INTRODUCTION

The increasing development of new experimental techniques and theoretical models made it possible detailed investigations of new reaction dynamics aspects in nuclear collisions. One aspect in this field, that arose a considerable interest in the last decade, is the study of nuclear collisions involving weakly bound nuclei at energies around the Coulomb barrier. In fact, it has been shown that the peculiar structure of such nuclei, which have very low break-up thresholds and also an extended matter distribution in the case of the nuclear halo, can strongly affect the reaction mechanisms around the Coulomb barrier.

For instance, the fusion process has been systematically studied for several decades for a huge variety of collisions in order to understand the barrier penetration process and its links with other open reaction channels. In former times, it was attempted to describe the fusion of two heavy ions by the single barrier penetration model (SBPM), which involves just the radial distance between the centers of mass of the two ions [1,2]. The effective potential between the two colliding ions is the sum of the nuclear, Coulomb and centrifugal potentials. For a fixed incident angular momentum l, the effective potential as a function of the distance between the two nuclei shows a relative maximum corresponding to a specific distance between the two colliding nuclei. For $l = 0$ the value of this maximum of the effective potential is the so-called Coulomb barrier. It has been observed that at energies around and below the Coulomb barrier the SBPM is not sufficient to describe the reaction dynamics since in such energy range the experimental sub-barrier fusion cross-sections were much larger then the predicted ones and strongly dependent by the participant structure [3,4]. It was then understood that in this energy region, reference to specific internal degrees of freedom of the colliding partners must be invoked in order to explain the fusion phenomenon. In this case the strong coupling of the entrance channel with inelastic excitations or other reaction channels like transfer leads to a modulation of the barrier resulting in an enhancement of the fusion cross-section with respect to SBPM [5].

When one of the participants of the collision is a weakly bound nucleus the fusion process may not follow the expected behavior. A weakly bound nucleus is a nuclear system with a very low break-up threshold (lower than 1.5 MeV) which is the minimum energy to be given to the system in order to break it in two or more parts. As a consequence of their low binding energy such nuclei may easily break-up during the collision. Moreover their matter distribution may extend far over the rms radius calculated by the usual radius-mass relation. In the extreme case of the halo structure, the valence nucleons form a low-density region identified by a very long tail in the matter distribution. There are indeed several possible effects on fusion dynamics due to the low binding energy of the colliding nuclei and their structure. These effects can be classified under two categories: static effects and dynamical effects. Static effects are due to the extended or diffused matter distribution of weakly bound nuclei. In this case the Coulomb barrier is lower than usual and the fusion cross-section may be enhanced. Dynamical effects are more complex. In weakly bound nuclei the coupling to inelastic excitations corresponds to the coupling with the break-up channel: is important to understand if the break-up will remove flux from fusion or the coupling to break-up will produce an enhancement of the sub-barrier fusion. Moreover, the process is made complicated by the importance of the incomplete fusion processes due to the low break-up threshold. Several authors in the last years studied reactions involving weakly bound nuclei in order to understand the role of the break-up on the fusion, nevertheless a definitive conclusion has not yet been reached.

The peculiar structure of weakly bound nuclei may also affect the elastic scattering. In the last years several papers studied the Optical Potential threshold anomaly (TA) in collision involving weakly bound nuclei [6-8]. The optical model (OM) describes the interaction between the projectile and the target using a complex potential. The real part of the potential is the sum of a Coulomb term, a centrifugal term and a nuclear term. The imaginary part takes into account all open reaction channels that remove flux from the elastic one. Both parts of the complex potential are function of the incident energy and have been studied since the 60’s of the last century. The usual potential dependence on the bombarding energy is characterized by a localized “bump” in the real part around the energy corresponding to the barrier and by a reduction of the imaginary part in the same energy region as the incident energy decreases. This behavior was called “Threshold Anomaly” (TA). The rise in the real part is due to an attractive polarization potential that is linked to the importance of the coupling effects, which are not explicitly taken into account in the OM. In the case of weakly bound nuclei it has been suggested that the coupling to the break-up process may introduce a repulsive polarization potential destroying the usual threshold anomaly. In some cases, the observed effect is opposite to the usual threshold anomaly (i.e. the rise of the imaginary part at the

Coulomb barrier energy and the correspondent decrease of the real one). Some authors called this behavior "break-up threshold anomaly" [9].

In this work will be presented the results from a set of experiments concerning the study of elastic scattering, fusion and total reaction cross-section at several energies around the Coulomb barrier for the $^{6,7}Li+^{64}Zn$ systems. The ^{6}Li and ^{7}Li nuclei are good candidates to study the reaction dynamics in collisions involving weakly bound nuclei. The two stable lithium isotopes have among the lowest binding energies of all stable nuclides. In particular ^{6}Li has a α+d cluster structure [11] with a separation-energy (1.48 MeV) lower than the ^{7}Li one (2.54 MeV), which shows an α+t cluster structure. Moreover the ^{6}Li nucleus has no bound excited states whereas the ^{7}Li one has a bound excited state at E = 478 KeV.

The elastic scattering angular distributions for both the systems have been measured at different energies around the Coulomb barrier. Different kinds of OM fits have been performed in order to investigate on the TA and look for possible differences due to the differing structures of the two projectiles. Moreover the total reaction cross-section has been extracted.

The study of the fusion excitation functions was further motivated by the presence of existing fusion data for the same two systems [13] that do not really explore the energy region below the Coulomb barrier. Moreover it has been suggested recently [14] that such data may be affected by a systematic error and have been underestimated. Another goal of the measurements was to look for differences between the fusion excitation functions of the two systems below the Coulomb barrier due to the different structures of the two projectiles as suggested by [12] in the case of the $^{6,7}Li+^{59}Co$ fusion. The technique used for the extraction of the total fusion cross-section consists in the activation of a thick target followed by the off-line detection of the atomic X-rays emitted in the decay of the evaporation residues [36]. This technique does not present the experimental problems bound to the direct detection of the very low energy evaporation residues and allows the extraction of the fusion cross-section at energies far below the Coulomb barrier.

This work is organized as follow:

- In chapter 1 will be described the problematic concerning the study of reaction mechanisms in collision involving weakly bound nuclei around the Coulomb barrier. Existing results in the literature, concerning the fusion, the elastic scattering and other reaction mechanisms will be presented. Physical motivations and goals of this work will be discussed.

- In chapter 2 the performed elastic scattering experiments for both the $^{6,7}Li+^{64}Zn$ systems will be described and the obtained results discussed.
- In chapter 3 the experimental techniques used to measure the $^{6,7}Li+^{64}Zn$ fusion excitation functions will be detailed and discussed.
- In chapter 4 the data analysis and the results obtained from the fusion data will be discussed.
- In chapter 5 all the obtained results will be summarized.