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Title: Analysis of the First NIF Neutron Images (U)

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NIC

Analysis of the First NIF Neutron Images

53rd APS Division of Plasma Physics, Nov 14-18, 2011

D.C. Wilson, O.S.Jones, G.P. Grim, F. E. Merrill
and a *HUGE* NIF team

Los Alamos and Lawrence Livermore National Laboratories – National Ignition Campaign

his work performed under the auspices of the U.S. DOE by Los Alamos and Lawrence Livermore National Laboratories under Contracts DE-AC52-06NA25396 and DE-AC52-07NA2734

A *Huge multi-laboratory* team contributed to this talk.

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[2] *Lawrence Livermore National Laboratory*

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plus:

the Diagnostics teams at LANL, LLNL, LLE, and MIT,

the Target Fabrication teams at General Atomics and LLNL,

and the NIF operations staff.

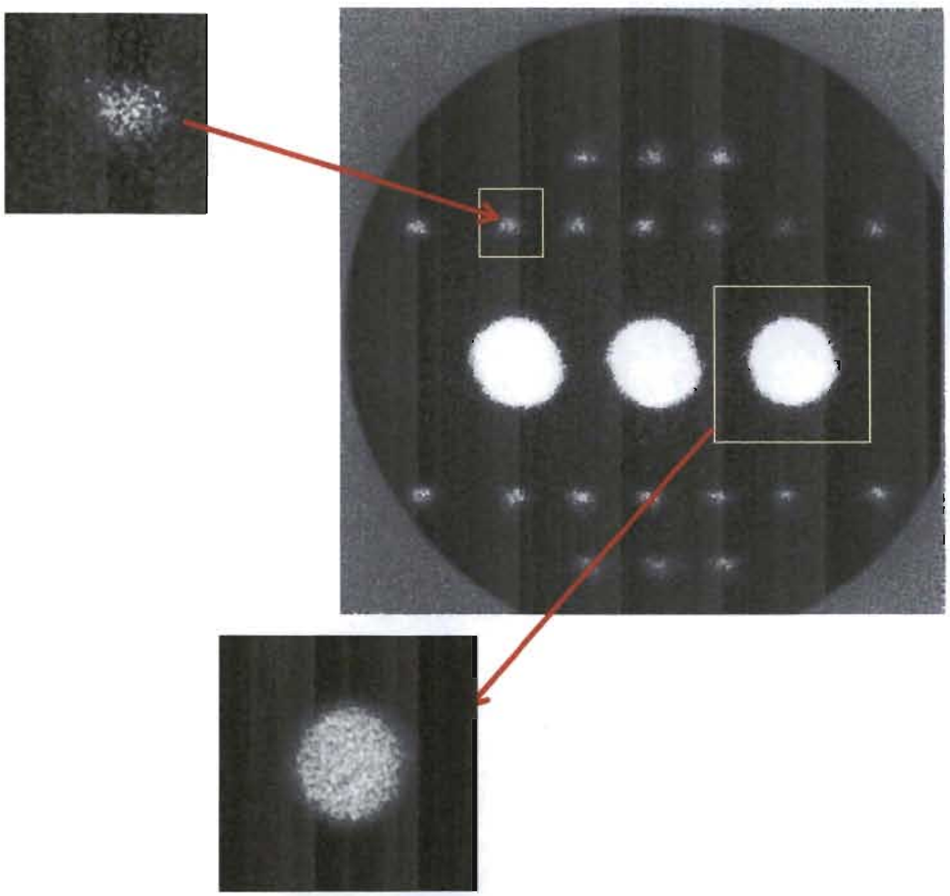
ABSTRACT

The NIF Neutron Imaging system obtains both pinhole and penumbral images in two energy bands, > 13 MeV, and 10-12 MeV. Pinhole images provide higher neutron source resolution that penumbral images, but for capsule yields < 5e+14, there is inadequate signal to use pinhole images for down-scattered images. Our analysis shows for directly driven capsules that X-ray emission isdominated by the hot glass shell, and neutrons by the hot DT fuel. Neutron images are more oblate (pancaked) than calculated, and neutron emission fits within glass shell X-ray emission.

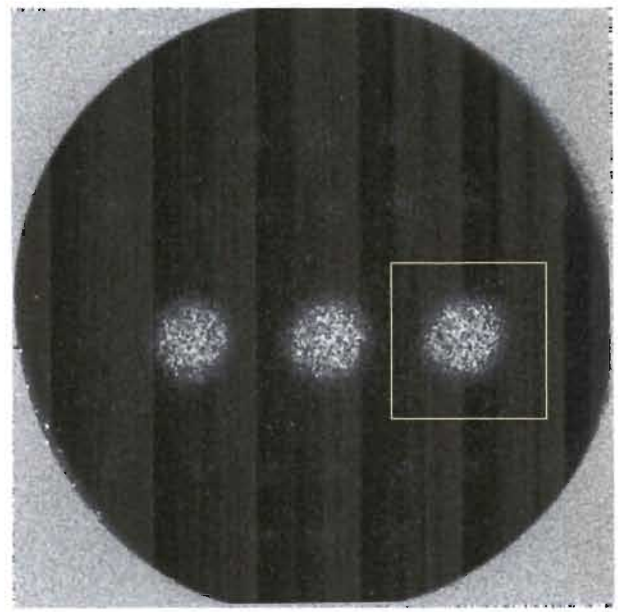
For radiation driven capsules calculations with hohlraum asymmetry and surface roughness overestimate convergence (too high dsr, too small images). For oblate implosions dense fuel surrounding a burning torus can appear as a bar along the hohlraum axis. In some implosions the neutron emission comes from a smaller region than calculated. In the future calculations need to be redone forcing less convergence to make a better comparison with observed images.

The NIF Neutron Imaging system obtains both pinhole and penumbral images in two energy bands.

Primary Neutrons (>13 MeV)



Down-Scattered (10-12 MeV)



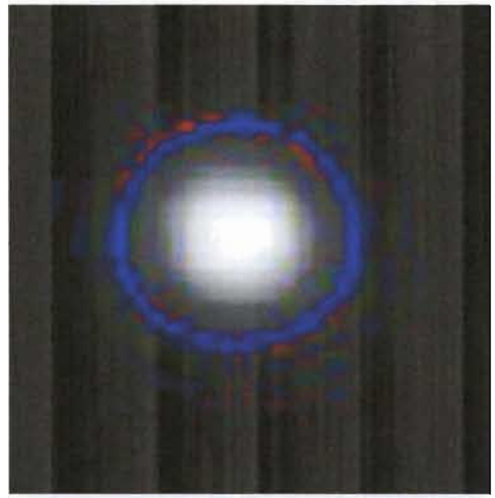
Pinhole images provide higher neutron source resolution that penumbral images.

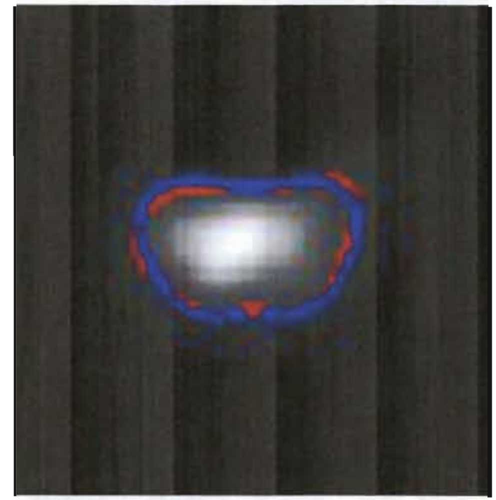
- The penumbral images have a elliptical shape and larger size that can't currently be explained.
- These lead to larger differences between data and modeled images after reconstruction.
- Comparing 14 MeV reconstructions, penumbral source reconstructions have less high frequency content (lower resolution) and somewhat larger sizes. ~ 5 μm larger, P2/P0 closer to 0.
- Nevertheless, the low yields of all but one DT cryo shot required using penumbral reconstructions.

From Penumbral image

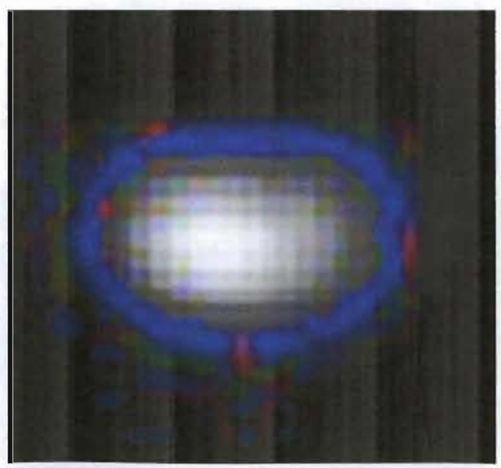
From Pinhole image

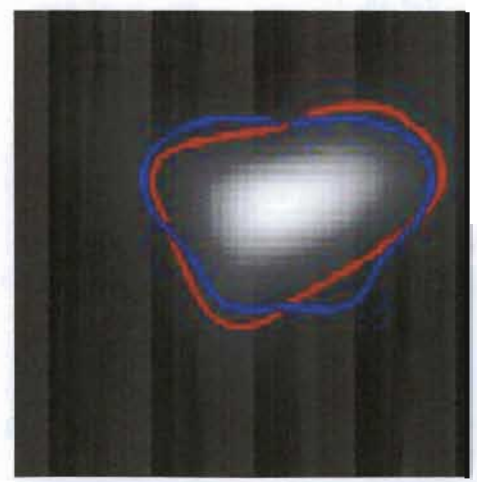
N110608





N110603-001

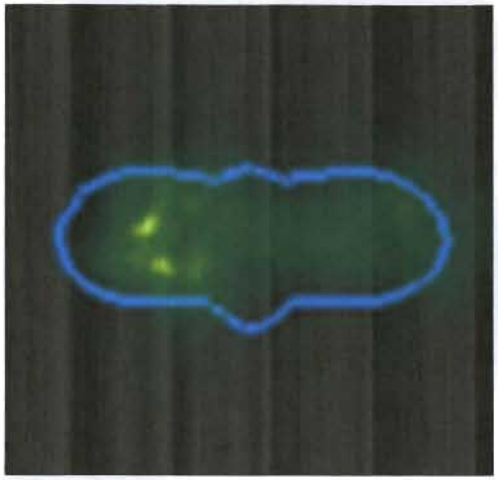




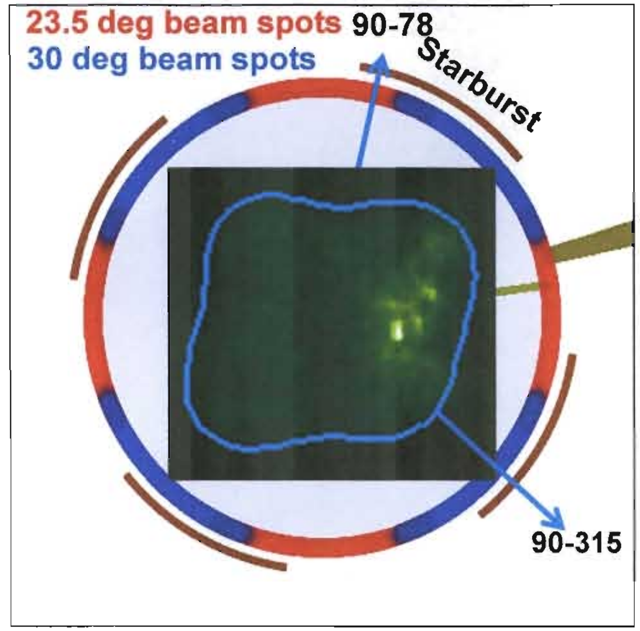
Neutron images and the various X-ray sources are viewed from different directions

All frames are ~ 100x100 μm

hGXI near Peak Brightness Equatorial (90-78)

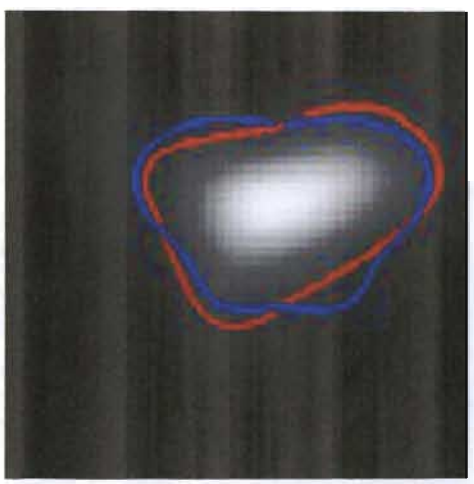


hGXI near Peak Brightness Polar

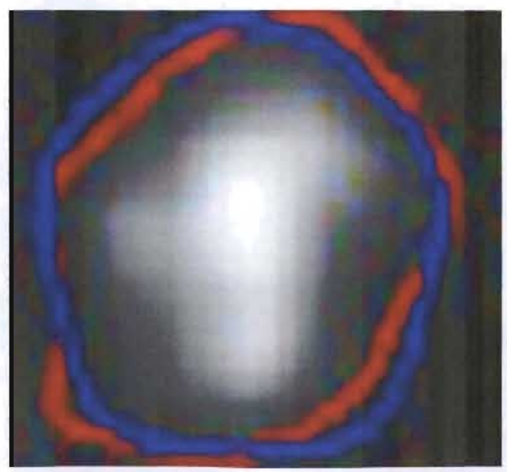


Neutrons, Equatorial (90-315)

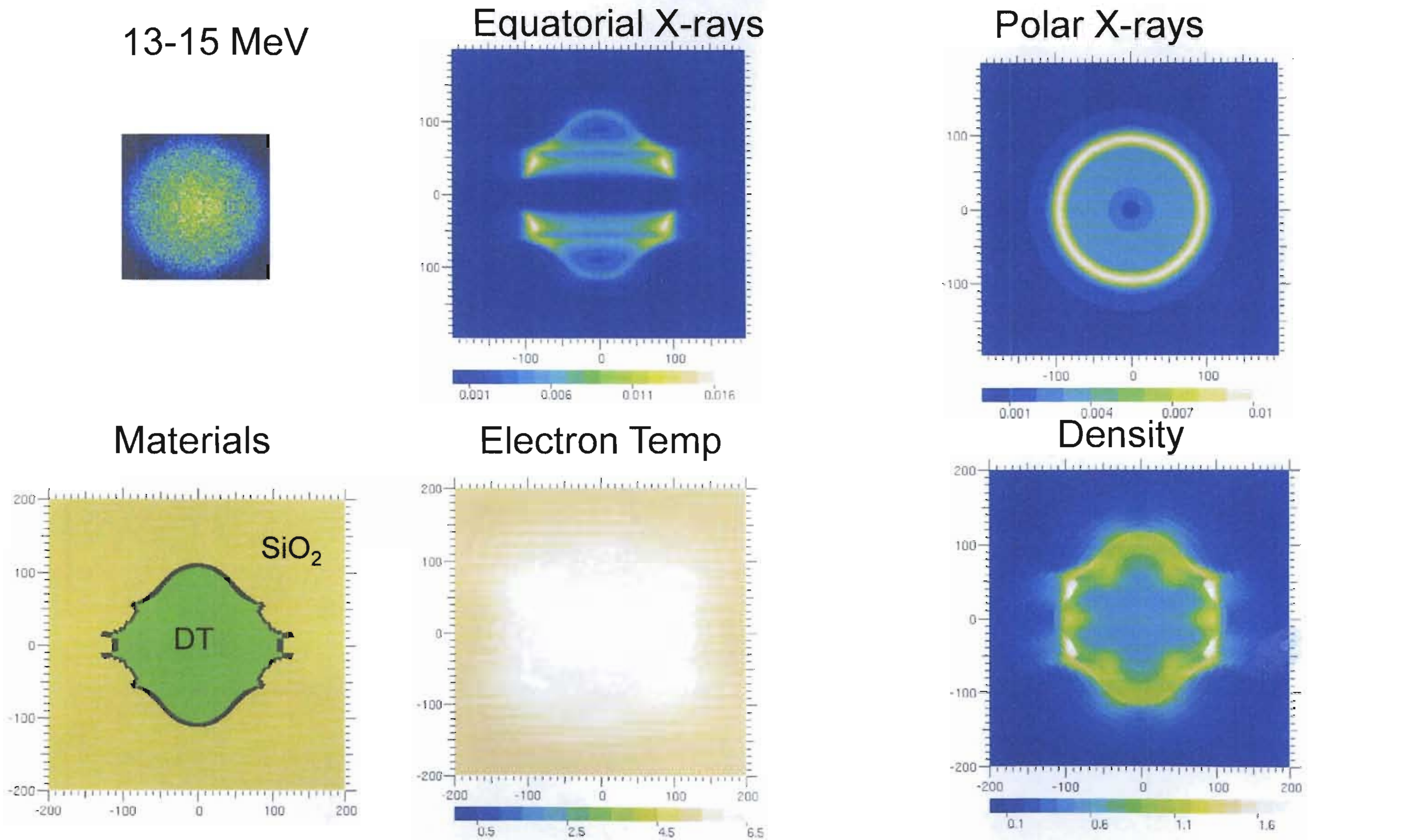
Pinhole 13-17 MeV



Penumbral 10-12 MeV



For Directly driven gas capsules, X-ray emission is dominated by the hot glass shell, and neutrons by the hot DT fuel

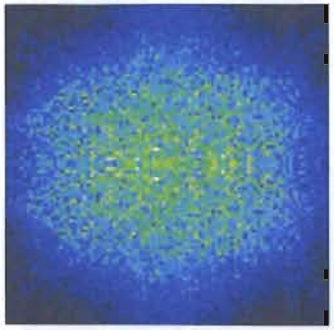


- **X-ray is from hot SiO2;neutron emission from a ~sphere of hot, low density DT fuel.**

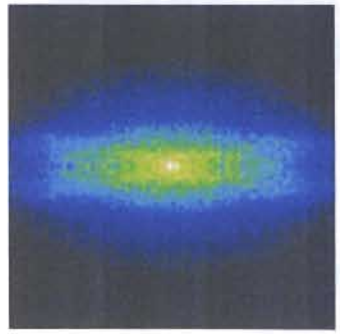
Polar Direct Drive laser powers were adjusted to give a round implosion calculated by Hydra

eutron Images

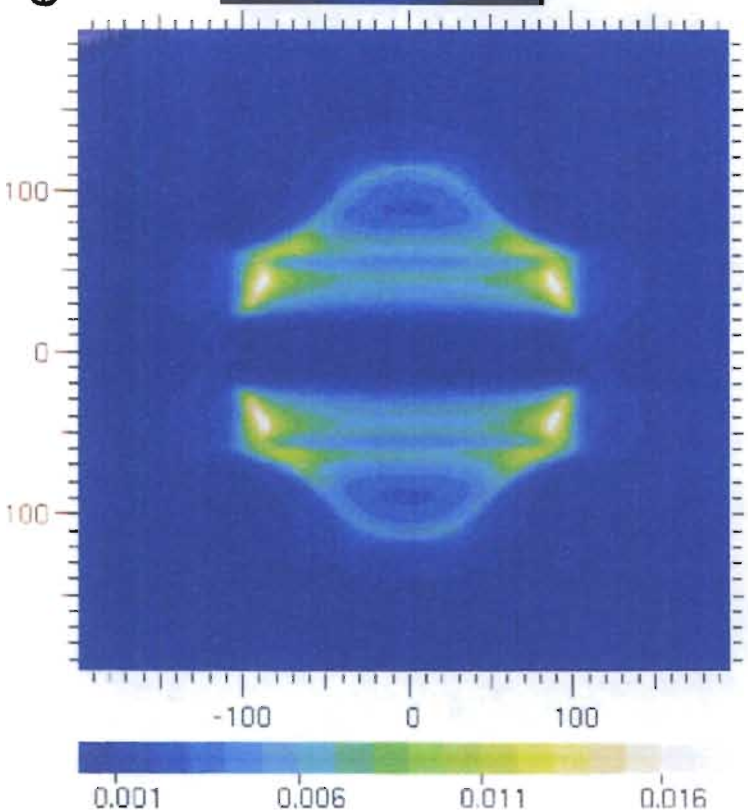
Nominal Calculation

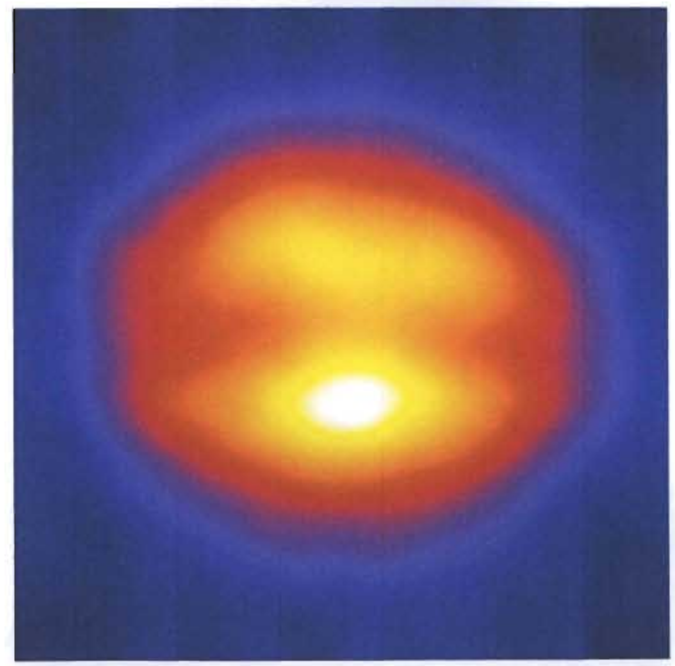


+10% Outers -20% Inners



Observed Image

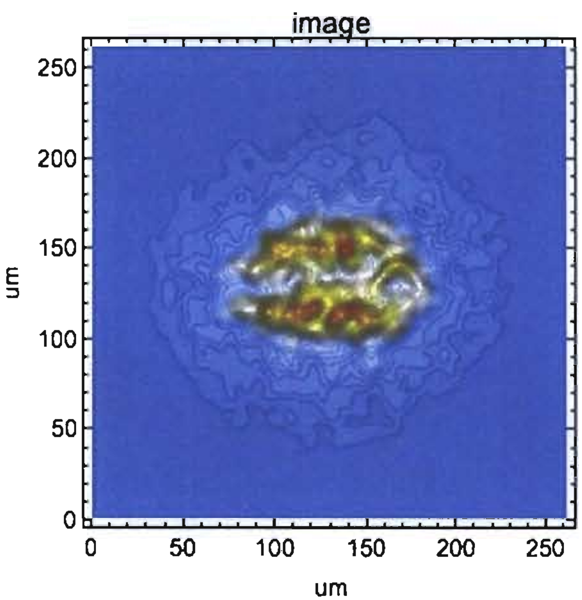




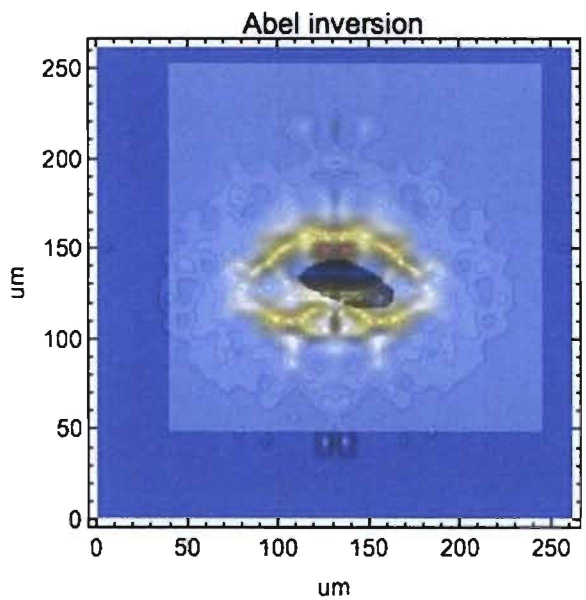
- **200x200 micron neutron frames**
- **400x400 X-ray frames**

The neutron image can fit inside the shell of X-ray emission

X-ray Image



Abel Inverted
X-ray emission



Neutron Image

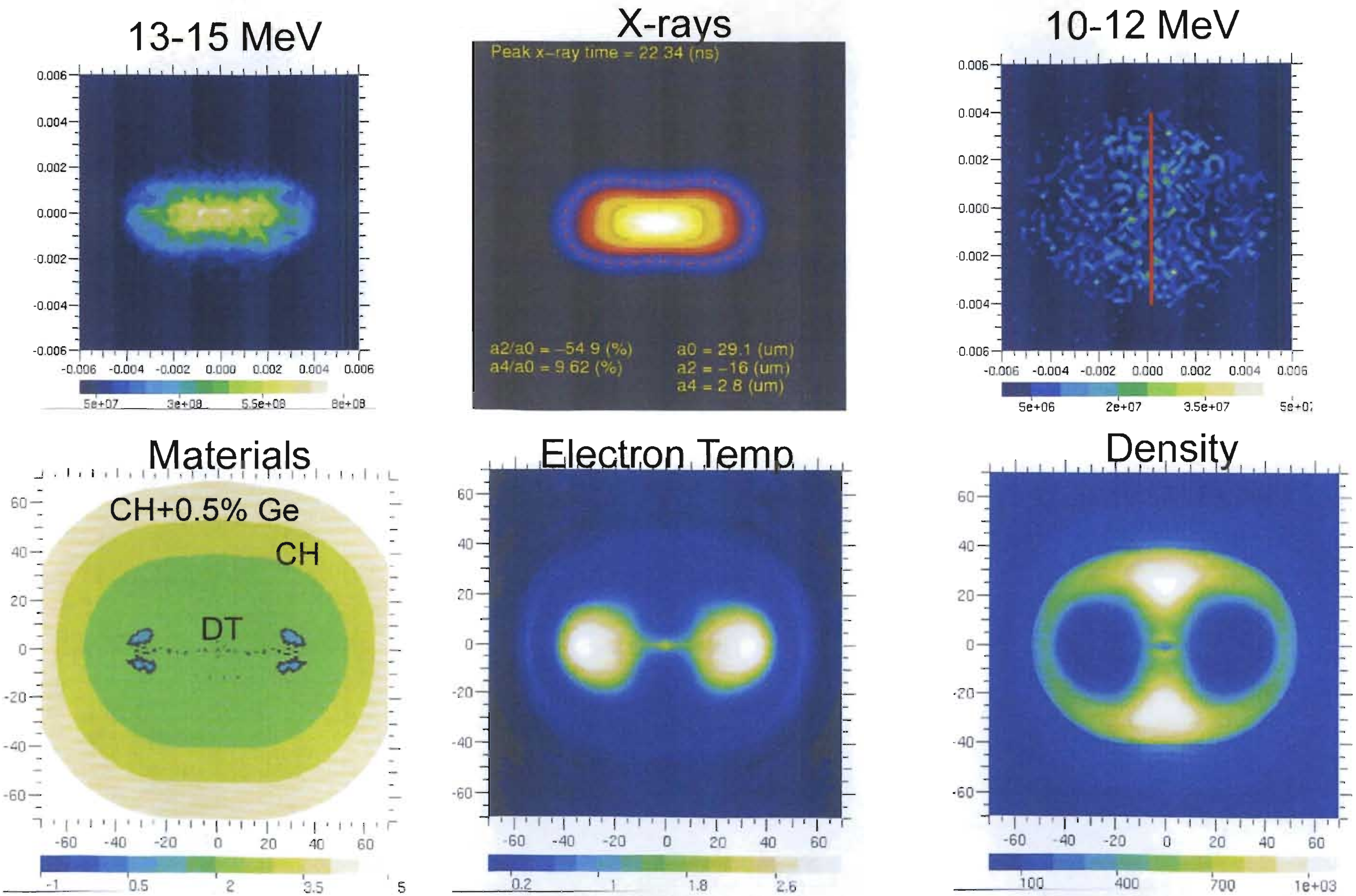
- The relative position of the X-ray and neutron images is not measured

THD and DT capsules are simulated with HYDRA

- 2D Hydra calculations by O. Jones (see KI3.00001) and:
  - Laser powers adjusted to give proper shock velocities and timing
  - A beam power transfer script used to get approximately correct X-ray image symmetry.
- Monte Carlo Neutron and Charged Particle Transport
  - Escaping neutrons are collected to form energy resolved neutron images viewed from the equator.
- Calculated yields are larger than observed yields.
  - Ion temperatures agree.
- Calculations consistently over estimate down-scattered ratios, i.e. rho-r and convergence.

- Need to be redone forcing the capsule on a higher adiabat (intentional shock mis-timing)

In a clean THD or DT ignition capsule X-ray emission arises from hot , low density DT fuel, not CH or Ge doped CH

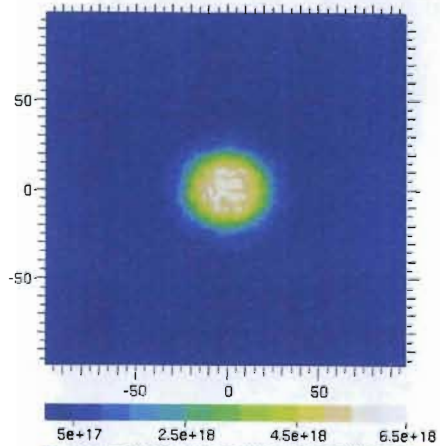


- **Both X-ray and neutron emission is from a torus of hot, low density DT fuel.**

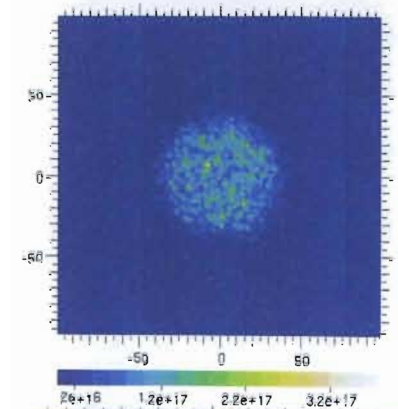
Changing drive symmetry and surface roughnesses change the neutron image shape.

NIC

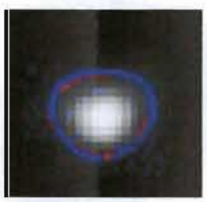
Symmetrized



N110620sm
Yield=9.4e+15
Dsr=6.69%

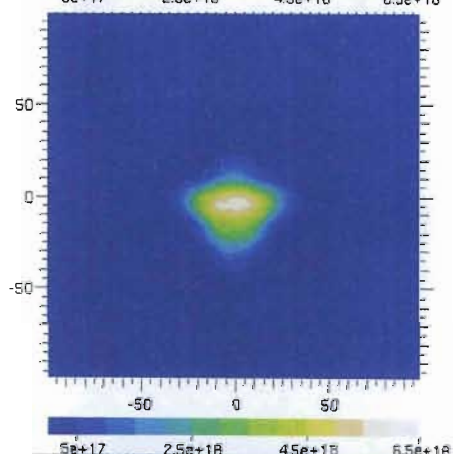


N110620
Observed
13-15 MeV

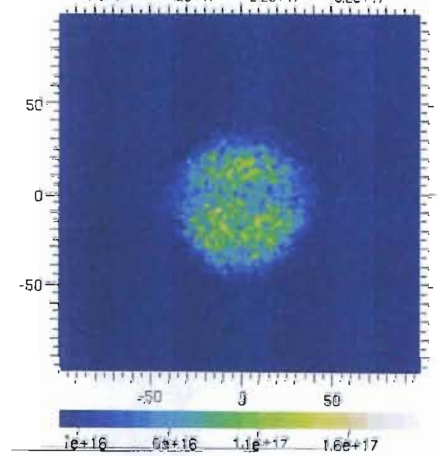


Yield=4.11e+14
Dsr=4.53%

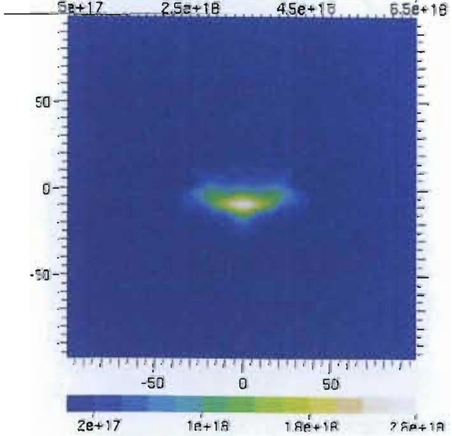
Hohlraum
Asymmetry



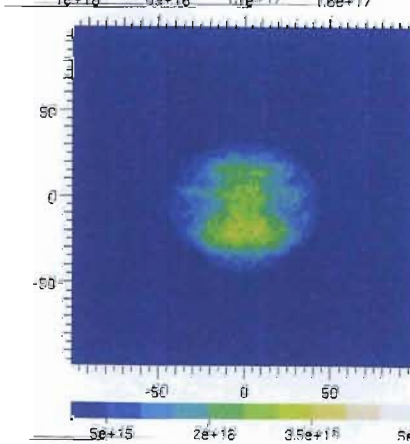
N110620
Yield=7.2e+15
Dsr=6.87%



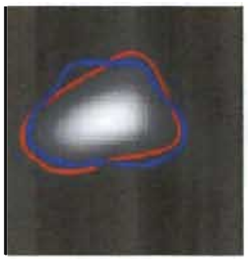
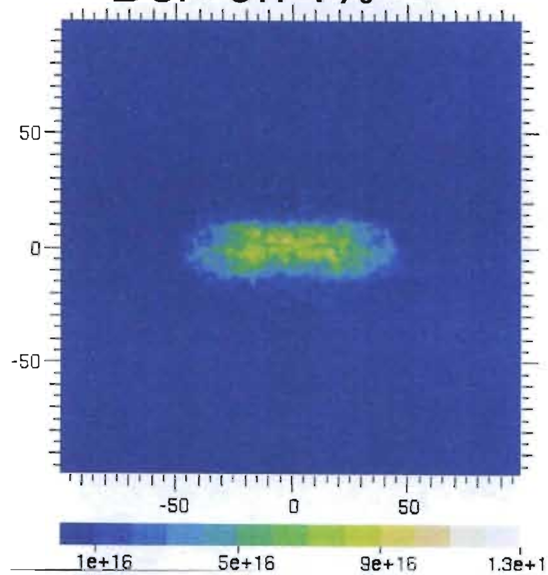
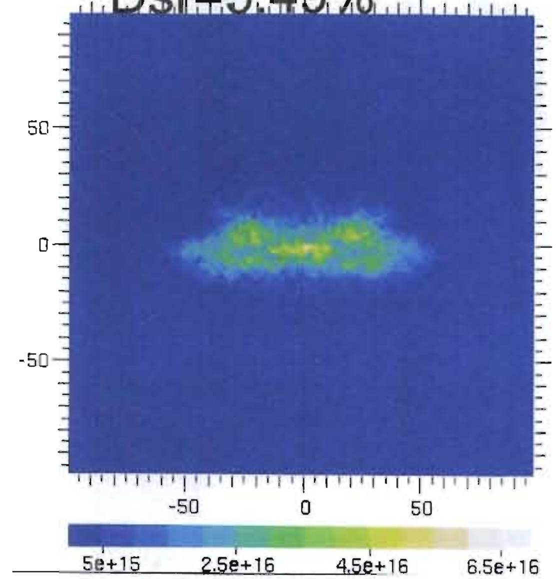
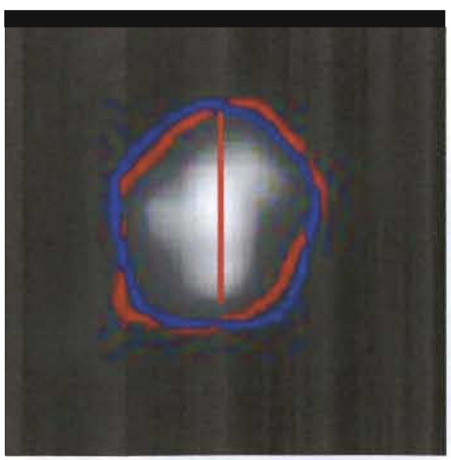
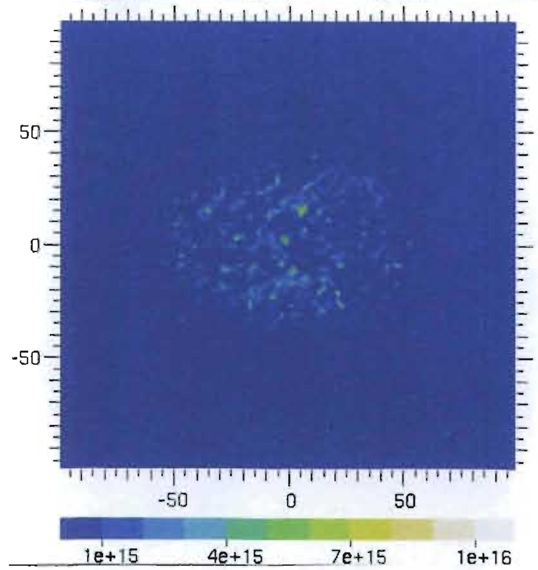
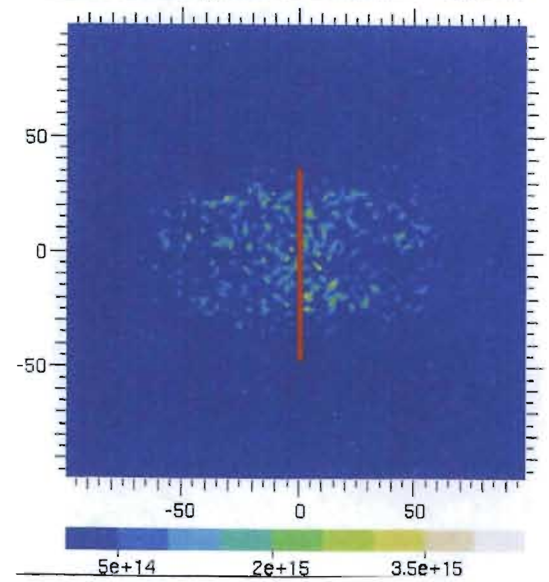
Random
Surface
Roughness



N110620nifsurfs
Yield=2.3e+15
Dsr=7.226%

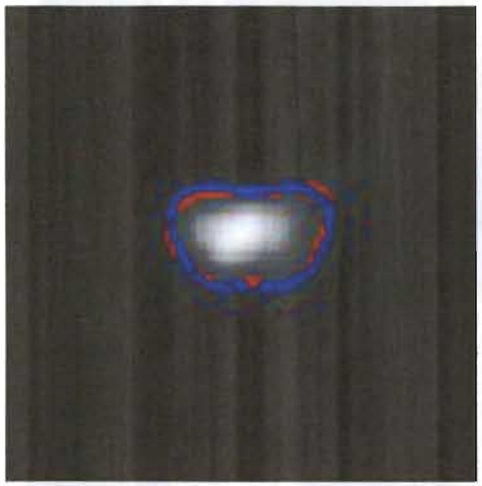
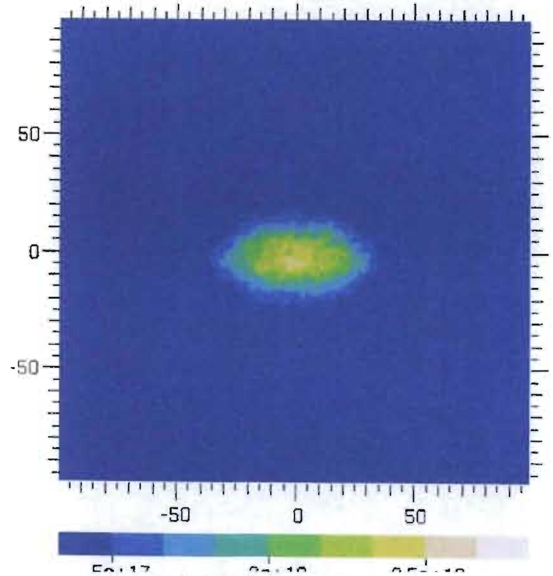
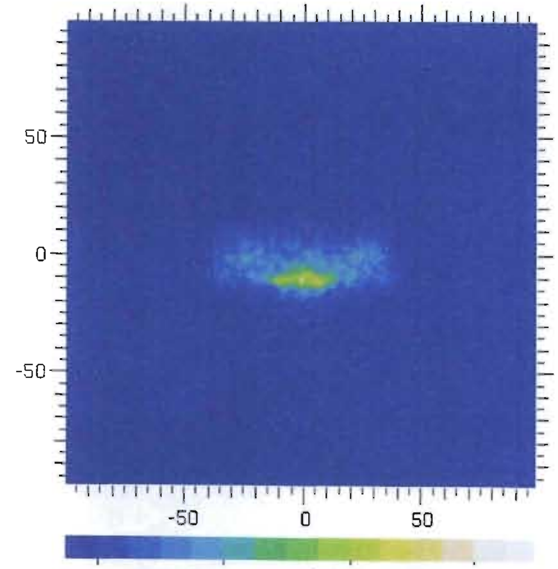
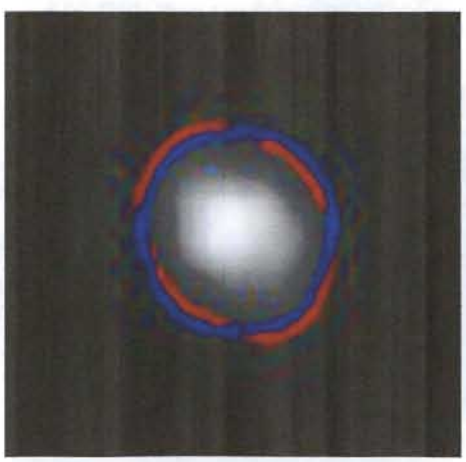
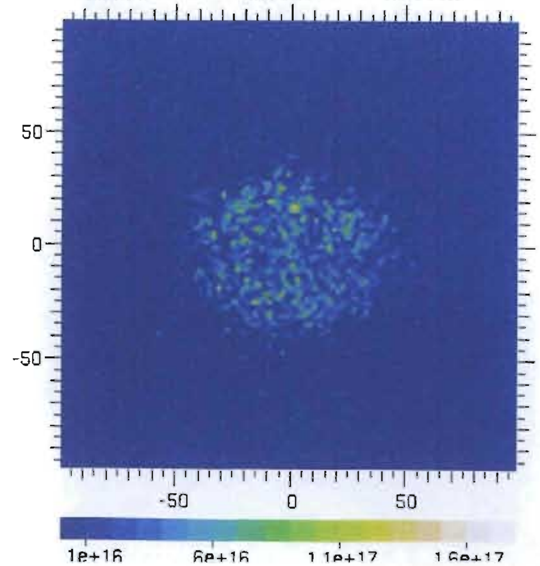
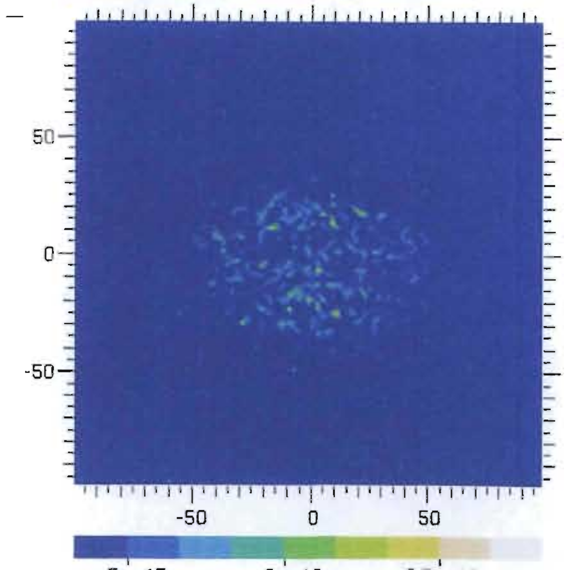


N110603 may show the down-scattered vertical band

	Observed Yield=6.49e+13 Dsr=4.68%	Calculated Yield=1.46e+14 Dsr=5.74%	Calculated with surfs Yield=9.62e+13 Dsr=5.49%
13-15 MeV			
10-12 MeV			

For N110608 the neutron images are the same size as calculated with too much convergence (too high dsr)

NIC

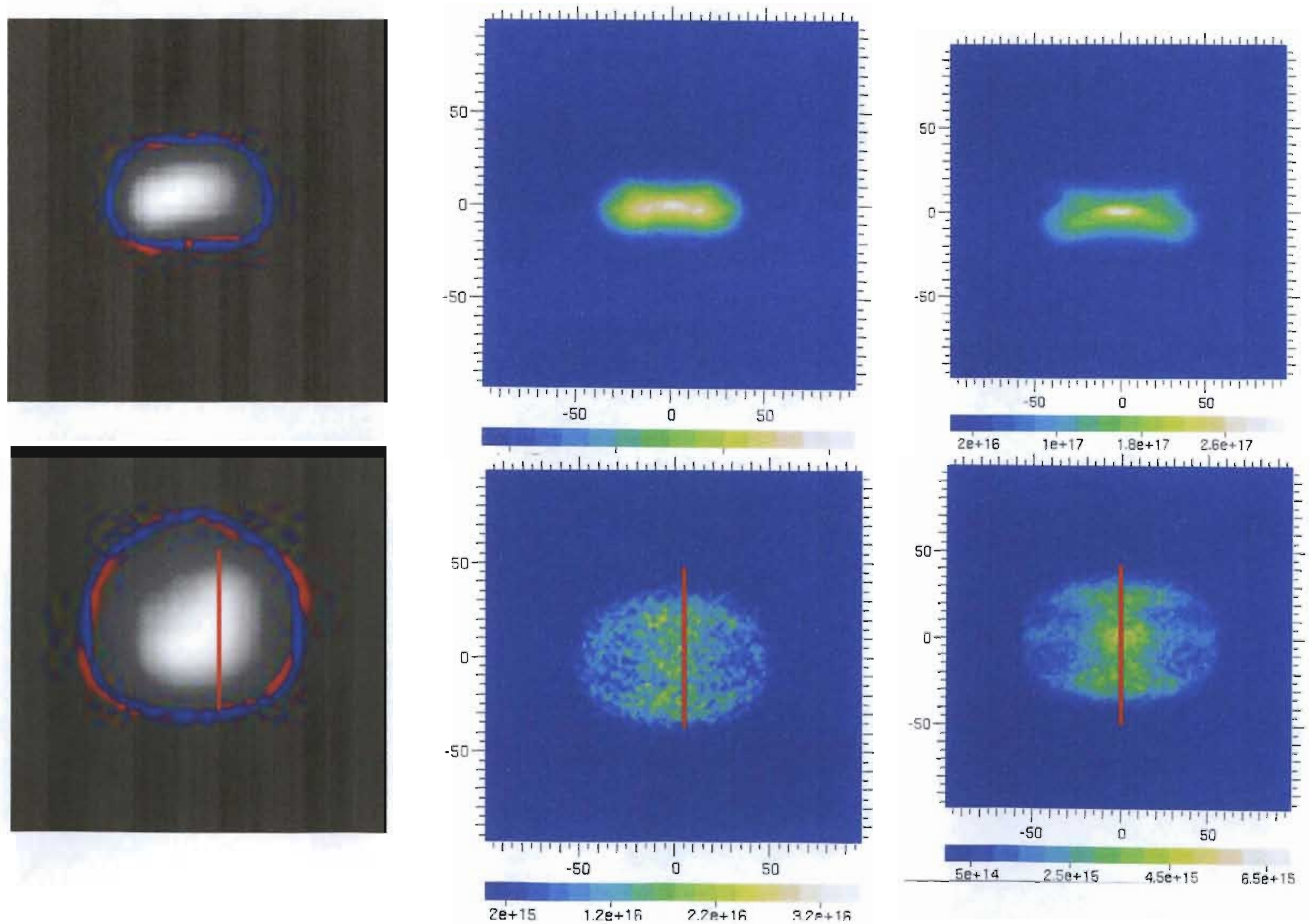
	Observed Yield=1.91e+14 Dsr=4.52%	Calculated Yield=4.33e+15 Dsr=5.99%	Calculated with surfs Yield=5.78e+14 Dsr=7.16%
13-15 MeV			
10-12 MeV			

For N110615 calculated images are smaller than observed. A vertical down-scatter bar suggests a torus.

	Observed	Calculated	Calculated with surfs
	Yield=4.28e+14	Yield=1.80e+15	Yield=5.47e+14
	Dsr=3.63%	Dsr=4.84%	Dsr=5.05%

13-15 MeV

10-12 MeV

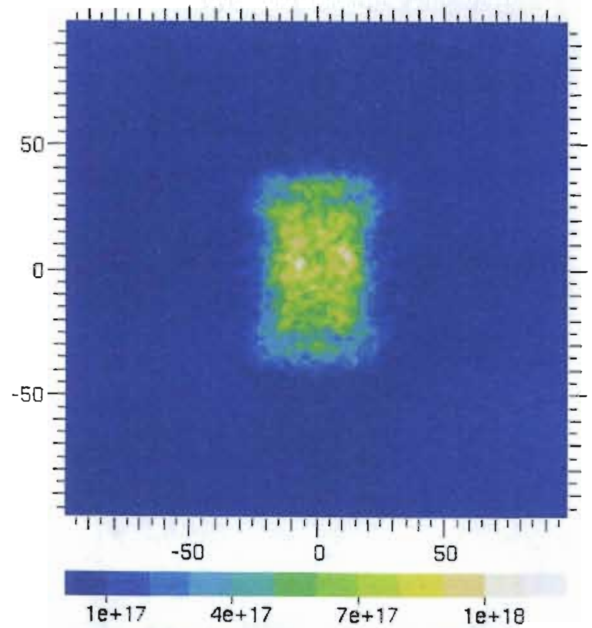


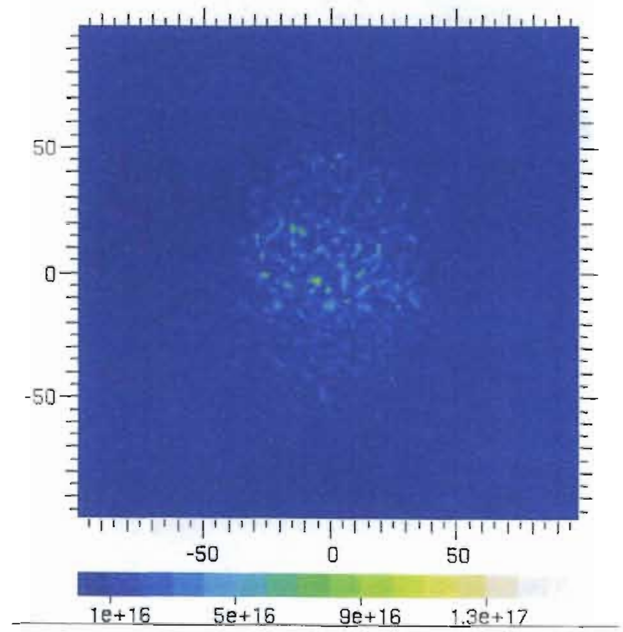
For N110826 the observed neutron image is smaller and rounder than calculated.

13-15 MeV

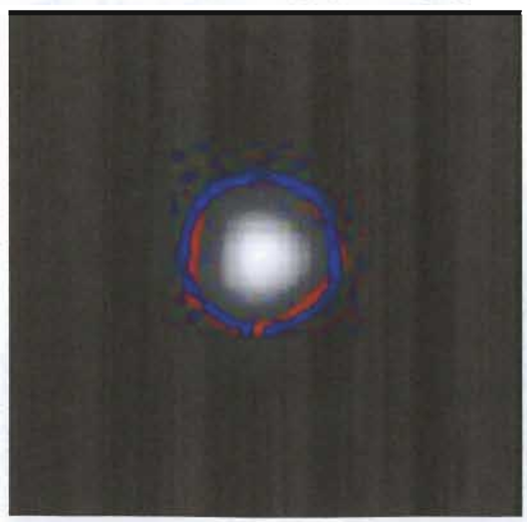
10-12 MeV

Calculated
Y13=2.33e+15
Dsr=5.24%





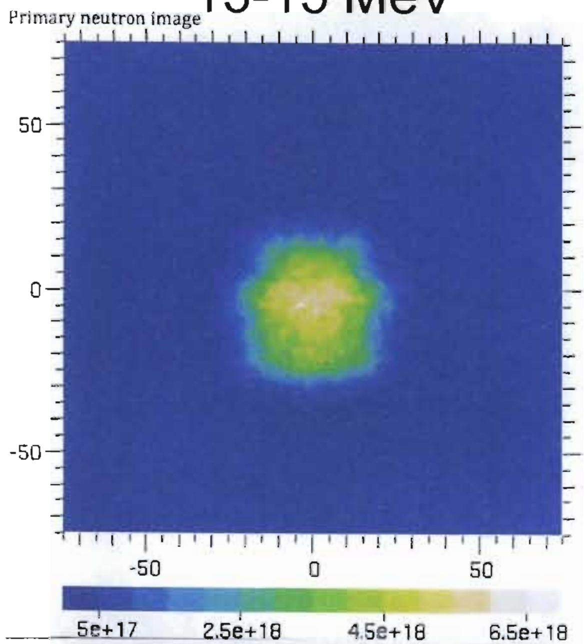
Observed
Y13=1.71e+14
Dsr=3.95%



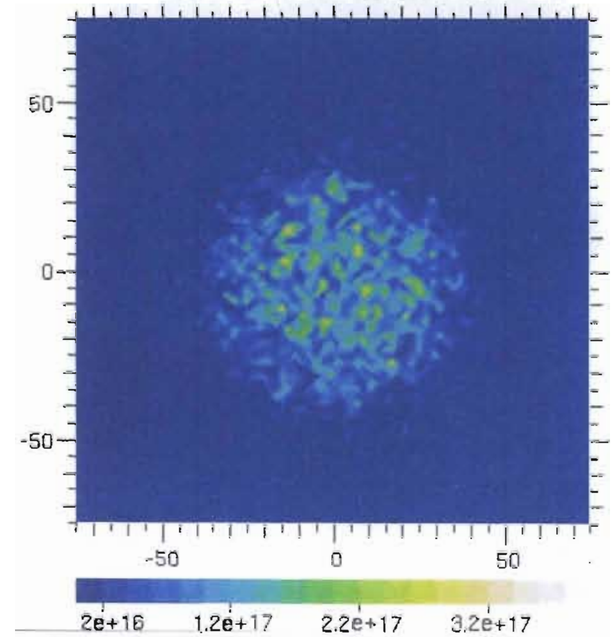
For N110914 the neutron images are the same size as calculated with too much convergence (too high dsr)

Calculated
Y13=7.59e+15
Dsr=7.078%

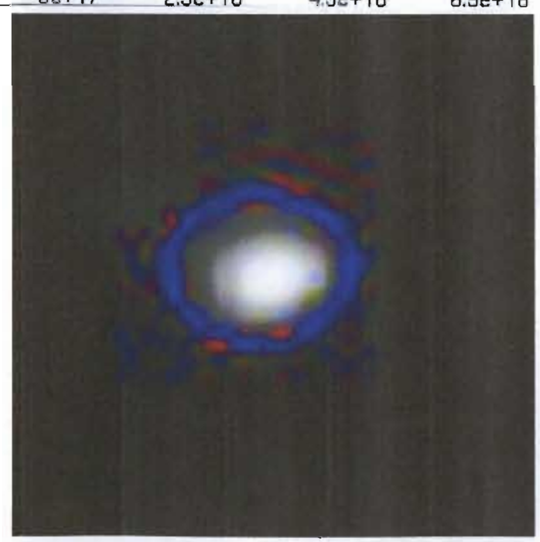
13-15 MeV



10-12 MeV



Observed
Y13=5.9e+14
Dsr=5.1%



Radius 39±1.1μm
P2/P0 -9±2%
Analysis in Progress

Analysis of the first NIF neutron images suggests:

- For directly driven capsules:
  - Neutron images are more oblate (pancaked) than calculated
  - Neutron emission fits within glass shell X-ray emission.
- For radiation driven capsules:
  - Calculations with hohlraum asymmetry and surface roughness overestimate convergence (too high dsr, too small images).
  - For oblate implosions dense fuel surrounding a burning torus can appear as a bar along the hohlraum axis.
  - In some implosions the neutron emission comes from a smaller region than calculated.
  - Calculations need to be redone forcing less convergence