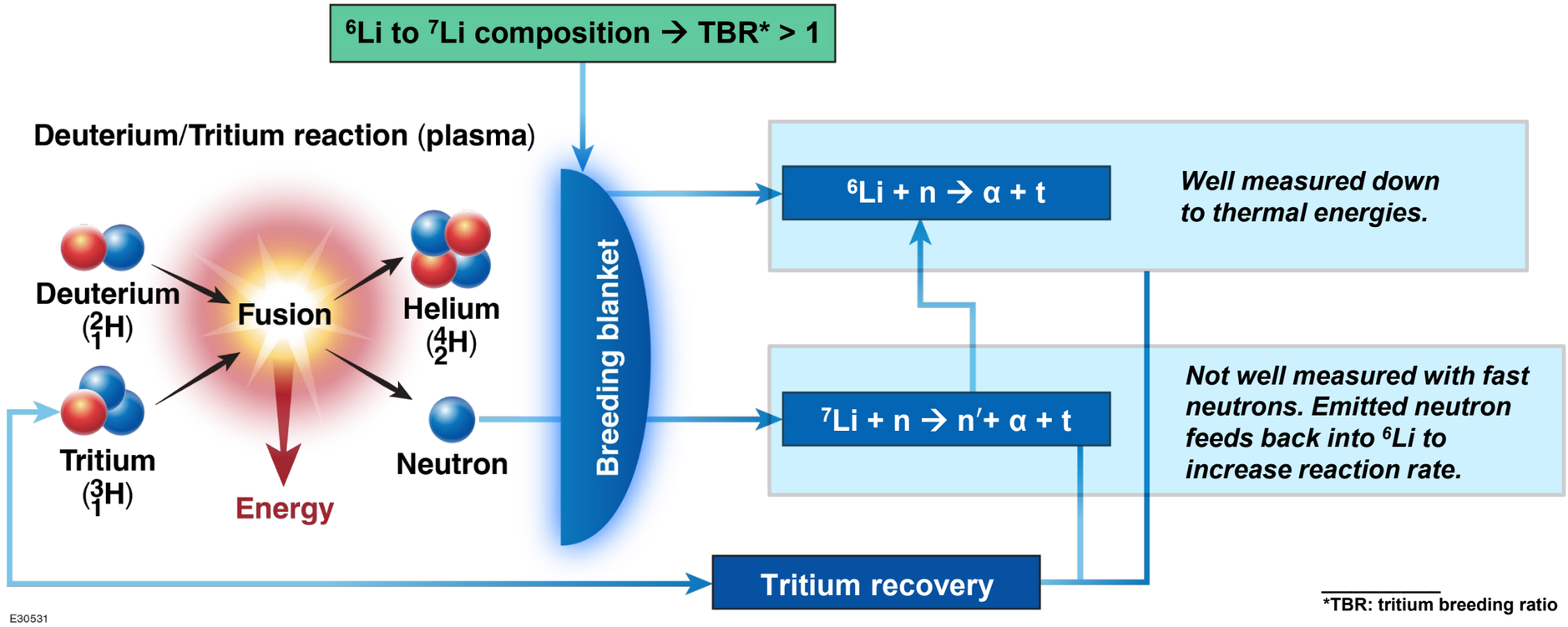
The Scattering Interactions of Neutrons with ^{6}Li and ^{7}Li at Incident Neutron Energies of 14 MeV Using an Inertial Confinement Fusion Platform



C. J. Forrest
University of Rochester
Laboratory for Laser Energetics

64th Annual Meeting of the American Physical Society Division of Plasma Physics
Spokane, WA October 17–21 2022

Summary

Discrepancies between measured spectra from the neutron-induced scattering reactions and theoretical calculations still exist for lithium isotopes

- Lithium isotopes are one of the primary components being proposed for DT fusion reactor liners for the breeding of tritium from ^{6}Li(n,t)α and ^{7}Li(n,n′)tα reaction channels*
  - the amount tritium required for commercial applications of fusion reactors for energy generation does not occur in nature
- Knowledge of the particle production cross sections from interactions of 14-MeV neutrons in thick targets is required for simulations of neutronics and the tritium breeding rates
- A platform to measure the neutron-induced scattering reactions between light-*Z* nuclei has been developed at the OMEGA Laser System

The bright neutron source available on the OMEGA laser makes this an important instrument to measure neutron-induced breakup reactions of light-*Z* nuclei in the near 0˚ emission angle.

*M. Rubel *et al.*, Fusion Eng. Des. 136, 579 (2018).

Collaborators

J. P. Knauer[1], W. U. Schroeder[2], V. Yu. Glebov[1], K.L. Marshall[1], P. B. Radha[1], S. P. Regan[1], T. C. Sangster[1], A. Schwemmlein[1], and C. Stoeckl[1]

[1]University of Rochester Laboratory for Laser Energetics
[2]University of Rochester Departments of Chemistry and Physics

G. Hale and M. Paris

Los Alamos National Laboratory

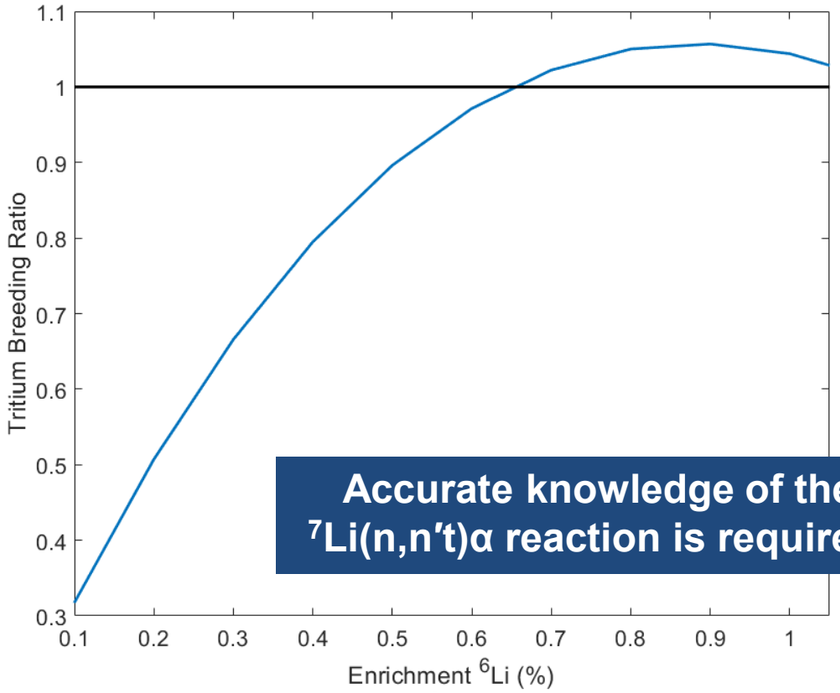
B. Appelbe and A. Crilly

Imperial College

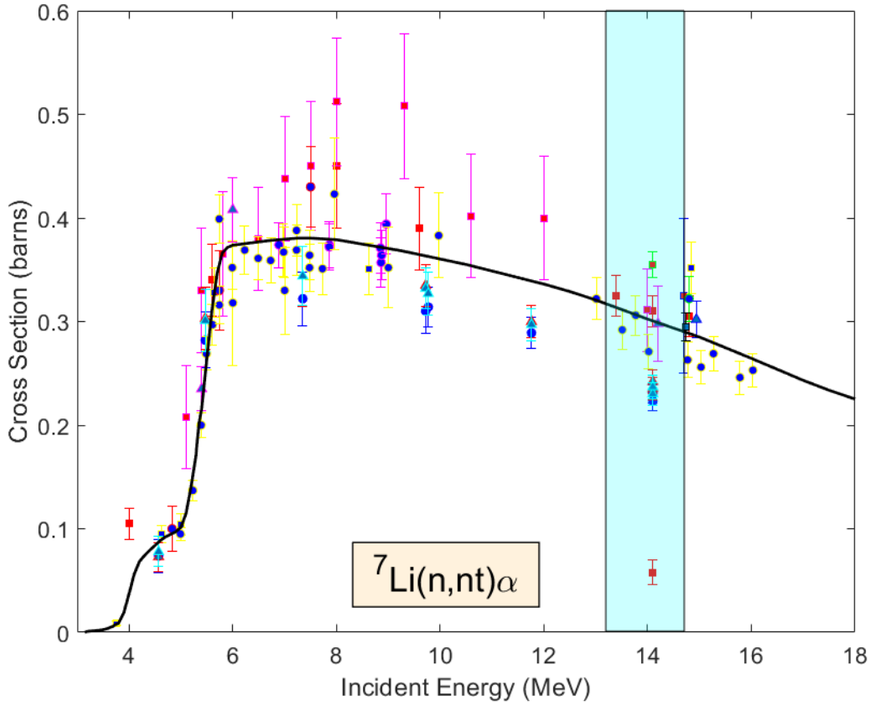
Breeding Tritium from a Lithium Blanket

Natural lithium as breeder material will not lead to a tritium breeding rate large enough for a reactor to sustain self-sufficiency

The only possible solution is increasing the content of ^{6}Li(%) to a level required to achieve a tritium-breeding ration (TBR > 1).



Accurate knowledge of the ^{7}Li(n,n′t)α reaction is required.

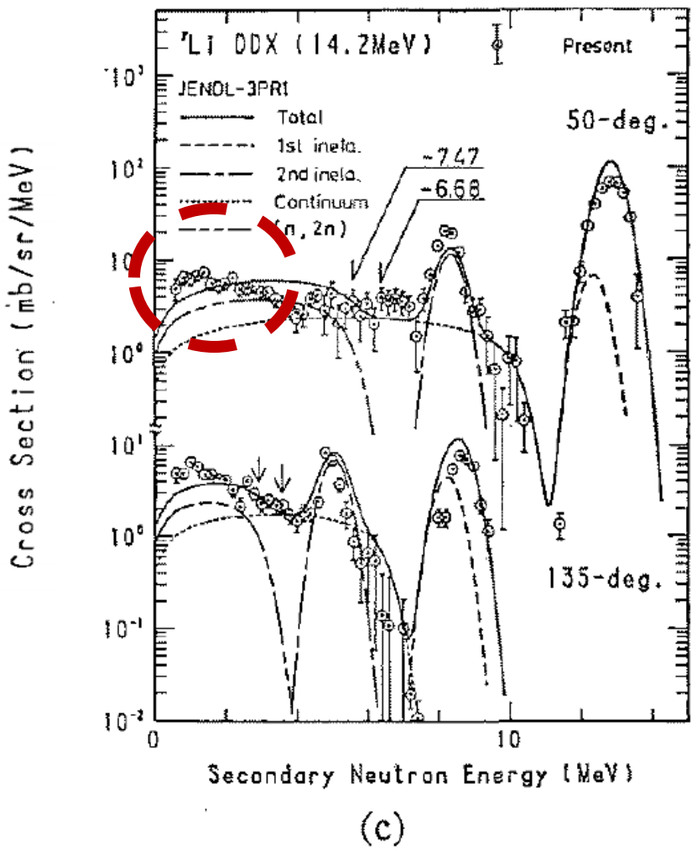


The measured cross sections for the ^{7}Li(n,n′t)α reaction channel available in the literature vary significantly.

Inelastic Scattering ^{6,7}Li – Motivation

Experiments to study neutron-induced breakup reactions are required since past measurements show significant differences

Lithium-7



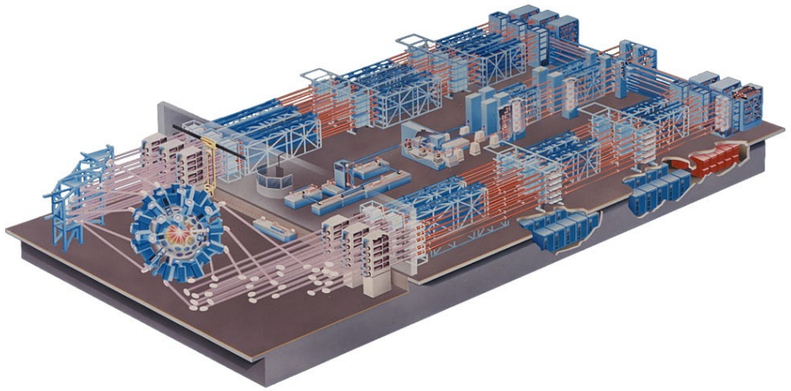
- Earlier experimental data as compared to the available evaluated nuclear data (JENDL) show a large disagreement below the second inelastic excited state.
- Enhancement in the lower-energy region is believed to be caused by the excitation of higher energy states that have not been fully resolved.
- There is no available experimental data that measured the cross section below 30° with 14-MeV neutrons.
  - the experimental platform on OMEGA has been shown to make successful measurements near 0°. **
  - Experimental data from both ^{6}Li and ^{7}Li will be presented for completeness.

* S. Chiba *et al.*, J. Nucl. Sci. Technol. 22, 771 (1985).
** C. J. Forrest *et al.*, Phys. Rev. C. 100, 034001 (2019).

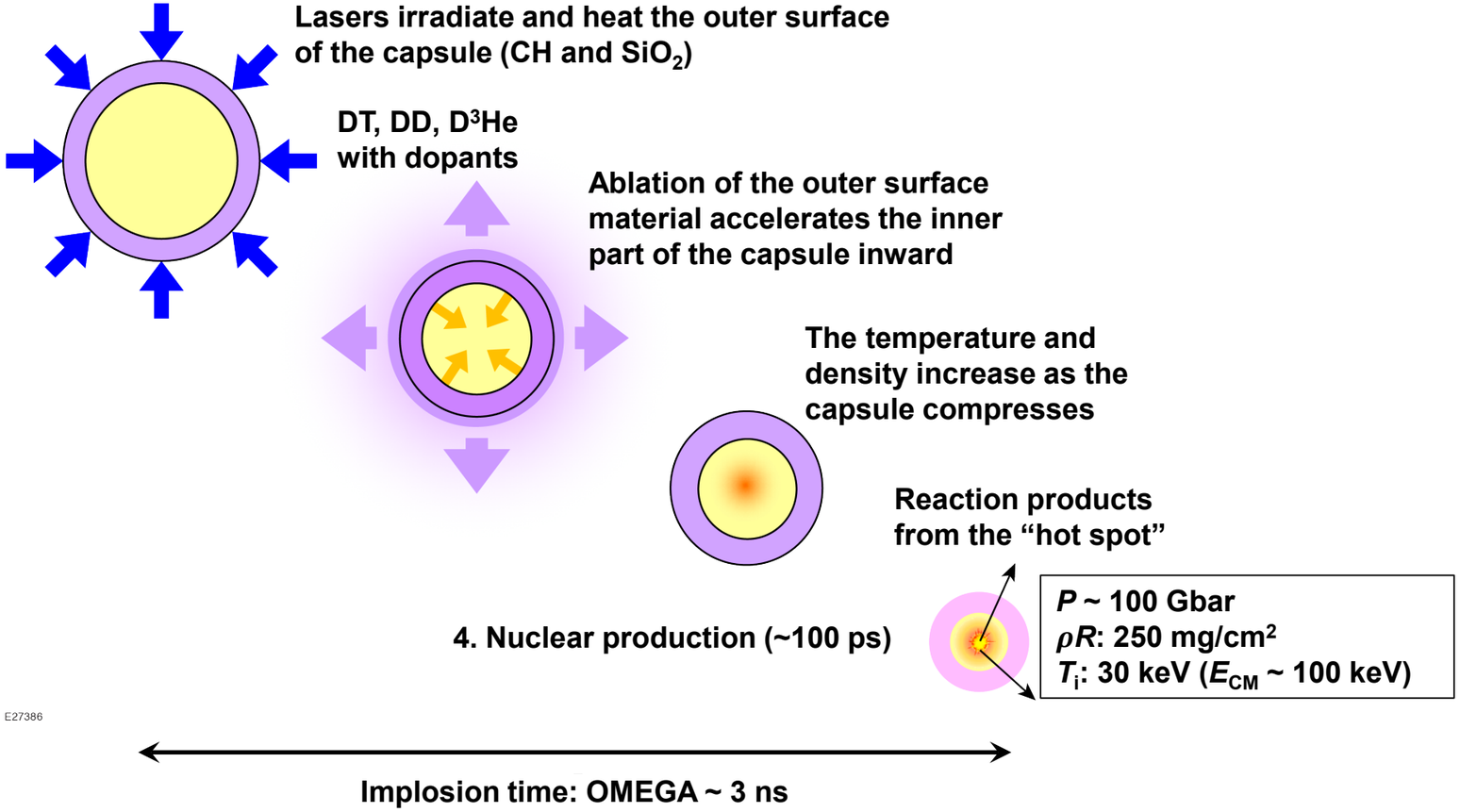
A high-yield neutron source is achieved with ICF lasers that create pressures of ~100 Gbar and plasma temperatures up to 100 keV

UR LLE

The OMEGA Laser System

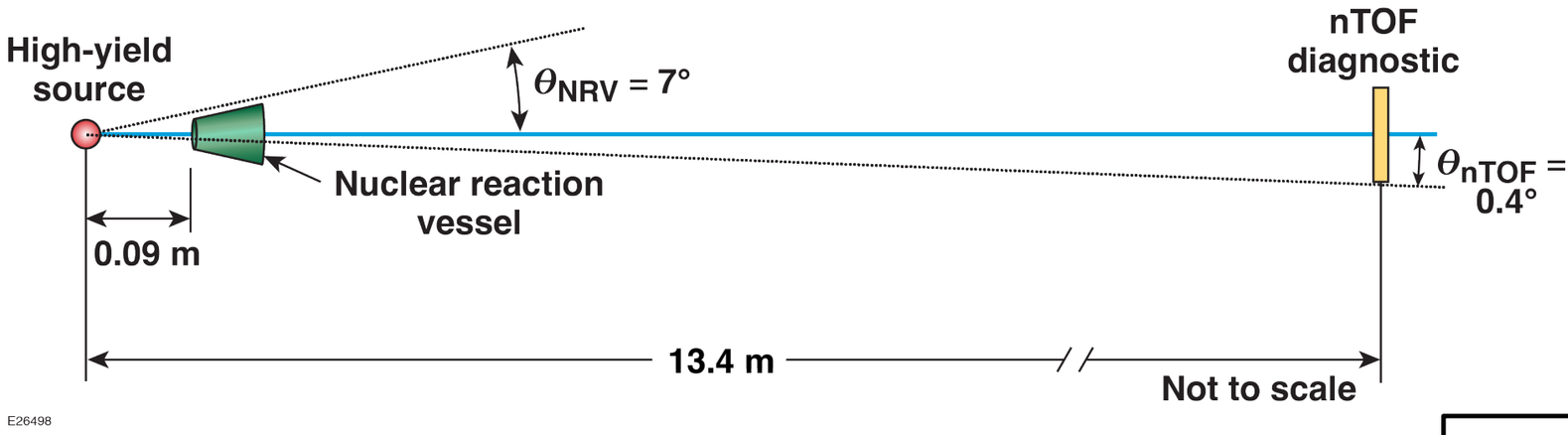


- 60 beams
- Symmetric configuration
- Maximum 30 kJ_{UV} on target
- Up to 16 shots/day (1600/yr)
- 3.2-m target chamber
- DT fusion Y_n up to 2×10^{14}
- <40-μm-diam hot spot
- <100-ps burn

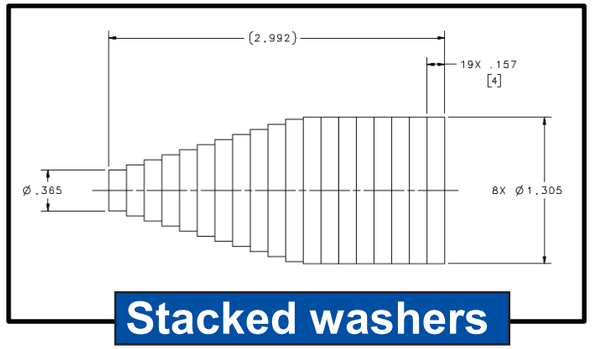


Experimental Setup

A novel approach to measure the neutron-induced scattering reactions between light-*Z* nuclei has been developed at the OMEGA Laser Facility.



- **The vessel is located as close as possible to the implosion, maximizing the solid angle without interfering with the laser pulses required for illuminating the DT implosion target.**



Stacked washers

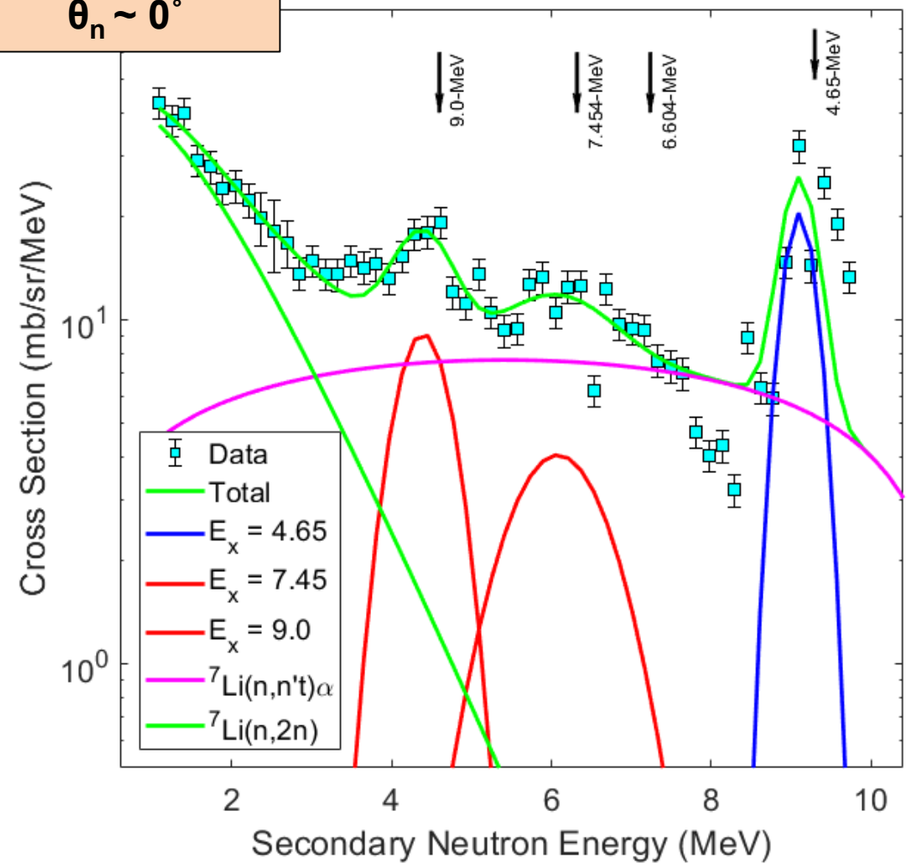
The experimental time-of-flight data are post-processed to achieve a "model-independent" energy spectrum of the inelastic scattering contributions.*

* C. J. Forrest *et al.*, Rev Sci. Instrum. 93 .(2022).

Inelastic Scattering ^{7}Li – Experimental Data

A trial function was used to evaluate the scattering cross sections from the different reaction channels*

Forrest (2021)
$\theta_n \sim 0^\circ$



1st 2nd 3rd

$$\frac{d^2\sigma}{d\Omega dE'}(E_{in},\theta,E') = \sum_{i=1}^{n} A_i \exp\left(-\frac{(E'-E_i)^2}{\sigma_i^2}\right) + A_{n+1}C_0^2\rho(E_{in},\theta,E') + A_{n+2}E'\left(-\frac{E'}{T}\right)$$

1st Term: The discrete energy levels from the scattered neutrons.

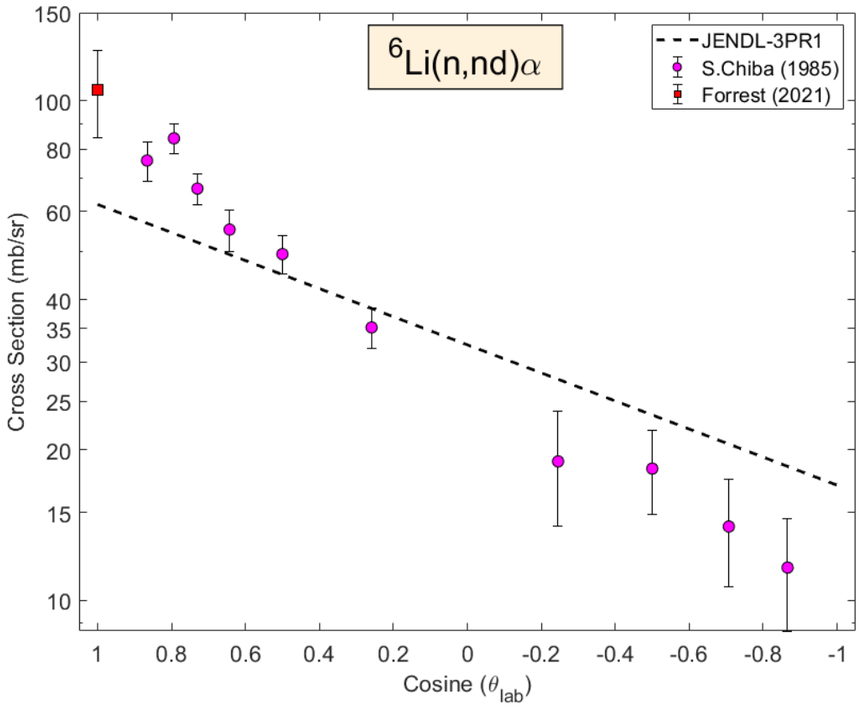
2nd Term: The three-body phase space distribution for ^{6}Li(n,n′)dα and ^{7}Li(n,n′)tα reaction channels.

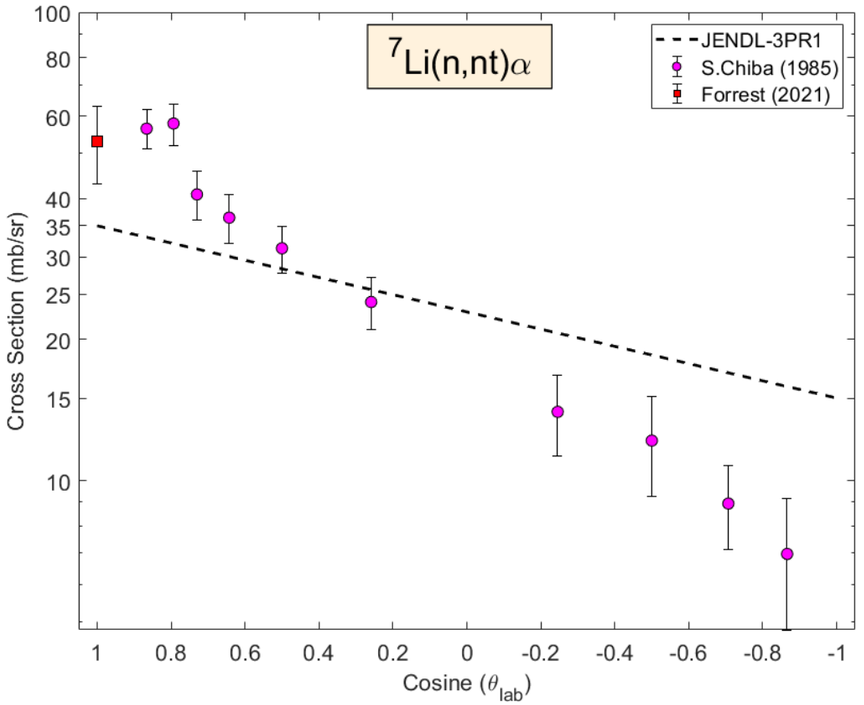
3rd Term: The evaporation term for the n,2n reactions.

The 2nd term of this trial function does not capture the decrease in the signal above 8 MeV.

* S. Chiba *et al.*, J. Nucl. Sci. Technol. 22, 771 (1985).

The three-body breakup from ^{6}Li(n,n′)dα and ^{7}Li(n,n′)tα show good agreement with earlier measurements

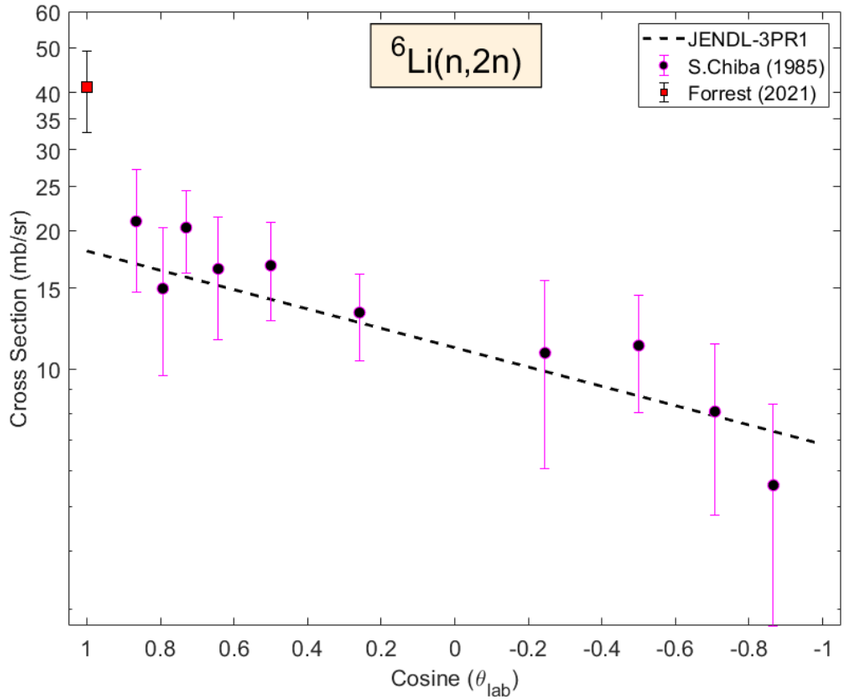


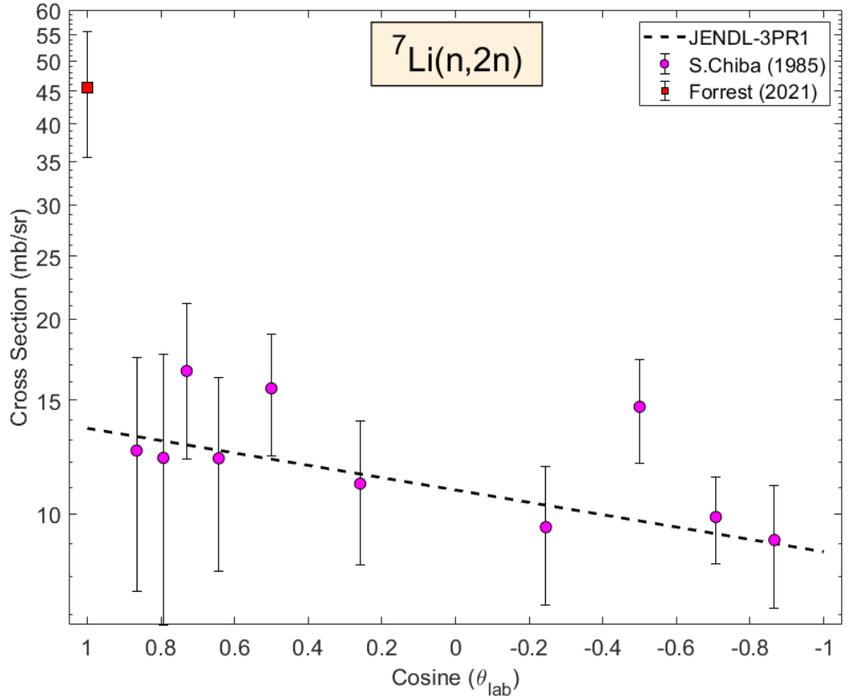


- The evaluated data (JENDL-3PR1) show a smaller cross-section at lower neutron emission angles for both ^{6}Li and ^{7}Li
- First measurements with a neutron emission angle at θ_{lab} ~ 0˚

Experimental Results – ^{6,7}Li

A significant deviation in the cross section at the near-zero neutron emission angle is observed for both ^{6}Li and ^{7}Li.



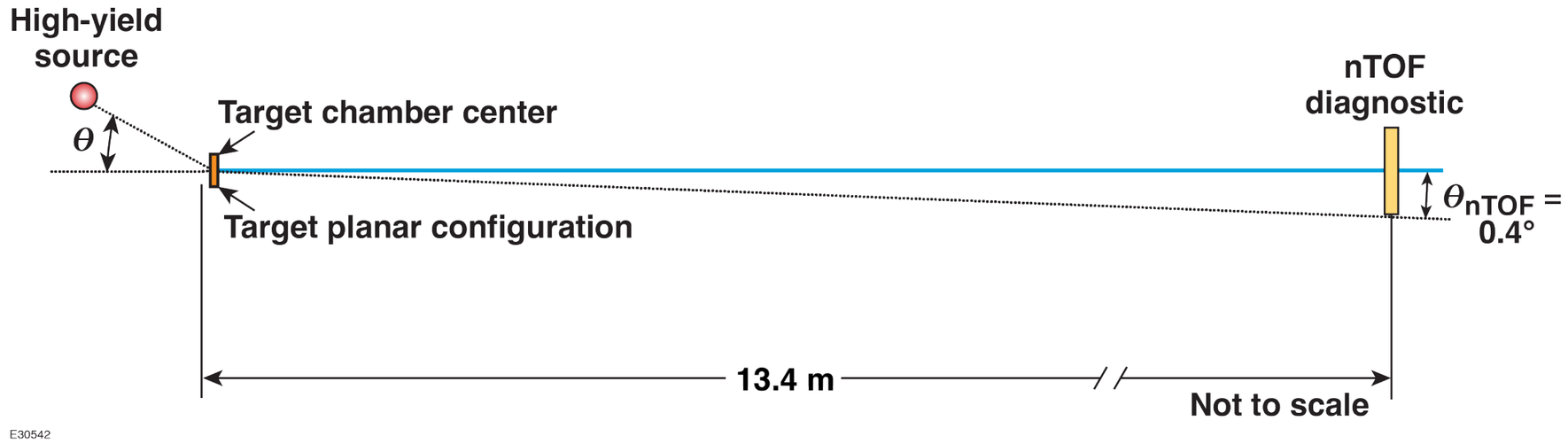


- Only a single data set for (n,2n) cross sections with 14 MeV incident neutrons are available in the literature
- Again, first measurements with a neutron emission angle at $\theta_{lab} \sim 0^{\circ}$

New Experimental Platform

An experimental platform to measure the emitted neutron with increasing angles is under development at the Omega Laser Facility

- **Experimental data in the lower energy region <4 MeV with increasing neutron emission angles (0˚ to 90˚) is required to reduce the uncertainty in the TBR <3%.**



This configuration will allow for less lithium since the neutron source will be much closer to the target sample.

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