them out.

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RESONANCE IN THE ($\Xi\pi$) SYSTEM AT 1.53 GeV*

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We wish to report the existence of a narrow resonance in the ($\Xi\pi$) system which we observed in the study of the interactions of negative K mesons in the LRL 72-in. hydrogen bubble chamber. The separated incident K^- beam, originating in the Bevatron, had a momentum of 1.80 ± 0.08 GeV/c; the uncertainty includes both the 6% momentum spread of the beam and the momentum loss in the chamber. The film was scanned for events with the following topology: "one positive secondary, one negative secondary with a decay, and one or two associated V's." This topology includes the reactions

$$K^- + p \to \Xi^- + K^+, \tag{1}$$

$$\to \Xi^- + K^+ + \pi^0, \tag{2}$$

$$\to \Xi^- + K^0 + \pi^+. \tag{3}$$

The events located by the scanners were analyzed using the kinematic fitting programs PANG and KICK. Based on a second scan of 80% of the film, the scanning efficiency was 99%. Only one possible example of multiple pion production was found. Table I gives the observed numbers of events of types (1), (2), and (3). Four events with charged K_1^0 decay were also consistent with the reaction $\pi^- + p \to \Sigma^- + K^0 + \pi^+$ due to a (presumed but as yet not studied) pion background. However, the χ^2 for this hypothesis is quite abnormal. Furthermore, the expected ratios of events of type (3) with charged Λ decay only, charged K_1^0 only, and with both charged Λ and charged K_1^0 decays, 4:1:2, agree well with the experimental numbers. These observations, coupled with the fact that the effective-mass distribution for ($\Xi\pi$) systems for events with charged K_1^0 agrees with those for the other cases, suggest strongly that all of these events are, in fact, examples of Reaction (3). Preliminary cross sections, based on a τ count and including corrections for neutral decays and for scanning bias of events with Ξ's shorter than 0.5 cm, are given in the third column of Table I. The detailed results of a study of our examples of Reaction (1) will be communicated in the near future.

Table I. Summary of Ξ^- production events at 1.80 GeV/c.

Reaction			Events	σ (μb)
$\Xi^- K^+$			94	135 ± 22
$\Xi^- K^+ \pi^0$			20	30 ± 8
$\Xi^- K^0 \pi^+$:	Λ decay	38		
	K_1^0 decay	10		
	Λ and K_1^0 decay	18		
	Total $\Xi^- K^0 \pi^+$		66	75 ± 13

Figure 1 shows Dalitz plots of the invariant mass squared of the ($\Xi\pi$) systems, $M_{\Xi\pi}^2$, vs $M_{K\pi}^2$ for the observed examples of Reactions (2) and (3). In both neutral ($\Xi^-\pi^+$) and charged

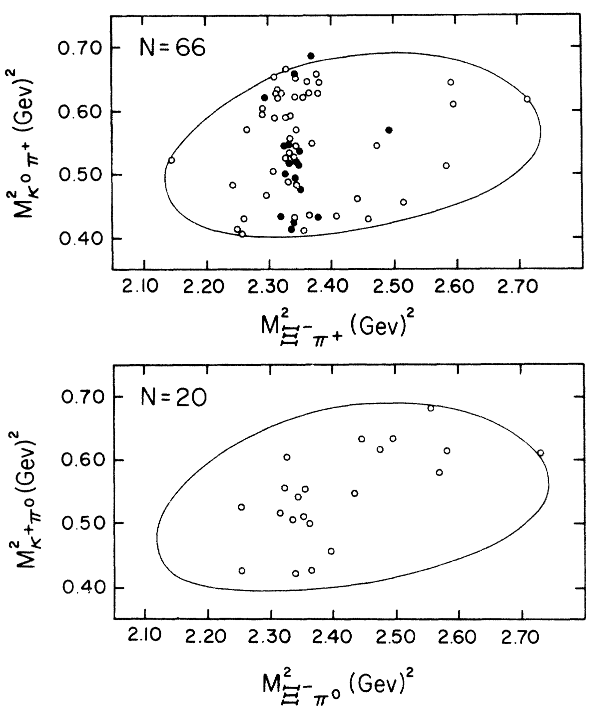

FIG. 1. Invariant-mass-squared Dalitz plots for the examples of Reactions (2) and (3). Solid dots represent events with both charged Λ and K_1^0 decays.

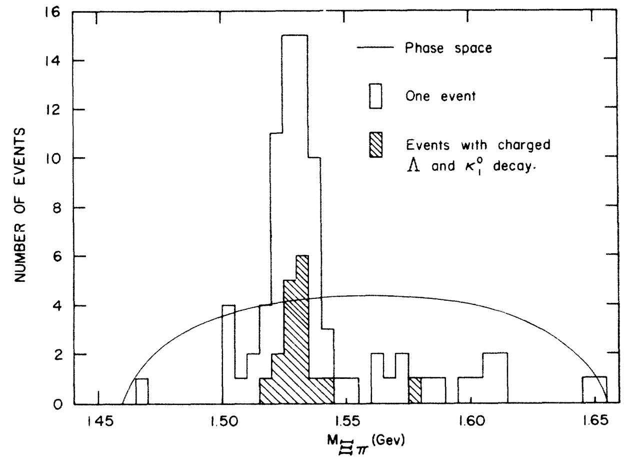

FIG. 2. Effective-mass plot for all $\Xi\pi$ systems observed in this experiment. The line is the relativistic three-body phase space.

($\Xi^-\pi^0$) systems, but especially the former, there is evidence for a pronounced resonance. There is no evidence for a resonance in other particle pairs. Figure 2 shows an effective-mass plot for all ($\Xi\pi$) pairs, regardless of charge. Defining all events between 1.515 and 1.545 GeV as within the resonance and neglecting the small nonresonant background, the resonance peaks at $M_{\Xi\pi} = 1.529 \pm 0.005$ GeV. The uncertainty is due primarily to as yet incompletely studied systematic errors. The resonance is quite sharp. The observed $\Gamma/2$ is comparable with our experimental errors which are typically ~5 MeV. In the case of events of type (3) where both Λ and K_1^0 decay via charged modes (shown shaded in Fig. 2), the momenta of all final reaction products may be individually measured. The experimental errors are accordingly somewhat smaller, ~2.5 MeV. The calculated Γ for these events is ~7 MeV. Within our precision, the width of the resonance can therefore not be determined, but it is not likely to be larger than $\Gamma = 7$ MeV.

The production amplitudes for the ($\Xi\pi K$) reaction, starting with K^- on protons, may be written as follows:

$$\Xi^-\pi^0K^+ \to [-\sqrt{2}\,a_{3/2,1} + a_{1/2,1} - a_{1/2,0}], \qquad \text{(a)}$$

$$\Xi^-\pi^+K^0 \to [a_{3/2,1} + \sqrt{2}\,a_{1/2,1} + \sqrt{2}\,a_{1/2,0}], \qquad \text{(b)}$$

$$\Xi^0\pi^0K^0 \to [\sqrt{2}\,a_{3/2,1} - a_{1/2,1} - a_{1/2,0}], \qquad \text{(c)}$$

$$\Xi^0\pi^-K^+ \to [-a_{3/2,1} - \sqrt{2}\,a_{1/2,1} + \sqrt{2}\,a_{1/2,0}], \qquad \text{(d)}$$

where $a_{t,T}$ is the amplitude for the production of the ($\Xi\pi$) system in isospin state t from an overall isospin state T. Assuming that the resonance occurs in a unique isospin state and neglecting interference effects with nonresonant backgrounds, (a) and (b) predict a production ratio $(\Xi^-\pi^0K^+)/(\Xi^-\pi^+K^0) = 2$ for $t = \frac{3}{2}$. The observed ratio in the $M_{\Xi\pi}$ region between 1.515 and 1.545 GeV is, in fact, 0.21 ± 0.07 which suggests strongly that the ($\Xi\pi$) resonance occurs in the $t = \frac{1}{2}$ state where the $a_{1/2,1}$ and $a_{1/2,0}$ amplitudes may interfere such as to give any $(\Xi^-\pi^0K^+)/(\Xi^-\pi^+K^0)$ production ratio. If the $a_{3/2,1}$ amplitude is indeed negligible, then the reaction

$$K^- + p \to \Xi^0 + \pi^- + K^+ \qquad (4)$$

should occur twice as often as Reaction (2). Accordingly, we expect to find ~40 events in our film. We have searched 25% of our total exposure for events with the topology "two prong plus V" and found six events which fit only Hypothesis (4) while three additional ones fit (4) and other hypotheses, although with very high χ^2's. The observed number of examples of (4) is thus not in disagreement with the expected

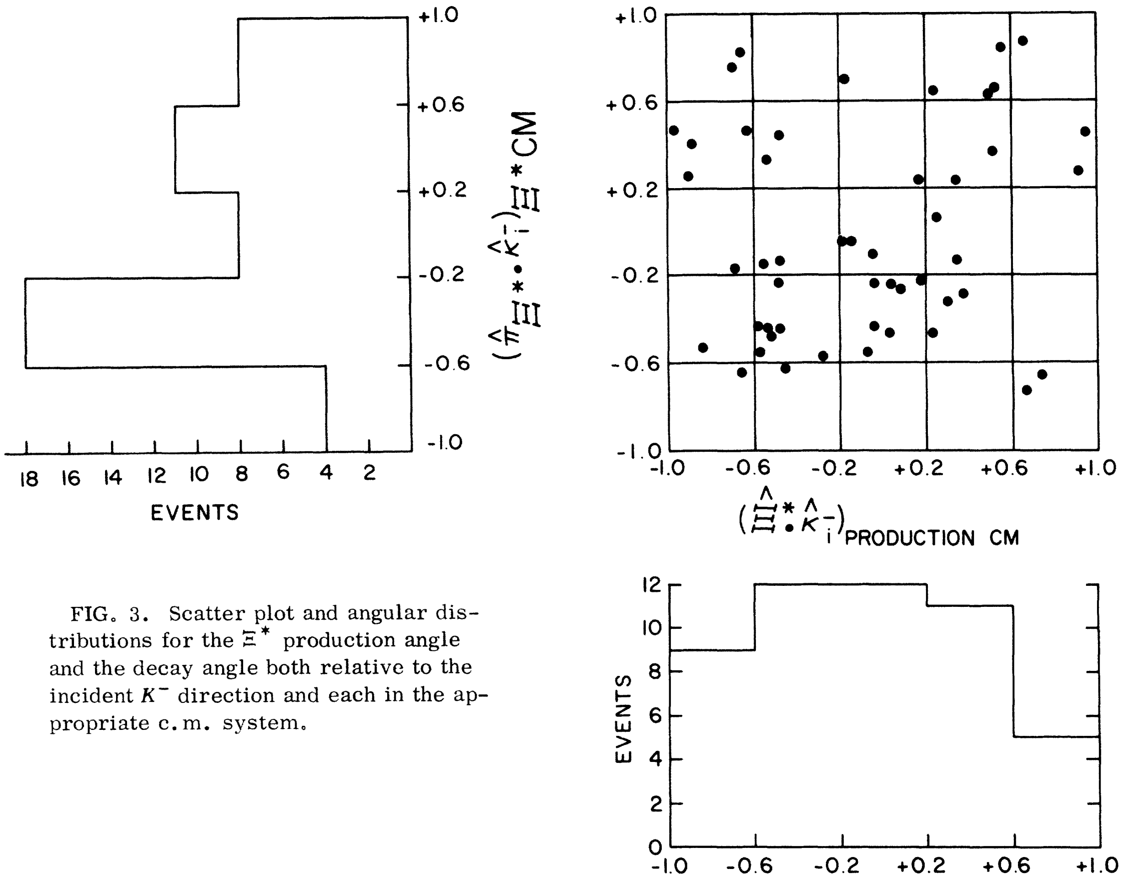

FIG. 3. Scatter plot and angular distributions for the Ξ^* production angle and the decay angle both relative to the incident K^- direction and each in the appropriate c.m. system.

number, ~10. Pending clarification of the systematics of boson-baryon resonances, the $(\Xi\pi)$ resonance should therefore be called $\Xi_{1/2}{}^*$.

Figure 3 shows a scatter diagram of the cosine of the Ξ^* production angle in the production c.m. system versus the cosine of the emission angle of the pion from Ξ^* decay with respect to the direction of the incident K^-. Only $\Xi^-\pi^+K^0$ events in the $M_{\Xi\pi}$ range from 1.515 to 1.545 GeV have been used. As only 14% of the events are expected to show charged $K_1{}^0$ decay alone, the detection of the events depends primarily on the existence of a Ξ track of observable length. At our cutoff of 0.50 cm, the probability of missing an event varies from 9% for extreme forward Ξ's to 24% for extreme backward Ξ's. Hence, large systematic biases in Fig. 3 are not likely. The angular distribution at production appears isotropic. At a $\Gamma \leq 7$ MeV, the mean separation of the Ξ^* and K^0 at the time of Ξ^* decay is $\gtrsim 20$F; hence final-state interactions between the K^0 and the other particles do not appear likely. This seems to be borne out by the fact that there appears to be no significant asymmetry about 90° in the Ξ^* decay relative to the Ξ^* direction of motion. The outgoing momentum in the two-body process

$$K^- + p \to \Xi^{*0} + K^0 \qquad (5)$$

is 0.32 GeV/c and large P-wave contributions are not expected but cannot be ruled out experimentally. At corresponding outgoing momenta the Ξ^-K^+ reaction shows large contributions from higher partial waves.[1] The distribution of the Ξ^* decay angle relative to the incident K^- also appears isotropic within statistics. According to the well-known argument of Adair,[2] S-wave production coupled with a flat decay distribution along the production direction would establish the Ξ^* spin to be $\frac{1}{2}$.

However, in view of the poor statistics, it is impossible to rule out some suitably chosen combination of S and P waves, coupled with a $\Xi_{1/2}{}^*$ with spin $\frac{3}{2}$. Hence, the Ξ^* spin is as yet not determined. Further work on this question is in progress.

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THEOREM ON LOCAL ACTION OF LEPTON CURRENTS*

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It is generally supposed that in any reaction involving a lepton pair the individual lepton fields have a common space-time point as their respective argument in the effective interaction density for the reaction. This idea is here called the local action of lepton currents. It may apply to decay reactions where both leptons appear in the final state as well as to scattering processes, one lepton in, one lepton out.

This absence of smearing out effects reflects the following dynamical assumptions. (1) There exist no other forces between (e, ν) or (μ, ν) than local weak couplings. (2) These local weak couplings are to be treated only to lowest order. Such assumptions can be entertained irrespective of whether or not intermediate bosons mediate weak interactions.

In recent times there has developed a growing interest in the question of higher order weak interaction effects, in particular as to their high-frequency behavior. One way in which such effects could show up is in violation of the local action of lepton currents. This is one of the reasons why it is interesting to know what local action implies in practice.

This problem was first studied[1] in connection with K_{l3} decays (l stands for either μ or e). The following result was obtained. Let $W(p, \cos\theta)$ be the decay distribution in the K rest system, where p is the π momentum and θ the angle between the pion and the neutrino. Then we have

$$K(p, \cos\theta) W(p, \cos\theta) = A(p) + B(p)\cos\theta + C(p)\cos^2\theta. \tag{1}$$

The kinematic factor K is a known function of p and $\cos\theta$. The functions A, B, and C, on the other hand, can only be determined from the complete dynamics of the problem which we do not master. However, we do know that they depend on p only. The assumption of local action now says that the product KW is, in general, a quadratic function of $\cos\theta$.

Equation (1) was derived before it was even known that in ordinary β decay we have a V-A interaction. It was, in fact, one of the aims of the investigation to find out what one can say about the structure functions, A, B, and C, depending on the choice among the usual five covariants. It turned out that there are criteria of practical interest for the case where one may neglect the lepton mass as in K_{e3} decay. In this special case these criteria have already led to useful experimental information.[2,3] It should be emphasized, however, that the general form (1) is rigorous and does not depend on the value of the lepton mass.

Let us now gladly accept that K_{l3} decay goes via V coupling. Then, for finite lepton mass the number of structure functions is reduced to two independent ones.[1] It may be noted that further refined measurements on both K_{e3} and $K_{\mu3}$ could tell us something about local action. Even if deviations from local action were to exist, one would not expect them to show up sizably in these decays, however, as the momentum transfers are not very high.

It is often useful[4] to take the lepton energy ω as a distribution variable instead of θ. We have

$$\omega = \frac{(m-E)^2 + p^2 + \mu^2 + 2p(m-E)\cos\theta}{2(p\cos\theta + m - E)}. \tag{2}$$

E is the pion energy, m and μ are the K and lepton mass, respectively. It follows from Eqs. (1) and (2) that

$$K'(p, \omega) W'(p, \omega) = a_0(p) + a_1(p)\omega + a_2(p)\omega^2. \tag{3}$$