S_{17} Astrophysical Factor from the Breakup of ^{8}B at 30-300 MeV/u

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This past year we proposed an indirect method to extract astrophysical S-factors from one-nucleon-removal (or breakup) reactions of loosely bound nuclei at intermediate energies. Through the work of different groups at laboratories such as RIKEN, MSU, GSI, GANIL, it is understood today that the structure of halo nuclei is dominated by one or two nucleons orbiting a core. We showed that the breakup of halo or loosely bound nuclei is essentially a peripheral process and that the breakup cross-sections can give precise information about the normalization of the tail of the wave function of the last nucleon around the core. More precisely, asymptotic normalization coefficients (ANCs) can be determined from a comparison of the experimental data with calculations. Then, these ANCs can be used to determine the astrophysical S factors for radiative proton capture reactions, and in some cases for radiative neutron capture reactions.

Using this approach we described the breakup of ^{8}B in terms of an extended Glauber model. The proton and the ^{7}Be core are moving on a straight line and each is interacting independently with the target. The breakup cross sections depend on the interactions between the partners and on the relative p-core motion, which is described by a one-body potential adjusted to reproduce the experimental proton binding energy. To obtain the folded potentials needed in the S-matrix calculations we used the effective nucleon-nucleon JLM interaction with parameters fitted to data. These interactions were folded with Hartree-Fock densities for the partners to obtain the interaction potentials used to calculate the scattering matrix elements.

The ^{8}B ANC is extracted from existing breakup data at energies between 30-300 MeV/u and on different targets ranging from carbon to lead (Refs. 1-3). In Fig. 1 we show, for the case of the breakup of ^{8}B at 38 MeV/u on a Si target [1], that the reaction is peripheral by comparing the spectroscopic factors (dots) and the ANCs (triangles) extracted when we vary the (unknown) geometry of the proton binding potential. While the spectroscopic factor depends on the geometry used in the calculations, making it uncertain to extract, the ANC extracted is almost constant, making it nearly model independent [4]. The ANCs are shown in Table I for all 10 experiments

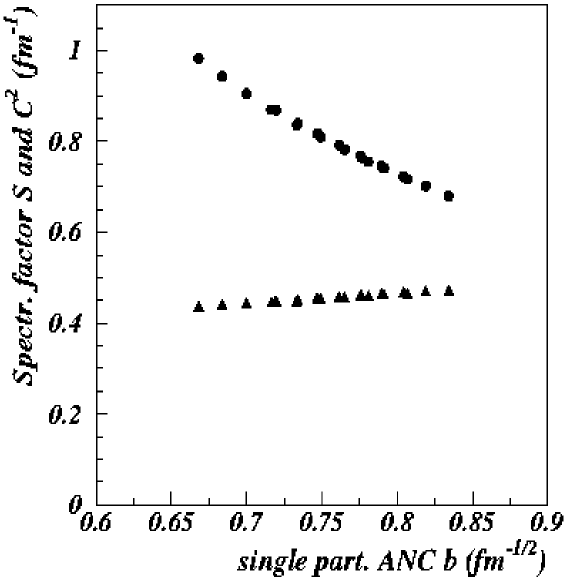

Figure 1: Comparison of the spectroscopic factors S (dots) and of the ANC C^2_{tot} (triangles) extracted from the ^{8}B breakup data on Si at 38 MeV/u [1], for different parameters of the single particle proton binding potentials.

considered and are compared to one another and with the average value in Fig. 2. We found an average C^2_{tot}=0.450±0.039 fm^{-1}. The uncertainty contains the experimental uncertainties and those of the calculations. This value leads to the astrophysical factor $S_{17}(0)$=17.4±1.5 eV b for the key reaction for solar neutrino production ^{7}Be(p,()^{8}B. The same asymptotic normalization coefficient (ANC) for $^8B \rightarrow {}^7Be + p$, that has been determined here using breakup reactions at intermediate energies, was extracted before using the peripheral proton transfer reactions ^{10}B(^{7}Be,^{8}B)^{9}Be and ^{14}N(^{7}Be,^{8}B)^{13}C at 12 MeV/u [5]. An analysis of these two reactions yielded a weighted average C^2_{tot}=0.449±0.046 fm^{-1}. The two values agree very well, in spite of the differences in the energy ranges and in the reaction mechanisms involved.

Table I: Summary of the ANC extracted from different ^{8}B breakup reactions.

Target	E/A (MeV/u)	exp c.s. (mb)	Ref	C^2_{tot} (fm^{-1})
^{8}Si	28	244(15)	[1]	0.435(31)
	35	225(15)	[1]	0.420(32)
	38	222(15)	[1]	0.423(32)
^{12}C	40	80(15)	[2]	0.250(50)*
	142	109(1)	[3]	0.597(65)*
	285	89(2)	[3]	0.482(65)
Sn	142	502(6)	[3]	0.547(42)
	285	332(6)	[3]	0.464(37)
^{208}Pb	142	744(9)	[3]	0.421(32)
	285	542(9)	[3]	0.460(35)
average				0.450(39)
avg sel				0.456(28)

*discarded in the selected average

The procedure used here can be extended to other systems. We also applied it for ^{9}C (next contribution), and for a series of other nuclei (^{15}C, ^{11}Be, ^{14}B). In addition to the requirement for a peripheral reaction, ensured more or less for the halo nuclei, one needs good absolute values for the breakup cross sections, with the identification of the final state of the core, and reliable cross section calculations. The method can be used to extract valuable information for nuclear astrophysics. Very difficult or even impossible direct measurements that would involve bombarding short-lived targets with very low energy protons can be replaced or supplemented by indirect methods seeking the relevant ANCs, rather than complete knowledge of the ground state wave function of these exotic nuclei. In addition, the indirect ANC method is subject to different systematic errors than the direct measurements.

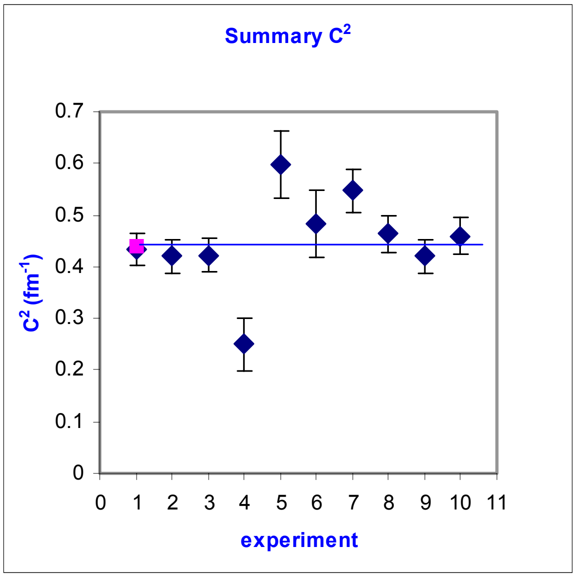

Figure 2: The ANC values from different breakup measurements compared to one-another and with the average. The experiment order is the one from Table I.

References

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