EVIDENCE FOR AN ISOSPIN-$\frac{1}{2}$ $K\pi$ ENHANCEMENT AT A MASS OF 1160 MeV PRODUCED IN K^-n INTERACTIONS AT 3.9 GeV/c*

David J. Crennell, Uri Karshon,† Kwan Wu Lai, John S. O'Neall, and J. Michael Scarr
Physics Department, Brookhaven National Laboratory, Upton, New York 11973
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We report the observation of an isospin-$\frac{1}{2}$ $K\pi$ enhancement at a mass of 1160 ±10 MeV with a width of 90 ± 30 MeV from the reaction $K^-n \rightarrow K_1^0\pi^-n$ at 3.9 GeV/c.

Two peaks in the $K\pi$ mass spectrum between the well-known $K_{1/2}*(890)$ and $K_{1/2}*(1400)$ resonances have been reported from the reaction $K^+p \rightarrow pK_1^0\pi^+$.[1] One is at 1080 MeV,[2] the other at 1260 ± 20 MeV.[3] The 1080-MeV $K_1^0\pi^+$ peak is observed mainly at an incident K^+ momentum of 3.5 GeV/c. Events in this peak also form the $N_{3/2}*(1238)^{++}$ in the π^+p mass combination. This interference [between the possible $K_1^0\pi^+$ effect and the $N_{3/2}*(1238)^{++}$ resonance] and the limited statistics inhibit any conclusion on the existence of a $K\pi$ resonance in this mass region. Evidence for the $K_1^0\pi^+$ peak at 1260 MeV is seen in a $K_1^0\pi^+$ mass distribution [with the $N_{3/2}*(1238)$ events removed] compiled from four experiments with incident K^+ momenta between 3 and 3.5 GeV/c. However, there is no strong indication of this peak from any one experiment with the possible exception of the one at 3.0 GeV/c. In addition to these observations from production experiments, a pole extrapolation attempt has been made[4] for the $K\pi$ interaction from the reaction $K^+p \rightarrow N_{3/2}*(1238)^{++}K^+\pi^-$ at 7.3 GeV/c via a single-pion-exchange model. To the extent that the model is valid the result of this attempt suggests a broad $K\pi$ enhancement at a mass of 1.1 GeV and a width of the order of 400 MeV.

In this Letter we report an isospin-$\frac{1}{2}$ $K\pi$ enhancement at a mass of 1160 ± 10 MeV and a width of 90 ± 30 MeV from the reaction $K^-n \rightarrow K_1^0\pi^-n$ at 3.9 GeV/c, an experiment with more than twice as many events as any other single reported experiment with a similar final state. However, we have not seen evidence for the previously reported $K\pi$ effects at 1080 and 1260 MeV.

The Brookhaven National Laboratory (BNL) 80-in. liquid-deuterium bubble chamber was exposed to a separated beam of 3.9-GeV/c K^- mesons. A partial analysis[5] of this exposure yields the following[6]:

Reaction	Number of events	Number of pictures analyzed
(1) $K^-n \rightarrow K_1^0\pi^-n$	3044[a]	~200 000
(2) $K^-n \rightarrow K^-\pi^-p$	201	~12 000

[a]Visible K_1^0 decays only.

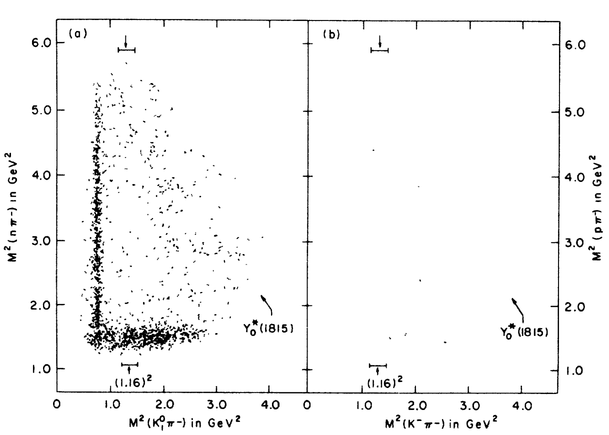

FIG. 1. (a), (b) Dalitz plots of final states for Reactions (1) and (2), respectively.

Figure 1(a) is the Dalitz plot for the $K_1^0\pi^-n$ final state from Reaction (1). The $K_{1/2}*(890)^-$ and the $N_{3/2}*(1238)^-$ are immediately obvious; the $Y_0*(1815)^0$ appears as a 45° band indicated on the plot. $K_{1/2}*(1400)^-$ is also produced in the reaction. In addition to these well-established resonances, the $K_1^0\pi^-$ mass projection (Fig. 2) shows an enhancement of about 5 standard deviations around 1.16 GeV. It is also evident from the Dalitz plot that the 1.16-GeV $K\pi$ enhancement occurs in the $N_{3/2}*(1238)^-$ band as well as in the $Y_0*(1815)$ band. This point is illustrated in Figs. 2(b) and 2(c) where the $K\pi$ mass projections are shown for the two halves of the Dalitz plot in which the K_1^0 goes forward or backward with respect to the $K\pi$ system. The 1.16-GeV enhancement occurs in both halves and although it is strengthened in the forward direction because of strong interference with the $N_{3/2}*(1238)$, there is still a significant signal in the backward direction. Therefore, it is unlikely that the $K\pi$ effect is manifested by peculiar decay angular distributions of the $N_{3/2}*(1238)^-$ and $Y_0*(1815)^0$ at exactly the same $K\pi$ mass (1.16 GeV). A more natural interpretation of this enhancement is to

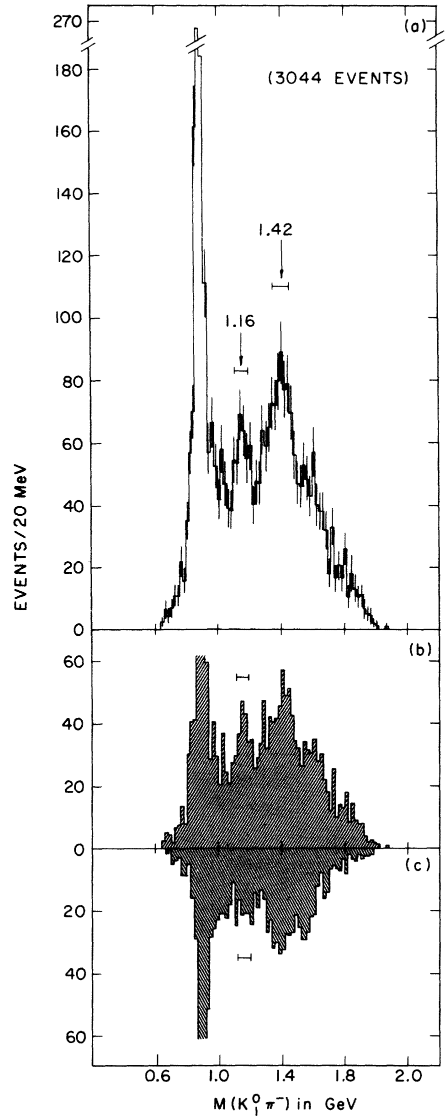

FIG. 2. (a) The $K_1^0\pi^-$ mass spectrum in Reaction (1). (b), (c) The $K_1^0\pi^-$ mass plots in Reaction (1) for the halves of the Dalitz plot in which the K_1^0 goes forward and backward with respect to the $K\pi$ system, respectively (see text for details).

assume a $K\pi$ resonance at 1.16 GeV. Although this $K\pi$ amplitude is relatively weak in this reaction, constructive interference with the strong $N_{3/2}^*(1238)^-$ and the $Y_0^*(1815)^0$ strengthens its intensity. This interpretation is further substantiated by examining the final state $K^-\pi^-p$ in which no strong $K\pi$ effect at 1.16 GeV is observed [see Fig. 1(b)] inside or outside the $N_{3/2}^*(1238)^0$ region.[7] It is interesting to note that we observe neither the 1080- nor the 1260-MeV $K_1^0\pi$ mass peaks in Fig. 2. It is also evident that these peaks are not seen in events either inside [Fig. 2(b)] or outside [Fig. 2(c)] the $N_{3/2}^*(1238)^-$ "mass band" as reported by other experiments.[2,3] It may be possible that the nature of the interference can cause these relatively weak $K\pi$ amplitudes at 1080 and 1260 MeV, if they exist, to be obscured at our energy.[8]

Assuming that there are three $K_1^0\pi$ resonances in the final state (1), a fit to the $K_1^0\pi^-$ mass spectrum yields the mass for this new $K\pi$ enhancement as 1160 ± 10 MeV, and masses 891 ± 2 and 1416 ± 10 MeV for the $K_{1/2}^*(890)$ and $K_{1/2}^*(1400)$, respectively.[9] These latter values are in good agreement with established values.[10] We obtain a width for this new $K\pi$ enhancement of 90 ± 30 MeV. This value is extremely sensitive to the shape assumed for the background in this mass region. The large error quoted here allows for this uncertainty. We now consider the isospin (I) and spin and parity (J^P) of this enhancement, assuming that it is indeed a resonance.

Isospin. – If I is $\frac{3}{2}$, then charge independence implies that $K^-n \to [(K^-\pi^-)_{3/2}p]/[(\bar{K}^0\pi^-)_{3/2}n] = 9$, becoming 27 after correction for the visible $\bar{K}^0$'s. However most of the $K\pi$ enhancement is due to interference with the $N_{3/2}^*(1238)^-$ and $Y_0^*(1815)^0$ bands. After calculating the relative interference rates for the $K^-\pi^-p$ final state and allowing for the track length difference, we expect at least 35 ± 4 events in the crossing regions of Reaction (2) and observe only 9 ± 3 events [see Fig. 1(b)], thus indicating an $I = \frac{1}{2}$ assignment.

Spin and parity. – Strong interference of this $K\pi$ enhancement with the $N_{3/2}^*(1238)^-$ and the $Y_0^*(1815)^0$ complicate the analysis. An attempt has been made to study J^P with and without events in these two baryon resonances using the moments method[11]; structures in the coefficients of the moments do show up in the $K_{1/2}^*(890)$ and $K_{1/2}^*(1400)$ mass regions, whereas the absence of structure in the 1.16-GeV region may indicate spin 0 for this object. Note that only the $J^P = 0^+, 1^-, 2^+, 3^- \cdots$ series is allowed by the strong decay to two pseudoscalar mesons.

In summary, we have seen evidence for an isospin-$\frac{1}{2}$ $K\pi$ enhancement at a mass of 1160 ± 10 MeV and a width of 90 ± 30 MeV. Further analysis of the $K^-\pi^-p$ final state is in progress in order to understand the production amplitudes for $Y_0^*(1815)\pi^-$ and $N_{3/2}^*(1238)K^-$ without the complication of this $I = \frac{1}{2}$ $K\pi$ amplitude, so that a detailed study of the spin and parity for this enhancement may be possible in the final state $K^0\pi^-n$.

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[2]W. de Baere, J. Debaisieux, P. Dufour, F. Grard, J. Heughebaert, L. Pape, P. Peeters, F. Verbeure, R. Windmolders, Y. Goldschmidt-Clermont, V. P. Henri, B. Jongejans, A. Moiseev, F. Muller, J. M. Perreau, A. Prokeš, and V. Yarba, Nuovo Cimento 51A, 401 (1967).

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[5]Events with a neutral V and one charged prong with no visible spectator or with a spectator proton of less than 6 cm were measured to study Reaction (1). A small sample of three-prong events with no neutral V were measured for Reaction (2). The events were measured on the Brookhaven flying-spot digitizer and analyzed with the Brookhaven QLOD system of programs, the selection on competing hypotheses being made from a fit to the measured ionization and the usual χ^2 value from the kinematic fit. Events for which there were insufficient or no measurements of ionization available were examined visually.

[6]Since we are interested in the reactions of K^- on quasifree neutrons, the proton from the deuteron is not mentioned in these reactions. Only those events for which the spectator proton was emitted with momentum less than 0.2 GeV/c were accepted for this analysis. Unseen spectators were assumed to have measured momentum components 0 ± 0.05 GeV/c for the purpose of fitting. The reactions with four-constraint kinematic fits then yielded a momentum spectrum for all spectator protons in good agreement with the Hulthén wave function.

[7]If the $K\pi$ enhancement in Reaction (1) were due to irregularities in the decay distribution of the $N_{3/2}^*(1238)^-$ and $Y_0^*(1815)^0$, then a similar enhancement of about the same intensity would be seen in Reaction (2) from the same sample of film. [The $Y_0^*(1815)^0 \to K^- p$ would be 3 times stronger since all K^-'s are visible, while the $N_{3/2}^*(1238)^0 \to \pi^- p$ would be 3 times weaker.]

[8]The interference between the $K\pi$ amplitude and the strong baryon resonant amplitudes may depend on the incident energy. Hence, it is possible that the intensity and position of the enhancement may vary within one width [see for instance R. H. Dalitz and D. H. Miller, Phys. Rev. Letters 6, 562 (1961)]. Consequently it would be difficult to distinguish this $K\pi$ enhancement at 1160 ± 10 MeV from the 1080-MeV and (1260 ± 20)-MeV effects. However, we noted earlier that this 1160-MeV $K\pi$ enhancement appears in both the $N_{3/2}^*(1238)^-$ and $Y_0^*(1815)^0$ bands, and it is unlikely that these two separate interferences should occur at the same $K\pi$ mass.

[9]The fit assumes no interference of the resonances with each other or with the background. This simple assumption is used to locate the various peaks in the distribution; the mass values are insensitive to the amount of background assumed.

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[11]In this analysis, the coefficients A_n of the angular distribution $I(X) = \sum A_n P_n(X)$ are calculated, where P_n is the nth Legendre polynomial and X is the cosine of the $K^- \to K_1^0$ scattering angle in the $K\pi$ c.m. system. The coefficients are given by $A_n \pm \Delta A_n = (n+\frac{1}{2})[\Sigma P_n] \pm (n+\frac{1}{2})[\Sigma P_n^2]^{1/2}$, where the sum is over all the events.