Strong $\Sigma_b N B$ and $\Sigma_c N D$ vertices in QCD

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Abstract

We study the strong interactions among the heavy bottom spin–1/2 $\Sigma_b$ baryon, nucleon and $B$ meson as well as the heavy charmed spin–1/2 $\Sigma_c$ baryon, nucleon and $D$ meson in the context of QCD sum rules. We calculate the corresponding strong coupling form factors defining these vertices using a three point correlation function. We obtain the numerical values of the corresponding strong coupling constants via different Dirac structures entering the calculations.

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1 Introduction

In the last few years, significant experimental progresses have been made on the spectroscopic and decay properties of heavy hadrons, which accompanied by theoretical studies on various properties of these hadrons. The mass spectrum of the baryons containing heavy quark has been studied via various methods (see for instance [1–11] and references therein). The necessity of a deeper understanding of heavy flavor physics requires a comprehensive study on the processes of baryons containing a heavy quark such as their radiative, strong and weak decays (for some related studies see [12–28] and references therein).

The investigation of the strong decays of heavy baryons can help us get valuable information on the perturbative and non-perturbative natures of QCD. The strong coupling constants defining such decays play important role in describing the strong interaction among the heavy baryons and other participated particles. Therefore, accurate determination of these coupling constants improves our understanding on the interactions as well as the nature and structure of the participated particles. The present work is an extension of our previous study on the coupling constants $g_{\Lambda_bNB}$ and $g_{\Lambda_cND}$ [29]. Here, we study the strong interactions among the heavy bottom spin–1/2 $\Sigma_b$ baryon, nucleon and $B$ meson as well as the heavy charmed spin–1/2 $\Sigma_c$ baryon, nucleon and $D$ meson in the context of QCD sum rules [30]. In particular, we calculate the strong coupling constants $g_{\Sigma_bNB}$ and $g_{\Sigma_cND}$. These coupling constants together with the $g_{\Lambda_bNB}$ and $g_{\Lambda_cND}$ discussed in our previous work, may also be used in the bottom and charmed mesons clouds description of the nucleon which can be used to explain the exotic events observed by different Collaborations. In addition, the determination of the properties of the $B$ and $D$ mesons in nuclear medium requires the consideration of their interactions with the nucleons, i.e.

$$
B^- + p \text{ or } n \to \Lambda_b^0 \text{ or } \Sigma_b^-,
$$
$$
D^0 + p \text{ or } n \to \Lambda_c^+ \text{, } \Sigma_c^+ \text{ or } \Sigma_c^0.
$$

(1)

Therefore, to determine the modifications on the masses, decay constants and other parameters of the $B$ and $D$ mesons in nuclear medium, one needs to consider the contributions of the baryons $\Sigma_b[c]$ together with the $\Lambda_b[c]$ and have the values of the strong coupling constants $g_{\Sigma_bNB}$ and $g_{\Sigma_cND}$ besides the couplings $g_{\Lambda_bNB}$ and $g_{\Lambda_cND}$ [31–35]. In the literature, one can unfortunately find only a few works on the strong couplings of the heavy baryons with the nucleon and heavy mesons. One approximate prediction for the strong coupling $g_{\Lambda_cND}$ was made at zero transferred momentum squared taking the Borel masses in the initial and final channels as the same [19]. The strong couplings of the charmed baryons with the nucleon and $D$ meson were also discussed in [25] in the framework of light cone QCD sum rules.

This paper is organized in three sections as follows. In the next section, we present the details of the calculations of the strong coupling form factors among the particles under consideration. In section 3, the numerical analysis of the obtained sum rules and discussions about the results are presented.
2 Theoretical framework

This section is devoted to the details of the calculations of the strong coupling form factors \( g_{\Sigma a,NB}(q^2) \) and \( g_{\Sigma c,ND}(q^2) \) from which the strong coupling constants among the participating particles are obtained at \( Q^2 = -q^2 = -m_{B[D]}^2 \), subsequently. In order to accomplish this purpose, the following three-point correlation function is used as a starting point:

\[
\Pi(p, p', q) = i^2 \int d^4x \int d^4y \ e^{-ipx} \ e^{ip'y} \langle 0 | T \left( J_N(y) \ J_{B[D]}(0) \ J_{\Sigma a[N]}(x) \right) | 0 \rangle, \tag{2}
\]

where \( T \) denotes the time ordering operator and \( q = p - p' \) is the transferred momentum. The interpolating currents included in the three-point correlation function can be written in terms of the quark field operators as:

\[
J_{\Sigma a[N]}(x) = \varepsilon_{ijk} (u^T(x)C \gamma_\mu d^j(x)) \gamma_5 \gamma_\mu b[c]^k(x),
\]

\[
J_N(y) = \varepsilon_{ijk} (u^T(y)C \gamma_\mu u^i(y)) \gamma_5 \gamma_\mu d^k(y),
\]

\[
J_{B[D]}(0) = \bar{u}(0) \gamma_5 b[c](0),
\]

where \( C \) is the charge conjugation operator; and \( i, j \) and \( k \) are color indices.

In the course of calculation of the three-point correlation function one follows two different ways. In the first way, called as OPE side, the calculation is made in terms of quark and gluon degrees of freedom using the operator product expansion in deep Euclidean region. In the second way, called as hadronic side, one considers the hadronic degrees of freedom to calculate it. The QCD sum rules for the coupling form factors are attained via the match of these two sides. To suppress the contributions of the higher states and continuum a double Borel transformation with respect to the variables \( p^2 \) and \( p'^2 \) are applied to both sides.

2.1 OPE Side

The OPE side of the correlation function which is calculated in deep Euclidean region, where \( p^2 \rightarrow -\infty \) and \( p'^2 \rightarrow -\infty \), requires the insertion of the explicit expressions of the interpolating currents into the correlation function, Eq. (2). Possible contraction of all quark pairs via Wick’s theorem leads to

\[
\Pi^{OPE}(p, p', q) = i^2 \int d^4x \int d^4y e^{-ipx} e^{ip'y} \varepsilon_{abc} \varepsilon_{ij\ell} \times \left\{ \gamma_5 \gamma_\mu S_{ij}^c(y - x) \gamma_\nu C S_{\ell k}^{b[c]}(y - x) C \gamma_\mu S_{\ell k}^{b[c]}(y - x) \gamma_5 \gamma_5 - \gamma_5 \gamma_\mu S_{ij}^c(y - x) \gamma_\nu C S_{\ell k}^{a[b]}(y - x) C \gamma_\mu S_{\ell k}^{a[b]}(y - x) \gamma_5 \gamma_5 \right\}, \tag{4}
\]

where \( S_{b[c]}(x) \) represents the heavy quark propagator which is given by [36]

\[
S_{b[c]}^{\alpha}(x) = \frac{i}{(2\pi)^4} \int d^4k e^{-ikx} \left\{ \frac{\delta_{\mu\nu}}{k - m_{b[c]}} - \frac{g_a G_{\alpha\beta}^{a,b}}{4} \sigma_{\alpha\beta} \left( k + m_{b[c]} \right) + \left( k + m_{b[c]} \right) \sigma_{\alpha\beta} \right\}, \tag{5}
\]

\[
+ \frac{\pi^2}{3} \left( \frac{\alpha_s G_G}{\pi} \right) \delta_{\mu\nu} m_{b[c]} \frac{k^2 + m_{b[c]}^2}{(k^2 - m_{b[c]}^2)^2} + \cdots \right\},
\]
and \( S_u(x) \) and \( S_d(x) \) are the light quark propagators and are given by

\[
S^{ij}_q(x) = \frac{i}{2\pi^2x^4} \delta_{ij} - \frac{m_q}{4\pi^2x^2} \delta_{ij} - \frac{\langle \bar{q}q \rangle}{12} \left(1 - \frac{i m_q}{4} \not{x}\right) \delta_{ij} - \frac{x^2}{192} \frac{\gamma_5^2}{m_0^2} \left(1 - \frac{i m_q}{6} \not{x}\right) \delta_{ij}
\]

\[
- \frac{ig_s \lambda^A_{ij} G_F^A}{32\pi^2x^2} \left[ \not{x} \sigma^\eta + \sigma^\eta \not{x} \right] + \cdots.
\]

(6)

After some straightforward calculations (for details refer to the Ref. [29]), the correlation function in OPE side comes out in terms of different Dirac structures as

\[
\Pi_{\text{OPE}}^{(p,p',q)} = \Pi_{1}(q^2)\gamma_5 + \Pi_{2}(q^2) \not{p} \gamma_5 + \Pi_{3}(q^2) \not{q} \gamma_5 + \Pi_{4}(q^2) \not{q} \gamma_5,
\]

where each \( \Pi_{i}(q^2) \) function includes the perturbative and non-perturbative parts and is written as

\[
\Pi_{i}^{\text{OPE}}(q^2) = \int ds \int d\not{p}^{pert}(s,s',q^2) + \rho_{i}^{\text{non-pert}}(s,s',q^2).
\]

(8)

The spectral densities, \( \rho_i(s,s',q^2) \), appearing in Eq. (8) are obtained from the imaginary parts of the \( \Pi_i \) functions, viz. \( \rho_i(s,s',q^2) = \frac{1}{\pi} Im[\Pi_i] \). Here to provide examples of the explicit forms of the spectral densities, among the Dirac structures presented above, we only present the results obtained for the Dirac structure \( \not{p} \gamma_5 \), that is \( \rho_2^{pert}(s,s',q^2) \) and \( \rho_2^{\text{non-pert}}(s,s',q^2) \), which are obtained as

\[
\rho_2^{pert}(s,s',q^2) = \int_0^1 dx \int_0^{1-x} dy \frac{1}{32\pi^4(x+y-1)^2} \left\{ 2m_{b[c]}^3 x \left(3x^2 - y - 2x + 3xy\right) 
\]

\[
- 3m_{b[c]}^2 x(x+y-1) \left[ -m_u(x+4y-2) + m_d(3x+6y-2) \right]
\]

\[
- q^2 m_{b[c]} x \left[ y - 3y^2 + x^2(8y-1) + x(1-6y+8y^2) \right] + m_{b[c]}(x+y-1)
\]

\[
\times \left[ sx(8x^2 - 3y - 5x + 8xy) + s'(8x^2 - 5xy - 2y^2 - 2x^2 + 8x^2 y) \right]
\]

\[
- (x + y - 1) \left[ 3m_d s \left(4x^3 + y - y^2 - 7x^2 + 12x^2 y + 3x - 12xy + 8xy^2\right) \right]
\]

\[
+ 3m_d q^2 y \left(4x - 4x^2 + y - 8xy\right) + 3m_d s' y \left(3 - 7x + 4x^2 - 11y + 12xy + 8y^2\right) \right]
\]

\[
- m_u s \left(4x^3 + y(3 - 2y) + x^2(20y - 13) + x(9 - 27y + 16y^2) \right)
\]

\[
+ m_u s' y \left(9 - 14x + 4x^2 - 26y + 20xy + 16y^2\right) \right]
\]

\[
+ m_u q^2 y \left(11x - 4x^2 + 2y - 16xy - 3\right)\right\} \Theta \left[L_2(s,s',q^2)\right],
\]

(9)

and

\[
\rho_2^{\text{non-pert}}(s,s',q^2) = \left\{ \frac{\langle u\bar{u} \rangle}{24\pi^2(q^2 - m_{b[c]}^2)} \left(3m_{b[c]} m_d - 3m_u m_d + 3m_u^2 - q^2 + s - s' \right)
\]

\[
+ \frac{\langle u\bar{u} \rangle}{192\pi^2(q^2 - m_{b[c]}^2)^2} \right\} \Theta \left[L_2(s,s',q^2)\right]
\]

(10)
where \( \Theta[...] \) stands for the unit-step function and \( L_1(s, s', q^2) \) and \( L_2(s, s', q^2) \) are defined as

\[
L_1(s, s', q^2) = s',
\]

\[
L_2(s, s', q^2) = -m_{b[c]}^2 x + s x - s x^2 + s'y + q^2 y - s x y - s' x y - s' y^2. \tag{11}
\]

### 2.2 Hadronic Side

On the hadronic side, the correlation function is saturated with the complete sets of intermediate \( \Sigma_b[\Sigma_c] \), \( B[D] \) and \( N \) hadronic states having the same quantum numbers as their interpolating currents. After performing the four-integrals, we get

\[
\Pi^{HAD}(p, p', q) = \frac{\langle 0 | J_N | N(p') \rangle \langle 0 | J_{B[D]} | B[D](q) \rangle \langle \Sigma_b[\Sigma_c](p) | \bar{J}_{\Sigma_b[\Sigma_c]} | 0 \rangle}{(p^2 - m_{\Sigma_b[\Sigma_c]}^2)(p'^2 - m_{\Sigma_b[\Sigma_c]}^2)(q^2 - m_{B[D]}^2)} \times \langle N(p')B[D](q) | \Sigma_b[\Sigma_c](p) \rangle + \cdots, \tag{12}
\]

where \( \cdots \) represents the contributions coming from the higher states and continuum. We use the following parameterizations for the matrix elements appearing in the above equation

\[
\langle 0 | J_N | N(p') \rangle = \lambda_N u_N(p', s'),
\]

\[
\langle \Sigma_b(p) | \bar{J}_{\Sigma_b[\Sigma_c]} | 0 \rangle = \lambda_{\Sigma_b[\Sigma_c]} u_{\Sigma_b[\Sigma_c]}(p, s),
\]

\[
\langle 0 | J_{B[D]} | B[D](q) \rangle = i \frac{m_{B[D]}^2 f_{B[D]}}{m_u + m_{b[c]}},
\]

\[
\langle N(p')B[D](q) | \Sigma_b[\Sigma_c](p) \rangle = g_{\Sigma_b[NB[\Sigma_c ND]} \bar{u}_N(p', s') i \gamma_5 u_{\Sigma_b[\Sigma_c]}(p, s), \tag{13}
\]

where \( \lambda_N \) and \( \lambda_{\Sigma_b[\Sigma_c]} \) are residues of the \( N \) and \( \Sigma_b[\Sigma_c] \) baryons, respectively, \( f_{B[D]} \) is the leptonic decay constant of \( B[D] \) meson and \( g_{\Sigma_b[NB[\Sigma_c ND]} \) is the strong coupling form factor among \( \Sigma_b[\Sigma_c] \), \( N \) and \( B[D] \) particles. Using Eq. (13) in Eq. (12) and summing over the spins of the particles, we obtain

\[
\Pi^{HAD}(p, p', q) = i^2 \frac{m_{B[D]}^2 f_{B[D]} \lambda_{\Sigma_b[\Sigma_c]} g_{\Sigma_b[NB[\Sigma_c ND]}}}{m_{b[c]} + m_u (p^2 - m_{\Sigma_b[\Sigma_c]}^2)(p'^2 - m_{\Sigma_b[\Sigma_c]}^2)(q^2 - m_{B[D]}^2)} \times \left\{ (m_{\Sigma_b[\Sigma_c]} - m_{B[D]}^2) \gamma_5 + (m_{\Sigma_b[\Sigma_c]} - m_N) \not{p} \gamma_5 + \not{q} \gamma_5 - m_{\Sigma_b[\Sigma_c]} \not{\Sigma} \gamma_5 \right\} + \cdots. \tag{14}
\]

To achieve the final form of the hadronic side of the correlation function we apply the double Borel transformation with respect to the initial and final momenta squared, viz.

\[
\hat{\Pi}^{HAD}(q) = i^2 \frac{m_{B[D]}^2 f_{B[D]} \lambda_{\Sigma_b[\Sigma_c]} g_{\Sigma_b[NB[\Sigma_c ND]}}}{m_{b[c]} + m_u (q^2 - m_{B[D]}^2)} e^{-\frac{m_{\Sigma_b[\Sigma_c]}^2}{M^2}} e^{-\frac{m_N^2}{M^2}} \times \left\{ (m_{\Sigma_b[\Sigma_c]} - m_{B[D]}^2) \gamma_5 + (m_{\Sigma_b[\Sigma_c]} - m_N) \not{p} \gamma_5 + \not{q} \gamma_5 - m_{\Sigma_b[\Sigma_c]} \not{\Sigma} \gamma_5 \right\} + \cdots, \tag{15}
\]

where \( M^2 \) and \( M'^2 \) are Borel mass parameters.
As it was already stated, the match of the hadronic and OPE sides of the correlation function in Borel scheme provide us with the QCD sum rules for the strong form factors. The consequence of that match for $p_{75}$ structure leads us to

\[ g_{\Sigma_b[NB][\Sigma_c ND]}(q^2) = -e^{-m_b^2/M^2} e^{M_0^2} \frac{(m_b[m] + m_u)(q^2 - m_{B(D)}^2)}{m_{B(D)}^2 f_{B(D)} \lambda_{\Sigma_b[N]} \lambda_N (m_N m_{\Sigma_b[N]} - m_{\Sigma_b[N]}^2)} \times \left\{ \int_{(m_b[m] + m_u + m_d)^2}^{s_0} ds \int_{(2m_u + m_d)^2}^{s_0'} ds' e^{-\frac{M_0^2}{M^2}} e^{-\frac{M_0^2}{M^2}} \left[ \rho_2^{pert}(s, s', q^2) + \rho_2^{non-pert}(s, s', q^2) \right] \right\}, \]

where $s_0$ and $s_0'$ are continuum thresholds in $\Sigma_b[N_c]$ and $N$ channels, respectively.

### 3 Numerical results

Having obtained the QCD sum rules for the strong coupling form factors, in this section we present the numerical analysis of our results and discuss the behavior of the strong coupling form factors under consideration with respect to $Q^2 = -q^2$. To this aim, beside the input parameters given in table 1, one needs to determine the working intervals of four auxiliary parameters $M^2$, $M_0^2$, $s_0$, and $s_0'$. These parameters originate from the double Borel transformation and continuum subtraction. The determination of the working regions of these parameters is made on the basis that the results obtained for the strong coupling form factors be roughly independent of these helping parameters.

The continuum thresholds $s_0$ and $s_0'$ depend on the energies of the first excited states in the initial and final states. They are the energy squares which characterize the beginning of the continuum in the initial and final channels. If we show the ground states masses in the initial and final channels by $m$ and $m'$, respectively, the quantities $\sqrt{s_0} - m$ and $\sqrt{s_0'} - m'$ are the energies needed to excite the initial and final particles to their first excited states with the same quantum numbers. These quantities are well known for the states under consideration [37], where they take place roughly between 0.1 GeV and 0.3 GeV. These values lead to the working intervals of the continuum thresholds as $34.9[6.5]$ GeV$^2 \leq s_0 \leq 37.4[7.6]$ GeV$^2$ and $1.04$ GeV$^2 \leq s_0' \leq 1.99$ GeV$^2$ for the strong vertex $\Sigma_b[NB][\Sigma_c ND]$.

To determine the Borel parameters $M^2$ and $M_0^2$, there are two main consideration which are pole dominance and convergence of the OPE. The working intervals for these parameters are established on the requirement that the pole contribution exceeds the contributions of the higher states and continuum, and that the contribution of the perturbative part exceeds the non-perturbative contributions. These considerations lead to the windows $10[2]$ GeV$^2 \leq M^2 \leq 20[6]$ GeV$^2$ and $1$ GeV$^2 \leq M_0^2 \leq 3$ GeV$^2$ for the Borel mass parameters of the strong vertex $\Sigma_b[NB][\Sigma_c ND]$ and for these intervals our results have weak dependencies on the Borel mass parameters (see figures 1-2).

Subsequent to the determination of the auxiliary parameters, their windows together with the other input parameters are used to find out the dependency of the strong coupling form factors on $Q^2$. From our analysis we observe that the dependency of the strong
coupling form factors on $Q^2$ is well described by the following fit function:

$$g_{\Sigma_bNB}[\Sigma_cND](Q^2) = c_1 \exp \left[-\frac{Q^2}{c_2}\right] + c_3,$$

where the values of the parameters $c_1$, $c_2$ and $c_3$ for different structures are presented in tables 2 and 3 for $\Sigma_bNB$ and $\Sigma_cND$, respectively. Considering the average values of the continuum thresholds and Borel mass parameters we demonstrate the dependence of the

| Parameters  | Values                     |
|------------|----------------------------|
| $m_b$      | $(4.18 \pm 0.03)$ GeV[37]  |
| $m_c$      | $(1.275 \pm 0.025)$ GeV[37]|
| $m_d$      | $4.8^{+0.3}_{-0.3}$ MeV[37]|
| $m_u$      | $2.3^{+0.5}_{-0.5}$ MeV [37]|
| $m_B$      | $(5279.26 \pm 0.17)$ MeV [37]|
| $m_D$      | $(1864.84 \pm 0.07)$ MeV [37]|
| $m_N$      | $(938.272046 \pm 0.000021)$ MeV [37]|
| $m_{\Sigma_b}$ | $(5811.3 \pm 1.9)$ MeV [37] |
| $m_{\Sigma_c}$ | $(2452.9 \pm 0.4)$ MeV [37] |
| $f_B$      | $(248 \pm 23_{\exp} \pm 25_{V_{ub}})$ MeV [38] |
| $f_D$      | $(205.8 \pm 8.5 \pm 2.5)$ MeV [39] |
| $\lambda_N^2$ | $0.0011 \pm 0.0005$ GeV$^2$ [40] |
| $\lambda_{\Sigma_b}$ | $(0.062 \pm 0.018)$ GeV$^3$ [22] |
| $\lambda_{\Sigma_c}$ | $(0.045 \pm 0.015)$ GeV$^3$ [22] |
| $\langle \bar{u}u\rangle(1 \text{ GeV})$ | $\langle \bar{d}d\rangle(1 \text{ GeV})$ | $-(0.24 \pm 0.01)^3 \text{ GeV}^3$ [41] |
| $\langle \frac{G^2}{F}\rangle$ | $(0.012 \pm 0.004)$ GeV$^4$ [42] |
| $m_0^2(1 \text{ GeV})$ | $(0.8 \pm 0.2)$ GeV$^2$ [42] |

Table 1: Input parameters used in calculations.
strong coupling form factors on \( Q^2 \) for both the QCD sum rules and fitting results in figure 3. The figure indicates the truncation of the QCD sum rules at some points at negative values of \( Q^2 \) and the overlap between QCD sum rules and fitting results up to these points are well. The fit function is used to determine the value of the strong coupling constant at \( Q^2 = -m_B^2 \) for all structures, and the results are presented in table 4. The errors existing in these results arise from the uncertainties of the input parameters together with the uncertainties coming from the determination of the working regions of the auxiliary parameters. Table 4 also contains the average of the coupling constants under consideration, obtained from all the structures used.

To summarize, in this work, the strong coupling constants among the heavy bottom spin–1/2 \( \Sigma_b \) baryon, nucleon and \( B \) meson as well as the heavy charmed spin–1/2 \( \Sigma_c \) baryon, nucleon and \( D \) meson, namely \( g_{\Sigma_B,NB} \) and \( g_{\Sigma_c,ND} \) have been calculated in the framework of the three-point QCD sum rules. The obtained results can be used in the analysis of the
Table 2: Parameters appearing in the fit function of the coupling form factor for $\Sigma_b NB$ vertex.

| structure | $c_1$(GeV$^{-1}$) | $c_2$(GeV$^2$) | $c_3$(GeV$^{-1}$) |
|-----------|-------------------|----------------|-------------------|
| $\gamma_5$ | 0.72 ± 0.20       | 20.30 ± 6.08   | 8.61 ± 2.50       |
| $p\gamma_5$ | 34.62 ± 10.39    | -128.29 ± 38.49 | -20.41 ± 5.71    |
| $\not{q}\gamma_5$ | 5.14 ± 1.44  | -62.58 ± 18.15 | 2.98 ± 0.89       |
| $\not{q}p\gamma_5$ | 0.72 ± 0.20 | 18.03 ± 4.87   | 9.60 ± 2.88       |

Table 3: Parameters appearing in the fit function of the coupling form factor for $\Sigma_c ND$ vertex.

| structure | $c_1$(GeV$^{-1}$) | $c_2$(GeV$^2$) | $c_3$(GeV$^{-1}$) |
|-----------|-------------------|----------------|-------------------|
| $\gamma_5$ | -0.21 ± 0.06      | -15.44 ± 4.63  | 4.59 ± 1.28       |
| $p\gamma_5$ | 42.28 ± 11.41     | -54.72 ± 16.41 | -34.47 ± 9.98     |
| $\not{q}\gamma_5$ | -133.65 ± 40.10  | 388.23 ± 108.70 | 136.44 ± 38.20    |
| $\not{q}p\gamma_5$ | -0.006 ± 0.002 | -6.78 ± 1.89   | 3.79 ± 1.02       |

related experimental results at LHC. The predictions can also be used in the bottom and charmed mesons clouds description of the nucleon that may be applied for the explanation of the exotic events observed by different experiments. These results may also serve the purpose of analyzing of the results of heavy ion collision experiments like $PANDA$ at FAIR. Obtained results may also come in handy in the exact determinations of the modifications in the masses, decay constants and other parameters of the $B$ and $D$ mesons in nuclear medium.

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References

[1] D. W. Wang, M. Q. Huang, Phys. Rev. D 68, 034019 (2003).
[2] Z. G. Wang, Eur. Phys. J. C 54, 231 (2008).
[3] F. O. Durães, M. Nielsen, Phys. Lett. B 658, 40 (2007).
\[ g_{\Sigma_b N_B}(Q^2 = -m_B^2)(\text{GeV}^{-1}) = 11.44 \pm 3.43 \]
\[ g_{\Sigma_c N_D}(Q^2 = -m_D^2)(\text{GeV}^{-1}) = 6.27 \pm 1.88 \]
\[ g_{\gamma_5} \]
\[ g_{\not{p}\gamma_5} \]
\[ g_{\not{q}\gamma_5} \]
\[ g_{\not{q}\not{p}\gamma_5} \]
\[ g_{\gamma_5} \]
\[ g_{\not{p}\gamma_5} \]
\[ g_{\not{q}\not{p}\gamma_5} \]

**Table 4**: Values of the $g_{\Sigma_b N_B}$ and $g_{\Sigma_c N_D}$ coupling constants for different structures.

[4] X. Liu, H. X. Chen, Y. R. Liu, A. Hosaka, S. L. Zhu, Phys. Rev. D 77, 014031 (2008).

[5] D. W. Wang, M. Q. Huang, C. Z. Li, Phys. Rev. D 65, 094036 (2002).

[6] N. Mathur, R. Lewis, R. M. Woloshyn, Phys. Rev. D 66, 014502 (2002).

[7] D. Ebert, R. N. Faustov, V. O. Galkin, Phys. Rev. D 72, 034026 (2005).

[8] M. Karliner, H. J. Lipkin, Phys. Lett. B 660, 539 (2008).

[9] M. Karliner, B. Keren-Zur, H. J. Lipkin, J. L. Rosner, arXiv:0706.2163 (2007).

[10] J. L. Rosner, Phys. Rev. D 75, 013009 (2007).

[11] T. M. Aliev, K. Azizi, A. Ozpineci, Nucl. Phys. B 808, 137 (2009).

[12] B. Julia-Diaz, D. O. Riska, Nucl. Phys. A 739, 69 (2004).

[13] S. Scholl, H. Weigel, Nucl. Phys. A 735, 163 (2004).

[14] A. Faessler, Th. Gutsche, M. A. Ivanov, J. G. Körner, V. E. Lyubovitskij, D. Nicmorus, and K. Pumsa-ard, Phys. Rev. D 73, 094013 (2006).

[15] B. Patel, A. K. Rai, and P. C. Vinodkumar, J. Phys. G 35, 065001 (2008); J. Phys. Conf. Ser. 110, 122010 (2008).

[16] C. S. An, Nucl. Phys. A 797, 131 (2007); A 801, 82(E) (2008).

[17] T. M. Aliev, A. Ozpineci, M. Savci, Phys. Rev. D 65, 096004 (2002).

[18] T. M. Aliev, K. Azizi, A. Ozpineci, Phys. Rev. D 79, 056005 (2009).

[19] F. S. Navarra, M. Nielsen, Phys. Lett. B 443, 285 (1998).

[20] P.-Z. Huang, H.-X. Chen, S.-L. Zhu, Phys. Rev. D 80, 094007 (2009).

[21] Z.-G. Wang, Eur. Phys. J. A 44, 105 (2010); Phys. Rev. D 81, 036002 (2010).
[22] K. Azizi, M. Bayar, A. Ozpineci, Phys. Rev. D 79, 056002 (2009).
[23] T. M. Aliev, K. Azizi, M. Savci, Phys. Lett. B 696, 220 (2011).
[24] H.-Y. Cheng, C.-K. Chua, Phys. Rev. D 75, 014006 (2007).
[25] A. Khodjamirian, Ch. Klein, and Th. Mannel, and Y.-M. Wang, J. High Energy Phys. 09 (2011) 106.
[26] E. Hernandez, J. Nieves, Phys. Rev. D 84, 057902 (2011).
[27] K. Azizi, M. Bayar, Y. Sarac and H. Sundu, Phys. Rev. D 80, 096007 (2009).
[28] T. Gutsche, M. A. Ivanov, J. G. Korner, V. E. Lyubovitskij, and P. Santorelli, arXiv:1410.6043 (2014).
[29] K. Azizi, Y. Sarac and H. Sundu, Phys. Rev. D 90, 114011 (2014).
[30] M. A. Shifman, A. I. Vainshtein, V. I. Zakharov, Nucl. Phys. B 147, 385 (1979); Nucl. Phys. B 147, 448 (1979).
[31] K. Azizi, N. Er, H. Sundu, Eur. Phys. J. C 74, 3021 (2014).
[32] A. Kumar, Adv. High Energy Phys. 2014, 549726 (2014).
[33] Z.-G. Wang and T. Huang, Phys. Rev. C 84, 048201 (2011).
[34] Z.-G. Wang, Int. J. Mod. Phys. A 28, 1350049 (2013).
[35] A. Hayashigaki, Phys. Lett. B 487, 96 (2000).
[36] L. J. Reinders, H. Rubinstein and S. Yazaki, Phys. Rep. 127, 1 (1985).
[37] K. A. Olive et al. (Particle Data Group), Chin. Phys. C 38, 090001 (2014).
[38] A. Khodjamirian, “B and D Meson Decay Constant in QCD,” in Proceeding of 3rd Belle Analysis School, 22, 2010 (KEK, Tsukuba, Japan, 2010).
[39] B. I. Eisenstein et al. (CLEO Collab.), Phys. Rev. D78, 052003 (2008).
[40] K. Azizi, N. Er, Eur. Phys. J. C 74, 2904 (2014).
[41] B. L. Ioffe, Prog. Part. Nucl. Phys. 56, 232 (2006).
[42] V. M. Belyaev, B. L. Ioffe, Sov. Phys. JETP 57, 716 (1983); Phys. Lett. B 287, 176 (1992).