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MEASUREMENT OF TOTAL HADRONIC PHOTOPRODUCTION CROSS SECTION IN ^{9}Be, ^{12}C, ^{16}O, ^{64}Cu NUCLEI IN THE PHOTON ENERGY RANGE E_{γ} = (0.25 - 2.7) GEV

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ИЗМЕРЕНИЕ ПОЛНОГО СЕЧЕНИЯ ФОТООБРАЗОВАНИЯ АДРОНОВ НА ЯДРАХ Be, C, O, Cu В ИНТЕРВАЛЕ ЭНЕРГИИ ФОТОНОВ E_γ = (0,25 - 2,7) ГэВ

В работе впервые приводятся экспериментальные результаты измерения полного сечения фотообразования адронов на ядрах Be, C, O, Cu для энергии фотонов (0,25-2,7) ГэВ, полученные с помощью обычного метода использования системы мечения γ-квантов и адронных детекторов, перекрывающих телесный угол $\sim 4\pi$. Результаты сравниваются с имеющимися в настоящее время данными по полному сечению фотообразования адронов для энергии до 400 МэВ и выше I,5 ГэВ.

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The experimental results of the measurement of total hadronic photoproduction cross section in ^{9}Be, ^{12}C, ^{16}O, ^{64}Cu nuclei for the photon energy range (0.25-2.7)GeV have been obtained for the first time using the photon tagging system and hadron detectors overlapping the solid angle of $\sim 4\pi$. The results are compared with the current data on total hadronic photoproduction cross section for the energy up to 400 MeV and above 1.5 GeV.

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Introduction

Measurements of total hadronic photoproduction cross section in nuclei in the energy range (2-180) GeV [1] corroborated the hadronic properties of the photon interaction with matter, being one of the main arguments in favour of the vector dominance model. The study of the hadron photoproduction in nuclei in the photon energy range (0.25-2) GeV is interesting for in this range the interaction of photons with nuclei occurs due to excitation of bound nucleons in nuclei and formation of baryon resonance states. The investigations of total cross sections in Δ resonance energy region allow one to get information on ΔN interaction [2]. The values of total cross sections in the energy range (0.5-2) GeV supplement the available results in low [3] and high [1] energy regions. That will permit one to control the sum rule of Gell-Mann - Goldberger - Thirring [4] as well as obtain information on γN interaction behaviour for the region of $\gtrsim$ 1000 GeV [5]. These results permit one to derive information also on nuclei static characteristics, such as the electric and magnetic polarizability of nuclei and so on [6].

The values of photoabsorption total cross sections in Li and Be nuclei in the energy region up to 350 MeV are obtained at Mainz [7] by the beam attenuation method. Total cross sections in H, D, He, C, Al, Ni, Mo, W nuclei in the energy region from the pion production threshold up to 500 MeV are obtained at the Kharkov electroproduction experiment at low transferred momenta [8]. The photoabsorption cross sections in H and D in the energy range (0.26-4.2) GeV are measured [9, 10] by the method generally employed at high energies, i.e. using tagging system for producing monochromatic photons and their monitoring as well as hadron detectors for recording the interaction events. By the analogous method there has been measured the total cross section of charged particles production ($p, \pi^{\pm}$) in nuclei in the energy range (215-380) MeV [11]. By a somewhat different means there has been measured the photoabsorption total cross section in carbon in the first resonance energy region [12].

We report for the first time the experimental results of the total hadronic photoproduction cross section in ^{9}Be, ^{12}C, ^{16}O, ^{64}Cu nuclei for the photon energy range (0.25-2.7) GeV. The data are obtained using the generally employed tagging system as well as hadronic detectors overlapping a solid angle of $\sim 4\pi$.

1. Experimental Setup

The measurements of the total hadronic photoproduction cross section in ^{9}Be, ^{12}C, H_2O, ^{64}Cu nuclei are carried out using the tagged photon beam of the Yerevan accelerator electron channel (see Fig.1).

Extracted electrons of 4.5 GeV primary energy, $\sim 10^{5} e^{-}$ per second intensity and 1 mrad angular divergence produce bremsstrahlung photons in a 0.021 X_o thick radiator R (X_o is radiation length). The tagging system hodoscope (Fig.2) overlaps the energy range (0.25-2.7) GeV. The produced beam of tagged photons being $\sim$ 1 cm in diameter strikes the target m surrounded with hadron detectors. The hadronic detectors overlapping a solid angle of $\sim 4\pi$ consist of five groups of scintillation counters. Each group consists of a lead sheet $\sim 1.5\ X_0$ thick and three scintillation counters in coincidence. A group of hadron counters placed across the γ -beam has a $\sim$ 12 cm diam hole for the passage of both non-interacted photons and the main part of electron-positron pairs produced in the target.

A shower counter presents a lead-scintillator sandwich $20\ X_0$ thick and effective area (30 x 30) cm^2. It serves for recording both non-interacted in the target photons and electron-positron pairs produced. A quantameter Q is employed to detect the main beam of electrons non-interacted in a radiator R. The quantameter reading monitores the intensity of the extracted electron beam.

Veto counters ($\bar{A}_1$ - $\bar{A}_4$) are used to suppress the beam halo effects and trident events in the radiator.

The electronic logic circuit is shown in Fig.3.

2. Measurement Procedure

The measurements are carried out for ^9Be, ^{12}C, H_2O, ^{64}Cu targets $0.1\ X_0$ thick and 5 cm in diameter. The number of events of hadron production per photon is measured. That corresponds to the coincidence of logic signals from one of the tagging system channels with those from hadron detectors (signals from the shower counter and veto ones being absent), divided by the number of photons measured by the coincidence of logic signals from one of the tagging system channels with those from the shower counter (SC).

To determine the SC inefficiency a (10 x 15) cm^2 scintillation counter

"X" is placed in front of SC in the way of a direct photon beam (see Fig.2). The SC inefficiency is determined by measuring the number of coincidence of signals from one of the tagging system channels with those of counter "X", the SC signals being absent, divided by the number of threefold coincidence of all these signals.

The number of produced in the target electron-positron pairs per photon striking the hadron detectors and stimulating hadron photoproduction events is determined as a threefold coincidence of logic signals from SC, hadron detectors and one of the tagging system channels. Such a measurement with respect to the SC inefficiency makes it possible to estimate our recorded portion of electromagnetic events together with the hadron production real number. All the above-mentioned measurements are carried out also for the empty target. During the whole experiment the level of accidental coincidence is regularly measured by introducing an additional strobe signal delay.

3. Data Analysis

The total hadronic photoproduction cross section is calculated by the formula

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

where M is the number of hadron-producing photons; N is the number of incident photons; N_0 is the number of target nuclei per unit area.

When analyzing the data the following factors are taken into account:

1. Correction due to γ -beam attenuation in the air and targets is (1-1.5)% and (5-7)%, respectively.
2. The efficiency of photon detection by the shower counter is (97-98)%.
3. The contribution of hadrons produced in the solid angle caused by the

hadron detectors hole is (1-5)%, versus photon energy.

4. Total efficiency of hadron detectors amounts to ~ 90%.
5. The hadron detectors geometric efficiency amounts to ~ 90%.
6. The contribution of multiple bremsstrahlung in the 0.021 X_0 thick radiator at a 100 MeV threshold of photon detection by the shower counter is ~ (2-6)%, versus photon energy.
7. The efficiency of neutral pion recording by a hadron detector for a 0.8 cm thick lead sheet averaged over angles of particles entrance into the detector amounts to ~ (60-90)%, versus π^0-meson energy. The efficiency correction for π^0-meson recording by hadron detectors is (8-2)% taking into account the fact that the neutral pion portion in the total cross section amounts to ~ 20%.

4. Measurement Results

The values of total hadronic photoproduction cross sections thus obtained for ^9Be, ^{12}C, H_2O, ^{64}Cu targets in the tagged photons energy range (0.25-2.7) GeV are listed in Table 1.

The energy dependence of total hadronic photoproduction cross section in carbon is shown in Fig.4 together with the energy dependence of the sum of photonucleon cross sections [8] . Ibidem are given for comparison the experimental data obtained at Kharkov [8] , Bonn [11] in the energy region up to 400 MeV and at DESY [1] in the energy region above 1.5 GeV.

Fig.5 illustrates the energy dependence of total hadronic photoproduction cross section in ^9Be together with the results derived at Bonn [11] and DESY in the energy region up to 400 MeV and above 1.5 GeV, respectively.

Fig.6 shows the values of total hadronic photoproduction cross section in H_2O in the photon energy range (250-700) MeV. Ibidem are given for comparison the results obtained by summing the total cross sections of π^0-meson photoproduction in ^{16}O measured by us and those of charged hadrons in H_2O measured at Bonn.

Fig.7 gives the values of total hadronic photoproduction cross section in ^{16}O derived from our data with H_2O using the total hadronic photoproduction cross section in proton [9] . Ibidem are given for comparison the Bonn experimental results [11] together with theoretical calculations within the framework of Δ -hole model [2] .

Fig.8 shows the values of total hadronic photoproduction cross section in copper together with the Cornell results [1] .

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Table 1. Total Hadronic Photoproduction Cross Section

Target \ E ± E MeV	250 ±60	320 ±30	460 ±50	600 ±50	710 ±50	890 ±90	1060 ±90	1230 ±90	1370 ±90	1530 ±90	2260 ±100	2700 ±100
9 Be	3.69 ±0.23	4.13 ±0.36	3.11 ±0.22	2.45 ±0.17	2.15 ±0.16	1.70 ±0.16	1.41 ±0.20	1.10 ±0.14	0.61 ±0.18	0.88 ±0.20	0.83 ±0.11	-
12 C	4.15 ±0.11	5.67 ±0.33	4.02 ±0.33	2.56 ±0.44	1.86 ±0.46	1.49 ±0.48	1.45 ±0.21	-	1.36 ±0.26	1.65 ±0.1	1.47 ±0.15	1.16 ±0.11
H_2O	6.12 ±0.14	6.74 ±0.21	4.82 ±0.24	3.71 ±0.25	2.01 ±0.21	-	-	-	-	-	-	-
64	-	29.7 ±7.6	28.2 ±2.99	24.2 ±2.5	17.1 ±1.1	12.9 ±1.2	9.2 ±1.27	8.67 ±1.34	-	7.1 ±1.4	4.39 ±2.30	2.96 ±1.76

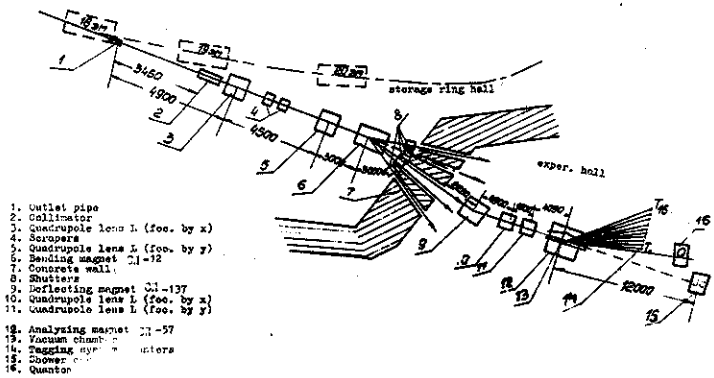

Fig.1. Diagram of the arrangement of the electron channel magnetic elements.

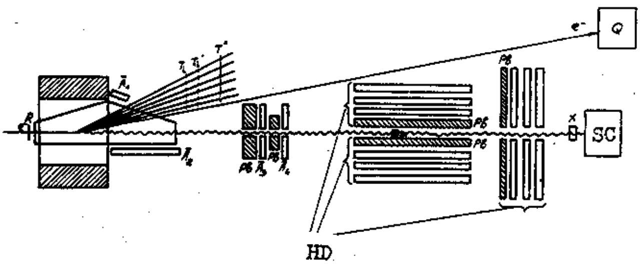

Fig.2. Arrangement of the experimental setup.

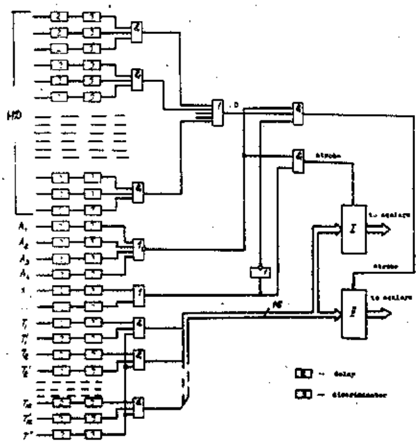

Fig.3. Electronic logic circuit.

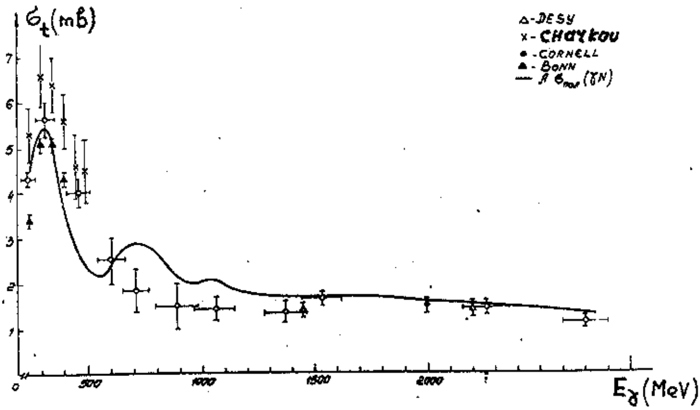

Fig.4. Energy dependence of the total hadronic photoproduction cross section in carbon:

- our results
- Kharkov [8]
- Bonn [11]
- DESY [1]
- sum of photonucleon cross sections [8]

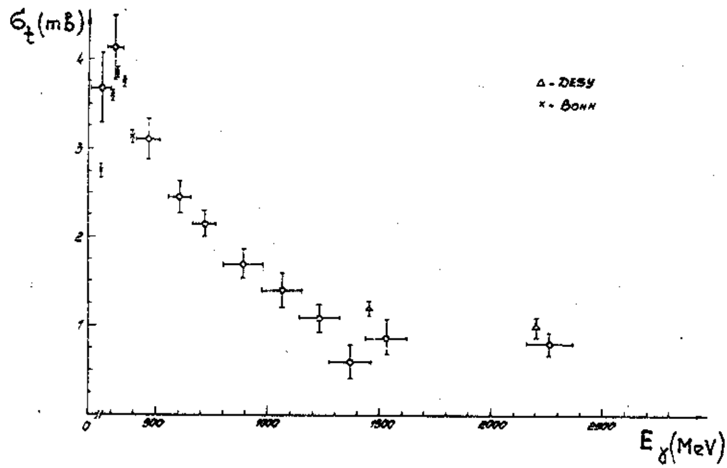

Fig.5. Energy dependence of the total hadronic photoproduction cross section in ^{9}Be:

- our results
- Bonn [11]
- DESY [I]

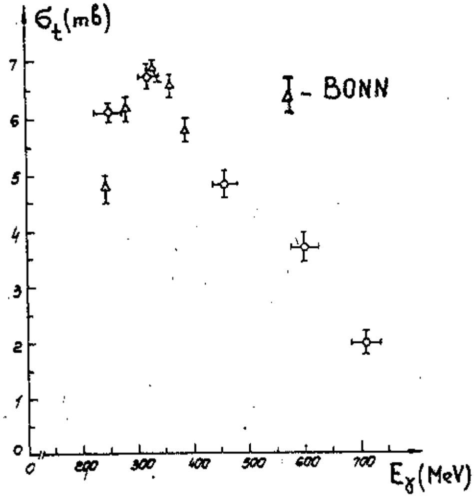

Fig.6. Energy dependence of the total hadronic photoproduction cross section in H_2O.

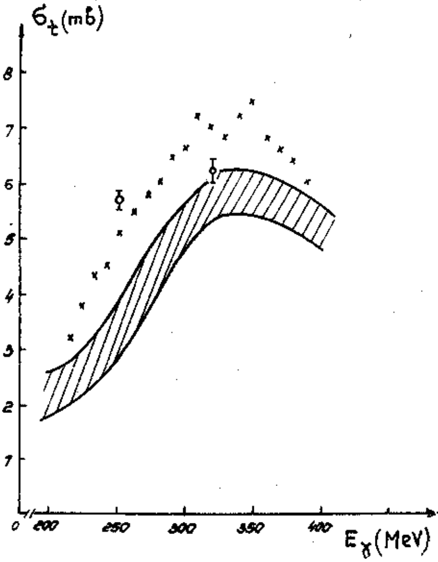

Fig.7. Total hadronic photoproduction cross section in ^{16}O:

- our results

- Bonn [11]

- theoretical calculations within the framework of Δ -hole model [2] .

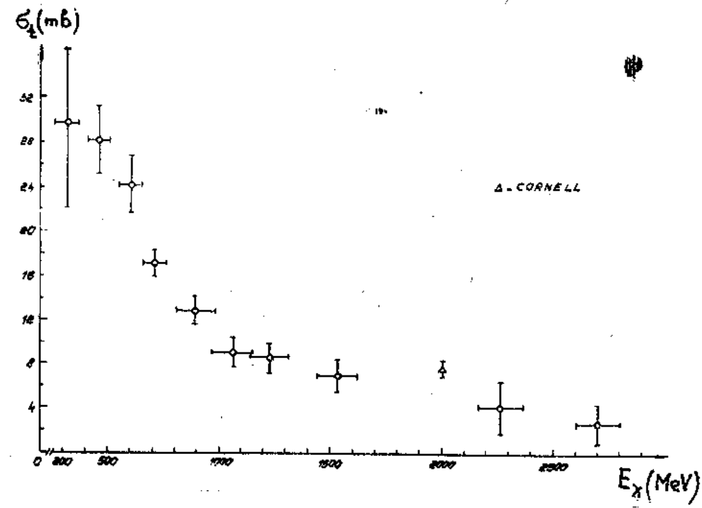

Fig.8. Energy dependence of the total hadronic photoproduction cross section in ^{64}Cu:

- our results

- Cornell [1].

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