Diagnosing Cryogenic DT Implosions at OMEGA Using Charged-Particle Spectrometry: Cryogenic deuterium–tritium (DT) capsules are routinely imploded at the OMEGA Laser Facility. These experiments are part of a major LLE and National Program campaign that is comprised of several concurrent efforts, including the experimental demonstration of improved implosion performance for progressively lower fuel-adiabat designs. Inferring the fuel areal density (ρR) in these cryogenic DT implosions is challenging, since it requires new spectrometry and analysis methods to be developed. In a collaboration with the MIT Plasma Science and Fusion Center, a novel magnetic recoil spectrometer (MRS),[1] is currently being implemented to measure the spectrum of elastically scattered DT neutrons, from which the areal density (ρR) of the fuel can be directly inferred. Since both magnitude and low levels of ρR asymmetry are important measures of implosion performance, the MRS adds significantly to the existing ρR-diagnostic suite consisting of two magnet-based, charged-particle spectrometers—CPS1 and CPS2. Figure 1 shows the three spectrometers on the OMEGA chamber. Through Monte-Carlo modeling of a cryogenic DT implosion, it has been demonstrated that ρR in moderate ρR ($\leq$200 mg/cm^2) cryogenic DT implosions can be determined from the spectrum of the knock-on deuterons (KO-D)[2] elastically scattered by primary DT neutrons. In particular, it was established that the shape of the KO-D spectrum depends mainly on ρR, and that effects of time and spatially varying density and temperature profiles are insignificant. The KO-D spectra were obtained by CPS1 and CPS2. Figure 2 shows examples of measured and simulated KO-D spectra for four different cryogenic DT implosions. The ρR analysis of the KO-D spectrum was validated by comparing these results to ρR data obtained for hydrodynamically equivalent cryogenic D_2 implosions. Since well-established ρR-analysis methods exist for cryogenic D_2 implosions,[3] this comparison provides a good check of the analysis method described herein. The comparison is made in Fig. 3, which illustrates the ρR (average of CPS1 and CPS2 measurements) as a function of 1-D predicted ρR for low-intensity, low-adiabat implosions. Both sets of data show a similar trend suggesting that the ρR analysis of the KO-D spectrum is accurate.

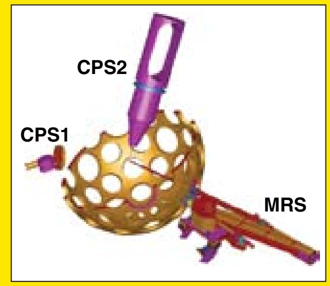

Figure 1. The MRS, CPS1, and CPS2 nuclear spectrometers on the OMEGA chamber. These spectrometers are used to simultaneously measure spectra of elastically scattered deuterons.

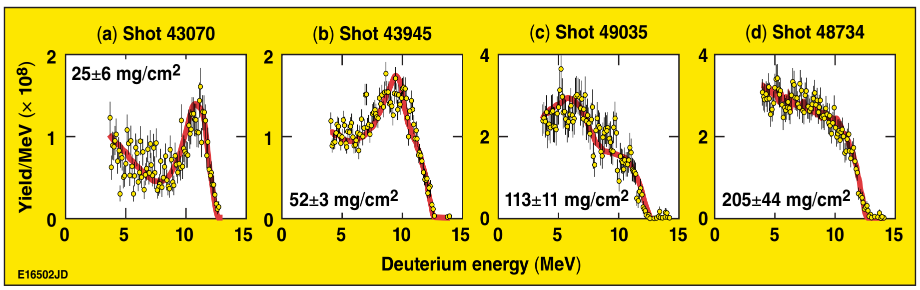

Figure 2. Examples of measured KO-D spectra for four different cryogenic DT implosions. Also shown in the figure are simulated fits (red lines) to the measured spectra. From the fits, ρR's of 25, 52, 113, and 205 mg/cm^2 were determined for shot (a), (b), (c), and (d), respectively.

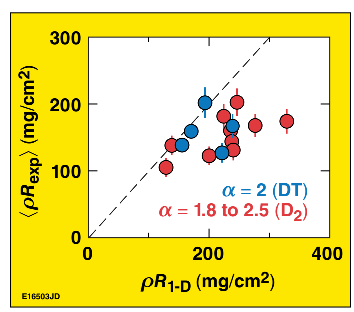

Figure 3. Experimental average ρR as a function of 1-D predicted ρR for low-intensity, low-adiabat cryogenic target implosions.

OMEGA Operations Summary: OMEGA conducted 118 target shots in January with an experimental effectiveness of 97.9%. Of these shots, 59 were for NIC and 59 for non-NIC experiments. The NIC experiments included 18 shots led by LLNL and 41 by LLE scientists, respectively. Four teams led by the University of Nevada, Reno, University of California, Berkeley, Rice University, and the University of Michigan conducted a total of 43 shots under the NLUF program. The remainder of the non-NIC shots were taken by LLE (seven) and LLNL (nine).

1. J. A. Frenje *et al.*, "A Magnetic Recoil Spectrometer (MRS) for ρR and T_i Measurements of Cryogenic OMEGA Implosions, and for Warm, Fizzle, and Ignited NIF Implosions," to be submitted to Review of Scientific Instruments.
2. S. Kacenjar *et al.*, J. Appl. Phys. **56**, 2072 (1984).
3. T. C. Sangster *et al.*, Phys. Plasmas **14**, 058101 (2007).