# Revisiting electroweak baryogenesis in context of cancelation scenario in the MSSM

Seyed Yaser Ayazi
*Institute for Studies in Theoretical Physics and Mathematics (IPM), P.O. Box 19395- 5531,Tehran, Iran.*

We study electric dipole moment bounds on CP-violating phases in the MSSM with special emphasis on the cancelation scenario. We find that in the range favored by electroweak baryogenesis (*i.e.*, $|\mu| \simeq M_1$ or $|\mu| \simeq M_2$), $\sin[\theta_\mu + \theta_{M_1}]$ can be as large as $\mathcal{O}(1)$, even for slepton masses below 500 GeV. Such large values of the phases promise a successful electroweak baryogenesis. We also discuss the possibility of large CP-odd effects at a linear collider.



## 1. INTRODUCTION

It is well-known that one of the requirements to explain baryon asymmetry of the universe, is the violation of the CP symmetry. On the other hand elementary particles can possess Electric Dipole Moments (EDMs), only if the CP symmetry is violated. Thus, studying EDMs of the elementary particles can play an important role on increasing our knowledge about creation of the baryon asymmetry of the universe. Observing CP-violation in decay of kaon mesons has been one of the greatest discoveries of the past century in the elementary particle physics. This phenomenon can be explained by the phase of the CKM mixing matrix in context of the Standard Model (SM). This phase gives rise to $d_e \sim 10^{-38}$ $e$ cm [1]. The prediction of CKM phase for $d_n$ ranges from $10^{-31}$ $e$ cm to $10^{-33}$ $e$ cm [2]. No electric dipole moment for the electron or neutron has been so far detected but strong bounds on these quantities have been obtained [3, 4, 5]

$$|d_e| < 1.4\times 10^{-27}\, e\,\text{cm} \qquad |d_n| < 3.0\times 10^{-26}\, e\,\text{cm}. \quad (1)$$

Experiments have been proposed to improve these bounds by several orders of magnitude in a few years [6]. But the predictions of the SM for the EDM of electron and neutron are so small that these bounds can not be probed in the near future experiment.

Nonzero electric dipole moment of mercury also indicates violation of CP. The present bound on the EDM of mercury is[7]

$$|d_{Hg}| < 2.1 \times 10^{-28}\ e\ \text{cm}. \quad (2)$$

The CP-violating phase of the CKM matrix is not large enough to explain the baryon asymmetry of the universe [8].

An additional potential source for CP-violation in the SM arises due to instanton effects in QCD, *i.e*, the famous $\theta_{QCD}$ [9]. However upper bound on the EDM of neutron constrain the associated dimensionless parameter $\theta_{QCD}$-term to be less than $2\times 10^{-10}$ [10] which again is too small for explaining the Baryon asymmetry of the universe [11]. Thus, in order to explain the baryon asymmetry, the SM should be extended to include new sources of CP-violation.

The Minimal Supersymmetric Standard Model (MSSM) is the most popular way of extending the SM as it gives a solution for stabilizing the hierarchy problem of the SM. In the general MSSM more than forty sources of CP violation appear [12]. Moreover, the MSSM in its most general form, introduces new sources of flavor violation which can give rise to lepton flavor violating radiative decay of leptons ( $\mu \to e\gamma$, $\tau \to e\gamma$ and $\tau \to \mu\gamma$) and a deviation of $Br(b \to s\gamma)$ from the prediction of the SM. There are strong bounds on the branching ratios of the lepton flavor violating decay [13] as well as on the deviation of $Br(b \to s\gamma)$ from the prediction of the SM [14]. Motivated by this observation constrained MSSM has been developed which reduces the number of the parameters of the SM by imposing universality condition at high energies. The cMSSM model is a particularly restrictive model in that there are only two new physical phases. These phases are associated with the phase of the A-term (the trilinear scalar terms in the soft supersymmetry breaking potential) and the mu-term (bilinear Higgs mass term in the superpotential). Considering the values for cMSSM parameters which phenomenologically are favorable, one finds that the EDMs of the electron, neutron and mercury exceed the experimental bounds by several orders of magnitude. In the literature, to solve this problem three solution are proposed:

- cMSSM phases are either zero or very small;
- The first generation of sleptons and the first two generations of squarks are very heavy [15];
- Different contributions of the cMSSM phases to EDMs cancel each other.

If the phases are very small, cMSSM cannot explain baryon asymmetry of the universe. Also if second solution is realized, the production and study cMSSM particles at ILC and LHC will be difficult, if possible at all [16, 17]. Then from the phenomenological point of view, first two solution are not favorable.

The third possibility has been extensively studied in the literature [18, 19]. Since it ostensibly allows for large amount of CP-violating phase with relatively small slepton and squark masses. Unfortunately it seems that cancelation scenario works only if the phase of $\mu$ is $\mathcal{O}(10^{-2})$ or less which is too small to result in detectable CP-violating effects in colliders. This is due to the fact that there are only two CP-violating phases which cannot simultaneously satisfy experimental upper bounds on $d_e$, $d_n$ and $d_{Hg}$, and also for large $\tan\beta$ regime, the contribution of $\theta_\mu$ to the EDMs of the electron as well as the down quark is enhanced such that it cannot be canceled by the effect of the phase of A-term, unless the phase of $\mu$ itself is small.

Consider situation that we have relaxed some of the universality conditions in the MSSM. This assumption leads to reproduction of some new phases. Therefore, possibility of cancelation between these new phases increases. Cancelation scenario for non-universality conditions in the parameter ranges which $|A_i| < 1$ TeV and, $\tan\beta < 10$ has been studied in Ref [20]. Also in [21], we have shown that cancelation scenario for $|A_s|, |A_d| > 1$ TeV, intermediate values of $\tan\beta$ and large values of $\mu$-phase and $A_i$ phases are possible. This letter is review of results which is studied in [21]. In section 2, we describe our model and some non-universal conditions which from phenomenological point of view are interesting. In section 3, we study the possibility of cancelation in the parameter range favored by resonant electroweak baryogenesis. In section 4, we discuss if the cancelation opens the possibility of large enough phases to cause sizeable CP-violating effects in phenomena at colliders.

## 2. THE MODEL

In this paper, we consider Minimal Supersymmetric Standard Model with the superpotential

$$\begin{aligned} W_{MSSM} &= Y_u \widehat{u^c}\ \widehat{Q}\cdot\widehat{H_u} - Y_d \widehat{d^c}\ \widehat{Q}\cdot\widehat{H_d} - Y_e \widehat{e^c}\ \widehat{L}\cdot\widehat{H_d} \\ &- \mu\ \widehat{H_u}\cdot\widehat{H_d} \end{aligned} \tag{3}$$

In the above formula, $\widehat{u^c}$, $\widehat{d^c}$ and $\widehat{e^c}$ are the chiral superfields associated with the corresponding right-handed fields. The soft supersymmetry breaking part of Lagrangian, at the electroweak scale, is taken to have the form

$$\begin{aligned} \mathrm{L}^{\mathrm{MSSM}}_{\mathrm{soft}} &= -1/2\left(M_3\widetilde{g}\widetilde{g} + M_2\widetilde{W}\widetilde{W} + M_1\widetilde{B}\widetilde{B} + \mathrm{H.c.}\right) \\ &- (A_{ui}Y_{uii}\widetilde{u_i^c}\ \widetilde{Q_i}\cdot H_u - A_{di}Y_{dii}\widetilde{d_i^c}\ \widetilde{Q_i}\cdot H_d \\ &- A_{ei}Y_{eii}\widetilde{e_i^c}\ \widetilde{L_i}\cdot H_d + \mathrm{H.c.}) - \widetilde{Q_i}^\dagger\ m^2_{\tilde{Q}ii}\widetilde{Q_i} \\ &- \widetilde{L_i}^\dagger\ m^2_{\tilde{L}ii}\widetilde{L_i} - \left(\widetilde{u_i^c}\right)^\dagger\ m^2_{\tilde{u}ii}\widetilde{u_i^c} - \left(\widetilde{d_i^c}\right)^\dagger\ m^2_{\tilde{d}ii}\widetilde{d_i^c} \\ &- \widetilde{e_i^c}^\dagger\ m^2_{\tilde{e}ii}\widetilde{e_i^c} - m^2_{H_u}\ H_u^\dagger\ H_u - m^2_{H_d}\ H_d^\dagger\ H_d \\ &- (\ b\ H_u\cdot H_d + \mathrm{H.c.}), \end{aligned} \tag{4}$$

where the "$i$" indices determine the flavor. We have relaxed universality assumption (*i.e.*, $m^2_{\tilde{\mu}} \neq m^2_{\tilde{e}} \neq m^2_{H_u} \neq m^2_{H_d}$). As mentioned before, flavor violating processes put strong bounds on the absolute values of flavor violating masses and A-term. For this reason, we have taken all matrices in (4) flavor diagonal. We have defined the A-parameters factoring out the corresponding Yukawa couplings and so in this model, A-parameters can possess different values and phases.

Notice that $m^2_{H_u}$, $m^2_{H_d}$ and sfermion masses are real because of hermiticity of lagrangian. The rest of parameters in Eq. 4 can in general be complex. By rephasing the fields of $H_u$ and $H_d$, we can absorb any phase in $b$. Also by rephasing gaugino fields we can make $M_2$ real. Therefore after performing the field rephasing, MSSM is specified by these phases: phases of $\mu$ and A-parameters as well as $M_3$ and $M_1$ (mass of gauginos).

As is well-known, the condition for electroweak symmetry breaking determines the values of $\mu$ in terms of $m^2_{H_d}$, $m^2_{H_u}$ and $\tan\beta$. In this paper, we do not make *a priori* any assumption on the values of $m^2_{H_u}$ and $m^2_{H_d}$ so we are free to assign any value to $|\mu|$. In this regard, our model resembles the Non-Universal Higgs Mass (NUHM) model which has recently received attention in the literature [22]. Here we show that cancelation scenario can revive electroweak baryogenesis for the range of parameters that slepton and squark are light.

As mentioned earlier, we relax the condition of universality at the GUT scale, and so we can have values of $A_e$ and $A_d$ as large as a few TeV while keeping the sfermion masses below TeV. For large values of A-terms, it is required to check CCB bounds which arises due to Color and Charge Breaking (CCB) vacua. It is shown [23] that (For positive $m^2_{H_d}$) to guarantee that no CCB occurs, it is sufficient to have [34]

$$A_e^2 < 3(m^2_{H_d} + m^2_{\tilde{e}_L} + m^2_{\tilde{e}_R}) \tag{5}$$

and

$$A_d^2 < 3(m^2_{H_d} + m^2_{\tilde{d}_L} + m^2_{\tilde{d}_R}). \tag{6}$$

Now we relax the unification of the masses at high energies and take $b$ (coefficient of b-term in soft SUSY lagrangian) to be of order of $|m^2_{H_u}|$. For large $\tan\beta$, from electroweak symmetry breaking condition in the MSSM, we find that $m^2_{H_d}$ can be positive and large. This means larger value for $m^2_{H_d}$ increases upper bounds on $A_e$ and $A_d$. Finally, since we are assuming that off-diagonal elements of the $A$-terms are absent (LFV), we do not need to be concerned about the region unbounded from below [24].

## 3. EDM BOUNDS AND ELECTROWEAK BARYOGENESIS

One of the unsolved mysteries of nature is the large asymmetry between amount of baryon and antibaryon in the universe. There is general consensus that the Baryon Asymmetry of the Universe (BAU) has been created in the early universe after the inflation. A number of different scenarios for generating baryon-antibaryon asymmetry have been suggested. Electroweak baryogenesis is one of the first scenarios that explains baryon asymmetry at electroweak scale. As pointed out by Sakharov [25], any theory which uses a particle physics model to generate BAU in the early universe, must satisfy the three following conditions:

- baryon number (B) violation;
- violation of C and CP;
- departure from thermal equilibrium.

It is shown that within the SM, baryogenesis cannot take place because of the lack of out-of equilibrium condition. The electroweak phase transition was regarded as a way to satisfy out-of equilibrium condition. The SM computations of the Higgs thermal potential show that, for first order phase transition, mass of Higgs must be smaller than 32 GeV [26], while experiments now demand a Higgs mass $m_H \geq 114$ GeV. Also both the C and CP symmetries should be violated in order for baryogenesis scenarios to succeed. C violation has been observed in weak interaction in context of SM. But as mentioned earlier, CP-violation sources in the SM are too small to account for observed BAU.

Baryogenesis at the electroweak phase transition needs new particles coupled to the Higgs in order to obtain both strong phase transition and to provide extra sources of CP violation. In context of MSSM, it is shown [26] that stop $(\widetilde{t})$ can couple strongly to the Higgs of MSSM and so it is possible to obtain departure from thermal equilibrium. In general, for sub-TeV sparticle mass, the upper bounds from the EDM consideration are so stringent that render electroweak baryogenesis unsuccessful. It is the subject of this section to show that thanks to cancelation scenario this mechanism can still explain the BAU even for sub-TeV sparticle masses.

In order to have strong first order phase transition in the context of supersymmetric electroweak baryogenesis, one of the top squarks has to be lighter than the top quark. Moreover if the lightest neutralino to be the lightest supersymmetric particle, this in line infer that first neutralino must be lighter than the top quark. Also in order to have successful electroweak baryogenesis, mass of the CP-odd Higgs boson, $m_{A^0}$, should be relatively low ($m_{A^0} \ll 1$ TeV). Another major requirement for having successful electroweak baryogenesis is of course having large enough CP-violating phases. However, in [17] it is shown that even for values of $\sin\theta_\mu$ as low as $10^{-2}$ successful electroweak baryogenesis can be a possibility provided that we are at the resonance region [27, 28] (i. e., $|\mu| \simeq |M_1|$ or $|\mu| \simeq |M_2|$).

Note that if the masses of selectron and sneutrino are below the TeV scale, even values of $\sin\theta_\mu$ as low as $10^{-2}$ will not be compatible with the bounds on the electric dipole moment of electron, unless the cancelation scenario is at work. Suppose future experiments (the LHC and ILC) confirm supersymmetry and find out that $m_{\tilde{\chi}_1^0} < m_{\tilde{t}_R} < m_t$ and discover a relatively light $A^0$. These conditions are tantalizingly close to the requirement for a successful electroweak baryogenesis. Now, suppose that the masses of selectrons turn out to be at the scale of few hundred GeV. Does this mean that the electroweak baryogenesis is ruled out? Figs (1,2) try to address this question by studying the possibility of cancelation between different contributions to $d_e$.

In this analysis, we consider only the one-loop effects, because in range of the parameters which the mass of sfermions are below the TeV scale, the dominant effects come from one-loop. Taking the two-loop effects into account only slightly shifts the cancelation point.

Fig. 1 shows the range of phases of $\mu$ and $M_1$ for which total cancelation among the contributions of the phases $\mu$, $M_1$ and $A_e$ to $d_e$ is possible. To draw this figure, we have set $\tan\beta = 10$, $m_{\tilde{e}_L} = 392$ GeV, $m_{\tilde{e}_R} = 218$ GeV, $m_{\tilde{\nu}_L} = 385$ GeV, and $M_2 = 415$ GeV. Moreover we have set $|M_1| = |\mu| = 200$ GeV which means we are in the neutralino-driven resonant electroweak baryogenesis regime [17]. For this choice of parameters the lightest neutralino is indeed lighter than the top quark. We have set $A_e = 700$ GeV which is smaller than $[3(m_{\tilde{e}_L}^2 + m_{\tilde{e}_R}^2)]^{1/2}$ thus, as long as $m_{H_d}^2$ is positive [23], no CCB will take place (see Eq. 5). Positiveness of $m_{H_d}^2$ sets a lower bound on $b\tan\beta \simeq m_{A^0}^2$ which for our choice of parameters is 190 GeV. Thus, for these parameters $A^0$ (the CP-odd Higgs boson) can still be sufficiently light. Increasing $A_e$ the cancelation can of course become possible for larger values of $\theta_\mu$ but the lower bound on $m_{A^0}$ will also be stronger and on the other hand, for heavier $m_{A^0}$ the produced baryon asymmetry is suppressed. As shown in [17], the neutralino-driven resonant baryogenesis is only marginally compatible with the indirect searches of dark matter so this choice of parameters in near future will be tested not only by collider data but also by further indirect dark matter searches.

From Fig. 1, we observe that for universal gaugino masses $[\theta_{M_1} = \theta_{M_2} = 0]$, cancelation can take place even for values of $|\sin\theta_\mu|$ up to 0.06 which according to [17] can easily yield the baryon-antibaryon asymmetry compatible with the WMAP results. This confirms the results of [27]. In the neutralino-driven electroweak baryogenesis regime, the combination of the phases which determines baryogenesis is $\theta_\mu + \theta_{M_1}$. Notice that $\theta_\mu + \theta_{M_1}$ is a rephasing invariant quantity. Fig. 1 shows that, relaxing the assumption of the

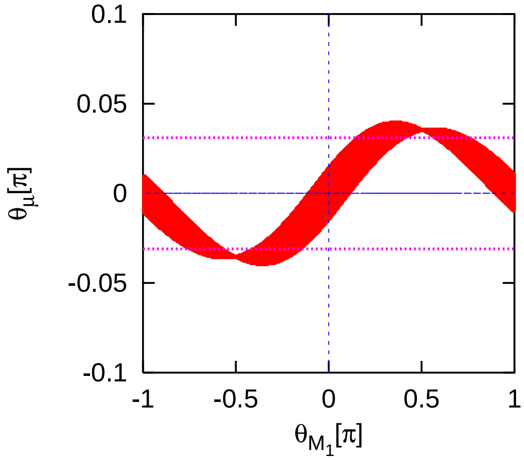


FIG. 1: The range of phases of $\mu$ and $M_1$ for which total cancelation among the contributions of the phases $\mu$, $M_1$ and $A_e$ to $d_e$ is possible. We have taken $m_{\tilde{e}_L} = 392$ GeV, $m_{\tilde{e}_R} = 220$ GeV, $m_{\tilde{\nu}_L} = 385$ GeV, $|A_e| = 700$ GeV, $|M_1| = 200$ GeV and $M_2 = 415$ GeV and $\tan\beta = 10$. We have set $|\mu| = 200$ GeV$= |M_1|$ which corresponds to the neutralino-driven resonance condition of electroweak baryogenesis. The horizontal dotted lines depict $\sin\theta_\mu = \pm 0.1$.

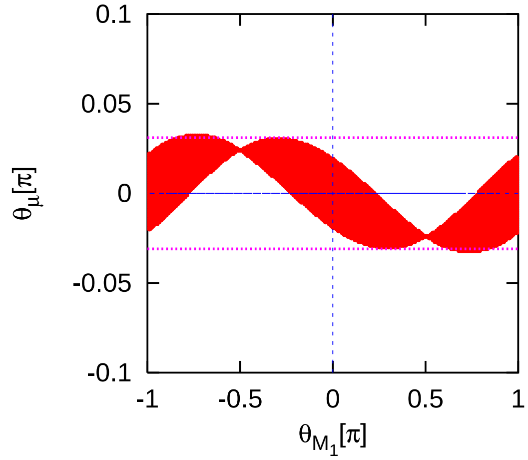


FIG. 2: The range of phases of $\mu$ and $M_1$ for which total cancelation among the contributions of the phases $\mu$, $M_1$ and $A_e$ to $d_e$ is possible. We have taken $m_{\tilde{e}_L} = 333$ GeV, $m_{\tilde{e}_R} = 187$ GeV, $m_{\tilde{\nu}_L} = 324$ GeV, $|A_e| = 700$ GeV, $|M_1| = 167$ GeV and $M_2 = 348$ GeV and $\tan\beta = 10$. We have set $|\mu| = 340$ GeV$\simeq M_2$ which corresponds to the chargino-driven resonance condition of electroweak baryogenesis. The horizontal dotted lines depict $\sin\theta_\mu = \pm 0.1$.

universality of the gaugino masses $[\theta_{M_1} \neq \theta_{M_2} = 0]$, cancelation makes $|\sin(\theta_\mu + \theta_{M_1})| \sim 1$ compatible with the bounds on $d_e$.

Note that in our analysis, we consider only EDM of electron. In the case of neutron and mercury there are 6 new sources of CP-violation in comparison with the SM [phases of $\mu$, $M_1$, $M_3$, $A_d$ , $A_u$ and $A_s$]. Thus, there exist large degrees of freedom which makes it possible for CP-violation phases to take large values in cancelation scenario.

Now let us discuss fine tuning required for such cancelation. If the phases of $\mu$ and $M_1$ are at the region where cancelation can take place, the generic value of $d_e$ is already around $10^{-26}$ e cm so to reduce the value of $d_e$ down to below the upper bound on it (see Eq. 1), a cancelation of 10% will be enough which means the fine tuning of the phases is not a problem. In Ref [21] fine tuning required for the cancelation scenario in the $d_n$ and $d_{Hg}$ have also been discussed and shown that it depends on formulas for $d_n$, $d_{Hg}$ in terms EDMs of quarks. Also fine tuning required for the cancelation scenario in these cases can be stronger than EDM of electron.

In the near future, the experiments are going to become sensitive to even smaller values of $d_n$, $d_{Hg}$ and $d_e$. Moreover, there are proposals to probe EDM of deuteron down to $(1-3)\times 10^{-27}$ e cm [29]. If one or more of these experiments detect a nonzero electric dipole moment, it will be a strong hint in favor of the electroweak baryogenesis. On the other hand, if they all report null results, we cannot still rule out the cancelation scenario even though a new piece of information (the bound on $d_D$) is added. However a greater degree of fine tuning would be necessary for the cancelation.

Fig. 2 explores the possibility of cancelation scenario and having large CP-violating phases in the chargino-driven resonant electroweak baryogenesis regime ($|\mu| \simeq M_2$). The above discussion holds in this case, too, with the difference that for the chargino-driven electroweak baryogenesis the combination of phases that are relevant for baryogenesis is $\theta_\mu + \theta_{M_2}$. [Notice that $\theta_\mu + \theta_{M_2}$ is a rephasing invariant quantity which in the basis we have chosen ($\theta_{M_2} = 0$) corresponds to $\theta_\mu$.] According to this figure $\sin(\theta_\mu)$ can reach 0.1 which may be enough for a successful baryogenesis [17]. In case of Fig. 2, since $|\mu|$ is larger, the lower bound on the CP-odd Higgs boson will be stronger: $m_{A^0} > 335$ GeV. Unlike the case of neutralino-driven electroweak baryogenesis, the chargino-driven electroweak baryogenesis is not sensitive to the indirect dark matter searches.

## 4. IMPLICATION OF CANCELATION SCENARIO FOR CP-VIOLATION SEARCHES IN THE COLLIDERS

The CP-violating phases can gives rise to both CP-even and CP-odd phenomena at the LHC [12, 30] and International Linear Collider, ILC [31, 32, 33]. Due to high precision and capability of polarizing the initial beams, the ILC will have a greater chance to observe CP-violation in the production and decay of sparticles. In [32, 33], it is shown that even small values of CP-violating phases can result in an asymmetry between $e^+e^- \to \tilde{\chi}^0_1 \tilde{\tau}^+_1 \tau^-$ and $e^+e^- \to \tilde{\chi}^0_1 \tilde{\tau}^-_1 \tau^+$. Following [32], let us define

$$A_{CP} \equiv \frac{P_2 - \bar{P}_2}{2}. \tag{7}$$

In the above definition, $P_2$ is the polarization of $\tau$ which is produced in the subsequent processes $e^+e^- \to \tilde{\chi}^0_1 \tilde{\chi}^0_i$ and $\tilde{\chi}^0_i \to \tau^- \tilde{\tau}^+$. The polarization vector is defined as

$$\vec{P} \equiv \frac{\mathrm{Tr}[\rho\vec{\sigma}]}{\mathrm{Tr}[\rho]}, \tag{8}$$

where $\rho$ is the spin density of $\tau$ and direction 2 is taken to be perpendicular to the plane defined by the momenta of the $\tau$ and the initial electron. Curves in Fig. 3, which are borrowed from Fig. 2.12.b of [32], show different contour lines corresponding to various values of $A_{CP}$. The input data for the curves are $\theta_{A_\tau} = 0$, $A_\tau = 250$ GeV and $(P_{e^-}, P_{e^+}) = (-0.8, 0.6)$. The rest of the input parameters are given in the caption of Fig. 3. Notice that the input parameters satisfy the relations that we would have expected in the mSUGRA. It is remarkable that $A_{CP} = \pm 45\%$ can be possible for values of $\theta_\mu$ as small as $\pm 0.1\pi$ and $\theta_{M_1} = \pm 1/6\pi$ or for $\theta_\mu = \pm 0.06\pi$ and $\theta_{M_1} = \pm\pi/2$. The shadowed areas superimposed on the curves show the region for which the cancelation scenario can result in vanishing $d_e$. In order to check if in the same area vanishing $d_n$ and $d_{Hg}$ is possible, we calculated the corresponding gluino and squark masses in the specific point in the mSUGRA space chosen above and inserted them in the formulae for $d_{Hg}$ and $d_n$. We found that for any given set of $\theta_\mu$ and $\theta_{M_1}$ total cancelation can simultaneously suppress the values of $d_n$ and $d_{Hg}$. The overlap of curves with the shadowed area indicates that even for light sfermion masses, we still have a hope to observe CP-violating effects at ILC provided that the systematic and statistical errors are under control.

Let us now discuss the fine tuning required for suppressing the EDMs below the upper bounds on them. Taking $\theta_\mu$ and $\theta_{M_1}$ in the shadowed area and assigning a general value between $-\pi$ and $\pi$ to $\theta_{A_e}$ we find that $d_e$ cannot exceed $10^{-26}$ e cm. This means that the fine tuning required to suppress $d_e$ below the bound in Eq. 1 is not greater than 10%. However, although simultaneous suppression of $d_n$ and $d_{Hg}$ is possible for a wider range of phases, we have found that the required fine-tuning in this case is greater and is of order of 1%.

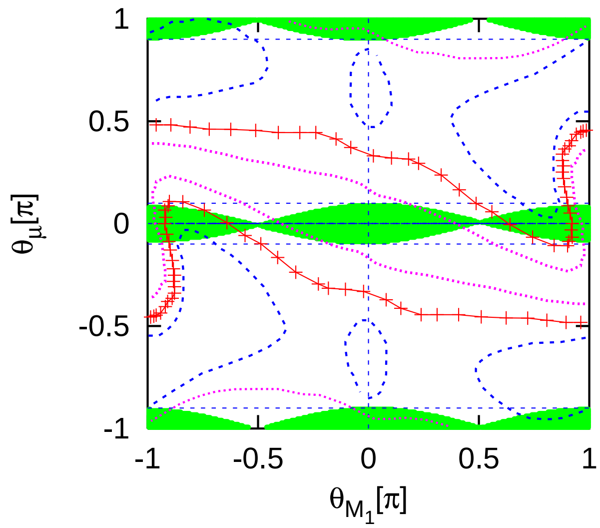


FIG. 3: Shadowed areas show the region where cancelation can yield vanishing $d_e$. The curves, which are borrowed from Fig. 2.12.b of [32], correspond to various values of $A_{CP}$ (see the text for the definition of $A_{CP}$): Dashed lines correspond to $A_{CP} = \pm 45\%$; curves marked with + indicate $A_{CP} = \pm 30\%$ and finally the thin curves correspond to $A_{CP} = \pm 15$ %. To draw the shadowed area we have used the same input parameters as in Fig 2.12.b of [32]: $|\mu| = 300$ GeV, $m_{\tilde{e}_L} = 378$ GeV, $m_{\tilde{e}_R} = 211$ GeV, $m_{\tilde{\nu}_L} = 370$ GeV, $|M_1| = 192$ GeV, $M_2 = 400$ GeV, $|A_e| = 2000$ GeV and $\tan\beta = 5$. The horizontal dotted lines correspond to $\theta_\mu = -0.9\pi, -0.1\pi, 0.1\pi$ and $0.9\pi$.

## 5. CONCLUSIONS

In this letter, we have studied the the cancelation scenario for EDMs in the context of general MSSM in the parameter range that is interesting from phenomenological point of view (*i.e.*, low sparticle masses). In our model, we assumed some of the conditions which phenomenologically are interesting. We have studied the possibility of cancelation for the region that electroweak baryogenesis is enhanced ($|\mu| \simeq |M_1|$ and $|\mu| \simeq |M_2|$) and found that, even for the sub-TeV slepton masses, $|\sin\theta_\mu| \simeq 0.1$ and $|\sin\theta_{M_1}| \simeq 1$ can be compatible with the EDM bounds. The main point is that relaxing the assumption of the universality of gaugino mass phases ($\theta_{M_1} \neq \theta_{M_2}$) makes more effective cancelation such that values of $|\sin[\theta_\mu + \theta_{M_1}]| \sim 1$ become compatible with the bounds on $d_e$. This opens new windows towards successful electroweak baryogenesis. Notice that in this range of parameters the fine-tuning required for successful cancelation is not too high.

We have then focused on CP-odd quantities associated with the decay of neutralinos at ILC and have found that thanks to cancelation, $A_{CP}$ ( see the definition in Eq. 7) as large as 45% can be possible.

## 6. ACKNOWLEDGEMENT

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