High-flux neutron sources from protons accelerated by a 1-PW-class laser

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The production of intense, ultra-short neutron pulses from relativistic laser-plasma interactions [1] is drawing increasing interest due to its relative ease of operation and its many envisioned applications [2]. Moreover, the prospect of achieving neutron fluxes far exceeding those currently attainable ($\lesssim 10^{19}$ n cm^{-2} s^{-1}) at conventional accelerator facilities renders laser-based schemes promising for investigating neutron capture processes under conditions relevant to heavy nucleosynthesis in the Universe [3].

This talk will report on numerical simulations of upcoming experiments on laser-induced neutron generation at the PW-class Apollon facility. In contrast with previous related works which exploited (p,n) reactions in light-ion converter targets exposed to laser-driven proton or gamma-ray beams [1], the enhanced proton energies expected at Apollon should make it possible to initiate more efficient spallation neutron reactions in high-Z secondary targets [3].

We will present results from 2D particle-in-cell (PIC) CALDER simulations, describing the laser acceleration of protons from single- and double-layer primary targets, coupled with 3D Monte Carlo FLUKA calculations, modelling the atomic and nuclear reactions involved during the transport of the protons through a secondary lead converter target. For the 2×10^{21} W cm^{-2}, 20 fs Apollon laser pulse impinging onto a plastic foil target of 64-115 nm thickness, proton energies in the 100 MeV range are predicted. Depending on the thickness of the Pb converter (25 µm $\leq l \leq$ 10 cm), those protons can generate up to 3×10^9 neutrons (at $l \simeq$ 1 cm) and fluxes exceeding 10^{22} n cm^{-2} s^{-1} (at $l \leq$ 250 µm). Interestingly, the highest neutron flux is obtained for a foil target twice thicker than that maximizing the proton energies [4] and the neutron yield. While double-layer targets may double the cutoff energy of the proton bunch, this comes at the expense of its total charge and divergence, and hence of the resultant neutron yield which does not surpass that achieved with single-foil targets.

References

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