Unparticle physics effects in $B_s - \bar{B}_s$ mixing

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Abstract
We investigate unparticle effects in $B_s - \bar{B}_s$ mixing. In particular we discuss the possibility of reproducing the experimental result of $\Delta M_s$, while having large effects on the mixing phase $\phi_s$, which might be visible in current experiments.

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1 Introduction

Unparticle physics has been recently suggested by Georgi [1, 2]. Besides the standard model (SM) fields one assumes the existence of a non-trivial scale invariant sector at very high energies. These new fields with a nontrivial infrared fixed point are called Banks-Zaks fields (BZ) [3]. The SM fields and the BZ fields interact via the exchange of particles of large mass $M_{U}$. This interaction has the following generic form

$$\frac{1}{M_{U}^{k}}O_{SM}O_{BZ},$$

where $O_{SM}$ is an operator of mass dimension $d_{SM}$ and $O_{BZ}$ is an operator of mass dimension $d_{BZ}$ made out of SM and BZ fields respectively. At a lower scale $\Lambda_{U}$ the renormalizable couplings of the BZ fields cause dimensional transmutation [4]. Below the scale $\Lambda_{U}$ the BZ operators match onto unparticle operators leading to new set interactions

$$C_{d_{BZ} - d_{U}}\frac{\Lambda_{U}^{d_{BZ} - d_{U}}}{M_{U}^{k}}O_{SM}O_{U},$$

where $C_{d_{U}}$ is a coefficient of the low energy effective theory and $O_{U}$ is the unparticle operator with scaling dimension $d_{U}$. Georgi showed in [1] that unparticle stuff with scale dimension $d_{U}$ looks like a non-integral number $d_{U}$ of invisible massless particles. Following the discussions in [1, 2] we only consider two kinds of unparticles, scalar unparticles $O_{U}$ and vector unparticles $O_{U}^{\mu}$. The coupling of these unparticles to quarks is given as

$$\frac{c_{S}^{q}q}{\Lambda_{U}^{d_{U}}}q^{\mu}(1 - \gamma_{5})q \partial^{\mu}O_{U} + \frac{c_{V}^{q}q}{\Lambda_{U}^{d_{U}}}q^{\mu}(1 - \gamma_{5})q O_{U}^{\mu} + h.c.,$$

(1)

where $c_{S,V}^{q}$ are flavor-dependent dimensionless coefficients. We will consider the case $q = b$ and $q' = s$, which corresponds to flavor changing neutral current (FCNC) transitions, giving contributions to the $B_{s} - \bar{B}_{s}$ mixing amplitude. The propagator for the unparticle field is given as [1, 5]

$$\int d^{4}xe^{iP \cdot x}\langle 0|TO_{U}(x)O_{U}(0)||0\rangle = \frac{A_{d_{U}}}{2 \sin d_{U} \pi} \frac{1}{(P^{2} + i\epsilon)^{2 - d_{U}}} e^{-i\phi_{U}},$$

(2)

$$\int d^{4}xe^{iP \cdot x}\langle 0|TO_{U}^{\mu}(x)O_{U}^{\nu}(0)||0\rangle = \frac{iA_{d_{U}}}{2 \sin d_{U} \pi} \frac{g^{\mu\nu} + P^{\mu}P^{\nu}/P^{2}}{(P^{2} + i\epsilon)^{2 - d_{U}}} e^{-i\phi_{U}},$$

(3)

with

$$A_{d_{U}} = \frac{16 \pi^{5/2}}{(2\pi)^{2d_{U}}} \frac{\Gamma(d_{U} + 1/2)}{\Gamma(d_{U} - 1)\Gamma(2d_{U})}, \quad \text{and} \quad \phi_{U} = (d_{U} - 2)\pi.$$

(4)

Theoretical aspects of unparticles have been further discussed in [6], while phenomenological consequences of unparticles have been investigated in [5, 7–11]. Mixing effects were already discussed in [8–11], where mostly effects on $\Delta M$ were studied. In this work we start from the
fact that large new physics effects in $\Delta M$ are experimentally excluded. Therefore we concentrate on new large contributions to the weak mixing phase. In section 2.1 we introduce our notation and we review the status of the standard model predictions for the mixing quantities, in section 2.2 we discuss new physics effects to mixing in general. Section 2.3 contains our main results, the unparticle physics effects in $B_s-\overline{B}_s$ mixing. All our formulas are given for the $B_s$-system. The generalization to the $B_d$-system is straightforward.

2 B mixing

2.1 Notation and SM contributions to $B_s-\overline{B}_s$ mixing

$B_s-\overline{B}_s$ oscillations are governed by a Schrödinger equation

$$\frac{i}{\hbar} \frac{d}{dt} \begin{pmatrix} |B_s(t)\rangle \\ |\overline{B}_s(t)\rangle \end{pmatrix} = \begin{pmatrix} M^s - i \Gamma^s/2 \end{pmatrix} \begin{pmatrix} |B_s(t)\rangle \\ |\overline{B}_s(t)\rangle \end{pmatrix}$$

(5)

with the mass matrix $M^s$ and the decay matrix $\Gamma^s$. The physical eigenstates $|B_H\rangle$ and $|B_L\rangle$ with the masses $M_H$, $M_L$ and the decay rates $\Gamma_H$, $\Gamma_L$ are obtained by diagonalizing $M^s - i \Gamma^s/2$. The $B_s-\overline{B}_s$ oscillations in Eq. (5) involve the three physical quantities $|\Delta M|$, $|\Delta \Gamma|$ and the CP phase $\phi_s = \arg(-M_{12}^s/\Gamma_{12}^s)$ (see e.g. [12]). $\Gamma_{12}$ stems from the absorptive part of the box diagrams - only light internal particles like up and charm quarks contribute, while $M_{12}$ stems from the dispersive part of the box diagram, therefore being sensitive to heavy internal particles like the top quark or heavy new physics particles. The calculable quantities $|\Delta M|$, $|\Delta \Gamma|$ and $\phi = \arg(-M_{12}^s/\Gamma_{12}^s)$ can be related to three observables (see [13–15] for a more detailed description):

- Mass difference $\Delta M = M_H^s - M_L^s \approx 2|M_{12}|$
- Decay rate difference $\Delta \Gamma = \Gamma_L^s - \Gamma_H^s \approx 2|\Delta M| \cos \phi$
- Flavor specific or semi-leptonic CP asymmetries: $a_f = \text{Im}\frac{\Gamma_{12}^s}{\Delta \Gamma} = \frac{\Delta M}{\Delta \Gamma} \tan \phi$.

Calculating the box diagram with internal top quarks one obtains

$$M_{12} = \frac{G_F^2}{12\pi^2}(V_{ts}^* V_{tb})^2 M_W^2 S_0(x_t) B_B f_{B_s}^2 M_{B_s} \hat{\eta}_B$$

(6)

where $G_F$ is the Fermi constant, the $V_{ij}$'s are CKM elements, $M_{B_s}$ and $M_W$ are the masses of $B_s$ meson and W boson. The Inami-Lim function $S_0(x_t = \bar{m}_t^2/M_W^2)$ [16] is the result of the box diagram without any gluon corrections. The NLO QCD correction is parameterized by $\hat{\eta}_B \approx 0.84$ [17]. The non-perturbative matrix element of the four-quark operator ($\alpha, \beta = 1, 2, 3$ are colour indices):

$$Q = \bar{\sigma}_\alpha \gamma_\mu (1 - \gamma_5)b_\alpha \bar{\sigma}_\beta \gamma_\mu (1 - \gamma_5)b_\beta.$$  

(7)

is parameterized by the bag parameter $B$ and the decay constant $f_{B_s}$.

$$\langle B_s|Q|\overline{B}_s\rangle = \frac{8}{3} M_{B_s}^2 f_{B_s}^2 B.$$  

(8)
For our numerical estimates we will always use the input parameters listed in [13]. In [13] we obtained
\[ \Delta M_s^{\text{Theo}} = 19.3 \pm 6.4 \pm 1.9 \text{ ps}^{-1}. \] (9)

The first error stems from the uncertainty in \( f_{B_s} \) and the second error summarizes the remaining theoretical uncertainties. This number has to be compared with the experimental value [18]
\[ \Delta M_s^{\text{Exp}} = 17.77 \pm 0.12 \text{ ps}^{-1}. \] (10)

Due to our lack of a precise knowledge of \( f_{B_s} \) there is still a sizeable room for new physics effects in \( \Delta M_s \).

\( \Gamma_{12} \) can be determined within the framework of the Heavy-Quark-Expansion (HQE) [19] as an expansion in \( \Lambda/m_b \) and \( \alpha_s \). The first contribution arises at order \( (\Lambda/m_b)^3 \)
\[ \Gamma_{12} = \frac{\Lambda^3}{m_b^3} \left( \Gamma_3^{(0)} + \frac{\alpha_s}{4\pi} \Gamma_3^{(1)} + \ldots \right) + \frac{\Lambda^4}{m_b^4} \left( \Gamma_4^{(0)} + \ldots \right) + \frac{\Lambda^5}{m_b^5} \left( \Gamma_5^{(0)} + \ldots \right) + \ldots. \] (11)

The leading term \( \Gamma_3^{(0)} \) was determined in [20]. The numerical and conceptual important NLO-QCD corrections (\( \Gamma_3^{(1)} \)) were determined in [15, 21]. Subleading \( 1/m \)-corrections, i.e. \( \Gamma_4^{(0)} \) were calculated in [22, 23] and even the Wilson coefficients of the \( 1/m^2 \)-corrections (\( \Gamma_5^{(0)} \)) were calculated and found to be small [13]. The smallness of these corrections was confirmed in [24]. In addition to \( Q \) now some new operators appear
\[ Q_S = \bar{s}_\alpha (1 + \gamma_5) b_\alpha \bar{s}_\beta (1 + \gamma_5) b_\beta, \] (12)
\[ \tilde{Q}_S = \bar{s}_\alpha (1 + \gamma_5) b_\beta \bar{s}_\beta (1 + \gamma_5) b_\alpha. \] (13)

We parameterise the matrix element of these operators as
\[ \langle B_s | Q_S | \bar{B}_s \rangle = -\frac{5}{3} M_{B_s}^2 f_{B_s}^2 B'_S, \] (14)
\[ \langle B_s | \tilde{Q}_S | \bar{B}_s \rangle = \frac{1}{3} M_{B_s}^2 f_{B_s}^2 \tilde{B}'_S(\mu_2), \] (15)

where we use the following abbreviation
\[ B'_X = \frac{M_{B_s}^2}{(m_b + m_s)^2} B_X. \] (16)

In the vacuum insertion approximation (VIA) the bag factors \( B, B_S \) and \( \tilde{B}_S \) are equal to one.

In [13] a strategy was worked out to reduce the theoretical uncertainty in \( \Gamma_{12}/M_{12} \) by almost a factor of 3:

- The latest set of input parameters was used.
- Logarithms of the type \( z \ln z \) were summed up to all orders, c.f. [25].
- Instead of the pole b-mass only the \( \overline{\text{MS}} \)-mass b-mass is used.
It was shown that the use of the operator basis \( \{ Q, \tilde{Q}_S \} \) instead of \( \{ Q, Q_S \} \) leads to smaller theoretical uncertainties. While it is obvious that for \( \Gamma_{12}/M_{12} \) the new basis has to be preferred - now the dominant part is completely free of non-perturbative uncertainties, while in the old basis the dominant term was proportional to the ratio of the bag factors \( B'_S \) and \( B \) - it is not a priori clear what to prefer in the case of \( \Gamma_{12} \). One might think about averaging over the results in the two bases [26]. Already this strategy reduces the error on \( \Gamma_{12} \) considerably. However having a closer look, one finds [13] that

- the numerical reduction of the \( 1/m_b \) corrections in the new basis is valid to all orders in \( \alpha_s \)
- the numerical correlations between \( B \) and \( B_S \) have not been taken fully into account in the old basis.

Therefore we strongly suggest to use the new operator basis.

See Fig. (1) for an illustration of the improvements and [27] for the shortcomings of the previous approach. One gets

![Figure 1: Error budget for the theoretical determination of \( \Delta \Gamma_s/\Delta M_s \). Compared to previous approaches (left) the new strategy lead to a reduction of the theoretical error by almost a factor of 3.](image)
\[ \frac{\Delta \Gamma_s}{\Delta M_s} = 10^{-4} \cdot \left[ 46.2 + 10.6 \frac{B'_s}{B} - 11.9 \frac{B_R}{B} \right]. \]  

(17)

where \( B_R \) stands for the bag parameters of the \( 1/m_b \) parameters. The dominant part of \( \Delta \Gamma / \Delta M \) can now be determined without any hadronic uncertainties (for more details see [13])! We obtained in [13] the following final numbers with very conservative ranges for the input parameters

\[ \Delta \Gamma_s = (0.096 \pm 0.039) \text{ps}^{-1}, \frac{\Delta \Gamma_s}{\Gamma_s} = 0.147 \pm 0.060, \]  

(18)

\[ a^s_{fs} = (2.06 \pm 0.57) \cdot 10^{-5}, \frac{\Delta \Gamma_s}{\Delta M_s} = (49.7 \pm 9.4) \cdot 10^{-4} \]  

(19)

\[ \phi_s = 0.0041 \pm 0.0008 = 0.24^\circ \pm 0.04^\circ. \]  

(20)

The authors of [24] presented recently a number for \( \Delta \Gamma \) which is lower than the number above - but consistent within the errors. Unfortunately the authors of [24] missed to include the above mentioned theoretical improvements, therefore their final number for \( \Delta \Gamma_s \) has to be taken with a pinch of salt.

### 2.2 General new physics contributions to \( B_s - \overline{B}_s \) mixing

New physics (see e.g. [28]) is expected to have almost no impact on \( \Gamma_{12} \) [29], (see [24, 30] for some alternative viewpoints) but it can change \( M_{12} \) considerably – we denote the deviation factor by the complex number \( \Delta \). Therefore one can write

\[ \Gamma_{12,s} = \Gamma_{12,s}^{SM}, \]  

(21)

\[ M_{12,s} = M_{12,s}^{SM} \cdot \Delta_s; \text{ with } \Delta_s = |\Delta_s|e^{i\phi_s}. \]  

(22)

With this parameterisation the physical mixing parameters can be written as

\[ \Delta M_s = 2|M_{12,s}^{SM}| \cdot |\Delta_s|, \]  

\[ \Delta \Gamma_s = 2|\Gamma_{12,s}^{SM}| \cdot \cos \left( \phi_s^{SM} + \phi_s^\Delta \right), \]  

\[ \frac{\Delta \Gamma_s}{\Delta M_s} = \frac{|\Gamma_{12,s}^{SM}|}{|M_{12,s}^{SM}|} \cdot \frac{\cos \left( \phi_s^{SM} + \phi_s^\Delta \right)}{|\Delta_s|}, \]  

\[ a^s_{fs} = \frac{|\Gamma_{12,s}^{SM}|}{|M_{12,s}^{SM}|} \cdot \sin \left( \phi_s^{SM} + \phi_s^\Delta \right). \]  

(23)

Note that \( \Gamma_{12,s}/M_{12,s}^{SM} \) is now due to the above mentioned improvements theoretically very well under control. Next we combine the current experimental numbers with the theoretical predictions to extract bounds in the imaginary \( \Delta_s \)-plane by the use of Eqs. [23], see Fig. [2]. The width difference \( \Delta \Gamma_s/\Gamma_s \) was investigated in [31]. The semi-leptonic CP asymmetry in the \( B_s \) system has been determined in [32] (see [13] for more details). We use as experimental input the latest
Figure 2: Current experimental bounds in the complex $\Delta s$-plane. The bound from $\Delta M_s$ is given by the red (dark-grey) ring around the origin. The bound from $\Delta \Gamma_s / \Delta M_s$ is given by the yellow (light-grey) region and the bound from $a_{fs}^s$ is given by the light-blue (grey) region. The angle $\phi_s^\Delta$ can be extracted from $\Delta \Gamma_s$ (solid lines) with a four fold ambiguity - one bound coincides with the x-axis! - or from the angular analysis in $B_s \to J/\Psi \phi$ (dashed line). If the standard model is valid all bounds should coincide in the point (1,0). The current experimental situation shows a small deviation, which might become significant, if the experimental uncertainties in $\Delta \Gamma_s$, $a_{fs}^s$ and $\phi_s$ will go down in near future.

combination of the D0 collaboration [33]

\[
\Delta \Gamma_s = 0.17 \pm 0.09 \text{ ps}^{-1}, \quad (24)
\]
\[
\phi_s = -0.79 \pm 0.56. \quad (25)
\]
\[
a_{fs}^s = (-5.2 \pm 3.9) \cdot 10^{-3}. \quad (26)
\]

The HFAG [34] obtains the following combined value

\[
\Delta \Gamma_s = 0.071^{+0.053}_{-0.057} \text{ ps}^{-1}. \quad (27)
\]

The result of the comparison of experiment and theory can be seen in Fig. 2 which is taken from [13]. Already at this stage some hints for possible new physics contributions are visible, which manifest themselves as sizeable contributions to the mixing phase $\phi_s$. In the next section we investigate, whether unparticle physics effects might create large contributions to $\phi_s$. 


2.3 Unparticle physics contributions to $B_s - \bar{B}_s$ mixing

In this section we determine possible contributions of unparticle physics effects to $B_s - \bar{B}_s$ mixing. Using the operators from Eq. (1) we obtain for the unparticle physics contribution to $M_{12}$

$$M'_{12} = \frac{f_{B_s}^2}{M_{B_s}} \frac{i e^{-i \phi_l} A_{d_{d_l}}}{4 \sin d_{d_l} \pi} \left( c_{sB}^2 \left( \frac{M_{B_s}}{M_{12}} \right)^2 d_{d_l} - \frac{5}{3} m_b^2 B_S - \frac{8}{3} B \right) + \left( \frac{M_{B_s}}{\Lambda_{d_{d_l}}} \right)^{2d_{d_l}} \frac{5}{3} M_{B_s}^2 B_S'$$

(28)

Using $\Delta M = 2|M_{12}|$ and setting $m_b = M_{B_s}$ and $B = 1 = B_S'$ we reproduce the results in [9–11] for the mass differences. With Eq. (28) we can determine $\Delta$:

$$\Delta = \frac{M_{12}}{M_{SM}^2} = 1 + \frac{M'_{12}}{M_{12}}$$

(29)

Inserting the expressions for the unparticle propagator we obtain

$$\frac{M'_{12}}{M_{12}^2} = \frac{f_{B_s}^2}{M_{B_s} M_{SM}^2} \frac{1 + i \cot(d_{d_l} \pi)}{\Gamma(d_{d_l} - 1) \Gamma(2d_{d_l})} \left( \frac{M_{B_s}}{2 \pi \Lambda_{d_{d_l}}} \right)^{2d_{d_l}} \left\{ -c_{sB}^2 + \frac{5}{3} (c_{sB}^2) \left( \frac{M_{B_s}}{\Lambda_{d_{d_l}}} \right)^2 \right\}$$

(30)

In order to simplify the expressions further we have to specify what scale $\Lambda_{d_{d_l}}$ we consider. For simplicity we discuss only the cases $\Lambda_{d_{d_l}} = 1 \text{ TeV}$ and $\Lambda_{d_{d_l}} = 10 \text{ TeV}$.

$$\Delta(\Lambda_{d_{d_l}} = 1 \text{ TeV}) \approx 1 - 1 [1 + i \cot(d_{d_l} \pi)] f_1(d_{d_l}) \left\{ (c_{sB}^2) - 4.8 \cdot 10^{-7} (c_{sB}^2) \right\}$$

(31)

$$\Delta(\Lambda_{d_{d_l}} = 10 \text{ TeV}) \approx 1 - 1 [1 + i \cot(d_{d_l} \pi)] f_{10}(d_{d_l}) \left\{ (c_{sB}^2) - 4.8 \cdot 10^{-7} (c_{sB}^2) \right\}$$

(32)

with

$$f_1(d_{d_l}) = 4.1 \cdot 10^{15} \frac{\Gamma(d_{d_l} + \frac{1}{2})}{\Gamma(d_{d_l} - 1) \Gamma(2d_{d_l})} \left( 7.3 \cdot 10^{-7} \right)^{d_{d_l}}$$

(33)

$$f_{10}(d_{d_l}) = 4.1 \cdot 10^{17} \frac{\Gamma(d_{d_l} + \frac{1}{2})}{\Gamma(d_{d_l} - 1) \Gamma(2d_{d_l})} \left( 7.3 \cdot 10^{-9} \right)^{d_{d_l}}$$

(34)

$f_1(d_{d_l})$ is a strictly monotonic decreasing function, with e.g. $f_1(1.1) \approx 6 \cdot 10^7$ and $f_1(1.9) \approx 2 \cdot 10^3$. $f_{10}(d_{d_l})$ is also strictly monotonic decreasing, but yielding smaller values as $f_1$, e.g. $f_{10}(1.1) \approx 4 \cdot 10^7$ and $f_{10}(1.9) \approx 35$. If one assumes real couplings, then the imaginary part of $\Delta$ is governed by the factor $\cot(d_{d_l} \pi)$. This factor vanishes at $d_{d_l} = 3/2$ and it is $\pm 1$ at $d_{d_l} = 5/4, 7/4$. Therefore one gets large imaginary contributions to $\Delta$ for values of $d_{d_l} \in ]1; 5/4[$ and $d_{d_l} \in ]7/4; 2[$.

For a further simplification we only consider a real coupling $c_V$ in the following. The measurement of $\Delta M_s$ tells us that $|\Delta| = 0.92 \pm 0.32$. Unparticle physics contributions yield

$$|\Delta| = \sqrt{1 - 2 c_{sB}^2 f(d_{d_l}) + [c_{sB}^2 f(d_{d_l})]^2 [1 + \cot(d_{d_l} \pi)]}$$

(35)
The measurements of $\Delta \Gamma_s$, $\Delta \Gamma_s/\Delta M_s$, $a^s_{fs}$ and $\phi_s$ give us information about $\phi_s$. Unparticle physics contributions yield

$$\tan \phi_s = \frac{c^2_v f(d_U) \cot(d_U \pi)}{1 - c^2_v f(d_U)} \quad (36)$$

Demanding $|\Delta|$ to be equal to one is equal to adjusting the coupling $c_V$ in such a way that $c^2_v f(d_U) = 2/(1 + \cot(d_U \pi))$. We get then

$$\phi_s = \arctan \left[ \frac{2}{1 - \tan(d_U \pi)} \right] \quad (37)$$

Plotting $\phi_s$ versus $d_U$ one sees that large contributions to $\phi_s$ can be obtained, even if the constraint from $\Delta M_s$ is fulfilled exactly.

From this figure one easily sees that large contributions to the mixing phase $\phi_s$ can be created by choosing an appropriate scaling dimension $d_U$: E.g $d_U = 1.3975$ corresponds to $\phi_s^\Delta \approx -\pi/4$ and $c_V = 7.3 \cdot 10^{-4}$ for $\Lambda_U = 1$ TeV or $c_V = 1.8 \cdot 10^{-3}$ for $\Lambda_U = 10$ TeV. This unparticle physics parameters yield $\Delta = 1$ and $\phi_s = -\pi/4$ and therefore one would measure

$$\Delta M_s = 17.4 \text{ ps}^{-1}, \quad \Delta \Gamma_s = 0.068 \text{ ps}^{-1}, \quad (38)$$

$$\frac{\Delta \Gamma_s}{\Delta M_s} = 3.91 \cdot 10^{-3}, \quad a^s_{fs} = -3.89 \cdot 10^{-3}. \quad (39)$$

This corresponds to an enhancement of $-200$ in the case of $a_{fs}$, while $\Delta M_s$ stays close to the measured value. Moreover if we assume the following theoretical and experimental uncertainties: $\Delta M_s : \pm 15\%$, $\Delta \phi_s : \pm 20\%$, $\Delta \Gamma_s/\Delta M_s : \pm 15\%$, $a^s_{fs} : \pm 20\%$, we obtain the regions in the $\Delta_s$-plane shown in figure 3.
3 Summary

In this paper we have investigated the unparticle effects to $B_s - \bar{B}_s$ mixing. We reproduce the results of [9–11] for the mass difference. In contrast to these works, we concentrate on large effects of unparticle stuff on the weak mixing phase $\phi_s$, while contributions to $\Delta M_s$ are small. The effects on the mixing phase vanish for $d_{ul} = 3/2$ a case which was investigated in many previous unparticle physics analyses, but it can be large for small deviations from 3/2. In particular we give an example for a parameter set $(\Lambda_{ul}, d_{ul}, c_V)$ for which one exactly reproduces $\Delta M_s$, and one gets in addition large new physics effects in quantities like the the semileptonic CP asymmetries. In the investigated case $a_{ls}$ is enhanced by a factor of almost -200 compared to its SM value. We are eagerly waiting for new experimental numbers to find out whether there is a sizeable mixing phase realized in nature.

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