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INTERFERENCE EFFECTS IN THE REACTION
$K^+p \rightarrow KN\pi$ AT 1.2 BeV/c

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Interference Effects in the Reaction $K^+p \rightarrow KN\pi$ at 1.2 BeV/c*

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ABSTRACT

Substantial interference has been observed between N^* and K^* production in 1.2-BeV/c $K^+ - p$ interactions.

Many reactions involve production of three-body final states in which two or all three of the possible particle pairs can be decay products of resonant states. Interference effects at the crossings of bands representing these resonances in a Dalitz plot have been considered previously, particularly in connection with the consequences of Bose statistics,[1] as for example in the reaction $K^- + p \rightarrow Y^{*\pm} + \pi^\mp \rightarrow \Lambda^0 + \pi^+ + \pi^-$. More recently Goldhaber et al. have reported evidence of constructive interference at the crossing of K^* and N^* bands in the reaction $K^+ + n \rightarrow K^+ + p + \pi^-$ at 2.3 BeV/c incident momentum;[2] and Friedman et al. have found sizeable constructive interference for the same resonances in the reaction $K^- + p \rightarrow K^- + \pi^+ + n$ at 1.45 BeV/c.[3] In the present paper, we report evidence for very substantial interference between the $K^*(891)$ and $N^*(1236)$ in the reactions

$$K^+ + p \rightarrow K^0 + p + \pi^+ \qquad \text{(2908 events)} \qquad (1)$$

and

$$K^+ + p \rightarrow K^+ + p + \pi^0 \qquad \text{(1104 events)} \qquad (2)$$

at an incident momentum of 1.2 BeV/c. The Dalitz-plot populations for (1) and (2) can be well accounted for by a model in which the K^* and N^* amplitudes are assumed to have phase variations over the Dalitz plot given by the appropriate Breit-Wigner terms, and in which the overall phase difference between the K^* and N^* amplitudes is determined by a best fit to the data.

The data were obtained in an exposure of the Lawrence Radiation Laboratory's 25-in. hydrogen bubble chamber to a separated K^+ beam at the Bevatron.[4] The sample for reaction (1) includes events with and without a visible K_1^0 decay. The film was measured principally with

the Berkeley Flying-Spot-Digitizer System.

The Dalitz plots for reactions (1) and (2) are shown in Fig. 1. It is particularly apparent in the $K^0 p\pi^+$ Dalitz plot that the population in the K^* - N^* overlap region greatly exceeds the sum of the individual N^* and K^* bands. To exhibit this interference effect more clearly, we have plotted in Fig. 2(a) the K-π invariant-mass distributions for events lying in two equally wide bands of $p\pi^+$ mass squared ($1.35 < M^2_{p\pi} < 1.55$ and $1.59 < M^2_{p\pi} < 1.79$ BeV^2) chosen to cross the K^* band at conjugate points.[5] The lower of these $p\pi$ mass bands is centered on the actual N^* peak, and the upper one is on the tail of the N^*. Subtraction of one of these distributions from the other leads to the histogram in Fig. 2(b). If there were no interference effect, the K^* peak should have been completely subtracted out in Fig. 2(b), and the distribution should be symmetric about the midpoint of the K-π mass range. In fact, there is a large excess of events in the K^* region, from which we conclude that substantial constructive interference occurs at the crossing of the N^* and K^* bands. We can express the magnitude of the effect and its statistical significance in the following more quantitative terms. If we consider the N^* and K^* overlap region--$1.35 < M^2_{p\pi} < 1.55$, $0.73 < M^2_{K\pi} < 0.83$ BeV^2--we find that in reaction (1) this region contains 576 events, whereas in the absence of interference one would expect 391 ± 24 events from the populations of the appropriate mass-conjugate regions of the Dalitz plot, leading to a net enhancement of 185 ± 34 events. Similarly in reaction (2), the overlap region contains 209 events, whereas only 145 ± 14 are expected, the enhancement being then 64 ± 20 events. These numbers completely rule out the possibility that the observed interference effect can be a statistical fluctuation. It is worth noting that if these enhancements

are indeed to be associated with $N^* - K^*$ interference, their ratios in reactions (1) and (2) are expected to be 3/1, in excellent agreement with the data.

We have attempted to interpret the Dalitz-plot populations just discussed in terms of the superposition of coherent N^* and K^* amplitudes and an incoherent "phase-space" background. Thus, the population is assumed to be given by

$$P = \left| A(N^*) \exp(i\phi_0) + A(K^*) \right|^2 + \text{phase space}, \qquad (3)$$

where ϕ_0 is an overall phase difference determined by fitting to the experimental data. We have represented the N^* amplitude by the lowest partial wave of the ρ-exchange magnetic-dipole amplitude,[6] a P-wave having the form

$$A(N^*) \sim (\underset{\sim}{q} \times \underset{\sim}{q}') \cdot (2\underset{\sim}{p} + i(\underset{\sim}{\sigma} \times \underset{\sim}{p})) \quad BW(N^*). \qquad (4)$$

Here $\underset{\sim}{q}$, $\underset{\sim}{q}'$ are the incident proton and outgoing N^* momenta respectively in the overall center of mass, $\underset{\sim}{p}$ is the decay-proton momentum in the N^* rest system, and $BW(N^*)$ is the product of a Breit-Wigner term by a barrier factor,

$$BW(N^*) = \frac{1}{(\omega^2 - \omega_0^2) + i\omega_0\Gamma} \; \frac{p}{[1 + (pR)^2]^{1/2}}, \qquad (5)$$

where ω is the $p\pi$ mass, ω_0 the resonance value of 1.236 BeV, Γ the mass-dependent width taken to be 0.120 BeV at resonance, and R a radius of interaction taken to be equal to $(m_\pi)^{-1}$.[7] For the K^* we have taken the P-wave term for a simple choice of vector exchange amplitude:[8]

$$A(K^*) \sim (\underset{\sim}{q} \times \underset{\sim}{q}' \cdot \underset{\sim}{p}) \quad BW(K^*), \qquad (6)$$

where $\underset{\sim}{q}$, $\underset{\sim}{q}'$ are the incident K and outgoing K^* momenta respectively, $\underset{\sim}{p}$ is the decay kaon momentum in the K^* rest system, and $BW(K^*)$ is the K^* Breit-Wigner term. The values of ω_0, Γ, and R for the K^* are taken as 0.891 BeV, 0.050 BeV, and zero, respectively. With these amplitudes, we have fitted the Dalitz-plot populations in reactions (1) and (2) using the magnitudes of the N^* and K^* amplitudes, the amount of phase-space background, and the overall phase angle ϕ_0 as variables to be optimized by the fit. Although the assumed form (3) is too simple to account for all details of the experimental distributions, it provides a satisfactory interpretation of the observed interference effect, as can be seen from Fig. 2 in which the curves are based on the fit to the Dalitz plot of reaction (1). The parameters for the independent fits to reactions (1) and (2) are given in Table I. The uncertainties given in the Table have been assigned generously to take account of the simple nature of the model used here. One cannot rule out the possibility that a more sophisticated analysis would shift the angle ϕ_0 and the interference and background contributions outside the quoted limits, although it appears improbable that the N^* and K^* intensities would change significantly. It is of interest to note that the ratios of N^* and of K^* in the two channels are 4.3 ± 1.1 and 1.3 ± 0.35 respectively, in reasonable agreement with the expected ratios of 4.5 and 2.0 based on isotopic-spin conservation. It should also be noted that while the constructive interference observed in the K^* - N^* overlap region is quite large, it is compensated in part by destructive interference in other regions of the Dalitz plot. Thus the overall enhancement in the $K^0 p \pi^+$ cross section is only $\sim 0.3 \pm 0.2$ mb. We have considered the possibility that the interference effect observed here could be related to the peak in the K^+p total cross section at 1.2

BeV/c recently observed by Cool et al.[9] We find, however, that the interference effect discussed here is not in itself large enough to account for the observed rise in the cross section at 1.2 BeV/c.

Given the substantial interference at 1.2 BeV/c described in this paper, one may ask whether such interference in the same channels occurs at higher momenta. Unfortunately, as the primary momentum increases, one can expect increasing difficulty in observing the interference, because the overlap region becomes a smaller fraction of the overall Dalitz plot, and because higher partial waves enter into the N^* and K^* production with resulting dilution of the expected effects. We have tried nevertheless to fit samples of 400 events of reaction (1) at 1.36 BeV/c and 706 events of reaction (1) at 1.58 BeV/c.[10] We find the fits to the Dalitz-plot populations to be substantially improved by inclusion of an interference term with the phase angle ϕ_0 taken about equal to that measured at 1.2 BeV/c.

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FOOTNOTES AND REFERENCES

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Table I. Phase angle and cross sections.[a]

Channel	ϕ_0 (rad)	N^* (mb)	K^* (mb)	Interference (mb)	Background (mb)	$\sigma(Kp\pi)$[b] (mb)
$K^0p\pi^+$	0.7 ± 0.2	2.9 ± 0.3	0.87 ± 0.14	0.3 ± 0.2	1.0 ± 0.3	5.1 ± 0.3
$K^+p\pi^0$	1.0 ± 0.3	0.67 ± 0.15	0.66 ± 0.12	-0.06 ± 0.15	0.7 ± 0.15	2.0 ± 0.2

a. The absolute cross sections were normalized to the value $\sigma_{tot} = 18.3 \pm 0.1$ mb given by Cool et al. (reference 9).

b. For completeness, we give also $\sigma(K^+n\pi^+) = 0.56 \pm 0.10$ mb.

FIGURE LEGENDS

Fig. 1. Dalitz plots for the reactions (a) $K^+ + p \rightarrow K^0 + p + \pi^+$ and (b) $K^+ + p \rightarrow K^+ + p + \pi^0$.

Fig. 2. (a) Distributions of $K^0\pi^+$ mass squared corresponding to the bands of $p\pi^+$ mass squared, $1.35 < M^2_{p\pi^+} < 1.55$ BeV^2 and $1.59 < M^2_{p\pi^+} < 1.79$ BeV^2, for the reaction $K^+ + p \rightarrow K^0 + p + \pi^+$. (b) Difference of the two distributions.

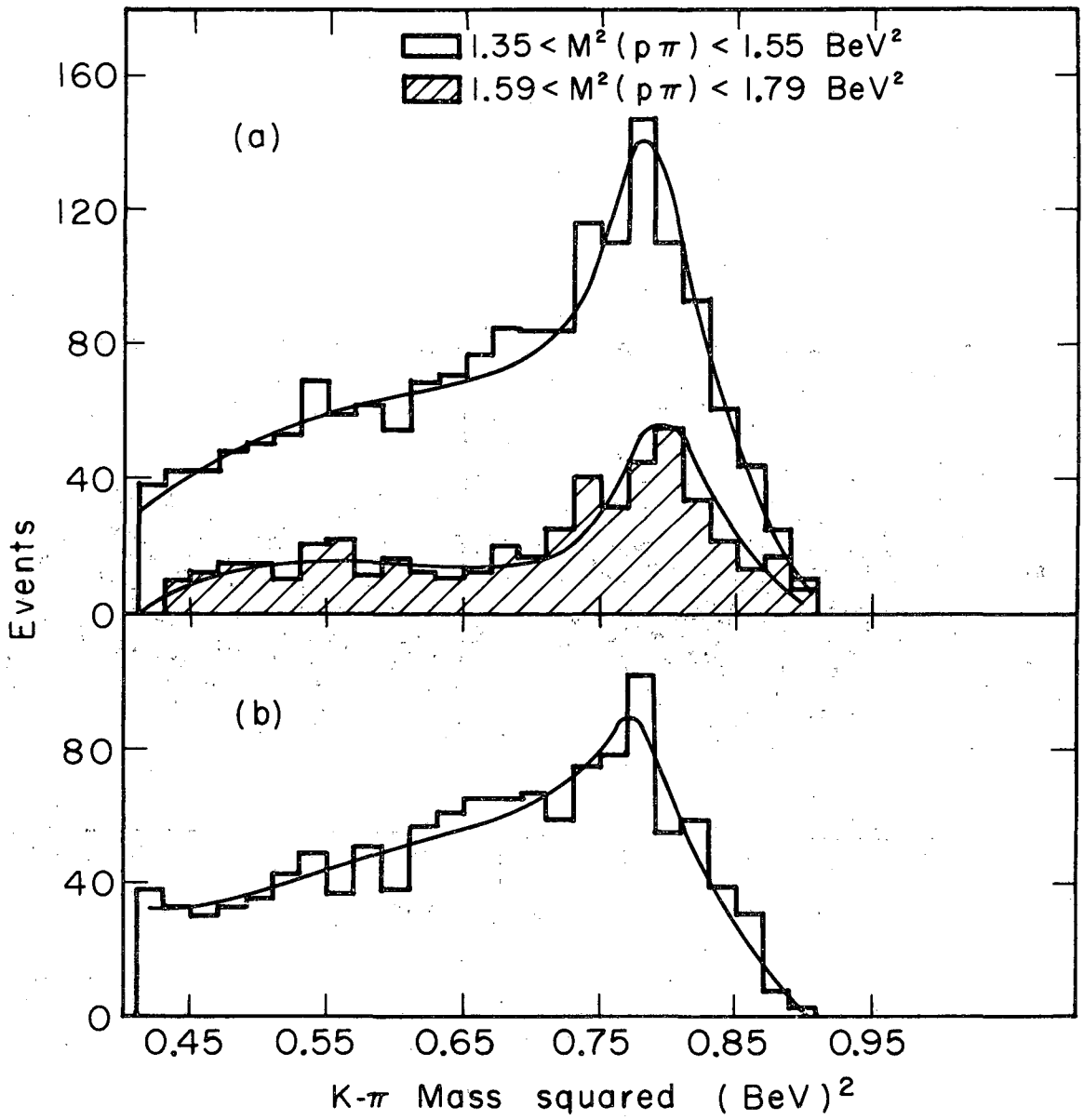

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Fig. 1

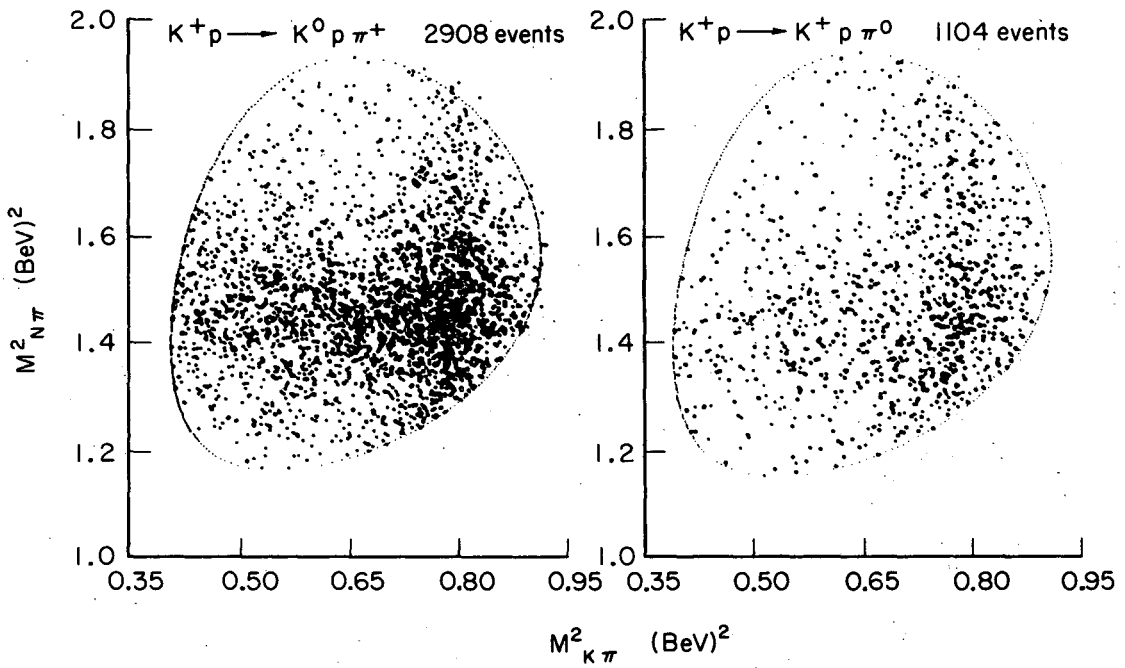

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Fig. 2

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