High-flux neutron generation by laser-accelerated ions from single- and double-layer targets

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Contemporary ultraintense, short-pulse laser systems provide extremely compact setups for the production of high-flux neutron beams, such as required for nondestructive probing of dense matter or research on neutron-induced damage in fusion devices. Here, by coupling particle-in-cell and Monte Carlo numerical simulations, we examine possible strategies to optimize neutron sources from ion-induced nuclear reactions using 1-PW, 20-fs-class laser systems such as the recently commissioned Apollon laser [1]. To improve ion acceleration, the laser-irradiated targets are chosen to be ultrathin solid foils, either standing alone or preceded by a near-critical-density plasma to enhance the laser focusing.

We compare the performance of these single- and double-layer targets, and determine their optimum parameters in terms of energy and angular spectra of the accelerated ions. These are then sent into a converter to generate neutrons, either traditionally through (p,n) reactions in beryllium or through spallation in lead. Overall, we identify configurations that result in a neutron yield as high as $\sim 10^9\,\mathrm{n\,sr^{-1}}$ and an instantaneous neutron flux above $10^{23}\,\mathrm{n\,cm^{-2}\,s^{-1}}$. Considering a realistic repetition rate of one laser shot per minute, the corresponding time-averaged neutron flux is predicted to reach record values of $7\times10^6\,\mathrm{n\ sr^{-1}\,s^{-1}}$, even with a simple thin foil as a primary target. A further boost up to above $5\times10^7\,\mathrm{sr^{-1}\,s^{-1}}$ is foreseen using double-layer targets with a deuterated solid substrate. Our results draw a pathway for improvement at upcoming 10 PW lasers in which case neutron generation will be more strongly dominated by spallation [2].

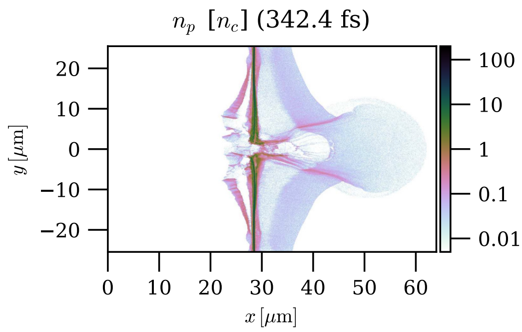

Figure 1: *PIC simulation of proton acceleration in relativistic transparency regime.*

References

[1] K. Burdonov *et al.*, Matter Radiat. Extremes **6**, 064402 (2021).

[2] B. Martinez *et al.*, Matter Radiat Extremes **7**, 024401 (2022).