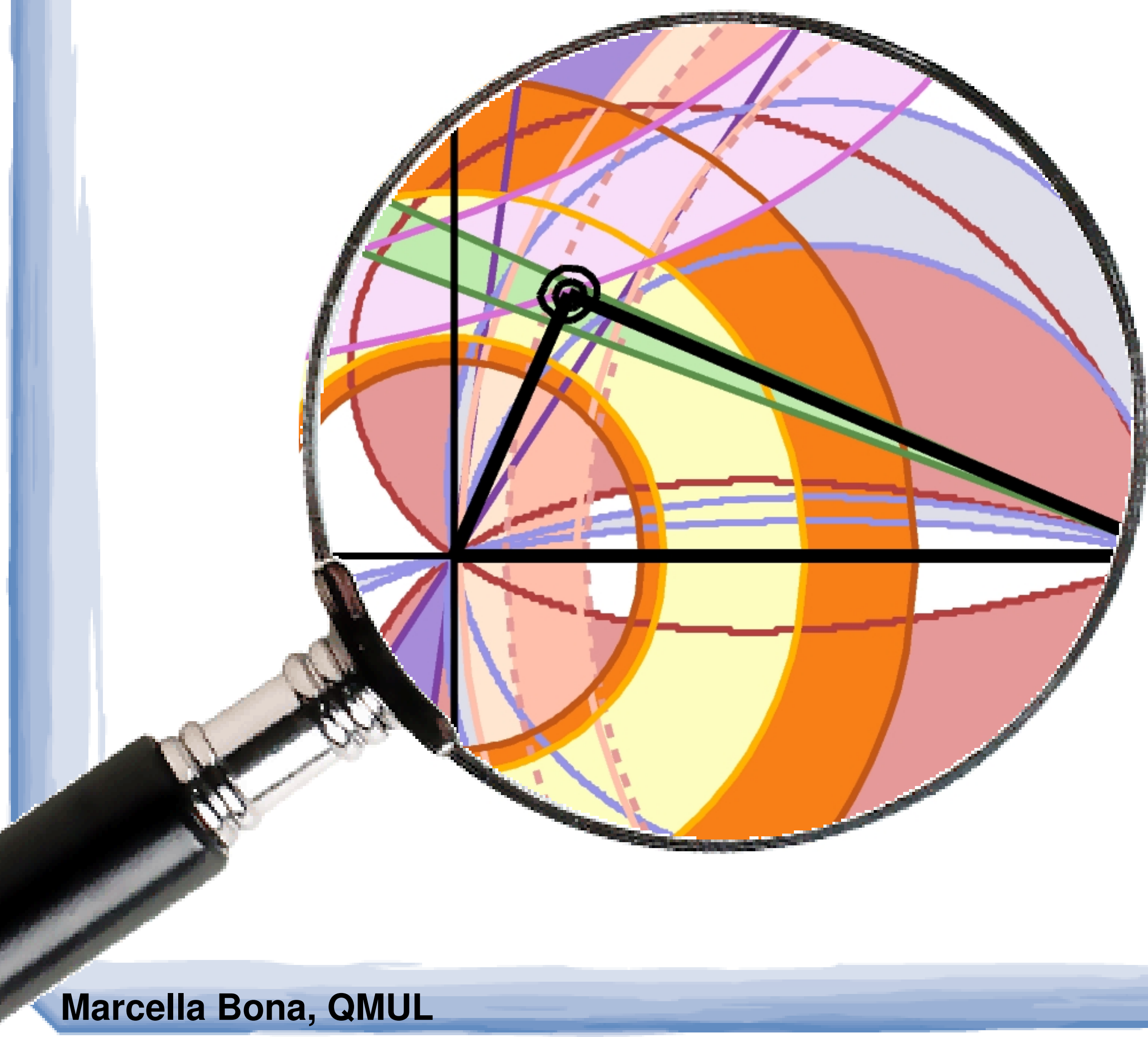
Updates from UTfit within and beyond the Standard Model



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SUSY 2013
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Trieste, Italy

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. $\sin 2\beta$, Δm_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

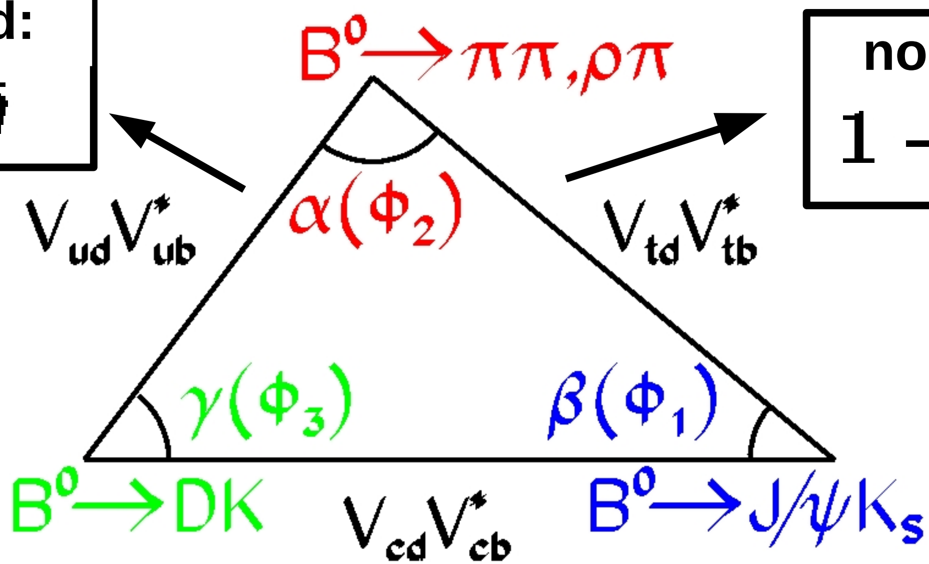
$$V_{ud}V_{ub}^{*} + V_{cd}V_{cb}^{*} + V_{td}V_{tb}^{*} = 0$$

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

$$\alpha = \pi - \beta - \gamma$$

normalized:

$$\bar{\rho} + i\bar{\eta}$$



normalized:

$$1 - \bar{\rho} - i\bar{\eta}$$

$$\gamma = atan\left(\frac{\bar{\eta}}{\bar{\rho}}\right)$$

$$\beta = atan\left(\frac{\bar{\eta}}{(1-\bar{\rho})}\right)$$

www.utfit.org

A. Bevan, M.B., M. Ciuchini, D. Derkach,
E. Franco, V. Lubicz, G. Martinelli, F. Parodi,
M. Pierini, C. Schiavi, L. Silvestrini, A. Stocchi,
V. Sordini, C. Tarantino and V. Vagnoni

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:

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

Bayes Theorem

$$X \equiv x_1,...,x_n = m_t, B_K, F_B, ...$$

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

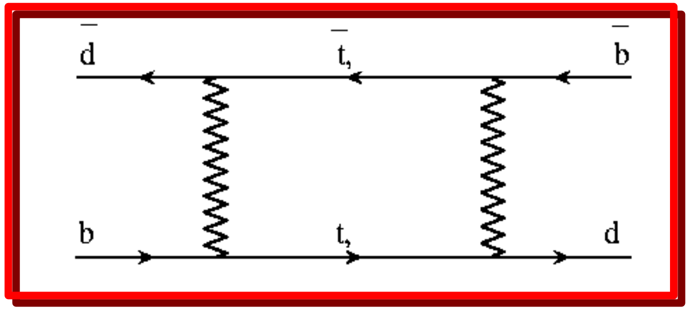
$(b\to u)/(b\to c)$	$\bar{\rho}^2+\bar{\eta}^2$	$\bar{\Lambda}, \lambda_1, F(1), \; ...$
ϵ_K	$\bar{\eta}[(1-\bar{\rho})+P]$	B_K }
Δm_d	$(1-\bar{\rho})^2+\bar{\eta}^2$	$f_B^2 B_B$
$\Delta m_d/\Delta m_s$	$(1-\bar{\rho})^2+\bar{\eta}^2$	ξ
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	

, mt

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



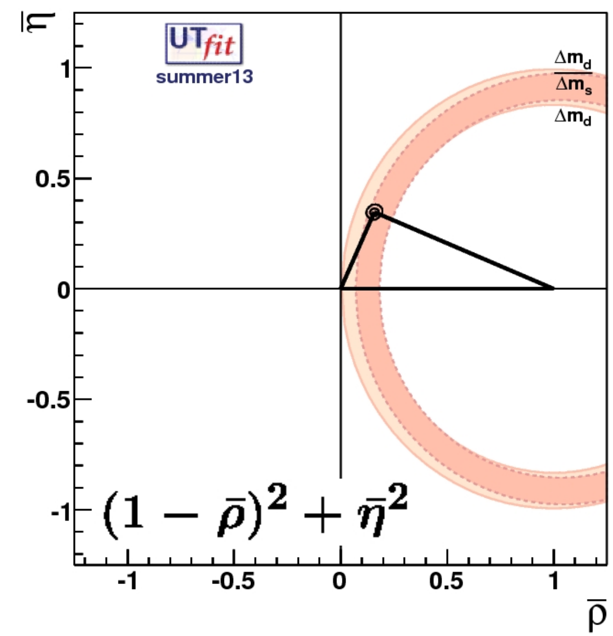
$\Delta m_d=(0.507 \pm 0.004)\ ps^{-1}$

$\Delta m_s=(17.72 \pm 0.04)\ ps^{-1}$

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

$$\Delta m_s \approx f_{B_s}^2 B_{B_s}$$

B_{B_q} and f_{B_q} from lattice QCD



$\Delta m_s / \Delta m_d$

Δm_d

B_K	0.766 ± 0.010
f_{B_s}	0.2277 ± 0.0045
f_{B_s}/f_{B_d}	1.202 ± 0.022
$\hat{B}_{B_s}$	1.33 ± 0.06
$\hat{B}_{B_s}/\hat{B}_{B_d}$	1.006 ± 0.011

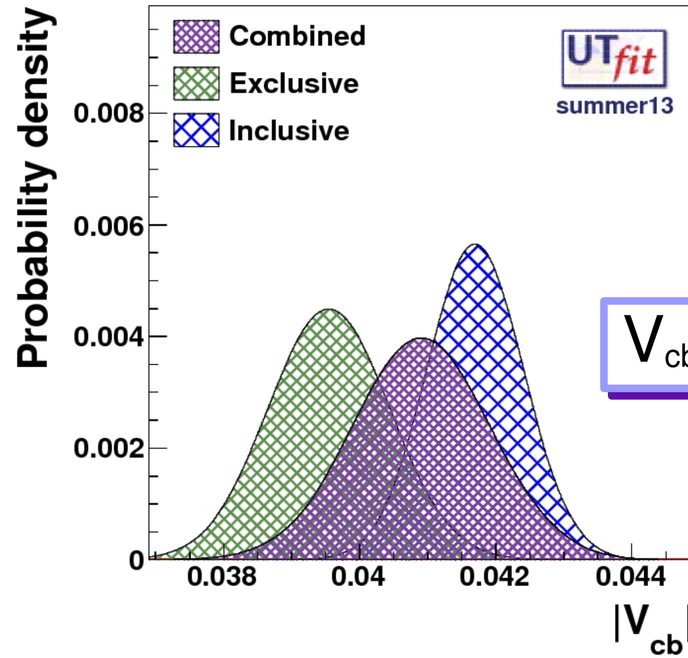
FLAG updated after Lattice'13

V_{cb} and V_{ub}

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

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

~1.9σ discrepancy



UTfit input value: average à la PDG

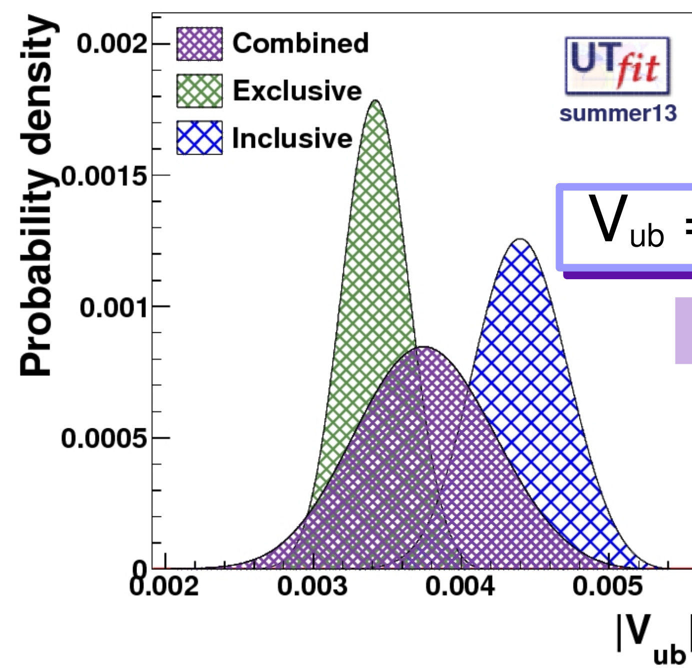
$V_{cb} = (40.9 \pm 1.0)\ 10^{-3}$

uncertainty ~ 2.4%

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

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

~2.5σ discrepancy

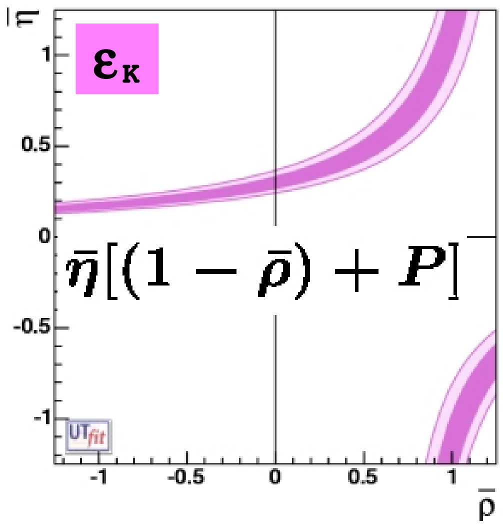


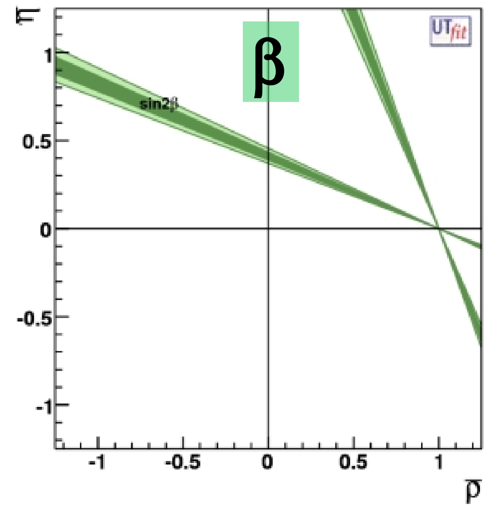
UTfit input value: average à la PDG

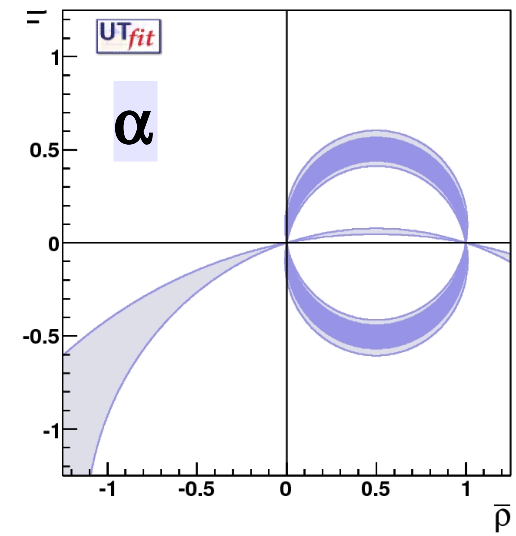
$V_{ub} = (3.75 \pm 0.46)\ 10^{-3}$

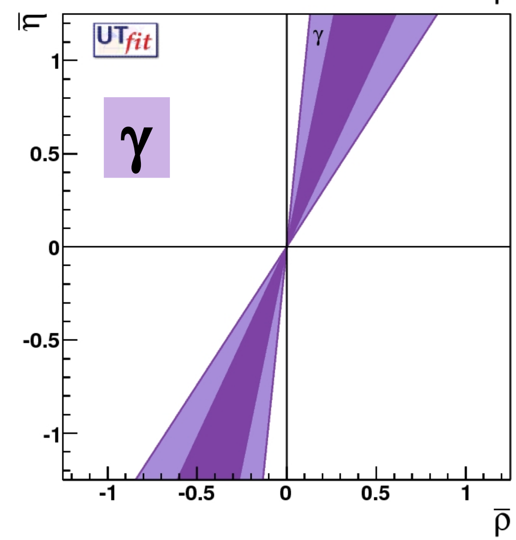
uncertainty ~ 12%

CP-violating inputs









ε_K from K-K mixing

$\rightarrow B_K = 0.766 \pm 0.010$ Lattice '13

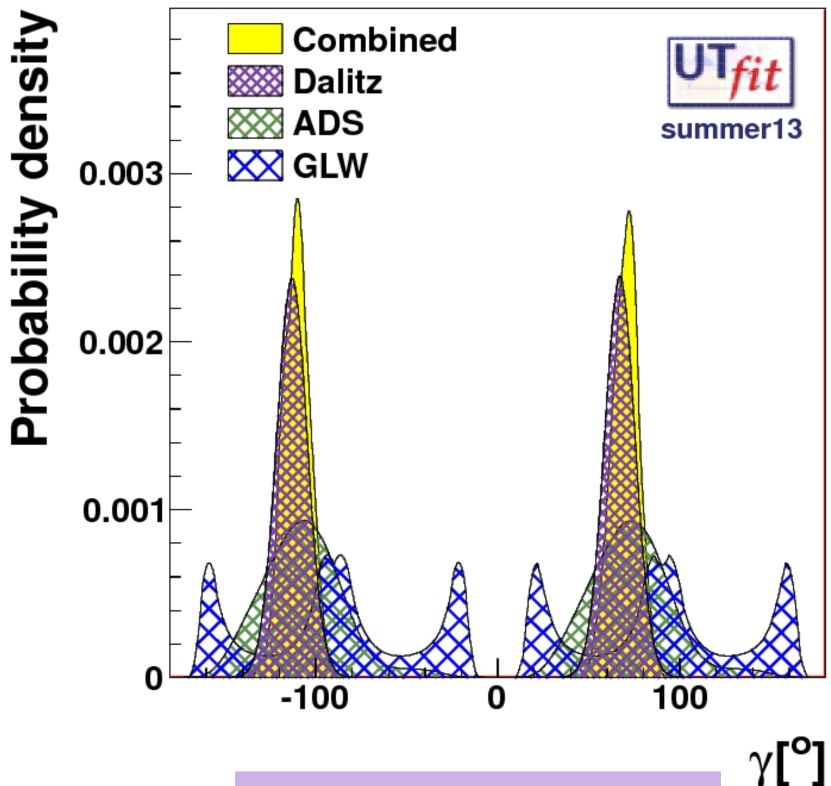
sin2β from $B \rightarrow J/\psi K^0$ + theory

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

α from ππ, ρρ, πρ decays:
combined: $(90.7 \pm 7.4)°$

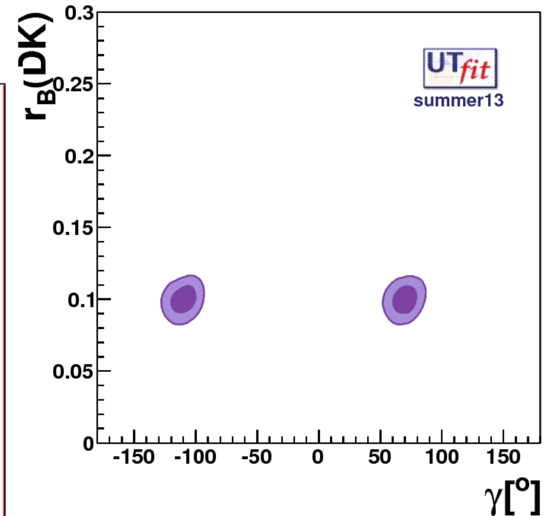
γ from $B \rightarrow DK$ decays (tree level)

γ and DK trees

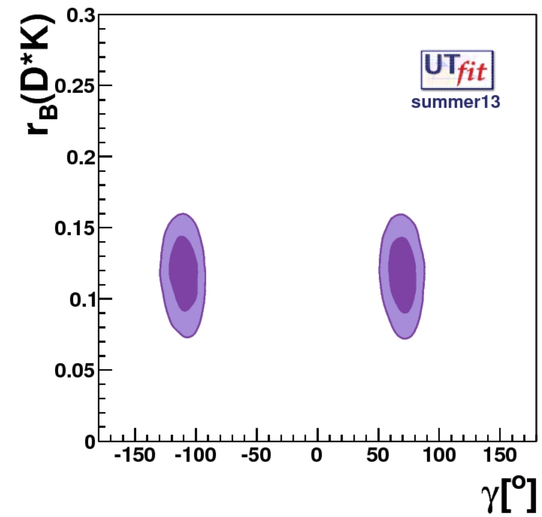


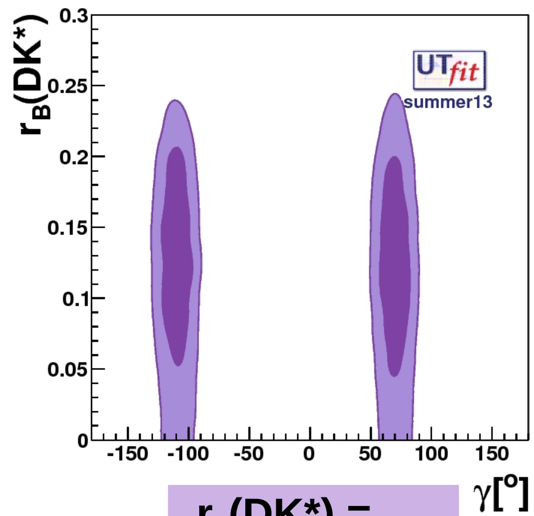
$\gamma = (70.1 \pm 7.1)^{\circ}$

$r_B(DK) = 0.0999 \pm 0.0059$



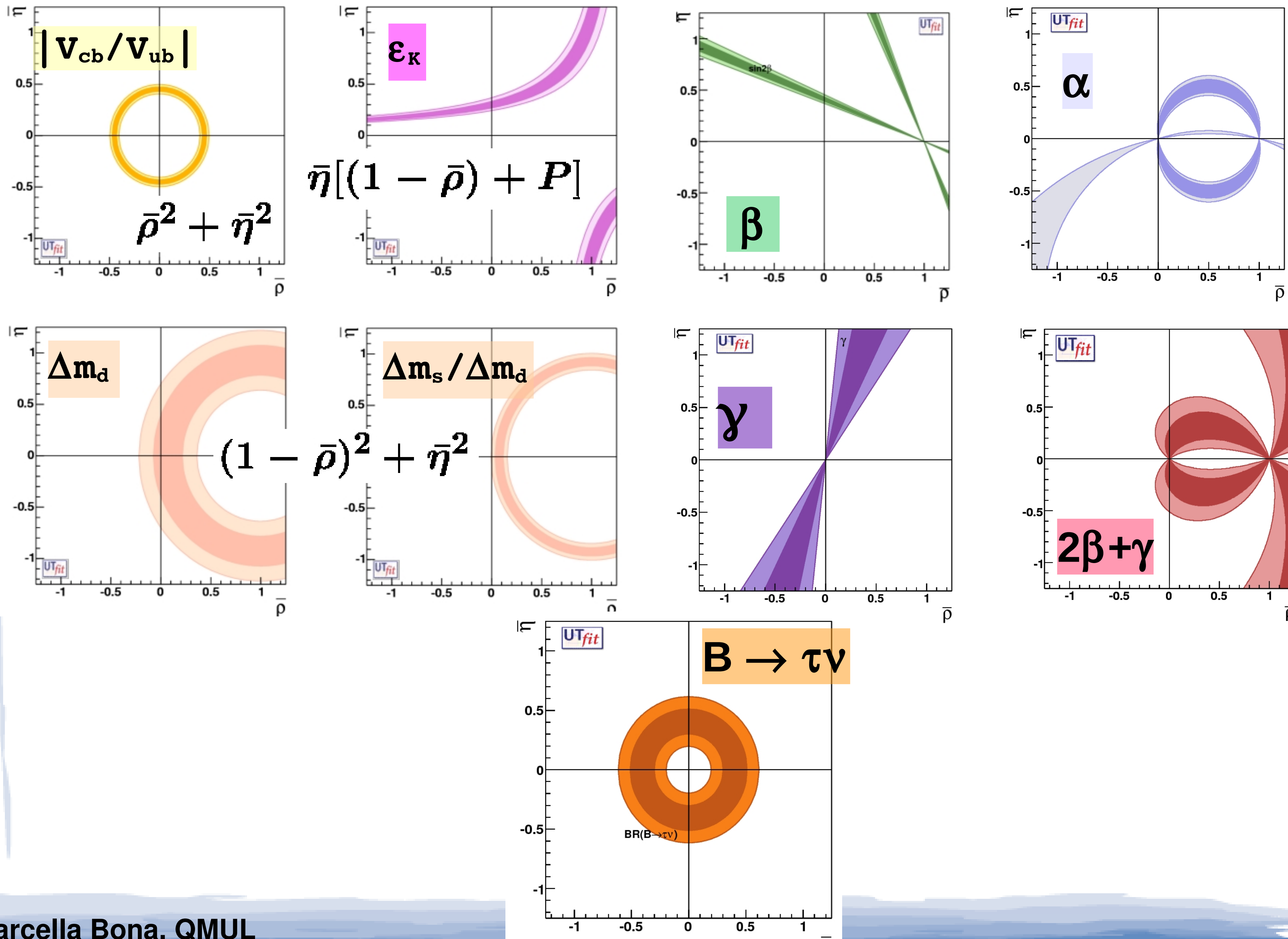
$r_B(D^*K) = 0.118 \pm 0.018$





$r_B(DK^*) = 0.130 \pm 0.057$

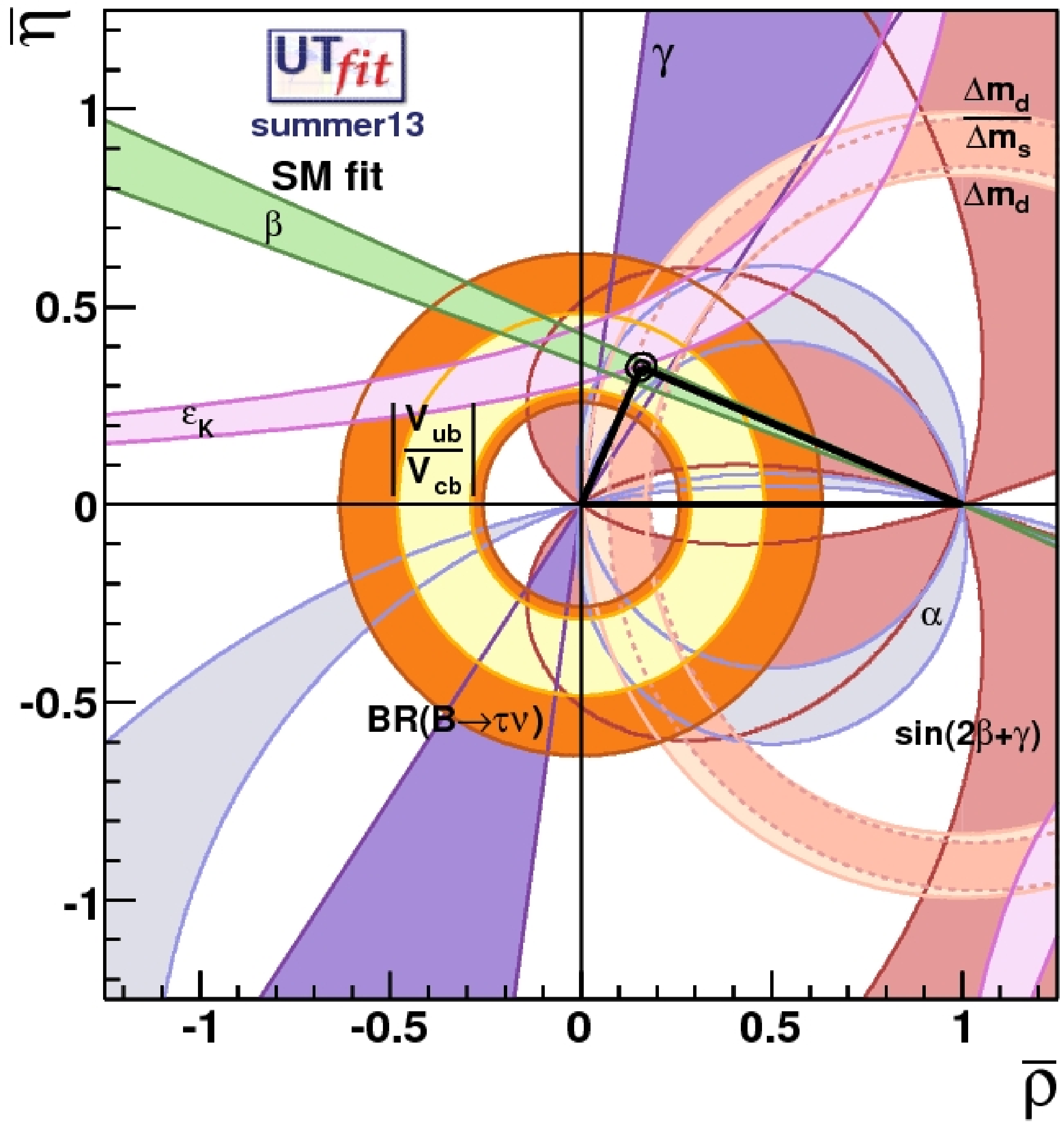
Unitarity Triangle analysis in the SM:



Unitarity Triangle analysis in the SM:

Observables	Accuracy
$\|V_{ub}/V_{cb}\|$	~ 13%
ε_K	~ 0.5%
Δm_d	~ 1%
$\|\Delta m_d/\Delta m_s\|$	~ 1%
$\sin 2\beta$	~ 3%
$\cos 2\beta$	~ 15%
α	~ 8%
γ	~ 10%
$BR(B \to \tau\nu)$	~ 19%

Unitarity Triangle analysis in the SM:

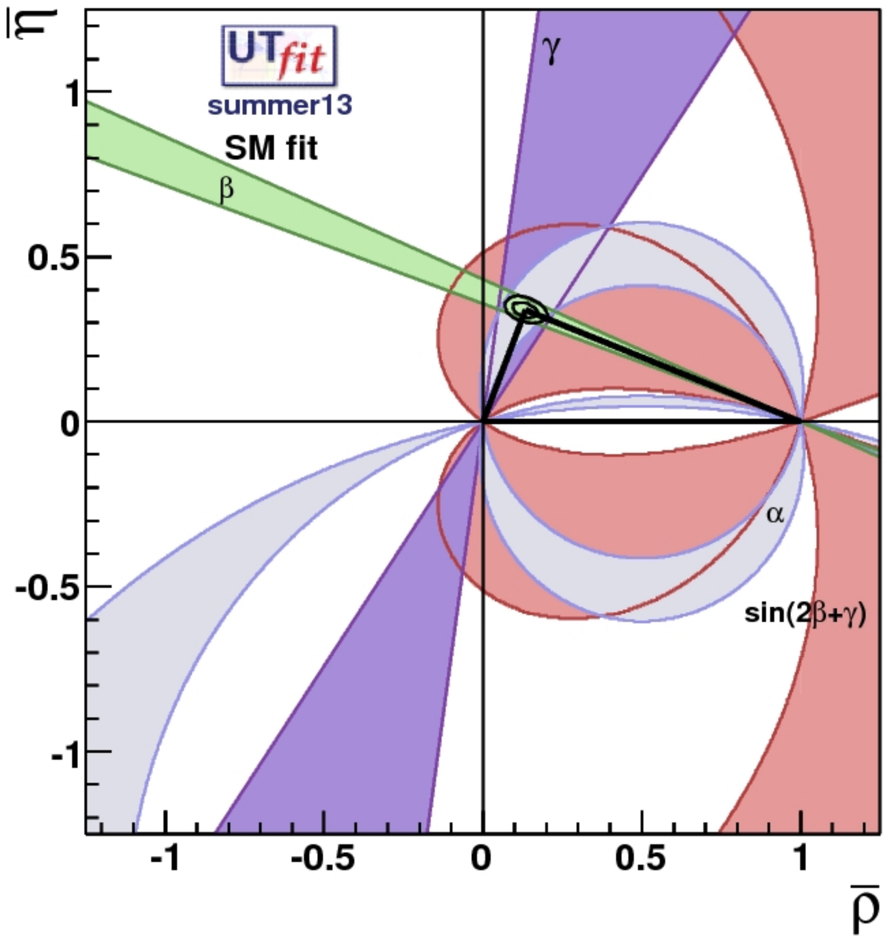


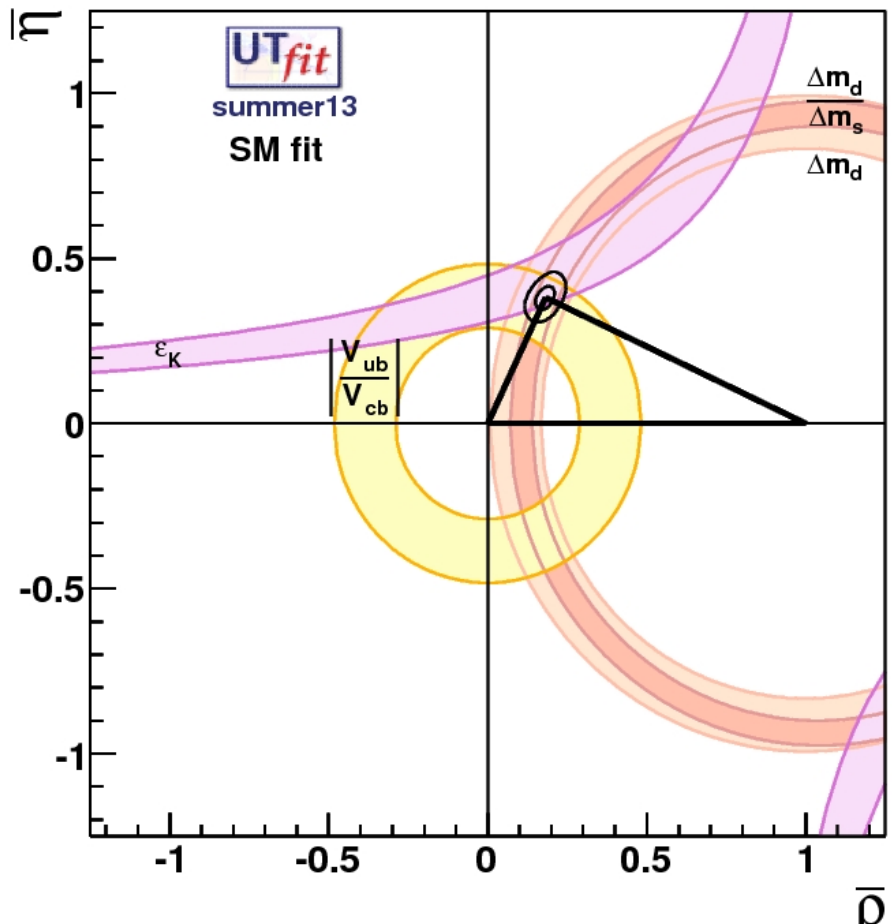
levels @
95% Prob

$\bar{\rho} = 0.159 \pm 0.015$
$\bar{\eta} = 0.346 \pm 0.013$

angles vs the others

levels @
95% Prob





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

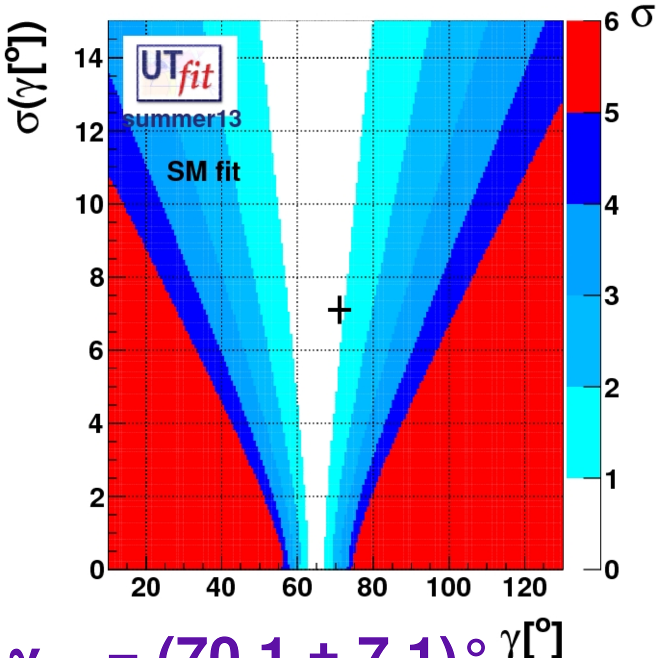
$\bar{\rho} = 0.182 \pm 0.023$
$\bar{\eta} = 0.382 \pm 0.030$

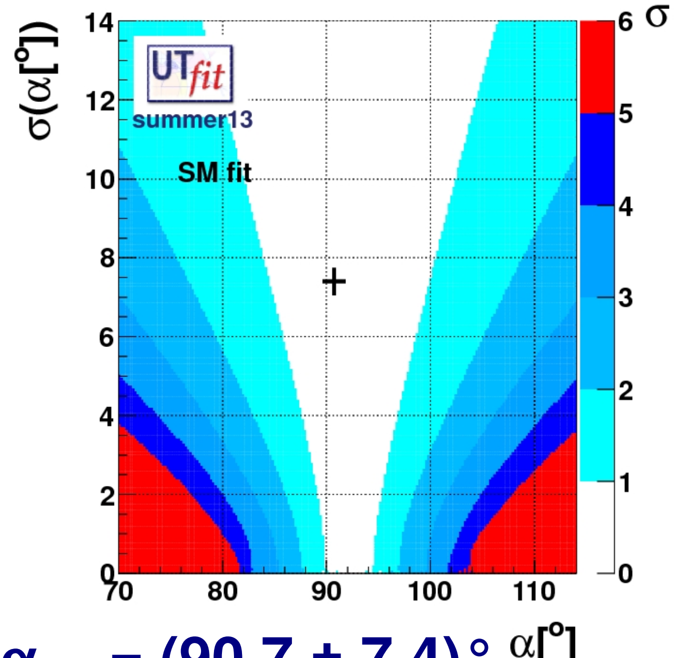
compatibility plots

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 flavor 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





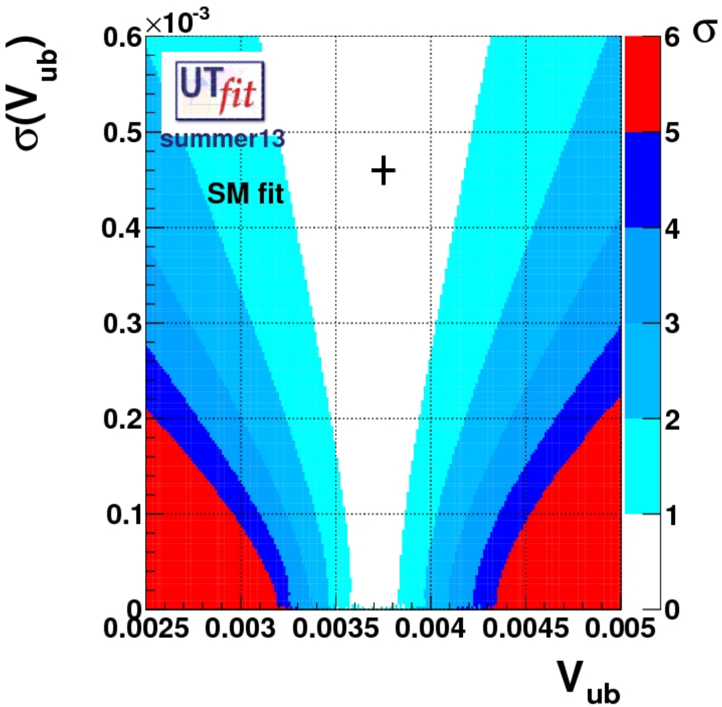
$\gamma_{exp} = (70.1 \pm 7.1)^\circ$

$\gamma_{UTfit} = (64.8 \pm 1.8)^\circ$

$\alpha_{exp} = (90.7 \pm 7.4)^\circ$

$\alpha_{UTfit} = (92.2 \pm 2.3)^\circ$

tensions



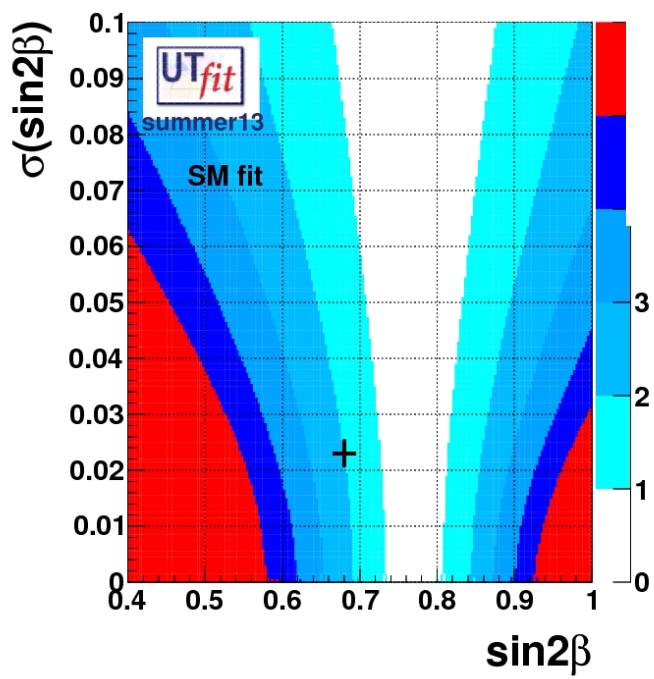
$Vub_{exp} = (3.76 \pm 0.46) \cdot 10^{-3}$

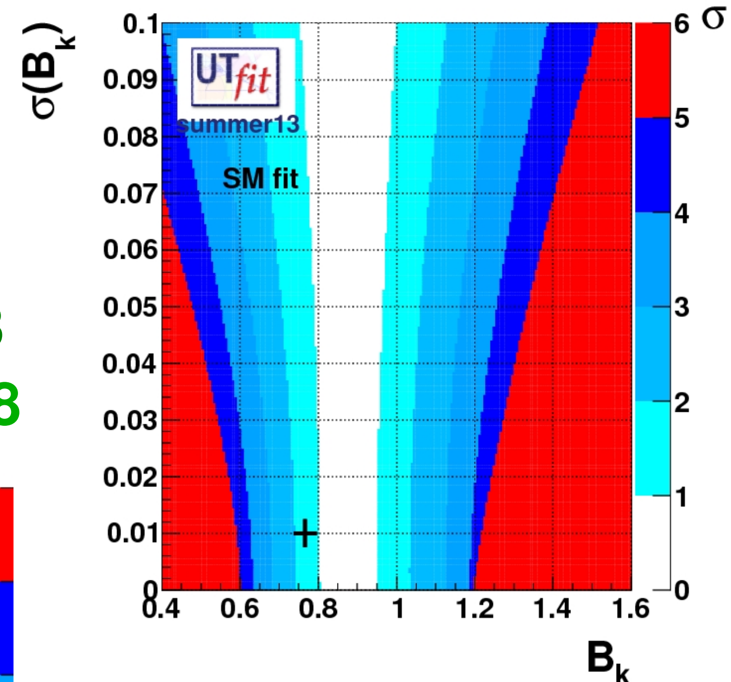
$Vub_{UTfit} = (3.70 \pm 0.12) \cdot 10^{-3}$

~2.0σ

$\sin 2\beta_{exp} = 0.680 \pm 0.023$

$\sin 2\beta_{UTfit} = 0.771 \pm 0.038$



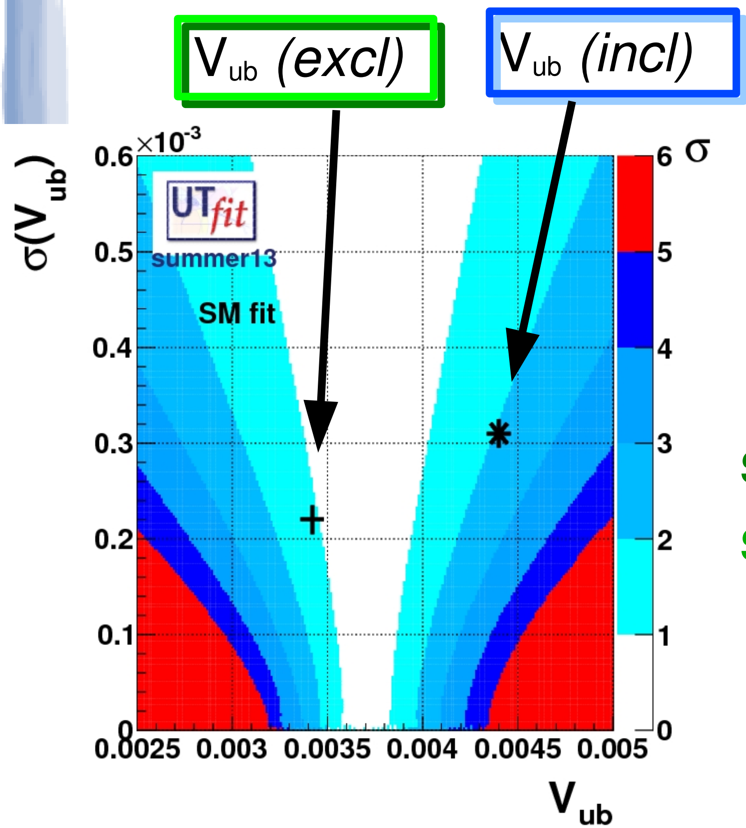


$B_{Kexp} = 0.766 \pm 0.010$

$B_{KUTfit} = 0.873 \pm 0.073$

~1.8σ

tensions



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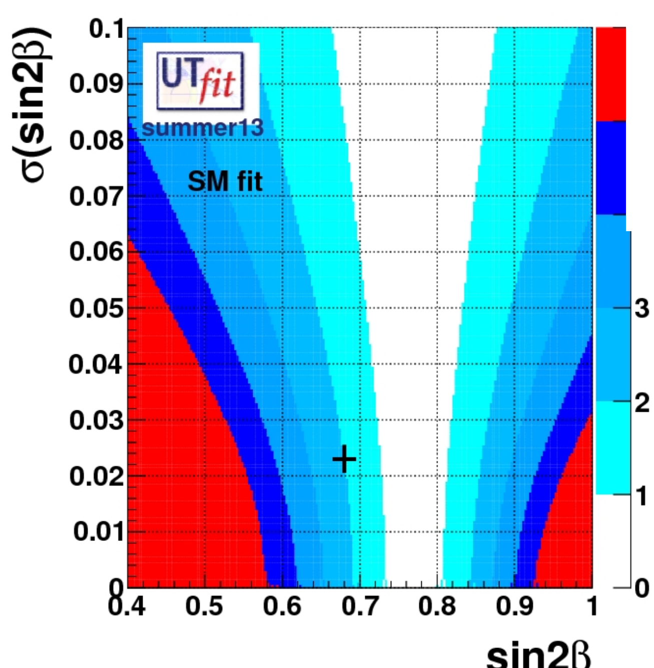
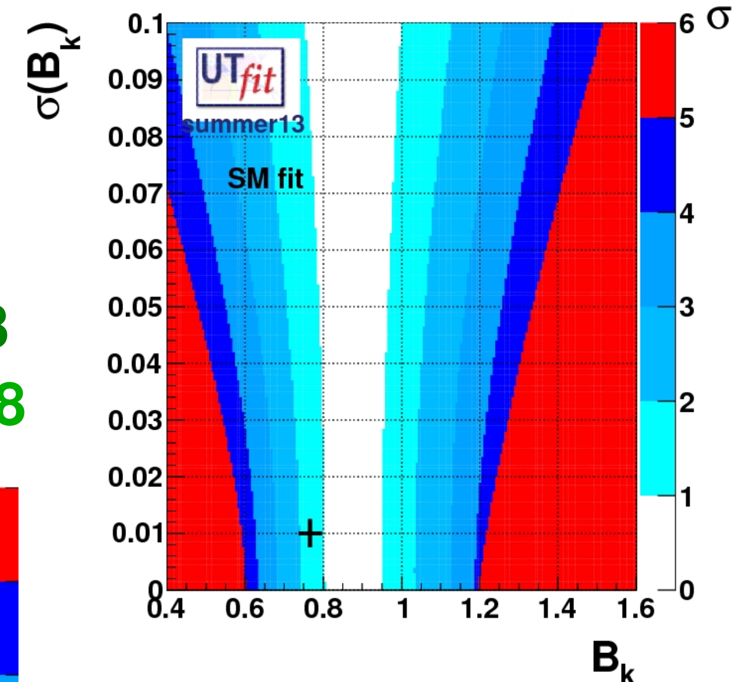




$B_{Kexp} = 0.766 \pm 0.010$

$B_{KUTfit} = 0.873 \pm 0.073$

~1.8σ

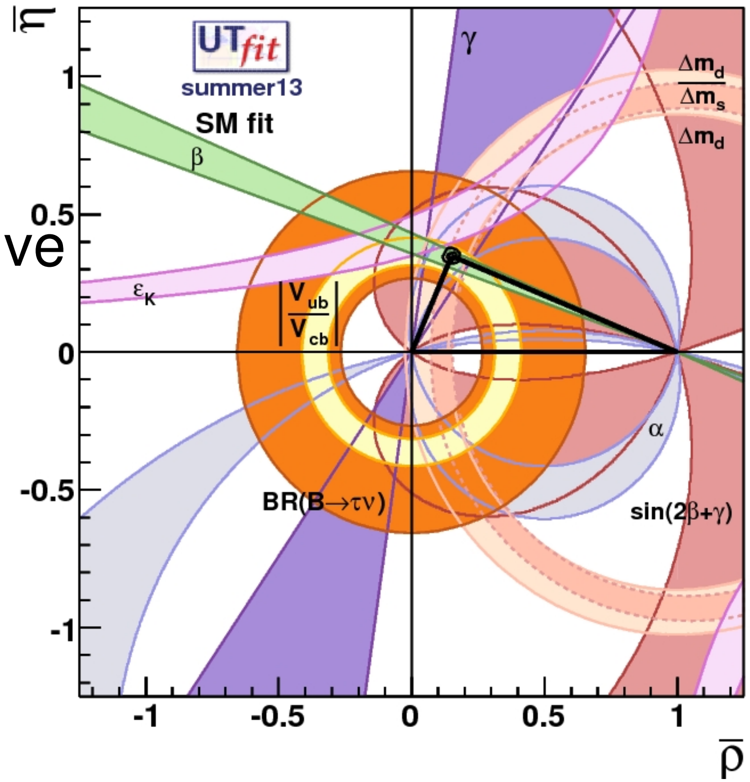
Unitarity Triangle analysis in the SM:

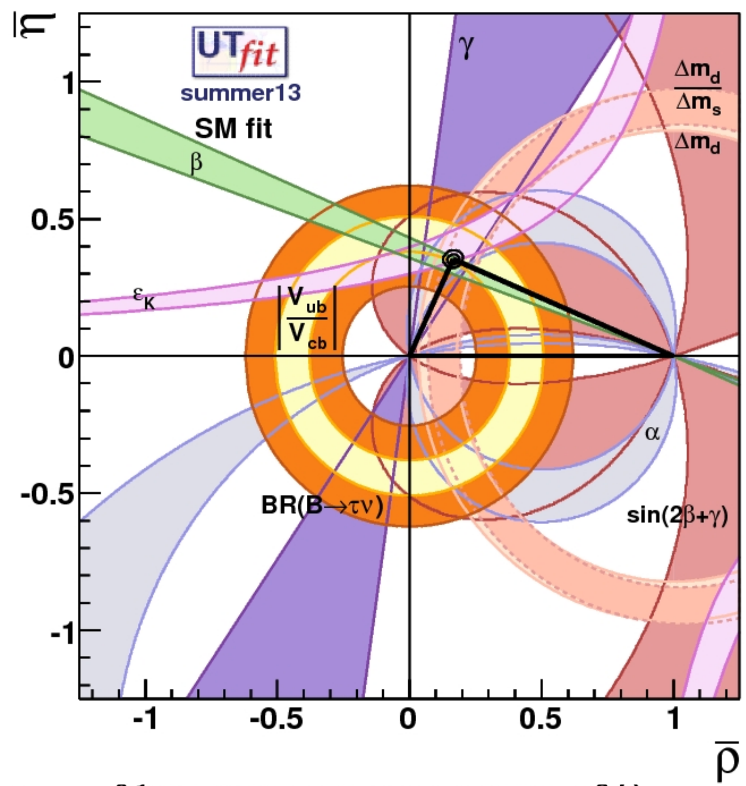
obtained excluding the given constraint from the fit

Observables	Measurement	Prediction	Pull (#σ)
$\sin 2\beta$	0.680 ± 0.023	0.771 ± 0.038	~ 2.0
γ	70.1 ± 7.1	64.8 ± 1.8	< 1
α	90.7 ± 7.4	92.2 ± 2.3	< 1
$\lvert V_{ub}\rvert \cdot 10^3$	3.75 ± 0.46	3.70 ± 0.12	< 1
$\lvert V_{ub}\rvert \cdot 10^3$ (incl)	4.40 ± 0.31	–	~ 2.0
$\lvert V_{ub}\rvert \cdot 10^3$ (excl)	3.42 ± 0.22	–	~ 1.1
$\lvert V_{cb}\rvert \cdot 10^3$	40.9 ± 1.0	42.52 ± 0.57	~ 1.3
B_K	0.766 ± 0.10	0.873 ± 0.073	~ 1.8
$BR(B \to \tau\nu)[10^{-4}]$	1.14 ± 0.22	0.811 ± 0.071	~ 1.4
$BR(B_s \to ll)[10^{-9}]$	2.9 ± 0.7	3.98 ± 0.16	~ 1.4
$BR(B_d$ ® $ll)[10^{-9}]$	0.37 ± 0.15	0.106 ± 0.004	~ 1.7

inclusives vs exclusives

only exclusive values

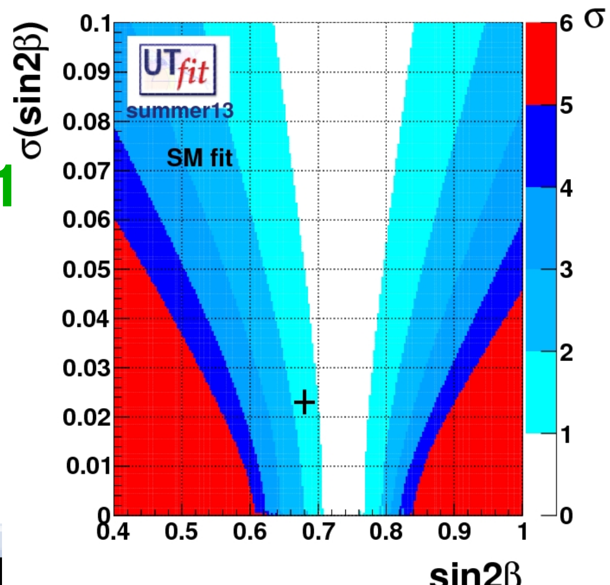


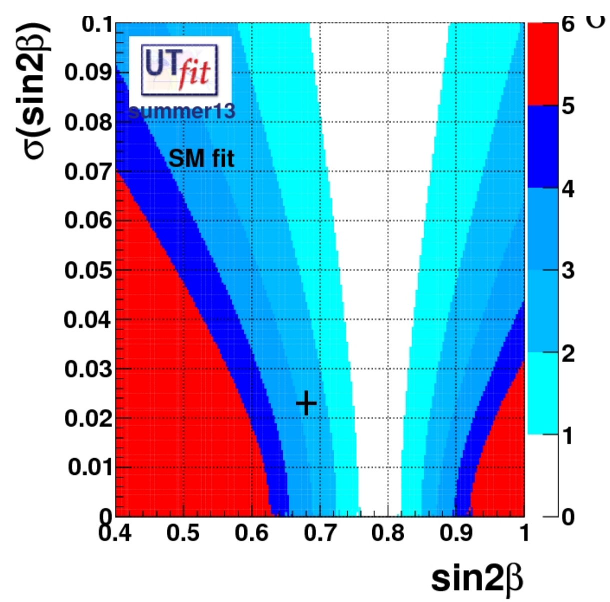


only inclusive values

$\sin 2\beta_{UTfit}$ = 0.745 ± 0.031

~1.5σ

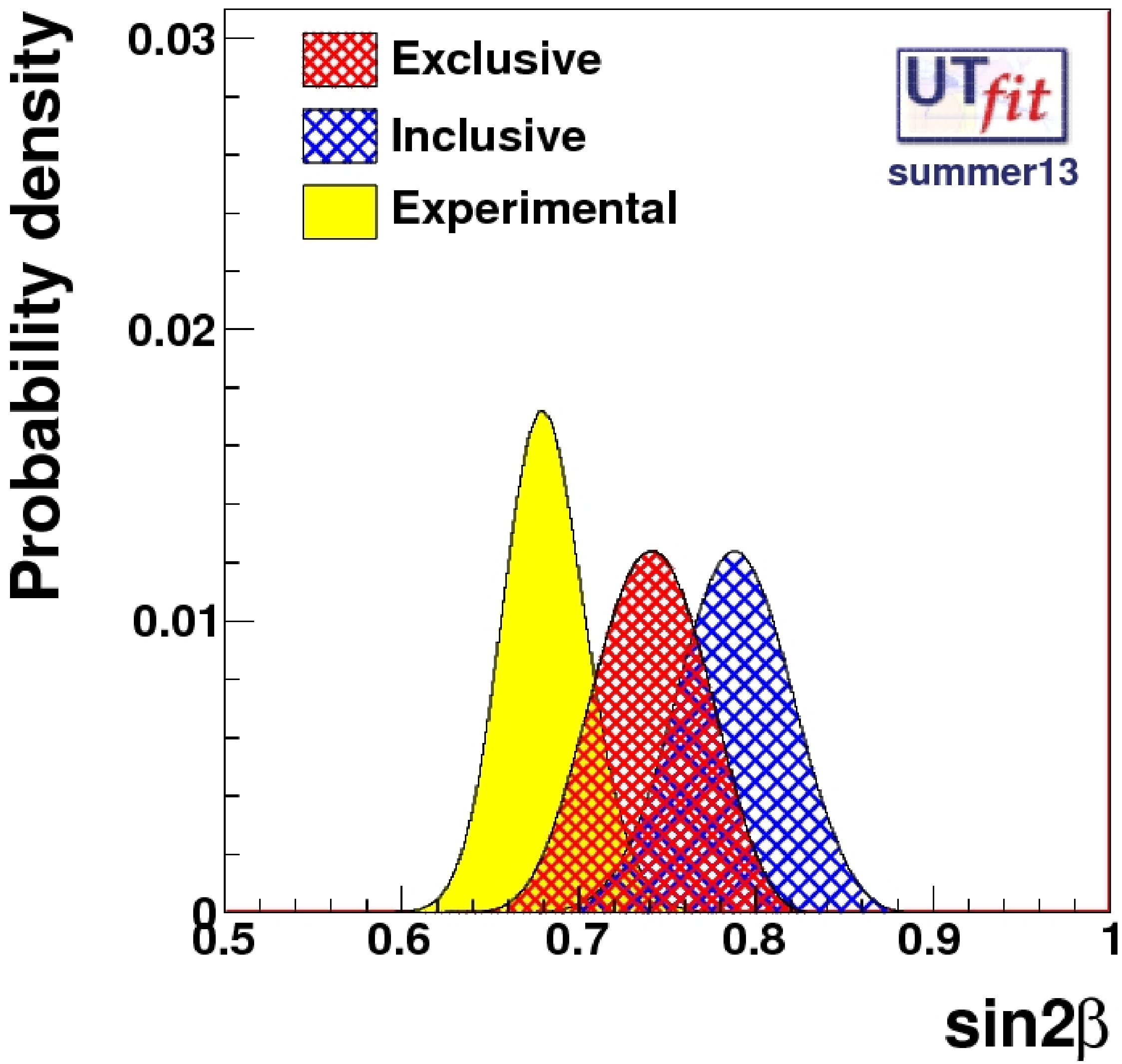




$\sin 2\beta_{UTfit}$ = 0.788 ± 0.031

~2.7σ

inclusives vs exclusives



only exclusive values

$\sin 2\beta_{\text{UTfit}} = 0.745 \pm 0.031$

$\sim 1.5\sigma$

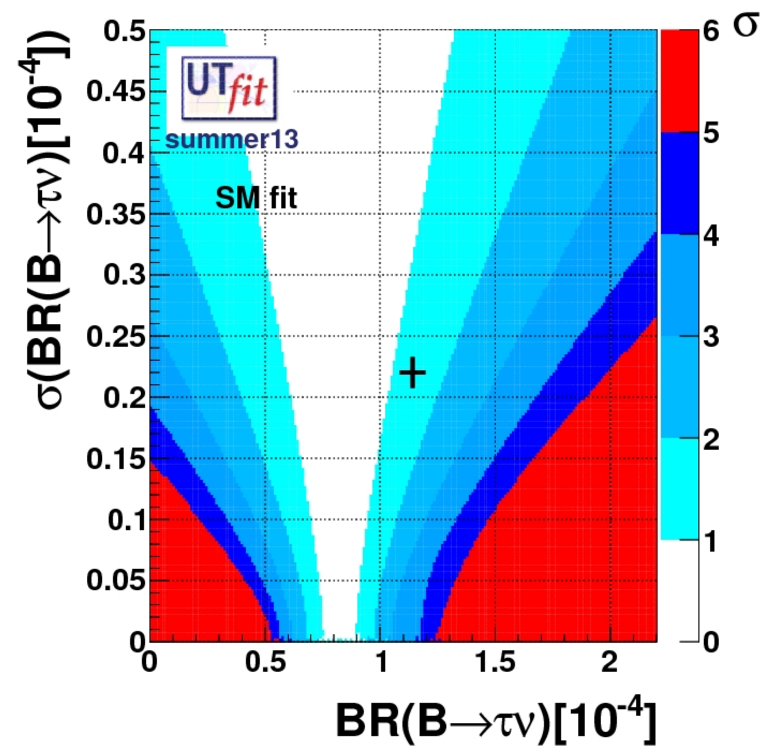
only inclusive values

$\sin 2\beta_{\text{UTfit}} = 0.788 \pm 0.031$

$\sim 2.7\sigma$

more standard model predictions:

$BR(B\to\tau\nu) = (1.14 \pm 0.22)\ 10^{-4}$



~1.4σ

indirect determinations from UT

$BR(B\to\tau\nu) = (0.811 \pm 0.071)\ 10^{-4}$

M.Bona et al, 0908.3470 [hep-ph]

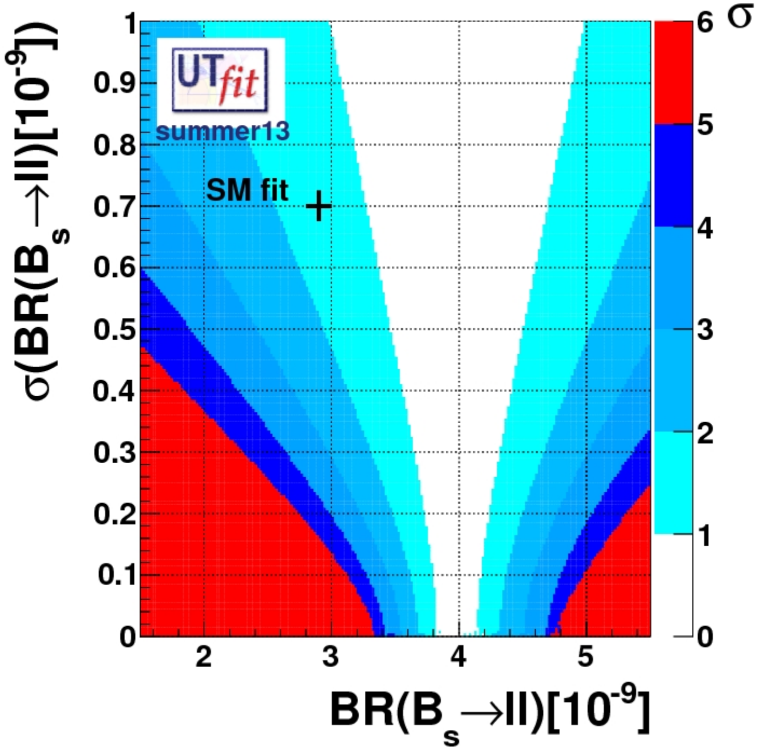
more standard model predictions:

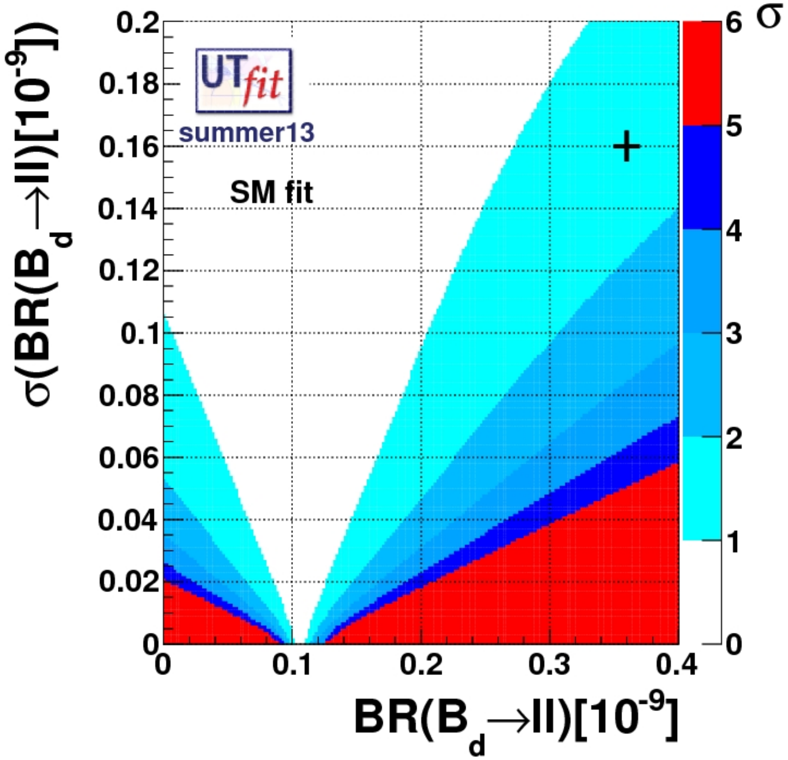
from CMS+LHCb

$BR(B_s \to \mu\mu) = (2.9 \pm 0.7)\ 10^{-9}$

from CMS+LHCb

$BR(B_d \to \mu\mu) = (3.7 \pm 1.5)\ 10^{-10}$





~1.4σ

~1.7σ

indirect determinations from UT

$BR(B_s \to ll) = (3.98 \pm 0.16)\ 10^{-9}$

$BR(B_d \to ll) = (1.06 \pm 0.04)\ 10^{-10}$

time-integration included

UT analysis including new physics

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 ΔF=2 transitions

B_d and B_s mixing amplitudes
(2+2 real parameters):

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

$$\boxed{\begin{array}{l} \Delta m_{q/K} = C_{B_q/\Delta m_K} (\Delta m_{q/K})^{SM} \\ A_{CP}^{B_d \to J/\psi K_s} = \sin 2(\beta + \phi_{B_d}) \\ A_{SL}^q = \mathrm{Im}\left(\Gamma_{12}^q / A_q\right) \end{array}}$$

$$\boxed{\begin{array}{l} \varepsilon_K = C_\varepsilon \varepsilon_K^{SM} \\ A_{CP}^{B_s \to J/\psi \phi} \sim \sin 2(-\beta_s + \phi_{B_s}) \\ \Delta\Gamma^q / \Delta m_q = \mathrm{Re}\left(\Gamma_{12}^q / A_q\right) \end{array}}$$

new-physics-specific constraints

$$A^s_{\mathrm{SL}} \equiv \frac{\Gamma(\bar{B}_s \to \ell^+ X) - \Gamma(B_s \to \ell^- X)}{\Gamma(\bar{B}_s \to \ell^+ X) + \Gamma(B_s \to \ell^- X)} = \mathrm{Im}\left(\frac{\Gamma^s_{12}}{A^{\mathrm{full}}_s}\right)$$

semileptonic asymmetries:

sensitive to NP effects in both size and phase

$A_{SL}(B_d)[10^{-3}] = -0.5 \pm 5.6$, $A_{SL}(B_s)[10^{-3}] = -4.1 \pm 4.5$

B factories, CDF + D0 + LHCb

same-side dilepton charge asymmetry:

D0 arXiv:1106.6308

admixture of B_s and B_d so sensitive to NP effects in both systems

$$A^{\mu\mu}_{\mathrm{SL}} \times 10^3 = -7.9 \pm 2.0$$

$$A^{\mu\mu}_{\mathrm{SL}} = \frac{f_d \chi_{d0} A^d_{\mathrm{SL}} + f_s \chi_{s0} A^s_{\mathrm{SL}}}{f_d \chi_{d0} + f_s \chi_{s0}}$$

lifetime τ^{FS} in flavour-specific final states:

average lifetime is a function to the width and the width difference (independent data sample)

$$\tau^{FS}_{B_s} = \frac{1}{\Gamma_s} \frac{1 - \left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}{1 + \left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}$$

$$\tau^{\mathrm{FS}}_{B_s}\ [\mathrm{ps}] = 1.417 \pm 0.042$$

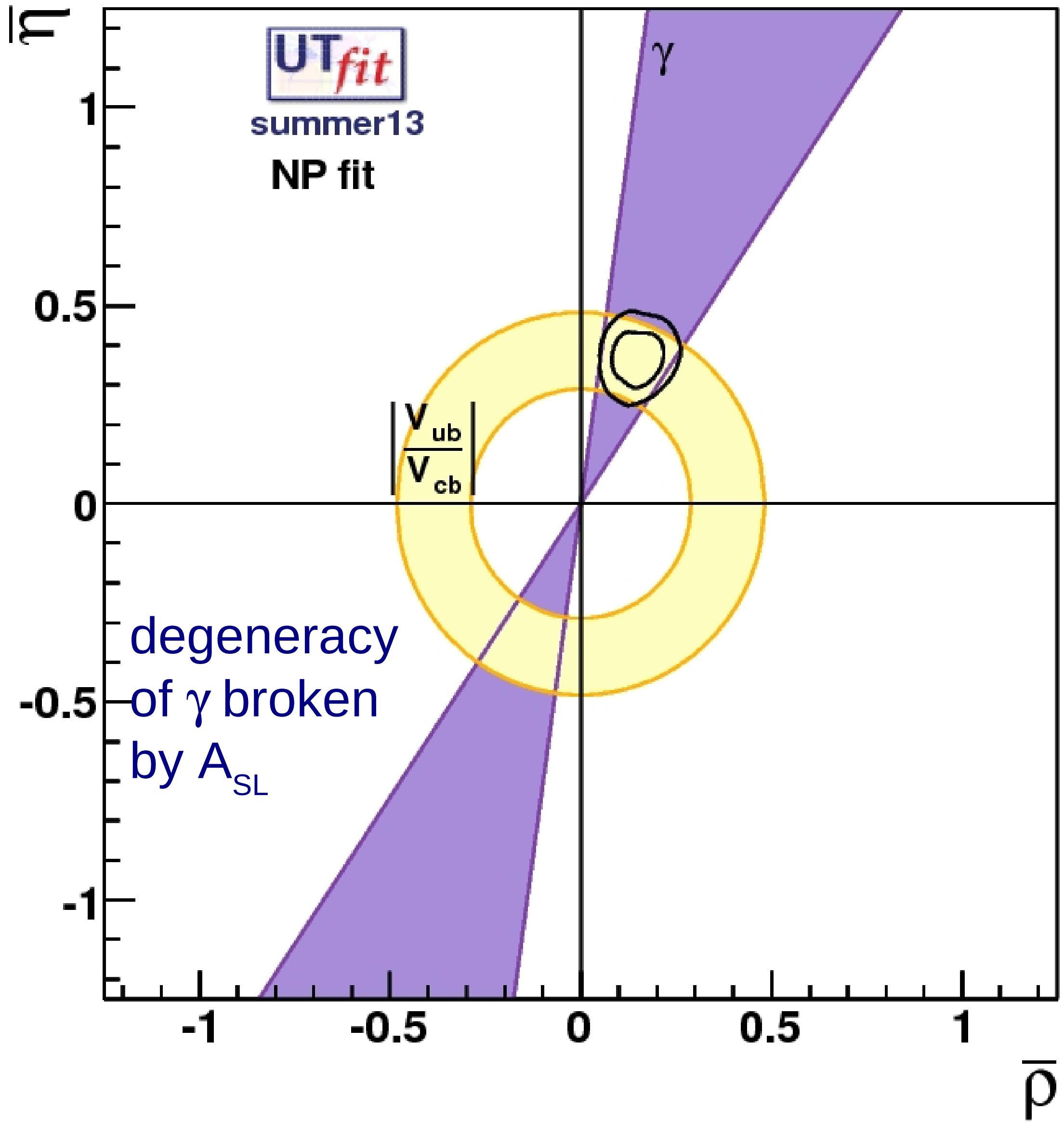
HFAG

$\phi_s = 2\beta_s$ vs $\Delta\Gamma_s$ from $B_s \to J/\psi\phi$

angular analysis as a function of proper time and b-tagging. Additional sensitivity from the $\Delta\Gamma_s$ terms

LHCb: Gaussian

NP analysis results



$\bar{\rho} = 0.147 \pm 0.045$
$\bar{\eta} = 0.368 \pm 0.048$

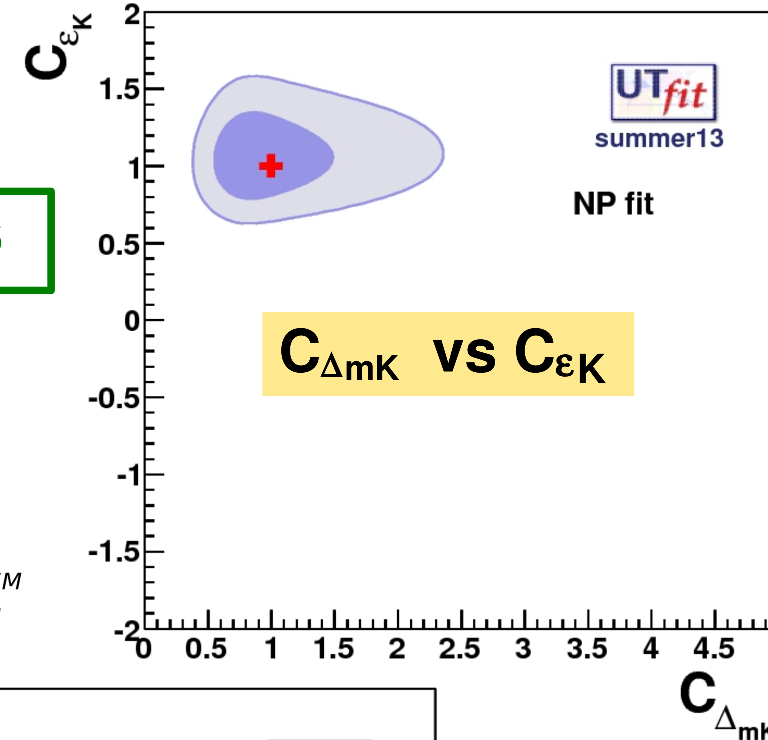
SM is

$\bar{\rho} = 0.159 \pm 0.015$
$\bar{\eta} = 0.346 \pm 0.013$

NP parameter results

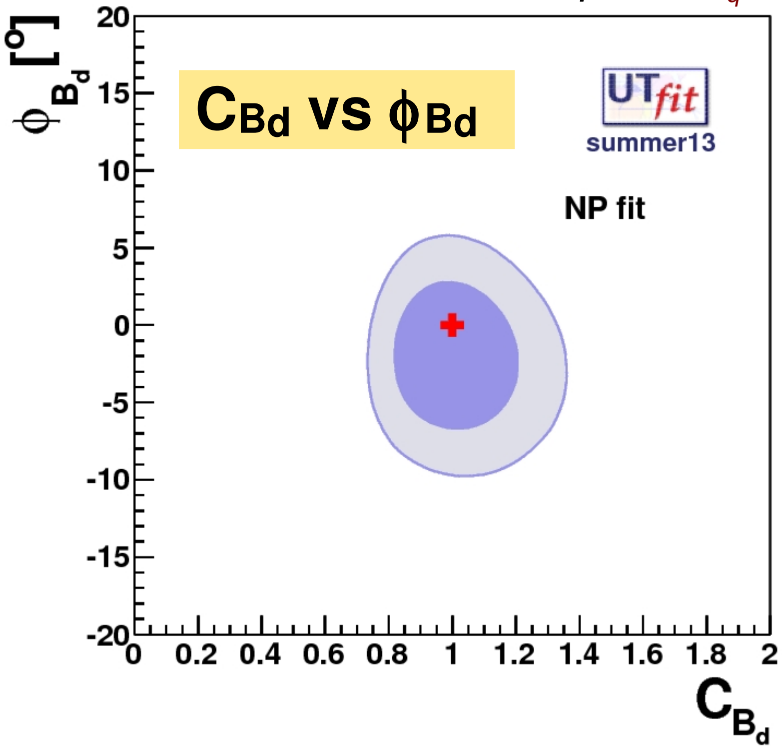
dark: 68%
light: 95%
SM: red cross

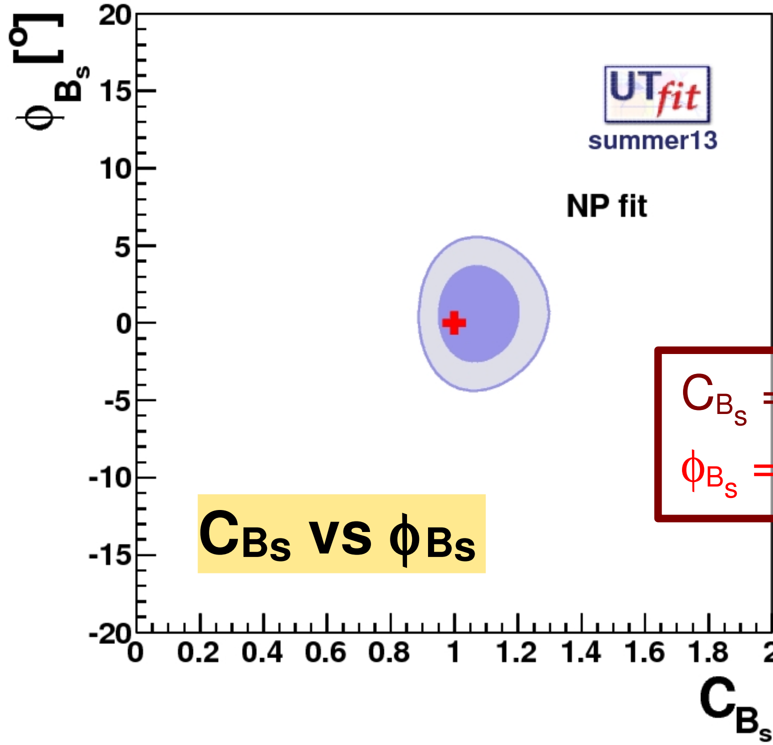
$C_{\varepsilon_K} = 1.05 \pm 0.16$



$C_{B_d} = 1.00 \pm 0.13$
$\phi_{B_d} = (-2.0 \pm 3.2)°$

$$A_q = C_{B_q} e^{2i\varphi_{B_q}} A_q^{SM} e^{2i\varphi_q^{SM}}$$

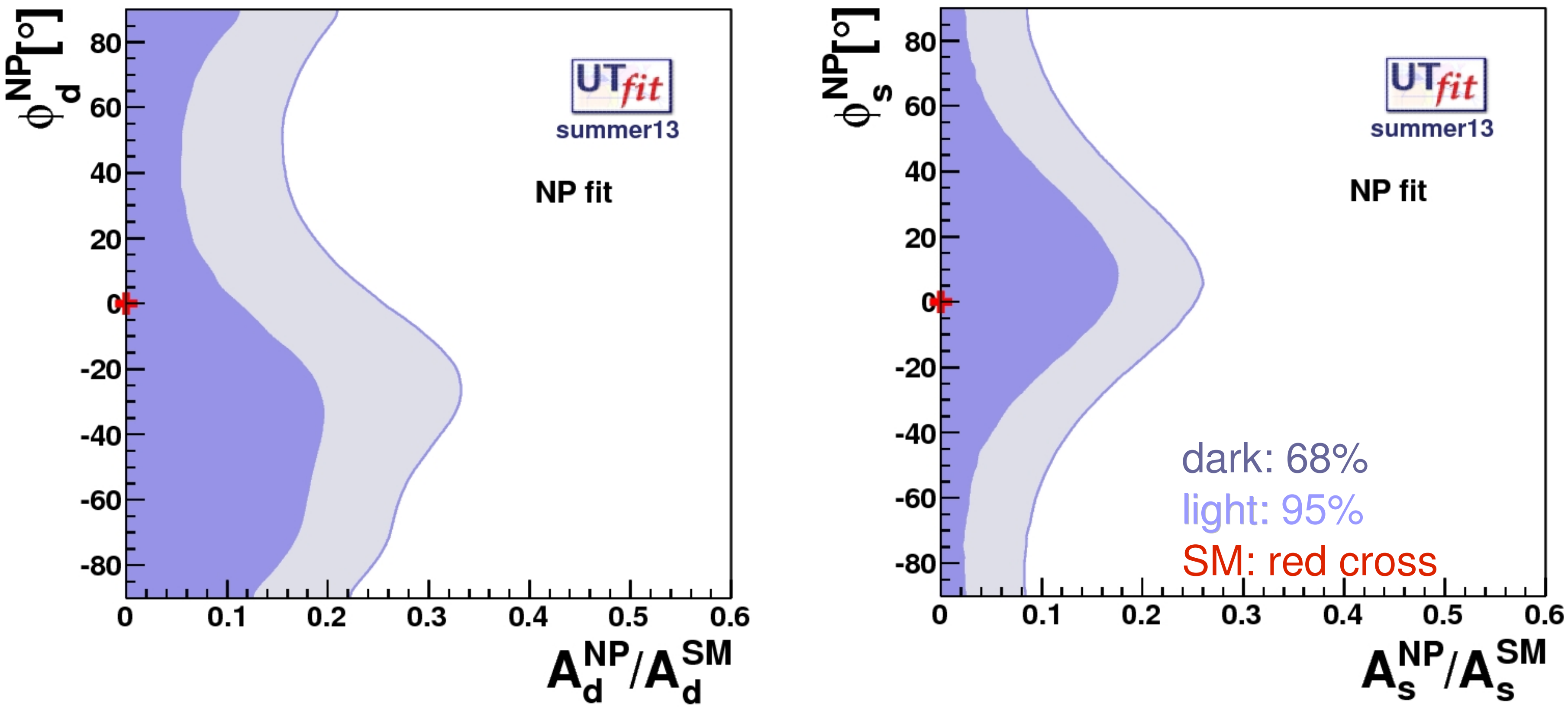




$C_{B_s} = 1.07 \pm 0.08$
$\phi_{B_s} = (0.6 \pm 2.0)°$

NP parameter results

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



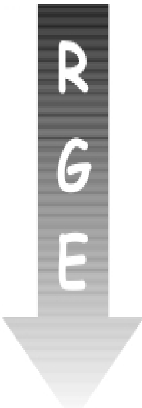
The ratio of NP/SM amplitudes is:

< 20% @68% prob. (34% @95%) in B_d mixing

< 18% @68% prob. (26% @95%) in B_s mixing

see also Lunghi & Soni, Buras et al., Ligeti et al.

testing the new-physics scale



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

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

$$\begin{aligned}
Q_1^{q_i q_j} &= \bar{q}_{jL}^{\alpha} \gamma_\mu q_{iL}^{\alpha} \bar{q}_{jL}^{\beta} \gamma^\mu q_{iL}^{\beta} , \\
Q_2^{q_i q_j} &= \bar{q}_{jR}^{\alpha} q_{iL}^{\alpha} \bar{q}_{jR}^{\beta} q_{iL}^{\beta} , \\
Q_3^{q_i q_j} &= \bar{q}_{jR}^{\alpha} q_{iL}^{\beta} \bar{q}_{jR}^{\beta} q_{iL}^{\alpha} , \\
Q_4^{q_i q_j} &= \bar{q}_{jR}^{\alpha} q_{iL}^{\alpha} \bar{q}_{jL}^{\beta} q_{iR}^{\beta} , \\
Q_5^{q_i q_j} &= \bar{q}_{jR}^{\alpha} q_{iL}^{\beta} \bar{q}_{jL}^{\beta} q_{iR}^{\alpha} .
\end{aligned}$$

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

M. Bona *et al.* (UTfit)
JHEP 0803:049,2008
arXiv:0707.0636

effective BSM Hamiltonian for ΔF=2 transitions

The Wilson coefficients C_i have in general the form

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

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

F_i: function of the NP flavour couplings

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

Λ: NP scale (typical mass of new particles mediating ΔF=2 transitions)

testing the TeV scale

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

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

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

α (L_i) is the coupling among NP and SM

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

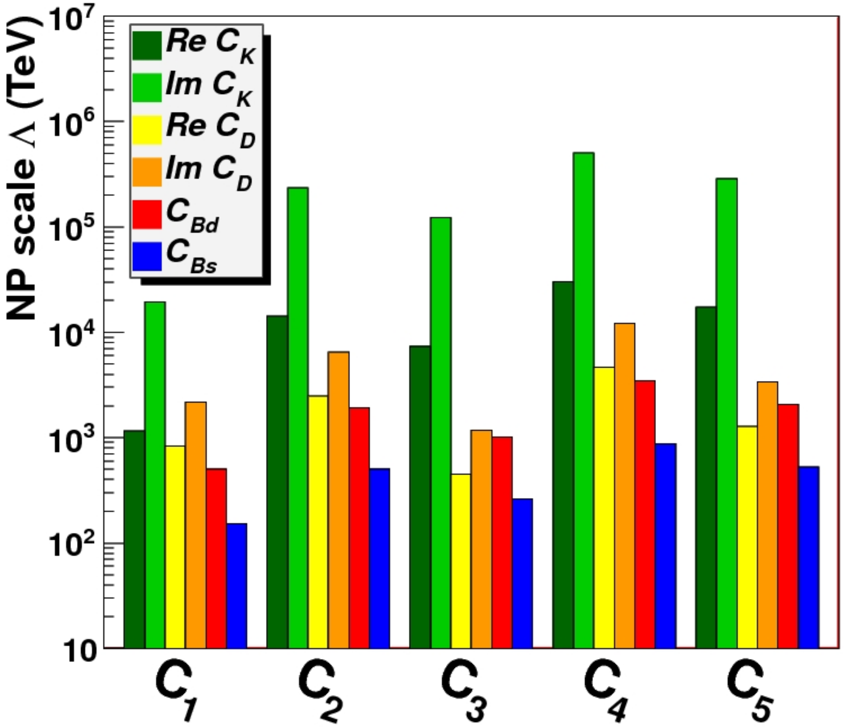
If no NP effect is seen
lower bound on NP scale Λ
if NP is seen
upper bound on NP scale Λ

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



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

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

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

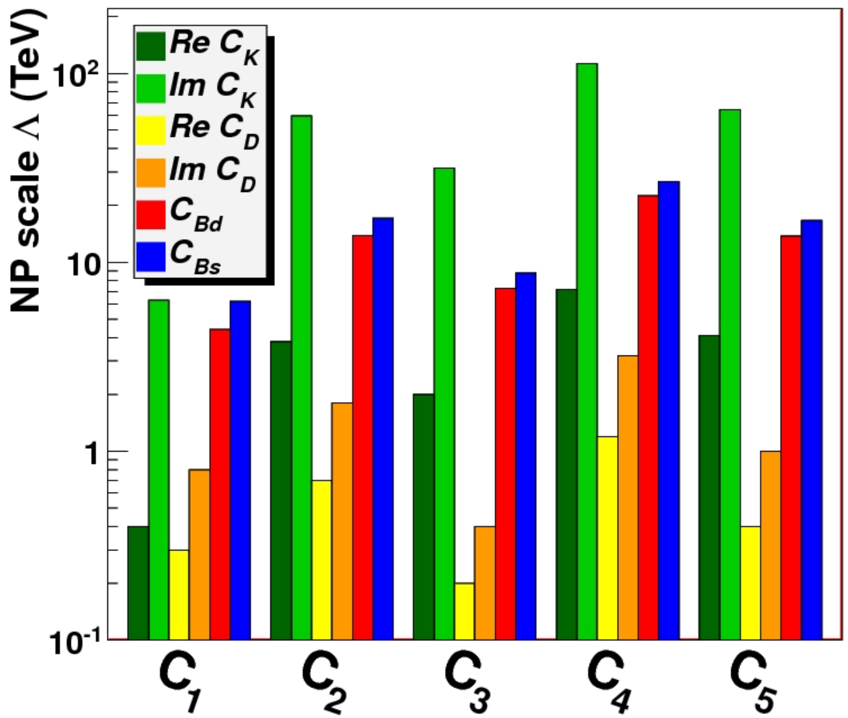
NP in α_W loops
$\Lambda > 1.5\ 10^4$ TeV

Non-perturbative NP
$\Lambda > 5.0\ 10^5$ TeV

results from the Wilson coefficients

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

$\alpha \sim 1$ for strongly coupled NP



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

Non-perturbative NP
$\Lambda > 113$ TeV

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

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

NP in α_W loops
$\Lambda > 3.4$ TeV

conclusions

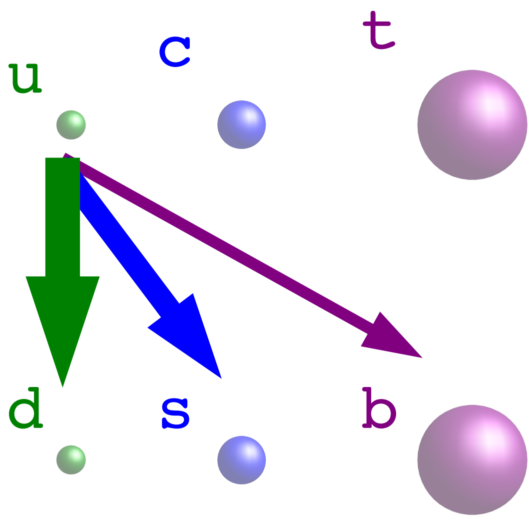
- SM analysis displays good overall consistency
- Still open discussion on semileptonic inclusive vs exclusive, new discussion on the new lattice averages?
- UTA provides determination also of NP contributions to $\Delta F=2$ amplitudes. It currently leaves space for NP at the level of 15-20%
- So the 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.

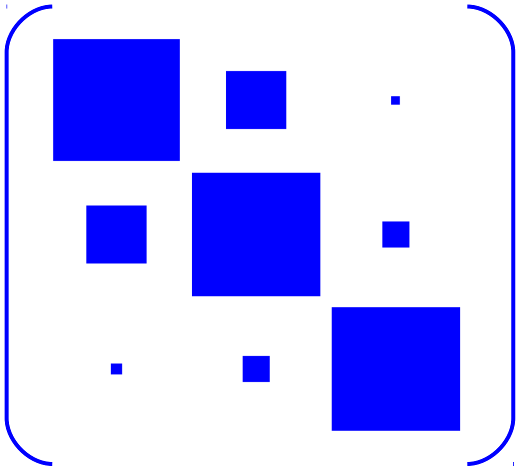
Back up slides

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_{CKM}.

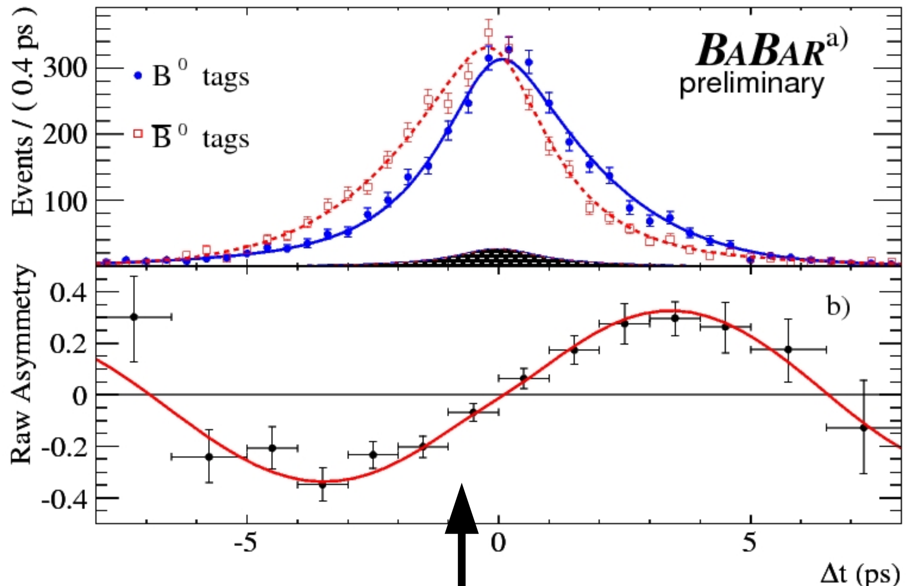
$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\bar{\rho}-i\bar{\eta}) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2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



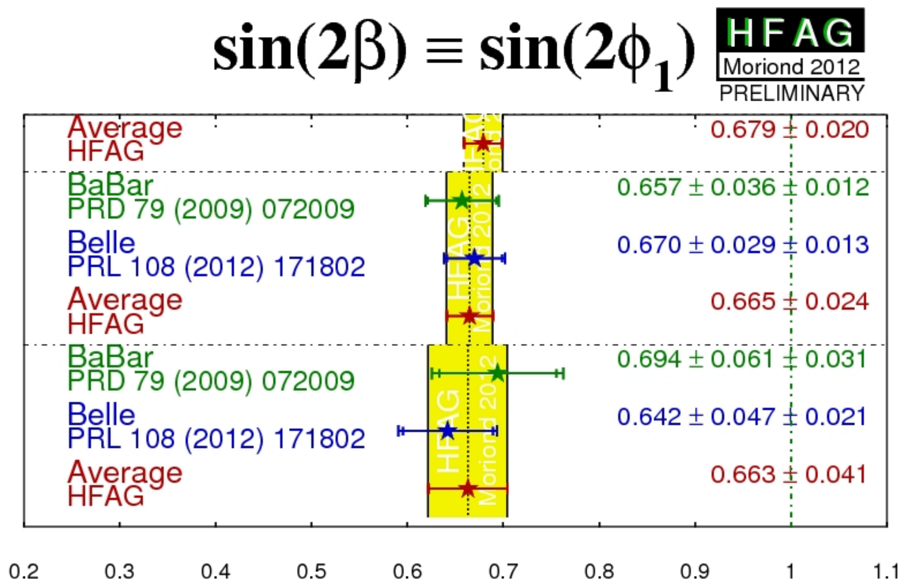


Latest sin2β results:

LHCb not competitive
yet with a 0.07 error



raw asymmetry
as function of Δt



BABAR Collaboration
PRD 79:072009, 2009

Belle Collaboration
PRL 108:171802, 2012

data-driven theoretical uncertainty

UTfit values

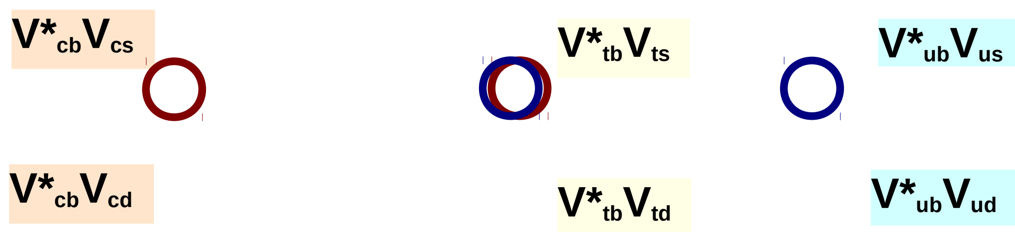
$$\boxed{\sin 2\beta(J/\psi K^0) = 0.665 \pm 0.024}$$

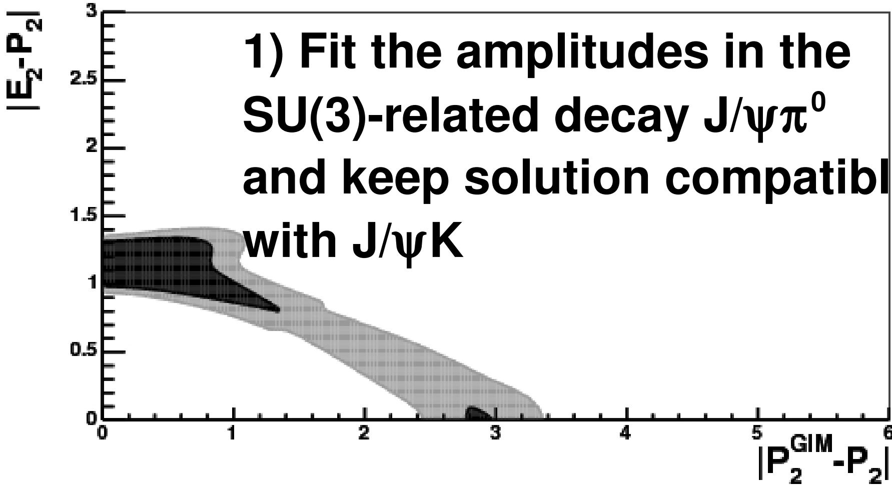
$$\boxed{\Delta S = 0.000 \pm 0.012}$$

M.Ciuchini, M.Pierini, L.Silvestrini
Phys. Rev. Lett. 95, 221804 (2005)

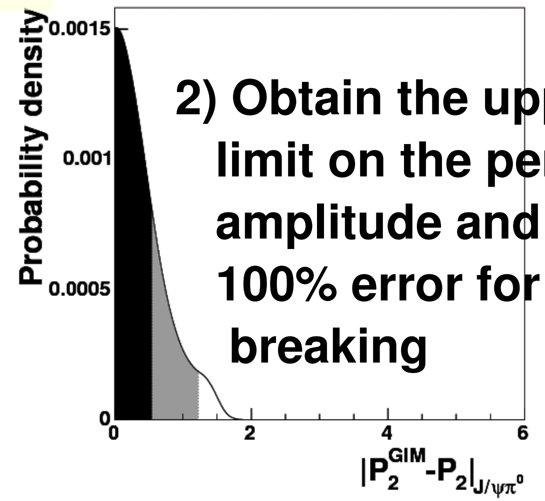
Theory error on sin2β:

A.Buras, L.Silvestrini
Nucl.Phys.B569:3-52(2000)



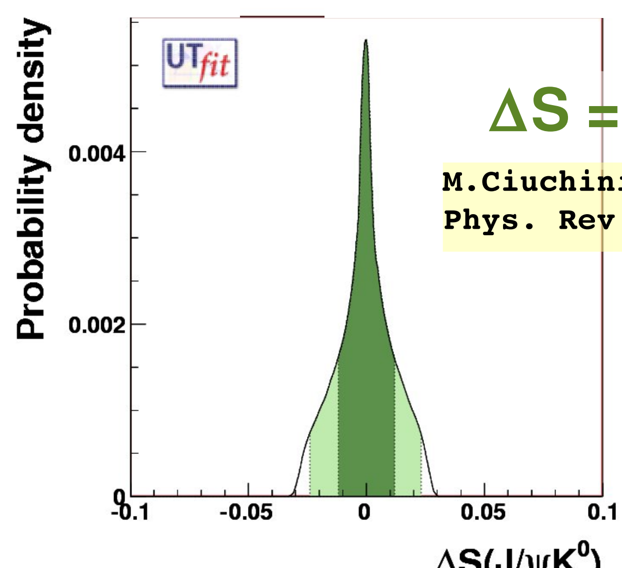


1) Fit the amplitudes in the SU(3)-related decay $J/\psi\pi^0$ and keep solution compatible with $J/\psi K$



2) Obtain the upper limit on the penguin amplitude and add 100% error for SU(3) breaking

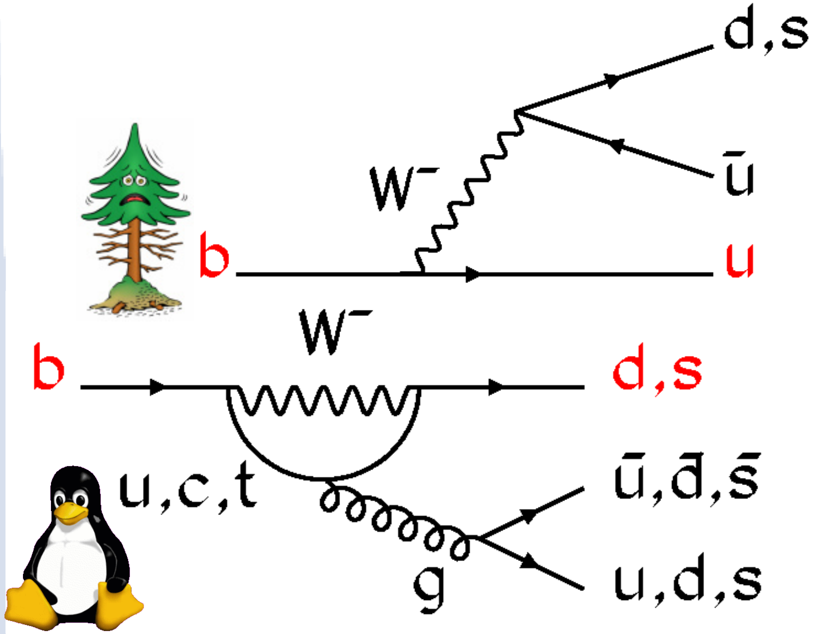
3) Fit the amplitudes in $J/\psi K^0$ imposing the upper bound on the CKM suppressed amplitude and extract the error on sin2β



$\Delta S = 0.000 \pm 0.012$

M.Ciuchini, M.Pierini, L.Silvestrini
Phys. Rev. Lett. 95, 221804 (2005)

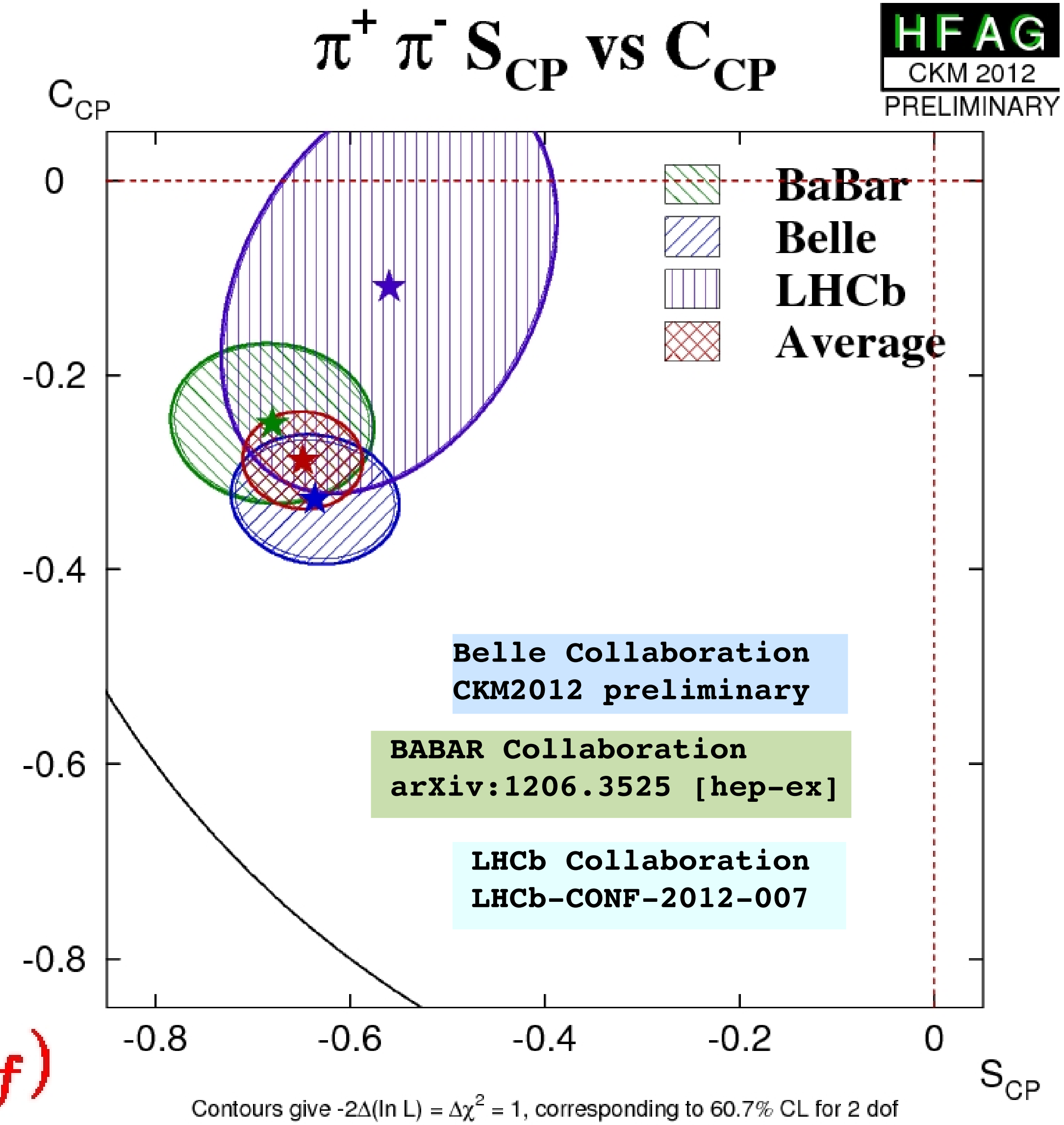
α: CP violation in $B^0 \to \pi\pi/\rho\rho$



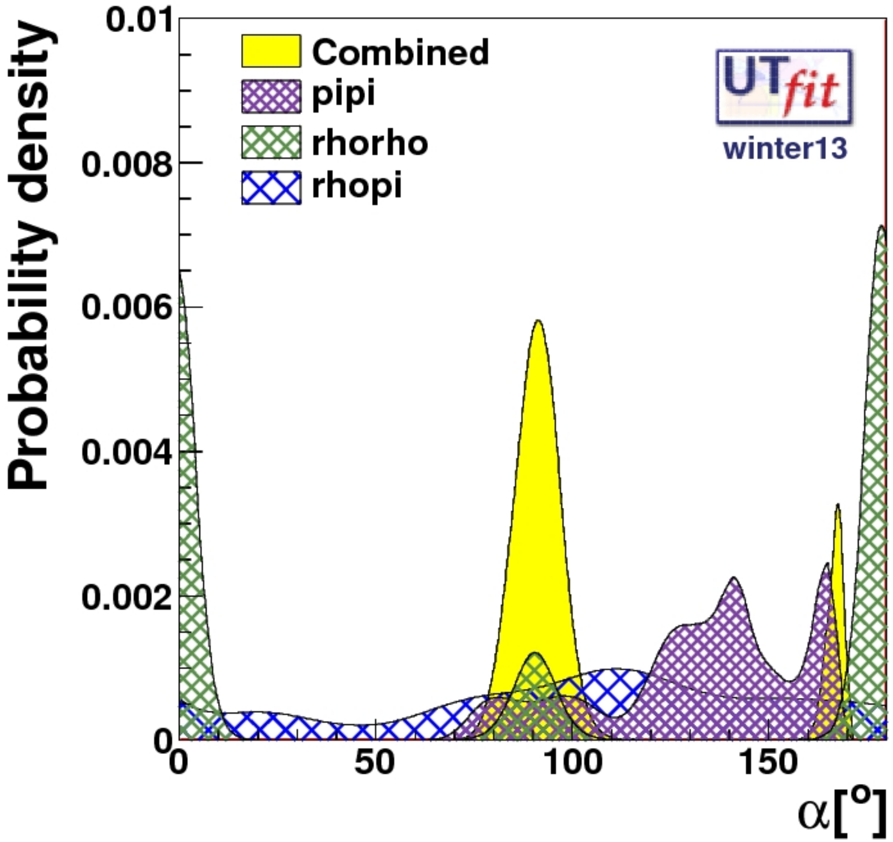
$$\lambda_{\pi\pi} = e^{2i\alpha}\frac{1+|P/T|e^{i\delta}e^{i\gamma}}{1+|P/T|e^{i\delta}e^{-i\gamma}}$$

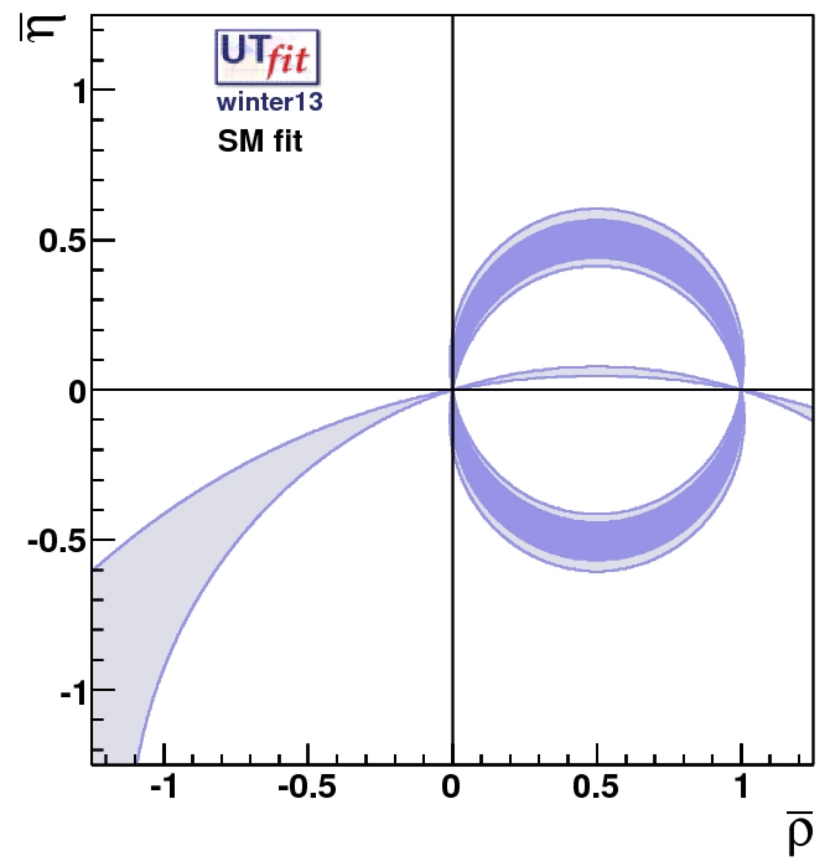
$$C_{\pi\pi} \propto \sin(\delta)$$

$$S_{\pi\pi} = \sqrt{1-C^2_{\pi\pi}}\,\sin(2\alpha_{eff})$$



α: CP violation in $B^0 \to \pi\pi/\rho\rho$





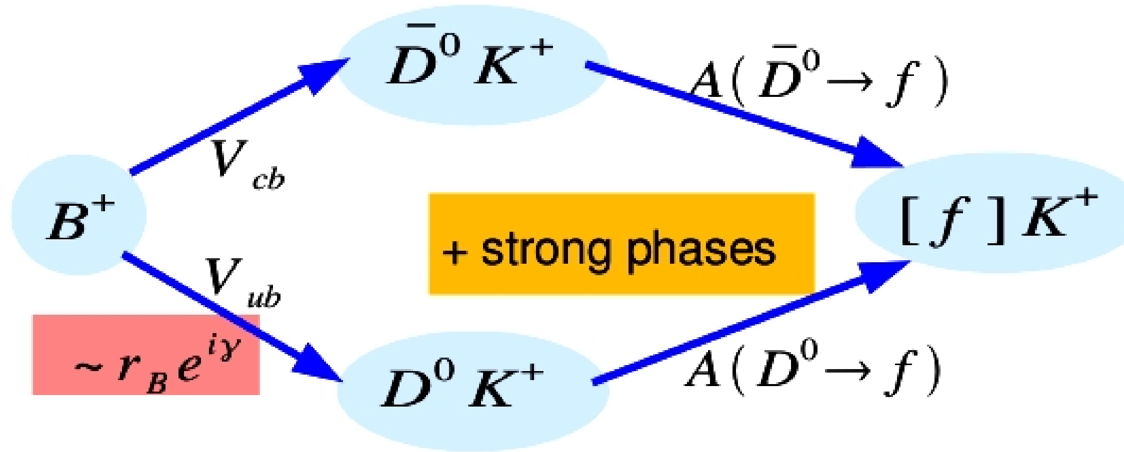
α from $\pi\pi$, $\rho\rho$, $\pi\rho$ decays:

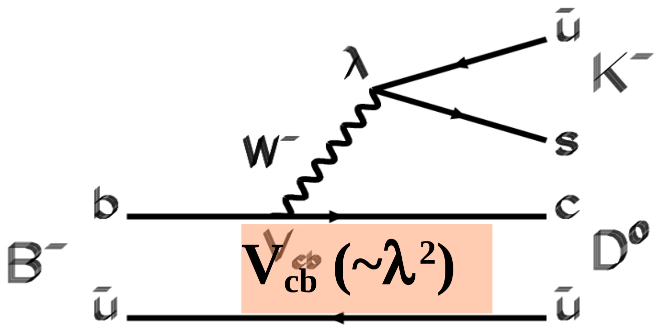
combined: $(91.1 \pm 6.7)^\circ$

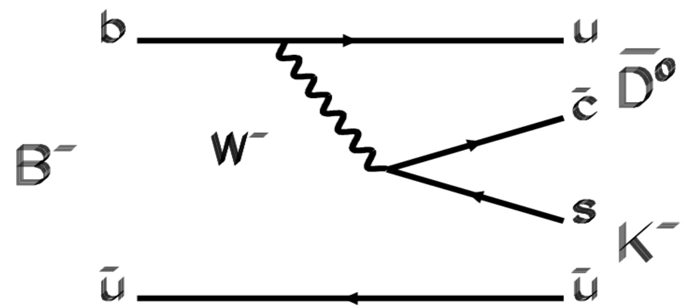
γ and DK trees

$B \to D^{(*)0} (\overline{D}^{(*)0}) K^{(*)}$

decays can proceed both through V_{cb} and V_{ub} amplitudes







$V_{ub}=|V_{ub}|e^{-i\gamma}$ (~λ^3)

δ_B = strong phase diff.

$$A(B^- \to D^0 K^-) = A_B \qquad A(B^- \to \bar{D}^0 K^-) = A_B r_B e^{i(\delta_B - \gamma)}$$

$$A(B^+ \to \bar{D}^0 K^+) = A_B \qquad A(B^+ \to D^0 K^+) = A_B r_B e^{i(\delta_B + \gamma)}$$

sensitivity to γ: the amplitude ratio r_B

$$r_B = \left| \frac{B^- \to \bar{D}^0 K^-}{B^- \to D^0 K^-} \right| = \sqrt{\bar{\eta}^2 + \bar{\rho}^2} \times F_{CS}$$

hadronic contribution channel-dependent

new-physics-specific constraints

B meson mixing matrix element NLO calculation
Ciuchini et al. JHEP 0308:031,2003.

C_{pen} and ϕ_{pen} are parameterize possible NP contributions from $b \to s$ penguins

$$\frac{\Gamma_{12}^q}{A_q^{\text{full}}} = -2\frac{\kappa}{C_{B_q}}\left\{e^{2\phi_{B_q}}\left(n_1 + \frac{n_6 B_2 + n_{11}}{B_1}\right) - \frac{e^{(\phi_q^{\text{SM}}+2\phi_{B_q})}}{R_t^q}\left(n_2 + \frac{n_7 B_2 + n_{12}}{B_1}\right)\right.$$
$$+ \frac{e^{2(\phi_q^{\text{SM}}+\phi_{B_q})}}{R_t^{q^2}}\left(n_3 + \frac{n_8 B_2 + n_{13}}{B_1}\right) + e^{(\phi_q^{\text{Pen}}+2\phi_{B_q})}C_q^{\text{Pen}}\left(n_4 + n_9\frac{B_2}{B_1}\right)$$
$$\left. - e^{(\phi_q^{\text{SM}}+\phi_q^{\text{Pen}}+2\phi_{B_q})}\frac{C_q^{\text{Pen}}}{R_t^q}\left(n_5 + n_{10}\frac{B_2}{B_1}\right)\right\}$$

$\phi_s=2\beta_s$ vs $\Delta\Gamma_s$ from $B_s \to J/\psi\phi$

angular analysis as a function of proper time and b-tagging
additional sensitivity from the $\Delta\Gamma_s$ terms

ϕ_s and $\Delta\Gamma_s$:
2D experimental likelihood from CDF and D0

ϕ_s and $\Delta\Gamma_s$:
central values with gaussian errors from LHCb

UT analysis including NP

M.Bona *et al* (UTfit)
Phys.Rev.Lett. 97:151803,2006

	ρ, η	C_{Bd}, ϕ_{Bd}	$C_{\varepsilon K}$	C_{bs}, ϕ_{Bs}
V_{ub}/V_{cb}	X			
γ (DK)	X			
ε_K	X		X	
$\sin 2\beta$	X	X		
Δm_d	X	X		
α	X	X		
A_{SL} B_d	X	X X		
$\Delta\Gamma_d/\Gamma_d$	X	X X		
$\Delta\Gamma_s/\Gamma_s$	X			X X
Δm_s				X
A_{CH}	X	X X		X X

model independent assumptions

SM → SM+NP

tree level

SM	SM+NP
$(V_{ub}/V_{cb})^{SM}$	$(V_{ub}/V_{cb})^{SM}$
γ^{SM}	γ^{SM}

Bd Mixing

SM	SM+NP
β^{SM}	$\beta^{SM}+\phi_{Bd}$
α^{SM}	$\alpha^{SM}-\phi_{Bd}$
Δm_d	$C_{Bd}\Delta m_d$

Bs Mixing

SM	SM+NP
Δm_s^{SM}	$C_{Bs}\Delta m_s^{SM}$
β_s^{SM}	$\beta_s^{SM}+\phi_{Bs}$

K Mixing

SM	SM+NP
ε_K^{SM}	$C\varepsilon_K\ \varepsilon_K^{SM}$

contribution to the mixing amplitutes

analytic expression for the contribution to the mixing amplitudes

Lattice QCD

$$\langle \bar{B}_q | \mathcal{H}_{\mathrm{eff}}^{\Delta B=2} | B_q \rangle_i = \sum_{j=1}^{5} \sum_{r=1}^{5} \left(b_j^{(r,i)} + \eta\, c_j^{(r,i)} \right) \eta^{a_j}\, C_i(\Lambda)\, \boxed{\langle \bar{B}_q | Q_r^{bq} | B_q \rangle}$$

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

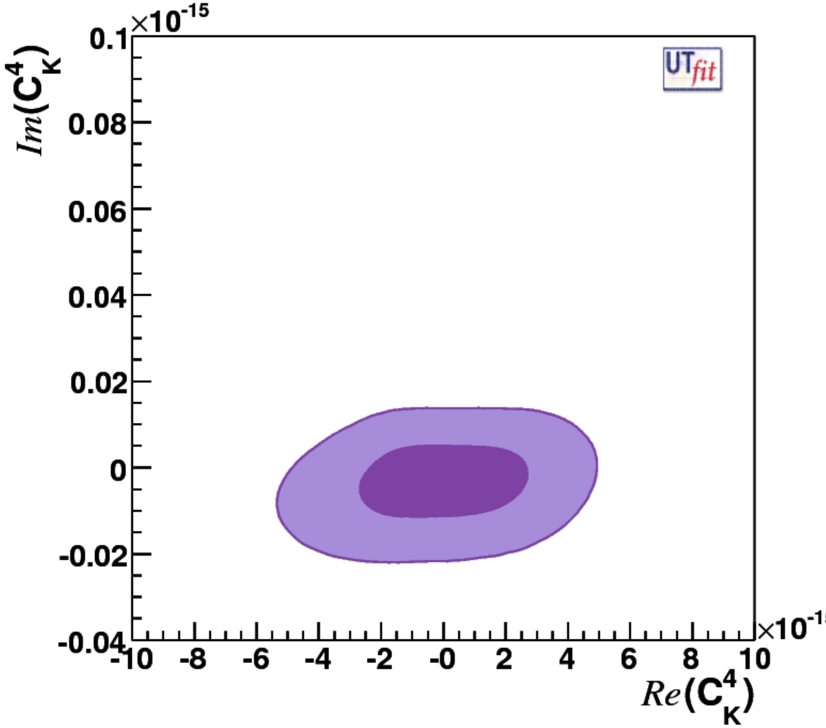
$$\langle \bar{K}^0 | \mathcal{H}_{\mathrm{eff}}^{\Delta S=2} | K^0 \rangle_i = \sum_{j=1}^{5} \sum_{r=1}^{5} \left(b_j^{(r,i)} + \eta\, c_j^{(r,i)} \right) \eta^{a_j}\, C_i(\Lambda)\, R_r\, \langle \bar{K}^0 | Q_1^{sd} | K^0 \rangle$$

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.

Results from the Wilson coefficients

the results obtained for the flavour scenarios:
In deriving the lower bounds on the NP scale, we assume L_i = 1, corresponding to strongly-interacting and/or tree-level NP.

Parameter	95% allowed range (GeV^{-2})	Lower limit on Λ (TeV) for arbitrary NP	Lower limit on Λ (TeV) for NMFV
$\mathrm{Re}C_K^1$	$[-9.6, 9.6] \cdot 10^{-13}$	$1.0 \cdot 10^3$	0.35
$\mathrm{Re}C_K^2$	$[-1.8, 1.9] \cdot 10^{-14}$	$7.3 \cdot 10^3$	2.0
$\mathrm{Re}C_K^3$	$[-6.0, 5.6] \cdot 10^{-14}$	$4.1 \cdot 10^3$	1.1
$\mathrm{Re}C_K^4$	$[-3.6, 3.6] \cdot 10^{-15}$	$17 \cdot 10^3$	4.0
$\mathrm{Re}C_K^5$	$[-1.0, 1.0] \cdot 10^{-14}$	$10 \cdot 10^3$	2.4
$\mathrm{Im}C_K^1$	$[-4.4, 2.8] \cdot 10^{-15}$	$1.5 \cdot 10^4$	5.6
$\mathrm{Im}C_K^2$	$[-5.1, 9.3] \cdot 10^{-17}$	$10 \cdot 10^4$	28
$\mathrm{Im}C_K^3$	$[-3.1, 1.7] \cdot 10^{-16}$	$5.7 \cdot 10^4$	19
$\mathrm{Im}C_K^4$	$[-1.8, 0.9] \cdot 10^{-17}$	$24 \cdot 10^4$	62
$\mathrm{Im}C_K^5$	$[-5.2, 2.8] \cdot 10^{-17}$	$14 \cdot 10^4$	37

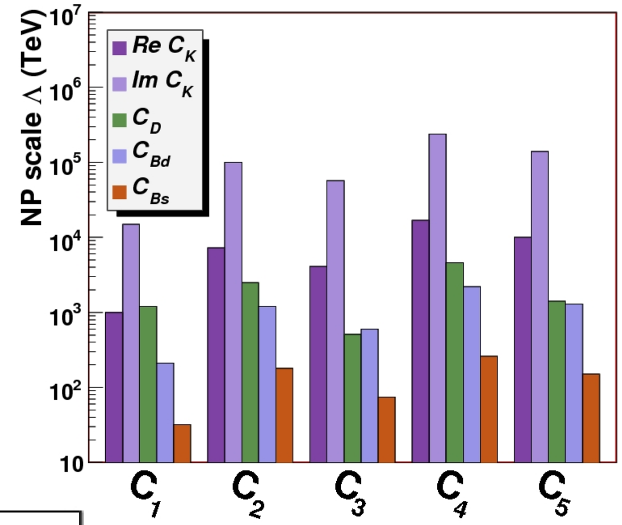


To obtain the lower bound for loop-mediated contributions, one simply multiplies the bounds by $\alpha_s \sim 0.1$ or by $\alpha_W \sim 0.03$.

Upper and lower bound on the scale

Lower bounds on NP scale from K and B_d physics (TeV at 95% prob.)

Scenario	strong/tree	α_s loop	α_W loop
MFV	5.5	0.5	0.2
NMFV	62	6.2	2
General	24000	2400	800



Upper bounds on NP scale from B_s:

Scenario	strong/tree	α_s loop	α_W loop
NMFV	35	4	2
General	800	80	30

- **the general case was already problematic (well known flavour puzzle)**
- **NMFV has problems with the size of the B_s effect vs the (insufficient) suppression in B_d and (in particular) K mixing**
- **MFV is OK for the size of the effects, but the B_s phase cannot be generated**

Data suggest some hierarchy in NP mixing which is stronger than the SM one

The future of CKM fits

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

SuperB reach from:
SuperB Conceptual Design Report, arXiv:0709.0451

	2015 10/fb (5 years)	1/ab (1 month at $\Upsilon(5S)$)
Δm_s	0.07%(+0.5%)	no
A^s_{SL}	?	0.006
ϕ_s ($J/\psi\ \phi$)	0.01+syst	0.14
		75/ab (5 years)
$\sin 2\beta$ ($J/\psi\ K_s$)	0.010	0.005
γ (all methods)	2.4°	1-2°
α (all methods)	4.5°	1-2°
$\lvert V_{cb}\rvert$ (all methods)	no	< 1%
$\lvert V_{ub}\rvert$ (all methods)	no	1-2%

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Hadronic matrix element	Current lattice error	60 TFlop Year [2011 LHCb]	1-10 PFlop Year [2015 SuperB]
$f_+^{K\pi}(0)$	0.9% (22% on 1-f_+)	0.4% (10% on 1-f_+)	< 0.1% (2.4% on 1-f_+)
$\hat{B}_K$	11%	3%	1%
f_B	14%	2.5 - 4.0%	1 – 1.5%
$f_{B_s}B_{B_s}^{1/2}$	13%	3 - 4%	1 – 1.5%
ξ	5% (26% on ξ-1)	1.5 - 2 % (9-12% on ξ-1)	0.5 – 0.8 % (3-4% on ξ-1)
$\mathcal{F}_{B\to D/D^*l\nu}$	4% (40% on 1-$\mathcal{F}$)	1.2% (13% on 1-$\mathcal{F}$)	0.5% (5% on 1-$\mathcal{F}$)
$f_+^{B\pi}, \ldots$	11%	4 - 5%	2 – 3%
$T_1^{B\to K^*/\rho}$	13%	----	3 – 4%

S.Sharpe @ Lattice QCD: Present and Future, Orsay, 2004 and report of the U.S. Lattice QCD Executive Committee