The ^{32}S (p, γ) Resonance: A Measurement of Level Widths and Excitation Energies

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Introduction

The motivation behind this project lies in determining the e$^+$-ν correlation from ^{32}Ar beta decay. In the decay of ^{32}Ar the spins of the e$^+$ and ν must couple to zero, so they are opposite. Following the standard model, by which the decay takes place through vector currents, the momenta will then tend to be in the same direction. However, extensions may be possible within the standard model where the weak interaction is mediated through scalar currents, allowing for particles to be left-handed and anti-particles to be right-handed. In this case the momenta would be in opposite directions.

In order to search for this new physics, the e$^+$-ν correlation is measured by observing the recoil of the daughter nucleus. ^{32}Ar beta decays to an excited state of ^{32}Cl, which further decays to ^{31}S + p. One can get the information about the ^{32}Cl recoil by observing Doppler broadenings of proton peaks. The shape of the proton peak tells much information regarding the e$^+$-ν correlation. If the positron and neutrino have momenta in the same direction, the peak would be more spread out. However, if their momenta are in opposite directions, then the proton energy curve is narrower (Figure1).

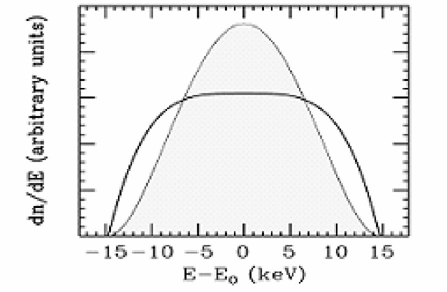

Figure 1 - Monte Carlo calculation of proton energy

Since the measurement is strongly dependent on the shape of the proton peaks, it is critical that the energies are measured very precisely. The energy calibration was done using β-delayed protons from ^{33}Ar beta decay. The energies of approximately five peaks are well-known from ^{32}S (p, γ) and ^{32}S (p, p) experiments. For our experiment we look at the width of a state in ^{33}Cl that was used in the calibration. When looking at the data from ^{33}Ar beta decay, that width is very narrow (≤1 keV), but previous measurements of ^{32}S (p, γ) indicate the width is larger. This indicates that perhaps the peak that is observed from ^{33}Ar decay does not correspond to the ^{32}S (p, γ) resonance and consequently it would jeopardize the energy calibration.

Experimental Setup

In a preliminary ^{32}S (p, γ) experiment, the width of the state of interest was determined to be about 7 keV. The limiting factor in this measurement was the thickness of the Ag_2S target. As an improvement, it was decided to use a very thin target that allowed us to hit the resonance without any unwanted background. We prepared thin targets in a variety of ways. In the first method a thin layer of Ag_2S was evaporated onto a thin carbon foil in vacuum. We observed that the carbon foil created γ-background (on being impinged by protons) in our energy range of interest.

As an alternative method, we heated a tiny fleck of sulfur approximately 2 cm away from a silver backing that was at high temperature following a method described by Watson [1]. Once the sulfur evaporates, it combines with the silver to form a thin layer of Ag_2S on the silver backing. The targets made using the evaporator had the advantage of immediately knowing the thickness of the target. Unfortunately we did not observe any gamma rays from ^{32}S (p, γ) using this evaporated target. However, the targets made following Watson's method worked, and their thicknesses were tested by varying the incident proton energy. For our measurement we decided to use a target that had a determined thickness of approximately $13\mu g/cm^2$ thick. To measure the gamma rays from the reaction we used a 50% High Purity Ge detector at 0° to the incident proton beam. We measure the resolution of the detector to be 3.7 keV using the 3.253 MeV gamma line from a ^{56}Co source.

^{32}S (p, γ) Experiment

In this experiment, a beam of protons is incident on a ^{32}S target. When it strikes the target, excited states of ^{33}Cl are formed, which then emit gamma rays to get to the ground state. The proton beam has an energy of 1757 keV. This energy corresponds to an excitation energy of 3972 keV, which will decay to the ground state either by giving off a 3972 keV gamma, or by emitting a gamma to get to the 811 keV excited state and then emitting a second gamma to get to the ground state. These gammas are detected in the germanium detector and then the resulting excitation function is plotted to analyze the data and get the final results.

Monte Carlo Calculations

We did Monte Carlo calculations to simulate the expected results from the experiment. The initial program was rather simple and was used to generate a random direction that the gamma rays to be detected could be emitted. From there the program was made more complex by only accepting gammas from a direction that would hit the detector, and by including effects of Doppler broadening, energy loss within the target, and a rotation of the detector.

Results

In the test runs of the experiment, some valuable data was collected. One of the thicker targets was used to plot an excitation function of the proton energy.

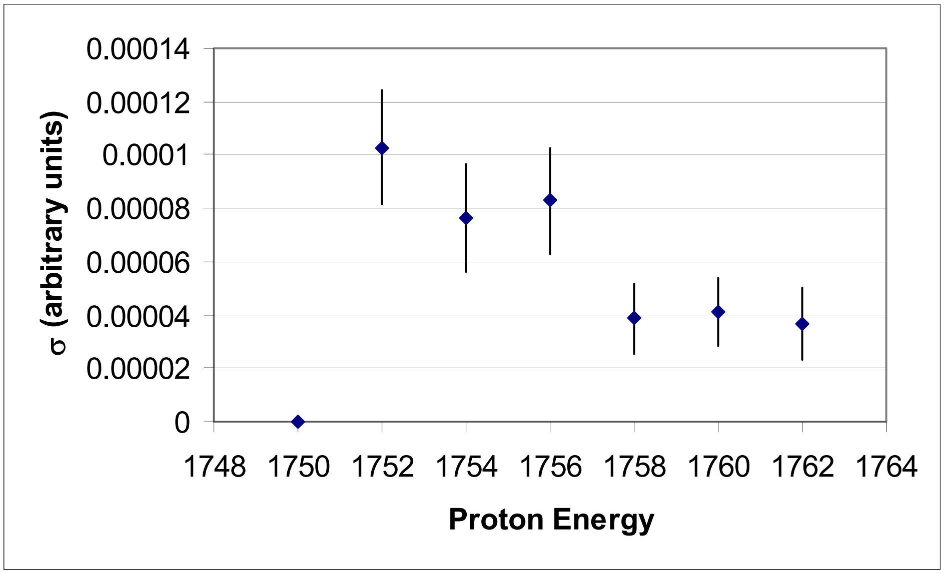

Figure 2 - Excitation Function of proton energy. The y-axis shows a number that is proportional to the area of the peak.

Since each run varied slightly in the amount of current and in the total time, the areas are scaled in order to properly compare the different values. This plot can be used to find the proton energy needed to create the excited state of ^{33}Cl that we want to examine. When the beam is incident on a thick target, gammas will be produced at a greater range of energies, so it is easier to see where the maximum is. This makes finding the approximate energy much easier. When the thin target is used, gammas are only produced at the exact proton energy that hits resonance.

Conclusion

The data from the test run tells several important things. It gives the thickness of the target, but more importantly, it tells that the necessary proton energy for striking resonance is approximately 1757 keV. This is crucial for the experiment in order to get the best results. For a thin target, the excitation function gives us the width of the state we are primarily interested in.

Acknowledgements

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References

[1] D. D. Watson, Rev. Sci. Instr. **37**, 1605 (1966).

[2] M. M. Aleonard et. al, Nucl. Phys. **A257**, 490 (1976).

[3] E.G. Adelberger et. al, Phys. Rev. Lett. **83,** 1299 (1999).