индекс 3624

ԵՐԵՎԱՆԻ ՖԻԶԻԿԱՅԻ ԻՆՍՏԻՏՈՒՏ
ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ

ЕФИ-597(84)-82

Y.A.ARAKELYAN, G.L.BAYATYAN, N.K.GRIGORYAN, A.H.KECHECHYAN, S.G.KNYAZYAN, A.T.MARGARYAN, G.G.MARIKYAN, S.P.SHAKHAZIZYAN, S.S.STEPANYAN, G.S.VARTANYAN

# MEASUREMENT OF TOTAL $\pi^{\circ}$-PHOTOPRODUCTION CROSS SECTION ON THE NUCLEI $^{9}Be, ^{12}C, ^{16}O$ IN THE ENERGY RANGE $E_{\gamma}$=0,25-1 GEV WITHOUT CHARGED PARTICLES IN FINAL STATE

ԵՐԵՎԱՆ 1982 ЕРЕВАН

1. Introduction

The interactions of photons with nuclei at $E_\gamma = (0.2 - 1)$ GeV take place via excitation of baryon resonances. The theoretical consideration of the photon-nucleus process is complicated by the need to take into account the interactions of excited baryon resonances with the nucleus. Therefore, at present there is not any distinct prediction describing the behaviour of total cross section of pion photoproduction in this energy range.

In the $\Delta$ -resonance region there exist various theoretical approaches to the pion photoproduction. In ref. [1] the pion photoproductions with nuclei are treated as photoproductions with quasifree nucleons allowing for the corrections due to the variation of propagator in the nuclear medium and the interaction of $\Delta$ -isobars and pions with nucleons in the final state. In refs.[2-4] the coherent scattering of photons and pions and the $\pi^\circ$ -photoproduction are discussed as a unified process in the isobar doorway model. Such a discussion yields some information on the amplitude of the $\Delta$ -isobar interaction with nucleons. The coherent $\pi^{\circ}$-photoproduction is also discussed for the investigation of pion wave function (in the nucleus of distorted wave inpulse approximation - DWIA).

At present there are papers [5-9] dealing with $\pi^{\pm}$-photoproduction with nucleons and light nuclei, $\pi^{\circ}$-photoproduction with nucleons, incoherent photoproduction with the nucleus. In this paper we report the first time the data on the total photoproduction cross section on the nuclei Be, O, C in the energy range (0.25 - 1) GeV.

The available data on incoherent pion photoproduction [5,9] and total hadron photoproduction cross section allow to investigate the coherent $\pi^{\circ}$-photoproduction and the nucleus photodisintegration process.

## 2. Experimental setup

The measurements are carried out on the extracted electron beam of the Yerevan synchrotron. In order to obtain monochromatic photons we have used the tagged photons method. The diagram of the tagged photon beam obtaining is presented in fig. 1. The collimated beam of electrons with the intensity $\sim (0.5 - 1) \cdot 10^5$ $e^-$ per second produces on a radiator with the thickness $0.021X_o$ ($X_o$ is the radiation length) $\sim 0.3 \cdot 10^4$ bremsstrahlung photons per second tagged in the energy range 0.25 - 1 GeV.

Ing fig. 2 the experimental setup is presented which may be conventionally divided into two parts. The first one, consisting of an energy-analyzing magnet M, a radiator R, a tagging system scintillation hodoscope T, a shower counter SC and a quantometer Q is designed for the formation and detection of tagged photon beam. The second part, consisting of a detector HD overlapping the solid angle $\sim 4\pi$, a target m and a number of veto counters $\bar{A}$, is used for the detection of $\pi^{\circ}$-photoproduction events.



The tagging systom hodoscope represents 16 channels of three rows (T, T', T'') of scintillation counters used in coincidence with each other. The main beam of electrons noninteracted in the radiator R strikes the quantometer Q, by whose readings we control the electron beam intensity.

The description of the shower counter with the effective area $(30 \times 30)\,cm^2$ and the thickness 20 $X_o$ is given in ref. [10].

The $4\pi$-detector HD is composed of five groups of scintillation counters surrounding the target m. Each group represents a $\gamma$-telescope of four 2 cm scintillation counters with a 0.8 cm lead layer sandwiched in the first two counters. The fifth group of counters located across the $\gamma$-beam has a hole 12 cm in diameter for the passage of both the photons noninteracted in the target and the main part of electron-positron pairs produced in the target. The veto counters $\bar{A}_1 + \bar{A}_4$ are designed for discarding the trident events in radiator and for suppression of the beam "halo". The scintillation counter "x" $(10 \times 16)\,cm^2$, located before the shower counter SC on a direct $\gamma$-beam, has been used for some control measurements.

The electronic logic circuit is presented in fig. 3.

## 3. Measurement technique

Measurements are carried out for beryllium, carbon and water targets with the diameter 5 cm and thickness $0.1X_0$.

In order to detect $\pi^\circ$-mesons against the background of charged hadrons in the target, the first row of the $4\pi$-detector counters, as is seen from fig. 3, is connected in veto with the remaining rows. Such a method excludes the possibility of detecting the incoherent $\pi^\circ$-meson production process with proton accompaniment $\sigma_{inc}(\gamma A \to A'\pi^\circ p)$. Thus, we measure the total $\pi^\circ$-photoproduction cross section as a sum of total cross section of coherent $\pi^\circ$-photoproduction on nuclei and the total cross section of incoherent $\pi^\circ$-photoproduction with neutron accompaniment.

$$\sigma_{tot} = \sigma_{coh}(\gamma A \to A\pi^\circ) + \sigma_{inc}(\gamma A \to A'\pi^\circ n)$$

We measure the number of produced $\pi^\circ$-mesons per photon hitting the target. It corresponds to the ratio of the coincidence of logical signals from one of the tagging system channels and $4\pi$-detector at the absence of signals from the shower counter and veto counters to the number of photons. The number of photons is measured by the coincidence of logical signals from one of the channels of tagging system and shower counter.

During the experiment the shower counter inefficiency is regularly measured as a ratio of the signals coincidence of one of the tagging system channels and detector "x" (see fig. 2) at the absence of a signal from the shower counter to the triple coincidence of signals from the shower counter, counter "x" and one of the tagging system channels.



A certain portion of electron-positron pairs produced at large angles, due to the inefficiency of the $4\pi$-detector veto counters ($\sim 5\%$) will be detected by the $4\pi$-detector, simulating the case of $\pi^\circ$-photoproduction. We determine the number of such cases per photon as a triple coincidence of logical signals from the shower counter, $4\pi$-detector and one of the tagging system channels. Such a measurement, taking into account the shower counter inefficiency, makes it possible to estimate the portion of electromagnetic cases detected along with the real number of $\pi^\circ$-photoproduction cases.

All measurements are carried out both with and without targets of $^9Be$, $^{12}C$, $H_2O$. During the experiment the level of accidental coincidences was regularly measured by introducing an additional delay ($\sim 120$ nsec) in the strobing signal (see fig. 3).

## 4. Data analysis

The total $\pi^\circ$-photoproduction cross section is calculated as

$$\sigma_{tot}(\gamma,\pi^\circ) = \frac{1}{N_0}\frac{M}{N}$$

where $M$ is the number of photons producing $\pi^\circ$-mesons; $N$ is the number of incident photons; $N_0$ is the number of target nuclei per unit area.

When analyzing the results the following factors, affecting $M$ and $N$, are taken into account:

1. $\gamma$ -beam attenuation in air and targets. The correction determined by it is (1 - 1.5)% and (5 - 7)%, respectively.

2. Inefficiency of the order (2 - 3)% of photons detection by a shower counter.

3. The contribution of $\pi^\circ$-mesons, discarded by the shower counter, is (1 - 4)% versus photon energy.

4. The total efficiency of $4\pi$ -detector scintillation counters is 90%.

5. We have calculated by the Monte Carlo mathod:

a) the contribution of multiple bremsstrahlung processes in the radiator with the thickness $0.021X_0$ for a 100 MeV threshold of photon detected by a shower counter. The correction due to it is (2 - 6)% versus photon energy.

b) the efficiency of $\pi^\circ$-meson detection allowing for the $4\pi$-detector geometrical efficiency and photons conversion efficiency for a 0.8 cm thickness of the lead layer in the detector (see fig. 2) versus $\gamma$-quanta energy and $\pi^\circ$-meson angular distribution. The calculated value of efficiency is (60 - 90)% for $E_\gamma$ = (0.25 - 1) GeV.

6. The contribution of the inefficiency (~ 5%) of the first row of $4\pi$-detector counters allowing to detect a certain portion of cases of the charged hadron photoproduction.

The values of $\pi^\circ$-production cross sections, calculated by the measured values of the number of cases of $\pi^\circ$-meson production per photon hitting the target, allowing for measurements and above corrections for the targets of $^9Be$, $^{12}C$, $^{16}O$ in the tagged photon energy range (250 - 1000) MeV, are presented in Table 1.



5. Discussion of results

Energy dependences of the total $\pi^\circ$-photoproduction cross section on the nuclei $^9Be$, $^{12}C$, $^{16}O$ are presented in figs.4, 5,6, respectively.

In fig. 4, along with our experimental results, for comparison are also presented the data on $\pi^\circ$-photoproduction calculated by the values of total hadron photoproduction cross section and total charged hadron photoproduction cross section taken from [11]. For the comparison with theoretical predictions we have determined the coherent part of $\pi^\circ$-meson photoproduction. During the calculations, along with the $\pi^\circ$-photoproduction cross sections obtained by us, we have also used the values of incoherent pion photoproduction with proton accompaniment [5] and the ratio of the cross sections of charged pions photoproduction on $^{12}C$ [9]. Similar calculations are carried out also for $^{16}O$ with an assumption that the incoherent pion photoproduction cross section for $^{16}O$ and $^{12}C$ makes the same percentage of total cross sections of hadron photproduction on $^{16}O$ and $^{12}C$. In figs. 7 and 8 these results are presented together with theoretical predictions [12,2] of coherent $\pi^\circ$-photoproduction energy dependences. The use of total cross sections of charged pions photoproduction [5] as well as of measured hadron and $\pi^\circ$-photoproduction total cross sections allowed to calculate the nuclear photodisintegration cross section for $^{12}C$. The comparison of this cross section with the equation:

$$\sigma = L \frac{NZ}{A} \sigma_d^{ex}$$

where $\sigma_d^{ex}$ is the meson exchange part of the deuteron photodisintegration cross section, $N, Z$ are the number of neutrons and protons in nucleus, $A = N + Z$ makes it possible to determine the Levinger factor L. At $E_\gamma = 250 \pm 60$ MeV and $320 \pm 30$ MeV we have obtained for carbon $L = 15.7 \pm 1.9$ and $11.7 \pm 1.4$ respectively, which coincides well with L presented in ref. 13 .

In conclusion we would like to express our thanks to A.Ts.Amatuni, H.A.Vartapetyan for their interest in the work, to V.M.Aslanyan, I.A.Hakopyan, A.R.Voskanyan, A.G.Movsisyan, S.O.Tatevosyan and Sh.K.Shiroyan for the help in the work as well as to the synchrotron staff for providing us with a beam.



TABLE 1

Total $\pi^\circ$-photoproduction cross section

| $E_\gamma \pm \Delta E_\gamma$ MeV / target | 250 ± 60 | 320 ± 30 | 460 ± 50 | 600 ±50 | 710 ±50 | 890 ±90 | 1060 ±90 |
|---|---|---|---|---|---|---|---|
| $^9Be$ | 1.08 ±0.11 | 1.33 ±0.35 | 0.88 ±0.14 | 0.59 ±0.2 | 0.49 ±0.14 | 0.44 ±0.11 | 0.35 ±0.12 |
| $^{12}C$ | 1.23 ±0.124 | 1.55 ±0.28 | 1.17 ±0.22 | 0.64 ±0.23 | 0.72 ±0.09 | 0.51 ±0.17 | 0.53 ±0.09 |
| $^{16}O$ | 1.36 ±0.07 | 1.45 ±0.10 | 1.18 ±0.09 | 0.87 ±0.12 | 0.51 ±0.13 | - | - |

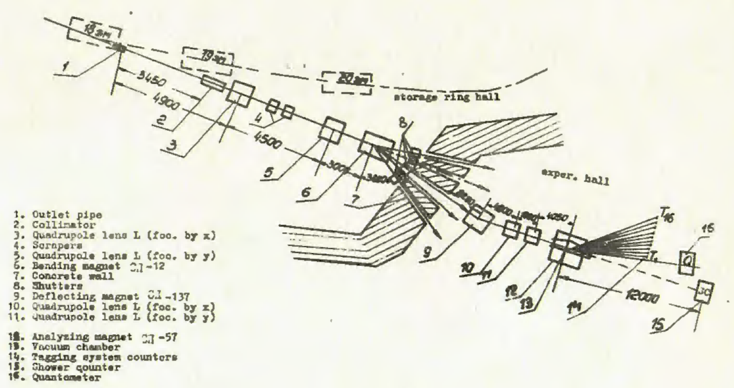


Fig. 1 Diagram of the arrangement of the electron channel magnetic elements.

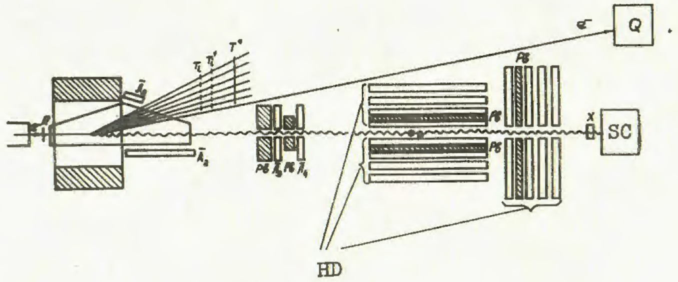


Fig. 2 Diagram of the arrangement of experimental setup.



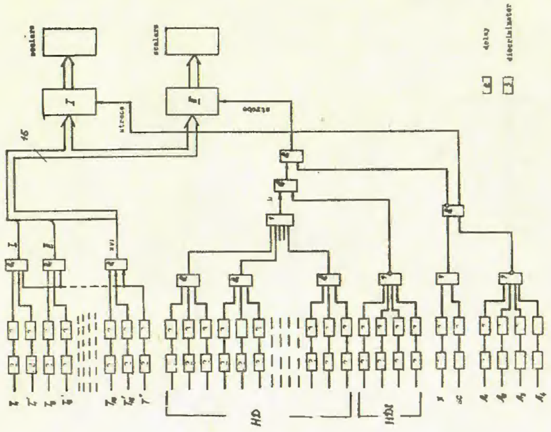


Fig. 3 Electronic logic circuits.

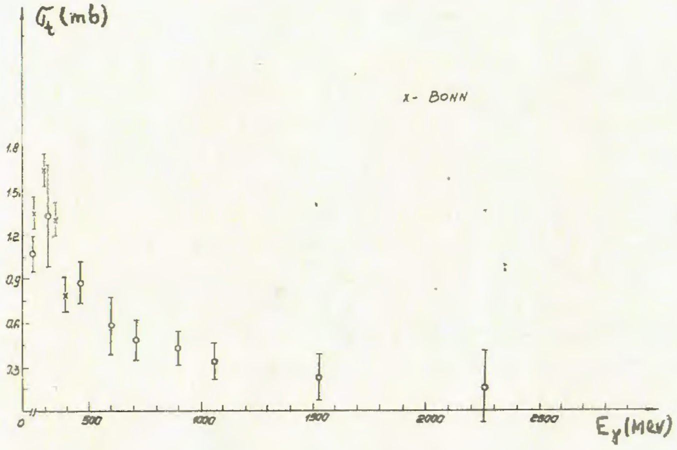


Fig. 4 Energy dependence of the total cross section of $\pi^\circ$-photoproduction for beryllium.

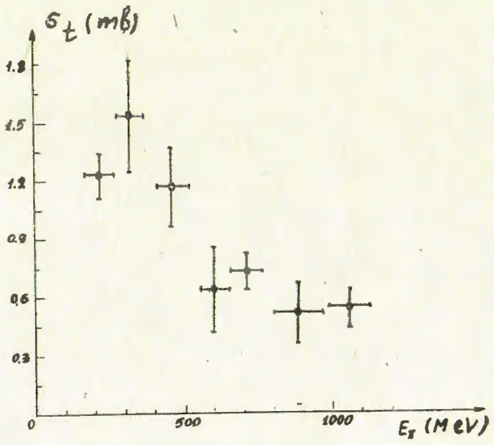


Fig. 5 Energy dependence of the total cross section of $\pi^\circ$-photoproduction for carbon.

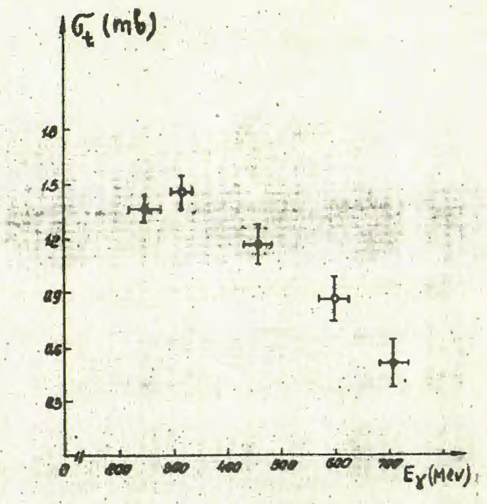


Fig. 6 Energy dependence of the total cross section of $\pi^\circ$-photoproduction for oxygen.

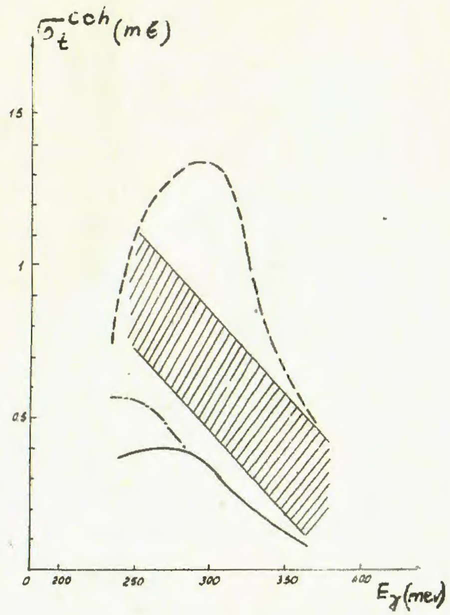


Fig. 7 Total coherent $\pi^\circ$-photoproduction cross section for carbon versus photon energy.

— — — plane wave impulse approximation (PWIA)

— • — • — distorted wave impulse approach (DWIA)

———— "isobar doorway" approximation calculation.

The shaded region corresponds to the results of this paper. Theoretical curves are taken from ref. [12].

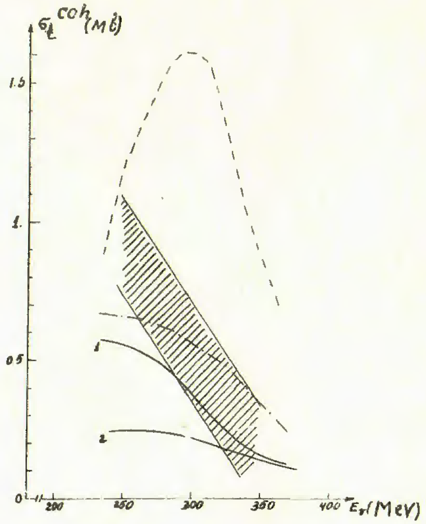


Fig. 8 Total coherent $\pi^{\circ}$-photoproduction cross section for oxygen versus photon energy.

— — — plane wave impulse approximation (PWIA)

— — — distorted wave impulse approach (DWIA)

——— "isobar doorway" approximation calculation.

Curve 1 corresponds to ref. [12], curve 2 and the other theoretical curves to ref. [2]. The shaded region corresponds to the results obtained in this paper.



References


1 Laget J.M. Pion Photoproduction on Few Body Systems.- Phys. Rep., 1981, vol. 69, No. 1.

2 Koch J.H. and Moniz E.J. Coherent $\pi^{\circ}$-Photoproduction in the Isobar-Hole Formalism.- Phys.Rev., 1979, vol.C20,p.235.

3 Moniz E.J. Isobar Propagation in Nuclei and Collective Effects.- Nuclear Physics with Electromagnetic Interactions, Lecture Notes in Physics, 1979, vol. 108, p.435.

4 Woloshyn R.M. Neutral Pion Photoproduction in a Phenomenological Isobar Doorway Model.- TRI-PP-77-14, TRIUMF, Vancuver, 1977.

5 Arends J., Eyink J., Hartmann H. et al. Inclusive Charged Pion Photoproduction on $^{12}C$ Using Tagged Photons in the Energy Range (200-390) MeV.- Bonn-HE-81-27, Bonn University, 1981.

6 Mecking B.A. Coincidence Experiments at the Bonn 500 MeV Synchrotron.- Nuclear Physics with Electromagnetic Interactions; Lecture Notes in Physics, 1979, vol. 108, p.382.

7 Ziegler B. Photoabsorption and Sum Rules.- Nuclear Physics with Electromagnetic Interactions, Lecture Notes in Physics, 1979, vol. 108, p.138.

8 Белоусов А.С.,Говорков Б.Б., Гольданский В.И. Обобщенный вид зависимости сечений фоторждения $\pi^{\circ}$ - мезонов на сложных ядрах от числа нуклонов. ЖЭТФ, I959, т.36, вып.I,с.244

9 Arends J., Eyink J., Hartmann H. et al. Experimental Study of the Photoemission of Protons off $^{12}C$ Using Tagged Photons in the Energy Range (200-385) MeV.- Bonn-HE-80-7,

Bonn University, 1980.

10 Arakelyan E.A., Bayatyan G.L., Vartanyan G.S. et al. Measurement of Total Cross Sections of Hadron Photoproduction in C, Cu and Pb Nuclei at $E_\gamma$ = (12-30) GeV.- Preprint EPI 257(50)-77, Yerevan 1977.

11 Arends J., Eyink J., Hegerath A. et al. Measurement of the Total Photonuclear Cross Section in the $\Delta$ -Resonance Region.- Phys.Lett., 1981, vol. 98B, No. 6, p.423.

12 Saharia A.N., Woloshyn R.M. Isobar Doorway Model for Coherent $\pi^0$-Photoproduction.o Phys.Rev., 1981, vol. C23, p.351.

13 Laget J.M. Pion Production of Light Nuclei From Collective States to Quarks in Nuclei.- Lec Notes in Physics, 1980, vol. 137, p.149.

The manuscript was received 2 September 1982.

Е.А.АРАКЕЛЯН, Г.Л.БАЯТЯН, Г.С.ВАРТАНЯН, Н.К.ГРИГОРЯН,
С.Г.КНЯЗЯН, А.О.КЕЧЕЧЯН, А.Т.МАРГАРЯН, Г.Г.МАРИКЯН,
С.С.СТЕПАНЯН, С.Р.ШАХАЗИЗЯН

ИЗМЕРЕНИЕ ПОЛНОГО СЕЧЕНИЯ ФОТООБРАЗОВАНИЯ $\pi^{\circ}$ - МЕЗОНОВ НА ЯДРАХ Be, C, O, В ИНТЕРВАЛЕ ЭНЕРГИИ $E_{\gamma}$= (0,25-I) ГЭВ БЕЗ ЗАРЯЖЕННЫХ ЧАСТИЦ В КОНЕЧНОМ СОСТОЯНИИ

(на английском языке, перевод Л.Н.Багдасаряна)
Ереванский физический институт

Редактор Л.П.Мукаян
Тех.редактор А.С.Абрамян

Заказ 62I ВФ-0404I Тираж 299

Препринт ЕФИ Формат издания 60x84/I6
Подписано к печати 30/XII-82 I.0 уч-изд.л. Ц. I5 к.

Издано Отделом научно-технической информации
Ереванского физического института, Ереван 36, Маркаряна 2

9