2^+ TRANSITION CHARGE DENSITIES IN Zn ISOTOPES

S.F. TSAI and G.F. BERTSCH*
Cyclotron Laboratory and Physics Department
Michigan State University, East Lansing, MI 48824, USA

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We use coordinate-space RPA to calculate transition charge densities from the ground state to the first and the second 2^+ states in the even Zn isotopes. Good agreement with measurement from recent electron scattering experiments is obtained for the first 2^+ states, but not for the second.

Very pretty results have come out recently from electron scattering, which deduce transition charge densities from the ground to low-lying states [1]. The new results on the 2^+ "phonon" states in Zn isotopes [2] stimulated us to compare these with the RPA theory. The self-consistent RPA in a large basis has been remarkably successful in describing the dynamics of heavy closed shell nuclei [3–5].

The Zn isotopes of course are not closed shell nuclei. The calculation is not well-defined in principle, since RPA demands a Hartree–Fock description of the ground state. We overcome this by assigning an occupation probability to each single-particle orbital. Assuming the $f_{7/2}$-subshell to be closed, we put the extra nucleons into the $p_{3/2}$- and $f_{5/2}$-subshells with partial occupation probability as shown in table 1. The RMS charge radii are also shown with the corresponding experimental values.

The single-particle spectrum for the unoccupied orbitals is then shifted with respect to the occupied orbitals so as to remove the degeneracy between the particle and the hole energy in the partially filled orbitals. (At this point self-consistency is given up from the theory.) The actual amount of the shift Δ is determined by requiring the energies of the first 2^+ states to come out at the experimental values. In table 2, we list the values of Δ used together with the RPA energies for the second 2^+ states. Operator set B of table 7 of ref. [3] with the neglect of σ and $\sigma\cdot r$ terms was used for the RPA particle-hole interaction vertices.

The nuclear matter transition density to the 2^+ states can be obtained as described in ref. [4], i.e.

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Table 1
Parameters for Hartree–Fock calculations.

a) Occupation Probability

		$f_{7/2}$	$p_{3/2}$	$f_{5/2}$	$p_{1/2}$
^{64}Zn	p	1	1/2	0	0
	n	1	1	1/3	0
^{66}Zn	n	1	1	2/3	0
^{68}Zn	n	1	1	1	0

b) RMS Charge Radii

	HF	Exp.*
^{64}Zn	3.88	3.918 (fm)
^{66}Zn	3.90	3.933
^{68}Zn	3.93	3.956

* Experimental values are taken from ref. [2].

$$\rho_{n0}(r) = \frac{1}{\sqrt{\pi}}\left[\int_{E_n-\epsilon}^{E_n+\epsilon} \mathrm{Im}G(r, r, E)\mathrm{d}E\right]^{1/2}. \quad (1)$$

In order to obtain the transition charge density, eq. (1) is then folded with a Gaussian proton-charge distribution,

$$f_p(r) = \frac{1}{(r_0\sqrt{\pi})^3}\exp(-r^2/r_0^2), \quad r_0 = 0.65 \text{ fm}. \quad (2)$$

The result for the transition charge densities are shown in figs. 1–2 together with the error bands from ref. [2]. In table 3, we list the reduced transition strengths. The RPA particle-hole excitation model seems to do well for the first excited 2^+ states, although there seems to be excessive contribution from

Table 2
Energy shift Δ and excitation energy for 2_2^+.

	Δ(MeV)	2_2^+(RPA)	2_2^+(Exp.)*
^{64}Zn	2.0	2.59	1.800 (MeV)
^{66}Zn	2.05	2.56	1.873
^{68}Zn	1.6	2.05	1.883

* Experimental values are taken from ref. [2].

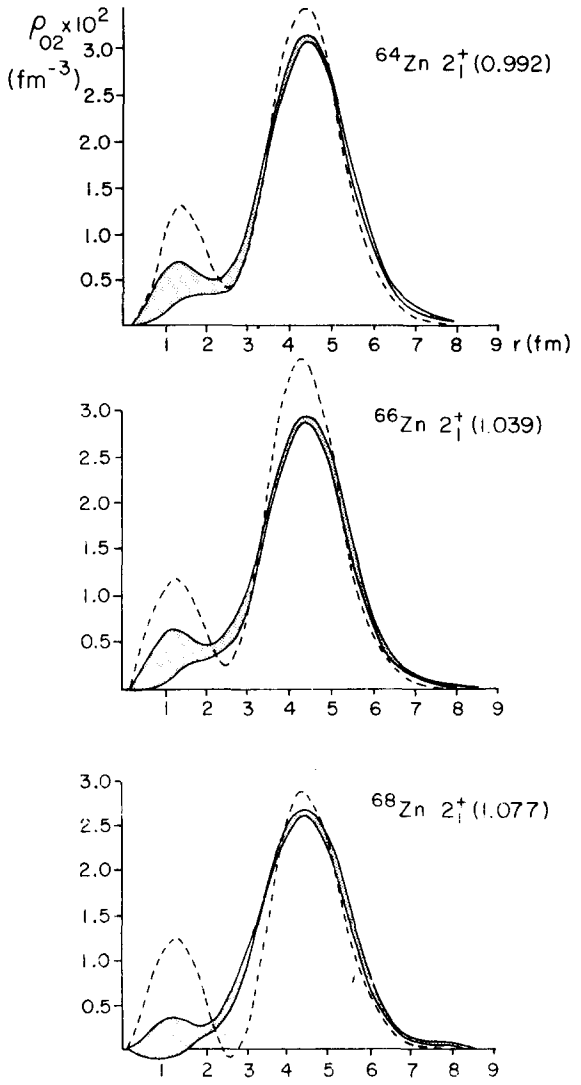

Fig. 1. Transition charge density from ground to the first 2^+ state in ^{64}Zn, ^{66}Zn and ^{68}Zn.

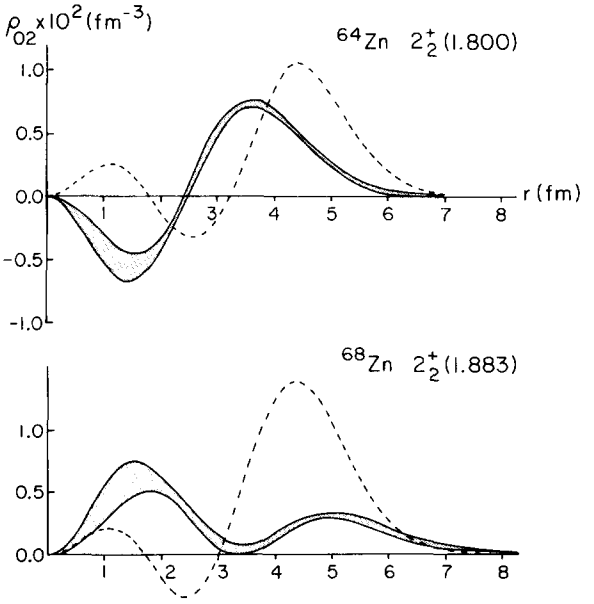

Fig. 2. Transition charge density from ground to the second 2^+ state in ^{64}Zn and ^{68}Zn.

Table 3
Reduced transition strengths

	RPA	Exp.*	RPA	Exp.*
	$B\uparrow(E2_1^+)$	(fm^4)	$B\uparrow(E2_2^+)$	(fm^4)
^{64}Zn	1182	1580±50	102	17.6±1.1
^{66}Zn	1216	1370±50	115	3.8±0.6
^{68}Zn	890	1360±60	190	44±8

* Experimental values are taken from ref. [2].

the p-orbitals at small distances. As for the second 2^+ states, the obvious disagreement implies that more complicated configuration mixing than that of 1p-1h is needed for the description of these two-phonon states. This could have been guessed beforehand.

References

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