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OBSERVATION OF THE Y_1*(1480) IN THE $(\Sigma\pi)^+$ AND $(p\bar{K}^0)$ SYSTEMS: COMMENTS ON SPIN AND SU(3) MULTIPLET ASSIGNMENT*

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We have recently reported the observation of a resonance in the $\Lambda\pi^+$ system at 1480 MeV. We have observed this same resonance decaying into the $(\Sigma\pi)^+$ and $(p\bar{K}^0)$ channels. The mass, width, and branching ratios for this resonance are presented. We comment on the spin of the Y_1*(1480) and its possible SU(3) multiplet assignment.

We recently reported the observation of a Y_1* resonance in the $\Lambda\pi$ system in the reaction[1]

$$\pi^+p \rightarrow K^+\Lambda\pi^+ \qquad (1)$$

at an incident π^+ momentum of 1.7 GeV/c. This paper reports the observation of the same resonance in the channels

$$\pi^+p \rightarrow K^+\Sigma^0\pi^+, \qquad (2)$$

$$\pi^+p \rightarrow K^+\Sigma^+\pi^0, \qquad (3)$$

and

$$\pi^+p \rightarrow K^+p\bar{K}^0 \qquad (4)$$

in the same experiment.

We have searched our data from Reactions (2)-(4) for evidence of resonance production. We report here 153 events of the type (2), 169 events of the type (3), and 37 events of the type (4). At this energy, we are below the K*(890) threshold and we do not know of any ΣK, K^+p, or $K^+\bar{K}^0$ resonances in the available mass ranges. Our data are consistent with no resonance production in these systems.

Figure 1 shows the distribution of the square of the $(\Sigma\pi)^+$ invariant mass for Reactions (2) and (3). The data from both channels have been added together. The mass resolution is about ±10 MeV. The dashed histogram represents the total data. There is a substantial amount of background. However, we see indications of Y_1*(1385) production near 1.9 GeV^2 and Y_1*(1480) production in the 2.14-GeV^2 region. We note that the central values of square of the invariant mass for the resonances in Reaction (2) are approximately 0.04 GeV^2 lower than those found in Reaction (3). This shift, however, is not statistically significant. For the remainder of this paper we refer to the resonance as the Y_1*(1475) in accordance with the weighted average mass presented below of 1475 ± 15 MeV.

In Reaction (1) we[2] found that the production

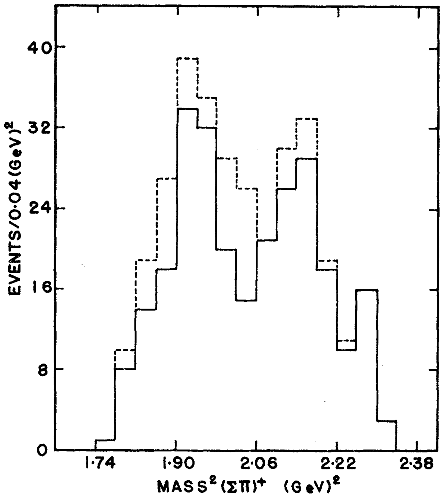

FIG. 1. The distribution of the square of the $(\Sigma\pi)^+$ invariant mass for Reactions (2) and (3). The dashed-line histogram is the total data and the solid-line histogram is the data with the cut $\Delta^2(\pi \rightarrow K) < -0.4$ GeV^2.

angular distribution of the $Y_1^{*+}(1385)K^+$ system peaks in the $\Delta^2(\pi\rightarrow K)$ range -0.4–-0.5 GeV^2 at this energy. $\Delta^2(\pi\rightarrow K)$ is the four-momentum transfer from the incident π^+ to the K^+ in the final state. Thus by making a $\Delta^2(\pi\rightarrow K)$ cut at -0.4 GeV^2 we hope to increase the resonance-to-background ratio. The data from Reactions (2) and (3) after this cut are shown in Fig. 1 as the solid histogram. There is little doubt that we observe both the $Y_1^*(1385)$ and the $Y_1^*(1475)$ in these channels. The remaining analysis and comments apply to the total data.

We have fitted our data assuming nonresonant background (i.e., constant interaction matrix element) and two constant-width Breit-Wigner resonances. The best fit obtained gave a confidence level of 65%. The resonance parameters are 30% $Y_1^*(1385)$, 15% $Y_1^*(1475)$, 55% nonresonant background, mass = 1465 ± 20 MeV, and $\Gamma = 25 \pm 20$ MeV.

Evidence for the $Y_1^*(1475)$ in the $\Sigma\pi$ mass system is further substantiated by the polarization of the Σ^0 from Reaction (2) and the polarization of the Σ^+ from Reaction (3).

The polarization of the Σ^0 can be obtained from the electromagnetic decay of the Σ^0 into $\Lambda\gamma$. The Σ^0 polarization is related to the Λ polarization by the relation $\bar{P}(\Sigma^0) = -3\bar{P}(\Lambda)$.[3] Figure 2(a) shows the values of $\alpha\bar{P}$ for the Λ hyperon as a function of $(\Sigma^0\pi^+)$ mass squared. The oscillation in the 2.10-GeV^2 region is clear.

From the parity-nonconserving decay $\Sigma^+\rightarrow p\pi^0$, $\alpha\bar{P}$ can be calculated. The polarization of the Σ^+ as a function of the $(\Sigma^+\pi^0)$ mass squared is presented in Fig. 2(b). Although the statistics are poor, we observe a change in $\alpha\bar{P}$ near 2.15 GeV^2. This occurs at approximately the same location as the enhancement found in the mass distribution.

The fact that the changes in $\alpha\bar{P}$ for Reactions (2) and (3) do not occur at the same value of the mass squared is a reflection of the 0.04-GeV^2 shift observed in the central values of the mass squared. This is, as pointed out before, compatible within the mass resolutions. Since we know of no kinematic effects which could cause the variations shown, we conclude that they are due to the formation of the $Y_1^*(1475)$.

We have attempted to determine a more precise value of the mass and width of this resonance from the two separate observations of the resonance. However, we notice that the $Y_1^*(1385)$ and the $Y_1^*(1475)$ in the $\Sigma\pi$ system appear to be shifted in mass from the masses observed in the $\Lambda\pi$ system. Since the $\Lambda\pi K$ reaction is more constrained in the kinematic fit we have accordingly given the fitted values from the $\Lambda\pi$ system more weight than those from the $\Sigma\pi$ system. The weight was chosen so as to be inversely proportional to the mass resolution. The weighted average values are

$M = 1475 \pm 15$ MeV,

$\Gamma = 30 \pm 15$ MeV

We also determined the following branching ratios:

$$[Y_1^*(1385)\rightarrow\Sigma\pi]/[Y_1^*(1385)\rightarrow\Lambda\pi] = 0.13 \pm 0.04,$$

$$[Y_1^*(1475)\rightarrow\Sigma\pi]/[Y_1^*(1475)\rightarrow\Lambda\pi] = 0.72 \pm 0.49.$$

Figure 3 shows the Dalitz plot for Reaction (4) and the projection of the $(p\bar{K}^0)$ mass squared. We attribute the peak in the 1465-MeV region to the decay of the $Y_1^*(1475)$ into $p\bar{K}^0$ and estimate that our data contain 10 ± 4 $Y_1^*(1475)$ events. The

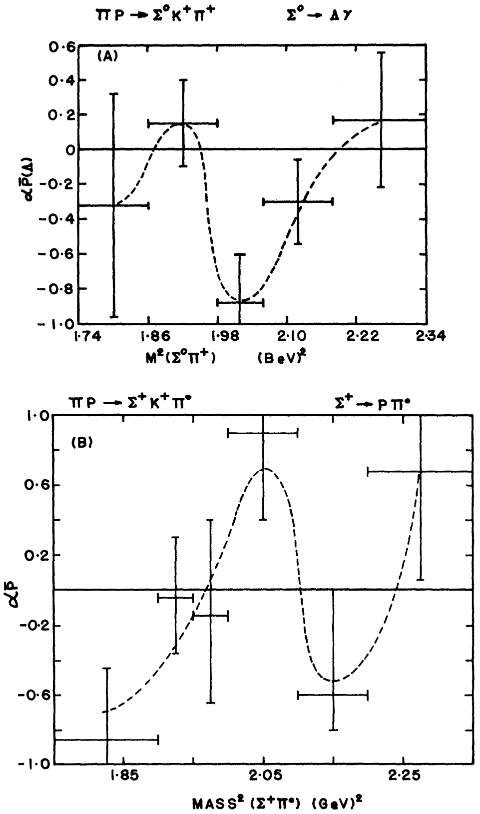

FIG. 2. (a) The Λ polarization as a function of the $\Sigma^0\pi^+$ mass squared. (b) The Σ^+ polarization as a function of the $\Sigma^+\pi^0$ mass squared. In both figures, the dashed lines are free-hand curves drawn through the experimental data.

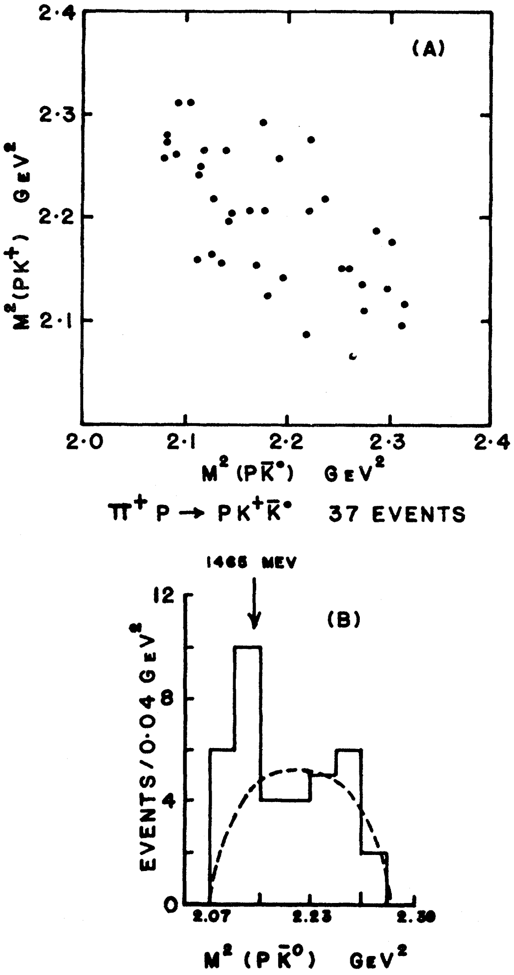

FIG. 3. (a) Dalitz plot for Reaction (4). (b) Distribution of the $\bar{K}^0p$ mass squared for Reaction (4). Dashed curve represents the estimated background.

branching ratio is then

$$[Y_1^*(1475)\rightarrow p\bar{K}^0]/[Y_1^*(1475)\rightarrow\Lambda\pi]=0.36\pm0.25.$$

This small branching ratio explains, in part, the reason for the inability of experimenters to observe this resonance in the $\bar{K}N$ system.

The spin-and-parity analysis is extremely difficult due to the small number of events [~75 events from Reaction (1) in the $Y_1^*(1475)$ region, of which ~50% are from background and $Y_1^*(1385)$, and about $\frac{2}{3}$ of this number of events from Reactions (2) and (3) together, again with about 50% from non-$Y_1^*(1475)$ events]. The multiple-partial-wave composition of the initial π^+p state at our energy (see the compilation by Lovelace,[4] for example) adds to the complexity of the spin-and-parity determination. With the above difficulties we are not able to make a definite spin-and-parity determination from our data.

Since the Λ and the N (nucleon) are members of the same SU(3) octet we expect their strong-interaction properties to be similar. We have looked at the πN phase shifts as a function of the c.m. momentum to estimate which partial waves are important in the 1475-MeV region of the $\Lambda\pi$ system.[4] We conclude that it is unlikely that the 1475-MeV resonance is F wave or higher. Even the D-wave possibility seems less likely than the P wave. The width of 30 MeV for this resonance argues against S-wave assignment. Thus, although we cannot make an experimental determination of the angular momentum state of this resonance, the P-wave possibility seems most likely with D wave also a reasonable choice.

SU(3) theory has been remarkably successful in classifying all existing baryon states into multiplets. We comment on the possible assignment of the $Y_1^*(1475)$ into the multiplet scheme.

Based only on the mass of this resonance, we are led to conclude the following:

(1) If we attempt to assign the $Y_1^*(1475)$ to an octet, then the Gell-Mann–Okubo mass formula

$$m=m_0+aY+b[I(I+1)-\tfrac{1}{4}Y^2]$$

with $a\sim-150$ MeV and $b\sim20$ MeV would predict, among other resonances, a $T=\frac{1}{2}$ N^* near 1295 MeV. There are no reported N^*'s in this region.

(2) If the $Y_1^*(1475)$ is assigned to a decuplet, the Gell-Mann–Okubo mass formula with the same parameters would require a $T=\frac{3}{2}$ N^* in the 1355-MeV region. The only such state known in this region is the $\Delta(1236)$, which has a firm assignment already.

(3) It is possible for this resonance to be assigned to a 27-plet, 35-plet, or higher representation; however, these assignments require the existence of a large number of "exotic" resonances. For example, in the 35-plet, the theory, in addition to other resonances, would require a $Y=1$ and $T=\frac{5}{2}$ resonance at a mass of 1430 MeV. No resonance with these quantum numbers has been found.[5]

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INELASTIC SCATTERING OF NEGATIVE PIONS FROM DEUTERONS AT 5.53 GeV/c *

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The differential cross sections for the total scattering and the inelastic scattering of negative pions by deuterium for 5.53-GeV/c incident pion momentum have been measured over the squared four-momentum transfer interval from ~0.3 (GeV/c)^2 to ~1.0 (GeV/c)^2. The results are compared with calculations based upon the impulse approximation and the Glauber approximation.

We have measured the differential cross section for the inelastic scattering of 5.53-GeV/c negative pions by deuterons. Previous experiments on pion-deuteron inelastic scattering have been concerned either with total cross sections or with angular distributions for incident momenta less than 1.0 GeV/c.[1] The theoretical analyses of these total cross-section data are based upon the Glauber high-energy approximation where both the single and double interaction effects have been taken into account.[2] The low-energy pion-deuteron differential cross sections were analyzed using the impulse approximation with limited success. In this note we shall compare our measured differential cross section with the impulse approximation and the Glauber approximation.

The experiment was performed at Argonne National Laboratory in the 17° beam of the zero-gradient synchrotron. The beam transport system determined the momentum of the pions to ±1% with an intensity of 2×10^5 pions/pulse for 580-msec pulses repeated at the rate of 1000 pulses/h. The beam angular divergence was ±5 mrad horizontally and ±3 mrad vertically at the 2.31-in. liquid-deuterium target. The liquid deuterium was maintained at a vapor pressure of 1 atm with a density of 0.1625 ± 0.002 g/cm^3. Beam pions were counted by a series of four scintillation counters with the last counter defining the beam size to be $\frac{3}{4}$ in. by $\frac{3}{4}$ in. The scattered pions were detected in a single-arm spectrometer consisting of a bending magnet, two scintillation counter arrays, and a single scintillation counter behind the first array to determine the azimuthal acceptance. The 1.0-in. width of an element in the first array determined the polar angular acceptance. A scintillation counter was placed downstream from the target to veto beam pions that did not interact with the target. The criteria for a good event were a count in the beam counters, a count in the azimuthal counter, a count in an element of the first array in coincidence with a count in a corresponding element of the second array, and no count in the veto counter. The desired events were then stored in a multichannel analyzer.

The background was determined by scattering in a carbon target and in an empty target. The ratio of background to desired event rate was found to vary from 40 to 76% depending upon the scattering angle. Corrections were applied to the data for electronic deadtime effects due to the veto counter, for muon and electron contamination of the pion beam, for nuclear absorption of the scattered pion in the liquid deuterium and the counter materials, for scattered pion decay, for impurities in the liquid-deuterium target, and for attenuation of the pion beam. The total scattering differential cross section is given in