LA-UR- 11-04270

Approved for public release; distribution is unlimited.

Title:	Performance Characteristics of The Neutron Imaging Diagnostic at NIF
Author(s):	Frank Merrill
Intended for:	ICOPS-SOFE 6/27-7/1/2011

Los Alamos NATIONAL LABORATORY EST.1943

Form 836 (7/06)

Performance Characteristics of The Neutron Imaging Diagnostic at NIF

F. Merrill, D. Clark, C. Danly, V. Fatherley, G. Grim, N. Guler, E. Loomis, D. Mares, G. Morgan, C. Munson, T. Murphy, J. Oertel, I. Tregillis, P. Volegov, C. Wilde, M. Wilke
Los Alamos National Laboratory, Los Alamos, NM 87544, USA

D. Fittinghoff, D. Bower, J. Dzenitis, B. Felker, M. Frank, J. Holloaway, D. Kalantar, J. Kingmann, R. Nyholm, B. Quivey, G Roberson, P. Weiss

Livermore National Laboratory, Livermore CA 94550,USA

R. Buckles
National Securities Technologies, Livermore, CA 94550

The neutron imaging diagnostic has recently been commissioned at the National Ignition Facility. We will present the diagnostic performance characteristics, which have been measured with the collection of these first neutron images. The goal for this diagnostic is to collect two pinhole images at two different times. The long flight path results in a chromatic separation of the neutrons, the first image will be of the 14 MeV neutrons and the second image of the 10-12 MeV neutrons. The combination of these two images will provide data on the size and shape of the compressed capsule as well as a measure of the quantity and spatial distribution of the cold fuel surrounding this core. The imager uses an array of 20 pinholes and three mini-penumbra machined in 20 cm of layered gold and tungsten, with an apex at 32.5 cm from the source to produce images in a scintillator array at 2800 cm. This geometry provides a magnification factor of 85 at the scintillator. The scintillator is a coherent array of scintillating fibers, which is viewed from the two ends by two fast-gated image collection systems. The first neutron images, collected in February, 2011, have provided the first measure of system performance at NIF. These results will be presented along with an interpretation of future system performance.

Performance Characteristics of The Neutron Imaging Diagnostic at NIF

Los Alamos National Laboratory

F. Merrill, D. Clark, C. Danly, V. Fatherley, G. Grim, N. Guler, E. Loomis, D. Mares, G. Morgan, C. Munson, T. Murphy, J. Oertel, I. Tregillis, P. Volegov, C. Wilde, M. Wilke

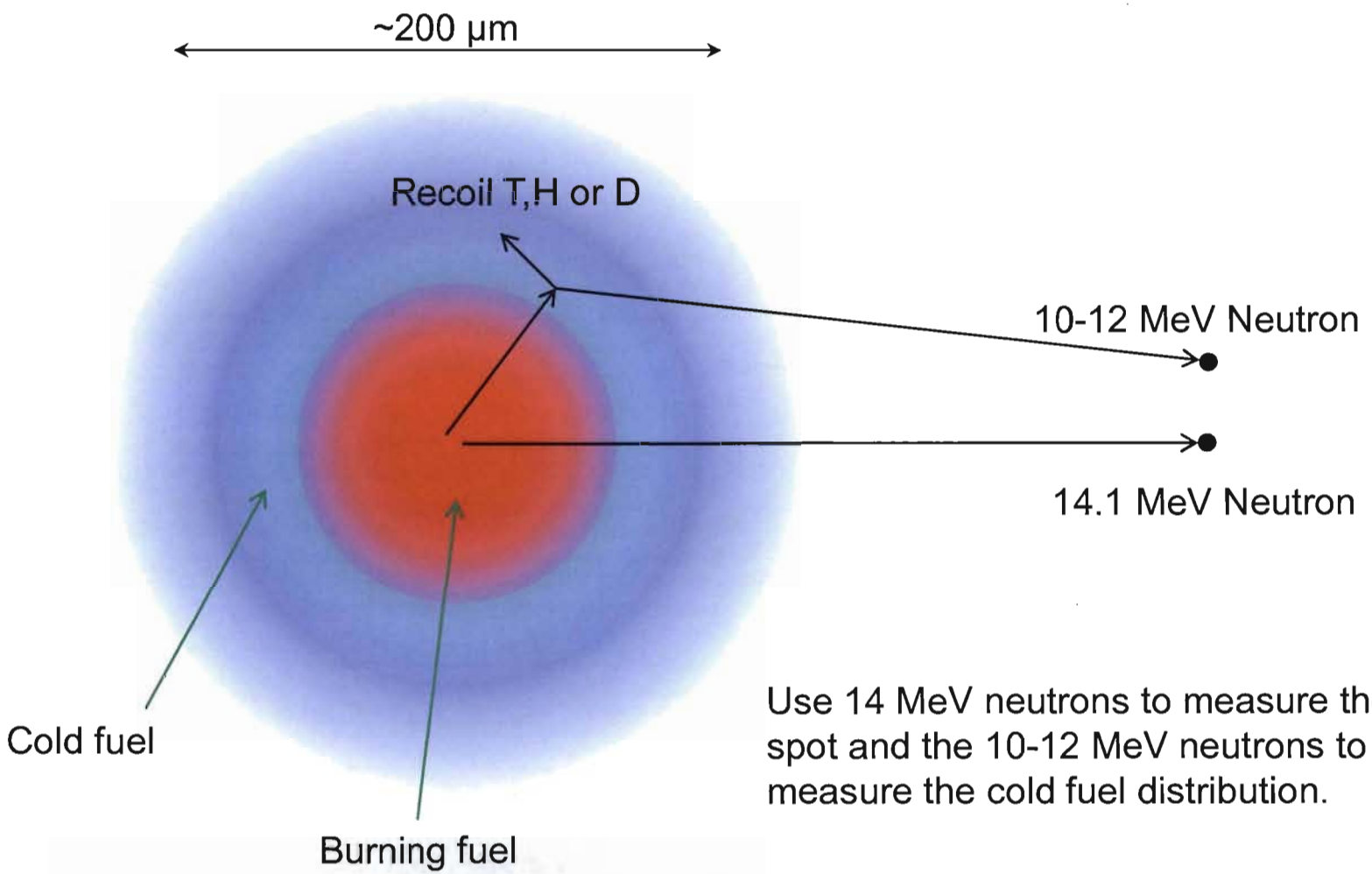
Livermore National Laboratory

D. Bower, J. Dzenitis, B. Felker, D. Fittinghoff, M. Frank, J. Holloaway, D. Kalantar, J. Kingmann, R. Nyholm, B. Quivey, G Roberson, P. Weiss

National Securities Technologies

R. Buckles, S. Lutz

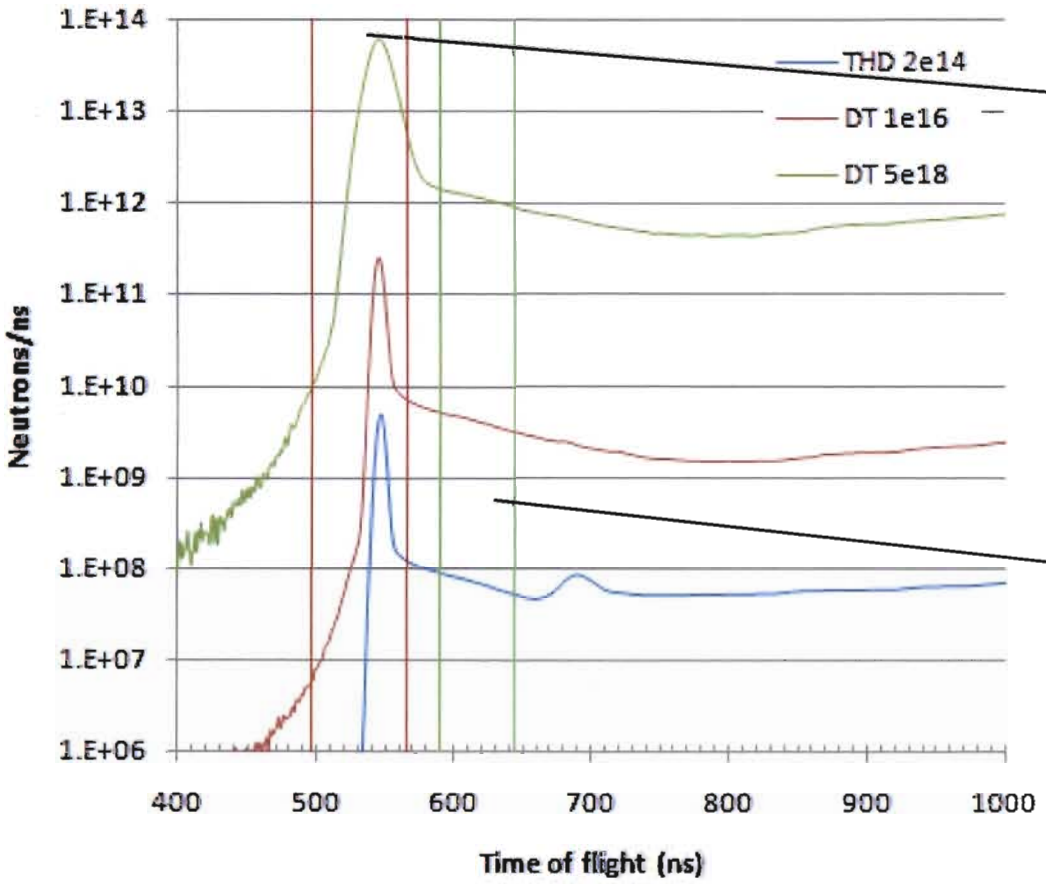
Neutron imaging is a key diagnostic for diagnosing ICF implosions



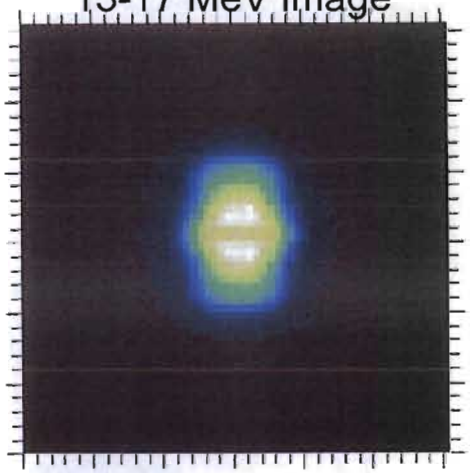
Use 14 MeV neutrons to measure the hot spot and the 10-12 MeV neutrons to measure the cold fuel distribution.

Temporal separation of neutrons after 28 m drift results in ability to collect two neutron images: Primary (13-17 MeV) & Down Scattered (10-12 MeV)

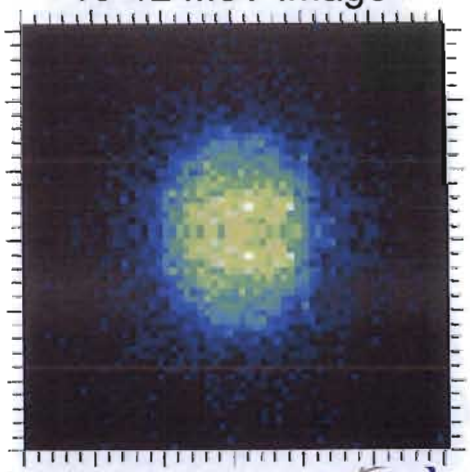
Neutron TOF Spectrum for 28 meter line of site



Simulated Primary 13-17 MeV Image



Simulated DownScattered 10-12 MeV Image



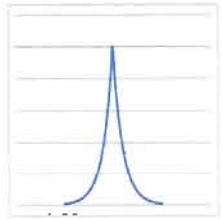
Need a time gated image system

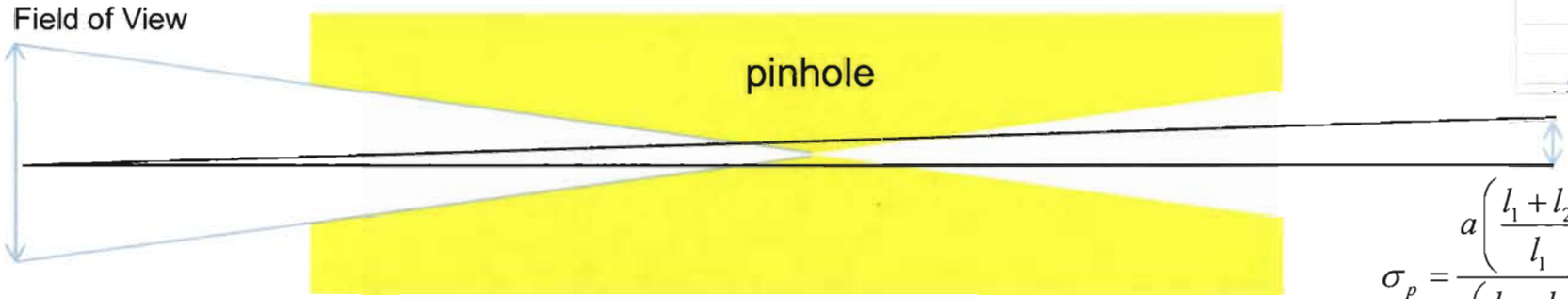
Basics of Neutron "Pinhole" Imaging

Magnification

$m=(l_2-l_1)/l_1$

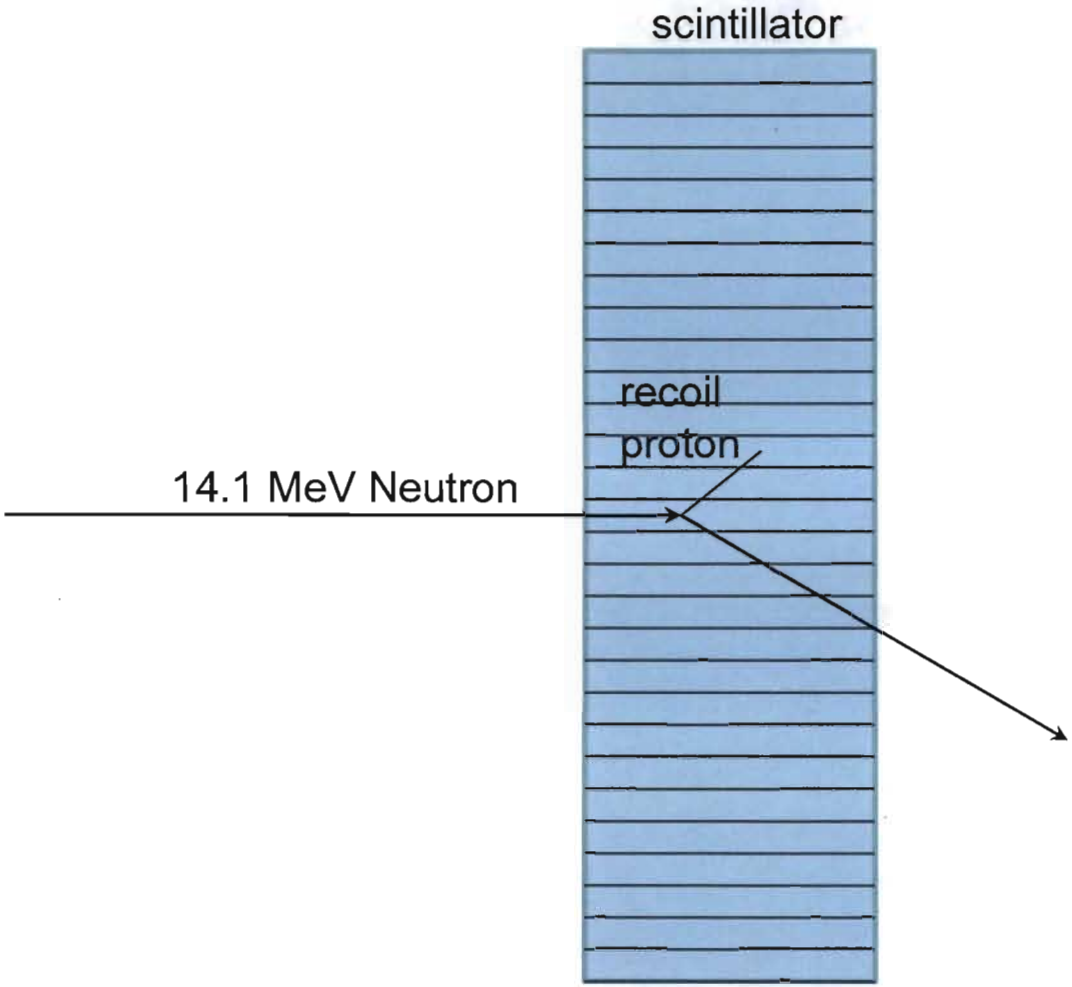
Resolution function





$$\sigma_p = \frac{a\left(\frac{l_1+l_2}{l_1}\right)}{\left(\frac{l_2-l_1}{l_1}\right)} \cong a\left(1+\frac{l_1}{l_2}\right)$$

Detector Resolution



$$\sigma_D = \frac{r}{m}$$

Detector contribution to resolution is set by the range of the recoil proton in the scintillator material.

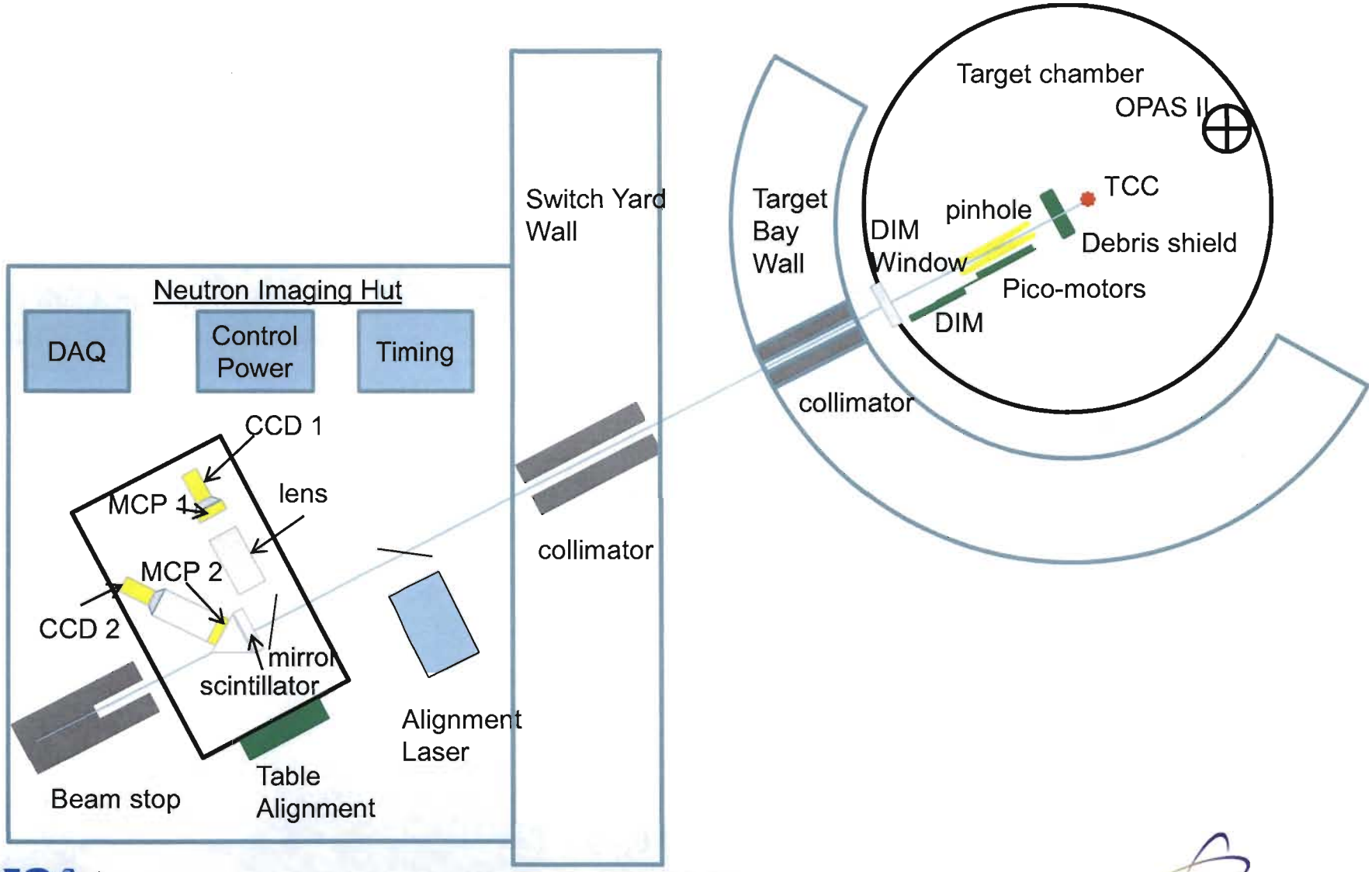
System Resolution can be approximated as

$$\sigma_D = \sqrt{\left(\frac{r}{m}\right)^2 + a^2}$$

Design Requirements

	Direct	Down-scattered
Measure size and shape of the imploded core	13-17 MeV	10-12 MeV
Minimum Field of View	100 microns	150 microns
Resolution FWHM (post-processed)	10 microns	10 microns
Yield	$5x10^{15}$-$1x10^{19}$	$5x10^{14}$-$1x10^{18}$
Signal-to-Noise ratio (peak)	22	22
Signal-to-Noise ratio (20%)	10	10
Line of Sight	28 m	28 m
Energy Resolution	0.3 MeV at 10 MeV (~10 ns)	

Block Outline

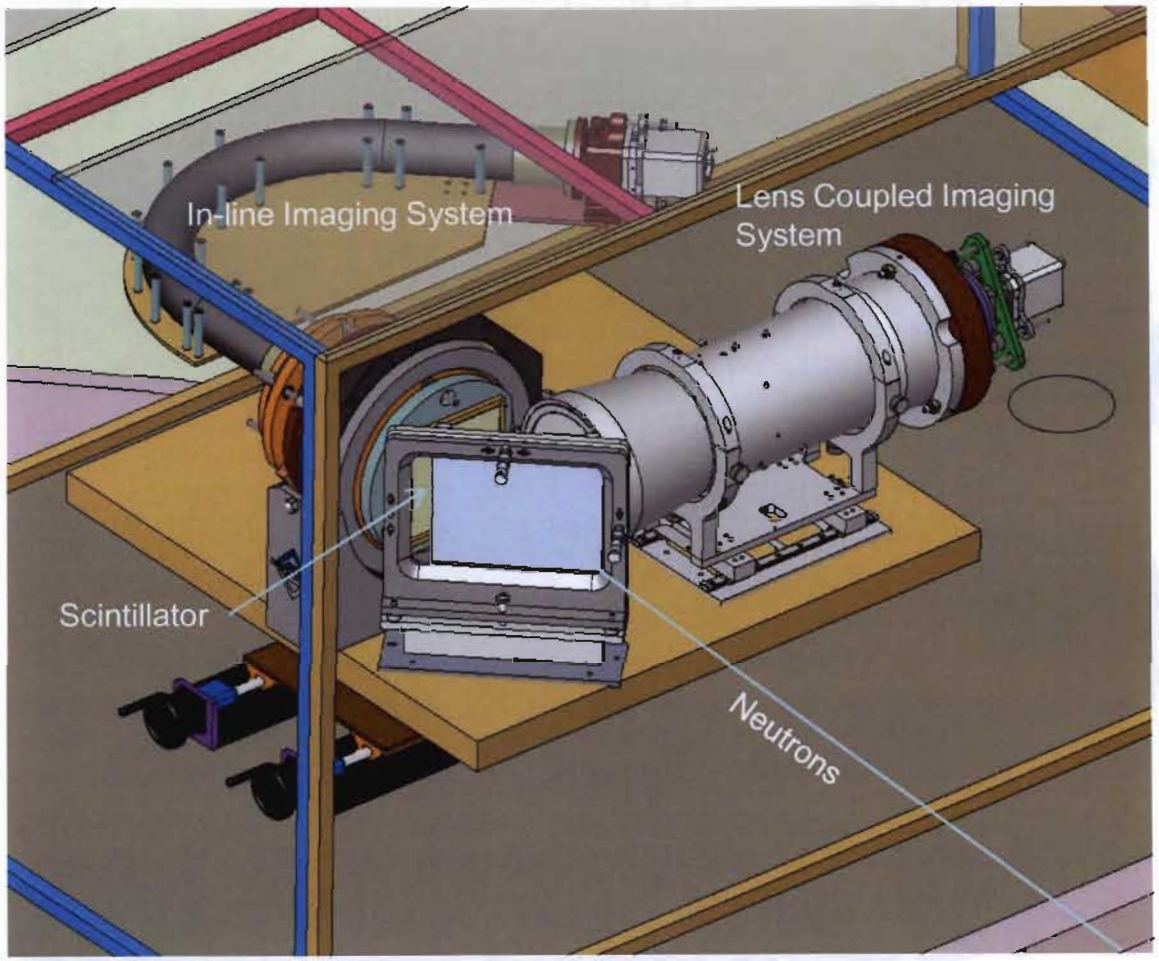


Imaging system design, fabrication and testing was completed at Omega

NIC

In-line Imaging system
- Scintillator BCF 99-55 160mm square 250μm fibers, 5cm thick
- 160 mm to 75 mm fiber taper
- 75 mm MCP (12 micron pore)
- 75 mm to 37 mm fiber taper
- 37 mm coherent fiber bundle
- CCD camera (4k x 4k SI-1000)

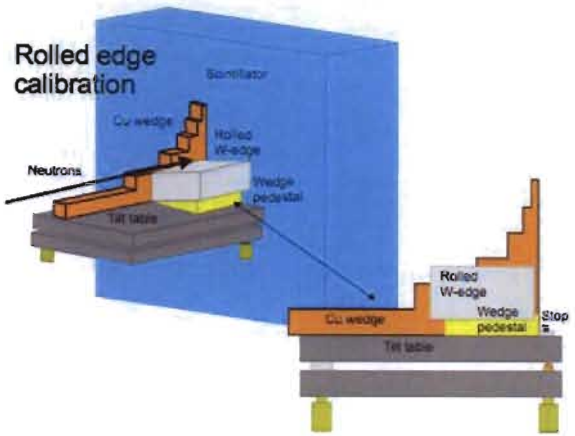
Lens-coupled Imaging system
- Scintillator BCF 99-55 160mm square 250μm fibers, 5cm thick
- Turning mirror
- Lens
- 75 mm MCP (12 micron pore)
- 75 to 37 mm 37 mm fiber taper
- CCD camera (4k x 4k SI-1000)

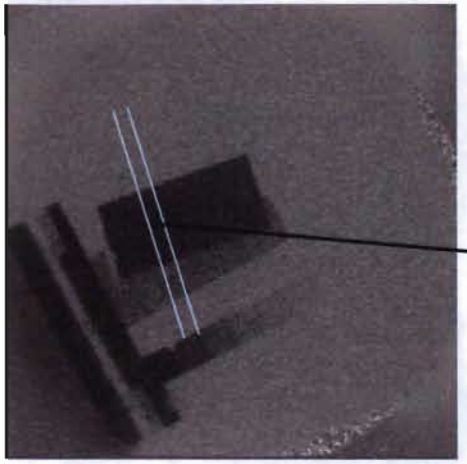


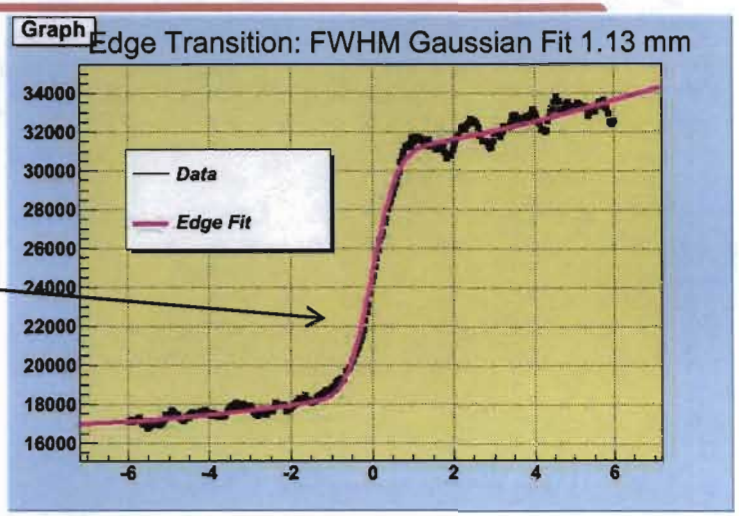
NNSA

Los Alamos

Image Recording System Resolution: 11 μm at magnification factor of 104

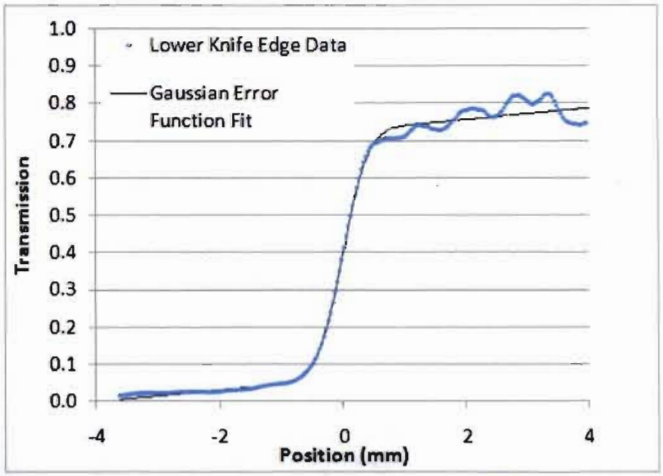






FWHM: 1.20 mm

- Resolution measured at the scintillator plane is 1.1 mm.
- With a magnification factor of 104 the uncorrected resolution at the object plane is 11 μm.

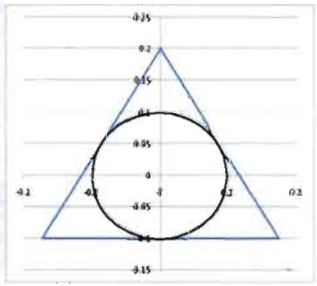


NNSA

Los Alamos

Two pinhole options

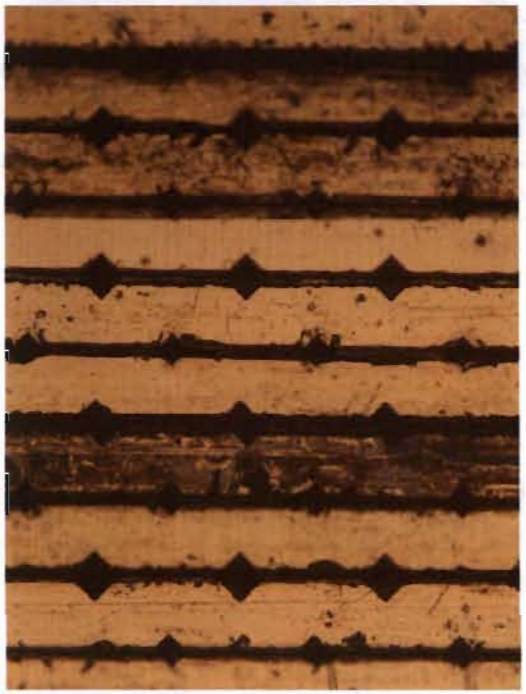
NIF Version 1

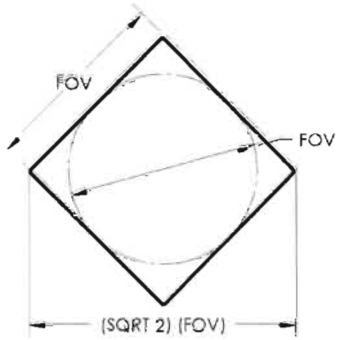


200 μm field of view

- "Triangular" point spread function
- ~ 19 micron (FWHM) contribution to resolution
- Characterized at Omega
- Penumbral openings allow for low statistics measurements

NIF Version 2



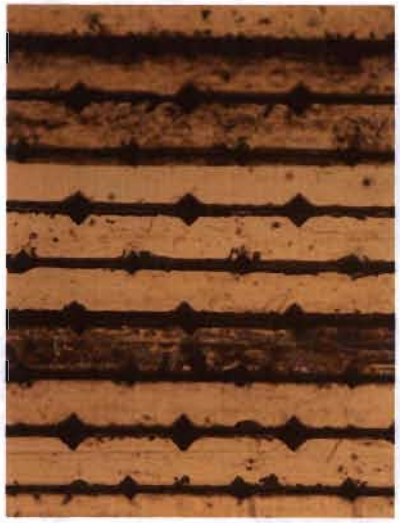


141 & 200 μm field of view

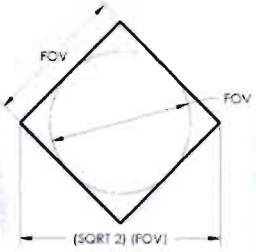
- "Square" point spread function
- ~ 8 micron (FWHM) contribution to resolution

Baseline System Resolution is ~14 microns

Pinhole

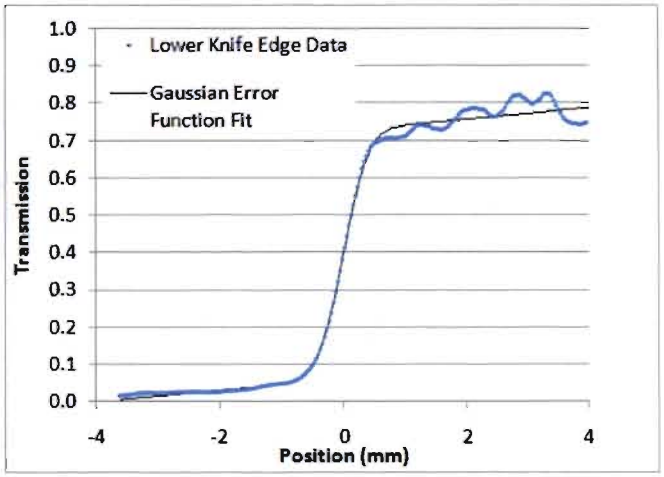


6 and 8 microns



141 & 200 μm
field of view

Image Recording System

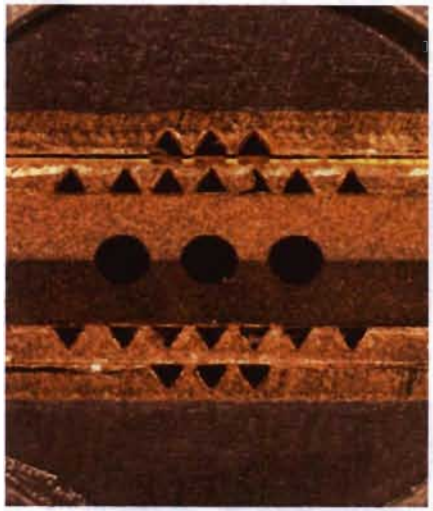


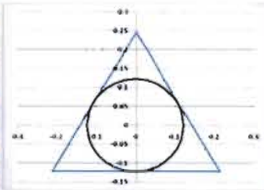
11 microns

Two contributions added in quadrature results in ~14 micron resolution for this system.

Compromises to enable the initial installation have degraded resolution slightly: ~23 microns

Pinhole: retracted to 32.5 cm

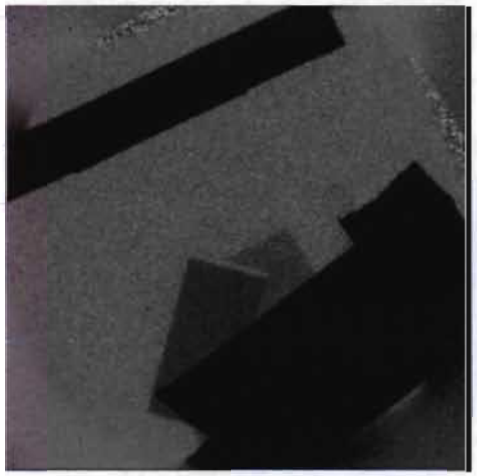


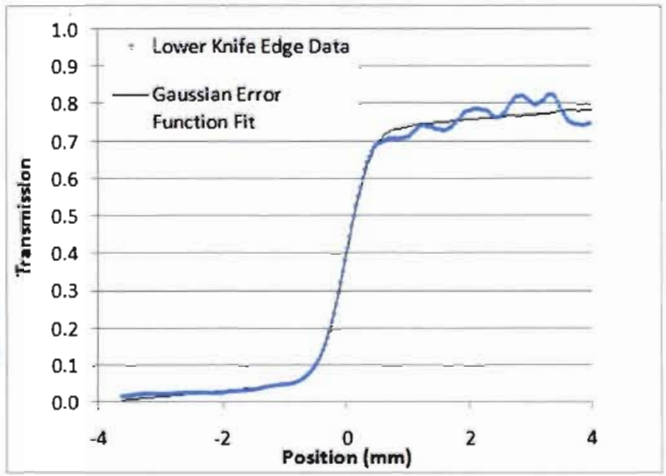


250 μm field of view

Larger pinholes result in larger blur function: 19 microns.

Image Recording System



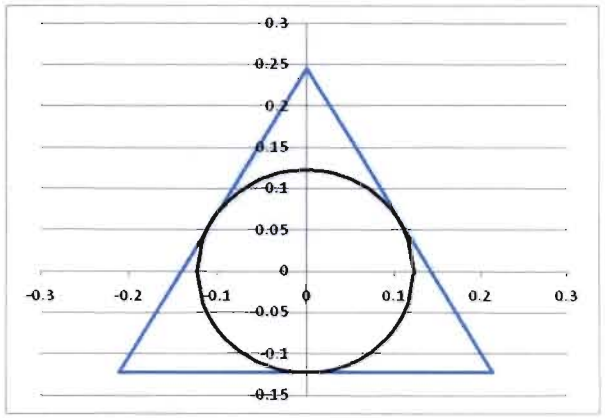


Retracted position results in smaller magnification and larger point spread function:13 microns

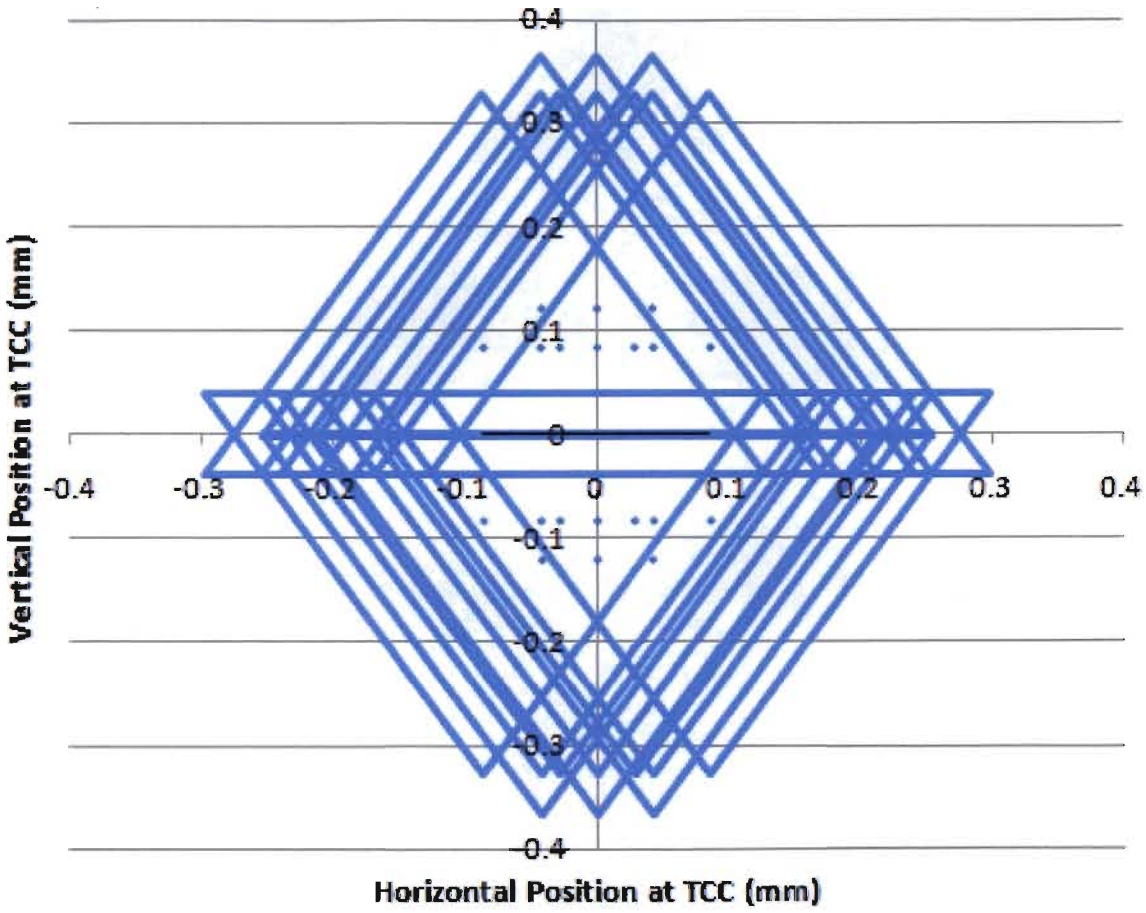
Two contributions added in quadrature results in 23 micron resolution for this system. Initial images will be of ~200 micron diameter objects.

The effective field of view has been nearly doubled by retracting the pinhole.

250 μm field of view

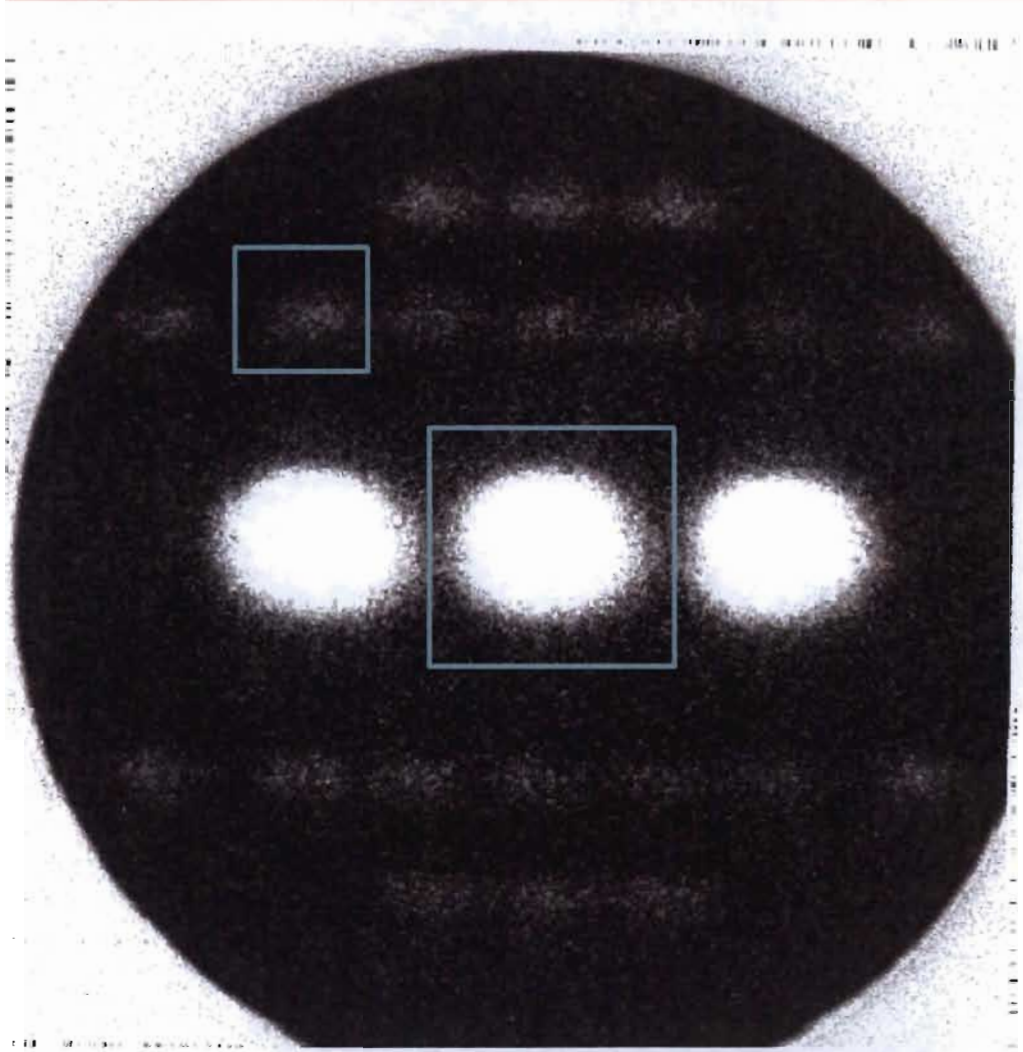


Slight degradation of resolution (from 22 microns to 23 microns) in exchange for increased field of view and operational ease.



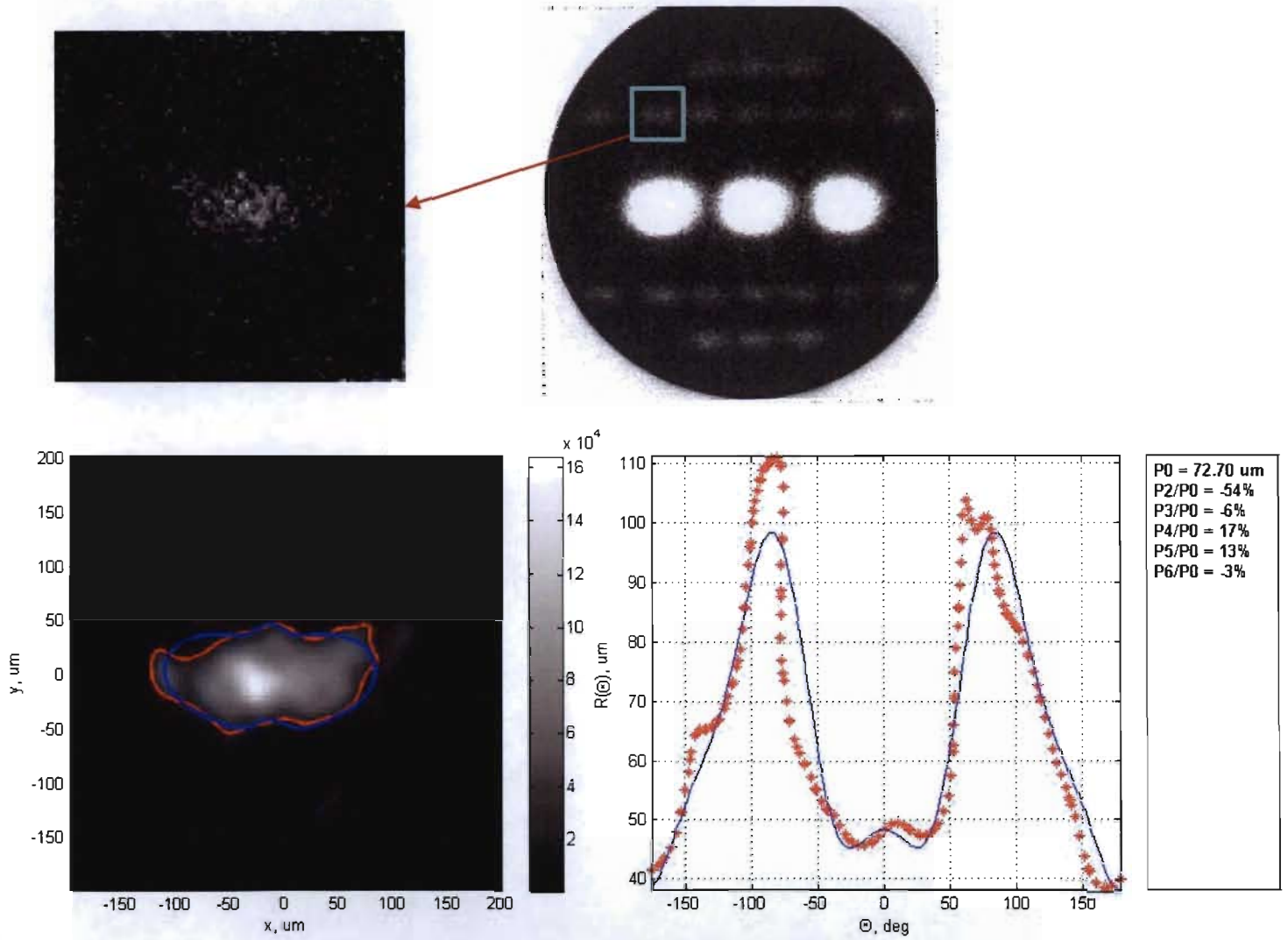
Each pinhole points at a different location at the target chamber center

Reconstruction of N110603-002 Neutron Source

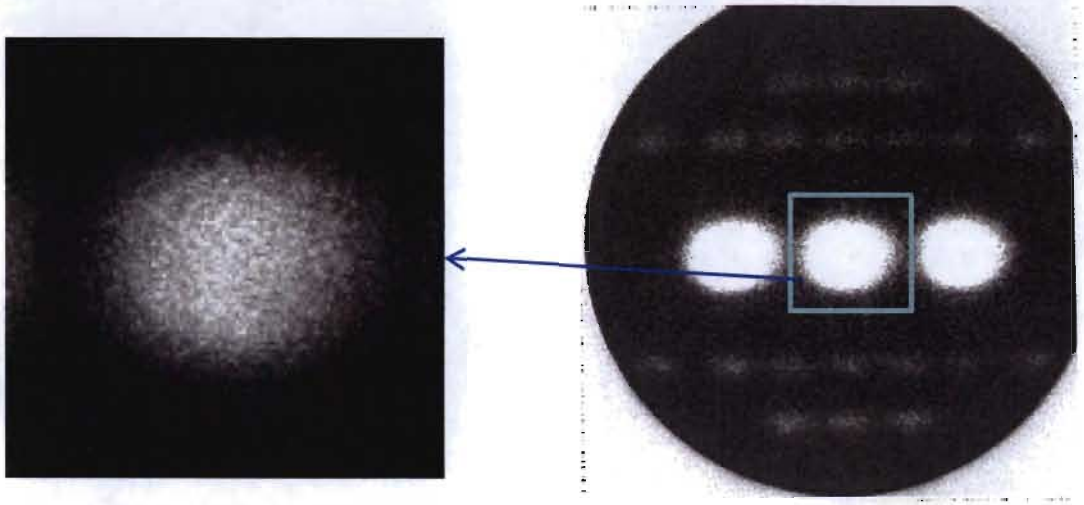


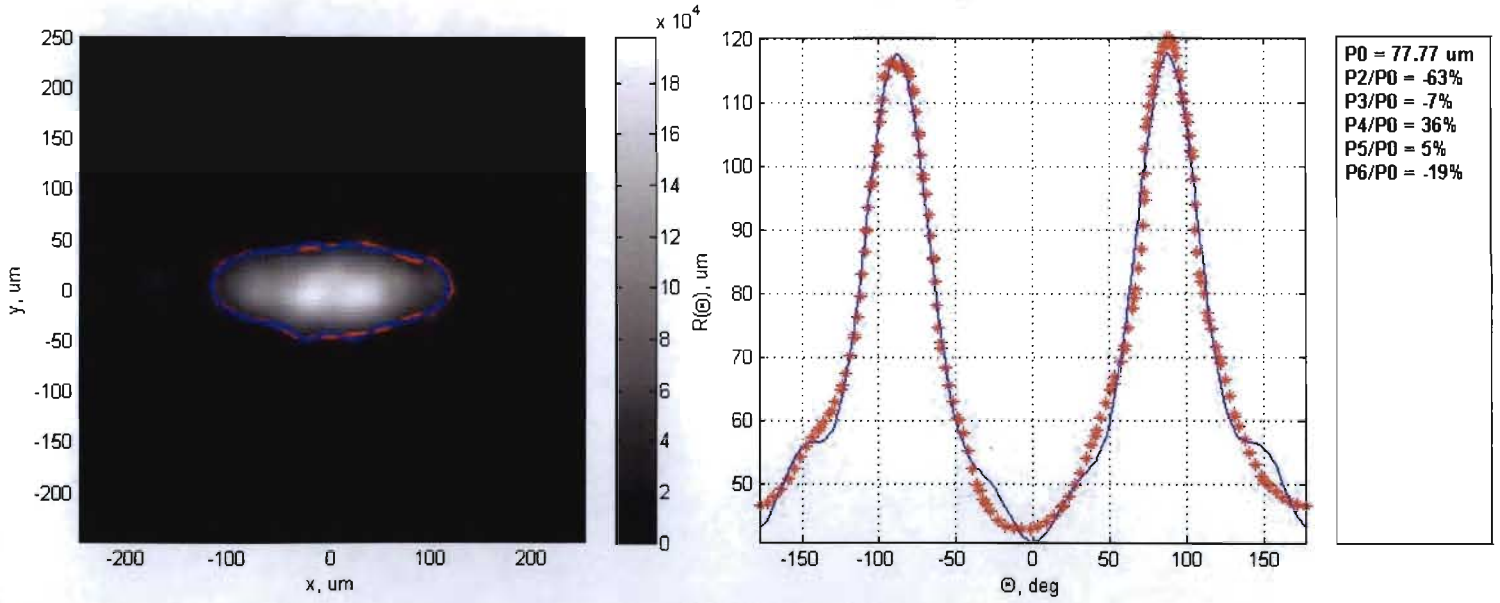
Direct-drive, DT filled glass micro-balloon exploding pusher shot fired on June 3 at NIF for calibration measurements.

Pinhole Reconstruction



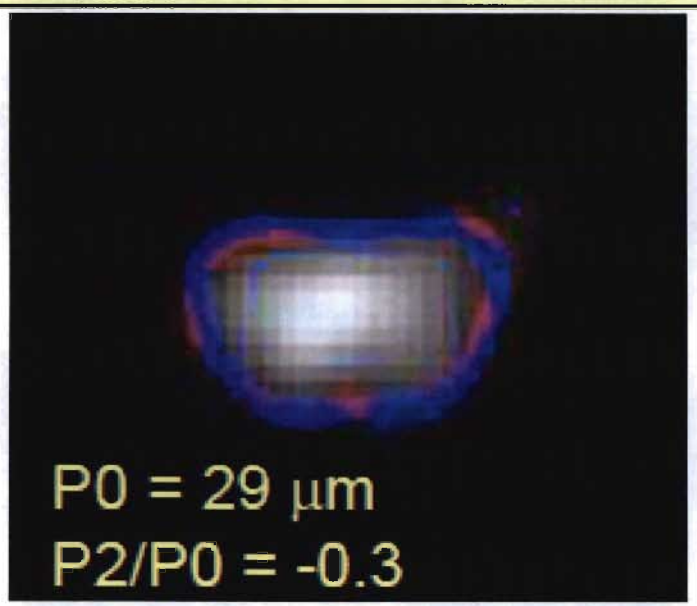
Penumbra Reconstruction



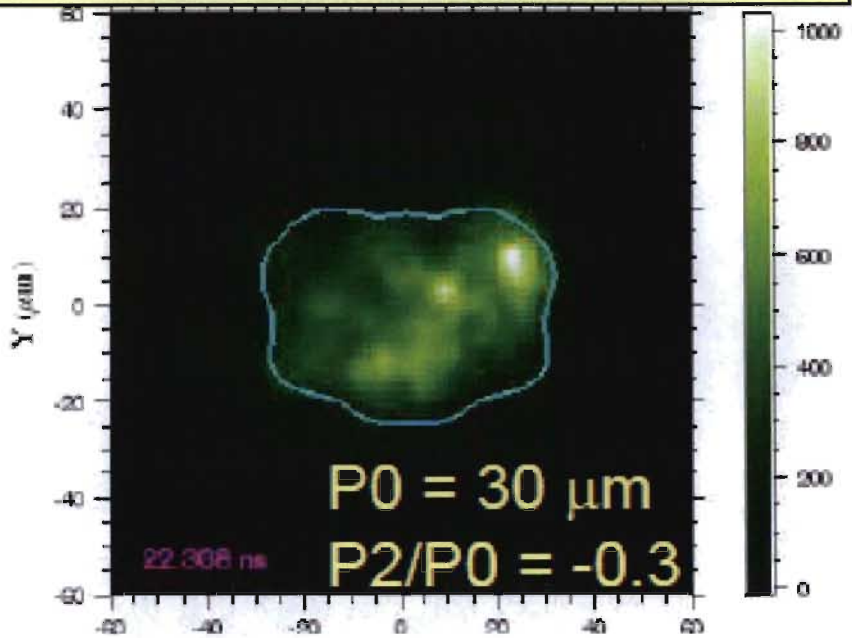


Neutron X-Ray Comparison

Neutron Image Data

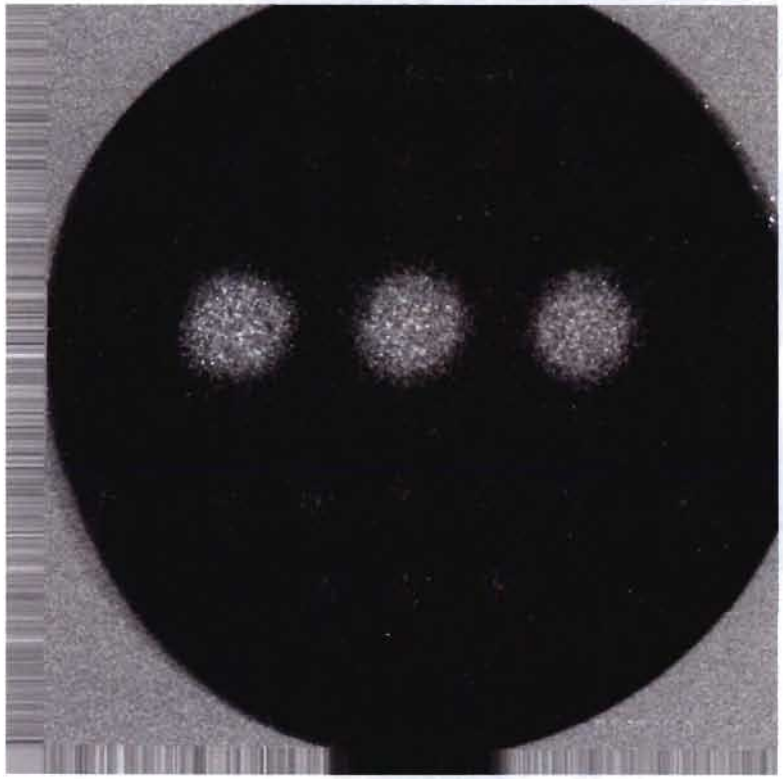


90-78 hGXI Data

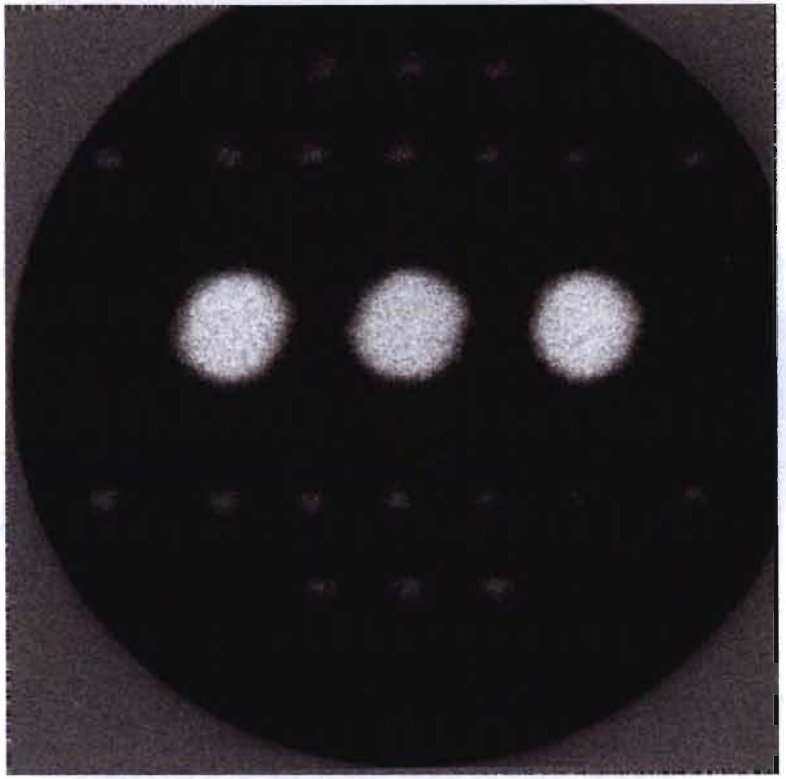


Down Scatter and Primary Neutron Measurement

C2: 10-12 MeV



C1: 13-17 MeV



Summary

- Initial configuration has provided 23 micron resolution with 500 micron FOV for the initial measurements.
- We have a relatively straight forward path to 14 micron resolution in the future.
- Commissioning experiments have been very successful.
- The system was used to collect primary and down scattered images from the recent THD and DT shots.
- We continue to work on the analysis and understanding of this new data set.