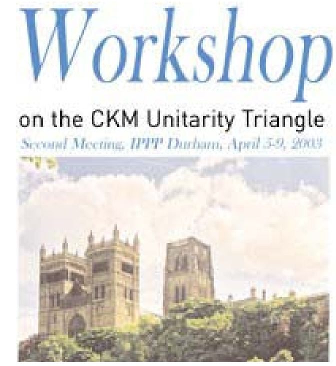
UT Fits in the Standard Model and Sensitivity to New Physics

M.Ciuchini, E.Franco, VL, F.Parodi,
L.Silvestrini, A.Stocchi



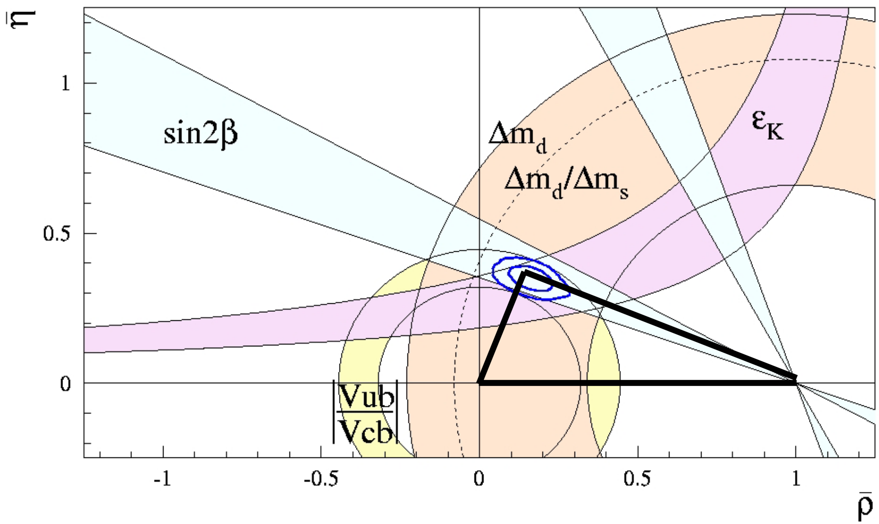
- **UTA in the Standard Model**
  With Updated Inputs after the CERN Workshop
- **Sensitivity to New Physics**

1. Impact of Improved Determinations
2. UTA with New Physics Contributions

1.
UTA in the Standard Model

With updated inputs after the CERN Workshop

The Unitarity Triangle Analysis



(b→u)/(b→c)	$\bar{\rho}^2 + \bar{\eta}^2$	$\bar{\Lambda}, \lambda_1, f_+, \ldots$
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
$A(J/\psi\, K_S)$	$\sin(2\beta)$	—

THE CKM MATRIX AND
THE UNITARITY TRIANGLE

Based on the workshop held at CERN, 13-16 February 2002

97

Editors: M. Battaglia, A.J. Buras, P. Gambino, A. Stocchi

D. Abbaneo[1], A. Ali[2], P. Amaral[3], V. Andreev[4], M. Artuso[5], E. Barberio[6], M. Battaglia[1], C. Bauer[6], D. Becirevic[8], M. Beneke[9], I. Bigi[10], C. Bozzi[11], T. Brandt[12], G. Buchalla[13], A.J. Buras[13], M. Calvi[14], D. Cassel[15], V. Cirigliano[16], M. Ciuchini[17], G. Colangelo[18], A. Dighe[19], G. Dubois-Felsmann[20], G. Eigen[21], K. Ecklund[15], P. Faccioli[22], R. Fleischer[1], J. Flynn[23], R. Forty[1], E. Franco[8], P. Gagnon[24], P. Gambino[1], R. Gupta[25], S. Hashimoto[26], R. Hawkings[1], D. Hitlin[20], A. Hoang[19], A. Hocker[27], T. Hurth[1], G. Isidori[1], T. Iijima[28], D. Jaffe[29], M. Jamin.[30] Y.Y. Keum[28], A. Khodjamirian[31], C.S. Kim[32], P. Kluit[33], A. Kronfeld[34], H. Lacker[27], S. Laplace[27], F. Le Diberder[27], L. Lellouch[35], A. Lenz[36], C. Leonidopoulos[34], A. Le Yaouanc[37], Z. Ligeti[38], D. Lin[23], G. Lopez-Castro[39], V. Lubicz[17], D. Lucchesi[40], T. Mannel[31], M. Margoni[40], G. Martinelli[8], D. Melikhov[29], M. Misiak[41], V. Morénas[42], H.G. Moser[19], U. Nierste[34], J. Ocariz[27], L. Oliver[37], F. Parodi[43], M. Paulini[44], C. Paus[45], O. Pène[35], M. Pierini[8], F. Porter[20], D. Počanić[46], J.-C. Raynal[35], J.L. Rosner[3], P. Roudeau[27], Y. Sakai[26], K. Schubert[12], C. Schwanda[26], B. Sciascia[47], O. Schneider[48], B. Serfass[12], L. Silvestrini[8], M. Smizanska[49], J. Stark[50], B. Stech[29], A. Stocchi[27], N. Uraltsev[14], M. Villa[22], A. Warburton[15], C. Weiser[31], G. Wilkinson[51], S. Willocq[52], N. Yamada[26]

Input Parameters

Parameter	Value	Gaussian σ	Theory uncertainty	$\sigma(2003)/\sigma(2002)$
λ	0.2240(0.2210)	0.0036 (*0.0020*)	-	▲ 1.80
$\lvert V_{cb}\rvert(\times10^{-3})$ (excl.)	42.1	2.1	-	
$\lvert V_{cb}\rvert(\times10^{-3})$ (incl.)	41.6 (*40.4*)	0.7	0.6(*0.8*)	▼ 0.93
$\lvert V_{ub}\rvert(\times10^{-4})$ (excl.)	33.0(*32.5*)	2.4(*2.9*)	4.6(*5.5*)	▼ 0.83
$\lvert V_{ub}\rvert(\times10^{-4})$ (incl.)	40.9	4.6	3.6	
ΔM_d (ps^{-1})	0.503 (*0.494*)	0.006 (*0.007*)	-	▼ 0.85
ΔM_s (ps^{-1})	> 14.4 (*14.9*) at 95% C.L.	sensitivity 19.2 (*19.3*)		▲
m_t (GeV)	167	5	-	
m_c (GeV)	1.3	-	0.1	
$F_{B_d}\sqrt{\hat{B}_{B_d}}$ (MeV)	223 (*230*)	33 (*30*)	12 (*15*)	▲ 1.08
$\xi = \frac{F_{B_s}\sqrt{\hat{B}_{B_s}}}{F_{B_d}\sqrt{\hat{B}_{B_d}}}$	1.24(1.18)	0.04 (*0.03*)	0.06 (*0.04*)	▲ 1.40
$\hat{B}_K$	0.86	0.06	0.14	
$\sin 2\beta$	0.734 (*0.762*)	0.054 (*0.064*)	-	▼ 0.93

Fit Method: we use the
Bayesian Approach

The Bayes Theorem:

$$f(\bar{\rho},\bar{\eta},\mathbf{x}|c_1,\ldots,c_m) \sim \prod_{j=1,m} f_j(\mathbf{c}|\bar{\rho},\bar{\eta},\mathbf{x}) \prod_{i=1,N} f_i(x_i)\, f_o(\bar{\rho},\bar{\eta})$$

$$\longrightarrow \quad f(\bar{\rho},\bar{\eta}|\mathbf{c}) \sim \mathcal{L}(\mathbf{c}|\bar{\rho},\bar{\eta})\, f_o(\bar{\rho},\bar{\eta})$$

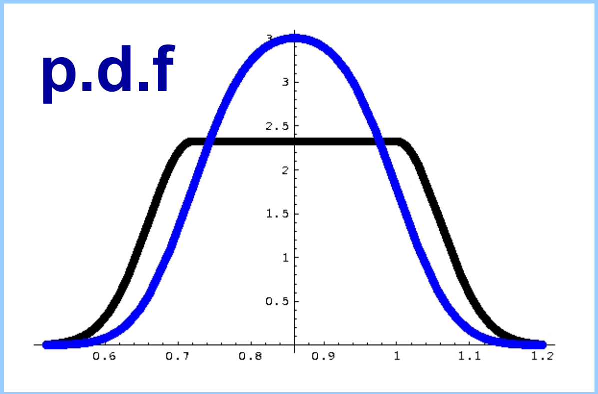
but also *frequentistic* approaches have been considered: *Rfit* , Scanning, ...

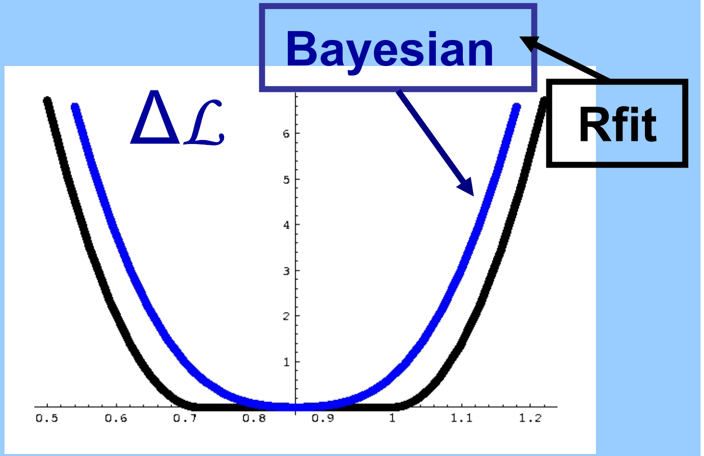
Conclusion of the CERN Workshop:

"The main origin of the difference on the output quantities between the Bayesian and the Rfit method comes from the likelihood associated to the input quantities"

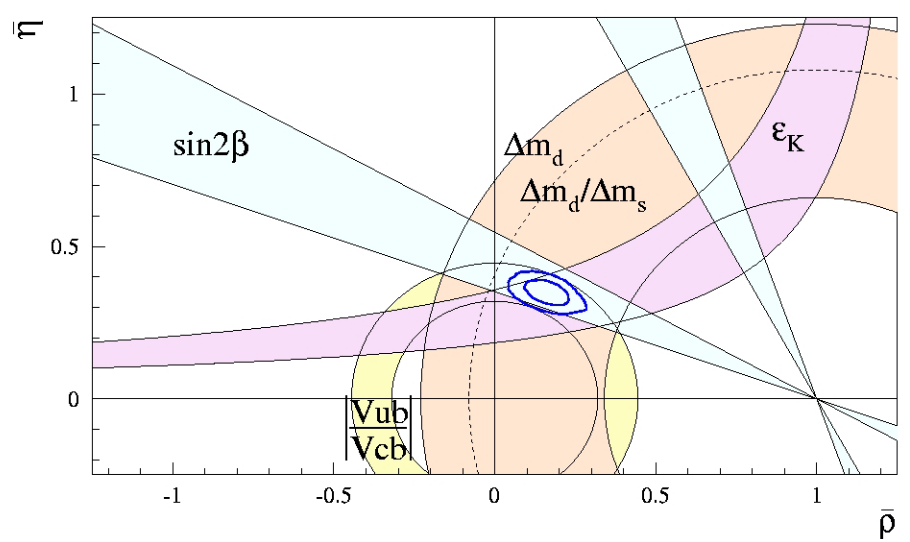
"If same (and any) likelihood are used the output results are very similar"

Example: $\hat{B}_K = 0.86 \pm 0.06 \pm 0.14$





UTA IN THE SM: FIT RESULTS

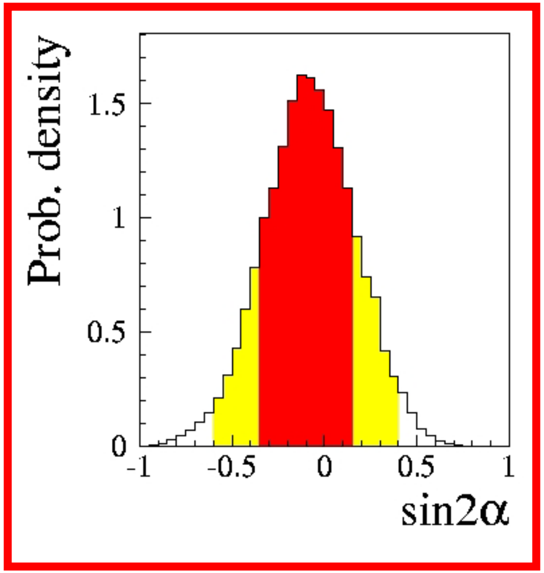


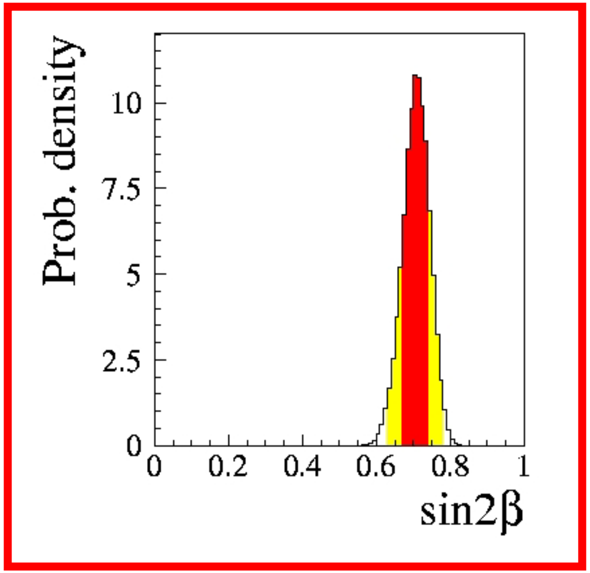
$\bar{\rho} = 0.162 \pm 0.046$ $\bar{\eta} = 0.347^{+0.029}_{-0.026}$

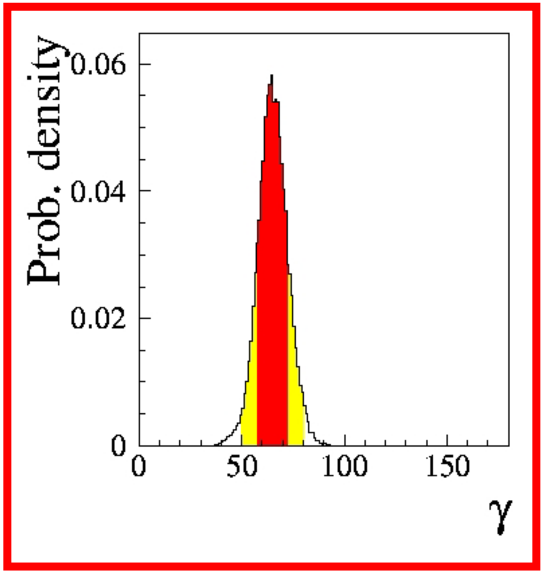
$\bar{\rho} = 0.203 \pm 0.040$ $\bar{\eta} = 0.355 \pm 0.027$

F. Parodi @ ICHEP 2002

$\sin 2\alpha$, $\sin 2\beta$ and γ







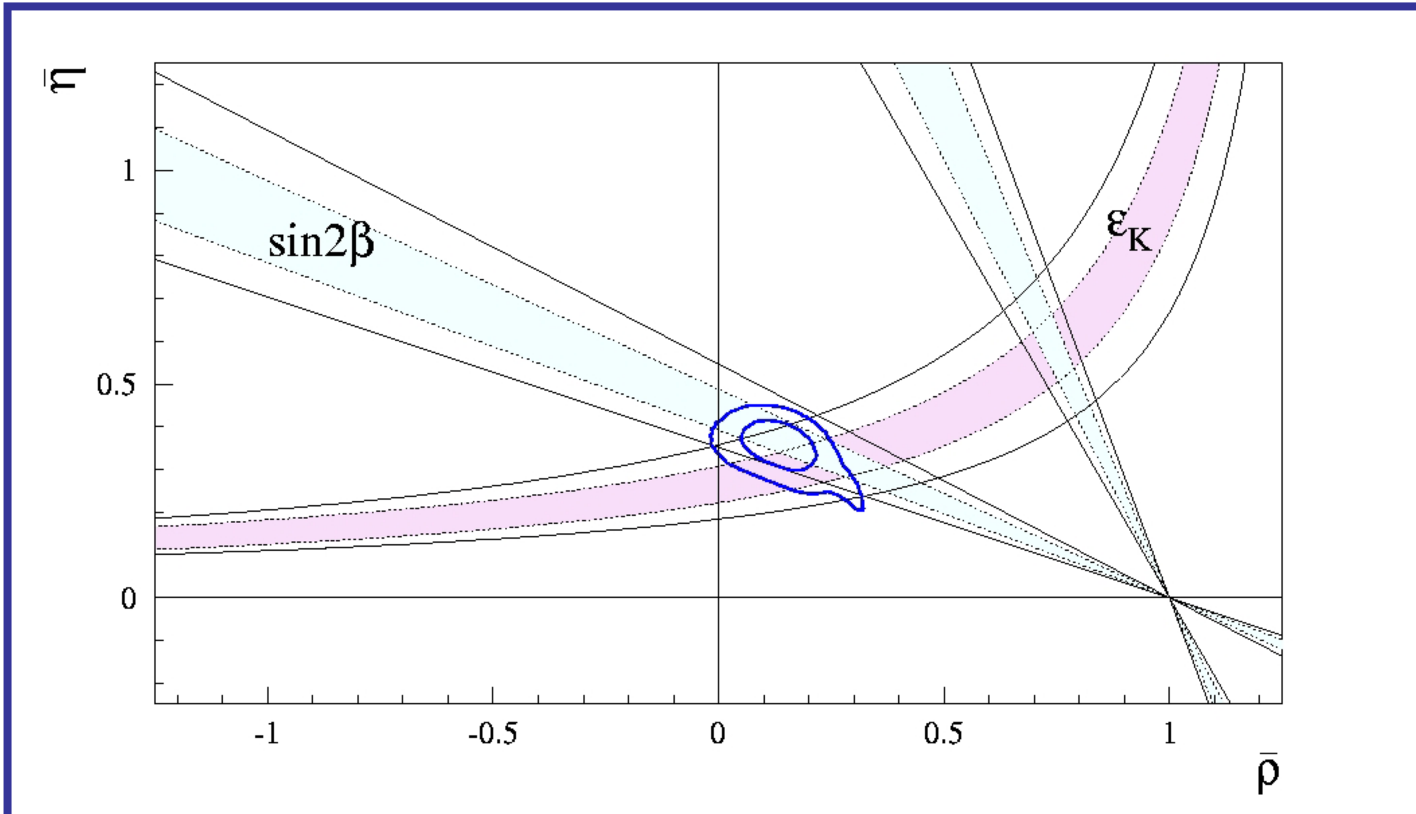
$\sin 2\alpha = -0.13^{+0.28}_{-0.23}$

$\sin 2\beta = 0.705 \pm 0.035$

$\gamma = 64.5^{+7.5}_{-6.5}$

Without including the χ-logs effect in ξ: **$\gamma = 60 \pm 6$**

INDIRECT EVIDENCE OF CP VIOLATION

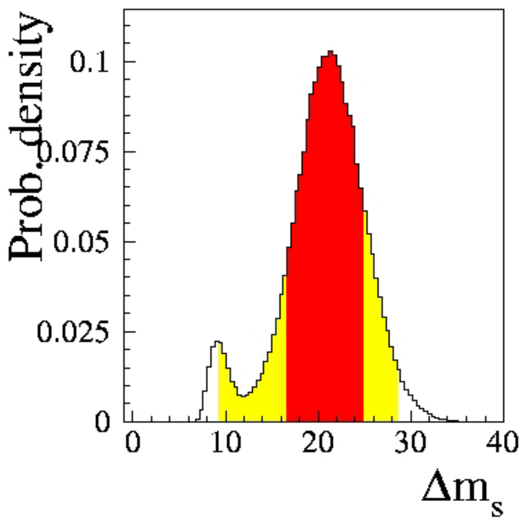


$\text{Sin}2\beta_{\text{INDIR.}}$ = 0.685 ± 0.055

$\text{Sin}2\beta_{\text{DIR.}}$ = 0.734 ± 0.054

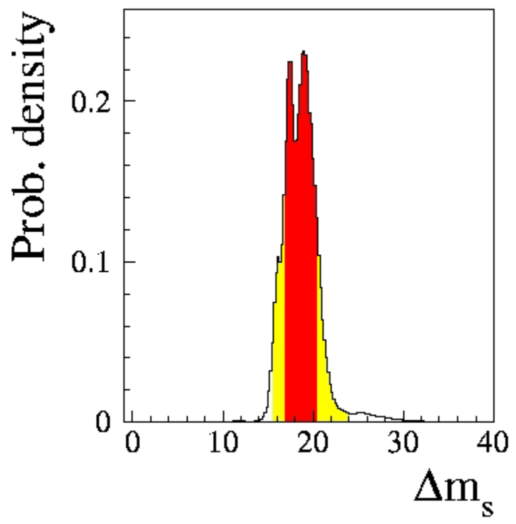
Predictions for Δm_s

WITHOUT Δm_s

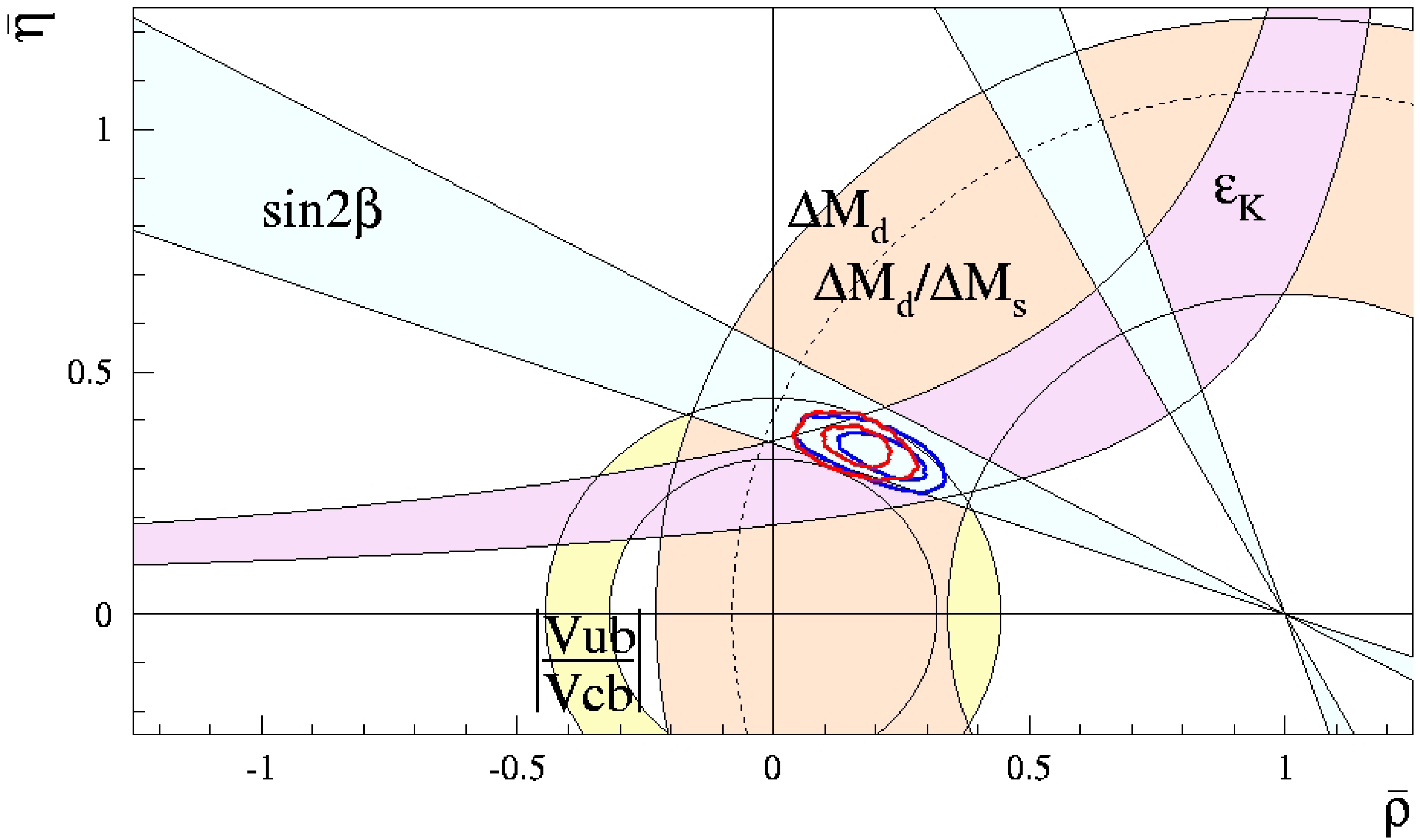


$\Delta m_s = (20.9\ ^{+3.9}_{-4.3})\ ps^{-1}$

WITH Δm_s



$\Delta m_s = (18.6 \pm 1.7)\ ps^{-1}$



RED: WITH ALL CONSTRAINTS / BLUE: WITHOUT Δm_s

By removing the constraint from Δm_s: $\gamma = 65 \pm 7 \rightarrow \gamma = 59 \pm 10$

2.

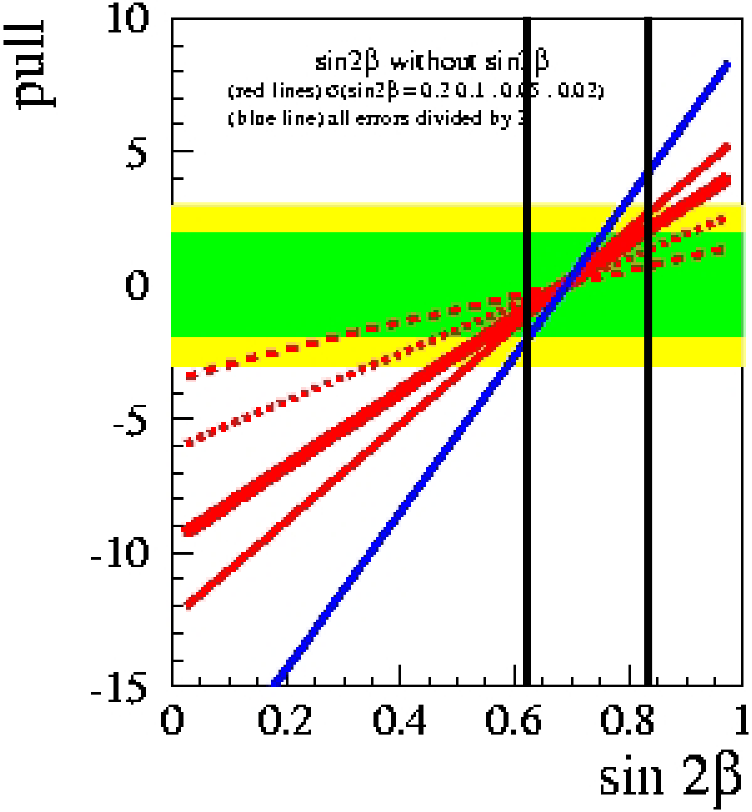
Sensitivity of the UT Fits to New Physics

1) Impact of improved experimental determinations

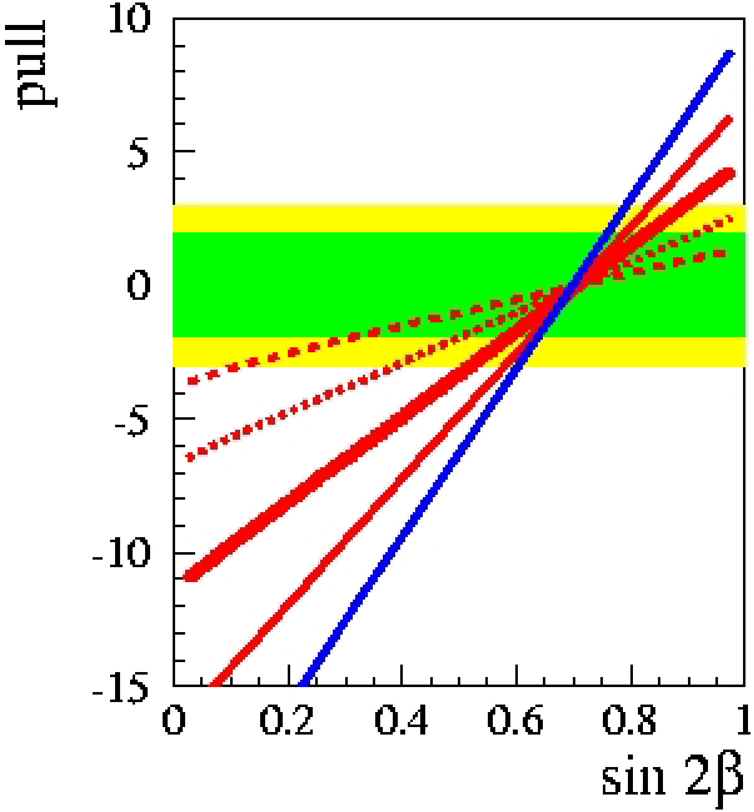
"To which extent improved determinations of the experimental constraints will be able to detect New Physics?"

MEASUREMENTS OF SIN2β

SM prediction without A(J/ψK$_s$)



SM prediction with A(J/ψK$_s$)

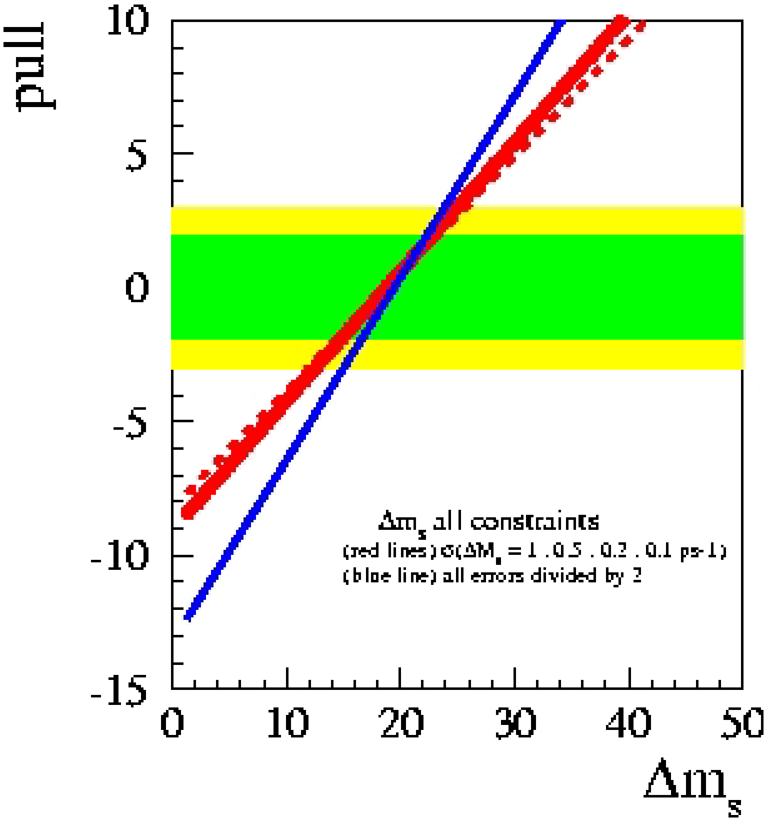


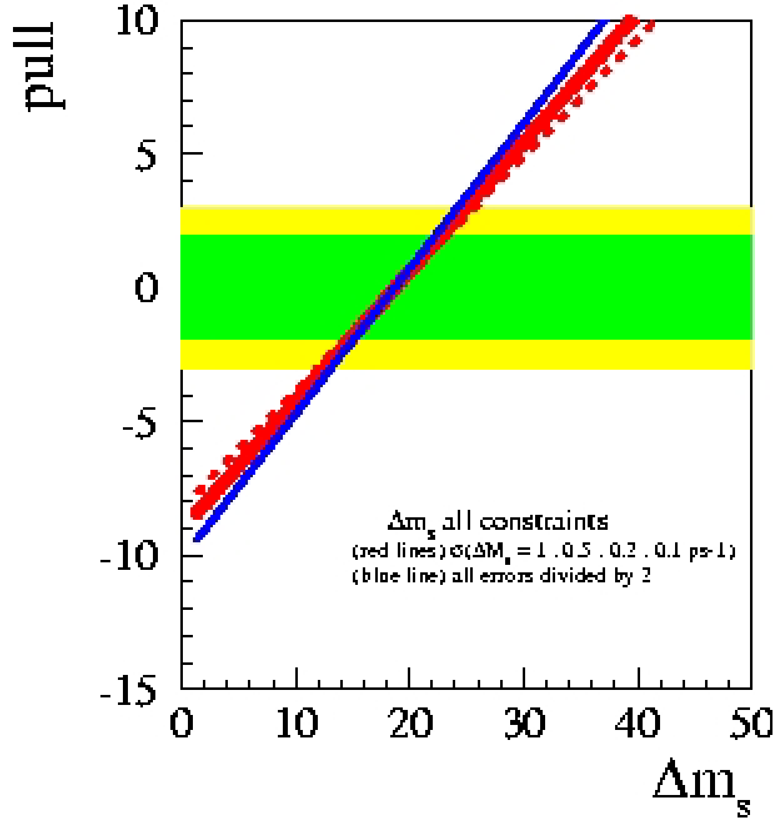
Red lines: σ = 0.2, 0.1, 0.05, 0.02

Blue line: all errors divided by 2

B →φK$_s$?

MEASUREMENT OF Δm_s



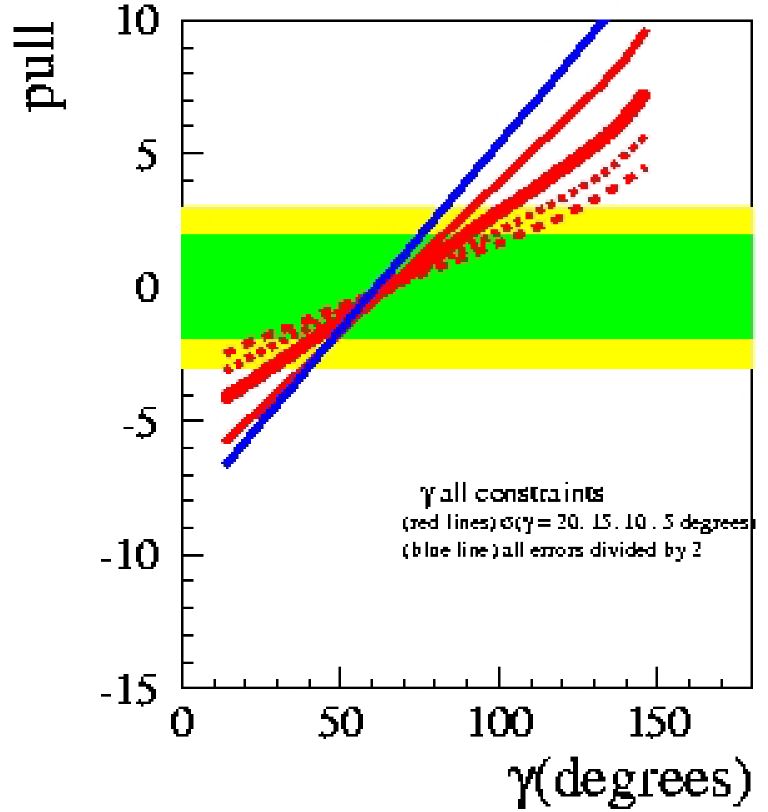


Red lines: σ = 1.0, 0.5, 0.2, 0.1 ps^{-1}

Blue line: all errors divided by 2

Blue line: error on ξ divided by 2

MEASUREMENT OF γ



Red lines: σ = 20, 15, 10, 5 degrees

Blue line: all errors divided by 2

2) UTA with New Physics contributions

"Given the present theoretical and experimental constraints, to which extent the UTA can still be affected by New Physics contributions?"

ASSUMPTIONS

1) Only 3 Families → we still have the CKM Matrix and a Unitary Triangle

2)

$(b\to u)/(b\to c)$	Δm_d, $A(J/\psi\, K_S)$	Δm_s	ε_K
Tree-level	B_d–$\bar{B}_d$ mixing	B_s–$\bar{B}_s$ mixing	K–$\bar{K}$ mixing

New Physics effects can only appears in one of the three mixing amplitudes.

Not true in several models: MFV,...

PARAMETERIZATION

The New Physics Hamiltonian contains in general new FC parameters, new short-distance coefficients and matrix elements of new local operators.

We parameterize the New Physics mixing amplitudes in a simple general form:

Soares, Wolfenstein 92
Grossman, Nir, Worah 97
....

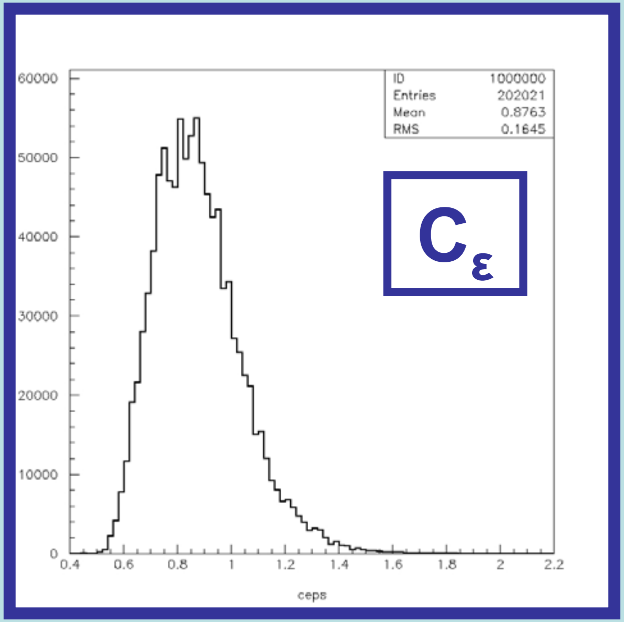
$$M_q = C_q \, e^{2i\varphi_q} (M_q)^{SM} \quad \text{for } B_q\text{-}\bar{B}_q \text{ mixing}$$

$$\mathrm{Im}(M_K) = C_\varepsilon \, \mathrm{Im}(M_K)^{SM} \quad \text{for } K\text{-}\bar{K} \text{ mixing}$$

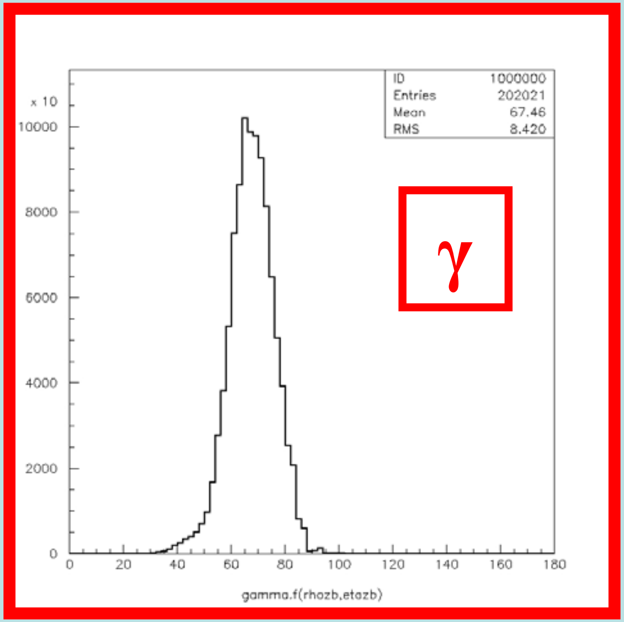
→ We introduce 4 real coefficients: $\{C_d, \varphi_d\}$, C_s, C_ε

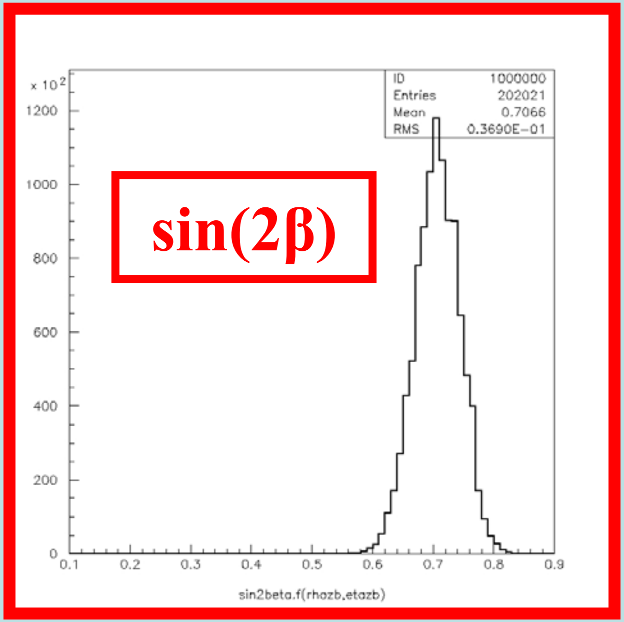
New Physics in $K-\bar{K}$ mixing

$$\varepsilon_K = C_\varepsilon \, (\varepsilon_K)^{SM}$$



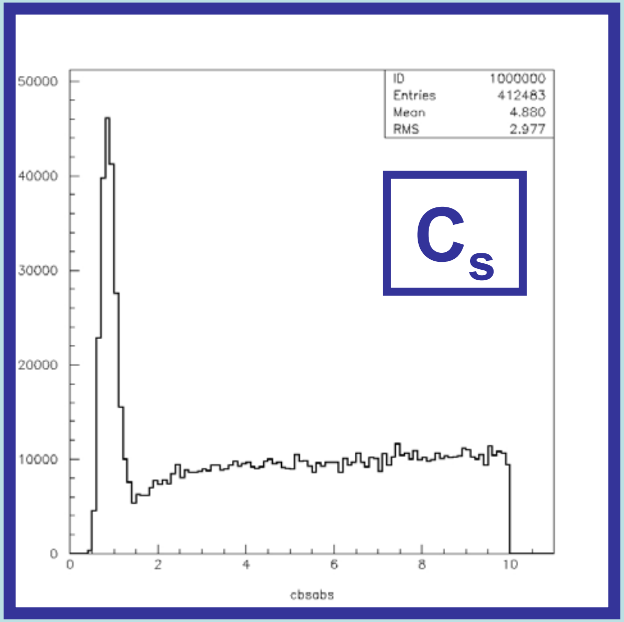
$$C_\varepsilon = 0.86 \, ^{+0.17}_{-0.14}$$

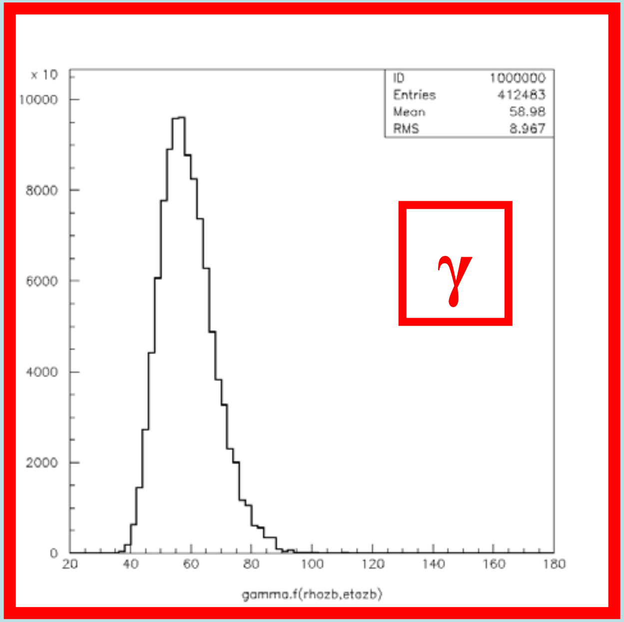


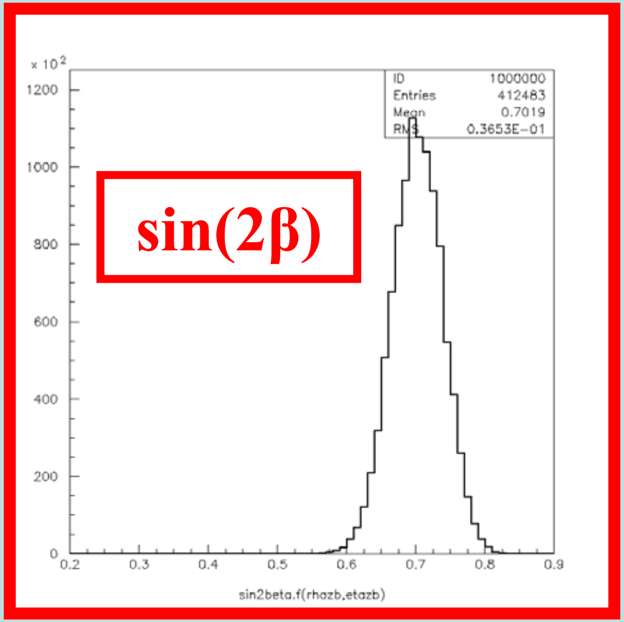


New Physics in B_s–$\overline{B}_s$ mixing

$$\Delta m_s = C_s \, (\Delta m_s)^{SM}$$





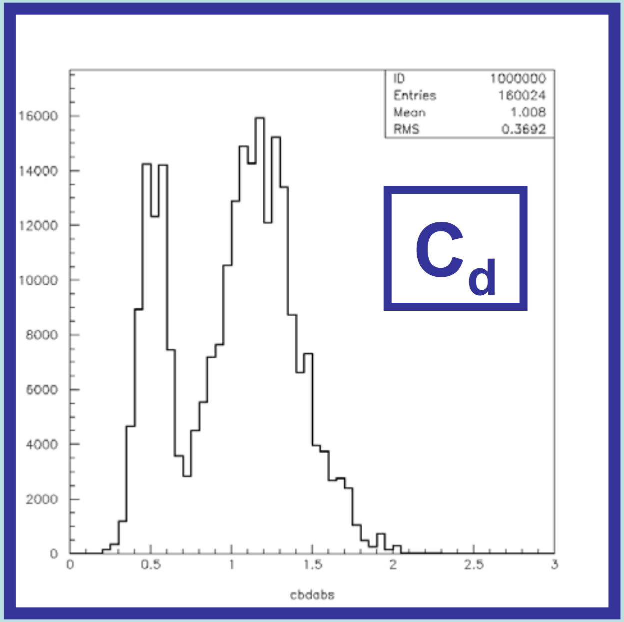


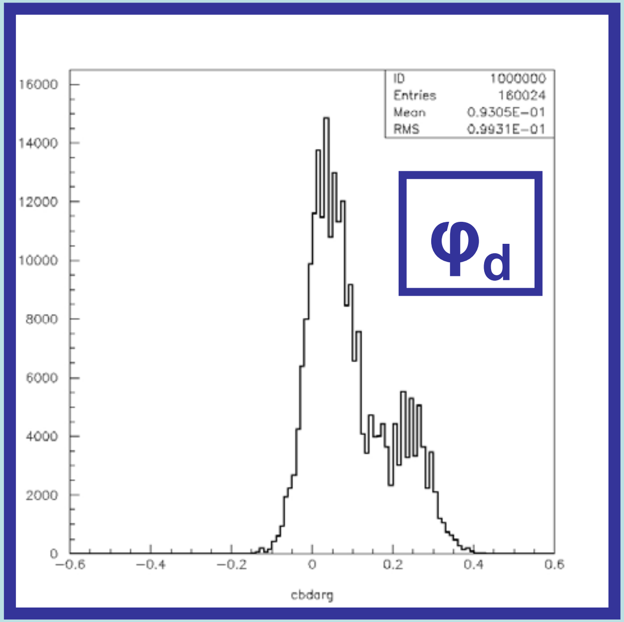
In the lack of an experimental determination of Δm_s, C_s can be arbitrarily large…

New Physics in B_d–$\overline{B}_d$ mixing

$$\Delta m_d = C_d\,(\Delta m_d)^{SM}$$

$$A(J/\psi\,K_S) \sim \sin 2(\beta+\varphi_d)$$

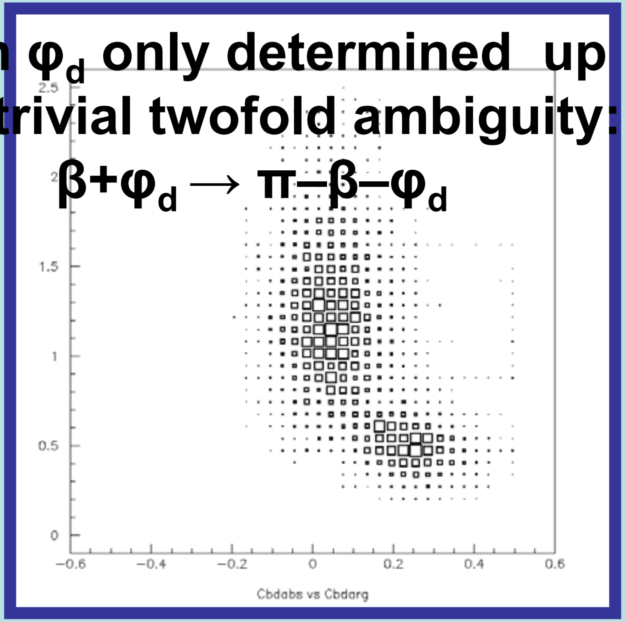




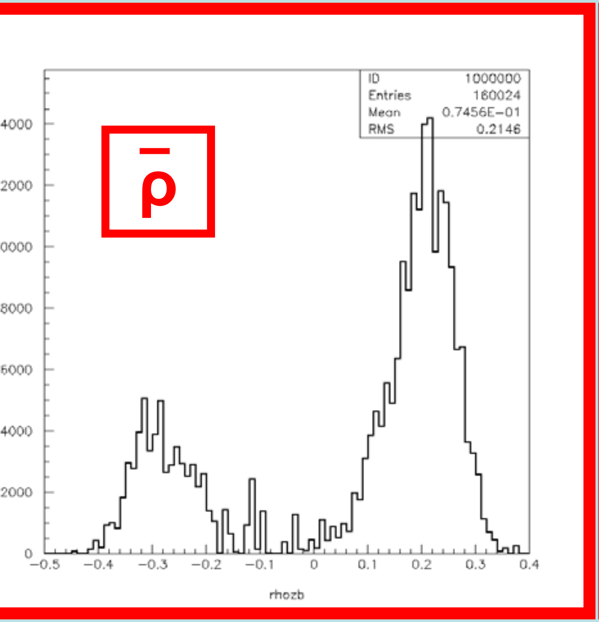
With φ_d only determined up to a trivial twofold ambiguity:

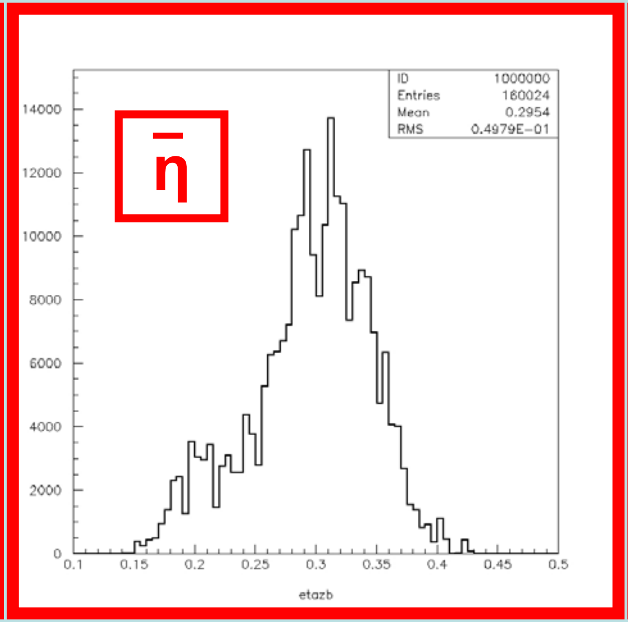
$$\beta+\varphi_d \rightarrow \pi-\beta-\varphi_d$$

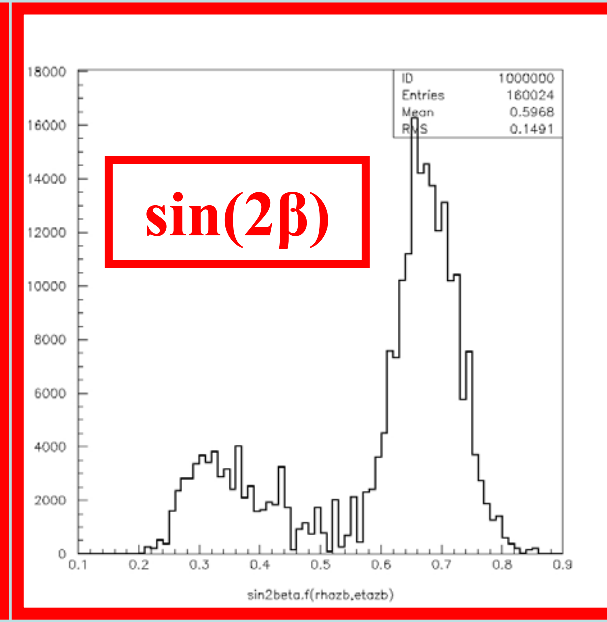
C_d

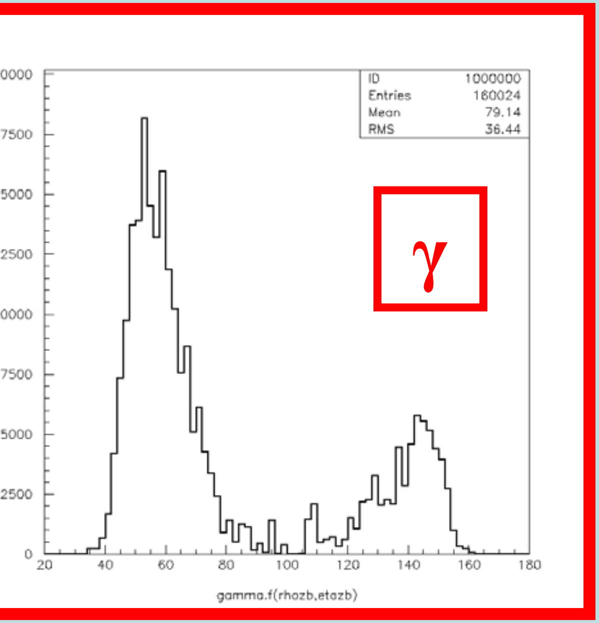


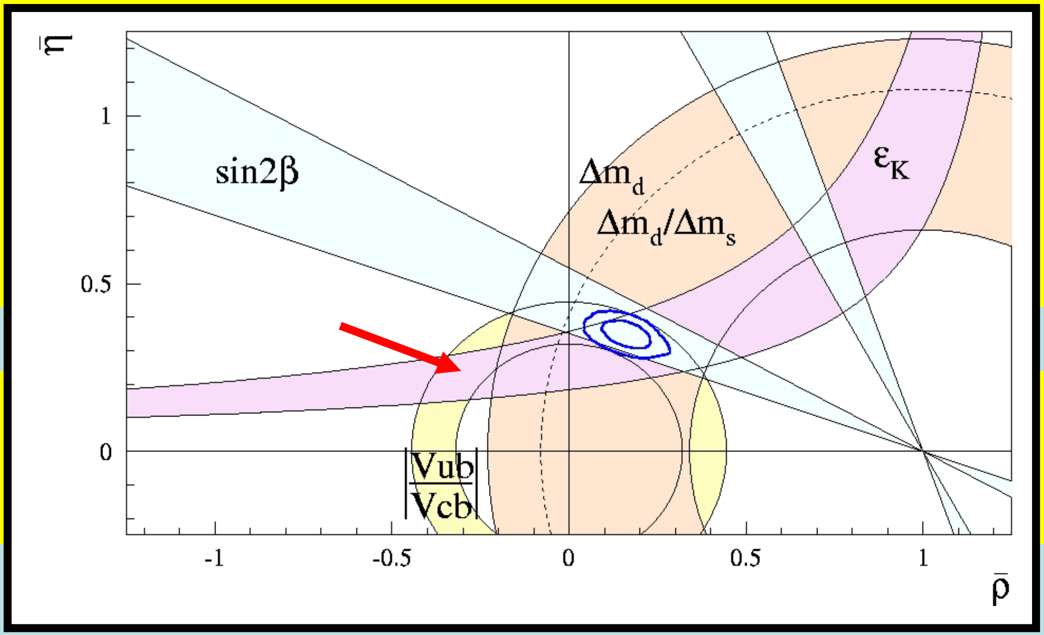
φ_d


ID 1000000
Entries 160024
Mean 0.7456E-01
RMS 0.2146
ρ̄
rhozb


ID 1000000
Entries 160024
Mean 0.2954
RMS 0.4979E-01
η̄
etazb


ID 1000000
Entries 160024
Mean 0.5968
RMS 0.1491
sin(2β)
sin2beta.f(rhozb,etazb)


ID 1000000
Entries 160024
Mean 79.14
RMS 36.44
γ
gamma.f(rhozb,etazb)


η̄
sin2β
Δm_d
Δm_d/Δm_s
ε_K
|Vub/Vcb|
ρ̄

CONCLUSIONS

- A LOT OF IMPORTANT WORK HAS BEEN DONE SINCE THE LAST CKM WORKSHOP IN ORDER TO IMPROVE THE DETERMINATION OF BOTH EXPERIMENTAL AND THEORETICAL INPUTS IN THE UTA

- THE RESULTS OF THE UTA ARE IN EXCELLENT AGREEMENT WITH THE STANDARD MODEL PREDICTIONS, BUT (LUCKILY) WE STILL HAVE ROOM FOR NEW PHYSICS.