DIFFRACTION MODEL OF HIGH ENERGY NEUTRINO INTERACTIONS

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1. INTRODUCTION

The success[1] of the "ρ-photon analogy" or "vector dominance" in describing the electromagnetic interactions of hadrons, particularly for high energy photoproduction of vector mesons, suggests that a similar model be used for high energy electroproduction or neutrino production when the electron or neutrino produces a hadronic system of high mass. The recent measurements of "deep" electroproduction total cross-sections should, by the γ-ρ analogy, predict something about the electro-ρ production, and as far as the weak vector current is concerned, it is, by C.V.C., just the isotopic rotation of the electromagnetic current. If the action of the electromagnetic (iso-vector) current at high energy is described by the scattering of a ρ^0 meson, then the weak vector current is necessarily described by the scattering of a $\rho^{\pm}$ meson.

To generalize this idea to theaxial weak current, we can use the A_1 meson as a chiral partner of the ρ, but since the current is not conserved there must be a component in the current beyond that corresponding to a simple spin one particle. The simplest assumption is that there is also a component like the gradient of the pion field. Hence we assume the axial current is proportional to a sum of the gradient of the pion field and the A_1 field. For the axial current, the P.C.A.C. hypothesis plays a role like that of current conservation for the vector current and gives certain restrictions on the relation between pion and A_1 contributions. It turns out that these restrictions play an important role near momentum transfer $q^2 \simeq 0$. The three basic constants $g_{\ell\rho}$, $g_{\ell A}$, and $g_{\ell\pi}$, giving the coupling of the mesons to the leptonic weak current play the role of the γ-ρ coupling in electromagnetic interactions and are in principle measured by the decays $\rho^+, A_1^+, \pi^+ \to \mu^+\nu$, given by effective couplings:

$$\frac{G}{\sqrt{2}} \bar{\mu} \gamma_\mu (1 + \gamma_5) \nu \left\{ \begin{matrix} g_\rho \; \rho_\mu \\ g_A \; A_{1\mu} \\ g_\pi \; \partial_\mu \; \Phi \end{matrix} \right\}$$

just as $g_{\gamma\rho}$ is given by $\rho^0 \rightarrow 2e$, While g_π is known directly in this manner $g_\pi = 0.93\, m_\pi$, g_ρ may be inferred from the measurement $\rho^0 \rightarrow 2e$ by C.V.C., or more simply by using the fact that (Fig.1) ρ dominance must give the correct nucleon beta decay constant.

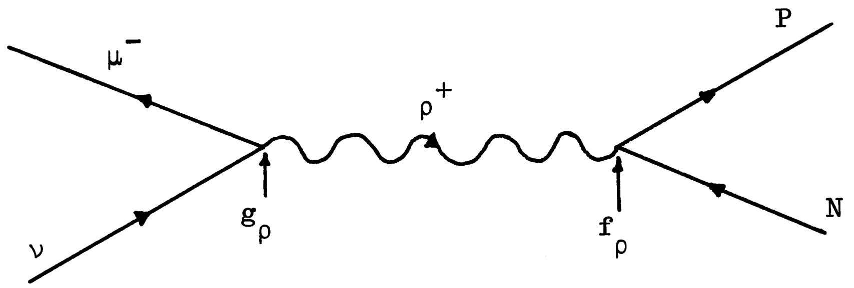

Fig.1

Let f_ρ be the universal ρ coupling constant $(f_\rho^2/4\pi \simeq 2.1)$ coupling the ρ like: $f_\rho \, \rho_\mu (\bar{\Psi} \gamma_\mu \frac{\tau}{2} \Psi + \Phi \times \partial_\mu \Phi + \ldots)$. Then at zero momentum transfer in Fig.1 we have for the vector part of the hadronic current

$$\frac{G}{\sqrt{2}} \bar{e} \gamma_\mu (1+\gamma_5) \nu \, \bar{P} \gamma_\mu N = \frac{G}{\sqrt{2}} \bar{e} \gamma_\mu (1+\gamma_5) \nu \, g_\rho \frac{1}{m_\rho^2} f_\rho \frac{1}{\sqrt{2}} \bar{P} \gamma_\mu N$$

so

$$g_\rho = \frac{\sqrt{2}}{f_\rho} m_\rho^2 \tag{1}$$

or

$$g_\rho^2 = \frac{2}{f_\rho^2/4\pi} \frac{1}{4\pi} m_\rho^4 \qquad \text{where} \quad f_\rho^2/4\pi \simeq 2.1$$

Since we know neither the A_1-nucleon coupling nor its weak decay, we must content ourselves with the chiral symmetry estimate [2)]

$g_A \simeq g_\rho$ *.(Note this implies $f_{A_1NN} > f_{\rho NN}$ coupling by repetition of the above argument for g_A).

With these numbers, then, our model can be represented by Fig.2, or rather by the sum of two such graphs in electroproduction, the q line representing ρ and ω. In neutrino production there are three for ρ, A_1, or a π. We then use experimental information or plausible guesses for the high energy reactions (ρ, A_1, π) + P → F . In particular, the electroproduction data gives us essentially the ρ contribution summed over all F.(From photoproduction the ω contribution is 1/9 that of the ρ and Φ is negligible).

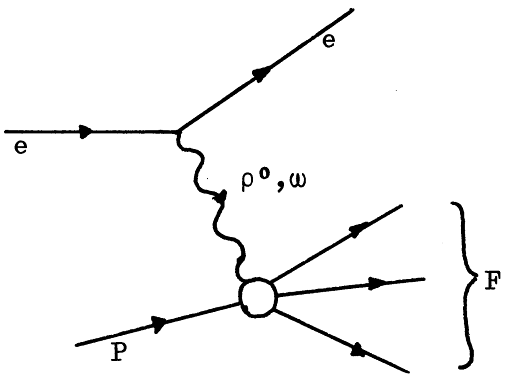

Fig.2a

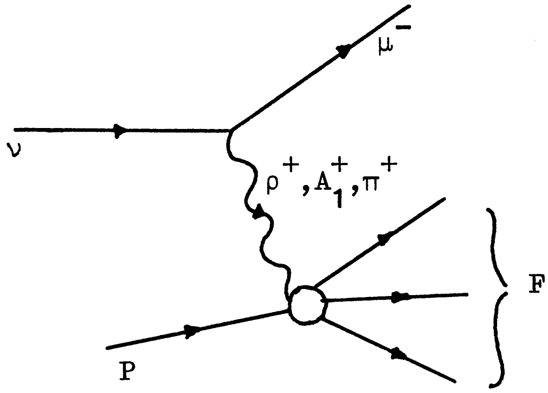

Fig.2b

The application of the model in practice involves then two fundamental assumptions :

1) Meson dominance of the currents in the manner assumed.

2) The use of physical estimates from real ρ, A_1, π scattering in the unphysical region $q^2 > 0$. The electroproduction data is, of course, already for $q^2 > 0$. This means that the range of validity of the model is restricted to high energy for the "incoming" meson, where we can hope one simple diffraction process is dominant and the kinematic effects of being off mass shell are small. In practice, we have restric-

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* This relation corresponds to the second Weinberg sum rule and is in agreement with the first one using $m_A = \sqrt{2}\, m_\rho$.

ted ourselves to the region $\omega^2 > 3$ GeV^2, ω^2 being the(mass)^2 of the system F, i.e. just above the region of the prominent resonances in πN scattering.

2. QUALITATIVE ASPECTS

Before getting to the technical details and the more or less reliable or dubious assumptions we are forced to make, let us note some of the general characteristics of the model, independent of the detailed treatment.

1) Production of high energy hadronic systems should have the general character of high energy meson-nucleon collisions (i.e. particles, momentum transfer distributions) with the leptonic momentum transfer direction as the "beam" direction.

2) The largest single modes of two-body production should be the final states F = ($\rho^{\pm}$P, $\pi^{\pm}$P, $A_1^{\pm}$ P) , the $\pm$ is for ν or $\bar{\nu}$ incident, (or with neutron for nuclear targets). We already know from photoproduction experiments that the ρ plays a large role in the vector current, by C.V.C. we should necessarily expect it in also the weak vector current. We also know from P.C.A.C.[3] that for very small q^2 the axial current acts like a π. The occurrence of significant A_1 production however would support the idea that it is a chiral partner of the ρ.

3) If indeed $g_A \simeq g_\rho$ and if A_1 scattering cross-sections are about the same as that for ρ, as might be expected from the quark model or vague chiral symmetry ideas, then we expect neutrino A_1 production to be less than neutrino ρ production since the coupling constants enter into the amplitude as $g^2/(m^2+q^2)$, and for forsee-able experimental energies, moderate q^2($\sim$ 1 GeV^2) will be dominant so that the effect of the heavier A_1 mass in the propagator will make cross-sections for the axial currents smaller than that for the vector. Below with these assumptions we find, for example, that neutrino ρ production is about 1.5 times A_1 production. Note that this should hold as well for the total cross-section (i.e. into all channels) coming from the axial current. Of course at q^2 = 0 where vector matrix elements are zero by

current conservation and axial matrix elements are not , axial effects are dominant. The special effects due to the π contribution in the axial current are however restricted to $q^2 \sim m_\pi^2$, which is also the region in which π production takes place by "elastic scattering". Thus, we expect if these off-shell scatterings are like real scatterings, that $\rho > A_1 > \pi$ for high energy for the hadron system F, these states making up perhaps $\sim 20\%$ of the total cross sections at a given q^2, ν*.

4) The total cross section $d\sigma/dq^2 d\nu$, summed over all F, at fixed q^2 should vary slowly with ν . The same holds for the two-body production insofar as it is like an elastic diffraction scattering. Below we find $d\sigma/dq^2 d\nu \sim 1/\nu$ for process of this type.

5) We expect vector-axial interference to become small, since the cross section for this, an interference term like $\sum_F \mathcal{M}(\rho \to F)\mathcal{M}^*(A_1 \to F)$ is proportional by the unitarity condition to the imaginary part of the amplitude for $\rho + N \to A_1 + N$, which being a non-diffractive process should become small at high energy. Thus the difference between νP and $\bar{\nu} N$ scatterings should become small. νP and $\bar{\nu} P$ are also the same to the extent $\rho^+ P$, $\rho^- P$ is the same. Again, we speak of the region where the energy of F is high. There is some support for the idea (at least for charge zero and transverse polarizations) that $\rho + N \to A_1 + N$ is small in that it is not seen or small in photoproduction where the photon should act like a ρ^o.

6) For processes where the effect of the axial current is small according to the model, as in ρ production, and the diffraction character makes it plausible to assume that ρ^+ and ρ^o scatterings are about equal, then we can have a certain degree of model independence by relating neutrino production directly to electroproduction, by way of :

$$\frac{d\sigma^{(\nu \to \rho^+)}}{dq^2 d\nu} = 4 q^4 G^2/e^4 \frac{d\sigma^{(e \to \rho o)}}{dq^2 d\nu} \tag{3}$$

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* ν is the energy of the "incoming" meson undergoing high energy diffraction scattering.

If it is indeed true, as suggested above, that the axial contribution to the total scattering is less than that of the vector, and since vector-axial interference is small, this formula can also be crudely used to estimate the total neutrino cross section to be expected (in the diffraction region) by adding perhaps 25-50% to account for the axial current.

$$d\sigma^{Tot}(\nu) \quad = \quad 4\, q^4\, G^2/e^4\, d\sigma^{Tot}(e)(1 + Ax)\ . \qquad (3')$$

In principle we should subtract the iso-scalar (ω^0) part from $d\sigma(e)$ but the vector dominance relation[1] for the total cross section in fact indicates that this contribution is only 1/9 of σ^{Tot}.

3. VECTOR CURRENT, ELECTROPRODUCTION

To see how we can get some quantitative estimates from the model, let us first consider the action of the vector current alone. We can also have a partial test of the ideas in the model by seeing how it compares with recent data on electroproduction of high mass states.[4]

The square and sum over final hadron states F of the matrix element $\ell_\mu J_\mu$, ℓ_μ the lepton current, J_μ the hadron current, lead to the tensor $\mathcal{M}_{\mu\nu} \sim \Sigma_F J_\mu^{Fi*} J_\nu^{Fi}$ containing the information on the hadron system. If Σ_F is over all spins and all momenta internal to F, $\mathcal{M}_{\mu\nu}$ can only be made from $\delta_{\mu\nu}$, P_μ from the target nucleon, q_μ for the incident virtual γ or ρ, four-momentum conservation removing the total four vector of F. Since the lepton masses are small, $q_\mu \ell_\mu \approx 0$; the q_μ terms do not affect the cross section even though they are present in $\mathcal{M}_{\mu\nu}$ to assure current conservation $q_\mu \mathcal{M}_{\mu\nu} = 0$. Thus we have

$$\mathcal{M}_{\mu\nu} \quad = \quad |\underline{q}|\,(\sigma_T\ \delta_{\mu\nu} + q^2\, \frac{(\sigma_T + \sigma_L)}{|\underline{q}|^2}\ \frac{P_\mu\ P_\nu}{M^2}) + q_\mu \text{ terms}$$

corresponding to the square of the invariant matrix element, $|\underline{q}|$ the lab. momentum of the virtual γ or ρ being a flux factor so that the cross section to the final set of states F for polarizations transverse (T) or longitudinal (L) are given by :

$$\sigma_T = \frac{1}{|\underline{q}|} \mathcal{M}_{\mu\nu}\, \epsilon_{T\mu}\, \epsilon_{T\nu} \quad , \quad \sigma_L = \frac{1}{|\underline{q}|} \mathcal{M}_{\mu\nu}\, \epsilon_{L\mu}\, \epsilon_{L\nu} \quad ,$$

with $\epsilon^2_{T,L} = \pm 1$.

$\mathcal{M}_{\mu\nu}$ must obey certain positivity conditions, namely the σ's > 0; and restrictions from current conservation at $q^2 = 0$, namely σ_T finite (= σ(γP) in electroproduction) and $\sigma_L \sim q^2$. We assume that $\mathcal{M}_{\mu\nu}$ is the logical quantity to extrapolate away from $q^2 = 0$, and we get for the W_1 and W_2 quantities studied in electroproduction:

$$W_1 = \frac{1}{\alpha} \frac{1}{4\pi^2} |\underline{q}|\, \sigma_T^{Tot}(\gamma P) \left(\frac{m_\rho^2}{q^2 + m_\rho^2}\right)^2$$

$$W_2 = \frac{1}{\alpha} \frac{1}{4\pi^2} \frac{(\sigma_T^{Tot}(\gamma P) + \sigma_L^{Tot}(\gamma P))}{|\underline{q}|}\, q^2 \left(\frac{m_\rho^2}{q^2 + m_\rho^2}\right)^2 \qquad (4)$$

Data on W_2 in "deep" electroproduction has been recently presented [4]) showing that at large ν (or $\underline{q}$) for q^2 fixed W_2 drops slowly perhaps as 1/ν. This is expected from (4) since the σ's should be constant with ν.

As for the behavior in q^2, we have written the naive vector dominance form where ρP scattering is assumed to be q^2 independent leading to

$$W_2 \sim \frac{q^2}{(1+q^2/m_\rho^2)^2} \quad .$$

Although there is no reason to believe this simple prescription should work (naive ρ dominance being no good for the nucleon form factor), it is amusing to note that this dependence is quite consistent with the W_2 data. The absolute magnitude for W_2 at large ν predicted in this way however, from $\sigma_T(\gamma P)$ alone is about a factor of 2 too small. This may be due to simply the σ_L contribution or to a more subtle q^2 behavior in general.

A second possibility entertained for W_2 is that it becomes independent of q^2, i.e. $q^2\left(\frac{m_\rho^2}{q^2+m_\rho^2}\right)^2 \sigma_\rho(q^2=0) \sim$ const. in our notation, also roughly consistent with the data available. Although the two possibilities thus give about the same results for our calculations where moderate q^2 are dominant, they eventually lead to different asymptotic behavior for the cross sections. Thus although we cannot calculate the absolute magnitude of W_2, the form of the data seems quite consistent with the diffraction viewpoint. If we now consider a final state F like ρP, where the vector current should dominate then $\mathcal{M}_{\mu\nu}$ leads to

$$\frac{d\sigma}{dq^2 d\nu} = \frac{G^2}{\pi^2 4E^2} g_\rho^2 \frac{q^2}{(q^2+m_\rho^2)^2} |\underline{q}| \left[\sigma_T(\rho\to F) + \frac{\sigma_T(\rho\to F)+\sigma_L(\rho\to F)}{|\underline{q}|^2} \frac{4EE'-q^2}{2} + \ldots \right] \tag{5}$$

where E = neutrino energy, E' = muon energy, $\nu = E-E'$, lab. quantities.

Fig.3, curve I, shows for an incident neutrino energy of 3 GeV the ρ production arrived at by normalizing to the value of W_2 in electroproduction for σ^{Tot} and then assuming $\sigma(\gamma\to\rho)/\sigma^{Tot} \sim 1/6$ as real photoproduction. This corresponds to $\sigma_T(\rho\to\rho) \simeq \sigma_L(\rho\to\rho) = 5.2$ mb in (5).

We note that in both neutrino and electroproduction it will be interesting to study the polarization of the produced ρ as well as to separate the T + L contributions to cross sections so that it can be seen what role is in fact played by longitudinal polarizations.

4. AXIAL CURRENT

The treatment of the axial current differs from that of the vector in two points, both concerning small q^2. There will be an axial $\mathcal{M}_{\mu\nu}$ tensor here also with $\delta_{\mu\nu}$, $P_\mu P_\nu$ and $q_\mu P_\nu$, $q_\mu q_\nu$ type terms as before, with terms representing A_1, π and $A_1-\pi$ interference contributions to the cross section. The π contribution appears in the q_μ terms, but we now cannot rule this out by $q_\mu \ell_\mu$ = (lepton mass) since it appears over the

π propagator which is big at small q^2. Note it drops rapidly with q^2 compared to other contributions, so that away from very small q^2 only the $\delta_{\mu\nu}$ and $P_\mu P_\nu$ terms are relevant for neutrino scattering as for the vector current.

The second point is that P.C.A.C. gives certain restrictions on $\mathcal{M}_{\mu\nu}$ just as current conservation does in the vector case. Away from small q^2 this places no essential restrictions, involving the ineffective q_μ terms. We will assume there that the A_1 scattering acts like that for the ρ and that there is no essential difference between the behavior of V and A currents beyond small q^2. At $q^2 = 0$, however the coefficient of $P_\mu P_\nu$ is fixed by P.C.A.C. to correspond to π scattering. In terms of the model, the scattering of a longitudinal A_1 at $q^2 = 0$ acts like π scattering, $q^2 \sigma_L(A_1) \sim \text{const.}\,\sigma(\pi)$. Away from small $q^2 (\sim m_\pi^2)$ we use then for the axial current, Eq.(5) with the A_1 label replacing ρ everywhere. For small q^2 we incorporate the P.C.A.C. restrictions by requiring

$$q^2 \; \sigma_L(A_1 \to F) \;=\; g_\pi^2 \frac{M_A^4}{g_A^2} \, \sigma(\pi \to F) \qquad (6)$$

at $q^2 = 0$ and the appropriate coefficients for the q_μ terms. This, of course, assures that we get Adler's relation[3)] for ν scattering at $q^2 = 0$

$$\frac{d\sigma}{dq^2 d\nu} \;=\; \frac{G^2}{2\pi^2} \, g_\pi^2 \, \sigma_{\pi\to F} \left[1 - \frac{\nu}{E}\left(1 + \frac{m^2}{q^2 + m_\pi^2}\right) + \frac{\nu^2}{4E^2} \, \frac{m^2 (q^2 + m^2)}{(q^2 + m_\pi^2)^2} \right] \qquad (7)$$

Here, as in the vector case, we can guess little about the behavior of σ_L away from $q^2 = 0$. Unless it should turn out, however, that longitudinal contributions play a dominant role, the resulting uncertainty should be within the kind of order of accuracy we expect for the model.

Putting everything together then, in the region $q^2 \gg m_\pi^2$ we have for the production of F

$$\frac{d\sigma}{dq^2 d\nu} = \frac{G^2}{\pi^2 4E^2}\left[|\underline{q}| \left\{ g_\rho^2 \frac{q^2}{(q^2+m_\rho^2)^2}\left[\sigma_T(\rho\to F) + \frac{\sigma_T(\rho\to F)+\sigma_L(\rho\to F)}{2|\underline{q}|^2}(4EE'-q^2)\right] \right.\right.$$
$$\left. + g_A^2 \frac{q^2}{(q^2+m_A^2)^2}\left[\sigma_T(A_1\to F) + \frac{\sigma_T(A_1\to F)+\sigma_L(A_1\to F)}{2|\underline{q}|^2}(4EE'-q^2)\right]\right\}$$
$$\left. + \frac{4\, g_\rho g_A}{(q^2+m_A^2)(q^2+m_\rho^2)}\, q^2 E \sqrt{\sigma_T(\rho\to F)\sigma_T(A_1\to F)} \right] \qquad (8)$$

where the last term is the V-A interference coming from a term $\epsilon_{\mu\nu\lambda\rho} q_\lambda P_\rho$ in $\mathcal{M}_{\mu\nu}$. The coefficient indicated is a maximum for the interference as set by the inequality

$$|\Sigma_F V_F^* A_F| \leqslant [(\Sigma_F |V_F|^2)(\Sigma_F |A_F|^2)]^{\frac{1}{2}} .$$

When the sum F is over all available states this term just corresponds to the imaginary part of the $\rho \to A_1$ amplitude by the unitarity condition.

5. RESULTS

We have already indicated the dominant "ρ-elastic" contribution to ρ production.To estimate A_1 production by the axial current, we have (7) for small q^2 with $\sigma(\pi+P \to P+A_1)$ known from experiment, an approximately constant diffraction like process, $\sigma \simeq 0.2$ mb. Away from $q^2 \approx 0$ we use (8), taking the cross section $\sigma_T^{A_1\to A_1}$ the same as for ρ. The result for $d\sigma/dq^2$ is shown for E = 3 GeV in Fig.4, Curve I' using (6) for σ_L , while curve I uses $\sigma_L \approx \sigma_T$.

Since $\pi+P \to P+\rho$ is also known from experiment, we use it to try to estimate by Eq.(6) the π and $\sigma_L(A_1\to \rho)$ contributions to ρ production, shown in Fig.3, curve III. For a given total incident neutrino energy E a non diffractive contribution like this goes down with ν, of course, since $\pi+P \to \rho+P$ drops with the energy of the incident π. Fig.3, curve II shows an upper limit for the transverse A_1 contribution if it is limited by the $\rho^0+P \to A_1^0 +P$ limit inferred from photoproduction (< 0.1 mb for $\nu > 2$ GeV). For π production, we have again (7) for small q^2. At larger q^2 where the propagators have dropped off, the constant with energy diffraction like contribution to π distribution must come from longitudinal A_1's. Taking experimental numbers from the physical region since this is an inelastic process its cross section, 0.2 mb, is not very large and we have a very small π production for q^2 larger than few m_π^2 (Fig.5, curve I). A much larger result comes from applying (6) away from $q^2 = 0$ (: curve I') . This is the one process where our presumably dominant contribution comes from the behavior of the little known longitudinal amplitudes. It will be interesting to see if in fact single-pion events are relatively rare in the high ω^2 region away from very small q^2. The vector contribution can be estimated from experimental data on $\pi+P \to \rho+P$ (mainly longitudinal ρ)(curve II) while photoproduction of π indicates the transverse ρ contribution (curve III).

Fig.6 shows the kind of integrated cross sections for $\rho^{\pm}$, $A_1^{\pm}$, $\pi^{\pm}$, these assumptions lead to curves II' and III' using (6) for σ_L away from $q^2 = 0$ while curve II uses $\sigma_L(A_1 \to A_1) \simeq \sigma_T(A_1 \to A_1)$ and curve III $\sigma_L(A_1 \to \pi) = \sigma_{exp}(\pi \to A_1)$.

Finally Fig.7 shows the total ν cross section as a function of the incident energy E. Due to the compensations between π and A_{1L} contributions the final result turn out to be the same taking for σ_L the experimental numbers from the physical region or applying the constraint from P.C.A.C. away from $q^2 = 0$.

6. ASYMPTOTIC BEHAVIOR

In the model the total cross section at a given (q^2, ν) is given (beyong small q^2) by the ρP and A_1P total cross sections inserted into (8). As indicated above, $\sigma_T^{Tot}(\rho P) = \sigma_L^{Tot}(\rho P) \simeq 31$ mb will fit the W_2 found in electroproduction and we assume the same for A_1. Since we take these cross sections to be constant with energy ν, we can find the total, integrated ν cross section coming from masses above our lower limit of $\omega^2 = 3$ GeV by assuming a definite q^2 behavior for the $\sigma^{Tot}(\nu,q^2)$.

It is this contribution, of course, which determines the asymptotic behavior of the total cross sections since the contribution of the resonances presumably levels off at the contribution of several times that of the proton after a few GeV. As can be seen from (8) the leading term comes from E^2 in $EE' = E^2 - E\nu$ and the essential integral to be evaluated is then of the form :

$$\int \frac{q^2}{(q^2+m_\rho^2)^2} \frac{\sigma(q^2,\nu)}{\nu} \, dq^2 \, d\nu \qquad (\text{since } \underline{q} \approx \nu \text{ for large } \nu).$$

The allowed kinematic region is expanding linearly with the incident ν energy E in both q^2 and ν . Thus if $\sigma(q^2)$ is independent of q^2 (naive ρ-dominance) the integrand $\sim 1/q^2$ and the asymptotic cross section is $\sim(\log E/M)^2$. If on the other hand, the second assumption $(1/q^2)\sigma(q^2) \sim$ const. holds at large q^2, then the asymptotic cross section $\sim$ E. If we put in the numbers we have been using the coefficient comes out

$$\sigma \sim 0.5 \times 10^{-38}\ \text{cm}^2\ (\ln E/M)^2 (1 + Ax)$$

$$\sigma \sim 0.8 \times 10^{-38}\ \text{cm}^2\ E/M\ (1 + Ax) \qquad E \to \infty$$

The relative axial contribution, less than that of the vector in the region of interest, has been indicated explicitely. Eventually, at least in the model where $\sigma \frac{q^2}{(q^2+m_\rho^2)^2} \to \sigma/q^2$ the cross section eventually become insensitive to the mass in the propagator, but this requires very high E, since the allowed kinematic region favors small q^2. Compare Fig.6 where the ρ and A_1 production curves I and II are directly proportional (by a factor 1/6) to the vector and axial contributions to the total cross sections.

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q^2 distribution for ρ - A_1 - π production E = 3 Gev

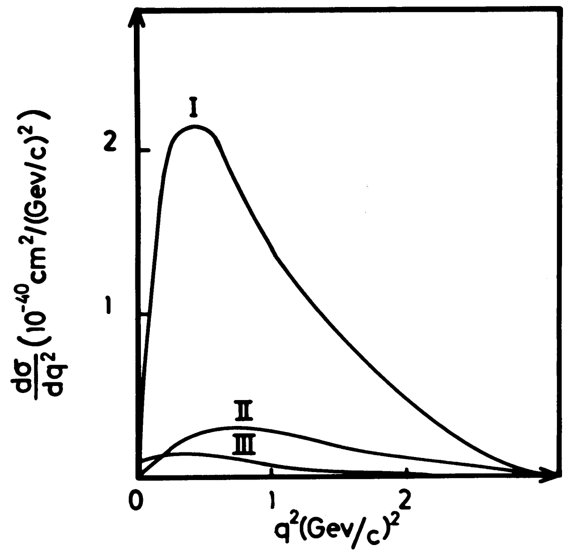

Fig. 3 : Curve I shows the diffractive-like ρ contribution calculated using electroproduction data ($\sigma_L \sim \sigma_T$). Curve II shows an upper limit for the interference A_1-ρ transverse contribution. Curve III shows the π-A_{1L} contribution using (6).

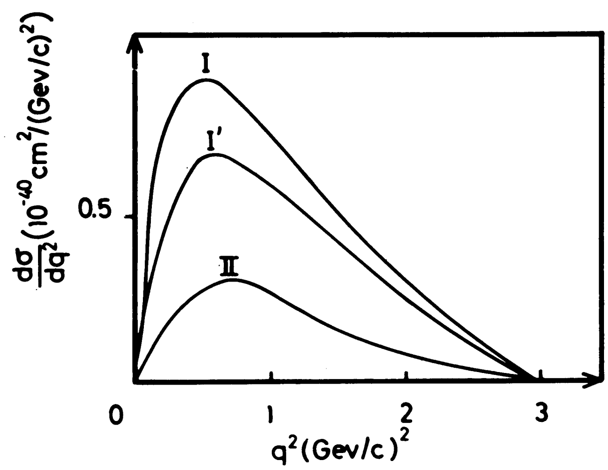

Fig. 4 : Curves I (and I') show the diffractive-like A_1 contribution with $\sigma_L \sim \sigma_T$ (and using (6) for σ_L). Curve II shows an upper limit for the interference A_1-ρ transverse contribution.

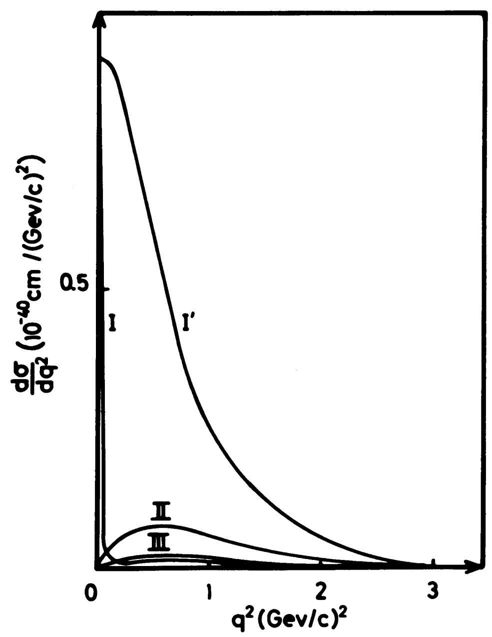

Fig. 5 : Curves I (and I') show the diffractive-like π and A_{1L} contributions with $\sigma_L = \sigma_{exp}(\pi - A_1)$ (and using (6) for σ_L). Curves II (and III) show the longitudinal (and transverse) ρ contributions.

Cross-section for $\rho^{\pm}$, $A_1^{\pm}$, $\pi^{\pm}$ production

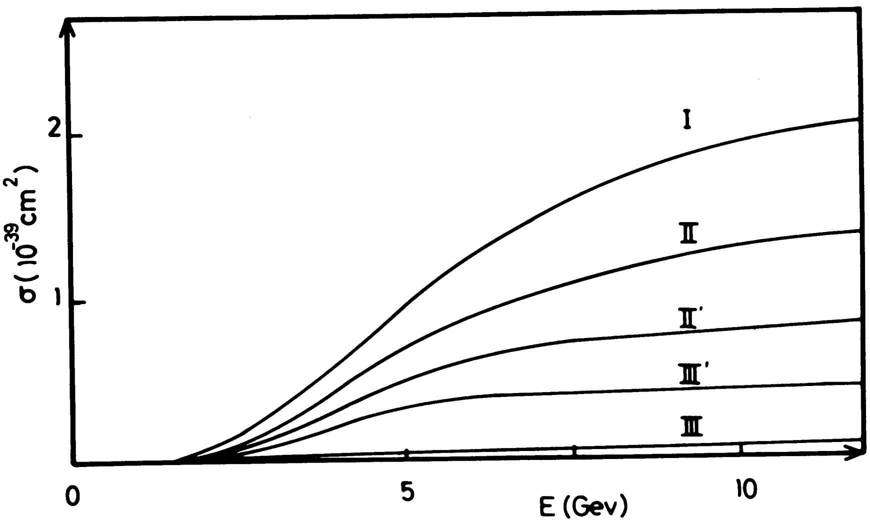

Fig. 6 : Curve I shows the ρ production. Curves II (and II') show the A_1 production with $\sigma_L \sim \sigma_T$ (and σ_L given by (6)). Curves III (and III') show the π production with σ_L $(A_1 - \pi) = \sigma_{exp}$ $(A_1 - \pi)$ (and σ_L given by (6)).

Total ν cross-section

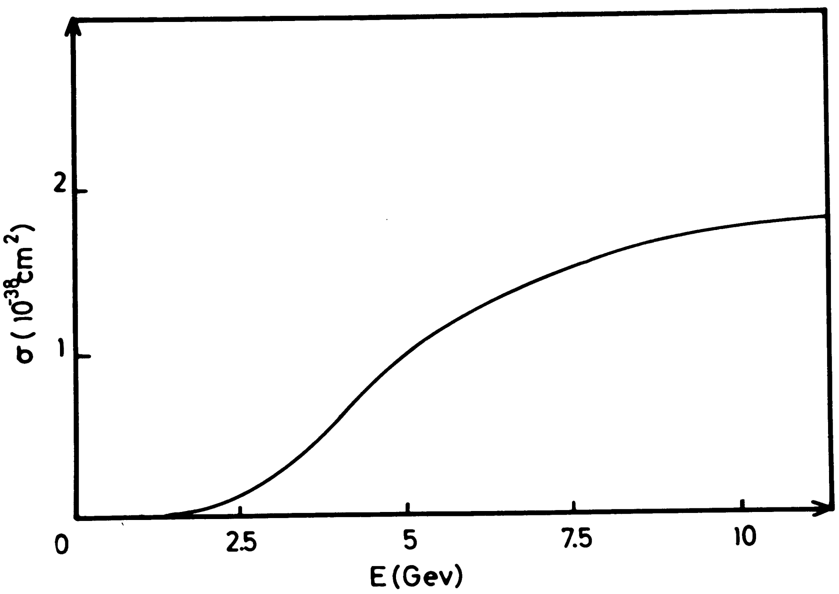

Fig. 7 : Total ν cross-section. Taking for σ_L the experimental numbers from the physical region or applying (6) away from $q^2 = 0$ gives the same result.