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PAIRING CORRELATION STUDY IN THE ^{40}Ar + ^{208}Pb MULTINUCLEON TRANSFER REACTION*

T. Mijatović[a], S. Szilner[a], L. Corradi[b], D. Montanari[c]
S. Courtin[c], E. Fioretto[b], A. Gadea[d], A. Goasduff[b], F. Haas[c]
D. Jelavić Malenica[a], G. Montagnoli[e], G. Pollarolo[f]
L. Prepolec[a], F. Scarlassara[e], N. Soić[a], A.M. Stefanini[b]
V. Tokić[a], C.A. Ur[e], J.J. Valiente-Dobon[b]

[a]Ruđer Bošković Institute, Zagreb, Croatia
[b]INFN — Laboratori Nazionali di Legnaro, Legnaro, Italy
[c]IPHC, CNRS/IN2P3 and Université de Strasbourg, Strasbourg, France
[d]IFIC, CSIC-Universidad de Valencia, Valencia, Spain
[e]INFN and Università di Padova, Padova, Italy
[f]INFN and Università di Torino, Italy

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The ^{40}Ar + ^{208}Pb multinucleon transfer reaction has been studied at $E_{\mathrm{lab}} = 255$ MeV with the large solid angle magnetic spectrometer PRISMA. Mass and charge yields, differential and total cross sections, total kinetic energy loss distributions of different channels were simultaneously measured. Angular distributions were measured in a wide angular range by matching different spectrometer angular settings. Absolute cross sections were obtained by careful evaluation of the spectrometer response function. These cross sections for different transfer channels allow the discussion of the role played by nucleon–nucleon correlations.

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1. Introduction

The recent revival of transfer reaction studies greatly benefited from the advent of the last generation large solid angle magnetic spectrometers based on trajectory reconstruction. Heavy-ion transfer reactions are an ideal tool to study components of the interaction responsible for particle correlations. In fact, in heavy ion reactions multiple transfer of nucleons becomes available giving the possibility to study the relative role of the single particle and pair transfer modes [1].

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The role played by neutron–proton correlations is attracting peculiar interest in the field, especially with radioactive ion beams. Nuclear models point out that such correlation is expected to be strongest in $N \sim Z$ nuclei where protons and neutrons occupy the same shell model orbitals. Since transfer process is governed by optimum Q-value and nuclear structure properties, with stable beams only neutron pick-up and proton stripping channels are dominantly populated. It is particularly important to study the $(+np)$ channel since it can be populated via a direct mechanism, while the $(-np)$ channel is of complex nature and can be strongly affected by the neutron evaporation mechanism. To reach this goal, one can use neutron-rich beams that populate $(\pm nn)$, $(\pm pp)$ and $(\pm np)$ channels with the same strength and give a possibility of their direct comparison.

2. The experiment

The $^{40}\mathrm{Ar} + {}^{208}\mathrm{Pb}$ reaction has been measured at $E_{\mathrm{lab}} = 255$ MeV (25% above the barrier) at three different PRISMA angles, $\theta_{\mathrm{lab}} = 46^\circ$, 54° and 59°. Being $\theta_{\mathrm{lab}} = 54^\circ$ the grazing angle, we covered most of the total transfer flux. The large solid angle magnetic spectrometer PRISMA [2] was used to detect projectile-like fragments. This large acceptance spectrometer uses an event-by-event trajectory reconstruction for mass and charge identification. The trajectory reconstruction is obtained from the measurement of the entrance and focal plane positions, and time of flight. In addition, PRISMA also provides the total energy of ions as well as their energy loss. Coincident γ rays were detected with the CLARA array [3].

The understanding of the reaction mechanism depends strongly on the determination of the absolute cross sections. In order to obtain the differential cross sections, the response function (or transmission) of the spectrometer [4], that depends in a complex way on the entrance positions and momenta of the reaction products, has been studied. A determination of the transmission was achieved with a simulation of ion trajectories, where the kinematics of the reaction and the geometry of the magnetic elements and detectors have been taken into account. The response function obtained in such a way has been used to get event distribution not affected by the transport in the spectrometer and has been applied as a correction to the experimental angular distributions and total cross sections.

3. Results and discussion

In the case of heavy-ion collisions, the extraction of true elastic scattering is hampered by the limited energy resolution of particle detectors. We took advantage of the fact that the measurement was performed with the PRISMA–CLARA set-up, which provides fragment-γ coincidences. The total kinetic energy loss distributions have been built in two ways assuming binary reactions; first, with the requirement of detecting a ^{40}Ar ion in PRISMA alone, and second, by requiring an additional coincidence with at least one γ ray measured by CLARA. These two spectra are normalized, for each measured angle, in the (inelastic) tail region. Their difference corresponds to the spectrum of the pure elastic scattering [2, 5]. To remind, PRISMA has large solid angle of 80 msr corresponding to ±6° in θ and ±11° in φ. By using three different angular settings of the spectrometer ($\theta_{\rm lab} = 46°$, 54° and 59°), a wide angular range, which covers also very forward angles, has been measured. At these forward angles, the elastic cross section is well approximated by the Rutherford scattering, defining thus the absolute normalization factor (in mb/sr) for all other reaction channels.

As an example, Fig. 1 displays the differential cross sections of ^{39}Cl (one-proton stripping channel) and ^{41}Ar (one-neutron pick-up channel). The angular distributions obtained by matching the different angular ranges and corrected by the spectrometer response function have been compared with the semiclassical calculations GRAZING [6] in the same figure.

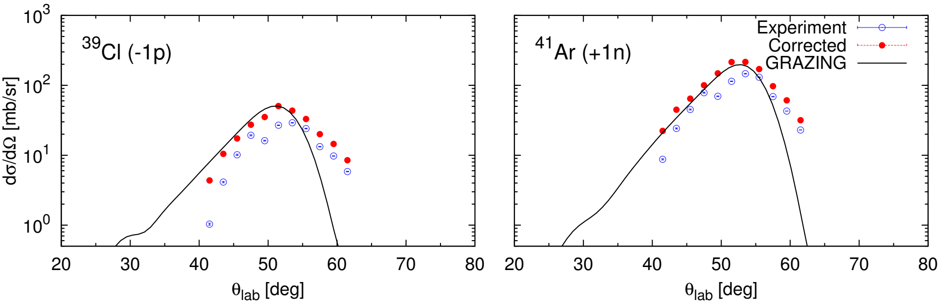

Fig. 1. Differential cross sections for the $(-1p)$ and $(+1n)$ channels in the ^{40}Ar + ^{208}Pb reaction at $E_{\rm lab} = 255$ MeV. Open circles represent experimental data, full circles data corrected for the transmission of the spectrometer, and solid line is the GRAZING calculation.

This model calculates the evolution of the reaction by taking into account, besides the relative motion variables, the intrinsic degrees of freedom of projectile and target. The exchange of nucleons proceeds via a multistep mechanism of single nucleons. Similarly to previously studied systems [1], calculations reproduce well, both in shape and magnitude, one-nucleon transfer channels. We also mention that, accordingly to previously performed studies, the cross sections for the neutron pick-up drop by almost a constant factor for each transferred neutron, as an independent particle mechanism would suggest. The pure proton cross sections behave differently, with the population of the $(-2p)$ channel as strong as the $(-1p)$ [7, 8]. This suggests the contribution of processes involving the transfer of proton pairs. The fact that the pure $(+1n)$ pick-up is an order of magnitude larger than the pure $(-1p)$ stripping channels may mask the effect of the pair mode in the pure neutron transfers. Pure neutron transfer channels were recently studied at energies below the Coulomb barrier [9], where the experimental cross sections have been well reproduced by microscopic calculations which incorporate nucleon–nucleon pairing correlations.

The good agreement between the represented angular distributions for ^{39}Cl and ^{41}Ar and the theory gives us confidence on the correct procedure adopted for the trajectory reconstruction and the validity of the response function. While a similar agreement has been obtained also for other one-nucleon transfer channels, the preliminary results for the $(+np)$ channel, underestimated by the GRAZING calculation, may indicate some additional degrees of freedom which need to be added in the calculations.

In this paper, the recent results of the distribution of the transfer flux studied with the large solid angle magnetic spectrometer PRISMA have been presented. The extracted angular distributions have been compared with the model GRAZING. Preliminary results of the PRISMA data indicate the importance of the neutron–proton correlations. The important complementary information from the γ rays detected in coincidence, in particular the distribution of the transfer flux over the different excited states, may provide a deeper understanding of the possible effects of the pairing interaction.

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