Meson-Baryon coupling constants in QCD sum rules

Erkol, Güray

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2006

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
In this work, we have used the external-field QCDSR method in order to evaluate the meson-baryon constants. We considered the vacuum-to-vacuum transition matrix element of two baryon interpolating fields in an external meson field. In this approach, one has to know the response of the various condensates in the vacuum to the external field, which can be described by various susceptibilities. We have used the values of these susceptibilities as estimated from various theoretical and phenomenological approaches in the literature. We first considered the sum rules in the SU(3)-limit to see if the predicted values for the meson-baryon coupling constants from the sum rules are consistent with the SU(3) relations. We showed that this is indeed the case for the scalar-, vector- and pseudoscalar-meson–baryon couplings which leads to a determination of the $F/(F + D)$ ratio of the scalar, vector and the pseudoscalar octets. Keeping track of these coupling constants with the SU(3) relations, we obtained the complete set of values for the meson-baryon coupling constants. We also considered the SU(3)-breaking effects for the sum rules to size the amount of breaking individually for each coupling. The coupling constants can be determined in terms of meson-quark coupling con-
stants in this method, where one has to rely on some model-dependent calculations. Nevertheless, the ratios of the coupling constants and the obtained values of the $F/(F + D)$ ratios are independent of meson-quark couplings. The typical $20−25\%$ uncertainties in the final results stem from the undetermined QCD parameters. The coupling constants obtained from the external-field QCDSR method are defined at $t = 0$, and therefore the comparison to the OBE model is appropriate. We have compared our results for the coupling constants and the $F/(F + D)$ ratios with the values from a successful OBE model of the NN and YN interaction, the Nijmegen soft-core potential, which was originally derived from Regge-pole theory. We have obtained nice agreement between the QCDSR and the NSC results, especially for the meson-nucleon coupling constants. It will be interesting to see how our QCDSR predictions will affect the Nijmegen potential model analyses in the future.

In Chapter 3, we have calculated the $NN\sigma$, $\Lambda\Lambda\sigma$, $\Xi\Xi\sigma$ and $\Sigma\Sigma\sigma$ coupling constants, which are significant inputs for the $NN$ and $YN$ interactions where the exchange of a $\sigma$ meson is needed to obtain enough medium-range attraction and a sufficiently strong spin-orbit force. We have evaluated the correlation function of the two baryon interpolating fields in the presence of an external constant isoscalar-scalar field and constructed the sum rules. We observed that the scalar-meson–baryon coupling constants, as obtained from the QCDSR, depend on the picture assumed for the structure of the scalar mesons ($q\bar{q}$ or $q^2\bar{q}^2$), whereas the $F/(F + D)$ ratio, which is $\alpha_s = 0.55$, remains intact in the two pictures. The obtained value of the nucleon-sigma coupling constant as $g_{NN\sigma} = 14.4 \pm 3.7$, is in agreement with the large value found in OBE models. One of the most significant coupling constants in this framework is the $\Lambda\Lambda\sigma$ coupling constant as the $\sigma$ exchange plays the most crucial role in $\Lambda\Lambda$ interactions. Our analysis of the $\Lambda\Lambda\sigma$ coupling constant in QCDSR both in the SU(3)-limit and with the SU(3)-breaking effects revealed that this coupling constant is small as compared to the $NN\sigma$ coupling constant. This implies that the $\Lambda\Lambda$ interaction is weak, in accordance with the recent experimental results.

In Chapter 4, we have followed an approach similar to the one above for the vector-meson–baryon coupling constants. We have evaluated the vector and
the tensor coupling constants of the vector mesons $\rho$ and $\omega$ to the $N$, $\Lambda$, $\Xi$ and $\Sigma$ baryons, employing the external-field QCDSR method. For this purpose, we have defined a constant background tensor-field in order to take account of both the vector and the tensor coupling. The values of the susceptibilities $\chi$, $\xi$ and $\kappa$ are relatively better-known from magnetic-moment calculations; we discussed the sensitivity of the results to the unknown vacuum susceptibility $\zeta$. Our results for the coupling constants and the $F/(F+D)$ ratio for the vector coupling, which is $\alpha_v = 1$, are in agreement with those from the OBE potential model and the VMD model. We have obtained $\alpha_m = 0.18$, for the $F/(F+D)$ ratio of the magnetic coupling, which is about half of those obtained in NSC potential model results.

In Chapter 5, we have revisited the calculations of the pion-nucleon coupling constant in the external-field QCDSR method. We have explored the two coupling schemes of the pseudoscalar-mesons to baryons, the pseudoscalar and the pseudovector couplings, which can be related to each other with the Goldberger-Treiman relation. The experimentally well-known value of the pion-nucleon coupling constant together with the nucleon sum rule evaluated in the presence of the external pion field provide an estimation of the pion susceptibility. We have used this estimation to obtain a numerical value for the pion-Delta coupling constant, which is a significant parameter for the pion-nucleon scattering away from threshold and in loop calculations of $\chi$PT. We have also carried out an independent calculation of the Delta axial coupling from the QCDSR, which is related to the pion-Delta coupling constant with the Goldberger-Treiman relation. We found that the two independent calculations lead to consistent results. Our calculations showed that the value of the $\Delta \Delta \pi$ coupling constant is larger than the $NN\pi$ coupling constant.