Letters to the Editor

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Interaction of Pi-Mesons with Carbon and Aluminum Nuclei

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THE experimental arrangemeut used for the production and observation of pi-mesons is shown in Fig. 1. The target T is exposed to 310-Mev bremsstrahlung radiation. Mesons produced

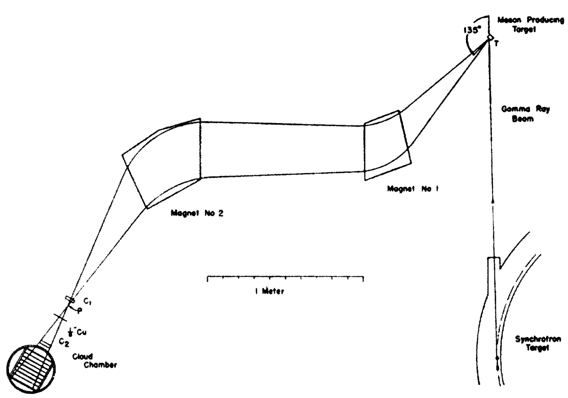

FIG. 1. Experimental arrangement of magnets and detectors.

in the target enter the double-focusing magnetic analyzer,[1] after which they are detected by a coincidence between Geiger counters C_1 and C_2 which triggers a 12-in. cloud chamber. The focusing properties of the magnets were investigated with a current carrying wire, and the magnetic fields were adjusted so that 60-Mev mesons were focused at point P.

The cloud chamber has provision for mounting nine absorber plates. To investigate the nature of the particles entering the cloud chamber, preliminary experiments were done with $\frac{1}{8}$-in. copper plates placed in the chamber. The range distribution of 91 particles is shown in Fig. 2. It is seen that approximately 80 percent of the particles have ranges between 15 g/cm^2 and 23 g/cm^2 corresponding to pi-meson energies between 55–70 Mev. The two tracks with ranges about 30 g/cm^2 are assumed to be mu-mesons. The tracks with ranges between 6 and 12 g/cm^2 are mesons which have undergone nuclear interactions. From the mean scattering angle of the particles in the copper and the absence of shower production, it is clear that the electron contamination is small. Of the 91 tracks observed, one was probably an electron.

The interaction of pi-mesons with carbon and aluminum was studied by mounting either carbon or aluminum plates in the cloud chamber. Light elements were chosen to minimize coulomb scattering and to increase the angular width of the diffraction scattering. The types of events observed were large angle scatterings, stars with 0, 1, and 2 prongs, and small angle scatterings. A large angle scattering is defined as being at an angle greater than

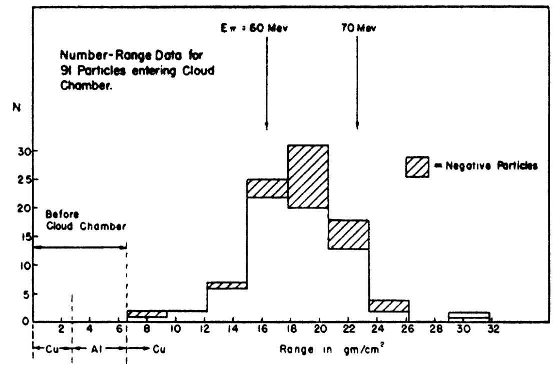

FIG. 2. Range distribution among 90 particles entering the cloud chamber containing $\frac{1}{8}$-in. Cu plates.

the first zero of the diffraction scattering distribution (75° in the case of carbon and 50° for aluminum). Figure 3 shows a picture of a large angle scattering and a star. There is some ambiguity in differentiating between large angle scatterings and one prong stars. However, these events are lumped together in the analysis of the data. Events which appeared to be scatterings of about 15° in the gas were also observed. These were almost certainly pi-mu decays.

Carbon Results:—In 4187 traversals of $\frac{1}{8}$-in. carbon plates, by approximately equal numbers of positive and negative mesons, the following events were observed:

	Scatterings		
Stars	(>75°)	(20°–75°)	(10°–20°)
17	3	7	21

The stars and large angle scatterings are assumed to be specific nuclear events. The scatterings from 20°–75° are assumed to be due

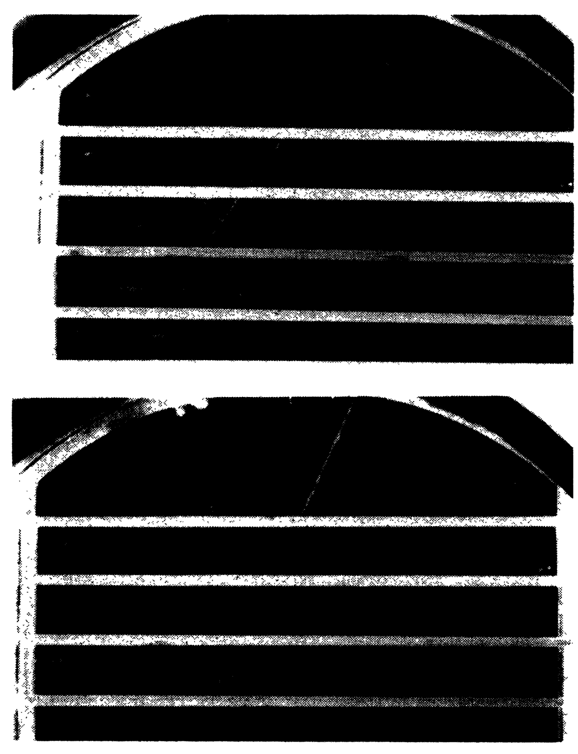

FIG. 3. A large angle scattering and a nuclear star produced by pi+ mesons in flight through $\frac{1}{8}$-in. Al plates.

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.
[1] M. Camac, Rev. Sci. Instr. 22, 197 (1951).
[2] Peterson, Gilbert, and White, Phys. Rev. 81, 1003 (1951).

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

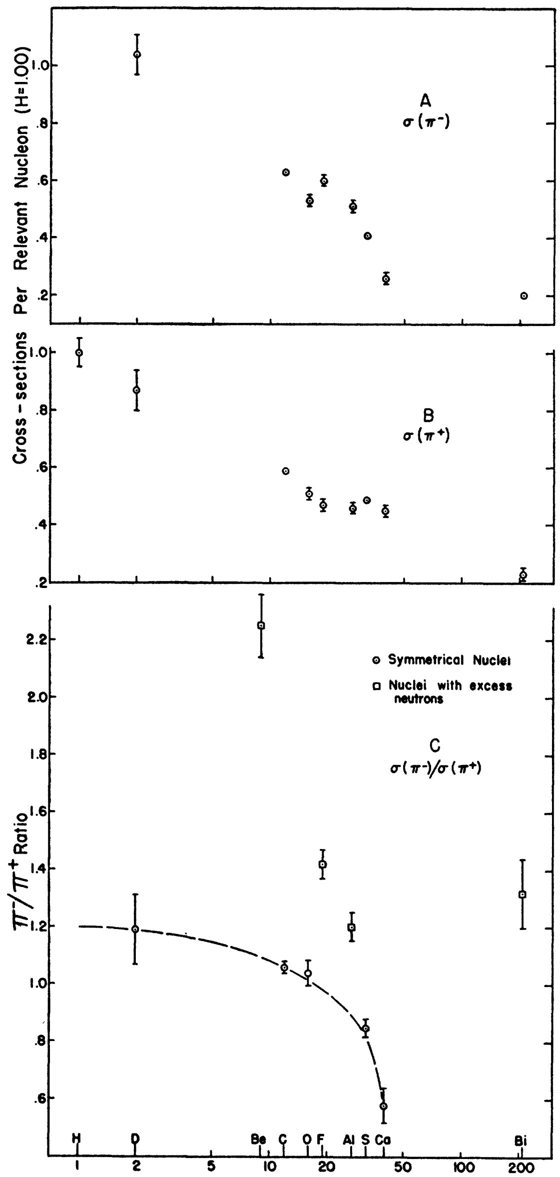

FIG. 1. A: π^- cross section per neutron; B: π^+ cross section per proton; C: π^-/π^+ ratio for the whole nucleus. Meson energy ~50 Mev, angle of emission (lab. system) = 135°. Errors are statistical standard deviations.

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

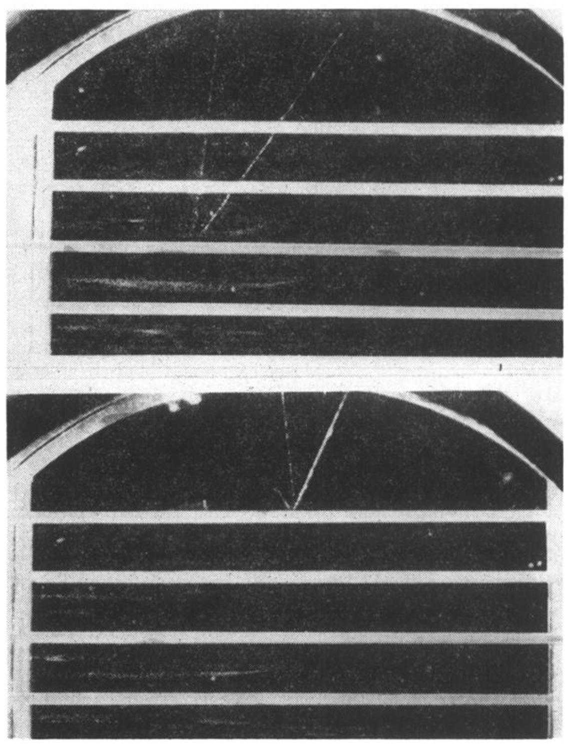

FIG. 3. A large angle scattering and a nuclear star produced by pi+ mesons in flight through ⅛-in. Al plates.