^{26m}Al beam production with CRIB

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The γ-ray emission associated with the radioactive decay of ^{26}Al is one of the key pieces of evidence indicating stellar nucleosynthesis is an ongoing process in our Galaxy. Its ground state ^{26g}Al has a half-life of 7×10^5 yr owing to its high spin $J^\pi = 5^+$, and it predominately decays to the first excited state in ^{26}Mg, which promptly de-excites by emitting a characteristic 1.809 MeV γ-ray. The situation is complicated by a low-lying isomeric state ^{26m}Al at 228 keV; this $J^\pi = 0^+$ isomer decays with a half-life of 6.3 s directly to the ground-state of ^{26}Mg.

Little is known about the ^{26m}Al(p, γ) reaction rate, and in a sensitivity study on ^{26}Al yields from massive stars, the (p, γ) rate on the isomeric state was assumed to be the same as for the ground state[1)], despite the large spin-parity difference. At present, there is only limited information on J^π and no proton partial widths Γ_p are known for low-spin resonances above the proton threshold in ^{27}Si.

In preparation for a measurement of proton elastic scattering, we undertook a two-day machine test to check the production yield, purity, and phase-space parameters of ^{26m}Al at the Center for Nuclear Study low-energy RIB separator (CRIB)[2)]. A primary beam of ^{26}Mg^{8+} was accelerated to 6.77 MeV/u and impinged on the CRIB cryogenic production target[3)], which was filled with 260 Torr of H_2 gas at 90 K (0.7 mg·cm^{-2}) and sealed with 2.5 μm Havar foils, producing the RIB of interest via the ^{1}H(^{26}Mg, ^{26}Al)n reaction. These conditions were chosen to optimize production of ^{26m}Al over ^{26g}Al based on the literature cross-sectional data[4)]. A sample particle identification plot at the achromatic focal plane F2 is shown in Fig. 1. ^{26}Al^{13+} production yield was optimized at 119.6 ± 1.5 MeV. After passing through a Wien filter, the ^{26}Al purity was 80–90% at the experimental focal plane F3, with ^{23}Na as the main contaminant. The typical intensity of ^{26}Al was 1×10^5 pps (at 25 pnA). The setup at the experimental focal plane consisted of two parallel plate avalanche counters (PPACs), a 7.5 mg·cm^{-2} CH_2 target, and a silicon telescope (SSDs).

A key purpose of the machine test was to determine the isomeric purity ^{26m}Al/^{26}Al in the cocktail beam. Although CRIB does not have the capability to distinguish between ^{26g,m}Al for individual ions, a previous measurement of ^{26g}Al(p, p) showed no resonant structure[5)]. The previous work reduces our inability to uniquely identify the state of ^{26}Al event-by-event to background subtraction, provided we have a reliable determination of the isomeric purity.

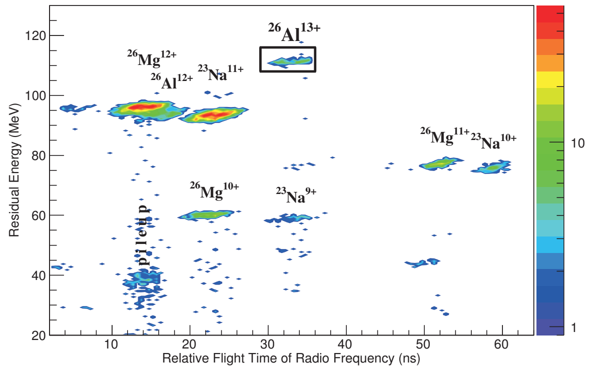

Fig. 1. Particle identification of the beam at the focal plane F2. The abscissa shows relative flight time and the ordinate shows the residual ion energy. The optical settings used to produce the histogram are not optimized for ^{26}Al but are useful for illustrative purposes.

To determine the isomeric purity, we performed a decay study by pulsing the primary beam in an on/off mode with a duty cycle of 12 s. When the beam was on it was implanted into the CH_2 target, and when the beam was off, we measured β^+ particles with the SSDs. Considering the long half-life of ^{26g}Al and that ^{23}Na is stable, it is reasonable to assume that all β^+ particles emitted from the target when the beam was off can be associated with the decay of ^{26m}Al (which does not decay by electron capture). Our preliminary measured half-life for the decay associated with these particles is 6.1 s; this value is close to the known ^{26m}Al half-life of 6.3 seconds considering we have yet to evaluate our error. The shape of our preliminary β^+-decay spectrum was also consistent with the expectation for ^{26m}Al. We tentatively calculate an isomeric purity of $\approx 40\%$ from the test run data. We anticipate that the developed ^{26m}Al beam is satisfactory to observe low-ℓ proton resonances with large widths in the future.

References

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