Development of a slit neutron imager for inertial confinement fusion experiments at the Sandia Z machine.

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SAND2018-3145C

Abstract

Understanding the neutron source shape is critical for improving Magnetized Liner Inertial Fusion (MagLIF) implosions at the Sandia Z machine. Measuring the shape is challenging due to the yields, extended axial source regions, x-ray backgrounds and physical shock waves produced by MagLIF sources. In this work, we present the design and initial tests of a slit neutron imager for 1-dimensional neutron imaging along the axial dimension of MagLIF implosions.

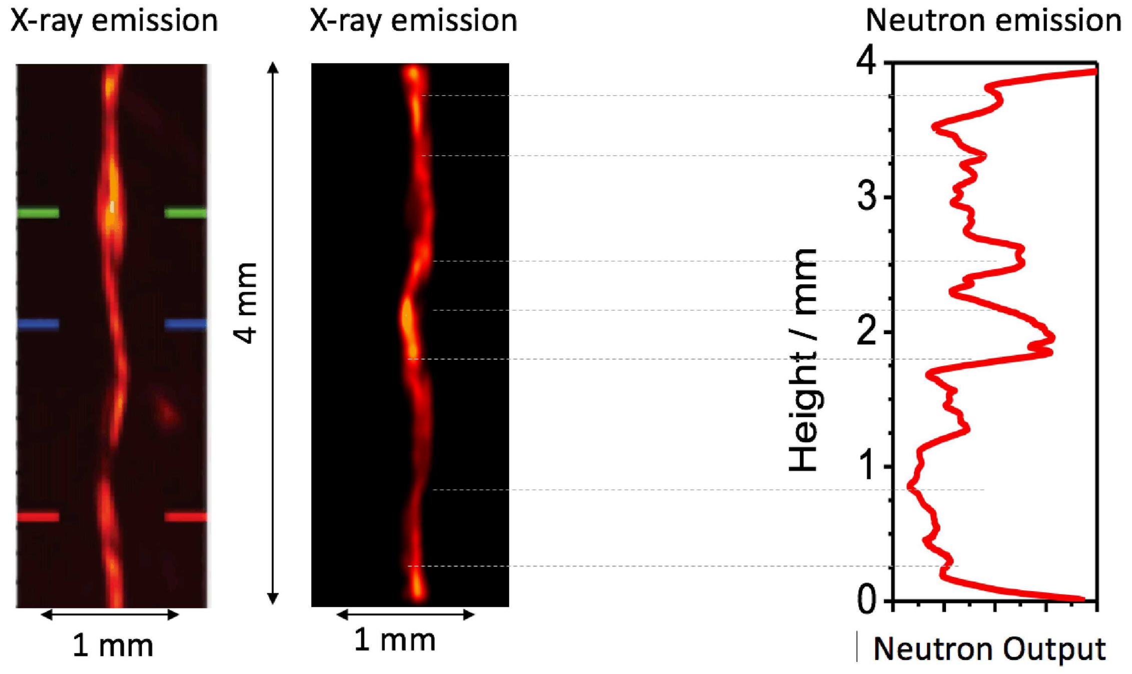

Fig. 1: Experimental and simulated 6.28 x-ray images and DD neutron emission for a MagLIF shot, see [1-4]. The simulations are from the Gorgon code.

Neutron Imaging Requirements

- Imaging: 1-D
- Yield: $>10^{12}$ DD neut.
- Resolution: 500-µm
- Vertical FOV: ~1-cm
- Detection: Passive
- Entirely within Z target chamber

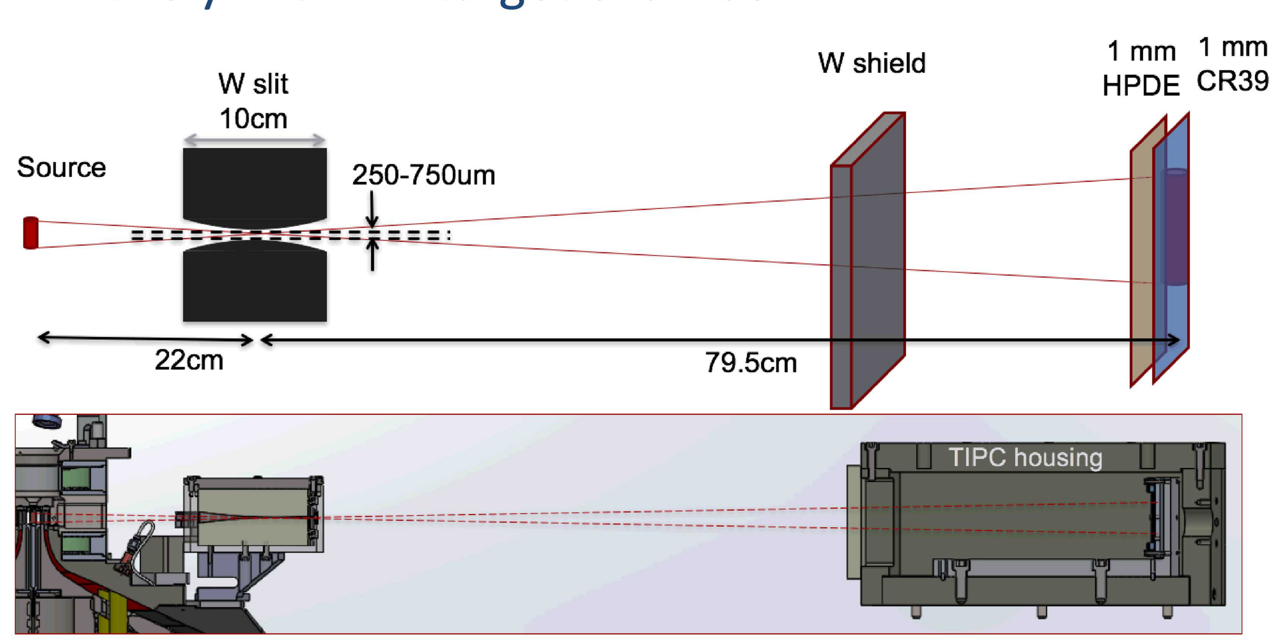

Fig. 2: Schematic drawing of the ODIN slit imager. The slit assembly mounts directly to the source assembly.

Rolled-slit imager design

- LOS length: 1015 mm
- Standoff: 220 mm
- Magnification: -3.6
- Rolled edge Radii: 500 mm
- Slit Separation: 250-1000 µm
- Slit width : 3 mm

Detectors

- HDPE (n,p) converter on image plate [5]
  Currently dominated by hard x-rays from the source and surroundings.
- CR39 plastic [6]
  - 2e7 DD neutrons through slit for 1e12 DD yield.
  - 1.2e-4 tracks per DD neutron
  - For 500-µm, the slit provides ~640-µm resolution (excluding detector) there are 16 resolving elements along height
  - 130 tracks per resolving element
    if average horizontally.
    Depends on slit width.

CR39 Resolution Test

Flat field illumination of a 1-m radius tungsten rolled edge.

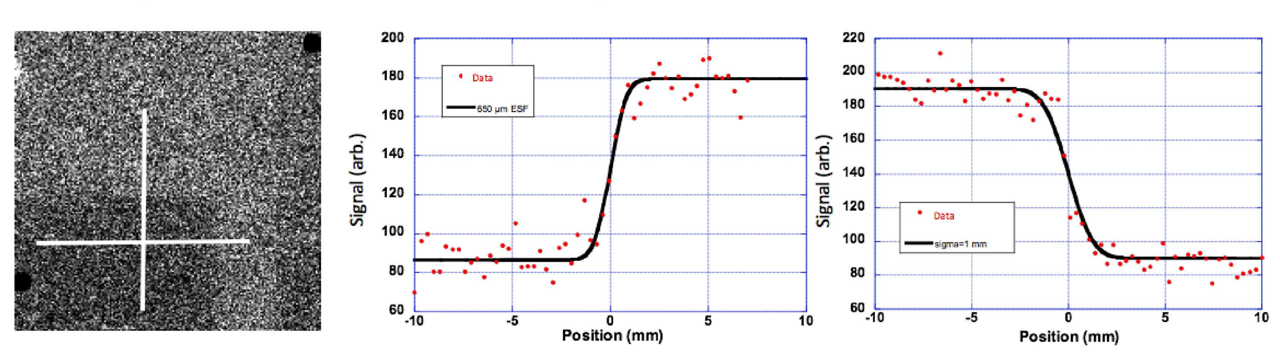

Figure 3 CR-39 image of a rolled edge for shot Z3018 horizontal and vertical lineouts across the rolled edges. The horizontal lineout is consistent with 650 µm edge-spread function. The vertical lineout is a long the axial dimension of the source and indicates that the source is extended in the vertical dimension.

Imaging

The imager has been successfully fielded on a number of shots at the Z facility.

Z3040; DD~4e12; 250 um slit (Adam Harvey Thompson)

Z3120; DD~2e12; 750 um slit (Matt Gomez)

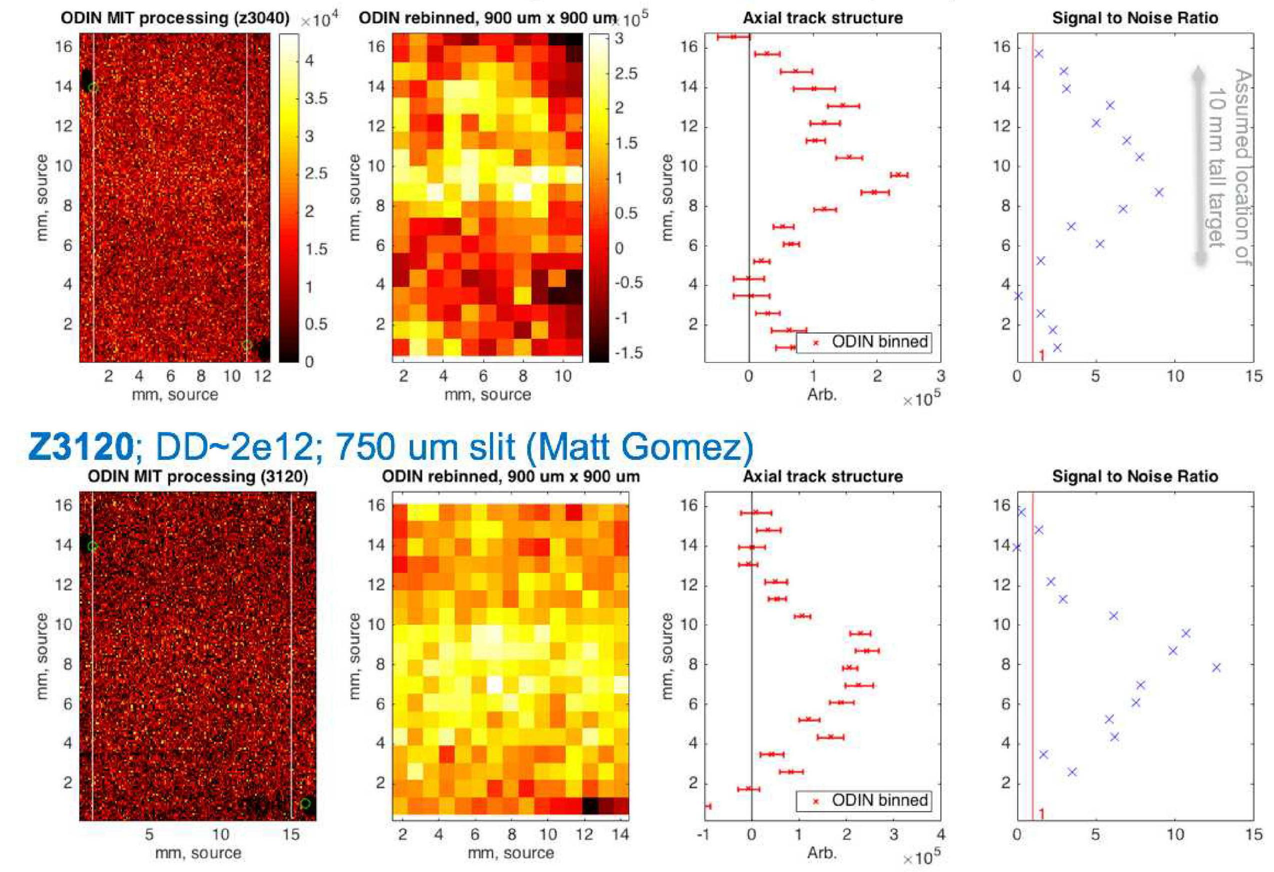

Figure 4 CR39 Images for Z3040 and Z3120. Z3040 should have 3x better resolution. The left column are the images scanned at 100-µm per pixel. The next columns are the 2D images rebinned at 900-µm per pixel along both axes. For each horizontal row, the next column are axial lineouts (the mean and standard error of binned data). Right-hand plots the signal to noise. The SNR >> 1 for ~8 mm height, which is most of the target height.

Reality Checks

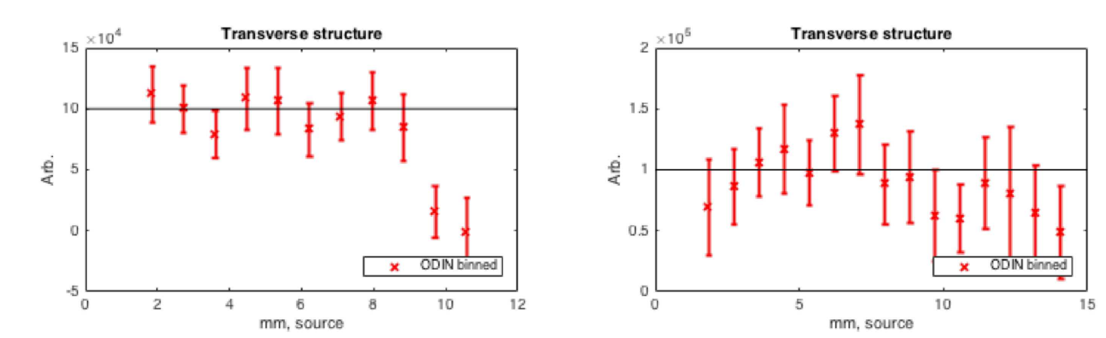

Figure 5 Transverse lineouts along the width of the slit. Confirms no transverse imaging. 3040 has drop off on right, which may be a symptom of clipping on the entrance to the detector housing.

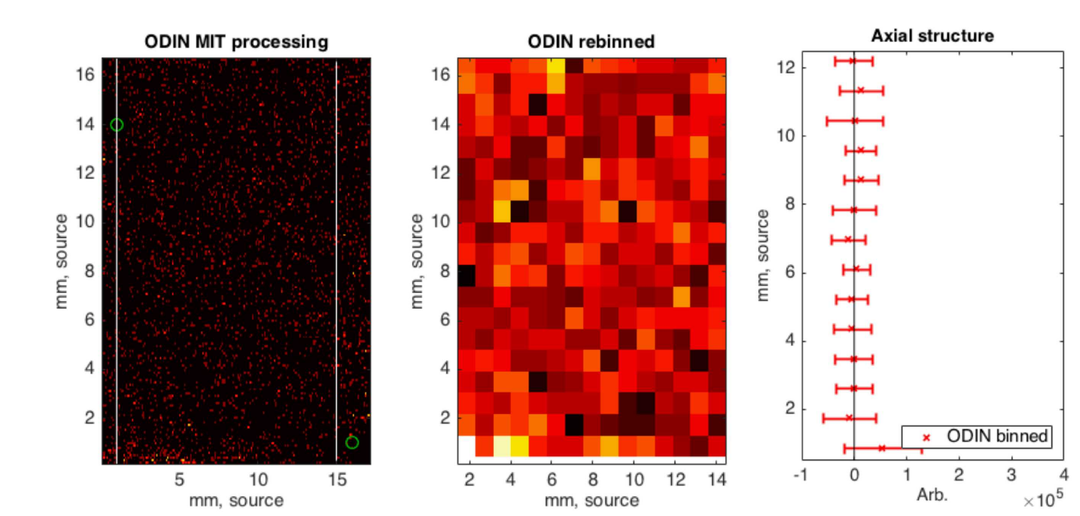

Figure 6 Imaging data for Z3121. The low shot yield of ~4e10 DD neutrons was dues to the failure of the ABZ magnetic field coils. Identical analysis as performed on high yield shot indicates no axial image present.

Comparison to X-ray Images

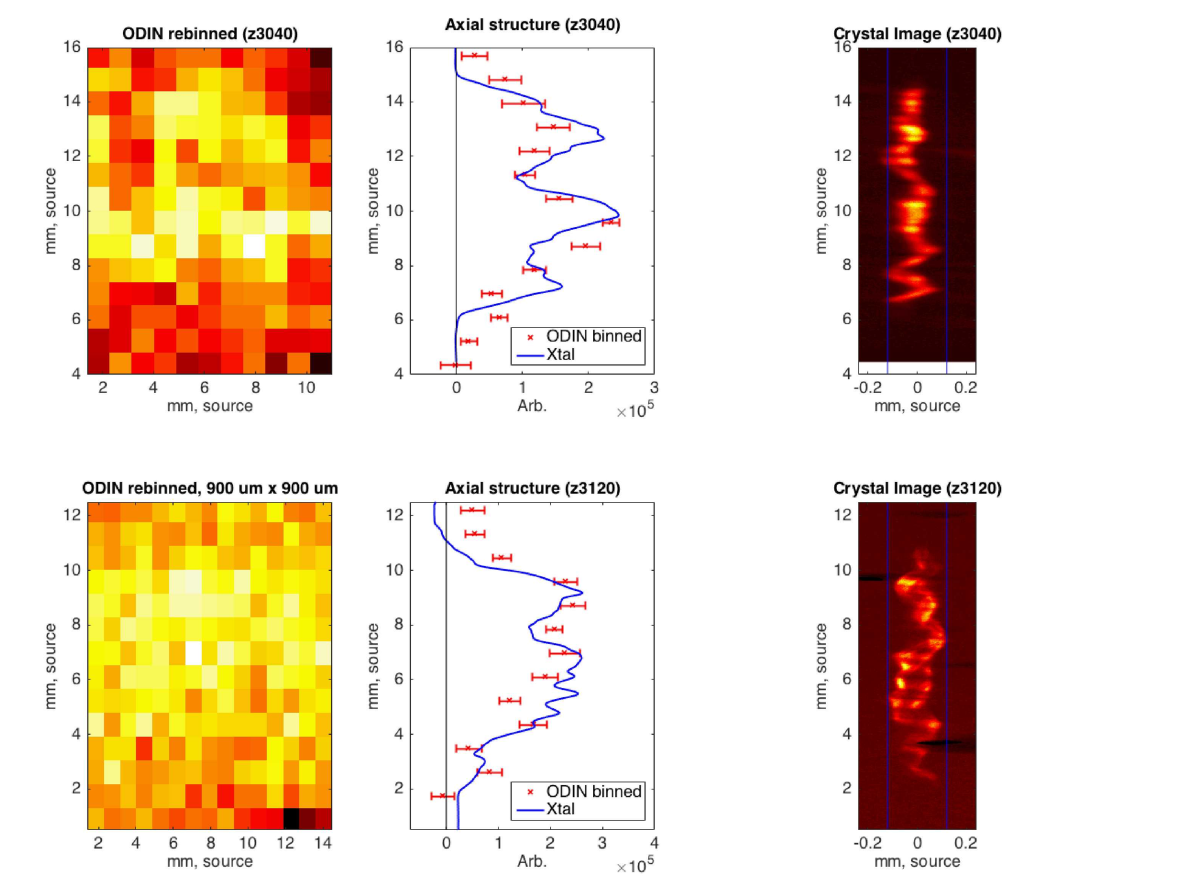

Figure 7 Axial DD neutron images for Z3040 and Z3120 compared to 6-keV x-ray images from the spherical crystal imager, which have been smoothed to the ODIN resolution. The heights have been registered based on the data and cropped to regions with data, and the relative intensity scaling is arbitrary.

Conclusions & Future Work

An imager using an HDPE converter and a CR-39 detector is producing neutron slit images at the Sandia Z machine. Improvements on both neutron and x-ray imaging on the line of sight are needed to make the imager more useful by increasing the SNR and registering the neutrons to the x-rays, including: reducing the attenuation in the LOS and better shielding of the detector package.

References

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Unclassified

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.