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Looking for non-statistical effects in the decay of ^{36,37}Ar*: First results

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Summary. — The system ^{24}Mg+^{12,13}C at an energy of 162 and 142 MeV respectively has been investigated with the GARFIELD and RingCounter detectors at LNL. Thanks to their large coverage and their good identification capability, it is possible to obtain a clean data set where the total charge of exited ^{36,37}Ar* compound nucleus is detected. The experimental data are compared with simulated events using the standard GEMINI++ statistical code.

1. – Introduction

The light nuclei reactions have been extensively studied with the GARFIELD+RCo apparatus at Laboratori Nazionali di Legnaro to verify possible clusterization effects which can still persist with increasing excitation energy [1] [2]. The experimental data are compared with statistical models in order to evidence possibile deviations in the various decay paths, which can be a signature of the possibility that α emission branching ratio (BR) might be higher due to the presence of α-structure in the compound nuclei (CN).

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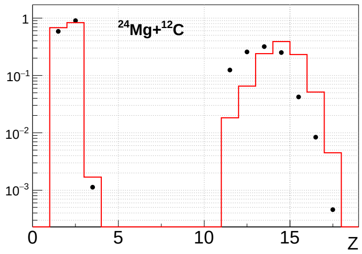

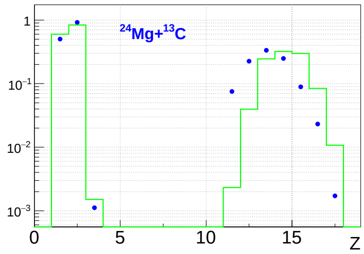

Fig. 1. – Charge distributions for Fusion-Evaporation complete events in the ^{24}Mg+^{12}C (left) and ^{24}Mg+^{13}C (right) reactions. Points are experimental data and lines the simulated and filtered GEMINI++ events.

For this analysis, the GEMINI++ statistical code is used as a reference [3]. Details about the experimental apparatus can be found elsewhere [4], but RCo and GARFIELD apparatus cover a complete azimuthal symmetry, with an angular range from 7° to 17° and from 30° to 150° respectively. In these experiments, GARFIELD is used to detect charge and mass of the Light Charged particles by means of Pulse Shape Analysis with digital electronics. RCo is used to detect Evaporation Residue and Fragments by means of ΔE-E tecniques in the ICvsSi correlations, but also LCP using the SivsCsI correlation and the CsI(Tl) digital Pulse Shape Analysis. The combination of the two devices allows for a geometrical efficiency of almost 70% of the solid angle, also ensuring a "good" granularity (around 300 electronic channels).

2. – Experimental results

The fusion-evaporation events have been selected via software gates requiring for an Evaporation Residue (ER) with charge Z_{ER} ≥11 detected in the RCo detector with at least one LCP in coincidence. An additional gate on the velocity of the ER has be used to reject the tails due to contamination of non-central reactions. Moreover, we also required the completeness of the detected charge: the sum of the charge of the detected fragments has to be equal to the charge of the system,Z_{sys}=18. The total momentum has to be conserved within ±10% to avoid contamination with spurious particles. After those selections, around 3.5 Million events called "complete events" for each system survive.

In Fig.1, the charge distribution of the ^{24}Mg+^{12}C at 162 MeV reaction (left panel) and ^{24}Mg+^{12}C at 142 reaction (right panel) is shown. The points represent the experimental data and the lines the GEMINI++ code events filtered through a software replica of the apparatus. All distribution are normalized to the number of complete events. Looking at Fig.1, it is clear that the ER experimental charge spectra are not well reproduced by the model in both cases. This is different from the previous results on the ^{12}C+^{12,13}C at 95 MeV reaction from [1,2] studied with the same experimental apparatus, where ER charge were rather well reproduced.

In Fig.2 the Energy spectra for proton and alfa particles from the GARFIELD detector for complete events are shown for the ^{24}Mg+^{12}C (and ^{24}Mg+^{13}C) system. The distribution are normalized to the integral, for a better shape comparison. In the legend, the multeplicities are reported. For both systems, the slope of the proton spectra are not well described by the model, differently from alpha particles. A small deviation in

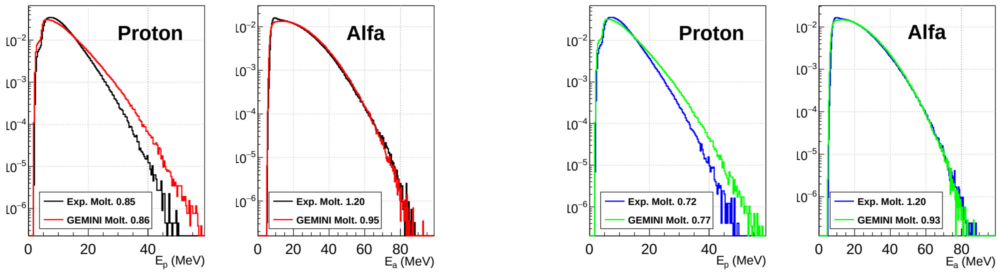

Fig. 2. – Proton and alfa energy spectra in the laboratory frame detected in GARFIELD for complete events (see text) for ^{24}Mg+^{12}C and ^{24}Mg+^{13}C. Distributions are normalized to the integral.

the alfa spectra is present at low energy due to the presence of some spurious events in some of the GARFIELD detectors to be refined. For the multiplicities, we obtain an opposite indication: proton multiplicity is well reproduced (expecially for ^{13}C target), while the alpha particles multiplicity is understimated by the model. Looking to the different decay channels, we can try to investigate the reason of those differences. In Fig. 3, the proton (first row) and alpha (second row) energy spectra are shown as a function of the ER charge in the case of ^{24}Mg+^{13}C reaction. The shapes are normalized to the integral. Similar results can be obtained also for the ^{24}Mg+^{12}C reaction, suggesting that the shape of the LCP spectra in GARFIELD are well reproduced by the GEMINI simulation for each possible ER.

Exploiting the charge completeness of the events, we can study the Branching Ratios (BRs) of the various decay chains. Tab.I reports the measured and predicted BR in some cases, for both investigated systems. The experimental BRs errors reflect the uncertainties due to the possible presence of ^{3}He in the α gates.

It is clear that for some ER only one decay channel is dominant. This is the case for Na, Mg, Al and P. More interesting are the cases of Si and S, where there is a competition between the emission of only α particles (a part from neutrons) and other chains involving protons. At variance with the previously studied systems ^{12}C+^{12,13}C [1] [2] where the larger discrepancies were observed for even-Z_{ER} values, here the decay channels with only α particles for Z_{ER}=12,14 are not dominant in the data. The GEMINI simulation

Table I. – *Branching Ratio for some decay channels of the two system compared with the GEMINI simulation.*

Decay Channel	^{24}Mg+^{12}C Exp.	^{24}Mg+^{12}C Gem.	^{24}Mg+^{13}C Exp.	^{24}Mg+^{13}C Gem.
Mg+3a+xn	86±3%	80%	97±4%	95%
Al+2a+1p+xn	95±4%	97%	95±4%	97%
Si+2a+xn	31±1%	45%	59±2%	70%
Si+a+2p+xn	60±2%	48%	34±1%	25%
P+a+p+xn	86±3%	93%	92±4%	94%
S+a+xn	28±1%	29%	41±1%	33%
S+2p+xn	60±2%	60%	46±1%	57%

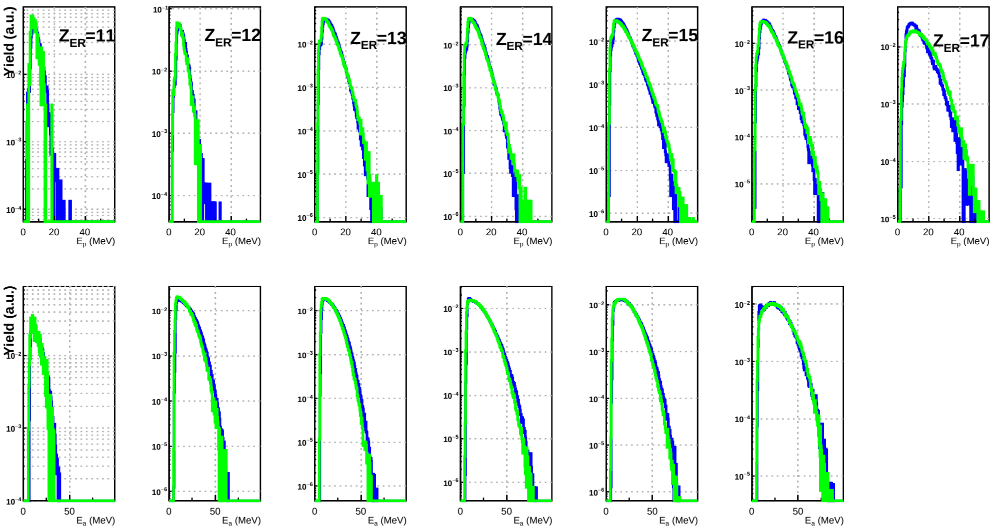

Fig. 3. – Proton (first row) and alfa (second row) energy spectra detected in GARFIELD in coincidence with different ER for fusion reaction ^{24}Mg+^{13}C. Distributions are normalized to the integral.

shows a similar trend, also if the absolute value of the BRs are not always well reproduced (in particular for the ^{24}Mg+^{13}C system).

3. – Conclusion

The preliminary results show, as expected, that the general behaviour is consistent with fusion-evaporation scenario governed by statistical assumptions. However, some discrepancies have been detected. For example, the energy spectra of protons present an harder energetic tail not predicted by the model. Also the predicted Z_{ER} distribution is centered toward heavier fragment than measured. A refinement of the GEMINI simulation is under discussion, probably connected to the angular momentum distributions of the Compound Nucleus. At difference with our previous studies on the lighter C+C system, there are not specific chains, those where the emission of only alpha (and neutrons) particles is possible, which are dominating in the experiment and not in the model. The interpretation of these effects is therefore on progress.

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