The $P$ and $T$ odd deuteron multipoles are calculated in the Reid nucleon-nucleon potential in the chiral limit $m_\pi \to 0$. The contact current generated by the $\pi$-meson exchange does not contribute to the anapole moment. The contact current generated by the vector meson exchange is negligible in comparison with other contributions of vector mesons. The result for the deuteron electric dipole moment is of great interest because of the experiment on its measurement discussed in Brookhaven. The deuteron photodisintegration cross section asymmetry at the threshold is also calculated. It is shown that its value strongly depends on the tensor forces and $d$-wave contribution to the deuteron wave function.

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I. INTRODUCTION

The anapole moment (AM) was introduced by Zel’dovich [1] as a very peculiar moment which involved both electromagnetic and weak interaction. A charged particle interaction with an AM has a contact nature. Actually, the interaction of electron with nuclei AM, being of the order of $\alpha G_F$, cannot be distinguished from radiative corrections to the weak interaction due to neutral currents. The study of Flambaum, Sushkov and Khriplovich [2] shows the growth of AM with the nuclei size as $A^{2/3}$. It means, the parity nonconservation (PNC) interaction of electron with heavy nuclei AM may become significant and provide important information about nuclei PNC forces. The competing contribution to this electron-nucleus interaction – radiative corrections to the neutral currents – does not have an enhancement in heavy nuclei.

The deuteron AM does not have the enhancement as heavy nuclei and its discussion is possible for another reason – it has isoscalar structure only. Radiative corrections to the electron-deuteron interaction due to $Z$-exchange contains both isoscalar and isovector contributions. The isoscalar part of interaction which is operative in deuteron is calculated with sufficiently good accuracy [3] and is of the same order of magnitude as the interaction of electron with the AM. Moreover the deuteron AM is defined mainly by the $\pi$-meson exchange and is singular in the $\pi$-meson mass.

The study of PNC effects in deuteron has a long history. On the one hand, the theoretical predictions are reliable due to small deuteron binding energy $\varepsilon_d \approx 2.23$ MeV. On the other hand the study of parity violation in the simplest nucleus – deuteron – is very important because of existing discrepancy between experimental data on PNC forces in $^{133}$Cs [4] and in some other nuclei [5,6].

The deuteron AM was discussed in the series of papers [2,7-11]. In [10] the zero range approximation was used to calculate AM. In [11] the deuteron AM was obtained using more realistic deuteron wave function, based on Argonne $\nu_{18}$-potential. The $d$-wave and vector meson contribution in the AM were also included in the consideration.

The same approach using effective field theory can be applied for $P$ and $T$ odd moments calculation: electric dipole moment (EDM) and magnetic quadrupole moment (MQM). The first of them is of a great interest because of the experiment on its measurement discussed in Brookhaven. The deuteron EDM and MQM have been considered in various models in papers [10,12,13].

The last part of the paper is devoted to the $P$ odd asymmetry of the deuteron photodisintegration cross section calculation in the Reid potential [14]. At present, there is a large dispersion of the theoretical predictions for this value [15-30]. Most of them considered various models of weak PNC interaction and deuteron wave functions. In [28] this magnitude was calculated using the zero range approximation approach and the obtained value at the threshold was about $A = 1 \times 10^{-7}$. The more complicated and reliable approaches used in papers [29] (with Argonne $\nu_{18}$ potential) and [30] (with Paris potential) gave the following answers $A = 0.253 \times 10^{-7}$ and $A = 0.335 \times 10^{-7}$ respectively. It seems to be very interesting to reveal the nature of the disagreement.

The aim of this paper is to calculate independently $P$ and $T$ odd electromagnetic moments and the deuteron cross section asymmetry in chiral limit using realistic wave functions obtained in the soft core Reid potential. It is very important to reveal the factors which have the greatest influence on $P$ and $T$ odd moments: $d$-wave contribution and the deuteron wave function behavior at small distances.

II. DEUTERON WAVE FUNCTIONS IN THE REID POTENTIAL

We can obtain the deuteron wave functions using the Reid potential [14]. We represent the deuteron $^3S_1-^3D_1$
state in the following form:

$$\psi_d = \frac{1}{r} \sqrt{\frac{m_\pi}{4\pi}} \left( u(x) + \frac{S_{12}}{\sqrt{8}} w(x) \right),$$  \hspace{1cm} (1)

where $x = m_\pi r$ -- the dimensionless distance, $S_{12} = 3(\sigma_1 \pi n)(\sigma_2 n) - (\sigma_1 \sigma_2)$, $m_\pi = 140$ MeV -- charged $\pi$-meson mass. Normalization condition gives

$$\int_0^\infty (u^2(x) + d^2(x)) \, dx = 1.$$

The Schrödinger equation for $u$ and $w$ components can be written as follows:

$$u''(x) + m(E - V_c(x))u(x) = 2\sqrt{2}m V_t(x)w(x),$$

$$w''(x) + m(E - V_c(x) + 2V_t(x) + 3V_{ls}(x))w(x) = 2\sqrt{2}m V_t(x)u(x).$$  \hspace{1cm} (2)

Here $V_c$, $V_t$, and $V_{ls}$ are used for the central, tensor, and spin-orbit parts of the nucleon-nucleon interaction potential, respectively:

$$V(x) = V_c(x) + V_t(x)S_{12} + V_{ls}(x)LS.$$

The calculated functions are plotted in Figure 1. The obtained energy and $d$-wave contribution are: $\varepsilon = 2.23$ MeV, $P_d = \int w^2(x) \, dx = 0.065$.

**FIG. 1:** Deuteron wave functions $u, w$

It should be mentioned that these results can be obtained using either the soft core or the hard core Reid potential. But in the future, we will use for calculation of $P$ and $T$ effects the soft core Reid potential only. The hard core Reid potential is obviously inappropriate for very small distances description.

## III. AM NUMERICAL CALCULATIONS

To calculate the perturbed deuteron wave function we will follow the way based on the direct solution of the Schrödinger equation. Indeed, the perturbed function can be written as

$$\psi_d(r) = \frac{1}{r} \sqrt{\frac{\mu}{4\pi}} \left[ u(x) + \frac{S_{12}}{\sqrt{8}} w(x) - i(\sigma_1 + \sigma_2)\nu_3 P_3(x) \right. + i(\sigma_1 - \sigma_2)\nu_1 P_1(x) \right].$$  \hspace{1cm} (3)

Functions $\nu_3 P_3$ and $\nu_1 P_1$ are $p$-waves with the total spin 1 and 0 respectively and the total angular momentum 1. To obtain these functions let us use the following weak PNC nucleon-nucleon potentials due to the $\pi$-meson exchange 31

$$V(r) = -i\frac{g_\pi}{4\pi m} (\sigma_1 + \sigma_2) \nabla e^{-m_n r}$$  \hspace{1cm} (4)

and $\rho$, $\omega$-meson exchange 31

$$W = -g_\rho \left[ h^0_\rho \tau_1 \tau_2 + \frac{1}{2} h^1_\rho (\tau^+_1 \tau^-_2 + \tau^-_1 \tau^+_2) + \frac{1}{2\sqrt{6}} h^2_\rho (3\tau^+_1 \tau^-_2 - \tau_1 \tau_2) \right] \times \frac{1}{2m} ((\sigma_1 - \sigma_2)\{p_1 - p_2, f_\rho(r)\} + 2(1+\chi_\rho) [\sigma_1 \times \sigma_2] \nabla f_\rho(r))$$

$$- g_\omega [h^0_\omega + \frac{1}{2} h^1_\omega (\tau^+_1 \tau^-_2)] \times \frac{1}{2m} ((\sigma_1 - \sigma_2)\{p_1 - p_2, f_\omega(r)\} + 2(1+\chi_\omega) [\sigma_1 \times \sigma_2] \nabla f_\omega(r))$$

$$- \frac{1}{2} (\tau^+_1 - \tau^-_2) (\sigma_1 + \sigma_2) \frac{1}{2m} (p_1 - p_2, g_\omega h^1_\omega f_\omega(r) - g_\rho h^1_\rho f_\rho(r)).$$  \hspace{1cm} (5)

The numerical values of used parameters are listed in Table 1 32.

| $g_\rho$ | $g_\omega$ | $\chi_\rho$ | $\chi_\omega$ | $h^0_\rho \cdot 10^7$ | $h^1_\rho \cdot 10^7$ | $h^2_\rho \cdot 10^7$ | $h^0_\omega \cdot 10^7$ | $h^1_\omega \cdot 10^7$ | $h^2_\omega \cdot 10^7$ |
|---------|------------|-------------|-------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| 2.79    | 8.37       | 3.7         | -0.12       | -11.4              | -0.2                | -9.5                | -1.9                | -1.1                |

**TABLE I:** Numerical values of the constants in potential 31

Then the Shrödinger equation

$$\left( -\frac{1}{m_r} \frac{d^2}{dr^2} + L(L+1) \right) \psi_d = E \psi_d$$  \hspace{1cm} (6)

can be split into four following equations

$$u''(x) + m(E - V_c(x))u(x) = 2\sqrt{2}m V_t w(x),$$

$$w''(x) + m(E - V_c(x) + 2V_t(x) + 3V_{ls}(x))w(x) = 2\sqrt{2}m V_t u(x),$$
\[ v''_1(x) - \frac{2}{x} v_1(x) + m(E - V_1 P_1(x)) v_1(x) \]

\[ = \left[ u(x) + \frac{1}{\sqrt{2}} w(x) \right] \frac{\partial}{\partial x} (F_\pi(x) + F_{\omega}^1(x) - F_{\omega}^0(x)) + \]

\[ + 2(F_{\rho}^1 - F_{\omega}^0) \left[ u'(x) + \frac{1}{\sqrt{2}} w'(x) \right] \]

\[ - \frac{2}{x} (F_{\rho}^1 - F_{\omega}^0)(u(x) - \sqrt{2} w(x)), \]

\[ v''_1(x) - \frac{2}{x} v_1(x) + m(E - V_1 P_1(x)) v_1(x) \]

\[ = (u(x) - \sqrt{2} w(x)) \frac{\partial}{\partial x} (3\chi_F^0(x) - \chi_\omega F_{\omega}^0(x)) - \]

\[ - 2(3\chi_F^0(x) - \chi_\omega F_{\omega}^0(x)) \frac{\partial}{\partial x} (u(x) - \sqrt{2} w(x)) \]

\[ + \frac{2}{x} (3\chi_F^0(x) - \chi_\omega F_{\omega}^0(x))(u(x) + 2\sqrt{2} w(x)) \] (7)

with used functions defined as

\[ F_\pi(x) = \frac{e^{-x}}{4\pi x}, \]

\[ F_{\omega}^0(x) = \frac{e^{-\frac{m_\omega x}{m_\omega}}}{4\pi x}, \]

\[ F_{\omega}^0(x) = \frac{e^{-\frac{m_\omega x}{m_\omega}}}{4\pi x}. \]

The general form of the AM operator is \[ 2 \]

\[ a_d = \frac{2\pi}{3} \int d|\mathbf{r} \times [\mathbf{r} \times \mathbf{j}(\mathbf{r})]| + a_N, \] (8)

where \( a_N \) is the nucleon contribution to the deuteron AM.

Let us consider the AM without nucleon contribution. The current operator \( \mathbf{j}(\mathbf{r}) \) in \[ 3 \] can be expressed in terms of the perturbed wave function \( \Psi \). Then the AM is \[ 2] 

\[ \mathbf{a}_d = - \frac{2\pi}{3m m_\pi} \left( m_p - m_n - \frac{1}{3} \right) \]

\[ \times \int_0^\infty dx \left[ u(x) + \sqrt{2} w(x) \right] v_1 P_1(x) \]

\[ - (m_p + m_n) \int_0^\infty dx \left( u(x) + \frac{1}{\sqrt{2}} w(x) \right) v_1 P_1(x) \] eI. \] (9)

The numerical solution of equations gives the following result for the AM without nucleon contribution:

\[ a_d = - \frac{eI}{6mm_\pi} (14.55\pi + 0.048h_\rho^1 - 0.132h_\omega^1 \]

\[ - 0.074h_\rho^0 - 0.051h_\omega^0). \] (10)

The nucleon AM (the \( \pi \)-meson exchange only) was calculated in \[ 10 \]

\[ a_p = a_n = - \frac{eI}{12mm_\pi} \left( 1 - \frac{6}{\pi} \frac{m_\pi}{m} \frac{m}{m_\pi} \right) \sigma_p \]

\[ = - \frac{eI}{12mm_\pi} 6.19 \sigma_p. \] (11)

The last numerical result \[ 33 \] was obtained considering vector meson exchange as well:

\[ a_{p,n} = - \frac{e}{12mm_\pi} \left( 7.61\pi + 8.25h_\rho^1 + 2.54h_\omega^0 \right) \sigma_{p,n}. \] (12)

We can see that the \( \pi \)-meson exchange contribution to the nucleon AM is very close to our analytical result which we will use further.

To find the nucleon contribution we should average the sum of the nucleons AM over the deuteron wave function:

\[ a_N = \int \left( u(x) + \frac{S_{\frac{1}{2}}}{\sqrt{8}} w(x) \right) (a_p + a_n) \]

\[ \times \left( u(x) + \frac{S_{\frac{1}{2}}}{\sqrt{8}} w(x) \right) dx = 2a_p \left( 1 - \frac{3}{2} P_d \right). \] (13)

Finally, the total value of the deuteron AM is

\[ a_d = - \frac{e}{6mm_\pi} (20.14\pi + 7.5h_\rho^1 - 0.132h_\omega^1 \]

\[ - 0.074h_\rho^0 + 1.78h_\omega^0). \] (14)

The contact current due to the \( \pi \)-meson exchange was obtained in \[ 10 \]

\[ j_c(\mathbf{r}) = \frac{eI}{2\pi m} \mathbf{r}(\mathbf{I} \nabla) e^{-\mathbf{m}_r^* \mathbf{r}}. \]

It was shown also that its contribution to the deuteron AM vanishes.

The last contribution to be calculated is the vector meson contact current contribution. In the momentum representation it equals

\[ j_c = - \frac{\partial W}{\partial A}. \]
But, instead of performing the calculations we can note that this contribution is suppressed by the factor $\kappa/m_g \sim 0.06$ in comparison with other vector meson contribution in (14). It means, these values are beyond the accuracy of calculations.

The total constant $C_{2d}$ of $P$-odd electron-deuteron interaction is the sum of two constants: $C_{2d}^r$ – radiative corrections to the neutral current and $C_{2d}^v$ – electromagnetic interaction with deuteron AM. The AM constant $C_{2d}^v$ is

$$C_{2d}^v = -\alpha a_d \left( \frac{eG_F}{\sqrt{2}} \right)^{-1} = 0.0075 \pm 0.0015. \quad (15)$$

We have estimated accuracy on the level about 20% at the fixed “best value” $\overline{\sigma} = 3.3 \times 10^{-7}$ [32].

Combining with the constant $C_{2d}^r$ due to radiative corrections to the neutral current [3]

$$C_{2d}^r = 0.014 \pm 0.003$$

we get

$$C_{2d} = 0.0215 \pm 0.0035. \quad (16)$$

The accuracy of this calculation is high enough to give a hope that the experimental measurement will be able to provide very useful information about PNC nuclear forces.

IV. ELECTRIC DIPOLE AND MAGNETIC QUADRUPOLE MOMENTS

The calculation of the electric dipole moment (EDM) is of a great interest because of planned experiments in Brookhaven National Laboratory.

Let us mention that the smallness of the vector meson exchange contribution to the deuteron AM is caused by the smallness of the corresponding coefficients. The deuteron EDM and MQM matrix elements have very close nature and consequently, vector meson exchange contribution to them should also be small in comparison with the $\pi$-meson contribution.

The deuteron EDM calculation can be performed in the same manner as the AM calculation was done. The perturbed wave function has the following form:

$$\psi_d(r) = \frac{1}{r} \sqrt{\frac{m_{\pi}}{4\pi}} \left( u(x) + \frac{S_{12}}{\sqrt{8}} w(x) \right)$$

$$+ (\sigma_1 + \sigma_2) n v_3 p_1(x) + (\sigma_1 - \sigma_2) n v_1 p_1(x). \quad (17)$$

The deuteron EDM is

$$d = \langle \psi_d | e \vec{r}_p | \psi_d \rangle =$$

$$= \frac{2e}{3m_{\pi}} \int_0^\infty dx \left( u(x) + \frac{1}{\sqrt{2}} w(x) \right) v_3 p_1(x) \mathbf{I}. \quad (18)$$

The simple calculation gives the following value

$$d = -\frac{e g_1}{12\pi m_{\pi}} 5.3 \mathbf{I}.$$ 

The deuteron magnetic quadrupole moment is

$$M_{zz} = \frac{e}{3m_{\pi}} \left[ 2(\mu_p - \mu_n) \int_0^\infty dxxu(x) v_3 p_1(x) \right.$$ 

$$- 2(\mu_p + \mu_n) \int_0^\infty dxxu(x) v_1 p_1(x)$$

$$- \frac{4\sqrt{2}}{5} (\mu_p - \mu_n - \frac{3}{4}) \int_0^\infty dxxw(x) v_3 p_1(x)$$

$$+ \frac{1}{\sqrt{2}} (\mu_p + \mu_n) \int_0^\infty dxxw(x) v_1 p_1(x) \right]. \quad (19)$$

The numerical calculation gives the following result:

$$M_{zz} = -\frac{e}{12\pi m_{\pi}} (11.5g_0 + 19.8g_1). \quad (20)$$

V. CROSS SECTION ASYMMETRY AT THE THRESHOLD

Another method to observe $P$ parity nonconservation in deuteron is measurement of the photodisintegration cross section asymmetry. Further, we will consider the asymmetry at the threshold of $\gamma d \rightarrow np$ reaction only because it has the maximum value there. The experimental result of Leningrad group [34] gives for this value

$$A = (1.8 \pm 1.8) \times 10^{-7}. \quad (21)$$

Unfortunately, this restriction cannot give additional information about PNC nuclear forces.

It is shown [28] that this value is about $10^{-7}$. But the value calculated is obtained in the zero range approximation model without $d$-wave mixture consideration. According to [18,19] these effects are significant and have a large influence on the final result.

Let us consider the deuteron photodisintegration cross section asymmetry at the threshold. It is clear that the transition $^3S_1 \rightarrow ^1S_0$ is the only possible at this energy. We have $M1$ regular transition and $E1$ admixed transition (Fig 2).

Only the spin nonconservation weak interaction contributes to the effect. Consequently, the deuteron wave functions and the wave function of the final $^1S_0$ state can be written as follows:

$$\psi_d(r) = \frac{1}{r} \sqrt{\frac{\mu}{4\pi}} \left[ u(x) + \frac{S_{12}}{\sqrt{8}} w(x) + i(\sigma_1 - \sigma_2) n v_1 p_1(x) \right],$$

$$\psi_{^1S_0} = \frac{1}{r} \left[ f(x) + i(\sigma_1 - \sigma_2) n g(x) \right]. \quad (22)$$
To get the value of the asymmetry we should solve the following system of equations:

\[ u''(x) + \frac{m}{m_{\pi}}(E_d - V_c(x))u(x) = 2\sqrt{2}m_{\pi}w(x), \]

\[ w''(x) + \frac{m}{m_{\pi}}(E_d - V_c + 2V_t + 3V_is)w(x) = 2\sqrt{2}m_{\pi}w(x), \]

\[ v''_t(x) - \frac{2}{x}v_0(x) + \frac{m}{m_{\pi}}(E_d - V_s(x))v_0(x) = (u(x) - \sqrt{2}w(x)) - \frac{\partial}{\partial x} (3\chi_0 F^0_\omega(x) - \chi_\omega F^0_{\omega}(x)) - 2(3\chi_0 F^0_\omega(x) - \chi_\omega F^0_{\omega}(x)) \frac{\partial}{\partial x} (u(x) - \sqrt{2}w(x)) \]

\[ + \frac{2}{x} (3\chi_0 F^0_\omega(x) - \chi_\omega F^0_{\omega}(x)) (u(x) + 2\sqrt{2}w(x)), \]

\[ f''(x) + \frac{m}{m_{\pi}}(E - V_s(x))f(x) = 0, \]

\[ g''(x) - \frac{2}{x^2}g(x) + \frac{m}{m_{\pi}}(E - V_s(x))g(x) = \frac{\partial}{\partial x} \left( (2 + \chi_\rho) F^0_\rho(x) + (2 + \chi_\omega) F^0_{\omega}(x) \right) f(x) \]

\[ + 2(\bar{F}^0_\rho(x) + F^0_{\omega}(x)) f'(x) - \frac{2}{x}(\bar{F}^0_\rho(x) + F^0_{\omega}(x)) f(x). \] (23)

The following symbols were used:

\[ F_\pi(x) = g_\rho \frac{e^{-x}}{4\pi x}, \]

\[ F^0_\rho(x) = g_\rho h^{0}_\rho \frac{e^{-x}}{4\pi x}, \]

\[ F^0_{\omega}(x) = g_\omega h^{0}_\omega \frac{e^{-x}}{4\pi x}. \]

The asymmetry is

\[ A = -\frac{4m}{3m_\pi(\mu_\rho - \mu_\omega)} \int_0^\infty f(x)u(x)dx \times \]

\[ \frac{\int_0^\infty g(x)(u(x) - \sqrt{2}w(x))dx}{\int_0^\infty f(x)v_0(x)dx}. \] (24)

The numerical value at “best values” parameters for \( P \)-odd nuclear forces is

\[ A = 0.16 \times 10^{-7}. \] (25)

This value is much less than the asymmetry calculated in the zero range approximation with modified wave functions. But the reasonable explanation can be given for this fact. The most crucial effect on the result has \( d \)-wave admixture to the deuteron state. Its influence is much stronger than the wave functions suppression at small distances. Actually, the same asymmetry calculated in the Reid potential without \( d \)-wave consideration gives the result

\[ A = 0.74 \times 10^{-7}. \]

It means that the \( d \)-wave content in the deuteron wave function should be determined very precisely to calculate the asymmetry at the threshold. The Reid potential provides \( P_d = 6.5\% \) for the \( d \)-wave content, whereas the same magnitude in Argonne \( v_{18} \) potential equals \( P_d = 5.7\% \). This discrepancy can affect the result very strongly.

VI. CONCLUSION AND COMPARISON

The deuteron AM calculation based on the phenomenological nucleon-nucleon interaction was discussed before in papers. The following magnitude was obtained

\[ a_d = a_\pi + a_{\text{nucleon}} + a_{\rho,\omega} = -\frac{e}{6m_{\pi}} (14.157 + 6.967) \]

\[ +7.6h^{1}_\rho - 0.14h^{0}_\rho - 0.2h^{1}_\omega + 2.33h^{0}_\omega \mathbf{I}. \] (26)

The \( \pi \)-meson exchange is splitted here in two terms – the contribution of the \( \pi \)-meson exchange between nucleons and the additive contribution of the nucleon anapole
moments. The π-meson contribution is almost the same in our consideration. The existed discrepancy is beyond the accuracy of both calculation. As to the vector meson exchange contributions, it differs from our result up to 50% in some cases. But actually, this difference has the simple explanation – the result dependence on the d-wave contribution, which is different for various potentials. Moreover, as distinct from the π-meson exchange, vector meson exchange contribution strongly depends on the wave function behavior at small distances (\( r \leq 0.3 \) fm), which makes the results dependent on nucleon-nucleon interaction model. The Reid potential, as any other potential description as well, fitting the scattering data up to 350 MeV cannot give reliable results for energy 770 – 780 MeV needed for the vector meson exchange description.

Our result for the deuteron EDM is close to that obtained in [12]:

\[
d = -\frac{e}{12\pi m_\pi}(6.06g_1 + 2.37g_0 + 1.05\overline{g}_\rho + 0.26\overline{g}_\omega)I. \tag{27}
\]

The main discrepancy concerns the term with \( g_0 \), which vanishes in our calculations. It could be explained by the fact that paper [12] considers terms, non singular in the π-meson mass. In our opinion considering this type terms is beyond accuracy and cannot be justified. The vector meson exchange contribution to the EDM is small, as it was expected.

The MQM result obtained in [12] is

\[
M_{zz} = -\frac{e}{12\pi m_\pi}(5.62g_0 + 18.6g_1). \tag{28}
\]

We have a reasonable agreement of our result in terms with \( g_1 \), the discrepancy in another term is large, and cannot be explained because of lack of details of calculation in [12].

The cross section asymmetry in \( \gamma d \rightarrow np \) reaction was calculated in the series of papers. The latest calculations, based on the realistic deuteron wave functions and the “best values” constants gave the following results [29, 30]:

\[
A = 0.253 \times 10^{-7},
\]

\[
A = 0.335 \times 10^{-7}. \tag{29}
\]

As we have pointed out this discrepancy can be explained by the strong d-wave influence on the result. Moreover, the above values show that the calculations of magnitude described by vector meson exchange cannot be reliably performed.

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