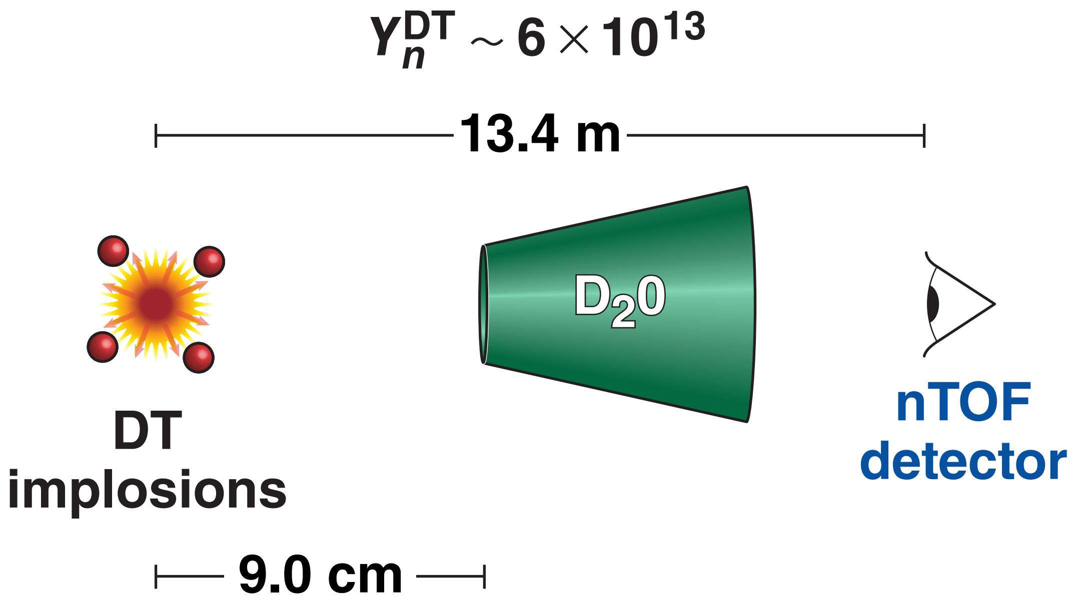
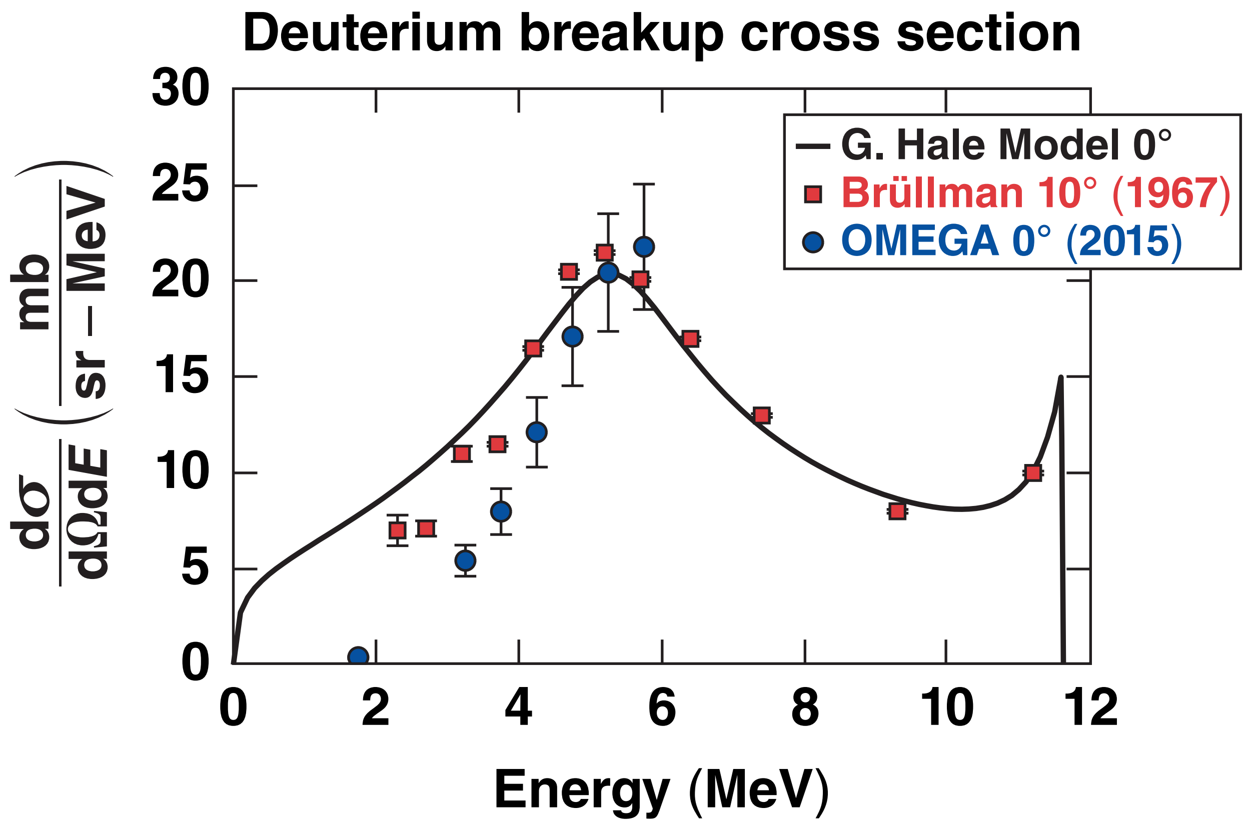
Neutron-Induced Deuterium Breakup in Inertial Confinement Fusion at the Omega Laser Facility





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Summary

The neutron spectrum from the deuterium breakup reaction have been measured in inertial confinement fusion (ICF) implosions

- Large discrepancies between the measured d(n,2n)p proton spectra and two-nucleon force (2NF) calculations are still not resolved
- A neutron transport code (MCNP) was used to model an experiment to measure the cross sections for the deuterium breakup reaction
- A comparison of the measured neutron spectra shows partial agreement with recent calculations using the n–p final state interaction

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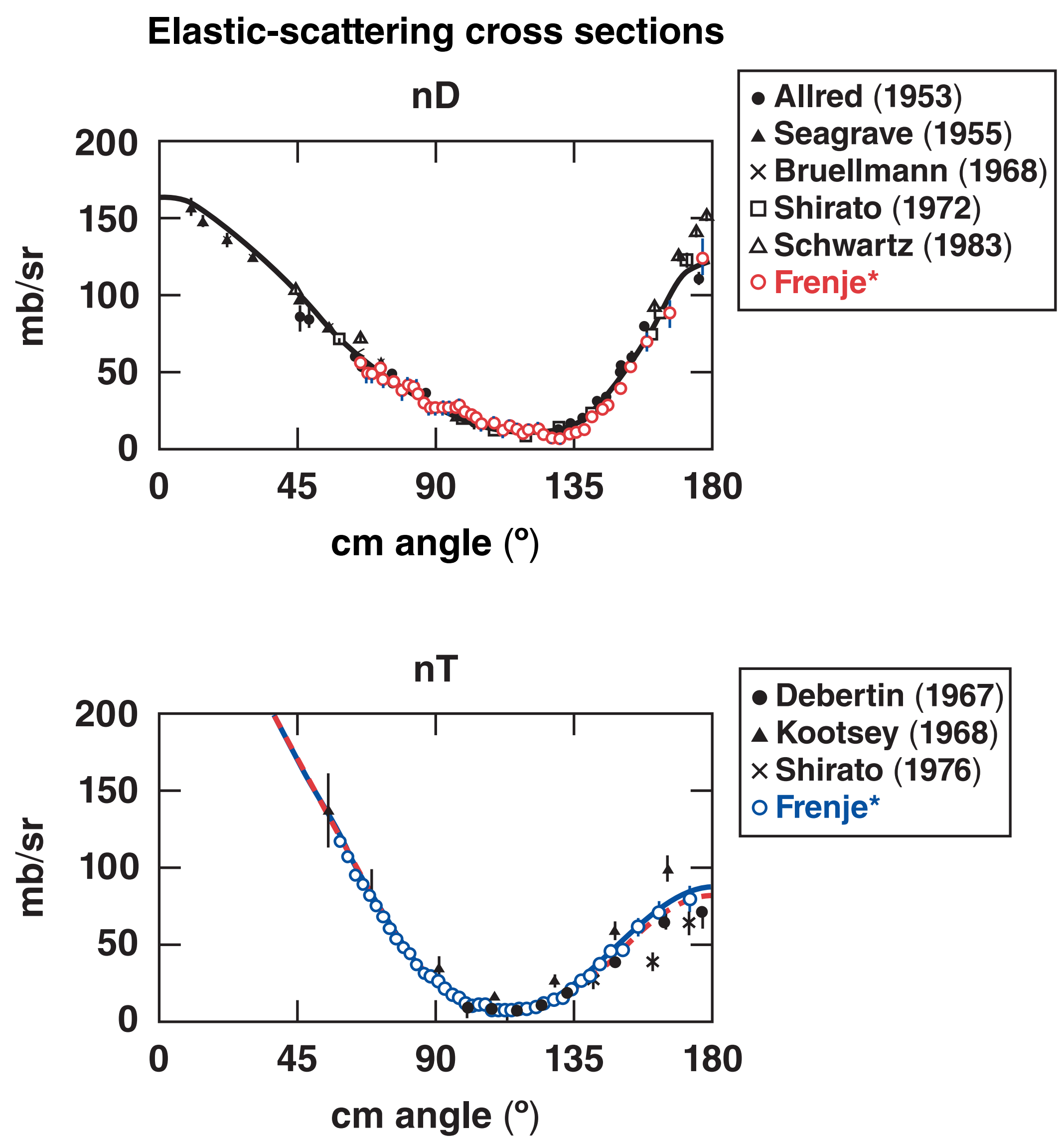
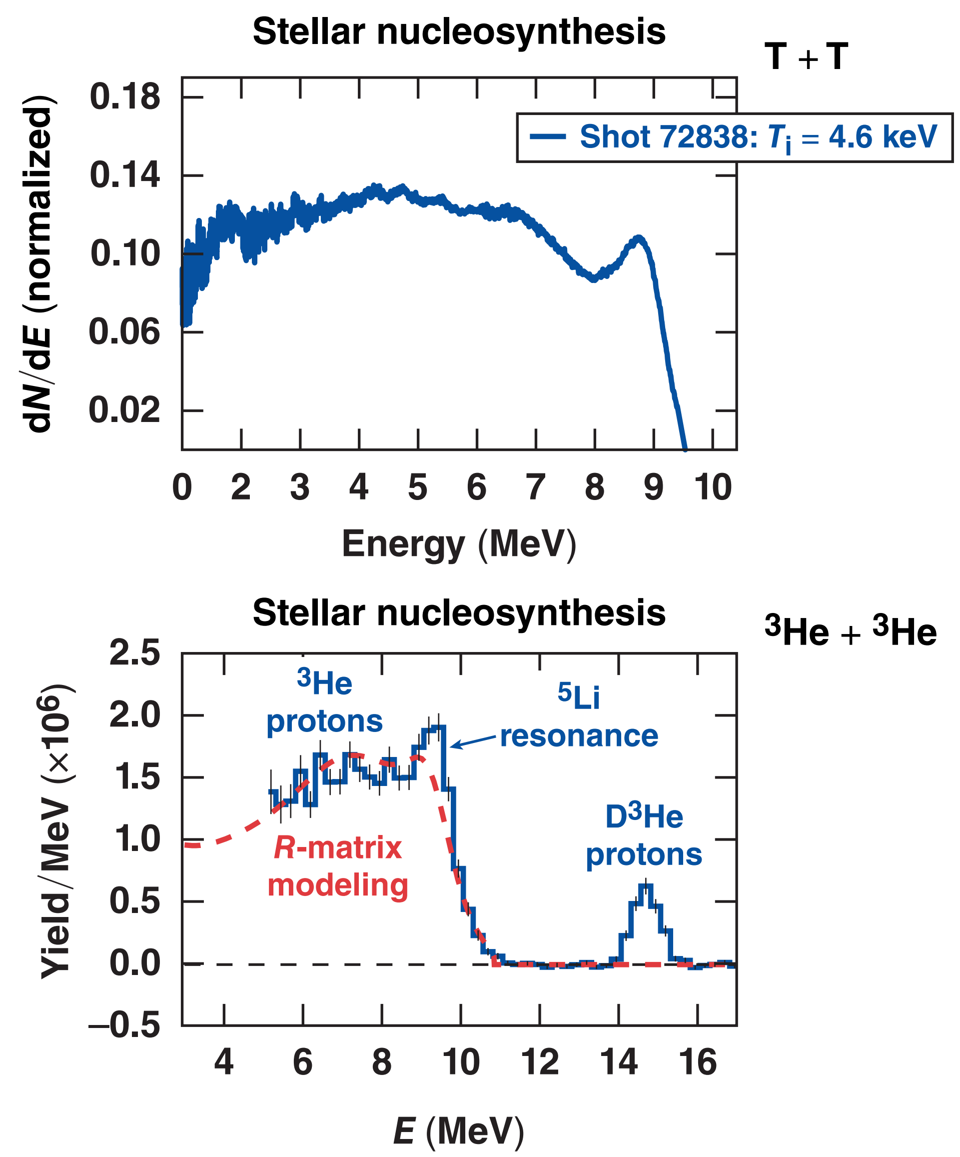
Fundamental nuclear physics questions can be answered using fusion products from ICF implosions





*J. A. Frenje *et al.*, Phys. Rev. Lett. 107, 122502 (2011).

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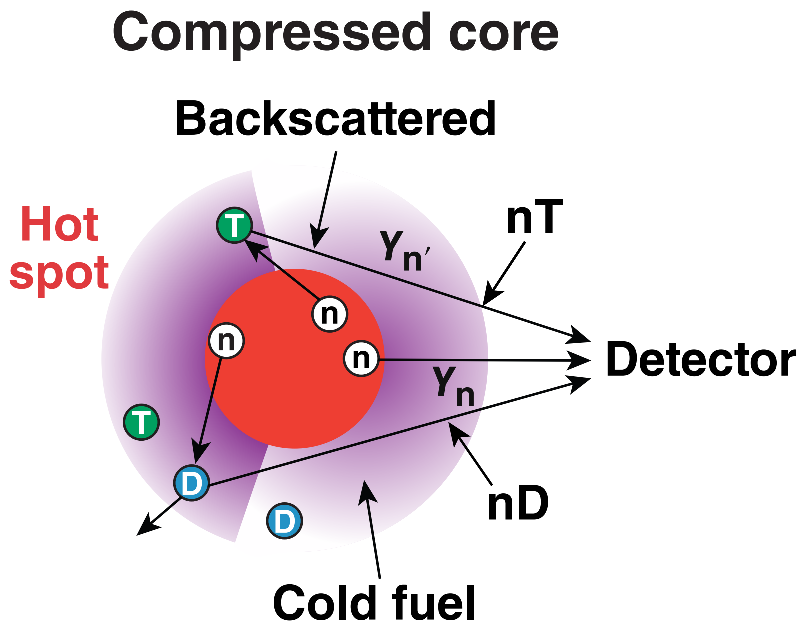
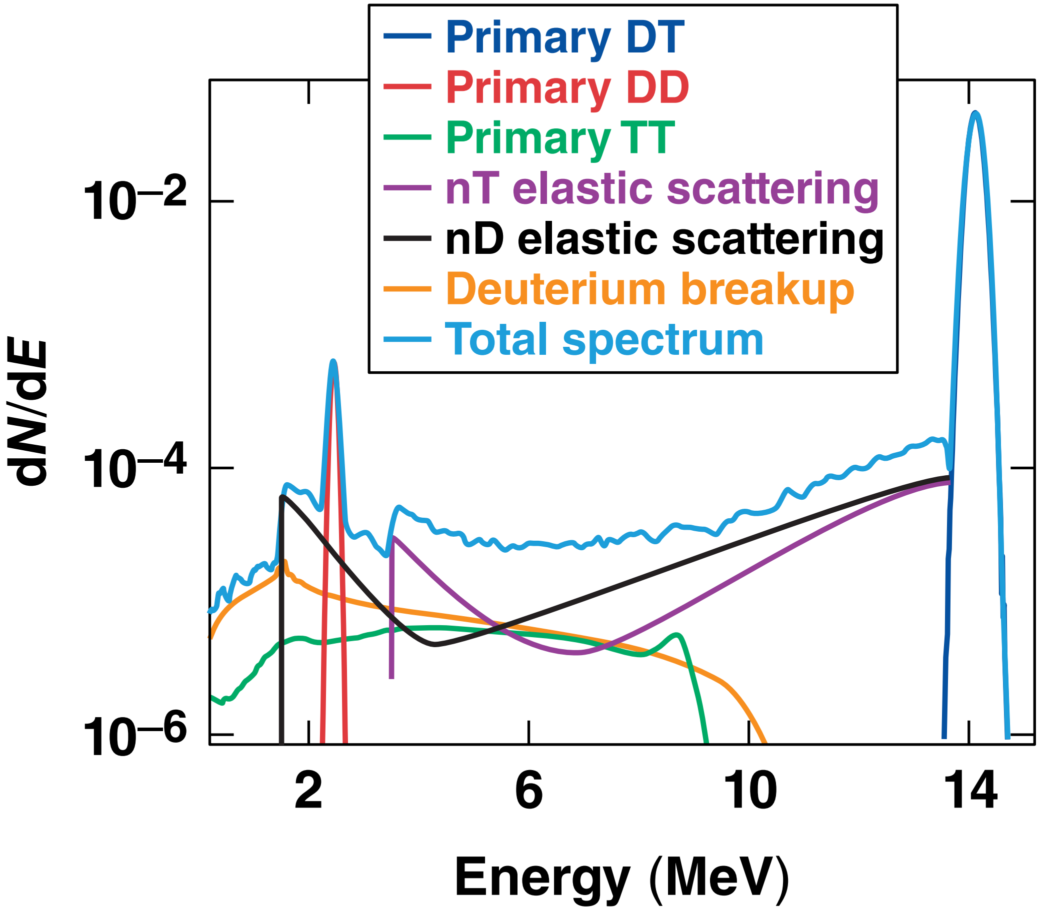
The neutron energy spectrum provides essential information about cryogenic DT implosion performance





- The energy spectrum is used to infer the primary monoenergetic yield, ion temperature, and neutron-averaged ρR

The least-understood energy component is caused by the neutron-induced breakup reaction that is directly proportional to the areal density.

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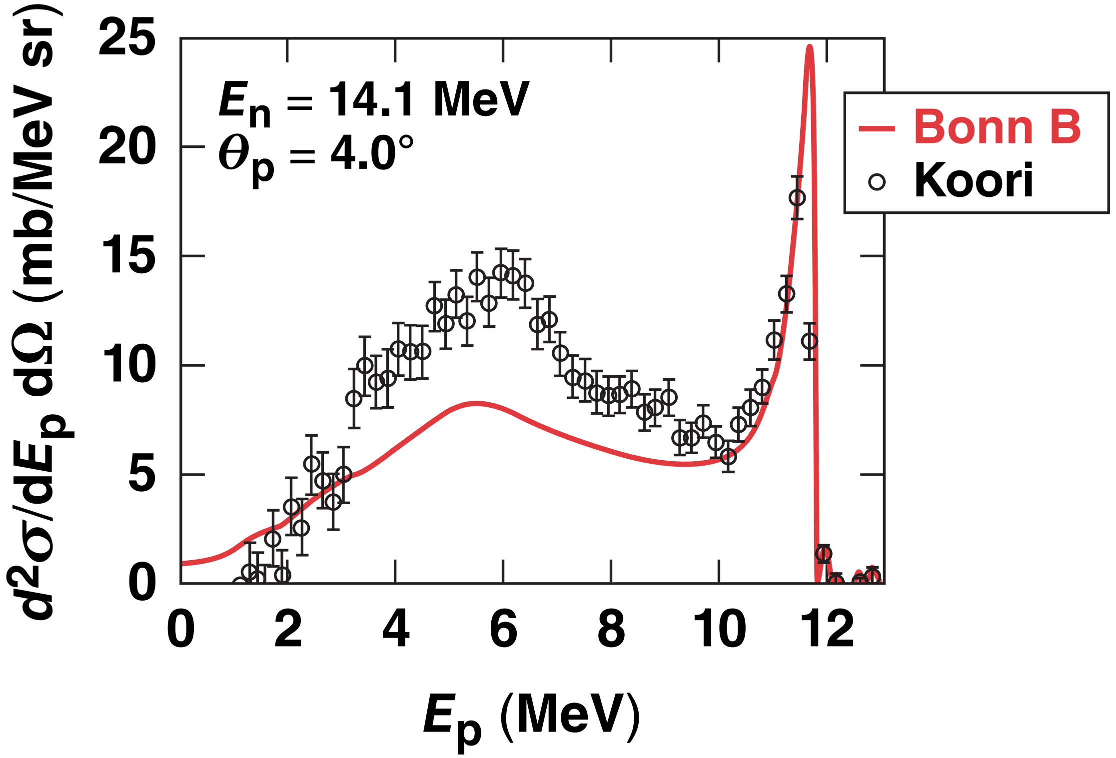
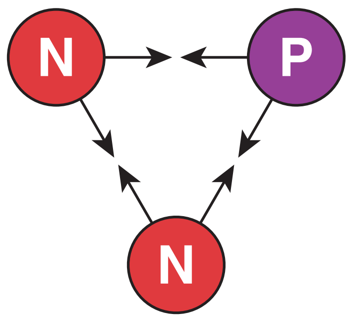
Disagreement between measured scattering cross sections and 2NF calculation has not been resolved

- Experimental data of the proton spectra from the deuterium breakup reaction is up to 25% higher than the prediction using 2NF



Two-nucleon force



The calculated cross section shown is achieved using the Bonn B nucleon–nucleon (NN) potential (charge dependent)

Experimental data on the continuous neutron spectrum is limited.

* N. Koori, J. Phys. Soc. Jpn. 32, 306 (1972).

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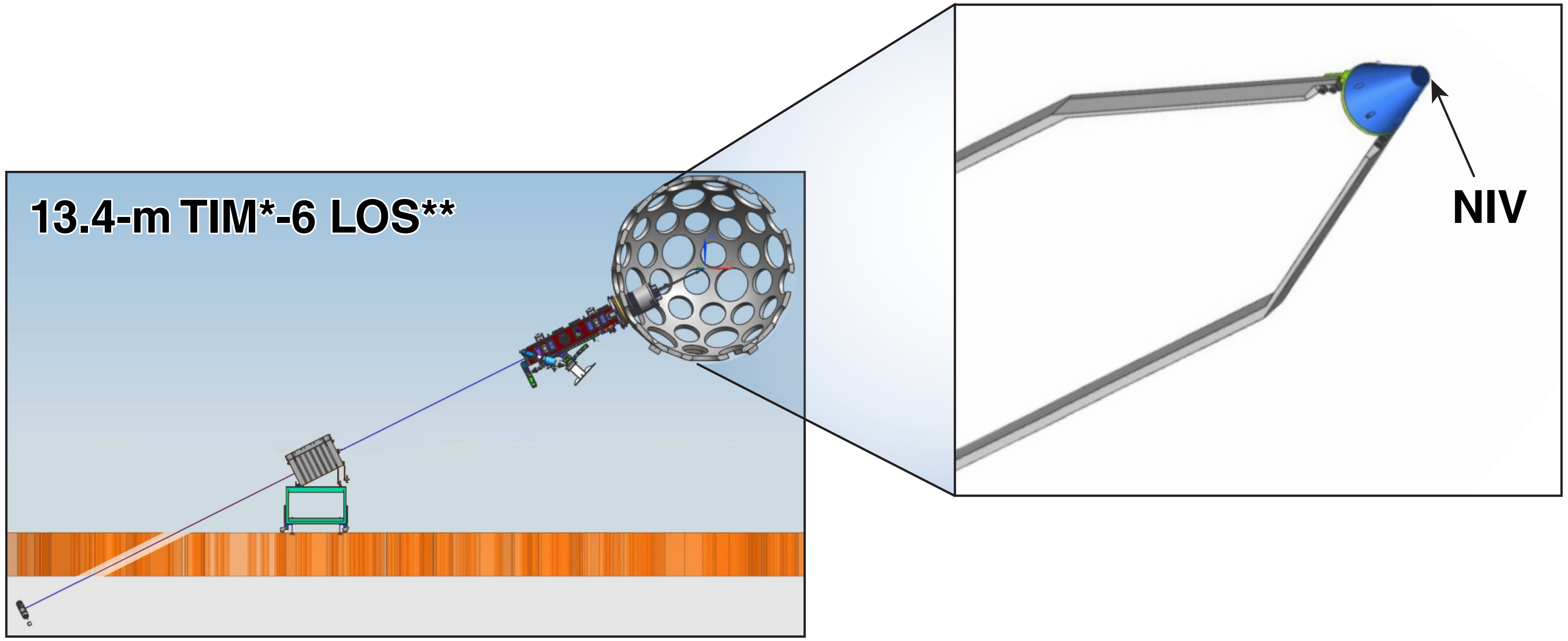
An experiment to measure the neutron-induced breakup reaction was performed at the Omega Laser Facility

- **Neutrons from high-yield DT implosions were incident on a nuclear interaction vessel (NIV)**



- **Volume = 68 cm^3**
- **Length = 7 cm**
- **Weight = 150 g**

- **Separate vessels contain either H_2O or D_2O**

- **The resulting neutron spectra were measured using high-resolution time-of-flight spectroscopy**

*TIM: ten-inch manipulator
**LOS: line of sight

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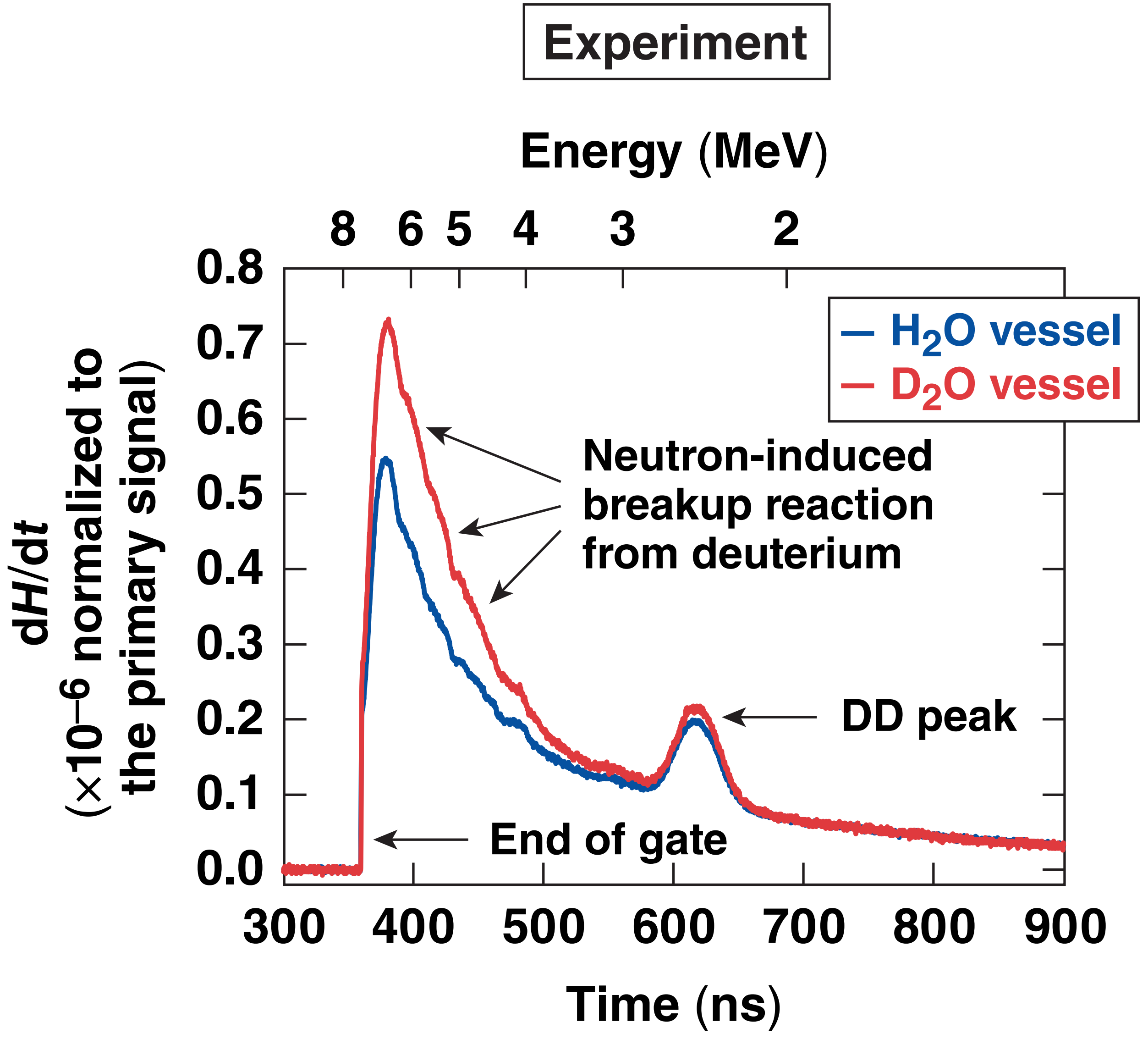
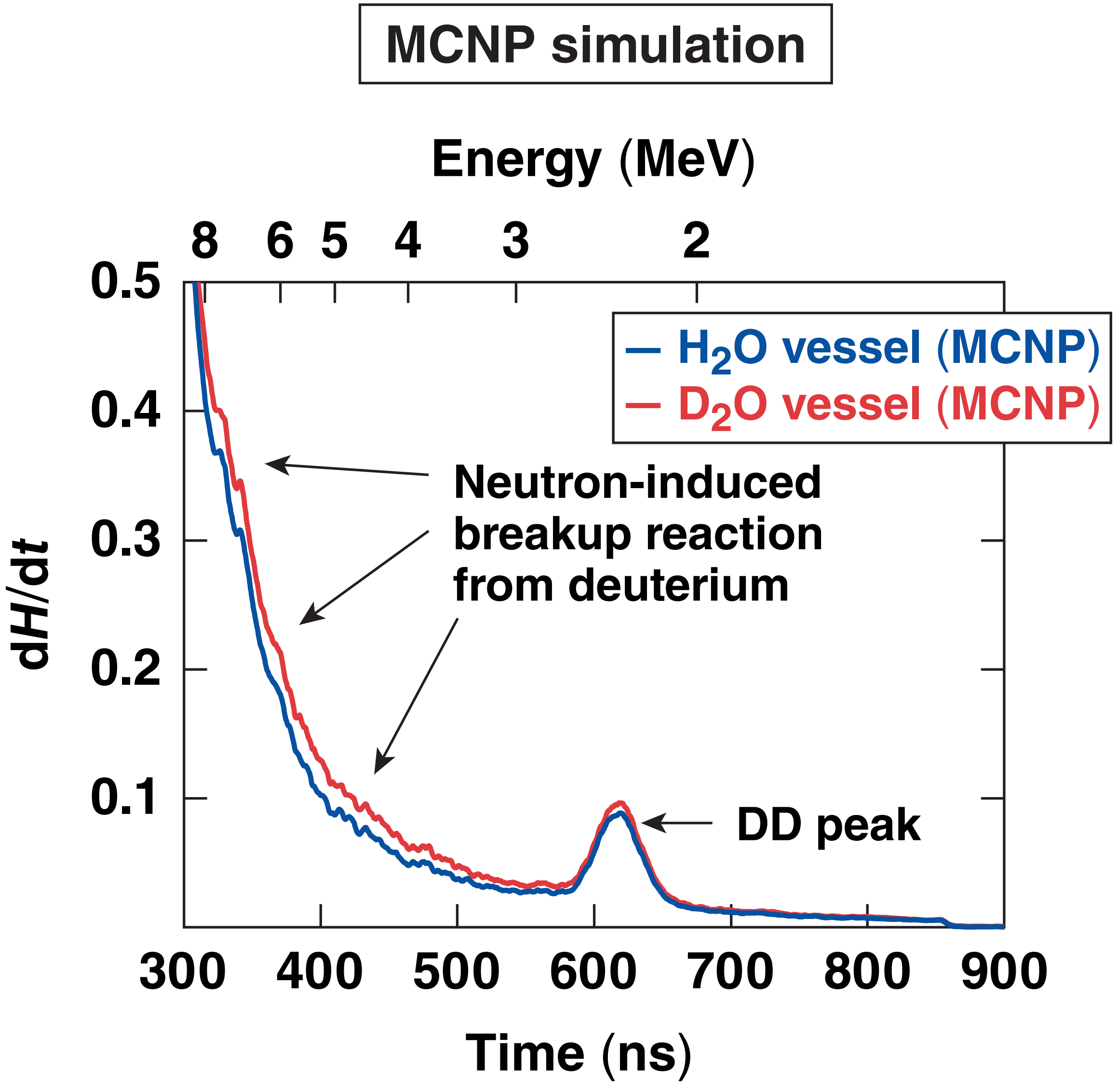
High-resolution time-of-flight spectra show an indication of a neutron-induced breakup reaction





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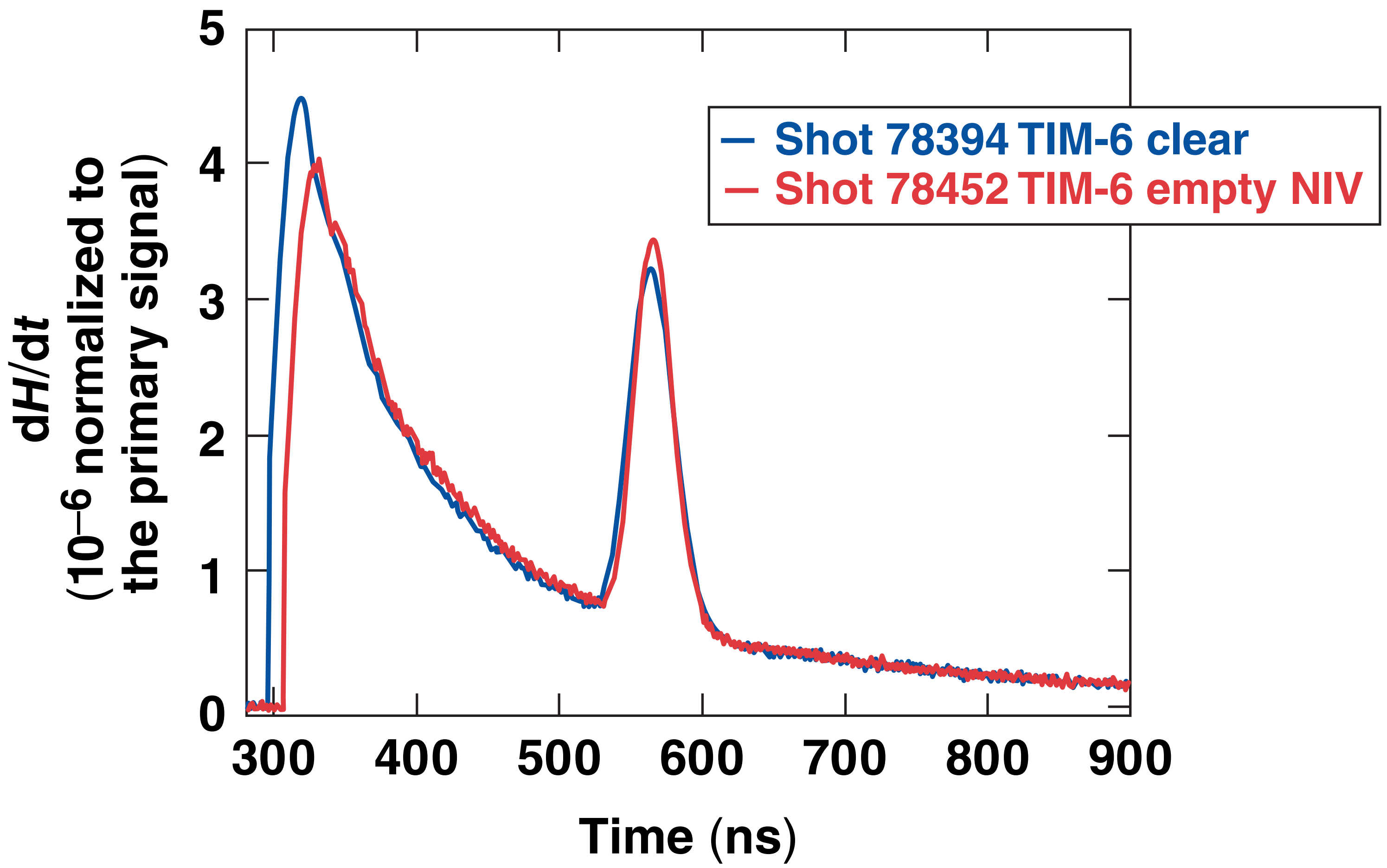
The vessel has a negligible effect on the shape of the time-of-flight signal



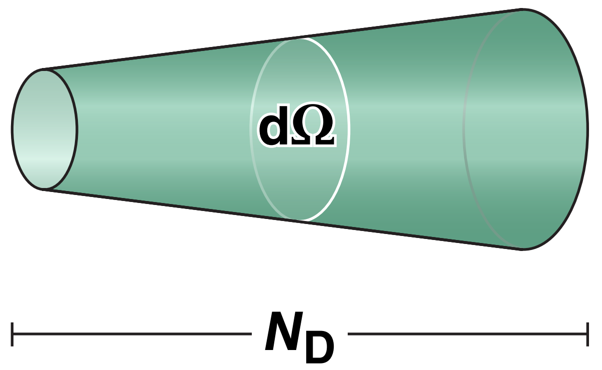
- Two implosions with and without the NIV in the TIM-6 line of sight show little change in the spectrum
- The difference in the signal is attributed to changes in the implosion

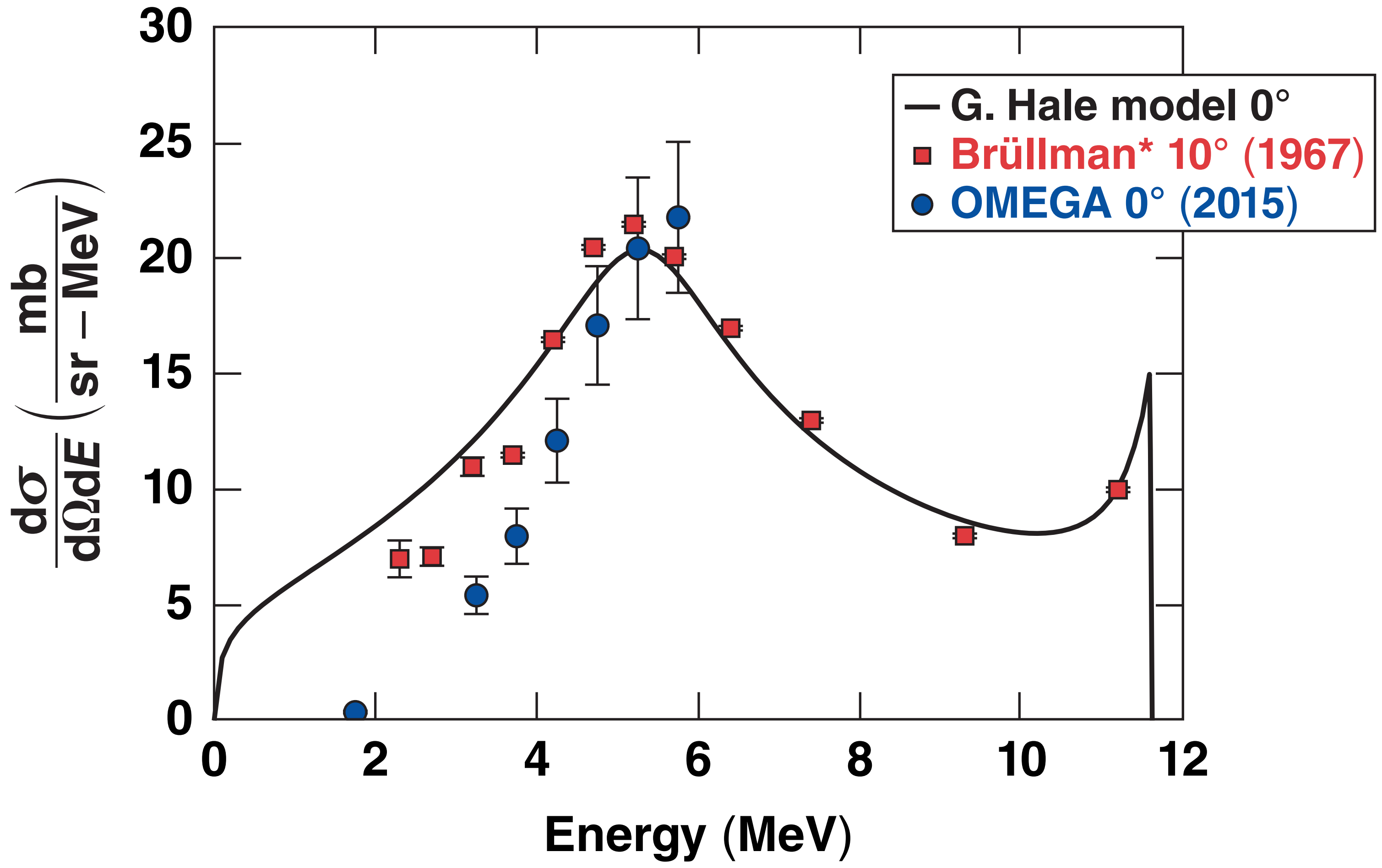
A preliminary cross-section has been inferred from the $Y_{n,2n}$ yield extracted from the time-of-flight spectrum

$$\frac{d\sigma}{d\Omega dE} = \frac{Y_{n,2n}}{Y_{DT}} \frac{1}{\Omega} \frac{1}{N_D}$$

Ω = solid angle of cone

N_D = number of deuterium per cm^2





*M. Brüllmann *et al.*, Phys. Lett. B 25, 269 (1967).

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A more-detailed analysis is underway to address the discrepancy that exists between the measurement and theoretical model

- The present measurement of the cross section is simplified
  - the solid angle (Ω) uses the center of the cone
  - a cylinder is used to estimate the number of deuterium per cm^2 (N_D)
- Introducing custom cross sections into MCNP would enable understanding the enhanced signal that was measured as compared to the expected signal from simulations
  - forward fitting the experimental data with the MCNP output will help to better understand the time-of-flight spectra
- Future experiments are being designed to measure the cross section up to 10 MeV
  - upgrading the diagnostic is underway to allow measurements higher up in energy

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