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CONVERSION OF GAMMA RAYS FROM THE DEGA Y ^{90}Sr

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CONVERSION OF GAMMA RAYS FROM THE DECAY $\eta^0 \rightarrow \pi^+ + \pi^- + \gamma$

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and Frank S. Crawford, Jr.

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ABSTRACT

A search for electron pairs produced in hydrogen by the gamma rays from a sample of 33 kinematically determined events of the type $\pi^+ p \rightarrow \pi^+ p \eta$, $\eta \rightarrow \pi^+ \pi^- \gamma$, has yielded one event. This can be compared with an "expected" 0.4 electron pairs, based on our gamma-ray path length and the known cross section for conversion.

A systematic search for six-pronged events in the same 72-in. bubble-chamber film has yielded three events. One event corresponds to the internal-conversion process $\pi^+ p \rightarrow \pi^+ p \eta$, $\eta \rightarrow \pi^+ \pi^- e^+ e^-$. Based on this event, and on a corrected denominator of 38.0 kinematically determined decays $\eta \rightarrow \pi^+ \pi^- \gamma$, we find an internal-conversion probability $\Gamma(\eta \rightarrow \pi^+ \pi^- e^+ e^-) / \Gamma(\eta \rightarrow \pi^+ \pi^- \gamma) = 0.026$.

The second six-pronged event corresponds to $\pi^+ p \rightarrow \pi^+ p \eta$, $\eta \rightarrow \pi^+ \pi^- \pi^0$, $\pi^0 \rightarrow e^+ e^- \gamma$. We expect 1.8 Dalitz decays of this type. The third six-pronged event corresponds to $\pi^+ p \rightarrow \pi^+ p \pi^0 \pi^0$, with both neutral pions undergoing single Dalitz decay $\pi^0 \rightarrow e^+ e^- \gamma$; 0.6 events is expected.

No events were found of the type $\pi^+ p \rightarrow \pi^+ p \pi^+ \pi^- \pi^+ \pi^-$, even though the center-of-mass energy is 120 MeV above threshold (the incident π^+ momentum is 1170 MeV/c). One such event would have corresponded to a cross section of 0.35 μb .

I. INTRODUCTION

The decay mode

$$\eta \rightarrow \pi^+ \pi^- \gamma \quad (1)$$

was established¹ by a purely kinematical analysis of four-pronged events of the type $\pi^+ p \rightarrow \pi^+ p \pi^+ \pi^- x^0$, 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

$$\pi^+ p \rightarrow \pi^+ p \eta, \quad \eta \rightarrow \pi^+ \pi^- \gamma \quad (2)$$

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 reexamined 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

$$\gamma p \rightarrow p e^+ e^- \quad (3)$$

and

$$\gamma e^- \rightarrow e^- e^+ e^-. \quad (4)$$

One electron pair was found (event 2196202). 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 $\eta \rightarrow \pi^+\pi^-\gamma$. One of the events (No. 2176531) gives an excellent fit⁵ to the sequence

$$\pi^+p \rightarrow \pi^+p\eta, \eta \rightarrow \pi^+\pi^-e^+e^- \quad (5)$$

The invariant mass of the electron pair is small (5 MeV). Thus the virtual gamma ray γ_v in $\eta \rightarrow \pi^+\pi^-\gamma_v \rightarrow \pi^+\pi^-e^+e^-$ 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 $\eta \rightarrow \pi^+\pi^-\gamma$ is $1/38.0 = 3.6\alpha$, based on one event.⁶

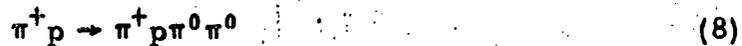
B. Event with one Dalitz decay. The second six-pronged event (No. 2201285) corresponds to the sequence

$$\pi^+p \rightarrow \pi^+p\eta, \eta \rightarrow \pi^+\pi^-\pi^0, \quad (6)$$

$$\pi^0 \rightarrow e^+e^-\gamma \quad (7)$$

(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. 2182402) corresponds to the reaction



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 $\pi^+ p$ is 280 MeV.) In the same film we have observed about 50 examples of reaction (8) with a single Dalitz decay.⁶ 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



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 μ b.

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FOOTNOTES AND REFERENCES

† This work was done under the auspices of the U. S. Atomic Energy Commission.

1. E. C. Fowler, F. S. Crawford, Jr., L. J. Lloyd, R. A. Grossman, and L. R. Price, Phys. Rev. Letters 10, 110 (1962).
2. F. S. Crawford, Jr. and L. R. Price, Lawrence Radiation Laboratory Report UCRL-16618, January 1966.
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. 3c of D. C. Gates, R. W. Kenny, and W. P. Swanson, Phys. Rev. 125, 1310 (1962). The average conversion efficiency 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 $\pi^+p \rightarrow \pi^+p\eta$ gives $\chi^2(1C) = 0.1$. The subsequent fit to $\eta \rightarrow \pi^+\pi^-e^+e^-$ 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.

7. N. P. Samios, Phys. Rev. 121, 275 (1961).
8. F. S. Crawford, Jr., L. J. Lloyd, and E. C. Fowler, Phys. Rev. Letters 10, 546 (1963).

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