^{26m}Al proton resonant elastic scattering with CRIB

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^{26}Al is known as the first specific radioactivity discovered with extraterrestrial origins.[1] The observed spatial and velocity profiles of galactic ^{26}Al provide insights to nucleosynthesis and galactic chemical evolution. In this context, the stellar nuclear reactions which produce and destroy ^{26}Al should be sufficiently constrained by experimental data when possible, in order to reduce the uncertainties on the ejected mass of ^{26}Al calculated in various stellar models. Knowledge of the reaction rate of radiative proton capture on the low-lying isomeric state ^{26m}Al(p,γ) is still lacking, particularly at higher excitation energies when the two species ^{26g,m}Al are expected to be in thermal equilibrium ($>$ 1 GK).

We performed the first measurement of mixed ^{26g,m}Al proton elastic scattering at the CNS low-energy RI beam separator (CRIB)[2] to search for low-spin states with large Γ_p which may influence the ^{26m}Al(p,γ) rate. Considering the isomer's excitation energy of 228 keV, the typical operating resolution of CRIB ($\frac{\Delta p}{p} \sim 1\%$) is insufficient to distinguish the two ^{26}Al species event by event. To make the measurement tractable, we considered that the ^{26}Mg(p, n)^{26}Al reaction cross section shows anticorrelated yield for ^{26g,m}Al depending on $E_{c.m.}$[3] as well as that the previous measurement of ^{26g}Al(p, p) showed only Rutherford scattering over the measured energy range.[4]

We produced the cocktail beam inflight via the ^{26}Mg(p, n)^{26}Al reaction in inverse kinematics. A primary beam of $^{26}Mg^{8+}$ was extracted from the Hyper-ECR ion source, accelerated up to 6.65 MeV/u by the AVF cyclotron, and delivered to CRIB with typical intensities of 25–50 pnA. The ^{26}Mg beam impinged on the CRIB cryogenic production target, which contained H_2 at 130–290 Torr at an effective temperature of 90 K over 8 cm (0.4 to 0.8 mg cm^{-2}). By varying the H_2 gas pressure as well as a removable Havar energy degrader foil upstream of the production target, we could control $E_{c.m.}$ and hence the isomeric purity of the cocktail beam. We regularly monitored the isomeric purity using β-decay measurements in a beam pulsing mode.

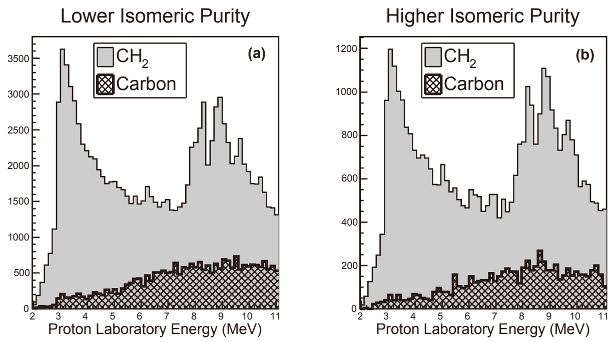

Fig. 1. Example laboratory residual proton energy spectra obtained near 0°. The isomeric purity of (b) is higher than (a).

The decay measurements were interpreted with the assistance of GEANT4 simulations, and we found the isomeric purity was approximately 40–60% depending on the experimental conditions. The ^{26}Al cocktail beams had an average intensity of 1.5×10^5 pps, 93% purity, and on-target energies of 68, 83, and 93 MeV

To measure the physics of interest, the ^{26}Al beam was tracked with two PPACs before fully stopping in a 7.5 mg cm^{-2} CH_2 foil which served as a proton target. Scattered protons were measured at forward laboratory angles with ΔE–E silicon telescopes. Background contributions from carbon in the polyethylene target were evaluated by intermittently exchanging the CH_2 foil with a 10.6 mg cm^{-2} carbon foil. Examples of the preliminary laboratory proton energy spectra are shown in Fig. 1. The background contribution from carbon (scaled to the number of incident ^{26}Al ions) looks smooth, and hints of some peak-like structures seem to emerge when the isomeric purity is higher. These preliminary results look promising for our future analysis, where we will add all the kinematic conditions including all energy losses to obtain the proton scattering excitation function in the center-of-mass frame. Finally, we plan to extract resonance parameters with an R-matrix analysis.

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