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Communications

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Odd-even differences in the elastic scattering of α particles by $A = 62$–66 nuclei*

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The elastic scattering of 48 MeV α particles by ^{62,64}Ni, ^{63,65}Cu, and ^{64,66}Zn is optical-model analyzed. The $\vec{I}\cdot\vec{L}$ potential depth is found to be much weaker than reported in previous optical-model analysis.

[NUCLEAR REACTIONS ^{62,64}Ni, ^{63,65}Cu, ^{64,66}Zn(α,α), $E=48$ MeV; measured $\sigma(\theta)$, $\theta=18$–$172°$; enriched targets; optical-model analysis.]

Odd-even differences in the elastic scattering of α particles have been reported several times and attributed to two effects:

(i) The $\vec{I}\cdot\vec{L}$ interaction between the spin I of the target and the relative angular momentum L of the system. This interaction was postulated to fit the angular distribution observed from isolated light nuclei (^{9}Be and ^{23}Na)[1,2] in the low energy region ($E_\alpha < 24$ MeV) where the optical potential is known to have resonances. An $\vec{I}\cdot\vec{L}$ term was also put forward in the analysis of the elastic scattering of ^{3}He from odd and even targets (V, Cr, Co, and Ni) at 60 MeV[3] to explain the deeper $\vec{L}\cdot\vec{S}$ potential needed to describe the scattering of ^{3}He from the odd targets. In all cases the $\vec{I}\cdot\vec{L}$ potential was about 1 to 2 MeV deep.

(ii) When the spin I of the target is greater than $\frac{1}{2}$, scattering from the multipole moments of the target can occur, which has the same effect on the angular distributions as an $\vec{I}\cdot\vec{L}$ potential. This was reported in the analysis of the elastic scattering of α particles from ^{24,25,26}Mg[4] and from ^{59}Co-^{60}Ni.[5]

This experiment was performed in order to test both hypotheses under more reliable conditions, i.e., looking for these effects in the elastic scattering of 48 MeV α particles from some odd-even neighboring nuclei in the $A = 60$ mass region, on the complete angular range. The choice of the energy and target nuclei ensures elimination of anomalous large angle scattering phenomena. The nuclei chosen were ^{62,64}Ni, ^{63,65}Cu, and ^{64,66}Zn whose nuclear properties are very similar: The coupling to inelastic channels, if any, should then be quite the same for all the nuclei.

The experimental method and a first analysis of the data were reported in a previous paper[6]: We evaluated there the quadrupole contribution[5,7] to the elastic scattering for the odd nucleus as

$$\sigma_{\mathrm{el}}(\mathrm{odd}) = \sigma_{\mathrm{el}}(\mathrm{even}) + C_2\sigma_{\mathrm{inel}}(\mathrm{even}, 0^+ \to 2^+)\ , \qquad (1)$$

where $\sigma_{\mathrm{el}}(\mathrm{odd})$ is the elastic cross section for the odd nucleus, $\sigma_{\mathrm{el}}(\mathrm{even})$ is the cross section for a neighboring even nucleus, $\sigma_{\mathrm{inel}}(\mathrm{even}, 0^+ \to 2^+)$ is the cross section for inelastic scattering from the first excited state (2^+) of this even nucleus, and C_2 is a coefficient calculated from the admixture of the quadrupole deformation in the odd nucleus. The agreement with the data was rather good at forward and poorer at backward angles.

We now present the optical-model analysis of the data. The standard optical potential with volume absorption was used:

$$V_{\mathrm{opt}} = V_C(r) - V_R f(x_R) - iW_v f(x_I)\ , \qquad (2)$$

$$f(x_j) = [1 + \exp(x_j)]^{-1}\ ,$$

$$x_j = (r - r_j A^{1/3})/a_j\ ,$$

where $V_C(r)$ is the Coulomb potential, V_R and W_V are the depths of the real and imaginary potentials, and $f(x_j)$ is the Woods-Saxon form factor where r_j and a_j are the radius and diffuseness.

In the fitting procedure, the searches were limited to a single family of real potentials, which was extrapolated from the unique family at higher

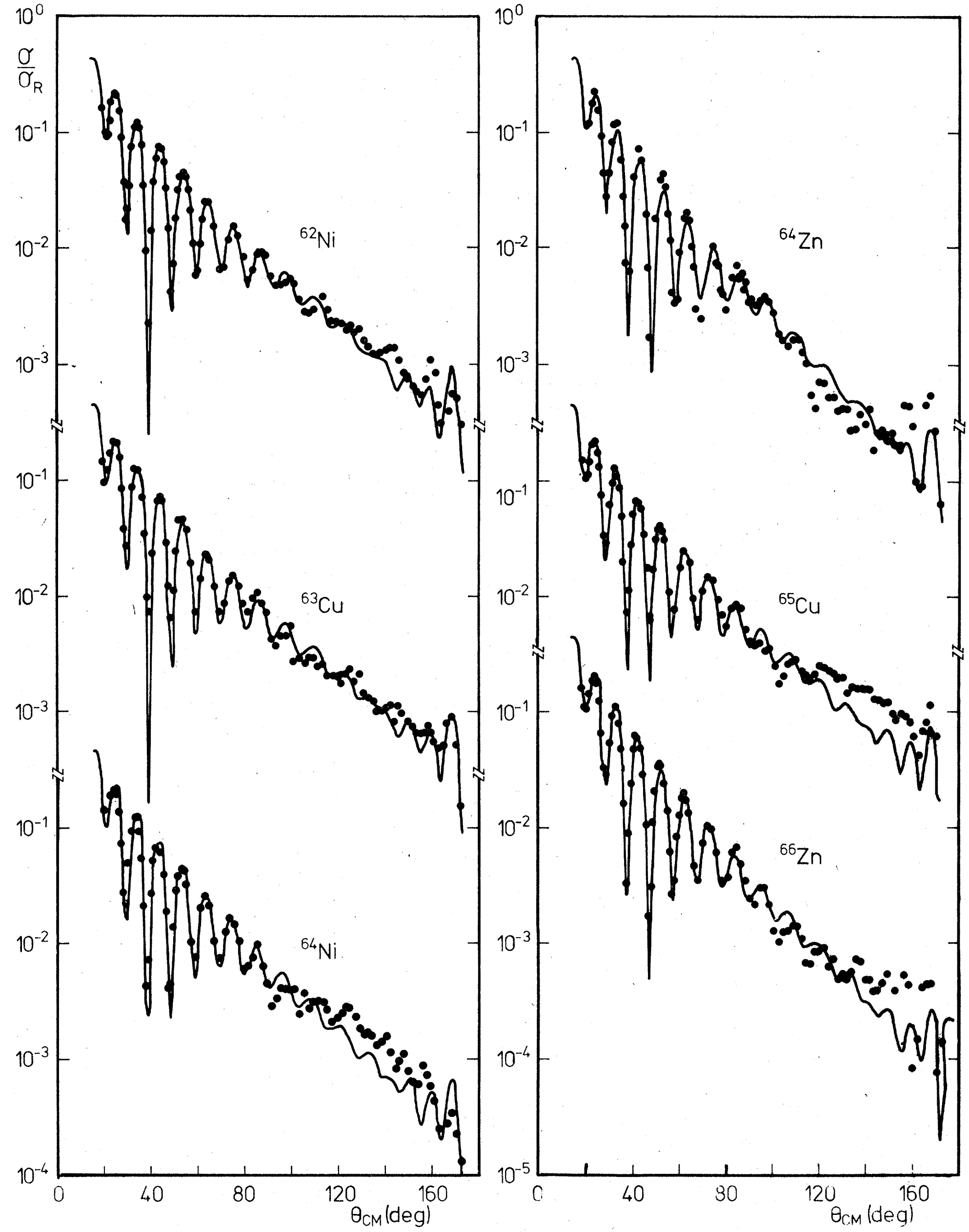

FIG. 1. Experimental angular distributions for elastic scattering of 48 MeV α particles by ^{62,64}Ni, ^{63,65}Cu, and ^{64,66}Zn. The curves are optical-model fits with the potentials of Table I.

TABLE I. Best fit optical-model parameters.

	V_R (MeV)	r_R (fm)	a_R (fm)	W_V (MeV)	r_I (fm)	a_I (fm)	J_R (MeV fm^3)
^{62}Ni	106.0	1.379	0.658	29.7	1.456	0.625	1332
^{63}Cu	105.9	1.384	0.658	29.9	1.446	0.638	1340
^{64}Ni	105.8	1.388	0.657	34.0	1.437	0.640	1348
^{65}Cu	105.7	1.390	0.657	31.1	1.446	0.638	1352
^{64}Zn	102.0	1.351	0.679	34.0	1.364	0.730	1208
^{66}Zn	102.3	1.372	0.679	39.4	1.363	0.731	1272

energy. The good family at 48 MeV was found to be around $J_R = 1300$ MeV fm^3. This J_R value of the volume integral of the real potential is extracted from the observed energy dependence of J_R at higher energies and agrees with the calculated dependence from microscopic models.[8-10] The Cu real potentials were deduced from the A dependence of the even Ni nuclei real potentials; the Zn data were not used to get these potential because they showed too different a picture in the backward region. The imaginary parameters were adjusted separately to give the best fit onto the odd nuclei. A spin-orbit term was then added which did not improve the fit to the odd nuclei. Table I and Fig. 1 present the best optical potentials and fits.

When comparing the optical-model fits to our first analysis, it is apparent that the quadrupole contribution has been overestimated. The data for the odd nucleus can be well represented by an optical potential without a spin-orbit ($\vec{I}\cdot\vec{L}$) term. The classical 2 MeV deep $\vec{I}\cdot\vec{L}$ potential, which was argued before, can be excluded. The best potential with a 2 MeV deep $\vec{I}\cdot\vec{L}$ term gives a much worse agreement to the ^{63,65}Cu data than the potentials of Table I and Fig. 1. The $\vec{I}\cdot\vec{L}$ potential, if any, must be much weaker and this seems to confirm the theoretical calculations.[11] Anyway, both the $\vec{I}\cdot\vec{L}$ potential and the scattering from multipole moments can be present at the same time, but their effects on the angular distributions of the Cu nuclei is very weak.

A tabulation of the cross section data on which this Communication is based is on deposit with the Physics Auxiliary Publication Source.[12]

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[12] See AIP document No. PAPS PRVCA-17-810-19 for 19 pages of cross section data. Order by PAPS number and journal reference from American Institute of Physics, Physic's Auxiliary Publications Service, 335 East 95th Street, New York, N. Y. 10017. The price is \$1.50 for microfilm or \$5 for photocopy; airmail additional. Make checks payable to American Institute of Physics. This material also appears in Current Physics Microfilm, the monthly microfilm edition of the complete set of journals following our article.