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The ^{39,41,42}Ar nuclides as probes of neutron-induced reactions in a high-density plasma at the National Ignition Facility: a proposed experiment and calibration measurements

Inertial fusion laser-induced implosions at the National Ignition Facility (NIF) are a unique environment to reproduce astrophysical conditions in the laboratory. The laser energy is used to compress and heat a capsule filled with deuterium-tritium fuel to conditions (density, temperature, and pressure) comparable to or exceeding those in the center of stars. Recent experiments at NIF first passed the burning-plasma threshold [1,2], where self-heating exceeded the external heating applied to the fuel and produced record fusion yields of ≈1 MJ . Neutrons are produced in a volume with a radius of ˜50 μm within ˜100 ps, representing a uniquely high neutron density approaching 10^{22} cm^{-3} close to those of the astrophysical r process and fluxes of 10^{31} cm^{-2}s^{-1}. In a dedicated NIF high-power laser shot, we plan to investigate the following neutron-induced reactions on ^{40}Ar incorporated in the capsule gas; the chemical inertness of noble gas Ar allows for reliable collection of reaction products. The ^{40}Ar$(n,2n)^{39}$Ar reaction is a direct monitor of the fast-neutron flux and the ^{40}Ar$(n,\gamma)^{41}$Ar and ^{40}Ar$(2n,\gamma)^{42}$Ar reactions are sensitive to energy downgraded neutrons. The latter reaction is a monitor of extreme neutron densities produced in the process and may provide an indication of the feasibility to study the important ^{58}Fe$(2n,\gamma)^{60}$Fe reaction [3] in the laboratory. The long-lived ^{39}Ar ($t_{1/2}$ = 268 y) and ^{42}Ar (33 y) nuclides are detected via noble-gas accelerator mass spectrometry at Argonne National Laboratory. We report here on calibration measurements of the total yield of the ^{40}Ar$(n,2n)^{39}$Ar reaction in a 14 MeV neutron activation, investigated for the first time. The neutron activation was performed with the DT neutron generator of Technical University Dresden located at Helmholtz-Zentrum Dresden-Rossendorf. Direct detection of the ^{42}Ar nuclide in a ^{40}Ar sample activated by the slow double-neutron capture reaction ^{40}Ar$(n,\gamma)^{41}$Ar$(n,\gamma)^{42}$Ar at the high flux reactor of Institut Laue-Langevin was successfully demonstrated for the first time. Preliminary results of these calibration experiments are presented.

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[1] A. B. Zylstra et al., Nature 93, 542 (2022).
[2] A. L. Kritcher et al., Nature Phys. 18, 251 (2022).
[3] W. Wang et al., Astrophys. J. 889, 169 (2020)

Length of presentation requested

Oral presentation: 17 min + 3 min questions

Please select between one and three keywords related to your abstract

Nuclear physics - experimental

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