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Indirect study of ^{11}B(p,α_0)^{8}Be and ^{10}B(p,α)^{7}Be reactions at astrophysical energies by means of the Trojan Horse Method: recent results

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Nuclear (p,α) reactions destroying the so-called "light-elements" lithium, beryllium and boron have been largely studied in the past mainly because their role in understanding some astrophysical phenomena, i.e. mixing-phenomena occurring in young F-G stars [1]. Such mechanisms transport the surface material down to the region close to the nuclear destruction zone, where typical temperatures of the order of $\sim10^6$ K are reached. The corresponding Gamow energy $E_0=1.22(Z_x^2 Z_X^2 T_6^2)^{\frac{1}{3}}$ keV [2] is about ~10 keV if one considers the "boron-case" and replaces in the previous formula $Z_x = 1$, $Z_X = 5$ and $T_6=5$. Direct measurements of the two ^{11}B(p,α_0)^{8}Be and ^{10}B(p,α)^{7}Be reactions in correspondence of this energy region are difficult to perform mainly because the combined effects of Coulomb barrier penetrability and electron screening [3]. The indirect method of the Trojan Horse (THM) [4–6] allows one to extract the two-body reaction cross section of interest for astrophysics without the *extrapolation*-procedures. Due to the THM formalism, the extracted indirect data have to be normalized to the available direct ones at higher energies thus implying that the method is a complementary tool in solving some still open questions for both nuclear and astrophysical issues [7–12].

1. EXPERIMENTS AND RESULTS

The ^{11}B(p,α_0)^{8}Be reaction was extensively studied in the past and the direct measurements are reported in Ref. [13] while two different theoretical approaches based on DWBA and R-Matrix calculation are reported in Refs. [14] and [15], respectively. The ^{11}B(p,α_0)^{8}Be reaction was also recently studied by means of the THM applied to the ^{2}H(^{11}B,α_0^{8}Be)n reaction. The experiment was performed at Laboratori Nazionali del Sud in Catania by using a 27 MeV ^{11}B beam (i_{beam}=2-4 enA) impinging on a CD$_2$ target (τ~150μg/cm^2). The emitted alpha's were detected by means of position sensitive silicon detectors (PSD) and the off-line reconstruction of ^{8}Be was performed by following the experimental procedure described in Refs. [9] and [16]. The ^{10}B(p,α)^{7}Be reaction was studied through direct measurement focusing on the astrophysical energy region in Ref. [19] while a theoretical DWBA approach can be also found in Ref. [14]. The indirect study of the ^{10}B(p,α)^{7}Be reaction was achieved through the ^{2}H(^{10}B,α^7Be)n experiment, performed at the Laboratori Nazionali del Sud in Catania with the aim of improving the experimental resolution on the relative E$_{\alpha Be}$ energy reached in a previous experiment [17]. A 24.4 MeV ^{10}B beam, with intensity of about 1 nA, impinges on 200 μg thick CD$_2$ target, placed at 90° with respect to the beam line direction. The exiting alpha's and Be particles were detected by means of PSD detectors and a telescope ΔE-E system respectively, as discussed in Ref. [18]. In both experiments, angular positions of the detection setups were chosen in order to investigate the quasi-free angular region, i.e. the kinematical region where a strong contribution of the quasi-free reaction mechanism is expected. According to the usual experimental approach of the method (more details in Refs. [7–12],[17,18]) the selection of the reaction channel was made by the determination of some kinematical quantities, i.e. the calculation of the experimental Q-value. By selecting all the events close to such experimental peak, the second step of the THM analysis is the selection of the reaction mechanism contributing to the three-body coincidence yield. For such reason the experimental distribution of neutron momentum values was extracted and compared with the theoretical calculation. Only after the selection of the reaction mechanism, i.e. selection of the quasi-free (QF) mechanism, it was possible to apply the THM to the ^{2}H(^{11}B,α_0^{8}Be)n and ^{2}H(^{10}B,α^7Be)n data.

The preliminary results of the ^{11}B(p,α_0)^{8}Be S(E)-factor by means of THM are shown in Fig.1 (black points), giving a preliminary value of S(0)=2.2±0.3 (MeV b) [16]. Such data show the presence of a resonant l=1 contribution superimposed on the non resonant l=0 one, in agreement with the direct data [13], shown as smeared histogram. The THM data were further normalized to the direct ones in the range of E$_{cm}$=0.3-0.6 MeV.

The TH S(E)-factor for the ^{10}B(p,α)^{7}Be reaction is shown in Fig.2 (black points). The astrophysical S(E) factor shows up the resonant l=0 contribution centered at about E$_{cm}$~10 keV, i.e. in correspondence to the Gamow peak. The behavior of the S-factor is strongly dominated by the ~10 keV resonant state, falling just in the Gamow peak energy region. The indirect THM data are normalized to the direct ones [19], smeared out for the energy resolution. Even if the experimental uncertainties affecting the TH data do not allow for definitive conclusions, these results encourage further investigations. For both reactions the TH investigation allowed to reach experimentally the Gamow energetic region in which, up to now, only extrapolations were present; in both cases data analysis are
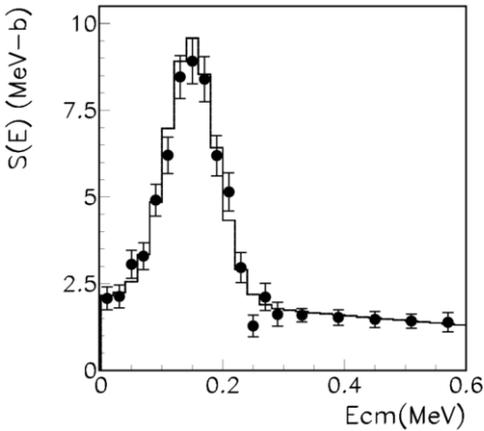
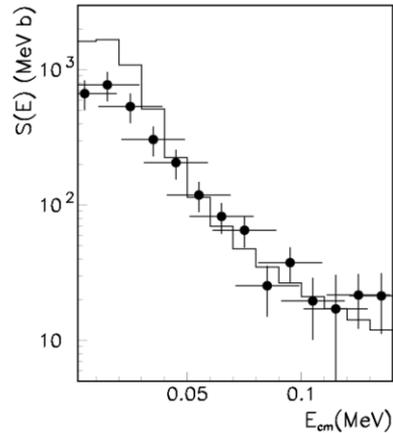Figure 1. ^{11}B(p,α_0)^{8}Be via THM: astrophysical S(E) factor (details in the text).

Figure 2. ^{10}B(p,α)^{7}Be via THM: astrophysical S(E) factor (details in the text).

still in progress.

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