Extraction of Optical-Model Parameters from α elastic scattering of highly-deformed ^{172}Yb

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Introduction

Giant resonances are the collective vibrational modes in nuclei. Among these collective modes, Isoscalar Giant Monopole Resonance (ISGMR) and Isoscalar Giant Dipole Resonance (ISGDR) are called compression modes, and they are of crucial importance because their excitation energies are directly related to the incompressibility of a finite nucleus [1]. Isoscalar giant resonances have been studied well for spherical nuclei, but a very few experimental data are available for deformed nuclei. In spherical nuclei, ISGMR strength distribution does not split due to the symmetry effect. However, in deformed nuclei, ISGMR strength distribution splits due to the coupling of ISGMR with the $K = 0$ component of the Isoscalar Giant Quadrupole Resonance (ISGQR), where K is the projection onto the symmetry axis. The splitting in ISGMR strength distribution has only been studied in ^{24}Mg [2], ^{28}Si [3] and in Sm isotopes [4, 5]. The splitting of the Isovector Giant Dipole Resonance (IVGDR) in deformed nuclei is well known for a very long time [6].

We have chosen ^{172}Yb due to its large deformation [7]. To extract the strength distributions of different modes of giant resonances, coupled-channel analysis under the Distorted-Wave Born Approximation (DWBA) framework will be performed. The parameters of the optical potential are obtained from the fitting of the elastic-scattering ^{172}Yb$(\alpha, \alpha)^{172}$Yb data.

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Experimental Method

The experiment was performed at the Research Center for Nuclear Physics (RCNP), Osaka University, Japan, using the high-resolution Grand Raiden (GR) spectrometer [8]. The α-particle beam with E_α = 386 MeV bombarded on a thin self-supporting ^{172}Yb target with a thickness of 2.95 ± 0.08 mg/cm^2.
The instrumental background was subtracted by utilising the double-focusing mode of the spectrometer. Inelastically scattered α-particles were momentum analyzed in the GR spectrometer and focused onto the focal-plane detector system comprising of two position-sensitive Multi-Wire Drift Chambers (MWDCs) and two plastic scintillators. To obtain the optical-model parameters, the elastic scattering data are taken in the angular range from 3.5° to 17.6°.

Results

The Optical-Model Parameters (OMPs) are extracted by fitting the elastic scattering data as shown in Fig 1. The angular distribution of the elastic scattering has been obtained after the particle identification, instrumental background subtraction, and ion-optical correction in the offline analysis [9].
We have used a complex potential in the form of $V + iW$ where the real (V) and the imaginary (W) terms are of the Woods-Saxon type and is given for the real potential by:

$$V(r) = \frac{V}{1 + exp(\frac{r-R}{a})} \tag{1}$$

The angular distributions were obtained from a coupled-channel code, and the χ^2 minimization was performed using brute-force

V_R (MeV)	R_R (fm)	a_R (fm)	V_I (MeV)	R_I (fm)	a_I (fm)	R_C (fm)
59.91	7.057	1.080	29.04	7.413	0.601	6.95

TABLE I: OMPs obtained from the fitting of the elastic scattering data after χ^2 minimization. Here V_R, R_R, a_R are the depth, radius, diffuseness of the real potential having the form given in Eqn 1. V_I, R_I, a_I are the corresponding terms for the imaginary part of the potential. R_C is the Coulomb radius.

and basin-hopping methods developed in the Python framework [10, 11]. The OMPs are listed in Table I. Since the energy resolution was around 230 keV during the time when we took the elastic scattering data, it is impossible to resolve the first 2^+ excited state of ^{172}Yb at 78 keV. Therefore, while obtaining the OMPs, the sum of the angular distribution of the elastic scattering and the 2^+ excited state should be taken for fitting the experimental data. In addition, the coupling of the ground state with the first 2^+ excited state should be taken care of, resulting in better agreement with the data. The above consideration is not shown in Fig 1 and the detailed process will be described elsewhere [9]. The OMPs will be used to calculate the angular distributions of different modes of isoscalar giant resonances.

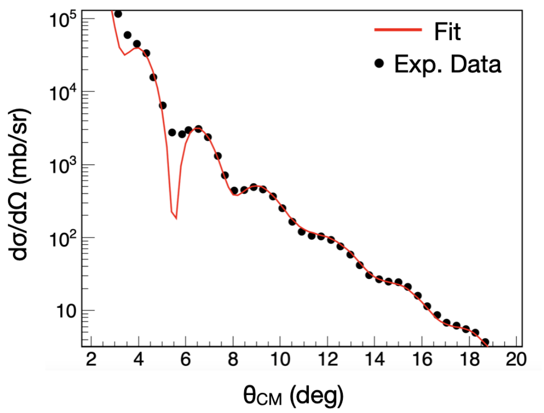

FIG. 1: (Colour Online) Fitting of ^{172}Yb(α, α)^{172}Yb elastic scattering data. The error bars are within the data points.

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