Contribution ID: **3** Type: **Contributed talks**

Direct neutron capture cross section measurements of trapped short-lived isotopes at SARAF-II

Monday, 28 June 2021 10:35 (20 minutes)

Direct measurements of neutron capture cross sections of short-lived isotopes, especially in the neutron-rich realm, are of vast interest to nuclear physics and astrophysics, but are currently impossible due to the instability of both projectile and targets. We propose a concept of such measurements for thermal (or cold) neutrons at Phase-II the Soreq Applied Research Accelerator Facility (SARAF-II), currently under construction in Yavne, Israel. SARAF-II will have the unique capability to produce a world-competitive rate of fission fragments and high-flux neutron beams in the same facility [1], making it an optimal site for such measurements.
Neutron-rich isotopes will be produced by neutron-induced fission of thin actinide targets and thermalized in a cryogenic gas-filled stopping cell. They will be extracted and mass-separated in an RFQ beam-line, and isotopes of a specific isobar chain will be accumulated in a special RF linear trap. The SARAF-II ion beam will then be diverted to a different target, which will produce thermal or cold neutrons that will irradiate the trapped neutron-rich isotopes. Using thermal or cold neutrons will enable us to guide and focus the neutrons onto the isotope cloud inside the trap, optimizing the reaction rate. The isotopes that capture a neutron will be ejected to a multiple-reflection time-of-flight mass-spectrometer (MR-TOF-MS), which is precise enough to identify them unambiguously by their mass. The overall ratio between the amounts of a specific A+1 isotopes and their A predecessors will provide the neutron capture cross section of each of the different A isotopes.
For the above system, our preliminary estimations indicate a rate of a few events/day/barn, for isotopes with half-lives down to the range of tens of minutes. Due to the cleanliness of our measurement that is basically background free, such a rate should be detectable. Based on theoretical cross section estimations, tens of new cross sections of unstable isotopes may be measured. In addition, we may discover more isotopes with surprisingly high neutron capture cross sections (see, e.g., [2]), which current theoretical cross-sections convolved with their fission yield render undetectable with our method.
The isotope-target trap will have to contain isotope kinetic energies of up to a few hundred eV due to ongoing beta decay in the trap and the recoil of the A+1 isotopes following thermal or cold neutron capture. We will present a conceptual design of such a trap, and possible ejection methods that single out A+1 isotopes with respect to A. Experimental tests of the maximal isotope storage amount and trapping duration will be performed in the near future on the triple-RFQ trapping system developed at Justus-Liebig-University Giessen, Germany [3].

[1] I. Mardor et al., Eur. Phys. Jour. A 54: 91 (2018)
[2] J. A. Shusterman et al., Nature 565, 328 (2019)
[3] E. Haettner et al. Nucl. Instr. Meth. A 880, 138 (2018)

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Session Classification: Introduction 2