Charge-State Resolved Laser Acceleration of Gold Ions to Beyond 7 MeV/u

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The rapid-neutron capture process (r-process) is responsible for generating most of the heavy elements beyond iron in the Universe. A full understanding of this process, however, still lacks information about the nuclear properties of the involved isotopes, especially around the waiting point at the magic neutron number N = 126. The fission-fusion reaction mechanism [1] was proposed to produce such neutron-rich nuclei around N = 126, exploiting unique properties of laser-driven ion acceleration. This mechanism requires heavy ions with kinetic above the fission barrier (ca. 7 MeV/u in this mass range) at ultra-high densities, as can only be provided by laser-driven heavy-ion bunches accelerated (with almost solid-state density) in the Radiation Pressure Acceleration (RPA) regime.

While still waiting for laser systems sufficiently intense for the realization of RPA, like the 2x10 PW laser currently commissioned at ELI-NP in Măgurele near Bucharest, we used available high-power (PW-class) lasers to explore laser-driven heavy ion acceleration. Most recently, the PHELIX laser at the GSI in Darmstadt, Germany, was used to accelerate gold ions to energies above 7 MeV/u, which is in reach of the fission threshold needed for the fission-fusion reaction scheme. Additionally, we were for the first time able to resolve individual gold ion charge states, which revealed a remarkable target thickness dependency of the charge state distributions. These results cannot be easily explained by the established ionization mechanisms, thus motivating the need for further theoretical and experimental investigations of the ionization dynamics in laser-generated plasmas.

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References

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