

## $X^0$ -Meson (960 MeV) Production in $K^-$ -p Collision and Determination of its Spin-Parity (\*).

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(ricevuto il 20 Luglio 1964)

A new meson (called  $X^0$ ) with mass 960 MeV has been observed in the study of  $K^-$ -p interactions at 2.3, 2.45, 2.63, and 2.70 GeV/c (<sup>1,2</sup>). The  $J^P = 0^-$  or  $1^-$  assignment to this meson seems to be consistent with the experimental data for the  $\pi^+\pi^-\eta$  decay mode (<sup>1</sup>). ITABASHI (<sup>3</sup>) has discussed a possibility that the  $X^0$  is a pseudoscalar meson corresponding to a unitary singlet in the  $SU_3$  scheme. Although experimental results for the decay process will give us important information concerning the properties of the  $X^0$ -meson, we now suggest, as another approach, a measurement of the angular distribution and excitation function for the reaction



since the character of production cross-sections depends strongly on the spin-parity of the  $X^0$ .

In the description of reaction (1) it may be reasonable to consider a reaction mechanism of peripheral collision (<sup>4</sup>). As a  $0^-$  or  $1^+$  meson cannot be produced by the process of one-K-meson-exchange, the one- $K^*$  (888 MeV)-exchange process (cf. Fig. 1) would play the most important role in the reaction. Employing this

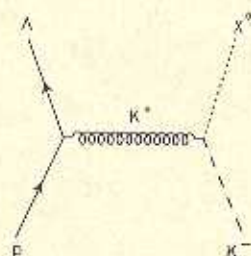


Fig. 1. - One- $K^*$  (888 MeV)-exchange process for the reaction  $K^- + p \rightarrow \Lambda + X^0$ .

(\*) Work supported by the National Science Foundation.

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(<sup>2</sup>) M. GOLDBERG, M. GUNZIK, S. LICHTMAN, J. LEITNER, M. PRIMER, P. L. CONNOLLY, E. L. HART, K. W. LAI, G. LONDON, N. P. SAMIOS and S. S. YAMAMOTO: *Phys. Rev. Lett.*, **12**, 546 (1964).

(<sup>3</sup>) K. ITABASHI: preprint.

(<sup>4</sup>) The latest experimental data concerning reaction (1) indicate that the  $X^0$ -meson production occurs predominantly in the forward direction which supports this assumption. We should like to express our thanks to Dr. J. LEITNER who informed us of the results of the recent experiments.

model we estimate the differential cross-section for the reaction at 2.3, 2.7, and 3.8 GeV/c under the assumptions that the X<sup>0</sup> is a 0<sup>-</sup> or 1<sup>-</sup> meson and that its isotopic spin *I* is equal to zero. The results are expressed in terms of the angle  $\theta$  between the directions of the K<sup>-</sup> and X<sup>0</sup> particles, and thus  $\pi - \theta$  gives the angular distributions of  $\Lambda$ -particles with respect to the direction of the incoming K<sup>-</sup> beam.

The interaction Hamiltonians are given as follows:

$$(2) \quad H_{N\Lambda K^*} = j\bar{\Psi}i\gamma_\mu\psi\Phi_\mu + \text{h.c.},$$

$$(3) \quad H_{K^*\bar{K}X^0} = \begin{cases} g\Phi_\mu \left( \psi \frac{\partial\phi}{\partial x_\mu} - \frac{\partial\psi}{\partial x_\mu} \phi \right), & \text{for } J^P = 0^-, \\ Gm_K\Phi_\mu\psi\phi, & \text{for } J^P = 1^-, \end{cases}$$

$$(4)$$

where  $\Psi$ ,  $\psi$ ,  $\Phi_\mu$ ,  $\psi(\varphi_\mu)$  and  $\phi$  are the field operators corresponding to the  $\Lambda$ ,  $N$ , K<sup>\*</sup>, X<sup>0</sup> and  $\bar{K}$  particles, and *f* and *g*(*G*) are the coupling constants for  $N\Lambda K^*$  and  $K^*\bar{K}X^0$  interactions, respectively. Straightforward calculation leads to the following results <sup>(5)</sup>.

Case a):  $J^P = 0^-$ .

As is shown in Fig. 2a, the angular distribution has a pronounced forward peak which becomes sharper with increasing incident K<sup>-</sup> energy. As a measure of the

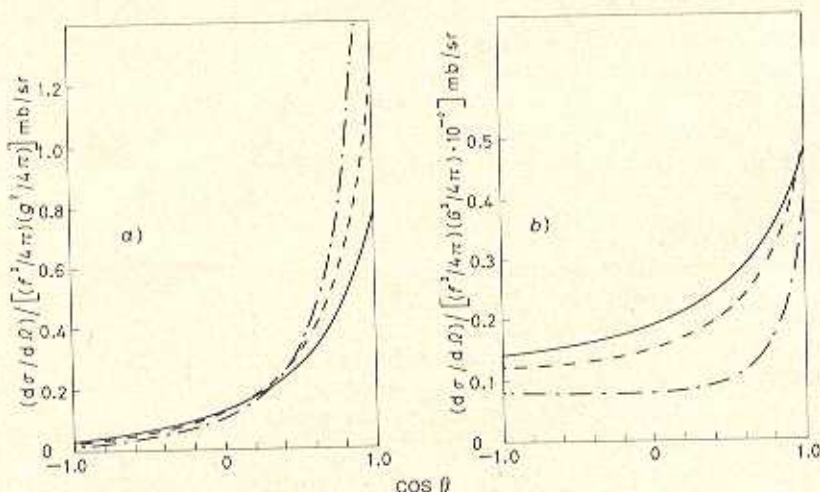


Fig. 2. - Differential cross-sections in the center-of-mass system for the reaction  $K^- + p \rightarrow \Lambda + X^0$  at 2.3, 2.7, and 3.8 GeV/c, where  $\theta$  is the angle between the directions of the K<sup>-</sup> and X<sup>0</sup> particles. a) Case a)  $J^P = 0^-$ ; b) Case b)  $J^P = 1^-$ . — 2.3 GeV/c, --- 2.7 GeV/c, - · - · 3.8 GeV/c.

<sup>(5)</sup> Another possibility for the interaction Hamiltonian in the case  $J^P = 0^-$  is

$$H_{K^*\bar{K}X^0} = g'\Phi_\mu\psi\frac{\partial\phi}{\partial x_\mu}.$$

The conclusions from the results obtained using this Hamiltonian are similar to those discussed in the text.

<sup>(6)</sup> It is not expected that the inclusion of form factors in our calculation will have a remarkable effect on our conclusions but this point will be considered in more detail in a future publication.

forward preponderance of  $X^0$ -meson production, we write down the ratio  $R$  of the integrated cross-section over the region between  $0^\circ$  and  $90^\circ$  to that over the region between  $90^\circ$  and  $180^\circ$ :

$$(5) \quad R = \begin{cases} 5.2 & \text{for } 2.3 \text{ GeV}/c, \\ 7.6 & \text{for } 2.7 \text{ GeV}/c, \\ 15.1 & \text{for } 3.8 \text{ GeV}/c. \end{cases}$$

We see that  $R$  increases significantly with increasing incident energy. The estimated values of the total cross-section ( $\sigma_t$ ) are

$$(6) \quad \sigma_t = \begin{cases} 2.5 \langle f^2/4\pi \rangle \langle g^2/4\pi \rangle \text{ mb} & \text{for } 2.3 \text{ GeV}/c, \\ 3.0 \langle f^2/4\pi \rangle \langle g^2/4\pi \rangle \text{ mb} & \text{for } 2.7 \text{ GeV}/c, \\ 3.9 \langle f^2/4\pi \rangle \langle g^2/4\pi \rangle \text{ mb} & \text{for } 3.8 \text{ GeV}/c. \end{cases}$$

Thus  $\sigma_t$  is an increasing function of the incident energy so far as the phenomena in the region  $(2.3 \div 3.8) \text{ GeV}/c$  are concerned.

Case *b*):  $J^P = 1^+$ .

The differential cross-sections  $d\sigma/d\Omega$  in this case are illustrated in Fig. 2*b*. The values of  $R$  and  $\sigma_t$  are estimated as follows:

$$(7) \quad R = \begin{cases} 1.8 & \text{for } 2.3 \text{ GeV}/c, \\ 1.9 & \text{for } 2.7 \text{ GeV}/c, \\ 1.7 & \text{for } 3.8 \text{ GeV}/c, \end{cases}$$

and

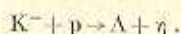
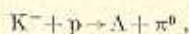
$$(8) \quad \sigma_t = \begin{cases} 2.8 \cdot 10^{-2} \langle f^2/4\pi \rangle \langle G^2/4\pi \rangle \text{ mb} & \text{for } 2.3 \text{ GeV}/c, \\ 2.3 \cdot 10^{-2} \langle f^2/4\pi \rangle \langle G^2/4\pi \rangle \text{ mb} & \text{for } 2.7 \text{ GeV}/c, \\ 1.3 \cdot 10^{-2} \langle f^2/4\pi \rangle \langle G^2/4\pi \rangle \text{ mb} & \text{for } 3.8 \text{ GeV}/c. \end{cases}$$

In this case also, the angular distribution has a forward peak. But there are the following important differences between cases *a*) and *b*):

- i) The peak in case *b*) is much less pronounced than in case *a*).
- ii) As the incident energy is increased, the value of  $R$  in case *b*) does not change appreciably whereas in case *a*) it increases significantly, as we have already seen.
- iii) As the incident energy is increased,  $\sigma_t$  decreases in case *b*) but increases in case *a*).
- iv) In case *b*), as distinct from case *a*), the angular distribution at 3.8 GeV/ $c$  is almost isotropic from  $\cos \theta = -1.0$  to  $\cos \theta = 0.4$  (cf. Fig. 2*b*).

Therefore we can conclude that a measure of the angular distribution as well as a measure of the energy-dependence of the total cross-section would enable us to determine the spin and parity of the X<sup>0</sup>.

We would like to add the following remark. In order to examine the SU<sub>3</sub> scheme, we think it worth-while to study the reactions



The cross-sections for these reactions can easily be estimated by a similar calculation to case a), where the X<sup>0</sup> in Fig. 1 is replaced by  $\pi^0$  or  $\eta$ . We show in Table I the results for  $R$  and  $\sigma_i$ .

TABLE I. - Values of  $R_\pi$  ( $R_\eta$ ) and  $\sigma_\pi$  ( $\sigma_\eta$ ) for the reaction  $K^- + p \rightarrow \Lambda + \pi^0$  ( $\eta$ ).  $R_\pi$  ( $R_\eta$ ) refers to the ratio of the integrated cross-section over the region between 0° and 90° to that over the region between 90° and 180°.  $\sigma_\pi$  ( $\sigma_\eta$ ) denotes the total cross-section, where  $g_\pi$  ( $g_\eta$ ) is the coupling constant for  $K^* \bar{K} \pi$  ( $K^* \bar{K} \eta$ ) interaction.

Incident K <sup>-</sup> momentum (GeV/c)	$R_\pi$	$R_\eta$	$\sigma_\pi / (f^2/4\pi)(g_\pi^2/4\pi)$ (mb)	$\sigma_\eta / (f^2/4\pi)(g_\eta^2/4\pi)$ (mb)
2.3	10.9	9.0	4.1	3.7
2.7	13.2	11.2	4.5	4.0
3.8	20.0	17.7	4.9	4.6