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Improved cross section measurement for the ^{7}Li$(p,\alpha)^4$He reaction and its importance for primordial nucleosynthesis and the lithium problem

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Abstract. The ^{7}Li$(p,\alpha)^4$He bare nucleus reaction rate plays a crucial role in primordial nucleosynthesis and lithium depletion. But the measurement of the bare nucleus cross section is usually very difficult because of the presence of the Coulomb barrier and the electron screening effect. The Trojan Horse Method (THM) can be applied to extract the energy dependence of $S_b(E)$ at very low energies without any extrapolation, by measuring the cross section of a proper three body process and has been applied to the ^{7}Li$(p,\alpha)^4$He reaction. The value deduced from this experiment is $S_b(0)$=55 ± 3 keV·b. From the obtained $S_b(E)$ values it is also possible to measure U_e=330±40 eV. The astrophysical implications of these measurements are discussed in the case of solar lithium problem and primordial nucleosynthesis.

Key words. nuclear reactions – sun: abundancies – stars: abundancies

1. Introduction

As for other charged particle reactions, experimental measurements of the

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^{7}Li$(p,\alpha)^4$He cross section faces the main difficulties given by the Coulomb barrier and the electron screening effect Assenbaum et al. (1987).

It should be pointed out that what is needed for astrophysical calculations is the bare nucleus cross section which must be inferred from the directly measured one by means of theoretical extrapolations. This has been done by the NACRE collaboration for the ^{7}Li$(p,\alpha)^4$He giving an extrapolated value S(E=0)= 59 keV·b. In this paper we will discuss the astrophysical implications of the Trojan Horse Method measurement, presented in Lattuada et al. (2001).

2. Discussion

The reaction ^{7}Li$(p,\alpha)^4$He has been studied via the three-body reaction ^{7}Li$(d,\alpha\alpha)n$ at the Laboratori Nazionali del Sud, Catania, according to the prescriptions of the Trojan Horse Method. An exhaustive discussion of the data analysis and the method can be found in Lattuada et al. (2001) and in references within. A second order polynomial fit to the indirect data gives S(E=0)= 55 keV·b, in agreement with theoretical R-Matrix predictions and only slightly smaller than the value obtained in the direct measurements Engstler et al. (1992). As one can easily predict, the small variation in the cross section is not expected to produce relevant variations in the current astrophysical scenarios. However it seems worthwhile to investigate the effects of the new value to the solar lithium problem and and primordial nucleosynthesis.

This has been done by using the FRANEC code, which is discussed in Ciacio et al. (1997). Two calculations were performed, the first adopting the bare nucleus cross section indirectly measured in Lattuada et al. (2001), the second using the one reported in Engstler et al. (1992). The results are extensively discussed in Pizzone et al. (2003) and the discrepancy between the two calculations is around 5%. For this reason, mechanisms other than the nuclear lithium burning are needed for explaining the solar lithium problem (e. g. uncertainties on opacity and equation of state, rotation, non standard mixings).

The THM cross section measured in Lattuada et al. (2001) was also applied to the primordial nucleosynthesis reaction network and the results are discussed in details in Pizzone et al. (2003). From the comparison of the calculation performed using the rate for the ^{7}Li$(p,\alpha)^4$He from NACRE and the THM one a small discrepancy in lithium abundance is seen at low η. Moreover from the comparison between primordial lithium abundance and the calculated yields, the following constraints on Ω_B are found,

$$0.016 < \Omega_B < 0.035$$

in agreement with several recent calculations.

Other reactions of astrophysical interest will be studied in the next future, via the same method; among them the ^{6}Li$(p,\alpha)^3$He whose analysis is currently in progress.

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