CP violation in SUSY with effective MFV

based on: R. Barbieri, P. Lodone and D.M.S., JHEP **1105** (2011) 049, arXiv:1102.0726

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Minimal Flavour Violation

The MFV principle

Yukawa couplings are the only spurions breaking the flavour symmetry in the quark sector,

$$G_F = U(3)_{Q_L} \otimes U(3)_{U_R} \otimes U(3)_{D_R} \to U(1)_B$$
$$\uparrow$$
$$Y_u,\, Y_d$$

Flavour violation is aligned with the SM, but
flavour blind CP violating phases are not forbidden.

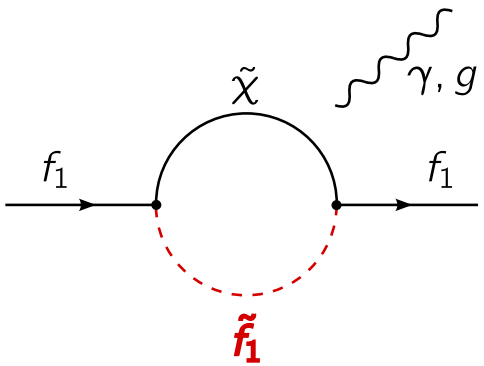
E.g. MSSM+MFV: μ-term, A-terms

$$A_u = a_u(1 + c_1\, Y_u^\dagger\, Y_u + \ldots)$$

in general complex

The CP problem

Flavour blind phases lead to contributions to electric dipole moments.



Experiment:

d_e → $|d_{\mathrm{Tl}}| < 9.4 \times 10^{-25}\ e\,\mathrm{cm}$

d_e → $|d_{\mathrm{Hg}}| < 3.1 \times 10^{-29}\ e\,\mathrm{cm}$

$d_{u,d}, \tilde{d}^c_{u,d}$ → $|d_n| < 2.9 \times 10^{-26}\ e\,\mathrm{cm}$

In MFV, this implies, e.g.

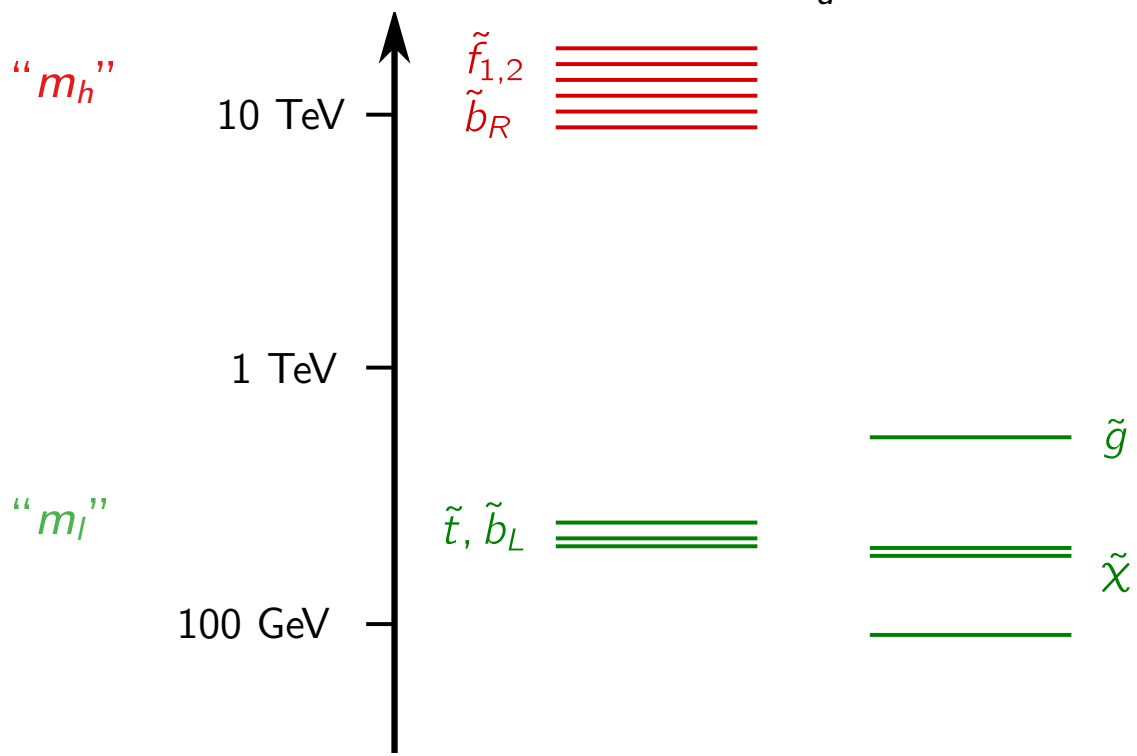
$$\sin\phi_\mu \tan\beta < 7 \times 10^{-2} \left(\frac{\tilde{m}}{500\ \mathrm{GeV}}\right)^2$$

Phases have to be tiny to meet EDM bounds.

Effective Minimal Flavour Violation

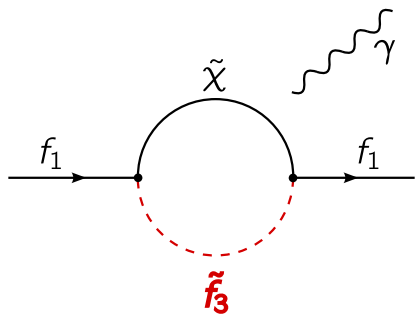
$$G_F = U(1)_U^3 \otimes U(3)_{D_R} \to U(1)_B$$

Y_d



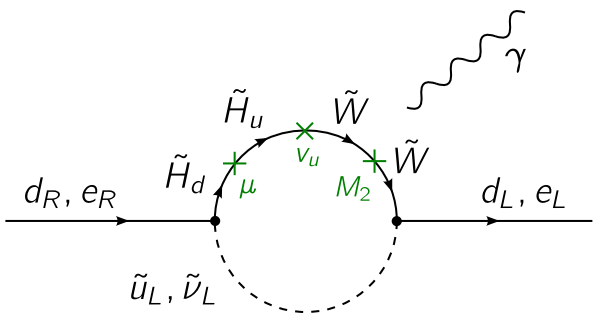
Now: allow all the phases not forbidden by G_F, in particular in μ and A_t

Electric dipole moments in EMFV: 1 loop



loop with 3rd generation sfermions:

$$\propto |V_{td}|^2 \Rightarrow \text{negligible}$$



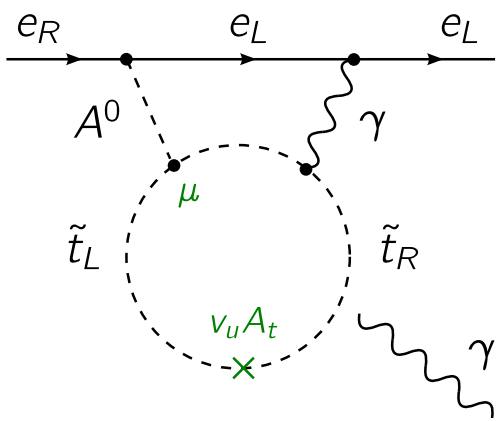
dominant 1-loop contribution:

$$\frac{d_{d,e}}{e} \propto \frac{\mu M_2}{m^2_{\tilde{u},\tilde{\nu}}} \tan\beta$$

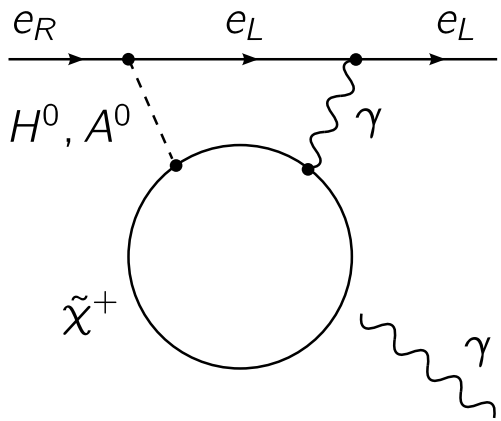
$$\left.\begin{array}{lcl} d_e & \Rightarrow & d_{\mathrm{Tl}} \\ d_d & \Rightarrow & d_n \end{array}\right\} \text{ under control if } \left\{\begin{array}{l} m_{\tilde{\nu}} > 4.0 \text{ TeV} \times (\sin\phi_\mu \tan\beta)^{\frac{1}{2}} \\ m_{\tilde{u}} > 2.7 \text{ TeV} \times (\sin\phi_\mu \tan\beta)^{\frac{1}{2}} \end{array}\right.$$

Electric dipole moments in EMFV: 2 loops

2-loop Barr-Zee diagrams: no mass suppression, no CKM suppression



$$\frac{d_e}{e} \propto \frac{\mu A_t}{m_l^2} \tan\beta$$



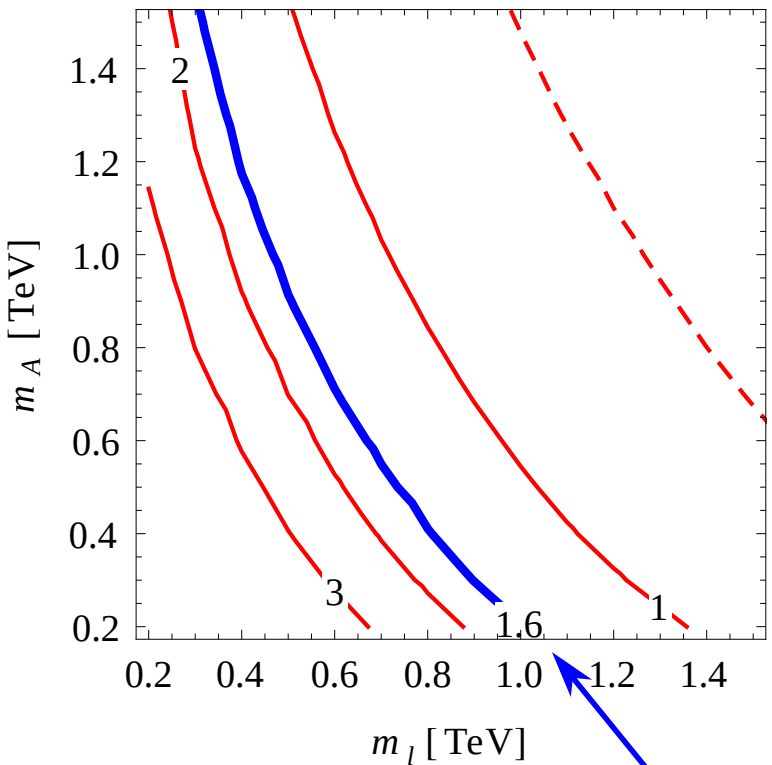
$$\frac{d_e}{e} \propto \frac{\mu M_2}{m_l^2} \tan\beta$$

see also
[Altmannshofer, Buras, Paradisi (2008)]

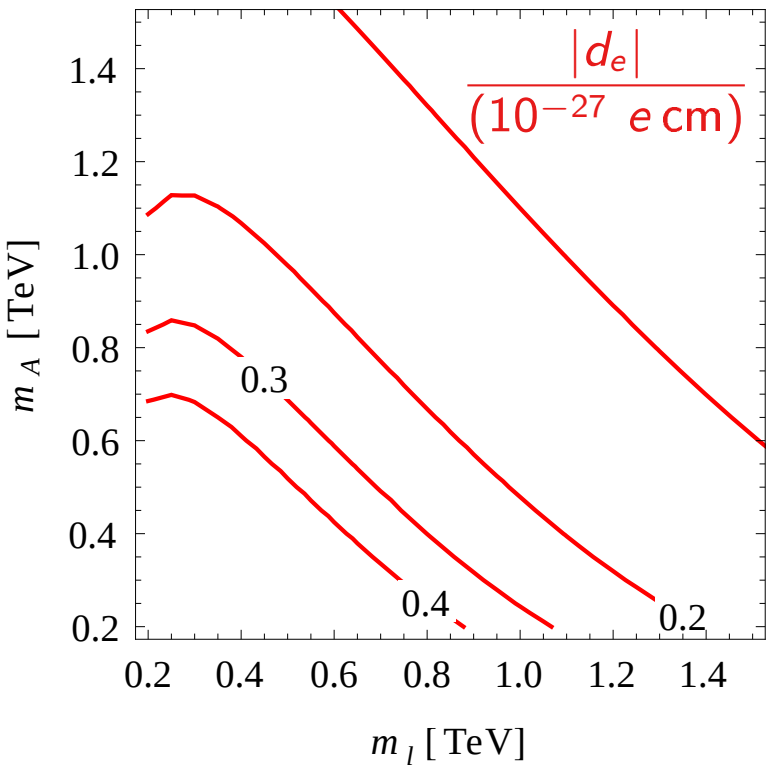
[Chang et al., Giudice & Romanino, Li et al., Ellis et al., Abel et al.]

Two-loop EDMs in EMFV

complex μ



complex A_t

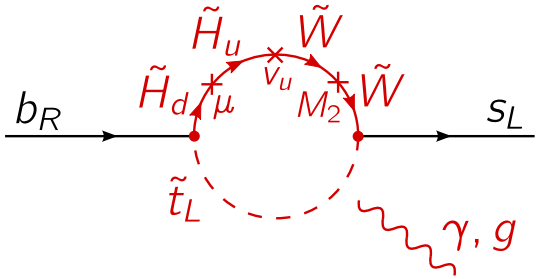


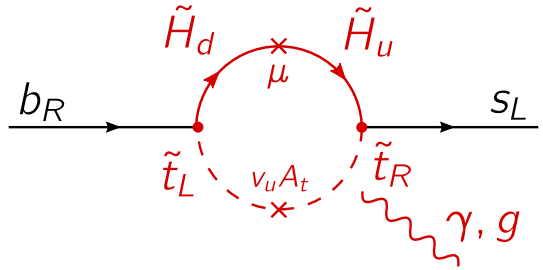
$|d_e|_{\mathrm{exp}} < 1.6 \times 10^{-27}\ e\,\mathrm{cm}$

$\tan\beta = 5$

B physics in EMFV

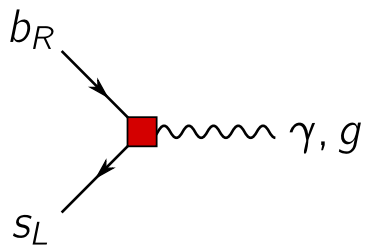
CP violating contributions to dipole operators not suppressed by 1st/2nd generation sfermion masses



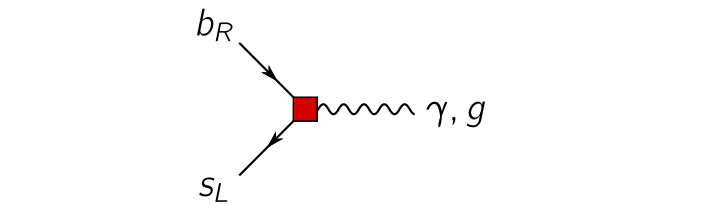


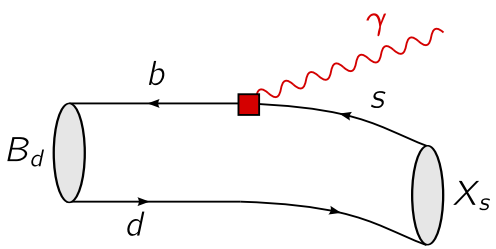
$$\mathcal{O}_7 = \frac{e}{16\pi^2} m_b (\bar{s}\sigma_{\mu\nu} P_R b) F^{\mu\nu}$$

$$\mathcal{O}_8 = \frac{g_3}{16\pi^2} m_b (\bar{s}\sigma_{\mu\nu} T^a P_R b) G^{\mu\nu\, a}$$

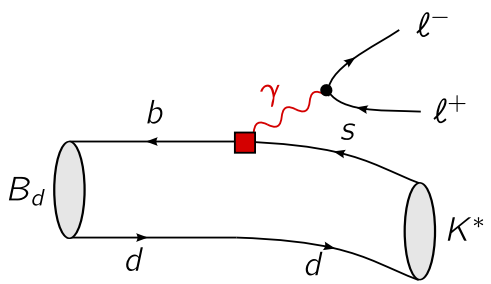


CP asymmetries in EMFV

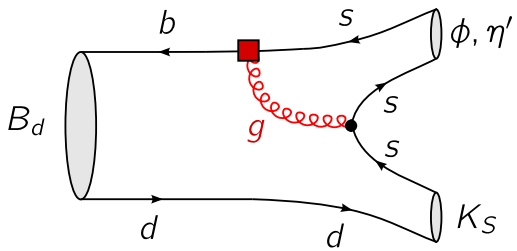




Direct CP asymmetry in $B \to X_s\gamma$



Angular CP asymmetries A_7, A_8 in $B \to K^*\ell^+\ell^-$



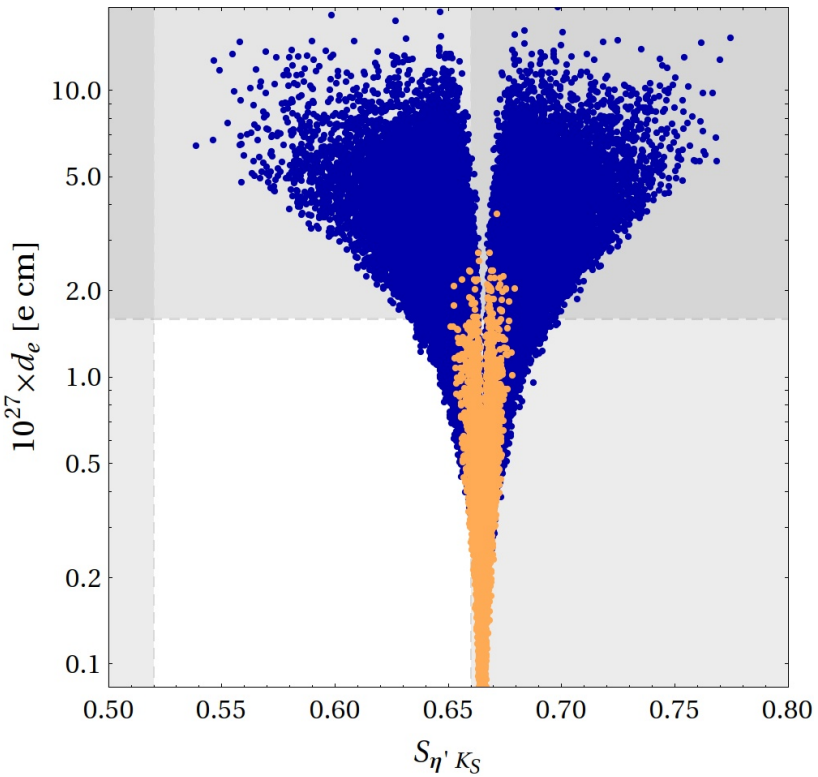
Mixing-induced CP as. in $B \to (\phi, \eta')K_S$

see e.g.
[Altmannshofer et al., 0811.1214]

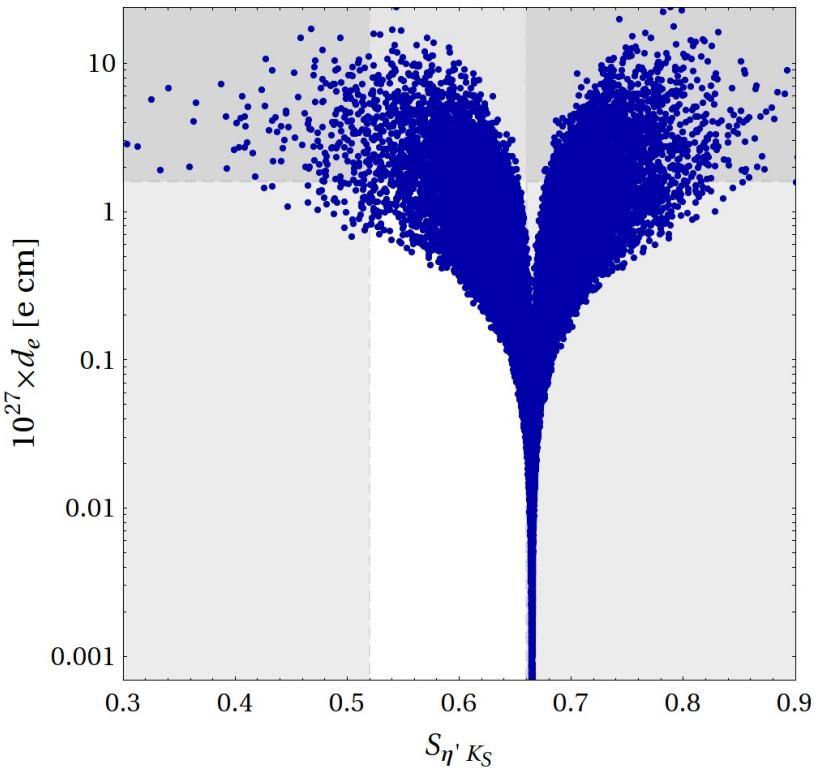
EMFV results I

Electron EDM vs. $S_{\eta' K_S}$

complex μ



complex A_t

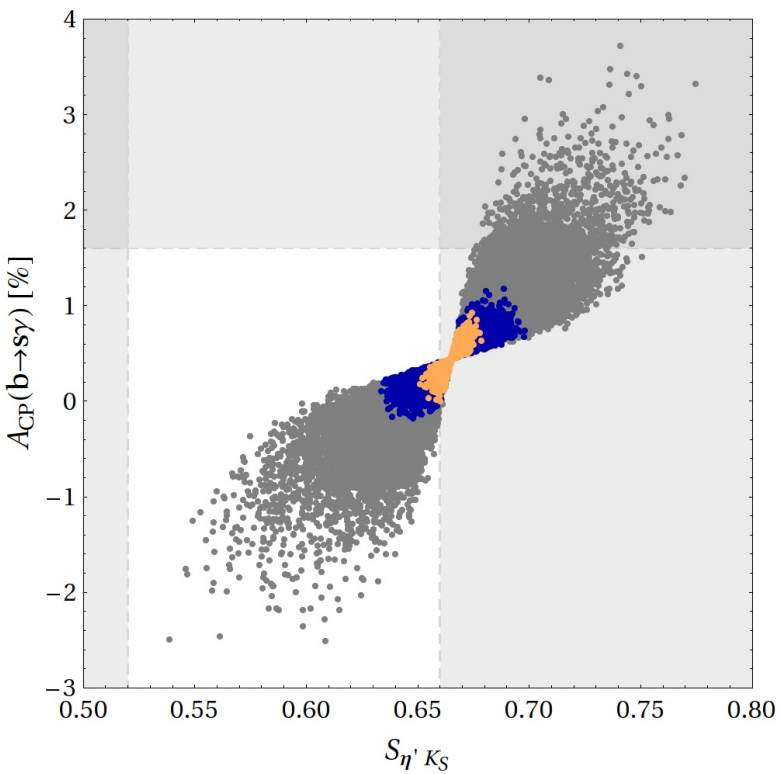


$\tan\beta < 10$, $m_{\tilde{f}_3} \in [200, 700]$ GeV

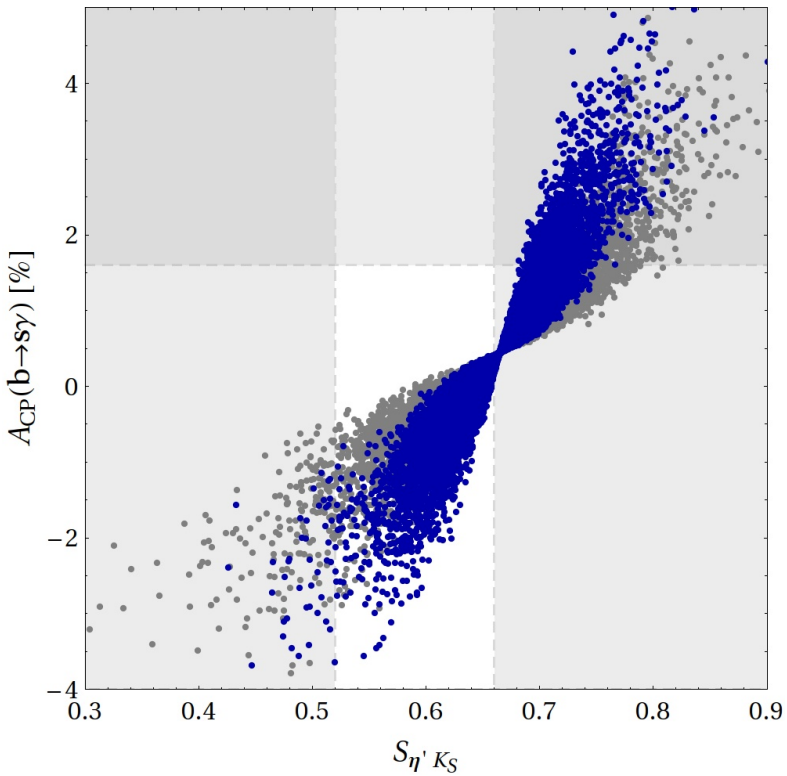
EMFV results III

CP asymmetry in $B \to X_s\gamma$ vs. $S_{\eta' K_S}$

complex μ



complex A_t

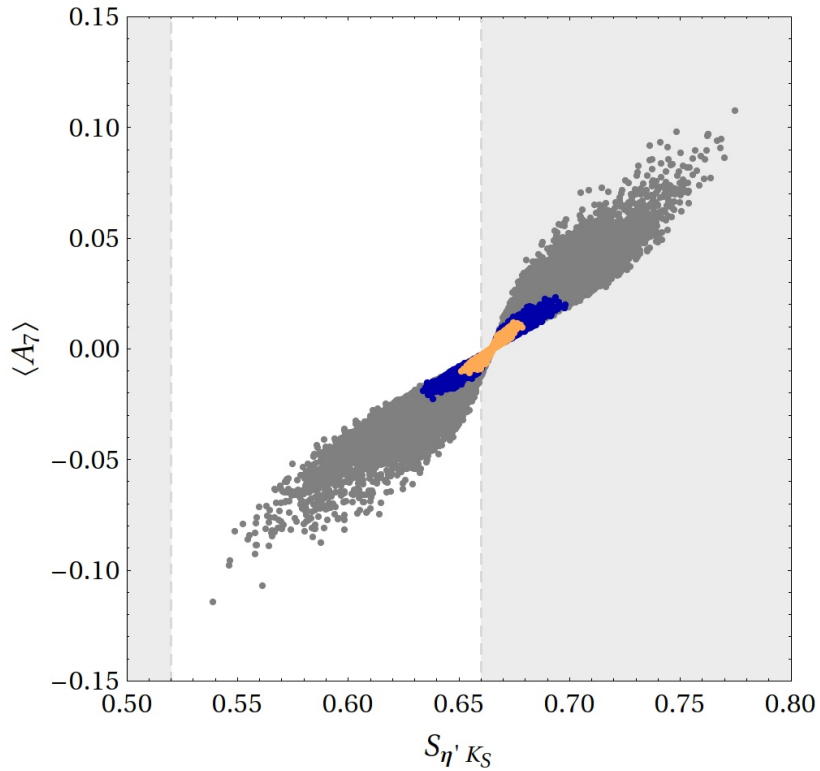


NB: SM theory uncertainty possibly large [Benzke et al. 1012.3167]

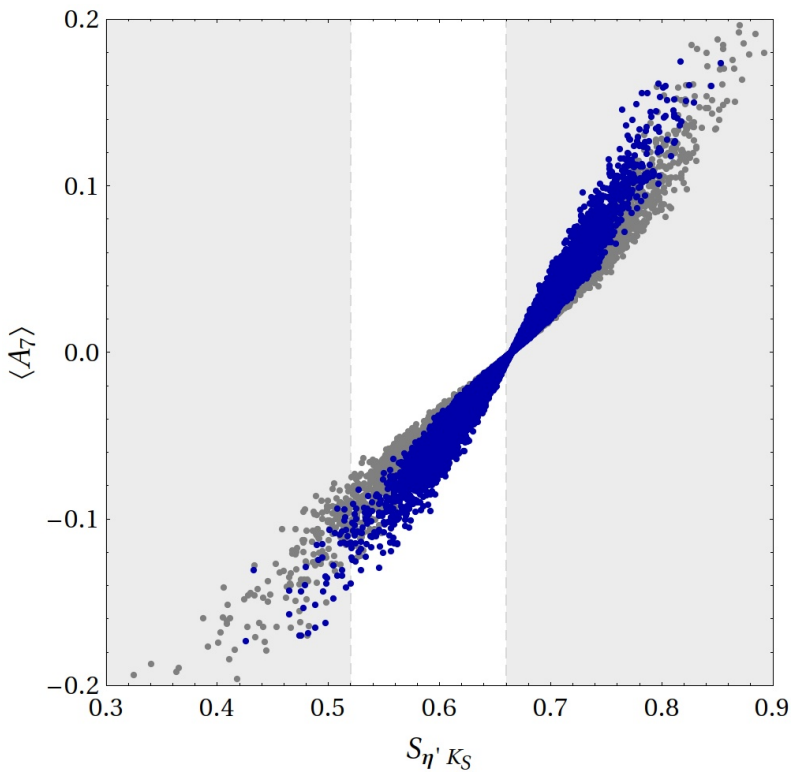
EMFV results II

CP asymmetry A_7 in $B \to K^* \ell^+ \ell^-$ vs. $S_{\eta' K_S}$

complex μ



complex A_t



Conclusions

MFV combined with hierarchical sfermions

- can **solve the SUSY flavour and CP problems**
- can lead to visible effects in CP asymmetries in ***B* physics** without violating the bounds on electric dipole moments

N.B.: the effects discussed here are present in all scenarios with hierarchical sfermions and flavour blind phases, but there can be additional contributions (e.g. $U(2)^3$ discussed yesterday by G. Isidori)