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Edinburgh U., PPE Seminar, September 6, 2006

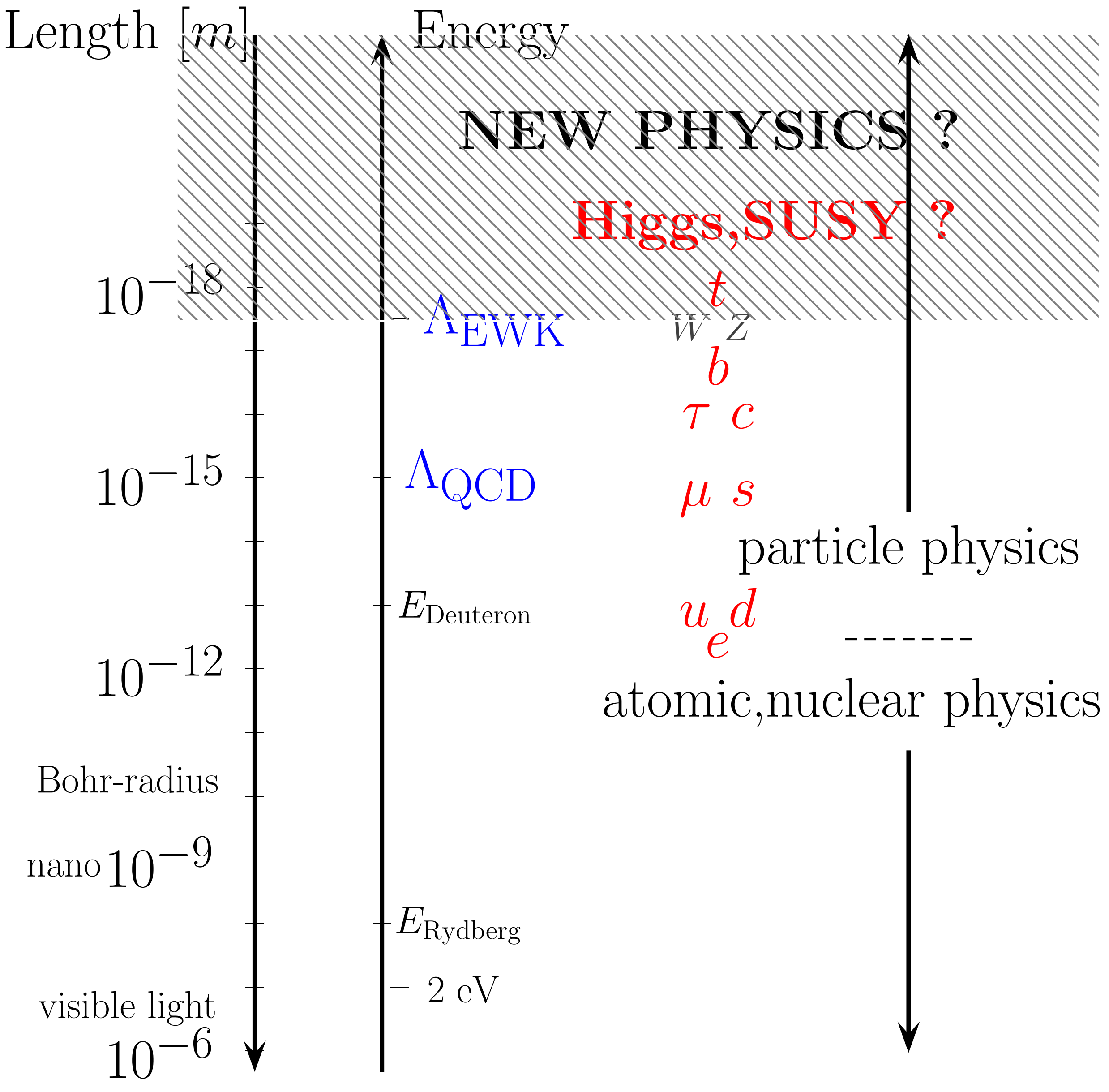
*“Where are we in penguin physics and what are we after “

- (quark)-flavor within SM and beyond: CKM and more
- rare processes: mixing, FCNC decays

- CP violation needed for baryogenesis $(n - \bar{n})/s \simeq 10^{-10}$
  SM not sufficient
- strong CP problem: Why is $\bar{\Theta} \lesssim 10^{-10}$ and $\delta_{CKM} = \mathcal{O}(1)$?
- origin of flavor; explanation of peculiar masses and mixings
- neutrino masses

... are core questions of the SM, plus: unification, Higgs mass, dark matter, dark energy, gravity

despite its impressive experimental support the SM is rather viewed as an effective theory valid up to $\Lambda \sim \mathcal{O}(m_W)$


Length [m]
Energy
NEW PHYSICS ?
Higgs,SUSY ?
10^{-18}
Λ_{EWK}
t
W Z
b
τ c
10^{-15}
Λ_{QCD}
μ s
particle physics
E_{Deuteron}
u d
e

10^{-12}
atomic,nuclear physics
Bohr-radius
nano 10^{-9}
E_{Rydberg}
2 eV
visible light
10^{-6}

flavor and CP in SM: $-\mathcal{L}_Y = \bar{Q} Y_u h^C U + \bar{Q} Y_d h D + \bar{L} Y_e h E + h.c.$

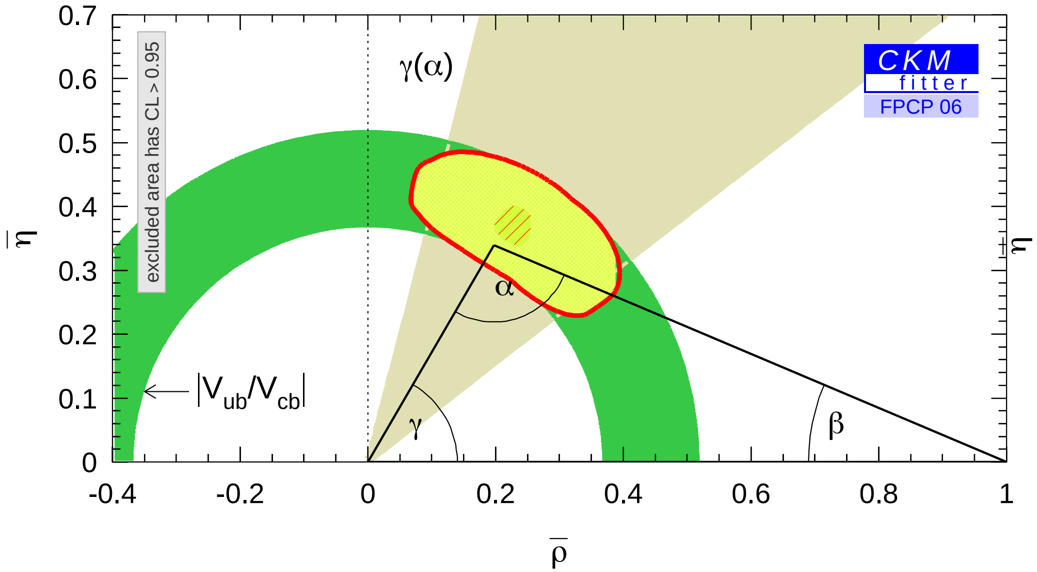
flavor symmetry: $U(3)^5 \xrightarrow{Y} U(1)_B \times U(1)_L \times U(1)_Y$

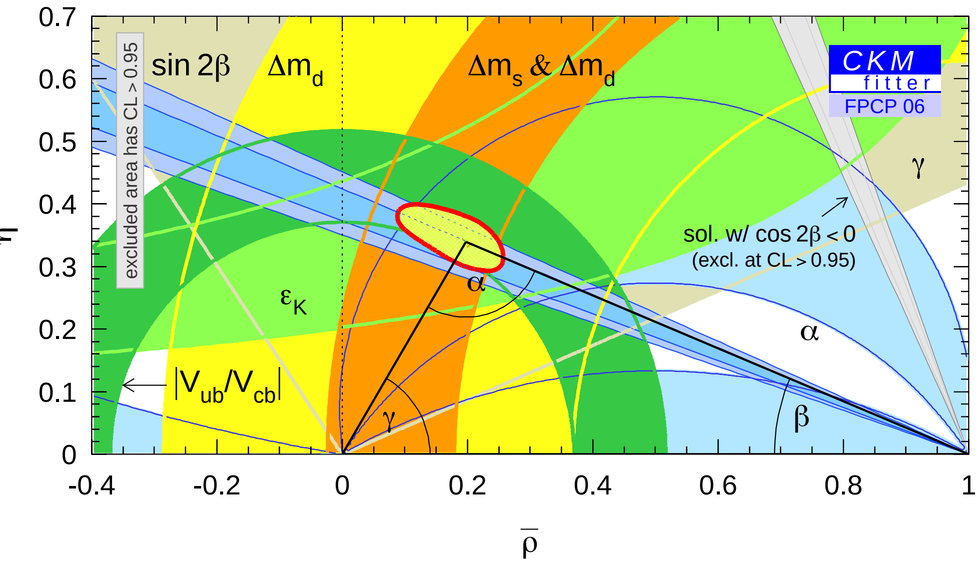
quarks: $Y_{u,d}$ 36 real numbers $\rightarrow$ 10 physical parameters: 6 quark masses plus CKM (3 angles, 1 phase)

- determine 10 parameters $\longrightarrow$ PDG, HFAG
- how do the Yukawas look like – and why ? top-down, GUT's, textures, extra dimensions, Froggatt-Nielsen, horizontal symmetries, anarchy, ..
- Is this all to flavor/CP violation, that is, does MFV hold ? minimal flavor violation = no further breaking of flavor than through Yukawas
- are there deviations from the SM in rare processes ?

CKM/Yukawa CP-violation from tree level, precision

the unitarity triangle $V_{ub}V_{ud}^* + V_{cb}V_{cd}^* + V_{tb}V_{td}^* = 0$





tree fit V_{ub} ($B \to (X_u, \pi)\ell\nu$, $B \to \tau\nu$), γ from $B \to DK$

loop input to full fit: $\epsilon_K, \triangle m_{d,s}$, $\sin 2\beta(\bar{c}c)$

SM/MFV-like at least for $b \to \bar{c}cs$, K-, B_d-mixing, $\triangle m_d / \triangle m_s$

CKM=precision input within SM $\epsilon(\alpha) = 5\%, \epsilon(\beta) = 4\%, \epsilon(\gamma) = 8\%$

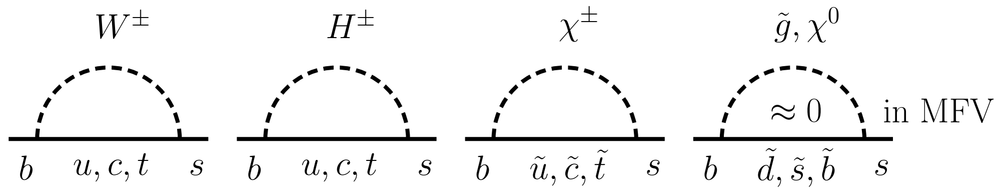
SM tests with indirect processes

indirect loop processes: $\Lambda \gtrsim m_W$ scale of New Physics

$$\mathcal{L}_{eff} = \sum_i c_i^{(n)} \frac{O_i^{(n)}}{\Lambda^n} \qquad c_i^{(n)} \leftrightarrow f(\underbrace{m_j, g_l, \ldots}_{colliders}; \underbrace{\varphi_{\rm CKM}, \varphi_m, \delta_n}_{flavorphysics})$$

no competition from large SM tree contributions

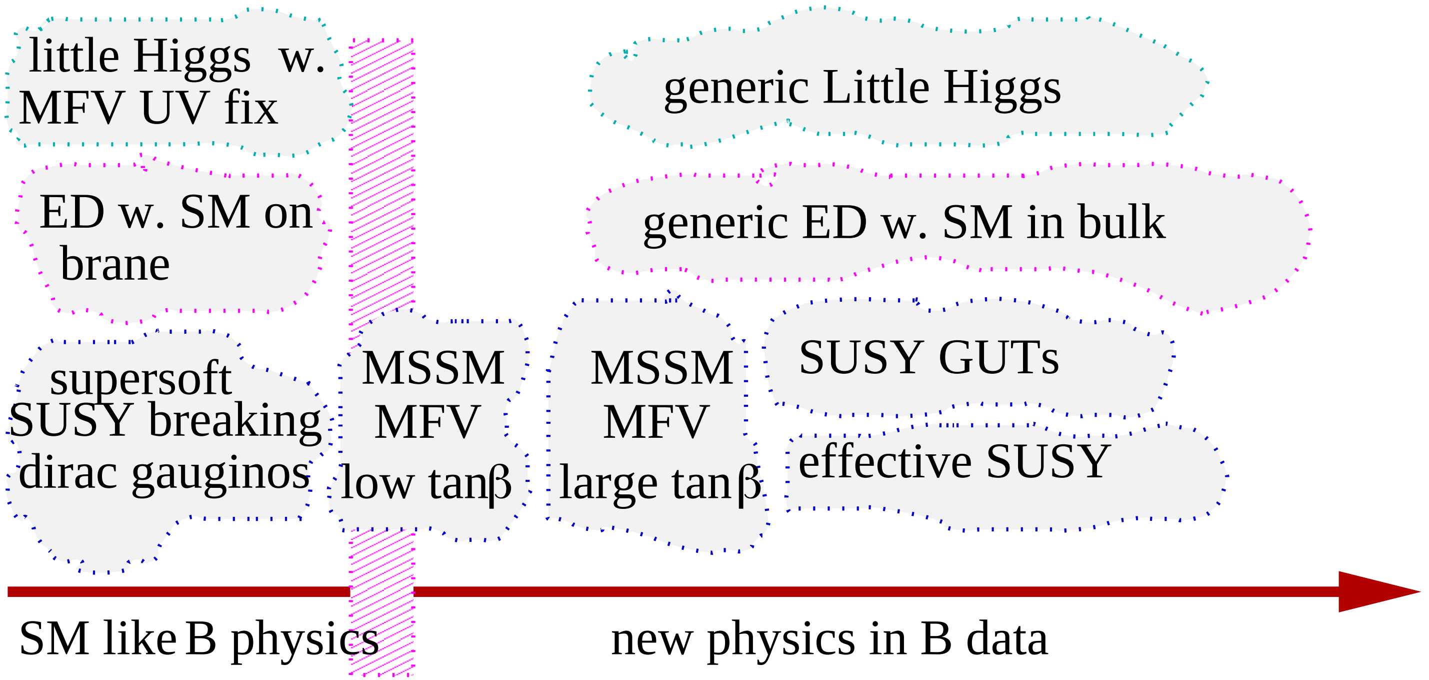
FCNC: sensitivity to SM, NP phases φ, flavor-breaking couplings δ



BSM-FCNC: offset rates, distort spectra, induce CP-asymmetries, V+A currents, ..

models of EWKSB with NP @ TeV

Fig from hep-ph/0207121

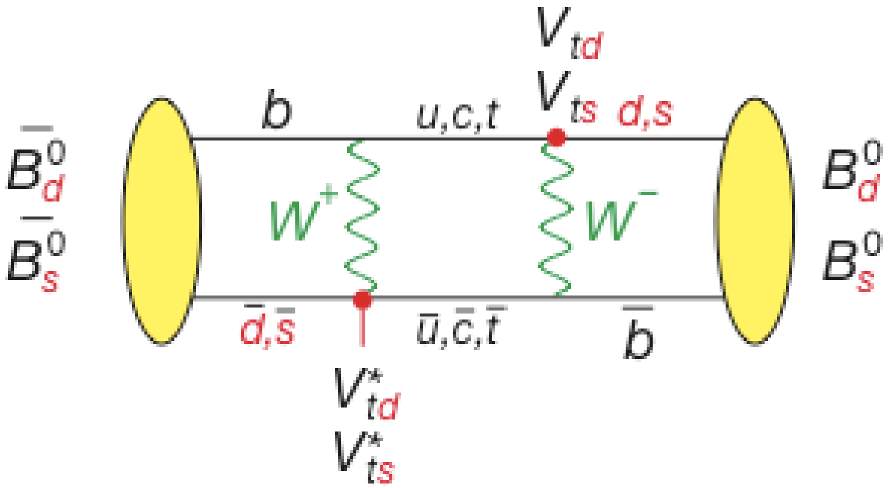


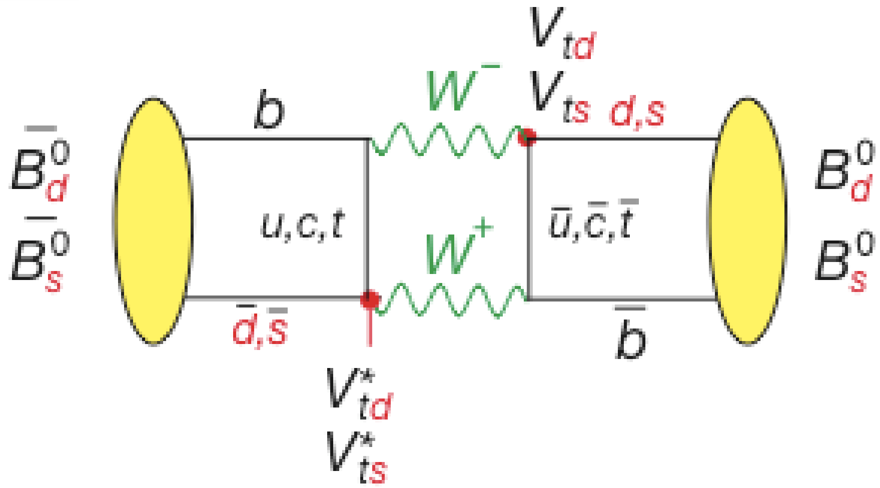
reach in indirect signals depends on beyond the SM flavor/CP violation (minimal=CKM), large parameters such as $\tan\beta$ and theoretical and experimental uncertainties todays and future impact of

- $B_s - \bar{B}_s$ mixing (new Tevatron data from Moriond '06)
- $b \to s\ell\ell$ modes

SM: $W-(u,c,t)$-box $\qquad \Delta m_s^{\rm SM} \sim (V_{tb}^* V_{ts})^2 \frac{g^4}{16\pi^2} \frac{(\bar b \Gamma s)(\bar b \Gamma' s)}{m_W^2}$

top dominated; $V_{tb} \simeq 1$, $V_{ts} = -A\lambda^2$ independent of CKM-triangle-fit





$\Delta m_d^{world\,ave} = 0.507 \pm 0.004\, ps^{-1}$ (HFAG '05)

$\Delta m_s^{\rm SM} = 18.3^{+6.5}_{-1.5}\, ps^{-1}$ (CKMfitter/EPS'05) $\Delta m_s^{\rm SM} = 20.0 \pm 1.8\, ps^{-1}$ (UTfit hep-ph/0501199)

D$\emptyset$: $17 < \Delta m_s < 21$ ps^{-1} at 90% C.L. hep-ex/0603029

CDF: $\Delta m_s = 17.31^{+0.33}_{-0.18} \pm 0.07$ ps^{-1} hep-ex/0606027

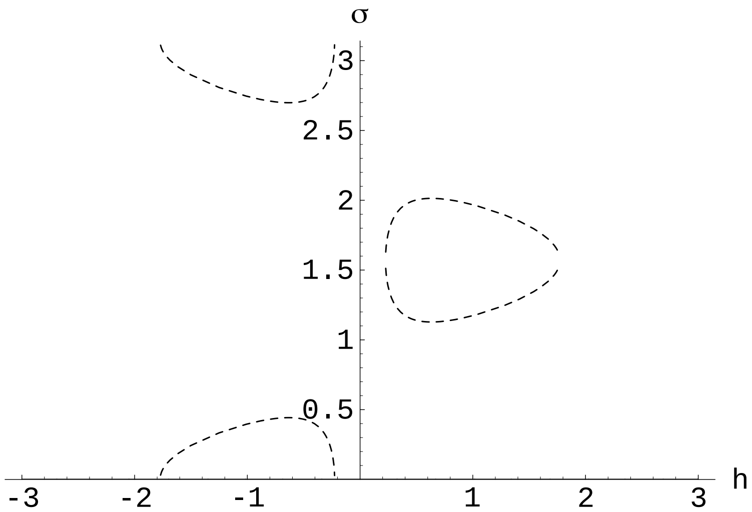
generic NP constraints from lower bound

assume in plots: $\Delta m_s^{\rm SM} = \Delta m_s^{data} = 19.0 \pm 2\, ps^{-1}$ @ 90 % C.L.

mixing with NP: $\Delta m_s = \Delta m_s^{\rm SM} \cdot \left|1 + h e^{2i\sigma}\right|$ see also hep-ph/0509117 for nicer plots

only lower bound near SM $\Delta m_s > 16.6\, ps^{-1}$ @ 95 % C.L. (HFAG '05)

$\Delta m_s > \Delta m_s^{\rm SM}(1-\epsilon)$:



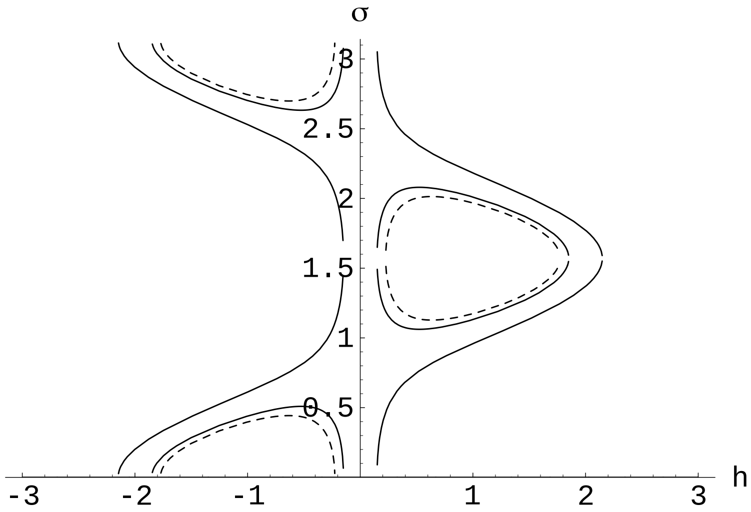
dotted: $\epsilon = 0.23$

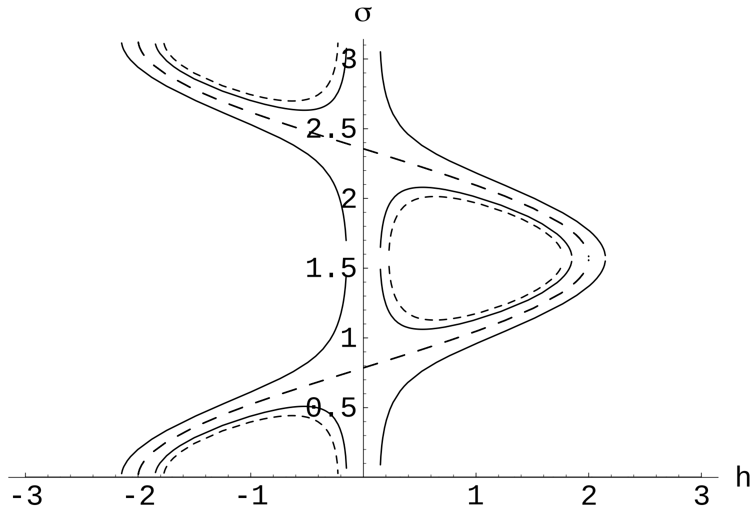
gaps excluded around $h \simeq +1$, $\sigma \simeq \pi/2$ and $h \simeq -1$ with $\sigma \simeq 0, \pi$

size of NP-amplitude h unconstrained

$\Delta m_s = \Delta m_s^{\rm SM} \cdot \left|1 + h e^{2i\sigma}\right|$; with $\Delta m_s \simeq \Delta m_s^{\rm SM}(1 \pm \epsilon)$

$\Delta m_s^{data} = 19.0 \pm 2\, ps^{-1}$ @ 90 % C.L.





dotted: lower bound only, solid: $\epsilon = 0.15$, dashed (and $h = 0$): $\epsilon = 0$

size of NP-amplitude $|h| < 2 + \epsilon$ limited

$\mathcal{O}(1)$ NP-amplitude possible if NP-phase σ cooperates

large $|h|$ is fine-tuned to some degree for small errors $\epsilon \to 0$

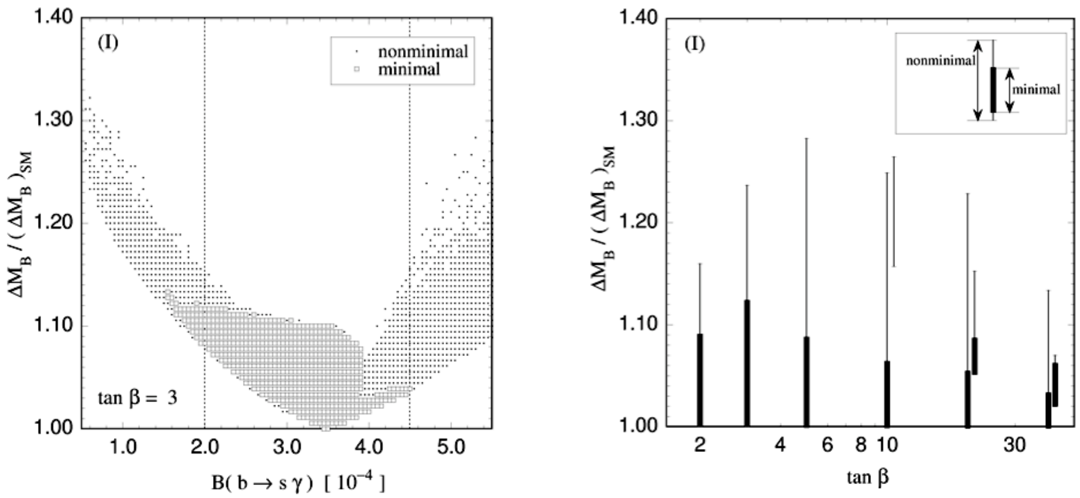
I. low $\tan\beta$: CKM-ology: hep-ph/9903535, SUGRA: hep-ph/9908499

$h = h_{H^\pm} + h_{\chi^\pm}$; $\sigma = 0$ (no BSM CP-violation)

$h > 0$ in whole parameter space h equal for B_d and B_s

ok with $b \to s\gamma$, $m_\chi > 91$ GeV, all other charged SUSY-partners above 80 GeV: $0 < h \lesssim 0.75$; h decreases for heavy $m_{\tilde{t}}$,$m_{\tilde{\chi}}$,$m_{H^\pm}$

SUGRA: $h \lesssim 0.4$; calc. only valid up to moderate $\tan\beta$ (see next slide)



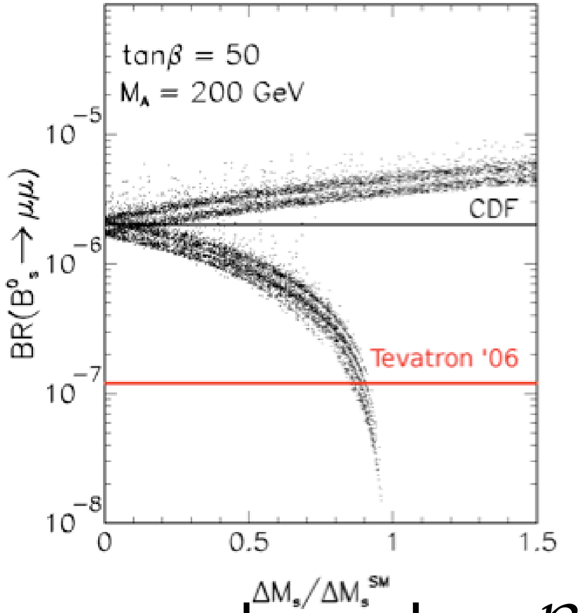
$B_s - \bar{B}_s$ mixing in MVF MSSM II

II. large $\tan\beta$: hep-ph/0210145 $h = \underbrace{h_{H^\pm}}_{<0} + \underbrace{h_{\chi^\pm}}_{>0} + \underbrace{h_{DP}}_{<0}$, $\sigma = 0$

$h < 0$ in most of the parameter space; $h(B_d) \neq h(B_s)$ due to DP

DP: double penguin from neutral Higgses: DP$(B_s) \propto m_s \tan\beta^4$ big!

Δm_s correlated with $\mathcal{B}(B_s \to \mu^+\mu^-) < 1.0 \cdot 10^{-7}$ hep-ph/0207241



Δm_s is lowered w.r.t. SM; predicts upper bound on $\mathcal{B}(B_s \to \mu^+\mu^-)$

$B_s - \bar{B}_s$ in MVF NMSSM @ large $\tan\beta$

$W = QY_uH_uU + QY_dH_dD + LY_eH_dE + \lambda H_dH_uN - \frac{1}{3}kN^3$ N:singlet

at large $\tan\beta$: naturally light pseudoscalar A_1^0, radiatively stable

A_1^0 masses as low as $\mathcal{O}(10\text{MeV})$ viable hep-ph/0404220

iff very light and weakly coupled, A_1^0 becomes missing E

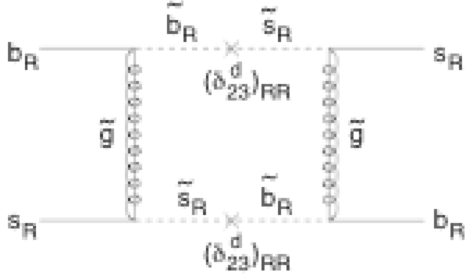
$h^0 \to A^0A^0$ very important for Higgs searches hep-ph/0005308

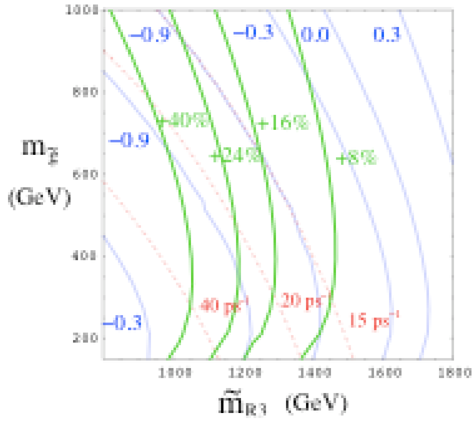
NMSSM at large $\tan\beta$: $h = h_{MSSM}^{large\ \tan\beta} + h_{A_1^0}$; $h_{A_1^0} \propto \tan\beta^2/m_{A_1^0}^2$

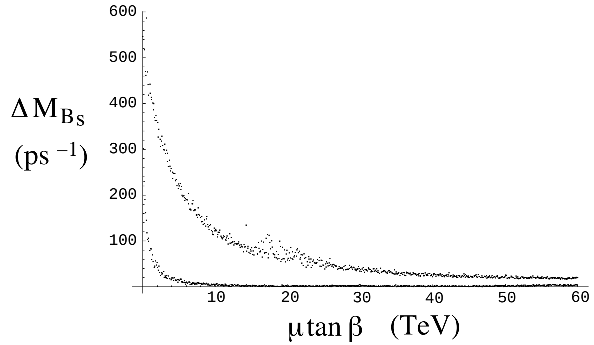
$h_{A_1^0}(B_d) = h_{A_1^0}(B_s)$

from Δm_d-measurement: $|h| \lesssim 0.4$

unlike MSSM, no correlation with $\mathcal{B}(B_s \to \mu^+\mu^-)$ hep-ph/0404220 large $\nu_\mu - \nu_\tau$ mixing in $SO(10)$ GUT models implies large mixing between right handed $\tilde{s} - \tilde{b}$: $(\delta^D_{23})_{RR}$ large and complex Figs from hep-ph/0212180





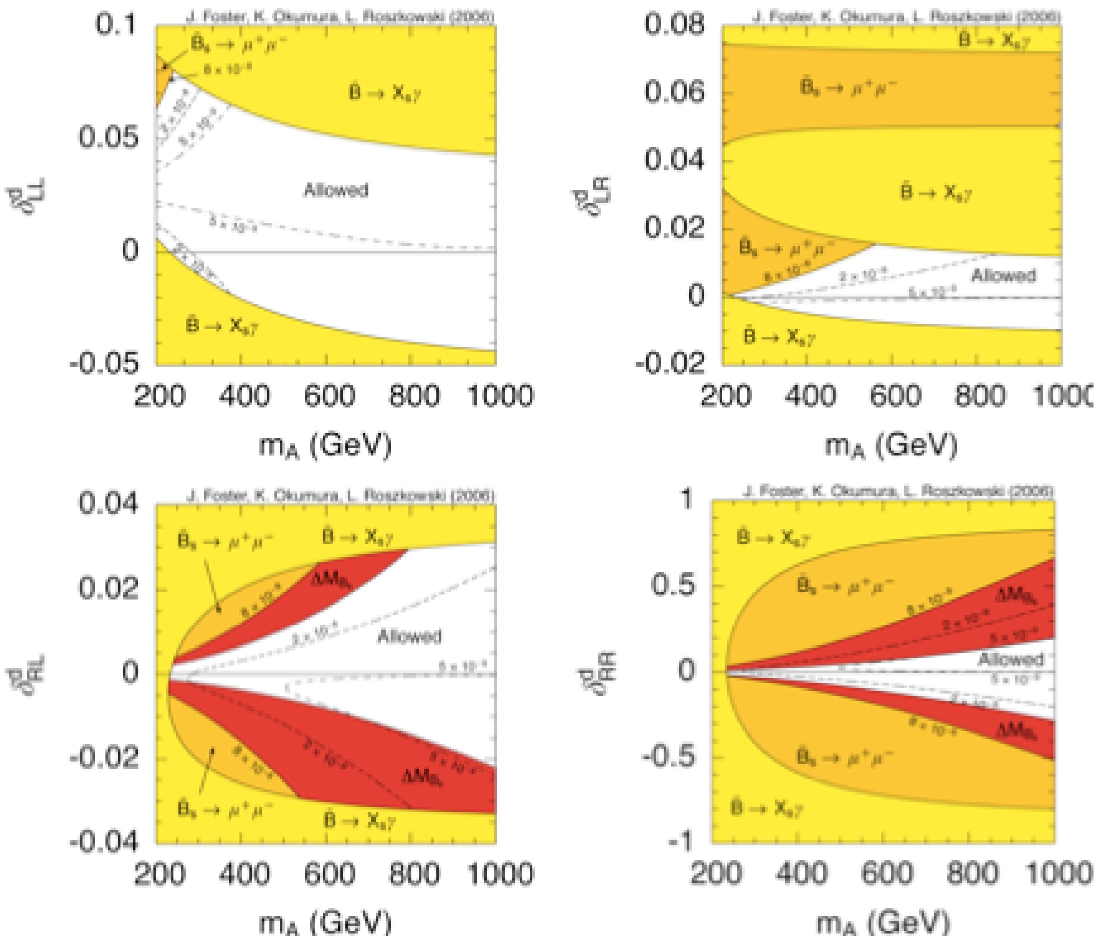


implications: Δm_s can be huge $\sim 100\ ps^{-1}$ (range in right fig) but can be also SM-like (middle fig):

needs heavy superpartners $m_{Q2,Q3,D2} \sim$ 2TeV
or small couplings $(\delta^D_{23})_{RR}$

(green: percent increase in $B(b \to s\gamma)$, blue: $S_{\Phi K_S}$)

Bounds on beyond MFV flavor mixing



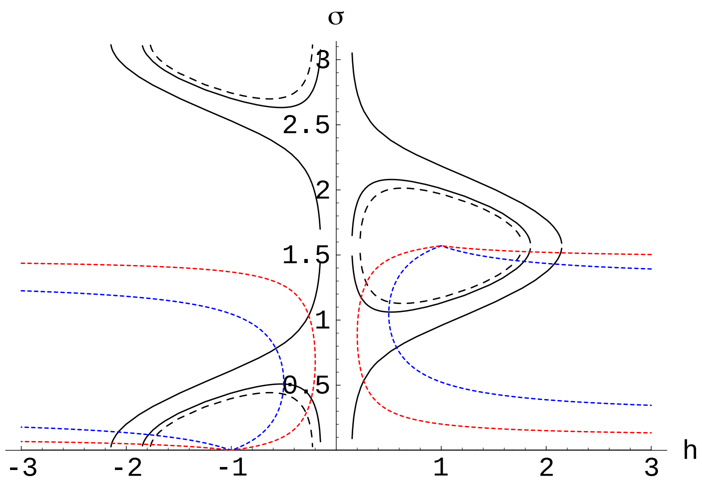
$m_{\tilde{g},q} = 1$ TeV, $\tan\beta = 40$, $\mu = -A_u = 500$ GeV Figs from hep-ph/0604121

Further information on $\Delta B = 2$: getting the phase

Time-dependent CP-asymmetries $B_s \to J/\Psi\Phi$ (predom. SM $b \to c\bar{c}s$ amplitude)

$S = \eta_{CP} \cdot \sin\left[2\beta_s - \arg(1 + he^{2i\sigma})\right] \qquad \beta_s = \arg(-V_{ts}V_{tb}^*/(V_{cs}V_{cb}^*)) \simeq \eta\lambda^2$

cf. $B_d \to J/\Psi K_S$: $S(J/\Psi K_S) = \sin\left[2\beta + \arg(1 + h_d e^{2i\sigma_d})\right]$



$S = 0.2$, $S = 0.5$, SM: $S/\eta_{CP} = \sin 2\beta_s = 0.038 \pm 0.003$ SM CKM fit

$B_s \to J/\Psi\Phi$ vs. $B_s \to (\eta_c, \chi_{0,1,2})\Phi$: NP on decay amplitude hep-ph/0307251

$S(B_s \to \Phi\Phi) = \eta_{CP} \sin\left[2\beta_s - \arg(1 + he^{2i\sigma}) + \Delta\varphi(b \to s\bar{s}s - \text{amplitude})\right]$

$\Delta B = 2$ phase from A_{SL}

asymmetry into wrong sign leptons:

$$A^q_{SL} \equiv \frac{\Gamma(\bar{B}^0_q(t)\to\ell^+ X) - \Gamma(B^0_q(t)\to\ell^- X)}{\Gamma(\bar{B}^0_q(t)\to\ell^+ X) + \Gamma(B^0_q(t)\to\ell^- X)} = \mathrm{Im}\frac{\Gamma^q_{12}}{M^{q\,SM}_{12}(1+h_q \exp 2i\sigma_q)}$$

$A_{SL} = 0$ means no CP violation in $\Delta B = 2$ mixing

data: $A^d_{SL} = 0.0011 \pm 0.0055$ CLEO,Belle,BaBar SM: $A^d_{SL} \simeq -1 \cdot 10^{-3}$ hep-ph/0202010

collider: $A_{SL} \equiv \frac{\Gamma(b\bar{b}\to\mu^+\mu^+ X) - \Gamma(b\bar{b}\to\mu^-\mu^- X)}{\Gamma(b\bar{b}\to\mu^+\mu^+ X) + \Gamma(b\bar{b}\to\mu^-\mu^- X)} = -0.0027 \pm 0.0029$ OPAL,ALEPH,DØ

$A_{SL} \simeq 0.6 A^d_{SL} + 0.4 A^s_{SL}$ extract $A^s_{SL} = -0.008 \pm 0.011$ hep-ph/0604112, 0605028

other parametrization: $M^s_{12}/M^{s\,SM}_{12} = r_s^2 \exp(2i\vartheta_s) = 1 + h \exp(2i\sigma)$

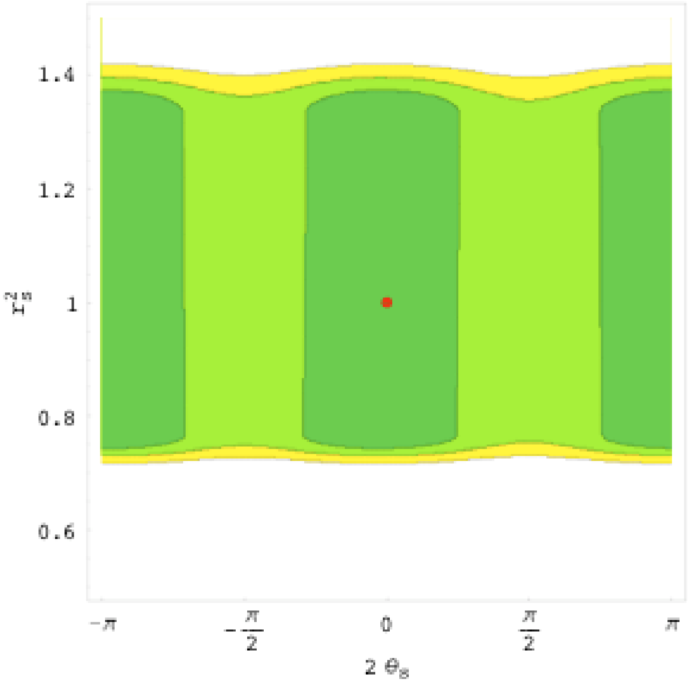
$A^s_{SL} = -\underbrace{\mathrm{Re}(\frac{\Gamma^s_{12}}{M^s_{12}})^{SM}}_{-0.0040\pm 0.0016} \frac{\sin 2\vartheta_s}{r_s^2} \to 2\vartheta_s \simeq \pi/2$ disfavored

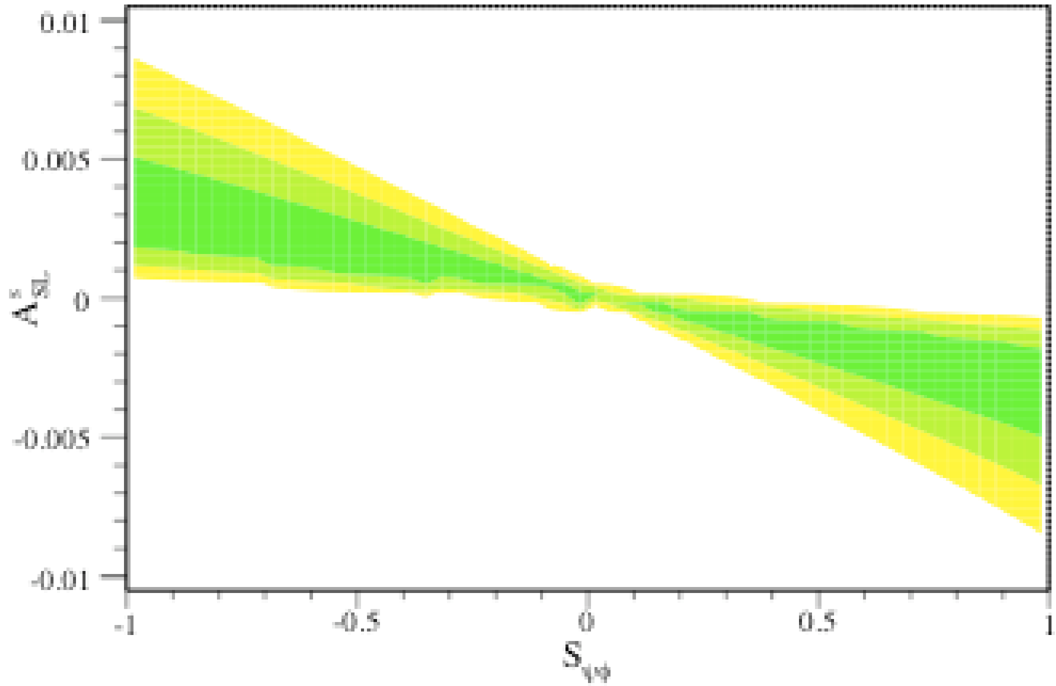
$\Delta B = 2$ phase from A_{SL} and $\Delta\Gamma^s$

$\Delta\Gamma^s_{CP} = -0.22 \pm 0.08 ps^{-1}$ CDF,ALEPH,DØ vs. $\Delta\Gamma^s_{CP} = \underbrace{\left((\Delta\Gamma^s)^{SM}\right)}_{-0.07\pm0.03 ps^{-1}} \cos^2 2\vartheta_s$

$\rightarrow 2\vartheta_s \simeq \pm\pi/2$ disfavored

Figs from hep-ph/0605028,0604112

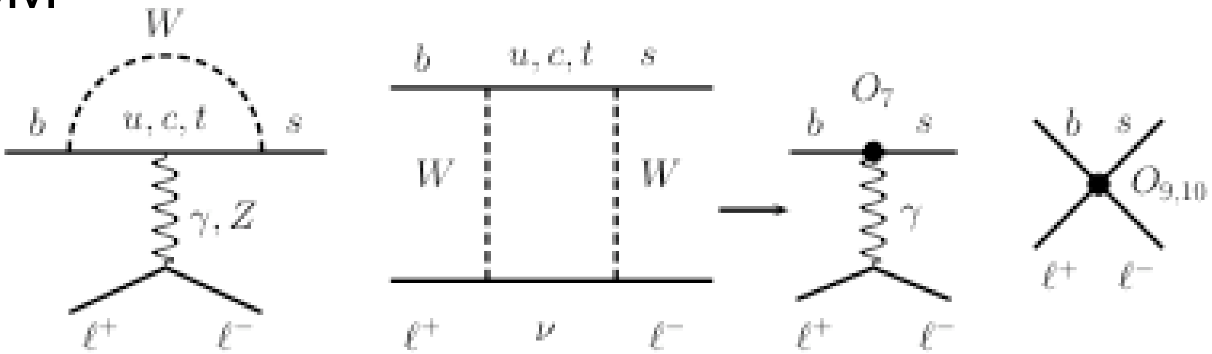




$S, A_{SL}, \Delta\Gamma, \Delta m$ correlated; constraints are still weak

SM tests with $b \to s\gamma, b \to s\ell^+\ell^-$ decays

diagrams in SM



$$\mathcal{H}_{\rm eff} = -4\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum C_i(\mu) O_i(\mu)$$

dipole operators $O_7 \propto \bar{s}_L \sigma_{\mu\nu} b_R F^{\mu\nu}$ $\quad O_8 \propto \bar{s}_L \sigma_{\mu\nu} b_R G^{\mu\nu}$

4-Fermi operators $O_9 \propto (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \ell)$ $\quad O_{10} \propto (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \gamma_5 \ell)$

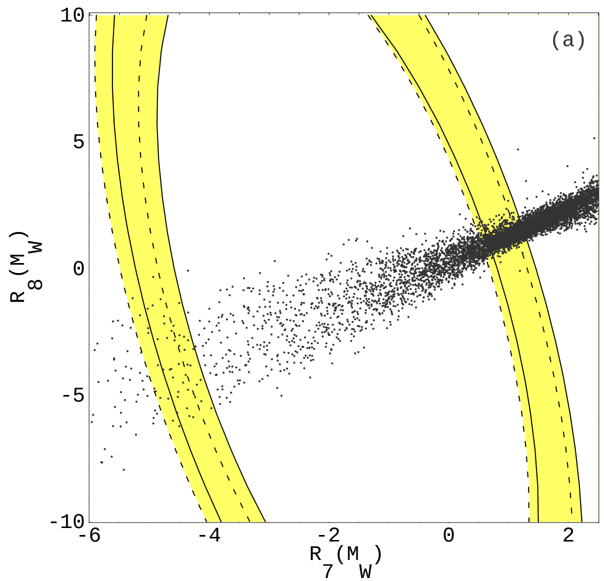
NP in Wilson coefficients $C_i = C_i^{SM} + C_i^{NP}$ or new operators

model-independent analysis: Br's, $A_{CP}, A_{FB} = f(C_i) \to$ fit! hep-ph/9408213

Constraints from $b \to s\gamma$ branching ratio

$\mathcal{B}(b \to s\gamma)_{LO} \sim |C_7(m_b)|^2$ at NLO $R \equiv \frac{C^{SM}+C^{NP}}{C^{SM}}$ hep-ph/0112300

$R_8 - R_7$:



theory errors renorm. scale and charm mass solid:pole, dashed:$\overline{\text{MS}}$

scatter points: MSSM with MFV: $C_7 = \underbrace{C_7^{SM} + C_7^{H^\pm}}_{<0} + C_7^{\chi^\pm}$

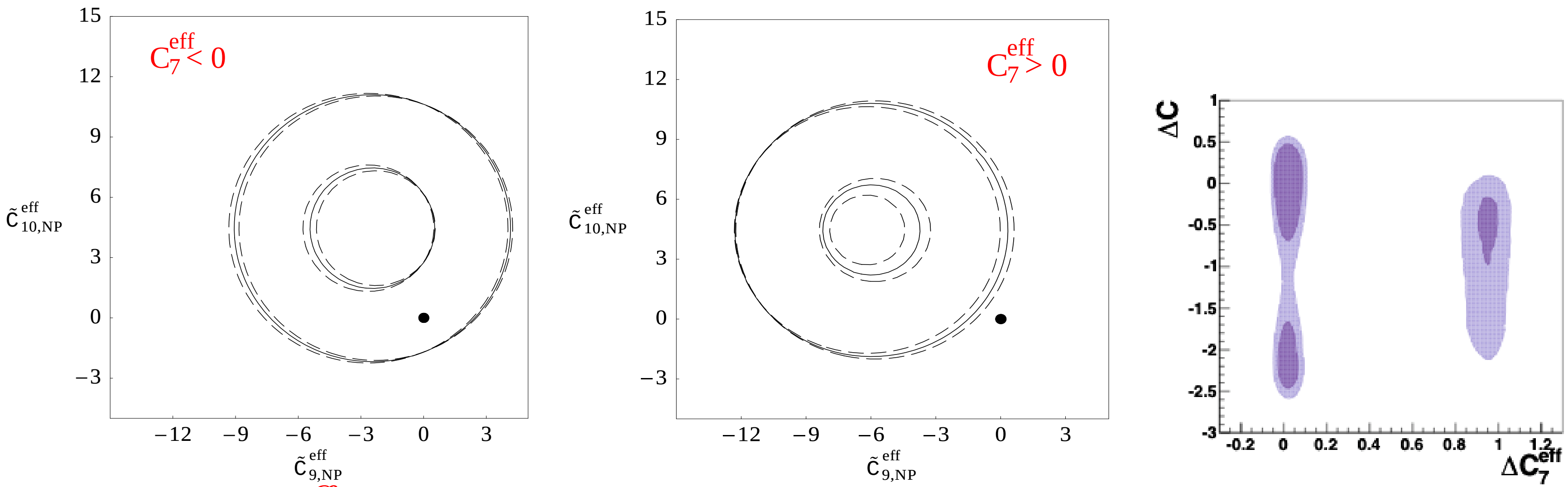
$C_7^{\chi^\pm} \propto \mu A_t \tan\beta f(m_{\tilde{t}_i}, m_{\tilde{\chi}_j}) m_b/(v(1+\epsilon\tan\beta))$; $\epsilon \propto (\alpha_s/\pi)\mu m_{\tilde{g}} \tan\beta$

beyond MFV: gluino loops with down squark-mixing δ_{23}^D e.g. hep-ph/0212397

Combined $b \to s\ell^+\ell^-$ and $b \to s\gamma$ data

$$\frac{d\Gamma(B \to X_s \ell^+\ell^-)}{d\hat{s}} = \left(\frac{\alpha}{4\pi}\right)^2 \frac{G_F^2 m_b^5 \left|V_{ts}^* V_{tb}\right|^2}{48\pi^3} (1-\hat{s})^2 \left[(1+2\hat{s})\left(\left|C_9^{\rm eff}\right|^2 + \left|C_{10}^{\rm eff}\right|^2\right) f_1 \right.$$
$$\left. + \; 4\,(1+2/\hat{s}) \left|C_7^{\rm eff}\right|^2 f_2 + 12 \mathrm{Re}\left(C_7^{\rm eff} C_9^{\rm eff *}\right) f_3 + f_c \right] \quad f_i\text{: } 1/m_{c,b}^2 \text{ corr.}$$

$\mathcal{B}(B \to X_s \mu\mu)_{SM} = 4.3 \pm 0.7 \cdot 10^{-6}$ vs data $= 4.3 \pm 1.2 \cdot 10^{-6}$ (full q^2)



non-SM sign $C_7^{\rm eff} > 0$ disfavored iff no BSM ops ph/0410155, 0505110 Inami-Lim-study

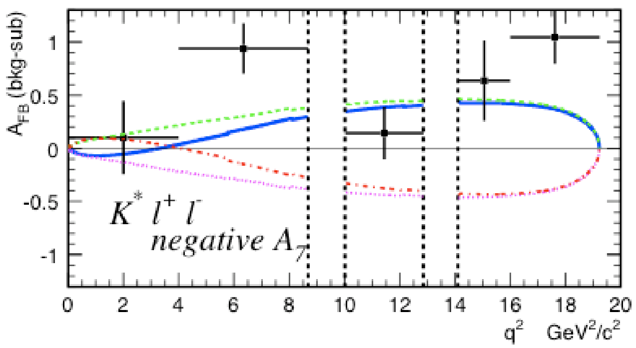
MSSM+MFV: C_9, C_{10} near SM, not $\tan\beta$ enhanced hep-ph/0112300

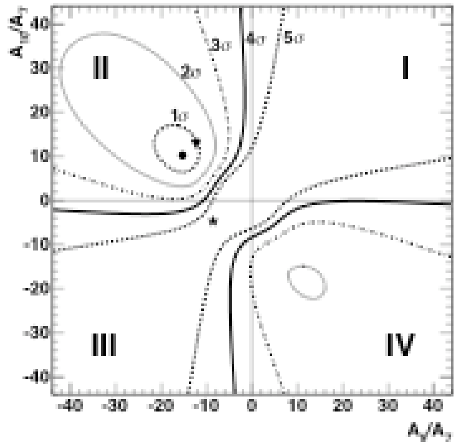
check for BSM operators: (pseudo)scalar (neutral Higgs), $L \leftrightarrow R$

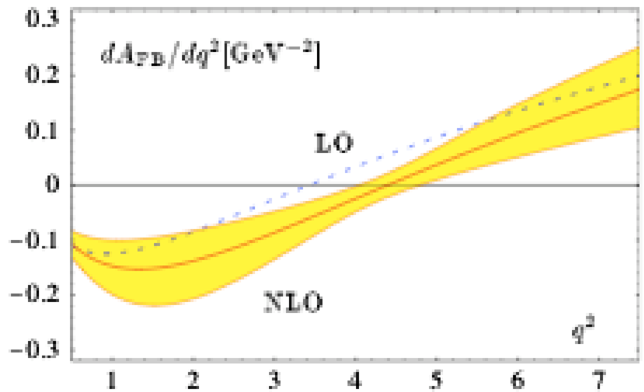
NP sensitivity of $b \to s\ell^+\ell^-$ spectra, perspectives

A_{FB}: # forward - # backward ℓ^+ in dilepton CMS w.r.t. $\bar{B}$ (CP-odd)

$A_{FB}(\hat{s}) \sim -\mathrm{Re}\left[C_{10}^*(C_7^{\rm eff} + \beta(\hat{s})C_9^{\rm eff})\right]$ also $B \to K^*\ell^+\ell^-$ Belle 0508009,0603018







shape sensitive to sign C_7; $A_{FB} \propto C_{10}$

zero X_S: $\hat{s}_{SM}^{NNLL} = 0.162 \pm 0.002(8)$ hep-ph/0208088,0209006

K^*: $s_{SM}^{NLO} = 4.4 \pm 0.4$ GeV^2 hep-ph/0106067

CP $A_{FB}^{CP} \equiv \frac{A_{FB}+\bar{A}_{FB}}{A_{FB}-\bar{A}_{FB}} \sim \arg C_{10} \arg C_9^{\rm eff}$; $A_{FB}^{CP}|_{SM} \lesssim 10^{-3}$ hep-ph/0006136

full angular analysis $B \to K^*(\to K\pi)\ell^+\ell^-$ hep-ph/9907386

$$d\Gamma^4 \sim I(s, \Theta_l, \Theta_{K^*}, \Phi) ds d\cos\Theta_l d\cos\Theta_{K^*} d\Phi$$

More model-independent studies, neutral Higgses

Higgses split between $\mu^+\mu^-$ and e^+e^- in $b \to s\ell^+\ell^-$

ratios with SAME cut on dilepton mass hep-ph/0310219

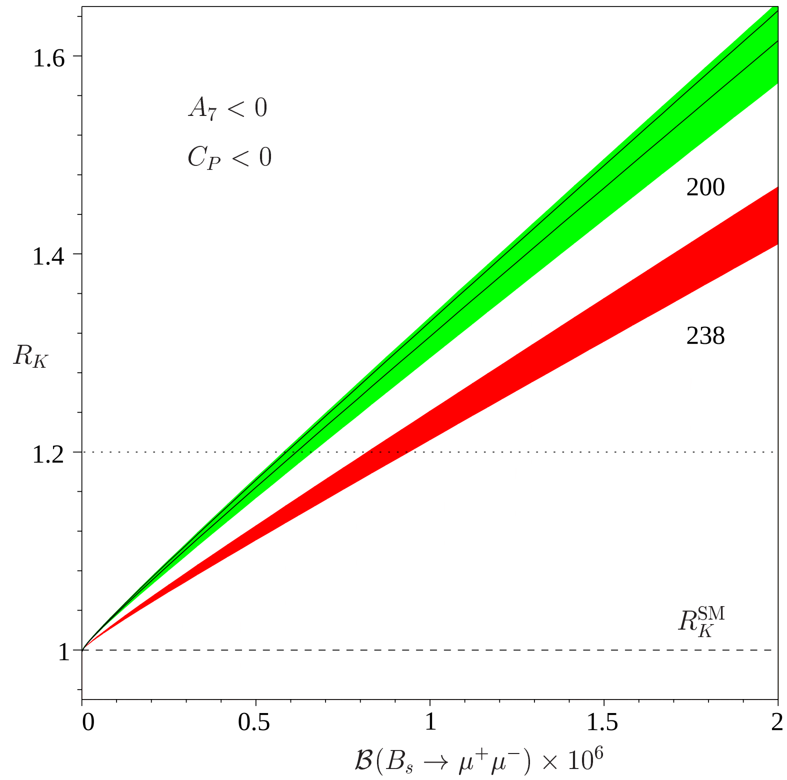
$$R_H \equiv \frac{\int_{4m_\mu^2}^{q^2_{\max}} dq^2 \frac{d\Gamma(B\to H\mu^+\mu^-)}{dq^2}}{\int_{4m_\mu^2}^{q^2_{\max}} dq^2 \frac{d\Gamma(B\to He^+e^-)}{dq^2}} \qquad H = X_s, K^{(*)}$$

$$R_H^{SM} = 1 + \mathcal{O}(m_\mu^2/m_b^2) \qquad \text{very clean}$$

$$R_K = 1.06 \pm 0.48 \pm 0.05$$ BaBar 0507005

$$R_K = 1.38^{+0.39+0.06}_{-0.41-0.07}$$ Belle 0410006

constrain (pseudo)-scalar couplings



R_K constrains $C_{S,P} + C'_{S,P}$, $\mathcal{B}(B_s \to \mu^+\mu^-)$ constrains $C_{S,P} - C'_{S,P}$

correlation breaks down if $C_{S,P} \not\propto m_\ell$

Summary

- CKM@tree: input for SM tests and flavor model building thanks to tremendeous exp (Belle, BaBar) and th (loops, HQET, lattice, ..) efforts
- $b \to s\ell\ell$ modes under th and exp investigation; model independent analysis (w. $b \to s\gamma$) $\to$ do e and μ separately long term goal: angular analysis in $B \to K^*(\to K\pi)\ell\ell$
- tool in penguin-physics: multi-observable analyses and fits
- $b \to d$ FCNCs beginning to be probed
- B_s, B_c, Λ_b-physics coming up CDF&D0; much more from LHC(b)

Summary

- data on $B_s - \bar{B}_s$ mixing touch unknown territory

with Δm_s near Δm_s^{SM}:

- generically, $O(1)$ NP allowed with some amount of fine-tuning and CP-phase; further constraints from $\Delta\Gamma$, A_{SL} (starting) and CP-asymmetries (to be done)
- models with MFV, such as CMSSM can accommodate SM-like $B_s - \bar{B}_s$-mixing within errors $|h| < \epsilon$
- models beyond MFV are constrained significantly
- so far no significant conflict with SM/MFV; many FCNCs only weakly or just un-constrained$V + A$, $\tau^{\pm}$, $\nu\bar{\nu}$, $b \to d$, B_s-physics

Some (further) SM tests with b-physics

	experiment	SM	comments
$a_{CP}(b \to s\gamma)$	$0.4 \pm 3.6\,\%$	$0.42 \pm 0.17\,\%$ hep-ph/0312260	CPX in $bs\gamma, g$
$a_{CP}(b \to d/s\gamma)$	-0.110 ± 0.116 BaBar'05	10^{-9} hep-ph/0312260	test MFV
$S_{K_S\pi^0\gamma}$	0.00 ± 0.28 Belle/BaBar'05	$-2m_s/m_b$	V+A FCNCs
spin $\Lambda_b \to \Lambda\gamma$	–	$\sim m_s/m_b$	V+A FCNCs
$\mathcal{B}(B \to X_s g)$	$< 9\%$ CLEO'97	$5.0 \pm 1.0 \cdot 10^{-3}$	NP in bsg
TDCPA $b \to s\bar{s}s$	$S_{ave} = 0.50 \pm 0.06$	$\sin 2\beta + \Delta S$	CPX
$\mathcal{B}(B \to X_s\bar{\mu}\mu)$	$4.3 \pm 1.2 \cdot 10^{-6}$	$4.3 \pm 0.7 \cdot 10^{-6}$	q^2-spectra
$a_{CP}(B \to X_s\bar{\ell}\ell)$	-0.22 ± 0.26	-0.2 ± 0.2 % hep-ph/9812267	CPX
$A_{FB}^{CP}(B \to K^*\bar{\ell}\ell)$	–	$\lesssim 10^{-3}$ hep-ph/0006136	CPX in bsZ
R_K $\mu\mu$ vs. ee	1.06 ± 0.48 BaBar'05	$1 + \mathcal{O}(m_\mu^2/m_b^2)$ hep-ph/0310219	non-SM Higgs
$\mathcal{B}(B \to K\nu\bar{\nu})$	$< 3.6 \cdot 10^{-5}$ Belle'05	$3.8^{+1.2}_{-0.6} \cdot 10^{-6}$	$O(10)$ from SM
$\mathcal{B}(B_s \to \mu^+\mu^-)$	$< 1.0 \cdot 10^{-7}$ CDF'06	$3.2 \pm 1.5 \cdot 10^{-9}$	$O(30)$ from SM
$\mathcal{B}(B_s \to \tau^+\tau^-)$	$< \mathcal{O}(5\%)$	$7.2 \pm 1.1 \cdot 10^{-7}$	$O(10^5)$ from SM
$\mathcal{B}(B_d \to \tau^+\tau^-)$	$< 3.4 \cdot 10^{-3}$ BaBar'05	$2.1 \pm 0.3 \cdot 10^{-8}$	$O(10^5)$ from SM

$$\Delta m_s^{\rm SM} \sim \quad (V_{tb}^* V_{ts})^2 \times \frac{g^4}{16\pi^2} \quad \times \frac{(\bar{b}\Gamma s)(\bar{b}\Gamma' s)}{m_W^2}$$

$$\Delta m_s^{\rm NP} \sim \quad {\rm flavor} \quad \times {\rm loop/tree} \times \frac{(\bar{b}\Gamma s)(\bar{b}\Gamma' s)}{\Lambda^2}$$

NP in B_s-mixing not bigger than SM implies:

	NP from loops	tree level NP
MFV	$\Lambda \gtrsim m_W \sim O(100)$ GeV	$\Lambda \gtrsim 4\pi m_W \sim O(1)$ TeV
non MFV	$\Lambda \gtrsim m_W/\lvert V_{ts}\rvert \sim O(2-3)$ TeV	$\Lambda \gtrsim 4\pi m_W/\lvert V_{ts}\rvert \sim O(30)$ TeV

origin of flavor is still a mystery

whether it is connected to the NP scale Λ we are probing now