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Neutron Source Reconstruction from One-Dimensional Imager of Neutrons Data at the Z Facility

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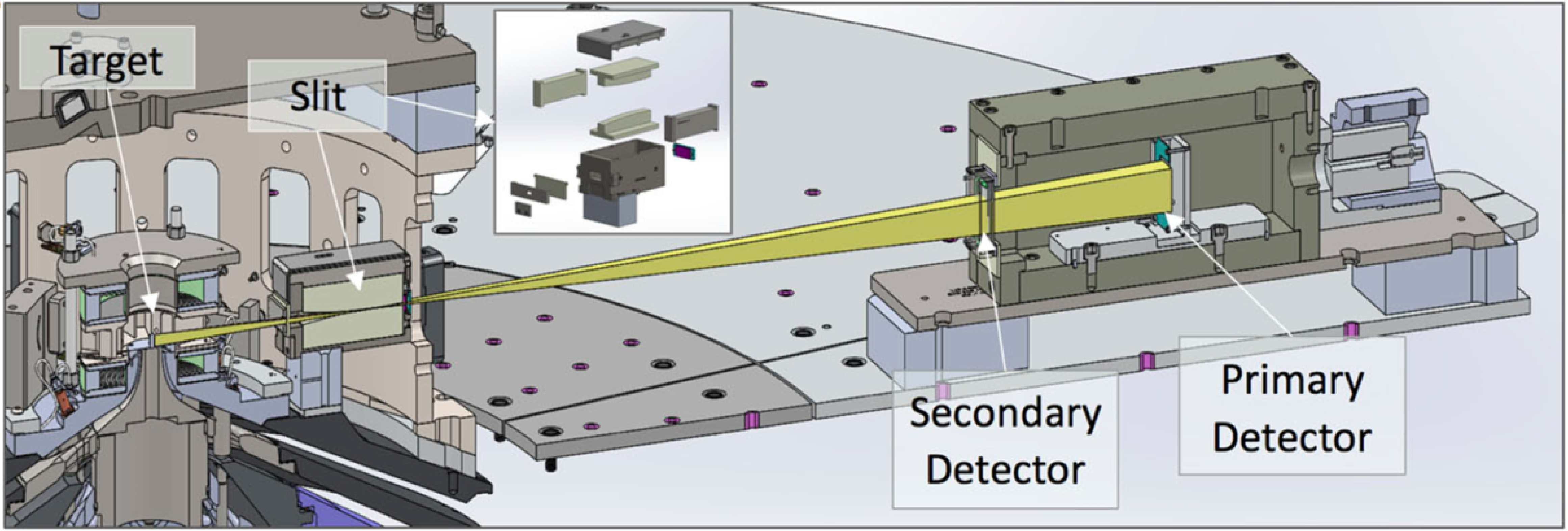
One-Dimensional Imager of Neutrons (ODIN)

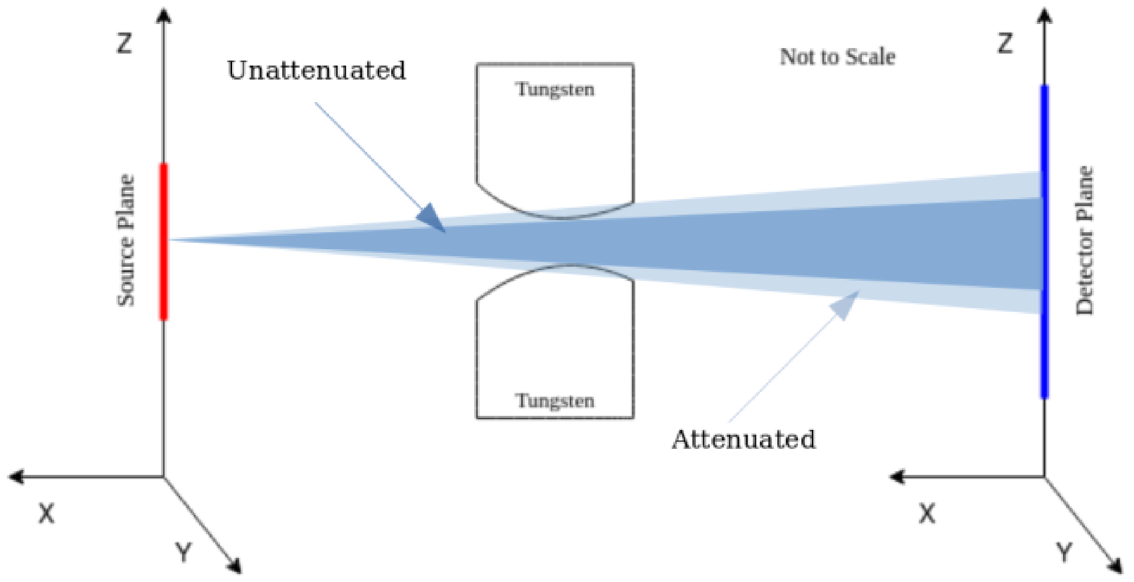


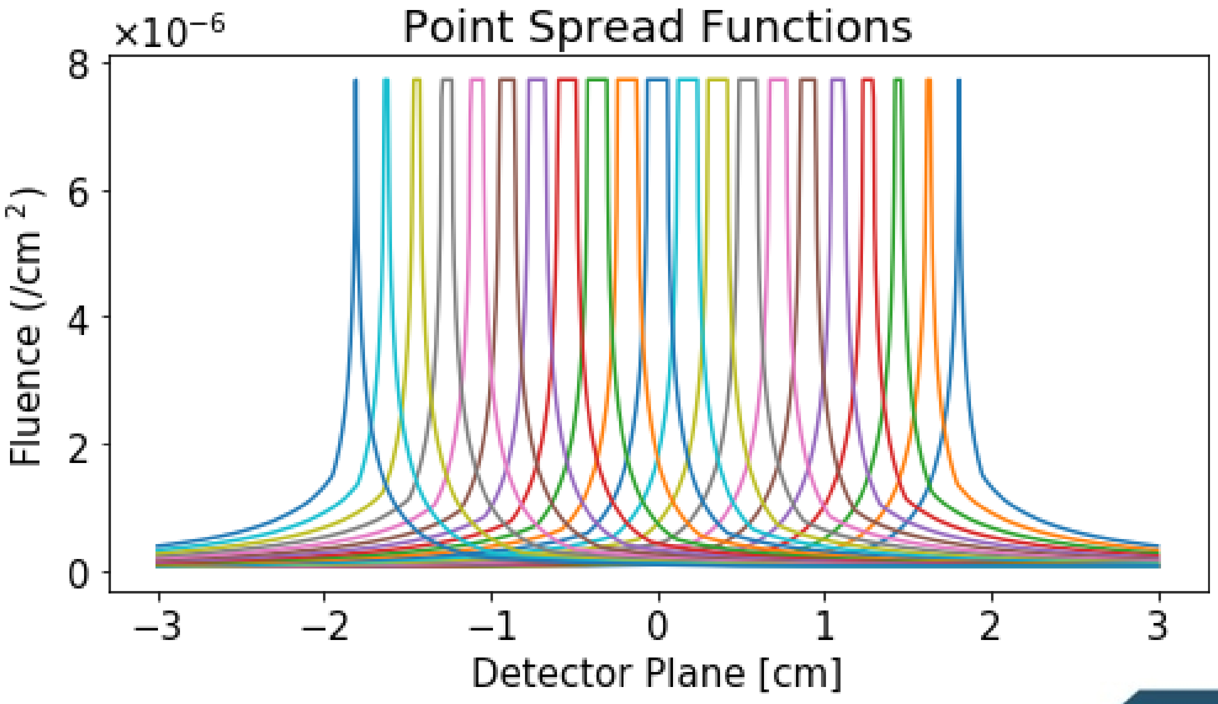
- Images neutrons emitted by Magnetized Liner Inertial Fusion (MagLIF) experiments on the Z facility
- Yields range from ~$1X10^{12}$ to ~$1X10^{13}$ from ~1cm tall target which are recorded as tracks on CR-39 pieces
- Microscope scans provide information on track location, diameter, contrast, and eccentricity for discrimination of incident neutrons
- **Objective: Use image reconstruction methods to improve imaging of the spatial distribution of neutron emissions from the stagnation column**

David J. Ampleford, et al. "One dimensional imager of neutrons on the Z machine", Review of Scientific Instruments 89, 10I132 (2018)

Forward Model

- Inverse problem with the Fredholm integral equation of the first kind:
  - $\int_a^b K(x,y)G_0(y)dy = N_0(x), c \le x \le d \quad (1)$
- Experimental measurements are altered by noise
  - $F(x) = N(x) + noise$
- Eq. 1 can be discretized to use an instrument response function (IRF) matrix, P_{ij}
  - $\sum_{j=1}^{m} P_{ij}\, G_j = N_i,\; i = 1, 2, \dots, n \quad (2)$
- Mathematical forward model is used to generate IRF matrices via attenuation calculations





Maximum Likelihood Principle

- The ML principle states that the vector $\mathbf{G_k}$ that brings this likelihood to a max, is the solution to eq. 2
- For a Gaussian noise distribution, the likelihood function can be expressed as eq. 3
- Eq. 4, is an iterative procedure to calculate the normalized vector, $\mathbf{g_k}$, which maximizes the likelihood function

$$S_i = \sum_{k=1}^{m} P_{ik} G_k$$

$$L = -\frac{1}{2}\sum_{i=1}^{n} \frac{(F_i - S_i)^2}{D_i} + constant \quad (3)$$

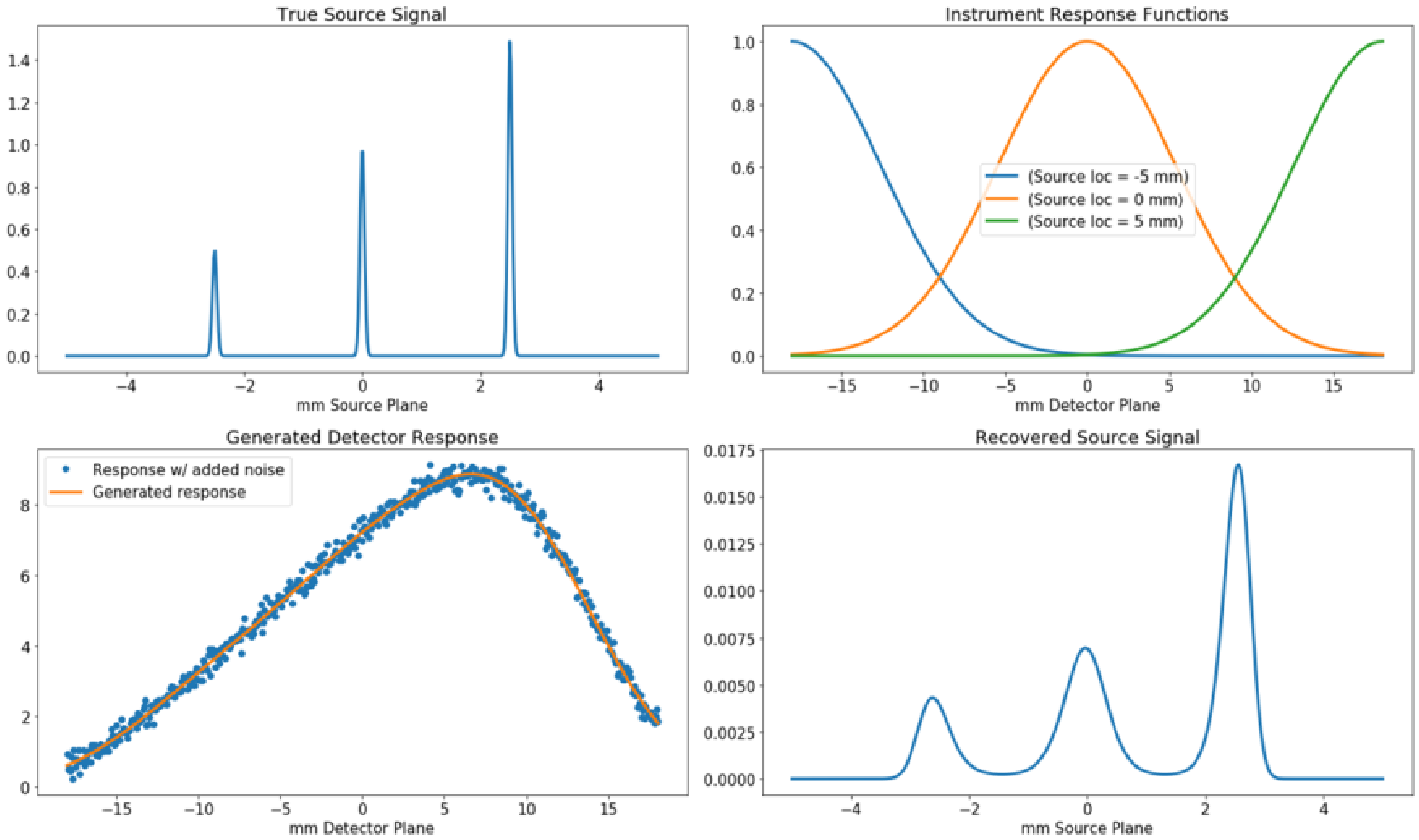
$$g_k^{(t+1)} = g_k^{(t)} + h\delta g_k^{(t)},$$

$$where\ \delta g_k^{(t)} = g_k^{(t)} \sum_{i=1}^{n} P_{ik} \frac{F_i - G \sum_j P_{ij} g_j^{(t)}}{D_i} \quad (4)$$

V. Gelfgat, E. Kosarev, and E. Podolyak, “Programs for signal recovery from noisy data using the maximum likelihood principle: I. general description,” Computer Physics Communications, vol. 74, no. 3, pp. 335–348, 1993.

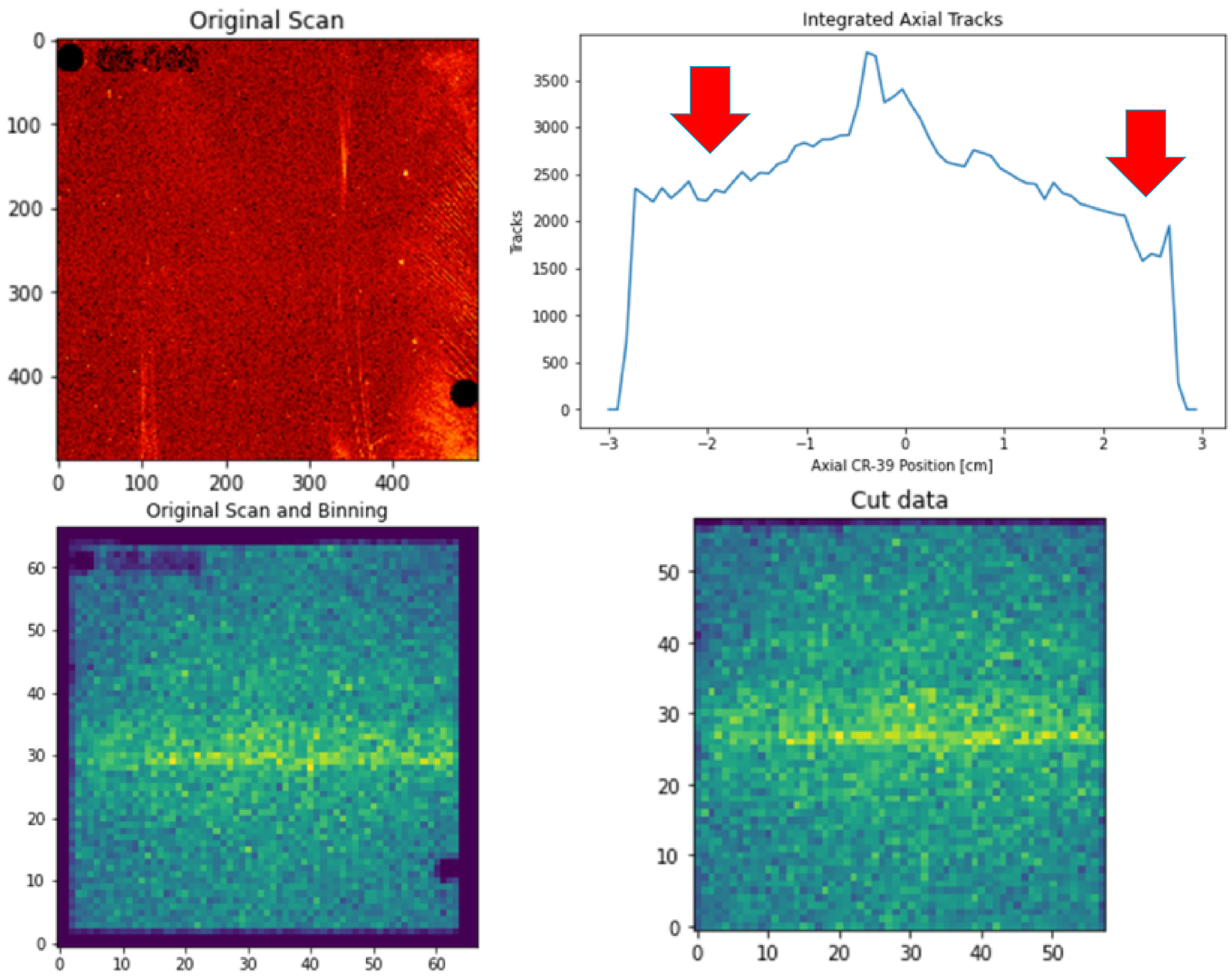
Maximum Likelihood Example

- A synthetic source is passed through a Gaussian IRF
- Results in a synthetic detector response, which noise is then added to
- Using the Maximum Likelihood iteration scheme, a probability distribution of the source profile is produced



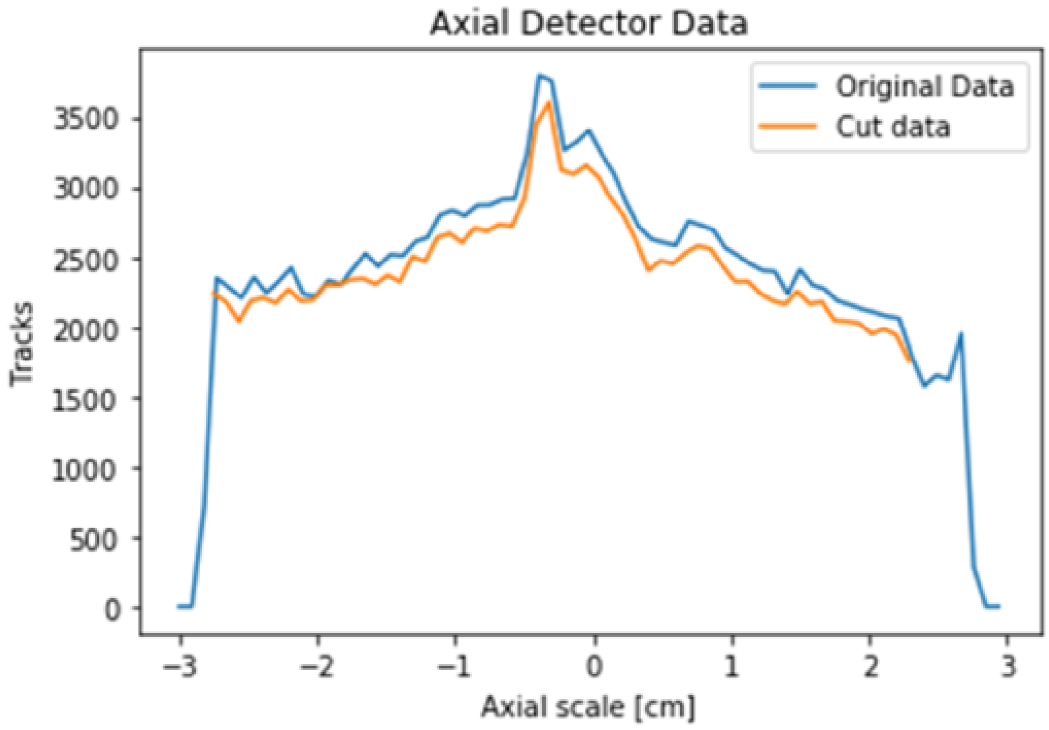
ODIN Data

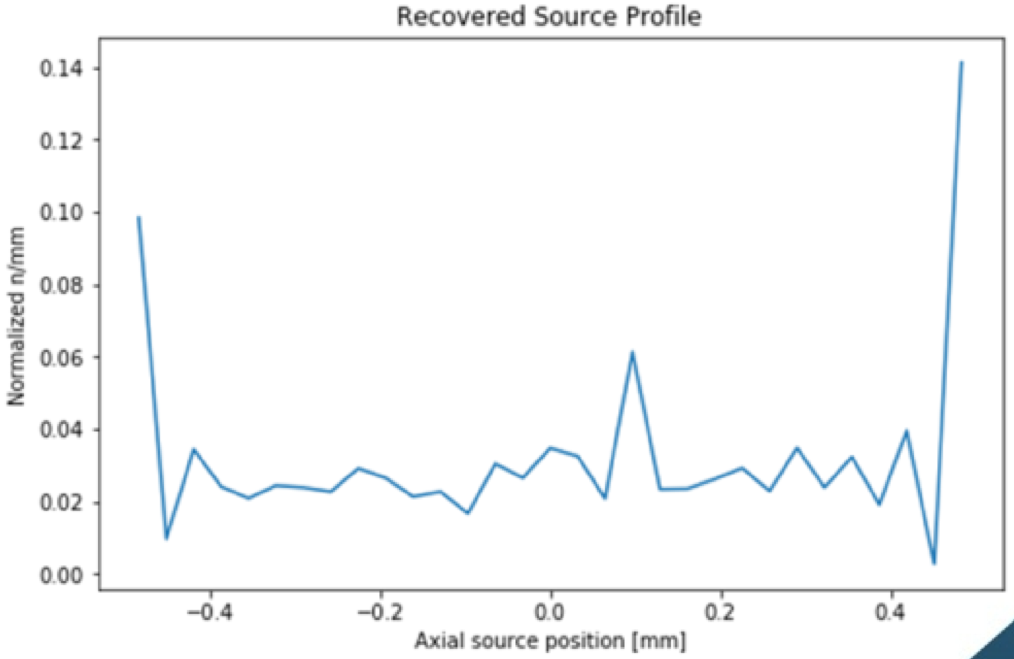
- Non-incident neutrons are filtered out, data rebinned to ODIN's resolution
- Data is integrated along the resolving axis to produce an axial detector measurement, F_i
- A subset of the data is used to remove the pinholes and tag number



Recovery of Cut ODIN Data

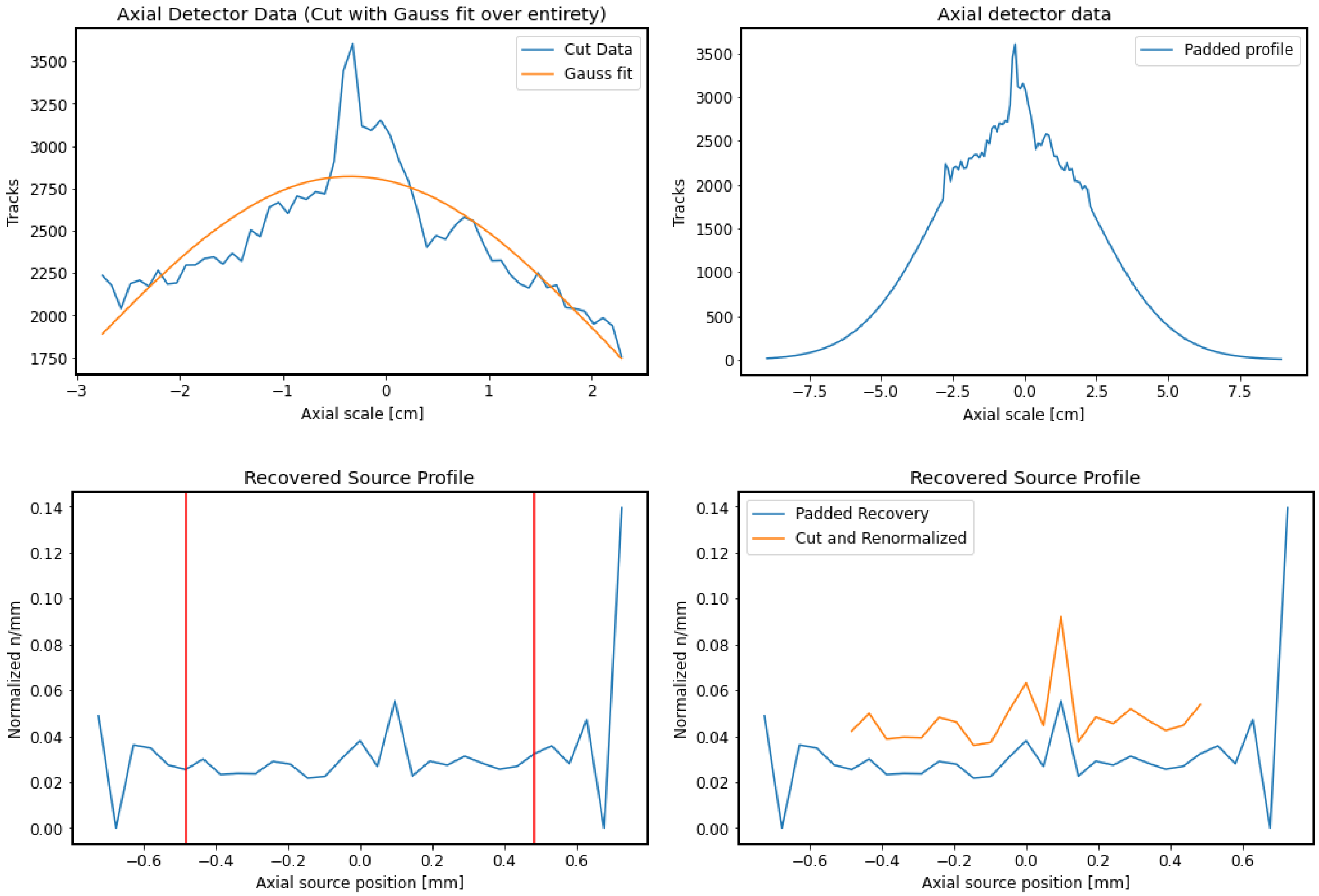
- Axial cut data used with truncated IRF matrix recovers a probability distribution of the source profile
- Significant edge effects distort the source profile
- Believed to be caused by:
  - incorrect estimation of noise
  - high condition number of the IRF matrix
  - data does not contain the full field of view of the experiment





Removing Edge Effects

- Possible solution is removing the edge effects completely
- Data can be extended with a Gaussian fit
- Source reconstruction dimensions increased to ~1.5 cm
- Profile is cut and renormalized



Questions?