EVIDENCE AGAINST THE EXISTENCE OF THE B^0 MESON*

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Recent theoretical work[1-3] on the electromagnetic structure of the nucleon has revived interest in the possibility of a bound state, of 3 pions with $I=0, J=1$. Such a particle might be of assistance in explaining the equality of the isoscalar and isovector parts of the nucleon charge distribution. It should be produced in γ-p collisions with a cross section[4] of $\sim 10^{-29}$ cm^2 and would decay rapidly, mainly in the mode

$$B^0 \to \pi^0 + \gamma. \quad (1)$$

The lifetime should be around 10^{-20} sec.

This note reports an attempt to observe the production of such a meson in the reaction

$$\gamma + p \to B^0 + p. \quad (2)$$

Two previous experiments[5,6] have attempted to measure the cross section for reaction (2) by measuring the proton counting rate at a given proton momentum and angle as a function of the end point of the bremsstrahlung photon beam. No evidence was found for the existence of two-body reactions other than the known π^0 production. The large background due to single π^0 production and π-pair production makes this technique somewhat insensitive.

In the experiment reported here we have used a different technique. Protons at a given angle and momentum were detected in coincidence with a photon on the opposite side of the beam. The photon spectrometer was located at such an angle that the maximum energy of the photons resulting from the decay of singly produced π^0 mesons was lower than the maximum energy of those from the B^0 mesons produced by reaction (2), which decayed according to (1).[7] Those events whose photon energy was between the π^0 cutoff and the B^0 cutoff were attributed to B^0 mesons. This technique is limited to B^0 mesons with mass larger than $\sim$3000 Mev; for smaller masses the difference between the two cutoffs is very small. The only possible background is due to π^0-pair production, but the decay photons from this process have only a small probability of falling in the B^0-sensitive region. There is also evidence[8] that the π^0-pair photoproduction cross section is small.

The experimental arrangement is shown in Fig. 1. The 1.1-Bev bremsstrahlung photon beam of the CalTech synchrotron was incident on a liquid hydrogen target. Protons arising from the target were detected by a wedge-shaped magnet and associated counter system previously described by Vette.[9] The decay photons were detected and their energy was measured with a large lead glass Čerenkov counter. When a proton, identified as such by the magnet and counter system, was in coincidence (resolving time 2×10^{-8} sec) with a pulse from the photon detector, a twenty-channel pulse-height analyzer recorded the height of the Čerenkov counter pulse.

The Čerenkov counter was calibrated with momentum-selected electrons and frequently checked by observing the pulse-height distribution from cosmic-ray μ mesons. The resolution of this counter is completely determined by the photoelectron statistics in the photomultipliers. The pulse-height distribution for monoenergetic photons has a standard deviation of

$$\sigma = 6.1(E_\gamma/10^3 \text{ Mev})^{1/2} \text{ Mev}.$$

The acceptance angles for the decay photons, defined by a 4-inch thick lead aperture, were $\pm 8°$ in the direction perpendicular to the plane of production and $\pm 9°$ in the production plane.

Throughout the experiment protons were selected whose momentum was 262 ± 12 Mev/c; the Čerenkov γ-ray detector was located at an angle of 23°, and the end point of the bremsstrahlung photon beam was set at 1130 Mev. Runs were taken at four different proton angle settings, 54°, 57°, 60°, and 66°. The runs at 66° were used to measure the π^0 photoproduction reaction in order to check the over-all efficiency of the system as well as the energy calibration of the Čerenkov counter. Figure 2 shows the observed and calculated Čerenkov counter pulse-height spectrum for the 66° runs. The agreement is quite satisfactory. The cross section for π^0 production obtained from this measurement is 1.26 ± 0.06 μb which is in good agreement with the measurement of Berkelman and Waggoner[10] of 1.1 ± 0.3 μb.

The results of the B^0 runs are presented in Fig. 3 and Table I. The Čerenkov counter pulse-height spectra obtained for the three proton

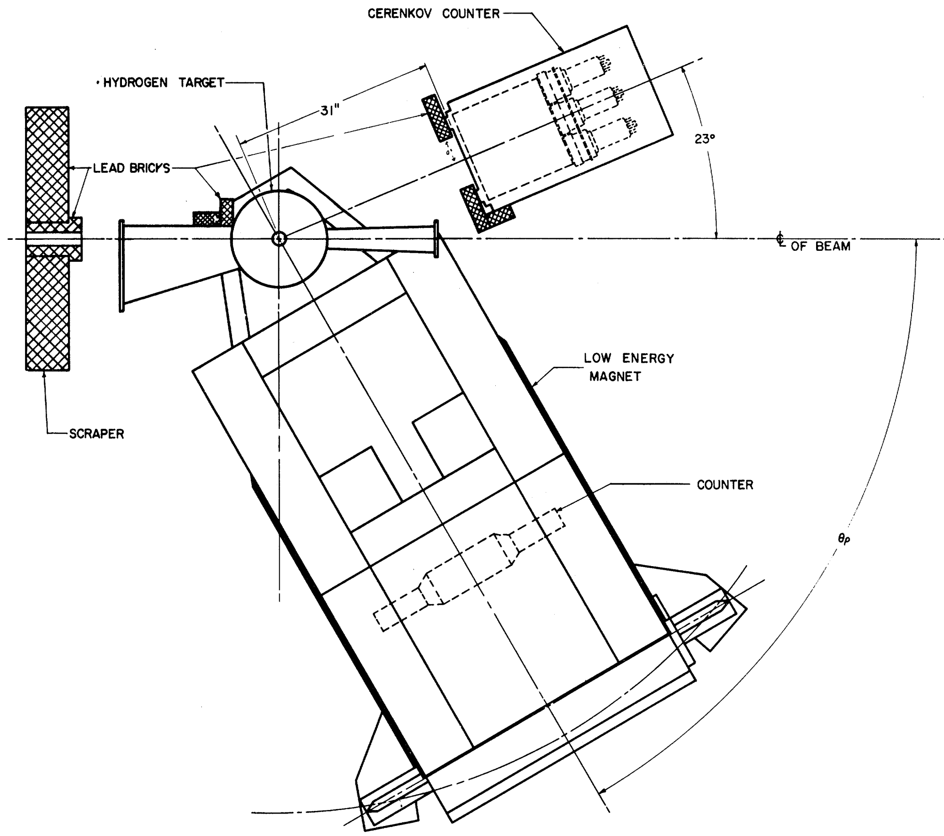

FIG. 1. Experimental arrangement.

spectrometer angles are shown by the broken lines in Fig. 3. The solid line histogram represents the photon spectrum calculated for single π^0 production, with the vertical scale adjusted to give the total of number of counts observed. The smooth solid lines are the spectra expected from B^0 mesons for assumed B^0 masses as indicated in the figure. These spectra were calculated for a differential production cross section of 10^{-30} cm^2 in the center-of-mass system, and the probability of detecting a photon from the π^0 meson which appears in the B^0 decay was neglected. Since the number of counts above the π^0 maximum energy is small, no attempt was made to measure background in this region. The measurements yield, therefore, an upper limit for the cross section of reaction (2). This upper limit, reported in Table I, was obtained by counting those events with energy above a certain energy E_t and calculating the corresponding cross sections for various B^0 masses. E_t was chosen, as indicated by the arrows in Fig. 3, so as to exclude all those

Table I. Average cross section for the photoproduction of B^0 mesons for various B^0 masses. These should be considered as an upper limit, since no backgrounds have been subtracted.

M_B (Mev)	$\sigma_{\text{c.m.}}(\theta)$ (cm^2)	Number of counts	$(\theta_B)_{\text{c.m.}}$	Incident photon energy interval (Mev)
320	3.2×10^{-32}	5	40°	690 - 1000
350	2.5×10^{-32}	5	38°	750 - 1000
380	2.7×10^{-32}	5	36°	750 - 1050
410	3.4×10^{-32}	4	34°	900 - 1100

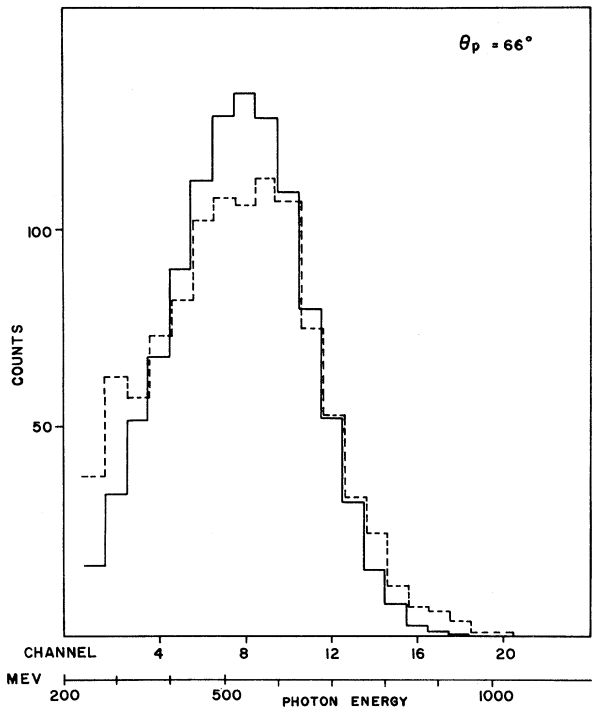

FIG. 2. Photospectra from π^0 meson for $\theta_p = 66°$. The broken line in the measured spectrum. The solid line is the calculated spectrum with the vertical scale adjusted to give the total number of counts observed.

events which clearly correspond to π^0-decay photons. Table I gives the average cross section obtained for four different values of M_B. It also gives the number of events used in calculating these cross sections, the average B^0 center-of-mass angle, and the incident photon energy interval to which these averages correspond.

As indicated above, this experiment becomes insensitive for B^0 masses below 300 Mev. However, if such a particle existed, the following reasoning suggests that it would already have been seen in K^+-decay experiments. Since the B^0 has $I = 0$, the reaction

$$K^+ \rightarrow \pi^+ + B^0 \tag{3}$$

satisfies the selection rule $\Delta I = 1/2$. Assuming this selection rule is valid, at least to the extent of explaining the factor of 1/500 between the $K_{\pi 2}{}^+$- and $K_{\pi 2}{}^0$-decay rates, the reaction (3) should have a rate based on the $K_{\pi 2}{}^0$-decay rate. If the energy release Q is small, the rate will be reduced by the necessity to generate a p wave and by the smaller phase space. It will be proportional to $Q^{3/2} R^2$, where R is the interaction ra-

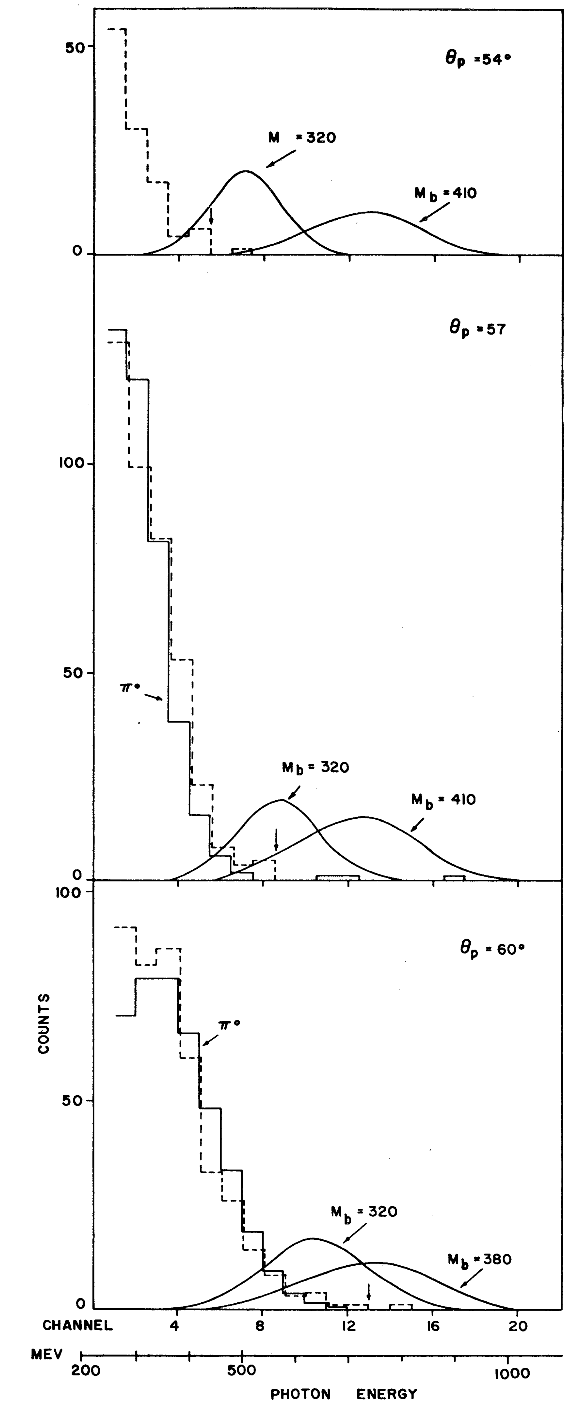

FIG. 3. Photon spectra for various proton angle settings. The broken lines are the observed spectra. The solid line histograms are the calculated spectra from π^0 mesons with the vertical scale adjusted to give the total number of count observed. The solid smooth lines are the expected spectra from B^0 mesons produced with a cross section of 10^{-30} cm^2 in the c.m. system; the various spectra correspond to different values of M_B as indicated in the figure.

dius. Taking the K-meson Compton wavelength for R, we find a rate of 1/250th of the K^0 rate, for a B^0 mass of 320 Mev. The decay mode (3) would appear as a peak in the π^+ energy spectrum from τ' decays. No such peak has been observed;[11] if one assumes that a peak of as much as 10% of the total number of τ' observed might have been missed through lack of statistics, then even this is only 10^{-5} of the K^0 rate, which seems to lie outside the uncertainty of the theoretical estimate. The same argument may also be used to exclude other strongly interacting particles with $J \leq 1$, $I \leq 2$, and $M \lesssim 325$ Mev.

This experiment, incidentally, gives another piece of information, namely a rough lower limit on the B^0 lifetime. Subject to the assumption that (1) is the dominant decay mode and that the cross section is not greatly reduced by accidental cancellations, a limit can be obtained because the decay vertex is also involved in one of the photoproduction matrix elements. At forward angles the nucleon plays a fairly passive role, merely absorbing the low-energy virtual pion, so we can express the probability of the production process in terms of the B^0 lifetime and the pion nucleon coupling constant. We find for the present experiment $\sigma_{\text{c.m.}}(\theta) \geq (2.2\times10^{-50}/\tau_B)$; inserting the limits for the cross section obtained in the experiment, we get for the lifetime

$$\tau_B > 10^{-18} \text{ sec.}$$

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[1]W. R. Frazer and J. R. Fulco, Phys. Rev. Letters 2, 365 (1959).

[2]G. F. Chew, Phys. Rev. Letters 4, 142 (1960).

[3]A vector meson with these quantum numbers has been discussed by Nambu. See Y. Nambu, Phys. Rev. 106, 1366 (1957).

[4]This number is based on a perturbation theory estimate. If the coupling to the nucleon were much weaker than this it seems unlikely that the particle could account for the larger isoscalar nucleon charge form factor (reference 3).

[5]A. Alberiji et al., reported by G. Bernardini, Ninth Annual International Conference on High-Energy Physics, Kiev, 1959 (unpublished).

[6]Matthew Sands (private communication).

[7]Since the experiment is only sensitive to decay mode (1), it can only measure the cross section for (2) times the branching ratio for (1).

[8]The π^0-pair photoproduction cross section seems to be very small for photons from 700 Mev to 1 Bev. See S. Richert and A. Silverman, Bull. Am. Phys. Soc. 5, 237 (1960).

[9]J. I. Vette and W. D. Wales, May 1957 (unpublished report).

[10]K. Berkelman and J. A. Waggoner, Phys. Rev. 117, 1364 (1960).

[11]S. Taylor, G. Harris, J. Orear, J. Lee, and P. Baumel, Phys. Rev. 114, 359 (1959).