Unitarity Triangle fit and new physics

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on behalf of the

UTfit Collaboration

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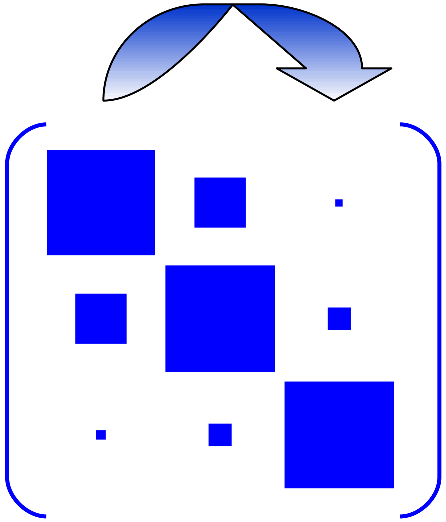
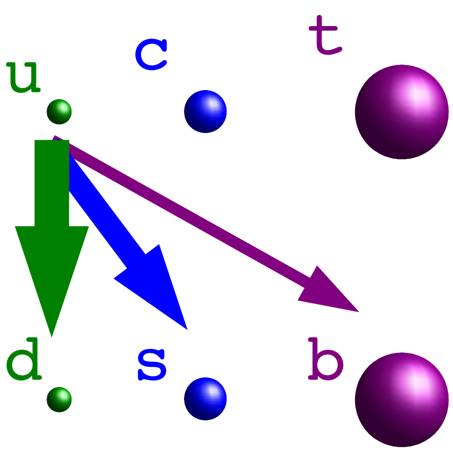
http://www.utfit.org

IV CKM Workshop, Nagoya, Japan
December 12th, 2006

ckm matrix and unitarity triangle

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



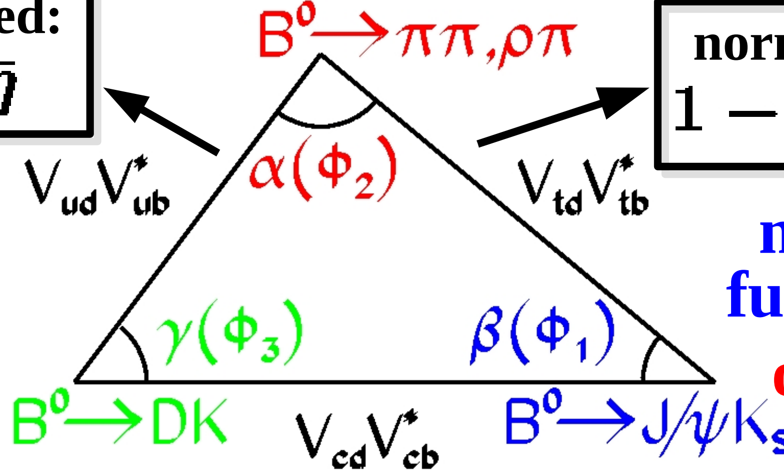


$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

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

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

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



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

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

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

overconstraining

outline

see:
G. Martinelli
in this session

- summary of the SM fit (very quickly)
- few words on the" *tension*" (also very quickly)
- new physics with the model independent analysis:
    - new *new-physics*-oriented constraints
    - results in K, B_d, B_S sectors for NP parameters
- MFV scenario analysis and results

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
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	

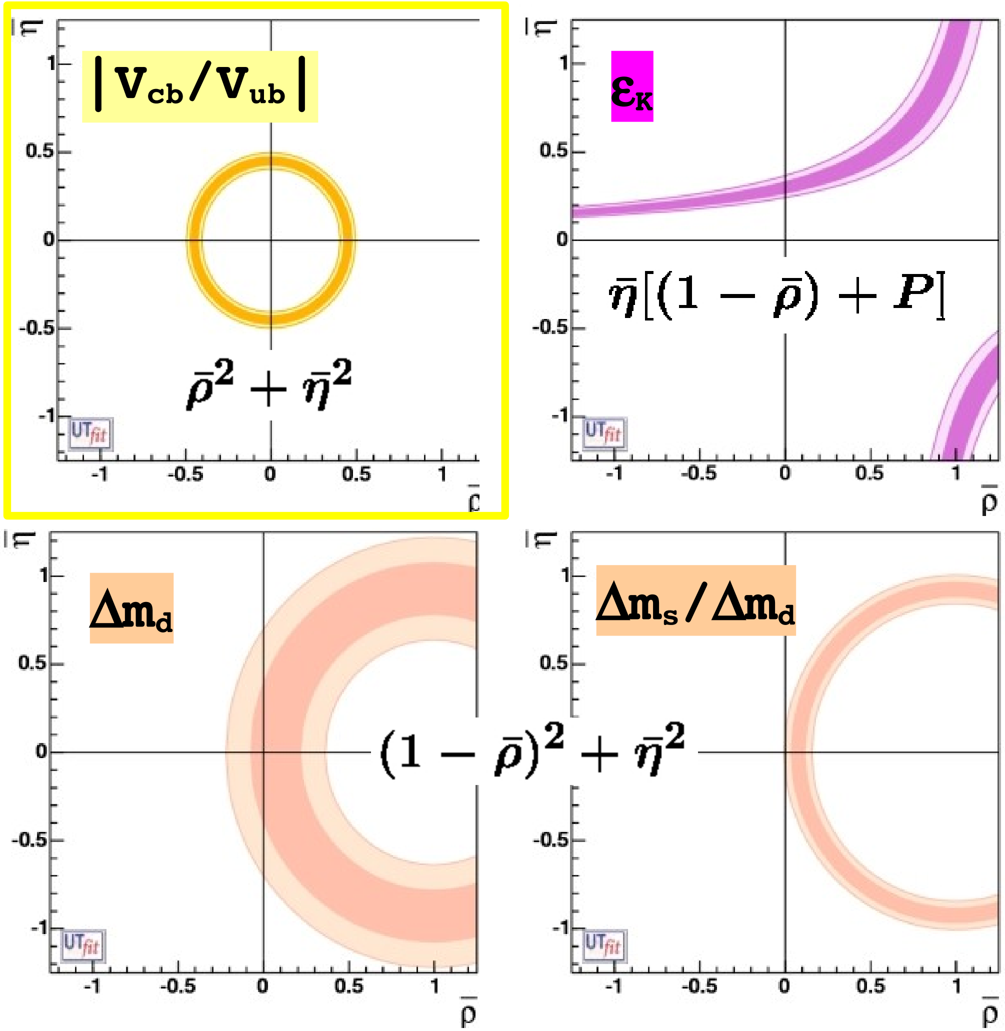
} , m_t

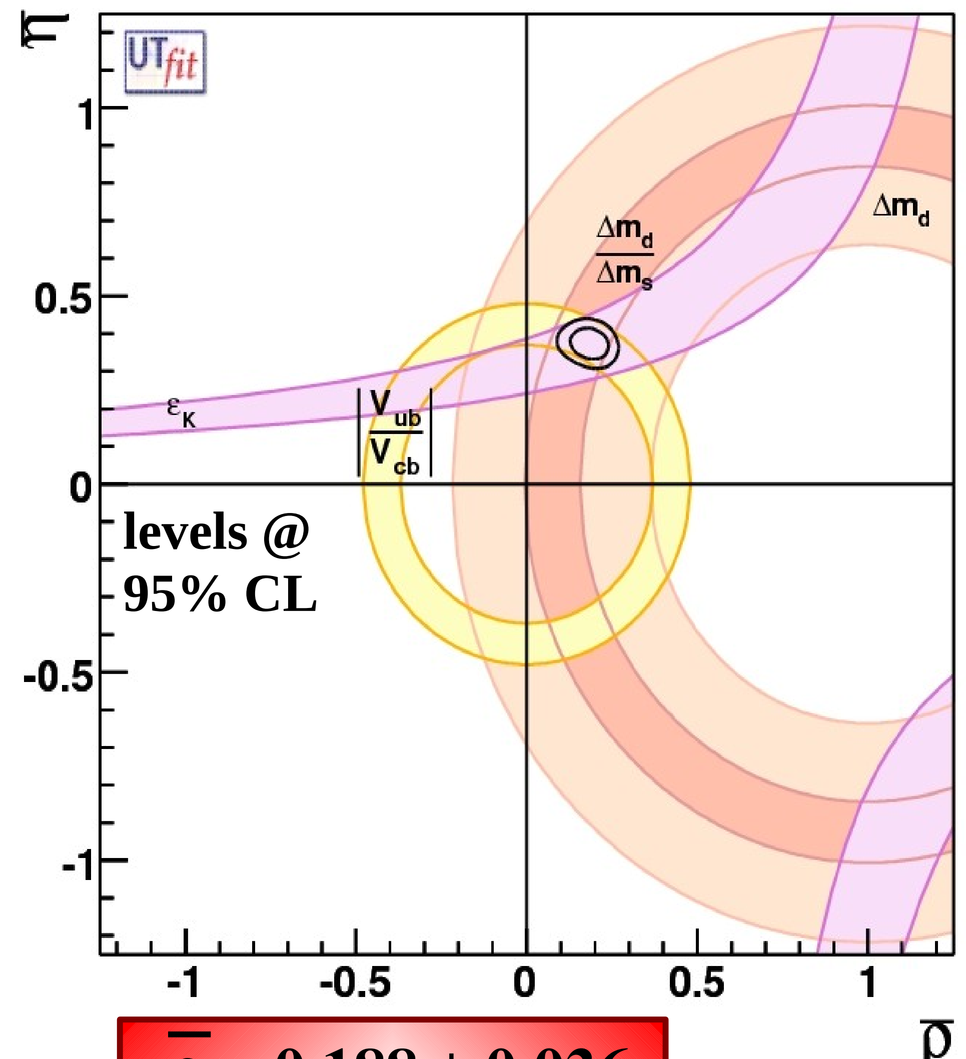
Standard Model +
OPE/HQET/
Lattice QCD
to go
from quarks
to hadrons

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

see also:
G. Martinelli at this session,
V. Lubicz at WG4 (Wed 13)
M. Pierini at WG joint session (Thur 14)

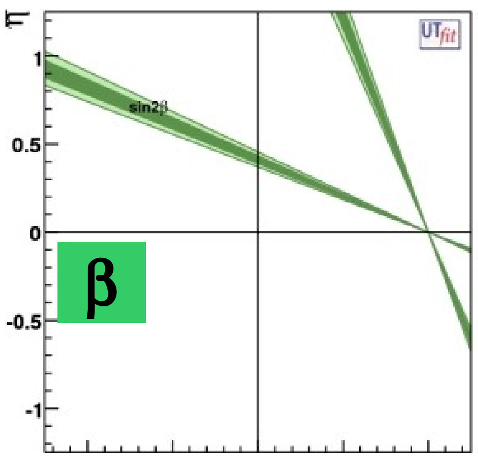
LEP-style analysis in the ρ-η plane:

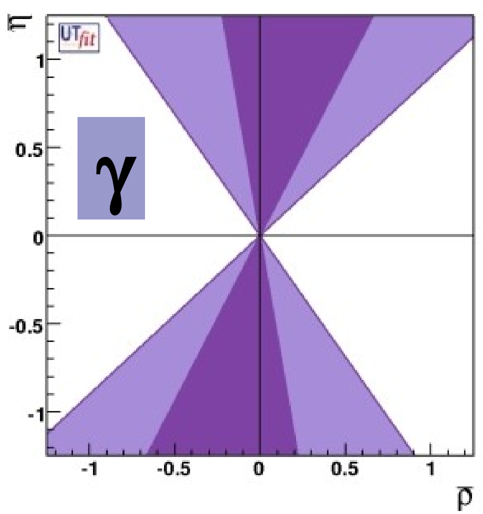


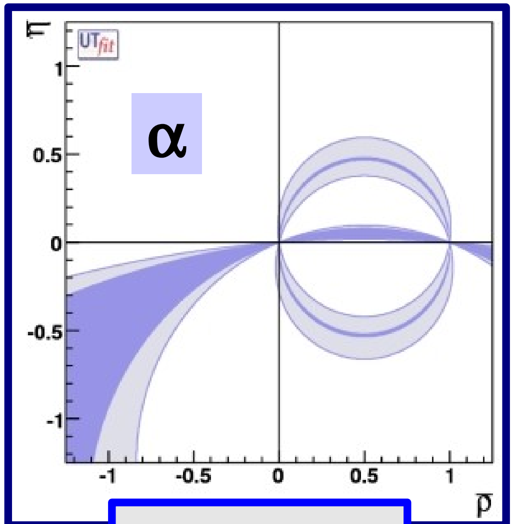


$$\bar\rho = 0.188 \pm 0.036$$
$$\bar\eta = 0.371 \pm 0.027$$

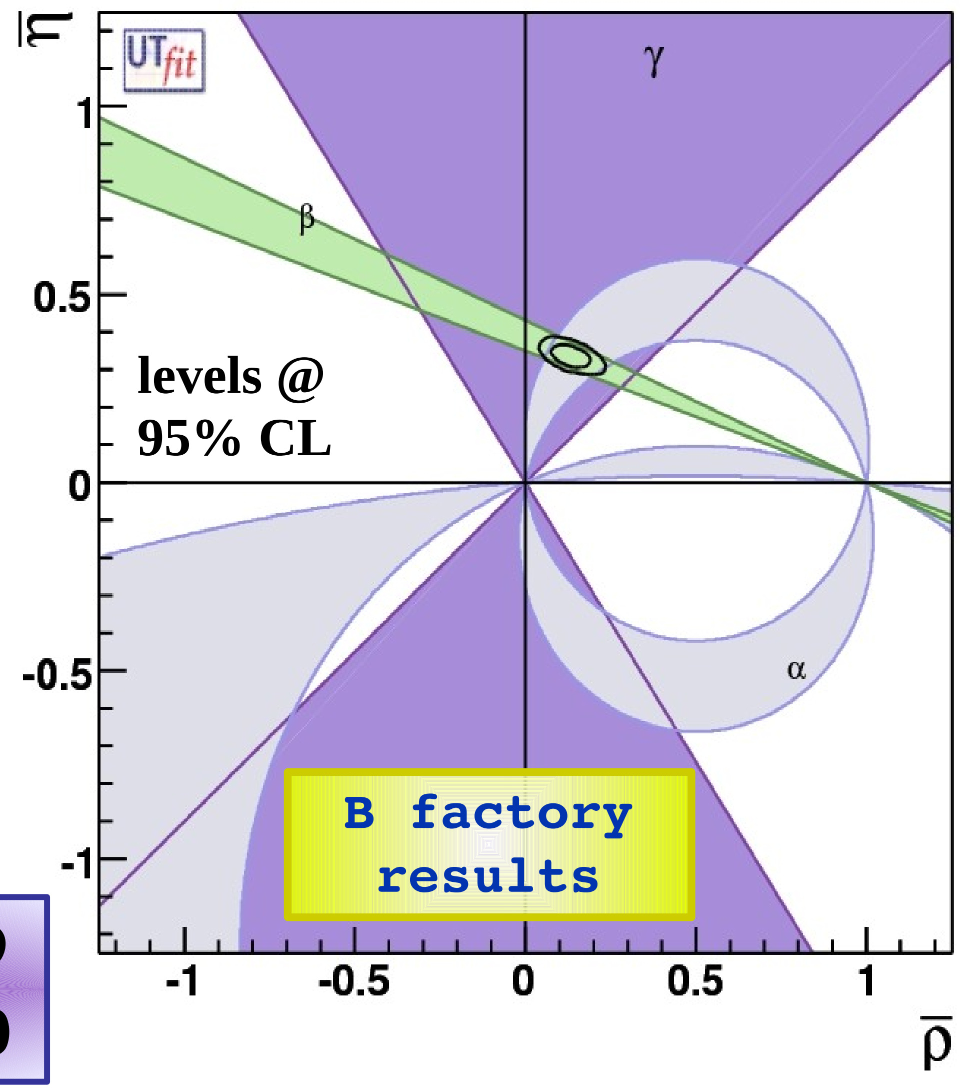
angle constraints in the ρ-η plane:







see:
V. Lubicz
in WG4



$$\bar{\rho} = 0.134 \pm 0.039$$
$$\bar{\eta} = 0.335 \pm 0.020$$

the global fit:

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

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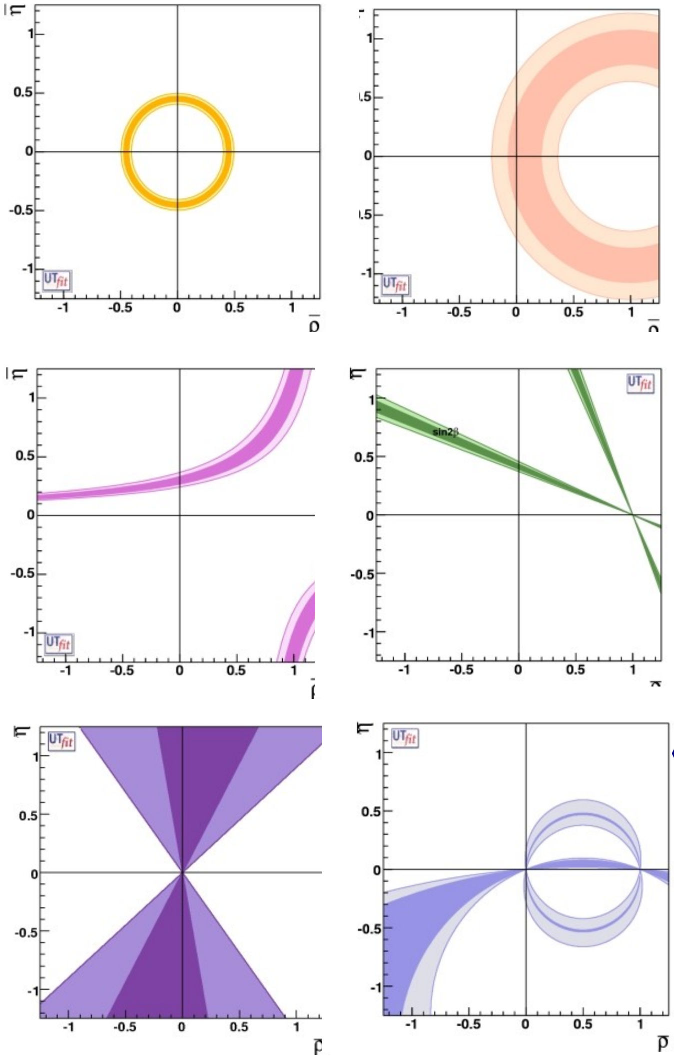
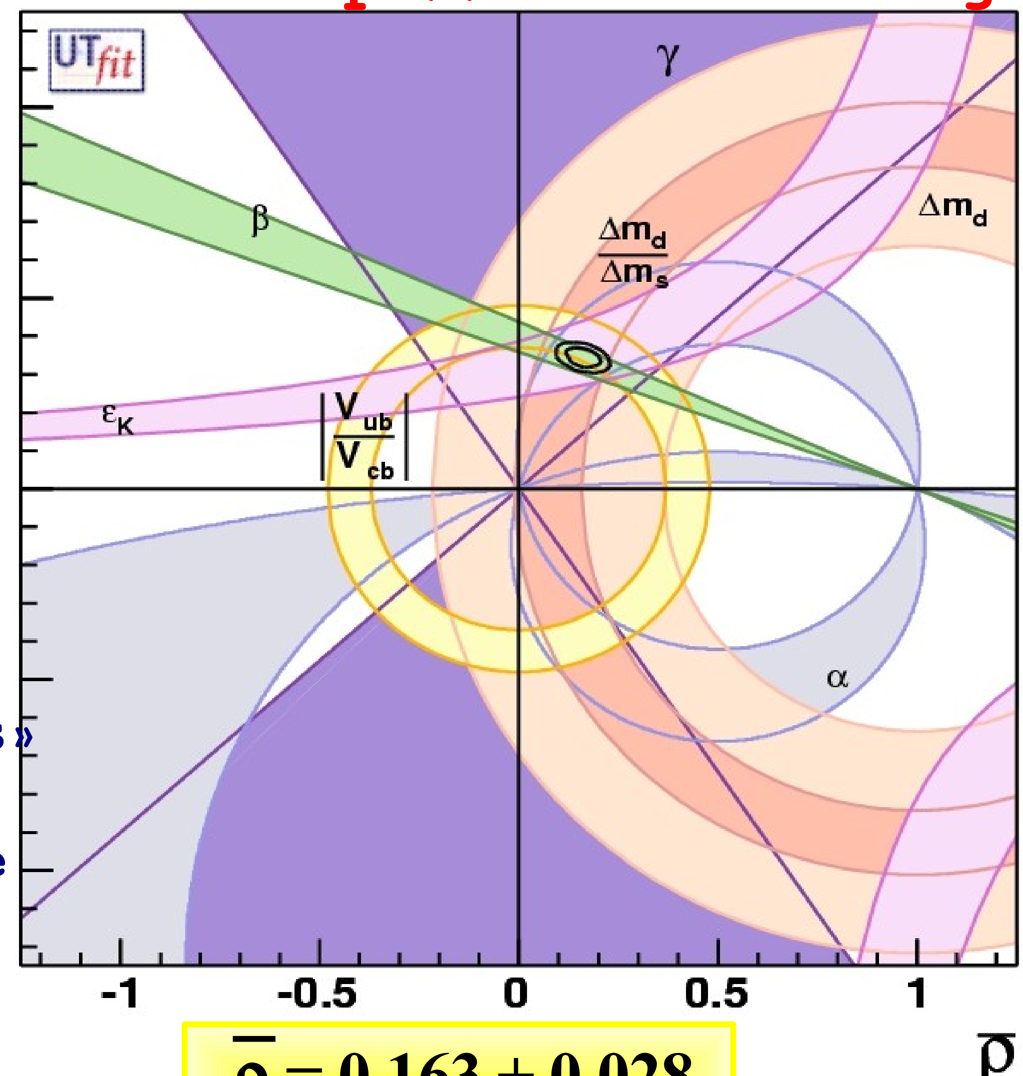


NP should appear as «corrections» to the CKM picture

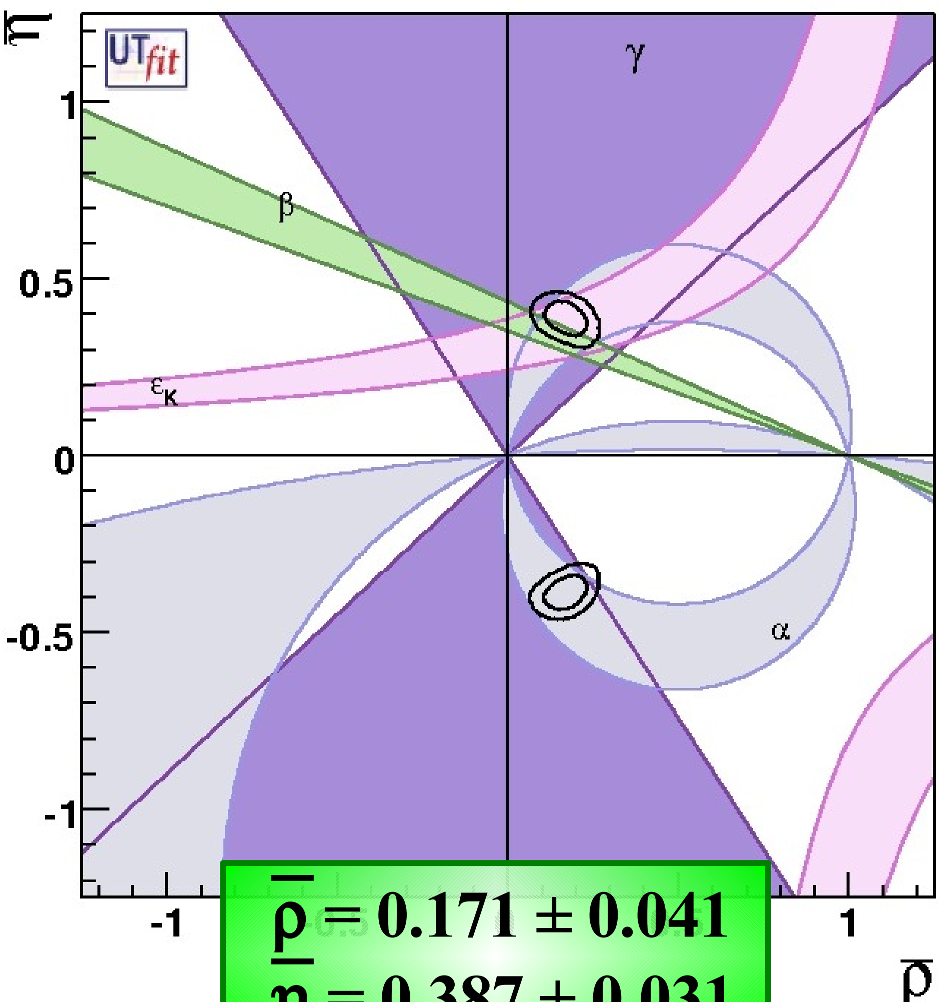


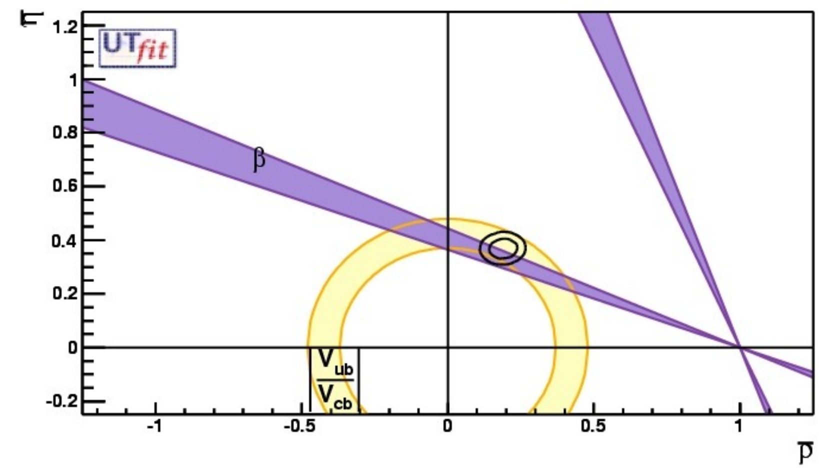
$$\bar{\rho} = 0.163 \pm 0.028$$
$$\bar{\eta} = 0.344 \pm 0.016$$

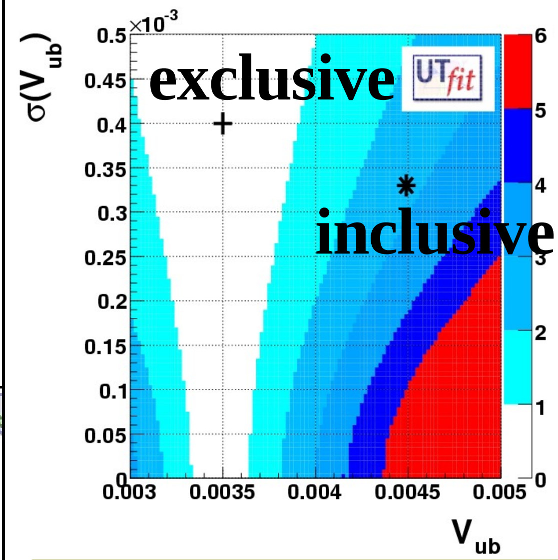
tension in the current results:

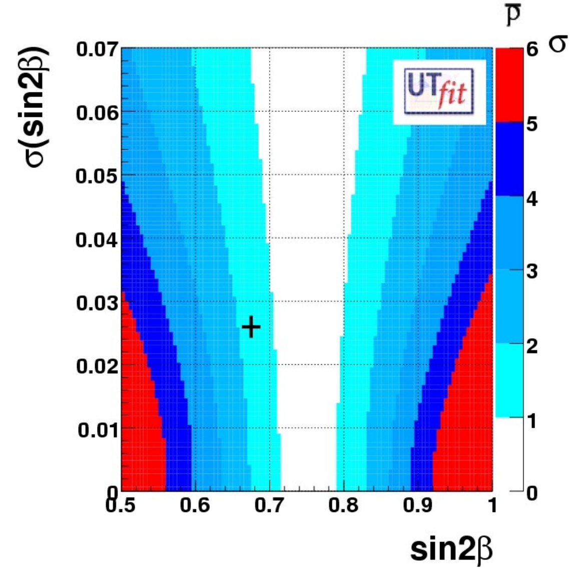
in the fit: $\Delta m_d + \Delta m_s + V_{ub} + V_{cb}$

compared to: $\varepsilon_k + \beta + \alpha + \gamma + 2\beta+\gamma$









$\bar{\rho} = 0.171 \pm 0.041$

$\bar{\eta} = 0.387 \pm 0.031$

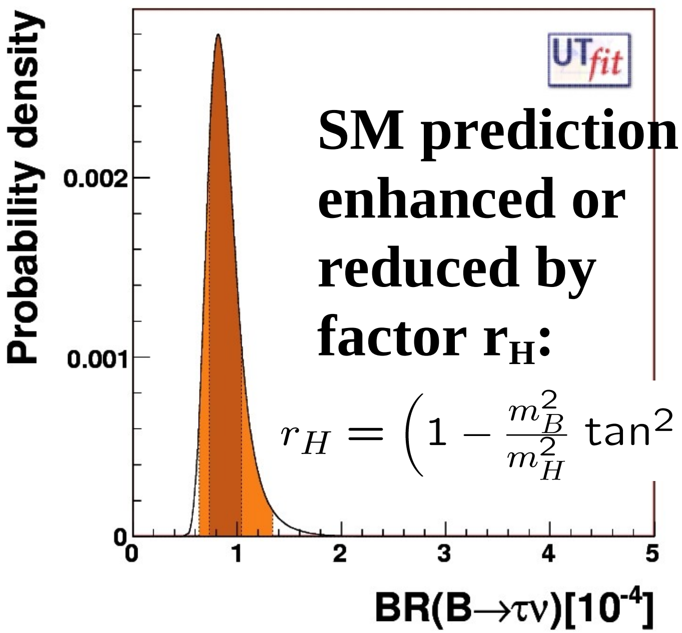
from indirect determination

$V_{ub} = (3.48 \pm 0.20)\ 10^{-3}$

$\sin 2\beta = 0.752 \pm 0.038$

from indirect determination

indirect measurement exploiting V_{ub}



SM prediction enhanced or reduced by factor r_H:

$$r_H = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

(Best SM prediction)

f_B = (190 ± 14) MeV [UTA] $BR(B \Rightarrow \tau\nu_\tau)$ (0.89 ± 0.16) 10^{-4}
V_{ub} = (36.7 ± 1.5) 10^{-4} [UTA]

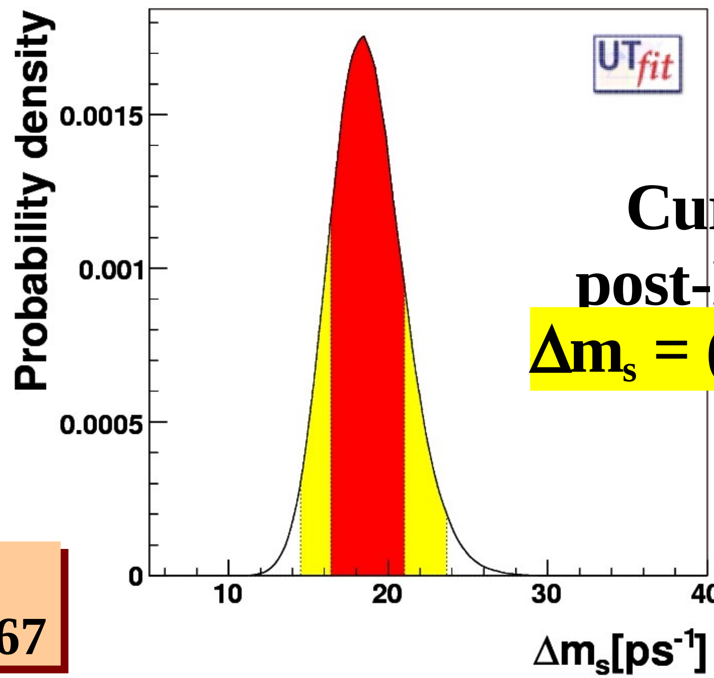
f_B = (189 ± 27) MeV [LQCD] $BR(B \Rightarrow \tau\nu_\tau)$ (0.84 ± 0.30) 10^{-4}
V_{ub} = (35.0 ± 4.0) 10^{-4} [Exclusive]

f_B = (189 ± 27) MeV [LQCD] $BR(B \Rightarrow \tau\nu_\tau)$ (1.39 ± 0.44) 10^{-4}
V_{ub} = (44.9 ± 3.3) 10^{-4} [Inclusive]

From $BR(B\to\tau\nu_\tau)$ and V_{ub}(UTA): f_B = (237 ± 37) MeV

Same game with Δm_s: ICHEP06 values

$\Delta m_{s\,All}$	$(19.4 \pm 2.5) ps^{-1}$
$\Delta m_{s\,V_{ub(incl)}}$	$(20.3 \pm 2.5) ps^{-1}$
$\Delta m_{s\,V_{cb(expl)}}$	$(18.3 \pm 2.0) ps^{-1}$



Current updated post-ICHEP06 value
Δm_s = (18.7 ± 2.3) ps^{-1}

M. Bona *et al.* (UTfit Collaboration) JHEP 0610:081,2006 hep-ph/0606167

fit with NP-independent constraints

using Tree-level processes assumed to be NP free

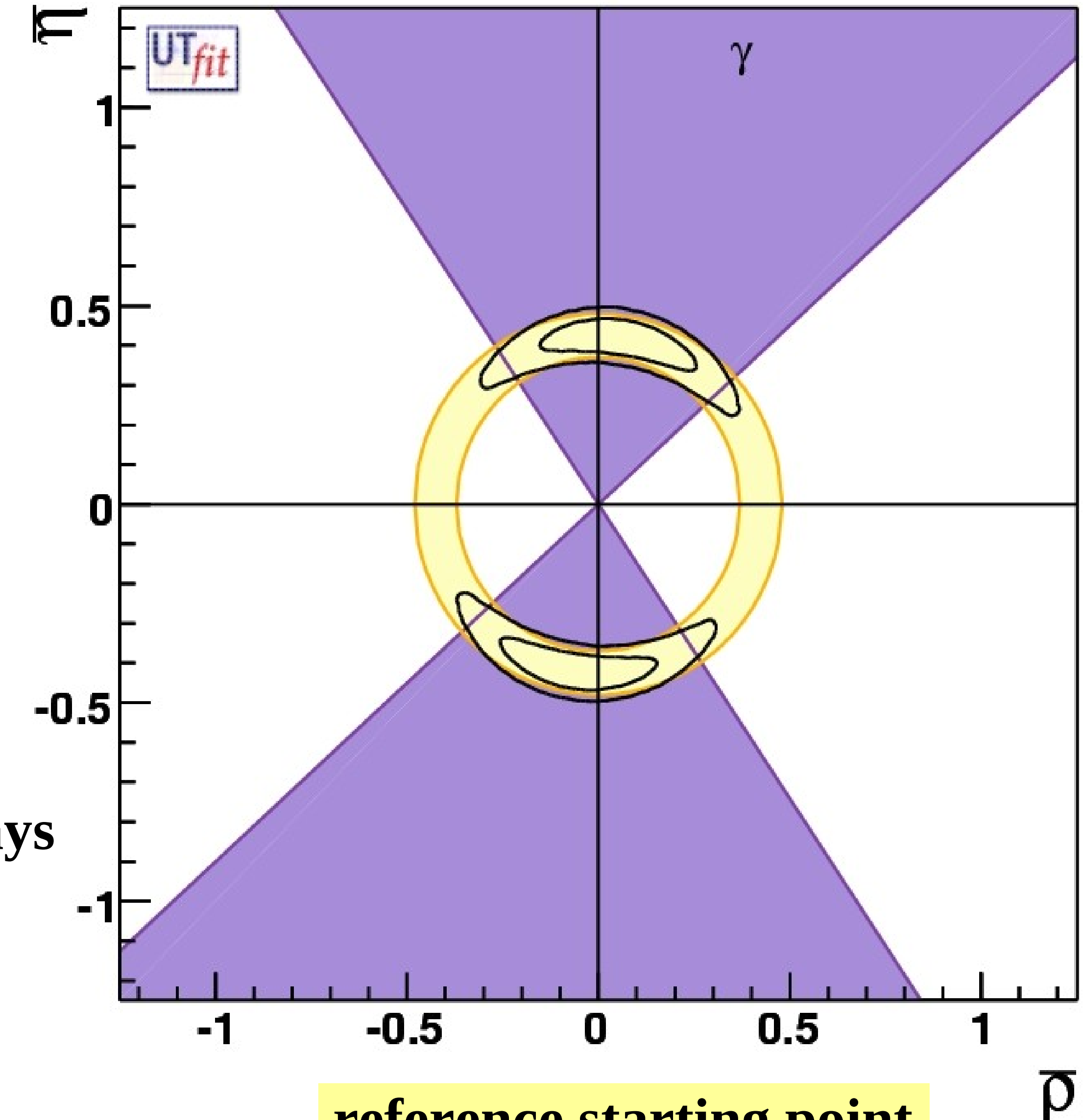
**the effect of the $\bar{D}^0$-D^0 mixing is negligible wrt the actual error*

$\bar{\rho} = \pm\, 0.00 \pm 0.15$

$\bar{\eta} = \pm\, 0.41 \pm 0.04$

very important to improve:

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



reference starting point for NP model building

model independent analysis

New Physics in $\Delta F=2$ amplitudes can be parameterized in a simple general form:

$$C_{B_q} e^{2i\phi_{B_q}} = \frac{\langle B_q^0 | H_{eff}^{full} | \overline{B}_q^0 \rangle}{\langle B_q^0 | H_{eff}^{SM} | \overline{B}_q^0 \rangle}, \quad (q=d,s)$$

$$C_{\epsilon_K} = \frac{\Im[\langle K^0 | H_{eff}^{full} | \overline{K}^0 \rangle]}{\Im[\langle K^0 | H_{eff}^{SM} | \overline{K}^0 \rangle]}$$

SM	→ SM+NP
tree level	
$(V_{ub}/V_{cb})^{SM}$	$(V_{ub}/V_{cb})^{SM}$
γ^{SM}	γ^{SM}
Bd Mixing	
β^{SM}	$\beta^{SM}+\phi_{Bd}$
α^{SM}	$\alpha^{SM}-\phi_{Bd}$
Δm_d	$C_{Bd}\Delta m_d$
Bs Mixing	
Δm_s^{SM}	$C_{Bs}\Delta m_s^{SM}$
β_s^{SM}	$\beta_s^{SM}+\phi_{Bs}$
K Mixing	
ε_K^{SM}	$C_{\varepsilon K}\,\varepsilon_K^{SM}$

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]

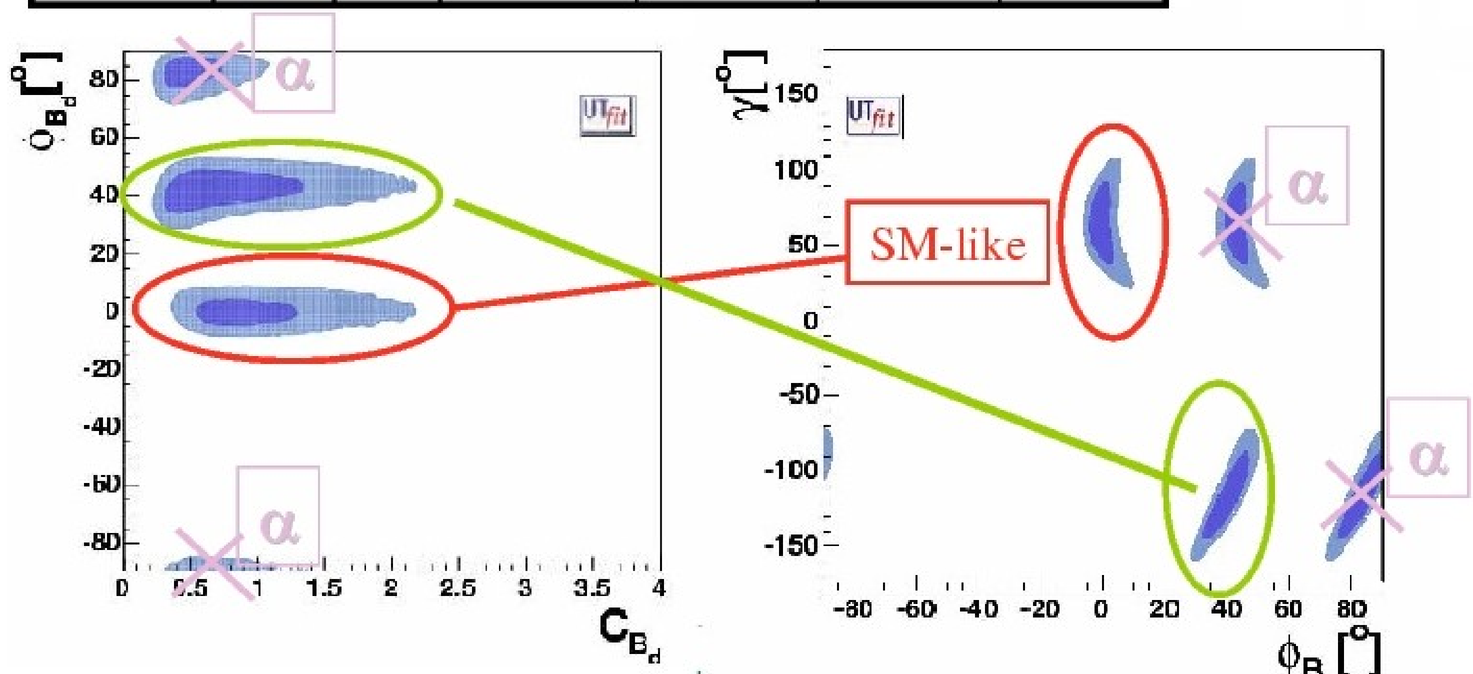
M. Bona *et al*. (UTfit Collaboration) JHEP 0603:080,2006 hep-ph/0509219

model independent approach in the fit

Using

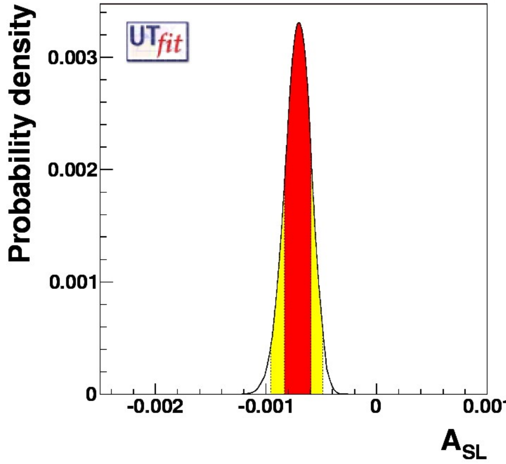
	γ	C_d	$\cos2(\beta+\phi)$	$\sin2(\alpha-\phi)$	$\sin(2\beta+\phi)$	A_{SL}
SM-LIKE	60°	1	0.68	-0.23	0.96	OK
NP1	60°	1	-0.68	0.96	-0.23	OK
NP2	-120°	0.4	0.68	-0.23	-0.96	10^{-2}
NP3	-120°	0.4	-0.68	0.96	0.23	OK

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



so we have to add → α, $\cos2\beta$, A_{SL}, A_{CH}, ..

SM prediction
$(-1.06\pm0.09)10^{-3}$



A_{SL} in B_d decays

This is the only observable that is sensitive to NP effect on both size and phase of B mixing

$$A_{\rm SL} \equiv \frac{\Gamma(\bar{B}^0 \to \ell^+ X) - \Gamma(B^0 \to \ell^- X)}{\Gamma(\bar{B}^0 \to \ell^+ X) + \Gamma(B^0 \to \ell^- X)}$$
$$= -{\rm Re}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{\rm SM} \frac{\sin 2\phi_{B_d}}{C_{B_d}} + {\rm Im}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{\rm SM} \frac{\cos 2\phi_{B_d}}{C_{B_d}}$$

Direct measurement new average = $(0.8\pm5.6)10^{-3}$ (large values in case of new physics)

A_{CH} in $B_{d,s}$ decays

First available bound on $\bar{B}$s-Bs mixing phase

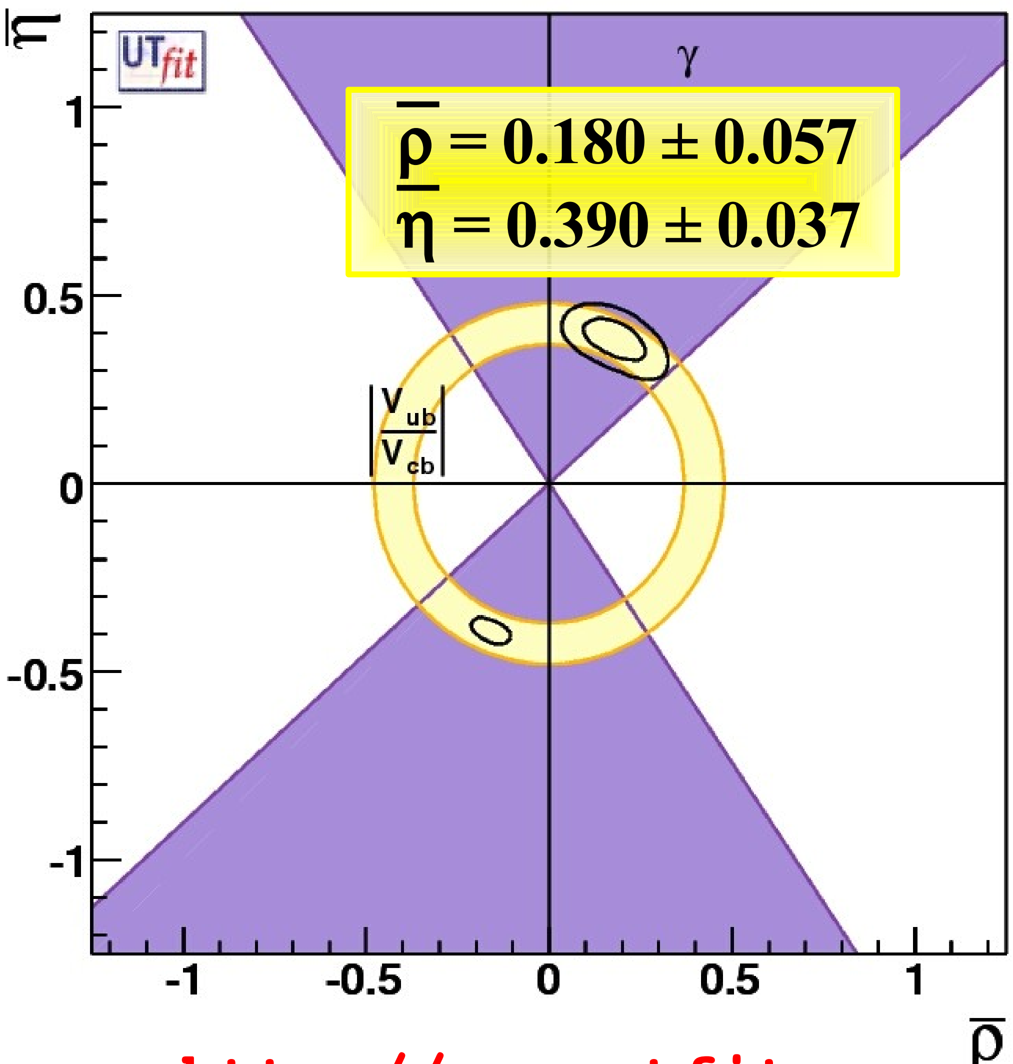
$$A = \frac{(\chi - \bar{\chi})(P_1 - P_3 + 0.3 P_8')}{\xi(P_1 + P_3) + (1-\xi)P_2 + 0.28 \cdot P_7 + 0.5 \cdot P_8' + 0.69 \cdot P_{13}} = (-1.3\pm1.2\pm0.8)10^{-3}$$

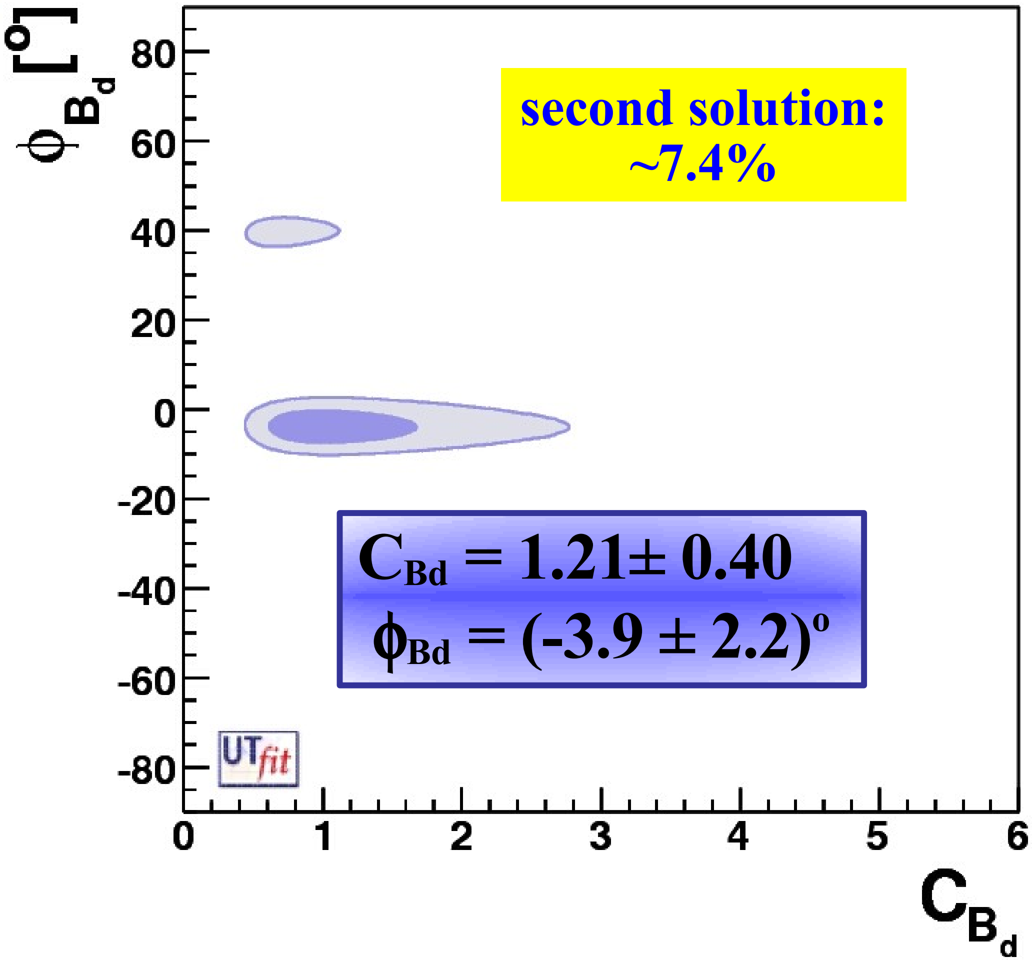
$$\chi = f_d \frac{\beta_d}{\langle\beta\rangle}\chi_d + f_s \frac{\beta_s}{\langle\beta\rangle}\chi_s$$
$$\bar{\chi} = f_d \frac{\beta_d}{\langle\beta\rangle}\bar{\chi}_d + f_s \frac{\beta_s}{\langle\beta\rangle}\chi_s$$

admixture of B_d and B_s dependent on $\bar{\rho}$ and $\bar{\eta}$ and on NP effects (C_{Bd}, ϕ_{Bd}, C_{Bs}, ϕ_{Bs})

M. Bona *et al*. (UTfit Collaboration) Phys.Rev.Lett.97:151803,2006 hep-ph/0605213

results of the model independent approach





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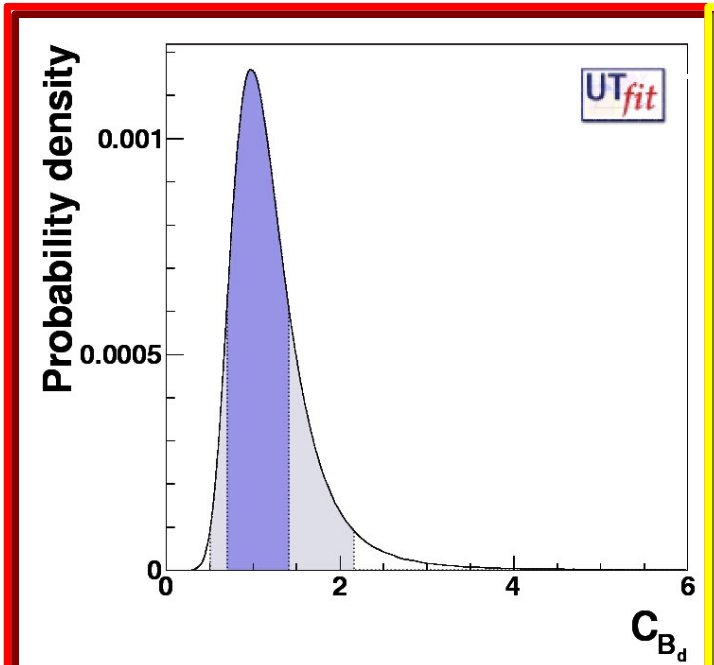
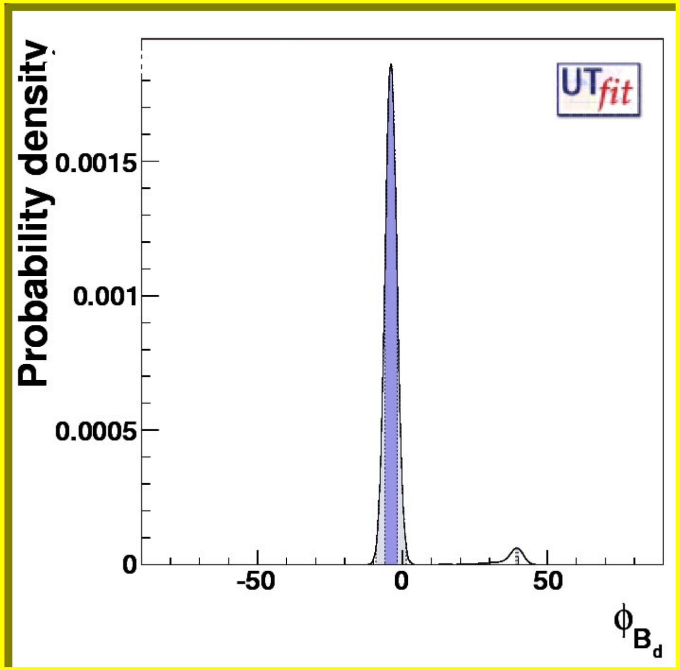
results in the B_d and K sectors:

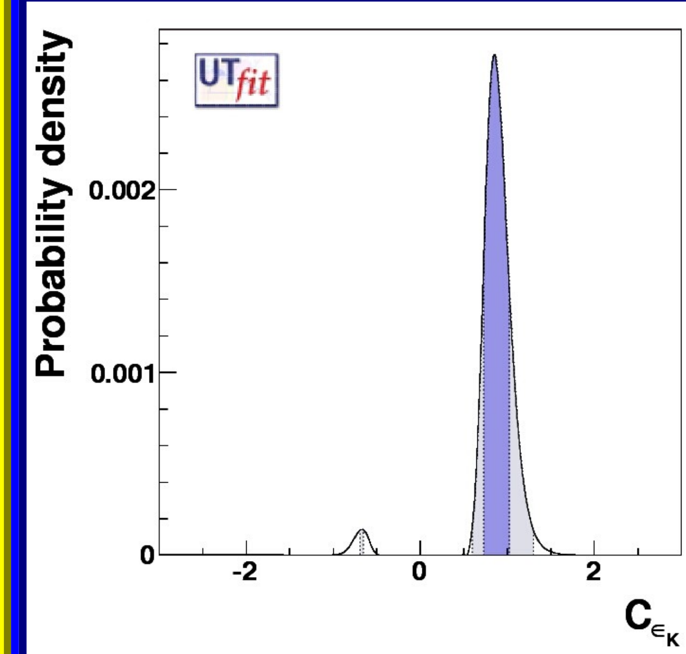
$C_{Bd} = 1.21 \pm 0.40$



$\phi_{Bd} = -(3.9 \pm 2.2)^o$



$C_{\varepsilon K} = 0.88 \pm 0.15$



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

exploring new physics in the B_S sector:

- Δm_S: same as usual
- A_{CH}: already illustrated
- $\Delta\Gamma_S/\Gamma_S$: only from CDF
- flavour-specific B_S lifetime: only from CDF
- TD($B_S \to J/\psi\,\phi$): time dependent 3-dimensional angular analysis from D0

C_{B_s}

C_{B_d} ϕ_{B_d} C_{B_s} ϕ_{B_s}

ϕ_{B_s}

C_{Pen} and ϕ_{Pen} to include $\Delta F = 1$ NP contributions

$\Delta\Gamma_S/\Gamma_S$

$$\frac{\Delta\Gamma_q}{\Delta m_q} = -\frac{\kappa}{C_{B_q}}\left\{\cos\left(2\phi_{B_q}\right)\left(n_1 + \frac{n_6 B_2 + n_{11}}{B_1}\right) - \frac{\cos\left(\phi_q^{SM} + 2\phi_{B_q}\right)}{R_t^q}\left(n_2 + \frac{n_7 B_2 + n_{12}}{B_1}\right) + \frac{\cos\left(2(\phi_q^{SM} + \phi_{B_q})\right)}{R_t^{q^2}}\right.$$
$$\left.\left(n_3 + \frac{n_8 B_2 + n_{13}}{B_1}\right) + \cos\left(\phi_q^{Pen} + 2\phi_{B_q}\right) C_q^{Pen}\left(n_4 + n_9\frac{B_2}{B_1}\right) - \cos\left(\phi_q^{SM} - \phi_q^{Pen} + 2\phi_{B_q}\right)\frac{C_q^{Pen}}{R_t^q}\left(n_5 + n_{10}\frac{B_2}{B_1}\right)\right\} \quad (7)$$

from angular analysis of $B_S \to J/\psi\,\phi$

in presence of new physics, the experimental measurement is actually a measurement of $\Delta\Gamma_q \cos 2(\phi_{B_q} - \beta_q)$

we use the CDF-only result

additional constraints the NP in the B_S sector:

flavour specific B_S lifetime

we use the CDF-only result

we now use τ_{B_S} only from the study of B_S decays to CP eigenstates which is connected to the values of Γ_S and $\Delta\Gamma_S$ by this relation

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

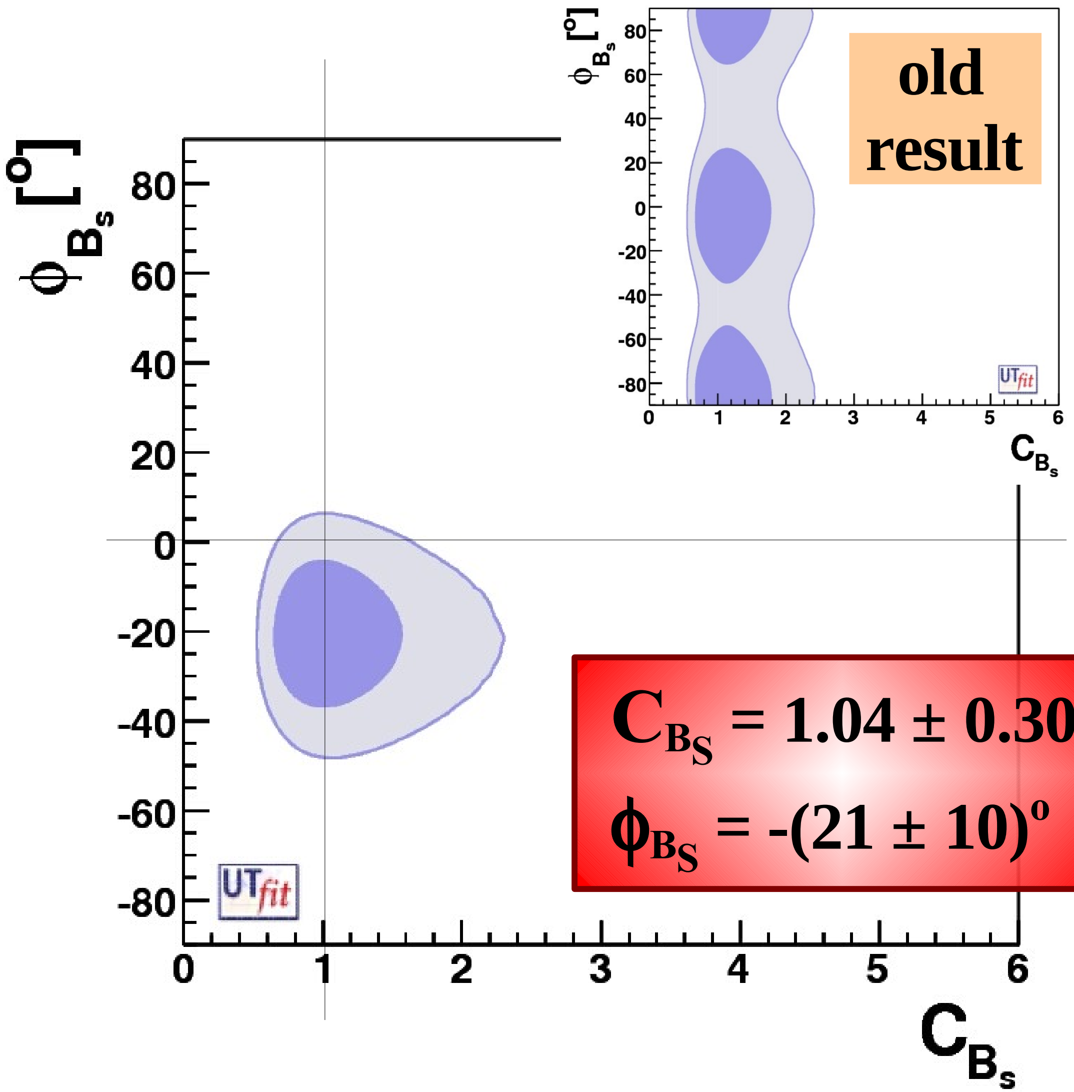
time-dipendent angular analysis in $B_S \to J/\psi\, \phi$

D0 provided simultaneous bounds on β_S, $\Delta\Gamma$ and Γ: we use the experimental likelihood including the 3x3 correlation matrix and we don't use D0 values in the other constraints (in order not to double count the measurements)

C_{B_S} ϕ_{B_S}

D0 result ICHEP06

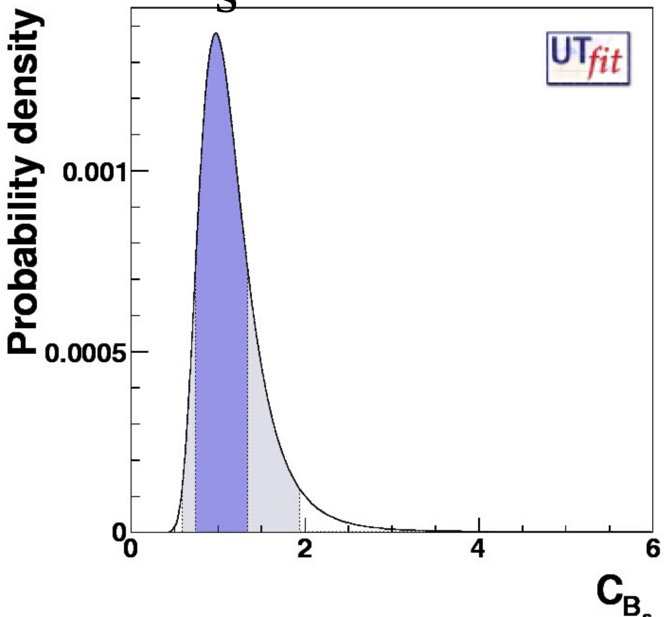
results in the B_S sector:



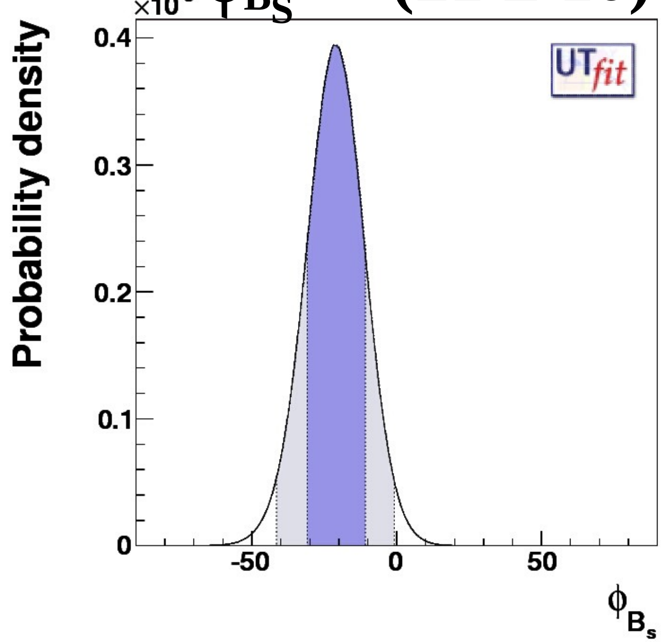
$C_{B_S} = 1.04 \pm 0.30$

$\phi_{B_S} = -(21 \pm 10)^o$

$C_{B_S} = 1.04 \pm 0.30$

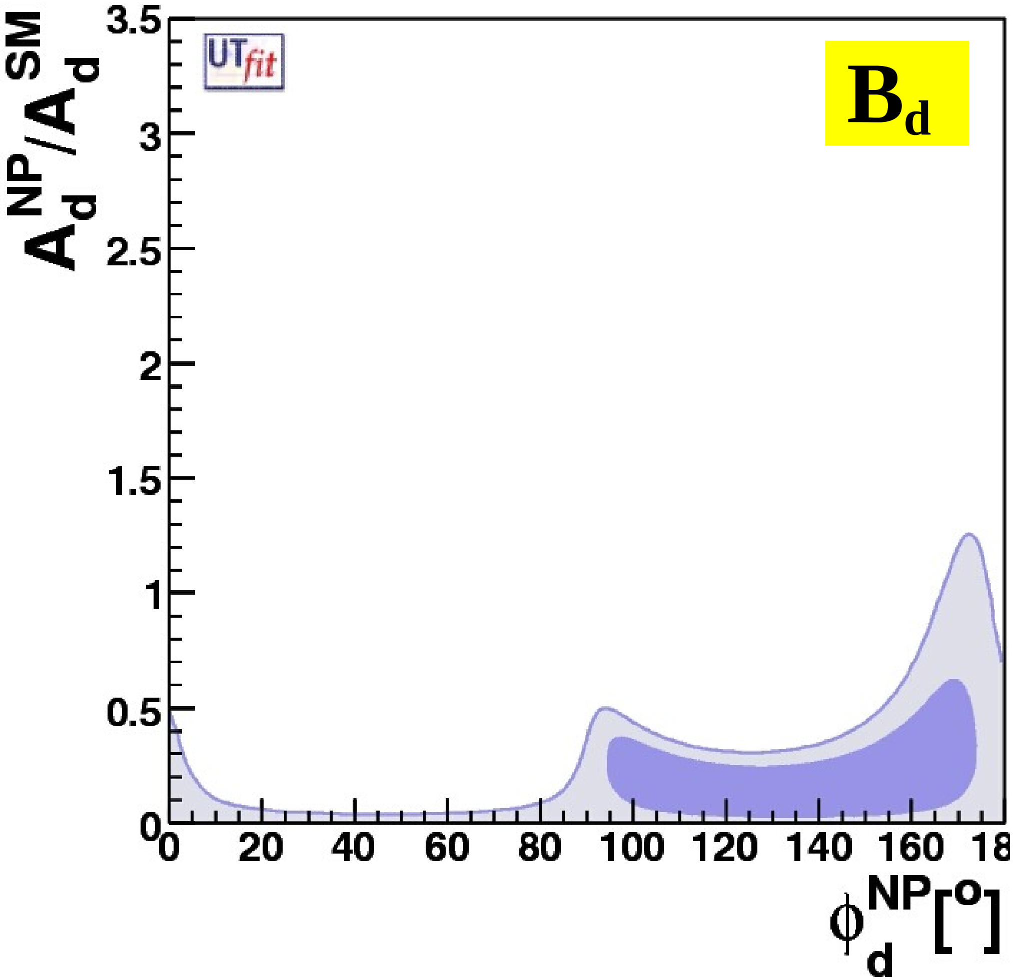


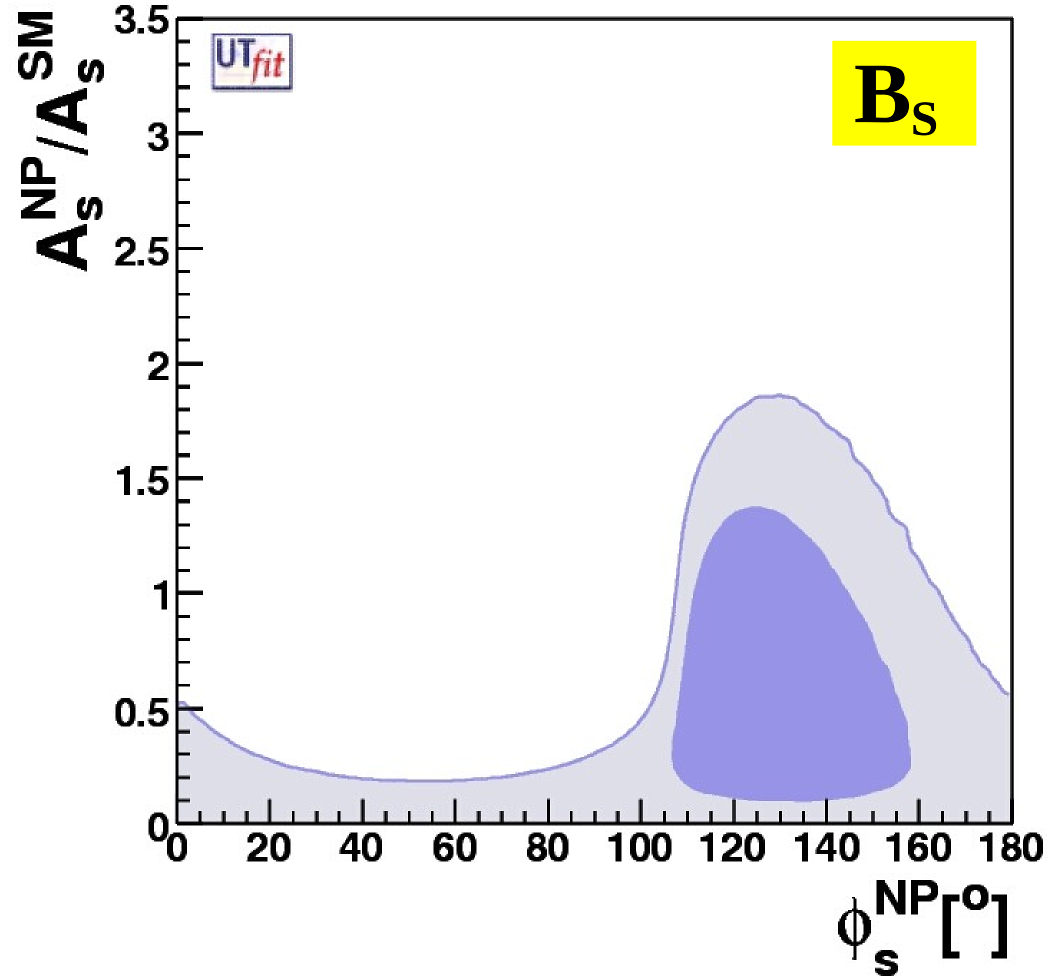
$\phi_{B_S} = -(21 \pm 10)^o$



or if you prefer:

$$C_{B_q} e^{2i\phi_{B_q}} = \frac{A_q^{\mathrm{SM}} e^{2i\beta_q} + A_q^{\mathrm{NP}} e^{2i(\beta_q + \phi_q^{\mathrm{NP}})}}{A_q^{\mathrm{SM}} e^{2i\beta_q}}$$





Are there new sources of CPV?

- New sources of CPV in $s \to d$ and/or $b \to d$ transitions are
  - strongly constrained by the UT fit
  - "unnecessary", given the great success and consistency of the fit

L. Silvestrini
LP05

- New sources of CPV in $b \to s$ transitions are
  - much less (un-) constrained by the UT fit
  - natural in many flavour models, given the strong breaking of family SU(3)

Pomarol, Tommasini; Barbieri, Dvali, Hall; Barbieri, Hall; Barbieri, Hall, Romanino; Berezhiani, Rossi; Masiero et al; …

  - hinted at by ν's in SUSY-GUTs

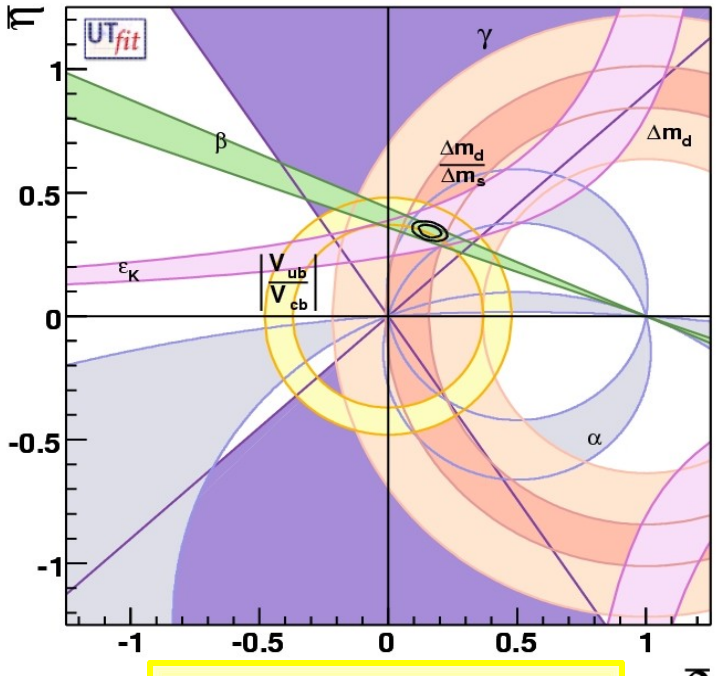
Baek et al.; Moroi; Akama et al.; Chang, Masiero, Murayama; Hisano, Shimizu; Goto et al.; …

exploring MFV scenario: starting from UUT

MFV = no additional flavour mixing
only mixing processes are sensitive to NP

Universal Unitarity Triangle

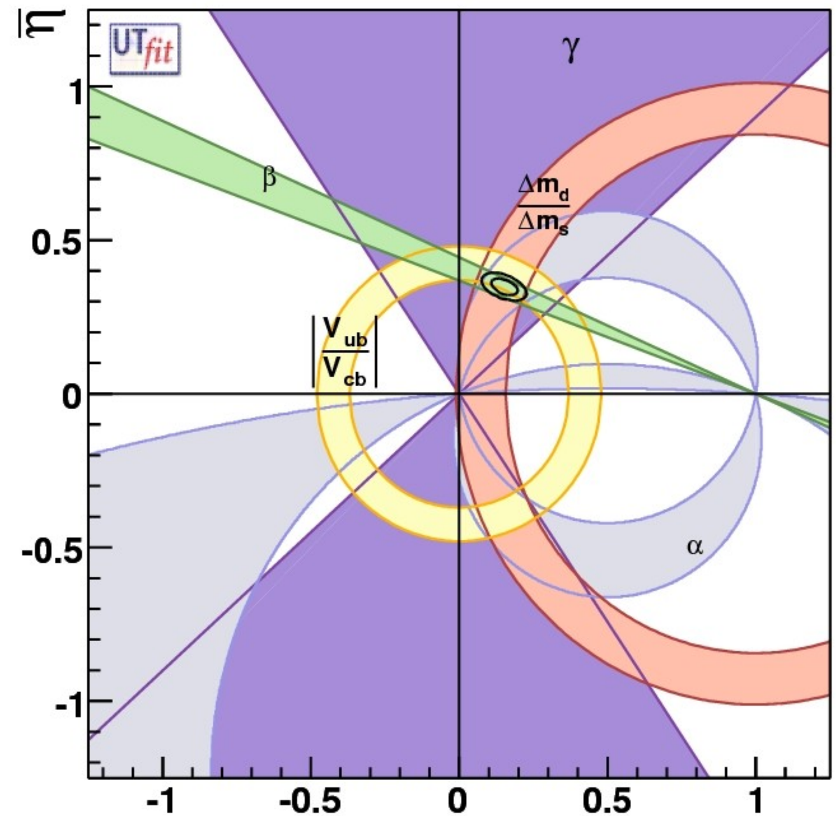
Buras et al. hep-ph/0007085



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

$\bar{\rho} = 0.163 \pm 0.028$
$\bar{\eta} = 0.344 \pm 0.016$

comparable precision between UUT and global fit



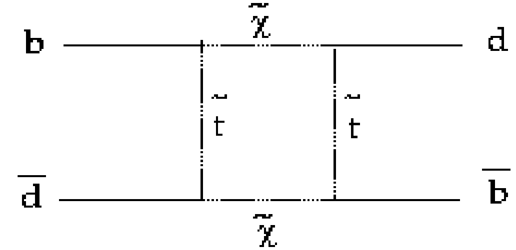
Determines $\bar{\rho}$ and $\bar{\eta}$ independently
on the presence of MFV NP

$\bar{\rho} = 0.153 \pm 0.030$
$\bar{\eta} = 0.347 \pm 0.018$

MFV analysis

Scale of NP can be indirectly tested

remaining constraints (ε_K, Δm_d, and Δm_s) probe NP in mixing



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

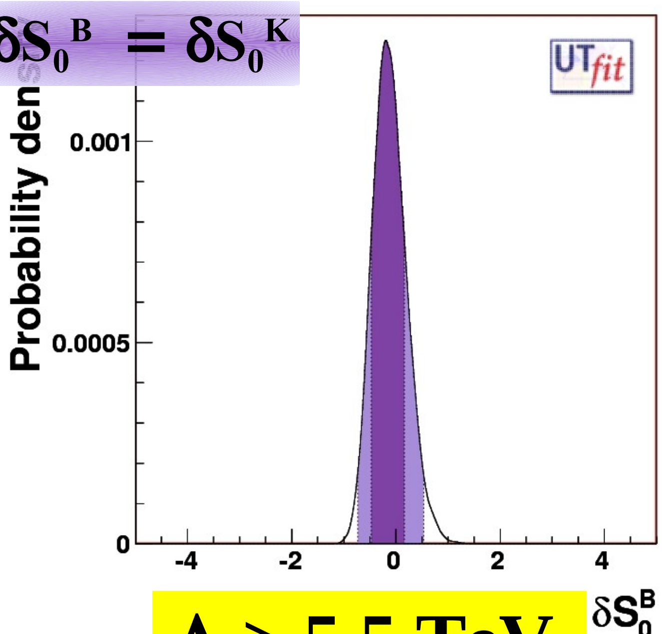
$$\delta S_0(x_t) = 4a\left(\frac{\Lambda_0}{\Lambda}\right)^2$$

a = 1 (as a reference) Λ_0 = 2.4 TeV

Λ_0 is the equivalent SM scale

In models with one Higgs doublet or low/moderate tanβ NP enters as additional contribution to the top box diagram

$\delta S_0^B = \delta S_0^K$

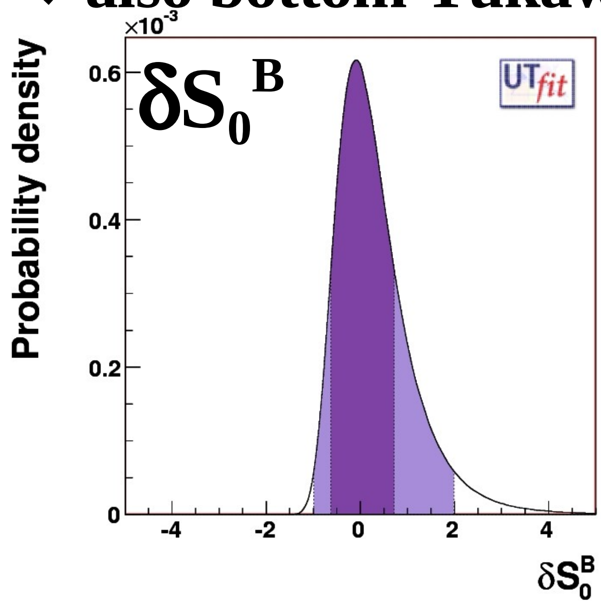


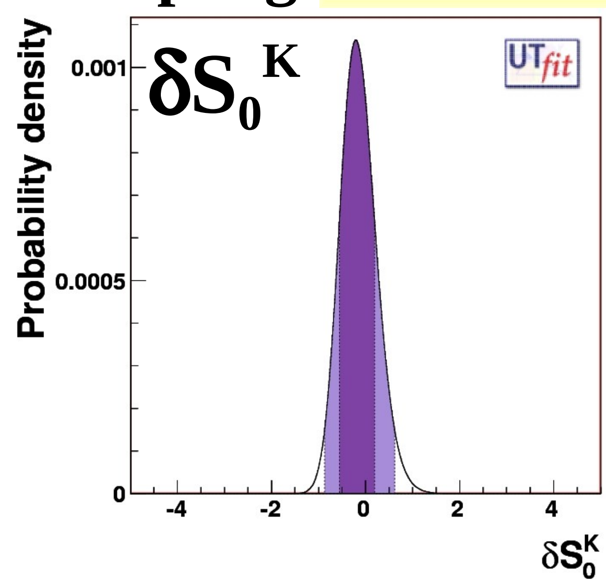
Λ > 5.5 TeV @ 95% Prob.

2 Higgs + large tanβ

➔ also bottom Yukawa coupling

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





Λ > 5.1 TeV @ 95% Prob.

summary and conclusion

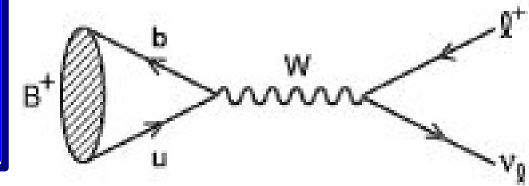
- $b \to d$ transition: given the enormous quantity of results the B factories have already achieved, the generalization of the UT analysis beyond the SM is already strongly effective in limiting the NP parameter space.
  - it gives serious constraints on model building
  - it points to MFV
- $b \to s$ transitions are starting to be impressively constrained, thanks to new measurements from the Tevatron:
  - from CDF: $\Delta\Gamma_S/\Gamma_S$, flavour specific τ_{B_S}
  - from D0: 3-dimensional β_S, $\Delta\Gamma$ and Γ bound
- in the MFV scenario it is possible to turn UT analysis into a probe for NP scale
- future scenarios..

see:
M. Pierini and V. Vagnoni in WG joint session

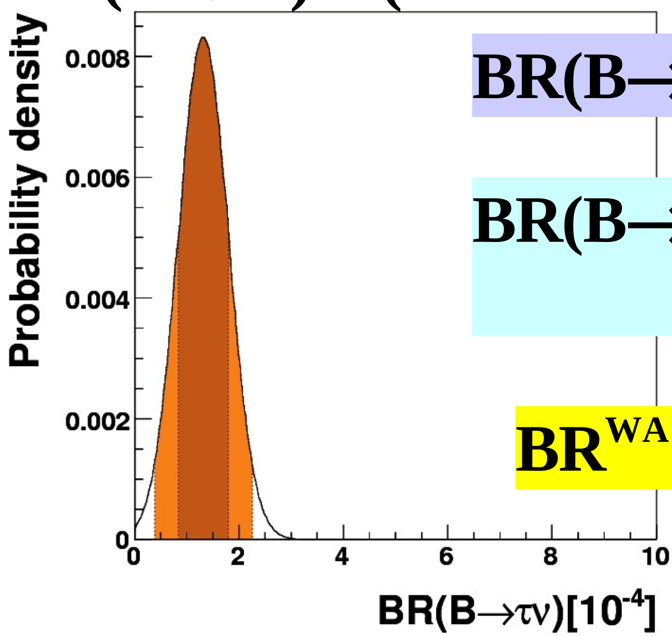
back-up slides

$B \to \tau\nu$

$$\mathcal{B}(B \to \ell\nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

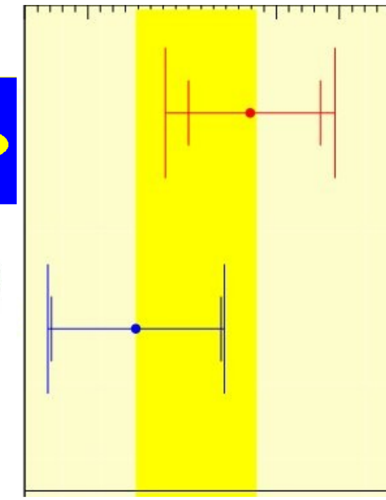


$BR(B\to\tau\nu) = (1.06 \pm 0.38)\ 10^{-4}$



$BR(B\to\tau\nu) = (1.79 \pm 0.52 \pm 0.43)\ 10^{-4}$ (BELLE)

$BR(B\to\tau\nu) = (0.88 \pm 0.68 \pm 0.11)\ 10^{-4}$
$BR < 1.80\ 10^{-4}$ @ 90% CL

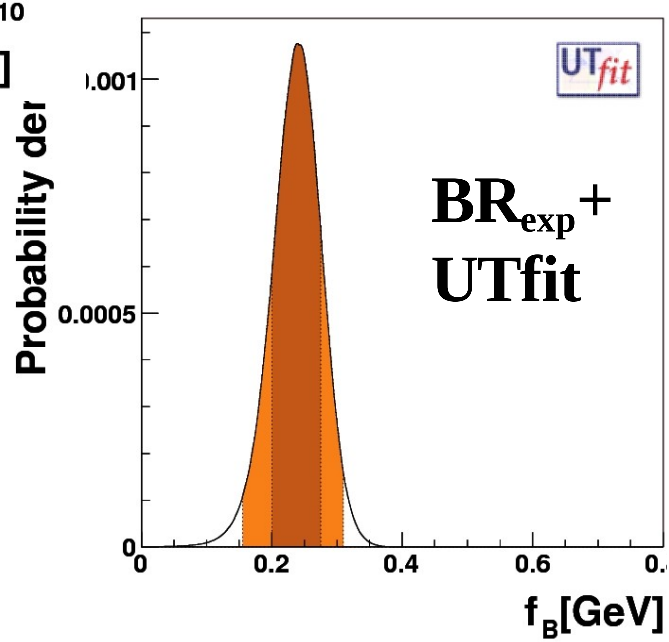


$BR^{WA}(B\to\tau\nu) = (1.36 \pm 0.48)\ 10^{-4}$

Assuming V_{ub} :

$f_{Bd} = 0.237 \pm 0.037$ GeV

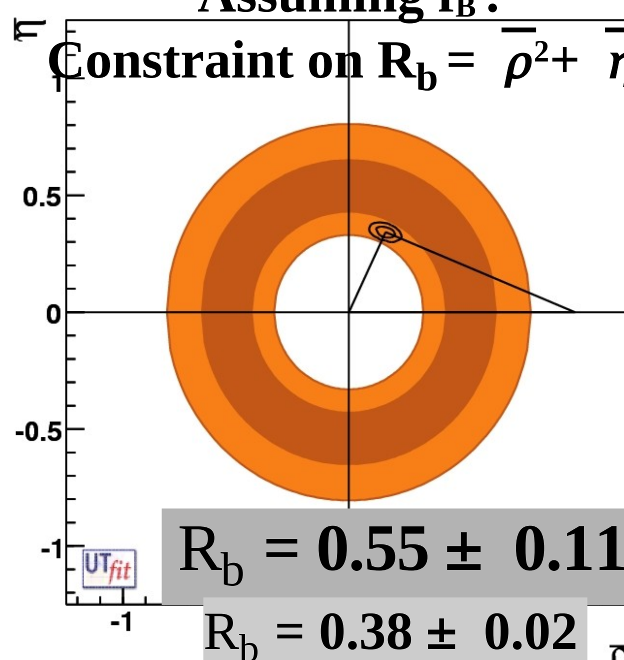
$f_{Bd} = 0.189 \pm 0.027$ GeV from lattice QCD



BR_{exp}+ UTfit

Assuming f_B :

Constraint on $R_b = \bar\rho^2 + \bar\eta^2$



$R_b = 0.55 \pm 0.11$

$R_b = 0.38 \pm 0.02$

MFV bound from radiative decays

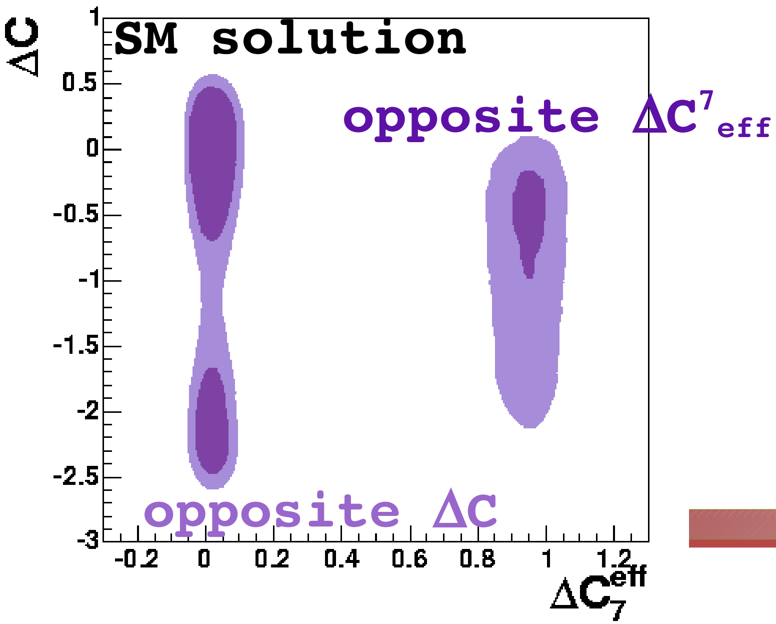
NP in MFV scenarios can be parameterized with few real parameters, shifts of the master functions in

- Z vertex
- cromomagnetic penguin
- box diagrams
- gluonic penguin

Relevant contributions in rare leptonic and radiative decays

Once CKM is known, we can bound NP with rare decays. At small/moderate tanβ, all the effects on leptonic/radiative modes from two parameters:

- ΔC: NP in Z vertex (bound from $b\to s\gamma$)
- ΔC^{7}_{eff}: NP in cromomagnetic penguin (bound from $b\to sll$)

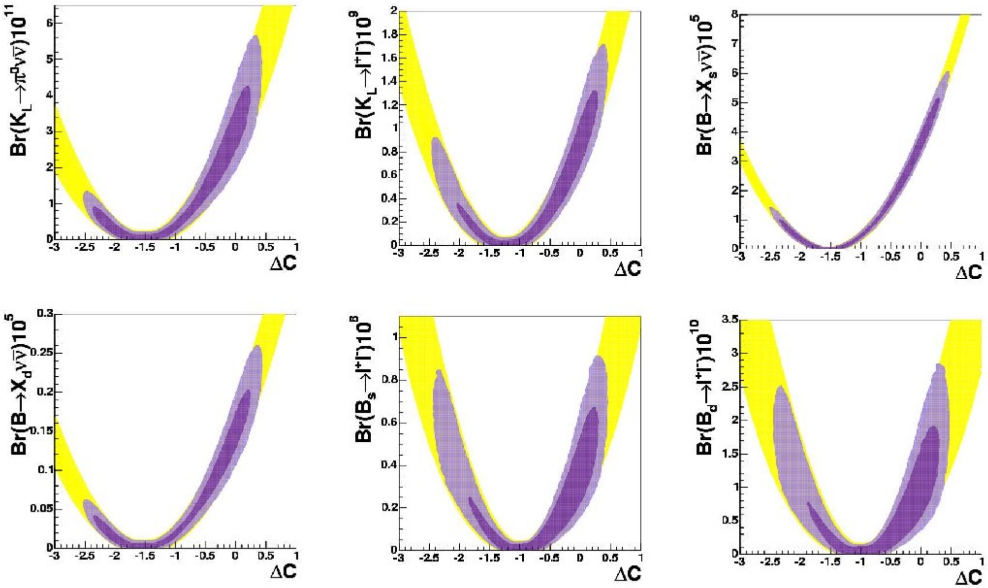


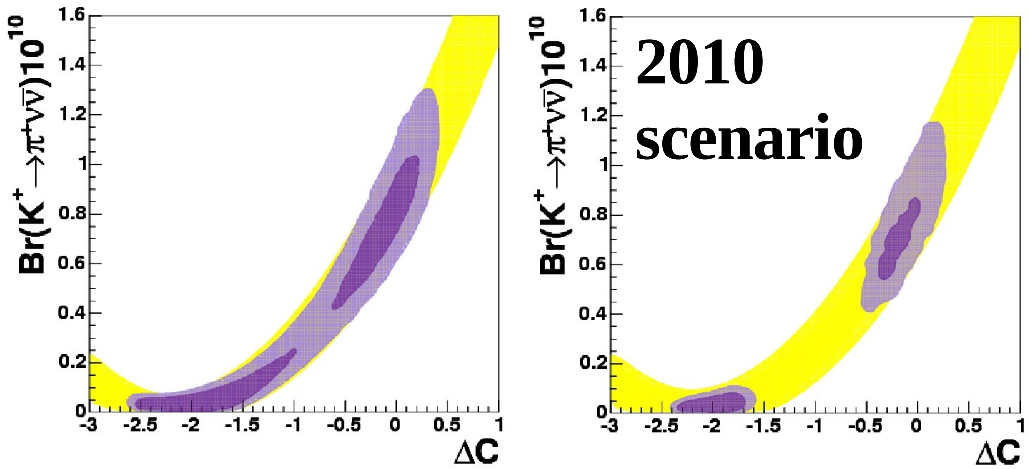
Predictions on rare decays can be obtained from this. This peculiar correlation can be tested with new measurements

C. Bobeth *et al.*
Nucl.Phys.B726:252-274,2005
hep-ph/0505110

MFV prediction for rare decays

low/moderate $\tan\beta$





Branching fractions	**MFV(95%)**	SM (95%)	exp
$Br(K^+ \to \pi^+ \nu\nu) \times 10^{11}$	**<11.9**	[6.1-10.9]	14.7+13.0-8.9
$Br(K_L \to \pi^0 \nu\nu) \times 10^{11}$	**<4.59**	[2.03-4.26]	$<5.9 \times 10^4$
$Br(K_L \to \mu\mu) \times 10^9$	**<1.36**	[0.63-1.15]	
$Br(B \to X_s \nu\nu) \times 10^5$	**<5.17**	[3.25-4.09]	<64
$Br(B \to X_d \nu\nu) \times 10^6$	**<2.17**	[1.12-1.91]	
$Br(B_s \to \mu\mu) \times 10^9$	**<7.42**	[1.91-5.91]	$<2.7 \times 10^2$
$Br(B_d \to \mu\mu) \times 10^{10}$	**<2.20**	[0.47-1.81]	$<1.5 \times 10^3$

K physics

$B_{d,s}$ physics

Very interesting the A_{FB} asymmetry of $B \to K^*ll$