per pulse. A dimuon version of this experiment, designed to increase significantly the high-mass dilepton data, is now in progress at Fermilab.

In summary, we have established a signal of massive dileptons above 5 GeV. A statistically significant clustering near 6 GeV suggests the existence of a narrow resonance.[9] The data are in good agreement with a color-added parton model although the broad transverse-momentum behavior is not predicted by the model.

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[8]An equivalent but cruder check is made by noting that the "continuum" background near 6 GeV and within the cluster width is ~ 4 events. The probability of observing 12 events is again $\lesssim 2\%$.

[9]We suggest the name Υ (upsilon) be given either to the resonance at 6 GeV if confirmed or to the onset of high-mass dilepton physics.

Evidence for a New Strangeness-One Pseudoscalar Meson*

G. W. Brandenburg,† R. K. Carnegie,‡ R. J. Cashmore, § M. Davier,‖ W. M. Dunwoodie, T. A. Lasinski, D. W. G. S. Leith, J. A. J. Matthews,¶ P. Walden,** and S. H. Williams

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

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The $J^P = 0^-$ partial waves of the $K\pi\pi$ system in the reactions $K^\pm p \to K^\pm \pi^+\pi^- p$ at 13 GeV are presented. Structure in intensities and relative phase variations suggest the existence of a pseudoscalar resonance, the K', with a mass of ~ 1400 MeV and a width of ~ 250 MeV decaying predominantly into ϵK.

The observation of pseudoscalar resonances is of fundamental importance to our understanding of the meson spectrum. Within the quark model[1] higher-mass recurrences of these states can occur only as radial excitations of the $L=0$ $q\bar{q}$ system. Evidence[2] for radial excitations in the meson system is provided by the ρ' and the ψ', although each of these states could have an alternative assignment in the $L=2$ $q\bar{q}$ supermultiplet. In this paper we present results which suggest the existence of a pseudoscalar, strangeness-one resonance, the K', with a mass in the vicinity of 1400 MeV.

The data on which these results are based were obtained in a spectrometer experiment studying the reactions $K^\pm p \to K^\pm\pi^+\pi^- p$ at 13 GeV. The salient features of the experiment[3-5] are high statistics, good resolution, K-π identification, and $K^\pm$ relative normalization uncertainty of $\pm 2\%$. We have described previously[3,4] the principal $J^P = 1^+$ and 2^+ partial waves[6] of the $K^\pm\pi^+\pi^-$ system. In addition to isolating a small, but clear, $K^*(1420)$ signal, we presented evidence for the existence of two axial-vector mesons, Q_1 with a mass of ~ 1300 MeV and Q_2 at ~ 1400 MeV.

As they are germane to our discussion of the

0^- waves, we briefly summarize certain features of these $J^P=1^+$ states. Although their total widths are comparable, they appear to have quite different production and decay properties. The production of Q_1 obeys approximate s-channel helicity conservation, and it seems to decay principally to ρK. In contrast, Q_2 production satisfies approximate t-channel helicity conservation, while its dominant decay mode is $K^*\pi$. The evidence for these different decay modes rests, in part, on the observed phase variations of the 1^+ ρK waves relative to 1^+0^+ $K^*\pi$: a forward motion of $\sim 70°$ for $1.20 \lesssim m(K\pi\pi) \lesssim 1.35$ GeV and a backward motion of $\sim 50°$ for $1.35 \lesssim m(K\pi\pi) \lesssim 1.45$ GeV. In addition, the 1^+ ρK mass spectra peak only in the region of 1300 MeV. We infer from these observations that the *absolute* phase of the 1^+ ρK waves has a Breit-Wigner variation in the 1300-MeV region but is slowly moving by 1400 MeV. On the other hand, the absolute phase of the 1^+0^+ $K^*\pi$ wave, associated with the Q_2 meson, would be rapidly moving in the 1400-MeV region. Since we are discussing the possibility of a 0^- resonance in the vicinity of 1400 MeV, it is clearly preferable that the reference wave exhibit limited phase motion in this region. Thus, for the results presented in this Letter, we use the 1^+0^+ ρK wave as the reference wave.

In Figs. 1(a) and 1(b) we show the 0^-0^+ ϵK cross section and relative phase as measured *with respect to* 1^+0^+ ρK. Cross sections for ambiguous solutions,[3] present only in the K^- data at low $K\pi\pi$ mass, are shown by crosses in those cases where they differ significantly from the highest-likelihood solutions. For $K\pi\pi$ masses where either the displayed wave or the reference wave is small in intensity, the relative phase measurement becomes unreliable and is not shown. The K^+ and K^- data both exhibit a broad (~ 250 MeV) bump at about 1400 MeV. The points above 1.6 GeV were obtained with the wave set of Ref. 3. While they indicate that all the 0^- waves are decreasing in this region, the qualification must be made that higher spin waves are becoming important beyond 1.6 GeV. Nevertheless a preliminary study of our data in the L region [$1.6 < m(K\pi\pi) < 2.0$ GeV] with an extended wave set indicates that all the 0^- waves have decreased in intensity by ~ 1.7 GeV.

The corresponding results for the 2^+1^+ $K^*\pi$ wave are shown in Figs. 1(c) and 1(d). The curves indicate the d-wave Breit-Wigner line shape and phase variation for the $K^*(1420)$,[2] and it is clear that the data are consistent with the expected behavior. In Figs. 1(a) and 1(b) the curves correspond to an s-wave Breit-Wigner parametrization with a mass of 1400 MeV and a width of 250 MeV.[7] Both the 0^-0^+ ϵK and the 2^+1^+ $K^*\pi$ waves are well described by these parametrizations for intensity and phase. This is strongly suggestive of a resonance interpretation for the 0^-0^+ ϵK wave.

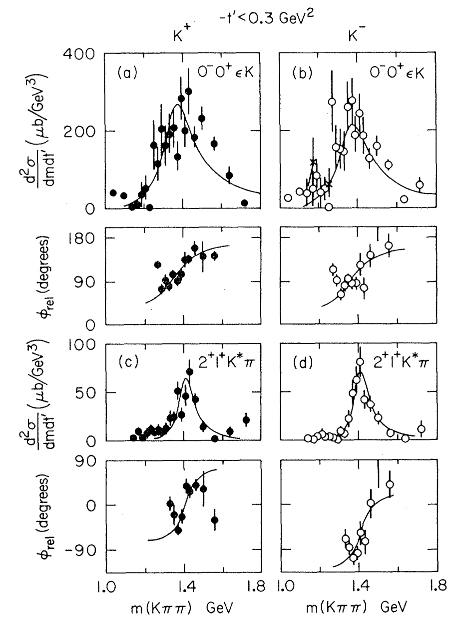

FIG. 1. The mass dependence of the 0^-0^+ ϵK and the 2^+1^+ $K^*\pi$ waves. Crosses correspond to ambiguous solutions, and $\varphi_{\rm rel}$ is measured with respect to the 1^+0^+ ρK wave. The curves correspond to simple Breit-Wigner parametrizations.

We turn next to the other significant 0^- partial waves.[8] In contrast to 0^-0^+ ϵK, the 0^-0^+ $K^*\pi$ wave [Figs. 2(a) and 2(b)] is already large by ~ 1.23 GeV and reveals some indication of a two-peak structure. While the lower-mass peak at ~ 1.23 GeV is of roughly the same strength in both K^+ and K^-, the K^+ intensity is greater than that for K^- in the 1.3–1.5-GeV mass region. This two-peak structure is similar to that for 1^+0^+ $K^*\pi$,[3] except that for the latter the higher-mass peak is stronger for K^- than for K^+. The relative phase measured with respect to 1^+0^+ ρK decreases by $\sim 60°$ for $1.23 \lesssim m(K\pi\pi) \lesssim 1.35$ GeV, where the 1^+ ρK system resonates, and increases by $\sim 50°$ for $1.35 \lesssim m(K\pi\pi) \lesssim 1.56$ GeV. We tentatively interpret these observations in terms of a two-component description of the 0^-0^+ $K^*\pi$ wave: a "Deck" background approximately constant in phase and peaking in intensity near 1.23 GeV together with a resonance contribution at ~ 1.4 GeV.

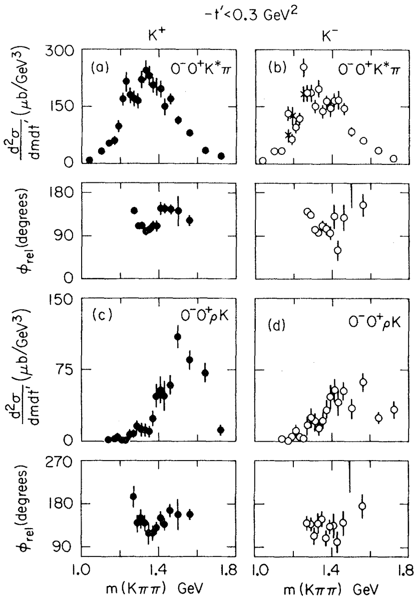

FIG. 2. The mass dependence of the 0^-0^+ $K^*\pi$ and the 0^-0^+ ρK waves. Crosses correspond to ambiguous solutions, and $\varphi_{\rm rel}$ is measured with respect to the 1^+0^+ ρK wave.

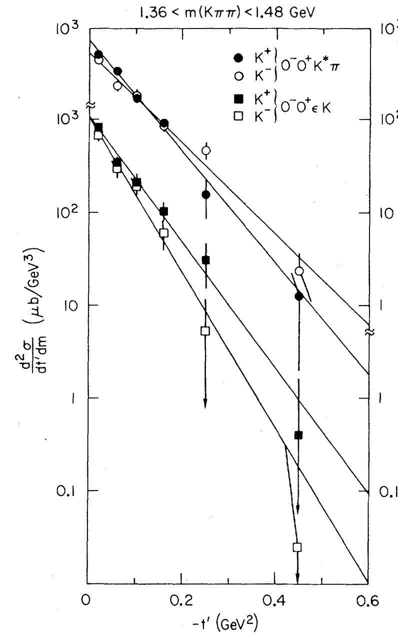

FIG. 3. The momentum transfer dependence of the 0^-0^+ $K^*\pi$ and 0^-0^+ ϵK waves. The lines are exponentials with the parameter values given in Table I.

The 0^-0^+ ρK wave [Figs. 2(c) and 2(d)] is about 30% the size of the 0^-0^+ ϵK wave in intensity and appears to peak at a somewhat higher $K\pi\pi$ mass. However, since its phase relative to 1^+0^+ ρK shows some forward motion in the 1.4-GeV region, we would conclude that the 0^- resonance may couple weakly to ρK.

The momentum transfer (t') dependence of the 0^-0^+ $K^*\pi$ and 0^-0^+ ϵK waves is shown in Fig. 3. The distributions for these waves are considerably steeper than those for the 1^+0^+ $K^*\pi$ waves.[4] Parameter values from fits to the data with the expression $A\exp(bt')$ are given in Table I. The 0^-0^+ ϵK waves are slightly larger near $t'=0$ than the 0^-0^+ $K^*\pi$ waves. There is an apparent "wrong-sign" crossover (i.e., $b_{K^+} > b_{K^-}$) in the 0^-0^+ $K^*\pi$ distributions, while none is evident for the 0^-0^+ ϵK waves, even though the K^- distribution is somewhat steeper than the K^+. We note that the presence of a 0^-0^+ $K^*\pi$ crossover is consistent with the difference between the K^+ and K^- mass spectra of Figs. 2(a) and 2(b) in the region of 1.4 GeV. However, because of the steepness of these waves, the limited statistics in the last two t' intervals, and certain technical considerations[9] in our method of analysis, we must at present consider this effect as an intriguing possibility. The difference in the production properties of these waves is presumably related to our previous observation that, whereas the 0^-0^+ ϵK wave appears to be purely resonant, the 0^-0^+ $K^*\pi$ wave may require a two-component description.

We have presented evidence for the existence of a $K\pi\pi$ pseudoscalar resonance, the K', of mass ~1400 MeV and width ~250 MeV. The predominant decay mode is ϵK with weaker couplings to $K^*\pi$ and, possibly, ρK. While it is conceivable that non-π-exchange Deck mechanisms could describe the 0^-0^+ ϵK mass spectrum, they are not expected to yield a phase variation such as that shown in Fig. 1; it is then natural to associate such phase motion with the existence of a 0^- resonance. In contrast, Deck contributions appear to

TABLE I. Parameter values from fits with $A\exp(bt')$ to the 0^-0^+ $K^*\pi$ and 0^-0^+ ϵK production distributions.

Wave	Beam	A (μb/GeV^3)	b (GeV^{-2})	χ^2
0^-0^+ $K^*\pi$	K^+	729 ± 49	13.8 ± 0.8	2.9
	K^-	546 ± 41	11.3 ± 0.7	5.1
0^-0^+ ϵK	K^+	1073 ± 130	15.6 ± 1.6	3.3
	K^-	1026 ± 131	19.1 ± 1.7	1.8

be significant for the $K^*\pi$ system, so that a determination of the K' coupling to $K^*\pi$ must await a quantitative interpretation of the data in terms of the two-component description mentioned above. Indeed a precise measurement of the K' mass and width also depends on how much the absolute phase of the 1^+0^+ ρK reference wave changes in the 1.3–1.5-GeV mass region. Nevertheless, the evidence for a 0^- $K\pi\pi$ resonance is already rather persuasive. In the quark model such a state would result from a radial excitation of the $L=0$ $q\bar{q}$ system and would imply the existence of other pseudoscalar mesons in the 1400-MeV mass region.

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†Now at Physics Department, Massachusetts Institute of Technology, Cambridge, Mass. 02139.

‡Now at Physics Department, Carleton University, Ottawa, Ont., Canada K1S 5B6.

§Now at Physics Department, Oxford University, Oxford, England.

‖Now at Laboratoire de l'Accélérateur Linéaire, Orsay, France.

¶Now at Physics Department, Michigan State University, East Lansing, Mich. 48824.

**Now at TRIUMF, University of British Columbia, Vancouver, B. C., Canada V6T 1W5.

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[6]We label partial waves by J^PM^η Iso, where J^P is spin and parity, M^η is magnetic substate and exchange naturality, and Iso denotes K^*, ρ, κ, or ϵ.

[7]Assuming a constant reference phase, we find for the fitted resonance parameters $m_0=1404\pm12$ MeV and $\Gamma_0=232\pm16$ MeV.

[8]We have no difficulty distinguishing 0^-0^+ $\kappa\pi$ and 0^-0^+ ϵK. Since the 0^-0^+ $\kappa\pi$ intensity never exceeds 40 μb/GeV^3 below 1.6 GeV, this wave is excluded from the present discussion.

[9]The different t' dependences of individual waves were not imposed. With regard to the mass spectrum, however, the analysis was also done in 40-MeV bins with narrower t' cuts (0–0.06 and 0.06–0.2 GeV^2). No significant differences from the results presented here were found. See G. Brandenburg *et al.*, to be published.

Total Muon Capture Rates in Nuclei

Aram Mekjian
Physics Department, Rutgers University, New Brunswick, New Jersey 08903
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Muon capture rates in nuclei can be accounted for by a simple three-parameter phenomenological formula. I present a microscopic analysis of this formula. Large discrepancies between the unperturbed shell-model results and the phenomenological parameters are found. Considerable improvement is obtained when long-range correlations are introduced. However, it is shown that the calculated total capture rate can be in agreement with experiment but that incompatibilities can still exist in the individual parameters.

The present Letter attempts to account for a recent phenomenological fit to total muon capture rates in nuclei. Specifically, the non-energy-weighted and energy-weighted expressions of Goulard and Primakoff[1] offer a simple parametric fit to muon capture rates for a whole spectrum of nuclei. However, to date, no microscopic analysis exists for the individual parameters. Here I will concentrate on the non-energy-weighted result of Ref. 1 and attempt a microscopic evaluation of the parameters. Firstly, a new version of the non-energy-weighted result will be developed which contains an additional term and in which parameters are formally defined in terms of the expectation values of a more suitable set of operators. Secondly, these parameters are then evaluated with unperturbed shell-model wave functions to see how well they can be accounted for in the lowest uncorrelated approximation. As we shall see, large discrepancies exist between the unperturbed values and the phenomenological values. Thirdly, the effect of correlations will then be studied microscopically.

To begin, the non-energy-weighted expression