K* (892) production in the rescattering model

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K* (892) production in the rescattering model

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Abstract. The rescattering model has been applied to explain the observed angular distributions at various energies for the process $K^-p \to K^{*-}p$. The theoretical calculations are in reasonable agreement with experiments regarding magnitude, shape and energy dependence.

1. Introduction

The K*(892) production has been observed (Alston *et al.* 1962, Gelsema *et al.* 1963, Lyons 1966) at various incident K^- momenta 1·2 to 2·1 BeV c^{-1} in the reaction

$$K^- + p \to K^{*-} + p. \tag{1}$$

Above 2·0 BeV c^{-1}, the production angular distribution shows a strong forward peak which can be understood in terms of the pseudoscalar meson exchange absorption model. However, below 2·0 BeV c^{-1} this correlation fails. At 1·2 BeV c^{-1} a peak is observed in the backward hemisphere. As baryon exchange is forbidden, it is difficult to understand the angular distribution on the basis of one-particle exchange alone. We will show in this note that, if we include the contribution of the two-pion exchange, which is the next singularity, this discrepancy can be removed.

2. Method of calculation

The one-pion exchange contribution is determined by the following amplitude:

$$T_1 = \bar{u}(p_2)\gamma_5 u(p_1) g_{\pi^0 pp} \frac{F(Q)}{Q^2 + m_\pi^2} \mathrm{i}(q_1 - Q)_\mu \epsilon_2{}^\mu g_{K^{*-}K^-\pi^0} \tag{2}$$

where ϵ_2^μ is the polarization vector of the K* meson. The momenta and masses are labelled in figure 1. $F(Q)$ is the suitable form factor to account for the off-mass-shell

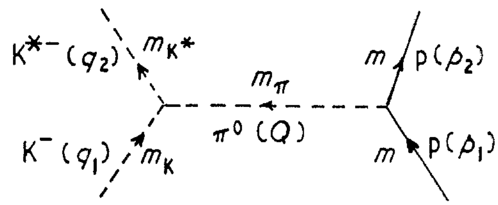

Figure 1. The one-pion-exchange diagram for the reaction $K^- + p \to K^{*-} + p$.

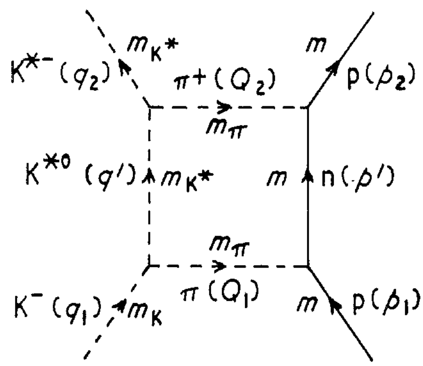

Figure 2. The two-pion-exchange diagram for the reaction $K^- + p \to K^{*-} + p$.

nature of the intermediate pion. We have chosen (Chan and Liu 1965)

$$F(Q) = \exp\{-2(Q^2+m_\pi{}^2)\}.$$

We assume that (i) the two-pion exchange diagram in the t channel can be approximated by the rescattering box diagram shown in figure 2, and (ii) the imaginary part of the amplitude gives the dominant contribution. The imaginary part of the amplitude is obtained by simply putting the s-channel particles K^{*0}, n on the mass shell implying that the reaction proceeds in two steps:

$$K^- + p \to K^{*0} + n \to K^{*-} + p.$$

Then the absorptive part of the amplitude can be written (Singh and Agarwal 1969) as

$$T_4 = \frac{g_{\pi^+pn}g_{K^{*-}K^{*0}\pi^-}g_{\pi^-pn}g_{K^{*0}K^-\pi^-}|q'|m}{16\pi^2 W}\int d\Omega'\,\bar{u}(p_2)$$
$$\times\,\gamma_5\frac{-i\gamma\,.\,p'+m}{2m}\gamma_5 u(p_1)\frac{1}{Q_1{}^2+m_\pi{}^2}2\epsilon_{\alpha\beta\gamma\delta}$$
$$\times\,q'^\alpha q_1{}^\beta q_2{}^\gamma\epsilon_2{}^\delta\frac{1}{Q_2{}^2+m_\pi{}^2} \qquad (3)$$

where $d\Omega = d\cos\theta'\,d\phi'$, and θ' and ϕ' are the centre-of-mass scattering and azimuthal angles of the intermediate particles. The integral in equation (3) can be evaluated by noting that the function

$$F = \frac{1}{(Q_1{}^2+m_\pi{}^2)(Q_2{}^2+m_\pi{}^2)}$$

is a rapidly varying function of $\cos\theta'$ and hence essentially determines the angular distribution. In the remaining integrand we put $\cos\theta' = 1$ for which F is maximum. Equation (3) then gives

$$T_4^{\mathrm{abs}} = \frac{g_{\pi^+pn}g_{K^{*-}K^{*0}\pi^-}g_{\pi^-pn}g_{K^{*0}K^-\pi^-}}{16\pi W}|q'|\,Y\bar{u}(p_2)\gamma_5$$
$$\times\,(-i\gamma\,.\,p'+m)\gamma_5 u(p_1)2\epsilon_{\alpha\beta\gamma\delta}q'^\alpha q_1{}^\beta q_2{}^\gamma\epsilon_2{}^\delta \qquad (4)$$

where

$$Y = \frac{1}{4|\boldsymbol{q}_1|\,|\boldsymbol{q}'|^2|\boldsymbol{q}_2|\sqrt{-\beta}}\ln\left(\frac{\alpha_1\alpha_2-\cos\theta+\sqrt{-\beta}}{\alpha_1\alpha_2-\cos\theta-\sqrt{-\beta}}\right)$$

$$\alpha_1 = \frac{2q_{10}q'_0-m_{K^*}{}^2-m_K{}^2+m_\pi{}^2}{2|\boldsymbol{q}_1|\,|\boldsymbol{q}'|}$$

$$\alpha_2 = \frac{2q_{20}q_0'-2m_{K^*}{}^2+m_\pi{}^2}{2|\boldsymbol{q}_2|\,|\boldsymbol{q}'|}$$

$$\beta = 1-\cos^2\theta-\alpha_1{}^2-\alpha_2{}^2+2\alpha_1\alpha_2\cos\theta$$

and

$$\cos\theta = \hat{q}_2\,.\,\hat{q}_1.$$

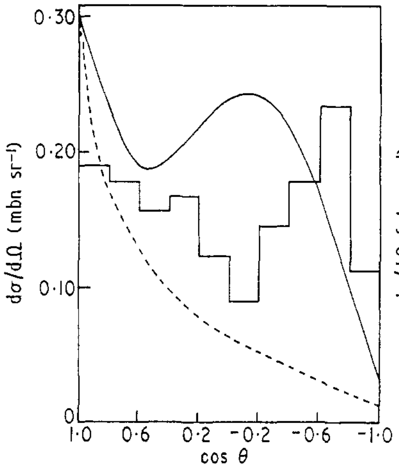

Figure 3(*a*). The production angular distribution for K* production in the reaction (1) at 1·22 BeV c^{-1}. The histogram represents the experimental data of Alston *et al.* (1962). The broken curve shows the contribution of one-pion exchange only and the full curve shows the result of including the two-pion exchange contribution.

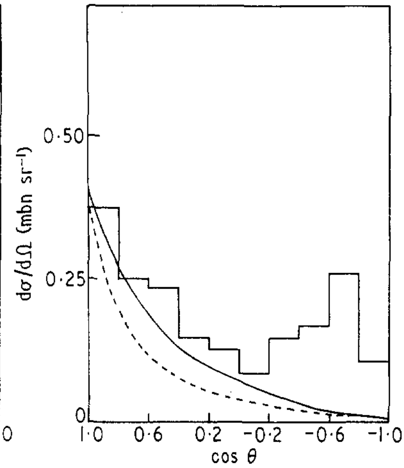

Figure 3 (*b*). The production angular distribution for K* production in the reaction (1) at 1·46 BeV c^{-1}. The histogram represents the experimental data of Alston *et al.* (1962). The broken curve shows the contribution of one-pion exchange only and the full curve shows the result of including the two-pion exchange contribution.

The usual sum over polarization and spin states gives

$$\frac{d\sigma}{d\Omega} = \frac{0{\cdot}3894\, g^2_{K^{*0}K^-\pi^-} g^2_{K^{*-}K^{*0}\pi^-} g^2_{\pi^+ pn} g^2_{\pi^- pn}}{512(2\pi W)^4} |q'|^2 \frac{|q_2|}{|q_1|} F_1 F_2 Y^2 \qquad \text{mbn sr}^{-1}$$

where

$$F_1 = 2\{(m^2+p_1 \cdot p')(m^2+p_2 \cdot p')\}$$

$$F_2 = -[-m_{K^*}^2\{m_K^2 m_{K^*}^2 - q_1 \cdot q_2^2\} - q_1 \cdot q'\{-m_{K^*}^2(q_1 \cdot q') - (q_1 \cdot q_2)(q_2 \cdot q')\} - q_2 \cdot q'\{-m_K^2 q_2 \cdot q' - (q_1 \cdot q')(q_2 \cdot q_1)\}].$$

We can calculate the $K^*K\pi$ coupling from the decay using

$$\frac{g^2_{K^*K\pi}}{4\pi} = \frac{3\Gamma_{K^*} m_{K^*}^2}{2K_{K^*}^3}$$

where K_{K^*} is the centre-of-mass momentum in the πK channel. $g_{KK^*\pi}/4\pi = 1{\cdot}0$. For $K^*K^*\pi$ coupling we shall use the relation (Chan and Liu 1965) $g_{K^*K^*\pi}/\sqrt{2} = g_{\rho\pi\pi}/M_0$ where $M_0 = 378$ BeV. This gives $g_{K^*K^*\pi}/4\pi = 8{\cdot}4$.

3. Results and discussions

The results of our calculation are shown in figure 3. We find a forward peaking together with a hump in the backward hemisphere for the incident K^- momentum of 1·22 BeV c^{-1} (figure 3(*a*)). The predicted hump does not exactly coincide with the observed hump but is in the correct direction. The broken curve shows the contribution from one pion pole. Thus the two-pion exchange contribution is comparable

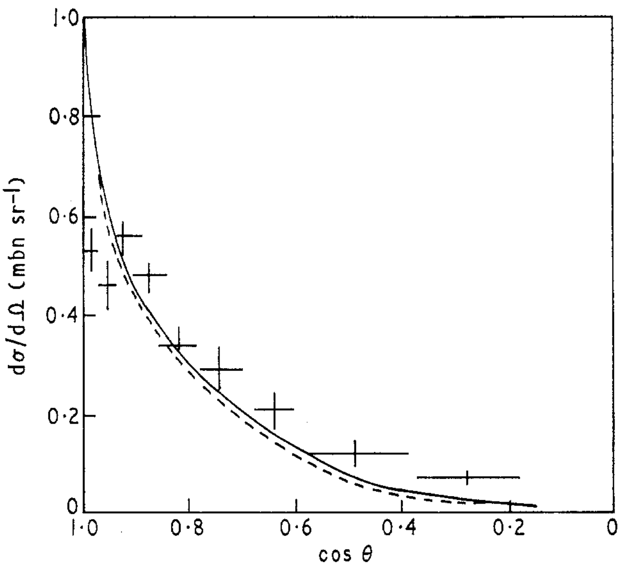

Figure 3(*c*). The production angular distribution for K* production in the reaction (1) at 2·10 BeV c^{-1}. The experimental data are those of Friedman and Ross (1966). The broken curve shows the distribution of one-pion exchange only and the full curve shows the result of including the two-pion exchange contribution.

with the one-pion pole contribution at this energy. As the energy is increased the strong energy dependence of the square diagram contribution allows the pion pole contribution to dominate, which is again in agreement with experiments. At 2·1 BeV c^{-1} (figure 3(*c*)) the pion pole contribution accounts for the entire histogram.

Our results definitely show that two-pion exchange contributions play an important role in the energy region, where they compete with the one-particle exchange contribution.

Acknowledgments

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References

Alston, M. H., Kabfleisch, G. R., Ticho, H. K., and Wojcick, S. G., 1962, *Proc. Int. Conf. on High Energy Physics, Geneva*, Ed. J. Prentki (Geneva: Cern Scientific Information Service), p. 291.

Chan, C. H., and Liu, Y. S., 1965, *Nuovo Cim.*, **35**, 298–307.

Friedman, J. H., and Ross, R. R., 1966, *Phys. Rev. Lett.*, **16**, 485–95.

Gelsema, E. S., *et al.*, 1963, *Proc. Sienna Int. Conf. on Elementary Particles and High Energy Physics*, Eds G. Bernardini and G. P. Puppi (Bologna: Società Italiana di Fisica), p. 170.

Lyons, L., 1966, *Nuovo Cim.*, **43A**, 888–910.

Singh, C. P., and Agarwal, B. K., 1969, *Phys. Rev.*, **177**, 2350–2.