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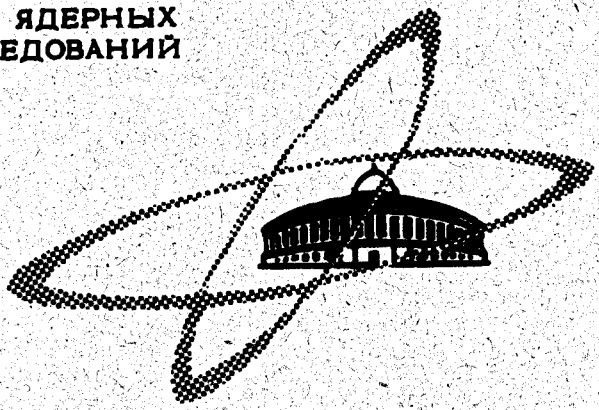

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STUDY OF THE DI-PION IN THE MASS VALUES REGION $M(\pi^\circ \pi^\circ) \leq 1.3$ GEV

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1. Introduction

In this paper we report on the results of investigation of the $\pi^0-\pi^0$ effective mass spectrum in the region of mass value $M(\pi^0\pi^0)$ within 270-1300 MeV. In comparison with our previous work [1], here the number of events is enlarged and more complete analysis of the experimental data is done.

2. Method

The scanning of over 500 000 photographs of the 550 x 275 x 160 mm^3 JINR xenon bubble chamber irradiated in 2.34 GeV/c π^+ beam was done twice for the interactions of $\pi^+ - Xe$ with one secondary observable charged particle , and accompanied by four gamma-quanta. The fiducial 290 x 120 x 50 mm^3 central volume of the chamber was accepted for the interactions analysed. In each event the angles of gamma-quanta emission were estimated with the accuracy $\Delta\theta_\gamma = (0.5 - 2)^\circ$ and the energy of gamma-quanta with

the accuracy $\Delta E_\gamma / E_\gamma$ = (12-30)%. The error of the effective mass estimation of the four gamma-quanta combination $\Delta M_{4\gamma} / M_{4\gamma}$ makes up about 10%.

Later on only these events were studied in detail, in which two independent combinations of two gamma-quanta, from six possible, gave the value for $M_{2\gamma}$ lying within the interval 90-180 MeV. This interval was accepted as permissible for the π^0 meson mass, for the π^0 recorded in the chamber.

The selected events, in accordance with the previous works /2-3/, can be interpreted as interactions of the type

$$\pi^+ + n \to \pi^0 + \pi^0 + p , \qquad (1)$$

and

$$\pi^+ + n \to \pi^0 + \pi^0 + \pi^+ + n ; \qquad (2)$$

i.e. π^+ with quasi-free neutrons in the Xenon nuclei.

Additional information concerning the methodical questions one can read in our work devoted to investigation of neutral bosons decaying into π^0 mesons and gamma-quanta.

3. Experimental Data

Out of 596 events with four gamma-quanta satisfying the scanning criteria 318 events were of the type (1) or (2) . 172 events were belonged for the type (1) and the other 146 events were appartained to the events of the type (2). The remaining group of 178 four gamma-quanta events is such a sample, in which only one two gamma-quanta combination lies into $M_{2\gamma}$ interval value 90-180 MeV, and the other values of the combinations lie outside the allowed

for the π^0 meson mass. The recording probability of gamma-quantum in the selected events equals, in average, 84% for the events of the type (1), and 83% for the events of the type (2).

The distribution of the effective mass $M(\pi^0\pi^0)$ from the sample of events of the type (1) is shown in fig. 1. The shaded part of the histogram presents the contamination of events from the reaction of the type $\pi^+ + n \to \pi^0 + \pi^0 + \pi^0 + n$, when one of three π^0 mesons was not recorded. The number of the false events was determined from the total number of six gamma-quanta events recorded in our experiment. In fig.2 the spectrum of the effective mass $M(\pi^0\pi^0)$ is presented for the events from the sample of the type (2). The shaded part of the histogram shows the contamination of wrong events from the reaction of the type $\pi^+ + n \to \pi^+ + n + \pi^0 + \pi^0 + \pi^0$.

4. Data Analysis

A. The reactions $\pi^+ + n \to \pi^0 + \pi^0 + p$

The experimentally obtained effective mass distribution $M(\pi^0\pi^0)$ was compared with the distribution of random π^0-π^0 combinations, after substraction of the contamination of the wrong events from the reactions with three π^0 mesons in final state. The distribution of random π^0-π^0 combinations was evaluated by the Monte-Carlo program using experimental angular and energetic spectra of gamma-quanta from a sample of events being under consideration. Normalization was performed to the total number of events in the $M(\pi^0\pi^0)$ values interval 270-500 MeV (fig. 3).

Fig.4 presents the distribution of $M(\pi^0\pi^0)$ without the contamination of the six gamma-quanta events and without the background of random π^0-π^0 combinations. Two groups of events are observed in this distribution: the first at $M(\pi^0\pi^0)$ effective mass values interval 600-900 MeV, and the second at the interval of $M(\pi^0\pi^0)$ values 1000-1300 MeV.

The sample of events belonging to the second group may be confronted with the particle $f^0 \to 2\pi^0$. The events lying into mass value interval 600-900 MeV may be interpreted as a result of $2\pi^0$ decay of some system with effective mass value near 700 MeV, or they may be apparent as a result of the reaction of the type $\pi^+ + n \to$ $\to N^{+}* + \pi^0 \to \pi^0 + \pi^0 + p$, where N^{+*} being the isobar with mass value 1238 MeV.

Let us consider the experimental distribution of the effective mass $M(\pi^0 p)$ (fig.5). It is possible practically to prepare the $M(\pi^0 p)$ spectrum only for these events of the type (1), in which the kinetical energy E_p of the proton is no less than 20 MeV. In order to examine the possible influence of N^{+*} on the creation of the peak, let us consider the $M(\pi^0\pi^0)$ distribution for the events in which the $M(\pi^0 p)$ values lie in the interval of mass values $M(N^{+*}(1238)) \pm$ $\pm 0.1\, M(N^{*}(1238))$ (fig.6). This interval was accepted because of the average accuracy of $M(\pi^0 p)$ mass value evaluation. It is obvious, from the fig.6, that these events in which the N^{+*} may be presented give no some significant rate to the peak observed in the analysed $M(\pi^0\pi^0)$ distribution at about 700 MeV.

May the events with $E_p < 20$ MeV cause contribution to the peak observed by means of the N^{+*} decay? The analysis of the spectrum of the π^0 meson momentum in π^+ c.m. system shows that in this sample of events does not exist a significant number of events which may be interpreted as the events of generation of the N^{+*} with successfully decay $N^{+*} \to \pi^0 + p$. The value of $P^*_{\pi^0}$ momentum evaluated is equal 810^{+140}_{-110} MeV/c, if the influence of Fermi momentum of nucleons in nuclei is taken into account. The events with such $P^*_{\pi^0}$ values are not presented in the spectrum of π^0 mesons observed.

Therefore, we must accept that the peak in the region of mass values 600-900 MeV is not caused by the decay of $N^{+}*$.

If we suppose the peak be caused by some $\pi^0-\pi^0$ system, then the Breit-Wigner analysis of $M(\pi^0\pi^0)$ distribution gives the following data:

$$\bar{M}(\pi^0\pi^0) = 730 \pm 30 \text{ MeV}, \qquad (3)$$
$$\Gamma = 170 \pm 87 \text{ MeV}.$$

Using information about the intensity of $\eta^0 \to 2\gamma$ production in our experiment, we estimate the relative intensity of generation of the $\pi^0-\pi^0$ system:

$$\frac{N(\pi^0-\pi^0)}{N(\eta^0 \to 2\gamma)} = 0.25 \pm 0.08. \qquad (4)$$

Assuming the relation (4) to be the same for elementary $\pi^+ + n$ interactions at 2.34 GeV/c, and using the value of intensity of $\eta^0 \to 2\gamma$ channel, we estimate the relation between cross sections:

$$\sigma[\pi^+ + n \to (\pi^0\pi^0) + p] \simeq 0.1\, \sigma[\pi^+ + n \to \eta^0 + p]. \qquad (5)$$

B. The reactions $\pi^+ + n \to \pi^+ + \pi^0 + \pi^0 + n$

The $M(\pi^0\pi^0)$ distribution was compared with the distribution of random $\pi^0-\pi^0$ combinations (fig.7). The random $\pi^0-\pi^0$ combinations effective mass distribution was evaluated by means of Monte-Carlo programme using experimentally evaluated energetic and angular spectrum of gamma-quanta belonging to the sample of events under consideration. Normalization of the histograms was performed to the total number of events observed.

Any peak does not exist in the $M(\pi^0\pi^0)$ spectrum at mass values near 700 MeV. The distribution of the total gamma-quanta energy ΣE_γ in the events of the type (1) has maximum at the values of ΣE_γ greater than in the sample of events of the type (2) (fig.8). In reactions (2) a big part of the initial energy is transformed into secondary π^+ kinetical energy. This may be the cause of absence of production of $\pi^0-\pi^0$ system with the mass value near 700 MeV in these reactions.

In fig. 7 we may observe some excess of events over the background level in the region of $M(\pi^0\pi^0)$ values 300-500 MeV. Supposing the excess observed to be caused by some $\pi^0-\pi^0$ system, we can ascribe to this system the average effective mass value

$$\bar{M}(\pi^0\pi^0) = 382 \pm 20 \text{ MeV}. \qquad (6)$$

We have not investigated some possible influence of the background reactions on such a peak creation, however. For example, we have not studied the possible influence of the reaction $\pi^+ + n \to \rho^+ + n + \pi^0 \to \pi^+ + n + \pi^0 + \pi^0$.

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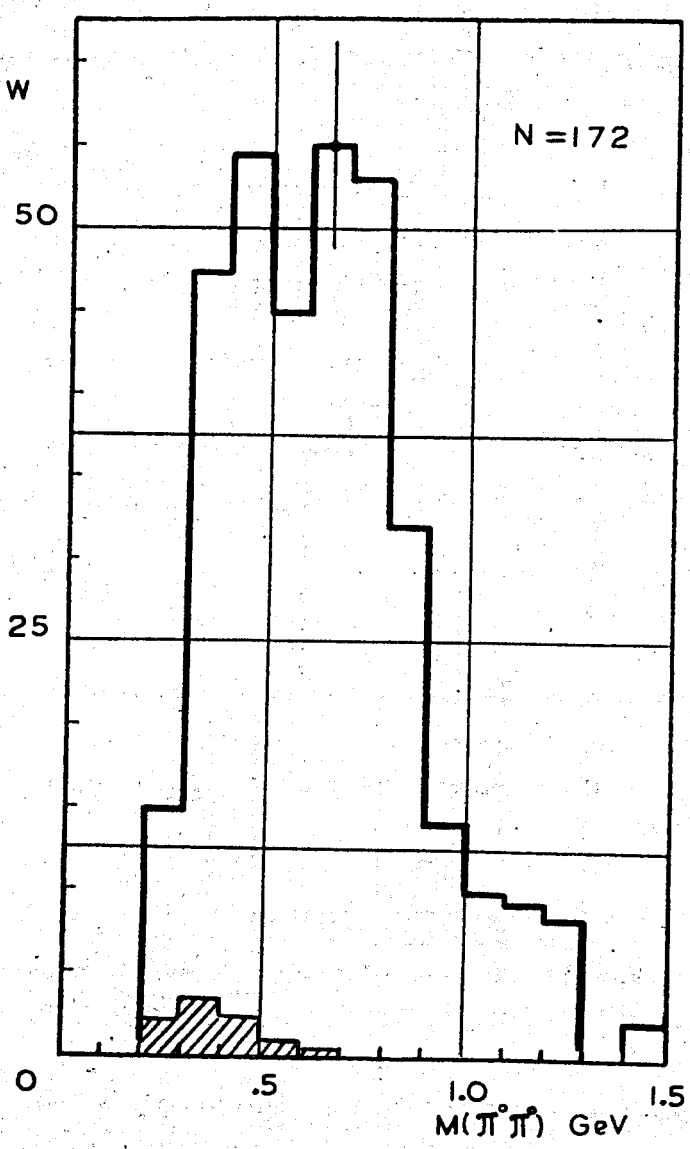


Fig.1. The experimental $M(\pi^0\pi^0)$ distribution for the reactions of the type $\pi^+ + n \to \pi^0 + \pi^0 + p$. The shaded part of the histogram shows the contamination of false events from the reaction of the type $\pi^+ + n \to \pi^0 + \pi^0 + \pi^0 + p$.

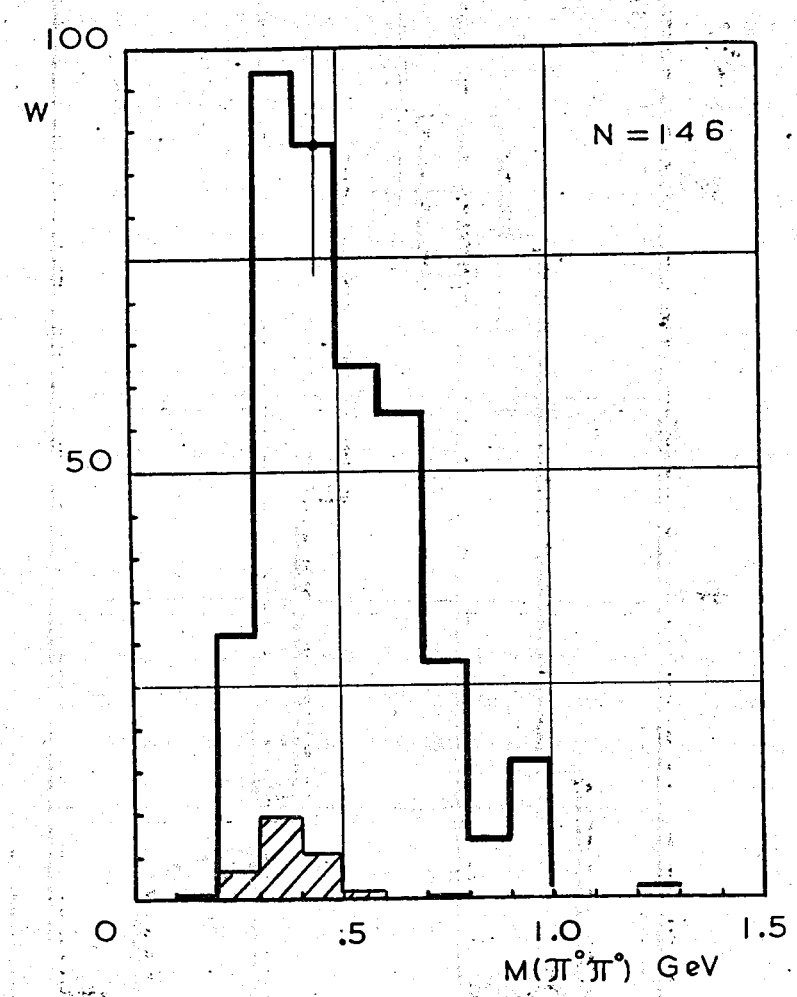


Fig.2. The experimental distribution of $M(\pi^0\pi^0)$ for the reactions of the type $\pi^+ + n \to \pi^+ + n + \pi^0 + \pi^0$. The shaded part presents the contamination of $\pi^0-\pi^0$ events from the reaction of the type $\pi^+ + n \to \pi^+ + n + \pi^0 + \pi^0 + \pi^0$.

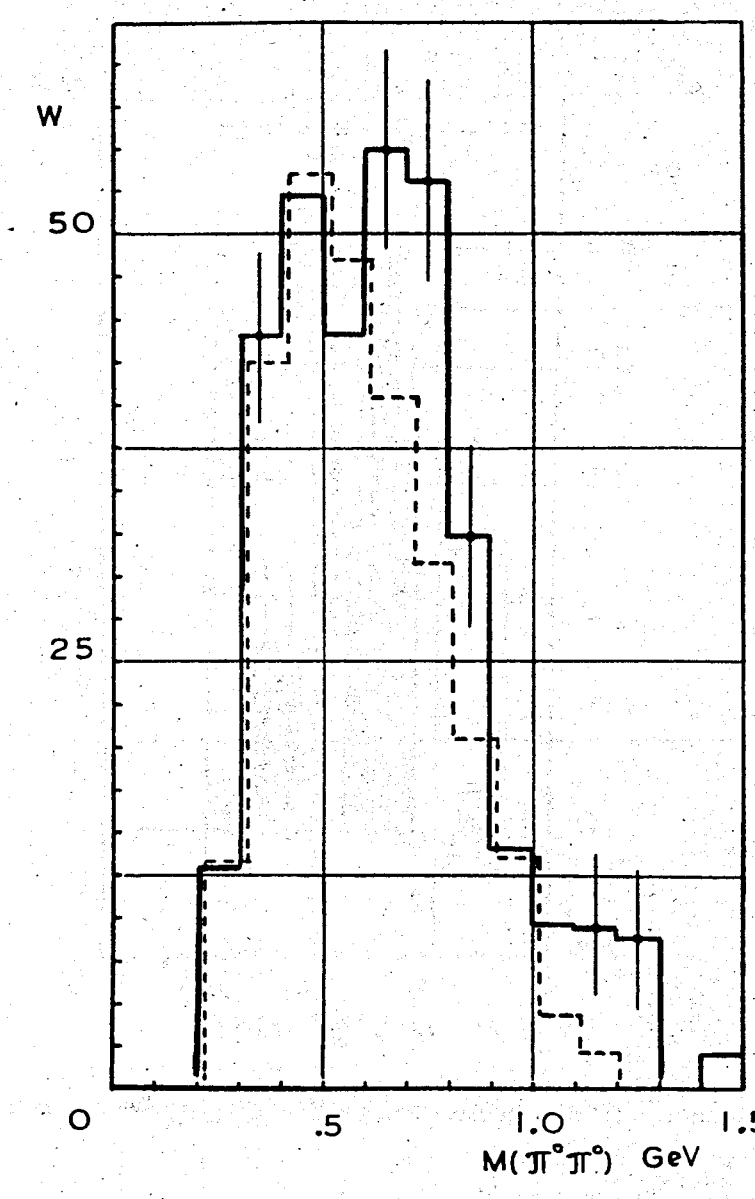
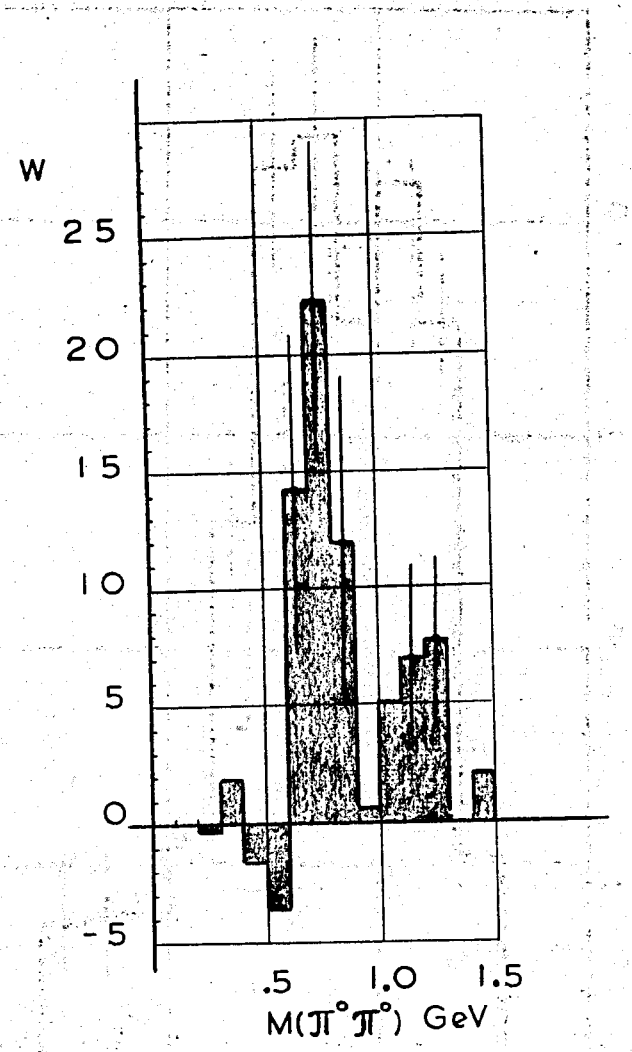


Fig.3. Comparison of the experimental $M(\pi^0\pi^0)$ spectrum reaction (1) with the calculated $\pi^0-\pi^0$ random comb spectrum. Normalization is performed to the mass interval 270-500 MeV.



g.4. Distribution of the effective mass $M(\pi^0\pi^0)$ without the background.

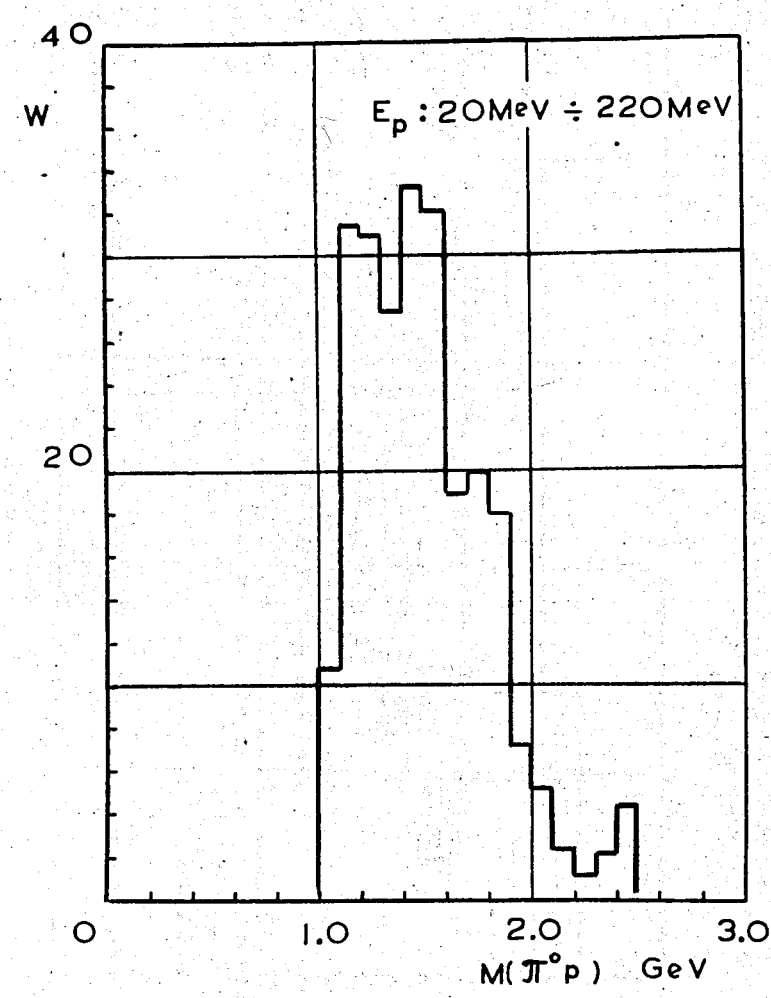


Fig.5. Distribution of the $M(\pi^0 p)$ effective mass.

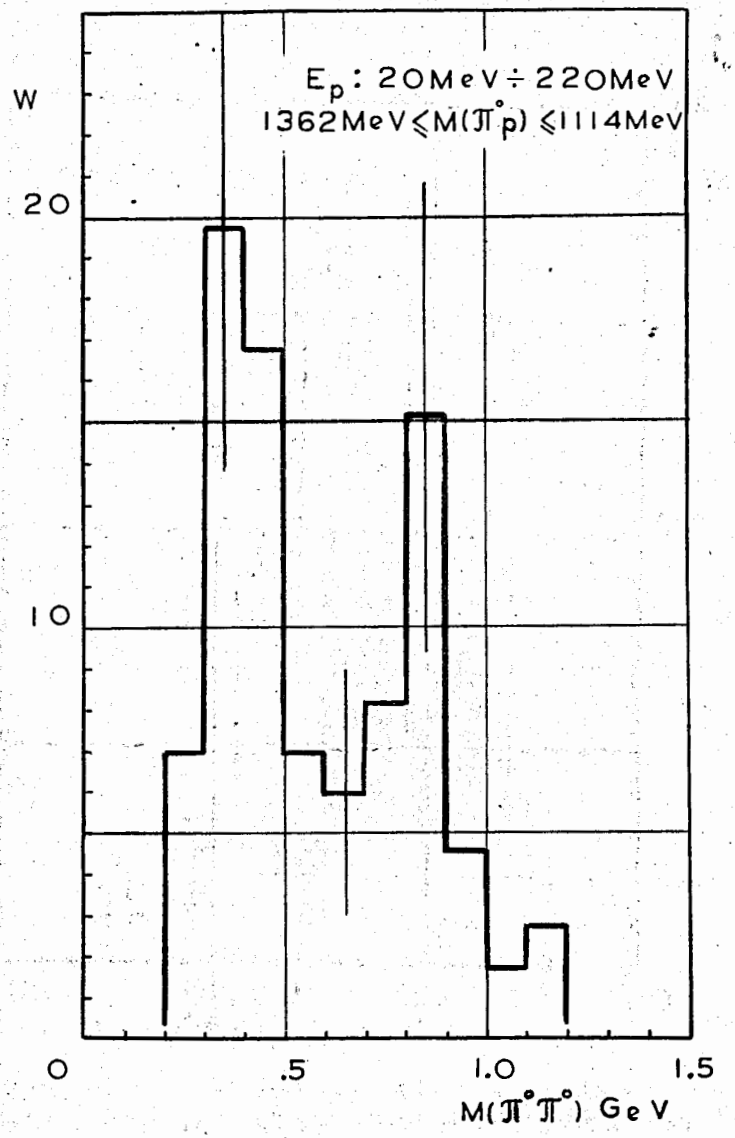


Fig.6. Distribution of the $M(\pi^0\pi^0)$ effective mass in the sample of events of the type (1), in which the $N^+(1238)$ may exist.

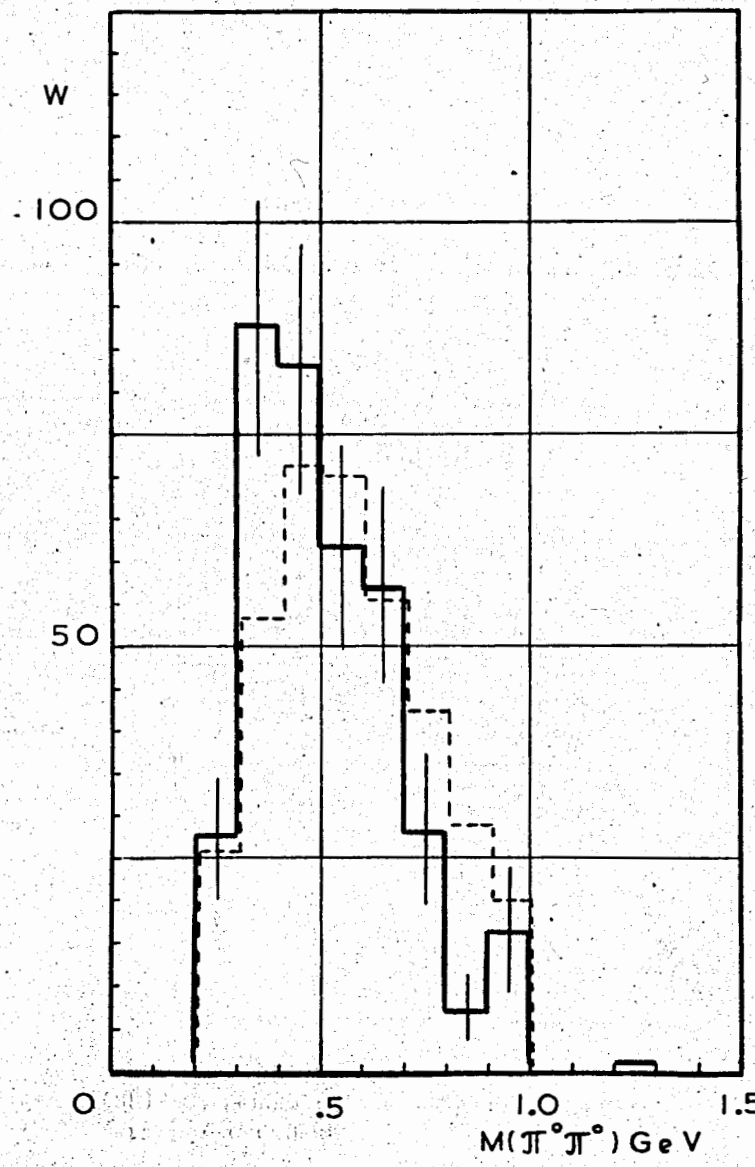


Fig.7. Distribution of the $M(\pi^0\pi^0)$ effective mass from the sa
of events of the type $\pi^- + n \to \pi^+ + n + \pi^0 + \pi^0$
(solid). Distribution of the random $\pi^0-\pi^0$ combinatior
malization is performed to the total number of even

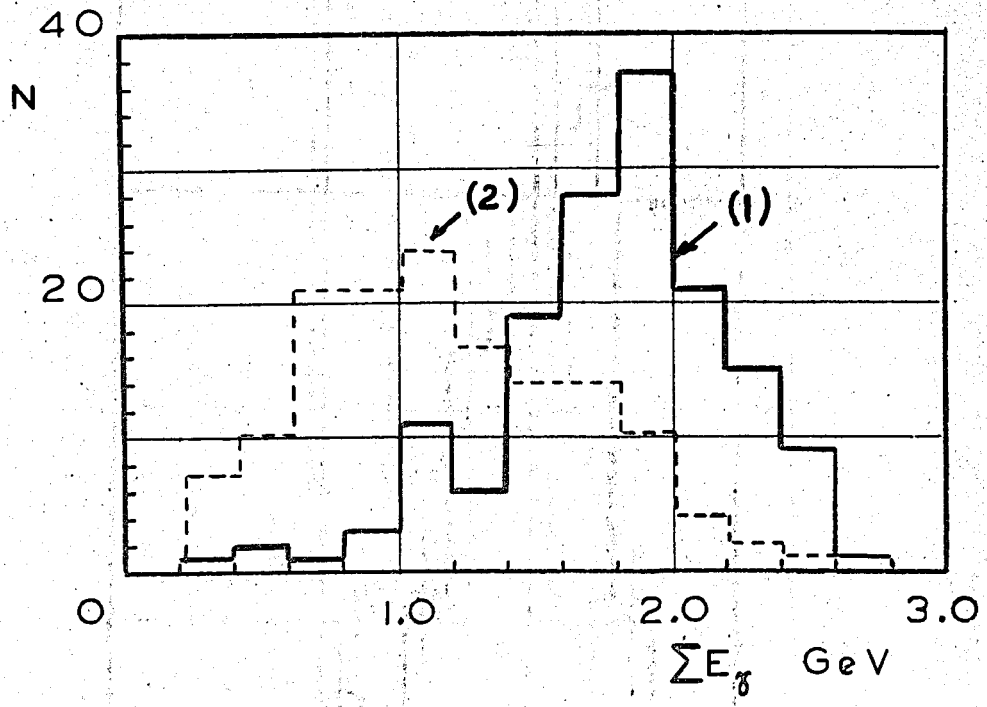


Fig.8. Distribution of the total energy of gamma-quanta emitted , in reactions of the type (1) and (2).