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Abstract

The decay of the $Y_0^*(1520) \rightarrow \Lambda + \gamma$ has been discovered in the reaction $K^- + p \rightarrow \Lambda +$ neutrals. The angular distribution and polarization of the $\Lambda$ are consistent with a pure electric dipole transition. The cross section yields a partial width for the decay of $0.15 \pm 0.03$ MeV.

A. Experimental Procedure

An exposure of $1.3 \times 10^6$ pictures in the Berkeley 25-inch hydrogen bubble chamber has yielded about 51,000 reactions of the type $K^- p \rightarrow \Lambda +$ neutrals, $\Lambda \rightarrow p\pi$. Among these reactions we have identified 258 events in which the missing mass of the neutral is consistent with zero and is kinematically cleanly separated from the mass of the neutral pion. The incident momenta ranged from 270 to 470 MeV/c. Most of the path length was close to 390 MeV/c, the incident momentum required to form the $Y_0^*(1520)$.

†Work done under auspices of the U. S. Atomic Energy Commission.
Following measurement of the events on the Spiral Reader a three-constraint fit to the $\Lambda$ decay was made, and the mass of the missing neutrals was calculated. Cuts were then made to retain only events with

(a) confidence level for the fit $>0.01$,
(b) lambda projected length $>2$ mm,
(c) proton length $>2$ mm.

About 42,000 events survived these cuts. The mean length of the $\Lambda$ was 2.6 cm, and their mean life agreed with the accepted value.

Without further cuts the $\gamma$ events could not be resolved from the $\pi^0$ events in the mass spectrum. The error in the square of the missing mass of the neutrals, $MM^2$, depends heavily on the error in the $\Lambda$ momentum, which in turn depends on the uncertainty in the momentum of the decay proton. When the proton came to rest in the chamber, the proton momentum was determined from range, and this led to a mean error in $MM^2$ of about 0.1, in units of the pion mass. Events with leaving protons, however, were more poorly determined and had a mean error of about 0.5. Those events in which the $\Lambda$ went backward in the center of mass were chosen for further investigation because they had a high probability for the proton to stop in the chamber.

For a more detailed investigation, events with backward $\Lambda$ and with $MM^2$ less than 0.6 were remeasured, with special attention to scatterings in the tracks and to the accurate determination of the proton range when the proton stopped in the chamber. If remeasurement showed the proton to be leaving, the event was removed from the sample. Since the decay point was difficult to measure accurately for lambdas with a wide opening angle, events with $\cos(\Lambda, p) > 0.9$ were removed from the sample.
The mass spectrum of unweighted events with stopping protons is shown in Fig. 1. The events with \( MM^2 < 0.6 \) are from the remeasured sample. The 258 events with \( |MM^2| < 0.44 \) were accepted as true \( \gamma \) events. The production cosine and decay cosine of these events are shown in Fig. 2. The unpopulated regions result from the cut on proton length (I), the cut on decay cosine (II), the requirement that the lambda go backward (III), and the requirement that the proton come to rest in the chamber (IV). The events were weighted to account for the fraction of the decay distribution removed by these cuts. In addition the events were weighted to account for \( \Lambda \) escape loss and the cut on the \( \Lambda \) length.

Finally, in order to obtain the best value for each production angle and momentum, a one-constraint fit was made for those events with \( MM^2 < 0.6 \) to the complete sequence \( K^- p \rightarrow \Lambda \gamma, \Lambda \rightarrow p \pi^0 \); all events fitted with a confidence level \( > 0.01 \).

B. Results

The production distribution for these events (Fig. 3) is consistent with \( 5 \cdot 3 \cos^2 \theta \), the distribution expected from a state of \( J^P = 3/2^- \) decaying by an electric dipole transition. Note that due to our cut III only radiative decays into the forward c.m. hemisphere can be studied in this experiment. The expected distribution for a pure magnetic quadrupole transition is \( 1 + \cos^2 \theta \). Decays to pure helicity \( 3/2 \) and \( 1/2 \) states (which are linear combinations of \( E1 \) and \( M2 \)) have decay distributions of \( \sin^2 \theta \) and \( 1 + 3 \cos^2 \theta \) respectively. None of these latter three appears consistent with the observed distribution.

The mean polarization of \( \Lambda \) is \( 0.17 \pm 0.16 \). This is consistent with zero, as expected from the decay of a single spin-parity state.
For the calculation of the $K^- p \rightarrow \Lambda \gamma$ cross section the number of $\Lambda \gamma$ events has been corrected to remove $\Sigma^0 \gamma$ events, a fraction of which extend into the $\Lambda \gamma$ mass region. Assuming the $Y_0^*(1520)$ is an SU(3) singlet and that the photon is a U-spin singlet, U-spin invariance requires that decay into the U-spin triplet linear combination $\Sigma^0 + \sqrt{3} \Lambda$ be zero. Thus the decay rates should be in the ratio $\Gamma(Y^* \rightarrow \Sigma^0 \gamma)/\Gamma(Y^* \rightarrow \Lambda \gamma) \approx 3$ (phase space) = 2.5. As the MM$^2$ spectrum of $\Sigma^0 \gamma$ extends from 0 to 6.0 (see Fig. 1), the events with MM$^2 < 0.44$ should contain about 15% $\Sigma^0 \gamma$. Subtraction of the estimated number of events leaves the mass spectrum symmetric about MM$^2 = 0$.

The cross section was then determined by comparing the number of $\Lambda \gamma$ events with the number of remaining neutrals, $\Lambda \pi^0$, $\Sigma^0 \pi^0$, and $\Lambda \pi^0 \pi^0$. The cross sections for the latter final states are known from previous measurements. The angular distribution for the $\Lambda \gamma$ final state was assumed to be symmetric in the production cosine. The energy dependence of the cross section (Fig. 4) clearly shows an enhancement at $E_{\text{c.m.}} = 1520$ MeV, confirming a new decay mode of the $Y_0^*(1520)$ into $\Lambda \gamma$. The cross section has been fitted with a Breit-Wigner shape of fixed mass and width ($M = 1519, \Gamma = 17.4$) plus an incoherent constant background. This gave a branching fraction of $0.86 \pm 0.14\%$, yielding a partial width for $Y_0^*(1520) \rightarrow \Lambda \gamma$ of $0.15 \pm 0.03$ MeV.

This radiative width may be compared with the radiative widths of other $J^P = 3/2^-$ states, which can be inferred from photoproduction experiments. From these experiments we calculate $\Gamma[N^*(1525) \rightarrow n\gamma] = 0.35$ MeV and $[N^+(1525) \rightarrow p\gamma] = 0.47$ MeV. However, since $Y_0^*(1520)$ is predominantly an SU(3) singlet, its electromagnetic coupling is unrelated through SU(3) to the electromagnetic decays of these other resonances.
Footnotes and References


Figure Captions

Fig. 1. Unweighted events vs \((\text{missing mass/m}_\pi0)^2\) for the reaction \(K^- p \rightarrow \Lambda + \text{neutrals}\) in which the proton from the \(\Lambda\) decay stops in the chamber. Events with \((\text{missing mass/m}_\pi0)^2 < 0.6\) are from the remeasured sample. The dashed rectangle is the estimated number of \(\Sigma^0\gamma\) events.

Fig. 2. The production cosine and decay cosine of the \(\Lambda\gamma\) events. The unpopulated regions result from the short proton cut (I), the cut on decay cosine (II), the requirement that the \(\Lambda\) go backward (III), and the requirement that the proton come to rest in the chamber (IV).

Fig. 3. (a). Weighted events vs production cosine of the \(\gamma\). The solid curve, normalized to the total number of events, is \(5 - 3\cos^2\theta\), corresponding to electric dipole decay. The dashed curve is \(1 + \cos^2\theta\), expected for magnetic quadrupole decay.

(b). Cross section for \(K^- p \rightarrow \Lambda\gamma\) in millibarns. The upper curve is the fit to a Breit-Wigner + constant background. The dashed line is the background.
Fig. 1.
Fig. 2. XBL6810-6967
Fig. 3a and b.
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