DIFFERENTIAL CROSS SECTION OF THE REACTION $\pi^+ + p \rightarrow K^+ + Y^*$ (1385) AT 4.0 AND 5.05 GeV/c

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Approximately 1900 events were obtained in the differential cross section measurements of the reaction $\pi^+ + p \rightarrow K^+ + Y^*$ (1385). Forward peaks were found with slopes of 2.3 ± 0.3 and 2.6 ± 0.4 (GeV/c)$^{-2}$ for 4 and 5.05 GeV/c respectively. This data together with that on other decuplet production reactions gives evidence of a large SU(3) violation as would be expected from the mass splitting of the strange and non-strange exchanged particles.

We report on the results of a recent experiment on the reaction $\pi^+ + p \rightarrow K^+ + Y^*$ (1385) at 4 and 5.05 GeV/c. The differential cross sections for the reaction were measured as a function of 4-momentum transfer from t = -0.1 to t = -1.0 (GeV/c)^2. The apparatus used in the experiment is the same as that used to study the reaction $\pi^+ + p \rightarrow K^+ + \Sigma^+$ [1].

The momentum and the scattering angle of the forward K^+ were detected with a wire spark chamber spectrometer connected to an on-line computer (ASI 6020). This allowed calculation of the missing mass. A set of 4 wire chambers detected the several charged decay products of the Y^*, most important of which was the proton.

The Y^* (1385)'s produced in the reaction decay largely (90%) into π^+ and Λ^0. The kinematics of the decay process Y^* (1385) $\rightarrow \pi^+ + \Lambda$, $\Lambda \rightarrow p + \pi^-$ is such that at the t values measured the proton is confined to a relatively small cone near the direction of Y^* (1385) production. In addition often one or two additional tracks would be expected due to the other Y^* (1385) decay products. These two cirteria were used to reduce background.

Fig. 1 shows the missing mass square plots for the events with one track within the proton cone and for the events with two tracks or three tracks in the Y^* chambers. The center peak of

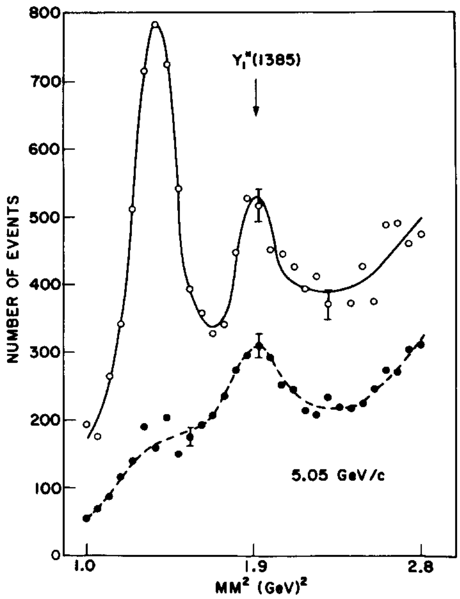

Fig. 1. Spectrum of missing mass squared. Solid curve requires one particle within kinematically allowed proton cone. Dashed curve requires detection of two or three particles in Y^* chamber.

the missing mass spectrum located at 1.91 (GeV)^2 is the Y^* (1385). The peak on the left corresponds to Σ^+ from the reaction $\pi^+ + p \rightarrow K^+ + \Sigma^+$. Since

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only one track is formed in Σ^+ decay into proton and π^0, the Σ^+ peak disappears in the missing mass squared distribution for 2 and 3 track events.

An event was accepted as a Y* (1385) candidate if the K^+ had the correct momentum for a Y* (1385) missing mass and if either there was a single track within the allowed proton cone or there were two or three tracks in the Y* chamber. (The proton cone criteria could not be used on two or three track events because of the ambiguity in spacial reconstruction.) Corrections to the data are similar to those discussed in our recent paper on $K^+ + \Sigma^+$ production with the exception of the corrections for two track efficiency of the set of wire chambers which detected the Y*. This efficiency was measured to be 60%. Since 60% of the data were tracks where only the proton was detected and for which the effeciency was high, the overall detection efficiency for Y* decay products was 80%. The dominant error in the final results was due to uncertainty in the background subtraction. The errors shown on the data in fig. 2 are largely systematic uncertainties in this subtraction. The statistical errors by comparison are negligible.

The curves show the forward peaks typical of exchange reactions. The slopes of the curves are 2.3 ± 0.3 and 2.6 ± 0.4 $(\mathrm{GeV}/c)^{-2}$ for 4 and 5.05 GeV/c respectively. These values are relatively small in comparison with the slope for the $K^+ + \Sigma^+$ reaction. By integrating $d\sigma/dt$ in the forward peaks we obtain cross sections of 27 and 13 μb

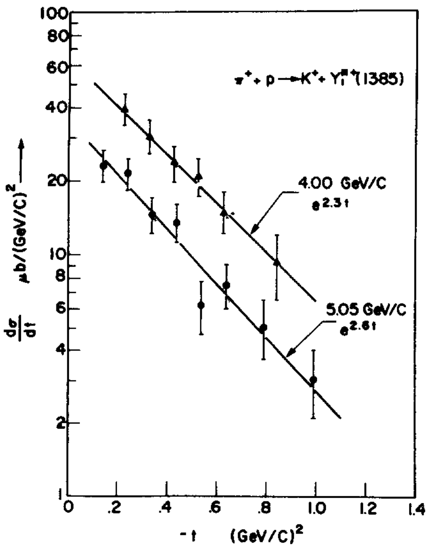

Fig. 2. Differential cross section for the reaction $\pi^+ + p \rightarrow K^+ + Y^{*+}$ (1385).

for 4 and 5.05 GeV/c respectively in agreement with other data within the errors [2,3]. The values for the slopes should be compared with the data of Mott et al. [4] which indicate an almost identical slope of 2.7 ± 0.4 $(\mathrm{GeV}/c)^{-2}$ at 5.5 GeV/c for the line crossed reaction, $K^- + p \rightarrow \pi^- + Y^{*+}$ (1385).

By combining our data with data on four other decuplet reactions we can test SU(3) symmetry in several ways. These reactions are:

$$K^+ + p \rightarrow K^0 + \Delta^{++} \quad (1)$$

$$\pi^+ + p \rightarrow \pi^0 + \Delta^{++} \quad (2)$$

$$\pi^+ + p \rightarrow \eta^0 + \Delta^{++} \quad (3)$$

$$\pi^+ + p \rightarrow K^+ + Y^{*+} \quad (4)$$

$$K^- + p \rightarrow \pi^- + Y^{*+} \quad (5)$$

From an SU(3) analysis [5] of the first four of these reactions one obtains a relation between the matrix elements.

$$|M_1|^2 = |M_2|^2 + 3|M_3|^2 - 3|M_4|^2 \quad (6)$$

The data for the reactions were first plotted at a given t as a function of $Q = \sqrt{s} - M_c - M_d$ where M_c and M_d are the masses of the two final state particles and $|M|^2 = 64\pi\, s p_{in}^2\, (d\sigma/dt)$. These plots for a typical t are shown in fig. 3a. As can be seen they vary only slowly with Q and therefore the assumption that the proper way to make SU(3) tests is at the same Q for all reactions is not a critical one. In fig. 3b the square of the matrix elements plotted as a function of t are shown by the ploted points. These are an interpolation from all the available data [6]. The solid lines are a best fit to the data together with a requirement that eq. (6) be satisfied. As can be seen the prediction of SU(3) is in excellent agreement with the data.

A second test of SU(3) can be made if we assume the reactions are due to meson exchange and specifically are dominated by the exchange of members of meson octets. A t channel SU(3) analysis then predicts that

$$|M_1|^2 = 3|M_5|^2 . \quad (7)$$

The experimental values [2,6] give $|M_1|^2 \approx \approx 10|M_5|^2$ indicating a large SU(3) breaking. This is not unexpected since reaction (1) involves nonstrange meson exchange while reaction (5) involves strange meson exchange. Using the ρ - K* mass difference and assuming parallel Regge trajectories

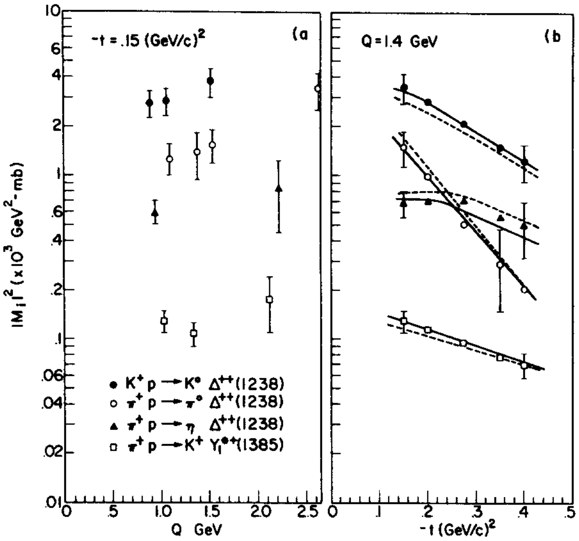

Fig. 3. a) Dependence of matrix elements on Q. b) Dependence of matrix elements on t. The points are experimental data. Solid curves are best fit of the data to eq. (6). Dashed curves are best fit if $|M_4|^2$ multiplied by $\frac{10}{3}$ is used in eq. (6).

one would expect reaction (5) to be suppressed by approximatley the amount observed. A quantitative comparison depends of course on the exact Regge model assumed.

A second piece of evidence that SU(3) breaking occurs can be obtained from a comparison of the phase angle between the vector and tensor meson trajectories expected from a Regge model with experimental data on reactions (1) through (4). Various two pole models give different predictions but in general values of $|\alpha_V - \alpha_T|$ range from 0 to 0.2 at small t. This corresponds to a phase angle φ between vector and tensor trajectories of $90^\circ \pm 20^\circ$. We assume, as is required by Regge pole theory, that φ is independent of helicity. The addition of cuts increases the allowed range of values somewhat.

If B_i and A_i are chosen as the amplitudes for the ith helicity state of reactions (2) and (3) respectivily, by an SU(3) analysis in the t channel one gets for reactions (1) through (4)

$$|M_1|^2 = \sum_i [\tfrac{3}{2}|A_i|^2 + \tfrac{1}{2}|B_i|^2 - \sqrt{3}|A_i|\ |B_i|\ \cos\varphi]$$

$$|M_2|^2 = \sum_i |B_i|^2$$

$$|M_3|^2 = \sum_i |A_i|^2$$

$$|M_4|^2 = \sum_i [\tfrac{1}{2}|A_i|^2 + \tfrac{1}{6}|B_i|^2 + \tfrac{1}{3}\sqrt{3}\,|A_i|\ |B_i|\ \cos\varphi]$$

If we assume that A_i/B_i = constant independent of i then

$$\cos\varphi = \frac{|M_1|^2 - 3|M_4|^2}{-2\sqrt{3}\,(|M_3|^2\ |M_2|^2)^{\frac{1}{2}}} \qquad (8)$$

This relation does not depend on octet dominance, however assuming the two pole octet dominance model φ is the phase angle between the vector and tensor amplitudes. It can easily be shown using the method of Lagrange multipliers that if the condition on A_i/B_i is relaxed $|\cos\varphi|$ will be increased. From the data we obtain $\cos\varphi = -0.8$ to -1.0 depending on t, in marked contrast to the value expected on the basis of the two pole model. Thus unless SU(3) breaking is present there is a large discrepancy between the data and Regge predictions.

With this evidence for SU(3) symmetry breaking one must question why eq. (6) works so well. We may start from eq. (7) and assume that symmetry breaking is due entirely to the difference between the strange and non-strange meson exchanges. Then the experimental value of $|M_4|^2$ and $|M_5|^2$ should be multiplied by $\sim \frac{10}{3}$ to correct for this breaking. The corrected value of (4) together with reaction (2) and (3) gives $\cos\varphi = -0.1$ in agreement with Regge theory. To satify eq. (6) including the correction of $\frac{10}{3}$ to reaction (4) the data would follow the dashed curves in fig. 3b. As can be seen this is still a very good fit to the data. Thus all three SU(3) tests are consistent with a large amount of SU(3) breaking in decouplet production which can be corrected for by assuming a difference between strange and non-strange meson exchanges.

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