Determination of hexadecapole deformation of $^{176}$Yb

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Introduction

Precise determination of nuclear hexadecapole ($\beta_4$) deformation parameter is challenging. Unlike quadrupole deformation, hexadecapole deformation can not be measured easily by electromagnetic probes. Scattering measurements ($\alpha, e^-$ and proton), Coulomb excitation and fusion excitation function measurements have been extensively used to determine $\beta_4$ [1–5]. Experimental uncertainity in the value of $\beta_4$ is high in some of these methods. Other experimental techniques that have potential to be used for the determination of the hexadecapole deformation parameter precisely are looked for. At the time of fusion reaction, the internal degrees of freedom of the reaction partners couple to the relative motion of fusion resulting in a distribution of barriers instead of a single uncoupled barrier. The distribution of the barrier height $D^{ fus}(E)$ carries the information about the nature as well as strength of the coupling. Hence by measuring the barrier distribution one can obtain the value of the hexadecapole deformation parameter provided other coupling conditions are properly taken care. For most of the even-even nuclei, the quadrupole deformation is experimentally measured with good precision [6]. Hence hexadecapole deformation parameter for these nuclei can be determined by measuring the barrier distribution. For obtaining the barrier distribution quasi elastic scattering measurement is an alternative to fusion excitation measurement [7] and can be used to obtain the value of $\beta_4$ [8]. In the present study we have measured the quasi elastic excitation function for the reaction $^{16}$O + $^{176}$Yb to measure the $\beta_4$ value for $^{176}$Yb.

Experiment

The experiment has been carried out at the BARC-TIFR 14UD Pelletron facility using $^{16}$O beam on $^{176}$Yb target. Enriched (96.63%) isotope of $^{176}$Yb with thickness 170 µg/cm$^2$ was deposited on carbon backing of thickness 25 µg/cm$^2$. Beam energy was varied by a step of 2 MeV in the energy range 54 to 84 MeV. To detect beam like particles at back angles four $\Delta E - E$ telescope detectors, consisting of silicon surface barrier detectors (SSBDs), were placed at $\pm 150^\circ$ and $\pm 170^\circ$ with respect to the beam direction. Thicknesses of $\Delta E$ detectors were 15 µm and that of $E$ detectors were 1500 µm. The detectors were placed at a distance of 27.7 cm from the target. Angular coverage of each telescope detector were $\pm 0.5^\circ$. Two monitor detectors were used at an angle of $\pm 20^\circ$ for normalization purpose.

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A typical spectrum of energy loss ($\Delta E$) versus residual energy ($E_{res}$) at 70 MeV beam energy is shown in Fig. 1. Quasi elastic yield was taken by considering elastic, inelastic and transfer events as shown in Fig. 1 by a rectangular cut. Quasi elastic differential cross sections were obtained by taking ratio of quasi elastic yield to the monitor detector yield. The ratio of quasi elastic differential cross section to the Rutherford differential cross section ($\frac{d\sigma_{qel}}{d\sigma_{Ruth}}$) was calculated as a function of energy which is shown in Fig.2(a). The centre of mass energy ($E_{c.m.}$) was corrected by incorporating the centrifugal correction to obtain the effective energy ($E_{eff}$). The quasi elastic barrier distribution (shown in Fig.2(b) ) was obtained by taking first derivative of ($\frac{d\sigma_{qel}}{d\sigma_{Ruth}}$) with respect to the effective energy.

Coupled channel calculation was carried out using a modified version of CC-FULL(CCQEL) [9] to reproduce the ($\frac{d\sigma_{qel}}{d\sigma_{Ruth}}$) values and corresponding barrier distribution. The value of $\beta_4$ was obtained using $\chi^2$ minimizing technique. The value of $\beta_4$ was compared with the values measured by other experimental techniques as well as with the theoretical prediction. The $\beta_4$ value, determined in the present experiment, shows agreement with the theoretical prediction as well as with the earlier reported values measured by $\alpha$, $e^-$ scattering whereas, large deviation was observed when compared with the values measured by Coulomb excitation and fusion excitation.

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References