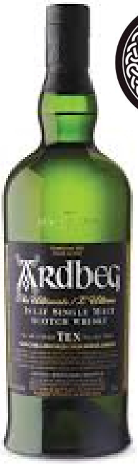
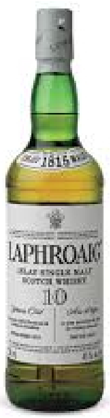


Ardbeg EST? 1815

LAGAVULIN™
ISLAY SINGLE MALT SCOTCH WHISKY

KILCHOMAN
ISLAY SINGLE MALT SCOTCH WHISKY

Unitarity Triangle analysis in the SM and beyond from UTfit



Bunnahabhain
Islay Single Malt Scotch Whisky

Marcella Bona
QMUL

LAPHROAIG®

Heavy Flavour 2016: Quo Vadis?
Thursday July 14th
Islay, Scotland
still UK.. still EU..

BOWMORE
ISLAY
SINGLE MALT
SCOTCH WHISKY

CAOL ILA
ISLAY SINGLE MALT WHISKY

BRUICHLADDICH

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

.. and beyond

- NP UT analysis:
  - model-independent analysis
  - provides limit on the allowed deviations from the SM
  - obtain the NP scale

UTfit

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://latticeaverages.org/)
Lunghi&Soni (1010.6069)

the method and the inputs:

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

Bayes Theorem

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

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

$(b\to u)/(b\to c)$	$\bar\rho^2+\bar\eta^2$	$\bar\Lambda, \lambda_1, F(1), \dots$
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
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	

, $\boxed{\mathbf{m}_t}$

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

V_{cb} and V_{ub}

V_{cb} *(excl)* = (39.19 ± 0.70) 10^{-3}

V_{cb} *(incl)* = (42.20 ± 0.70) 10^{-3}

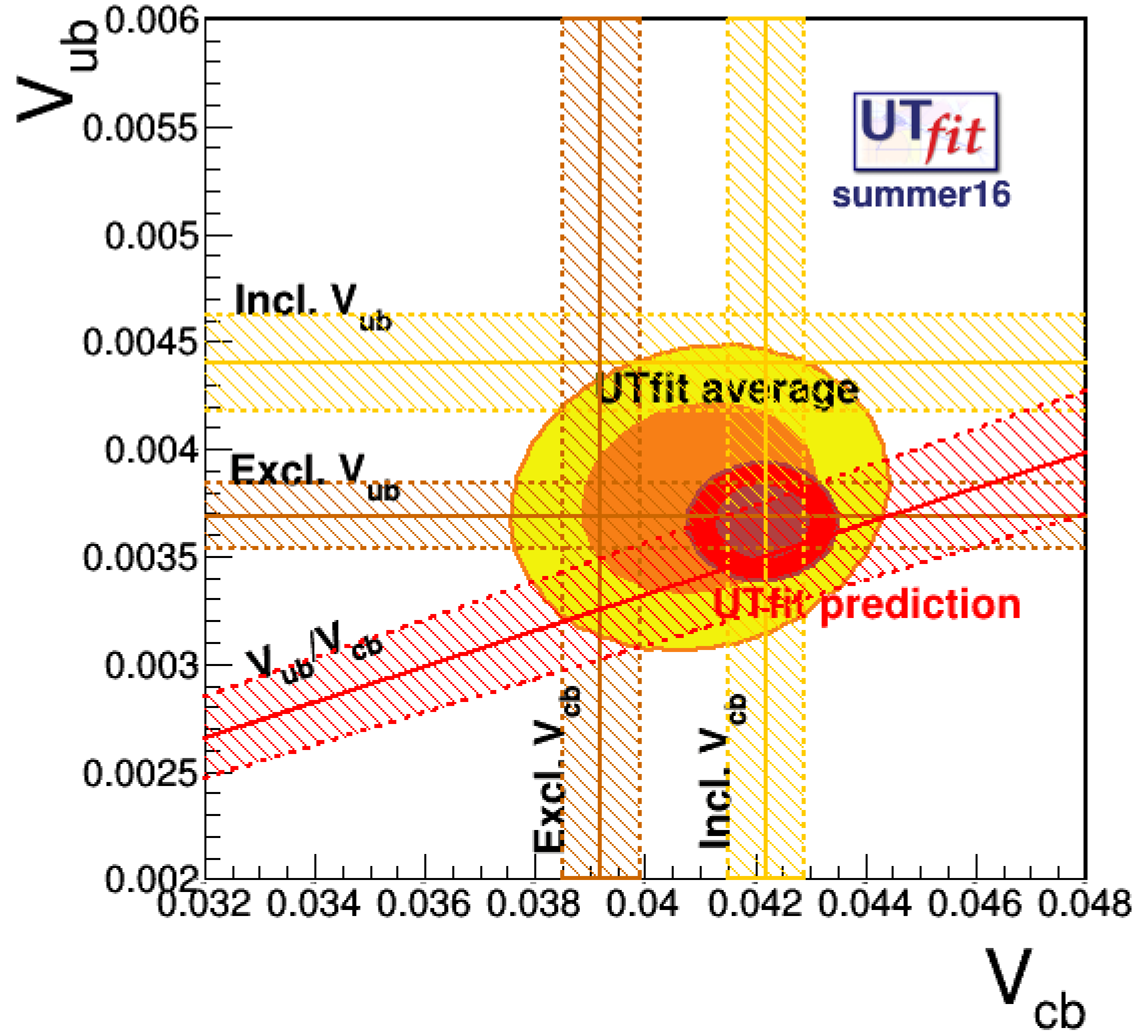
~3.0σ discrepancy

V_{ub} *(excl)* = (3.69 ± 0.14) 10^{-3}

V_{ub} *(incl)* = (4.40 ± 0.22) 10^{-3}

~2.7σ discrepancy

V_{ub} / V_{cb} *(LHCb)* = (8.3 ± 0.6) 10^{-2}



V_{cb} and V_{ub}

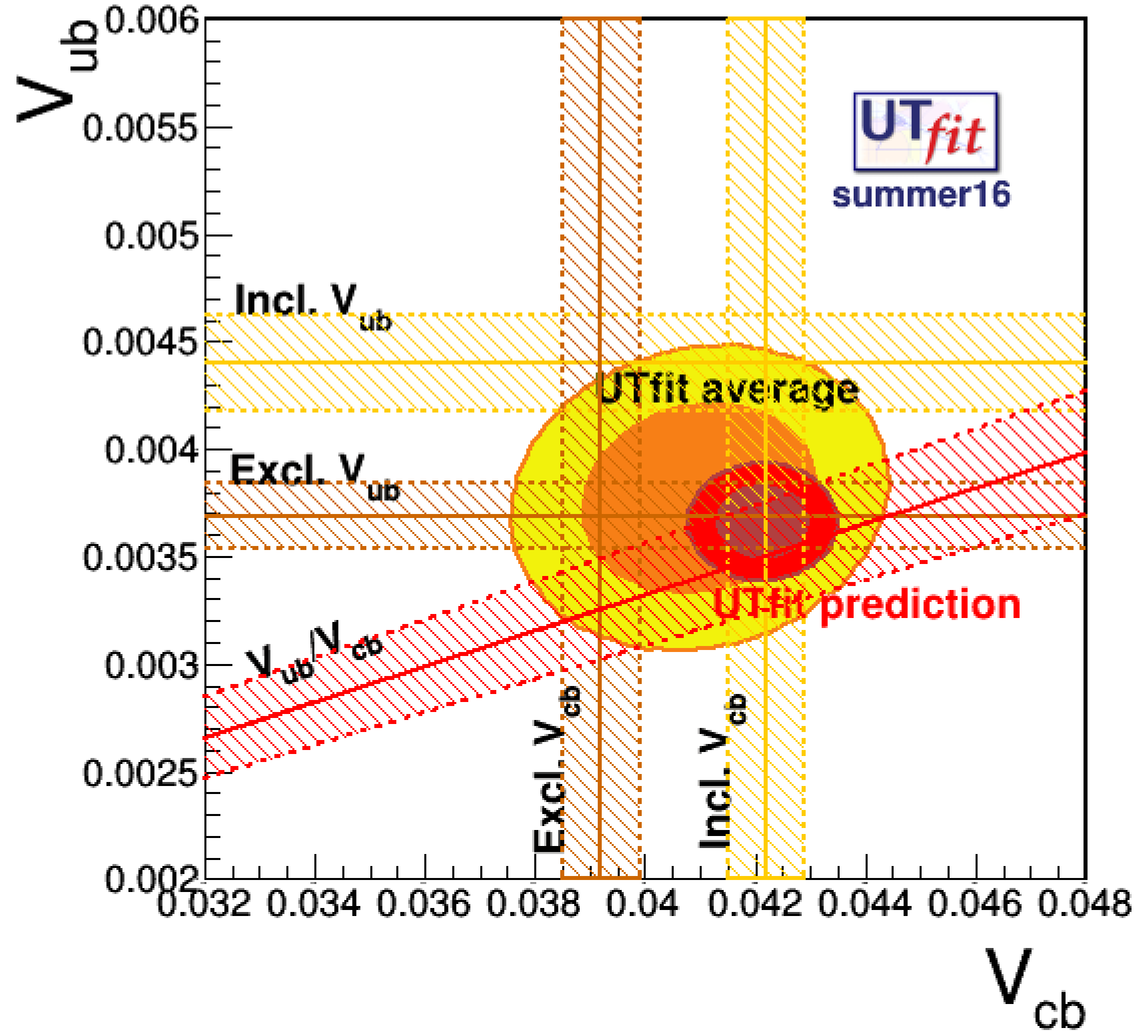
Average inspired by D'Agostini skeptical procedure (hep-ex/9910036).
However very similar results are obtained from a 2D a la PDG procedure.

$V_{cb} = (41.0 \pm 1.4)\ 10^{-3}$

uncertainty ~ 3.4%

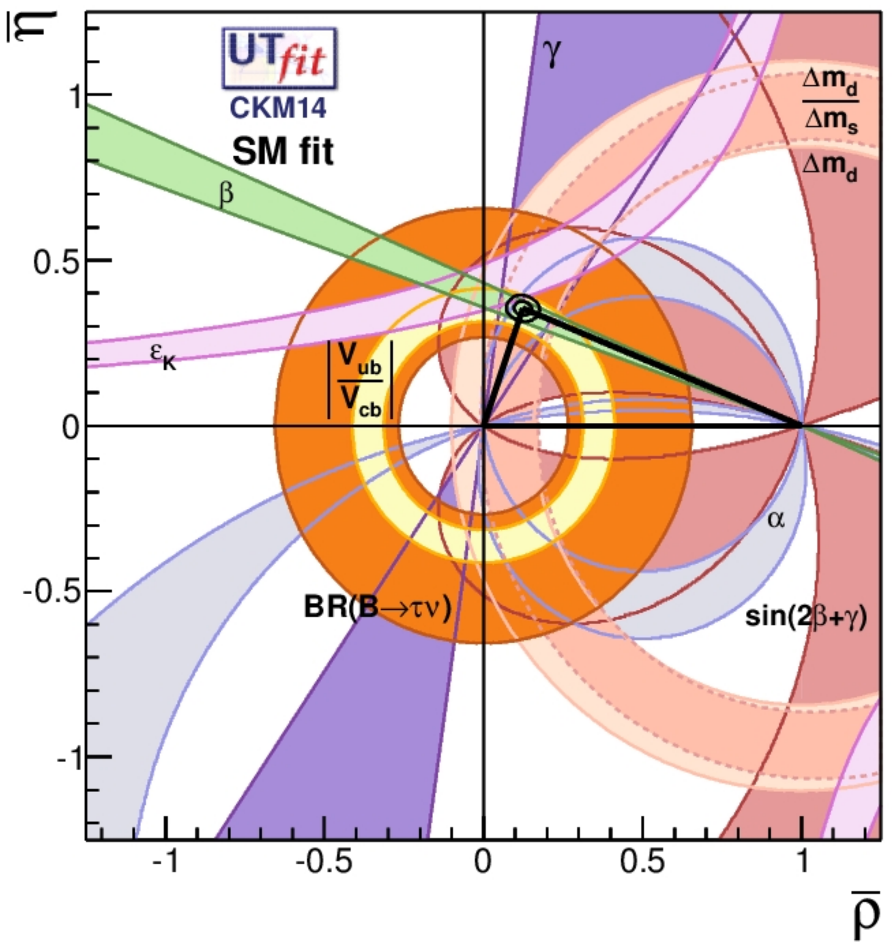
$V_{ub} = (3.77 \pm 0.29)\ 10^{-3}$

uncertainty ~ 7.7%

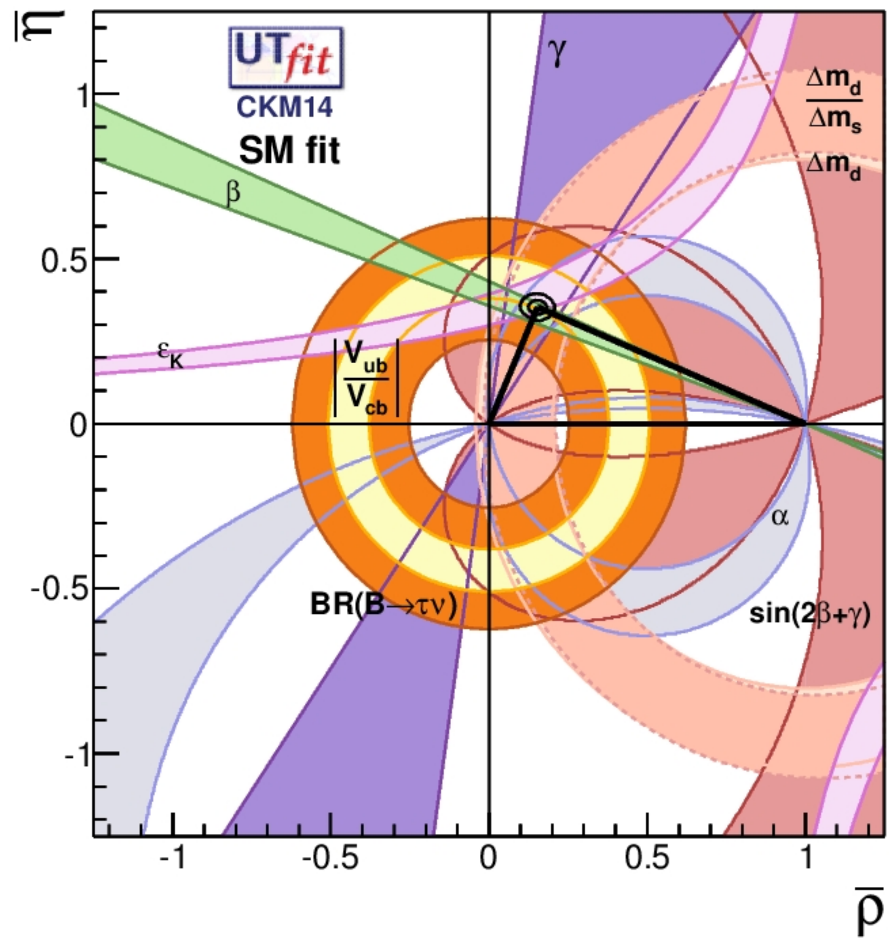


exclusives vs inclusives

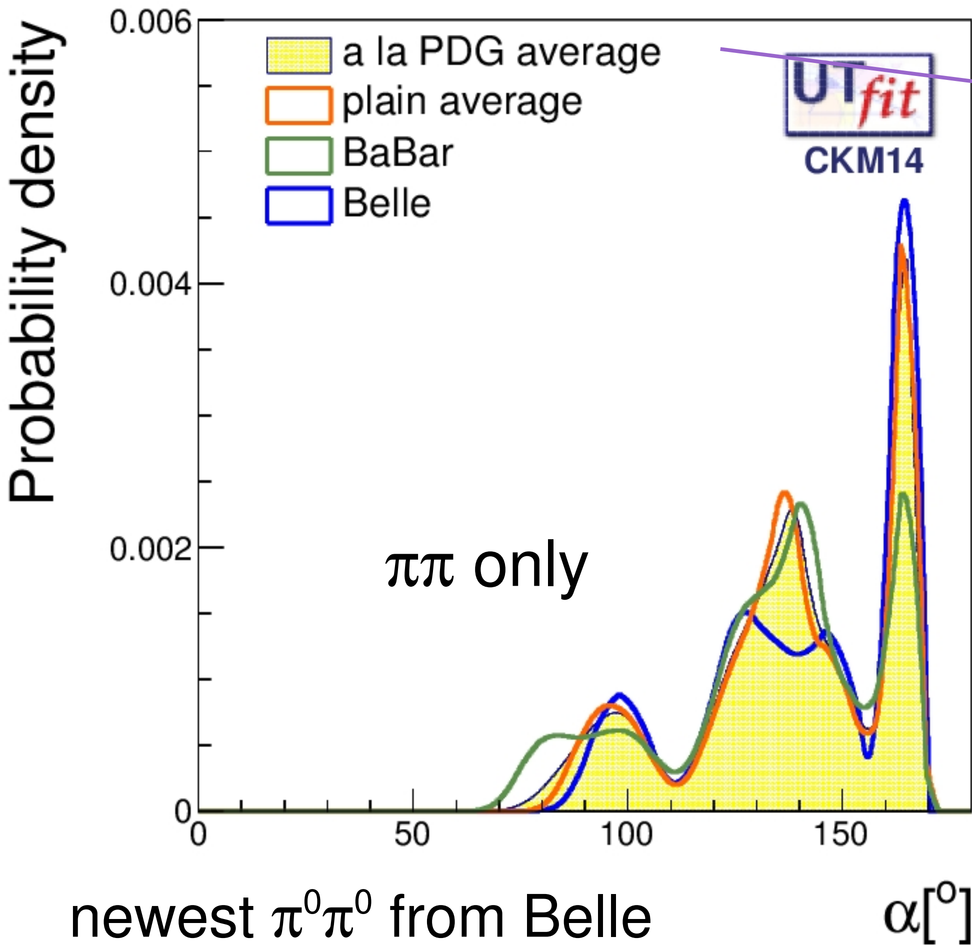
only exclusive values



only inclusive values



$\sin 2\alpha$ (ϕ_2) from charmless B decays: pp, ($\rho\rho$, $\pi\rho$)

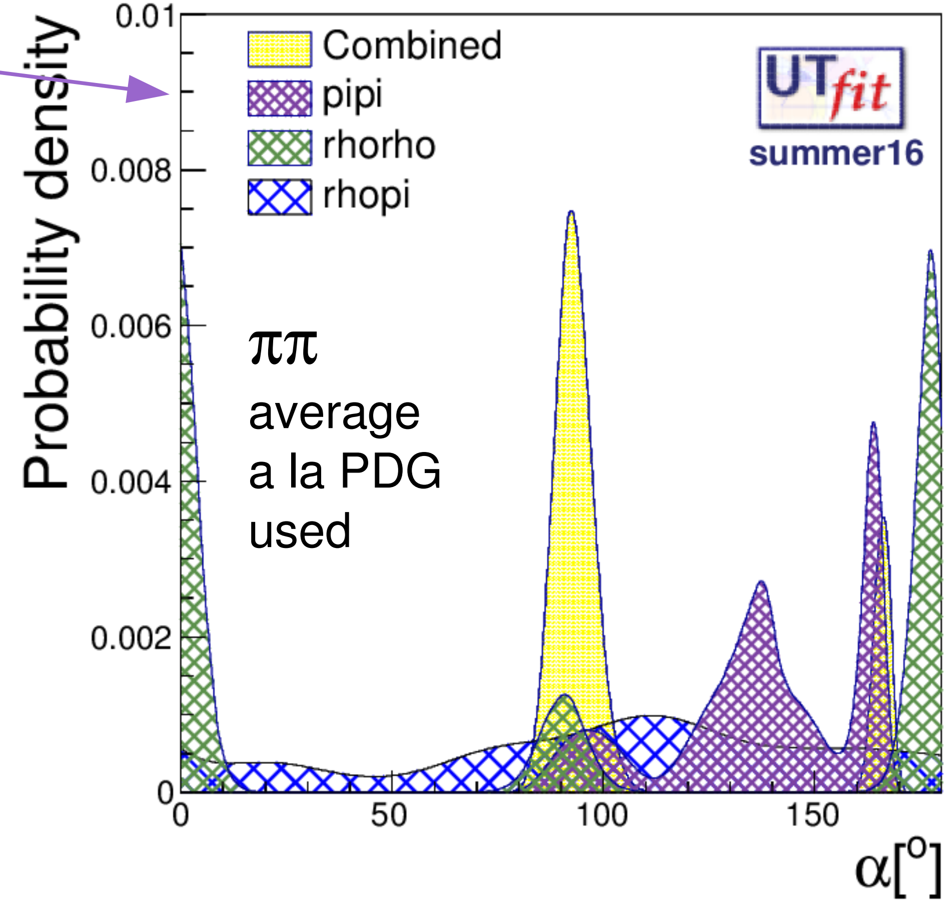


newest $\pi^0\pi^0$ from Belle

à la PDG average inflates the error

BR($\pi^0\pi^0$) = (1.15 ± 0.41) 10^{-6}

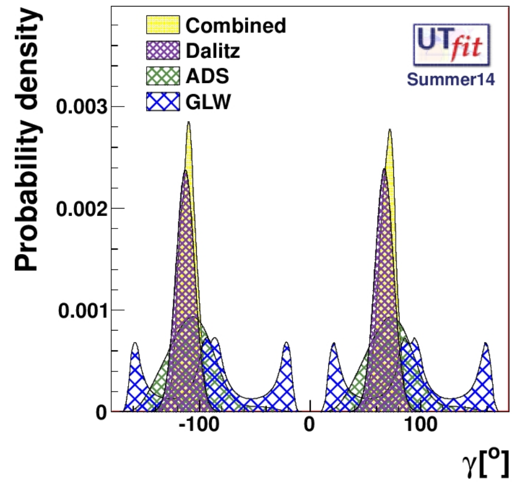
wrt plain average: (1.15 ± 0.13) 10^{-6}

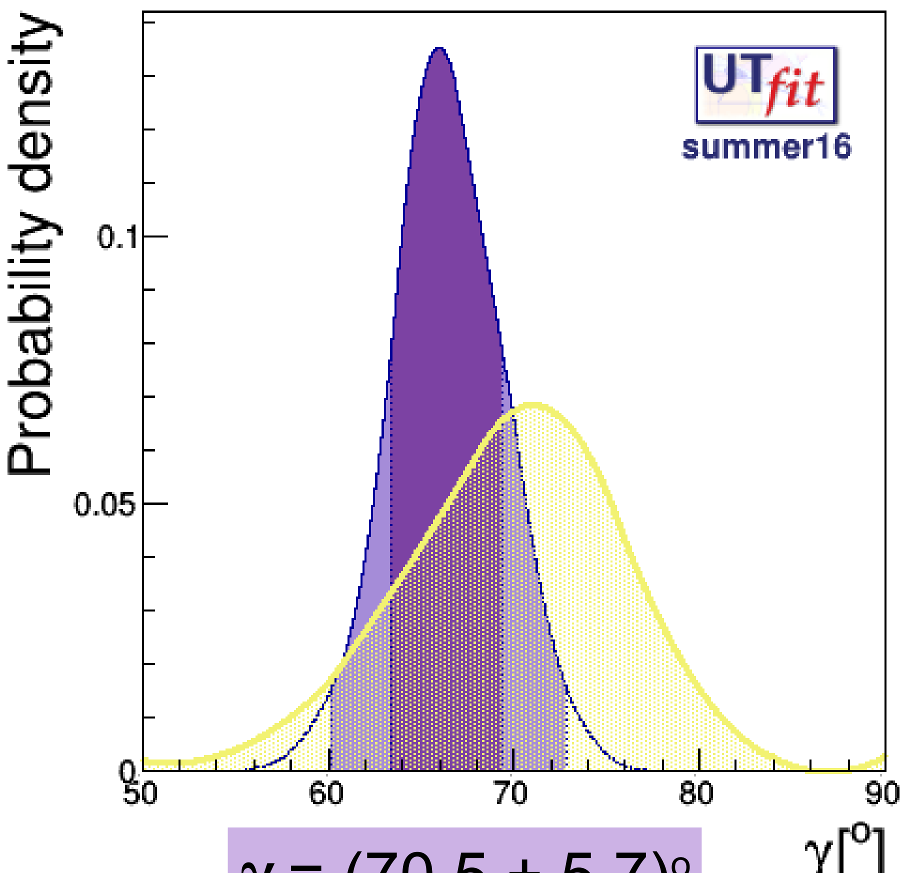


α from $\pi\pi$, $\rho\rho$, $\pi\rho$ decays:

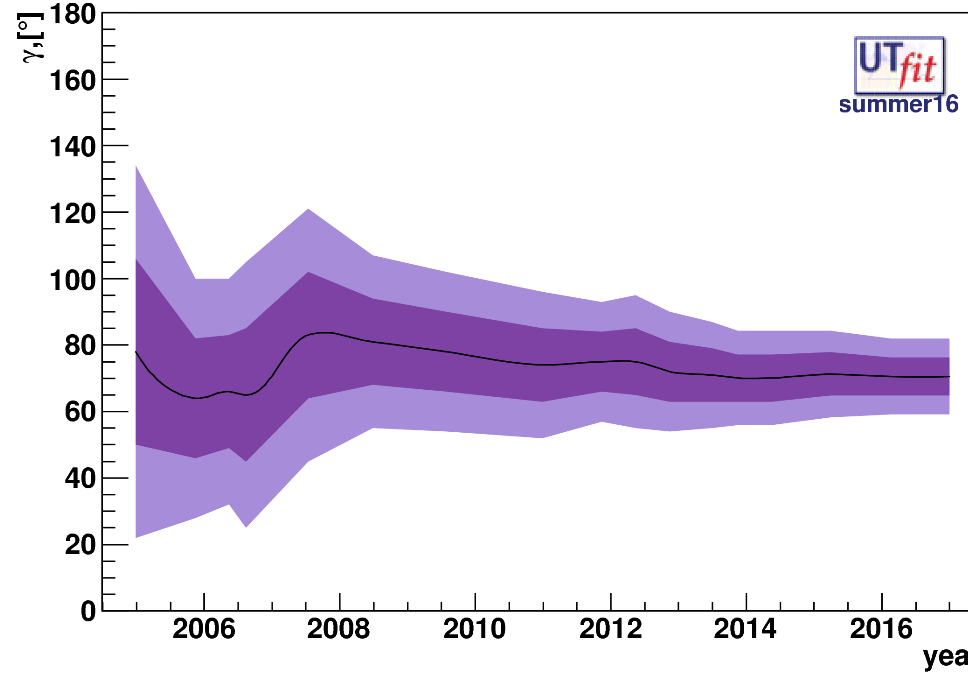
combined: (92.5 ± 5.5)°

γ and DK trees



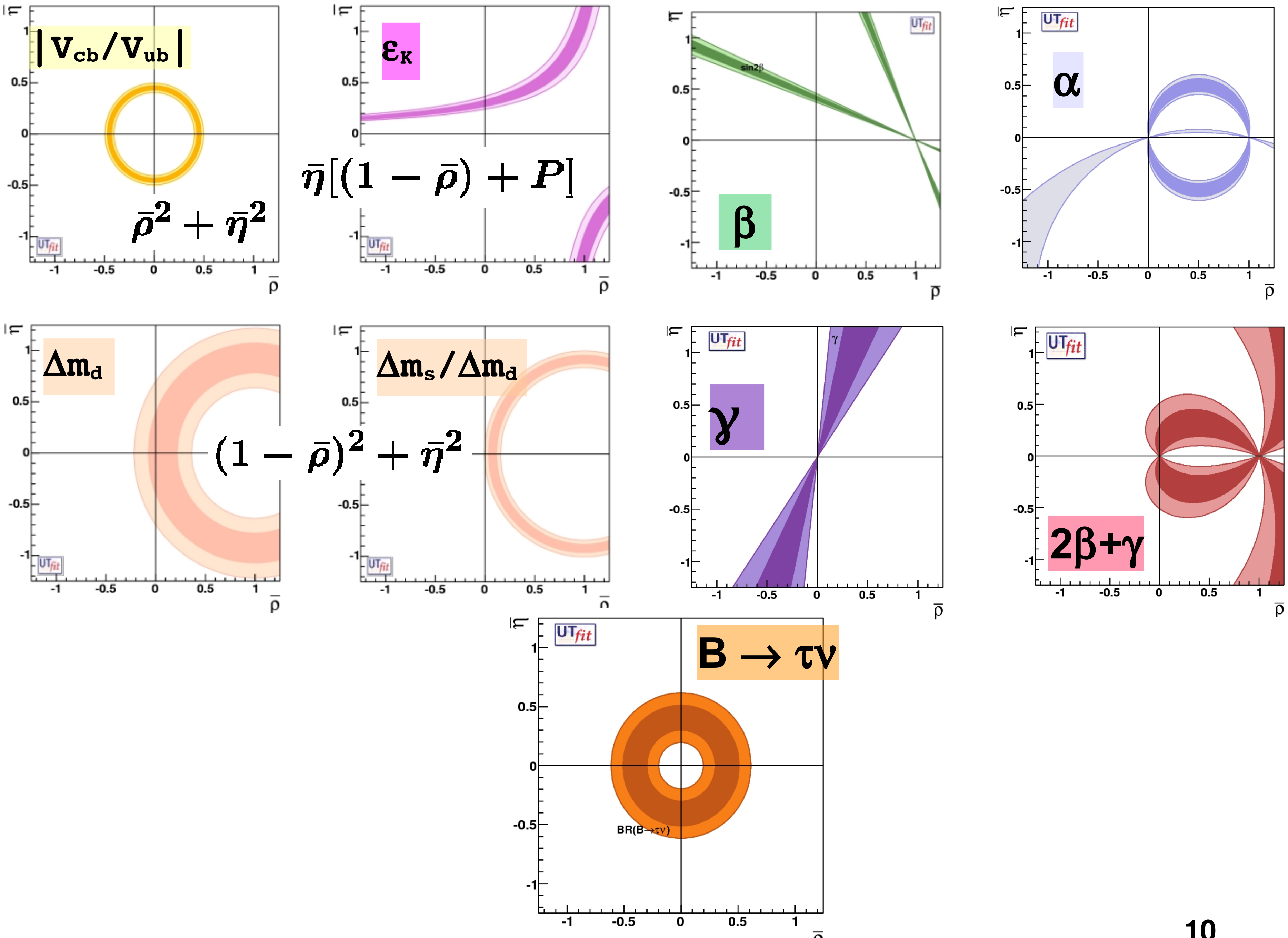


$\gamma = (70.5 \pm 5.7)^{\circ}$

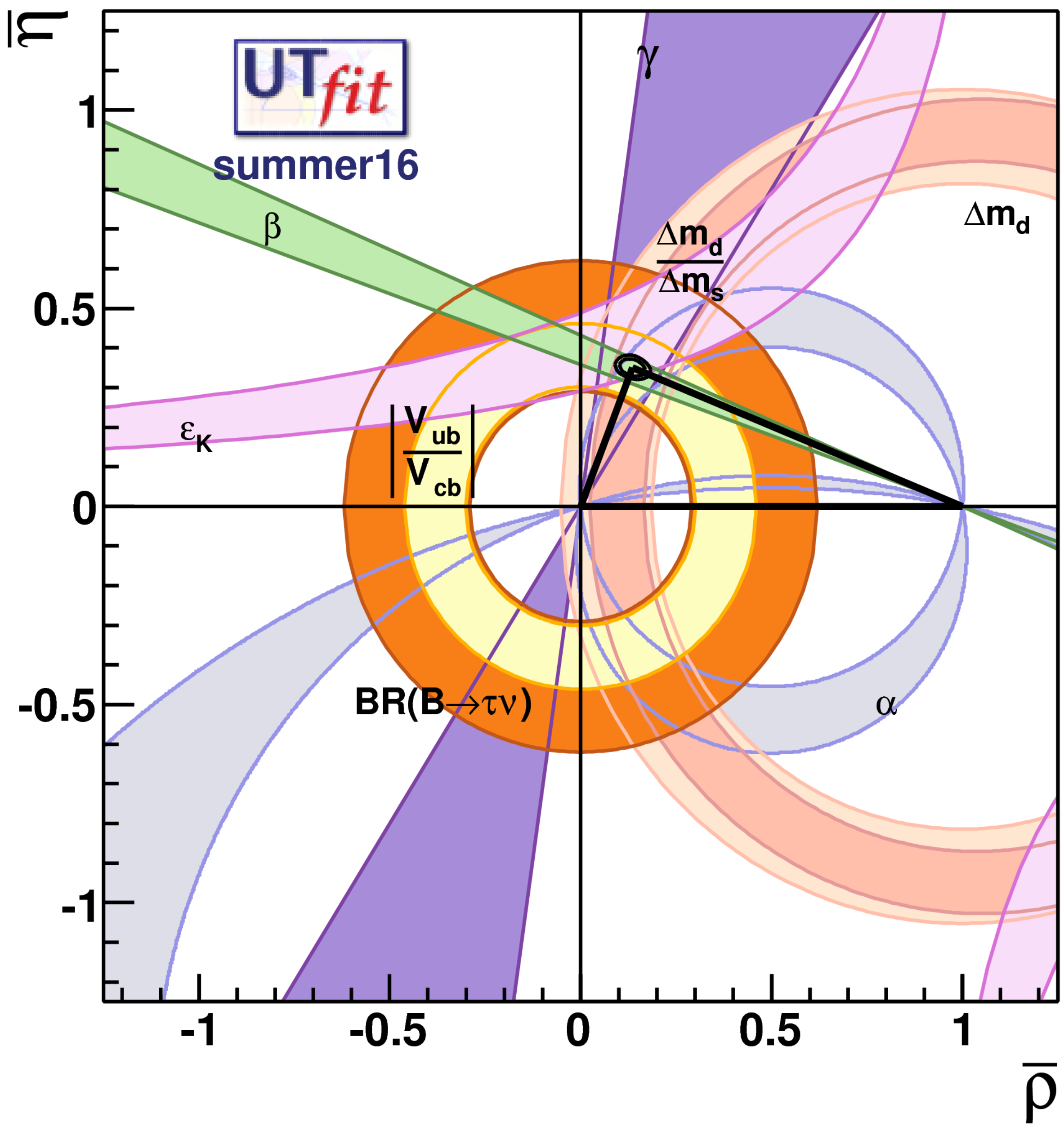


After a decade of analyses and almost 50 papers published, the world average uncertainty has decreased by a factor 3

Unitarity Triangle analysis in the SM:



Unitarity Triangle analysis in the SM:

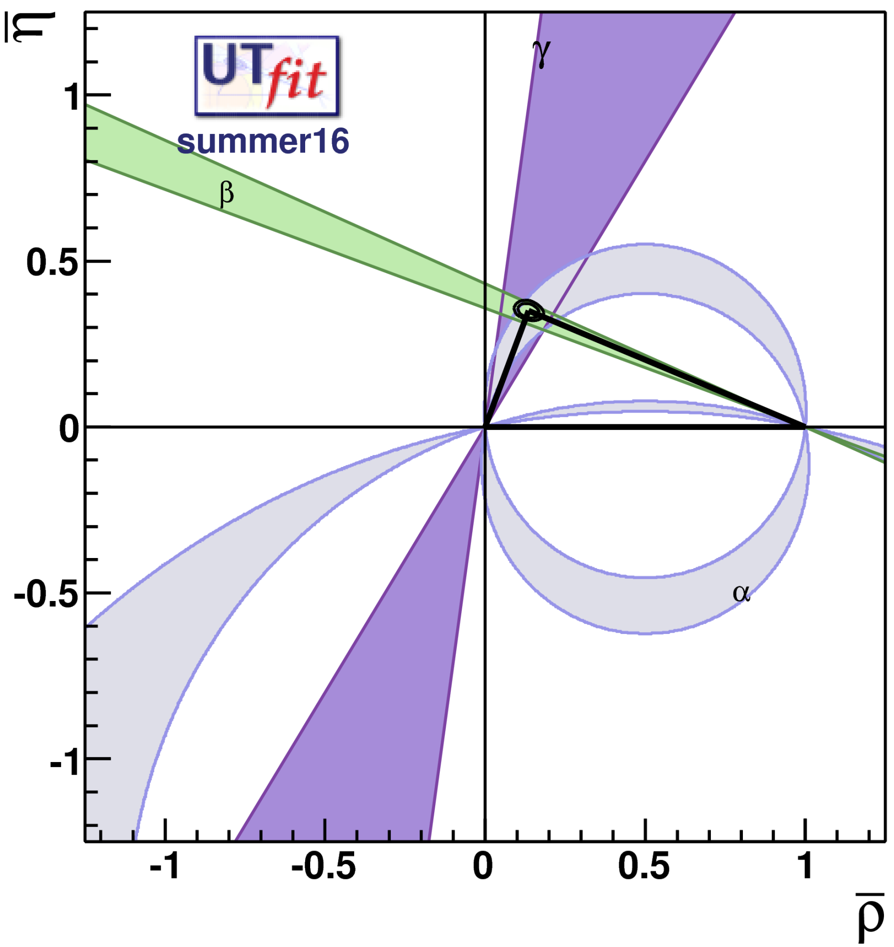


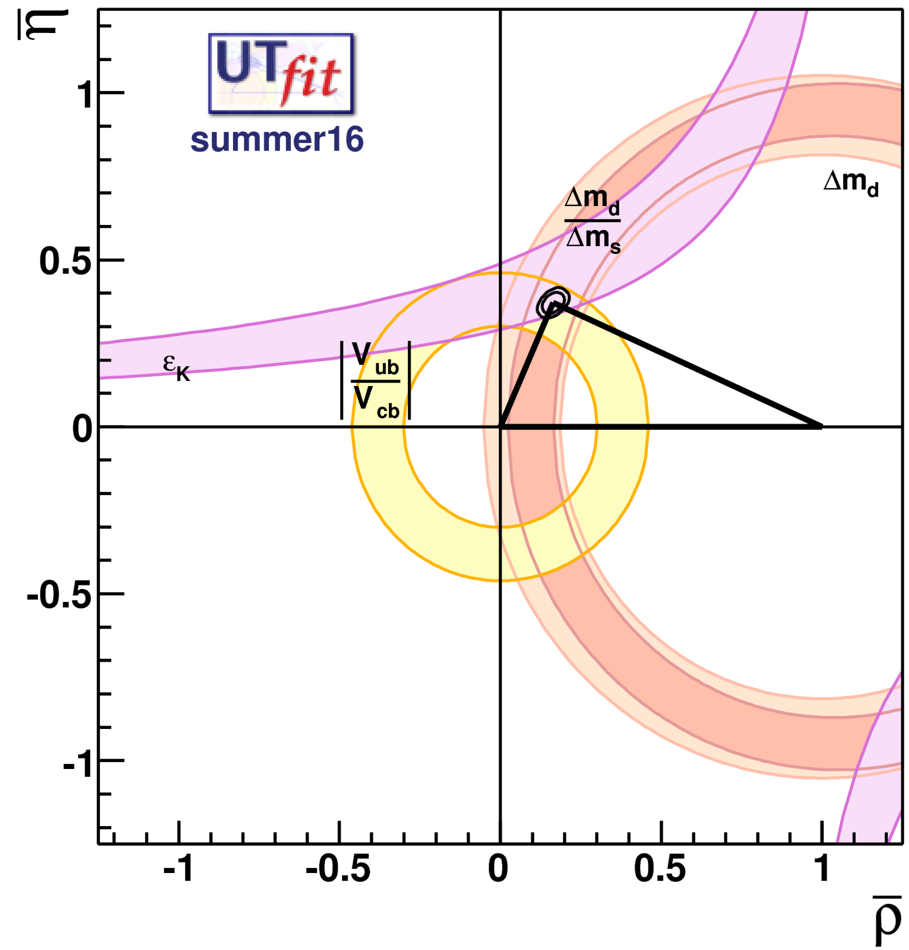
levels @
95% Prob

$\bar{\rho} = 0.144 \pm 0.018$
$\bar{\eta} = 0.346 \pm 0.012$

CP violating vs CP conserving

levels @
95% Prob



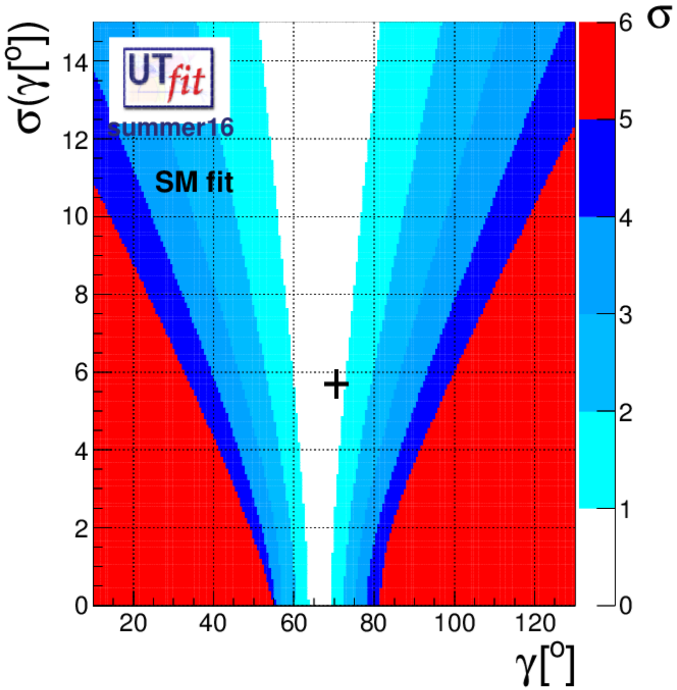


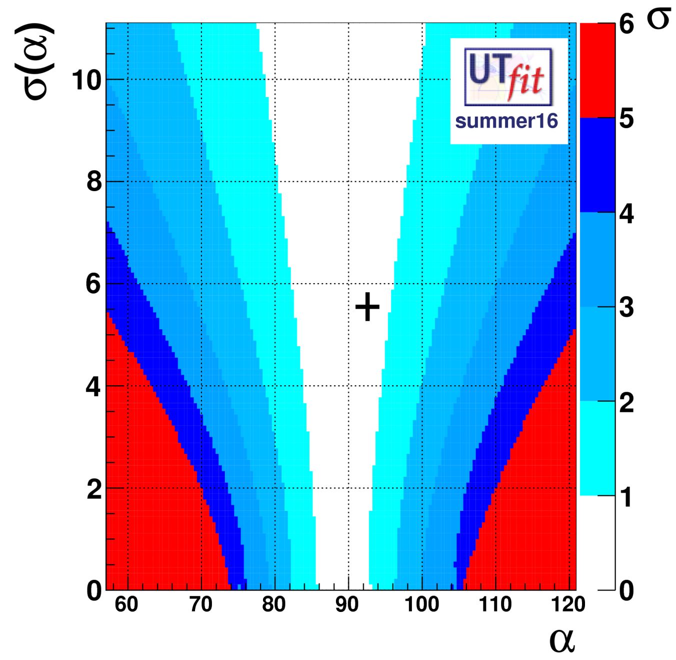
compatibility plots

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





$\gamma_{exp} = (70.5 \pm 5.7)^\circ$

$\gamma_{UTfit} = (66.3 \pm 3.0)^\circ$

$\alpha_{exp} = (92.5 \pm 5.5)^\circ$

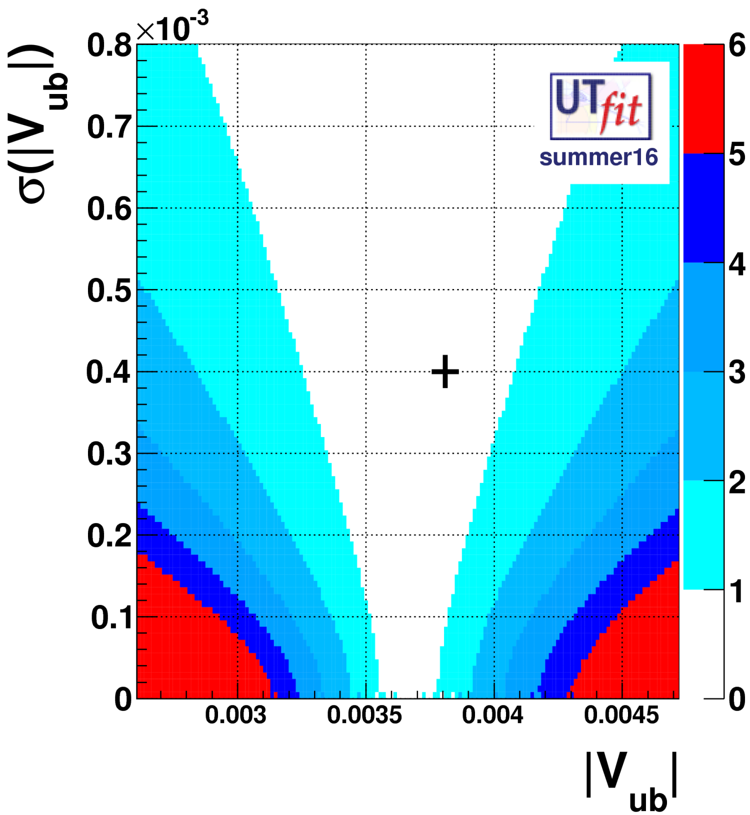
$\alpha_{UTfit} = (88.9 \pm 3.5)^\circ$

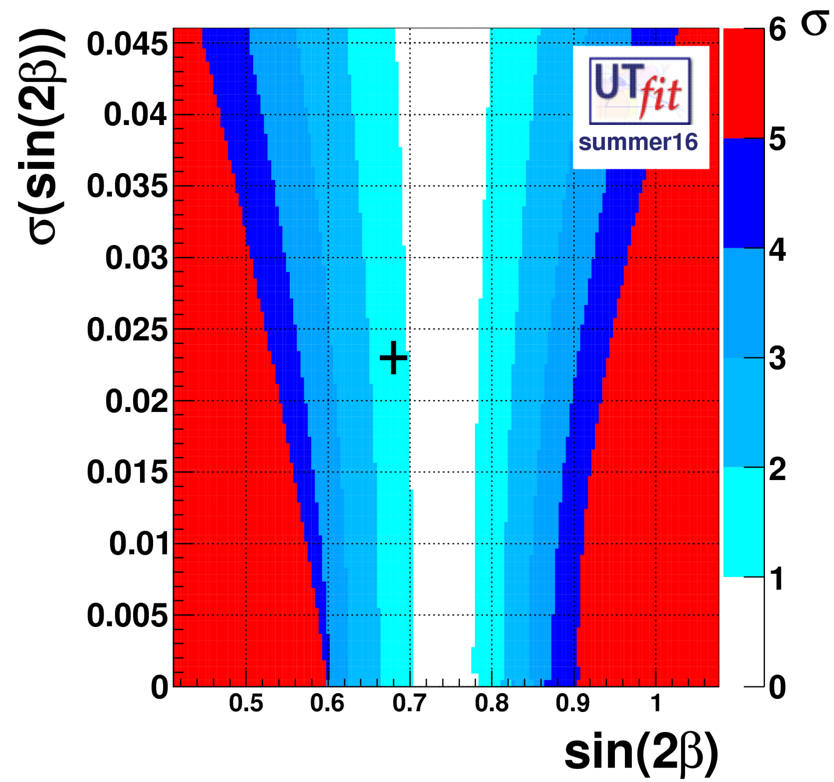
tensions? not any more..

~1.4σ

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

$\sin 2\beta_{UTfit} = 0.740 \pm 0.037$





$Vub_{exp} = (3.77 \pm 0.29) \cdot 10^{-3}$

$Vub_{UTfit} = (3.66 \pm 0.11) \cdot 10^{-3}$

Unitarity Triangle analysis in the SM:

obtained excluding the given constraint from the fit

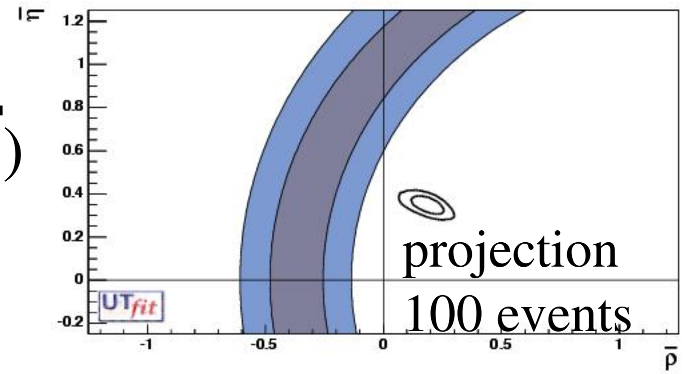
Observables	Measurement	Prediction	Pull (#σ)
$\sin 2\beta$	0.680 ± 0.023	0.740 ± 0.037	~ 1.4
γ	70.5 ± 5.7	66.3 ± 3.0	< 1
α	92.2 ± 6.2	87.3 ± 3.9	< 1
$\lvert V_{ub}\rvert \cdot 10^3$	3.77 ± 0.29	3.66 ± 0.11	< 1
$\lvert V_{ub}\rvert \cdot 10^3$ (incl)	4.40 ± 0.22	–	~ 3.0
$\lvert V_{ub}\rvert \cdot 10^3$ (excl)	3.69 ± 0.14	–	< 1
$\lvert V_{cb}\rvert \cdot 10^3$	41.0 ± 1.4	*42.3 ± 0.6*	< 1
β_s	0.97 ± 0.94	*1.05 ± 0.04*	< 1
B_K	0.766 ± 0.010	*0.832 ± 0.081*	< 1
$BR(B \to \tau\nu)[10^{-4}]$	1.06 ± 0.20	0.81 ± 0.06	~ 1.3
$A_{SL}^{d} \cdot 10^3$	-1.5 ± 1.7	-0.283 ± 0.024	< 1
$A_{SL}^{s} \cdot 10^3$	-7.5 ± 4.1	0.013 ± 0.001	~1.8

some old plots coming back to fashion:

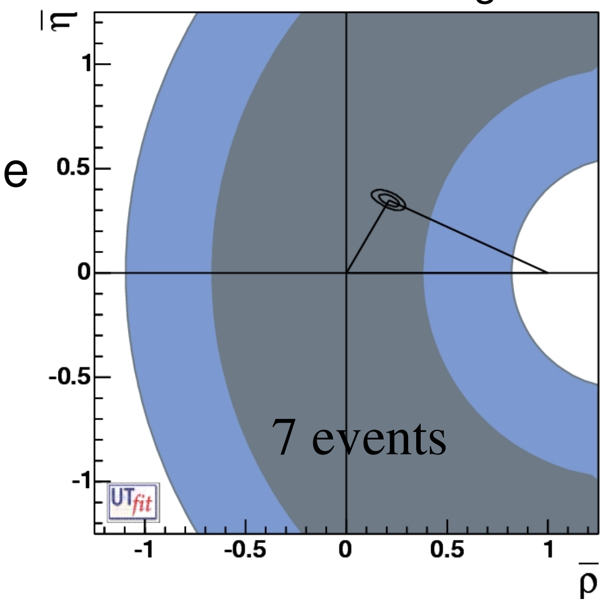
As NA62 and KOTO are approaching data taking:

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

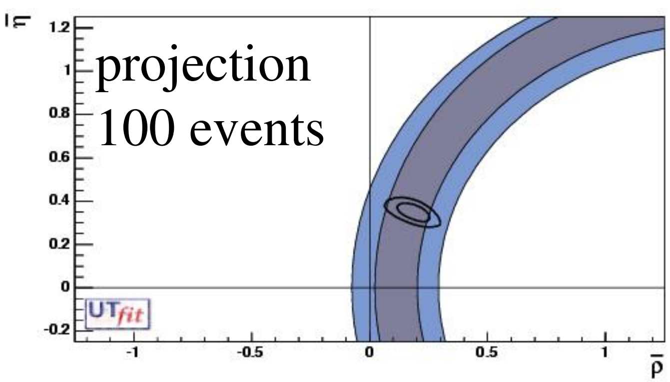
E949 central value

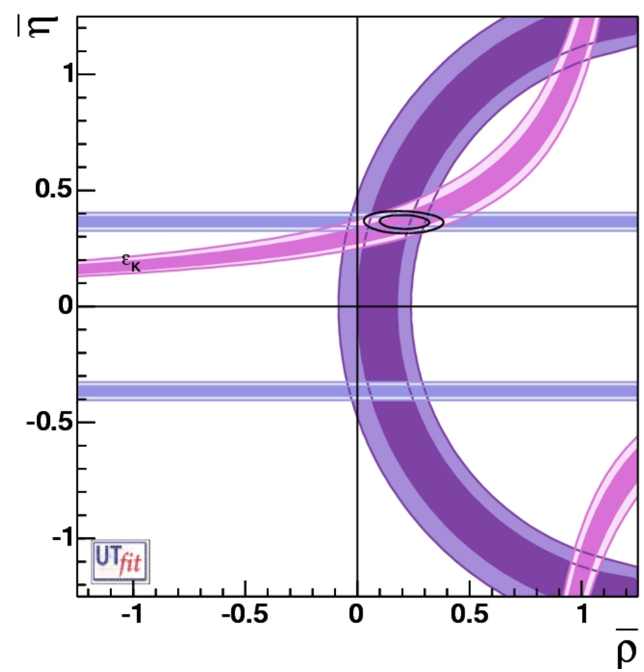


2007 global fit area



SM central value





including $\mathrm{BR}(K^0 \to \pi^0 \nu\bar{\nu})$ SM central value

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

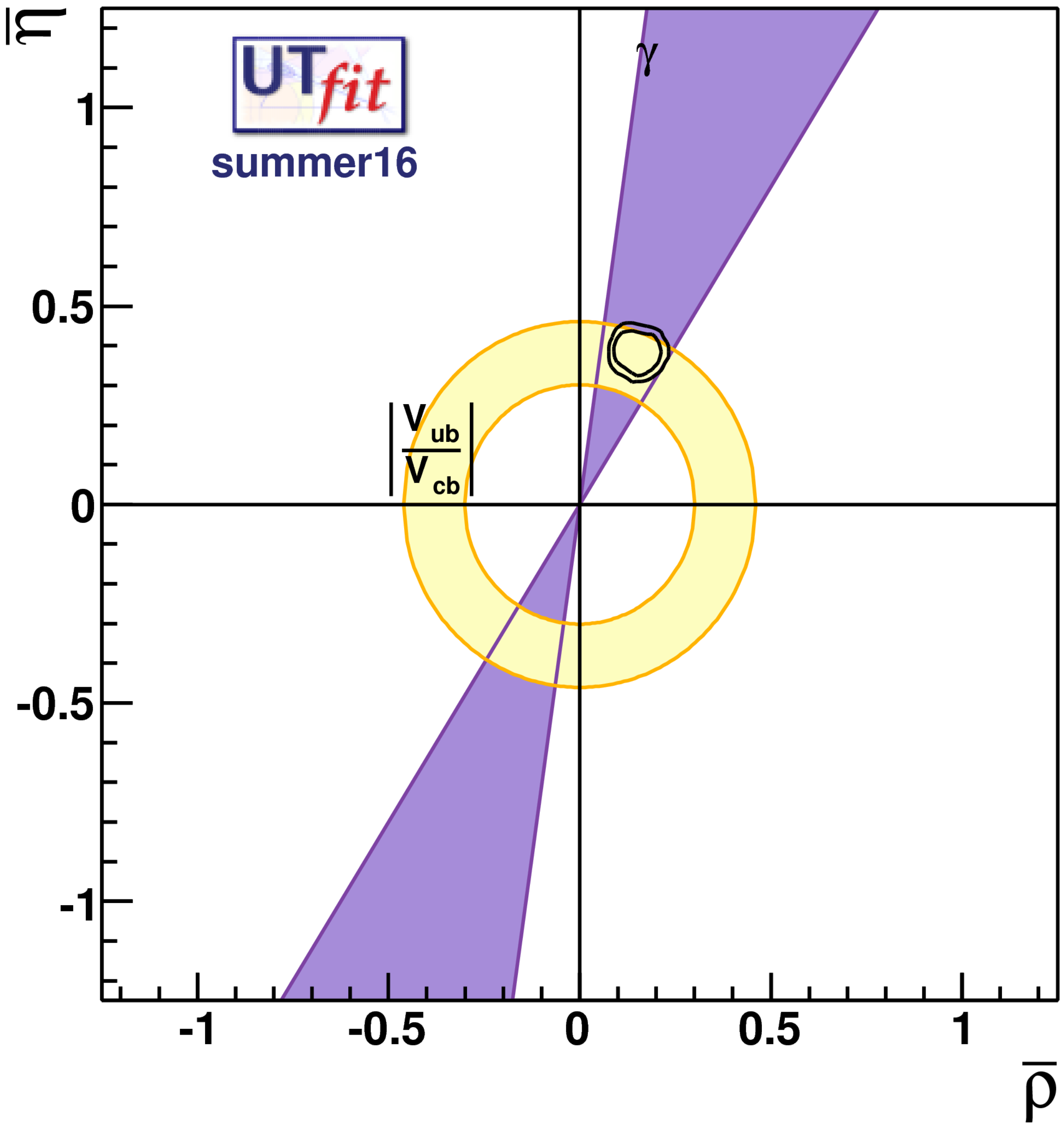
B_d and B_s mixing amplitudes
(2+2 real parameters):

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

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

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

NP analysis results



$\bar{\rho} = 0.151 \pm 0.040$
$\bar{\eta} = 0.384 \pm 0.037$

SM is

$\bar{\rho} = 0.144 \pm 0.018$
$\bar{\eta} = 0.346 \pm 0.012$

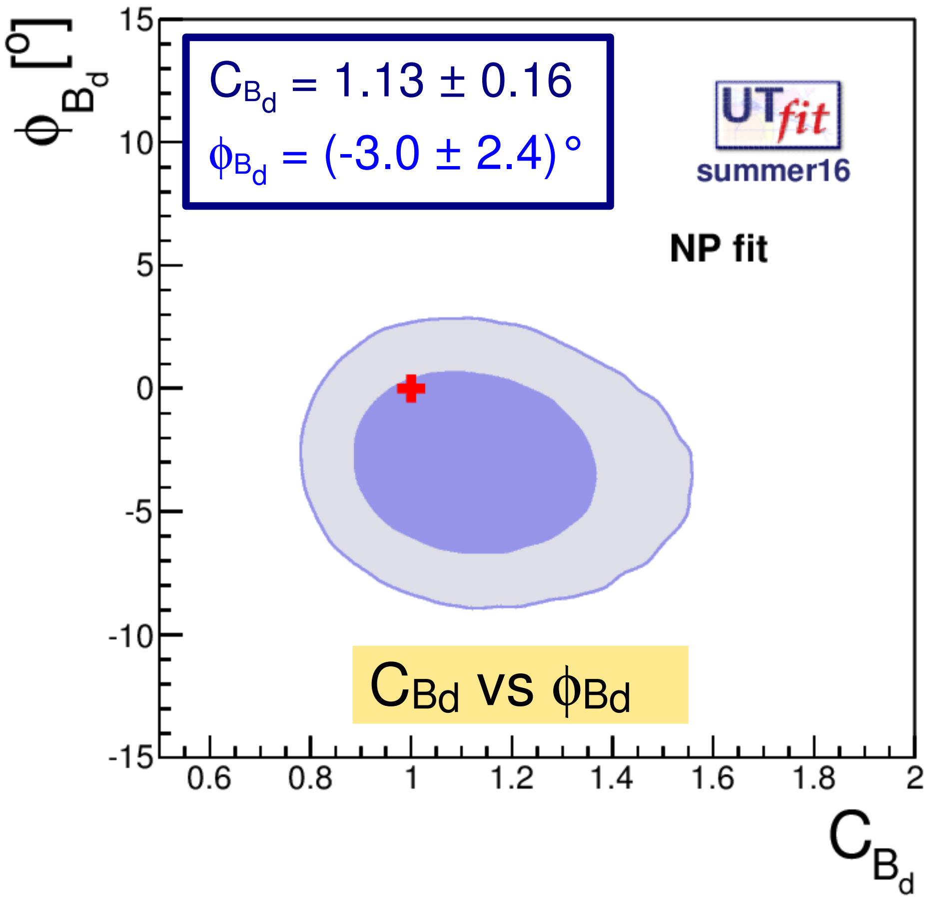
NP parameter results

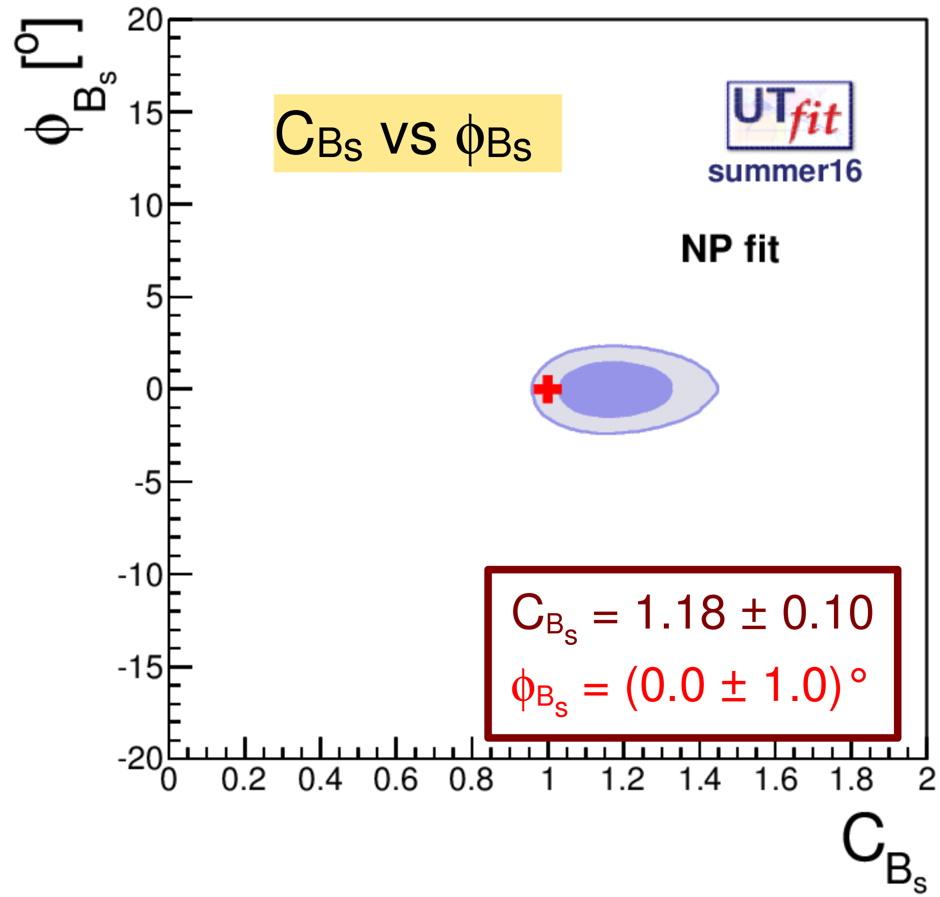
K system

$C_{\varepsilon_K} = 1.14 \pm 0.16$

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

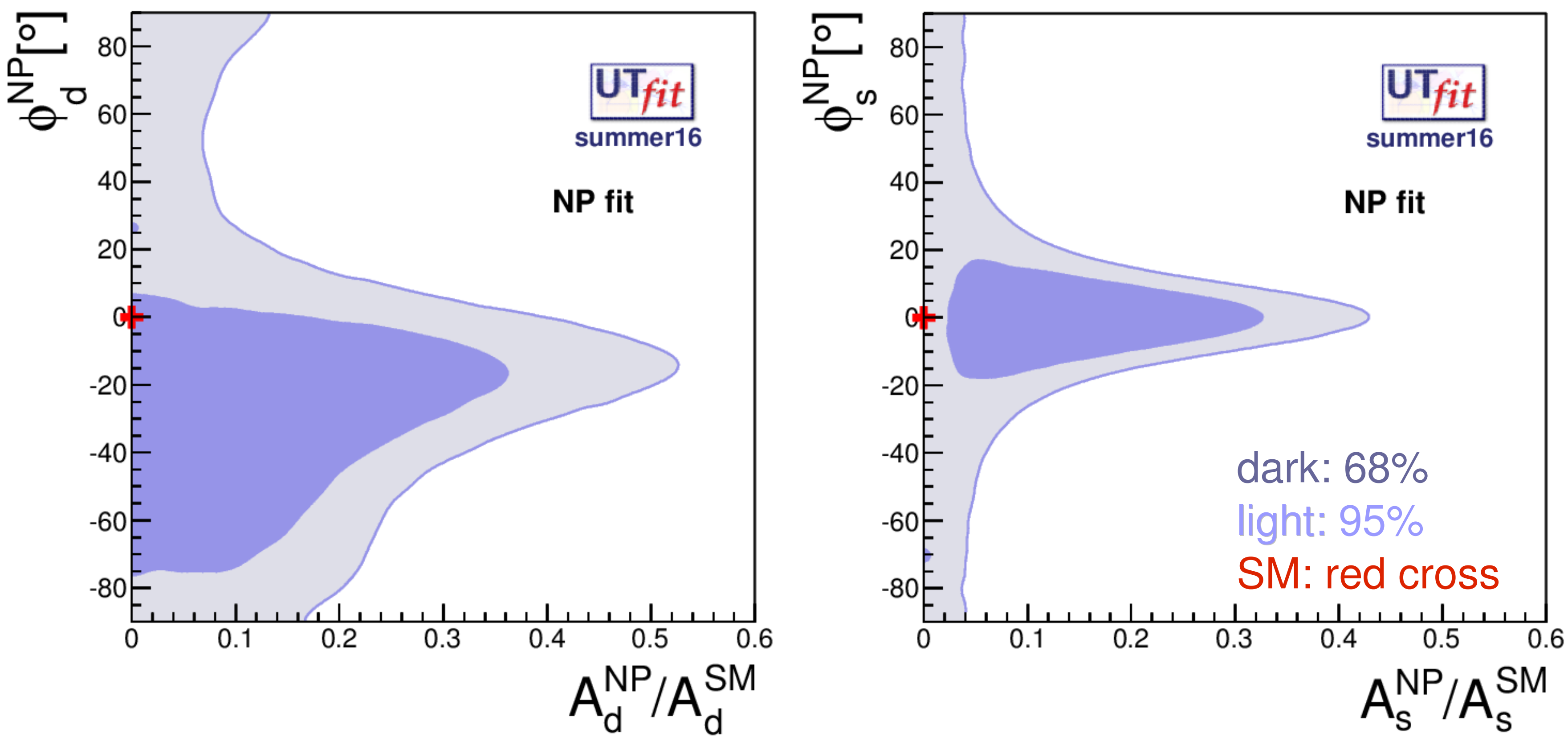
$$A_q = C_{B_q} e^{2i\varphi_{B_q}} A_q^{SM} e^{2i\varphi_q^{SM}}$$





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:

< 35% @68% prob. (50% @95%) in B_d mixing

< 30% @68% prob. (40% @95%) in B_s mixing

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

testing the new-physics scale

R
G
E

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

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

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

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

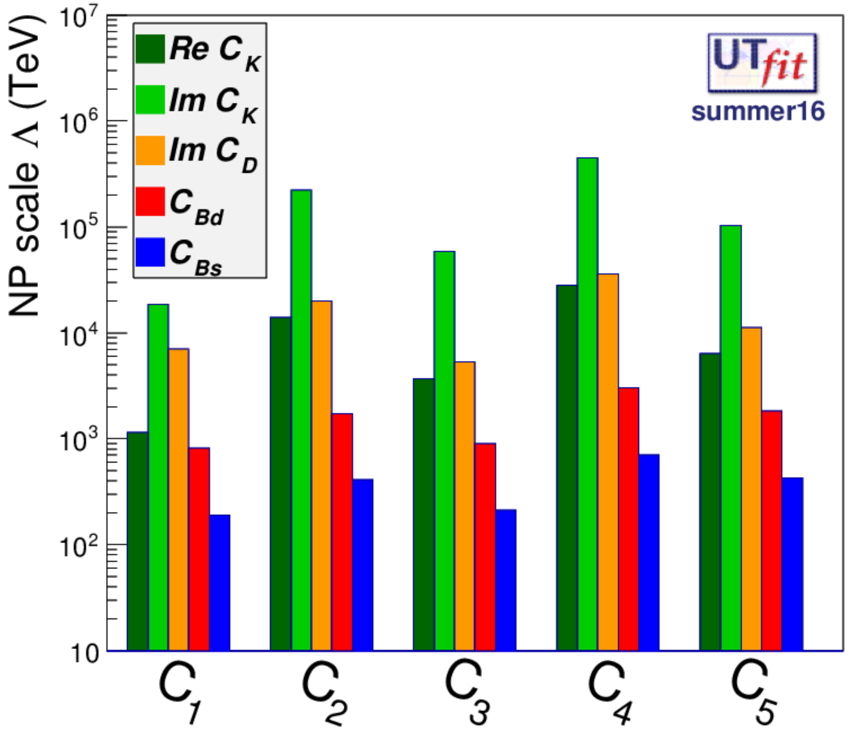
If no NP effect is seen
lower bound on NP scale Λ
if NP is seen
upper bound on NP scale Λ

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.)

Non-perturbative NP

$\Lambda > 4.5\ 10^5$ 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

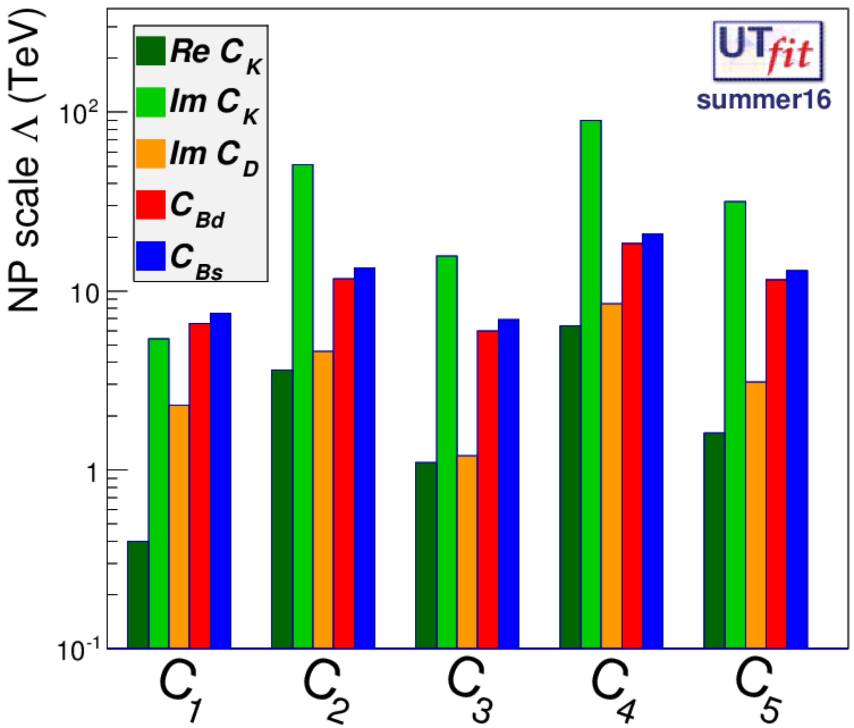
$\Lambda > 1.4\ 10^4$ TeV

Best bound from ε_K
dominated by CKM error
CPV in charm mixing follows,
exp error dominant
Best CP conserving from Δm_K,
dominated by long distance
B_d and B_s behind,
errors from both CKM
and B-parameters

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
$\Lambda > 90$ TeV

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

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

NP in α_W loops
$\Lambda > 2.7$ TeV

If new chiral structures present,
ε_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.

Look at the future

In the next decade, Belle-II and LHCb upgrade will push down the exp. error on sin 2β(s) to less than 0.01

Theory error can be kept below 0.01 using control channels as S($B \to J/\psi\pi$)

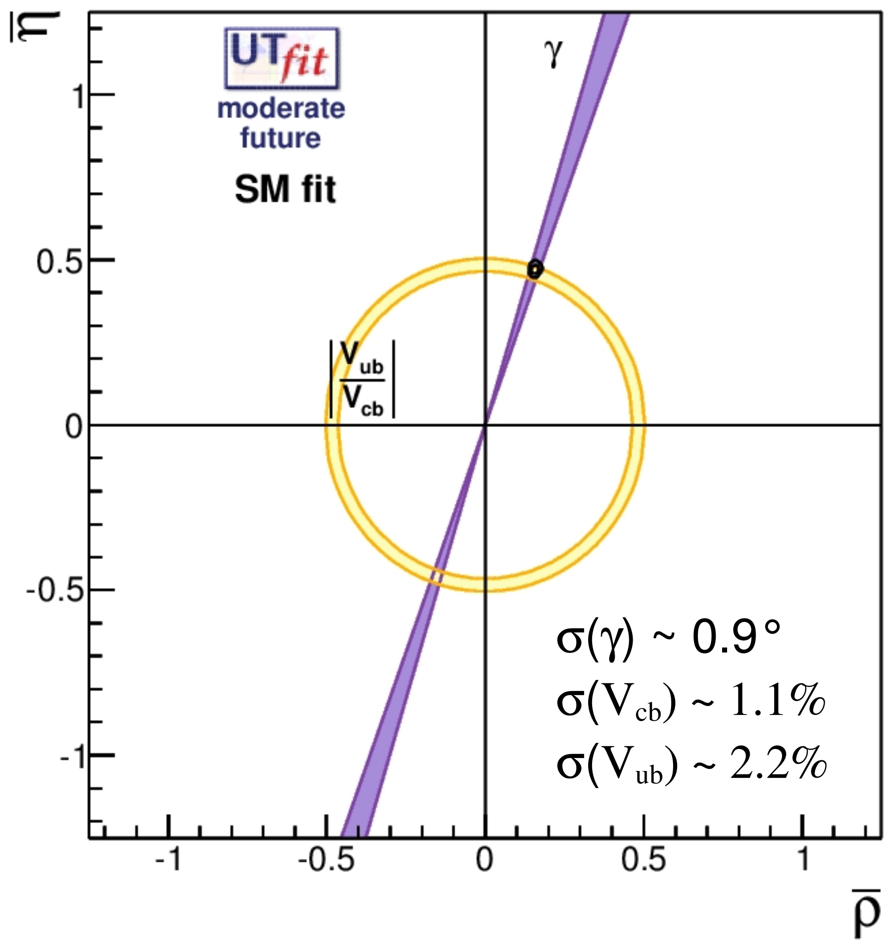
B-parameters will go below the % level, new ideas to attack long-distance in K and D

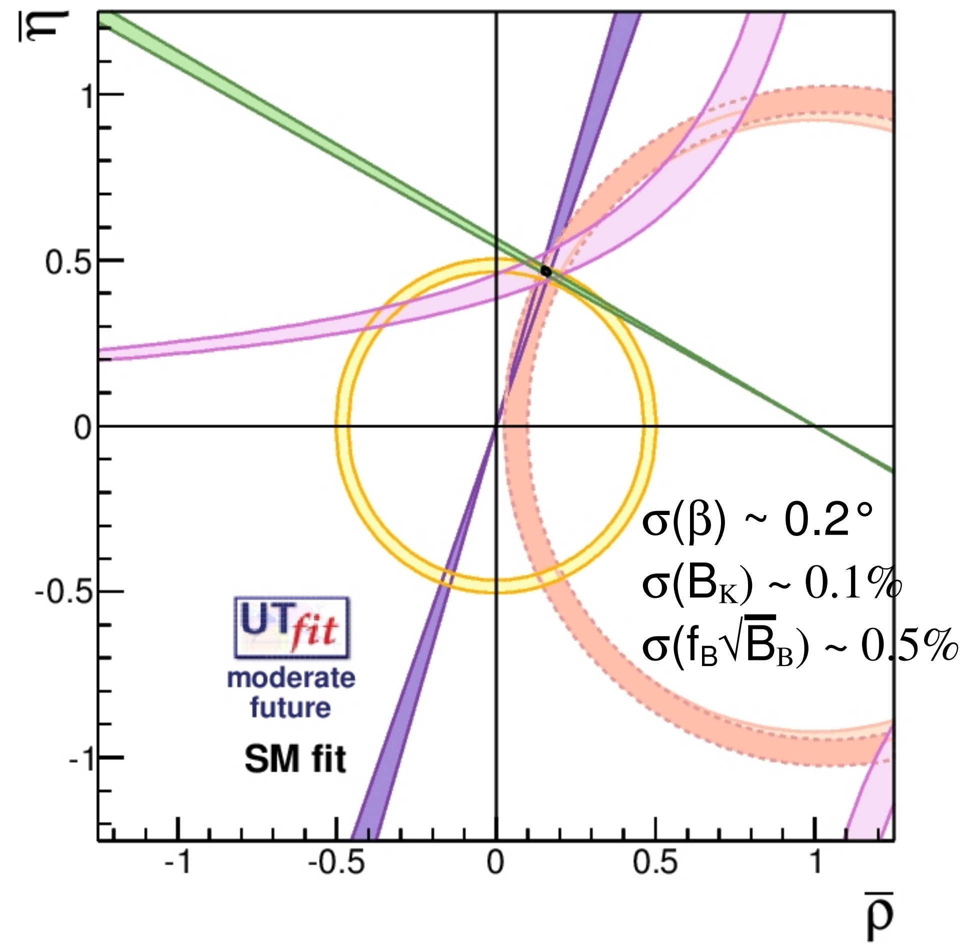
Improving γ, α and $|V_{cb}|$ & $|V_{ub}|$ crucial!

[Silvestrini@Pisa]

Look at the future

errors predicted from
Belle II + LHCb upgrade



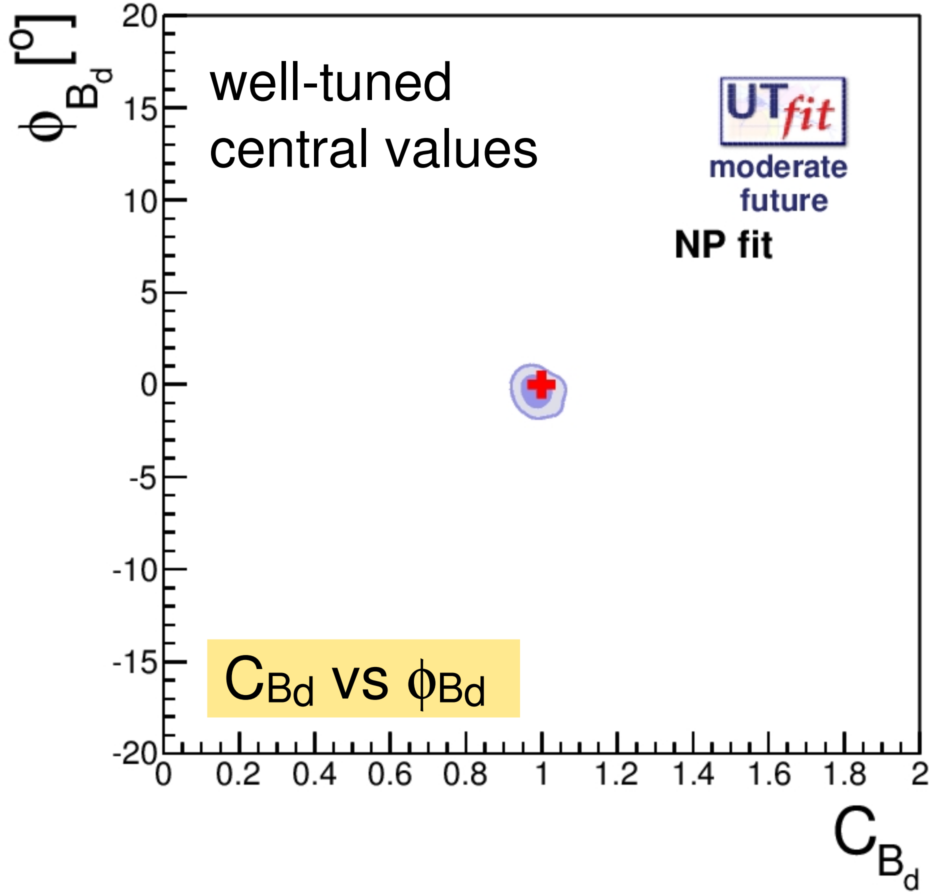


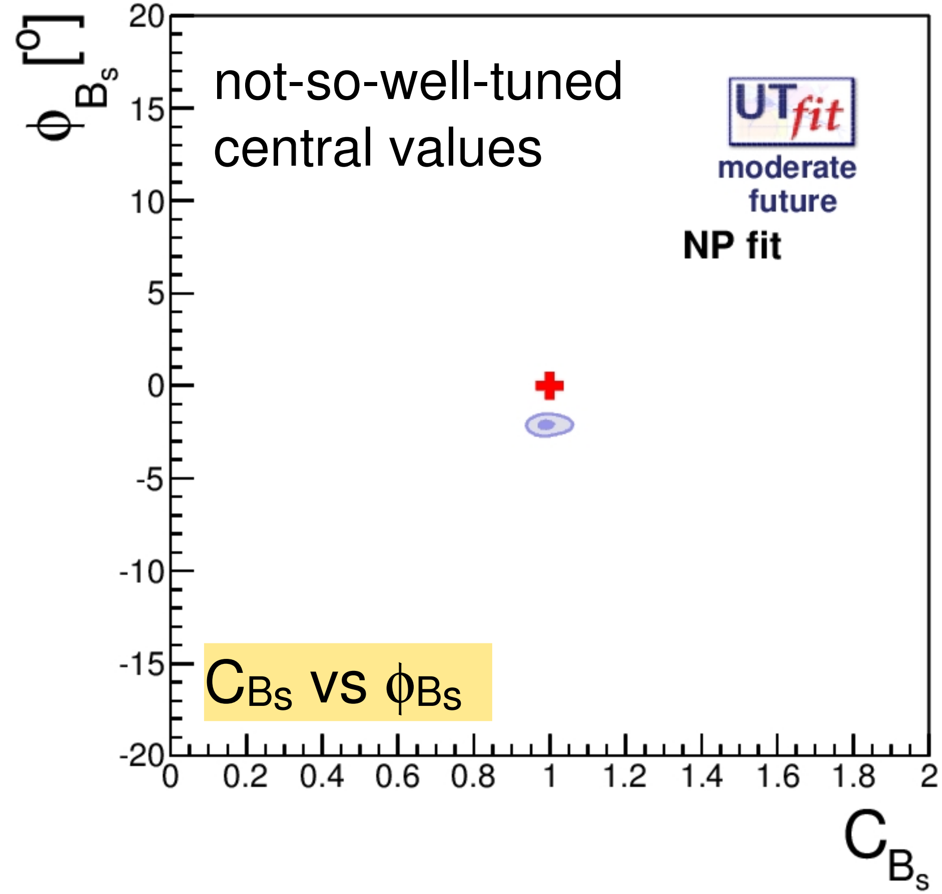
errors from tree-only fit on ρ and η:
σ(ρ) = 0.008 *[currently 0.040]*
σ(η) = 0.010 *[currently 0.037]*

errors from 5-constraint fit on ρ and η:
σ(ρ) = 0.005 *[currently 0.018]*
σ(η) = 0.004 *[currently 0.012]*

Look at the future

errors predicted from
Belle II + LHCb upgrade





errors on general NP parameters:

$\sigma(C_{Bd}) = 0.03$ *[currently 0.16]*

$\sigma(\phi_{Bd}) = 0.7$ *[currently 3.2]*

$\sigma(C_{Bs}) = 0.03$ *[currently 0.08]*

$\sigma(\phi_{Bs}) = 0.6$ *[currently 2.0]*

Parameter	Error				
	Now	50/fb	300/fb	1000/fb	3000/fb
$\bar{\rho}$ (SM fit)	0.002	0.0039	0.0023	0.0013	0.00064
$\bar{\eta}$ (SM fit)	0.021	0.0037	0.0019	0.0013	0.00068
γ [°] (SM fit)	6.5	0.6	0.35	0.2	0.09
α [°] (SM fit)	5.5	0.6	0.37	0.2	0.1
β [°] (SM fit)	4	0.2	0.10	0.07	0.04
β_s [°] (SM fit)	4	0.011	0.057	0.004	0.0023
$\bar{\rho}$ (NP fit)	0.002	0.006	0.0034	0.0028	0.0022
$\bar{\eta}$ (NP fit)	0.021	0.006	0.0053	0.0061	0.0052
γ [°] (NP fit)	6.5	0.9	0.4	0.2	0.09
α [°] (NP fit)	5.5	1	0.5	0.45	0.36
β [°] (NP fit)	4	0.8	0.7	0.7	0.7
β_s [°] (NP fit)	4	0.017	0.016	0.016	0.016
C_{ε_K}	0.14	0.065	0.065	0.065	0.064
C_{B_d}	0.15	0.024	0.024	0.024	0.022
Φ_{B_d}	2.8	0.48	0.36	0.36	0.35
C_{B_s}	0.087	0.02	0.02	0.02	0.02
Φ_{B_s}	0.96	0.26	0.11	0.063	0.038
$\Phi_{M_{12}}$ [°]	2.5	0.4	0.1	0.08	0.04
$\Phi_{\Gamma_{12}}$ [°]	–	1.2	0.4	0.24	0.12

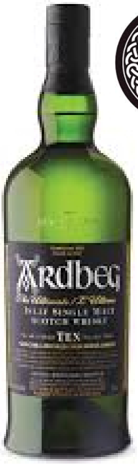
Crucial to improve SM predictions of rare decays!

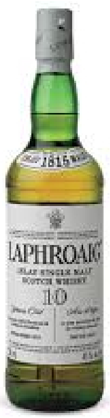
Need progress in $|V_{ub}|$ and $|V_{cb}|$

Steady improvement

Very preliminary!!!

[Silvestrini@Pisa]



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 30-40%
- So the scale analysis points to high scales for the generic scenario and at the limit of LHC reach for weak coupling. Indirect searches still essential.
- Even if we don't see relevant deviations in the down sector, we might still find them in the up sector.

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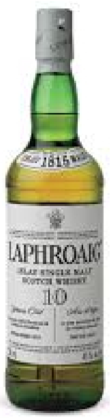

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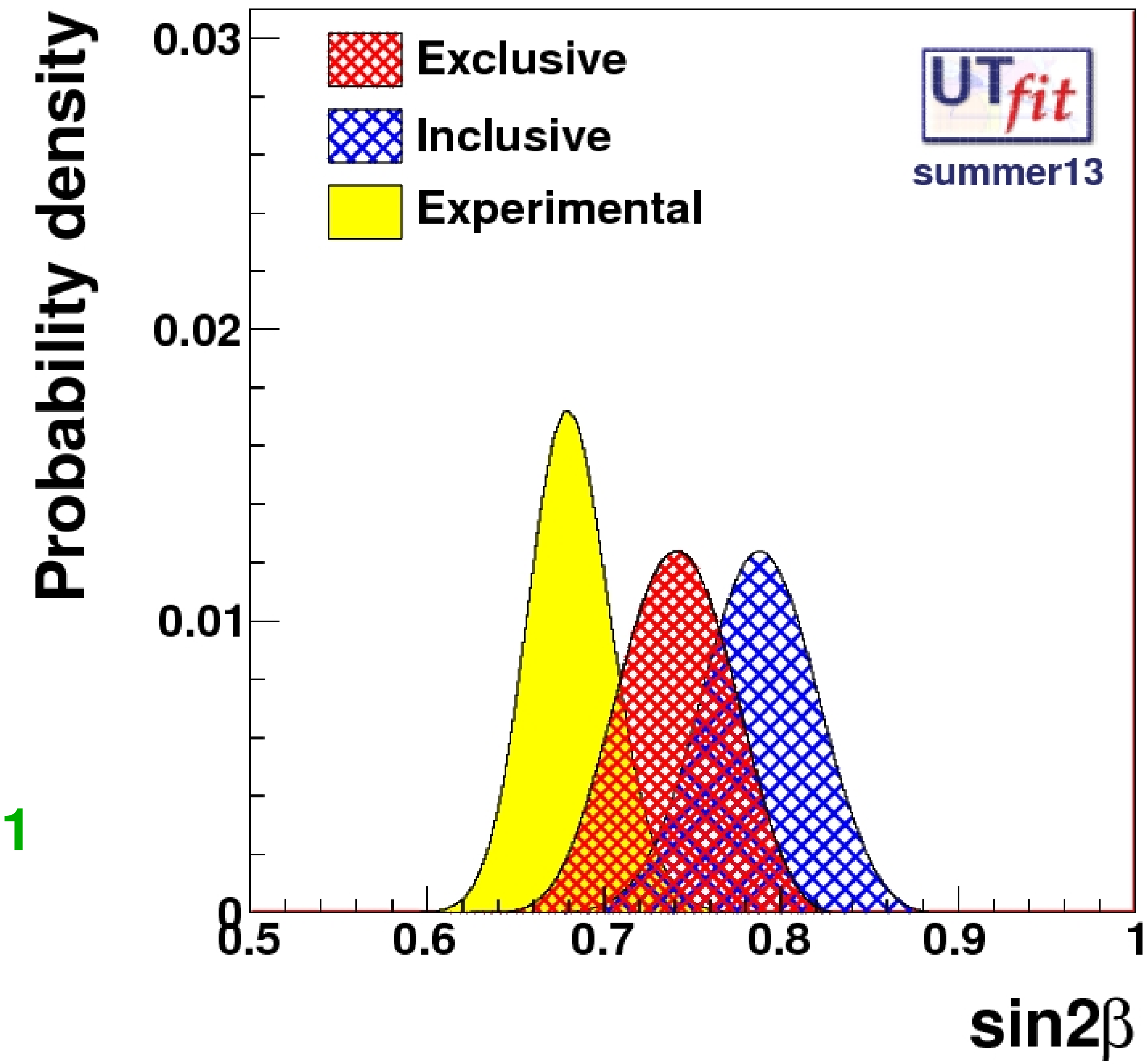
Back up slides

inclusives vs exclusives

only exclusive values

$\sin 2\beta_{UTfit}$ = 0.745 ± 0.031

~1.5σ



only inclusive values

$\sin 2\beta_{UTfit}$ = 0.788 ± 0.031

~2.7σ

new-physics-specific constraints

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

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

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

$\phi_s = 2\beta_s$ vs $\Delta\Gamma_s$ 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

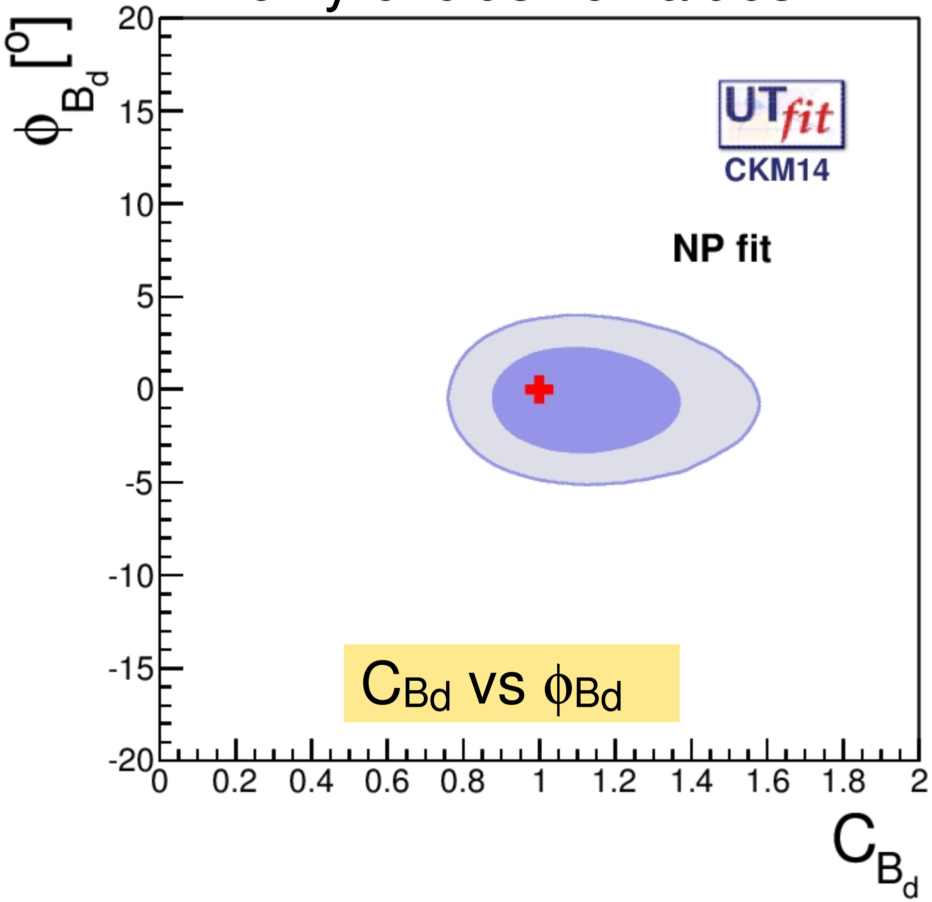
ϕ_S and $\Delta\Gamma_S$:
2D experimental likelihood from CDF and D0

ϕ_S and $\Delta\Gamma_S$:
central values with
gaussian errors from LHCb

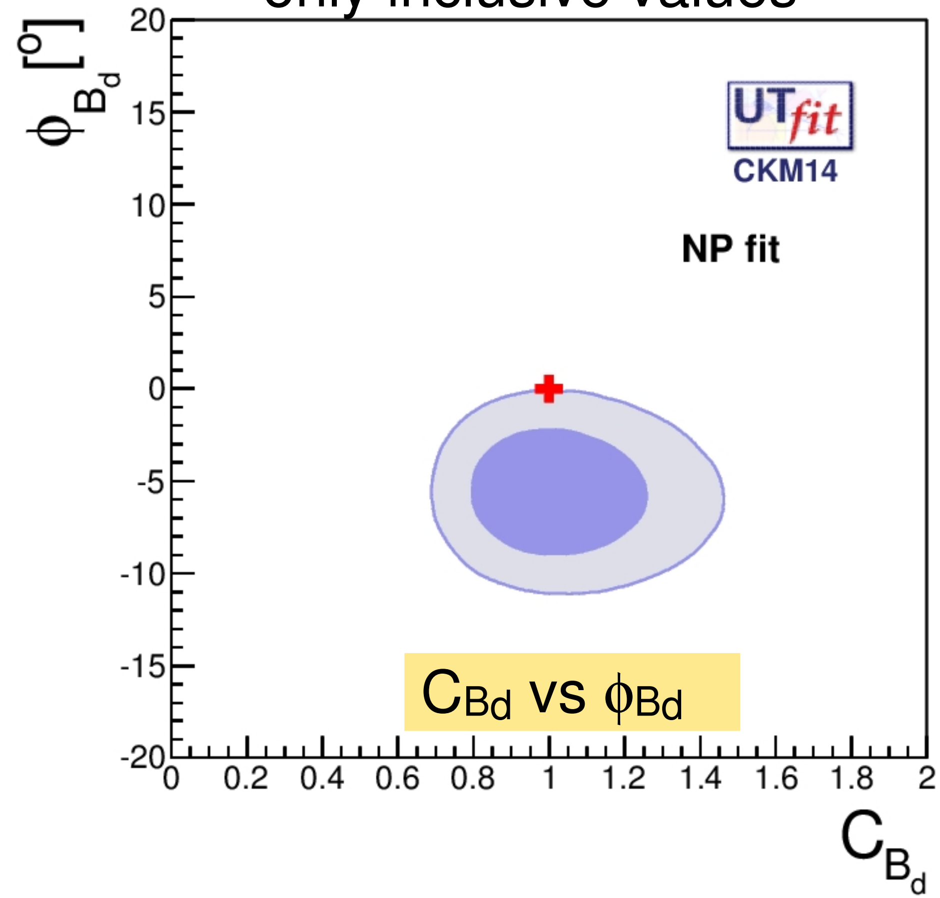
NP parameter results: exclusives vs inclusives

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

only exclusive values



only inclusive values



contribution to the mixing amplitudes

analytic expression for the contribution to the mixing amplitudes

Lattice QCD

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

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

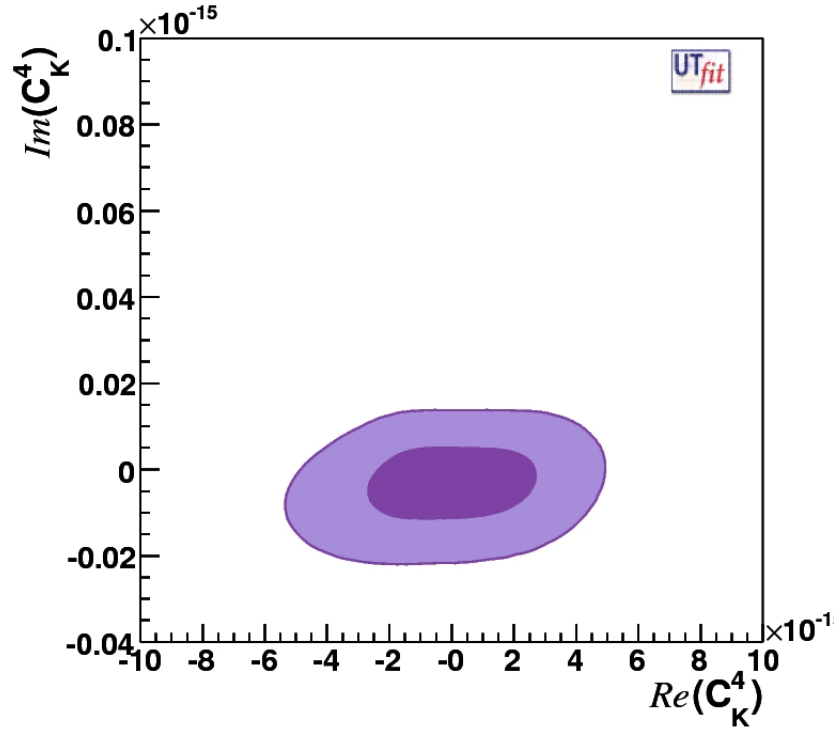
$$\langle \bar{K}^0 | \mathcal{H}_{\rm eff}^{\Delta S=2} | K^0 \rangle_i = \sum_{j=1}^{5} \sum_{r=1}^{5} \left(b_j^{(r,i)} + \eta\, c_j^{(r,i)} \right) \eta^{a_j}\, C_i(\Lambda)\, R_r\, \langle \bar{K}^0 | Q_1^{sd} | K^0 \rangle$$

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 $\alpha_W \sim 0.03$.

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

	LHCb 2015 10/fb (5 years)	SuperB 1/ab (1 month at Υ(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