Unitarity triangle fits: Standard model & Search for New Physics

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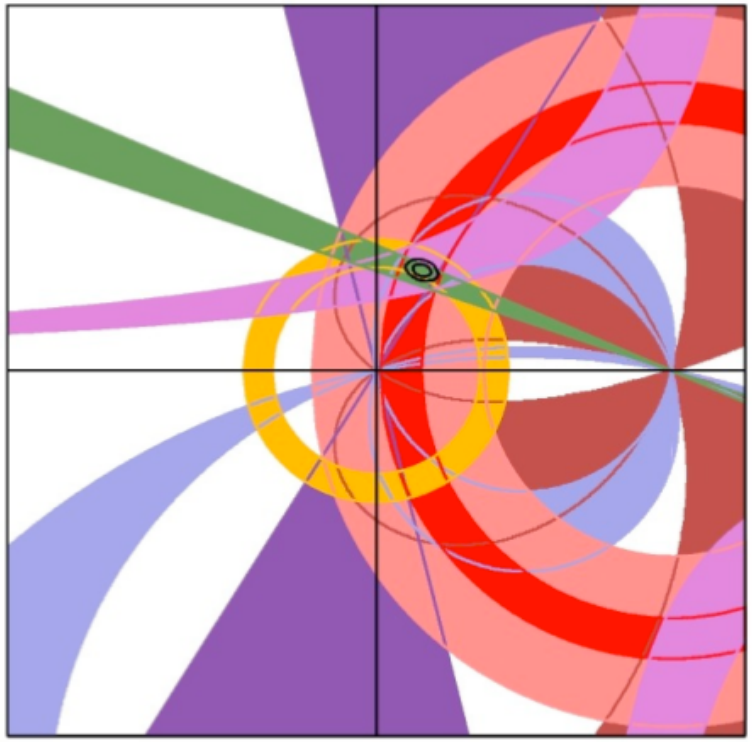
STANDARD MODEL UNITARITY TRIANGLE ANALYSIS



- *Provide the best determination of the CKM parameters;*
- *Test the consistency of the SM (``direct" vs ``indirect" determinations) @ the quantum level;*
- *Provide predictions for SM observables (in the past for example sin 2β and* Δm_s*)*

Flavor physics in the Standard Model

In the SM, the quark mass matrix, from which the CKM matrix and ~~CP~~ violation originate, is determined by the coupling of the Higgs boson to fermions.

$$\mathcal{L}^{\mathbf{quarks}} = \mathcal{L}^{\mathbf{kinetic}} + \mathcal{L}^{\mathbf{gauge}} + \mathcal{L}^{Yukawa}$$

CP invariant

~~CP~~ and symmetry breaking are striclty correlated

$$\mathcal{L}(\Lambda_{Fermi}) = \mathcal{L}(\Lambda, H, H^\dagger) + \mathcal{L}^{kin} + \mathcal{L}^{gauge}_{SM} + \mathcal{L}^{Yukawa}_{SM} + \frac{\mathcal{L}_5}{\Lambda} + \frac{\mathcal{L}_6}{\Lambda^2} + \ldots$$

EWSB

has many accidental simmetries

may violate accidental simmetries

Absence of FCNC at tree level (& GIM suppression of FCNC @loop level)

Almost no CP violation at tree level

Flavour Physics is extremely sensitive to New Physics (NP)

Flavor and New Physics

flavor physics can be used in two "modes":

1. "NP Lagrangian reconstruction"

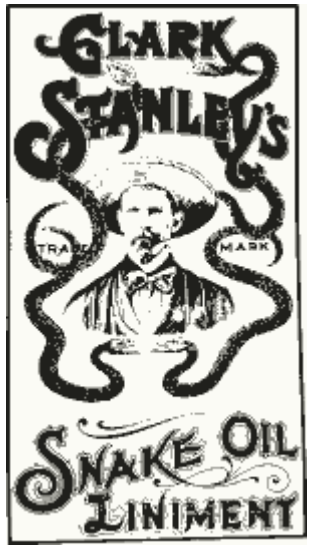
- *an external information on the NP scale is required (i.e. LHC)*
- *the main tool are correlations among observables*
- *needs good theoretical control on uncertainties of both SM and NP contributions*

2. "Discovery"

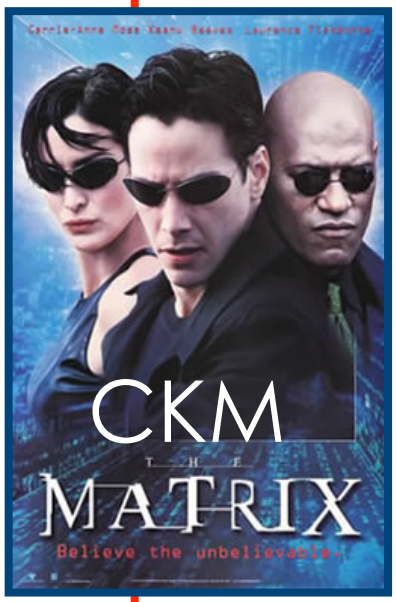
- *looks for deviation from the SM whatever the origin*
- *needs good theoretical control of the SM contribution only*
- *in general cannot provide precise information on the NP scale, but a positive result would be a strong evidence that NP is not too far (i.e. in the multi-TeV region)*

the path leading to TeV NP is narrower after the results of the LHC at 7 & 8 TeV

this will be further explored in the next run



UTfit



M.Bona *et al.*, UTfit
JHEP0507:028, 2005

www.utfit.org

A. Bevan, M. Bona, 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

The Wolfenstein Parametrization

$1 - 1/2\,\lambda^2$	λ	$A\,\lambda^3(\rho - i\,\eta)$
$-\lambda$	$1 - 1/2\,\lambda^2$	$A\,\lambda^2$
$A\,\lambda^3 \times (1 - \rho - i\,\eta)$	$-A\,\lambda^2$	1

V_{ub}

$+\ O(\lambda^4)$

V_{td}

$\lambda \sim 0.2 \quad A \sim 0.8$

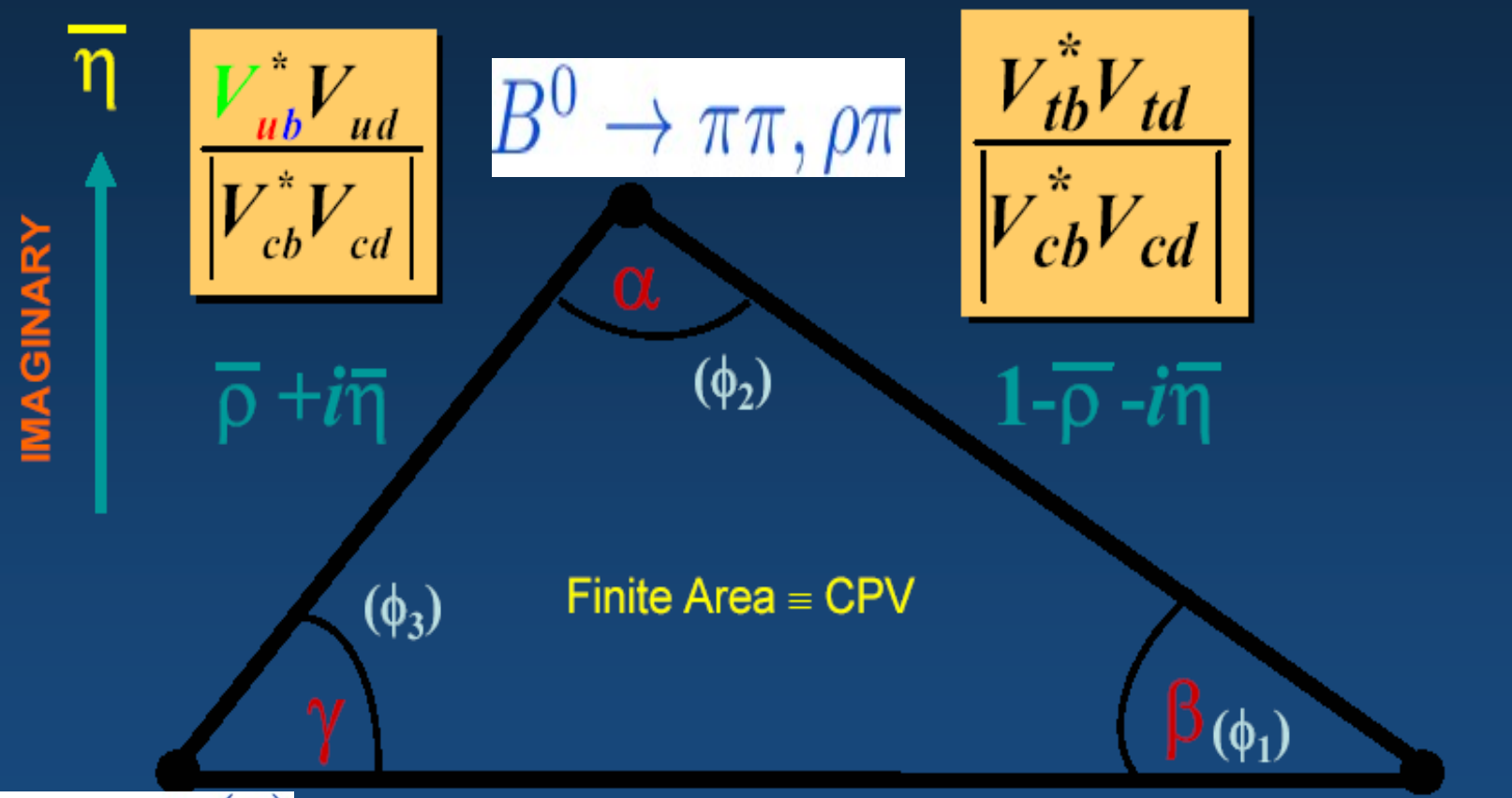
$\eta \sim 0.2 \quad \rho \sim 0.3$

$\sin\theta_{12} = \lambda$

$\sin\theta_{23} = A\,\lambda^2$

$\sin\theta_{13} = A\,\lambda^3(\rho - i\,\eta)$

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



$\gamma = tan^{-1}\left(\frac{\bar{\eta}}{\bar{\rho}}\right)$

$B^0 \to DK^{(*)}$

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

$B^0 \to J/\psi K_s$

Measure	V_{CKM}	Other NP parameters
$\Gamma(b \to u)/\Gamma(b \to c)$	$\bar{\rho}^2 + \bar{\eta}^2$	$\bar{\Lambda}, \lambda_1, F(1), \ldots$
ε_K	$\eta\,[(1-\bar{\rho}) + \ldots]$	B_K
Δm_d	$(1-\bar{\rho})^2 + \bar{\eta}^2$	$f_{B_d}^2 B_{B_d}$
$\Delta m_d/\Delta m_1$	$(1-\bar{\rho})^2 + \bar{\eta}^2$	ξ
$A_{CP}(B_d \to J/\psi\, K_s)$	$\sin 2\beta$	–

$$Q^{EXP} = V_{CKM} \times \langle H_F | \hat{O} | H_I \rangle$$

For details see:
UTfit Collaboration

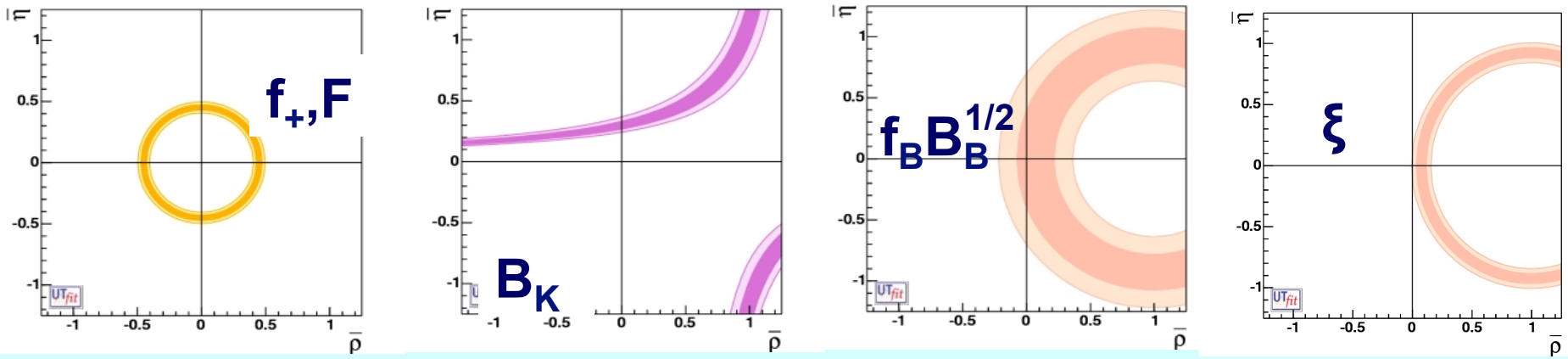
http://www.utfit.org

classical UT analysis

Quantities used in the Standard UT Analysis

levels @
68% (95%) CL

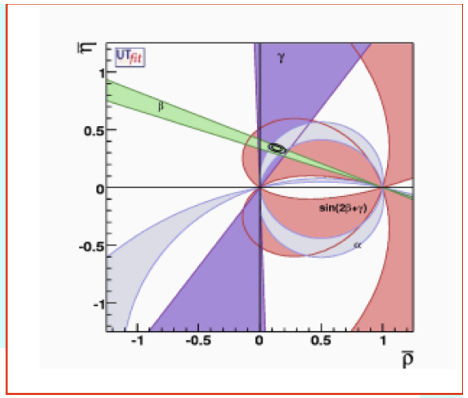
V_{ub}/V_{cb} | ε_K | Δm_d | $\Delta m_d/\Delta m_s$



Inclusive vs Exclusive
Opportunity for lattice QCD

UT-LATTICE

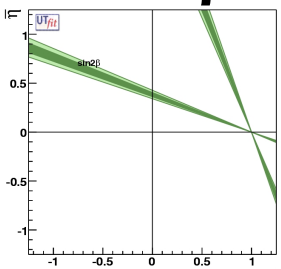
Other Quantities used in the UT Analysis



UT-ANGLES

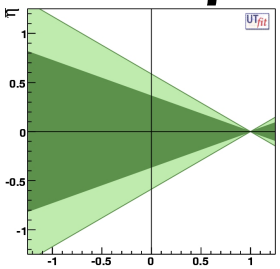
Several new determinations of UT angles are now available, thanks to the results coming from the B-Factory experiments

sin 2β



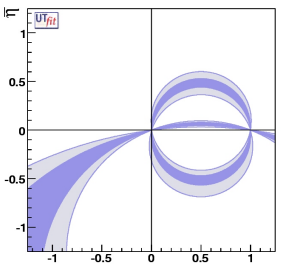
$B \to J/\Psi K^0$

cos 2β



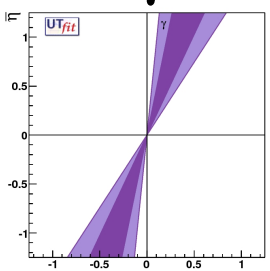
$B \to J/\Psi K^{*0}$

α



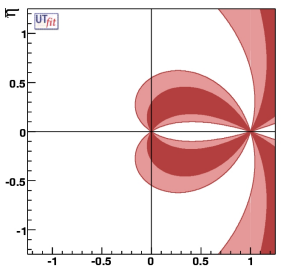
$B \to \pi\pi, \rho\rho$

γ



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

sin (2β+γ)

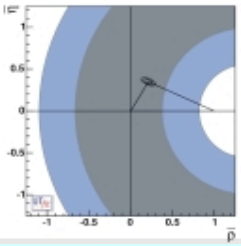


$B \to D^{(*)}\pi, D\rho$

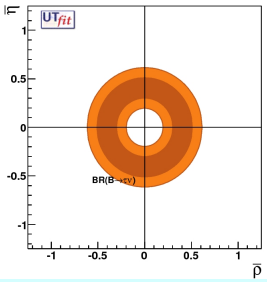
New Constraints from B and K rare decays (not used yet)

New bounds are available from rare B and K decays. They do not still have a strong impact on the global fit and they are not used at present.

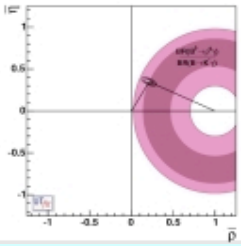
$K \to \pi \nu \bar{\nu}$

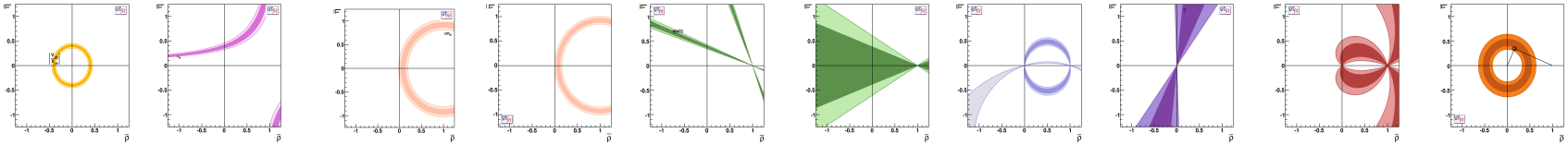


$B \to \tau \nu$



$(B \to \rho/\omega\, \gamma)/(B \to K^* \gamma)$

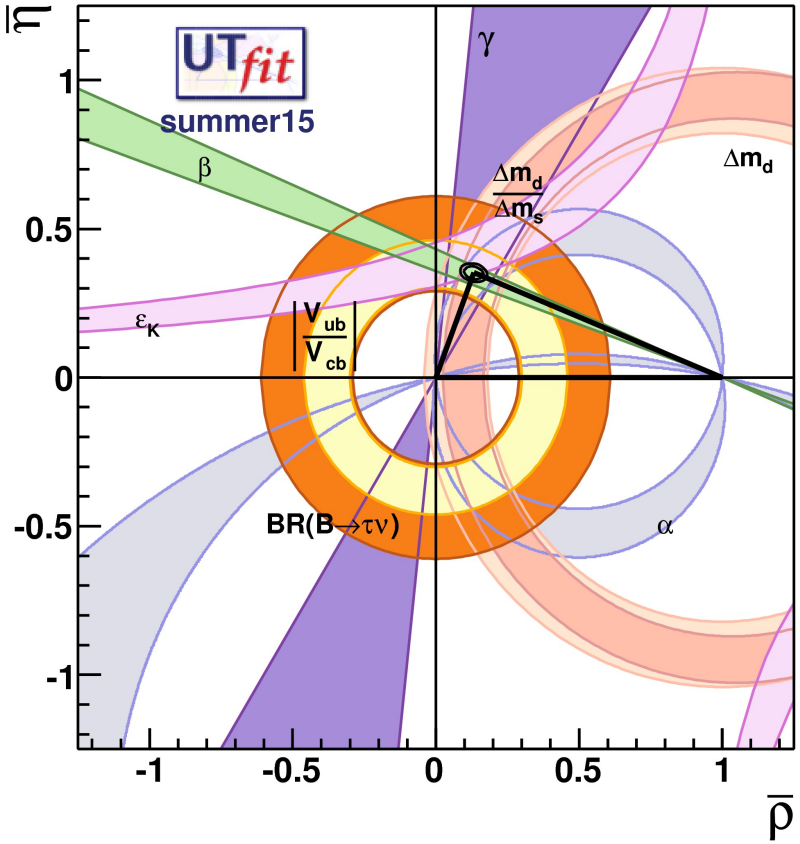




2015 results

$\bar{\rho} = 0.142 \pm 0.019$ $\bar{\eta} = 0.348 \pm 0.013$

In the hadronic sector, the SM CKM pattern represents the principal part of the flavor structure and of CP violation



$\alpha = (90.5 \pm 2.6)^0$

$\sin 2\beta = 0.691 \pm 0.018$

$\beta = (21.82 \pm 0.72)^0$

$\gamma = (67.4 \pm 2.7)^0$

$A = 0.828 \pm 0.012$

$\lambda = 0.22549 \pm 0.00066$

Consistence on an over constrained fit of the CKM parameters

CKM matrix is the dominant source of flavour mixing and CP violation

CKM-TRIANGLE ANALYSIS

State of The Art 2015

	Measurement	Fit	Prediction	Pull
α	$(92.7 \pm 6.2)^o$ 6.7 %	$(90.1 \pm 2.7)^o$ 2.9 %	$(88.3 \pm 3.4)^o$ 3.8 %	0.6
$\sin 2\beta$	0.680 ± 0.024 3.5 %	0.696 ± 0.022 2.6 %	0.747 ± 0.039 5.2 %	1.8
γ	$(71.4 \pm 6.5)^o$ 9.1 %	$(67.4 \pm 2.8)^o$ 4.2 %	$(66.7 \pm 3.0)^o$ 4.5 %	0.7
$\lvert V_{ub}\rvert \times 10^3$	3.81 ± 0.40 10 %	3.66 ± 0.12 3.3 %	3.64 ± 0.12 3.3 %	0.5
$\lvert V_{cb}\rvert \times 10^2$	4.09 ± 0.11 2.6 %	4.206 ± 0.053 1.2 %	4.240 ± 0.062 1.4 %	0.9
$\varepsilon_K \times 10^3$	2.228 ± 0.011 0.5 %	2.227 ± 0.011 0.5 %	2.08 ± 0.18 8.7 %	0.8
Δm_s (ps^{-1})	17.761 ± 0.022 0.1 %	17.755 ± 0.022 0.1 %	17.3 ± 1.0 5.7 %	0.2
$BR(B \to \tau\nu) \times 10^4$	1.06 ± 0.20 18.9 %	0.83 ± 0.07 7.9 %	0.81 ± 0.7 8.2 %	1.3
$\bar{B}R(B_s \to \mu\mu) \times 10^9$	2.9 ± 0.7 24.1 %	3.90 ± 0.15 3.8 %	3.94 ± 0.16 4.0 %	1.5 ew corrections not included
$BR(B_d \to \mu\mu) \times 10^9$	0.39 ± 0.15 38.5 %	0.1098 ± 0.0057 5.2 %	0.1103 ± 0.0058 5.2 %	1.9 ew corrections not included
β_s	$(0.97 \pm 0.95)^o$ 98 %	$(1.056 \pm 0.039)^o$ 4.4 %	$(1.056 \pm 0.039)^o$ 4.1 %	0.1 not included in the fit

$B(B \to \tau\,\nu)_{Old} = (1.67 \pm 0.30)\ 10^{-4}$

LATTICE PARAMETERS

	Lattice	Prediction	Pull
$\hat{B}_K$	0.766 ± 0.010 1.3 %	0.84 ± 0.07 8.3 %	0.9
f_{B_s}	0.226 ± 0.005 2.2 %	0.2256 ± 0.0039 2.7 %	0.0
f_{B_s}/f_{B_d}	1.204 ± 0.016 1.3 %	1.197 ± 0.056 0.4 %	0.0
B_s	0.875 ± 0.040 1.3 %	0.875 ± 0.030 0.4 %	0.0
B_s/B_d	1.03 ± 0.08 7.8 %	1.096 ± 0.062 5.7 %	0.7

CKM Matrix in the SM

The fit results for all the nine CKM elements are

$$V_{CKM} = \begin{pmatrix} (0.9743 \pm 0.00014) & (0.22509 \pm 0.00061) & (0.00366 \pm 0.00012)e^{i(-67.8\pm2.8)^\circ} \\ (-0.22498 \pm 0.00066)e^{i(0.0353\pm0.00095)^\circ} & (0.97343 \pm 0.00015)e^{i(-0.00188333\pm5\times10^{-5})^\circ} & (0.04206 \pm 0.00053) \\ (0.00876 \pm 0.00015)e^{i(-22.03\pm0.83)^\circ} & (-0.04129 \pm 0.00054)e^{i(1.054\pm0.039)^\circ} & (0.999107 \pm 2.235 \times 10^{-5}) \end{pmatrix}$$

Standard Parametrization (PDG)

$\text{Sin}\ \theta_{12} = 0.22504 \pm 0.00065$

$\text{Sin}\ \theta_{23} = 0.04206 \pm 0.00054$

$\text{Sin}\ \theta_{13} = 0.00366 \pm 0.00012 \qquad \delta = 67.8 \pm 2.8$

Wolfenstein Parametrization (PDG)

$\lambda = 0.22514 \pm 0.00066 \qquad A = 0.828 \pm 0.0.12$

inclusives **vs** **exclusives**

V_{ub}	$(4.41 \pm 0.22) \times 10^{-3}$	$(3.69 \pm 0.15) \times 10^{-3}$
V_{cb}	$(4.22 \pm 0.07) \times 10^{-2}$	$(3.92 \pm 0.07) \times 10^{-2}$

V_{ub} $(3.81 \pm 0.40) \times 10^{-3}$

V_{cb} $(4.09 \pm 0.11) \times 10^{-2}$

$\sin 2\beta_{exp}$ = 0.680 ± 0.024

$\sin 2\beta_{UTfit}$ = 0.747 ± 0.039

B_K= 0.84 ±0.07

$\sin 2\beta_{incl}$ = 0.782 ± 0.028

B_K= 0.74 ±0.05

$\sin 2\beta_{excl}$ = 0.725 ± 0.019

B_K= 0.93 ±0.07

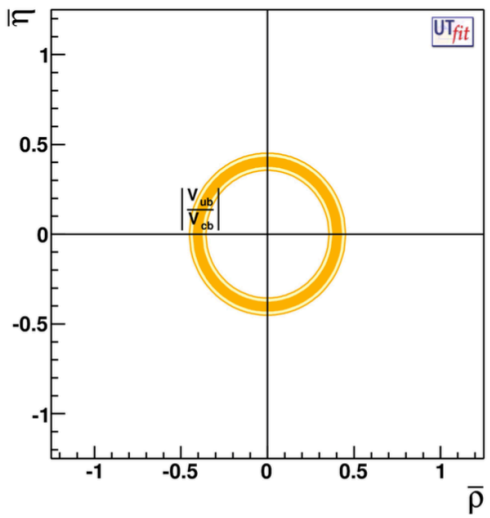
Courtesy of Denis Derkach

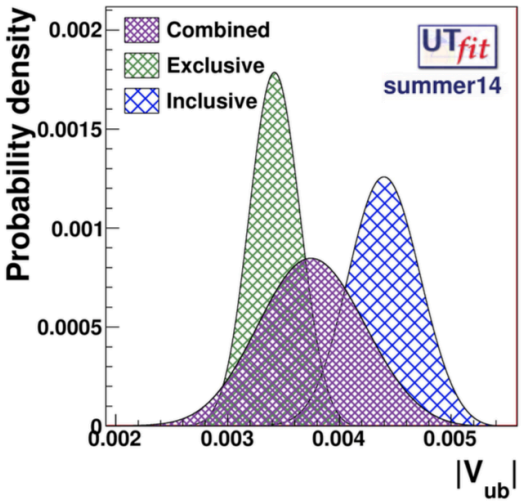
The relative ratio of CKM elements is easily calculable:

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

QCD corrections to be considered

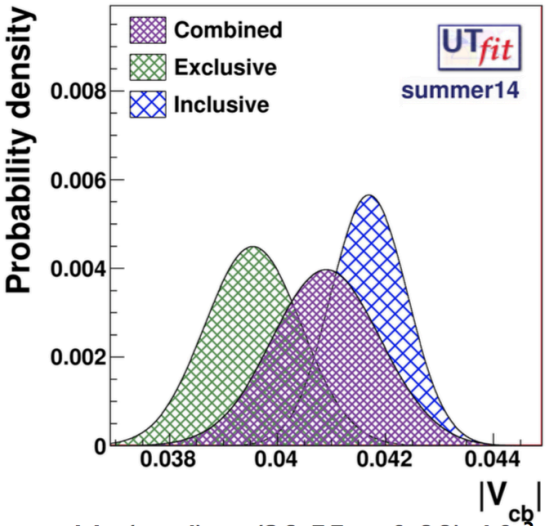
- inclusive measurements: OPE
- exclusive measurements: form-factors from lattice QCD





V_{ub}(excl) = (3.42 ± 0.22) 10^{-3}
V_{ub}(incl) = (4.40 ± 0.31) 10^{-3}
V_{ub} = (3.75 ± 0.46) 10^{-3}

~1.9 σ discrepancy

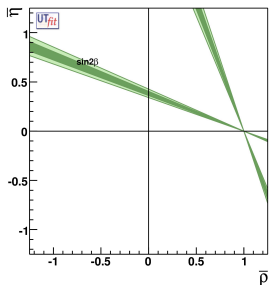


V_{cb}(excl) = (39.55 ± 0.88) 10^{-3}
V_{cb}(incl) = (41.7 ± 0.7) 10^{-3}
V_{cb} = (40.9 ± 1.0) 10^{-3}

~2.5 σ discrepancy

There is still an inconsistency between inclusive and exclusive measurements. We take this into account inflating the combined uncertainty (a-la PDG).

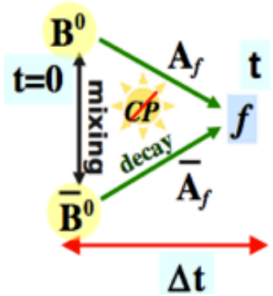
D. Derkach UTFIT@ICHEP2014



Beta results

$B^0 \to J/\Psi K^0$

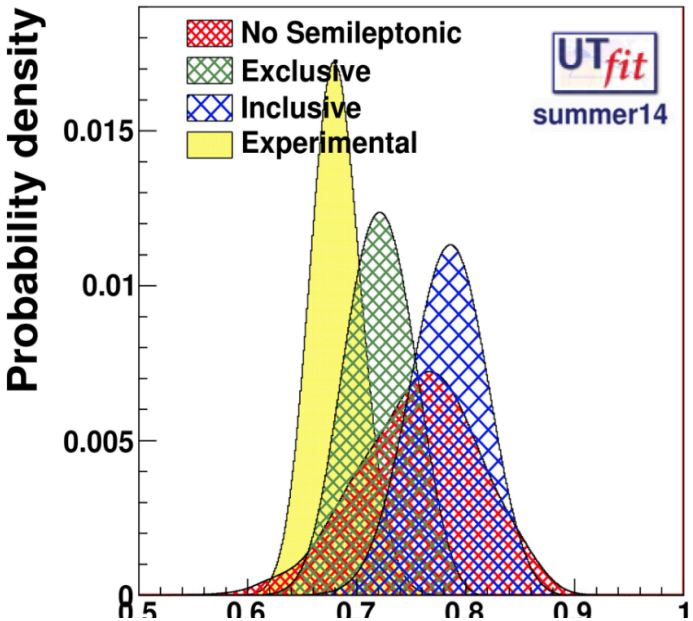
sin2β from time-dependent A_{CP} in $B \to J/\psi K$



$$a_{f_{CP}}(t) = \frac{\mathrm{Prob}(B^0(t) \to f_{CP}) - \mathrm{Prob}(\overline{B^0}(t) \to f_{CP})}{\mathrm{Prob}(\overline{B^0}(t) \to f_{CP}) + \mathrm{Prob}(B^0(t) \to f_{CP})} = C_f \cos \Delta m_d t \ + \ S_f \sin \Delta m_d t$$

The decay is dominated by a single (tree level) amplitude, thus a can be simplified:

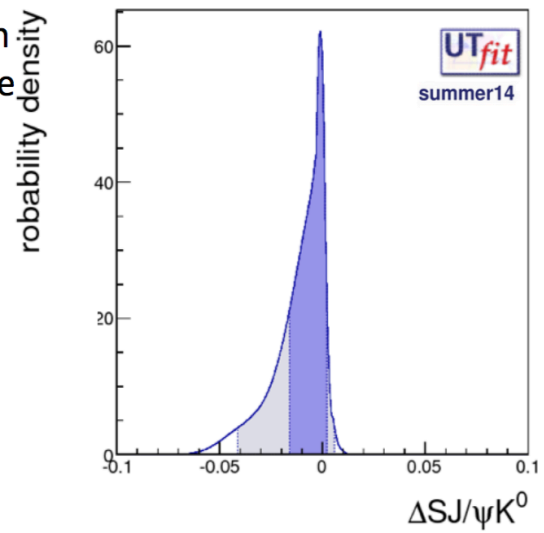
$$a_{f_{CP}}(t) = -\eta_{CP} \sin(\Delta m_d t) \sin 2\beta$$



We also analise $\bar{B}^0 \to J/\psi\pi^0$ to obtain the theoretical uncertainty related to the penguin polution in data-driven way. This gives us an additional correction:

data-driven theoretical uncertainty

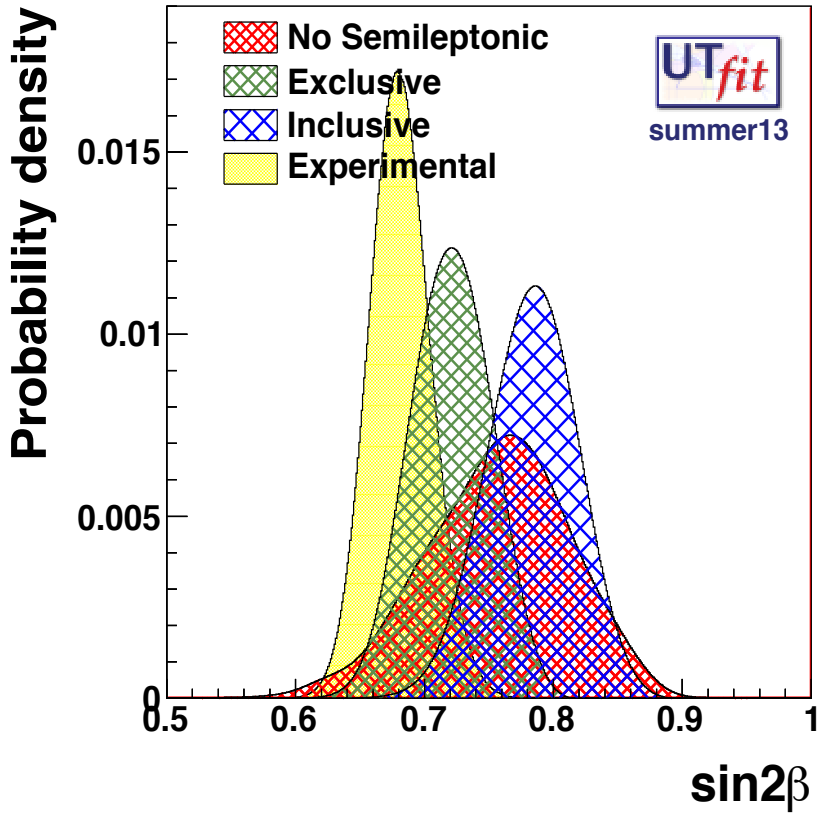
$\Delta S \in [-0.02, 0.00]$ at 68% prob.



$$\sin(2\beta) = (0.680 \pm 0.023)$$

inclusives vs exclusives

$\sin 2\beta_{exp}$ = 0.680 ± 0.024



only exclusive values

$\mathbf{Sin2\beta_{UTfit}}$ = **0.726 ± 0.020**

~1.3σ

only inclusive values

$\mathbf{\sin 2\beta_{UTfit}}$ = **0.781 ± 0.027**

~2.6σ

$\mathbf{\sin 2\beta_{UTfit}}$ **= 0.709 ± 0.029**

~0.9σ

preliminary

Many of the tensions of the past unfortunately disappeared

There still remain important differences between inclusive and exclusive determinations of V_{ub} and V_{cb}

But this seems rather to be a theory problem !!

Is the present picture showing a
Model Standardissimo ?

An evidence, an evidence, my kingdom for an evidence

From Shakespeare's *Richard III*

1) **Fit of NP-ΔF=2 parameters in a Model "independent" way**

2) **"Scale" analysis in ΔF=2**

What for a ``standardissimo" CKM which agrees so well with the experimental observations?

New Physics at the EW scale is "flavor blind"
-> MINIMAL FLAVOR VIOLATION, namely flavour originates only from the Yukawa couplings of the SM

New Physics introduces new sources of flavor, the contribution of which, at most < 20 % , should be found in the present data, e.g. in the asymmetries of Bs decays

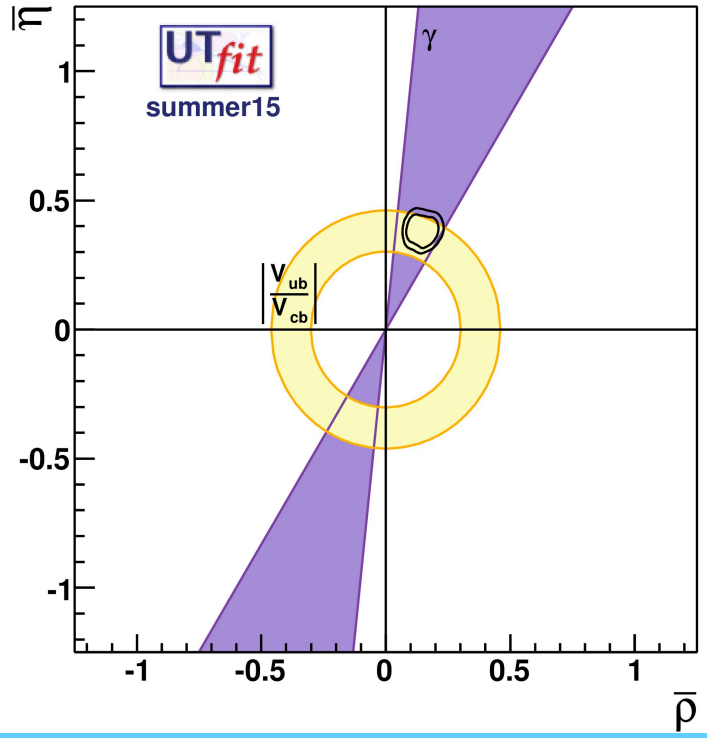
…. beyond the Standard Model

UT Analysis:

- **Model independent analysis**
- **Limits on the deviations**
- **NP scale update**

Only tree level processes Vub/Vcb and B-> DK(*)

CP VIOLATION PROVEN IN THE SM !!



Three generations, no NP in tree level decays, no large NP EWP in B $\pi\pi$

degeneracy of γ broken by A_{SL}

$$\Delta m_s = |A_s| = C_{B_s} \Delta m_s^{SM}$$

$$2\phi_s = -arg A_s = 2\,(\beta_s - \phi_{B_s})$$

$$A_{SL}^s = \frac{\Gamma(\bar{B}_s \to l^+ X) - \Gamma(B_s \to l^- X)}{\Gamma(\bar{B}_s \to l^+ X) + \Gamma(B_s \to l^- X)} = Im\left(\frac{\Gamma_{12}^s}{A_s}\right)$$

Main Ingredients and General Parametrizations

Fit simultaneously CKM and NP parameters (generalized Utfit)

$$H^{\Delta F=2} = \hat{m} - \frac{i}{2}\hat{\Gamma} \quad A = \hat{m}_{12} = \langle \bar{M}|\hat{m}|M\rangle \quad \Gamma_{12} = \langle \bar{M}|\hat{\Gamma}|M\rangle$$

Neutral Kaon Mixing

$$Re A_K = C_{\Delta m_K} Re A_K^{SM} \qquad Im A_K = C_\varepsilon Im A_K^{SM}$$

B_d and B_s mixing

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

$$C_{B_s} e^{2i\phi_{B_s}} = \frac{A_s^{SM} e^{-2i\beta_s} + A_s^{NP} e^{2i(\phi_s^{NP} - \beta_s)}}{A_s^{SM} e^{-2i\beta_s}} = \frac{\langle \bar{B}_s | H_{eff}^{full} | B_s \rangle}{\langle \bar{B}_s | H_{eff}^{SM} | B_s \rangle}$$

$$\begin{aligned}\frac{\Gamma_{12}^q}{A_q} = -2\frac{\kappa}{C_{B_q}} \Bigg\{ & e^{i2\phi_{B_q}} \left(n_1 + \frac{n_6 B_2 + n_{11}}{B_1}\right) - \frac{e^{i(\phi_q^{SM} + 2\phi_{B_q})}}{R_t^q} \left(n_2 + \frac{n_7 B_2 + n_{12}}{B_1}\right) \\ & + \frac{e^{i2(\phi_q^{SM} + \phi_{B_q})}}{R_t^{q^2}} \left(n_3 + \frac{n_8 B_2 + n_{13}}{B_1}\right) + e^{i(\phi_q^{Pen} + 2\phi_{B_q})} C_q^{Pen} \left(n_4 + n_9 \frac{B_2}{B_1}\right) \\ & - e^{i(\phi_q^{SM} + \phi_q^{Pen} + 2\phi_{B_q})} \frac{C_q^{Pen}}{R_t^q} \left(n_5 + n_{10} \frac{B_2}{B_1}\right) \Bigg\}\end{aligned}$$

C_q^{Pen} and ϕ_q^{Pen} parametrize possible NP contributions to Γ^q_{12} from b -> s penguins

Physical observables

$$\Delta m_s = |A_s| = C_{B_s} \Delta m_s^{SM}$$

$$2\phi_s = -arg A_s = 2\,(\beta_s - \phi_{B_s})$$

$$A_{SL}^s = \frac{\Gamma(\bar{B}_s \to l^+ X) - \Gamma(B_s \to l^- X)}{\Gamma(\bar{B}_s \to l^+ X) + \Gamma(B_s \to l^- X)} = Im\left(\frac{\Gamma_{12}^s}{A_s}\right)$$

$$A_{SL}^{\mu\mu} = \frac{f_d \chi_{d0} A_{SL}^d + f_s \chi_{s0} A_{SL}^s}{f_d \chi_{d0} + f_s \chi_{s0}}$$

$$\frac{\Delta\Gamma_s}{\Delta m_s} = Re\left(\frac{\Gamma_{12}^s}{A_s}\right) \qquad \tau_{B_s}^{FS} = \frac{1}{\Gamma_S} \frac{1 + (\Delta\Gamma_s/2\Gamma_s)^2}{1 - (\Delta\Gamma_s/2\Gamma_s)^2}$$

NP model independent Fit $\Delta F=2$

Parametrizing NP physics in ΔF=2 processes

$$C_{B_q} e^{2i\phi_{B_q}} = \frac{A^{NP}_{\Delta B=2} + A^{SM}_{\Delta B=2}}{A^{SM}_{\Delta B=2}}$$

$$\Delta m_d^{EXP} = C_{B_d} \Delta m_d^{SM} \qquad f(\rho,\eta,C_{B_d},QCD..)$$

$$A_{CP}(J/\Psi, K^0) = \sin(2\beta + 2\phi_{B_d}) \qquad f(\rho,\eta,\phi_{B_d})$$

$$\alpha^{EXP} = \alpha^{SM} - \phi_{B_d} \qquad f(\rho,\eta,\phi_{B_d})$$

$$|\varepsilon_K|^{EXP} = C_\varepsilon |\varepsilon_K|^{SM} \qquad f(\rho,\eta,C_\varepsilon,QCD..)$$

$$\Delta m_s^{EXP} = C_{B_s} \Delta m_s^{SM} \qquad f(\rho,\eta,C_{Bs},QCD..)$$

$$A_{CP}(J/\Psi, \phi) = \sin(2\beta_s - 2\phi_{B_s}) \qquad f(\rho,\eta,\phi_{B_s})$$

...

		ρ , η	C_d	φ_d	C_s	φ_s	$C_{\varepsilon K}$
Tree processes	γ (DK)	X					
	V_{ub}/V_{cb}	X					
1↔3 family	Δm_d	X	X				
	ACP (J/Ψ K)	X		X			
	ACP (Dπ(ρ),DKπ)	X		X			
	A_{SL}		X	X			
	α (ρρ,ρπ,ππ)	X		X			
	A_{CH}		X	X	X	X	
2↔3 family	τ(Bs), $\Delta\Gamma_s/\Gamma_s$				X	X	
	Δm_s				X		
	ASL(Bs)				X	X	
	ACP (J/Ψ ϕ)	~X				X	
1↔2 familiy	ε_K	X					X

5 new free parameters

C_s, φ_s	B_s mixing
C_d, φ_d	B_d mixing
$C_{\varepsilon K}$	K mixing

Today :
fit is overcontrained
Possible to fit 7 free parameters
(ρ, η, C_d,φ_d ,C_s,φ_s, $C_{\varepsilon K}$)

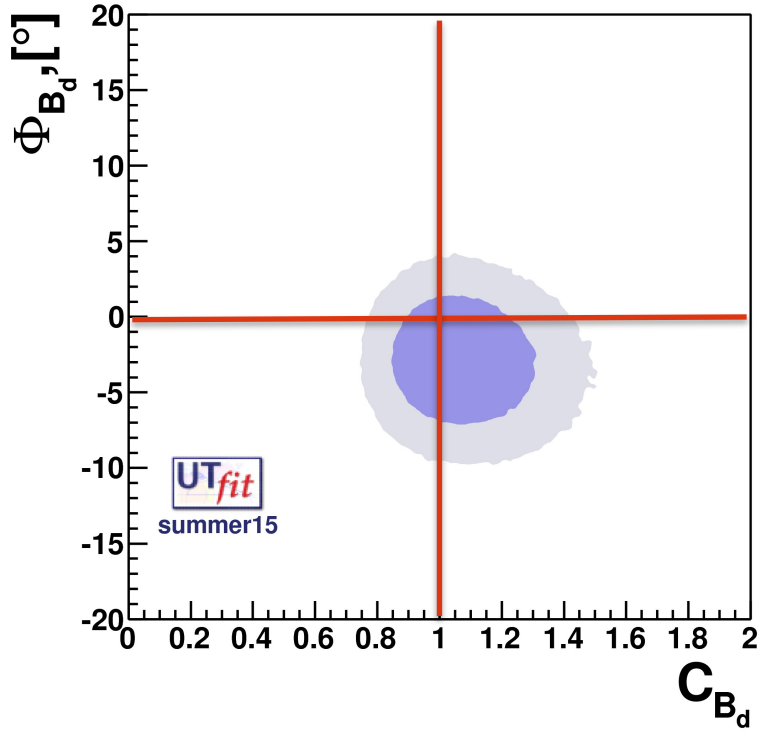
SM analysis	→	**NP-ΔF=2 analysis**
$\rho = 0.142 \pm 0.019$	→	$\rho = 0.147 \pm 0.043$
$\eta = 0.348 \pm 0.013$		$\eta = 0.384 \pm 0.044$

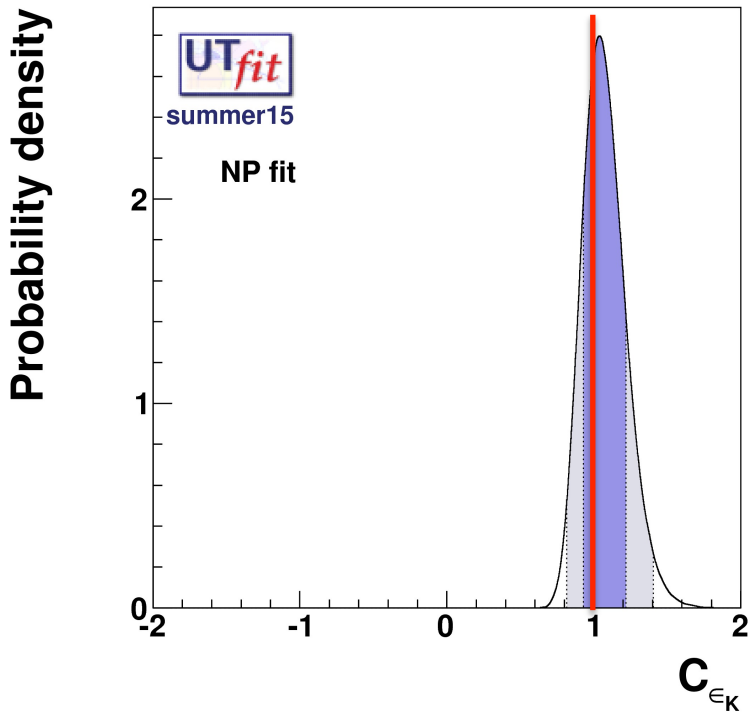
ρ,η fit quite precisely in NP-ΔF=2 analysis and consistent with the one obtained on the SM analysis [error double]

(main contributors tree-level γ and V_{ub})

Please consider these numbers when you want to get CKM parameters in presence of NP in ΔF=2 amplitudes (all sectors 1-2,1-3,2-3)

NP parameters (i)





$$C_{B_d} = 1.09 \pm 0.15$$

$$\phi_{B_d} = (-2.9 \pm 2.8)^0$$

$$C_{\varepsilon_K} = 1.07 \pm 0.14$$

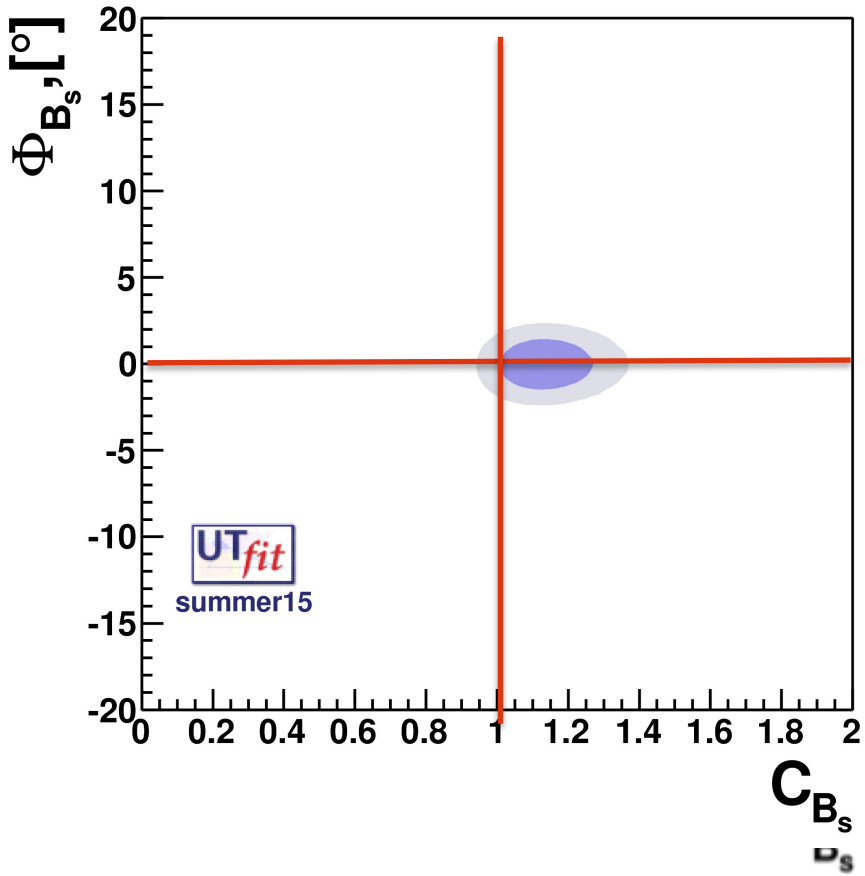
$$\Delta m_d = C_{B_d} (\Delta m_d)^{SM} \qquad a_{CP}^{B_d \to J/\psi K_S} \to \sin 2(\beta + \varphi_{B_d})$$

$$a_{SL}^d = \mathrm{Im}\left(\Gamma_{12}^d / A_d\right) \qquad \Delta\Gamma^d / \Delta m_d = \mathrm{Re}\left(\Gamma_{12}^d / A_d\right)$$

$$\mathrm{Im}\, A_K = C_\varepsilon \,\mathrm{Im}\, A_K^{SM}$$

$$\varepsilon_K = C_\varepsilon \, \varepsilon_K^{SM}$$

NP parameters (ii)



C_{B_s}= *1.14 ± 0.09*

Φ_{Bs}= *(-0.1 ± 1.0)*^{0}

$$\Delta m_s = C_{B_s} (\Delta m_s)^{SM} \qquad a_{CP}^{B_s \to J/\psi\varphi} \to -\beta_s + \varphi_{B_s}$$

$$a_{SL}^s = \mathrm{Im}\left(\Gamma_{12}^s / A_s\right) \qquad \Delta\Gamma^s / \Delta m_s = \mathrm{Re}\left(\Gamma_{12}^s / A_s\right)$$

TESTING THE NEW PHYSICS SCALE

Effective Theory Analysis ΔF=2

$$C_j(\Lambda) = \frac{LF_j}{\Lambda^2} \Rightarrow \Lambda = \sqrt{\frac{LF_j}{C_j(\Lambda)}}$$

Effective Hamiltonian in the mixing amplitudes

$$H_{eff}^{\Delta B=2} = \sum_{i=1}^{5} C_i(\mu) Q_i(\mu) + \sum_{i=1}^{3} \tilde{C}_i(\mu) \tilde{Q}_i(\mu)$$

$$Q_1 = \bar{q}_L^{\alpha} \gamma_\mu b_L^{\alpha} \bar{q}_L^{\beta} \gamma^\mu b_L^{\beta} \quad \text{(SM/MFV)}$$

$$Q_2 = \bar{q}_R^{\alpha} b_L^{\alpha} \bar{q}_R^{\beta} b_L^{\beta} \qquad Q_3 = \bar{q}_R^{\alpha} b_L^{\beta} \bar{q}_R^{\beta} b_L^{\beta}$$

$$Q_4 = \bar{q}_R^{\alpha} b_L^{\alpha} \bar{q}_L^{\beta} b_R^{\beta} \qquad Q_5 = \bar{q}_R^{\alpha} b_L^{\beta} \bar{q}_L^{\beta} b_R^{\beta}$$

$$\tilde{Q}_1 = \bar{q}_R^{\alpha} \gamma_\mu b_R^{\alpha} \bar{q}_R^{\beta} \gamma^\mu b_R^{\beta}$$

$$\tilde{Q}_2 = \bar{q}_L^{\alpha} b_R^{\alpha} \bar{q}_L^{\beta} b_R^{\beta} \qquad \tilde{Q}_3 = \bar{q}_L^{\alpha} b_R^{\beta} \bar{q}_L^{\beta} b_R^{\beta}$$

C(Λ) coefficients are extracted from data

L is loop factor and should be :
L=1 tree/strong int. NP
L=α^2_s or α^2_W for strong/weak perturb. NP

$F_1 = F_{SM} = (V_{tq} V_{tb}^*)^2$
$F_{j=1} = 0$ — **MFV**

$|F_j| = F_{SM}$
arbitrary phases — **NMFV**

$|F_j| = 1$
arbitrary phases — **Flavour generic**

Results from a fit to the Wilson Coefficients

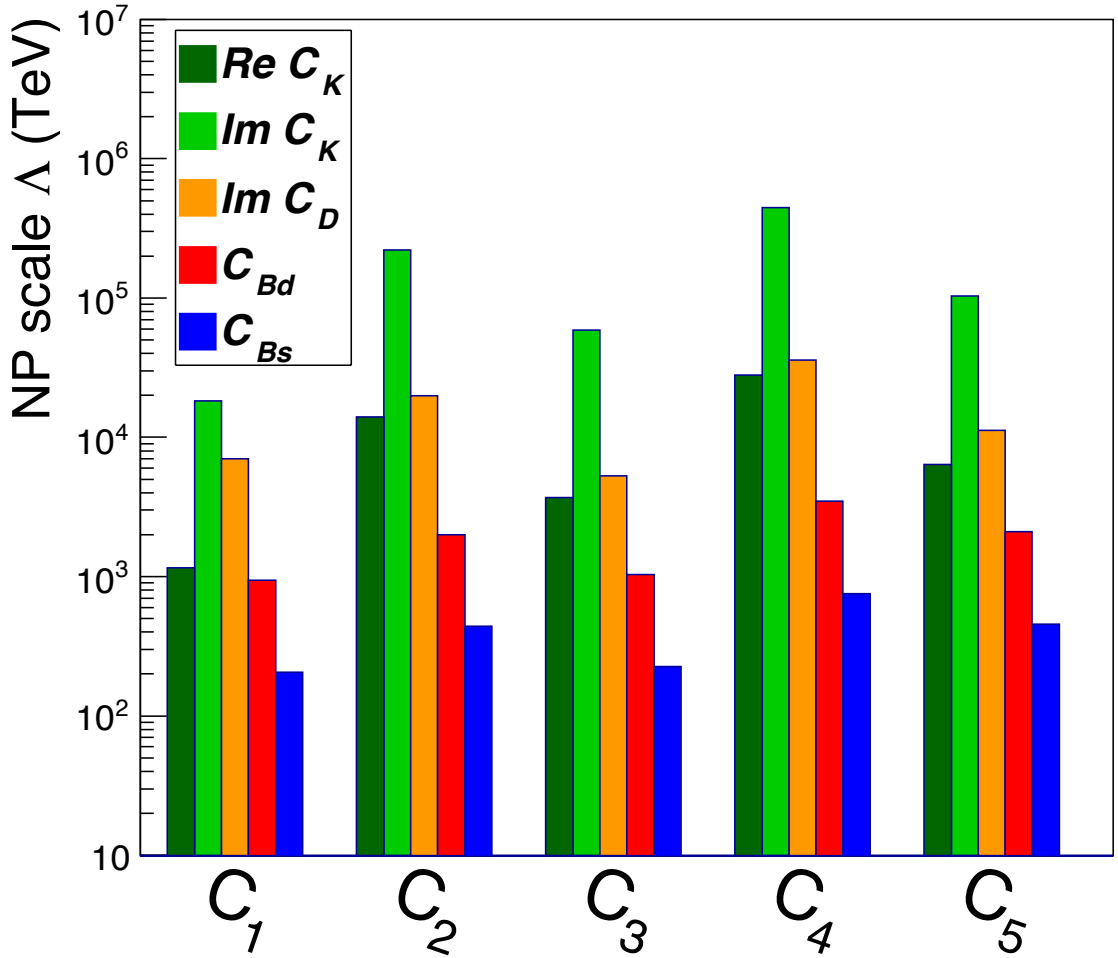
Results obtained with L=1 corresponding to tree level NP effects and an arbitrary flavor structure

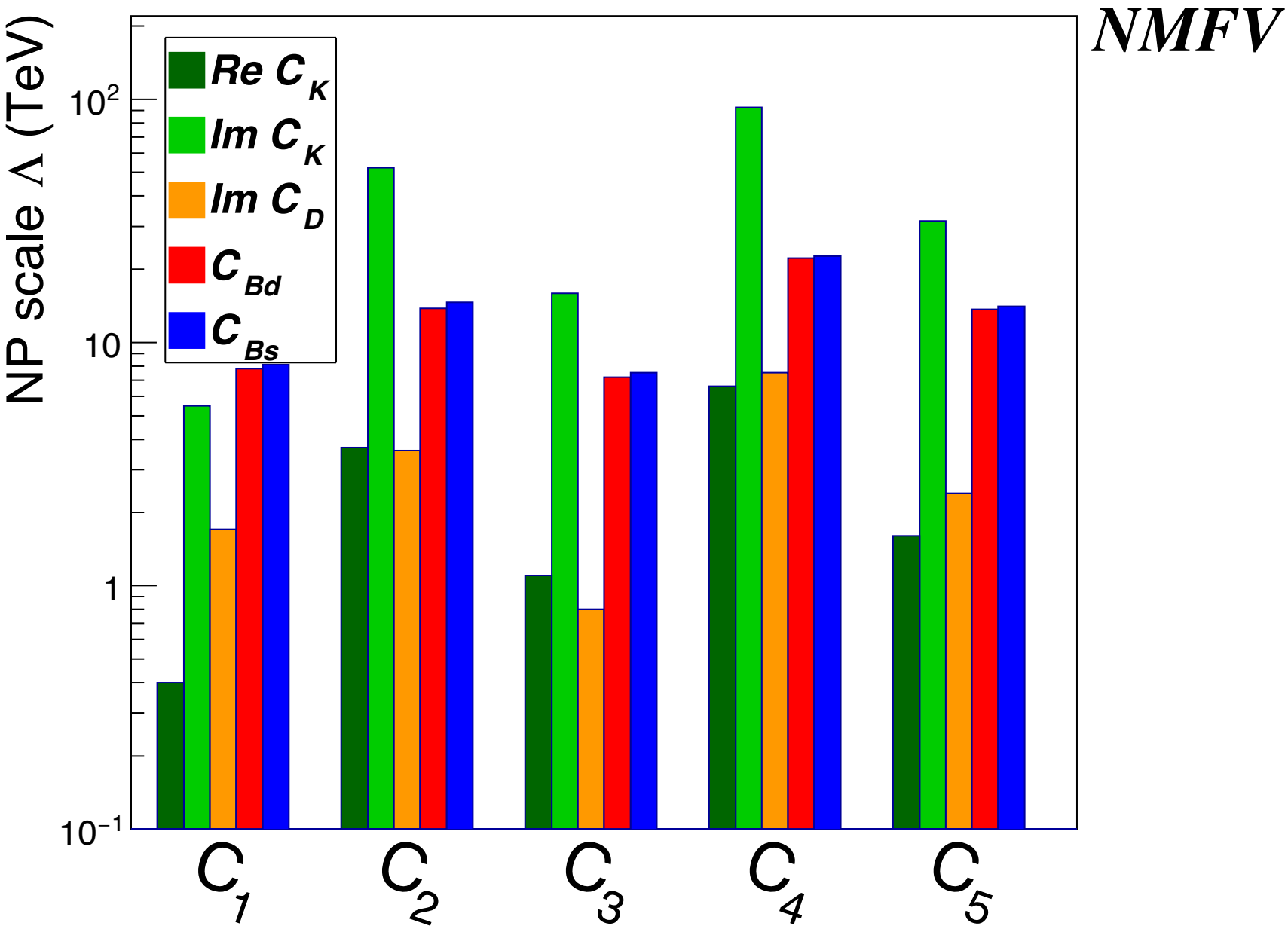
ε_K $\Lambda = 5\ 10^5$ TeV

D $\Lambda = 10^4$ TeV

B_d $\Lambda = 3\ 10^3$ TeV

B_s $\Lambda = 8\ 10^2$ TeV




NMFV
NP scale Λ (TeV)
Re C_K
Im C_K
Im C_D
C_Bd
C_Bs
10^2
10
1
10^-1
C_1
C_2
C_3
C_4
C_5

CONCLUSIONS

1) The high precision of the SM UT Analysis allows to test the SM and to search for NP at a level which is competitive with direct searches
2) CKM matrix is the dominant source of flavour mixing and CP violation $\sigma(\rho)\sim 15\%$ & $\sigma(\eta)\sim 4\%$. SM analysis shows a very good overall consistency
3) The main tensions disappeared
4) Inclusive vs exclusive semileptonic decays still need theoretical improvement and BK !!

Thus for the time being we have to remain with a STANDARDISSIMO STANDARD MODEL but …

THANKS FOR YOUR ATTENTION

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