Electroexcitation of giant multipole resonances in 63Cu

著者	Kawazoe Yoshiyuki, Miyase Haruhisa, Tsubota Hiroaki, Yokokawa Jun, Oyamada Masayuki, Torizuka Yoshiharu
journal or publication title	Physical Review. C
volume	33
number	6
page range	1917-1919
year	1986
URL	http://hdl.handle.net/10097/53384

doi: 10.1103/PhysRevC.33.1917

PHYSICAL REVIEW C VOLUME 33, NUMBER 6 JUNE 1986

Electroexcitation of giant multipole resonances in ^{63}Cu

Yoshiyuki Kawazoe
Education Center for Information Processing, Tohoku University, Kawauchi, 980 Sendai, Japan

Haruhisa Miyase and Hiroaki Tsubota
Department of Physics, College of General Education, Tohoku University, Kawauchi, 980 Sendai, Japan

Jun Yokokawa, Masayuki Oyamada, and Yoshiharu Torizuka
Laboratory of Nuclear Science, Tohoku University, Mikamine, 982 Sendai, Japan

(Received 13 January 1986)

Giant multipole resonances in ^{63}Cu were investigated by inelastic electron scattering. From a model-dependent analysis assuming resonant parts expressed as a sum of Breit-Wigner shapes and a smooth background, the centroid excitation energies, the widths, and the sum rule depletions were deduced and compared with the results on neighboring isotones. Our results were in excellent agreement with photoreaction data.

Giant multipole resonances other than $E1$ have long been studied by inelastic electron[1] and hadron scattering.[2] For example, the transition strength, centroid excitation energy E_R, and width Γ of the isoscalar giant quadrupole $E2$ resonance (ISGQR) have been investigated systematically through the periodic table; the transition strengths exhaust 60–100% of the values expected from the $E2$ energy weighted sum rule. The systematic expressions for E_R and Γ are expressed as $60/A^{1/3}$ MeV and $90/A^{2/3}$ MeV, respectively.[3]

These experimental studies, however, concern even-mass nuclei with few exceptions.[3] To our knowledge there are almost no data available for medium odd-mass nuclei by inelastic electron scattering. The reason is simply that the characteristics of giant resonances are expected to reflect only bulk properties of nuclei and to depend little on shell structure. Additionally, it is very difficult to analyze the data on odd-mass nuclei theoretically in terms of the shell model. Thus the systematics for E_R and Γ mentioned above have been determined mainly by the data on even-mass nuclei. The values of these parameters may be somewhat altered by additional new data on odd-mass nuclei. The main purpose of this paper is to provide such data.

The experiment was performed using the Tohoku University 300 MeV electron linear accelerator. Scattered electrons were momentum analyzed with a magnetic spectrometer and detected by a 33 channel ladder of solid state detectors set along the focal plane. The excitation energy range measured in the present study is up to about 50 MeV to cover most of the expected giant multipole resonances. The inelastically scattered electrons have been detected at forward angles (30°–60°) to enhance Coulomb excitation. The effective momentum transfer q_{eff} at $E_x = 20$ MeV (around the giant multipole resonances) ranges from 0.29 to 1.13 fm^{-1} in the present experiment, which covers the first maximum of the $L = 0$–3 multipole form factors in ^{63}Cu.

The experimentally obtained counts of scattered electrons have been corrected for the effect of radiation in the target.[1] The ^{12}C data, which were taken under the same experimental conditions, have been used to normalize the ^{63}Cu data.

The electron scattering cross section is expressed as an incoherent sum of multipole transition strengths within the plane wave Born approximation (PWBA). In previous electron scattering studies concerning multipole giant resonances, multipole components have been deduced by (i) subtracting a phenomenological background independently from each spectrum and fitting the extracted structures with multiple resonance curves,[1] or by (ii) multipole expansion of the response function in each excitation energy bin.[4,5] The former method depends much on individual interpretation. The multipole components determined by the latter method include the transverse cross sections, instrumental scattering, and room background.

In this paper, ten (e,e′) spectra covering the expected giant multipole resonance region are simultaneously analyzed, and an overall fit to the data is systematically studied by the following equation, which assumes resonant parts expressed as a sum of Breit-Wigner shapes and a smooth background;

$$\frac{d^2\sigma}{d\Omega\,dE_x} = \sigma_M \eta \frac{d\omega}{dE_x} \left[\sum_i c_i \,|F_i(q_k)|^2 \frac{\left[\dfrac{\Gamma_i}{2}\right]^2}{(E_x - E_{R_i})^2 + \left[\dfrac{\Gamma_i}{2}\right]^2} \frac{E_x}{E_{R_i}} + a_k + b_k E_x \right], \tag{1}$$

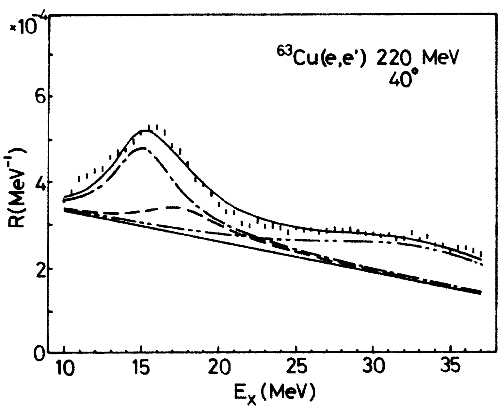

FIG. 1. Response function R [$=(d^2\sigma/d\Omega dE_x)/\sigma_M$] at 220 MeV, 40° after radiative corrections for ^{63}Cu(e,e') together with the best fit curves discussed in the text. The dash-dotted curve is that for the GDR, the dashed one for the ISGQR, and the dash-two-dotted one for IVGQR. The straight line indicates the estimated background contribution.

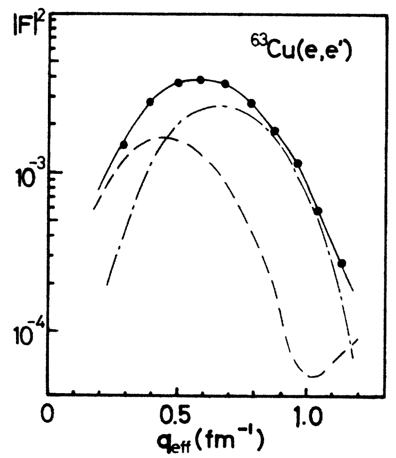

FIG. 2. The form factor in the energy range of 10—40 MeV for ^{63}Cu(e,e') together with the best fit curve. The dashed curve indicates the $E1$ contribution and the dash-dotted one is for the $E2$.

where E_{R_i} is the centroid energy of the ith giant multipole resonance, Γ_i the resonance width, c_i the transition strength, $|F_i(q_k)|^2$ the form factor under the kth experimental condition, and $a_k+b_kE_x$ the background contribution. The background defined here includes mainly the higher Coulomb multipole components and the transverse components. In addition, the instrumental scattering and room backgrounds may contribute to the background strengths. The Coulomb multipole components having the same multipolarities as the giant resonances are also considered as part of the background, which interferes with the resonances. These strengths, however, are expected to be much smaller than the other contributions to the background. We use the Goldhaber-Teller model for the giant dipole resonance (GDR) and the Tassie model for other multipole giant resonances. The ground state charge distribution is taken to be a two-parameter Fermi distribution,

$$\rho(r)=\frac{\rho_0}{1+\exp[(r-c)/z]}\,, \tag{2}$$

where $c=4.214$ fm and $z=0.586$ fm for ^{63}Cu.[6] The DWBA form factors are calculated by the computer code DUELS.[7]

Since the available experimental data are limited, it is very difficult to deduce all the expected multipole contributions. After having tried a number of combinations of multipole contributions, we have found that the minimum value of normalized χ^2 is achieved with three components, namely GDR, ISGQR, and isovector giant quadrupole resonance (IVGQR), together with a smooth background. Since the $q_{\rm eff}$ dependence of the monopole form factor is almost the same as the quadrupole one in inelastic electron scattering, the quadrupole form factor obtained here may contain a monopole component. Inelastic hadron scattering will play a significant role in distinguishing this component.

In Fig. 1, typical experimental data at $E_e=220$ MeV and $\theta=40°$ are shown together with the best fitted curves based on Eq. (1). All the other measured data are also judged to be satisfactorily reproduced by the present model. These numerical results show that the proposed model explains the experimental data very consistently in the overall (q,ω) region considered. Figure 2 shows the integrated experimental form factor in the energy range $E_x=10$—40 MeV. The momentum transfer dependence of the form factor is also very well reproduced by the present model.

Table I contains a summary of the deduced parameter values for the centroid excitation energy, the width, and the sum rule depletion. The results obtained here concerning ^{63}Cu are compared with previously published results on ^{62}Ni (Ref. 8) and ^{64}Zn (Ref. 9). The values of the sum rule depletion for ^{63}Cu are defined as the integrated values of the Breit-Wigner curves in the measured energy

TABLE I. The obtained resonance parameters compared with neighboring even-mass nuclei.

	^{62}Ni^a			^{63}Cu			^{64}Zn^b		
	IVGDR	ISGQR	IVGQR	IVGDR	ISGQR	IVGQR	IVGDR	ISGQR	IVGQR
E_R (MeV)	18.0	16.1	34.4	17.2	14.9	32.0	(17.7 21.4)	15.0	30.4
Γ (MeV)	6.0	4.7	10.4	6.1	5.0	18.2	(4.3 3.5)	6.0	5.0
EWSR (%)	115	94	59	109	89	82	(63 40)	49	16

^{a}Reference 8.
^{b}Reference 9.

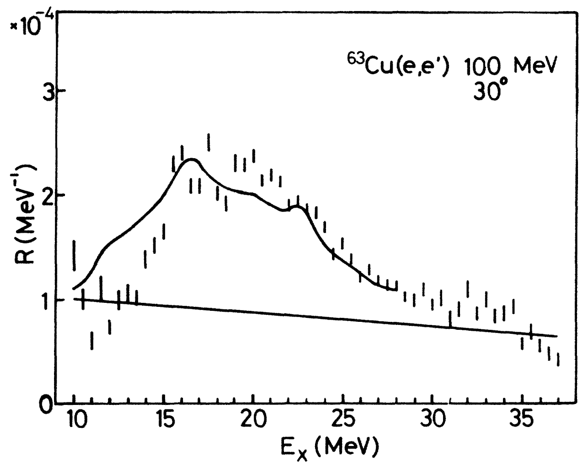

FIG. 3. Spectrum at 100 MeV, 30° for ^{63}Cu(e,e') compared with the photoreaction data. The straight line indicates the estimated background contribution.

region of 10 to 40 MeV. They satisfy the sum rule almost perfectly in all cases. The deduced centroid excitation energy and the width of the ISGQR are 14.9 MeV and 5.0 MeV, which are very close to $60/A^{1/3}$ MeV and $90/A^{2/3}$ MeV, respectively. Concerning IVGQR, we should be careful to say that these obtained values are conclusive, since if we take octupole resonance structure into our analysis, these parameter values are altered significantly. Although isospin splittings in GDR and IVGQR are expected theoretically,[10,11] it is impossible to separate these components using only the present data.

Our electron scattering data are also compared with previously published photoreaction data. We estimate the total photoabsorption cross section by adding the (γ,Sn) data of Fultz *et al.*[12] to the (γ,p) data of Tanaka (measured at 90°, multiplied by 4π).[13] Figure 3 shows the presently measured inelastic electron scattering data for the lowest momentum transfer $q_{\text{eff}}=0.29$ fm^{-1} together with the above-mentioned photoabsorption data, which were transformed hypothetically to this q_{eff} value by using the Siegert theorem with the Goldhaber-Teller model. The two kinds of data coincide very satisfactorily with each other.

To study the background contribution due to instrumental scattering, we are now measuring its strength by taking a very weak electron beam from the linac directly into the spectrometer, so as to hit the spectrometer wall. Quantitative results will be reported in a separate paper.

To summarize, the giant resonance energy region of ^{63}Cu was investigated by electron scattering, and giant multipole resonance parameters deduced. The sum rule depletions, centroid excitation energies, and resonance widths have been compared with those of neighboring nuclei. Using only the present results, we cannot establish odd-even differences in these values. It is highly desirable to accumulate experimental data for odd-mass nuclei, such as exist for even-mass ones, to settle this problem.

The authors would like to thank the electron scattering group and the machine crew of the Laboratory of Nuclear Science, Tohoku University for their help during the experiment. They are also very grateful to Professor D. W. L. Sprung for his careful reading of the manuscript.

---

[1] S. Fukuda and Y. Torizuka, Phys. Rev. Lett. **29**, 1109 (1972); M. Nagao and Y. Torizuka, *ibid.* **30**, 1068 (1972).

[2] M. B. Lewis, Phys. Rev. Lett. **29**, 1257 (1972); G. R. Satchler, Nucl. Phys. **A195**, 1 (1972).

[3] F. E. Bertrand, Nucl. Phys. **A354**, 129c (1981).

[4] M. Sasao and Y. Torizuka, Phys. Rev. C **15**, 217 (1977).

[5] R. Klein *et al.*, Phys. Lett. **145B**, 25 (1984).

[6] H. Gompelman, H. J. Blaawv, and C. W. deJager, At. Data Nucl. Data Tables **14**, 491 (1974).

[7] S. T. Tuan, K. E. Wright, and D. S. Onley, Nucl. Instrum. Methods **60**, 70 (1968).

[8] Y. Hozumi *et al.*, Res. Rep. Lab. Nucl. Sci. Tohoku Univ. **16**, 21 (1983).

[9] S. C. Fultz *et al.*, Phys. Rev. C **10**, 608 (1964).

[10] R. Ö. Akyüz and S. Fallieros, Phys. Rev. Lett. **27**, 1016 (1971).

[11] Y. Kawazoe and T. Tsukamoto, Phys. Rev. C **23**, 2364 (1981).

[12] S. C. Fultz, R. L. Bramblett, J. T. Caldwell, N. E. Hansen, and C. P. Jupiter, Phys. Rev. **128**, 2345 (1962).

[13] T. Tanaka, M. Hirooka, H. Tsubota, and M. Sugawara, Res. Rep. Lab. Nucl. Sci. Tohoku Univ. **14**, 137 (1981); and private communication.