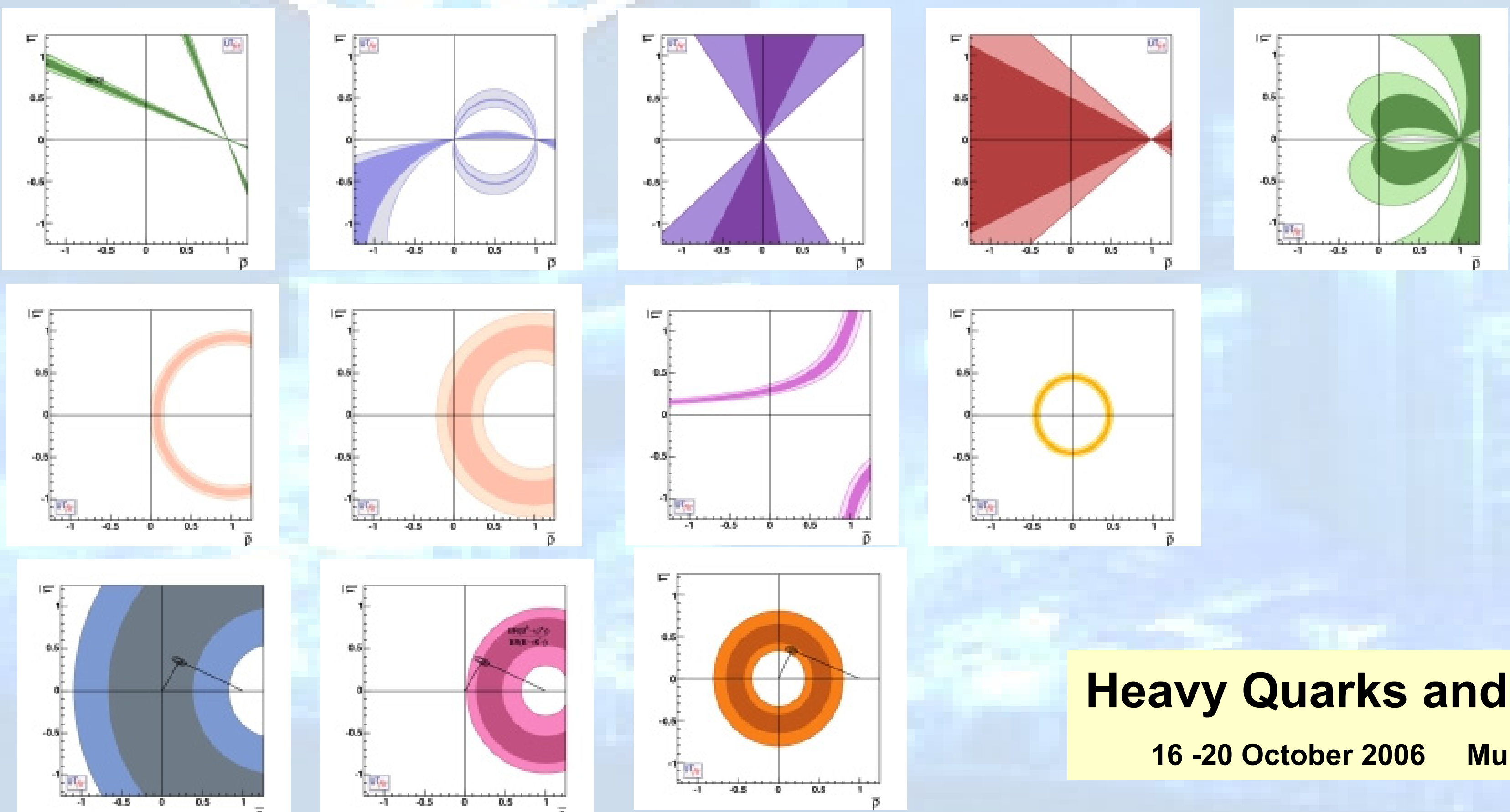
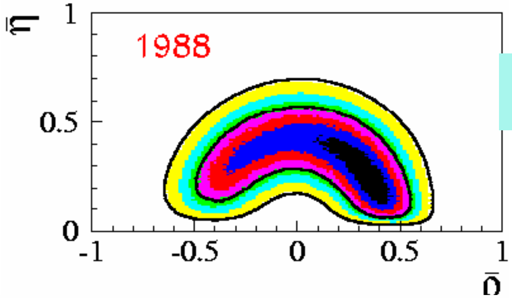
New evaluation of the CKM-matrix and Unitarity Triangle Parameters

Achille Stocchi
(LAL Orsay/IN2P3-CNRS)

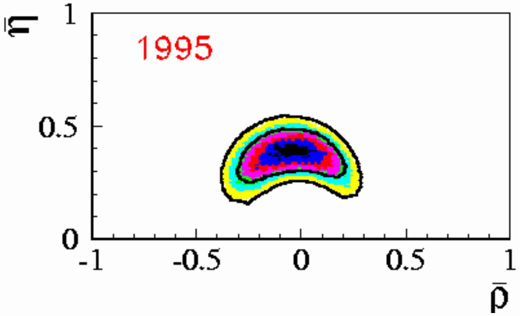


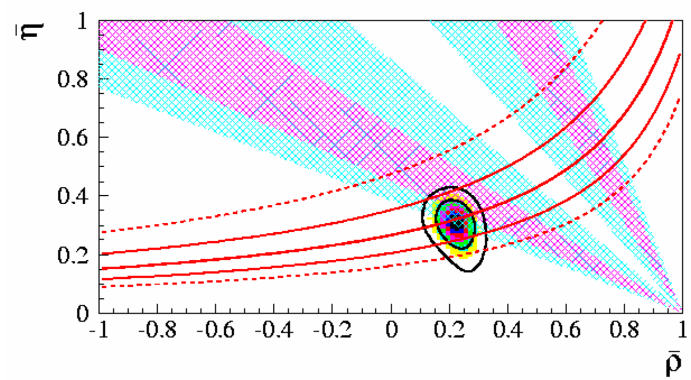
Heavy Quarks and Leptons

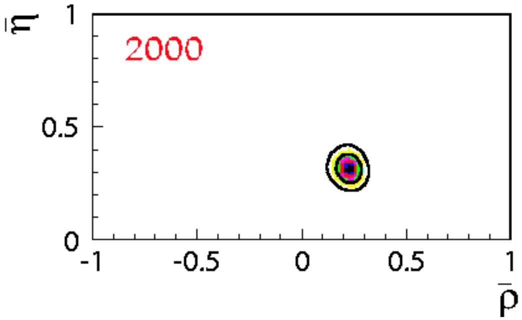
16 -20 October 2006 Munich, Germany

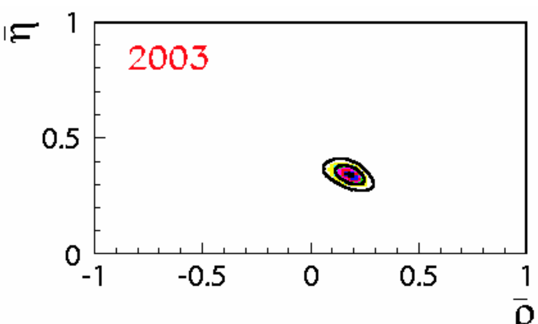


From Childhood

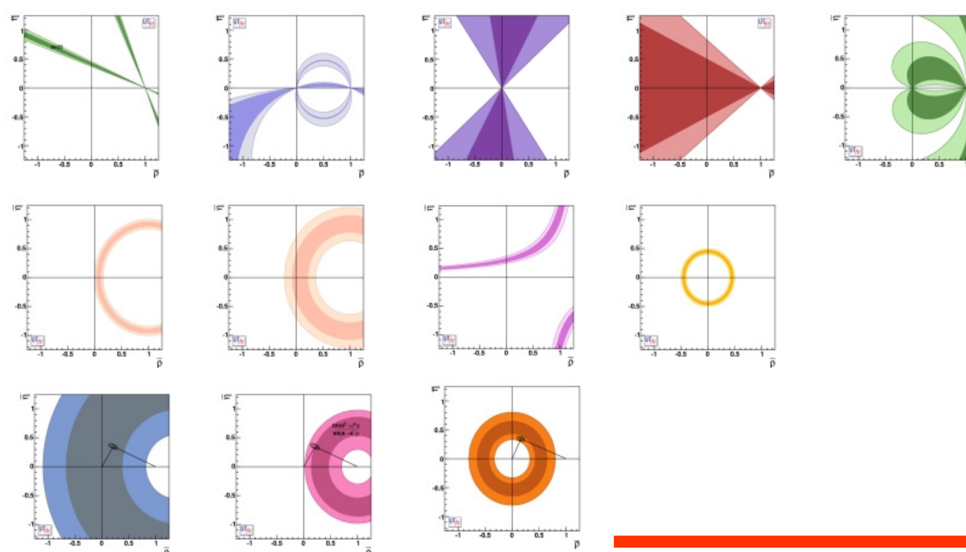








To precision era



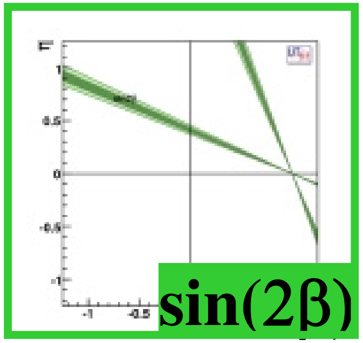
B Factories

the angles..

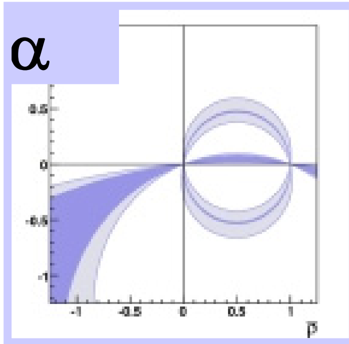
- Expected..
- Less expected…

..and new measurments are coming…

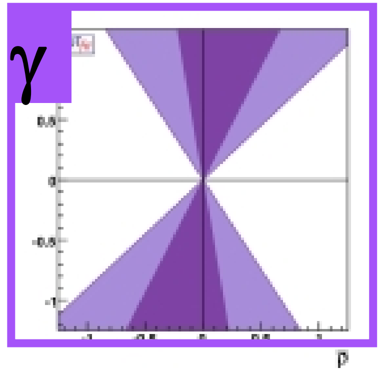
β with B→ J/ψ K

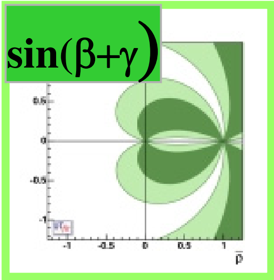


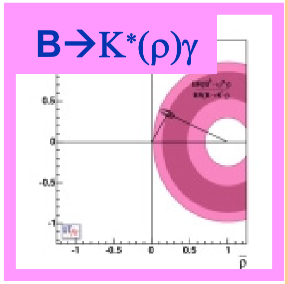
α with charmless

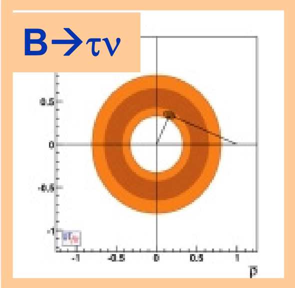


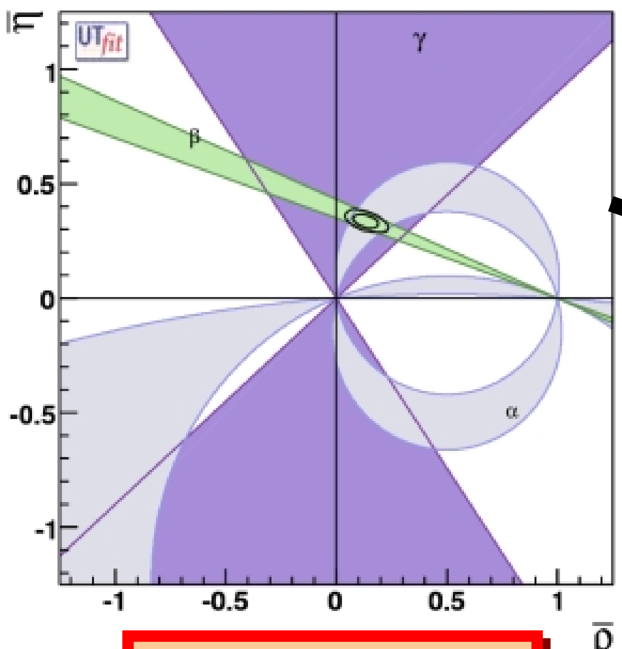
γ with B→ DK









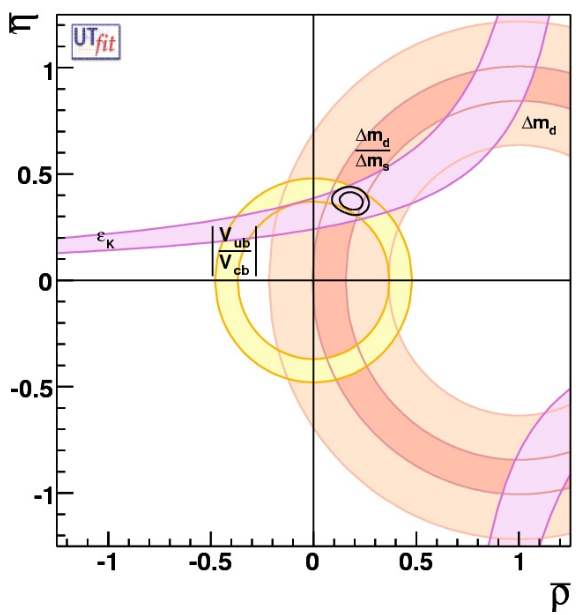


$\rho = 0.134 \pm 0.039$

$\eta = 0.335 \pm 0.020$

To be compared with

Sides + ε_K



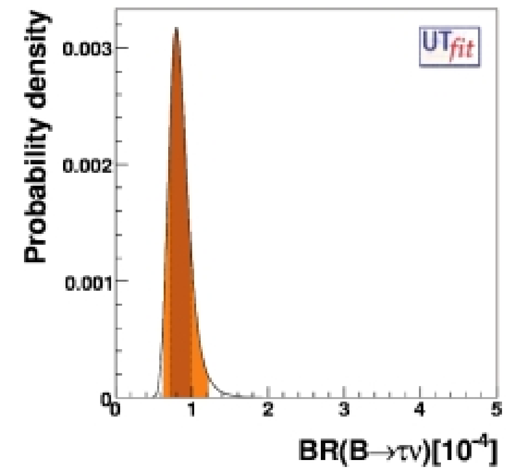
$\rho = 0.188 \pm 0.036$

$\eta = 0.371 \pm 0.027$

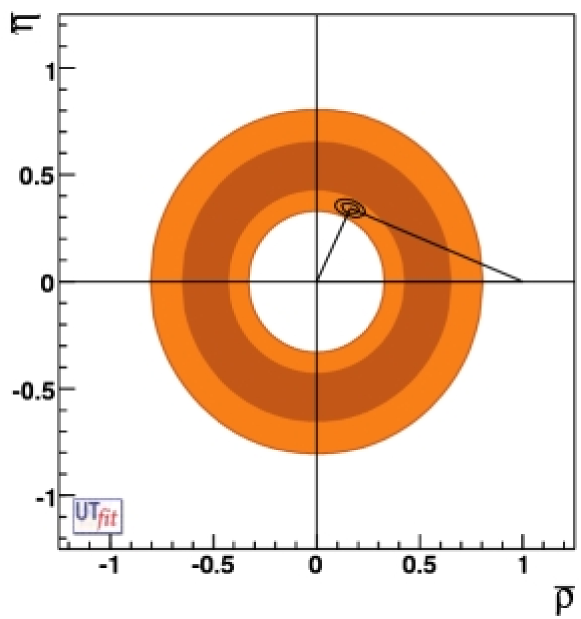
B → τν

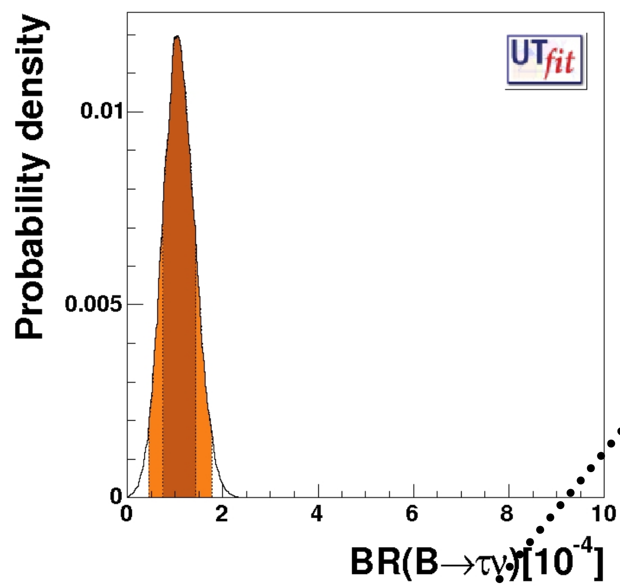
$$\mathcal{B}(B \to \ell\nu) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

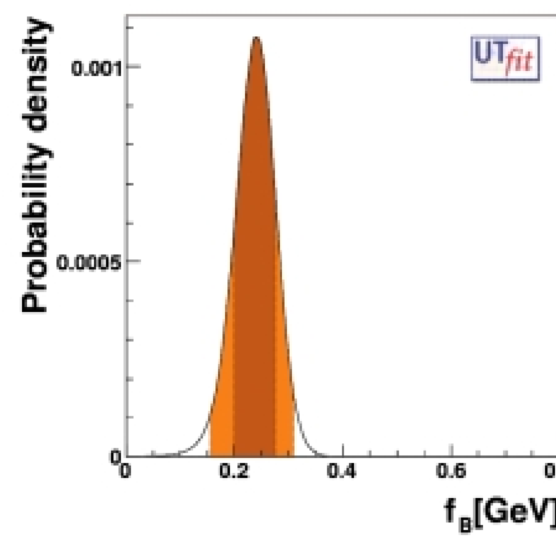
SM expectation



BR(B → τ ν) = (0.85 ± 0.13)10^{-4}





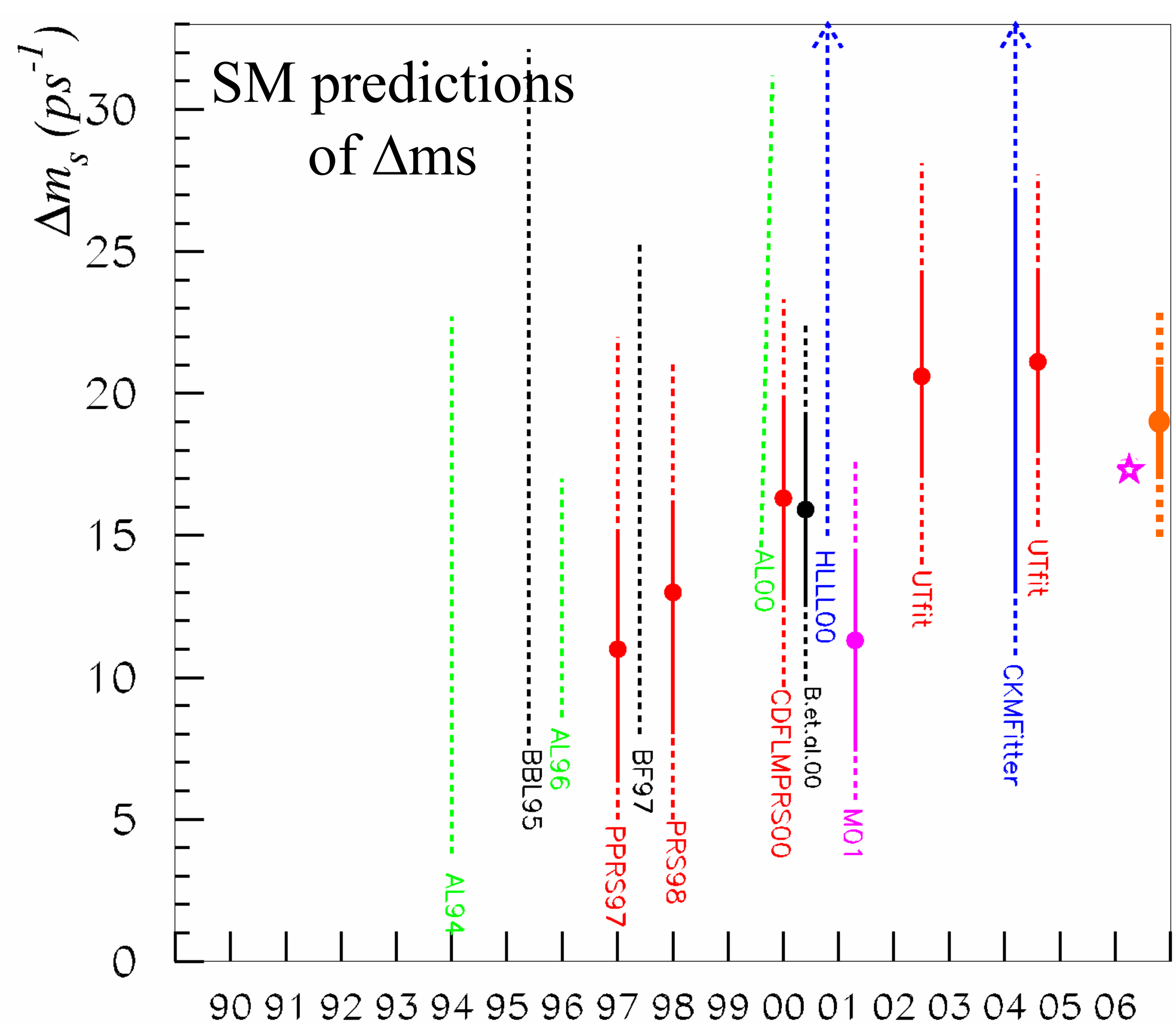


Exp. likelkihood
BR(B → τ ν) = (1.31 ± 0.48)10^{-4}
([0.38,2.25] @ 95% prob.)

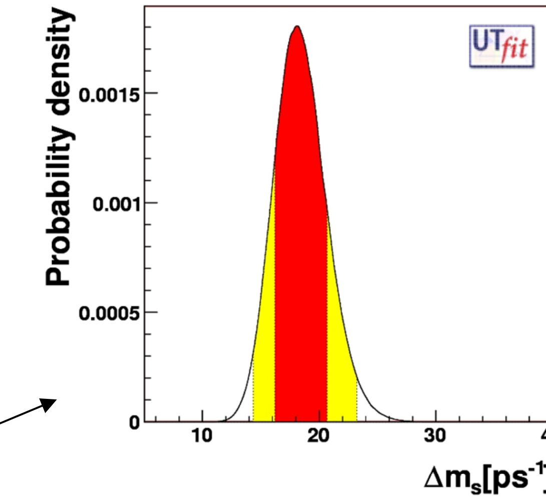
f_B = 237 ± 37 GeV from exp+UTfit
f_B = 189 ± 27 GeV Lattice QCD

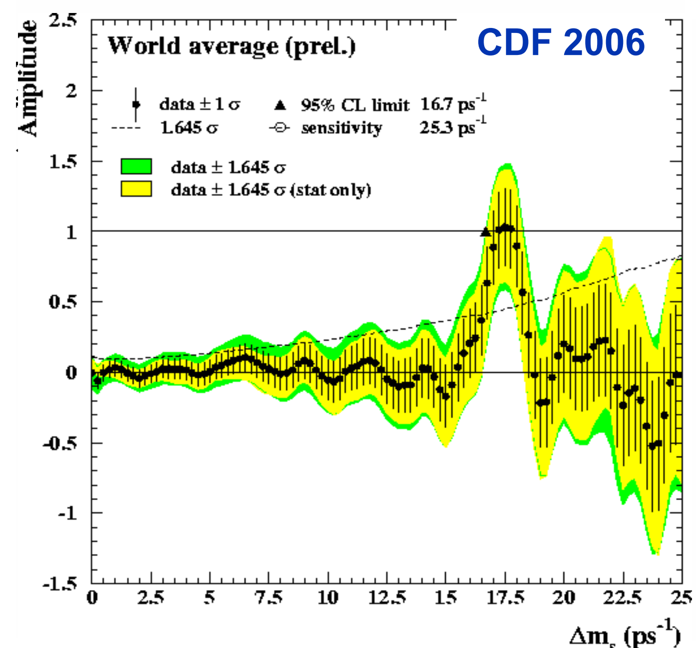
Tevatron

New ! Measurement of Δms



SM expectation
$\Delta m_s = (18.4 \pm 2.4)\ ps^{-1}$

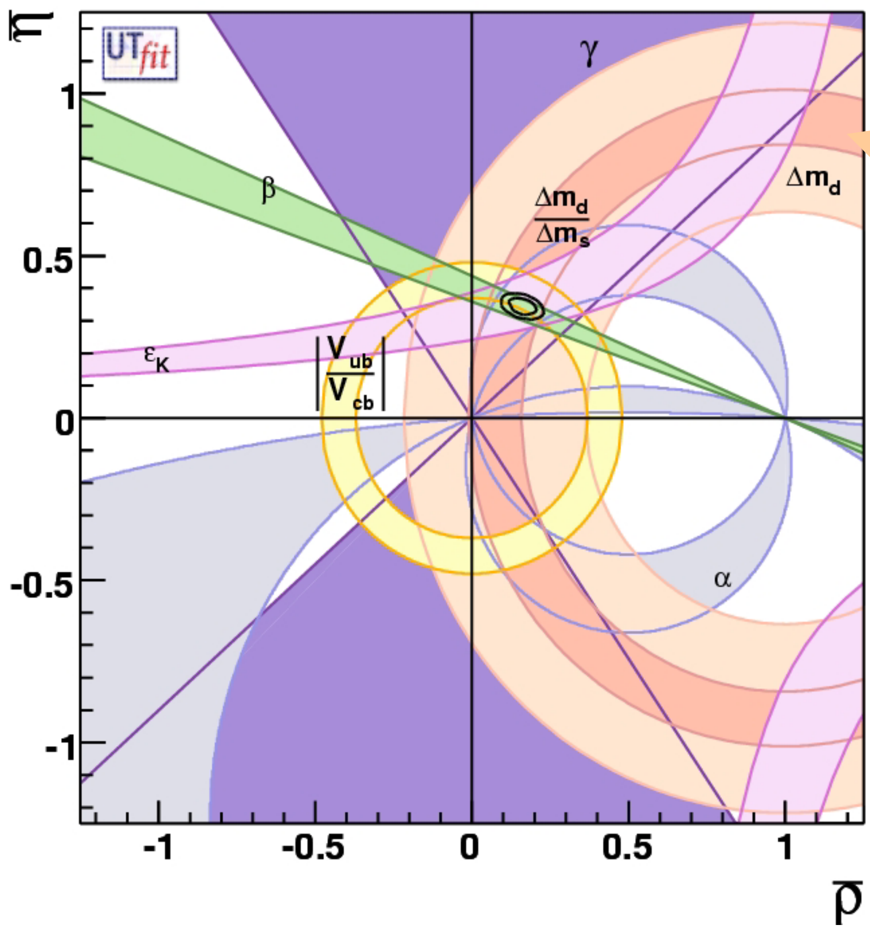




since few days CDF only :
signal at 5σ

Global Fit

$\Delta m_d, \Delta m_s, V_{ub}, V_{cb}, \varepsilon_k + \cos 2\beta + \beta + \alpha + \gamma + 2\beta+\gamma$



New Measurments of Δm_s

Dominated by theo. uncertainties (LATTICE)

$\bar{\rho} = 0.163 \pm 0.028$

$\bar{\eta} = 0.344 \pm 0.016$

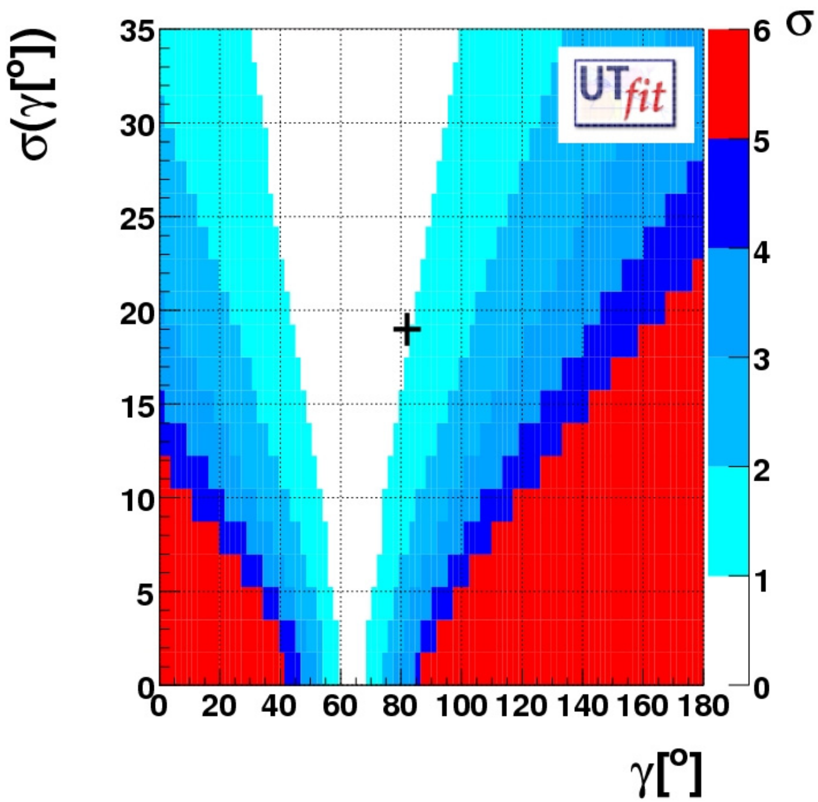
We are probably beyond the era of « alternatives» to the CKM picture.
NP should appear as «corrections» to the CKM picture

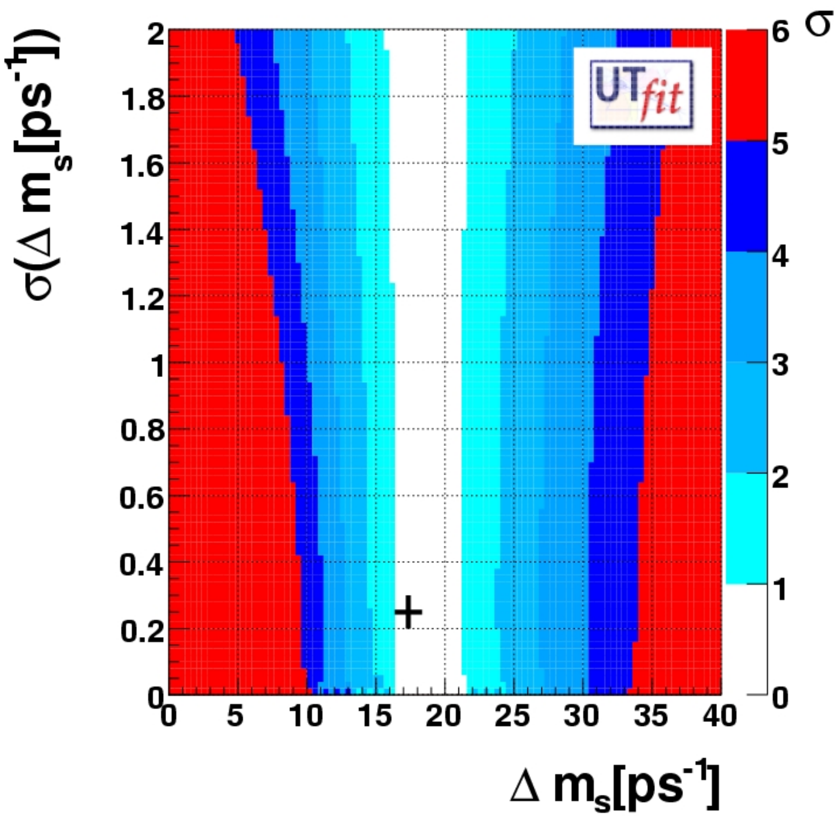
Are there evidence of disagreement in the actual fit ?

agreement between the predicted values and the measurements at better than :

1σ   3σ   5σ

2σ   4σ   6σ

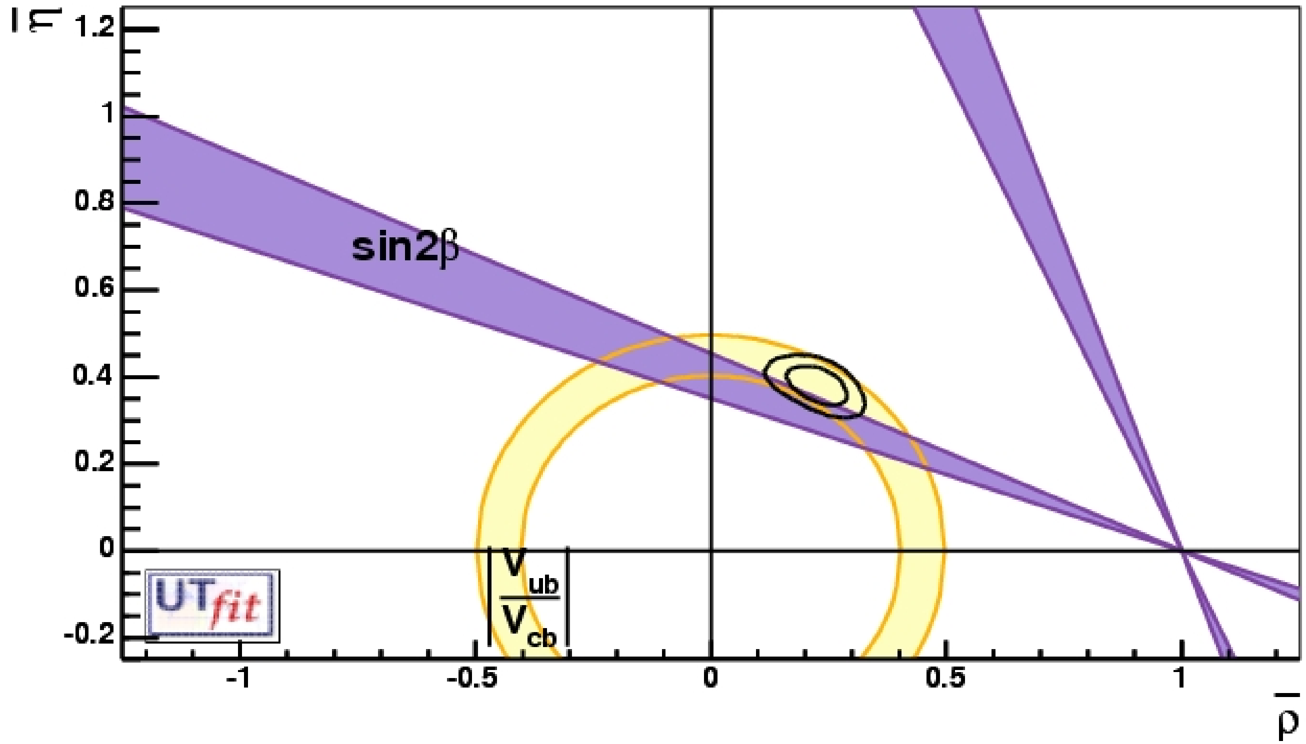




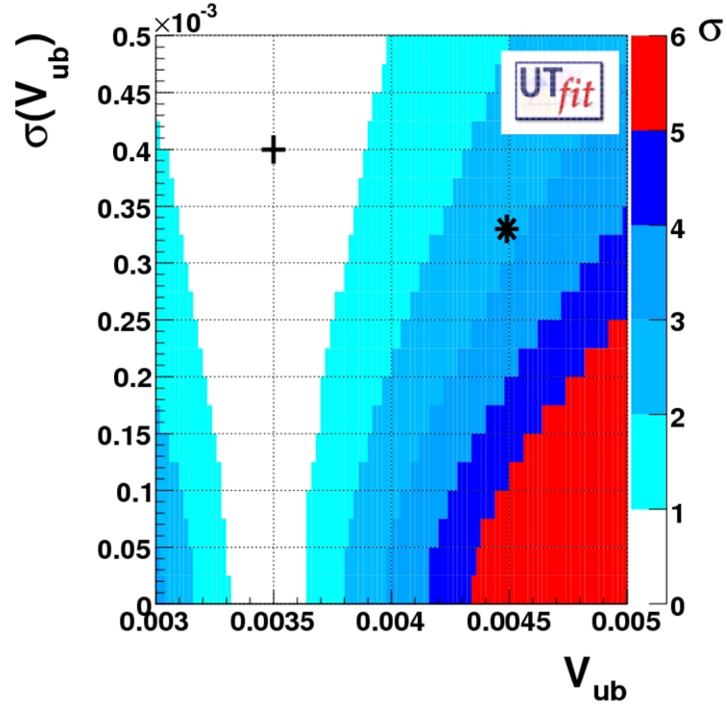
No disagreement for γ et Δm_s

SM Fit

Look for discrepencies…



we have a weak sign of a disagreement



sin2β=0.675±0.026
From direct measurement

sin2β =0.764± 0.039
from indirect determination
(all included by sin2β)

Could be the new value of inclusive V_{ub}

We should keep an eyes on these kinds of disagreements. Could be NP

Fit in a NP model independent approach

ΔF=2

Parametrizing NP physics in ΔF=2 processes

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

→

$$\Delta m_d^{EXP} = C_q \Delta m_d^{SM}$$

$$A_{CP}(J/\Psi K^0) = \sin(2\beta + 2\phi_d)$$

$$\alpha^{EXP} = \alpha^{SM} - \phi_d$$

$$|\varepsilon_K|^{EXP} = C_\varepsilon |\varepsilon_K|^{SM}$$

Soares, Wolfenstein PRD47;
Deshpande, Dutta, Oh PRL77;
Silva, Wolfenstein PRD55;
Cohen et al. PRL78;
Grossman, Nir, Worah PLB407;
Ciuchini et al. @ CKM Durham

Constraints

		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			
	ASL		X	X			
	α (ρρ,ρπ,ππ)	X		X			
	ACH		X	X	X	X	
2↔3 family	$\Delta\Gamma_s/\Gamma_s$				X	X	
	Δm_s				X		
1↔2 familiy	ε_K	X					X
	In future :						
	ACP (J/Ψ ϕ)	~X				X	
	ASL(Bs)				X	X	
	γ (D_sK)	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 possible with <u>10 contraints</u>
and <u>7 free parameters</u>
(ρ, η, C_d,φ_d ,C_s,φ_s, $C_{\varepsilon K}$)

Fit in a NP model independent approach

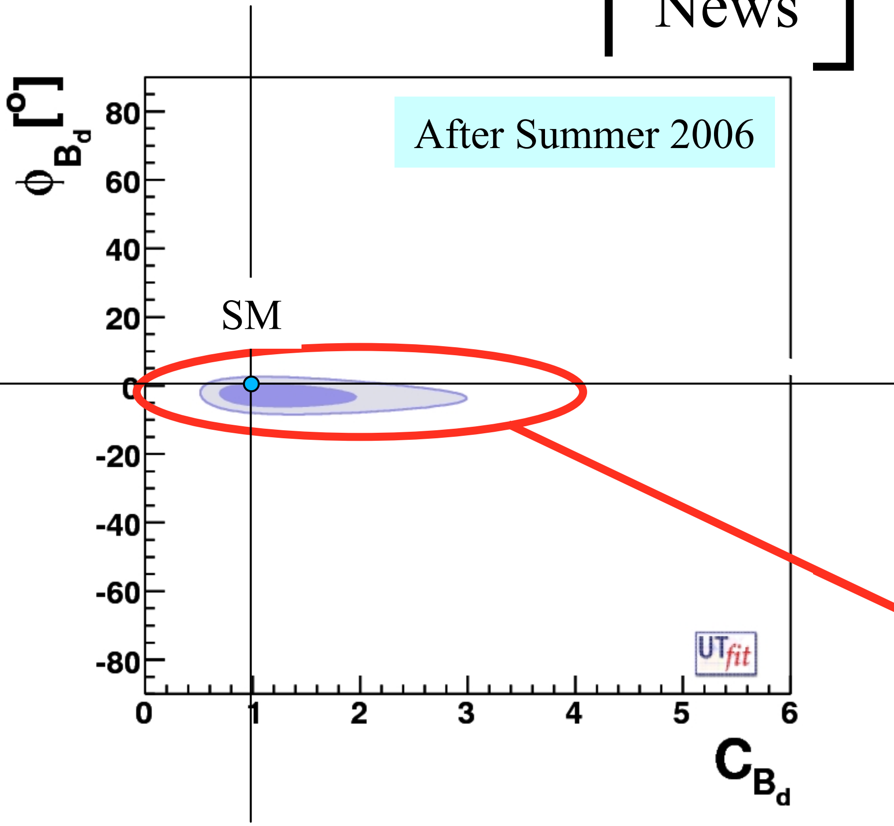
Using

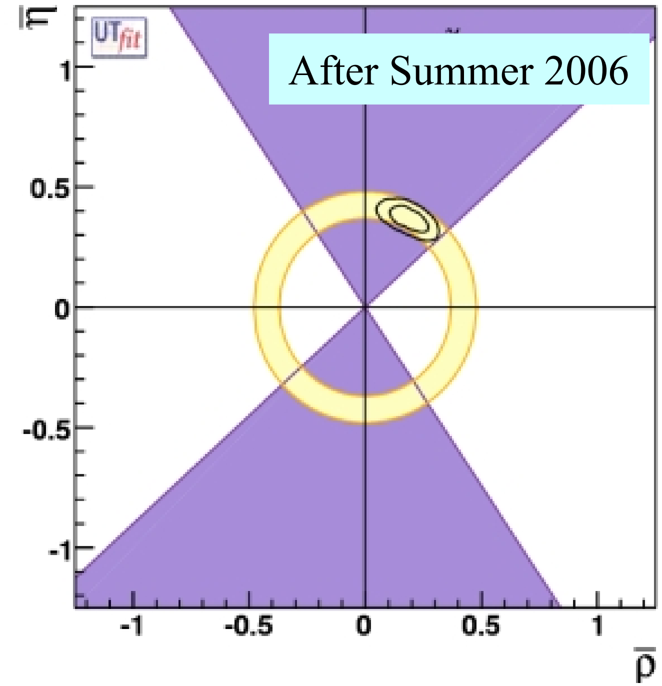
V_{ub}/V_{cb} Δm_d ACP (J/Ψ K)

γ (DK) ε_K

α cos2β A_{SL} A_{CH}

News





SM-like solution 100%

SM or small NP with arbitrary phase or large NP with SM phase.

$$A_{SL} \equiv \frac{\Gamma(\bar{B}^0 \to \ell^+ X) - \Gamma(B^0 \to \ell^- X)}{\Gamma(\bar{B}^0 \to \ell^+ X) + \Gamma(B^0 \to \ell^- X)}$$

$$A_{SL} = -\mathrm{Re}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\sin 2\phi_d}{C_d} + \mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\cos 2\phi_d}{C_d}$$

Laplace et al., PRD65 NLO effects included

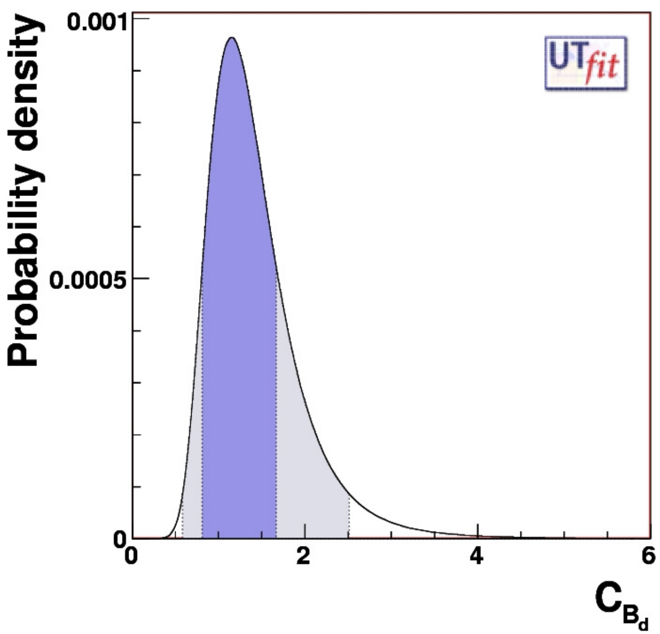
$$A_{CH} = \frac{N^{++} - N^{--}}{N^{++} + N^{--}} \sim f(C_{Bd}, \varphi_{Bd})$$

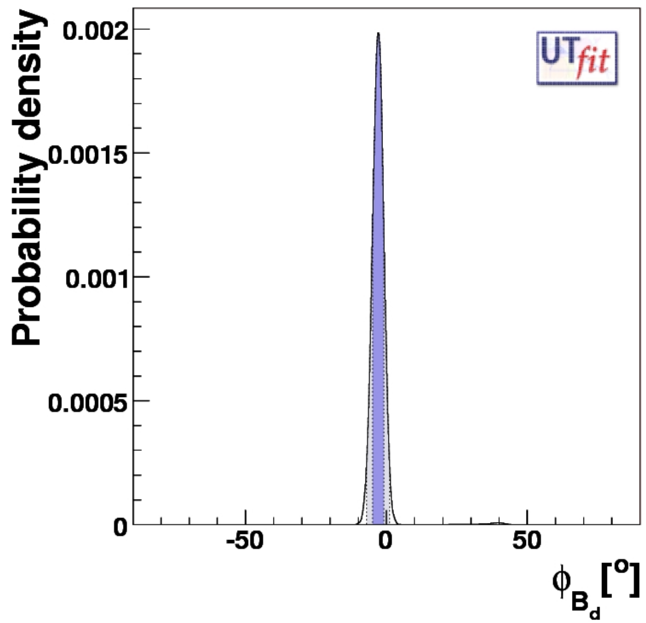
from D0

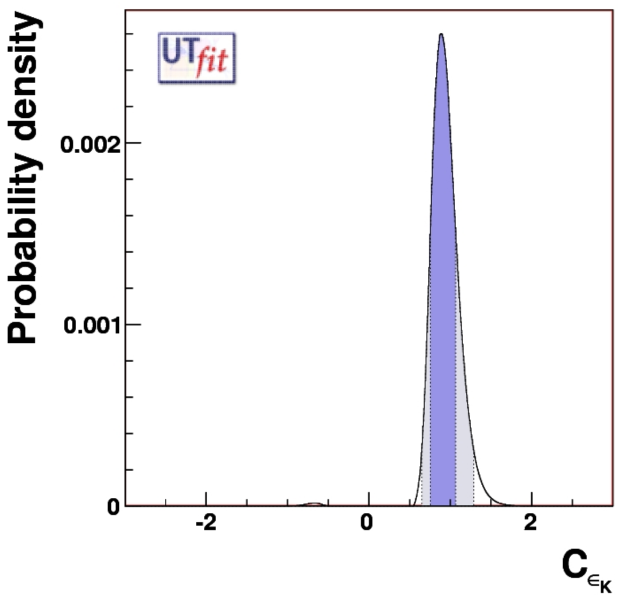
$C_{Bd} = 1.24 \pm 0.43$

$\phi_{Bd} = -(3.0 \pm 2.0)^o$

$C_{\varepsilon} = 0.91 \pm 0.15$







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

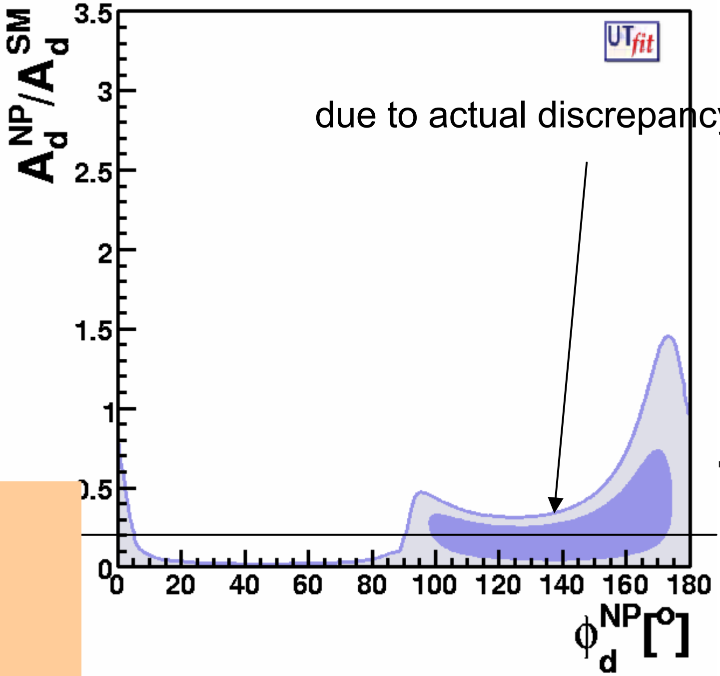
A_{NP}/A_{SM} vs ϕ_{NP}

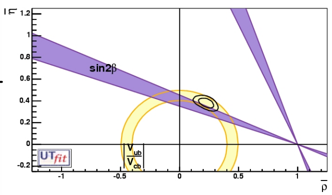
$$C_{B_d} e^{2i\phi_{B_d}} = \frac{A_{\rm SM} e^{2i\beta} + A_{\rm NP} e^{2i(\beta+\phi_{\rm NP})}}{A_{\rm SM} e^{2i\beta}}$$

With present data $A_{NP}/A_{SM} \neq 0$ @ 2σ

$A_{NP}/A_{SM} \sim 1$ only if $\phi_{NP} \sim 0$
$A_{NP}/A_{SM} \sim 0\text{-}40\%$ @95% prob.

Take at face value this is
an evidence of NP at ~2σ level





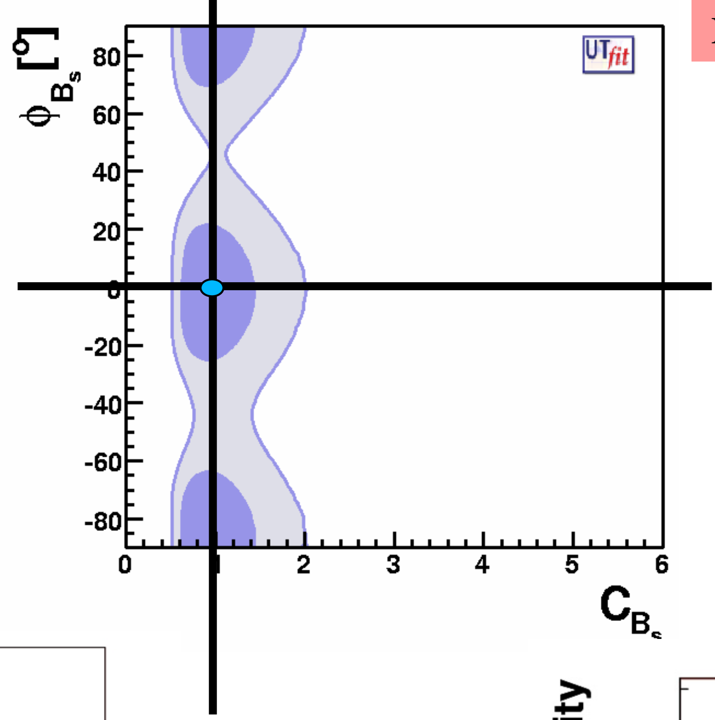
Actual sensitivity
for a generic NP phase
$r = A_{NP}/A_{SM} \sim 20\%$

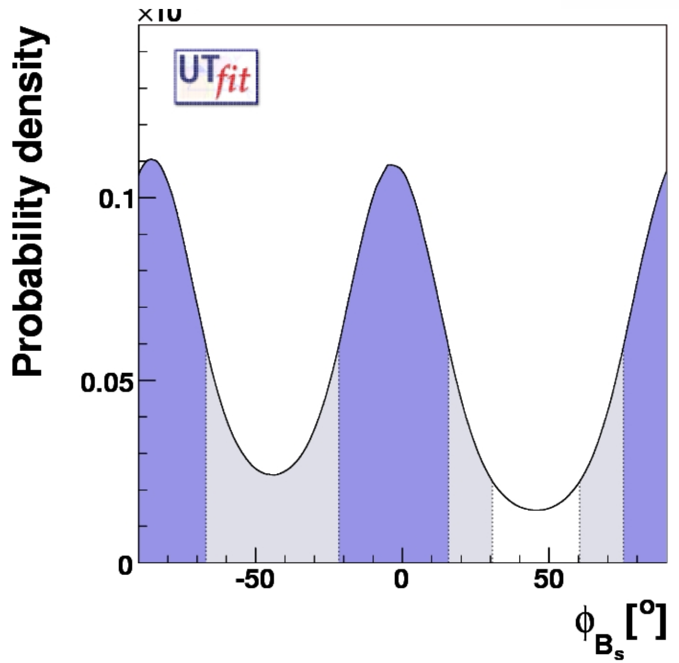
$$\left|\frac{Q^{NP}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}\right| \le r \quad \rightarrow \quad \frac{|\delta_{bq}|}{\Lambda_{eff}} \le \sqrt{r}\,\frac{|V^*_{tb}V_{tq}|}{M_W}$$

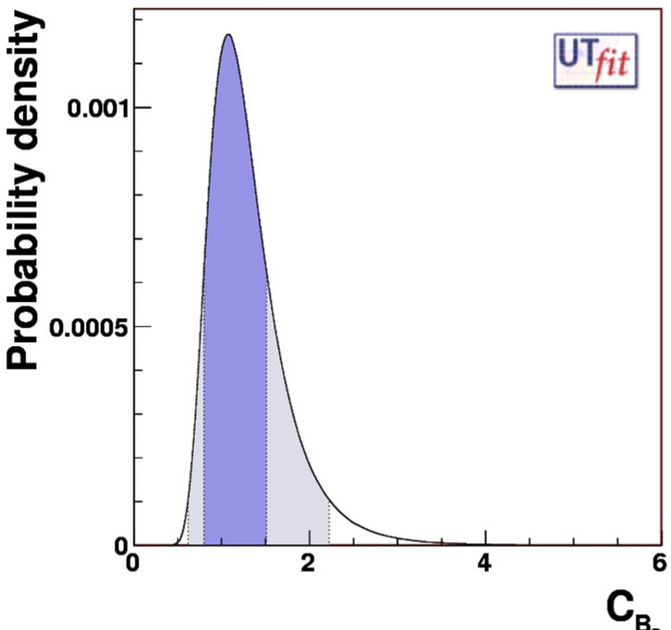
r upper limit of the relative contribution of NP
δ_{bd} NP physics coupling
Λ_{eff} NP scale (masses of new particles)

Take a case where $\delta_{q'd} \approx V^*_{tq'} V_{td}$ ➞ $\Lambda_{eff} \sim 80/\sqrt{r}$ GeV ➞ $\Lambda_{eff} \sim 180$ GeV

New ! Bs sector starts to be constrained.
by
Δm_s (C_s)
A_{CH} +$\Delta\Gamma_s/\Gamma_s$ (C_s and ϕ_s)







φ_{Bs} = (-3 ± 19) U (94 ± 19)°

C_{Bs} = 1.15 ± 0.36

Error on C_d and C_s dominated by the knowledge of hadronic parameter

MFV

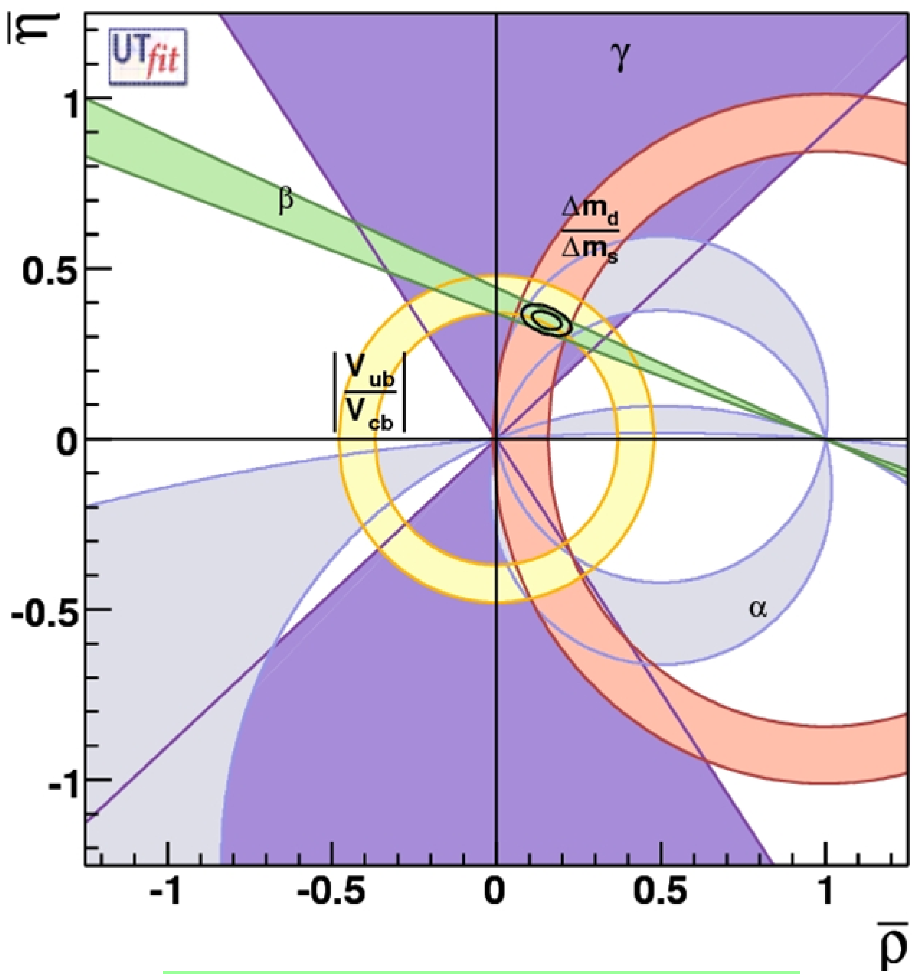
The previous fits → MFV ? $\varphi(B_d)$ ~0

MFV = CKM is the only source of CP violation

Universal UT*fit*

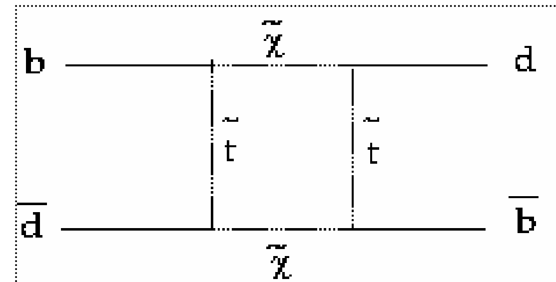
Buras et al. hep-ph/0007085

Fit without ε_K **and** Δm_d valid in SM and MFV

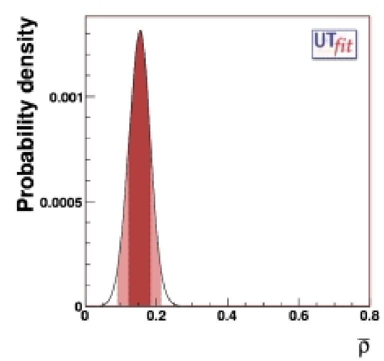


Almost as good as the SM !!

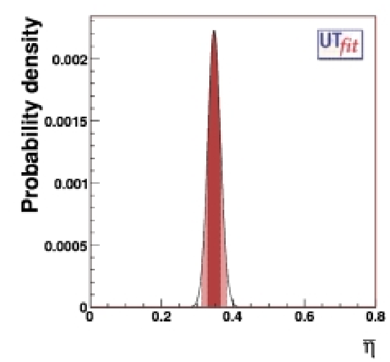
ε_K and Δm_d are sensitive to NP



Very tiny space for see effects beyond the SM



$\rho = 0.153 \pm 0.030$



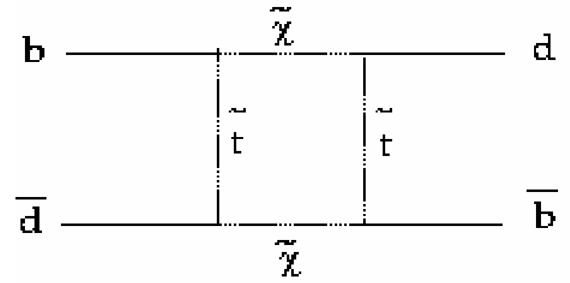
$\eta = 0.347 \pm 0.018$

MFV

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

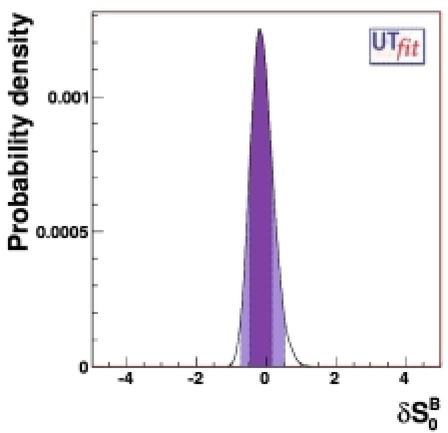
$$\delta S_0(x_t) = 4a\left(\frac{\Lambda_0}{\Lambda}\right)^2 \qquad \Lambda_0 = 2.4 TeV$$

Λ_0 is the equivalent SM scale



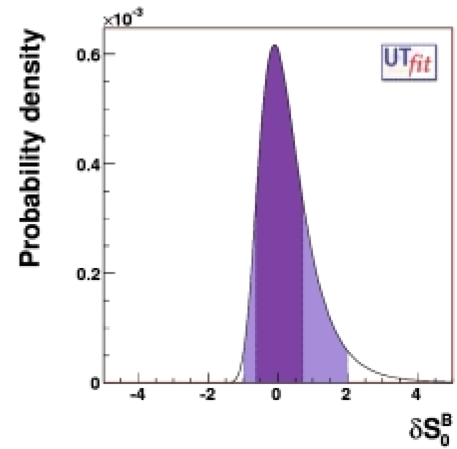
In models with **one Higgs doublet or low/moderate tanβ** (D'Ambrosio et al. hep-ph/0207036) NP enters as additional contribution in top box diagram

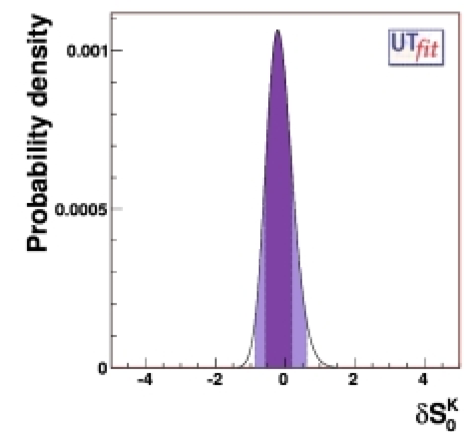
$\delta S_0^B = \delta S_0^K$



2Higgs + large tanβ → also bottom Yukawa coupling must be considered

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





$\delta S_0 = -0.16 \pm 0.32$	**$\delta S_0^B = 0.05 \pm 0.67$**	**$\delta S^0_K = -0.18 \pm 0.37$**
Λ > 5.5 TeV @95% Prob. for small tanβ	**Λ > 5.1 TeV @95% Prob. for large tanβ**	

Starting point for studies of rare decays see for instance : Bobeth et al. hep-ph/0505110

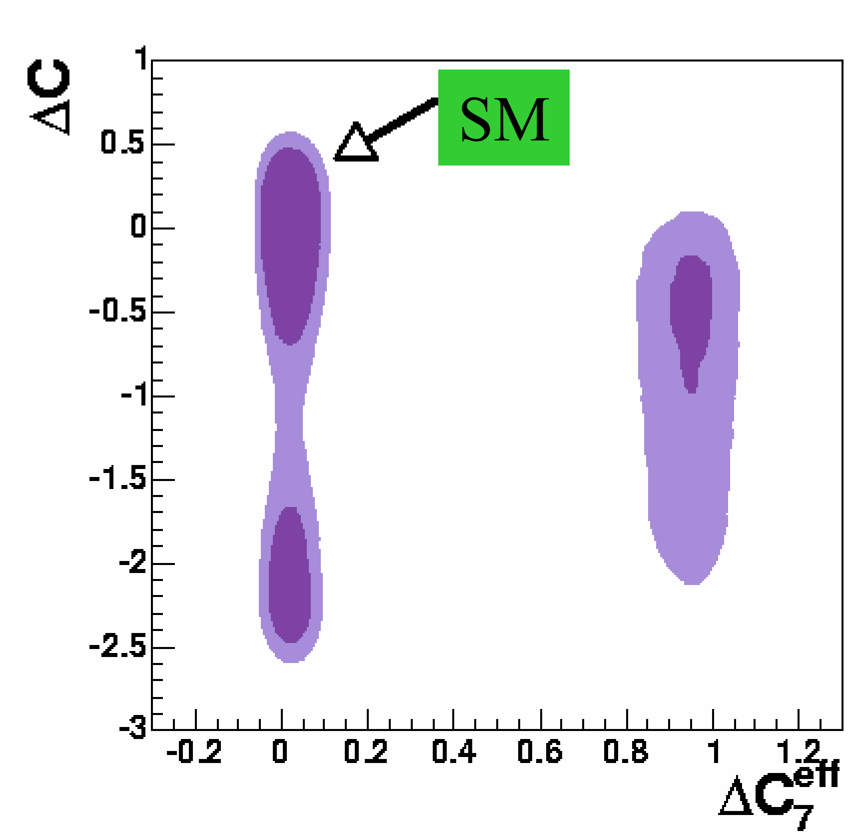
Rare decays in MFV

$-\rho,\eta$ from UUT

-FCNC effective Z vertex [NP in ΔC] from $Br(B \to X_s ll)$, $Br(K \to \pi^+ \nu\nu)$

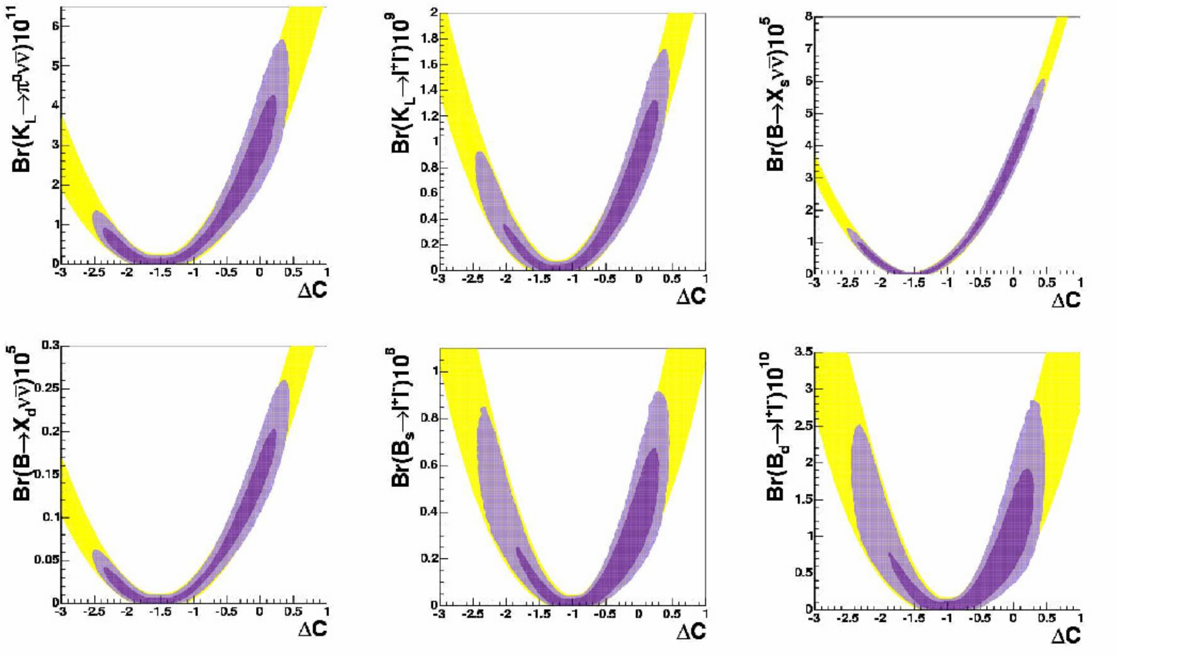
-cromomagnetic penguin [NP in ΔC^7_{eff}] from $Br(B \to X_s,\gamma)$

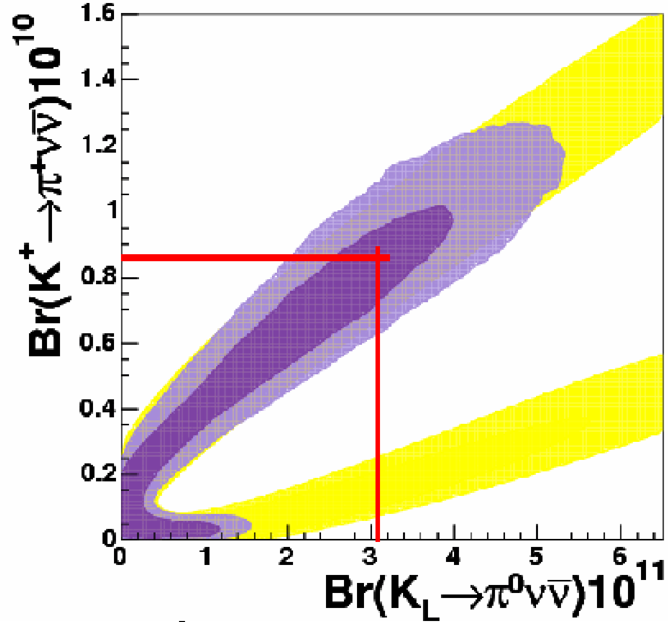
-(penguins,boxes)



GET predictions for RARE DECAYS

MFV





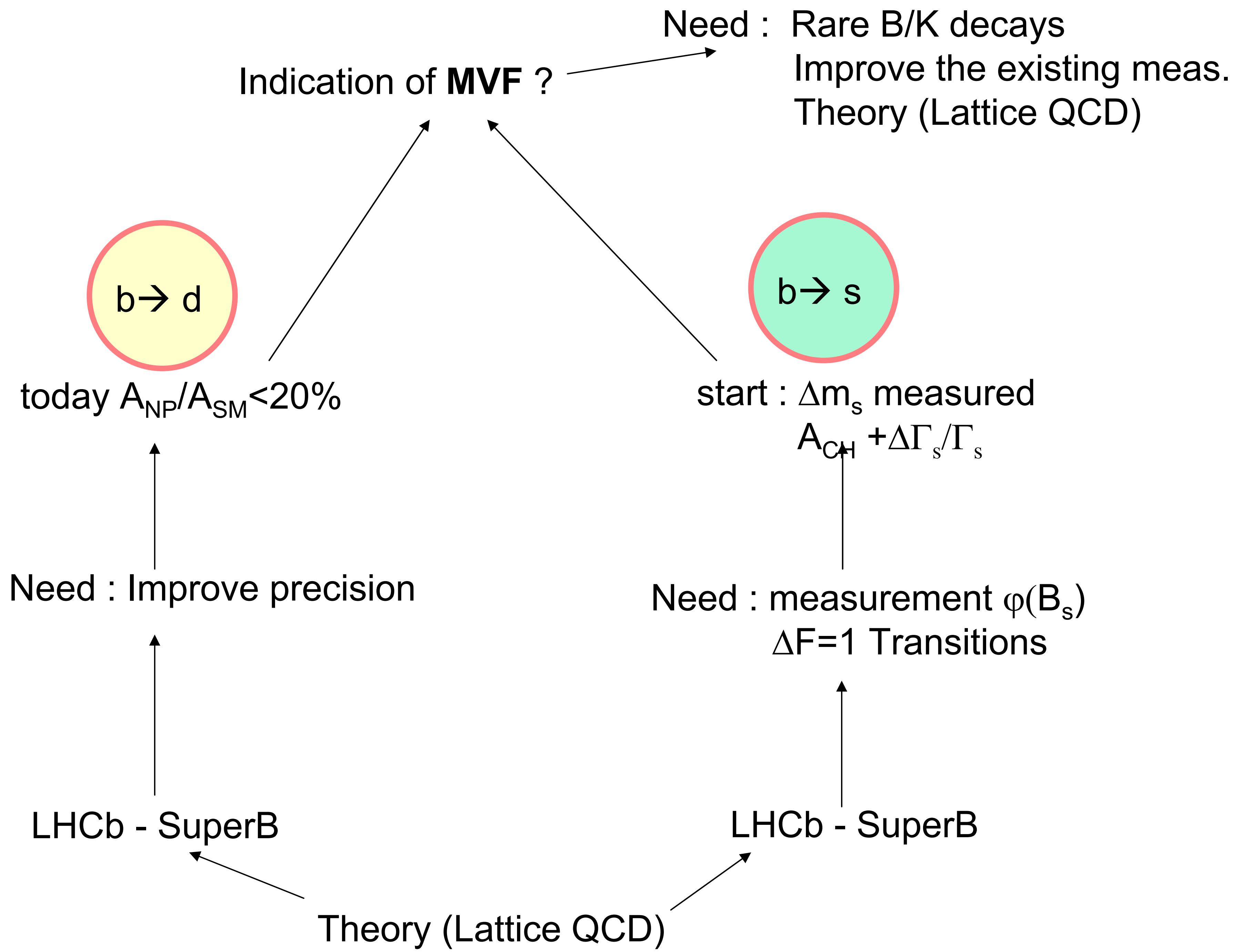
Branching fractions	**MFV(95%)**	SM (95%)	exp
$Br(K^+ \to \pi^+ \nu\nu) \times 10^{11}$	**<11.9**	[6.1-10.9]	14.7+13.0-8.9
$Br(K_L \to \pi^0 \nu\nu) \times 10^{11}$	**<4.59**	[2.03-4.26]	$<5.9 \times 10^4$
$Br(K_L \to \mu\mu) \times 10^9$	**<1.36**	[0.63-1.15]	
$Br(B \to X_s \nu\nu) \times 10^5$	**<5.17**	[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 physics

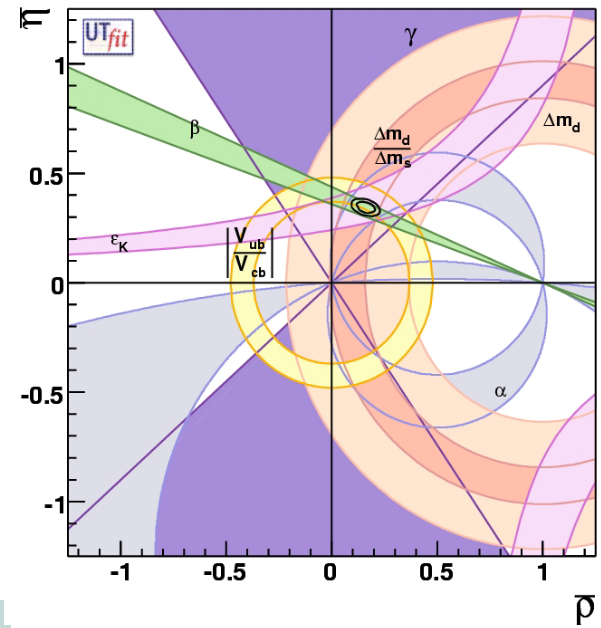
Very interesting the AFB asymmetry of B→K*ll

Any violation of the UL mplies new sources of flavour and CP violation



ANYHOW THE “MOT D’ORDRE” IS IMPROVE !!

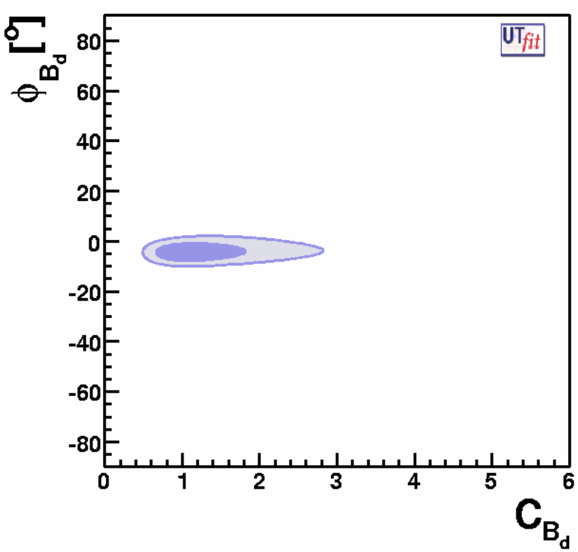
Conclusions

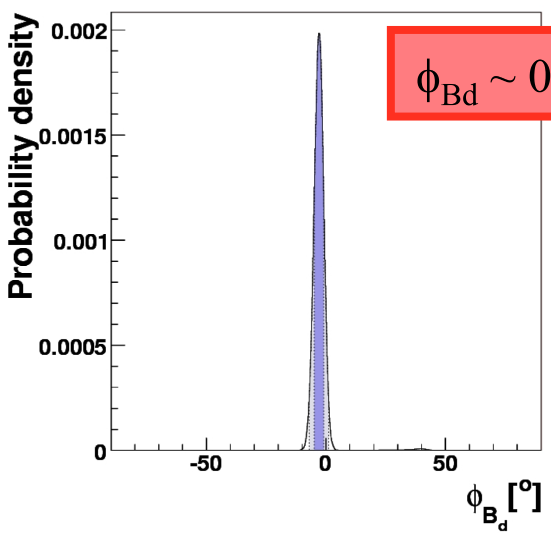


UT*fits* are in a mature age with recent precise measurement of UT sides and angles

The SM CKM picture of CP violation and FCNC is strongly supported by data

Generic NP in the b → d start to be quite constrained





$\phi_{Bd} \sim 0$

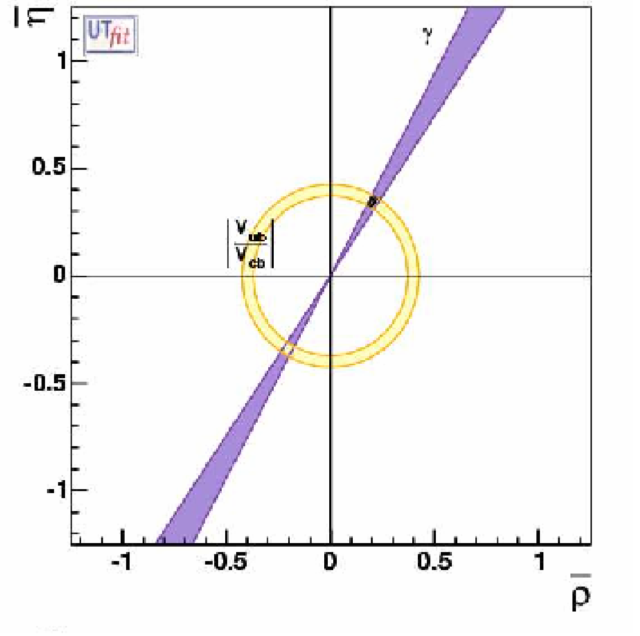
At least in this sector, we are beyond the alternative to CKM picture, and we should look at « corrections ».

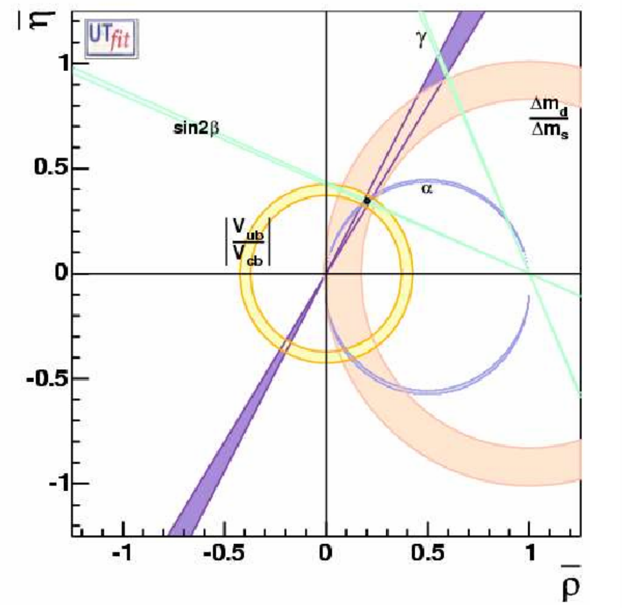
MFV ?

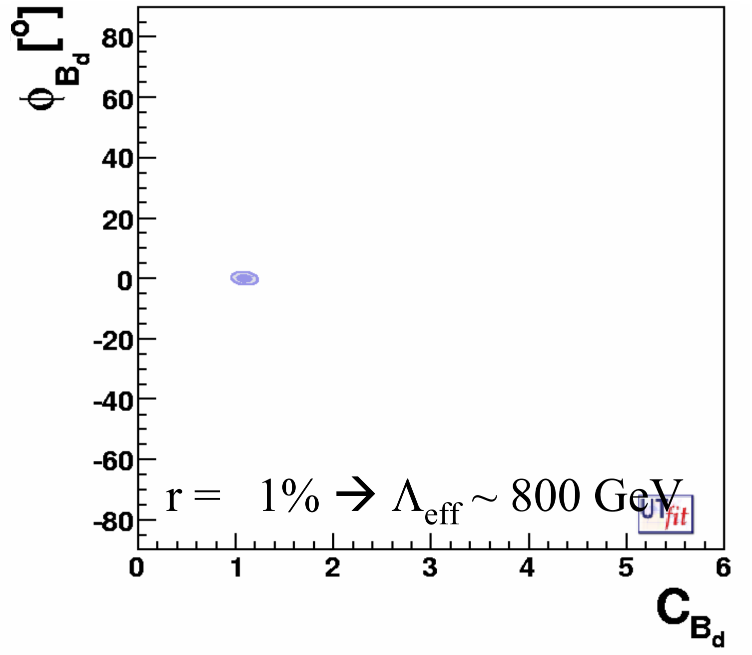
We need to improve the precision

$50ab^{-1}$ SuperB

+hadronic parameters at 1%-1.5% : MANDATORY







In the hypothesis that LHC will observe NP we need next facilities be able to study the structure of the NP up to the TeV scale

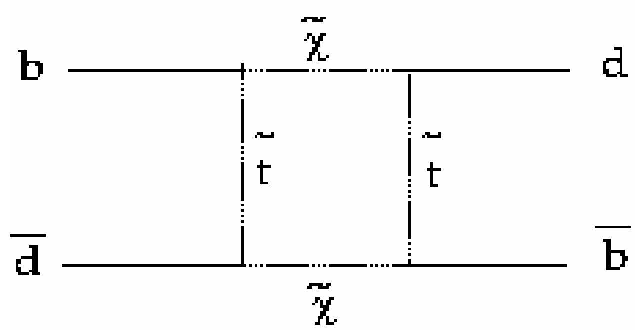
But we need theorists ! …
in particular to push down the precision on the hadronic parameters (via QCD calculations)

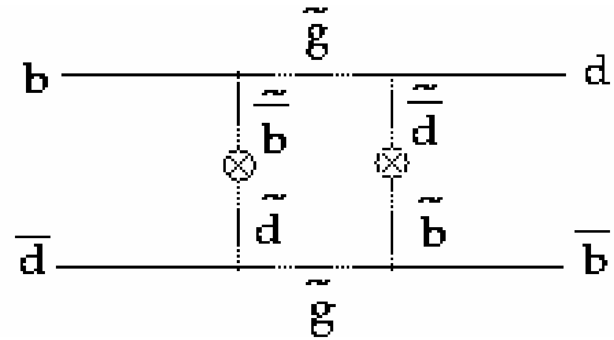
BACKUP MATERIAL

Why working and keep working on flavour physics ?

Flavour physics, with FCNC, CP violation phases… is the ideal place for looking for New Physcis effects beyond the Standard Model (since many processes are suppressed in SM) even if mediated by heavy (not too heavy) particles

Example for B oscillations (FCNC-$\Delta B=2$) :





$$\left|\frac{Q^{NP}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}\right| \le r \quad \rightarrow \quad \frac{|\delta_{bq}|}{\Lambda_{eff}} \le \sqrt{r}\,\frac{|V^*_{tb}V_{tq}|}{M_W}$$

r upper limit of the relative contribution of NP

δ_{bd} NP physics coupling

Λ_{eff} NP scale (masses of new particles)

If couplings ~ 1

$\delta_{bq} \sim 1$ $\Lambda_{eff} \sim 10/\sqrt{r_r}$ TeV

$\delta_{bs} \sim 1$ $\Lambda_{eff} \sim 2/\sqrt{r}$ TeV

all possible intermediate possibilities

←

$\delta_{bq} \sim 0.1$ $\Lambda_{eff} \sim 1/\sqrt{r}$ TeV

$\delta_{bs} \sim 0.1$ $\Lambda_{eff} \sim 0.2/\sqrt{r}$ TeV

Minimal Flavour Violation

$$\delta_{q'd} \approx V^*_{tq'}V_{td}$$

(couplings small as CKM elements)

$\Lambda_{eff} \sim 0.08/\sqrt{r}$ TeV

« *Schematically* Two possible solutions »

Λ_{eff} very high > 10-100 TeV

difficult to learn from rare decays (but maybe the only way…), and very difficult to find evidence of NP at LHC….

Λ_{eff} ~ 1TeV + flavour-mixing protected by additional symmetries (as MFV)

much to learn from flavour physics now and in future when NP will be discovered.

(this solution is also more similar to the case of the SM)

The second solution is the one matching with the naturality for the Higgs mass which would place the NP arround ~ 1 TeV

Complémentarity LHC/precision measurements

$\delta_{q'd} \approx V^*_{tq'} V_{td}$

$\Lambda_{eff} \sim 0.08/\sqrt{r}$ TeV

r = 20% → Λ_{eff} ~ 180 GeV

r = 10% → Λ_{eff} ~ 250 GeV

r = 1% → Λ_{eff} ~ 800 GeV

If the coupling are not even smaller

Suppose Λ_{eff}~250GeV
→ δ mesurable

Parenthesis for Lattice people

We have supposed that

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

Inputs

$\beta < 1°$ from charmonium

$\alpha \sim 7°$

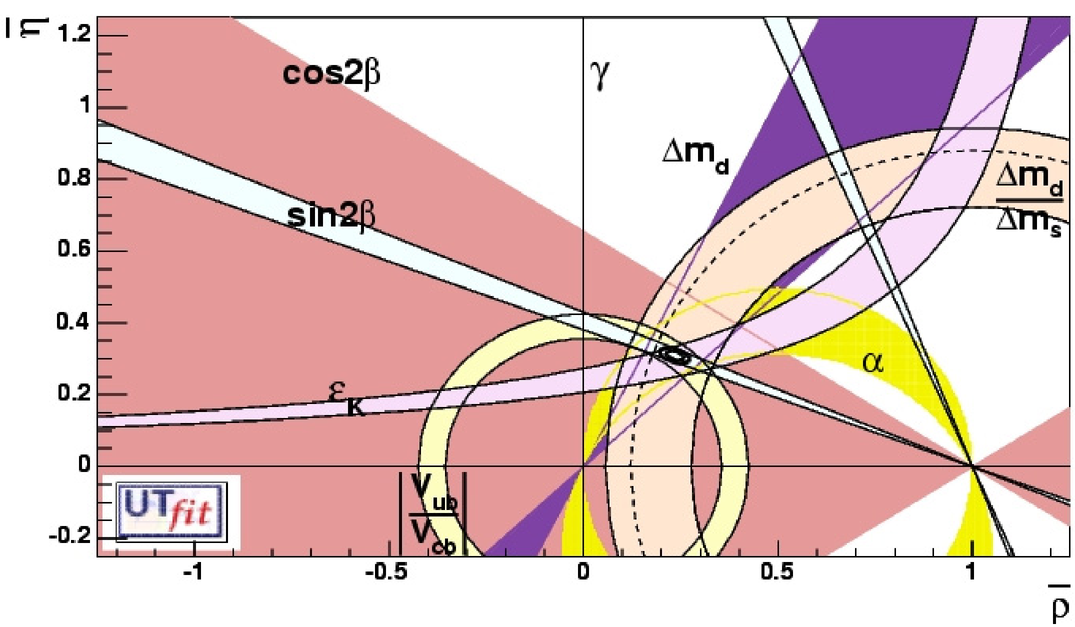
$\gamma \sim 5°$
(half B-factories/half LHCb)

$\sin 2\chi \pm 0.045$

$V_{ub} \sim 5\%$
$V_{cb} \sim 1\%$

Δm_s at $0.3ps^{-1}$
(Tevatron or/and LHCb)

$f_B\sqrt{B_B} \sim 5\%$
$\xi \sim 3\%$
$B_K \sim 5\%$
Lattice

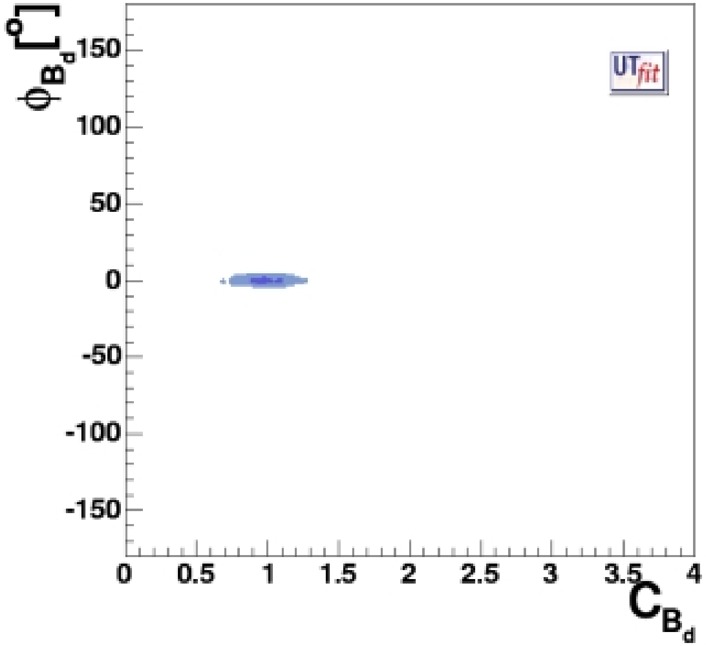


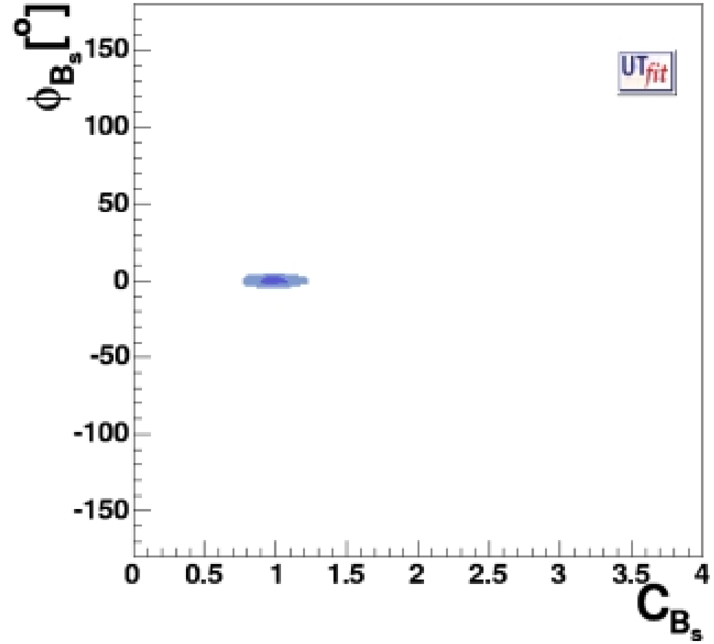
An important point is that the relative precisions on CP-violating quantities are on phase with CP-conserving quantities
IF

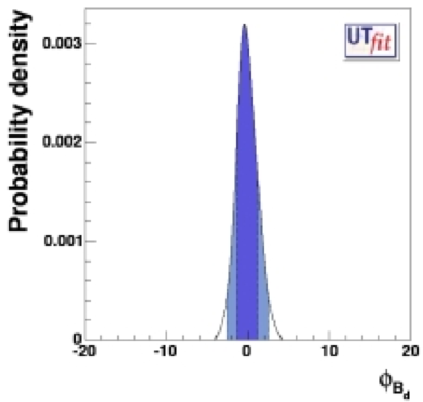
Lattice calculations at few % level

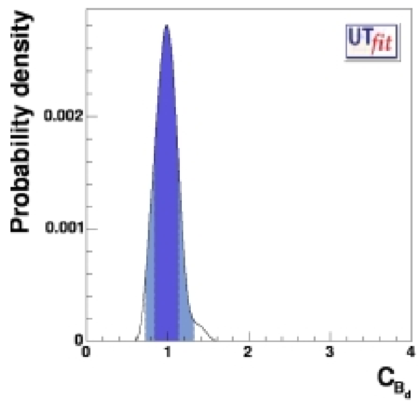
In the « sad » hypotesis the SM still work in 2010….

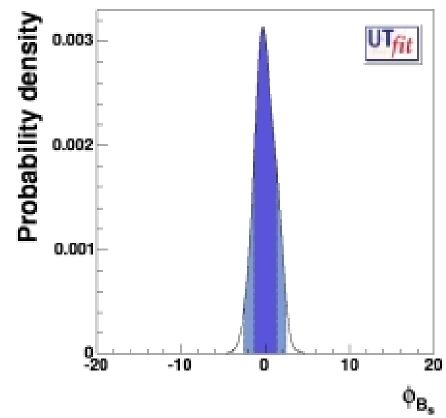
CKM2010

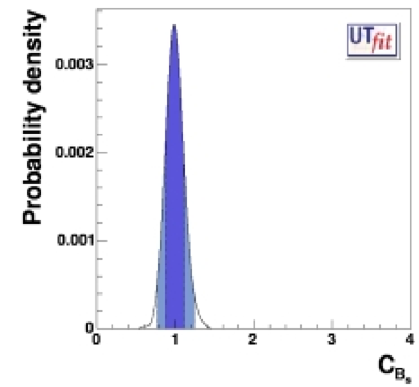












$\varphi_{Bd} = (-0.1 \pm 1.3)^o$

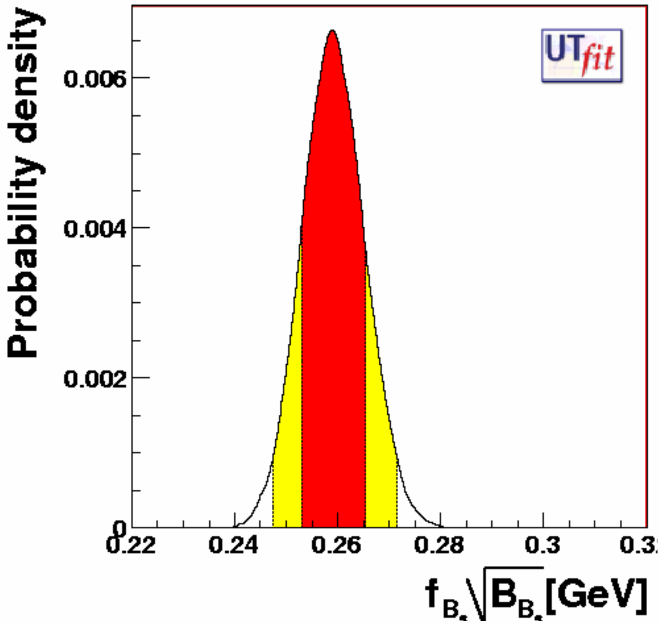
$C_{Bd} = 0.98 \pm 0.14$

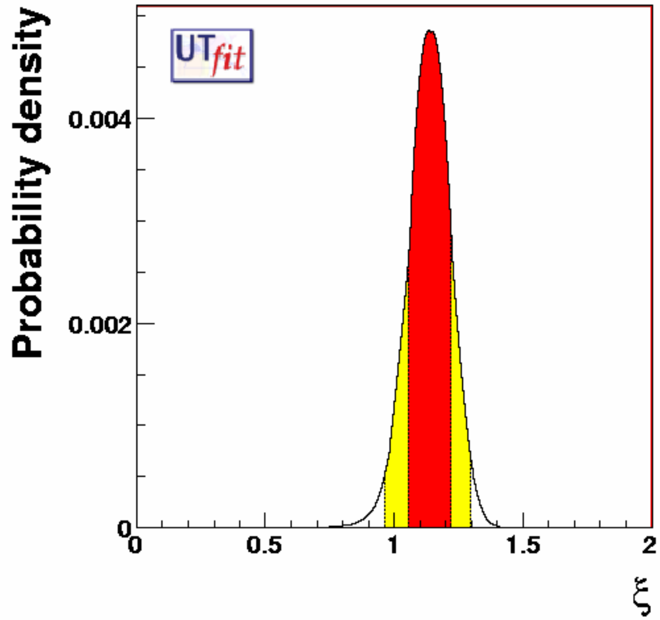
$\varphi_{Bs} = (0.0 \pm 1.3)^o$

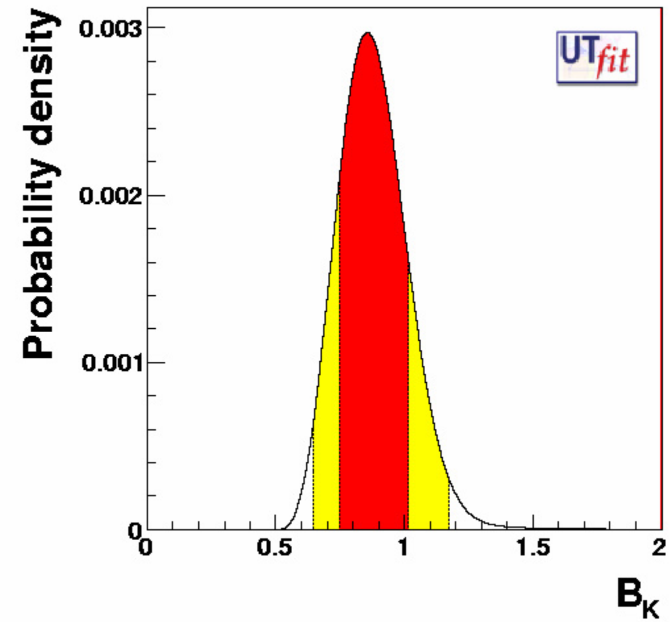
$C_{Bs} = 0.99 \pm 0.12$

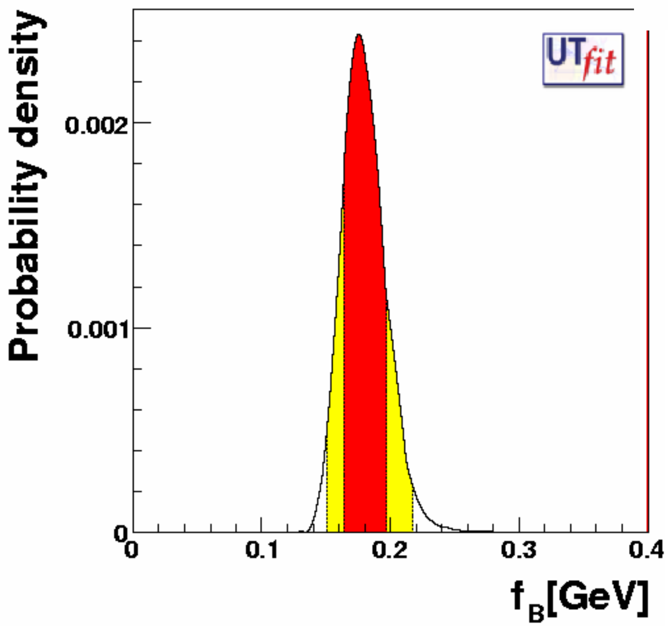
VERY IMPORTANT in $\leq$ 2010 : same and impressive precision on b $\rightarrow$d and b $\rightarrow$s transitions

Hadronic parameters as obtained from the UTfit and from Lattice calculations









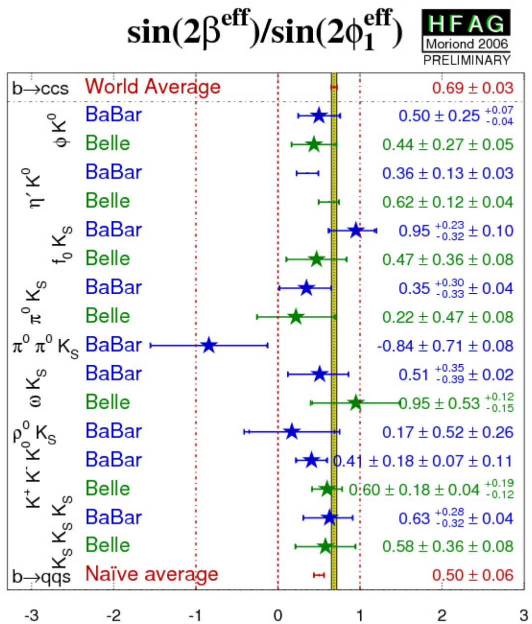
parameter	from UTfit	from calculation
B_K	0.94 ±0.17	0.74 ± 0.04 ± 0.08
F_{Bs} sqrt(B_{Bs})	(257 ± 6) MeV	(262 ± 35) MeV
ξ	1.06 ± 0.09	1.23 ± 0.06
f_B	(217 ± 19) MeV	(189 ± 27) MeV

The errors from UTfit fix the precisions needed from calculations to have an impact in the determination of CKM parameters and to test NP

Observable	**CKM2010**	**SuperB**	**Comments**
sin(2β) (b→ccs)	<1°	<1°	no improvement
sin(2β) (Peng.) φK $(f_0,\eta'\pi^0)K^0$ 3K	 ~4° ~(6,3,5)° ~3°	 ~2° ~(2,1,2)° ~1°	Globally could be a factor 5 improvement
α (ππ,ρρ,ρπ)	5°	~1°	
γ (DK)	(5-10)°	(1-2)°	(Tree decays)GLW+ADS+Dalitz Competition with $_{DsK}$ LHCb
V_{cb}-incl V_{cb}-excl	1% 4%	? -	More theo. parameters from data Depends on Lattice
B →D*τν	10-15%	2-3%	SM -senstitive to NP ($H^{\pm}$)
V_{ub}-incl V_{ub}-excl	10% 10%	? -	More theo. parameters from data Depends on Lattice
Br(B → lν)	10%	1-2%	>5 improvement
Br(B → (ρ,ω),γ)	0.1×10^{-6}	0.03×10^{-6}	$\|V_{td}/V_{ts}\|$ from ργ/K*γ dep. Lattice
A_{FB} $(X_s l^+ l^-)$ Br(B → $X_s l^+ l^-$)	±0.12 ($s<s_0$) 7% (5-14%syst)	±0.015 ($s<s_0$) 7% (1-6%syst)	Competition with LHCb Syst. difficult to extrapolate
A_{FB} $(X_s\gamma)$ A_{FB} $(K^*\gamma)$	3% 0.65%	[0.5-1]% ~0.15%	Interesting if σ<0.5 (SM) Interesting if σ<0.5 (SM)

ΔF=1

b→ s transitions are very sensitive to NP contributions (ΔF=1)



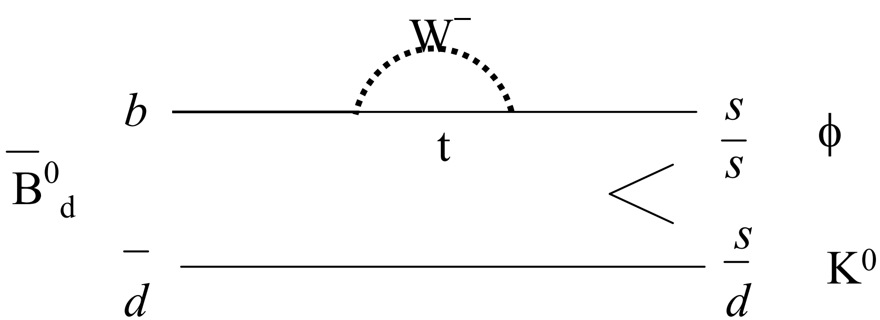
Constraints on b ==> s transitions:

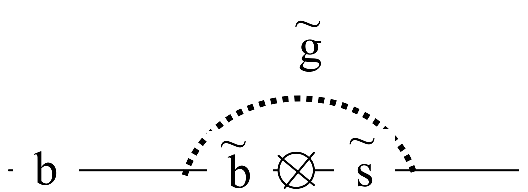
$$BR(B \to X_s \gamma) = (3.29 \pm 0.34) \times 10^{-4}$$

$$A_{CP}(B \to X_s \gamma) = (-0.02 \pm 0.04)$$

$$BR(B \to X_s l^+ l^-) = (6.1 \pm 1.4 \pm 1.3) \times 10^{-6}$$

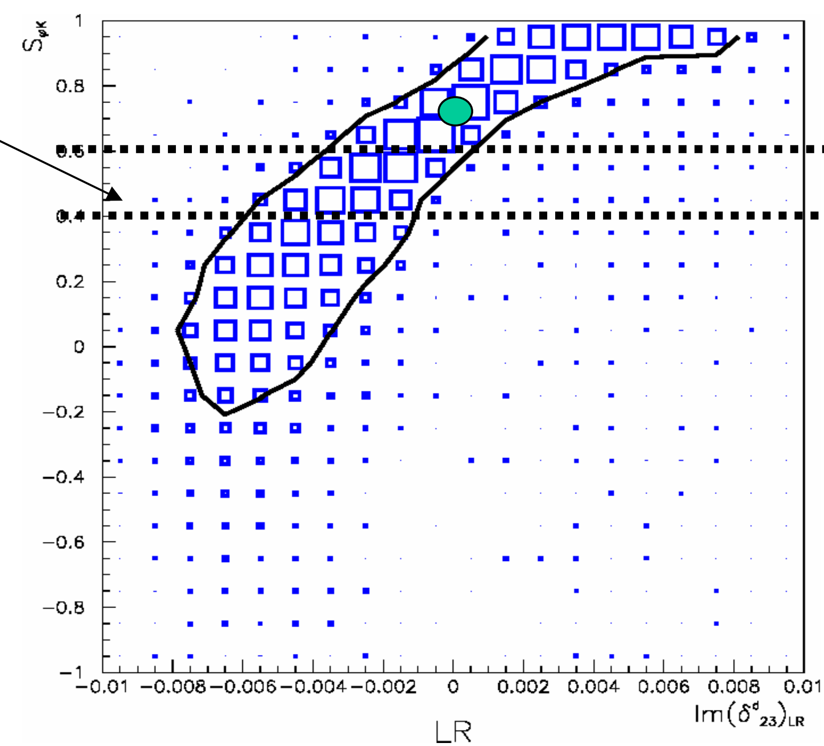
$$\Delta M_s > 14.4\ \text{ps}^{-1} \qquad BR(B \to K\pi)$$





$(\delta^d_{23})_{LR}$

New Physics contribution (2-3 families)



$(\delta^d_{23})_{LR}$

$m_{\tilde{q}} = m_{\tilde{g}}$

350 GeV

CFMS

SUSY effects could account for the observed value of S(Kϕ)