Supersymmetry and Electric Dipole Moments

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Plan of the talk

- Flavour and CP Violation in the MSSM

- Electric Dipole Moments

- Geometric Approach for Optimizing CP Violation

- Nuclei with Enhanced Schiff Moments

- Summary

• Flavour and CP Violation in the MSSM

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$$31 \oplus 33 \oplus 47 = \mathbf{111}$$

• **Gaugino masses:** $\mathbf{3} \oplus \mathbf{3} = \mathbf{6}$

$$-\mathcal{L}_{\rm soft} \supset \frac{1}{2}(M_3\,\widetilde{g}\widetilde{g} + M_2\,\widetilde{W}\widetilde{W} + M_1\,\widetilde{B}\widetilde{B} + {\rm h.c.})$$

• **Trilinear couplings:** $\mathbf{a}_{\mathbf{f}ij} \equiv \mathbf{h}_{\mathbf{f}ij} \cdot \mathbf{A}_{\mathbf{f}ij}$: $\mathbf{3} \times (\mathbf{3} \oplus \mathbf{6} \oplus \mathbf{9}) = \mathbf{54}$

$$-\mathcal{L}_{\rm soft} \supset (\widetilde{u}^*_R\,\mathbf{a_u}\,\widetilde{Q}H_u - \widetilde{d}^*_R\,\mathbf{a_d}\,\widetilde{Q}H_d - \widetilde{e}^*_R\,\mathbf{a_e}\,\widetilde{L}H_d + {\rm h.c.})$$

• **Sfermion masses:** $\mathbf{5} \times (\mathbf{3} \oplus \mathbf{3} \oplus \mathbf{3}) = \mathbf{45}$

$$-\mathcal{L}_{\rm soft} \supset \widetilde{Q}^\dagger\,\mathbf{M}^2_{\widetilde{\mathbf{Q}}}\,\widetilde{Q} + \widetilde{L}^\dagger\,\mathbf{M}^2_{\widetilde{\mathbf{L}}}\,\widetilde{L} + \widetilde{u}^*_R\,\mathbf{M}^2_{\widetilde{\mathbf{u}}}\,\widetilde{u}_R + \widetilde{d}^*_R\,\mathbf{M}^2_{\widetilde{\mathbf{d}}}\,\widetilde{d}_R + \widetilde{e}^*_R\,\mathbf{M}^2_{\widetilde{\mathbf{e}}}\,\widetilde{e}_R$$

• **Higgs masses:** $\mathbf{3} \oplus \mathbf{1} = \mathbf{4}$, and the μ-**term**: $\mathbf{1} \oplus \mathbf{1} = \mathbf{2}$

$$-\mathcal{L}_{\rm soft} \supset M^2_{H_u} H^\dagger_u H_u + M^2_{H_d} H^\dagger_d H_d + (B\mu H_u H_d + {\rm h.c.})$$

• Flavour and CP Violation in the MSSM

$\mathbf{31 \oplus 33 \oplus 45 = 109}$ **!**

- **Gaugino masses:** $\mathbf{3 \oplus 3 = 6}$

$$-\mathcal{L}_{\rm soft} \supset \frac{1}{2}(M_3\, \widetilde{g}\widetilde{g} + M_2\, \widetilde{W}\widetilde{W} + M_1\, \widetilde{B}\widetilde{B} + {\rm h.c.})$$

- **Trilinear couplings:** $\mathbf{a}_{\mathbf{f}ij} \equiv \mathbf{h}_{\mathbf{f}ij} \cdot \mathbf{A}_{\mathbf{f}ij}$: $\mathbf{3 \times (3 \oplus 6 \oplus 9) = 54}$

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• Minimal Flavour Violating Approach to Flavour and CP

- The MFV:

$$m_0(M_{\rm MFV})\,,\ \ m_{1/2}(M_{\rm MFV})\,,\ \ A(M_{\rm MFV})\,;\ \ \tan\beta(m_t)\,,\ \ M_Z\ \ \text{up to}\,{\rm sign}(\mu)$$

with real and positive m_0, $m_{1/2}$, and A

- **Minimal Flavour Violating Approach to Flavour and CP**

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- Next to MFV:

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with complex $m_{1/2}$ and A

• Minimal Flavour Violating Approach to Flavour and CP

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- What is the maximal extension to MFV?

- Breaking of the $[SU(3) \otimes U(1)]^5$ flavour symmetries in the MSSM:

[R. S. Chivukula and H. Georgi, PLB188 (1987) 99;
G. D'Ambrosio, G. F. Giudice, G. Isidori, A. Strumia, NPB645 (2002) 155;
Generalization of GIM mechanism: S.L. Glashow, J. Iliopoulos, L. Maiani, PRD2 (1970) 1285.]

$$
\begin{aligned}
\mathbf{h}_{u,d} &\longrightarrow \mathbf{U}^\dagger_{U,D}\, \mathbf{h}_{u,d}\, \mathbf{U}_Q\,, \qquad \mathbf{h}_e \longrightarrow \mathbf{U}^\dagger_E\, \mathbf{h}_e\, \mathbf{U}_L\,,\\
\widetilde{\mathbf{M}}^2_{Q,L,U,D,E} &\longrightarrow \mathbf{U}^\dagger_{Q,L,U,D,E}\, \widetilde{\mathbf{M}}^2_{Q,L,U,D,E}\, \mathbf{U}_{Q,L,U,D,E}\,,\\
\mathbf{a}_{u,d} &\longrightarrow \mathbf{U}^\dagger_{U,D}\, \mathbf{a}_{u,d}\, \mathbf{U}_Q\,, \qquad \mathbf{a}_e \longrightarrow \mathbf{U}^\dagger_E\, \mathbf{a}_e\, \mathbf{U}_L\,.
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- Maximal CP and Minimal Flavour Violation (MCPMFV)

[e.g. J. Ellis, J. S. Lee, A. P., PRD76 (2007) 115011.]

$$M_{1,2,3}\,, \quad M^2_{H_{u,d}}\,, \quad \widetilde{\mathbf{M}}^2_{Q,L,U,D,E} = \widetilde{M}^2_{Q,L,U,D,E}\,\mathbf{1}_3\,, \quad \mathbf{A}_{u,d,e} = A_{u,d,e}\,\mathbf{1}_3$$

$3 \oplus 3$ 2 5 $3 \oplus 3$

$13 \oplus 6 = 19$ Parameters !

• Electric Dipole Moments

T Violation $\Longleftrightarrow$ **CP Violation** (under CPT)

Experimental limits:

$$|d_{\rm Tl}| \ < \ 9\times 10^{-25}\ e\cdot{\rm cm} \quad \to \quad |d_e| \ < \ 1.7\times 10^{-27}\ e\cdot{\rm cm}$$

[B. C. Regan, E. D. Commins, C. J. Schmidt, D. DeMille, PRL88 (2002) 071805]

$$|d_{\rm n}| \ < \ 3\times 10^{-26}\ e\cdot{\rm cm}$$

[C. A. Baker *et al.*, PRL97 (2006) 131801.]

$$|d_{\rm Hg}| \ < \ 3.1\times 10^{-29}\ e\cdot{\rm cm}$$

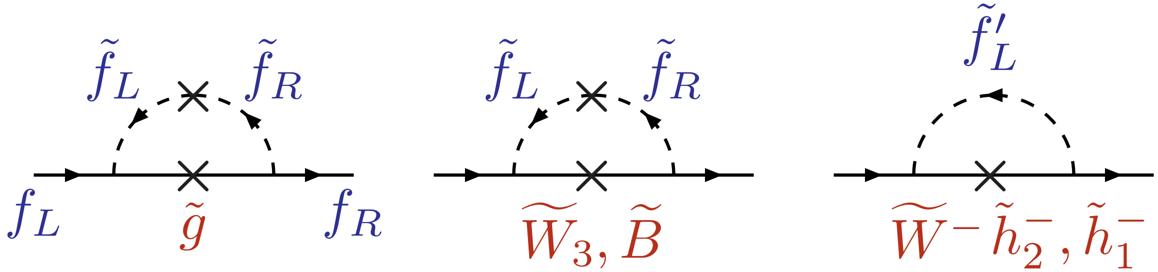
[W. C. Griffith et al, PRL102 (2009) 101601.]

Future Deuteron EDM:

[Y. K. Semertzidis *et al.* [EDM Collaboration], AIP Conf. Proc. 698 (2004) 200;
Y. F. Orlov, W. M. Morse, Y. K. Semertzidis, PRL96 (2006) 214802.]

$$|d_{\rm D}| \ < \ (1\text{–}3)\times 10^{-27}\ e\cdot{\rm cm} \quad \to \quad 10^{-29}\ e\cdot{\rm cm}$$

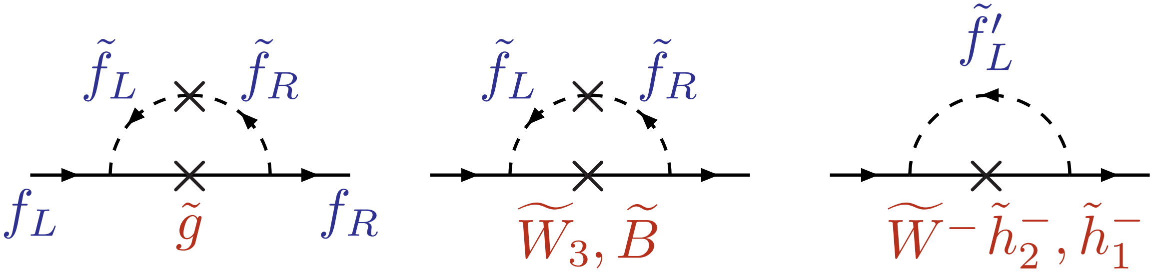
• EDMs in the MSSM



with $f = e,\ u,\ d$

$$\left(\frac{d_f}{e}\right)^{1-\mathrm{loop}} \sim (10^{-25}\,\mathrm{cm})\times\frac{\{\mathrm{Im}\,m_\lambda,\ \mathrm{Im}\,A_f\}}{\max(M_{\tilde{f}}, m_\lambda)}\left(\frac{1\ \mathrm{TeV}}{\max(M_{\tilde{f}}, m_\lambda)}\right)^2\left(\frac{m_f}{10\ \mathrm{MeV}}\right)$$

- **EDMs in the MSSM**



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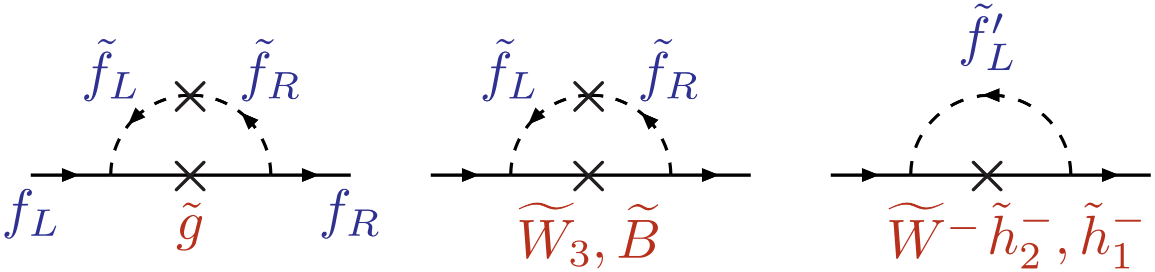
Schemes for resolving the 1-loop CP crisis:

• EDMs in the MSSM



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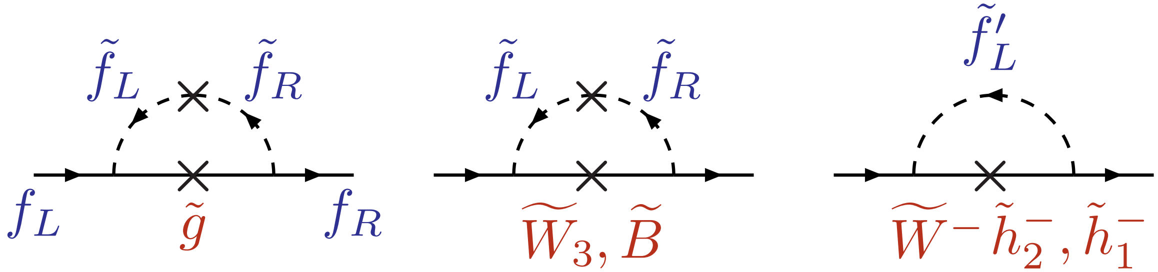
Schemes for resolving the 1-loop CP crisis:

- $\text{Im}\, m_\lambda/|m_\lambda|,\ \text{Im}\, A_f/|A_f| \lesssim 10^{-3};\ M_{\tilde{f}}, m_\lambda \sim 200$ GeV

- **EDMs in the MSSM**



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- CP phases ~ 1, <u>but</u> $M_{\tilde{f}} \gtrsim$ 5–10 TeV, for $\tilde{f} = \tilde{u}, \tilde{d}, \tilde{e}, \tilde{\nu}_L$

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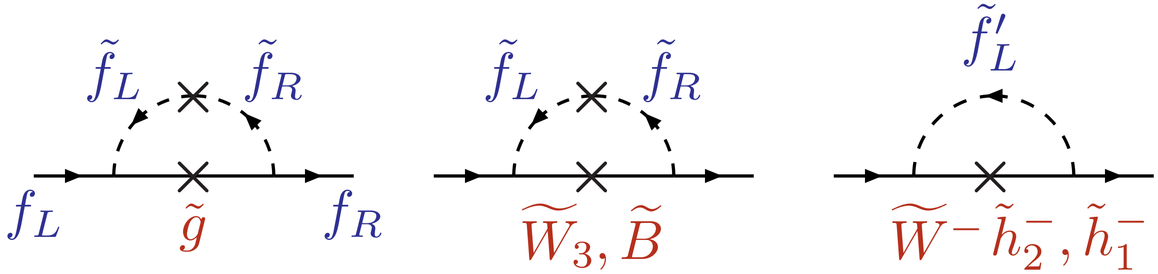

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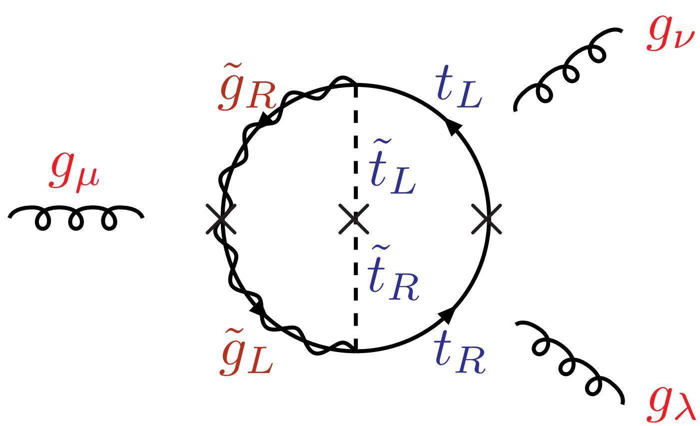
- CP phases ~ 1, but $M_{\tilde{f}} \gtrsim$ 5–10 TeV, for $\tilde{f} = \tilde{u}, \tilde{d}, \tilde{e}, \tilde{\nu}_L$
- Cancellations between the different EDM terms

An incomplete list of studies of EDMs:

- 1-loop EDMs:
  J. Ellis, S. Ferrara and D.V. Nanopoulos, PLB114 (1982) 231;
  W. Buchmüller and D. Wyler, PLB121 (1983) 321;
  J. Polchinski and M. Wise, PLB125 (1983) 393; . . .
- Heavy squark/gaugino decoupling:
  P. Nath, PRL66 (1991) 2565;
  Y. Kizukuri and N. Oshimo, PRD46 (1992) 3025
- Cancellation mechanism:
  T. Ibrahim and P. Nath, PLB418 (1998) 98;
  M. Brhlik, L. Everett, G.L. Kane and J. Lykken, PRL83 (1999) 2124.
- Constraints from $d_{\rm Hg}$:
  T. Falk, K.A. Olive, M. Pospelov and R. Roiban, NPB600 (1999)3;
  S. Abel, S. Khalil and O. Lebedev, NPB606 (2001) 151.
- EDMs induced by the $3g$-Weinberg operator:
  J. Dai, H. Dykstra, R.G. Leigh, S. Paban and D. Dicus, PLB237 (1990) 216.
- Higgs-Mediated 2-Loop EDMs:
  D. Chang, W.-Y. Keung and A.P., PRL82 (1999) 900;
  A.P., NPB644 (2002) 263.
- Reviews:
  M. Pospelov, A. Ritz, Annals Phys. 318 (2005) 119;
  J. R. Ellis, J. S. Lee, A. P., JHEP0810 (2008) 049.

Weinberg's three-gluon operator



$$\mathcal{L}_{3g} \;=\; -\tfrac{1}{3!}\, d_{3g}\, f^{abc}\, \widetilde{G}^{a\,\mu}_{\nu}\, G^{b\,\nu}_{\lambda}\, G^{c\,\lambda}_{\mu}$$

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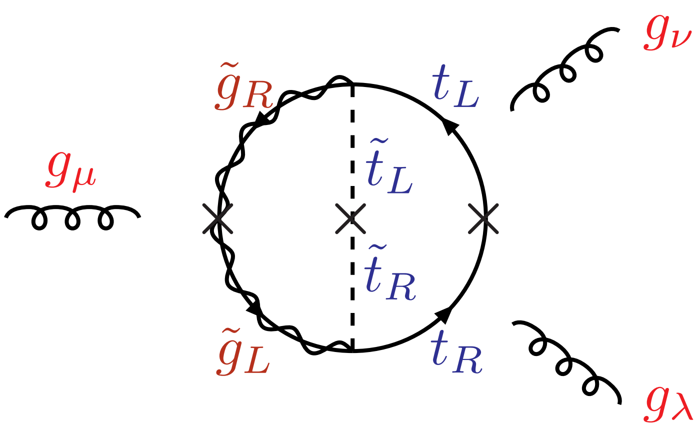


$$\mathcal{L}_{3g} \;=\; -\tfrac{1}{3!}\, d_{3g}\, f^{abc}\, \widetilde{G}^{a\,\mu}_{\nu}\, G^{b\,\nu}_{\lambda}\, G^{c\,\lambda}_{\mu}$$

Estimate based on naive dimensional analysis:

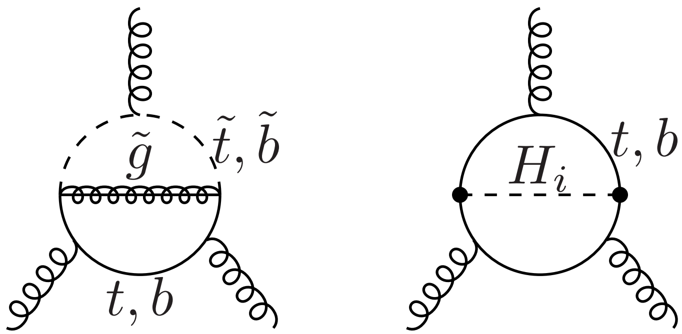
$$d_{3g} \;\sim\; \frac{g_s^3}{4\pi}\,\frac{3\alpha_s^2}{16\pi^2}\,\frac{m_{\tilde{g}}\, m_t^2\, \mathrm{Im}\,(A_t - \mu^* \cot\beta)}{m_{\tilde{g}}^4\, M_{\tilde{t}}^2}$$

$$\Longrightarrow \quad \left(\frac{d_n}{e}\right)^{3g} \;\sim\; (10^{-26}\ \mathrm{cm}) \times \left(\frac{0.5\ \mathrm{TeV}}{m_{\tilde{g}}}\right)^2 \frac{m_t^2\, \mathrm{Im}\,(A_t - \mu^* \cot\beta)}{M_{\tilde{t}}^2\, m_{\tilde{g}}}$$

EDM constraint: $m_{\tilde{g}} \gtrsim 400$ GeV.

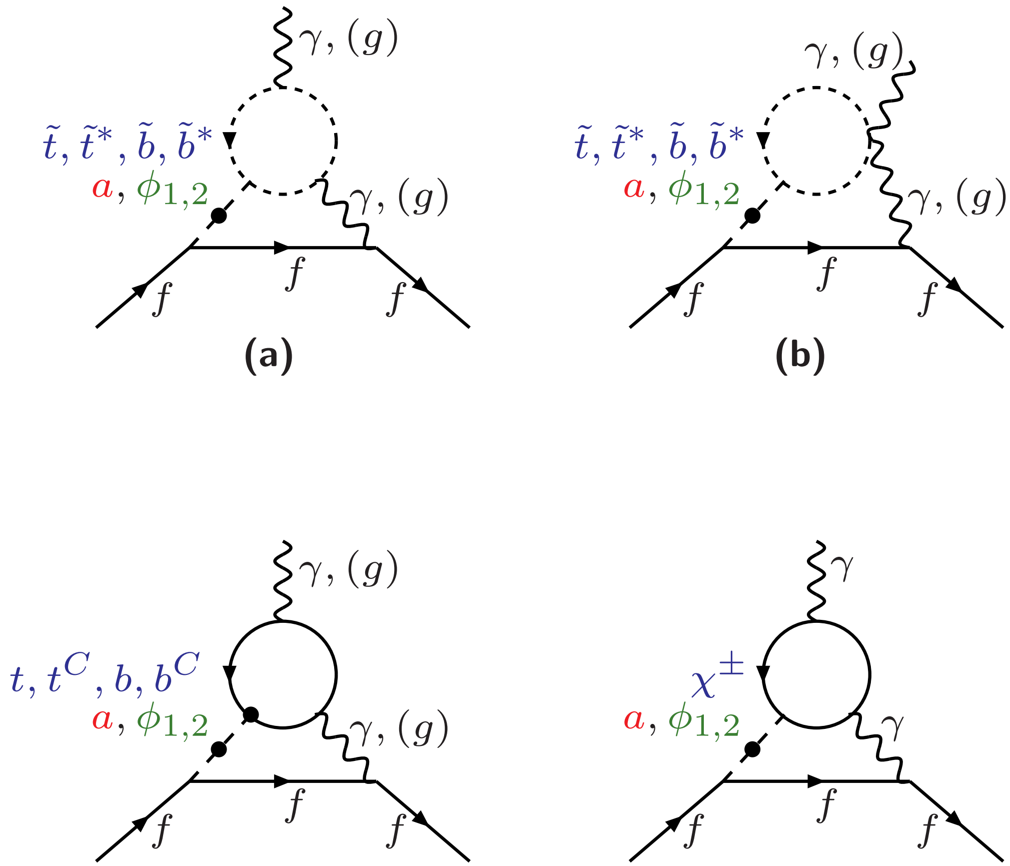
The proper Weinberg three-gluon operator in the MSSM

[S. Weinberg, PRL63 (1989) 2333;
D. A. Dicus, PRD41 (1990) 999;
J. R. Ellis, J. S. Lee, A. P., JHEP0810 (2008) 049]



Higgs-Mediated 2-Loop EDMs

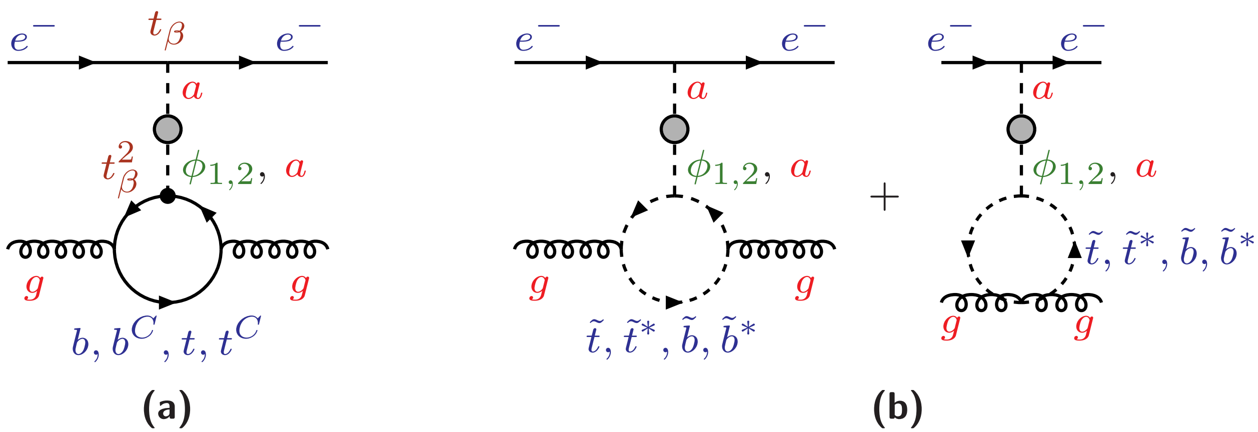
[D. Chang, W.-Y. Keung, A.P., PRL82 (1999) 900; A.P., NPB644 (2002) 263;
SUSY extension of the mechanism by S.M. Barr, A. Zee, PRL65 (1990) 21.]



$$d_f \;\propto\; \arg(\mu A_t,\ \mu m_{\tilde{g}},\ \mu m_{\widetilde{W}}),\ \tan\beta\,,\ \frac{1}{M_a}$$

Other Higgs-mediated contributions

[A.P., NPB644 (2002) 263;
D. A. Demir, O. Lebedev, K. A. Olive, M. Pospelov and A. Ritz, NPB680 (2004) 339;
initially studied in the 2HDM by S. Barr, PRL68 (1992) 1822.]



$$C_S^{(b,b^C)} \ \propto\ \arg(\mu A_t,\ \mu m_{\tilde{g}})\,,\ \tan^3\beta\,,\ \frac{1}{M_a^3}$$

And . . . more EDM contributions:

- FCNC effects on EDMs

[J. Hisano, M. Nagai, P. Paradisi, PRD78 (2008) 075019.]

- Higgsino-mediated 2-loop EDMs

[A.P., PRD62 (2000) 016007.]

- Other subdominant 2-loop EDMs

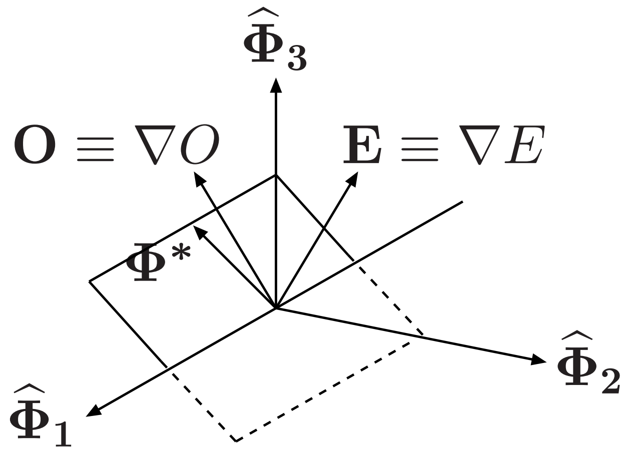
[A.P., PLB471 (1999) 174;
Y. Li, S. Profumo, M. Ramsey-Musolf, PLB673 (2009) 95.]

Most EDM contributions now included in CPsuperH2.2

[J.S. Lee, M. Carena, J. Ellis, A.P., C. Wagner, CPC180 (2009) 312.]

• Geometric Approach for Optimizing CP Violation

Simple 3D Example:



CP-violating observable: $O(\Phi_{1,2,3}) \approx \mathbf{\Phi} \cdot \mathbf{O}$, with $\mathbf{O} = \nabla O$.

EDM constraint: $E(\Phi_{1,2,3}) \approx \mathbf{\Phi} \cdot \mathbf{E} = 0$, with $\mathbf{E} = \nabla E$.

Optimal CP-odd direction: $\mathbf{\Phi}^* \; = \; \mathbf{E} \times \Big(\mathbf{O} \times \mathbf{E}\Big)$.

Maximum allowed value: $O \; = \; \phi^* \, \widehat{\mathbf{\Phi}}^* \cdot \mathbf{O} \; = \; \pm\, \phi^* \sqrt{|\mathbf{O}|^2 \, - \, (\mathbf{O} \cdot \widehat{\mathbf{E}})^2}$.

• Generalization to N Dimensions

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]

A 6D Example: the MCPMFV model with **3** EDM constraints $E^{a,b,c} = 0$

$$\mathbf{E} \quad \Longrightarrow \quad A_{\alpha\beta\gamma} \; = \; E^a_{[\alpha}\, E^b_\beta\, E^c_{\gamma]} \; : \qquad \text{Triple exterior product.}$$

$$\mathbf{O}\times\mathbf{E} \quad \Longrightarrow \quad B_{\mu\nu} \; = \; \varepsilon_{\mu\nu\lambda\rho\sigma\tau}\, O_\lambda\, E^a_\rho\, E^b_\sigma\, E^c_\tau \; : \qquad \text{Hodge-dual product}$$

6D Optimal direction for the CP-odd observable O:

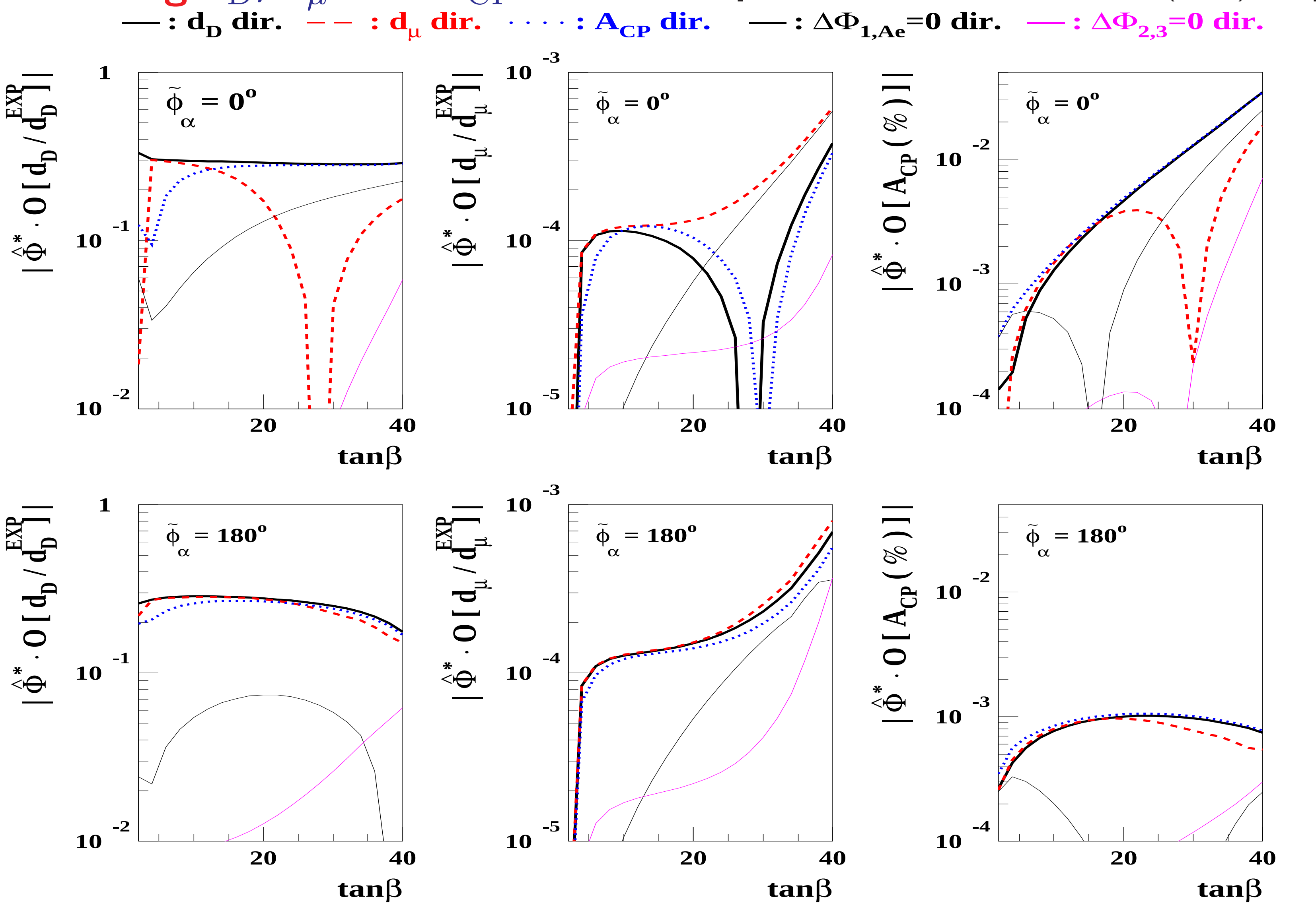
$$\Phi^*_\alpha \; = \; \mathcal{N}\, \varepsilon_{\alpha\beta\gamma\delta\mu\nu}\, A_{\beta\gamma\delta}\, B_{\mu\nu} \; = \; \mathcal{N}\, \varepsilon_{\alpha\beta\gamma\delta\mu\nu}\, \varepsilon_{\mu\nu\lambda\rho\sigma\tau}\, E^a_\beta\, E^b_\gamma\, E^c_\delta\, O_\lambda\, E^a_\rho\, E^b_\sigma\, E^c_\tau$$

Maximum allowed value for the observable O:

$$O \; = \; \phi^*\, \widehat{\Phi}^*_\kappa\, O_\kappa \; = \; \pm\, \mathcal{N} \left| \varepsilon_{\mu\nu\alpha\beta\gamma\delta}\, \varepsilon_{\mu\nu\lambda\rho\sigma\tau}\, O_\alpha\, O_\lambda\, E^a_\beta\, E^b_\gamma\, E^c_\delta\, E^a_\rho\, E^b_\sigma\, E^c_\tau \right| ,$$

Maximazing $d_{\rm D}$, d_μ and $A_{\rm CP}$

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]

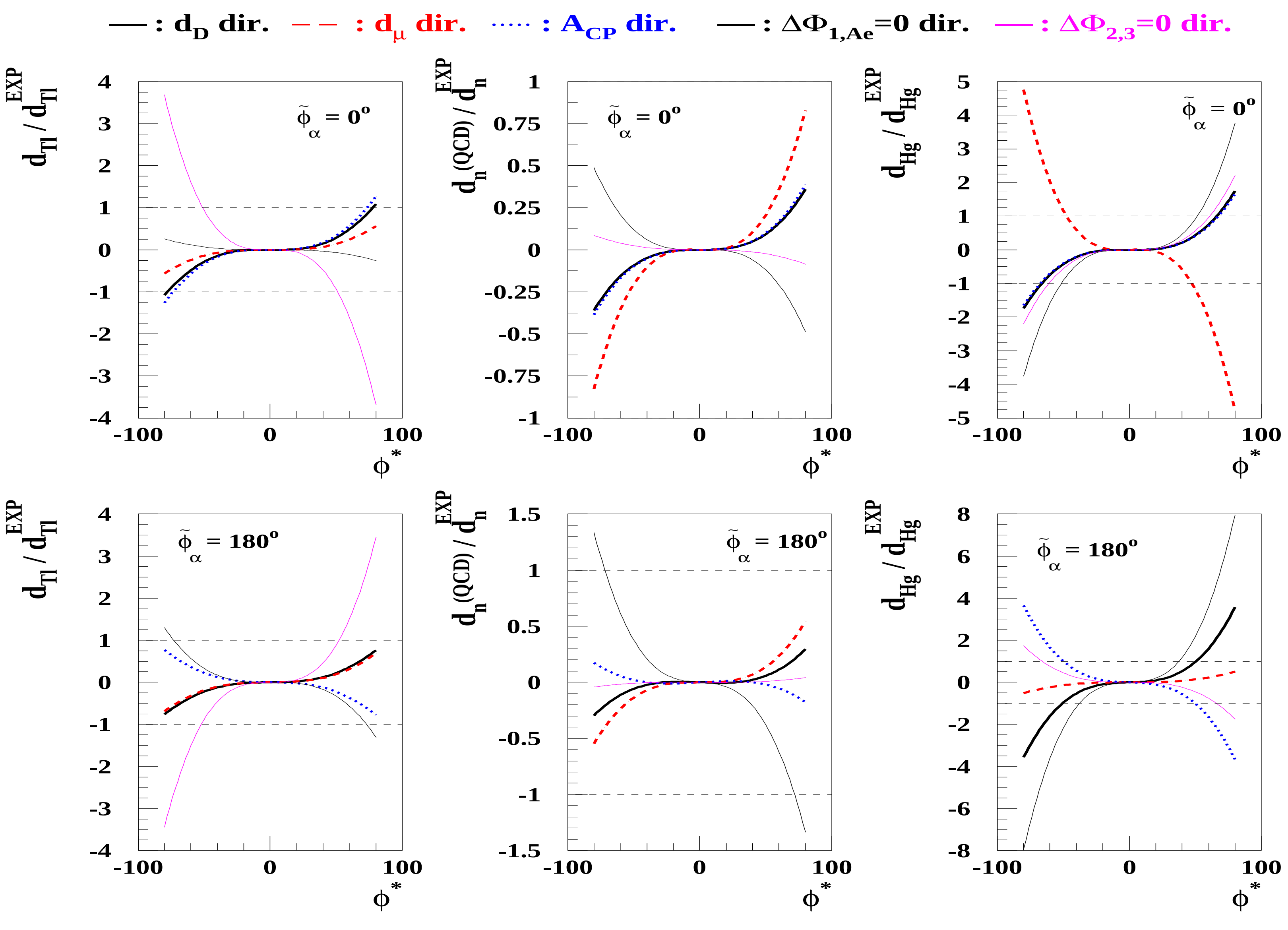


$$M^2_{H_u} = M^2_{H_d} = \widetilde{M}^2_Q = \widetilde{M}^2_U = \widetilde{M}^2_D = \widetilde{M}^2_L = \widetilde{M}^2_E = (100 \ \ {\rm GeV})^2\,,$$

$$|M_{1,2,3}| = 250 \ \ {\rm GeV}\,, \quad |A_u| = |A_d| = |A_e| = 100 \ \ {\rm GeV}\,, \quad \tan\beta = 40$$

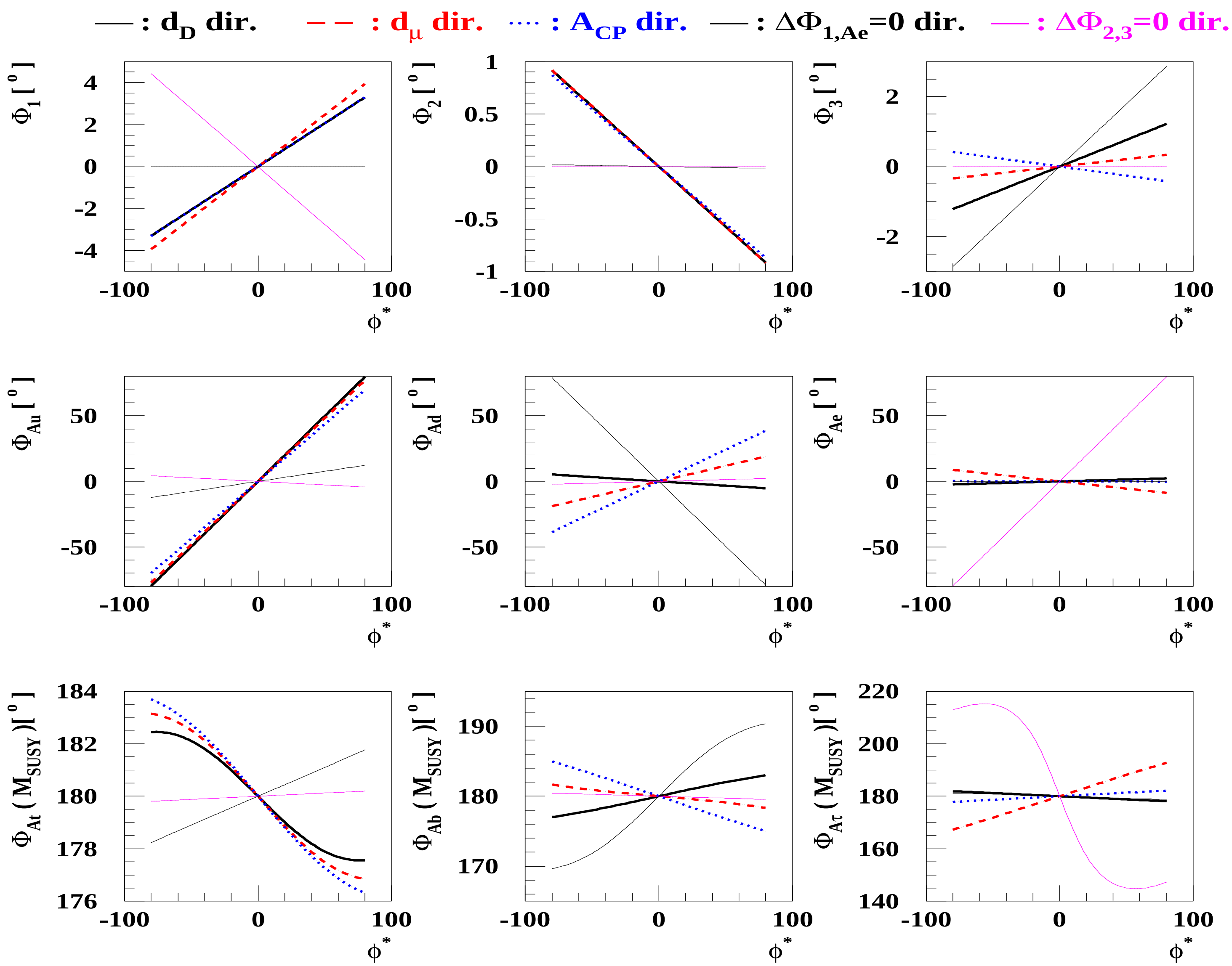
EDM constraints on the length $\phi^* = |\mathbf{\Phi}^*(M_{\rm GUT})|$

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]



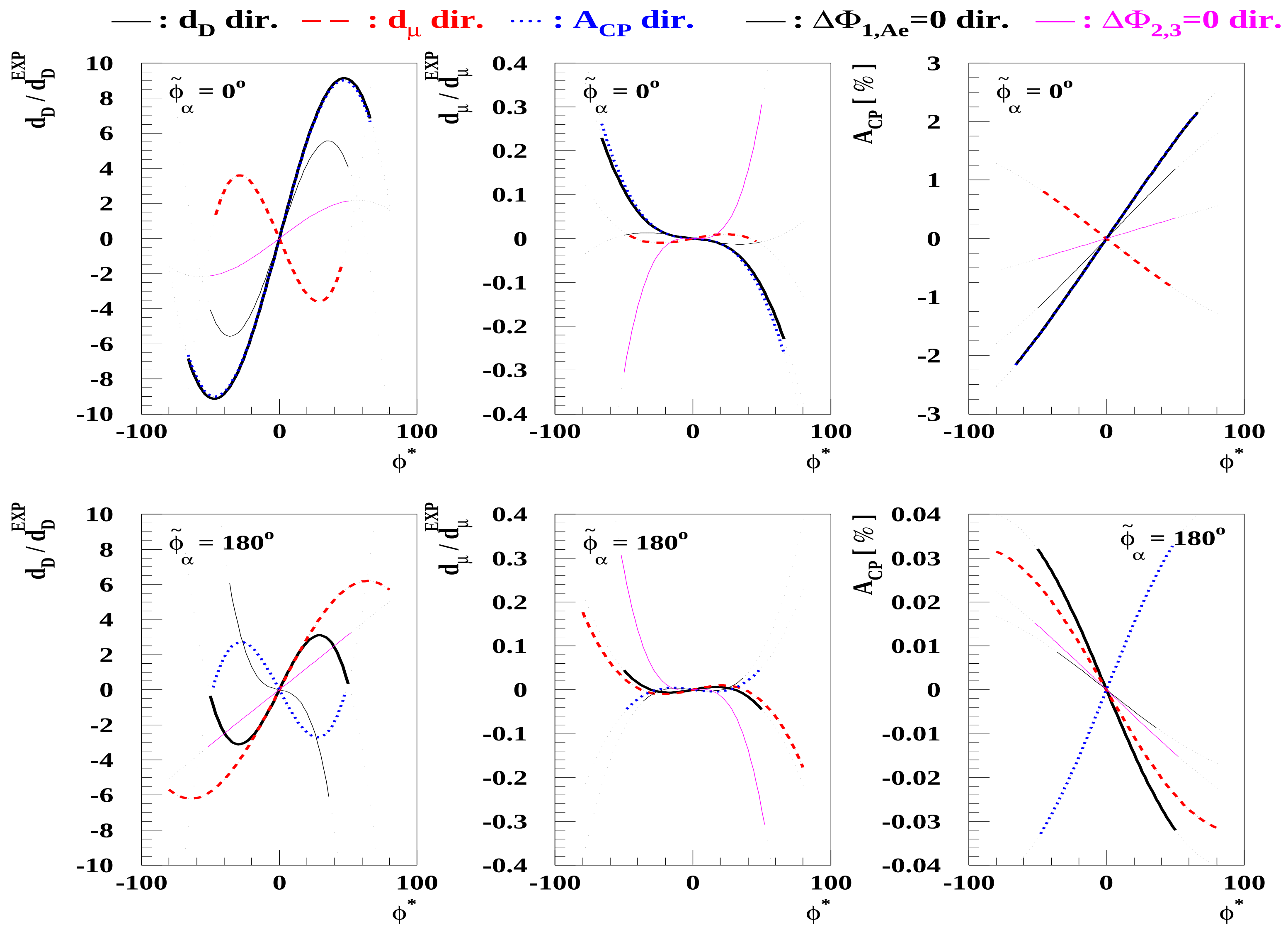
EDM constraints on CP-odd phases at $M_{\rm SUSY}$, for $\tan\beta = 10$

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]



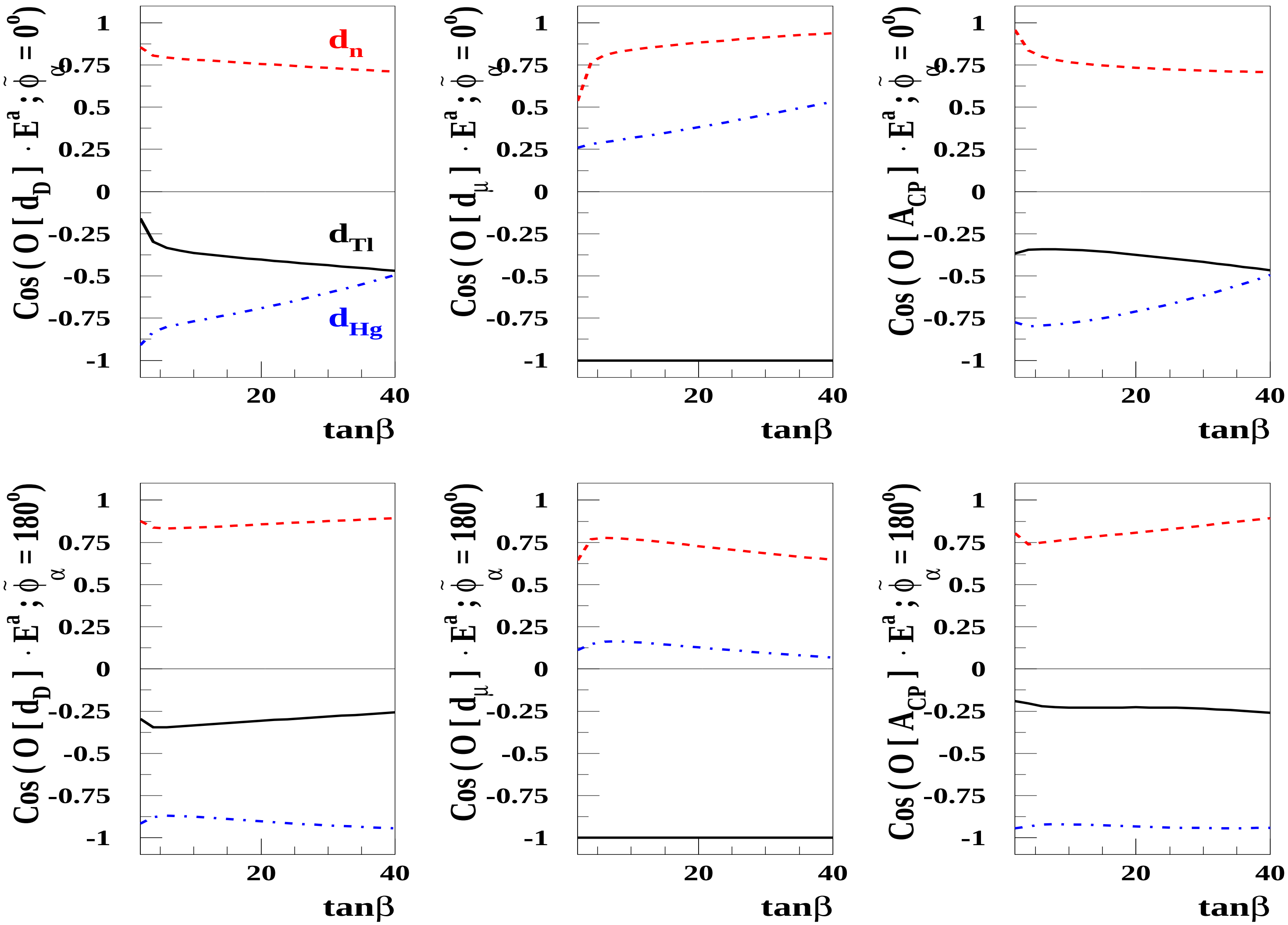
Maximal allowed values for $d_{\rm D}$, d_μ and $A_{\rm CP}$

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]



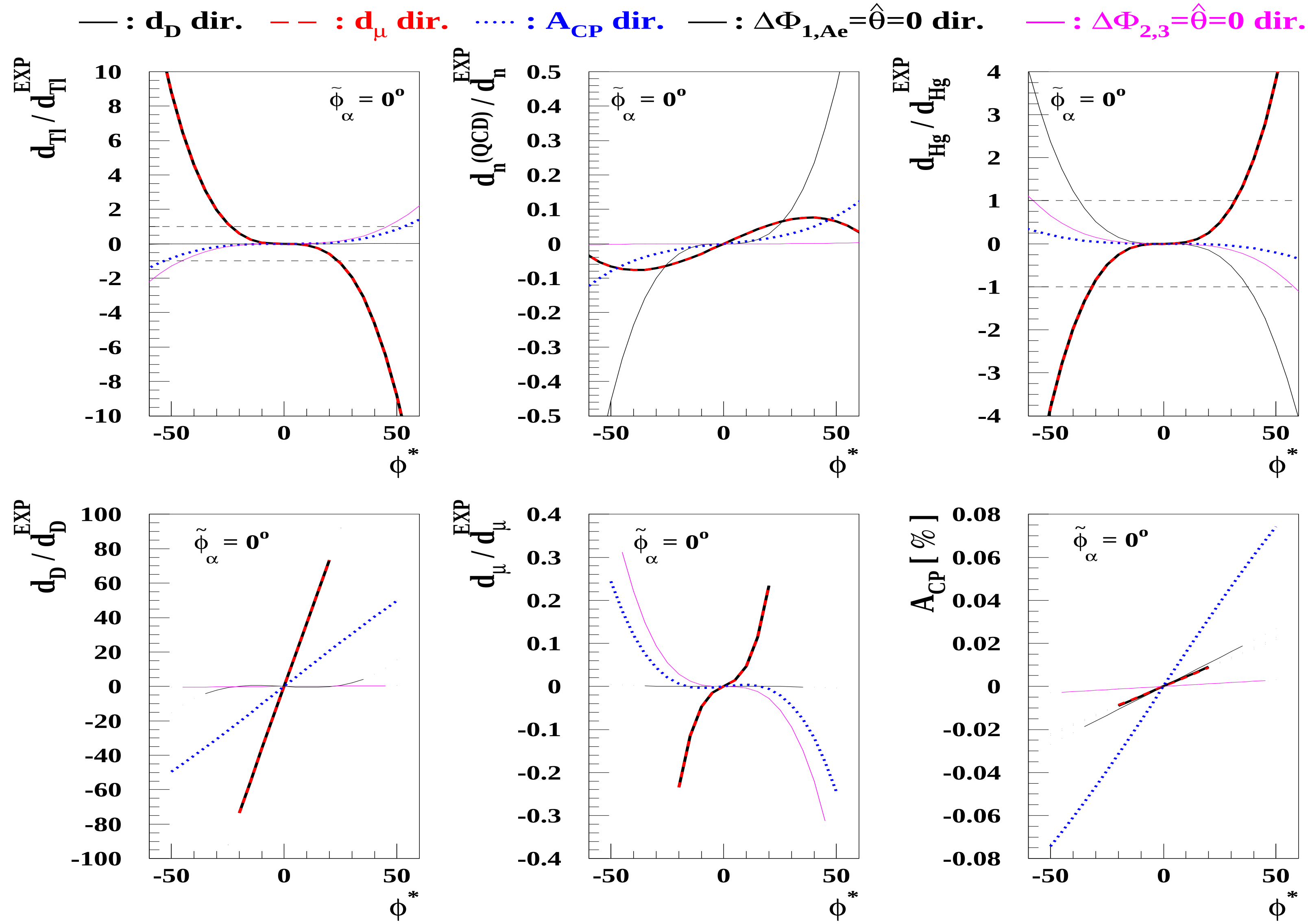
Interplay between EDMs and Observables

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]



7D Extension: including $\theta_{\rm QCD}$ ($\tan\beta = 10$)

[J. Ellis, J. S. Lee, A.P., JHEP10 (2010) 049.]



• Nuclei with Enhanced Schiff Moments

[L. I. Schiff, Phys. Rev. 132 (1963) 2194;
I. B. Khriplovich, R. A. Korkin, Nucl. Phys. A665 (2000) 365.]

T/CP-odd πNN interactions:

$$\mathcal{L}^{\not T}_{\pi NN} = \bar{g}^{(0)}_{\pi NN}\overline{N}\tau^a N\pi^a + \bar{g}^{(1)}_{\pi NN}\overline{N}N\pi^0 + \bar{g}^{(2)}_{\pi NN}\left(\overline{N}\tau^a N\pi^a - 3\overline{N}\tau^3 N\pi^0\right)$$

Schiff moment:

$$S = (a_0 + b)\, g_{\pi NN}\bar{g}^{(0)}_{\pi NN} + a_1\, g_{\pi NN}\bar{g}^{(1)}_{\pi NN} + (a_2 - b)\, g_{\pi NN}\bar{g}^{(2)}_{\pi NN}\,,$$

$g_{\pi NN}$: CP/T-even strong coupling constant, $g_{\pi NN} = 13.45$.
$a_{0,1,2}$: dependence of the Schiff moment on T-odd interactions.
b: dependence on the nucleon dipole moment.

$\bar{g}^{(0),(1)}_{\pi NN}$ receive contributions predominantly from CEDMs d^C_u and d^C_d, with

$$\frac{\bar{g}^{(0)}_{\pi NN}}{\bar{g}^{(1)}_{\pi NN}} = 0.2 \times \frac{d^C_u + d^C_d}{d^C_u - d^C_d}$$

[M. Pospelov, PLB530 (2002) 123.]

• EDMs of ^{199}Hg and ^{225}Ra due to enhanced Schiff moments:

[J. Ellis, J. S. Lee, A.P., JHEP02 (2011) 045, for references]

^{199}Hg EDM: $d_{\rm Hg}[S] \;=\; 10^{-17}\, \mathcal{C}^S_{\rm Hg}\; e\cdot{\rm cm} \times \left(\frac{S}{e\cdot{\rm fm}^3}\right)$.

Both $\mathcal{C}^S_{\rm Hg}(= -2.8)$ and S are model-dependent:

$$
\begin{aligned}
d^{\rm I}_{\rm Hg}[S] &\simeq 1.8\times 10^{-3}\, e\, \bar{g}^{(1)}_{\pi NN}\,/{\rm GeV}\,,\\
d^{\rm II}_{\rm Hg}[S] &\simeq 7.6\times 10^{-6}\, e\, \bar{g}^{(0)}_{\pi NN}\,/{\rm GeV} + 1.0\times 10^{-3}\, e\, \bar{g}^{(1)}_{\pi NN}\,/{\rm GeV}\,,\\
d^{\rm III}_{\rm Hg}[S] &\simeq 1.3\times 10^{-4}\, e\, \bar{g}^{(0)}_{\pi NN}\,/{\rm GeV} + 1.4\times 10^{-3}\, e\, \bar{g}^{(1)}_{\pi NN}\,/{\rm GeV}\,,\\
d^{\rm IV}_{\rm Hg}[S] &\simeq 3.1\times 10^{-4}\, e\, \bar{g}^{(0)}_{\pi NN}\,/{\rm GeV} + 9.5\times 10^{-5}\, e\, \bar{g}^{(1)}_{\pi NN}\,/{\rm GeV}\,.
\end{aligned}
$$

^{225}Ra EDM to the $10^{-27}\ e\cdot{\rm cm}$ level (HIE-ISOLDE project):

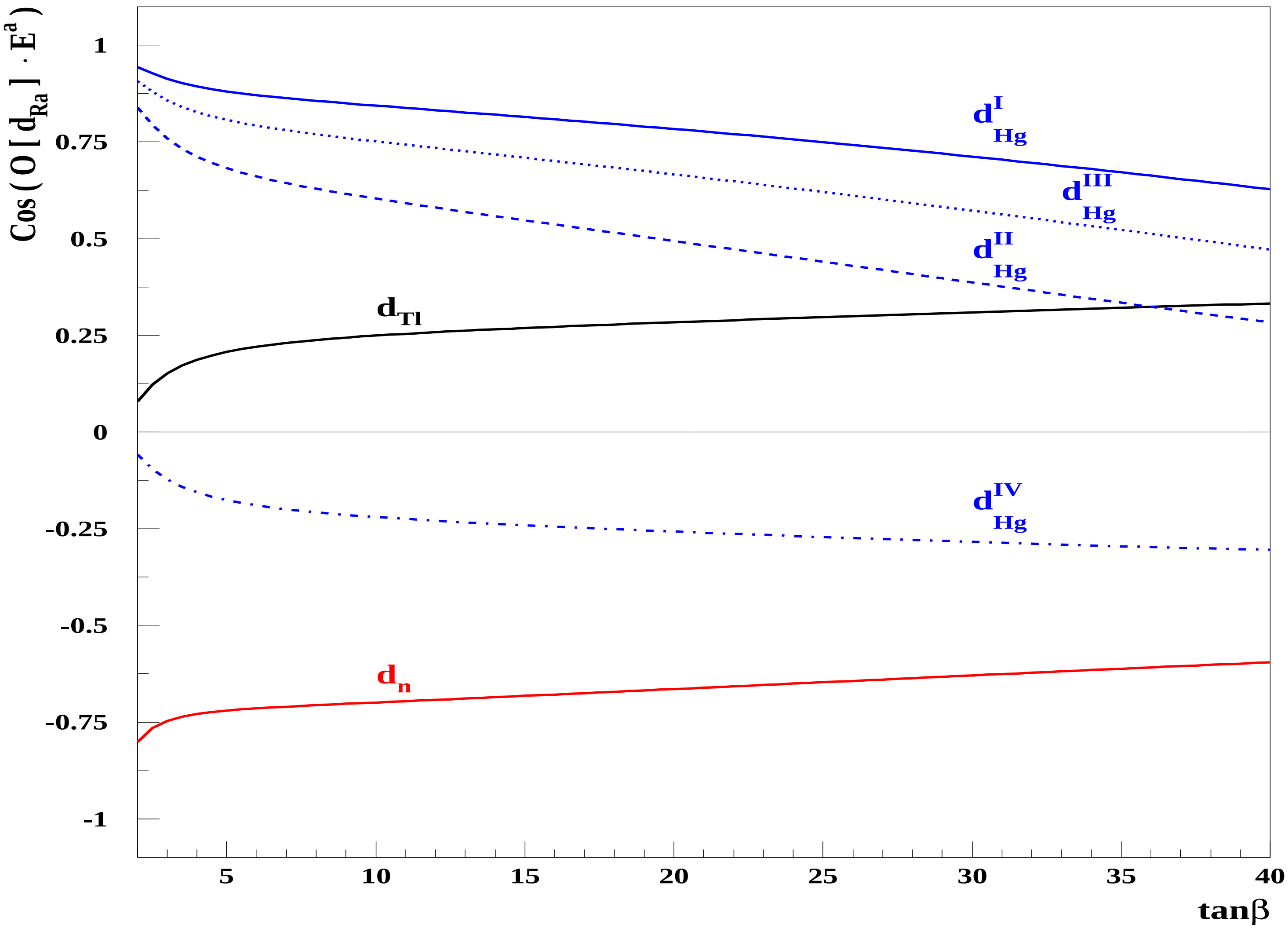
[L. Willman, K. Jungmann, H.W. Wilshut, CERN-INTC-2010-049;
J. Pakarinen et al, CERN-INTC-2010-022.]

$$
d_{\rm Ra}[S] \;\simeq\; -8.7\times 10^{-2}\, e\, \bar{g}^{(0)}_{\pi NN}\,/{\rm GeV} + 3.5\times 10^{-1}\, e\, \bar{g}^{(1)}_{\pi NN}\,/{\rm GeV}\ .
$$

Typical enhancement factor: $d_{\rm Ra}[S]/d_{\rm Hg}[S] \;\sim\; 200$

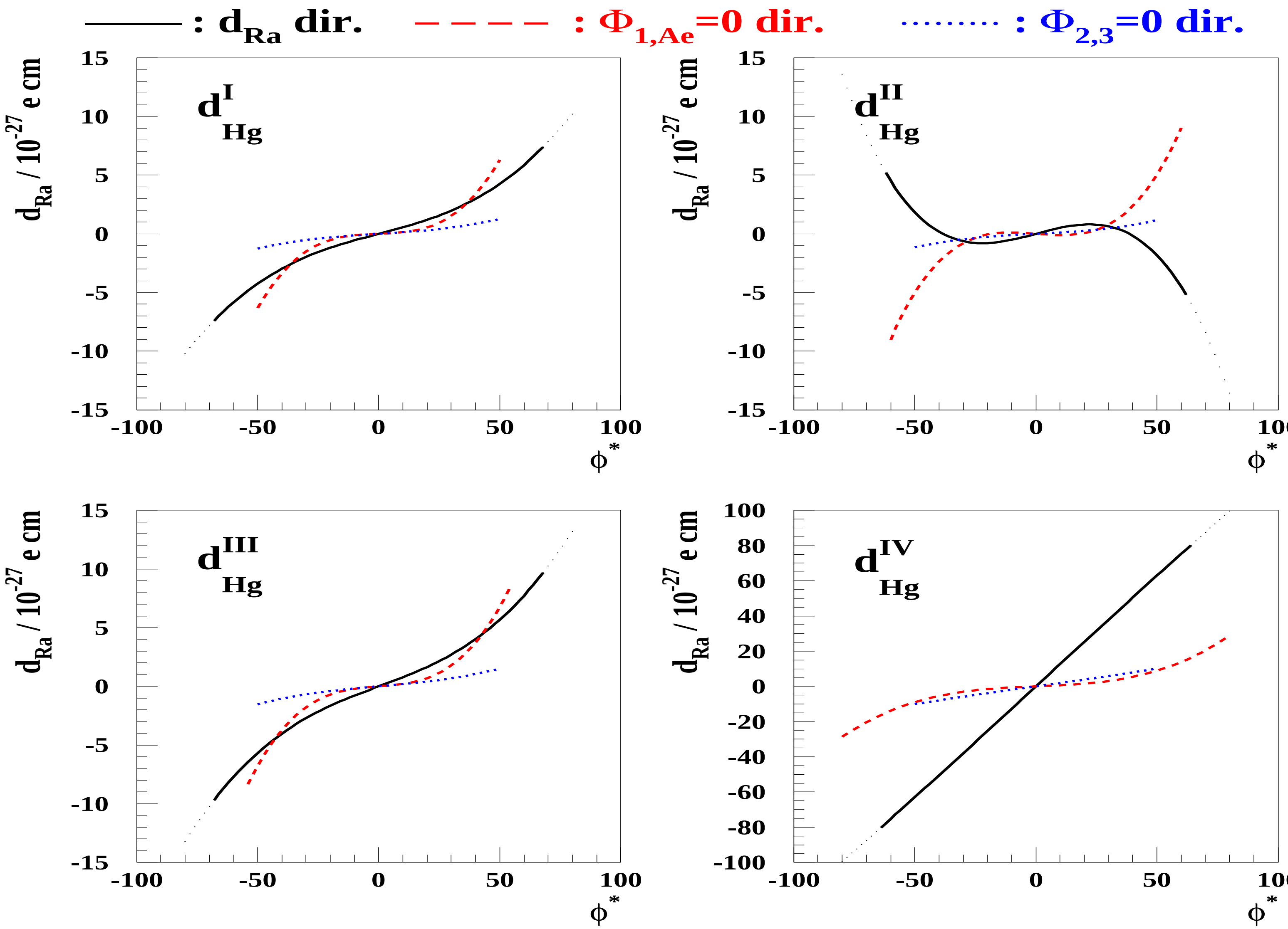
Interplay of ^{199}Hg and ^{225}Ra EDMs

[J. Ellis, J. S. Lee, A.P., JHEP02 (2011) 045.]



Maximal ^{225}Ra EDM for $\tan\beta = 40$

[J. Ellis, J. S. Lee, A.P., JHEP02 (2011) 045.]



• SUMMARY

- The MSSM with MFV extended to MCPMFV is an interesting framework for studying New Physics.
  It contains 19 parameters = 13 CP-even $\oplus$ 6 CP-odd.

- Non-observation of Thallium, neutron and Mercury EDMs give strict constraints on 3 combinations of the 6 soft CP-odd phases of MFV-type scenarios.

- Geometric approach introduced for maximazing CP observables in the small phase approximation.

- Interplay of future EDM observables (Deuteron and Radium) will further constrain soft CP violation in SUSY, including $\theta_{\rm QCD}$.
  $\Longrightarrow$ Pushing the limit to $\theta_{\rm QCD} \lesssim 10^{-12}$

- **EDMs constrain:**
  - *Radiative* **Higgs-sector CP violation at Tevatron and LHC.**
    [A.P., PLB435 (1998) 88; A.P., C. Wagner, NPB553 (1999) 3;
    S.Y. Choi, M. Drees, J.S. Lee, PLB481 (2000) 57;
    M. Carena et al, NPB586 (2000) 92; NPB659 (2003) 145.]
  - **Resonant CP Violation at LHC, ILC (e^+e^-) and $\gamma\gamma$ colliders.**
    [A.P., NPB504 (1997) 61;
    J. Ellis, J.S. Lee, A.P., PRD70 (2004) 075010; PRD72 (2005) 095006; NPB718 (2005) 247.]
  - **FCNC observables:**
    $\Delta M_{K,B}$, ϵ_K, ϵ'/ϵ, $\mathcal{B}(B_{d,s} \to \ell^+\ell^-)$, $\mathcal{A}_{\rm CP}(B_{d,s} \to \ell^+_{L(R)}\ell^-_{L(R)})$, $\mathcal{B}(B \to X_s\gamma)$, . . .
    [For review, see, T. Ibrahim and P. Nath, RMP80 (2008) 577;
    talk by M. Neubert]
  - **Electroweak Baryogenesis in the MSSM**
    [M. Carena, M. Quiros, M. Seco, C. Wagner, NPB650 (2003) 24;
    T. Konstandin, T. Prokopec, M. G. Schmidt, M. Seco, NPB738 (2006) 1;
    D. J. H. Chung, B. Garbrecht, M. J. Ramsey-Musolf and S. Tulin, PRL102 (2009) 061301.]