Plasma Nuclear Science at the Omega Laser Facility: The University of Rochester's Omega Laser Facility has been the springboard for many innovations in probing matter under extreme high-energy-density conditions. In an experiment, reported in the 15 September 2011 issue of Physical Review Letters, Johan Frenje of MIT and fellow researchers from MIT's Plasma Science and Fusion Center, Lawrence Livermore National Laboratory, and the University of Rochester's Laboratory for Laser Energetics, conducted an NLUF experiment at the Omega Laser Facility to make a precise measurement of a fundamental nuclear process: the differential scattering cross section for elastic neutron–triton (n–^{3}H) and neutron–deuteron (n–^{2}H) at 14.1 MeV. This is the first time that a fundamental nuclear physics experiment has been conducted on an inertial confinement fusion facility.[1] An accurate description of low-energy light-ion reactions is important to several fields. For example, radiative-capture reactions take place in red giants at temperatures that are so low that it is difficult to make direct laboratory measurements of the reaction rates. Accurate measurements of the cross sections of light-ion reactions are needed for fusion energy research. For ignition experiments on NIF, for example, the differential cross section for elastic n–^{3}H scattering needs to be known with an uncertainty of ~5% to estimate the fuel areal density from the ratio of the scattered neutrons and the primary neutrons.

These experiments were carried out on the OMEGA 60-beam UV laser by imploding DT-filled glass shells (~850-μm diameter and ~3.5-μm thickness, irradiated with up to 30 kJ of laser energy delivered in a 1-ns square-shaped pulse). Each capsule implosion acts as both a source of 14.1 neutrons and a deuterium–tritium (DT) target. Burn-averaged ion temperatures were ~8.5±0.5 keV and the neutron yield was typically ~4×10^{13}. The energy spectra of the ^{3}H and ^{2}H ions elastically scattered off the 14.1-MeV neutrons were simultaneously measured using the MIT-developed magnet-based charged-particle spectrometer (CPS).[2] Using the measured spectra, the differential cross section for the elastic n–^{3}H and n–^{2}H scattering was determined as shown in Figs. 1(a) and 1(b). The inferred cross sections are averages over three shots. The resulting uncertainty ranges from 4% to 7% in the center of mass-angle range of 60º to 80º. This high level of precision compares with an uncertainty larger than 20% for the only other measurements carried out to date in this angular range using conventional accelerator-based techniques.[3]

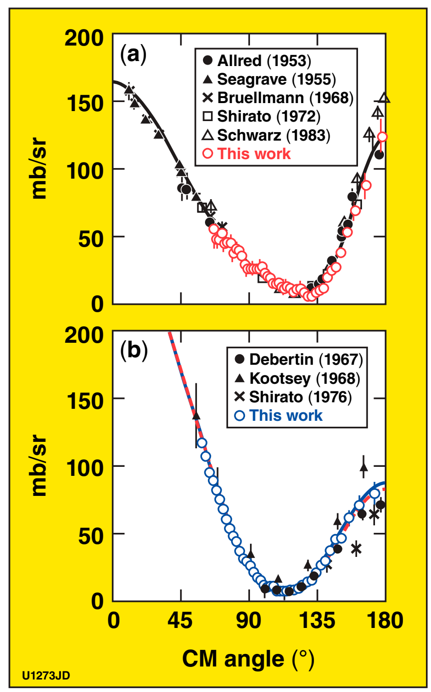

Figure 1. (a) Measured differential cross section for the elastic n–^{2}H scattering, which has been normalized to a Faddeev[4] calculation. (b) Measured and calculated differential cross section for the elastic n–^{3}H scattering. The experimental data have been normalized with the deuterium–tritium fuel ratio modified normalization factor derived in (a). The blue solid curve represents an *ab-initio* NCSM/RMG calculation, and the red dashed curve represents an *R*-matrix calculated n–^{3}H cross section.

It is expected that variations of this technique will soon be realized. A series of measurements on other fundamental nuclear processes in this plasma environment is planned. One such experiment is the fusion of ^{3}He and ^{3}He ions, important because it is the dominant energy-producing step by which our sun generates its vast energy.

Omega Facility Operations Summary: The Omega Laser Facility had scheduled 82 target shots in September but actually conducted 102 target shots (64 shots on the OMEGA 60-beam laser and 38 shots on the OMEGA EP laser). The overall average experimental effectiveness was 88.2% (88.3% on OMEGA and 88.2% on OMEGA EP). The NIC accounted for 29 target shots taken by teams led by LLE scientists and two LLNL teams carried out 15 target shots for HED campaigns. Two NLUF teams led by MIT and the University of Michigan carried out 24 target shots and one LLNL LBS experiment was conducted with 14 target shots. CEA teams carried out two campaigns accounting for 20 target shots.

1. J. A. Frenje *et al*., Phys. Rev. Lett. **107**, 122502 (2011).
2. F. H. Séguin *et al*., Rev. Sci. Instrum. **74**, 975 (2003).
3. J. M. Kootsey, Nucl. Phys. **A113**, 65 (1968).
4. S. P. Merkur'ev and L. D. Faddeev, *Quantum Scattering Theory for Several Particle Systems*, Mathematical Physics and Applied Mathematics, Vol. 11 (Kluwer Academic, Dordrecht, The Netherlands, 1993).