ELASTIC PHOTOPRODUCTION OF π^0*-MESONS ON CARBON AT* 155 MeV

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The angular dependence of the cross section for the $\gamma + C^{12} \rightarrow C^{12} + \pi^0$ reaction at a mean energy of 155 MeV was determined from coincidences between the two γ quanta from the π^0-meson decay. Comparison of the experimental results with the calculations in the impulse approximation indicates that the distribution of nuclear matter in the C^{12} nucleus is the same as the charge distribution determined in electron scattering experiments.

THE investigation of elastic photoproduction of π^0 mesons on nuclei makes it possible to obtain information on the spatial distribution of nuclear matter and the properties of pions.[1-3] This process has been studied earlier[1,4,5] at energies close to the threshold (~137 MeV). The energy region near the threshold was chosen for two reasons. First, in this region (for primary photon energies up to ~180 MeV) the process of coherent photoproduction of π^0 mesons on nuclei predominates, since the inelastic photoproduction is strongly suppressed as the result of the Pauli principle. Second, the effects of absorption and scattering of the produced pions are small.

We have measured the angular distribution of the π^0 mesons produced on carbon nuclei by photons of mean energy 155 MeV. The experiment was performed at the synchrotron of the Physics Institute of the Academy of Sciences.

To observe the neutral pions, we recorded coincidences of the two decay γ quanta. The γ quanta were recorded by two "telescopes" set in the plane formed by the angle θ_π and the primary photon beam. This angle determined the mean angle of emission of the recorded π^0 mesons. The mean energy of the π^0 mesons is determined from the relation $\cos \frac{1}{2}\psi = \beta_\pi$, where ψ is the angle between the "telescopes" and β_π is the pion velocity. From the kinematics of the process, it follows that the π^0-meson energy depends very weakly on θ_π, owing to the fact that the mass of the carbon nucleus is much greater than the rest mass of the pion. Therefore, the angle ψ varies very weakly in the measurements, and was, on the average, 126°.

Each "telescope" consisted of two ordinary liquid scintillation counters. Lead converters 5 mm thick were set in front of the "telescopes." The pulses from all four counters were applied simultaneously to four coincidence circuits with a resolving time of $\sim 5 \times 10^{-9}$ sec. In one of the control experiments, we measured the dependence of the coincidence counts for each angle θ_π on the maximum energy of the bremsstrahlung spectrum of the synchrotron ($E_{\gamma\,max}$) with the aid of the time-analysis method.[6]

Figure 1 shows the data obtained for the angle $\theta_\pi = 90°$. Similar results were obtained for all other investigated angles. The sharp decrease

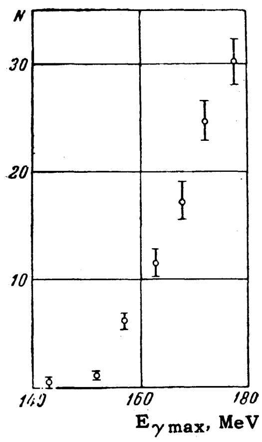

FIG. 1. Coincidence counting rate as a function of the maximum energy of the synchrotron bremsstrahlung spectrum.

in the yield in the region of primary photon energies below 150 MeV indicates that the random-coincidence counting rate and the counts of charged-particle pairs (the "telescopes" did not distinguish charged particles) were negligible in comparison with the counting rate due to the effect under study. The counting rate without the target was no greater than 2% of the counting rate with the employed carbon target of thickness 2 cm.

The absolute value of the primary photon flux was determined with the aid of graphite detectors from their activization in the reaction $C^{12}(\gamma, n)C^{11}$.

The direct results of the basic measurements were the number of coincidences from the two "telescopes" relative to the primary flux when the carbon target was irradiated by the synchrotron bremsstrahlung spectrum with $E_{\gamma\,max} = 180$ MeV. The measurements were made at six angles: 30, 60, 90, 110, 140, and 180°. We determined from the measured yields N the differential cross section for the elastic photoproduction of π^0 mesons with the aid of the relation

$$N = n \int_{E_{\gamma\,\min}}^{E_{\gamma\,\max}} \eta(E_\gamma, E_{\gamma\,\max})\, dE_\gamma \int_0^\pi \frac{d\sigma}{d\Omega}(\theta_\pi, E_\gamma) \sin\theta_\pi\, d\theta_\pi \times \int_0^{2\pi} \varepsilon(\theta_\pi, \varphi_\pi, E_\gamma)\, d\varphi_\pi, \quad (1)$$

where n is the number of nuclei per cm² of target; $\eta(E_\gamma, E_{\gamma\,max})$ is the synchrotron bremsstrahlung spectrum; $\epsilon(\theta_\pi, \varphi_\pi, E_\gamma)$ is the probability of recording π^0 mesons emitted in the l.s. direction $(\theta_\pi, \varphi_\pi)$ for an incident γ-quantum energy E_γ (this value was calculated from the kinematics of the process and the specific geometry of the experiment); $E_{\gamma\,min}$ is the minimum energy of the primary photons at which the recording of π^0 mesons is possible with our arrangement.

Calculation of the energy distribution $dN(E_\gamma)/dE_\gamma$ showed that in our experiment the resolution was approximately the same for all angles and was equal to 5.5 MeV. Figure 2 shows the calculated energy resolution for $\theta_\pi = 90°$ and the angular resolution $dN(\theta_\pi)/d\theta_\pi$ of the arrangement.

Figure 3 shows the measured differential cross sections for the process at different angles θ_π. The solid curve represents the differential cross sections for the elastic photoproduction of π^0 mesons on carbon nuclei calculated in the impulse approximation. It was assumed in the calculation that the protons and neutrons make the same contribution to coherent photoproduction of pions and that the spatial distribution of nuclear matter is equivalent to the charge distribution in the nucleus obtained from experiments in which electrons were scattered on nuclei.[7] Good agreement between the experimentally measured quantities and the theoretical calculations confirms, within the limits of experimental error, the correctness of the assumptions made in the calculation of the differential cross sections for the process.

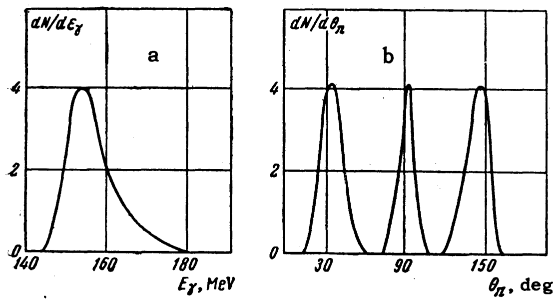

FIG. 2. Energy (a) and angular (b) resolutions of the arrangement.

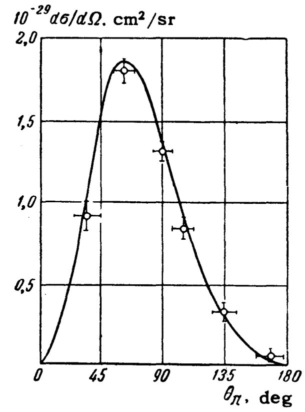

FIG. 3. Differential cross sections for elastic photoproduction of π^0 mesons on carbon at $E_\gamma = 155$ MeV.

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Translated by E. Marquit