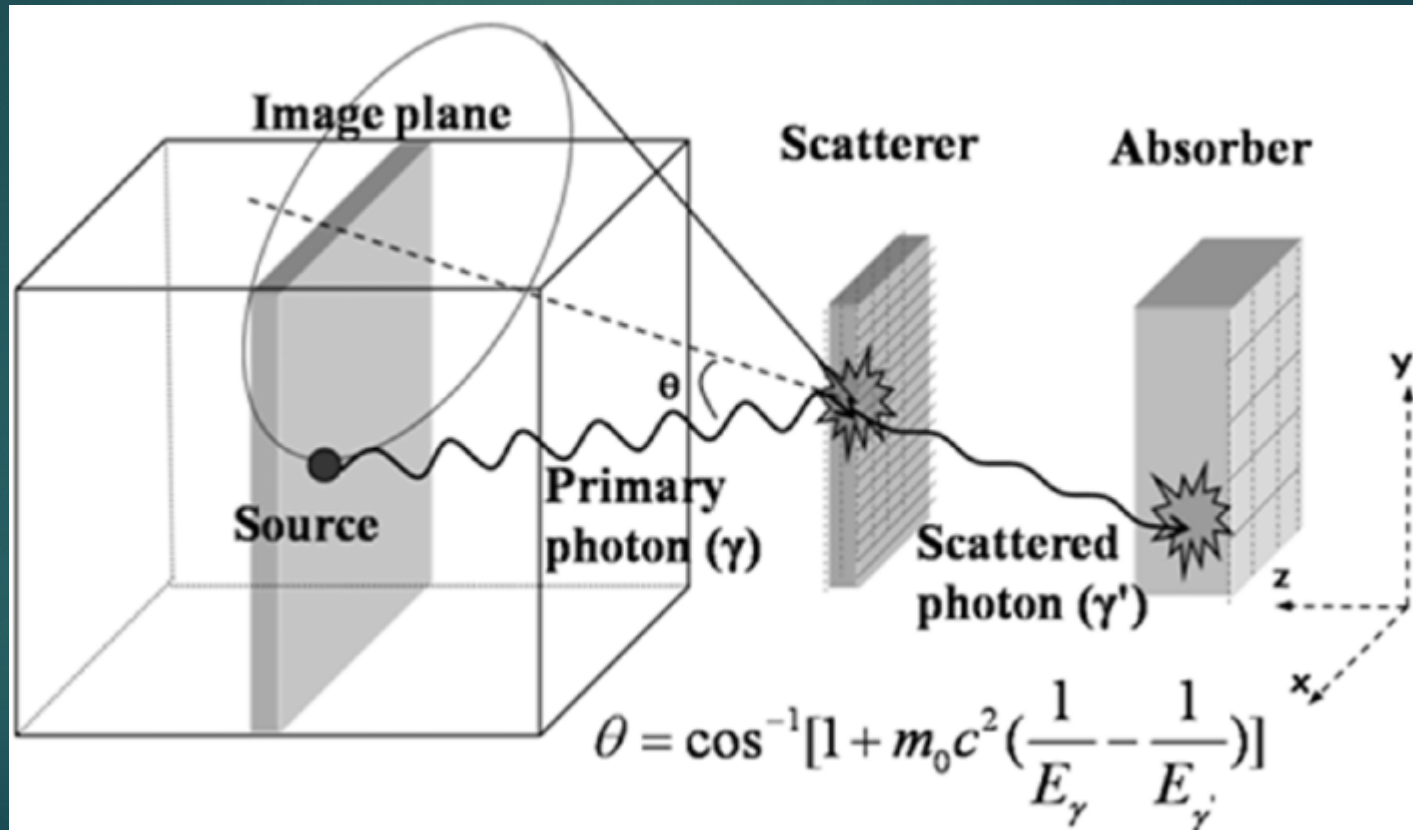# Source position determination using Compton scattering (Compton Camera)

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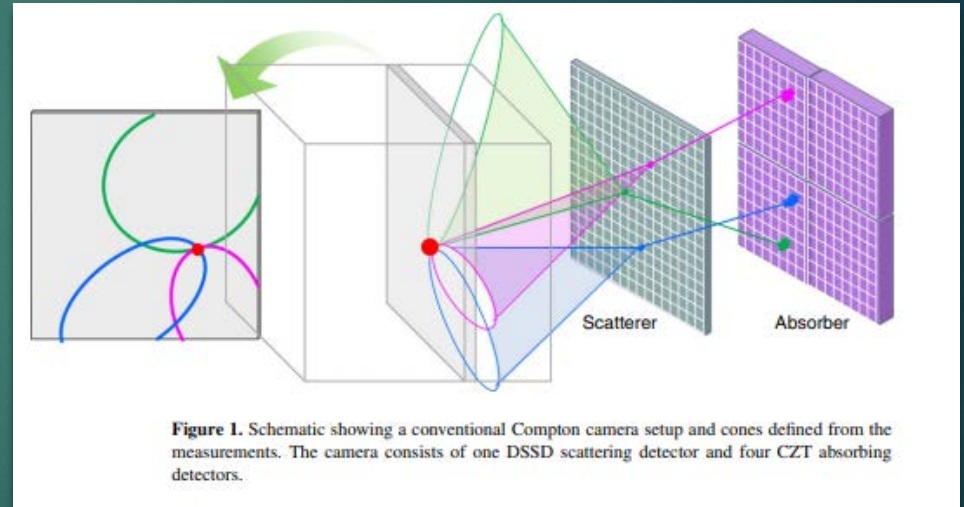
How Compton scattering can be used to determine the source position

$$\theta = \cos^{-1}[1 + m_0 c^2 (\frac{1}{E_\gamma} - \frac{1}{E_{\gamma'}})]$$
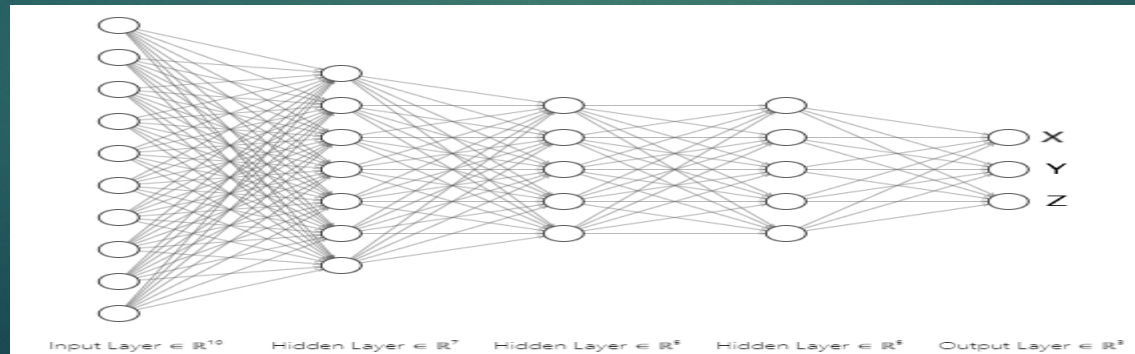
Cones intersection

▶ 3 cones intersection can be enough to track the gamma source in 2D.

▶ The error in the interactions positions and the energy will increase the number of cones needed to determine the source position.

Figure 1. Schematic showing a conventional Compton camera setup and cones defined from the measurements. The camera consists of one DSSD scattering detector and four CZT absorbing detectors.

https://doi.org/10.1088/0031-9155/58/9/2823

Solving the problem using neural networks

- Feature selection : 3D Position of the first and the second interactions and the cone angle.
- Use a bunch of events to allow the model of predicting the source position.
- The number of features fed to the network will be the product of the bunch size and the number of features

Input Layer ∈ $\mathbb{R}^{10}$ Hidden Layer ∈ $\mathbb{R}^{7}$ Hidden Layer ∈ $\mathbb{R}^{5}$ Hidden Layer ∈ $\mathbb{R}^{5}$ Output Layer ∈ $\mathbb{R}^{3}$

# Neural network performance on perfect data

- TensorFlow python library was used to train this network.
- The training using GPU(graphical processing unit) took 20min.
- The performance of the network was relatively good.
- The network performed better the closer the source to the center.

Real source position (4.0,-156.3,116.3) →
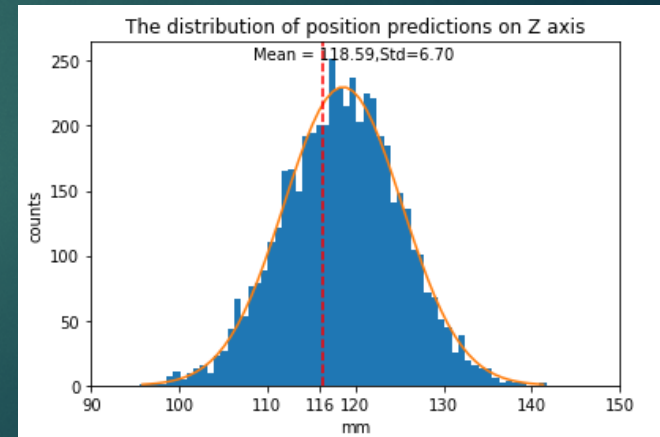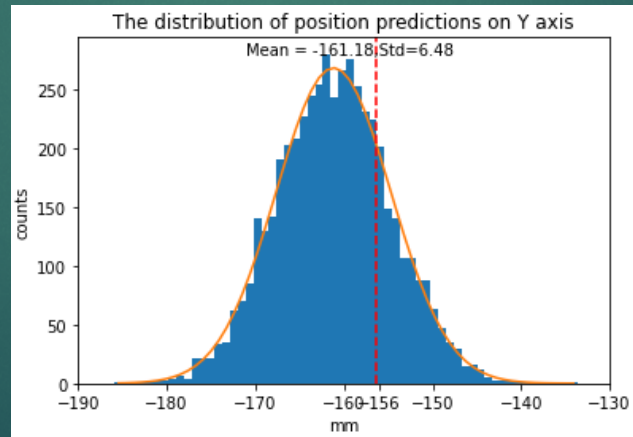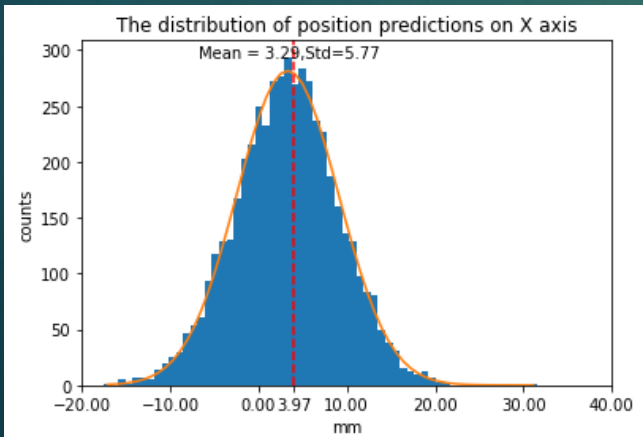
Neural network performance on the tracking results of the simulated data

- The network was able to predict the X axis which is closer to the center but failed for the other axes which are away from the center.
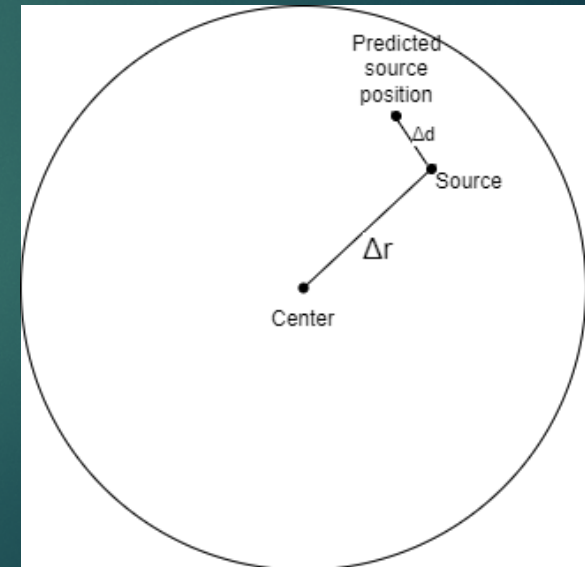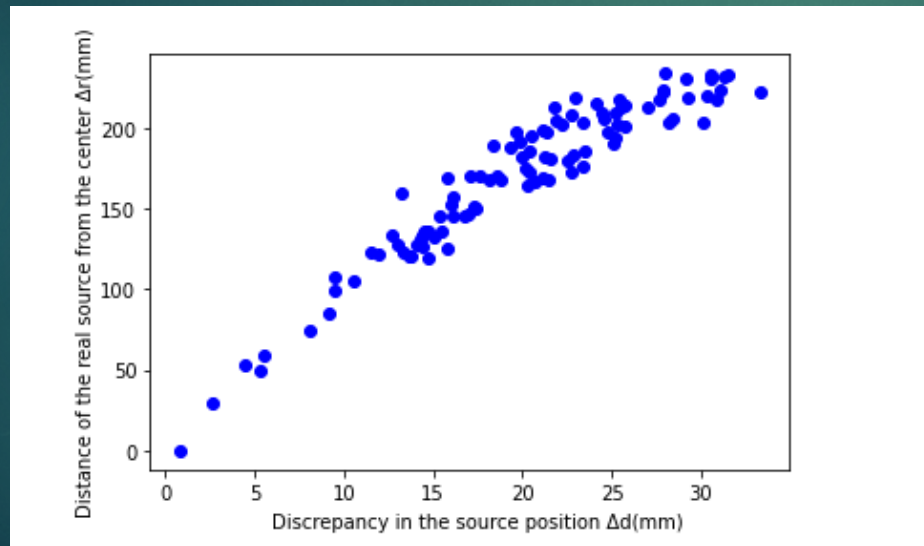
Real source position (4.0,-156.3,116.3) →
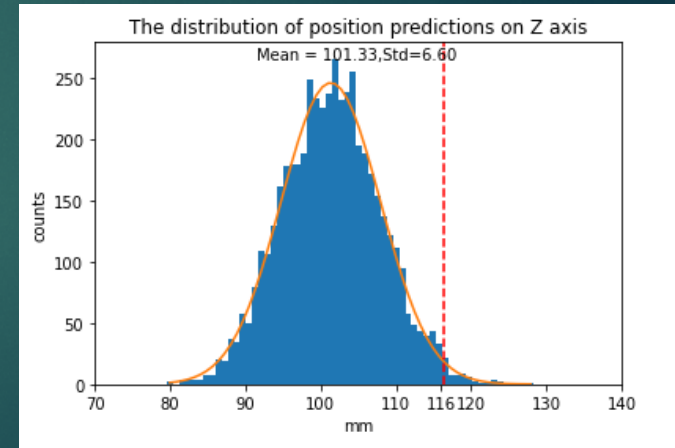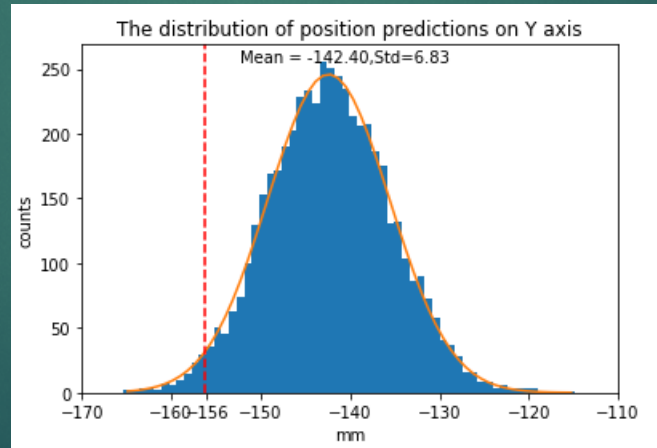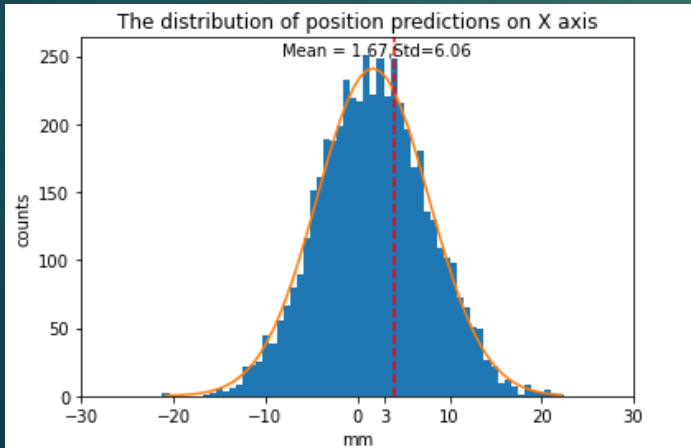
The problem faced with ML

- There is a clear dependence on the position of the source inside the AGATA sphere.
- This lead us to find that the network is not doing cones intersection.
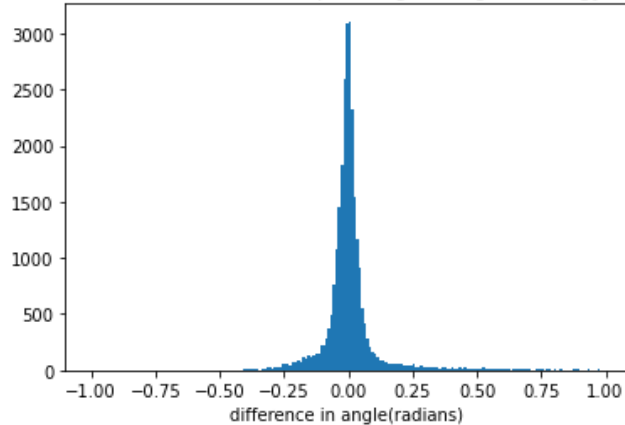- The network is unreliable.
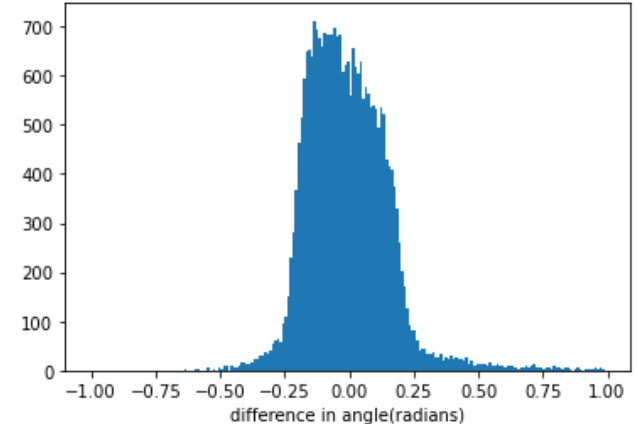
Solving the problem using an optimizer

- The scattering angle can be calculated from the energy and from the position.
- Minimizing the difference between the two will give the source position
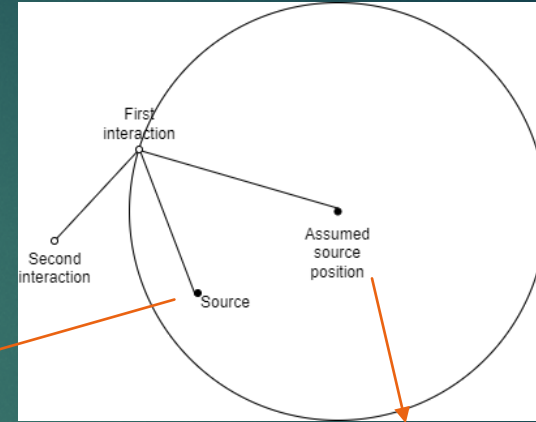
Difference between the calculated compton angle using the energy and the position

Difference between the calculated compton angle using the energy and the position

# Results of the minimizer with perfect simulated data

- Scipy python library was used for the minimization.

- The nelder-mead algorithm was used.

- It takes the minimizer **3 seconds** on average to determine the source position for 10^5 gamma-rays.

- This method gave almost exactly the source position.

- There was no dependence on the source position.
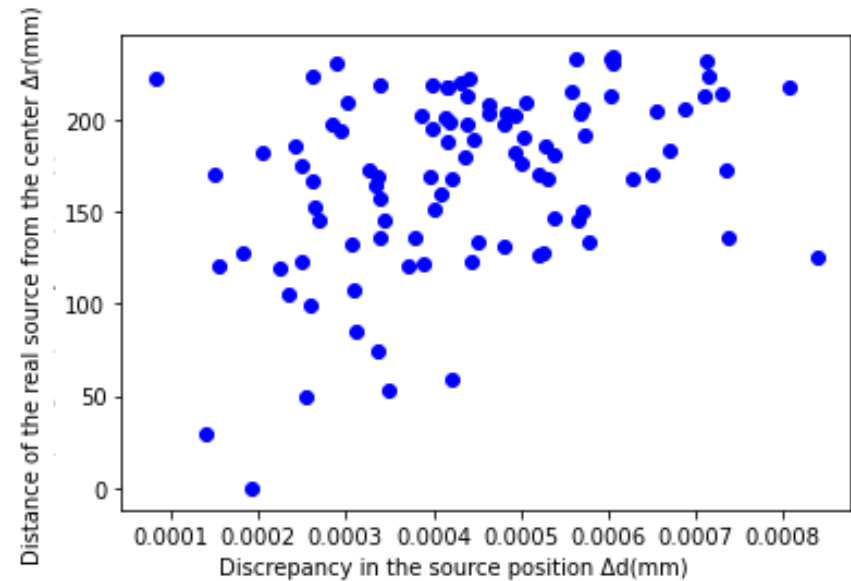
Ring source image produced by the minimizer

- A smaller bunch size can be used to do imaging.
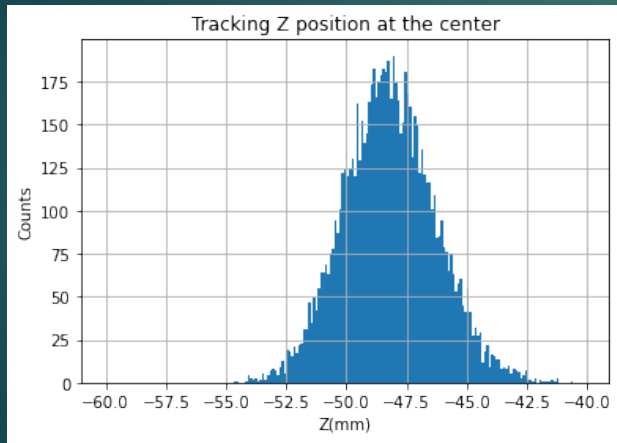- The plot is of a simulated ring source at the center with radius 5cm
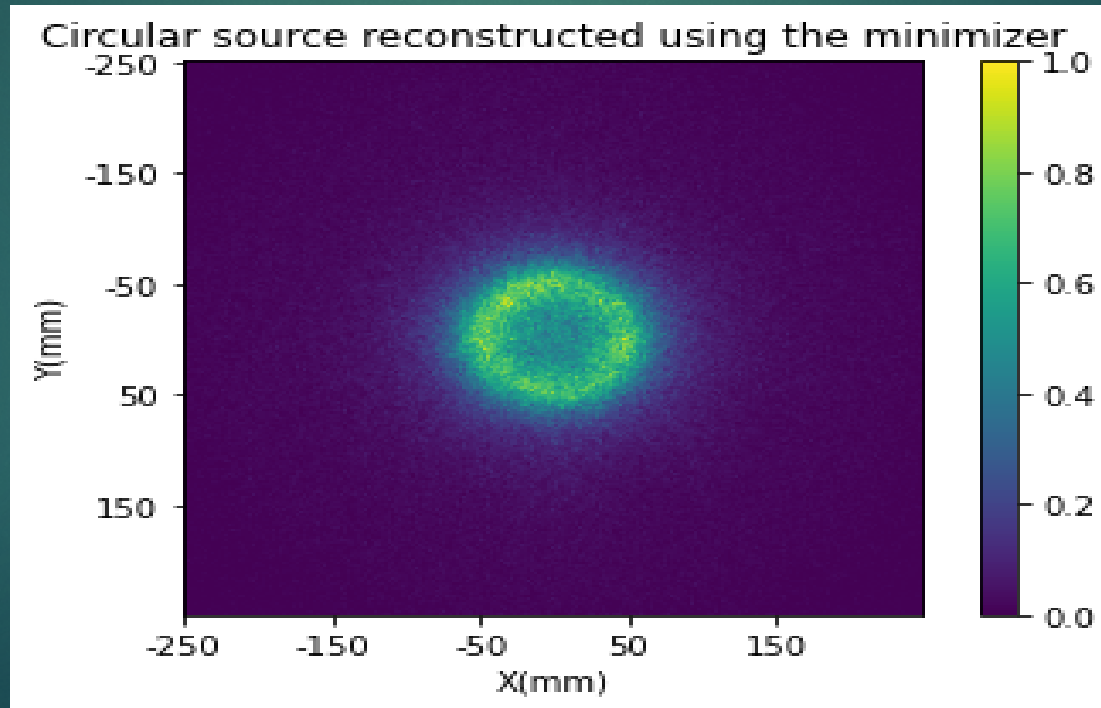
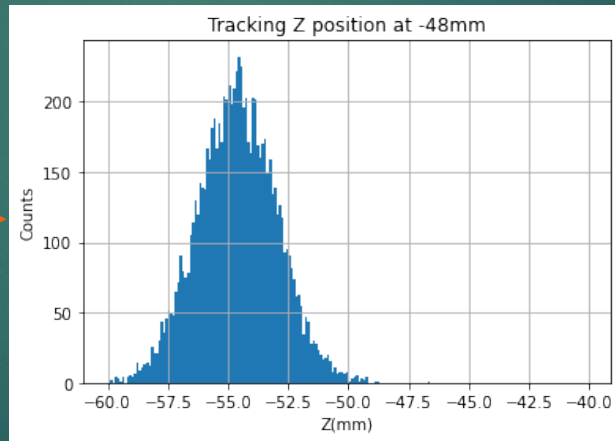# Results of the minimizer with experimental data

- This source run was conducted during GANIL campaign in the autumn of 2021.
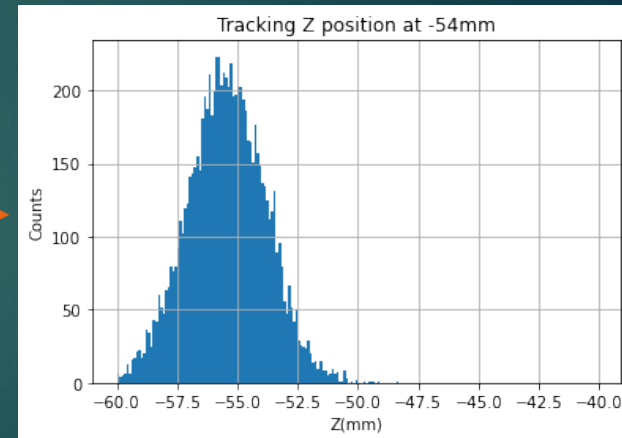- The source used is Eu located at (0,0,-55)mm.

[-3.63   0.55 -48.23]   [-3.8   0.5 -54.58]   [-3.71   0.52 -55.46]

FWHM: 4.5mm   3.83mm   3.78mm

Conclusions

- The neural network is unreliable to be used to predict the source position in experimental conditions.

- The minimizer is very fast and reliable way to determine the source position.

- this method can be used to characterize the PSA.

- The tracking algorithm can cause a bias to the results of the minimizer.

- The use of bunches of gamma-rays requires the knowledge that it's coming from the same source.