Conversion of Gamma Rays from the Decay $\eta^0 \to \pi^+ + \pi^- + \gamma$†

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A search for electron pairs produced in hydrogen by the gamma rays from a sample of 33 kinematically determined events $\pi^+p \to \pi^+p\eta$, $\eta \to \pi^+\pi^-\gamma$ has yielded one event, where 0.4 events are expected. A search for six-pronged events in the same 72-in. bubble-chamber film yielded three events. One event is an example of the internal-conversion process $\eta \to \pi^+\pi^-e^+e^-$, and gives an internal-conversion probability $\Gamma(\eta \to \pi^+\pi^-e^+e^-)/\Gamma(\eta \to \pi^+\pi^-\gamma) = 0.026$, based on one event. (The other two events arise from ordinary Dalitz decays of π^0.) No example was found of $\pi^+p \to \pi^+p\pi^+\pi^-\pi^+\pi^-$, although the c.m. energy is 120 MeV above threshold. One event would have corresponded to a cross section of 0.35 μb.

I. INTRODUCTION

THE decay mode

$$\eta \to \pi^+\pi^-\gamma \tag{1}$$

was established[1] by a purely kinematical analysis of four-pronged events of the type $\pi^+p \to \pi^+p\pi^+\pi^-x^0$, where the missing neutral x^0 is identified as a gamma ray if it has zero rest mass (but nonzero energy). In the present paper we establish the fact that the gamma rays from (1) are perfectly ordinary, in the sense that they exhibit both "external" and "internal" electromagnetic conversion into e^+e^-, with roughly the expected probability. (We find one example of each.) To the best of our knowledge, the internal-conversion process from reaction (1) has not been previously observed.

II. FOUR-PRONGED EVENTS WITH ASSOCIATED GAMMA-RAY CONVERSIONS

We start with 33 good four-pronged events of the type

$$\pi^+p \to \pi^+p\eta, \quad \eta \to \pi^+\pi^-\gamma \tag{2}$$

produced by 1170-MeV/c positive pions incident on the Alvarez 72-in. hydrogen bubble chamber. Each event is identified by a purely kinematical analysis.[2] The events are then re-examined on the scanning table. We look along the predicted line of flight of the gamma ray for electron pairs (or triplets) produced in the liquid hydrogen via the (external-conversion) reactions

$$\gamma p \to pe^+e^-, \tag{3}$$

and

$$\gamma e^- \to e^-e^+e^-. \tag{4}$$

One electron pair was found (event 2 196 202). We find excellent self-consistent kinematic fits to all stages of the sequence given by Eqs. (2) and (3).[3] The non-eta background for (2) is almost negligible.[2] Our observed conversion (3) is therefore almost certainly due to a gamma ray from eta decay (2). The path length and gamma-ray energy distributions are such that we expect 0.40 conversions in the hydrogen.[4]

III. SIX-PRONGED EVENTS

The same sample of film was systematically scanned for six-pronged events. Only three events were found. They may be classified as follows:

A. Internal conversion in $\eta \to \pi^+\pi^-\gamma$. One of the events (No. 2 176 531) gives an excellent fit[5] to the sequence

$$\pi^+p \to \pi^+p\eta, \quad \eta \to \pi^+\pi^-e^+e^-. \tag{5}$$

The invariant mass of the electron pair is small (5 MeV). Thus the virtual gamma ray γ_v in $\eta \to \pi^+\pi^-\gamma_v \to \pi^+\pi^-e^+e^-$ is "almost real." We expect the internal-conversion probability to be of order α. Experimentally, this probability is given by the number of events of type (5), namely one event, divided by the corrected number of events of type (2), which is 38.0. We thus find that the internal-conversion probability in the decay $\eta \to \pi^+\pi^-\gamma$ is $1/38.0 = 3.6\alpha$, *based on one event.*[6]

B. Event with one Dalitz decay. The second six-pronged event (No. 2 201 285) corresponds to the

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[3] The fit to reaction (2) gives $\chi^2(2C) = 2.7$. The fit to the subsequent conversion (3) gives $\chi^2(1C) = 2.0$, with a transverse momentum transfer to the proton of 9 MeV/c.

[4] The average potential gamma-ray path is about 30 cm. The average laboratory gamma-ray energy is 144 MeV. The (energy-weighted) average cross section for materialization of pairs or triplets is 11.3 mb, and is obtained from Fig. 3(c) of D. C. Gates, R. W. Kenney, and W. P. Swanson, Phys. Rev. **125**, 1310 (1962). The average conversione fficiency is then 0.012, and the expected number of conversions is $33 \times 0.012 = 0.40$; the probability of getting at least one conversion is $1 - \exp(-0.40) = 0.33$.

[5] The proton, e^+, and e^- are unambiguously identified on the scanning table. The fit to $\pi^+p \to \pi^+p\eta$ gives $\chi^2(1C) = 0.1$. The subsequent fit to $\eta \to \pi^+\pi^-e^+e^-$ gives $\chi^2(4C) = 3.2$.

[6] This event also gives a good fit to the external-conversion sequence given by Eqs. (2) and (3). However, the corresponding gamma-ray path has zero length (with an experimental upper limit of about 2 mm); we therefore discount the possibility of external conversion.

sequence

$$\pi^+p \rightarrow \pi^+p\eta, \quad \eta \rightarrow \pi^+\pi^-\pi^0, \tag{6}$$

$$\pi^0 \rightarrow e^+e^-\gamma. \tag{7}$$

(The e^+ and e^- are identified on the scanning table.) The film contains 140.8 (corrected) events of type (6) where the π^0 does not undergo Dalitz decay (7). We therefore expect about 140.8/80=1.8 associated Dalitz decays.[7]

C. Event with two Dalitz decays. The last six-pronged event (No. 2 182 402) corresponds to the reaction

$$\pi^+p \rightarrow \pi^+p\pi^0\pi^0, \tag{8}$$

where both neutral pions undergo single Dalitz decay (7). (The two positrons and two electrons are identified on the scanning table. The invariant mass recoiling against the final π^+p is 280 MeV.) In the same film we have observed about 50 examples of reaction (8) with a single Dalitz decay.[8] Therefore the expected number of events of type (8) with two Dalitz decays is about 50/80=0.6.

D. Events without electron pairs. No example was found of the reaction

$$\pi^+p \rightarrow \pi^+p\pi^+\pi^-\pi^+\pi^-. \tag{9}$$

The incident π^+ momentum is 1170 MeV/c, corresponding to a c.m. energy 120 MeV above threshold for this reaction. If we had found one event, it would have yielded a cross section of 0.35 μb.

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Photoproduction on Hydrogen of ρ^0 Mesons between Threshold and 6 BeV†

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Data are presented on the details of the interaction $\gamma+p \rightarrow p+\rho^0$ observed in a 12-in. hydrogen bubble chamber exposed to a bremsstrahlung photon beam of 6-BeV maximum energy at the Cambridge Electron Accelerator. The energy dependence of the cross sections, the production angular distributions, and the decay angular distributions of the ρ^0's are compared with the predictions of the one-pion-exchange (OPE) mechanism and with a diffraction or multiperipheral model proposed by Berman and Drell. These data, as well as a comparison with ω^0 and with $\rho^0+N^*(1238)$ production, reject the OPE model and favor a diffraction mechanism.

I. INTRODUCTION

THIS is the first of a series of papers reporting on the final results of the first bubble-chamber study of meson and hyperon production by photons of energy greater than 1 BeV. This experiment, performed at the Cambridge Electron Accelerator (CEA), utilized a 12-in. hydrogen bubble chamber exposed to bremsstrahlung beams of maximum energy varying between 4.8 and 6.0 BeV. The experimental conditions and some preliminary observations have previously been reported.[1] The details of the experiment and the analysis and interpretation of the events contained in 865 000

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