Comments and Addenda

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Associated Production of $\Sigma^- K^+$ in the Rescattering Model

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

RECENTLY the Lawrence Radiation Laboratory group has studied[1] the associated production reaction

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

in the energy range 1.5–4.0 BeV/c. They find (i) a backward peak in the angular distribution and (ii) strong energy dependence for the cross section. The single-baryon-exchange diagram can give only a qualitative description of the backward peaking. In fact, it predicts much too high a cross section. We have shown[2] that for the u channel of reaction (1), $K^- + p \to \Sigma^- + \pi^+$, the lowest singularity is given by the exchange of two mesons in the t channel. A look at the diagram given in Fig. 2 of Ref. 2 will convince one that a similar situation arises for reaction (1). Consequently, we can again hope that (1) receives the dominant contribution from a two-meson-exchange graph. The purpose of this paper is to investigate this possibility and to find support for earlier findings.[2]

We represent the two-meson-exchange graph by the rescattering square diagram shown in Fig. 1. The cuts indicate that we have put the s-channel particles on their mass shell. Thus we are regarding reaction (1) as a two-step process

$$\pi^- + p \to \rho + n \to \Sigma^- + K^+ . \tag{2}$$

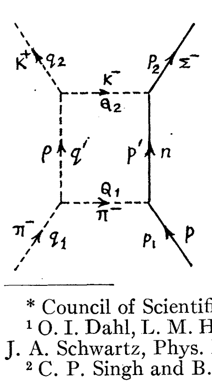

FIG. 1. Rescattering diagram for $\pi^- + p \to K^+ + \Sigma^-$.

The absorptive part of the amplitude can then be written as[2]

$$T_4^{\rm abs} = \frac{Y|\mathbf{q}'|}{8\pi W}\bar{u}(p_2) g_{\Sigma^- K^- n}\gamma_5(-i\gamma\cdot p' + m)\gamma_5 g_{np\pi^-}$$
$$\times i g_{\rho K^- K^+}(q_2 - Q_2)_\nu(\delta_{\mu\nu} + q_\mu' q_\nu'/m_\rho^2)$$
$$\times i g_{\rho\pi\pi}(q_1 + Q_1)_\mu u(p_1)\cdots, \tag{3}$$

where

$$Y = \frac{1}{8|\mathbf{q}_1|\,|\mathbf{q}'^2|\mathbf{q}_2|}\frac{1}{\sqrt{(-\beta)}}\ln\frac{\alpha_1\alpha_2 - \cos\theta + \sqrt{(-\beta)}}{\alpha_1\alpha_2 - \cos\theta - \sqrt{(-\beta)}},$$

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

$$\alpha_1 = \frac{2q_{10}q_0' - m_\rho^2}{2|\mathbf{q}_1|\,|\mathbf{q}'|}, \quad \alpha_2 = \frac{2q_{20}q_0' - m_\rho^2}{2|\mathbf{q}_2|\,|\mathbf{q}'|},$$

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

Two of the couplings occurring in Eq. (3) are well known: $g_{pp\pi}^2/4\pi = 15$ and $g_{\rho\pi\pi}^2/4\pi = 2.4$. We can relate the $\rho K\bar{K}$ coupling with the $\rho\pi\pi$ coupling by invoking $SU(3)$, $g_{\rho\pi\pi}^2 = 2g_{\rho K\bar{K}}^2$. We adjust the remaining coupling, $g_{p\bar{K}\Sigma^-}^2/4\pi = 1.5$, so as to obtain correct normalization with the experimental curve at 2.35 BeV/c. This value is close to $SU(3)$ value when the mixing parameter is taken to be 0.34. The other model-dependent values are <1 in the constant-scattering-length ap-

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[1] O. I. Dahl, L. M. Hardy, R. I. Hess, J. Kirz, D. H. Miller, and J. A. Schwartz, Phys. Rev. **163**, 1430 (1967).
[2] C. P. Singh and B. K. Agarwal, Phys. Rev. **177**, 2350 (1969).

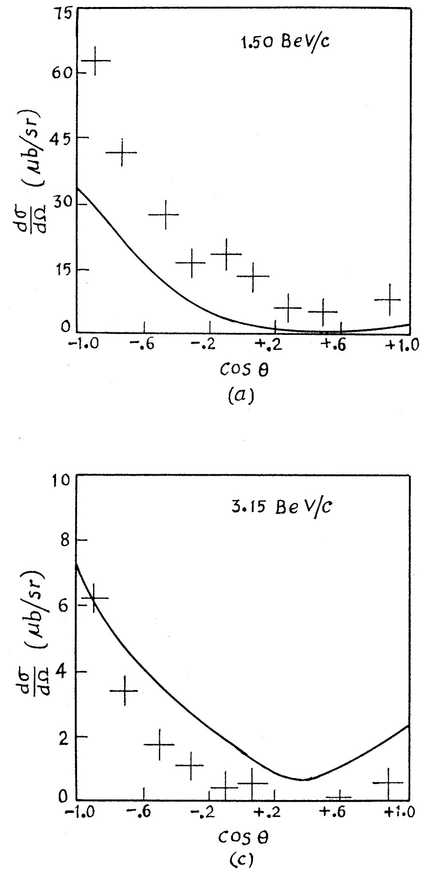

FIG. 2. Production angular distribution in reaction (1) at a π momentum of (a) 1.50, (b) 2.35, (c) 3.15, and (d) 4.00 BeV/c. The solid curve is the theoretical prediction. The histogram represents the experimental data of Dahl *et al.* (Ref. 1).

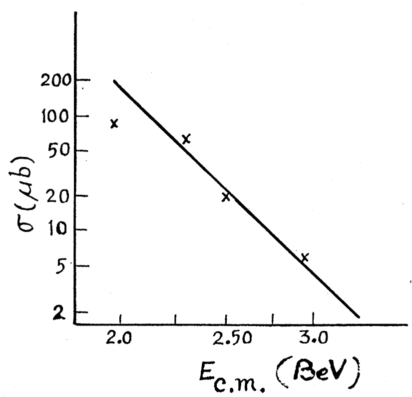

FIG. 3. Variation of total cross section for the process $\pi^- + p \to \Sigma^- + K^+$ with center-of-mass energy. The line represents the experimental data (Ref. 1) and the points yield our calculation.

proximation[3] and <3 in the multichannel-effective-range approximation.[4] Thus our value appears to be reasonable.

In Fig. 2, we compare the predicted angular distribution with the experimental results at incident momenta 1.5, 2.35, 3.15, and 4.00 BeV/c. The calculated curves are in reasonable agreement both in magnitude and shape with the experiments. The energy dependence is also favorably reproduced. This can be easily seen from Fig. 3, where we have plotted the total cross section against the total energy. The theoretical points lie along the experimental curve. The departure at 1.93 BeV, which corresponds to incident momentum 1.5 BeV/c, indicates that the rescattering model works well when we are not too close to the threshold.

[3] N. Novko, Phys. Letters **23**, 143 (1966).

[4] J. K. Kim, Phys. Rev. Letters **19**, 1074 (1967); **19**, 1079 (1967).