PHYSICAL REVIEW D VOLUME 8, NUMBER 1 1 JULY 1973

Low-Momentum $\bar{p}p \to \bar{K}K$ †

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(Received 2 January 1973)

An analysis of $\bar{p}p \to \bar{K}K$ measurements in the region $P_L \lesssim 700$ MeV/c is made on the basis of a proposed boson triad (ρ', ω', ϕ'). No contradictions appear, and the $\bar{p}p$ channel for the resonances if present is ^3D; but it appears not possible to decide between $^3D_1$ and $^3D_3$.

Recent measurements[1-5] of $\bar{p}p \to \bar{K}K$ in the region $\sqrt{s} = 1.9$ to 2.0 GeV show some fairly strong structure and a general absence of $C = +1$ states. It appears likely[2,4] that the dominant $\bar{p}p$ channels are ^3D. The present note attempts to relate these effects to a proposed[6] boson triad in this region. Analysis of angular distributions for $\bar{K}_0K_0$ slightly favors $^3D_1$ over $^3D_3$ for the triad; but the stronger K^+K^- data seem to favor $^3D_3$.

Throughout the following we simplify the analysis by neglecting $C = +1$ states as a first approximation. They cannot be entirely absent, of course, but appear definitely negligible in K^0K^0 and not strongly required for K^+K^-. One may speculate that the s region lies at a mass below a strong $^3F_2$ resonance and above a first excited A_2 state, $^3P_2'$. The corresponding $J^P = 2^+$ amplitude should then go through a zero in the s neighborhood; and if that amplitude is the dominant contributor to $C = +1$ in $\bar{p}p \to \bar{K}K$, channels with this signature will be suppressed.

1. The $\bar{p}p \to K^0K^0$ Data

Independent measurements[4,5] of $\bar{p}p \to K^0K^0$ in the s region agree on the almost total absence of $C = +1$ annihilations yielding $K_S^0K_S^0$ ($+K_L^0K_L^0$). They also give comparable average cross sections for $\bar{p}p \to K_S^0K_L^0$ but do not display the same degree of structure: Reference 4 shows a pronounced dip around $p_L = 400-500$ MeV/c and a peak around 600–650 MeV/c, while Ref. 5 shows little variation of cross section with p_L. An average of their measurements is sketched in Fig. 1; some dip-peak structure remains and is exaggerated in appearance by the logarithmic scale.

The resonances adumbrated in Ref. 6 were (ρ', ω', ϕ') at $p_L = 440$, 560, and 730 MeV/c. This corresponds with the dip-peak structure in Fig. 1 if the dip is associated with ρ', and the peak with an unresolved but about equal mixture of ω' and ϕ'. This is the sort of striking sign reversal pointed out some time ago[7]: a smooth background of roughly constant phase (dashed line in Fig. 1) interfering with the negative ($I = 1$) and positive ($I = 0$) amplitudes for $\bar{p}p \to K^0K^0$. Depending on how much of the smooth background interferes with the resonances, the resonant cross section alone will be

$$\sigma(\bar{p}p \to K_S^0K_L^0) \approx 4 \text{ to } 10\ \mu\text{b}. \tag{1}$$

To consider the angular distribution for $\bar{p}p \to K_S^0K_L^0$, assume three main triplet amplitudes labeled by appropriate coefficients D_3, D_1, and S_1. In terms of Legendre polynomials $P_2(\cos\theta)$ and $P_4(\cos\theta)$,

$$\begin{aligned}
&\frac{d\sigma}{d\Omega} \sim A_0 + A_2P_2 + A_4P_4,\\
&A_0 = 7|D_3|^2 + 3|D_1|^2 + 3|S_1|^2,\\
&A_2 = 8|D_3|^2 + 3|D_1|^2 + 6\,\mathrm{Re}[S_1^*(\sqrt{7}\,D_3 - \sqrt{2}\,D_1)],\\
&A_4 = 6|D_3|^2 - \tfrac{36}{7}\mathrm{Re}[(\sqrt{7}D_3^*)(\sqrt{2}\,D_1)].
\end{aligned} \tag{2}$$

The rough variations of A_2/A_0 and A_4/A_0 are shown in Fig. 2, averaged again between Refs. 4 and 5. The curves just pass through all but one error bar in both sets of measurements, but A_4/A_0 is fairly uncertain and could, with about 10% confidence, be consistent with zero. No significant A_6 or higher terms have been reported.

Comparison of Eq. (2) with Fig. 2 makes it seem unlikely that the S_1 amplitude could contain the resonances, and that the interference term in A_2 must be non-negligible in order to give an average $A_2/A_0 = 1.6 > 1.0$ in this region. Beyond that, it is difficult to make any definite statement. The trend of A_4/A_0 is easiest to reproduce with resonant D_1 and a small D_3 background; but since significant $A_4 \neq 0$ occurs only at the highest momenta, additional interference terms may be of importance. Thus, the $K_S^0K_L^0$ angular data favor ^3D over ^3S for the (ρ', ω', ϕ') resonances if they are dominant, but just weakly favor $^3D_1$ over $^3D_3$.

Of course the absence of A_6 terms argues only against $^3G_3$ and not against $^3D_3$; as in low-energy nuclear physics, the maximum power of $\cos^2\theta$ present is the smaller of (J, L).

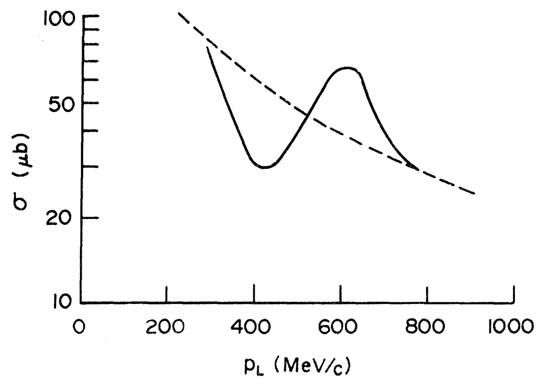

FIG. 1. Cross section for $\bar{p}p \to K_S^0 K_L^0$. The solid line is a simple average of the data from Refs. 4 and 5. The dashed line is a smoothed value, extrapolated from measurements at $p_L \gtrsim 1000$ MeV/c and summarized in Ref. 8.

2. The $\bar{p}p \to K^- K^+$ Data

Figure 3 shows the total cross section for $\bar{p}p \to \bar{K}K$, which is the sum[1,3,8] of $\sigma(\bar{p}p \to K^-K^+)$ and $\sigma(\bar{p}p \to K_S^0 K_L^0)$, the remaining cross section $\sigma(\bar{p}p \to K_S^0 K_S^0 + K_L^0 K_L^0)$ being experimentally zero in this region. The resonant part of the cross section is[7]

$$\sigma(\bar{p}p \to \bar{K}K) = 2\sigma(\rho' \to K_S^0 K_L^0) + 2\,|\,\sigma^{1/2}(\omega' \to K_S^0 K_L^0) + \sigma^{1/2}(\phi' \to K_S^0 K_L^0)|^2 . \tag{3}$$

The curve in Fig. 3 falls exactly into two peaks—a narrow one around 450 MeV/c, a broad one around 650 MeV/c—corresponding to the two terms in Eq. (3), if we draw a judicious dashed line for background. Their integrated areas are comparable, which implies that if the SU_3 coupling is predominantly F-type,[6] the ω' and ϕ' amplitudes in Eq. (3) are opposite in sign. If we assume that

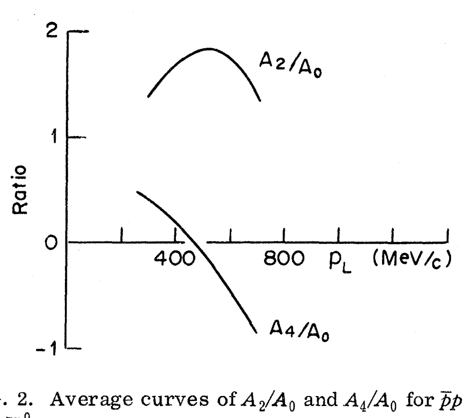

FIG. 2. Average curves of A_2/A_0 and A_4/A_0 for $\bar{p}p \to K_S^0 K_L^0$.

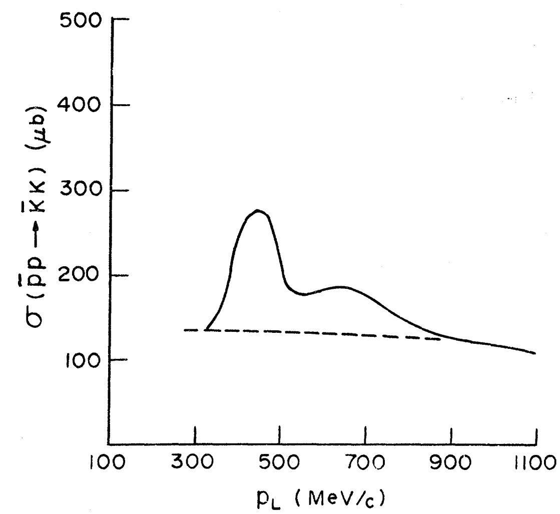

FIG. 3. Total cross section $\sigma(\bar{p}p \to \bar{K}K)$.

the large peak at $\rho' \to \bar{K}K$ represents maximal interference with background, then the resonant cross section alone would be

$$\tfrac{1}{2}\sigma(\rho' \to \bar{K}K) = \sigma(\rho' \to K_S^0 K_L^0) \approx 8\ \mu\text{b}, \tag{4}$$

which is compatible with Eq. (1) above. This value in combination with the resonance parameters of Ref. 6 indicates that $\Gamma_{\bar{K}K}/\Gamma_{\text{tot}} \approx 1\times10^{-3}$ for the ρ' resonance, with similar values for the ω' and ϕ'.

Angular distributions from K^-K^+ are much more significant than from $\bar{K}^0K^0$. The charged decay mode is much more immediately measurable, and the K^-K^+ cross section is several times larger than the $\bar{K}^0K^0$ throughout this region. It is therefore of interest to note that these distributions uniformly favor D_3 over D_1. For analysis it is appropriate not to try detailed curve fitting, but to rely on the simple fact[9] that for $\bar{N}N$ (triplet) $\to$ (two pseudoscalar), the angular distributions do not have very distinct bumps and wiggles in the intermediate angular range, but show forward and backward peaking with characteristic angular half-widths. For $^3D_1$ and $^3D_3$ these are, respectively, $\Delta\mu \gtrsim 0.4$ and $\Delta\mu \lesssim 0.2$, where $\mu = |\cos\theta|$.

The angular distribution in Ref. 1 is predominantly that for $\bar{p}p \to K^-K^+$ at the ρ' resonance; the backward peak shows $\Delta\mu \lesssim 0.2$ and is more likely to be free of interference effects than the forward peak. The angular distribution in Ref. 3 is folded and refers only to $p_L \approx 0.7$ GeV/c; it shows $\Delta\mu \approx 0.2$ also. This simple approach indicates $^3D_3$ as the only likely common J^P of the (ρ', ω', ϕ') system—if it exists and is dominant.

In conclusion it may be of interest to note that here we have had to assume considerable nonresonant background as well as the resonances; indeed, the resonance effects are generally visible only as interference with the background. An absolute bump of magnitude 8 μb would be difficult to extract experimentally.

The author wishes to thank Professor J. Button-Shafer and Professor R. R. Kofler for stimulating discussions.

†This work is supported in part through funds provided by the Atomic Energy Commission under Contract No. AT11-1-3069.

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Amplitudes and Model for πN Backward Scattering at 6 GeV/c

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(Received 24 October 1972)

Using reasonable assumptions concerning the s-channel helicity-nonflip amplitude $M_{++}^{3/2}$ of isospin $\frac{3}{2}$ in the u channel and the helicity-flip amplitude $M_{+-}^{1/2}$, we extract from the data at 6 GeV/c on πN backward scattering the remaining amplitudes. We find that the isospin-$\frac{3}{2}$ amplitudes can be described in a Regge-pole model with absorption. A description of $M^{1/2}$ amplitudes is given, using degenerate N_α and N_γ trajectories. The N_γ couplings are found to be fairly important, especially in the $M_{++}^{1/2}$ amplitude which then has to be strongly absorbed.

I. INTRODUCTION

Whereas a description of forward meson-baryon scattering in terms of Regge-pole exchanges with absorption is sufficiently well established so that refinements to it in terms of Regge-Regge cuts can be examined, backward scattering is still far from being understood. The question of which poles exactly contribute to πN backward scattering is not even resolved, despite the fact that $\pi N \to N\pi$ has been rather extensively studied, both theoretically and experimentally. Pion-nucleon backward scattering is described by isospin-$\frac{1}{2}$ and -$\frac{3}{2}$ exchange in the u channel. The isospin $\frac{1}{2}$ is very probably dominated by N_α exchange. What mechanism—wrong-signature nonsense zero or pole-cut interference—is responsible for the dip observed in the $\pi^+ p \to p\pi^+$ differential cross section is a problem which is not settled. Unanswered too is the question of the presence or absence of the N_γ trajectory in the isospin-$\frac{1}{2}$ amplitude. A very strong N_γ, besides the N_α, seems needed in pion backward photoproduction and $pp \to d\pi^+$ where no dip corresponding to the one in $\pi N \to N\pi$ is observed. What part the N_γ plays in πN backward scattering however is difficult to resolve as long as the dip mechanism is associated with the N_α trajectory. What is clear is that the isospin-$\frac{3}{2}$ amplitudes, which are the only ones contributing to $\pi^- p \to p\pi^-$, are dominated by Δ_δ exchange. However, there is discussion about whether the Δ_δ residue should change sign or not when it varies