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Assessment of the feasibility of measuring neutron-induced reactions at a laser-driven neutron beam

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The fast development of high-power lasers (> 10ˆ19 W/cm2) with ultrashort pulses (˜ fs), and their applications as compact particle accelerators, are emerging as a promising alternative to conventional accelerators for producing neutron beams. Laser-driven neutron sources (LDNS) are especially attractive for nuclear physics applications based on the time-of-flight technique due to their short pulse length and high instantaneous flux. However, the feasibility of carrying out nuclear physics experiments with laser-driven neutron beams is subject to the response of the detectors currently used in conventional neutron sources.

Recently, the neutron beams user community has been focusing its attention on developing small-scale and compact neutron sources as a complement to major facilities to fully exploit all the possibilities of these techniques. In this context, laser-driven ion sources are garnering the interest of the nuclear physics community due to the fast development of ultra-short (˜ fs) and ultra-high power lasers and their applications as compact particle accelerators. Laser-driven neutron sources (LDNS) are particularly attractive for nuclear physics applications based on the time-of-flight technique thanks to their short pulse length and high instantaneous flux.

There are several recent works about neutron production by laser reaching fluxes per pulse competitive to those of conventional neutron sources, but there is a lack of studies in terms of their application
to nuclear physics experiments. There has been a lot of effort aimed at mitigating the impact of the harsh prompt radiation and the electromagnetic background in sensitive neutron diagnostics, mostly based on single-shot PW-class and TWclass lasers at high repetition rates. However, the typical current-mode operation of neutron detectors in LDNS experiments is not suitable to carry out neutron-induced nuclear reaction experiments, since those require the detection of single signals corresponding to the observables from the individual reactions and processes involved.

In 2021, an experimental campaign was carried out in the complex environment of an LDNS at the DRACO laser facility of the Helmholtz Center Dresden-Rossendorf (HZDR) in Dresden, Germany, producing neutron shots at 0,02 Hz in a high-power system in stable conditions. In addition to conventional scintillators and bubble detectors operated in current/integrated mode, multi-shot neutron production made it possible to use a neutron and charged particle detector with low efficiency, i.e. diamond detector, to measure individual signals from fast neutron interactions. The characterization of the neutron source resulting from two different nuclear reactions, Cu(p,n) and LiF(p,n), by means of the individual signals and the time-of-flight technique, has been positively validated against Monte Carlo simulations, confirming the feasibility of measuring single fast neutron interactions at an LDNS.

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