Updates from UTfit within and beyond the Standard Model

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unitarity Triangle analysis in the SM

SM UT analysis:

- provide the best determination of CKM parameters
- test the consistency of the SM ("direct" vs "indirect" determinations)
- provide predictions for SM observables (ex. sin2\(\beta\), \(\Delta m_s\), ...)

.. and beyond

NP UT analysis:

- model-independent analysis
- provides limit on the allowed deviations from the SM
- updated NP scale analysis
**CKM matrix and Unitarity Triangle**

\[ V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0 \]

\[ \alpha = \pi - \beta - \gamma \]

\[ \bar{\rho} + i\bar{\eta} \]

\[ \gamma = \tan\left(\frac{\eta}{\bar{\rho}}\right) \]

\[ \beta = \tan\left(\frac{\bar{\eta}}{(1 - \bar{\rho})}\right) \]

- **many observables**
  - functions of $\bar{\rho}$ and $\bar{\eta}$:
  - overconstraining

\[ B^0 \rightarrow \pi\pi, \rho\pi \]

\[ B^0 \rightarrow J/\psi K_s \]
Other UT analyses exist, by:

CKMfitter (http://ckmfitter.in2p3.fr/),
Laiho&Lunghi&Van de Water (http://krone.physik.unizh.ch/~lunghi/webpage/LatAves/page3/page3.htm),
Lunghi&Soni (1010.6069)
the method and the inputs:

\[
f(\bar{\rho}, \bar{\eta}, X | c_1, ..., c_m) \sim \prod_{j=1,m} f_j(C | \bar{\rho}, \bar{\eta}, X) \cdot \prod_{i=1,N} f_i(x_i) f_0(\bar{\rho}, \bar{\eta})
\]

\[
X \equiv x_1, ..., x_n = m_t, B_K, F_B, ...
\]

\[
C \equiv c_1, ..., c_m = \epsilon, \Delta m_d/\Delta m_s, A_{CP}(J/\psi K_S), ...
\]

\[
(b \to u)/(b \to c) \quad \bar{\rho}^2 + \bar{\eta}^2 \\
\epsilon_K \quad \bar{\eta}[(1 - \bar{\rho}) + P] \\
\Delta m_d \quad (1 - \bar{\rho})^2 + \bar{\eta}^2 \\
\Delta m_d/\Delta m_s \quad (1 - \bar{\rho})^2 + \bar{\eta}^2 \\
A_{CP}(J/\psi K_S) \quad \sin 2\beta
\]

\[
\bar{\Lambda}, \lambda_1, F(1), ...
\]

Standard Model + OPE/HQET/Lattice QCD to go from quarks to hadrons

M. Bona et al. (UTfit Collaboration) JHEP 0507:028,2005 hep-ph/0501199
M. Bona et al. (UTfit Collaboration) JHEP 0603:080,2006 hep-ph/0509219
**B_d and B_s mixing**

\[ \Delta m_d = (0.510 \pm 0.004) \text{ ps}^{-1} \]

\[ \Delta m_s = (17.72 \pm 0.04) \text{ ps}^{-1} \]

\[ \Delta m_d \approx \left(1 - \rho^2 + \eta^2\right) \frac{f_{B_s}^2 B_{B_s}}{\xi^2} \]

\[ \Delta m_s \approx f_{B_s}^2 B_{B_s} \]

\[ B_{B_q} \text{ and } f_{B_q} \text{ from lattice QCD} \]

\[ \Delta m_s / \Delta m_d \]

\[ \Delta m_d \]

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>( B_K )</td>
<td>0.766 ± 0.010</td>
</tr>
<tr>
<td>( f_{B_s} )</td>
<td>0.2277 ± 0.0045</td>
</tr>
<tr>
<td>( f_{B_s} / f_{B_d} )</td>
<td>1.202 ± 0.022</td>
</tr>
<tr>
<td>( \hat{B}_{B_s} )</td>
<td>1.33 ± 0.06</td>
</tr>
<tr>
<td>( \hat{B}<em>{B_s} / \hat{B}</em>{B_d} )</td>
<td>1.06 ± 0.11</td>
</tr>
</tbody>
</table>

*updated results from FLAG-2*
**$V_{cb}$ and $V_{ub}$**

$V_{cb}$ (excl) = $(39.55 \pm 0.88) \times 10^{-3}$

$V_{cb}$ (incl) = $(41.7 \pm 0.7) \times 10^{-3}$

~$1.9\sigma$ discrepancy

$V_{ub}$ (excl) = $(3.42 \pm 0.22) \times 10^{-3}$

$V_{ub}$ (incl) = $(4.40 \pm 0.31) \times 10^{-3}$

~$2.5\sigma$ discrepancy

UTfit input value: average à la PDG

$V_{cb} = (40.9 \pm 1.0) \times 10^{-3}$

uncertainty ~ 2.4%

$V_{ub} = (3.75 \pm 0.46) \times 10^{-3}$

uncertainty ~ 12%
Unitarity Triangle analysis in the SM:
Unitarity Triangle analysis in the SM:

<table>
<thead>
<tr>
<th>Observables</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>V_{ub}/V_{cb}</td>
</tr>
<tr>
<td>$\varepsilon_K$</td>
<td>~ 0.5%</td>
</tr>
<tr>
<td>$\Delta m_d$</td>
<td>~ 1%</td>
</tr>
<tr>
<td>$</td>
<td>\Delta m_d/\Delta m_s</td>
</tr>
<tr>
<td>$\sin2\beta$</td>
<td>~ 3%</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>~ 8%</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>~ 10%</td>
</tr>
<tr>
<td>$\text{BR}(B \rightarrow \tau\nu)$</td>
<td>~ 19%</td>
</tr>
</tbody>
</table>
Unitarity Triangle analysis in the SM:

 levels @ 95% Prob

\[ \bar{\rho} = 0.129 \pm 0.024 \]
\[ \bar{\eta} = 0.353 \pm 0.016 \]
angles vs the others

\[ \bar{\rho} = 0.134 \pm 0.029 \]
\[ \eta = 0.339 \pm 0.017 \]

\[ \bar{\rho} = 0.144 \pm 0.046 \]
\[ \eta = 0.376 \pm 0.030 \]
compatibility plots

A way to “measure” the agreement of a single measurement with the indirect determination from the fit using all the other inputs: test for the SM description of the flavour physics

Color code: agreement between the predicted values and the measurements at better than 1, 2, ...nσ

The cross has the coordinates (x,y)=(central value, error) of the direct measurement

\[ \gamma_{\text{exp}} = (70.1 \pm 7.1)° \]
\[ \gamma_{\text{UTfit}} = (69.8 \pm 3.9)° \]

\[ \alpha_{\text{exp}} = (90.7 \pm 7.4)° \]
\[ \alpha_{\text{UTfit}} = (86.4 \pm 3.9)° \]
**tensions**

\[
\sin^2 \beta_{\text{exp}} = 0.680 \pm 0.023 \\
\sin^2 \beta_{\text{UTfit}} = 0.752 \pm 0.043
\]

\[
V_{ub_{\text{exp}}} = (3.75 \pm 0.46) \times 10^{-3} \\
V_{ub_{\text{UTfit}}} = (3.62 \pm 0.13) \times 10^{-3}
\]

\[
B_{K_{\text{exp}}} = 0.766 \pm 0.010 \\
B_{K_{\text{UTfit}}} = 0.841 \pm 0.078
\]
**tensions**

\[
\sin^2 \beta_{\text{exp}} = 0.680 \pm 0.023 \\
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V_{ub_{\text{exp}}} = (3.75 \pm 0.46) \cdot 10^{-3} \\
V_{ub_{\text{UTfit}}} = (3.62 \pm 0.13) \cdot 10^{-3}
\]
## Unitarity Triangle analysis in the SM:

The table below summarizes the measurements and predictions for various observables in the Standard Model (SM). The pull (in standard deviations) is indicated for each entry.

<table>
<thead>
<tr>
<th>Observables</th>
<th>Measurement</th>
<th>Prediction</th>
<th>Pull (σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sin2β</td>
<td>0.680 ± 0.023</td>
<td>0.752 ± 0.043</td>
<td>~ 1.5</td>
</tr>
<tr>
<td>γ</td>
<td>70.1 ± 7.1</td>
<td>69.8 ± 3.9</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>α</td>
<td>90.7 ± 7.4</td>
<td>86.4 ± 3.9</td>
<td>&lt; 1</td>
</tr>
<tr>
<td></td>
<td>V_{ub}</td>
<td>· 10^{3}</td>
<td>3.75 ± 0.46</td>
</tr>
<tr>
<td></td>
<td>V_{ub}</td>
<td>· 10^{3} (incl)</td>
<td>4.40 ± 0.31</td>
</tr>
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<td>· 10^{3} (excl)</td>
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</tr>
<tr>
<td></td>
<td>V_{cb}</td>
<td>· 10^{3}</td>
<td>40.9 ± 1.0</td>
</tr>
<tr>
<td>B_K</td>
<td>0.766 ± 0.010</td>
<td>0.841 ± 0.078</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>BR(B → τν)[10^{-4}]</td>
<td>1.14 ± 0.22</td>
<td>0.811 ± 0.061</td>
<td>~ 1.4</td>
</tr>
<tr>
<td>BR(B_s → ll)[10^{-9}]</td>
<td>2.9 ± 0.7</td>
<td>3.92 ± 0.16</td>
<td>~ 1.3</td>
</tr>
<tr>
<td>BR(B_d → ll)[10^{-9}]</td>
<td>0.37 ± 0.15</td>
<td>0.115 ± 0.007</td>
<td>~ 1.7</td>
</tr>
<tr>
<td>A_{SL}^d · 10^{3}</td>
<td>-4.8 ± 5.2</td>
<td>0.012 ± 0.002</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>A_{μμ} · 10^{3}</td>
<td>-7.9 ± 2.0</td>
<td>-0.12 ± 0.02</td>
<td>~ 3.9</td>
</tr>
</tbody>
</table>

Note: The pull values indicate the deviation of measurements from predictions.

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[Marcella Bona, QMUL]
inclusives vs exclusives

\[ \sin^2 \beta_{\text{UTfit}} = 0.720 \pm 0.031 \]
\~1.0\sigma

\[ \sin^2 \beta_{\text{UTfit}} = 0.782 \pm 0.035 \]
\~2.4\sigma
Marcella Bona, QMUL

\[ \sin^2\beta_{\text{UTfit}} = 0.720 \pm 0.031 \]

\[ \sin^2\beta_{\text{UTfit}} = 0.782 \pm 0.035 \]

inclusive vs exclusives

Probability density

\~1.0\sigma

\~2.4\sigma

0.005

0.01

0.015

0.05

0.6

0.7

0.8

0.9

1

No Semileptonic

Experimental

Inclusive

Exclusive

summer'13

UTfit updates
more standard model predictions:

\[ \text{BR}(B \to \tau \nu) = (1.14 \pm 0.22) \times 10^{-4} \]

indirect determinations from UT

\[ \text{BR}(B \to \tau \nu) = (0.811 \pm 0.061) \times 10^{-4} \]

M. Bona et al, 0908.3470 [hep-ph]
more standard model predictions:

from CMS+LHCb

\[ \text{BR}(B_s \to \mu\mu) = (2.9 \pm 0.7) \times 10^{-9} \]

\[ \text{BR}(B_d \to \mu\mu) = (3.7 \pm 1.5) \times 10^{-10} \]

\[ \text{BR}(B_s \to ll) = (3.92 \pm 0.16) \times 10^{-9} \]

\[ \text{BR}(B_d \to ll) = (1.15 \pm 0.07) \times 10^{-10} \]

~1.3\sigma

indirect determinations from UT

time-integration included
predictions on lattice parameters:

<table>
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<tr>
<th>Observables</th>
<th>Measurement</th>
<th>Prediction</th>
<th>Pull (#σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_K$</td>
<td>$0.766 \pm 0.010$</td>
<td>$0.841 \pm 0.078$</td>
<td>0.9</td>
</tr>
<tr>
<td>$f_{Bs}$</td>
<td>$0.2277 \pm 0.0045$</td>
<td>$0.2270 \pm 0.0065$</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>$f_{Bs}/f_{Bd}$</td>
<td>$1.202 \pm 0.022$</td>
<td>$1.19 \pm 0.06$</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>$B_{Bs}$</td>
<td>$0.875 \pm 0.040$</td>
<td>$0.879 \pm 0.045$</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>$B_{Bs}/B_{Bd}$</td>
<td>$1.06 \pm 0.11$</td>
<td>$1.137 \pm 0.076$</td>
<td>0.5</td>
</tr>
</tbody>
</table>

obtained excluding the given constraint from the fit
Including NNLO $\varepsilon_K$ corrections:

Levels @ 95% Prob

Standard results

$$\bar{\rho} = 0.129 \pm 0.024$$

$$\bar{\eta} = 0.353 \pm 0.016$$
Including NNLO $\varepsilon_K$ corrections:

**corrected plot**

**levels @ 95% Prob**

**corrected results**

- $\rho = 0.130 \pm 0.025$
- $\eta = 0.352 \pm 0.016$

**standard results**

- $\rho = 0.129 \pm 0.024$
- $\eta = 0.353 \pm 0.016$

Marcella Bona, QMUL
fit simultaneously for the CKM and the NP parameters (generalized UT fit)

- add most general loop NP to all sectors
- use all available experimental info
- find out NP contributions to $\Delta F=2$ transitions

**$B_d$ and $B_s$ mixing amplitudes**

(2+2 real parameters):

$$A_q = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_{SM}} = \left(1 + \frac{A_{NP}^{q}}{A_{SM}^{q}} e^{2i(\phi_{NP} - \phi_{SM})}\right) A_{SM}^{q} e^{2i\phi_{SM}}$$

- $\Delta m_{q/K} = C_{B_q/\Delta m_K} (\Delta m_{q/K})^{SM}$
- $A_{CP}^{B_d \rightarrow J/\psi K_s} = \sin 2(\beta + \phi_{B_d})$
- $A_{SL}^{q} = \text{Im}\left(\Gamma_{12}^{q}/A_{q}\right)$
- $\epsilon_K = C_{\epsilon} \epsilon_K^{SM}$
- $A_{CP}^{B_s \rightarrow J/\psi \phi} \sim \sin 2(-\beta_s + \phi_{B_s})$
- $\Delta \Gamma_{12}^{q}/\Delta m_q = \text{Re}\left(\Gamma_{12}^{q}/A_{q}\right)$
new-physics-specific constraints

semileptonic asymmetries:
sensitive to NP effects in both size and phase
\[ A_{SL}(B_d)[10^{-3}] = 3.2 \pm 2.9, \quad A_{SL}(B_s)[10^{-3}] = -4.8 \pm 5.2 \]

same-side dilepton charge asymmetry:
admixture of \( B_s \) and \( B_d \) so sensitive to NP effects in both systems
\[ A_{SL}^{\mu\mu} \times 10^3 = -7.9 \pm 2.0 \]

lifetime \( \tau^{FS} \) in flavour-specific final states:
average lifetime is a function to the width and the width difference (independent data sample)
\[ \tau_{B_s}^{FS} \text{ [ps]} = 1.417 \pm 0.042 \]

\( \phi_s = 2\beta_s \text{ vs } \Delta \Gamma_s \text{ from } B_s \rightarrow J/\psi \phi \)
angular analysis as a function of proper time and b-tagging. Additional sensitivity from the \( \Delta \Gamma_s \) terms

\[ \phi_s: \text{LHCb: Gaussian} \]
\[ \Delta \Gamma_s: \text{average: Gaussian} \]
NP analysis results

\[ \rho = 0.150 \pm 0.046 \]
\[ \eta = 0.369 \pm 0.049 \]

SM is
\[ \bar{\rho} = 0.129 \pm 0.024 \]
\[ \bar{\eta} = 0.355 \pm 0.016 \]

degeneracy of \( \gamma \) broken by \( A_{SL} \)
**NP parameter results**

- Dark: 68%
- Light: 95%
- SM: red cross

- \( C_{\varepsilon_K} = 1.08 \pm 0.16 \)

- \( C_{B_d} = 1.10 \pm 0.17 \)
- \( \phi_{B_d} = (-2.1 \pm 3.2)° \)

- \( A_q = C_{B_q} e^{2i\phi_{B_q}} \)

- \( A_q^{SM} e^{2i\phi_{q}^{SM}} \)

- \( C_{B_s} = 1.08 \pm 0.09 \)
- \( \phi_{B_s} = (0.6 \pm 2.0)° \)
NP parameter results

$$A_q = \left(1 + \frac{A_q^{NP}}{A_q^{SM}} e^{2i(\phi_q^{NP} - \phi_q^{SM})}\right) A_q^{SM} e^{2i\phi_q^{SM}}$$

The ratio of NP/SM amplitudes is:

- < 28% @68% prob. (47% @95%) in $B_d$ mixing
- < 17% @68% prob. (26% @95%) in $B_s$ mixing

see also Lunghi & Soni, Buras et al., Ligeti et al.
The D0 dimuon asymmetry remains @ 3.9σ.
At the high scale

new physics enters according to its specific features

At the low scale

use OPE to write the most general effective Hamiltonian.

the operators have different chiralities than the SM

NP effects are in the Wilson Coefficients C

NP effects are enhanced

◉ up to a factor 10 by the values of the matrix elements especially for transitions among quarks of different chiralities

◉ up to a factor 8 by RGE
effective BSM Hamiltonian for $\Delta F=2$ transitions

The Wilson coefficients $C_i$ have in general the form:

$$C_i(\Lambda) = \frac{F_i L_i}{\Lambda^2}$$

- $F_i$: function of the NP flavour couplings
- $L_i$: loop factor (in NP models with no tree-level FCNC)
- $\Lambda$: NP scale (typical mass of new particles mediating $\Delta F=2$ transitions)

Putting bounds on the Wilson coefficients give insights into the NP scale in different NP scenarios that enter through $F_i$ and $L_i$. 
testing the TeV scale

The dependence of $C$ on $\Lambda$ changes on flavor structure. We can consider different flavour scenarios:

- **Generic**: $C(\Lambda) = \alpha/\Lambda^2$  \[ F_i \sim 1, \text{ arbitrary phase} \]
- **NMFV**: $C(\Lambda) = \alpha \times |F_{\text{SM}}|/\Lambda^2$  \[ F_i \sim |F_{\text{SM}}|, \text{ arbitrary phase} \]
- **MFV**: $C(\Lambda) = \alpha \times |F_{\text{SM}}|/\Lambda^2$  \[ F_1 \sim |F_{\text{SM}}|, F_{i \neq 1} \sim 0, \text{ SM phase} \]

$\alpha (L_i)$ is the coupling among NP and SM

- $\alpha \sim 1$ for strongly coupled NP
- $\alpha \sim \alpha_W (\alpha_S)$ in case of loop coupling through weak (strong) interactions

If no NP effect is seen, lower bound on NP scale $\Lambda$ if NP is seen, upper bound on NP scale $\Lambda$
results from the Wilson coefficients

Generic: \( C(\Lambda) = \alpha/\Lambda^2, \ F_i \sim 1, \) arbitrary phase

\( \alpha \sim 1 \) for strongly coupled NP

\( \alpha \sim \alpha_W \) in case of loop coupling through weak interactions

NP in \( \alpha_W \) loops

\( \Lambda > 1.5 \times 10^4 \) TeV

Non-perturbative NP

\( \Lambda > 5.0 \times 10^5 \) TeV

To obtain the lower bound for loop-mediated contributions, one simply multiplies the bounds by \( \alpha_s (\sim 0.1) \) or by \( \alpha_W (\sim 0.03) \).
results from the Wilson coefficients

NMFV: \[ C(\Lambda) = \alpha \times |F_{SM}|/\Lambda^2, \quad F_i \sim |F_{SM}|, \quad \text{arbitrary phase} \]

\[ \alpha \sim 1 \quad \text{for strongly coupled NP} \]

To obtain the lower bound for loop-mediated contributions, one simply multiplies the bounds by \( \alpha_s (\sim 0.1) \) or by \( \alpha_W (\sim 0.03) \).

\( \alpha \sim \alpha_W \) in case of loop coupling through weak interactions

NP in \( \alpha_W \) loops

\[ \Lambda > 3.4 \text{ TeV} \]

Lower bounds on NP scale (in TeV at 95\% prob.)

Non-perturbative NP

\[ \Lambda > 113 \text{ TeV} \]
conclusions

- SM analysis displays good overall consistency
- Still open discussion on semileptonic inclusive vs exclusive
- UTA provides determination also of NP contributions to $\Delta F=2$ amplitudes. It currently leaves space for NP at the level of 15-20%
- So the scale analysis points to high scales for the generic scenario and even above LHC reach for weak coupling. Indirect searches become essential.
- Even if we don't see relevant deviations in the down sector, we might still find them in the up sector.
Back up slides
**UUT and MFV:**

Universal Unitarity Triangle (UUT): unaffected by MFV-NP

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**low/moderate tanβ:**

MFV: $Y_{u,d}$ only source of flavour and CPV

Bounds on MFV models @ low/moderate tanβ,

NP effects amount to a modification of the top loop:

in $\Delta F=2$, $S_0(x_t) \rightarrow S_0(x_t) + \delta S$,

with $\delta S = 4c(\Lambda_{SM}/\Lambda)^2$ and $\Lambda_{SM} \sim 2.4$ TeV

We find $\delta S \in [-0.28,0.48]$ @ 95% probability

This corresponds to $\Lambda > 6.9$ TeV for $c=1$ and to $\Lambda > 9.1$ TeV for $c=-1
**MFV at large tanβ:**

For large tanβ, Y_b becomes important, and Higgs exchange can dominate over SM in helicity-suppressed amplitudes: B→τν, B_s→μμ

- In 2HDMII, \((\tanβ/m_{H^+})^4\)-enhanced contributions:
  \[\text{BR/BR}_{\text{SM}} \sim (1 – m_B^2 \tan^2β/m_{H^+}^2)^2\]

- In the MSSM, loop effects induce \((\tanβ/m_{H^+})^6\)-enhanced contributions to \(B_s→μμ\) \((μA_t/m_{stop}^2 \tan^3β/m_{H^+}^2)^2\)

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**2HDMII**

All constraints:
\[\tanβ < 55 \text{ m}_{H^+}/\text{TeV}\]

**MSSM**

All constraints:
\[\tanβ < 47 \text{ m}_{H^+}/\text{TeV}\]
Flavour mixing and CP violation in the Standard Model

- The CP symmetry is violated in any field theory having in the Lagrangian at least one phase that cannot be re-absorbed.
- The mass eigenstates are not eigenstates of the weak interaction. This feature of the Standard Model Hamiltonian produces the (unitary) mixing matrix $V_{\text{CKM}}$.

\[
\begin{pmatrix}
V_{ud} & V_{us} & V_{ub} \\
V_{cd} & V_{cs} & V_{cb} \\
V_{td} & V_{ts} & V_{tb}
\end{pmatrix}
\approx
\begin{pmatrix}
1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\
-\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\
A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1
\end{pmatrix}
\]
CP-violating inputs

$\varepsilon_K$ from K-K mixing

$\rightarrow B_K = 0.766 \pm 0.010 \quad \text{FLAG-2}$

$\sin 2\beta$ from $B \rightarrow J/\psi K^0 + \text{theory}$

$\sin 2\beta(J/\psi K^0) = 0.680 \pm 0.023 \quad \text{HFAG + CPS}$

$\alpha$ from $\pi\pi$, $\rho\rho$, $\pi\rho$ decays:

combined: $(90.7 \pm 7.4)\degree \quad \text{UTfit}$

$\gamma$ from $B \rightarrow D K$ decays (tree level)
\[ \gamma = (70.1 \pm 7.1)^{\circ} \]

\[ r_B(DK) = 0.0999 \pm 0.0059 \]

\[ r_B(D^*K) = 0.118 \pm 0.018 \]

\[ r_B(DK^*) = 0.130 \pm 0.057 \]
new-physics-specific constraints

B meson mixing matrix element NLO calculation

\[
\frac{\Gamma_{12}}{\Delta_{q}^{\text{full}}} = -2 \kappa C_{B_{q}} \left\{ \begin{array}{c}
2\phi_{B_{q}} \left( n_{1} + \frac{n_{6}B_{2} + n_{11}}{B_{1}} \right) - e^{2\phi_{q}^{\text{SM}} + 2\phi_{B_{q}}} \left( n_{2} + \frac{n_{7}B_{2} + n_{12}}{B_{1}} \right) \\
+ \frac{e^{2(\phi_{q}^{\text{SM}} + \phi_{B_{q}})}}{R_{t}^{q}} \left( n_{3} + \frac{n_{8}B_{2} + n_{13}}{B_{1}} \right) + e^{2(\phi_{q}^{\text{Pen}} + 2\phi_{B_{q}})} C_{q}^{\text{Pen}} \left( n_{4} + \frac{n_{9}B_{2}}{B_{1}} \right) \\
- e^{2(\phi_{q}^{\text{SM}} + \phi_{q}^{\text{Pen}} + 2\phi_{B_{q}})} \frac{C_{q}^{\text{Pen}}}{R_{t}^{q}} \left( n_{5} + \frac{n_{10}B_{2}}{B_{1}} \right) \end{array} \right\}
\]

C_{\text{pen}} and \phi_{\text{pen}} are parameterize possible NP contributions from \( b \rightarrow s \) penguins.
# UT analysis including NP

M. Bona et al. (UTfit)

<table>
<thead>
<tr>
<th></th>
<th>$\rho, \eta$</th>
<th>$C_{Bd}, \phi_{Bd}$</th>
<th>$C_{eK}$</th>
<th>$C_{Bs}, \phi_{Bs}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ub}/V_{cb}$</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma$ (DK)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_k$</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$\sin2\beta$</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta m_d$</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_{SL}B_d$</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$\Delta \Gamma_d/\Gamma_d$</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$\Delta \Gamma_s/\Gamma_s$</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$\Delta m_s$</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$A_{CH}$</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**model independent assumptions**

SM $\Rightarrow$ SM+NP

**tree level**

$$ (V_{ub}/V_{cb})^{SM} \rightarrow (V_{ub}/V_{cb})^{SM} $$

$$ \gamma^{SM} \rightarrow \gamma^{SM} $$

**Bd Mixing**

$$ \beta^{SM} $$

$$ \beta^{SM} + \phi_{Bd} $$

$$ \alpha^{SM} $$

$$ \alpha^{SM} - \phi_{Bd} $$

$$ \Delta m_d $$

$$ C_{Bs}\Delta m_s^{SM} $$

**Bs Mixing**

$$ \Delta m_s^{SM} $$

$$ C_{Bs}\Delta m_s^{SM} $$

$$ \beta^{SM}_s $$

$$ \beta^{SM}_s + \phi_{Bs} $$

**K Mixing**

$$ \varepsilon_k^{SM} $$

$$ C\varepsilon_k \varepsilon_k^{SM} $$
contribution to the mixing amplitudes

analytic expression for the contribution to the mixing amplitudes

\[
\langle \bar{B}_q | \mathcal{H}_{\text{eff}}^{AB=2} | B_q \rangle_i = \sum_{j=1}^{5} \sum_{r=1}^{5} \left( b_j^{(r,i)} + \eta c_j^{(r,i)} \right) \eta^{a_j} C_i(\Lambda) \langle \bar{B}_q | Q_{r}^{b_q} | B_q \rangle
\]

\text{Lattice QCD}

arXiv:0707.0636: for ”magic numbers” a, b and c, \( \eta = \alpha_s(\Lambda)/\alpha_s(m_t) \)

(numerical values updated last in summer'12)

analogously for the K system

\[
\langle \bar{K}^0 | \mathcal{H}_{\text{eff}}^{AS=2} | K^0 \rangle_i = \sum_{j=1}^{5} \sum_{r=1}^{5} \left( b_j^{(r,i)} + \eta c_j^{(r,i)} \right) \eta^{a_j} C_i(\Lambda) R_r \langle \bar{K}^0 | Q_1^{s_d} | K^0 \rangle
\]

To obtain the p.d.f. for the Wilson coefficients \( C_i(\Lambda) \) at the new-physics scale, we switch on one coefficient at a time in each sector and calculate its value from the result of the NP analysis.

Marcella Bona, QMUL
The future of CKM fits

LHCb reach from:
O. Schneider, 1st LHCb Collaboration Upgrade Workshop

SuperB reach from:

Marcella Bona, QMUL

2015

$\Delta m_s$ 10/fb (5 years) 1/ab (1 month)
0.07% (+0.5%) no at Y(5S)

$A_{SL}$

$\phi_s (J/\psi \phi)$ 0.01+syst

sin2$\beta$ (J/$\psi$ K$_s$) 0.010

$\gamma$ (all methods) 2.4$^o$ 1-2$^o$

$\alpha$ (all methods) 4.5$^o$ 1-2$^o$

$|V_{cb}|$ (all methods) no <1%

$|V_{ub}|$ (all methods) no 1-2%

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Today

With a SuperB in 2015