$=-0.55E$. This difference is partly due to the use of backward angles in the latter analysis and perhaps to its neglect of core excitations. We have found that the decrease of cross section with angle requires $\beta=2$ for protons and $\beta=1$ for deuterons. This larger value of $\beta$ increases the damping of contributions from the interior and may imply a considerably higher rate of energy dependence of the real potential than suggested by the work of Buck and Perey.

The $J$ dependence for $l=1$ particle-transfer reactions at $E_d=23$ MeV appears to be qualitatively in good agreement with the distorted-wave predictions. This suggests the possibility that the $l=1, J=l-\frac{1}{2}$ effect of Lee and Schiffer may be due to the interference of direct reaction with some other type of reaction mechanism.

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[1]L. L. Lee, Jr., and J. P. Schiffer, Phys. Rev. Letters 12, 108 (1964).
[2]R. C. Johnson and F. D. Santos, Phys. Rev. Letters 19, 364 (1967).
[3]J. L. Yntema and H. Ohnuma, in Proceedings of the International Conference on Nuclear Physics, Tokyo, Japan, 7-13 September 1967 (to be published), p. 307.
[4]We are indebted to Dr. R. M. Drisko for use of the code JULIE.
[5]L. L. Lee, Jr., and J. P. Schiffer, Phys. Rev. 136, B405 (1964).
[6]R. H. Bassel, private communication.
[7]G. R. Satchler, Nucl. Phys. A92, 273 (1967).
[8]F. G. Perey and D. S. Saxon, Phys. Letters 10, 107 (1964).
[9]We are indebted to Dr. Perey for the use of his code.
[10]F. Perey and B. Buck, Nucl. Phys. 32, 353 (1962).
[11]F. G. Perey, Phys. Rev. 131, 745 (1963).

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# EVIDENCE FOR THE ISOBARIC SPLITTING OF THE GIANT RESONANCE FROM THE REACTION $^{89}Y(p,\gamma_0)^{90}Zr$†

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A small but well-defined resonance was found in $^{90}$Zr near the predicted $T_>$ component of the giant dipole resonance.

Several years ago, Fallieros, Goulard, and Ventner[1] suggested that the giant dipole resonance in nuclei is split into two components: The larger component occurs at lower energy and has the same isospin as the target (i.e., $T_<$). The $T_>$ counterpart was predicted to be about 5 MeV higher in energy for $^{90}$Zr. Although an excess of photoneutrons above a classical Lorentz line shape has been reported[2] above the giant dipole resonance in $^{90}$Zr, an obvious resonant cross section near the predicted location of the $T_>$ component has not been identified. This paper identifies the position and width of what is probably the $T_>$ resonance. It would be interesting if experiments sensitive to other decay modes of $^{90}$Zr could be performed in order to provide additional information about the $T_>$ state.

The $^{89}Y(p,\gamma_0)^{90}Zr$ cross section at 90°, shown in Fig. 1, and obtained at the Los Alamos Scientific Laboratory tandem facility, shows a definite resonance centered at an excitation energy of $21.0\pm0.15$ MeV with a full width at half-maximum of about 0.6 MeV.

The integrated $(p,\gamma_0)$ cross section in this small resonance is 1.5 MeV $\mu$b/sr corresponding to a $(\gamma,p_0)$ integrated cross section of 0.75 MeV mb/sr. This integrated cross section is considerably smaller than the predicted partition of dipole strength would imply if the $(p,\gamma_0)$ cross section were equally sensitive to the $T_>$ and $T_<$ giant resonance components. How-

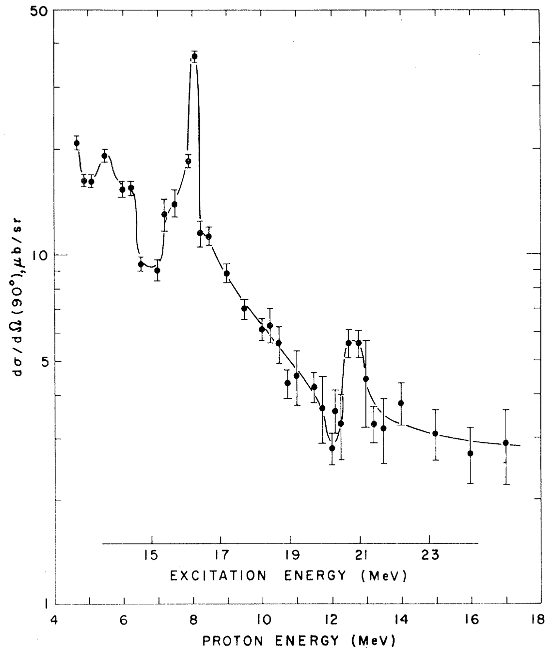


FIG. 1. Differential cross section of process $^{89}$Y($p$, $\gamma_0$)$^{90}$Zr at 90°. The errors shown are statistical. Because of some uncertainty in the gamma-detector efficiency, absolute values are good probably to within 35%.

ever, because much of the ($p, \gamma_0$) strength is associated with two narrow resonances previously reported,[3] it is not clear that the ($p, \gamma_0$) cross section reflects the correct relative strength of the $T_<$ and $T_>$ dipole components. Although the resonance shown in Fig. 1 near 21-MeV excitation has not been unambiguously identified as the predicted $T_>$ giant resonance component, this interpretation is the most plausibly available one at present for what would otherwise be a surprisingly narrow concentration of dipole strength.

Below $E_p = 10$ MeV, the curve in Fig. 1 is in good agreement with the unpublished results of Black and Hall.[4] Below $E_p = 5$ MeV, the work of these authors and the recent results of Obst, Rauch, and Wahsweiler[5] indicate profuse fine structure indicative of compound nucleus formation. The present work is being extended. It would appear that the cross section from 15- to 20.5-MeV excitation energy is dominated by the well-known giant dipole resonance, while the high cross section at lower energies (away from the analog states) may be attributed chiefly to compound nuclear processes.

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[1]S. Fallieros, B. Goulard, and R. H. Ventner, Phys. Letters 19, 398 (1965).

[2]B. L. Berman, J. T. Caldwell, R. R. Harvey, M. A. Kelly, R. L. Bramblett, and S. C. Fultz, Phys. Rev. 162, 1098 (1964).

[3]J. L. Black and N. W. Tanner, Phys. Letters 11, 135 (1964).

[4]J. L. Black and I. Hall, private communication.

[5]E. Obst, F. Rauch, and H. G. Wahsweiler, to be published.