Nuclear Diagnostics for probing Inertial Confinement Fusion (ICF) implosions and for conducting Basic Nuclear Science

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This talk is divided into two sections. The first part discusses the suite of nuclear diagnostics used in support of the ignition experiments at the National Ignition Facility (NIF). The second part of the talk focuses on the basic nuclear science that has been conducted on an ICF facility using these diagnostics.

A suite of nuclear diagnostics, including different types of spectrometers, activation detectors, imaging systems, bang time and reaction-rate diagnostics has been implemented and used extensively on the NIF for diagnosing implosion performance of deuterium-tritium (dt) implosions. The data obtained from these diagnostics indicate that the implosion performance has improved more than two orders of magnitude since the first shot taken in September 2010. By combining the areal-density data with information about the spatial extent of the high-density region, it has been demonstrated that densities are well above 500 g/cm^3 and pressure-time ($P\tau$) products are approaching 20 atm·s, which are according to simulations about a factor of two from ignition conditions. In the most recent experiments, the signature of significant alpha heating has also been observed in the nuclear data.

The implementation of the nuclear-diagnostic techniques on the NIF and other ICF facilities has opened a new window to basic nuclear science. Traditionally, nuclear science experiments have been conducted with conventional accelerators. Gleaning good data from these experiments can however sometimes be problematic. For instance, characterization of thermonuclear reaction rates at solar energies requires cold-matter screening corrections and often extrapolation from high-energy measurements that are based on nuclear models that are not entirely reliable. Those nuclear models are also not satisfactory, as they fail to describe the spectra of the reaction products in the final breakup state. Nuclear science research has therefore benefitted from an enlarged toolkit for studies of various fundamental nuclear reactions using ICF facilities. Here, we highlight four nuclear science experiments conducted on NIF and the OMEGA laser facility. In the first experiment, the differential cross sections for elastic neutron-triton (n-T) and neutron-deuteron (n-D) scattering at 14.1 MeV were measured with significantly higher accuracy than achieved in previous accelerator experiments. In the second experiment, the T+T reaction, which is an important mirror reaction to the ^{3}He+^{3}He solar fusion reaction was studied to unprecedented accuracy at low CM energies. In the third experiment, ICF implosions were uniquely used to directly study the ^{3}He+^{3}He solar fusion reaction, while in the fourth experiment, the T+^{3}He reaction were probed. This work was supported in part by the U.S. DOE (DE-FG52-09NA29553), NLUF (NA0000877), FSC (Rochester Subaward PO No. 415023-G, UR Account No. 5-24431), LLE (412160-001G), LLNL (B580243), and prepared in part by LLNL (under DE-AC52-07NA27344).

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