- IFSA2025 –

Numerical studies of foam-based target designs for stable direct-drive implosions

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In laser-driven inertial confinement fusion (ICF), target stability is essential to achieve high compression and ignition. Hydrodynamic instabilities, seeded by laser nonuniformities and target imperfections, can severely degrade implosion symmetry and performance. Polymer foams have emerged as a promising mitigation strategy, modifying plasma conditions at the ablation front and smoothing initial perturbations.

While indirect-drive ignition has been demonstrated at the National Ignition Facility (NIF) [1], no existing large-scale facility is currently optimized for direct-drive fusion. In this context, the Taranis project in France, led by GenF, aims to develop a next-generation direct-drive laser fusion reactor. This approach relies on robust and easily manufacturable targets, where foam-based designs are particularly attractive for reducing imprint and enhancing implosion stability [2,3].

In this work, we use 1D hydrodynamic simulations with the MULTI code [4] and 2D particle-in-cell simulations with SMILEI [5] to study the role of low-density CH foams in mitigating imprint and stabilizing direct-drive implosions. These simulations capture key plasma properties including laser energy deposition, density evolution, and perturbation growth. We analyze how foam parameters affect imprint generation and early-time instability development.

By leveraging these complementary numerical tools, we provide guidance for designing robust foam-based targets optimized for direct-drive implosions in the MJ regime. These findings support the development of advanced target concepts for next-generation laser fusion experiments and inertial confinement fusion reactors.

References

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