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Solving the Puzzle of the Cosmochronometer 92Nb Production Sites

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Charge-Exchange (CE) reactions are an important tool for studying the spin-isopin response of nuclei. They can be utilized to obtain information about interactions mediated by the weak nuclear force, such as β and electron capture decay. Using the proportionality between Gamow-Teller strength (B(GT)) and the CE differential cross section, B(GT) distributions can be extracted indirectly. Since CE reactions are not limited to a narrow Q value window, they provide information that is complementary to information obtained from β and electron capture decay. Such data are necessary for constraining reaction rates that happen in dense and hot astrophysical environments. The main goal is to combine measurements in which GT strengths are extracted with γ-decay measurements, utilizing the Charge-Exchange Oslo (CE-Oslo) method to extract level densities and γ-ray strength functions, which are also important for constraining astrophysical reaction rates. As an initial test, the CE-Oslo method is being tested on 93Nb(t,3He+γ) data taken previously with the S800 spectrometer in coincidence with the GRETINA γ-ray detector at FRIB. The γ-coincidence data for 93Zr was applied with the Oslo method to develop the CE-Oslo method, and nuclear level densities (NLDs) and γ-ray strength functions (γSFs) of 93Zr were then extracted. These NLDs and γSFs were then used as inputs for the Hauser-Feshbach calculations using the TALYS to indirectly constrain the 92Zr(n,γ) cross sections, and hence 92Zr(n,γ) Maxwellian-averaged cross sections, which are crucial for understanding the astrophysical s-process nucleosynthesis. The results of this analysis will be published soon as the first publication of the CE-Oslo method. It is also planned to measure the 92Zr(3He,t+γ) reactions in RCNP, as well as 93Nb(p,d+γ) reactions in the Oslo-Cyclotron laboratory to independently apply the CE-Oslo method and Oslo Method, respectively, and extract reaction rates for the nucleosynthesis of cosmochronometer 92Nb. This high-precision study will lay a solid foundation for using the CE-Oslo method in future (p,n+γ) experiments in inverse kinematics with rare isotopes and make it possible to simultaneously extract NLDs, γSFs, β-decay strengths, and (β-delayed) neutron decay probabilities (Pn) on neutron-rich unstable nuclei, which are important for several nucleosynthesis processes, including the r, i, γ, and ν processes. The high resolution available for (3He,t) experiments at RCNP will also make it possible to extract level densities in two independent manners: by using the CE-Oslo technique and by using the fine-structure analysis. From the measurement on 92Zr, it will be possible to extract level densities and γ-ray strength functions which are relevant for the γ-process in type Ia supernovae and Gamow-Teller strength distributions of relevance for the ν-process in core-collapse supernovae. These astrophysical phenomena are the possible sites for the production of long-lived 92Nb, which can serve as a cosmochronometer.

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Author: DEVA PATHIRANA, Neshad (Michigan State University and Facility for Rare Isotope Beams)

Co-authors: Prof. ZEGERS, Remco (Michigan State University and Facility for Rare Isotope Beams); Prof. SPYROU, Artemis (Michigan State University and Facility for Rare Isotope Beams); Prof. LARSEN, Ann-Cecilie (University of Oslo); Prof. GUTTORMSEN, Magne (University of Oslo); Dr NOJI, Shumpei (Facility for Rare Isotope Beams); Dr GAO, Bingshui (Institute of Modern Physics); Prof. RILEY, Lewis (Ursinus College)

Presenter: DEVA PATHIRANA, Neshad (Michigan State University and Facility for Rare Isotope Beams)