Background free measurement of β-delayed protons from ^{27}P for the astrophysical ^{26m}Al(p,γ)^{27}Si reaction

A. Saastamoinen, I. Stefanescu,[1] S. Hallam,[2] G. Lotay,[2] E. Pollacco,[2] B. Reed,[2] B.T. Roeder, A. Spiridon,[1] L. Trache,[1] and R.E. Tribble

[1]*National Institute of Physics and Nuclear Engineering, Bucharest-Magurele, Romania*

[2]*IRFU, CEA Saclay, Gif-sur-Yvette, France*

The cosmic gamma-ray emitter ^{26}Al has been observed throughout the galactic plane of the Milky Way. Its short half-life of only about 720,000 years is an evidence about ongoing nucleosynthesis in our galaxy. The exact sites of creation and destruction of ^{26}Al are not pinpointed yet. The main candidates range from asymptotic giant branch stars to Wolf-Rayet stars to explosive scenarios such as oxygen-neon novae and core collapse supernovae. Nucleosynthesis in these hydrogen burning stellar scenarios occurs via network of radiative proton capture (p,γ) reactions. Among these reactions, proton capture from either the ground state, or the low-lying isomer state, of ^{26}Al to states in ^{27}Si can lead to depletion of ^{26}Al. Therefore, understanding of the properties of states beyond the proton separation threshold (S_p) in ^{27}Si is a crucial input for the modeling and understanding the origins of ^{26}Al in our galaxy. Several indirect and direct measurements have identified states relevant for both ^{26g,m}Al(p,γ)^{27}Si reactions. However some of the spin-parity assignments remain uncertain, especially in case of ^{26m}Al(p,γ)^{27}Si.

We have used selective nature of beta-decay of ^{27}P to populate states in ^{27}Si to improve the situation with the spin-parity assignments of the states just above the proton threshold in ^{27}Si. This decay was studied previously at the Cyclotron Institute by using the implantation-decay station utilizing Si and HPGe detectors [1,2]. As before, for this experiment the ^{27}P beam was produced through ^{1}H(^{28}Si,^{27}P)2n reaction with 40 MeV/u ^{28}Si beam from the K500 cyclotron impinging on LN_2 cooled H_2 target at 2 atm pressure. The reaction products were separated and identified with MARS resulting about 76% pure ^{27}P with average intensity of 1200 pps during the 7 day run. Immediately before and after the ^{27}P data taking run a beam of ^{25}Si was produced for calibration purposes through fragmentation with same primary beam hitting a 10 mil aluminum target.

β-delayed protons from ^{27}P were measured with the AstroBox2 detector [3,4] which suppresses the β-background down to ~100 keV and allows unambiguous measurement of low-energy β-delayed protons in the region of astrophysical interest. AstroBox2 was operated with ultra-pure P5 gas mixture (Ar/CH_4: 95%/5%) at 800 torr with drift field of about 200 V/cm and amplification field of about 30 kV/cm. While the ^{25}Si was spread throughout the active volume for calibration purposes, ^{27}P was tuned to over the centermost pads with the optimized background suppression capabilities. To ensure a pure sample impurity components of the beam with possible particle emitters (^{24}Al and ^{25}Si) were made to exit completely the main volume and only ^{27}P and ^{26}Si (only beta-gamma emission) impurity were stopped inside the active volume resulting 96% pure sample of ^{27}P over the centermost pads with most implants.

During the beam time total of 1.5e8 ^{27}P were implanted over the pads with best background rejection. Fig. 1. shows a preliminary sum spectrum of multiplicity one (only one pad triggering at the time) events from these pads. The main previously known β-delayed proton groups from decay of ^{27}P at 466(3), 612(2), and 731(2) keV [5] are clearly visible. In addition, several previously unobserved low energy particle groups are present. Detailed analysis of the data is work in progress.

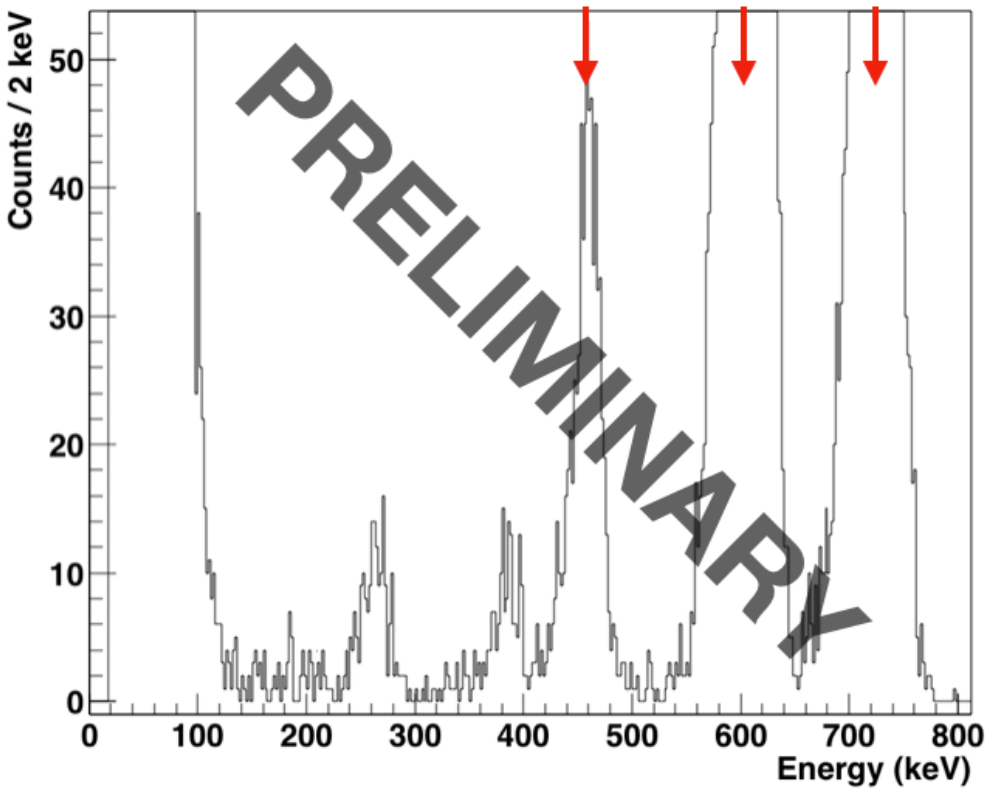

Fig. 1. Preliminary sum spectrum of the centermost pads with multiplicity one condition (only one pad firing at a time). The main previously known β-delayed proton groups from decay of ^{27}P at 466(3), 612(2), and 731(2) keV [5] are indicated with arrows. Several previously unobserved low-energy proton groups are present in the spectrum.

[1] E. Simmons, PhD Thesis, Texas A&M University, 2013.

[2] E. McCleskey *et al.*, Phys. Rev. C **94.** 065806 (2016).

[3] A. Saastamoinen *et al.*, Nucl. Instrum. Methods Phys. Res. **B376**, 357 (2016).

[4] A. Saastamoinen *et al.*, Nucl. Instrum. Methods Phys. Res. **B463**, 251 (2020).

[5] T.J. Ognibene *et al.,* Phys. Rev. C **54** 1098 (1996).