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Measurement of the ^{25}Mg(α,n)^{28}Si reaction cross section at LNL

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Abstract. The detection of the 1809 keV emission line associated with the decay of ^{26}Al in the interstellar medium provides a direct evidence of recent nucleosynthesis events in our galaxy.
^{26}Al is thought to be mainly produced in massive stars, but in order to have a quantitative understanding of the ^{26}Al distribution, the cross section of all the nuclear reactions involved in its production should be accurately known.
A recent sensitivity study demonstrated that the ^{25}Mg(α,n)^{28}Si is the reaction with the strongest impact on the synthesis of ^{26}Al during explosive Neon and Carbon burning [4].
In order to improve the experimental knowledge of the ^{25}Mg(α,n)^{28}Si cross section, a new direct measurement has been performed at Legnaro National Laboratories.
The experimental setup, the data analysis and preliminary results are discussed.

1 Introduction

The detection of short lived radionuclides inside the Milky Way represents an observational evidence of the theory of stellar nucleosynthesis.
^{26}Al is one of the first radioactive isotopes detected in the interstellar medium. Its lifetime ($\tau \sim 1.04 \cdot 10^6$ years) is shorter than the timescale of the chemical evolution of the galaxy ($\sim 10^{10}$ years). Therefore, the presence of ^{26}Al can be associated with recent nucleosynthesis events.
^{26}Al decays to the first excited state of ^{26}Mg that, in turn, de-excites emitting a characteristic 1809 keV gamma-ray. All-sky observations done by the CGRO (Compton Gamma-Ray Observatory) [1] and INTEGRAL (International Gamma-Ray Astrophysics Laboratory) [2] space-borne missions provided maps of the intensity of the 1809 keV ^{26}Al line in our Galaxy, and allowed for the identification of the regions where ^{26}Al is intensively produced.
Moreover, the analysis of pre-solar grains found in pristine meteorites reveald an excess of ^{26}Mg. This excess can be interpreted assuming that ^{26}Al was present at the epoch of the formation of the Solar

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System, and gives information on the composition of the pre-solar nebula [3].
In order to explain the ^{26}Al abundance in the Milky Way, the main sources of ^{26}Al should be identified.
Gamma-ray observations of our Galaxy demonstrated that the ^{26}Al abundance has a maximum in the galactic plane, and that it is particularly intense in the stellar-forming regions. Moreover, analyzing the Doppler shift of the 1809 keV line it has been possible to deduce that ^{26}Al is co-rotating with the Galaxy. All this observational evidence favour the massive stars as the main sources of ^{26}Al [5].
According to standard models of stellar evolution, massive stars may synthesize ^{26}Al in three different evolutionary phases: C/Ne shell burning, explosive C/Ne burning and, for stars more massive than 30 solar masses, core H burning [6]. In all those phases, ^{26}Al is mainly produced by proton capture on ^{25}Mg.
The final abundance of ^{26}Al depends on the rate of all the nuclear reactions that contribute to its production or destruction. The ^{25}Mg(α, n)^{28}Si reaction destroys the ^{25}Mg seeds from which ^{26}Al is produced, and it is the nuclear reaction with the largest impact on the production of ^{26}Al in explosive C/Ne burning [4].
Explosive C/Ne burning occurs at a peak temperature of 2.3 GK. At this temperature, the Gamow window of the ^{25}Mg(α, n)^{28}Si reaction extends from 1 to 4 MeV.
In the energy range E_α = 1 - 6 MeV, the ^{25}Mg(α,n)^{28}Si cross section has been reported by many authors ([7] - [11]). A summary of the currently available experimental cross sections is reported in fig. 1.
Below 2.5 MeV the literature data are characterized by large uncertainties mainly due to beam - induced background, and the reaction rate reported by NACRE [12] is calculated adopting the unpublished cross section reported in [10].
Above 2.5 MeV, the NACRE rate is based on Hauser-Feshbach calculations, disregarding the existing experimental cross sections even in the energy region where they are in good agreement.
The ^{25}Mg(α,n)^{28}Si reaction has been studied at Legnaro National Laboratories at beam energies between 3 and 5 MeV. As illustrated in fig. 1, above 3.6 MeV the literature data are in good agreement while between 3 and 3.5 MeV the discrepancy is as high as a factor of 2.

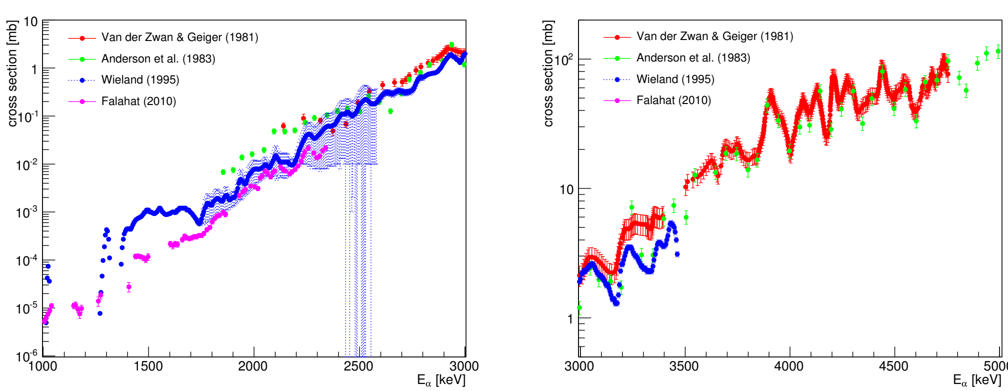

Figure 1. Summary of cross section data currently available in the literature. Below 1740 keV, the data of Wieland et al. are upper limits [10].

2 Experimental setup

A sketch of the experimental setup is shown in fig. 2.
A pulsed alpha beam with a repetition period of 333 ns and an integrated beam current of about 200 nA was delivered by the CN Van de Graaf accelerator. The beam current was measured with the backscattering technique, using two Si detectors placed at 150 degrees with respect to the beam direction.
Our targets were made of 95.75% enriched ^{25}MgO (70 μg/cm^2) evaporated on a 1 mg/cm^2 gold backing. Reaction neutrons were detected with ten BC501 liquid scintillators from the RIPEN array [13], positioned at 2 m from the target and covering the angular range from 17.5 to 106 degrees with respect to the beam direction. The neutron energy was measured with the time-of-fligth (TOF) technique. Two LaBr$_3$:Ce detectors were placed close to the target chamber, in order to study the gamma radiation produced by the reaction.

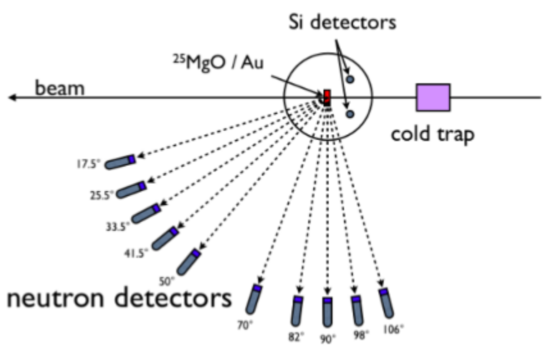

Figure 2. Schematic view of the experimental setup

3 Data analysis and preliminary results

The pulse shape analysis (PSA) technique was used to perform gamma-neutron discrimination and to reduce the background due to uncorrelated gamma rays (fig. 3).
The neutron TOF is determined with respect to the prompt gamma radiation emitted from the reaction. Measuring the neutron energy, it is possible to determine the contribution to the cross section of different ^{28}Si excited states, and to identify background neutrons produced by (α,n) reactions on light contaminants (mainly ^{13}C, ^{18}O and ^{19}F) possibly accumulated on the target.

The differential cross section has been evaluated independently for each detector, in order to determine the angular distribution of neutrons. Preliminary results at 5 MeV beam energy are shown in fig. 4.

The data analysis is still ongoing. In particular, Rutherford backscattering spectrometry measurements to evaluate the precise target thickness are planned for the end of 2013 at the AN2000 accelerator of Legnaro National Laboratories.

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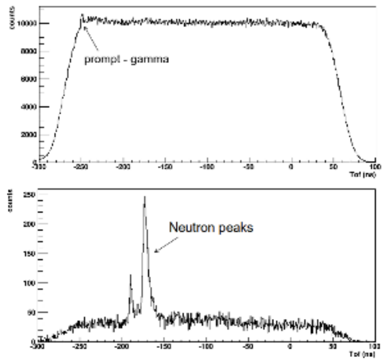

Figure 3. TOF spectrum before (top) and after (bottom) applying PSA at 3 MeV beam energy.

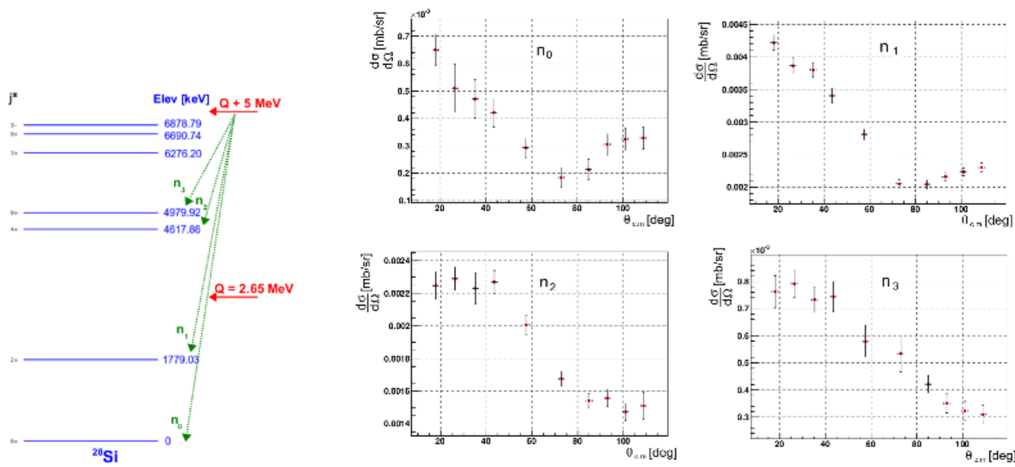

Figure 4. Left: partial level scheme of ^{28}Si. The reaction Q - value and the observed transitions are also given. Right: preliminary angular distribution evaluated for all the neutron transitions observed at E_α = 5 MeV. Only the statistical uncertainty is reported.

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