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ORIGINAL ARTICLE

The astrophysical S-Factor of ^{4}He(^{3}He,γ)^{7}Be reaction at very low-energies

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Abstract The astrophysical S-factor for ^{4}He-^{3}He radiative capture is calculated at very low-energies. We construct conserved two- and three-body electromagnetic currents, using minimal substitution in the explicit momentum dependence of the two- and three-cluster interactions. The realistic Argonne v_{18} two-nucleon and Urbana IX or Tucson-Melbourne three-cluster interactions are considered for calculation. The zero energy S-factor is found to be $S(0) = 0.563$ (0.581) keV b, with (without) three-body interactions, in satisfactory agreement with other theoretical results and experiment data.

Keywords The astrophysical S-factor · ^{4}He-^{3}He system · Radiative capture · Few-body systems

1 Introduction

The ^{4}He(^{3}He,γ)^{7}Be reaction plays a major role in the solar proton-proton chain in Hydrogen burning from which the ^{7}Be and ^{8}B neutrinos are generated. It is also a fundamental reaction in Big-Bang Nucleosynthesis (BBN) and significantly important in the verification of the Standard Solar Model. The astrophysical S-factors, determining the threshold behavior of cross sections, are very important parameters in models of big-bang nuclear synthesis, stellar hydrogen burning, solution of the Sun-neutrino puzzle etc. This capture process occurs through the formation of a ^{7}Be nucleus with the emission of γ-radiation coming from the direct capture into the ground state and the first excited state of ^{7}Be. Solar neutrino fluxes depend on nuclear physics inputs, namely on the cross sections of the reactions responsible for neutrino production inside the Solar core.

The experimental situation regarding the capture cross section was not clear, for a long time, due to conflicting experimental results (Adelberger et al. 1998; Alexander et al. 1984; Nara Singh et al. 2004; Bemmerer et al. 2007; Confortola et al. 2007; Brown et al. 2007; Di Leva et al. 2009). Recently, a new series of measurements has begun, starting with an activation measurement. These new studies tried to measure the reaction with high precision and therefore to investigate the possible discrepancy between two different experimental approaches that could be given underestimated systematic errors and possible non radiative transitions. The aim of these experiments were therefore to provide high precision data obtained simultaneously using different methods (Nara Singh et al. 2004; Brown et al. 2007; Confortola et al. 2007; Bemmerer et al. 2007). Cross section of the ^{4}He(^{3}He,γ)^{7}Be reaction has been remeasured by Weizmann (Nara Singh et al. 2004), the LUNA Collaboration (Bemmerer et al. 2007; Confortola et al. 2007), the Seattle group (Brown et al. 2007), and the ERNA Collaboration (Di Leva et al. 2009) now providing consistent high precision data. Furthermore, it is still not possible to reach the low-energies relevant in nuclear burning.

In theoretical frameworks, some groups are studying the radiative capture cross section for ^{4}He(^{3}He,γ)^{7}Be reaction. For such reactions, solving the many-body problem with realistic interactions is hard and consistent *ab initio* reaction calculations have been possible only for single nucleon projectiles (Nollett et al. 2007; Quaglioni and Navratil 2009; Navratil et al. 2007; Neff 2011). Up to now, none of calculations is successful in describing the energy dependence of the capture cross section data. Neff has investigated consistently the bound state properties, and the scattering phase

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