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DISCRIMINATION OF PROCESSES AND OPTICAL MODEL ANALYSIS IN THE ^{17}O+^{58}Ni COLLISION AROUND THE COULOMB BARRIER*

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The ^{17}O+^{58}Ni collision was studied by means of a detailed analysis of the experimental spectra based on Monte Carlo simulations. The elastic scattering angular distributions were measured at five near-barrier energies in the range of 40–50 MeV and were investigated within the framework of the Optical Model, observing a relation between the imaginary radius parameter and the target mass. The Optical Model potential trend shows a normal Threshold Anomaly whereas the total reaction cross section, compared to the ^{16}O+^{58}Ni case, is in agreement with the theoretical predictions.

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1. Introduction

The study of the reaction dynamics involving weakly bound nuclei has been characterized by a growing interest in recent years. In fact, it has been observed that the low binding energy of the projectile might raise the relevance of several reaction channels such as the projectile breakup, direct reactions and incomplete fusion. Furthermore, the coupling of two or more reaction channels might significantly alter the reactivity of a colliding system leading to unexpected behavior such as an unusual Threshold Anomaly and a total reaction cross-section enhancement at near barrier energies [1].

The ^{17}O nucleus has a neutron separation energy of $S_n = 4.134$ MeV and can be classified in an intermediate range between well-bound ($S \sim 8$ MeV) and weakly-bound nuclei ($S \lesssim 2$ MeV). It can be described as an $^{16}\mathrm{O}+n$ structure and its features make it a good candidate for the investigation of the influence of the projectile binding energy on the reaction dynamics.

2. Experiment and discrimination of processes

The experiment was performed at the Laboratori Nazionali di Legnaro, Italy, employing the experimental setup described in [2] (shown in the left-hand side of Fig. 1) and exploring a beam energy range of 40–50 MeV with steps of 2.5 MeV. The ^{17}O ions emerging from a double layered target (^{58}Ni 150 μg/cm^2+^{208}Pb 50 μg/cm^2) were completely stopped in two 300 μm thick DSSSDs at forward angles (A and B in Fig. 1) and a 43 μm-thick DSSSD at backward angles (C). Each detector was 64×64 mm^2 wide and each side was segmented in 32 strips.

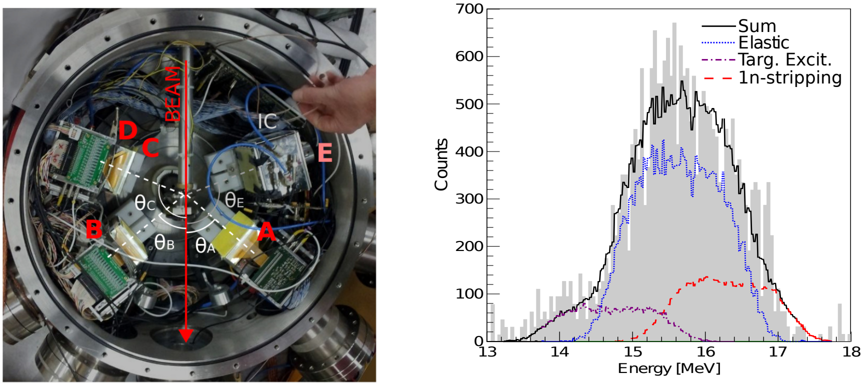

Fig. 1. (Color online) Left: Photograph of the experimental setup. A, B and D are 300 μm-thick DSSSDs, C is a 43 μm-thick DSSSD. Right: Deconvolution of the $^{17}\mathrm{O}+^{58}\mathrm{Ni}$ spectrum collected at $\theta_{\mathrm{cm}} = 85°$ and $E_{\mathrm{lab}} = 42.5$ MeV.

Four reaction channels were considered as contributing to the experimental peaks generated by the ^{17}O+^{58}Ni interaction and collected by the detector C: (a) elastic scattering; (b) 1n-stripping ^{17}O+^{58}Ni $\Rightarrow$ ^{16}O+^{59}Ni, $Q_{gg} = 4.856$ MeV; (c) projectile inelastic scattering ($E^* = 871$ keV $J^\pi = 1/2^+$); (d) target inelastic scattering ($E^* = 1.454$ MeV $J^\pi = 2^+$). As shown in the right-hand side of Fig. 1, these peaks were studied employing several Monte Carlo simulations with the following features: a uniform distribution for the depth of impact inside the target (responsible for $\sim 95\%$ of the peak width); the energy loss and energy straggling in the target before and after the collision, calculated employing Ziegler's tables [3]; the kinematics of the 1n-stripping process, simulated according to the model of Brink [4]; a target non-uniformity of 15% FWHM; the kinematic broadening, reproduced employing the Rutherford differential cross section; a phenomenological description of the processes (*e.g.* multiple scattering [5]) responsible for the exponential tails in the low-energy side of the experimental peaks.

3. Optical Model analysis and results

The angular distributions for the elastic scattering process were extracted by the self-normalization formula in [2] and analyzed in the Optical Model framework employing Woods–Saxon potentials for both real and imaginary part. The geometrical parameters for the real part approximately converged to the standard values, in fact little differences can be noticed, *i.e.* a fairly smaller radius parameter ($r_0^{\mathrm{R}} = 1.16$ fm) and a slightly larger diffuseness ($a^{\mathrm{R}} = 0.7$ fm) which might be a hint of possible coupling effects. Furthermore, the geometric parameters of the imaginary part, especially the radius parameter ($r_0^{\mathrm{I}} = 1.42 \pm 0.04$ fm), resulted in a good agreement with the trend observed for several targets, as shown in Fig. 2. This trend suggests that

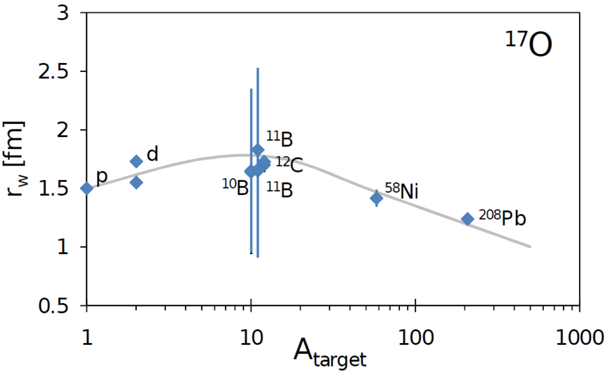

Fig. 2. (Color online) Trend of the imaginary radius parameter (r_0^{I}) for several collisions involving the same ^{17}O projectile with respect to the target mass (A$_{\mathrm{target}}$): p, d+^{17}O [6, 7], ^{17}O+^{10,11}B [8, 9], ^{17}O+^{12}C [10] and ^{17}O+^{208}Pb [11]. The solid line is intended to guide the eye.

the binding energy of the target influences the imaginary radius parameter, as observed also for the real radius parameter ($r_0^{\rm R}$) with protons [12], but is not deducible for $r_0^{\rm R}$ in the ^{17}O systematics currently available.

The behavior of the Optical Model potential is displayed in the left-hand side of Fig. 3 and exhibits the usual Threshold Anomaly. The total reaction cross section was extracted as well, and the right-hand side of Fig. 3 shows a good agreement with the prediction of [13] ($a = 1.19$, $b = -1.33$).

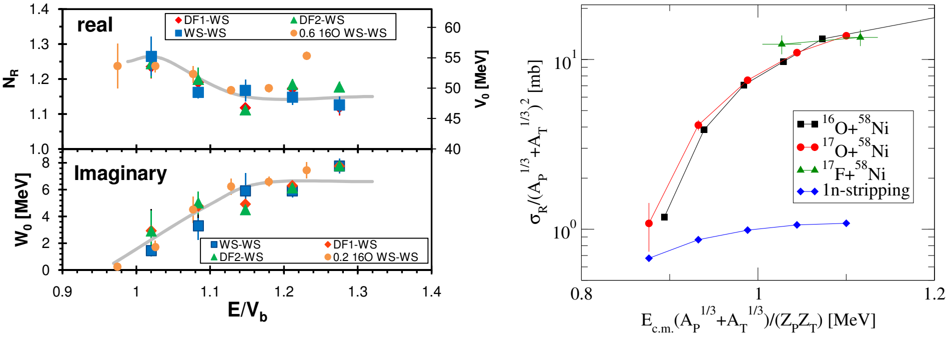

Fig. 3. (Color online) Left: Threshold Anomaly plot for 3 potentials (WS — Woods–Saxon, DF — Double Folding) compared with the fits to existing ^{16}O+^{58}Ni data [14]. The solid line is intended to guide the eye. Right: ^{17}O+^{58}Ni reaction cross section compared with the prediction of [13] and the ^{16}O+^{58}Ni data.

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