The Standard Model Fit

Two Important Experimental Novelties:

CDF

$$\Delta m_s = (17.77 \pm 0.10 \pm 0.07)\ \mathrm{ps}^{-1}$$

Belle: $(1.79\ {}^{+0.56}_{-0.49}\ {}^{+0.39}_{-0.46}) \times 10^{-4}$

BaBar: $(0.88\ {}^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$

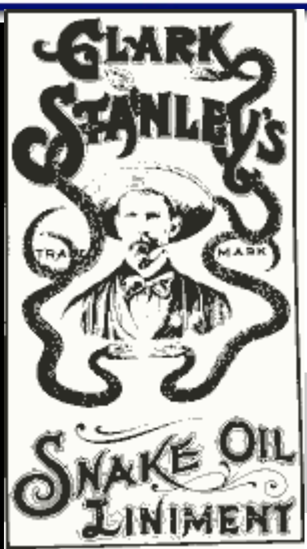
Average: $(1.31 \pm 0.48) \times 10^{-4}$

$\sin 2\beta_{measured} = \mathbf{0.726 \pm 0.037} \Rightarrow \mathbf{0.675 \pm 0.026}$

OUTLINE OF THE TALK

1) **Predictions vs Postdictions**
2) **Lattice vs angles**
3) **V_{ub} inclusive, V_{ub} exclusive vs sin 2β**
4) **Experimental determination of lattice parameters**

THE COLLABORATION



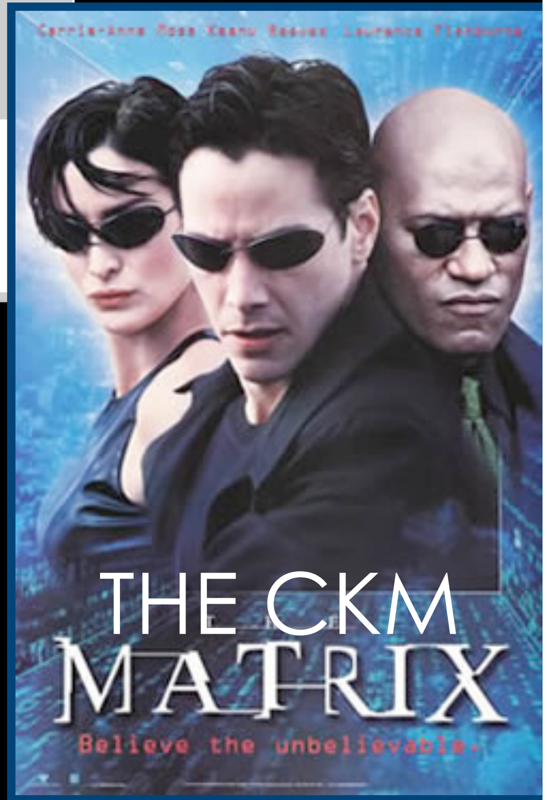
M.Bona, M.Ciuchini, E.Franco, V.Lubicz,
G.Martinelli, F.Parodi, M.Pierini,
P.Roudeau, C.Schiavi, L.Silvestrini,
V. Sordini, A.Stocchi, V.Vagnoni

Roma, Genova, Annecy, Orsay,
Bologna

2006 ANALYSIS

- New quantities e.g. B -> DK included
- Upgraded exp. numbers (after ICHEP)
  - CDF & Belle new measurements

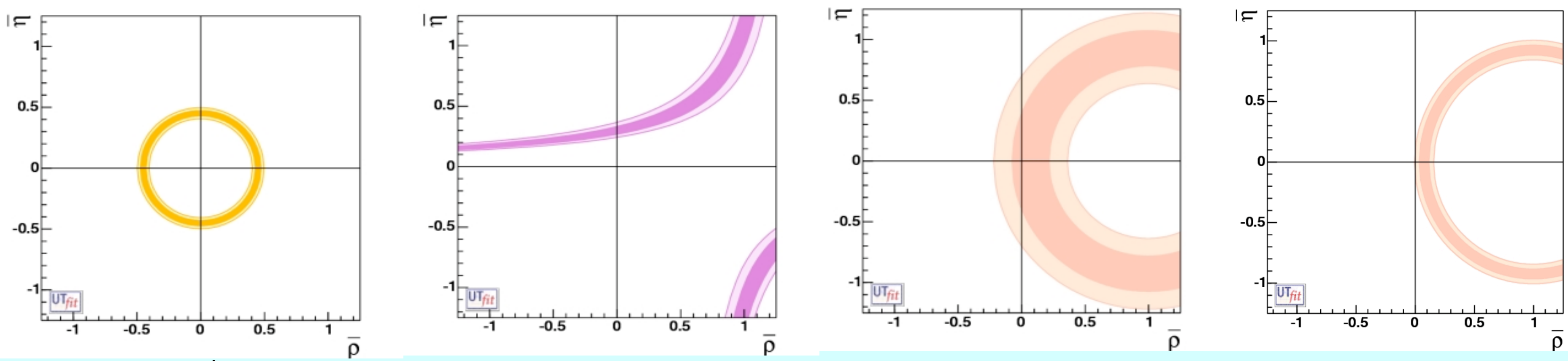
www.utfit.org



Classical Quantities used in the Standard UT Analysis

levels @ 68% (95%) CL

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



UT-LATTICE

Inclusive vs Exclusive
Opportunity for lattice QCD
see later

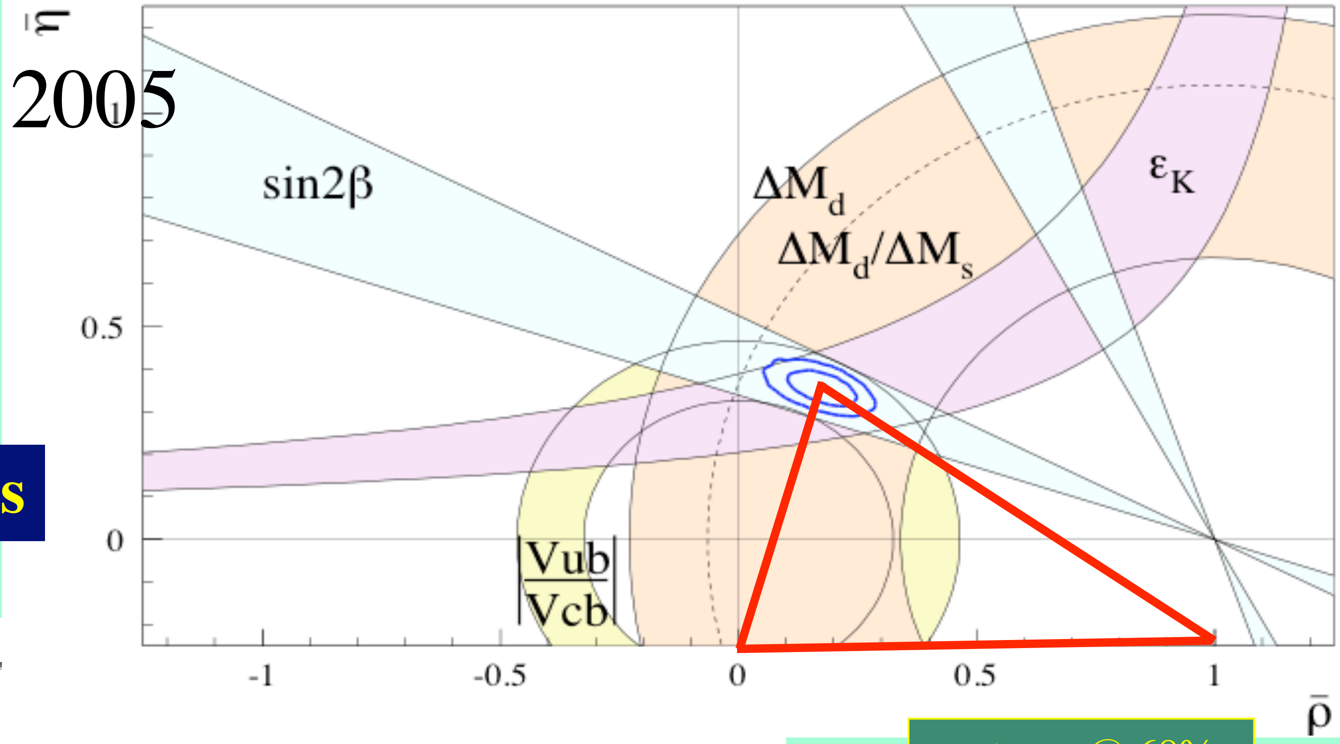
NEW !! before
Only a lower bound

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
hep-ph/0501199
hep-ph/0509219
hep-ph/0605213
hep-ph/0606167
http://www.utfit.org

Unitary Triangle SM



contours @ 68% and 95% C.L.

semileptonic decays

Experimental co

Meas.	$V_{CKM} \times$other	$(\bar{\rho}, \bar{\eta})$
$\frac{b\to u}{b\to c}$	$\lvert V_{ub}/V_{cb}\rvert^2$	$\bar{\rho}^2 + \bar{\eta}^2$
Δm_d	$\lvert V_{td}\rvert^2 f_{B_d}^2 B_{B_d}$	$(1-\bar{\rho})^2 + \bar{\eta}^2$
$\frac{\Delta m_d}{\Delta m_s}$	$\left\lvert \frac{V_{td}}{V_{ts}} \right\rvert^2 \xi^2$	$(1-\bar{\rho})^2 + \bar{\eta}^2$
ϵ_K	$f(A, \bar{\eta}, \bar{\rho}, B_K)$	$\propto \bar{\eta}(1-\bar{\rho})$
$A(J/\psi K^0)$	$sin2\beta$	$\frac{2\bar{\eta}(1-\bar{\rho})}{\sqrt{\bar{\eta}^2+(1-\bar{\rho})^2}}$

$K^0 - \bar{K}^0$ mixing

$B^0_{d,s} - \bar{B}^0_{d,s}$ mixing

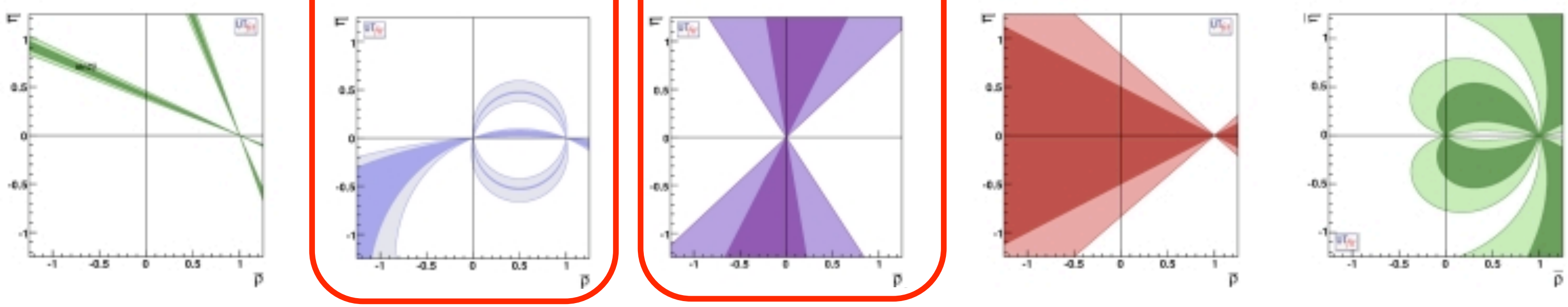
B_d Asymmetry

New 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

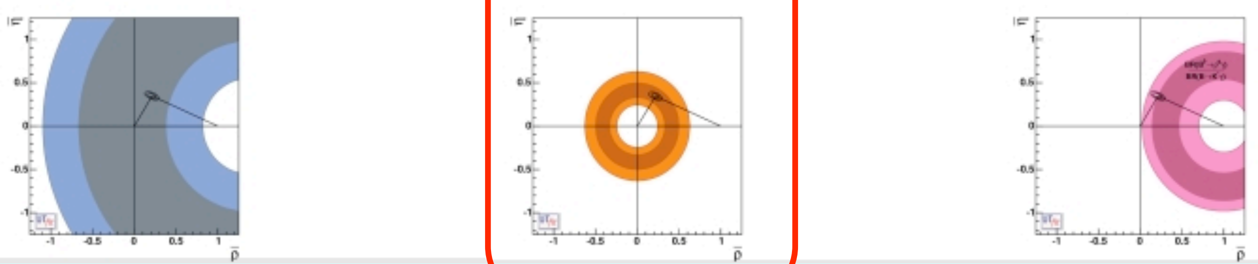
sin2β **angle α** **angle γ** **cos 2β** **sin(2β+γ)**



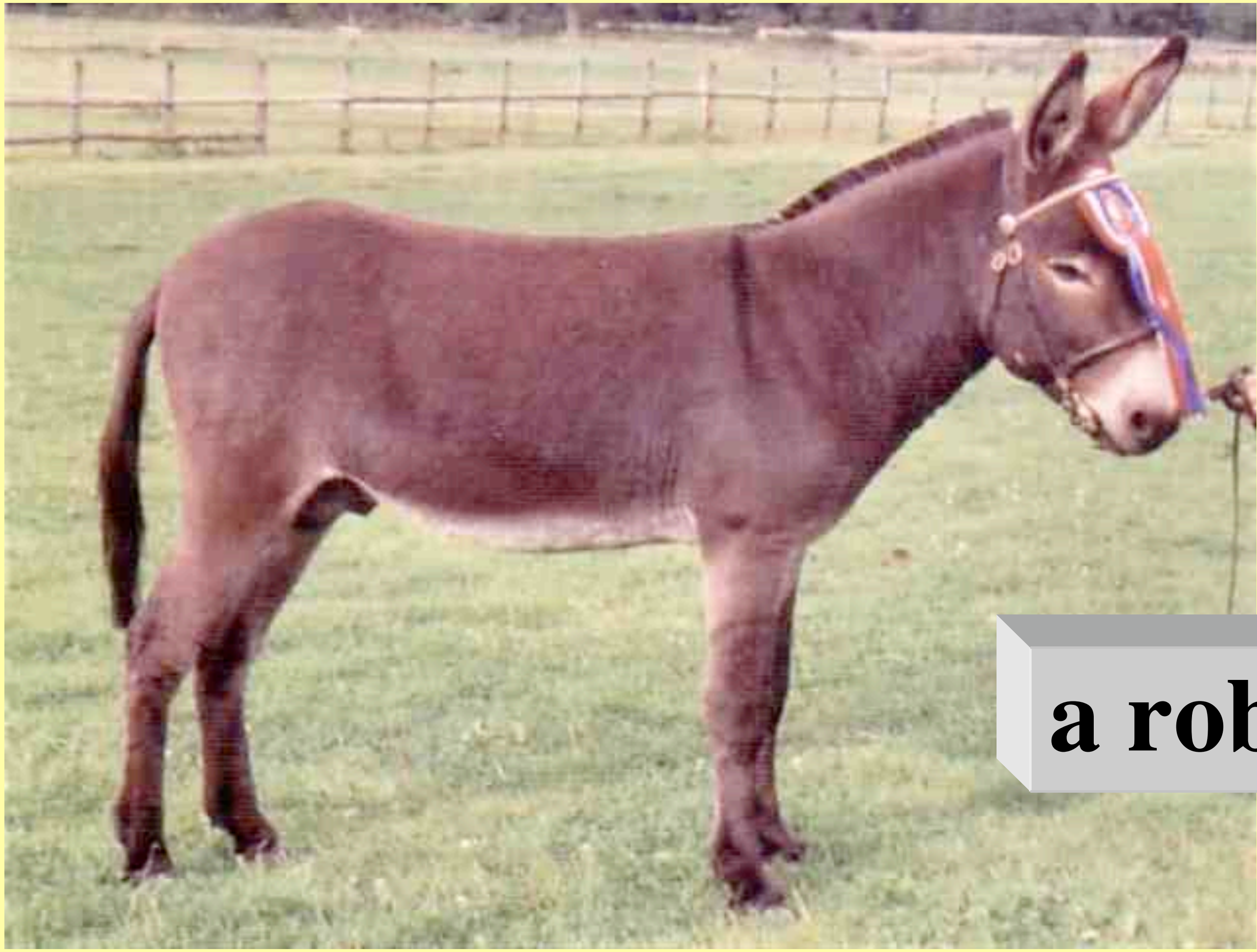
New Constraints from B and K rare decays (not used yet)

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.

$K \rightarrow \pi \nu \bar{\nu}$ **$B \rightarrow \tau \nu$** **$(B \rightarrow \rho/\omega\, \gamma)/(B \rightarrow K^* \gamma)$**



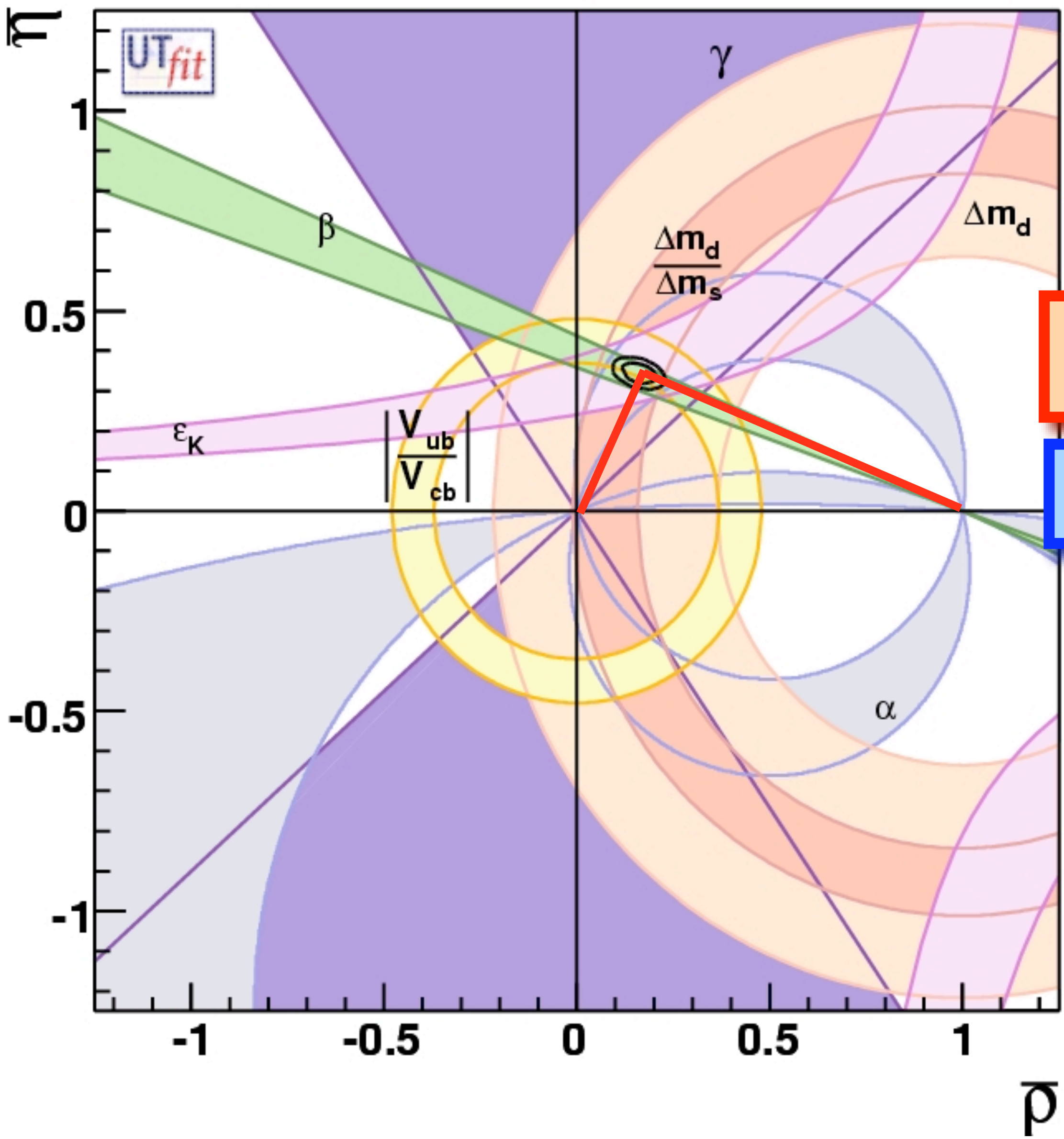
the Standard Model



a robust animal

Results for ρ and η & related quantities

With the constraint from Δm_s



contours @ 68% and 95% C.L.

$\rho = 0.163 \pm 0.028$

$\eta = 0.344 \pm 0.016$

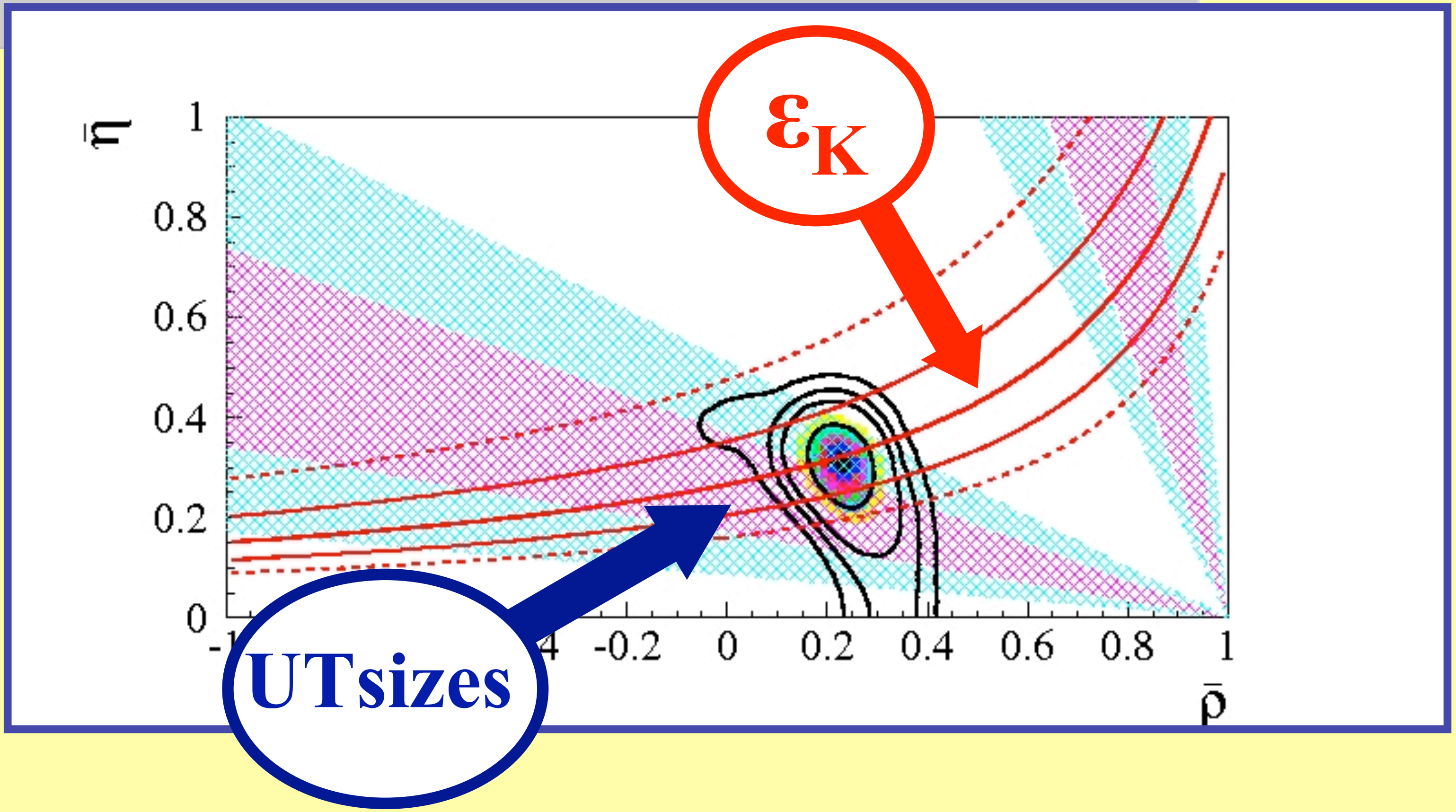
$\alpha = (92.7 \pm 4.2)^0$

$\sin 2\beta = 0.701 \pm 0.022$

A closer look to the analysis:

1) Predictions vs Postdictions
2) Lattice vs angles
3) V_{ub} inclusive, V_{ub} exclusive vs sin 2β
4) Experimental determination of lattice parameters

CKM origin of CP Violation in $K^0 - \bar{K}^0$ Mixing



Ciuchini et al. ("pre-UTFit"),2000

Comparison of $\sin 2\beta$ from direct measurements (Aleph, Opal, Babar, Belle and CDF) and UT analysis

$\sin 2\beta_{measured} = \mathbf{0.675 \pm 0.026}$

$\sin 2\beta_{UTA} = 0.755 \pm 0.039$

correlation (tension) with V_{ub}, see later

$\sin 2\beta_{UTA} = 0.698 \pm 0.066$

prediction from Ciuchini et al. (2000)

$\sin 2\beta_{UTA} = 0.65 \pm 0.12$

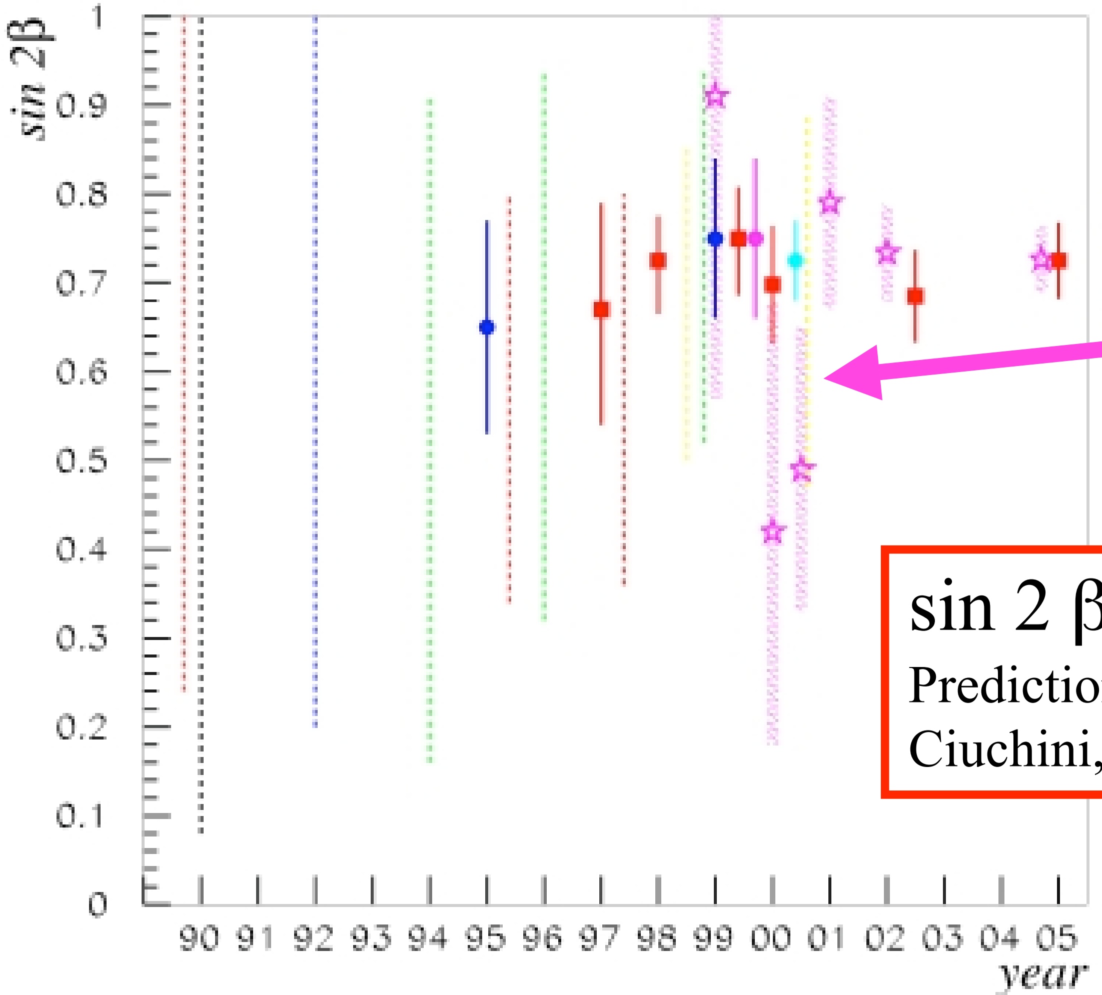
Prediction 1995 from Ciuchini,Franco,G.M.,Reina,Silvestrini

$\sin 2\beta_{tot} = 0.701 \pm 0.022$

Very good agreement

no much room for physics beyond the SM !!

Theoretical predictions of Sin 2 β in the years



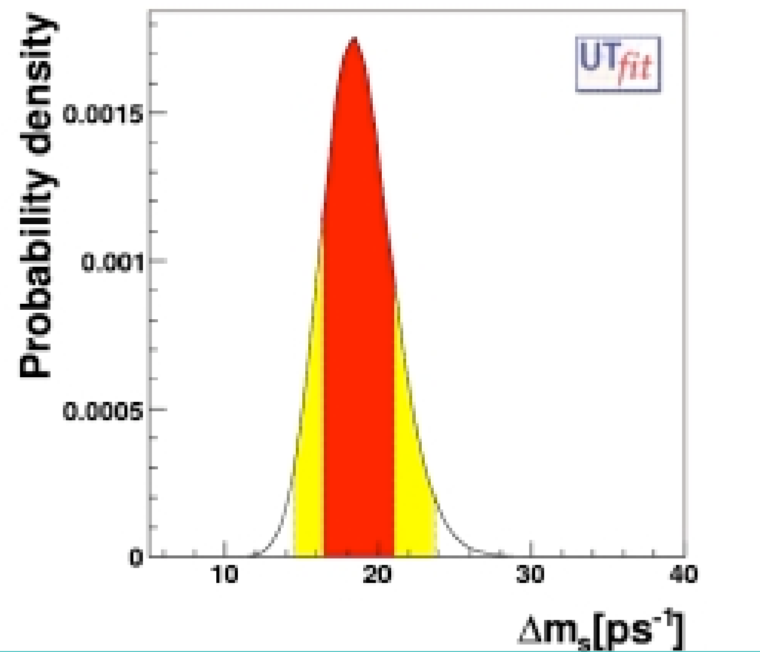
predictions exist since '95

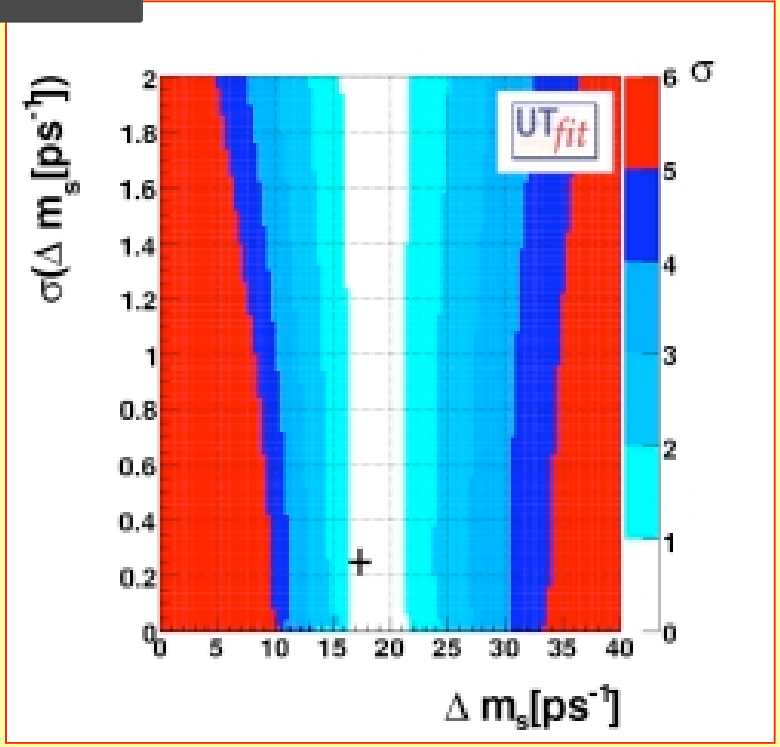
experiments

$\sin 2\,\beta_{UTA} = 0.65 \pm 0.12$

Prediction 1995 from Ciuchini,Franco,G.M.,Reina,Silvestrini

NEWS from NEWS (Standard Model)



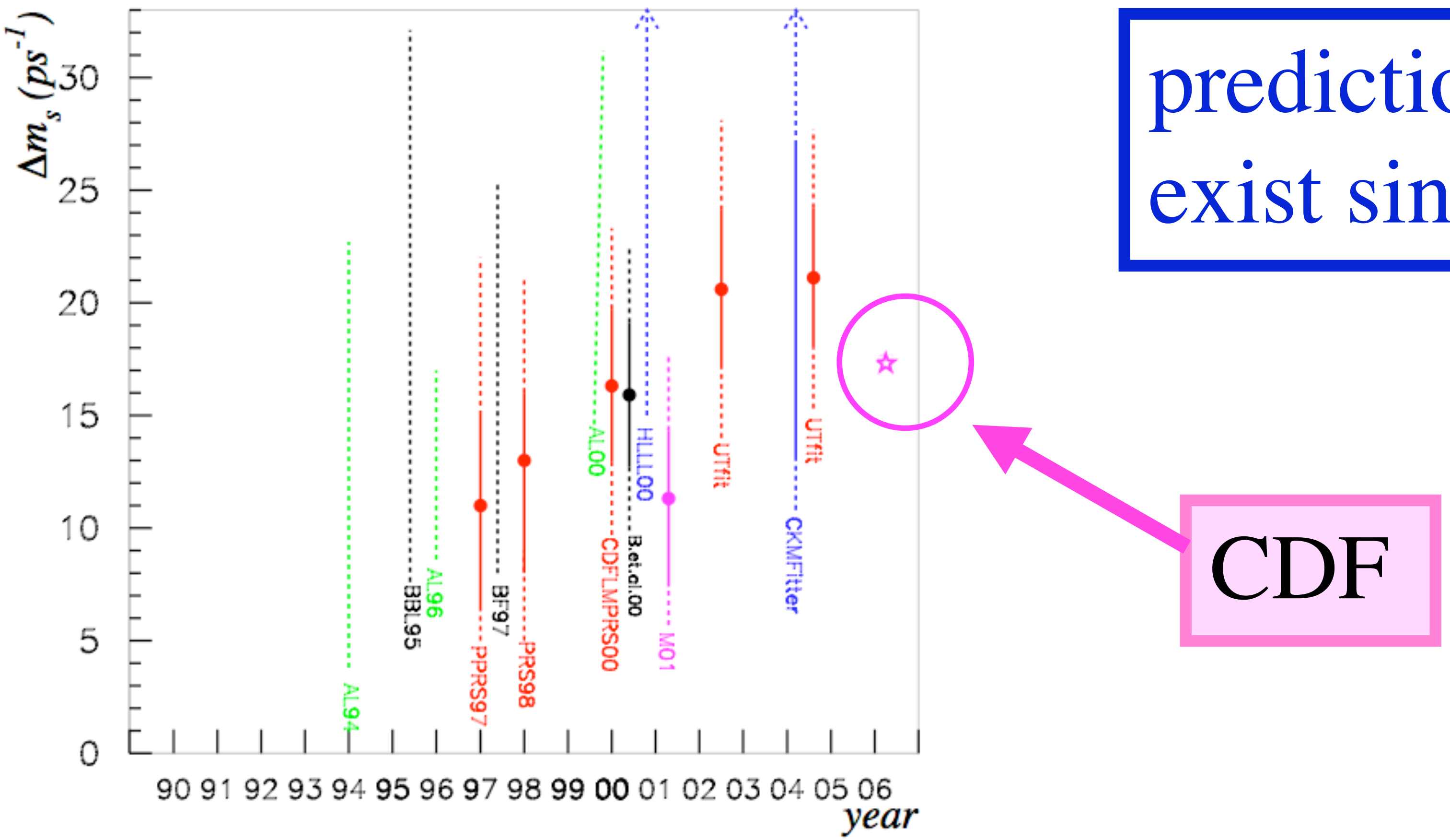


Δm_s Probability Density

$$\Delta m_s = (16.3 \pm 3.4)\ ps^{-1}$$
Ciuchini et. al. 2000

$$\Delta m_s = 18.4 \pm 2.4\, ps^{-1} \qquad INDIRECT$$
$$\Delta m_s = 17.77 \pm 0.12\, ps^{-1} \qquad DIRECT$$

Theoretical predictions of Δm_s in the years



predictions exist since '97

A GREAT SUCCESS OF (QUENCHED) LATTICE QCD CALCULATIONS

A closer look to the analysis:

1) Predictions vs Postdictions
2) Lattice vs angles
3) V_{ub} inclusive, V_{ub} exclusive vs sin 2β
4) Experimental determination of lattice parameters

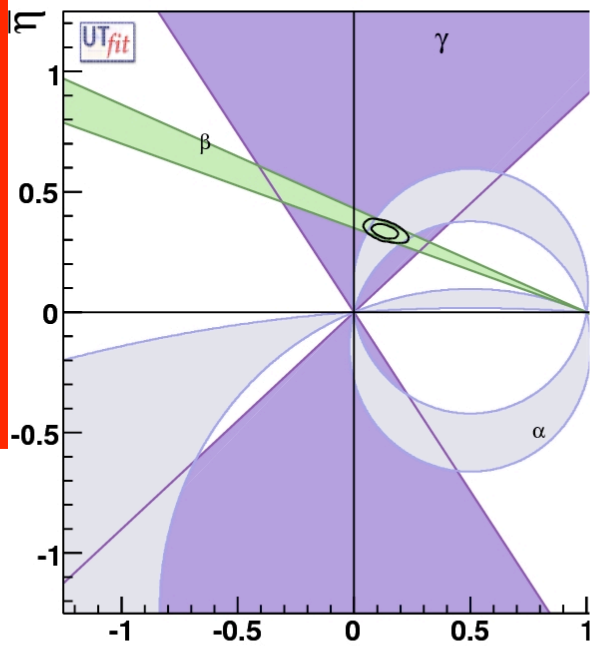
The UT-angles fit does not depend on theoretical calculations (treatement of errors is not an issue)

Comparable accuracy due to the precise sin2β value and substantial improvement due to the new Δm_s measurement

<u>Crucial to improve measurements of the angles, in particular γ</u> (tree level NP-free determination)

Still imperfect agreement in $\bar{\eta}$ due to sin2β and V_{ub} tension

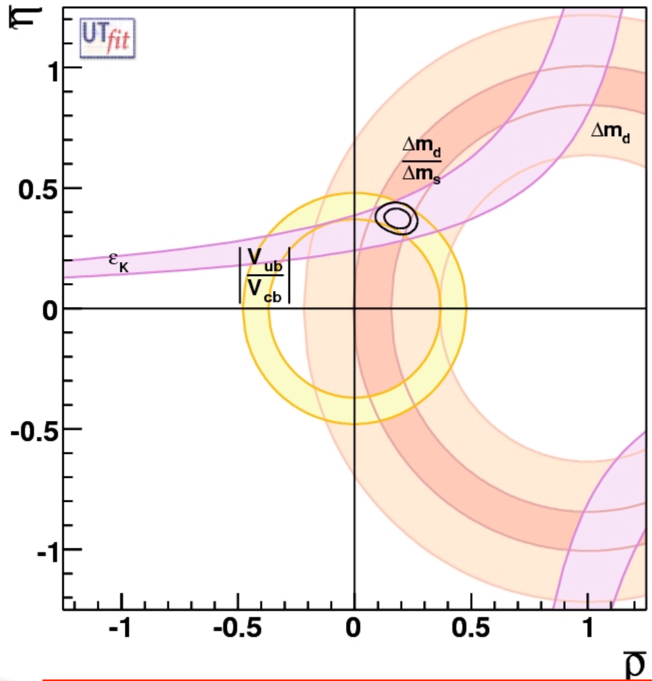
UT-angles



$\rho = 0.134 \pm 0.039$

$\eta = 0.335 \pm 0.020$

UT-lattice



$\rho = 0.188 \pm 0.036$

$\eta = 0.371 \pm 0.027$

ANGLES VS LATTICE

A closer look to the analysis:

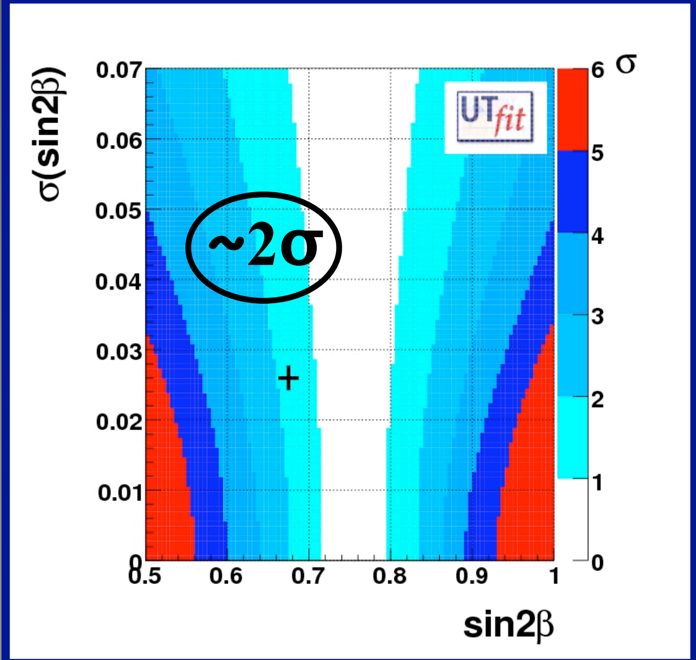
1) **Predictions vs Postdictions**
2) **Lattice vs angles**
3) **V_{ub} inclusive, V_{ub} exclusive vs sin 2β**
4) **Experimental determination of lattice parameters**

Correlation of sin 2 β with V_{ub}

$\sin 2\beta_{measured} = 0.675 \pm 0.026$

$\sin 2\beta_{UTA} = 0.755 \pm 0.039$

Although compatible, these results show that there is a ``tension" . This is mainly due to the correlation of Vub with sin 2 β



V_{UB} PUZZLE

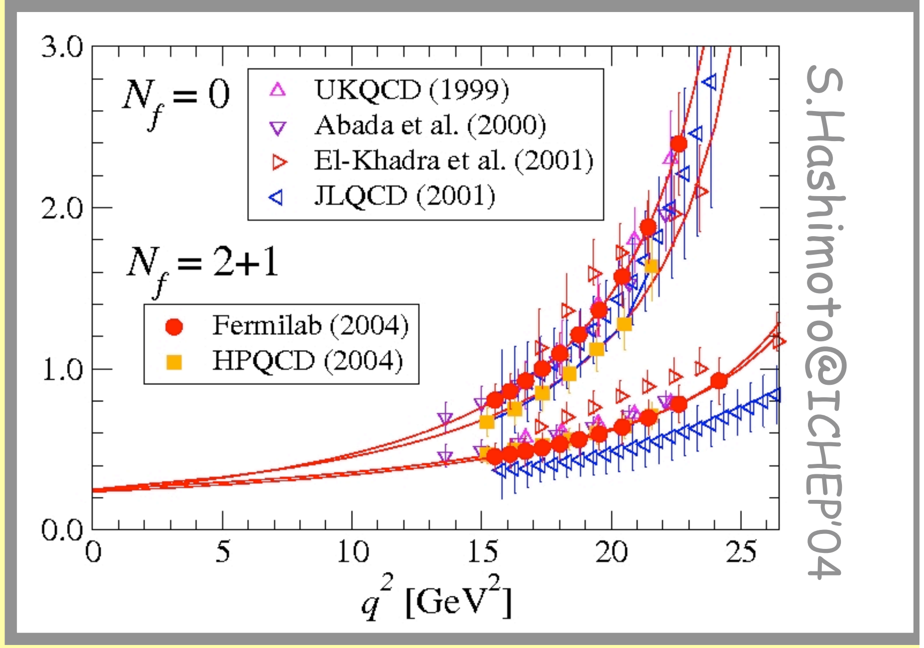
$\lvert V_{ub}\rvert \times 10^4$	excl.	35.0	4.0	Lattice QCDSR
$\lvert V_{ub}\rvert \times 10^4$	incl.	44.9	3.3	HQET+Model
$\lvert V_{ub}\rvert \times 10^4$	average	40.9	2.5	

Inclusive: uses non perturbative parameters most **not** from lattice QCD (fitted from the lepton spectrum)

$$\bar{\Lambda} \quad \lambda_1 \sim \frac{\bar{b}\vec{D}^2 b}{2m_b} \quad \lambda_2 \sim \frac{\bar{b}\sigma_{\mu\nu}G^{\mu\nu}b}{2m_b}$$

Exclusive: uses non perturbative form factors from LQCD and QCDSR

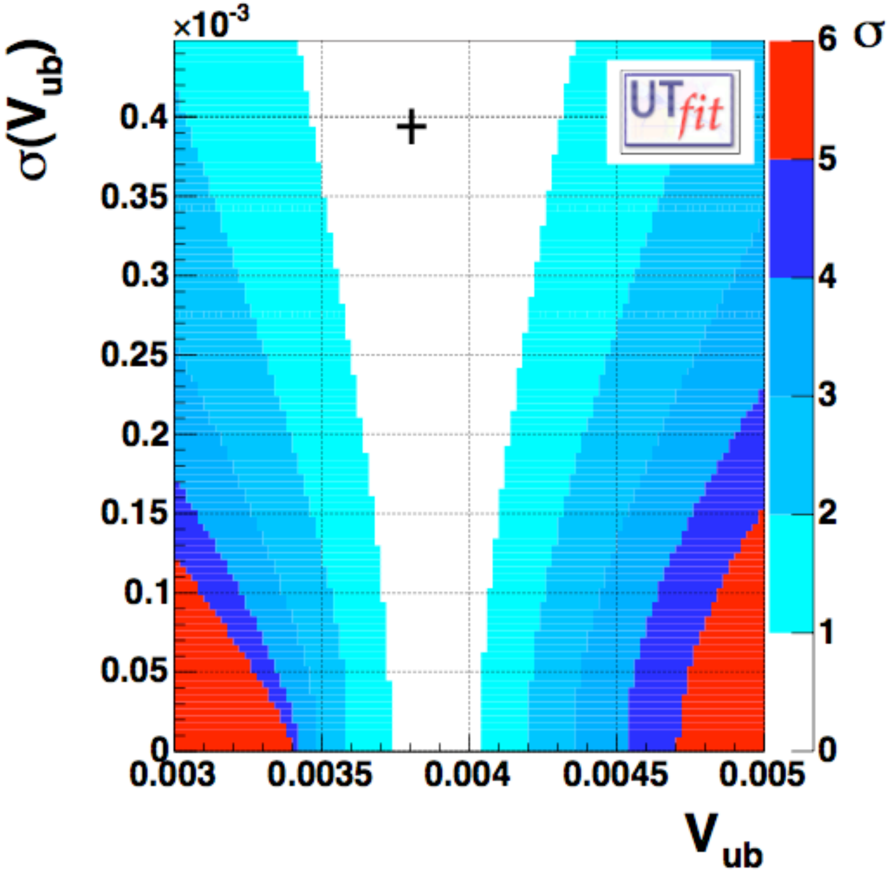
$$f^+(q^2) \quad V(q^2) \quad A_{1,2}(q^2)$$

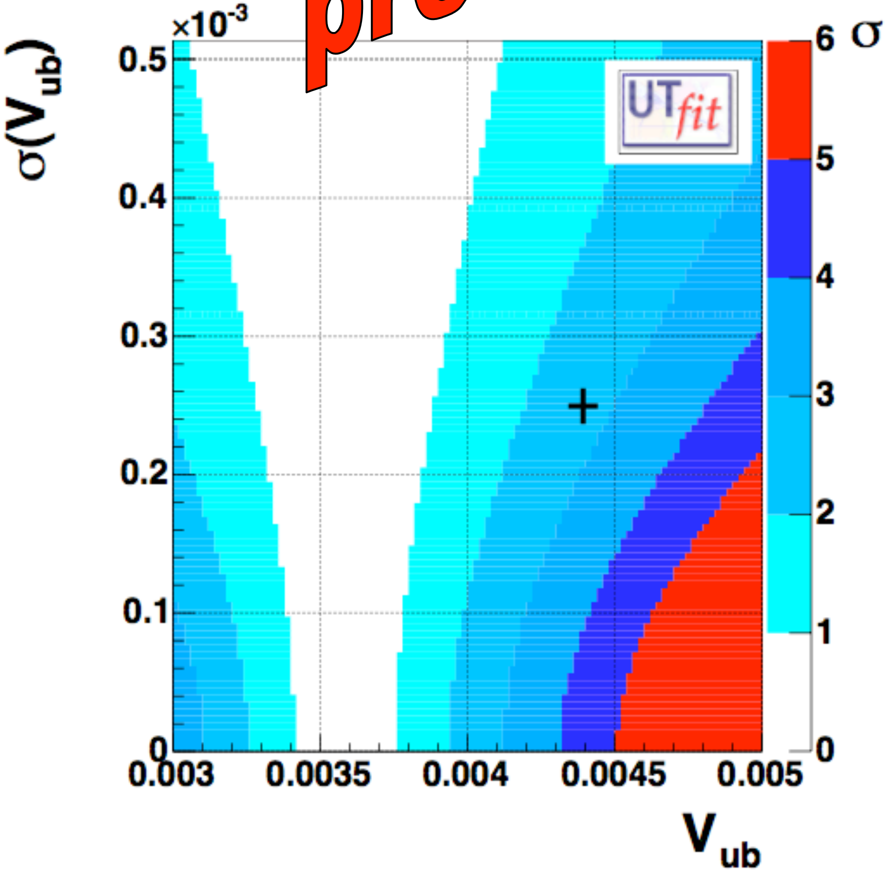


1) Use only exclusive and predict inclusive
2) Use only inclusive and predict exclusive

1) Use only exclusive and predict inclusive
2) Use only inclusive and predict exclusive

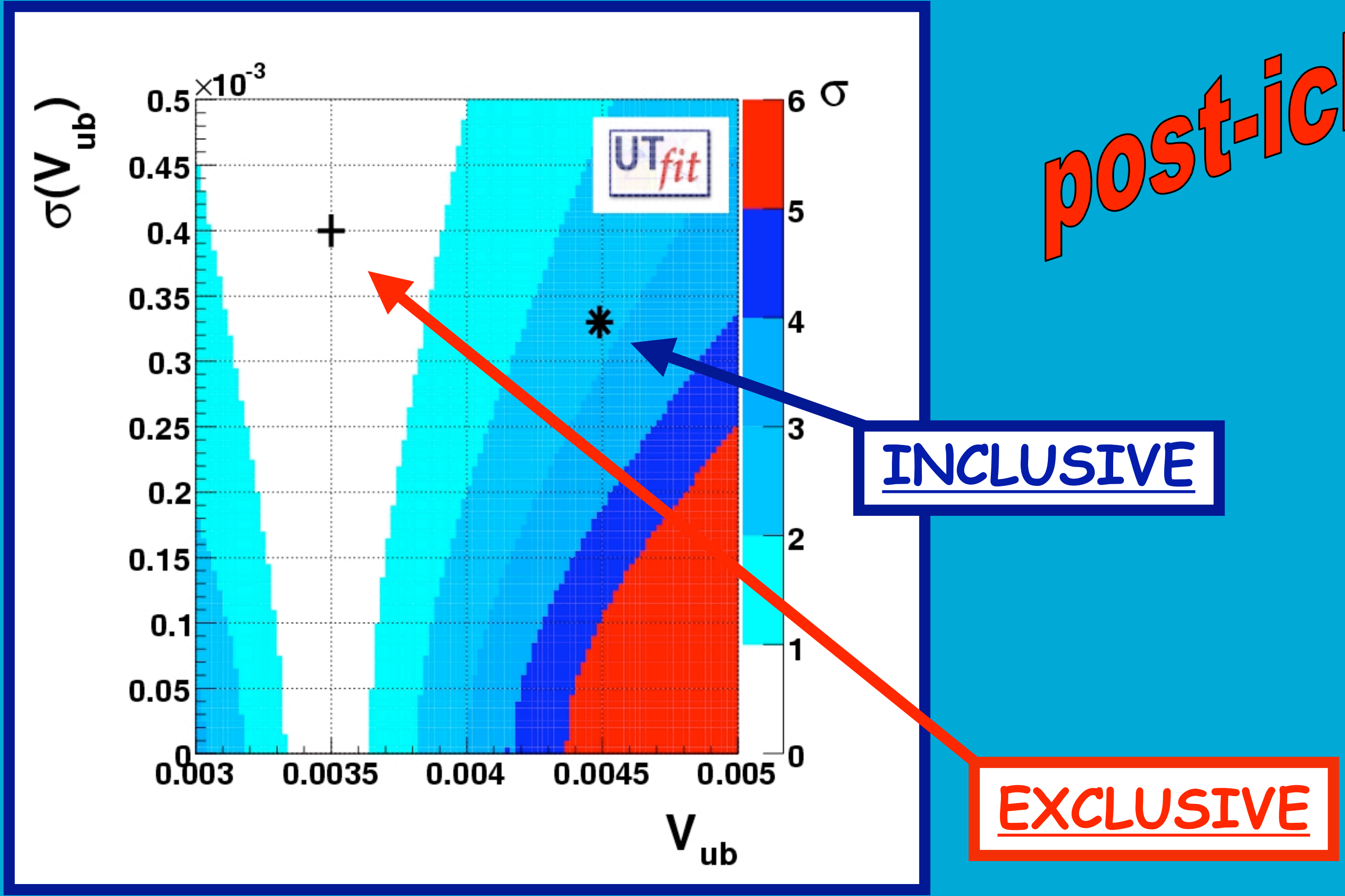
pre-ichep





Tension between inclusive Vub and the rest of the fit

Tension between inclusive Vub and the rest of the fit



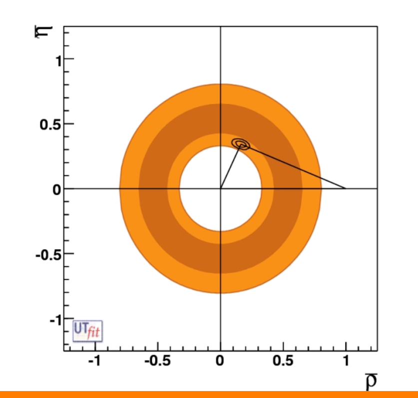
post-ichep

$B \to \tau\nu_\tau$

BaBar: $(0.88\,^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$

Belle: $(1.79\,^{+0.56}_{-0.49}\,^{+0.39}_{-0.46}) \times 10^{-4}$

Average: $(1.31 \pm 0.48) \times 10^{-4}$



Potentially large NP contributions (i.e. MSSM at large tanβ, Isidori & Paradisi)

f_B = (190 ± 14) MeV [UTA]
V_{ub} = (36.7 ± 1.5) 10^{-4} [UTA]

$$BR(B \to \tau\nu_\tau) = (0.89 \pm 0.16) \times 10^{-4}$$

(Best SM prediction)

f_B = (189 ± 27) MeV [LQCD]
V_{ub} = (35.0 ± 4.0) 10^{-4} [Exclusive]

$$BR(B \to \tau\nu_\tau) = (0.84 \pm 0.30) \times 10^{-4}$$

(Independent from other NP effects)

f_B = (189 ± 27) MeV [LQCD]
V_{ub} = (44.9 ± 3.3) 10^{-4} [Inclusive]

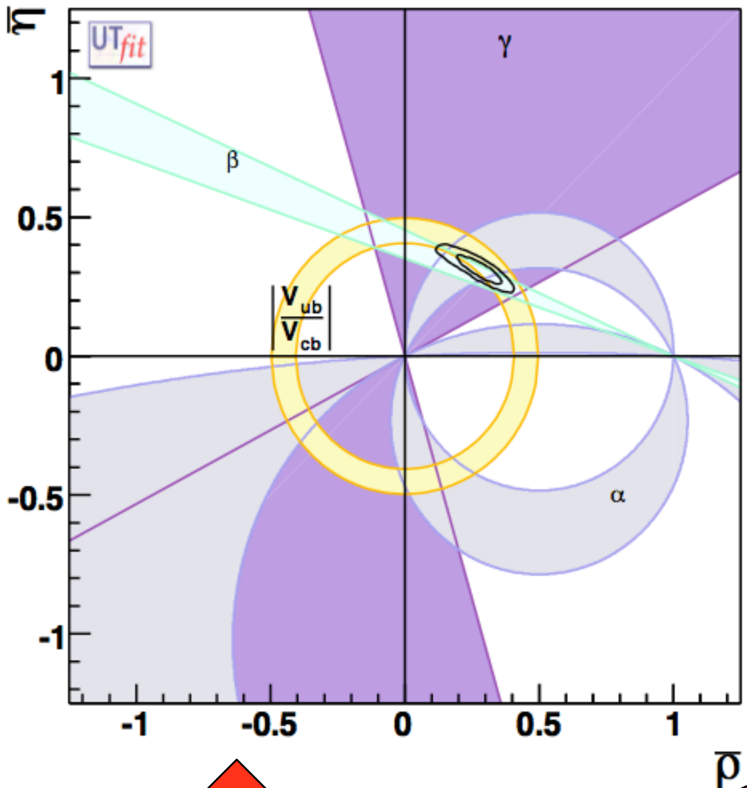
$$BR(B \to \tau\nu_\tau) = (1.39 \pm 0.44) \times 10^{-4}$$

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

Hadronic Parameters From UTfit

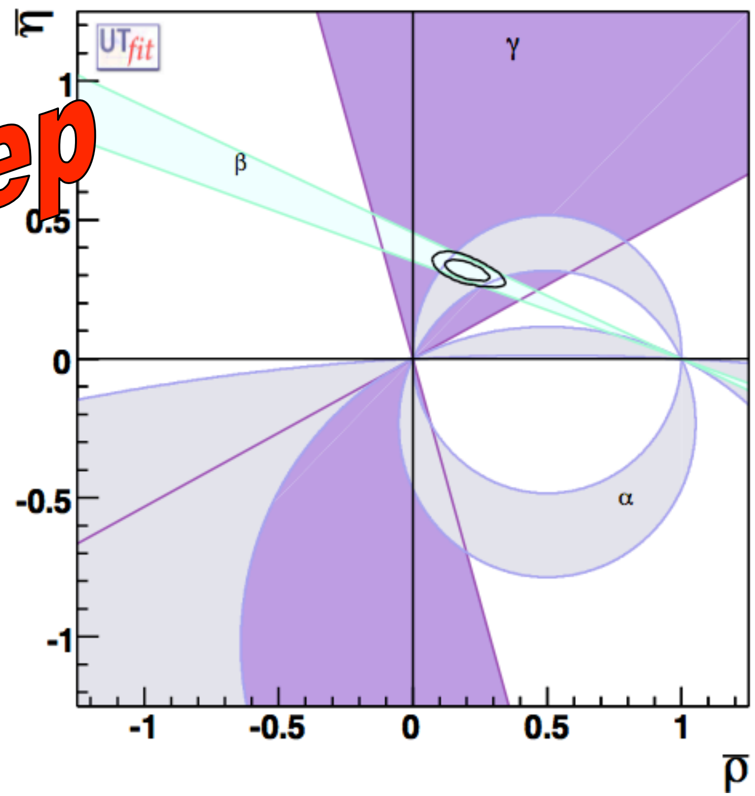
1) Predictions vs Postdictions
2) Lattice vs angles
3) V_{ub} inclusive, V_{ub} exclusive vs sin 2β
4) Experimental determination of lattice parameters

The new measurements allow the analysis WITHOUT THE LATTICE HADRONIC PARAMETERS (eventually only those entering Vub)



with Vub

pre-ichep



Without Vub

IMPACT of the NEW MEASUREMENTS on LATTICE HADRONIC PARAMETERS

$$f_{B_s}\hat{B}_{B_s}^{1/2} \qquad \xi \qquad \hat{B}_K$$

Comparison between experiments and theory

Comparison between experiments and theory

exps vs predictions

$f_{B_s}\sqrt{B_{B_s}} = 262 \pm 35$ MeV

lattice

$f_{B_s}\sqrt{B_{B_s}}=261 \pm 6$ MeV

UTA 2% ERROR !!

$\xi = 1.24 \pm 0.09$ **UTA**

$\xi= 1.23 \pm 0.06$

lattice

$B_K = 0.75 \pm 0.09$

$B_K = 0.79 \pm 0.04 \pm 0.08$

Dawson

$f_B = 187 \pm 0.13$ MeV

$f_B = 189 \pm 27$ MeV

SPECTACULAR AGREEMENT (EVEN WITH QUENCHED LATTICE QCD)

exps vs predictions

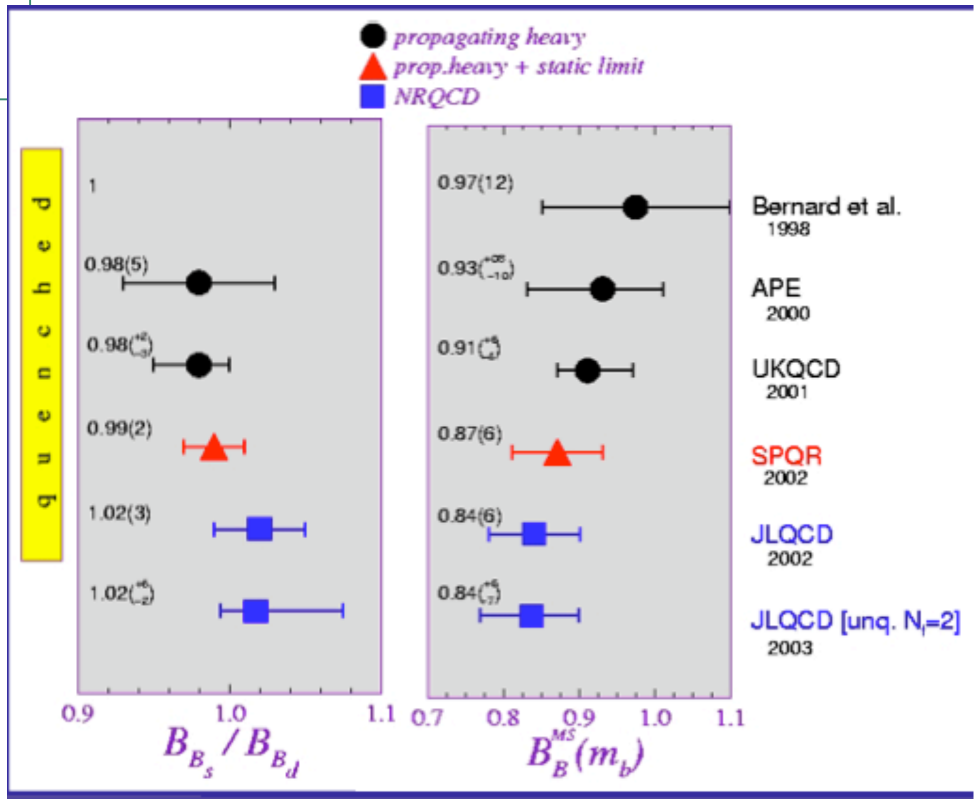
Using the lattice determination of the B-parameters $B_{Bd} = B_{Bs} = 1.28 \pm 0.05 \pm 0.09$

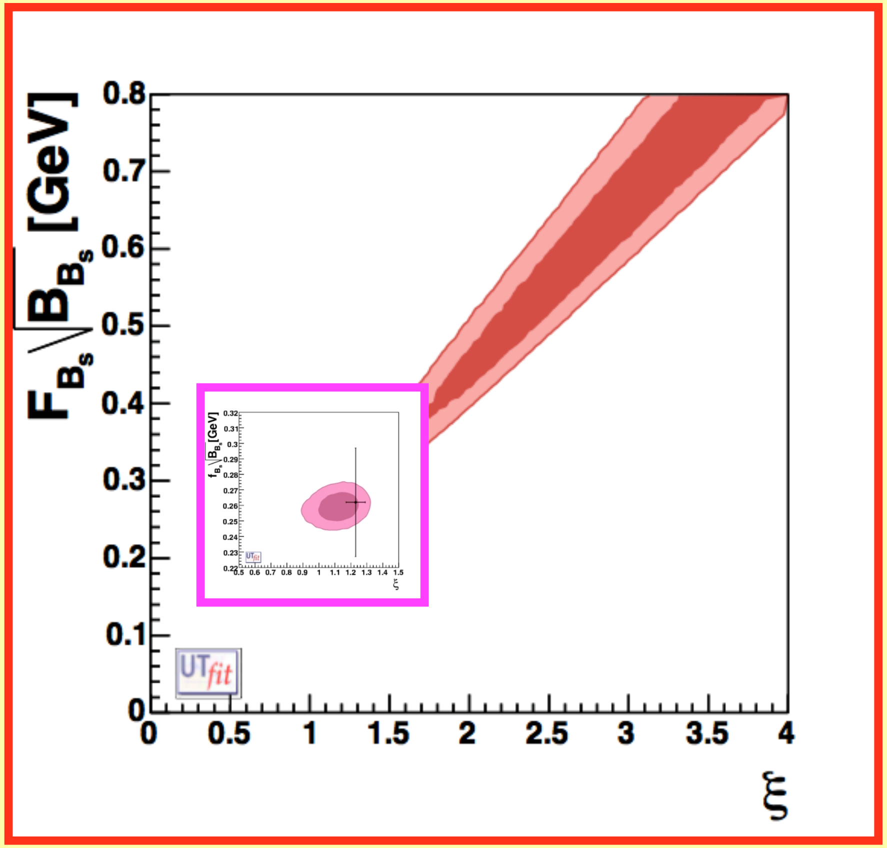
$f_B = 190 \pm 14$ MeV

$f_B = 189 \pm 27$ MeV

$f_{Bs} = 229 \pm 9$ MeV

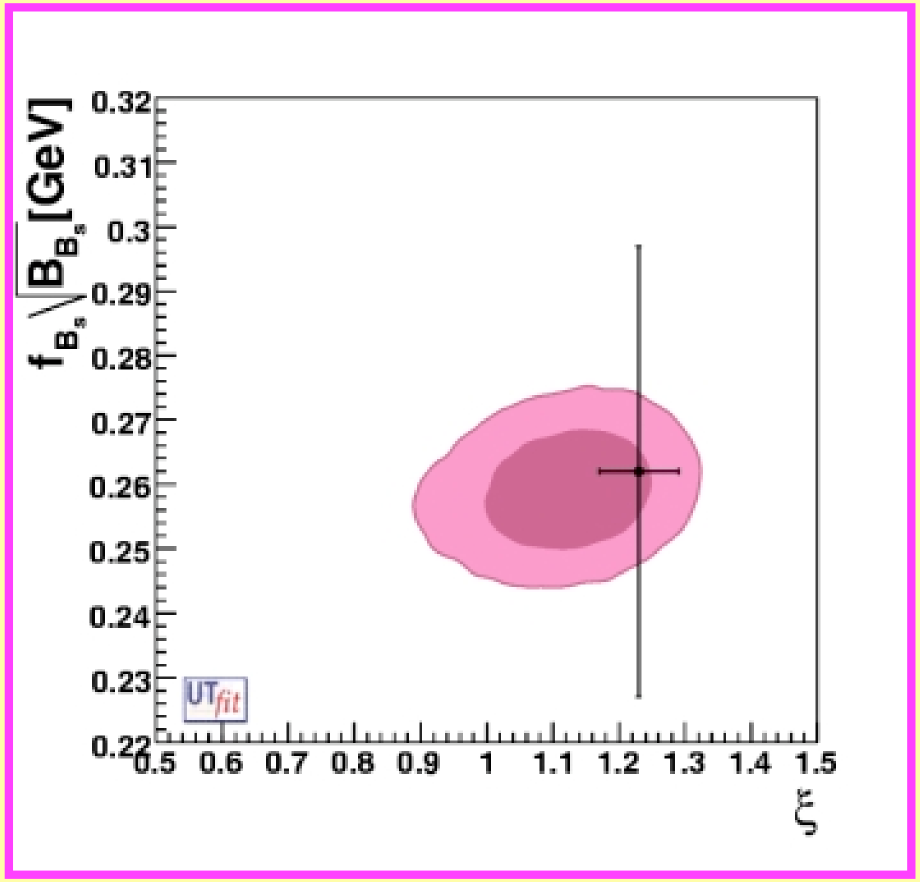
$f_{Bs} = 230 \pm 30$ MeV





OLD

NEW

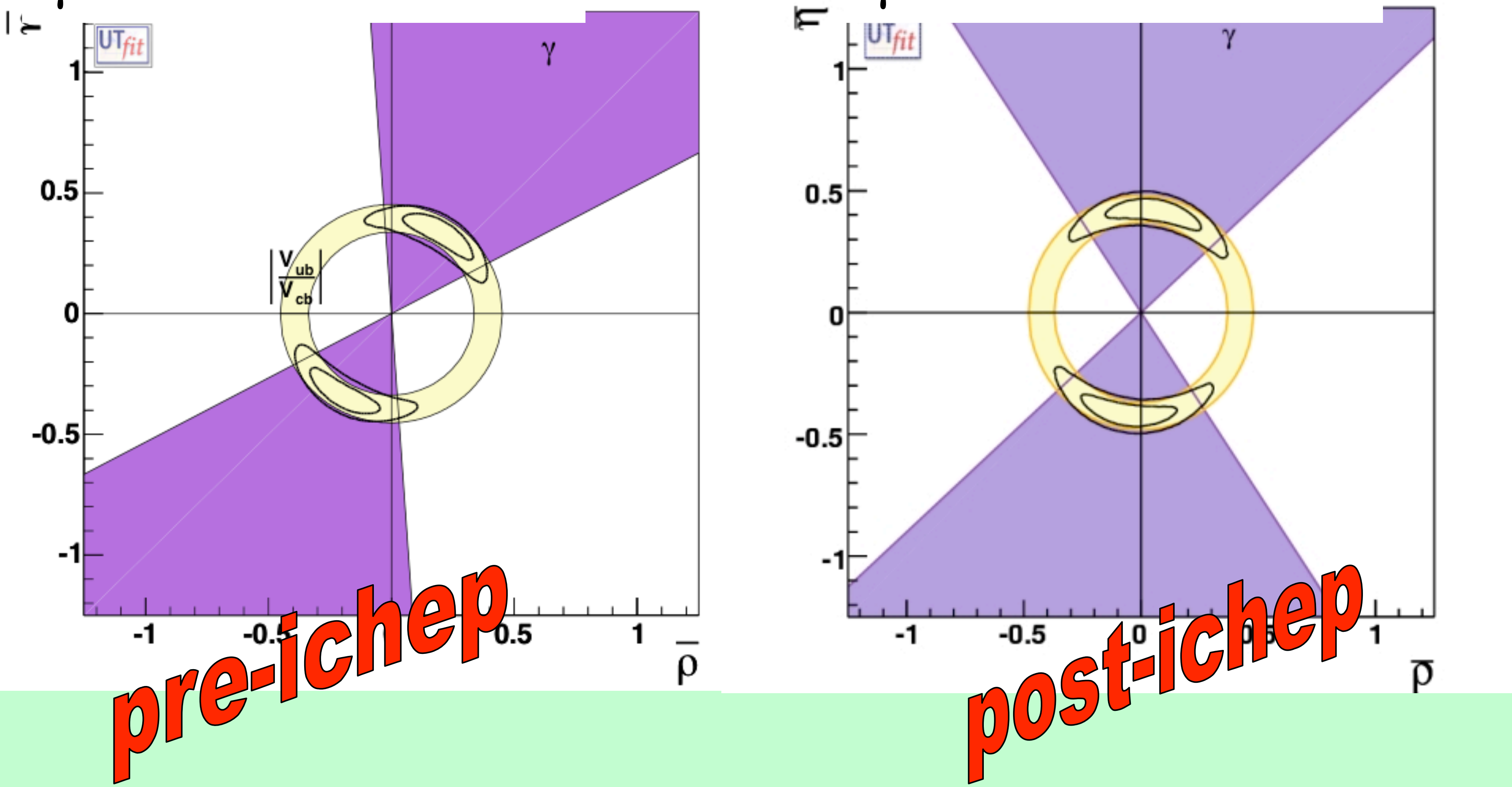


Only tree level processes

CP VIOLATION PROVEN IN THE SM !!

$B \to DK \quad B \to DK^*$

$\gamma = 65 \pm 20 \;\; U \; -115 \pm 20$ $\qquad$ $\gamma = 82 \pm 19 \;\; U \; -98 \pm 19$



CONCLUSIONS

SM Predictions of Bayesian Analysis, using Lattice QCD confirmed by Experiments (sin 2 β_{UTA} and Δm_s)

Extraordinary experimental progresses allow **the extraction of several hadronic quantities from the data**.
It is very important to **reduce the lattice errors** particularly for B_K

A special effort must be done for the semileptonic **form factors necessary to the extraction of V_{ub}**

It is crucial to reduce the error on **the direct determination of the angle γ** from B -> DK, D*K and DK* decays