Testing Standard Model and New Physics with the Unitarity Triangle fit

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on behalf of UT_{fit} Collaboration

http://www.utfit.org

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Unitarity Triangle

Using the Unitarity of the CKM matrix in the SM we can build the Unitarity Triangle.

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

CP violation in SM is ruled only by one parameter.

- Determine it in several ways (test of SM)
- Fit simultaneously for SM and New Physics quantities

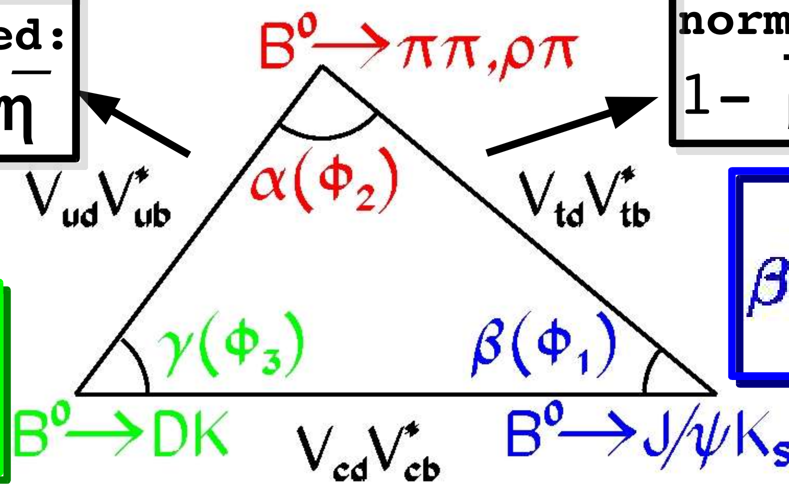
UT_{fit} Coll, hep-ph/0501199

UT_{fit} Coll, hep-ph/0509219

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

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

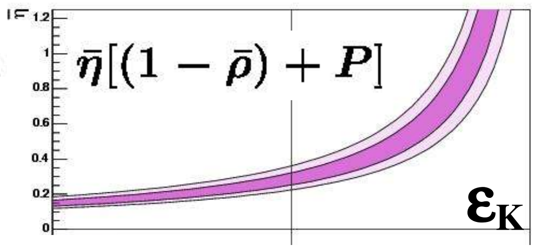
normalized: $1 - \bar{\rho} + i\,\bar{\eta}$

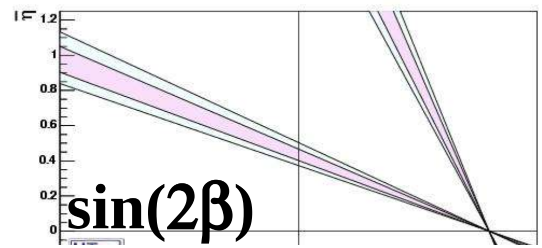


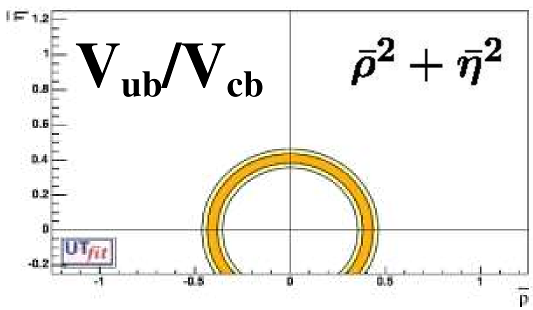
$$\beta = atan\left(\frac{\bar{\eta}}{(1-\bar{\rho})}\right)$$

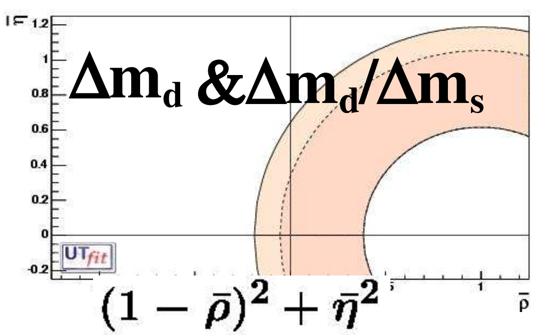
$$\gamma = atan\left(\frac{\bar{\eta}}{\bar{\rho}}\right)$$

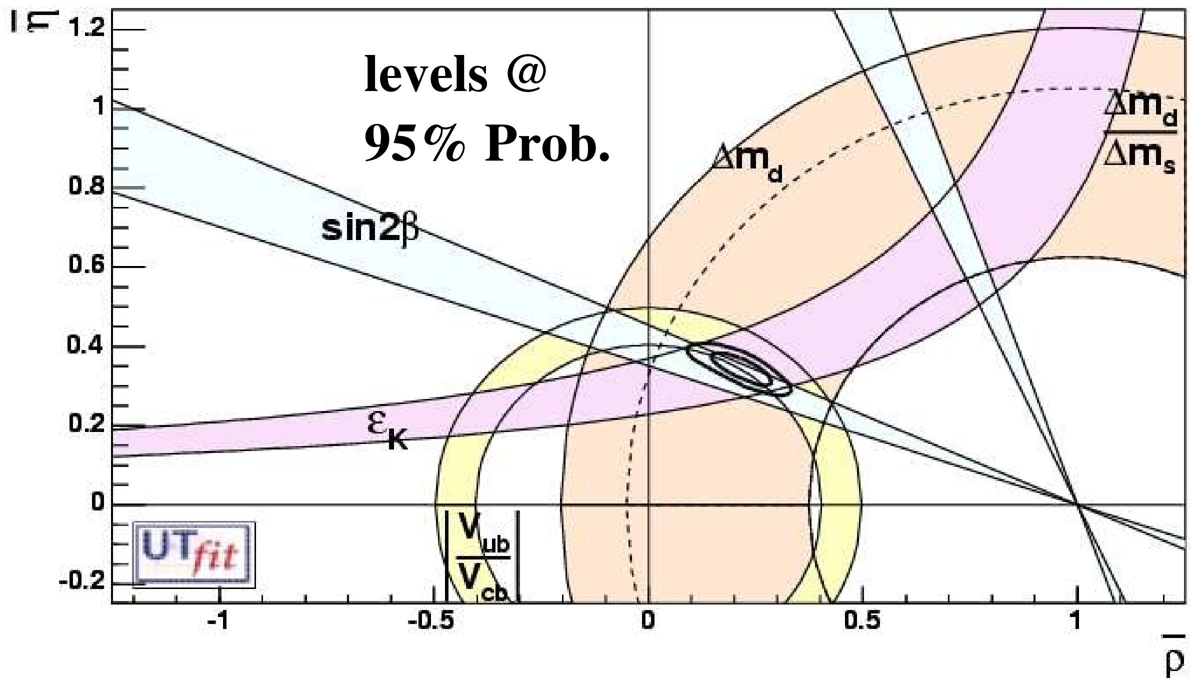
The "Classic Fit"...







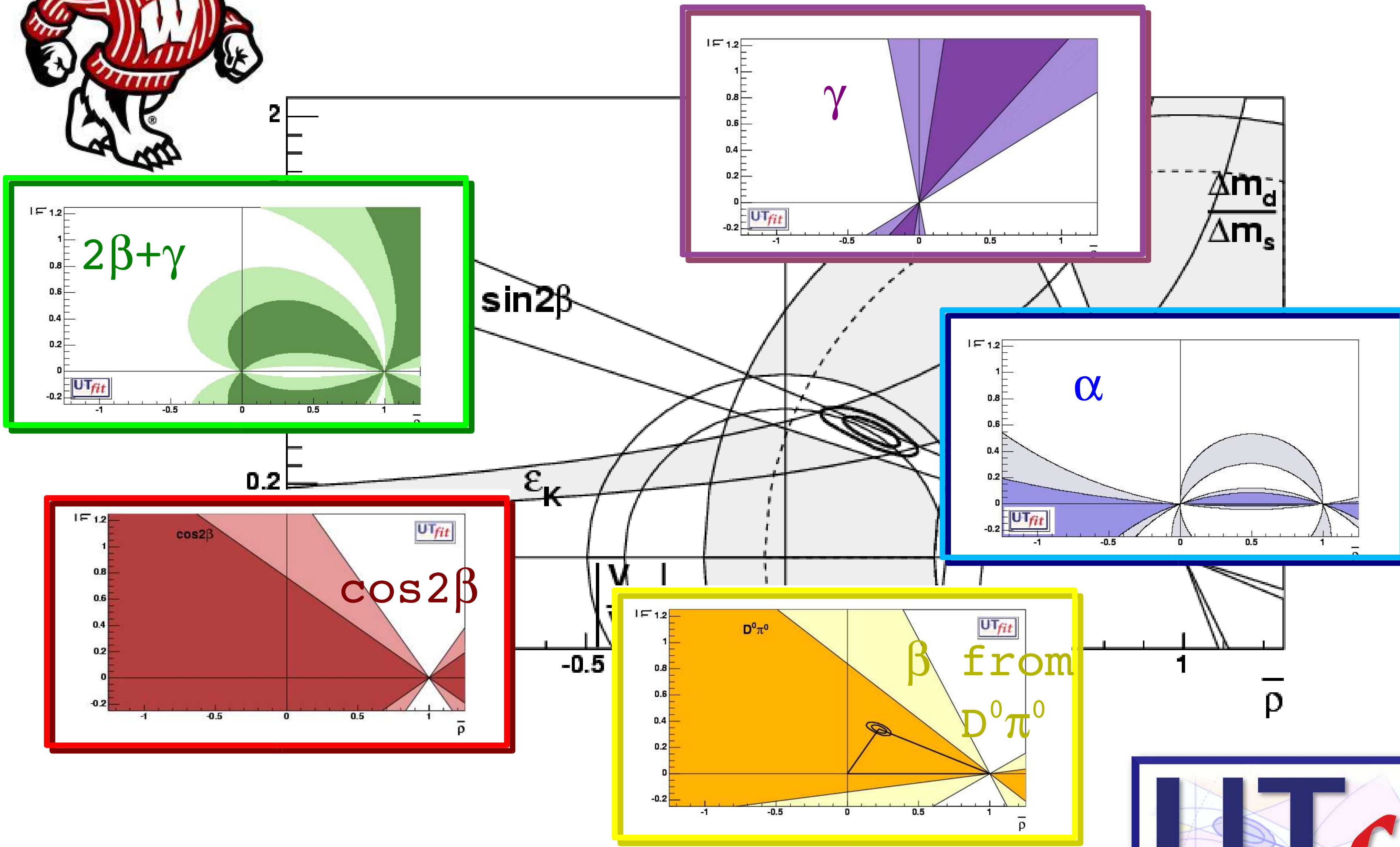




$\bar{\rho} = 0.214 \pm 0.047$
[0.112, 0.307] @ 95% Prob.

$\bar{\eta} = 0.343 \pm 0.028$
[0.289, 0.396] @ 95% Prob.

..and new bounds from B factories



α from isospin analysis: $\pi\pi$, $\rho\rho$, $\rho\pi$

See J.Malclès' & A.Kusaka's talks

From the SU(2) amplitudes ($\pi\pi$, $\rho\rho$):

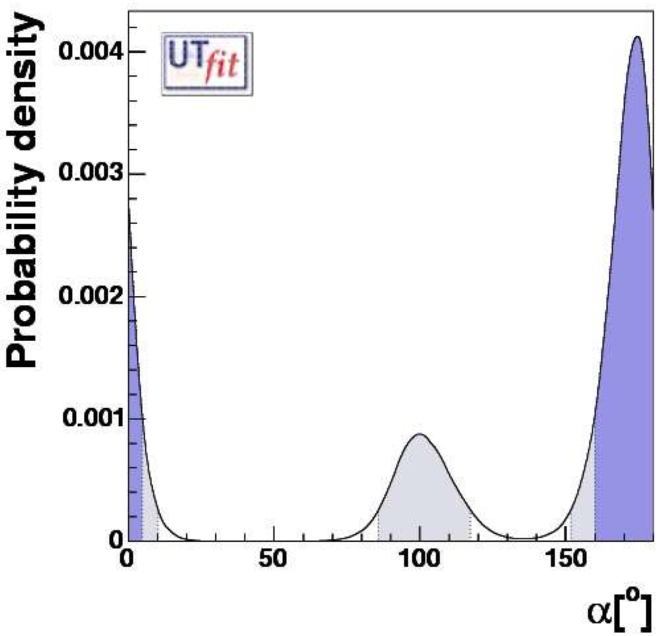
$$A^{+-} = -Te^{-i\alpha} + Pe^{i\delta_P}$$

$$A^{+0} = -1/\sqrt{2}\, e^{-i\alpha}\,(T + T_C\, e^{i\delta_C})$$

$$A^{00} = -1/\sqrt{2}\,(T_C\, e^{i\delta_C}\, e^{-i\alpha} + Pe^{i\delta_P})$$

unknowns: $T, P, T_C, \delta_P, \delta_{T_C}, \alpha$

observable: 3x BR, C_{+-}, S_{+-}, C_{00}



α = [86, 107]° U [152, 90]° @ 95% Prob.

Similar analysis for $(\rho\pi)^0$ on the Dalitz plane

$$A^k = T^k e^{-i\alpha} + P^k$$

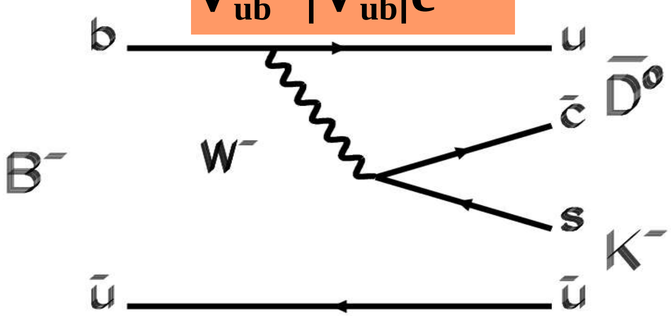
$$\bar{A}^k = T^{\bar{k}} e^{i\alpha} + P^{\bar{k}}$$

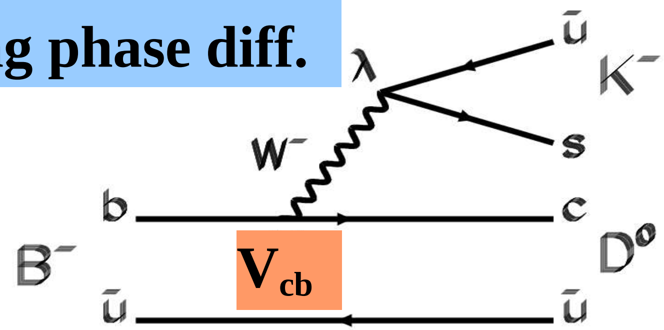
with k=+- for $\rho^+\pi^-$, -+ for $\rho^-\pi^+$, e 00 for $\rho^0\pi^0$

γ from $B \to D^{(*)}K^{(*)}$ decays

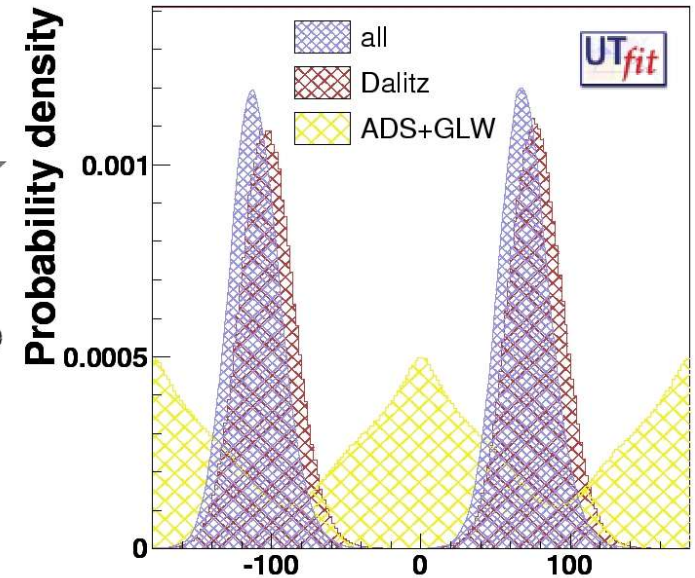
r_B = ratio of amplitudes
δ_B = strong phase diff.

$V_{ub}=|V_{ub}|e^{-i\gamma}$





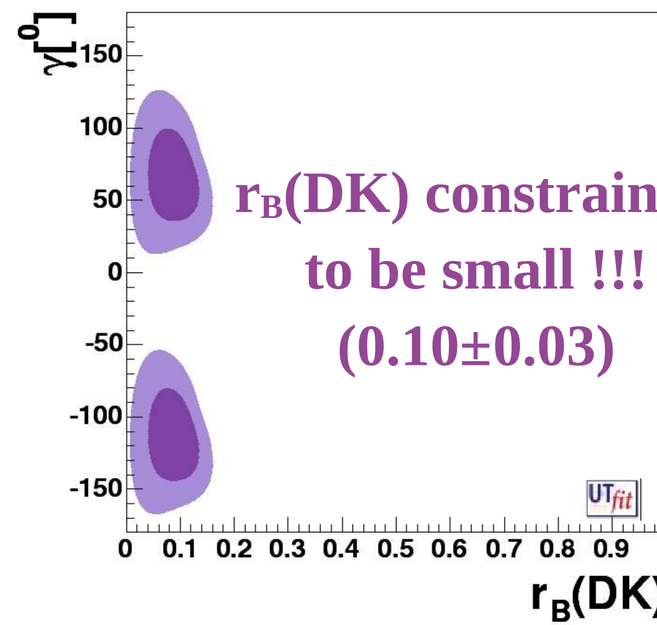
V_{cb}



See J.Malclès' talk

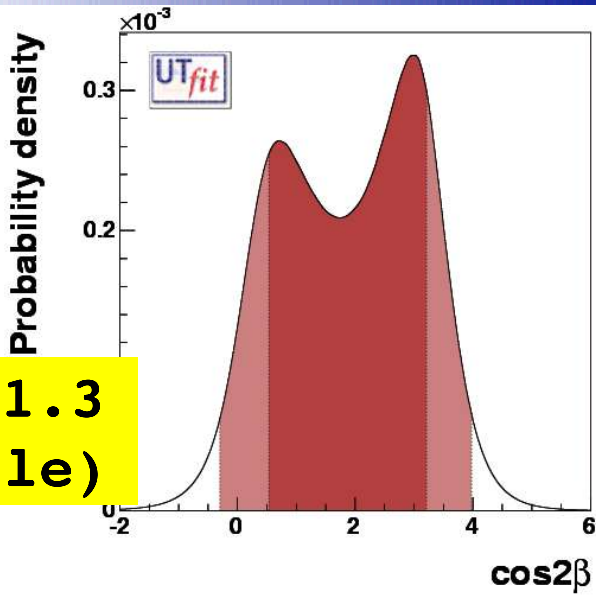
$\gamma = (66 \pm 17)^o$ U $(-114 \pm 187)^o$

- ADS(Atwood,Dunietz,Soni) method:
  B^0 and $\overline{B}^0$ into the same final state
  $$R_{ADS} = r_B^2 + r_{DCS}^2 + 2 r_B r_{DCS} \cos\gamma \cos(\delta_B + \delta_D)$$
- GLW(Gronau, Londow,Wyler) method:
  use the CP eigenstates $D^{(*)0}_{CP}$
  $$R_{CP\pm} = 1 + r_B^2 \pm 2 r_B \cos\gamma \cos\delta_B$$
- D^0 Dalitz plot analysis with
  $B^- \to D^{(*)0}[K_S\pi^+\pi^-]\, K^-$

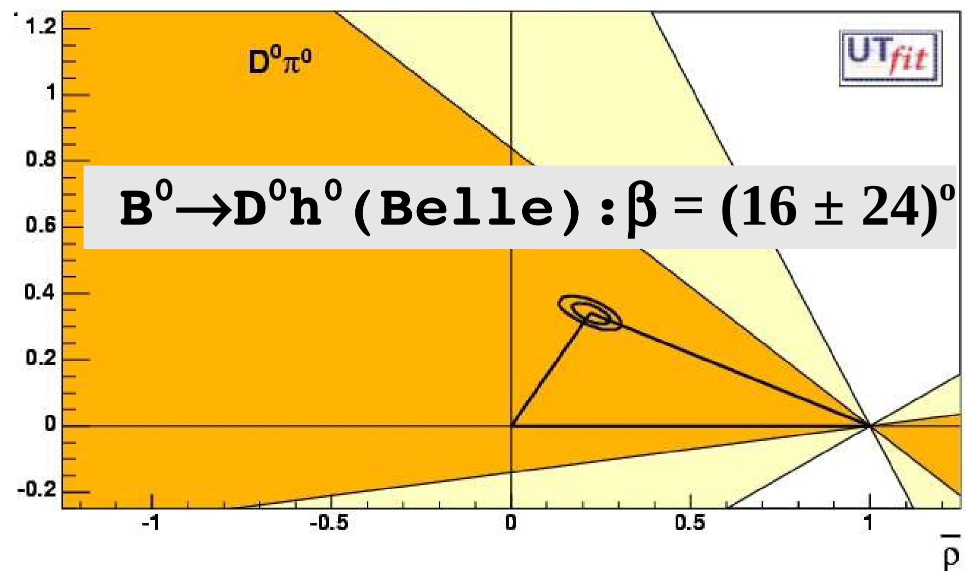


r_B(DK) constrained to be small !!! (0.10±0.03)

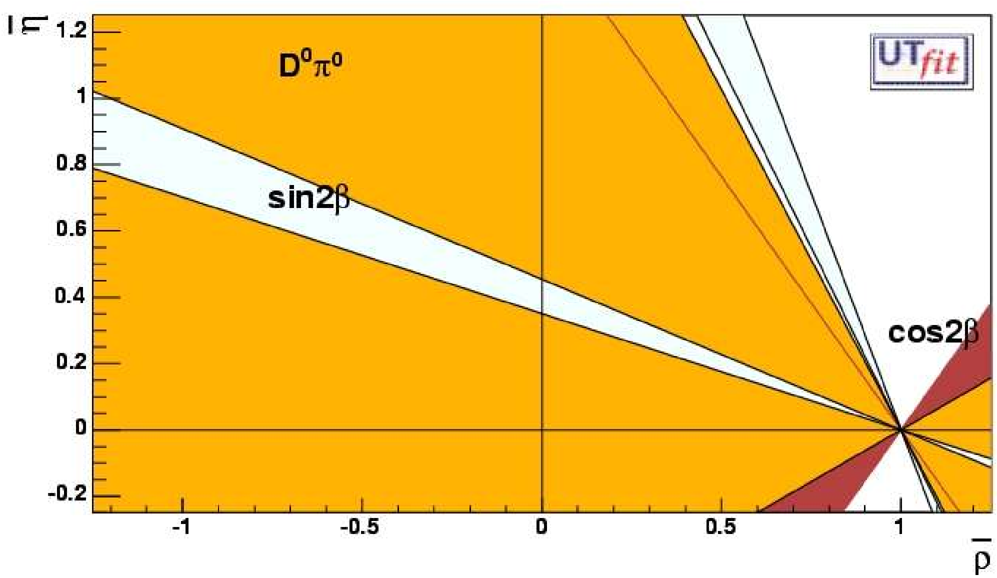
$\cos 2\beta$ from $B \to J/\psi\ K^{*0}$ and $B \to D^0 h^0$



$\cos 2\beta = 1.9 \pm 1.3$ (BaBar+Belle)



$B^0 \to D^0 h^0$ (Belle) : $\beta = (16 \pm 24)^o$

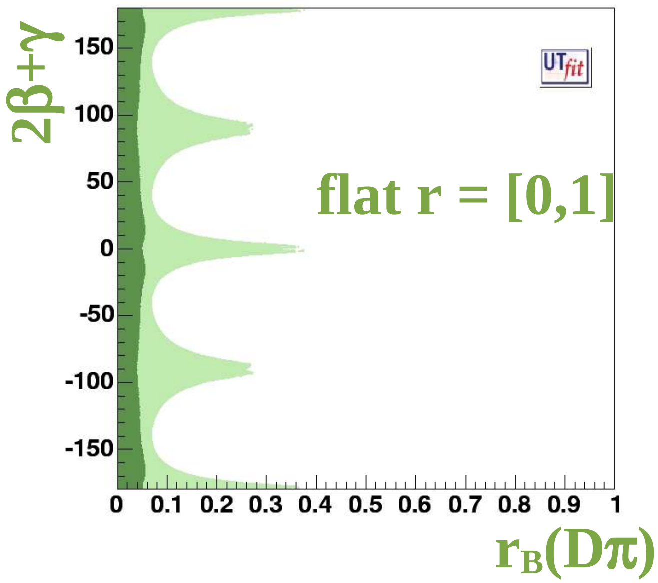


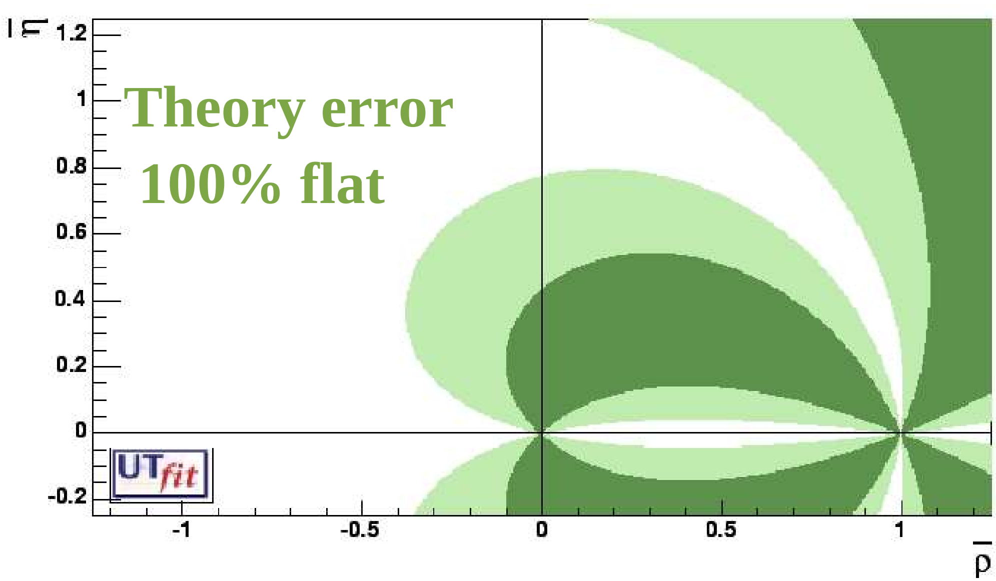
Removes the ambiguity on β coming from $\sin 2\beta$

$2\beta+\gamma$ from $B\rightarrow D^{(*)}\pi(\rho)$

$$a^{(*)} = 2r^{(*)}\sin(2\beta+\gamma)\cos\delta^{(*)}$$

$$c_{lep}^{(*)} = 2r^{(*)}\cos(2\beta+\gamma)\sin\delta^{(*)}$$



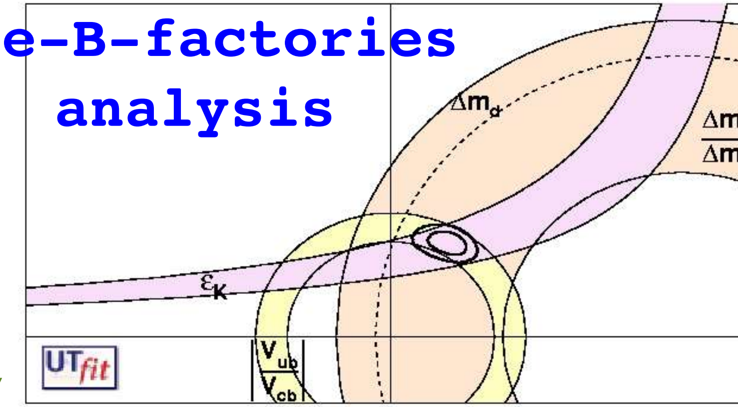


- Interference $b\rightarrow u$ vs $b\rightarrow c$ like in DK decays
- Open system: 2 observables for $2\beta+\gamma$, r and δ
- Only assuming r we can extract $2\beta+\gamma$
  - Extraction of r from $B\rightarrow D_s\pi$
  - Theory error ~100% flat to take into account SU(3) breaking and annihilations in $B\rightarrow D\pi$

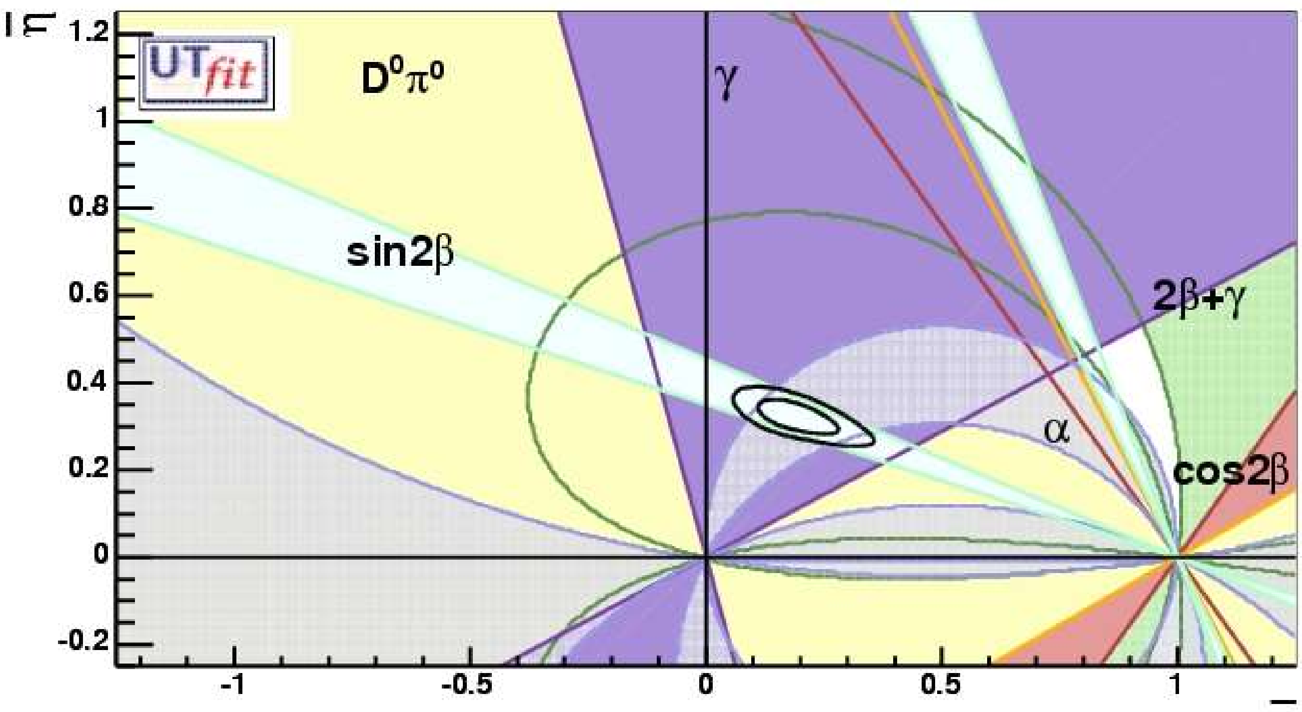
See D. Pirjol, talk at Beauty 2005

Angles Only

pre-B-factories analysis



$\sin 2\beta + \cos 2\beta + \beta + \gamma + \alpha + 2\beta+\gamma$



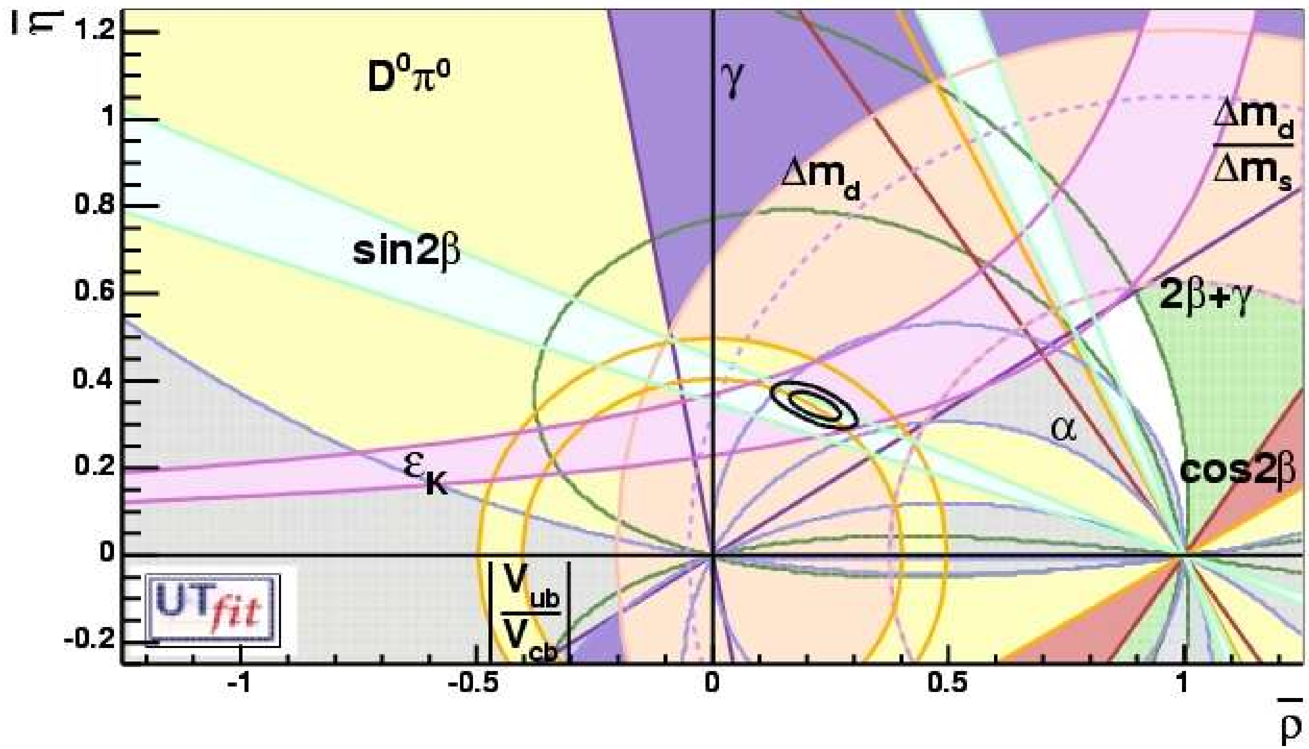
Precision comparable to the pre-B-factories analysis

$\bar{\rho} = 0.193 \pm 0.057$
[0.083, 0.321] @ 95% Prob.

$\bar{\eta} = 0.321 \pm 0.027$
[0.266, 0.376] @ 95% Prob.

Including all the constraints

classic fit + cos2β + β + γ + α + 2β+γ



$\bar{\rho} = 0.216 \pm 0.036$
[0.143, 0.288] @ 95% Prob.

$\bar{\eta} = 0.342 \pm 0.022$
[0.300, 0.385] @ 95% Prob.

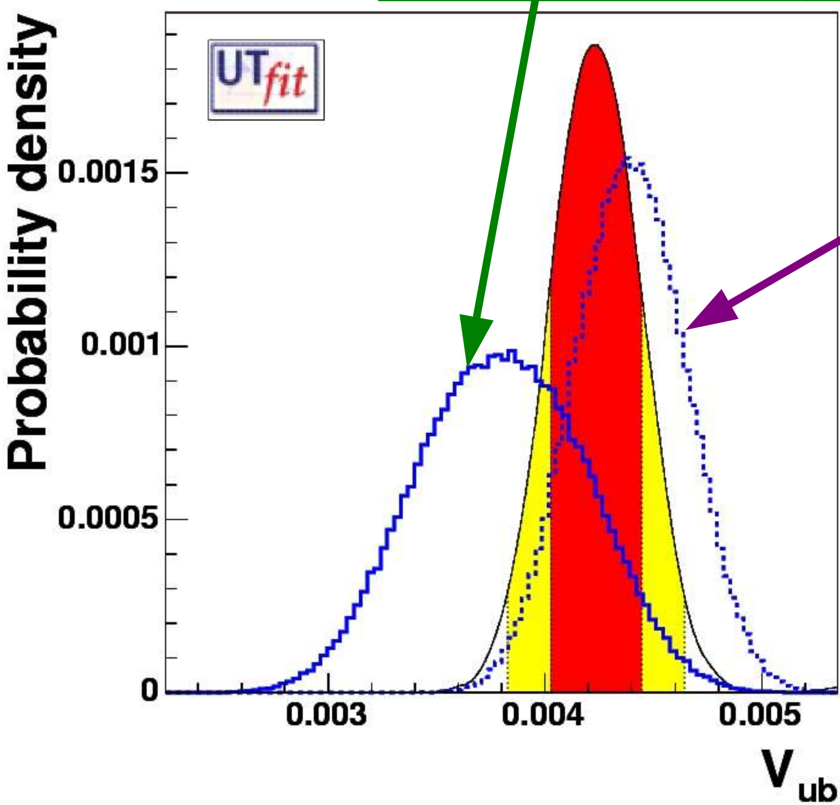
Tension in the fit

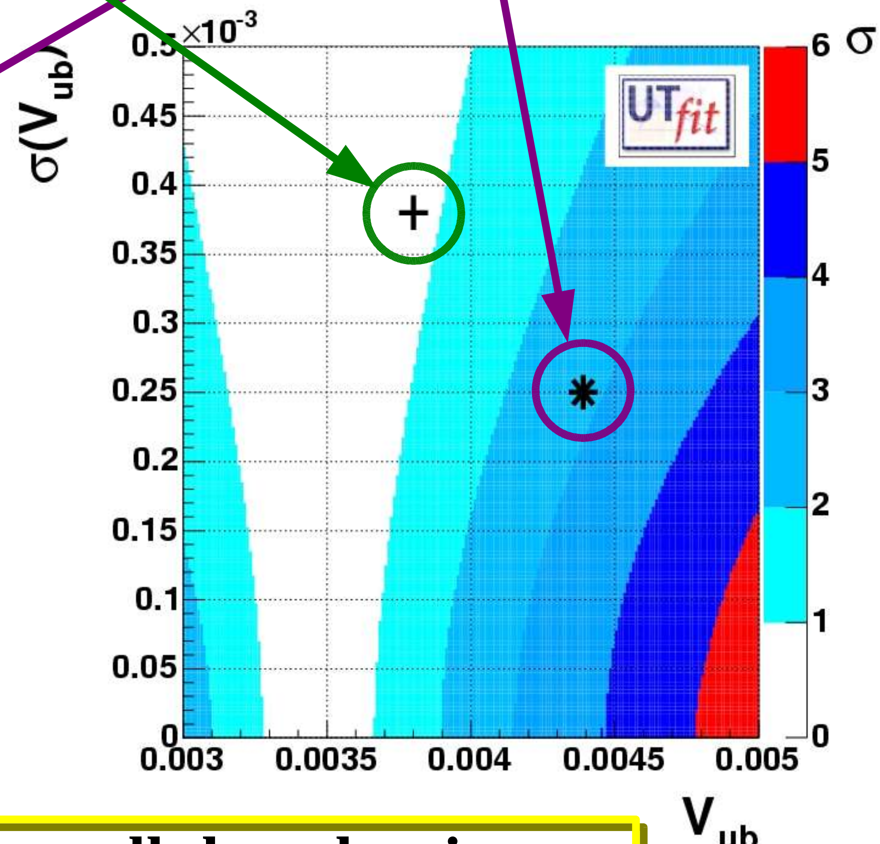
exclusive: BRs from HFAG;
form factor from
quenched LQCD

$V_{ub}=(3.80\pm0.27\pm0.47)10^{-3}$

inclusive from HFAG

$V_{ub}=(4.38\pm0.19\pm0.27)10^{-3}$





incl.+excl.

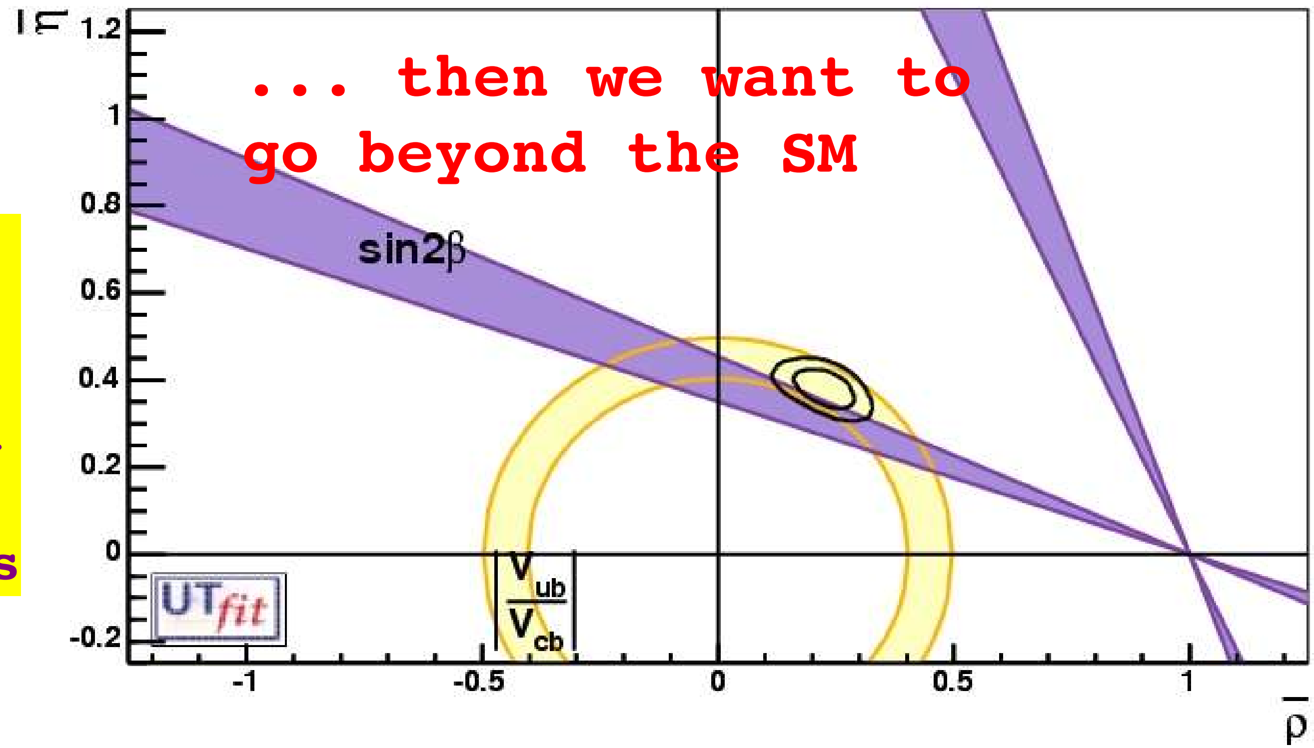
$V_{ub} = (4.22 \pm 0.20)\ 10^{-3}$

from all the other inputs:

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

But if you believe into V_{ub}...

... then we want to go beyond the SM



Ciuchini, M.P, Silvestrini
hep-ph/0507290
Model independent estimation of theoretical errors

$\sin 2\beta = 0.791 \pm 0.034$
from indirect determination

$\sin 2\beta = 0.687 \pm 0.032 \pm 0.017$
From direct measurement

Fit with NP-independent constraints

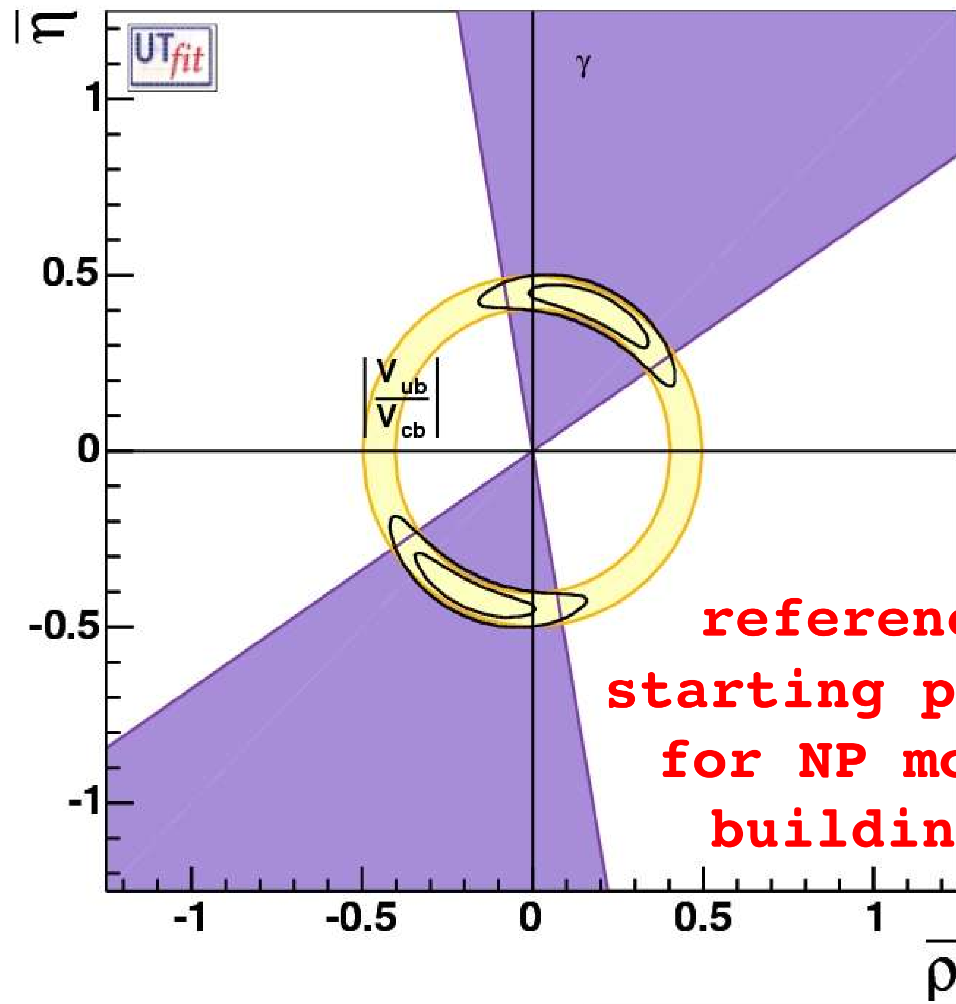
Assuming no NP at tree level

- *the effect of the D0-D0 mixing to γ is negligible wrt the actual error*
- *semileptonic decays are clean*

We have a NP free determination of $\bar{\rho}$ and $\bar{\eta}$

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

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



reference starting point for NP model building

NP: model independent approach

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

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

5 unknowns

	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 ($\rho\rho$,$\rho\pi$,$\pi\pi$)	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

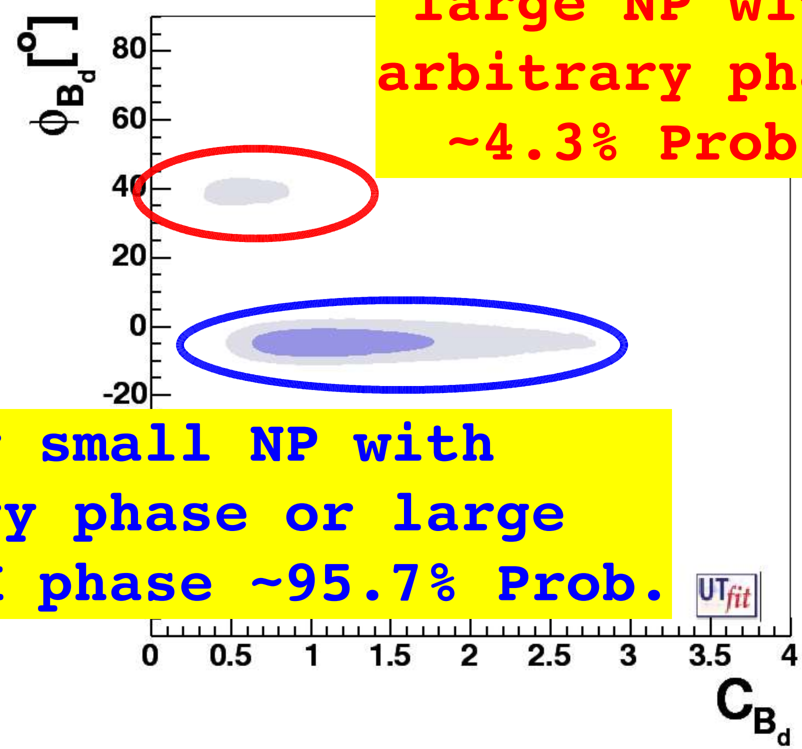
model indepentent assumptions

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]

The UT$_{fit}$ beyond the SM

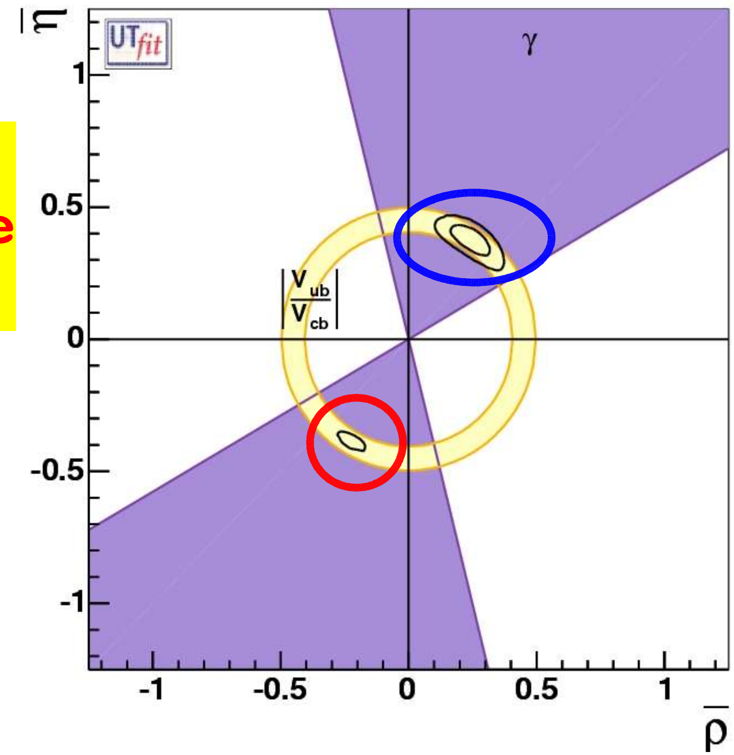
"SM" $\overline{\eta} = 0.379 \pm 0.039$
"NP" [-0.398, -0.381] @ 95% Prob.

"SM" $\overline{\rho} = 0.246 \pm 0.053$
"NP" [-0.230, -0.212] @ 95% Prob.



large NP with arbitrary phase ~4.3% Prob.

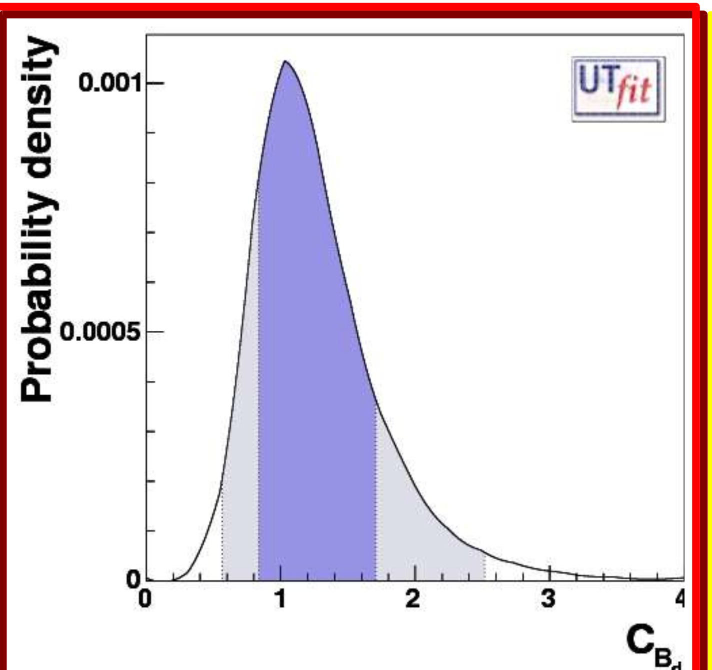
SM or small NP with arbitrary phase or large NP with SM phase ~95.7% Prob.

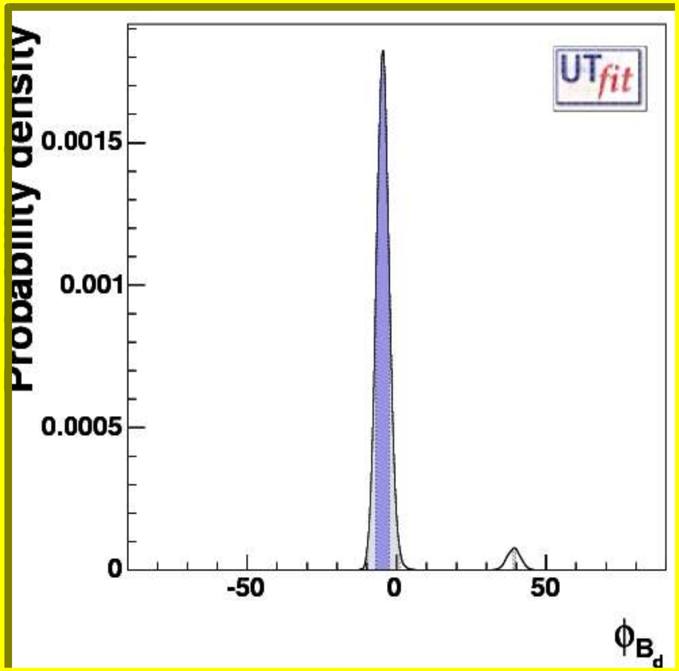


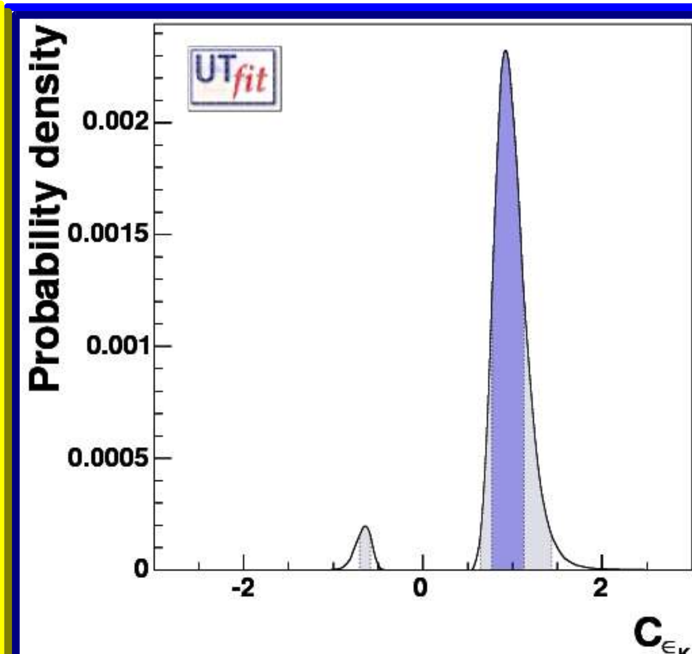
Bounds on NP parameters

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

$C_{B_d} = 1.27 \pm 0.44$ $\phi_{B_d} = -4.7 \pm 2.3^o$ $C_{\varepsilon K} = 0.95 \pm 0.18$



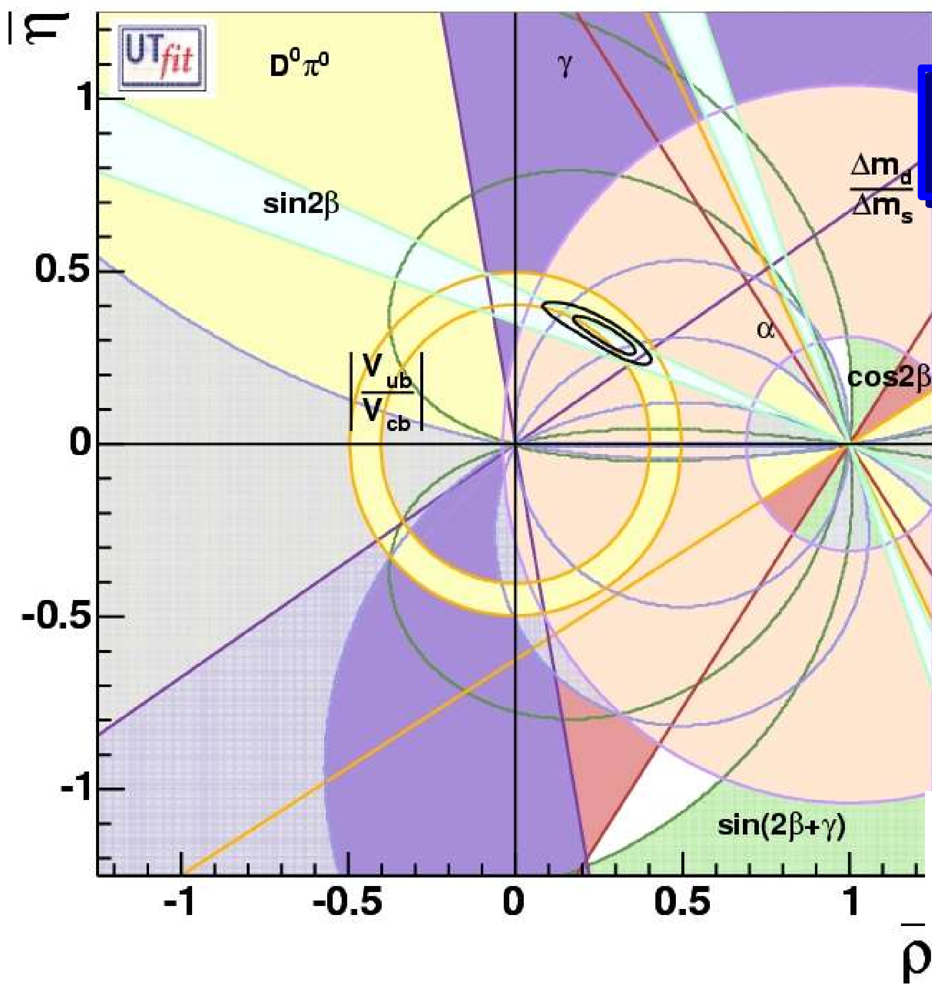


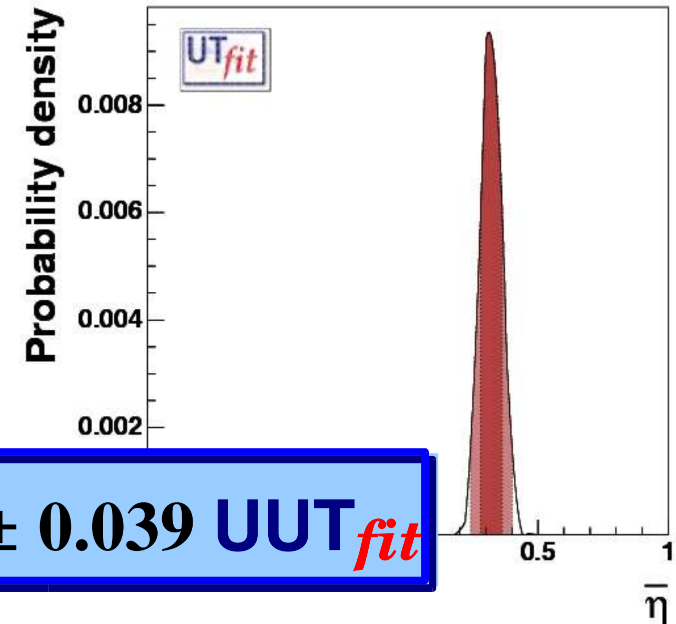


Universal UT$_{fit}$: reference for SM and MFV

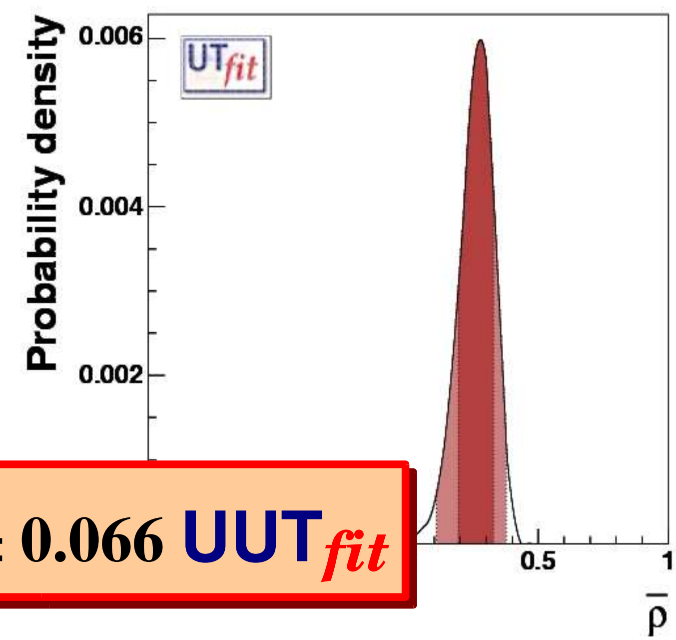
Buras et al.
hep-ph/0007085

MFV = CKM is the only source of flavour mixing. ε_K and Δm_d are not used (sensitive to NP).





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



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

Bounds on NP in MFV from UUT$_{fit}$: Small tanβ

NP enters as additional contribution to the top box diagram

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

D'Ambrosio et al.
hep-ph/0207036

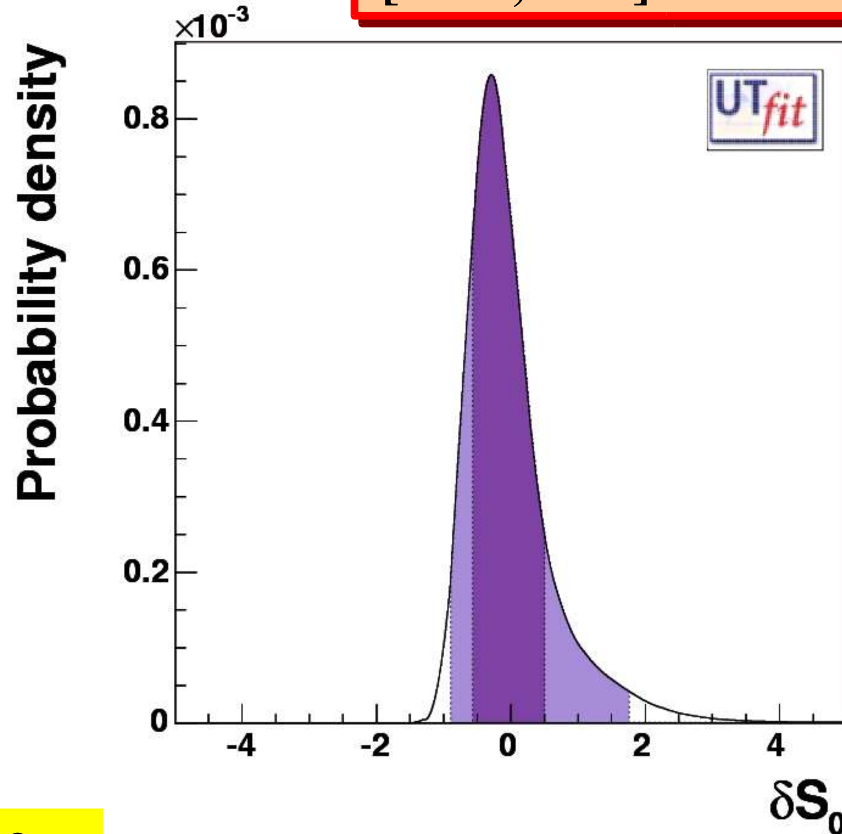
$$S_0(x_t) \rightarrow S_0(x_t) + \delta S_0(x_t)$$

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

a = 1 (as a reference)

Λ_0 = 2.4 TeV

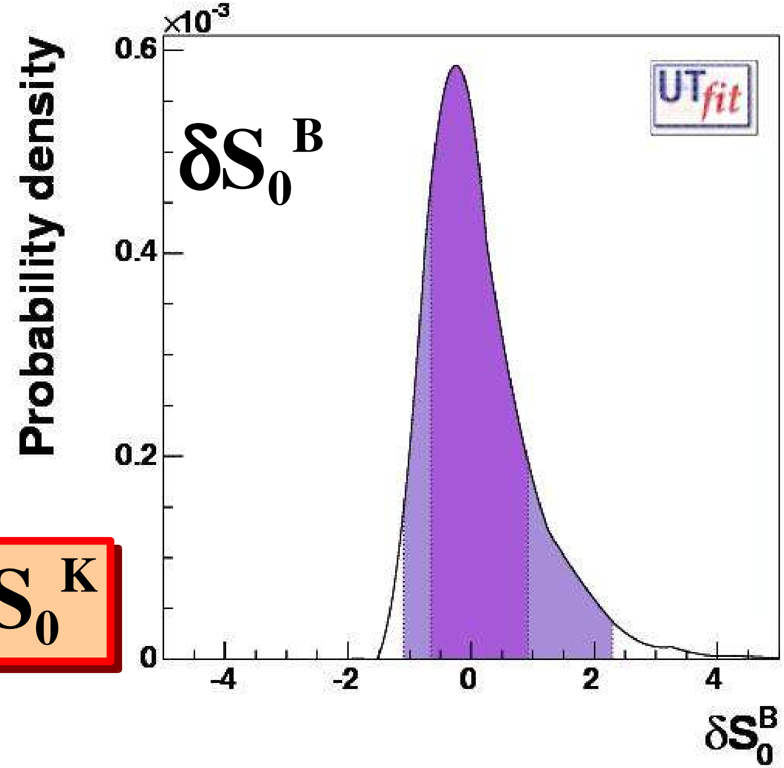
Λ_0 is the equivalent SM scale

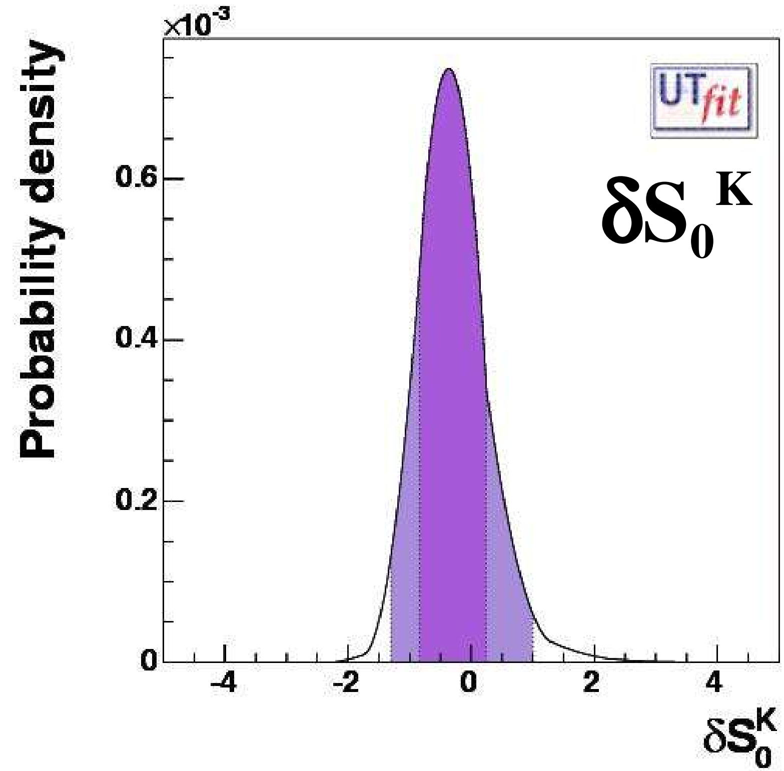


$\Lambda > 3.6$ TeV @ 95% for $\delta S_0(x_t) > 0$

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

Bounds on NP in MFV from UUT$_{fit}$: Large tanβ



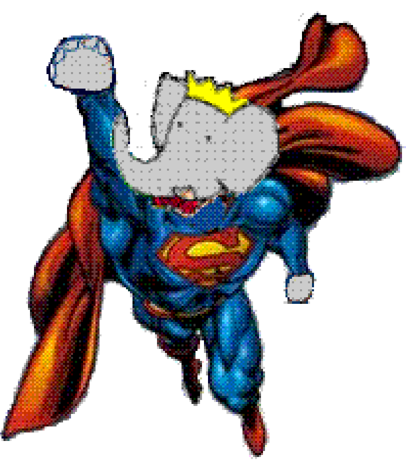


$\delta S_0^B \neq \delta S_0^K$

$\Lambda > 2.6$ 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 $\delta S_0(x_t) < 0$	$\Lambda > 4.9$ TeV @ 95% for $\delta S_0(x_t) < 0$

Conclusions

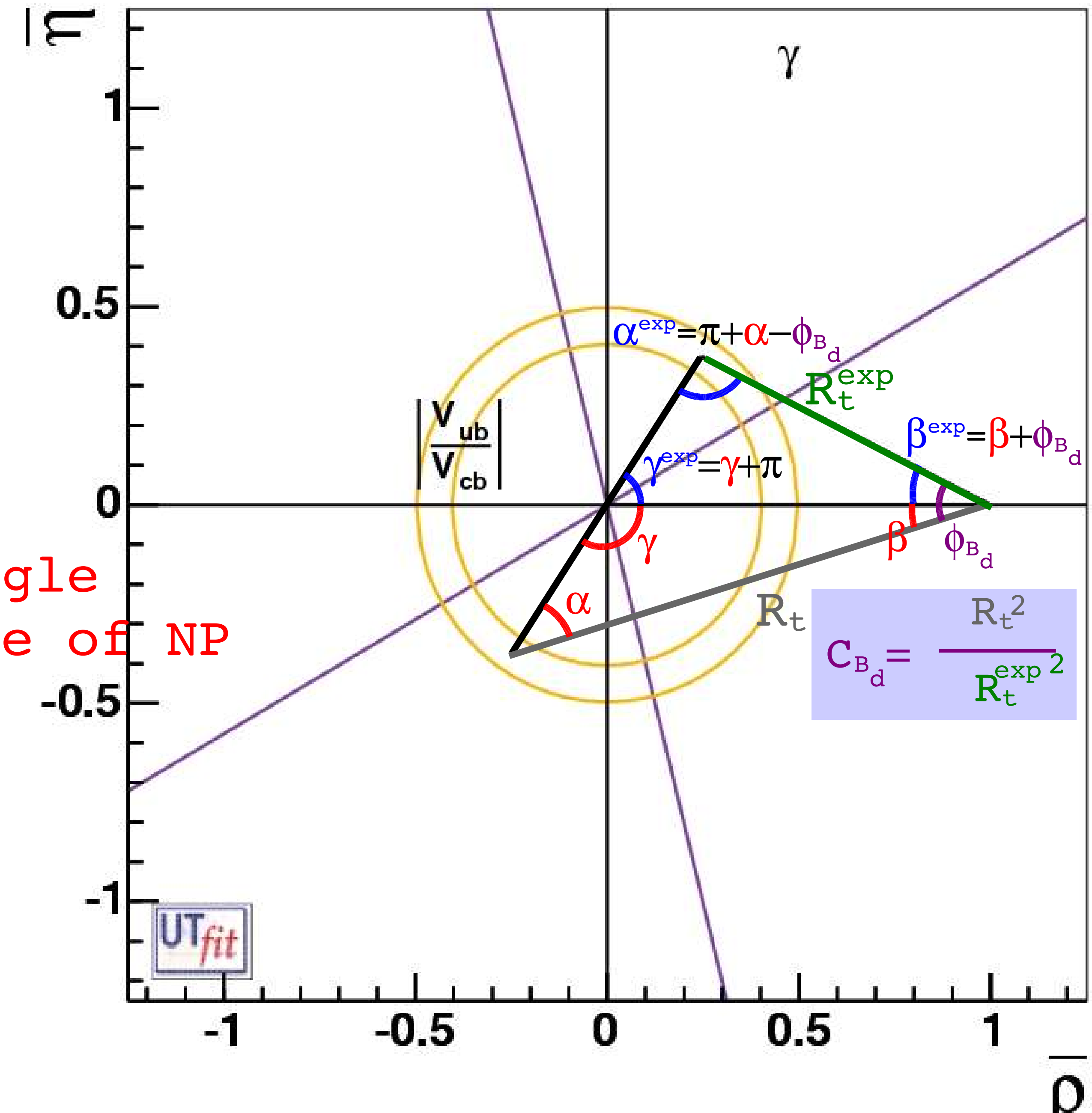
- Large set of new bounds from B-factories allows overconstraining of the Unitarity Triangle
- But the only tension in the fit comes from the "classic" constraaints ($\sin 2\beta$ vs V_{ub})
- We have a ("NP free") tree level determination of $\bar{\rho}$ and $\bar{\eta}$
- All the NP models have to agree with it
- We can start from here to fit SM ($\bar{\rho}$ and $\bar{\eta}$) and NP (corrections to SM in mixing and mixing phases) together
- We go back to the SM solution (up to a fine tuned region)
- Eighter NP effects are small with arbitrary phase...
- ...Or NP effects are large with the same phase of SM MFV
  - UUT as the starting point of SM and MFV analysis
  - We can translate the measurement of MFV NP sensitive quantities (mixing) into bounds on tested scale



We need more data (a Super B factory?)to clarify the interesting situation

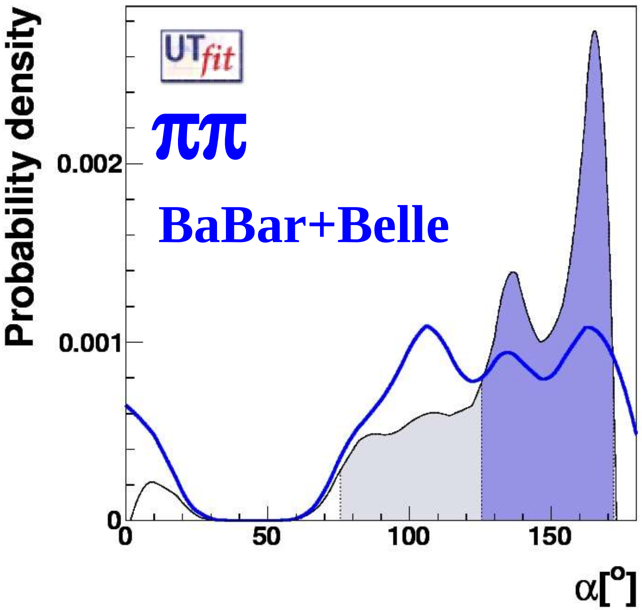
UTfit

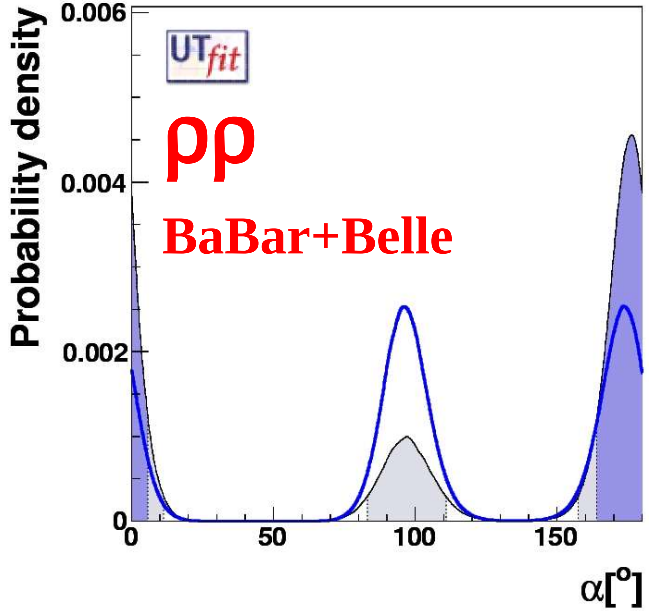
Backup Slides

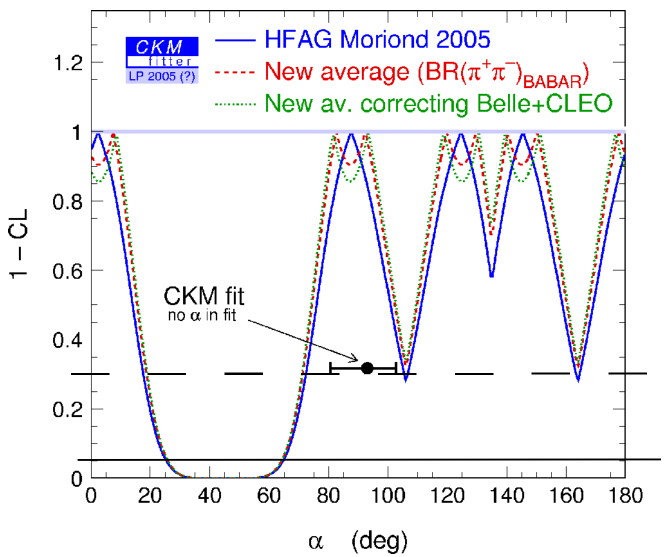


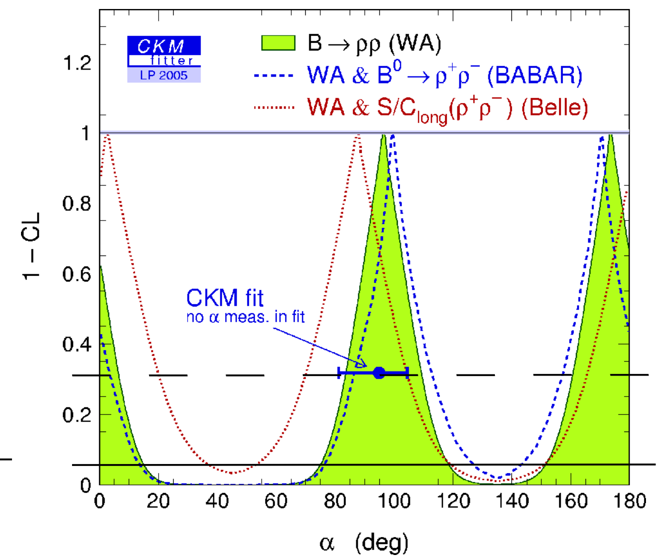
How the triangle change in the case of NP

α from isospin analysis (III): $\pi\pi$ and $\rho\rho$









$C_{\pi\pi}$ and $S_{\pi\pi}$ equal to 0 are excluded

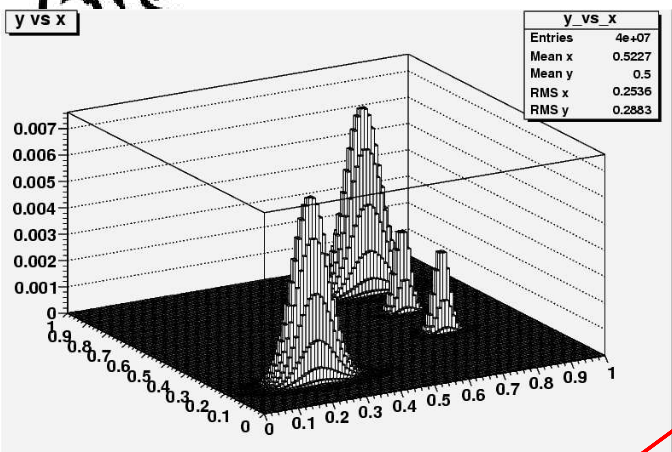
$$C_{\pi\pi} = -0.37 \pm 0.10$$
$$S_{\pi\pi} = -0.50 \pm 0.12$$

$$C_{\rho\rho} = -0.03 \pm 0.17$$
$$S_{\rho\rho} = -0.21 \pm 0.22$$

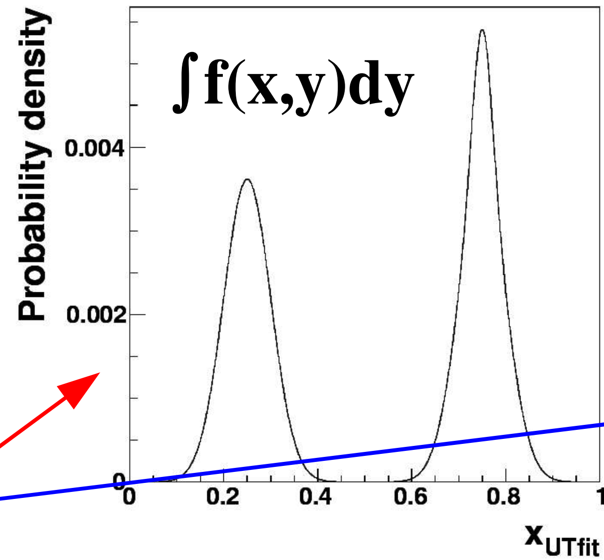
$C_{\rho\rho}$ and $S_{\rho\rho}$ equal to 0 are preferred

α from isospin analysis (IV): toy

what does the difference in peak height mean?

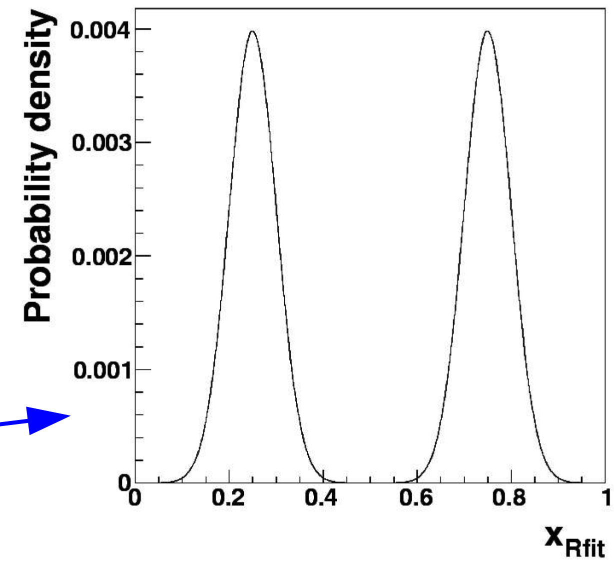


UTfit

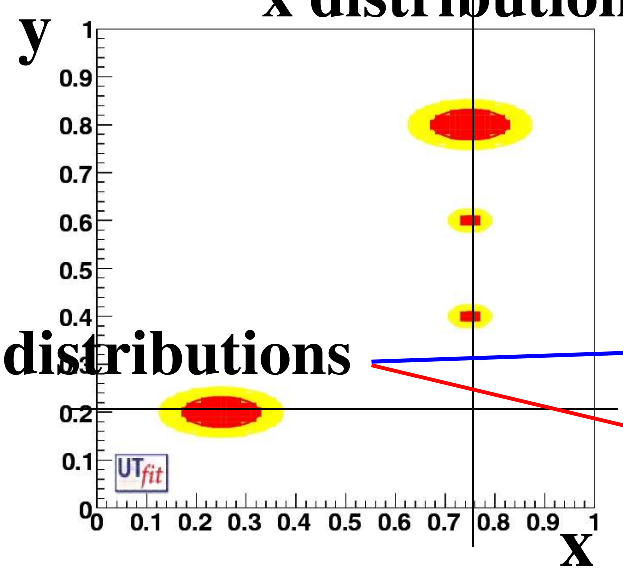


Rfit

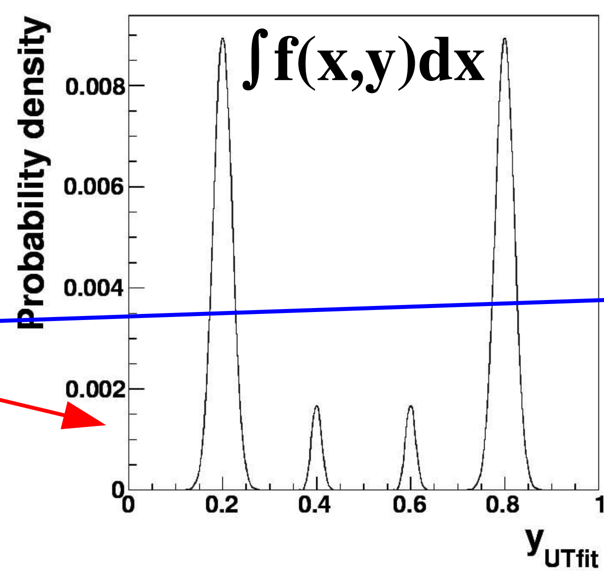
$f(x,y_{MAX})$

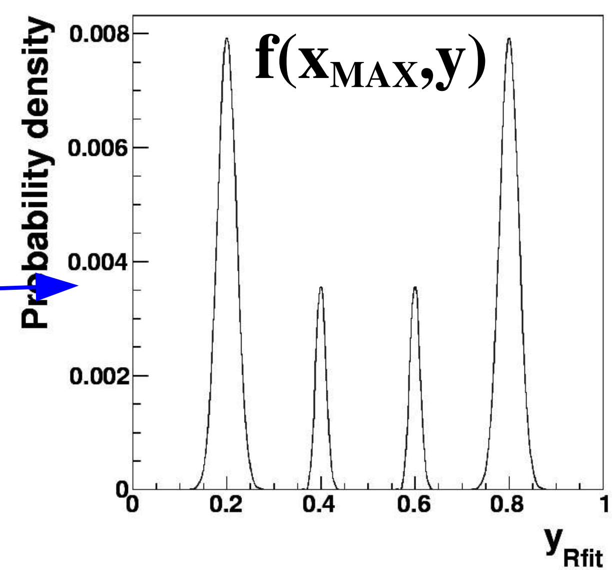


x distributions



y distributions



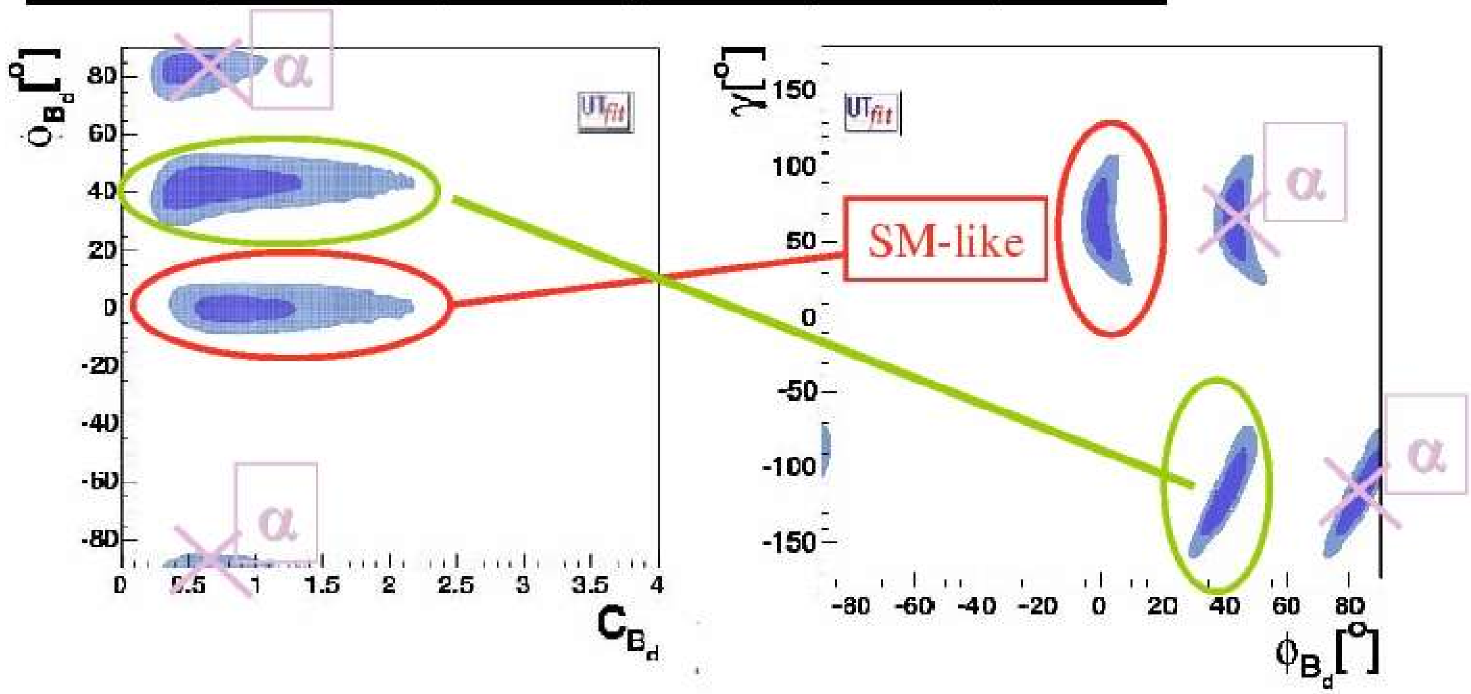


Tree level+sides(fixing C's) and sin2β

	γ	C_d	cos2(β+φ)	sin2(α−φ)	sin(2β+φ)	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

Using

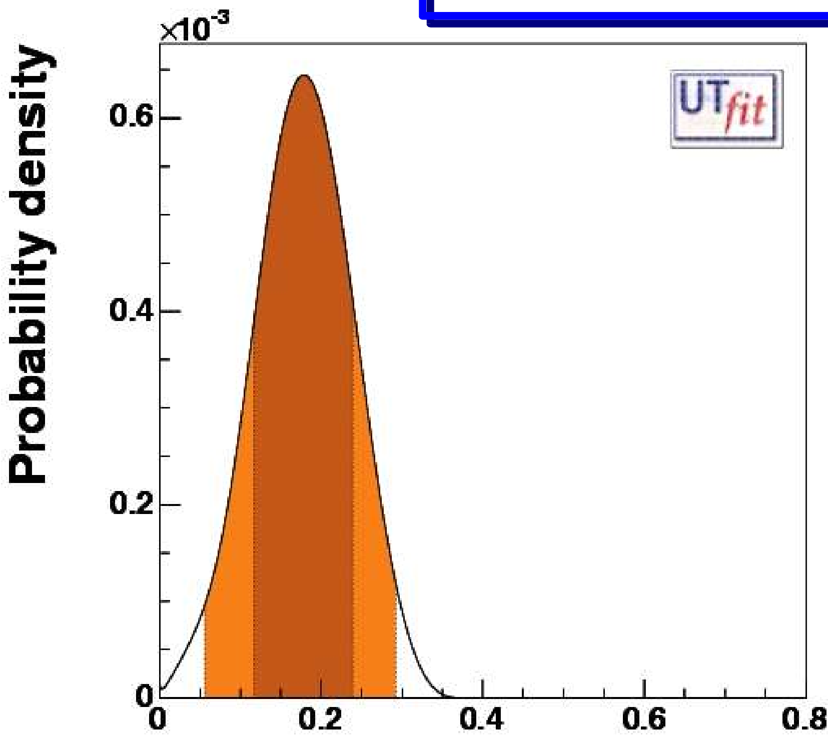
- $|V_{ub}/V_{cb}|$
- Δm_d
- ε_K
- $A_{CP}(J/\psi K^0)$
- $\gamma(DK)$



$B \to \tau\nu$

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

$< 1.8\ 10^{-4}$ @ 90% CL



$f_{Bd} = 0.178 \pm 0.062$ GeV

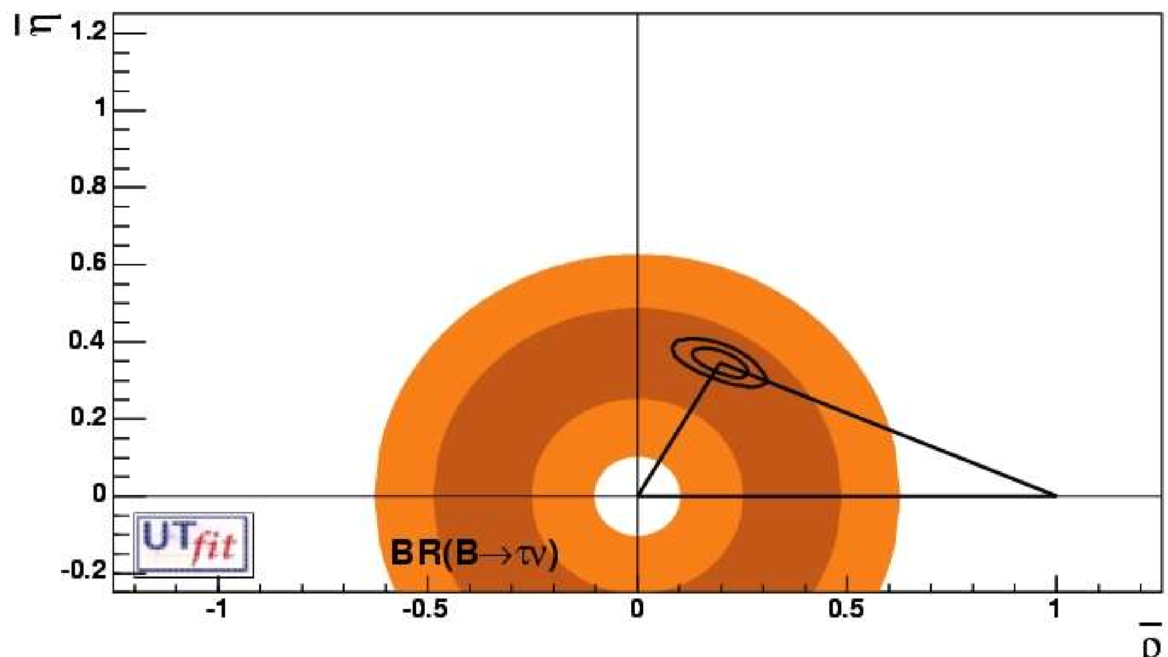
$f_{Bd} = 0.192 \pm 0.026 \pm 0.009$ GeV

from lattice QCD

Assuming f_B :

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

$R_b = 0.37 \pm 0.13$



BR(B → ργ) / BR(B → K*γ)

$$R = c_\rho^2 \frac{r_m}{\xi^2} \frac{|a_7^c(\rho\gamma)|^2}{|a_7^c(K^*\gamma)|^2} \frac{|V_{td}|^2}{|V_{ts}|^2} (1+\Delta R)$$

In case of penguin dominance, R = BR(B → ρ/ωγ)/BR(B → K*γ) can be used to extract $|V_{td}/V_{ts}|$, adding information wrt $\Delta m_d/\Delta m_s$.

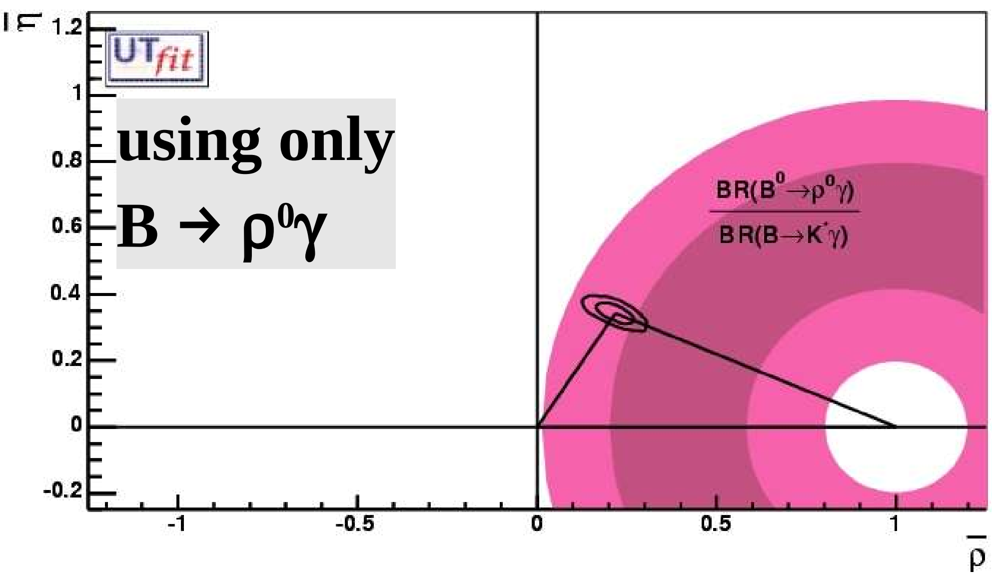
caveat: * SU(3) breaking effect

$\Delta R \sim O(\Lambda_{QCD}/m_b)$

QCD factorisation

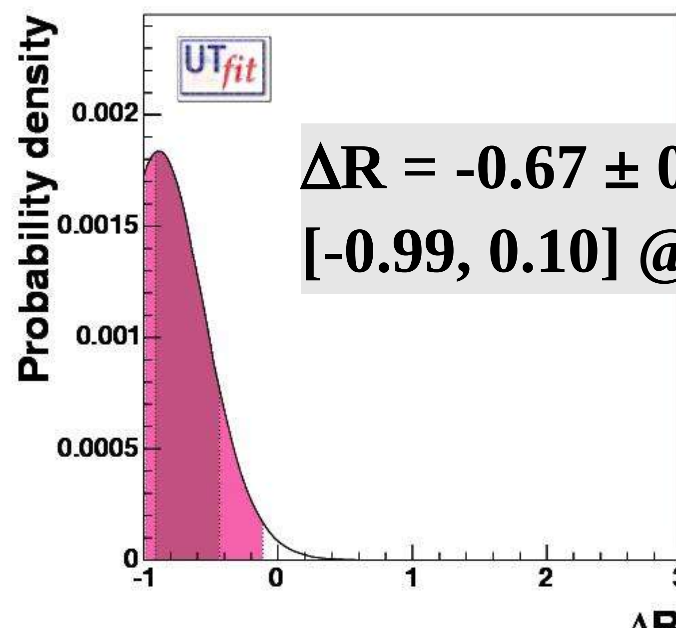
* annihilation in B to ρ/ω γ not in B to K*γ associated to a different CKM factor ($\sim V_{ub}{}^*V_{ud}$)

$|V_{td}/V_{ts}| = 0.10 \pm 0.45$
[0.02,0.18] @ 95% Prob.



using only
B → $\rho^0\gamma$

Using the $|V_{td}/V_{ts}|$ value from the SM, we can extract ΔR.



ΔR = -0.67 ± 0.24
[-0.99, 0.10] @ 95%

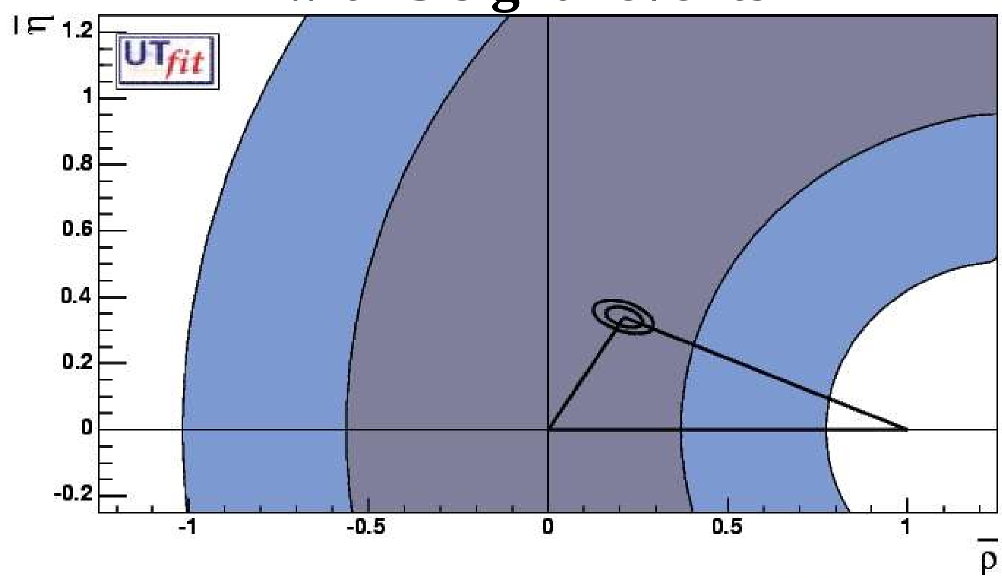
$K^\pm \to \pi^\pm \nu\bar{\nu}$

D'Ambrosio, Isidori
hep-ph/0112135

$$\underbrace{(\sigma\bar{\eta})^2 + (\bar{\rho}-\bar{\rho}_0)^2}_{} = \frac{\sigma BR(K^+ \to \pi^+ \nu\bar{\nu})}{\bar{\kappa}_+ |V_{cb}|^4 X^2(x_t)}$$

ellipse centered in (ρ^0, 0)

with 3 signal events



latest result from E949:

$BR(K^\pm \to \pi^\pm \nu\bar{\nu}) = 1.47^{+1.30}_{-0.89}\ 10^{-10}$

with the hypothesis of ~100 signal events