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REMARKS ON THE EXISTENCE OF TWO Σ(1660) RESONANCES

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We are in the process of analyzing the following reactions:

$$K^-p \to \Sigma^+\pi^+\pi^-\pi^- \quad (1)$$

$$\to \Sigma^-\pi^+\pi^+\pi^- \quad (2)$$

$$\to \Sigma^0\pi^+\pi^- \quad (3)$$

$$\to \Sigma^+\pi^0\pi^- \quad (4)$$

$$\to \Lambda\pi^+\pi^- \quad (5)$$

for the purpose of studying the quasi-two-body reaction

$$K^-p \to X^+\pi^- \quad (6)$$

with special emphasis on the X^+ mass region near 1660 MeV.

The data were obtained from an exposure of the Berkeley 72-inch hydrogen bubble chamber to a K^- beam from the Bevatron at momenta of 2.1, 2.58, 2.61, and 2.70 GeV/c. The K^- pathlength equivalent at 2.1 GeV/c is 5.8 events/μb and for the combined upper three momenta it is 12.8 events/μb.

In a previous publication[1] we discussed the data of reactions (1) through (4) at the upper three momenta for various center-of-mass production cosine (cos Θ*) intervals, where Θ* is the angle between the target proton and X^+. These intervals were: $.95 < \cos\Theta^* < 1.0$ (region I), $.9 < \cos\Theta^* < .95$ (region II), and $.7 < \cos\Theta^* < .9$ (region III).

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We measured the production differential cross section in each of these intervals for a $\Sigma(1660)$ resonance decaying via the modes $\Sigma^0\pi^+$, $\Sigma^+\pi^0$ $\Sigma^{\pm}\pi^{\mp}\pi^+$ under the assumption of no interference between resonance and background amplitudes. The measurements showed that the ratio $\Sigma^0\pi^+/\Sigma^+\pi^0$ is consistent with unity in all three intervals. However, the ratio of $(\Sigma\pi\pi)$ to $\Sigma\pi$ is different in interval I by more than 3 standard deviations from its value in interval III.

For this conference, we have performed a similar analysis at 2.1 GeV/c. These data exhibit the same general behavior, thus corroborating the results obtained at the upper momenta. As in reference 1, we interpret the above phenomenon to imply the existence of two $\Sigma(1660)$ resonances. The existence of two such resonances allows a variety of possibilities of which the following are three extreme cases:

1. There are two $\Sigma(1660)$ resonances, essentially degenerate in mass and width, but whose amounts are never affected by interference effects between them after integration over all decay angles.

2. There are two $\Sigma(1660)$ resonances, degenerate in mass and width, interfering after integration over decay angles. This of course can happen only if they have the same spin-parity.

3. There are two $\Sigma(1660)$'s of the same spin-parity, one of mass and width similar to that observed on the mass plot, and another one at a different mass and very broad, but overlapping the 1660 region. Both would have fixed branching ratios into $\Sigma\pi\pi$, $\Sigma\pi$, and $\Lambda\pi$ states and would be interfering.

Case 2 and 3 are considered in addition to case 1 because there exists in the literature separate spin-parity determinations of $3/2^-$ for a $\Sigma(1660)$ resonance in the $\Sigma\pi\pi$ (Reference 2) and $\Sigma\pi$ (Reference 3) modes of decay. However, for the production experiments, the analyses assumed the presence of one resonance only.

We plan to add information from reaction (5) and employ a new analysis [4] based on three distinct channels of decay in order to further help distinguish between these three cases.

We intend to measure for various incident energy and production cosine intervals the following partial branching ratios of the 1660-MeV enhancement: $R_1=(\Sigma\pi)^+/T$, $R_2=\Lambda(1405)\pi^+/T$, and $R_3=\Lambda\pi^+/T$, where $T=(\Sigma\pi)^+ + \Lambda(1405)\pi^+ + \Lambda\pi^+$. Only two of the three ratios are independent since $R_1 + R_2 + R_3=1$ for any experiment.

The results of any experiment measuring the three rates can be recorded as a point in a plane with Cartesian axes for the variables R_1 and R_2. The physical domain for the case R_1, R_2, $R_3 > 0$ is a triangle as shown in Fig. 1.

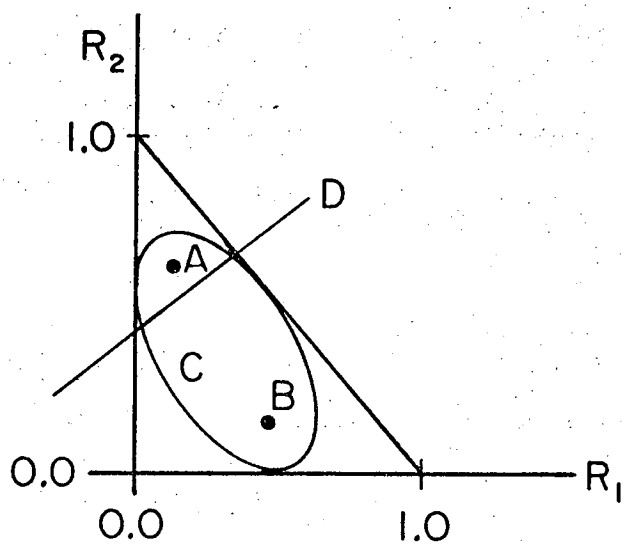

Fig. 1. Illustration of a partial branching ratio plot.

For a single resonance, all experiments must give answers consistent with a single point in the plane, such as point A in Fig. 1.

Two noninterfering resonances (case 1) having different branching ratios corresponding to points A and B on Fig. 1 would give rise to experimental results that could lie anywhere on the line joining points A and B.

If there exist two interfering resonances, it is possible to have different results, depending on the relation between the masses and widths. Cases 2 and 3 are the extreme possibilities. Case 2 (interfering resonances, degenerate in mass and width) would give rise to experimental results anywhere within an ellipse that is tangent to all three sides of the triangle, such as curve C. The other extreme case (case 3) could yield the same results as case 2. However, if the different decay amplitudes are relatively real, then the results would be constrained to lie on a line passing through the triangle. It is even possible in this case for experiments to show negative amounts in some of the channels, and therefore the corresponding points would lie outside the triangle, such as D of Fig. 1.

At this conference, a plot based on preliminary results was presented for purposes of illustrations. The points were such that no conclusion could be drawn about the relative likelihood of cases 1, 2, and 3. However, the results were only preliminary and are subject to future modifications. When definitive results are obtained, we hope to be able to differentiate between some of those cases.

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