Towards optimizing the generation of proton beams in fast ignition of laser-driven inertial fusion targets

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The recent successful demonstration on NIF of achieving, for the first time, a target gain G>1 has renewed interest in inertial fusion energy (IFE). While this historic result has validated the scientific basis for laser-driven inertial fusion, many scientific and technical challenges remain on the path to developing a commercially viable IFE scheme.

Proton fast ignition (PFI) is an advanced ignition scheme separating the stages of deuterium-tritium fuel compression and ignition, promising higher target gains and more robust performance. First, the fuel shell is compressed around a re-entrant cone to high densities using a quasi-spherical implosion driven by ns-scale laser pulses. Then, an energetic proton beam is generated through target normal sheath acceleration (TNSA) during the interaction of ps-scale laser pulses with a curved foil inserted inside the cone. The proton beam is focused into the compressed fuel to heat a small volume to ~10 keV, initiating ignition and burn. The success of this approach relies on the ability to generate a proton beam with the right characteristics to heat and ignite the isochoric fuel assembly.

We will discuss the strategy to study and further optimize the physics of TNSA proton beam generation, focusing, and beam transport in the context of PFI. Our approach is based on large-scale numerical studies that are complemented and benchmarked by experimental results obtained at currently available smaller-scale laser facilities. As part of our numerical effort, we have explored the target and laser parameter space surrounding laser-to-proton conversion efficiency and worked on the optimization of the target geometry for proton focusing. We have also performed sensitivity studies of the PFI target design to variations in the proton beam parameters. We will present preliminary experimental results obtained at the ALEPH laser system (Colorado State University), where we performed a systematic study of the focusing properties of hemispherical foils at a moderate repetition rate.