B Mixing 'n' Things

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B Mixing: the State of the Art

- $\Delta m_d = (0.502 \pm 0.004 \pm 0.005)\,\mathrm{ps}^{-1}$
- $\Delta m_s > 14.5\,\mathrm{ps}^{-1}$ @95% CL
- UTfit predicts $\Delta m_s = (21.2 \pm 3.2)\,\mathrm{ps}^{-1}$ (without known exp. constraints on Δm_s), $\Delta m_s = (18.5 \pm 1.6)\,\mathrm{ps}^{-1}$ (with such constraints)
- $|q/p|_d = 1.0013 \pm 0.0034$
- $\sin 2\beta$(all charmonium) $= 0.726 \pm 0.037$, $\sin 2\beta_{\mathrm{eff}}$(all $b \to s$ penguin) $= 0.41 \pm 0.07$ HFAG, hep-ex/0412073

Relation to UT parameters:

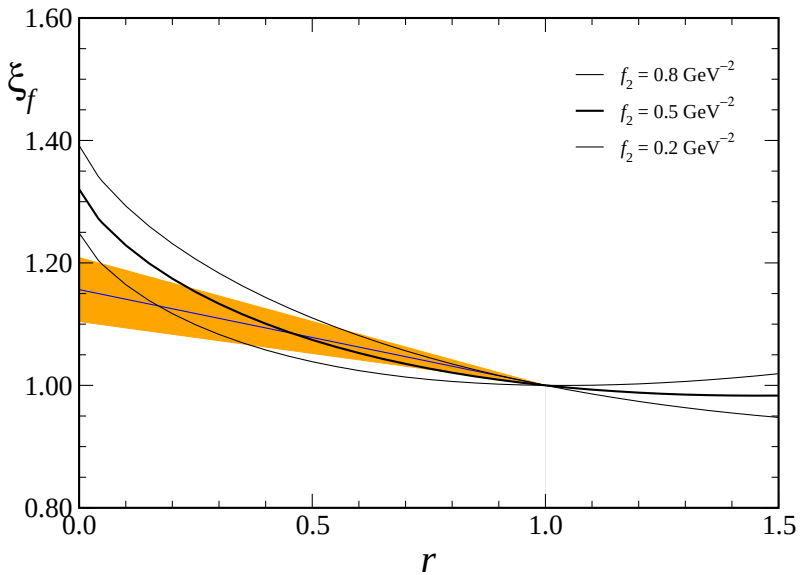
$$\text{used to be } \Delta m_d \propto \left[(1-\bar{\rho})^2 + \bar{\eta}^2\right] f_{B_d}^2 \hat{B}_{B_d}$$

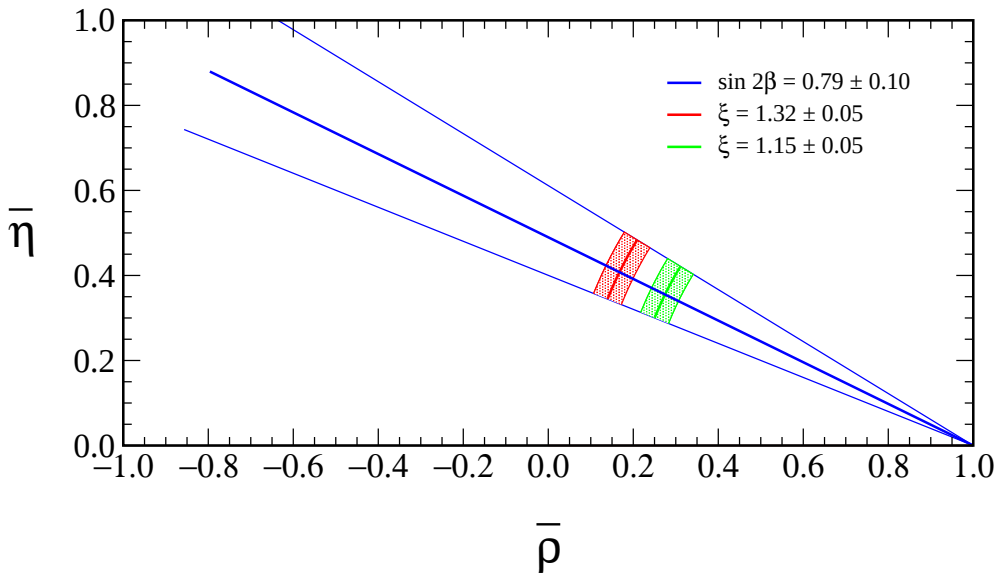
$$\Delta m_s \propto |V_{ts}|^2 f_{B_s}^2 \hat{B}_{B_s} \equiv |V_{ts}|^2 f_{B_d}^2 \hat{B}_{B_d} \xi^2$$

Now (Lubicz, Lattice 2004, hep-lat/0410051):
replace $f_{B_d}^2 \hat{B}_{B_d}$ as independent quantity by $f_{B_s}^2 \hat{B}_{B_s} = (276 \pm 38)^2 \mathrm{MeV}^2$.
Why? Trouble with chiral extrapolation to $m_d \ll m_s$!

B Mixing Matrix Elements from Lattice

Kronfeld/Ryan 2002: "standard value" $\xi_f = 1.15 \pm 0.05$ may be too small; Lubicz quotes (and UTfit use) $\xi_f = 1.24 \pm 0.04 \pm 0.06$

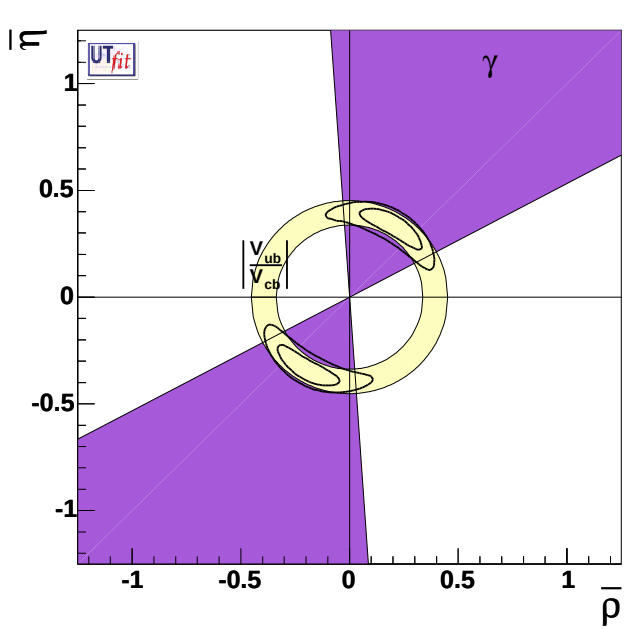




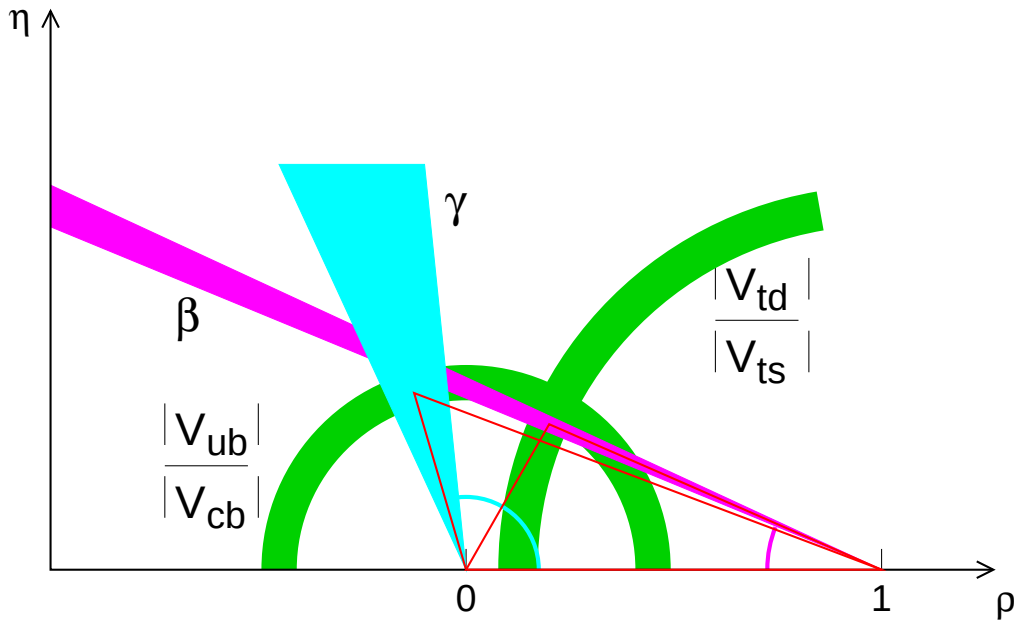
$r = m_q/m_s$: linear extrapolation spoiled by chiral logs:
larger ξ_f shifts apex of UT
Wingate, Lattice 2004 (hep-lat/0410008): *no* updated value for ξ_f given $\rightarrow$ need more (lattice) data!

Impact on UTfits?

$\Delta m_s/\Delta m_d$ may very well contain NP — so what do we know about the SM UT?



UFfit cn., hep-ph/0501199



U. Egede at CKM03, hep-ex/0307022

New (2004) measurements of tree processes $B \to DK$ yield $\gamma = 59.1 \pm 16.7$ (quoted from UTfit cn.) – up to 2-fold discrete ambiguity. In very good agreement with fits!

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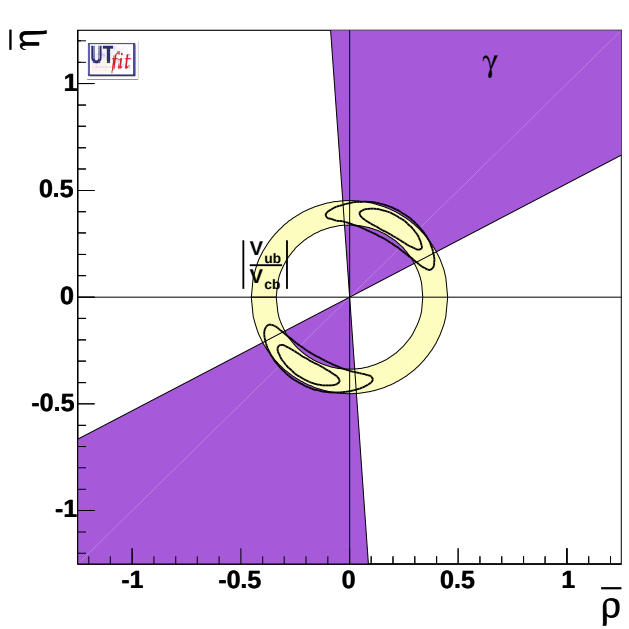

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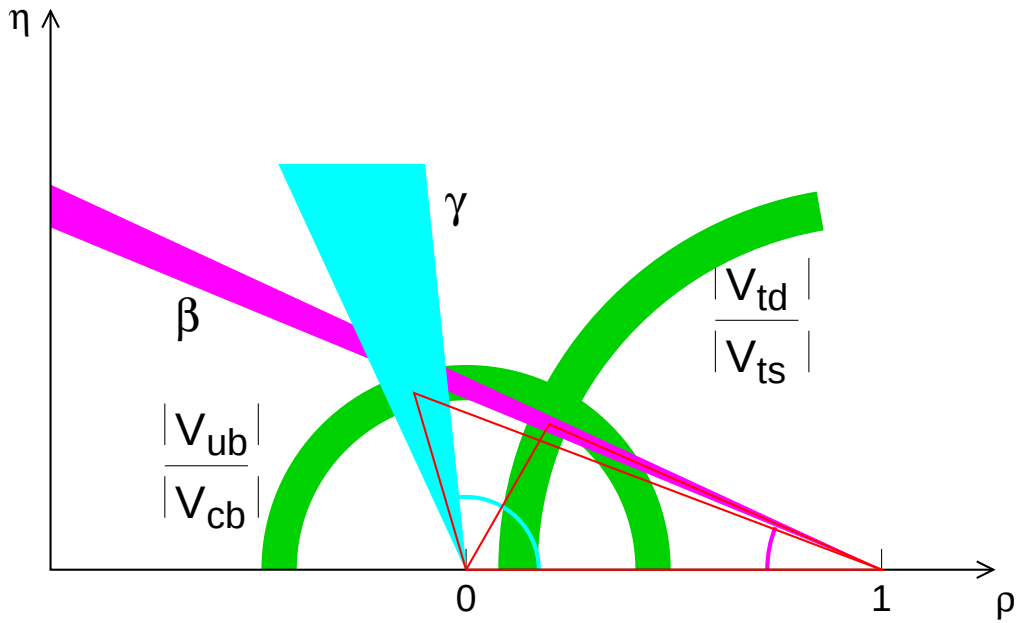

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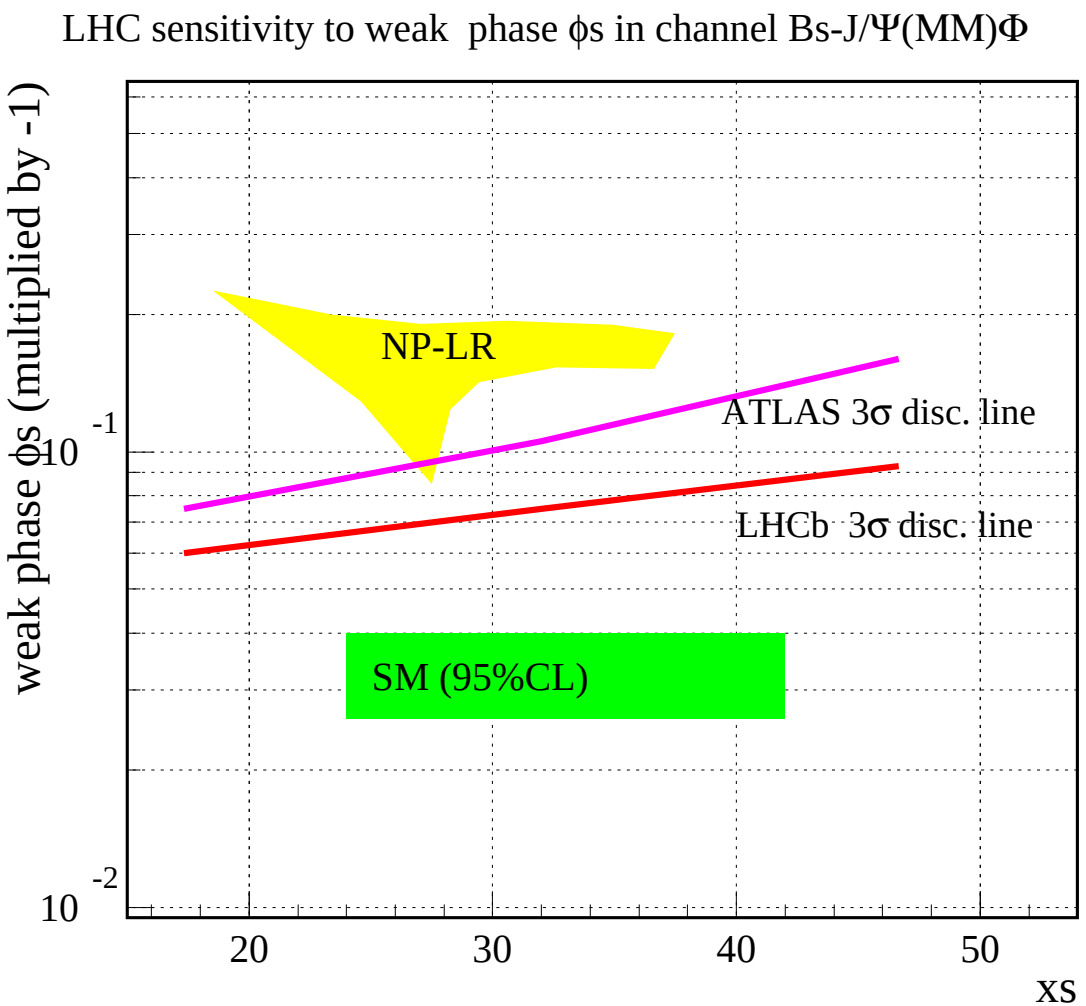
Atwood/Soni 2004: $\Delta\gamma = 8^o$ may be possible at B factories with 5 to 10×10^8 B pairs.

Models for B_s Mixing

- B_s mixing angle near zero in SM — *any* sizeble deviation would indicate new physics
  $\rightarrow B_s \rightarrow J/\psi\phi(\eta^{(\prime)})$ prime candidates!
- $\sin 2\beta$(charmonium) $\neq \sin 2\beta_{\rm eff}$($b \rightarrow s$ penguin) indicates sth. may be going on in $b \rightarrow s$
- Any realistic models for NP in B_s mixing?
  - should be embedded (or at least "inspired") by consistent high-energy theory (SO(10) etc.)
  - should fulfill all flavour constraints from B_d and K (and, if CDF/D0 deliver, explain Δm_s)
  - should predict *large* effects in B_s mixing
- any NP in Γ_s?
  First measurement $\Delta\Gamma_s/\Gamma_s = (65^{+25}_{-33} \pm 1)\%$ (CDF, hep-ex/0412057)
  not yet very constraining.

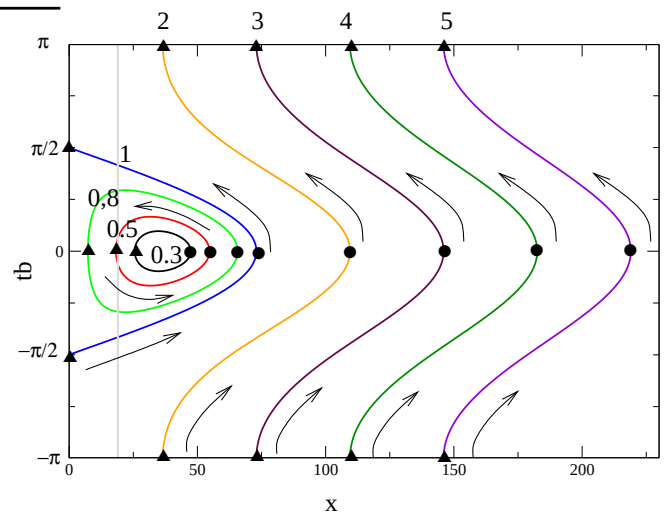
The Physics Reach of the LHC – as of 1999

Ball et al., B Decays at the LHC hep-ph/0003238

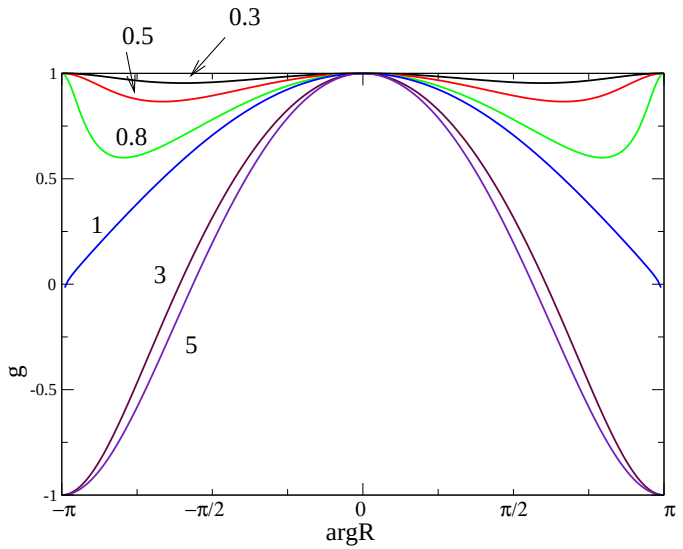


Any news about the fate of the non-SUSY left-right symmetric model?

Other Models: SUSY Effects in MIA



(a)



(b)

Ball/Khalil/Kou
hep-ph/0311361

- NP contributions to M_{12} parametrized as $R \equiv M_{12}^{NP}/M_{12}^{SM}$; R in MIA depending on average squark and gluino masses and $(\delta_{23}^d)_{LL,LR,RR}$
- constraints from $b \to s\gamma$ and requirement $S_{\phi K_s} < 0$ imply ϕ_s small ($\sin 2\phi_s = O(10^{-2})$), unless Δm_s huge: $> 35\,\mathrm{ps}^{-1}$
- if $S_{\phi K_s} \approx +0.4$, then $\sin 2\phi_s = 0.2$ or larger also possible for SM-like $\Delta m_s \approx 20\,\mathrm{ps}^{-1}$

Extra Heavy Z' (has become rather popular?)

Langacker/Plümacher, hep-ph/0001204
Barger et al., hep-ph/0405108

- Z' with nonuniversal family couplings: can "naturally" occur as U(1)' in string models
- induces tree-level FCNC: severely constrained for 1st and 2nd generation fermions, but less so for bs and ts
- $\Delta m_s = \Delta m_s^{SM} \left|1 + 3.858 \times 10^5 \rho_L^2 e^{2i\phi_L}\right|$: NP enhanced by factor $\sim 1/G_F$ (can also include right-handed couplings if wanted)
- $\rho_L = (g_2 m_Z)/(g_1 m_{Z'}) B_{sb}^L$;
  ballpark estimate $\rho_L \sim 1 \times 0.1 \times |V_{tb} V_{ts}^*| \sim O(10^{-3})$
- model is very versatile: also simultaneously explains $S_{\phi K_s}$ and $B \to \pi K$ puzzle (acc. to Barger et al.)
- still waiting for truly combined analysis? (would be rather model-dependent as one e.g. needs to know rotation matrix for R chiral quarks)

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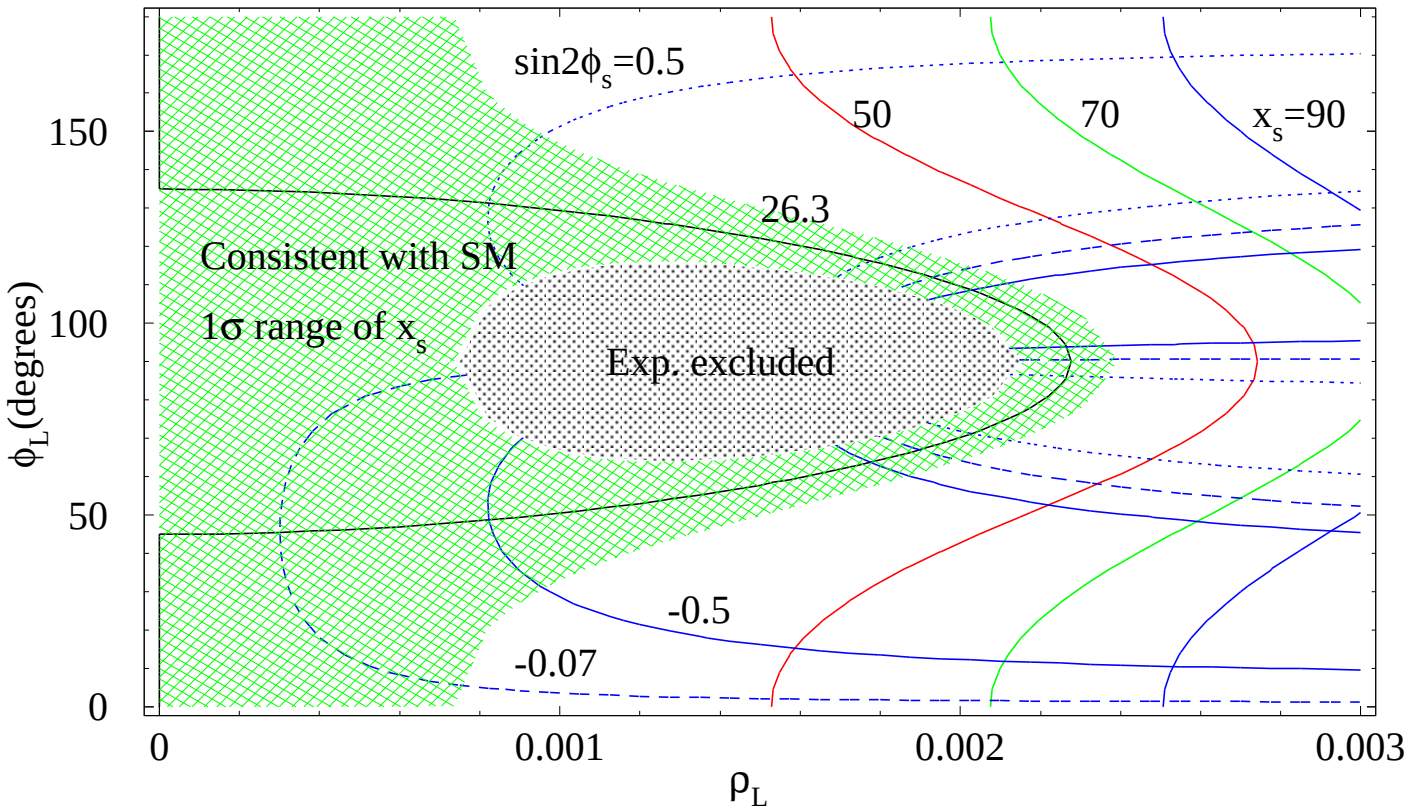

SUSY SO(10) or similar

- looks pretty complete. . . Babu/Pati/Rastogi/Wilczek 2000/2004
- links fermion masses, ν oscillations, CP violation, flavour violation in SUSY SO(10) or $SU_L(2) \times SU_R(2) \times SU(4)_C$
- model specified in terms of flavour-blind SUSY parameters m_0, $m_{1/2}$, $\tan\beta$ (A_0 small or real); assume CP violation generated by phases in fermion mass matrix; fermion mass matrices motivated from group structure
- all weak scale flavour and CP parameters, flavour-preserving sfermion transition ME predicted within the model
- distinguished from CMSSM and MSSM by presence of GUT-scale physics inducing enhanced flavour violation
- predictions for B_s physics under study. . .

Summary & Conclusions

- L(attice)QCD needs to sort out their B mixing parameters — at present, and *assuming* the SM, UTfits yield $f_{B_s}(\hat{B_{B_s}})^{1/2}$ and $\hat{B}_K$ with *better* precision than LQCD, and ξ_f with about the same precision. The values agree within uncertainties. There is the possibility that with improved lattice precision the values will disagree which would signal NP in $\Delta m_{d,s}$.
- The SM-UT needs to be determined with better precision from tree decays (b semileptonic for $|V_{ub}/V_{cb}|$ and $B \to DK$ for γ). What is the potential impact of NP on these decays? (e.g. charged Higgs at large $\tan\beta$)
- It'd be a shame if the B_s mixing phase was just as predicted in the SM!
- And if it isn't – and $\sin 2\beta_{\rm eff}$ from $b \to s$ penguins stays different from $\sin 2\beta$ (charmonium) – what models do consistently describe all flavour data?