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†Present address: University of Bologna, Bologna, Italy.

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K^0 PHOTOPRODUCTION CROSS SECTIONS COMPARED TO QUARK-MODEL PREDICTIONS*

Charles E. Roos
Department of Physics and Astronomy, Vanderbilt University, Nashville, Tennessee

and

Joe H. Mullins and Donald G. Coyne†
Department of Physics, California Institute of Technology, Pasadena, California
(Received 19 May 1967)

The upper limit of the ratio of K^0 production from the neutron to that from the proton at forward c.m. angles is determined experimentally. This limit is about 20 times less than the ratio predicted on the basis of quark wave functions, at the energies of this experiment. The maximum Q value for these reactions is 240 MeV, with forward three-momentum transfers in the range 260-390 MeV/c.

The K^0 photoproduction from nucleons has been studied at forward c.m. angles with the Caltech electron synchrotron. The ratio of K^0 production from the neutron will be compared with recent theoretical predictions by Kupsch[1] and by Rubinstein, Scheck, and Socolow.[2] In both papers, the authors assume that the photon interacts directly with a single quark in the nucleon resulting in a predominantly forward scattered meson. The reaction amplitudes can be expressed in terms of the wave function predicted by the quark model for the baryons. The pseudoscalar-meson reactions can be expressed in terms of a single amplitude and similar predictions of ratios of cross sections were independently made by the above authors.[1,2]

The three reactions studied experimentally which can be compared to the predicted ratios are

$$\gamma + n \to K^0 + \Sigma^0, \tag{1}$$

$$\gamma + p \to K^0 + \Sigma^+, \tag{2}$$

$$\gamma + n \to K^0 + \Lambda^0. \tag{3}$$

The theoretical ratios for these reactions before kinematic corrections are 1:2:27.[1,2]

The cross sections for Reaction (2) have been determined[3,4] for the backward c.m. Σ^+ (forward K^0) in the course of an emulsion experiment which measured the magnetic moment of the Σ^+.[4,5] The differential cross sections are shown in Fig. 1 in terms of the kaon c.m. angle. This cross section must be considered as a lower limit since the major effort of the Σ^+ experiment was the determination of the Σ^+ moment. The Σ^+ cross sections are a compilation from several different exposures at energies between 1.3 to 1.5 BeV. If corrected for scanning efficiency, these cross sections could be raised by some 25%. The mean lower limit of the total cross section for K^0 production of protons, between c.m. angles of 10 and 90°, averaged over the photon energy range of 1.1 to 1.5 GeV, is 3.8 ± 1.2 μb. The angular distribution for Reaction (2) indicates a forward peaking of the K^0, which might be expected with the impulse approximation of the quark-model calculations.[1,2] The polarization of the Σ^+ averaged over energy, and backward c.m. angle, is $+0.85 \pm 0.25$[5] with the spin in the direction $\gamma \times P_\Sigma$, where P_Σ is the Σ^+ momentum at production.

The reactions (1) and (3) were also investigated over the energy range 1.1 to 1.5 GeV with a heavy-liquid bubble chamber, employing a gaseous deuterium target.[6,7] This experiment used the identical beam, energy, and beam-monitoring equipment as that used for the experiment which measured Reaction (2). Furthermore, the Σ^+ runs were taken both before and after each bubble-chamber run. The fact that no reactions of the type $\gamma + n \rightarrow K^0 + (\Lambda, \Sigma^0)$ were found in the bubble-chamber experiment sets an upper limit on the production cross section. We obtain the largest upper limit on the cross section for Reaction (3) by assuming that Reaction (1) contributes negligibly (the two reactions would not be distinguishable in the bubble-chamber runs). This limit is about 1-μb total cross section at the 50% confidence level and 3.3-μb total cross section at the 90% confidence level.[6] The experiment was sensitive between c.m. angles of approximately 20 and 170°. If one assumes that the angular distributions for Reactions (2) and (3) are the same then one obtains the dashed line in Fig. 1 for the 90% confidence upper limit of the differential cross sections for Reaction (3). These limits are supported by the results of a separate experiment by Alyea,[8] in which K^0 photoproduction from a carbon target was measured for c.m. angles in the range 18-40°, at γ energies up to 1.3 GeV. The results gave a differential cross section for all three reactions combined in this angular range of 1 ± 0.5 μb/sr (see Fig. 1).

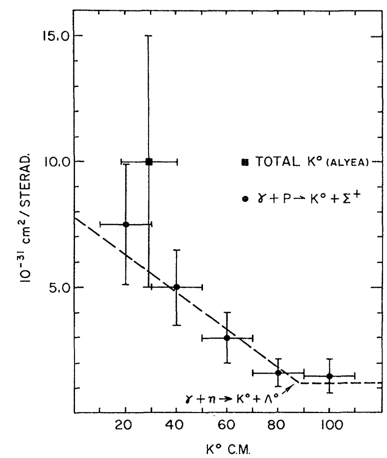

FIG. 1. The differential cross section per nucleon is plotted as a function of kaon c.m. angle for the reaction $\gamma + p \rightarrow K^0 + \Sigma^+$. This should be considered as a lower limit since no correction was made for scan efficiency. The 90% confidence upper limit for the reaction $\gamma + n \rightarrow K^0 + (\Lambda^0, \Sigma^0)$ is assigned the same angular distribution as the Σ^+ reaction and is shown as a dashed line. The measurement of the total K^0 production per nucleon from both reactions by Alyea (Ref. 8) provided additional evidence that K^0 production from neutrons is not greater than that from protons.

The ratio of the kinematical corrections for Reaction (2) to those for Reaction (3) range from 0.75 to 0.81 over the γ energies of interest, when calculated in accordance with the prescription of Ref. 2. These are in a direction such as to suppress the experimental cross section of $K^0\Sigma^+$ relative to $K^0\Lambda$. The model thus predicts the ratio of cross sections

$$(\gamma + n \rightarrow K^0 + \Lambda):(\gamma + p \rightarrow K^0 + \Sigma^+) = 17:1,$$

while the experimental ratio is about 20 times smaller than this prediction. The ratio of the upper limits for Reactions (1) and (3) to the lower limit for Reaction (2) is <0.9.

The significant experimental disagreement with the predictions of the quark model may possibly be due to the energy at which this ratio is measured.[9] The maximum Q value for the reactions is 240 MeV, giving forward three-momentum transfers in the range 260-390 MeV/c. The $\lambda\!\!\!^-$ for the mean photon energy of this experiment is 0.15 F. The cross section for Reaction (2) has a marked K^0 forward peak, and a quark model which assumes energy transfer to the other quarks in the baryon[2] might be expected to produce a more isotropic Σ^+ distribution even if it could account for the 20-fold discrepancy.

The relationship of baryon magnetic moments obtained by Rubenstein, Scheck, and Socolow,[2]

$$\mu_\Lambda + 3\mu_{\Sigma^+} = (8/3)\mu_p, \tag{4}$$

is in agreement with the value of the Σ^+ moment.[10] The Λ^0 and Σ^+ moments have a 25 to 30% error, and this does not permit one to distinguish between the above relationship and other theoretical predictions for the hyperon moments.[11]

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ASYMPTOTIC SU(3), SUPERCONVERGENCE, AND THE K_{l3} FORM-FACTOR F_+

L. K. Pandit
Tata Institute of Fundamental Research, Bombay, India
(Received 23 May 1967)

Assuming that in the asymptotic region of large S, the π_{l3} and K_{l3} form factors $f(S)$ and $F_+(S)$ are related by the SU(3) symmetry, a superconvergence relation is suggested, from which, on saturation by the ρ and the K^*, we obtain the approximate result $F_+(0) = -(1/\sqrt{2})M_\rho^2/M_{K^*}^2$.

It has been emphasized by Gell-Mann[1] that a higher symmetry like SU(3), which is evidently broken with the attendent large mass differences within a multiplet, may yet be exact in the asymptotic regions of very large energies and large momentum transfers where finite mass differences do not matter any more. This idea is only just beginning to be useful, as the suggestion has been put forward by Costa and Zimerman[2] that a quantitative formulation of it may be made through statements of superconvergence[3] of such combinations of amplitudes that would vanish if the SU(3) symmetry were to hold exactly. This, of course, can be applied to any other symmetry too.

In this note a simple application of this idea is made to the case of a form factor. Form factors are perhaps even more suited to such a treatment than scattering amplitudes since the spins of the states contributing to the former are much more restricted.

We shall consider the F_+ form factor entering the following matrix element:

$$\langle \pi^0(q') | V_{\mu 3}{}^1(0) | K^+(q) \rangle = (4V^2 q_0 q_0')^{-1/2} \times [F_+(S)(q+q')_\mu + F_-(S)(q-q')_\mu], \tag{1}$$