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Measurement of the ^{27}Al(p,α)^{24}Mg Reaction at Astrophysical Energies via the Trojan Horse Method

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We report on the preliminary results about the study of the ^{27}Al(p,α)^{24}Mg reaction at astrophysical energy performed by using the Trojan Horse Method applied to the ^{2}H(^{27}Al,α^{24}Mg)n three-body reaction.

KEYWORDS: nuclear reactions, nucleosynthesis, abundances

1. Introduction

The source of ^{26}Al in the present day and in the ancient Galaxy is an important issue in nuclear astrophysics. The occurrence of nucleosynthesis is currently proved by the detection of the 1809 keV gamma emission. While the abundance of ^{26}Al in the past is hinted by geochemical analysis of ancient meteorites, which reveal a superabundance of the ^{26}Al daughter nucleus (^{26}Mg) in comparison with the most abundant Mg isotope (^{24}Mg). From the ratios of the abundances ^{26}Mg/^{24}Mg and ^{26}Mg/^{27}Al it is possible to estimate the ^{26}Al/^{27}Al ratio in the ancient Galaxy and date meteorites (or early Solar System solids) [1, 2] . For this reason, it is crucial to know with high precision the nucleosynthesis process not only of ^{26}Al but also of ^{27}Al and ^{24}Mg. Extensive discussion on the role of aluminum isotopes in the Solar System can be found in [1, 3].

In particular, in high temperature (T = 0.055 GK) H-burning typical of massive stars, the ^{27}Al(p,α)^{24}Mg reaction drives the destruction of ^{27}Al and the production of ^{24}Mg closing the so-called Mg-Al cycle. However, at temperatures lower than 10^8K the uncertainties affecting the ^{27}Al(p,α)^{24}Mg reaction rate make it difficult to establish who prevails between it and the competing channel ^{27}Al(p,γ)^{28}Si. This fact makes astrophysical predictions unreliable. In detail, at T_9=0.1 the lower, median and upper values of the most recent rate recommended for the ^{27}Al(p,α)^{24}Mg span almost an order of magnitude, and the uncertainty range is e larger at lower temperatures [4]. In this framework more data are mandatory at low energies that are of interest for astrophysics, e.g. Gamow energy for T = 0.055 GK is about 100 keV. For this reason we apply the Trojan Horse Method (THM) [5, 6] to study the ^{27}Al(p,α)^{24}Mg reaction by using the three-body quasi-free (QF) reaction ^{2}H(^{27}Al,α^{24}Mg)n, where the proton is brought inside the nuclear field of ^{27}Al, while the neutron acts as a spectator to the ^{27}Al(p,α)^{24}Mg reaction. The mechanism is reported in a schematic view by figure1. We investigate the proton capture on ^{27}Al reaction in the energy range of astrophysical importance, between the threshold and 1.5 MeV, and in a broad energy region where direct measurements are available, to normalize the THM S-factor and validate the method, by comparison with the existing data.

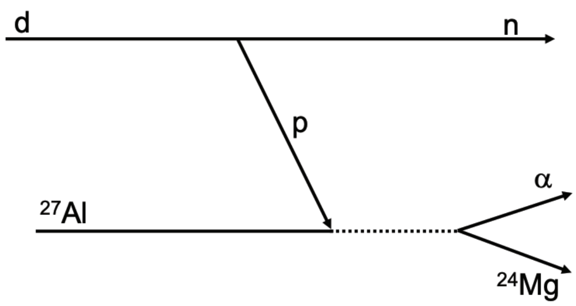

Fig. 1. Sketch of the QF ^{2}H(^{27}Al,α^{24}Mg)n reaction, where the proton is brought inside the nuclear field of ^{27}Al, while the neutron acts as a spectator to the ^{27}Al(p,α)^{24}Mg reaction.

2. The Experiment

The experiment was performed at the INFN Laboratori Nazionali del Sud in Catania (Italy) by using a 60 MeV ^{27}Al beam, provided by the SMP Tandem accelerator, with intensities up to 1.5-2 nA, impinging onto a deuterated polyethylene target (CD_2) of about 150 μg/cm^2, placed at 90° with respect to the beam axis. The ejected α particles and the ^{24}Mg recoils, with their energies and angles of emission, were detected in coincidence by using an experimental set-up, symmetric with respect to the beam axis, which consisted of two telescopes and two silicon position sensitive detectors (PSD). The two telescopes covered a range from 4° to 8° on the left and on the right of the beam line, respectively. They were made up of an ionization chamber (IC) and a silicon position sensitive detector (PSD) and optimized to identify the ^{24}Mg and to discriminate between Mg and Al nuclei via the ΔE-E technique. The IC were filled with 65 mbar isobutane gas that provided an energy resolution of about 10%. The other two silicon PSDs optimized for coincident detection of the α particles, were posed to cover about 20° from 15° to 35° degrees on the left and on the right of the beam line, respectively. The four 1000-micron PSDs had 50 x 10 mm^2 sensitive area with 0.5 mm position resolution and an energy one of 0.5%. A scheme of the experimental setup is given in figure2.

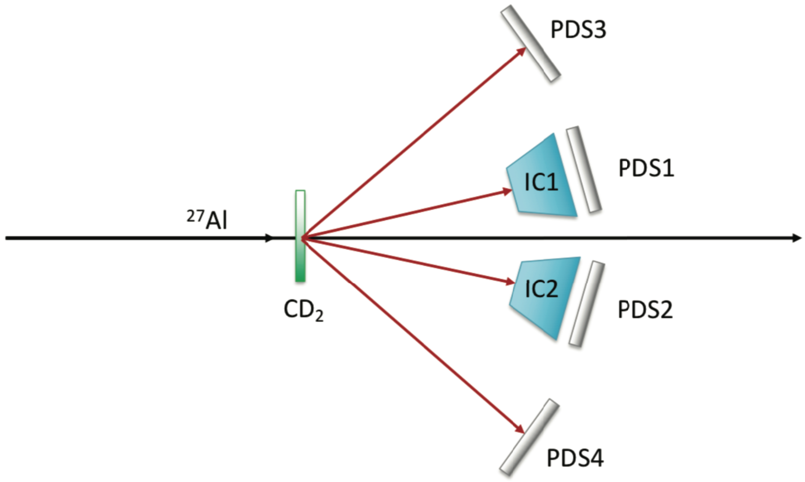

Fig. 2. Sketch of the experimental set-up.

3. Data Analysis and Preliminary Results

After detector energy and position calibration, the ^{2}H(^{27}Al,α^{24}Mg)n channel was selected by gating on the ΔE-E spectra in telescope 1, which shows the contribution from scattered ^{27}Al beam particles separated from the Mg locus (panel A of figure 3). Panel B of figure 3 shows energy of α particles detected by PSD 4 as a function of the energy of Mg nuclei detected, in coincidence, by PSD 1, this locus can be easily identified as the one of the ^{2}H(^{27}Al,α^{24}Mg)n, because of its agreement with simulation. Similar results are deduced from the symmetric pair PSD2-PSD4. This result is supported by the experimental Q-value spectrum, given in panel C of figure 3, that show a peak centred at about -0.6 MeV, which is the Q-values for the ^{2}H(^{27}Al,α^{24}Mg)n reaction. This fact confirms the identification of the reaction channel, even if more statistic is needed to better insulated the -0.6 MeV peak from other process. The data analysis is still going on.

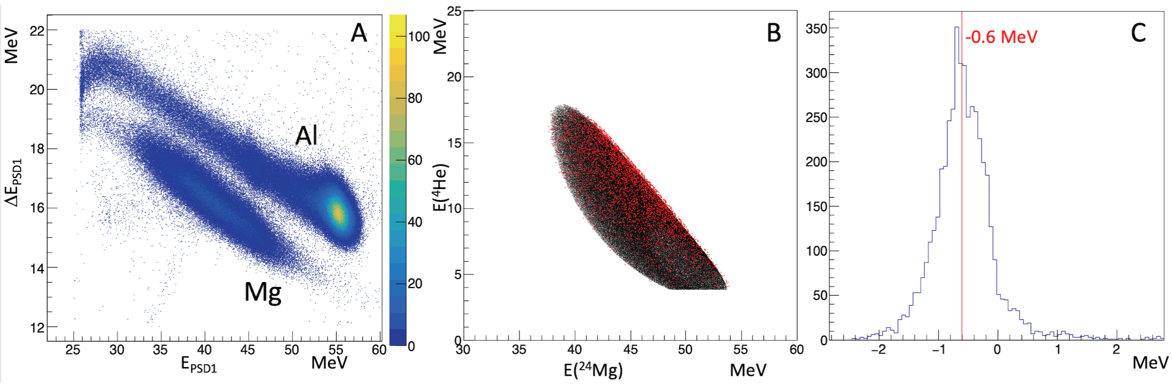

Fig. 3. Panel A. The ΔE-E spectra in telescope 1 shows the scattered ^{27}Al beam particles separated from the Mg locus, as indicated by the labels. Panel B. α emission energy as a function of the ^{24}Mg kinematic energy: output of kinematical simulation for the ^{2}H(^{27}Al,α^{24}Mg)n reaction at 60 MeV beam energy (black markers) are compared with experimental data (red dots). Panel C. Reconstructed Q-value spectrum. The Q-value for the ^{2}H(^{27}Al,α^{24}Mg)n is marked by the red line.

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