We have determined the decay schemes with the aid of NaI(Tl) crystals and display them in Fig. 1. The measured gamma-ray

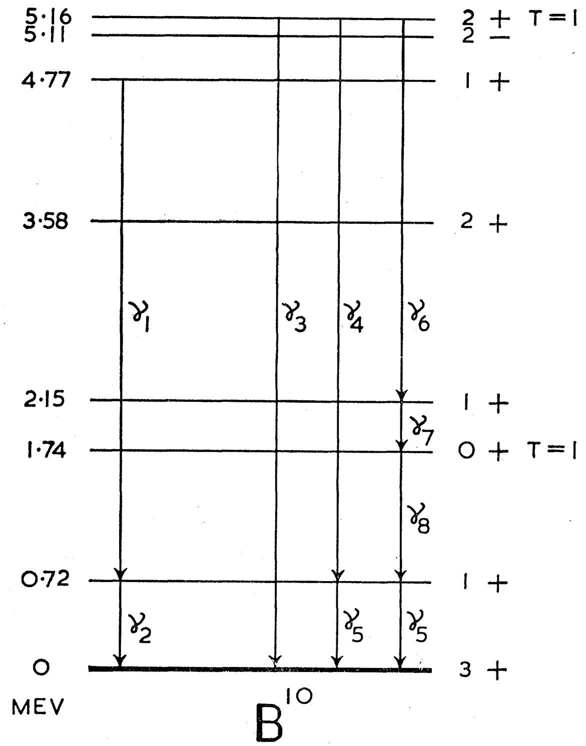

FIG. 1. Level scheme of B^{10} showing the gamma rays observed in the present investigation. The spin and parity assignments for the top three states are those suggested here; the rest are taken from Ajzenberg and Lauritsen (reference 1).

energies are shown in Table I where the "expected energies" are taken from the work of Bockelman *et al.*,[3] and Rasmussen *et al.*[5] (No corrections have been made for Doppler shift—our own observations were made in poor geometry at 0° to the alpha-particle beam.)

The relative intensities of the gamma rays coming from the 2.15-Mev level have been determined with the aid of the results of Rasmussen *et al.*,[5] Pruitt, Hanna, and Swartz,[6] and Ajzenberg.[2]

The 5.16-Mev state we believe to be the (2+) $T=1$ companion of the 3.37-Mev state of Be^{10};[4] its formation is not a serious violation of the isotopic spin rules. This assignment is supported by the observed decay scheme which is most reasonably explained by $J=2$ (though $J=1$ is not excluded); negative parity is unlikely because all our observed initial gamma rays would then be isotopic-spin forbidden $E1$ transitions, but with a discouragement factor of less than 10 which is improbably low. The $T=1$ assignment is also supported by the fact that this state emits gamma rays in successful competition with alpha particles[7] as would be expected of a $T=1$ but not a $T=0$ level.

TABLE I. Measured and expected γ-ray energies. Relative intensity refers to the strength of the transition relative to the sum of all transitions from the initial level in question.

Gamma ray	Relative intensity	Measured energy (Mev)	Expected energy (Mev)
γ_1	1	4.02 ±0.04	4.054±0.010
γ_2	1	0.703±0.010	0.717±0.001
γ_3	0.05	5.25 ±0.10	5.159±0.010
γ_4	0.25	4.49 ±0.05	4.442±0.010
γ_5	0.77	0.716±0.010	0.717±0.001
γ_6	0.70	2.99 ±0.03	3.007±0.014
γ_7	0.25	0.413±0.010	0.414±0.001
γ_8	0.25	1.017±0.010	1.022±0.002

The 4.77-Mev state we believe to be (1+). The decay scheme favors $J=0$ or 1; (0+) we cannot form and odd parity is again unlikely because a (1−) state would decay predominantly by an allowed $E1$ transition to the 1.74-Mev (0+) $T=1$ state while the (0−) assignment would again imply anun expectedly small isotopic-spin discouragement factor for the then forbidden $E1$ transition to the first excited state.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952).
[2] F. Ajzenberg, Phys. Rev. **88**, 298 (1952); T. W. Bonner and J. W. Butler, Phys. Rev. **83**, 1091 (1951).
[3] Bockelman, Browne, Sperduto, and Buechner, Phys. Rev. **90**, 340 (1953).
[4] G. A. Jones and D. H. Wilkinson, Phys. Rev. **90**, 722 (1953).
[5] Rasmussen, Hornyak, and Lauritsen, Phys. Rev. **76**, 581 (1949).
[6] Pruitt, Hanna, and Swartz, Phys. Rev. **87**, 534 (1952).
[7] Chao, Lauritsen, and Rasmussen, Phys. Rev. **76**, 582 (1949).

Positive π-Meson Production by Negative π Mesons*

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(Received July 27, 1953)

A STACK of Ilford G-5, 600- and 1000-micron thick plates was exposed in the 220-Mev negative π-meson beam of the University of Chicago cyclotron. The plates were arranged with the emulsion of one plate in contact with the adjacent plate so that the tracks could be followed through both plates. Two methods of area scanning were employed. Initially the plates were searched for each π-meson interaction. A total of 4160 meson interactions were found and studied. 12 $\pi-\mu$ decays were observed along with 123 negative π-meson stars. Of the 123 mesons, 20 were observed to originate from high-energy π-meson interactions. Additional plates have been scanned for slow meson tracks only, with a low magnification. By this method 292 negative π-meson stars and 24 $\pi-\mu$ decays have been found. Of these 292 negative π mesons, 51 were observed to originate from a high-energy π-meson interaction. In two cases the π-meson track from the $\pi-\mu$ decay originated from a high-energy meson interaction. In 21 of the $\pi-\mu$ decays, the μ meson stopped in the emulsion. In each case the range of the μ meson was normal and a decay electron track was observed from the end of the μ-meson track. Since the probability of decay in flight of a negative π meson is very small[1] ($<10^{-3}$) and since the range of the μ-meson track was normal, it was assumed that the π mesons which decay into μ mesons were positively charged. This assumption was further substantiated by the subsequent decay of each of the μ mesons (only 36±2 percent of th enegative μ mesons, which stop in a photographic emulsion, decayed into an electron).[2]

A projection drawing of event 1 is shown in Fig. 1. The incident π-meson track (track 1) is parallel with the other meson tracks and has the same grain density and multiple scattering as the other tracks. Since the π mesons were magnetically analyzed twice, it is assumed that in this case the incident meson was also negatively charged. Track 2 is 200 microns long and is 1.2±0.2 times minimum ionizing. It is assumed that the particle which produced the track was a π meson of about 50 Mev. The π-meson track 3 is 250 microns long and ends in the emulsion. The μ-meson track from the π-meson decay leaves the emulsion after about 500 microns. A short recoil track is observed which indicates that the target nucleus was a light nucleus. The event is interpreted as the inelastic scattering, of a negative π meson with the production of a positive π meson,

$$\pi^- + p \text{ (in nucleus)} \rightarrow \pi^- + n + \pi^+. \quad (1)$$

There is no evidence for the formation of a ζ^0 meson.

A projection drawing of event 2 is shown in Fig. 2. Track 1 is the track of the incident π meson. Track 2 is 8 microns long and the result of a charged nuclear particle. Track 3 was produced by a proton of 4.4 Mev. Track 4 leaves the surface of the emulsion after 2100 microns and exhibits the multiple scattering of a π meson of a velocity which corresponds to the observed grain density. This meson track has been followed into the adjacent plate and ends

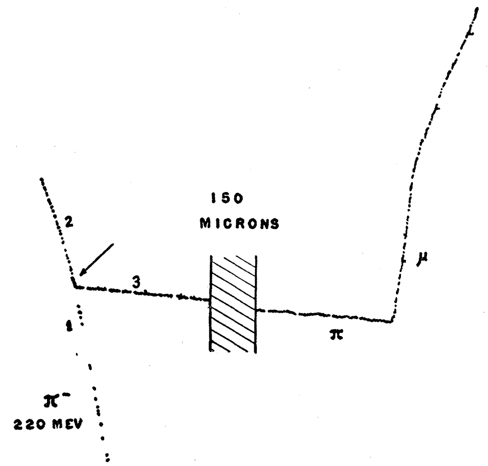

FIG. 1. A projection drawing of a negative π-meson interaction in a photographic emulsion. A positive π meson (track 3) was produced in the collision with a light nucleus.

after 2900 microns. The μ-meson track from the $\pi-\mu$ decay is 610 microns long. A decay electron is observed from the end of the μ-meson track. The event is interpreted as the production of a positive π meson by a negative π meson by a double charge exchange reaction:

$$\begin{aligned}\pi^-+p \text{ (in a nucleus)} &\rightarrow \pi^0+n,\\ \pi^0+p \text{ (in the same nucleus)} &\rightarrow \pi^++n.\end{aligned} \tag{2}$$

A very crude estimate of the probability per nuclear interaction of positive π-meson production by negative π mesons can be made from the number of π^- meson stars and $\pi-\mu$ decays. A π meson of energy less than about 20 Mev from an interaction will on the average stop in the stack of plates. A lower limit of the probability that a positive π meson of energy less than about 20 Mev will be produced in an interaction is estimated from the ratio of the

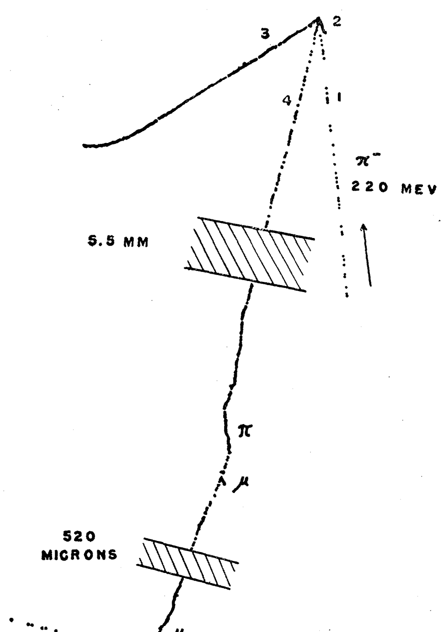

FIG. 2. A projection drawing of a negative π-meson interaction is shown above. A positive π meson (track 4) was produced in the collision.

number of π^+ to π^- times the probability of finding a π^- meson of energy less than 20 Mev from an interaction,

$$(36/415)\times(20/4160)\cong 4\times 10^{-4}.$$

The author is grateful to Professor H. L. Anderson for the use of the facilities of the University of Chicago cyclotron. The author is indebted to Mr. A. Rosenfeld and Mr. J. Orear for their assistance with the exposures and for many helpful discussions. Many discussions with Dr. G. Takeda were helpful.

* Supported in part by the Research Committee of the graduate school from funds supplied by the Wisconsin Alumni Research Foundation.

[1] W. F. Fry, Phys. Rev. **91**, 130 (1953); **84**, 385 (1951). W. F. Fry and George R. White, Phys. Rev. **90**, 207 (1953).
[2] W. F. Fry, Nuovo cimento **10**, 490 (1953); Phys. Rev. **85**, 676 (1952).

Far Ultraviolet Radiation from the Cornell Synchrotron*

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(Received July 17, 1953)

THE existing experimental studies[1-3] of the properties of the radiation due to transversely accelerated high-energy electrons have been confined to the visible and near ultraviolet regions of the spectrum. An attempt was therefore made to extend the region of observation to the vacuum ultraviolet. Since a grazing incidence spectrograph was available and could readily be modified for this purpose, it was decided to omit the observations in the Schumann region and to proceed directly with the exploration of the soft x-ray region (50A to 500A). The spectrograph was equipped with a lightly ruled 30 000-line grating whose radius of curvature was 154 cm. The grazing angle of incidence was set at 4.5° with a resulting calculated short-wavelength limit of 30A.

The spectrograph slit housing was connected to a porthole in the synchrotron "donut" by sections of tubing containing a vacuum gate-valve provided with a retractable quartz window. The latter was used only in the initial determination of the height and direction of the visible beam prior to positioning of the spectrograph. The valve served to isolate the spectrograph chamber from the "donut" of the synchrotron while the spectrograph was being pumped out. Upon evacuation of the spectrograph, the gate-valve was opened, allowing the radiation to pass through the evacuated interconnecting tube and fall directly upon the slit of the spectrograph.

The radiation is emitted tangentially from the electron orbit and is confined to a narrow cone centered on the instantaneous direction of the motion of the electron. The angular opening of the cone is of the order of 1/600 radian for a 300-Mev electron. This property demands that great care be exercised in aligning the axis of the spectrograph (line joining mid-points of grating and slit) with the axis of the cone of radiation. This adjustment was carried out by first observing through a theodolite the image of a visible spot of light at the orbit as reflected by a mirror placed opposite the quartz window located at the end of the porthole tube. The axial direction of the radiation in space was thus established and the spectrograph was slid into position so that its optical axis fell into coincidence with the direction of the light beam. The latter adjustment was also accomplished with the now fixed mirror and theodolite by sighting through them at two reference points fixed in the body of the spectrograph. The reference points were previously so located as to define the axis of the spectrograph. The final alignment was further verified by the use of a photocell placed within the spectrograph so as to detect the light from the central image when the usual trap for the central image was moved out of the way. The various runs reported here were exploratory in nature and were designed to determine whether the radiation could be detected within reasonable exposure times and, if so, to gain qualitative information concerning the intensity distribution and