COMPARING $\bar{p}p \to \pi^-\pi^+$ AND $\bar{p}p \to K^-K^+$*

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A partial wave amplitude analysis of $\bar{p}p \to \pi^-\pi^+$ and $\bar{p}p \to K^-K^+$ has been performed for data obtained at LEAR in the range $p_{\rm lab} = 360$ - 1000 MeV/c. For $\bar{p}p \to \pi^-\pi^+$ partial wave amplitudes with $J = 0$, 1, 2, and 3 are required, while for $\bar{p}p \to K^-K^+$ amplitudes with $J = 0$, 1, and 2 are sufficient to fit the data in this energy range.

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The reactions $\bar{N}N \to \pi\pi$ and $\bar{N}N \to KK$ are two of the more basic annihilation and subsequent hadronization reactions. Therefore data on these reactions may reveal details of the underlying mechanisms and clarify the nature of the degrees of freedom necessary to describe these short range hadronic processes. Recent low energy data from the CERN Low Energy Antiproton Ring [LEAR] for both reactions [1] for $d\sigma/d\Omega$ and A_{on} show a rather rich angular dependence which changes rapidly with increasing energy. The recent data agree with earlier data [2–5] at corresponding momenta, but the LEAR data cover a much wider momentum range and have smaller error bars. Our aim in analyzing these data is to extract information about the annihilation mechanism.

In both reactions there are only two helicity amplitudes. So far two observables $d\sigma/d\Omega$ and $A_{\rm on}$ have been measured. Therefore any analysis has ambiguities unless a third spin-observable like A_{ss} or A_{ls} is measured preferably at the same set of LEAR-energies. This would require polarized beam and target. It is not likely that experiments with polarized antiprotons

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will be feasible at present. A standard method to avoid ambiguities in such a case is to make use of some theoretical input. We are in a bind here, because the theory of this process is very poorly known. Parity conservation requires that the orbital angular momentum L of the $\bar{p}p$ initial state is different from the orbital angular momentum J of the two-meson final state. This requires the $\bar{p}p$ spin to be S = 1. Since only spin triplet angular momentum states are allowed, the number of parameters in the analysis is restricted considerably. As mentioned above, ambiguities arise because only two observables have been measured. However, it turns out that even from an analysis which uses only the data of two observables, and no theoretical input, very interesting physical requirements can be extracted. In particular the analysis shows which angular momenta are necessary and sufficient.

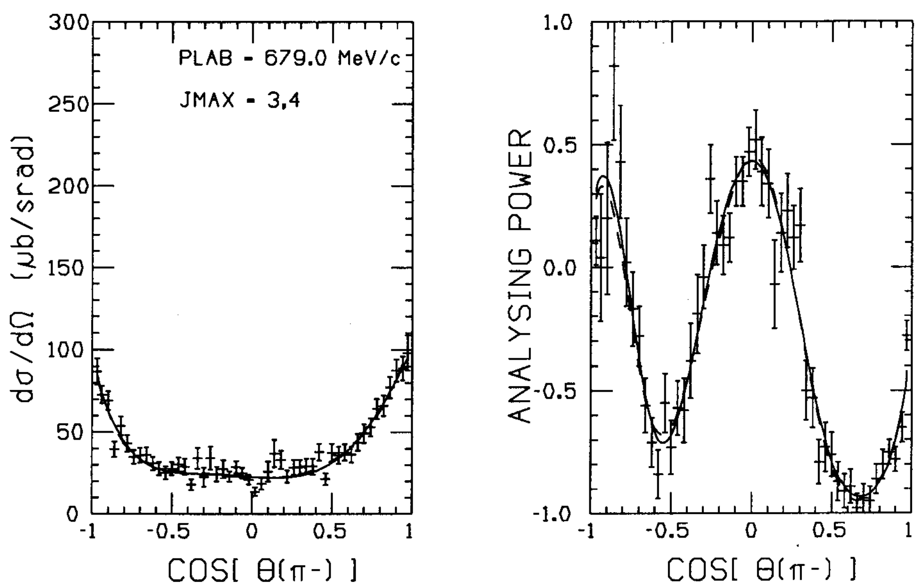

Fig. 1. $d\sigma/d\Omega$ and A_{on} at $p_{lab} = 679$ MeV/c for $\bar{p}p \to \pi^-\pi^+$. The solid curves give the fit for $J_{max} = 3$ and the dashed curves are the fit for $J_{max} = 4$.

We find that the present data for $\bar{p}p \to \pi^-\pi^+$ starting from $p_{lab} = 360$ MeV/c up to 1 GeV/c, can be fitted with partial wave amplitudes with total angular momentum $J \leq 3$. At the same time the data for the reaction $\bar{p}p \to K^-K^+$ require only angular momentum less or equal to $J = 2$. As an example, fits at $p_{lab} = 679$ GeV/c for both reactions $\bar{p}p \to \pi^-\pi^+$ and $\bar{p}p \to K^-K^+$ are shown in Figs. 1 and 2, respectively. The corresponding χ^2 per degree of freedom are shown in Tables I and II for all measured momenta including 679 MeV/c. In the same table the values of χ^2 are

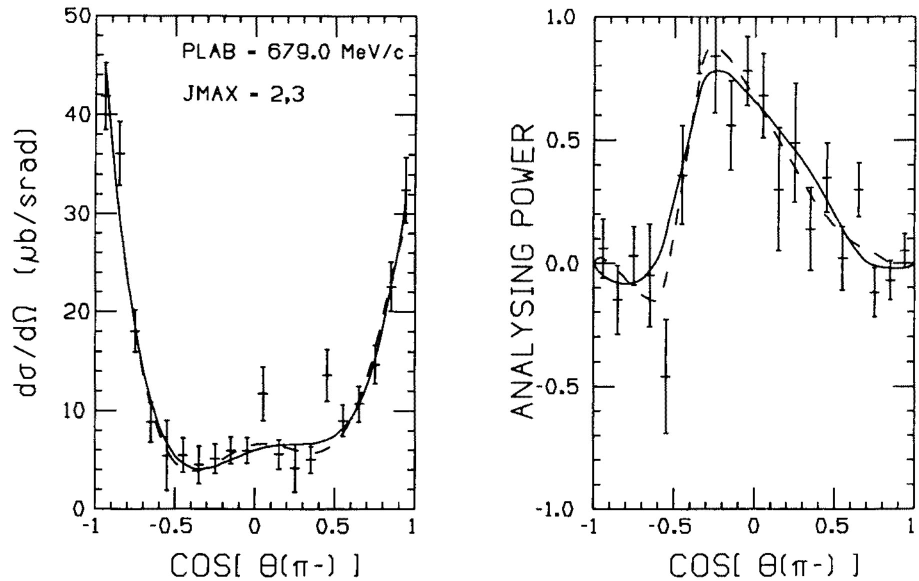

Fig. 2. $d\sigma/d\Omega$ and A_{on} at $p_{lab} = 679$ MeV/c for $\bar{p}p \rightarrow K^-K^+$. The solid curves give the fit for $J_{max} = 2$ and the dashed curves are the fit for $J_{max} = 3$.

given for smaller and larger sets of partial waves, where J_{max} is the highest partial wave included. From the values of χ^2 for $\bar{p}p \rightarrow \pi^-\pi^+$ in Table I one concludes that the fits do not improve beyond $J_{max} = 3$. From Table II, which shows the values of χ^2 for $\bar{p}p \rightarrow K^-K^+$ one concludes that for this reaction the fits do not improve beyond $J_{max} = 2$. These findings put constraints on theoretical descriptions of these annihilation processes, which present models [6–8] do not seem to satisfy.

The fact that very few partial waves are needed in the analysis, indicates that both annihilations are very central processes. The annihilation into K^-K^+ may occur in an even smaller volume than the annihilation into $\pi^-\pi^+$. It should be kept in mind that even at these low energy $\bar{p}$ momenta, the final center of mass momenta of both the $\pi^-\pi^+$ and K^-K^+ channels are very similar. The very few partial wave amplitudes required by data put stringent constraints [9] on possible model descriptions of these basic annihilation reactions.

TABLE I

Values of χ^2 per degree of freedom for $\pi^-\pi^+$ at momenta below 1 GeV/c

$p_{\rm lab}$ (MeV/c)	$\chi^2(J_{\rm max}=1)$	$\chi^2(J_{\rm max}=2)$	$\chi^2(J_{\rm max}=3)$	$\chi^2(J_{\rm max}=4)$
360	2.56	1.96	1.77	1.74
404	2.18	1.38	1.12	1.12
467	5.75	1.98	1.31	1.18
497	8.38	3.04	1.50	1.45
523	8.16	2.63	1.45	1.43
585	10.5	1.96	1.51	1.57
679	15.3	2.17	1.50	1.53
783	21.9	2.50	1.49	1.47
886	21.7	3.21	1.23	1.13
988	24.0	4.39	1.85	1.55

TABLE II

Values of χ^2 per degree of freedom for K^-K^+ at momenta below 1 GeV/c

$p_{\rm lab}$ (MeV/c)	$\chi^2(J_{\rm max}=1)$	$\chi^2(J_{\rm max}=2)$	$\chi^2(J_{\rm max}=3)$	$\chi^2(J_{\rm max}=4)$
360	2.26	0.93	0.97	0.95
404	2.32	1.23	1.40	1.44
467	1.90	1.00	1.13	0.92
497	3.81	1.40	1.02	1.03
523	4.70	1.03	0.72	0.80
585	3.25	0.95	0.98	0.79
679	3.42	1.44	1.53	1.52
783	6.92	2.45	2.41	2.22
886	5.08	1.59	1.37	1.30
988	4.73	2.80	1.06	1.20

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