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Enhancing the proton cutoff energy in Target Normal Sheath Acceleration via an improved laser-to-electron coupling in long-scale plasma gradients

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Proton bunches produced via Target Normal Sheath Acceleration have unique features (ultra-short duration, high-flux and low emittance at the source), which could enable a plethora of new applications. However, the beam maximum energy and quality are still open challenges.
Recent experimental results obtained at the Intense Laser Irradiation Laboratory (INO-CNR, Italy) demonstrated a reliable path toward increasing the proton cutoff energy via pre-expanding in a controllable way the front surface of not-so-thin foils (Gizzi et al. 2021 Sci. Rep. 11, 13728). In this talk, I will present results from two and three-dimensional Particle-In-Cell simulations performed under the same experimental conditions and discuss the physics underpinning this energy enhancement. Simulations indicate that in the presence of a long-scale pre-plasma, a standing wave is generated in the under-dense pre-plasma. Electron motion in the standing wave becomes stochastic, enabling a more efficient laser energy absorption. As a result, electrons get heated to higher temperatures, and protons from the back surface of the target are accelerated to energies up to three times higher than the cases with no pre-plasma. The long-scale pre-plasma seems to further positively affect the quality of the proton bunch by also reducing the overall divergence of the beam.

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