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DISCLAIMER

INVESTIGATION OF $K^-\pi^-$ AND K^-p INTERACTIONS *

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The reaction $K^-n \to K^-\pi^-p$ has been studied for an incident K^- momentum of 1.51 Gev/c, by using the 72-inch Lawrence Radiation Laboratory bubble chamber filled with deuterium. Twenty thousand pictures were taken and analyzed. A motivation for the investigation was to explore the possibility of $K\pi$ resonances in $T = \frac{3}{2}$ by using a pure isotopic spin channel free from obscuring effects of K*(888) which dominates the $T = \frac{1}{2}$ $K\pi$ interaction in this mass region. Furthermore, for the study of the $K\pi$ system in $T = \frac{3}{2}$ this channel is favored by a factor of 27 over the charge channel $K^-p \to \bar{K}^0\pi^-p$ which is normally investigated ***. No $K\pi$ resonances have been found up to a mass of 1 GeV. With peripheral interactions thus found to play a minor role, the reaction is a particularly suitable means of investigating the K^-p interaction. In addition to Y_0*(1520), a K^-p enhancement is observed with a mass of about 1765 MeV.

The major kinematic ambiguity concerned the distinguishing of K^- from π^-. Visual inspection of ionization was done in order to resolve most of the ambiguities. In only about 3% of the events was this impossible and in these cases the fit with the lower χ^2 was chosen. The cross section for this reaction was found to be 1.5 mb.

With the reaction taking place on deuterium, we have verified that the impulse approximation is reasonably well satisfied at this high momentum. The laboratory momentum distribution of the spectator proton fits the Hulthén distribution up to 280 MeV/c, while the laboratory angular distribution is slightly peaked forward from the expected isotropy for a non-participating spectator. In 70% of the events the spectator proton was too short to be measured. Those events (11%) with spectator proton momenta greater than 280 MeV/c were rejected as not satisfying the impulse approximation.

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*** A factor of 9 arises from Clebsch-Gordan coefficients and of 3 from the branching ratio of $\bar{K}^0$ into charged pions.

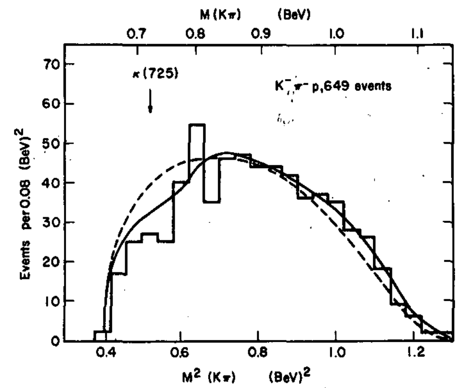

Fig. 1. Plot of the $M_{K^-\pi^-}{}^2$ distribution. The dashed line is phase space while the solid line represents the distortion of phase space due to the projection of the resonances in fig. 2 on the $M_{K^-\pi^-}{}^2$ axis.

The fitted $K^-\pi^-p$ effective mass is centered at 2.015 GeV with a full width at half height, arising mainly from deuteron internal momentum, of 84 MeV.

Fig. 1 shows the $K\pi$ effective mass distribution. The dashed line is phase space, weighted in accordance with the observed K^-n c. m. energy distribution and normalized to the total number of events. The solid line represents phase-space modified by resonances in the K^-p pairing. No structure is apparent over the mass interval $0.64 < M < 1.00$ GeV. In several experiments [2] an effect at $M_{K\pi}$ = 725 MeV is observed as a persistent enhancement low on the shoulder of K*(888). In the reaction $K^-p \to \bar{K}^0\pi^-p$ at our momentum of 1.51 GeV/c, Wojcicki et al. [1] report a κ(725) production cross section of 12 ± 5 μb. If this were a $K\pi$ resonance in $T = \frac{3}{2}$ we should see, for our analyzed path length, 55 ± 23 events over phase space. No enhancement is observed, confirming the $T = \frac{1}{2}$ assignment previously suggested for this effect.

Turning to the K^-p effective mass distribution shown in fig. 2, we make the following observations concerning excited hyperons with a mass great enough to decay into K^-p:

(a) Y_0*(1520) is the dominant feature of the reaction, comprising perhaps 25% of the events. The

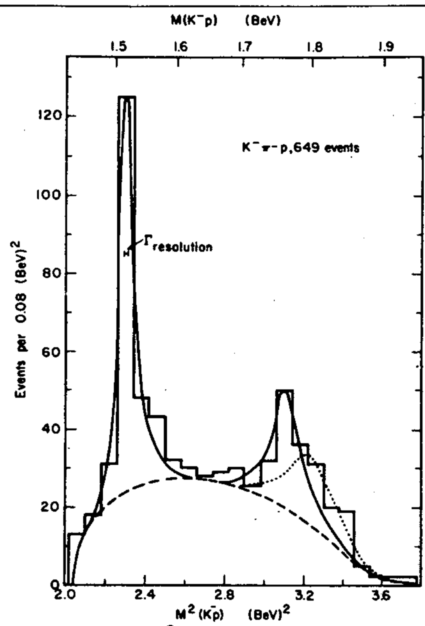

Fig. 2. Plot of the $M_{K^-p}{}^2$ distribution. The dashed line is phase space while the solid line has superposed on phase space the product of phase space with Breit-Wigner resonances at 1517 and 1765 MeV. The dotted line indicates the expected mass distribution for a resonance at 1815 MeV with a full width of 120 MeV.

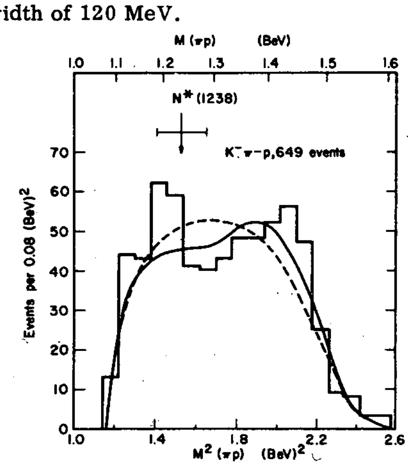

Fig. 3. Plot of the $M_{\pi^-p}{}^2$ distribution. The dashed line is phase space while the solid line represents the distortion of phase space due to the projection of the resonances in fig. 2 on the $M_{\pi^-p}{}^2$ axis.

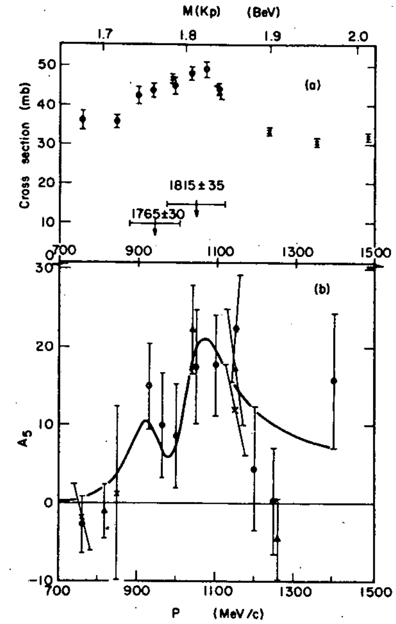

Fig. 4. a. The K⁻p total cross section plotted versus K⁻ laboratory momentum. The experimental data are obtained from ref. 5): crosses from Cook et al., and circles from Chamberlain et al.
b. The coefficient of $\cos^5\theta$ in the angular distribution for K⁻p elastic scattering plotted versus K⁻ laboratory momentum. The experimental data are obtained from ref. 6): circles from Beall et al., triangles from Sodickson et al., and crosses from Bastien and from Graziano and Wojcicki. The curve is derived from resonance parameters as given in the text.

central value and width are in good agreement with that reported by Ferro-Luzzi et al. *. From the narrowness of the peak the mass resolution of this experiment is seen to be good, agreeing with the experimentally calculated resolution of 7 MeV in this mass region.

* Our experiment yields for Y_0^*(1520) a mass of 1517.2±3 MeV and a full width of about 16 MeV after subtracting the experimental resolution. The latest values reported by Watson et al. 3) are M = 1519.4±2 MeV and Γ = 16.4±2 MeV.

(b) Y_1*(1660) is not observed 4). This may be partially a consequence of its reported branching ratio to the K⁻p channel of only ≈ 10% as well as an absence of its excitation at this energy.

(c) A small but statistically significant enhancement is noted at a mass of about 1765 MeV. A Breit-Wigner resonance centered at this mass value with a width Γ = 50 MeV gives a reasonable fit to the data.

Fig. 3 shows the π^-p effective-mass distribution. Again, the dashed line represents phase space and the solid line the distribution expected from phase space plus projections of the enhancements of fig. 2. N*(1238) seems to be produced to some extent.

Returning to the K⁻p enhancement at 1765 MeV, let us investigate its relationship to the prominent and unsymmetrical bump in the K⁻p total cross section 5) ranging over K⁻ momenta from approximately 850 to 1150 MeV/c. It has been described loosely as one resonance, Y_0*(1815) with a width Γ = 120 MeV, although a more complex structure is admissible and is indeed suggested by the data, which we reproduce in fig. 4a. A mass of 1765 MeV corresponds to an incident K⁻ laboratory momentum of 940 MeV/c where, if one is so inclined, a leveling off can be read into the rising K^-p total and elastic cross section data [5,6]. Our observation of an enhancement at 1765 MeV thus adds some substance to the conjecture that $Y_0^*(1815)$ may consist of two resonances. In fig. 2 a few events appear above the resonance curve in the vicinity of 1815 MeV, indicating that some $Y_0^*(1815)$ is perhaps also produced in this reaction.

The presence of two adjacent resonances, both rather elastic, leads to prominent interference effects in the K^-p and $\bar{K}^0n$ angular distributions and polarizations in this momentum region. The published angular distribution data [6], when analyzed in terms of coefficients A_n, given by

$$d\sigma/d\Omega = \tfrac{1}{4}\lambda^2 \sum_n A_n \cos^n\theta \ ,$$

show that a complexity up to $n = 5$ is both necessary and sufficient to fit all observations. This suggests $D_{\frac{5}{2}} - F_{\frac{5}{2}}$ interference since $A_5 = (225/2)\ \mathrm{Re}\ D_{\frac{5}{2}}^* F_{\frac{5}{2}}$ when the angular distribution is expanded through $J = \frac{5}{2}$ partial waves. Let us take the following resonance parameters which are consistent with the observed K^-p total, elastic, and charge-exchange cross sections after subtracting reasonable background effects: $M_1 = 1765$ MeV, $\Gamma_1 = 60$ MeV, x_1 (=elasticity = $\Gamma e/\Gamma$) = 0.6; $M_2 = 1815$ MeV, $\Gamma_2 = 70$ MeV, $x = 0.8$ - with both Γ having momentum dependence appropriate to radii of interaction $R = \frac{1}{2}\lambda\!\!\!^{-}_{\pi}$. We take the lower resonance to be $D_{\frac{5}{2}}$ and the upper to be $F_{\frac{5}{2}}$ although this choice enters only into the momentum dependence of Γ. We then obtain for the A_5 coefficient in K^-p scattering, the curve shown in fig. 4b, which is seen not to be in disagreement with the published data. In the momentum region between the resonances the two amplitudes are nearly orthogonal, so a decrease in A_5 is predicted. For this reason the polarization term proportional to Im $D_{\frac{5}{2}}^* F_{\frac{5}{2}}$ should here be large, and a measurement of its sign would suffice to resolve the $D_{\frac{5}{2}} - F_{\frac{5}{2}}$ ambiguity.

The $T = 0$ isotopic spin assignment for $Y_0^*(1815)$ has been suggested [5] by comparison of the K^-p and K^-n total cross sections. However, the K^-n data are somewhat contradictory and if one admits two resonances then the possibility that the lower resonance is $T = 1$ is not completely excluded *.

* The K^- deuterium data are subject to two corrections arising from the internal momentum of deuterium: (a) An internal momentum resolution curve with an effective width $\Gamma \approx 50$ MeV must be folded into any K^-n resonance. This causes the resonance to appear some 30% lower and broader than if it were observed on a stationary neutron. (b) The K^-p cross section bump must be lowered and broadened in the same way before subtracting it from K^-d in order to obtain the K^-n cross section. This has the effect of raising the published K^-n cross sections in the vicinity of the K^-p peak and lowering them on either side of the peak, thereby enhancing the observed rise by about 4 mb.

More K^- deuterium data in this region would be useful. The K^-d elastic scattering would, in particular, depend sensitively on isotopic spin due to coherent effects. In connection with the isotopic spin assignments, the reaction $K^-p \to \bar{K}^0n$ is of great interest. The angular distributions from 1000 to 1150 MeV/c as reported by Wohl et al. [7] and by Graziano and Wojcicki [6] show the same behavior as elastic scattering for the magnitude of A_5, but with opposite sign. This is as one would expect if one resonance were $T = 0$ and the other $T = 1$.

The quantum number assignments used here for the higher mass resonance ($\frac{5}{2}^+$, $T = 0$) are compatible with it being the Regge recurrence of the Λ. The 1765-MeV enhancement with the quantum numbers as suggested here ($\frac{5}{2}^-$, $T = 1$) has not, to our knowledge, been predicted by any theoretical considerations.

If $Y_0^*(1815)$ is to be regarded as only one resonance then one must find an alternative interpretation for the enhancement we observe at 1765 MeV. We discuss several alternatives:

(a) Statistics. In the peak region there are 96 events over a background of 92 so the enhancement is clearly significant. It is remotely possible that statistical fluctuations in the bin populations - combined with other effects - could displace the peak to 1765 MeV.

(b) Displacement of the peak by interference with background. Such interference effects are difficult to evaluate. However, we make the observation that elementary particle resonances produced in numerous reactions have given agreement on the various resonance masses to about 10 MeV. Displacements as great as 20 MeV are rare. The 50-MeV displacement between our peak and the K^-p total cross section peak seems then quite unlikely.

(c) A high centrifugal barrier in the production reaction. For example, the K^-p total energy in our reaction corresponds approximately to the conjectured Regge recurrence of $Y_1^*(1385)$. If this $\frac{7}{2}^+$ state were formed and subsequently decayed into $Y_0^*(1815) + \pi$, then the later process would occur in the p state. The upper mass region of $Y_0^*(1815)$ would be suppressed by a p-wave centrifugal barrier. To achieve a 50-MeV displacement would require, however, at least a d-wave barrier. Furthermore, no anisotropies nor alignment effects usually associated with high angular momenta are indicated by the data.

(6) Another possibility is that the 1765-MeV bump could be due to an interference effect with $N^*(1238)$ whose projection in fig. 2 extends over $2.6 < M_{K^-p}^2 < 3.4$. Again, there is no indication of such an interference in the data since the enhancement occurs both inside and outside the interference region. We thus regard one or more of these alter-

native possibilities as being less likely than the interpretation set forth in this letter.

In conclusion, a resonance at 1765 MeV is suggested by our data and is furthermore consistent with the present overall experimental situation; the discussion concerning its quantum numbers is somewhat speculative. The problem merits further study, especially through investigation of this region in direct two-body processes.

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