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MODEL FOR LOW-ENERGY KAON-NUCLEON SCATTERING

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The algebra of currents together with the hypothesis of partially conserved axial current predict for the meson-nucleon scattering lengths values which are in good agreement with experimental results [1]. Mani et al. [2] have shown that, with a model based on an effective Lagrangian satisfying to lowest order the conditions of algebra of currents and PCAC, it is possible to obtain for the pion-nucleon low energy parameters values which are in very good agreement with the available

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experimental data. Such an effective Lagrangian has to include a contact term in order to preserve the well known success of the ρ dominance model in the prediction of the pion-nucleon low energy data. The very interesting point is that the model has no free parameters, since all coupling constants are determined elsewhere.

It would certainly be interesting to build and test a similar model, describing low energy K-N scattering. Of course in this case no model can be proved to work extremely well because information is rather poor both on the values of the coupling constants and on the experimental values of the low energy parameters. By analogy with the successful model used by Mani et al.[2] in the $\pi - N$ case, we then propose for the K-N scattering the following effective Lagrangian:

$$L_I' = -(f_\Lambda/m_K)(i\,\bar\psi\,\gamma_5\,\gamma_\mu\,\psi_\lambda\,\partial_\mu\,\phi_K + c.c.) - (f_\Sigma/m_K)(i\,\bar\psi\gamma_5\gamma_\mu\tau^\alpha\psi_\Sigma^\alpha\partial_\mu\phi_K + c.c.)$$
$$- g\,J_\lambda^\alpha\rho_\lambda^\alpha - J_\lambda^Y(g'\,\varphi_\lambda + g''\,\omega_\lambda)$$

J_λ^α and J_λ^Y are the isotopic spin and hypercharge currents [3]:

$$J_\mu^\alpha = i\,\bar\psi\,\gamma_\mu\,\frac{\tau^\alpha}{2}\psi + i(\partial_\mu\,\phi_K^+\,\frac{\tau^\alpha}{2}\,\phi_K - \phi_K^+\,\frac{\tau^\alpha}{2}\,\partial_\mu\,\phi_K) + \ldots$$

$$J_\mu^Y = i\,\bar\psi\,\gamma_\mu\psi + i(\partial_\mu\,\phi_K^+\,\phi_K - \phi_K^+\,\partial_\mu\,\phi_K) + \ldots$$

where ψ, ψ_Λ, ψ_Σ^α and ϕ_K, ρ_λ^α, φ_λ, ω_λ are the fields of the N, Λ, Σ baryons and of the K, ρ, φ, ω mesons respectively. For a more complete analogy with the pion-nucleon case we can define:

$$J^{\alpha}_{\mu} = i\,\overline{\psi}\,\gamma_{\mu}\,\frac{\tau^{\alpha}}{2}\,\psi + i(\pi^{\alpha+}_{\mu}\,\phi_K - \phi^{+}_{K}\,\pi^{\alpha}_{\mu}) + \ldots$$

$$J^{Y}_{\mu} = i\,\overline{\psi}\,\gamma_{\mu}\,\psi + 4i\,(\pi^{Y}_{\mu}\phi_K - \phi^{+}_{K}\,\pi^{Y}_{\mu}) + \ldots$$

where:

$$\pi^{\alpha}_{\mu} = \frac{\partial L}{\partial\left(\frac{\tau^{\alpha}}{2}\partial_{\mu}\,\phi_K\right)} = -\frac{1}{4}\,\frac{\tau^{\alpha}}{2}\,\partial_{\mu}\,\phi_K - f_{\Sigma}/m_K(i\,\overline{\psi}\,\gamma_5\,\gamma_{\mu}\,\psi^{\alpha}_{\Sigma} + \text{c.c.})$$

$$+ g\,\phi^{+}_{K}\,\rho^{\alpha}_{\mu}$$

$$\pi^{Y}_{\mu} = \frac{\partial L}{\partial\left(\partial_{\mu}\,\phi_K\right)} = -\frac{1}{4}\,\partial_{\mu}\,\phi_K - f_{\Lambda}/m_K(i\,\overline{\psi}\,\gamma_5\,\gamma_{\mu}\,\psi_{\Lambda} + \text{c.c.})$$

$$+ \phi^{+}_{K}\,(g'\,\varphi_{\mu} + g''\,\omega_{\mu})$$

In this last formula the definition of π^{Y}_{λ} as a derivative of the Lagrangian is only formal, in the sense that the derivative with respect to $\partial_{\mu}\phi_K$ is to be taken only in the terms where this quantity does not appear in the form $\tau^{\alpha}\partial_{\mu}\phi_K$.

From π^{α}_{μ} and π^{Y}_{μ} in a manner similar to that of reference 2 we can define axial currents and write commutation relations.

The above Lagrangian does not include a possible direct exchange of $S = +1$ baryons, since these are not well established [4], and limits the contributions of crossed terms to the Λ and Σ exchanges, neglecting isobar contributions (Y^{*}_{0} and Y^{*}_{1} exchanges). This is due to the fact that by comparing the K - N to the π - N singularities we may expect to have a vector boson exchange dominance and a weak contribution coming from the crossed physical cut.

We use for the coupling constants g, g' and g" the values obtained by Scotti and Wong [5] in their analysis of the nucleon-nucleon interaction. Neglecting the magnetic coupling for the ρ mesons, we obtain from the first solution of Scotti and Wong $g^2/4\pi = g_\rho^2 = 1.27$, $g'^2/4\pi = g_\varphi^2/4 = 0.565$ and $g''^2/4\pi = g_\omega^2/4 =$ $= 0.6925$. Adopting the second set of solutions of Scotti and Wong causes only slight changes in the results that follow, so that we restrict ourselves to the values obtained with the first set.

By taking into account only the contributions of ρ, φ and ω exchanges, we obtain for the s wave scattering lengths a_I in K - N states with isotopic spin I = 0 and I = 1 the values $a_o = 0.01$ f and $a_1 = -0.28$ f, to be compared with the experimental values [6] $a_o = -0.11 \pm 0.66$ and $a_1 = -0.26 \pm 0.02$ or [7] $a_o = 0.04 \pm 0.04$ and $a_1 = 0.29 \pm 0.01$.

This agreement with experimental data indicates the validity of a vector boson exchange model in the K - N system. In order to keep this pleasant result, we follow the arguments of Mani et al., and add to the effective Lagrangian a contact term which compensates for the contributions of the Λ and Σ crossed Born terms. That is, we write:

$$L_I = L_I' - \left[\frac{m_k^2}{m + m_\Lambda - m_k} \left(\frac{f_\Lambda}{m_k} \right)^2 - \frac{m_k^2}{m + m_\Sigma - m_k} \left(\frac{f_\Sigma}{m_k} \right)^2 \right] \bar{\psi}\, \phi_K\, \phi_K^+\, \psi + $$

$$+ \frac{2m_k^2}{m + m_\Sigma - m_k} \left(\frac{f_\Sigma}{m_k} \right)^2 \bar{\psi}\, \psi\, \phi_K^+\, \phi_K$$

where the ordering of the fields determines the isotopic spin dependence. If we include in the Lagrangian terms corresponding to the crossed Y_o^* and Y_1^* exchanges, adequate contact terms have to be introduced in order to preserve the vector boson exchange dominance.

The values of the s wave scattering lengths a_I, effective ranges r_I, and p wave scattering lengths $a_{2J,I}$ are given in table I. We present figures obtained with a pure vector-boson dominance model, and with a model consisting of vector boson exchange plus Λ and Σ crossed terms, plus contact terms. We have used $f_\Lambda^2 = 0.348$ (corresponding to $g_{N\Lambda K}^2/4\pi = 6.$) and $f_\Sigma^2 = 0.107$ (corresponding to $g_{N\Sigma K}^2/4\pi = 2$). These values for these coupling constants are of the order of magnitude suggested by analysis of experimental data [8]. The results given in table I however are not very sensitive to these values, except in the case I = 0 if the ratio $g_{N\Lambda K}^2/g_{N\Sigma K}^2 = 3$ is not mantained.

We call attention to the fact that in this calculation we have no free parameters. From the results indicated in the table we first conclude that a pure vector meson exchange model describes reasonably well the available data. On the other hand by introducing Σ and Λ exchange together with the corresponding contact terms, although not affecting the s wave scattering lengths, we may alter in an undesired way some of the smaller or less well known parameters. This may indicate that inclusion of contributions corresponding to Y_o^* and Y_1^* exchanges should be included when better data are available.

Table 1

	a_o	a_1	r_1	a_{10}	a_{11}	a_{30}	a_{31}
vector bosons exchange only	-0.01	-0.28	1.9	-0.002	-0.08	0.001	-0.01
vector bosons and Λ, Σ exchange	∓ 0.01	-0.28	-2.4	0.01	-0.16	0.001	0.005
experiments	-0.11 ± 0.06 or 0.04 ± 0.04	-0.26 ± 0.02 or -0.29 ± 0.01	0.5 ± 0.15		small		small

Table 1 - Values of low energy K - N scattering parameters in fermi units. a_I and r_I are the scattering lengths and effective ranges in isotopic spin state I. The effective range for I = 0 is meaningless because a_o is very small. The p wave scattering lengths are indicated by $a_{2J,I}$. Experimental results from references 6 and 7.

REFERENCES:

1. A. P. Balachandran, M. G. Gundzik, F. Nicodemi - Nuovo Cimento **44**, 1257 (1966).
2. H. S. Mani, Y. Tomozawa, York-Peng Yao - Phys. Rev. Letters **18**, 1084 (1967).
3. J. J. Sakurai - Annals of Phys. **11**, 1 (1960).
4. J. Meyer - Report on "Baryonic Resonances with S $\neq$ 0", Heildelberg International Conference on Elementary Particles, 1967.
5. A. Scotti, D. Y. Wong - Phys. Rev. **138B**, 145 (1965).
6. R. Chand - Bull. Am. Phys. Soc. **11**, 37 (1966).
7. V. J. Stenger, W. E. Slater, D. M. Stork, H. T. Ticho, G. Goldhaber, S. Goldhaber - Phys. Rev. **134B**, 1111 (1964).
8. N. Zovko - Phys. Letters **23**, 143 (1966).

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