Constraints on the CKM matrix and on New Physics in Mixing

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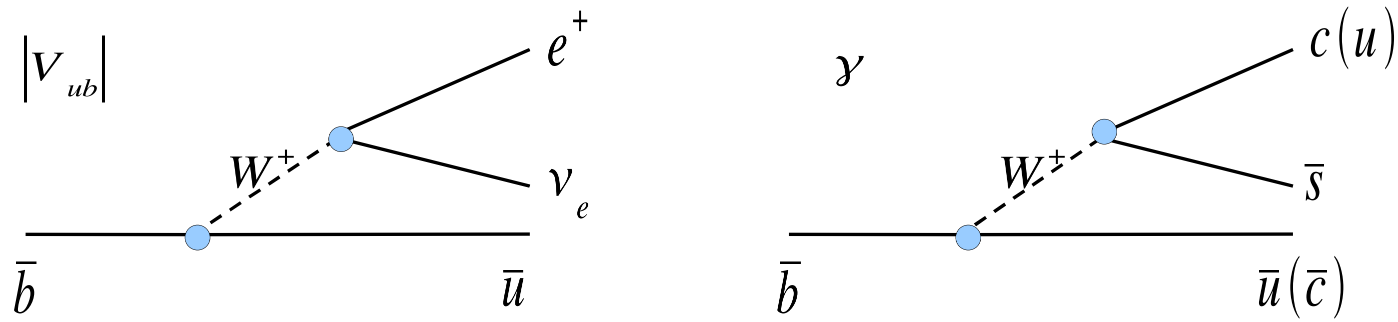
Focus here on recent work:

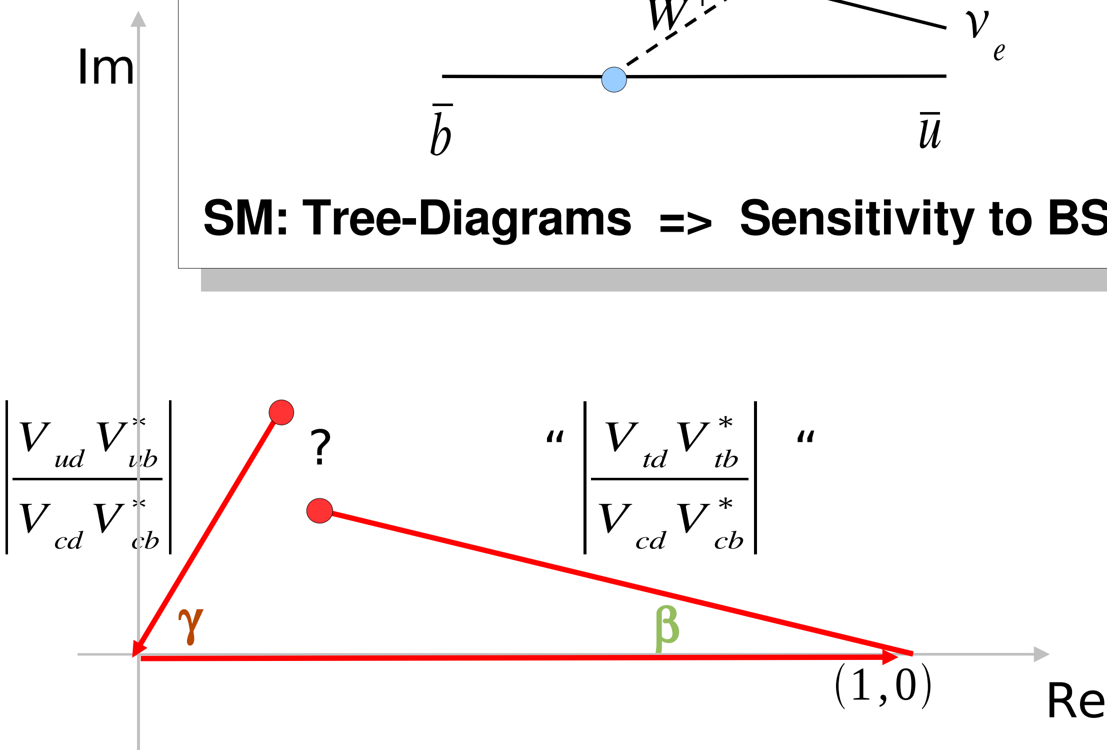
Lenz, Nierste &
Charles, Descotes-Genon, Jantsch, Kaufhold, L., Monteil, Niess, T'Jampens (CKMfitter), «Anatomy of New Physics in B-$\bar{B}$ mixing», PRD 83, 036004 (2011)

See also: **Lunghi, Laiho, van de Water, 1102.3917 [hep-ph]**
Lunghi and Soni, PLB 697, 323 (2011) for UT analysis quantifying possible New Physics contributions and scale of New Physics

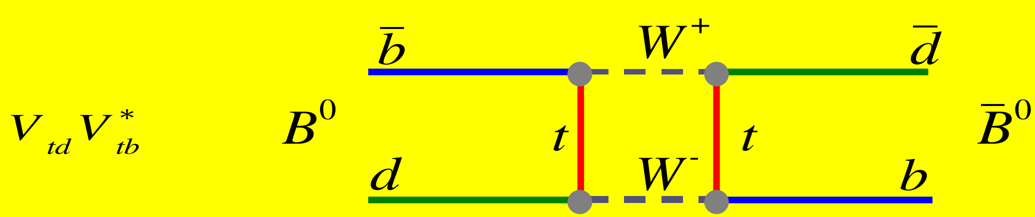
Hunting for New Physics in FCNC (in particular ΔF=2) processes



SM: Tree-Diagrams => Sensitivity to BSM physics small (with some exceptions)



SM: ΔF=2 process loop and CKM suppressed



=> Enhanced sensitivity to BSM

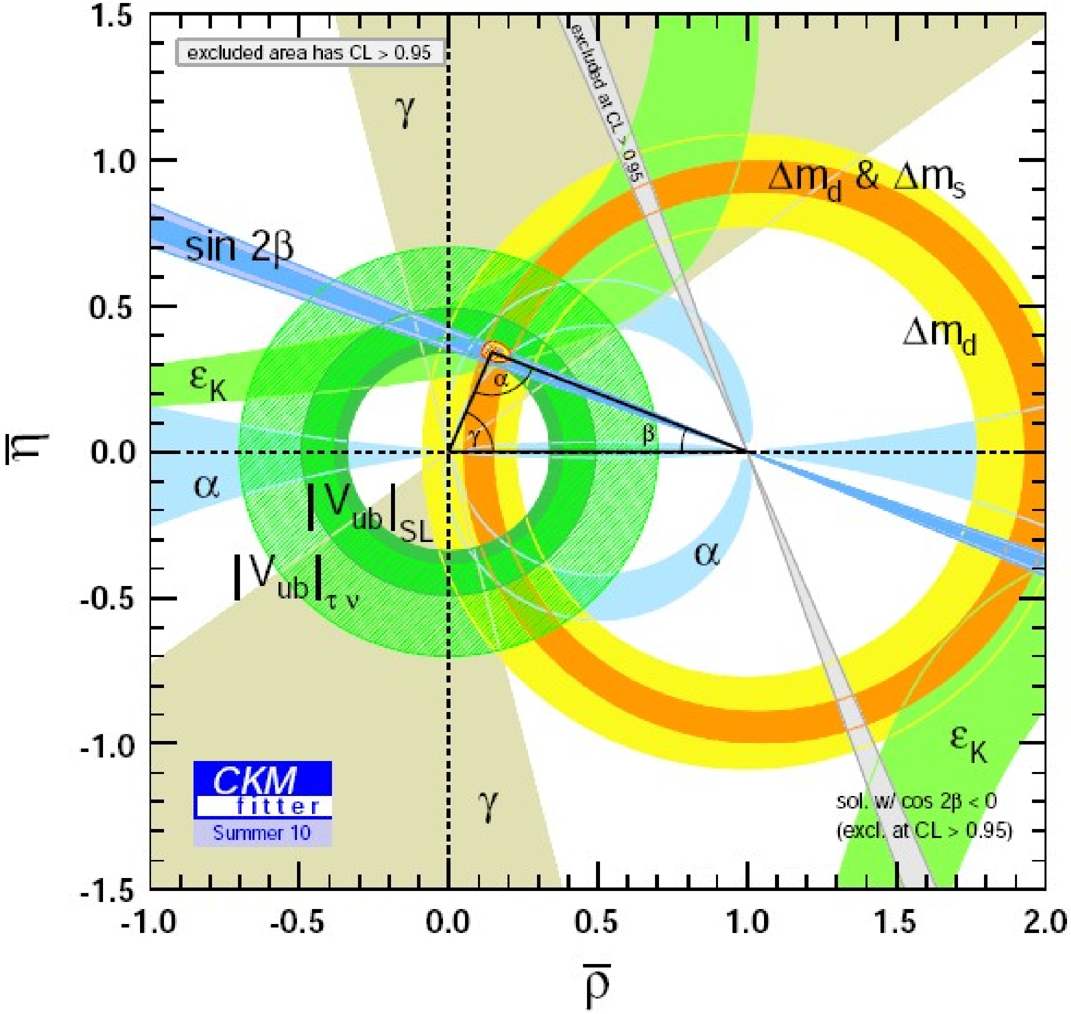
Inputs to the numerical analysis

Tree-level	$\lvert V_{ud}\rvert$	0.97425 ± 0.00022
	$\lvert V_{us}\rvert$	0.2254 ± 0.0013
	$\lvert V_{cb}\rvert$	$(40.89 \pm 0.38 \pm 0.58) \times 10^{-3}$
	$\lvert V_{ub}\rvert$	$(3.92 \pm 0.09 \pm 0.45) \times 10^{-3}$
	$B(B^+ \to \tau^+ \nu)$	$(1.68 \pm 0.31) \times 10^{-4}$
	γ	$(71^{+21}_{-25})^\circ$
B_d Mixing	Δm_d	$(0.507 \pm 0.005)\ ps^{-1}$
	$a_{SL}(B_d)$	$(-47 \pm 46) \times 10^{-4}$
	$\sin 2\beta$	0.673 ± 0.023
	$\cos 2\beta$	> 0
	α	$(89.0^{+4.4}_{-4.2})^\circ$
B_s Mixing	Δm_s	$(17.77 \pm 0.12)\ ps^{-1}$
	$a_{SL}(B_s)$	$(-17 \pm 93) \times 10^{-4}$
	A_{SL}	$(-85 \pm 28) \times 10^{-4}$
	$(\phi_s^\Delta - 2\beta_s) - \Delta\Gamma_s (B_s \to \psi\phi)$	(CDF-D0 av. (2.8 fb^{-1}))
Kaons	ϵ_K	$(2.229 \pm 0.010) \times 10^{-3}$

Theory parameter ± σ(stat) ± σ(theo,Rfit)

B Mixing	f_{B_s}	$(231 \pm 9 \pm 15)$ MeV
	$B_{B_s}(m_b)$	$0.841 \pm 0.013 \pm 0.020$
	f_{B_s}/f_{B_d}	$1.209 \pm 0.007 \pm 0.023$
	B_{B_s}/B_{B_d}	$1.01 \pm 0.01 \pm 0.03$
	$\hat{\eta}_B$	0.8393 ± 0.0034
	$m_t(m_t)$	$(165.017 \pm 1.156 \pm 0.11)$ GeV
Kaon Sector	$\hat{B}_K$	$0.724 \pm 0.004 \pm 0.067$
	κ_ϵ	$0.940 \pm 0.013 \pm 0.023$
	η_{tt}	0.5765 ± 0.0065
	η_{ct}	0.47 ± 0.04
	η_{cc}	$(1.30 \pm 0.35)(1.29\ \mathrm{GeV}/m_c)^{1.1}$
	$m_c(m_c)$	$(1.286 \pm 0.013 \pm 0.040)$ GeV
$\Gamma_{12}/(M_{12})$	$\tilde{B}_{S,B_s}/\tilde{B}_{S,B_d}$	$1.01 \pm 0 \pm 0.03$
	$\tilde{B}_{S,B_s}(m_b)$	$0.91 \pm 0.03 \pm 0.12$
	B_{R_0}	1.0 ± 0.5
	$B_{\tilde{R}_1}$	1.0 ± 0.5
	B_{R_1}	1.0 ± 0.5
	$B_{\tilde{R}_2}$	$1.0 \pm 0 \pm 0.5$
	$B_{\tilde{R}_3}$	$1.0 \pm 0 \pm 0.5$

CKM fit within the SM



- **Qualitative picture:**
  b→u & b→d transitions fit into CKM mechanism and are in agreement with s→d transitions

Quantity	Central $\pm$C.L. $\equiv 1\sigma$	$\pm$C.L. $\equiv 2\sigma$	$\pm$C.L. $\equiv 3\sigma$
A	$0.815^{+0.011}_{-0.029}$	$0.815^{+0.020}_{-0.038}$	$0.815^{+0.029}_{-0.046}$
λ	$0.22543^{+0.00077}_{-0.00077}$	$0.2254^{+0.0015}_{-0.0015}$	$0.2254^{+0.0023}_{-0.0023}$
$\bar{\rho}$	$0.144^{+0.029}_{-0.018}$	$0.144^{+0.054}_{-0.028}$	$0.144^{+0.068}_{-0.037}$
$\bar{\eta}$	$0.342^{+0.016}_{-0.016}$	$0.342^{+0.030}_{-0.028}$	$0.342^{+0.045}_{-0.037}$

- **NP (TeV scale?) suppressed wrt SM**
- **By how much? Focus on NP in mixing including Minimal Flavour Violation**

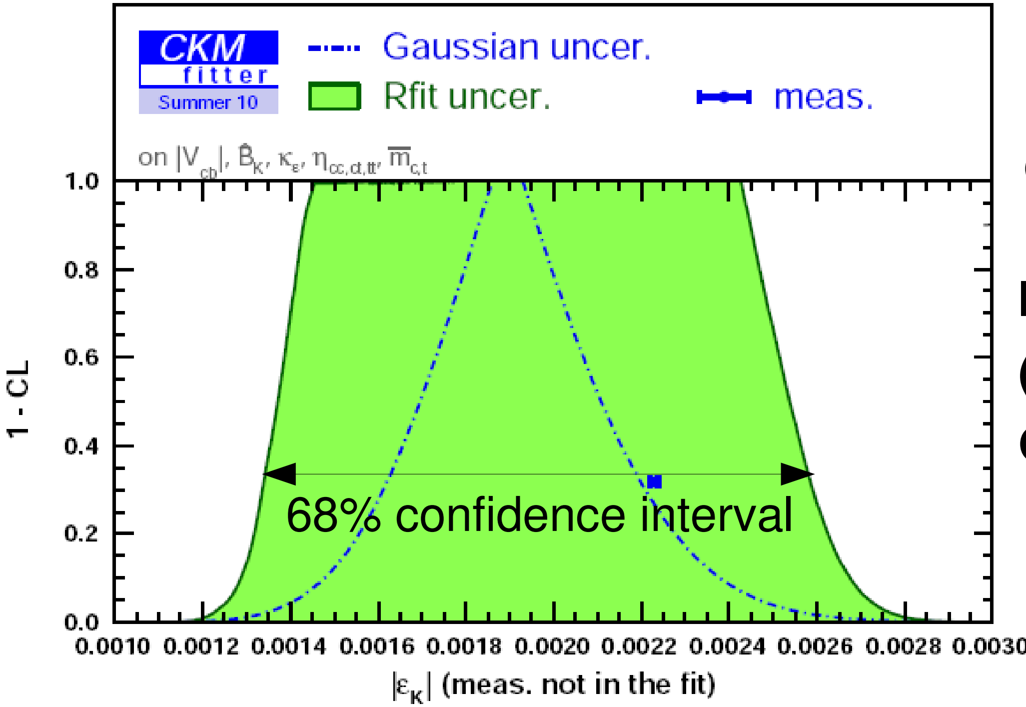
<u>However: quantitatively interesting "Anomalies"/"deviations"</u>

Kaon sector: ε_K

B_d sector: **sin2β & B→τν**

B_s sector: **A_{SL}(D0) & ϕ^{Δ}_s-2β_s**

ε_K anomaly ?



Theory Prediction

Gaussian errors: $10^3|\epsilon_K| = 1.89^{+0.26}_{-0.23}\ (1.2\,\sigma)$

Inputs from Lunghi (FPCP2010) and Gaussian errors: $10^3|\epsilon_K| = 1.77^{+0.18}_{-0.16}\ (2.4\,\sigma)$

Deviation sensitive to B_K input (Laiho, Lunghi, van de Water @ CKM2010: 0.724±0.020)

+ other inputs/CKM params, in particular: $|\varepsilon_K| \sim |V_{cb}|^4$

$|V_{cb}|$(Lunghi, FPCP10) = $40.43 \cdot 10^{-3}$

$|V_{cb}|$(CKMfitter) = $40.89 \cdot 10^{-3}$ => $10^3 \cdot |\varepsilon_K|$: 1.77 → 1.85

sin2β - B→τν anomaly

$$\mathcal{B}(B \to \tau\nu) = \frac{G_F^2 m_{B^+} m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_{B^+}^2}\right)^2 |V_{ub}|^2 f_B^2 \tau_{B^+}$$

* **Predicted:** $(0.764^{+0.087}_{-0.072})\times 10^{-4}$

  ↕ **2.9σ**

* **Measured:** $(1.68 \pm 0.31)\times 10^{-4}$

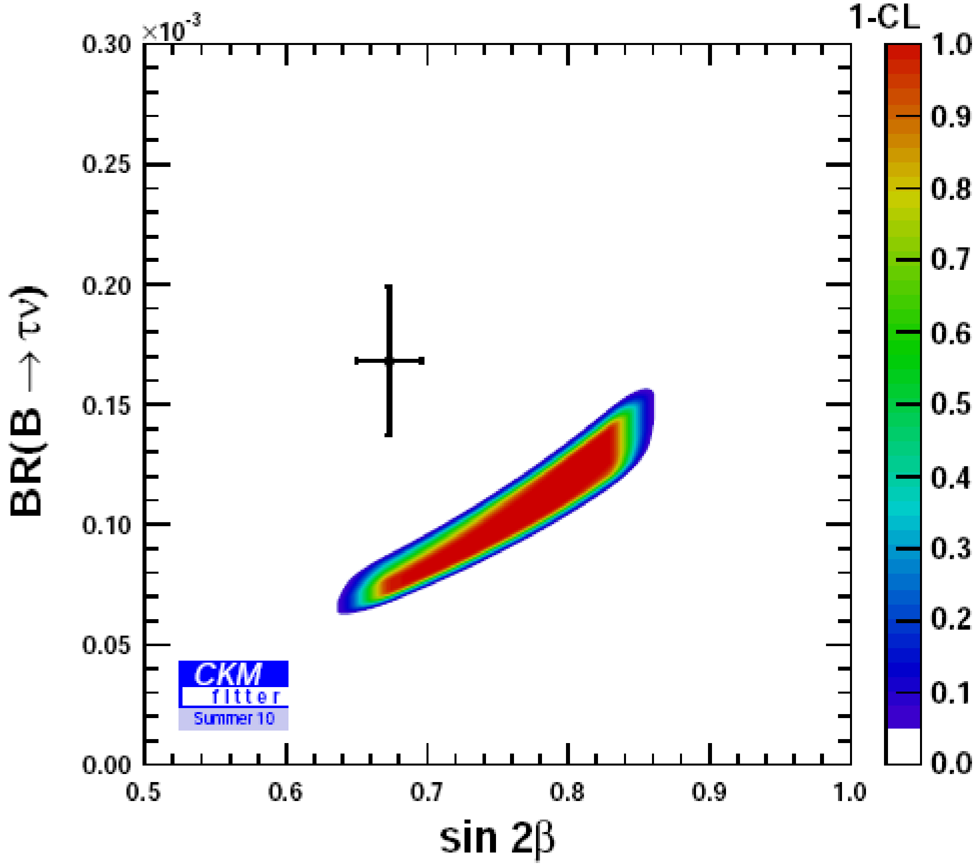
Recoil	Belle (10^{-4})	BABAR (10^{-4})
Hadronic	$1.79^{+0.56\,+0.46}_{-0.49\,-0.51}$	$1.80^{+0.57}_{-0.54} \pm 0.26$
DlνX	$1.54^{+0.38\,+0.29}_{-0.37\,-0.31}$	$1.7 \pm 0.8 \pm 0.2$

* **Not driven by $|V_{ub}|$ from $B\to\pi\ell\nu/X_u\ell\nu$ as $|V_{ub}|$ well constrained from α and β:**

$$|V_{ub}|_{pred} = (3.56^{+0.15}_{-0.20})\times 10^{-3}$$

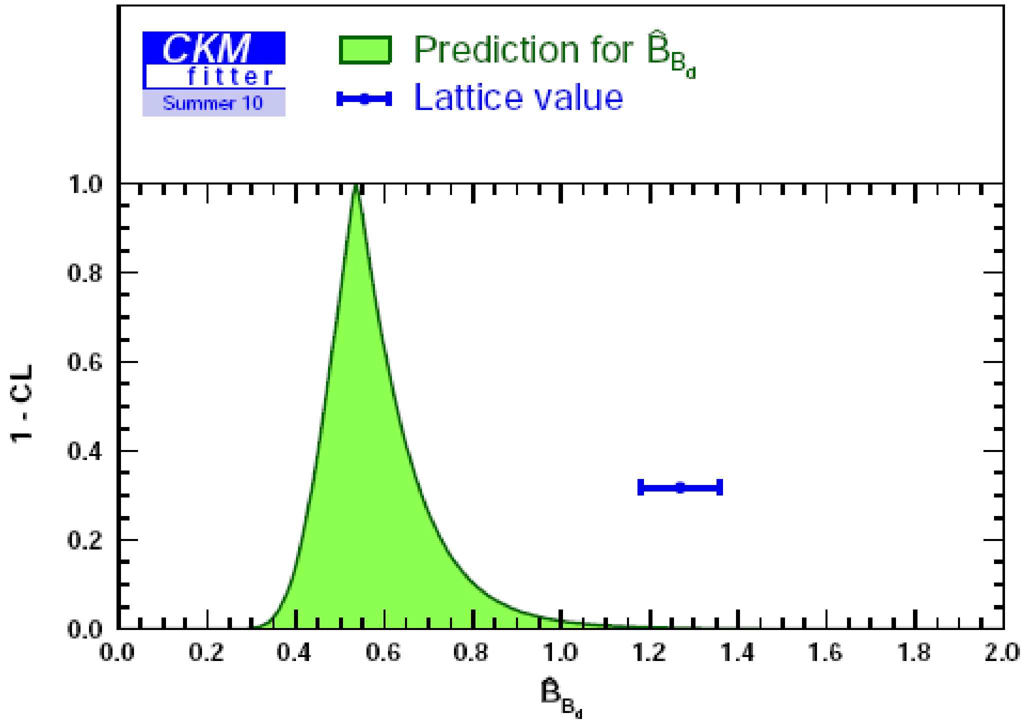
Average for $B\to\pi\ell\nu$ & $X_u\ell\nu$ used:

$$|V_{ub}| = (3.92 \pm 0.09 \pm 0.45)\times 10^{-3}$$



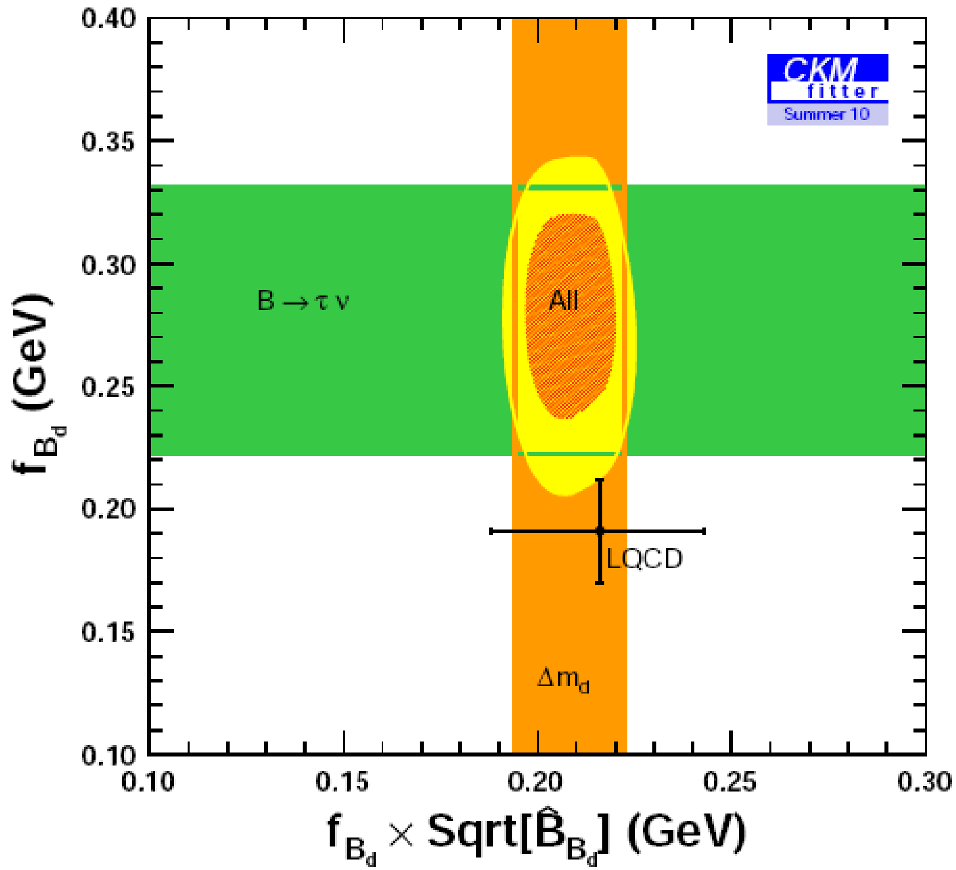
sin2β - B→τν anomaly

* Experimental effect:
  fluctuation, background, ...?
* Bias in LQCD calculation of f_{Bd}?
* NP in B→τν (difficult)
  and/or sin2β (easier) ?



* In this ratio f_{Bd} cancels:

$$\frac{\mathcal{B}(B\to\tau\nu)}{\Delta m_d} = \frac{3\pi}{4}\frac{m_\tau^2}{m_W^2 S(x_t)}\left(1-\frac{m_\tau^2}{m_{B^+}^2}\right)^2 \tau_{B^+} \times \frac{1}{\hat{\mathcal{B}}_{B_d}\eta_B}\frac{1}{|V_{ud}|^2}\left(\frac{\sin\beta}{\sin\gamma}\right)^2$$



* If f_{Bd} is the culprit: B_{Bd} is also off in such a way that Δm_d(meas) & Δm_d(pred) fit

New Physics in Mixing: Assumptions

1. 3x3 CKM-unitarity
2. SM4FC: $b \to q_1 \bar{q}_2 q_3 (q_1 \neq q_2 \neq q_3)$ SM only
3. Neglect NP in decay in $B_d \to J/\Psi\, K$, $B_s \to J/\Psi\, \phi$
4. Leptonic meson decays are SM-like (e.g. no charged Higgs)
5. Γ_{12} not affected by NP
6. NP shows only up in M_{12}

B Mixing:

$$M_{12}^q \equiv M_{12}^{\mathrm{SM},q} \cdot \Delta_q, \qquad \Delta_q \equiv |\Delta_q| e^{i\phi_q^\Delta}$$

K Mixing:

$$M_{12}^K \equiv \frac{\langle K | H^{|\Delta S|=2} | \bar{K} \rangle}{2M_K} = (V_{ts}V_{td}^*)^2 M_{12}^{tt} + 2V_{ts}V_{td}^* V_{cs}V_{cd}^* M_{12}^{ct} + (V_{cs}V_{cd}^*)^2 M_{12}^{cc}$$

$$M_{12}^{ij} = M_{12}^{\mathrm{SM},ij} \Delta_K^{ij} \equiv M_{12}^{\mathrm{SM},ij} |\Delta_K^{ij}| e^{i\phi^{\Delta_K^{ij}}}$$

B sector simpler than K sector: charm contributions suppressed in M_{12}^q

New Physics in Mixing

Scenario I:

No assumption about flavour structure of NP contributions to mixing

(E.g.: MSSM with general flavour structure of soft breaking terms and small tanβ)

=> $$\epsilon_K = \frac{\kappa_\epsilon}{\sqrt{2}} e^{i\phi_\epsilon} \left[\frac{\mathrm{Im} M_{12}^{(6)}}{\Delta M} \right] = C_\epsilon \kappa_\epsilon e^{i\phi_\epsilon} \hat{\mathcal{B}}_K \Bigg[\mathrm{Im}[(V_{cs} V_{cd}^*)^2 \Delta_K^{cc}] \eta_{cc} S\left(\frac{\bar{m}_c^2}{M_W^2}\right) + \mathrm{Im}[(V_{ts} V_{td}^*)^2 \Delta_K^{tt}] \eta_{tt} S\left(\frac{\bar{m}_t^2}{M_W^2}\right) + 2\,\mathrm{Im}(V_{ts} V_{td}^* V_{cs} V_{cd}^* \Delta_K^{ct}) \eta_{ct} S\left(\frac{\bar{m}_c^2}{M_W^2}, \frac{\bar{m}_t^2}{M_W^2}\right) \Bigg]$$

=> Kaon sector: 3 independent parameters but only one observable

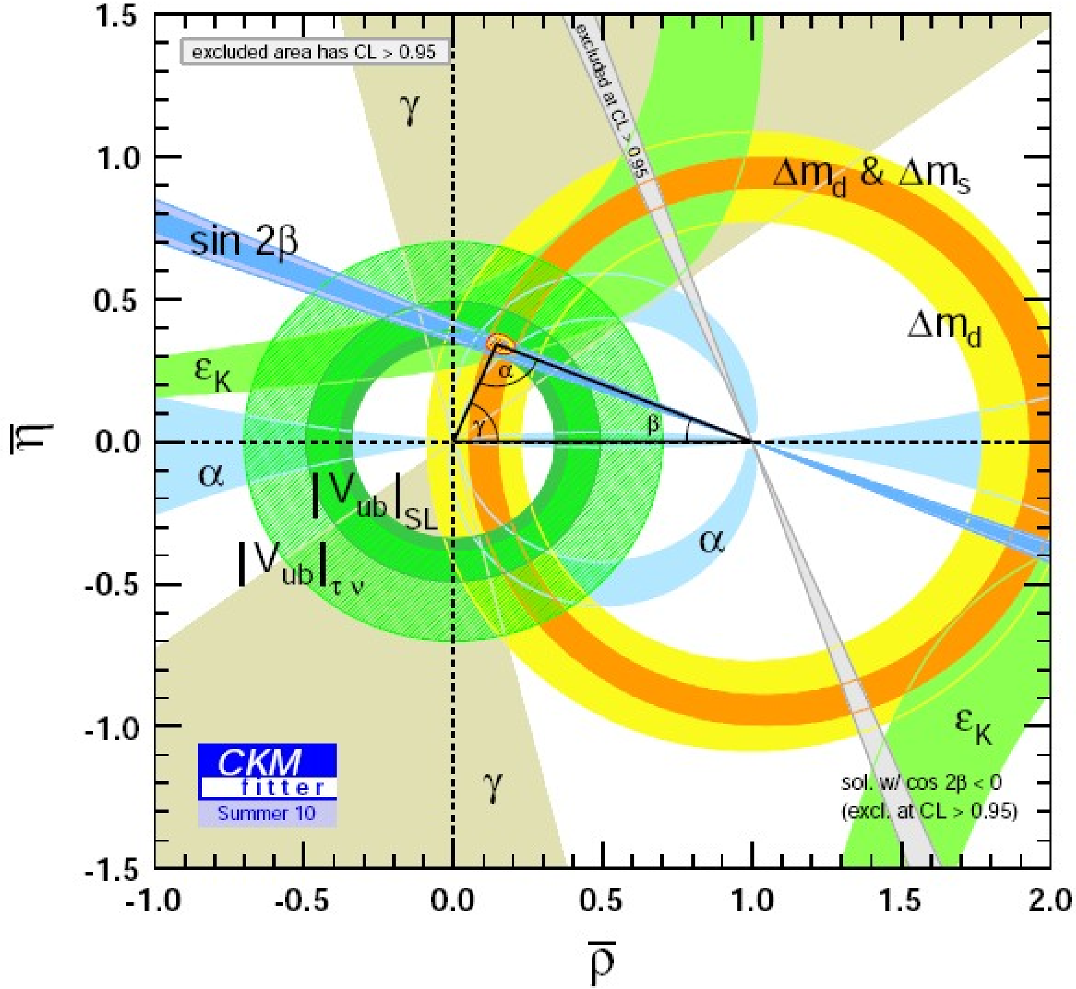
=> Consider only B_d and B_s sector: 2 new complex parameters Δ_s, Δ_d

New Physics in Mixing: Scenario I (no relation btw sectors)

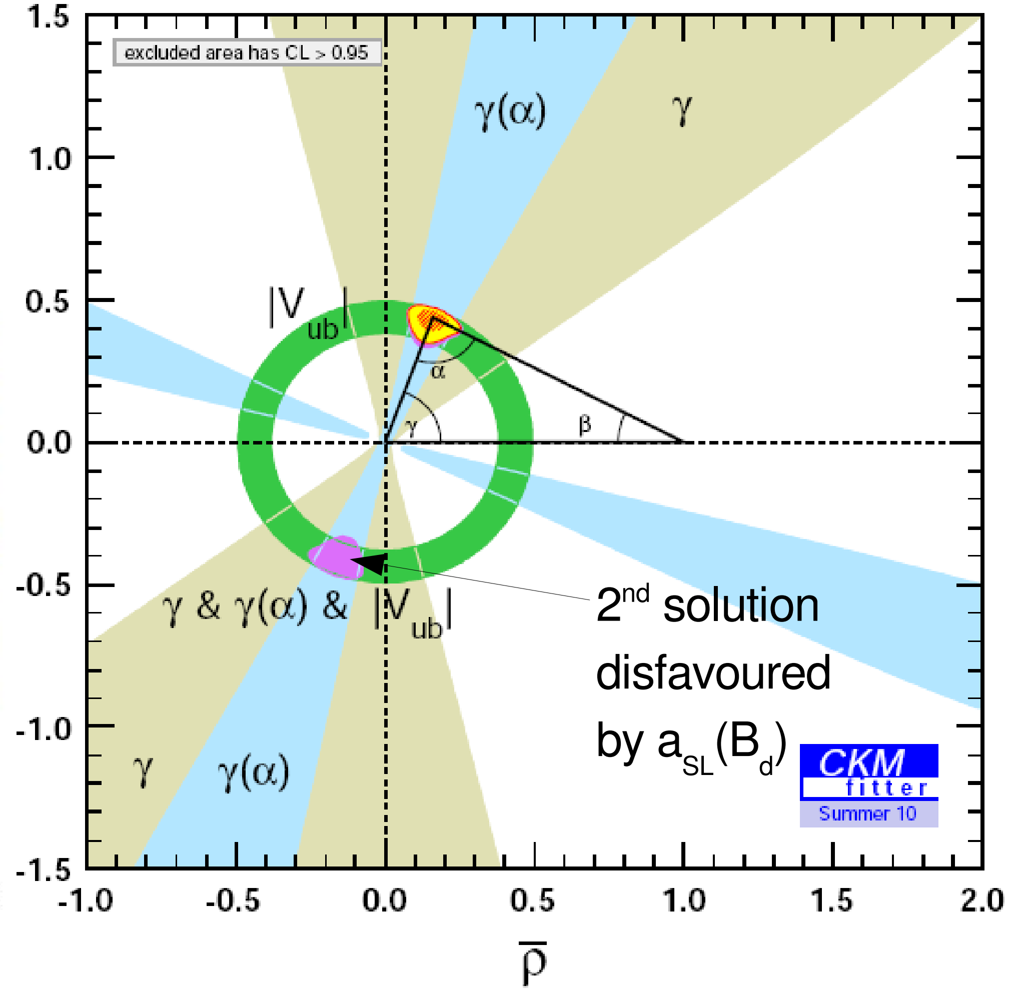
Even in the presence of NP in B-mixing:

γ can be obtained from "α"($\pi-\gamma-\beta-\phi^{\Delta}_{d}/2$) and "$\beta$"($2\beta+\phi^{\Delta}_{d}$) as ϕ^{Δ}_{d} drops out

UT in SM fit

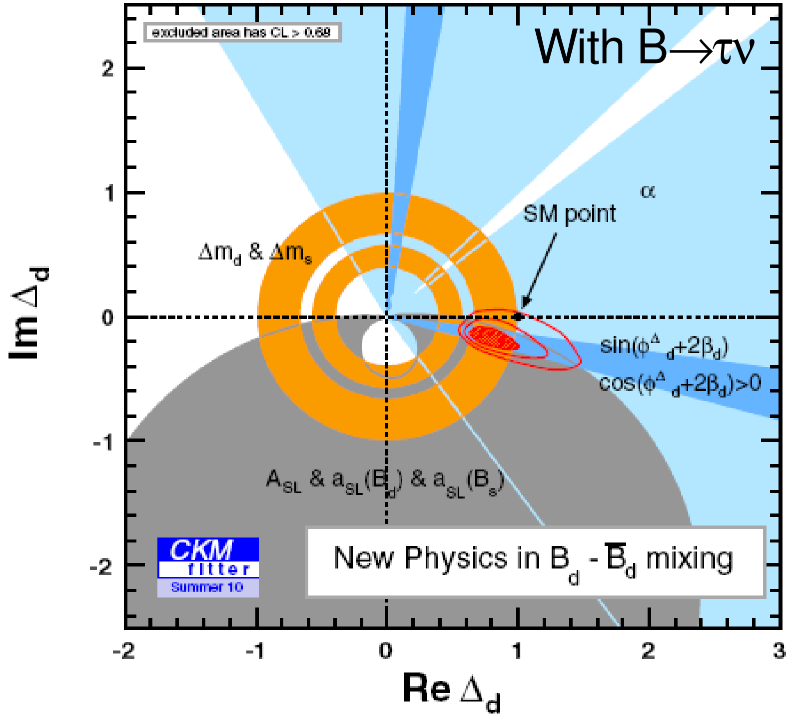


UT in Scenario I: "Reference UT"



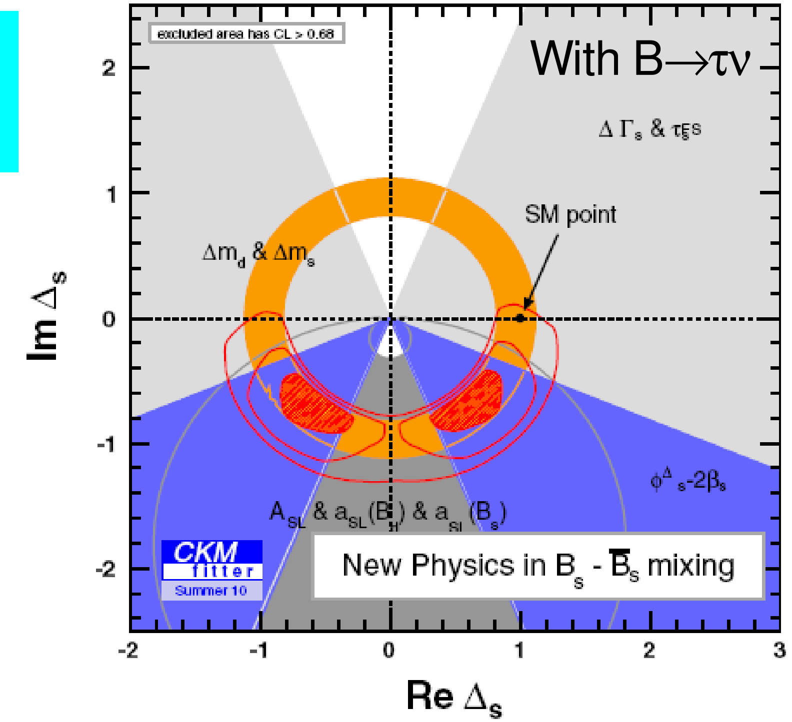
=> ρ-η constraint significantly weaker when allowing for NP in B mixing!

New Physics in B-mixing: Scenario I

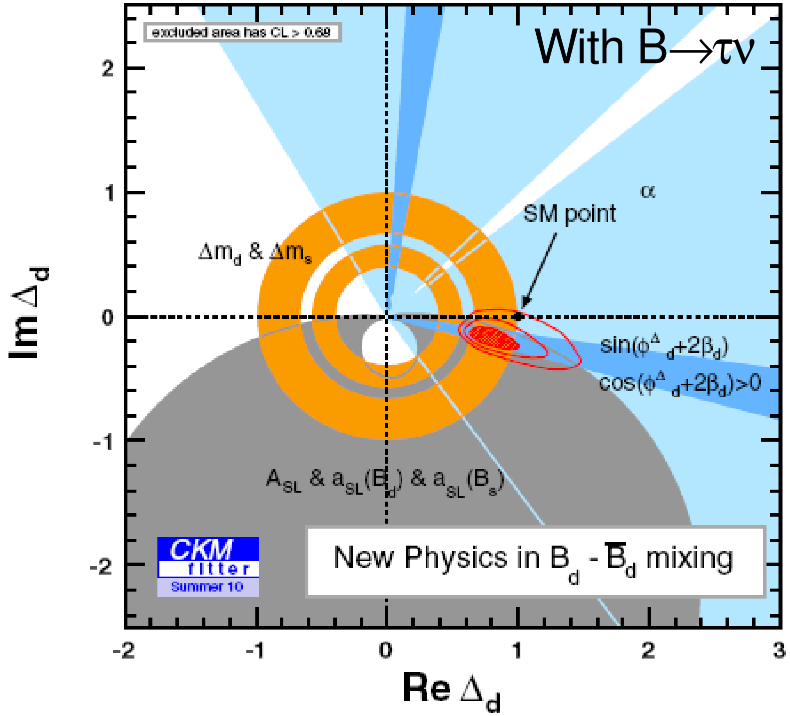


2 rings ↔ 2 ρ-η-sols.

($a_{SL}(B_d)$ disf. 2^{nd} sol.)



New Physics in B-mixing: Scenario I



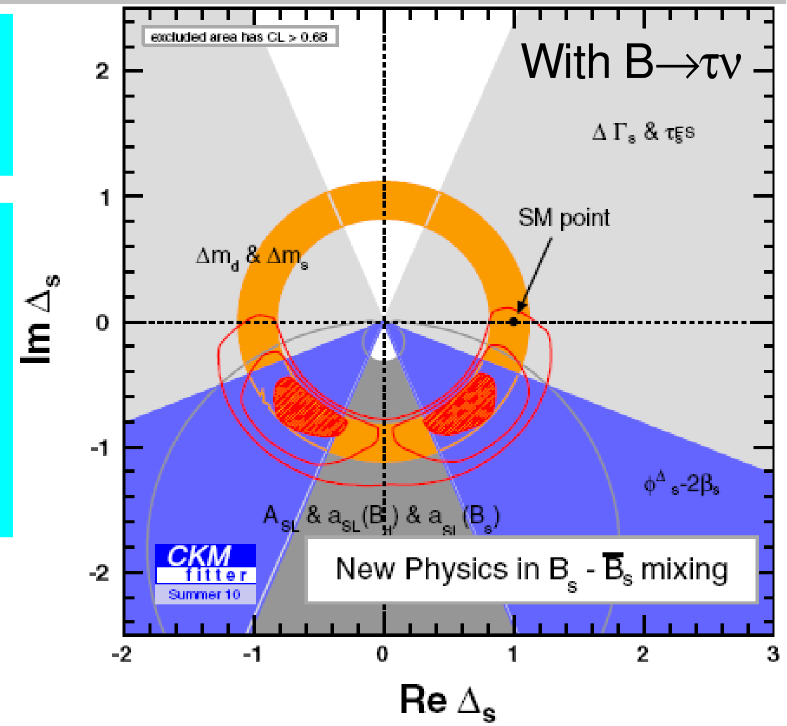
2 rings ↔ 2 ρ-η-sols. ($a_{SL}(B_d)$ disf. 2nd sol.)

$\sigma(|\Delta_s|) < \sigma(|\Delta_d|)$:

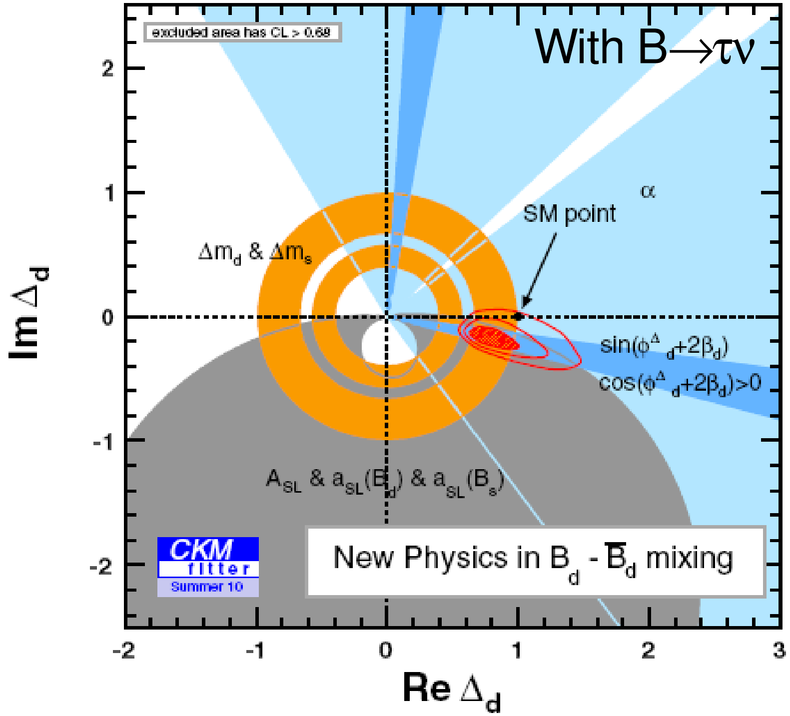
*$\sigma(f_{Bs}^2 B_{Bs}) < \sigma(f_{Bd}^2 B_{Bd})$

*$|\Delta_d|$: ρ–η dependent

($\rightarrow |V_{ub}|$ & $\gamma(\alpha)$)



New Physics in B-mixing: Scenario I



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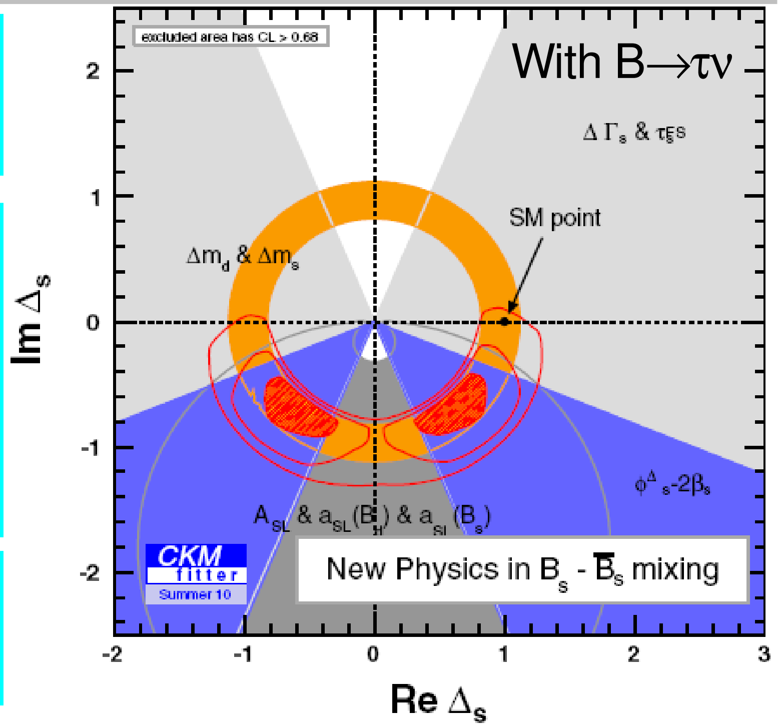
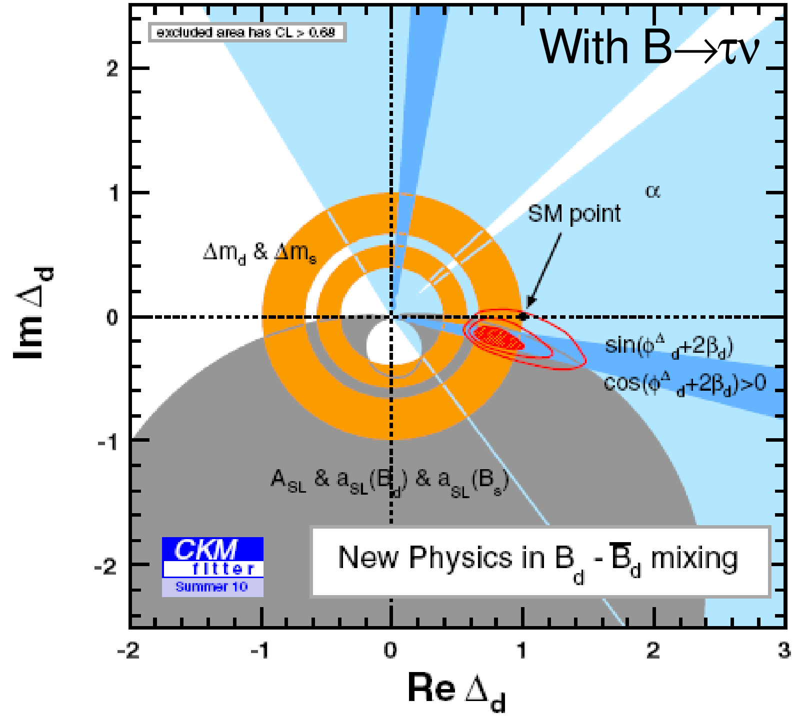
*$|\Delta_d|$: ρ–η dependent

(→ $|V_{ub}|$ & γ(α))

NP contributions can be as large as 40%



New Physics in B-mixing: Scenario I



$$\phi_d^{\Delta}=(-12.9^{+8.9}_{-4.9})^{\circ} \quad (2\sigma)$$

2 rings ↔ 2 ρ-η-sols. ($a_{SL}(B_d)$ disf. 2[nd] sol.)

$\sigma(|\Delta_s|) < \sigma(|\Delta_d|)$:

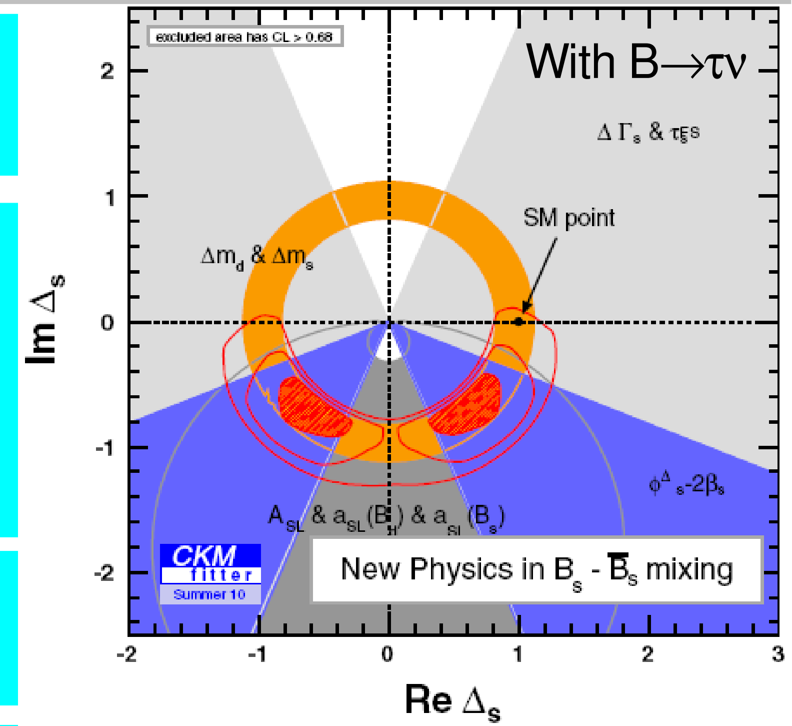
*$\sigma(f_{Bs}^{\ 2} B_{Bs}) < \sigma(f_{Bd}^{\ 2} B_{Bd})$

*$|\Delta_d|$: ρ–η dependent (→ $|V_{ub}|$ & γ(α))

NP contributions can be as large as 40%

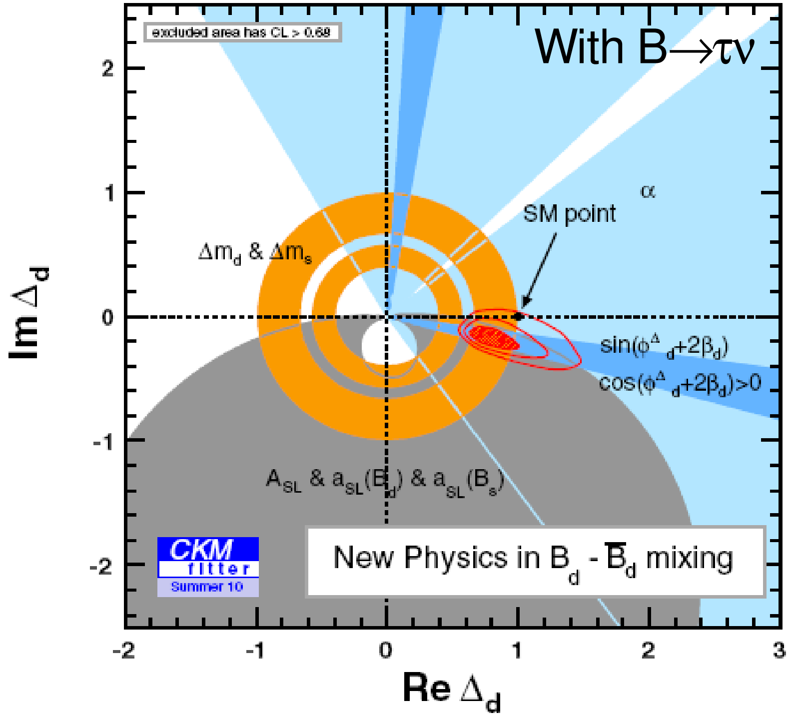
ϕ^{Δ}_{s}(3.3σ): A_{SL} & B_s→ψϕ (Tevatron)

ϕ^{Δ}_{d}(2.8σ): sin2β – B→τν (B-factories)



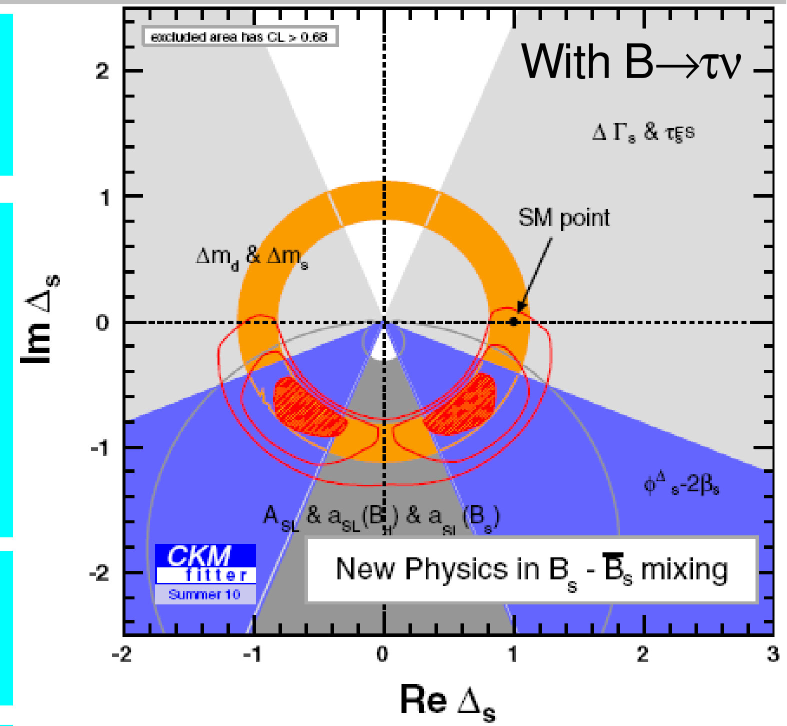
$$\phi_s^{\Delta}-2\beta_s=(-55^{+33}_{-25})^{\circ} \quad (2\sigma)$$

New Physics in B-mixing: Scenario I



2 rings ↔ 2 ρ-η-sols.

($a_{SL}(B_d)$ disf. 2nd sol.)



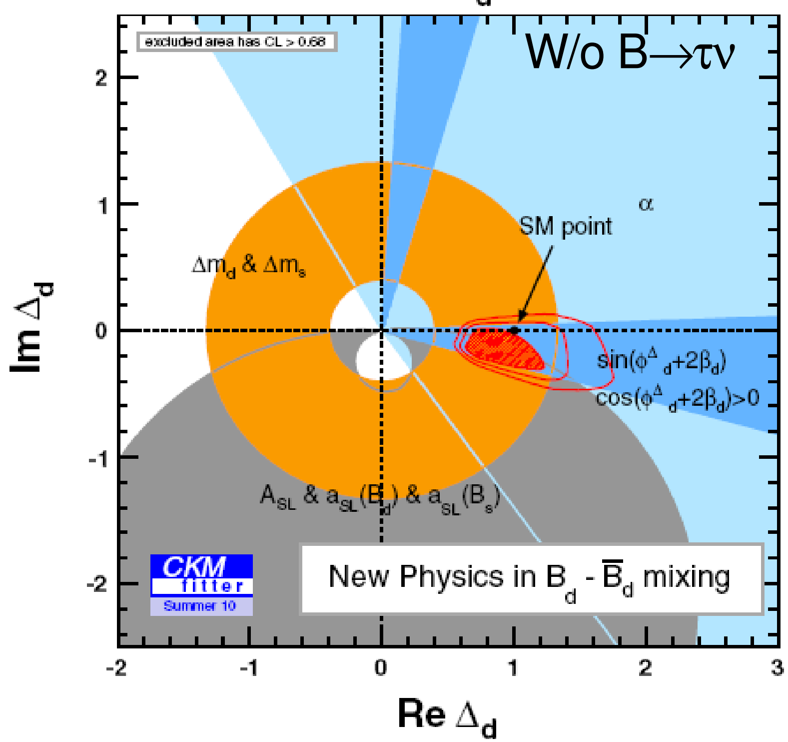
$\sigma(|\Delta_s|) < \sigma(|\Delta_d|)$:

*$\sigma(f_{Bs}^{\ 2} B_{Bs}) < \sigma(f_{Bd}^{\ 2} B_{Bd})$

*$|\Delta_d|$: ρ–η dependent

(→ $|V_{ub}|$ & γ(α))

NP contributions can be as large as 40%

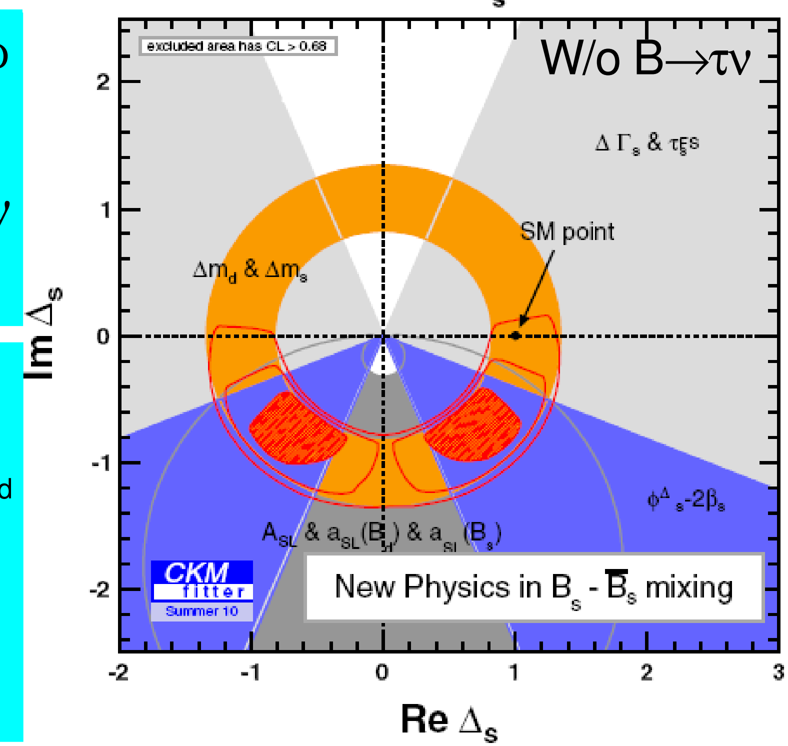


ϕ^Δ_s(3.3σ): A_{SL} & $B_s \to \psi\phi$

(Tevatron)

ϕ^Δ_d(2.8σ): sin2β – B→τν

(B-factories)



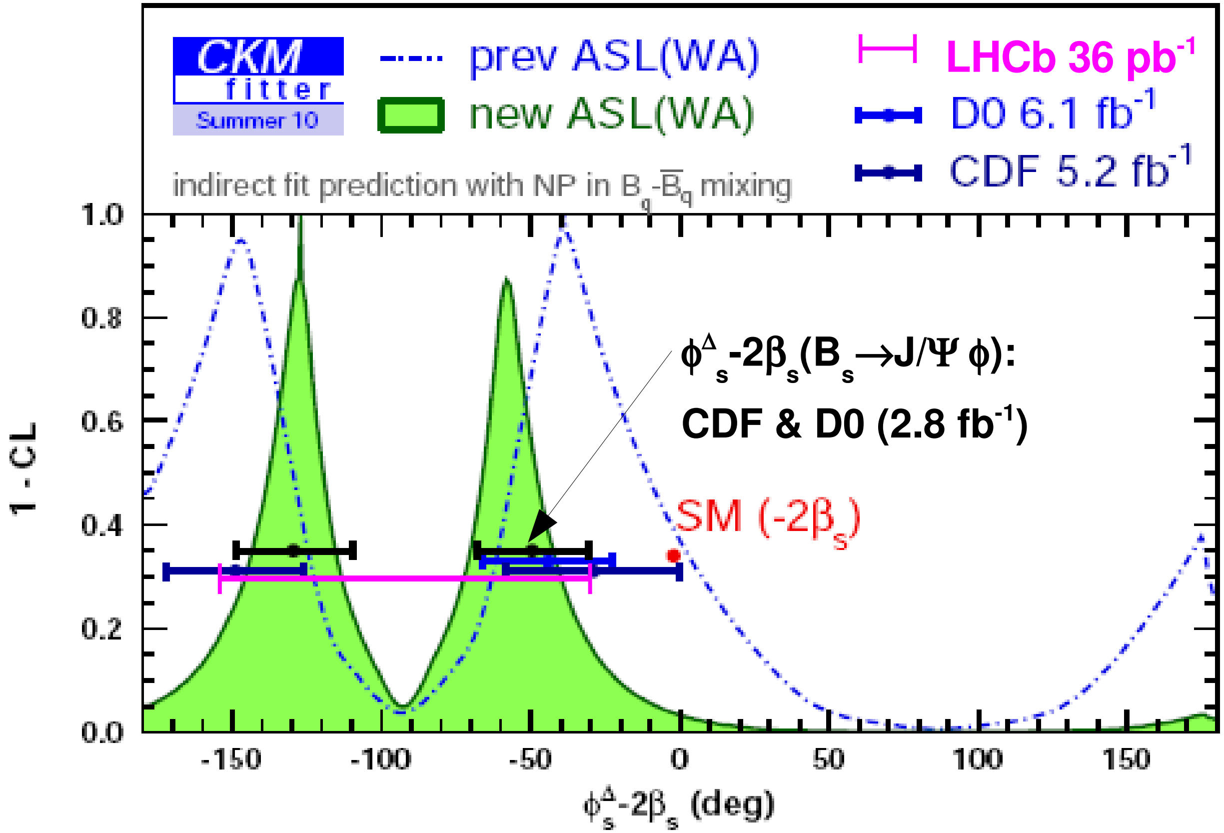
B→τν:

*$\sigma(|\Delta_d|)\downarrow$ by removing f_{Bd}

*$\sigma(|\Delta_s|)\downarrow$ thanks to ξ:

$$\frac{f_{B_s}^2 B_{B_s}}{f_{B_d}^2 B_{B_d}} f_{B_d}^2 B_{B_d} = \xi^2 f_{B_d}^2 B_{B_d}$$

New Physics in B mixing: Scenario I



- A_{SL}(D0&CDF): (very) good agreement with
  - $\phi^{\Delta}_{s}-2\beta_{s(Bs\to\psi\phi)}$ CDF-D0 average (2.8 fb^{-1})
  - $\phi^{\Delta}_{s}-2\beta_{s}(B_{s}\to\psi\phi)$ from CDF(5.2 fb^{-1}) & D0(6.1 fb^{-1}) (no average yet)

- If A_{SL} driven by NP in mixing & stays large: more driven by NP in B_s mixing since $a_{sl}(B_d)$ well constrained by "sin2β"

- First tagged LHCb result for $B_s\to\psi\phi$ prefers $\phi^{\Delta}_{s}-2\beta_{s} < 0$

New Physics in B mixing: Scenario I

Test specific combinations of Δ's taking their SM values (SM null hypothesis composite!)

Most natural choice (?): $\Delta_s=\Delta_d=1$ (3.6σ)

Might dilute the anomalies (CP violation)
=> Test: $\text{Im}(\Delta_s)=\text{Im}(\Delta_d)=0$ (3.8σ)

Hypothesis	p-value
$\text{Im}(\Delta_d) = 0$ (1D)	$2.7\ \sigma$
$\text{Im}(\Delta_s) = 0$ (1D)	$3.1\ \sigma$
$\Delta_d = 1$ (2D)	$2.7\ \sigma$
$\Delta_s = 1$ (2D)	$2.7\ \sigma$
$\text{Im}(\Delta_d) = \text{Im}(\Delta_s) = 0$ (2D)	$3.8\ \sigma$
$\Delta_d = \Delta_s$ (2D)	$2.1\ \sigma$
$\Delta_d = \Delta_s = 1$ (4D)	$3.6\ \sigma$

New Physics in Mixing: Minimal Flavour Violation (MFV)

$$H_q^{|\Delta B|=2} = (V_{tq}^* V_{tb})^2 [CQ + C_S Q_S + \tilde{C}_S \tilde{Q}_S] + \text{H.c.}$$

$$Q = \bar{q}_L \gamma_\mu b_L \bar{q}_L \gamma^\mu b_L \qquad Q_S = \bar{q}_L b_R \bar{q}_L b_R \qquad \tilde{Q}_S = \bar{q}_L^\alpha b_R^\beta \bar{q}_L^\beta b_R^\alpha$$

Chivukala & Georgi (1987), Hall & Randall (1990),
Gabrielli & Guidice (1995/97), Ali & London (1999)
Buras et al. (2001), D'Ambrosio et al. (2002)

Lenz, Nierste, Charles et al., PRD83, 036004 (2011)
See also: Kagan et al., PRD80, 076002 (2009)

Scenario II: Small b-Yukawa couplings

$$C_S, \tilde{C}_S \approx 0, \quad C \text{ real}$$

(E.g.: MSSM with MFV and small tanβ)

$$\Delta_d = \Delta_s = \Delta_K^{tt} = \Delta$$

$$\phi_s^\Delta = \phi_d^\Delta = \phi_K^{ij\Delta} = 0$$

Scenario III: Large b-Yukawa couplings

$$C_S, \tilde{C}_S, C \text{ complex}$$

(E.g.: certain 2HDMs)

$$\Delta_d = \Delta_s \equiv \Delta \qquad \Delta_K^{tt}$$

$$\phi_s^\Delta = \phi_d^\Delta$$

$$\Delta_K^{cc} = 1$$

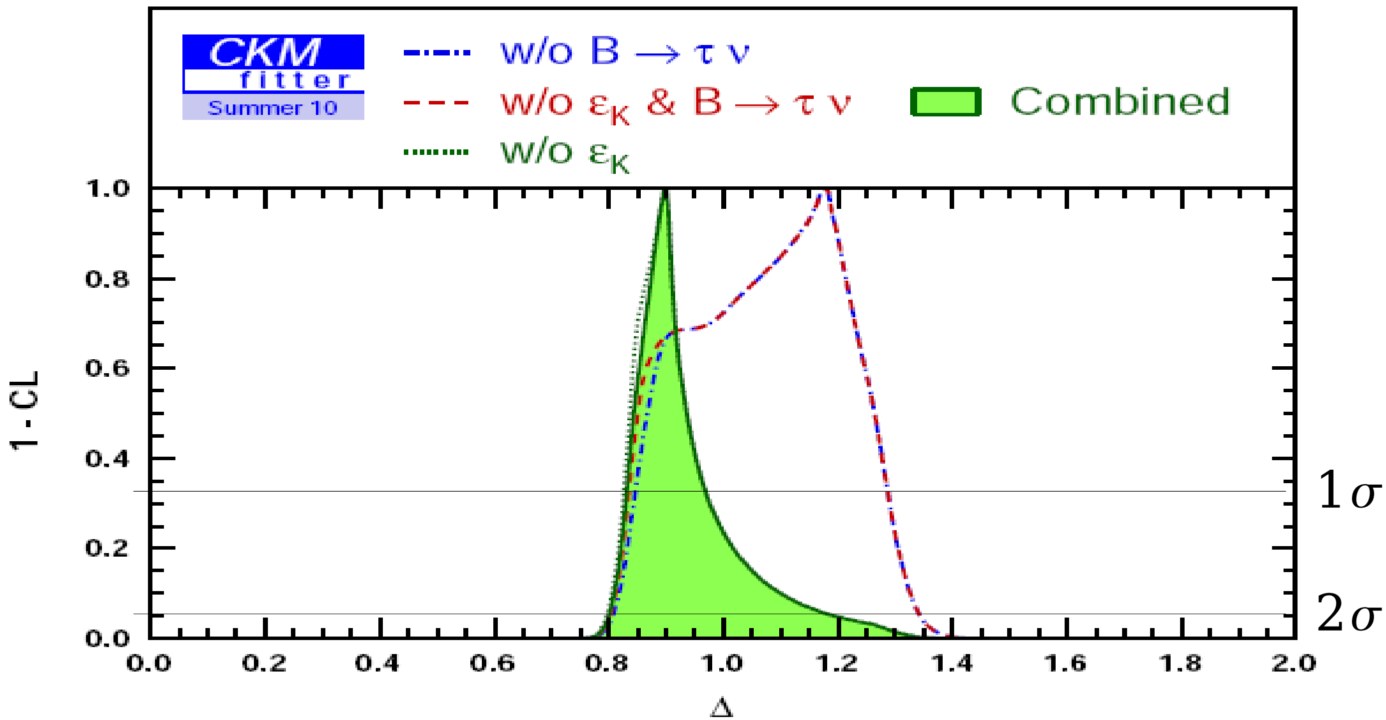
$$\Delta_K^{ct} = 1 + \lambda_K \frac{\bar{m}_c^2(\bar{m}_t)}{\bar{m}_t^2(\bar{m}_t)} \frac{S(\bar{m}_t^2/M_W^2)\eta_{tt}}{S(\bar{m}_c^2/M_W^2, \bar{m}_t^2/M_W^2)\eta_{ct}} (\Delta_K^{tt} - 1)$$

$$0.5 \leq \lambda_K \leq 2$$

Scenario II: MFV with small b-Yukawa couplings

$$\Delta_s = \Delta_d = \Delta_K^{tt} \quad \text{with} \quad \phi_s^\Delta = \phi_d^\Delta = \phi_K^{ij\Delta} = 0$$

$$\Delta_K^{ct} = 1 + \lambda_K \frac{\bar{m}_c^2(\bar{m}_t)}{\bar{m}_t^2(\bar{m}_t)} \frac{S(\bar{m}_t^2/M_W^2)\eta_{tt}}{S(\bar{m}_c^2/M_W^2, \bar{m}_t^2/M_W^2)\eta_{ct}}(\Delta_K^{tt} - 1) \qquad \Delta_K^{cc} = 1$$



- **B→τν: significant impact; ε_K: only minor impact (with our inputs)**

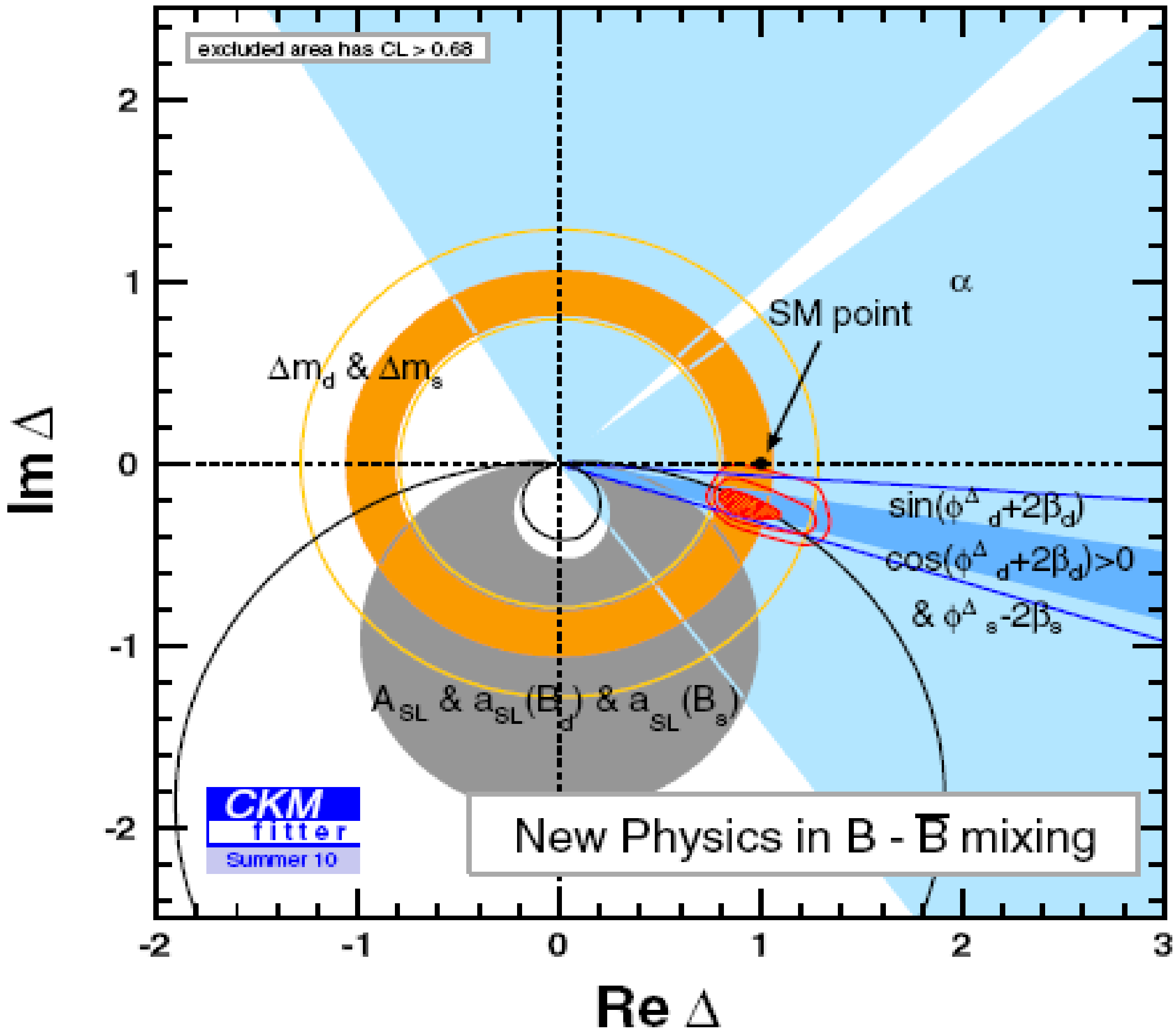
- **No new NP phases => Similar data-theory discrepancy as for SM**

  Hypothesis test within Scenario I: $\Delta_d = \Delta_s = \Delta$ with $\Im(\Delta) = 0$: 3.7σ

- **mSUGRA/CMSSM: special cases of scenario II => Disfavoured**

Scenario III: MFV with large b-Yukawa couplings

$\Delta_d = \Delta_s \equiv \Delta \qquad \phi_s^\Delta = \phi_d^\Delta \qquad \Delta_K^{tt}$



Test of SM hypothesis:

Hypothesis	p-value
$\mathrm{Im}(\Delta) = 0$ (1D)	$3.5\ \sigma$
$\Delta = 1$ (2D)	$3.3\ \sigma$

Test of Scenario III within I:

$\Delta_d = \Delta_s = \Delta$	$2.1\ \sigma$

$\Delta_K^{tt} = 1.01^{+0.53}_{-0.43}$ (2σ range)

Summary

- CKM mechanism well-established but NP in Mixing of up to O(40%) allowed

- ε_K anomaly: B_K and $|V_{cb}|$ crucial

  $B \to \tau\nu$: * 2.9σ wrt SM (have to wait for Belle II/SuperB)
  * If not an experimental effect: NP in B_d mixing?
  * If f_{Bd} underestimated by a factor of 0.7 on the Lattice then B_{Bd} overestimated by > 2 on the Lattice to meet Δm_d

  A_{SL} & ϕ^{Δ}-2β_s: 3.3σ wrt SM

  ϕ^{Δ}-2β_s ($B_s \to \psi\phi$): average for new CDF-D0 results?, LHCb!

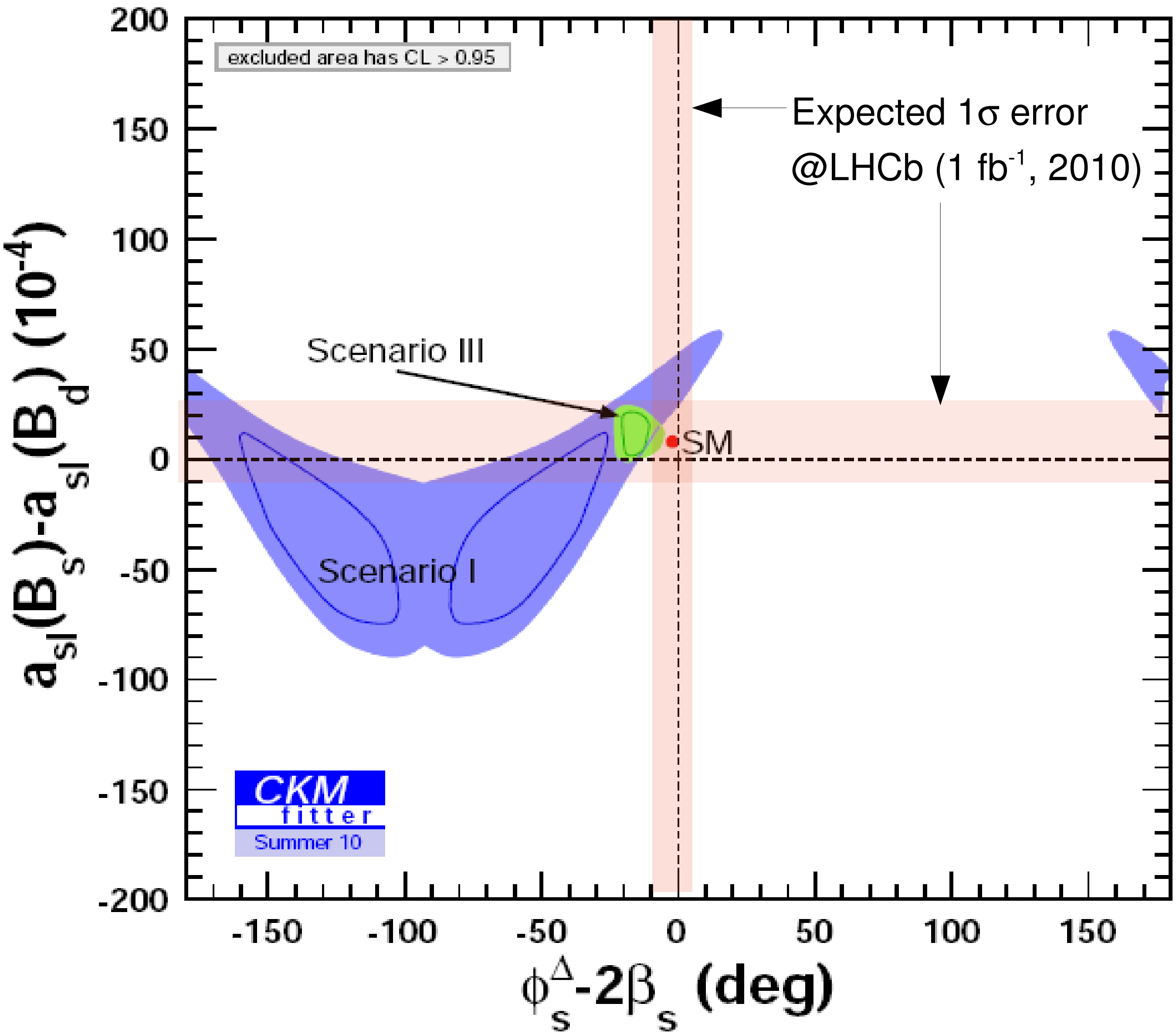
- NP phase < 0 preferred in B_d & B_s => MFV with large b-Yukawa's? (p-value: 2.1σ)

- Scenario I fits best
  p-values for SM hypothesis: 3.6σ (Δ_s=Δ_d=1), 3.8 σ(Im(Δ_s)=Im(Δ_d)=0)

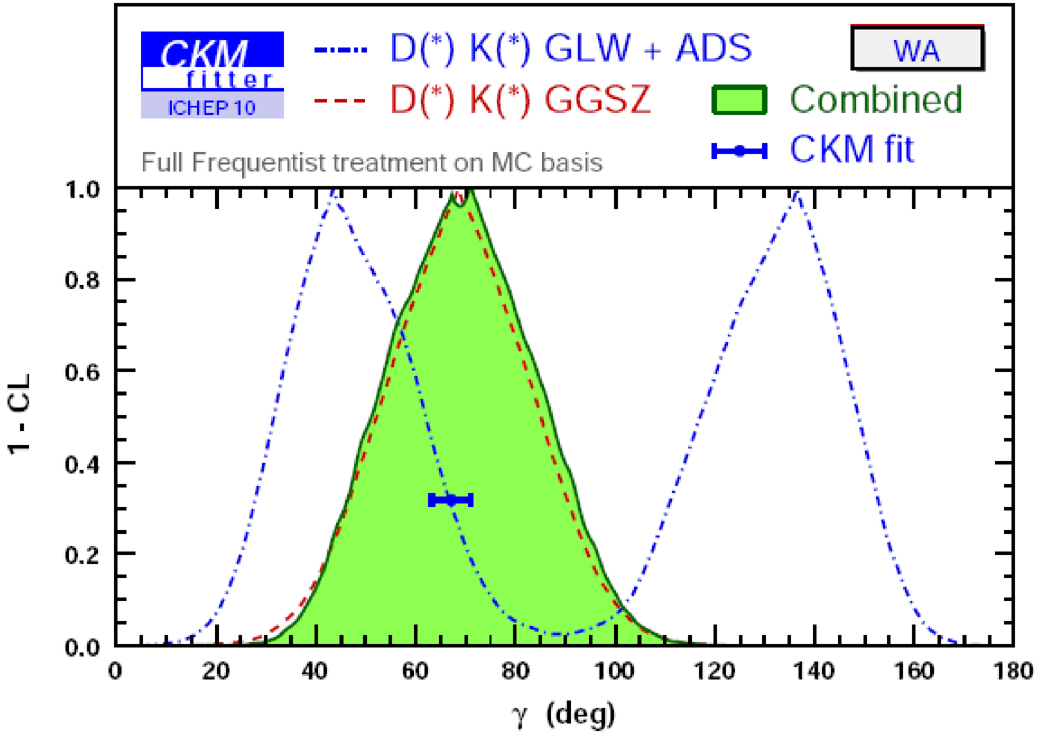
- Scenario II: p-value: 3.7σ => Troublesome for mSUGRA/CMSSM

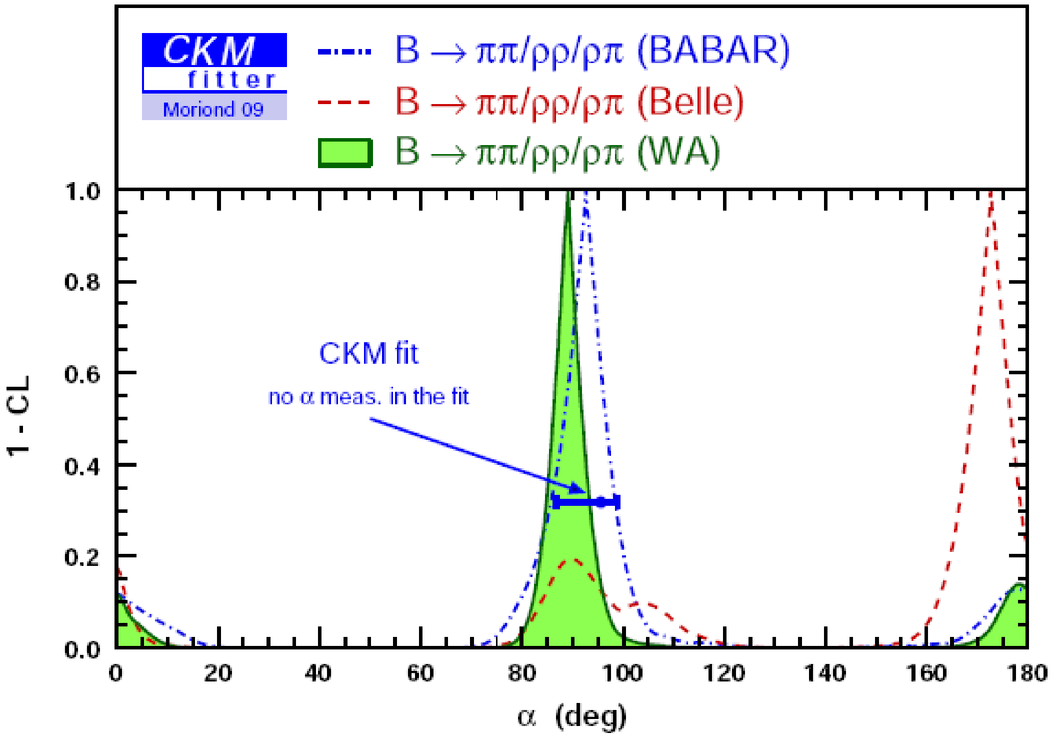
Outlook

- **LHCb can further test these different scenarios**



α and γ


CKM fitter
ICHEP 10
D(*) K(*) GLW + ADS
D(*) K(*) GGSZ
WA
Combined
CKM fit
Full Frequentist treatment on MC basis
1 - CL
γ (deg)


CKM fitter
Moriond 09
B → ππ/ρρ/ρπ (BABAR)
B → ππ/ρρ/ρπ (Belle)
B → ππ/ρρ/ρπ (WA)
CKM fit
no α meas. in the fit
1 - CL
α (deg)

Averages of Lattice QCD parameters

- **Algorithmic procedure for averaging (using unquenched 2 and 2+1 calculations):**
  - **stat. & well-contr. syst. (Gaussian); Remaining part: Rfit, several sources added linearly**
  - **Combine using only Gaussian error & assign smallest Rfit error**
- **Alternative attempts: Lubicz & Tarantino, NCSIF B123, 674 (2008) (Not algorithmic)**
  Laiho, Lunghi, Van de Water, PRD81, 034503 (2010) (algorithmic)

Collaboration	N_f	$f_{B_s} \pm \sigma_{\rm stat} \pm \sigma_{R\rm fit}$
CP-PACS01	2	$242 \pm 9^{+53}_{-34}$
MILC02	2	$217 \pm 6^{+58}_{-31}$
JLQCD03	2	$215 \pm 9^{+19}_{-15}$
ETMC09	2	$243 \pm 6 \pm 15$
HPQCD03	2 + 1	$260 \pm 7 \pm 39$
FNAL-MILC09	2 + 1	$243 \pm 6 \pm 22$
HPQCD09	2 + 1	$231 \pm 5 \pm 30$
Our average		$231 \pm 3 \pm 15$

Collaboration	N_f	$f_{B_s}/f_{B_d} \pm \sigma_{\rm stat} \pm \sigma_{R\rm fit}$
CP-PACS01	2	$1.179 \pm 0.018 \pm 0.023$
MILC02	2	$1.16 \pm 0.01^{+0.08}_{-0.04}$
JLQCD03	2	$1.13 \pm 0.03^{+0.17}_{-0.02}$
ETMC09	2	$1.27 \pm 0.03 \pm 0.04$
FNAL-MILC09	2 + 1	$1.245 \pm 0.028 \pm 0.049$
HPQCD09	2 + 1	$1.226 \pm 0.020 \pm 0.033$
RBC/UKQCD10	2 + 1	$1.15 \pm 0.05 \pm 0.20$
Our average		$1.209 \pm 0.007 \pm 0.023$

Collaboration	N_f	$\hat{\mathcal{B}}_{B_s} \pm \sigma_{\rm stat} \pm \sigma_{R\rm fit}$
JLQCD03	2	$1.299 \pm 0.034^{+0.122}_{-0.095}$
HPQCD06	2 + 1	$1.168 \pm 0.105 \pm 0.140$
RBC/UKQCD07	2 + 1	$1.21 \pm 0.05 \pm 0.05$
HPQCD09	2 + 1	$1.326 \pm 0.04 \pm 0.03$
Our average		$1.28 \pm 0.02 \pm 0.03$

Collaboration	N_f	$\mathcal{B}_{B_s}/\mathcal{B}_{B_d} \pm \sigma_{\rm stat} \pm \sigma_{R\rm fit}$
JLQCD03	2	$1.017 \pm 0.016^{+0.076}_{-0.017}$
HPQCD09	2 + 1	$1.053 \pm 0.020 \pm 0.030$
RBC/UKQCD10	2 + 1	$0.96 \pm 0.02 \pm 0.03$
Our average		$1.006 \pm 0.010 \pm 0.030$

Collaboration	N_f	$\mathcal{B}_K(2\ {\rm GeV}) \pm \sigma_{\rm stat} \pm \sigma_{R\rm fit}$
JLQCD08	2	$0.537 \pm 0.004 \pm 0.072$
HPQCD/UKQCD06	2 + 1	$0.618 \pm 0.018 \pm 0.179$
RBC/UKQCD07	2 + 1	$0.524 \pm 0.010 \pm 0.052$
ALVdW09	2 + 1	$0.527 \pm 0.006 \pm 0.049$
Our average		$0.527 \pm 0.0031 \pm 0.049$

$|V_{ub}|$ input

$|V_{ub}|$(incl.): BLNP

$(4.32^{+0.21}_{-0.24} \pm 0.45) \times 10^{-3}$

Start from HFAG average

Add linearly uncertainties from SF, SSF, WA, scale matching & additional m_b unc. of 50 MeV

(neglect of higher orders)

$|V_{ub}|$(excl.)

$(3.51 \pm 0.10 \pm 0.46) \times 10^{-3}$

$|V_{ub}|$ average

$(3.92 \pm 0.09 \pm 0.45) \times 10^{-3}$

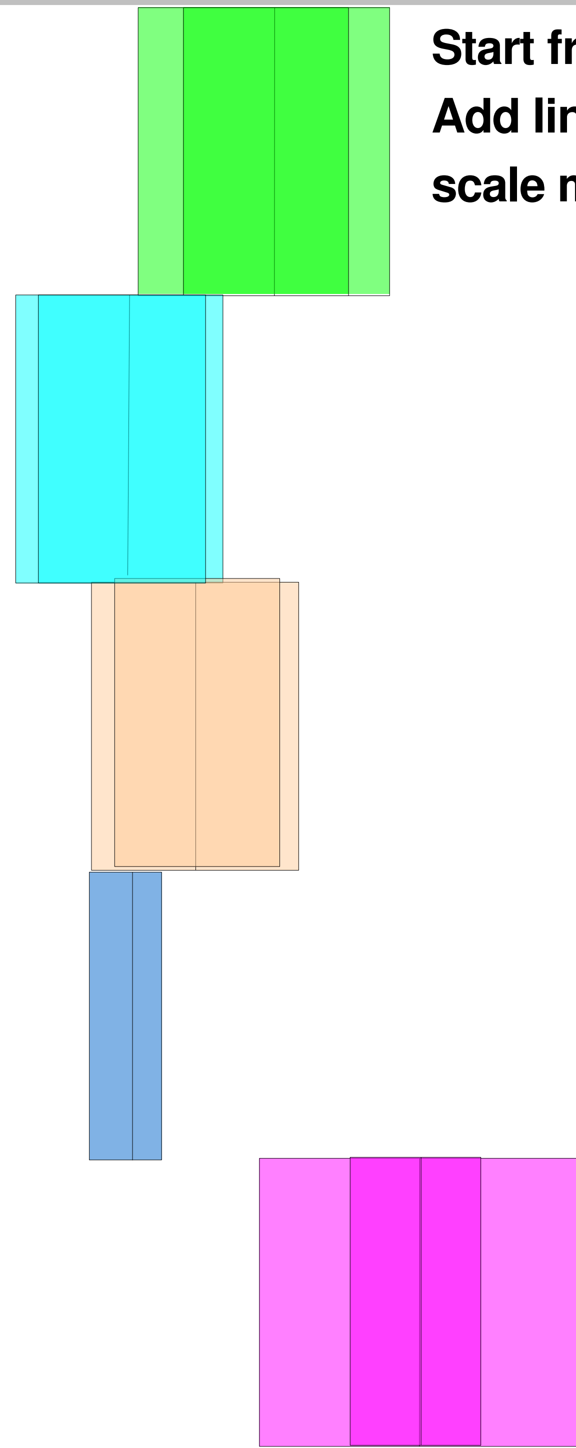
$|V_{ub}|$ fit prediction

$(3.56^{+0.15}_{-0.20}) \times 10^{-3}$

$|V_{ub}|$ from $B \to \tau\nu$

(using f_{Bd}=191±13 MeV)

$(5.10 \pm 0.47 \pm 0.35) \times 10^{-3}$



Recent developments

1. $|V_{cb}|$(excl.): $(38.85\pm0.77\pm0.84)\times10^{-3}$ $\xrightarrow[F(1)_{new}=0.9077\pm0.0051\pm0.0088]{F(1)_{old}=0.921\pm0.013\pm0.020}$ $(39.42\pm0.61\pm0.69)\times10^{-3}$

=> Discrepancy wrt inclusive ($(41.85\pm0.43\pm0.59)\times10^{-3}$) reduced

However, no significant change in our average value: $(40.88\pm0.35\pm0.59)\times10^{-3}$

2. sin2β from Belle: **0.668 ± 0.023 ± 0.013 (711 M BBbar)**

(0.642 ± 0.031 ± 0.017 (553 M Bbbar))

(0.687 ± 0.028 ± 0.012 (BABAR))

My personal average: 0.676 ± 0.020

(HFAG average was: 0.673±0.023)

=> ε_K "anomaly" slightly reduced

=> sin2β & $B\to\tau\nu$ "anomaly" slightly reduced

3. First Δm_s measurement from LHCb in perfect agreement with CDF

4. New analysis results on γ => New global analysis necessary

ε_K anomaly ?

$$\epsilon_K = \sin\phi_\epsilon e^{i\phi_\epsilon}\left[\frac{\mathrm{Im}M_{12}^K}{\Delta M_K} + \xi\right] = \frac{\kappa_\epsilon}{\sqrt{2}} e^{i\phi_\epsilon}\left[\frac{\mathrm{Im}M_{12}^{(6)}}{\Delta M}\right] \qquad \xi = \frac{\mathrm{Im}A_0}{\mathrm{Re}A_0} \qquad \tan\phi_\epsilon = \frac{2\Delta M_K}{\Delta\Gamma_K}$$

For a long time: $\kappa_\epsilon = 1$

1. **Measurement:** $\sin\phi_\epsilon = (43.5 \pm 0.7)^\circ$
2. **ξ from measured ε'/ε, $\omega = \mathrm{Re}A_2/\mathrm{Re}A_0$ + estimate of R_8 (assumes no NP in ε'/ε)**
3. **Higher dimension contributions (d=8) to Im M_{12}**

=> $\kappa_\epsilon = 0.940 \pm 0.013 \pm 0.023$

In agreement with first estimate: $\kappa_\epsilon = 0.94 \pm 0.02$

(Buras, Guadagnoli, Isidori PLB 688, 309 (2010))

(See also: Buras & Guadagnoli, PRD78, 033005 (2008); PRD79, 053010 (2009)
Andriyash, Ovanesyan, Vysotzky, PLB599, 253 (2004))

Deviation of measured observables wrt Theory predictions

Quantity	Deviation			
	wrt SM fit	wrt Sc. I	wrt Sc. II	wrt Sc. III
α	1.1σ	0.2σ	0.7σ	1.0σ
$\phi_d^\Delta + 2\beta$	2.8σ	0.8σ	2.6σ	1.3σ
γ	0.0σ	0.0σ	0.0σ	0.0σ
$\phi_s^\Delta - 2\beta_s$	2.3σ	0.5σ	2.4σ	1.6σ
$\|\epsilon_K\|$	0.0σ		0.0σ	
Δm_d	1.0σ	0.9σ	1.0σ	0.8σ
Δm_s	0.3σ	0.7σ	0.9σ	1.2σ
A_{SL}	2.9σ	1.2σ	2.9σ	2.2σ
a_{SL}^d	0.9σ	0.2σ	0.8σ	0.3σ
a_{SL}^s	0.2σ	0.7σ	0.2σ	0.0σ
$\Delta\Gamma_s$	1.0σ	0.2σ	1.1σ	0.9σ
$\mathcal{B}(B \to \tau\nu)$	2.9σ	0.7σ	2.6σ	1.0σ
$\mathcal{B}(B \to \tau\nu)$ and A_{SL}	3.7σ	0.9σ	3.5σ	2.0σ
$\phi_s^\Delta - 2\beta_s$ and A_{SL}	3.3σ	0.8σ	3.3σ	2.3σ
$\mathcal{B}(B \to \tau\nu)$, $\phi_s^\Delta - 2\beta_s$ and A_{SL}	4.0σ	0.6σ	3.8σ	2.1σ

A_{sl}

$A_{sl}^{meas}=(-85\pm28)\times10^{-4}$ $A_{SL}=(0.506\pm0.043)a_{sl}(B_s)+(0.494\pm0.043)a_{sl}(B_d)$

If A_{SL} driven by NP in mixing & stays large: mainly NP in B_s mixing since

$a_{sl}(B_d)$ constrained by "sin2β": $a_{sl}^{meas}(B_d)=(-47\pm46)\times10^{-4}$ $a_{sl}^{pred}(B_d)=(-36^{+23}_{-11})\times10^{-4}$

(Scenario I)