hep-ph/0408079

Unitarity Triangle fit and New Physics

www.utfit.org

Marcella Bona
INFN ed Università di Torino

on behalf of UTfitters
M.B., M. Ciuchini, G. D'Agostini, E. Franco, V. Lubicz, G. Martinelli, F. Parodi, M. Pierini, P. Roudeau, C. Schiavi, L. Silvestrini, A. Stocchi

EuroGDR
Frascati, November 26, 2004

Method and inputs:

Bayes Theorem

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

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

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

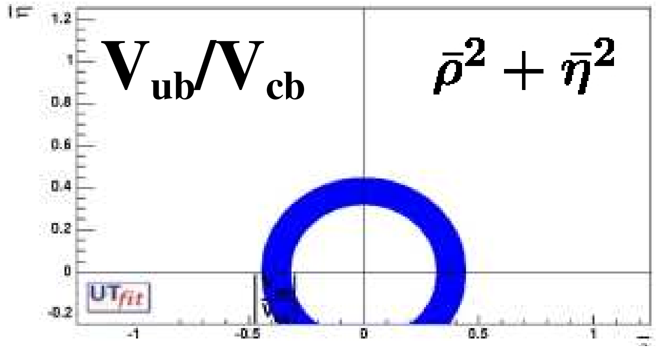
$(b \to u)/(b \to c)$	$\bar\rho^2 + \bar\eta^2$	$\bar\Lambda, \lambda_1, F(1), \ ...$
ϵ_K	$\bar\eta[(1-\bar\rho)+P]$	B_K
Δm_d	$(1-\bar\rho)^2 + \bar\eta^2$	$f_B^2 B_B$
$\Delta m_d/\Delta m_s$	$(1-\bar\rho)^2 + \bar\eta^2$	ξ
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	$-$

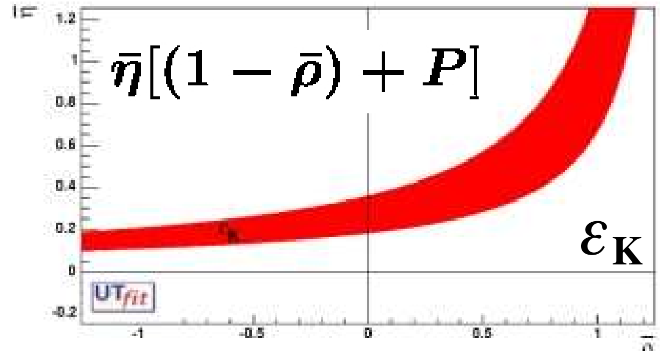
$\left.\begin{matrix} \bar\Lambda, \lambda_1, F(1), ... \\ B_K \\ f_B^2 B_B \\ \xi \end{matrix}\right\}, \boxed{m_t}$

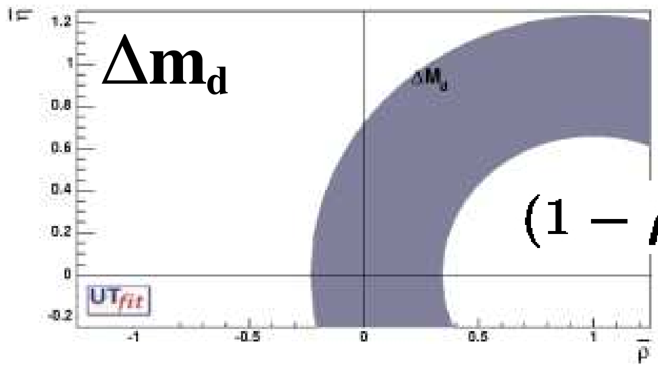
Standard Model + OPE/HQET/ Lattice QCD to go from quarks to hadrons

λ	0.2265 ± 0.020	flat component
V_{cb} inclusive	$41.4 \pm 0.7 \pm \boxed{0.6} \cdot 10^{-3}$	average from inclusive
V_{cb} exclusive	$42.1 \pm 1.1 \pm 1.9 \cdot 10^{-3}$	average from exclusive
V_{ub} inclusive LEP	$4.09 \pm 0.62 \pm \boxed{0.47} \cdot 10^{-3}$	LEP average
V_{ub} inclusive HFAG	$4.57 \pm 0.61 \cdot 10^{-3}$	HFAG Winter 04
V_{ub} exclusive	$3.30 \pm 0.24 \pm 0.46 \cdot 10^{-3}$	
Δm_d	$0.502 \pm 0.007\ ps^{-1}$	LEP/SLD/CDF/B-Factories
Δm_s	$> 14.5\ ps^{-1}$	LEP/SLD/CDF-1
m_t	$167 \pm 5\ GeV$	CDF/D0
m_c	$1.3 \pm 0.1\ GeV$	
$f_{B_s}\sqrt{\hat{B}_{B_s}}$	$276 \pm 38\ MeV$	Lattice QCD
ξ	$1.24 \pm 0.04 \pm \boxed{0.06}$	Lattice QCD
B_K	$0.86 \pm 0.06 \pm \boxed{0.14}$	Lattice QCD
$\sin 2\beta$	0.726 ± 0.037	B-Factories

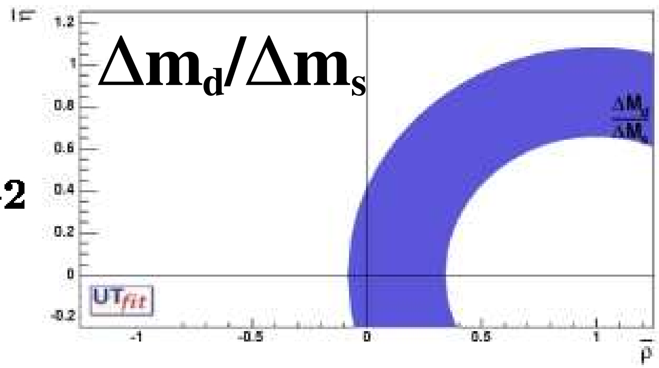
The standard inputs in the $\bar{\rho}$-$\bar{\eta}$ plane:

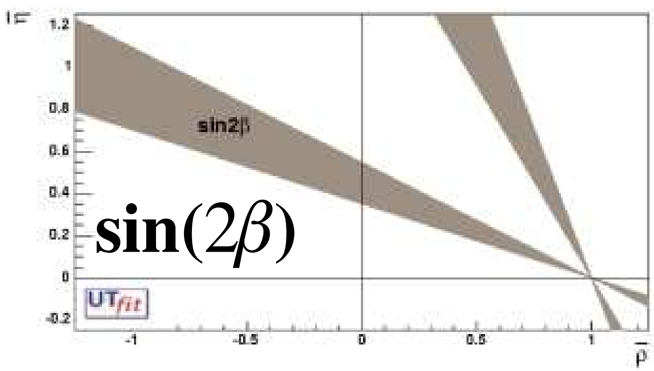




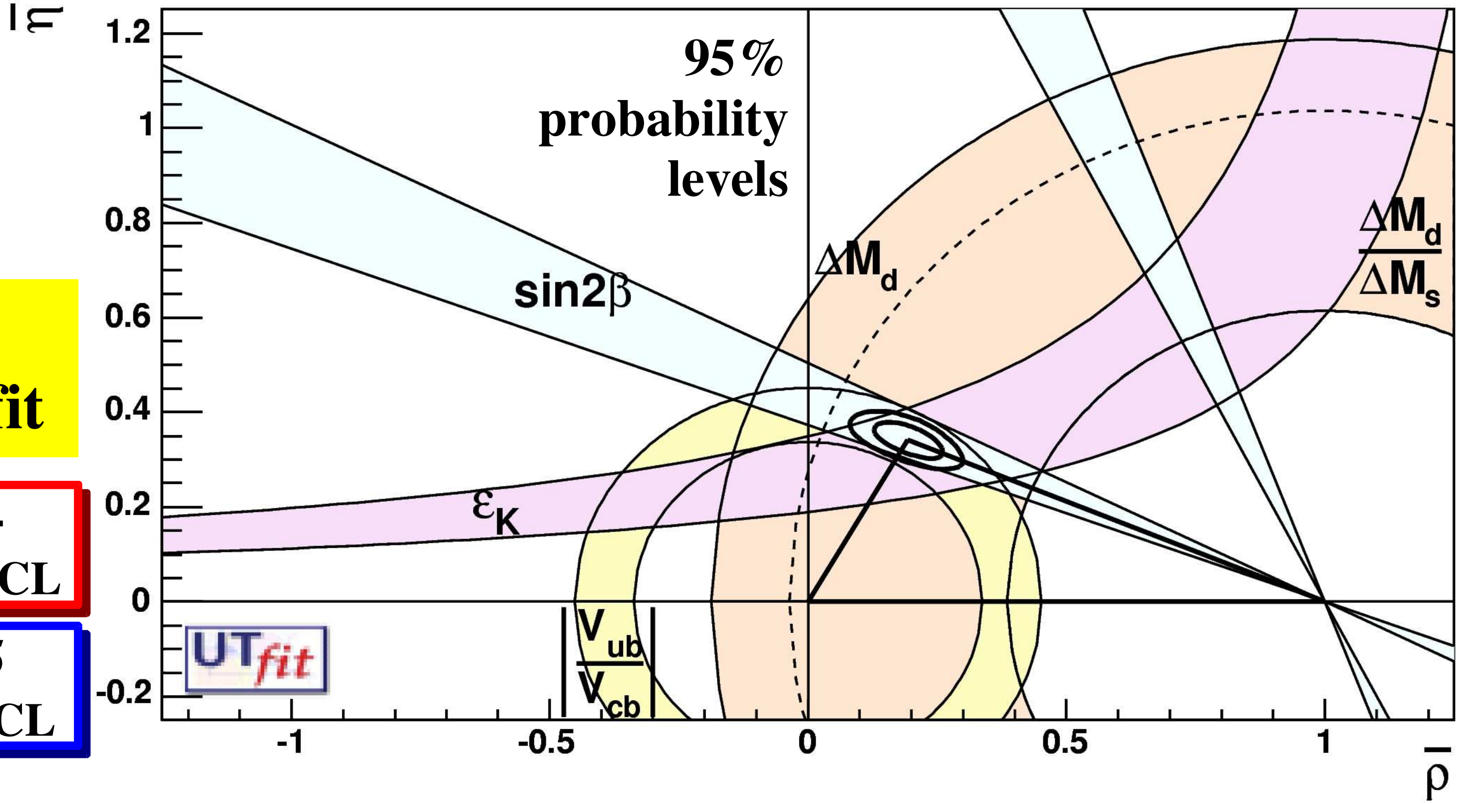


$$(1-\bar{\rho})^2 + \bar{\eta}^2$$





...and putting all together...



Result from the standard fit

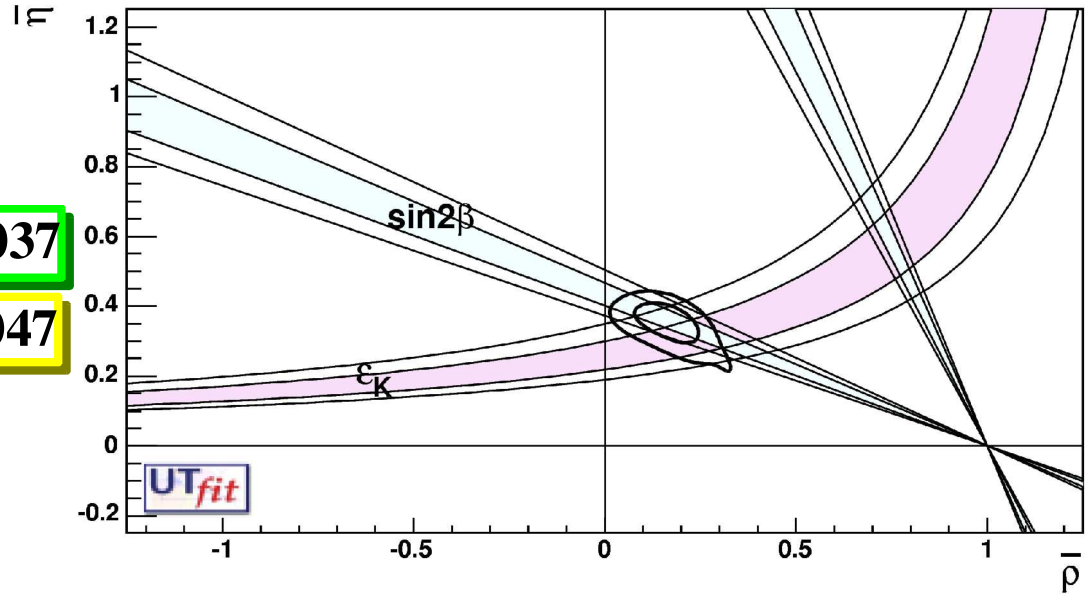
$\bar{\rho} = 0.197 \pm 0.044$
[0.104, 0.278] @ 95% CL

$\bar{\eta} = 0.342 \pm 0.025$
[0.293, 0.390] @ 95% CL

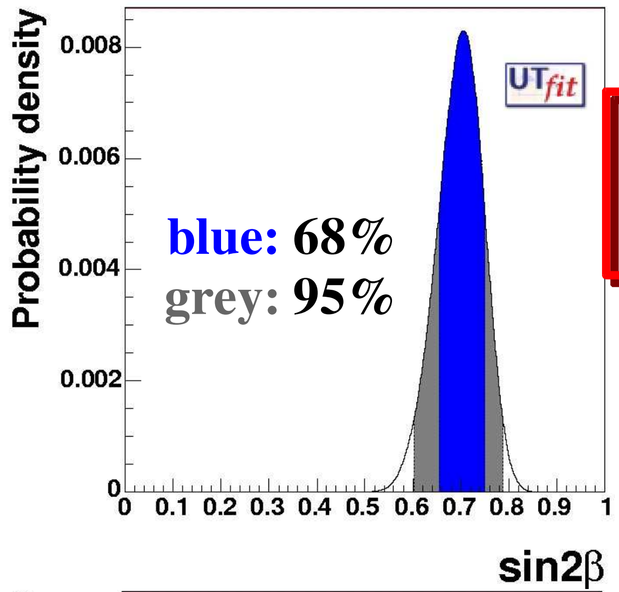
test of the SM:
CP-violating parameters from CP-conserving observables

from charmonium: $\sin 2\beta = 0.726 \pm 0.037$

from side-only fit: $\sin 2\beta = 0.720 \pm 0.047$

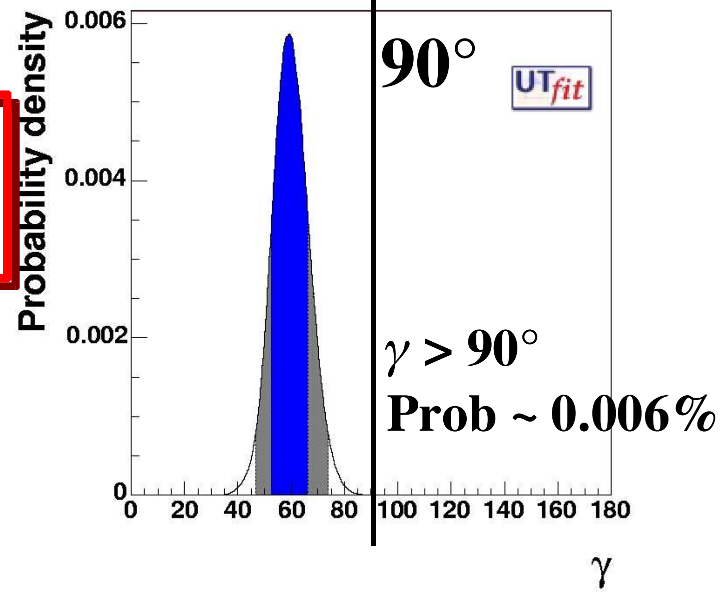


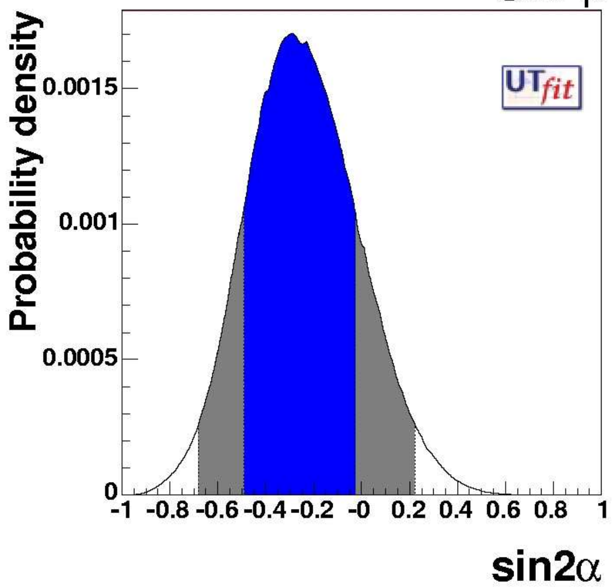
Indirect determinations: a posteriori



$\sin 2\beta = 0.704 \pm 0.047$
[0.602, 0.788] @ 95% CL

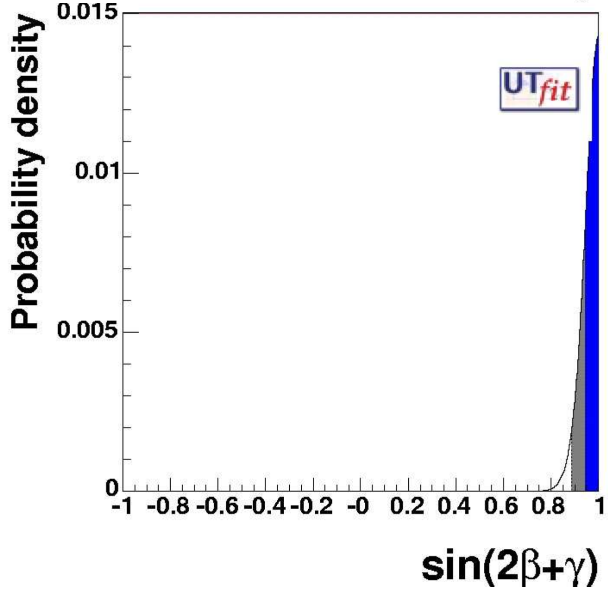
$\gamma = 60.1^\circ \pm 6.8^\circ$
[46.7, 73.8] @ 95% CL





$\sin 2\alpha = -0.24 \pm 0.23$
[-0.68, 0.22] @ 95% CL

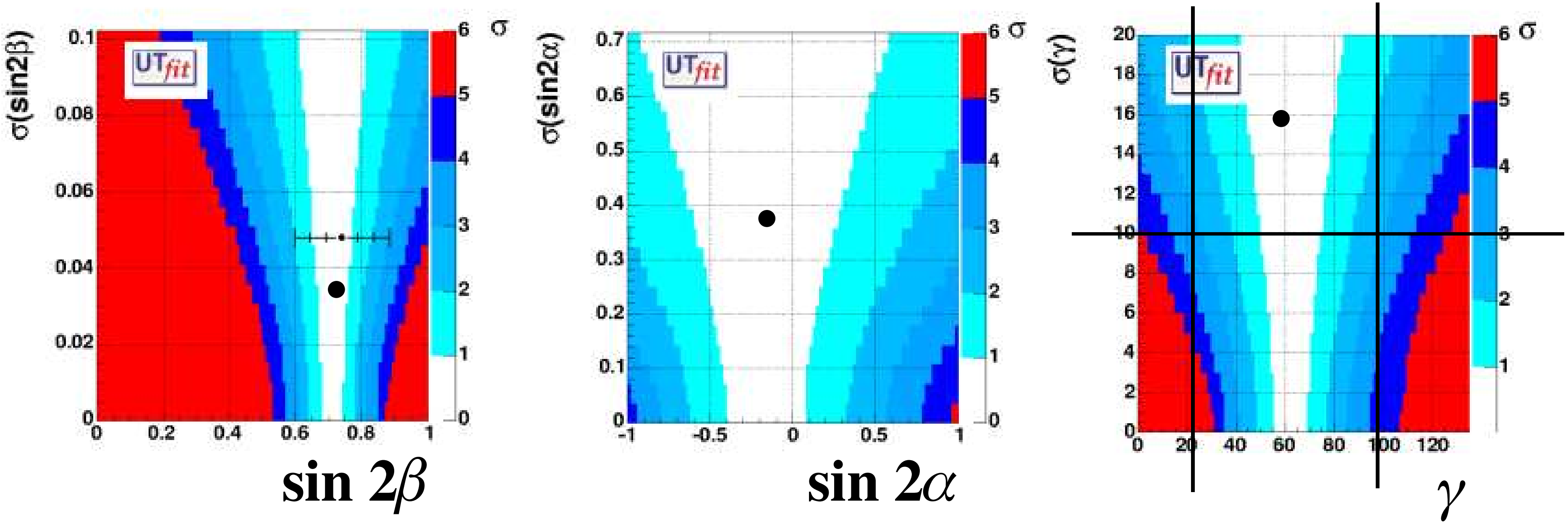
$\sin(2\beta+\gamma) > 0.88$
@ 95% CL



Compatibility plots:

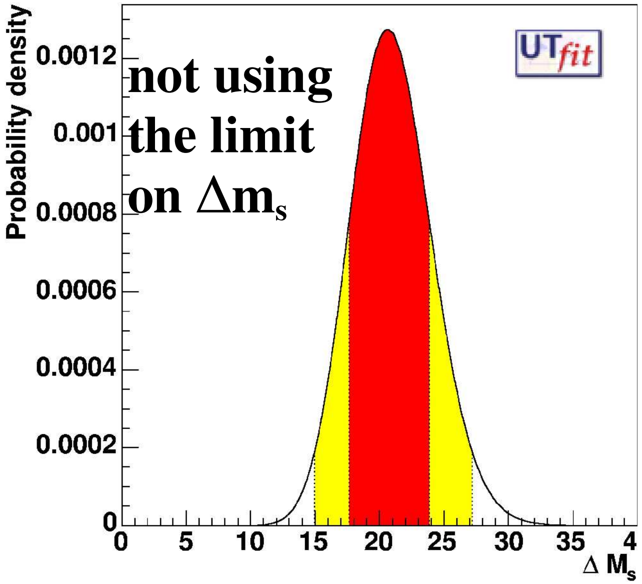
red: 5σ exclusion zone

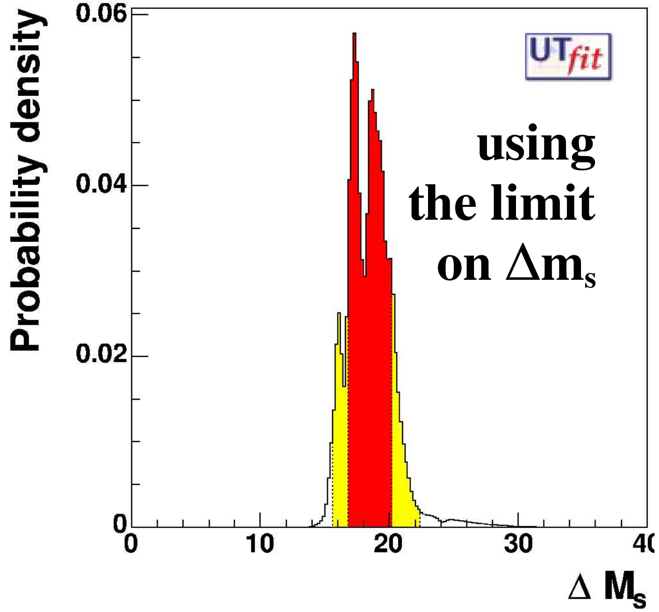
$\gamma > 100°$, $\gamma < 25°$ } new physics @ 3σ level

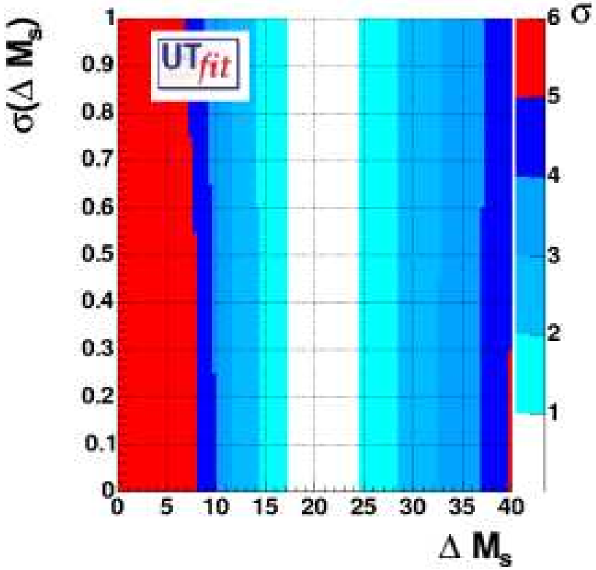


comparison between the indirect determination and a (hypothetical) direct experimental determination

Indirect determination and compatibility plot for Δm_s:







$\Delta m_s = 20.7 \pm 3.1\ ps^{-1}$
[14.4, 27.1] @ 95% CL

$\Delta m_s = 18.3 \pm 1.6\ ps^{-1}$
[15.5, 22.0] @ 95% CL

if $\Delta m_s > 30\ ps^{-1}$
new physics @ 3σ

Looking for New Physics:

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

model indepentent assumptions

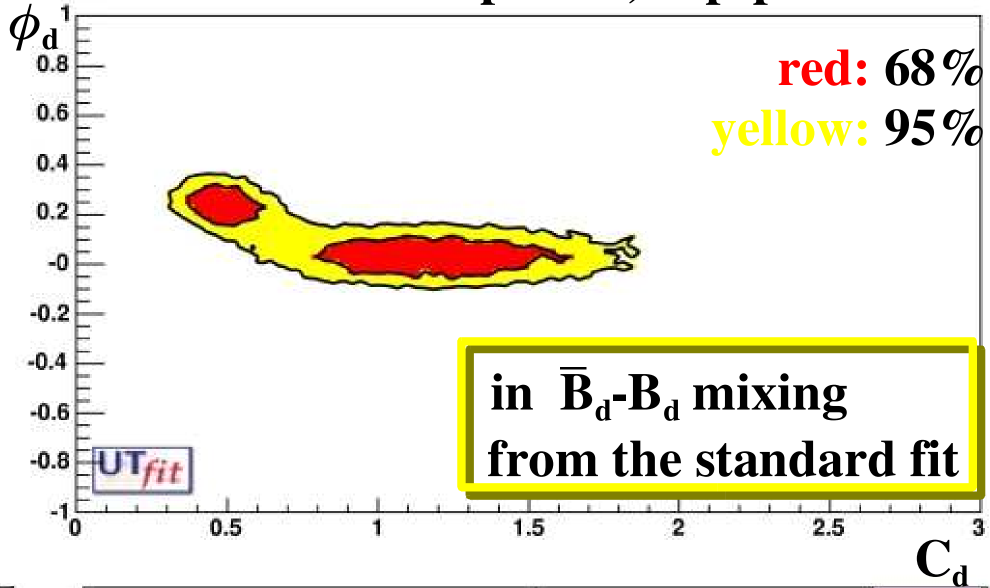
- $|\varepsilon_K|^{EXP} = C_\varepsilon \cdot |\varepsilon_K|^{SM}$
- $\Delta m_d^{EXP} = C_d \cdot \Delta m_d^{SM}$
- $\Delta m_s^{EXP} = C_s \cdot \Delta m_s^{SM}$
- $A_{CP}(J/\psi K^0) = \sin(2\beta + \phi_d)$

From the standard fit:
few constraints
↓
so we switch on NP
one component at a time
(to extract also $\bar{\rho}$ and $\bar{\eta}$)

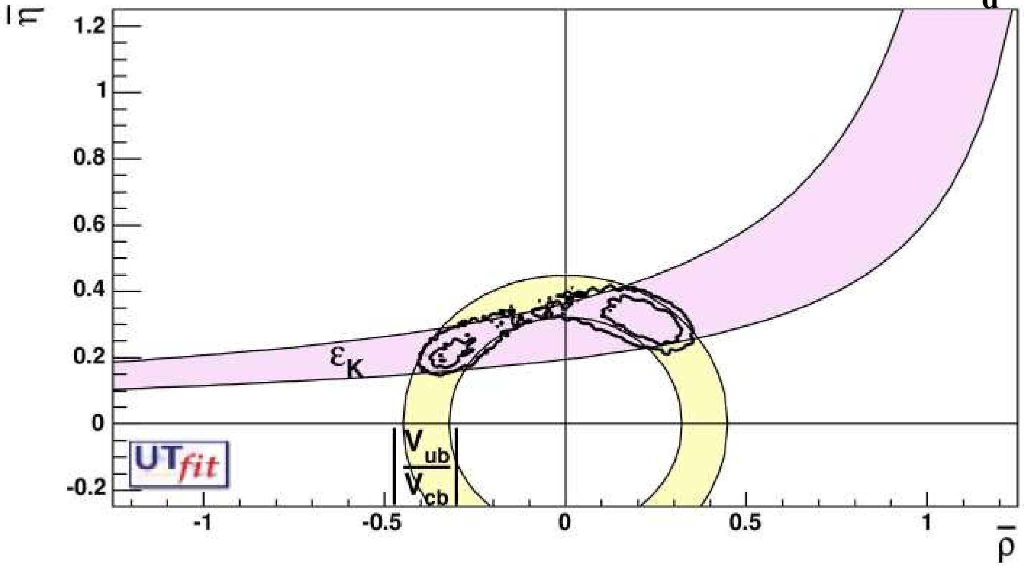
J. M. Soares and L. Wolfenstein, Phys. Rev. D 47 (1993) 1021;
N. G. Deshpande, B. Dutta and S. Oh, Phys. Rev. Lett. 77 (1996) 4499 [arXiv:hep-ph/9608231]
J. P. Silva and L. Wolfenstein, Phys. Rev. D 55 (1997) 5331 [arXiv:hep-ph/9610208]
A. G. Cohen et al., Phys. Rev. Lett. 78 (1997) 2300 [arXiv:hep-ph/9610252]

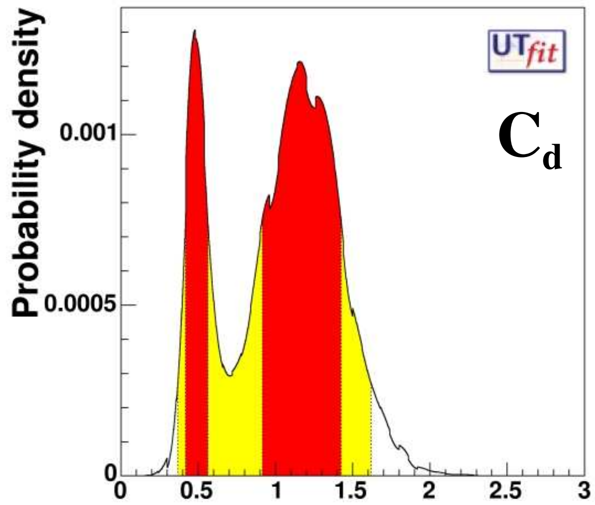
New Physics (II): $\bar{B}_d$-B_d mixing

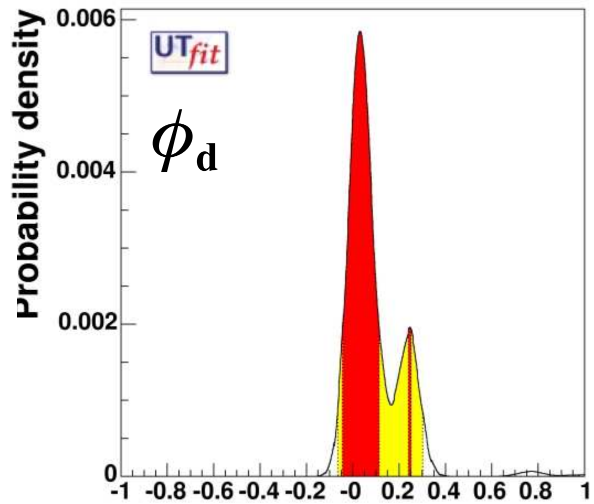
Second CKM workshop 2003, hep-ph/0307195



in $\bar{B}_d$-B_d mixing from the standard fit







sin2α with SU(2) analysis

Gronau-London, Phys. Rev. Lett. 65, 3381–3384 (1990)

Starting from the SU(2) amplitudes:

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

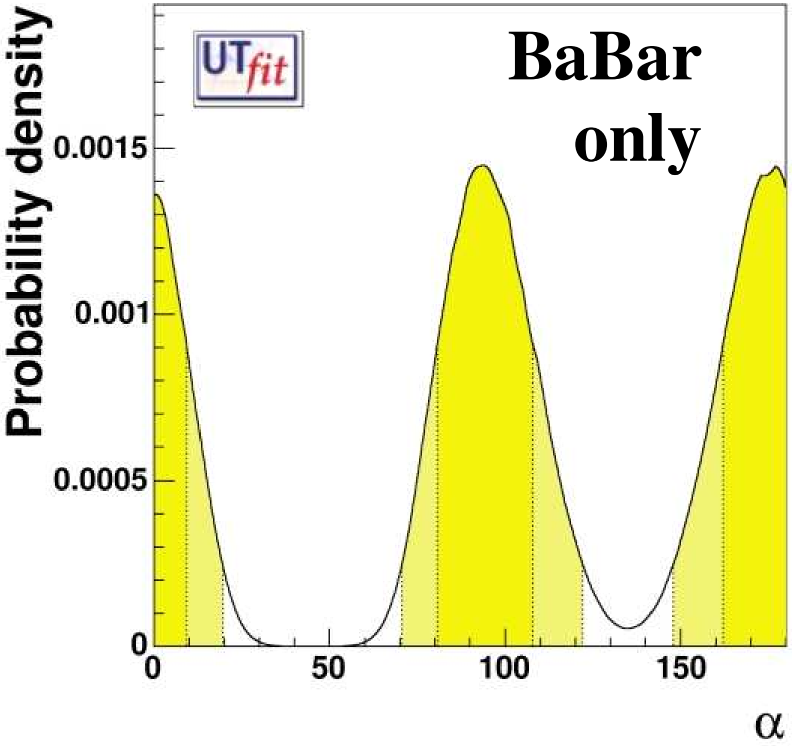
$A^{+0} = -1/\sqrt{2}\, e^{-i\alpha}\, (T + T_C e^{i\delta_C})$

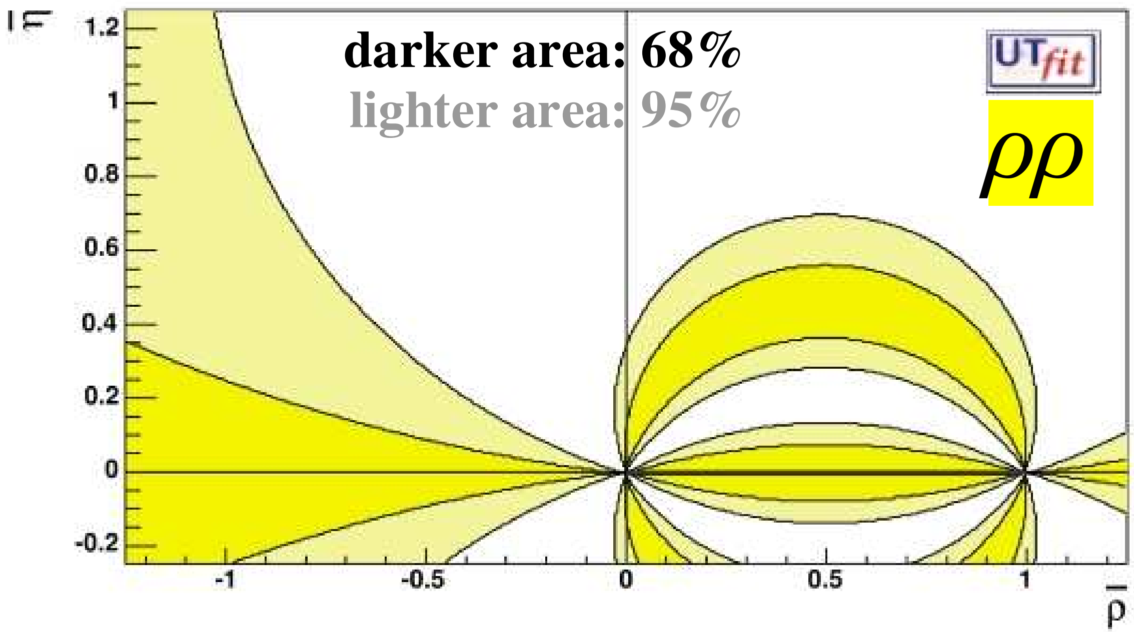
$A^{00} = -1/\sqrt{2}\, (T_C e^{i\delta_C} e^{-i\alpha} + Pe^{i\delta_P})$

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

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

$\alpha = 95° \pm 13°\ \ (174° \pm 13°)$

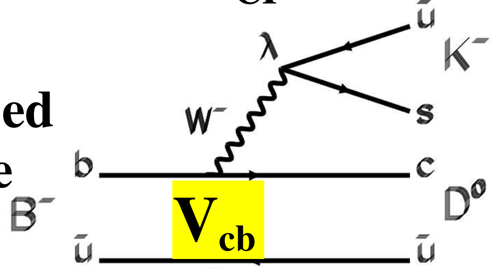


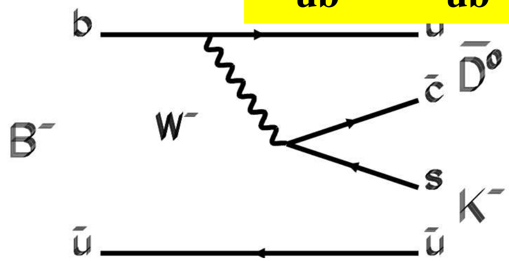


γ: from $B^{\pm} \to D_{CP}K^{\pm}$ decays

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

colour-soppressed are also possible





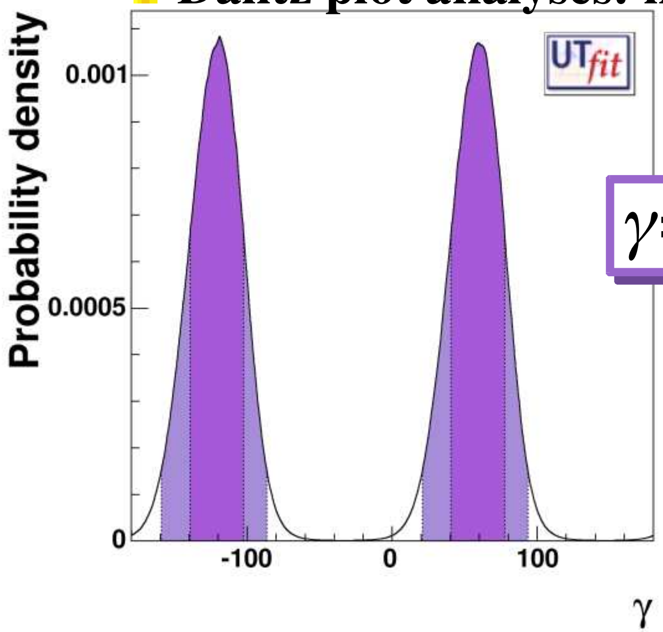
δ_B = strong phase diff.

r_B= ratio of amplitudes

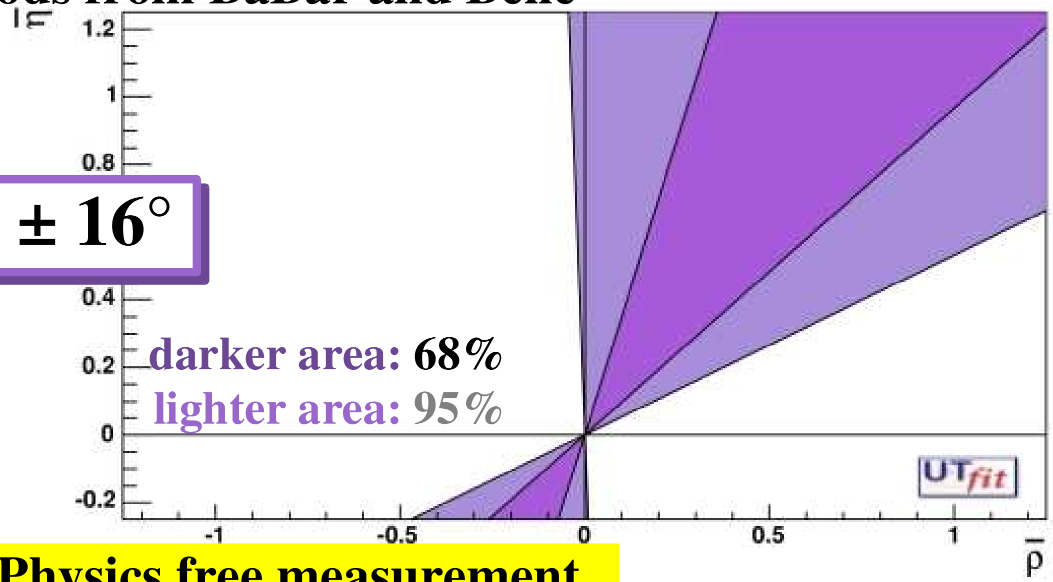
$$A(B^- \to D^0K^-) = A_B \qquad A(B^- \to \bar{D}^0K^-) = A_B r_B e^{i(\delta_B-\gamma)}$$

$$A(B^+ \to \bar{D}^0K^+) = A_B \qquad A(B^+ \to D^0K^+) = A_B r_B e^{i(\delta_B+\gamma)}$$

- GLW(Gronau, Londow,Wyler) method: looks at D^0_{CP} states
- ADS(Atwood,Dunietz,Soni) method: B^0 and $\bar{B}^0$ to the same final state
- Dalitz plot analyses: likelihoods from BaBar and Belle



γ= 60° ± 16°

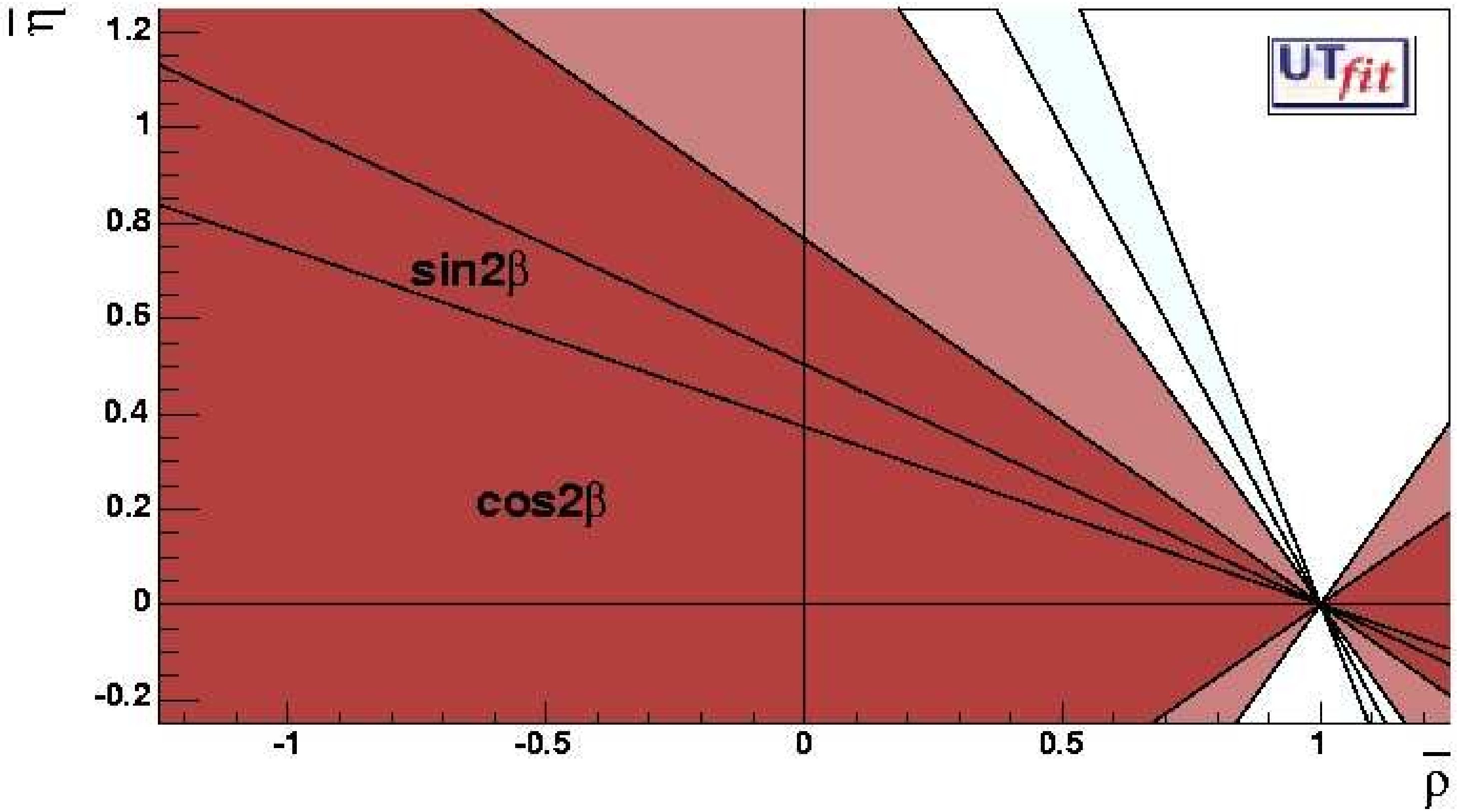


New Physics free measurement

$\cos 2\beta$:

From the time dependent analysis of the decay $B \to J/\psi\ K^{*0}$ it is possible to extract the values of both $\sin 2\beta$ and $\cos 2\beta$

Prob ($\cos 2\beta < 0$) ~ 13%

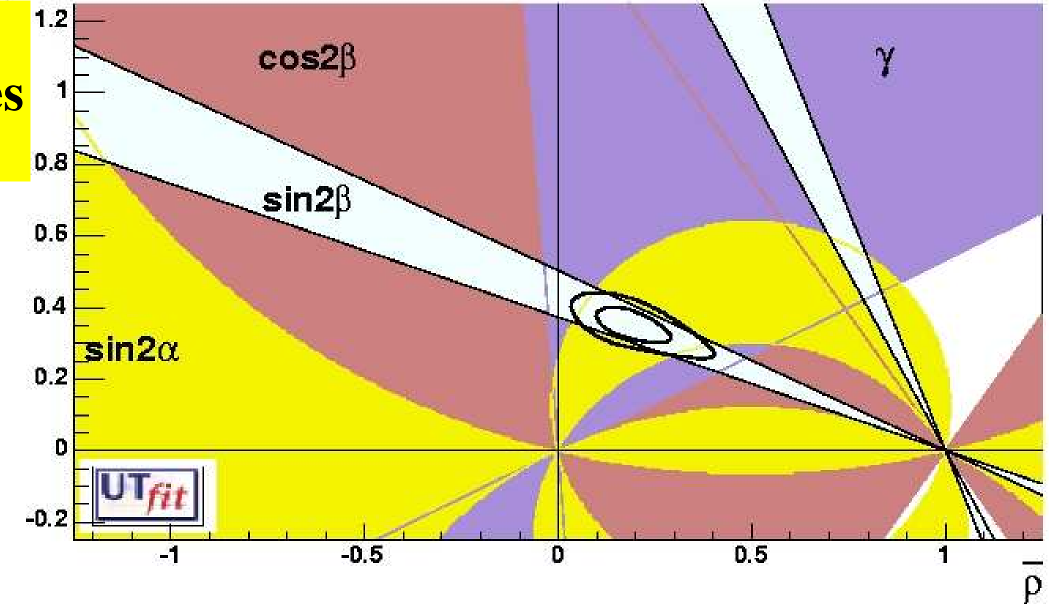


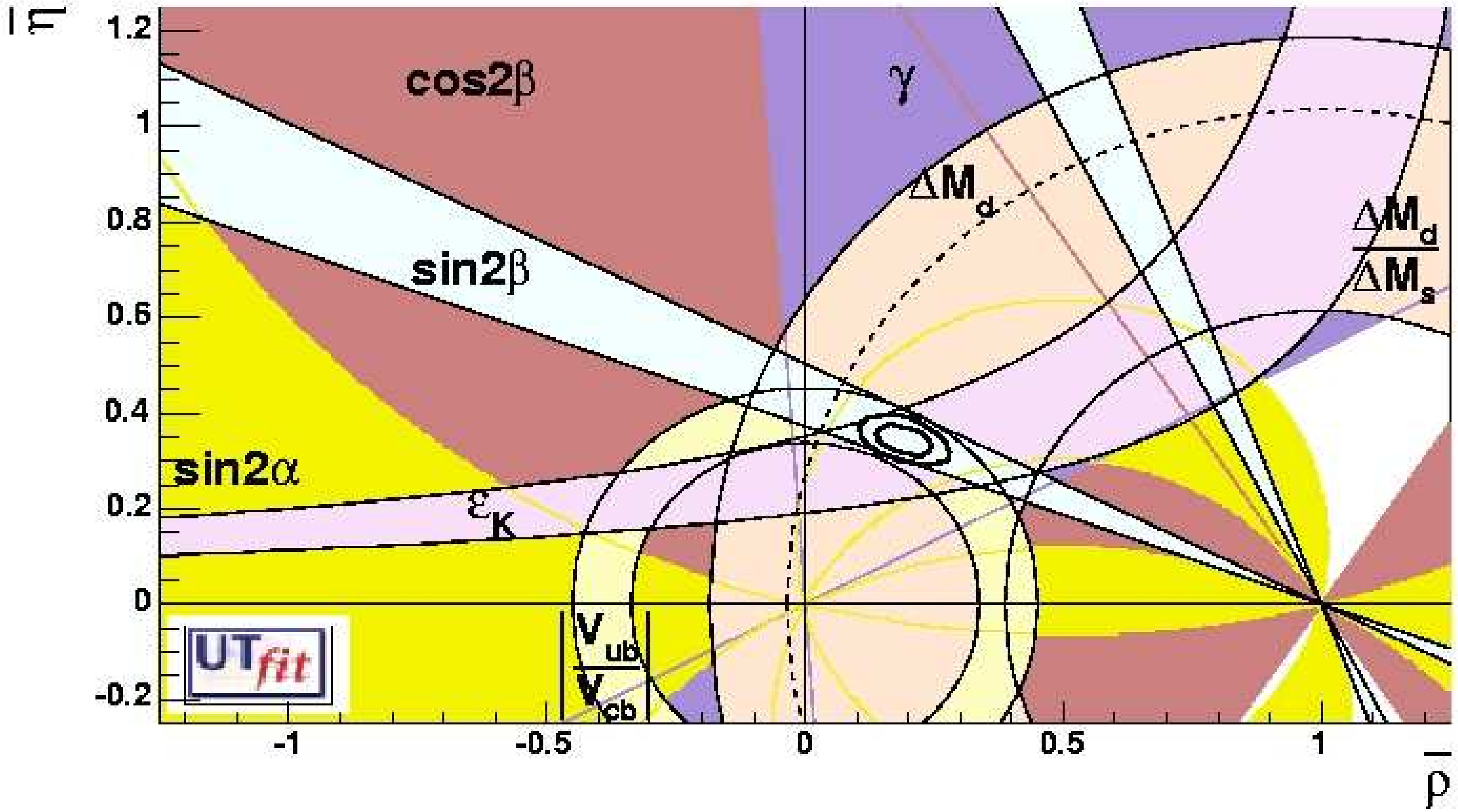
contribution
from the B-Factories
using angles only:

$\bar{\rho} = 0.187 \pm 0.063$
[0.059, 0.348] @ 95% CL

$\bar{\eta} = 0.350 \pm 0.033$
[0.279, 0.423] @ 95% CL

$\gamma = 62° \pm 9°$
[40°, 80°] @ 95% CL





including
all the new
constraints

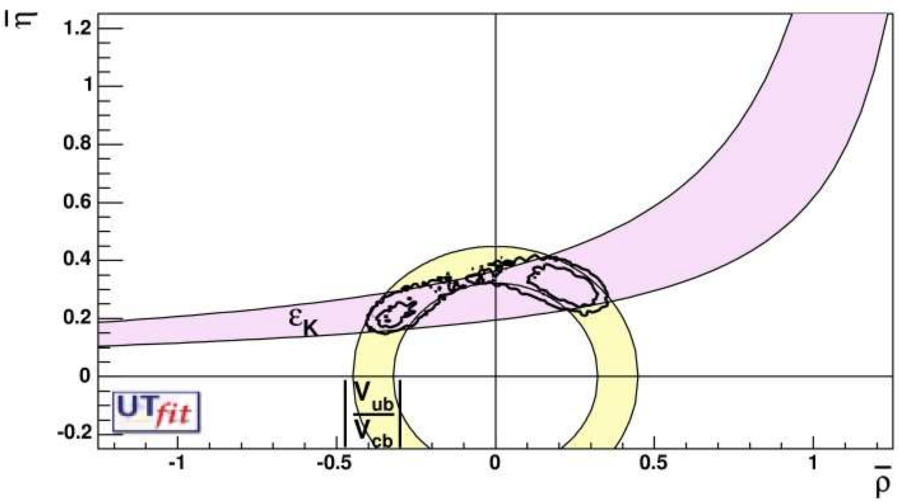
$\bar{\rho} = 0.189 \pm 0.035$
[0.121, 0.260] @ 95% CL

$\bar{\eta} = 0.343 \pm 0.021$
[0.301, 0.384] @ 95% CL

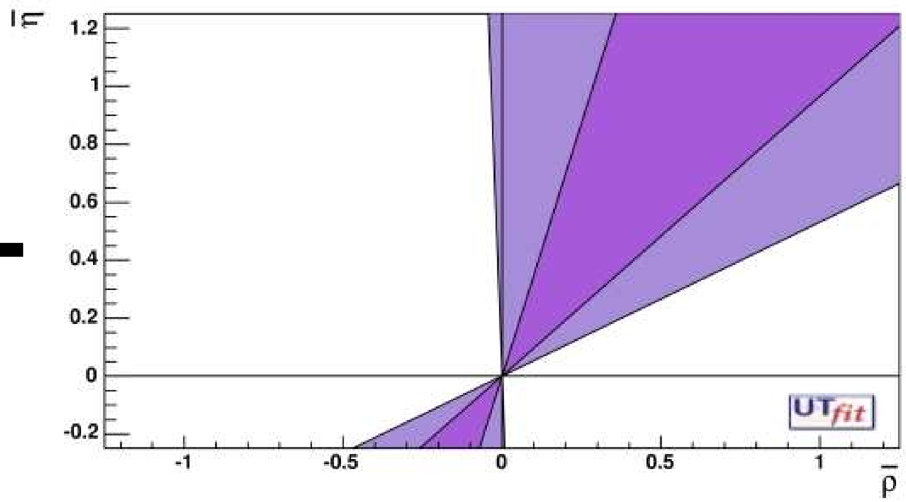
$\gamma = 61° \pm 5°$
[51°, 72°] @ 95% CL

Looking for New Physics in 2004:

- the B_d sector is fully constrained
  - observables: $\Delta m_d, \beta, \alpha, \gamma$ vs unknowns: ρ, η, Cd, ϕ
- we can use the general parameterization of New Physics
  - ε_K is a handle to quantify deviation from the SM
  - also expectations on Δm_s can be obtained



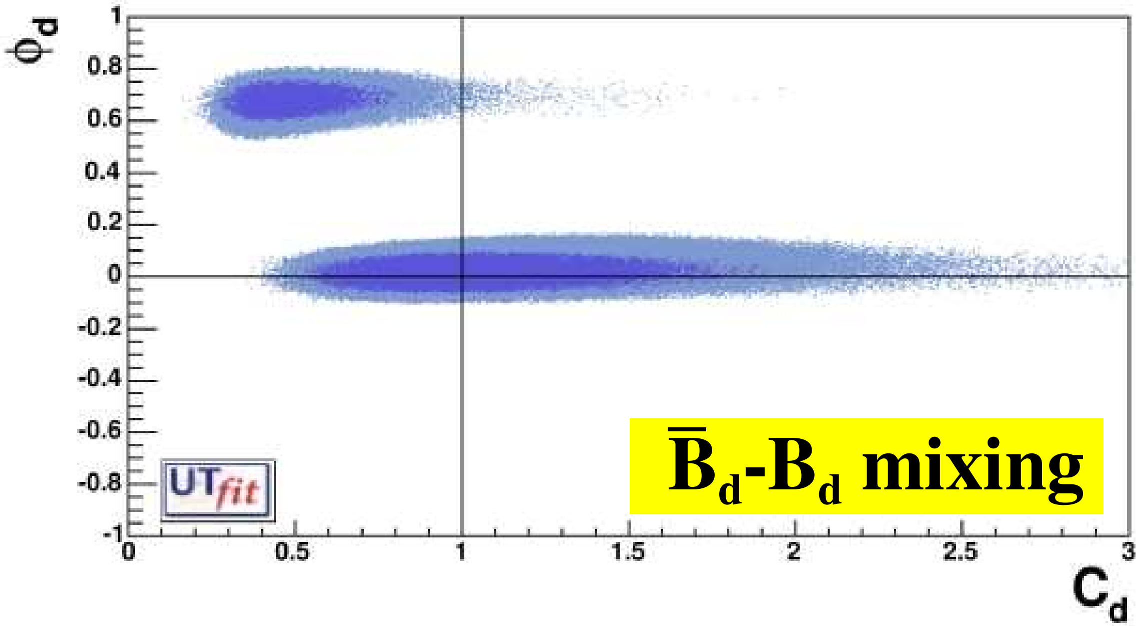
+

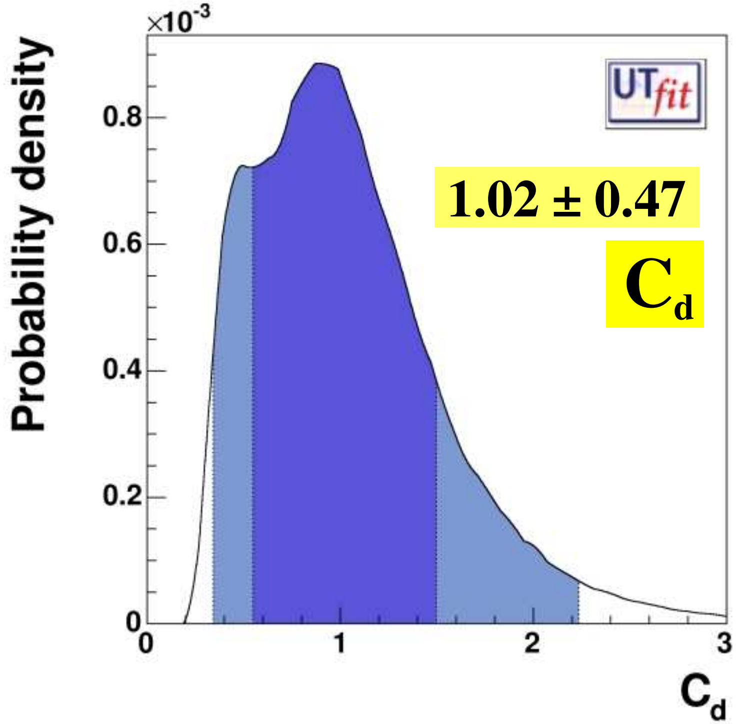


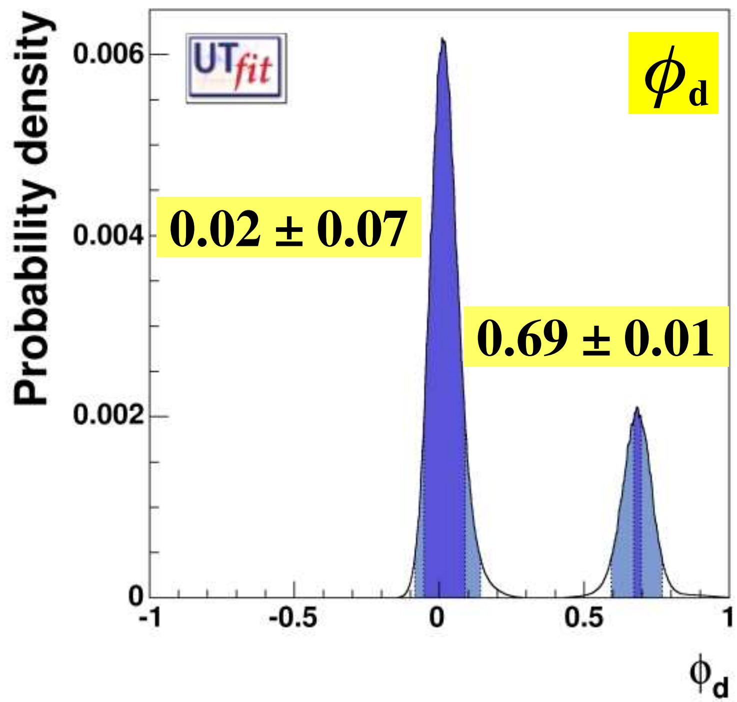
New Physics in 2004 (II):

Using the new constraints:

- **we can switch on the New Physics in all the sectors**
- **in the B_d sector a new second solution appears**



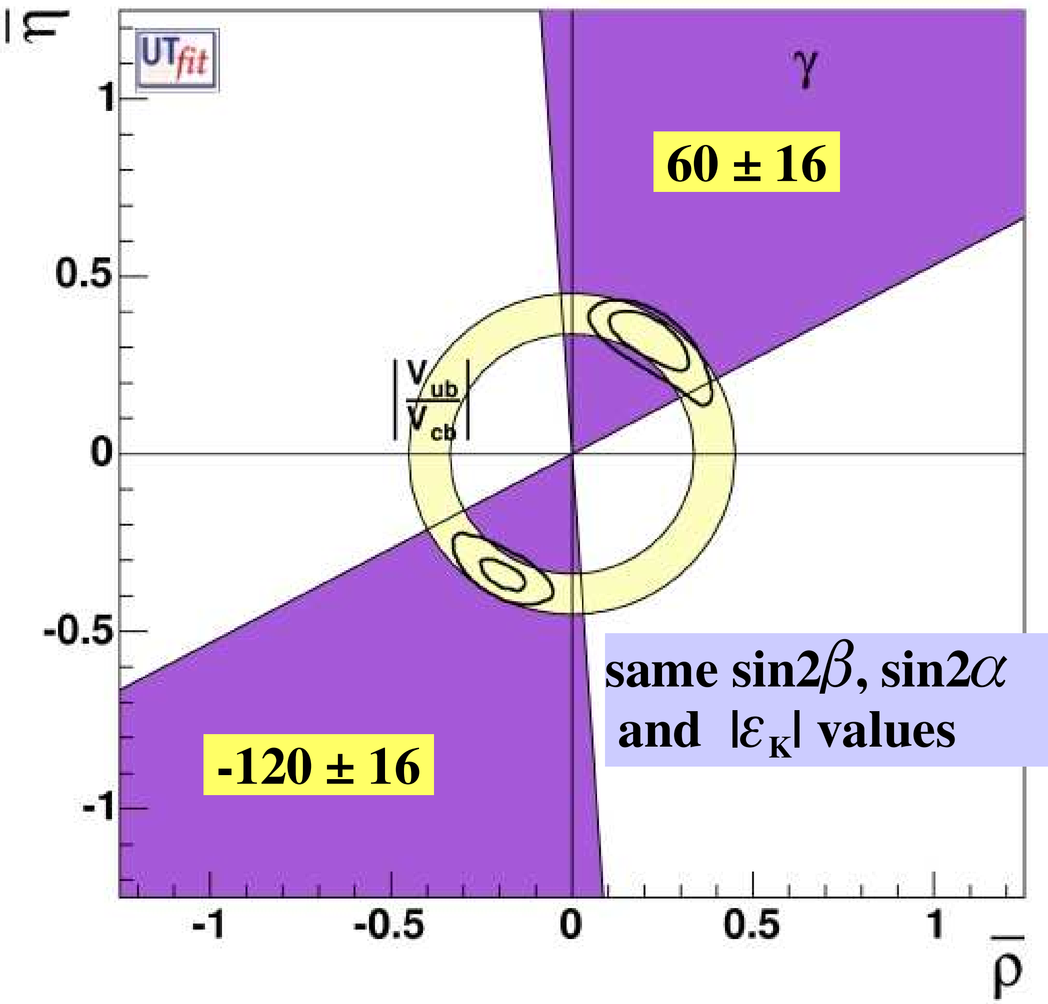


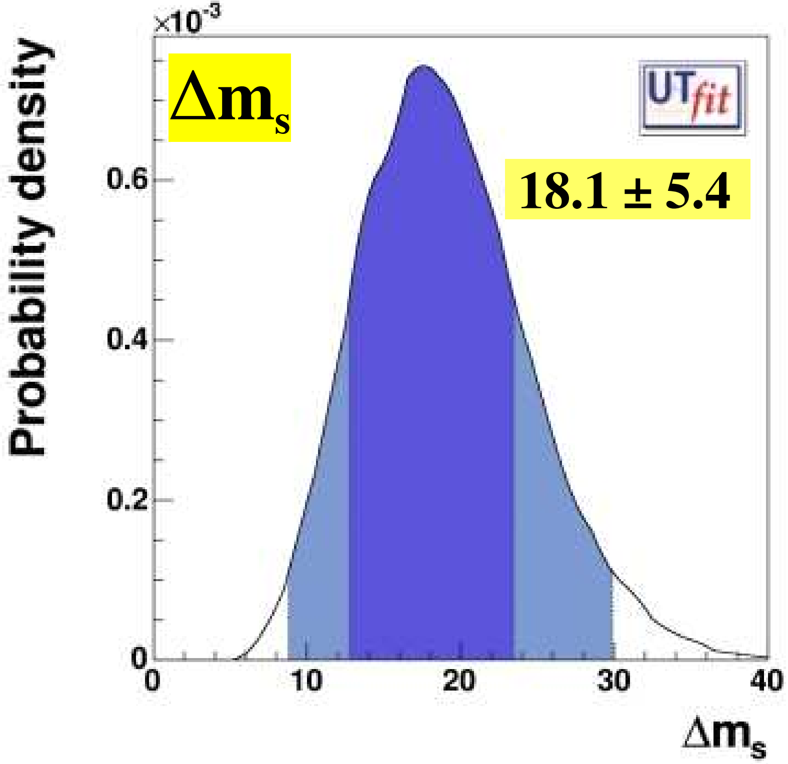


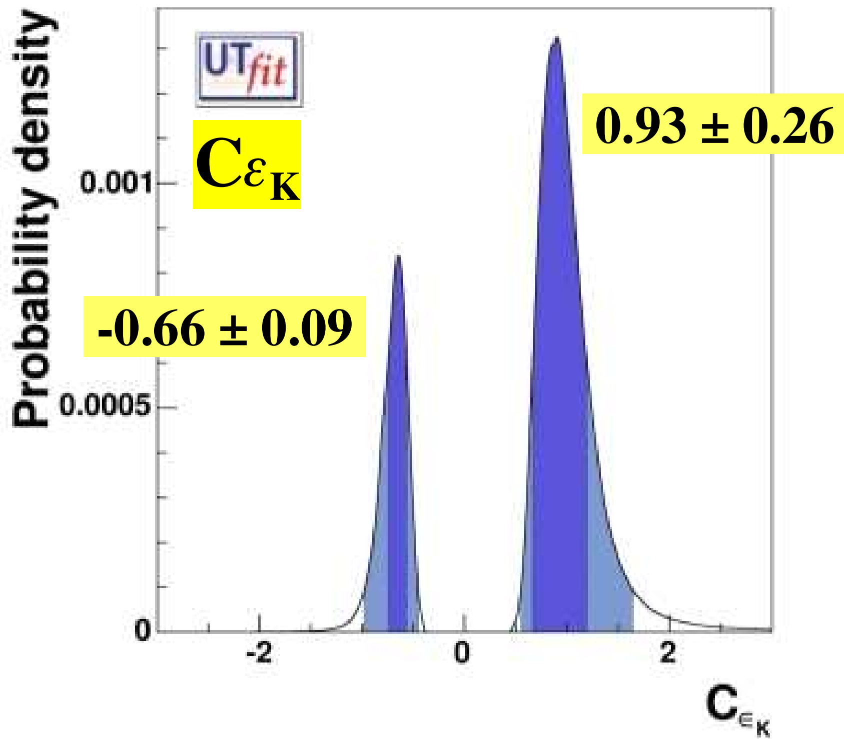
Marcella Bona, INFN Torino

New Physics in 2004 (III):

- the B_s sector is not bounded from the actual experimental result ➡ (since we have just a limit on Δm_s)



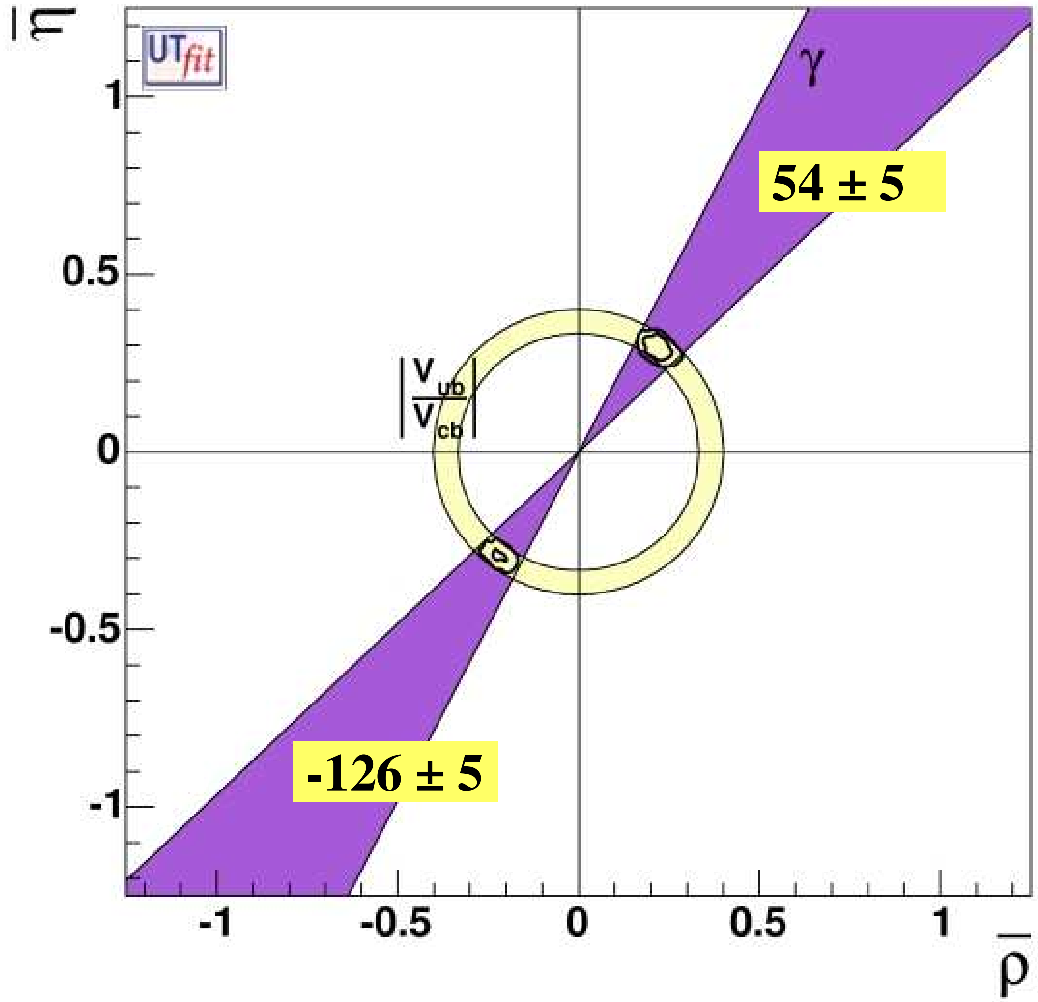


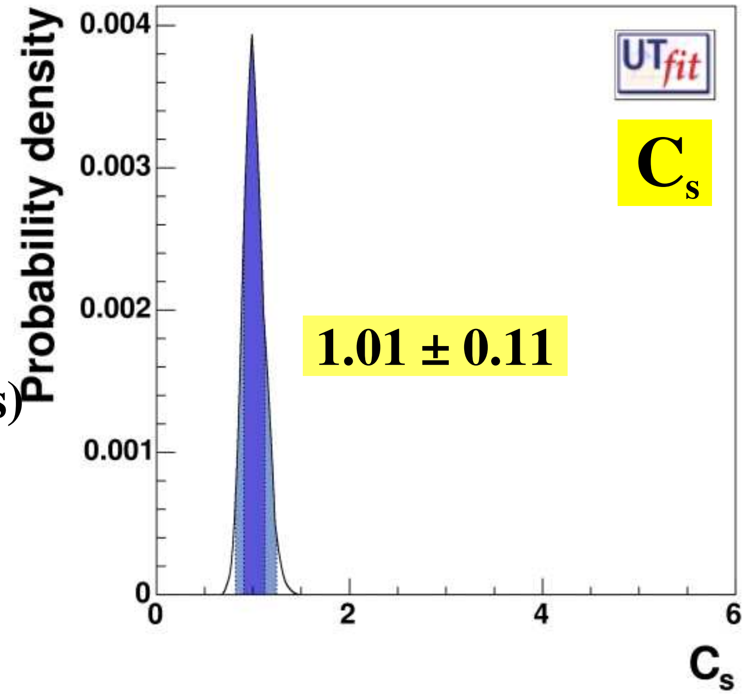


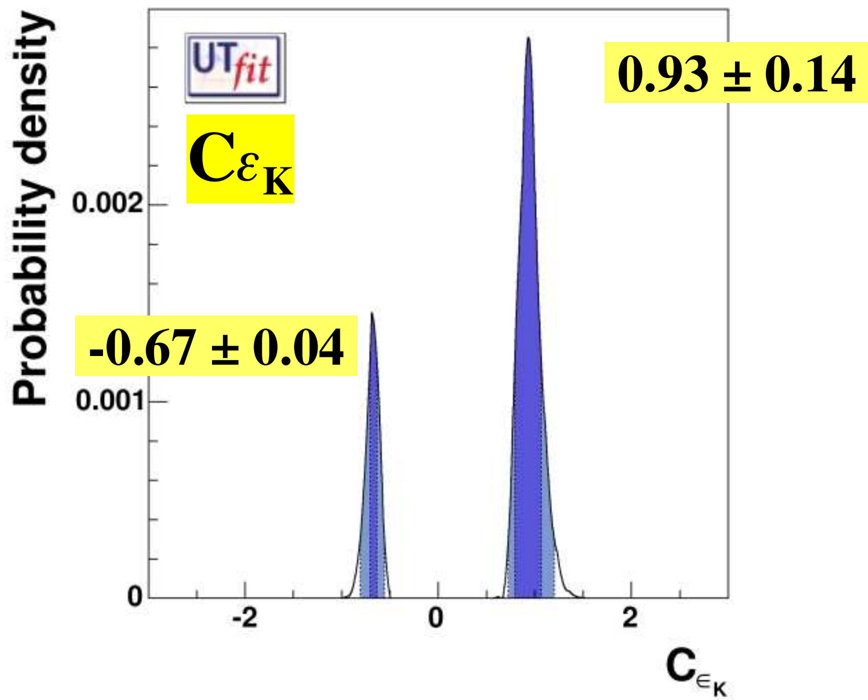
What can we expect from the future?

2010 scenario:

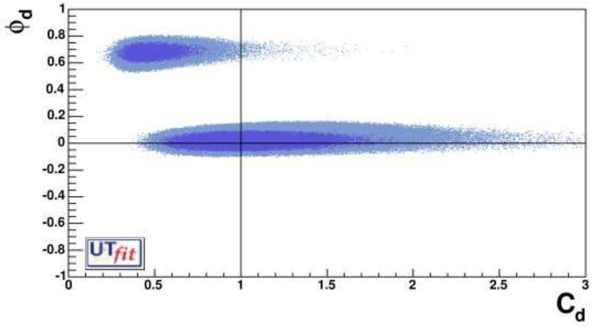
- centered on the SM values with projected errors
- no more flat errors from Lattice
- γ with two-fold ambiguity (if Dalitz still dominates)





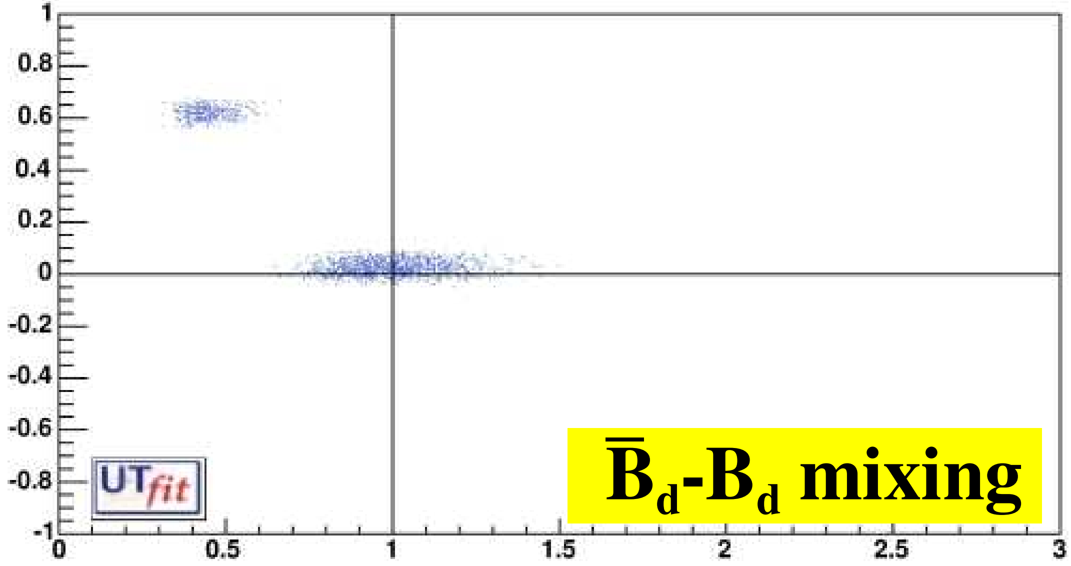


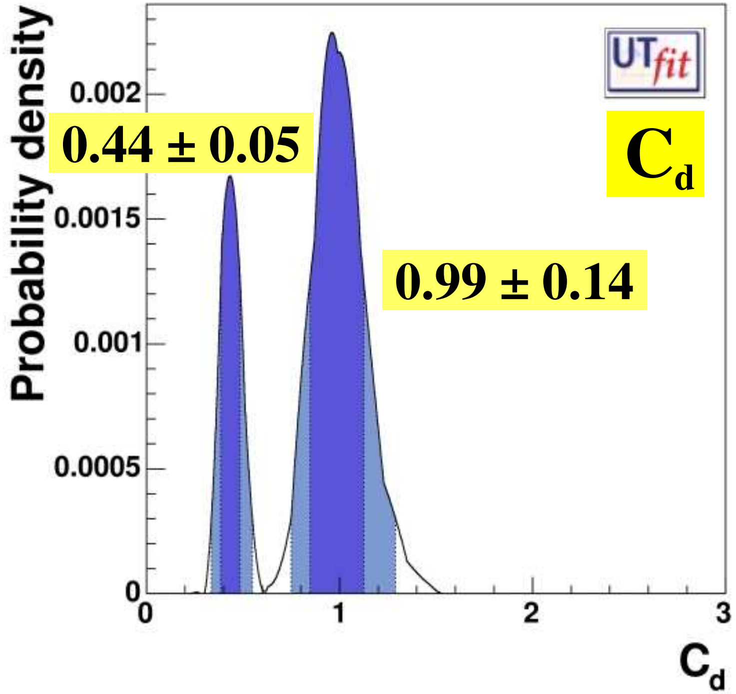
2010 Scenario (II):

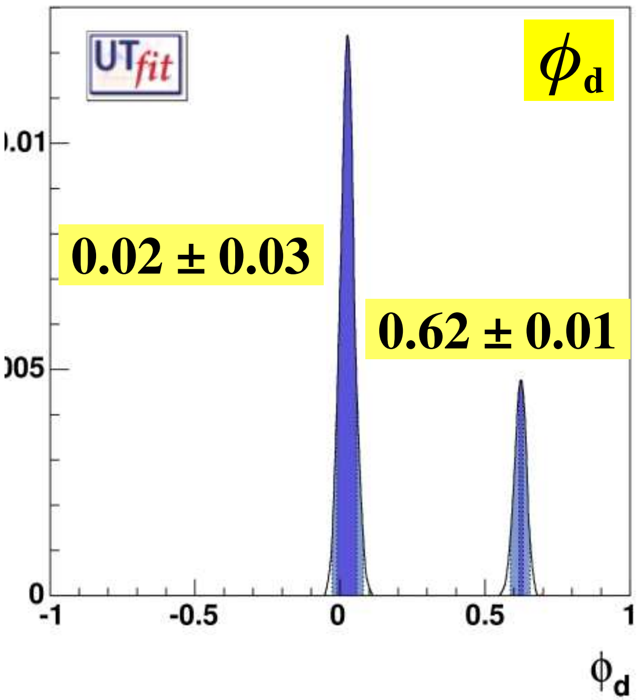


in the B_d sector:

- errors reduced
- second solution stays

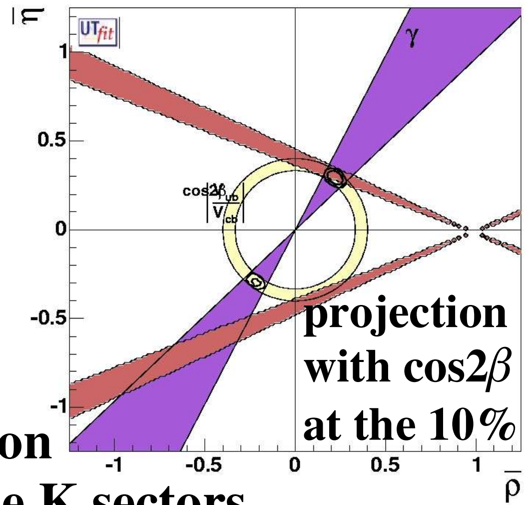






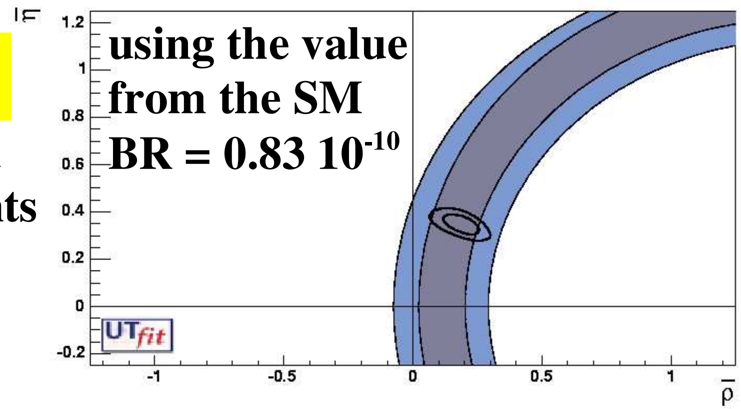
Summary and conclusions

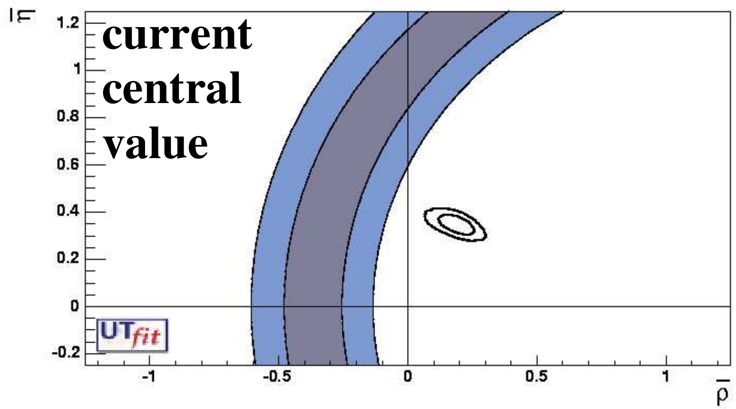
- the standard fit shows an impressive agreement with the SM expectations
  - the new inputs from B-Factories (α, γ and cos2β) have a deep impact in improving this agreement
- new bounds also allow to fully constrain the B_d sector
  - the only "NP" solution comes from the ambiguity in the determination of γ
  - same sin2β, same α, same $|\varepsilon_K|$
- in a 2010 scenario
  - errors will be dramatically reduced
  - the ambiguity will survive to the increase in precision
  - more measurements needed both in the B and in the K sectors



$K^\pm \to \pi^\pm \nu\nu$

projections with ~100 signal events





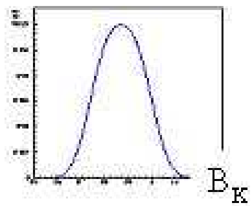
back-up slides

Input treatment:

Ex : $B_K = 0.87 \pm 0.06\ (\text{gaus}) \pm 0.13\ (\text{theo.})$

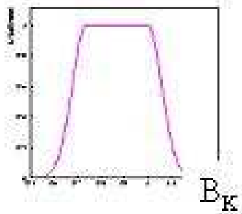
RFit-CKMfitter | **Bayesian-UTfit**

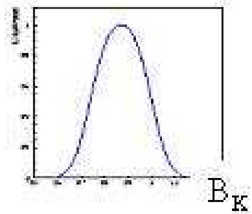
The theoretical likelihood does not contribute to the χ^2 of the fit while the corresponding parameters take values within the allowed ranges.



p.d.f from the convolution (sum in quadrature)

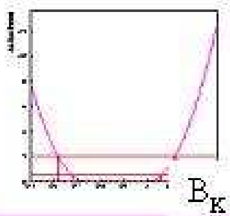
Likelihood obtained summinng linearly the two errors

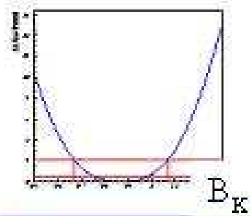




Likelihood from the inversion of the p.d.f

ΔLikelihood





ΔLikelihood

At 68% CL [0.68-1.06] [0.76-0.98]

In the frequentistic approach, the selected region does not have a precise statistical meaning: at least 95%.

Estimates of the uncertainties for lattice determinations should be given by the lattice community just like the experimental ones are given by the experimental collaborations.

B Oscillations: Δm_s

$$P_{B_q^0 \to B_q^0(\bar{B}_q^0)} = \frac{1}{2} e^{-t/\tau_q} (1 \pm A \cos \Delta m_q t)$$

given the λ^2 factor, we expect

$\Delta m_s \sim 20\ \Delta m_d$

excellent time resolution is necessary

A is measured given a fixed Δm_s:

A=0 → no oscillation

A=1 → oscillation

Δm_s ~ excluded @ 95% CL

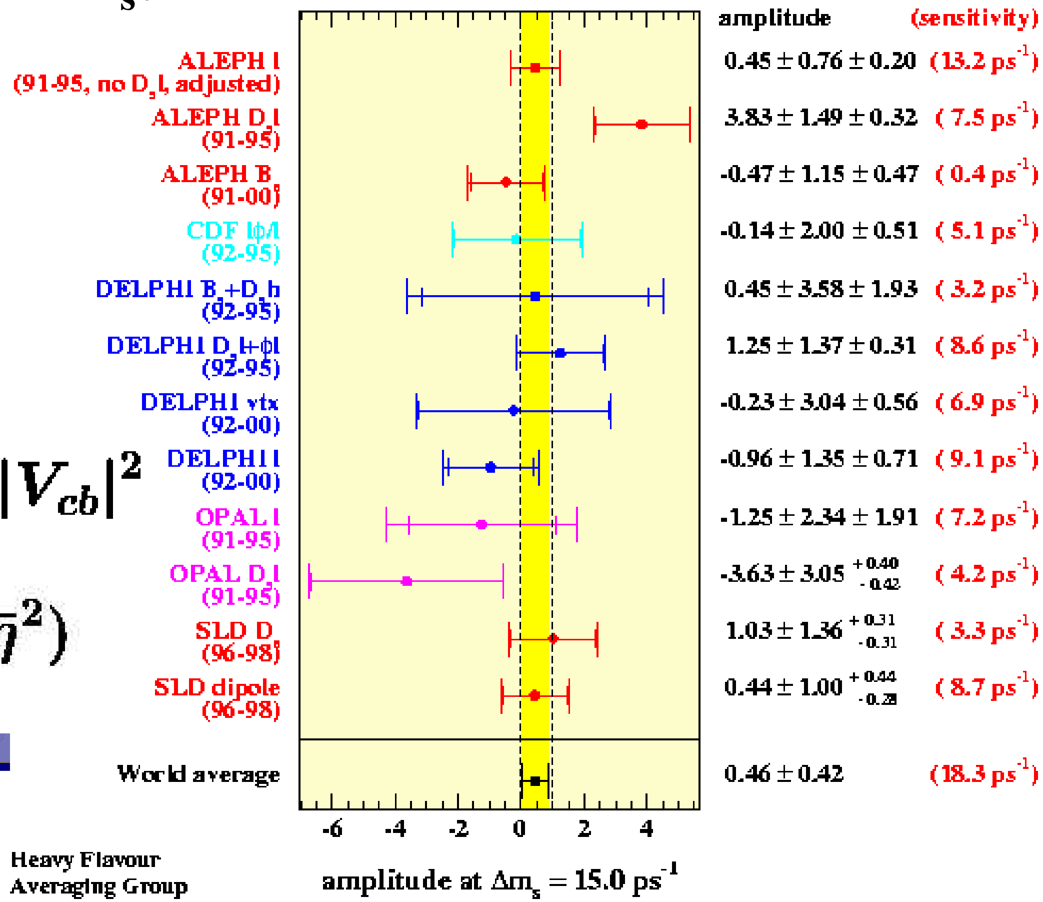
→ $A+1.645\sigma_A < 1$

sensitivity: $1.645\sigma_A = 1$

$$\Delta m_s \propto f_{B_s}^2 B_{B_s} |V_{ts}|^2 \propto f_{B_s}^2 B_{B_s} |V_{cb}|^2$$

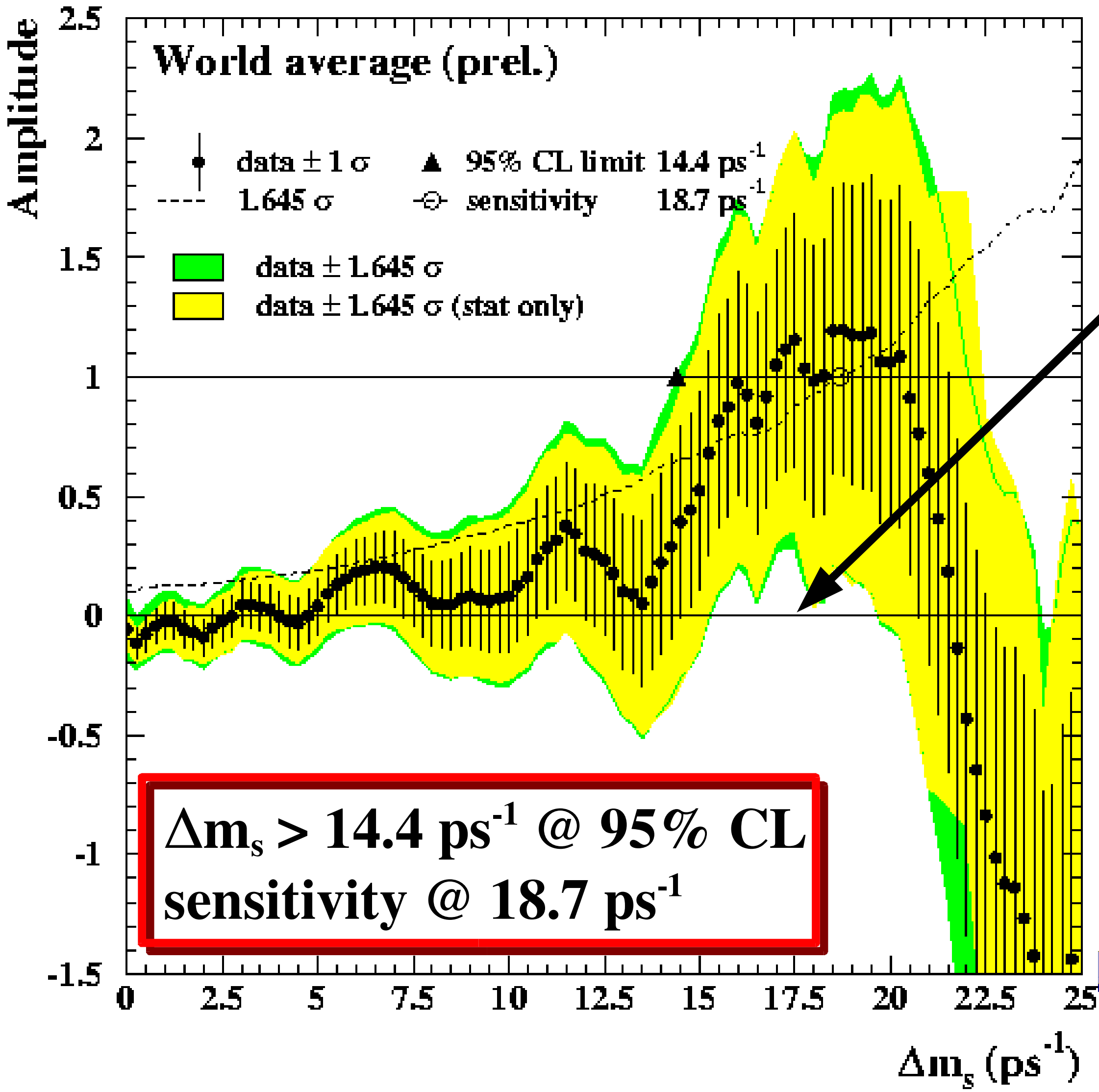
$$\frac{\Delta m_d}{\Delta m_s} \propto \frac{f_{B_d}^2 B_{B_d}}{f_{B_s}^2 B_{B_s}} \lambda^2 ((1-\bar{\rho})^2 + \bar{\eta}^2)$$

in the $\bar{\rho}$-$\bar{\eta}$ plane it corresponds to a circle centered in (1,0)



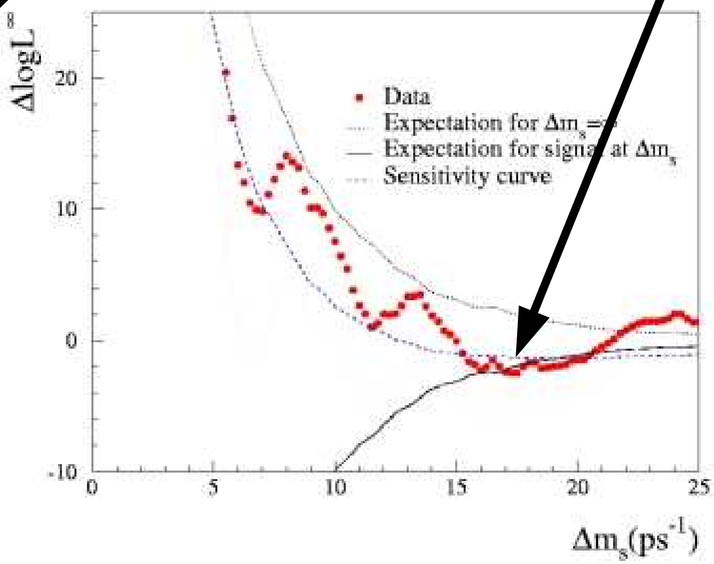
B Oscillations: Δm_s (II)

$$P_{B_q^0 \to B_q^0(\bar{B}_q^0)} = \frac{1}{2} e^{-t/\tau_q} (1 \pm A \cos \Delta m_q t)$$



$\Delta m_s > 14.4\ ps^{-1}$ @ 95% CL
sensitivity @ 18.7 ps^{-1}

hint of a signal
@ $\Delta m_s \sim 17.5\ ps^{-1}$
with significance $\sim 2\sigma$



New Inputs: $K^\pm \to \pi^\pm \nu\bar{\nu}$

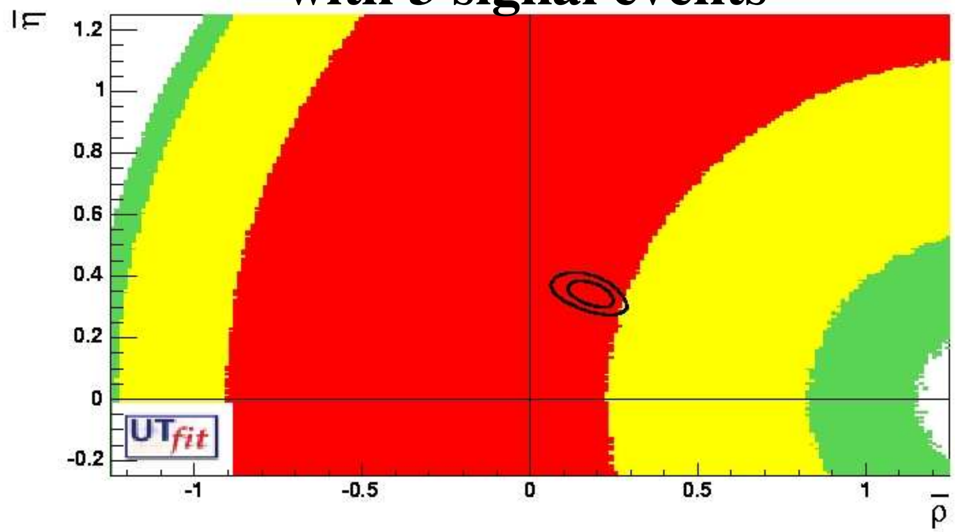
D'Ambrosio, Isidori
hep-ph/0112135

$$\underbrace{(\sigma\bar{\eta})^2 + (\bar{\rho} - \bar{\rho}_0)^2}_{\text{ellipse centered in } (\rho^0,\, 0)} = \frac{\sigma BR(K^+ \to \pi^+ \nu\bar{\nu})}{\bar{\kappa}_+ |V_{cb}|^4 X^2(x_t)}$$

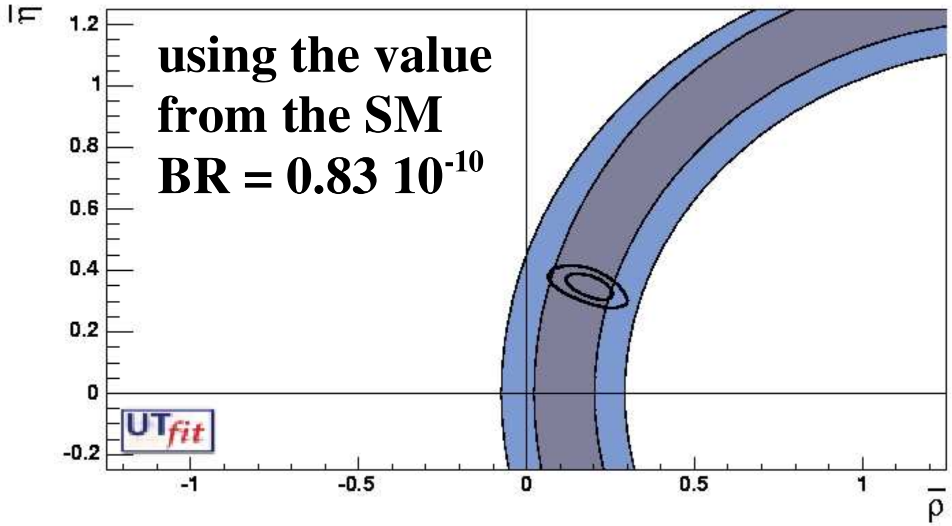
recent result from E949:

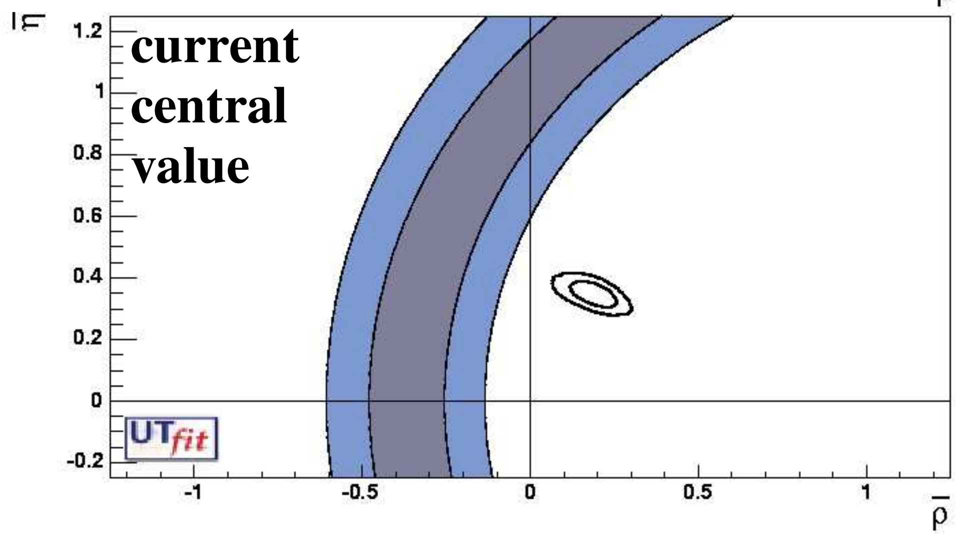
$BR(K^\pm \to \pi^\pm \nu\bar{\nu}) = 1.47^{+1.30}_{-0.89}\ 10^{-10}$

with 3 signal events



with ~100 signal events





Details from the future

2010 scenario:

- centered on the Standard Model values:

  V_{cb}(excl) = 0.04210 +/- 0.00084
  V_{cb}(incl) = 0.04160 +/- 0.00042
  V_{ub}(excl) = 0.00330 +/- 0.000165
  V_{ub}(incl LEP) = same (of course.. :)
  V_{ub} (incl HFAG) = 0.00457 +/- 0.00061
  B_K = 0.93 +/- 0.0465
  $F(B_s)$ = 0.276 +/- 0.014
  ξ = 1.20 +/- 0.0372
  Δms = 20.5 +/- 0.3
  $\sin 2\beta$ = 0.695 +/- 0.695
  $\sin 2\alpha$ = -0.5 +/- 0.2
  γ = 54 +/- 5 (and $-\pi$ solution)