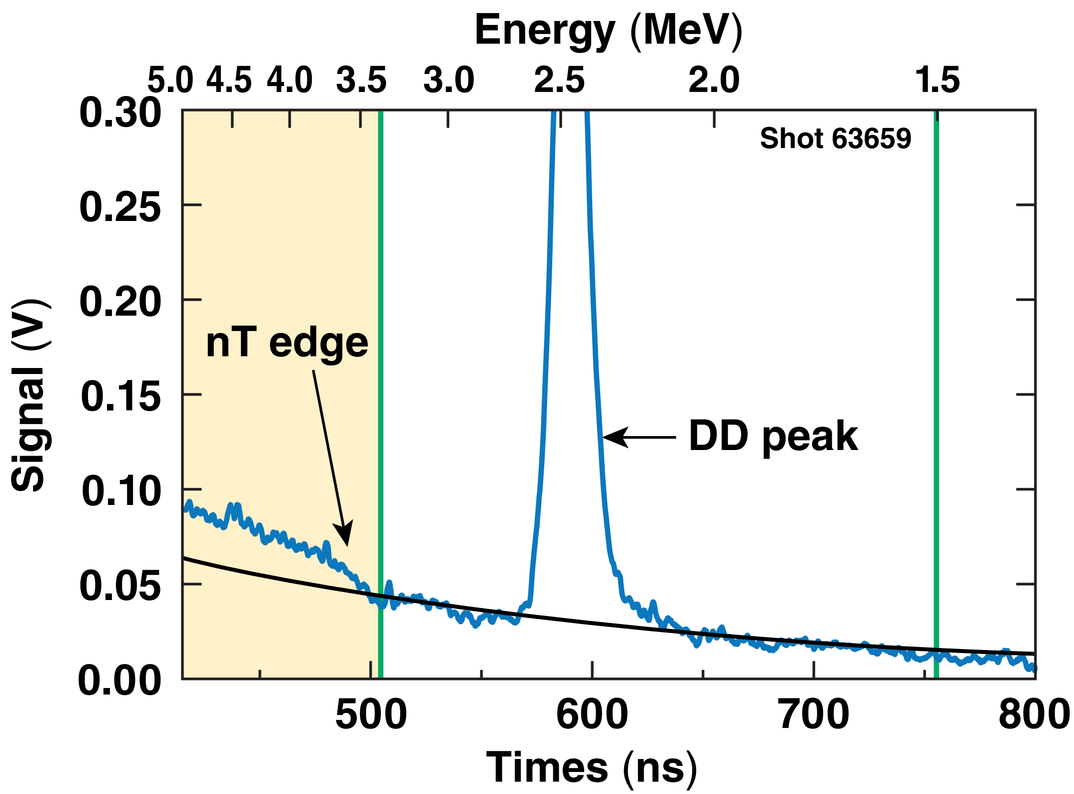
Measurement of the Areal Density (ρR) Using Neutron-Triton Elastic Backscattering on OMEGA



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LLE is developing a new diagnostic technique to infer the areal density (ρR) on OMEGA cryogenic-DT implosions

- The down-scattered neutron ratio (DSR) is not suitable for ρR measurements with neutron time-of-flight (nTOF) spectroscopy on OMEGA
- Measuring the nT backscatter neutron ratio (BSR) is possible with the yields and ρR for cryogenic-DT experiments on OMEGA
- The backscattered ratio Y(nT)/Y(DT) is proportional to the fuel ρR
- Preliminary results indicate the BSR has promise for high accuracy ρR measurement

Collaborators

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One of the main goals of the cryogenic campaign on OMEGA is to validate modeling of ρR, T_i, and yield

- R. Betti developed an ignition threshold factor* based on measureable conditions at neutron-production time

$$\chi = \langle \rho R \rangle^{0.8} \left(\frac{\langle T_i \rangle}{4.7\ \mathrm{keV}} \right)^{1.6} \mathrm{YOC}^{0.5} \qquad \chi > 1 \text{ required for ignition}$$

- The ρR on cryogenic DT implosions on OMEGA is currently based on a single MRS** measurement

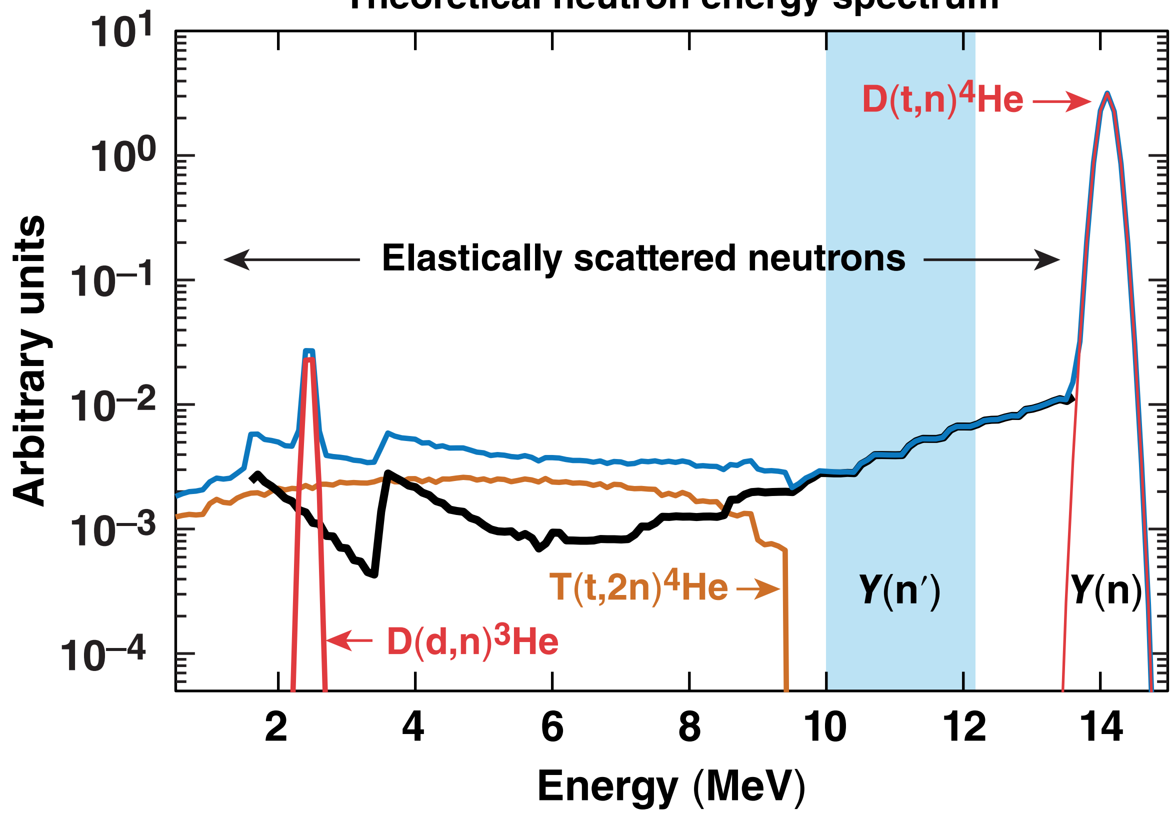
An additional independent measure of ρR would give higher confidence in the inferred values of χ.

* R. Betti *et al*., Phys. Plasmas 17, 058102 (2010).
** J. A. Frenje *et al*., Phys. Plasmas 17, 056311 (2010).

In current cryogenic-DT experiments, ρR is inferred based on the down-scattered neutron ratio (DSR)

- The MRS and nTOF* DSR techniques are well developed in the 10- to 12-MeV region

Theoretical neutron energy spectrum



$$\rho R \propto \frac{Y(n')}{Y(n)}$$

The TT spectrum does not affect the measurement in the 10- to 12-MeV region.

E20371

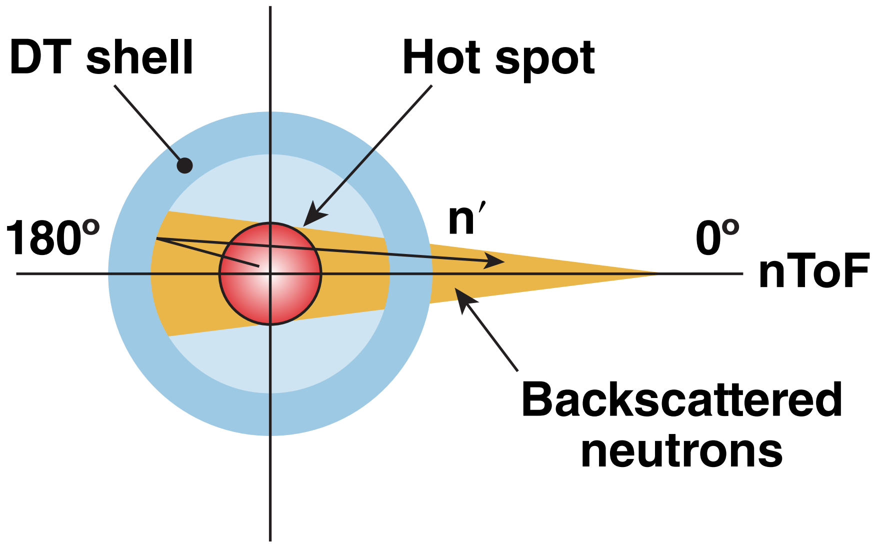
*J. P Knauer, NO6.00003

A DSR measurement is impractical on OMEGA for cryogenic-DT experiments

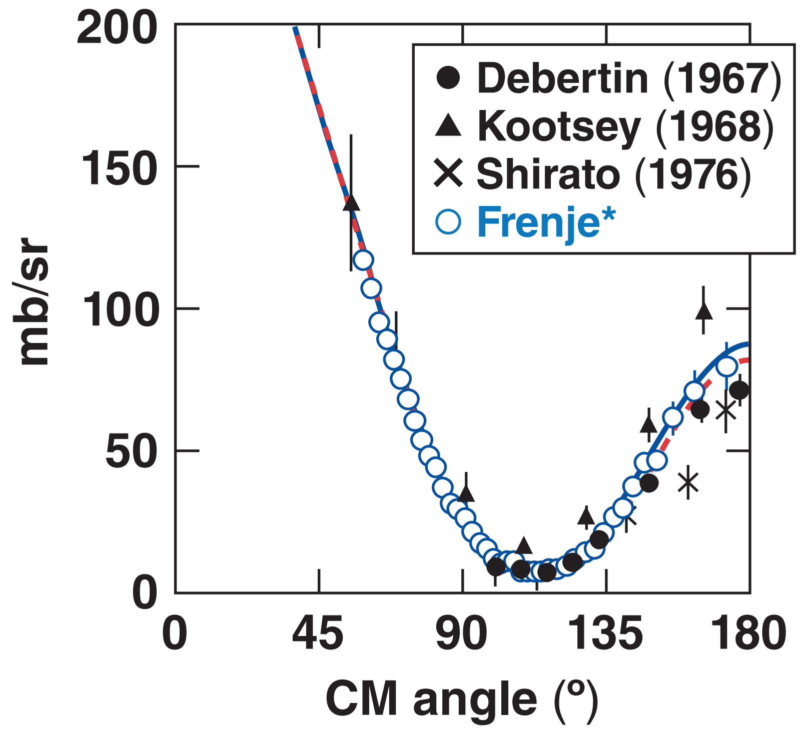
- ρR's on OMEGA (<300 mg/cm^2) would down-scatter about 1% of the primary neutrons into the 10 to 12 MeV range
- The light decay after the DT primary signal is smaller on the NIF than on OMEGA since the detector is 2× further away
- The DT primary neutron afterglow from the scintillator is 3× the expected down-scatter signal (S/B ~ 0.3)

A new approach to infer ρR on OMEGA cryo-DT implosions is needed.

The nT backscatter yield is proportional to ρR



$$\rho R \propto \frac{Y_{nT}}{Y_{DT}}$$



- The nT differential cross section has been measured with a charged-particle spectrometer (CPS) on OMEGA

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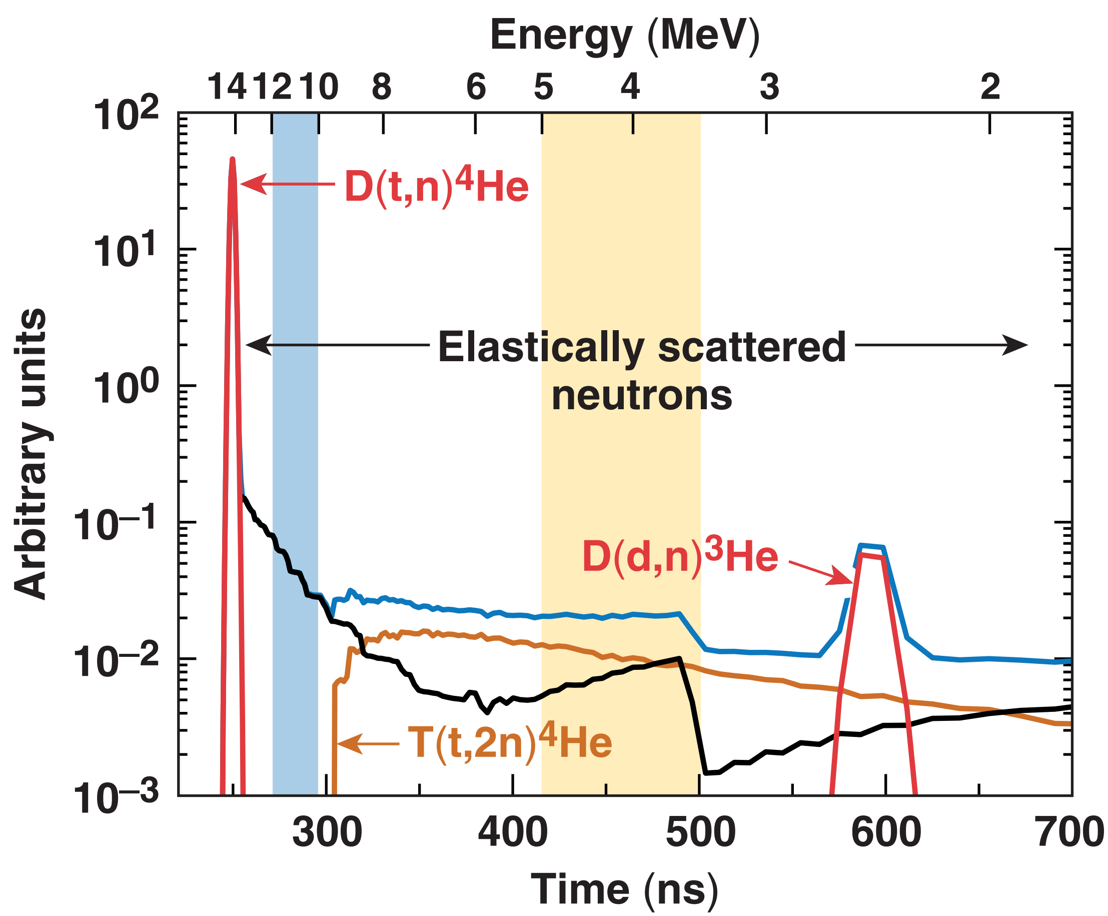
*J. A. Frenje *et al*., Phys. Rev. Lett. 107, 122502 (2011).

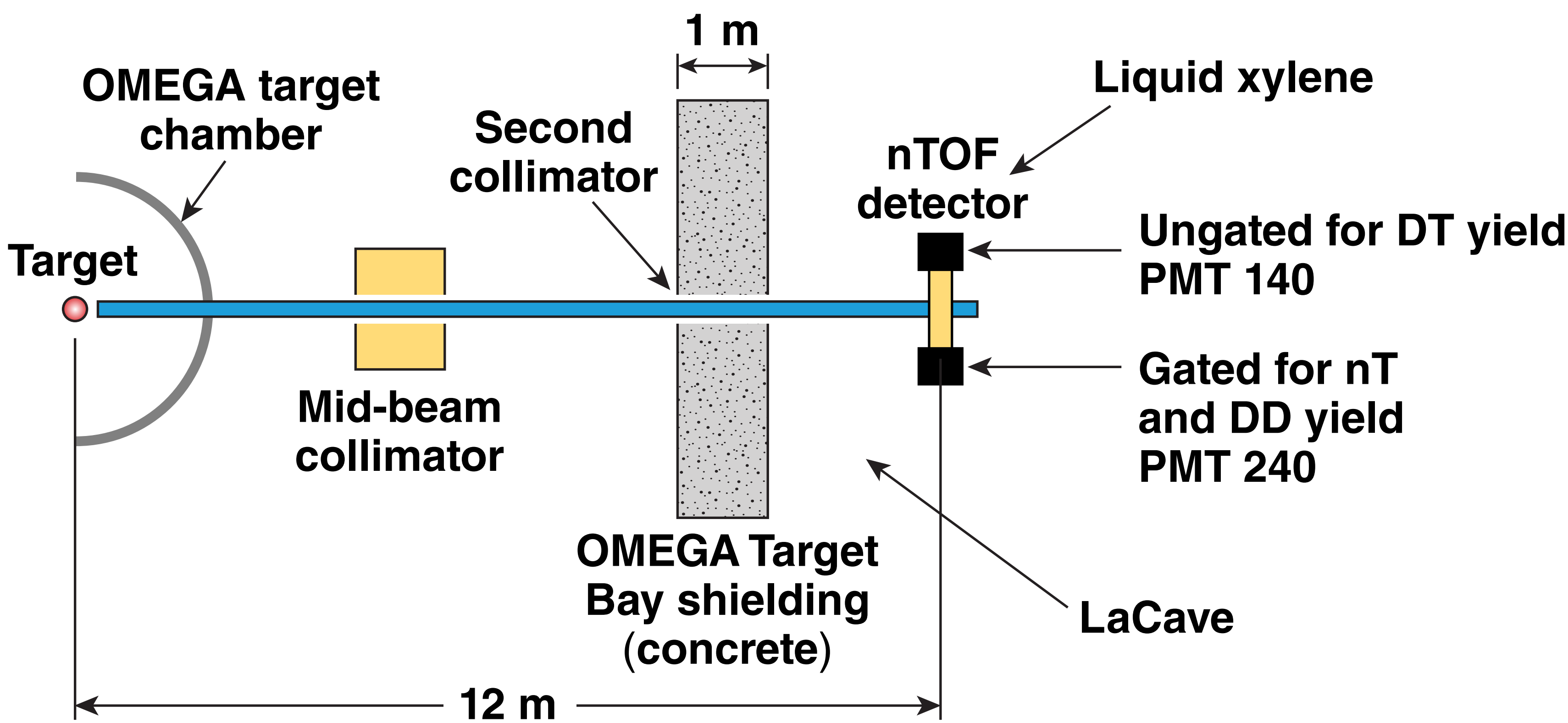
The nT backscattered ratio has the potential for a higher signal to background measurement

- The 3.5- to 5.0-MeV neutrons correspond to 6% of the down-scattered neutrons
- An accurate measurement of the nT kinematic edge is possible since the TT spectrum is well behaved
- The nT neutron sensitivity is linearly proportional to the DD sensitivity*



*T. Phillips, private communications (2011).

MCNP has been used to optimize shielding to increase the signal to background at the detector



For ρR ~ 250 mg/cm^2 and Y_n ~ 5×10^{12} the estimated nT neutron yield is 10^4.

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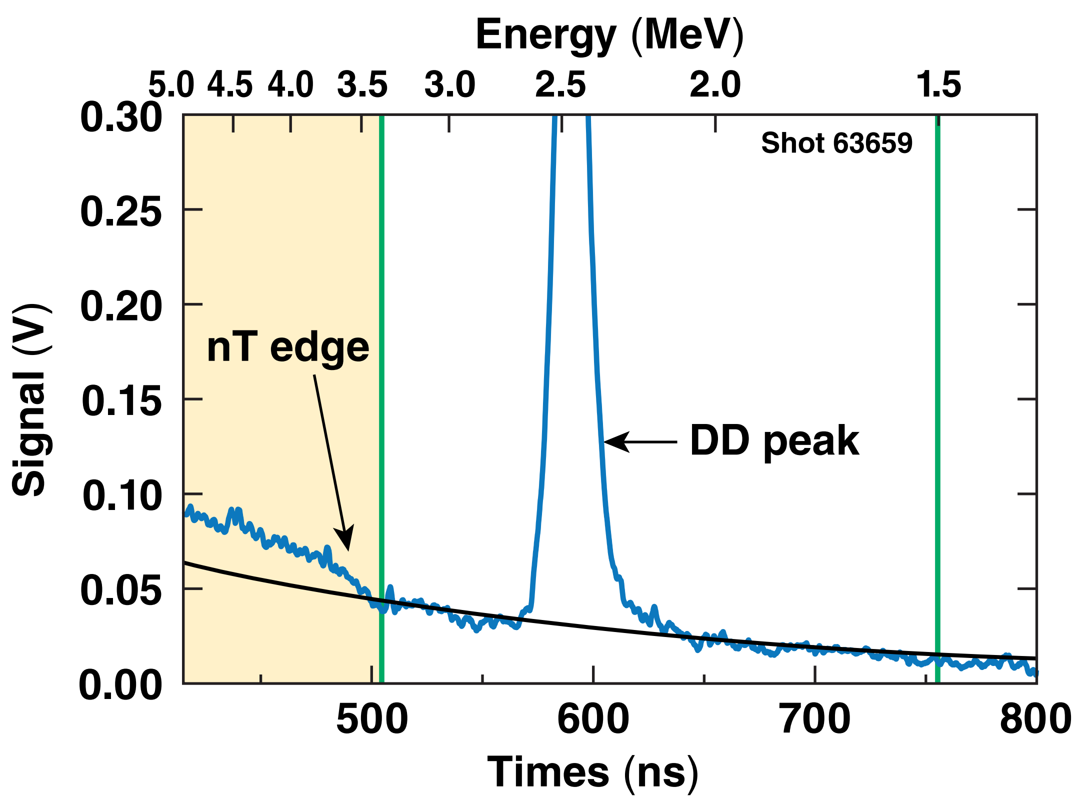
Preliminary measurements of backscattered neutrons confirm our sensitivity estimates



	Charge (pC)	Detected neutrons
DD yield	171	4.2×10^5
nT	31	4.4×10^4

Preliminary ρR is consistent with 1-D prediction; more work is needed to estimate an error bar.

E20377

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A particle transport code is used to minimize neutron scattering from surrounding structures

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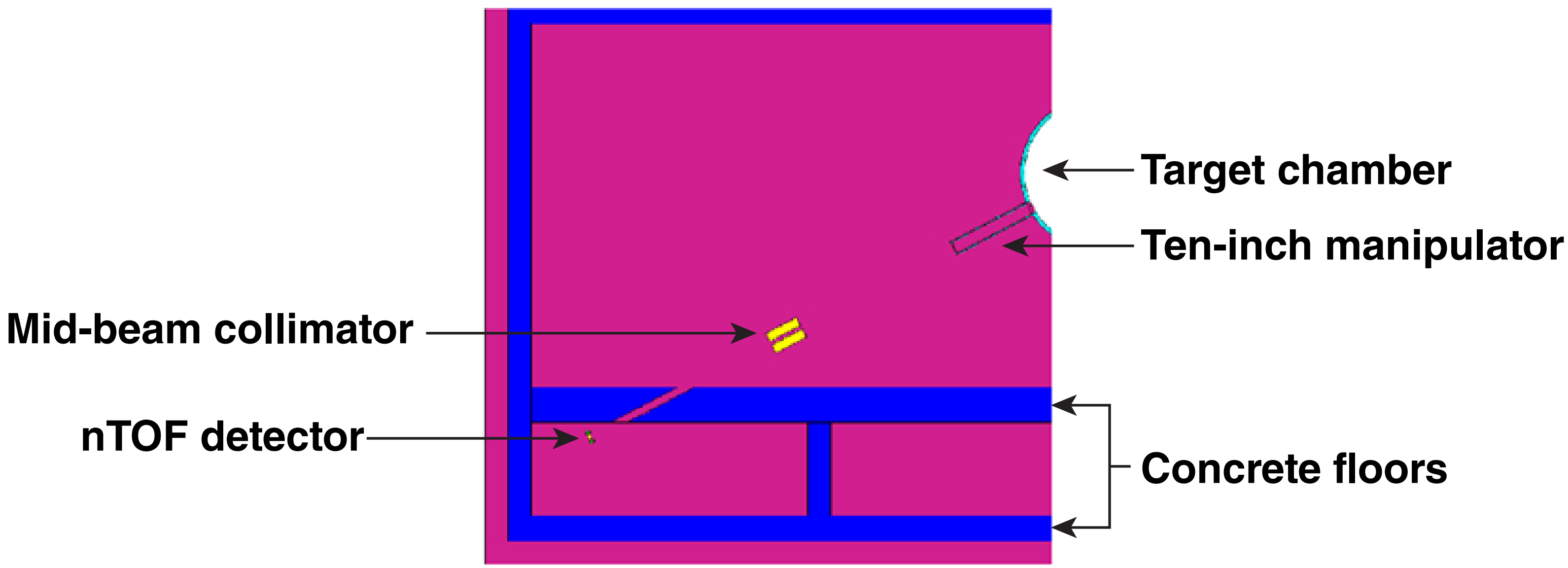
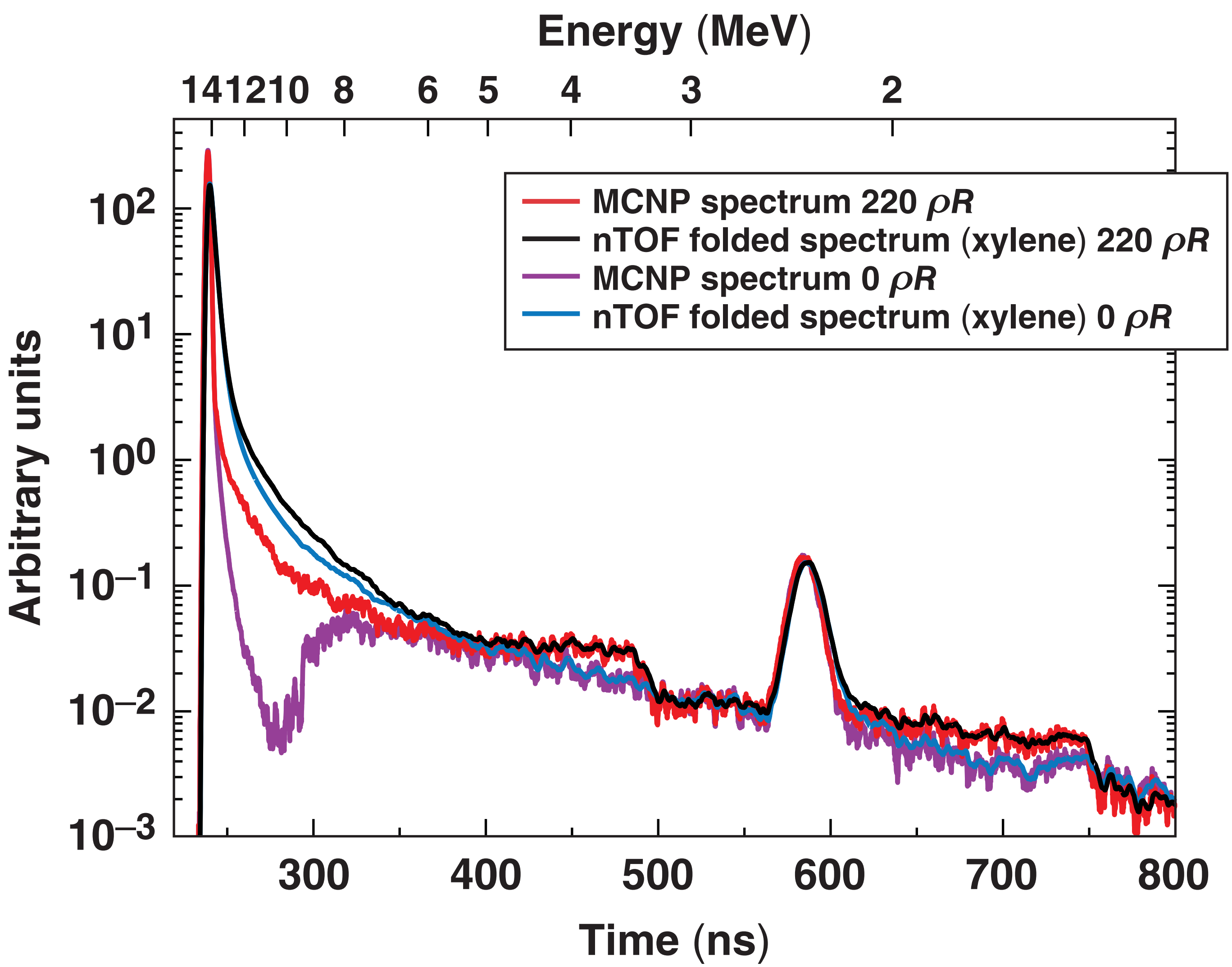
- Monte Carlo n-particle (MCNP) transport code for neutrons, photons, and electrons
- The theoretical energy spectrum is inserted into the code with relevant geometry
- These simulations are used to help guide the accuracy of the neutron energy spectrum



A cross section of the geometry in MCNP with relevant surrounding structures.

MCNP simulated spectra folded with xylene scintillator response function



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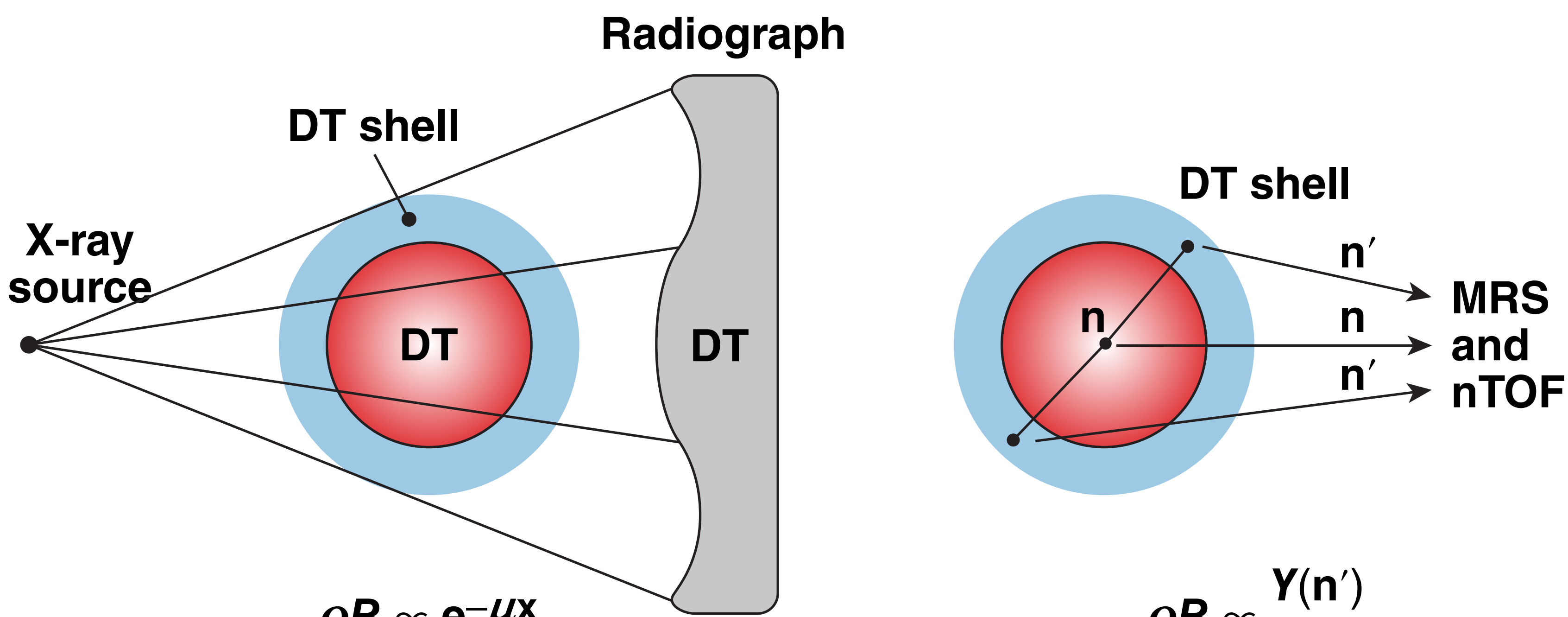
There are two ways to infer the fuel ρR—external probes (radiography) and internal probes (n scattering)



$\rho R \propto e^{-\mu x}$

$\rho R \propto \frac{Y(n')}{Y(n)}$

*R. Tommasini *et al*., Phys. Plasmas 18, 056309 (2011).