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Electron screening effects in (p,α) reactions induced on boron isotopes studied via the Trojan Horse Method

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Abstract. The Trojan Horse Method is a powerful indirect technique allowing one to measure the bare nucleus S(E)-factor and the electron screening potential for astrophysically relevant reactions without the needs of extrapolations. The case of the (p,α) reactions induced on the two boron isotopes ^{10,11}B is here discussed in view of the recent Trojan Horse (TH) applications to the quasi-free ^{10,11}B+^{2}H reactions. The comparison between the TH and the low-energy direct data allowed us to determine the electron screening potential for the ^{11}B(p,α) reaction, while preliminary results on the ^{10}B(p,α) reaction have been extracted.

1. Method and results

The Trojan Horse Method (THM) [1-4] is an indirect technique allowing one to measure the low-energy S(E)-factor of a charged particle induced reaction $a + x \rightarrow c + C$ in correspondence of the Gamow energy, at which the direct cross section measurements exhibit a drastic exponential decrease because of the Coulomb barrier. The method selects the quasi-free (QF) contribution on a suitable 2$\rightarrow$3 reaction $a + A \rightarrow c + C + s$, performed at energies well above the Coulomb barrier, thus ensuring the $a + x$ interaction without any influence of the Coulomb penetration effects [5-6]. In that framework, the Trojan Horse nucleus A is chosen because of its large amplitude for the $A = x \oplus s$ cluster configuration and, once the Impulse Approximations (IA) hypothesis are fulfilled, x represents the *participant* while s is the *spectator* [7]. The THM has been applied for shedding light on different astrophysical problems, such as the study of

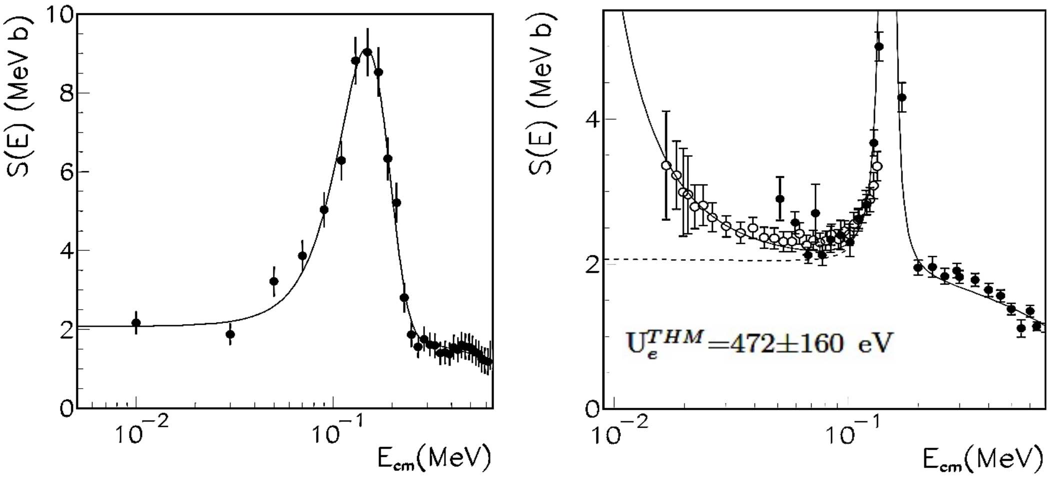

Figure 1. Left panel: the TH ^{11}B(p,α)^{8}Be data (black points) with the corresponding fit. Right panel: the low-energy direct data [21] have been fitted by means of the enhancing factor exp($\pi\eta U_e/E$) [26], with a value of the screening potential of U_e=472 eV.

light element burning reactions ([8-15]), CNO reactions (see [16-19]), and removing/producing neutron reactions ([20-22]).
Recently in [23] we have reported on the study of the astrophysically relevant ^{11}B(p,α)^{8}Be reaction, via the THM application to the ^{2}H(^{11}B,α^{8}Be)n reaction induced at the boron beam energy of 27 MeV in the laboratory, where the ^{2}H has been used as TH-nucleus thanks its obvious p⊕n structure. Once the contribution of the QF reaction mechanism has been carefully selected, the experimental momentum distribution for the p-n relative motion has been extracted and it was found to be in agreement with the expected Hulthén wave function in momentum space. In addition, in a further work, we investigated also the possible influence of the d-state component in the p-n relative motion obtaining a contribution of less than 1% with respect the s-state one [24]. The ^{11}B(p,α)^{8}Be have been then studied from ~600 keV down to ~10 keV, the last corresponding to the Gamow energy window for quiescent boron burning. In particular the zero-energy S(E)-factor measurements leads, after a normalization to the direct data (see [25] and references therein), to the value of S(0)=2.07±0.41 MeV b (left panel of Fig. 1) and, from the comparison with the available direct measurements, a corresponding electron screening potential of 472±160 eV has been extracted (right panel of Fig. 1).

In order to complement the information about electron screening gained in the previous case, the TH has been also applied for studying the ^{10}B(p,α)^{7}Be reaction. In that case, the ^{2}H(^{10}B,α^{7}Be)n experiment have been performed, by using a 24 MeV boron beam on a CD_2 target at LNS, Catania. Left panel of Fig.2 shows the experimental Q-value for the three-body reaction, centered at ~-1.1 MeV in excellent agreement with the theoretical one. Right panel of Fig. 2 shows the preliminary TH S(E)-factor in arbitrary units. 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 where, up to now, the NACRE compilation [25] reports only an R-matrix calculation. Even if the experimental uncertainties affecting the TH data do not allow for definitive conclusions, these results encourage further investigations. The U_e^{THM} obtained for the ^{11}B(p,α)^{8}Be is in agreement with the value of 430±80 eV (see [25] and references therein), though it is higher than the upper limit of 340 eV predicted by the adiabatic limit. The same conclusions apply to the lithium-burning reactions for which a value

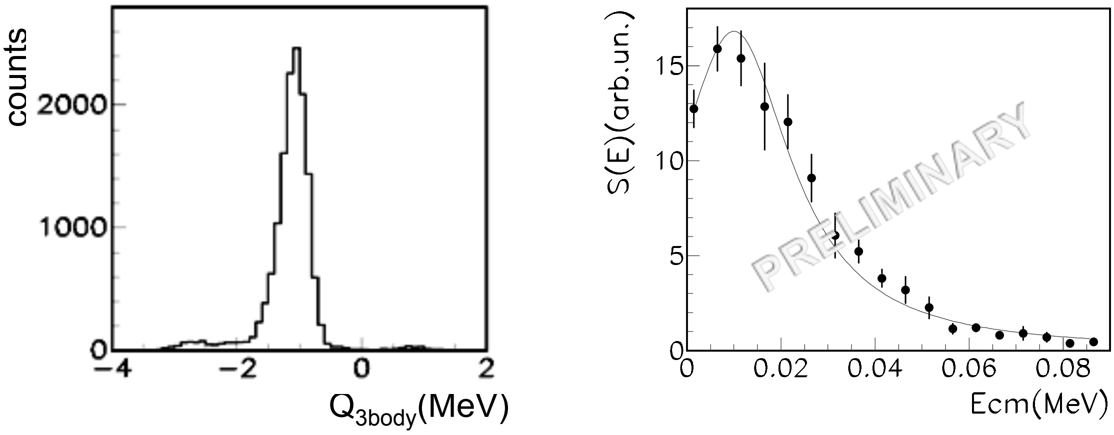

Figure 2. Left panel: the experimental Q-value for the 3body ^{2}H(^{10}B,α^{7}Be)n reaction. Right panel: preliminary TH ^{10}B(p,α)^{7}Be S(E)-factor in arbitrary units.

of 425±60 eV has been recently deduced in [15], in contradiction with the theoretical one of 175 eV. Thus, the deviation from the adiabatic limit confirms once again the systematic discrepancy between experimental and theoretical values for the electron screening potential, thus leaving the electron screening understanding as an important open question for nuclear physics and astrophysics, as well as atomic physics or condensed matter physics [26].

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