5. SUMMARY AND FUTURE PROSPECTIVES

The goal of the present study was to give a contribution to the study of reaction mechanisms in collisions involving weakly bound nuclei around the Coulomb barrier. As discussed in chapter 1 it has been observed that, at energies around and below the Coulomb barrier, the SBPM is not sufficient to describe the fusion process since the experimental sub-barrier fusion cross-section strongly depends on the participant structure and the internal degrees of freedom. Weakly bound nuclei are characterized by very low break-up thresholds hence, according to the previsions of the coupled channels formalism, the presence of a strong break-up channel (and therefore the coupling to the continuum) may influence the fusion. Other effects have been observed in the threshold anomaly of the optical potential. The coupling to the continuum can destroy the usual threshold anomaly or even produce the opposite behavior, showing an increase of the imaginary potential around the barrier (break-up threshold anomaly). Several works have been undertaken in order to understand the role of these effects on the fusion cross-section and the threshold anomaly. The conclusions of different authors concerning fusion reactions involving weakly bound projectiles agree in some cases. For instance in the case of heavy targets all authors observed a complete fusion cross-section suppression above the barrier. The results are in other cases still controversial, as in the case of heavy targets at sub-barrier energies; whereas in some cases there is a lack of data to reach clear conclusions (that is the case of sub-barrier fusion with medium and light mass targets). Controversial results have been obtained by different authors also in the study of the threshold anomaly in the optical potential in collisions involving weakly bound nuclei.

In order to give an additional contribution to the study of the above topics the elastic scattering angular distributions and the fusion cross-sections at several energies around the barrier s have been measured for the $^{6,7}Li+^{64}Zn$ system.

The elastic scattering and the angular distributions at several energies around the barrier have been measured. This measure is difficult because at low energies, even at very backward angles, the pure coulomb contribution is dominant so it is necessary high accuracy. Five silicon telescopes have been mounted on a rotating plate to cover a wide angular range. Using telescopes it has been possible to discriminate the scattered ^{6}Li and ^{7}Li ions from lighter particles produced by other reaction channels. In addition, events corresponding to inelastic excitation of the target or projectile have been separated from the elastic scattering. The angular distributions have been measured covering also very backward angles because only in this angular region the elastic cross-section presents a deviation from the pure Coulomb one in the energy range around and below the Coulomb barrier. The elastic-scattering angular distribution best fit has been performed using two different model potentials:

(a) The renormalized double folding potential for both real and imaginary part.

(b) The renormalized double folding potential for the real part and the Woods-Saxon potential for the imaginary part.

The resulting total reaction cross-sections from the best-fit procedures agree within 4% at the higher energies and up to ~ 10% for the lowest energy. The real and imaginary potential trend with the energy are compatible for all best-fit procedures and the observed behavior for the ^{6,7}Li+^{64}Zn systems is in contrast to the usual threshold anomaly found in the case of tightly bound nuclei. Moreover ^{6}Li data are consistent with the presence of the break-up threshold anomaly observed for ^{6}Li scattering on different targets showing, around the barrier, an increasing imaginary potential as the bombarding energy decreases.

The fusion cross-sections for the ^{6,7}Li+^{64}Zn systems have been measured using an activation technique. This method is divided into two parts: the activation and the activity measure. The incident beam was passing through a thin gold foil in order to perform a Rutherford scattering and, detecting the scattered particles by two monitors, the current profile during the activation has been extracted. Subsequently the beam was impinging on the stack, which is formed by a ^{64}Zn target followed by a thick catcher layer. The purpose of the catcher is the collection of the evaporation residues produced in the target during the activation. For each bombarding energy a different stack has been activated. Immediately after the activation step, each activated stack, one per bombarding energy, has been placed in front of a Si-Li detector in order to detect the X-rays emitted following the electron capture decay of the produced evaporation residues. The charge of each evaporation residue has been identified by the X-ray characteristic energy of the daughter nucleus. Measuring the X-ray emission from each stack several times during a period of some months the activity curve for each element in a stack has been reconstructed. The overall measured activity curve is the result of the decay of different isotopes of the considered element. Each isotope contributes with an exponential decay with its own decay constant. Fitting the activity curve as the sum of exponential functions it has been possible to measure the activity at the end of activation for each produced evaporation residue. This activity is proportional to the number of produced evaporation residues. Properly considering different parameters (such as the beam current as a function of time during the activation, the Kα fluorescence probability, the detection efficiency etc.) the production cross-section for each evaporation residue has been extracted. These steps have been repeated for each stack, corresponding to different bombarding energies. For each energy the experimental relative yield for different ERs of total fusion (i.e. CF+ICF) has been compared with the predictions of the statistical code CASCADE for CF. In the comparisons for the ^{6}Li+^{64}Zn collision can be observed a strong contribution of deuteron-ICF and a possible neutron transfer contribution. Such contribution increases as the bombarding energy decreases below the barrier showing that the complete fusion is dominant above the barrier whereas at sub-barrier energies the ICF is the dominant mechanism for the heavy residue production. Such kind of behavior has been never observed before and its identification has been possible thanks to ER mass and charge identification allowed by the used technique. The fusion cross-section has been extracted as the sum of the cross-sections for the different ERs and has been compared with the one measured by Gomes et al. [13]. The total fusion cross-section appears to be larger than the existing data, confirming the possible presence of experimental problems in the data of [13] as suggested by the same authors in [14]. The total reaction cross-section extracted via the OM analysis of the elastic scattering angular distributions agrees with the existing data in [13]. As a consequence the very large elastic (non capture) break-up cross-sections extracted in [13] as the difference between the total reaction cross-section and the total fusion one is now reduced.

A similar behavior with the ICF contribution that becomes dominant when the energy decreases below the Coulomb barrier has been also observed for the ^{7}Li+^{64}Zn system.

The ratio between the total fusion excitation function for the ^{6}Li+^{64}Zn system and the ^{7}Li+^{64}Zn one has been studied as done by Back et al. [12] in the case of ^{6,7}Li+^{59}Co systems. Data on ^{6,7}Li+^{64}Zn systems seems to confirm the behavior observed for the ^{6,7}Li+^{59}Co systems: the total fusion cross-section for the ^{6}Li+^{64}Zn system increases with respect to the ^{7}Li+^{64}Zn system one. Additional calculations (i.e. the coupled channels prediction for fusion cross-section) in the CDCC formalism have still to be performed for a complete interpretation of the collected data.