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Study of ^{24}Mg resonances relevant to carbon burning nucleosynthesis

V Tokić[1], N Soić[1], S Blagus[1], S Fazinić[1], D Jelavić-Malenica[1], Đ Miljanić[1], L Prepolec[1], N Skukan[1], S Szilner[1], M Uroić[1], M Milin[2], A Di Pietro[3], P Figuera[3], M Fisichella[3,5], M Lattuada[3,4], V Scuderi[3], E Strano[3], D Torresi[3,8], N Ashwood[6], N Curtis[6], M Freer[6], V Ziman[6], I Martel[7], A M Sánchez-Benítez[7] and L Acosta[7]

[1]Ruđer Bošković Institute, Bijenička cesta 54, 10000 Zagreb, Croatia
[2]Faculty of Science, University of Zagreb, Bijenička cesta 32, 10000 Zagreb, Croatia
[3]INFN-Laboratori Nazionali del Sud, via S.Sofia 62, 95125 Catania, Italy
[4]Department of Physics, University of Catania, Piazza Universita, 2 I, 95124 Catania, Italy
[5]Department of Physics, University of Messina, Piazza Pugliatti 1, 98122 Messina, Italy
[6]School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK
[7]University of Huelva, Department of Applied Physics, Avda. Fuerzas Armadas, s/n, 21071 Huelva, Spain

E-mail: `vtokic@irb.hr`

Abstract. We have studied the decays of the resonances of ^{24}Mg at excitation energies 1–6 MeV above the ^{12}C+^{12}C decay threshold, using the ^{12}C(^{16}O,α)^{24}Mg* reaction at E(^{16}O) = 94 MeV. Some preliminary results are presented and further analysis is in progress.

1. Introduction

Carbon-carbon burning has an important role in many stellar systems, which include super AGB stars, SN-type Ia systems and superbursts. To see how likely this fusion process is in these environments, we need to know the cross section in the energy range that occurs in these systems. The relevant energy range of cross section measurements for super AGB stars and SN-type Ia is $E_{c.m.}$ = 1.5–3.3 MeV for the ^{12}C+^{12}C reaction, while for the superbursts this energy range extends up to 5.7 MeV [1]. The available experimental data for the cross section cover the energy range down to $E_{c.m.}$ = 2.14 MeV [2, 3, 4]. Since there are resonances in the cross section at energies higher than the Gamow peak (E_G = 1.5 MeV for temperature $5{\cdot}10^8$ K), an extrapolation to the energy range required is uncertain, therefore, new data are needed. As this region is far below Coulomb barrier, it is extremely difficult to obtain these results.

2. Experiment

Instead of the direct cross section measurements used in [2, 3, 4], we decided to take a different approach. We have studied the ^{12}C(^{16}O,α)^{24}Mg* reaction at E(^{16}O) = 94 MeV. The decay channels of ^{24}Mg* and some threshold energies are presented in Table 1. The main idea was to

[8] Present address: INFN-Sez. di Padova, Via Marzolo 8, 35131 Padova, Italy

Table 1. Decay channels of ^{24}Mg* and threshold energies E_{th}.

decay channel	^{12}C+^{12}C	^{8}Be+^{16}O	α+^{20}Ne	p+^{23}Na
E_{th} (MeV)	13.93	14.14	9.31	11.69

study the resonance structures of ^{24}Mg at excitation energies from 1 up to 6 MeV above the ^{12}C+^{12}C decay threshold and to determine their parameters by detecting decay fragments and recoil nuclei. The experiment was performed at INFN-LNS, using a Tandem accelerator and a large Si detector array. Our experimental setup consisted of 6 Si detector telescopes, each of them included a thin ΔE detector (their thickness was 19 or 20 μm), and one thick Position-Sensitive Silicon Strip Detector (PSSSD) or a Double-Sided Silicon Strip Detector (DSSSD).

3. Results

In calibrating the detectors we have noticed that the thin detectors are nonuniform in thickness (Fig. 1). The energy loss of the detected ions was calculated using the SRIM-2010 code. Similar results were obtained in Ref. [5].

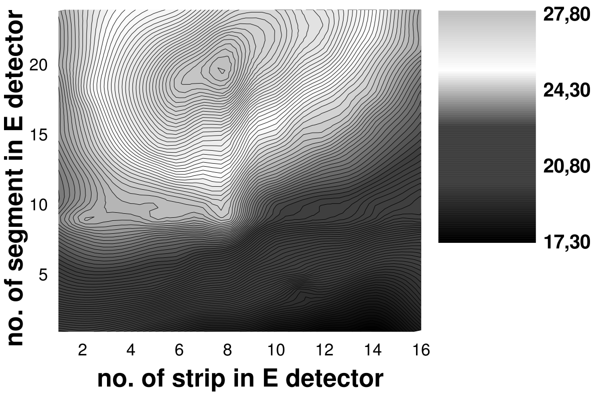

Figure 1. Thickness variation in μm of a 20 μm detector, made by Micron Semiconductor Ltd.

The Romano plot [6] for the coincidence of ^{12}C and α in one of the reaction channels is presented in Fig. 2. From these data it is inferred that the third, undetected particle has $A = 12$, while the Q-value of this reaction is –7.6 MeV (Fig. 2, inset 1), and $A = 12.03$ with a Q-value of –12.1 MeV (Fig. 2, inset 2). This difference in Q-value is about 4.4 MeV which corresponds to the energy of the first excited state of ^{12}C. This indicates that the third, undetected particle is also ^{12}C indeed, and in one case both nuclei ^{12}C are in their ground state, while in the other case one of them is in its first excited state. The Q-value as determined at various angles θ of the detected ^{12}C is presented in Fig. 3.

Further analysis is in progress.

4. Acknowledgments

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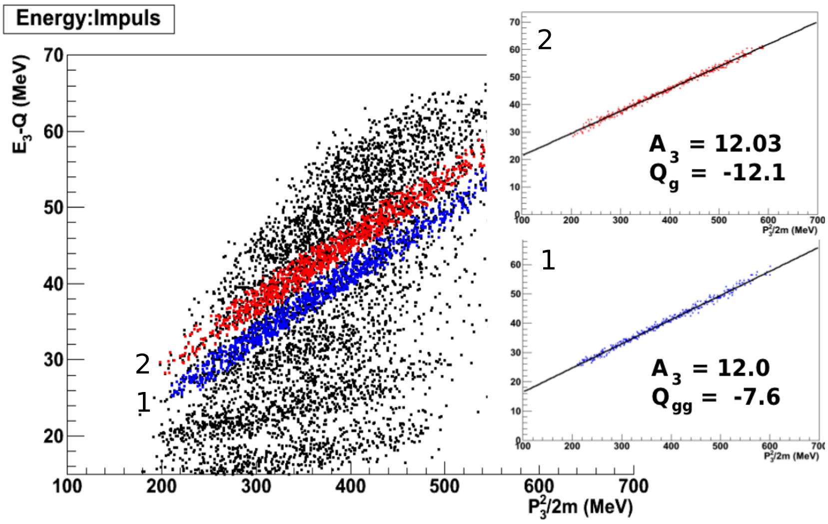

Figure 2. The difference $E_3 - Q$ of the energy of the third, undetected particle and the Q-value as a function of the $P_3^2/2\mathrm{m}$ (P_3 being the momentum of the third particle and m the nucleon mass) for the measurement of the coincidence of a ^{12}C and an α. From the crossing of the perpendicular axis and the slope of each 'stripe' we get $-Q$ and $1/\mathrm{A}_3$.

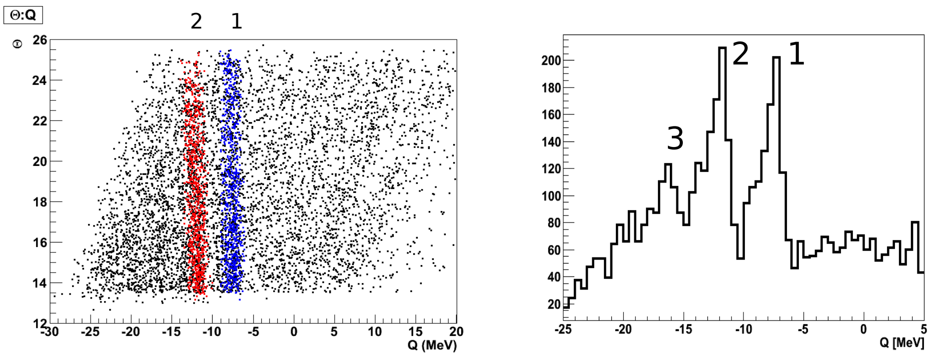

Figure 3. Detection angle θ of ^{12}C versus the Q-value (left) and the number of detected particles as a function of the Q-value (right). The Q-value peaks are at –7.6 MeV (1) and –12.1 MeV (2), corresponding to two ^{12}C in ground state and one in the ground state and the other in the first excited state, respectively. There is also an indication for a third peak (3).

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