COMMENTS

Comments are short papers which comment on papers of other authors previously published in the **Physical Review**. *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "Wave function of ^{14}N"

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It is pointed out that low-energy pion photoproduction provides an important constraint for the wave functions of p-shell nuclei.

In a recent paper, Amos *et al.*[1] compared existing ^{14}N wave functions with experimental data from (p,p') and (p,n) reactions, form factors, and β- and γ-decay rates, and concluded that standard shell model wave functions are superior to phenomenologically obtained nuclear structure coefficients. We would like to point out that charged pion photoproduction can serve as an important additional constraint on the nuclear structure input.

A number of recent experiments at Mainz,[2-3] Bates,[4] NIKHEF,[5] and Sendai[6] have provided new, high quality data for pion photoproduction from p-shell nuclei. In most cases the nonlocal distorted-wave impulse approximation (DWIA) has been used with considerable success to describe the general features of $(\gamma,\pi^{\pm})$ nuclear reactions. Theoretical calculations carefully incorporate the following three basic ingredients: an elementary one-body operator,[7] which has been extracted from the dynamics of pion production from free nucleons, pion optical-model wave functions obtained from the analysis of pion elastic scattering data,[8] and many-body nuclear wave functions.

Because of the weakness of the electromagnetic process in the initial state, the DWIA in photopion reactions is a much better approximation then in, say, pion-nucleus scattering. So far, there is no need for second-order electromagnetic processes, while the strong final-state interactions are included to all orders. Since the nuclear matrix elements are evaluated in momentum space,[9] Fermi motion as well as nonlocalities arising from the various propagators in the elementary amplitude are naturally included. The main appeal of the DWIA is that of a simple physical picture of a pion which is produced off a bound nucleon in the nucleus and then distorted by a final state interaction, can be implemented in a microscopic parameter-free calculation.

In Fig. 1 we compare experimental data with our theoretical calculations using four different sets of nuclear matrix elements given in Table I. Two of those were obtained by specifying a Hamiltonian for light nuclei and tuning it to reproduce static nuclear properties,[10] while the other two were determined by selecting a parametrized form of the wave function whose strength coefficients were then adjusted to static and dynamic observables.[2,11] For low energies and small momentum transfers the (γ,π^{+}) reaction is dominated by the Kroll-Ruderman term $\sigma\cdot\epsilon\tau_{\alpha}$. Therefore, the process $^{14}\mathrm{N}(\gamma,\pi^{+})^{14}\mathrm{C}_{\mathrm{g.s.}}$ at small pion angles is sensitive to the Gamow-Teller matrix element with $J=1$, $L=0$, $S=1$, and $T=1$. The wave function CK(8−16)POT, preferred by Ref. 1 from hadronic scattering, overpredicts the data point at $\theta_{\pi}=25°$ by more than a factor of 3, while the other three wave functions are in reasonable agreement. However, at backward angles the two Cohen-Kurath (CK) wave functions overpredict the data at both energies by more than a factor of 4, while the two phenomenological sets of coefficients give an excellent description of the data. Note that the $H1$ wave function were determined *without* using the (γ,π^{+}) data as an input.

In Fig. 2, we compare calculations using the four wave functions with the experimental elastic and inelastic $M1$ form factors of ^{14}N. While all wave functions can reproduce the elastic form factor, the two Cohen-Kurath wave functions exceed the inelastic data by a factor of 3. As already mentioned in Ref. 1, this is due to the $L=2$ transition strength which is too large by a factor of 2 (see Table I). The same nuclear structure coefficient $\psi_{1(21)}$ causes

TABLE I. Nuclear structure matrix element $\psi_{J(LS);T=1}$ for the reaction $^{14}\mathrm{N}(\gamma,\pi^{+})^{14}\mathrm{C}_{\mathrm{g.s.}}$.

Wave function	CK(8−16) POT	CK(8−16) 2BME	$H1$	Röhrich
$\psi_{1(10)}$	0.346	0.320	0.339	0.333
$\psi_{1(01)}$	−0.090	−0.029	−0.033	−0.039
$\psi_{1(11)}$	−0.064	−0.102	0.040	−0.144
$\psi_{1(21)}$	0.826	0.836	0.435	0.428
Reference	10	10	11	2

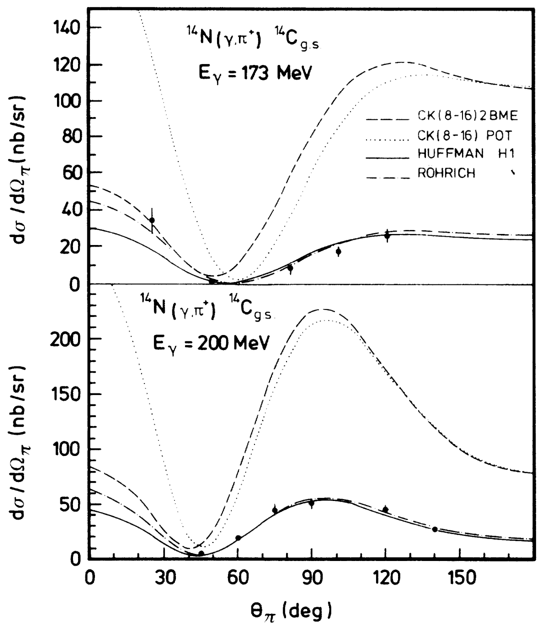

FIG. 1. The process $^{14}N(\gamma,\pi^+)^{14}C_{g.s.}$ at $E_\gamma=173$ and 200 MeV using the wave functions *H*1 (——), Röhrich (—·—·—·), CK(8−16)2 BME (— — —), and CK(8−16) POT (· · · ·). The data are from Refs. 2 and 4.

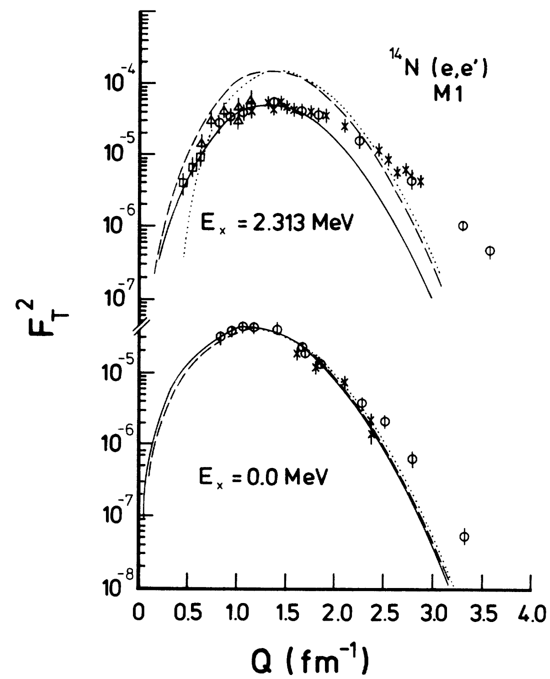

FIG. 2. Elastic and inelastic *M*1 form factors of ^{14}N. The curves represent the same wave functions as in Fig. 1; the calculation using the coefficients of Röhrich is identical to that of *H*1. For a list of references on the data, see Ref. 11.

the disagreement for the process $^{14}N(\gamma,\pi^+)^{14}C_{g.s.}$ when CK wave functions are employed. There are a number of cases among *p*-shell nuclei where the $J=1$, $L=2$, $S=1$ strength is not properly reproduced, such as the elastic *M*1 form factors of ^{6}Li (Ref. 12) and ^{13}C (Ref. 13), or the inelastic *M*1 form factors of ^{12}C*(15.11) (Ref. 14) and ^{14}N*(2.31). In our opinion, this systematic discrepancy has fueled the interest in phenomenological wave functions, which have been developed for ^{6}Li (Ref. 15), ^{12}C (Ref. 14), ^{13}C (Ref. 16), and other nuclei.

Using in turn these fitted nuclear structure coefficients generally gives a good description of nuclear photopion data. We therefore believe that using phenomenological wave functions can be justified despite the theoretical difficulties addressed in Refs. 1 and 17. To use again the example of $^{14}N(\gamma,\pi^+)^{14}C_{g.s.}$, fixing the nuclear structure input in low-energy pion production ($E_\gamma \le 200$ MeV) allows one to extract information on delta medium modifications at higher energies[18] ($E_\gamma \ge 260$ MeV). What is, in our opinion, necessary is to repeat the analysis of Cohen and Kurath[10] taking into account all the information on dynamical observables that has been accumulated over the last twenty years and, if possible, include configurations from outside the 1*p* shell. Such wave functions would clearly be superior to those of Cohen and Kurath as well as those determined phenomenologically.

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