to diffraction scattering. The scatterings less than 20° were ignored, since coulomb scattering and pi-mu decay falsify the results in this region. If the number of nuclear events is corrected to include the nuclear scatterings at angles less than 75°, assuming an isotropic distribution, the total is 21. This corresponds to an interaction cross section of (0.22±0.05)b. The geometrical cross section is 0.37b. In the angular range from 20°–75°, seven events were observed. This is reduced to five if one subtracts the expected number of nuclear scatterings and pi-mu decays in this region. The number to be expected in this angular interval from a "black" nucleus is 26. It seems clear that the carbon nucleus is partially transparent to mesons of energy between 20 Mev and 60 Mev. The data are consistent with a transparency of roughly 60 percent.

Aluminum Results:—1323 traversals of $\frac{1}{8}$-in. aluminum plates yielded the following results:

		Scatterings	
Stars	(>50°)	(20°–50°)	(10°–20°)
6	5	4	10

Correcting the large angle scatterings as above, we obtain 12 nuclear events, corresponding to a cross section of (0.48±0.14)b. The geometrical cross section is 0.60b. The expected number of diffraction scatterings in the 20°–50° region for a "black" aluminum nucleus is 8, while the corrected observed number is 3. The data are consistent with a nuclear transparency of about 80 percent but do not exclude a "black" nucleus.

An additional result of the experiment, obtained by reversing the magnetic field of the analyzer, is the ratio of negative to positive mesons produced in several targets. For meson energies between 55 Mev and 70 Mev, this ratio is 1.12±0.07 for carbon and 2.40±0.20 for beryllium. The carbon result is in good agreement with the results of Peterson, Gilbert, and White.[2] It seems likely that the high ratio in beryllium is due to the extra neutron. The result depends on the decay time for pi$^+$ and pi$^-$ mesons being the same.

* This work was done under an ONR contract.
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Production of Photomesons*

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The beam of bremsstrahlung from the 300-Mev electron synchrotron was allowed to strike targets containing various elements in their natural isotopic compositions. Charged mesons[1] emitted at 135°, and of energies about 50 Mev, were selected by a double-focusing system of magnets (see the preceding letter),[2] and detected in an array of coincidence counters. Cloud-chamber evidence[2] as well as rough absorption measurements indicated that the contamination of the meson beam by electrons, if any, was extremely small. A small percentage of μ-mesons was observed, but since these represent decay products of the π-mesons they do not falsify the present results, unless the decay characteristics of the positive and negative π-mesons are not identical. In the latter case a systematic error could be present in the measured π^-/π^+ ratios, since the time of flight of the mesons through the apparatus is about $\frac{1}{2}$ the mean life. The densities of the targets (except Be) were so adjusted that they had equal stopping powers for mesons. All counting rates were normalized to unit gamma-ray flux and corrected for gamma-ray absorption in the thickness of the target.

The elements so far examined are: ${}_1H^1$ (99.98 percent) in H_2O and in hydrocarbon mixtures of suitable density and known composition; ${}_1D^2$ (>99.8 percent) in D_2O; ${}_4Be^9$ (100 percent); ${}_6C^{12}$ (98.9 percent); ${}_8O^{16}$ (99.8 percent) in H_2O; ${}_9F^{19}$ (100 percent) in $(CF_2)_n$; ${}_{13}Al^{27}$ (100 percent); ${}_{16}S^{32}$ (96 percent); ${}_{20}Ca^{40}$ (96.8 percent) in CaF_2; and ${}_{83}Bi^{209}$ (100 percent).

Assuming that the photoproduction of mesons takes place according to the reactions

$$p+\gamma\rightarrow n+\pi^+$$

and

$$n+\gamma\rightarrow p+\pi^-,$$

we have calculated the production cross sections *per relevant nucleon* for each of the above elements. The results are displayed in Fig. 1, where the cross sections have been normalized arbitrarily

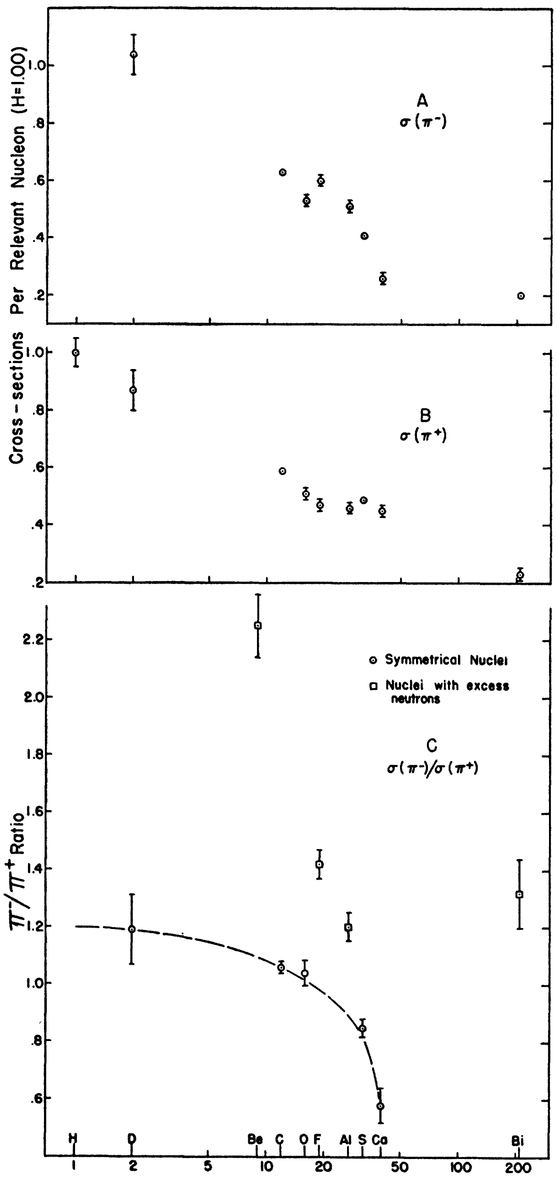

FIG. 1. A: π^- cross section per neutron; B: π^+ cross section per proton; C: π^-/π^+ ratio for the whole nucleus. Meson energy ~50 Mev, angle of emission (lab. system) = 135°. Errors are statistical standard deviations.

to $\sigma_{\pi^+}(H)=1.00$. On this scale, the π^- cross section for H is 0.04±0.05. The π^- and π^+ cross sections of D do not differ very significantly from the π^+ cross section of H. Figure 1(c) shows the π^-/π^+ ratio for each *nucleus*. The sum of the π^- and π^+ cross sections *per nucleus* has been plotted logarithmically against mass number in Fig. 2; the points from D to Bi follow an $A^{\frac{2}{3}}$ law fairly

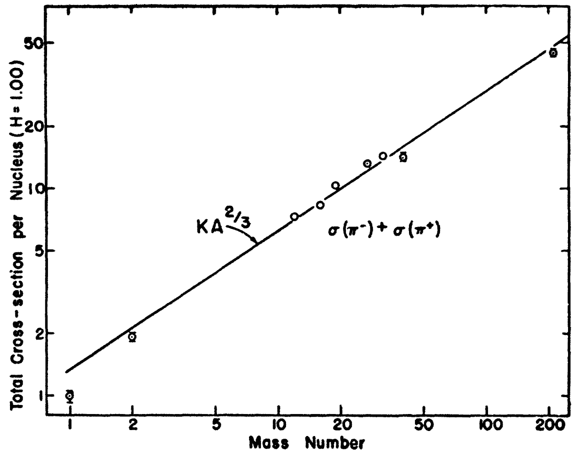

FIG. 2. Sum of π^- and π^+ cross sections per nucleus.

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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* This work performed under contract with the ONR.
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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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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 ½ inch, produced