Editorial: Using High Energy Density Plasmas for Nuclear Experiments Relevant to Nuclear Astrophysics

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Thermonuclear reaction rates and nuclear processes have traditionally been explored by means of accelerator experiments, which are difficult to execute at conditions relevant to nucleosynthesis. High energy density (HED) plasmas generated using lasers, such as the inertial confinement fusion (ICF) platform, more closely mimic astrophysical environments in several ways, including with thermal distributions of reacting ions as opposed to mono-energetic ions impinging on a cold target; stellar-relevant plasma temperatures and densities; and neutron flux densities not found anywhere else on earth [1]. The most extreme conditions can currently be achieved at the National Ignition Facility (NIF) laser in the US, where densities of 10^3 g/cm^3 and neutron fluxes up to $5{\cdot}10^{27}$ neutrons/cm/s [2] have been demonstrated over a time period of a few tens of picoseconds. The HED platform is emerging as an interesting complement to accelerator experiments.

This Research Topic explores the potential of this new platform for helping address questions including nuclear rates in plasmas, plasma effects on nuclear reactions, electron screening, and neutron reactions on excited states, with emphasis placed on how accelerator and HED experiments can complement each other to generate answers. For example, **Aliotta and Langanke** summarize the current understanding of screening effects in stellar environments. They identify an open question in that accelerator measurements suggest a higher screening potential than expected in the adiabatic limit, and discuss how laser facilities hold promise for solving this problem. In particular, accelerator measurements of charged particle-induced reactions are handicapped by the rapidly declining cross section and the uncertainties in the screening. **Thomson** describes how the high neutron flux environment in ICF plasmas opens up possibilities for second neutron scattering or reactions on excited states at much higher energies than previously possible. To study these unique reaction paths, the lifetimes of the newly accessible excited states must be understood; he uses statistical Hauser-Feshbach decay models to calculate relevant lifetimes.

At large laser facilities such as the NIF and OMEGA [3], stellar-like conditions are achieved by symmetrically illuminating a target using a large number of high-energy laser beams. This leads to compression of the target materials, which subsequently generates a high-density, high-temperature plasma environment. Using deuterium and tritium as fuel in the target, this process can also produce high neutron yields (up to $1{\cdot}10^{18}$ at the NIF) over a short (~100ps) time window through fusion reactions. The platform has been successfully used for studying rates of low-Z reactions, using the reactants as fuel in the target, as reported in [4,5,6] and in **Mohamed et al.**. Future directions for this path of research are explored by **Casey et al.**, who lay the foundations for using this platform to study plasma screening including discussion of practical constraints, and **Wiescher et al.**, who examine feasibility of studying three charged-particle-induced reactions involving mid-Z reactants using this platform. **Despotopulos et al.** review available techniques for adding small amounts of seed nuclei of interest for stellar nucleosynthesis into or in close proximity to the target for exposure to stellar-like conditions or nucleosynthesis-relevant neutron fluxes.

High neutron fluxes in short time periods can also be achieved using high-power, short-pulse lasers based on chirped pulse amplification [7]. This path to stellar-relevant experiments is the subject of two of the papers in this collection, **Jiao et al.** and **Burggraf and Zylstra**.

The HED platform comes with its own challenges. Rapid gradients in space and time must be considered. In some cases, thermalization rates may be lower than plasma confinement times, which means standard hydrodynamic and Maxwellian assumptions must be examined. **Crilly et al.** address these challenges by theoretically investigating impact of hydrodynamic and kinetic effects on S-factors inferred from ICF-type experiments.

The new platform cannot be exploited without state-of-the-art diagnostics [1,8]. **Despotopulos et al.** review the radiochemistry diagnostic suite available at the NIF. **Mohamed et al.** review gamma detection capabilities available at OMEGA and the NIF, and identify a gamma spectrometer as an additional tool that would enable many more experiments. Additional nuclear diagnostics are also available at the various facilities, and should be exploited as research continues (see, e.g., Refs [9,10]).

Broad interdisciplinary nuclear, plasma and astrophysical expertise will be required to tap the potential of this new line of research. The intent with this Research Topic is to advertise the platform's capabilities to attract the necessary expertise to this emerging field, and to gather momentum behind the efforts to utilize these new capabilities to answer questions previously impossible to address in terrestrial experiments.

References

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