

Il Triangolo Unitarizio nel Modello Standard e oltre

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on behalf of **UT***fit* Collaboration

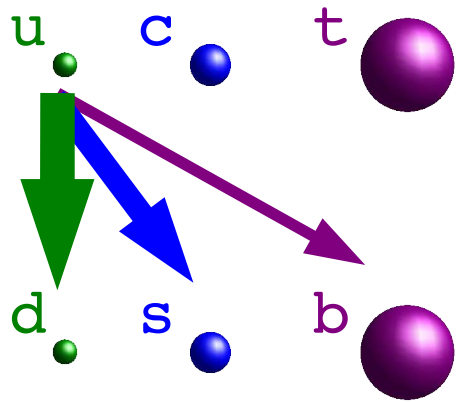
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<http://www.utfit.org>



Modello Standard e Violazione CP

Gli **autostati di massa** non sono autostati dell'interazione debole. La Lagrangiana dello Standard Model contiene la **matrice di mescolamento** V_{CKM}



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \simeq \begin{pmatrix} 1 - \frac{\lambda^2}{2} & \lambda & A\lambda^3(\bar{\rho} - i\bar{\eta}) \\ -\lambda & 1 - \frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1 - \bar{\rho} - i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

L'esistenza delle **tre famiglie** di quark implica la presenza di una **fase non riassorbibile** nella ridefinizione dei quark. La presenza di un elemento complesso porta alla **violazione di CP**



Il Triangolo di unitarietà

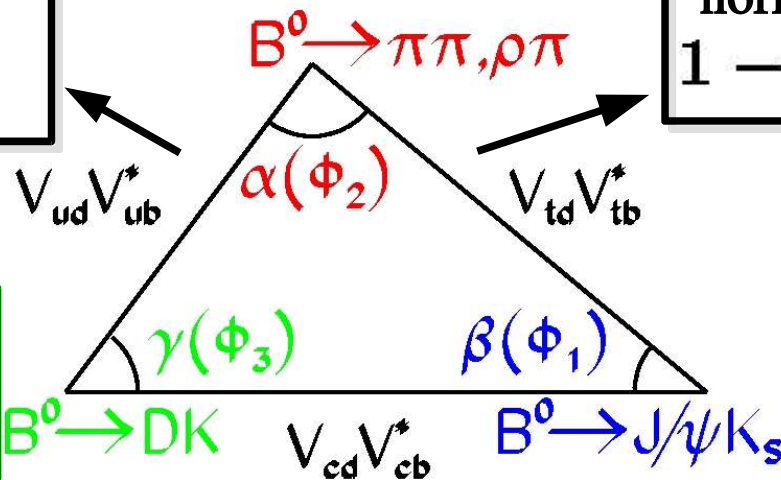
La matrice CKM viene da una **rotazione nella base dei quark**. Conservazione della probabilità \rightarrow **Unitarietà**

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

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

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

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

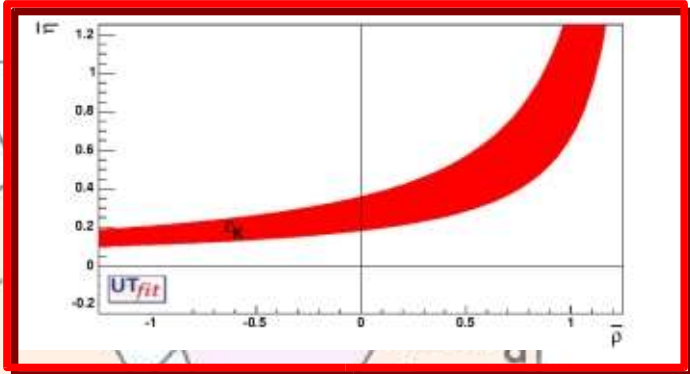
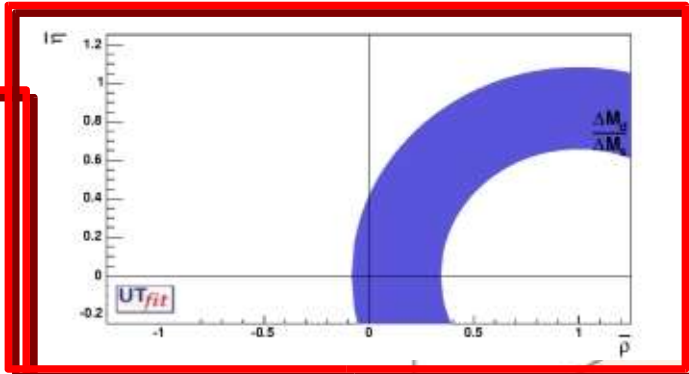
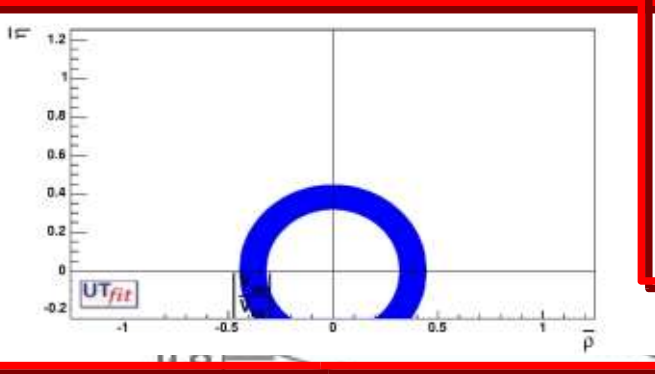


numerose osservabili
funzioni di $\bar{\rho}$ ed $\bar{\eta}$:
overconstraining

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

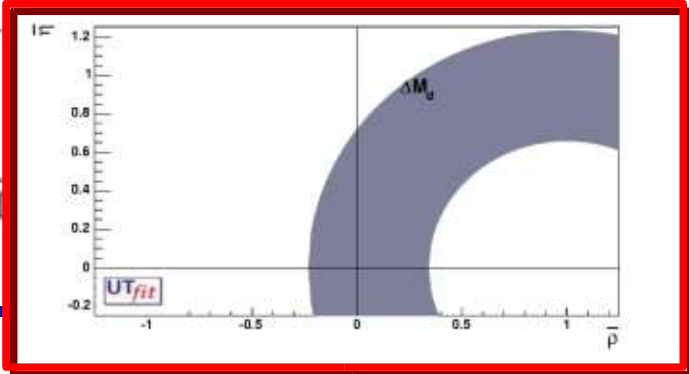
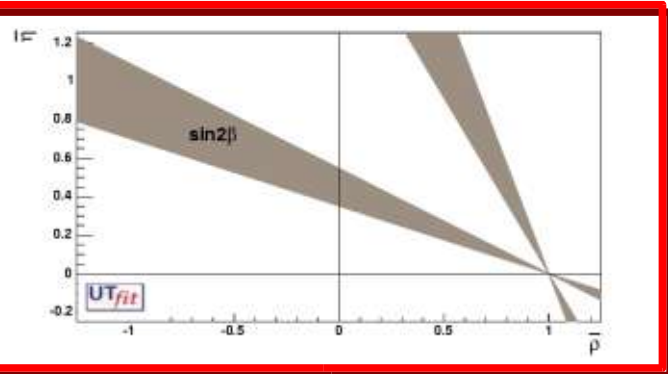
$$\beta = \text{atan} \left(\frac{\bar{\eta}}{(1 - \bar{\rho})} \right)$$





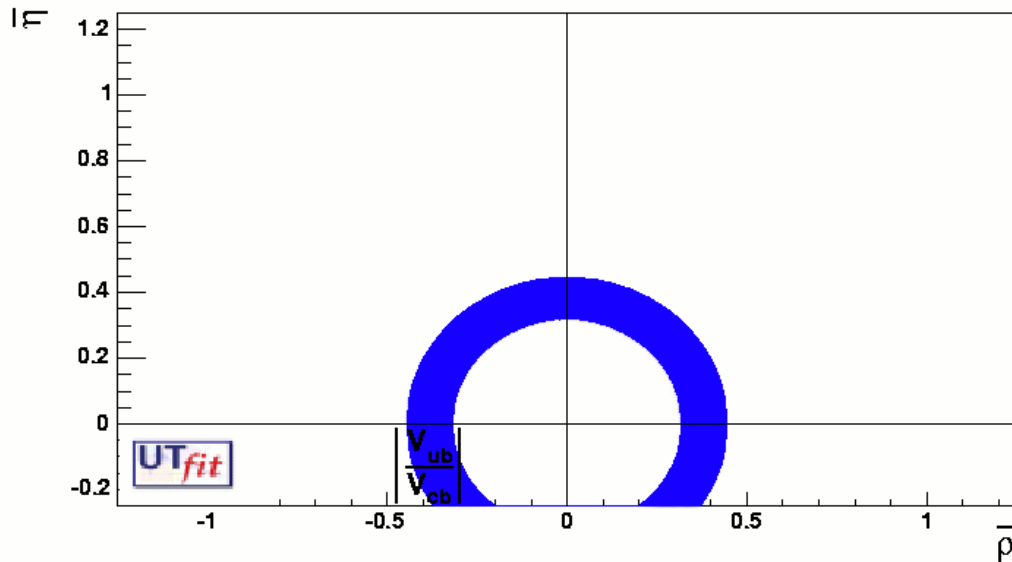
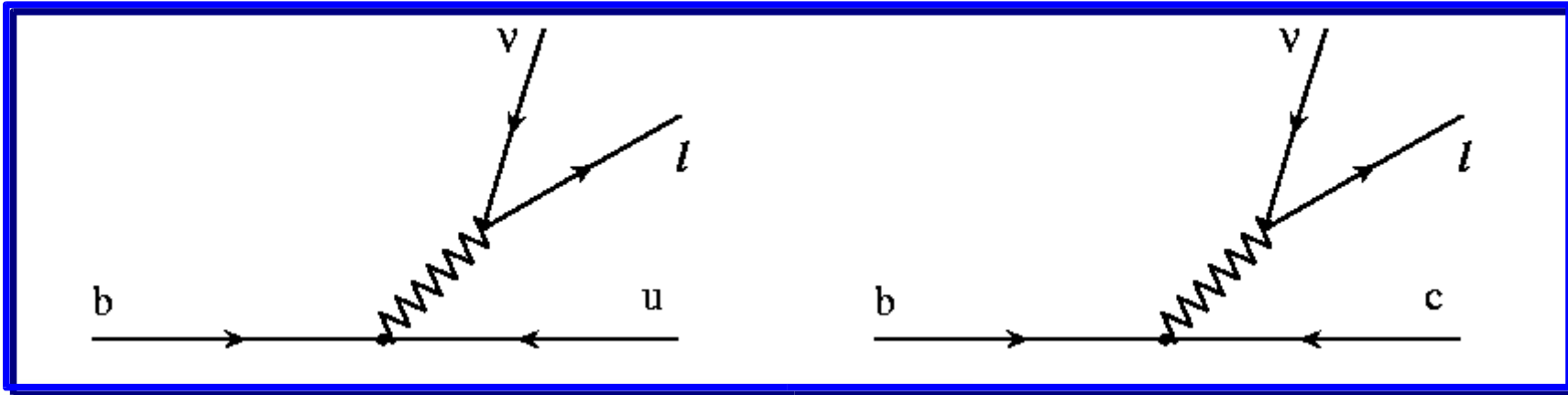
0.6
 0.4
 0.2
 0
 -0.2
 -0.4
 -0.6
 -0.8
 -1.0
 -1.2

I constraint "Classici"



$$\left| \frac{V_{ub}}{V_{cb}} \right|$$

Processo ad albero \rightarrow eventuali contributi nuova fisica trascurabili



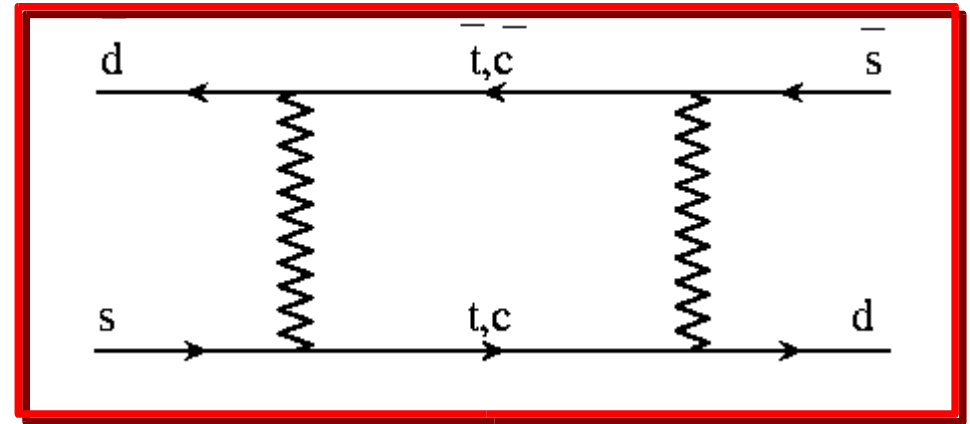
$$\left| \frac{V_{ub}}{V_{cb}} \right| = \frac{\lambda}{1 - \frac{\lambda^2}{2}} \sqrt{\bar{\rho}^2 + \bar{\eta}^2}$$



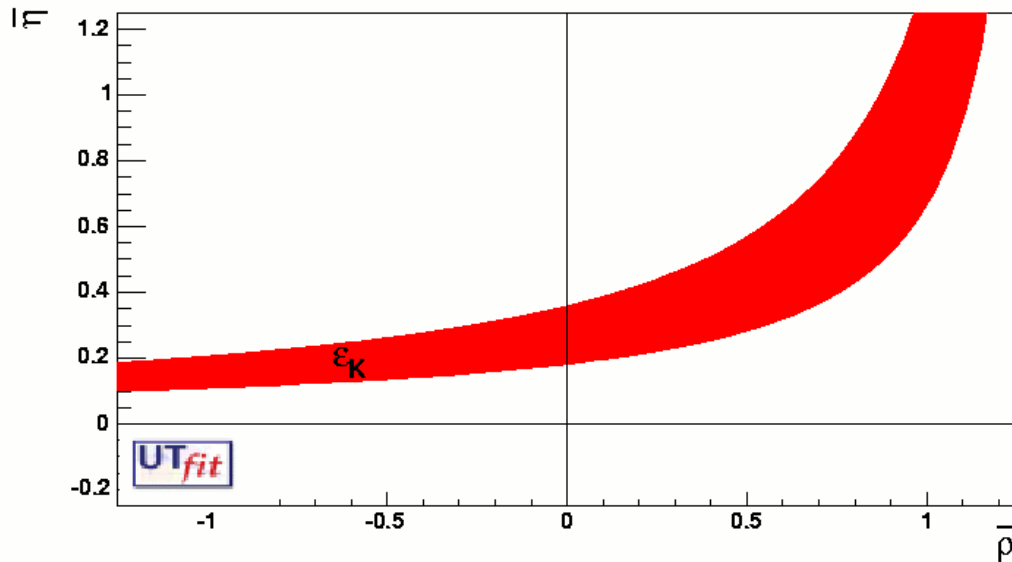
ϵ_K dal mixing $\bar{K}-K$

$$B_K = \frac{\langle K | J_\mu J^\mu | \bar{K} \rangle}{\langle K | J_\mu | 0 \rangle \langle 0 | J^\mu | \bar{K} \rangle}$$

da lattice QCD



$$|\epsilon_K| = C_\epsilon B_K A^2 \lambda^6 \bar{\eta} \{ -\eta_1 S_0(x_c) (1 - \lambda^2/2) + \eta_3 S_0(x_c, x_t) + \eta_2 S_0(x_t) A^2 \lambda^4 (1 - \bar{\rho}) \}$$

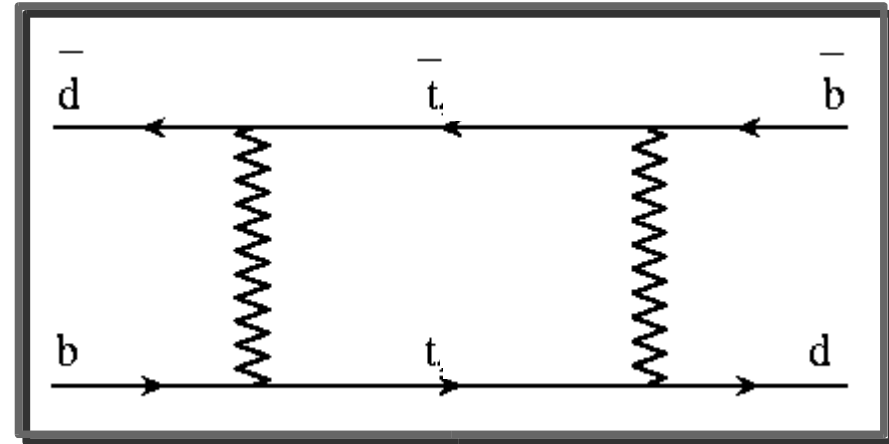
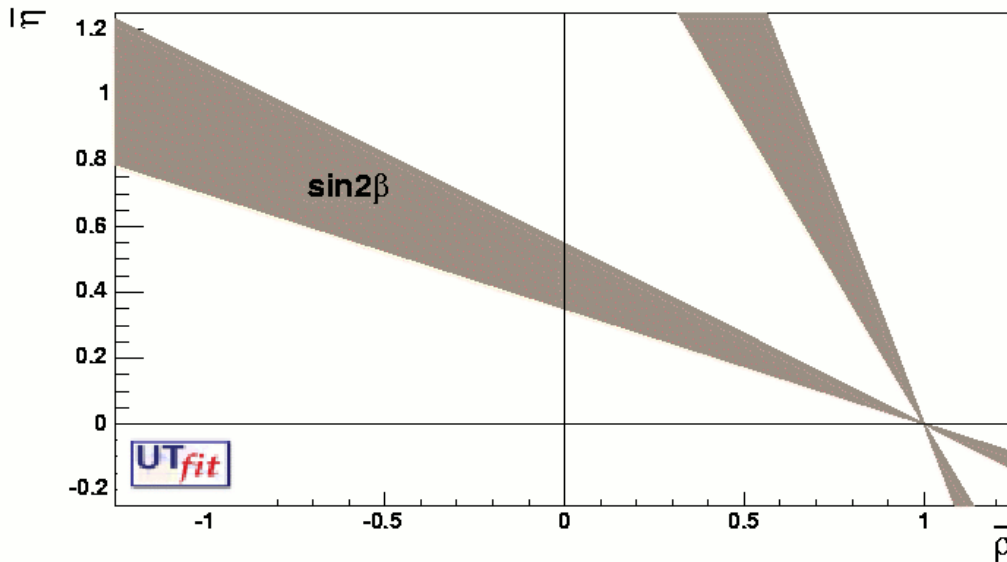


S_0 = Funzioni di Inami-Lim
per contributi $c-c$, $c-t$, e $t-t$
(da calcoli perturbativi)

$\sin 2\beta$ da $A_{CP} B^0 \rightarrow J/\psi K^0$

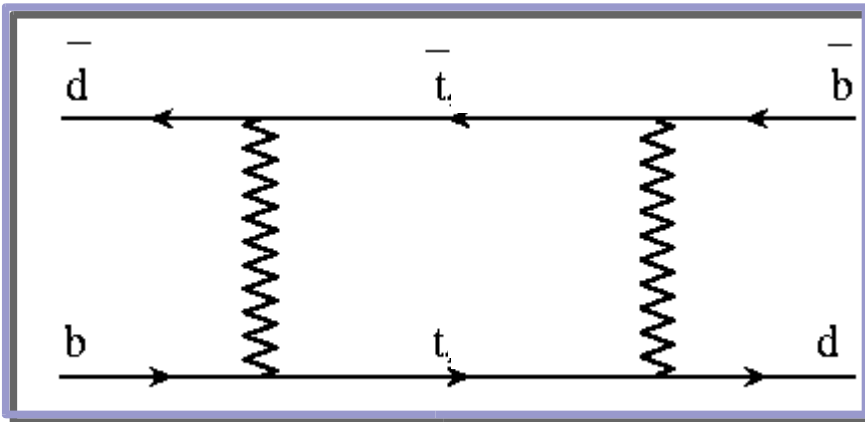
$$a_{f_{CP}}(t) = \frac{\text{Prob}(B^0(t) \rightarrow f_{CP}) - \text{Prob}(\bar{B}^0(t) \rightarrow f_{CP})}{\text{Prob}(B^0(t) \rightarrow f_{CP}) + \text{Prob}(\bar{B}^0(t) \rightarrow f_{CP})} = C_f \cos \Delta m_d t + S_f \sin \Delta m_d t$$

$$a_{f_{CP}}(t) = -\eta_{CP} \sin \Delta m_d \Delta t \sin 2\beta$$



Δm_d dal $\bar{B}_d - B_d$ mixing

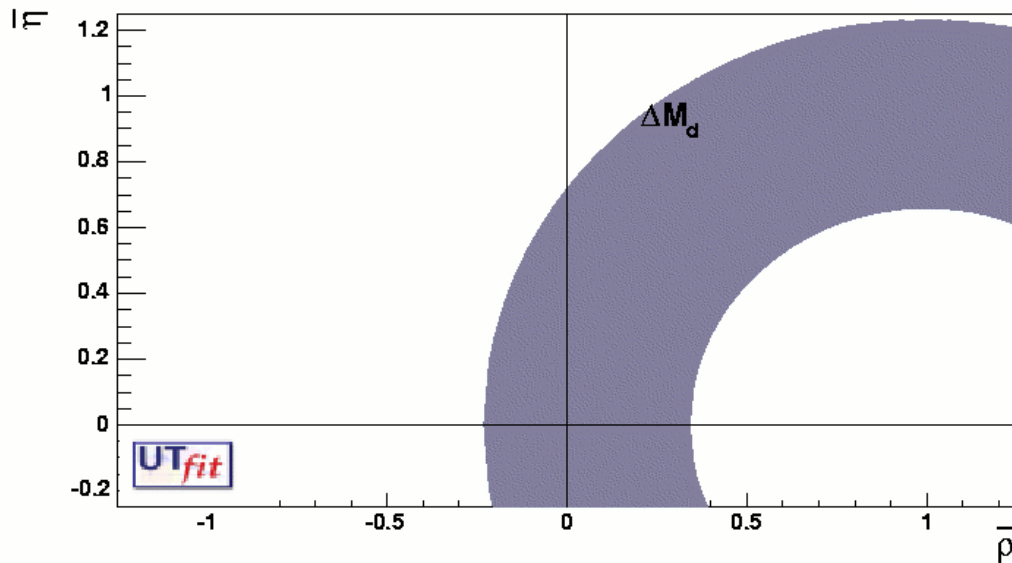
S = Funzione di Inami Lim
per contributo t-t
(da calcoli perturbativi)



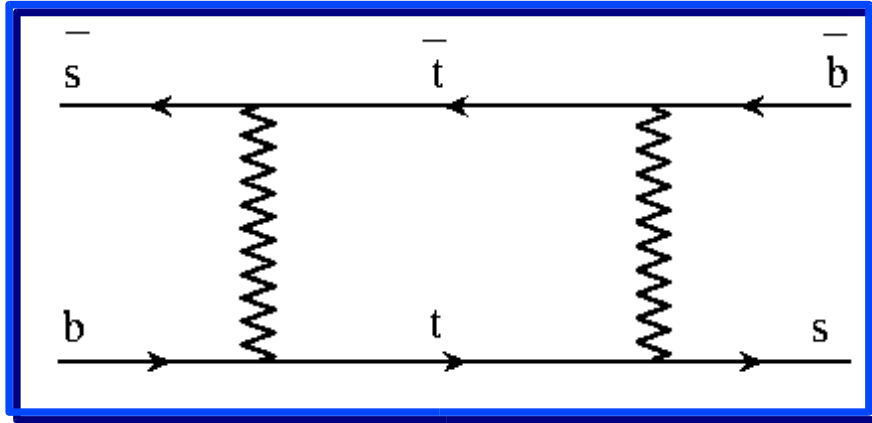
$$\Delta m_d = \frac{G_F^2}{6\pi^2} m_W^2 \eta_b S(x_t) m_{B_d} f_{B_d}^2 \hat{B}_{B_d} |V_{ib}|^2 |V_{td}|^2 =$$

$$= \frac{G_F^2}{6\pi^2} m_W^2 \eta_b S(x_t) m_{B_d} f_{B_d}^2 \hat{B}_{B_d} |V_{cb}|^2 \lambda^2 ((1-\bar{\rho})^2 + \bar{\eta}^2)$$

B_{B_d} e f_{B_d} da lattice QCD



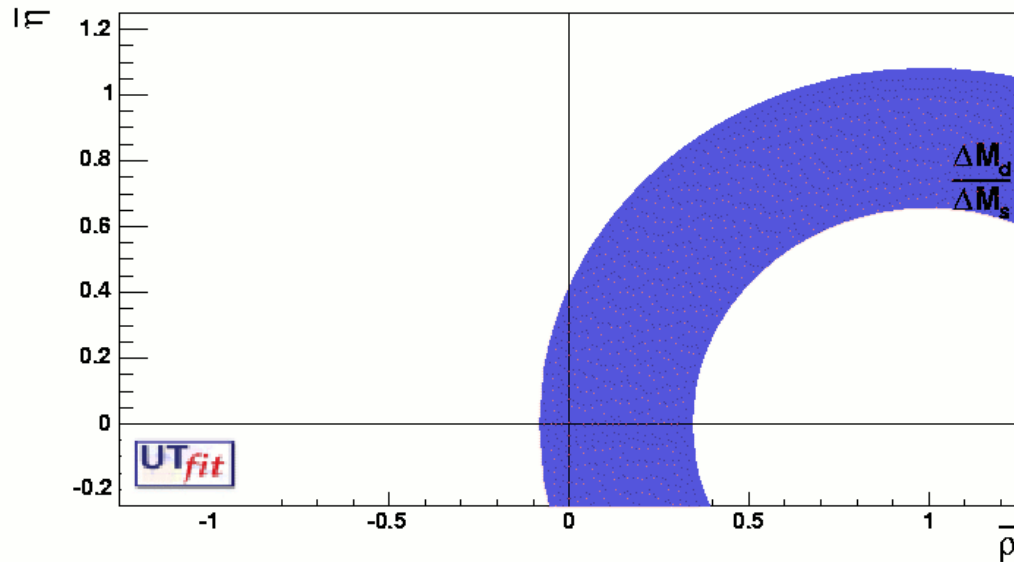
Δm_s dal $\bar{B}_s - B_s$ mixing (I)



$$\Delta m_d \approx [(1-\rho)^2 + \eta^2] \frac{f_{B_s}^2 B_{B_s}}{\xi^2}$$

$$\Delta m_s \approx f_{B_s}^2 B_{B_s}$$

Nessuna dipendenza da $\bar{\rho}$ ed $\bar{\eta}$, ma impatto su Δm_d attraverso ξ e $f_{B_s} B_{B_s}$ (da lattice QCD)



NB: novità rispetto al passato: in questo modo si riduce l'incertezza delle estrapolazioni in LQCD

Δm_s dal $\bar{B}_s - B_s$ mixing (II)

The two choices are equivalent in principle. But an important issue is the correlation among the errors:

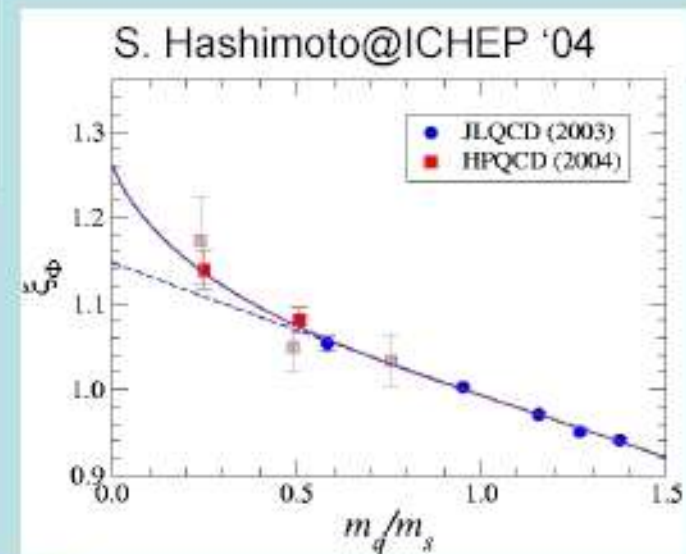
Lattice calculations are mostly done with light quark masses in the region $m_s/2 \leq m_q \leq m_s$

$$f_{B_s} \sqrt{B_{B_s}} = (276 \pm 38) \text{ MeV}$$

$$f_{B_d} \sqrt{B_{B_d}} = (223 \pm 33 \pm 12) \text{ MeV}$$

$$\xi = 1.24 \pm 0.04 \pm 0.06$$

CORRELATED !!



This correlation is difficult to take into account.



Use $f_{B_s} \sqrt{B_{B_s}}$ and ξ

Il metodo Statistico

Le grandezze misurate, funzioni di $\bar{\rho}$ ed $\bar{\eta}$, sono messe in relazione a $\bar{\rho}$ ed $\bar{\eta}$ tramite il teorema di Bayes

$$f(\bar{\rho}, \bar{\eta}, X | c_1, \dots, c_m) \sim \prod_{j=1, m} f_j(\mathcal{C} | \bar{\rho}, \bar{\eta}, X) *$$

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

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

$$j=1, m$$

$$\prod_{i=1, N} f_i(x_i) f_0(\bar{\rho}, \bar{\eta})$$

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

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

$$m_t$$

Input utilizzati

Nuovi dati
ma WA non
ancora
disponibili

λ	0.2265 ± 0.020	
V_{cb} inclusive	$41.6 \pm 0.7 \pm 0.6 \cdot 10^{-3}$	average from inclusive
V_{cb} exclusive	$41.4 \pm 2.1 \cdot 10^{-3}$	average from exclusive
V_{ub} inclusive LEP	$4.09 \pm 0.62 \pm 0.47 \cdot 10^{-3}$	LEP average
V_{ub} inclusive HFAG	$4.70 \pm 0.44 \cdot 10^{-3}$	HFAG Winter 04
V_{ub} exclusive	$3.30 \pm 0.24 \pm 0.46 \cdot 10^{-3}$	
Δm_d	$0.502 \pm 0.007 \text{ ps}^{-1}$	LEP/SLD/CDF/B-Factories
Δm_s	$> 14.5 \text{ ps}^{-1}$	LEP/SLD/CDF
m_t	$168.5 \pm 4.1 \text{ GeV}$	CDF/D0
m_c	$1.3 \pm 0.1 \text{ GeV}$	
$f_{B_s} \sqrt{\hat{B}_{B_s}}$	$276 \pm 38 \text{ MeV}$	Lattice QCD
ξ	$1.24 \pm 0.04 \pm 0.06$	Lattice QCD
B_K	$0.79 \pm 0.04 \pm 0.09$	Lattice QCD
$\sin 2\beta$	0.725 ± 0.037	B-Factories

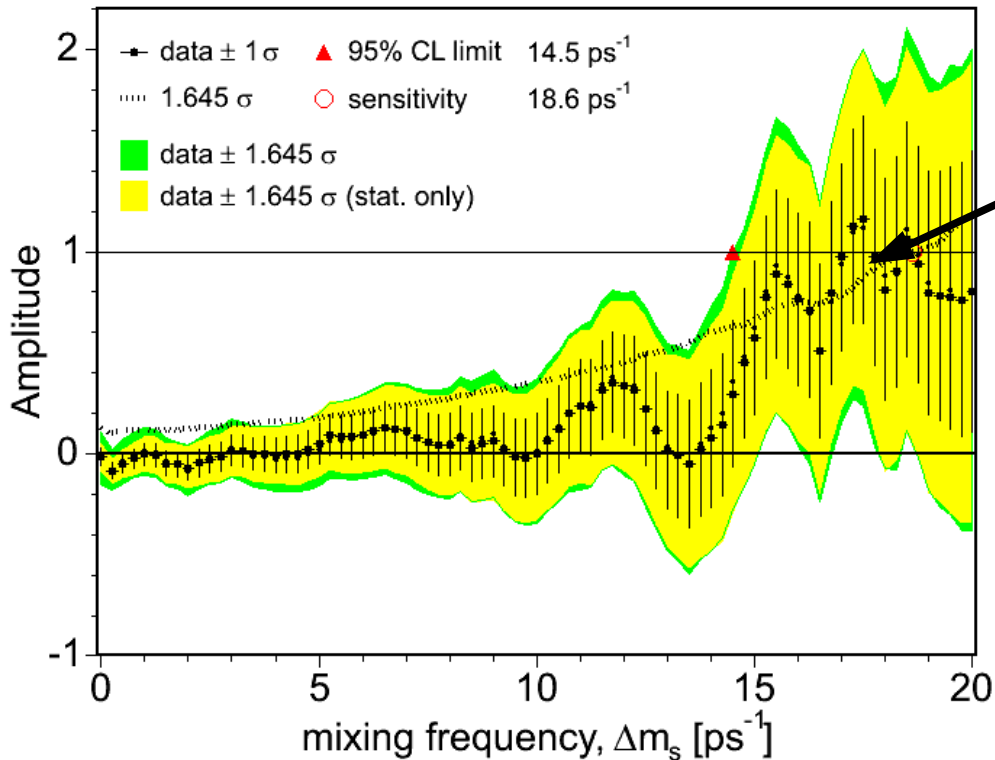
novità da
Tevatron

novità
da LQCD

Nuova Likelihood di Δm_s

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

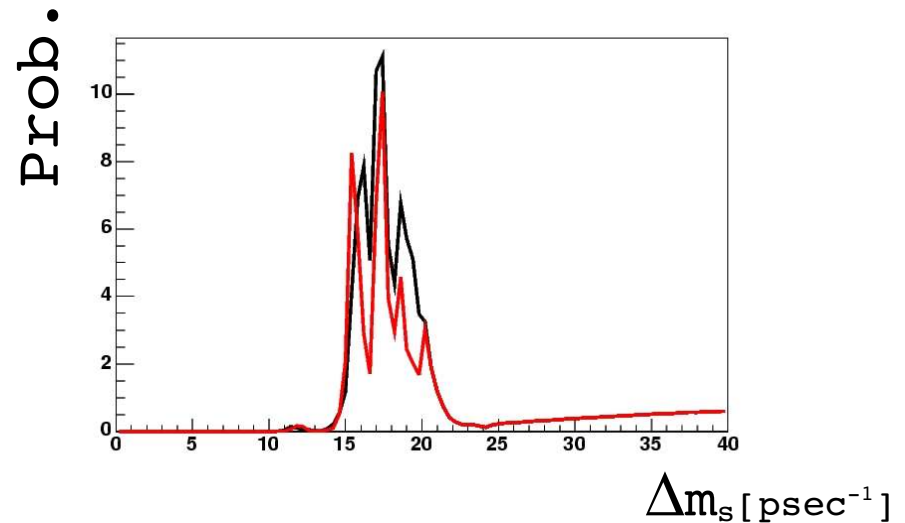
World Average and CDF II



hint di segnale @
 $\Delta m_s \sim 17.5 \text{ ps}^{-1}$ con
 $\sim 2\sigma$ di significanza

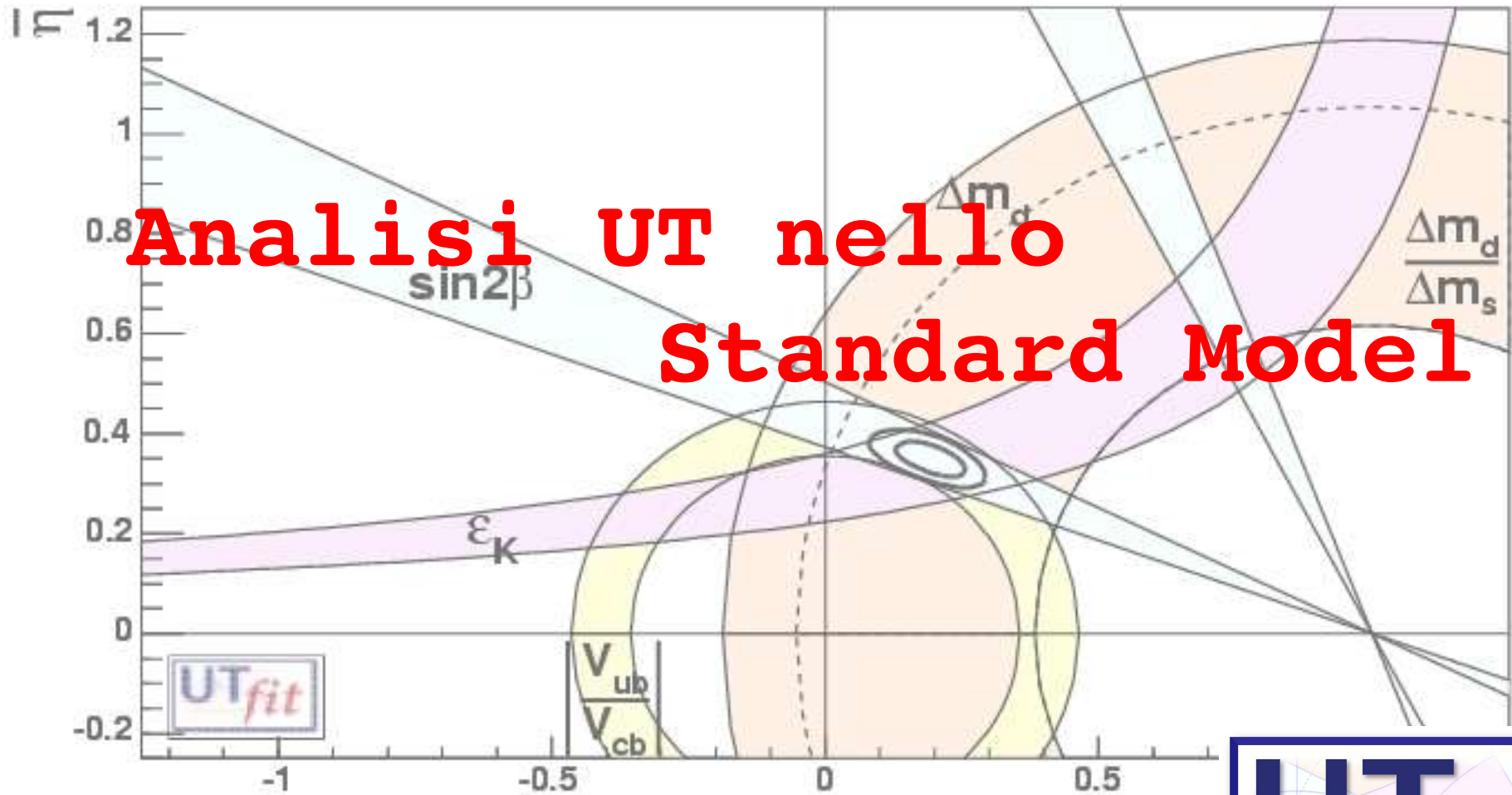
nero: pre-CKM2005

rosso: CKM2005



$\Delta m_s > 14.5 \text{ ps}^{-1}$ @ 95% CL
sensibilità @ 18.6 ps^{-1}

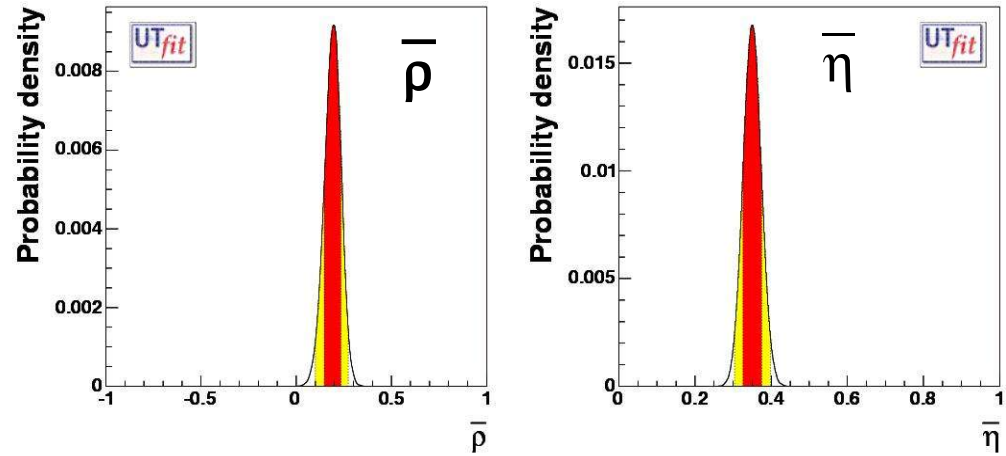
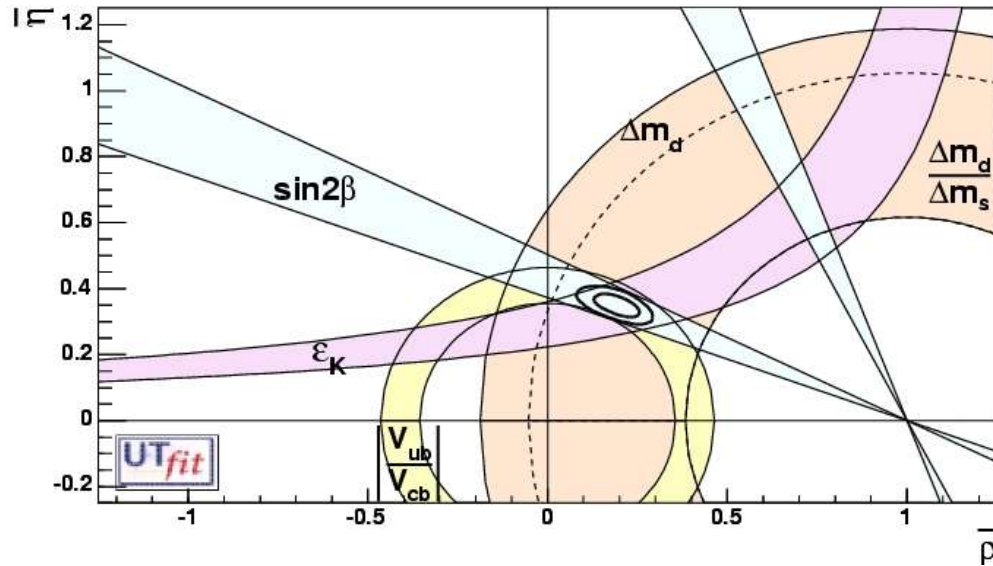




Analisi UT nello Standard Model



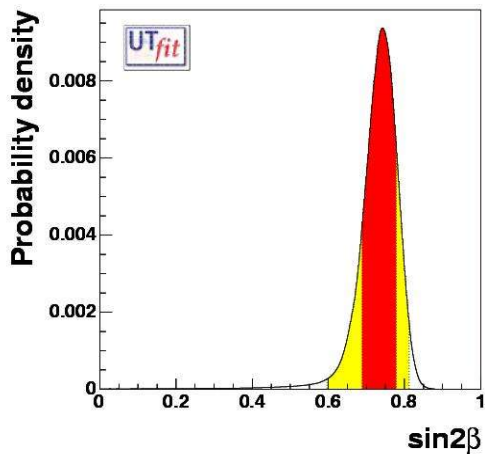
Utilizzando
tutti i vincoli



$\sin 2\beta$ misurato con precisione
confrontabile alla misura "indiretta"

$$\bar{\eta} = 0.349 \pm 0.024$$

$$\bar{\rho} = 0.190 \pm 0.044$$



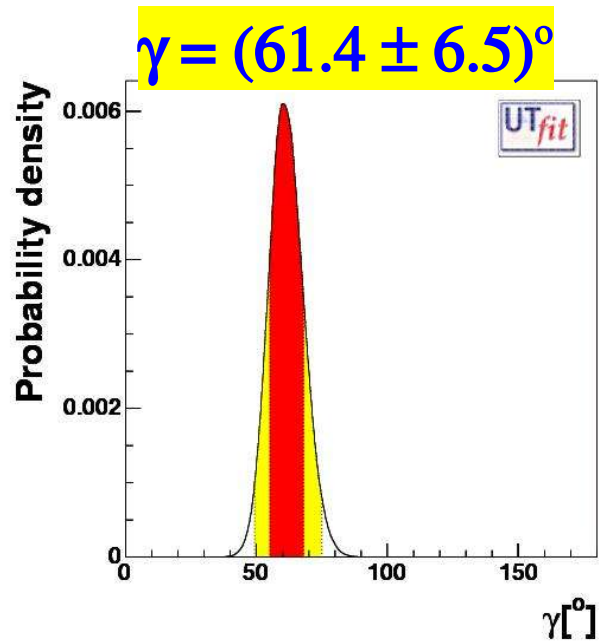
$$\sin 2\beta = 0.729 \pm 0.042$$

(da lati UT + ϵ_K)

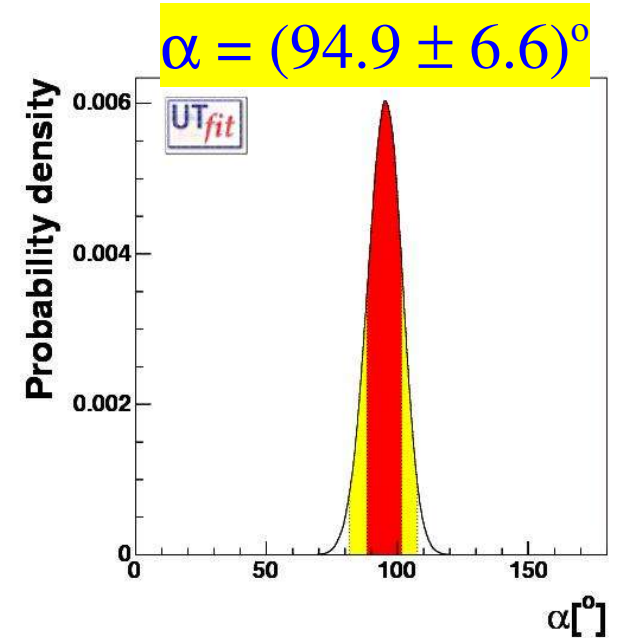
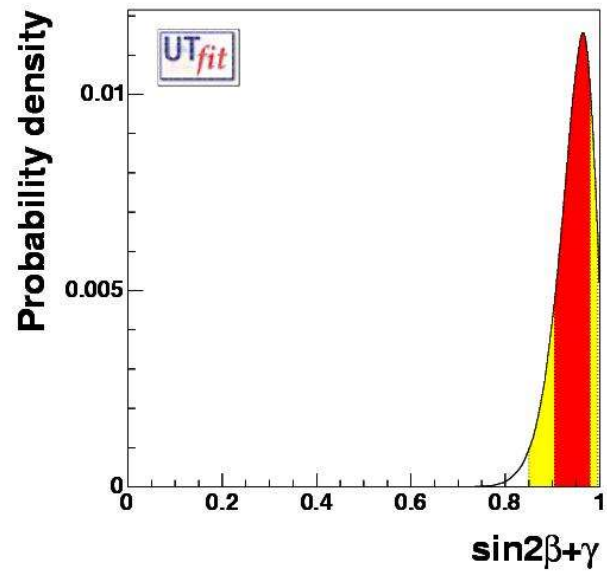
$$\sin 2\beta = 0.726 \pm 0.037$$

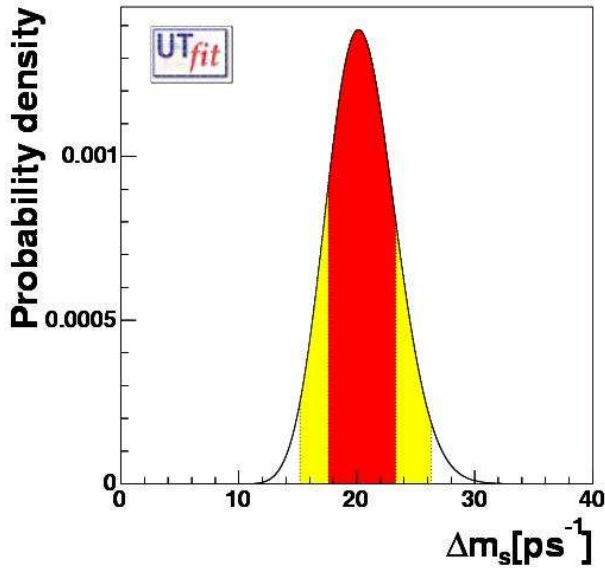
(da $J/\psi K^0$)



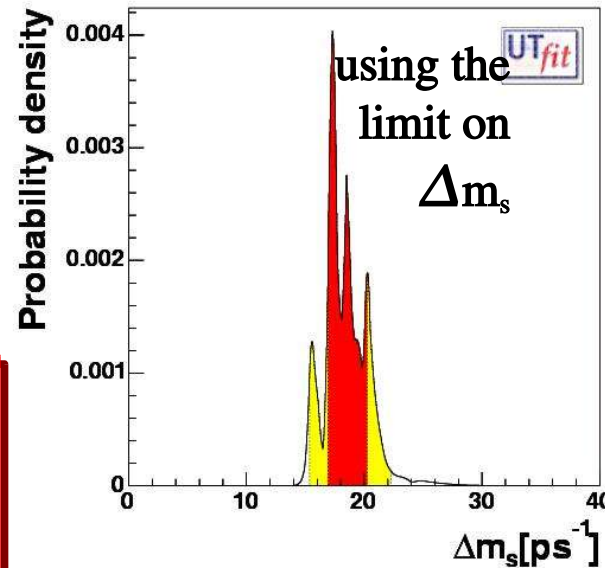


$\sin(2\beta + \gamma) = 0.941 \pm 0.038$

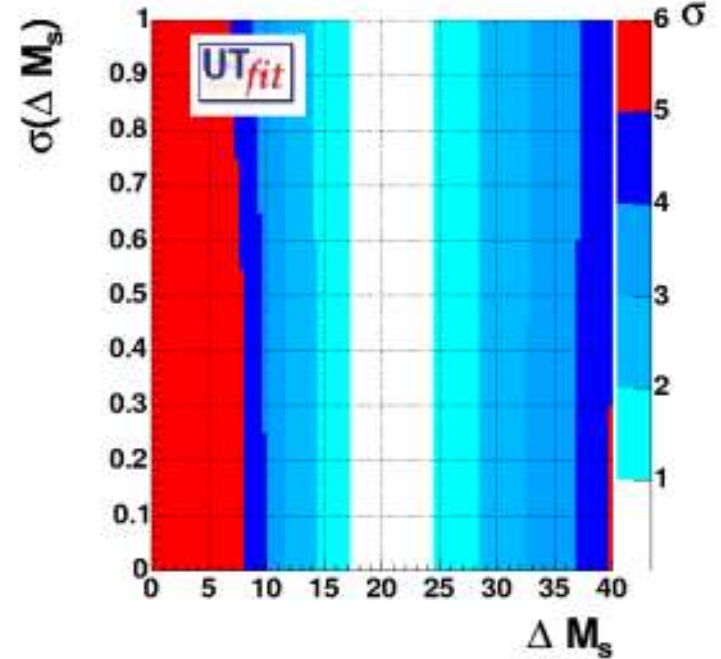




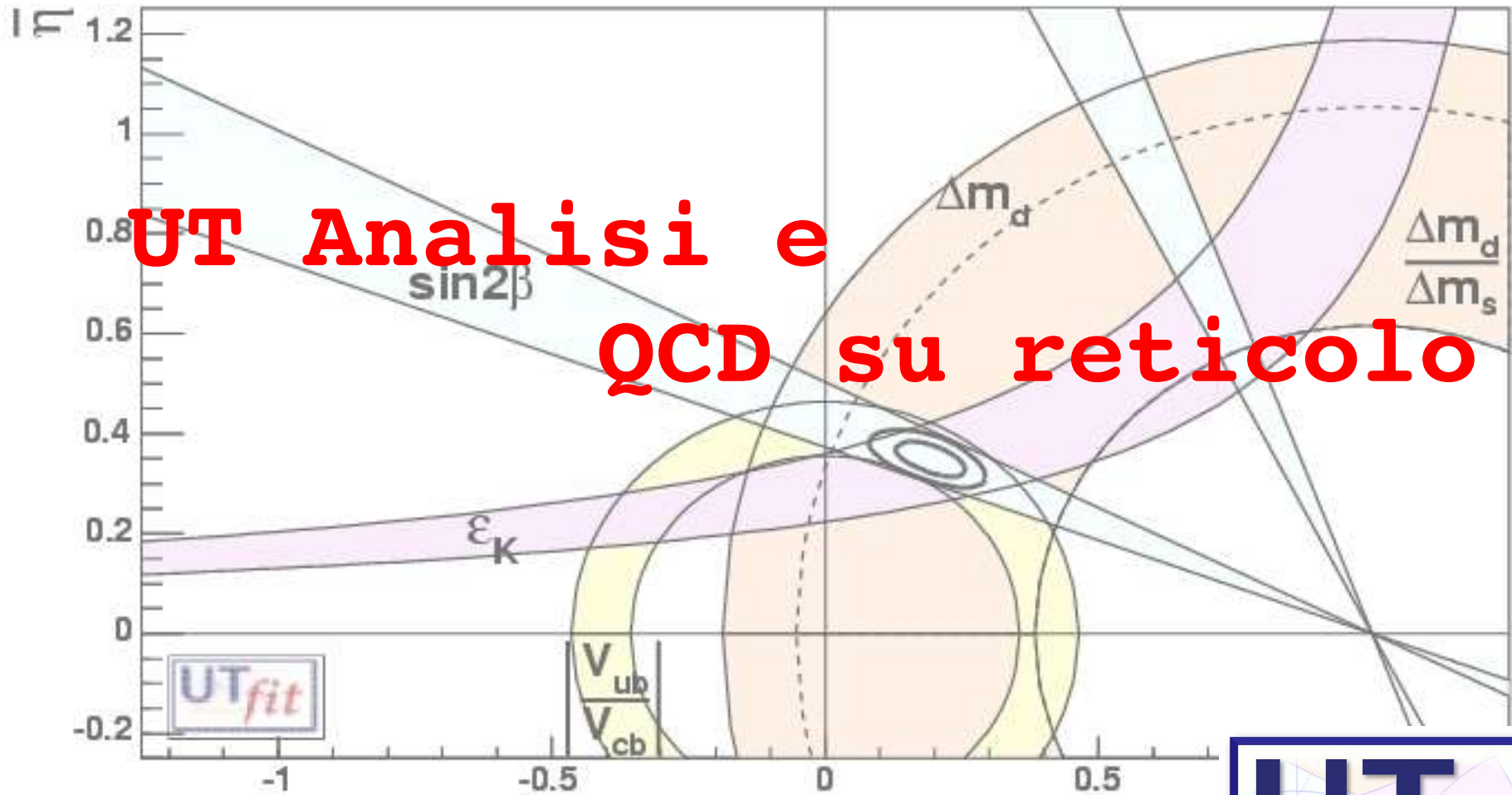
$\Delta m_s = 20.4 \pm 2.8 \text{ ps}^{-1}$
senza bound
sperimentale



$\Delta m_s = 20.4 \pm 2.8 \text{ ps}^{-1}$
con bound
sperimentale



$\Delta m_s > 31 \text{ ps}^{-1}$
Nuova Fisica @ 3σ

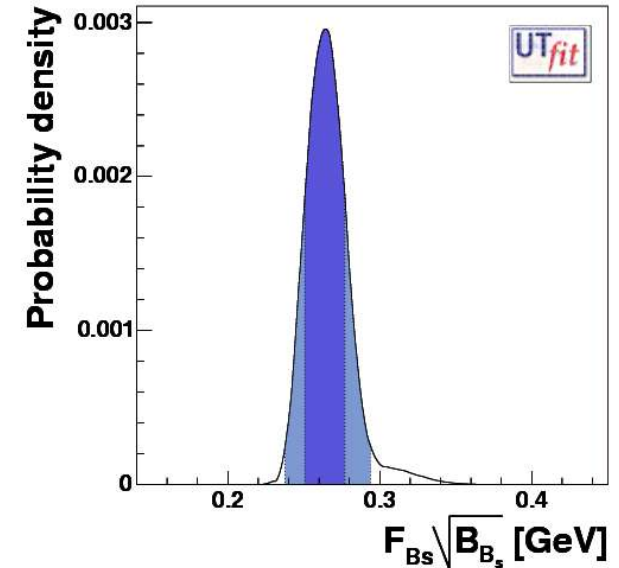
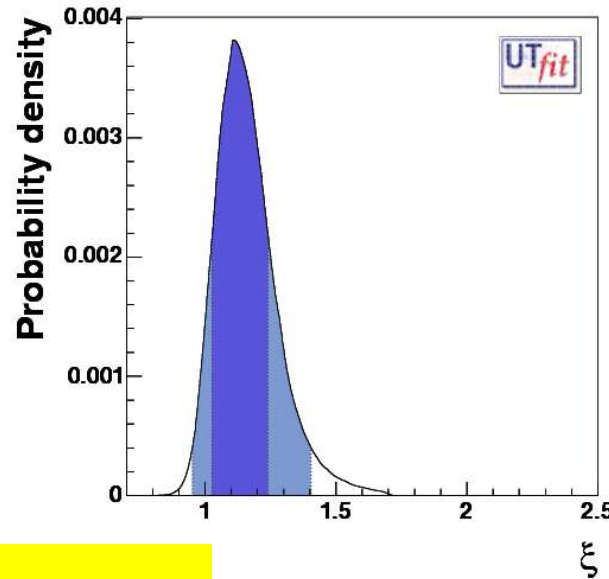
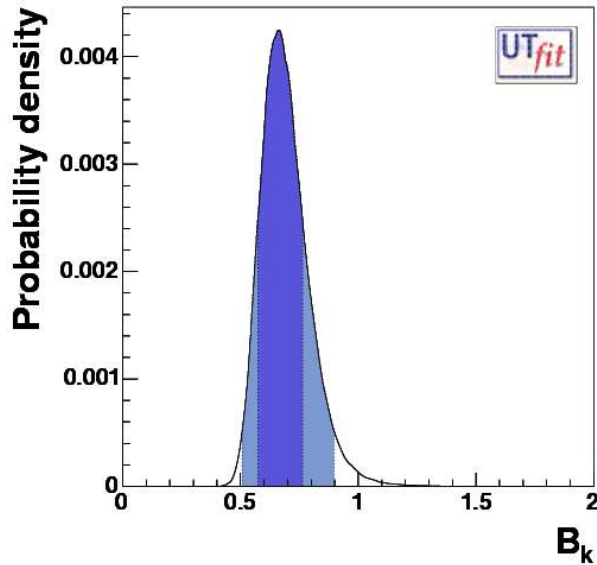


UT_{fit} e predizioni LQCD (I)

E' possibile ottenere predizioni sui parametri di Lattice QCD utilizzando le altre informazioni

$$B_K = 0.69 \pm 0.10 \text{ UT}_{fit}$$

$$B_K = 0.79 \pm 0.04 \pm 0.09 \text{ LQCD}$$



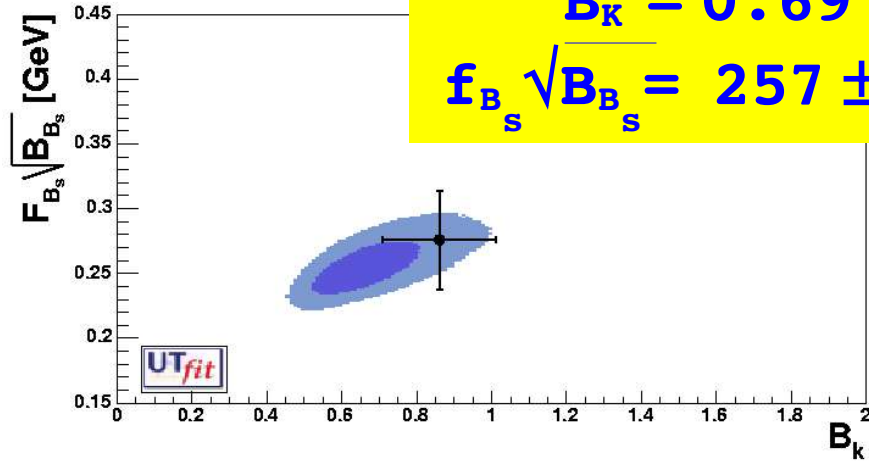
$$f_{B_s} \sqrt{B_{B_s}} = 265 \pm 13 \text{ UT}_{fit}$$

$$f_{B_s} \sqrt{B_{B_s}} = 276 \pm 38 \text{ LQCD}$$

$$\xi = 1.15 \pm 0.11 \text{ UT}_{fit}$$

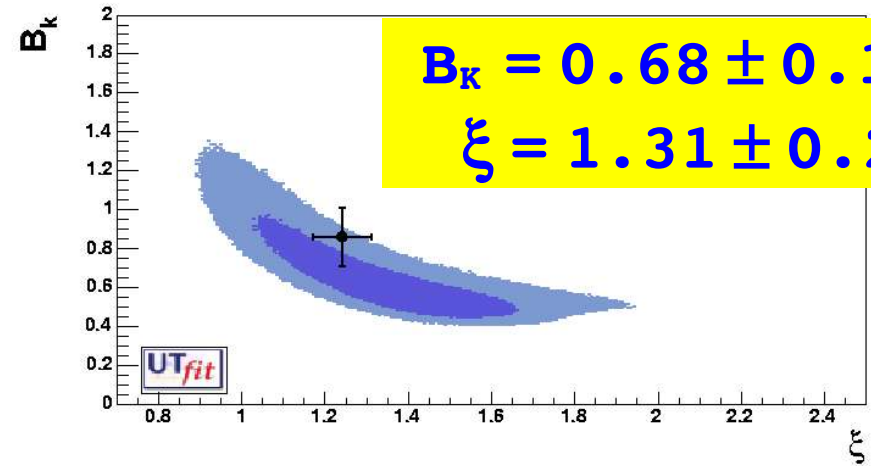
$$\xi = 1.24 \pm 0.04 \pm 0.06 \text{ LQCD}$$

UT_{fit} e predizioni LQCD (II)



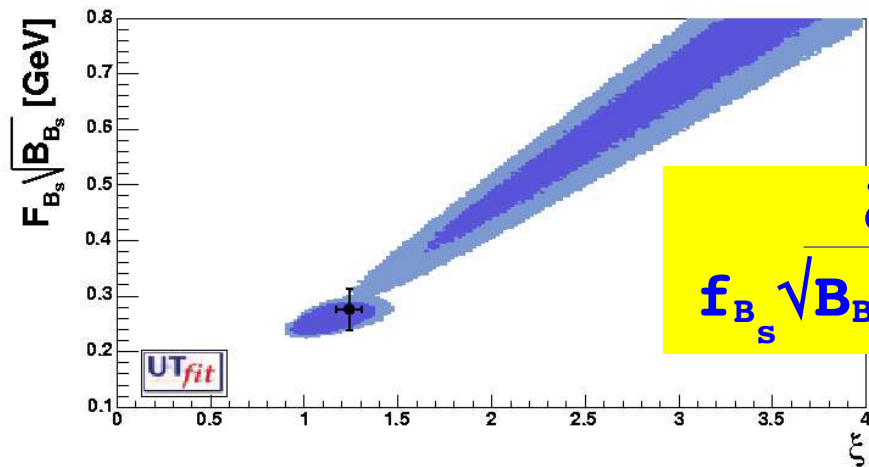
$$B_K = 0.69 \pm 0.10$$

$$f_{B_s} \sqrt{B_{B_s}} = 257 \pm 15 \text{ MeV}$$



$$B_K = 0.68 \pm 0.18$$

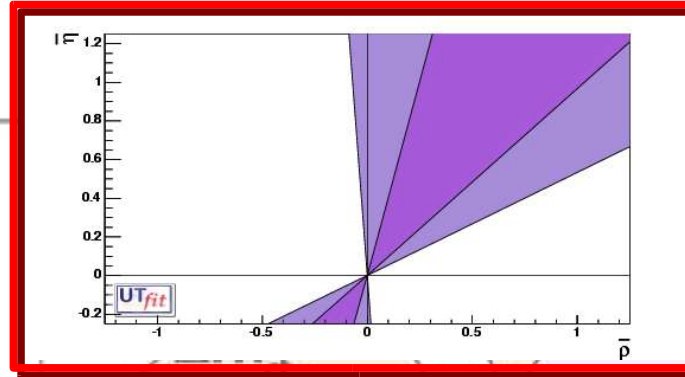
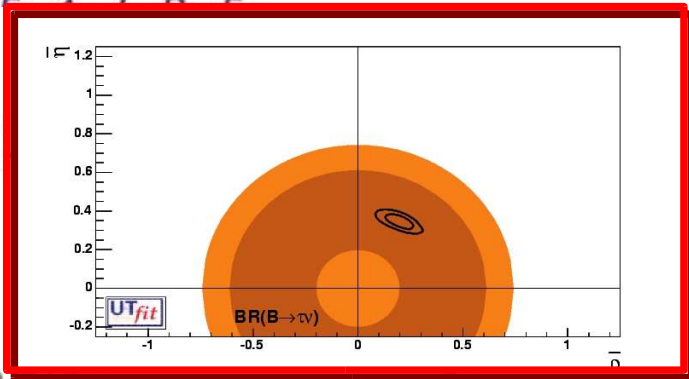
$$\xi = 1.31 \pm 0.21$$



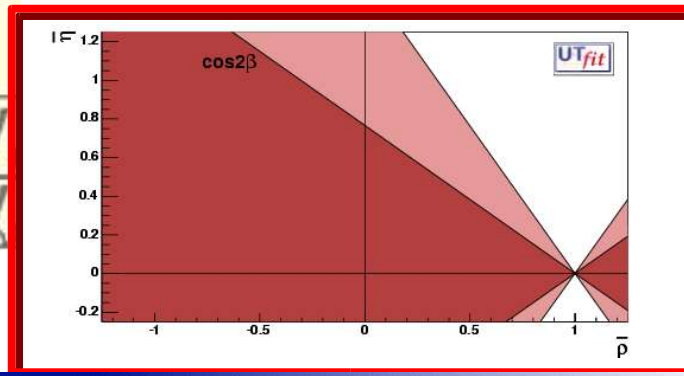
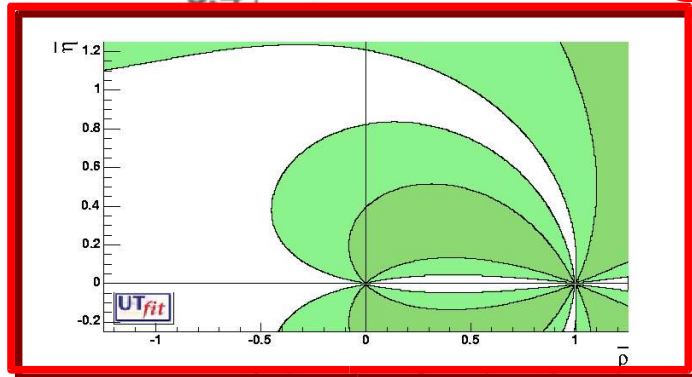
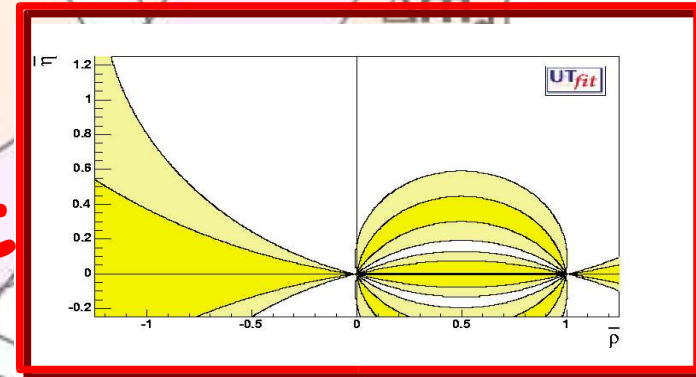
$$\xi > 0.9$$

$$f_{B_s} \sqrt{B_{B_s}} > 200 \text{ MeV}$$





I Nuovi Constraint



α da analisi SU(2)

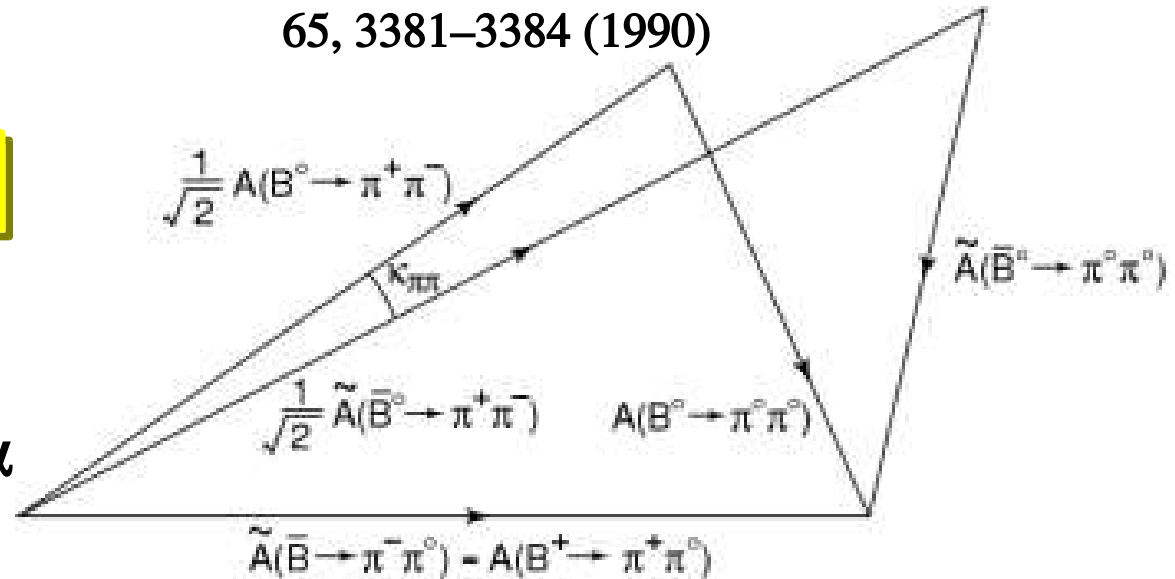
Utilizzando SU(2) per scrivere le ampiezze:

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

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

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

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



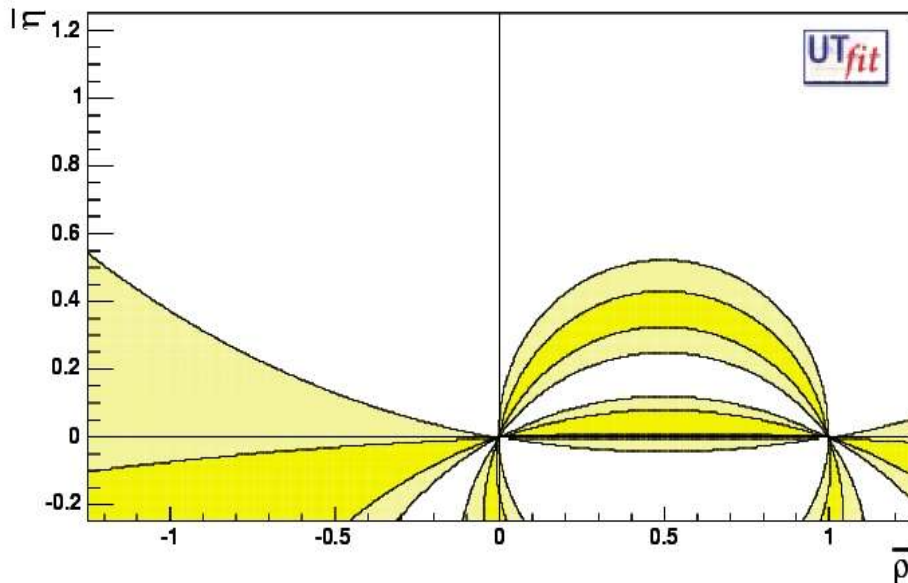
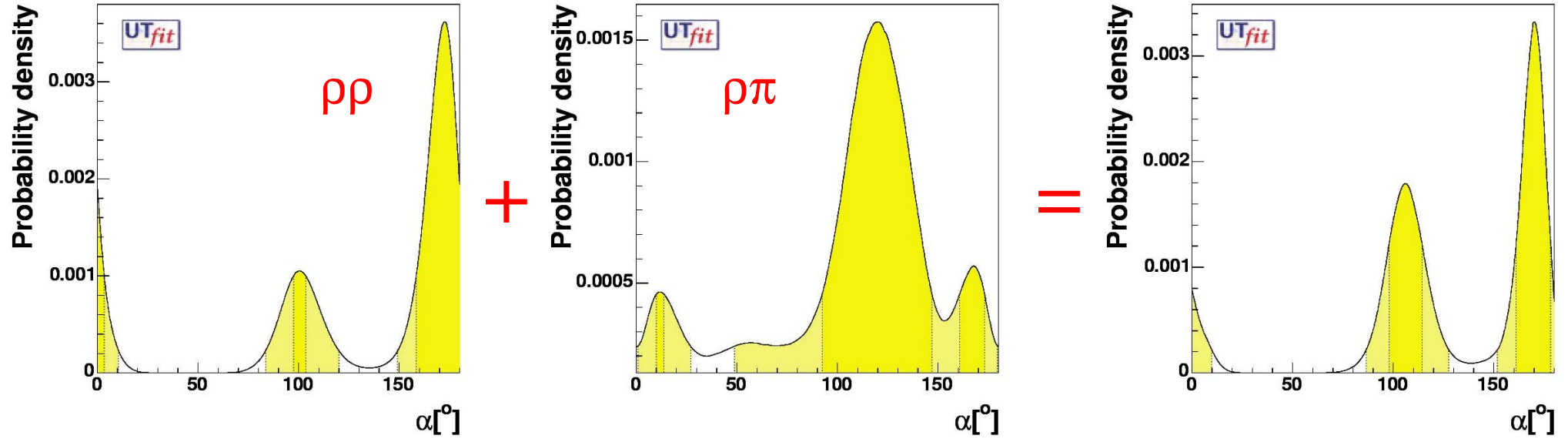
incognite: $T, P, T_C, \delta_P, \delta_{T_C}, \alpha$

osservabili: $3x BR, C_{+-}, S_{+-}$

Simile approccio studiando $(\rho\pi)^0$
sul piano di Dalitz



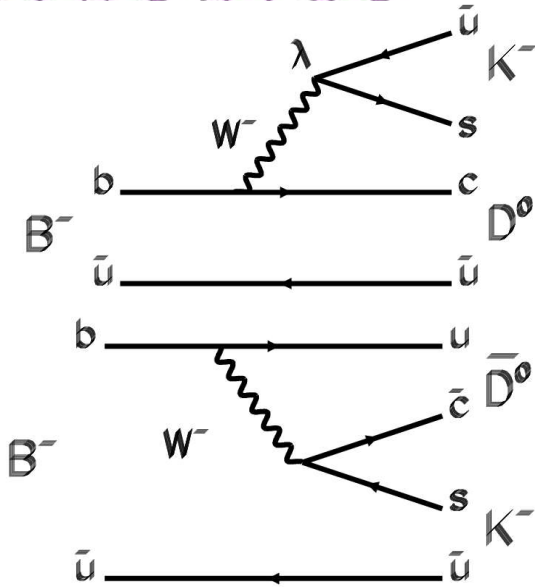
α da analisi SU(2)



$$\alpha = (106 \pm 8)^\circ \cup (170 \pm 9)^\circ$$



γ da $B \rightarrow D^{(*)} K (I)$



$\sim V_{cb}$

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

$$A(B^- \rightarrow D^0 K^-) = A_B$$

$$A(B^+ \rightarrow \bar{D}^0 K^+) = A_B$$

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

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

$r_B =$ rapporto di ampiezze

$\delta_B =$ fase forte relativa

● **GLW (Gronau, Londow, Wyler):** uso di autostati di CP del D, D_{CP}^0

$$R_{CP\pm} = 1 + r_B^2 \pm 2r_B \cos \gamma \cos \delta_B \quad A_{CP\pm} = \frac{\pm 2r_B \sin \gamma \sin \delta_B}{1 + r_B^2 \pm 2r_B \cos \gamma \cos \delta_B}$$

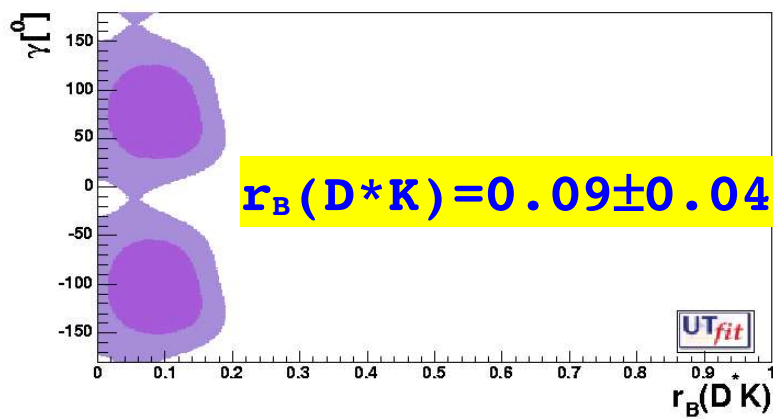
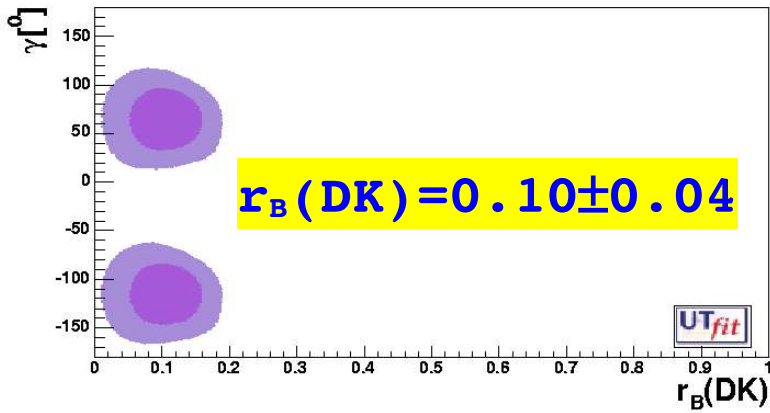
● **ADS (Atwood, Dunietz, Soni):** B^0 and \bar{B}^0 nello stesso stato finale

$$R_{ADS} = r_B^2 + r_{DCS}^2 + 2r_B r_{DCS} \cos \gamma \cos(\delta_B + \delta_D)$$

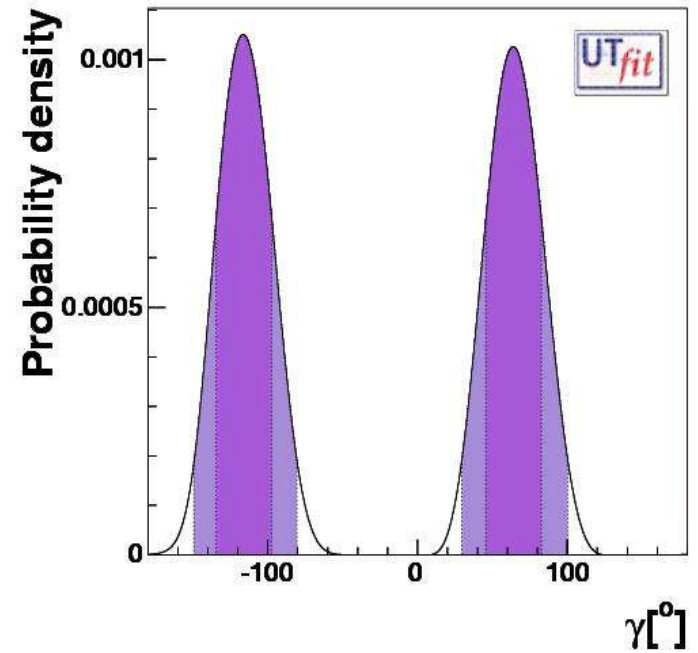
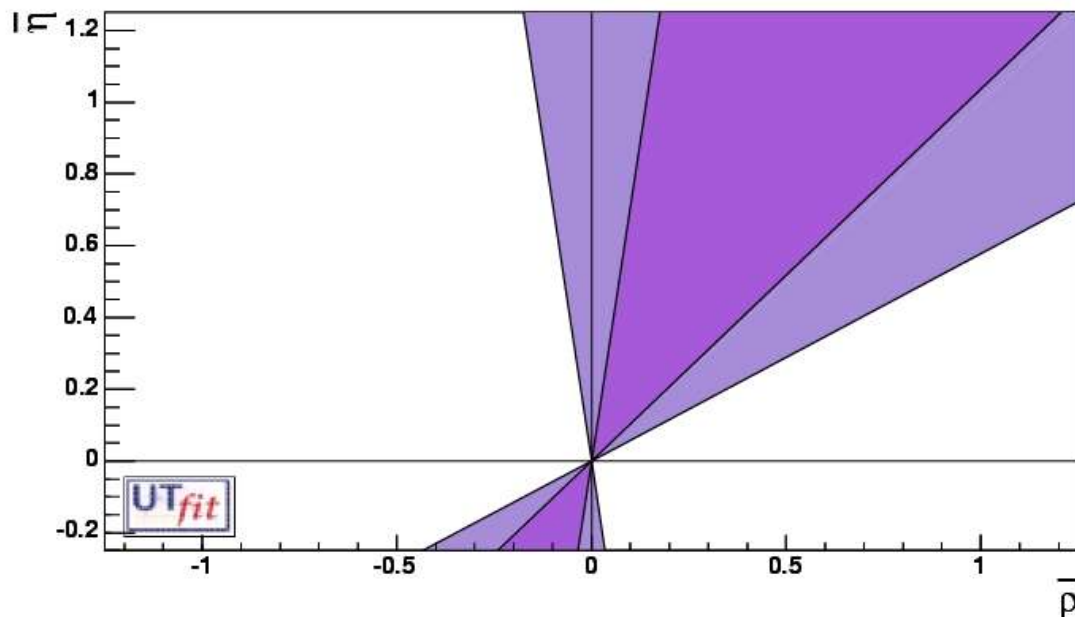
● **Analisi Dalitz plot in 3 corpi:**
ad esempio $D^0 \rightarrow K_S \pi^+ \pi^-$



γ da $B \rightarrow D^{(*)} K$ (II)

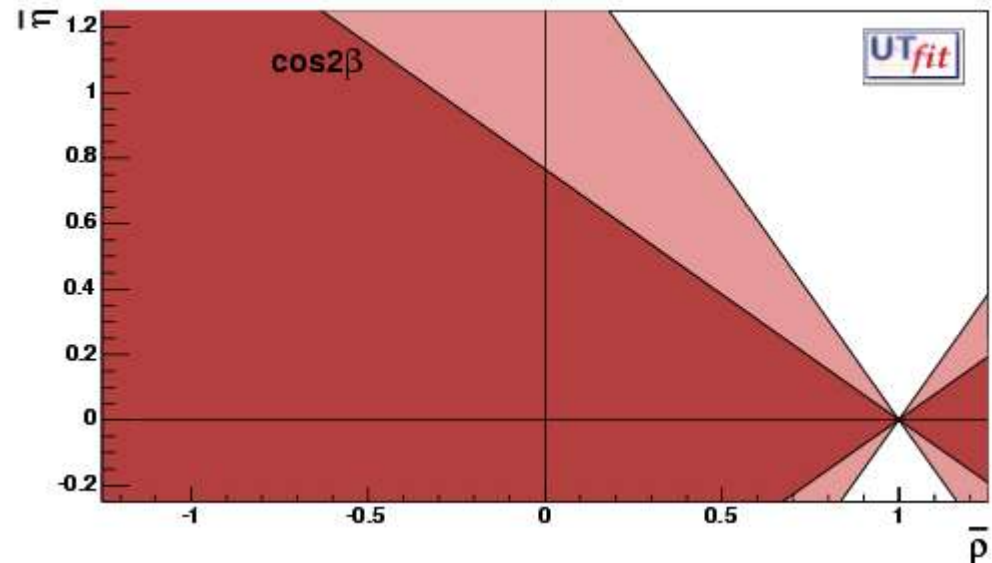
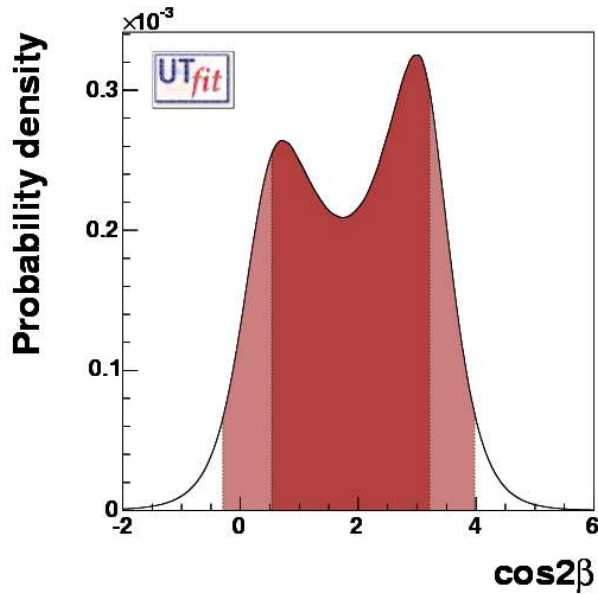


$$\gamma = (64.0 \pm 18.2)^\circ \cup (-116.0 \pm 18.2)^\circ$$



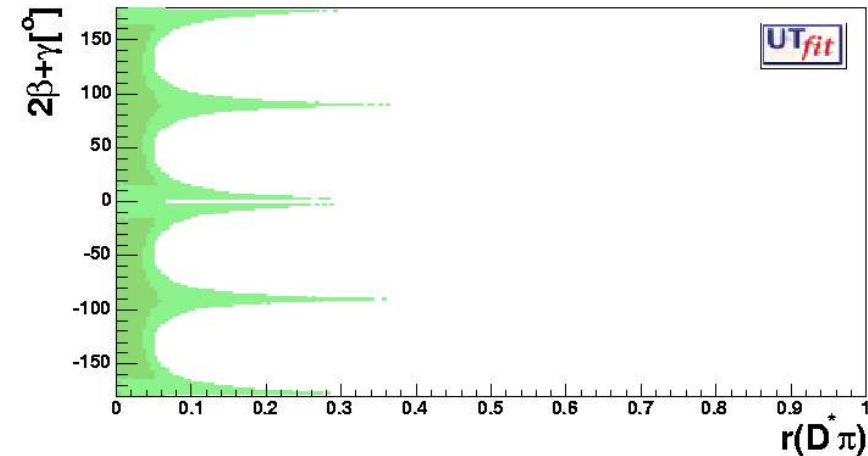
$\cos 2\beta$ da $B \rightarrow J/\psi K^{*0}$

Combinazione scettica dei
risultati di BaBar e Belle
 $\cos 2\beta = 1.9 \pm 1.3$
> 0 @ 87% Probabilità

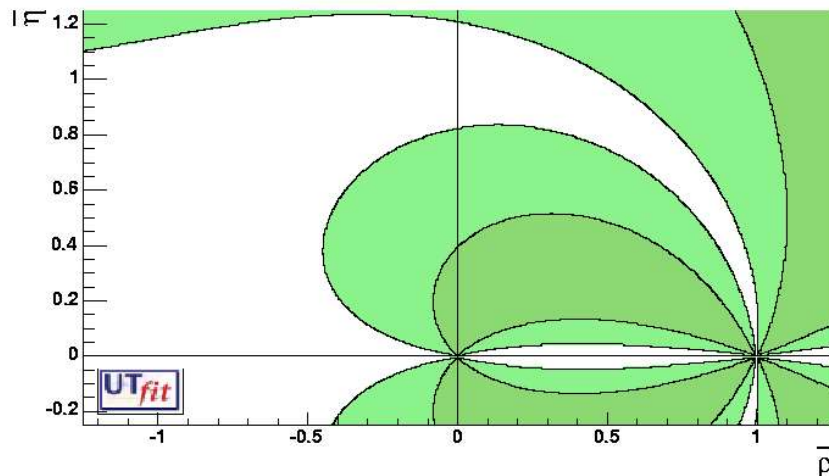


**Rimossa ambiguità
associata a $\sin 2\beta$**

$\sin 2\beta + \gamma$ da $B \rightarrow D^{(*)} \pi(\rho)$



- Interferenza $b \rightarrow u$ vs $b \rightarrow c$ come per DK
- Sistema aperto (2 osservabili per $2\beta + \gamma$, r e δ)
- Solo conoscendo r si può estrarre $2\beta + \gamma$

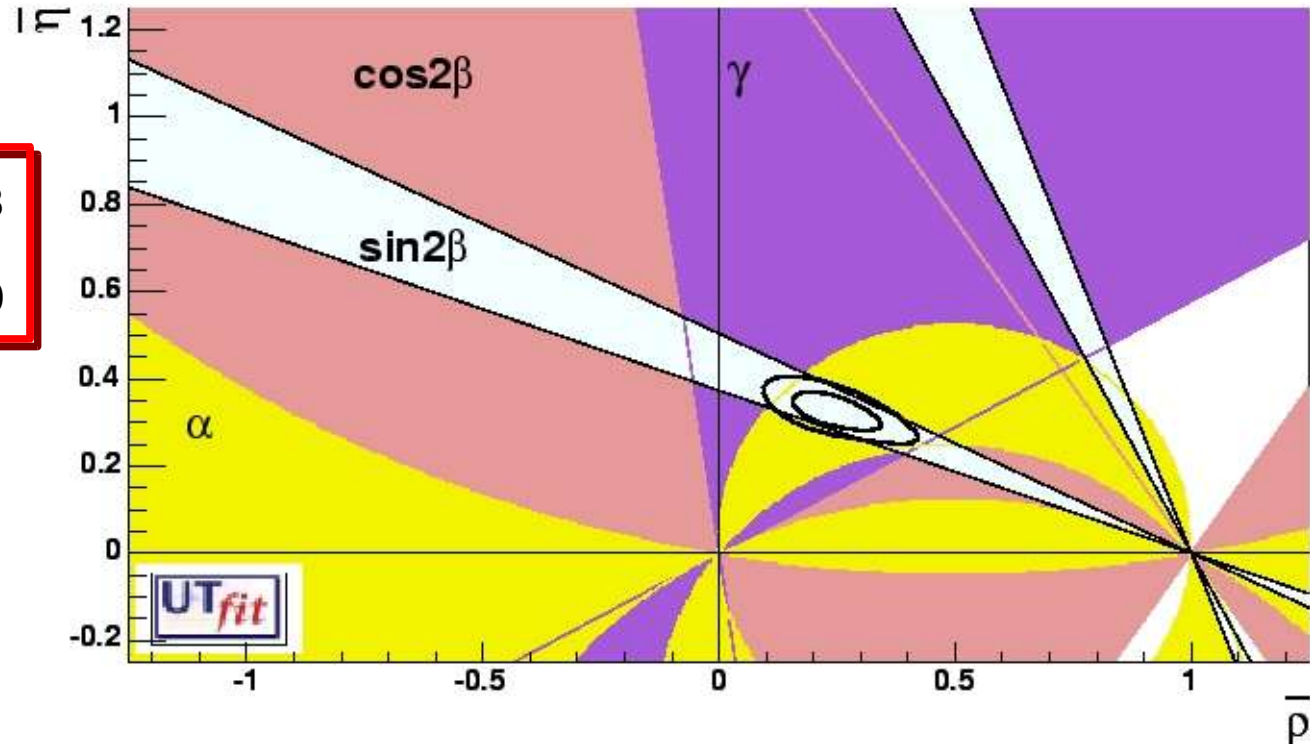


- ◆ Estrazione di r da $B \rightarrow D_s \pi$
- ◆ Errore teorico 30% (guessed)
- ◆ Incertezza fuori controllo, **non incluso nel fit**



Fit solo Angoli

$$\sin 2\beta + \cos 2\beta + \gamma + \alpha$$



$$\bar{\rho} = 0.246 \pm 0.063$$

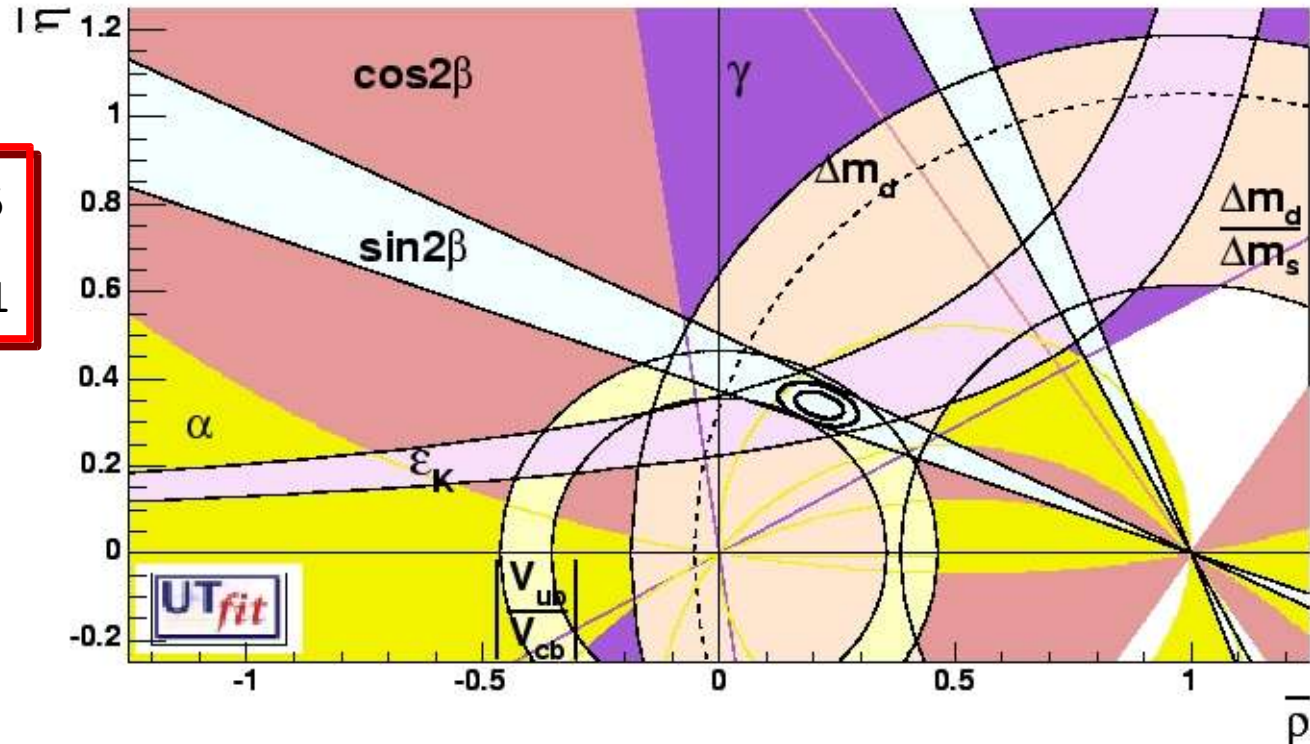
$$\bar{\eta} = 0.325 \pm 0.030$$

Precisione comparabile a quella
dell'analisi nell'era pre B factory



Fit da tutte le info

Analisi Standard + $\cos 2\beta + \gamma + \alpha$



$$\bar{\rho} = 0.210 \pm 0.035$$

$$\bar{\eta} = 0.339 \pm 0.021$$

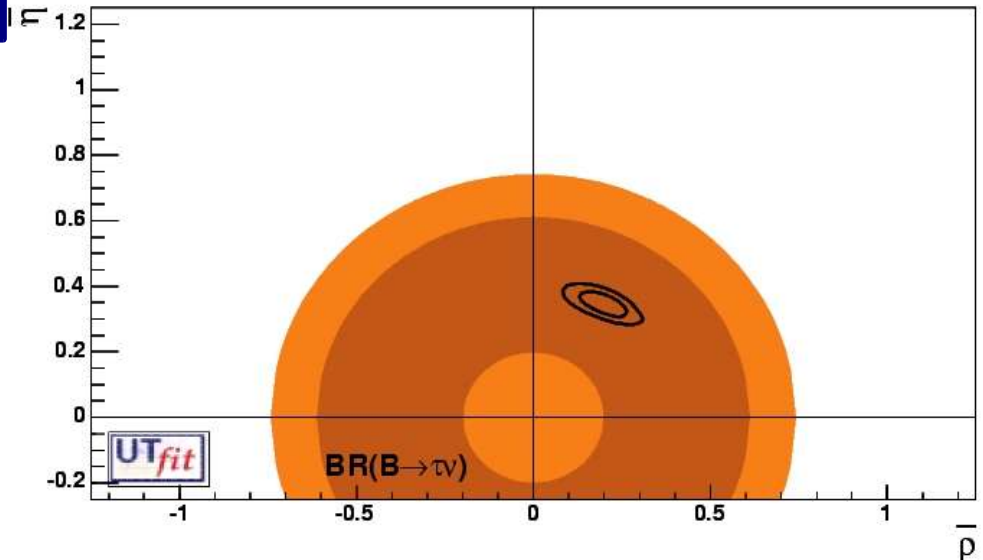
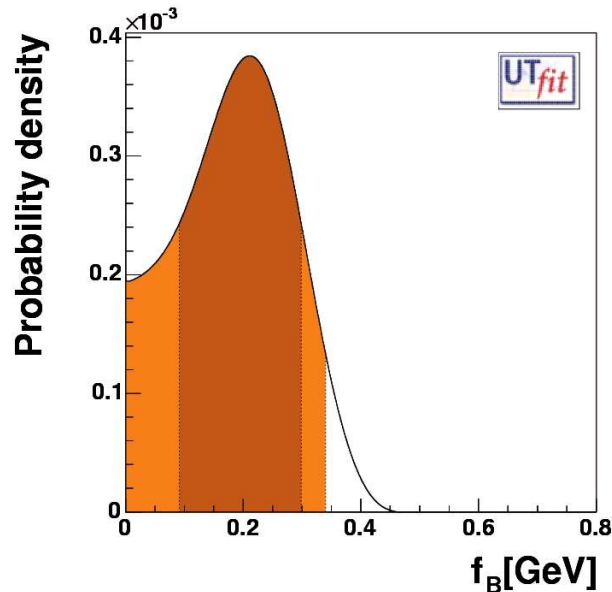
Perfetto accordo tra le nuove misure
e l'analisi: meccanismo CKM
spiega la violazione di CP



B → τν (BaBar)

Assumendo $f_B \rightarrow$
 Constraint su $R_b^2 = \bar{\rho}^2 + \bar{\eta}^2$
 < 0.75 @95% Prob.

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

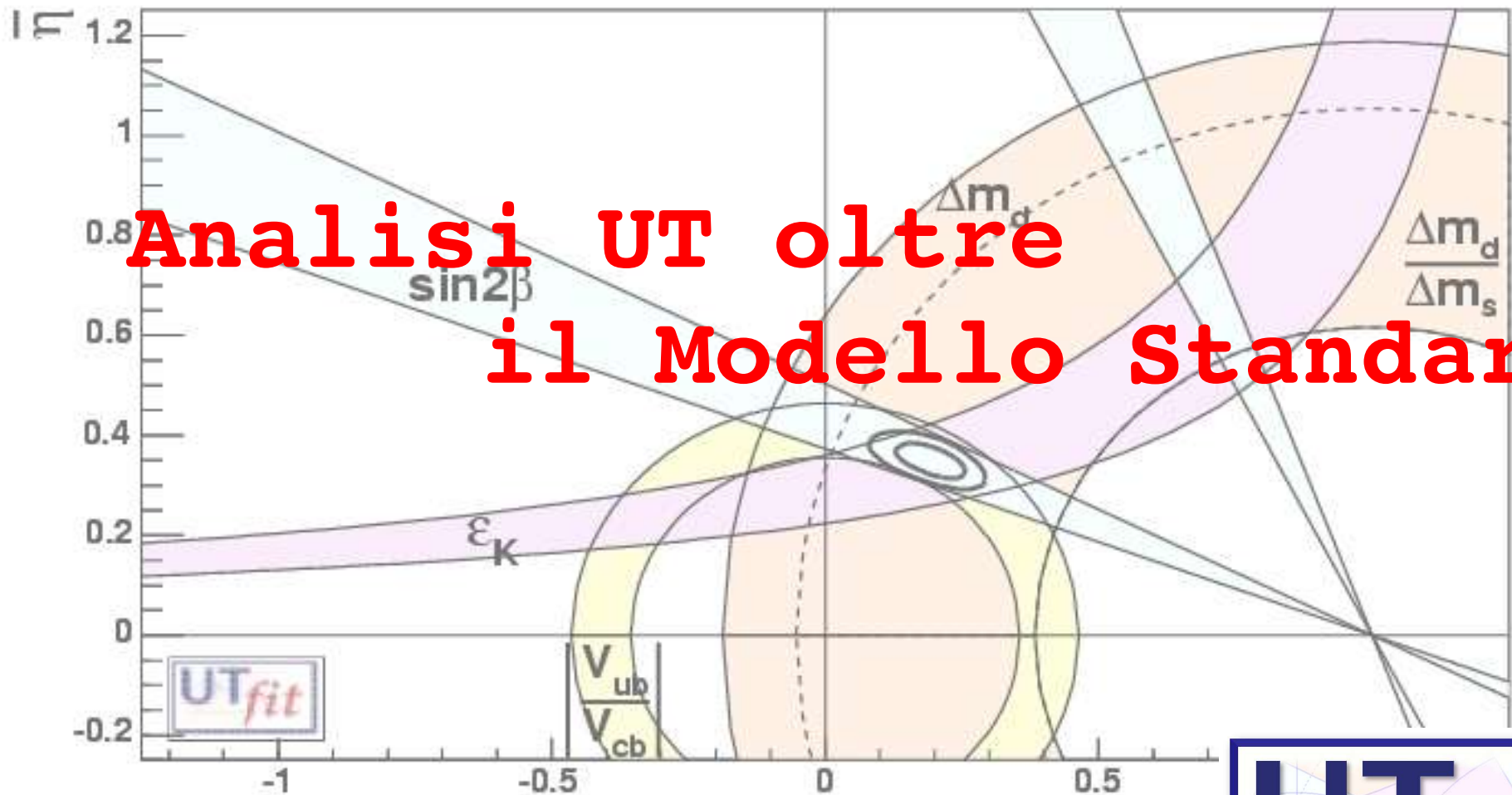


$$f_{Bd} = 0.20 \pm 0.10 \text{ GeV}$$

$$f_{Bd} = 0.192 \pm 0.026 \pm 0.009 \text{ GeV}$$

da Lattice QCD





**Analisi UT oltre
il Modello Standard**



Determinazione di $\bar{\rho}$ e $\bar{\eta}$ da processi ad albero

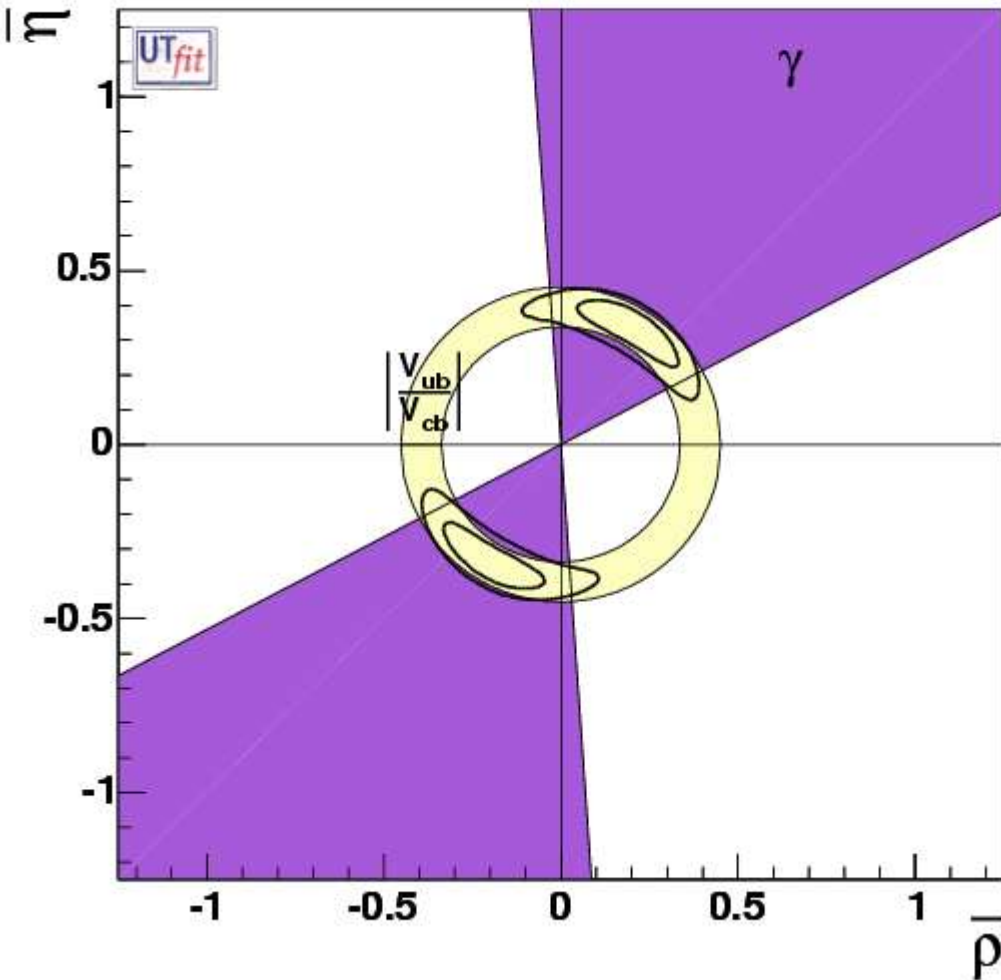
Con le nuove misure dalle B factory, (trascurando effetti di NP nel mixing \bar{D} -D) è possibile determinare $\bar{\rho}$ and $\bar{\eta}$ da $|V_{ub}/V_{cb}|$ e γ fornendo un paradigma a tutti i modelli di NP in letteratura

$$\bar{\rho} = \pm 0.21 \pm 0.10$$

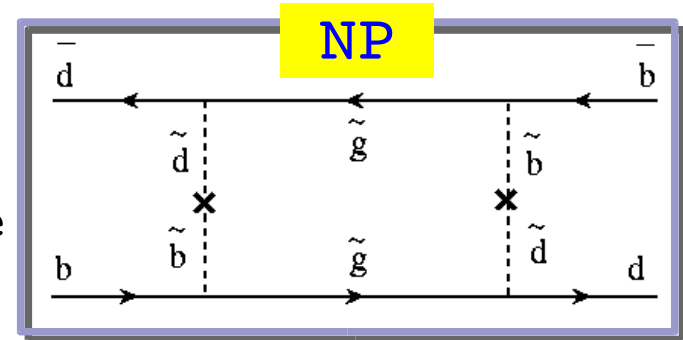
$$\bar{\eta} = \pm 0.36 \pm 0.06$$

$$\sin 2\beta = 0.724 \pm 0.074 \text{ U } -0.556 \pm 0.089$$

$$\alpha = (95 \pm 15)^\circ \text{ U } (-43 \pm 15)^\circ$$



Parametrizzazione generalizzata della NP nella Hamiltonian $|\Delta F|=2$. Possiamo fittare i nuovi parametri $\bar{\rho}$ ed $\bar{\eta}$ insieme



$$\begin{aligned}
 \diamond |\epsilon_K|^{\text{EXP}} &= C_\epsilon \cdot |\epsilon_K|^{\text{SM}} & \diamond \Delta m_d^{\text{EXP}} &= C_{Bd} \cdot \Delta m_d^{\text{SM}} \\
 \diamond \alpha^{\text{EXP}} &= \alpha^{\text{SM}} - \phi_{Bd} & \diamond A_{\text{CP}}(J/\psi K^0) &= \sin(2\beta + 2\phi_{Bd})
 \end{aligned}$$

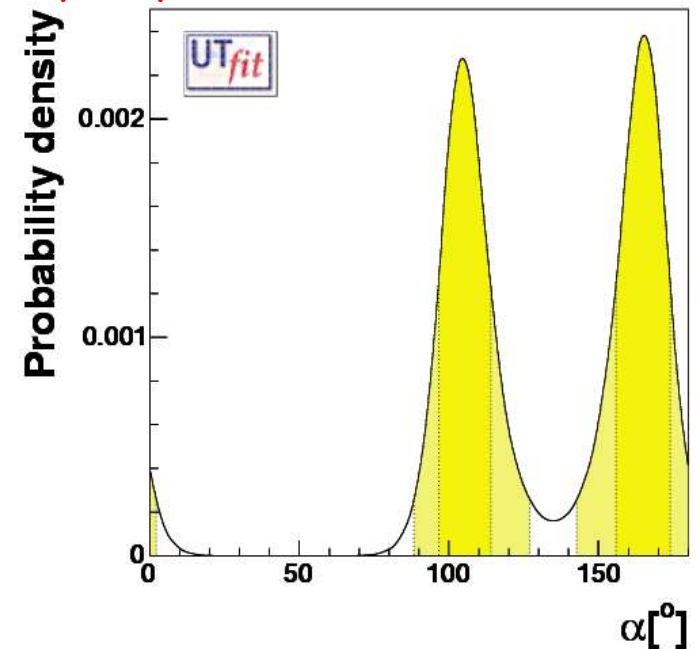
Assumendo SU(2), la NP nella Hamiltoniana $|\Delta F|=1$ introduce solo **nuove fasi deboli nei pinguini in α** .

Basta generalizzare il bound su α per tenerne conto

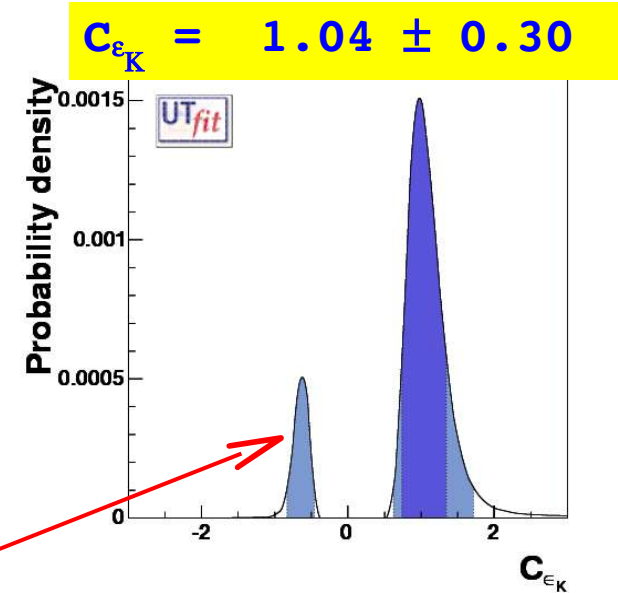
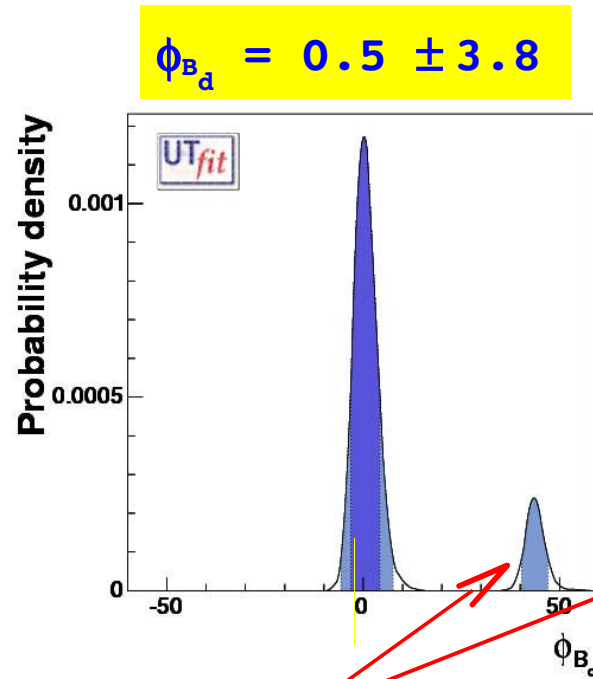
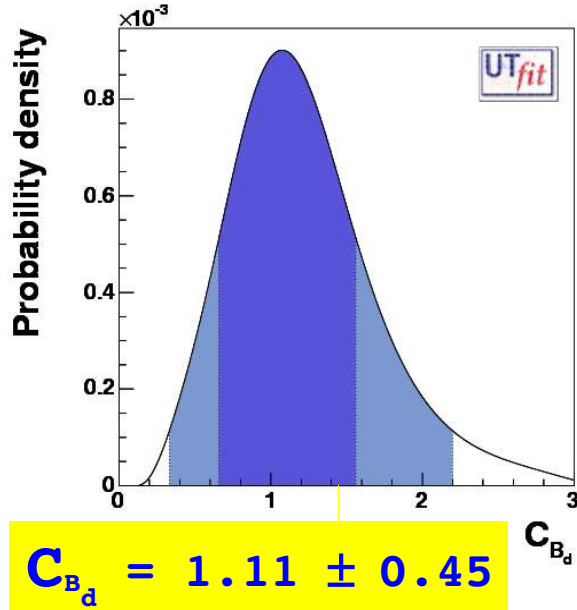
$$A^{+-} = -T e^{-i\alpha} + P e^{i\phi_P} e^{i\delta_P}$$

$$A^{+0} = -\frac{1}{\sqrt{2}} \left[e^{-i\alpha} (T + T_c e^{i\delta_{Tc}}) \right]$$

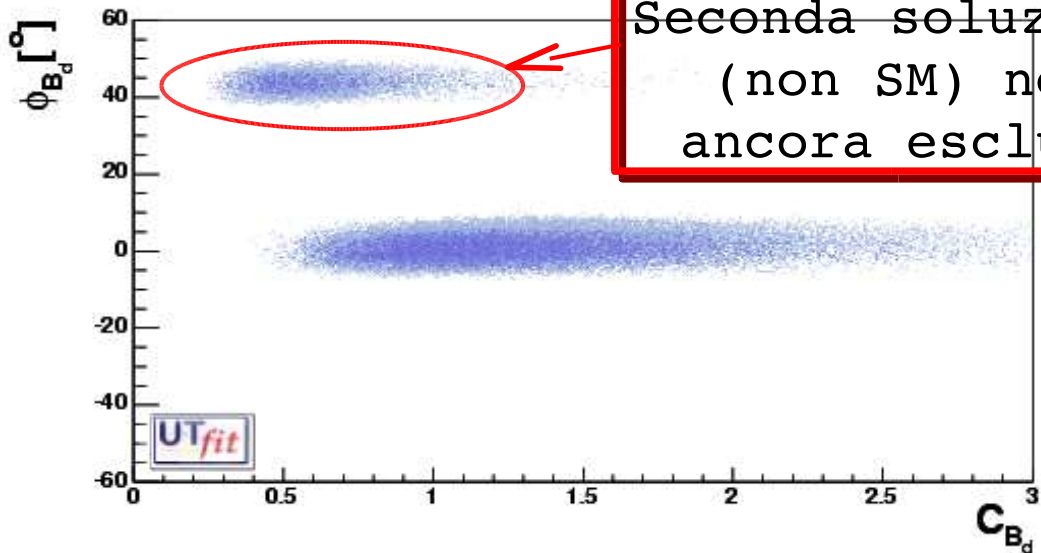
$$A^{00} = -\frac{1}{\sqrt{2}} \left[T_c e^{-i\alpha} e^{i\delta_{Tc}} + P e^{i\phi_P} e^{i\delta_P} \right]$$



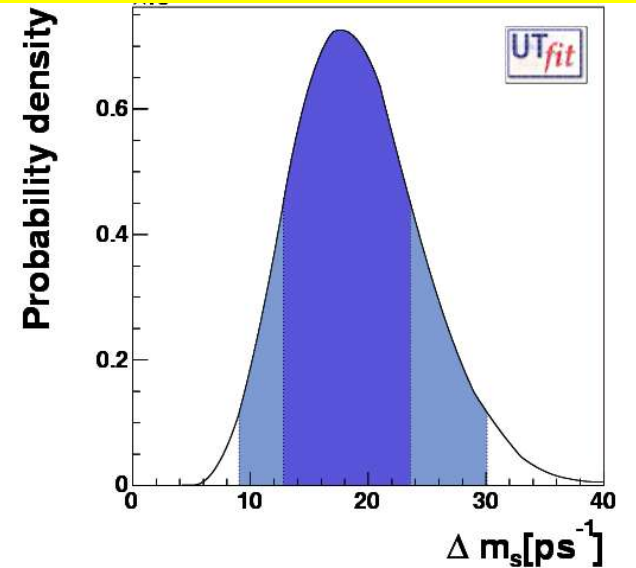
Risultati per parametri NP e Δm_s



$\Delta m_s = 18.2 \pm 5.4$
(analisi SM 21.2 ± 2.3)



Seconda soluzione
(non SM) non
ancora esclusa



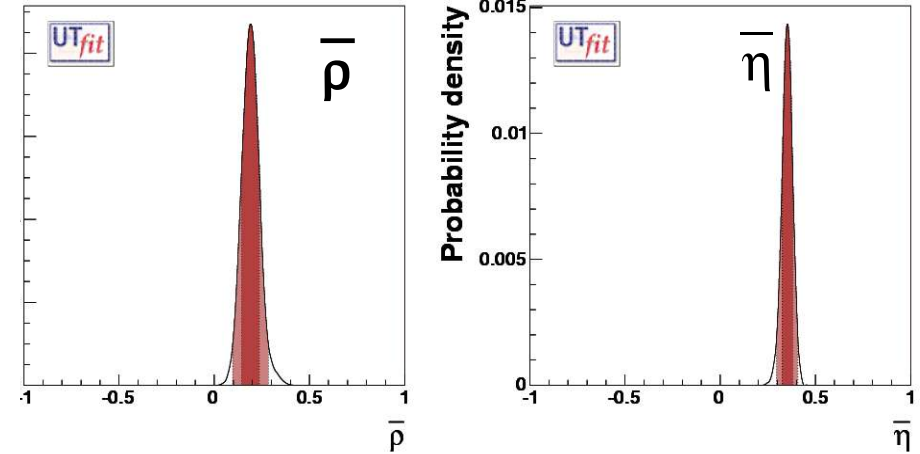
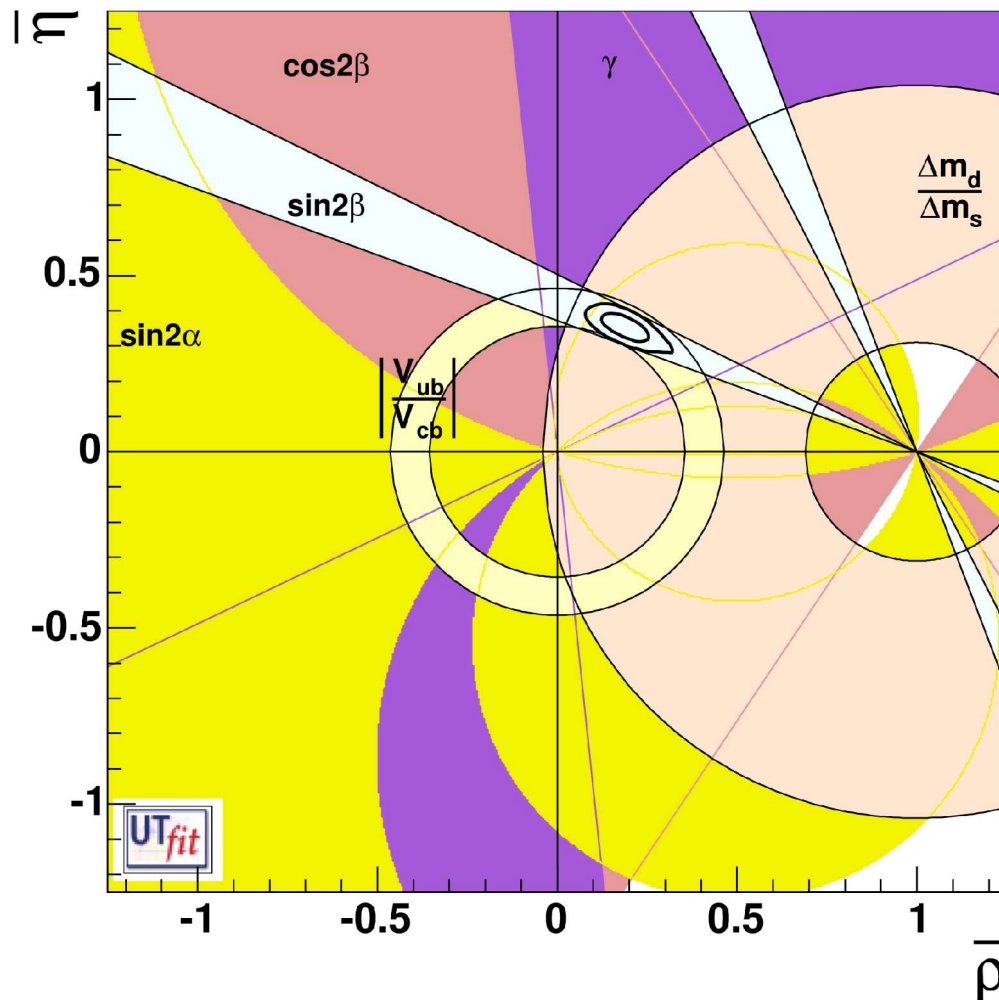
Nessuna ulteriore sorgente di mescolamento in MFV. Solo processi di mixing sono sensibili a NP:

✚ Escludiamo ε_K dal fit

✚ Usiamo solo il rapporto $\Delta m_d / \Delta m_s$ (NP si cancella)

Buras et al.

hep-ph/0007085



$$\bar{\eta} = 0.353 \pm 0.028$$

$$\bar{\rho} = 0.191 \pm 0.046$$

Predizioni per quantità UUT

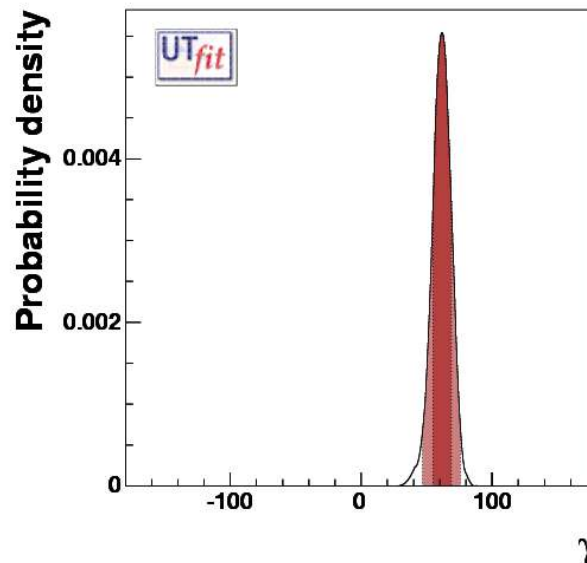
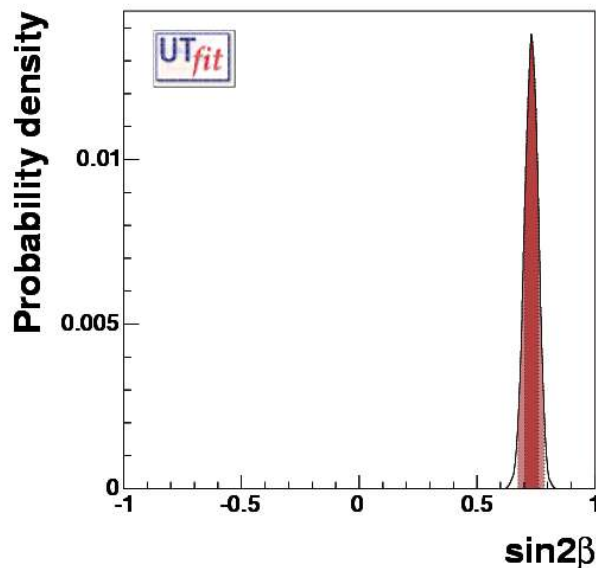
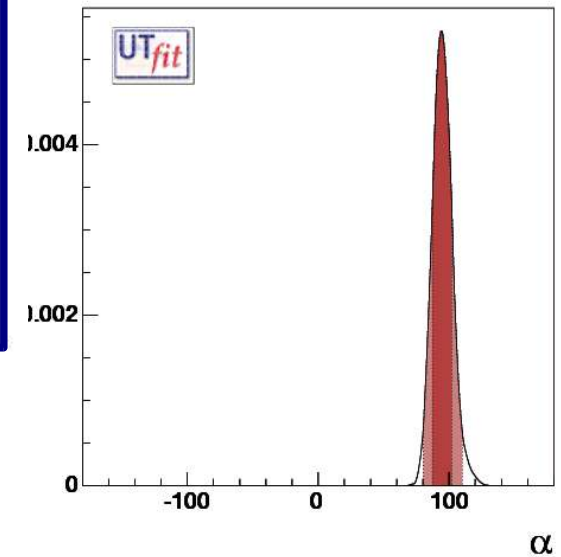
Precisa circa come
analisi standard

Universal Unitarity Triangle analysis

UUT (68%) UUT (95%) SM (68%) SM (95%)

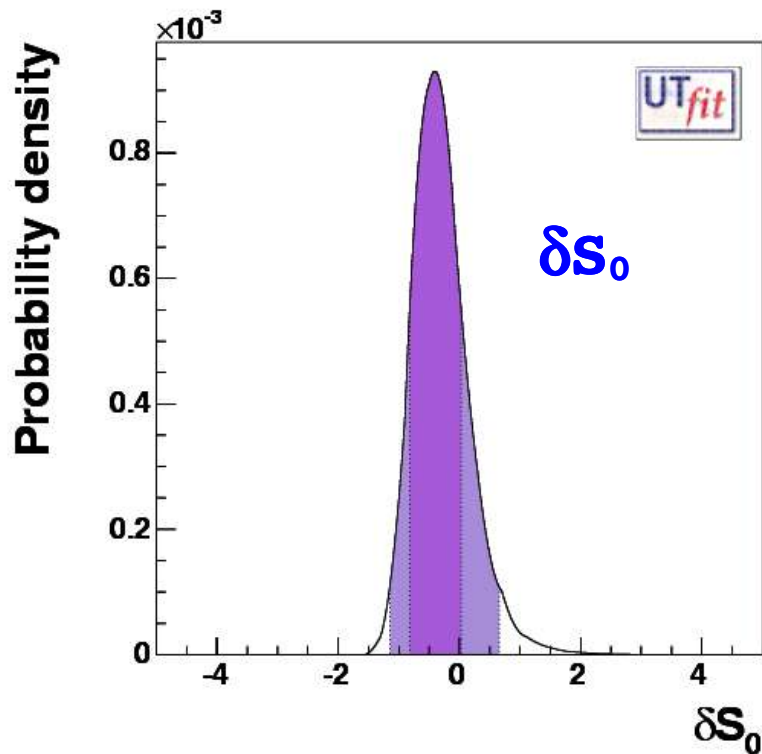
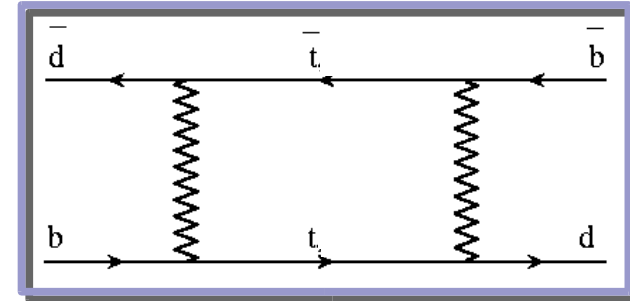
UT parameters

$\bar{\rho}$	0.191 ± 0.046 [0.097, 0.285]	0.207 ± 0.038 [0.129, 0.282]
$\bar{\eta}$	0.353 ± 0.028 [0.296, 0.408]	0.341 ± 0.023 [0.296, 0.386]
$\sin 2\beta$	0.733 ± 0.029 [0.675, 0.786]	0.726 ± 0.028 [0.670, 0.780]
$\alpha [^\circ]$	94.7 ± 7.4 [80.2, 110.1]	96.1 ± 7.0 [82.1, 110.0]
$\gamma [^\circ]$	61.9 ± 7.1 [47.0, 75.9]	60.3 ± 6.8 [47.0, 74.2]
$(2\beta + \gamma) [^\circ]$	109.4 ± 7.8 [92.5, 123.8]	107.3 ± 7.4 [92.6, 121.6]



Limiti sulla NP in MFV(I)

In modelli con un doppietto di Higgs o piccolo $\tan\beta$ (D'Ambrosio et al. [hep-ph/0207036](http://arxiv.org/abs/hep-ph/0207036)) la NP entra come contributo universale ai diagrammi a box



$$S_0(x_t) \rightarrow S_0(x_t) + \delta S_0, \quad |\delta S_0| = 4 \left(\frac{\Lambda_0}{\Lambda} \right)^2$$

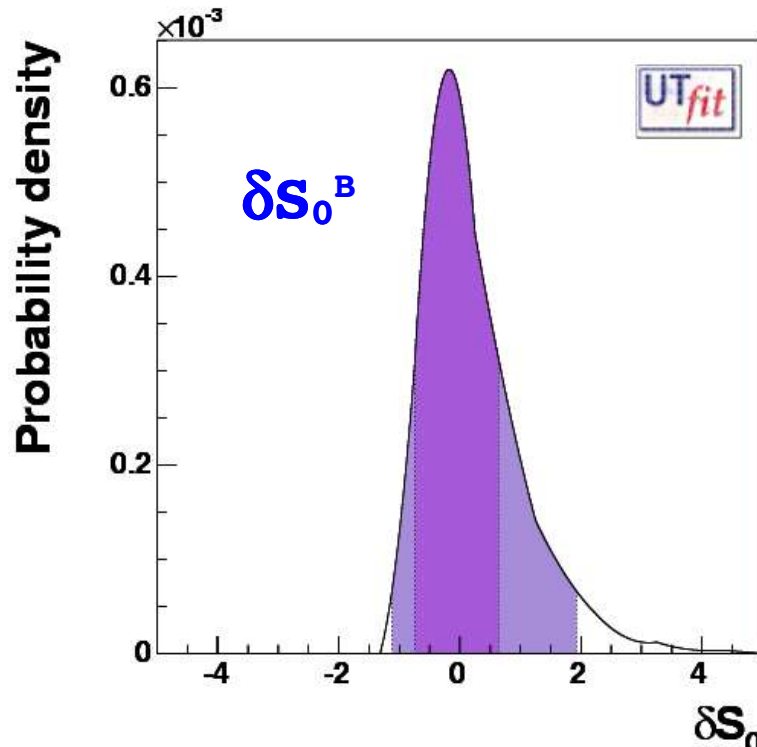
$$\Lambda_0 = \lambda_t \sin^2 \theta_w M_W / \alpha_{EM} \sim 2.4 \text{ TeV}$$

$\Lambda > 6.0$ @95% for positive δS_0

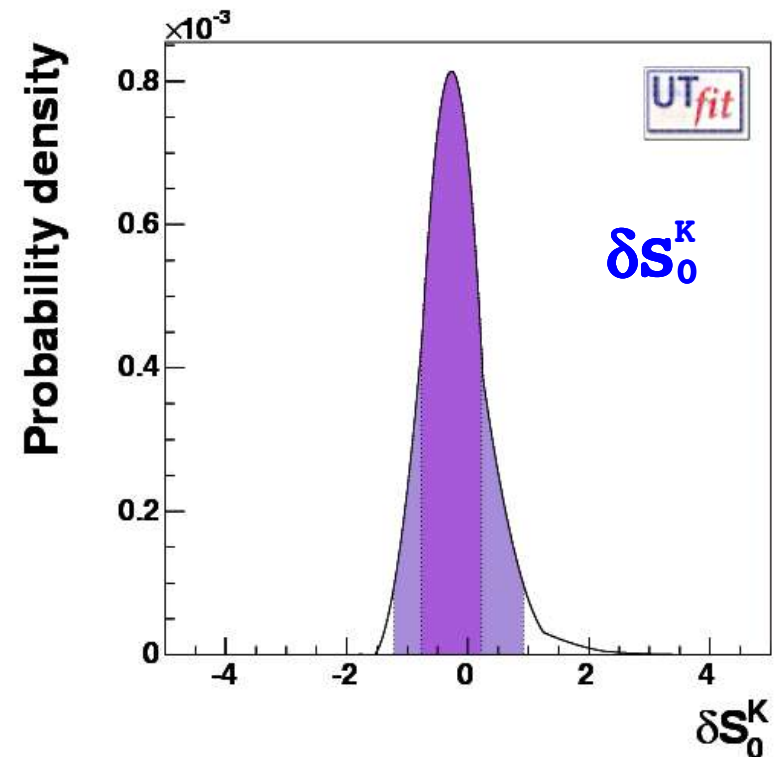
$\Lambda > 4.8$ @95% for negative δS_0

Limiti sulla NP in MFV(II)

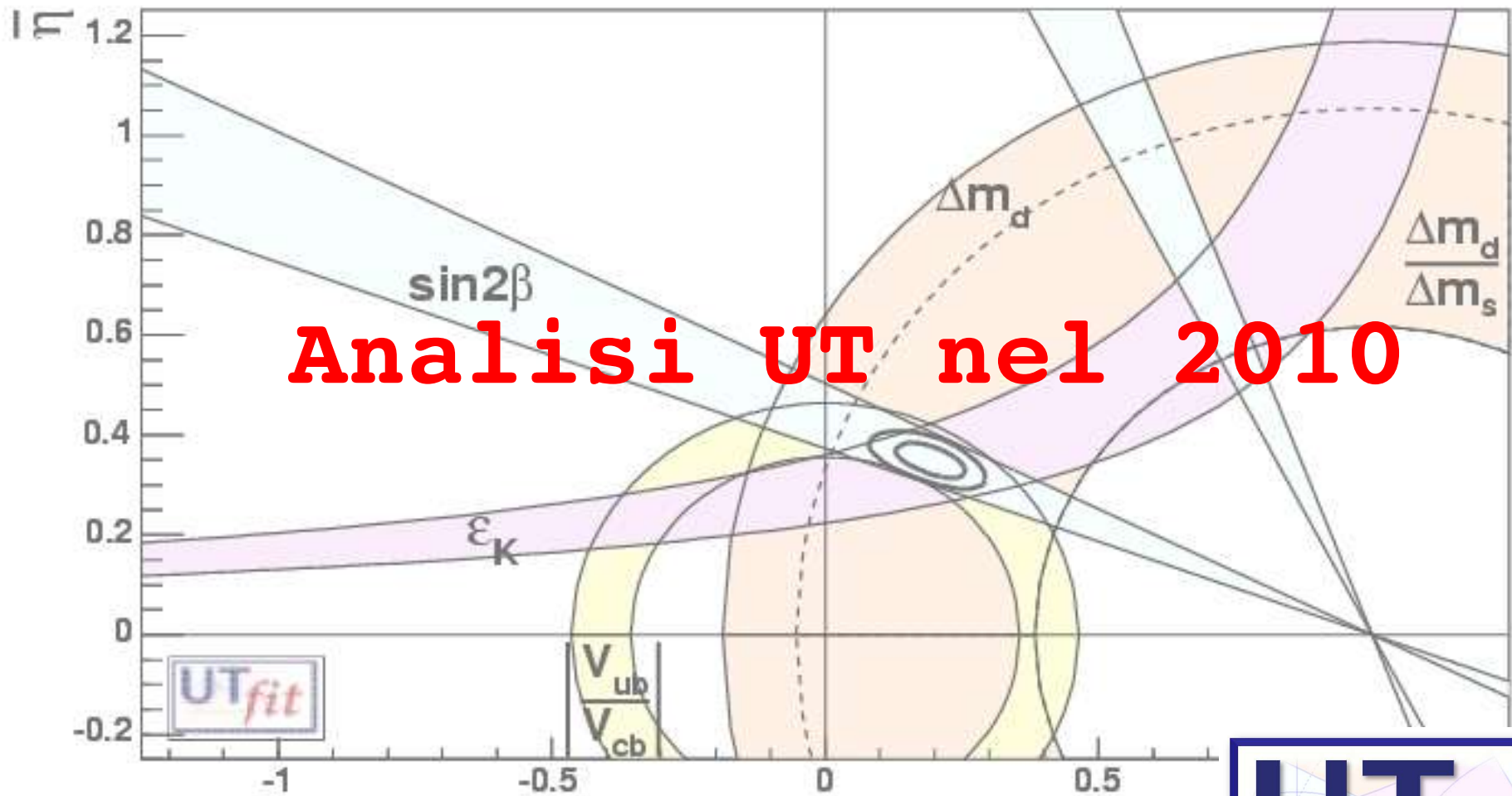
Per valori grandi di $\tan\beta$, la NP cambia diversamente ε_K e i processi di mixing del B.
Due diversi δS_0 in questo caso



$\Lambda > 3.4$ @95% for positive δS_0
 $\Lambda > 4.6$ @95% for negative δS_0



$\Lambda > 5.0$ @95% for positive δS_0
 $\Lambda > 4.3$ @95% for negative δS_0

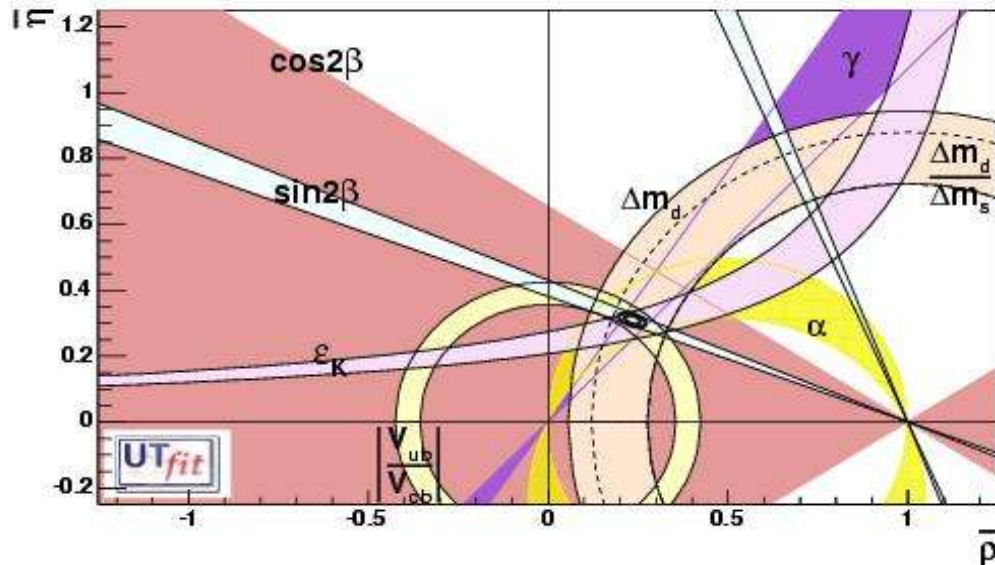


Analisi UT nel 2010



Uno sguardo al futuro(I)

Abbiamo giocato con uno scenario realistico per il 2010: fino a che punto siamo sensibili alla NP se non osserviamo nessuna deviazione dallo SM?

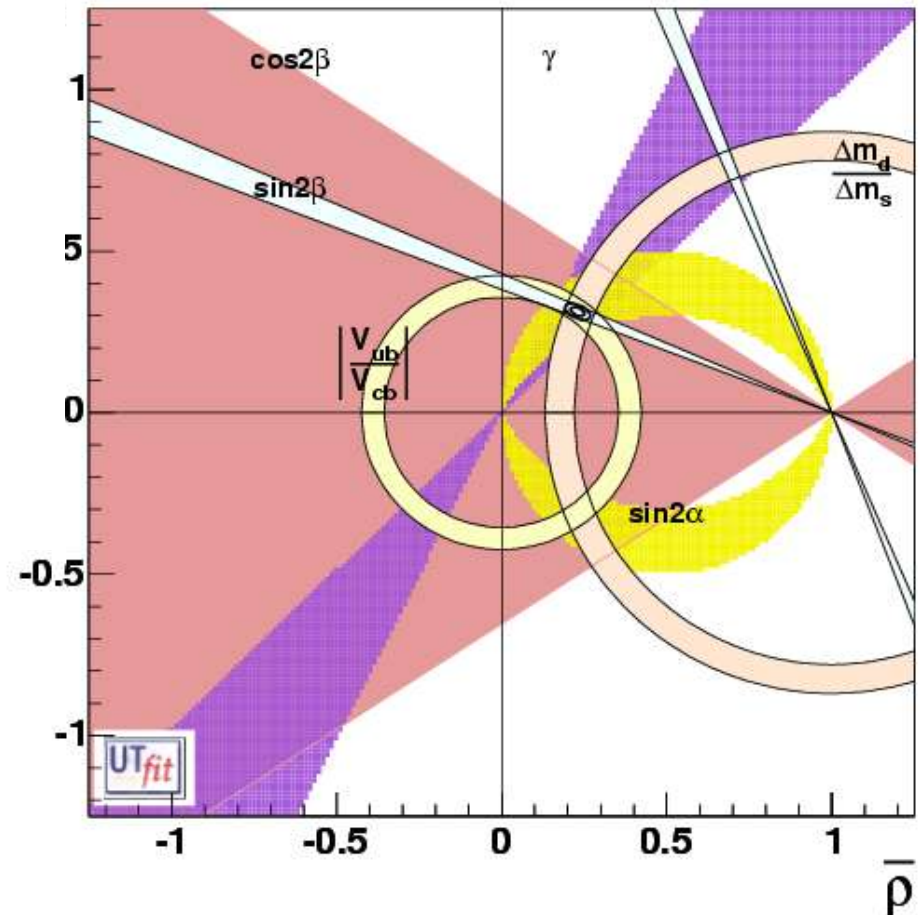
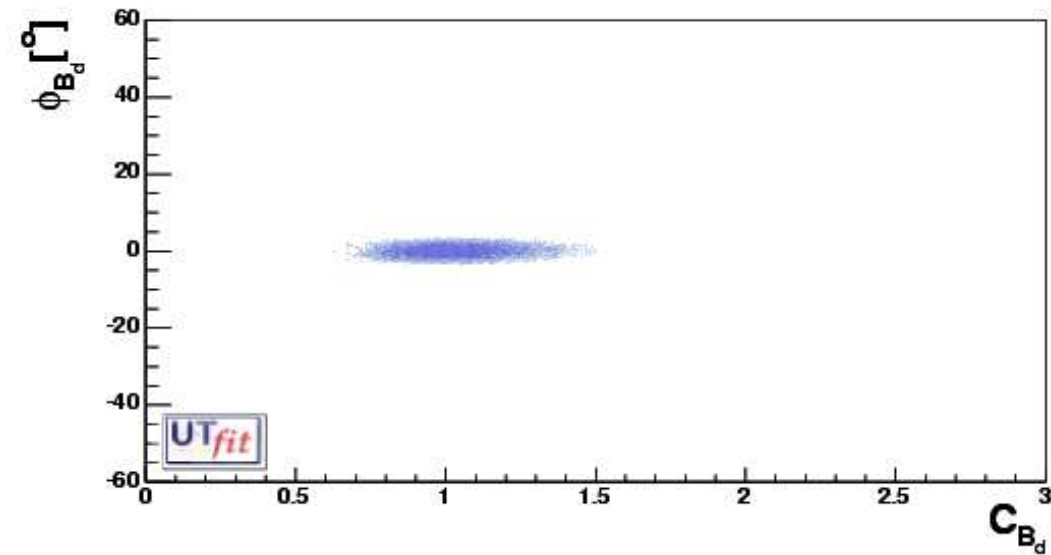


$$\sigma(\bar{\rho}) = 0.017$$

$$\sigma(\bar{\eta}) = 0.011$$

Observable	projected values/error
$\sin 2\beta$	0.695 ± 0.015 (2%)
$\alpha[^\circ]$	$(104 \pm 7)^\circ$
$\gamma[^\circ]$	$(54 \pm 5)^\circ$
B_K	0.930 ± 0.047 (5%)
$F_{B_s} \sqrt{\hat{B}_{B_s}}$ [MeV]	0.276 ± 0.014 (5%)
ξ	1.200 ± 0.037 (3%)
$ V_{cb} $ -(incl+excl) (10^{-3})	41.7 ± 0.4 (0.9%)
$ V_{ub} $ -(incl+excl) (10^{-4})	36.4 ± 1.6 (4.2%)
Δm_d	0.503 ± 0.003 (0.6%)
Δm_s	20.5 ± 0.3 ps $^{-1}$
m_t [GeV]	171 ± 3.0
$\lambda_{Cab.}$	0.2240 ± 0.008

$$\sigma(\bar{\eta}) = 0.013 \quad \sigma(\bar{\rho}) = 0.018$$



$$\begin{aligned} \sigma(C_{B_d}) &= 0.15 & \sigma(\phi_{B_d}) &= 1.6^\circ \\ \sigma(C_{B_s}) &= 0.12 & \sigma(C_{\varepsilon_K}) &= 0.12 \end{aligned}$$

$\Lambda > 8 \text{ TeV @95\%}$

Conclusions

- ➔ Il crescente numero di vincoli permette una determinazione sempre più precisa dei parametri della CKM
- ➔ L'abbondanza di informazioni permette di rinunciare ad alcuni dei vincoli per testare le tecniche di calcolo su reticolo
- ➔ Per la prima volta è possibile vincolare $\bar{\rho}$ ed $\bar{\eta}$ utilizzando esclusivamente transizioni ad albero (NP trascurabile) e fornire un riferimento quantitativo ai modelli di NP
- ➔ La generalizzazione dell'analisi oltre lo SM mostra la presenza di una seconda soluzione non ancora esclusa
- ➔ In uno scenario MFV, è possibile vincolare $\bar{\rho}$ ed $\bar{\eta}$ utilizzando l'analisi UUT e quantificare la minima scala di NP a cui si è sensibili (almeno $> 3.4 \text{ TeV}$ @95% Prob.)
- ➔ In caso non vedessimo effetti di NP a bassa energia, possiamo compiere con l'analisi UT un tipo di ricerca complementare a quello di LHC

