Pion and Strange Particle Production by 1 GeV Neutrinos.

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Summary. — Estimates are made of cross-sections for the production of pions or strange particles by high-energy neutrinos incident on nuclei. At 1 GeV the production of pions via the (33) resonance is found to augment the total cross-section by about 50%.

1. — Introduction.

There have been several discussions (1) of « elastic » neutrino-induced processes of the type

\[ \nu + n \rightarrow p + e \text{ (or } \mu) . \]

Here we present some crude estimates for inelastic processes in which pions or strange particles are produced. The replacement of the final nucleon by a hyperon is considered in Section 2. Single pion production is discussed in Section 3. In Section 4 some observations are made on the case of a nucleus rather than a nucleon as target.

In general we ignore the lepton mass, so, strictly speaking, we deal with electrons rather than muons. Calculations are made particularly for a neutrino energy of about 1 GeV, in the range relevant for current experiments (2). The elastic process (1.1) is then expected (1) to have a cross-section of about

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0.85 \times 10^{-38} \text{ cm}^2. \text{ We use units such that } \hbar = c = M \text{ (nucleon mass)} = 1, \text{ and the metric}

\[ q^2 = q_1^2 + q_2^2 + q_3^2 + q_4^2 = q_1^2 + q_2^2 + q_3^2 - q_0^2. \]

2. Strange particle production.

Perhaps the simplest inelastic processes involving neutrinos or antineutrinos are those where the target nucleon is converted to a hyperon, i.e.,

\begin{align*}
& (2.1a) \quad \nu + n \rightarrow \Sigma^+ + e^- (\mu^-) \\
& (2.1b) \quad \bar{\nu} + p \rightarrow \Lambda (\Sigma^0) + e^+ (\mu^+) \\
& (2.1c) \quad \bar{\nu} + n \rightarrow \Sigma^- + e^+ (\mu^+) .
\end{align*}

If the \( \Delta S = \Delta Q \) rule is valid then (2.1a) is forbidden.

The baryon current for a particular reaction (2.1) will have the general structure

\[ J_\mu = G[(F_1 + \mu F_2)\gamma_\mu + \mu F_2 K_\mu + F_3 q_\mu + iG_1 \gamma_\mu \gamma_5 - iG_2 K_\mu \gamma_5 - iG_3 q_\mu \gamma_5], \]

where \( G \) is the weak coupling constant, \( K_\mu \) the nucleon 4-momentum, \( (K_\mu - q_\mu) \) the hyperon momentum, and the form factors \( F \) and \( G \) are functions of \( q^2 \). The contributions from \( F_3 \) and \( G_3 \) contain the lepton mass as a factor, and will be ignored. With the interaction

\[ J_\mu \bar{\psi} \gamma_\mu (1 + \gamma_5)/\sqrt{2} \psi, \]

or

\[ J_\mu \bar{\psi} \gamma_\mu (1 - \gamma_5)/\sqrt{2} \psi, \]

the differential cross-section in the laboratory frame is (2)

\[ \frac{d\sigma}{d\Omega} = \frac{G^2}{2\pi^2} \frac{e'^2}{1 + 2es^2} \left\{ \left| F_1 \right|^2 + \left| F_2 \right|^2 \gamma^2 + \Re \mu F_1 F_2^* (1 - \gamma) [1 - s^2] + \right. \\
+ 2s^2 \gamma |F_1 + \mu F_2|^2 \left[ [G_2]^2 \gamma^2 - \Re G_1 G_2^* (1 - s^2) \right] + \\
+ \frac{1}{2} q^2 (2 |F_1 + \mu F_2|^2 s^2 + (|F_2|^2 + |G_2|^2)(1 - s^2)) + \\
+ G_1^2 [1 - s^2 + (1 - \gamma)s^2 + \frac{1}{2} q^2 s^2] \pm \\
\left. \pm 2 \Re [G_1^2 (F_1 + \mu F_2)s^2] [2e - \frac{1}{2} q^2 + 2\gamma (1 - \gamma)]. \right\} \]

\(^{(a)}\) This formula was not quoted correctly in ref. (a).