Decay of a $J^{\pi}=36^{+}$ Resonance in the $^{24}Mg + ^{24}Mg$ Reaction

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INTRODUCTION

For the ^{24}Mg + ^{24}Mg reaction, striking narrow and correlated resonance structures have been observed previously in the excitation functions of the elastic and low-lying inelastic channels [1]. In our study, we have decided to focus on the resonance at E_{CM}= 45.7 MeV, which is known to have $J^{\pi}=36^{+}$ [2]. Despite the very high excitation energy (~ 60 MeV) in the ^{48}Cr composite system, this resonance has a narrow total width of 170 keV [2]. To determine precisely which states in the inelastic ^{24}Mg channels carry away the resonance flux, an experiment, on the ^{24}Mg + ^{24}Mg reaction at energies ON and OFF resonance, has been performed at the Legnaro Tandem accelerator using the PRISMA fragment spectrometer associated with the CLARA γ array [3].

EXPERIMENTAL SET-UP

The ^{24}Mg + ^{24}Mg reaction has been studied at the Legnaro XTU Tandem using a ^{24}Mg beam of 91.72 MeV for the ON resonance measurement and of 92.62 MeV for the OFF resonance measurement. The target consisted of a thin film of ^{24}Mg (40 µg/cm^2) deposited on a 15 µg/cm^2 ^{12}C backing. The ^{24}Mg fragments produced in the reaction were detected and identified in the PRISMA spectrometer [4]. The detection angular range was 43°± 5°, i.e inside a range where resonances in the studied reactions have been observed previously [1]. The γ-rays emitted by the fragments have been detected in coincidence using the CLARA array composed of 24 clover detectors [5]. In PRISMA [4], the fragments are identified in Z and A and their velocity vectors are determined. More experimental details and a preliminary report on the experiment can be found in Ref. [6].

STATUS OF THE ART

In order to determine which states in the inelastic channels carry away the resonant flux, the yields of the corresponding γ-ray transitions have been measured ON and OFF resonance energies. The ratio R of these yields for different transitions and for different Q-value gates is represented in Fig.1. Of course, if R equals 1 there is no resonance effect. The first gate on Q corresponds to an inelastic excitation energy between 1 and 4.6 MeV and thus to the ^{24}Mg channels (2^+_1, 0^+_1), (2^+_1, 2^+_1) and (4^+_1, 0^+_1). For both transitions $2^+_1 \rightarrow 0^+_1$ and $4^+_1 \rightarrow 2^+_1$, R equals 2 and thus both 2^+_1 and 4^+_1 states are resonant states, the strongest contribution in this gate comes from the (2^+_1, 2^+_1) channel. The second gate on Q-value corresponds to an excitation energy between 4.7 and 7.3 MeV. For this gate, a resonant effect is seen again in the yields of the $2^+_1 \rightarrow 0^+_1$ and $4^+_1 \rightarrow 2^+_1$ transitions. In this gate, the main contribution comes from the (4^+_1, 2^+_1) channel. The ratio R for $2^+_1 \rightarrow 0^+_1$ is smaller than for $4^+_1 \rightarrow 2^+_1$, this can probably be explained by a weak feeding of 2^+_1 by states of the $K^{\pi}=2^+$ band, which will be shown later to be non-resonant. The third gate corresponds to an excitation energy between 7.3 and 11 MeV. As before, a resonant effect is seen in the yields of $2^+_1 \rightarrow 0^+_1$ and $4^+_1 \rightarrow 2^+_1$, in this gate the main contribution comes from the (4^+_1, 4^+_1) channel. Finally the fourth gate corresponds to the total excitation energy from 1 to 11 MeV. The $2^+_1 \rightarrow 0^+_1$ and $4^+_1 \rightarrow 2^+_1$ show strong resonant effects, the yields of the other transitions ($6^+_1 \rightarrow 4^+_1$ and the second band $K^{\pi}=2^+$) are weak and non-resonant (R~1). For the ON resonance measurement, the direct feeding yields of the different ^{24}Mg states have been extracted and are represented in Fig.2. It is obvious that for the ^{24}Mg

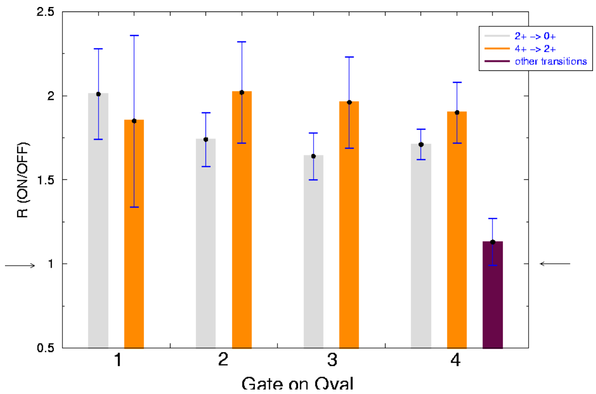

***FIG. 1**: ON and OFF yield ratios for ^{24}Mg transitions and for different Q-value gates.*

excitation energy region investigated in our experiment, the 2^+_1 and moreover the 4^+_1 play an essential role in the decay of the ^{24}Mg + ^{24}Mg resonance.

To put it in a nutshell, the ^{24}Mg + ^{24}Mg resonance decay flux is essentially observed in the ^{24}Mg 4^+_1 and 2^+_1 states (present measurements) and also in the elastic channel from previous measurements [1,2], i.e. in the first three members of the ^{24}Mg $K^\pi=0^+$ ground state band. This is in agreement with the molecular model proposed by Uegaki and Abe [7] to describe the ^{24}Mg + ^{24}Mg high spin resonances, in which the collective motions of the system are described in the rotating molecular frame of the dinuclear system. The important result that emerges from this calculation is the existence of a potential energy minimum for the pole-to-pole configuration. This configuration has the largest possible moment of inertia for two touching prolate ^{24}Mg nuclei. The identification of the observed resonance with this configuration (a ^{48}Cr hyperdeformed molecular state) agrees with excitation, spin and decay of the $J^\pi=36^+$ resonance at E_{CM}= 45.7 MeV. In this picture, the ground state ^{24}Mg rotational band and especially the 0^+, 2^+ and 4^+ states play the dominant role in the description of the resonance as demonstrated in our experiment and in previous work [1,2].

CONCLUSION

We have demonstrated in our experiment that the resonant flux of the ^{24}Mg + ^{24}Mg $J^\pi=36^+$ resonance at E_{CM}= 45.7 MeV is essentially carried away in the inelastic channels by the ^{24}Mg 2^+_1 and 4^+_1 states. It is known that for the ^{24}Mg + ^{24}Mg reaction the elastic and inelastic channels are ten times stronger than the α transfer channels and that all the direct reaction channels absorb only 30% of the resonance flux [2]. We propose therefore in an upcoming experiment to search for the missing resonance flux in the ^{24}Mg(^{24}Mg, 2α or ^{8}Be)^{40}Ca fusion evaporation channels feeding the deformed and superdeformed bands in ^{40}Ca. This experiment has been accepted and will take place in Legnaro this year using the γ array GASP and the Si array EUCLIDES with the same target and energy that have been taken for the experiment presented here. We will also measure ON and OFF resonance. In the case of selective feeding, this would clearly establish a link between the ^{48}Cr molecular state and the ^{40}Ca superdeformed states.

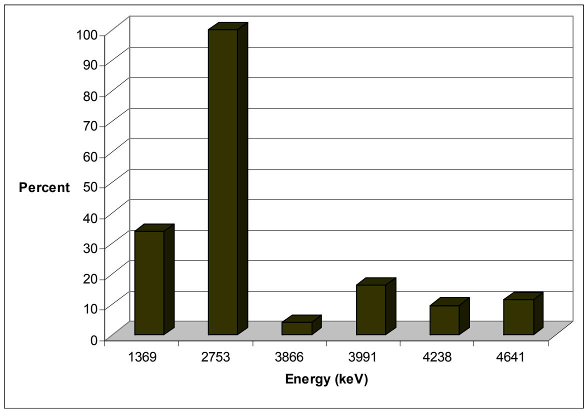

***FIG. 2**: ON resonance direct feeding of the ^{24}Mg states.*

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