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Abstract

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PHOTOPRODUCTION OF π^0 MESONS ON COMPLEX NUCLEI

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The study of the photoproduction of π^0 mesons on nuclei at different γ-ray energies can provide information as to whether mesons are produced throughout the entire volume of the nucleus or only on its surface.

In experiments on the study of the photoproduction of π^0 mesons ([1]), as well as of charged π mesons ([2]), on nuclei under the action of bremsstrahlung with a maximum energy of 320 MeV, it was shown that in both cases the cross section for the production of photomesons per nucleus increases in proportion to $A^{2/3}$, where A is the atomic number of the nucleus. This result was explained by the reabsorption of mesons produced inside nuclei, as a result of which only the nuclear surface, proportional to $A^{2/3}$, proves effective with respect to meson production.

Measurement of the cross sections for the interaction of charged mesons with nuclei ([3]) showed that the mean free path of a meson in nuclear matter depends strongly on the meson energy, increasing as its energy decreases. In experiments ([1]) and ([2]), mesons with energies from 60 to 100 MeV were recorded; for these, the cross section for interaction with nuclei is equal to the geometrical cross section. If, however, mesons with energies below 20 MeV are recorded, for which nuclei should be transparent to a considerable degree, then we should obtain a dependence of the π-meson yield on the atomic number A approaching a linear one ($\sigma \sim A$ instead of $A^{2/3}$), provided that meson production occurs throughout the entire volume of the nucleus. In the case where meson production occurs only on the nuclear surface, changing the energy spectrum of the recorded mesons should not change the character of the dependence of the meson yield per nucleus on the atomic number.

The energy spectrum of π^0 mesons can be changed by varying the energy of the γ rays under whose action these mesons are produced.

The experimental arrangement is shown in Fig. 1. The measurements were carried out at the synchrotron of the Physics Institute of the Academy of Sciences of the USSR. After collimation, the synchrotron γ-ray beam fell on the target under study. The target thickness was chosen to be of the order of 0.1 radiation unit, in order to ensure identical attenuation of the γ rays in all samples. The

Fig. 1. Experimental arrangement: M. k. –monitor ionization chamber, Sc –scintillators, P. m. –photomultipliers, C –C absorber 7 cm, Al –Al absorber 1 cm, K –Pb converter 5 mm

Figure 1: Fig. 1. Experimental arrangement: M. k. –monitor ionization chamber, Sc –scintillators, P. m. –photomultipliers, C –C absorber 7 cm, Al –Al absorber 1 cm, K –Pb converter 5 mm

Fig. 2

Figure 2: Fig. 2

samples were mounted in a special device that made it possible to change the targets remotely.

The γ quanta from the decay of π^0 mesons were recorded by a telescope of scintillation counters placed at an angle of 90° to the synchrotron beam. The telescope consisted of four counters, one connected in an anticoincidence circuit and three in a coincidence circuit. In front of the anticoincidence counter a carbon block 7 cm thick was placed, which absorbed γ quanta and charged particles of low energies. Between the anticoincidence and coincidence counters a lead converter 5 mm thick was placed. Aluminum absorbers, each 1 cm thick, were inserted between the coincidence counters; as a result, the energy threshold of the telescope was approximately 35 MeV. Liquid scintillators were used in all counters (a solution of terphenyl in xylene

5 g/l). The dimensions of the scintillators were $5 \times 5 \times 3$ cm. The scintillations were recorded by FEU-19 photomultipliers. The pulses from the photomultiplier outputs were shaped and fed to a coincidence circuit with a resolving time $\tau = 2 \cdot 10^{-8}$ sec.

Fig. 1. Experimental arrangement: $M. k.$ –monitor ionization chamber, Sc –scintillators, $P. m.$ –photomultipliers, C –C absorber 7 cm, Al –Al absorber 1 cm, K –Pb converter 5 mm

Measurements of the dependence of the yield of π^0-mesons on atomic number were carried out at values of E_γ^m, the maximum energy of the bremsstrahlung beam, of 265 and 200 MeV.

To reduce the background of random coincidences, the telescope was surrounded by lead shielding; in addition, the duration of the synchrotron γ-ray pulse was stretched from 3000 μsec at an energy of 265 MeV to 1000 μsec at 200 MeV.

The intensity of the synchrotron beam was measured by a thin-walled ionization chamber placed in the beam.

Measurements at an energy of 265 MeV were carried out with Li, C, Al, Cu, Cd, and Pb targets, and at an energy of 200 MeV with the same targets, except for Li.

Fig. 2

The results of the measurements are given in Fig. 2. In the first case ($E_\gamma^m = 265$ MeV) all points coincide with the curve corresponding to the dependence $\sigma \sim A^{2/3}$, within the accuracy of the measurements, which in this case was 3%. At $E_\gamma^m = 200$ MeV the law $\sigma \sim A^{2/3}$ remains valid within an error of 10%, with the exception of the point corresponding to Pb, which lies above the curve. Such a deviation may be due to the contribution from Thomson scattering of γ-rays on nuclei, whose cross section depends strongly on the atomic number of the target material.

The same reason made it impossible to measure the cross section for photoproduction of π^0-mesons on nuclei at γ-ray energies close to the meson photoproduction threshold by the method of registering mesons through one decay γ-quantum.

The results obtained show that the character of the dependence of the cross section for the formation of π^0-mesons on nuclei on atomic number remains

unchanged at E_γ^m, equal to 310 MeV [1], 265 MeV, and 200 MeV, despite the fact that in this case the maximum of the energy spectrum of π^0-mesons shifts from 100 to 20 MeV.

The results obtained cannot be explained by the reabsorption of π^0-mesons produced inside nuclei, since a change in the energy of the mesons should be accompanied by a change in their mean free path in nuclear matter. The fact that the character of the dependence of the cross section for photoproduction of π^0-mesons on atomic number does not change when the energy spectrum of the produced mesons changes in the interval from 100 to 20 MeV may be due to the presence of a competing process that suppresses the production of mesons inside nuclei and leads to surface production of mesons.

In conclusion, we take this opportunity to express our gratitude to Corresponding Member of the Academy of Sciences of the USSR V. I. Veksler and to Prof. P. A. Cherenkov for their attention to this work, to S. Grebenshchikov for assistance in constructing the apparatus, to S. Rusakov for assistance in carrying out the measurements, and also to the members of the accelerator operation group for ensuring the operation of the synchrotron.

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