a large energy loss. Hence, along with the interactions associated with almost 100% energy loss, there must also be weak interactions which involve little energy loss, and which occur with significantly higher probability.

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## *PHOTOPRODUCTION OF $\pi^0$—MESONS FROM CARBON NEAR THRESHOLD*

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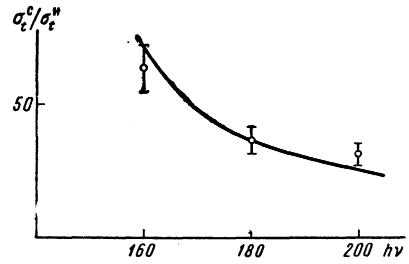
It has been shown[1,2] that in the photoproduction of $\pi^0$ mesons from helium at energies between threshold and ~ 200 Mev, the elastic production dominates. To investigate the role played by the elastic process in the photoproduction of $\pi^0$ mesons from more complex nuclei, we measured in the present work the ratios of the total cross sections for photoproduction from carbon and from hydrogen at primary photon energies of 160, 180, and 200 Mev. The geometry and the experimental method for the carbon measurements, which were made on the 265-Mev synchrotron of the P. N. Lebedev Physics Institute of the U.S.S.R. Academy of Sciences, are similar to those previously described[3] for hydrogen experiments.

Curves were obtained for the energy dependence of the emerging $\gamma$ rays from the decay of the $\pi^0$ mesons from carbon, for three angles. The emerging decay $\gamma$ rays were measured to within 1 or 2%. The energy dependence of the cross section for producing the decay $\gamma$ rays was calculated by the method of "photon differences" from the corresponding measured energy-dependence curves. The angular distributions of the decay photons obtained in this way were then integrated to obtain the total cross sections for the photoproduction of $\pi^0$ mesons from carbon ($\sigma_t^C$) in relative units.

The ratios of the number of decay $\gamma$ rays emerging from carbon and hydrogen at angles of less than 90°, obtained by measuring the counting rate of decay photons from hydrogen and styrofoam ($C_8H_8$) targets with the same geometry, were used to determined the ratio of the total cross sections $\sigma_t^C/\sigma_t^H$. The measured values of these ratios are shown in the figure.




The results obtained were compared with the predictions of the theory of elastic photoproduction of $\pi^0$ mesons from nuclei.[1] According to the theory, the differential cross section for $\pi^0$-meson photoproduction from a nucleus with nucleon number A and spin zero can be expressed in the form

$$(d\sigma(k)/d\Omega)_A = A^2 (d\sigma(k)/d\Omega)_H F_A^2(qR)/F_H^2(q), \tag{1}$$

where q is the nuclear recoil momentum, while $F_A^2(qR)$ and $F_H^2(q)$ are the nuclear and proton form factors; the second can be set equal to unity. From electron scattering experiments on carbon[4] it is known that the form factor for the carbon nucleus is expressed as follows

$$F_C^2(qR) = \left\{\left[1 - \frac{\alpha a^2 q^2}{2(2+3\alpha)}\right] e^{-q^2a^2/4}\right\}, \tag{2}$$

where $\alpha = 4/3$, $a = 1.635 \times 10^{-13}$ cm, $(d\sigma(k)/d\Omega)_H$ is the spin-independent differential cross section for $\pi^0$-meson photoproduction from hydrogen. From the form of the matrix elements for $\pi$-meson photoproduction from nucleons one can easily get

$$(d\sigma(k)/d\Omega)_H = (3/8\pi)\, \sigma_t \sin^2\theta_\pi, \tag{3}$$

where $\theta_\pi$ is the angle of emission of the $\pi^0$ meson in the center-of-mass system, and $\sigma_t$ is the spin-independent part of the total cross section for $\pi^0$-meson photoproduction from protons.

Substituting (3) into (1) and integrating over the solid angle, we obtain

$$\sigma_t^C = 17.2 \cdot \sigma_t \int_0^\pi F_C^2(qR) \sin^3\theta_\pi \, d\theta_\pi.$$

The integrals on the right-hand side were computed graphically and then normalized by analytic evaluation of the integral for the threshold photon energy when $F_C^2(qR) = \text{const}$.

From the analysis of the experimental data[3] of $\pi^0$-meson photoproduction from protons,[5] it follows that within 10% accuracy, for the energy region of primary photons studied, one can neglect the contributions of the $M(\frac{1}{2})$, E1, and E2 photoproduction amplitudes to the total cross section $\sigma_t^H$. Hence taking into account only the amplitude $M(^3/_2)$ in the total cross section for $\pi^0$-meson photoproduction from protons, we can easily determine that $\sigma_t = {}^2/_3\,\sigma_t^H$. To calculate $\sigma_t$ we use the total cross section $\sigma_t^H$ measured in reference 6. The calculated curve $\sigma_t^C/\sigma_t^H$ is compared with the experimental points in the figure. Calculation of the contribution of the E1 amplitude makes a small reduction in the calculated magnitude of $\sigma_t^C/\sigma_t^H$ for $h\nu = 160$ Mev; however this change lies within the limits of the statistical uncertainty of the experiments.

As can be seen from the figure, there is good agreement between theory and the observed experimental results. Therefore at primary photon energies of 160 to 200 Mev the elastic photoproduction of $\pi^0$ mesons from carbon dominates. At higher energies it seems that inelastic processes begin to appear in $\pi^0$-meson photoproduction which show up as small deviations of the experimental ratio $\sigma_t^C/\sigma_t^H$ from that calculated theoretically. This is consistent with the conclusion recently given.[7]

Similar measurements we have made of the $\pi^0$-meson photoproduction cross section from beryllium nuclei do not show any significant differences between the energy dependence of the total cross section for $\pi^0$-meson photoproduction from carbon and beryllium.

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## *CALCULATION OF ENERGY LEVELS OF* $Tl^{206}$ *AND* $Bi^{210}$ *NUCLEI*

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1. To calculate the energy levels of the $Tl^{206}$ and $Bi^{210}$ nuclei we used the data of Sliv and Volchok[1] on the neighboring nuclei. The nucleus ${}_{81}Tl^{206}_{125}$ has one neutron hole and one proton hole. Using the single-particle neutron wave functions of $Pb^{207}$ ($p_{1/2}$ — ground state, $f_{5/2}$ — 620 kev) and the proton wave functions of $Tl^{207}$ ($s_{1/2}$ — ground state, $d_{3/2}$ — 350 kev), we can plot a zeroth-approximation level scheme for $Tl^{206}$ up to 1 Mev. With the aid of these data for $Tl^{206}$ we obtain the following multiplets with corresponding energies, spins, and parities: $(p_{1/2}s_{1/2})$, 0 kev, $I = 0^-, 1^-$; $(p_{1/2}d_{3/2})$, 350 kev, $I = 1^-, 2^-$; $(f_{5/2}s_{1/2})$, 620 kev, $I = 2^-, 3^-$; $(f_{5/2}d_{3/2})$, 970 kev, $I = 1^-, 2^-, 3^-, 4^-$. The problem is to determine the forces that split the levels belonging to individual multiplets. Such forces may be: 1) interaction with the surface of the nucleus, and 2) weak paired interaction of the neutron and proton holes, located in different shells. The interaction with the surface was computed in the weak-coupling approximation.[2] It was found significant that regardless of the choice of parameters, the interaction with the surface does not split the doublet levels, but shifts them as a whole. The magnitude of this shift is a function of the energy $\hbar\omega$ of the first vibration level and of the "hardness" C of the $Tl^{206}$ nucleus. Calculation has shown that as C changes from 1000 to 1500 Mev, and as $\hbar\omega$ changes from 1 to 3 Mev, the relative distances between the doublets do not change substantially.