A COMPARISON OF K[±]N CHARGE EXCHANGE REACTIONS

AT 8.5 AND 13 GeV/c *

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ABSTRACT

The cross sections for the line reversed reaction pairs $K^{\dagger}n \rightarrow K^{0}p$, $K^{-}p \rightarrow \overline{K}^{0}n$, $K^{+}p \rightarrow K^{0}\Delta^{++}$ and $\overline{K}^{-}n \rightarrow \overline{K}^{0}\Delta^{-}$ have been determined with high statistics and good relative normalization at 8.36 and 12.8 GeV/c in a spectrometer experiment at SLAC. The cross sections for the K^{+} induced reactions are larger than for the K^{-} , contrary to the expectations of weakly exchange degenerate Regge pole models. The ratio of the reaction cross sections is about the same as at lower energies and shows little change with momentum transfer.

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The dominant t-channel exchanges for the reactions

$$K^{\dagger}n \rightarrow K^{O}p$$
 (1a)

$$\overline{K} p \rightarrow \overline{K} n$$
 (1b)

are the ρ and A_2 trajectories. Simple weakly exchange degenerate Regge pole models¹ predict that the cross sections for these two reactions should be equal. Previous detailed comparisons of (1a) and (1b) have determined that the ratio of the K⁺ to K⁻ total cross section is essentially constant from 3 to 6 GeV/c at a value of about 1.3.^{2,3}

The situation for the reactions

$$K^{+}p \rightarrow K^{0}\Delta^{++}(1236)$$
 (2a)

$$K^{-}n \rightarrow \overline{K}^{0}\Delta^{-}(1236)$$
 (2b)

is similar; the cross section ratio for this pair has been observed at 4 and 6 GeV/c and is greater than for reactions (1). 3

This letter describes a comparison of the reactions pairs (1) and (2) at 8.36 and 12.8 GeV/c with high statistics and good relative normalization.

The experiment was performed using the downstream spectrometer of the large aperture solenoid spectrometer (LASS) at SLAC.⁴ An rf separated kaon beam was incident upon a 90 cm long liquid deuterium target. The production of a K^o was detected via the $K_s^o \rightarrow \pi^+\pi^-$ decay mode using the wire spark chambers and scintillation counter hodoscopes in the spectrometer .

Reactions (1) and (2) were identified by means of the distribution in missing mass squared (MM^2) recoiling against the K^O. The K^O sample was defined by assuming the particles to be pions and then requiring the two particle effective mass to be in the interval (.478 - .518) GeV (Fig. 1a). The MM² calculated for these events is shown for the 8.36 GeV/c K⁺ data in Fig. 1b, the distributions for the other charge and energy being similar except for poorer resolution

at the higher energy. Fermi motion did not significantly affect the MM² resolution for the momentum transfer region being studied.

The number of events for the reactions of interest was obtained by fitting a four component function to the MM^2 distribution for each t' = t-t_{min} interval, where t is the four momentum transfer from the incident kaon to the final state kaon. The four components represented (a) the nucleon recoil signal. (b) the Δ recoil signal, (c) the nonresonant background from the process $KN \rightarrow K^{O}X$. and (d) the non- K^0 background resulting from the absence of particle identification in the experiment. Specifically, a gaussian resolution function was used to describe the nucleon peak, and a p-wave Breit-Wigner broadened by the resolution function for the Δ line shape.⁵ The contribution from multiparticle production and nonresonant background was parametrized by a smooth function for (1 < MM^2 < 3) GeV². The small background from non-K⁰ events within the K⁰ mass region was eliminated by subtracting events from control regions on either side of the K⁰ mass cut (see Fig. 1a). This four component function provided a good description of the K^+ and K^- data at both energies, with only three variable parameters. The χ^2 per degree of freedom of these fits averaged 1.0 and in all cases was less than 1.8.

Isospin invariance was used to obtain the number of events for the reactions (2) from the measured Δ signal, which included contributions from both target protons and neutrons. The number of nucleon and Δ events obtained in each t' interval was corrected for geometric acceptance, absorption by the material in the spectrometer and pion decay losses as determined by a Monte Carlo simulation of the spectrometer characteristics. Corrections for track reconstruction efficiency (12%), logic deadtime (1%), beam particle decays (5%) and H₂ and HD contamination of the liquid deuterium (3%) were also applied. The losses due to the unseen decay modes of the K⁰ were evaluated using .6867 for the K⁰_S $\rightarrow \pi^+\pi^-$ decay branching fraction.⁶ In the case of reactions (1), the measured differential cross sections were corrected for the suppression of events at small t' $(|t'| < 0.1 \text{ GeV}^2)$ caused by the Pauli exclusion principle. This correction was computed assuming no spin flip contribution to the cross section and a deuteron form factor calculated from the Hulthen wave function.

The measured differential and total cross sections are presented in Table I. The total cross sections were obtained by integrating the differential cross sections up to $|t'|=1.0 \text{ GeV}^2$. The total cross section uncertainties include all systematic effects which we estimate to be about 11%. The differential cross section uncertainties in Table I do not include the systematic errors. We estimate that the uncertainty in the relative normalization between the reactions in each pair (1) and (2), is 4% at each beam momentum.

The observed differential cross sections show a change of slope, or turnover, in the forward direction which indicates substantial spin flip amplitudes. The forward dip for pair (2) is seen to be significantly greater than for pair (1).

The ratio of the K^+ to K^- total cross sections for reactions (1) is 1.37±.22 at 8.36 GeV/c and 1.38±.09 at 12.8 GeV/c, where the errors include the relative systematic error. These results are plotted in Fig. 2a and indicate no energy dependence of the ratio from 3 to 13 GeV/c. We discuss the s dependence of these reactions in terms of this ratio because this experiment, as well as the lower energy Argonne experiments, ^{2, 3} was designed to measure both reactions in the same apparatus with the same analysis procedures, thus minimizing the relative error in the cross section measurements. A fit of the form $R^N(p_{lab}) = Ap^n_{lab}$ to the data in Fig. 2a yields the values $A = 1.28 \pm 0.13$ and $n = 0.014 \pm 0.060$. The shaded region in Fig. 2a shows the one standard deviation error band for this fit. The ratio for the differential cross sections

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for the high statistics 12.8 GeV/c data is shown in Fig. 2b and reveals no substantial t' dependence.

The corresponding results for reactions (2a) and (2b) is shown in Figs. 3a and 3b. A fit of the form Ap_{lab}^{n} to our data and the Argonne data of Ref. 3 gives the values A = 1.55 ± 0.38 and n = -0.02 ± 0.11 , with the one standard deviation error band shown in Fig. 3a. For this reaction pair we find no dependence of the cross section ratio on s and a ratio consistent with no dependence on t'.

These results are in clear contradiction to the predictions of simple weakly exchange degenerate Regge models. More importantly, they severely restrict any modifications to such models since most interpretations of the observed behavior, such as nondegenerate ρ -A₂ trajectories or lower lying trajectories, predict a ratio that approaches unity as s increases, a behavior we do not observe. The lack of t' dependence, if confirmed by better measurements in the forward direction, would suggest that the degeneracy breaking mechanism is present in both the helicity flip and nonflip amplitudes.

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- A detailed description of the spectrometer and data analysis may be found in: M.G.D. Gilchriese, Ph.D. dissertation, Stanford University (1977); M.G.D. Gilchriese <u>et al.</u>, to be published.
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BW(M) =
$$\frac{M}{P} \frac{\Gamma(M)}{(M_0^2 - M^2)^2 + M_0^2 \Gamma^2(M)}$$

with a mass dependent width

$$\Gamma(\mathbf{M}) = \Gamma_0 \left(\frac{\mathbf{P}}{\mathbf{P}_0}\right)^3 \frac{\rho(\mathbf{M})}{\rho(\mathbf{M}_0)}$$

where P is the magnitude of the momentum of the decay products in the center of mass frame for a particle of mass M, P_0 is the corresponding value for a particle of mass M_0 , the central value of the resonance, and $\rho(M) = \left\{am_{\pi}^2 + P^2\right\}^{-1}$, a=1.3 as given by M. Gell-Mann and K. Watson, Ann. Rev. Nucl. Sci. <u>4</u>, 219 (1954). The Δ mass region was restricted to $MM^2 \leq 2.0 \text{ GeV}^2$. If the upper limit were 3.0 GeV² the cross sections would increase by about 15%. The terms used in the fit were essentially of the same form as described in G. W. Brandenburg <u>et al.</u>, Phys. Rev. D 15, 617 (1977).

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		8.36	<u>GeV/c</u>				12.8 G	eV/c	
tt "	×+		K.	; t	t t	×+		K.	
GeV ²	к [†] п→К ^о р	[*] ⁺ ^{p→} K ⁰ Δ ⁺⁺	K [−] p→K ⁰ n	K [−] n→K ⁰ ∆ [−]	GeV	к⁺п→к°р	k ⁺ p→K ⁰ Δ ⁺⁺	K [−] p+K ⁰ n	K [−] n→K ⁰ Δ [−]
0.0 -0.04	386±77	144±57	263±69	144±51	0.0 -0.02	191±42	63±30	107±41	31±26
0.04-0.08	380±40	329±52	250±35	340±40	0.02-0.04	192±23	82±21	152±22	75±19
0.08-0.12	326±39	367±44	215±36	355±59	0.04-0.08	212±14	156±14	169±13	110±11
0.12-0.16	205±36	372±54	188±37	271±42	0.08-0.12	160±11	169±12	108±10	122±11
0.16-0.22	261±35	257±42	135±29	202±41	0.12-0.16	135±11	179±12	109±10	103±10
0.22-0.30	124±25	177±31	118±27	146±33	0.16-0.22	113± 8	123± 8	83± 7	74± 7
0.30-0.50	72±19	75±20	84±20	98±24	0.22-0.30	73± 5	67± 6	49± 5	46± 5
0.50-1.0	13±13	17±17	14±14	18±18	0.30-0.50	34± 3	45± 3	28± 2	26± 3
					0.50-1.00	5.9±1.1	11± 1	2.6± 1	7± 1
σ _T (μb)	98±14	102±16	72±12	97±16	ЧD	50.2±5.8	50± 6	36.3±4.4	32± 4
Slope, B	4.6±0.8	5.9 ± 1.1	4.4±1.1	4.3±1.0	Slope, B	5.3±0.3	4.6±0.2	5.7±0.3	4.7±0.4
Events	394±23	492±35	255±20	427±30	Events	1745±48	2492±77	1215±42	1517±62

Table I. The differential and total cross sections in $\mu b/GeV^2$. The slope parameter B was determined by a fit to $Ae^{-B|t'|}$ for .12 < |t'| < 1.0 GeV².

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FIGURE CAPTIONS

- .4.a) The two-pion effective mass distribution at 12.8 GeV/c showing the K^O region. Events in the regions labelled "background sample" were used to estimate the background under the K^O. (b) The MM² distribution for K⁺ at 8.36 GeV/c K⁺ showing the proton and Δ signals.
 - 2. (a) The energy dependence of the ratio

$$\mathbf{R}^{N}(\mathbf{p}_{lab}) = \left\{ \sigma_{T}(\mathbf{K}^{\dagger}\mathbf{n} \rightarrow \mathbf{K}^{O}\mathbf{p}) / \sigma_{T}(\mathbf{K}^{\dagger}\mathbf{p} \rightarrow \mathbf{\bar{K}}^{O}\mathbf{n}) \right\}$$

The shaded area represents the one standard deviation envelope for a fit of the form Ap_{lab}^{n} . (b) The t' dependence of the ratio

$$\mathbb{R}^{N}(t') = \left\{ (d\sigma/dt') \ (K^{+}n \to K^{0}p)/(d\sigma/dt') \ (K^{-}p \to \overline{K}^{0}n) \right\} \text{ at } 12.8 \text{ GeV/c.}$$

3. (a) The energy dependence of the ratio

$$\mathbf{R}^{\Delta}(\mathbf{p}_{lab}) = \left\{ \sigma_{\mathbf{T}}(\mathbf{K}^{+}\mathbf{p} \to \mathbf{K}^{0}\Delta^{++}) / \sigma_{\mathbf{T}}(\mathbf{K}^{-}\mathbf{n} \to \mathbf{\bar{K}}^{0}\Delta^{-}) \right\}$$

The shaded area is as in Fig. 2a. (b) The t' dependence of the ratio

$$\mathbf{R}^{\Delta}(\mathbf{t}^{\prime}) = \left\{ (\mathrm{d}\sigma/\mathrm{d}\mathbf{t}^{\prime}) \; (\mathbf{K}^{+}\mathbf{p} \to \mathbf{K}^{0}\Delta^{++}) / (\mathrm{d}\sigma/\mathrm{d}\mathbf{t}^{\prime}) \; (\mathbf{K}^{-}\mathbf{n} \to \mathbf{\overline{K}}^{0}\Delta^{-}) \right\}$$

at 12.8 GeV/c.



Fig. 1



Fig. 2



