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^{12}C + ^{12}C cross-section measurements at low energies

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Abstract. In order to study the ^{12}C + ^{12}C reaction at low energies, a combination of an intense heavy ion beam on a thick target and the detection of secondary gamma rays on a well-shielded germanium detector has been used. Preliminary cross-section results are reported for $E_{\rm c.m.} = 2.63$–$3.45\,$MeV.

PACS. 25.70.Jj Fusion and fusion-fission reactions – 26.50.+x Nuclear physics aspects of novae, supernovae, and other explosive environments – 97.10.Cv Stellar structure, interiors, evolution, nucleosynthesis, ages

1 Introduction

The ^{12}C + ^{12}C cross-section at low energies ($E_{\rm c.m.}$ = 1–3 MeV) is needed in order to constrain supernovae events detonated by explosive carbon burning in normal intermediate mass stars [1,2,3], and binary systems [4,5,6]. However, the lowest center-of-mass energy at which this cross-section has been measured is only 2.45 MeV [7].

2 Secondary gamma rays and thick target

For the ^{12}C + ^{12}C system, even at low energies, the excitation energy of the compound nucleus ^{24}Mg is enough to decay by particle emission. Below $E_{\rm c.m.} = 3\,$MeV, the only open evaporation channels accompanied with a gamma ray are alpha and proton (see fig. 1). Daughter nuclei ^{23}Na and ^{20}Ne are formed in states below all particle emission thresholds and the residual excitation energy is emitted as gamma rays. Through the detection of the first to ground-state decay gamma rays, we can work out our way back to the original ^{12}C(^{12}C, p_1)^{23}Na and ^{12}C(^{12}C, α_1)^{20}Ne cross-sections. We have combined this technique with the use of a graphite thick target, whose thickness exceeds the range of the incident particles. This target is strong enough to withstand the intense beam required for very low cross-section measurements. In this way, the cross-section is not just measured at a single energy, instead, the whole energy interval from the beam energy to zero is inspected; in essence, we are measuring the thick target yield.

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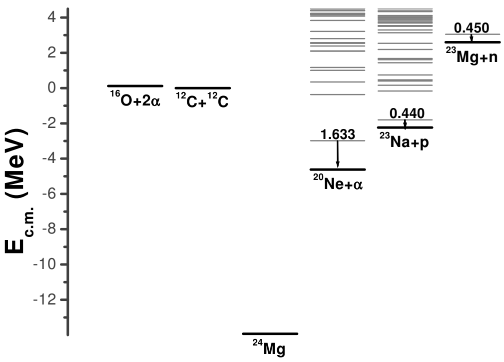

Fig. 1. ^{12}C + ^{12}C system and its decay modes.

3 Experimental procedures

Measurements were carried out at the IFUNAM 3 MV tandem accelerator. An intense ^{12}C beam (1 to 15 μA) was directed to a graphite thick target (1 mm thick) placed in the back of our reaction chamber. Gamma rays were detected by a hyper-pure germanium crystal (30% intrinsic efficiency), placed just behind the target. In order to reduce the background radiation, this detector and the reaction chamber were surrounded by lead shielding (9 cm thick). To obtain the total number of carbon ions incident in the target, a thin ^{197}Au coating (90×10^{15} atoms/cm^2) was deposited on the front of the target, so that the elastically backscattered particles can be monitored by a solid state detector (PIPS) mounted at 135 degrees,

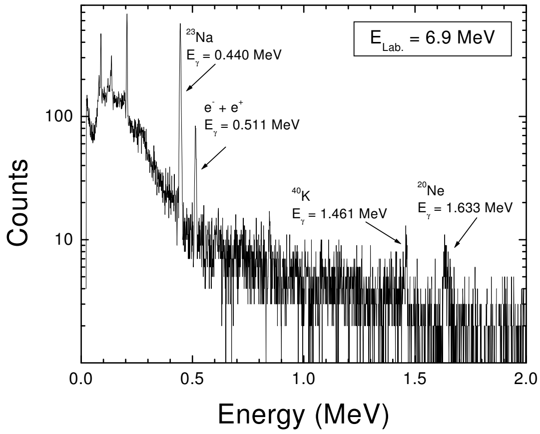

Fig. 2. Gamma-ray spectrum obtained for the ^{12}C + ^{12}C reaction at indicated laboratory system energy.

1.5 cm away from the target center. A very small collimator ($\Omega = 3.42 \times 10^{-5}$ sr) was placed in front of the monitor to reduce the intense flux of backscattered particles.

4 Results and discussion

Data at six different beam energies from 7 to 5.3 MeV was taken. For every beam energy, we obtained a gamma-ray spectrum in which the ^{23}Na and ^{20}Ne peaks can be distinguished (fig. 2). The deconvolution of thick target yield measurements to obtain the $^{12}C(^{12}C, p_1)^{23}Na$ and $^{12}C(^{12}C, \alpha_1)^{20}Ne$ cross-sections was carried out as is described in reference [8]; preliminary results are shown in fig. 3. Our monitor detector for the elastically backscattered ^{12}C from the ^{197}Au layer, suffered enough radiation damage to deform the spectrum in a way to turn difficult the desired absolute normalization. We estimate an additional error to the statistical one (shown in fig. 3), from 20% to 50%. A different approach to obtain the required absolute normalization will be used in future experiments. However, since both, the proton and alpha channels are measured simultaneously in the same spectrum, the relative thick target yield can be extracted without necessity of charge integration. The results of such analysis, that could verify the discrepancies observed in fig. 3, will appear in a coming publication.

5 Conclusions

The measurement of the thick target yield of secondary gamma emission allowed us to reach reaction cross-sections down to very low energies. Although absolute normalization is a matter that needs to be addressed further, our results show some inconsistencies with data found in the literature [7].

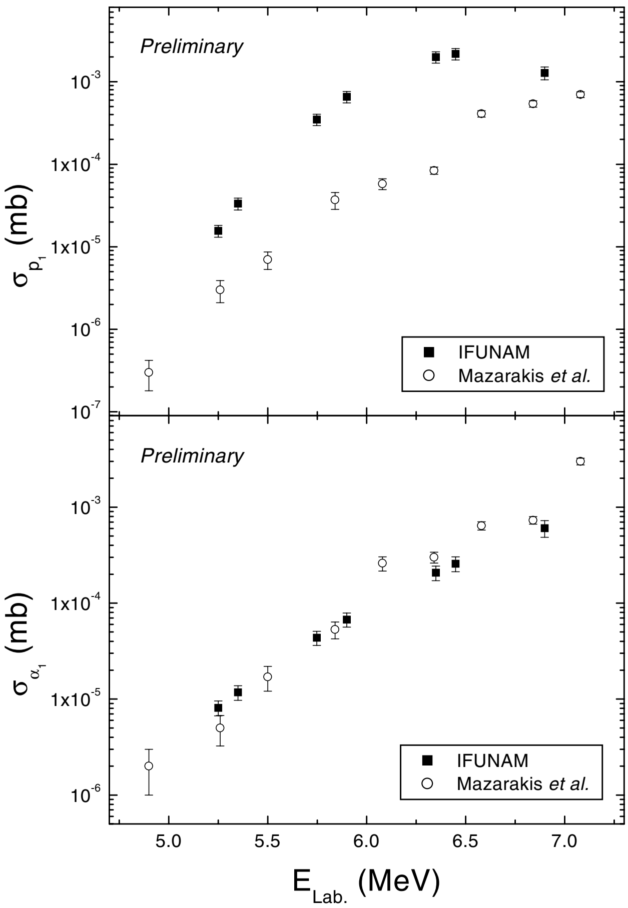

Fig. 3. $^{12}C(^{12}C, p_1)^{23}Na$ and $^{12}C(^{12}C, \alpha_1)^{20}Ne$ normalized cross-sections.

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