CERN/TC/PHYSICS 63-22
17.9.1963

PRELIMINARY RESULTS ON $\Xi^- + K^{\overset{+}{0}} + n\pi$ FINAL STATES PRODUCED BY 3.5 GeV K^-

P. Bellière, V. Brisson, P. Petiau, A. Rousset
Ecole Polytechnique, Paris

G. Myatt, O. Skjeggestad, H.H. Bingham*, H. Burmeister, D.C. Cundy,
M. Paty, CERN

F.W. Bullock, B.S. Luetchford
University College London

C.M. Fisher, J.M. Scarr
Rutherford Laboratory, Chilton

A. Halsteinslid, R. Møllerud, J.M. Olsen
Bergen University, Norway

* FORD Foundation Fellow

PS/4011/dac

T11 Version 1

We have recently reported[1] preliminary (and negative) results of a search for the predicted[2] $S = -3$ hyperon (the Ω^- or Z^-), and for possible $I = 3/2$ resonances in the $\Xi^-\pi^-$ system (produced by a 3.5 GeV/c K^- beam[3] in the CERN 1.15 m diameter, 2.1Web/m^2, freon (CF_3Br) bubble chamber[4] at the CERN PS). The $I_Z = \frac{1}{2}$, $\Xi^-\pi^+_0$ mass distribution showed (in addition to the 1530 MeV Ξ_5) 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 Ξ^-), 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 Ξ_δ , 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 Ξ^- 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 Ξ^-($\lesssim \frac{1}{2}$), 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 $\lesssim \frac{1}{4}$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 correction for nuclear absorption of the Ξ^-).

Search for a Strangeness -3 Hyperon (Ω^- or Z^-)

Our present upper limits to the cross section for production of the predicted [2] $S = -3$, $I = 0$, $M \approx 1.67$ GeV hyperon Ω^- or Z^- in the reaction;

$$K^- + \begin{Bmatrix} p \\ n \end{Bmatrix} \rightarrow \begin{Bmatrix} K^+ \\ K^o \end{Bmatrix} + K^o + Z^- \qquad \begin{Bmatrix} 1a \\ 1b \end{Bmatrix}$$

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

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

3) < % $\sigma(\Xi^-)$ i.e. $\lesssim$ μb/ nucleon; from absence of events (with or without signature) with π^o produced along the Ξ^- track (without evidence of nuclear excitation). For this estimate the Z^- must have lifetime $\gtrsim \frac{1}{2} \times 10^{-10}$ 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 $\sim$ μb, (for decay involving Ξ^-). If current unitary symmetry ideas[7] are relevant, this is perhaps not surprising. Reaction 1 may be similar to the reaction:

$$K^- p \rightarrow \pi^+ \bar{K}^o N^{*-}_{33} \qquad (2)$$

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 ($\sigma \lesssim$ μb).

Search for $I = 3/2$ $\Xi\pi$ Resonances

$I = 3/2$, $S = -2$, $\Xi\pi$ 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 $\underline{10}^*$, $\underline{27}$ (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 $\underline{10}^*$; or $I = 2$, $Y = 0$, i.e., an $I = 2$, $\Sigma\pi$ resonance for a $\underline{27}$. 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 $\Xi^-\pi^-$ distribution is shown in Fig. 1. Of the events, $\Xi^-\pi^-K^+$ ("3 body") are shaded; are with two π s ("4 body"), and with three or more π 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^o. (Essentially all π^o 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 π^+ would not significantly bias our $M_{\Xi^-\pi^+}$ spectrum).

The "phase space" distribution of $M_{\Xi\pi}$ to be expected is, of course, the end result of the effects of Fermi motion, cross section variations, reflections of possible resonances of the Ξ^- or π^- 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 μb/nucleon).

<u>Search for I = ½, $\Xi\pi$ and $\Xi\pi\pi$ Resonances</u>

Among predicted I = ½, S = -2 states are one at 1.6 GeV[11] (and one at 1.74 GeV[12]) which would complete the "γ octet" (the 1.74 GeV Ξ^* might be generated[13] by the Peierls mechanism[14] operating on the Ξ_δ (1530)); and one perhaps[11] near 1.95 GeV which would be the "Regge Recurrence" of the Ξ (the Ξ^{II}_{α}).

Fig. 2 shows our I_Z = ½, $\Xi^-\pi^{\overset{+}{0}}$ mass distribution for events: the shaded events have only one π ("3 body"),   have two π s and   have three or more π 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 Ξ_δ peak.

There is a significant concentration of events in the Ξ_δ region

(events where would be expected from curve A and from curve B; i.e., > standard deviations. One event corresponds to ~ 1/ of the total Ξ^- production cross section or to roughly μb/nucleon).

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

Fig. 3 shows the $I_Z = \frac{1}{2}\,\Xi^-\pi^+\pi^{\overset{\circ}{-}}$ mass distribution for events (with only two π s are shaded, are with three or more π 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 Ξ_δ region, and events from curve C normalised to the events outside both the Ξ_δ 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 $M_{\Xi-\pi^{\pm}_{0}}$ histogram. The Ξ_δ region peak gives an idea of our resolution. (The Ξ_δ width is only ~ 7 MeV in the absence of interferences(16)). The second peak occurs at ~ GeV with width ~ 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

$K\pi$ resonances at 880 and 730 MeV, and of the $\Xi\,\delta$ (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 $M_{\Xi^-\pi^-}$ and $M_{\Xi^-\pi^{+}_{0}}$ 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 $\Xi\pi K$ 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 Ξ_{γ} (as the Tuan argument [13] would suggest), i.e., part of a $J^P = 3/2^-$ octet with the $N^*_{\frac{1}{2}}$ (1512) and the Y^*_0 (1520), either the Okubo mass formula does not apply [12] 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 Ξ^{π}_{α} (although the Ξ Regge trajectory would then have smaller slope than those of the nucleon and Λ), then (using N^{π}_{α} (1.69) and Λ^{π}_{γ}(1.82)) the Ξ^{π}_{α} 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).

PS/4011/dac

References

1. P. Bellière et al. Physics Letters (in press)

2. M. Gell Mann, CERN Conf. (1962), p. 805

3. J. Goldberg, J.M. Perreau, CERN 63-12

4. C.R. Ramm, L. Resegotti, Int. Conf. on Instr. (Berkeley, 1960), p. 127

5. R. Böck, Nucl. Instr. and Meth. 20, 435, (1963)
   A.M. Cnops, THRESH, DD/EXP/63/12
   A.G. Wilson, NIRL/M/38
   J.W. Burren, J. Sparrow, NIRL/R/14

6. L.Jauneau et al. Physics Letters 5, 261, (1963)

7. c.f., e.g., H.J. Lipkin, Unitary Symmetry for Pedestrians, Argonne National Laboratory Seminar Lecture, August 1963

8. E. Malamud, H. Filthuth, private communication

9. c.f., e.g. R.H. Dalitz, EFINS 63-33

10. c.f., e.g. S. Minami and K. Mori, Phys. Lett. 5, 220, 1963

11. c.f., e.g. S.L. Glashow and A.H. Rosenfeld, Phys. Rev. Lett. 10, 192, 1962

12. c.f., e.g. T. Takabayasi, Phys. Lett. 5, 73, 1963

13. S.F. Tuan, Preprint of talk at Washington meeting of A.P.S. (1963)

14. R. Peierls, Phys. Rev. Lett. 6, 641, 1961

15. P.L. Connolly et al. Ohio U. Conf. (April 1963)

16. P.E. Schlein et al. Phys. Rev. Lett. 11, 167, 1963

Acknowledgements

We are very grateful to Professors L. Leprince-Ringuet, C.A. Ramm, R.G.P. Voss, Ch. Peyrou, R. Armenteros, C. Henderson, B. Trumpy and J. Prentki for their interest and advice.

We thank especially Prof. A. Lagarrigue who heads our collaboration.

The beam was due to the efforts of many people. We thank particularly Drs. J.M. Perreau, H. Goldberg, D. Leith and F. Muller.

We are grateful for the hard work of our linkman, Dr. F. Bonaudi, of the bubble chamber crew under Dr. P. Innocenti and of the many people in the CERN NPA and MPS divisions who contributed to the run and the preparation of the experiment.

We thank the many authors of our data analysis systems, notably R. Böck, Mlle A. Cnops, H. Nikolić and K. Soop (CERN), A. Wilson, R.H. Thomas and J. Sparrow (NIRNS), and B. Grung (Bergen); also the many scanners etc. who make these systems work.

The UCL group acknowledges the financial support of the Department of Scientific and Industrial Research.