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Vector mesons in nuclear $\mu^- - e^-$ conversion

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Abstract

We study nuclear $\mu^- - e^-$ conversion in the general framework of an effective Lagrangian approach without referring to any specific realization of the physics beyond the Standard Model (SM) responsible for lepton flavor violation (\not{L}_f). We show that vector meson exchange between lepton and nucleon currents plays an important role in this process. A new issue of this mechanism is the presence of the strange quark vector current contribution induced by the ϕ meson. This allows us to extract new limits on the \not{L}_f lepton–quark effective couplings from the existing experimental data.

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1. Introduction

Muon-to-electron ($\mu^- - e^-$) conversion in nuclei

$$\mu^- + (A, Z) \longrightarrow e^- + (A, Z)^* \quad (1)$$

is a lepton flavor violating (\not{L}_f) process forbidden in the Standard Model (SM). It is commonly recognized

as one of the most sensitive probes of lepton flavor violation and of related physics beyond the SM (for reviews, see [1–3]).

The present experimental situation on $\mu^- - e^-$ conversion is as follows. There is one running experiment, SINDRUM II [4], and two planned ones, MECO [5,6] and PRIME [7]. The SINDRUM II experiment at PSI [4] with ^{48}Ti as stopping target has established the best upper bound on the branching ratio [4]

$$R_{\mu e}^{\text{Ti}} = \frac{\Gamma(\mu^- + {}^{48}\text{Ti} \rightarrow e^- + {}^{48}\text{Ti})}{\Gamma(\mu^- + {}^{48}\text{Ti} \rightarrow \nu_\mu + {}^{48}\text{Sc})} \leq 6.1 \times 10^{-13} \quad (90\% \text{ C.L.}) \quad (2)$$

The MECO experiment with ^{27}Al is going to start soon

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at Brookhaven [6]. The sensitivity of this experiment is expected to be at the level of $R_{\mu e}^{\text{Al}} \leq 2 \times 10^{-17}$ [6]. The PSI experiment is also running with the very heavy nucleus ^{197}Au aiming to improve the previous limit by the same experiment [4,8] up to $R_{\mu e}^{\text{Au}} \leq 6 \times 10^{-13}$. The proposed new experiment PRIME (Tokyo) [7] is going to utilize ^{48}Ti as stopping target with an expected sensitivity of $R_{\mu e}^{\text{Ti}} \leq 10^{-18}$.

These experimental limits would allow to set stringent limits on mechanisms of μ^-e^- conversion and the underlying theories of \not{L}_f . In the literature various mechanisms beyond the SM have been studied (see [1–3] and references therein). They can be classified as photonic and non-photonic, that is with and without photon exchange between the lepton and nuclear vertices, respectively. These two categories of mechanisms differ significantly from each other in various respects. In fact, they receive different contributions from the new physics and also require different treatments of the effects of the nucleon and the nuclear structure. Latter aspect is, in particular, attributed to the fact that the two mechanisms operate at different distances and, therefore, involve different details of the nucleon and nuclear structure.

In this Letter we focus on the non-photonic mechanisms of μ^-e^- conversion. The generic effect of physics beyond the SM in μ^-e^- conversion can be described by an effective Lagrangian with all possible 4-fermion quark–lepton interactions consistent with Lorentz covariance and gauge symmetry. Here, our interest focuses on the vector interactions which receive a contribution from vector meson exchange. We will show that the vector meson contribution to the μ^-e^- conversion rate is important.

2. General framework

We start with the 4-fermion effective Lagrangian describing the non-photonic μ^-e^- conversion at the quark level. The most general form of this Lagrangian has been derived in Ref. [9]. Here we present only those terms which contribute to the coherent μ^-e^- conversion:

$$\mathcal{L}_{\text{eff}}^{lq} = \frac{1}{\Lambda_{\text{LFV}}^2} [(\eta_{VV}^q j_\mu^V + \eta_{AV}^q j_\mu^A) J_q^{V\mu} + (\eta_{SS}^q j^S + \eta_{PS}^q j^P) J_q^S], \quad (3)$$

where Λ_{LFV} is the characteristic high energy scale of lepton flavor violation attributed to new physics. The summation runs over all the quark species $q = \{u, d, s, b, c, t\}$. Lepton and quark currents are defined as: $j_\mu^V = \bar{e}\gamma_\mu\mu$, $j_\mu^A = \bar{e}\gamma_\mu\gamma_5\mu$, $j^S = \bar{e}\mu$, $j^P = \bar{e}\gamma_5\mu$, $J_q^{V\mu} = \bar{q}\gamma^\mu q$, $J_q^S = \bar{q}q$. The \not{L}_f parameters η^q in Eq. (3) depend on a concrete \not{L}_f model.

The next step is the derivation of a Lagrangian in terms of effective nucleon fields which is equivalent to the quark level Lagrangian (3). First, we write down the lepton–nucleon \not{L}_f Lagrangian of the coherent μ^-e^- conversion in a general Lorentz covariant form with the isospin structure of the μ^-e^- transition operator [9]:

$$\mathcal{L}_{\text{eff}}^{lN} = \frac{1}{\Lambda_{\text{LFV}}^2} [j_\mu^a (\alpha_{aV}^{(0)} J^{V\mu(0)} + \alpha_{aV}^{(3)} J^{V\mu(3)}) + j^b (\alpha_{bS}^{(0)} J^{S(0)} + \alpha_{bS}^{(3)} J^{S(3)}), \quad (4)$$

where the summation runs over the double indices $a = V, A$ and $b = S, P$. The isoscalar $J^{(0)}$ and isovector $J^{(3)}$ nucleon currents are defined as $J^{V\mu(k)} = \bar{N}\gamma^\mu\tau^k N$, $J^{S(k)} = \bar{N}\tau^k N$, where N is the nucleon isospin doublet, $k = 0, 3$ and $\tau_0 \equiv \hat{1}$. This Lagrangian is supposed to be generated by the one of Eq. (3) and, therefore, must correspond to the same order $1/\Lambda_{\text{LFV}}^2$ in inverse powers of the \not{L}_f scale. The Lagrangian (4) is the basis for the derivation of the nuclear transition operators.

Now one needs to relate the lepton–nucleon \not{L}_f parameters α in Eq. (4) to the more fundamental lepton–quark \not{L}_f parameters η in Eq. (3). This implies a certain hadronization prescription which specifies the way in which the effect of quarks is simulated by hadrons. In the absence of a true theory of hadronization we rely on some reasonable assumptions and models.

There are basically two possibilities for the hadronization mechanism. The first one is a direct embedding of the quark currents into the nucleon (Fig. 1(a)), which we call direct nucleon mechanism (DNM). The second possibility is a two stages process (Fig. 1(b)). First, the quark currents are embedded into the interpolating meson fields which then interact with the nucleon currents. We call this possibility meson-exchange mechanism (MEM). In general one expects all the mechanisms to contribute to the coupling constants α in Eq. (4). However, at present the relative

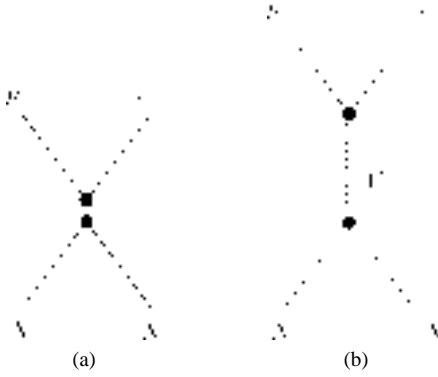


Fig. 1. Diagrams contributing to the nuclear μ^-e^- conversion: direct nucleon mechanism (a) and meson-exchange mechanism (b).

amplitudes of each mechanism are unknown. In view of this problem one may try to understand the importance of a specific mechanism, assuming for simplicity, that only this mechanism is operative and estimating its contribution to the process in question. We follow this procedure for the case of μ^-e^- conversion and consider separately the contributions of the direct nucleon mechanism $\alpha_{[N]}$ and the meson-exchange one $\alpha_{[MN]}$ to the couplings of the Lagrangian (4).

In the present Letter we concentrate on the meson-exchange mechanism. The contribution of the direct nucleon mechanism has been derived in Ref. [9]. Here we present only the results of Ref. [9] relevant for our analysis which are the couplings of the vector nucleon currents in Eq. (4):

$$\begin{aligned}\alpha_{aV[N]}^{(3)} &= \frac{1}{2}(\eta_{aV}^u - \eta_{aV}^d)(G_V^u - G_V^d), \\ \alpha_{aV[N]}^{(0)} &= \frac{1}{2}(\eta_{aV}^u + \eta_{aV}^d)(G_V^u + G_V^d),\end{aligned}\quad (5)$$

where $a = V, A$. The nucleon form factors G_V^q define the strong isospin symmetric normalization of the quark current matrix elements between nucleon states:

$$\begin{aligned}\langle p|\bar{u}\gamma_\mu u|p\rangle &= G_V^u \bar{p}\gamma_\mu p, \\ \langle n|\bar{d}\gamma_\mu d|n\rangle &= G_V^u \bar{n}\gamma_\mu n, \\ \langle p|\bar{d}\gamma_\mu d|p\rangle &= G_V^d \bar{p}\gamma_\mu p, \\ \langle n|\bar{u}\gamma_\mu u|n\rangle &= G_V^d \bar{n}\gamma_\mu n.\end{aligned}\quad (6)$$

Since the maximal momentum transfer q in μ^-e^- conversion is much smaller than the typical scale of the nucleon structure we can safely neglect the q^2 -dependence of the nucleon form factors G_V^q . At

$q^2 = 0$ these form factors are equal to the total number of the corresponding species of quarks in the nucleon and, therefore, $G_V^u = 2$, $G_V^d = 1$, while the form factors corresponding to s, c, b, t quarks are equal to zero. This is the reason why they do not contribute to the couplings of the vector nucleon current in Eq. (5). In the next section we will show that the vector meson exchange may drastically modify this situation and introduce the contribution of strange quarks into these couplings.

3. Vector meson contribution

Now let us turn to the contributions of the meson-exchange mechanism to the couplings α of the lepton–nucleon Lagrangian (4). The mesons which can contribute to this mechanism are the unflavored vector and scalar ones. Since the case of the scalar meson candidate $f_0(600)$ is still quite uncertain [10] we do not study its contribution. Thus, we are left with the vector mesons. The lightest of them, giving the dominant contributions, are the isovector $\rho(770)$ and the two isoscalar $\omega(782)$, $\phi(1020)$ mesons. We use ideal singlet-octet mixing for the quark content of the ω and ϕ mesons [10]: $\omega = (u\bar{u} + d\bar{d})/\sqrt{2}$ and $\phi = -s\bar{s}$.

First, we derive the \not{L}_f lepton–meson effective Lagrangian in terms of the interpolating ρ^0 , ω and ϕ fields retaining all the interactions consistent with Lorentz and electromagnetic gauge invariance. It can be written as:

$$\begin{aligned}\mathcal{L}_{\text{eff}}^{lV} &= \frac{\Lambda_H^2}{\Lambda_{\text{LFV}}^2} \left[\{(\xi_V^\rho j_\mu^V + \xi_A^\rho j_\mu^A)\rho^{0\mu}\right. \\ &\quad + (\xi_V^\omega j_\mu^V + \xi_A^\omega j_\mu^A)\omega^\mu + (\xi_V^\phi j_\mu^V + \xi_A^\phi j_\mu^A)\phi^\mu\} \\ &\quad \left. + \frac{1}{\Lambda_H^2} \{ \xi_V^{\rho(2)} j_\mu^V \partial^\mu \partial^v \rho_v^0 + \dots \} + \dots \right],\end{aligned}\quad (7)$$

with the unknown dimensionless coefficients ξ to be determined from the hadronization prescription. Since this Lagrangian is supposed to be generated by the quark–lepton Lagrangian (3) all its terms have the same suppression $\Lambda_{\text{LFV}}^{-2}$ with respect to the large \not{L}_f scale Λ_{LFV} . Another scale in the problem is the hadronic scale $\Lambda_H \sim 1$ GeV which adjusts the physical dimensions of the terms in Eq. (7). Typical momenta involved in μ^-e^- conversion are $q \sim m_\mu$, where m_μ is the muon mass. Thus, from naive dimensional

counting one expects that the contribution of the derivative terms to μ^-e^- conversion is suppressed by a factor $(m_\mu/\Lambda_H)^2 \sim 10^{-2}$ in comparison to the contribution of the non-derivative terms. Therefore, at this step in Eq. (7) we retain only the dominant non-derivative terms. However, it is worth noting that a true hadronization theory, yet non-existing, may forbid such terms so that the expansion in Eq. (7) starts from the derivative terms. In a forthcoming paper [11] we are going to demonstrate how this happens in a particular model of hadronization and what is the phenomenological impact of this situation.

In order to relate the parameters ξ of the Lagrangian (7) with the “fundamental” parameters η of the quark–lepton Lagrangian (3) we use an approximate method based on the standard on-mass-shell matching condition [12]

$$\langle \mu^+ e^- | \mathcal{L}_{\text{eff}}^{lq} | V \rangle \approx \langle \mu^+ e^- | \mathcal{L}_{\text{eff}}^{lV} | V \rangle, \quad (8)$$

with $|V = \rho, \omega, \phi\rangle$ corresponding to vector meson states on mass-shell. We solve Eq. (8) using the well-known quark current matrix elements

$$\begin{aligned} \langle 0 | \bar{u} \gamma_\mu u | \rho^0(p, \epsilon) \rangle &= -\langle 0 | \bar{d} \gamma_\mu d | \rho^0(p, \epsilon) \rangle \\ &= m_\rho^2 f_\rho \epsilon_\mu(p), \\ \langle 0 | \bar{u} \gamma_\mu u | \omega(p, \epsilon) \rangle &= \langle 0 | \bar{d} \gamma_\mu d | \omega(p, \epsilon) \rangle \\ &= 3m_\omega^2 f_\omega \epsilon_\mu(p), \\ \langle 0 | \bar{s} \gamma_\mu s | \phi(p, \epsilon) \rangle &= -3m_\phi^2 f_\phi \epsilon_\mu(p). \end{aligned} \quad (9)$$

Here p , m_V , f_V and ϵ_μ are the vector-meson four-momentum, mass, $V \rightarrow \gamma$ decay constant and the polarization state vector, respectively. The quark operators in Eq. (9) are taken at $x = 0$. The coupling constants f_V are determined from the $V \rightarrow e^+e^-$ decay width: $\Gamma(V \rightarrow e^+e^-) = (4\pi/3)\alpha^2 f_V^2 m_V$, where α is the fine-structure constant. The current central values of the meson couplings f_V and masses m_V are [10]:

$$\begin{aligned} f_\rho &= 0.2, & f_\omega &= 0.059, & f_\phi &= 0.074, \\ m_\rho &= 771.1 \text{ MeV}, & m_\omega &= 782.57 \text{ MeV}, \\ m_\phi &= 1019.456 \text{ MeV}. \end{aligned} \quad (10)$$

Solving Eq. (8) with the help of Eqs. (9), we obtain the desired expressions for the coefficients ξ of the lepton–meson Lagrangian (7) in terms of generic

\not{L}_f parameters η of the lepton–quark effective Lagrangian Eq. (3):

$$\begin{aligned} \xi_a^\rho &= \left(\frac{m_\rho}{\Lambda_H} \right)^2 f_\rho (\eta_{aV}^u - \eta_{aV}^d), \\ \xi_a^\omega &= 3 \left(\frac{m_\omega}{\Lambda_H} \right)^2 f_\omega (\eta_{aV}^u + \eta_{aV}^d), \\ \xi_a^\phi &= -3 \left(\frac{m_\phi}{\Lambda_H} \right)^2 f_\phi \eta_{aV}^s, \end{aligned} \quad (11)$$

where $a = V, A$.

Now we derive the vector meson exchange contributions to the couplings of the effective Lagrangian in Eq. (4) expressed on the nucleon level. To this end we introduce the effective Lagrangian describing the interaction of nucleons with vector mesons [13–15]:

$$\mathcal{L}_{VNN} = \frac{1}{2} \bar{N} \gamma^\mu [g_{\rho NN} \vec{\rho}_\mu \vec{\tau} + g_{\omega NN} \omega_\mu + g_{\phi NN} \phi_\mu] N. \quad (12)$$

In this Lagrangian we neglected the derivative terms, irrelevant for coherent μ^-e^- conversion. For the meson–nucleon couplings g_{VNN} we use numerical values taken from an updated dispersive analysis [15]

$$g_{\rho NN} = 4.0, \quad g_{\omega NN} = 41.8, \quad g_{\phi NN} = -18.3. \quad (13)$$

Substituting the values of the g_{VNN} constants from Eq. (13) into the $SU(3)$ relation [16] $g_{\phi NN} = g_{\rho NN}(\sqrt{3}/\cos\theta_V) - g_{\omega NN} \tan\theta_V$, we estimate the ω – ϕ mixing angle to be $\theta_V = 32.4^\circ$, which is close to the ideal one $\theta_V^I = 35.3^\circ$, consistent with our initial assumption on the quark content of the ω and ϕ mesons.

At this point the following comment is in order. The relatively large value of the ϕNN coupling $g_{\phi NN} = -18.3$ in Eq. (13) has been derived in Ref. [15] on the basis of the assumption on the “maximal” violation of the Okuba–Zweig–Iizuka (OZI) rule. It was also stressed in Ref. [15] that this value corresponds to the upper limit for the ϕNN coupling which parameterizes the full spectral function in the mass region of ~ 1 GeV within ϕ pole dominance approximation. The inclusion of other contributions such as the $\pi\rho$ continuum leads to a significant reduction of the $g_{\phi NN}$ coupling [17]. The detailed analysis of various meson and baryon cloud contributions to the vector ϕNN coupling results in the value $g_{\phi NN} = -0.24$ [17]. In what

follows, we quote this value as “physical” one. For completeness in our numerical analysis we consider both values of $g_{\phi NN}$ coupling:

$$\begin{aligned} g_{\phi NN}^{\text{phys}} &= -0.24 \quad (\text{“physical”}), \\ g_{\phi NN}^{\text{max}} &= -18.3 \quad (\text{“maximal”}). \end{aligned} \quad (14)$$

The vector meson-exchange contribution to the nucleon–lepton effective Lagrangian (4) arises in second order in the Lagrangian $\mathcal{L}_{\text{eff}}^{LV} + \mathcal{L}_{VN}$ and corresponds to the diagram in Fig. 1(b). We estimate this contribution only for the coherent μ^-e^- conversion process. In this case we disregard all the derivative terms of nucleon and lepton fields. Neglecting the kinetic energy of the final nucleus, the muon binding energy and the electron mass, the momentum transfer squared q^2 to the nucleus has a constant value $q^2 \approx -m_\mu^2$. In this approximation the vector meson propagators convert to δ -functions leading to lepton–nucleon contact operators. Comparing them with the corresponding terms in the Lagrangian (4), we obtain for the vector meson-exchange contribution to the coupling constants:

$$\begin{aligned} \alpha_{aV[MN]}^{(3)} &= -\beta_\rho (\eta_{aV}^u - \eta_{aV}^d), \\ \alpha_{aV[MN]}^{(0)} &= -\beta_\omega (\eta_{aV}^u + \eta_{aV}^d) - \beta_\phi \eta_{aV}^s, \end{aligned} \quad (15)$$

with $a = V, A$ and the coefficients

$$\begin{aligned} \beta_\rho &= \frac{1}{2} \frac{g_{\rho NN} f_\rho m_\rho^2}{m_\rho^2 + m_\mu^2}, & \beta_\omega &= \frac{3}{2} \frac{g_{\omega NN} f_\omega m_\omega^2}{m_\omega^2 + m_\mu^2}, \\ \beta_\phi &= -\frac{3}{2} \frac{g_{\phi NN} f_\phi m_\phi^2}{m_\phi^2 + m_\mu^2}. \end{aligned} \quad (16)$$

Substituting the values of the meson coupling constants and masses from Eqs. (10) and (13), and including the two different options for the $g_{\phi NN}$ constant (14), we obtain for these coefficients

$$\begin{aligned} \beta_\rho &= 0.39, & \beta_\omega &= 3.63, \\ \beta_\phi^{\text{phys}} &= 0.03, & \beta_\phi^{\text{max}} &= 2.0. \end{aligned} \quad (17)$$

A new issue of the vector meson contribution (15) is the presence of the strange quark vector current contribution associated with the LFV parameter η_{aV}^s , absent in the direct nucleon mechanism as it follows from Eq. (5). This opens up the possibility of deriving new limits on this parameter from the experimental data on μ^-e^- conversion. Another surprising result is that the contribution (15) of the meson-exchange

mechanism is comparable to the contribution (5) of the direct nucleon mechanism.

4. Constraints on \mathcal{L}_f parameters from μ^-e^- conversion

From the Lagrangian (4), following the standard procedure, one can derive the formula for the branching ratio of coherent μ^-e^- conversion. To leading order in the non-relativistic reduction the branching ratio takes the form [1]

$$R_{\mu e^-}^{\text{coh}} = \frac{\mathcal{Q}}{2\pi \Lambda_{\text{LFV}}^4} \frac{p_e E_e (\mathcal{M}_p + \mathcal{M}_n)^2}{\Gamma(\mu^- \rightarrow \text{capture})}, \quad (18)$$

where p_e, E_e are 3-momentum and energy of the outgoing electron, $\mathcal{M}_{p,n}$ are the nuclear μ^-e^- transition matrix elements. The factor \mathcal{Q} has the form [9]

$$\begin{aligned} \mathcal{Q} &= |\alpha_{VV}^{(0)} + \alpha_{VV}^{(3)}\phi|^2 + |\alpha_{AV}^{(0)} + \alpha_{AV}^{(3)}\phi|^2 \\ &\quad + |\alpha_{SS}^{(0)} + \alpha_{SS}^{(3)}\phi|^2 + |\alpha_{PS}^{(0)} + \alpha_{PS}^{(3)}\phi|^2 \\ &\quad + 2 \text{Re}\{(\alpha_{VV}^{(0)} + \alpha_{VV}^{(3)}\phi)(\alpha_{SS}^{(0)} + \alpha_{SS}^{(3)}\phi)^* \\ &\quad + (\alpha_{AV}^{(0)} + \alpha_{AV}^{(3)}\phi)(\alpha_{PS}^{(0)} + \alpha_{PS}^{(3)}\phi)^*\} \end{aligned} \quad (19)$$

in terms of the parameters of the lepton–nucleon effective Lagrangian (4) and the nuclear structure factor $\phi = (\mathcal{M}_p - \mathcal{M}_n)/(\mathcal{M}_p + \mathcal{M}_n)$.

In Refs. [1,9] it was argued that for all the experimentally interesting nuclei the parameter ϕ is small $\sim 10^{-2}$. Therefore the nuclear structure dependence of \mathcal{Q} can always be neglected except for a very special narrow domain in the \mathcal{L}_f parameter space where $\alpha^{(0)} \leq \alpha^{(3)}\phi$. Another important issue of the smallness of the ratio ϕ in Eq. (19) is the dominance of the isoscalar contribution associated with the coefficients $\alpha^{(0)}$. For this reason the role of the ρ -meson exchange in μ^-e^- conversion is expected to be unimportant except for the above mentioned very special case.

The nuclear matrix elements $\mathcal{M}_{p,n}$ in Eq. (18) have been calculated in Refs. [9,18] for the nuclear targets ^{27}Al , ^{48}Ti and ^{197}Au . With these matrix elements upper limits on the \mathcal{L}_f parameters have been deduced from the experimental constraints [9]. In particular, for the case of the present experimental constraint (2) it was found that

$$\alpha_{aV}^{(0)} \left(\frac{1 \text{ GeV}}{\Lambda_{\text{LFV}}} \right)^2 \leq 1.2 \times 10^{-12}, \quad (20)$$

Table 1

Upper bounds on the \not{L}_f parameters inferred from the SINDRUM II data on ^{48}Ti [Eq. (2)] corresponding to the direct nucleon mechanism (DNM) and the meson exchange mechanism (MEM). The subscript notation is $a = V, A$. The value in square brackets refers to the $g_{\phi NN}^{\max}$ value of ϕNN coupling presented in Eq. (14)

Parameter	DNM	MEM
$ \eta_{aV}^{u,d} (1 \text{ GeV}/\Delta_{\text{LFV}})^2$	8.0×10^{-13}	3.3×10^{-13}
$ \eta_{aV}^s (1 \text{ GeV}/\Delta_{\text{LFV}})^2$	no limits	4.0×10^{-11} [6.0×10^{-13}]

for the combination of the dimensionless couplings $\alpha_{aV}^{(0)}$ ($a = A, V$) and the characteristic \not{L}_f scale Δ_{LFV} in the effective lepton–nucleon Lagrangian (4). From the above limit one can deduce the individual limits on different terms determining the coefficients $\alpha_{aV}^{(0)}$ in the direct nucleon and meson-exchange mechanisms, assuming that significant cancellations (unnatural fine-tuning) between different terms are absent. In this way we derive constraints for the η parameters of the quark–lepton Lagrangian (3) for the meson-exchange mechanism (MEM). We present these limits in Table 1. For the parameter $|\eta_{aV}^s|$ we derive the limits for the two different cases of $g_{\phi NN}$ coupling, given in Eq. (14). In Table 1 we also show for comparison the limits corresponding to the direct nucleon mechanism (DNM) derived in Ref. [9]. The limits presented in Table 1 show the importance of the vector meson exchange contribution to $\mu^- - e^-$ conversion.

5. Summary

We studied nuclear $\mu^- - e^-$ conversion in a general framework based on an effective Lagrangian without referring to any specific realization of the physics beyond the standard model responsible for lepton flavor violation. We demonstrated that the vector meson-exchange contribution to this process is significant. A new issue of the meson-exchange mechanism in comparison to the previously studied direct nucleon mechanism is the presence of the strange quark vector current contribution induced by the ϕ meson. This allowed us to extract new limits on the \not{L}_f lepton–quark effective couplings from the existing experimental data.

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