Testing New Physics with the Unitarity Triangle Fit


Recent papers:
M. Bona et al. hep-ph/0509219 in publication

http://www.utfit.org
Total Fit

\[ \Delta m_d, \Delta m_s, V_{ub}, V_{cb}, \varepsilon_k + \cos2\beta + \beta + \alpha + \gamma + 2\beta+\gamma \]

\[ \eta = 0.342 \pm 0.022 \]
\[ [0.300, 0.385] \text{ @ 95\% Prob.} \]

\[ \bar{\rho} = 0.216 \pm 0.036 \]
\[ [0.143, 0.288] \text{ @ 95\% Prob.} \]
$\rho = 0.224 \pm 0.042$
$[0.136, 0.306] \text{ @ 95\% Prob.}$

$\eta = 0.381 \pm 0.030$
$[0.320, 0.437] \text{ @ 95\% Prob.}$

$\rho = 0.193 \pm 0.057$
$[0.083, 0.321] \text{ @ 95\% Prob.}$

$\eta = 0.321 \pm 0.027$
$[0.266, 0.376] \text{ @ 95\% Prob.}$
The presence of **New Physics** might appear as a **disagreement between** the new **measurements** and what the **fit predicts** (given by the color code).

α and γ (for the moment) are **OK**.

The **next validation** will come from Δm_s for the b → s sector.
Test of SM (II)

$\sin^2 \beta = 0.791 \pm 0.034$

from indirect determination

$\sin^2 \beta = 0.687 \pm 0.032$

From direct measurement

we have a weak sign of a disagreement

$\sin^2 \beta = 0.687 \pm 0.032$

From direct measurement

$\sin^2 \beta = 0.791 \pm 0.034$

from indirect determination
Tension in the fit

exclusive: BRs from HFAG;
form factor from quenched LQCD

$V_{ub} = (3.80 \pm 0.27 \pm 0.47) \times 10^{-3}$

inclusive from HFAG
$V_{ub} = (4.38 \pm 0.19 \pm 0.27) \times 10^{-3}$

incl.+excl.
$V_{ub} = (4.22 \pm 0.20) \times 10^{-3}$

from all the other inputs:
$V_{ub} = (3.48 \pm 0.20) \times 10^{-3}$

It can be interpreted as a problem with data, but it could be evidence of New Physics.
Where do we really are on our knowledge of UT?

Fit with NP independent variables

Fit in a NP model independent approach
Fit with NP independent variables

If we use only Tree level processes -which can be assumed to be NP free-

<table>
<thead>
<tr>
<th>$\bar{\rho}$</th>
<th>$\pm (0.18 \pm 0.11)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{\eta}$</td>
<td>$\pm (0.41 \pm 0.05)$</td>
</tr>
</tbody>
</table>

(similar plot in Botella et al. hep-ph/0502133)
Fit in a NP model independent approach

Parametrizing NP physics in $\Delta F=2$ processes

$$C_q e^{2i\phi_d} = \frac{Q^{NP}_{\Delta B=2} + Q^{SM}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}$$

$\Delta m_d^{EXP} = C_q \Delta m_d^{SM}$

$A_{CP}(J/\Psi K^0) = \sin(2\beta + 2\phi_d)$

$\alpha^{EXP} = \alpha^{SM} - \phi_d$

$|\epsilon_K|^{EXP} = C_\epsilon |\epsilon_K|^{SM}$

Soares, Wolfenstein PRD47;
Deshpande,Dutta, Oh PRL77;
Silva, Wolfenstein PRD55;
Cohen et al. PRL78;
Grossman, Nir, Worah PLB407;
Ciuchini et al. @ CKM Durham

<table>
<thead>
<tr>
<th>Constraints</th>
<th>$\rho, \eta$</th>
<th>$C_d, \phi_d$</th>
<th>$C_\epsilon K$</th>
<th>$C_s, \phi_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{ub}/V_{cb}$</td>
<td>X</td>
<td></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>$\epsilon_K$</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>ACP $(J/\Psi K)$</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha (\rho \rho, \rho \pi, \pi \pi)$</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\gamma (D K)$</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta m_s$</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ACP $(J/\Psi \phi)$</td>
<td>~X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>$\gamma (D_s K)$</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

5 new free parameters
$C_s, \phi_s$ $B_s$ mixing
$C_d, \phi_d$ $B_d$ mixing
$C_\epsilon K$ $K$ mixing

Not yet available

Today: fit possible with 6 contraints and 5 free parameters $(\rho, \eta, C_d, \phi_d, C_\epsilon K)$
Using

\[ \frac{V_{ub}}{V_{cb}}, \quad \Delta m_d, \quad ACP (J/\Psi K), \quad \gamma (DK), \quad \varepsilon_K \]

\[ \alpha \cos 2\beta \quad A_{SL} \]

\[ A_{SL} \equiv \frac{\Gamma(\bar{B}^0 \to \ell^+ X) - \Gamma(\bar{B}^0 \to \ell^- X)}{\Gamma(\bar{B}^0 \to \ell^+ X) + \Gamma(\bar{B}^0 \to \ell^- X)} \]

SM-like solution 96%

NP solution 4%

large NP with arbitrary phase

SM or small NP with arbitrary phase or large NP with SM phase.

Laplace et al., PRD65. NLO effects included
NP in $\Delta B=2$ and $\Delta S=2$ could be up to 50% wrt SM only if has the same phase of the SM
$C_{B_d}e^{2i\phi_{B_d}} = \frac{A_{SM}e^{2i\beta} + A_{NP}e^{2i(\beta+\phi_{NP})}}{A_{SM}e^{2i\beta}}$

With present data $A_{NP}/A_{SM} \neq 0 @ 1\sigma$

$A_{NP}/A_{SM} \sim 1$ only if $\phi_{NP} \sim 0$

$A_{NP}/A_{SM} \sim 0-40% @ 95\%$ prob.

Sensitive to small effects

**Artificially** removing the present disagreement

$\sim 20\% @ 95\%$ prob for generic $\phi_{NP}$
TWO POSSIBLE SCENARIOS

MFV

New CP in $b \to s$

What to do?

- Improvements existing measurements

- Rare decays (not discussed in this talk)

- $\Delta F=1$ Penguins transitions (not discussed in this talk)

- The $B_s$ physics (LHCb/Tevatron)
MFV = CKM is the only source of flavour mixing. $\varepsilon_K$ and $\Delta m_d$ are not used (sensitive to NP).

Almost as good as the SM!!

Starting point for studies of rare decays see for instance: Bobeth et al. hep-ph/0505110
In models with one Higgs doublet or low/moderate tan$\beta$
(D’Ambrosio et al. hep-ph/0207036)
NP enters as additional contribution in top box diagram

$$S_0(x_t) \rightarrow S_0(x_t) + \delta S_0(x_t)$$

$$\delta S_0(x_t) = 4a \left( \frac{\Lambda_0}{\Lambda} \right)^2 \quad \Lambda_0 = 2.4TeV$$

$\Lambda_0$ is the equivalent SM scale

$\Lambda_0 > 5.1TeV \quad @95\% \quad \text{for positive } \delta S(x_t)$

$\Lambda_0 > 3.6TeV \quad @95\% \quad \text{for negative } \delta S(x_t)$

$$\Lambda / \Lambda_0 \sim 2$$

To be compared with tested scale using for instance $b \rightarrow s\gamma (9-12TeV)$
D’Ambrosio et al. hep-ph/0207036
2Higgs + large $\tan\beta$ → also bottom Yukawa coupling must be considered

$\delta S^B_0 \neq \delta S^K_0$

Could give information on the $\tan\beta$ regime …not yet at the present

\[ \Lambda > 2.6 \text{ TeV} @ 95\% \text{ for } \delta S_0(x_t) > 0 \]
\[ \Lambda > 4.9 \text{ TeV} @ 95\% \text{ for } \delta S_0(x_t) < 0 \]

Correlation coefficient = 0.52
CKM Matrix in ≤2010-where we will be

We have supposed that
- **B Factories** will collect 2ab⁻¹
- two years data taking at LHCb (4fb⁻¹)

\[
\begin{align*}
\beta &< 1^\circ & \text{from charmonium} \\
\alpha &\sim 7^\circ \\
\gamma &\sim 5^\circ \\
\end{align*}
\]

(half B-factories/half LHCb)

\[
\begin{align*}
V_{ub} &\sim 5\% \\
V_{cb} &\sim 1\% \\
\Delta m_s &\text{ at } 0.3\text{ps}^{-1} \\
&\text{(Tevatron or/and LHCb)} \\
f_B \sqrt{B_B} &\sim 5\% \\
\xi &\sim 3\% \\
B_K &\sim 5\% \\
\end{align*}
\]

\[\sin 2\chi \pm 0.045\]

**Inputs**

\[
\begin{align*}
\rho &\sim 0.307 \pm 0.010 \\
\eta &\sim 0.694 \pm 0.012 \\
\gamma &\sim 51.7 \pm 3.0 \\
\end{align*}
\]

**Outputs**
In the « sad » hypothesis the SM still work in 2010….

\[ \phi_{B_d} = (-0.1 \pm 1.3)^\circ \]
\[ C_{B_d} = 0.98 \pm 0.14 \]
\[ \phi_{B_s} = (0.0 \pm 1.3)^\circ \]
\[ C_{B_s} = 0.99 \pm 0.12 \]

VERY IMPORTANT in \( \leq 2010 \): same and impressive precision on \( b \to d \) and \( b \to s \) transitions
**Conclusions**

UTfits are in a mature age with recent precise measurement of UT sides and angles.

The SM CKM picture of CP violation and FCNC is strongly supported by data.

Generic NP in the $b \rightarrow d$ start to be quite constrained.

At least in this sector, we are beyond the alternative to CKM picture, and we should look at « corrections ». 
Studied predented in MFV. We start to test interesting NP scales.

We need precision measurements to test NP and to push the NP scale in interesting ranges and to play the complementarity at LHC.

What about the $b \to s \Delta B=2$ sector? Still large room for NP. LHCb plays the central role on it.
and if SuperB.....

Plots from preliminary work from M.Pierini, M.Ciuchini....
BACKUP SLIDES
Next Step: Rare Decays (I)

\[ B \rightarrow \tau \nu \]

Assuming \( f_B \):

\[ \text{Constraint on } R_B = \rho^2 + \eta^2 \]

\[ R_B = 0.37 \pm 0.13 \]

\[ \mathcal{B}(B \rightarrow \ell \nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi} \left( 1 - \frac{m_\ell^2}{m_B^2} \right)^2 f_B^2 |V_{ub}|^2 \tau_B \]

< 1.8 \times 10^{-4} \text{ @ 90\% CL}
Next Step: Rare Decays (II)

\[ \frac{\text{BR}(B \to \rho \gamma)}{\text{BR}(B \to K^* \gamma)} \]

\[ R = \frac{c^2_{\rho} \tau_m}{\xi^2} \frac{|a^c_{\tau}(\rho \gamma)|^2}{|a^c_{\tau}(K^* \gamma)|^2} \frac{|V_{td}|^2}{|V_{ts}|^2} (1 + \Delta R) \]

caveat: * SU(3) breaking effect
  * $\Lambda_{QCD}/m_b$ corrections $B(\sim \cos \alpha)$ to $\rho/\omega \gamma$
    (smaller for $B^0$ than $B^+$)

$|V_{td}/V_{ts}| = 0.10 \pm 0.45$

[0.02, 0.18] @ 95% Prob.

Using the $|V_{td}/V_{ts}|$ value from the SM, we can extract $\Delta R$.

\[ \Delta R = -0.67 \pm 0.24 \]

[-0.99, 0.10] @ 95%
Next Step: Rare Decays (III)

\[ K^\pm \rightarrow \pi^\pm \nu\bar{\nu} \]

\[
\left( \sigma \eta \right)^2 + \left( \bar{\rho} - \bar{\rho}_0 \right)^2 = \frac{\sigma \text{BR}(K^+ \rightarrow \pi^+ \nu\bar{\nu})}{\kappa_+ |V_{cb}|^4 X^2(x_t)}
\]

ellipse centered in \((\rho^0, 0)\)

latest result from E949:

\[
\text{BR}(K^\pm \rightarrow \pi^\pm \nu\bar{\nu}) = 1.47^{+1.30}_{-0.89} \times 10^{-10}
\]

10% error with current central value (BR = 0.83 \times 10^{-10})
Using

\[ V_{ub}/V_{cb} \quad \Delta m_d \quad ACP (J/\Psi K) \quad \gamma \ (DK) \quad \varepsilon_K \]

<table>
<thead>
<tr>
<th></th>
<th>( \gamma )</th>
<th>( C_d )</th>
<th>( \cos(\beta+\phi) )</th>
<th>( \sin(\alpha-\phi) )</th>
<th>( \sin(2\beta+\phi) )</th>
<th>( A_{SL} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM-LIKE</td>
<td>60°</td>
<td>1</td>
<td>0.68</td>
<td>-0.23</td>
<td>0.96</td>
<td>OK</td>
</tr>
<tr>
<td>NP1</td>
<td>60°</td>
<td>1</td>
<td>-0.68</td>
<td>0.96</td>
<td>-0.23</td>
<td>OK</td>
</tr>
<tr>
<td>NP2</td>
<td>120°</td>
<td>0.4</td>
<td>0.68</td>
<td>-0.23</td>
<td>-0.96</td>
<td>( 10^{-2} )</td>
</tr>
<tr>
<td>NP3</td>
<td>120°</td>
<td>0.4</td>
<td>-0.68</td>
<td>0.96</td>
<td>0.23</td>
<td>0K</td>
</tr>
</tbody>
</table>

SM-like
In MFV

Now

2010

± 0.54

± 0.26