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STUDY OF THE EFFECTIVE MASS SPECTRA OF $\pi^\circ\gamma$, $\eta^\circ\gamma$, AND $\pi^\circ\pi^\circ\gamma$ SYSTEMS

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STUDY OF THE EFFECTIVE MASS SPECTRA OF $\pi^{\circ}\gamma$, $\eta^{\circ}\gamma$, AND $\pi^{\circ}\pi^{\circ}\gamma$ SYSTEMS

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Исследование спектров эффективных масс систем из $\pi^\circ\gamma$, $\eta^\circ\gamma$ и $\pi^\circ\pi^\circ\gamma$

В работе исследуются спектры эффективных масс $M(\pi^\circ\gamma)$, $M(\eta^\circ\gamma)$, $M(\pi^\circ\pi^\circ\gamma)$ во взаимодействиях $\pi^- + Xe$ при 3,5 ГэВ/с. Для исследований применяется 180-литровая ксеноновая пузырьковая камера. Получены соотношения между разными нейтральными каналами распада ω° и Φ° частицы.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

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Study of the Effective Mass Spectra of $\pi^\circ\gamma$, $\eta^\circ\gamma$ and $\pi^\circ\pi^\circ\gamma$ Systems

The spectra of the effective masses $M(\pi^\circ\gamma)$, $M(\eta^\circ\gamma)$, $M(\pi^\circ\pi^\circ\gamma)$ are investigated. The branching ratios for the neutral decay channels $\pi^\circ\gamma$, $\eta^\circ\gamma$, $\pi^\circ\pi^\circ\gamma$ of ω° and Φ° mesons are estimated.

The investigation has been performed at the Laboratory of High Energies, JINR.

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1. INTRODUCTION

The production and decays of neutral bosons into gamma quanta, via π° and η° mesons, have been the subject of research in many works, especially during last ten years, firstly, due to the important physical problems connected with the possible existence of new neutral mesons and special decay channels of these bosons [1-6] and, secondly, due to the tendency to obtain a complete set of information concerning the neutral decays of η°, ω° and other mesons [7].

This work starts a series of papers which continue the articles appeared a few years ago [5,8-10]. It is based on the new experimental material obtained by means of a large 180 litre, instead of 26 litre, xenon bubble chamber.

In this paper the distributions of the effective masses $M(3\gamma)$, $M(\pi^{\circ}\gamma)$, $M(\eta^{\circ}\gamma)$, $M(\pi^{\circ}\pi^{\circ}\gamma)$, $M(\eta^{\circ}\eta^{\circ}\gamma)$ from $\gamma \ldots \gamma$ combinations are studied in one-prong π^{-}+Xe interactions at 3.5 GeV/c. Especially the $\omega^{\circ} \to \pi^{\circ}\gamma$, $\omega^{\circ} \to \eta^{\circ}\gamma$ and $\omega^{\circ} \to \pi^{\circ}\pi^{\circ}\gamma$ decays are searched for.

2. METHOD

The effective mass spectra of $M(3\gamma)$ and $M(5\gamma)$ have been studied by means of the 104x40x40 cm^3 xenon bubble chamber irradiated with a 3.5 GeV/c π^{-} beam at the accelerator of the Institute of Theoretical and Experimental Physics in Moscow.

The scanning of photographs was done for the one-prong $\pi^- + Xe$ interactions occuring in a 48x11x11 cm^3 central fiducial volume, accompanied by any number of gamma quanta. The selected events can be interpreted as interactions of the type

$$\pi^- + n \rightarrow \pi^- + n + X_{\hookrightarrow k\gamma} \quad , \quad (k = 0, 1, 2, \ldots), \qquad (1)$$

i.e., as π^- with a quasi-free neutron in the xenon nucleus [11,12].

In each event the angles of gamma quanta emission were measured with an accuracy of $\Delta\Theta_\gamma = (0.5-2)^\circ$, and the energies of gamma quanta with an accuracy of $\Delta E_\gamma / E_\gamma = (15-30)\%$ [13].

The gamma quantum recording probability was estimated for every gamma quantum taking into account the possibility of measuring its energy with an accuracy of better than 35%. The gamma quantum recording probability in the selected events is, on an average, 0.977-0.986 depending on the number of gamma quanta in events. The average recording probability for 2 gamma quanta events is equal to 0.977, for 3 gamma quanta events 0.970, for four gamma quanta events 0.968, for 5 gamma quanta events 0.965. The average gamma quantum observation probability equals 0.97%.

Using the information that the main sources of the gamma quanta accompanying the reactions are π° and η° mesons and taking into account a large, near 100%, registration efficiency of gamma quanta, the correction of energy values of gamma quanta has been made. This correction does not influence the results concerning the problem under investigation.

The background was determined using similar effective mass distributions of a sample of events with a larger number of gamma quanta.

3. EXPERIMENTAL RESULTS

About 200 000 photographs of the chamber have been used in this experiment. The total number of 3906 events of the type (1) was found out of which 386 are 3 gamma quanta events and 134, 5 gamma quanta ones.

a) Three gamma quanta events

In this sample of events the correlations in effective masses of pairs of gamma quanta have been made to look for the sources of the gamma quanta - π° or η° mesons.

Figure 1 presents the effective mass spectrum of 3 gamma quanta, $M(3\gamma)$ for 269 events. The histogram contains natural 3 gamma quanta events and the background caused by their registration efficiency smaller than 100% and due to the mistakes

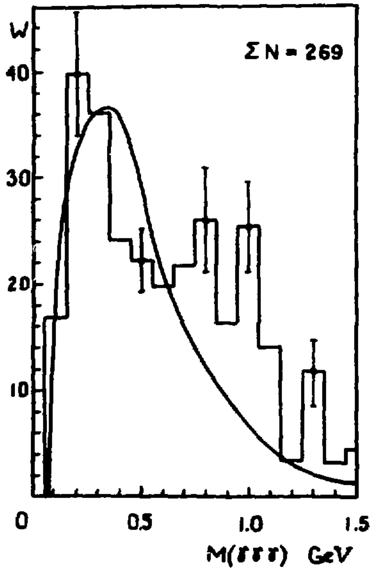

Fig. 1. Distribution of the type (1) according to the effective mass $M(3\gamma)$.

of scanners in classification of events with larger numbers of gamma quanta as 3 gamma quanta events. To reduce this background, the combinations of 3 gammas have been made from the sample of 4 gamma quanta events in the $M(3\gamma)$ effective masses. The solid curve superimposed on the histogram represents the distribution of such effective masses. The curve is normalized to the total number of events represented by the histogram at $M(3\gamma)$ values no larger than 500 MeV. Due to a large registration efficiency, the fraction of background events from the reactions accompanied by larger than 4 gammas is negligibly small.

Some number of events with mass values in an interval of about 700–1400 MeV cannot be attributed to the background caused by the registration efficiency less than 100% or by the mistakes of scanners. The detailed analysis of this sample of 3 gamma quanta events should give some information concerning the nature of the peaks appearing in fig. 1.

Let us select the events which can be interpreted as $\pi^0\gamma$ events. The corresponding effective mass spectrum is shown in Fig. 2 for 204 such events.

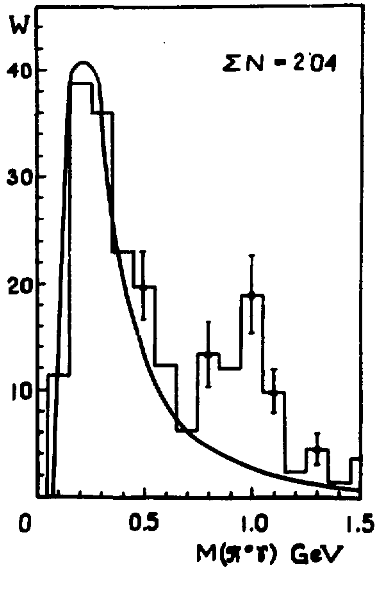

Fig. 2. Distribution of the events of the type with 3 gamma quanta in the configuration $\pi^0\gamma$ according to the effective mass $M(\pi^0\gamma)$.

The solid curve represents the background from 4 gamma quanta events normalized at $M(\pi^0\gamma) \leq$ ≤ 500 MeV. A wide peak in the region of effective masses of 750–1400 MeV should contain the $\omega^0 \to \pi^0\gamma$ events which must be placed at masses of about 600–1000 MeV according to the accuracy of our mass estimation. Then, the remaining events should be attributed to the other particle decaying into $\pi^0\gamma$.

Among the known particles in the region of effective masses of about 1000 MeV the particle with a mass of 1020 MeV can decay into such a mode. We have no other possibility of identifying the particle beyond the mass value criterion. We assume that the peak at about 1000 MeV represents the $\Phi^0 \to \pi^0\gamma$ decay. The third peak at about 1300 MeV is here statistically insignificant.

The other sample of 3 gamma quanta events contains $\eta^0\gamma$ combinations. The effective mass spectrum for these 53 events is shown in Figure 3. The solid curve represents the background from the corresponding events in interactions with 4 gamma quanta normalized at mass values of $M(\eta^0\gamma) \leq$ ≤ 750 MeV. The peaks are distinctly seen in spite of a small number of events represented by the histogram.

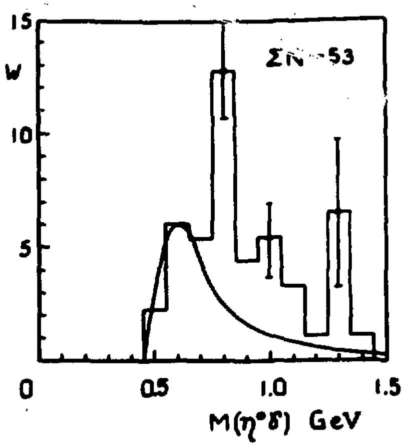

Fig. 3. Distribution of the effective mass $M(\eta^0\gamma)$ in the type (1) 3 gamma quanta events.

The first peak can be attributed to the $\omega^{\circ} \to \eta^{\circ}\gamma$ decays, the second one to the $\Phi^{\circ} \to \eta^{\circ}\gamma$ decays at about 1000 MeV and the third one cannot be attributed to any known particle at about 1300 MeV which can decay via $\eta^{\circ}\gamma$ channel.

b) Five gamma quanta events

Among the 5 gamma quanta events almost all are $\pi^{\circ}\pi^{\circ}\gamma$ events. The distribution of such events according to the effective masses $M(\pi^{\circ}\pi^{\circ}\gamma)$ is shown in Figure 4. The solid curve represents the corresponding background from the 6 gamma quanta events normalized to the total number of events represented by the histogram. No evident peaks are observed but some indications of a small intensity of $\pi^{\circ}\pi^{\circ}\gamma$ channels at about 800 MeV and 1060 MeV can be obtained.

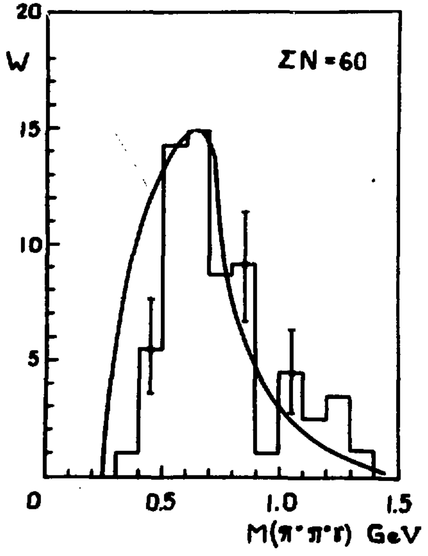

Fig. 4. Distribution of the effective mass $M(\pi^{\circ}\pi^{\circ}\gamma)$ in the events of the type (1) accompanied by 5 gamma quanta.

4. DISCUSSION

The histograms presented above contain the information that the systems decaying into $\pi^0\gamma$, $\eta^0\gamma$, and $\pi^0\pi^0\gamma$ are produced in quasi-free π^--neutron reactions. Supposing that some number of such three and five gamma quanta events lying above the background level in the region of mass values ω^0 and Φ^0 is due to the ω^0 and Φ^0 meson neutral decays, one can estimate the branching ratios of the ω^0 and Φ^0 meson neutral decay modes.

The numbers of events above the background level have been estimated using the Gaussian distributions for the ω^0 and Φ^0 effective masses /7/ with three standard deviations corresponding to the accuracy of the experimental mass evaluation of about 8%.

In the Table the numbers of events which can be ascribed to the Φ^0 and ω^0 neutral decays into π^0, η^0, and gamma quanta are presented. In the sample of $\eta^0\gamma$ decays 7±2 events can be attributed to a possible system with a mass of about 1300 MeV decaying into $\eta^0\gamma \to 3\gamma$. Assuming that the system exists, we can attribute to it 2±1 $\pi^0\gamma$ and 3±2 $\pi^0\pi^0\gamma$ - decays.

Table

The numbers of ω^0 and Φ^0 events recorded

Decay mode	Number of events
$\omega^0 \to \pi^0\gamma$	16 ± 4
$\omega^0 \to \eta^0\gamma \to 3\gamma$	11 ± 3
$\omega^0 \to \pi^0\pi^0\gamma \to 5\gamma$	< 3
$\Phi^0 \to \pi^0\gamma$	20 ± 4
$\Phi^0 \to \eta^0\gamma \to 3\gamma$	7 ± 2
$\Phi^0 \to \pi^0\pi^0\gamma \to 5\gamma$	3

Using the data presented in Table 1, we estimate the following branching ratios:

$$\frac{N(\omega^{\circ} \to \eta^{\circ}\gamma \to 3\gamma)}{N(\omega^{\circ} \to \pi^{\circ}\gamma \to 3\gamma)} = 0.68 \pm 0.18, \quad (2)$$

$$\frac{N(\omega^{\circ} \to \pi^{\circ}\pi^{\circ}\gamma \to 5\gamma)}{N(\omega^{\circ} \to \pi^{\circ}\gamma \to 3\gamma)} < 0.18, \quad (3)$$

$$\frac{N(\Phi^{\circ} \to \eta^{\circ}\gamma \to 3\gamma)}{N(\Phi^{\circ} \to \pi^{\circ}\gamma \to 3\gamma)} = 0.35 \pm 0.12, \quad (4)$$

$$\frac{N(\Phi^{\circ} \to \pi^{\circ}\pi^{\circ}\gamma \to 5\gamma)}{N(\Phi^{\circ} \to \pi^{\circ}\gamma \to 3\gamma)} < 0.15. \quad (5)$$

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