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New experimental techniques to inform neutron-induced reaction cross sections on rare isotopes with surrogate reactions.

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Understanding neutron-induced reaction rates on rare isotopes is important in fission and nucleosynthesis processes and applications in nuclear energy and forensics and stewardship science. Informing these rates requires indirect methods and rare isotope beams. The Surrogate Reaction Method (SRM) [1], where beams interact with light-element targets, has been demonstrated [2] as a valid method to inform neutron-induced reaction rates. In the SRM the same compound nucleus (CN) can be formed as in the neutron-induced reaction and differences, in particular entrance spin-parity distributions, can be accounted for with nuclear reaction calculations. To date most of the SRM applications for (n,γ) reactions have involved measuring discrete γ-ray transitions in an established level scheme, to determine the gamma-decay probabilities of the CN. Low beam intensities of rare isotope beams require high efficiency, high resolution arrays of gamma-ray detectors to detect the discrete transitions. However, even the state-of-the-art γ-ray detector arrays are only about 15% efficient, with efficiency strongly dependent on γ-ray energy. A particular challenge is when the final nucleus is odd-odd, where not only may little be known about the level scheme, but the decay of the compound nucleus is likely to fragment into many paths. Our collaboration has recently developed the techniques to measure the γ-ray decay probability of a final nucleus in a surrogate (d,p) reaction, without requiring discrete γ-ray transitions.

The Oak Ridge Rutgers University Barrel Array (ORRUBA) of position sensitive silicon strip detectors was coupled to the S800 spectrograph at NSCL to inform 84Se(n,γ) rates with the SRM (d,p) reaction [3]. Beam-like reaction products were measured in the focal plane of the S800 in coincidence with (d,p) reaction protons. By measuring the S800 focal plane energy loss as a function of time of flight, the 85Se recoils could be separated from the un-reacted 84Se beam, with about 35% efficiency. The 84Se from neutron emission from the 85Se CN has sufficiently different kinematics that these ions are well separated from the 85Se desired product and can be blocked in the focal plane, along with most of the unreacted 84Se beam. By careful measurement of the proton singles in the 84Se(d,p) reaction, the (n,γ) cross sections as a function of neutron energy can be informed. The collaboration is scheduled to measure the (d,pγ) reaction with ORRUBA coupled to GRETINA and the S800 in April 2024 with 80Ge and 75Ga FRIB beams. These measurements would inform (n,γ) rates important for nucleosynthesis processes intermediate between slow and rapid neutron capture.

This talk would present the experimental techniques used in the earlier 84Se measurement of ORRUBA +S800 and how (n,γ) rates can be informed, as well as preliminary results from the Spring 2024 FRIB measurements.

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[1] J.E. Escher et al., Rev. Mod. Phys. 84, 253 (2012)
[2] A. Ratkiewicz et al., Phys. Rev. Lett. 122, 052502 (2019).
[3] H.E. Sims, PhD Dissertation Rutgers University (2020) and to be published.

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