^{35}K experiments

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One the most important questions that nuclear physics is trying to address the origin and abundance of the elements in the universe. Proton-gamma capture reactions, X(p, γ)Y, play an important role in the creation of elements in processes like X-ray bursts or novae explosions [1-3]. The main focus of this work is one of these reactions, ^{34g,m}Cl(p,γ)^{35}Ar. In novae, production of ^{34}S depends on the amount of ^{34}Cl, which β-decays into ^{34}S with a half-life $T_{1/2}$=1.5266 s. Sulfur isotopic ratios can be used for classification of presolar grains, which can be found in the meteorites. One way to destroy ^{34}Cl, is the reaction ^{34g,m}Cl(p,γ)^{35}Ar. The rate of this reaction will eventually determine how much ^{34}Cl will be left for the creation of ^{34}S. To be able to accurately predict the reaction rate of ^{34}Cl(p,γ)^{35}Ar, one needs to know the resonances in ^{35}Ar, including their energy, spin-parity, and proton width. We chose to study this reaction by means of an indirect method where we populate states in ^{35}Ar just above the proton threshold, S_p, and observe them decaying into ^{34}Cl + proton. The detection of low energy protons becomes the major challenge for the experiment. The AstroBoxII was built to address this problem [4,5]. To test our system we had an experiment in March, 2017. A beam of ^{36}Ar at 36 MeV/u was obtained from the K500 cyclotron and impinged on an H_2 cryogenic gas target in the target chamber of MARS [6]. Through the reaction ^{1}H(^{36}Ar,^{35}K)2n we created a secondary beam of ^{35}K and then implanted it into the AstroBoxII. After gain matching the AstroBoxII anode pads, we calibrated two HPGe detectors with ^{137}Cs and ^{152}Eu sources. The estimated production rate for ^{35}K was 2.77 event/nC. An Al degrader (13 mil) on a rotary mechanism was used to control the position for the implantation of ^{35}K in the AstroBoxII. Due to a number of technical issues the beam time was very limited with only about 6 hours of data available. This was sufficient to determine that the system was working as expected.

In July, 2017, we had a second experiment with a ^{35}K secondary beam produced through MARS. After initial calibration of the AstroBoxII by the beam of ^{25}Si we switched to a ^{35}K beam. The production rate for ^{35}K was 2.9 event/nC. Along with the AstroBoxII, we used four HPGe Clover detectors (borrowed from LLNL Hyperion array) that allowed us to measure the coincidences between protons and gamma rays. It was necessary for the setup to be sure that the excited states in ^{35}Ar that were populated by β-decay of ^{35}K are decaying directly to the ground state of ^{34}Cl after emission of a proton. Due to relatively low intensity of the ^{35}K beam to improve our results it was decided to have a third experiment in October, 2017. The setup was identical to the one we had in July, but with more time and higher beam current we significantly improved the statistics for the low energy proton spectrum, which was the main goal of the experiment.

The data analysis for these experiments was done as a part of the Ph.D. thesis of R. Chyzh. The major result is the report of a new proton group at an energy of 441(11) keV that corresponds to the 6348(11) keV level observed in ^{35}Ar. It was assumed that ^{35}Ar was decaying into ^{34}Cl in the ground state. The information available yields a limitation on the spin-parity for the state of $1/2^+$, $3/2^+$, and $5/2^+$. The information about the energy and spin-parity was used to estimate the reaction rate of $^{34}Cl(p,\gamma)^{35}Ar$ for this resonance. It was found to be in good agreement with a theoretical calculation provided by JINAWEB [7]. It is worth mentioning that the information on the resonance strength was not directly measured and future experiments are needed to extract full set of physical parameters required for such calculation.

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