then one may expect a deviation from the energy dependence of the cross section as given by the usual one-level formula. For example, in the capture of s-wave neutrons and protons by C^{12}, deviations from this energy dependence of more than a factor of two are found which can be attributed to the extra-nuclear contribution to the electric dipole moment, as in the case of the capture of thermal neutrons by Li^7. This problem will be considered in detail in a paper which is in preparation.

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Search for Production of V^0 Particles by a 310-Mev Bremsstrahlung Beam

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A SEARCH has been made for the production of V^0-particles by 310-Mev bremsstrahlung radiation incident on carbon and lead. If, as the most recent evidence[1] seems to indicate, the products of the disintegration of the V^0-particles are three or more heavy particles (mesons or nucleons), production of V^0's by 310-Mev γ-rays is energetically impossible. If however the V^0-particles disintegrate according to the scheme: $V^0 \rightarrow$proton $+\pi^-$-meson$+Q$ (with $Q \cong 30$ Mev), as indicated by earlier experiments,[2] V^0-particles may be produced by 300-Mev γ-rays, the threshold for the process being at $\sim$190 Mev, in carbon.[3]

Assuming the two-particle disintegration with $Q=30$ Mev, one find that the energy of a V^0 produced in carbon by 300-Mev γ-rays at 90° to the beam direction lies between 65 and 110 Mev, depending on whether momentum is conserved via recoil of one nucleon or of the entire nucleus. Assume that a 65-Mev V^0 ($\beta=0.3$) is produced at 90° to the beam direction; in the laboratory system its path length before disintegration is $\simeq$1 cm ($\tau \simeq 10^{-10}$ sec).[4] The angle that the decay proton makes with the direction of the V^0-particle never exceeds 15°, and its energy lies between 30 Mev and 90 Mev. The meson, however, can be emitted in any direction with respect to the direction of the V^0, with energy from 5 Mev to 66 Mev. The most probable angle between the two decay products is approximately 60° and the corresponding energies are $E_p=58$ Mev and $E_\pi=37$ Mev.

The detection of the two disintegration products has been attempted with the arrangement sketched in Fig. 1 (a and b). A V^0-particle emitted at 90° to the γ-ray beam and disintegrating in the region Σ of Fig. 1(b) would give rise to a proton detected by the scintillating counter P, and a meson detected by the crystal counters a and b. The $\frac{3}{8}$-in. Pb-shield separating the carbon target from the counters served the purpose of absorbing most of the ionizing particles emitted by the target, thus lowering the background substantially, without affecting the V^0-particles very much. A particle produced in the target had to traverse an average path in lead of approximately 4 cm in order to reach counters a and b. The proton counter (NaI, 7.5 g cm^{-2} thick) was biased to detect protons of energies greater than 15 Mev. Counters a and b were biased to detect mesons of energies between 18 and 70 Mev. The coincidences $(P+b)$ were recorded with a resolving time of 2×10^{-8} sec and the threefold coincidences $[(P+b)+a]$ with a resolving time of 5×10^{-7} sec. Most of the chance coincidences were caused by events involving a real coincidence between a and b. With a beam of approximately 2×10^9 "Q"/min ("Q" effective quanta), as measured with an integrating ion chamber, the expected rate of chance coincidence $[(P+b)+a]$ was approximately 1/hr. Several runs have been made in which the angle between proton detector and meson detector was varied from 65° to 115°.

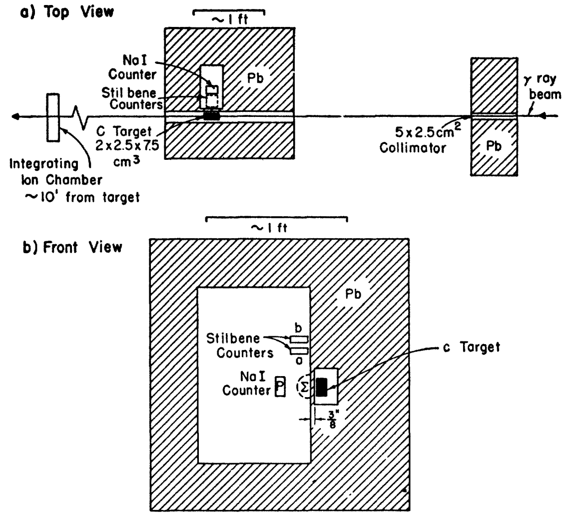

FIG. 1.

With an integrated beam of 9×10^{11} "Q", 9 coincidences were observed. The expected number of chance coincidences was 10. Assuming that all the observed coincidences are decay products of V^0-particles and that the life-time is 10^{-10} sec one can establish that the upper limit of the differential cross section per carbon nucleus for production of V^0-particles is 5×10^{-32} cm^2/sterad "Q". This is approximately 0.3 percent of the cross section for production of charged mesons in carbon.

The same experiment has been performed with lead as the target material, as well as with geometry appropriate to detect disintegration products of V^0-particles emitted at approximately 30° with respect to the γ-ray beam. The events recorded never exceeded the rate of chance coincidences. These negative results may be an additional evidence that the two-particle decay hypothesis is not correct.

We would like to express our thanks to Professor R. R. Wilson for many valuable discussions during the course of this work.

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Scintillations in Thallium-Activated CaI_2 and CsI*

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SEVERAL samples of polycrystalline thallium-activated CaI_2 have been prepared in this laboratory by adding 1 percent of TlI to the melt of CaI_2 in a helium atmosphere. It has been found that this material scintillates with a high luminous efficiency.

Measurements of pulse size and decay constant have been made on polycrystals and small crystal fragments as follows. Individual CaI_2(Tl) scintillations due to Co^{60} gamma-rays have been photographed on an oscilloscope screen and subsequently plotted and measured. An integrating RC load of time-constant 22 microseconds was used in all the measurements. This value of time constant is long enough to allow the $CaI_2(Tl)$ pulses to approach saturation. Under these conditions the decay constant $(1/e)$ for $CaI_2(Tl)$ has been measured as 1.1 ± 0.1 microsecond. A small correction has been included for the superimposed decay of the load circuit.[1] Under the same conditions the pulse heights of $CaI_2(Tl)$ and NaI(Tl) have been compared and are equal within the experimental error ($\sim$3 percent). Applying again the small corrections caused by the load circuit, the integrated light output for $CaI_2(Tl)$ is 10 percent larger than that of NaI(Tl). [Possibly a larger result might be obtained with a single crystal of $CaI_2(Tl)$.] This result has been obtained with both 5819 photomultiplier and with the ultraviolet sensitive (C7140) counterpart of this tube. A large fraction of the emitted light lies in the blue-green so that the output should be nearly the same in both tubes, as found. The large pulse size of $CaI_2(Tl)$ may possibly make this crystal useful in measurements of energies of gamma-rays.

With the same apparatus, Harshaw-supplied crystals of CsI(Tl)[2] have been examined. The integrated light output for CsI(Tl) is about 0.28 ± 0.03 that of NaI(Tl) as measured with a 5819 tube and 22-microsecond load circuit. The decay constant $(1/e)$ for CsI(Tl) is also 1.1 ± 0.1 microsecond. This value agrees with an earlier determination made by one of the authors and Mr. E. C. Booth at Princeton University.

We wish to thank the Harshaw Chemical Company for kindly supplying us with the CsI(Tl) sample.

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[1] Specifically we take the voltage curve to be $V=I_0R[\tau/(\tau_0-\tau)]\times(\exp(-t/\tau_0)-\exp(-t/\tau))$, where the scintillator light output is proportional to $I=I_0\exp(-t/\tau)$ and τ_0 = time constant of load circuit $=RC$.

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The Interaction of π-Mesons with Carbon Nuclei*

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IN an earlier experiment[1] an investigation of the interaction of positive and negative π-mesons with carbon and aluminum nuclei was begun. The work with carbon has now been considerably extended. The experimental arrangement used is very similar to that of the earlier experiment (see Fig. 1 of reference 1). π-mesons, produced in targets placed in the 310-Mev bremsstrahlung beam of the synchrotron, are focused by a double magnet system into a 12-inch cloud chamber containing 9 thin carbon plates. The mesons incident on the cloud chamber have an initial energy of 65 ± 5 Mev; their energy in the chamber is primarily between 35 and 60 Mev, averaging 48 Mev.

The pictures have been analyzed stereoscopically and only events and traversals occurring within a prescribed region have been counted. Deflections in a plate with no perceptible change of ionization (<10–15-Mev energy loss) have been classified as elastic scatterings. All other events—inelastic scatterings and 0-, 1-, 2-, and 3-prong stars—have been classified as nuclear interactions. The data are presented in Table I.

The elastic scatterings with angles <20° include a large number of undetected π-μ decays occurring in or near the plates. Twelve of the 17 events in this group are expected to be π-μ decays or coulomb scatterings. The remaining five events agree well with the number of scatterings expected from the calculated diffraction pattern, assuming that all elastic scatterings are diffraction scatterings.

TABLE I. The number of nuclear interactions, scatterings, and traversals observed.

	Nuclear interactions (stars and inel. scat.)	Elastic scatterings 10°–20°	20°–75°	>75°	No. of traversals of 0.520 g/cm² C plates
π^+	33	10	11	2	6133
π^-	20	7	8	0	3310
Total	53	17	19	2	9443

TABLE II. The corrected mean-free-paths and corresponding cross sections for nuclear interactions and elastic scatterings.

	Nuclear interactions (stars and inel. scat.) λ_{ni}, g/cm²	σ_{ni}, mb	Elastic scatterings (>20°) λ_{el}, g/cm²	σ_{el}, mb	Total diffraction scat. (>0°) λ_d, g/cm²	σ_d, mb
π^+	93 ± 16	214 ± 37	255 ± 75	78 ± 23	....	....
π^-	83 ± 19	240 ± 54	210 ± 75	96 ± 34	....	....
Total	89 ± 13	223 ± 32	237 ± 55	84 ± 19	175 ± 35	115 ± 25

One of the π^+ scatterings with angle >20° can be expected to be an undetected π-μ decay. The number of traversals must also be corrected for a 3 percent contamination[1] of the beam by μ-mesons and electrons. After making these corrections, the cross sections listed in Table II have been calculated. From the diffraction angular distribution, about 75 percent of the total number of diffraction scatterings are expected to occur with angles >20° and outside of the solid angle obscured by the carbon plate containing the event. Thus, the total diffraction cross section has been calculated on the basis of (21–1)/0.75 or 27 scatterings. The errors indicated are the statistical standard deviations.

These results agree with those of the previous experiment.[1] As we observed earlier,[2] the cross sections for π^+- and π^--mesons are equal within the present statistics. Contrary to the measurement of Steinberger and collaborators[3] with 85-Mev π^--mesons, we find the carbon nucleus considerably transparent (Table III). The difference may be a result of the energy dependence of the interactions.

From the opacity $(=\sigma_{ni}/\pi R^2)$ one can calculate the mean-free-path λ of π-mesons in nuclear matter and the corresponding cross section σ_i for interaction of a meson and a nucleon in the nucleus. This has been done for several values of the nuclear radius R (Table III) to indicate the variation of the various quantities with this uncertain parameter. The unusually large value of r_0 in column 4 has been included to indicate the possible effect of the meson's finite wavelength. From the transparent nucleus theory[4] as extended by Bethe and Wilson,[5] one can calculate the average potential in the nucleus V_0 and from this the total scattering cross section σ_s of a meson by a nucleon: $\sigma_s=0.735r_0^6V_0^2\mu b$, where r_0 is measured in units of 10^{-13} cm and V_0 in Mev. This calculation[5] assumes that the amplitudes for scattering a meson by a proton, a_P, and a neutron, a_N, are isotropic and equal in magnitude and sign.

For pseudoscalar mesons, the amplitudes would have the same sign for pseudoscalar coupling, and opposite signs for pseudovector coupling.[6] Anderson[7] has measured the total scattering cross section of 50-Mev mesons by protons: 11 ± 5 mb for π^- and 37 ± 8 mb for π^+-mesons. If a_P and a_N have the same sign, one would expect in carbon $\sigma_s\approx|\frac{1}{2}(37^{\frac{1}{2}}+11^{\frac{1}{2}})|^2=22\pm5$ mb, which disagrees considerably with our calculated σ_s. If they have opposite signs, $\sigma_s\approx|\frac{1}{2}(37^{\frac{1}{2}}-11^{\frac{1}{2}})|^2=1.9\pm1.4$ mb, which agrees very well. This indicates that a_P and a_N have opposite signs and that the coupling is probably pseudovector.

TABLE III. Nuclear and interaction parameters calculated from the observed σ_{ni} and σ_d.

$r_0=RA^{-\frac{1}{3}}$, $\times10^{13}$, cm	1.37	1.47	1.70
Opacity $=\sigma_{ni}/\pi R^2$	0.72 ± 0.10	0.63 ± 0.09	0.47 ± 0.07
λ, mean free path of meson in nuclear matter, $\times10^{13}$, cm	3.0 ± 1.0	4.3 ± 1.1	7.8 ± 1.6
σ_i, cross section for interaction of meson and nucleon in the nucleus, mb	36 ± 12	31 ± 8	27 ± 6
V_0, Mev	15 ± 15	15 ± 9	12 ± 5
σ_s, total scattering cross section of meson by nucleon, mb	$1.1^{+3.3}_{-1.1}$	$1.7^{+2.6}_{-1.5}$	$2.5^{+2.5}_{-1.6}$