Pre-equilibrium emission during 46Ti* thermalization

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THE EXPERIMENT

The comparative study of the four reactions: $^{16}O+^{30}Si$, $^{18}O+^{28}Si$ and $^{19}F+^{27}Al$ at 7 MeV/u and $^{16}O+^{30}Si$ at 8 MeV/u has been performed using the GaRFIELD+RCo array [1] at Legnaro National Laboratories. This is an essential part of the extensive program on pre-equilibrium emission of light charged particles from hot nuclei, carrying out by the NUCL-EX collaboration [2].

The main goal of the experiment is to measure and compare the pre-equilibrium component of the particle emission spectra for these systems at about 130 MeV; the energies have been chosen just above the α-emission threshold to obtain a lower limit of the pre-equilibrium emission. For central impact parameters, the systems lead to the same compound nucleus, $^{46}Ti^*$. In reactions with the same beam velocity, the non-equilibrium processes are predicted to be almost the same [3]; therefore, the ratios between statistical and pre-equilibrium light charged particle multiplicities and between different exit channels ($^{3}He/^{4}He$, p/d, p/t, $^{4}He/p$) allow to extract information about the influence of possible α-clustering in these medium-mass systems. The other beam energy has been chosen to be 8 MeV/u in order to have the same compound nucleus excitation energy of the $^{18}O+^{28}Si$ at 7 MeV/u; hence the same statistical component.

THE PRELIMINARY ANALYSIS

To study the pre-equilibrium emission, the central events selection is required. A first events selection has been performed on-line with triggers on particles detectors. Then, a better selection of the central events has been made in the first analysis step through the coincidence of residues with light charged particles.

The complete analysis is performing on an event-by-event basis. The experimental data have been compared to the theoretical predictions filtered through a software replica of the setup.

The theoretically predicted events have been generated by numerical codes based on pre-equilibrium and statistical models: GEMINI++ [4] and TWINGO [5]. The GEMINI code is based on Hauser-Feshbach model, in which the Weisskopf description of evaporation mechanism is coupled with a quantum description of angular momentum. It can describe only the thermalized emission from a compound nucleus, but it gives information on the differences between the four reactions connected to the major part of the cross section, which is related to the de-excitation of a thermalized source (CN). While, the TWINGO code, based on the SMF (Stochastic Mean Field), allows to simulate the dynamical part of the reaction. To generate the complete event, TWINGO has been followed by an after-burn decay code (GEMINI++) to simulate also the statistical decay of the compound nucleus formed following the thermalization of nucleus.

Differences between the experimental data and the predicted data put into evidence effects related to the entrance channel and to the clustering nature of the colliding ions.

THE PRELIMINARY RESULTS

The comparisons between the experimental light charged particles emission spectra and the simulated ones have shown a good agreement for proton on the whole angular range; only at very forward angles (8.8°-17.4°) a slight overproduction, mainly due to the pre-equilibrium emission, appears. Figure 1 shows the proton experimental spectra compared with predictions of statistical code GEMINI++ and with predictions of dynamical code TWINGO coupled with GEMINI++ for $^{16}O+^{30}Si$ at 7 MeV/u. Similar results are obtained for the other reactions.

A good agreement between experimental α-particles spectra and statistical predictions has been shown at backward angles (97.5°-150.4°), but at forward angles an over-production of α-particles appears. This over-production can be related to some dynamical process, as pre-equilibrium. Figure 2 shows the comparison of α-particles experimental spectra with predictions for $^{16}O+^{30}Si$ at 7 MeV/u. The shape of other reactions spectra is slightly different.

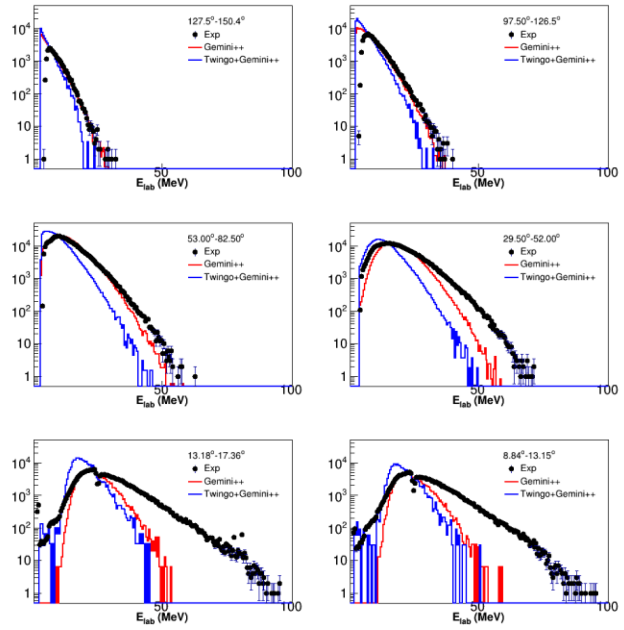

Fig.1 Comparison at different angles of Experimental Proton Spectra (black dots with error bars) with theoretical predictions made by Statistical Code GEMINI++ (red lines) and by Dynamical Code TWINGO coupled with GEMINI++ (blue lines).

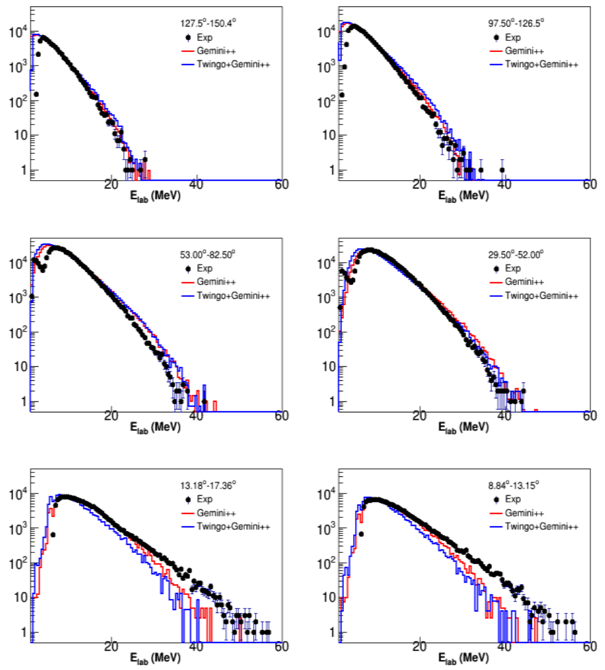

Fig.2 Comparison at different angles of Experimental (black dots with errors bars) and Predicted (red lines for GEMINI++ and blue lines for TWINGO+GEMINI++) α-particles Spectra.

CONCLUSIONS

The preliminary comparisons between the experimental and the simulated spectra have stressed that the shape of the proton spectra in the almost whole angular range and shape of the α-particle spectra at backward angles have reasonably reproduced by the statistical model. While at forward angles the experimental α-particle spectra have shown an overproduction of α-particles at higher energies.

The analysis is still in progress. A deeper analysis is needed to understand the process, looking to pre-equilibrium models which also take into account possible clusters formation, for example using the Moscow model based on the Hybrid model [6]. This will permit to better disentangle the pre-equilibrium emission. A complete analysis will be performed to correlate the velocity and angular ranges of the heavy fragments and light charged particles.

Moreover, an analysis of the peripheral reactions for the de-excitation of the projectile is in progress aiming at studying possible resonant states in projectile-like products.

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