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INCOHERENT PRODUCTION OF ρ^0 MESONS FROM NUCLEI AND VECTOR DOMINANCE

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Incoherent photoproduction of ρ^0 mesons on the nucleus is calculated assuming vector dominance. The results are sensitive to the ρ-nucleon total cross section which is found to decrease with energy. One finds a relatively weak dependence on energy of the incoherent effective nucleon number.

Recently[1,2] there have been measurements of the incoherent photoproduction of ρ^0 mesons on atomic nuclei at incident photon energies of 2.7, 4, and 8 GeV and momentum transfers $\sqrt{-t} \sim 0.25$ to 0.35 GeV/c. The relative constancy of the measurements at 4 and 8 GeV is pointed out by the authors of Ref. 2. This could imply some question as to the validity of the vector dominance hypothesis or at least for the eikonal models[3,4] normally used to calculate incoherent production.

The purpose of this note is to point out that (1) there is good reason to believe that the total ρ^0-nucleon cross section, σ_ρ, decreases with energy, following the π-nucleon cross section closely in value; and (2) as a result of σ_ρ decreasing, and being smaller in value than some authors have deduced, the cross section for incoherent production of ρ^0 mesons in atomic nuclei varies considerably less with energy than one might expect.

Gottfried and Yennie[3] describe incoherent ρ^0 production in terms of a superposition of one- and two-step processes. In the one-step process the ρ^0 meson is produced incoherently on a nucleon and then proceeds, with some damping, to be emitted from the nucleus which has been excited. The two-step process consists of coherent production on one nucleon (no nuclear excitation) followed by incoherent scattering (nuclear excitation occurs) of the ρ^0 meson on another nucleon. The cross section for these processes is given by

$$d\sigma^{(I)}/dt = \int d^2b\,dz\,I(b,z) \equiv [d\sigma_0(t)/dt]N_{\text{eff}}, \tag{1}$$

$$I(b,z) = D(b,z)\frac{d\sigma_0(t)}{dt}\exp[-\sigma_\rho \textstyle\int_z^\infty D(b,z')dz'] \tag{2}$$

$$\varphi(b,z) = -\tfrac{1}{2}\sigma_\rho \int_{-\infty}^{z} dz' D(b,z')\exp[-\tfrac{1}{2}\sigma_\rho \textstyle\int_{z'}^{z} D(b,z'')dz''], \tag{3}$$

where $d\sigma_0(t)/dt$ is the ρ^0 photoproduction differential cross section on a neutron or proton (taken equal) and $D(b,z)$ is the A-particle nucleon density function. We neglect the real part of the ρ-nucleon forward-scattering amplitude. The wave numbers for the photon and ρ^0 meson are k_γ and k_ρ, respectively. Nuclear c.m. motion and nuclear correlations are neglected. The effective nucleon number N_{eff} is a function of A, energy, and σ_ρ.

At low enough energies (~2 GeV) the one-step process dominates. The two-step process is inhibited due to mismatch of the photon and ρ^0-meson wave numbers because of the mass of the ρ^0 meson. One has then an incoherent production cross section

$$\frac{d\sigma^{(I)}(t)}{dt} \simeq \frac{d\sigma_0(t)}{dt}N(A;0,\sigma_\rho). \tag{4}$$

The effective nucleon numbers $N(A;\sigma_1,\sigma_2)$ are defined by Kölbig and Margolis.[5] At very high energy where the mass of the ρ^0 is negligible, one finds

$$\frac{d\sigma^{(I)}(t)}{dt} = \frac{d\sigma_0(t)}{dt}N(A;\sigma_\rho,\sigma_\rho). \tag{5}$$

The photon in this case behaves as though it were a ρ meson. Since $N(A;\sigma_\rho,\sigma_\rho)$ is considerably less than $N(A;0,\sigma_\rho)$ the cross section has fallen in go-

Table I. The total ρ^0-nucleon cross section as a function of equivalent photon momentum using Eq. (6) and photoproduction data from Ref. 7. The data of Ref. 7 are approximated in this table by $d\sigma_0(0)/dt = 81.6(1+1.2/p)^2$.

p (GeV/c)	$d\sigma_0(0)/dt$ [μb/(GeV/c)^2]	σ_ρ (mb)
3	160	29.2
4	138	27.2
5	127	26.1
6	118	25.1
8	108	24.1
16	94	22.5

ing from photon energies of a couple of GeV to infinite energy. At intermediate energies the cross section decreases monotonically as the calculations of Refs. 2 and 3 show.

We now examine photoproduction of ρ^0 mesons on protons. Assuming vector dominance one has[6]

$$\frac{d\sigma_0(0)}{dt} = \frac{1}{16}\frac{\alpha}{4\pi}\left(\frac{\gamma_\rho^2}{4\pi}\right)^{-1}\sigma_\rho^2. \tag{6}$$

One has assumed here that the ρ^0-nucleon forward-scattering amplitude is pure imaginary. There is a large body of data[6] for either photons or ρ^0 mesons on the mass shell which yield for the ρ^0-photon coupling constant $\gamma_\rho^2/4\pi = 0.5$. We accept this value and using photoproduction data from Ting[7] obtain the values for σ_ρ given in Table I. These values decrease with increasing energy. Further indication that σ_ρ falls with energy comes from the fact that $\sigma_{\rm tot}(\gamma p)$ is decreasing with energy in a similar manner at energies of several GeV.[8] It is to be noted that according to vector dominance, for pure-imaginary forward-scattering amplitudes,

$$\sigma_{\rm tot}(\gamma p) = \frac{\alpha}{4}\sum_{V=\rho,\omega,\varphi}\left(\frac{\gamma_V^2}{4\pi}\right)^{-1}\sigma_V. \tag{7}$$

Again, the additive quark model gives $\sigma_\rho = \frac{1}{2}[\sigma_{\rm tot}(\pi^+p) + \sigma_{\rm tot}(\pi^-p)]$ and the π-nucleon cross sections also fall with energy at a rate similar to that deduced for σ_ρ here.

We have calculated incoherent production of ρ^0 mesons as a function of energy as a combined effect on one- and two-step processes using formulas (1)-(3). The results are shown in Fig. 1 along with the available experimental data.

We conclude from a comparison of theory and experiment that there is no clear discrepancy with vector dominance nor with the eikonal model used here for the calculations. It would be valuable to have other measurements for incoherent production of ρ^0 mesons in the energy range from around 3 GeV up.

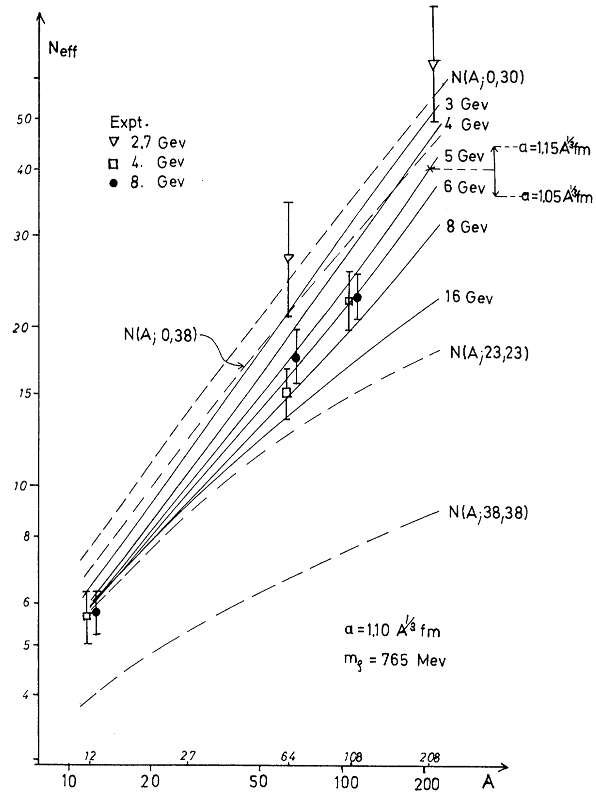

FIG. 1. Experimental and theoretical values of $N_{\rm eff}$ for several energies as a function of A. The values of σ_ρ are given in Table I. The nuclear density $D(b,z) = D(r) = A\rho_0/(1+e^{(r-a)/c})$ with $a = 1.10A^{1/3}$ fm and $c = 0.545$ fm. The range of values for $N_{\rm eff}$ where a ranges from (1.05 to 1.15) $\times A^{1/3}$ fm is shown for $A = 208$ at $k_\gamma = 5$ GeV/c. Limiting effective numbers $N(A;0,30)$, $N(A;0,38)$, $N(A;23,23)$ and $N(A;38,38)$ are also plotted. These limiting effective numbers show by comparison the lessening of the energy dependence of $N_{\rm eff}$ due to a σ_ρ which is smaller and decreasing with increasing energy.

We remark that there should be some correction due to higher order multiple-step incoherent processes. These are difficult to evaluate in detail and we do not expect them to be large. In any case it appears to us that present data do not make necessary their consideration.

Finally we note that one expects a similar weakening of the energy dependence of the effective nucleon number for the photon-nucleus total cross section[3,9] due to the decrease of σ_ρ with energy.

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PARITY-FORBIDDEN DECAY OF THE 8.88-MeV ^{16}O STATE

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The decay rate of the 8.88-MeV state of ^{16}O is estimated with a parity-nonconserving force involving ρ exchange. It is pointed out that this decay can be of crucial importance for testing part of the nonleptonic weak interaction, because isospin conservation in the α decay limits the interaction responsible for the parity mixing in the initial state to the $\Delta I=0$ part arising from the strangeness-nonchanging nonleptonic weak currents.

Nuclear experiments of parity nonconservation offer a distinct means of testing the current-current form of the nonleptonic weak interactions.[1] So far, parity nonconservation has only been observed in heavy nuclei.[2] Although several experiments in light nuclei have been proposed[3] to separate the isospin $\Delta I=0, 2$ parts from the $\Delta I=1$ part of the parity-nonconserving nucleon-nucleon force, these experiments are extremely difficult and have not yet been carried out. Within the context of the current-current form of the weak interaction, the importance of the isospin selection rules is that the dominant term of the $\Delta I=1$ parity-nonconserving potential, $V_{\rm pv}$, is due to pion exchange; the source of this term is the strangeness-changing weak current. On the other hand, the $\Delta I=0, 2$ parts of $V_{\rm pv}$ have important contributions from vector-meson exchanges and arise from strangeness-nonchanging currents. The ρ-exchange weak force has been computed using vector-meson dominance and nucleon form factors.[4] Recent calculations using current algebra have given a much smaller strength for this force[5,6]; if correct, these last results make the vector-meson exchange force ineffective. Measurements of the $\Delta I=0$ part of the parity-nonconserving force are thus clearly of high interest.

Recent searches[7] for the parity-forbidden alpha decay of the 8.88-MeV 2^- state of ^{16}O have resulted in an upper limit of $\Gamma_\alpha \lesssim 1.1\times10^{-9}$ eV and better measurements can be expected. The decay occurs from a state with $I=0$ to a final state with $I=0$. Hence, to within electromagnetic corrections of order of the fine-structure constant, only admixed 2^+ states of $I=0$ contribute to the decay rate ($\hbar=c=1$)[8]

$$\mathcal{R}=2\pi|\textstyle\sum_n \mathfrak{F}_{0,n}\langle\psi_f|S|2_n{}^+\rangle|^2\rho_f, \tag{1a}$$

$$\mathfrak{F}_{0,n}\equiv\frac{\langle 2_n{}^+|V_{\rm pv}|2^-(8.88)\rangle}{8.88\ \mathrm{MeV}-E_n}. \tag{1b}$$

Here $|2_n{}^+\rangle$ are the 2^+, $I=0$ excited states of ^{16}O which are admixed to the 2^- state by the $I=0$ part of $V_{\rm pv}$. Because the $I=0$, 0^- states of ^{4}He and ^{12}C are far removed from their respective ground states, their contributions to $\mathcal{R}$ can be and have been neglected in Eqs. (1). $\mathfrak{F}_{0,n}$ is the