Testing new physics with the Unitarity Triangle fit

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on behalf of the

UTfit Collaboration

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http://www.utfit.org

HEP2005 International Europhysics Conference on High Energy Physics, Lisboa, Portugal, July 21st 2005

The Method and the Inputs:

Bayes Theorem

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

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

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

$(b \to u)/(b \to c)$	$\bar{\rho}^2+\bar{\eta}^2$	$\bar{\Lambda}, \lambda_1, F(1), ...$
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

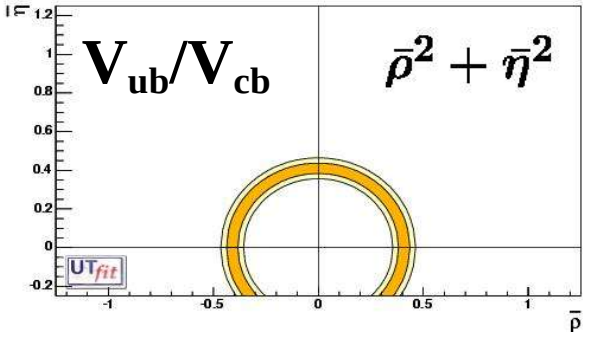
Standard Model + OPE/HQET/ Lattice QCD *to go from quarks to hadrons*

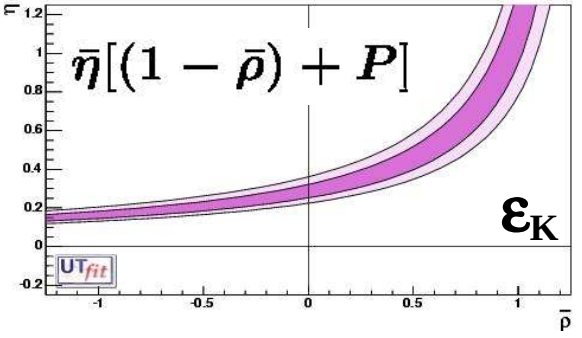
see also: M.B., UTfit talk at the *CP violation* session

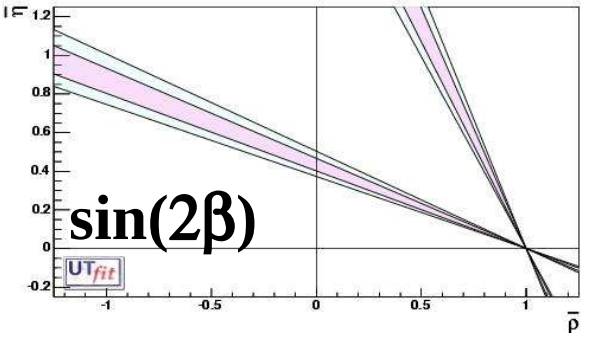
M. Bona *et al.* (UTfit Collaboration) JHEP07(2005) 028 hep-ph/0501199

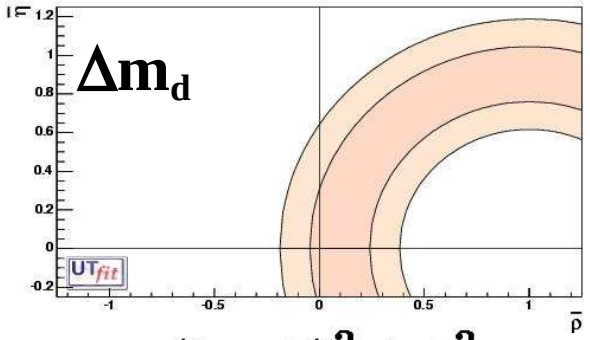
M. Bona *et al.* (UTfit Collaboration) paper in preparation

Standard constraints in the ρ-η plane:

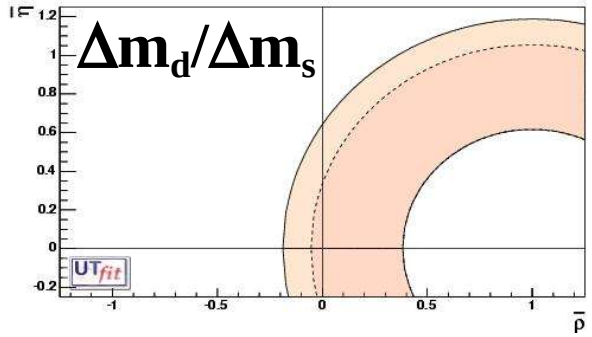


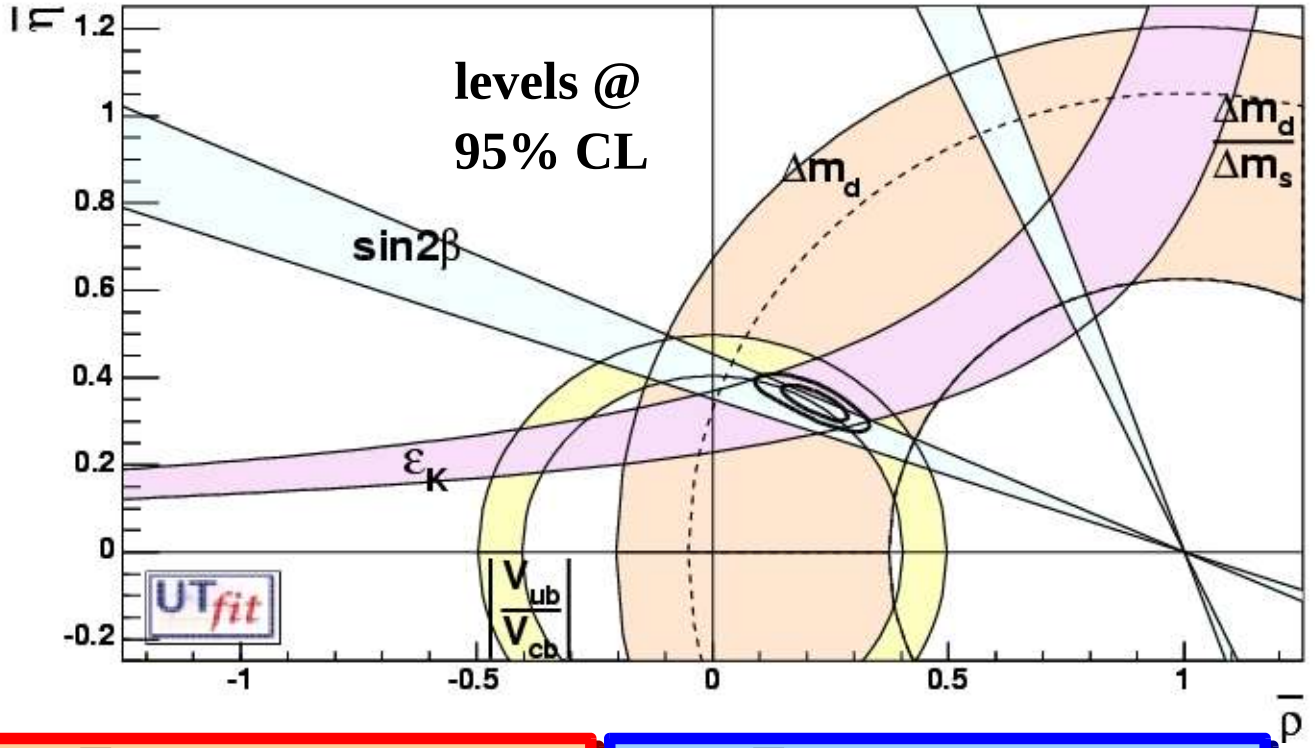






$(1-\bar{\rho})^2 + \bar{\eta}^2$





$\bar{\rho} = 0.214 \pm 0.047$

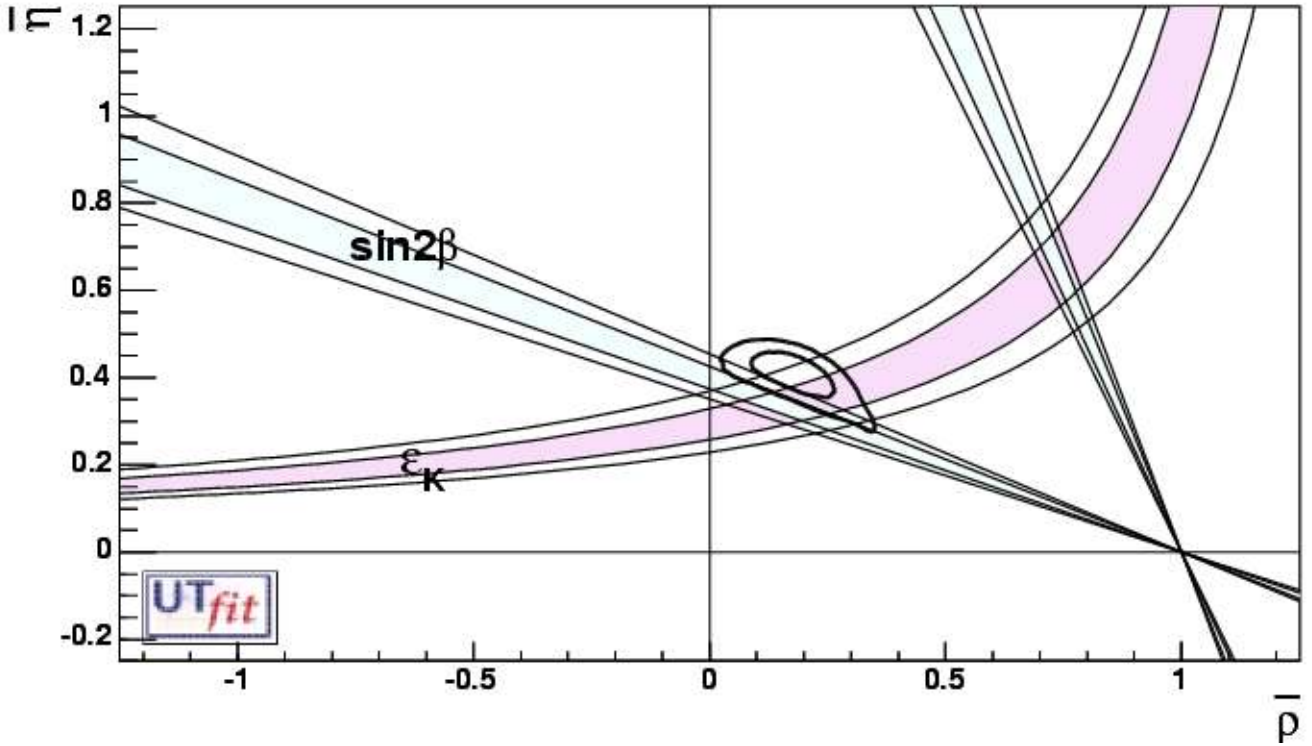
[0.112, 0.307] @ 95% Prob.

$\bar{\eta} = 0.343 \pm 0.028$

[0.289, 0.396] @ 95% Prob.

Crucial test of the Standard Model:

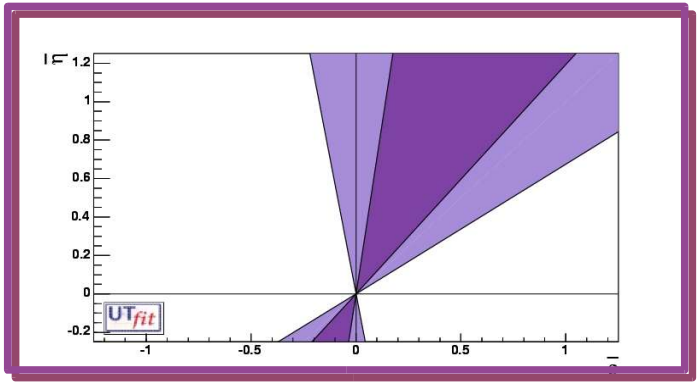
determination of CP-violating parameters measuring CP-conserving observables: only side results included and CP-violation areas overimposed.

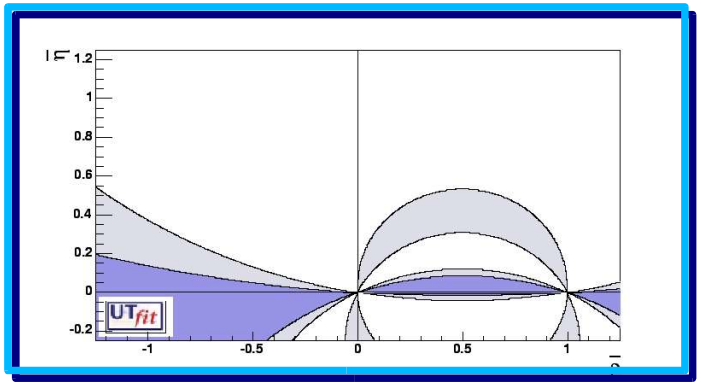


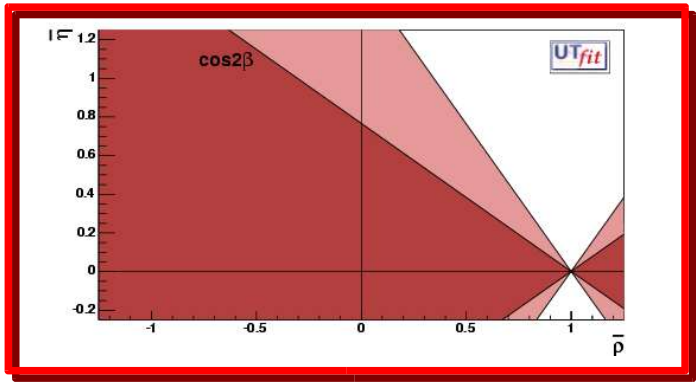
{ **sin 2β = 0.687 ± 0.032** experimental value from charmonium

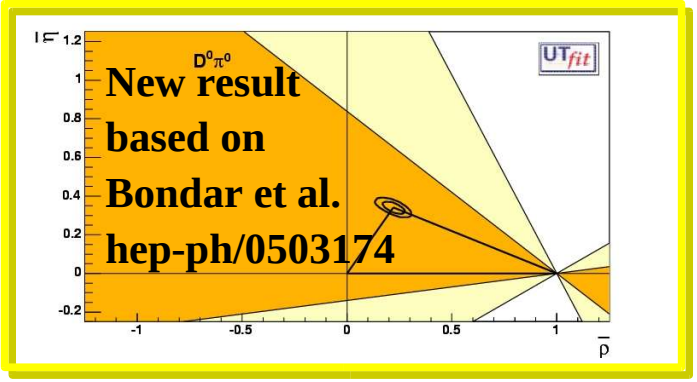
sin 2β = 0.793 ± 0.033 expectation from side-only results

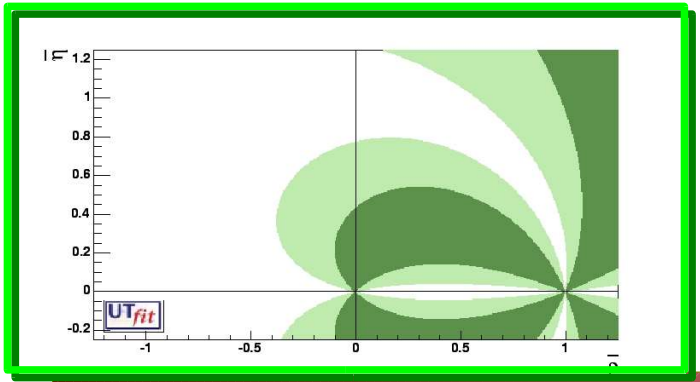
Including all the constraints

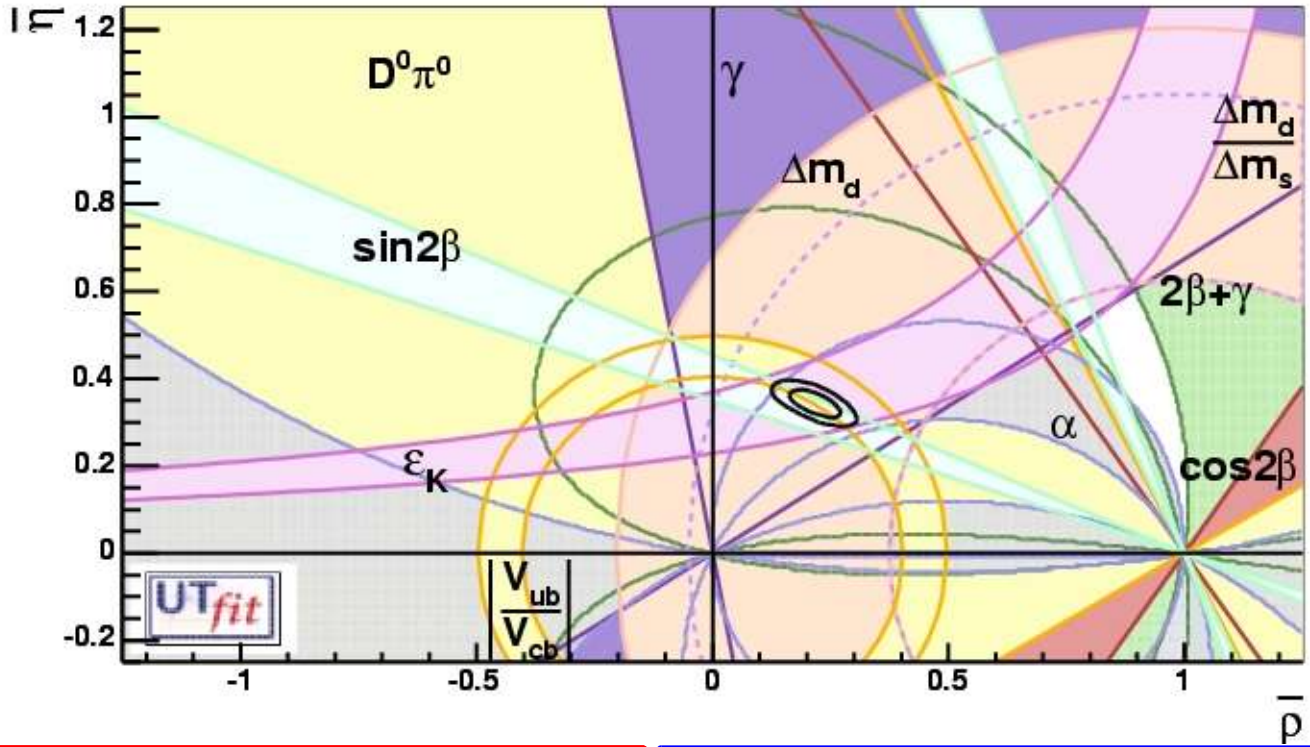












$\bar{\rho} = 0.215 \pm 0.037$

[0.141, 0.286] @ 95% Prob.

$\bar{\eta} = 0.343 \pm 0.022$

[0.300, 0.385] @ 95% Prob.

Fit with NP-independent constraints

using Tree-level processes
assumed to be NP free

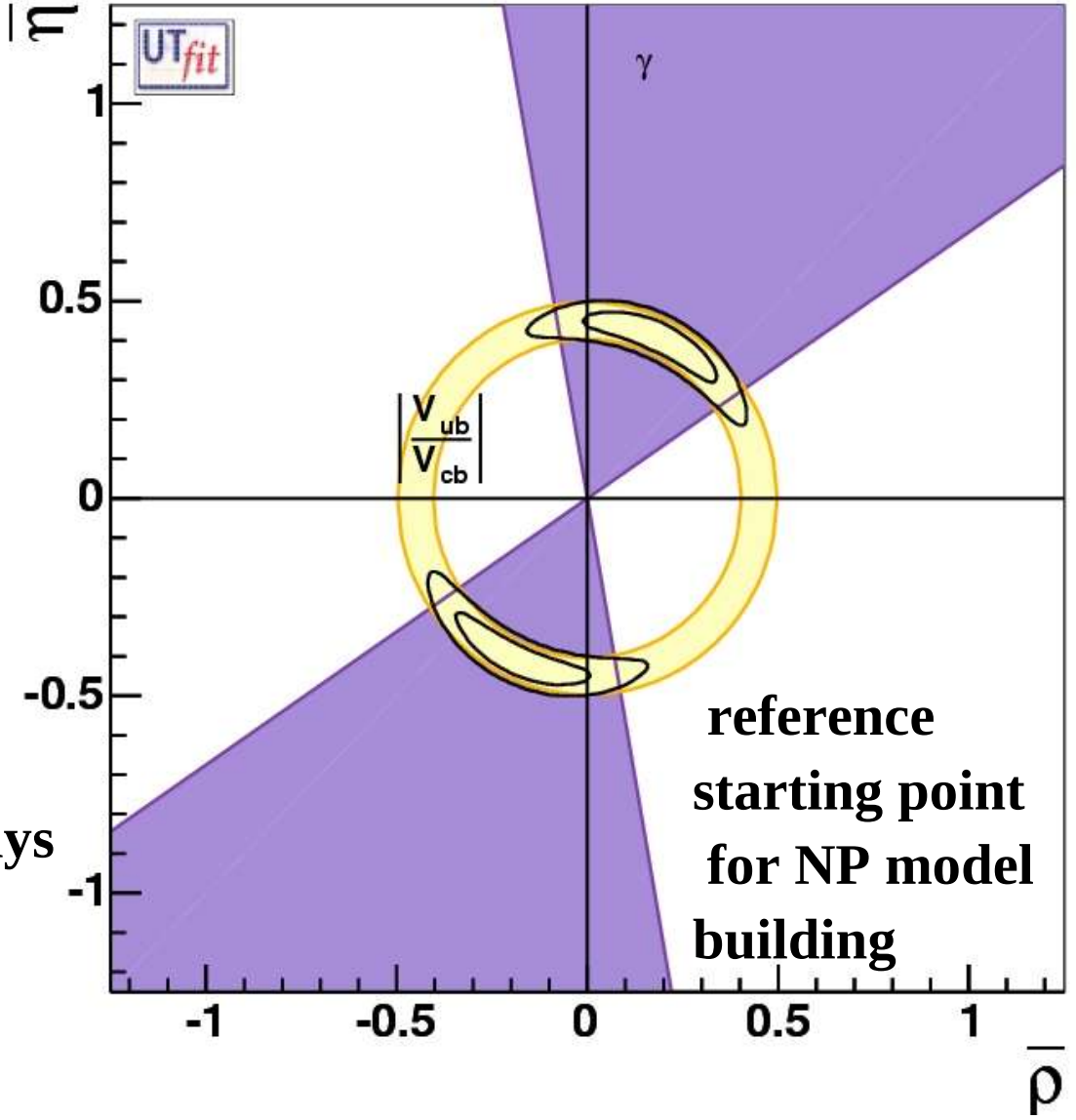
******the effect of the D0-D0 mixing*
is negligible wrt the actual error

$\bar{\rho} = \pm 0.18 \pm 0.11$

$\bar{\eta} = \pm 0.41 \pm 0.05$

very important to improve:

- **V_{ub}/V_{cb} from semileptoic decays**
- **γ from tree level processes**



NP: model independent approach

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

We can generalize the analysis beyond the Standard Model parameterizing the deviations in $|\Delta F|=2$ processes in a model independent way:

- $|\varepsilon_K|^{EXP} = C_\varepsilon \cdot |\varepsilon_K|^{SM}$
- $\Delta m_s^{EXP} = C_s \cdot \Delta m_s^{SM}$
- $\alpha^{EXP} = \alpha^{SM} - \phi_d$
- $\Delta m_d^{EXP} = C_d \cdot \Delta m_d^{SM}$
- $A_{CP}(J/\psi K^0) = \sin(2\beta + \phi_d)$

5 free parameters

	ρ, η	C_d, φ_d	$C_{\varepsilon K}$	C_s, φ_s
V_{ub}/V_{cb}	X			
Δm_d	X	X		
ε_K	X		X	
ACP (J/Ψ K)	X	X		
α (ρρ,ρπ,ππ)	X	X		
γ (DK)	X			
Δm_s				X
ACP (J/Ψ φ)	~X			X
γ (D_sK)	X			X

6 available constraints

not yet available

model indepentent assumptions

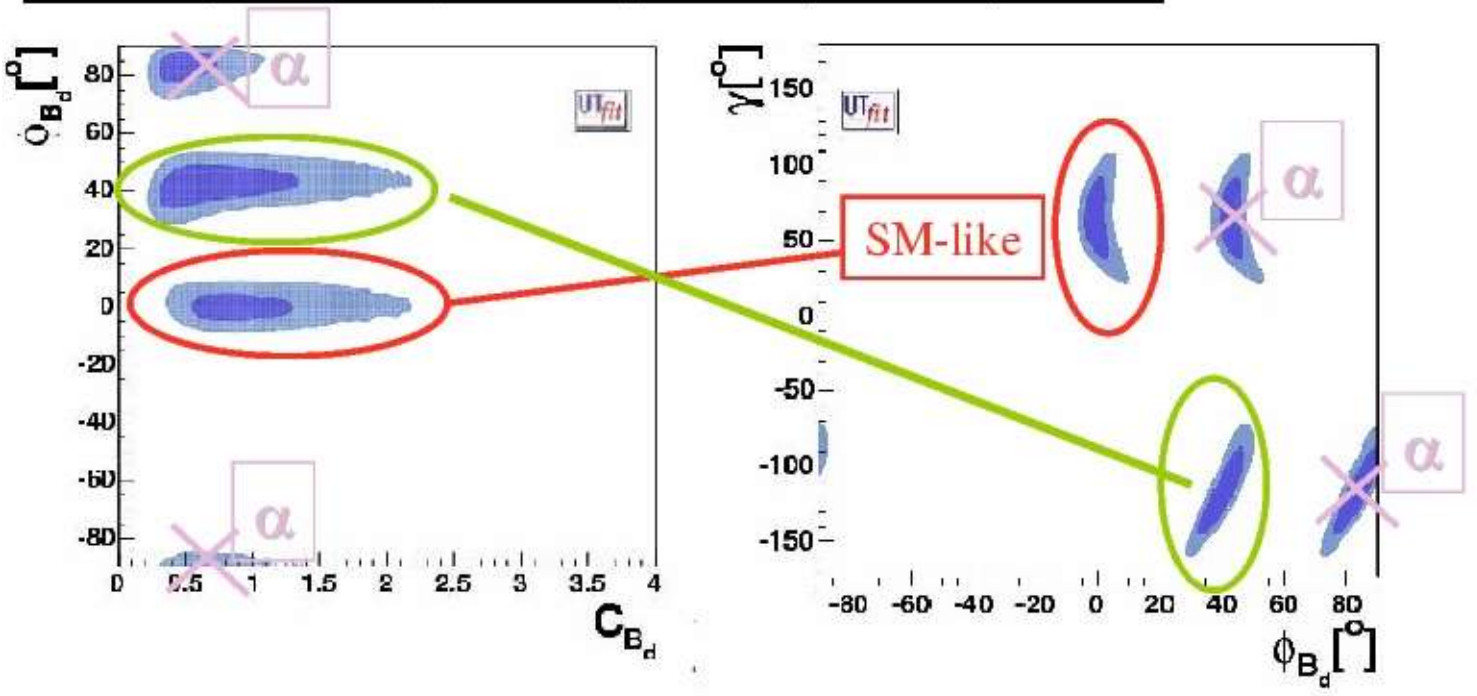
J. M. Soares and L. Wolfenstein, Phys. Rev. D 47 (1993) 1021;
N. G. Deshpande, B. Dutta and S. Oh, Phys. Rev. Lett. 77 (1996) 4499 [arXiv:hep-ph/9608231]
J. P. Silva and L. Wolfenstein, Phys. Rev. D 55 (1997) 5331 [arXiv:hep-ph/9610208]
A. G. Cohen *et al.*, Phys. Rev. Lett. 78 (1997) 2300 [arXiv:hep-ph/9610252]
Y. Grossman, Y. Nir and M. P. Worah, Phys. Rev. Lett. B 407 (1997) 307 [arXiv:hep-ph/9704287]

NP: model independent approach in the fit

Using

$|V_{ub}/V_{cb}|$
Δm_d
ε_K
$A_{CP}(J/\psi K^0)$
$\gamma(DK)$

	γ	C_d	$\cos2(\beta+\phi)$	$\sin2(\alpha-\phi)$	$\sin(2\beta+\phi)$	A_{SL}
SM-LIKE	60°	1	0.68	-0.23	0.96	OK
NP1	60°	1	-0.68	0.96	-0.23	OK
NP2	-120°	0.4	0.68	-0.23	-0.96	10^{-2}
NP3	-120°	0.4	-0.68	0.96	0.23	OK

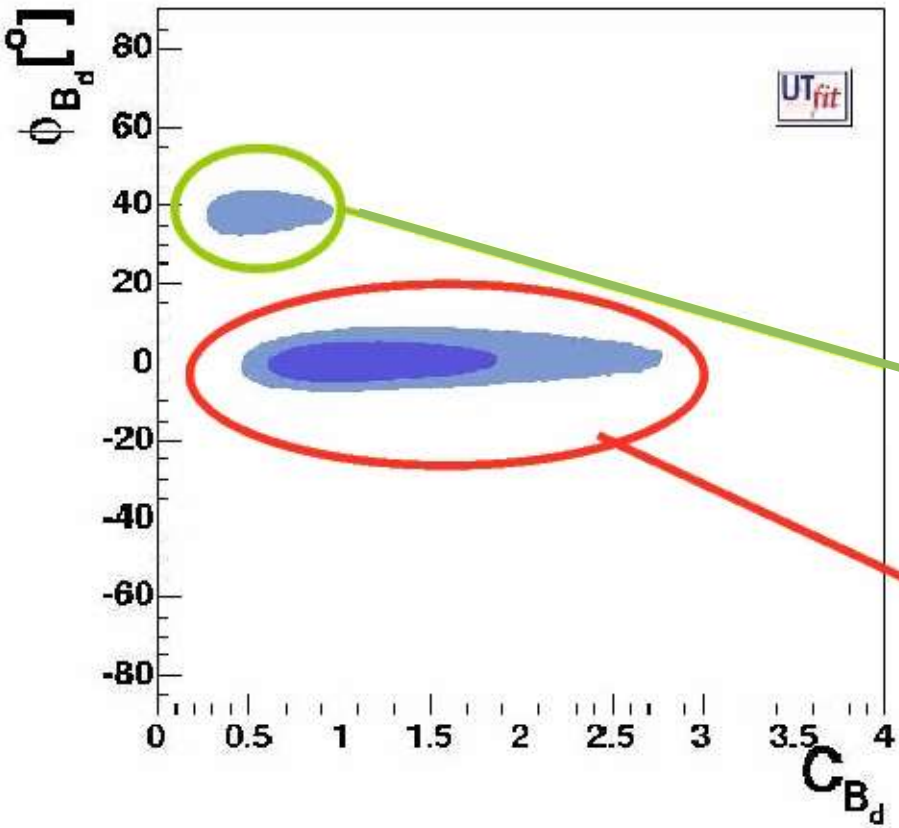


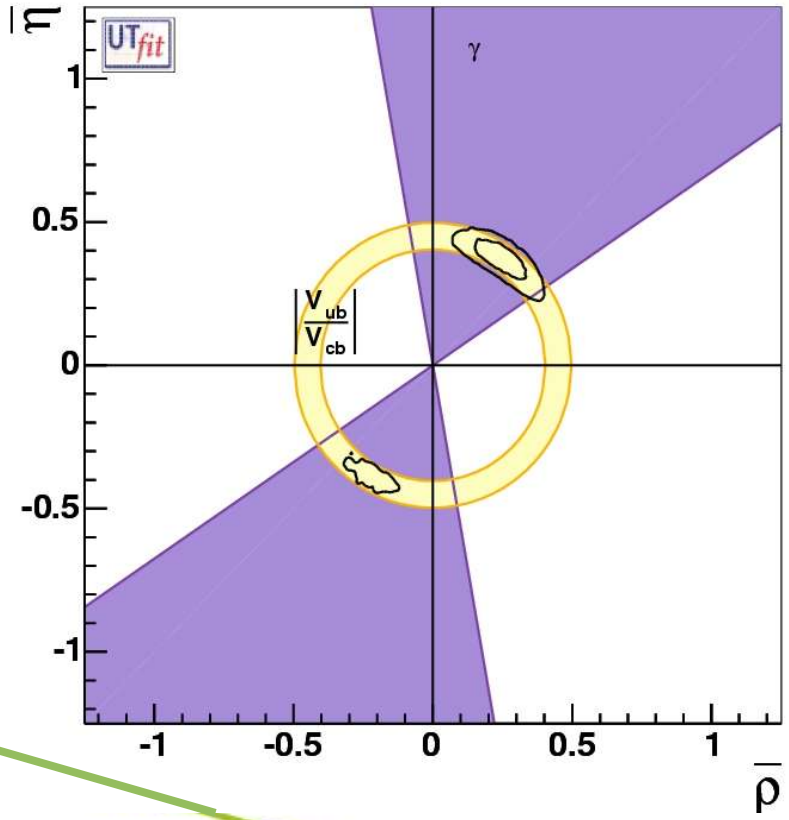
NP: model independent approach in the fit (II)

$|V_{ub}/V_{cb}|$
Δm_d
ε_K
$A_{CP}(J/\psi K^0)$
$\gamma(DK)$

+

α
$\cos 2\beta$
A_{SL}



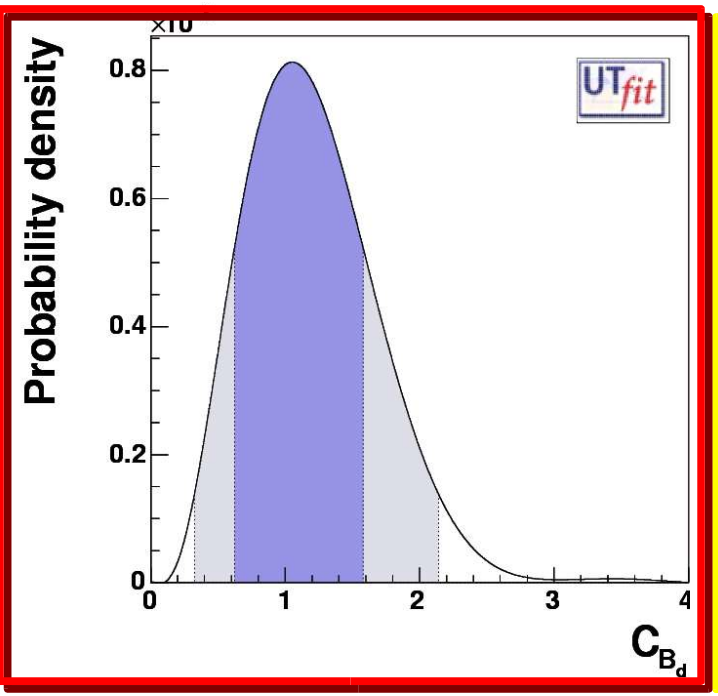


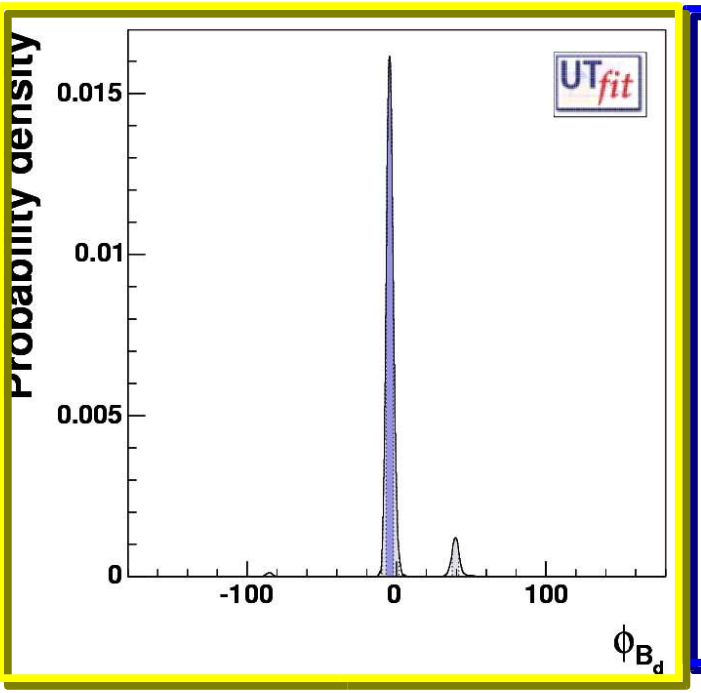
NP solution 7%

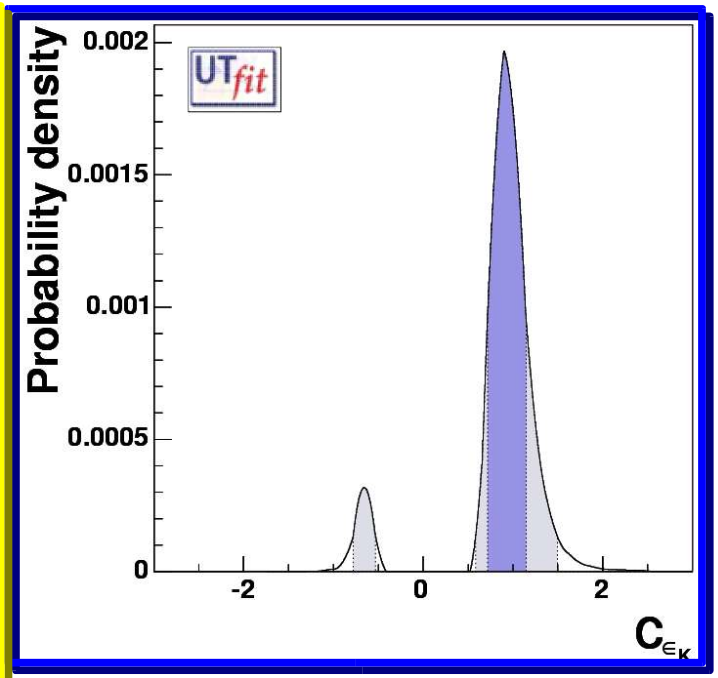
SM-like solution 93%

NP: model independent approach in the fit (III)

$C_{B_d} = 1.10 \pm 0.48$ $\phi_{B_d} = -4.6 \pm 2.6^o$ $C_{\varepsilon K} = 0.93 \pm 0.22$







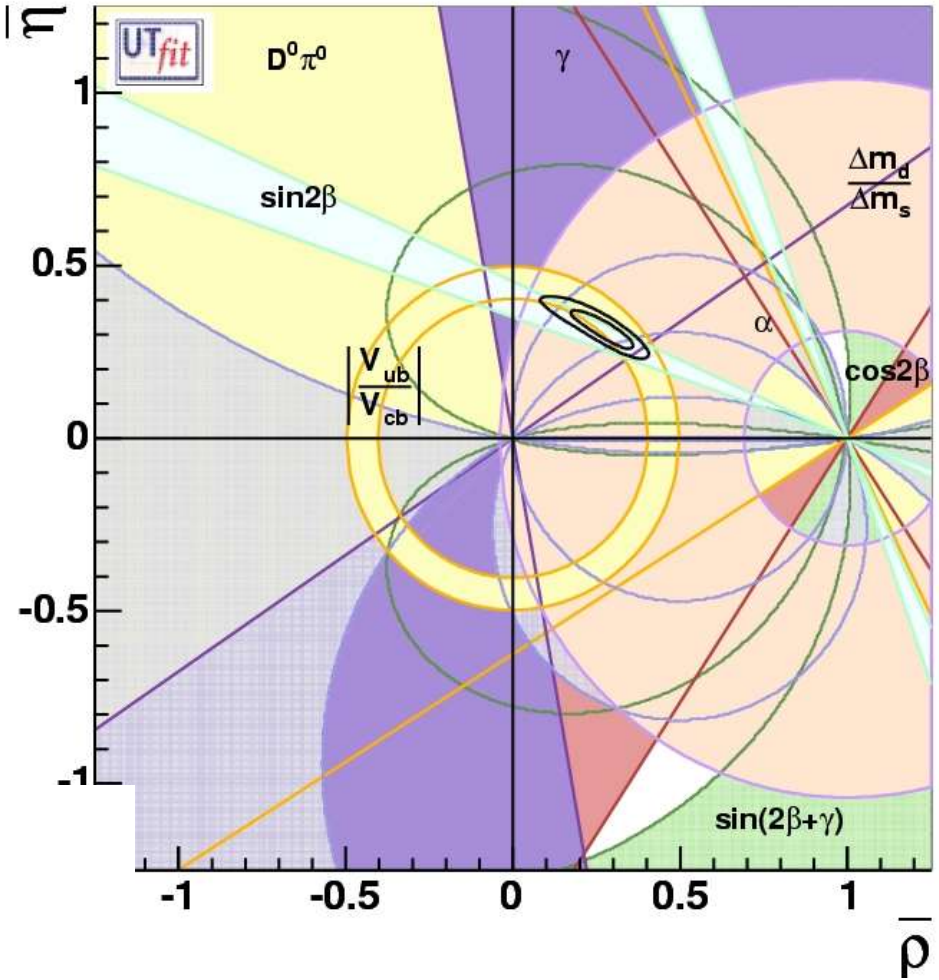
NP in $\Delta B=2$ and $\Delta S=2$ could be up to 50% with respect to the SM only if it has the same phase of the SM

Universal Unitarity Triangle: generalized SM analysis and MFV

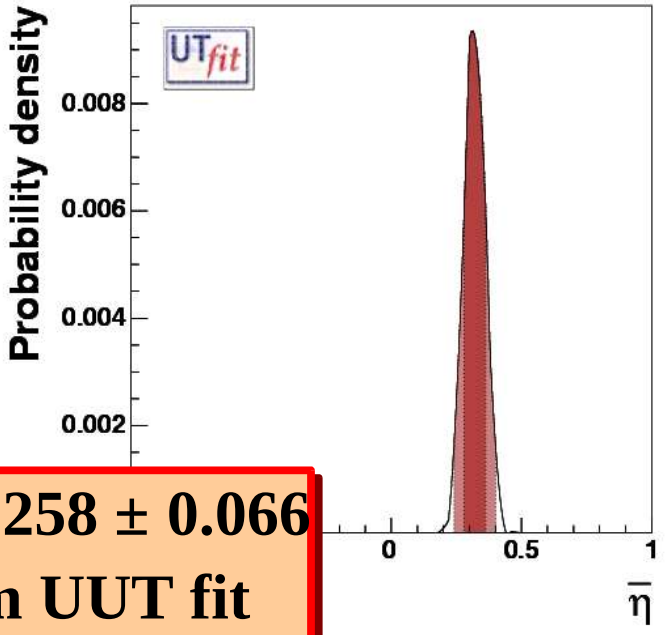
MFV = no additional flavour mixing

only mixing processes are sensitive to NP

For UUT we do not use ε_K and Δm_d in the fit

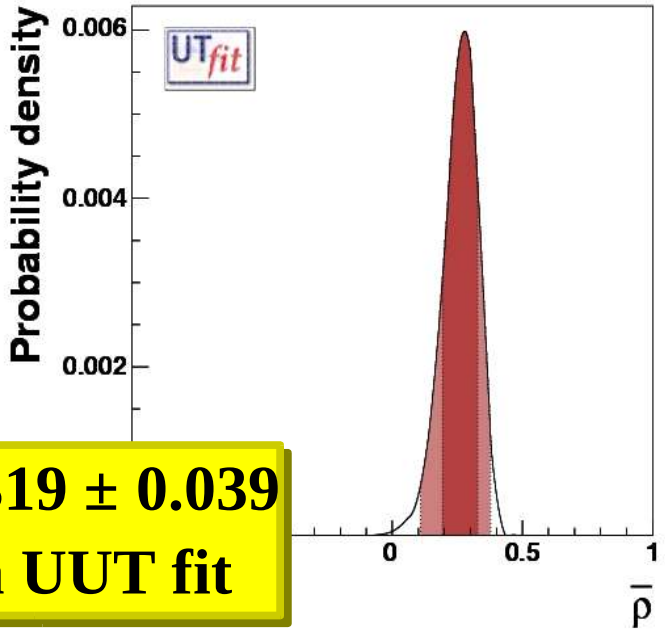


Buras et al. hep-ph/0007085



$\bar{\rho} = 0.258 \pm 0.066$ from UUT fit

See T. Ewerth's talk at the joint *CP-violation/ Rare decays* session



$\bar{\eta} = 0.319 \pm 0.039$ from UUT fit

MFV:

In models with one Higgs doublet or low/moderate tanβ
(D'Ambrosio et al. hep-ph/0207036)
NP enters as additional contribution to the top box diagram

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

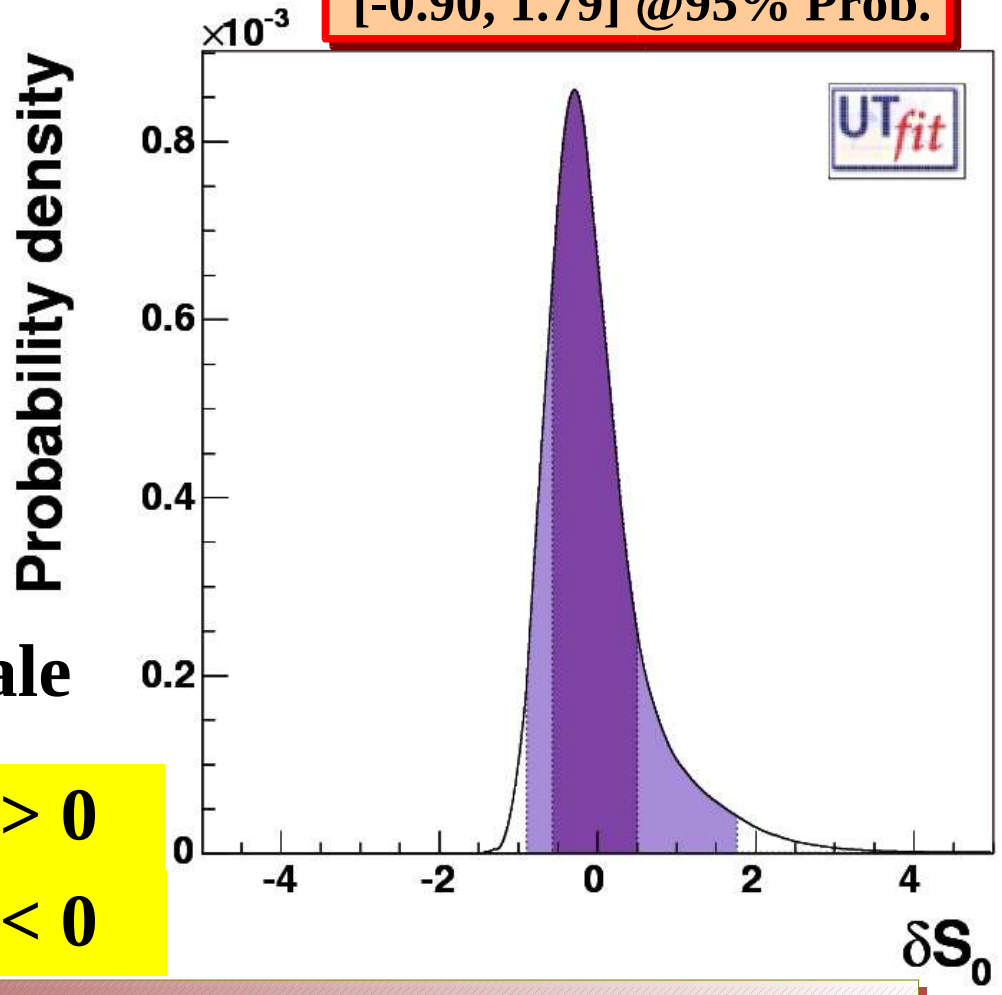
$$\delta S_0(x_t) = 4a \left(\frac{\Lambda_0}{\Lambda}\right)^2$$

a = 1 (as a reference)

Λ_0 = 2.4 TeV

Λ_0 is the equivalent SM scale

δS_0 = -0.03 ± 0.54
[-0.90, 1.79] @95% Prob.



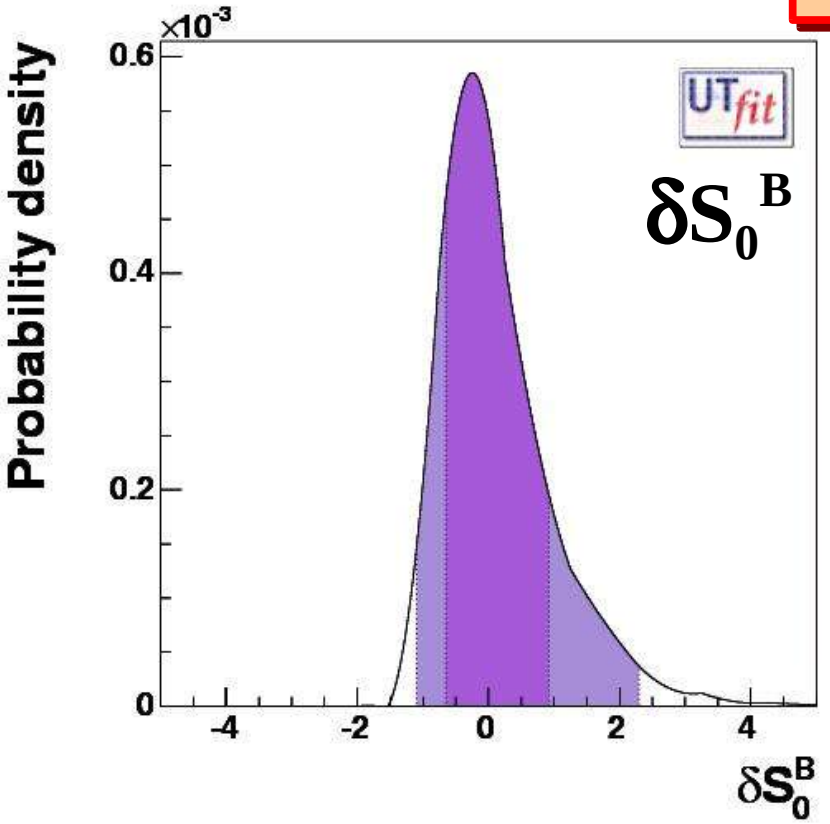
Λ > 3.6 TeV @ 95% for $\delta S_0(x_t)$ > 0

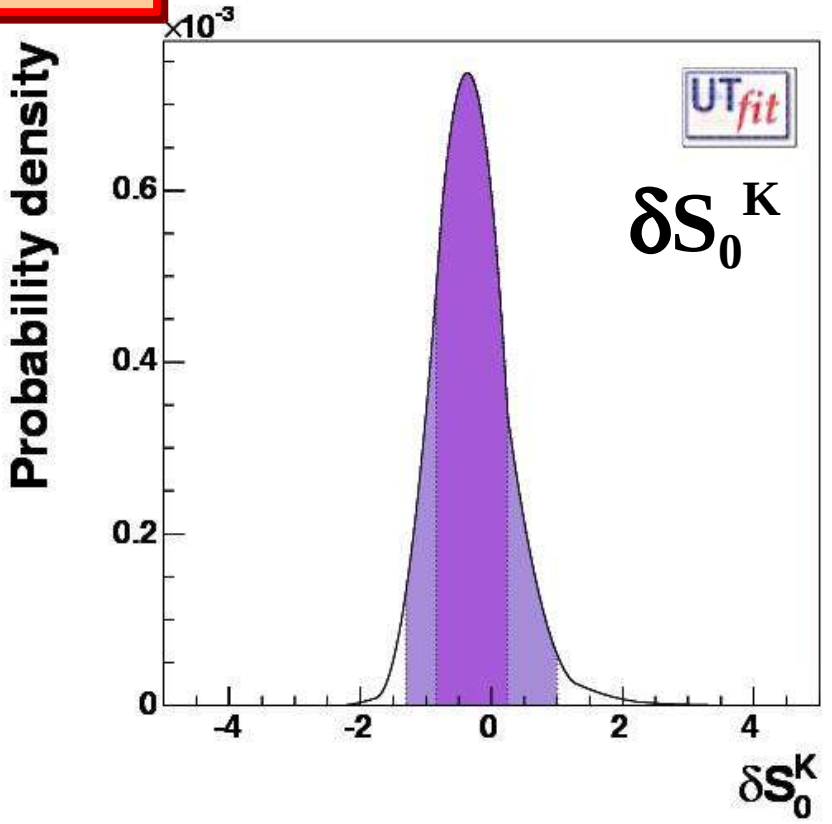
Λ > 5.1 TeV @ 95% for $\delta S_0(x_t)$ < 0

MFV (II): 2 Higgs + large tanβ

→ also bottom Yukawa coupling must be considered

$$\delta S_0^B \neq \delta S_0^K$$





$\Lambda > 2.6$ TeV @ 95% for $\delta S_0(x_t) > 0$

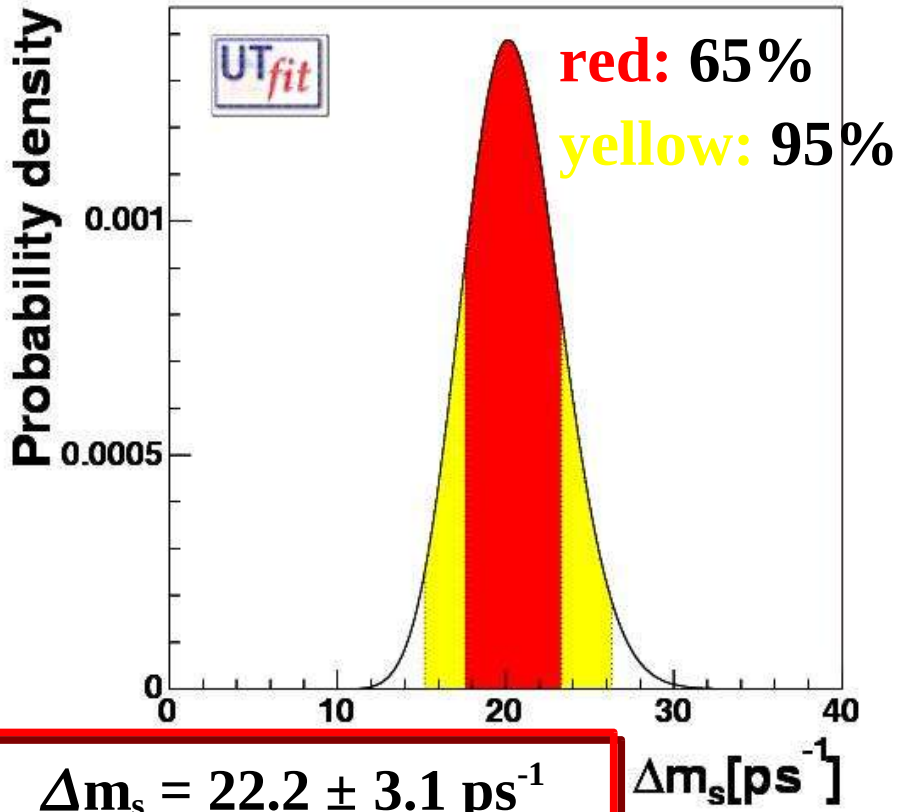
$\Lambda > 4.9$ TeV @ 95% for $\delta S_0(x_t) < 0$

$\Lambda > 3.2$ TeV @ 95% for $\delta S_0(x_t) > 0$

$\Lambda > 4.9$ TeV @ 95% for $\delta S_0(x_t) < 0$

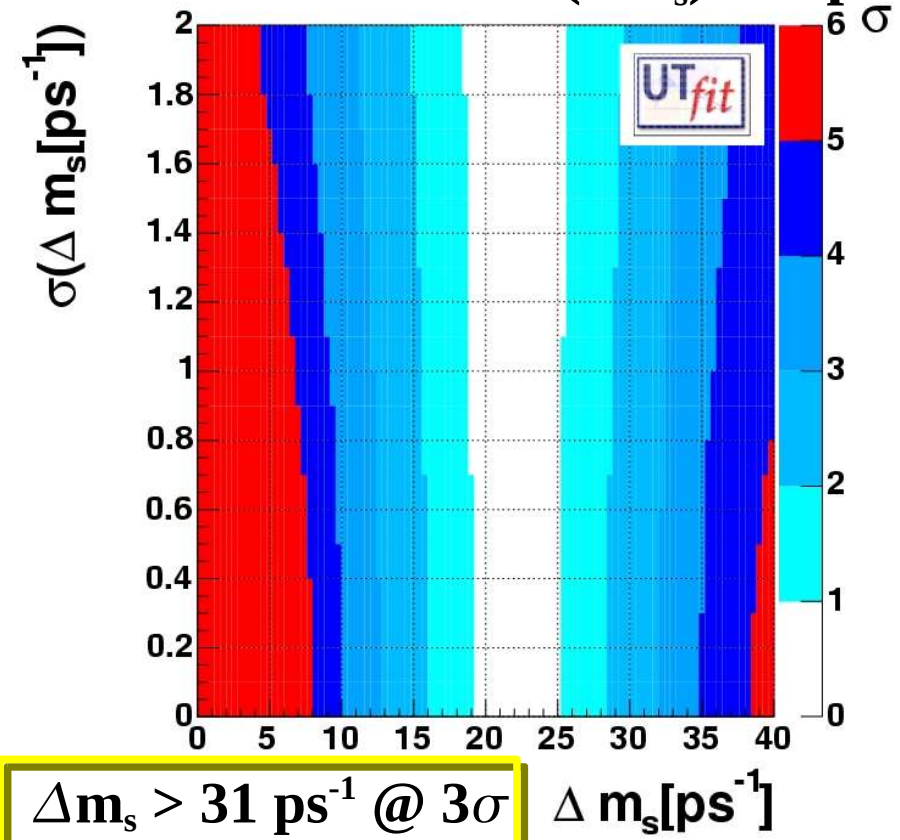
b → s transitions (ΔF=2)

Without the experimental bound



$\Delta m_s = 22.2 \pm 3.1$ ps^{-1}
[16.1, 28.4] @ 95% Prob.

Δm_s will be precisely measured as soon as it is measured with $\sigma(\Delta m_s) < 1$ ps^{-1}



$\Delta m_s > 31$ ps^{-1} @ 3σ
> 38 ps^{-1} @ 5σ

It is crucial to improve the precision on the lattice quantities (f_{B_s}, ξ) to have a better precision on Δm_s to be compared to the future measurements

b → s transitions (ΔF=1)

1.4σ or less from the charmonium sin2β

$\sin(2\beta^{eff})/\sin(2\phi_1^{eff})$

HFAG
HEP 2005
PRELIMINARY

b→ccs	World Average	0.69 ± 0.03
ϕK^0	BaBar	$0.50 \pm 0.25 \,^{+0.07}_{-0.04}$
	Belle	0.44 ± 0.27 ± 0.05
	Average	0.47 ± 0.19
$\eta' K^0$	BaBar	0.36 ± 0.13 ± 0.03
	Belle	0.62 ± 0.12 ± 0.04
	Average	0.50 ± 0.09
$f_0 K_S$	BaBar	$0.95 \,^{+0.23}_{-0.32} \pm 0.10$
	Belle	0.47 ± 0.36 ± 0.08
	Average	0.75 ± 0.24
$\pi^0 K_S$	BaBar	$0.35 \,^{+0.30}_{-0.33} \pm 0.04$
	Belle	0.22 ± 0.47 ± 0.08
	Average	0.31 ± 0.26
$\pi^0 \pi^0 K_S$	BaBar	-0.84 ± 0.71 ± 0.08
	Average	-0.84 ± 0.71
ωK_S	BaBar	$0.50 \,^{+0.34}_{-0.38} \pm 0.02$
	Belle	$0.95 \pm 0.53 \,^{+0.12}_{-0.15}$
	Average	0.63 ± 0.30
$K^+ K^- K^0$	BaBar	0.41 ± 0.18 ± 0.07 ± 0.11
	Belle	$0.60 \pm 0.18 \pm 0.04 \,^{+0.19}_{-0.12}$
	Average	$0.51 \pm 0.14 \,^{+0.11}_{-0.08}$
$K_S K_S K_S$	BaBar	$0.63 \,^{+0.28}_{-0.32} \pm 0.04$
	Belle	0.58 ± 0.36 ± 0.08
	Average	0.61 ± 0.23

-3 -2 -1 0 1 2 3

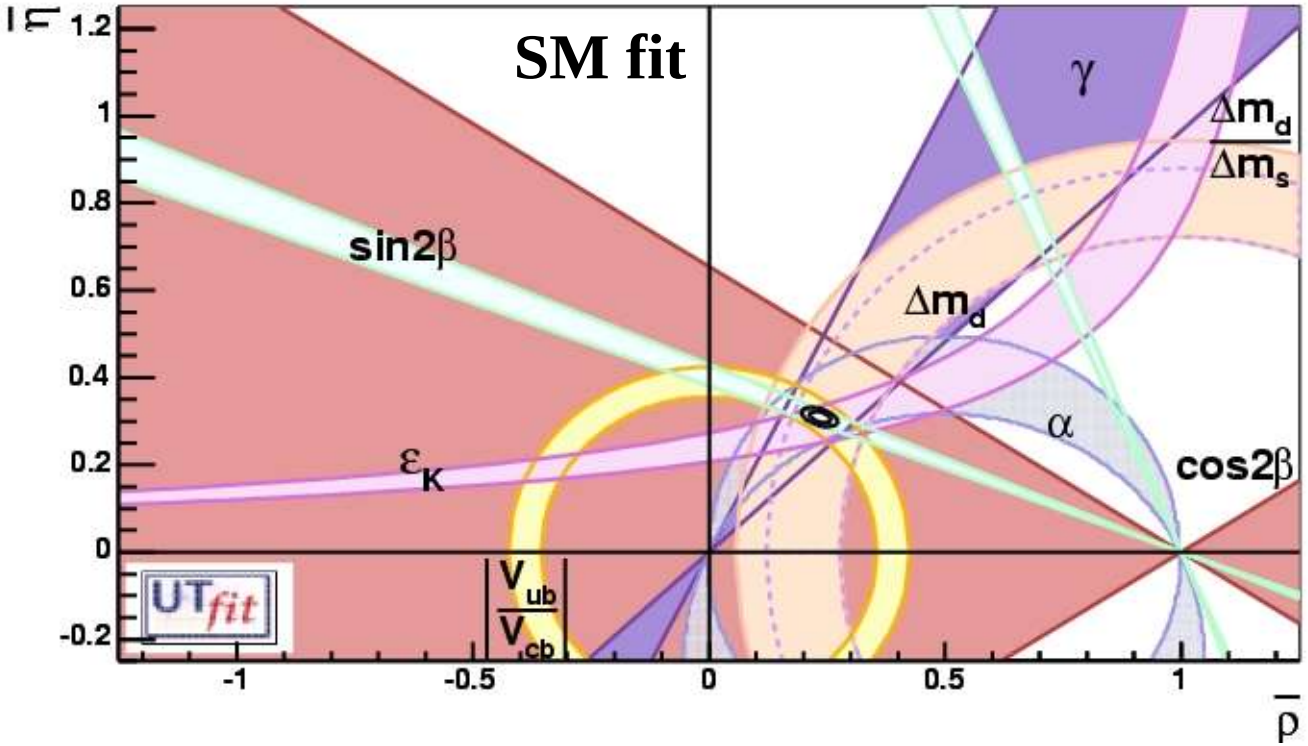
CKM matrix in 2010

Assuming that:

- **B factories will collect 2 ab^{-1}**
- **2 years of data taking at LHCb (4fb^{-1})**

input

$\beta < 1°$		from charmonium
$\alpha \sim 7°$		
$\gamma \sim 5°$		(half B factories and half LHCb)
$\sin 2\chi = \pm 0.045$		
$V_{ub} \sim 5\%$	$V_{cb} \sim 1\%$	
$\sigma(\Delta m_d) \sim 0.3 ps^{-1}$		(Tevatron and/or LHCb)
$f_B\sqrt{B_B} \sim 5\%$	$\xi \sim 3\%$	$B_K \sim 5\%$

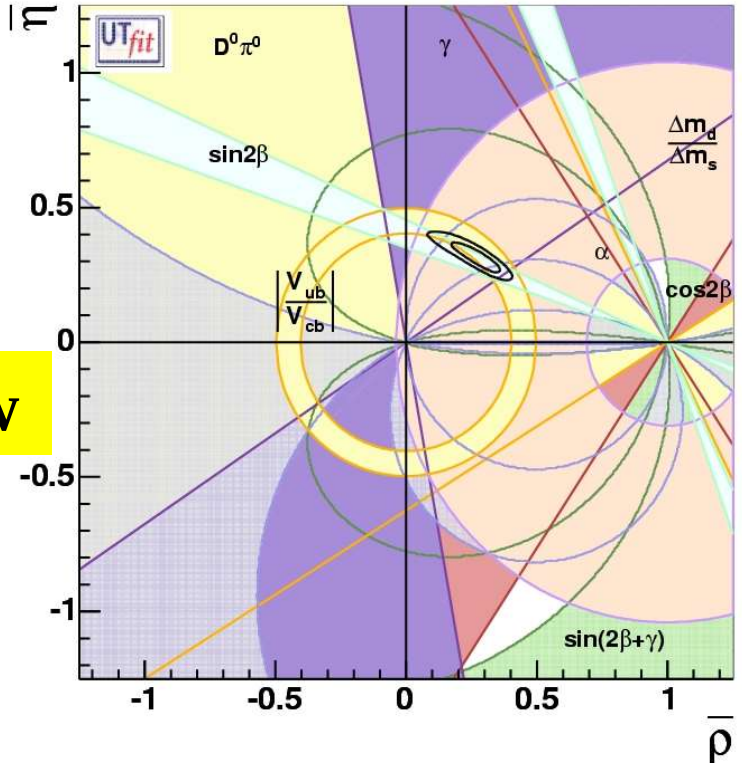


output

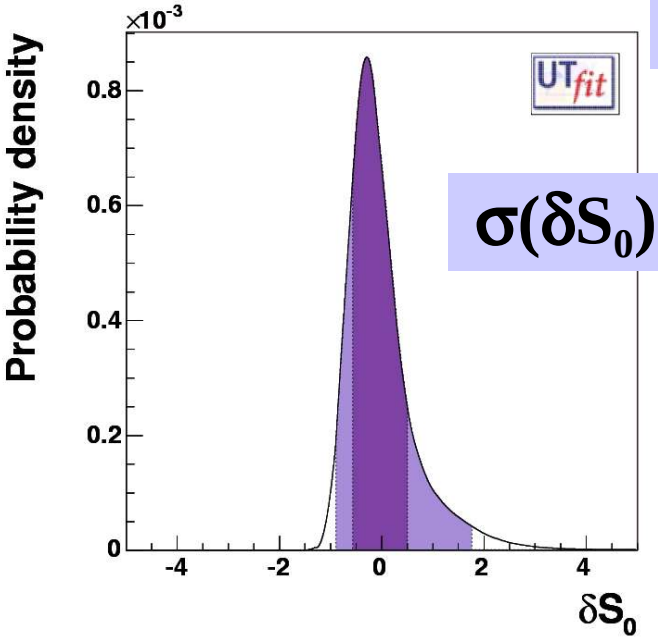
$\sin 2\beta$	0.694 ± 0.012
$\sin 2\alpha$	-0.543 ± 0.093
$\gamma[°]$	51.7 ± 3.0
$\bar{\rho}$	0.240 ± 0.017
$\bar{\eta}$	0.307 ± 0.010

UUT

now

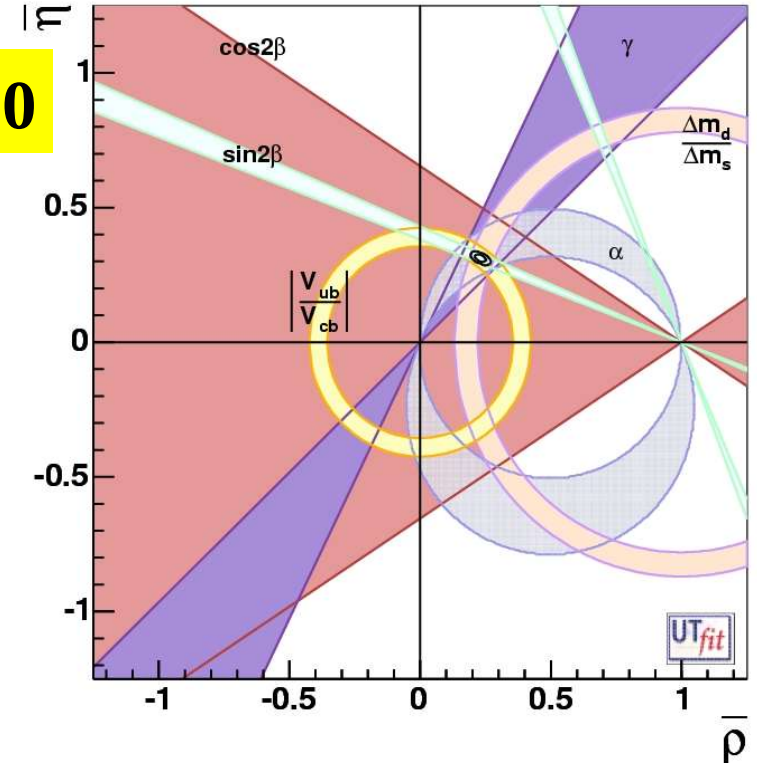


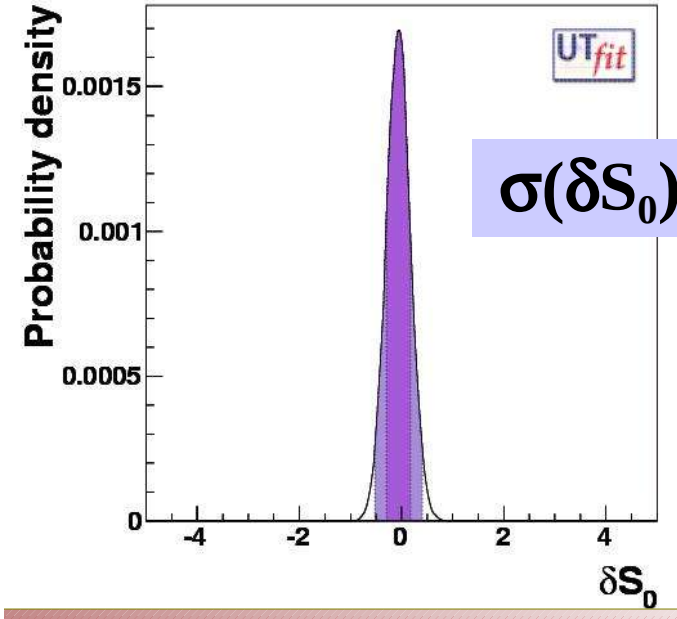
MFV



$\sigma(\delta S_0) = 0.54$

2010

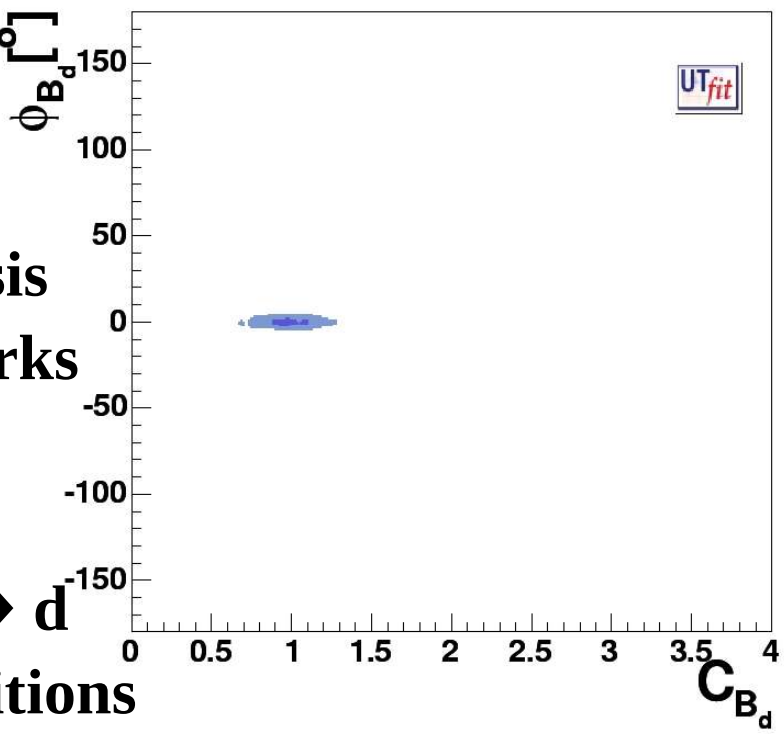


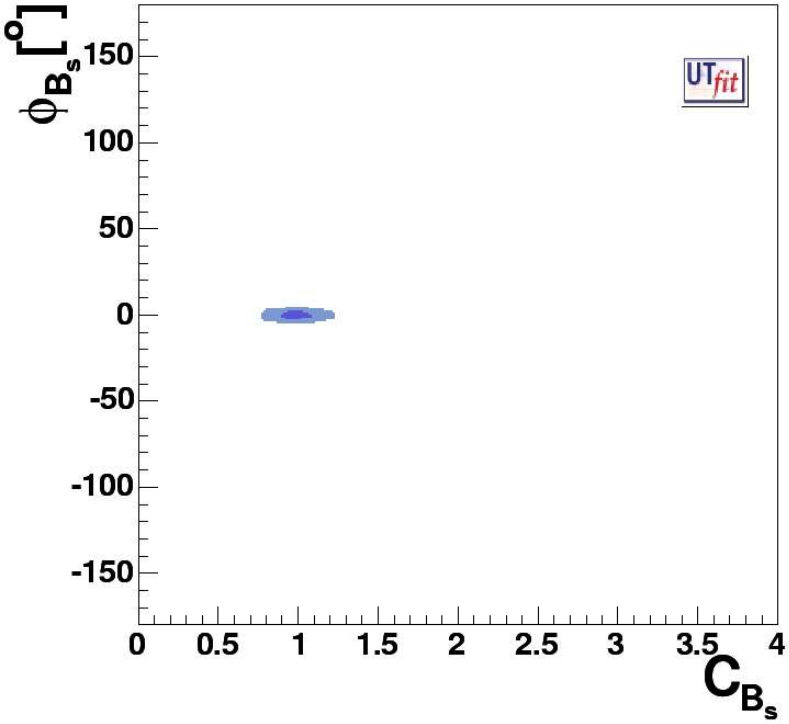


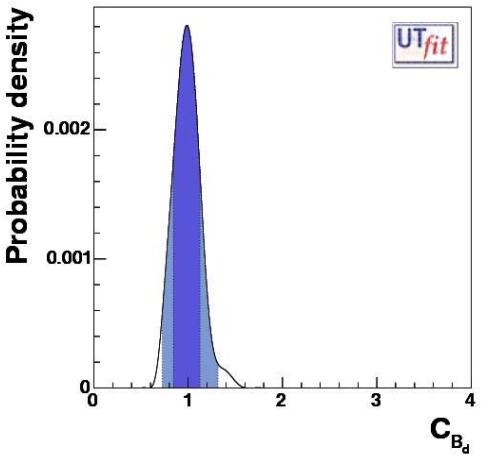
$\sigma(\delta S_0) = 0.26$

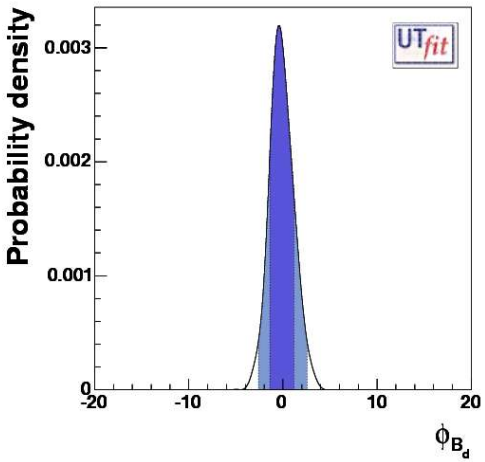
2010 scenario

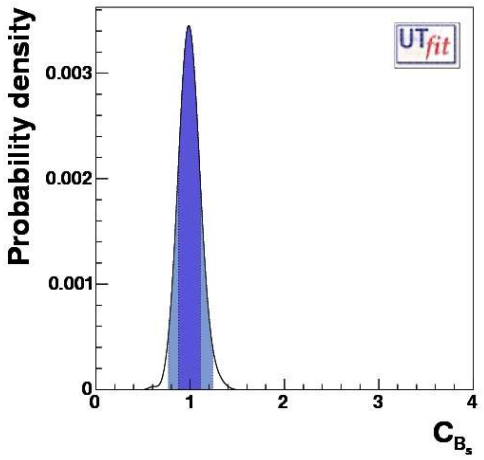
In the hypothesis the SM still works in 2010: impressive precision on b→ d and b→ s transitions

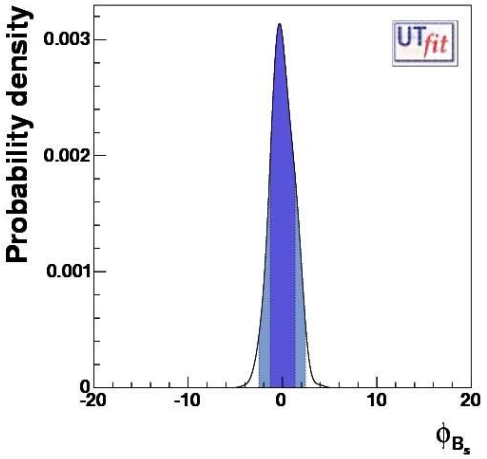












$C_{B_d} = 0.98 \pm 0.14$

$\phi_{B_d} = -0.1 \pm 1.3^{\circ}$

$C_{B_s} = 0.99 \pm 0.12$

$\phi_{B_s} = 0.0 \pm 1.3^{\circ}$

Summary and conclusion

- At this moment the generalization of the UT analysis beyond the SM constrains enormously the NP parameter space.
  - it gives serious constraints on model building
  - it points to MFV
- b → s transitions are still unconstrained
- In MFV it is also possible to turn UT analysis into a probe for NP scale
- 2010 scenario: stringent bound to NP in case of no breaking of the CKM picture

back-up slides