# Nucleon-Nucleon Pairing Correlations probed in the $^{118}$Sn+$^{206}$Pb Transfer Reactions

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## INTRODUCTION

The pairing interaction induces nucleon-nucleon correlations that are essential in defining the properties of finite quantum many-body systems close to their ground states [1, 2]. A very specific probe of this pairing component in the nuclear interactions, which ties up nucleons in a highly correlated state, the nuclear Cooper pairs, is the two-nucleon transfer reactions.

How paring correlations can be probed in heavy-ion collisions, is still an open question. Several experiments have been performed in the past, searching for signatures mainly via extraction of the enhancement coefficients, defined as the ratio of the actual transfer cross section and the prediction of the model using uncorrelated states [3, 4]. Unfortunately, experimental evidence of these factors is marred by the fact that all existing studies involve reactions at energies higher than the Coulomb barrier, where the reaction mechanism is the result of the interplay between nuclear and Coulomb interactions.

With the development of new instrumentation, nowadays it has become possible to measure heavy-ion transfer reaction with high efficiency and good ion identification even at very low bombarding energies, where nuclei interact at large distances. The use of the large-acceptance spectrometer PRISMA, combined with the inverse kinematics condition, allowed one to measure transfer probability $P_{\mathrm{tr}}$ down to very large values of the distance of closest approach $D$, sufficiently far from the nuclear absorption region. In the well $Q$-value-matched system $^{60}$Ni+$^{116}$Sn, with the the ground state to ground state $Q$ values for one- and two-neutron transfers very close to the optimum, the microscopically calculated transfer probabilities for the $(1n)$ and $(2n)$ channels, which incorporate nucleon-nucleon pairing correlation, could reproduce the experimental ones in absolute value and slope (we refer to Refs. [5–7] for details). The same calculations were successful in the description of the $^{40}$Ca+$^{96}$Zr reaction [8].

## THE EXPERIMENT

We report below some preliminary analysis of the recently performed study of the $^{118}$Sn+$^{206}$Pb reaction. In the experiment, by employing the inverse kinematics condition, we could detect the "light" target-like ions in PRISMA with sufficient $A$, $Z$ and $Q$-value resolution also at energies below the Coulomb barrier and corresponding to large $D$ values. We used a 2-pnA $^{206}$Pb beam delivered by the PIAVE positive-ion injector followed by the ALPI post-accelerator of LNL, impinging onto a 200 $\mu$g/cm$^2$ (2-mm strip) $^{118}$Sn target. We measured an excitation function at three different bombarding energies, $E_{\mathrm{lab}} = 1200$, 1090 and 1035 MeV. For the highest energy, PRISMA was initially placed close to the grazing angle at $\theta_{\mathrm{lab}} = 35^\circ$ and then at $25^\circ$. Decreasing the bombarding energy, the angle of PRISMA was kept fixed at $25^\circ$, since below the barrier the transfer angular distributions are peaked at forward angles in the laboratory frame (backward angles in the center-of-mass reference frame). In this configuration, target-like recoils entering PRISMA had sufficient kinetic energies (from 6.2 to 7.7 MeV/nucleon) to be detected with good resolution, also at low bombarding energies.

## PRESENT STATUS OF THE DATA ANALYSIS

After the first phase of the calibration and tuning procedure of all raw signals, then selecting gates on proton stripping and proton pick-up channels (Z - selection) on the $E$ vs $\Delta E$ matrix, the next steps were to selectively gate on the event distributions corresponding to the different ions charges in the $E$ vs. $\rho\beta$ matrix, where $\rho$ is the curvature radius and $\beta$ is $v/c$ of incident ions.

As a further step, we constructed the mass spectra for the various isotopes at the measured bombarding energies and angular settings. As an example, in Fig. 1 is reported the two-dimensional spectrum, mass for Cd isotopes (-2p channels) vs. Q-value at $E_{\mathrm{lab}} = 1200$ MeV and $\theta_{\mathrm{lab}} = 35^\circ$. The

Q-value distributions were reconstructed assuming a pure binary process and taking into account the conservation of momentum. This example illustrates the achieved separation of different $A$. The obtained mass resolution turns out to be $\Delta A/A \approx 1/190$.

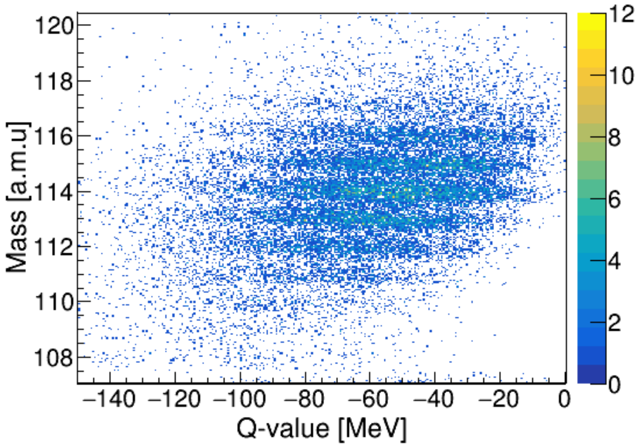


Fig. 1. The Mass spectra for Cd isotopes vs. Q-value, measured at $E_{\mathrm{lab}} = 1200$ MeV at $\theta_{\mathrm{lab}} = 35°$.

To achieve such resolution, it was crucial in the analysis to correct the optical aberrations by applying an empirical correction [9]. The procedure is illustrated in Fig. 2 where $A/Q$ (where $Q$ represent atomic charge state) spectrum is zoomed and shown in the respect to the $x$ axis in the microchannel plate (MCP) detector. The red curve represents the fit to the mean value for every tenth bin of $A/Q$ projection. These were used to correct the $A/Q$ lines, i.e to straighten the lines. The same procedure was also applied to the $y$ axis (see Fig. 3).

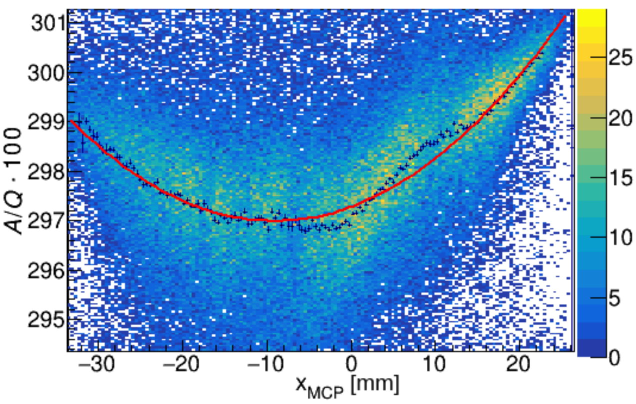


Fig. 2. A line of $A/Q$ spectra vs. $x$ axis in the MCP detector. The red curve is the fit to corresponding mean value for every tenth bin of $A/Q$ projection in this matrix.

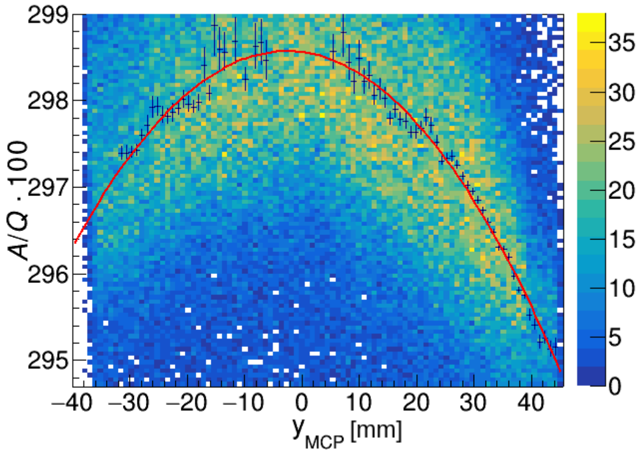


Fig. 3. A line of $A/Q$ spectra vs. $y$ axis in the MCP detector. The red curve is the fit to corresponding mean value for every tenth bin of $A/Q$ projection in this matrix.

In further analysis, we will concentrate on neutron transfer channels, in particular on extract the transfer probability, $P_{\mathrm{tr}}$ for the different distances of closest approach, $D$. This will allow us to understand whether and to what extent the effect of nucleon-nucleon correlations in the evolution of the reaction is modified in the presence of high Coulomb fields. Particularly interesting will be the case of Sn isotopes at the lowest measured bombarding energy, where the $Q$-value distributions are expected to be very narrow.

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