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Improved information on astrophysical *S*-factor for the ^{10}B(p,α_0)^{7}Be reaction using the Trojan Horse method

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Abstract. The ^{10}B(p,α_0)^{7}Be reaction has been studied by applying the Trojan Horse method to the ^{2}H(^{10}B,α_0 ^{7}Be)n reaction. The bare-nucleus astrophysical *S(E)*-factor in absolute units was extracted in a wide energy range, from 2.2 MeV to 3 keV and normalized to the direct experimental data, thus allowing determination of the electron screening potential for which a value of U_e=391±74 eV was obtained.

1 Introduction

For a proper understanding of the stellar structure and evolution, the precise determination of the abundances of light elements such as Li, Be and B is crucial. Since the depletion of these elements occurs at different depths in stars, their surface abundances are strongly influenced by the burning process as well as by the extension of the convective layer. Therefore, these elements can be used as a probe for the internal stellar structure [1–3]. The ^{10}B burning process mostly proceeds via the (p,α) reaction. The cross section for this process is dominated by a strong resonance at 10 keV (J^π=$\frac{5}{2}^+$, 8.699 MeV ^{11}C level), laying exactly at the energy corresponding to the Gamow peak (E_G) [4]. Since the presence of low-energy resonances can introduce significant uncertainties in the extrapolation procedure, the proper evaluation of the ^{10}B(p,α)^{7}Be reaction rate can be done by applying the Trojan Horse Method (THM) [5–13] to the ^{2}H(^{10}B,α ^{7}Be)n three-body reaction, escaping in this way all the difficulties related to the Coulomb barrier suppression or electron screening effects. The experiment presented in this paper is a further study of the ^{10}B(p,α_0)^{7}Be reaction, performed in order to complete the previously started experimental program [14, 15].

2 Experimental set-up

In order to study the ^{10}B(p,α_0)^{7}Be reaction, the experiment has been performed at the *INFN - Laboratori Nazionali del Sud* in Catania. A 56 μg/cm^2 self-supported deuterated polyethylene (CD_2) target was bombarded with the 28 MeV ^{10}B ion beam, intensity of around 2 enA, provided by the SMP Tandem Van de Graaff accelerator. Using a collimator, the beam spot on the target was reduced to 1 mm in diameter. The detection system (sketched in Fig. 1) has been consisted of four 500 μm thick Position

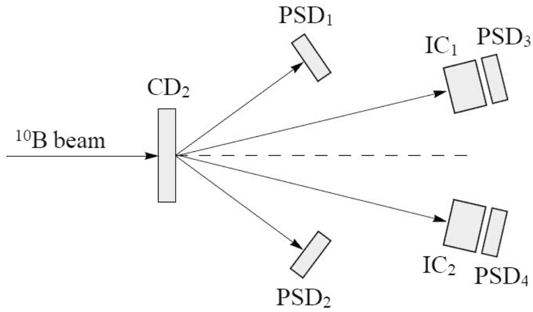

Figure 1. A schematic view of the experimental set-up.

Sensitive Silicon Detectors (PSD) two of which were centred at opposite sides of the beam axis at the laboratory angle of 14.5° covering an angular range of ±3.5°. Other two PSD's were fixed at the laboratory angle of -28°/+28° and covered an angular range of ±7°. Particle identification was carried out using the standard ΔE-E technique. Namely, two Ionization Chambers (IC) filled with isobutane gas (C_4H_{10}) at a pressure of 100 mbar with 1.5 μm thick Mylar entrance and exit windows, have been placed in front of an inner pair of PSD's (PSD_3 and PSD_4 in Fig. 1). A symmetric configuration of the experimental apparatus has been chosen in order to double the statistic. The deterioration of the target was continuously controlled by monitoring the ratio between the measured ^{7}Be yield and the charge collected in the Faraday cup at the end of the beam line.

3 Data analysis and results

After the position-energy calibration and selection of the events corresponding to the investigated three-body reaction were done, following the standard THM procedure, the selected experimental data were compared with the Monte Carlo simulation, confirming the correct identification of the ^{2}H(^{10}B,α_0 ^{7}Be)n reaction (a detailed description of the procedure is given in [14, 15]). Further, with the aim to deduce the two-body cross section by applying the THM formalism, a restriction for neutron momentum of -40 MeV/c $\leq$ p_s $\leq$ 40 MeV/c, deduced by studying the shape of the spectator (neutron) momentum distribution, was set in order to select the Quasifree (QF) contribution and to minimize the other reaction mechanisms that can possibly produce the same particles in the final state (^{7}Be, α and n), such as Sequential Decay (SD) or Direct Breakup (DBU).

Since the Plane-Wave Impulse Approximation (PWIA) was used for the calculation of the two-body cross section $\sigma(E)$, this quantity was obtained in arbitrary units [13] and a normalization of TH data to the ones obtained from direct measurements was necessary. However, due to different direct data sets providing cross section functions that are not consistent between each other [14–24], to obtain the bare-nucleus TH S-factor in absolute units, the THM data have been normalised to the R-matrix calculation of [15], leading to a more accurate S_b(10 keV)=2950±291 MeV b value comparing to S_b(10 keV)=2942±395 MeV b reported in [15]. Fig. 2 shows a result obtained for the astrophysical S-factor as a function of center-of-mass energy in comparison with data from [15] and data from [14] renormalised as suggested in [15]. As it can be seen, all three sets of data are in good agreement within their error bars.

Due to an optimization of the experimental set-up we improved energy resolution by 80% in the present experiment compared to the previous THM study [15], thus ensuring more accurate determination of the ^{10}B(p,α_0)^{7}Be bare-nucleus astrophysical S-factor and consequently, of the electron

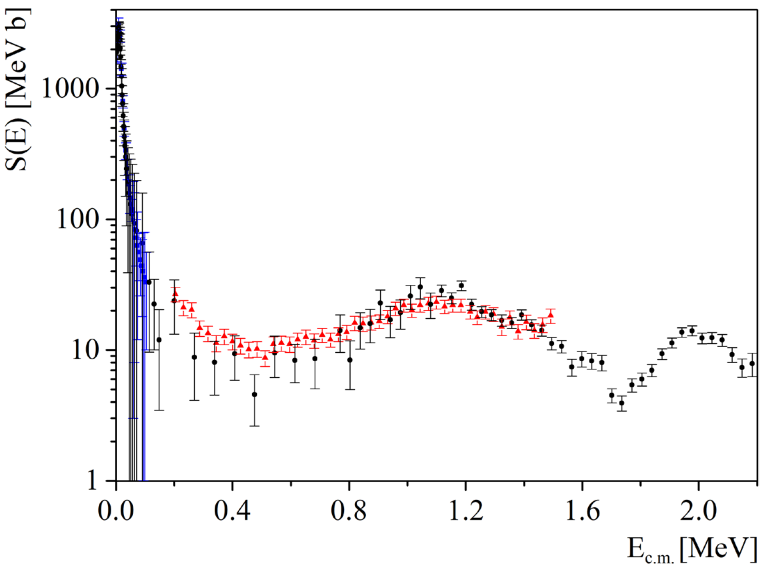

Figure 2. TH astrophysical *S(E)*-factor (black points) compared with the data from [15] (red triangles) and data from [14] (blue squares) renormalised as suggested in [15].

screening potential (U_e). This was also possible due to the wide energy range available for the normalization procedure. A value for the electron screening potential of U_e=391±74 eV has been determined and found to be in a good agreement (within uncertainties) with the theoretical value calculated for the adiabatic limit U_e^{ad}=340 eV.

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