PRELIMINARY RESULTS ON $\Xi^+ K^+ n $ FINAL STATES PRODUCED BY 3.5 GeV $K^-$

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We have recently reported\(^{(1)}\) preliminary (and negative) results of a search for the predicted\(^{(2)}\) \(S = -3\) hyperon (the \(\Xi^-\) or \(\Xi^0\)), and for possible \(I = 3/2\) resonances in the \(\Xi^- \eta^-\) system (produced by a 3.5 GeV/c K\(^-\) beam\(^{(3)}\) in the CERN 1.15 m diameter, 2.1 kWe/\(m^2\); freon (CF\(_3\)Br) bubble chamber\(^{(4)}\) at the CERN PS). The \(I_\Xi = \frac{1}{2}\), \(\Xi^- \eta^0\) mass distribution showed (in addition to the 1530 MeV \(\Xi_s^-\)) an indication (2 standard deviations) of a second peak between 1.7 and 1.8 GeV.

We confirm these results here, with somewhat improved statistics (now \(\Xi^-\)), and give a further analysis of this second peak. We conclude that the odds against its being a statistical fluctuation out of the background distribution are more than to one, and that it is not a simple "reflection" of the \(\Xi^-\), the \(K^*(880)\), or the kappa (730).

These results are still preliminary: re-scanning of the \(\sim\) photos (containing \(\sim 1\) useful K\(^-\) interaction per photo) and further analysis are continuing. Data analysis systems\(^{(5)}\) and selection criteria for \(\Xi^-\) events, and for K\(^+\) and K\(^0\) "signatures" are similar to those of references 1 and 6.

We can effectively detect only particles and resonances whose absorption probability in the production nucleus is not much greater than that for \(\Xi^- (\Xi^0 \frac{1}{2})\), and whose decay width is not much greater than \(\sim 40\) MeV. (The broader the resonance, the more often it decays inside the production nucleus). For numerical estimates of cross sections, we assume that \(\sigma (\Xi^-)\) is \(\sim \frac{1}{2}\)mb (near 3.5 GeV) as our preliminary data suggest. (Our observed events correspond to production cross section on the order of 0.15 mb/nucleon without

PS/4011/dac
correction for nuclear absorption of the $\Xi^{-}$).

**Search for a Strangeness $-3$ Hyperon ($\Lambda^{-}$ or $Z^{-}$)**

Our present upper limits to the cross section for production of the predicted $S = -3$, $I = 0$, $M \approx 1.67$ GeV hyperon $\Lambda^{-}$ or $Z^{-}$ in the reaction:

$$K^{-} + (p^+)^{(n)} \rightarrow \{K^{+}\} + K^{0} + Z^{-} \quad \{1a\}$$

followed by decay $Z^{-} \rightarrow \Xi^{-} + \pi^0$ are (with 90% confidence):

1) $< \% \sigma (\Xi^{-})$ i.e. $< \mu b$/nucleon; from absence of $\Xi^{-}$ accompanied by $K^{+}K^{0}$ or $K^{0}K^{0}$ pair, both visible. For this estimate the $Z^{-}$ need not have long (i.e. $\sim 10^{-10}$ sec) lifetime, nor the predicted mass.

2) $< \% \sigma (\Xi^{-})$ i.e. $< \mu b$/nucleon; from absence of events with one visible $K^{+}$ or $K^{0}$ signature, with $M \approx \pi^{0}$ between 1625 and 1725 MeV, and with kinematical possibility of a second undetected $K^{0}$. For this estimate we consider only $Z^{-} \rightarrow \Xi^{-} + \pi^{0}$ with lifetime $\leq \frac{1}{3} \times 10^{-10}$ sec and mass near that predicted.

3) $< \% \sigma (\Xi^{-})$ i.e. $< \mu b$/nucleon; from absence of events (with or without signature) with $\pi^{0}$ produced along the $\Xi^{-}$ track (without evidence of nuclear excitation). For this estimate the $Z^{-}$ must have lifetime $\geq \frac{1}{3} \times 10^{-10}$ sec (as expected), but need not have the predicted mass.

See reference 1 for details of the analyses leading to 1, 2 and 3.

We conclude that the $Z^{-}$ probably has production cross section (by $3.5$ GeV/c $K^{-}$ in heavy liquid) less than $\sim \mu b$, (for decay involving $\Xi^{-}$). If current unitary symmetry ideas (7) are relevant, this is perhaps not surprising. Reaction 1 may be similar to the reaction:

PS/4011/dac
\[ K^- p \rightarrow \pi^+ K^0 N_{33} \quad (2) \]

where the final state particles have each the negative of the \( U_Z \) of the corresponding final state particles in reaction 1.

About 100 MeV would be available for kinetic energy (in the \( K^- p \) CMS) for reaction 2 by \( K^- \) of \( \sim 1.4 \) GeV/c (corresponding to 100 MeV available in reaction 1a by \( K^- \) of 3.4 GeV). Reaction (2) has not yet been observed\(^8\) for \( K^- \) of 1.45 GeV/c (\( \sigma \approx \mu b \)).

**Search for \( I = 3/2 \equiv \pi^- \) Resonances**

\( I = 3/2, S = -2, \equiv \pi^- \) resonances might be expected in analogy with \( I = 3/2 N \pi \) resonances, or, e.g., from current unitary symmetry schemes\(^7\)\(^9\) postulating possible existence of \( 10^*, 27 \) (or larger) representations. As yet, however, there has been no report of some expected companion states: e.g., \( I = 0, Y = 2 \), i.e. a \( KN \) resonance for a \( 10^* \); or \( I = 2, Y = 0 \), i.e., an \( I = 2, \equiv \pi^- \) resonance for a \( 27 \).

Some proposed formulas\(^10\) relating the quantum numbers of observed baryon states, would predict that no state should exist with \( S = -2 \) and \( I = 3/2 \).

Our \( \equiv \pi^- \) distribution is shown in Fig. 1. Of the events, \( \equiv \pi^- K^+ \) ("3 body") are shaded; are with two \( \pi \) s ("4 body"), and with three or more \( \pi \) s. Some 15% of the events are ambiguous, i.e. could be either n body with unidentified \( K^+ \) or n + 1 body with missing \( K^0 \). (Essentially all \( K^0 \) are identified via \( \gamma \rightarrow e^+e^- \) in the 11 cm radiation length freon). We have separated these ambiguous events statistically, using the visible energy, as described in reference 1, (and we have verified that the small contamination of \( K^+ \) taken as \( \pi^+ \) would not significantly bias our \( M = -\pi^+ \) spectrum).

The "phase space" distribution of \( M = \pi^- \) to be expected is, of
course, the end result of the effects of Fermi motion, cross section variations, reflections of possible resonances of the $\Xi^-$ or $\Pi^-$ with other outgoing particles, the effects of interactions and scatters of incoming or outgoing particles in the target nucleus, etc. The curves in Fig. 1 are shown only for comparison, and are simply appropriately normalised 3 plus 4 body phase space distributions, calculated for target nucleon at rest, and for head-on and tail-on collisions with a nucleon of 0.2 GeV/c Fermi motion.

The observed $\Xi^-\Pi^-$ mass distribution is consistent with a phase-space-like smooth distribution, such as curve A in Fig. 1. Thus it seems that no (narrow) resonance dominates $\Xi^-\Pi^-$ production at these energies. (One event corresponds roughly to 1.3 mb/nucleon).

Search for $I = \frac{3}{2}, \Xi^+\Pi^-$ and $\Xi^-\Pi^+$ Resonances

Among predicted $I = \frac{3}{2}, S = -2$ states are one at 1.6 GeV\(^{(1)}\) (and one at 1.74 GeV\(^{(12)}\)) which would complete the "$\Lambda$ octet" (the 1.74 GeV $\Xi^*$ might be generated\(^{(13)}\) by the Peierls mechanism\(^{(14)}\) operating on the $\Xi^0$ (1530)); and one perhaps\(^{(11)}\) near 1.95 GeV which would be the "Regge Recurrence" of the $\Xi$ (the $\Xi^{II}$).

Fig. 2 shows our $I_Z = \frac{1}{2}, \Xi^-\Pi^+$ mass distribution for events: the shaded events have only one $\Pi^+$ ("3 body"), have two $\Pi^+$s and have three or more $\Pi^+$s. The "phase space" curve shown for comparison, is the smooth curve A, found consistent with the $\Xi^-\Pi^-$ mass distribution, and thus probably a good approximation to our effective phase space. It is normalised to the total number of events. Curve B is the same curve normalised to the events outside the $\Xi^0$ peak.

There is a significant concentration of events in the $\Xi^0$ region
(events where would be expected from curve A and from curve B; i.e., > standard deviations. One event corresponds to \( \sim 1/ \) of the total \( \Xi^- \) production cross section or to roughly \( \mu b/\text{nucleon} \).

We see no indication of the predicted \( \Xi \gamma \) near 1.6 GeV, but the proximity of the \( \Xi \gamma \) peak, the phase space maximum in this region, (and our \( \sim \pm 30 \text{ MeV} \) resolution) prevent us from effectively studying it. Also no striking concentration of events appears in the \( \Xi \gamma \) region.

Fig. 3 shows the \( I = \frac{1}{2} \Xi^{-} \pi^{+} \pi^{0} \) mass distribution for events (with only two \( \pi \)'s are shaded, are with three or more \( \pi \)'s).

**The Mass Region 1.7 to 1.8 GeV**

We have events with \( M = \Xi \pi \) between 1.7 and 1.8 GeV where would be expected from curve B normalised to all the events outside the \( \Xi \gamma \) region, and events from curve C normalised to the events outside both the \( \Xi \gamma \) region and the 1.7 - 1.8 GeV region. Thus the odds against a statistical fluctuation of this magnitude happening in this region are at least to one, and happening in one region among, say 10, is at least to one.

Fig. 4 shows a preliminary ideogram (with 3 body events shaded) corresponding to the Fig. 2 \( M = \Xi \pi \) histogram. The \( \Xi \gamma \) region peak gives an idea of our resolution. (The \( \Xi \gamma \) width is only \( \sim 7 \text{ MeV} \) in the absence of interferences\(^{16} \)). The second peak occurs at \( \sim \) GeV with width \( \sim \) GeV, compatible with our resolution.

We have not thought of a mechanism (other than statistical fluctuation, of course, or a resonance) which would produce so narrow a bump. Possible scanning and measuring biases, reflections of the
Kπ resonances at 880 and 730 MeV, and of the ΣΔ (in 4 body final states) are all much broader than our peak (especially when Fermi motion is included), and are not maximum in the GeV region.

Possible reflections in 4 body states should affect the Mπ -- and MπΔ distributions in similar ways and thus are already included in curves A and B. Any specifically nuclear effect would be expected to smear, rather than sharpen such a peak.

A hint of peaking in this region has previously been reported\(^{(15)}\) in 3 body ΣπK final states produced by 2.4 GeV K\(^-\) in hydrogen.
A final speculation: if this peak is due to a resonance (which we have not proved), one could ask where this resonance could fit into current unitary symmetry models:

i) if it is the $\Xi \gamma$ (as the Tuan argument would suggest), i.e., part of a $J^P = 3/2^-$ octet with the $N_8^*(1512)$ and the $Y_0^*(1520)$, either the Okubo mass formula does not apply or the $Y_1^*(1660)$ belongs somewhere else. In this case the Okubo formula would predict a $Y_1^*$ at about 1.95 GeV, which has not been observed;

ii) if it is the $\Xi \eta$ (although the $\Xi$ Regge trajectory would then have smaller slope than those of the nucleon and $\Lambda$), then (using $N_8^{1/2}(1.69)$ and $\Lambda_\eta^{1/2}(1.82)$) the $\Xi \eta$ would occur near 1.4 GeV, and thus could perhaps have been missed in the $Y_1^*(1385)$ tail, (and perhaps have contributed to the difficulty in determining the $Y_1^*(1385)$ spin).
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