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Communications

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Correlation between the (d, γ_0) and (p, γ_0) cross sections in the giant dipole resonance of ^{16}O

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The reaction theory of Fano is applied to the analysis of the ^{15}N$(p, \gamma_0)^{16}$O data *vis à vis* the ^{14}N$(d, \gamma_0)^{16}$O data. The result is consistent with the Gillet model which attributes the structure near 22.9 MeV in ^{16}O to a 2p-2h quasibound state.

[NUCLEAR STRUCTURE ^{16}O; extracted resonance energy of quasibound state from ^{15}N$(p, \gamma)^{16}$O data. Compared to Gillet's model.]

Previous papers[1-3] have given considerable attention to the resonance observed in the ^{14}N(d, γ_0)-^{16}O reaction. The question which has been discussed is whether this resonance, presumably correlated with a 2p-2h quasibound state in ^{16}O,[4] occurs at an energy of 22.7 ± 0.05 MeV[1] [the energy at which the ^{15}N$(p, \gamma_0)^{16}$O cross section exhibits a dip] or of 22.84 ± 0.05 MeV[2] [an energy which is close to a peak in the ^{15}N$(p, \gamma_0)^{16}$O cross section]. This correlation has been used to compare the 2p-2h calculations of Gillet, Melkanoff, and Raynal[4] with the 3p-3h model of Shakin and Wang.[5] The purpose of this comment is to carry this comparison of (d, γ_0) and (p, γ_0) cross sections one step further and to show that a somewhat more careful analysis indicates that the (d, γ_0) peak observed at 22.84 ± 0.05 MeV is at just about the correct energy which one would expect for a quasibound state as observed in the (p, γ_0) data.

A correct treatment of course would require a full-fledged continuum calculation in which both the 1p-1h and the quasibound 2p-2h states are coupled to their respective continua [the (γ, d) threshold is at ~20.7 MeV]. Then the peak in the (d, γ_0) spectrum could be directly compared with the (p, γ_0) spectrum. Instead, in this note we do not want to do a model calculation, but we rather want to extract the parameters of the resonances from the data. We shall do that in the framework

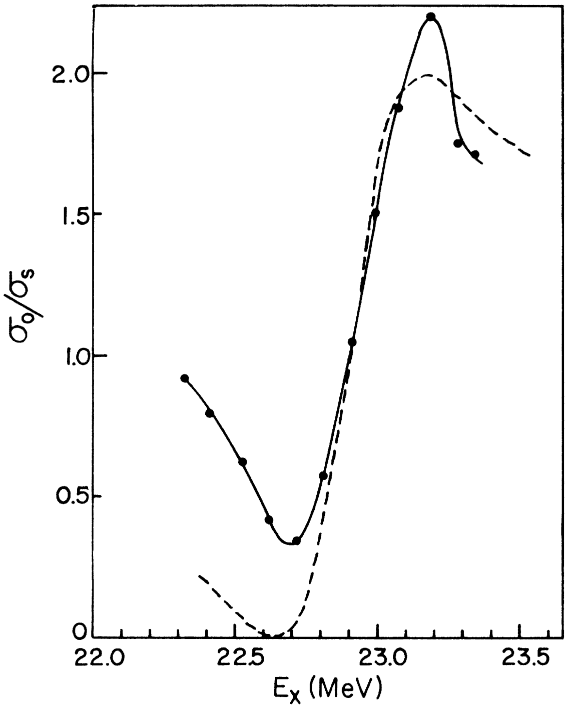

FIG. 1. The solid line is the line shape obtained from the ^{15}N$(p,\gamma_0)^{16}$ cross section data in the giant dipole resonance region of ^{16}O. The dashed curve is the theoretical curve obtained from Ref. 6 as described in the text.

of the treatment by Fano.[6] He gives universal curves for a ratio of cross sections σ_0/σ_S, where for our case σ_S is the photon absorption cross section of the unperturbed (1p-1h) system, while σ_0 is that of the coupled (1p-1h) +quasibound state system. However, explicit curves are given only for the case of a single open continuum; the interference minimum in the cross section then always reaches $\sigma = 0$. In the case of several continua the minimum has a finite cross section. This corresponds to the present case. Therefore the contributions of the different continua should be separated out. In a spectrum as complicated as that of the photon absorption cross section of ^{16}O, such a separation is not easy to perform. Rather, we shall rely on the assumption that around the interference pattern, i.e., around 23 MeV, all parameters vary very slowly except for σ_0 and for the relevent mixing parameters of the quasibound state to the 1p-1h continuum. Thus we proceed in the following way.

We begin by taking the $^{15}\mathrm{N}(p, \gamma_0)^{16}\mathrm{O}$ cross section data σ_0 integrated over angles (i.e., A_0)[7] and drawing a symmetric peak for the strong resonance at 22.25 MeV. This yields values for the quantity σ_S on the high energy side (i.e., $E_x > 22.25$ MeV) of the resonance. We then calculate the ratio

$$S_E = \frac{\sigma_0}{\sigma_S}\,, \tag{1}$$

which is plotted as a solid line in Fig. 1. The dashed line represents the theoretical line shape [Eq. (21), Ref. 6]

$$S_T = \frac{(q+\epsilon)^2}{1+\epsilon^2} \tag{2}$$

and

$$\epsilon = \frac{E - E_R}{\frac{1}{2}\Gamma}\,, \tag{3}$$

where the parameter q has the value $q = 1.0$, $E_R = 22.9$ MeV, and $\Gamma = 500$ keV. The value of q is estimated to be uncertain by a factor of ±0.1. For this case ($q = +1.0$) the value of $\epsilon = 0$ occurs where the function S_T equals 1.0.[6] The value of $\epsilon = 0$ means just $E = E_R = E_\phi + F$ (in Fano's notation[6]), which is the value of the resonance energy of the perturbed quasibound state (or autoionized level). Hence the (d, γ_0) peak should occur at about 22.9 MeV in ^{16}O, which is in good agreement with the recent observation of 22.84 ± 0.05 MeV. We can also extract the width parameter from the line shape of Fig. 1. Because of (3) and (2) the width determined from the (p, γ_0) data is simply related to the energy difference between the maximum and the minimum value of the line shape. Calling this difference δE, we have

$$\Gamma = 2\delta E/(q + q^{-1})\,. \tag{4}$$

This yields $\Gamma = 500$ keV which compares well with the (d, γ_0) width of about 600 keV. Of course the values of E_R and Γ depend on the details of the assumed shape of the symmetric cross section, σ_S, and are uncertain by about 50 keV. Also, the other assumptions made above certainly may break down for $E - E_R \gtrsim \frac{1}{2}\Gamma$. However, from the present results we conclude that, in contrast to the remarks of the authors of Ref. 2, the new value for the (d, γ_0) resonance of 22.84 ± 0.05 MeV is consistent with the Gillet *et al.*[4] interpretation.

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[1] M. Suffert, Nucl. Phys. 75, 226 (1965).

[2] H. R. Weller, R. A. Blue, and S. L. Blatt, Phys. Rev. C 5, 648 (1972).

[3] M. Suffert, in *Proceedings of the International Conference on Photonuclear Reactions and Applications, Asilomar, 1973*, edited by B. L. Berman (Lawrence Livermore Laboratory, Univ. of California, Livermore, 1973), Vol. 2, p. 741.

[4] V. Gillet, M. A. Melkanoff, and J. Raynal, Nucl. Phys. A97, 631 (1967).

[5] C. M. Shakin and W. L. Wang, Phys. Rev. Lett. 26, 902 (1971).

[6] U. Fano, Phys. Rev. 124, 1866 (1961).

[7] W. J. O'Connell, G. L. Latshaw, J. L. Black, and S. S. Hanna, in *Proceedings of the International Conference on Photonuclear Reactions and Applications, Asilomar, 1973* (see Ref. 3), Vol. 2, p. 939.