are 1.2 ± 0.05 for the energy interval 24 - 30 MeV and 1.0 ± 0.03 for 24 - 52 MeV.

We can draw the following conclusion: The ratios of the (γ, p) and (γ, n) reaction cross section obtained by us as well as by Gorbunov and by Dodge and Murphy differ insignificantly from unity, a fact that can be attributed, according to Londergan and Shakin [7], to a number of factors not connected with violation of the charge symmetry of the nuclear forces.

The authors are indebted to A.I. Gorbunov and V.N. Gur'ev for useful discussions.

[1] B.L. Berman, S.C. Fultz and M.A. Kelly, Phys. Rev. 4, 723 (1971).
[2] B.L. Berman, F.W.K. Firk, and C.P. Wu, Nucl. Phys. A179, 791 (1972).
[3] A.N. Gorbunov, Doctoral dissertation, Physics Institute, USSR Academy of Sciences, 1969.
[4] W.E. Meyerhof, M. Suffert, and W. Feldman, Nucl. Phys. A148, 211 (1970).
[5] Yu.M. Arkatov, P.I. Vatset, V.I. Voloshchuk, ZhETF Pis. Red. 9, 462 (1969) [Sov. Phys.-JETP Lett. 9, 278 (1969)]; Yad. Fiz. 13, 256 (1971) [Sov. J. Nucl. Phys. 13, 142 (1971)].
[6] F.C. Barker and A.K. Mann, Phil. Mag. 2, 5 (1957).
[7] I.T. Londergan and C.M. Shakin, Phys. Rev. Lett. 28, 1729 (1972).
[8] W.K. Dodge and I.I. Murphy, Phys. Rev. Lett. 28, 842 (1972).

EXPERIMENTAL INVESTIGATION OF THE MECHANISM OF THE (π^-, π^-p) REACTION ON Al^{27} AT SMALL MOMENTUM TRANSFERS TO THE NUCLEUS

Yu.D. Bayukov, L.S. Vorob'ev, V.M. Kolybasov, G.A. Leksin, V.L. Smolin, and V.B. Fedorov
Institute of Theoretical and Experimental Physics,
Submitted 26 February 1973
ZhETF Pis. Red. 17, No. 7, 359 - 362 (5 April 1973)

Continuing our cycle of studies of the mechanism of proton knock-out from nuclei by π^- mesons with momentum 1 GeV/c [1 - 4], we have measured the characteristics of the reaction

$$\pi^- + Al^{27} \to \pi^- + p + Mg^{26*} \qquad (1)$$

at momentum transfers $q \lesssim \sqrt{2M\varepsilon}$, where ε is the proton binding energy in the nucleus and M is the reduced mass of the proton and of the remainder of the nucleus. The formulation of the problem and the apparatus are perfectly analogous to those described earlier [1]. The resolution attained in the earlier experiments ($\Delta\varepsilon_{exc} \simeq \pm 20$ MeV, $\Delta q \simeq \pm 10$ MeV/c), which did not make it possible to separate the levels of the nuclear remainder from the excitation energy spectrum, dictated the choice of the investigated nucleus. The previously investigated (π^-, π^-p) reaction on Li^6 and C^{12} led to formation of a residual nucleus in the ground state and in low excited states. It would be of interest to determine whether the mechanism of the reaction is altered if the nucleus is produced only in excited states. The choice of Al^{27} was governed by the fact, seen from work on inelastic knockout of protons, i.e., from the study of the reaction (p, 2p) on Al^{27}, that the ground state of the residual nucleus Mg^{26} remains practically unexcited. The experimentally measured [5] peaks have the following positions on the excitation-energy scale: $\varepsilon_{exc} \sim 5.8$ MeV ($\ell = 0$) with width 5.5 MeV and $\varepsilon_{exc} \sim 11.3$ MeV ($\ell \neq 0$) with width 9 MeV. The excitation-energy spectrum obtained in the present study for the residual nucleus Mg^{26*} agrees with the data of [5 - 6].

By performing the experiment in a non-complanar geometry we were able to obtain the momentum distribution of the residual nucleus, and also the distribution with respect to the Treiman-Yang angle and with respect to the polar emission angle of the nucleus for different ranges of q. It is these distributions, with allowance for the geometrical efficiency of the aparatus, which are the most sensitive to the reaction mechanism [2 - 3] discussed below.

Figure 1a shows the distribution of the number of events with respect to the momentum q of the residual nucleus. Figure 1b shows also the distribution divided by the phase volume. The solid curve is the result of calculation in accordance with the pole diagram with allowance for the knock-out of s and p protons. We used in the calculations the Butler form factor and assumed variation of the radii and of the intensities of both channels. We see that agreement between calculation of experiment is observed in the region $q < 120$ MeV/c, at the chosen channel radii 4F.

Figures 2 and 3 show the distributions with respect to the polar angle of the recoil nucleus and with respect to the Treiman-Yang angle for the regions $0 < q < 120$ MeV/c and $120 < q < 170$ MeV/c. The solid curves in Fig. 2 are the results of a calculation in the pole approximation for two chosen regions of q. The distribution with respect to the Treiman-Yang angle, shown for the indicated regions of q in Fig. 3, is compared with the isotropic distribution. We

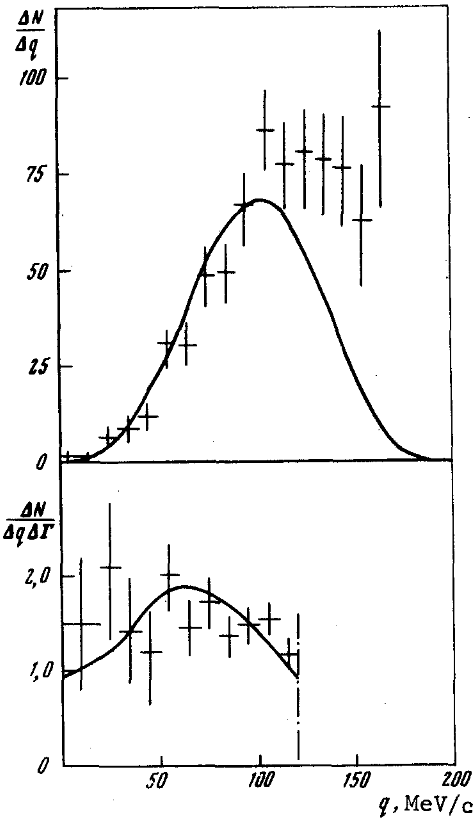

Fig. 1

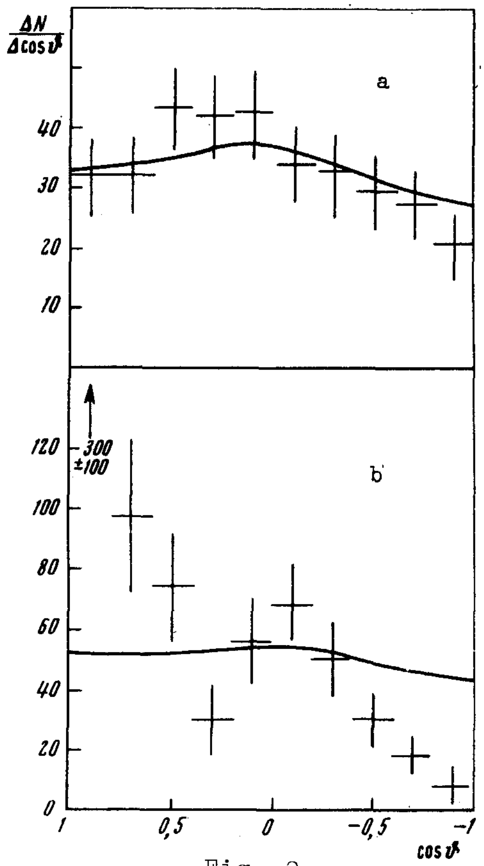

Fig. 2

Fig. 1. a) Distribution with respect to the momentum of the residual nucleus, b) The same divided by the phase volume.

Fig. 2. Distribution with respect to the cosine of the polar angle of the recoil nucleus: a) $0 < q < 120$ MeV/c, b) $120 < q < 170$ MeV/c.

see that there is a good agreement between the predictions of the pole mechanism experiment in the region $q < 120$ MeV/c for both distributions in Figs. 2 and 3. The results obtained for the nucleus with an average weight (Al^{27}) confirm the previous conclusions drawn from experiments on the nuclei Li^6 and C^{12}, namely that the pole diagram makes the decisive contribution at small q. With increasing q, the contributions of other diagrams become important.

Since the transition is to an excited state of Mg^{26*}, it can be assumed that the mechanism of the (π^-p) reaction does not depend on the state of the residual nucleus. The analysis of the presented distributions with respect to the polar nucleus-emission angle and the Treiman-Yang angle, and comparison with the previously obtained distributions on the nuclei C^{12} and Li^6 in the region of large q, shows that the character of the deviation from the pole approximation is also independent, in the main, of the choice of the target nucleus.

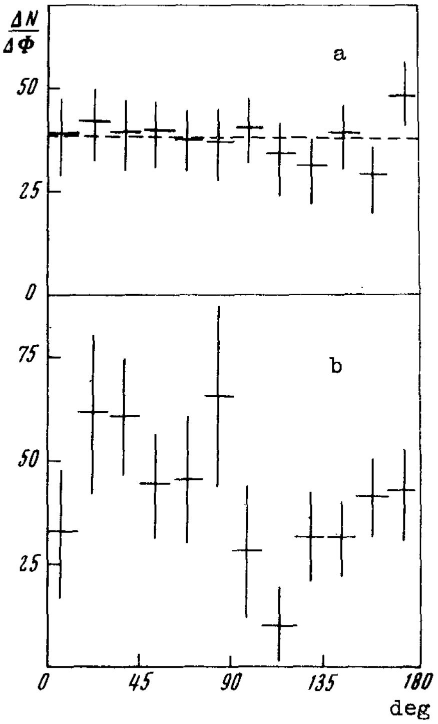

Fig. 3. Distribution with respect to the Treiman-Yang angle: a) $0 < q < 120$ MeV/c, b) $120 < q < 170$ MeV/c.

[1] A.O. Aganyants, Yu.D. Bayukov, et al., Phys. Lett. 27B, 590 (1968); Nucl. Phys. B11, 79 (1969).
[2] Yu.D. Bayukov, V.B. Fedorov, et al., Phys. Lett. 33B, 416 (1970).
[3] Yu.D. Bayukov and L.S. Vorob'ev et al., in: Problemy sovremennoi yadernoi fiziki (Problems of Modern Nuclear Physics), Nauka, 1971, p. 410.
[4] G.A. Leksin, Review Paper at the Fourth International Conference on High-energy Physics and Nuclear Structure (Dubna, September 1971).
[5] G. Tibell, O. Sundberg, and P.U. Remberg, Ark. Fys. 25, 433 (1963).
[6] H. Tyren, S. Kullander, O. Sundberg, et al., Nucl. Phys. 79, 321 (1966).

ANOMALY OF THE (n, n'f) REACTION THRESHOLD

B.I. Fursov, V.M. Kuprianov, and G.N. Smirenkin
Submitted 26 February 1973
ZhETF Pis. Red. 17, No. 7, 362 - 366 (5 April 1973)

We investigated experimentally the dependence of the fission cross sections of U^{238}, Pu^{239}, Pu^{240}, and Pu^{242} on the neutron energy E_n in the range $E_n = 1.5 - 7.5$ MeV, and the dependence of the angular anisotropy of the fission of Pu^{240} and Pu^{242} on E_n at $E_n = 4.0 - 5.5$ MeV. We have observed that the reaction (n, n'f) has a noticeable probability appreciably below the threshold energy value known from the data on the fission cross sections in the (n, f) reaction. The effect increases with increasing charge of the fissioning nucleus. The investigated "anomaly" is interpreted within the framework of the two-hump barrier model as (n, n'f) reaction with emission of neutrons in the second well.