the center of mass of the proton-He^3 system. The preponderance of negative values of $\cos\theta$ for all events plotted is a well-known effect[1] due to the identification bias favoring long He^3 recoils, as discussed above. Figure 2 summarizes the scanty experimental information on the spin of this Li^4 state and is consistent with a $\cos^2\theta$ distribution. ${}_\Lambda He^4$ has $J=0$ and the decay $\Lambda \to p+\pi^-$ goes dominantly to an s-wave final state. Simple arguments then show that the quantum numbers $J^p = 1^-$ are the only ones consistent with a $\cos^2\theta$ distribution.

In conclusion, an effect in the π^--energy histogram from ${}_\Lambda He^4$ decays in nuclear emulsions has been observed, and is best interpreted as evidence for an excited state of Li^4, (10.62 $\pm$ 0.20) MeV above decay to proton and He^3. The width observed is (0.23 $\pm$ 0.20) MeV, which agrees with the pion energy resolution (~0.40 MeV) in nuclear emulsions only if the upper limit (0.43 MeV) is taken. The narrow resonance width at this excitation energy could be understood in terms of an $I=2$ state of Li^4, whose p-He^3 decay would be forbidden by isospin conservation. However, a number of difficulties are encountered if we adopt this isospin assignment: (1) There are 3 MeV available for the allowed $3p+n$ decay mode which is not seen; (2) application of the $\Delta I=\frac{1}{2}$ rule suggests that the decay ${}_\Lambda He^4 \to \pi^+ + H^{4*}$ should occur with frequency equal to ${}_\Lambda He^4 \to \pi^- + Li^{4*}$, which is inconsistent with present hyperfragment observations; and (3) arguments given earlier suggest a spin of 1^-, but with isospin assignment $I=2$, a 1^- state is rather unlikely.[13]

These results should be checked by conventional experiments such as proton-He^3 scattering in the previously unexplored energy region around[7] $E_p = 11.5$ to $E_p = 19$ MeV.[14]

We wish to thank Dr. F. Von Hippel and Dr. F. Abraham for helpful discussion, and Mr. B. Beeken for his faithful computer work.

---

*Research supported by the U. S. Air Force Office of Scientific Research.

†Present address: CERN, Geneva, Switzerland.

[1]R. Ammar, R. Levi Setti, W. E. Slater, S. Limentani, P. E. Schlein, and P. H. Steinberg, Nuovo Cimento 13, 1156 (1959).

[2]D. H. Davis, R. Levi Setti, and M. Raymund, Nucl. Phys. 41, 13 (1963).

[3]K. P. Artemov, S. P. Kalinin, and L. N. Samilov, Zh. Eksperim. i Teor. Fiz. 37, 663 (1959) [translation: Soviet Phys. –JETP 10, 474 (1960)].

[4]S. Bashkin, R. W. Kavanagh, and P. D. Parker, Phys. Rev. Letters 3, 518 (1959).

[5]H. A. Brench, W. L. Imhof, and F. J. Vaughn, Bull. Am. Phys. Soc. 7, 268 (1962).

[6]T. A. Tombrello, C. Miller Jones, G. C. Phillips, and J. L. Weil, Nucl. Phys. 39, 541 (1962).

[7]T. B. Clegg, A. C. L. Barnard, J. B. Swint, and J. L. Weil, Nucl. Phys. 50, 621 (1964).

[8]N. A. Blasov, G. F. Bogdanov, S. P. Kalinin, B. V. Rybakov, and V. A. Sidorov, Proceedings of the International Conference on Neutron Interactions with Nuclei, Columbia University, 1957 [Atomic Energy Commission Report TID-7547 (unpublished)], p. 236.

[9]T. A. Tombrello, Bull. Am. Phys. Soc. 9, 164 (1964); and private communication.

[10]M. Raymund, Nuovo Cimento 32, 555 (1964).

[11]M. M. Block, R. Gessaroli, S. Ratti, L. Grimellini, T. Kikuchi, L. Lendinara, L. Monari, and E. Harth, Nuovo Cimento 28, 299 (1963).

[12]The authors are indebted to the helium bubble chamber group for the opportunity of examining their data on the π^- spectrum from ${}_\Lambda He^4 \to \pi^- + p + He^3$ decay.

[13]R. H. Dalitz, private communication.

[14]A. A. Vanetsian and E. D. Fedchenko, At. Energ. (USSR) 2, 123 (1957).

EVIDENCE FOR AN N^* RESONANCE AT 1425 MeV*

Stuart Lee Adelman
Cavendish Laboratory, Cambridge, England
(Received 9 September 1964)

Strong evidence has been found for the existence of a resonance in the pion-nucleon system at an effective mass of approximately 1425 MeV.

A sample of 30 000 photographs was obtained from the CERN 32-cm hydrogen bubble chamber of a separated K^- meson beam of momentum $P_K = 1.455 \pm 0.025$ GeV/c.[1,2] All events of two-prong topology were studied. We base our conclusions on those which were kinematically fitted in the inelastic modes:

(a) $K^- + p \to \pi^+ + K^- + n$ (732 events),

(b) $K^- + p \to p + K^- + \pi^0$ (381 events),

(c) $K^- + p \to p + \pi^- + K^0$ (553 events).

The mode identifications were checked by measuring the bubble density along each track and comparing it with the expected ionization due to the fitted momentum. In addition, we assessed the reliability of our mode assignments by studying the distributions of missing mass and the error on missing mass as well as the momentum distributions of the neutral particles for each mode. In all cases we were satisfied that unambiguous identifications of the above-mentioned numbers of events had been made.

Plots of numbers of events vs invariant mass of the pion-nucleon system, as well as center-of-mass momentum distribution of the emitted kaons, which were calculated from the measured data by two independent programs, reveal a strong peak in modes (a) and (b) in the mass channel 1400-1450 MeV/c^2, with no corresponding peak in mode (c).[2] Studies of these curves indicate a width assignment of $\Gamma \sim 50$-100 MeV/c^2. The presence of the peak seems to agree with the indications found by Roper[3] at Berkeley, in a phase-shift analysis of a possible resonance in this channel at approximately the same mass, as well as being consistent with the evidence seen by Cocconi et al.[4] at CERN in p-p counter experiments, and by Bareyre et al.[5] at Saclay in π-p collisions.

In Fig. 1(a) the solid-line histogram shows the invariant-mass distribution of the π^+n system in mode (a), from which those events falling under the peak corresponding to the $K^*(888)$ in the π^+K^- distribution were removed, while the dotted-line histogram shows the π^+n distribution with all events included. Both phase-space curves are normalized to exclude $K^*(888)$ events. Figure 1(b) shows the invariant-mass distribution of pion-nucleon events in mode (b) with all events included, as does Fig. 1(c) for mode (c). In both (b) and (c) subtraction of the events under the $K^*(888)$ peak had the same effect on the pion-nucleon peaks at 1238 and 1425 MeV as was illustrated in the case of mode (a); namely, reduction of background only. In all the invariant-mass distributions the left-hand peak is that of the $N^*(1238)$.

Figures 2(a), 2(b), and 2(c) show the Dalitz plots for modes (a), (b), and (c), respectively.

The ratio (number of π^+n events)/(number of π^0p events) for the peaks corresponding to the $N^*(1238)$ is approximately the reciprocal of a similar ratio taken from the peaks corresponding to the $N^*(1425)$ after the peaks are cleared of events corresponding to K^* and Y^* resonances as well as nonresonant background. This may be an indication that the $N^*(1425)$ and the $N^*(1238)$ differ in isospin, a result that would be consistent with the results obtained by both Bareyre and Roper.[3,5] It should be pointed out, however, that the ratio mentioned above for all events falling under the $N^*(1238)$ peak does not agree with the well-established value of $I=\frac{3}{2}$ for the isospin of that resonance. This discrepancy

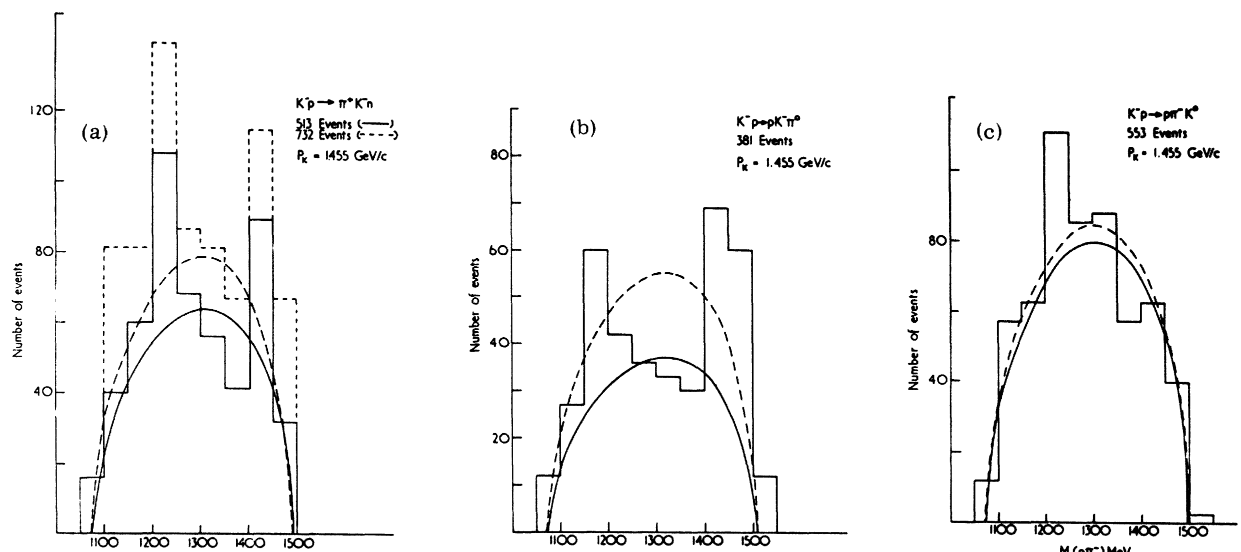

FIG. 1. (a) Invariant-mass distribution of the pion-nucleon system in the mode $K^- + p \rightarrow \pi^+ + K^- + n$. The solid-line histogram shows the distribution of all events in this mode except the ones which fall under the $K^*(888)$ peak. The dashed-line histogram includes the $K^*(888)$ events. Both phase-space diagrams are normalized to the solid-line distribution. (b) Invariant-mass distribution for the mode $K^- + p \rightarrow p + K^- + \pi^0$, including all events fitted to this mode. (c) Invariant-mass distribution for the mode $K^- + p \rightarrow p + \pi^- + K^0$. The significant reduction of the 1425-MeV peak in this charge state is shown.

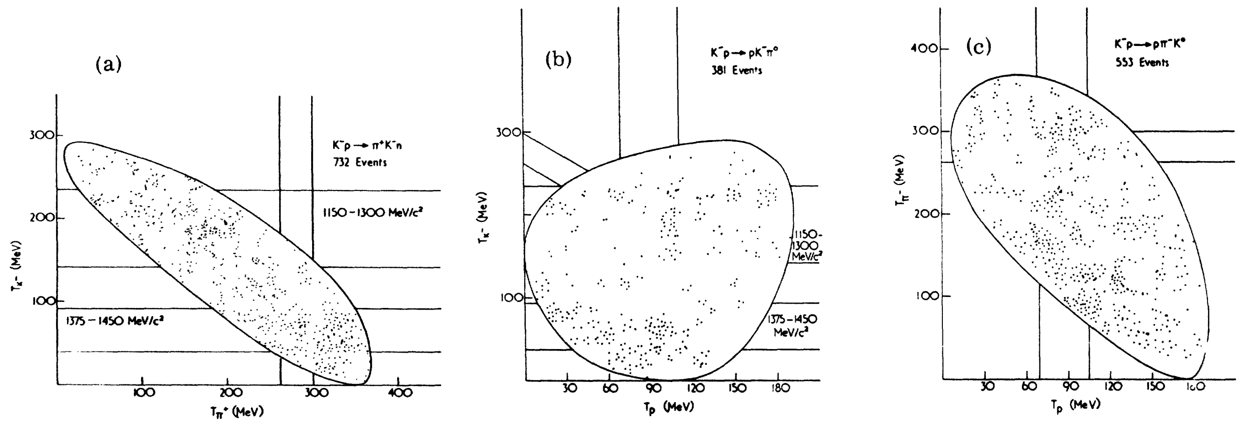

FIG. 2. (a) Dalitz plot of c.m. kinetic energy of the K^- meson vs the π^+ for the mode $K^- + p \to \pi^+ + K^- + n$. (b) Dalitz plot of K^- vs p for the mode $K^- + p \to p + K^- + \pi^0$. (c) Dalitz plot of π^- vs p for the mode $K^- + p \to p + \pi^- + K^0$.

may be due to interference with the background or to double-resonance effects with the K^* and Y^* resonances. Similar discrepancies have been observed before in bubble chamber experiments. If this is the case then no conclusion concerning the isospin of the $N^*(1425)$ can be drawn from the presently available data.

If the three reaction modes that we studied proceed by single-particle exchange, then, by conservation of parity and angular momentum, the exchanged particle could only be a vector meson (ω or ρ). The absence of the 1425 peak in mode (c) seems to indicate that charge is not being carried across the vertex, and, assuming the single-particle model to hold, this would be evidence that the reaction in fact proceeds by ω exchange.

The author wishes to thank Professor O. R. Frisch and Dr. K. F. Riley of the Cavendish Laboratory, and Dr. D. V. Bugg of the Rutherford Laboratory, National Institute for Research in Nuclear Science, for their criticism and advice during the course of this analysis. His gratitude extends also to the members of the Nuclear Group, Cavendish Laboratory, and to the staff of the CERN proton synchrotron and track chamber groups.

*Accepted without review under policy announced in Editorial of 20 July 1964 [Phys. Rev. Letters 13, 79 (1964)].

[1]G. Amato et al., Nucl. Instr. Methods 20, 47 (1963).

[2]S. L. Adelman, thesis, University of Cambridge (unpublished).

[3]L. D. Roper, Phys. Rev. Letters 12, 340 (1964).

[4]G. Cocconi et al., Phys. Letters 8, 134 (1964).

[5]P. Bareyre et al., Phys. Letters 8, 137 (1964).