A $2^{\%}$ Level of ^{8}B and the ^{7}Be(p,( )^{8}B *S*-factor

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In a recent ^{7}Be + p elastic scattering experiment, Gol'dberg *et al.* [1] found evidence for a wide *s*-wave $1^{\%}$ or $2^{\%}$ level of ^{8}B at an excitation energy of E_x =3.0 MeV. They speculate on how such a level would affect the low-energy *S* factor for the ^{7}Be(p,( )^{8}B reaction, which plays a crucial role in the solar neutrino problem. Measurements of the *S* factor at laboratory energies ($E_{c.m.}$>100 keV), where $E_{c.m.}$ is the relative p -^{7}Be energy, have to be extrapolated to the effective energy in the sun's interior ($E_{c.m.}$=20 keV) using a calculated energy dependence, and this could be changed if a fit to the properties of this ^{8}B level were imposed.

Gol'dberg [2] has identified the level as $2^{\%}$ with a width between 1 and 4 MeV, and has given the experimental energy resolution as 0.25 MeV. A $2^{\%}$ level near 3 MeV may not be unexpected; for example, van Hees and Glaudemans [3], in their shell-model calculations, predict a $2^{\%}$ state in ^{8}Li, and in its mirror nucleus ^{8}B, at 2.91 MeV (unless otherwise indicated, energies are excitation energies). Most direct measurements of the ^{7}Be(p,( )^{8}B *S* factor have been confined to the region with E_x < 2 MeV.

We here, using R-matrix formulae with parameter values chosen to ^{7}Li + n data, consider the role of $2^{\%}$ states of ^{8}B} in the calculated *S* factors for the ^{7}Be(p,( )^{8}B reaction, and the modification of the *S* factor caused by the lowest $2^{\%}$ state to be at an excitation energy of 3 MeV. In the R-matrix calculation [4], the spectroscopic factor for the lowest $2^{\%}$ state of ^{8}Li or ^{8}B was taken from a shell-model calculation, and the energy of the state was then determined by fitting the ^{7}Li + n scattering length a_2= -3.63fm. Now that an experimental value of the resonance, E_r= 3.0 MeV [1], is available for the energy of the state in ^{8}B, it seems more reasonable to make use of that, giving the eigenvalue E_1= 3.0 MeV, and to adjust the spectroscopic factor in order to fit a_2. The resultant value of the resonance width '^{0} lies within Gol'dberg's suggested range of 1 – 4 MeV [2] for channel radius *a* = 4.0 fm, and is somewhat larger for the larger values of *a*. Attempts to fit the data with a much smaller value of '^{0} for the $2^{\%}$ level of ^{8}B at 3 MeV (say 2 MeV or less) would immediately have difficulty in fitting the ^{7}Li + n scattering length a_2. Apart from that, the 1^{+} and 2^{+} spectroscopic factors for ^{8}Li and the thermal-neutron capture data could be fitted, but the predicted $F_{n(}$ at higher energies would be higher than the experimental values, and the predicted ^{7}Be(p,( )^{8}B *E*1 *S* factor would become larger than the experimental values near 3 MeV. The calculated total S_{17}-factor and the *s*-wave $2^{\%}$ *S* factor containing the contribution from the resonance at 3 MeV are shown in Fig. 1. The low-energy *S* factor is shown in Fig. 2 in comparison with the most-recent direct measurements by Hammache *et al.* [5] and Hass *et al.* [6]. Fig. 2 also shows the earlier direct measurements by Vaughn *et al.* [7] and Filippone *et al.* [8]. Recent experimental values of the *E*1 *S* factor determined from the Coulomb dissociation of ^{8}B [9,10] tend to lie higher and are also shown in Fig. 2. Recapping we can conclude that the width of the $2^{\%}$ level at 3 MeV in ^{8}B needs to be near the upper end of the range 1 – 4 MeV suggested by Gol'dberg [2], in order to fit all the data. Assumption of a width as small as, say, 2 MeV makes it impossible to fit the ^{7}Li + n data and leads to unreasonably large values at higher energies for the ^{7}Be(p,γ)^{8}B S factor. A measurement of the width of the 2$^-$ level from a reaction such as ^{7}Be(^{3}He,d)^{8}B [11] seems desirable. More accurate new direct measurements of the S_{17} factor at energies above 2 MeV seem also important.

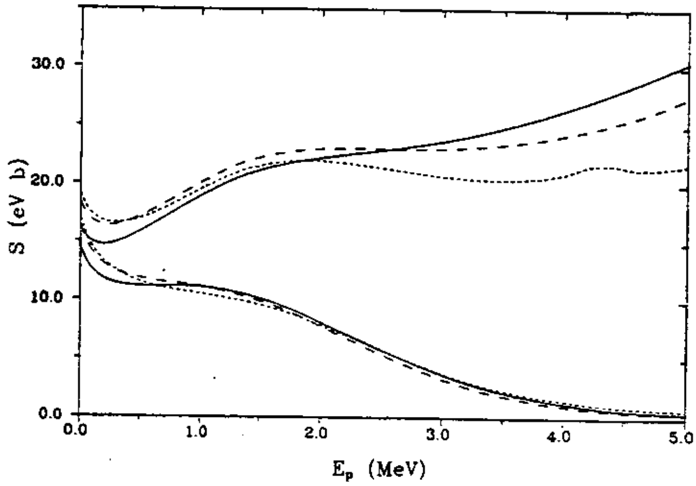

Figure 1. Calculated ^{7}Be(p,γ)^{8}B $E1$, S factor as a function of proton energy, for channel radius a = 4.0 fm (solid curve), 5.0 fm (dashed curve) and 6.0 fm (short dashed curve), in the four-level, four-channel R-matrix approximation. The s-wave 2$^-$ contribution is shown in the lower curves.

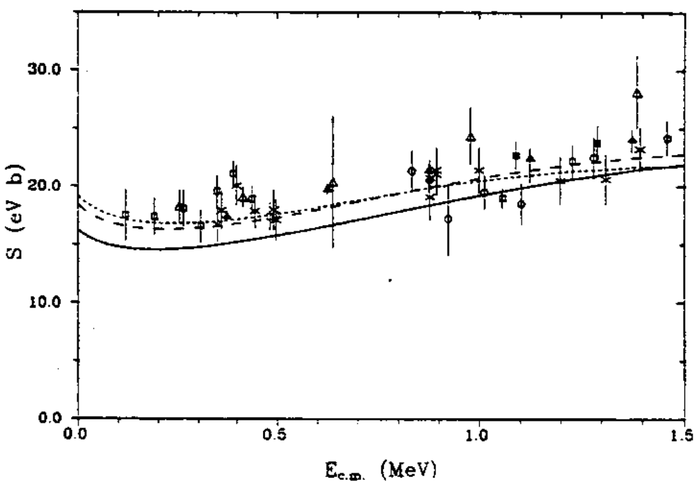

Figure 2. ^{7}Be(p,γ)^{8}B S factor as a function of ^{7}Be + p c.m. energy. The experimental points are from Hammache *et al.* [5] (crosses), Hass *et al.* [6] (solid squares), Vaughn *et al.* [7] (circles), Filippone *et al.* [8] (open squares), Kikuchi *et al.* [9] (closed triangles), and Iwasa *et al.* [10] (open triangles). The curves are the predicted $E1$ S factor for a=4.0 m (solid curve), 5.0 fm (dashed curve) and 6.0 fm (dotted curve), in the one-level, one-channel R-matrix approximation.

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