Unitarity Triangle analysis
in the Standard Model
and beyond from UTfit

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on behalf of the UTfit Collaboration

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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 (from data..) for SM observables
- charm mixing averages

.. and beyond

NP UT analysis:

- model-independent analysis
- provides limit on the allowed deviations from the SM
- obtain the NP scale
Updates from UTfit

the method and the inputs:

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

Bayes Theorem

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

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

\[
\begin{array}{|c|c|c|}
\hline
(b \to u)/(b \to c) & (b \to u)/(b \to c) & (b \to u)/(b \to c) \\
\hline
\epsilon_K & \rho^2 + \eta^2 & \bar{\Lambda}, \lambda_1, F(1), ... \\
\hline
\Delta m_d & \eta[(1 - \rho) + P] & B_K \\
\hline
\Delta m_d/\Delta m_s & (1 - \rho)^2 + \eta^2 & f_B^2 B_B \\
\hline
A_{CP}(J/\psi K_S) & (1 - \rho)^2 + \eta^2 & \xi \\
\hline
\end{array}
\]

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

M. Bona et al. (UTfit Collaboration)

M. Bona et al. (UTfit Collaboration)
\[ |V_{cb}| (\text{excl}) = (38.88 \pm 0.60) \times 10^{-3} \]

\[ |V_{cb}| (\text{incl}) = (42.19 \pm 0.78) \times 10^{-3} \]

\[ |V_{ub}| (\text{excl}) = (3.65 \pm 0.14) \times 10^{-3} \]

\[ |V_{ub}| (\text{incl}) = (4.50 \pm 0.20) \times 10^{-3} \]

\[ \frac{|V_{ub}|}{|V_{cb}|} (LHCb) = (8.0 \pm 0.6) \times 10^{-2} \]
Updates from UTfit

2D average inspired by D'Agostini skeptical procedure (hep-ex/9910036) with $\sigma=1$. Very similar results obtained from a 2D a la PDG procedure.

$$|V_{cb}| = (40.5 \pm 1.1) \times 10^{-3}$$
uncertainty $\sim 2.4\%$

$$|V_{ub}| = (3.74 \pm 0.23) \times 10^{-3}$$
uncertainty $\sim 5.6\%$

$$|V_{cb}| = (42.7 \pm 0.7) \times 10^{-3}$$

$$|V_{ub}| = (3.61 \pm 0.12) \times 10^{-3}$$

(EPS17) UTfit predictions

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exclusives vs inclusives

only exclusive values

only inclusive values
Updates from UTfit

exclusives vs inclusives

predictions from the EPS17 fit:

$$\sin^2 \beta_{\text{UTfit}} = 0.729 \pm 0.017$$

$$\sin^2 \beta_{\text{UTfit}} = 0.793 \pm 0.026$$

$$\sin^2 \beta_{\text{exp}} = 0.670 \pm 0.022$$

$$\sin^2 \beta_{\text{UTfit}} = 0.740 \pm 0.032$$

EPS17: updated input value

J/$\psi$ $K^0$ average $0.680 \pm 0.019$ (B-factories + LHCb)

adding $-0.01 \pm 0.01$ as data-driven theory uncertainty
Unitarity Triangle analysis in the SM:

- $|\mathbf{v}_{cb}/\mathbf{v}_{ub}|$
- $\rho^2 + \eta^2$
- $\eta[(1 - \rho) + P]$
- $\Delta m_d$
- $(1 - \rho)^2 + \eta^2$
- $\Delta m_s/\Delta m_d$
- $\alpha$
- $\beta$
- $\gamma$
- $2\beta + \gamma$
- $B \rightarrow \tau\nu$

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Unitarity Triangle analysis in the SM:

$\rho = 0.151 \pm 0.014$

$\eta = 0.342 \pm 0.013$

$\sim 9\%$

$\sim 4\%$
Unitarity Triangle analysis in the SM:

- Tree-level processes: DK decays and semileptonic B decays → reference for model building

- Levels @ 95% Prob

- $\bar{\rho} = 0.137 \pm 0.040 \approx 29\%$
- $\bar{\eta} = 0.374 \pm 0.029 \approx 8\%$

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Unitarity Triangle analysis in the SM:

fit area from the sides+$\varepsilon_K$ fit compared to the areas of the three angle constraints.

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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, ... $\sigma$

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

$$\gamma_{\text{exp}} = (70.5 \pm 5.7)^\circ$$
$$\gamma_{\text{UTfit}} = (65.6 \pm 2.2)^\circ$$

$$\alpha_{\text{exp}} = (94.2 \pm 4.5)^\circ$$
$$\alpha_{\text{UTfit}} = (91.0 \pm 2.5)^\circ$$
tensions? not really.. still that $V_{ub}$ inclusive

$V_{ub} (excl) = (3.65 \pm 0.14) \cdot 10^{-3}$

$V_{ub} (incl) = (4.50 \pm 0.20) \cdot 10^{-3}$

$V_{ub_{exp}} = (3.74 \pm 0.23) \cdot 10^{-3}$

$V_{ub_{UTfit}} = (3.61 \pm 0.12) \cdot 10^{-3}$

$\sin2\beta_{exp} = 0.670 \pm 0.022$

$\sin2\beta_{UTfit} = 0.740 \pm 0.032$

$\sim 1.8\sigma$
Unitarity Triangle analysis in the SM:

<table>
<thead>
<tr>
<th>Observables</th>
<th>Measurement</th>
<th>Prediction</th>
<th>Pull (##)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sin2β</td>
<td>0.670 ± 0.022</td>
<td>0.740 ± 0.032</td>
<td>~ 1.8</td>
</tr>
<tr>
<td>γ</td>
<td>70.5 ± 5.7</td>
<td>65.6 ± 2.2</td>
<td>&lt; 1</td>
</tr>
<tr>
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<tr>
<td></td>
<td>V_{ub}</td>
<td>· 10³</td>
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<tr>
<td></td>
<td>V_{cb}</td>
<td>· 10³</td>
<td>40.5 ± 1.1</td>
</tr>
<tr>
<td>BR(B → τν)[10^{-4}]</td>
<td>1.06 ± 0.19</td>
<td>0.79 ± 0.06</td>
<td>~ 1.3</td>
</tr>
<tr>
<td>A_{SL}^d · 10³</td>
<td>-2.1 ± 1.7</td>
<td>-0.289 ± 0.027</td>
<td>~ 1</td>
</tr>
<tr>
<td>A_{SL}^s · 10³</td>
<td>-0.6 ± 2.8</td>
<td>0.013 ± 0.001</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

obtained excluding the given constraint from the fit
Mixing in the charm sector

Fit to data with parameters: $x$, $y$, $|q/p|$, $R_{K\pi}$, $\delta_{K\pi}$, $\delta_{K\pi\pi}$

*Summer17* UTfit average:

$x = (3.5 \pm 1.5) \times 10^{-3}$

$y = (5.8 \pm 0.6) \times 10^{-3}$

$|q/p|-1 = (0.2 \pm 1.8) \times 10^{-2}$

$\phi = \text{arg}(q/p) = (-0.08 \pm 0.57) ^\circ$
Mixing in the charm sector

Fit to data with parameters: $x, y, |q/p|, R_{k\pi}, \delta_{k\pi}, \delta_{k\pi\pi}$

The corresponding results on fundamental parameters are

$|M_{12}| = (4.3 \pm 1.8)/\text{fs}$,
$|\Gamma_{12}| = (14.2 \pm 1.4)/\text{fs}$
$\Phi_{12} = (0.3 \pm 2.6)^\circ$
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):

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

\[ \Delta m_{q/K} = C_{B_q/\Delta m_K} (\Delta m_{q/K})^{SM} \]
\[ A_{B_d \rightarrow J/\psi K_s}^{|CP|} = \sin 2(\beta + \phi_{B_d}) \]
\[ A_{SL}^q = \text{Im} \left( \Gamma_{12}^q / A_q \right) \]

\[ \varepsilon_K = C_{\varepsilon} \varepsilon_K^{SM} \]
\[ A_{CP}^{B_s \rightarrow J/\psi \phi} \sim \sin 2(-\beta_s + \Phi_{B_s}) \]
\[ \Delta \Gamma_{q}^{q/\Delta m_q} = \text{Re} \left( \Gamma_{12}^q / A_q \right) \]
NP analysis results

\[ \bar{\rho} = 0.154 \pm 0.029 \]
\[ \bar{\eta} = 0.377 \pm 0.029 \]

SM is
\[ \bar{\rho} = 0.151 \pm 0.014 \]
\[ \bar{\eta} = 0.342 \pm 0.013 \]
NP parameter results

\[ A_q = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_{q}^{SM}} \]

\[ A_q = \left( 1 + \frac{A_q^{NP}}{A_q^{SM}} e^{2i(\phi_{q}^{NP} - \phi_{q}^{SM})} \right) A_q^{SM} e^{2i\phi_{q}^{SM}} \]

\[ C_{B_d} = 1.08 \pm 0.13 \]
\[ \phi_{B_d} = (-3.0 \pm 1.9)^\circ \]

\[ C_{B_s} = 1.12 \pm 0.10 \]
\[ \phi_{B_s} = (0.4 \pm 0.9)^\circ \]

Ratio of NP/SM amplitudes is:
\[ < 20\% @68\% \]
\[ (40\% @95\%) \]
in \( B_d \) mixing
\[ < 25\% @68\% \]
\[ (30\% @95\%) \]
in \( B_s \) mixing

dark: 68%
light: 95%
SM: red cross
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

\[ C_i(\Lambda) = \frac{F_i}{\Lambda^2} \]

\[ \mathcal{H}_{\text{eff}}^{\Delta B=2} = \sum_{i=1}^{5} C_i Q_i^{bq} + \sum_{i=1}^{3} \tilde{C}_i \tilde{Q}_i^{bq} \]

\[ Q_1^{q_i q_j} = \bar{q}^\alpha_{jL} \gamma_\mu q^\alpha_{iL} \bar{q}^\beta_{jL} \gamma^\mu q^\beta_{iL}, \]
\[ Q_2^{q_i q_j} = \bar{q}^\alpha_{jR} q^\alpha_{iL} \bar{q}^\beta_{jR} q^\beta_{iL}, \]
\[ Q_3^{q_i q_j} = \bar{q}^\alpha_{jR} q^\beta_{iL} \bar{q}^\beta_{jR} q^\alpha_{iL}, \]
\[ Q_4^{q_i q_j} = \bar{q}^\alpha_{jR} q^\alpha_{iL} \bar{q}^\beta_{jL} q^\beta_{iR}, \]
\[ Q_5^{q_i q_j} = \bar{q}^\alpha_{jR} q^\beta_{iL} \bar{q}^\beta_{jL} q^\alpha_{iR}. \]
The dependence of $C$ on $\Lambda$ changes depending on the flavour structure. We can consider different flavour scenarios:

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

$F$ is the flavour coupling and so $F_{SM}$ is the combination of CKM factors for the considered process.
results from the Wilson coefficients

**Generic:** \( C(\Lambda) = \alpha / \Lambda^2, \)

\( F_i \sim 1, \) arbitrary phase

\[ \alpha \sim 1 \] for strongly coupled NP

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

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

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

**NMFV:** \( C(\Lambda) = \alpha \times |F_{SM}| / \Lambda^2, \)

\( F_i \sim |F_{SM}|, \) arbitrary phase

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

\( \Lambda > 1.14 \) TeV

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

\( \Lambda > 3.4 \) TeV

for lower bound for loop-mediated contributions,
simply multiply by \( \alpha_s (\sim 0.1) \) or by \( \alpha_W (\sim 0.03). \)
Look at the near future

**future I** scenario:
errors from
Belle II at 5/ab
+ LHCb at 10/fb

\[
\begin{align*}
\varrho &= \pm 0.015 \\
\eta &= \pm 0.015 \\
\bar{\varrho} &= 0.154 \pm 0.015 \\
\bar{\eta} &= 0.346 \pm 0.013 \\
\end{align*}
\]

**current sensitivity**
\[
\begin{align*}
\bar{\varrho} &= 0.150 \pm 0.027 \\
\bar{\eta} &= 0.363 \pm 0.025 \\
\end{align*}
\]

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conclusions

- SM analysis displays very good overall consistency
- Still open discussion on semileptonic inclusive vs exclusive
- UTA provides determination of NP contributions to $\Delta F=2$ amplitudes. It currently leaves space for NP at the level of 25-40%
- So the scale analysis points to high scales for the generic scenario and at the limit of LHC reach for weak coupling. Indirect searches are complementary to direct searches.
- Even if we don't see relevant deviations in the down sector, the up sector is still very much open.
Back up slides
Updates from UTfit

www.utfit.org


Other UT analyses exist, by:
CKMfitter (http://ckmfitter.in2p3.fr/),
Laiho&Lunghi&Van de Water (http://latticeaverages.org/)
Lunghi&Soni (1010.6069)
CKM matrix and its parameters

\[ W^+ \xrightarrow{V_{ij}} V \]
\[ q_i = u, c, t \]
\[ q_j = \bar{d}, \bar{s}, \bar{b} \]

\[ V = \begin{pmatrix}
1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\bar{\rho} - i\bar{\eta}) \\
-\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\
A\lambda^3(1 - \bar{\rho} - i\bar{\eta}) & -A\lambda^2 & 1
\end{pmatrix} \]

where here we use the Buras correction to the Wolfenstein parametrisation

\[ \bar{\rho} = \rho \left(1 - \frac{\lambda^2}{2}\right) \]
\[ \bar{\eta} = \eta \left(1 - \frac{\lambda^2}{2}\right) \]

\[ A = 0.831 \pm 0.013, \quad \lambda = 0.22510 \pm 0.00064 \]
$$\sin 2\alpha \ (\phi_2) \text{ from charmless } B \text{ decays: } \pi\pi, \rho\rho, \pi\rho$$

$$\pi^0\pi^0 \text{ from Belle at CKM14}$$

to be updated soon (\?)

$$\text{BR}(\pi^0\pi^0) = (1.17 \pm 0.13) \times 10^{-6}$$

HFAG 2014

a à la PDG average would give
an inflated uncertainty of 0.41

$$\rho^+\rho^- \text{ average updated including}$$

Belle arXiv:1510.01245

$$\rho^0\rho^0 \text{ average updated including}$$

LHCb arXiv:1503.07770

$$\alpha \text{ from } \pi\pi, \rho\rho, \pi\rho \text{ decays:}$$

combined: $$(94.2 \pm 4.5)^\circ$$

UTfit prediction: $$(90.6 \pm 2.5)^\circ$$
(γ and DK trees)

After a decade of analyses and almost 50 papers published, the world average uncertainty has decreased by a factor 3 combined: $\left(70.5 \pm 5.7\right)^\circ$

UTfit prediction: $\left(65.5 \pm 2.1\right)^\circ$
some old plots coming back to fashion:

As NA62 and KOTO are approaching data taking:

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu})$$

2007 global fit area

- **E949 central value**
- **projection**
  - 100 events
- **SM central value**
  - **projection**
  - 100 events

2007 global fit area

- **7 events**
- Including
  - $$BR(K^0 \rightarrow \pi^0 \nu \bar{\nu})$$
  - **SM central value**
Updates from UTfit

some new extra results @CKM16: a lay(wo)man’s visualisation..

new BaBar result for inclusive $V_{ub}$ @Kowalewski on Tue in WG2
Updates from UTfit

\[ \sin^2 \alpha (\phi_2) \] from charmless B decays: pp, (\(\rho\rho\), \(\pi\rho\))

\[ \alpha \text{ from } \pi\pi, \rho\rho, \pi\rho \text{ decays: combined: } (94.2 \pm 4.5)^\circ \]

\[ \text{BR}(\pi^0\pi^0) = (1.17 \pm 0.13) \times 10^{-6} \]

given as a la PDG average giving an inflated uncertainty of 0.41
Unitarity Triangle analysis in the SM:

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<th>Pull (#σ)</th>
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</thead>
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<tr>
<td>$B_K$</td>
<td>$0.740 \pm 0.029$</td>
<td>$0.81 \pm 0.07$</td>
<td>$&lt; 1$</td>
</tr>
<tr>
<td>$f_{B_s}$</td>
<td>$0.226 \pm 0.005$</td>
<td>$0.220 \pm 0.007$</td>
<td>$&lt; 1$</td>
</tr>
<tr>
<td>$f_{B_s}/f_{B_d}$</td>
<td>$1.203 \pm 0.013$</td>
<td>$1.210 \pm 0.030$</td>
<td>$&lt; 1$</td>
</tr>
<tr>
<td>$B_{B_s}/B_{B_d}$</td>
<td>$1.032 \pm 0.036$</td>
<td>$1.07 \pm 0.05$</td>
<td>$&lt; 1$</td>
</tr>
<tr>
<td>$B_{B_s}$</td>
<td>$1.35 \pm 0.08$</td>
<td>$1.30 \pm 0.07$</td>
<td>$&lt; 1$</td>
</tr>
</tbody>
</table>

in general: average the Nf=2+1+1 and Nf=2+1 FLAG averages, through eq.(28) in arXiv:1403.4504

for $B_K$, $f_{B_s}$, $f_{B_s}/f_{B_d}$:

FLAG Nf=2+1+1 (single result) and Nf=2+1 average

for $B_{B_s}$, $B_{B_s}/B_{B_d}$:

update w.r.t. the Nf=2+1 FLAG average (no Nf=2+1+1 results yet)

updating the FNAL/MILC result to FNAL/MILC 2016 (1602.03560)

summer 2016

obtained excluding the given constraint from the fit
new-physics-specific constraints

\[ A_{SL}^s \equiv \frac{\Gamma(B_s \rightarrow \ell^+ X) - \Gamma(B_s \rightarrow \ell^- X)}{\Gamma(B_s \rightarrow \ell^+ X) + \Gamma(B_s \rightarrow \ell^- X)} = \text{Im} \left( \frac{\Gamma_{12}^s}{A_{full}^s} \right) \]

**semileptonic asymmetries in B^0 and B_s:** sensitive to NP effects in both size and phase. Currently using a 2D average done by LHCb in 1605.09768 (pre-ICHEP16 value).

**same-side dilepton charge asymmetry:** admixture of B_s and B_d so sensitive to NP effects in both.

\[ A_{\mu\mu}^{s} \times 10^3 = -7.9 \pm 2.0 \]

**lifetime \( \tau^{FS} \) in flavour-specific final states:** average lifetime is a function to the width and the width difference

\[ \tau^{FS}(B_s) = 1.511 \pm 0.014 \text{ ps} \]

**\( \phi_s = 2\beta_s \) vs \( \Delta \Gamma_s \) from B_s → J/\psi\phi**

angular analysis as a function of proper time and b-tagging

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NP parameter results

dark: 68%
light: 95%
SM: red cross

\[ A_q = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi^{SM}_{q}} \]

\( C_{B_d} = 1.04 \pm 0.12 \)
(\( \phi_{B_d} = (-1.8 \pm 1.7)^\circ \))

\( C_{B_s} = 1.07 \pm 0.09 \)
(\( \phi_{B_s} = (0.1 \pm 1.0)^\circ \))

K system

\( C_{eK} = 1.05 \pm 0.11 \)
The ratio of NP/SM amplitudes is:

- $< 15\%$ @68% prob. (30\% @95\%) in $B_d$ mixing
- $< 15\%$ @68% prob. (25\% @95\%) in $B_s$ mixing

see also Lunghi & Soni, Buras et al., Ligeti et al.
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
The Wilson coefficients $C_i$ have in general the form

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

function of the NP flavour couplings

$F_i$: loop factor (in NP models with no tree-level FCNC)

$L_i$: 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 $L_i$. 
Results from the Wilson coefficients

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

$\alpha \sim 1$ 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

$\Lambda > 1.5 \times 10^4$ TeV

Best bound from $\epsilon_K$
dominated by CKM error

CPV in charm mixing follows,
exp error dominant

Best CP conserving from $\Delta m_K$,
dominated by long distance

$B_d$ and $B_s$ behind,
errors from both CKM and B-parameters

Non-perturbative NP

$\Lambda > 5.0 \times 10^5$ TeV
Non-perturbative NP
\[ \Lambda > 114 \text{ TeV} \]

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

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

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

\( \Lambda > 3.4 \) TeV

If new chiral structures present, \( \varepsilon_K \) still leading

\( B_s \) mixing provides very stringent constraints, especially if no new chiral structures are present

Constraining power of the various sectors depends on unknown NP flavour structure.