Experimental techniques for surrogate neutron induced reactions with radioactive ion beams*

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Most of the elements heavier than iron are synthesized via neutron-induced reactions in stars and explosive scenarios in the cosmos. The slow neutron capture s-process proceeds along the line of nuclear stability and occurs in AGB stars. The rapid neutron capture r-process produces very neutron rich isotopes in explosive scenarios such as core collapse supernovae or mergers of neutron stars. There are also weak r- and intermediate i-processes that occur in specific stars and stellar scenarios. To understand the abundance patterns of heavy elements, requires nuclear properties, including neutron capture (n, γ) rates on specific isotopes. Neutron capture rates important for nucleosynthesis can be informed by measuring light-ion reactions with radioactive ion beams (RIBs) and subsequent analysis with the Surrogate Reaction Method (SRM) [1]. Because of the low intensity of RIBs, detector systems need to have large solid angle coverage and good energy resolution and include light-charged particle, heavy recoil and gamma-ray detectors.

The GODDESS system [2] has been developed for radioactive ion beam studies and surrogates for neutron- induced reactions. GODDESS - Gamma-array ORRUBA: Dual Detectors for Experimental Structure Studies - deploys the Oak Ridge Rutgers University Barrel Array of position sensitive silicon detectors for light ions and coupled to large arrays of Ge detectors, most recently GRETINA. GODDESS has been coupled to the S800 spectrograph for studies with Facility for Rare Isotope beams and CD_2 targets for surrogate measurement. This presentation will summarize the experimental techniques and preliminary results from measurements with $A \sim 80$ RIBs that could inform neutron-induced reaction rates for nucleosynthesis.

[1] J.E. Escher *et al.*, Rev. Mod. Phys. **84** (2012) 253
[2] S.D. Pain *et al.*, Phys. Procedia **90** (2017) 455.

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