Non statistical effects in the decay of excited light nuclear systems

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In central and semicentral collisions at low incident energy (5-15 MeV/u), the dominant reaction mechanism is the formation of a compound nucleus. This system is obtained from the fusion of the projectile and target nuclei. Its decay can be described and studied using a statistical decay approach, which represents one of the most well known results of nuclear physics. The statistical decay model, among other nuclear parameters, uses both the knowledge of discrete levels states, at low excitation energies, and that of the level density at higher excitation energies. The former are quite well studied and characterized with different reaction mechanism whereas the level density, expecially above the particle decay threshold, stills needs further and more precise studies. Therefore, in this framework fusion and compound nucleus decay represents a unique tool for studying this quantity.

Recently, the NUCL-EX group started an advanced experimental campaign of systematic measurements to study the decay of light nuclear systems formed at relatively high excitation energies. These reactions mainly lead to the formation of a compound nucleus(CN) in the mass region below A=60 with an excitation energy of 2-3 MeV/u . So far, the ^{12}C+^{12}C, ^{14}N+^{10}B and ^{12}C+^{13}C reactions have been performed. The first two reactions were used to form the same excited compound nucleus ^{24}Mg* (2.6 MeV/u) [1]. The last reaction instead was used to form an isotopes of the previous CN nucleus, namely ^{25}Mg* [2]. One important result was the deviation of the experimental Branching Ratio (BR) in the α emission channels in coincidence with an even-Z evaporation residue (ex. ^{12}C+3α) with respect to the statistical decay model. These differences can be attributed to structure effects which are not included in the model or to reaction mechanisms different from complete fusion. A good example of the latter is the precompound particle emission [3]. On the other hand, the structure effects can be related to the α-cluster nature of the issued CN or of the reaction partners. These clustering effects are a very interesting ongoing subject in nuclear physics as described in detail in literature [4].

My PhD project will consist of participating to this experimental campaign, from the detector preparation to the data analysis, where a CN and/or excited projectile are produced in nuclear reactions with light ions. A first reaction already in the data analysis phase is ^{16}O+^{12}C at three different incident energies (90.5, 110 e 130 MeV). The reaction was performed at the LNL (Legnaro National Laboratorie of INFN) using the experimental appartus formed by coupling the GARFIELD and RingCounter detectors [5]. First preliminary results were presented in my master thesis [6] and pubblished in the Annual Report of LNL [7]. A key point of our measurements, is the availability of well reconstructed events complete in charge. As for the previous reactions, the data was compared with a dedicated Monte-Carlo based on the Hauser-Feshbach statistical decay model [8]. Most of the inclusive observables such as energy, angular or charge distribution showed a good agreement with the model. Nevertheless, also in this case we observed clear deviation in the BR of the alpha emission channels in coincidence with an even-Z residue. Moreover, a particular increased BR is also observed for an odd-Z residue channel at 130 MeV which needs further investigation.

Another reaction currently under investigation is ^{24}Mg+^{12}C, in order to study the decay of the ^{36}Ar* compound nucleus formed in central collisions or the decay of ^{24}Mg* excited in more peripheral collisons. All these systems have in common the fact of being N=Z systems which are supposed to manifest an alpha-cluster structure [9]. A way of highlighting these effects is by comparing the values of exclusive observables, such as the BR, with the ones predicted by the model. One can also try to investigate their excitation energy dependence when different beam energies are available as we are pursuing for the ^{16}O+^{12}C reaction. Furthermore, along the decay chain one can populate the Hoyle state [10] of ^{12}C at 7,65 MeV. This level is known to have a great importance for the stellar nucleosynthesis of the Carbon element.

As far as the experimental part is regarded, my PhD project foresees also to perform other reactions where new light nuclear systems are issued. These will be studied both with the GARFIELD+RCo and the FAZIA [11] appartuses. The former detectors will be used with the RIB (*Radioactive Ion Beams*) production soon available at LNL whithin the SPES [12] project. Fazia instead will be employed for studying light ion reactions at higher energies (Fermi regime) in order to better evidence possible alpha-cluster structures or resonance decays of light hot systems formed at/or above the multifragmentation threshold.

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