Coulomb-nuclear interference in the inelastic scattering of $^6$Li on $^{76}$Ge

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Abstract. Angular distribution for the inelastic scattering of 28 MeV $^6$Li on $^{76}$Ge was measured using the São Paulo Pelletron Enge Split-pole Spectrograph facility. The coulomb-nuclear interference (CNI) analysis was applied to the first quadrupole state transition. The values of $C_L = \delta_c^L / \delta_N^L$, the ratio of charge to isoscalar deformation lengths, and of $(\delta_N^L)^2$ were extracted through the comparison of experimental and DWBA-DOMP predicted cross section. The ratio of reduced charge to isoscalar transition probabilities, $B(\text{EL})$ to $B(\text{ISL})$ respectively, are related to the square of the parameter $C_L$ and were thus obtained with the advantage of scale uncertainties cancellation. The value of $C_L = 1.10(2)$ obtained indicate a slight predominance of the protons relative to the neutrons for $^{76}$Ge.

1. Introduction

The characteristics of excited states $2^+_1$ are widely used as indicators of nuclear structure, particularly the electric reduced transition probability $B(E2)$ is used as a measure of the collectivity of these transitions. The $B(E2)$ is in principle sensitive only to the contribution of the charge and to quantify the contributions of neutrons is also an important ingredient to characterize the collectivity. This aim is achieved through the isoscalar (mass) reduced transition probability $B(IS2)$ obtained from the inelastic scattering. Particularly suitable are the measurements in an incident energy that enhances coulomb-nuclear interference (CNI) and allows simultaneous extractions of $B(IS2)$ and the ratio between electric and isoscalar reduced transition probabilities $B(E2)/B(IS2)$ [1-3]. The ratio $B(E2)/B(IS2)$ is related to the square of the parameter $C_2$. The previous CNI work, in the A~ 70 transitional mass region, considering the germanium isotopic chain [3] demonstrate an abrupt change for $^{74}$Ge with $C_2 = 0.775(8)$: although for $^{70,72}$Ge, values of the order of 1.0 or slightly higher were obtained. In particular, the present work pursues the study of CNI in the inelastic scattering of $^6$Li on $^{76}$Ge, in order to determine the relative contributions of protons and neutrons in the transition to the first quadrupole state.

2. Experimental setup

Measurements of the inelastic scattering of $^6$Li on $^{76}$Ge were obtained using the Pelletron Enge Split-pole Spectrograph facility. A solid-state position sensitive detector (PSD) of 500 µm thickness, and $47 \times 8$ mm$^2$ area was positioned on the focal plane. The 28.0 MeV energy $^6$Li beam was focused after passing defining slits of 1.0 x 2.0 mm$^2$ on an enriched target of $^{76}$Ge with 510.5 $10^{15}$ particles/cm$^2$ thickness. A solid angle of 0.65 msr was used in the spectrometer entrance. Twenty-six spectra were measured at carefully chosen scattering angles in a range of $10^\circ \leq \theta_{\text{lab}} \leq 55^\circ$, in order to characterize CNI in the angular distribution corresponding to the first quadrupole excitation.
A surface barrier detector, with 10 mm diameter and 1000 μm thickness, was placed inside the scattering chamber at an angle of 30° relative to the ion beam. Relative normalization of the data for the various scattering angles was obtained through the total charges collected by the Faraday cup and the elastic scattering measurements from the monitor detector.

The digital pulse processing (DPP) acquisition system used in the measurement was composed by the board PCI-6133 from National Instrument with a sample of analogic inputs up to 2.5 MS/s. The analysis of the pulse shape and the use of electronic noise filters provide an important resolution improvement, which is the advantage of this acquisition system. Figure 1 shows the position spectrum along the focal plane at the scattering angle θ_{Lab} = 31°. The three peaks observed on figure are associated with the elastic peak on ^{76}\text{Ge}, the 2_{1}^{+} state inelastic peak and the elastic peak on the silicon contaminant. The energy resolution achieved was about 37 keV.

![Figure 1. Position spectrum at the scattering angle θ_{Lab} = 31°.](image)

3. Data analysis and Results

The distorted wave Born approximation (DWBA) prediction using the deformed optical potential model (DOMP) approach with global optical parameters was applied. The value of the ratio between charge (δ_{L}^{C}) and mass (δ_{L}^{N}) deformation lengths C_{L} is obtained from the angular distribution shape. The square of mass deformation length, (δ_{L}^{N})^2, is also extracted, as a scale factor. The procedure applied for the χ^2 minimization was the iterative method of Gauss [4], extracting the correlated parameters δ_{2}^{N} and C_{2}.

Figure 2 illustrates the preliminary results obtained from the angular distribution of ^{76}\text{Ge}(^{6}\text{Li}, ^{6}\text{Li'})^{76}\text{Ge} to the first quadrupole excited state 2_{1}^{+} in comparison with DWBA-DOMP prediction obtained in the fit (red solid curve). In order to illustrate the sensitivity of the method, two predictions corresponding to C = 0.78 (green dash curve) and C = 1.00 (blue dash curve) are also shown.

The results for the two correlated parameters in a preliminary data analysis are C_{2} = 1.10(2) and δ_{2}^{N} = 1.08(2) fm. The C_{2} value obtained is slightly higher than 1.0, indicating a homogeneous excitation with a small predominant contribution of protons in the first quadrupole excited state 2_{1}^{+} of ^{76}\text{Ge}. 
Figure 2. Experimental angular distribution in comparison with DWBA-DOMP predictions.

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