UCRL-17514

University of California

Ernest O. Lawrence Radiation Laboratory

SEARCH FOR $\eta \rightarrow \pi^+\pi^-\pi^0\gamma$

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Submitted to Physical Review Letters

UCRL-17514
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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Stanley M. Flatté

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Singer has made a detailed theoretical analysis[1] of the decay mode $\eta \to \pi^+\pi^-\pi^0\gamma$, and predicts $\Gamma(\eta \to \pi^+\pi^-\pi^0\gamma)/\Gamma(\eta \to \pi^0\gamma\gamma) \approx 0.23\%$. Since recent results indicate[2] $\Gamma(\eta \to \pi^0\gamma\gamma) \approx \Gamma(\eta \to \pi^+\pi^-\pi^0)$, we shall take his prediction as $\Gamma(\eta \to \pi^+\pi^-\pi^0\gamma)/\Gamma(\eta \to \pi^+\pi^-\pi^0) < 1\%$ for the purposes of this paper. On the other hand, Singer shows[1] that on the basis of order-of-magnitude arguments on powers of α, as well as the A-quantum-number arguments of Bronzan and Low,[3] one would expect $\Gamma(\eta \to \pi^+\pi^-\pi^0\gamma)/\Gamma(\eta \to \pi^+\pi^-\pi^0) \approx 1$. And aside from this, simple models fail to account for the branching ratios of the η by factors like 10^3, so that a priori we cannot assume that $\eta \to \pi^+\pi^-\pi^0\gamma$ is small. We therefore have a clear-cut experimental question; Is the $\eta \to \pi^+\pi^-\pi^0\gamma$ mode comparable in magnitude to the $\eta \to \pi^+\pi^-\pi^0$ mode, or is it very much smaller?

Our experimental result is $\Gamma(\eta \to \pi^+\pi^-\pi^0\gamma)/\Gamma(\eta \to \pi^+\pi^-\pi^0) < 0.07$. Although this result appears to be in mild disagreement with the A-quantum-number calculations, one should remember that their prediction is only order-of-magnitude. However, our result serves to reassure physicists that no large $\eta \to \pi^+\pi^-\pi^0\gamma$ decay mode is lurking in the background.

Following is a resumé of the experimental method.

The 72-inch hydrogen bubble chamber was exposed to a beam of K^- mesons with momenta between 1.2 and 1.7 BeV/c. More than 31 000 events with a visible Λ decay into $p\pi^-$, and with two prongs at the production vertex, have been identified. After rejecting all events that fit the hypothesis $K^-p \rightarrow \Lambda\pi^+\pi^-$ we are left with more than 14 000 events of the type $K^-p \rightarrow \Lambda\pi^+\pi^-$ (neutrals), where (neutrals) can be γ, π^0, or some system of neutrals such as $\pi^0\gamma$.

Figure 1(a) plots the mass of the system recoiling against the Λ in the region of the η. Taking those events in Fig. 1a which have a recoil mass between 520 and 580 MeV, we plot the mass squared of the system recoiling against the $\Lambda\pi^+\pi^-$ [i.e., the mass squared of (neutrals)]. Figure 1b shows the results. The shaded 246 events have been identified as $K^-p \rightarrow \Lambda\eta \rightarrow (p\pi^-)\,(\pi^+\pi^-\pi^0)$ by fitting to the hypothesis $K^-p \rightarrow \Lambda\pi^+\pi^-\pi^0$ and subtracting background under the η.[4] The large peak at zero mass squared is partly from the decay $\eta \rightarrow \pi^+\pi^-\gamma$, but mostly from events of the type $K^-p \rightarrow \Sigma^0\pi^+\pi^-$, which fall in the background under the η peak.

The solid curve in Fig. 1b is the distribution in $\pi^0\gamma$ mass squared, that would be obtained from $K^-p \rightarrow \Lambda\eta \rightarrow (p\pi^-)\,(\pi^+\pi^-\pi^0\gamma)$ events, normalized to the same area as the shaded events. Singer's matrix element has been used.[1] The dashed curve is the expected $\pi^0\gamma$ mass-squared distribution for simple four-body phase space. From either of these curves we deduce that $\approx 35\%$ of the $\eta \rightarrow \pi^+\pi^-\pi^0\gamma$ events should have a (neutrals) mass squared greater than 0.04 $(\text{BeV})^2$. (We have folded our experimental resolution function with the theoretical distribution to obtain this percentage; the curves in Fig. 1b do not include the effects of the resolution function.) Since there is a total of six events above 0.04 $(\text{BeV})^2$, we can conclude that there are no more than seventeen events with $\eta \rightarrow \pi^+\pi^-\pi^0\gamma$ in our

experiment, and our result is $\Gamma(\eta \to \pi^+\pi^-\pi^0\gamma)/\Gamma(\eta \to \pi^+\pi^-\pi^0) < 17/246 \approx 0.07$.

The six events have been looked at on the scan table, and nothing untoward was found. There is, of course, no indication whatsoever that these six events are from $\eta \to \pi^+\pi^-\pi^0\gamma$ decays; for instance, they could arise from events of the type $K^-p \to \Sigma^0\pi^+\pi^-\pi^0$.

We thank Professor M. Lynn Stevenson and Professor Luis Alvarez for their encouragement and support, and we thank the Scanning and Measuring Group for their contribution to this work.

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†Work done under auspices of the U. S. Atomic Energy Commission.

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Figure Caption

Fig. 1. Mass distributions for $K^- p \to \Lambda \pi^+ \pi^-$ (neutrals) events. (a) Mass of the system recoiling against the Λ, showing the η peak near 550 MeV. (b) Mass squared of the system recoiling against the $\Lambda \pi^+ \pi^-$ system for events between 520 and 580 MeV in (a). The shaded 246 events have been identified as $K^- p \to \Lambda \eta \to \Lambda \pi^+ \pi^- \pi^0$ events. The peak at zero mass squared comes partly from $\eta \to \pi^+ \pi^- \gamma$, but mostly from $K^- p \to \Sigma^0 \pi^+ \pi^-$ events under the η peak. The dashed curve represents the phase-space prediction for the $\pi^0 \gamma$ mass-squared distribution for $\eta \to \pi^+ \pi^- \pi^0 \gamma$ events, normalized to the number (246) of $\eta \to \pi^+ \pi^- \pi^0$ events. The solid curve represents the $\pi^0 \gamma$ mass-squared distribution expected when Singer's matrix element is used.

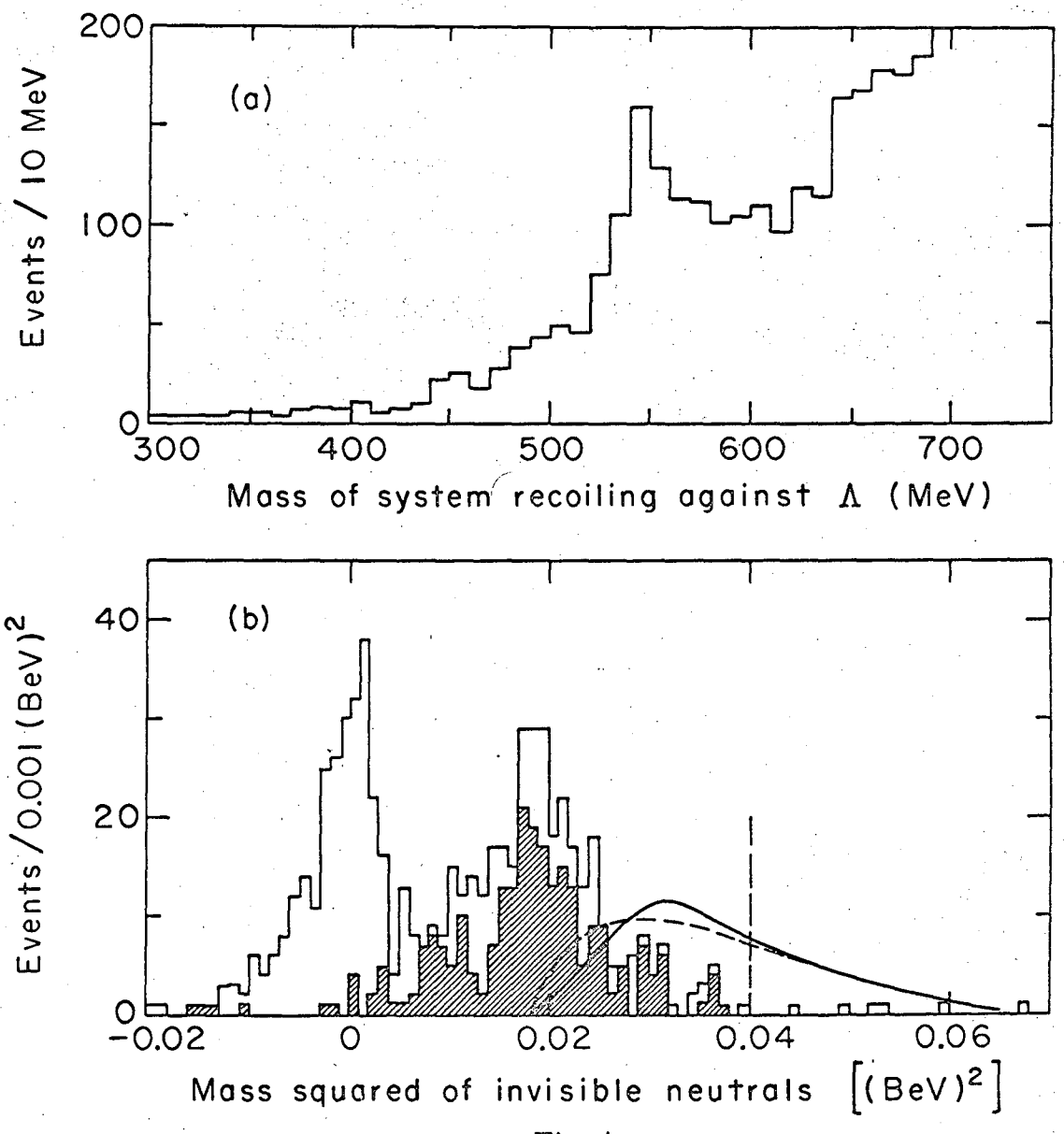

Fig. 1

XBL674-2876