Laboratori Nazionali di Frascati

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M. Bassetti: PHOTOPRODUCTION OF NEUTRAL VECTOR MESONS.

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Photoproduction of Neutral Vector Mesons.

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The striking (¹) success of the $\Delta T=\frac{1}{2}$ rule in explaining the experimental branching ratios in Λ^0-decay and in K^0-decay and in giving a consistent explanation of the data for Σ-decay and for τ-decay has led to the general belief that this rule may correspond to a fundamental symmetry property of weak interactions. It is well-known (²) that the $\Delta T=\frac{1}{2}$ rule can be embodied in the theory of weak interactions if one introduces weak neutral currents besides charged currents — provided there is no coupling of the strangeness non-conserving neutral current to the leptons. In the intermediary meson theory of weak interactions such currents are coupled to hypothetical spin-one bosons. LEE and YANG (³) assume a minimal set of such bosons, leading to four particles W^+W^0, $\overline{W}^0W^-$, of isospin $\frac{1}{2}$ coupled in a charge-independent way to the strangeness non-conserving currents. The set W^+, $-(1/\sqrt{2})(W^0+\overline{W}^0)$, W^- of isospin 1 is similarly coupled in a charge-independent way to the strangeness-conserving currents.

We shall calculate here the cross-section for the process

$$\gamma+p\rightarrow p+X\,,$$

where X is a neutral vector meson.

If one adopts the Lee-Yang suggestion, X is to be identified with $-(1/\sqrt{2})\cdot(W^0+\overline{W}^0)$, and is coupled in a charge-independent way to pairs of nucleons. This allows one to determine the strength of its coupling from the strength of the coupling of the charged W's.

Since there is no coupling of W^0 to leptons (or at most a very weak coupling) W^0 will only decay through its coupling to the neutral strangeness-conserving current (pion decay modes) or to the neutral strangeness non-conserving current

(¹) See for instance the report by M. SCHWARTZ at the Rochester Conference 1960 (*Proceedings of the 1960 Annual International Conference on High Energy Physics of Rochester*, p. 727).

(²) See, for instance, R. GATTO: Lectures at the International School of Physics, Varenna 1958, in *Supplemento al Nuovo Cimento*, **14**, 340, 1959.

(³) LEE and YANG: *Phys. Rev.*, **119**, 1410 (1960).

(K-decay modes). Among the pion decay modes, $W^0 \to \pi^+ + \pi^-$, can serve to the identification of the intermediate W^0. For energies lower than that required for $\gamma + p \to \Lambda + K$, any K-decay mode of W^0 would simulate a process with strangeness change. If W^0 decays according to $W^0 \to K^- + \pi^+$ the corresponding threshold for direct production of the secondaries would be that of the reaction $\gamma + p \to K^- + K^+ + p$ of much higher threshold. However indirect K^- production can be obtained through K^0 production together with a $K^0 \to \overline{K}{}^0$ transition [4] and $\overline{K}{}^0 \to K^-$ by charge exchange.

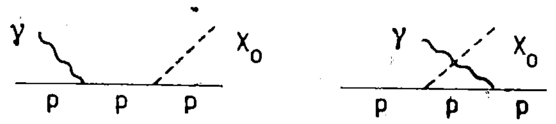

Fig. 1.

In the first perturbation approximations the diagrams for $\gamma + p \to X + p$ are (fig. 1).

We have assumed the Lagrangians $-ie\overline{\psi}\gamma_\mu\psi A_\mu$ for the electromagnetic vertex, and $ig\overline{\psi}\gamma_\lambda(1+a\gamma_5)\psi\gamma_\lambda$ for the other vertex with $(g^2/M_X^2) = 10^{-5}$.

Assuming charge independence, from the rate of axial and vector coupling of β-decay, « a » is about 1.21.

The result, averaged on the polarization of the initial particles and summed on the polarization of the final one is, in the c.m.

$$\frac{d\sigma}{d\Omega} = \left(\frac{e^2}{4\pi}\right)\left(\frac{g^2}{M_X^2}\right)\left(\frac{1}{16\pi}\right)\frac{M_X^2 K_{p'}}{\omega_p\omega_K(\omega_p+\omega_K)}\cdot$$
$$\cdot\left\{\left\{(2M^4+M^2M_X^2)\left|\frac{1}{(pK)}-\frac{1}{(p'K)}\right|^2+\frac{2M^2M_X^2+M_X^4}{(pK)(p'K)}+2\left[\frac{(pK)}{(p'K)}+\frac{(p'K)}{(pK)}\right]-\right.\right.$$
$$\left.-(4M^2+2M_X^2)\left[\frac{1}{(pK)}-\frac{1}{(p'K)}\right]\right\}-a^2\left\{(4M^4-M^2M_X^2)\left[\frac{1}{(pK)}-\frac{1}{(p'K)}\right]^2+\right.$$
$$+\frac{4M^2M_X^2-M_X^4}{(pK)(p'K)}-2\left[\frac{(pK)}{(p'K)}+\frac{(p'K)}{(pK)}\right]-(8M^2-2M_X^2)\left[\frac{1}{(pK)}-\frac{1}{(p'K)}\right]-$$
$$\left.\left.-\frac{4M^2}{M_X^2}\,\frac{[(pK)-(p'K)]^2}{(pK)(p'K)}\right\}\right\}.$$

The meaning of the symbols in the (2) is:

- M_X mass of the vector meson;
- M nucleon mass;
- ω_p initial nucleon's energy;
- ω_K photon's energy;
- p initial nucleon's four-momentum;
- p' final nucleon's four-momentum;
- K photon's four-momentum;
- K_p space-momentum of the vector meson.

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[4] A. Pais and O. Piccioni: *Phys. Rev.*, 100, 1488 (1955).

Integrating in $d\Omega$ we have obtained the total cross section in the c.m.

$$\sigma = \left(\frac{e^2}{4\pi}\right)\left(\frac{g^2}{M_X^2}\right)\frac{M_X^2 K_{p'}}{4\omega_p\omega_K(\omega_p+\omega_K)}\cdot$$

$$\cdot\left\{\left\{[(2M^4+M^2M_X^2)-a^2(4M^4-M^2M_X^2)]\frac{1}{(pK)^2}\right\}+\left\{[4M^4-M_X^4-2(pK)^2-4M^2(pK)+\right.\right.$$

$$-2M_X^2(pK)]-a^2\left[8M^4-6M^2M_X^2+M_X^4+2(pK)^2-8M^2(pK)+2M_X^2(pK)+\right.$$

$$\left.\left.+\frac{4M^2}{M_X^2}(pK)^2\right]\right\}\frac{\ln(\omega_{p'}+K_{p'})/M}{(pK)\omega_K K_{p'}}+\left\{\frac{2M^4+M^2M_X^2-a^2(4M^4-M^2M_X^2)}{M^2\omega_K^2}\right\}+$$

$$\left.-\left\{\frac{2\omega_{p'}\omega_K+4M^2+2M_X^2+a^2(2\omega_{p'}\omega_K-8M^2+2M_X^2)}{(pK)}\right\}-\left\{\frac{a^2[4M^2(pK)+4M^2\omega_{p'}\omega_K]}{(pK)M_X^2}\right\}\right\}.$$

The following formulae give the relations between the quantities in the c.m. frame and the photon's energy « E » in the laboratory.

$$\omega_K=\frac{ME}{\sqrt{M^2+2ME}},\qquad \omega_p=\frac{M(M+E)}{\sqrt{M^2+2ME}},\qquad \omega_p+\omega_K=\sqrt{M^2+2ME},$$

$$K_{p'}=\frac{[(2ME-M_X^2)^2-4M^2M_X^2]^{\frac{1}{2}}}{2\sqrt{M^2+2ME}},\qquad \omega_{p'}=\sqrt{M^2+K_{p'}^2},\qquad (pK)=-ME\,.$$

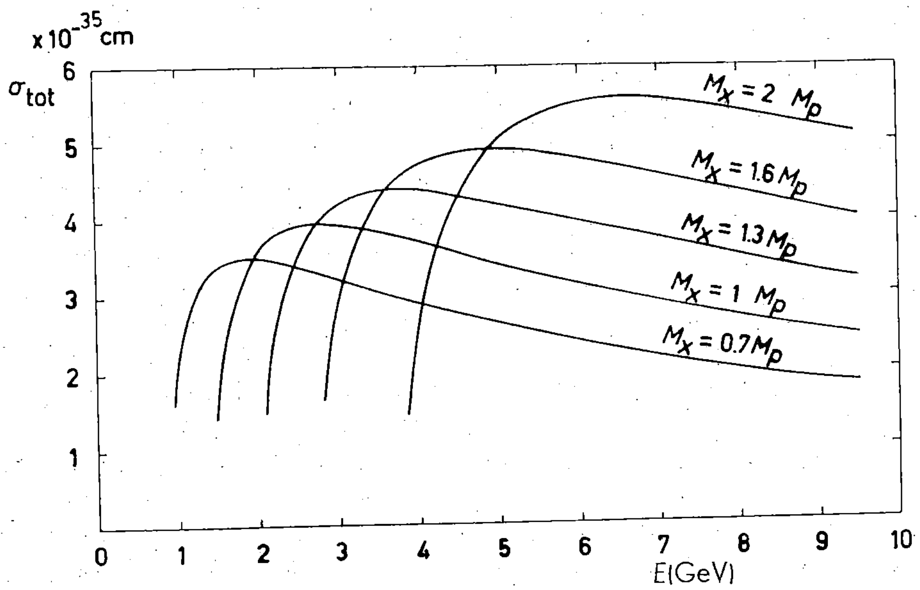

Fig. 2.

In Fig. 2 we give the plot of the total cross-section *vs.* « E », for different values of the schizon's mass using a H_2 target.