CKM metrology from Unitarity Triangle fits

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Technische Universität
Vienna, Austria


BLACK IPA
DUNKLE MATERIE
BREW AGE


-DARK MATTER COFFEE-
COFFEE COLD

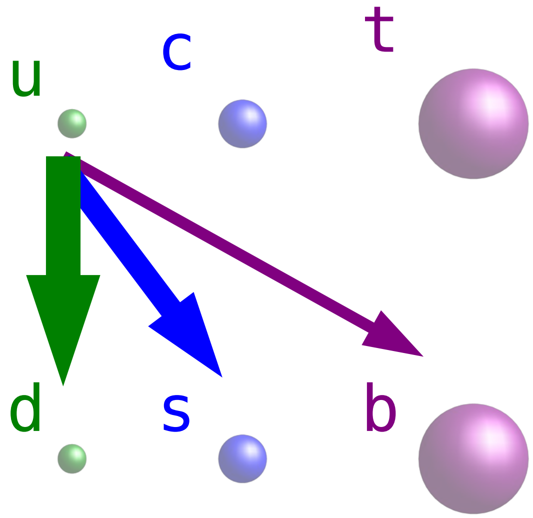

ESTD 1815
Ardbeg
SUPERNOVA
The Ultimate
ISLAY SINGLE MALT SCOTCH WHISKY
ARDBEG DISTILLERY LIMITED
DISTILLED & BOTTLED IN SCOTLAND
70cl

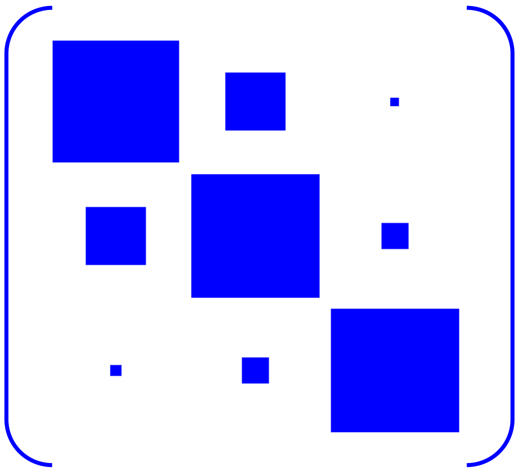

Dark Matter
SCOTLAND
OUR CURIOSITY DRIVES US WHILE SCIENCE INSPIRES US. COMBINING KNOWLEDGE AND IMAGINATION WE OBSESSIVELY PURSUE FLAVOUR THROUGH SYSTEMATIC STUDY, OBSERVATION AND EXPERIMENT.
SPICED RUM
700ml
40%

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}.

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





The CKM matrix and the Unitarity Triangle

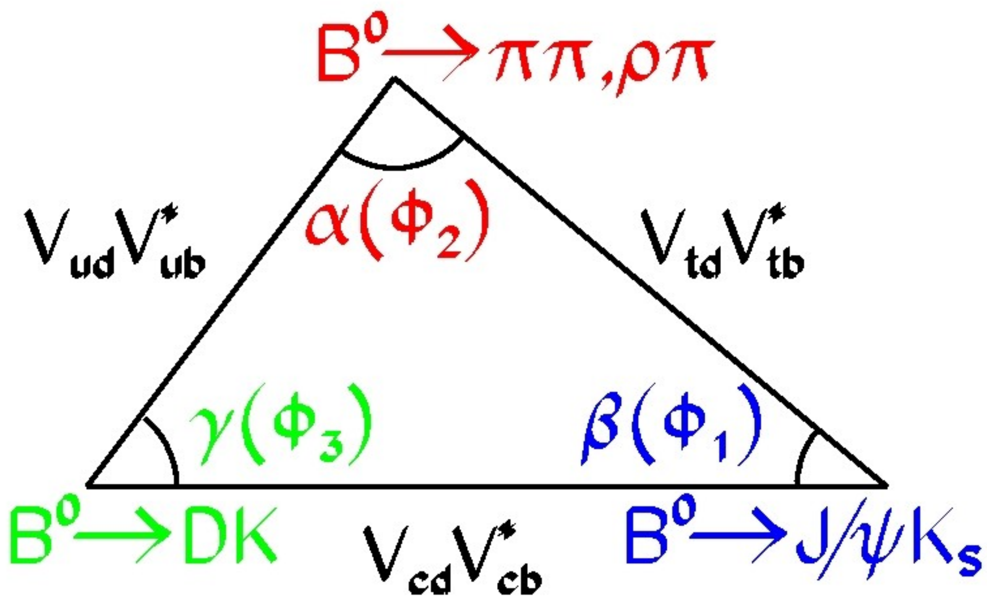
$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\overline{\rho}-i\overline{\eta}) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\overline{\rho}-i\overline{\eta})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

- With three families of quarks, the unitary CKM matrix has four independent parameters: three rotation angles and one phase. This phase allows CP violation in the SM. All the flavour mixing processes are related (through the unitarity of the V_{CKM}) to this phase.

Unitarity Triangle

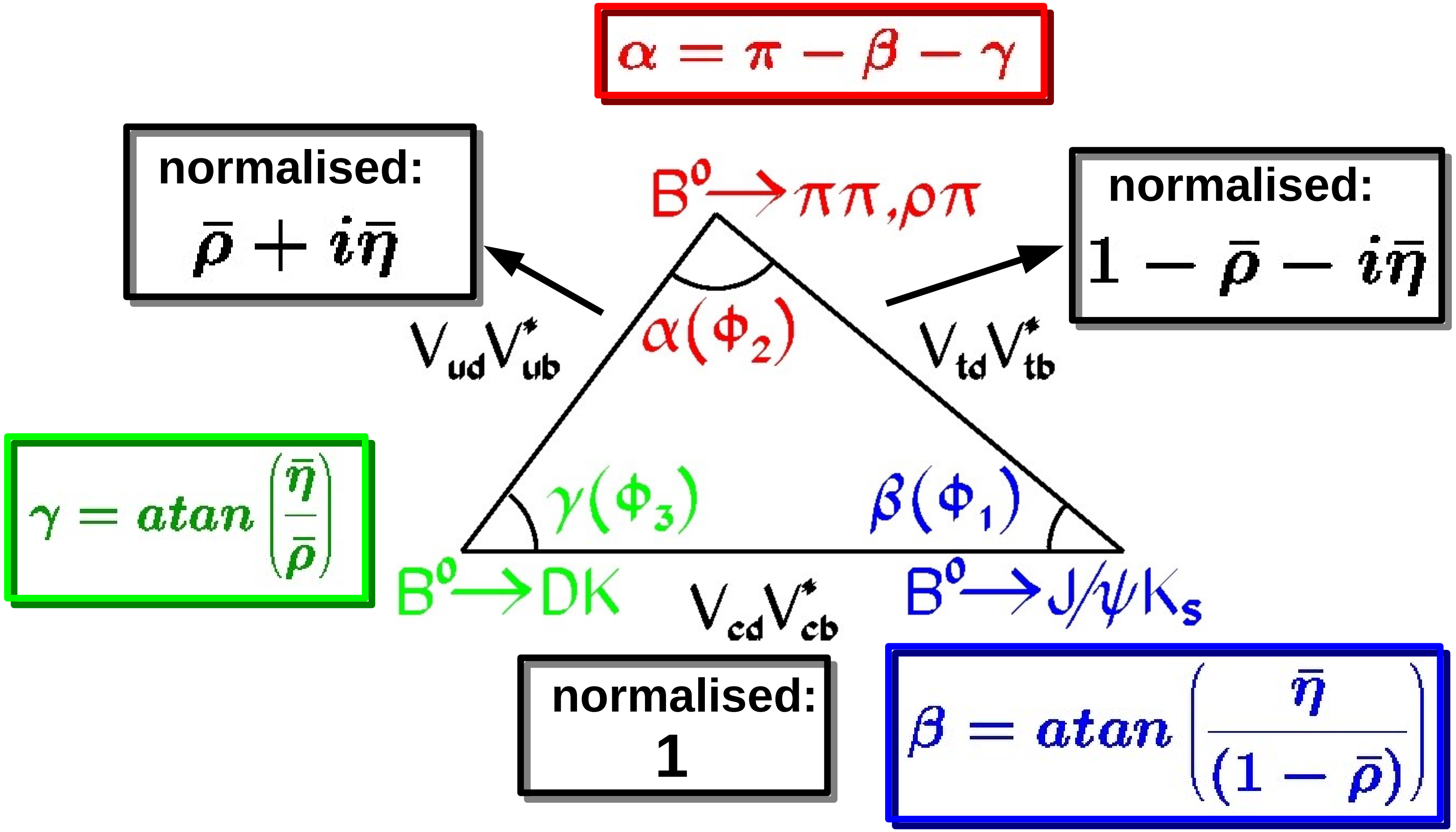
$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

All the angles are related to the CP asymmetries of specific B decays



The CKM matrix and the Unitarity Triangle

- The Wolfenstein-Buras parameterisation of the CKM matrix allows to obtain a simplified (and approximate) form of the matrix, maintaining its unitarity. The four independent parameters being λ, A, $\bar{\rho}$ and $\bar{\eta}$.
- The unitarity triangle can be drawn in the $\bar{\rho}$-$\bar{\eta}$ plane and its sides and angles can be linked to various processes involving B mesons



Unitarity Triangle analysis in the Standard Model

- Standard Model (SM) Unitarity Triangle analysis:
  - All updated with Summer 2022 inputs
  - 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

- New Physics (NP) Unitarity Triangle analysis:
  - Also all updated with Summer 2022 inputs
  - model-independent analysis
  - provides limit on the allowed deviations from the SM
  - obtain the NP scale

UTfit

www.utfit.org

RELOADED

M.Bona, M. Ciuchini, D. Derkach, F. Ferrari, E. Franco,
V. Lubicz, G. Martinelli, M. Pierini, L. Silvestrini, S. Simula,
A. Stocchi, C. Tarantino, V. Vagnoni, M. Valli and L. Vittorio

Plots and numbers in this talk are obtained with inputs updated this summer hence they are labelled “summer22”.
Some changes have been included in July 22 for ICHEP22 and for this talk with respect to the results presented in May 2022 at LHCP22 and FPCP22.

Statistical method and 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

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

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

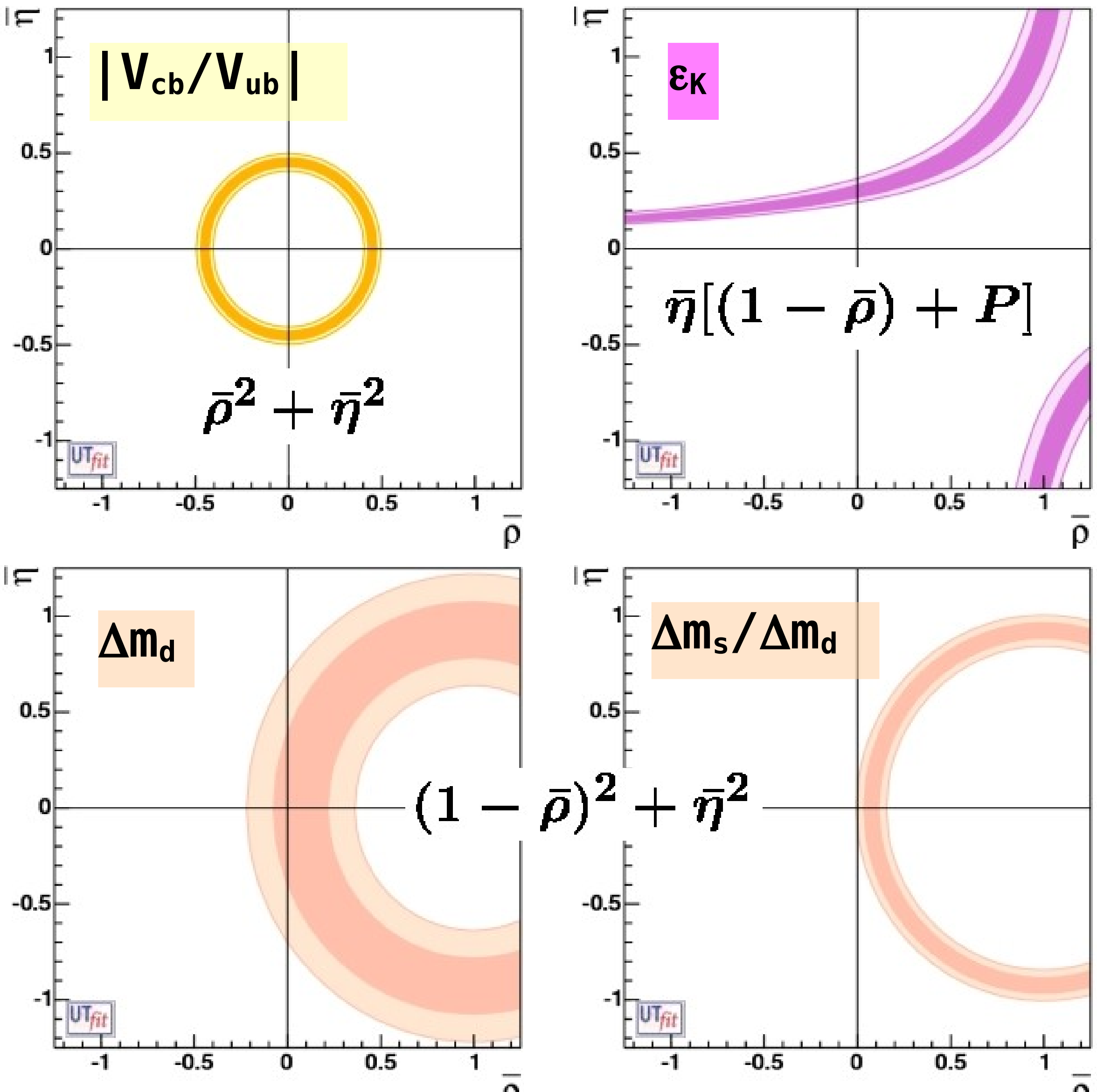
$(b\to u)/(b\to c)$	$\bar\rho^2+\bar\eta^2$	$\bar\Lambda, \lambda_1, F(1), ...$
ϵ_K	$\bar\eta[(1-\bar\rho)+P]$	B_K
Δm_d	$(1-\bar\rho)^2+\bar\eta^2$	$f_B^2 B_B$
$\Delta m_d/\Delta m_s$	$(1-\bar\rho)^2+\bar\eta^2$	ξ
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	

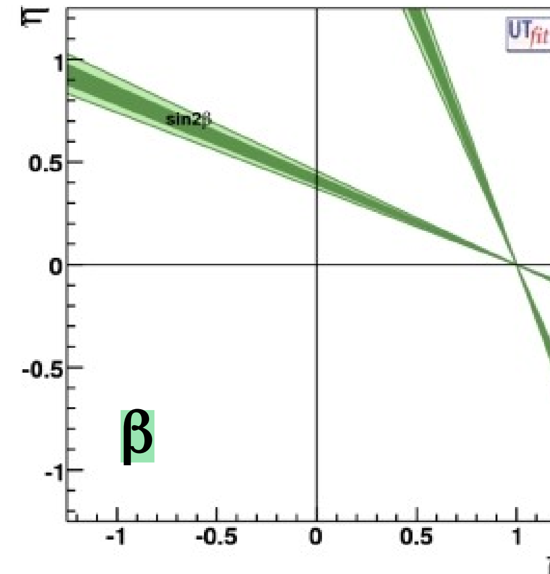
, m_t

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

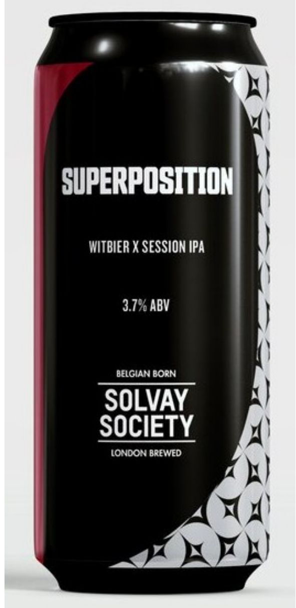
M. Bona *et al*. (UTfit Collaboration) JHEP 0507:028,2005 hep-ph/0501199
M. Bona *et al*. (UTfit Collaboration) JHEP 0603:080,2006 hep-ph/0509219

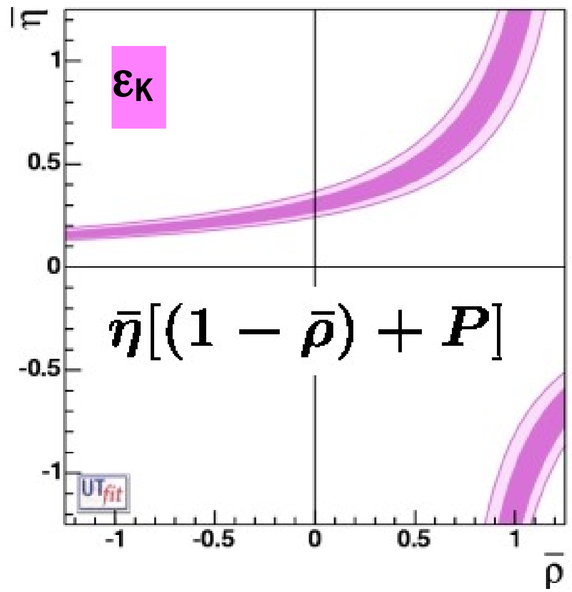
Inputs mapped on the $\bar{\rho}$-$\bar{\eta}$ plane:





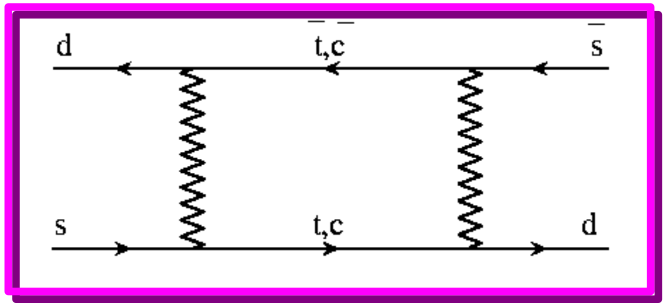
Meson mixing: K and $B_{d/s}$





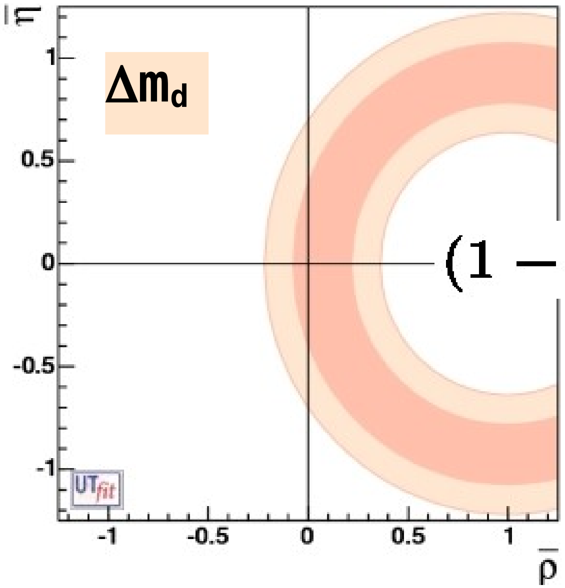
$$\bar{\eta}[(1-\bar{\rho})+P]$$

ε_K from $\overline{K}$-K mixing

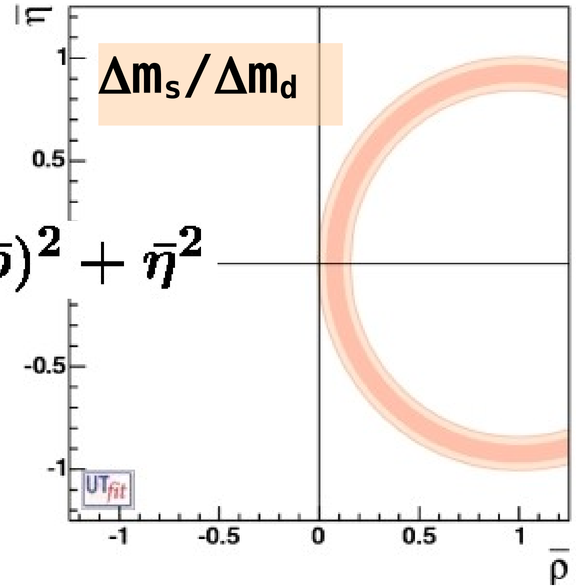


$\varepsilon_K = (2.228 \pm 0.011) \cdot 10^{-3}$

PDG

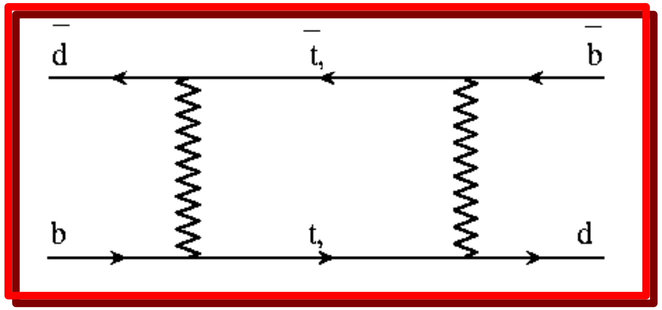


$$(1-\bar{\rho})^2+\bar{\eta}^2$$



Δm_q from $\overline{B}_q$-B_q mixing

q=d.s



$\Delta m_d = 0.5065 \pm 0.0019\ ps^{-1}$

$\Delta m_S = 17.765 \pm 0.006\ ps^{-1}$

HFLAV

Lattice QCD inputs:

$$|\varepsilon_K| = C_\varepsilon B_K A^2 \lambda^6 \bar{\eta} \{ -\eta_1 S_0(x_c)(1-\lambda^2/2) + \eta_3 S_0(x_c, x_t) + \eta_2 S_0(x_t) A^2 \lambda^4 (1-\bar{\rho}) \}$$

S_0 = Inami-Lim functions for c-c, c-t, e t-t contributions
(from perturbative calculations)

$$\Delta m_d = \frac{G_F^2}{6\pi^2} m_W^2 \eta_b S(x_t) m_{B_d} f_{B_d}^2 \hat{B}_{B_d} |V_{tb}|^2 |V_{td}|^2 = \frac{G_F^2}{6\pi^2} m_W^2 \eta_b S(x_t) m_{B_d} f_{B_d}^2 \hat{B}_{B_d} |V_{cb}|^2 \lambda^2 ((1-\bar{\rho})^2 + \bar{\eta}^2)$$

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

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

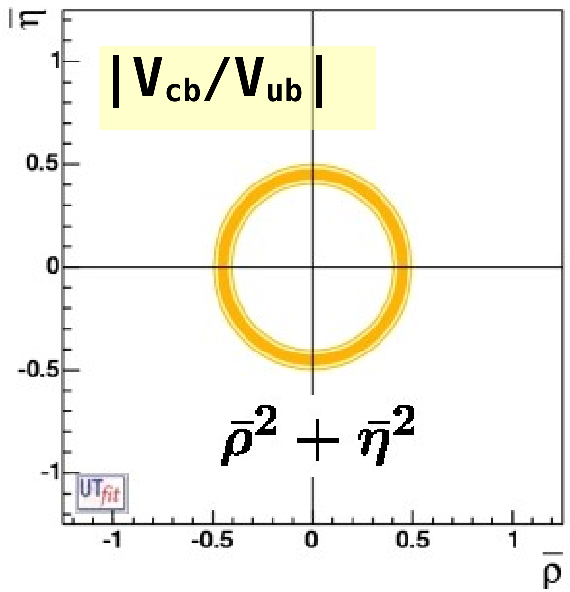
lattice inputs updated for this summer

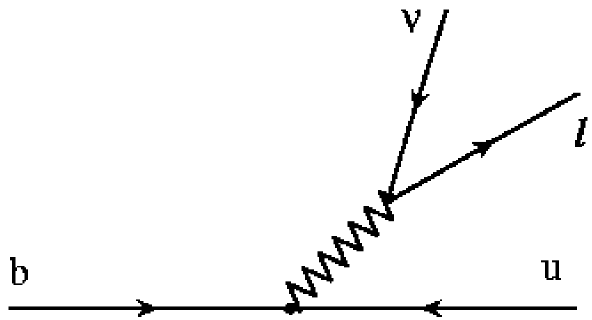
Observables	Measurement
B_K	0.756 ± 0.016
f_{Bs}	0.2301 ± 0.0012
f_{Bs}/f_{Bd}	1.208 ± 0.005
B_{Bs}/B_{Bd}	1.015 ± 0.021
B_{Bs}	1.284 ± 0.059

We quote the weighted average of the N_f=2+1+1 and N_f=2+1 results with the error rescaled when chi2/dof > 1, as done by FLAG for the N_f=2+1+1 and N_f=2+1 averages separately

[new HPQCD (2+1+1) result 1907.01025]

V_{cb} and V_{ub}





tree diagrams

b → c and b → u transition

- negligible new physics contributions
- inclusive and exclusive semileptonic B decay branching ratios

QCD corrections to be included

- inclusive measurements: OPE
- exclusive measurements: form factors from lattice QCD

$$\left|\frac{V_{ub}}{V_{cb}}\right| = \frac{\lambda}{1-\frac{\lambda^2}{2}}\sqrt{\bar{\rho}^2+\bar{\eta}^2}$$

V_{cb} and V_{ub}

from UTfit (coming soon)

$|V_{cb}|$ *(excl)* = (39.44 ± 0.63) 10^{-3}

$|V_{cb}|$ *(incl)* = (42.16 ± 0.50) 10^{-3}

from Bordone et al. arXiv:2107.00604

~3.3σ discrepancy

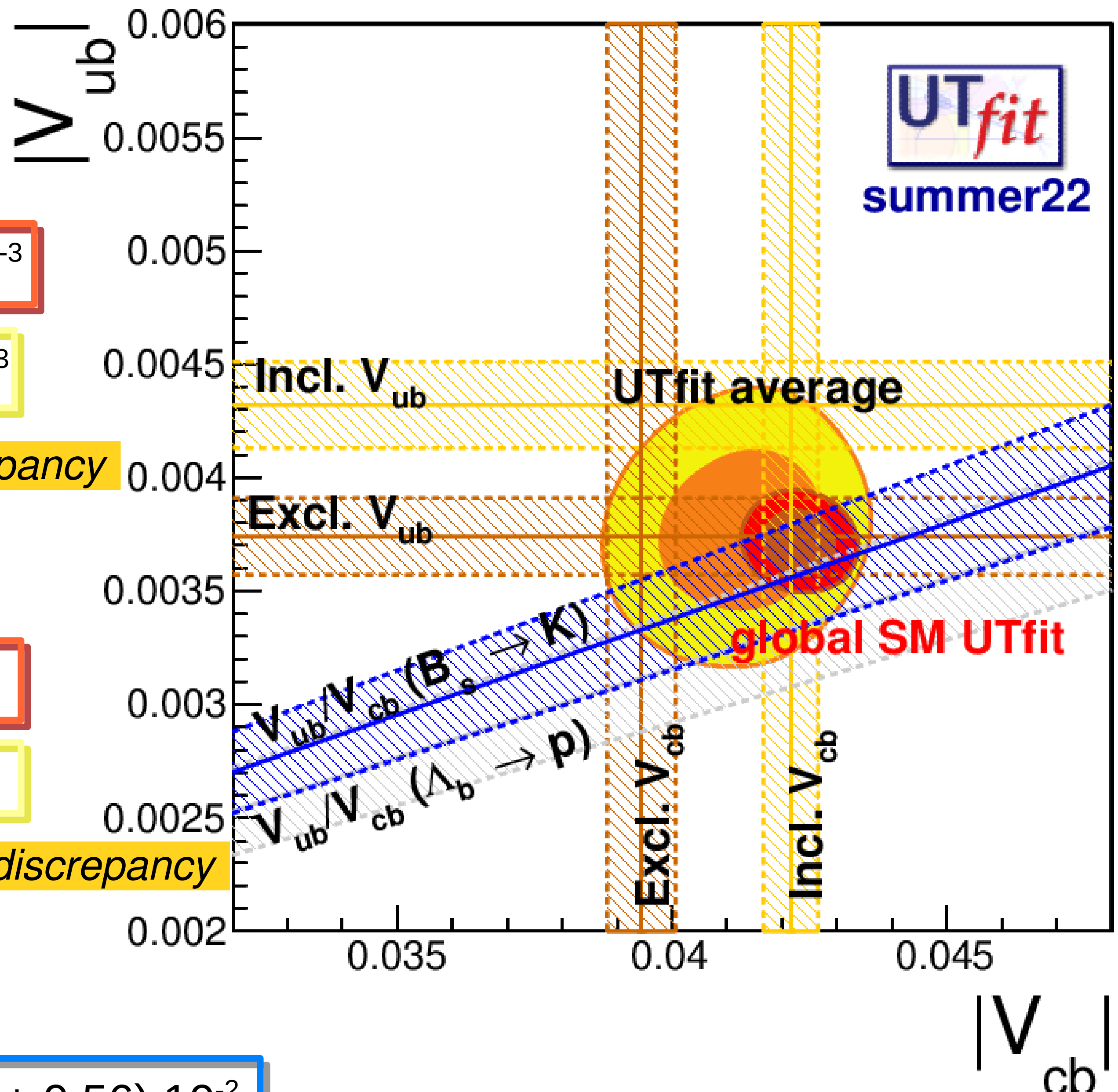
from UTfit (coming soon)

$|V_{ub}|$ *(excl)* = (3.74 ± 0.17) 10^{-3}

$|V_{ub}|$ *(incl)* = (4.32 ± 0.29) 10^{-3}

from UTfit (coming soon)

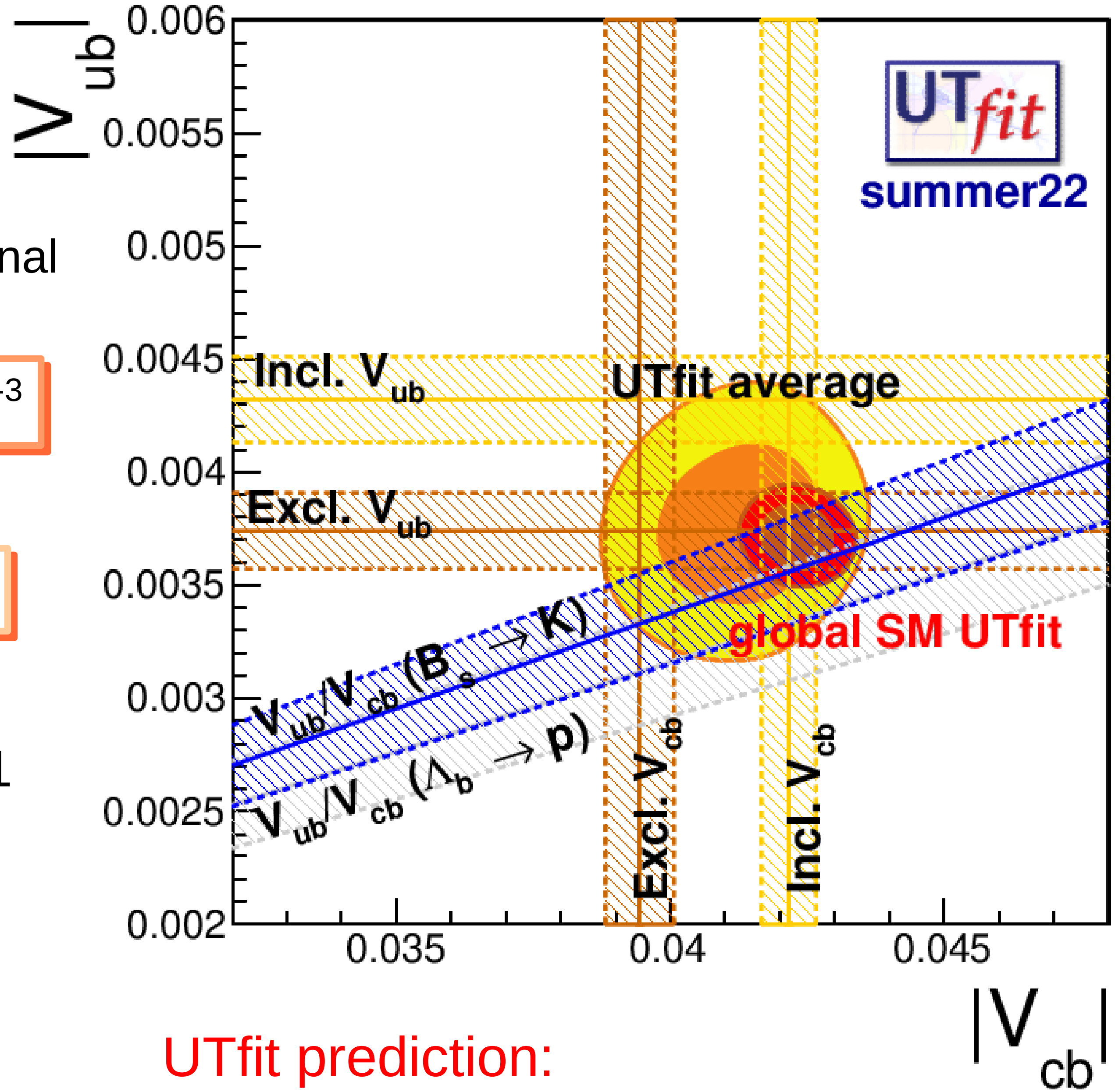
~1.7σ discrepancy



$|V_{ub} / V_{cb}|$ *(LHCb)* = (8.44 ± 0.56) 10^{-2} From B_s to K (LHCb and FLAG)

$|V_{ub} / V_{cb}|$ *(LHCb)* = (7.9 ± 0.6) 10^{-2} From Λ_b, excluded following FLAG guidelines

V_{cb} and V_{ub}



A-la-D'Agostini two-dimensional average procedure:

$|V_{cb}| = (41.25 \pm 0.95)\ 10^{-3}$

uncertainty ~ 2.3%

$|V_{ub}| = (3.77 \pm 0.24)\ 10^{-3}$

uncertainty ~ 6.4%

Correlation $\rho = 0.11$

Updated averages including correlation

From global SM fit

$|V_{cb}| = (42.3 \pm 0.4)\ 10^{-3}$

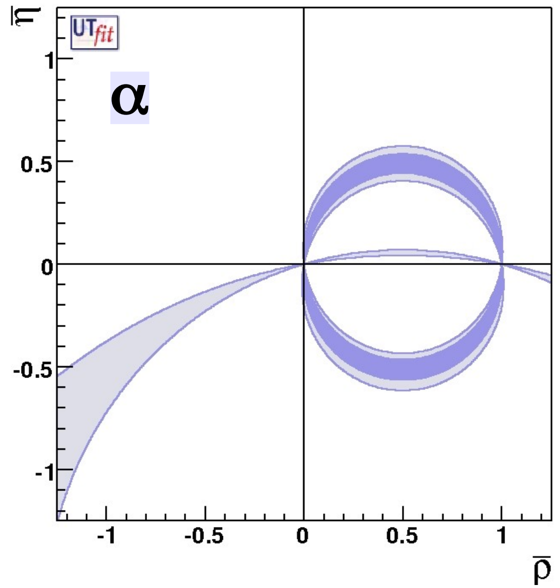
$|V_{ub}| = (3.72 \pm 0.09)\ 10^{-3}$

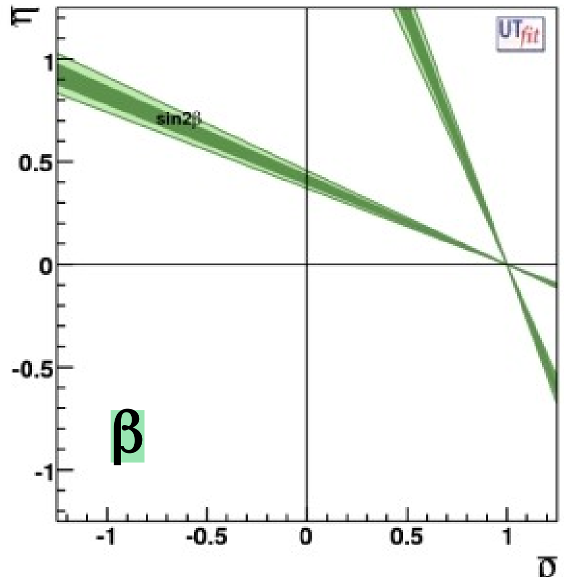
UTfit prediction:

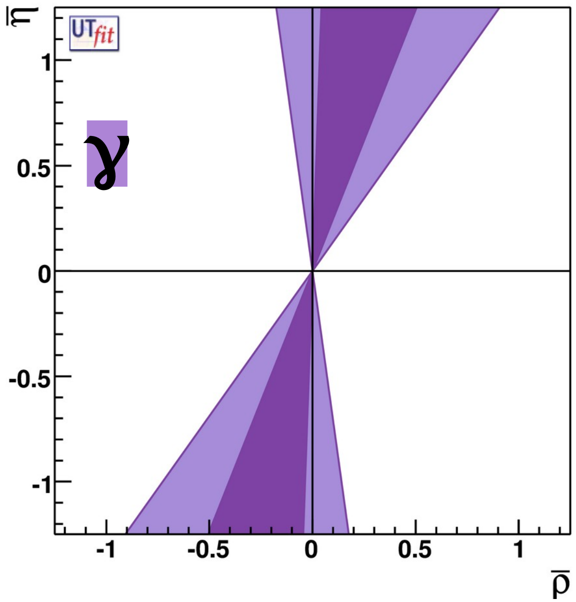
$|V_{cb}| = (42.6 \pm 0.5)\ 10^{-3}$

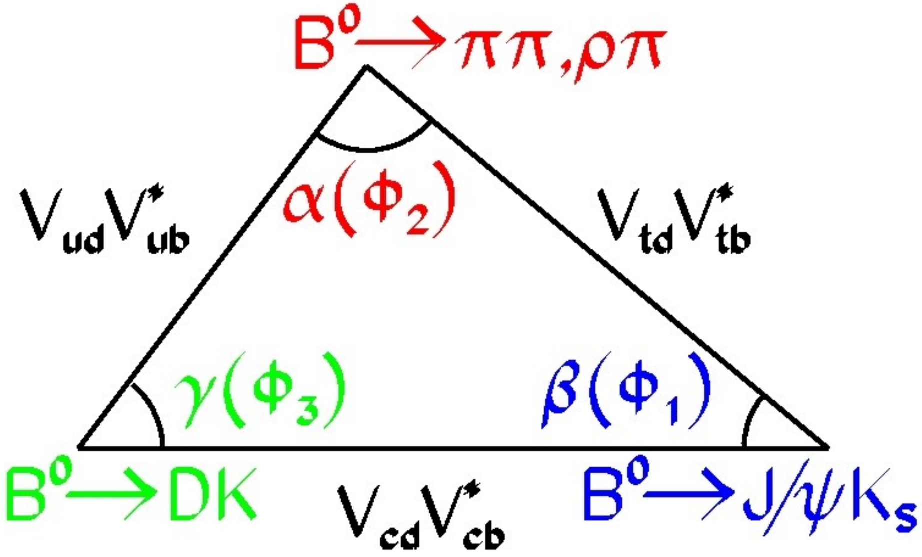
$|V_{ub}| = (3.70 \pm 0.10)\ 10^{-3}$

Angle constraints in the $\bar{\rho}$-$\bar{\eta}$ plane:

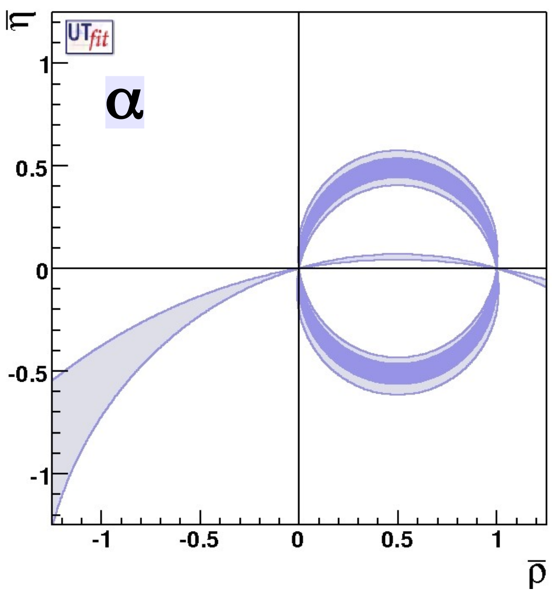


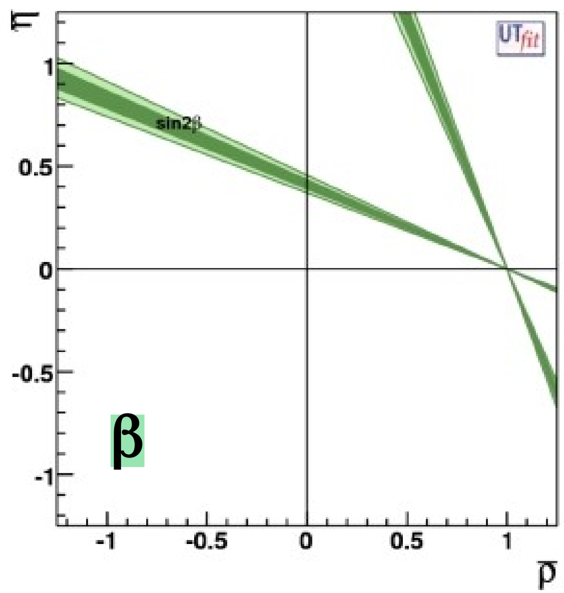


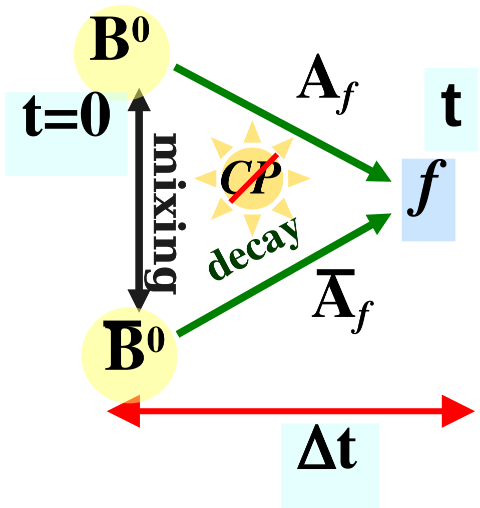




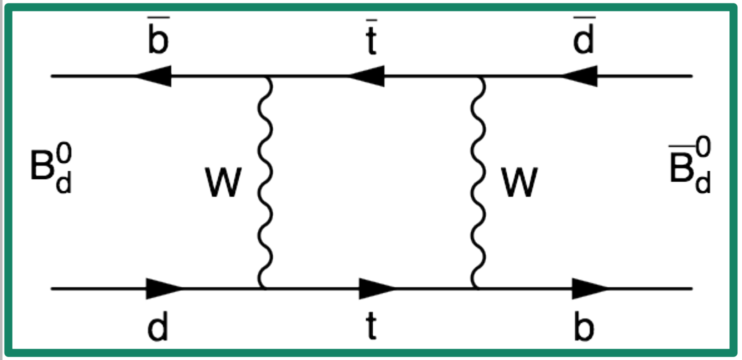
Time-dependent CP asymmetry:

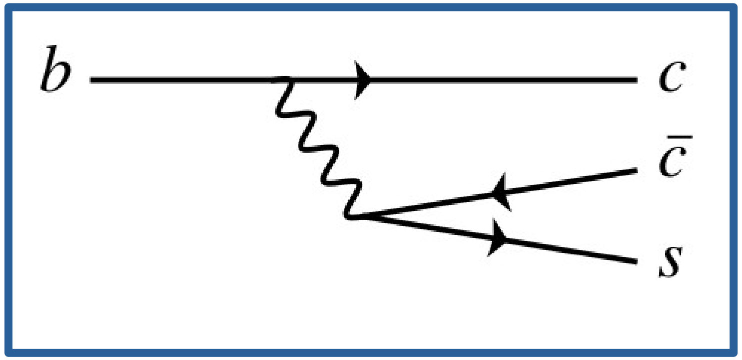


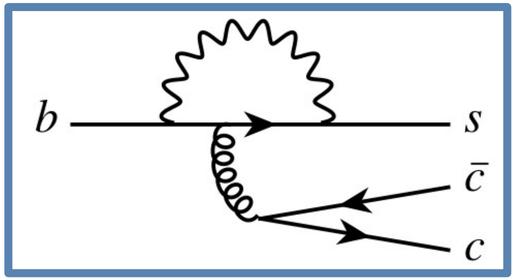




CP Violation in interference between mixing and decay:

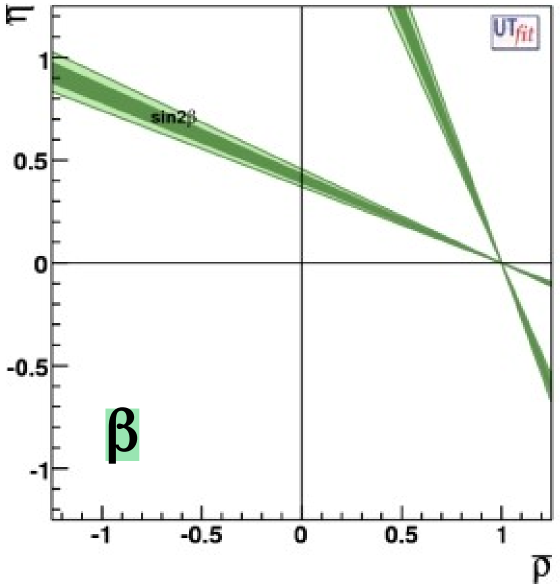


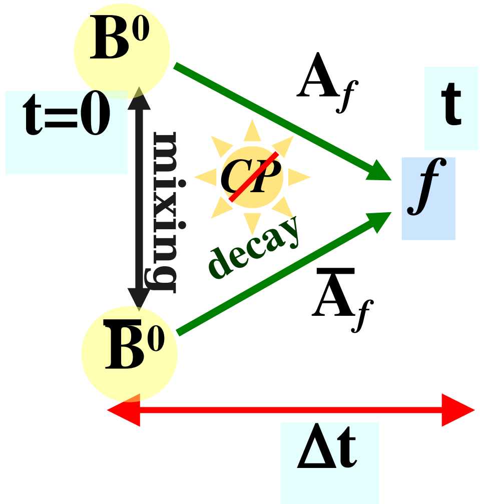




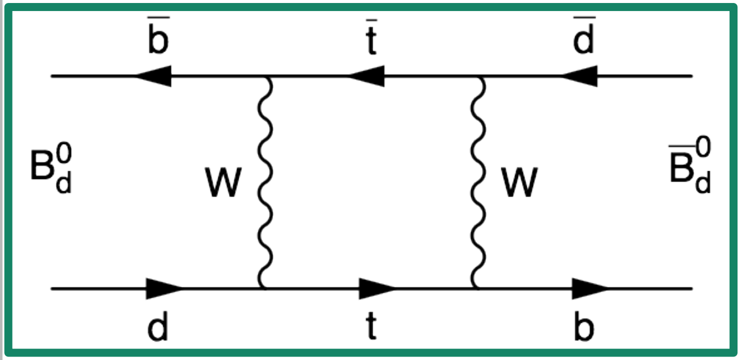
Time-dependent CP asymmetry:

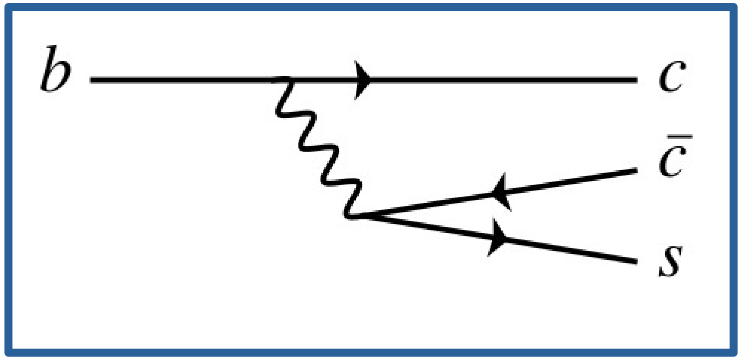
sin2β from time-dependent A_{CP} in $B \to J/\psi K^0$

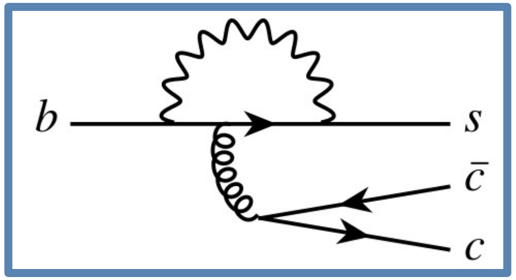




CP Violation in interference between mixing and decay:







CKM-suppressed pollution by penguins

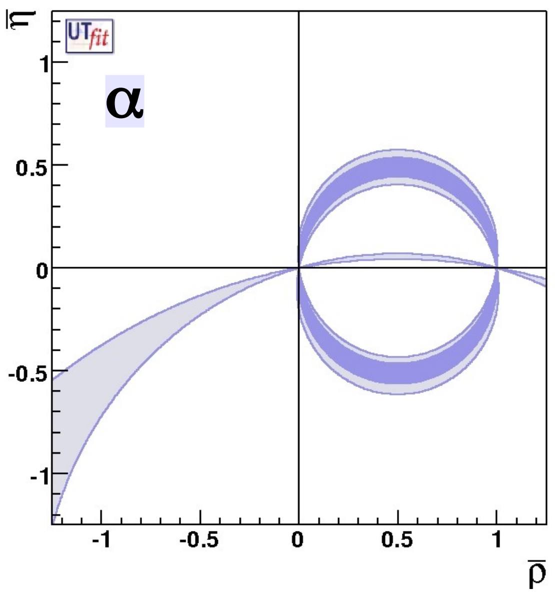
$$a_{f_{CP}}(t) = -\eta_{CP} \sin \Delta m_d \Delta t \sin 2\beta$$

ΔS = -0.01 ± 0.01

data-driven theory uncertainty

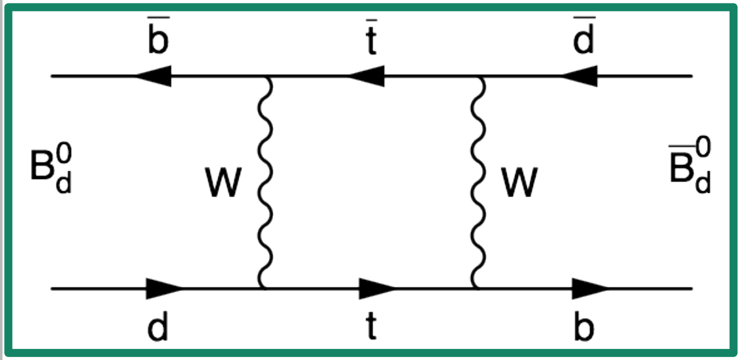
Time-dependent CP asymmetry:

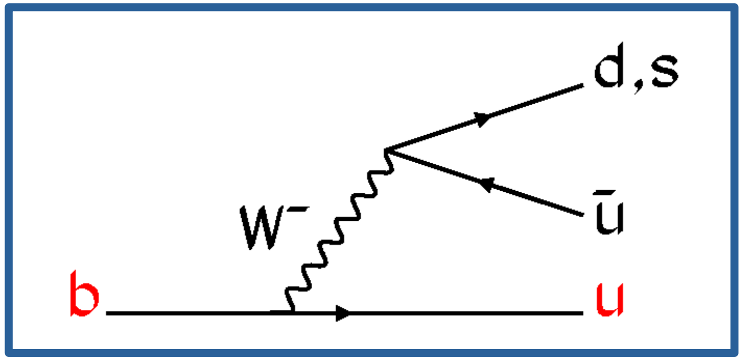
α: CP violation in $B^0 \rightarrow \pi^+\pi^-$

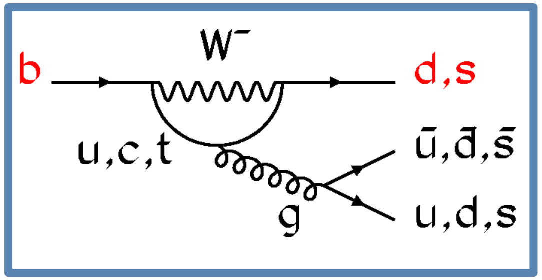


- considering the tree (T) only:
  $C_{\pi\pi} = 0$
  $S_{\pi\pi} = \sin(2\alpha)$
- adding the penguins (P):
  $C_{\pi\pi} \propto \sin(\delta)$
  $S_{\pi\pi} = \sqrt{1 - C^2_{\pi\pi}}\,\sin(2\alpha_{eff})$

CP Violation in interference between mixing and decay:

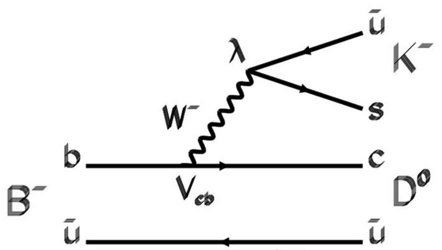






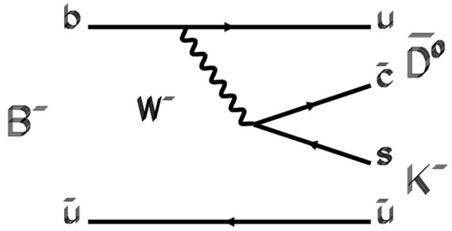
Direct CP asymmetry:

γ and DK trees

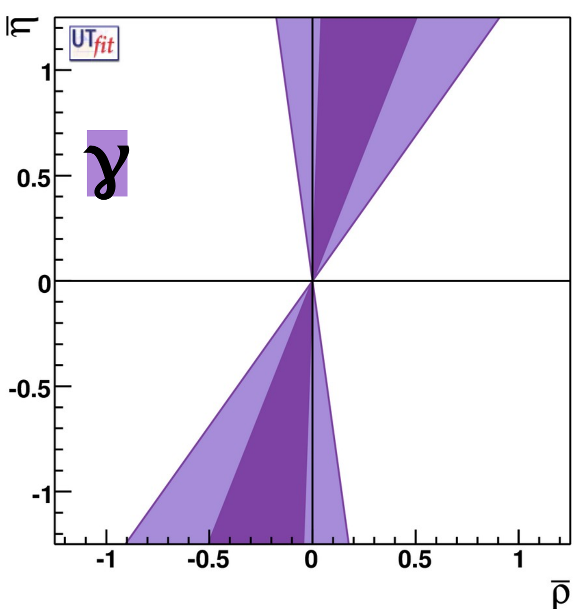


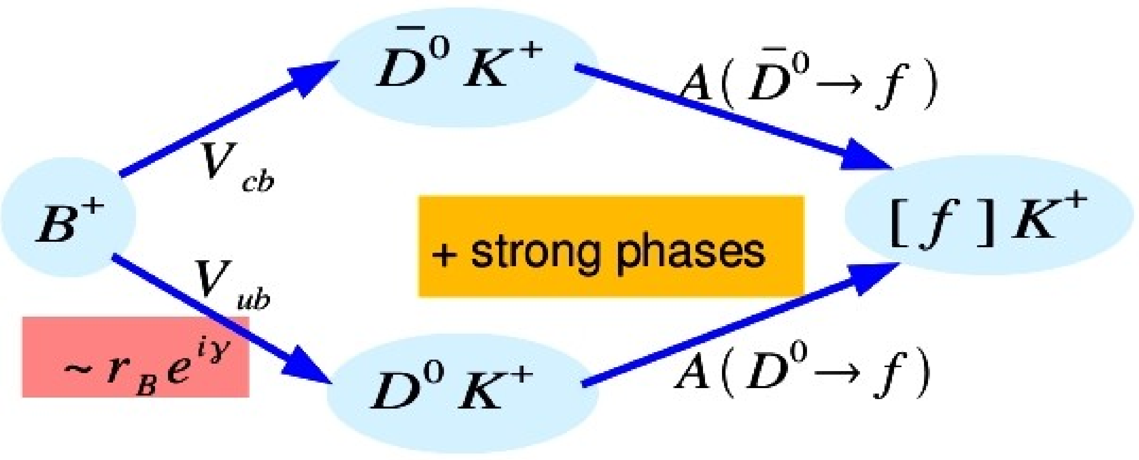
$V_{cb}\ (\sim\lambda^2)$

$V_{ub}=|V_{ub}|e^{-i\gamma}\ (\sim\lambda^3)$



- $D^{(*)}K^{(*)}$ decays: from BRs and BR ratios, no time-dependent analysis, just rates
- the phase γ is measured exploiting interferences: two amplitudes leading to the same final states
- some rates can be really small: ~ 10^{-7}

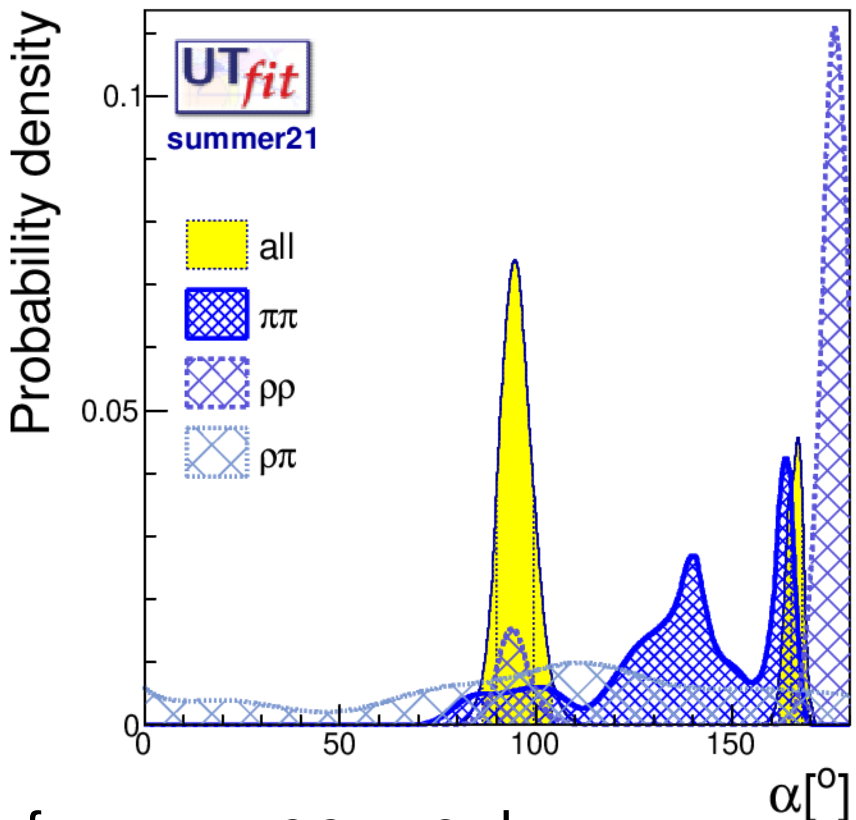




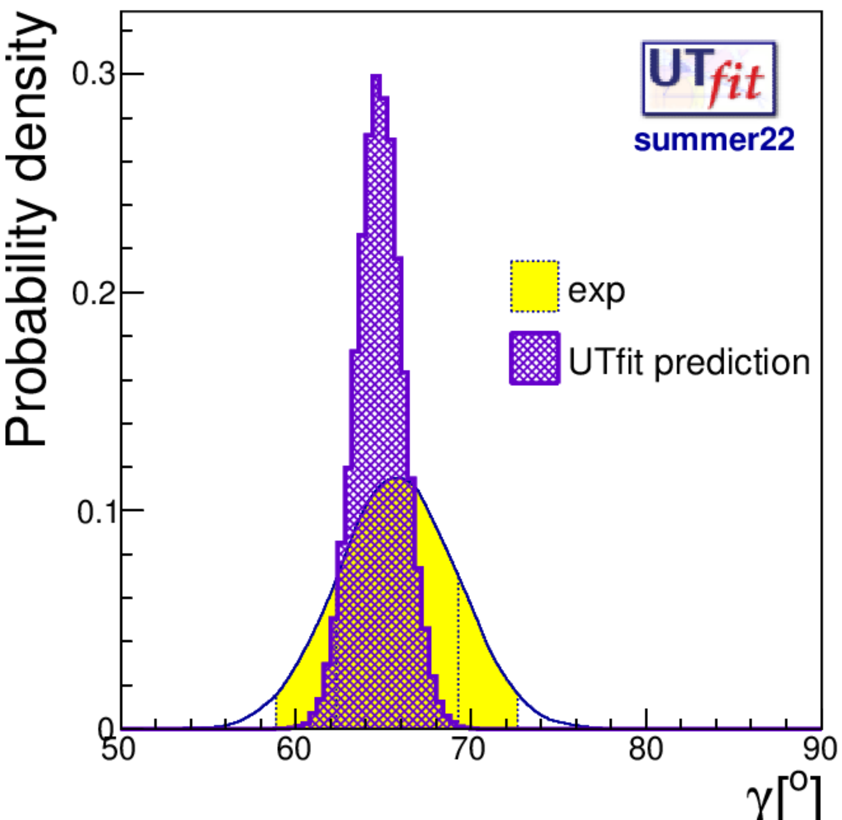
$B \to D^{(*)0}(\overline{D^{(*)0}})K^{(*)}$ decays can proceed both through V_{cb} and V_{ub} amplitudes

$\sin 2\alpha$ (ϕ_2) and γ (ϕ_3)

α with $\pi\pi/\rho\rho$ BR and C/S results and $\rho\pi$ analysis



γ updated with all the latest results (LHCb)

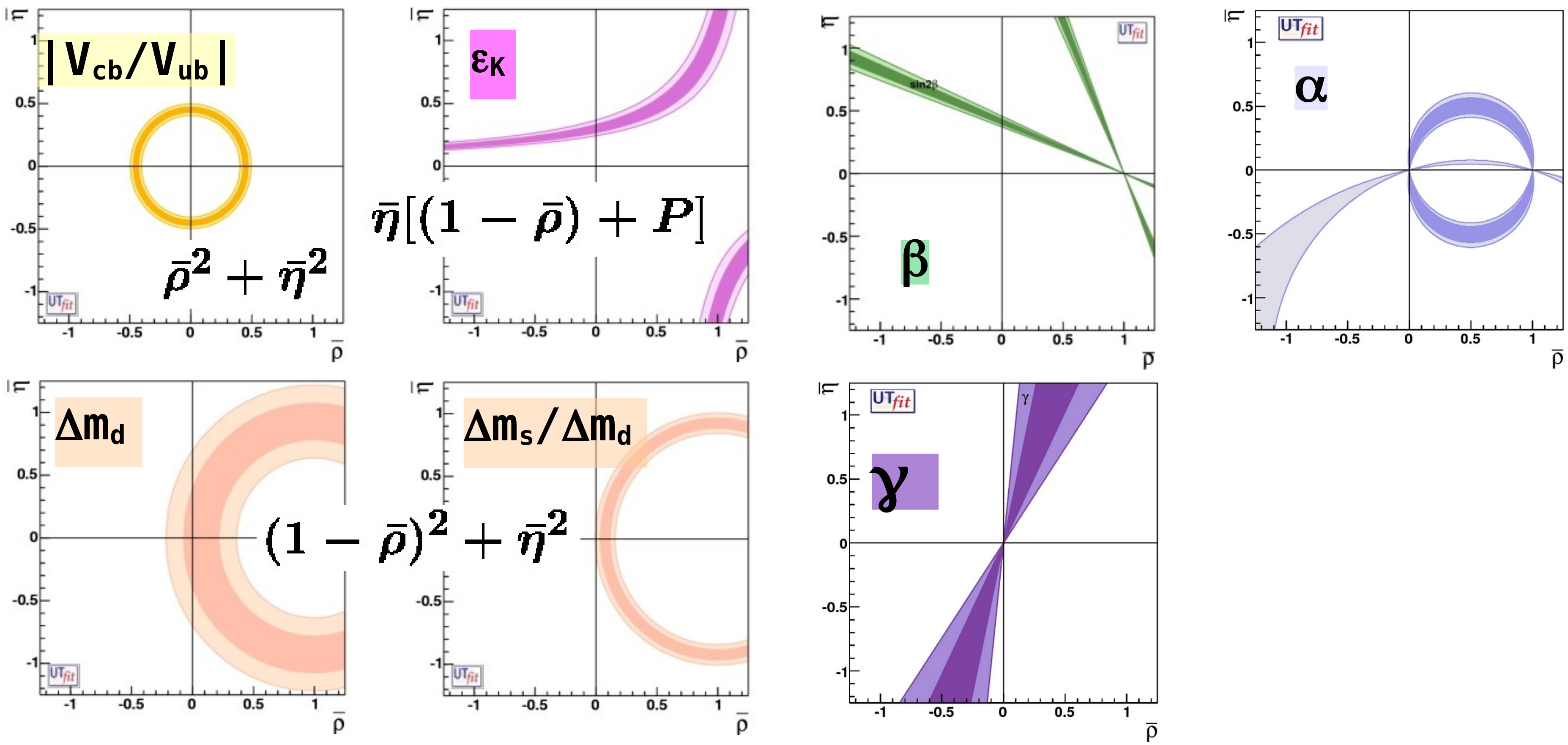


α from $\pi\pi$, $\rho\rho$, $\pi\rho$ decays:
combined SM: $(95.0 \pm 4.7)°$
UTfit prediction: $(92.3 \pm 1.5)°$

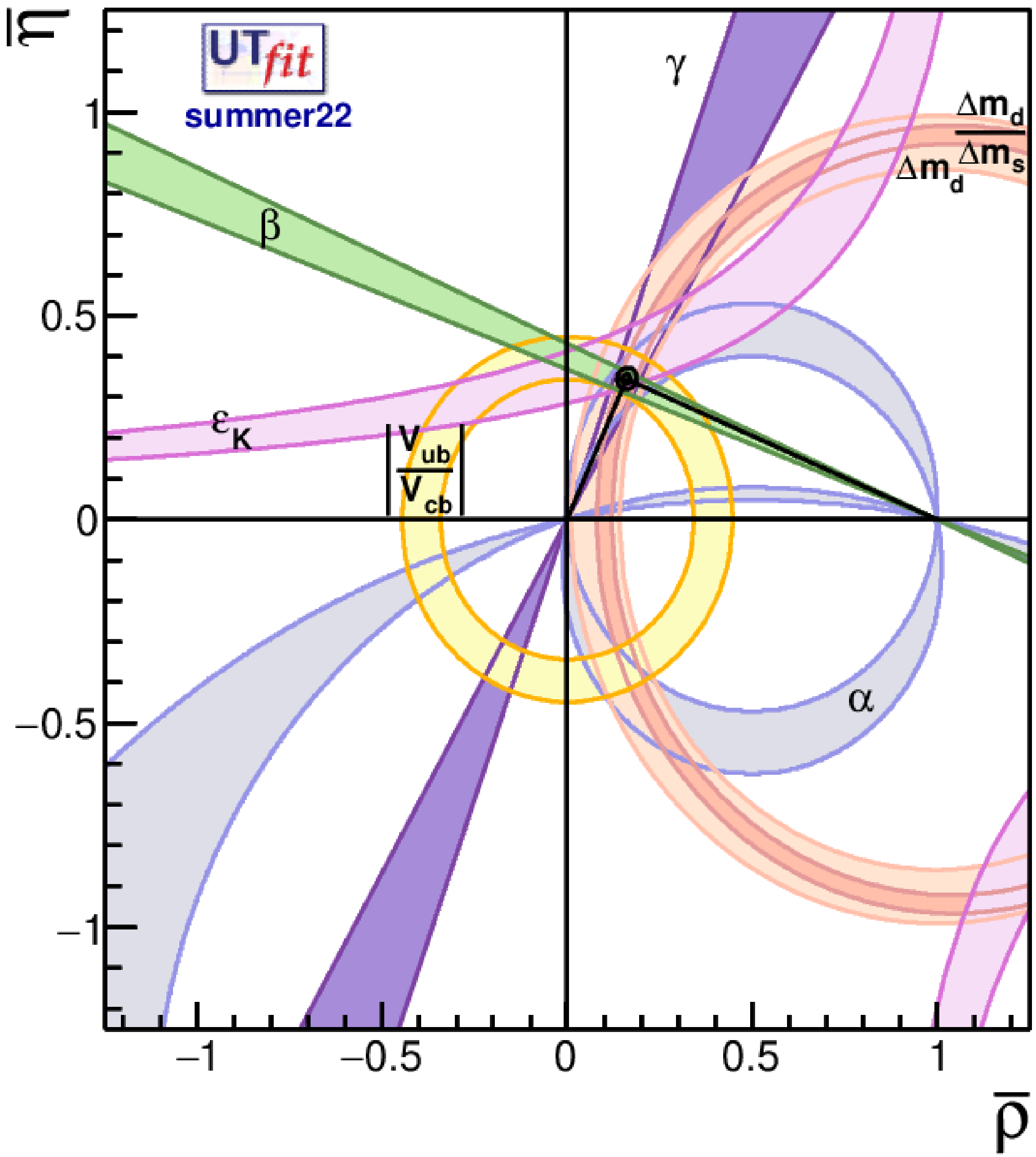
α from HFLAV: 85.5 ± 4.6

γ from B into DK decays:
HFLAV: $(65.8 \pm 3.4)°$
UTfit prediction: $(64.9 \pm 1.3)°$

Unitarity Triangle analysis in the SM:



Unitarity Triangle analysis in the SM:



levels @
95% Prob

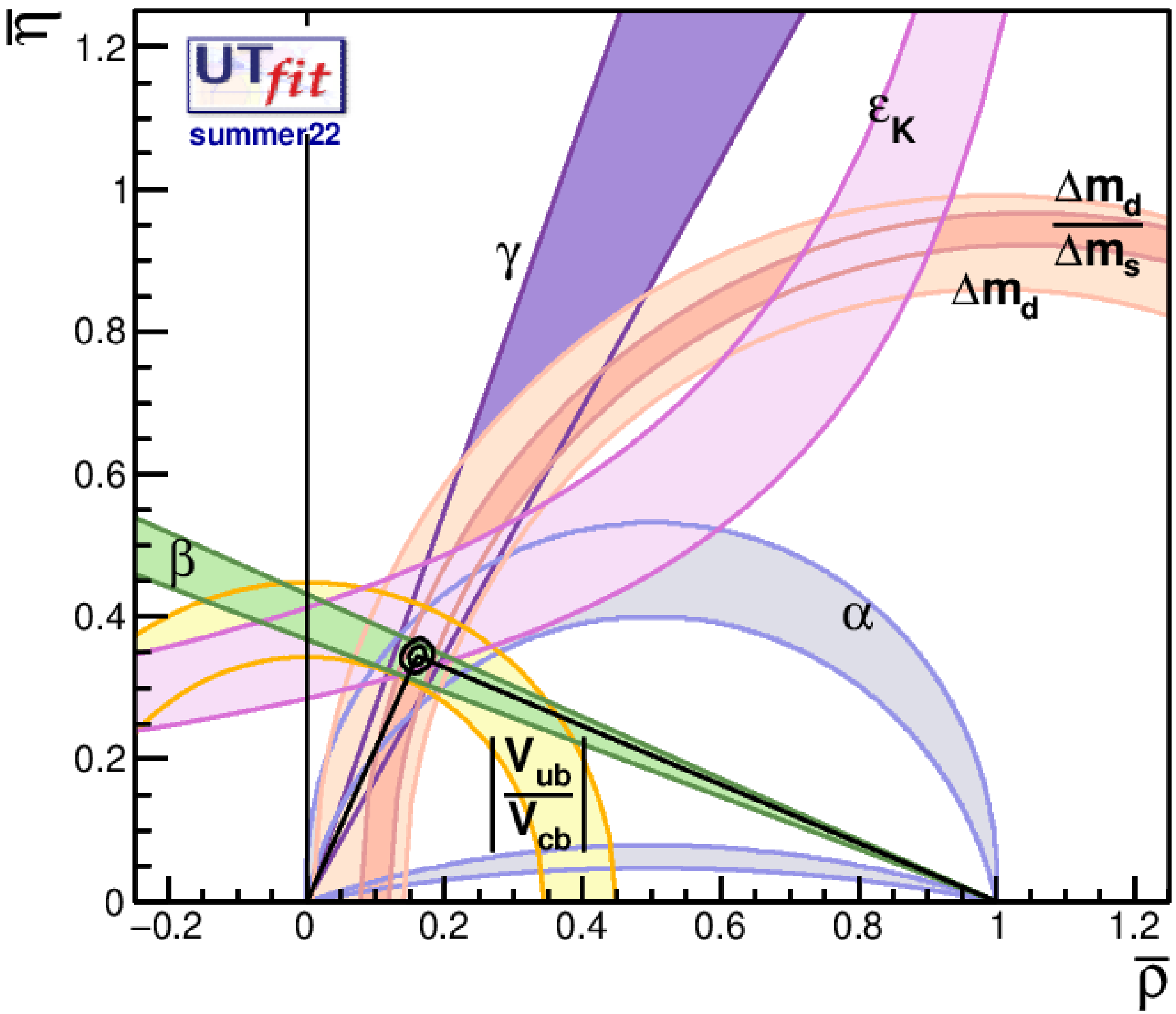
~6%

$\bar{\rho} = 0.160 \pm 0.009$
$\bar{\eta} = 0.345 \pm 0.009$

~3%

Unitarity Triangle analysis in the SM:

zoomed in..



levels @
95% Prob

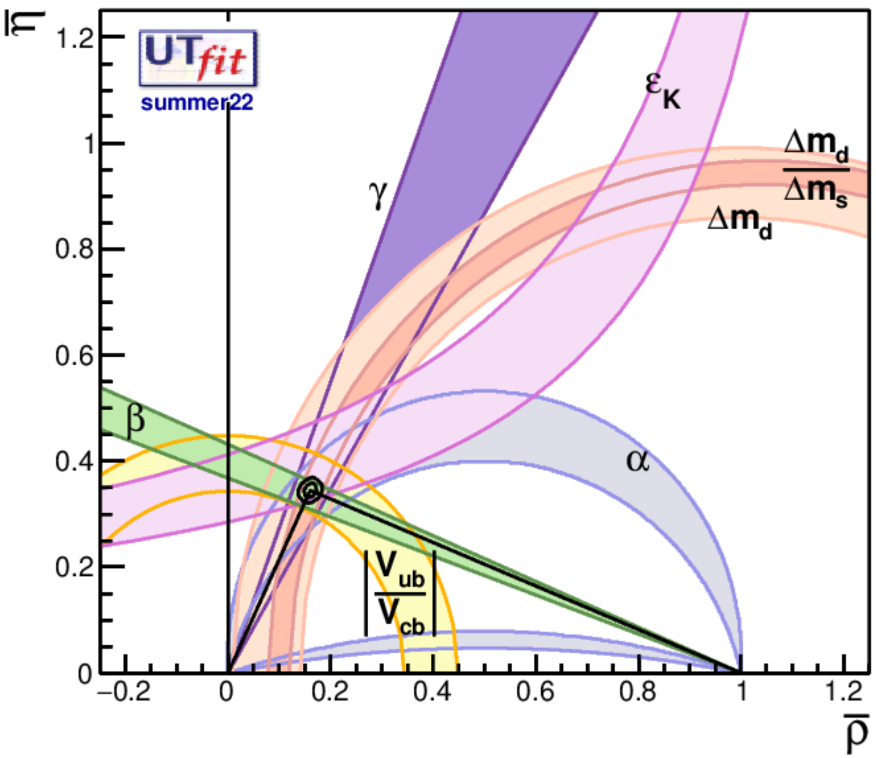
~6%

$\bar{\rho} = 0.160 \pm 0.009$
$\bar{\eta} = 0.345 \pm 0.009$

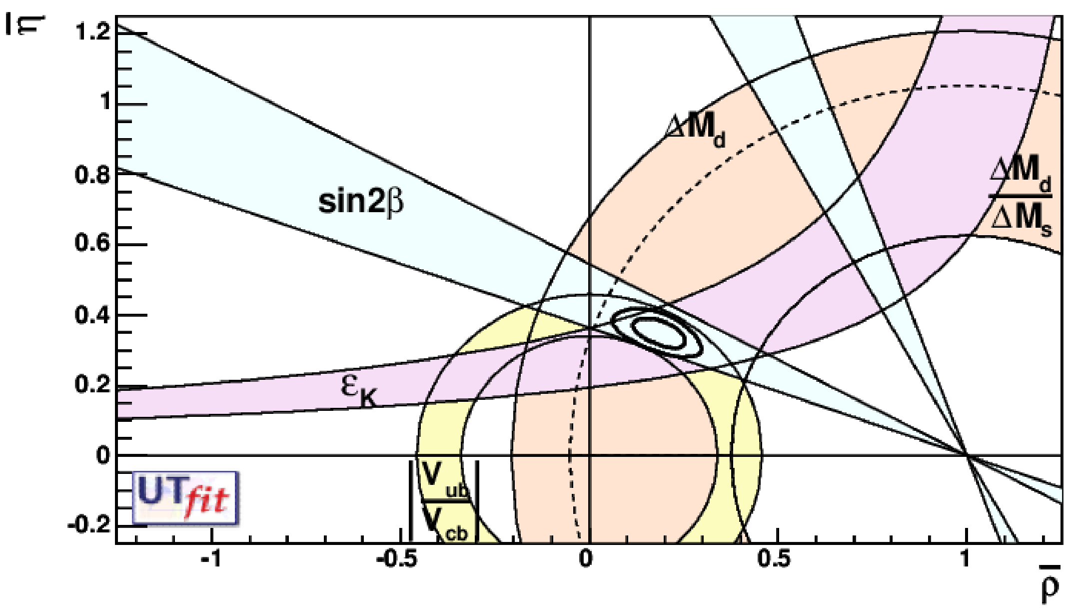
~3%

Unitarity Triangle analysis in the SM:

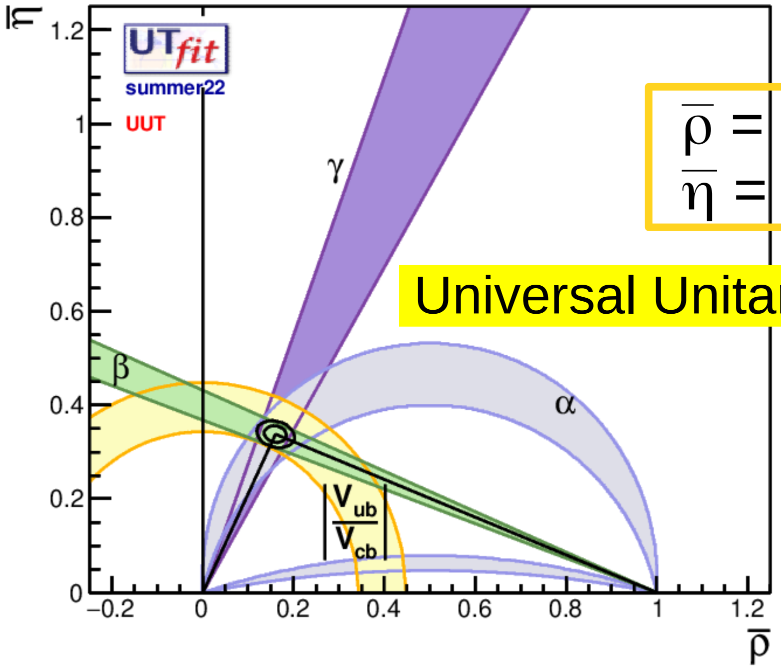
2022



2004



Some interesting configurations

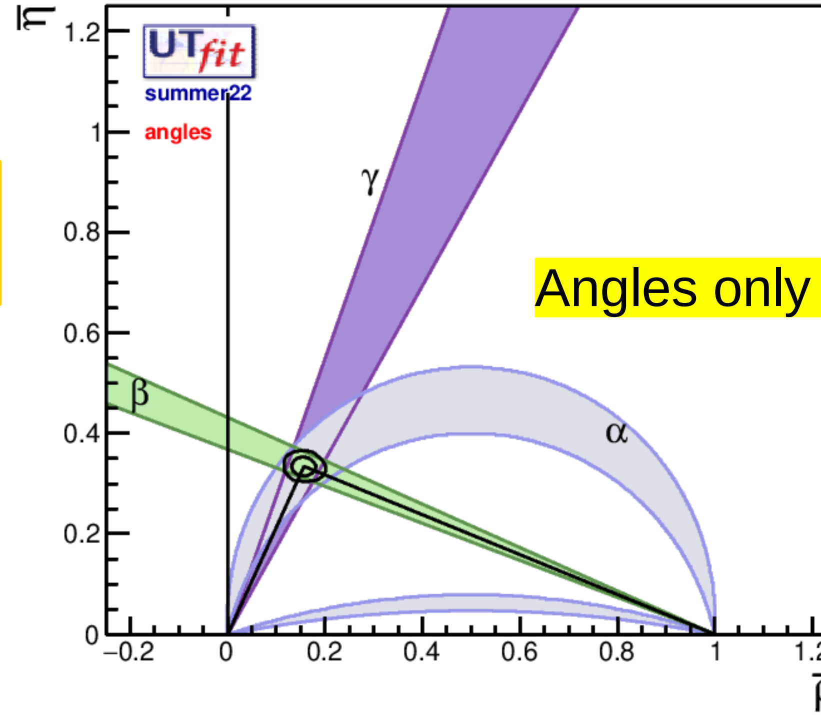


~11%

$\bar{\rho}$ = 0.160 ± 0.017
$\bar{\eta}$ = 0.338 ± 0.011

~3%

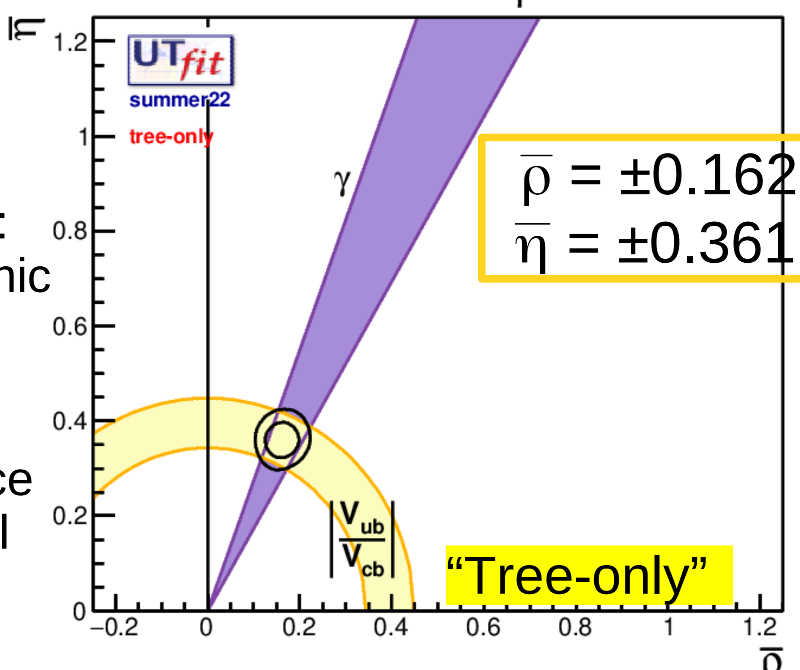
Universal Unitary Triangle



Angles only

Tree-level processes: Semileptonic and DK B decays

→ reference for model building

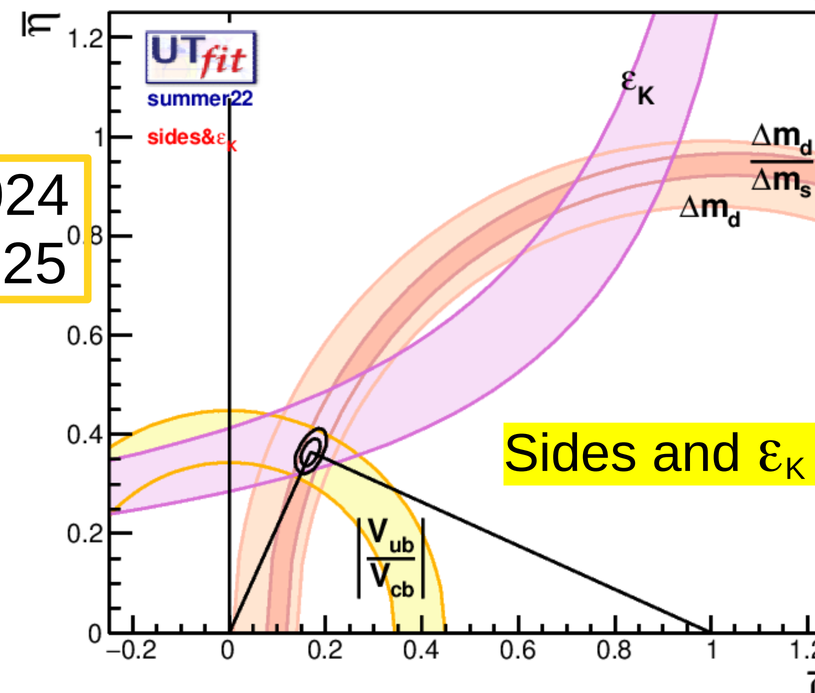


~15%

$\bar{\rho}$ = ±0.162 ± 0.024
$\bar{\eta}$ = ±0.361 ± 0.025

~7%

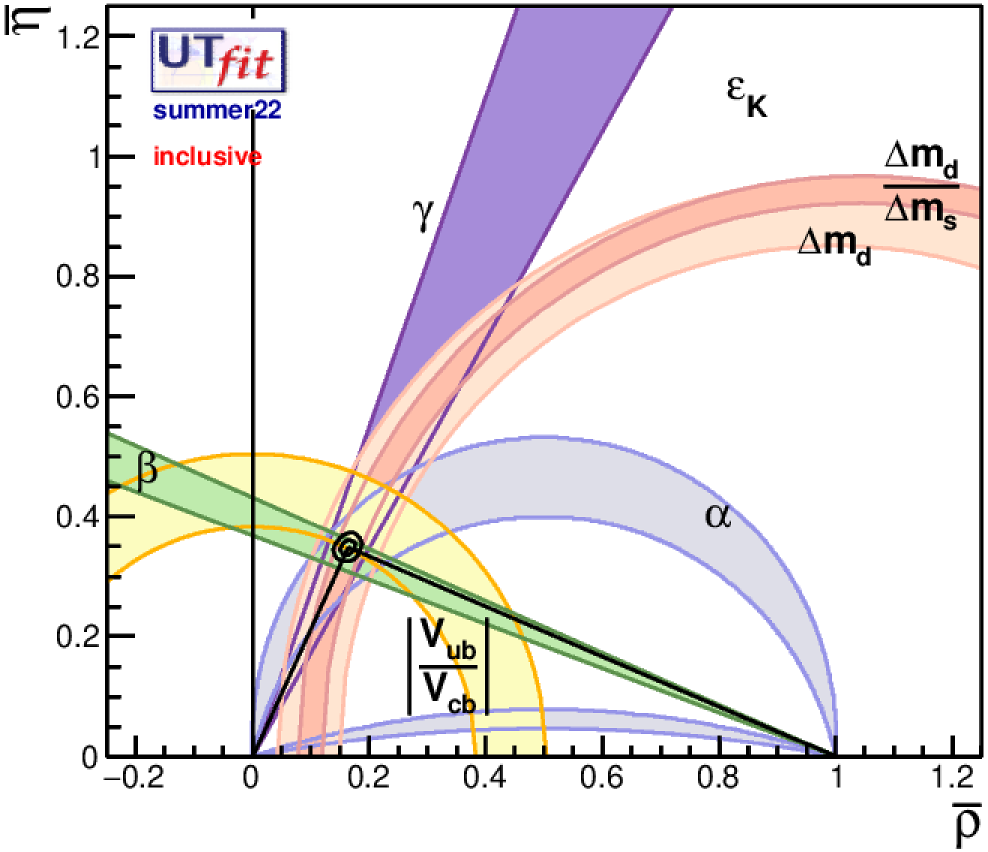
“Tree-only”



Sides and ε_K

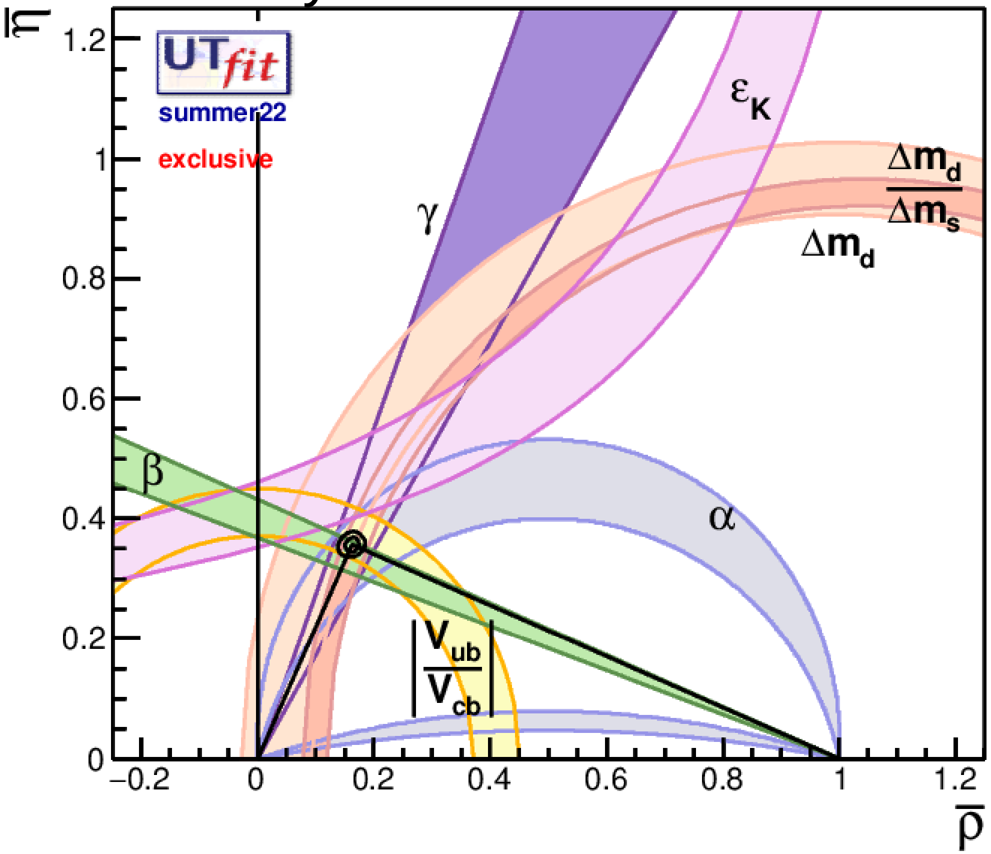
Inclusive vs Exclusive

only inclusive values



$$\bar{\rho} = 0.164 \pm 0.009$$
$$\bar{\eta} = 0.348 \pm 0.009$$
$$\sin 2\beta = 0.753 \pm 0.028$$

only exclusive values



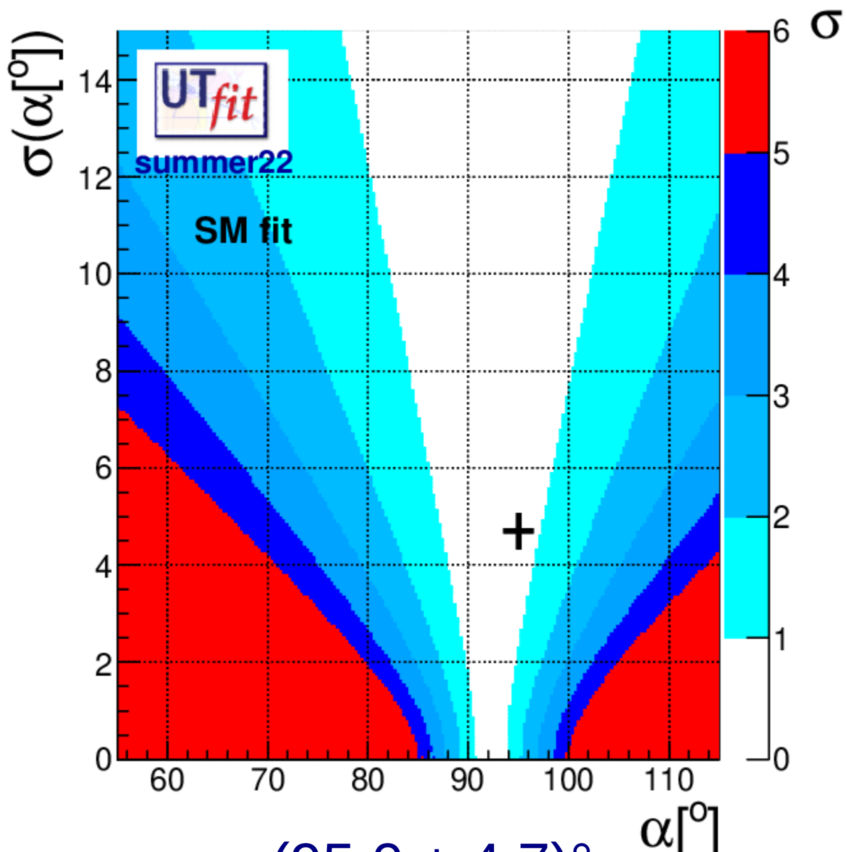
$$\bar{\rho} = 0.162 \pm 0.009$$
$$\bar{\eta} = 0.356 \pm 0.009$$
$$\sin 2\beta = 0.755 \pm 0.020$$

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

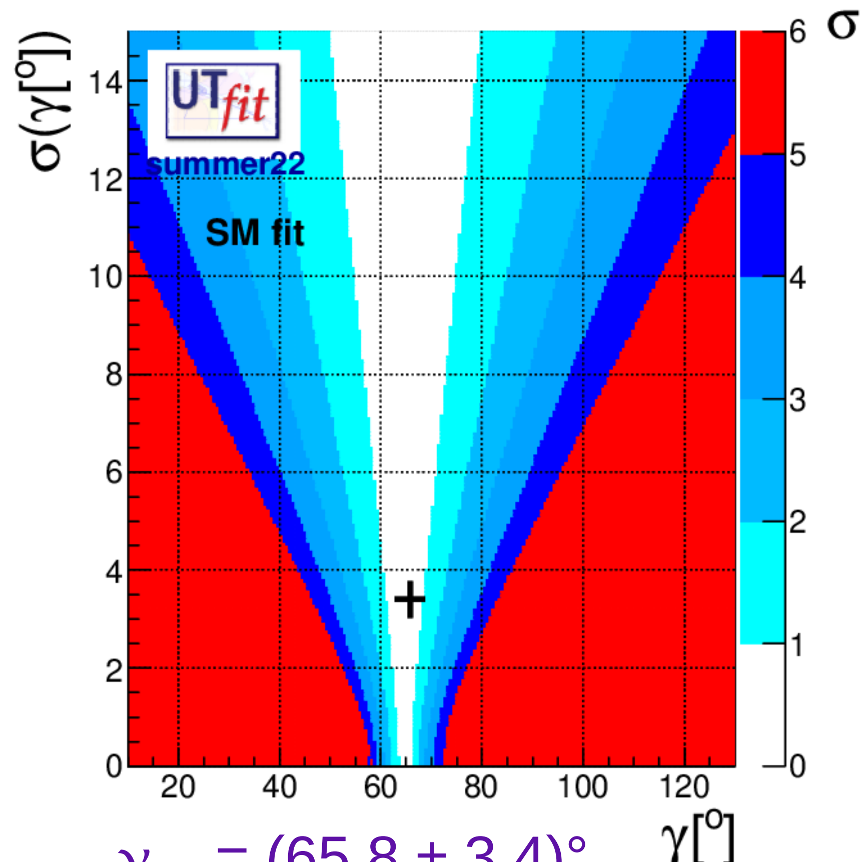
Color code: agreement between the predicted values and the measurements at better than 1, 2, ...nσ

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



α_{exp} = (95.0 ± 4.7)°

α_{UTfit} = (92.3 ± 1.5)°



γ_{exp} = (65.8 ± 3.4)°

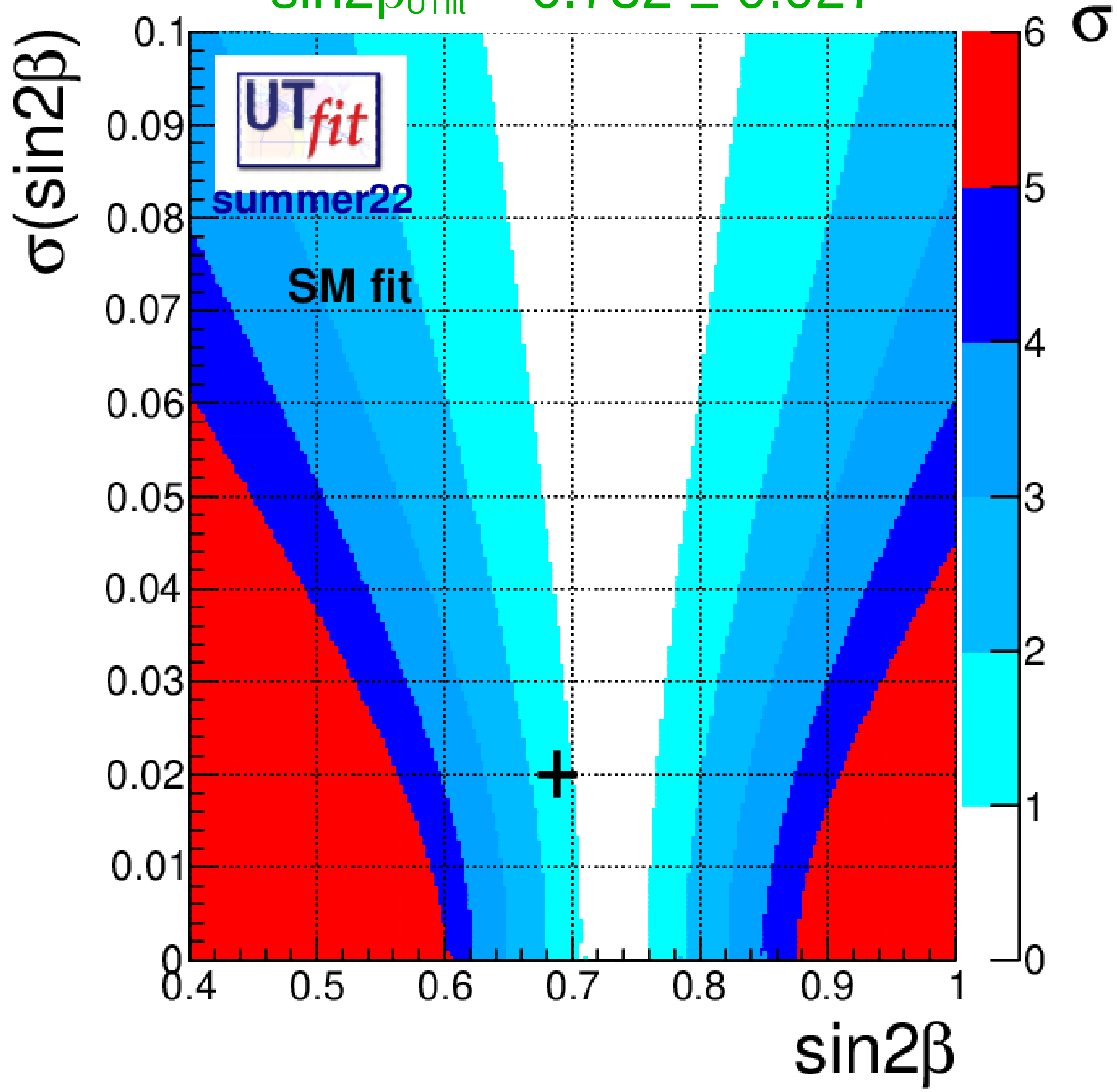
γ_{UTfit} = (64.9 ± 1.3)°

Checking the usual *tensions..*

~1.3σ

$\sin 2\beta_{exp} = 0.688 \pm 0.020$

$\sin 2\beta_{UTfit} = 0.732 \pm 0.027$



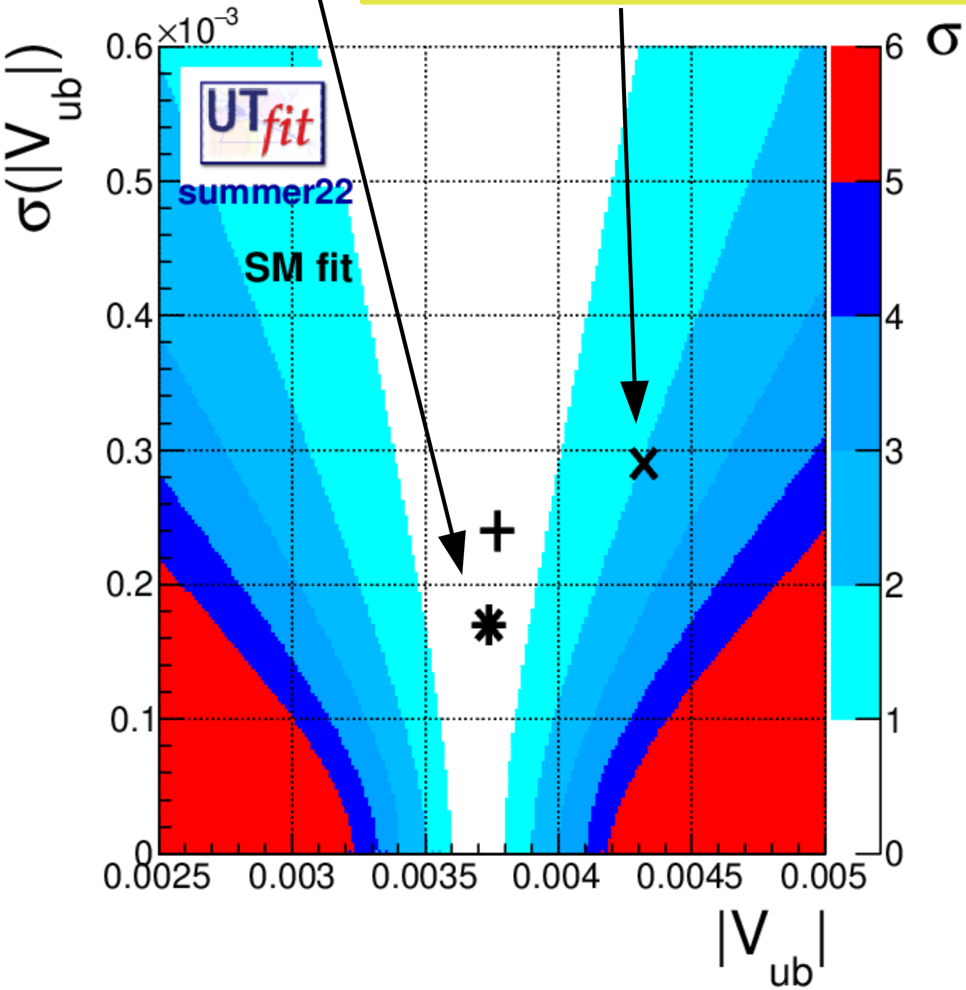
Checking the usual *tensions*..

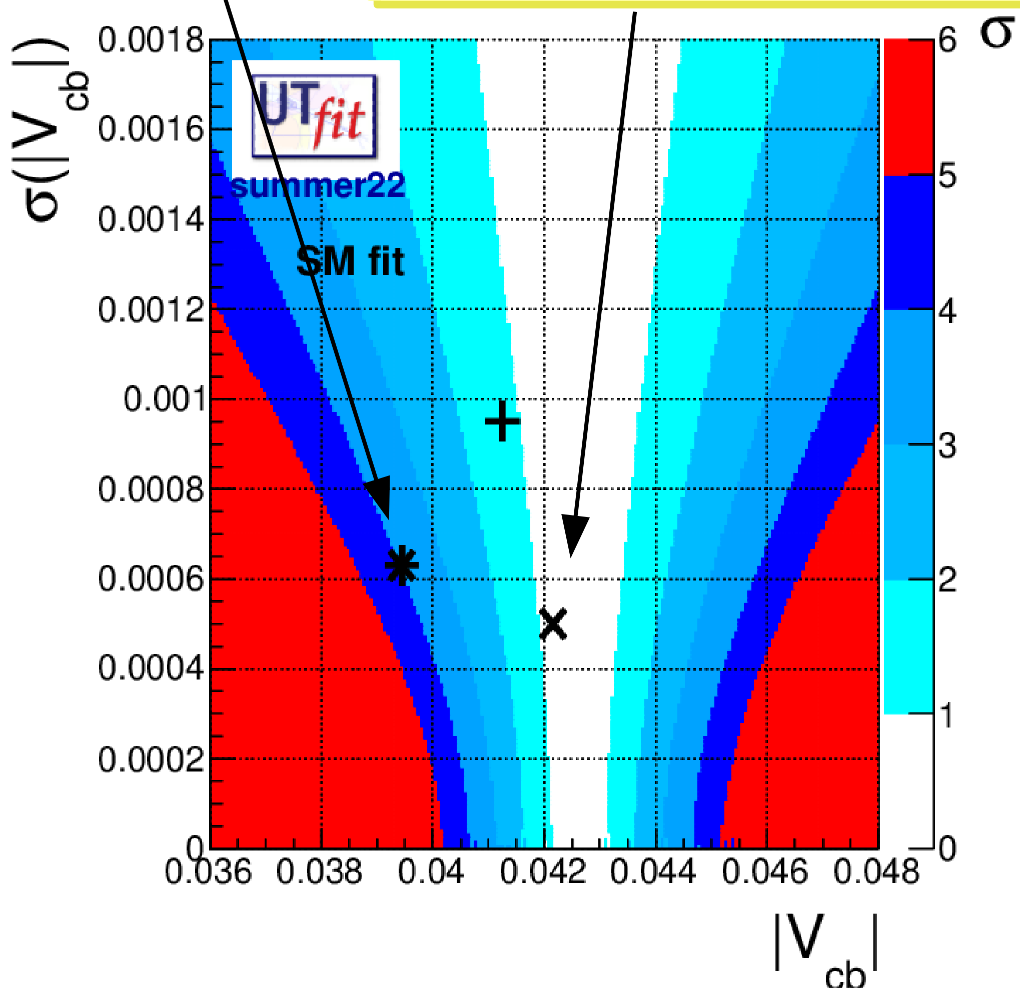
$|V_{ub}|$ *(excl)* = (3.74 ± 0.17) 10^{-3}

$|V_{ub}|$ *(incl)* = (4.32 ± 0.29) 10^{-3}

$|V_{cb}|$ *(excl)* = (39.44 ± 0.63) 10^{-3}

$|V_{cb}|$ *(incl)* = (42.16 ± 0.50) 10^{-3}





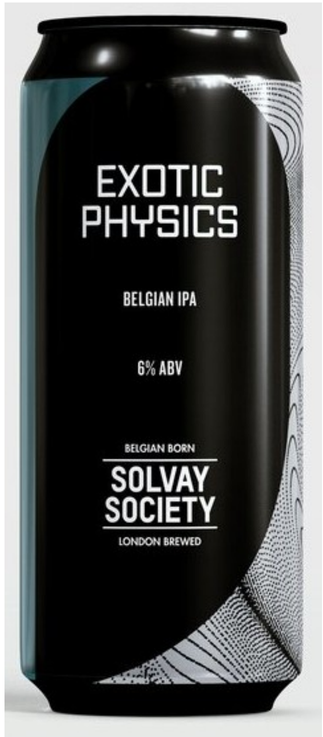
Vub_{exp} = (3.77 ± 0.24) · 10^{-3}

Vub_{UTfit} = (3.70 ± 0.10) · 10^{-3}

Vcb_{exp} = (41.25 ± 0.95) · 10^{-3}

Vcb_{UTfit} = (42.6 ± 0.5) · 10^{-3}

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

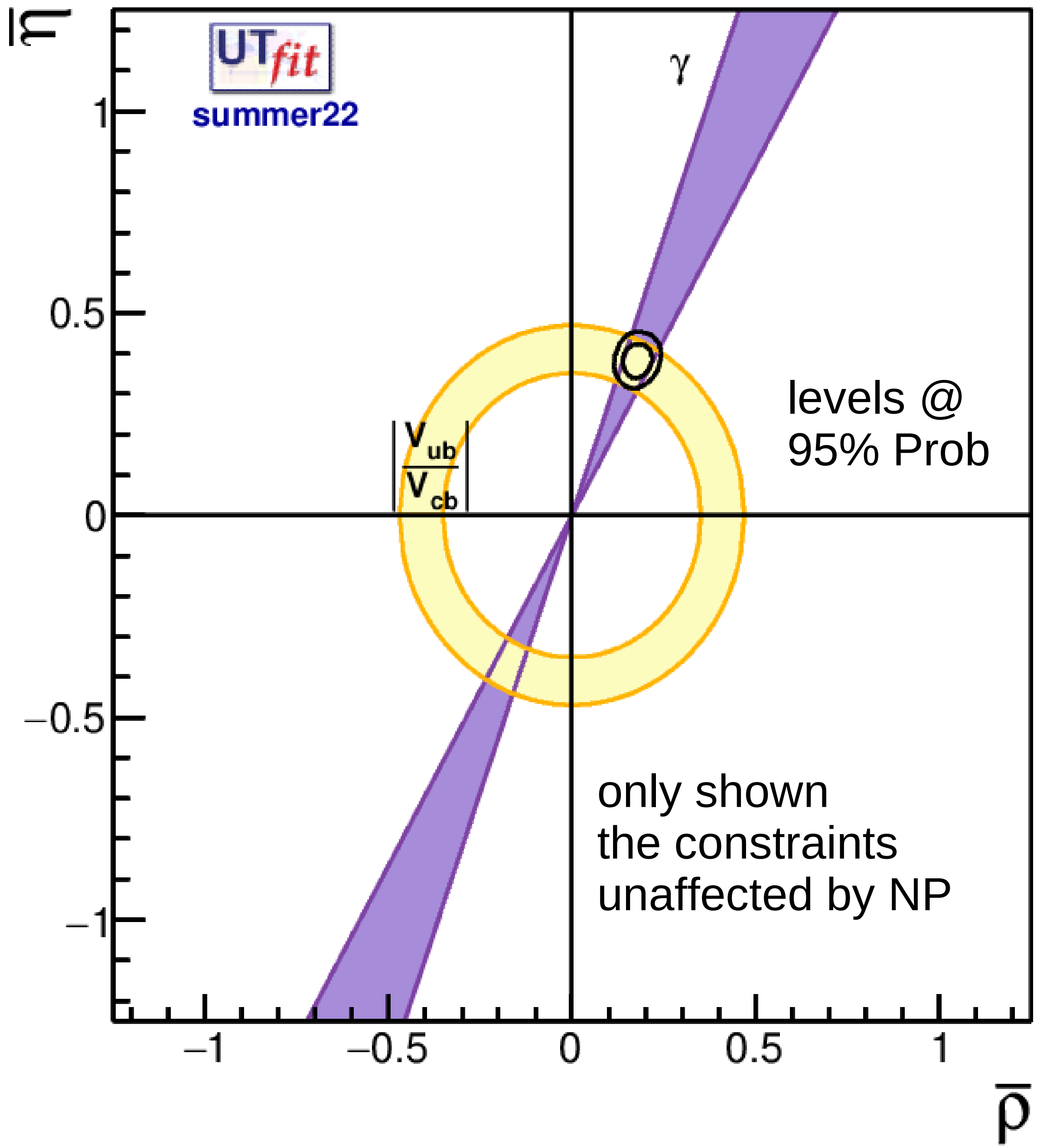
B_d and B_s mixing amplitudes
(2+2 real parameters):

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

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

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

NP analysis results



$\bar{\rho} = 0.169 \pm 0.025$
$\bar{\eta} = 0.365 \pm 0.026$

SM is

$\bar{\rho} = 0.160 \pm 0.009$
$\bar{\eta} = 0.345 \pm 0.009$

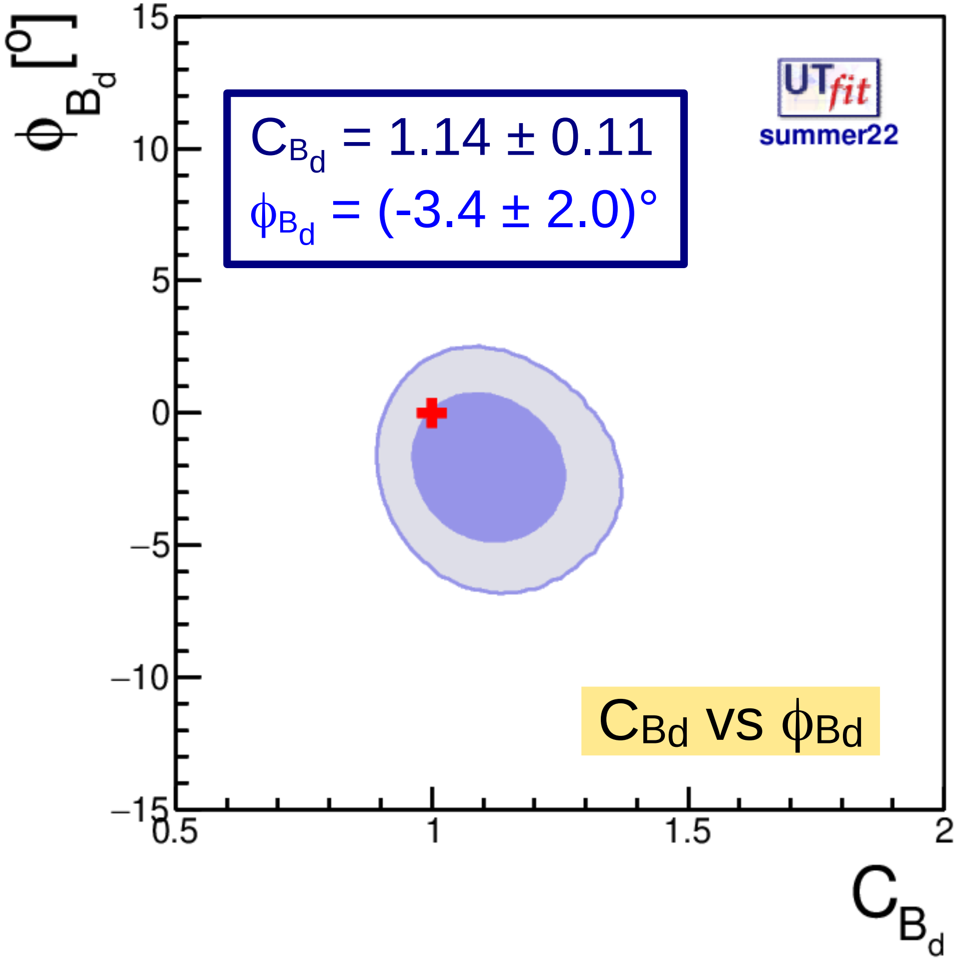
NP parameter results

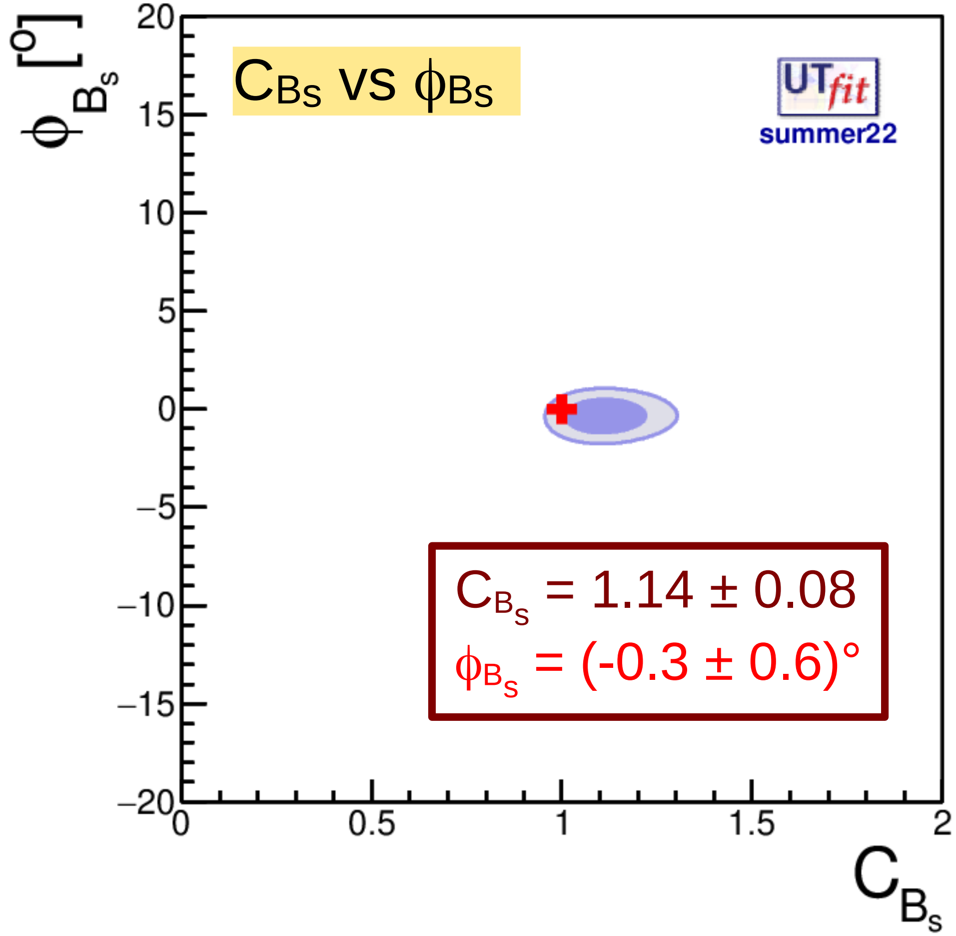
$$A_q = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_q^{SM}}$$

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

K system

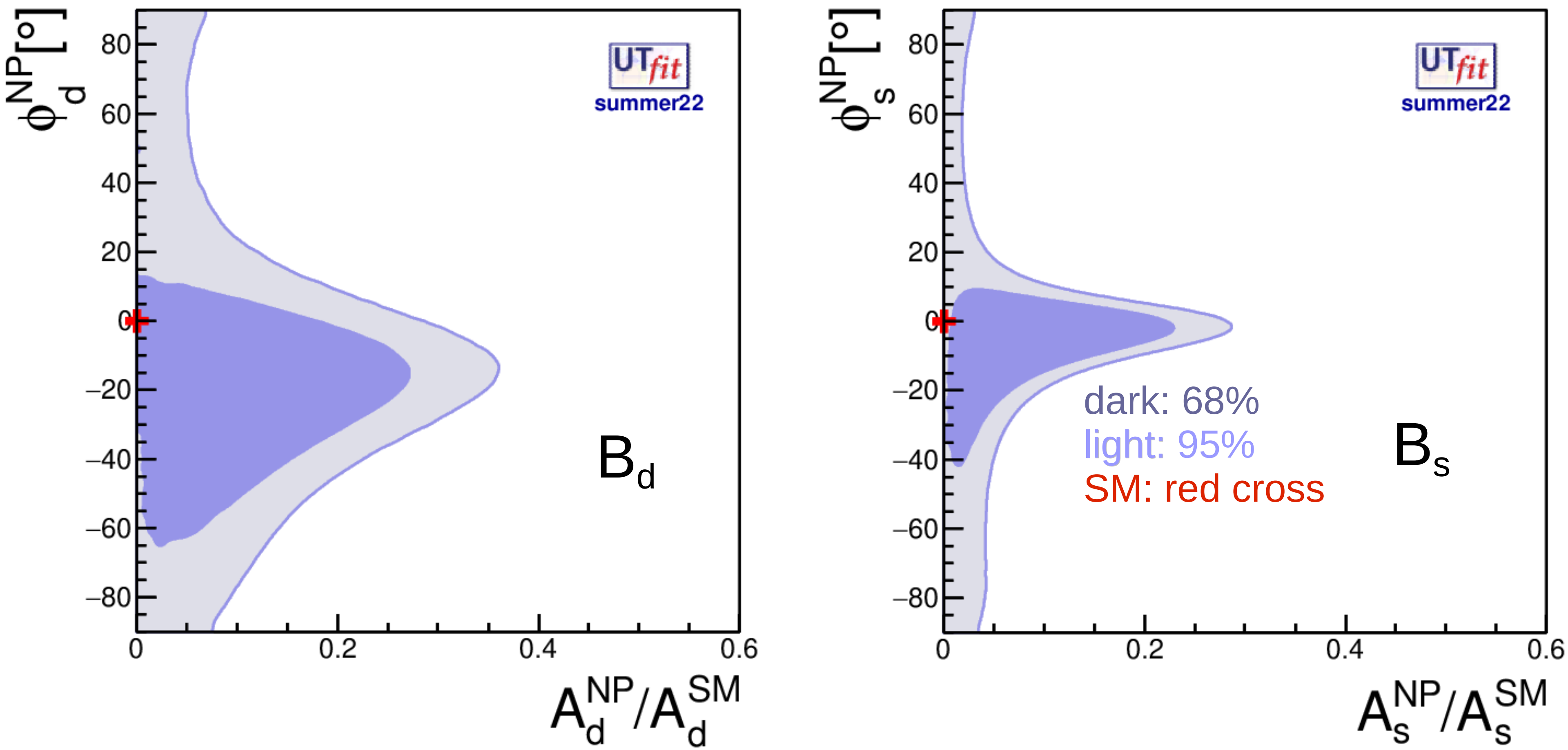
$C_{\epsilon_K} = 1.12 \pm 0.12$





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:

< 25% @68% prob. (35% @95%) in B_d mixing

< 25% @68% prob. (30% @95%) in B_s mixing

testing the new-physics scale

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

RGE

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

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

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

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

- 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 $\Delta F=2$ processes)

testing the TeV scale

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

The dependence of C on Λ changes depending on the flavour 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

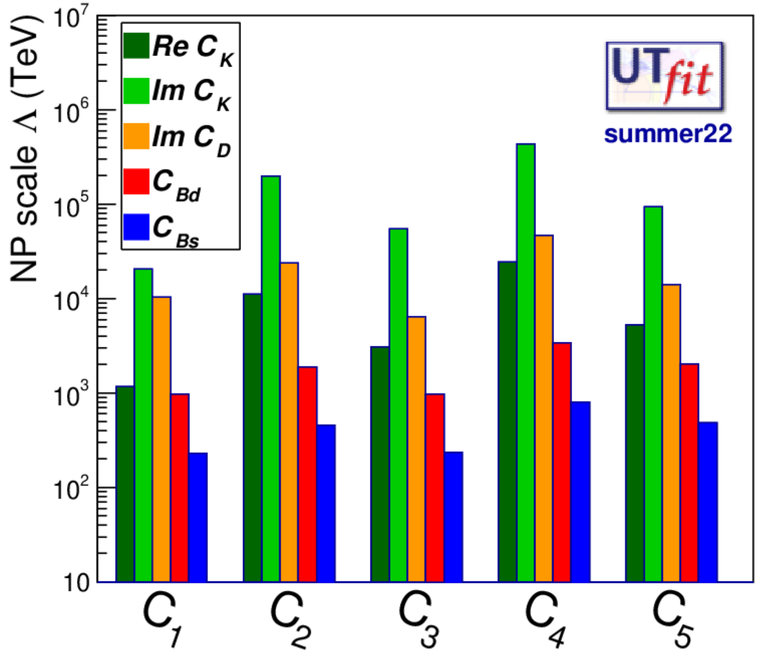
If no NP effect is seen lower bound on NP scale Λ

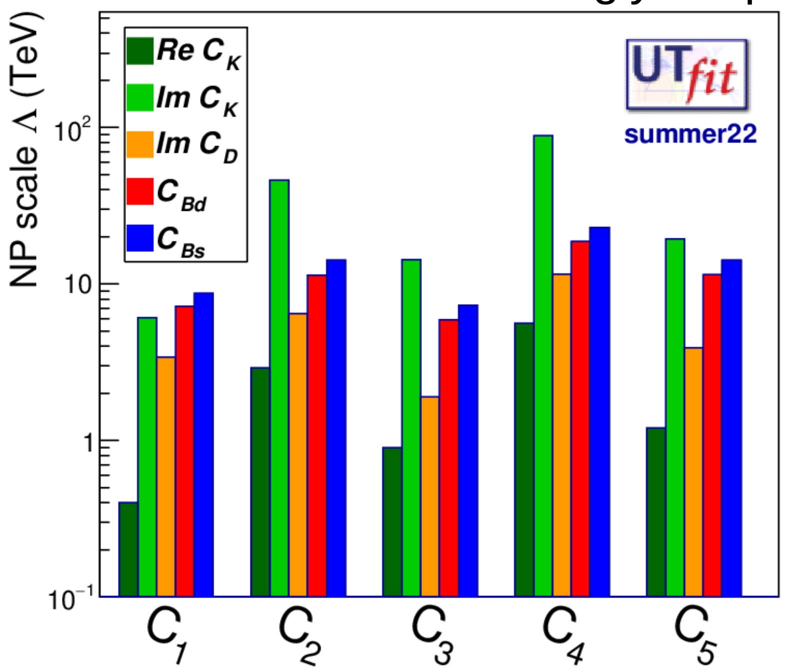
F is the flavour coupling and so
F_{SM} is the combination of CKM factors for the considered process

results from the Wilson coefficients

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

NMFV: $C(\Lambda) = \alpha \times |F_{SM}|/\Lambda^2$, $F_i \sim |F_{SM}|$, arbitrary phase
$\alpha \sim 1$ for strongly coupled NP





$\Lambda > 4.4\ 10^5$ TeV

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

$\Lambda > 95$ TeV

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

$\Lambda > 1.3\ 10^4$ TeV

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

$\Lambda > 2.9$ TeV

for lower bound for loop-mediated contributions, simply multiply by α_s (~ 0.1) or by α_W (~ 0.03).

Cornelia Parker

3
COLD DARK MATTER:
AN EXPLODED VIEW

'We watch explosions daily, in action films, documentaries and on the news in never-ending reports of conflict. I wanted to create a real explosion, not a representation. I chose the garden shed because it's the place where you store things you can't quite throw away.

The shed was blown up at the Army School of Ammunition. We used Semtex, a plastic explosive popular with terrorists. I pressed the plunger that blew the shed skywards. The soldiers helped me comb the field afterwards, picking up the blackened, mangled objects.

conclusions

- SM analysis displays very good (improved) overall consistency
- Still open discussion on semileptonic inclusive vs exclusive: exclusive fit shows tension, V_{cb} now showing the biggest discrepancy..
- UTA provides determination of NP contributions to $\Delta F=2$ amplitudes. It currently leaves space for NP at the level of 25-35%
- 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 not only complementary to direct searches, but they might be the main way to glimpse at new physics.

Back up slides

Some updated inputs

lattice inputs updated for this summer

Observables	Measurement
B_K	0.756 ± 0.016
f_{Bs}	0.2301 ± 0.0012
f_{Bs}/f_{Bd}	1.208 ± 0.005
B_{Bs}/B_{Bd}	1.015 ± 0.021
B_{Bs}	1.284 ± 0.059

We quote, instead, the weighted average of the N_f=2+1+1 and N_f=2+1 results with the error rescaled when chi2/dof > 1, as done by FLAG for the N_f=2+1+1 and N_f=2+1 averages separately [new HPQCD (2+1+1) result 1907.01025]

V_{ud} and V_{us} updated for this summer

Observables	Measurement
V_{ud}	0.97433 ± 0.00019
V_{us}	0.2249 (± 0.0004)

V_{ud} is taken from the PDG average of V_{ud} FLAG numbers (for 2+1+1 and 2+1) and superallowed beta decays value. PDG scale factor S=2.0

V_{us} is not used in the fit

Unitarity Triangle analysis in the SM:

obtained excluding the given constraint from the fit

Observables	Measurement	Prediction	Pull (#σ)
$\sin 2\beta$	0.688 ± 0.020	0.732 ± 0.027	~ 1.3
γ	65.8 ± 3.4	64.9 ± 1.3	< 1
α	95.0 ± 4.7	92.3 ± 1.5	< 1
$\varepsilon_K \cdot 10^3$	2.228 ± 0.001	2.04 ± 0.14	< 1
$\|V_{cb}\| \cdot 10^3$	41.25 ± 0.95	42.6 ± 0.5	< 1
$\|V_{cb}\| \cdot 10^3$ (incl)	42.16 0.50		< 1
$\|V_{cb}\| \cdot 10^3$ (excl)	39.44 0.63		~ 4.0
$\|V_{ub}\| \cdot 10^3$	3.77 ± 0.24	3.70 ± 0.10	< 1
$\|V_{ub}\| \cdot 10^3$ (incl)	4.32 ± 0.29	-	~ 2.0
$\|V_{ub}\| \cdot 10^3$ (excl)	3.74 ± 0.17	-	< 1
$BR(B \to \tau\nu)[10^{-4}]$	1.09 ± 0.24	0.88 ± 0.05	< 1
$A_{SL}^d \cdot 10^3$	-2.1 ± 1.7	-0.33 ± 0.02	< 1
$A_{SL}^s \cdot 10^3$	-0.6 ± 2.8	0.014 ± 0.001	< 1

Unitarity Triangle analysis in the SM:

We obtain the predictions for the lattice parameters in different configurations in the fit:

- only lattice parameters ratios
  - (F_{Bs}/F_B, B_{Bs}/B_{Bd} used)
- only B parameters
  - (B_{Bs}^1, B_{Bs}/B_{Bd} used)
- only decay constants f
  - (f_{Bs}, f_{Bs}/f_B included)

Observables	Measurement	Prediction
B_K	0.756 ± 0.016	0.832 ± 0.054
No B lattice		
$f_B\sqrt{B_{Bd}}$	(0.2142 ± 0.0056)	0.212 ± 0.010
$f_{Bs}\sqrt{B_{Bs}}$	(0.2607 ± 0.0061)	0.259 ± 0.010
ξ	(1.217 ± 0.014)	1.225 ± 0.033
Ratios only		
f_{Bs}	0.2301 ± 0.0012	0.227 ± 0.009
B_{Bs}	1.284 ± 0.059	1.30 ± 0.10
B pars only		
f_{Bs}/f_{Bd}	1.208 ± 0.005	1.215 ± 0.028
f_{Bs}	0.2301 ± 0.0012	0.228 ± 0.008
f pars only		
B_{Bs}/B_{Bd}	1.015 ± 0.021	1.017 ± 0.028
B_{Bs}	1.284 ± 0.059	1.290 ± 0.065

new-physics-specific constraints

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

semileptonic asymmetries in B^0 and B_s: sensitive to NP effects in both size and phase. Taken from the latest HFLAV.

Cleo, BaBar, Belle, D0 and LHCb

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

D0 arXiv:1106.6308

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

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

lifetime τ^{FS} in flavour-specific final states: average lifetime is a function to the width and the width difference

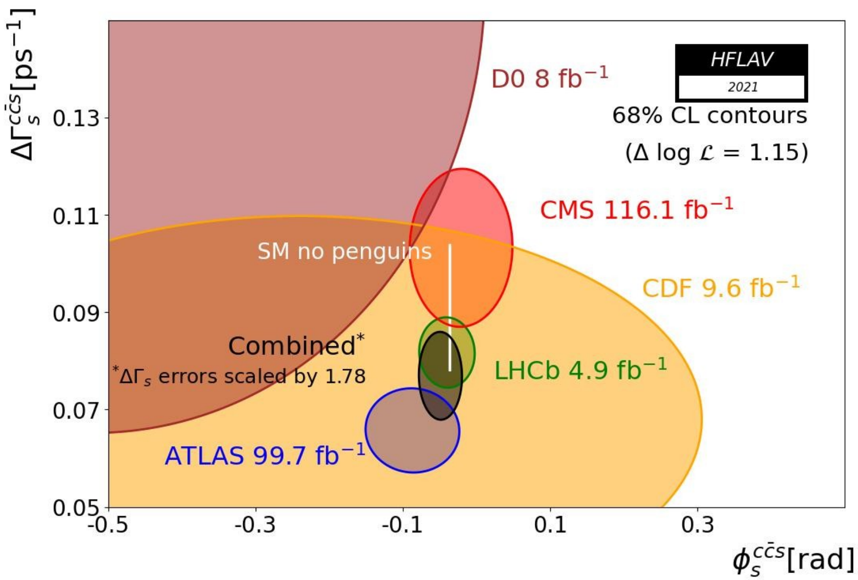
$$\tau^{FS}(B_s) = 1.527 \pm 0.011 \text{ ps}$$

HFLAV

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

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

$$\phi_s = -0.049 \pm 0.019 \text{ rad}$$

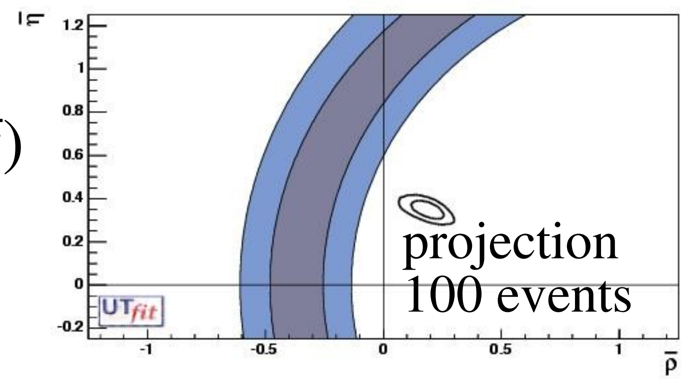


some old plots coming back to fashion:

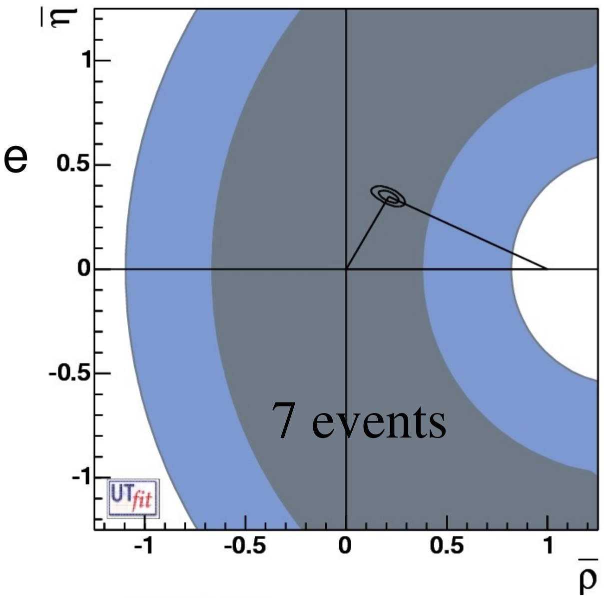
As NA62 and KOTO are analysing data:

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

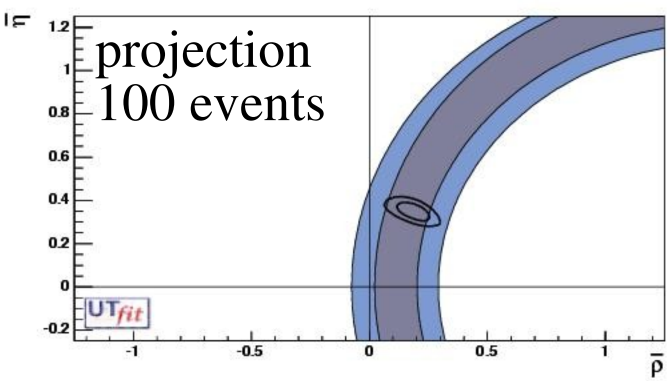
E949 central value

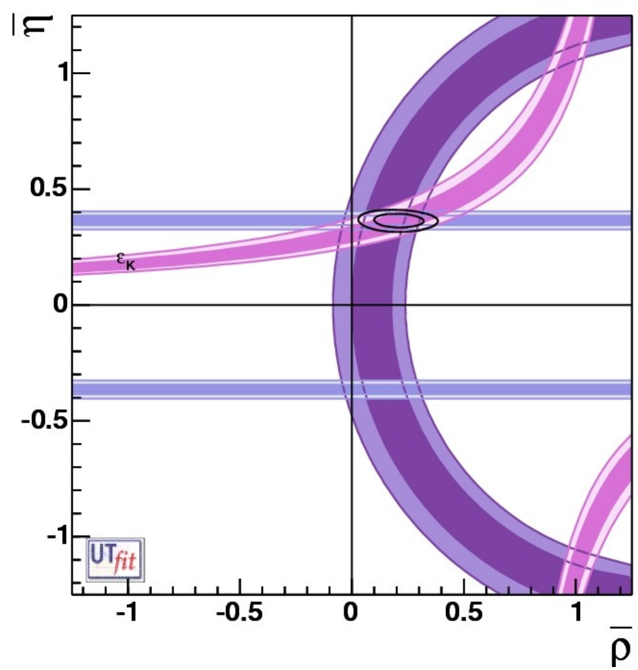


2007 global fit area



SM central value

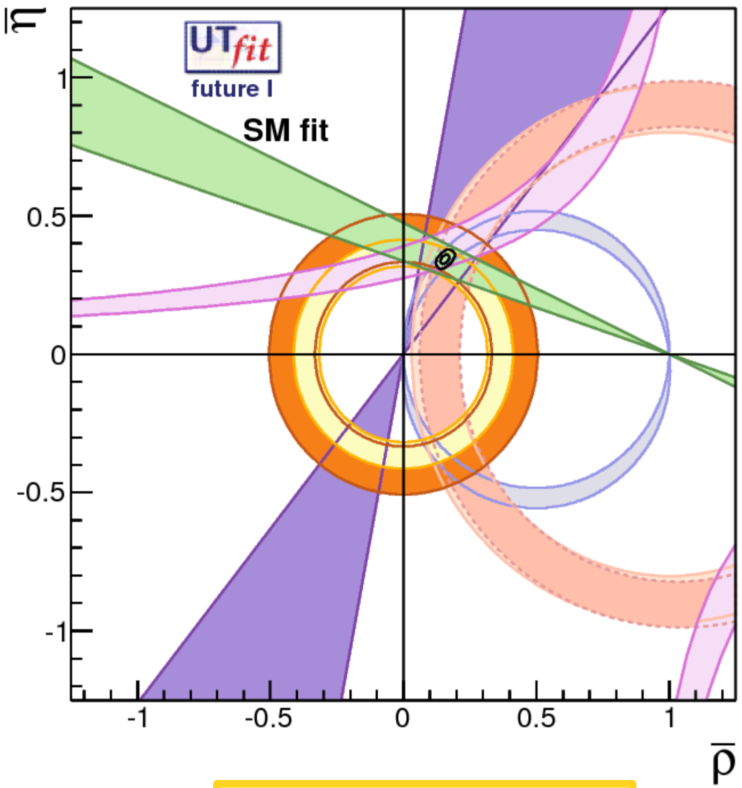




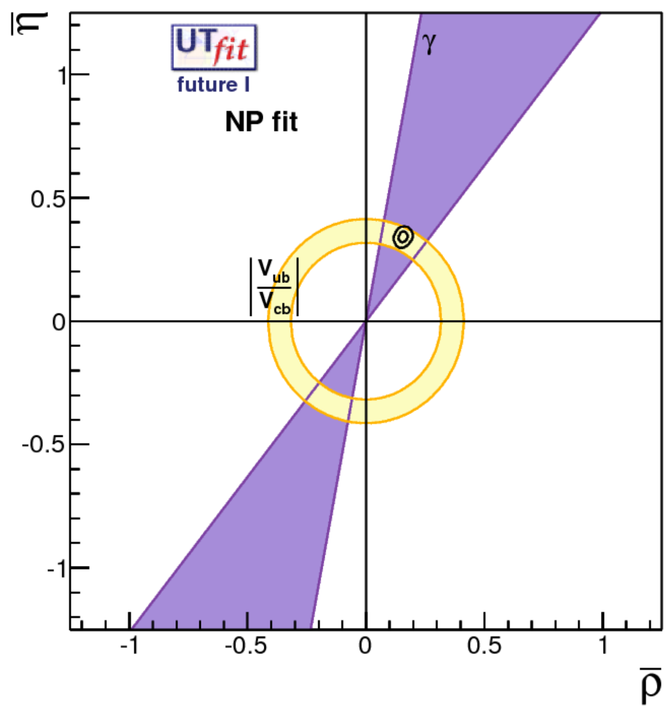
including
$BR(K^0 \to \pi^0 \nu \bar{\nu})$
SM central value

Old future predictions..

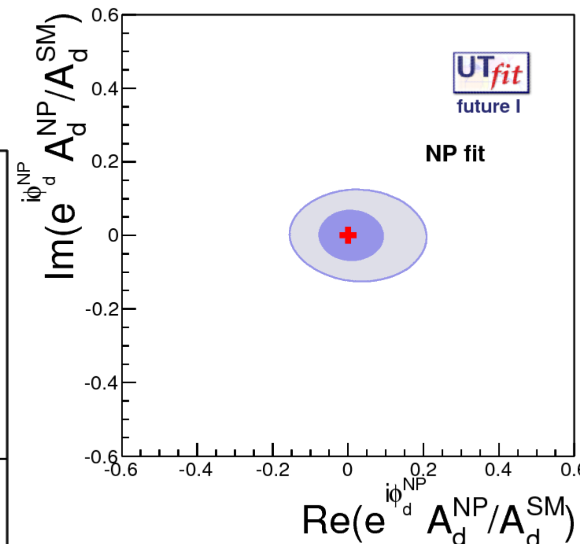
future I scenario:
errors from
Belle II at 5/ab
+ LHCb at 10/fb

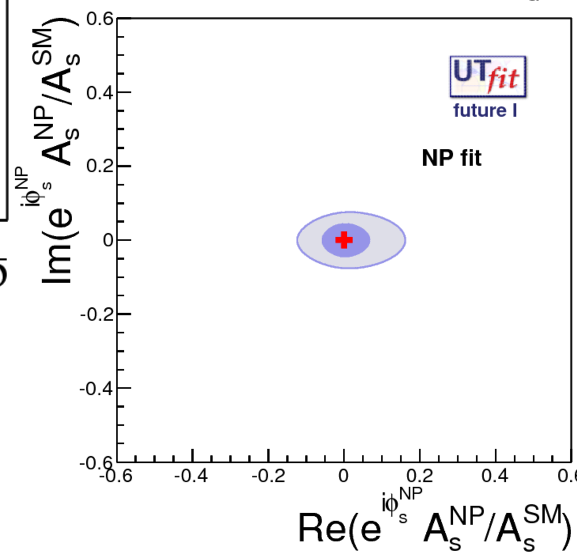


$\rho = \pm\, 0.015$
$\eta = \pm\, 0.015$



$\rho = \pm\, 0.016$
$\eta = \pm\, 0.019$





$\bar{\rho} = 0.154 \pm 0.015$
$\bar{\eta} = 0.344 \pm 0.013$

current sensitivity

$\bar{\rho} = 0.150 \pm 0.027$
$\bar{\eta} = 0.363 \pm 0.025$