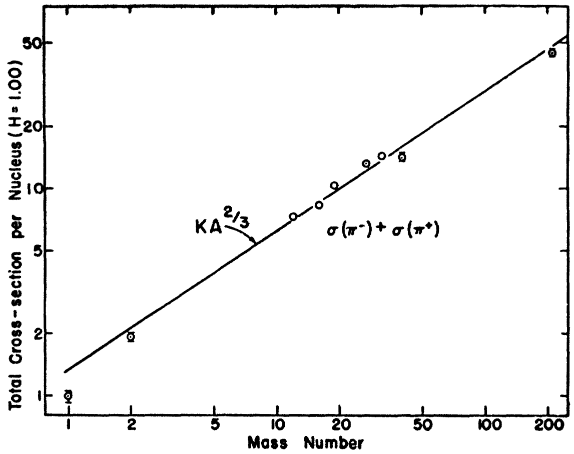

FIG. 2. Sum of π^- and π^+ cross sections per nucleus.

closely, i.e., $\sigma_{\text{total}}\sim$surface area of the nucleus. This would be the expected law if mesons created below the surface had a small escape probability.[3]

The results exhibit some interesting features. (1) For the symmetrical nuclei D, C, O, S, and Ca, the π^-/π^+ ratio, which is 1.19±0.12 for D, shows a steady decrease with increasing A, reaching the value 0.58±0.06 for Ca. Unfortunately no stable symmetrical nuclei exist in nature above the magic Ca^{40}. (2) The nuclei Be^9, F^{19}, and Al^{27}, each with an unpaired neutron, have π^-/π^+ ratios lying considerably above the curve for symmetrical nuclei. If we assume that this enhanced ratio is due entirely to the production of π^- from the unpaired neutron, we can calculate the cross section for this neutron in terms of the cross section for one of the paired neutrons in the nucleus. The ratios obtained are 4.6±0.5, 3.8±0.5, and 3.9±0.7 for Be^9, F^{19}, and Al^{27}, respectively. Clearly, under this quite arbitrary assumption, the unpaired neutrons in all three nuclei would make roughly the same large contribution. However, it is interesting to note that the heavy nucleus Bi^{209}, which contains 50 percent excess neutrons, has a π^-/π^+ ratio of only 1.32±0.12.

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[1] McMillan, Peterson, and White, Science **110**, 579 (1949); J. Steinberger and A. S. Bishop, Phys. Rev. **78**, 494 (1950); Peterson, Gilbert, and White, Phys. Rev. **81**, 1003 (1951).

[2] Camac, Corson, Littauer, Shapiro, Silverman, Wilson, and Woodward, Phys. Rev. **82**, 745 (1951).

[3] R. F. Mozley, Phys. Rev. **80**, 493 (1950).

Ratio of Negative to Positive π-Mesons in the Stratosphere*

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SINGLE stacks of 12 electron sensitive NTB-3 plates were exposed in the stratosphere by means of meteorological balloons at altitudes near 60,000 feet. On the average a total of 500 grams of material, consisting mainly of Al, glass, and paper was in the immediate vicinity of the plates. The plates weighed an additional 100 grams. They were searched for meson tracks which stopped in the emulsion. Incidental to a study of low energy electrons from μ-mesons,[1] the number of meson induced stars and the number of π-μ-decays were noted. A total of 118 meson stars and 41 π-μ-decays were found in the same plates, along with 500 mesons which stopped in the emulsion without associated particles other than electrons. It has been shown that essentially all of the negative π-mesons which stop in photographic emulsions are captured and do not decay,[2] while essentially all of the positive π-mesons which stop in photographic emulsions decay into μ-mesons.[3] It is known that 27 percent of the negative π-mesons which stop in photographic emulsions do not produce stars.[4] Recent studies[5] indicate that 8.7±1.7 percent of the negative μ-mesons cause stars in photographic emulsions. Nearly all of these stars are one prong stars. This conclusion is further substantiated by a comparison of the prong distribution of the 118 meson stars with the known prong distribution of stars produced by negative π-mesons.[4] Correcting for the number of negative π-mesons which did not produce stars, 37±6 percent of the mesons produced one prong stars. Assuming that 8.7 percent of the negative μ-mesons produced one prong stars, then 26±6 percent of the negative π-mesons produced one prong stars which is in agreement with the results of Adelman and Jones[4] who found that 23.6 percent of the negative π-mesons which stopped in photographic emulsions produced one prong stars.

Of the 118 stars due to mesons, about $(500)(0.087)/2=22$ are caused by negative μ-mesons. The remaining 96 stars are presumably due to negative π-mesons. Correcting for the number of negative π-mesons which did not produce stars in the emulsion, the ratio of negative to positive low energy π-mesons would seem to be $(96)/(0.73)(41)=3.2\pm0.7$. This ratio is in agreement with similar measurements at lower altitudes. Bonetti[6] found 89 σ-stars and 45 π-μ-decays in plates exposed at 2800 meters. Barton, George, and Jason[7] found the ratio of negative to positive π-mesons to be 3.1±0.25 in plates exposed under carbon absorbers at 3457 meters. However, Barbour[8] found 87 σ-stars and 147 π-μ-decays in plates exposed in a magnetic field at altitudes of 70,000 and 90,000 feet.

Since the π-mesons traversed the glass backing of the outer plates, they must have been created with a kinetic energy greater than 6 Mev. Similarly, an estimate can be made of the maximum initial kinetic energy of the π-mesons which stopped in the emulsion, by assuming that they traversed the entire stack of plates. Since the lifetime of the π-mesons is very short, the energy lost in the air is small. Therefore nearly all of the π-mesons which stopped in the emulsions must have been generated with a kinetic energy in the interval from 6 to 50 Mev. It is to be expected that the probabilities of escaping from a nucleus would be about the same for negative or positive π-mesons if their energy were greater than the potential energy of the barrier. Assuming that p-p and p-n interactions are about equal, the relative numbers of negative and positive π-mesons should be determined essentially by the number of ways that mesons of either sign can be formed.[2] The excess of negative π-mesons indicates that a large portion of the low energy mesons ($6\text{ Mev}<E<50\text{ Mev}$) are produced at these altitudes by neutrons.

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[1] W. F. Fry, Phys. Rev. **79**, 893 (1950).

[2] H. Bradner, Univ. Calif. Rad. Report No. 486, 1949 (unpublished).

[3] F. M. Smith, Phys. Rev. **81**, 897 (1951).

[4] F. L. Adelman and S. B. Jones, Phys. Rev. **75**, 1468A (1949).

[5] E. P. George and J. Evans, Proc. Phys. Soc. (London) **64**, 193 (1951).

[6] A. Bonetti, private communication (1950).

[7] Barton, George, and Jason, Proc. Phys. Soc. (London) **64**, 175 (1951).

[8] I. Barbour, Phys. Rev. **78**, 518 (1950).

Angular Distribution of Photons in Showers in Lead*

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A STUDY of the angular distribution of photons in showers in lead has been carried out using the 322-Mev x-ray beam of the Berkeley synchrotron.[1] The experimental arrangement is shown in Fig. 1. The x-ray beam, collimated to ¼ inch, produced