Areal-Density Variations from Cold-Fuel Distributions in Layered Cryogenic-DT Implosions

Symmetric mode

Asymmetric mode

Down-scattered neutron energy spectrum

Symmetric mode

Asymmetric mode

Backscattered

Forward scattered

Energy (MeV)

0 2 4 6 8 10 12

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DT cold fuel

OMEGA

nTOF detector

DT cold fuel

OMEGA

nTOF detector

dN/dE

0 50 100 150 200
Summary

Modeling shows that (low-mode) cold-fuel distributions can be inferred from the down-scattered neutron energy spectrum

- The neutron spectrum in the (1- to 6- meV) range is used to infer the areal density of cryogenic-DT implosions on OMEGA*
- The Monte Carlo neutron-particle (MCNP) is used to understand the down-scattered neutron energy spectrum from DT implosions (1 to 14 MeV)
- MCNP simulations show that areal-density measurements on OMEGA are not affected by the multiple scattering background process

Collaborators


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The neutron energy spectrum in ICF implosions depends on well-understood nuclear processes in the fuel.

The total neutron energy spectrum is required to infer the fuel $\rho R$ in the backscattered region (1 to 6 meV).

The theoretical down-scattered neutron energy spectrum is based only on the elastic scattering cross sections. MCNP is used to determine possible modifications to the measured neutron energy spectrum caused by multiple scattering.

\[
\frac{dN}{dE} = \frac{\rho R}{Y_n^\prime/Y_n} \tag{\textsuperscript{†}}
\]

Elastically scattered neutrons

\[
\text{nD endpoint, nT endpoint}
\]

Primary DT

\[
Y_n^\prime, Y_n
\]

\[
\text{Energy (MeV)}
\]

Hydro simulations

IRIS\textsuperscript{*}


The shapes of the elastic neutron scattering cross sections have been confirmed with high accuracy.

The accuracy of the scattering cross sections is the basis for the $\rho R$ measurements.

MCNP is a standard tool for neutron transport simulations.

Custom tallies in the code record the last position and energy of the particle as seen by the nTOF.
A visualization tool (IViPP)\(^*\) is used as a consistency check on the MCNP recorded output.

\(\text{OMEGA} \quad \text{nTOF detector} \)

\(\text{Scatter event} \quad \begin{align*} 1 & \rightarrow \text{green} \\ 2 & \rightarrow \text{purple} \\ 3 & \rightarrow \text{red} \\ 4 & \rightarrow \text{yellow} \end{align*} \)

Cross sections

\(\text{nD} \quad nT \)

*\(D.\) Baldwin, IViPP, http://cs.geneseo.edu/~baldwin/ivipp/\)
Simulations show that the multiple scattering component does not affect the backscattered neutron measurement.

The multiple scattering component becomes nonlinear with higher areal densities ($\rho R > 300$ mg/cm$^2$).

- Average $\rho R$ on OMEGA 200 mg/cm$^2$
An asymmetric (low-mode) cold-fuel distribution does affect the neutron energy spectrum.
Asymmetries in the cold-fuel distribution can be measured with specific detection positions.

A single line of sight that measures both the forward and backscattered neutron energy spectrum is another approach to infer $\rho R$ asymmetries.
Summary/Conclusions

Modeling shows that (low-mode) cold-fuel distributions can be inferred from the down-scattered neutron energy spectrum

- The neutron spectrum in the (1- to 6- meV) range is used to infer the areal density of cryogenic-DT implosions on OMEGA*

- The Monte Carlo neutron-particle (MCNP) is used to understand the down-scattered neutron energy spectrum from DT implosions (1 to 14 MeV)

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