RATIO OF Λ AND Σ^0 PHOTOPRODUCTION CROSS SECTIONS; HIGH-MASS HYPERON RESONANCES*

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The ratio of Λ to Σ^0 photoproduction cross sections has been measured to be 1.25 ± 0.15. The measurement was carried out at center-of-mass angles of about 30°; the observed ratio disagrees with predictions of a quark model. In the study of K^+ photoproduction for photon energies from 4.0 to 6.1 BeV, we obtained evidence for Y^* states at 2360 and 2530 MeV.

The yield of K^+ mesons photoproduced from hydrogen has been studied over a range of photon energies from 2.88 to 6.1 BeV in an experiment using the bremsstrahlung beam of the Cambridge Electron Accelerator. The production of hyperon resonances in reactions of the type $\gamma+p\rightarrow K^+ + Y^0$ was investigated by analyzing the momentum of the K^+ mesons and computing the missing mass in the reaction corresponding to the end-point energy of the bremsstrahlung spectrum. Y^0 refers to Σ^0, Λ, or any neutral hyperon resonance with isospin 0, 1, or 2. The K^+ mesons produced at a laboratory angle of 10° were identified by momentum analysis with a 2.5-BeV/c spectrometer and velocity analysis with two differential gas Cherenkov counters. The spectrometer consists of scintillation-counter hodoscopes with a momentum acceptance of ±7%. The apparatus was briefly described in a separate publication on similar studies of K^- yields in photoproduction.[1] A missing-mass resolution of about 20 MeV made it possible to resolve clearly the Λ and Σ^0 states. K-meson yields were obtained as a function of synchrotron energy with all parameters associated with the spectrometer kept constant. An absolute normalization was obtained with a quantameter which had been calibrated against a Faraday cup. The relative quantameter response from point to point was checked by comparing it with an ionization chamber and with the smoothly varying π-meson yield measured simultaneously with the spectrometer.

The relative production cross sections of the Σ^0 and Λ hyperons have been measured and compared with predictions of a quark model for photoproduction of pseudoscalar mesons.

Data were taken for five bremsstrahlung end-point energies in the vicinity of the Λ and Σ^0 thresholds at 2.88- and 2.98-BeV photon energy. The absolute momentum setting of the spectrometer was determined from the data by using known hyperon masses in the analysis. Because of the available mass resolution of the spectrometer, the ratio of Σ^0 and Λ cross sections can be obtained without elaborate analysis. The relative differential cross sections for Σ^0 and Λ photoproduction are completely independent of the detailed properties of the spectrometer except for the small variation in relative efficiency with momentum. This has been extracted from other K^+-yield data taken in the course of the experiment.

The Σ^0 and Λ production data and least-squares fits are shown in Fig. 1. The data are shown normalized per equivalent quantum so that two-body thresholds appear as steps in the yield. The observed ratio of the differential cross sections is $d\sigma(\Lambda)/d\sigma(\Sigma^0) = 1.25 \pm 0.15$. The center-of-mass angles of Λ and Σ^0 production were 27.9° and 28.4°. A calculation of the ratio of cross sections based on a quark model discussed recently[2,3] predicts a ratio of 27:1. Kinematical corrections increase the predicted ratio by about 20%. The model assumes forward

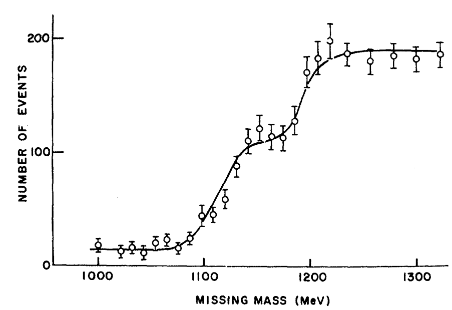

FIG. 1. The yield of K^+ mesons observed at 10° in the laboratory. The data points have been taken at several synchrotron energies near 3.0 BeV; the kaon momentum is centered at about 2.5 BeV/c. The data points have been fitted for the processes $\gamma+p\rightarrow K^+ + \Lambda$ and $\gamma+p\rightarrow K^+ + \Sigma^0$ assuming a Gaussian resolution for the spectrometer. The missing mass has been calculated using the end-point energy of the bremsstrahlung spectrum.

production and independent quarks. Data obtained under other kinematic conditions in several other experiments[4] also show order-of-magnitude disagreement with this model.

In a search for high-mass hyperon resonances, positive K-meson yields were studied for the missing-mass region from 1800 up to about 2600 MeV. Altogether, five separate data-taking runs were made with overlapping mass ranges. In general, the spectrometer parameters were fixed at 2.5 BeV/c, while the synchrotron energy was varied from 4.0 to 6.1 BeV. To reach the upper part of the mass range, the spectrometer momentum was reduced to 2.0 BeV/c. The missing-mass region from 2400 to 2600 MeV was studied at both kaon-momentum settings, providing a check on the kinematic shift for two-body structure in this mass interval.

The identification of Y^* resonant states depends on the two-body nature of the reactions. For these reactions, thresholds appear as steps in the yield as the synchrotron energy is increased. Multibody final states such as those with K-meson pairs and states involving pions and also $K^*\Sigma$, $K^*\Lambda$, and K^*Y^* reactions are all characterized by yield curves which are quite smooth with increasing energy once the threshold is passed[1] and, in fact, are nearly linear over wide ranges of the energy region of interest. Monte Carlo calculations show that the contribution of K^+ mesons from K^* decay produced together with Y^* states is reduced by about a factor 10 because of the three-body nature of the process and the properties of the spectrometer. Since the positive K meson is observed at 10° and is required to have a momentum near 2.5 BeV/c, the apparent threshold in the laboratory for all processes which involve K^+ mesons in the production channels occurs at a photon energy far above that for which the given reaction becomes energetically possible in the center-of-mass system. Thus, an unusual threshold behavior of these reactions which may simulate resonancelike shapes with widths of about 150 MeV is never observed in this type of production experiment. The K^+ yield for multibody final states can be computed on the basis of spectrometer properties and kinematics and reasonable assumptions as to energy dependence of the cross sections without detailed knowledge of threshold behavior. Only anomalously rapid variation of cross sections for multibody processes at high energies could simulate resonant structures whose characteristic widths are typically less than 150 MeV.

Earlier work by a Yale group at the Cambridge Electron Accelerator has indicated[5] that two-body final states constitute an important part of the K^+ yield in photoproduction at high energies. Similarly, the present data show that the background processes may account for about half of the yield, although the size of the background is not accurately determined from the data; neither, however, is the interpretation of the data in terms of resonances sensitive to it. In particular, the masses of the resonances as determined from the best fit are quite independent of the size and slope of the background; the widths and especially the cross sections, on the other hand, do depend on the nature of the three-body contributions.

The data were analyzed for the presence of resonant states by a least-squares procedure. A theoretical function was computed by assuming Breit-Wigner shapes for resonant states with the amplitude, width, and center for each left as free parameters. Backgrounds from various multibody processes were represented by a linear term plus a constant since the statistical quality of the data did not seem to justify more complicated assumptions. The functions were numerically integrated over the bremsstrahlung spectrum and converted to a missing-mass scale. The data from each of seven 2% momentum bins were converted to a mass scale but were allowed to have an independent normalization factor.

Evidence for several states is obtained for the first time in photoproduction processes. Figure 2 shows the K^+-meson yield converted to a missing-mass scale at the upper end of the region we have studied. Attempts were made to fit the data with background functions alone. The value of χ^2 when no resonant states were included was more than $3\frac{1}{2}$ standard deviations from that obtained as a best fit with Breit-Wigner resonances. The confidence level for the highest resonant state included in the fit is about $1\frac{1}{2}$ standard deviations. Based on these fits, a resonance is observed at 2360 ± 20 MeV with a width (Γ) of about 60 MeV and another is seen at 2530 ± 20 MeV with a width of 150 MeV; differential cross sections are typically 0.1-0.2 μb/sr. Measurements of K^-p and K^-d total cross sections at Brookhaven National Laboratory[6,7] have revealed Y^*

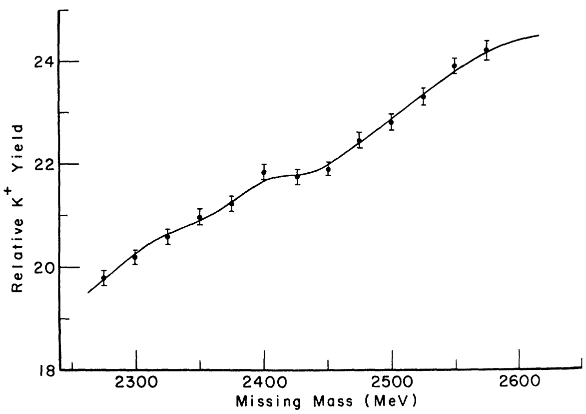

FIG. 2. The yield of K^+ mesons observed at 10° for synchrotron energies from 4.0 to 6.1 BeV. Data taken with the spectrometer set for both 2.0 and 2.5 BeV/c have been combined on a missing-mass scale using the bremsstrahlung end-point energy. Each datum point shown includes data from approximately five synchrotron energies and kaon-momentum intervals; the errors are statistical. The solid curve is the sum of the background and two Breit-Wigner resonances at 2360 and 2530 MeV as described in the text. This function is normalized and fitted to the data points by a least-squares procedure.

resonances with masses up to about 2600 MeV. An attempt was made to fit the upper part of the data with two resonances at 2455 and 2595 MeV in accordance with the results of Ref. 7. The quality of the fit with two resonances does not differ significantly from that with one resonance at 2530 MeV.

The spins of most of the resonances below 2100 MeV have been directly determined[8,9] and some of these can be assigned to SU(3) multiplets. The Y^* states at 1820 and 1915 fit into a $\frac{5}{2}^+$ octet which is a recurrence of the familiar baryon octet. The $I=1$ resonance near 2035 is a member of a $\frac{7}{2}^+$ decuplet,[9] a recurrence of the tenfold representation of baryons. The states near 2260 and 2340 may belong to as yet incomplete $\frac{9}{2}$ multiplets. The newly discovered high-mass state at 2530 MeV, if it has isospin 1, could be assigned to an 11/2 decuplet together with a known nucleon resonance at 2420.

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