Title: Are the weak channels really weak?

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ARE THE WEAK CHANNELS REALLY WEAK?*

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The transfer probabilities for ^{20}Ne + ^{90}Zr and ^{20}Ne + ^{92}Zr at energies near the Coulomb barrier were measured. This quantity turned out to be very similar for both Zr isotopes and does not explain the observed differences in the barrier height distributions for these systems.

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1. Introduction

The potential barrier between two interacting nuclei does not have a unique value. The coupling between different reaction channels gives rise to a barrier height distribution. The shape of the distribution can be a fingerprint of the couplings involved.

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It has been shown [1] that one can experimentally determine the barrier distribution from the flux of ions which have not penetrated the barrier. The cross section for quasi-elastic scattering (elastic, inelastic and transfers) σ_{qe}, measured at backward angles normalized to the cross section for Rutherford scattering σ_{Ruth}, gives the barrier distribution via the following formula:

$$D_{\mathrm{qe}} = -\frac{d}{dE}\left(\frac{\sigma_{\mathrm{qe}}}{\sigma_{\mathrm{Ruth}}}\right) . \tag{1}$$

Our experimental program was focused on the ^{20}Ne projectile. It is known that this nucleus has an extremely large deformation: $\beta_2 = 0.46$, $\beta_3 = 0.39$ and $\beta_4 = 0.27$ [2,3]. Coupled-channels calculations predict a structured (with two maxima) barrier distribution for such a deformed projectile and relatively inert target. The results of the first experiments were astonishing: for ^{20}Ne + $^{\mathrm{nat}}$Ni the measured barrier distribution was in agreement with CC calculations whereas for ^{20}Ne + ^{118}Sn, the structure in the measured barrier distribution was "smoothed out" [5]. The higher transfer probability for a ^{118}Sn compared to a $^{\mathrm{nat}}$Ni target (according to Rehm's systematics [6]) was considered to be the most probable cause of this difference and of the discrepancy with theoretical calculations in which transfer channels are usually not explicitly taken into account. The first step towards verification of this hypothesis was the experimental determination of the barrier distribution for ^{90}Zr and ^{92}Zr targets for which the Rehm systematics predict significantly different transfer cross sections. Coupled-channels calculations (with no transfer channels included) gave identical barrier distributions for both Zr isotopes. The result of the experiment was in agreement with expectations: for the ^{90}Zr target where the transfer probability should be low the barrier distribution showed structure, whereas for ^{92}Zr, for which a higher transfer probability was predicted, the barrier distribution was wider and the structure disappeared [4] (see Fig. 1). This observation was confirmed in a recently repeated measurement and the results will be published soon.

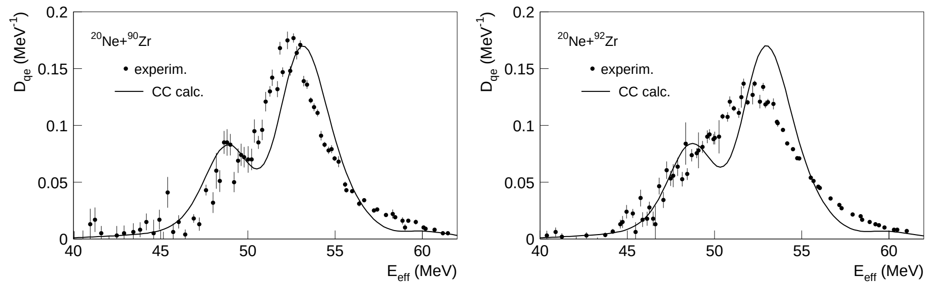

Fig. 1. Barrier height distributions for ^{20}Ne+^{90}Zr (left panel) and ^{20}Ne+^{92}Zr (right panel) compared with the results of coupled channels calculations (Ref. [4]).

Since there were no experimental data on transfer probability for these systems, the explanation of the widening of the barrier distribution and disappearance of structure was based solely on the predictions of the systematics [6]. Thus, measurements of transfer probabilities for the ^{20}Ne + $^{\mathrm{nat}}$Ni, ^{118}Sn, ^{208}Pb and ^{90,92}Zr systems were performed in order to verify the predictions.

2. Experimental setup

The measurements were performed in Jyväskylä and Warsaw, using very similar methods giving similar results. In Warsaw the multidetector system ICARE installed at the Heavy Ion Laboratory, University of Warsaw was used.

The scheme of the experimental set-up is presented in the left panel of Fig. 2. The ToF (Time of Flight) technique was used to identify the masses of backscattered ions. The "start" signal was given by the MCP (Microchannel Plate) detector. The "stop" signal was triggered by four Si detectors (an array of four 20 mm $\times$ 20 mm detectors) placed at a laboratory angle of 142° with respect to the beam. These detectors measured the energy of the reaction products. The base length of the ToF system was 82 cm. Very good time resolution of 250 ps was achieved which gave us a mass resolution of 0.15 a.m.u (FWHM). Two ancillary detectors were employed simultaneously: a telescope identifying the charge of the reaction products and a silicon detector ("Rutherford") placed at a forward angle used to monitor the beam energy. The targets were bombarded with ^{20}Ne ions accelerated by the Warsaw U200-P Cyclotron. The effective beam energy (Ref. [5]) was adjusted

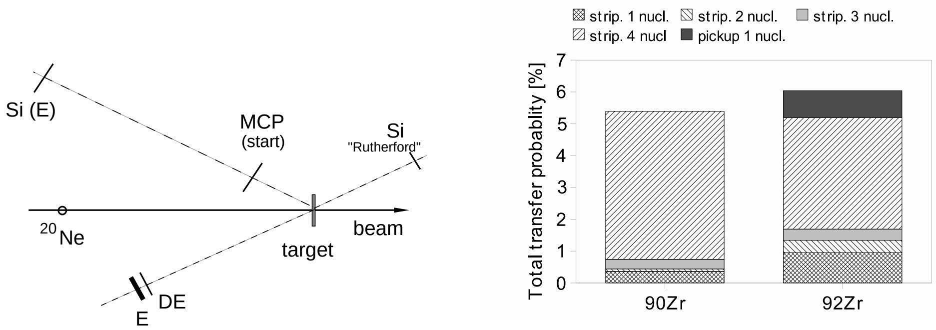

Fig. 2. Left: schematic view of the experimental set-up (see detailed description in the text). Right: the transfer probability determined for backscattering of ^{20}Ne ions on ^{90,92}Zr targets (at $E_{\mathrm{eff}} = 50.5$ MeV). "Pickup 1 nucl." denotes 1 neutron pickup by the ^{20}Ne projectile; stripping means mainly charged particle stripping; stripping of 4 nucleons corresponds to α-particle stripping.

in order to investigate the region of the "structure" in the barrier distribution ($E_{\rm eff} \simeq 50\,$MeV). The ^{90}Zr and ^{92}Zr targets were $100\,\mu$m/cm^2 thick on 20μm/cm^2 carbon backings.

3. Experimental results

The experimental results were surprising. The total transfer probability for ^{90}Zr and ^{92}Zr turned out to be very similar: 5.7(3)% and 6.6(3)%, respectively (see Fig. 2). This is in contradiction to the prediction of the systematics where the total transfer cross section for ^{90}Zr was half that for ^{92}Zr. This in itself is not very surprising, as the transfer systematics [6] are based on reaction Q values only, without taking into account structural factors. What is, however, difficult to understand, is that in spite of almost the same measured transfer probabilities, the barrier distributions are significantly different.

4. Summary and conclusions

The experimentally determined barrier height distributions for ^{20}Ne + ^{90}Zr and ^{92}Zr differ significantly while CC calculations predict almost identical distributions for both isotopes. Experimentally determined transfer probabilities turned out to be very similar, so cannot explain the observed differences between the barrier distributions. Some other, except transfer, weak channels (all of them not taken into account in our CC calculations) must therefore play a significant role here in determining the shape of the barrier distribution.

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