NUCLEON-ANTINUCLEON CHARGE-EXCHANGE SCATTERING USING U(6, 6) AND THE ABSORPTION MODEL*

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We present the results of a calculation, based on the absorption model with U(6, 6) symmetry imposed at the peripheral vertices, of the reaction $p+\bar{p}\to n+\bar{n}$ at 3.0, 3.6, 5.0, 6.0, 7.0, and 9.0 GeV/c. Agreement within the experimental errors is obtained at all energies for $-t\leq 0.6$ (GeV/c)^2. At larger momentum transfers there are discrepancies as expected for a peripheral-type model.

In this Letter we present calculations of nucleon-antinucleon charge-exchange scattering, $p+\bar{p}\to n+\bar{n}$. U(6, 6) symmetry at the vertices is used to write down the peripheral matrix elements for pseudoscalar and vector exchange,[1] and the absorption model is used to allow for the fact that there are many competing open channels available to the initial and final states.[2]

In a previous calculation on nucleon-antinucleon charge exchange[3] using the absorption model, only the contribution of the t-channel singularity nearest the physical region, the π pole, was considered. The results fit the experimental data for $0.1\ (\mathrm{GeV}/c)^2\leq -t\leq 0.6\ (\mathrm{GeV}/c)^2$ at 3.0 and 3.6 GeV/c. We consider the contributions of the two t-channel singularities closest to the physical region, the π and the ρ poles, and, of course, the interference between the two. Rather than use an arbitrary mixture of π- and ρ-exchange matrix elements which would be varied at will to fit the experimental data, we use the U(6, 6) symmetry scheme to fix uniquely the relative magnitude of each contribution. This use of U(6, 6) for vertex parts is in accordance with the suggestions of Salam, Delbourgo, and Strathdee in their original paper.[1] It is not in conflict with physical unitarity.[4] The absorption corrections are a deliberate attempt to incorporate some of the implications of unitarity in the peripheral model.

The U(6, 6) currents applicable to $p+\bar{p}\to n+\bar{n}$ are

$$J_5=g\left(1+\frac{2m}{S}\right)\frac{P^2}{4m^2}\left(\bar{N}\gamma_5N\right)_{D+\frac{2}{3}F},$$

$$J_\mu=g\frac{P_\mu}{2m}\left(1+\frac{q^2}{2Vm}\right)(\bar{N}N)_F+g\left(1+\frac{2m}{V}\right)\left(\bar{N}\frac{r_\mu}{4m^2}N\right)_{D+\frac{2}{3}F},$$

where N is the baryon of mass m, q is the four-momentum transfer, and S and V are the average masses of the pseudoscalar and vector nonets, respectively. The U(6, 6) coupling constant g is fixed by the known $g_{NN\pi}$ coupling constant, i.e.,

$$\frac{g_{NN\pi}{}^2}{4\pi}=\frac{g^2}{4\pi}\left(1+\frac{2m}{S}\right)^2\frac{25}{9}=14.9.$$

In the uncorrected peripheral model, the production amplitude corresponding to considering the effects of π and ρ exchange is

$$\varphi(E,\theta)=B_\pi(E,\theta)+B_\rho(E,\theta).$$

These terms are calculated using second-order perturbation theory and the helicity representation of Jacob and Wick.[5] [Here E = c.m. system energy and θ = c.m. system scattering angle.] There are five independent helicity amplitudes $\varphi_i(\theta)$ $(i=1,\cdots,5)$ to be constructed.

After the $\varphi_i(\ )$'s are expanded in a partial-wave series, the absorptive corrections are imposed using the technique suggested by Sopkovich,[6]

$$T_{\beta\alpha}{}^{j'}=(S_{\beta\beta}{}^j)^{1/2}T_{\beta\alpha}{}^j(S_{\alpha\alpha}{}^j)^{1/2},$$

where $T_{\beta\alpha}{}^{j'}$ is the partial-wave amplitude corrected for absorption, $T_{\beta\alpha}{}^j$ is the unmodified peripheral partial-wave amplitude, and $S_{\alpha\alpha}{}^j$ and $S_{\beta\beta}{}^j$ are the elastic-scattering amplitudes for the initial and final states, respectively. Assuming a Gaussian model of elastic scattering, we have

$$S_{\alpha\alpha}{}^j=1-Ce^{-j(j+1)/v^2p^2},$$

where j is the angular momentum, p is the c.m. system three-momentum of the initial particles, and v is the elastic radius of interaction of the particles in the channel α. The parameters C and v are determined from the elastic-scattering data of the particles in the channel α.

We make the plausible assumption that $p\bar{p}$ and $n\bar{n}$ elastic scattering are essentially identical. So we obtain

$$T_{\beta\alpha}^{\;j'} = \left(1 - Ce^{-j(j+1)/v^2p^2}\right) T_{\beta\alpha}^{\;j}.$$

When the partial-wave expansion, for each independent helicity amplitude, is summed using the modified partial waves, the modified production amplitudes are obtained.

For mass splitting in U(6, 6),[7,8] we use $S = 417$ MeV, the mean 0^- meson mass; $V = 850$ MeV, the mean 1^- meson mass; and $m = 938$ MeV. The physical masses were used for the exchanged particles. The elastic radius of interaction was taken to be $(0.188\ \text{GeV})^{-1}$ at 3.0 GeV/c, $(0.190\ \text{GeV})^{-1}$ at 3.6 GeV/c, $(0.193\ \text{GeV})^{-1}$ at 5.0 GeV/c, $(0.199\ \text{GeV})^{-1}$ at 6.0 GeV/c, $(0.202\ \text{GeV})^{-1}$ at 7.0 GeV/c, and $(0.207\ \text{GeV})^{-1}$ at 9.0 GeV/c.[9]

The results of our calculations are shown in in Figs. 1 and 2 in comparison with the experimental data, which are taken from Astbury et al.[10] and Czyzewski et al.[11] From Fig. 1 we note the following:

(i) By considering both π and ρ exchange, we see that the contribution from ρ exchange tends to fill in the dip, in the small momentum-transfer region, which one obtains by considering

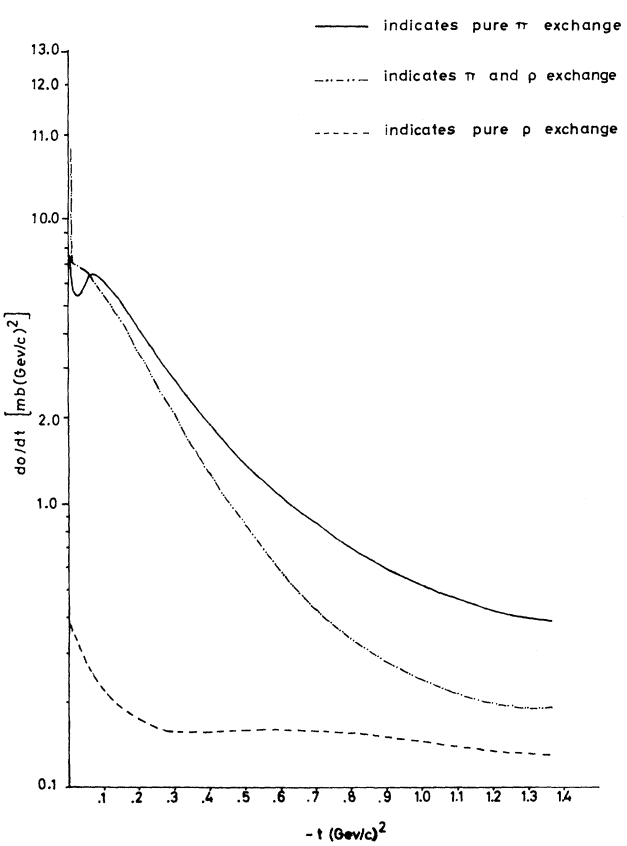

FIG. 1. The relative contributions of π and ρ exchange to the total momentum-transfer distribution for $p+\bar{p} \rightarrow n+\bar{n}$. These results were obtained at 3.0 GeV/c.

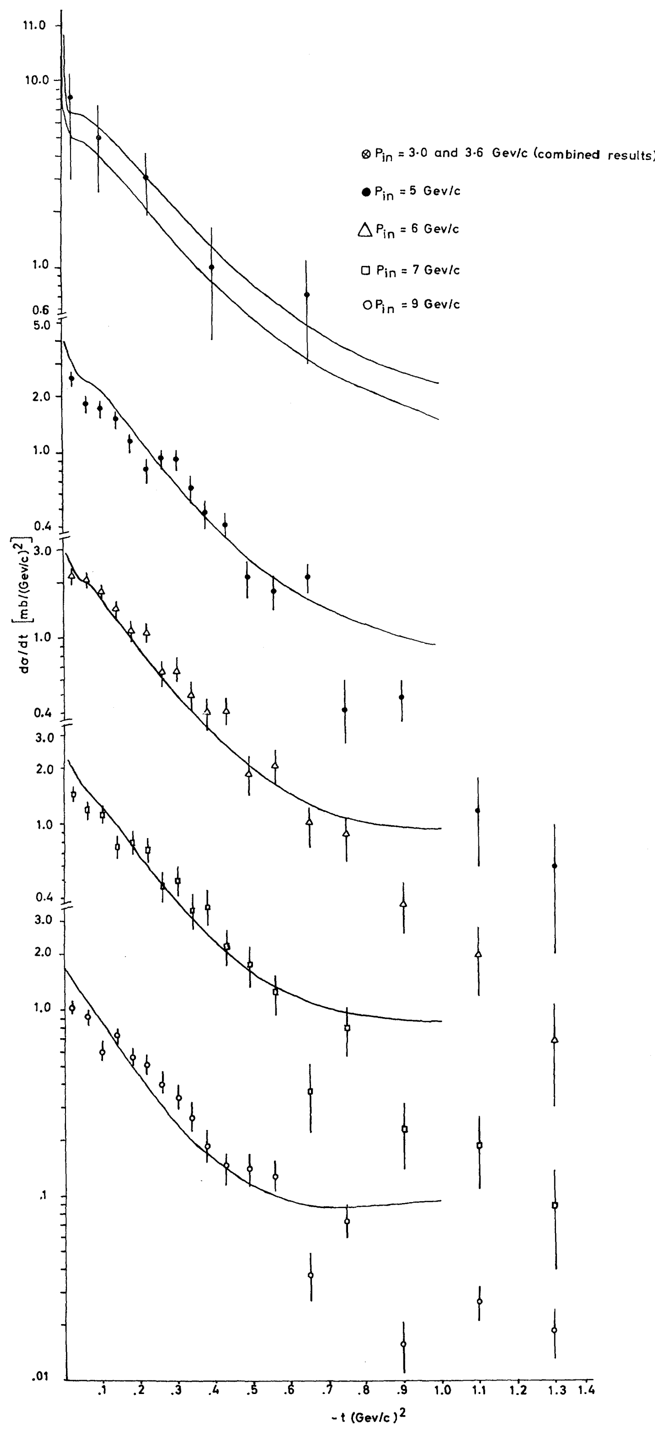

FIG. 2. The energy variation of the momentum-transfer distributions for $p+\bar{p} \rightarrow n+\bar{n}$.

just π exchange alone. This dip arises from the interference between helicity-flip and helicity-nonflip amplitudes.

(ii) Destructive interference between π and ρ exchange tends to decrease the result one would obtain from pure π exchange, in the larger momentum-transfer region.

Several interesting points should be noted about Fig. 2:

(i) The theoretical differential cross section does not shrink with an increase of the antiproton laboratory momentum, in agreement with experiment.

(ii) As the laboratory momentum of the incident antiprotons increases by a factor of 3 the magnitude of the forward differential cross section (theoretical) decreases by a factor of about 10, again in agreement with experiment.

We wish to emphasize that this fit to the data arises from the use of U(6, 6) symmetry and absorptive corrections. Since the coupling strength is taken from π-N scattering, there are no adjustable parameters in the model. The model also gives good agreement with experiment for $p+\bar{p}\rightarrow Y+\bar{Y}$ (to be published shortly).[7]

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COMMENTS ON MEASURING $\mathrm{Re}(A_2/A_0)$ IN THE DECAY $K_S^0\rightarrow\pi+\pi$

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Two recent experiments[1,2] have thrown interesting light on the phenomena of K^0 decay. In particular, these experiments yield knowledge about the imaginary part of A_2/A_0 where the amplitudes A_2 and A_0 were defined by Wu and Yang.[3]

It was pointed out in Ref. 3 that the real part of A_2/A_0 can only be obtained experimentally by measuring accurately the difference

$$\frac{R_S(+-)-2R_S(00)}{R_S(+-)+R_S(00)}=2\sqrt{2}\,\mathrm{Re}(A_2/A_0)\cos(\delta_2-\delta_0). \quad (1)$$

It was also pointed out[3] that electromagnetic corrections lead to small changes in the Clebsch-Gordan coefficients and in the phase shifts δ_2-δ_0. A partial estimation of the electromagnetic correction was given by Lee and Wu.[4] We give here an estimate of the electromagnetic correction to Eq. (1) and discuss the feasibility of measuring $\mathrm{Re}(A_2/A_0)$.