LOW-ENERGY K^--p INTERACTION AND INTERPRETATION OF THE 1405-MeV Y_0^* RESONANCE AS A $\bar{K}N$ BOUND STATE

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In order to investigate the low-energy K^--p interaction, the following six reactions have been studied in the region of K^- momentum below 300 MeV/c:

$$K^- + p \to K^- + p,$$
$$K^- + p \to \bar{K}^0 + n,$$
$$K^- + p \to \Sigma^+ + \pi^-,$$
$$K^- + p \to \Sigma^- + \pi^+,$$
$$K^- + p \to \Sigma^0 + \pi^0,$$
$$K^- + p \to \Lambda + \pi^0.$$

Experimental cross sections and angular distributions have been obtained. The results have been fitted to the Dalitz-Tuan theory,[1] which assumes that the effective range is zero for the K^--p system. In a systematic chi-square search,[2] two solutions have been found. One of these can be eliminated on the basis of a very large chi-square value. A similar analysis was attempted by Humphrey and Ross.[3] The present analysis, however, was performed on an experimental sample ten times as large as that used in their analysis, thus allowing the exclusion of one solution and determining a set of scattering parameters very accurately. The mass and width of the K^--p bound state in the isotopic spin zero channel has then been calculated from the $I=0$ scattering parameters.

The experimental results are based on the analysis of events obtained by the exposure of the 30-inch Columbia-Brookhaven hydrogen bubble chamber to the separated low-energy K^- beam at the AGS. Approximately 13 500 events were measured and fitted. The detailed experimental results will be published elsewhere together with a description of the experimental procedure. In the notation of Dalitz-Tuan, the two solutions are presented in Table I.

Because of the very poor fit of solution II to the experimental data, this solution can be excluded. Figure 1 presents some of the experimental data compared to the two solutions.

Two additional pieces of evidence favor solution I. The first is an argument of Akiba and Capps.[4] In order to explain the interference of the s-wave amplitudes with the 395-MeV/c $D_{3/2}$ resonance, Tripp, Ferro-Luzzi, and Watson[5] are forced to assume that $\Psi_0-\Psi_1$ is negative at this energy. Since no violent fluctuations in the Σ^-/Σ^+ ratio are observed between 0 and 400 MeV/c, the phase difference must be negative. This eliminates solution II definitely because of its positive phase difference.

The second is an argument of Capps and Schult[6] to explain the difference in the ratio $(\Sigma^-\pi^+)/(\Sigma^+\pi^-)$, observed when K^- are absorbed in hydrogen and in deuterium. This ratio is approximately two in hydrogen, and one in deuterium. According to this argument, a_0 has to be smaller than -1.3. Thus the elimination of solution II from two solutions is definite.

Solution I implies the presence of a K^--p bound state. Assuming energy independence of the scattering length, Dalitz[7] derived the mass and the width of this bound state using a linear approximation of the Breit-Wigner form to the denominator factor of the elastic scattering amplitude,

$$E_r = M_p + M_K - (2u_K a_0^2)^{-1}, \quad \Gamma = 2b0/(u_K |a_0|^3),$$

where U_K is the reduced mass of K-p system.

Table I. Two sets of s-wave zero-effective range $\bar{K}$-N scattering parameters, which best fit the K^--p data up to 280 MeV/c. $A_0 = a_0 + ib_0$ is the $I=0$ s-wave complex scattering length in fermis; $A_1 = a_1 + ib_1$ is the $I=1$ s-wave complex scattering length in fermis; ϵ is the $[\Lambda/(\Lambda+\Sigma)]_{I=1}$ ratio at rest; $\Psi_0-\Psi_1$ is the phase difference between the $I=0$ absorption amplitude and the $I=1$ absorption amplitude at $\bar{K}N$ threshold.

	Solution I. $\chi^2 = 85.6$, 98 degrees of freedom	Solution II. $\chi^2 = 196.0$, 98 degrees of freedom
A_0	$(-1.674 \pm 0.038) + i(0.722 \pm 0.040)$	$(-0.654 \pm 0.127) + i(1.544 \pm 0.071)$
A_1	$(-0.003 \pm 0.058) + i(0.688 \pm 0.033)$	$(-0.852 \pm 0.064) + i(0.157 \pm 0.025)$
ϵ	0.318 ± 0.021	0.491 ± 0.046
γ	2.093 ± 0.091	2.460 ± 0.086
$\Psi_0-\Psi_1$	$-53.8°$	$70.5°$

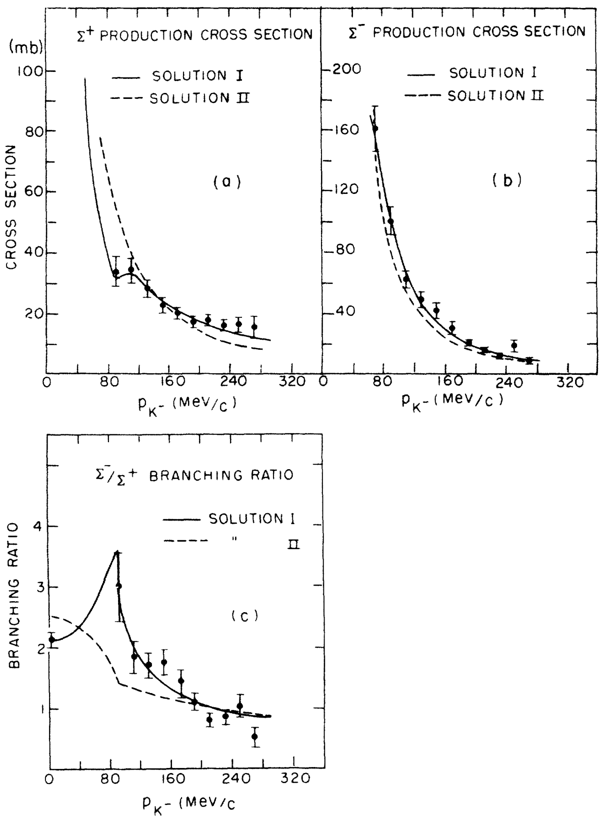

FIG. 1. (a) Cross sections for $K^- + p \rightarrow \Sigma^+ + \pi^-$. (b) Cross sections for $K^- + p \rightarrow \Sigma^- + \pi^+$. (c) Branching ratios Σ^-/Σ^+, as a function of incident K^- momentum. The continuous curve is the expected value from solution I, and the broken curve is the expected value from solution II.

Using the scattering length of solution I, the mass and the width of this resonance in the isotopic zero channel are

$$E_r = 1410.7 \pm 1.0 \text{ MeV}, \quad \Gamma = 37.0 \pm 3.2 \text{ MeV}.$$

These values should be compared with the mass and the width of the $Y_0^*(1405)$ resonance: mass $= 1405$ MeV,[8,9] width $= 50$ MeV,[8] or 35 ± 5 MeV.[9] The Y_0^* mass is well determined, but the width of this resonance is not as well established. The agreement between the calculated value and experimental value is reasonable; the discrepancy of 5.7 MeV in the mass is not unreasonable in view of the simplicity of the theoretical model. The inclusion of an effective-range term of the order of the Compton wavelength of the K^- meson would shift the calculated mass toward the experimental value. To explore this possibility, experimental data are being fitted to the effective-range treatment of Ross and Shaw.[10] It is hoped that this can be reported at a later time.

However, the agreement of the calculated parameters of the resonance with the experimental parameters is sufficiently striking to permit the conclusion that the Y_0^* of mass 1405 MeV is to be understood as an s-wave K^--p bound state. This then establishes the spin and parity of the 1405 Y_0^* as $\frac{1}{2}^-$, using the convention of negative kaon parity.

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