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Quasielastic reactions around the Coulomb barrier in ^{16}O + ^{118}Sn

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Abstract. Measurement of elastic and quasielastic reaction cross sections were done in ^{16}O + ^{118}Sn system at two different energies above the barrier. Attempts are being made to understand the results in the framework of coupled reaction channel model.

Keywords. Quasielastic reactions; coupled channel; multinucleon transfer.

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1. Introduction

Important role played by couplings between the different direct reactions and fusion channels have been of immense interest both from theoretical and experimental view points in recent years [1–5]. This is one of the areas where the scenario from the semiclassical and quantum theories are well understood, but experimental data in different systems are still lacking to test all the aspects of such theories. Some of the systems studied to probe the role of higher order couplings, multiphonon couplings, N/Z ratios, break-up channels, etc. have been presented in this workshop.

In order to investigate the interplay between the various reaction channels in heavy ion collision above the Coulomb barrier and the nature of the multinucleon transfer channels, we have carried out experiments in ^{16}O + ^{118}Sn system at two different energies above the Coulomb barrier. This system is particularly interesting because it was shown [6] that the enhancement of sub-barrier fusion (SBF) cross sections are small in this system, which have been attributed to smaller quasielastic transfer strengths and negative Q-values of the transfer channels. However, a comparison of the experimental fusion cross section data with the coupled reaction channel (CRC) calculation shows that (see figure 1) the smaller enhancement in SBF cross section can be well accounted for by inclusion of inelastic excitation channels alone in this system. The role played by the transfer channels are, therefore, not important. Our aim in this experiment is to investigate the role played by the transfer channels on the other direct reaction channels.

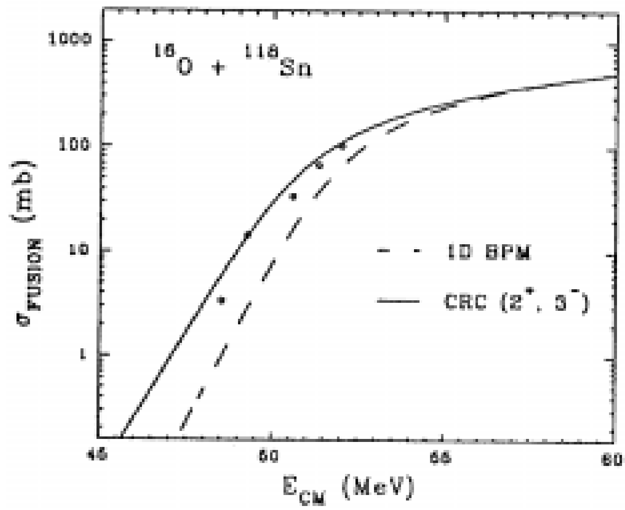

Figure 1. Comparison of experimental fusion cross section data with CRC and 1D BPM calculations in ^{16}O + ^{118}Sn system. The CRC calculation takes into account only the 2^+ and 3^- inelastic couplings.

2. Experiment

The experiments were done at the General Purpose Scattering Chamber Facility using ^{16}O beam at 70 MeV and 90 MeV energies from the 16UD Pelletron of the Nuclear Science Centre. ^{118}Sn targets (98% enrichment) were used. Angular distribution of the projectile-like reaction products were measured with one SSB detector time-of-flight (TOF) telescope. Excellent mass resolution ($\sim$ 2%) was achieved by cooling and overbiasing the SSB detectors to improve time resolution (better than 170 ps FWHM) of the TOF system. This was necessary to separate the one-neutron transfer channel in presence of high elastic yield. Two other SSB detectors were used to study the elastically and inelastically scattered particles.

The angular distributions were obtained from the experimental data for the different reaction channels. The elastic scattering data at two energies are shown in the figure 2(a). Optical model parameters were extracted from the elastic data. A short range volume imaginary potential was introduced *a priori* to account for the experimental fusion cross section data [6]. The results at two energies were found to agree reasonably well. A surface term in the imaginary potential was found to be necessary in this case to fit the data.

Quantum mechanical coupled channel calculations using the code FRESCO [2] including the inelastic and transfer couplings were done. Detailed observation based on these calculations will be described elsewhere [7]. The results for the 2^+ state in ^{118}Sn are shown in figure 2(b). Some of the results for the neutron transfer channels are shown in figure 3. It is observed that the elastic, inelastic and one-neutron transfer $(+1n)$ data agree reasonably well with the FRESCO predictions. The data show reasonable agreement with the DWBA calculation as well, though the agreement is relatively better with coupled channel calculations.

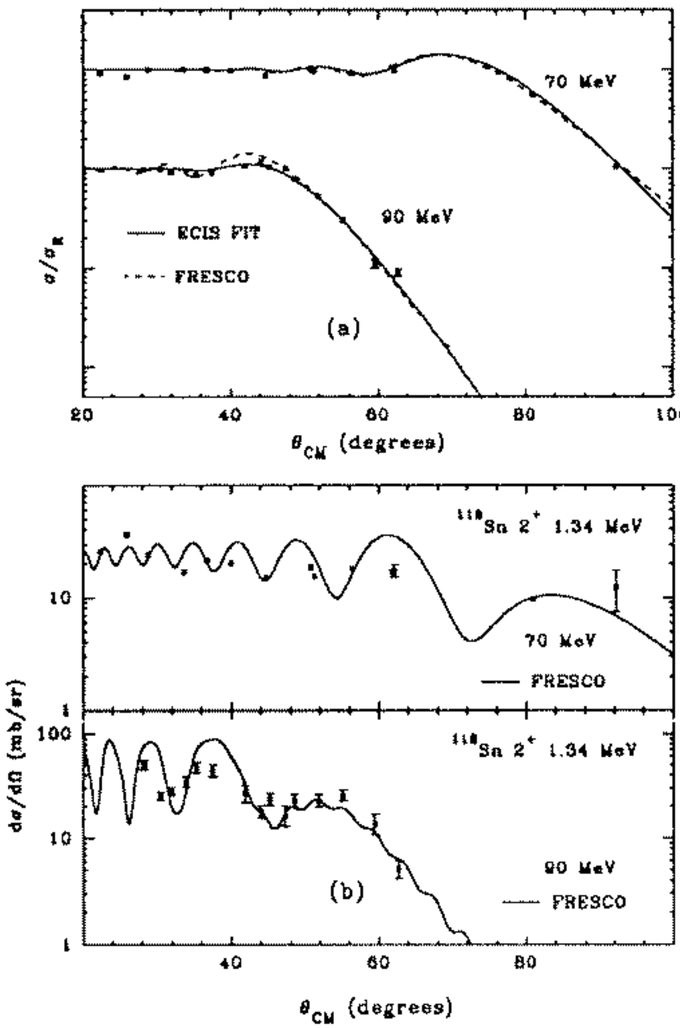

Figure 2. Angular distributions for elastic scattering and excitation of 2^+ state in ^{118}Sn. Results of fit to the elastic data and CRC calculation are shown in (a). Reasonable agreement between the data and the CRC results can be seen in both (a) and (b).

However, one-proton transfer (–1p) data do not agree well, particularly at forward angles at 90 MeV, but the measured angular distribution at 70 MeV agree reasonably well with the theoretical prediction (see figure 4). Furthermore, the nature of the multinucleon transfer (indicated by $+2n$, –2p, –2p1n, etc.) angular distributions show enhancement at forward angles, deviating from the typical bell-shaped nature.

Similar feature was also observed in the heavier systems studied by Corradi *et al* [5] in ^{40,48}Ca + ^{124}Sn systems, which was found to be consistent with the post-transfer neutron evaporation scenario. On the other hand, the deviation observed for the –1p channel in

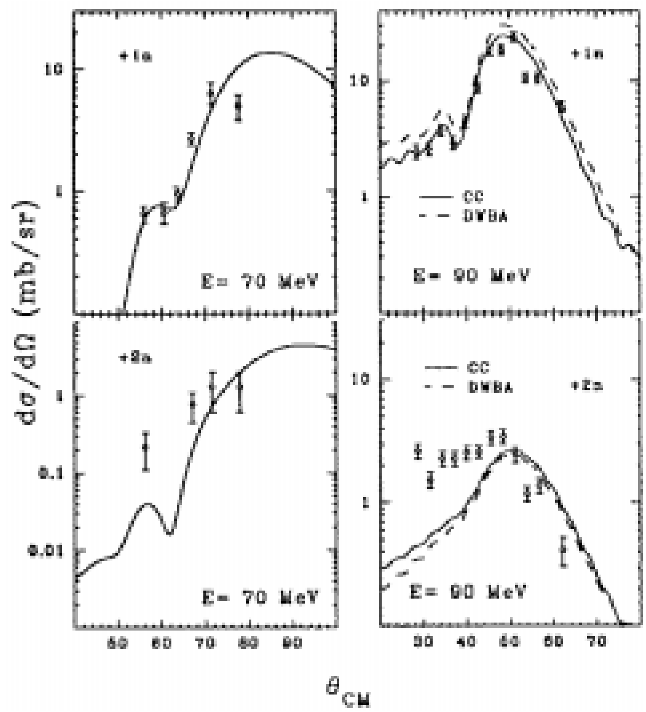

Figure 3. Angular distribution plots for the neutron transfer channels.

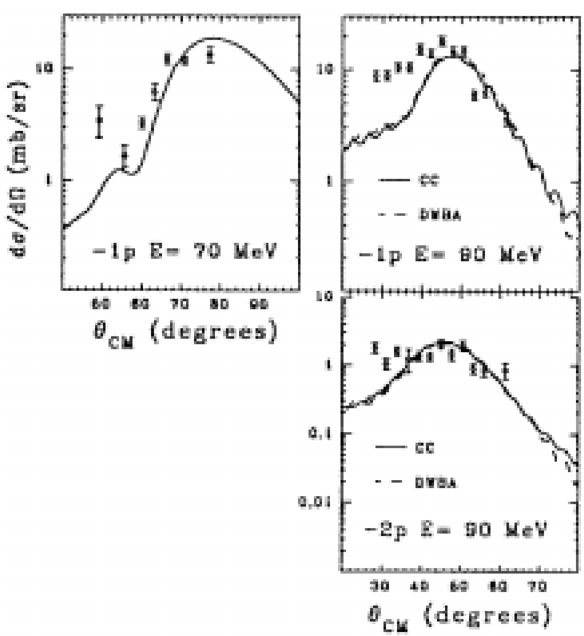

Figure 4. Angular distribution plots for the proton transfer channels.

^{16}O + ^{118}Sn system at 90 MeV is of a different nature, and possibly indicates a large contribution from low impact parameter region. This apparently indicates the onset of deep inelastic processes. The forward angle enhancement of the multinucleon transfer channels also follow the same nature, and is also correlated with significant energy loss as observed for the projectile-like particles. Further details of these observations will be published elsewhere [7].

In summary, the role of channel couplings on the nucleon transfer channels were studied in $^{16}\mathrm{O} + {}^{118}\mathrm{Sn}$ system. The role of couplings was found to be of lesser importance in this system, which is consistent with the observation made by Henning *et al* [6]. However, the angular distributions for the nucleon transfer channels indicate forward angle enhancement over the predictions based on direct reaction model, which indicates overlap of the direct and the deep inelastic reaction channels for the low impact parameter trajectories. Deep inelastic model based calculation is necessary to explain the apparent discrepancy in the forward angle data.

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