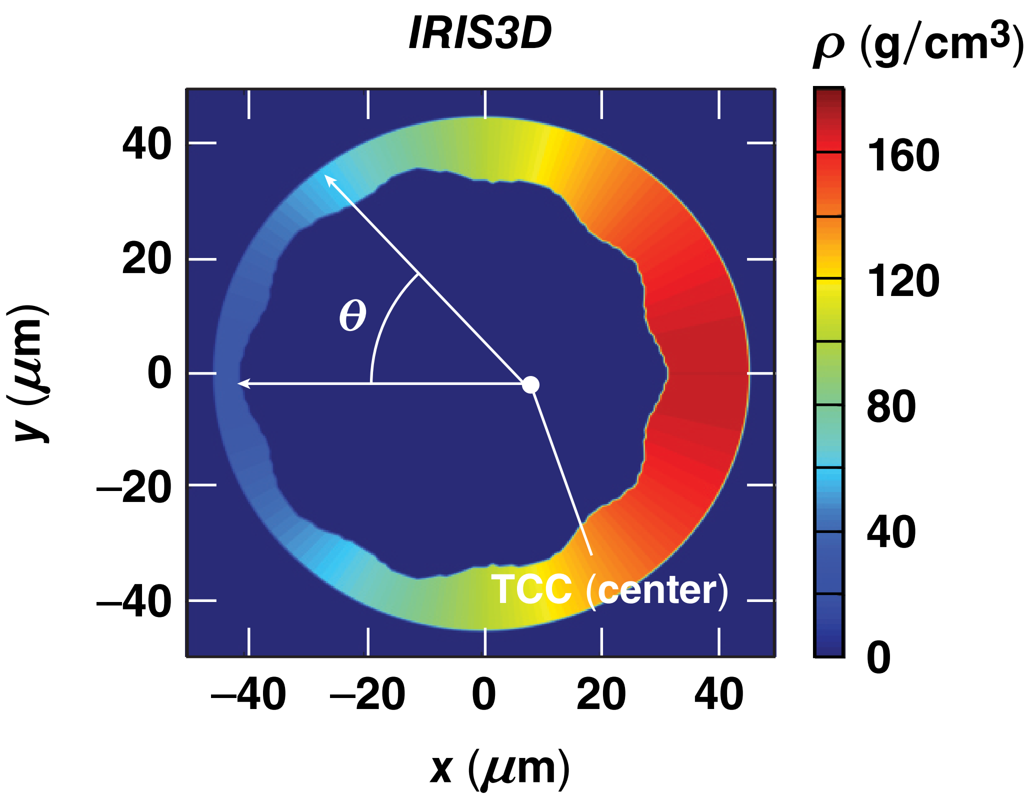
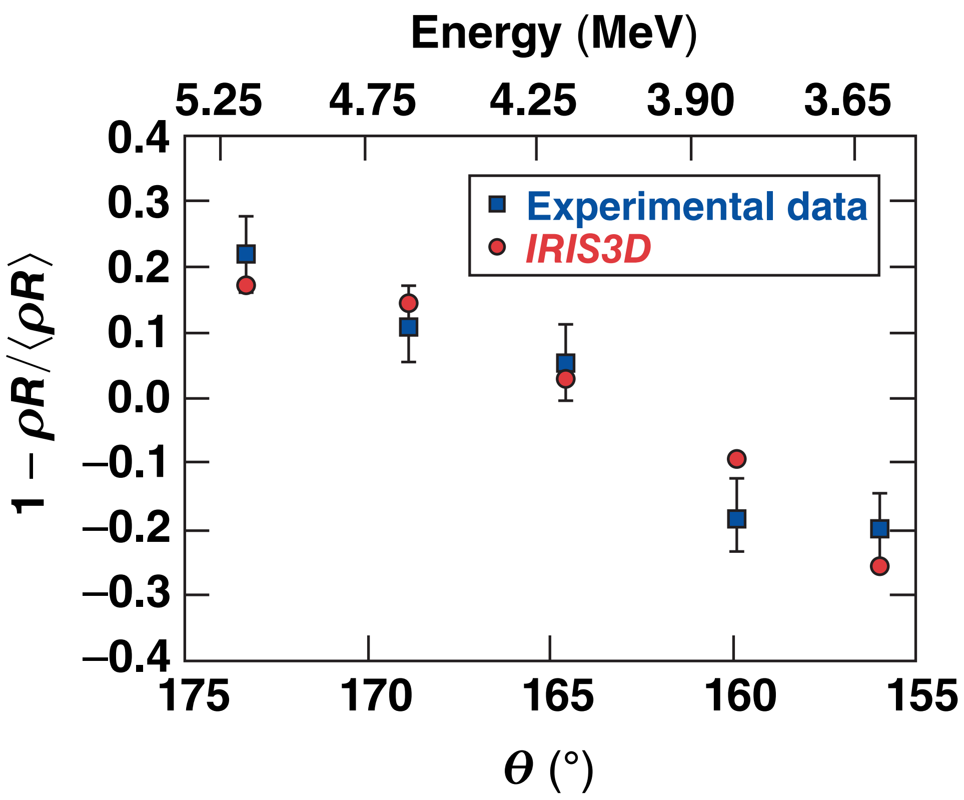
Low-Mode Variations of the Cold-Fuel Distribution in Cryogenic DT Implosions on OMEGA





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Summary

Neutron spectroscopy has been used to observe low-mode asymmetry of the cold-fuel distribution from cryogenic DT implosions

- **The neutron energy spectrum generated from cryogenic D–T direct-drive implosions in ICF* experiments is sensitive to low-mode cold-fuel distributions**
- **A 3-D neutron transport code (*IRIS3D*) is being used to interpret the measured neutron time-of-flight spectrum in cryogenic DT implosions**
- **The comparison of measurement and simulation indicates the presence of a dominant low mode ($\ell = 1$) in recent experiments**

*ICF: inertial confinement fusion

Collaborators

K. S. Anderson, V. Yu. Glebov, V. N. Goncharov, J. P. Knauer,
O. M. Mannion, P. B. Radha, S. P. Regan, T. C. Sangster, and C. Stoeckl

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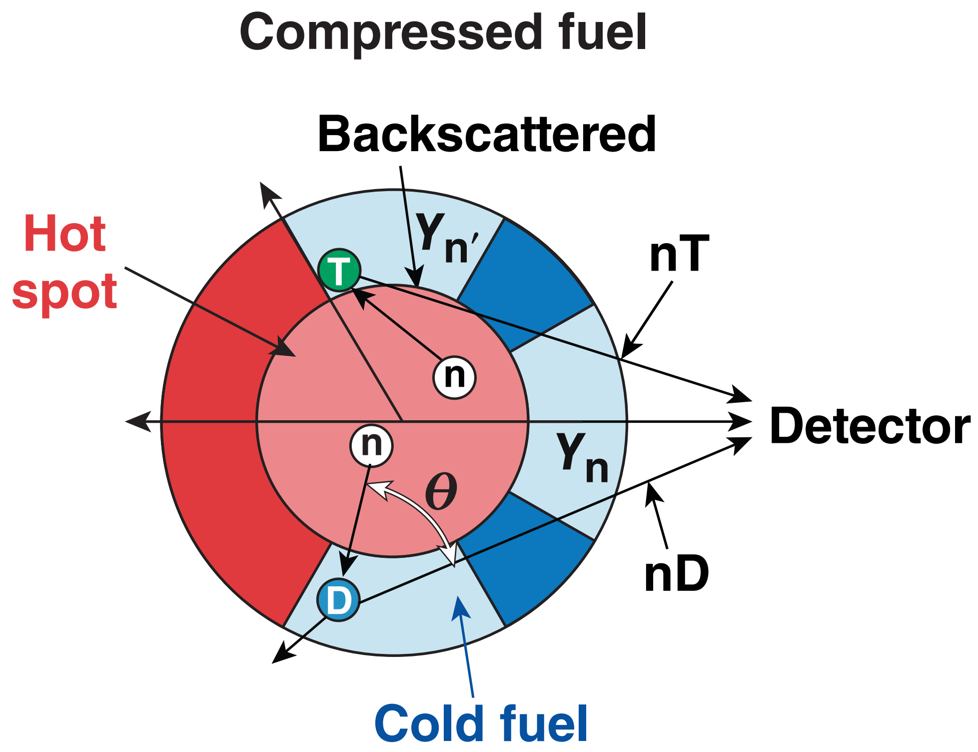
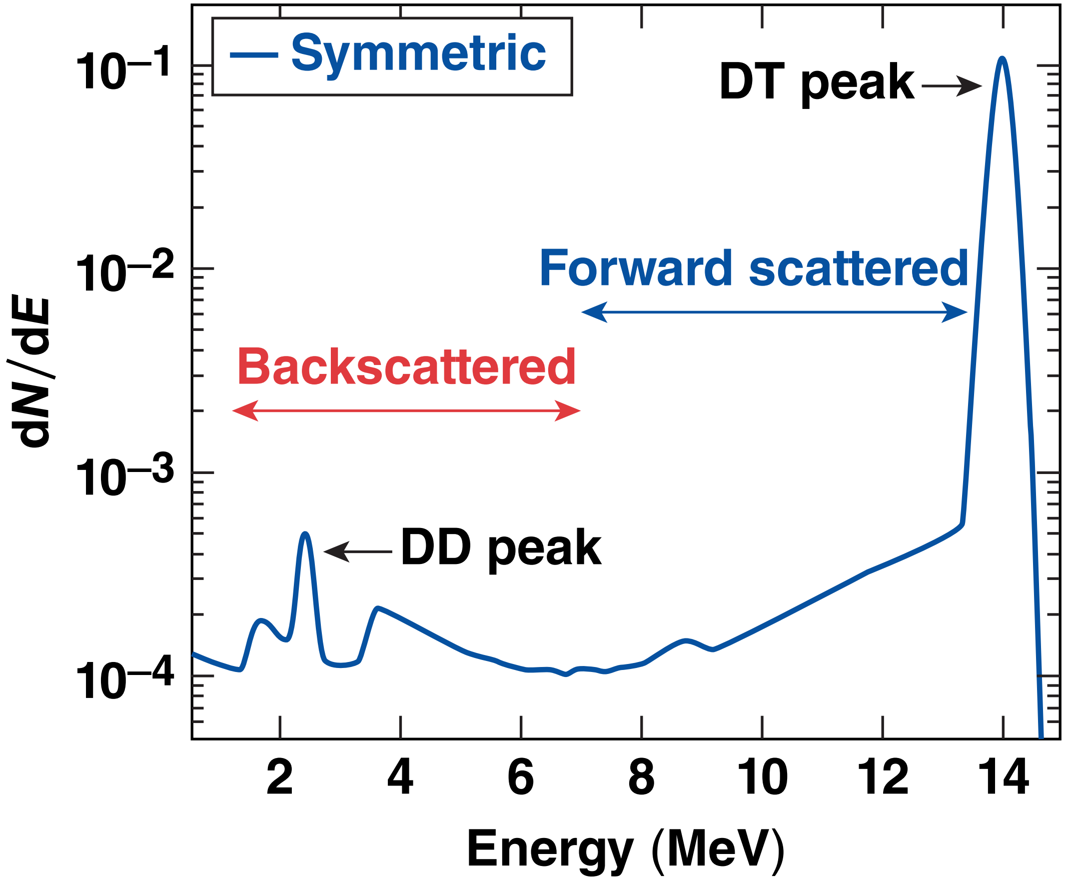
The neutron energy spectrum encodes important information about implosion performance produced in cryogenic DT experiments





$$\mathrm{D + T \rightarrow {}^4He(3.5\ MeV) + n(14\ MeV)}$$

$$\mathrm{D + D \rightarrow {}^3He(0.8\ MeV) + n(2.45\ MeV)}$$

$$\mathrm{T + T \rightarrow {}^4He(0\ to\ 3.5\ MeV) + 2n(0\ to\ 9.4\ MeV)}$$

- Nuclear experimental quantities
  - Y_n: DT and DD
  - T_i: DT and DD
  - ρR: elastically scattered neutrons

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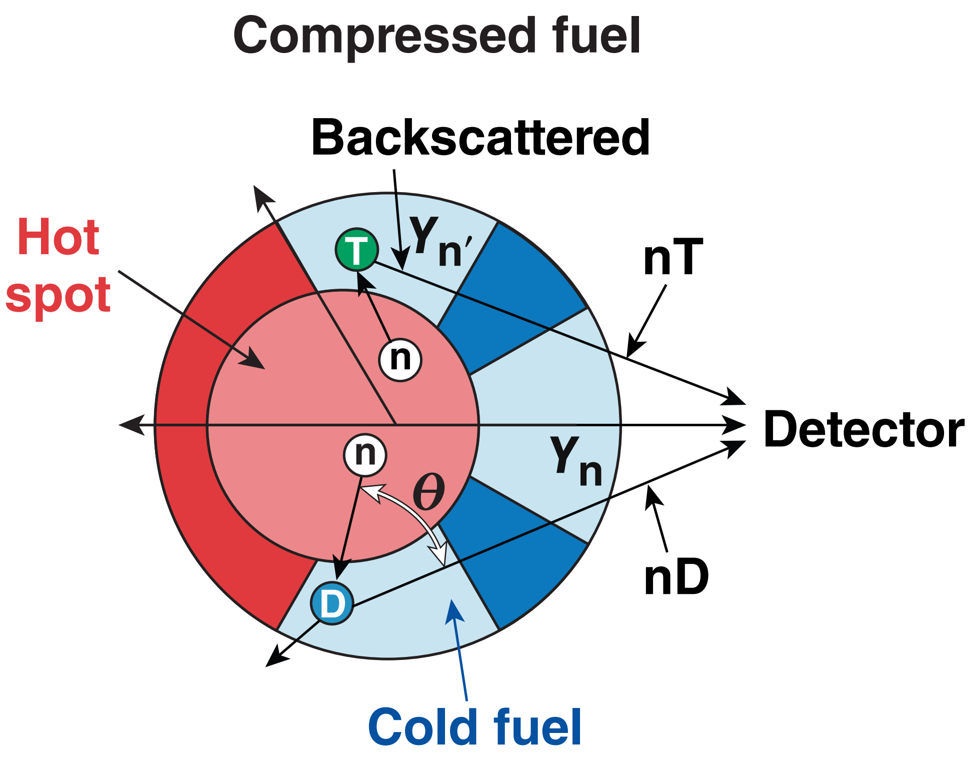
Asymmetries in fuel distribution generate observable differences in the neutron energy spectrum



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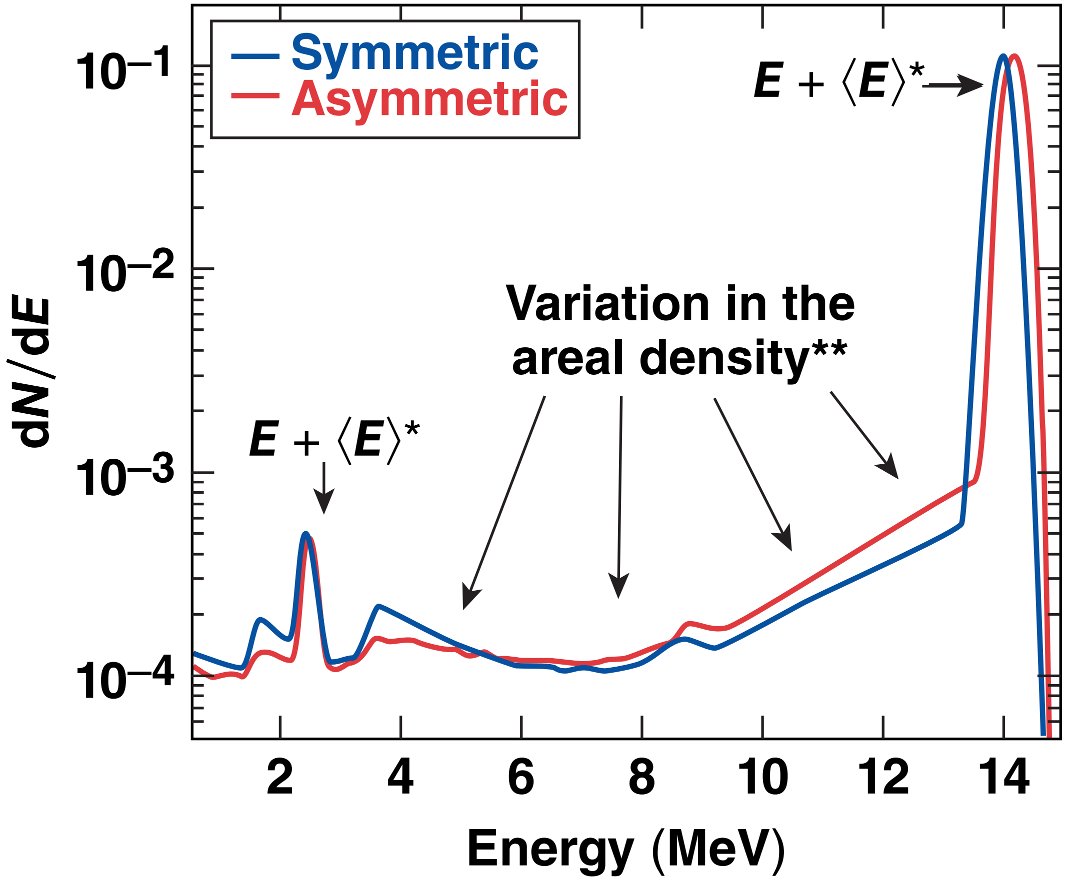


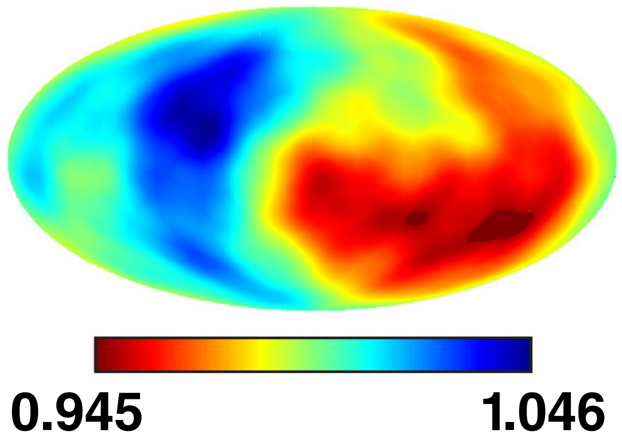
- Mean energy shifts caused by collective fluid motion
- Variation in cold-fuel distribution

*O. M. Mannion, CO8.00003, this conference.
**Z. L. Mohamed, UO7.00010, this conference.

TC13284

Several experimental parameters can induce low-mode variations of the cold-fuel distribution in cryogenic implosions

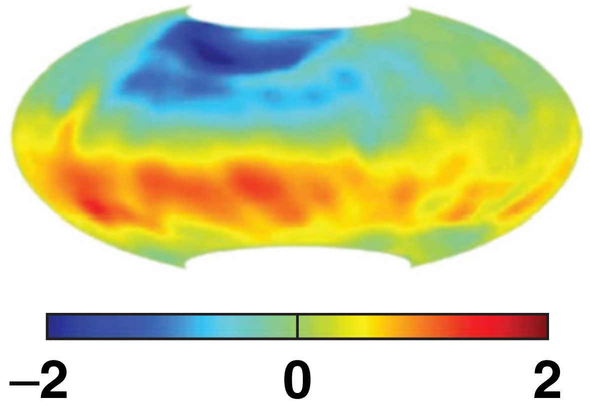
Laser-beam power imbalance*



Illumination on target (normalized)

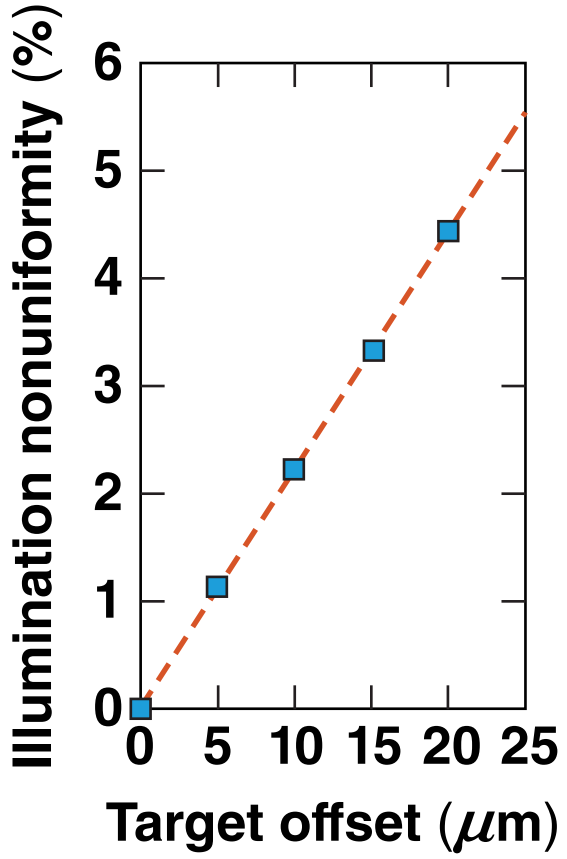
Beam mispointing also imparts nonuniformity on the fuel distribution.

Ice-surface roughness



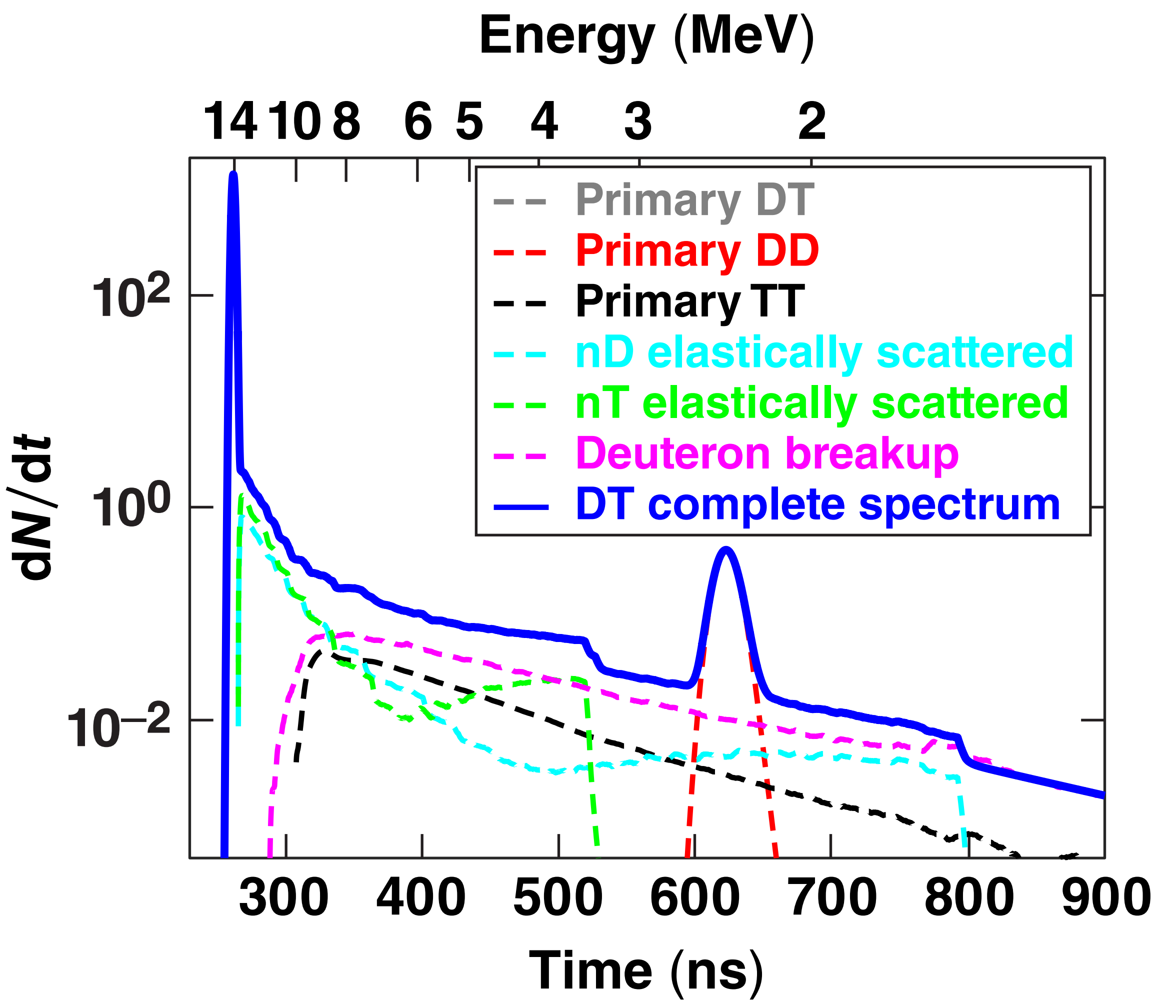
Thickness variation (μm)

Target offset



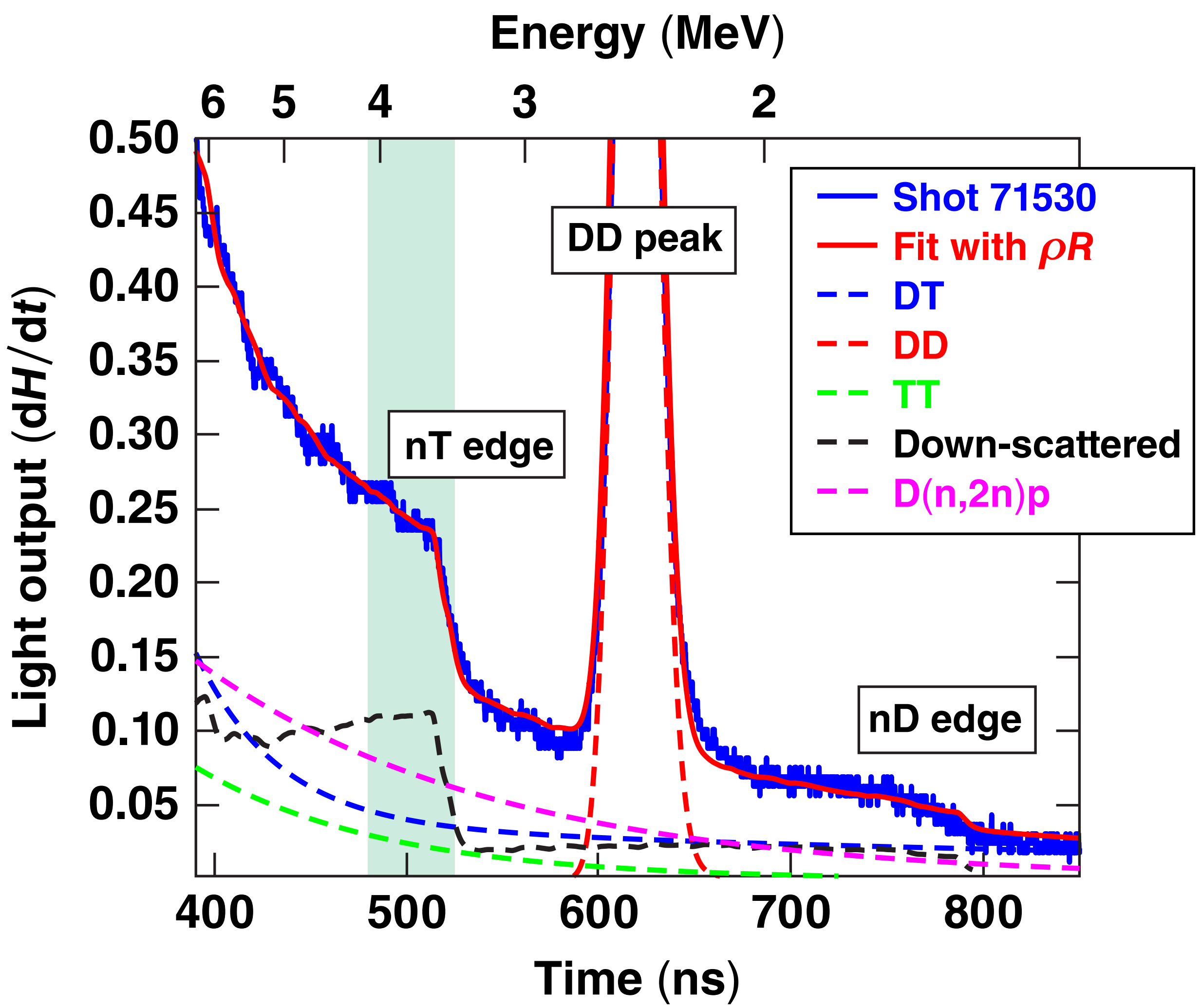
*K. S. Anderson *et al.*, UO7.00003, this conference.

The transport code *IRIS3D* post-processes the simulations to generate synthetic time-of-flight spectra



- Density, temperature, and velocity profiles are post-processed with *IRIS3D* code
- Neutrons are transported out of the hot-neutron–producing region and tallied along a specified line of sight (13.4 m)
- The simulated spectrum allows for an accurate determination of backgrounds in the measured signal to infer the ρR and T_i variations along multiple lines of sight

A high-dynamic-range neutron time-of-flight (nTOF)* spectrum is used to infer parameters that represent the fuel conditions at peak compression



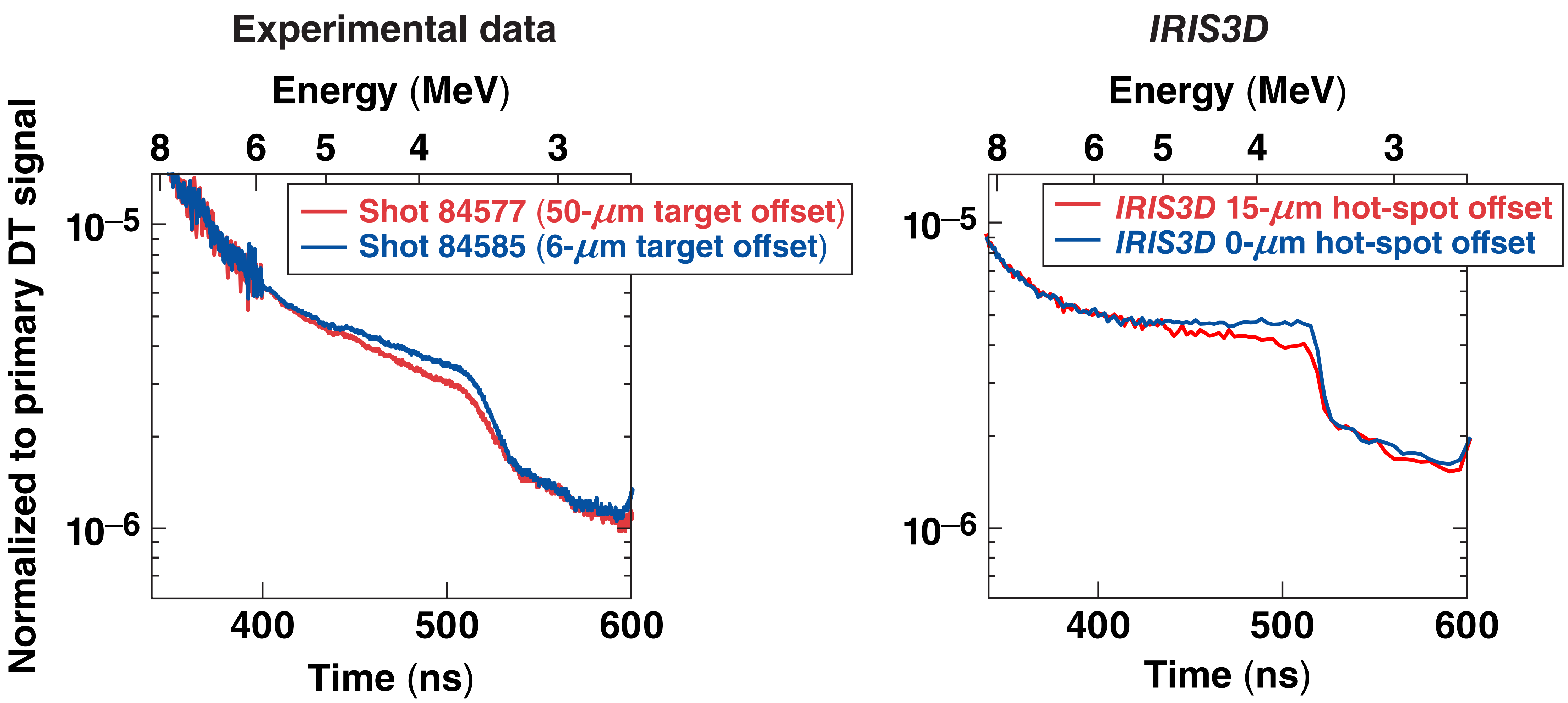
- A best fit to the experimental data is achieved using the known neutron contributions
- The areal density is inferred in specific energy regions to map out variations of the cold-fuel distribution (3.5 to 4.0 MeV)
- The neutron loses energy as a function of the elastic scatter angle off the cold-fuel distribution

$$E_R = \frac{4A}{(1+A)^2} \cos^2\theta \, En$$

* C. J. Forrest *et al.*, Rev. Sci. Instrum. 87, 11D814 (2016).

E26729

Significant differences from the expected shape of the down-scattered spectrum have been measured for some recent implosions on OMEGA



The synthetic data from *IRIS3D* have not been corrected with an IRF*

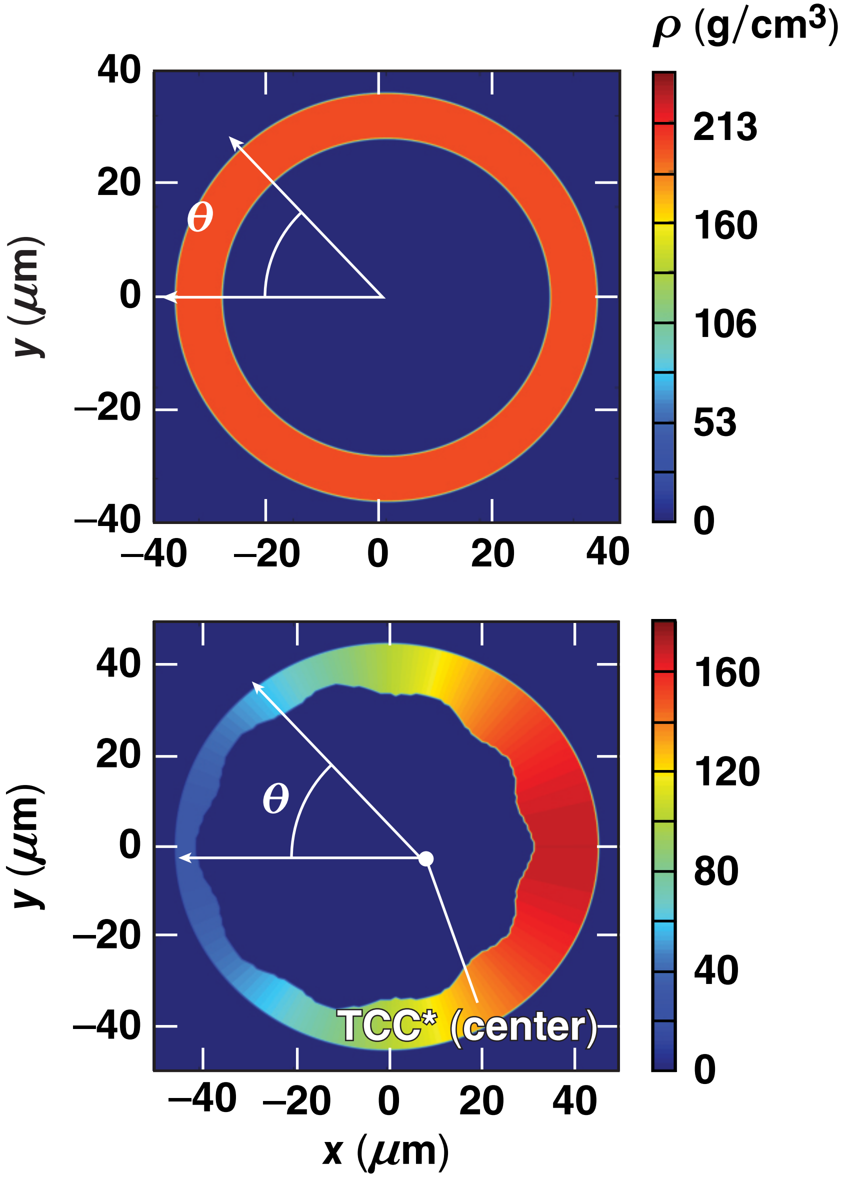
*IRF: impulse response function

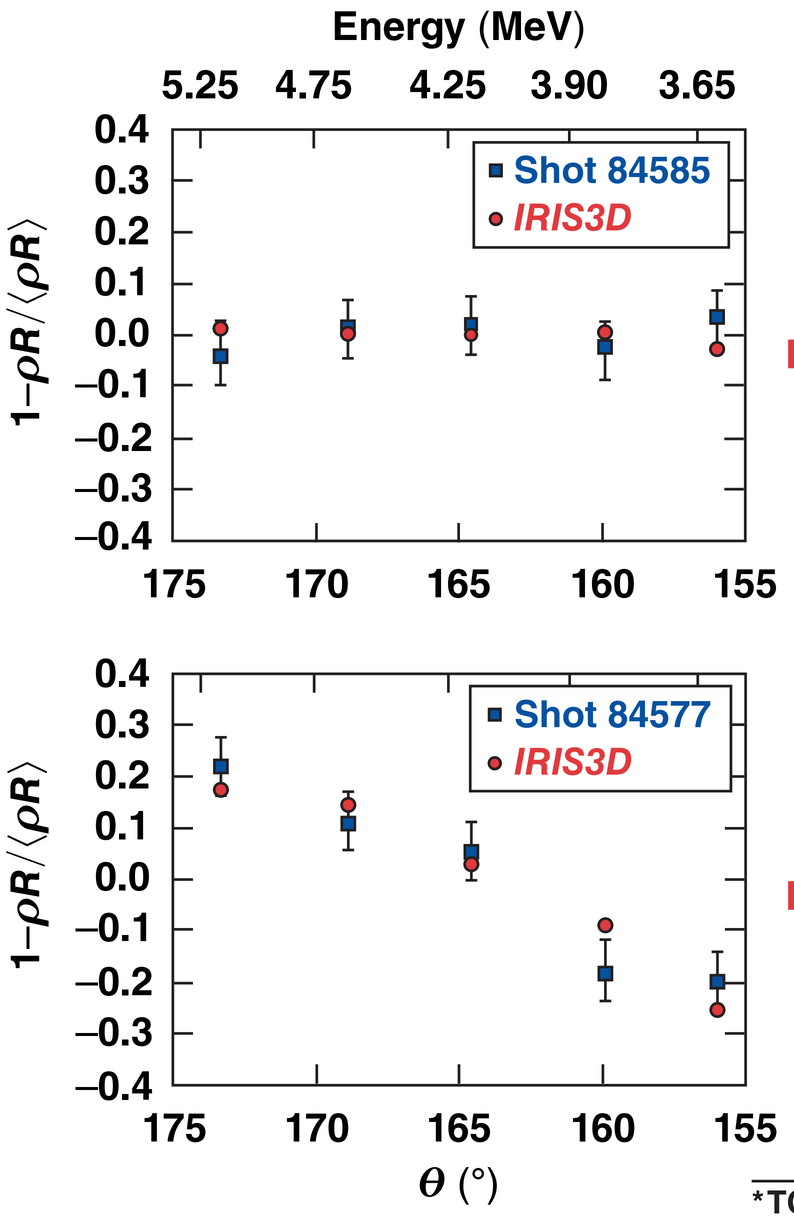
E26697

The comparison of measurement and simulation indicates the presence of a dominant low mode ($\ell = 1$) in a recent experiment with a large target offset

Symmetric fuel distribution

Asymmetric fuel distribution





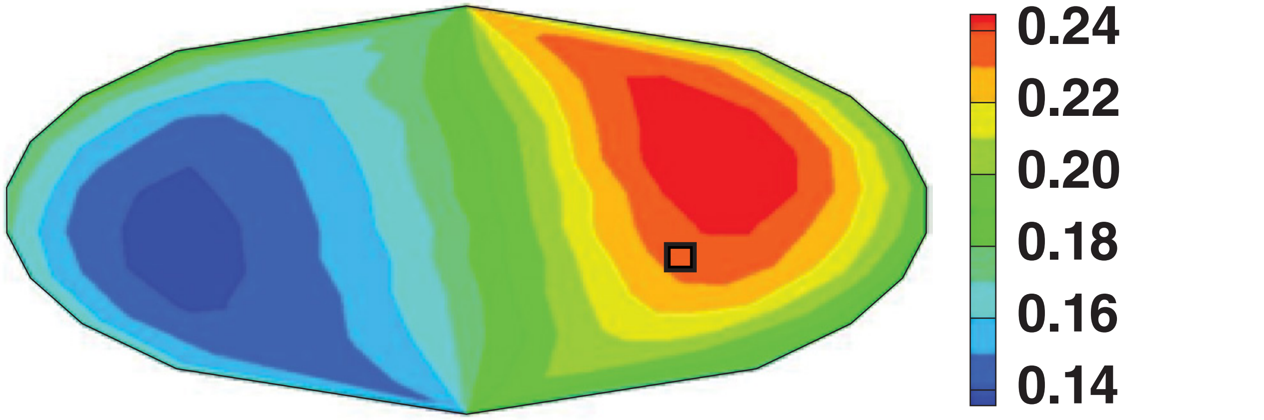
Target offset 6 μm
Hot-spot offset 0 μm

Target offset 50 μm
Hot-spot offset 15 μm

*TCC: target chamber center

Additional lines of sight can be used to reconstruct the areal density of the cold-fuel distribution with the low-energy portion of the spectrum

Single line of sight



- The black squares represent the locations of the nTOF line of sight
- A single line of sight using the low-energy region can infer $\ell = 1$ mode
- A second line of sight is under construction on OMEGA at ~100° from the existing line of sight

TC13285

*LLE Review Quarterly Report 150, 100 (2017).

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