Coulomb-nuclear interference in the inelastic scattering of ^{6}Li to the first quadrupole state in the Ge isotopic chain

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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-Spectrograph facility. The Coulomb-nuclear interference (CNI) analysis was applied to the first quadrupole state transition. The value of $C_2 = \delta_2^C/\delta_2^N$, the ratio of charge to isoscalar deformation lengths, and of δ_2^N were extracted through the comparison of experimental and DWBA-DOMP predicted cross sections. The ratio of reduced charge to isoscalar transition probabilities, B(E2) to B(IS2) respectively, is related to the square of the parameter C_2 and was thus obtained due to the advantage of scale uncertainty cancellation with a relative accuracy of less than 4%. The value of $C_2 = 1.101(20)$ obtained indicates a slight predominance of the protons relative to the neutrons in the transition for ^{76}Ge.In this context the present result composed with previous results of CNI measurements obtained in ^{70,72,74}Ge suggests for ^{74}Ge a strong ground state configuration mixing.

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 collective characteristic of these transitions. The B (E2) is in principle sensitive, if polarization effects may be disregarded, only to the contribution of the charge and to quantify the contributions of neutrons is also an important ingredient to characterize the collective behaviour. The Ge (Z=32) isotopic chain, in the transitional mass region around A=70, is particularly well suited to study the role of the neutrons. In fact, the evolution of B (E2) values indicate around N=40 a transition and furthermore the nucleus ^{72}Ge presents a 0^+ first state, possible consequence of the correspondent subshell closure [1,2]. In this context it to be stressed that direct access to reduced isoscalar transition probability B (IS2) is also required. Particularly suitable to reach this aim are inelastic scattering measurements of isoscalar interacting projectiles in an incident energy that enhance coulomb-nuclear interference (CNI). These measurements allow simultaneous extractions of B(IS2) and the ratio between electric and isoscalar reduced transition probabilities B(E2)/B(IS2) [3-5]. The values of $C_2 = \delta_2^C/\delta_2^N$, the ratio of charge to isoscalar deformation lengths, and of $(\delta_2^N)^2$ are extracted through the comparison of experimental and DWBA-DOMP predicted angular distributions. The ratio of reduced charge to isoscalar transition probabilities, B(EL) to B(ISL) respectively, are related to the square of the parameter C_2 and were thus obtained with the advantage of scale uncertainties cancellation. This paper refers to the CNI study of 28 MeV ^{6}Li inelastic scattering on ^{76}Ge recently measured using the São Paulo Pelletron-Enge-Spectrograph facility in comparison with the results of the previous work on ^{70,72,74}Ge [5]. The C_2 values obtained for ^{70,72}Ge are slightly higher than 1.0, indicating a homogeneous excitation with a small predominant contribution of protons in the transition to the first quadrupole state 2_1^+. On the other hand an abrupt change with C_2 = 0.775(8) was obtained for ^{74}Ge.

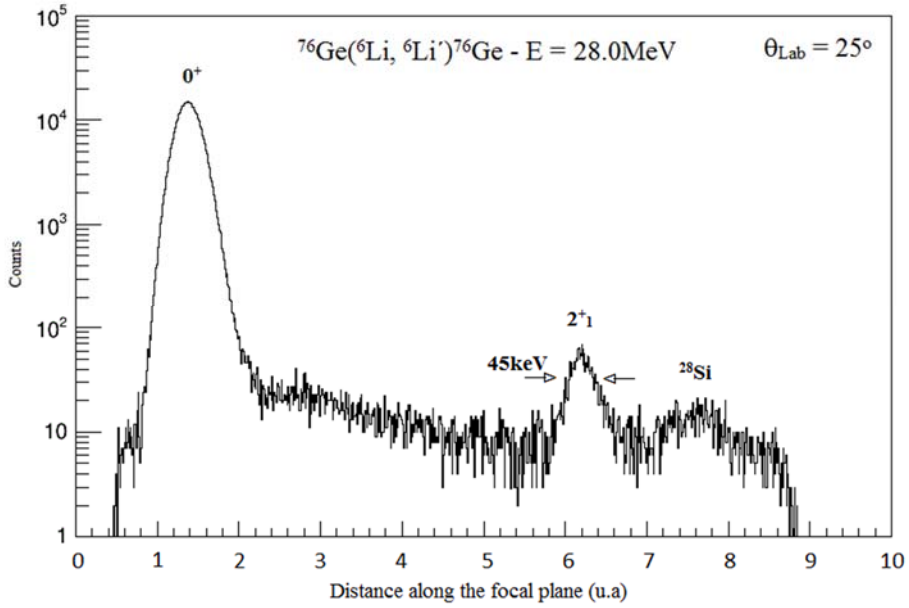

Fig. 1: Position spectrum at the scattering angles $\theta_{Lab} = 25^{o}$.

2 Experimental setup

Inelastic scattering of ^{6}Li on ^{76}Ge data were obtained using the Pelletron-Spectrograph-Magnet-Enge facility. A solid-state position sensitive detector (PSD) of 500 μm thickness, area 47 x 8 mm^2 was positioned on the focal plane. The ^{6}Li is the lightest isoscalar projectile appropriate for CNI measurements in the region around A=70, at bombarding energies suitable for stable operation of the São Paulo Pelletron accelerator. 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 self-supported target of ^{76}Ge with 510.5 10^{15} atoms/cm^2 thickness. An entrance solid angle of 0.65 msr was used, the emerging ions of the reaction admitted and momentum analysed by the field of the spectrograph were detected in the PSD. Twenty-six spectra were measured at carefully chosen scattering angles in a range of $10^{o} \leq \theta_{Lab} \leq 55^{o}$, in order to characterize CNI in the angular distribution corresponding to the first quadrupole excitation. Relative normalization of the data for the various scattering angles was obtained through the total charges collected by the Faraday cup. The absolute normalization was obtained from the target thickness and the solid angle values. The scale uncertainty was estimated to be around 20%.

The digital pulse processing (DPP) acquisition system used in the measurement was composed by the board PCI-6133 from National Instrument, setting 2.5 MS/s as the maximum rate sample of analogic inputs for the digitalization. The analysis of the pulse shape and the use of electronic noise filters provide an important resolution improvement. Figure 1 shows the position spectrum along the focal plane at the scattering angle $\theta_{Lab} = 25^{o}$. The three peaks observed on figure are associated with the elastic scattering, the inelastic scattering to the 2_1^+ state and the elastic scattering on silicon contaminant. The energy resolution achieved was about 45 keV.

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.

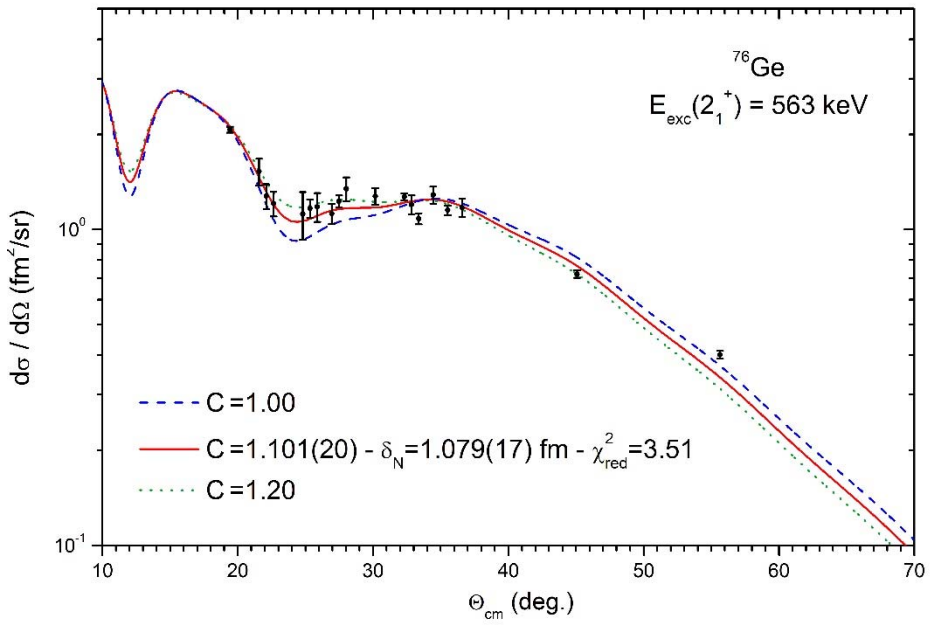

Fig. 2: Experimental angular distribution in comparison with DWBA-DOMP predictions.

The value of the ratio between charge (δ_2^C) and mass (δ_2^N) deformation lengths C_2 was obtained from the angular distribution shape. The square of mass deformation length, $(\delta_2^N)^2$, is also extracted, as a scale factor. The procedure applied for the χ^2 minimization was the iterative method of Gauss [6], extracting the correlated parameters δ_2^N and C_2.

Figure 2 illustrates the results obtained in the fit from the experimental angular distribution of ^{76}Ge(^{6}Li,^{6}Li')^{76}Ge to the first quadrupole excited state in comparison with the DWBA-DOMP prediction. The error bars shown represent only the relative uncertainties. These ones are composed by the statistical uncertainties and the contribution from the background and contaminant subtraction. The prediction was calculated using the global optical model parameters of Cook [7] and considering the reduced Coulomb radius r_C = 1.22 fm (red curve). The results for the two correlated parameters in the data analysis are C_2 = 1.101(20) and δ_2^N = 1.079(17) fm. In order to illustrate the sensibility of the method and that the experimental angular distribution does not admit a fit that could result in a C_2 value much smaller than one, as obtained for the neighbor ^{74}Ge[5], two predictions corresponding to C_2 = 1.00 (interrupted blue curve) and C_2 = 1.20 (dotted green curve) are also shown.

The C_2 value extracted is slightly higher than 1.0, indicating a homogeneous excitation with a slight predominant contribution of protons in the first quadrupole excited state 2_1^+ of ^{76}Ge. Due to the uncertainty scale cancellation, the experimental ratio B(E2)/B(IS2) e^2, proportional to the square of C_2, was obtained with a relative accuracy of less than 4%.

The present CNI study composed with the results of the previous work [5], using the same technique, indicates that although the protons relative to the neutrons reveal a small predominant contribution in ^{70,72,76}Ge to the first quadrupole excitation, the neutron role is strongly enhanced in ^{74}Ge. In fact a C_2 abrupt change is shown comparing the ^{74}Ge value with those observed for neighbor isotopes ^{72,76}Ge.

Discontinuities of some experimental indicators in even-A germanium chain from ^{70}Ge to ^{76}Ge were associated with shape transition or shape coexistence and described in the literature by a two-state coexistence model of some kind [8,9]. The investigation by means of large–scale shell model calculation suggested that a rapid increase in the number of $g_{9/2}$ protons and neutrons could explain the structure change near N=40 [2], associated with the strong neutron-proton interaction. The basic idea of the two-

state model is the existence of different configurations which may coexist and mix in different proportions to form the physical states observed. The experimental results obtained by Coulomb excitation and two neutron transfer measurements [10-13] indicate that the ground state configuration transition should occur between ^{72}Ge and ^{74}Ge. The analyses of the L= 0 transfers in both (t,p) and (p,t) reactions, had shown transition strengths indicating similar nature between the ground states of ^{74}Ge and ^{76}Ge. On the other hand, the CNI results reveal a C_2 value strongly depressed in the first quadrupole excitation for ^{74}Ge, in comparison with the almost homogeneous excitation in ^{76}Ge. It is to be noted that the inelastic scattering, even if there is configuration mixing in the ground state, would excite only the configuration that connects the ground and the 2_1^+ states of each isotope which are rather pure [8,14]. In this context, the ^{74}Ge C_2 value suggests a strong ground state configuration mixing involving not only the neutron degree of freedom, but also probably other configurations. One possibility could be an alpha plus ^{70}Zn (Z=30, N=40) isomeric state configuration involving a subshell closure.

Acknowledgements

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