Unitarity Triangle fit: state of the art 2004

www.utfit.org

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on behalf of UTfitters
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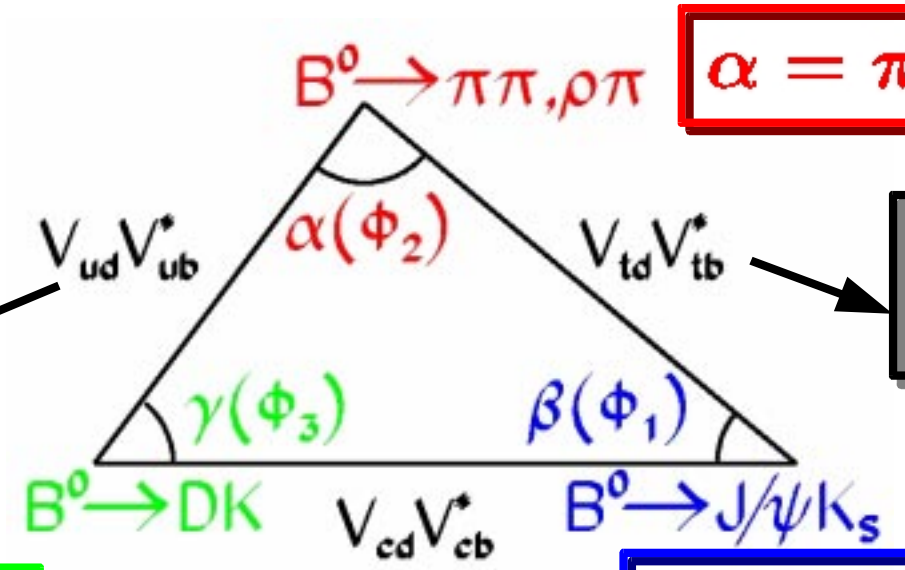
"Bruno Touschek" LNF Spring School
Frascati, May 18th, 2004

The Unitarity Triangle:

order of magnitude: $\lambda^3+\lambda^3+\lambda^3$

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



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

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

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

γ = arg (V_{ub})

β = arg (V_{td})

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

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

$-A\lambda^3$

normalization side

The Method and the Inputs:

Bayes Theorem

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

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

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

$(b\to u)/(b\to c)$	$\bar{\rho}^2+\bar{\eta}^2$	$\bar{\Lambda}, \lambda_1, F(1), \cdots$
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
$A_{CP}(J/\psi K_S)$	$\sin 2\beta$	–

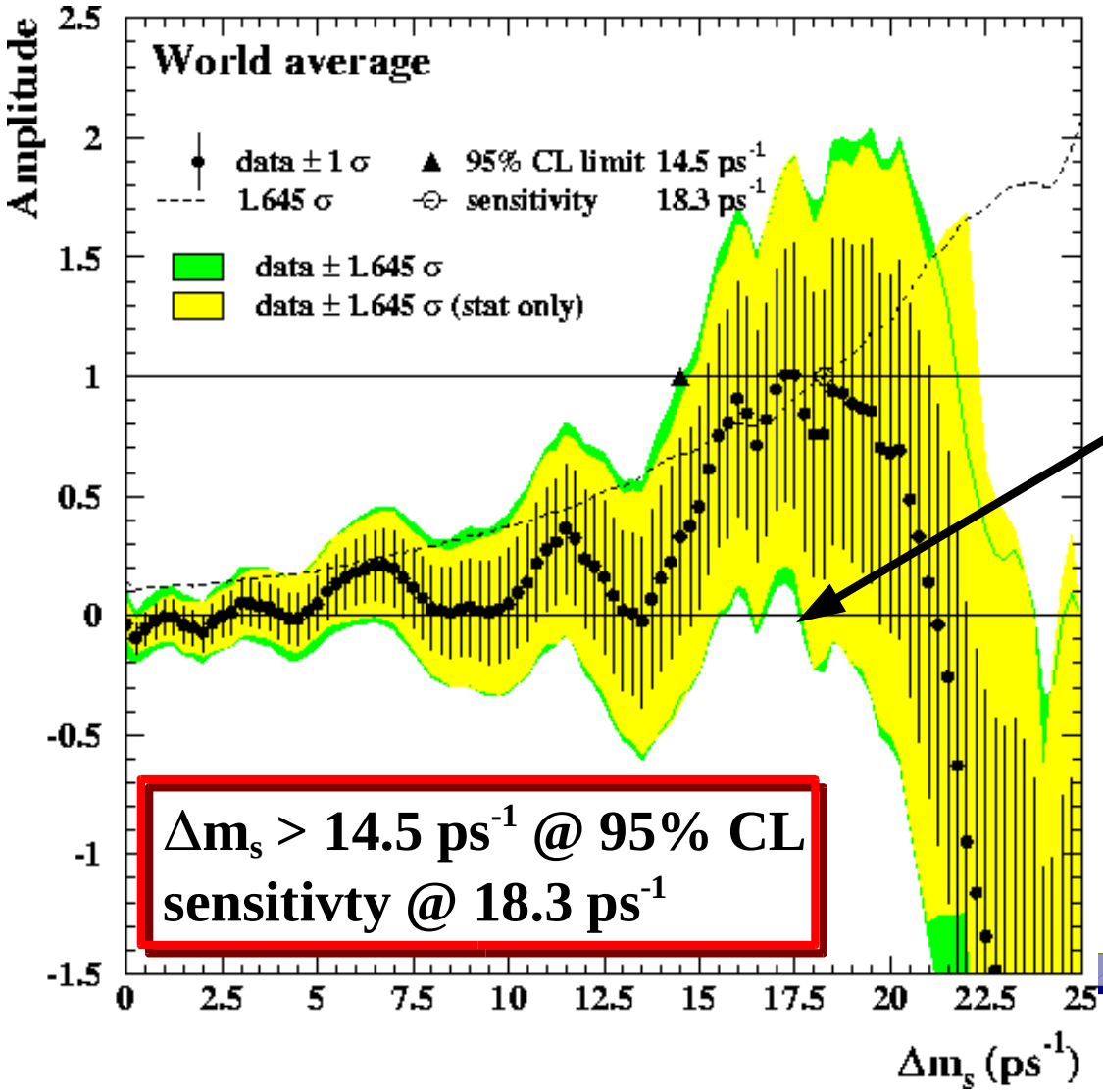
, m_t

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

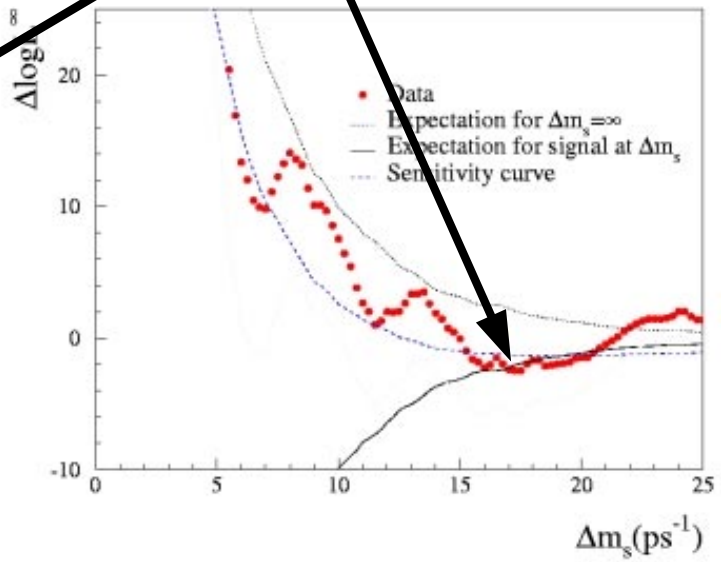
λ	0.2240 ± 0.036	
V_{cb} inclusive	$41.4 \pm 0.7 \pm 0.6 \cdot 10^{-3}$	average from inclusive
V_{cb} exclusive	$42.1 \pm 1.1 \pm 1.9 \cdot 10^{-3}$	average from exclusive
V_{ub} inclusive	$4.09 \pm 0.46 \pm 0.36 \cdot 10^{-3}$	CLEO
V_{ub} exclusive	$3.30 \pm 0.24 \pm 0.46 \cdot 10^{-3}$	LEP+CLEO end point
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	$1.24 \pm 0.04 \pm 0.06$	Lattice QCD
B_K	$0.86 \pm 0.06 \pm 0.14$	Lattice QCD
$\sin 2\beta$	0.739 ± 0.048	B-Factories

B Oscillations: Δm_s

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

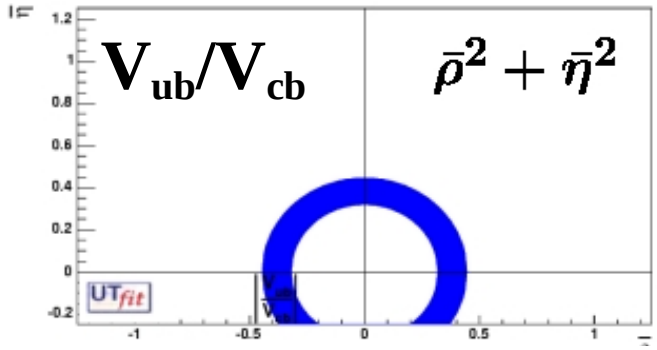


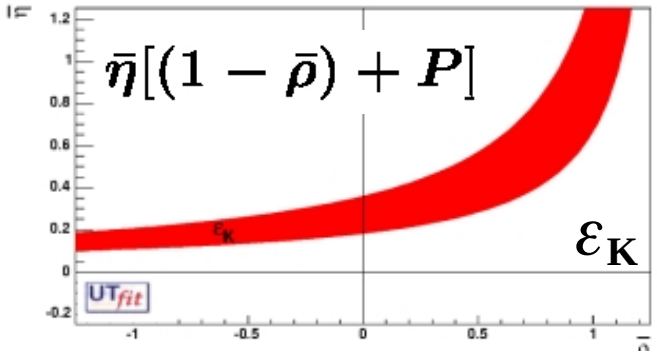
hint of a signal
@ $\Delta m_s \sim 17.5$ ps^{-1}
with significance ~2σ

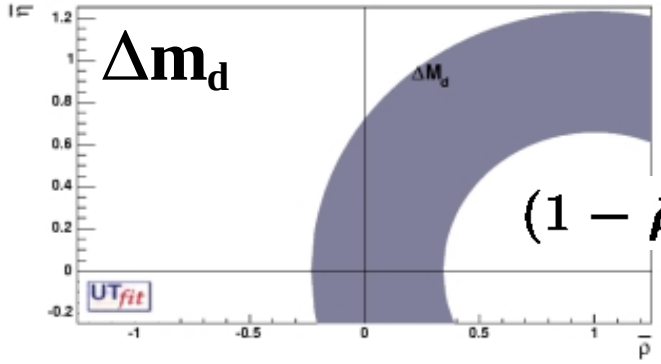


$\Delta m_s > 14.5$ ps^{-1} @ 95% CL
sensitivty @ 18.3 ps^{-1}

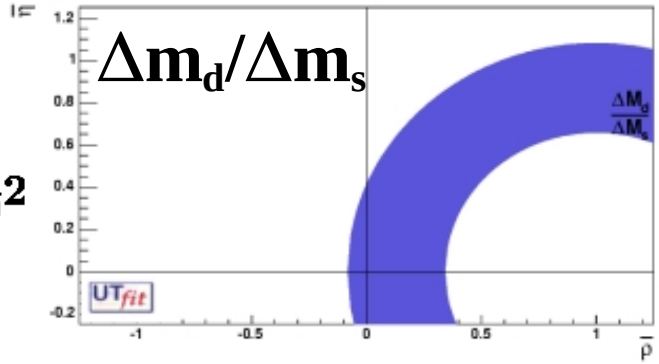
Summarizing the inputs in the $\bar{\rho}$-$\bar{\eta}$ plane:

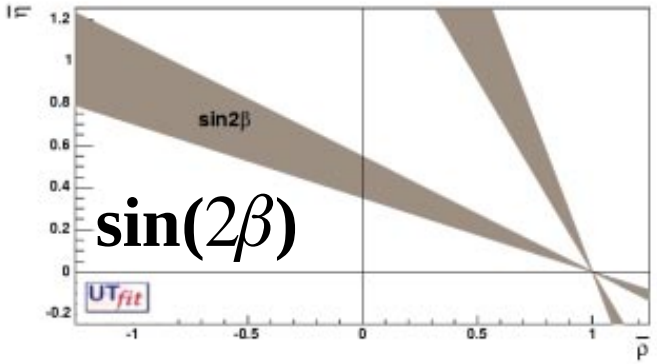






$$(1-\bar{\rho})^2 + \bar{\eta}^2$$

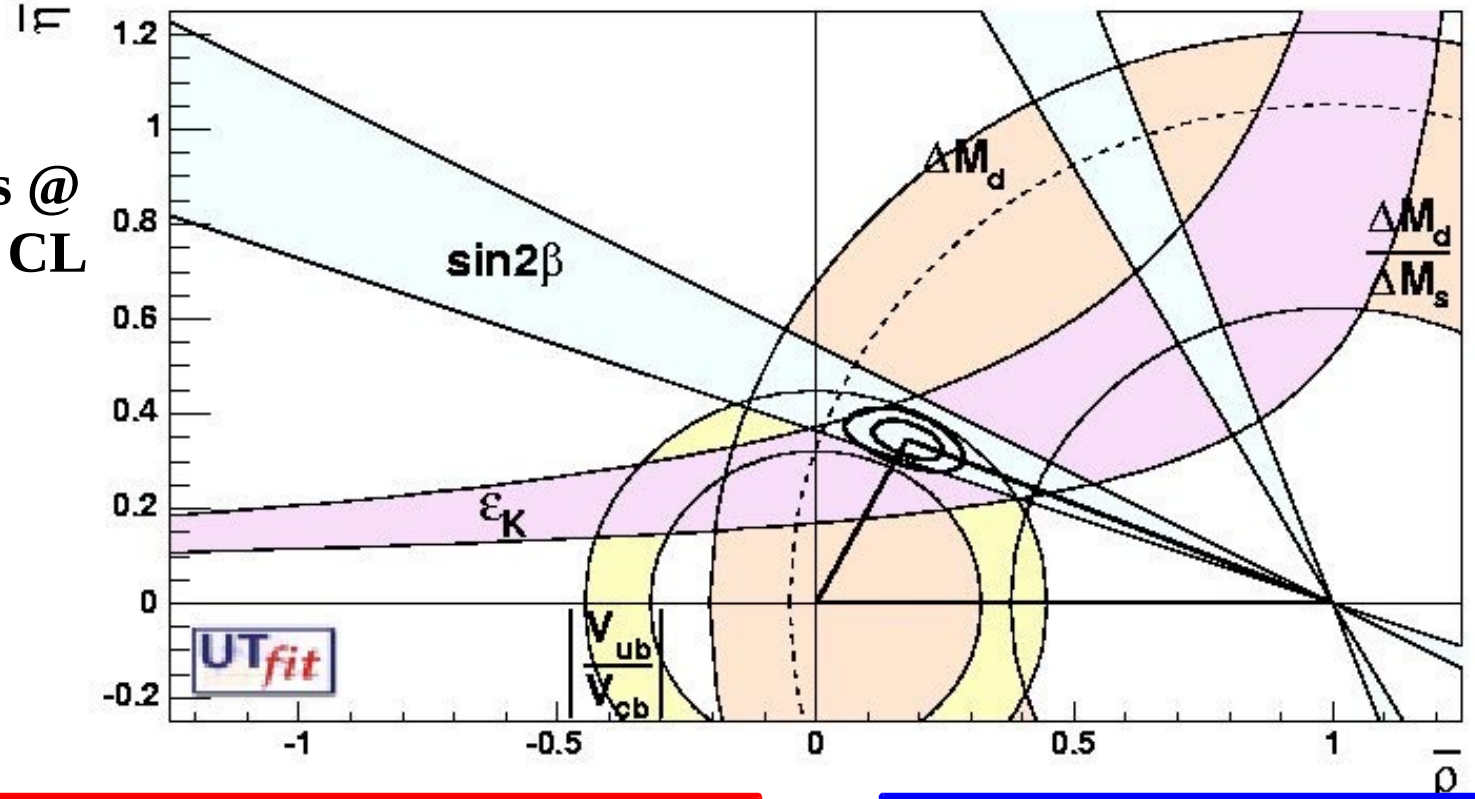




...and putting all together...

Results from the Standard Fit:

levels @ 95% CL

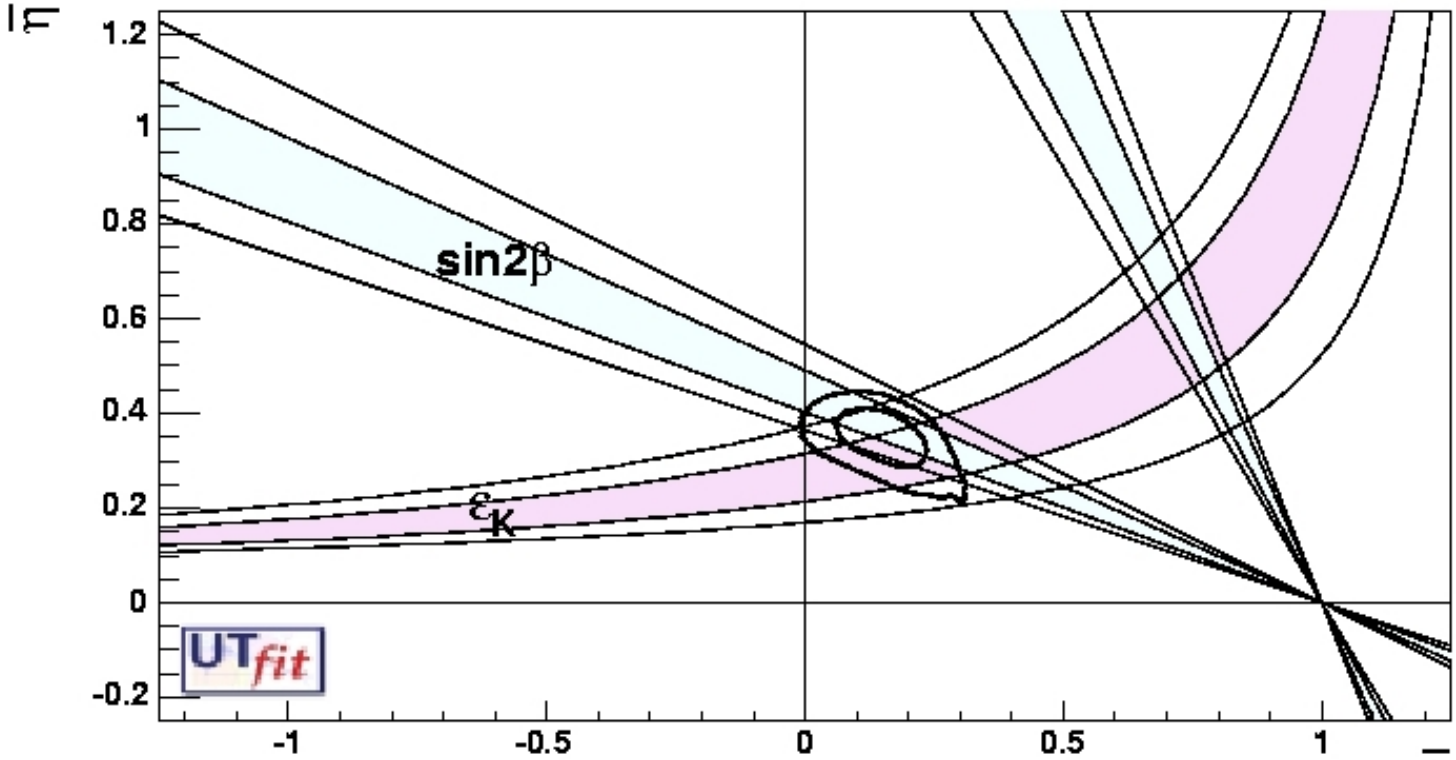


$\bar{\rho} = 0.174 \pm 0.048$
[0.076, 0.260] @ 95% CL

$\bar{\eta} = 0.344 \pm 0.027$
[0.291, 0.396] @ 95% CL

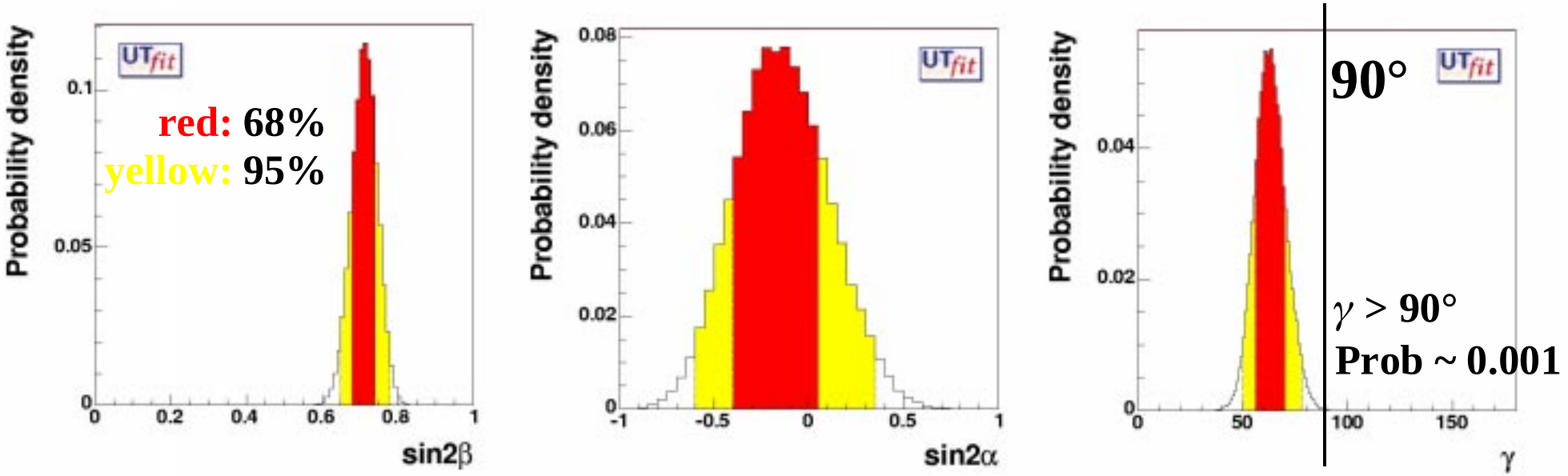
Crucial test of the Standard Model:

determination of CP-violating parameters measuring CP-conserving observables: only side results included and CP-violation areas overimposed.



$\left\{\begin{array}{ll} \sin 2\beta = 0.739 \pm 0.048 & \text{experimental value from charmonium} \\ \sin 2\beta = 0.685 \pm 0.047 & \text{expectation from side-only results} \end{array}\right.$

Indirect determination of sin2α, sin2β e γ:



sin 2β = 0.697 ± 0.036
[0.637, 0.761] @ 95% CL

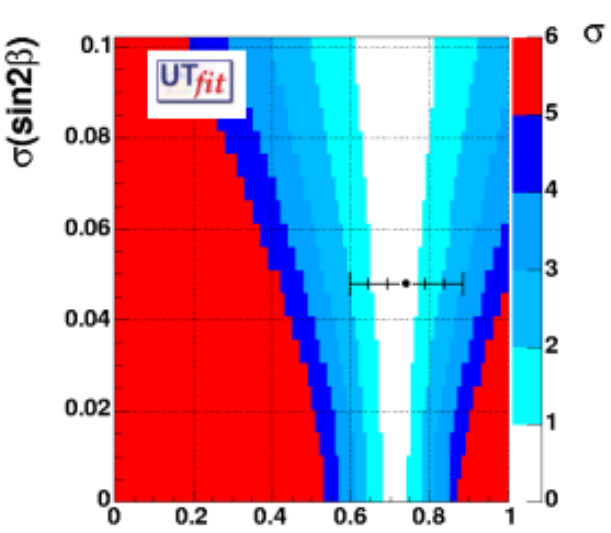
sin 2α = - 0.14 ± 0.25
[-0.62, 0.34] @ 95% CL

γ = 61.9° ± 7.9°
[48.6, 76.0] @ 95% CL

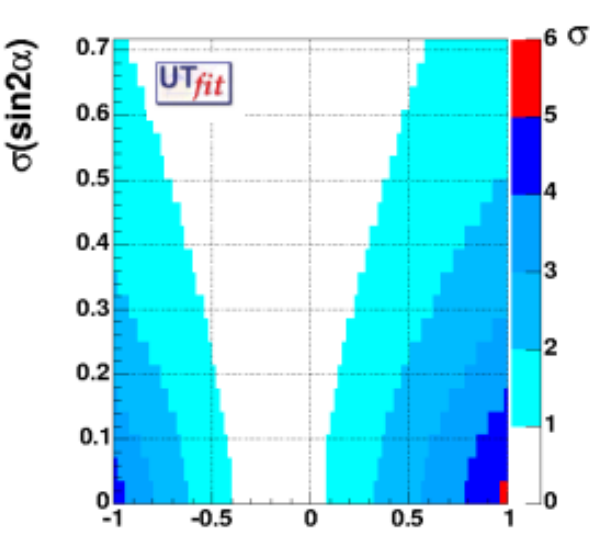
Compatibility plots:

red: 5σ **exclusion zone**

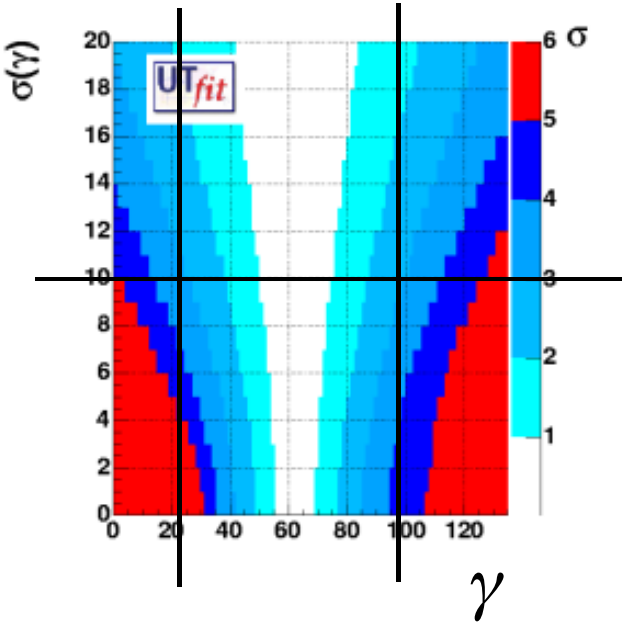
$\gamma > 100°$ } **new physics**
$\gamma < 25°$ } **@** 3σ **level**



sin 2β



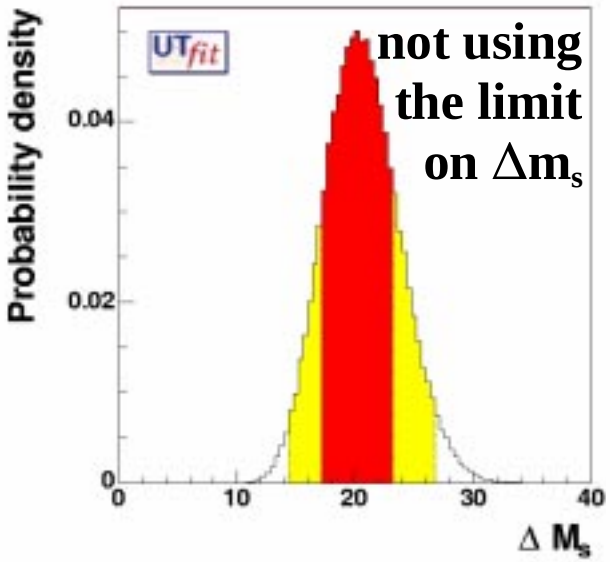
sin 2α

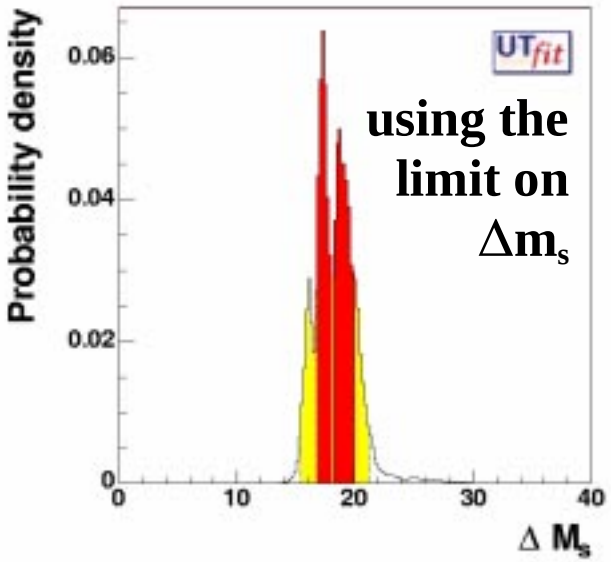


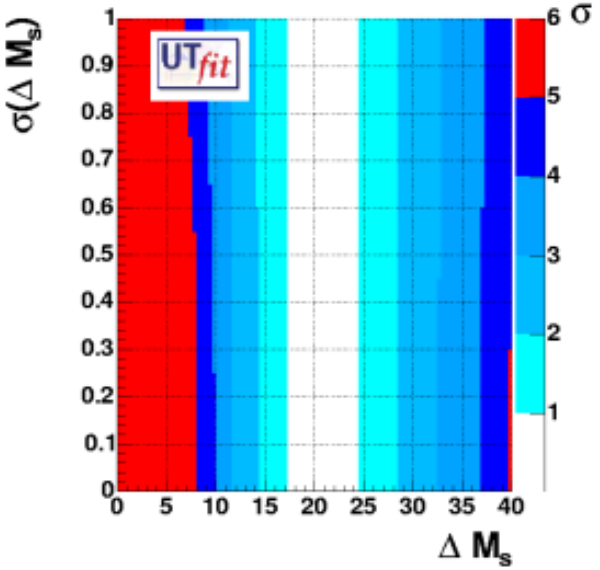
γ

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

Indirect determination and compatibility plot for Δm_s:







$\Delta m_s = 20.5 \pm 3.2\ ps^{-1}$
[14.4, 27.1] @ 95% CL

$\Delta m_s = 18.0 \pm 1.6\ ps^{-1}$
[15.5, 21.6] @ 95% CL

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

New inputs: sin2α

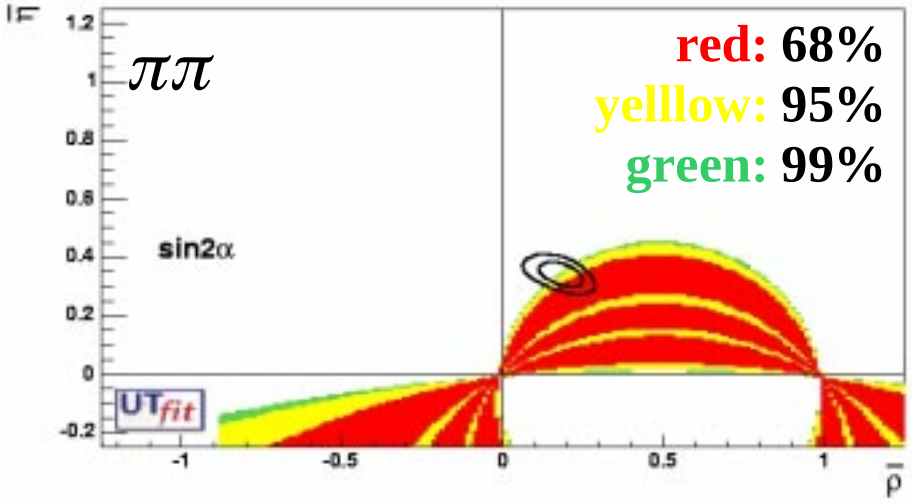
time-dependent analyses of $\pi\pi$ and $\rho\rho$:
measurements of $2\alpha_{eff} = 2\alpha + \delta$

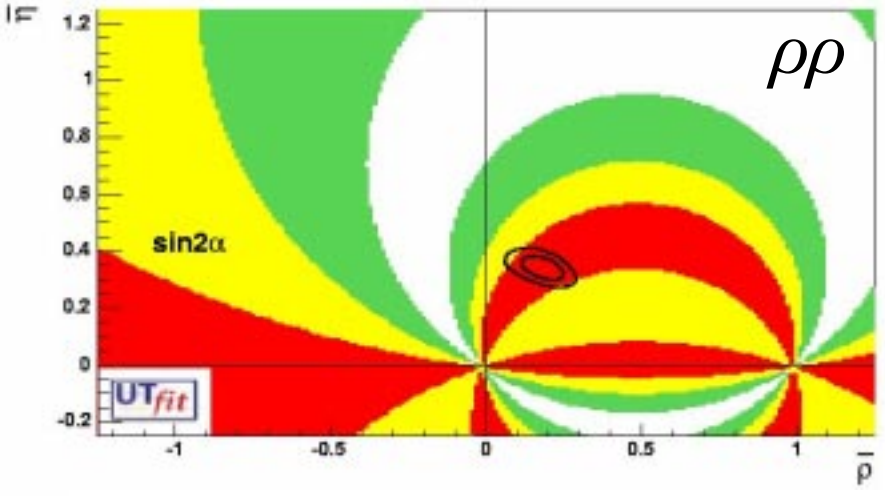
$|\alpha_{eff}-\alpha|_{\pi\pi} < 43.0°$ @ 95% CL

$|\alpha_{eff}-\alpha|_{\rho\rho} < 17.0°$

Grossman-Quinn bound:

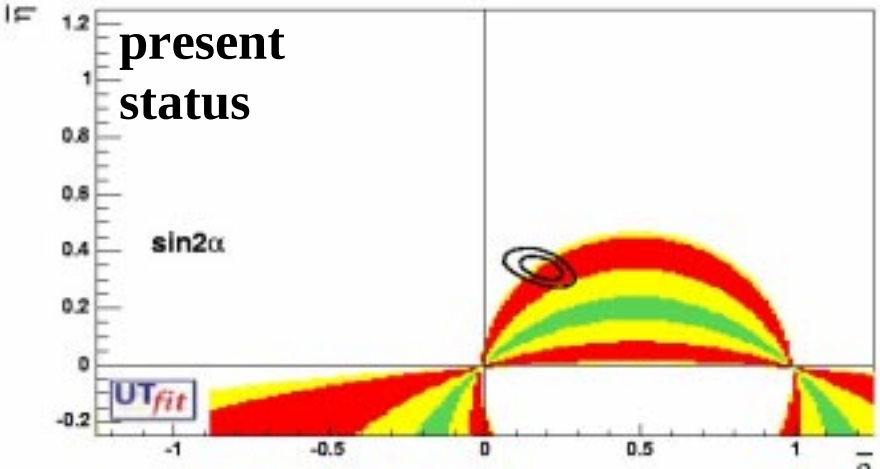
$$\sin^2\delta \leq \frac{BR(B^0 \to \pi^0\pi^0) + BR(\bar{B}^0 \to \pi^0\pi^0)}{BR(B^+ \to \pi^+\pi^0) + BR(B^- \to \pi^-\pi^0)}$$

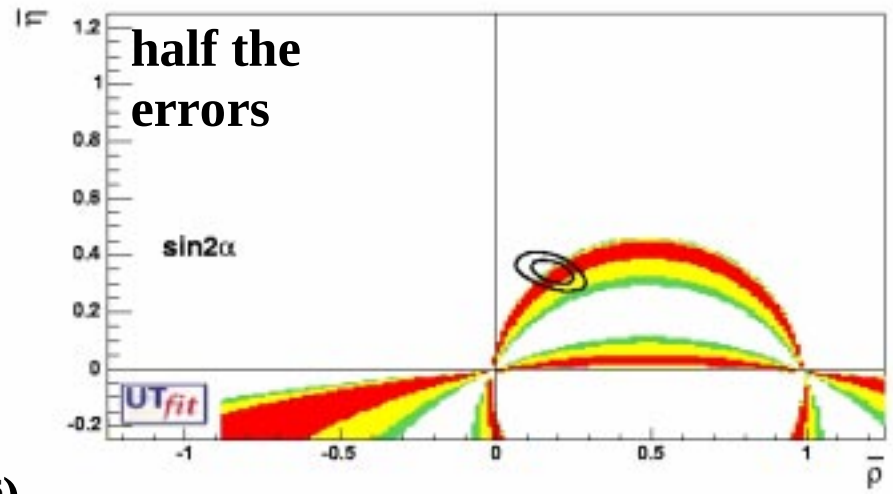




New Inputs: sin2α (II)

considering both $\pi\pi$ and $\rho\rho$: present status and with 4 times the statistics





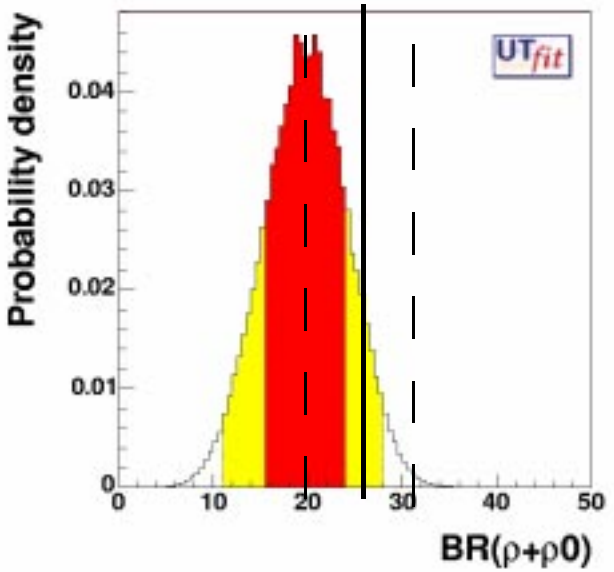
with a small value of $\rho^0\rho^0$ ($< 1.0\ 10^{-6}$)

→ SU(2) breaking

→ no more applicable bounds

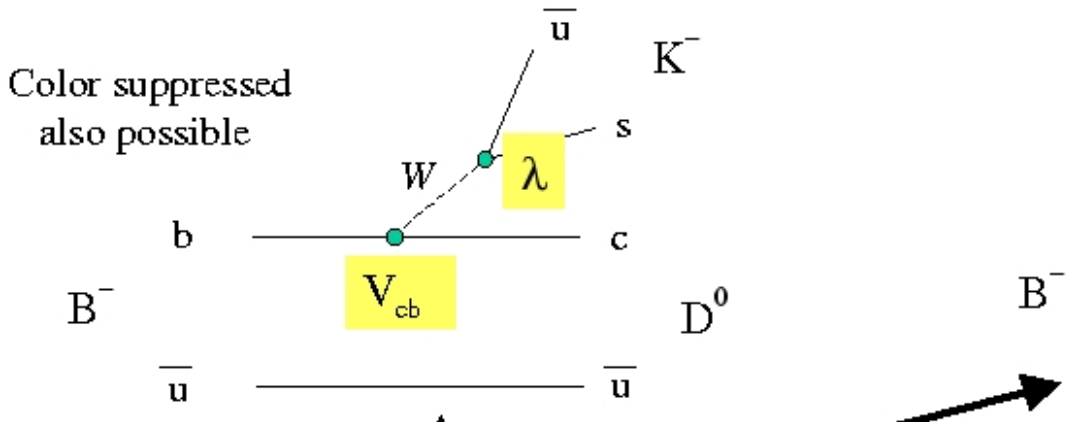
instead of apply the bounds, decay amplitudes should be parameterized adding the BR experimental values as inputs

→ the SU(2) breaking effects can be shown

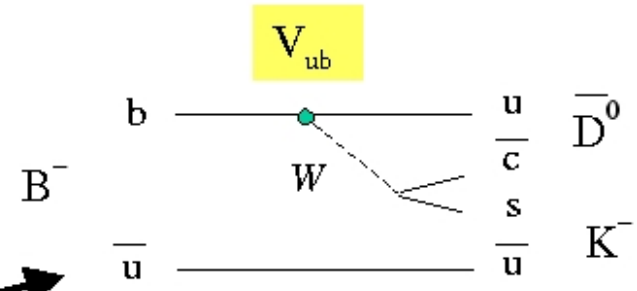


New Inputs: γ

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



$$|D^0_{CP\pm}\rangle = \frac{1}{\sqrt{2}}\left(|D^0\rangle \pm |\overline{D}^0\rangle\right)$$



$$A_-(B^- \to f) = v_1 A_1 e^{i\alpha_1} + v_2 A_2 e^{i\alpha_2} \quad , \quad A_+(B^+ \to \overline{f}) = v_1^* A_1 e^{i\alpha_1} + v_2^* A_2 e^{i\alpha_2}$$

$$A_{CP\pm} = \frac{\Gamma(B^+ \to D^0_{CP\pm}K^+) - \Gamma(B^- \to D^0_{CP\pm}K^-)}{\Gamma(B^+ \to D^0_{CP\pm}K^+) + \Gamma(B^- \to D^0_{CP\pm}K^-)} = \frac{\pm 2r\sin\gamma\sin\delta}{1 + r^2 \pm 2r\cos\gamma\cos\delta}$$

$\delta = \alpha_1 - \alpha_2$
$r \equiv r(DK^-)$

$$R_{CP\pm} = \frac{\Gamma(B^+ \to D^0_{CP\pm}K^+) + \Gamma(B^- \to D^0_{CP\pm}K^-)}{\Gamma(B^+ \to \overline{D}^0K^+) + \Gamma(B^- \to D^0K^-)} = 1 + r^2 \pm 2r\cos\gamma\cos\delta$$

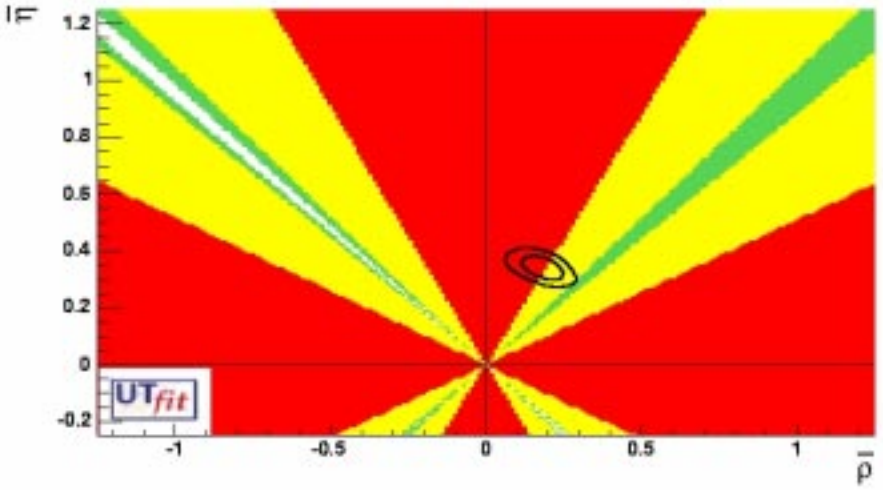
GWL method

$$r \equiv r(DK^-) = \frac{|A_1||v_1|}{|A_2||v_2|} = \frac{|A_1||V_{ub}|}{|A_2||V_{cb}|\lambda} = \frac{|A_1|}{|A_2|}R_b$$

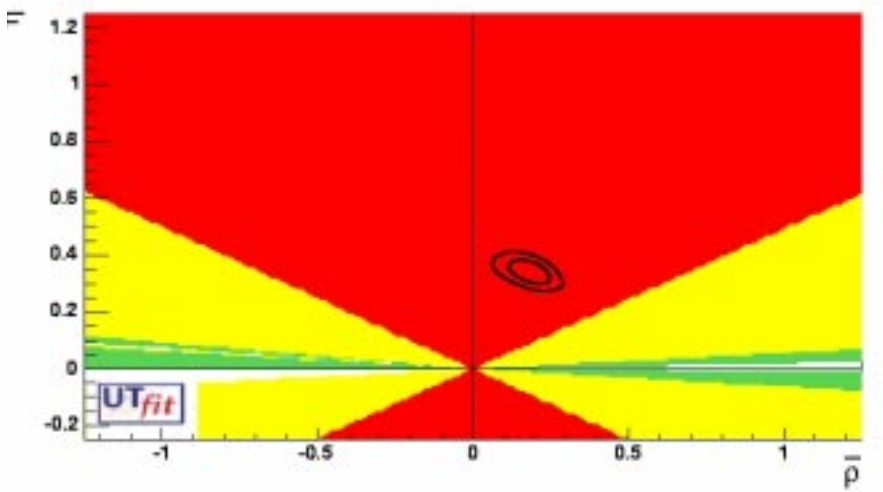
$$R_b = \sqrt{\bar{\rho}^2 + \bar{\eta}^2}$$

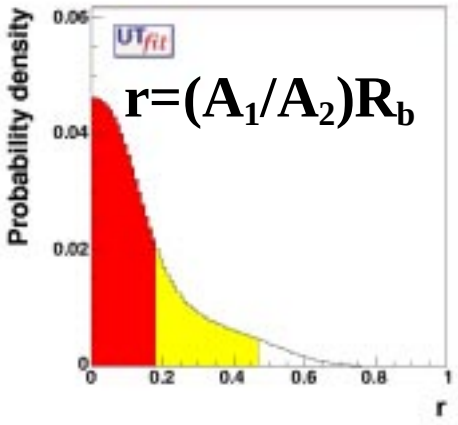
New Inputs: γ (II) from $B^{\pm} \to D_{CP}K^{\pm}$ decays

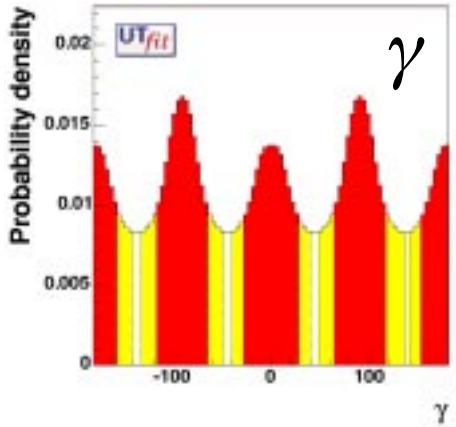
method GLW: $A^{\pm}$, $R^{\pm}$

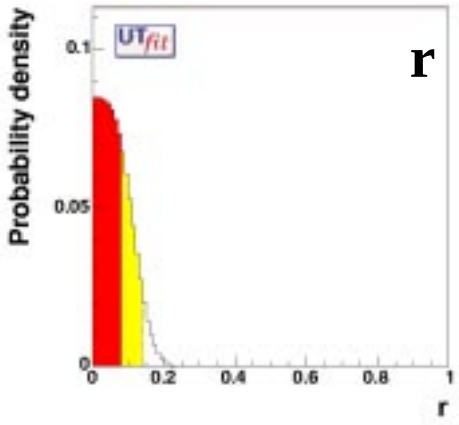


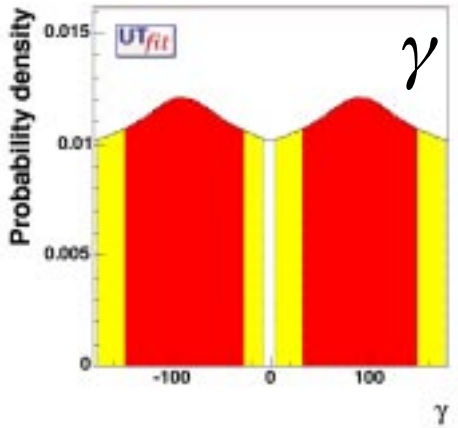
adding ADS: $+R_{ADS}$











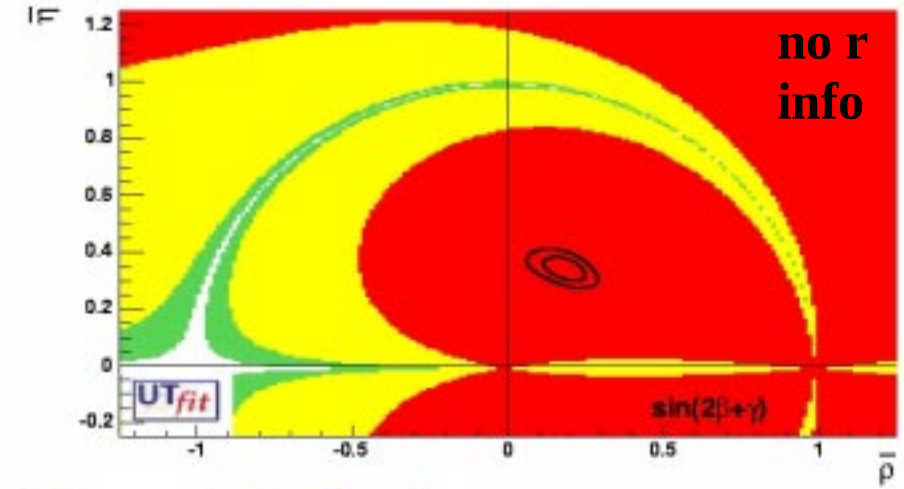
New Inputs: sin(2β+γ)

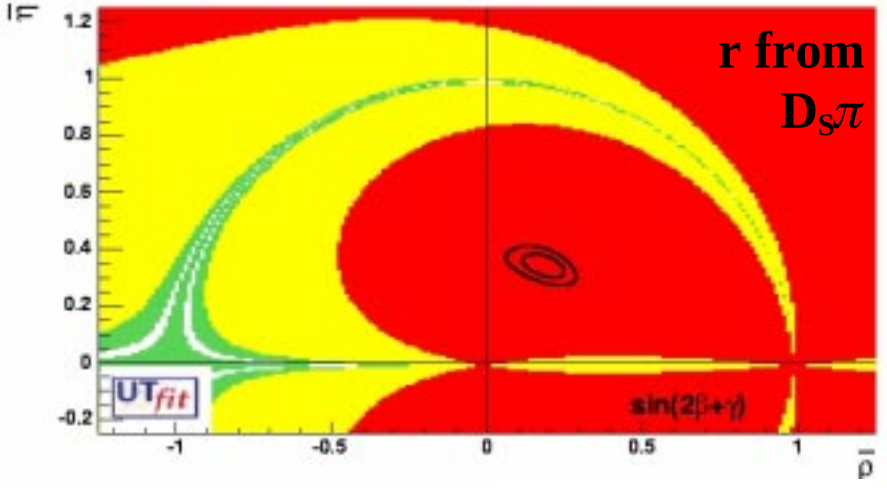
$B^0 \to D^{\pm(*)}\pi^{\pm}$

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

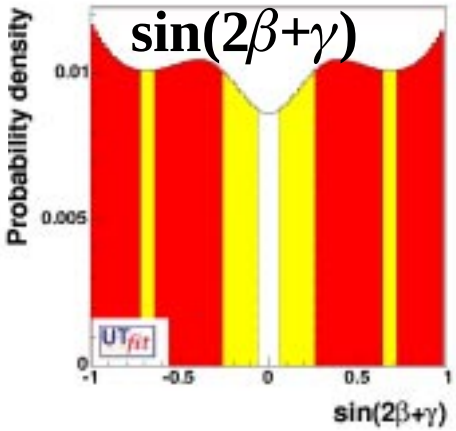
$c^{(*)} = 2r^{(*)}\cos(2\beta+\gamma)\sin\delta^{(*)}$ (leptonic tag)

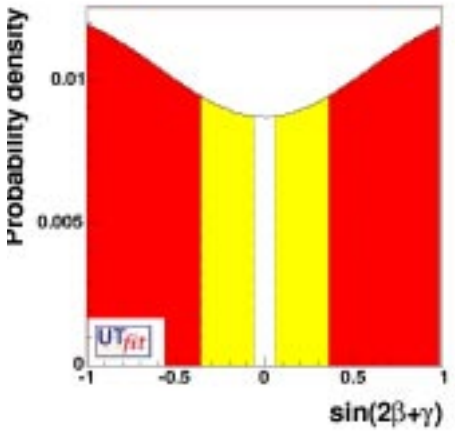
averages from HFAG

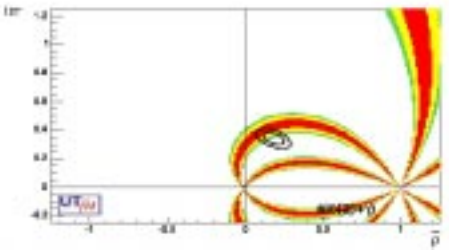




with infinite statistics







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

D'Ambrosio, Isidori
hep-ph/0112135

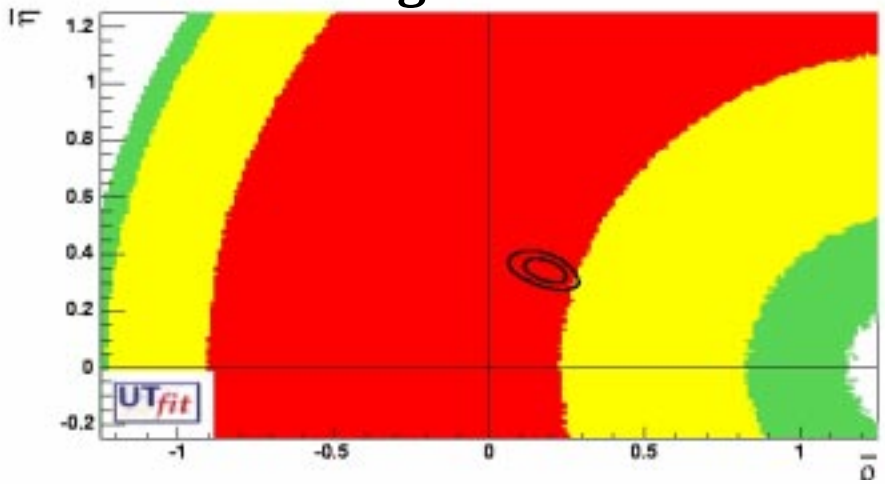
$$(\sigma\bar{\eta})^2 + (\bar{\rho} - \bar{\rho}_0)^2 = \frac{\sigma BR(K^+ \to \pi^+\nu\bar{\nu})}{\bar{\kappa}_+ |V_{cb}|^4 X^2(x_t)}$$

ellipse centered in $(\rho^0, 0)$

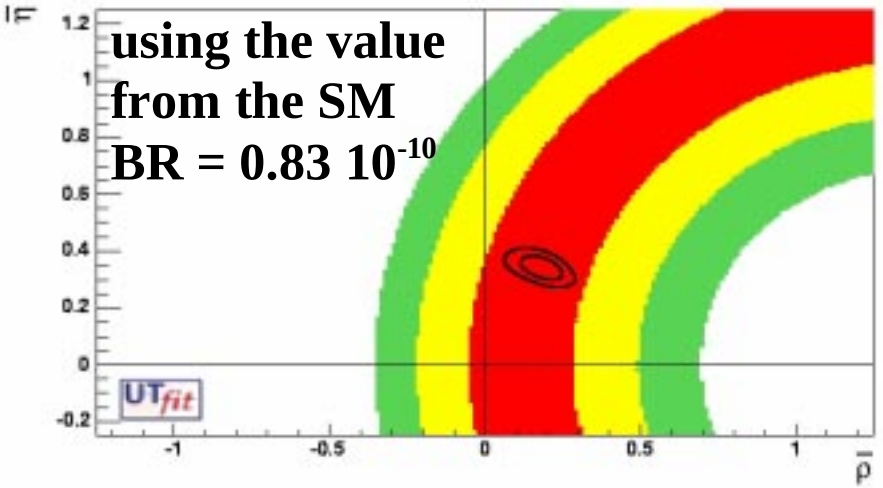
recent result from E949:

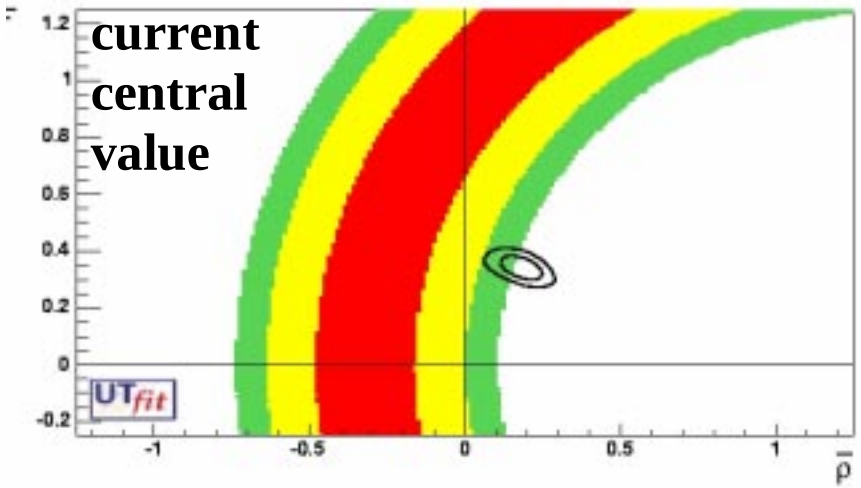
$BR(K^{\pm} \to \pi^{\pm}\nu\bar{\nu}) = 1.47^{+1.30}_{-0.89}\ 10^{-10}$

with 3 signal events



with ~50 signal events

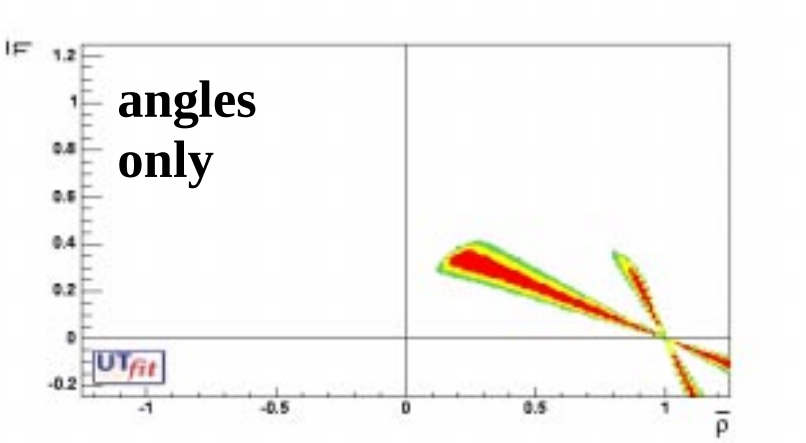


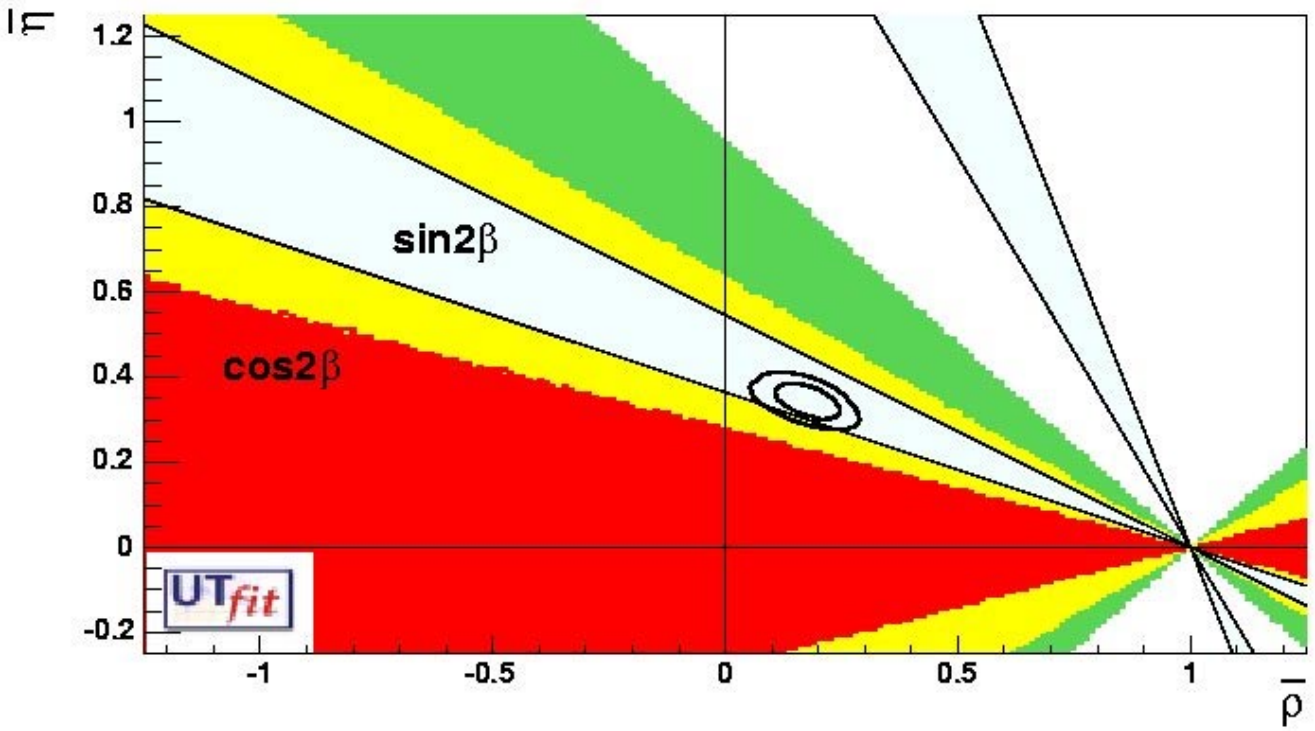


New Inputs: cos2β

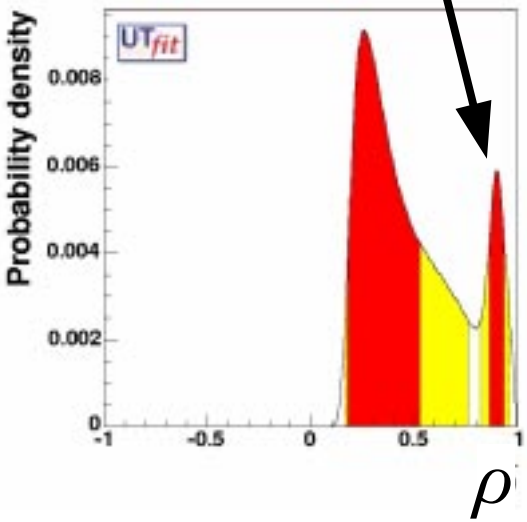
new result from BaBar

$$\cos 2\beta = +3.32\ ^{+0.76}_{-0.96} \pm 0.27$$





excluded solution



Conclusions:

- **In the standard fit:**
  - **$|V_{ub}/V_{cb}|$, Δm_d, Δm_s, ε_K, sin2β**
  - **the results from the UTfit are in good agreement with the Standard Model expectations**
- **New inputs from B-Factories:**
  - **sin2α, γ, sin(2β+γ), cos2β, ...**
- **and from K rare decays:**
  - **$K^{\pm} \to \pi^{\pm}\nu\bar{\nu}$, ...**
- **the overconstraining from the new measurements can test the presence of new physics**
  - **still room for surprises...**

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