The Widths of the E2 ($\Delta T = 0$ and $\Delta T = 1$) Giant Resonances in ^{165}Ho *

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Inelastic electron scattering confirms broadening of the isoscalar (ΔT=0) E2 giant resonance in ^{165}Ho as compared to spherical nuclei. Discrepancies in magnitude between results of other experiments are reconciled. The isovector (ΔT=1) E2 giant resonance is, for the first time, observed to be split into at least two parts.

Since the discovery of giant resonances with a multipolarity different from E1 much information using various excitation methods has been collected concerning the E2 ($\Delta T = 0$) resonance at $E_x = 63\ A^{-1/3}$ MeV [1]. Less information has been reported concerning the other resonance identified, the M1 giant resonance, and even less is known for the E2 ($\Delta T = 1$) isovector giant resonance around 130 $A^{-1/3}$ MeV, which was mentioned, but not identified with certainty in the same paper. The information available concerning the latter has been collected recently by Paul [2].

Although the best data available are from electron scattering, their accuracy has been hampered by the uncertainty in the calculation of the radiation tail. This uncertainty may be overcome in the investigation of isolated low-lying levels by interpolating a fitted smooth background between regions in the spectrum without lines. In the region of the giant dipole resonance the radiation tail is determined by fixing the background through the known strength and natural width of the E1 resonance. No such remedy is possible in the higher continuum above the giant dipole resonance and better radiation tail calculations are needed. Heuristic insertion of all known practical improvements in the theoretical calculation of the radiative tail into a fitting routine has led to the result that the calculated radiation tail now accounts for virtually all radiative background in our measurements, a fact which opens up new possibilities for the investigation of the higher energy resonances.

The experiment reported here was carried out with electrons of a primary energy between 60 and 105 MeV from the 120 MeV linear electron accelerator of the Naval Postgraduate School, a three-section LINAC of the Stanford type [3]. This investigation was specifically undertaken to show whether or not the giant quadrupole resonances are split or broadened in a deformed nucleus. Earlier experiments in ^{208}Pb and ^{197}Au had shown a gradual broadening of all the electric resonances observed as one proceeds from the spherical doubly magic nucleus ^{208}Pb to the non-magic ^{197}Au. The latter still has a (quasi) spherical ground state, so that the observed broadening of the giant resonances, as compared to ^{208}Pb, can only be explained as due to dynamic deformation [4]. ^{165}Ho was chosen as the target nucleus because it is highly deformed and it lies between ^{140}Ce and ^{208}Pb, in which we had evaluated the giant quadrupole ($\Delta T = 0$) resonance using similar techniques. The mea-

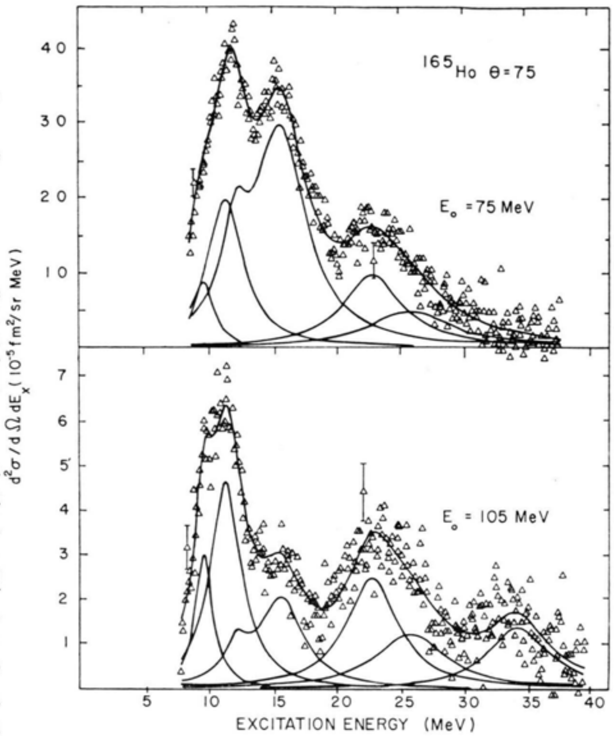

Fig. 1. Spectrum of 75 and 105 MeV electrons, scattered inelastically from ^{165}Ho at a scattering angle of 75°. The resolution is 500 keV. The background which consists of the radiation tail and the machine background has been subtracted. Note that the relative strength of the E1 and E2 resonances more than reverses, if one goes from 75 MeV to 105 MeV. Typical raw spectra; i. e., background not substracted, may be found in Ref. [4]. The form of the E1 resonance was taken from (γ, n) measurements (Ref. [9]); the height was fitted. The energy weighed sum rule exhaustion found for the E1 resonance is 108%, in excellent agreement with the values reported in Ref. [9], thus proving the reliability of the background subtraction.

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surements were restricted to a forward scattering angle of 75°, in order to avoid complications with transverse contributions [1, 4]. A more detailed account of our experiment will be published elsewhere; here we will report our findings for the E 2 resonances.

The single most important result is the observed splitting of the isovector giant resonance into two parts at 23 and 26 MeV excitation energy (Figure 1). The strength ratio of the two components is observed to be 3:2. They both follow separately an E 2 DWBA calculation [5] and together they comprise $(100 \pm 30)\%$ of the E 2 sum rule. No other experiments on the isovector E 2 giant resonances in deformed nuclei have been reported.

This result agrees with what one would expect from the extrapolation of the results in ^{208}Pb and ^{197}Au, as implied by the observed splitting of the E 1 resonances due to the (dynamic) deformation of the nuclei in the continuum. It is also in qualitative agreement with the results of a perturbation theory calculation where the effect of the deformed ground state is represented by adding to the spherical potential a term proportional to Y_{20}, in analogy to calculations for the E 1 ($\Delta T = 1$) resonance.

The result for the low lying E 2 ($\Delta T = 0$) resonance is displayed in Table 1 and compared with the best available values. The broadening observed in this experiment, $\Gamma_{\text{deformed}} - \Gamma_{\text{spherical}}$, agrees with the corresponding result in the (α, α') experiment [6], but the absolute widths are smaller. However, it has already been observed that the widths of resonances excited by slow hadronic interacting particles generally are greater than that found from the electromagnetic processes [7]. The disagreement with the results from Nd arises from the fact that the effects of the resonance at 9.8 MeV ($53\,A^{-1/3}$ MeV) were taken into acount in the present experiment. From the ^{165}Ho data alone one would not be able to conclude definitively the existence of this resonance. But a resonance at the corresponding energy of $53\,A^{-1/3}$ MeV has consistently been seen in many nuclei between ^{58}Ni [8] and ^{208}Pb [4]. All the different electric excitation modes discovered so far have exhibited a very smooth dependence of strength and excitation energy as a function of A, so that the assumption of its presence seems well justified. If we do not assume the presence of this resonance we find $\Gamma_{\text{nat}} = (5.1 \pm 0.3)$ MeV, in agreement with [7]. In turn, we conclude that with this resonance taken into account, the value for ^{150}Nd would be in agreement with ours for ^{165}Ho, which would bring all the measured relative broadenings in Table I in agreement.

Since the deformation of the three deformed nuclei is practically identical [9], one would expect a similar broadening, an expection which is supported by the fact that the E 2 ($\Delta T = 0$) resonances in spherical nuclei as different as ^{140}Ce and ^{208}Pb have the same width.

Table 1. Comparison of the natural width of E 2 ($\Delta T = 0$) resonances in spherical and deformed nuclei. The fifth column shows that the splitting of the giant dipole resonance, i. e., the deformation of the nucleus at about 14 MeV excitation energy, is practically identical in the deformed nuclei considered.

Excitation Method	$\Gamma_{\text{spherical}}$ [MeV]	Γ_{deformed} [MeV]	$\Delta\Gamma$ [MeV]	ΔE 1 [MeV] [a]	$E_x \cdot B$(E 2) [%]
(e,e′)	2.8 ± 0.2 (^{142}Nd) [b]	5.0 ± 0.2 (^{150}Nd) [b]	2.2	3.74	88
(α,α')	3.9 ± 0.2 (^{144}Sm) [c]	4.7 ± 0.3 (^{154}Sm) [c]	0.8	3.57	102
(e,e′)	2.8 ± 0.2 (^{140}Ce) [d] 2.8 ± 0.3 (^{208}Pb)	4.0 ± 0.4 (^{165}Ho) [e]	1.2	3.53	75

[a] Ref. [9]; [b] Ref. [7]; [c] Ref. [6]; [d] Ref. [1, 4]; [e] this work.

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