CM-P00058212

Ref.TH.1094-CERN

CROSSING $K^-p \rightarrow \pi^- \pi^+ \Lambda$ INTO $\pi^+p \rightarrow K^+ \pi^+ \Lambda$

USING THE GENERALIZED VENEZIANO MODEL

Nils A. Törnqvist ^{*)}

CERN - Geneva

A B S T R A C T

The dual multiparticle model for $K^-p \rightarrow \pi^- \pi^+ \Lambda$ suggested by Petersson and the present author is applied to the crossed reaction $\pi^+p \rightarrow K^+ \pi^+ \Lambda$. We avoid the complication due to Pomeron exchange by limiting ourselves mainly to the dominant subprocess $\pi^+p \rightarrow K^+ Y^{*+}(1385)$. The model predicts correctly the energy dependence and differential cross-sections and even the normalizing parameter within a factor of two. An alternative model suggested by the Harari-Rosner rules fails to give a good fit.

^{*)} On leave from Institute for Nuclear Physics,
University of Helsinki, Helsinki, Finland.

Recently, B. Petersson and the present author studied the reaction $K^- p \rightarrow \pi^- \pi^+ \Lambda$ using a five-point Veneziano model ¹⁾. In spite of many assumptions a qualitatively good fit was obtained to all data above 3 GeV/c with essentially only the normalizing parameter free. A similar model ²⁾ has also been applied to the reactions $K^+ p \rightarrow K^0 \pi^+ p$, $K^- p \rightarrow \bar{K}^0 \pi^- p$ and $\pi^- p \rightarrow K^0 K^- p$, with again qualitatively good agreement with the data.

One of the most appealing features of dual models is the crossing symmetry. It is therefore of interest to see whether the model of Ref. ¹⁾ (the P.T. model) can be used to describe crossed processes. At the same time one obtains a test on some of the assumptions made in Ref. ¹⁾. Especially the result of Ref. ¹⁾ that the rules obtained from the Harari-Rosner diagrams ³⁾ had to be violated in order to get a good fit was slightly disturbing. An especially good test on the correctness of this result is provided by the crossed reaction $\pi^+ p \rightarrow K^+ \pi^+ \Lambda$ since the P.T. model predicts no resonance effects in the $\pi^+ p$ system.

When double-charged $K\pi$ systems are excluded, there remain six permutations of the external particles. In Fig. 1 we have drawn the corresponding Harari-Rosner diagrams and labelled them as in Ref. ¹⁾ A-F. For A and B, the strange quark between the K and the Λ must cross another quark line which violates the Harari-Rosner rules.

When constructing the amplitude the following alternative is of interest :

$$A_1 = \varepsilon_{\alpha\beta\gamma\delta} p_\alpha^1 p_\beta^2 p_\gamma^3 p_\delta^4 (A + B + F) , \quad (1)$$

$$A_2 = \varepsilon_{\alpha\beta\gamma\delta} p_\alpha^1 p_\beta^2 p_\gamma^3 p_\delta^4 (c_1 C + c_2 (D+E) + c_3 F) . \quad (2)$$

where A-F refer to five-point functions, with the external particles in the ordering given in Fig. 1. The parameters of the trajectories are given in the Table. For a more detailed discussion on how these are chosen, see Refs. 1) and 2). We refer to the amplitude (1) as the P.T. model and to (2) as the alternative suggested by the Harari-Rosner rules.

COMMENTS ON THE P.T. MODEL AND $K^-p \rightarrow \pi^+\pi^-\Lambda$

The graph F in (1) was not included in Ref. 1) because in $K^-p \rightarrow \pi^+\pi^-\Lambda$ it always proceeds by baryon exchange and is small at high energies. The graphs A, B and F are added with equal weights since this does not disagree with the data and is implied by exchange-degeneracy (E.D.) arguments. The addition of the graph E completes the picture based on E.D. arguments given in Ref. 1), since the Y_1^* is non-exchange degenerate (N.E.D.) in both charge states $Y_1^{*\pm}$, while all other trajectories are E.D. We have also changed the Y_1^* trajectory in the K^-p system to the Λ trajectory. This does not alter the predictions of Ref. 1) because at high energies the predictions are insensitive to this trajectory. The Λ trajectory is suggested by the fact that the most prominent peak in the total cross-sections 4) for $K^-p \rightarrow \pi^-\pi^+\Lambda$ corresponds to the $\Lambda(1820)$ and by the fact that it couples a little stronger than Y_1^* to K^-p 5). From isospin arguments both $T = 0$ and $T = 1$ trajectories must be present. Thus strictly speaking our Λ is a degenerate Λ - Σ trajectory. With the Λ trajectory the model works approximately for $K^-p \rightarrow \pi^-\pi^+\Lambda$ down to 1.7 GeV/c. At still lower energies the mass distributions are qualitatively good but the total cross-section is too low by a factor of 2 or more. Here one should add several trajectories (Λ , Y_1^* , Σ , etc.) in order to reproduce the resonance spectrum and very likely spin effects, and K exchange at the $p\Lambda$ vertex are important.

THE HARARI-ROSNER ALTERNATIVE

The second amplitude (2) contains only permutations allowed by the Harari-Rosner rules. The coefficient for D and E are put equal in order to have the Δ trajectory N.E.D. By breaking other E.D. arguments, for which the experimental evidence is less convincing, the coefficients c_1 , c_2 and c_3 can be varied to fit the data. To get approximately correct branching ratios for ρ , $Y_1^{*+}(1385)$ and $Y_1^{*-}(1385)$ in $K^-p \rightarrow \pi^+\pi^-\Lambda$, $c_1, c_2, c_3 \approx 1 : 2 : 4$.

THE REACTION $\pi^+_p \rightarrow K^+\pi^+\Lambda$

Experimentally the reaction $\pi^+_p \rightarrow K^+\pi^+\Lambda$ is dominated by $Y_1^*(1385)$ production (for $P_{lab} \leq 2$ GeV/c to almost 100%, which is predicted by both amplitudes). In Fig. 2 we show the predicted $\Lambda\pi^+$ mass distribution at the highest available energy 8 GeV/c compared with the data⁶⁾. Here as in the following figures the solid curve is predicted by (1) and the dashed one by (2). The second experimental bump is believed to be the $Y_1^*(1690)$. This lies on a lower trajectory and could well be the daughter of the $Y_1^*(1765)$. By adding A and B we have killed the $Y_1^*(1765)$ but not the daughter. Unfortunately this daughter is too small in our prediction although the mass distribution otherwise agrees rather well with the data. (This is the same situation as in $K^-p \rightarrow \pi^+\pi^-\Lambda$.) With the second amplitude the second bump must be interpreted as the $Y_1^*(1765)$, and the agreement in other parts of the mass-distribution is lost. In the same experiment there is indication of some N^* production at a mass of 1700 MeV which probably is produced by Pomeron exchange. This assumption is supported by both amplitudes (1) and (2), since they both predict very little $N^*(1688)$.

THE REACTION $\pi^+ p \rightarrow K^+ Y_1^{*+}(1385)$ AND $K^- p \rightarrow \pi^- Y_1^{*+}(1385)$

We can avoid the complication due to the Pomeron, which is not described by the model, by limiting ourselves to the dominant subprocess $\pi^+ p \rightarrow K^+ Y_1^{*+}(1385)$ and compare it with $K^- p \rightarrow \pi^- Y_1^{*+}(1385)$. In the amplitude (1) Y_1^{*+} 's are produced only by graphs A and B and in the amplitude (2) only by D and E. The constants c_1 and c_2 in (2) are therefore unimportant and we are left in both cases with only the normalizing parameter free. In Fig. 3, we compare the predicted total cross-sections with the data for $\pi^+ p \rightarrow K^+ Y_1^{*+}(1385)$ with varying incident energy. Note that the normalization is taken from the crossed process $K^- p \rightarrow \pi^- Y_1^{*+}(1385)$ at 5.5 GeV/c. As can be seen the predictions are only a little too high which we consider as a rather good test of the crossing symmetry. The energy dependence is also in good agreement with the data. Unfortunately the data are not accurate enough to distinguish between the smooth and the oscillating prediction. However, when one looks at the differential cross-sections the predictions differ drastically. In Fig. 4a-c we compare the predictions with the data for the differential cross-sections for $\pi^+ p \rightarrow K^+ Y_1^{*+}(1385)$ between 1.7 - 5 GeV/c ^{7),8)}. The smooth prediction of the P.T. model agrees well with the data while the other amplitude predicts a strong angular dependence as expected from direct channel resonances. This agrees with the conclusion reached in Ref. ⁷⁾ for the lowest energies that direct channel resonances cannot easily reproduce the data, while a pure vector meson exchange model gives a good agreement. A more detailed model including spin effects, etc., will of course change the quantitative predictions, but it is very unlikely that the predictions will be smoothed to the extent that they would agree with experiment.

Also if one compares the prediction for $d\sigma/d\cos\theta$ for $K^- p \rightarrow \pi^- Y_1^{*+}(1385)$ with the data ^{9),10),11)} the amplitude (2) predicts a large backward peak due to Δ exchange (Fig. 4d-f) which is not seen experimentally. However, Δ exchange is poorly described in Veneziano type models giving a too large contribution. Therefore we consider the differential cross-sections of $\pi^+ p \rightarrow K^+ Y_1^{*+}(1385)$ as the most significant test of our anti-Harari-Rosner hypothesis.

We conclude that the Harari-Rosner rules do not work, at least not within the framework of the generalized Veneziano model, neither for $K^-p \rightarrow \pi^+ \pi^- \Lambda$ nor for $\pi^+ p \rightarrow K^+ \pi^+ \Lambda$, while the simple model suggested in Ref. ¹⁾ works rather well as a first approximation.

We thank Professor Chan Hong-Mo for discussions and a critical reading of the manuscript, and we are grateful to Professor W. Thirring and Professor J. Prentki for their hospitality at the Theoretical Study Division at CERN.

Below Threshold	Above Threshold
$\alpha_g(t) = +0.48 +0.9 t$ $\alpha_K^*(t) = +0.28 +0.9 t$ $\alpha_{V_1}^*(t) = -0.22 +0.9 t$ $\alpha_\gamma(t) = -0.68 +0.9 t$ $\alpha_N(t) = -0.30 +0.9 t$ $\alpha_\Delta(t) = +0.13 +0.9 t$	$\alpha_g(s) = +0.48 +0.9 s + i 0.13 \sqrt{s-0.08}$ $(\alpha_K^*(s) = +0.35 +0.82 s + i 0.07 (s-0.29), \text{ not used here})$ $\alpha_{V_1}^*(s) = -0.22 +0.9 s + i 0.13 (s-1.57)$ $\alpha_\gamma(s) = -0.68 +0.95 s + i 0.13 (s-2.1)$ $\alpha_N(s) = -0.37 +1.0 s + i 0.13 (s-1.0)$ $\alpha_\Delta(s) = +0.13 +0.9 s + i 0.13 (s-1.0)$
<p>The arguments of the B_5 are always $1-\alpha(t)$.</p>	<p>The arguments of the B_5 are $1-\alpha(s), \frac{1}{2}-\alpha(s)$ or $\frac{3}{2}-\alpha(s)$ depending on whether the spin of the first resonance is $1, \frac{1}{2}$ or $\frac{3}{2}$.</p>

REFERENCES

- 1) B. Petersson and N.A. Törnqvist - Nuclear Phys. to be published ;
CERN Preprint TH. 1040.
- 2) Chan Hong-Mo, R. Raitio, G.H. Thomas and N.A. Törnqvist - to be
published.
- 3) H. Harari - Phys.Rev.Letters 22, 563 (1969) ;
J. Rosner - Phys.Rev.Letters 22, 689 (1969).
- 4) R. Armenteros, M. Ferro-Luzzi, D. Leith, R. Levi-Setti, A. Minten,
R. Tripp, H. Filthuth, V. Hepp, E. Klugl, H. Schneider,
R. Barlaudaud, P. Granet, J. Meyer and J.P. Porte - Z.Phys.
202, 486 (1967).
- 5) C. Schmid - Nuovo Cimento Letters 1, 165 (1969).
- 6) Aachen - Berlin - CERN - Krakow - Warsaw Collaboration - Nuclear
Phys. B11, 259 (1969).
- 7) S.P. Ying, C. Akerlof, D. Meyer, S. Pruss, L. Lales, R. Lundy,
D. Rust, C. Ward and D. Yovanovich - Phys.Letters 30B, 289
(1969).
- 8) D.W. Davies - Ph.D. Thesis U.C.R.L. 19263 (1969).
- 9) P.O. Huwe - Phys.Rev. 181, 1824 (1969).
- 10) Amsterdam - Ecole Polytechnique - Saclay Collaboration - to be
published.
- 11) J. Mott, R. Ammar, R. Davis, W. Kropac, D. Slate, B. Werner,
S. Dagan, M. Derrik, T. Fields, J. Loken and
F. Schweingruber - Phys.Rev. 177, 1966 (1969).

FIGURE CAPTIONS

- Figure_1 The six graphs that remain when double charged $K\pi$ systems are forbidden. For A and B the Harari-Rosner rules are violated since the strange quark between the Λ and the K must cross another quark line. All particles are considered as incoming.
- Figure_2 The $\pi^+\Lambda$ mass distribution at 8 GeV/c⁸). The solid curve is the prediction from the amplitude (1) (P.T. model) and the dashed one from the amplitude (2) with $c_1 : c_2 : c_3 = 1 : 2 : 4$.
- Figure_3 The energy dependence for $\pi^+p \rightarrow K^+Y_1^{*+}(1385)$ total cross-sections compared with the predictions of amplitude (1) (solid curve) and (2) (dashed curve).
- Figure_4 The differential cross-sections for $\pi^+p \rightarrow K^+Y_1^{*+}(1385)$ (a-c), and $K^-p \rightarrow \pi^-Y_1^{*+}(1385)$ (d-f) compared with the predictions of the amplitude (1) (solid curve) and (2) (dashed curve).

FIG.1

FIG. 2

FIG. 3

FIG.4