Signals for CP Violation in Split Supersymmetry

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Abstract

Split supersymmetry is characterized by relatively light chargino and neutralino sector and very heavy sfermion sector. We study the consequence of CP violation in this scenario by evaluating two-loop contributions to electric dipole moments of fermions from Higgs-photon as well as W-Wdiagrams. These contributions add coherently and produce electron and neutron electric dipole moments close to present bounds. We then explore Higgs production at a photon-photon collider, and consider the feasibility of measuring CP violating $h\gamma\gamma$ coupling induced by chargino loops. Methods of enhancing the sensitivity are discussed. For lower chargino masses and lower Higgs boson masses, the effect of the CP violation can be observed with 90% confidence level significance.

I. INTRODUCTION

Supersymmetry(SUSY) has been one of the most promising candidates for the extension of the Standard Model(SM). It provides an elegant solution to the gauge hierarchy problem. Recently a new scenario of SUSY model was proposed, in which solution of the naturalness problem is no longer required [1]. This scenario is dubbed split SUSY because of the hierarchical mass difference between the scalar and the fermionic superpartners. The other two prominent features of SUSY, gauge coupling unification and dark matter candidate are retained in split SUSY. By allowing the existence of fine-tuning, the SUSY breaking scale can be relaxed to be much higher than 1 TeV. Subsequently, the heavier sfermion masses help to eliminate several unpleasant aspects of SUSY, including excessive flavor and CP violation, fast dimension-5 proton decay and the non-observation of the lightest CP even Higgs boson. Various aspects of phenomenology in the split SUSY scenario have been explored in Refs. [2, 3, 4].

Split supersymmetry is characterized by relatively light (100 GeV-1 TeV) charginos and neutralinos and much heavier squarks and sleptons. In this note we further explore some of the consequences of CP-violation in split SUSY. We shall consider electric dipole moment (EDM) of electron and quarks, and arrive at their value in split SUSY versus in standard SUSY. Similarly, we consider CP violating coupling of the Higgs boson to photons, and examine the feasibility of measuring this effect at a $\gamma\gamma$ collider. We shall allow CP violating phases in the SUSY potential to take values of O(1), and all suppressions of one-loop contribution is attributed to higher masses of the supersymmetric particles.

Electric dipole moments of fermions arise at one loop in conventional SUSY. As squark and slepton masses exceed 5 TeV and charginos and neutralinos remains light, the one-loop contributions become comparable to the two-loop contributions. In split SUSY, the twoloop contributions arise from a set of Higgs-photon diagram considered before [2], as well as the W-W diagram, that we consider here ¹. Allowing SUSY parameters to have arbitrary complex values, we show that these two contributions always add coherently. The predicted values of the electron EDM in particular set useful constraint on split SUSY mass scale, and further improvement in measurements [5] can provide strong constraints on the theory. We

¹ As we were preparing to submit this paper, we noticed a similar study by Chang, Chang and Keung [4] was submitted to the arXiv.

similarly discuss neutron EDM.

Another CP violation signal is through the study of the $h\gamma\gamma$ coupling. In the SM, the Higgs coupling to photons arises predominantly through W-boson and top-quark loop, and is CP conserving. In supersymmetry, a CP violating coupling can arise through chargino loop, provided the complex phases in the chargino sector are non-zero [2, 6]. The CP violating effect is similar to that in a two Higgs doublet model with CP violating mixing of scalor and pseudo-scalar Higgs. We extend the work of Ref. [6] to a more realistic level and examine the sensitivity of measuring CP violation at a future $\gamma\gamma$ collider.

After the introductions, we discuss the EDM in Sec. II and $h\gamma\gamma$ coupling in Sec. III. Our conclusions are presented in Sec. IV.

II. ELECTRIC DIPOLE MOMENTS

In split SUSY, as the sfermions get heavy, the one-loop contributions to the fermion EDM get suppressed due to the large sfermion mass. The neutralinos, charginos and the lighter CP even Higgs boson remain light. The CP phases in the gaugino sector can induce EDM for fermions at 2-loop level. Study of the two-loop fermion EDMs in the SM and SUSY can can be found in Refs. [7, 8, 9, 10, 11, 12, 13]. In split SUSY, the diagrams involving charged Higgs bosons are suppressed due to the very large charged Higgs boson masses. The typical diagrams, shown in Fig. 1, include a set of diagrams that involve a Higgs boson and a photon (left) and those that involve two W bosons (right). The contributions from the Higgs diagrams have been studied in Ref. [2]. We focus on the contributions from the W-W diagram.

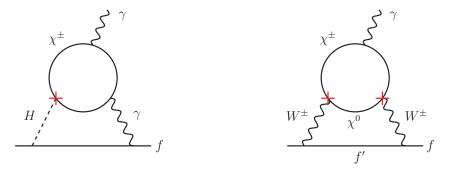


FIG. 1: Feynman diagrams of the fermion EDMs at two-loop level. The (red) crosses indicate CP violating couplings.

To specify our notation, we start with the chargino and neutralino mass matrices. The chargino mass matrix is

$$M_{\chi^{+}} = \begin{pmatrix} M_{2} & gv_{2}^{*}/\sqrt{2} \\ gv_{1}^{*}/\sqrt{2} & \mu \end{pmatrix} , \qquad (1)$$

where g is the weak coupling and m_W is the W boson mass. In general, the gaugino and higgsino mass parameter M_2 and μ , and the vacuum expectation values v_1 and v_2 are all complex. After absorbing three of the complex phases through field redefinition, there are only one independent phase ϕ_{μ} left. The chargino mass matrix can be diagonalized by unitary matrices U and V,

$$U^{\dagger}M_{\chi^{+}}V = \text{diag}(m_{\chi^{+}_{1}}, m_{\chi^{+}_{2}}) , \qquad (2)$$

with the chargino masses satisfying $m_{\chi_1^+} < m_{\chi_2^+}$. The neutralino mass matrix depends on an additional gaugino mass parameter M_1 ,

$$M_{\chi^0} = \begin{pmatrix} M_1 & 0 & -g'v_1^*/2 & g'v_2^*/2 \\ 0 & M_2 & gv_1^*/2 & -gv_2^*/2 \\ -g'v_1^*/2 & gv_1^*/2 & 0 & -\mu \\ g'v_2^*/2 & -gv_2^*/2 & -\mu & 0 \end{pmatrix},$$
(3)

and after redefinition of fields, two independent phases remain, ϕ_1 of M_1 and ϕ_{μ} . From now on, we keep only the complex phases ϕ_{μ} and ϕ_1 and set all other parameters to be real. The mass matrix above can be diagonalized by an unitary matrix N,

$$N^T M_{\chi^0} N = \text{diag}(m_{\chi^0_1}, m_{\chi^0_2}, m_{\chi^0_3}, m_{\chi^0_4}) , \qquad (4)$$

where the neutralino masses are in the order of $m_{\chi_1^0} < m_{\chi_2^0} < m_{\chi_3^0} < m_{\chi_4^0}$. In this notation, the two loop contribution to fermion EDM from the Higgs-photon digram is,

$$d_{f}^{h} = \frac{e \alpha Q_{f} m_{f} g^{2}}{32\sqrt{2}\pi^{3} m_{W} m_{h}^{2}} \left(1 - \frac{4\alpha}{\pi} \ln \frac{m_{h}}{m_{f}}\right)$$

$$\operatorname{Im} \sum_{j=1}^{2} (\cos \beta U_{i2} V_{i1} + \sin \beta U_{i1} V_{i2}) m_{\chi_{i}^{+}} f\left(\frac{m_{h}^{2}}{m_{\chi_{i}^{+}}^{2}}\right) , \qquad (5)$$

$$f(x) = \frac{2\sqrt{x}}{\sqrt{x-4}} \left[\ln x \ln \frac{\sqrt{x-4} + \sqrt{x}}{\sqrt{x-4} - \sqrt{x}} + \operatorname{Li}_{2} \left(\frac{2\sqrt{x}}{\sqrt{x} - \sqrt{x-4}}\right) - \operatorname{Li}_{2} \left(\frac{2\sqrt{x}}{\sqrt{x} + \sqrt{x-4}}\right)\right] .$$

Here Q_f and m_f are the charge and mass of the fermion respectively, m_h is the mass of the lightest CP even Higgs boson and $\tan \beta$ is the ratio of v_2 and v_1 , $\tan \beta = v_2/v_1$.

To evaluate the W-W diagram, it is necessary to write out the Lagrangian involving W boson, neutralinos and charginos

$$\mathcal{L} = \frac{1}{\sqrt{2}} g \overline{\chi_i^0} \gamma^\mu \left(L_{ij} \frac{1 - \gamma_5}{2} + R_{ij} \frac{1 + \gamma_5}{2} \right) \chi_j^+ W_\mu^- + H.C. , \qquad (6)$$

where the couplings L_{ij} and R_{ij} (i = 1, 2, 3, 4 and j = 1, 2) are

$$L_{ij} = \sqrt{2}N_{i2}V_{j1}^* + N_{i3}V_{j2}^* ,$$

$$R_{ij} = \sqrt{2}N_{i2}^*U_{j1} - N_{i4}^*U_{i2} ,$$
(7)

and they have different complex phases.

For electron, up and down quarks, their masses and the masses of their SU(2) partners are much smaller than the W boson mass. It is safe to neglect these small masses in the loop integrations. Taking this limit and following Ref. [13], the EDM of a fermion arising form the W-W diagram in Fig. 1 can be approximated by

$$d_{f}^{W} \approx \mp e \left(\frac{\alpha}{4\pi \sin^{2} \theta_{W}}\right)^{2} \sum_{i=1}^{4} \sum_{j=1}^{2} \operatorname{Im}(L_{ij}^{*}R_{ij}) \frac{m_{\chi_{i}^{0}} m_{\chi_{j}^{+}} m_{f}}{2m_{W}^{4}} \\ \int_{0}^{1} dx \frac{(1-x)m_{W}^{2}}{x m_{\chi_{i}^{0}}^{2} + (1-x)m_{\chi_{j}^{+}}^{2}} \ln \left[\frac{x(1-x)m_{W}^{2}}{x m_{\chi_{i}^{0}}^{2} + (1-x)m_{\chi_{j}^{+}}^{2}}\right] .$$

$$(8)$$

The minus/plus sign in front of the expression corresponds to fermions with third component of their isospin being 1/2 and -1/2 respectively.

Before presenting the numerical results, a few comments are in order. The CP violating $WW\gamma$ coupling can induce EDM for W boson at one-loop level. Directly measuring the W boson EDM is difficult. It can be constrained by measuring the electron and neutron EDMs. Unlike in the one-loop case, where the electron and neutron EDM values are enhanced by large value of tan β , the two-loop contributions are suppressed as tan β increases. We use d^h to denote the Higgs-photon contribution and d^W the W-W contribution to the electron EDM. Both d^h and d^W decreases as m_{χ^+} increases, while d^h is also reduced as m_h gets larger. With our choice of independent complex phases, d^h depends only on ϕ_{μ} and d^W depends on both ϕ_{μ} and ϕ_1 .

To show the dependence of d^W on the complex phases ϕ_{μ} and ϕ_1 , we choose the following parameters for illustrative purpose

$$|M_1| = 100 \,\text{GeV}, \quad M_2 = 200 \,\text{GeV},$$

 $|\mu| = 300 \,\text{GeV}, \quad \tan \beta = 1.0 \;.$ (9)

Although d^W depends on both ϕ_1 and ϕ_μ , the effect of varying ϕ_μ is more important. We show d^W as a function of ϕ_1 for $\phi_\mu = 0, \pi/4$, and $\pi/2$ in the left panel of Fig. 2. The variation of d^W due to ϕ_1 is an order of magnitude smaller than the variation due to ϕ_μ . Numerical evaluation also show that d^h has the same sign as d^W and is about twice in magnitude. Thus, for large enough ϕ_μ , independent of changes in ϕ_1 , d^h and d^W always add constructively.

In the right panel of Fig. 2, we show both the contributions form the Higgs-photon diagram and the W-W diagram. Here, we use $\phi_1 = 0$, $\phi_{\mu} = \pi/2$, $\tan \beta = 1$, $m_h = 120 \text{ GeV}$ and the unification inspired mass relation $M_1 = 5/3 \tan^2 \theta_W M_2$ to reduce the number of variables. As we vary M_2 , we change μ accordingly to maintain the chargino mass ratio $m_{\chi_2^+}/m_{\chi_2^-} = 2$. We see that the W-W diagram contribution is about 25% to 50% of that of the Higgs-photon diagram for chargino mass range from 100 GeV to 2 TeV. For larger m_h , d^h will be reduced, hence the relative importance of d^W increases. The dash line in the plot shows the current 95% confidence level upper bound on the electron EDM, $|d_e| < 1.7 \times 10^{-27} \text{ cm}$ [14]. If the CP phases are indeed of order O(1), the electron EDM bound constraints the chargino masses in split SUSY to be $m_{\chi_1^+} \gtrsim 150 \text{ GeV}$. The next generation EDM experiments can improve the sensitivity by a few order of magnitude [5]. Again assuming order O(1) CP phases, these measurements will either observe the electron EDM or put stronger constraints on chargino masses in split SUSY.

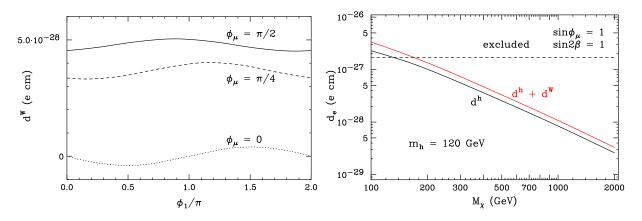


FIG. 2: Left: W-W diagram contribution d^W as a function of the complex phase ϕ_1 for $\phi_\mu = 0$ (dotted), $\pi/4$ (dashes) and $\pi/2$ (solid). Right: The dominant 2-loop contributions to the electron EDM d^h (black) and $d^h + d^W$ (red) as functions of $m_{\chi_1^+}$, for $\phi_1 = 0$, $\phi_\mu = \pi/2$, $\tan \beta = 1$ $m_h = 120$ GeV and $m_{\chi_2^+}/m_{\chi_1^+} = 2$.

If the sfermion masses are of the order of TeV, the one-loop diagrams involving sfermions

and gauginos or gluions will dominate the EDM contribution. In the MSSM, the predicted EDM values of the fermions can be much larger than the current experimental bounds. The fact that we have not observed large EDMs can be explained by, small complex phase, larger supersymmetric particle masses, cancellation at work or a combination of the above [15]. If we assume that the phases are of order O(1) and no large cancellation is present, the remaining explanation is to adopt heavy sfermion masses. In Fig. 3, we plot the one-loop prediction of electron EDM coming from the neutralino-selectron and chargino-sneutrino diagrams as a function of the selectron mass, while the sneutrino mass is set to be the same as the selectron mass. We see that, for $\tan \beta = 1$, a selectron mass of $m_{\tilde{e}} \approx 5$ TeV is sufficient to suppress the electron EDM to be below the experimental bound. For $\tan \beta = 10$, the corresponding mass is $m_{\tilde{e}} \approx 20$ TeV. If we compare Fig. 3 to the right panel of Fig. 2, it is interesting to note that, in the SUSY parameter space where sfermion masses are of a few TeV and the gauginos are light, both the one-loop and the two-loop contributions are equally important.

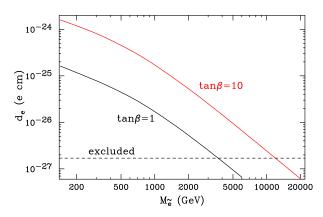


FIG. 3: One-loop electron EDM values as a function of the selectron mass.

The same two-loop diagrams can also generate EDMs for up and down quarks, when the one-loop contributions are suppressed by the large squark masses. The quark EDMs manifest through the EDM of neutron. In the conventional SUSY, when squarks are around 1 TeV, there are also chromoelectric dipole moments and gluonic dipole moments. As the squarks become heavy, both one-loop and two-loop contributions from these sources are suppressed. Lacking the full knowledge of the neutron wave function, we use the chiral quark model approximation [16] to estimate the neutron EDM from the quark EDMs,

$$d_n = \frac{\eta_e}{3} (4d^d - d^u) , \qquad (10)$$

where d^d and d^u are the down quark and up quark EDMs and $\eta_e \approx 1.53$ is the QCD correction factors. We evaluate the two-loop induced neutron EDM for the same set of parameters as in Eq.(9). The estimated neutron EDM is 4.0×10^{-26} e cm, which is close to the current experimental 90% confidence level upper bound of 6.3×10^{-26} e cm [17]. The predicted value will be smaller for larger tan β , m_{χ^+} and m_h , as in the case of electron EDM.

III. CP VIOLATION IN $\gamma\gamma$ TO h PRODUCTION

The loop induced $h\gamma\gamma$ coupling in the SM is CP conserving. However, if there exists mixing of the CP even and the CP odd Higgs bosons, there would be CP violating $h\gamma\gamma$ coupling in two Higgs doublet models. On the other hand, the chargino loop can induce CP violating $h\gamma\gamma$ coupling due to the complex phases in the chargino mass matrix. In principal, this CP violation can manifest in both the Higgs boson decay into two photons and production of a Higgs boson in photon-photon collisions. It is, in practice, difficult to determine the helicities of the outgoing photons from the Higgs decay. The mixing of Higgs bosons of different CP state has been discussed in Ref. [18, 19]. Similar to these analysis, the chargino loop induced CP violation can also be explored at a photon collider [2, 6]. We study in more detail the experimental observables and the backgrounds and estimated the sensitivity in determining the CP violating coupling.

The Higgs production rate in $\gamma\gamma$ collision is related to $h \to \gamma\gamma$ decay width at a given $\gamma\gamma$ center-of-mass energy $E_{\gamma\gamma}$ and the two colliding photon helicities, λ and λ' [20]

$$\sigma(\gamma\gamma \to h \to X) = \frac{8\pi\Gamma(h \to \gamma\gamma)\Gamma(h \to X)}{(E_{\gamma\gamma}^2 - m_h^2)^2 + \Gamma_h^2 m_h^2} (1 + \lambda\lambda') , \qquad (11)$$

where $\Gamma(h \to X)$ is the partial width of Higgs boson decay to X and Γ_h is the total decay width of the Higgs boson. The $h \to \gamma \gamma$ decay partial width is given by

$$\Gamma(h \to \gamma \gamma) = \frac{\alpha^2 g^2 m_h^3}{1024 \pi^3 m_W^2} (|e|^2 + |o|^2) , \qquad (12)$$

$$e = \frac{4}{3} F_{1/2} \left(\frac{4m_t^2}{m_h^2} \right) + F_1 \left(\frac{4m_W^2}{m_h^2} \right) + \sqrt{2} \operatorname{Re} \sum_{i=1}^2 (\cos\beta U_{i2} V_{i1} + \sin\beta U_{i1} V_{i2}) \frac{m_W}{m_{\chi_i^+}} F_{1/2} \left(\frac{4m_{\chi_i^+}^2}{m_h^2} \right) , \qquad (13)$$

$$o = \sqrt{2} \operatorname{Im} \sum_{i=1}^{2} (\cos \beta U_{i2} V_{i1} + \sin \beta U_{i1} V_{i2}) \frac{m_W}{m_{\chi_i^+}} F_{1/2} \left(\frac{4m_{\chi_i^+}^2}{m_h^2} \right) , \qquad (14)$$

where the integration functions for spin-1/2 and spin-1 particles in the loop are

$$F_{1/2}(x) = -2x \left[1 + (1-x) \left(\arcsin \frac{1}{\sqrt{x}} \right)^2 \right] , \qquad (15)$$

$$F_1(x) = 2 + 3x \left[1 + (2 - x) \left(\arcsin \frac{1}{\sqrt{x}} \right)^2 \right]$$
 (16)

Note because of the tininess of the bottom quark loop contribution, we ignore it here. The magnitude of the CP violation can be characterized by the ratio $R_{CP} = |o/e|$. We show R_{CP} for different chargino masses as a function of the Higgs boson mass in the left panel of Fig. 4. R_{CP} stays rather constant for different values of m_h until m_h approach the threshold for decay into two W bosons. Increasing $m_{\chi_1^+}$ to 150 GeV will reduce R_{CP} by about a factor of 2. For $m_{\chi_1^+} = 100 \text{ GeV}$, $\phi_{\mu} = \pi/2$, and $m_h = 120 \text{ GeV}$, R_{CP} is about 0.135.

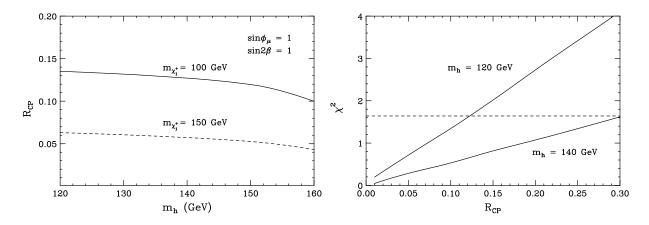


FIG. 4: Left: The ratio of R_{CP} as a function of m_h . The solid curve is for $m_{\chi_1^+} = 100 \text{ GeV}$ and $m_{\chi_2^+} = 200 \text{ GeV}$ and the dashed curve for $m_{\chi_1^+} = 150 \text{ GeV}$ and $m_{\chi_2^+} = 300 \text{ GeV}$. Right: The statistical significance as a function of R_{CP} for $m_h = 120 \text{ GeV}$ and $m_h = 140 \text{ GeV}$.

Three asymmetries can be constructed from e and o

$$A_1 = \frac{-2\mathrm{Im}(eo^*)}{|e|^2 + |o|^2} , \quad A_2 = \frac{-2\mathrm{Re}(eo^*)}{|e|^2 + |o|^2} , \quad A_3 = \frac{|e|^2 - |o|^2}{|e|^2 + |o|^2} .$$
(17)

In the current case, both e and o are real, and o is small compared to e. Therefore, A_1 is always 0 and the deviation of A_3 from ± 1 is of order $(o/e)^2$. The deviation of A_2 from 0 is of order (o/e), thus rendering A_2 the most promising observable. The Higgs production rate can now be expanded in terms of the asymmetries [6, 18]

$$dN = \frac{1}{2} dL_{\gamma\gamma} d\Gamma(|e|^2 + |o|^2) [(1 + \langle \zeta_2 \zeta_2' \rangle) + (\langle \zeta_3 \zeta_1' \rangle + \langle \zeta_1 \zeta_3' \rangle) A_2] , \qquad (18)$$

where, $dL_{\gamma\gamma}$ is the luminosity of the back-scattered photons, $d\Gamma$ is the phase space of the decay particles and he ζ_i are the Stokes parameters, which indicate the degree of linear and circular polarizations [21]. In the above expression we have dropped the A_1 term and we "turn off" the A_3 term by setting the azimuthal angle between the maximum linear polarization direction of the two back-scattered photons κ [21] to satisfy $\cos 2\kappa = 0$. The quantity A_2 can be accessed by measuring the difference between the production rates with $\sin 2\kappa = -1$ and 1. To accentuate the effect of A_2 , it is preferable to make $(\langle \zeta_3 \zeta_1' \rangle + \langle \zeta_1 \zeta_3' \rangle)$ as large as possible. This is achieved by setting the ratio of the emitted photon energy to the initial electron energy to be close to it is maximal value [6, 18]. Thus the electron-electron center of mass energy shall be slightly higher than the Higgs threshold, *e.g.*, $\sqrt{s_{ee}} = 150 \text{ GeV}$ for $m_h = 120 \text{ GeV}$ and $\sqrt{s_{ee}} = 175 \text{ GeV}$ for $m_h = 140 \text{ GeV}$.

As the Higgs boson in the mass range of 120 - 140 GeV decays significantly into $b\bar{b}$, we observe the Higgs boson production signal in the $b\bar{b}$ final state. Since it is only necessary to tag one of the two *b*-jets, the tagging efficiency is $2\epsilon_b - \epsilon_b^2 \approx 98\%$, with $\epsilon_b = 85\%$ being the tagging efficiency of one *b*-jet [22]. There exist a large $\gamma\gamma \rightarrow b\bar{b}$ and $c\bar{c}$ backgrounds. Assuming the rate of mistagging a *c*-jet as a *b*-jet is $\epsilon_c = 4.5\%$ [22], then the overall mistagging rate is $2\epsilon_c - \epsilon_c^2 \approx 0.2\%$. These two sources of backgrounds can be significantly reduced by imposing the invariant mass cut, $|m_{bb} - m_h| \leq 10$ GeV and the angular cut on outgoing *b*-jet direction relative to the beam line direction, $30^\circ < \theta_{bz} < 150^\circ$. With these cuts imposed, the background cross sections are $\sigma_{bb} = 5.7$ fb and $\sigma_{cc} = 9.1$ fb. As a comparison, for $m_h = 120$ GeV and $R_{CP} = 0.10$, the signal cross section with $\sin 2\kappa = 1$ is $\sigma_+ = 5.03$ fb and that with $\sin 2\kappa = -1$ is $\sigma_- = 4.66$ fb. The total of 1 ab^{-1} luminosity will be divided into 500 fb⁻¹ for the each of the $\sin 2\kappa = -1$ and 1 runs. In our analysis, we use 80% initial electron polarization and 100% polarization for linearly polarized initial photons [23].

The statistical significance is presented by

$$\chi^2 = \frac{N_+ - N_-}{\sqrt{N_+ + N_- + 2N_{BG}}} , \qquad (19)$$

where N_+ and N_- are the event number with $\sin 2\kappa = 1$ and -1 respectively and N_{BG} is the sum of the $b\bar{b}$ and $c\bar{c}$ background event numbers. In the right panel of Fig. 4, we show the statistical significance as a function of the ratio R_{CP} , where the dash line indicates the significance corresponding to a 90% confidence level measurement. For $m_h = 120$ GeV and with a 1 ab⁻¹ integrated luminosity, $R_{CP} \approx 0.12$ can be observed with 90% confidence level. Thus for $m_{\chi_1^+} = 100 \text{ GeV}$ and $m_h = 120 \text{ GeV}$, the predicted $R_{CP} = 0.135$ can be observed with 90% confidence level significance at a future $\gamma\gamma$ collider. For $m_h = 140 \text{ GeV}$, the predicted $R_{CP} = 0.13$ is harder to observe because of the reduced branching ratio of Higgs boson decay to $b\bar{b}$. Increasing luminosity will improve the significance, as also including other channels of Higgs boson decay.

IV. CONCLUSION

We have explored the consequences of CP violation in split SUSY. Assuming all CP phases are of O(1), we find that fermion EDMs arise from two loop diagrams in which gauginos are in the loops. We have shown that apart from Higgs-photon diagram already considered, W-boson diagram is of comparable importance. Furthermore, the two diagrams always add constructively, and sum of their contributions are close to the present experimental bounds. In the case of the electron, we already see that the present bound requires $m_{\chi_1^+} \gtrsim 150 \text{ GeV}$, provided that phase $\phi_{\mu} \approx \pi/2$. An order of magnitude improvement in the electron EDM would definitely constrain the chargino masses and would thus be competitive with accelerator bounds. We have also observed that unlike one loop contribution, the two loop gaugino contribution is largest for small $\tan \beta$. We have compared with the one-loop sfermion contribution, and we see that the contribution becomes small as sfermion masses exceed several TeV, the precise value being a function of $\tan \beta$. We have also estimated the neutron EDM from two-loop diagrams and find the predicted value close to the present bound, again for choice of large complex phase.

Another consequence of the CP phase in the gaugino sector is the loop induced CP violation in the $h\gamma\gamma$ coupling. We have considered studying this CP violating coupling at a future $\gamma\gamma$ collider, by the measurement of the Higgs production cross section for different initial photon polarizations. We have optimized the signal by arranging the initial electron and photon polarization and minimized the background with kinematic cuts. We conclude that with a luminosity of 1 ab^{-1} , for $m_{\chi_1^+} = 150 \text{ GeV}$, the lower $R_{CP} = 0.06$ might be difficult to observe. A 90% confidence level observation of CP violation can be achieved for $R_{CP} = 0.12$. In the split SUSY the predicted value for $m_{\chi_1^+} = 100 \text{ GeV}$ and $m_h = 120 \text{ GeV}$ is about 0.135, thus it is hopeful that this effect can be observed. For higher Higgs boson masses, it will be necessary to increase the luminosity and to include other decay channels.

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