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First inverse-kinematics fission measurements in a gaseous active target

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Abstract

The fission of a variety of actinides was induced by fusion and transfer reactions between a ^{238}U beam and ^{12}C nuclei, in the active target MAYA. The performance of MAYA was studied, as well as its capability to reconstruct the fission-fragment trajectories. Furthermore, a full characterization of the different transfer reactions was achieved, and the populated excitation-energy distributions were investigated as a function

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of the kinetic energy in the entrance channel. The ratio between transfer- and fusion-induced fission cross-sections was also determined, in order to investigate the competition between both reaction types and its evolution with the incident energy. The experimental results will be discussed with a view to forthcoming radioactive-ion beam facilities, and next-generation active-target setups.

Keywords: Active target; Inverse kinematics; Fission; Surrogate reactions; Nucleon transfer; Fusion

1. Introduction

Accurate fission models remain today phenomenological [1], and they tend to fail when applied to unknown systems. Therefore, the requirements of fundamental and applied research in predictive power of models often remain unaccomplished. This status reflects the need of enlarging the body of data, and, more specifically, the number of fissioning systems available to experimental research.

From an applied perspective, many of the nuclei of interest for nuclear-energy applications are highly radioactive and difficult to study in the laboratory. Fundamental research reaches an even more exotic domain, and it requires model-dependent extrapolations. In nuclear astrophysics, the determination of reliable fission barriers and fission-fragment distributions is an urgent need for understanding nucleosynthesis processes [2]. Moreover, theoretical predictions of the fission barriers of exotic systems, whose existence would be caused by structural effects, drive the quest for superheavy nuclei [3].

In the framework of surrogate-reaction studies [4], nucleon-transfer reactions provide experimental access to fissioning systems that can not be investigated by standard neutron irradiation. This technique has been widely used to measure fission probabilities and to study actinide fission barriers [5]. It also allows the neutron-induced fission cross sections to be estimated when direct measurements are not available [6].

Transfer-induced fission experiments have traditionally employed very light projectiles, such as protons, deuterons, or helium, and actinide targets [7]. Under these circumstances, the transfer is restricted to a few nucleons, and only systems close to the limited available targets can be produced. A different approach has been developed at GANIL [8], which is based on an inverse-kinematics configuration. In a single experiment [9], the transfer of nucleons between a ^{238}U beam and a ^{12}C target produced a wide variety of neutron-rich fissioning systems. Using an accelerated heavy-ion beam, the kinematic boost of the fission fragments has brought new physical observables into the surrogate-reaction studies. Accurate measurements of the fission-fragment isotopic yields were performed [10,11], and unprecedented access to the scission-point configuration was obtained [12].

However, the excitation energy, the angular momentum, and the fission barrier of the compound nucleus influence its decay through fission [4]. In order to apply the data obtained via transfer reactions to scenarios where fission is induced by neutrons, the properties of the compound nucleus must be understood. Important examples of neutron-induced fission scenarios are nuclear reactors and, in the astrophysical domain, the r-process of nucleosynthesis.

In Ref. [9], the excitation-energy distributions and the fission probabilities of the actinides produced through $^{238}\text{U} + {}^{12}\text{C}$ transfer reactions were measured. Additional information on the

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