DOE/ER/40427--17-N9

DE90 003334

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Received by OSTI

NOV 3 0 1989

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Few Body Problems in Physics (Few Body XII)

Vancouver, BC, July 1989

$^3P_0$ AND $^3S_1$ CONTRIBUTIONS TO $\bar{p}p \to \bar{\Lambda}\Lambda$*

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1. INTRODUCTION

We have proposed[1] a quark model for $\bar{N}N$ annihilation which consists of a linear superposition of the so-called $^3P_0$ (scalar) and $^3S_1$ (vector) models. We have argued that this approach is more consistent with QCD and the analogous NN system than the use of either model alone. Recent precise measurements[2] of the $\bar{p}p \to \bar{\Lambda}\Lambda$ reaction by the PS185 collaboration at LEAR provide a test of this model. An advantage of strange baryon production is the polarization information that can be obtained due to their weak decays. Spin effects are known to be more sensitive to details of the reaction mechanism. In this paper we present the results of distorted wave calculations for the production of $\bar{\Lambda}\Lambda$; distortion effects due to real and imaginary (absorptive) potentials in both initial and final states are included. Our results at $p_{lab} = 1.5075$ GeV/c and $p_{lab} = 1.564$ GeV/c show that the best fits to the differential cross section and polarization data are obtained with an interference between scalar and vector terms. The sensitivity of our results to the parameters of the $\bar{\Lambda}\Lambda$ potential indicates that this reaction may be used to provide information about the hyperon-antihyperon interaction, about which very little is known.

2. REACTION MECHANISM

One possible description of the $\bar{p}p \to \bar{\Lambda}\Lambda$ reaction is that of K- and K*-meson exchange.[3–6] Such exchanges are of short range, at distances for which quark effects might be expected to play a role. Therefore alternative descriptions[5,7–10] based on constituent quark dynamics have been developed. These models are based on either the $^3P_0$ model, in which a $\bar{u}u$ pair annihilation into the vacuum is followed by an $\bar{s}s$ creation, or the "$^3S_1$" model, in which a virtual vector quantum is exchanged. The simplest graphs for these models are shown in Fig. 1. We have proposed that the correct description for $\bar{N}N$ annihilation consists

* Supported in part by the U.S. Department of Energy

of a superposition of the $^3P_0$ and "$^3S_1$" mechanisms, since the former can arise from the confining scalar force and the latter describes the vector quantum exchange expected in the $\bar{N}N$ interaction.

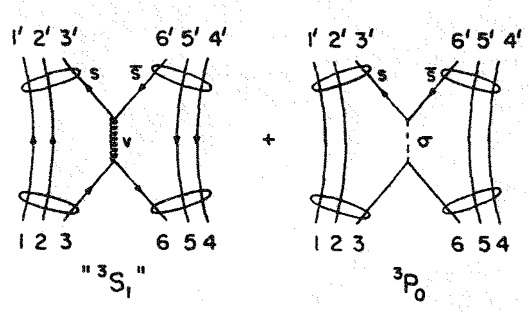

FIGURE 1
Lowest order diagrams for $\bar{p}p \to \bar{\Lambda}\Lambda$.

In our model, the operator for vector exchange is

$$I_v = g_v \, \sigma'_3 \cdot \sigma_3$$

and that for scalar exchange is

$$I_s = g_s \overleftarrow{\sigma}'_3 \cdot \left(\frac{\overleftarrow{\nabla}_{3'} - \overleftarrow{\nabla}_{6'}}{2m_s} \right) \overrightarrow{\sigma}_3 \cdot \left(\frac{\overrightarrow{\nabla}_3 - \overrightarrow{\nabla}_6}{2m} \right) ,$$

where m_s and m are the strange and up quark masses respectively. Our matrix element for the reaction is

$$\mathcal{M}_{\bar{p}p \to \bar{\Lambda}\Lambda} \sim \langle \Phi_{\Lambda\bar{\Lambda}}(1'2'3';4'5'6')\phi(1'2'3')\phi(4'5'6') | (I_v + I_s) | \phi(123)\phi(456)\Phi_{\bar{N}N}(123;456) \rangle ,$$

in which $\Phi_{\bar{\Lambda}\Lambda}$ and $\Phi_{\bar{N}N}$ are distorted waves and ϕ is a harmonic oscillator wavefunction.

3. INITIAL AND FINAL STATE INTERACTIONS

We used the same distorting potentials for $\bar{N}N$ and $\bar{\Lambda}\Lambda$ as Kohno and Weise.[5] For $\bar{N}N$ the real part of the potential is determined by G-parity transformation of the long-range part of a realistic one-boson exchange potential, with a smooth extrapolation to $r = 0$. The imaginary part, which represents annihilation, is of Gaussian form and is adjusted to produce good fits to experimental data. For the real part of the $\bar{\Lambda}\Lambda$ interaction Kohno and Weise use the isoscalar boson exchanges of the real part of the $\bar{N}N$ potential. The annihilation term is taken to be of the same form as that for the $\bar{N}N$, but with a strength adjusted to fit total cross section data.

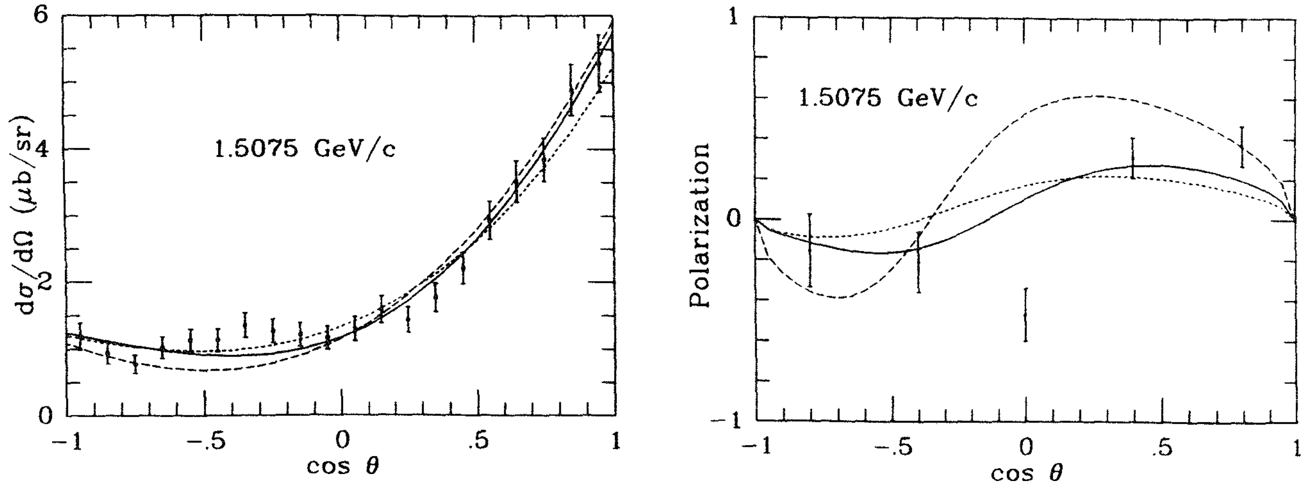

FIGURE 2
Differential cross section and polarization for $\bar{p}$ lab momentum of 1.5075 GeV/c. The long-dashed curve is the vector contribution (for r_0 = .65 fm) and the short-dashed curve is the scalar contribution (for r_0 = .56 fm). The solid curves are the result of a linear combination $(I_v - I_s)$, with g_v = -.19 g_s and r_0 = .89 fm.

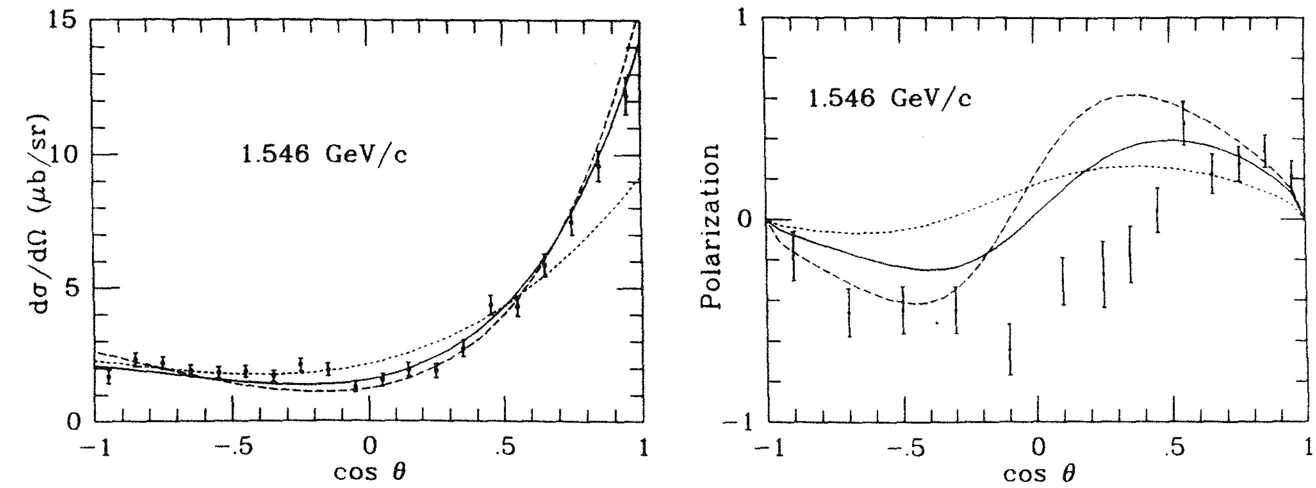

FIGURE 3
Differential cross section and polarization for $\bar{p}$ lab momentum of 1.564 GeV/c. The long-dashed curve is the vector contribution (for r_0 = .82 fm) and the short-dashed curve is the scalar contribution (for r_0 = .62 fm). The solid curves are the result of a linear combination $(I_v - I_s)$ with g_v = -.42g_s and r_0 = .98 fm.

4. RESULTS

Our results for differential cross sections and polarization at 1.5075 GeV/c and 1.564 GeV/c are shown in Figs. 2 and 3. Our best fits (minimum χ^2) to the experimental data[2] are shown for the scalar model alone, the vector model alone, and the superposition. For the scalar and vector models alone we searched on the oscillator radius r_0; for our superposition we searched on r_0 and the ratio g_v/g_s. As seen in Fig. 2, at the lower momentum the differential cross section can be fit reasonably well by either term alone or the superposition, but a much better fit to the polarization data is obtained by using the combined terms, with $r_0 = .89$ fm and $g_v/g_s = -.19$. At the higher momentum shown in Fig. 3 the vector term alone fits the differential cross section better than the scalar, but neither fits the polarization well. An improved fit is found by using the linear combination, with $r_0 = .98$, $g_v/g_s = -.42$. One characteristic of the polarization data that we, as well as other authors, have found difficult to fit is the crossing point, i.e. the angle at which the polarization changes sign.

Because not much is known about the $\bar{\Lambda}\Lambda$ interaction, we studied the effect of varying the strengths of the various components of the $\bar{\Lambda}\Lambda$ potential, which includes a real central term, an imaginary central term, and real spin-orbit and tensor terms. We found our results to be very sensitive to the strengths of all but the tensor term. For example we can obtain a much better fit to the polarization data at 1.546 GeV/c by turning off the real part of the central potential as shown in Fig. 4. Similar fits are found by changing the sign of the spin-orbit term, or by multiplying the strength of the imaginary part of the potential by a factor of 3. In each case the fit to the differential cross section is not as good at backward angles as we found with Weise's $\bar{\Lambda}\Lambda$ potential, but the overall χ^2 is still acceptable. This strong dependence of our results on the parameters of the $\bar{\Lambda}\Lambda$ interaction suggests that a fit to the reaction data at all available energies may provide us with information about the various components of this little-known interaction. Such a fit is now in progress.

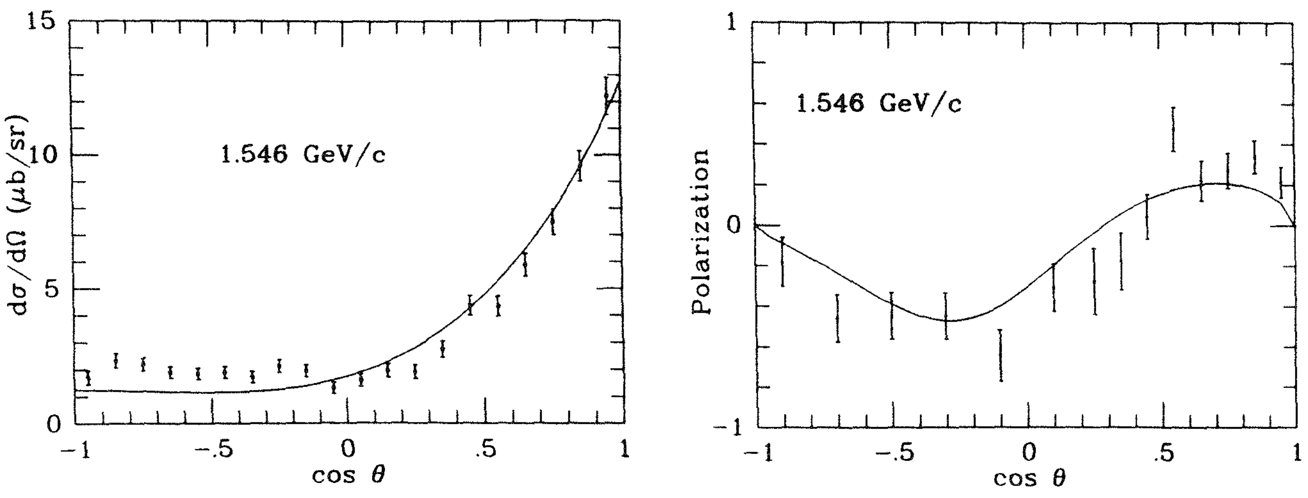

FIGURE 4
Differential cross section and polarization for $\bar{p}$ lab momentum of 1.564 GeV/c. The solid curves are found by keeping our best fit parameters of Fig. 3, but turning off the real part of the central term in the $\bar{\Lambda}\Lambda$ potential.

5. CONCLUSION

We have shown that the best fit to $\bar{p}p \to \bar{\Lambda}\Lambda$ at two energies occurs for an interference between scalar and vector mechanisms, rather than for either term alone. The sensitivity of our results to the parameters of the $\bar{\Lambda}\Lambda$ potential indicates that the $\bar{p}p \to \bar{\Lambda}\Lambda$ reaction may be a source of information on the $\bar{\Lambda}\Lambda$ interaction.

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