Direct (p,n) Reaction Measurements of Astrophysical Interest Using Radioactive Beams: A Novel Approach with SECAR

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The synthesis of elements beyond iron heavily relies on neutron-induced reactions. Studies indicate that certain key (n,p) reactions, such as ^{56}Ni(n,p)^{56}Co and ^{64}Ge(n,p)^{64}Ga, can accelerate the neutrino-p process (vp-process), contributing to element creation between Ni and Sn during type II Supernovae. This process occurs in regions with a slight excess of protons within the v-driven wind of core-collapse supernovae, involving a sequence of proton-capture and (n,p) reactions. The limited neutron abundance essential for (n,p) reactions originates from anti-neutrino captures on free protons.

The new approach introduced in this study involves investigating (n,p) reactions through the measurement of the reverse (p,n) reactions in inverse kinematics, using a heavy radioactive beam directed at a hydrogen target, and applying the detailed balance principle [1]. Reaction recoils are separated from the unreacted beam and detected using SECAR (SEparator for CApture Reactions) [2] at FRIB (Facility for Rare Isotope Beams). Measuring (p,n) reactions poses challenges due to the almost identical masses of recoils and unreacted projectiles. Nonetheless, an appropriate separation is achieved by employing neutron tagging alongside SECAR. In a recent experiment, the direct measurement of the ^{58}Fe(p,n)^{58}Co reaction in inverse kinematics, at 3.65 MeV/u was successfully performed by detecting emitted neutrons at the target location and ^{58}Co ions at the end of the SECAR beamline. Neutron detection utilized a combination of organic liquid and plastic scintillators, while for heavy ions, the SECAR's ΔE-E detection system consisting of an Ionization Chamber (IC) and a Double-sided Silicon Strip Detector (DSSD) was employed. This direct measurement of the ^{58}Fe(p,n)^{58}Co reaction complements earlier results obtained via activation techniques and is expected to enhance cross-section data. It also opens the path for further (p,n) reaction measurements with significant astrophysical importance using radioactive beams. The first results and experimental details of this technique will be presented.

References

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