PRODUCTION AND DECAY OF $Y_1^*(1760)$ IN THE REACTION $K^- + p \to K^- + p + \pi^0$

S. Fenster, N. M. Gelfand,* D. Harmsen, R. Levi Setti, and M. Raymund
The Enrico Fermi Institute for Nuclear Studies and Department of Physics,
The University of Chicago, Chicago, Illinois

and

J. Doede and W. Männer
Argonne National Laboratory, Argonne, Illinois‡
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This Letter reports evidence for the reaction chain

$$K^- + p \to Y_1^*(1760) \to Y_0^*(1520) + \pi^0, \qquad (1)$$

$$Y_1^*(1520) \to K^- + p. \qquad (2)$$

The excitation function for this sequence yields for the $Y_1^*(1760)$ mass and width the values $M = 1746 \pm 8$ MeV and $\Gamma = 70 \pm 20$ MeV, respectively, providing at the same time the assignment $I = 1$ for the resonance. The production-decay angular correlation in the $Y_0^*(1520)$ gives an unambiguous $J^P = \frac{5}{2}^-$ assignment for the spin-parity of $Y_1^*(1760)$. These results substantiate the previous quantum-number assignment for $Y_1^*(1760)$ by Armenteros et al.,[1] which was based on a study of Reactions (1) and (2) among the $\Sigma^\pm\pi^\pm\pi^0$ and $\Lambda\pi^+\pi^-\pi^0$ final states, and by others.[2,3] Preliminary results of this analysis were reported previously.[4]

The data to be described are part of a more comprehensive study of two-prong events in the exposure of the Saclay 81-cm hydrogen bubble chamber to a separated beam of K^- mesons in the momentum interval 780-1220 MeV/c at the CERN proton synchrotron.[1,5,6]

Approximately 47 000 photographs, sampling 22 different momenta, were scanned and rescanned within a restricted fiducial volume, yielding ~13 000 two-prong events. Among these, 524 were attributed to the reaction

$$K^- + p \to K^- + p + \pi^0. \qquad (3)$$

The K^- path length was determined by counting all beam tracks in the frames scanned. The μ,π contamination was obtained by δ-ray counting; it ranged between 5 and 10%.

The K^-p invariant-mass distribution for the $K^-p\pi^0$ events is shown in Fig. 1, for K^- incident momenta in the ranges 838-1061 and 1080-1182 MeV/c, respectively. In the lower momentum region, production of $Y_0^*(1520)$ is dominant, while in the upper momentum region this phenomenon has practically disappeared. The fraction of the actual number of events to be attributed to $Y_0^*(1520)$ was obtained from fits to the mass distributions for broad momentum intervals, by assuming a superposition of phase space and resonant contribution only. $Y_0^*(1520)$ production accounts for as much as 70% of the K^-p mass distribution in the region 916-991 MeV/c. The cross sections for Reaction (1), obtained for each momentum, are given in Fig. 2(a), and they suggest resonant behavior, with a maximum at ~920 MeV/c, corresponding to a c.m. energy of ~1750 MeV.

Under the assumption that all the $Y_0^*(1520)$ production originates in the decay of $Y_1^*(1760)$, the data were fitted to a Breit-Wigner excitation function. The energy dependence of the widths was taken to correspond to a d-wave entrance elastic channel and to a p-wave reaction channel. Limiting the fit to the region below 1070 MeV/c, the following parameters were obtained for the resonance: $M = 1746 \pm 8$, $\Gamma = 70 \pm 20$ MeV. Our values for the mass and width of $Y_1^*(1760)$ are consistent with those given in Refs. 1 and 2. The fraction of $Y_1^*(1760)$ decaying according to (1) is estimated, from our data, as 0.24 ± 0.06, for elasticity $x = \Gamma_e/$

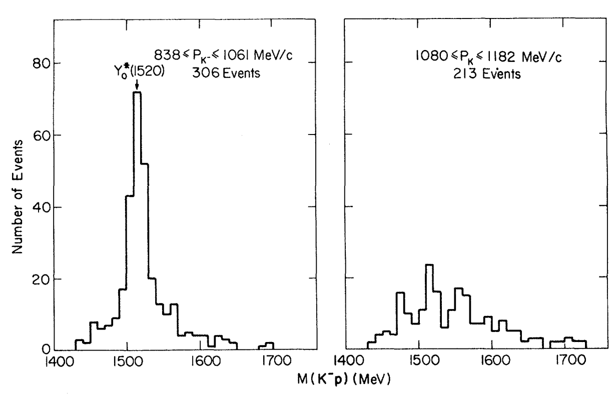

FIG. 1. K^-p invariant-mass distributions from the reaction $K^- + p \to K^- + p + \pi^0$.

$\Gamma=0.5$ and using the known branching fraction of $Y_0^*(1520)$ into the $\bar{K}N$ channel.[7]

An independent determination of the spin parity of $Y_1^*(1760)$ has been attempted here, based on arguments similar to those already used by several authors. In particular, the production and decay angular distributions of $Y_0^*(1520)$ have been tested against the predictions following the two possible assignments $J^P=\frac{5}{2}^\pm$ for $Y_1^*(1760)$.

We obtain a joint distribution function $I(\mu,\nu)$, where $\mu=\cos\theta_1$, $\nu=\cos\theta_2$, with θ_1 the c.m. system production angle of $Y_0^*(1520)$ and θ_2 the angle of the decay proton with respect to the production c.m. system as seen in the $Y_0^*(1520)$ rest frame. Let a_λ be the probability amplitude for finding $Y_0^*(1520)$ $(J^P=\frac{3}{2}^-)$ with helicity $\lambda(=\pm\frac{3}{2},\pm\frac{1}{2})$. The joint distribution in the variables μ and ν is given by

$$I(\mu,\nu)=|a_{1/2}|^2+|a_{3/2}|^2+(2/7)(4|a_{1/2}|^2+|a_{3/2}|^2)P_2(\mu)+(3/7)(2|a_{1/2}|^2-3|a_{3/2}|^2)P_4(\mu)+[|a_{1/2}|^2-|a_{3/2}|^2 + (2/7)(4|a_{1/2}|^2-|a_{3/2}|^2)P_2(\mu)+(3/7)(2|a_{1/2}|^2+3|a_{3/2}|^2)P_4(\mu)]P_2(\nu). \quad (4)$$

To simplify this result, we first note that we may normalize so that

$$|a_{1/2}|^2+|a_{3/2}|^2=1. \quad (5)$$

Further simplification requires additional assumptions. As pointed out in Ref. 1, since the difference in mass between $Y_1^*(1760)$ and $Y_0^*(1520)+\pi^0$ is small, we may assume that the angular-momentum barrier inhibits large values of orbital angular momentum l in the decay of $Y_1^*(1760)$. If the spin parity of $Y_1^*(1760)$ were $\frac{5}{2}^-$, we would have the two possibilities $l=1$ and $l=3$. By neglecting the amplitude for $l=3$, we find[8]

$$|a_{3/2}|^2=\tfrac{2}{3}|a_{1/2}|^2. \quad (6)$$

In that case,

$$I(\mu,\nu)=1+\frac{4}{5}P_2(\mu)+\left[\frac{1}{5}+\frac{4}{7}P_2(\mu)+\frac{36}{35}P_4(\mu)\right]P_2(\nu). \quad (7)$$

Alternatively, if the spin-parity of $Y_1^*(1760)$ were $\frac{5}{2}^+$, we could have $l=2$ and $l=4$. If once more the amplitude for the higher orbital angular momentum is neglected, we find

$$|a_{3/2}|^2=6|a_{1/2}|^2 \quad (8)$$

and obtain the joint distribution

$$I(\mu,\nu)=1+\frac{20}{49}P_2(\mu)-\frac{48}{49}P_4(\mu)+\left[-\frac{5}{7}-\frac{4}{49}P_2(\mu)+\frac{60}{49}P_4(\mu)\right]P_2(\nu). \quad (9)$$

Similar joint distribution functions can be caluclated using, to describe the decay of the

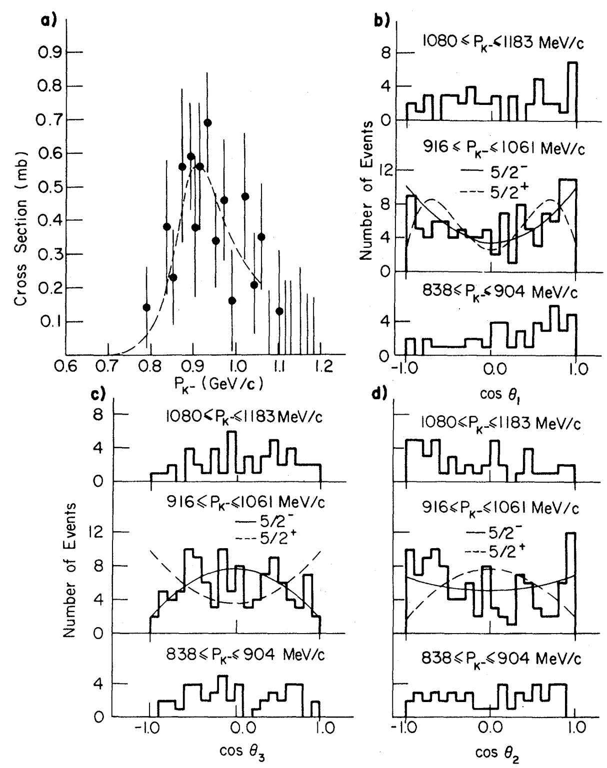

FIG. 2. Data for the reaction sequence $K^-+p \to Y_1^*(1760)\to Y_0^*(1520)\pi^0 \to K^-+p+\pi^0$. (a) Excitation function for the reaction. The dashed curve is a Breit-Wigner fit to the data for $M=1746\pm 8$ MeV, $\Gamma=70\pm 20$ MeV. (b) $Y_0^*(1520)$-production angular distribution, compared with the predictions for $J^P=\frac{5}{2}^+$ as the spin parity of $Y_1^*(1760)$. (c) $Y_0^*(1520)$-decay angular distribution. The decay angle is referred, in the $Y_0^*(1520)$ rest frame, to the normal to the $Y_0^*(1520)$ production plane. (d) $Y_0^*(1520)$-decay angular distribution. The decay angle is referred to the $Y_0^*(1520)$ production c.m. system, as seen in the $Y_0^*(1520)$ rest frame.

$Y_0^*(1520)$, the angle θ_3 of the decay proton, in the c.m. system of $Y_0^*(1520)$, with respect to the normal to the $Y_0^*(1520)$ production plane, as chosen in Ref. 1. Denoting $\eta = \cos\theta_3$, we have

$$I(\mu,\eta) = 1 + \frac{4}{5}P_2(\mu) + \left[-\frac{7}{10} - \frac{1}{5}P_2(\mu)\right]P_2(\eta) \quad (10)$$

for $J^P = \frac{5}{2}^-$, and

$$I(\mu,\eta) = 1 + \frac{20}{49}P_2(\mu) - \frac{48}{49}P_4(\mu) + \left[\frac{33}{42} - \frac{1}{49}P_2(\mu) - \frac{48}{49}P_4(\mu)\right]P_2(\eta) \quad (11)$$

for $J^P = \frac{5}{2}^+$.

Our (μ,ν) data in the interval 916-1061 MeV/c, for K^-p invariant masses between 1505 and 1530 MeV, are compatible with expression (7) ($J^P = \frac{5}{2}^-$) with 48% probability, while they disagree by 6.4 standard deviations with the prediction of expression (9) ($J^P + \frac{5}{2}^+$). Similarly, a comparison of the (μ,η) set of data with expressions (10) and (11) yields 94% probability for the $\frac{5}{2}^-$ solution against a discrepancy of 7.0 standard deviations for the $\frac{5}{2}^+$ solution.

The joint distribution functions, integrated over ν or η (production) and over μ (decay) yield the conventional production and decay angular distributions, which are compared with the data in Figs. 2(b)-2(d). The Legendre polynomial coefficients of the expansion

$$N(\cos\theta) = \frac{1}{4\pi}\sum_n A_n P_n(\cos\theta) \quad (12)$$

are given in Table I for these distributions. The μ, ν, and η angular distributions are given also for the K^- momentum intervals below and above the region chosen for the spin-parity analysis.

The projected distributions of Fig. 2 translate in visual form the content of the above joint correlation test. They do not add, in fact, any information relevant to the choice between $\frac{5}{2}^-$ and $\frac{5}{2}^+$ solutions which was not already taken into account by such test. On the other hand, the Legendre expansion could give information on the presence of partial waves other than those which the present model accounts for. In particular, the deviations of the observed A_2 coefficients from their expected values, if only p-($\frac{5}{2}^-$) or d-($\frac{5}{2}^+$) waves were present in the decay $Y_1^*(1760) \to Y_0^*(1520) + \pi^0$, may be related to an admixture of p and f waves, or d and g waves, respectively.[9] It would seem more plausible, however, that such effects arise from the presence of nonresonant backgrounds at both steps of the reaction sequence.

Table I. Reaction $K^- + p \to Y_1^*(1760) \to Y_0^*(1520)\pi^0 \to K^- + p + \pi^0$.

Coefficient	Observed value	J^P $\frac{5}{2}^+$	$\frac{5}{2}^-$
$Y_0^*(1520)$-production angular distribution: $N(\cos\theta_1) = \frac{1}{4\pi}\sum_n A_n P_n(\cos\theta_1)$, $\cos\theta_1 = \hat{K}^-_{\text{in}} \cdot Y_0^*$. $916 \le P_{K^-} \le 1061$ MeV/c; $1505 \le M(K^-p) \le 1530$ MeV.			
A_0	1	1	1
A_1	0.23 ± 0.19	0	0
A_2	0.68 ± 0.24	0.41	0.80
A_3	0.20 ± 0.28	0	0
A_4	0.33 ± 0.33	-0.98	0
A_5	-0.04 ± 0.35	0	0
A_6	0.28 ± 0.40	0	0
$Y_0^*(1520)$-decay angular distribution: $N(\cos\theta_3) = \frac{1}{4\pi}\sum_n A_n P_n(\cos\theta_3)$, $\cos\theta_3 = \hat{p} \cdot (\hat{K}^-_{\text{in}} \times \hat{Y}_0^*)$.			
A_0	1	1	1
A_1	-0.06 ± 0.15	0	0
A_2	-0.44 ± 0.18	0.78	-0.70
A_3	0.17 ± 0.22	0	0
A_4	-0.40 ± 0.27	0	0
$Y_0^*(1520)$-decay angular distribution: $N(\cos\theta_2) = \frac{1}{4\pi}\sum_n A_n P_n(\cos\theta_2)$, $\cos\theta_2 = \hat{p} \cdot \hat{Y}_0^*$.			
A_0	1	1	1
A_1	-0.20 ± 0.19	0	0
A_2	0.65 ± 0.26	-0.71	0.20
A_3	0.07 ± 0.28	0	0
A_4	0.59 ± 0.33	0	0

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ERRATA

POLARIZATION MEASUREMENT OF THE 6-GeV COHERENT BREMSSTRAHLUNG FROM THE HAMBURG ELECTRON SYNCHROTRON. L. Criegee, G. Lutz, H. D. Schulz, U. Timm, and W. Zimmermann [Phys. Rev. Letters 16, 1031 (1966)].

On page 1031, first column, the true crystal axes are (110), (001), and $(1\bar{1}0)$. Further, $\alpha = 49.6$ mrad should be replaced by $\alpha_1 = 23.1$ mrad.

MEASUREMENT OF THE MEAN ENERGY REQUIRED TO CREATE AN ELECTRON-HOLE PAIR IN SILICON BETWEEN 6 AND 77°K. W. R. Dodge, S. R. Domen, T. F. Leedy, and D. M. Skopik [Phys. Rev. Letters 17, 653 (1966)].

(1) Page 654, second column, second paragraph, line 6, replace $\eta = \eta_T + \eta_R$ by $\eta = \eta_T \eta_R$.

(2) In Eq. (3) the sign inside the square bracket should be + instead of −.

(3) Fig. 2 caption, ηe should be $\eta\epsilon$.