Decay of ^{24}Mg+^{24}Mg resonances and associated ^{48}Cr molecular states studied with the Prisma-Clara array

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ABSTRACT

The narrow (Γ = 170 keV) and high-spin ($J^\pi = 36^+$) resonance in the ^{24}Mg+^{24}Mg reaction at E_{CM} = 45.7 MeV has been associated with a hyperdeformed molecular state in ^{48}Cr composed of two pole-to-pole prolate ^{24}Mg nuclei. Such a description has important consequences for the resonance decay into the favoured inelastic channels. States in ^{24}Mg located below 9 MeV of excitation energy have been populated in the ^{24}Mg+^{24}Mg reaction and their deexcitation has been measured on and off resonance using the Prisma-Clara setup.

THE PHYSICS CASE

Excitation functions for the elastic and inelastic channels have been measured for ^{24}Mg+^{24}Mg at large scattering angles around θ_{CM}= 90° where it is known that the resonance phenomena are the strongest. Strikingly narrow and correlated structures have been observed in the elastic and low-lying inelastic channels. The present study is focused on the resonance at E_{CM}= 45.7 MeV and J^π=36$^+$. Despite the very high excitation energy (~60 MeV) in the ^{48}Cr composite system, the resonance has a narrow total width of 170 keV [1].

Different models have tried to explain the ^{24}Mg+^{24}Mg resonances, such as the molecular model introduced by Uegaki and Abe [2,3] 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^π=36$^+$ resonance at E_{CM}= 45.7 MeV.

In this picture, the ground state ^{24}Mg rotational band would play a special role and might account for the strong population of excitations of this band in the resonance scattering. In the vicinity of the resonance energy, the excitation energy spectrum of the ^{24}Mg+^{24}Mg exit channel presents two distinct regions [4]: above an excitation energy of ~7 MeV, the observed strong structures can be explained by mutual high-spin excitations of the fragments which are well described by the statistical fission calculations [4], this is not the case at lower energies where resonant effects dominate. In the excitation region 0 to 4 MeV, the resonant flux can only go to channels involving the 0$^+$ and 2$^+$ ground state band members. In the region between 4 and 7 MeV, the situation is unclear because no high-resolution fragment-γ experiment had been performed for ^{24}Mg+^{24}Mg.

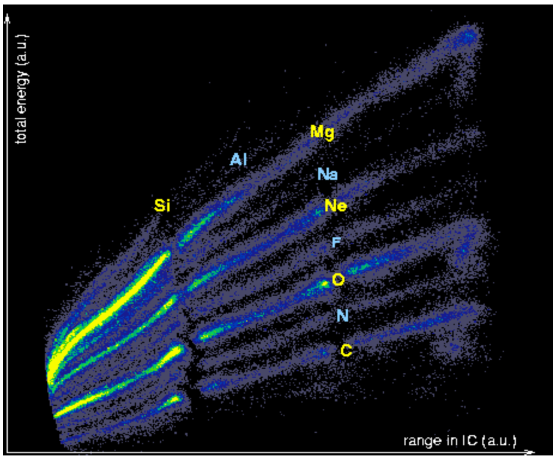

FIG. 1*: Total energy versus range measured in the Prisma IC array in this ^{24}Mg+^{24}Mg run.*

THE EXPERIMENT AND PRELIMINARY COMMENTS ON THE DATA

The aim of this study is to determine which states in the fragments carry away part of the resonance decay strength. The ^{24}Mg+^{24}Mg reaction has been performed at the end of October 2004 at LNL using a ^{24}Mg beam from the XTU tandem successively at 91.72 MeV (on-resonance) and

92.62 MeV (off-resonance) on a ^{24}Mg target consisting of 40μg/cm^2 ^{24}Mg deposited on a thin ^{12}C backing (15 μg/cm^2). Fragments are identified in the Prisma spectrometer [5] and the gamma-rays emitted are detected in coincidence in the 23 clover detectors of the Clara array [6]. The fragment mass is determined by the entrance position in the spectrometer (micro-channel plate (MCP) signal), its exit position (multi-wire parallel plate (MWPPAC) signal), time of flight (between MCP and MWPPAC) and total energy (measured in an array of transverse field multiparametric ionization chambers (IC)). The energy loss, and mean range of the fragments is also measured in this array. Figure 1 presents the total energy versus range measured in the IC array in our experiment showing the Z separation of the fragments. One sees that the even-even ^{12}C, ^{16}O, ^{20}Ne, ^{24}Mg, ^{28}Si nuclei are preferentially populated compared to the Z odd nuclei in the collisions ^{24}Mg on ^{24}Mg and ^{12}C (target backing). For these α-like systems, this is simply due to Q-value effects.

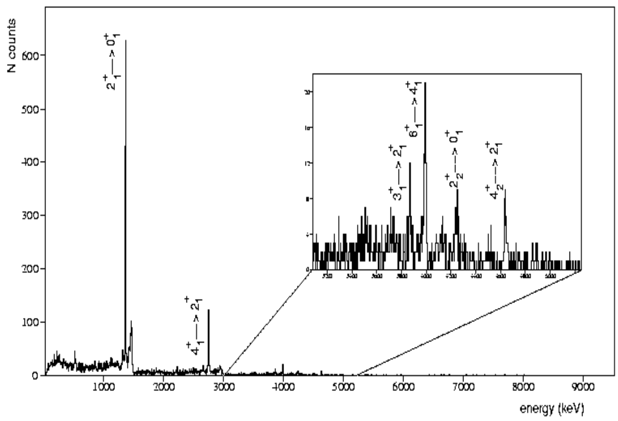

***FIG. 2**: Gamma spectrum measured in the Clara array conditionned by Z=12 (see Fig.1) and A = 24, showing decays between low-lying ^{24}Mg states.*

Figure 2 shows the gamma spectrum obtained in the Clara array after Z=12 and A=24 (^{24}Mg) selection. The measurement of the velocity vector of the fragment (v/c ~ 6%) in Prisma allows a Doppler correction of the gamma energies leading to 0.6% resolution at 1369 keV (2^+ to 0^+ g.s. of ^{24}Mg). This Doppler correction is of course crucial in the case of the rather high energy γ-rays (1 to 5 MeV) emitted in this light nucleus. From Fig.2 we clearly see decays of the 2^+_1 (1367 keV), 4^+_1 (4122 keV), 3^+_1 (5235 keV), 2^+_2 (4238 keV), 4^+_2 (6010 keV) and 6^+_1 (8113 keV) ^{24}Mg excited states. In this symmetrical exit channel, fragments (^{24}Mg) that are not detected in Prisma lead to uncorrected gamma rays (bottom of the γ-lines). From this preliminary γ spectrum we see that the feeding of the 2^+ and 4^+ states of ^{24}Mg seems to dominate the resonance decay. The data is under analysis: a detailed study will allow to evaluate the relative contribution of the flux passing through these states with regard to the other ^{24}Mg excited states.

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