STUDY OF THE SPIN AND PARITY OF THE B MESON*

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In a previous Letter, we have reported the existence of the B resonance ($\pi\omega$ resonance, $M = 1220$ MeV, $\Gamma = 100 \pm 20$ MeV).[1] In this Letter we want to report the study of its spin and parity. Our data favor the 1^- assignment but statistical limitations and background do not permit us to eliminate entirely the other assignments.

In the preceding Letter, Halpern[2] has proposed a method to determine the spin and parity of the B resonance. We use the same notation as defined in his Letter, and have numerically evaluated the integrals to obtain the density distribution for the spin-parity assignments 0^-, 1^-, $2^-(l=1)$, $1^+(l=0)$, $1^+(l=2)$, and phase space.[3] Halpern does not give the prediction for 2^- with $l=J+1$, for 2^+ and for $J \geq 3$. These spin and parity assignments are less probable because they require $l \geq 2$ (in particular, for $J^P = 3^-$ we need $l=3$).

Figure 1 shows isometric drawings of these density distribution predictions over the equilateral triangle. The symmetry with respect to reflection about any of the three axes OZ, $O'X$, $O''Y$ is apparent. Only the 1^- assignment predicts a significant depopulation at the center of the triangle.

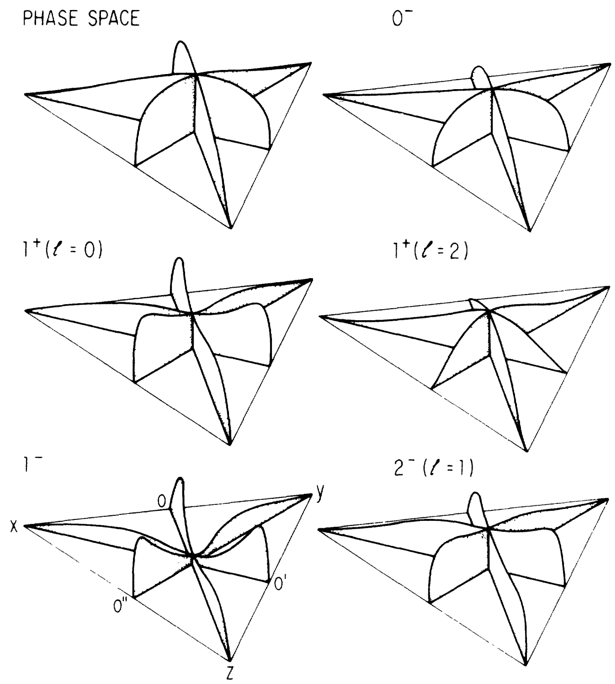

FIG. 1. Isometric drawings of the predicted density distributions of events on the Halpern triangle for various spin and parity assignments.

Figure 2(a) is a plot of the events within the B peak (1120 MeV $< M_{\pi\omega} <$ 1320 MeV). To eliminate possible confusion from the $N^* + \omega$ reaction,[1] we have removed events with 1120 MeV $< M_{\pi p} <$ 1320 MeV.[4] A depopulation of the center region is observable. In our previous Letter the $M_{\pi\omega}$ distribution[5] shows a background under the B peak equal to 60% of the total number of events within the B

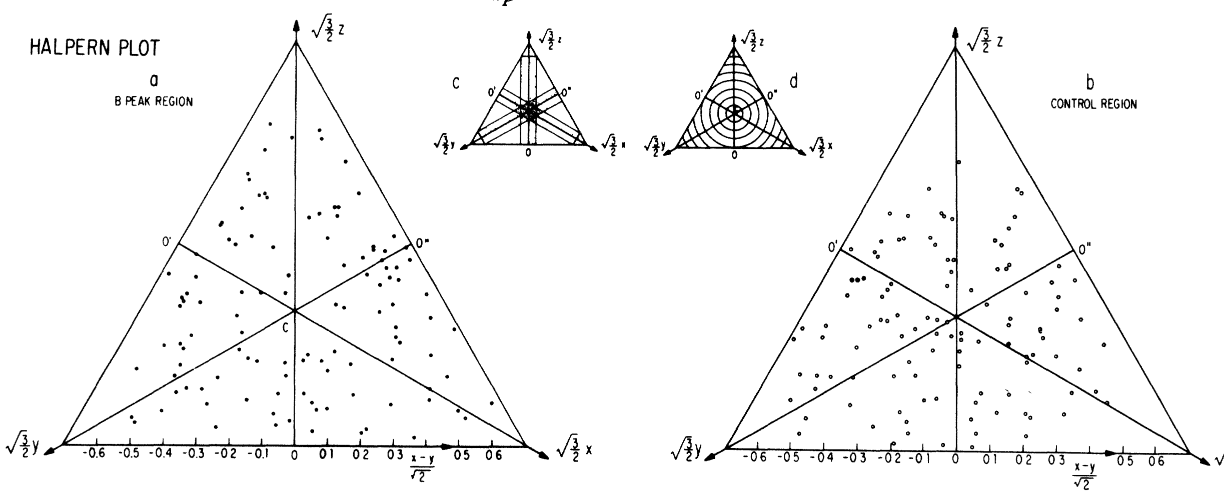

FIG. 2. Halpern plot (a) of 114 events within the B-peak region (1120 MeV $< M_{\pi\omega} <$ 1320 MeV); (b) of 111 events in the control region (1340 MeV $< M_{\pi\omega} <$ 1600 MeV); (c) showing the region used to obtain the strip distributions; (d) showing the regions used to obtain radial density distributions.

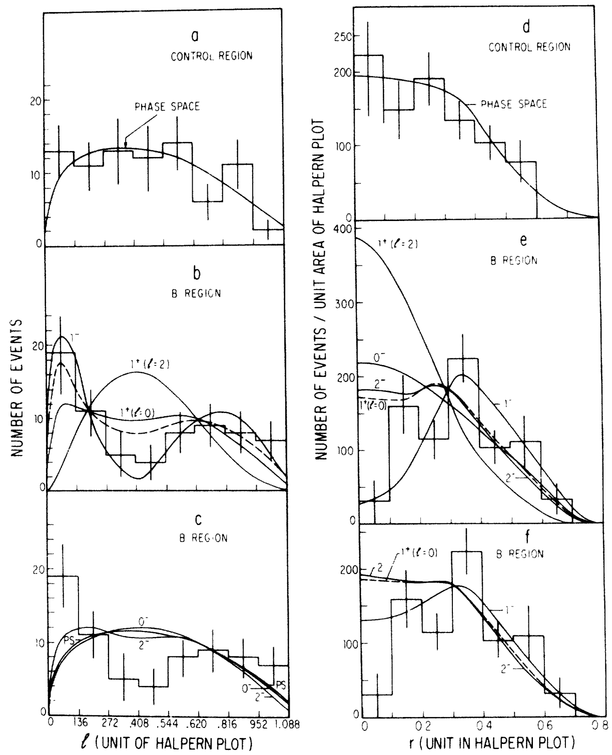

FIG. 3. (Left) Histogram of events in the strips (a) for the control region, (b) and (c) for the peak region. The solid curves are the predictions for various spin and parity assignments. The dashed curve is for 40 % 1^- plus 60 % phase space. (Right) Radial density distributions (d) for events in the control regions; (e) and (f) for events in the B-peak region. Curves are predictions from phase space and various spin and parity assignments (e) assuming no background and (f) assuming 60 % phase-space background.

mass range. As a representation of this background we take those events with ($1340\text{ MeV} < M_{\pi\omega} < 1600\text{ MeV}$) and plot them in Fig. 2(b). There is no strong depopulation of the center region. One way to display the differences in the predictions is to take a strip (0.16 wide in units of the Halpern plot) centered on any axis and plot the predicted density distribution [see Fig. 2(c)]. Figure 3(a) shows for the control region the histogram of the observed events in these three strips with the prediction of phase space. Figures 3(b) and 3(c) show the corresponding histogram for the events in the B peak. Also shown are the prediction for different spin-parity assignments assuming no background. We also plot the prediction for 40% 1^- plus 60% phase space[6] (dashed curve).

This representation emphasizes the difference between 1^- and the other assignments, but uses only about half of the data. All of the data will be used if one plots a radial density distribution from the center of the triangle [see Fig. 2(d)]. Figure 3(d) is such a density plot for the control region, and is quite consistent with the phase-space prediction. Figure 3(e) shows similar plots for the B mass region together with the predictions from different spin-parity assignments assuming no background. Figure 3(f) is the same plot with predictions for 40% J^P plus 60% phase space.[6] The 1^- spin-parity assignment seems to be favored. The other assignments differ little from one another. In order to obtain a quantitative estimate, we have calculated the likelihood ratio,[7] R, of (40% 1^- plus 60% phase space) to [40% $1^+(l=0)$ plus 60% phase space] directly from the triangle plot. We find $R=9$, which suggests a 1^- assignment but, of course, does not entirely eliminate the other assignments.[8] We have explored R as a function of the amount of phase space assumed and find that for 50% to 70% phase space R varies from 10 to 7.

In Fig. 4 we plot the histogram of the momentum transfer between initial and final proton for events (a) outside the B peak and (b) inside the B peak. In Fig. 4(b) we also show (shaded) the distribution of Fig. 4(a) normalized to 60% of the B-peak events. It is apparent that the momentum-transfer distribution inside the B region peaks more sharply at low values of the momentum transfer than that for the events outside the B region. A one-pion-exchange mechanism, which exists only for a 1^- ($3^-, 5^-, \cdots$) assignment, would require such a momentum transfer distribution. The 1^- assignment would allow a 2π decay mode. This decay mode does not seem to be observed; however, Frazer, Patil, and Xuong suggested that the neutral 2π decay mode be the f^0, and have proposed a model which shows how the charged 2π decay mode may have escaped detection.[9]

Before ending, we would like to mention the article of Alfaro and Vitale,[10] who use the hypothesis that a state of many pions is stable when it has the maximum number of ρ states ($I=1, J=1$). They predict that if a four-pion resonance exists, it is most likely in the form of a $\pi\omega$ resonance.

The interest and advice of Professor O. Piccioni were invaluable for the success of this experiment. We would like to thank Dr. W. Frazer, Dr. J. Fulco, and Dr. F. Halpern for many fruitful discussions and Mr. Tareah Hendricks for his help with the calculations. Thanks are due to

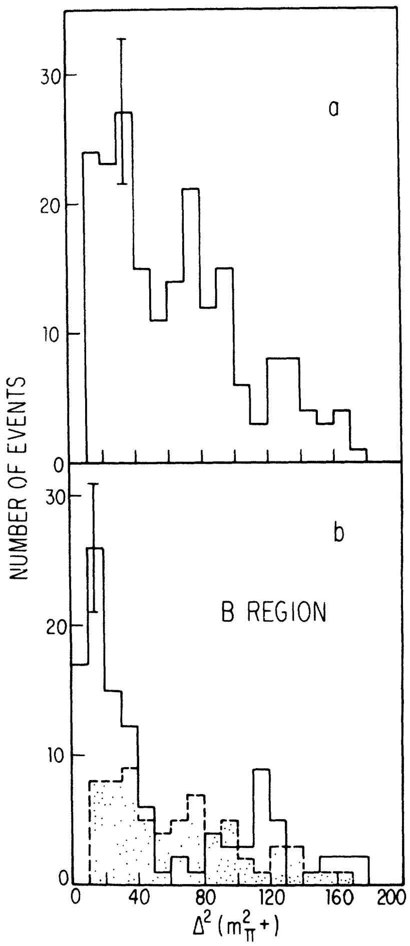

FIG. 4. Momentum-transfer distribution for events outside the B peak (a) and inside the B peak (b). The shaded region in (b) represents the data of Fig. (a) normalized to 60 % of the B-peak events.

Dr. Ralph Shutt and his group for the use of the 20-in. bubble chamber, to the Yale and Brookhaven groups for setting up the beam, to Dr. M. H. Blewett, Dr. H. Brown, Dr. R. Good, Dr. W. Mehlhop and to the 20-in. chamber crew for their help during the runs. The careful work of our scanners and technicians is appreciated. The Western Data Processing Center has given us graciously many hours of IBM-7094 computer time.

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[1]M. Abolins, R. L. Lander, W. W. Mehlhop, N.-h. Xuong, and P. M. Yager, Phys. Rev. Letters 11, 381 (1963).

[2]F. R. Halpern, preceding Letter [Phys. Rev. Letters 12, 252 (1964)].

[3]Phase space here means the matrix element was set equal to unity.

[4]P. Eberhard and M. Pripstein, Phys. Rev. Letters 10, 351 (1962), have proposed using the "conjugate" B events as a sample equivalent to those in the N^* overlap region. We find that these "conjugate" events appear to be distributed in a way similar to the B events outside the overlap region.

[5]See Fig. 2(c) of reference 1.

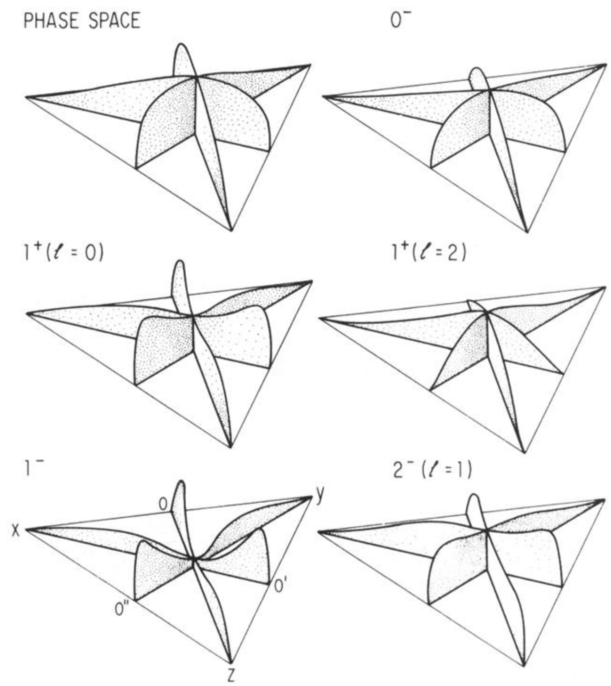
[6]Since all angles have been integrated over, the cross section $d^2\sigma/dxdy$ (density of the Halpern plot) is just a sum of distinct angular-momenta contributions (private communication from F. Halpern). Therefore it is justified to treat the background incoherently.

[7]J. Orear, University of California Radiation Laboratory Report UCRL-8417, 1958 (unpublished).

[8]C. Zemach (to be published) has proposed to look at the $\cos\theta$ and $\cos\beta$ distributions (with $\cos\theta = \hat{\pi}\cdot\hat{Q}$ and $\cos\beta = \hat{\pi}\cdot\hat{e}$, where $\hat{\pi}$ is the unit vector of the free π^+ direction in the B rest frame, $\hat{Q}$ is the vector normal to the plane of production of B, and $\hat{e}$ is the vector perpendicular to the decay plane of the ω in its rest frame). We found the $\cos\theta$ distribution to be very different for events inside and outside the B peak. A simple subtraction of these two regions would give a distribution strongly dominated by a $\cos\theta$ term in agreement with $J=1$. We cannot, however, distinguish between even and odd parity in the $\cos\beta$ distribution.

[9]W. Frazer, S. Patil, and N.-h. Xuong, Phys. Rev. Letters 12, 178 (1964). This paper gives references to the experimental data.

[10]V. De Alfaro and B. Vitale, Phys. Rev. Letters 7, 72 (1961).



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