Progress on the analysis of the beta-delayed proton and gamma decay study of ^{27}P

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The first observation in the interstellar medium of the 1.809 MeV gamma-ray line originating from the β-decay of ^{26}Al [1] was an important discovery in the history of Nuclear Astrophysics. Due to its (relatively speaking) short half-life of 7.2 x 10^5 years, its observation in the galactic environment was indicative of ongoing nucleosynthesis. The destruction of ^{26}Al can be accomplished by proton capture on either the ground state or the metastable-state. Therefore, understanding all processes involved is key to pinpointing the currently unknown stellar creation and destruction sites. The purpose of this experiment was to look into the $^{26}Al^m(p,\gamma)$ reaction.

The very nature of stars make this reaction very difficult to study directly because of the extremely low cross section involved (due to tunneling through the Coulomb barrier) and the presence of electrical noise and natural background in the lab environment, which can be minimized but never entirely eliminated. Thus, an indirect method was employed to gain the required information, the β-delayed proton decay of ^{27}P. This method was chosen because the selection rules involved populated the same states of interest in the indirect as well as the direct approach, summarized below in Fig. 1. The states of interest, resonances in the direct proton capture process, are located above the proton threshold (E* > Sp + E(0+) = 7.463 + 0.228 = 7.691 MeV), so that they can then decay by proton emission to the metastable-state in ^{26}Al.

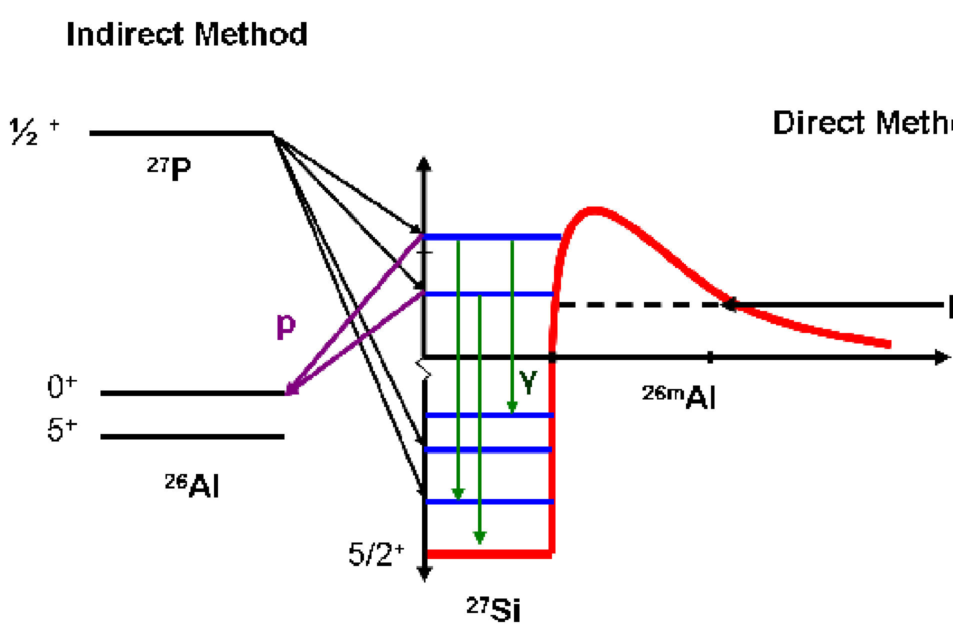

FIG. 1. Comparison between direct and indirect processes.

The general experimental setup was covered in detail by [2,3], however, significant changes were made to the implantation and decay station placed at the end of MARS for this experiment. The main goal of the re-design was to move the HPGe detectors in as close as possible to the point of implantation in the thin silicon detector. This involved a total re-location of all internal parts such as the water cooling pipes and the detector holder itself, as well as the external parts such as the electrical feedthrough components. The efficiency was greatly increased, especially in the low energy region, as desired, but it should be noted that this increased efficiency also increased the presence of sum peaks in the gamma-ray spectra, requiring careful peak identification.

The protons observed by the Berkeley group [4], whom were the first to study the β-delayed proton decay of ^{27}P, were also identified in this experiment. However, in the region of interest (~200 keV), only background was observed despite the fact that this experiment reduced the noise level significantly from earlier experiments of the same type. This was due to the extremely low proton branching ratio involved (estimated originally at 0.07%). Attempts to subtract out this background resulted in a 'bulge' remaining, as shown below in Fig. 2 [5]. With an upper and lower estimate on the β-background included, the total proton branching ratio was found to be 0.155(3)% – 0.163(3)%. A detector that is less sensitive to β-particles while retaining good energy resolution, efficiency and linearity would be ideal to improve upon the conclusions reached with this experiment.

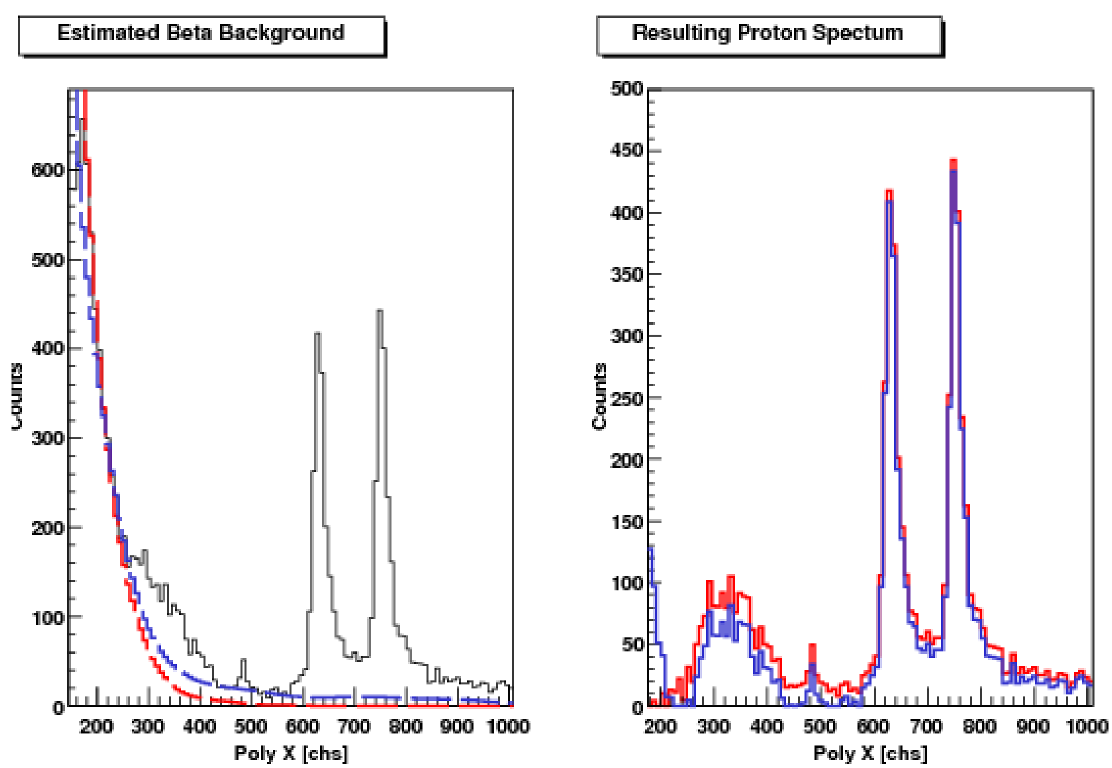

FIG. 2. Upper and lower estimates for the β-background from the 22P decay measurement. The right panel shows the β -delayed proton spectrum after the β -background are subtracted.

Never before has a study been done on the population of states in ^{27}Si from the β-decay of ^{27}P. Thus, several gamma-rays that were predicted but never seen due to selection rules [6, 7] have been confirmed, as well as the identification of gamma-rays never before observed. With the aid of a better half-life value (soon to be published) the log *ft* values for each level identified were calculated and the spin and parity were assigned based on selection rules. Most importantly, the isobaric analog state was found to lie at 6638 (1) keV, differing significantly from previous values [8, 9]. Currently work is being done on improving all calibrations and final numbers in preparation for publication. A Geant4 simulation is being created to estimate the efficiency of the silicon detector setup and to help understand the overall results.

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