A New Measurement of the Proton Capture Rate on \(^{7}\text{Be}\)

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We report on a new measurement of the cross section of this reaction, following our previous experiment with an implanted \(^{7}\text{Be}\) target, a raster scanned beam and the elimination of the backscattering loss. Measurements were done at energies above and below the resonance as well as a detailed measurement of the resonance. We obtain an extrapolated value of \(S_{17}(0) = 21.2 \pm 0.7\) from the entire set of measurements.

1. Introduction

The \(^{7}\text{Be}(p,\gamma)^{8}\text{B}\) reaction and the accurate determination of the astrophysical \(S_{17}(0)\) factor is of great importance to the study of solar neutrinos since \(^{8}\text{B}\) is the major source of high energy solar neutrinos. In previous publications \([1,2]\) we have demonstrated a new method for measuring the cross section of the \(^{7}\text{Be}(p,\gamma)^{8}\text{B}\) reaction by overcoming several of the recognized potential systematic errors in earlier measurements. Our method involved a small diameter implanted \(^{7}\text{Be}\) target from ISOLDE(CERN), incorporating the elimination of back-scattering loss of \(^{8}\text{B}\) through the use of an implanted target, and a raster scanned beam over an area larger than the target spot, avoiding the difficulties encountered with targets of poorly known areal distribution. Several experiment \([3-5]\) have recently been published, quoting \(S_{17}(0)\) values of (3-10)\% accuracy, two of those \([4,5]\) using similar methods to \([2]\). However, there still exist large, up to 20\% discrepancies among experimental results as well as the extracted \(S_{17}(0)\) values of these measurements. The present work has been undertaken in order to provide a new, firm input for the determination of this cross section by exploiting fully the advantages of the implanted target.

2. Experimental Details

The important features of the implanted target are:

1. The implantation profile is known from simulation. One parameter of this simulation - the depth of the centroid of the distribution - has been confirmed by a measurement.
Table 1
The measured $S_{17}(E)$. The * indicate the set of measurements carried out at $E_{\text{lab}} = 992$ keV; the slightly different values of $E_{\text{c.m.}}$ are due to gradual carbon build-up as derived from repeated measurements of the $^7\text{Be}(p,\gamma)^7\text{B}$ resonance. A combined value of the measurements near $E_{\text{c.m.}} = 850$ keV is also given.

| $E_{\text{c.m.}}$(keV) | $S_{17}(E)$(eV b) |
|-------------------------|-------------------|
| 1078                    | 25.5 ± 0.9        |
| 856*                    | 24.3 ± 0.6        |
| 853*                    | 23.8 ± 0.6        |
| 849*                    | 23.8 ± 0.8        |
| 844*                    | 23.6 ± 0.8        |
| 415                     | 20.2 ± 0.6        |
| 356                     | 18.8 ± 1.2        |
| 302                     | 18.1 ± 2          |
| 850                     | 24.0 ± 0.5        |

of the energy shift of the $^7\text{Be}(p,\gamma)^7\text{B}$ resonance.

2. The elemental composition of the target is known precisely; the target consists of copper, $^7\text{Be}$ and $^7\text{Li}$. We had immediately after implantation ($t=0$) $1.17 \times 10^{16}$ $^7\text{Be}$ atoms and $10^{15}$ $^7\text{Li}$ atoms in a cylindrical volume of copper, 2 mm diameter and 2500 Å deep, containing a total of $6.7 \times 10^{16}$ Cu atoms. This knowledge of the composition and the $^7\text{Be}$ density profile is important information in evaluating the backscattering loss of $^8\text{B}$'s from the target. We computed the $^8\text{B}$ backscattering loss to be 0.2%, small enough to be ignored.

3. The target is robust. We have direct evidence that both the $^7\text{Be}$ and $^7\text{Li}$ atoms remained stable in the Cu matrix.

4. The target was calibrated for $^7\text{Be}$ content by monitoring the $\gamma$-rays following the $^7\text{Be} \rightarrow ^7\text{Li} \beta$ decay. The gamma measurements were carried out in standard counting arrangements, which however required the $\gamma$ activity of the sample to be below a limit much smaller than the actual activity of our target. With the implantation technique it was possible to produce a secondary target about 300 times weaker than the primary target, identical with it in all aspects but the $\gamma$ intensity.

3. Results

The results of our measurements are summarized in Table I.

In attempting to compare our results with other recent measurements we note that while our work emphasizes a selected energy point, all other measurements are spread over wide ranges with relatively large individual errors. Those errors in turn are partially
statistical and partially systematic and may be common to the whole range. Hence, the only meaningful approach appears to be a comparison of the values of $S_{17}(0)$. As stated above, this is justified since the energy dependence tends to be consistent and the extrapolation procedure is similar for all measurements. The $S_{17}$ results from recent direct-capture measurements are: $20.3 \pm 1.2$ eV·b, $18.8 \pm 1.7$ eV·b, $18.4 \pm 2.2$ eV·b and $22.3 \pm 0.7$ eV·b (Refs. [2–5], respectively). From these results we arrive at a mean value: $S_{17}(0) = 21.2 \pm 0.4$ with $\chi^2/\nu = 1.7$ suggesting some discrepancy. If we omit the value of [5] (which is being revised) from the list we get a mean value: $S_{17}(0) = 20.6 \pm 0.6$ with $\chi^2/\nu = 1$. If we add to this in quadrature an ‘error in theory’ of $(\pm 0.5)$, as suggested in [5], we get a consistent common value: $S_{17}(0) = 20.6 \pm 0.8$.

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