Photoproduction of K^+ Mesons from Deuterium*

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The differential cross section for the reaction $\gamma+n\rightarrow K^++\Sigma^-$ has been measured. The data are obtained by observing the charged K particle with a magnet spectrometer alternately from hydrogen and from deuterium. For γ-ray energy of 1122 Mev and for $\theta_{\text{c.m.}}=82°$ we get $d\sigma_{n\Sigma^-}/d\sigma_{p\Sigma^0}=1.6\pm0.7$.

IN order to obtain an estimate of the cross section for $K^+\Sigma^-$ photoproduction from the free neutron we have measured K^+ production from deuterium. The experiment consisted of measuring the K^+ yield from both a liquid hydrogen and a liquid deuterium target under identical conditions, namely at a laboratory angle of 25°, K^+ momenta of 405 and 455 Mev/c, and with a bremsstrahlung beam of peak energy 1170 Mev. The three reactions which contribute to the K^+ yield are

$$\gamma+p\rightarrow K^++\Lambda^0,\quad 911\text{ Mev},\tag{1a}$$

$$\gamma+p\rightarrow K^++\Sigma^0,\quad 1046\text{ Mev},\tag{1b}$$

$$\gamma+n\rightarrow K^++\Sigma^-,\quad 1051\text{ Mev},\tag{1c}$$

where the number at the right is the laboratory threshold energy of the γ ray. The cross sections for reactions (1a) and (1b) have been previously measured at Cornell[1,2]; from these measurements and the total K^+ yield from deuterium one is able to estimate the cross section for reaction (1c).

The experimental apparatus and technique used was very similar to that previously employed at Cornell by McDaniel *et al.* and is described fully in reference 1. After momentum analysis, the K^+ mesons are identified by pulse height in three scintillation counters plus observation of a decay count. An additional procedure used here was to record the three pulse heights for each event, allowing a correlated pulse height analysis. After the correlated pulse height analysis the background (defined as the yield with the peak photon energy below threshold) was 5%.

Under the conditions stated above, we found experimentally that the total K^+ yield per deuteron is 25% larger than the yield per free proton. This ratio is not very meaningful without further analysis since it clearly will be a function of the peak energy of the bremsstrahlung beam. This can be seen from Fig. 1 where we have plotted the counting rate of K^+ mesons from a proton due to reactions (1a) and (1b) as a function of the peak energy of the synchrotron beam. The solid curve is that obtained for free protons (see reference 1), the dashed curve gives the qualitative behavior for a proton bound in the deuteron; the nice saturation property of the free nucleon target is smeared out due to the internal motion of the deuterium nucleons.

To extract from the experimental data an estimate of the free-neutron cross section we assumed the impulse approximation, in which the sole effect of the deuteron is to impart an initial momentum distribution to the nucleon. The momentum distribution was taken from the Hulthén wave function. If we calculate the ratio of (1c) to (1b) then the only cross-section data needed are the data in the ratio of (1a) to (1b); this ratio is known to about 20%.[1,2] The results of the calculation

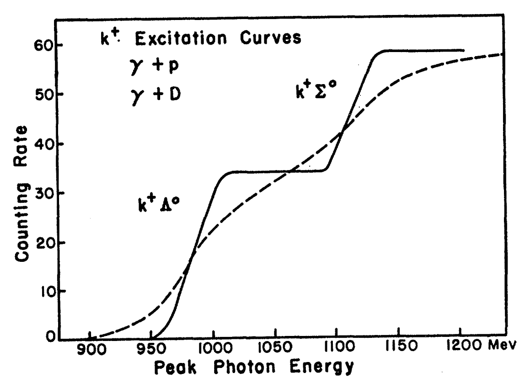

FIG. 1. Counting rate of K^+ mesons from the proton in hydrogen and deuterium as a function of peak energy of the synchrotron.

are given in Table I. The errors on the ratio arise from the number of counts and the uncertainties in the free-proton data. The γ-ray energy and c.m. angle in Table I pertain to the free proton production; for the neutron one really measures an average over small energy and angular intervals centered on these values.

There are three obvious effects due to the spectator nucleon in the deuteron which can alter this simple analysis:

1. The K^+ yield can be increased over the free-nucleon value by producing a K^0 on the neutron which charge exchange scatters on the spectator proton.
2. The K^+ yield can be reduced by the K^+ charge-exchange scattering on the spectator neutron.
3. A real π^+ or π^0 produced on one of the nucleons may interact with the other to give a K^+.

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[1] B. C. McDaniel, A. Silverman, R. R. Wilson, and G. Cortellessa, Phys. Rev. 115, 1039 (1959).
[2] R. L. Anderson, D. A. Edwards, F. Turkot, and W. M. Woodward, *Proceedings of the 1960 Annual International Conference on High-Energy Physics at Rochester* (Interscience Publishers, Inc., New York, 1960).

TABLE I. Calculated ratio of free-neutron to free-proton differential cross sections.

k (Mev)	$\theta_{c.m.}$	$\gamma+p\rightarrow K^++\Sigma^0$ (10^{-31} cm^2/sr)	$\dfrac{\gamma+n\rightarrow K^++\Sigma^-}{\gamma+p\rightarrow K^++\Sigma^0}$
1122	82°	0.6±0.1	1.6±0.7
1146	75°	1.1±0.2	0.8±0.6

An estimate of these effects indicates that they would tend to increase the calculated ratios, perhaps as much as a factor of 1.5.

It should be pointed out that this method of observing only the K^+ at one peak photon energy does not rule out the possibility of the reactions

$$\gamma+p\rightarrow K^++\Lambda^0+\pi^0,\quad 1153\text{ Mev},\qquad (2a)$$

$$\gamma+n\rightarrow K^++\Lambda^0+\pi^-,\quad 1159\text{ Mev},\qquad (2b)$$

from simulating $K\Sigma$ production for a deuterium target. To obtain a K^+ at 25° and 405 Mev/c from a free proton via reaction (2a) requires a photon energy greater than 1227 Mev; this threshold will, of course, be reduced below 1170 Mev in the case of deuterium. To reach the recently reported $\Lambda^0\pi^-$ resonance[3] via reaction (2) on a free nucleon requires a γ ray of 1405 Mev; hence it is unlikely that reaction (2) makes a significant contribution in our measurement.

At present no strong theoretical prediction can be made for the ratio in Table I. Assuming charge independence and that only the electric dipole matrix element is important, one predicts a ratio of four to one. Capps[4] has calculated this ratio near threshold on the basis of lowest order perturbation theory including anomalous magnetic moments; global symmetry is used for estimating the hyperon moments. The answer obtained depends on the parity of the $K\Sigma$ system; the ratio tends to be greater than one (perhaps as large as 80) for odd parity and less than one for even parity.

[3] M. Alston, L. W. Alvarez, P. Eberhard, M. L. Good, W. Graziano, H. T. Ticho, and S. G. Wojcicki, Phys. Rev. Letters **5**, 520 (1960).

[4] R. H. Capps, Phys. Rev. **114**, 920 (1959).