spin, the spin couplings, which in the "π" rest frame correspond to a state with the same spin as the "π," are turned into other states by the Lorentz transformation. (It should be realized that these spin couplings, which are usually neglected, introduce powers of momentum which will tend to broaden the "A_1" peak.) These features are suggestive of a purely kinematical picture (of forward high-energy diffraction reactions with spin change) in which the incident particle has some overlap with a final state of a different spin and mass simply due to the transformation from one frame to the other. Finally, it should perhaps be re-emphasized that processes of type Fig. 1 via dissociations like $\pi \to (\bar{\Lambda}, \Sigma)$, $(\bar{\Xi}, \Xi)$, or even $K^- \to (\bar{\Xi}^0, \Omega^-)$ [or maybe $\to (\bar{q}q)$?], offer a mechanism for the production of high strangeness free of strangeness exchange or statistical limitations, once the energy is sufficiently high.

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[2]M. L. Good and W. D. Walker, Phys. Rev. 120, 1857 (1960). These authors emphasized the importance of the parameter Δ_0 introduced below.

[3]M. Ross and L. Stodolsky, Phys. Rev. 149, 1172 (1966), give a more recent discussion and a detailed application to photoproduction of vector mesons.

[4]By calculating the quantity s for both the reaction as a whole and the lower vertex, both before and after the scattering, and comparing, we get

$$\frac{M_{A_1}{}^2 - M_{\text{inc}}{}^2 - \vec{P}'^2}{K_0} - \frac{\mu^2 - q'^2 - \vec{P}'^2}{q_0'} = 2\vec{P}' \cdot (\hat{Q} - \hat{q}).$$

The quantity on the right, where $Q = q + K'$ is the momentum of the "A_1," is essentially the scalar product of the "decay" angle of the A_1 and the recoil proton momentum $\vec{P}'$, and thus is zero for forward production. Similarly, P' is very small for forward production and so our approximation, viz. $(M_{A_1}{}^2 - M_{\text{inc}}{}^2)/K_0 = (\mu^2 - q'^2)/q_0'$, is excellent (except for the small strip on the Dalitz plot where the lower vertex energy is very small —we always neglect this region). For nonforward production the equation may be examined in detail, but the general condition is roughly that the recoil momentum $P'^2 \ll M_{A_1}{}^2 - M_{\text{inc}}{}^2$.

[5]Orsay-Milan-Saclay-Berkeley Collaboration, Nuovo Cimento 46A, 737 (1966). I would like to thank R. Huson and V. Barnes for their help in making this comparison.

[6]R. Huson, private communication; see also the comments of Resnick (Ref. 1, Sec. 4).

[7]The ρ mass spectrum recently observed in photoproduction experiments at Deutches Elektronen-Synchrotron shows good agreement with $(1/\Delta_0{}^2) \times$ (Breit-Wigner), using normal values for the ρ mass and width (S. Ting, private communication).

[8]That these features ought to be present in diffraction production has been noted by Marc Ross (unpublished).

SEARCH FOR $\eta \to \pi^+ + \pi^- + \pi^0 + \gamma$†

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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 mode $\eta \to \pi^+ + \pi^- + \pi^0 + \gamma$ comparable in magnitude to the mode $\eta \to \pi^+ + \pi^- + \pi^0$, 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-in. 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 $K^-+p\to\Lambda+\pi^++\pi^-$ we are left with more than 14 000 events of the type $K^-+p\to\Lambda+\pi^++\pi^-+$(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. 1(a) 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)].

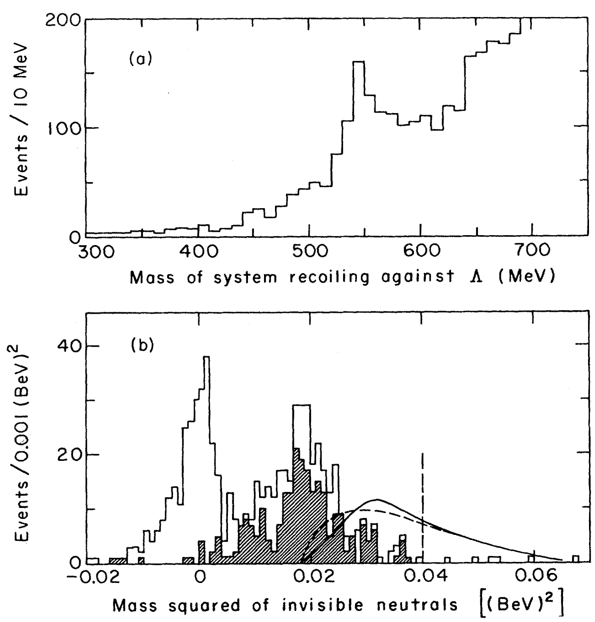

FIG. 1. Mass distributions for $K^-+p\to\Lambda+\pi^++\pi^-$ + (neutrals) events. (a) Mass of the system recoiling against the Λ, showing the η peak near 550 MeV. (b) Mass squared of the system recoiling against the $\Lambda+\pi^++\pi^-$ system for events between 520 and 580 MeV in (a). The shaded 246 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.

Figure 1(b) shows the results. The shaded 246 events have been identified as $K^-+p\to\Lambda+\eta\to(p+\pi^-)+(\pi^++\pi^-+\pi^0)$ by fitting to the hypothesis $K^-+p\to\Lambda+\pi^++\pi^-+\pi^0$ and subtracting background under the η.[4] The large peak at zero mass squared is partly from the decay $\eta\to\pi^++\pi^-+\gamma$, but mostly from events of the type $K^-+p\to\Sigma^0+\pi^++\pi^-$, which fall in the background under the η peak.

The solid curve in Fig. 1(b) is the distribution in $\pi^0\gamma$ mass squared that would be obtained from $K^-+p\to\Lambda+\eta\to(p+\pi^-)+(\pi^++\pi^-+\pi^0+\gamma)$ 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 ≈35 % of the $\eta\to\pi^++\pi^-+\pi^0+\gamma$ events should have a (neutrals) mass squared greater than 0.04 (BeV)^2. [We have folded our experimental resolution function with the theoretical distribution to obtain this percentage; the curves in Fig. 1(b) do not include the effects of the resolution function.] Since there is a total of six events above 0.04 (BeV)^2, we can conclude that there are no more than 17 events with $\eta\to\pi^++\pi^-+\pi^0+\gamma$ in our experiment, and our result is $\Gamma(\eta\to\pi^++\pi^-+\pi^0+\gamma)/\Gamma(\eta\to\pi^++\pi^-+\pi^0)<17/246\approx0.07$.

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 $K^-+p\to\Sigma^0+\pi^++\pi^-+\pi^0$.

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