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PROSPECTS FOR Y^* EXPERIMENTS

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PROSPECTS FOR Y^* EXPERIMENTS†

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Over the years, the accumulated knowledge of Y^*s has lagged behind that of the nucleonic resonances. As a measure of this retardation, if we inspect the 1973 edition of the PDG tables[1] we find that there are 22 N and Δ states whose quality classification is either 3 star or 4 star, whereas there are but 21 such Λ and Σ states. If progress had been equally rapid in both domains one would have expected—according to the popularly accepted SU(3) classifications into decuplets, octets, and singlets—about twice as many of the latter states. This is because for every Δ there should be a Σ, for every N there should be both a Λ and a Σ, and including SU(3) singlets there should be solitary Λ states as well.

A major problem with Y^* studies stems from difficulty in constructing low-momentum K^- beams of high intensity which could be employed in formation experiments using electronic means to accumulate high statistics. Essentially all our knowledge of N and Δ resonances is obtained from such high-statistics counter experiments with intense $\pi^\pm$ beams, whereas the bulk of data on Y^*s come from systematic formation experiments done with bubble chambers in low-intensity K^- beams. Below a K^- momentum of 1 GeV/c (1790 MeV c.m. energy) there have been, apart from total cross-section experiments, no fruitful counter experiments. Now as a result of a greater effort to build more intense K^- beams, it appears feasible to extend the region of K^- counter experiments down to about 500 MeV/c.

Looking first at the status of bubble chamber experiments, Fig. 1 exhibits a compilation of path lengths[2] for all K^-p exposures relevant to formation experiments up to 2 GeV/c. It displays on a logarithmic scale the path length averaged over the indicated momentum interval of the experiment (except for two low-energy exposures where the path length varies greatly with momentum). In many of the exposures only certain reaction topologies have been analyzed. Several generations of experiments are shown. In the more recent and unpublished ones most regions are covered at a level of at least 1000 events/mb per 25 MeV/c. However, it is appalling to see that the only comprehensive experiment between 450 and 800 MeV/c is that of CHS, and most of our understanding of the spin parity of Y^*s

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in this region is based upon this relatively-low-statistics experiment. Forthcoming Tennessee-Massachusetts data will improve the upper momentum region, as will a higher statistics CERN-Heidelberg-Munich experiment whose analysis is just beginning. As indicated by the dashed line, a track-sensitive target (a hydrogen target surrounded by a hydrogen-neon mixture) is now running at the Rutherford laboratory and plans call[2a] for extending this exposure into the critically deficient region below 600 MeV/c. The chamber has an average gamma-ray detection efficiency of about 20% so that separation of $\Lambda\pi^0$, $\Sigma^0\pi^0$, and $\Lambda\pi^0\pi^0$ will also be more reliable than in a conventional bubble chamber experiment. It is interesting to note that the most recent experiments are all being done in European laboratories —the U.S. has essentially abandoned and is dismantling its capacity to do systematic high-statistics studies, despite the obvious deficiency of currently published experiments to do any more than expose the dominant resonant structures.

Figures 2 and 3 display corresponding path-length plots for K^--deuterium[3] and K^0_L-p[4] bubble chamber experiments. The deuterium exposures are in reasonable balance with respect to the hydrogen experiments, and the K^0_L bubble chamber activity—long in coming—appears now at a level where it may contribute substantially to the knowledge of the pure I = 1 state of $\bar{K}N$. In particular the recent RGEPB exposure in the CERN 2-meter chamber uses an essentially monoenergetic K^0_L beam of $\Delta P/P = \pm 2.5\%$. This additional constraint permits the study of more reactions types.

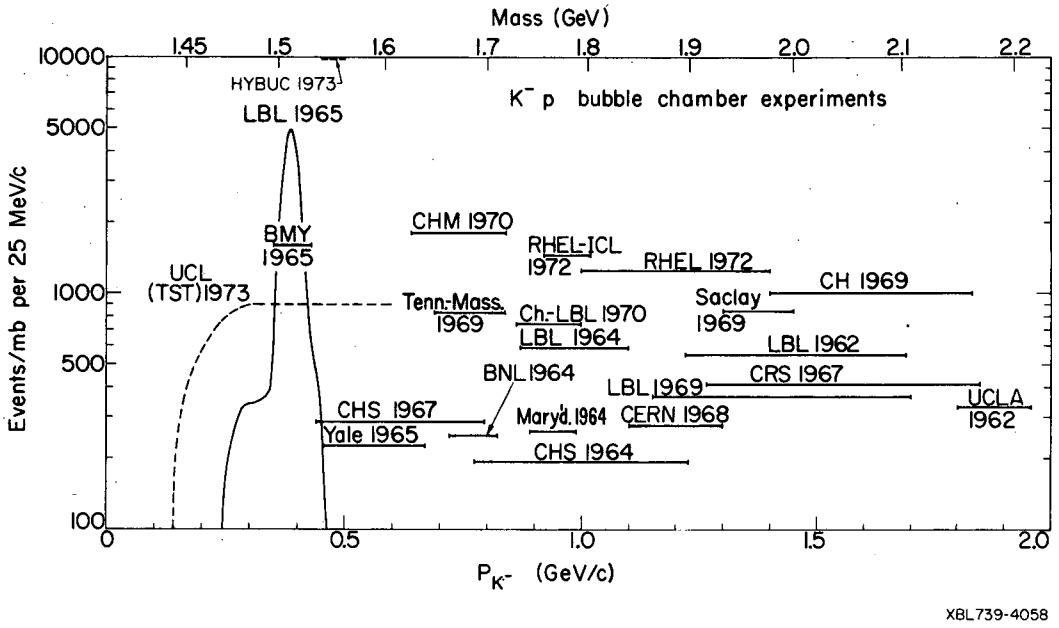

Fig. 1. K^-p bubble chamber path lengths below 2 GeV/c. Numbers refer to the approximate date of the exposure. Horizontal lines show the momentum interval and the average level of the exposure over that interval. Abbreviations and references are in Ref. 2.

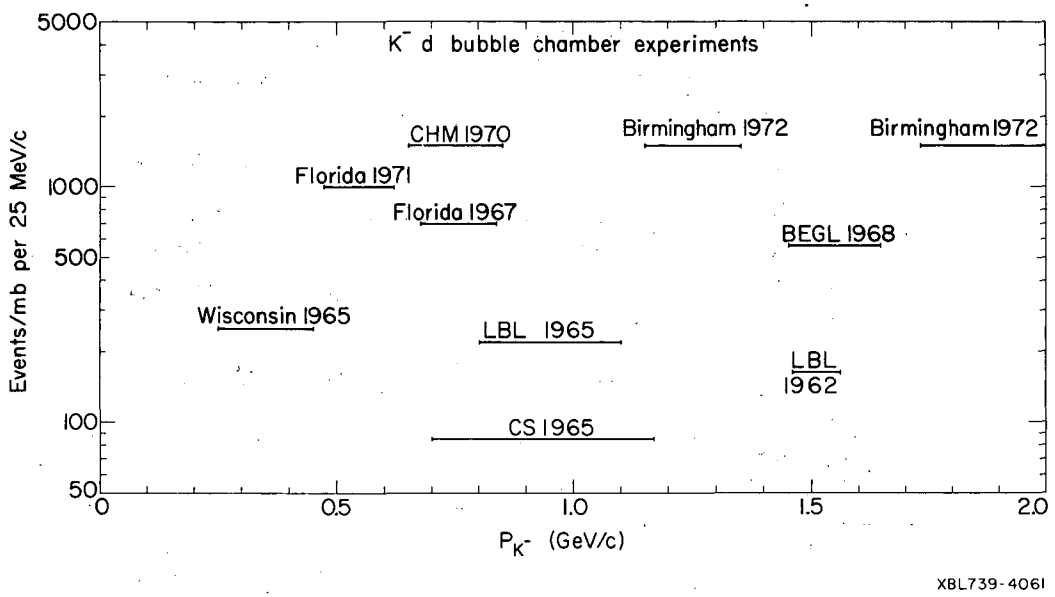

Fig. 2. K^- deuterium bubble chamber path lengths below 2 GeV/c. Numbers refer to the approximate date of the exposure. Abbreviations and references are in Ref. 3.

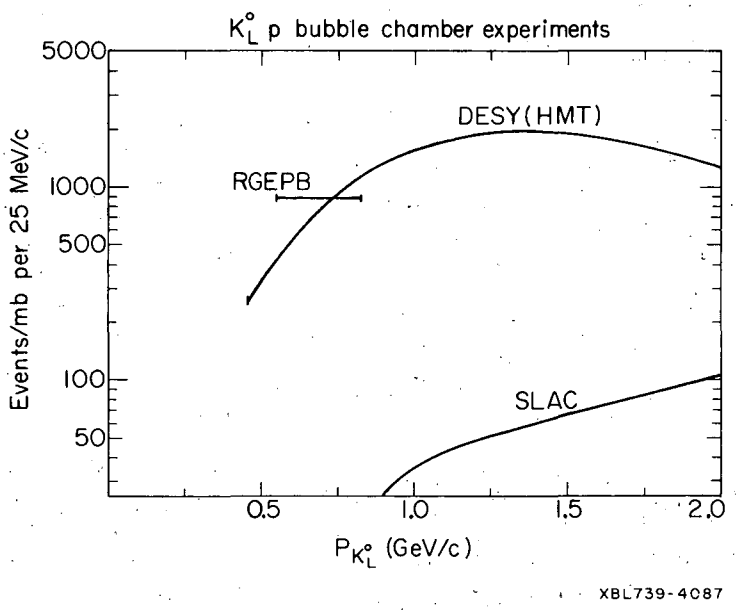

Fig. 3. K_L^o bubble chamber path lengths below 2 GeV/c. References are in Ref. 4.

A display of all $\bar{K}N$ electronic experiments which have, or may in the near future, contribute to Y^* studies is shown in Fig. 4.[5] Of recent interest is the BNL total cross-section experiment,[5d] as yet unpublished, which has revealed new structure at a momentum of 540 MeV/c. Two RHEL experiments, still being analyzed, promise to improve the statistics on K^-p elastic scattering; despite several

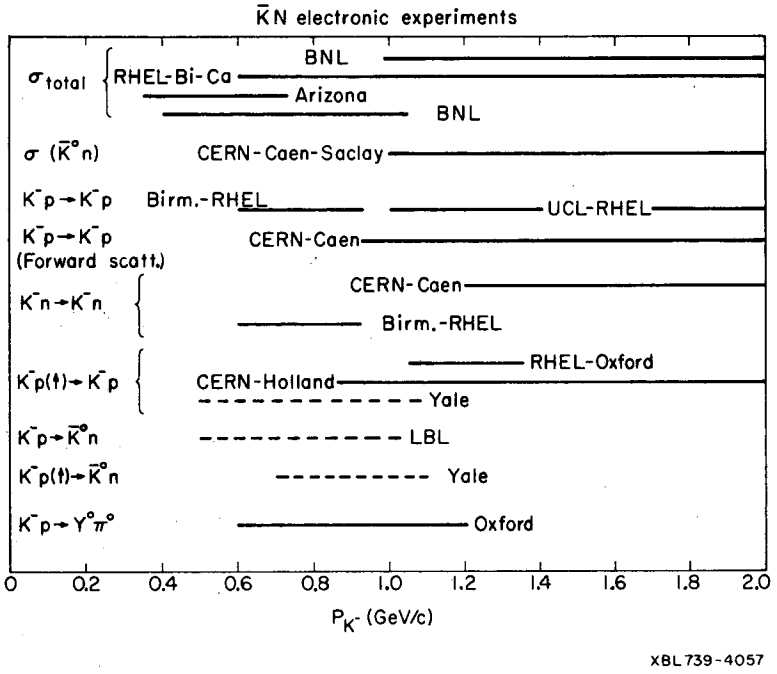

Fig. 4. $\bar{K}N$ electronic experiments relevant to Y* studies. Horizontal lines indicate the momentum interval covered. Dashed lines are proposed experiments. References are in Ref. 5.

previous efforts of electronic experiments to overwhelm bubble chamber data with this simplest of reactions, the latter still dominate Y^* analysis. In 1972 CERN-Caen did a wire chamber experiment in the Coulomb-nuclear interference region to obtain the real part of the K^-p forward scattering amplitude. This will be a useful constraint in future Y^* partial wave analyses. Two K^-n elastic scattering experiments are also in the analysis stages and should improve considerably the knowledge of the $I = 1$ elastic scattering amplitude, both in statistics and in the purity of the data compared with the same bubble chamber reaction in deuterium.

An obvious way in which electronic experiments can contribute to the study of Y^*s is through experiments with polarized targets. In the past this has been extended down to a momentum of 865 MeV/c, below which beam fluxes became prohibitively low. Although no new resonances or spin-parity assignments were revealed by the two experiments, they did serve to instill greater confidence in the energy-dependent elastic partial wave analyses since they had correctly predicted the subsequently measured polarizations. (These analyses had to that time been based only upon elastic and charge exchange angular distributions.) In contrast, energy-independent pion-nucleon analyses in recent years have been notoriously deficient in their predictive powers with respect to new experiments.[6] That such success will not be the case at lower K^- momenta and for other K^- reactions is apparent in Fig. 5, where polarization predictions for three elastic partial wave analyses are shown [7, 9e, 2m] for K^-p

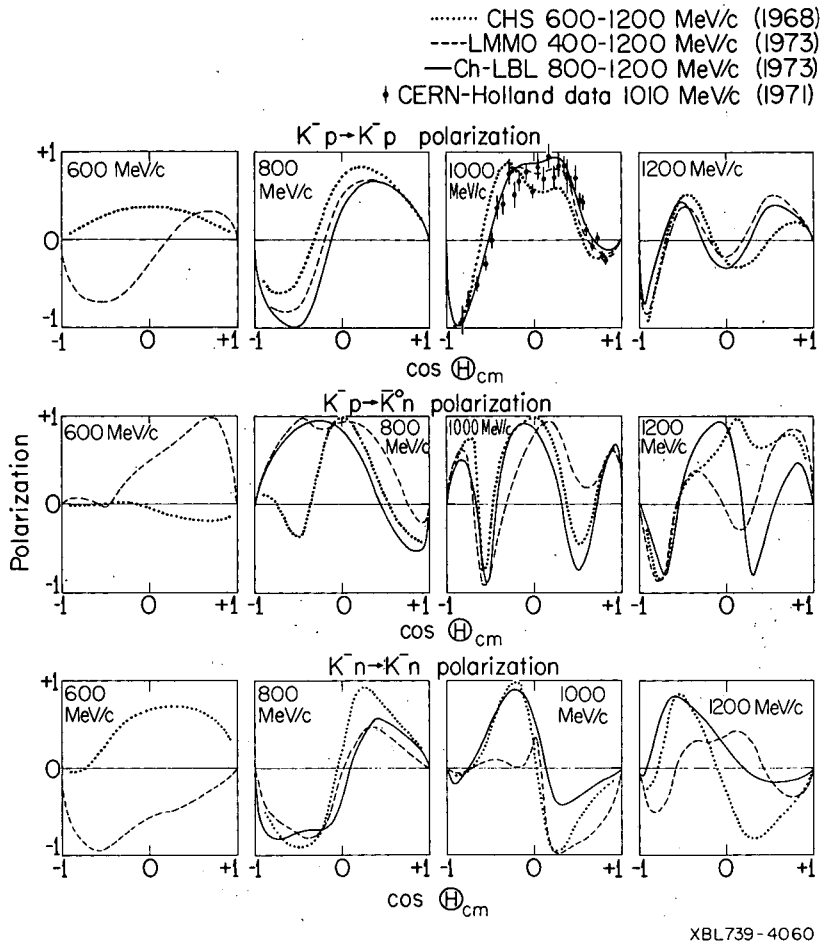

Fig. 5. Polarization predictions from three $\bar{K}N$ partial wave analyses at 600, 800, 1000, and 1200 MeV/c. Only K^-p polarization has been measured and only from a momentum of 865 MeV/c upward.

elastic and charge exchange scattering and for K^-n elastic scattering. In particular the K^-p polarization predictions for two analyses at 600 MeV/c are vastly different. An experiment has been proposed by the Yale group to extend the K^-p polarization measurements down to 500 MeV/c, using the BNL high-intensity K^- beam.[8] Figure 6 shows the fluxes of K^+, K^-, and $\bar{p}$ available from this beam per 10^{12} protons; several times this number can currently be delivered to the target by the AGS per pulse. The Yale group is also considering an experiment to measure charge exchange polarization down to comparable momenta. We (LBL) are proposing to measure the charge exchange angular distribution from 500 to 1000 MeV/c at a series of momenta with a statistical precision of a bubble chamber exposure of 10 000 events per mb per 25 MeV/c; i.e., corresponding to an experiment at the top of Fig. 1. This would also utilize the BNL K^- beam. A K beam of comparable intensity is coming into operation at ANL, so that we may anticipate an enhanced experimental effort on Y^* formation experiments.

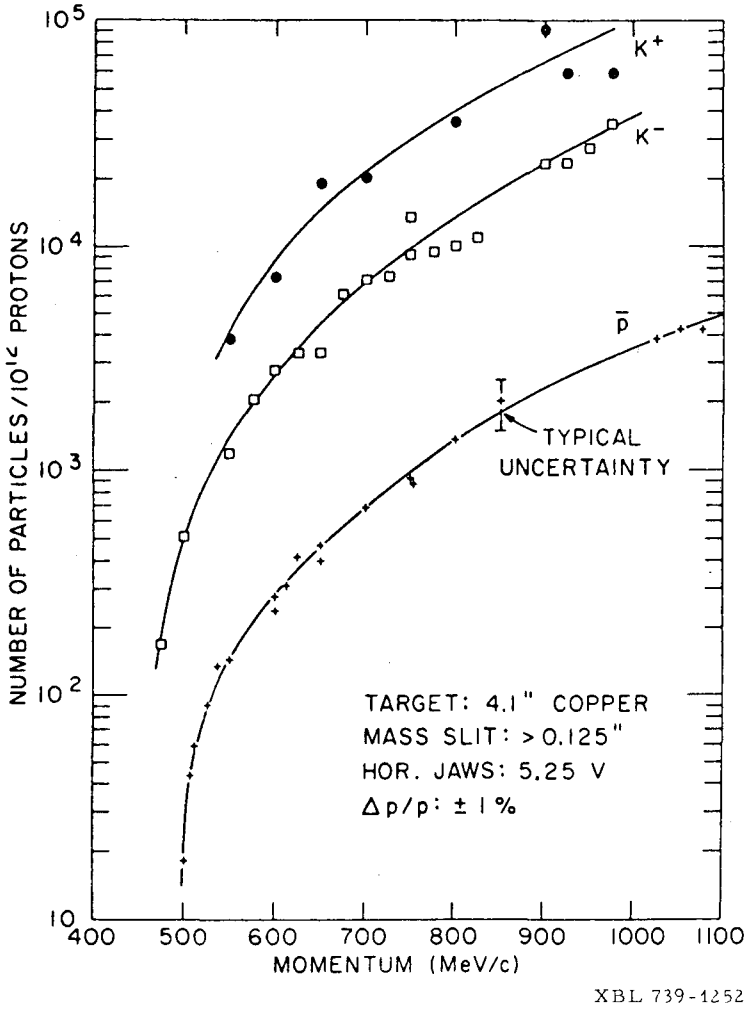

Fig. 6. Particle fluxes from the BNL partially separated low-energy beam.

The present situation concerning hyperon resonances accessible to formation experiments up to a mass of 1.9 GeV is summarized in Fig. 7.[9] The well-established 3-star and 4-star resonances are shown at the bottom. Above those appears a chaos of possible resonant states suggested with varying degrees of conviction by a number of partial wave analyses of bubble chamber data augmented by total cross-section and K^-p polarization data. About the only persistent suggestion in these analyses is that there appears to be, in addition to $\Sigma(1670)$, another Σ resonance in the vicinity of 1620 MeV either in the S-wave or P wave. As indicated farther up in the figure, such a state has been reported in the recent BNL total cross-section experiment but, alas, at a significantly different mass and width. (There was also a suggestion for such a state in the earlier Arizona total cross-section measurements.)

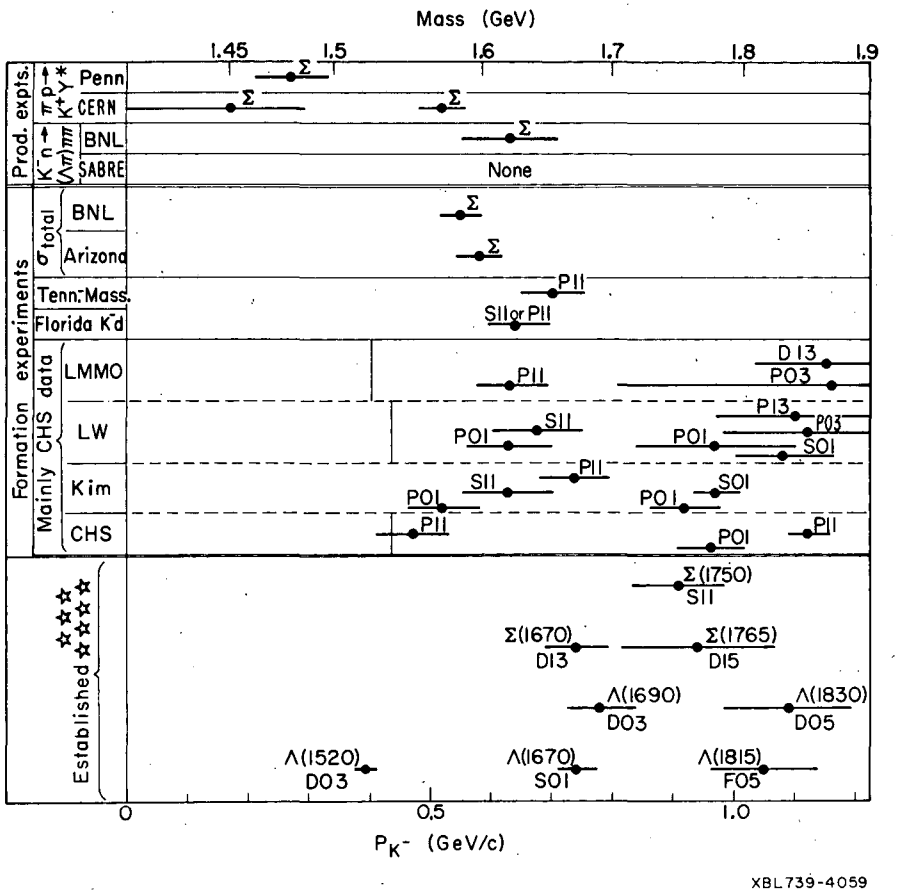

Fig. 7. Y* states--established and conjectured--between 1.43 and 1.9 GeV mass.

The first evidence for a Σ resonance in the vicinity of 1600 MeV appeared many years ago in production experiments; this is shown at the top of Fig. 7. The BNL-CCNY bubble chamber experiment[9k] found indications in the reaction $K^- n \to (\Lambda\pi)^- \pi^+\pi^-$ at a $\Lambda\pi$ mass of 1620 MeV, whereas a European collaboration (SABRE)[9j] doing a similar experiment at a slightly lower bombarding energy did not confirm such a state.

Much earlier than these experiments, in the all-but-forgotten past, there were two $\pi^- p \to Y^{*-} K^+$ missing-mass type experiments done with counters at CERN,[9ℓ] where only the K^+ was detected as the bombarding energy was varied. One of these observed the K^+ at 0° in the cm while the other covered the K^+ c.m. angular region $0.8 > \cos\theta > -0.5$. The former is shown in Fig. 8a, where in addition to enchancements at the Σ and $Y^*(1385)$ masses, structure is suggested at 1570 MeV, similar in mass and width to the BNL total cross-section bump. At the time, the evidence was understandably found to be unconvincing both statistically and because a plausible alternative explanation could be invoked to explain the structure,

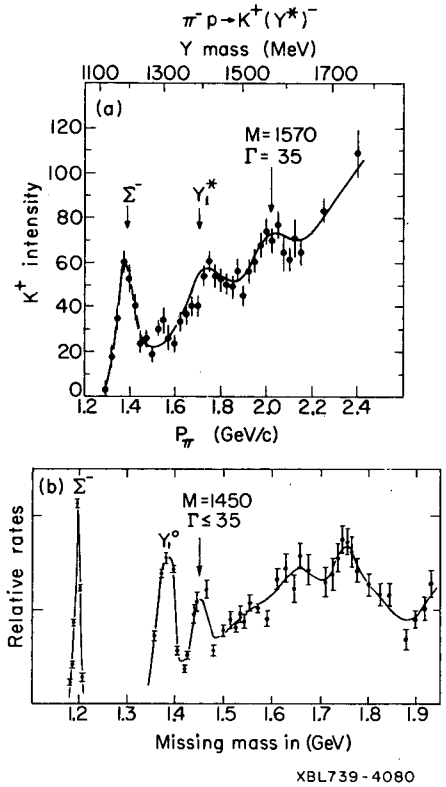

Fig. 8. Evidence for Σ resonant states from CERN missing-mass experiments (Ref. 91). In (a) the K^+ is produced at 0° in the c.m. and in (b) it is produced at larger angles. Masses and widths are estimated.

namely a changing amplitude in the s-channel of the pion-nucleon system as the incident pion momentum was changed to sweep through the mass region of the Y^* sampled by the apparatus. Likewise Fig. 8b shows the result of the latter experiment, where evidence for another Σ resonance at a mass of 1450 MeV was presented. Such a state has also been claimed in the same reaction at approximately the same incident pion momentum (1.7 GeV/c) in a high-statistics bubble chamber production experiment.[9m] The evidence from that experiment is shown in Fig. 9, where a suggestion of structure is seen at 1475 MeV. Occasional evidence for such a state has also been rumored in K^-N formation experiments,[2b, 10] but the indications are weak. If the state exists at all its branching fraction into the $\bar{K}N$ channel is very low so that it is formed with only a small amplitude. The additional path length of the new track-sensitive target exposure shown in Fig. 1 may be sufficient to clarify this mass region.

I have touched on some production experiment evidence for Y^*s, although I do not think that this type of experiment will be of great value in the future compared with high-statistics formation experiments which determine at the same time the spin and parity of the resonance. The reason for discussion production experiments at all is that if the coupling of the Y^* to the $\bar{K}N$ channel is very small, then they may be the only way in which the Y^*s existence can be revealed. Indeed, in some SU(3) octets the D and F couplings can be such that the Λ or Σ resonance has an exceedingly small branching fraction into the incident $\bar{K}N$ channel. Then a production experiment

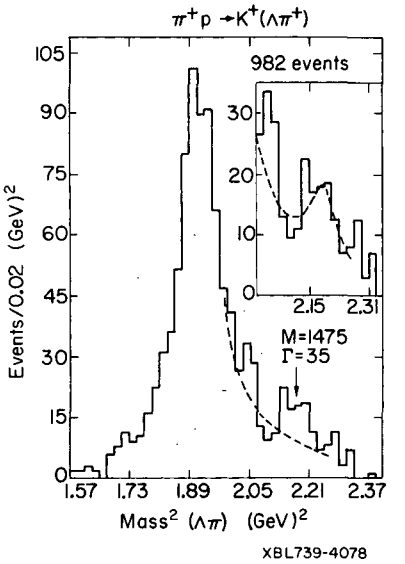

Fig. 9. Distribution of the $\Lambda\pi^+$ effective mass squared for the reaction $\pi^- p \to K^+\Lambda\pi^+$. Dashed line shows the tail of $Y^*(1385)$ plus background. In the insert another resonance is added in order to fit the observed enhancement.

proceeding either by K^* exchange or perhaps via the decay of an s-channel nucleon resonance into Y^* and K may be the only feasible way of detecting the hyperon resonance. Hints from the production experiments just described suggest that these Y^*s are produced most copiously slightly above threshold. A more elaborate version of a missing-mass experiment using a streamer chamber or a hybrid bubble chamber to selectively trigger on the K^+ and at the same time permitting analysis of the missing-mass disintegration products would appear to be the most favorable means of exposing such elusive states.

REFERENCES

1. Rev. Mod. Phys. 45, S1 (1973).

2. Reading from left to right, the abbreviations and references are:
   (a) UCL(TST)[University College London (Track Sensitive Target)]: D. J. Miller - RHEL/R 245 and private communication. Path length distribution is roughly estimated. The precise momentum range and distribution are still to be determined.
   (b) LBL 1965: R. Tripp, UCRL-20655 (1971).
   (c) HYBUC 1973 (Hyperon Bubble Chamber): R. Settles, private communication. The exposure was made for measurement of Σ^+ magnetic moment. If other topologies are measured, they may be useful for Y^* studies.
   (d) BMY 1965 (Brookhaven, Massachusetts, Yale): D. Berley et al., Phys. Rev. D 1, 1996 (1970).
   (e) Yale 1965: N. S. Wong, Nuovo Cimento 2A, 353 (1971).
   (f) CHS 1967 (CERN, Heidelberg, Saclay): R. Armenteros et al., Nucl. Phys. B21, 15 (1970).
   (g) CHM 1970 (CERN, Heidelberg, Munich): H. Oberlack, private communication.
   (h) Tenn.-Mass. 1969 (Tennessee - Massachusetts): E. Hart, private communication.
   (i) BNL 1964: D. Berley et al., Phys. Rev. Lett. 15, 641 (1965).
   (j) CHS 1964: R. Armenteros et al., Nucl. Phys. B8, 233 (1968).
   (k) Maryland. 1964: R. P. Uhlig et al., Phys. Rev. 155, 1448 (1967).
   (ℓ) LBL 1964: D. F. Kane, Phys. Rev. D 5, 1583 (1972).
   (m) Ch.-LBL 1970 (Chicago - LBL): D. Merrill et al., Berkeley APS Meeting 1973.
   (n) RHEL - ICL 1972 (Rutherford-Imperial College London): G. Kalmus, private communication.
   (o) CERN 1968: M. Ferro-Luzzi, CERN/D. Ph. 11/Phys. 71-9.
   (p) Saclay 1969: M. Ferro-Luzzi, ibid.
   (q) LBL 1962: D. O. Huwe, Phys. Rev. 181, 1824 (1969).
   (r) CRS 1967 (College de France, Rutherford, Saclay): P. J. Litchfield et al., Nucl. Phys. B30, 125 (1971).
   (s) CH 1969 (CERN-Heidelberg): M. Ferro-Luzzi, ibid.
   (t) UCLA 1962: P. M. Dauber, UCLA report 90024 (Thesis) (1966).

3. Reading from left to right, the abbreviations and references are:
   (a) Wisconsin 1965: D. Cline et al., Phys. Rev. Lett. 21, 1372 (1968).
   (b) Florida 1967, 1971: J. Albright, private communication.

(c) CHM 1970 (CERN, Heidelberg, Munich): H. Oberlack, private communication.
(d) LBL 1965: N. Jew and G. Kalmus, Nucl. Phys. B22, 205 (1970).
(e) CS 1965 (CERN-Saclay): R, Armenteros et al., Nucl. Phys. B18, 425 (1970).
(f) Birmingham 1972: R. Armenteros, private communication.
(g) BEGL 1968 (Birmingham, Edinburgh, Glasgow, Imperial College London): G. F. Cox et al., Nucl. Phys. B19, 61 (1970).
(h) LBL 1962: A. Barbaro-Galtieri et al., Phys. Lett. 6. 296 (1963).

4. (a) RGEPB (Rutherford, Glasgow, Edinburgh, Pisa, Bologna): G. Kalmus, private communication.
(b) DESY(HMTA) (Heidelberg, Minnesota, Tel-Aviv): E. Coleman, private communication.
(c) SLAC: D. Leith, private communication.

5. Reading from the top down, the references are:
(a) BNL: R. L. Cool et al., Phys. Rev. D 1, 1887 (1970).
(b) RHEL-Bi-Ca: Bugg et al., Phys. Rev. 168, 1466 (1968).
(c) Arizona: T. Bowen et al., Phys. Rev. D 2, 2599 (1970).
(d) BNL: A Carroll et al., Paper presented at Berkeley APS Meeting, August 1973.
(e) CERN-Caen-Saclay: C. Bricman et al., Phys. Lett. 31B, 148 (1970).
(f) Birm.-RHEL, UCL-RHEL: from G. Manning, UCRL-20655 (1971).
(g) CERN-Caen: T. Ypsilantis, Purdue conference on Baryon Resonances, 1973.
(h) CERN-Caen: M. Ferro-Luzzi, private communication.
(i) Birm.- RHEL: from G. Manning, UCRL-20655 (1971).
(j) RHEL-Oxford: C. R. Cox et al., Phys. Rev. 184, 1443 (1969).
(k) CERN-Holland: C. Daum et al., Nucl. Phys. B6, 273 (1968); and S. Anderson-Almehed et al., Nucl. Phys. B21, 515 (1970).
(ℓ) Yale: BNL Proposal (1973).
(m) LBL: BNL Proposal (1973).
(n) Yale: Possible BNL Proposal, M. Zeller, private communication.
(o) Oxford: from G. Manning, UCRL-20655 (1971).

6. M. Ferro-Luzzi, CERN/D. Ph. II Internal Note 71-2.
J. Nelson et al., LBL-2002 (1973).

7. R. Armenteros et al., Nucl. Phys. B8, 195 (1968).

8. BNL report of D. N. Michael (1973).

9. Reading from the bottom up, the abbreviations and references are:
(a) Established 3- and 4-star resonances refer to the Particle Data Group classification, Rev. Mod. Phys. 45, S1 (1973).
(b) CHS (CERN-Heidelberg-Saclay): R. Armenteros et al., in Proceedings of the Duke Conference on Hyperon Resonances (1970), edited by E. Fowler.

(c) Kim: Phys. Rev. Lett. 27, 356 (1971).
(d) LW (Langbein and Wagner): Nucl. Phys. B47, 477 (1972).
(e) LMMO (Lea, Martin, Moorhouse, and Oades): Nucl. Phys. B56, 77 (1973).
(f) Florida: W. A. Morris (thesis), Florida State University, 1973.
(g) Tenn. - Mass.: Tennessee - Massachusetts Collaboration paper presented by E. L. Hart at Purdue Conference on baryon resonances, 1973.
(h) Arizona: Bowen et al., Phys. Rev. D 2, 2599 (1970).
(i) BNL: Preliminary data presented by A. Carroll at Berkeley APS Meeting, August 1973.
(j) SABRE: (Saclay, Amsterdam, Bologna Rehovoth, Ecole Polytechnique Collaboration) Nucl. Phys. B16, 201 (1970).
(k) BNL: Crennell et al., Phys. Rev. Lett. 21, 648 (1968) and Lund Proceedings (1969).
(ℓ) CERN: Dowell et al., Phys. Lett. 1, 53 (1962) and Blackall et al., Phys. Lett. 16, 336 (1965).
(m) Penn.: Pan and Forman, Phys. Rev. Lett. 23, 806 (1969).

10. D. Cline et al., Lett. Nuovo Cimento 6, 205 (1973).

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