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ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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ЦЕНТРАЛЬНЫЙ НАУЧНО-ИССЛЕДОВАТЕЛЬСКИЙ ИНСТИТУТ
ИНФОРМАЦИИ И ТЕХНИКО-ЭКОНОМИЧЕСКИХ ИССЛЕДОВАНИЙ
ПО АТОМНОЙ НАУКЕ И ТЕХНИКЕ

ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

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TOTAL CROSS SECTION OF π^0 -MESON PHOTOPRODUCTION
ON Be, C, O AND Al NUCLEI IN THE ENERGY RANGE
 $E_\gamma = (180-650)$ MEV WITHOUT CHARGED PARTICLES
IN FINAL STATE

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Be, C, O, Al В ИНТЕРВАЛЕ ЭНЕРГИИ $E_\gamma = (180-650)$ МэВ
БЕЗ ЗАРЯЖЕННЫХ ЧАСТИЦ В КОНЕЧНОМ СОСТОЯНИИ

Приводятся новые экспериментальные результаты измерения полного сечения фотопроизводства π^0 -мезонов на ядрах Be, C, O и Al для энергии фотонов (180-650) МэВ, полученные на меченом фотонном пучке. Оцениваются сечения когерентного фотопроизводства π^0 -мезонов для углерода и кислорода, фоторасщепления ядра углерода и экспериментальное значение фактора Левин-Джера. Данные сравниваются с теоретическими предсказаниями и экспериментальными значениями последних лет.

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1. Introduction

The photon-nuclei interaction in the energy range of (0.2-1) GeV takes place via the excitation of baryon resonances. In the $\Delta(3.3)$ -resonance energy region within the existing theories of isobar-hole formalism [1,2] and isobar doorway model [3], the photon and pion processes are treated as unique, supplementing each other. The analysis of the pion-nuclei interaction cross sections within the isobar-hole formalism representation made it possible to obtain for the first time the experimental information on the ΔN interaction potential [4]. This is the reason for resuming interest at present to the photoproduction reactions, in particular to the π^0 -meson photoproduction on nuclei in the Δ -resonance energy region. Since the fifties, the π^0 -meson photoproduction on nuclei in this energy region was investigated on the bremsstrahlung photon beam with continuous spectrum. In the recent years, they have started the similar investigations with the tagged photon beams. In our previous work [5], we presented the total cross sections of the π^0 -meson photoproduction on Be, C and O nuclei in the energy range of (0.25-1.0) GeV without charged particles in final state. In this work we give the new data on the total cross section of the π^0 -meson photoproduction on Be, C, O and Al nuclei in the energy range of (0.18-0.65) GeV.

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obtained on the Yerevan electron synchrotron tagged photon beam formed on the extracted electron beam [6].

2. Experiment

The experiment was performed on the formed secondary electron beam with $\sim 4 \cdot 10^5$ el. per second intensity and 1.65 GeV energy. The radiator thickness to obtain the tagged photons was 0.01 rad. units.

The experimental setup used for measuring the total cross section of π^0 -meson photoproduction on nuclei was described in Ref. [5]. The photons of definite energy detected by the coincidence of the signals from the tagging system counters and from the shower detector produced π^0 -mesons on the target placed at the centre of the 4 π -detector (see Fig.1). The 4 π -detector consisting of five groups of γ -telescopes registered one or two photons from the π^0 -meson decay. The experiment logic enabled one to measure the sum of total cross section of neutral pion coherent and incoherent photoproduction both with neutron accompaniment and with transition of residual nucleus to low-energy excited states. Thus, our measured cross section was

$$\sigma = \sigma(\gamma A \rightarrow A\pi^0) + \sigma(\gamma A \rightarrow A'\pi^0 n) + \sigma(\gamma A \rightarrow A''\pi^0)$$

The experimental technique was identical to that described in Ref. 5. The number of π^0 -mesons produced per one photon was measured as a ratio of the number of coincidences of logic signals from one of the channels of the tagging system with the signals from the 4 π -detector in the absence of the signals from the shower detector and the veto counters to the number of photons striking the target.

During the experiment, the background and control measurements were carried out: the determination of the shower detector efficiency, the determination of the number of events when one of the particles of the electron-positron pair was registered by the 4 π -detector, and the other one by the shower detector, the determination of the level of accidental coincidences.

The main part of the electron-positron pairs produced in the target passed through the 4 π -detector hole provided for the passage of the main γ -beam and it was excluded by the shower detector operating in anticoincidence with the 4 π -detector. The events of the production of electron-positron pairs at large angles when both particles fell upon the 4 π -detector were suppressed by the first layer of counters of the 4 π -detector operating in anticoincidence with the other layers. Some portion of the electron-positron pairs, being not registered by the anticoincidence counter because of a different from 100% efficiency of the 4 π -detector first layer, simulated the π^0 -meson photoproduction events. This portion was determined by the Monte-Carlo method and subtracted from the measured value of the π^0 -meson photoproduction cross section.

The π^0 -meson detection efficiency with account of the geometric one, of the efficiencies of the 4 π -detector scintillation counters and of the photon conversion efficiency versus the γ -quanta energy and of angular distribution of produced π^0 -mesons, was calculated by the Monte-Carlo method [7].

While analysing the obtained cross section results, there were taken into account also the attenuation of the photon beam in the air and target, the loss of a number of π^0 -mesons when the decay photons transformed into electron-positron pairs directly in the target or in the first layer of the 4 π -detector, and when one of the decay photons struck the anticoincidence

shower detector.

3. Discussion of the Results

The values of π^0 -meson photoproduction cross section without charged particles in final state for Be, C, O and Al nuclei in the tagged photon energy range $E_\gamma = (180-650)$ MeV are listed in the table. Fig.2 presents our measured carbon cross sections together with our earlier data [5] and the results of Bonn analogous measurements [8,9] given in the range $E_\gamma = (200-400)$ MeV. Ref.[8] deals with the data on carbon only; and besides, as a target they employed a scintillator, the signal from which was used to determine the coherent and incoherent parts of the π^0 -meson photoproduction cross section. In Ref.[9] they used the usual Be, C, Al, Cu and Pb targets. To detect the π^0 -mesons they also used the 4 π^- -detector, but in contrast to us, they registered the electron-positron pairs from both decay γ -quanta with a multiwire coordinate detector. As one can see from Fig.2, our carbon results are in satisfactory agreement with those in [9] and somewhat exceed the results of [8] in the energy region up to 300 MeV. For Be and Al there is also a satisfactory agreement between our results and those of Ref.[9].

Of independent interest is the obtaining of hadron photoproduction cross section by adding the charged hadron cross section measured at Bonn [10] to our measured neutral meson cross section. Fig.3 shows the hadron photoproduction total cross sections on oxygen both in the form of the above-quoted sum and by adding the Monte-Carlo calculated [10] value of neutral particle cross section to the charged hadron cross sections. Ibidem is presented for comparison the theoretical prediction, in the framework of impulse approximation, of isobar doorway model [11] and isobar-hole formalism [12]. Our total cross sections of hadron photoproduction are consider-

ably lower than impulse approximation and agree satisfactorily with the predictions of isobar-hole formalism. This points out the significant role of the Δ N-interaction in the hadron photoproduction process in the $\Delta(3,3)$ resonance energy region.

Estimating by the method described in [5] the cross section of the meson incoherent photoproduction or using the results of a direct measurement of this cross section [8], we can obtain from our measured total cross section of π^0 -meson photoproduction the cross section of π^0 -meson coherent photoproduction.

Figs.4 and 5 show the cross sections of π^0 -meson coherent photoproduction on C and O nuclei together with the theoretical predictions, and for C - also with experimentally measured [8] coherent and incoherent cross sections.

One can see that our obtained values are considerably lower than the impulse approximation prediction and higher than the isobar-hole formalism prediction. The latter may be connected with some incoherent admixture in our obtained coherent photoproduction cross sections, due to the π^0 -mesons accompanied by the transition of the residual nucleus to the low-energy states.

The next interesting possibility is the determination of the cross section of the carbon nucleus photodisintegration by means of our measured total cross sections of hadron [13] and of π^0 -meson photoproduction and measured at Bonn [14] charged pion cross sections.

$$\sigma_{p.d.}(\gamma^{12}\text{C}) = \sigma_{tot}(\gamma^{12}\text{C}) - \sigma_{tot}(\gamma^{12}\text{C} \rightarrow C^1\pi^\pm, \pi^0)$$

A comparison of thus obtained photodisintegration cross sections with the formula from [15]

$$\sigma_{p.d.} = L \frac{nZ}{A} \sigma_d^{ex}$$

enables one to determine the Lvinger factor L. Here σ_d^{ex} is a part of the deuteron photodisintegration cross section responsible for the exchange currents, n, Z is the number of neutrons and protons in the nucleus.

$$A = n + Z$$

Fig.6 presents the factor L energy dependence taken from Ref. [15]. It is seen that our obtained values of L for carbon are in good agreement with the recent results.

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TABLE
Total cross section of π -meson photoproduction
on Be, C, O and Al

E_γ MeV target	185±40	208±44	292±47	375±52	430±70	472±58	500±40	591±35	634±50
Be	0.55 ±0.06	0.898 ±0.08	1.03 ±0.09	1.12 ±0.09	0.67 ±0.07	0.68 ±0.05	0.37 ±0.06	-	0.19 ±0.05
C	-	1.07 ±0.10	0.85 ±0.095	1.36 ±0.1	1.18 ±0.09	1.08 ±0.08	0.51 ±0.2	0.32 ±0.07	0.21 ±0.07
O	0.68 ±0.12	0.95 ±0.14	1.39 ±0.16	1.57 ±0.2	1.32 ±0.23	1.2 ±0.19	0.76 ±0.18	0.44 ±0.23	-
Al	-	-	1.55 ±0.4	3.68 ±0.7	2.52 ±0.7	2.24 ±0.6	0.91 ±0.6	0.05 ±0.03	-

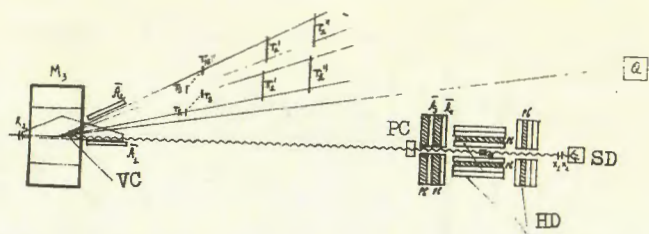


Fig.1. A general diagram of the experimental setup.

R_2 - radiator, M_3 - tagging system magnet, VC - vacuum chamber, $\bar{A}_1 - \bar{A}_4$ - veto counters, $T_1 - T_{1B}, T_{1,2}, T_{1,2}''$ - tagging system counters, Q - quantometer, PC - multiwire proportional chamber, HD - 49T -detector, m - target, Pb -lead converter, X_1, X_2 - scintillation counters, SD - shower detector.

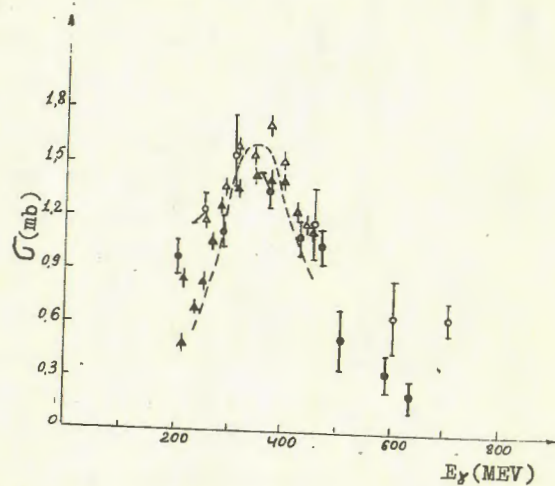


Fig.2. Energy dependence of total cross section of π^0 -meson photoproduction on carbon.

● - our results, ○ - Yerevan-83 [5], ▲ - Bonn [8], △ - Bonn [9]. Dashed curve - the sum of cross sections of π^0 -meson coherent and incoherent photoproduction [9].

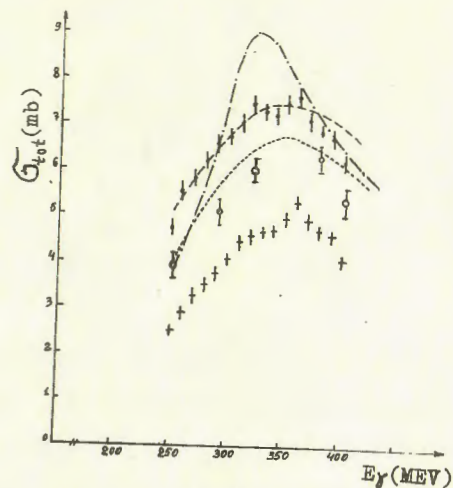


Fig.3. Energy dependence of total cross section of hadron photoproduction on oxygen.

○ - the sum of cross sections of photoproduction of π^0 -mesons (our results) and charged hadrons [10], + - charged hadron cross section [10], ● - the sum of charged and neutral cross sections. Neutral hadron cross section is calculated by the Monte-Carlo method [10]. Curves taken from Ref. [11] correspond to: dash-dotted - to plane wave impulse approximation, dashed - to the isobar doorway model, dotted - to isobar-hole formalism.

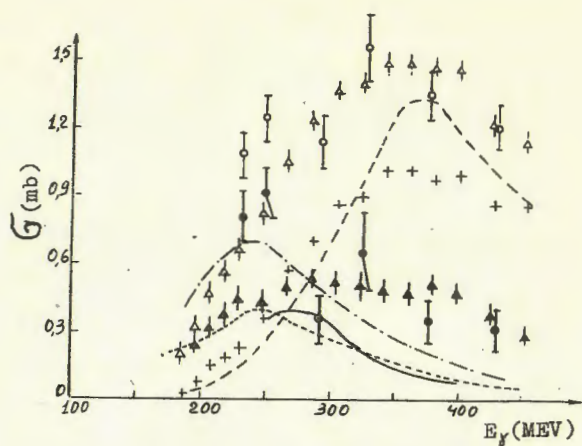


Fig. 4. Energy dependence of coherent cross section of π^0 -meson photoproduction on carbon. Also total and incoherent cross sections of π^0 -meson photoproduction are given.

●, ○ - cross sections of coherent and total photoproduction of π^0 -mesons, respectively (our results), ▲, +, △ - the values of the Bonn group [8] for coherent, incoherent and total cross sections of π^0 -meson photoproduction, respectively. Curves taken from Ref. [8] correspond to: dash-dotted and dotted - to isobar-hole formalism for the cross section of π^0 -meson coherent photoproduction with and without account of spreading potential, respectively, solid - to the isobar doorway model for the cross section of π^0 -meson coherent photoproduction, dashed - to impulse approximation for the total cross section of π^0 -meson photoproduction.

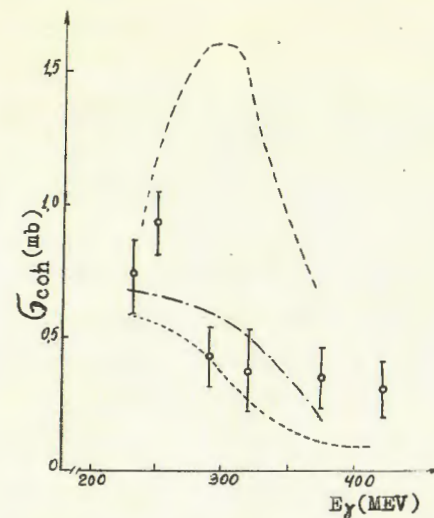


Fig. 5. Energy dependence of coherent cross section of photoproduction on oxygen. Curves taken from Ref. [1] correspond to: dashed - to plane wave impulse approximation, dash-dotted - to distorted wave impulse approximation, dotted - to isobar-hole formalism.

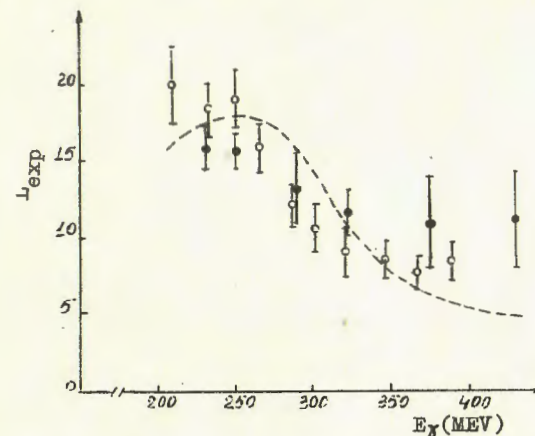


Fig. 6. Energy dependence of the Levinger factor for the carbon nucleus. ● - our obtained values, ○ - carbon values taken from Ref. [15]. The curve is plotted by averaging L over different nuclei [15].

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