Measurement of β-delayed protons from decay of ^{31}Cl covering the Gamow window of $^{30}P(p,\gamma)^{31}S$ at typical nova temperature

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The thermonuclear runaway in classical novae proceeds through radiative proton capture reactions (p,γ) involving proton rich sd-shell nuclei close to the dripline. Many of the capture reactions at typical peak nova temperatures of 0.2-0.4 GK are dominated by resonant capture. Therefore, the key parameters in understanding the astrophysical reaction rates are the energies, decay widths and spins of these resonances. One of the bottleneck reactions in the ONe nova nucleosynthesis is the radiative proton capture $^{30}P(p,\gamma)^{31}S$.

In absence of intense ^{30}P radioactive beams, the experimental efforts for finding and studying the resonances in ^{31}S have concentrated on using a variety of indirect methods. One indirect method with high selectivity is the allowed β-decay of the $3/2^+$ ground state of ^{31}Cl which populates excited states in ^{31}S, corresponding to $l = 0$ resonances ($J^\pi = 1/2^+,3/2^+$) and $l = 2$ resonances ($J^\pi = 5/2^+$). An observation, or non-observation, of β -delayed protons or γ -rays from the levels with uncertain or contradicting spin assignments [1] will help constraining the possible astrophysically important states. The previous efforts on measuring β-delayed protons from the states of astrophysical interest in ^{31}S ($E_x \sim 100-500$ keV) have not been successful for the fact that these studies suffered from the intense β-background in the setups utilizing Silicon detectors [2,3]. Recently, a high statistics measurement of β-delayed γ-rays from decay of ^{31}Cl identified a new candidate for a resonance in the middle of the Gamow window [4]. Since the new level is seen populated in β-decay, it opens possibility for determining the proton branching ratio, which is one of the pieces of information needed for the experimental determination of the experimental value of the resonance strength.

We have done a measurement of β-delayed protons from ^{31}Cl with the newly built and commissioned AstroBox2 detector, based on Micro Pattern Gas Amplifier Detector (MPGAD) technology [5]. An intense and pure beam of ^{31}Cl was produced by bombarding a LN_2 cooled H_2 target at 2 atm with a 40-MeV/u ^{32}S beam from the K500 cyclotron at the Cyclotron Institute. The ^{31}Cl beam resulting from $^1H(^{32}S,^{31}Cl)^2n$ inverse kinematics reaction were separated with the MARS separator. The beam was implanted and stopped inside the gas volume of the AstroBox2 for the decay study. In this experiment we managed to suppress the β-background down to 100 keV, allowing a background free study of β-delayed proton emitting states in ^{31}S throughout the whole Gamow window of the $^{30}P(p,\gamma)^{31}S$ reaction. The experiment was calibrated by using known β-delayed protons from ^{25}Si [5,6]. Fig. 1 shows a multiplicity = 1 gated spectrum from one of the MPGAD pads, compared to a GEANT4 simulation. The data shows a good agreement with previously known higher energy protons. Moreover, a previously unobserved proton group is seen at the low energy part of the spectrum. The measured decay energy agrees with the new state which was observed in a recent βγ-study of decay of ^{31}Cl [4]. The data are under further analysis.

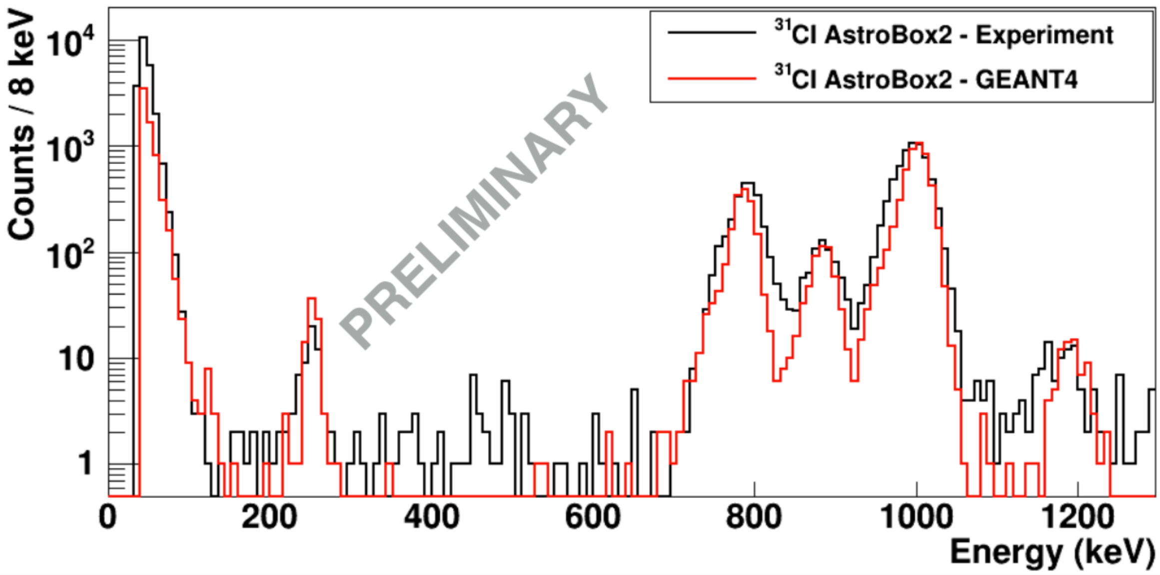

FIG. 1. The spectrum of β-delayed protons from ^{31}Cl compared to GEANT4 simulation. The intensities of the known proton groups agree with the experiments conducted with Si-detectors [2,3]. The low energy peak is in close agreement with the recently observed β-delayed γ-rays from a state in ^{31}S [6], suggesting the same origin.

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