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LETTER TO THE EDITOR

# Odorico zeros for exotic exchange processes

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**Abstract.** On assuming that the exotic exchange reaction $\pi^- p \to \Sigma^- K^+$ occurs as a result of multiple non-exotic exchanges $\pi^- p \to \rho^0 n \to \Sigma^- K^+$, we find that the imaginary parts of the invariant amplitudes $A$ and $B$ for the above reaction show Odorico zeros at almost fixed and small value of momentum transfer. The recent phase shift analysis of Langbein and Wagner supports our result.

Recently we have calculated (Saxena *et al* 1970) the contributions to the exotic exchange reaction

$$\pi^- + p \to \Sigma^- + K^+, \tag{1}$$

in which the reaction $\pi^- p \to \rho^0 n$ feeds the final-state interaction. We have thus evaluated the contribution to Im $T$ from a two-particle intermediate state $\rho^0 n$ and making $t$-channel single-pole approximations to the amplitudes for the processes $\pi^- p \to \rho^0 n$, $\rho^0 n \to \Sigma^- K^+$. The imaginary part of the amplitude thus constructed accounts well for the observed production angular distributions and the strong energy dependence of the cross section without using any arbitrary parameter. The purpose of this letter is to show that the imaginary parts of the invariant amplitudes $A$ and $B$ for the above reaction give Odorico zeros (Odorico 1971) at small value of $t$ and they are almost independent of energy. The recent energy-independent phase shift analysis of Langbein and Wagner (1973) clearly displays the presence of this behaviour for Odorico zeros for the reaction $\pi^- p \to \Sigma^- K^+$.

With the definition of the invariant amplitudes given as

$$\bar{u}(p_2) T u(p_1) = \bar{u}(p_2)[-A(s,t) + i\gamma \cdot Q B(s,t)] u(p_1), \tag{2}$$

we find on using the standard Feynman rules and our method (Agarwal *et al* 1971, Singh and Agarwal 1969) of evaluation of the resulting integral that the invariant amplitudes arising from the box diagram take the forms (Singh 1973):

$$\begin{aligned} \mathrm{Im}\, A = {} & \frac{Y|\boldsymbol{q}'|}{4\pi\sqrt{s}} g_{\rho\pi\pi} g_{\rho K\bar{K}} g_{\bar{K}n\Sigma} g_{np\pi} \left[ m_p \frac{|\boldsymbol{q}'|}{|\boldsymbol{q}_1|} + \frac{1}{2}(m_p + m_\Sigma)\left(p_0' - p_{10}\frac{|\boldsymbol{q}'|}{|\boldsymbol{q}_1|}\right) + m_p \right] \\ & \times \left[ q_2 \cdot q_1 + \left( \boldsymbol{q}_2 \cdot \boldsymbol{q}_1 \frac{|\boldsymbol{q}'|}{|\boldsymbol{q}_1|} - q_{20} q_0' \right) \frac{|\boldsymbol{q}_1||\boldsymbol{q}'| - q_{10} q_0'}{m_\rho^2} \right] \end{aligned} \tag{3}$$

and

$$\begin{aligned} \mathrm{Im}\, B = {} & -\frac{Y|\boldsymbol{q}'|}{4\pi s} g_{\rho\pi\pi} g_{\rho K\bar{K}} g_{np\pi} \left( p_0' - p_{10} \frac{|\boldsymbol{q}'|}{|\boldsymbol{q}_1|} \right) g_{\bar{K}n\Sigma} \left[ q_2 \cdot q_1 + \left( \boldsymbol{q}_2 \cdot \boldsymbol{q}_1 \frac{|\boldsymbol{q}'|}{|\boldsymbol{q}_1|} - q_{20} q_0' \right) \right. \\ & \left. \times \frac{|\boldsymbol{q}_1||\boldsymbol{q}'| - q_{10} q_0'}{m_\rho^2} \right], \end{aligned} \tag{4}$$

where

$$Y = \frac{1}{4|q_1|\,|q'|^2\,|q_2|}\frac{1}{\sqrt{-\beta}}\ln\left(\frac{\alpha_1\alpha_2-\cos\theta+\sqrt{-\beta}}{\alpha_1\alpha_2-\cos\theta-\sqrt{-\beta}}\right)$$

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

$$\alpha_1 = \frac{2q_{10}q_0'-m_\rho^2}{2|q_1|\,|q'|}$$

$$\alpha_2 = \frac{2q_{20}q_0'-m_\rho^2}{2|q_2|\,|q'|}$$

$$\cos\theta = \frac{q_2\cdot q_1}{|q_2|\,|q_1|},$$

and $|q_1|$, $|q'|$ and $|q_2|$ are the magnitudes of the centre-of-mass momentum of the initial, intermediate and final mesons, respectively. Also $p_0'(q_0')$ is the centre-of-mass energy of the intermediate $n(\rho^0)$ particle, $p_{20}(q_{20})$ is the centre-of-mass energy of the final $\Sigma$(K) particle and $p_{10}(q_{10})$ is the centre-of-mass energy of the initial $p(\pi)$ particle.

The results of our calculation of Odorico zeros for the imaginary parts of the invariant amplitudes $A$ and $B$ are shown in figure 1. Our result for either Im $A$ or Im $B$

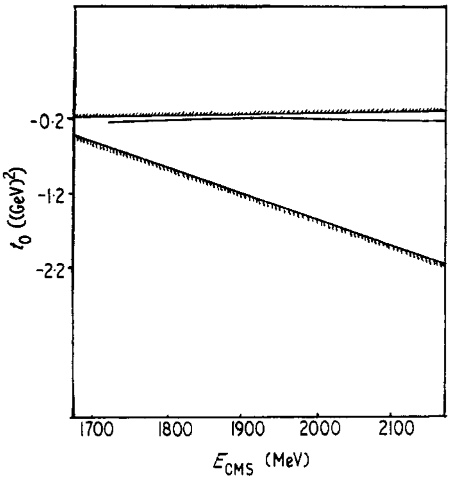


**Figure 1.** The calculated $t$ values of the zeros of the Im $A$ or Im $B$ invariant amplitudes for reaction (1) have been shown by a full curve as function of the CM energy. The region between the shaded lines exhibits the physical region.

clearly shows Odorico zeros at almost fixed value of momentum transfer ($t \simeq -0{\cdot}2$) which is in close agreement with the result of Langbein and Wagner. These results thus further demonstrate the significant role of the box diagram amplitudes for the exotic exchange processes constructed from an iteration of amplitudes without exotic exchange connected by on-mass-shell two-body or quasi-two-body intermediate states.

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