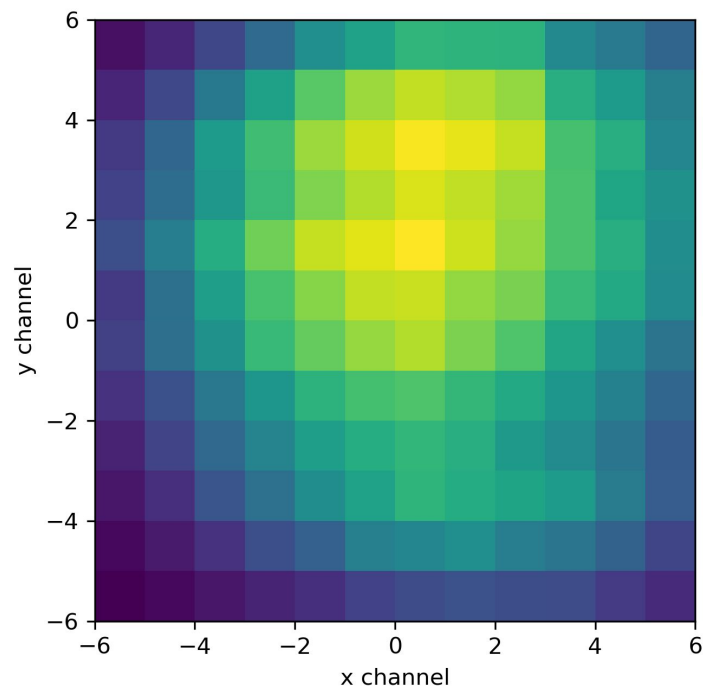
Backup slides



Hodoscope calibration

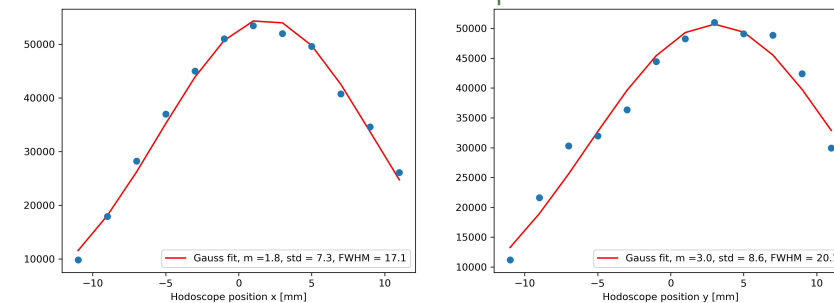
Result:

Positrons

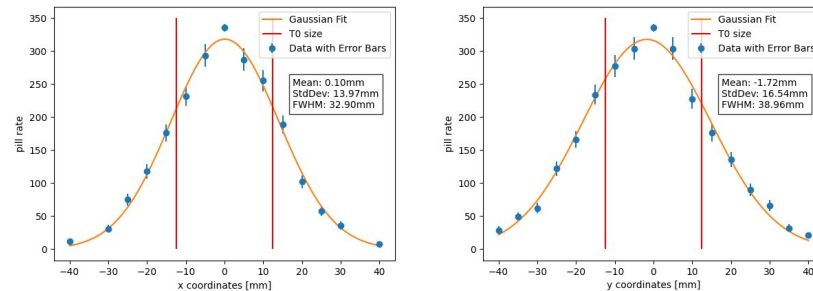


Beam size:

Hodoscope



Pill counter

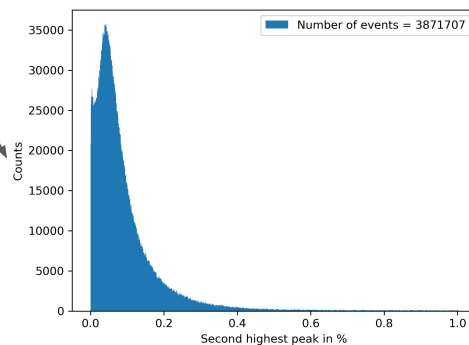
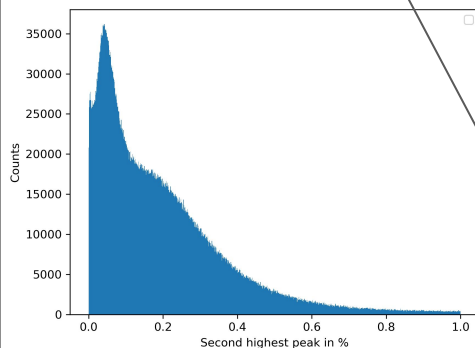
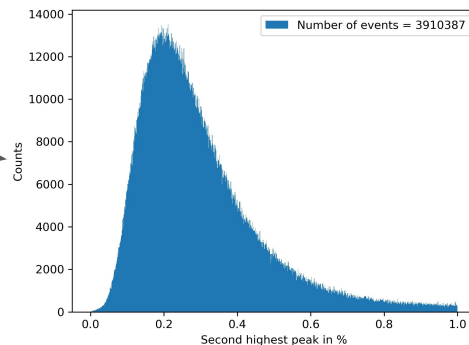


Hodoscope crosstalk

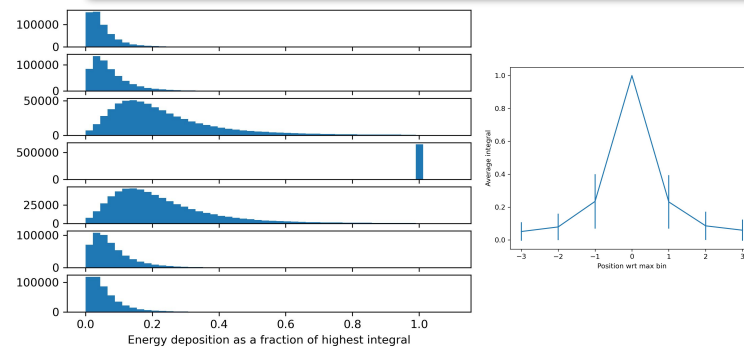
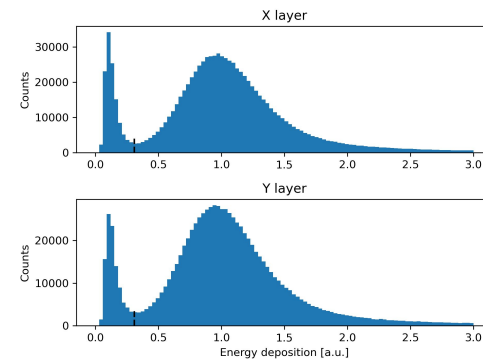
Crosstalk characterization:

Second highest peak:

- distance = 1
- distance > 1
- all



Noise:

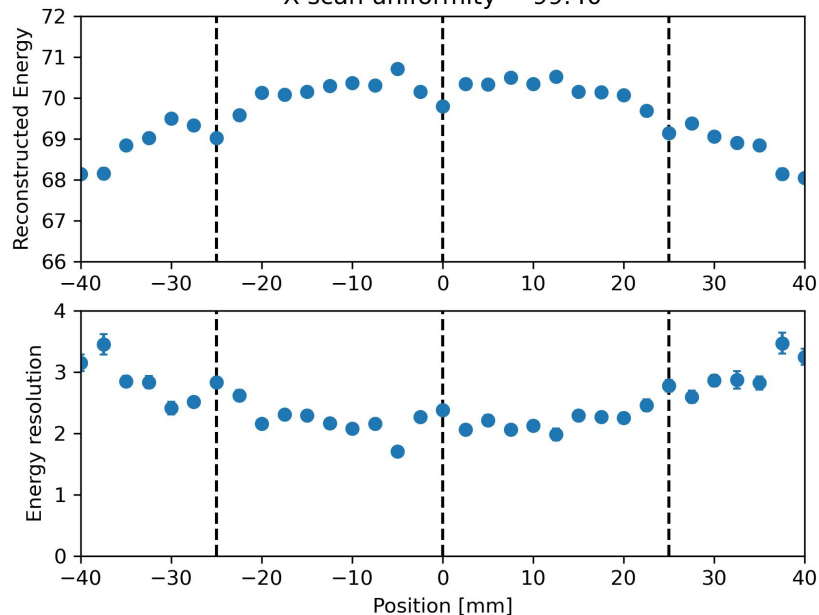


Position calibration

X-scan in simulation:

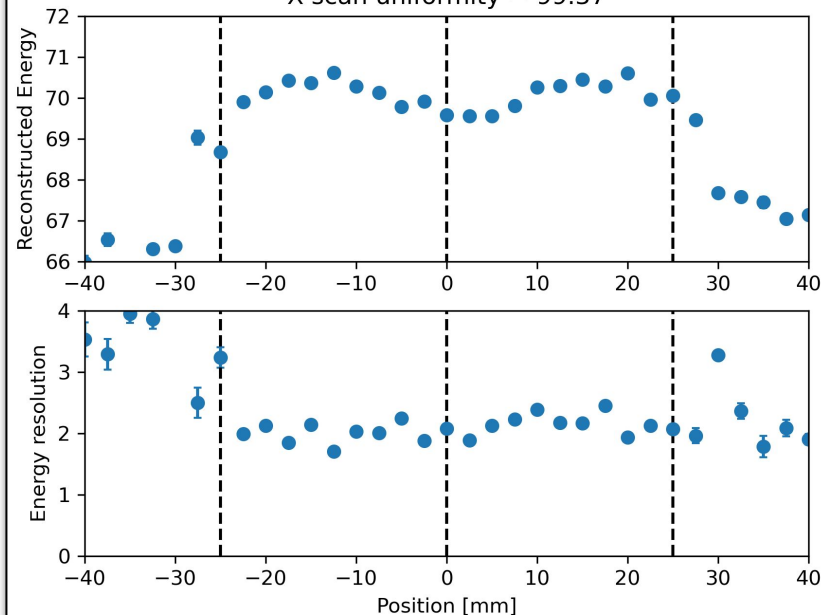
Difference: no NaI detectors

X-scan uniformity = 99.40



X-scan from measurement:

X-scan uniformity = 99.37



Position resolution of LYSO array

Simulation data:

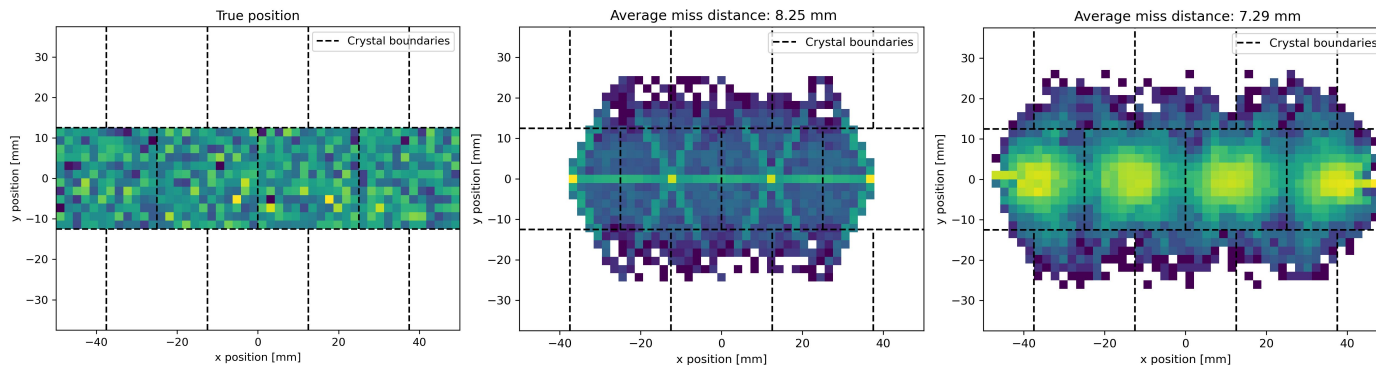
Position resolution:

COM: $\sigma_x = 6.6$ mm,

$\sigma_y = 6.3$ mm

NN: $\sigma_x = 5.7$ mm,

$\sigma_y = 5.9$ mm



X-scan data:

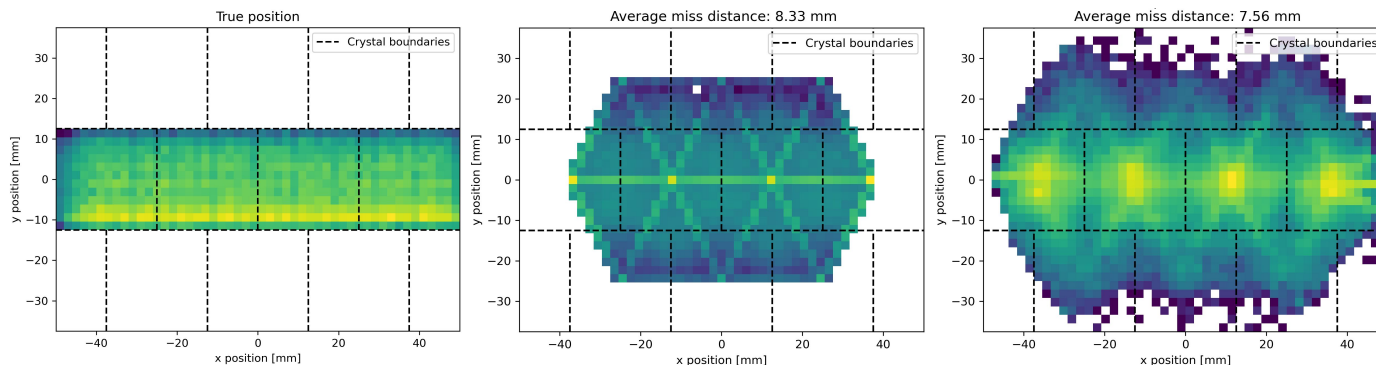
Position resolution:

COM: $\sigma_x = 7.2$ mm,

$\sigma_y = 6.3$ mm

NN: $\sigma_x = 6.4$ mm,

$\sigma_y = 6.0$ mm



Position resolution of LYSO array

Simulation data:

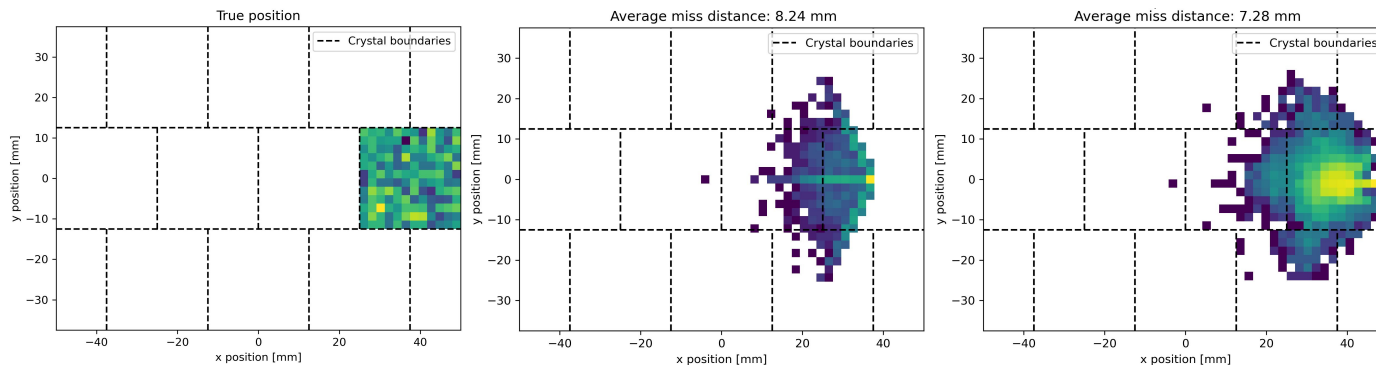
Position resolution:

COM: $\sigma_x = 6.5$ mm,

$\sigma_y = 6.4$ mm

NN: $\sigma_x = 5.7$ mm,

$\sigma_y = 6.0$ mm



X-scan data:

Position resolution:

COM: $\sigma_x = 7.2$ mm,

$\sigma_y = 6.3$ mm

NN: $\sigma_x = 6.4$ mm,

$\sigma_y = 6.2$ mm

