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One Dimensional Imager of Neutrons on the Z machine

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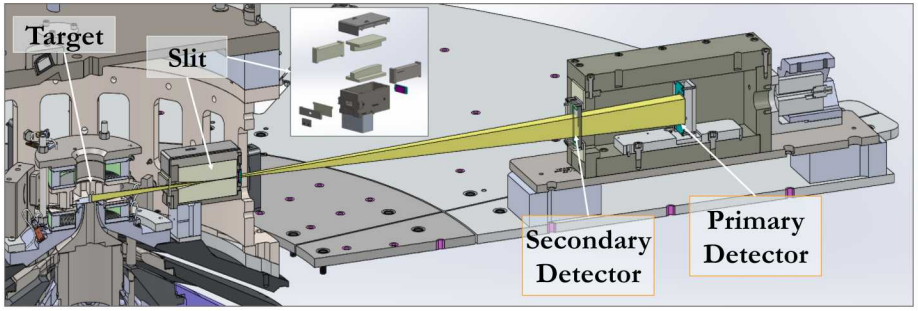
Abstract: Sandia has recently developed a one-dimensional imager of neutrons (ODIN) on the Z facility. The instrument is designed for MagLIF experiments, which produce DD neutron yields ~3e12 and, from x-ray imaging, produce a 1-cm long, ~100-μm diameter stagnation column. The small radial extents and present yields precluded useful radial resolution so a one-dimensional imager was developed. The imaging component is 10-cm thick tungsten slit; a rolled-edge slit limits variations in acceptance angle along the source. CR39 was chosen as a detector due to its negligible sensitivity to the bright x-ray environment in Z. A layer of high density poly-ethylene is used to enhance the sensitivity of the CR39. We present data from fielding the instrument on Z, demonstrating reliable imaging and track densities consistent with diagnosed yields. For yields ~2-3e12 we obtain resolutions ~500 μm with good signal to noise. Finally, we show planned modifications to allow co-liner x-ray imaging to provide better registration to other diagnostics.



Slit design

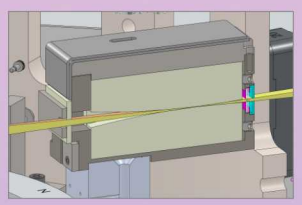
- Aiming to diagnose neutron emission in MagLIF.[1]
- Expected ~3e12 DD neutrons from emission region 10 mm tall, 100 μm diameter, motivating a one-dimensional imager.
- Thick W slit used as imaging element
  - 100 mm provides 1e-2 contrast.
- Rolled edge slit design minimizes vignetting
  - 500 mm radius of curvature to view 10-mm tall target.
- Design includes 250-μm, 500-μm, 750-μm slit spacings.

Detector

- CR39 plates were selected as the detector due to low sensitivity to x-rays and Bremsstrahlung radiation.[2]
- A 1 mm thick layer of high density polyethylene (HDPE) was positioned ahead of the CR39.
- Incident neutrons interact with the HDPE producing a proton, which has a much higher efficiency than neutrons in the CR39.
- Two detector magnifications provide confidence in data.

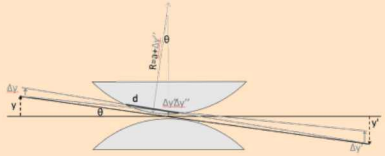
Modifications for co-linear x-ray imaging

- The ratio of x-ray yield to neutron yield is a measure of mix.
- We would like a local measure of mix, which would require local diagnosis of x-ray/neutron emissivity.
- Currently cross-registration of x-ray and neutron images is completely driven by features in the data.
- We are adapting ODIN to capture a 1-dimensional x-ray image.
- Slit housing has now been adapted to allow x-ray transmission at ~8 keV, removing high Z-materials from data path.



Performance estimates

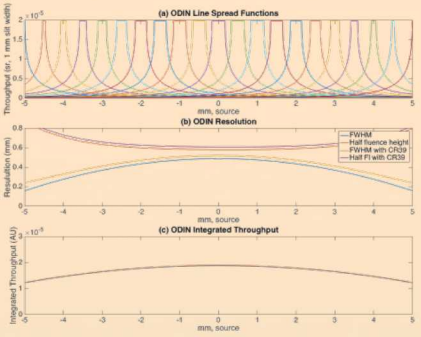
We can use geometry to determine path length through W:



$$d = 2\sqrt{R^2 - \left(R - \left(\Delta y'' - \frac{h_{eff}}{2}\right)\right)^2}$$

To translate to the object place we scale to $\Delta y' = (M+1)\,\Delta y''/M$. From the calculated path lengths and the known mean free path, λ, the expected transmission of the slit is:

If $\Delta y'' > \frac{h_{eff}}{2}$ $\quad T = e^{-\frac{d}{\lambda}}$ $\qquad$ If $\Delta y'' < \frac{h_{eff}}{2}$ $\quad T = 1$

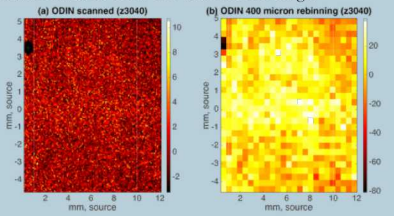


MCNP calculations of small angle scattering are underway.[4]

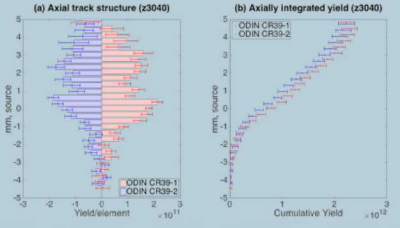
Parameter	Expectation
Collection Solid Angle	6.2e-5 sr
DD Neutrons through slit for Y_{DD}~3e12	1.5e7
P-induced tracks from HDPE	1.3e4 (650/cm²)
Resolution (250 μm slit)	500 μm

Data and analysis

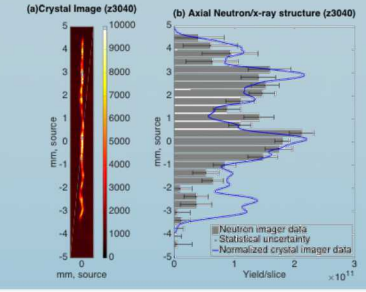
- CR39 plates are etched in NaOH for 5 hours to reveal tracks.
- Data is scanned with a microscope; image processing techniques are used to isolate DD neutron induced tracks.[3]
- Raw data has high noise level, but rebinning at instrument resolution starts to show one-dimensional image.



- Multiple CR39 plates at primary detector location show 1D image.
- We use the standard error in the mean to quantify noise.
- Efficiency estimates used to quantify emissivity; within factor of 2 of yield diagnostics.



- We can compare 1D neutron image with 1D profile from 6 keV crystal imager.
- Similar shapes; discrepancies may be indicator of mix.



References

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2. M.T. Collopy *et al.*, Rev. Sci. Instrum. **63**, 4892 (1992)
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