The Coupling Constants of Strong Interactions

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From the recent experiments about the strange particles it is known that there are several strong interactions. In this paper we shall estimate the order of the magnitude of these coupling constants by the perturbation methods. For this purpose the experimental data on the \( K^+ \)-nucleon scattering, the \( \pi^- \)-proton scattering, and the strange particle production by the \( \pi^- \)-proton collision are used.

If we assume the spin \( \frac{1}{2} \) for \( \Lambda \) and \( \Sigma \) particles, there are four possible assignments of their parities; namely \( \alpha \) : \( \Lambda \) is \( \frac{3}{2}^- \) and \( \Sigma \) is \( \frac{1}{2}^- \), \( \beta \) : \( \Lambda \) is \( \frac{1}{2}^+ \) and \( \Sigma \) is \( \frac{3}{2}^- \), \( \gamma \) : \( \Lambda \) is \( \frac{3}{2}^- \) and \( \Sigma \) is \( \frac{1}{2}^+ \), \( \delta \) : \( \Lambda \) is \( \frac{3}{2}^+ \) and \( \Sigma \) is \( \frac{1}{2}^- \).

We assume furthermore that the nucleon is \( \frac{1}{2}^+ \) and the \( K \) particle is \( 0^+ \), then we can take the simplest interaction Hamiltonian densities as follows,

\[
\begin{align*}
H_{NN\pi} &= i g_N^2 \gamma_{1/2} \Pi \gamma_{1/2} \phi_{\pi} \phi_{\Lambda} + H \cdot C \\
H_{N\Lambda K} &= G_1^2 \gamma_0 \Pi \gamma_0 \phi_{\pi} \phi_{K} + H \cdot C \\
H_{N\Sigma K} &= G_2^2 \gamma_2 \Pi \gamma_2 \phi_{\pi} \phi_{K} + H \cdot C \\
H_{\Lambda \Sigma} &= g_3^2 \gamma_3 \Pi \gamma_3 \phi_{\pi} \phi_{\Lambda} + H \cdot C \\
H_{\Sigma \Sigma} &= g_4^2 \gamma_4 \Pi \gamma_4 \phi_{\pi} \phi_{\Lambda} + H \cdot C
\end{align*}
\]

where \( \Pi \) is either \( i \gamma_0 \) or 1.

The value of the \( NN\pi \) coupling constant, \( g_N^2/4\pi \doteq 10 \), for \( ps(\bar{p}s) \) interaction has been estimated from low energy phenomena, but if we adopt here this value, it leads to the unfavorable results. Assuming that \( g_N^2/4\pi \) should be adjusted at each energy in the case of calculation by the lowest order perturbation, we determine the value of effective coupling constant \( g_N^2/4\pi \) at the higher energy \( \sim 1.3 \text{ BeV} \) (kinetic energy of \( \pi \) mesons in the laboratory system). According to Walker, the elastic scattering cross section at 1.3 BeV is 2\( \sim 3 \text{ mb} \) extracting the shadow scattering (\( \theta < 60^\circ \)). From this data we obtain the value of the \( NN\pi \) coupling constant, \( 1.6 \lesssim g_N^2/4\pi \lesssim 2.0 \).

Lannutti et al. observed the nuclear interactions of \( K^+ \) mesons in flight in energy region of \( 30 \sim 120 \text{ MeV} \). These
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cross sections are 6 mb per nucleon. Furthermore there are 4 charge exchange events and 36 non-exchange ones, namely $36/4=R$. While, according to the Göttingen group the cross section of the elementary process, $K^+ + p \rightarrow p + K^+$ is $14 \sim 18$ mb. To see how to choose the values of the coupling constants when we adopt various experimental data, we use 6 mb as the lower limit for the cross section, while 18 mb as the upper limit from the perturbational expressions for various cross sections, and take $R = 36/4 = 5 \sim 15$. The we obtain the two possible sets of values for the NAK coupling constant $G_s^2/4 \pi$ and the NΣK coupling constant $G_s^2/4 \pi$ at 50 MeV in the cases $\alpha$) and $\beta)$. The results are given in Table 1. But in the cases $\gamma)$ and $\delta)$ we find no solutions.

We have no experimental data about $K^+$-nucleon scattering at high energy $\geq 500$ MeV. But we assume that the order of magnitude of $G_s^1/4 \pi$, $G_s^2/4 \pi$ at high energy is the same as that of the ones at 50 MeV.

By Forler et al. or Steinberger et al., the cross sections of the strange particle production in $\pi^- + p$ collision are $\sim 1$ mb at 1.3 BeV. Moreover Steinberger et al. observed 37 neutral particle production.

From these data and above mentioned values of $g_s^2/4 \pi$, $G_s^2/4 \pi$ and $G_s^2/4 \pi$, we can obtain the four possible values for the $\Lambda \Sigma \Pi$ coupling constant $g_s^2/4 \pi$ and the $\Sigma \Xi K$ coupling constant $g_s^2/4 \pi$ which are listed in Table 1.

We have no reason to exclude any of these eight types of solutions in Table 1. However if we take the (B) solution for the assignment $\alpha)$ which contains $\bar{g}_3$ in interaction Hamiltonians, the values of these five coupling constants are of the same order of magnitude. Thus it seems to be possible to assume universality of coupling constants. This possibility for the strong interaction, however, is based on the results obtained by the lowest order perturbation. Therefore, in future, with more accumulated experiments and improved methods of calculation, we shall again discuss this attractive possibility.

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Table 1

<table>
<thead>
<tr>
<th>case $\alpha$</th>
<th>case $\beta$</th>
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<tr>
<td>$1.9 \leq G_s^1/4 \pi \leq 3.4$</td>
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<tr>
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<td>$9 \leq g_s^2/4 \pi \leq 14$</td>
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<td>$0 \leq g_s^2/4 \pi \leq 0.3$</td>
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