Pion-Pion Interactions and Pion Production Branching Ratios at the Third Resonance*

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A SIMPLE model of pion-pion interaction for single-pion production in pion-nucleon collisions has been discussed by Carruthers and Bethe in an attempt to account for the third $\pi^- - p$ resonance at 900 Mev.[1]

A final-state two-pion system, isospin states $t=0$, 1, 2 with amplitudes a_0, a_1, a_2, interacting with a nucleon, could result in $t=\frac{1}{2}$ or $\frac{3}{2}$ isospin states for the over-all final system. By considering the admixture of the $\frac{3}{2}$ state negligible, a_2 vanishes and a simple relation between a_1/a_0 and the branching ratio of pion-production reactions results. Specifically, in the reactions

$$\pi^- + p \rightarrow \pi^- + \pi^+ n \tag{1}$$

and

$$\pi^- + p \rightarrow \pi^- + \pi^0 + p, \tag{2}$$

the branching ratio r is defined as

$$r = \frac{\text{cross section of reaction (1)}}{\text{cross section of reaction (2)}},$$

and then Carruthers and Bethe state that

$$|a_1|^2/|a_0|^2 = (r-\tfrac{1}{2})^{-1}. \tag{3}$$

The experimental branching ratios used by Carruthers and Bethe consisted of hydrogen bubble chamber measurements at energies ~800, 950, and 1000 Mev, and an emulsion measurement at 900 Mev. The bubble chamber measurements gave about the same branching ratio whereas the emulsion value was considerably lower. Consequently, Eq. (3) gave a sharp maximum at 900 Mev, indicating a resonant $t=1$ pion-pion state.

The branching ratios of reactions (1) and (2) at three different energies have been measured at Brookhaven, giving, at 1100 Mev,[2] $r=1.56\pm0.19$, at 960 Mev[3], $r=1.67\pm0.13$, and at 905 Mev, $r=1.70\pm0.17$, and at 905 Mev,[4] $r=1.70\pm0.17$. These measurements show a constant branching ratio within the uncertainties stated. With these values, Eq. (3) requires that a_0 and a_1 be equal or nearly equal.

These measurements and those reported by other workers with hydrogen bubble chambers are listed in Table I. The measurements of the Bologna group[5] at 960 Mev and of the Munich workers[6] at 1020 Mev are consistent with a constant or nearly constant branching ratio in this region. On the low-energy side at 810 Mev, there is a measurement from Berkeley,[7] which does not differ significantly from the approximately constant value above 900 Mev.

Thus, it is not possible to adduce evidence for a resonant pion-pion state from Eq. (3) and branching ratios determined by existing bubble chamber measurements. The low value, 0.7 ± 0.3, from the emulsion measurements[8] may be due partly to low statistics and partly to the difficulty of distinguishing a collision with a free proton from a collision with an edge nucleon of an emulsion nucleus. The latter type would tend to contribute to events classified as reaction (2).[9]

That single-pion production by ~1-Bev incident pions may, however, involve a final-state pion-pion resonance is suggested not by the branching ratios but by the analysis of the momentum spectra of the reactions. Indications of this resonance in reaction (2) at 960[3,10,11] and at 1020 Mev[12] have appeared, and similar

TABLE I. Branching ratios r for incident pion kinetic energies E.

E (Mev)	810[a]	905[b]	960[c]	960[d]	1020[e]	1100[f]
r	2.5 ± 0.4	1.70 ± 0.17	1.25 ± 0.16	1.56 ± 0.19	2.0 ± 0.5	1.67 ± 0.13

[a] See reference 7. [b] See reference 4. [c] See reference 5. [d] See reference 3. [e] See reference 6. [f] See reference 2.

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indications have been found in both reactions at 1100 Mev.[2]

The spectra show marked evidence for the presence of the $\frac{3}{2}$, $\frac{3}{2}$ resonance.[2–7] Peierls has shown how a mixture of nucleon-isobar and pion-pion states might account for the branching ratio at 960 Mev.[13] Carruthers has made an extensive analysis of the relations between pion-pion interactions and nucleon isobars, in which the $T=\frac{3}{2}$ state as well as the $T=\frac{1}{2}$ state is included, but up to the present date these relations have not yielded calculable branching ratios.[14]

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Progress Report on an Experiment to Study Lambda^0-K^0 Production at Sigma-K Threshold*

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I. INTRODUCTION

Baz and Okun[1] and, independently, Adair[2] have pointed out that a cusp phenomena, the nature of which was first investigated by Wigner,[3] should occur in the amplitude for the process $\pi^-+p\rightarrow\Lambda^0+K^0$ at the threshold for the threshold for the process $\pi^-+p\rightarrow\Sigma+K$.

If one assumes that $\Sigma-K$ production starts out in the s wave, then one can write the S matrix, above $\Sigma-K$ threshold, connecting states with $J=\frac{1}{2}$, $I=\frac{1}{2}$, and parity$=P(\Sigma K)$ as (in the notation of Baz and Okun)

$$\begin{array}{cc} & \begin{array}{cccc}\pi^--p & \Lambda^0-K^0 & \cdots & \Sigma-K\end{array}\\ S=\begin{array}{c}\pi^--p\\ \Lambda^0-K^0\\ \cdot\\ \cdot\\ \cdot\\ \cdot\\ \Sigma-K\end{array} & \left(\begin{array}{cccc} S_{11} & S_{12} & \cdots & m_1k^{\frac12}\\ S_{21} & S_{22} & \cdots & m_2k^{\frac12}\\ \cdot&\cdot&\cdots&\cdot\\ \cdot&\cdot&\cdots&\cdot\\ \cdot&\cdot&\cdots&\cdot\\ \cdot&\cdot&&\cdot\\ m_1k^{\frac12} & m_2k^{\frac12} & \cdots & x\end{array}\right),\end{array}$$

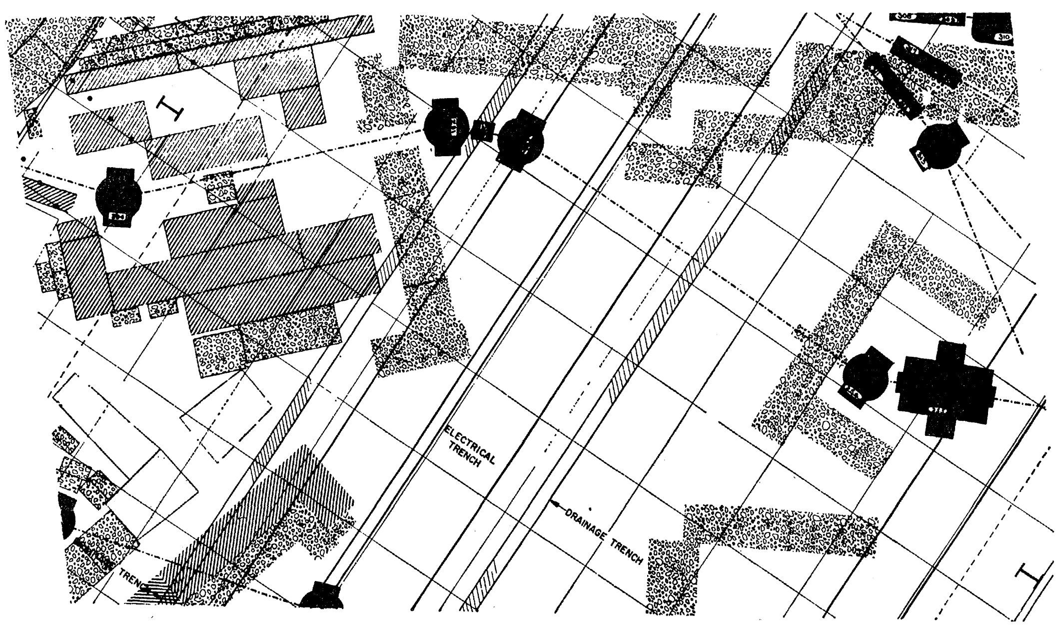

Fig. 1. Beam setup for experiment.

* Presented by M. Schwartz.

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