Constraints on New Physics from γ and $|V_{ub}|$

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The SM Unitarity Triangle

- whatever new physics there may be — there is a SM UT
- fixed by two parameters (one side + one angle)
- other sides and angles from unitarity
- input from tree-level processes:
  - λ, $|V_{ub}|$, $|V_{cb}|$ from semileptonics
  - γ from CP asymmetry in $B \to D^{(*)} K^{(*)}$

What do we know about it?

Status of $|V_{ub}|$: exclusive

My talk in WG 5: $|V_{ub}|_{\text{excl}}$ with a little bit of help from our experimental friends: shape of form factor fixed from $B \to \pi e \nu$:

LCSR (QCD sum rules)	$f_+(0) = 0.26 \pm 0.03$ $|V_{ub}| = (3.5 \pm 0.4(\text{shape+norm.}) \pm 0.1(\mathcal{B})) \times 10^{-3}$
HPQCD (lattice)	$f_+(0) = 0.21 \pm 0.03$ $|V_{ub}| = (4.3 \pm 0.5 \pm 0.1) \times 10^{-3}$
FNAL (lattice)	$f_+(0) = 0.25 \pm 0.03$ $|V_{ub}| = (3.7 \pm 0.4 \pm 0.1) \times 10^{-3}$

- reduced theoretical uncertainty as shape of FF is fixed by experimental data
- reduced experimental uncertainty as total $\mathcal{B}(B \to \pi e \nu)$ can be used

Status of $|V_{ub}|$: inclusive

HFAG gives results using three theoretical descriptions:

- Lange/Neubert/Paz (BLNP): $(4.49 \pm 0.19(\text{exp}) \pm 0.27(\text{th})) \times 10^{-3}$
- Andersen/Gardi (DGE): $(4.46 \pm 0.20(\text{exp}) \pm 0.20(\text{th})) \times 10^{-3}$
- Bauer/Ligeti/Luke (LLR): $(4.43 \pm 0.45(\text{exp}) \pm 0.29(\text{th})) \times 10^{-3}$

Central values consistently equal and consistently above exclusive determination!

Note that

- experimental error for inclusive is larger than for exclusive: $0.2 \leftrightarrow 0.1$
- theoretical uncertainty for inclusive is quoted as smaller than for exclusive: $\sim 0.2 - 0.3 \leftrightarrow 0.4$

Status of γ: $B \to D^{(*)} K^{(*)}$

- only “true” tree-level determination
- Gronau/Wyler/London (GLW): so far no useful constraints on γ
- Atwood/Dunietz/Soni (ADS): again no useful results (yet)
- “best” results from Dalitz analysis of $B^- \to D^0 K^-$ with $(D^0, \bar{D}^0) \to K_S^0 \pi^+ \pi^-$ (Giri/Grossman/Soffer/Zupan 03)
  - BaBar: $\gamma = (92 \pm 41 \pm 11 \pm 12)^\circ$
  - Belle: $\gamma = (53^{+15}_{-18} \pm 3 \pm 9)^\circ$

Status of γ: SU(3) Fits & QCDF & SCET

Note: penguin contaminated!

- e.g. from $B \to \pi\pi$ and $B \to \pi K$: $(70.0^{+3.8}_{-4.3})^\circ$, see R. Fleischer, talk in WG 4
- from all $B \to PP$, SU(3): $\gamma = (77 \pm 4)^\circ$ (Chiang/Zhou 2006)
- from $B \to (PP), (PV), (VV)$, using U-spin: $\gamma = (80^{+6}_{-8})^\circ$ (Soni/Suprun 2006)
- from $B \to PV$, QCDF: $\gamma = (62 \pm 8)^\circ$ (Beneke/Neubert 2003) update?
- from $B \to \pi\pi$, SCET: $\gamma = (73.9^{+7.4}_{-10.7})^\circ$ (Stewart, talk at CKM06)

Status of γ: $B \to (\rho, \omega)\gamma$ (penguin dominated)

My talk in WG 3:

From 2006 BaBar data for $\overline{\mathcal{B}}(B \to (\rho,\omega)\gamma)/\overline{\mathcal{B}}(B \to K^*\gamma)$:

$$\left|\frac{V_{td}}{V_{ts}}\right| = 0.199^{+0.022}_{-0.025}(\text{exp}) \pm 0.014(\text{th}) \leftrightarrow \gamma = (61.0^{+13.5}_{-16.0}(\text{exp})^{+8.9}_{-9.3}(\text{th}))^\circ$$

Recall $\left|\frac{V_{td}}{V_{ts}}\right| = \lambda\sqrt{1 - 2R_b\cos\gamma + R_b^2}(1 + O(\lambda^2))$

- $|V_{td}/V_{ts}|$ depends on $\cos\gamma$
- discrete ambiguity $\gamma \leftrightarrow -\gamma$

- CP asymmetry in $B \to D^{(*)}K^{(*)}$
- discrete ambiguity $\gamma \leftrightarrow \gamma + \pi$

Remove discrete ambiguity! $\gamma < 180^\circ$ is favoured!

CKM Input: tree-level quantities

Express all CKM factors in terms of λ, $|V_{ub}|$, $|V_{cb}|$ and γ:

$$
\begin{aligned}
|V_{td}^* V_{tb}|^2 &= |V_{cb}|^2 \lambda^2 (1 - 2R_b \cos\gamma + R_b^2) \\
\text{with } R_b &\equiv \left(1 - \frac{\lambda^2}{2}\right) \frac{1}{\lambda} \left|\frac{V_{ub}}{V_{cb}}\right| \\
|V_{ts}^* V_{tb}|^2 &= |V_{cb}|^2 \left\{1 - (1 - 2R_b \cos\gamma)\lambda^2 + O(\lambda^4)\right\}
\end{aligned}
$$

- $\gamma = (65 \pm 20)^\circ$ (simple-minded average over tree+SU(3) determinations)
- $R_b = 0.45 \pm 0.03$ with $|V_{ub}| = (4.4 \pm 0.3) \times 10^{-3}$ from inclusive decays
- $R_b = 0.39 \pm 0.06$ with $|V_{ub}| = (3.8 \pm 0.6) \times 10^{-3}$ from exclusive decays
- $|V_{td}^* V_{tb}| = (8.6 \pm 1.5) \cdot 10^{-3}$: very sensitive to γ!
- $|V_{ts}^* V_{tb}| = (41.3 \pm 0.7) \cdot 10^{-3}$

Implications of $|V_{ub}|$, γ for ϕ_d

ϕ_d: B_d mixing phase:

from $b \to c\bar{c}s$: $\sin\phi_d = \sin(2\beta + \phi_d^{\rm NP}) = 0.675 \pm 0.026$

Relation to tree-level CKM parameters: $$\sin\beta = \frac{R_b \sin\gamma}{\sqrt{1 - 2R_b\cos\gamma + R_b^2}}$$

Depending on value of $|V_{ub}|$, get

$$\phi_d^{\rm NP}\big|_{\rm incl} = -(11.0 \pm 4.3)^\circ\,, \qquad \phi_d^{\rm NP}\big|_{\rm excl} = -(3.4 \pm 7.9)^\circ$$

- error of $\phi_d^{\rm NP}$ dominated by $|V_{ub}|$
- dependence on γ small
- no non-perturbative parameters involved*

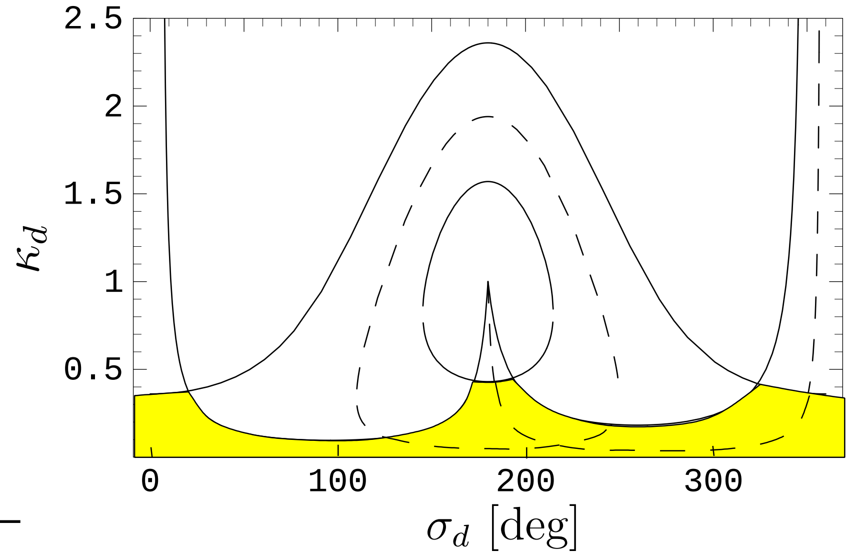
  * in addition to $|V_{ub}|$ extraction and up to tiny $O(\lambda^2)$ effects

Implications for New Physics in B_d Mixing

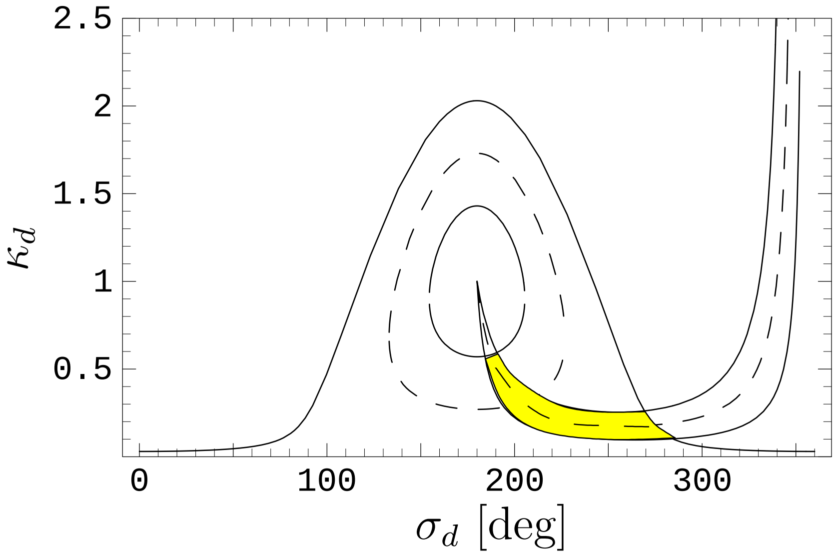
$\Delta M_d = 2|M_{12}^d|$, $\phi_d = \arg M_{12}^d$ with

- $$M_{12}^d = M_{12}^{d,\mathrm{SM}}(1 + \kappa_d e^{i\sigma_q})$$
- $\kappa_d > 0$: NP amplitude
- σ_d: new CP-violating phase

Lattice: JLQCD:



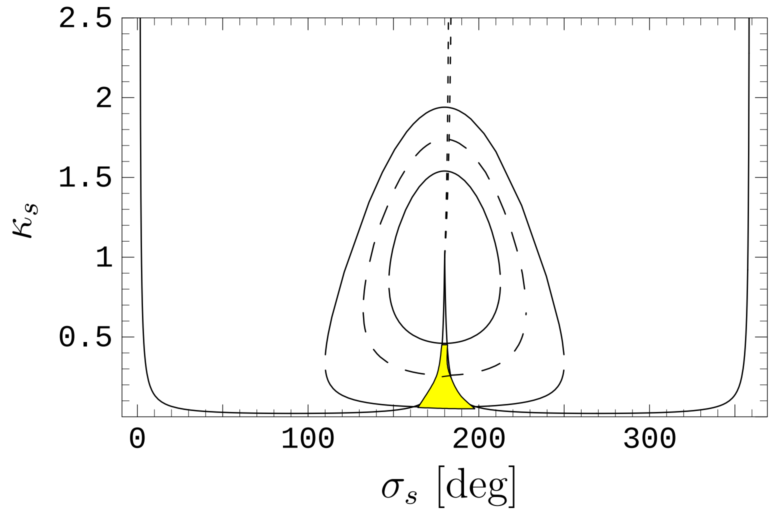
(HP+JL)QCD:



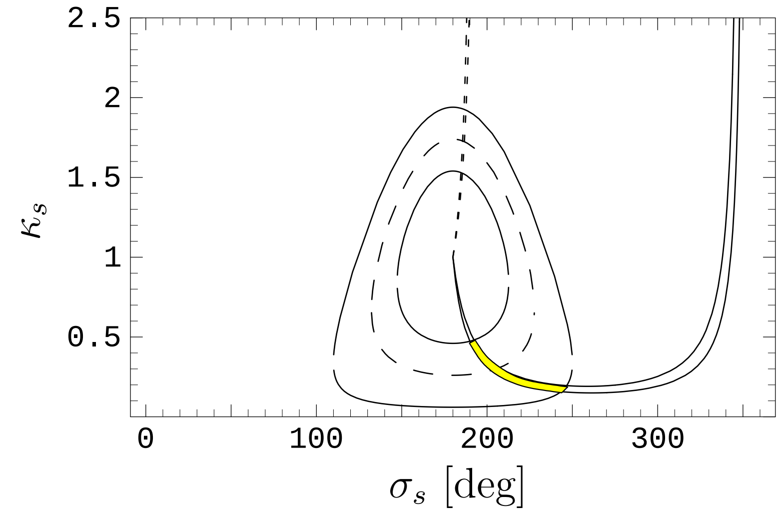
Implications for New Physics in B_s Mixing

- no meaningful constraints on ϕ_s yet*
- wait for $\Delta\Gamma_s$ and more precise $A_{\rm SL}$ from Tevatron and $B_s \to J/\psi\phi$ at LHC

* except for Grossman/Nir/Raz, hep-ph/0604028, who exclude large positive $\sin\phi_s$ from the D0 measurement of $A_{\rm SL}$



$\phi_s^{\rm SM}$ and (HP+JL)QCD values



assume $\phi_s^{\rm NP} = -(10 \pm 3)^\circ$ and (HP+JL)QCD values

Constraints on Specific NP Models: Z'

- assume absence of Z–Z' mixing, i.e. flavour-diagonal Z couplings
- assume flavour non-diagonal Z' couplings only to q_L
- constrain $\rho_L \exp(i\phi_L) \equiv (g' M_Z)/(g M_{Z'}) B^L_{sb}$ with B^L_{sb} being $\bar{s}Z'b$ coupling
- $\kappa_s < 2.5 \quad \longleftrightarrow \quad \rho_L < 2.6 \cdot 10^{-3}$
- can translate this into bound on Z' mass:

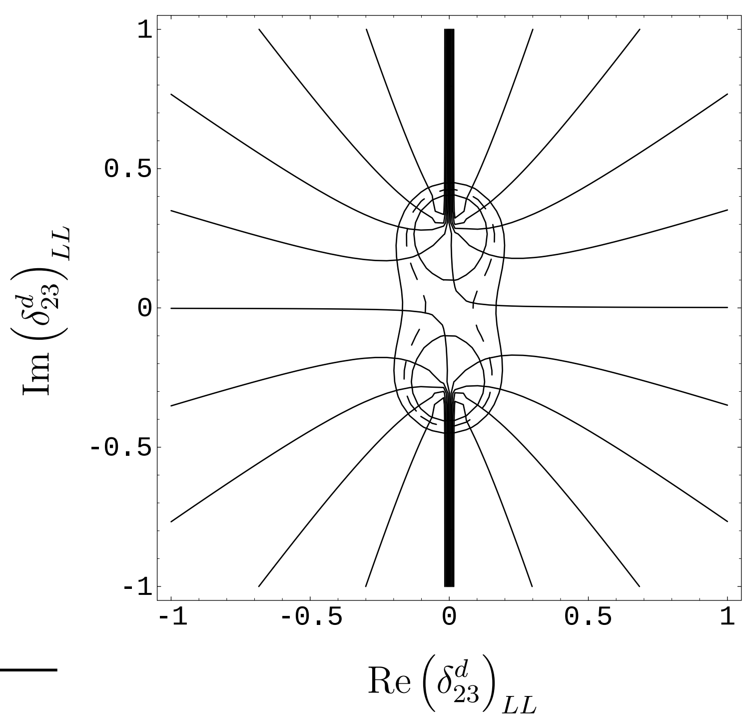
$$1.5\,\text{TeV} \left(\frac{g'}{g}\right) \left|\frac{B^L_{sb}}{V_{ts}}\right| < M_{Z'}$$

- should be interesting for direct searches!

MSSM (in MIA)

- MSSM (box diagram) contributions from charged Higgs, neutralinos, photinos, gluinos and charginos*
- for B_s mixing, only gluino contributions relevant
- full NLO analysis in preparation

* also from double Higgs penguins, which are however only relevant for large $\tan\beta$



Constraints on $(\delta_{23}^d)_{LL}$ insertion using JLQCD lattice data.
Open lines: constraints from a future measurement of ϕ_s.

Summary

- depending on value of $|V_{ub}|$, get non-zero new physics phase in B_d mixing: $\phi_d^{\mathrm{NP}} = -(11.0 \pm 4.3)^\circ$ for $|V_{ub}|$ from inclusive decays, which implies $\kappa_d > 0.09$
- mainly driven by low value of $\sin\phi_d$ from $b \to ccs$
- to reduce error, need more precise value of $|V_{ub}|$!
- need to measure NP phase in B_s mixing!
- good channel at the LHC: $B_s \to J/\psi\phi$
- even a small NP mixing phase implies sizable NP contributions in ΔM_s ($\phi_s = -10^\circ \leftrightarrow \kappa_s > 0.2$)
- more info also from $\Delta\Gamma_s$ and A_{SL} (Tevatron & LHC)