EPJ Web of Conferences **66**, 03087 (2014)
DOI: 10.1051/epjconf/201466603087

Elastic scattering of ^{17}O ions from ^{58}Ni at near-barrier energies

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Abstract. Elastic scattering has been studied for the collisions induced by ^{17}O on ^{58}Ni target at energies around and above the Coulomb barrier. The elastic scattering angular distributions were measured for several energies and were analyzed within the framework of the optical model to obtain total reaction cross sections. The reaction cross-sections of the tightly bound ^{17}O were compared with those of weakly bound ^{17}F on the same targets in order to investigate the effects of the low binding energy in the reaction dynamics.

1 Introduction

Over the past years many efforts were devoted to the study of the reaction dynamics in collision induced by light stable and unstable nuclei at energies around the Coulomb barrier. In particular reactions induced by radioactive nuclei nuclei has been one of the most studied topics. The effects of the breakup channel on the fusion and on the elastic scattering processes of weakly bound projectiles have been studied extensively, both experimentally and theoretically (see, e.g., Ref. [1] and references therein). The effects of the high breakup probability that characterizes such exotic projectiles nuclei on the fusion cross section it has been rather controversial. On one hand one may expect the fusion cross section for these weakly bound nuclei to be reduced due to the loss of flux in the entrance channel. On the other hand the strong coupling to the breakup channel should enhance the fusion cross section. This two opposite views were somehow reconciled by Hagino et al. [2] who predicted that couplings

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to breakup states lead to the enhancement of the complete fusion cross section at sub-barrier energies and to a reduction of the complete fusion cross section above the barrier.

Information on the structure of such nuclei and on its effect on the reaction dynamics can be obtained from high-quality elastic scattering angular distributions data such as shown for the systems ^{9,10,11}Be on ^{64}Zn [4] and ^{6}He on ^{208}Pb[5]. Within this framework we undertook the study of the ^{17}F reaction dynamics on a ^{208}Pb [8] and, more recently, on a ^{58}Ni target [3]. The results obtained in the latest experiments were compared with those of system ^{16}O+^{58}Ni [7]. With the aim to add a further system to the entire scenario, we measured the elastic scattering angular distributions for the systems ^{17}O on ^{58}Ni and ^{208}Pb targets at several energies around the Coulomb barrier. ^{17}O is indeed the mirror nucleus of the radioactive weakly-bound ^{17}F. The two isobars have similar shell model configurations with $d_{5/2}$ ground states and low-lying $s_{1/2}$ first excited states, but while the the first is very well bound S_n = 4.143 MeV for ^{17}O, the second is weakly bound S_p = 0.600 MeV for ^{17}F.

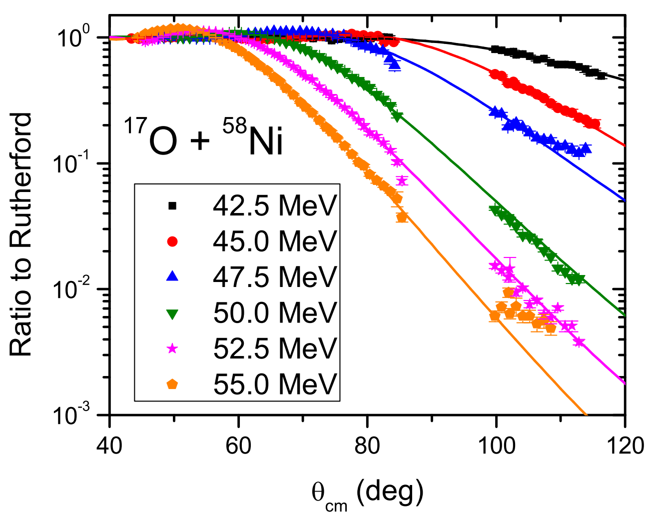

Figure 1. Elastic scattering angular distributions for the system ^{17}O + ^{58}Ni at different energies. Lines represent the results of optical model best-fit analysis.

2 Experimetal set-up

The measurements of the elastic scattering for the system ^{17}O + ^{58}Ni was included in the framework of the commissioning of the new detector system EXPADES [9]. This array consists of eight identical modules, each module is a telescope made of a 64×64 mm^2 large Double Sided Silicon Strip Detector (DSSSD), 300 μm thick as second stage. As first stage alternatively a 40 μm thick DSSSD or a gas chamber can be used. DSSSD has both electrodes segmented into 32 strips. For the thick DSSSDs the readout electronics is based on an 32-channel ASIC chip-set, manufactured by IDEAS-GM (Norway), while for the thin detectors a home-made traditional electronics was developed.

The measurement was performed using the ^{17}O beam delivered by the TANDEM-XTU accelerator at the Laboratori Nazionali di Legnaro. The targets were 150 μg/cm^2 thick ^{58}Ni foil with a backing of ^{208}Pb (50 μg/cm^2 thick) for normalization purpose. The targets were tilted by 45° with respect to the beam axis. For the first target energy ranged from 42.5 to 55 MeV in steps of 2.5 MeV, while for the second target five energies in the interval 78-87 MeV were studied. In this experiment two of the total eight modules of the EXPADES detector array were used. The first was placed at forward angles covering the angular range 35°-70°, while the second was placed at backward angle covering the angular range 80°-110°. They both consist of a single stage DSSSD 300 μm thick detector. Elastically scattered ^{17}O particles were selected according to their energy. The angular resolution allowed by the EXPADES pixel geometry, as can be seen from figure 1 was better than 1°. For normalization purposes two additional monitor detectors were placed at 20°.

3 Preliminary results

The elastic scattering angular distributions were properly normalized by assuming that the scattering at small angles (i.e. where the monitor detectors were located) was purely of the Rutherford type. Preliminary angular distributions for the system ^{17}O+^{58}Ni at energies: 42.5, 45, 47.5, 50, 52.5, 55 MeV are shown in figure 1.

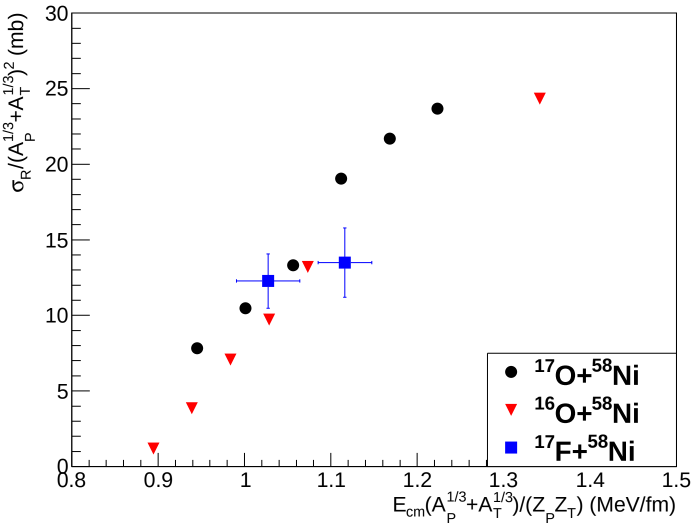

Figure 2. Total reaction cross section for ^{17}O + ^{58}Ni (circles) ^{16}O + ^{58}Ni (triangles) ^{17}F + ^{58}Ni (squares). The data were reduced according the formalism of Ref. [11].

A very preliminary optical model analysis of the experimental data has been also performed. The interaction potential between the ^{17}O and ^{58}Ni nuclei was described according to a standard Akyüz-Winther [12] parameterization. The fits were performed with the SFRESCO subroutine of the main coupled-channel code FRESCO [10] and are displayed in figure 1 with continuous lines. For the moment we assumed all events as originating from a pure elastic scattering process, even if the experimental energy resolution did not allow to separate events leading to the excitation of the ^{17}O first excited state at Ex = 0.871 MeV from elastic events. The preliminary results for the reaction cross sections for the system ^{17}O + ^{58}Ni are the following: 253 mb at 42.5 MeV, 452 mb at 45 MeV, 590 mb at 47.5 MeV, 694 mb at 50 MeV, 779 mb at 52.5 MeV and 869 mb at 55 MeV. In figure 2 are shown the total reaction cross section of three systems ^{17}O + ^{58}Ni, ^{16}O + ^{58}Ni [7] and ^{17}F + ^{58}Ni [3]. In order to account for the different geometrical sizes of the colliding nuclei and the different Coulomb barrier heights, the data were reduced according the procedure described in Ref. [11].

4 Concluding remarks

The elastic scattering angular distribution for the system ^{17}O on a ^{58}Ni has been measured at energy close and above the Coulomb barrier. The data have been analyzed within the framework of the optical model in order to extract the total reaction cross section. The differences in the reaction dynamics between the two mirror nuclei: the weakly bound ^{17}F and the well bound ^{17}O can be ascribed, at least in first approximation, to the different binding energy of the less bound nucleon. Considering that the data reduction should account for all static effects and for dynamical effects related to bound states, the tiny difference between the ^{17}F data point and the ^{17}O curve in figure 2 leaves very small room to the breakup channel.

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