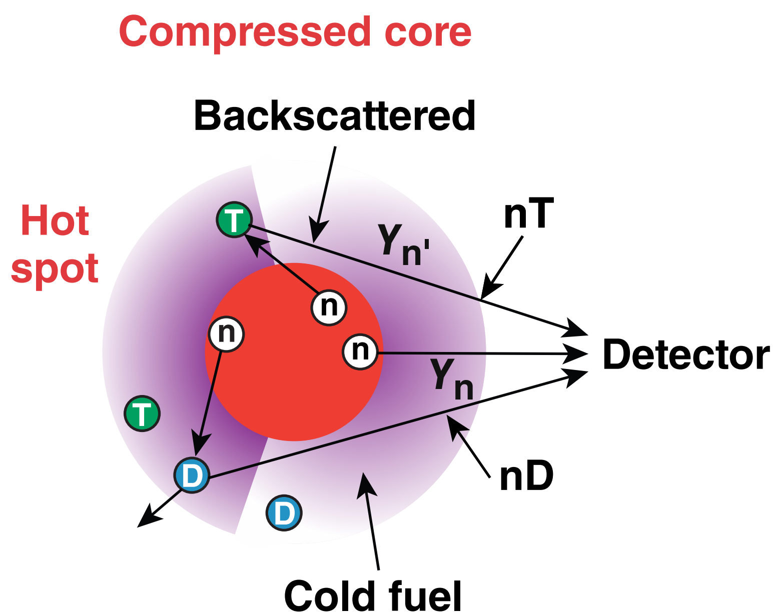
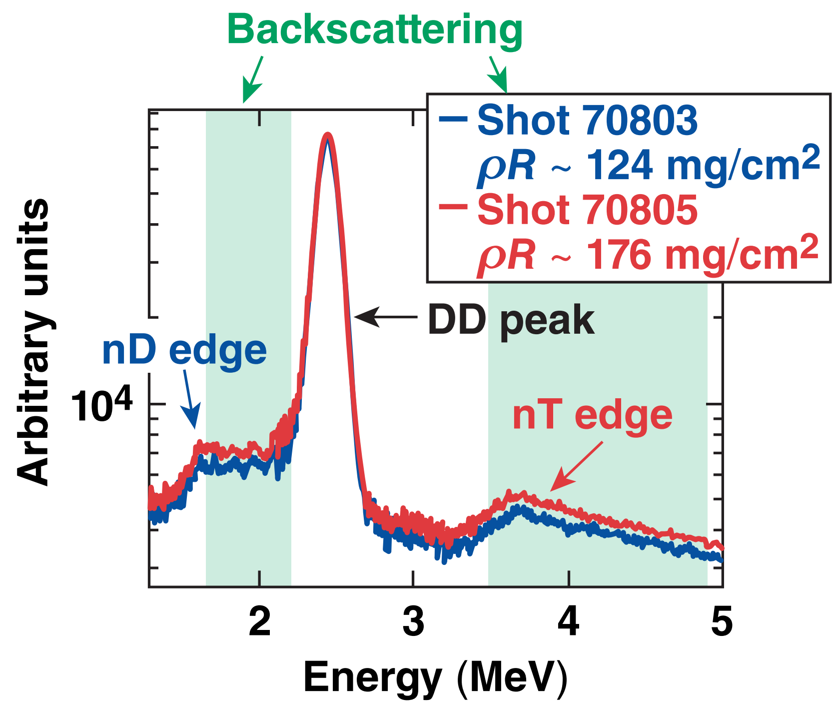
Diagnosing Cryogenic DT Implosion Performance Using Neutron Spectroscopy on OMEGA





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

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Low-adiabat ($\alpha < 3.5$) cryogenic implosions show that the areal density falls precipitously when compared with 1-D *LILAC* simulations

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- Neutron spectroscopy is essential to measure important parameters in inertial confinement fusion (ICF) experiments
  - the primary yield, ion temperature, and areal density
- Both the forward-scattered and backscattered region of the energy spectrum is used to infer the areal density
- Two separate neutron spectroscopic diagnostics show that the areal density decreases significantly with low-adiabat cryogenic DT implosions on OMEGA

Collaborators

V. Yu. Glebov, V. N. Goncharov, S. X. Hu, D. D. Meyerhofer,
P. B. Radha, T. C. Sangster, and C. Stoeckl

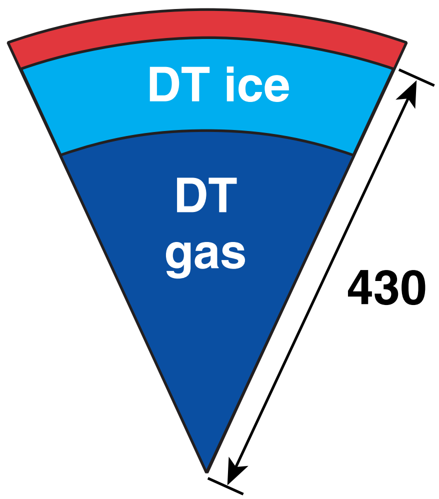
University of Rochester
Laboratory for Laser Energetics

J. A. Frenje and M. Gatu Johnson

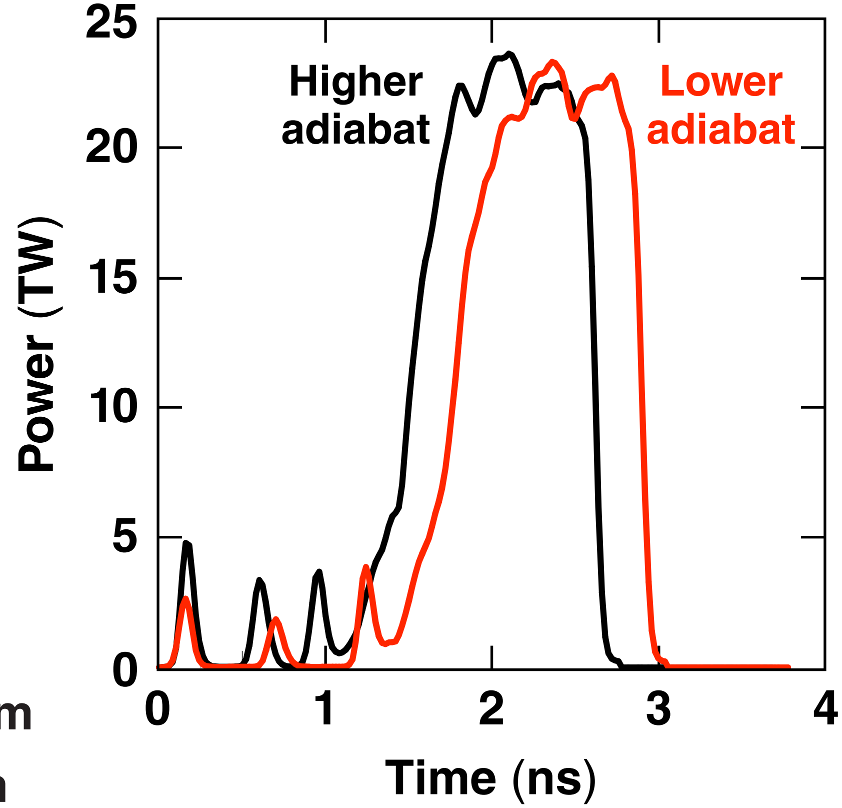
Plasma Science and Fusion Center
Massachusetts Institute of Technology

Motivation

Recent symmetric direct-drive implosions have varied the implosion velocity, in-flight aspect ratio (IFAR), and adiabat



Adiabat and IFAR are controlled by pulse shaping



- Two additional parameters are used to control the V_{imp} and IFAR
  - CD ablator thickness: 7 to 10 μm
  - DT shell thickness: 40 to 75 μm

V. N. Goncharov, GI3.00001, this conference (invited).

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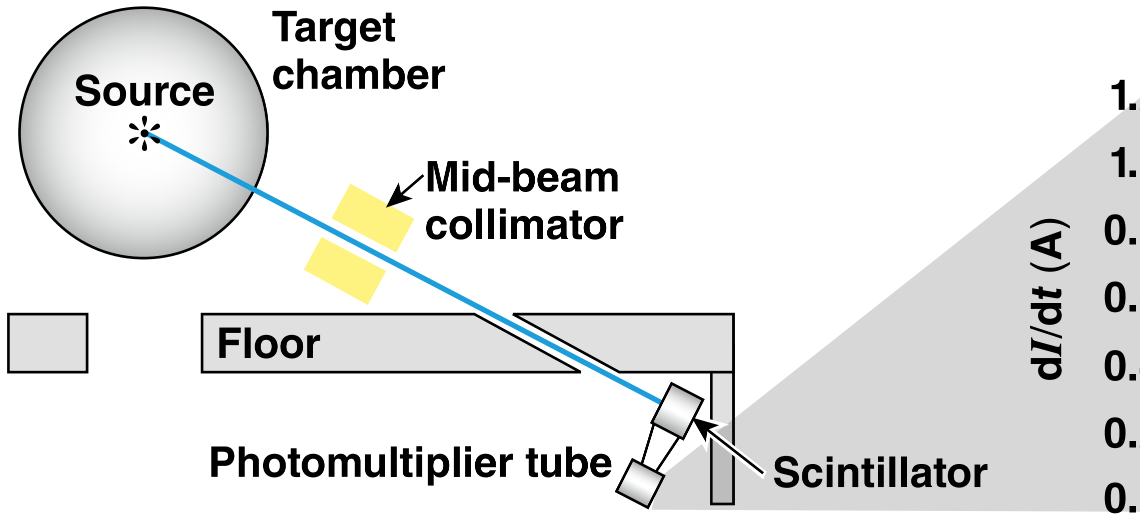
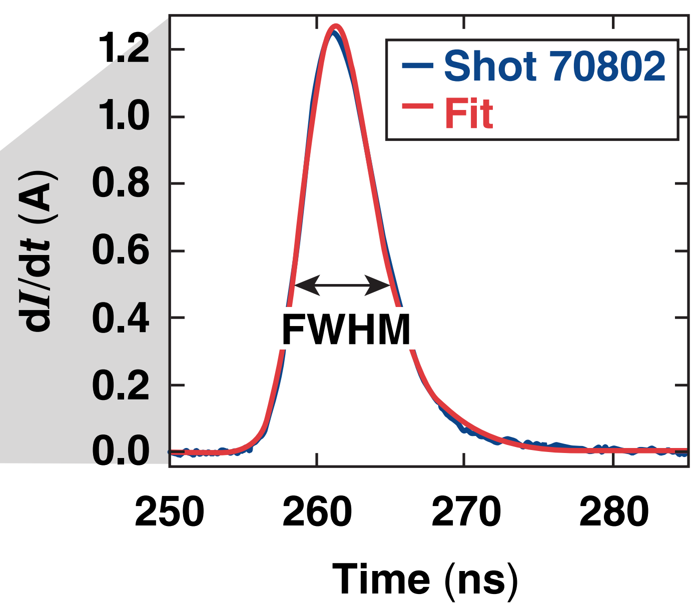
Neutron time-of-flight (nTOF) spectroscopy can measure the primary yield (Y_{DT}) and average the ion temperature T_i





$$Y_{DT} = \int_V n_D n_T \langle \sigma \nu \rangle T_i \, dV$$

nT, nD = particle composition
dV = hot-spot volume
$\langle \sigma \nu \rangle$ = DT fusion-reaction rate
T_i = ion temperature

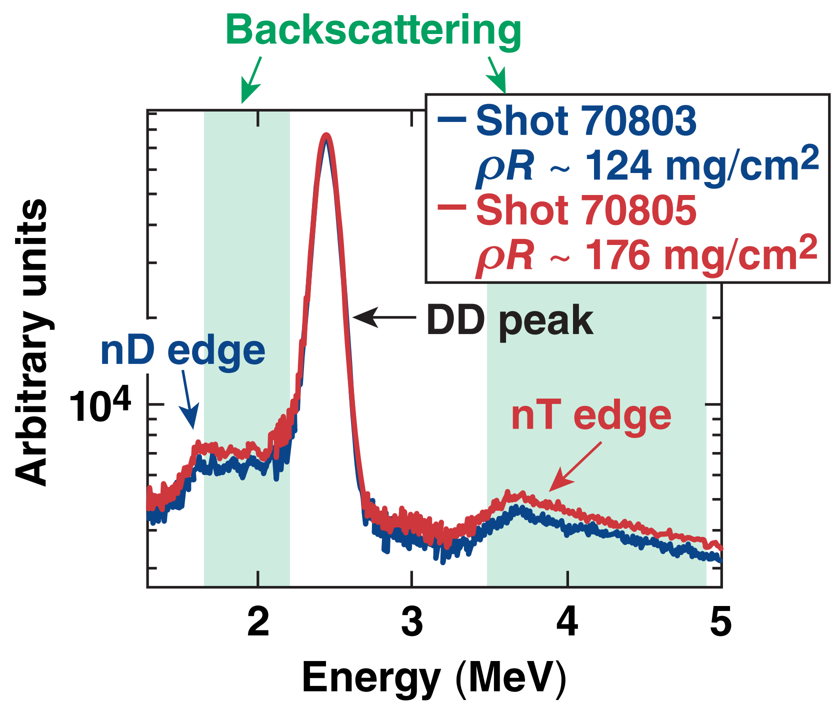
$$T_i = \left[\frac{2\sqrt{2\ln(2)}\,\text{FWHM}}{k_\beta^2 \times d \times 0.122} \right]^2 \text{(keV)}$$

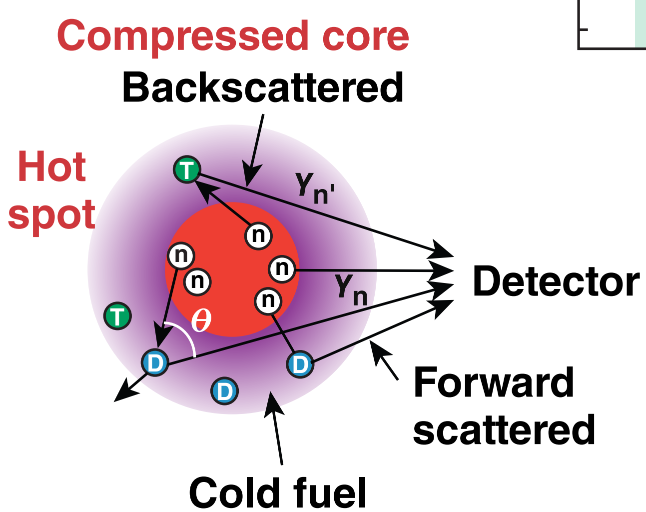
- d = distance from target chamber center (TCC)
- k_B = Boltzmann constant

E22467a

*T. J. Murphy, R. E. Chrien, and K. A. Klare, Rev. Sci. Instrum. 68, 610 (1997).

The nT scattered neutron yield in the 3.5- to 5.5- MeV region is directly related to the compressed fuel areal density (ρR)





$$\frac{Y_{nT}}{Y_{DT}} = \frac{N_{av}}{M_T}\frac{3}{5}\rho R_{DT}\int_{E_i}^{E_f}\frac{d\sigma_{nT}}{dE}dE$$

- Measurement of the nD yield is being developed

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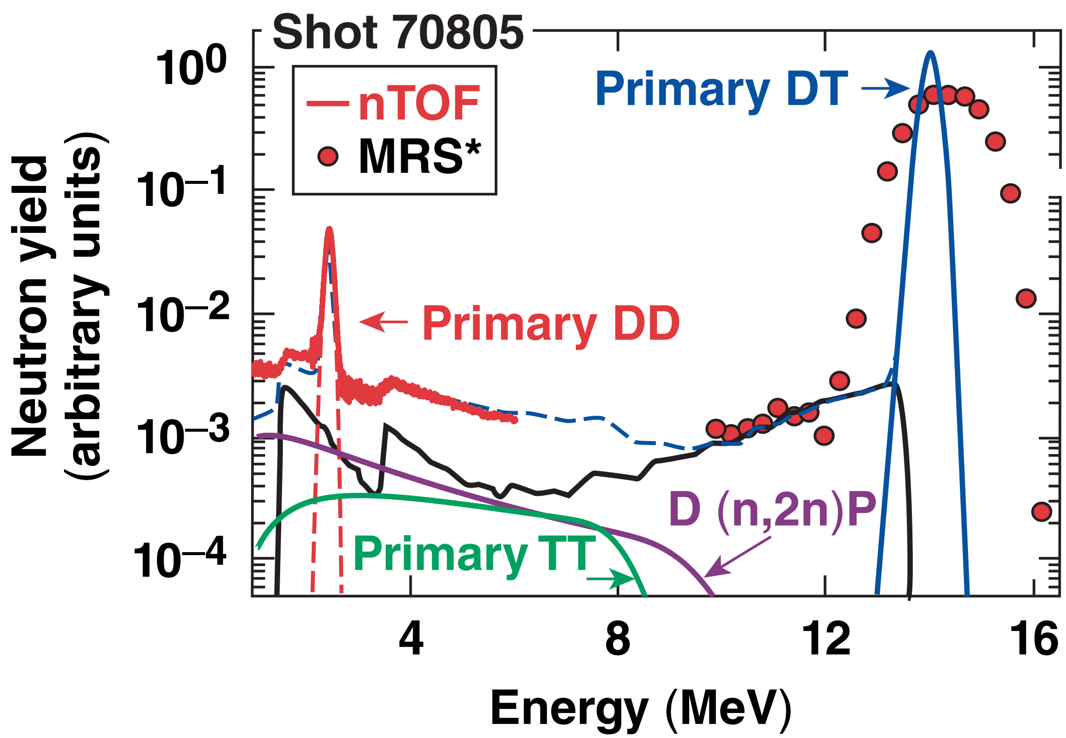
Two separate diagnostics measure the down-scattered energy spectrum in the forward-scattered region



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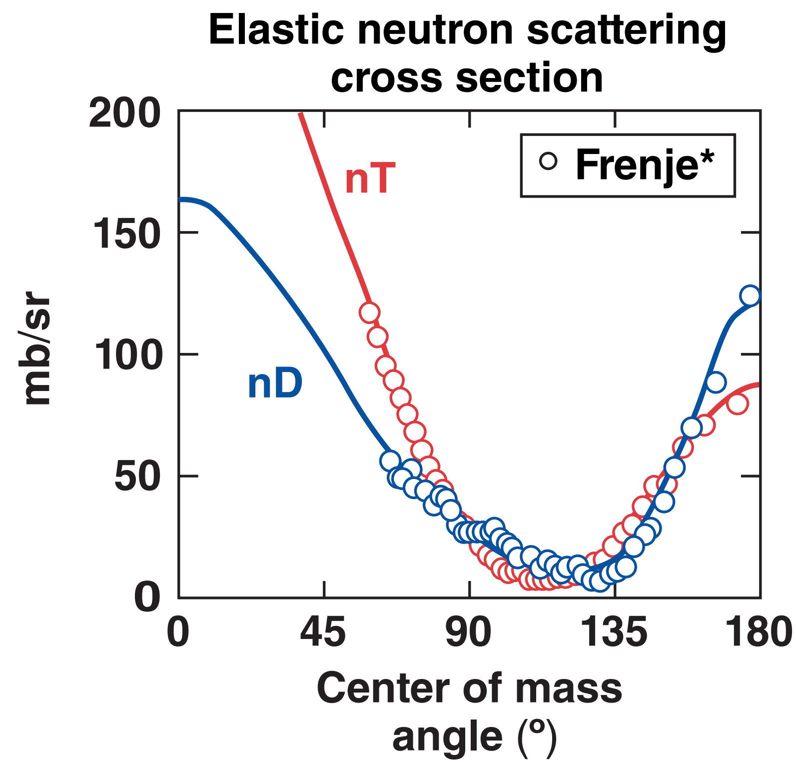
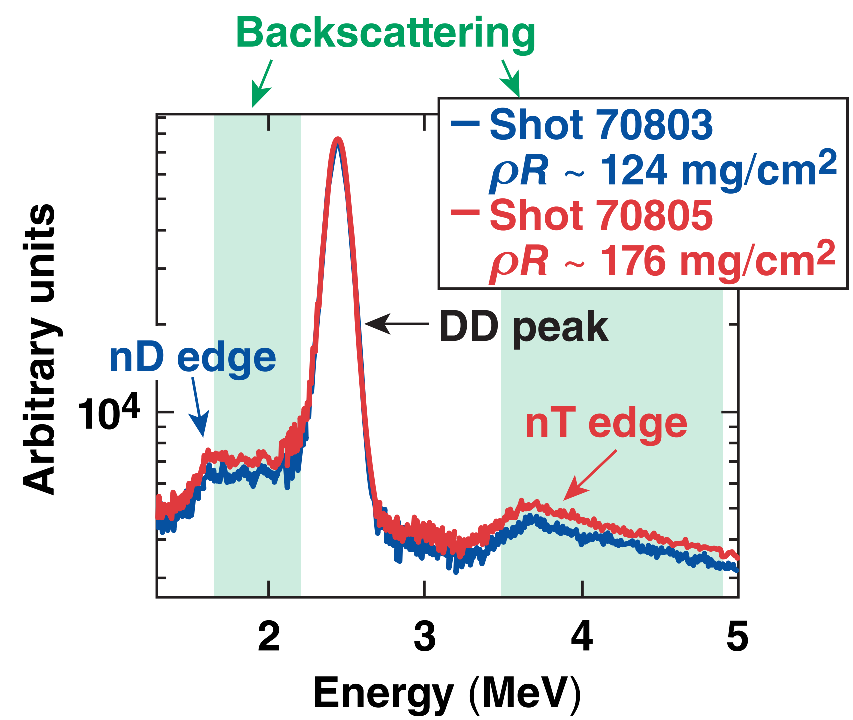
*Magnetic recoil spectrometer

An advanced nTOF detector infers the areal density from the backscattered neutron yields



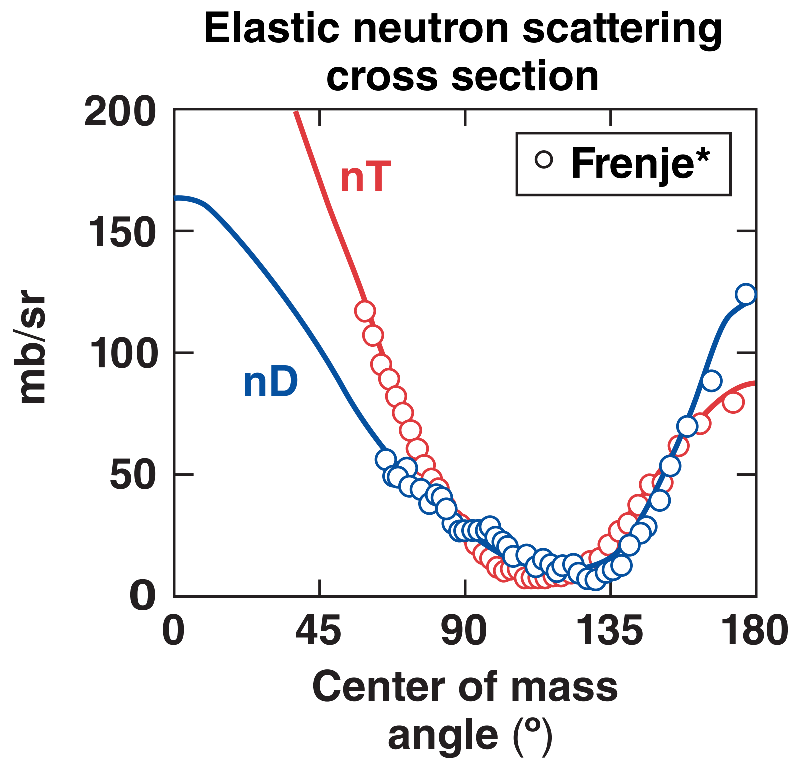
$$E_s = \left[E_n - E_n \frac{4A}{(1+A)^2} \cos^2\theta \right]$$

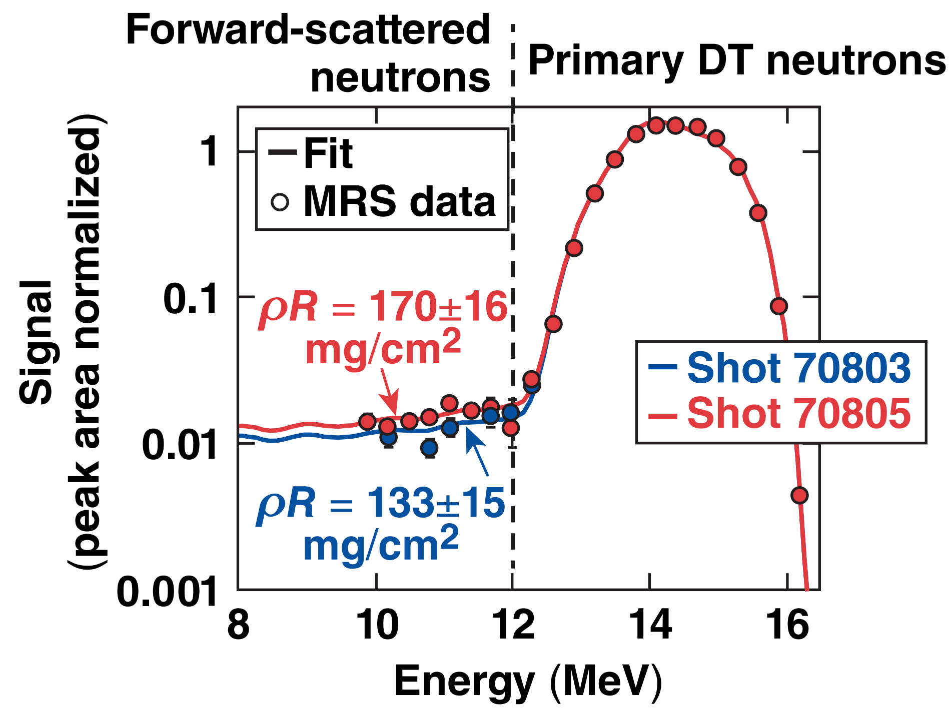


$$E_s^{min}(nD) = 1.57 \text{ MeV}$$
$$E_s^{min}(nT) = 3.53 \text{ MeV}$$

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

The MRS† infers the areal density using the forward-scattered neutrons





*J. A. Frenje *et al.*, Phys. Rev. Let. 107, 122502 (2011).
†J. A. Frenje *et al.*, Rev. Sci. Instrum 72, 854 (2001).

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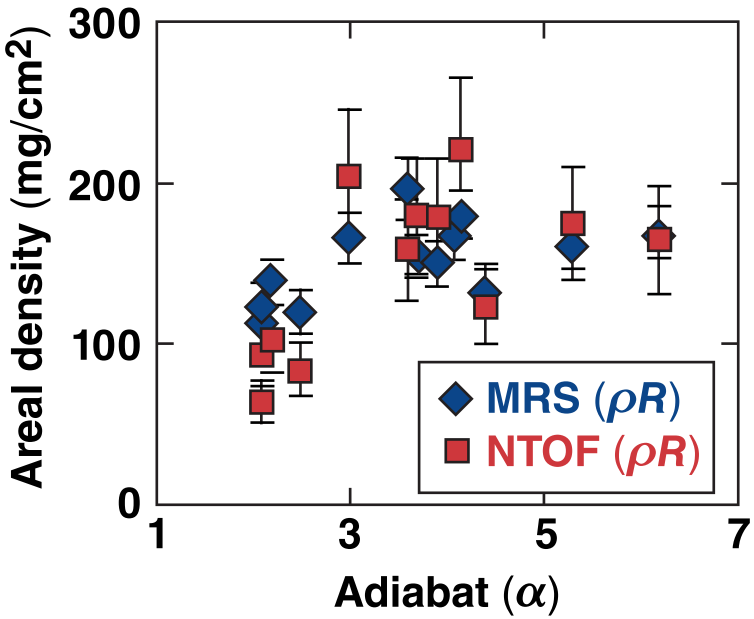
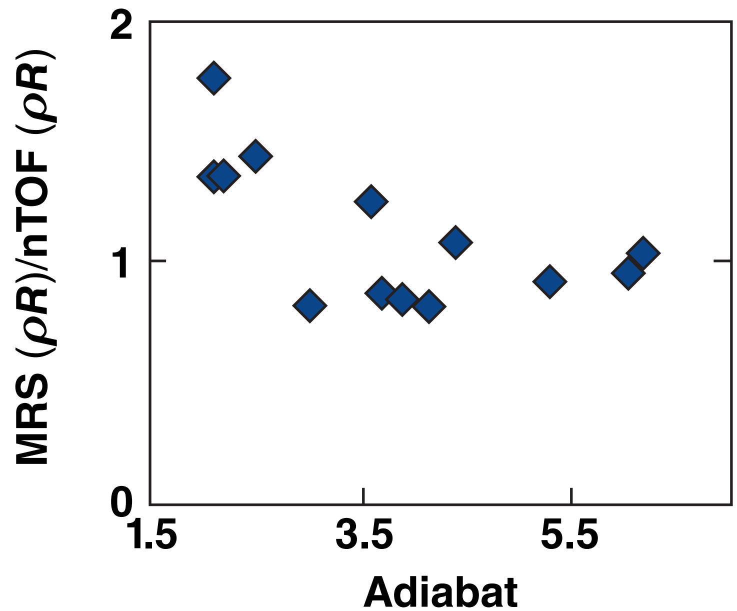
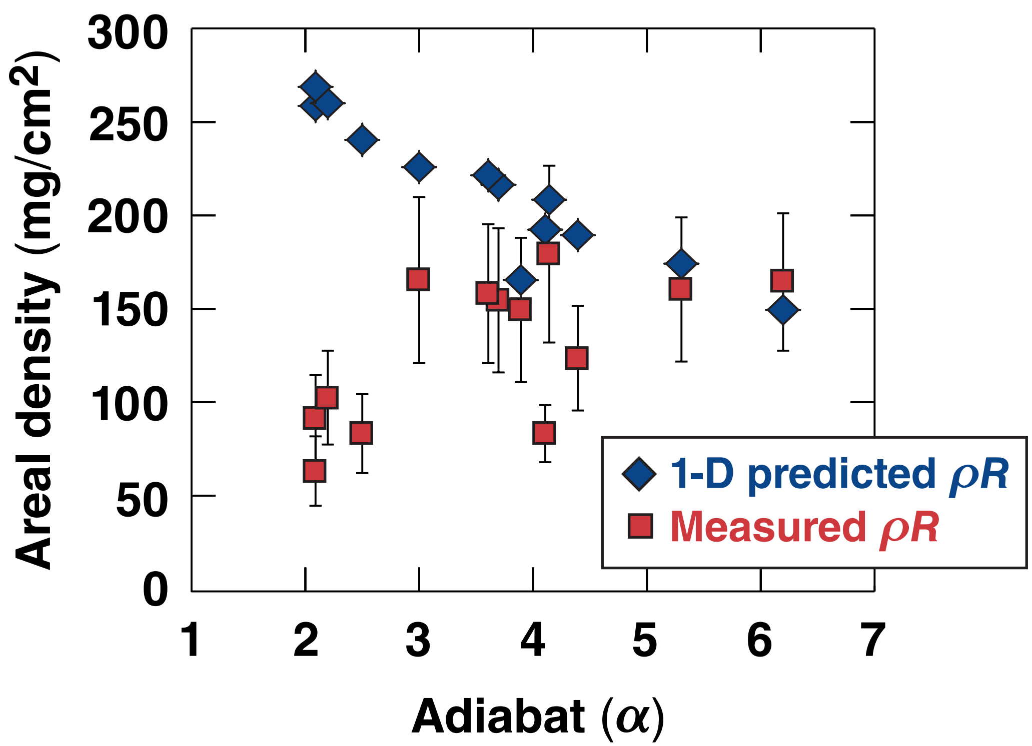
Two separate diagnostics show that the areal density decreases significantly with low-adiabat implosions





In low-adiabat implosions the areal density values from two separate diagnostics diverge from 1-D predictions



- Measured ρR is from averaging both the MRS and nTOF values

Summary/Conclusions

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