PHOTOPRODUCTION OF LOW ENERGY CHARGED PIONS FROM COMPLEX NUCLEI

V. M. POPOVA, N. G. SEMASHKO, and F. R. YAGUDINA

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor November 21, 1958

J. Exptl. Theoret. Phys. (U.S.S.R.) **36**, 1357-1359 (May, 1959)

The yields of charged photomesons with energies from 0 to 3 Mev at an angle of 90° to a photon beam were investigated for Be, C, Al and Cu nuclei. The maximum photon energy was 265 Mev. The dependence on the negative π-meson yield and the ratio of the positive versus negative π yield on the atomic number were found. Comparison of the experimental data with the physical calculations of Baldin and Lebedev[8] gave the result that the mesons are formed from the nucleons on the nuclear surface.

It is known that the experimentally-observed dependence of the yield of fast charged π mesons on the atomic number is described by the $A^{2/3}$ law. (references 1 — 3). This character of the dependence can be explained by the fact that the creation of mesons comes from only the nucleons on the nuclear surface and that the creation of mesons inside the nucleus is strongly suppressed. However, there exists another point of view, according to which the creation takes place in the whole volume of the nucleus, but the mesons formed by the inner nucleons are absorbed on passing through the nucleus. The truth of the last model can be tested by investigating the yield of mesons whose mean free path in the nuclear matter exceeds the dimensions of the nucleus. The yield of such mesons should be proportional to the number of nucleons involved in their creation. However, recently published experimental results on the photoproduction of 12 Mev positive mesons by various nuclei[4] did not give a unique solution to this problem, even though it was found that the meson yield was proportional to $A^{2/3}$. The authors calculate that such a dependence can be got from the results of the Coulomb field on the yield of mesons created in all the nucleons of the nucleus.

In the present work we investigate the yield of positive and negative photomesons with energies from 0 to 3 Mev for an angle of 90° ± 20° to the direction of the photons in the laboratory system. The work was carried out on the Academy of Science Physics Institute synchrotron with maximum photon energies of 265 Mev.

The gamma-ray beam was collimated by a lead block with a rectangular aperture 3 × 21 mm and was purified of charged particles by a magnetic field of 7000 oersteds. For targets we used thin foils of the following elements: Be — 0.0659 g/cm^2, C — 0.0446 g/cm^2, Al — 0.0377 g/cm^2, and Cu — 0.141 g/cm^2. The average angle for multiple Coulomb scattering in targets of these thicknesses did not exceed 5°; the energy losses were 0.1 Mev for 3-Mev mesons. The targets were strengthened by thin caprone filaments (diameter 0.0015 mm) located outside of the beam.

The mesons were detected by photographic plates, NIKFI type K, with emulsion thickness 400 μ. During irradiation, the target and plates were placed in a vacuum chamber whose front wall lay in a magnetic field. Lead and graphite shields guarded the chamber from background effects.

The main outline of the experimental setup is given in Fig. 1.

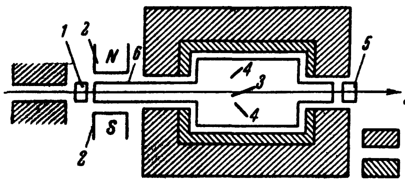

FIG. 1. Schematic diagram of the experimental setup. 1, 5 – ionization chambers, 2 – magnet, 3 – target, 4 – photographic plates, 6 – vacuum chamber.

The plates were examined twice. The effectiveness of the double examination was 96 — 98%. In the scanning, the tracks of π's were chosen which ended in stars (negative π mesons) and in π-μ decays (positive mesons).

The distribution of stars according to the number of prongs corresponded well with the distribution known from other work. Consequently, one can take as rather securely determined the number of negative mesons accompanying visible stars. To determine the entire number of π^- mesons one has to take into account the cases in which the capture of a meson by an emulsion nucleus is not accompanied by star formation. The probability of observing such cases would be greatly lowered by the strong proton background, but its contribution to the total number of disintegrations depending on π^- mesons is well known and amounts to 27%.[5] The quantity of π^+ mesons was determined by introducing geometrical corrections to the number of observed π-μ decays. The π energy was measured by its residual range in the emulsion. The error in the energy measurement did not exceed 3%.

In calculating the cross section for meson formation on nucleons, no account was taken of charge-exchange and inelastic effects in the scattering of mesons by the nucleons of the nucleus. As shown in references 6 and 7, these effects are rather small for small angles.

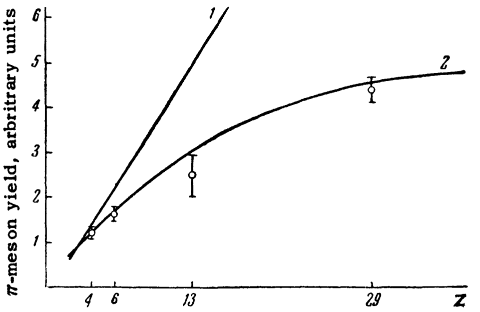

FIG. 2. Dependence of the output of negative mesons on the atomic number. Solid curves are calculated: 1 – for meson creation on all the nucleons in the nucleus, 2 – for nucleons of the surface layer of the nucleus. Statistical errors are shown.

The cross sections for the photoproduction of negative mesons are shown in Fig. 2. For comparison, the theoretical curves for 2-Mev mesons from the work of Baldin and Lebedev[8] are given. Curve 2 corresponds to meson production on nucleons of the outer layer of the nucleus, curve 1 to production throughout the nuclear volume. Both curves were calculated to take into account the interactions of the outgoing mesons with the nuclear and Coulomb fields of the nucleus. As seen on Fig. 2, the experimental points lie well on curve 2, thus confirming the model according to which meson creation inside the nucleus is strongly suppressed. Attention should be called to the absence of maxima for nuclei with excess neutrons, in contrast to previous work[2] in which the dependence of 65 Mev meson output on atomic number was investigated.

Figure 3 shows the ratio of the output of positive and negative mesons as a function of atomic

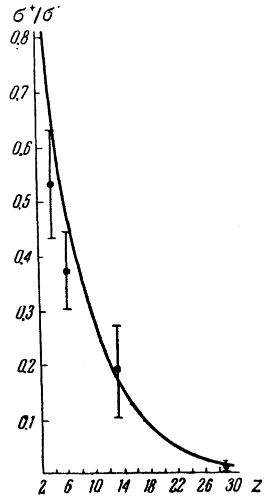

FIG. 3. Dependence of the ratio of outgoing π^+ and π^- mesons on the atomic number. Curve calculated by Baldin and Lebedev.

number. For our energies, the π^+ to π^- ratio decreased with increasing A. This effect can be explained by the interaction of the outgoing mesons with the Coulomb field of the nucleus, which for slow mesons leads to a big difference in the output of mesons of different signs. This interaction was studied by Baldin and Lebedev (private communication); the experimental points agree with their curve.

In ending, we must express our thanks to V. I. Veksler for guiding the work, and also to A. M. Baldin and A. I. Lebedev for reviewing the results.

[1] R. M. Mozley, Phys. Rev. **80**, 493 (1950).

[2] R. M. Littauer and D. Walker, Phys. Rev. **86**, 838 (1952).

[3] Williams, Crowe, and Friedman, Phys. Rev. **105**, 1940 (1957).

[4] Imhof, Knapp, Easterday, and Perez-Mendez, Phys. Rev. **108**, 1040 (1957).

[5] Menon, Muirhead, and Rochat, Phil. Mag. **41**, 583 (1950).

[6] É. G. Gorzhevskaya and N. M. Panova, Dokl. Akad. Nauk SSSR **111**, 1205 (1956), Soviet Phys. "Doklady" **1**, 757 (1956).

[7] Belousov, Rysakov, and Tamm, J. Exptl. Theoret. Phys. (U.S.S.R.) **35**, 355 (1958), Soviet Phys. JETP **8**, 247 (1959).

[8] A. M. Baldin and A. I. Lebedev, J. Exptl. Theoret. Phys. (U.S.S.R.) **33**, 1221 (1957); Soviet Phys. JETP **6**, 940 (1958).

Translated by W. Ramsay
268