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[12] Not all the events below the background curve in Fig. 3, between 520 and 580 MeV, are to be counted as background in the $\eta\to\pi^++\pi^-+\pi^0$ sample since about half of them did not make the required fit to the chain (4a).

[13] One might, however, ask a different question, i.e., what is the joint probability that there being no C-invariance violation, the three independent observations should obtain the reported values all with the same sign. This probability is 2.3×10^{-5}.

NEW STRUCTURE IN THE K^--p AND K^--d TOTAL CROSS SECTIONS BETWEEN 1.0 AND 2.45 GeV/c*

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The K^--p and K^--d total cross sections have been measured with increased precision and resolution in the momentum interval 1.0 to 2.45 GeV/c using a partially separated K^- beam at the Brookhaven alternating-gradient synchrotron (AGS). Data were obtained at momentum intervals of 50 MeV/c with $\Delta p/p=\pm0.01$. The statistical standard deviations are ±0.25% for hydrogen and ±0.13 for deuterium above 1.35 GeV/c, and increase progressively with decreasing momentum. The total cross sections in this energy range show considerable structure. Preliminary analysis indicates two K^--nucleon resonances above $Y_0^*(1815)$ in the $I=0$ state and very likely three in the $I=1$ state above $Y_1^*(1765)$.

The K^- mesons were produced in a 1-mm-diam, 13-mm-long Be-wire target at 10° to the internal proton beam of the AGS. First, the particles were focused with a quadrupole triplet to a beam parallel vertically and slightly converging horizontally, then momentum analyzed. This beam passed through two 15-ft-long electrostatic separators (about 400 kV on a 4-in. gap) and, before being deflected by a 12° angle, was refocused horizontally at a sextupole and vertically onto a mass slit further downstream. Following the mass slit, the beam was recombined in momentum and imaged at the transmission counters. A nuclear fluxmeter was used to calibrate the momentum of the beam at selected values to better than ±0.5%. The flux varied from about 16×10^3 K^- mesons per 10^{12} protons at momenta above 1.8 GeV/c to about 300 K^- mesons per 10^{12} protons at 1 GeV/c.

The K^- mesons were identified by a liquid differential Cherenkov counter with a 3-cm-thick radiator filled with C_6F_{12}. Incorporated into the counter was an anticoincidence arrangement for rejecting fast particles. Thus the contamination of the K^- mesons by other particles was maintained below 0.5% at all momenta. A time-of-flight criterion also had to be imposed to achieve this low contamination at 1.0 and 1.05 GeV/c.

The hydrogen and deuterium targets were identical and were 36 in. long and 5 in. in diameter. Both targets were at a temperature of 20.97°K corresponding to a hydrogen vapor pressure at 18.00 psi. The densities of the liquid hydrogen and liquid deuterium were 0.069 97 g/cm^3 and 0.1691 g/cm^3, respectively. A double-jacketed design provided long-term density stability to better than 0.03%. The cross section at each momentum was determined from the transmission measured successively in the H_2 and D_2 targets and a dummy target. At least two such sequences were repeated and a measurement with a carbon target was also made at each momentum.

The K^--meson telescope consisted of the Cherenkov counter in coincidence with one scintillation counter defining the beam at the exit of the last quadrupole, another behind the Cherenkov counter defining the beam at the entrance to the target. Adjacent to it was a counter with a hole whose signal was in anticoincidence with the telescope. Almost all of the fast particles and nonbeam particles were thus eliminated electronically. Accidental coincidences, primarily due to K^- mesons in the beam, were a negligible effect since the AGS spill was quite uniform over a time interval exceeding 0.4 sec. An artificial dead time of 60 nsec was introduced following each K^- count to eliminate pile-up in the 20-Mc/sec scalers.

The K^- mesons which passed through the tar-

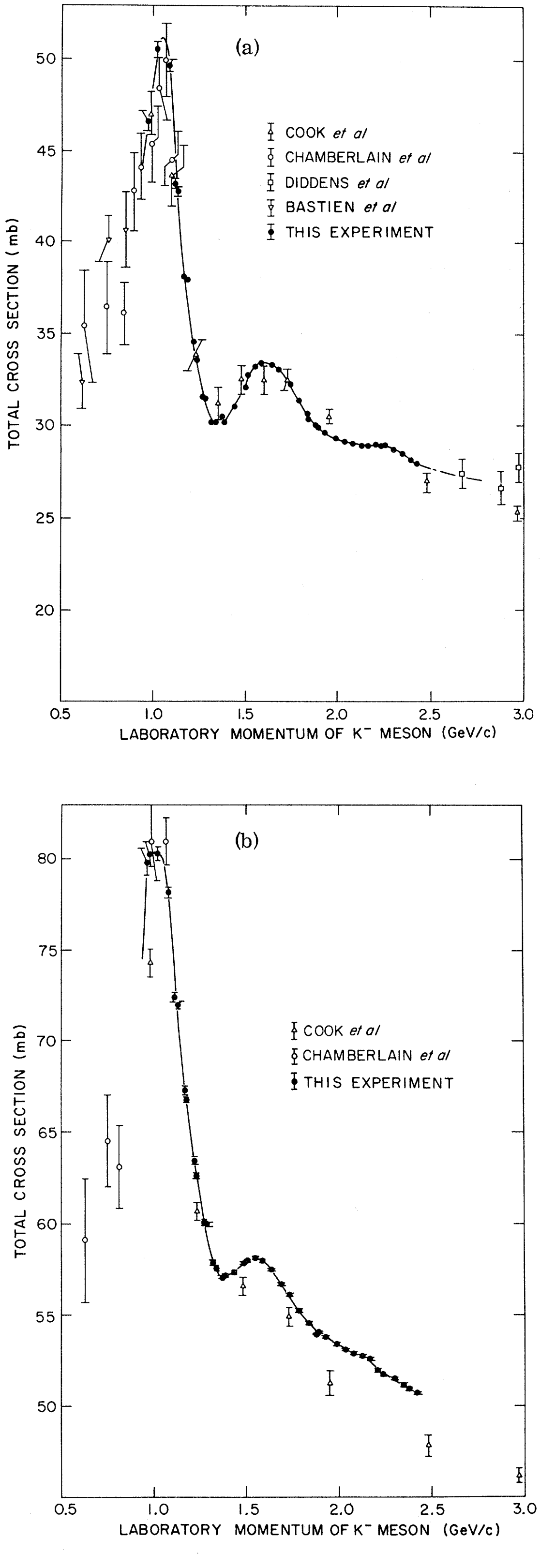

FIG. 1. The total cross section of K^- mesons on (a) protons, (b) deuterons.

get were detected in seven transmission counters situated at the final K^--meson focus. The transmission counters subtended at the center of the target solid angles ranging from 1.2 to 13.2 msr. Each of these counters was separately connected in coincidence with the K-meson telescope and the individual coincidences scaled. The data were transferred from the scalers onto cards and processed by an IBM-7094 computer to check for internal consistency and to calculate the partial cross sections. A linear extrapolation to zero solid angle was made to obtain the total cross section.

The data were corrected for the increased decay rate of K^- mesons after having passed through the targets due to energy loss by ionization. This correction $\Delta\sigma$ on $\sigma(K^- \text{-} p)$ varied from $\Delta\sigma = -0.47$ mb at 2.3 GeV/c to $\Delta\sigma = -2.46$ mb at 1.0 GeV/c.

Figures 1(a) and 1(b) show the measured total cross sections. Shown also are the results of previous measurements[1-3] in this momentum interval. There is a general agreement with the trend of the earlier data but not with the absolute scale of the K^--d cross section.

The K^--p and K^--d total cross sections can be expressed in terms of the total cross sections σ_0 and σ_1 in the pure isotopic spin states $I = 0$ and $I = 1$, respectively:

$$\sigma_T(K^- \text{-} p) = \tfrac{1}{2}(\sigma_0 + \sigma_1), \tag{1}$$

$$\sigma_T(K^- \text{-} d) = \tfrac{1}{2}(\sigma_0 + 3\sigma_1) - \sigma_G, \tag{2}$$

where

$$\sigma_G = (1/4\pi)\langle r^{-2}\rangle \sigma_T(K^- \text{-} p)\sigma_T(K^- \text{-} n) \tag{3}$$

is the Glauber screening correction[4]; $\langle r^{-2}\rangle$ is the average of the inverse square of the separation of nucleons in the deuteron. We used $\langle r^{-2}\rangle = 0.0423\ \text{mb}^{-1}$.[5] Formula (3) neglects a term containing the product of the real parts of the forward scattering amplitudes in K^--n and K^--p.

Three structures are clearly evident in the K^--p total cross-section data of Fig. 1(a) at laboratory momenta of 1.06, 1.66, and 2.31 GeV/c. There are also three structures in the K^--d total cross-section data of Fig. 1(b). While the two enhancements in $\sigma_T(K^- \text{-} d)$ above 1.10 GeV/c appear at approximately the same momenta as that in $\sigma_T(K^- \text{-} p)$, the central values do not in fact correspond exactly but appear shifted to lower momenta. This could be interpreted in one of two ways. One possibility is that each enhancement in the total cross section is a mixture of two resonances of different isotopic spin states. Another possibility is that the K^--nucleon resonances observed from deuterium collisions might be shifted to lower momenta because of coherent processes involving the bound state of the deuteron. An apparent shifting of a resonance peak in a production experiment in D_2 had been observed previously.[6] In a more analogous situation, we have searched for a possible shifting of the well-known N^* peaks in π-deuteron total cross sections. From charge symmetry one has

$$\sigma_T(\pi^+\text{-}d)=\sigma_T(\pi^-\text{-}d)=\sigma_T(\pi^+\text{-}p)+\sigma_T(\pi^-\text{-}p)-\sigma_G. \quad (4)$$

Therefore, by measuring the four cross sections indicated in (4) the situation is over-determined and we may check if and to what extent resonances may be shifted and determine σ_G experimentally. The range covered was from 900 MeV/c to 2.4 GeV/c in steps of 50 or 100 MeV/c and to a statistical accuracy of 0.1%. Both the 1688- and 1920-MeV N^*'s were observed. If any shifting existed, it was negligible compared to the displacements between corresponding peaks in $\sigma_T(K^-\text{-}p)$ and $\sigma_T(K^-\text{-}d)$. For this reason we have assumed that an energy shift in K-N data may be neglected. Considerable broadening due to Fermi momentum was observed in both $N^*(1688)$ and $N^*(1920)$.

Before determining σ_0 and σ_1 it was necessary to take the Fermi momentum broadening in $\sigma_T(K^-\text{-}d)$ into account. A spread-out K^- meson-proton cross section "σ_p" was computed from the experimental values σ_p, then the corresponding spread-out "σ_1" and "σ_0" were calculated, and finally the Fermi momentum unfolded. "σ_p" is given by

$$\text{“}\sigma_p(S)\text{”}=\int\sigma_p(S')\,|\varphi(q)|^2d^3q, \quad (5)$$

where $S=(p_1+p_2)^2$, $S'=(p_1+p_2-q)^2$; p_1 and p_2 are the four-momenta of the K^- meson and proton, respectively; q is the Fermi momentum of the proton in the deuteron; $\varphi(q)$ is the deuteron wave function. Both Hulthén and Gaussian wave functions were used. The computed σ_0 and σ_1 cross sections using the two wave functions with several different values of the parameters are not significantly different.

The determination of σ_0 and σ_1 is subject to certain assumptions, namely that the real parts of the forward scattering amplitudes and coherent and higher order rescattering effects on the deuteron cross section are small enough to be neglected. Figure 2 shows the total cross sections in the isotopic spin states $I=0$ and $I=1$.

The $I=0$ curve shows three enhancements; one is the well-known $Y_0^*(1815)$.[7] The other peaks appear at center-of-mass total energies of 2100 ± 20[8] and 2340 ± 20 MeV. The last peak is sensitive to the type of deuteron wave function used and to the experimental data above 2.5 GeV/c which have large errors. In spite of these uncertainties the existence of this structure is very probable.

The $I=1$ curve shows three peaks and one shoulder. The peak at 0.95 GeV/c is due to the well-known $Y_1^*(1765)$.[7] The other two peaks appear at center-of-mass total energies of 2040 $\pm$ 20 and 2260 ± 20 MeV.[9] The $Y_1^*(1765)$ peak seems to be slightly asymmetric. The shoulder at 1.26 GeV/c (1915-MeV mass)[10] is about a 5 statistical standard-deviation effect. This

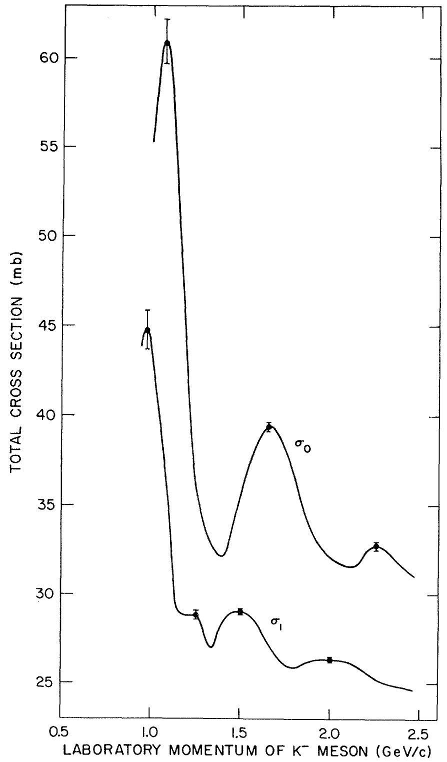

FIG. 2. The total cross sections σ_0 and σ_1 for the $I=0$ and $I=1$ isotopic spin states, respectively, for the K^-N system; typical statistical errors for a single point are shown for each structure.

Table I. Parameters of the hyperon resonances observed in total cross sections. Values quoted are preliminary. Symbols are defined in text.

Notation	I	P_k lab (GeV/c)	W (MeV)	Γ (MeV)	σ_R (mb)	$4\pi\bar{\lambda}^2$ (mb)	$(J+\frac{1}{2})x$
$Y_0^*(2100)$	0	1.68	2100 ± 20	160	10	8.7	1.15
$Y_0^*(2340)$	0	2.27	2340 ± 20	105	3	5.9	0.51
$Y_1^*(1915)$	1	1.26	1915 ± 20	65	4	12.8	0.31
$Y_1^*(2040)$	1	1.54	2040 ± 20	150	6	9.7	0.62
$Y_1^*(2260)$	1	2.06	2260 ± 20	180	3	4.3	0.70

shoulder falls within the large bumps due to the $Y_1^*(1765)$ and $Y_0^*(1815)$ and is computed as the difference between two large numbers. Its shape and height, but not its position, are sensitive to the deuteron wave function used. A further complication may come from the fact that the thresholds for K^*N and N^*K reactions fall in this same energy region. Therefore it is difficult to establish the existence of this shoulder as conclusively as the other $I=1$ structures.

Table I gives the relevant parameters of the structures found in this total-cross-section measurement. From the expression for σ_R which is

$$\sigma_R = 4\pi\bar{\lambda}^2(J+\tfrac{1}{2})x, \tag{6}$$

where $4\pi\bar{\lambda}^2(J+\frac{1}{2})$ is the unitarity limit on the cross section in the partial wave of total angular momentum J and x is the elasticity of the resonance, the values of $(J+\frac{1}{2})x$ have been evaluated.

All the hyperons described in Table I could be located in a plot of Regge trajectories for hyperons as follows: The $Y_0^*(2100)$ may be a recurrence of the $Y_0^*(1520)$ and therefore be a $\frac{7}{2}^-$ state. The $Y_0^*(2340)$ may be the second recurrence of the Λ and thus have an assignment of $\frac{9}{2}^+$. The $Y_1^*(2040)$ could be a recurrence of the $Y_1^*(1385)$ and thus have a spin assignment of $\frac{7}{2}^+$, consistent with results of Wohl, Solmitz, and Stevenson.[9] The $Y_1^*(2260)$ could be the recurrence of the $Y_1^*(1765)$ and could have a spin $\frac{9}{2}^-$. It could also be a recurrence of the $Y_1^*(1660)$ whose spin is still unsettled. The $Y_1^*(1915)$ could be a recurrence of the Σ in which case it would have spin $\frac{5}{2}^+$. From the point of view of SU(3) the $Y_1^*(1915)$ could be the missing member of the $\frac{5}{2}^+$ baryon octet together with $N_{1/2}^*(1688)$, $Y_0^*(1815)$, and $\Xi^*(1933)$.

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[8] The total-cross-section measurements of Cook *et al.*[1] indicated an enhancement in the K^--p total cross sections between 1.2 and 2.0 GeV/c, but these data were not complete enough to show the details of a resonance. A resonance of unknown isospin has been reported at a

mass of 2097 MeV by R. K. Böck et al. [Phys. Letters 17, 166 (1965)], but the reported width (38 MeV) is much narrower and may not correspond to the $Y_0^*(2100)$ reported here.

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[10] The $Y_1^*(1915)$ may be connected with the $Y_1^*(1942 \pm 9)$ observed by Böck et al.[8]