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The ^{10}B(p,α)^{7}Be S(E)-factor from 5 keV to 1.5 MeV using the Trojan Horse Method

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Abstract. The ^{10}B(p,α)^{7}Be reaction is the main responsible for the ^{10}B destruction in stellar interior [1]. In such environments this p-capture process occurs at a Gamow energy of 10 keV, and takes places mainly through a resonant state (Ex = 8.701 MeV) of the compound ^{11}C nucleus. Thus, a resonance right in the region of the Gamow peak is expected to significantly influence the behavior of the astrophysical S(E)-factor. The ^{10}B(p,α)^{7}Be reaction was studied via the Trojan Horse Method (THM) applied to the ^{2}H(^{10}B,α^{7}Be)n in order to extract the astrophysical S(E)-factor in a wide energy range, from 5 keV to 1.5 MeV.

1 Introduction

The study of the abundances of light elements Li, Be and B provides important indications about chemical evolution of the Galaxy, stellar structure and about the nucleosynthesis. In particular a comprehensive study of Li Be B abundances can confirm the presence of non-standard mixing processes in stellar envelopes [2]. These elements are destroyed by nuclear fusion reactions at different depths inside stars corresponding to temperatures of about 2.5×10^{6} K for Li, 3.5×10^{6} K for Be and 5×10^{6} K for B [1]. The most involved processes are (p,α) reactions, induced at Gamow energy E_G of a few keV, which require precise cross section measurements. In particular the THM allows to extract the cross section for a charged-particle-induced reaction by selecting the quasi-free contribution

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to a suitable three body reaction. Moreover the THM allows one to measure the bare nucleus S(E)-factor for astrophysically relevant reactions without experiencing Coulomb penetrability effects. The details of the method are explained in [3–5]. In this work the THM [3] has been applied to the^{2}H(^{10}B,α^7Be)n three-body reaction in order to measure the astrophysical S(E)-factor for the ^{10}B(p,α)^{7}Be reaction. The importance of this reaction is due to the presence of a resonance at about E_{cm}=10 keV corresponding to the Gamow peak for this reaction. The resonance corresponds to the ^{11}C*(8.701 MeV, J=5/2$^+$) excited state. Moreover the ^{10}B(p,α)^{7}Be reaction is of interest also for nuclear physics in fact it allows to investigate ^{11}C states presently poorly known [6][7] .

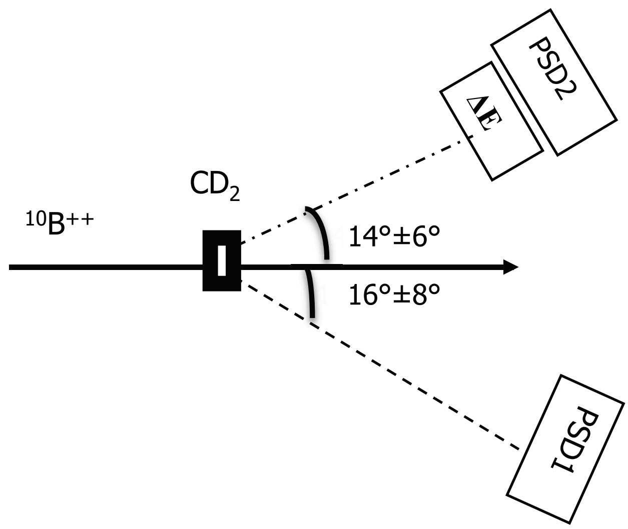

Figure 1. The experimental setup for the Pelletron Linac Institute experiment. The ΔE-E system devoted to ^{7}Be detection and a position sensitive detector (PSD) for alpha particle detection are shown.

2 Experimental setup

In order to study the ^{10}B(p,α)^{7}Be reaction two experiments were performed, one devoted to study the resonance at 10 keV in ^{10}B-p center of mass and the other one to investigate the ^{11}C high-energy excited states. The first experiment was performed at Pelletron Linac Laboratory in Sao Paolo (Brazil). The Tandem accelerator provided a 27 MeV ^{10}B beam and intensity up 1 nA, the beam energy was chosen in order to span the relative energy range from 1.5 MeV down to zero [8].The detection setup consisted of a position sensitive detector (PSD) and a telescope system having a proportional counter (PC) as ΔE and a standard PSD as E detector, the experimental setup for Sao Paolo measurement is shown in fig.1. The second experiment was performed at Laboratory Nazionali del Sud in Catania [9], the Tandem Van der Graff provided 24.5 MeV ^{10}B beam and intensity 1.5 nA, in this case the main goal was the study of the 10 keV resonance. The detection setup consisted of a ΔE-E system made up of a ionization chamber filled with butane gas and a PSD to measure the residual energy of the emitted particles. Two position sensitive detectors were placed at opposite sides with respect the beam direction, more detail are in [9]. The experimental setup was chosen to cover the whole quasi-free angular range [3] known from a Monte Carlo simulation. Energy and position signals for

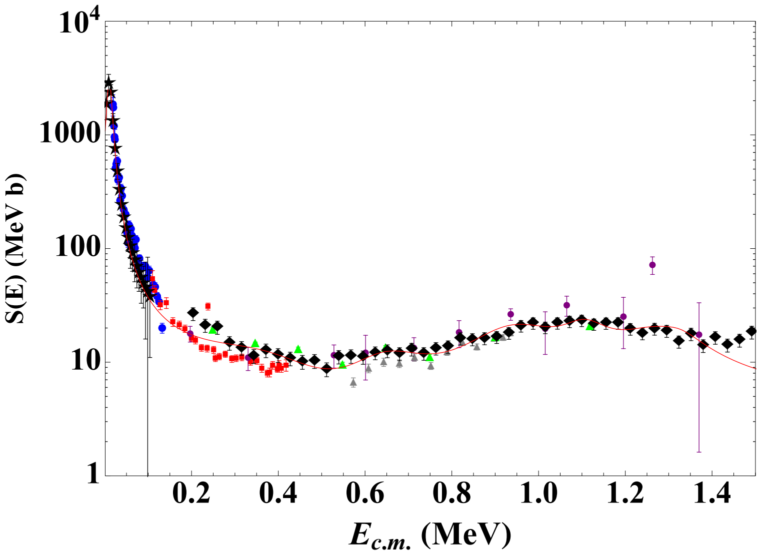

Figure 2. The resulting S(E)-factor in absolute units displayed as black diamonds obtained in [8] and the previous data sets [9] S(E)-factor shown as black stars.This S(E)-factor is compared with data from the ref[15] as blue circles, with the data from [14] corrected for the factor 1.83 as recommended in [15] and reported as red squares. Moreover thick-target data in [11] reported as purple circles, and recent works [12] and [13] S(E) -factors as green and grey triangles, respectively. R-matrix fit of the THM data is reported as red line

the detected particles were processed by standard electronics and sent to the acquisition system for the on-line monitoring and data storage.

3 Data analysis

After the calibration of the involved detectors, the first step in the analysis was the ^{2}H(^{10}B,α^7Be)n channel identification, which has been obtained by means of the comparison between the experimental and theoretical kinematical locus, as a standard THM procedure [10]. The next step in the analysis was to select the quasi-free contribution, in order to extract this contribution the data were studied as a function of the neutron momentum. The analysis procedure is fully described in [8][9]. The aim of this work was to study the astrophysical S(E)-factor from 5 keV to 1.5 MeV. For this purpose the two sets of experimental data were studied together. The ^{10}B(p,α)^{7}Be astrophyisical factor has been measured for the first time at the Gamow peak at the LNS experiment. In order to study the 10 keV resonance the energy resolution effects and selection of the events of interest for the THM investigation have been carefully evaluated together with the corresponding uncertainties [9]. The THM astrophysical factor in absolute units has been obtained by normalization to direct data [11–13] in a energy range from 200 to 1200 keV. Thanks to this wide normalization range we are able to reach a very low normalization uncertainty (4%). The effect of the reduced normalization error influences the 10 keV astrophysical factor, leading to a more accurate S_b (10 keV) = 3127 ± 583 MeV b, where the uncertainties include statistical, subthreshold level subtraction, normalization, and channel radius uncertainties [8]. In the Figure 2 is shown the comparison of the THM S(E)-factor displayed as black diamonds obtained in [8] with the all data reported in literature as explained in the figure caption. A very good agreement is found between the direct data and the THM ones after normalization. The availability of THM data up to 1.5 MeV represents a very good opportunity to revise the THM low energy S(E)-factor [8]. In fact by performing a weighted scaling of the THM S(E)-factor to the available direct data, the normalization error turned out to be equal to 4% which is significantly smaller than what is given in [9] namely 18%. Moreover we use R-matrix fit of the THM data (in fig 2 as red line), where the fitting parameters of the lowest laying resonances at 10 and 500 keV were fixed to those in [9], which is dominated by a 10 keV resonance. In order to improve this results a new measurement has been performed by using the THM in the same energy interval.

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