PRODUCTION OF PIONS AND K-MESONS IN PROCESSES INVOLVING HIGH ENERGY NEUTRINOS

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The cross sections of multiple pion and K-meson production by neutrinos are estimated. Possibilities for experimental investigations of the structure of the weak interaction vector current are analyzed.

PREVIOUSLY [1] the author has considered one possibility of studying the structure of the vector current in weak interactions by utilizing the Chew-Low extrapolation method [2] to analyze the processes of single pion or K-meson production in neutrino-nucleon collisions. In the present paper we consider the same possibility on the basis of an experimental investigation of the processes of multiple pion or K-meson production by neutrinos on nucleons:

$$\nu + N \rightarrow (e^-, \mu^-) + \pi + (N + \pi + \ldots, Y + K + \ldots), \quad (1)$$
$$\nu + N \rightarrow (e^-, \mu^-) + K + (Y + \pi + \ldots, N + \bar{K} + \ldots), \quad (2)$$
$$\nu + N \rightarrow (e^-, \mu^-) + \pi + (Y + \pi + \ldots, N + K + \ldots), \quad (3)$$
$$\nu + N \rightarrow (e^-, \mu^-) + K + (N + \pi + \ldots, Y + K + \ldots) \quad (4)$$

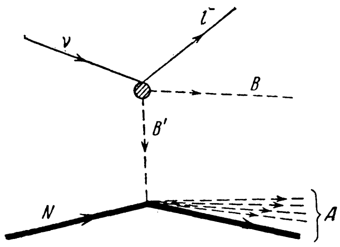
and corresponding reactions involving antineutrinos.

As in the case of single meson production processes, considered in [1], the amplitudes for the corresponding processes have a pole corresponding to one meson exchange. We shall write these processes in the general form:

$$\nu + N \rightarrow l^- + B + A, \quad (5)$$

where B designates either a pion or a K-meson and A represents the systems $N + \pi + \ldots$, $Y + K + \ldots$ etc.

The pole diagram corresponding to exchange of one meson B′ is shown in the figure. We denote by μ, M, m, and m′ the masses of the charged lepton l^-, the nucleon, and the mesons B and B′ respectively; W and ω are the effective masses of the systems A and l^- respectively; k is the momentum transfer between the leptons; Δ is the momentum transfer between the neutrino and the $B + l^-$ system, and E is the total energy in the center of mass system. As in the case of multiple pion electro-production considered by Drell [3] the cross section for the process (5) has a sharp maximum in the region of small Δ^2. In this region the



pole diagram represented in the figure gives the main contribution to the cross-section and the differential cross section has the approximate form:

$$\frac{\partial^4\sigma}{\partial W^2 \partial\omega^2 \partial k^2 \partial\Delta^2} = \frac{G^2}{4(2\pi)^4} \frac{F(\Delta^2)\,\sigma_W^{B'}(\Delta^2)}{[\Delta^2 + m'^2]^2} \times \frac{W^2[1 - 2(M^2 - \Delta^2)/W^2 + (M^2 + \Delta^2)^2/W^4]^{1/2}}{(E^2 - M^2)^2(\omega^2 + \Delta^2)}, \quad (6)$$

where G is the universal weak coupling constant, $\sigma_W^{B'}(\Delta^2)$ is the total cross-section for the reaction $B' + N \rightarrow A$ for the virtual meson B′, and $F(\Delta^2)$ is obtained from Eq. (6) in [1] by the substitution $m'^2 \rightarrow -\Delta^2$.

The differential cross section for the reaction (5), multiplied by $[\Delta^2 + m'^2]^2$ becomes in the pole $\Delta^2 = -m'^2$

$$\frac{\partial^4\sigma}{\partial W^2 \partial\omega^2 \partial k^2 \partial\Delta^2}[\Delta^2 + m'^2]\Big|_{\Delta^2 = -m'^2} = \frac{G^2}{4(2\pi)^4} = \frac{W^2[1 - 2(M^2 + m'^2)/W^2 + (M^2 - m'^2)^2/W^4]^{1/2}}{(E^2 - M^2)^2(\omega^2 - m'^2)} F\sigma_W^{B'}, \quad (7)$$

where F is determined by Eq. (6) in [1] and $\sigma_W^{B'}$ is the total cross section for the reaction $B' + N \rightarrow A$.

The corresponding quantities for antineutrino reactions $\bar{\nu} + N \rightarrow l^+ + B' + A'$ also have the expressions (6) and (7) with the substitutions $m \rightleftarrows m'$ and replacing $\sigma_W^{B'}$ by the cross section σ_W^B of the reaction $B + N \rightarrow A'$.

The extrapolation of the experimental values to the pole[1)] allows the determination of the form factors in matrix elements of the form $\langle B'| j_\mu^V, S_\mu^V |B\rangle$ and a test of the hypothesis on the structure of vector currents[1].

For a numerical estimate of cross sections for processes of the type (5) one may consider the form factors as constants, assume $\sigma_W(\Delta^2) \approx \sigma_W$ and take σ_W from experiments[6]. Integration of Eq. (6) shows that the cross section for the reaction (1) equals 2×10^{-40} and 3×10^{-39} cm^2 for neutrino energies (in the lab system) of 1 and 5 BeV, respectively, and the cross section for reaction (2) equals 10^{-40} and 5×10^{-40} cm^2 at neutrino energies of 2 and 5 BeV, respectively.

In conclusion, let us note that the results obtained in [1] and in the present paper can be applied also to the investigation of the structure of symmetric neutral currents, which have been discussed in many papers (cf. [7] and further references given there). In this case the final state does not contain a charged lepton, but a neutrino or an antineutrino.

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1)The extrapolation procedure and its errors have been considered in detail in many papers devoted to the analysis of similar processes (cf. e.g. [4,5]).

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