New Physics from Flavour

Vincenzo Vagnoni

INFN Bologna

on behalf of the UTfit Collaboration

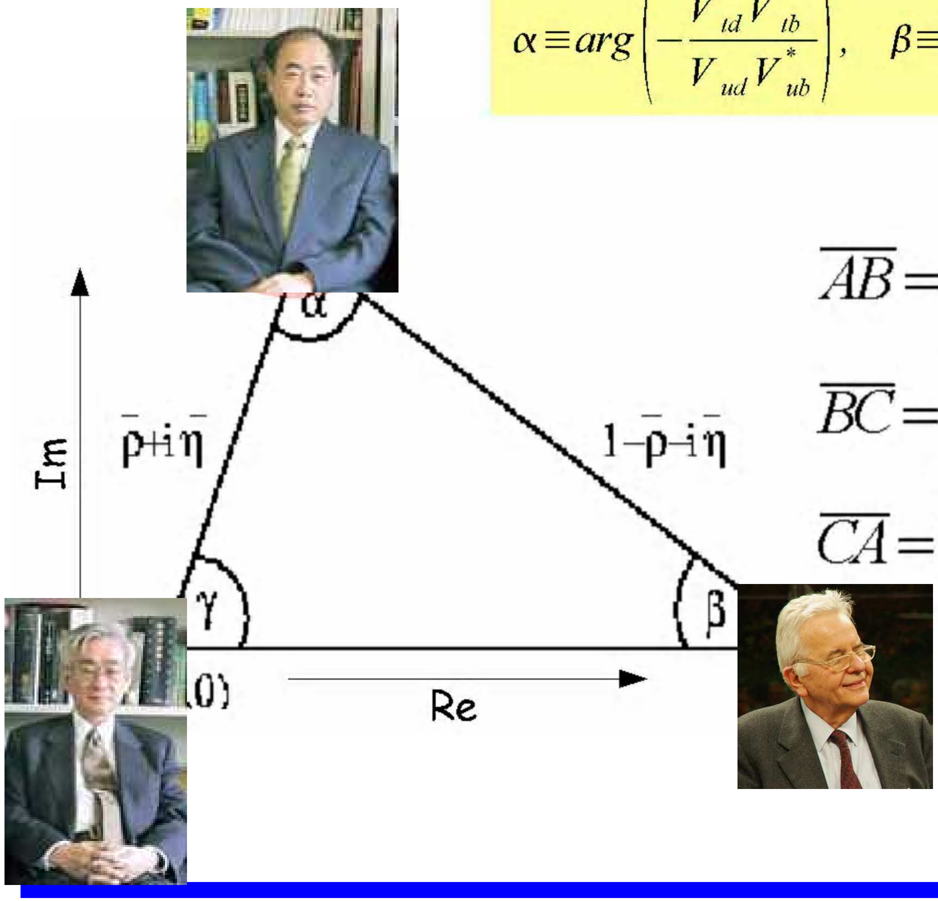
http://www.utfit.org

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

Cabibbo-Kobayashi-Maskawa (face to face)

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

$$\alpha \equiv arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right),\quad \beta \equiv arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right),\quad \gamma \equiv arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right),\quad \beta_s \equiv arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$



$$\overline{AB} = \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}$$

$$\overline{BC} = 1$$

$$\overline{CA} = \frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

$$V = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\bar{\rho}-i\bar{\eta}) & -A\lambda^2 & 1 \end{pmatrix}$$

Where New Physics enters the game

The SM works beautifully up to a few hundred GeV. Several arguments suggest that it might be an effective theory up to some scale Λ

$$\mathcal{L}(M_W) = \Lambda^2 H^\dagger H + \lambda (H^\dagger H)^2_{SM} + \mathcal{L}^{gauge}_{SM} + \mathcal{L}^{Yukawa} + \mathcal{L}^5/\Lambda + \mathcal{L}^6/\Lambda^2$$

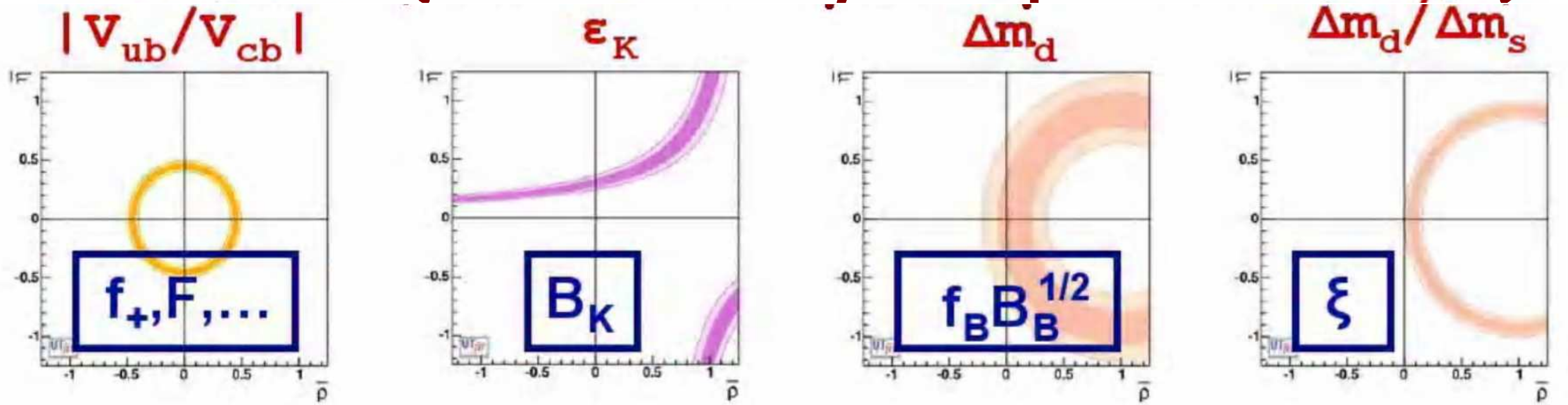
EW scale

NP contribution to EW precision, FCNC processes, CPV, g-2, $b\to s\gamma$, etc..

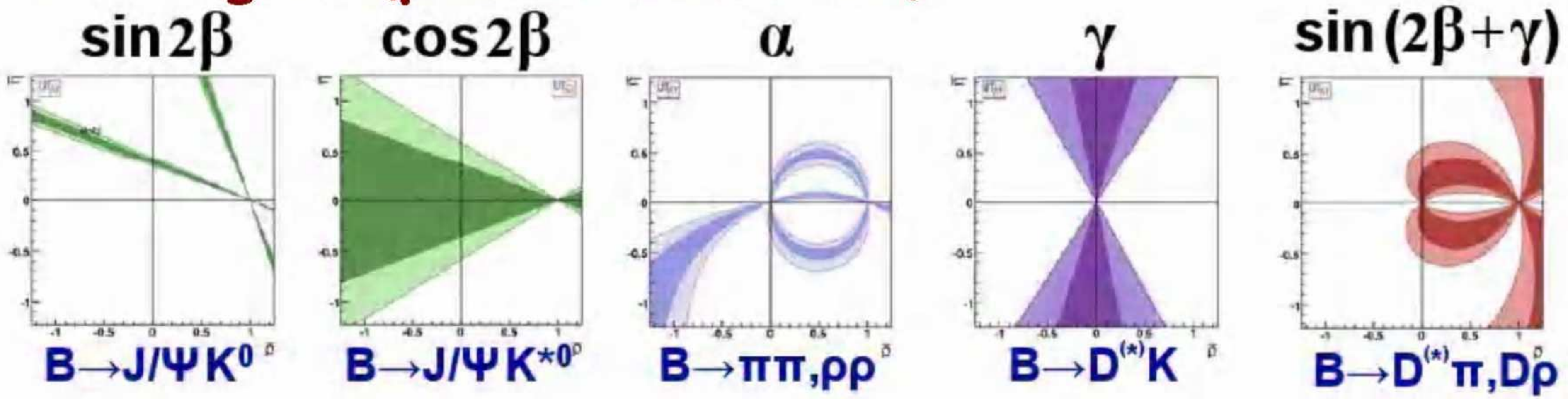
The new contributions, in general, introduce new sources of CP violation and flavour mixing.
The consistency of the Standard Model becomes a puzzle in this framework.
We should see some discrepancy

Constraints in the $\bar{\rho}$-$\bar{\eta}$ plane

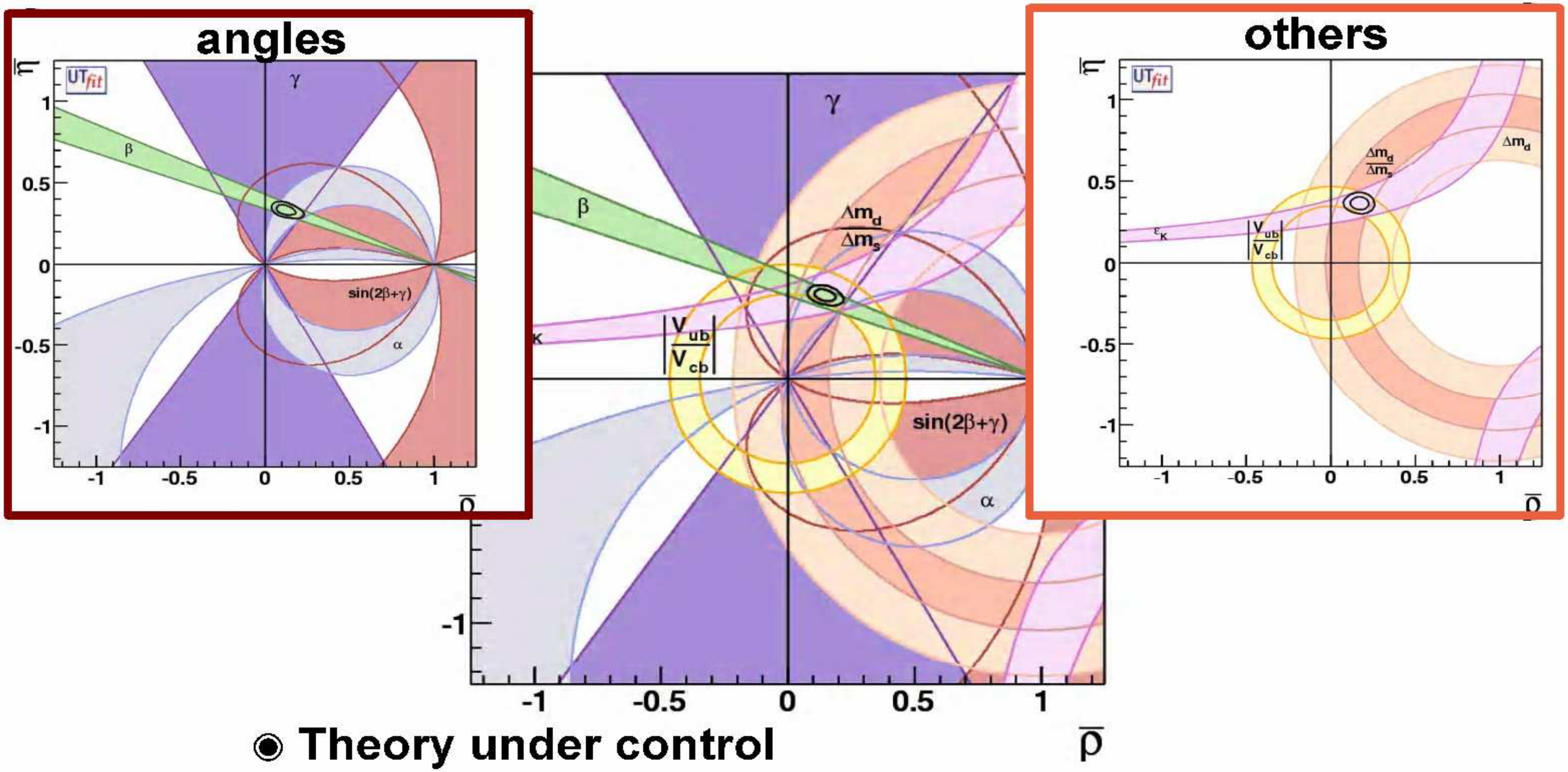
UT-lattice ("classic" analysis – pre B factories)



UT-angles (post B factories)



Experimental situation



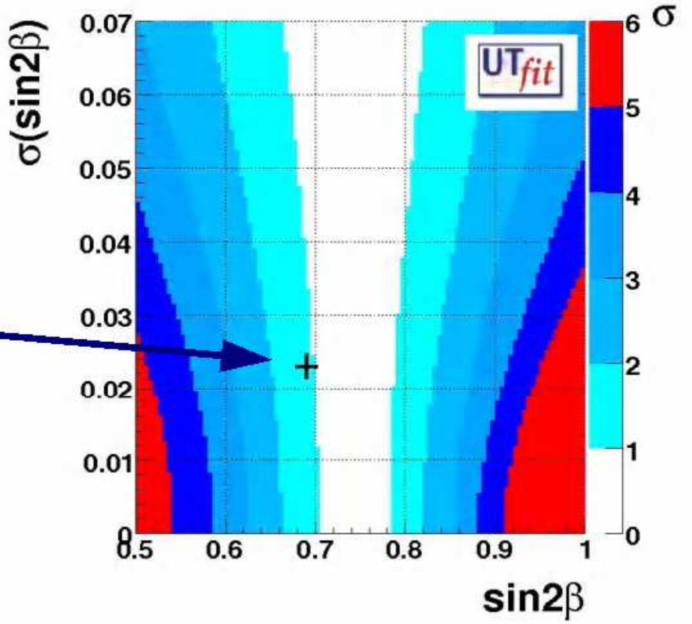
- Theory under control
- Data in agreement
- NP, if any, does not introduce additional CP or flavour violation in b ↔ d transitions

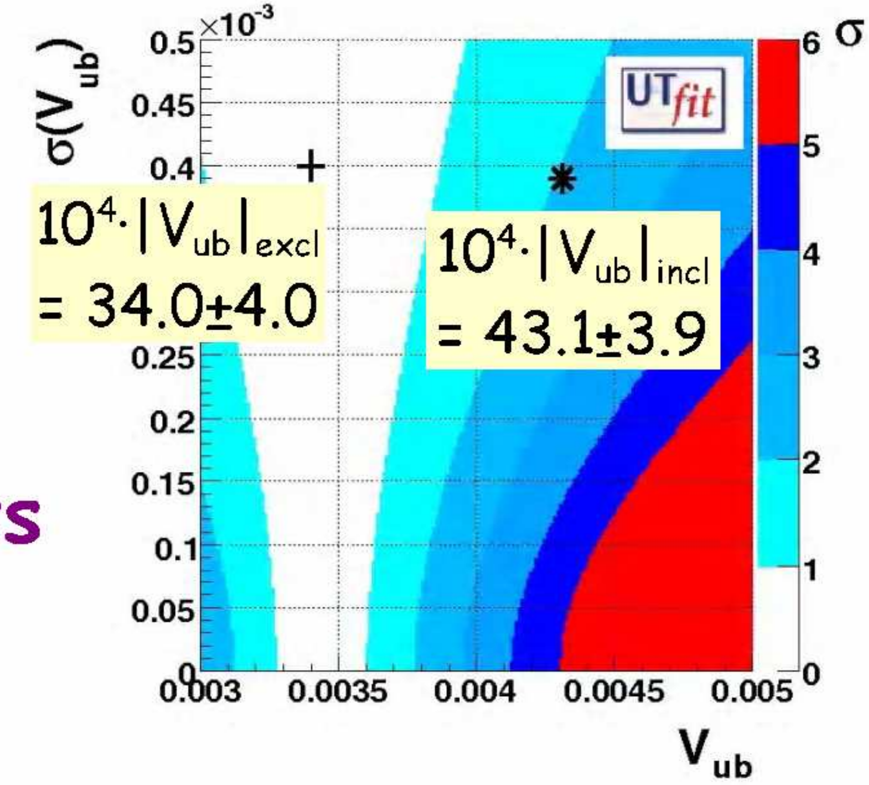
Sin2β-|V_{ub}| tension

$\sin 2\beta_{b\to c\bar{c}s} = 0.681 \pm 0.025$

$\sin 2\beta_{fit} = 0.744 \pm 0.039$

$\sin 2\beta_{all} = 0.690 \pm 0.023$





Possibile explanations:

* NP in B_d mixing
* problem with theory in $b \to u$ semileptonic decays
* both

Parameterization of NP contributions to the mixing amplitudes

K mixing amplitude (2 real parameters):

$$\mathrm{Re}\,A_K = C_{\Delta m_K}\,\mathrm{Re}\,A_K^{SM} \qquad \mathrm{Im}\,A_K = C_{\varepsilon}\,\mathrm{Im}\,A_K^{SM}$$

B_d and B_s mixing amplitudes (2+2 real parameters):

$$A_q e^{2i\phi_q} = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_q^{SM}} = \left(1 + \frac{A_q^{NP}}{A_q^{SM}} e^{2i(\phi_q^{NP} - \phi_q^{SM})}\right) A_q^{SM} e^{2i\phi_q^{SM}}$$

Including NP in UT analysis

	ρ, η	C_{Bd}, ϕ_{Bd}	$C_{\varepsilon K}$	C_{Bs}, ϕ_{Bs}
V_{ub}/V_{cb}	X			
γ (DK)	X			
ε_K	X		X	
sin2β	X	X		
Δm_d	X	X		
α ($\rho\rho$,$\rho\pi$,$\pi\pi$)	X	X		
A_{SL} B_d	X	X X		
$\Delta\Gamma_d/\Gamma_d$	X	X X		
$\Delta\Gamma_s/\Gamma_s$	X			X X
Δm_s				X
A_{CH}	X	X X		X X

model independent assumptions

SM → **SM+NP**

tree level

$(V_{ub}/V_{cb})^{SM}$ → $(V_{ub}/V_{cb})^{SM}$

γ^{SM} → γ^{SM}

Bd Mixing

β^{SM} → $\beta^{SM}+\phi_{Bd}$

α^{SM} → $\alpha^{SM}-\phi_{Bd}$

Δm_d → $C_{Bd}\Delta m_d$

Bs Mixing

Δm_s^{SM} → $C_{Bs}\Delta m_s^{SM}$

β_s^{SM} → $\beta_s^{SM}+\phi_{Bs}$

K Mixing

ε_K^{SM} → $C_{\varepsilon K}\varepsilon_K^{SM}$

Tree level UT fit

B factories are constraining the UT with tree-level processes

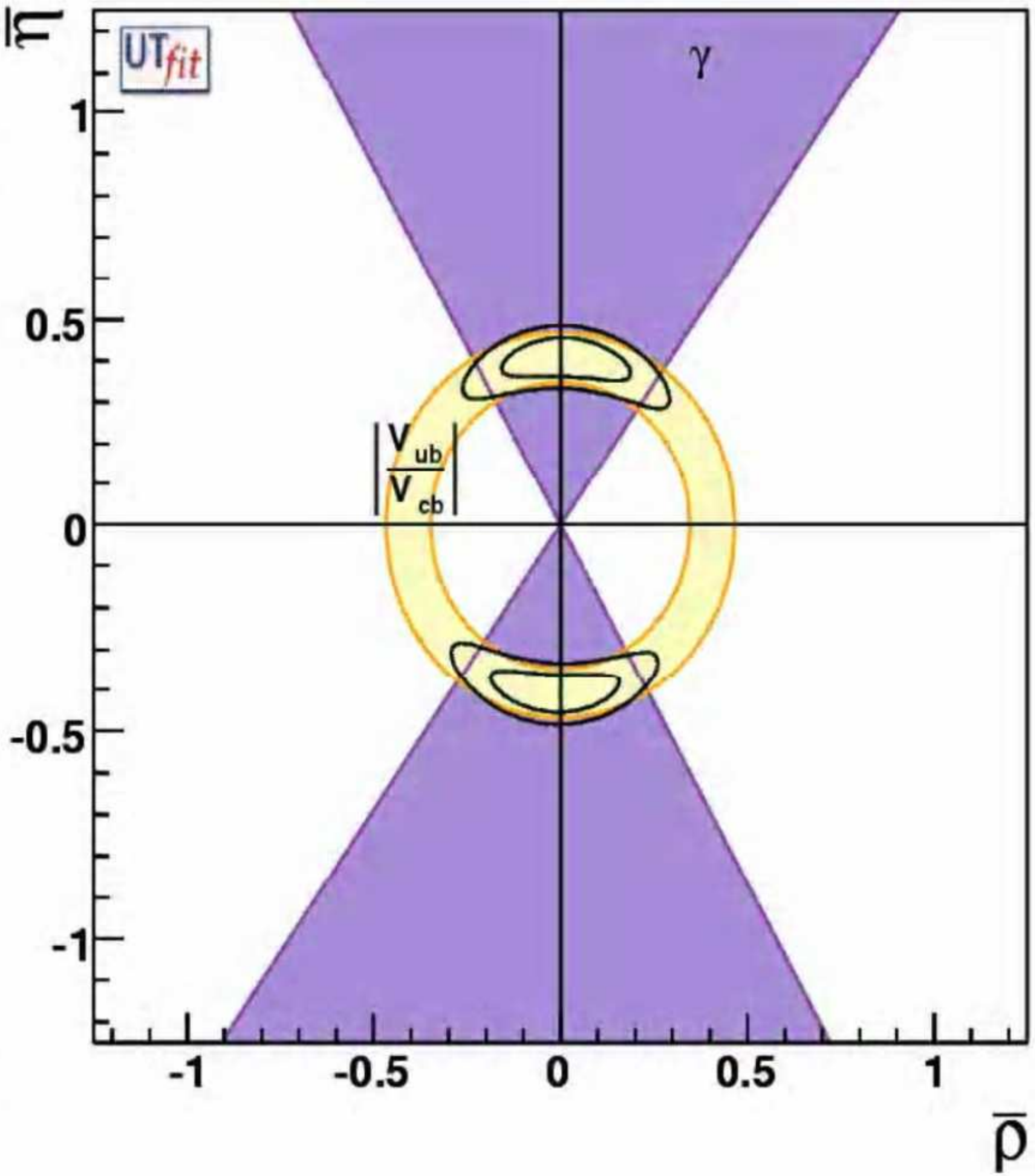
Assuming no NP at tree level
(the effect of the $\bar{D}^0$-D^0 mixing to γ are small wrt the present error and can be accounted for in the future)

We can determine $\bar{\rho}$ and $\bar{\eta}$ regardless of NP

$$\bar{\rho} = \pm\, 0.18 \pm 0.11$$

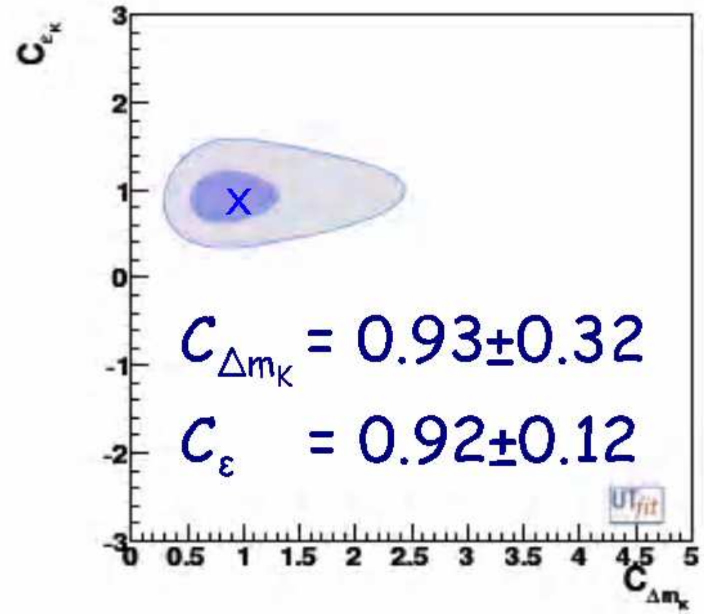
$$\bar{\eta} = \pm\, 0.41 \pm 0.05$$

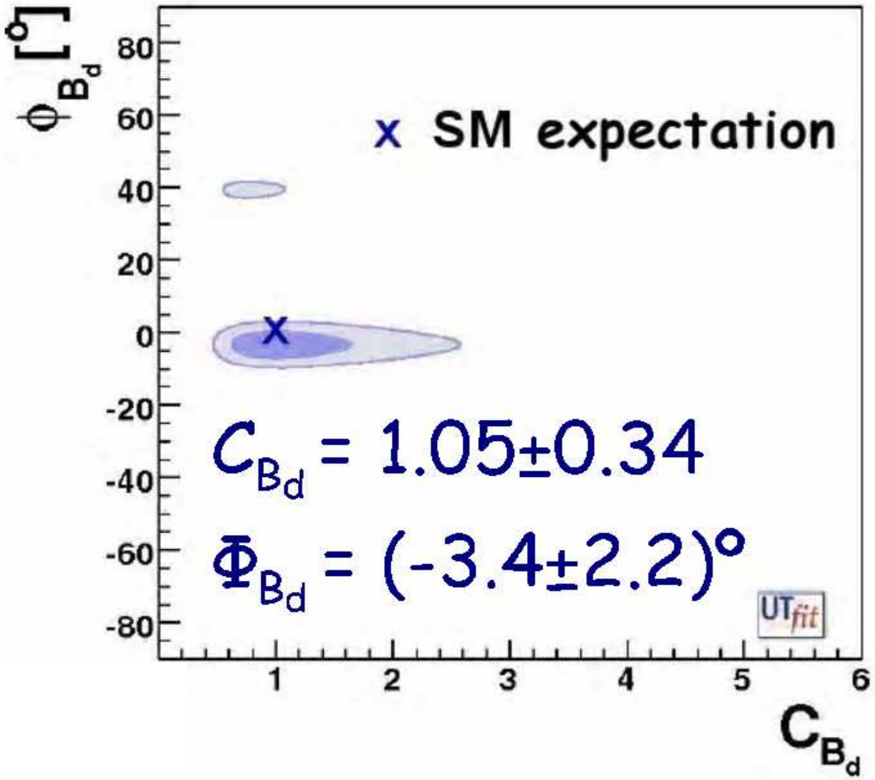
Values in agreement with SM within the errors

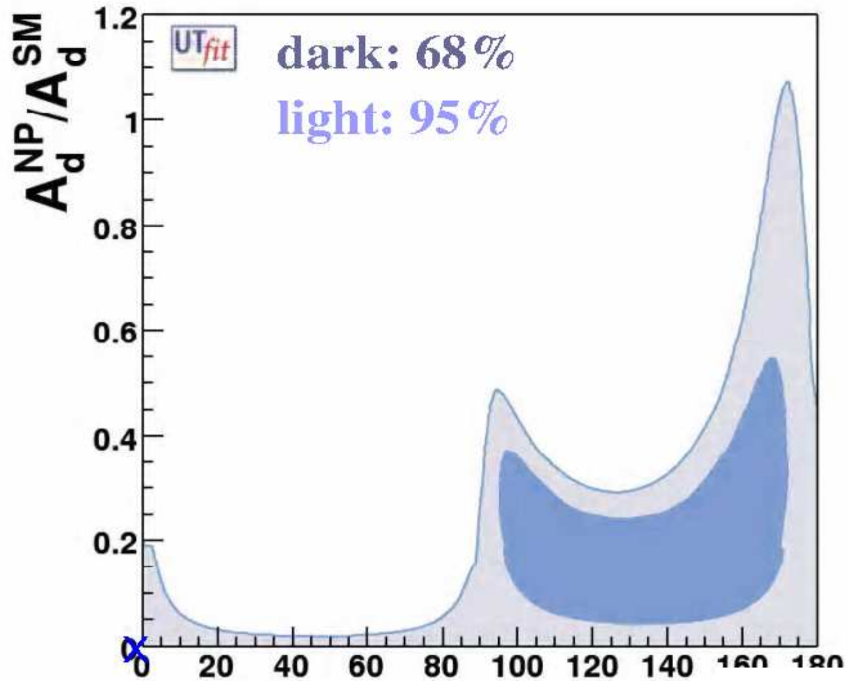


NP in K^0 and B^0 mixing

* the sin2β tension produces the 1.5σ effect of Φ_{B_d} and the asymmetry in (A^{NP}/A^{SM}, Φ_d^{NP})



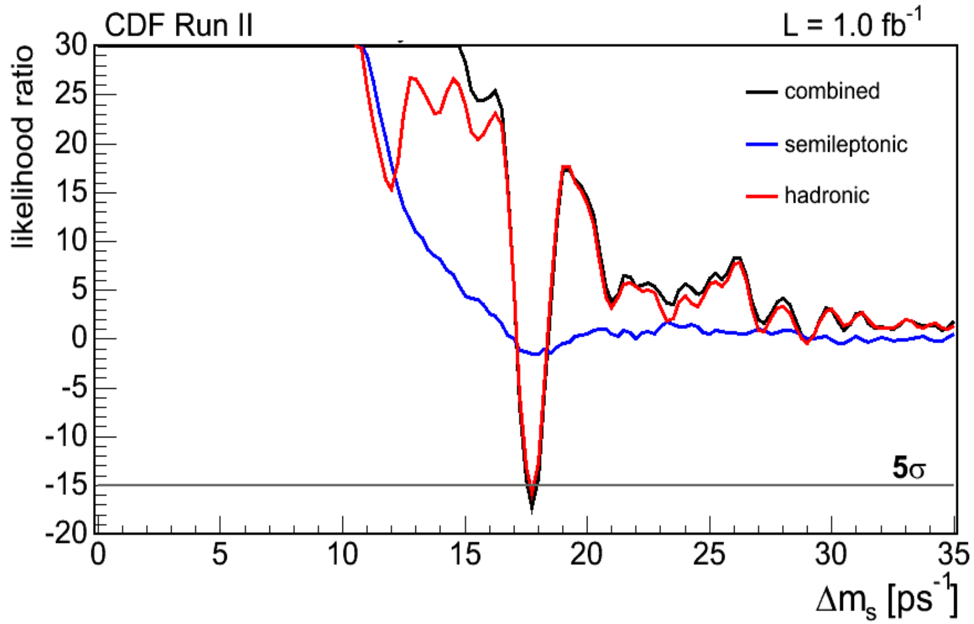




Tevatron breakthrough in the B_s sector

TEVATRON experiments have started test the b↔s sector with Bs mixing

- Measurement of Δm_s

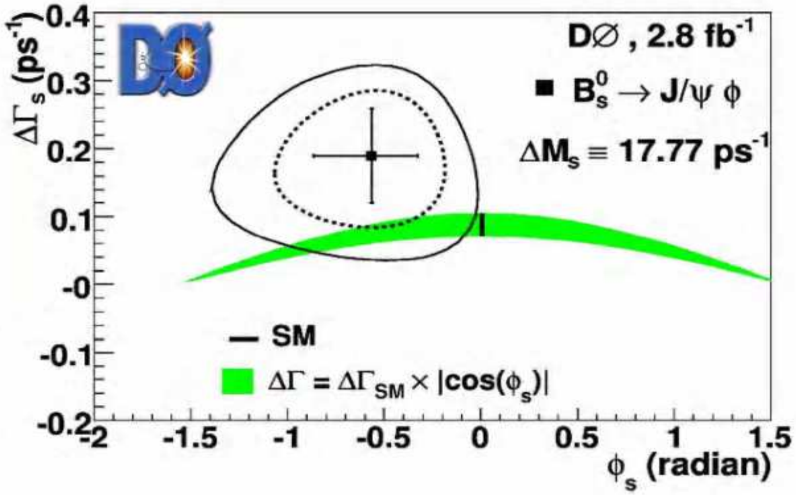


- Measurement of dilepton charge asymmetry
- Semileptonic asymmetry
- Measurement of $\Delta\Gamma_s/\Gamma_s$
- B_s lifetime measurement in flavour specific final states

Indirect constraints on the mixing phase

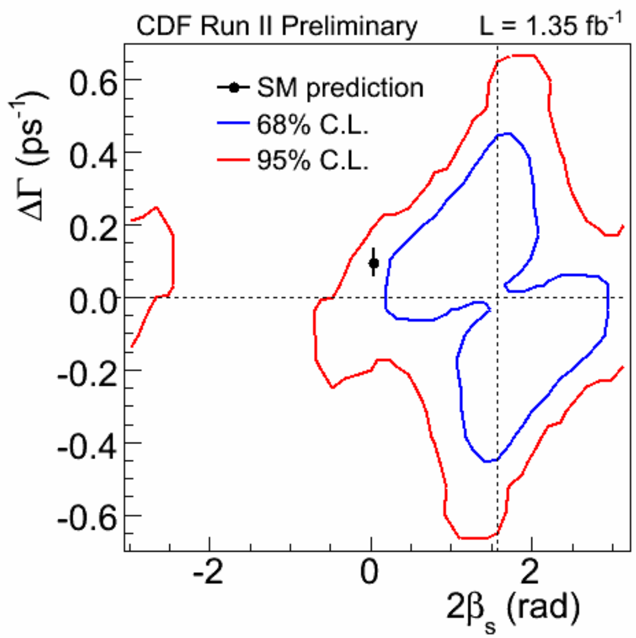
- 2D bound on β_s vs $\Delta\Gamma$ from tagged angular analysis of $B_s \to J/\psi\phi$ decays

discrepancy with Standard Model observed



Combining CDF and D0 measurements

2D likelihood ratio for $\Delta\Gamma$ and Φ_s
2-fold ambiguity present, no assumption on the strong phases

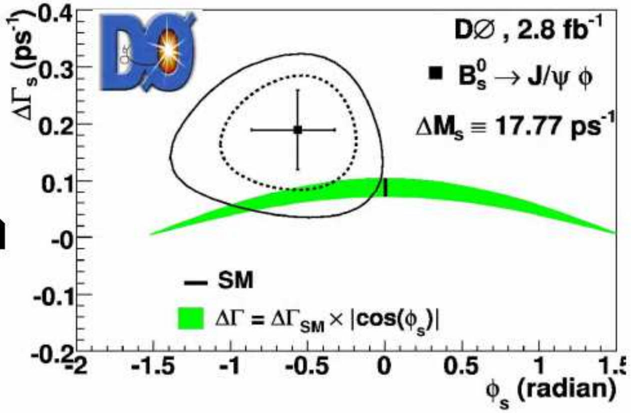


7-parameter fit + correlation matrix or 1D likelihood profiles of $\Delta\Gamma$ and Φ_s
2-fold ambiguity removed using strong phases from B -> J/Ψ K* + SU(3) + ?

Combining the two measurements requires some gymnastic with the DØ results...

- **D0: arXiv:0802.2255 [hep-ex]**
  - $\tau_s = 1.52 \pm 0.06$ *(stat)* ± 0.01 *(syst)* ps
  - $\Delta\Gamma_s = 0.19 \pm 0.07$ *(stat)* ${}^{+0.02}_{-0.01}$ *(syst)* ps^{-1}
  - $\phi_s = -2\beta_s = -0.57\,{}^{+0.24}_{-0.30}$ *(stat)* ${}^{+0.07}_{-0.02}$ *(syst)* rad
- **CDF: arXiv:0712.2397 [hep-ex]**
  - **Feldman-Cousins likelihood ratio with systematics included**

Modeling D0 data

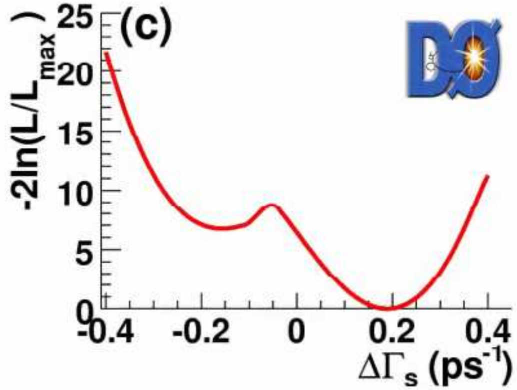


Unlike for CDF, it was not possible to obtain the 2D likelihood from D0.
We use three different approaches:

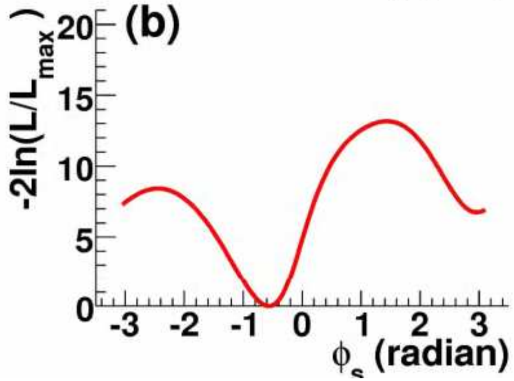
Default result: take the quoted result + 2x2 correlation matrix

To include non-Gaussian tails:

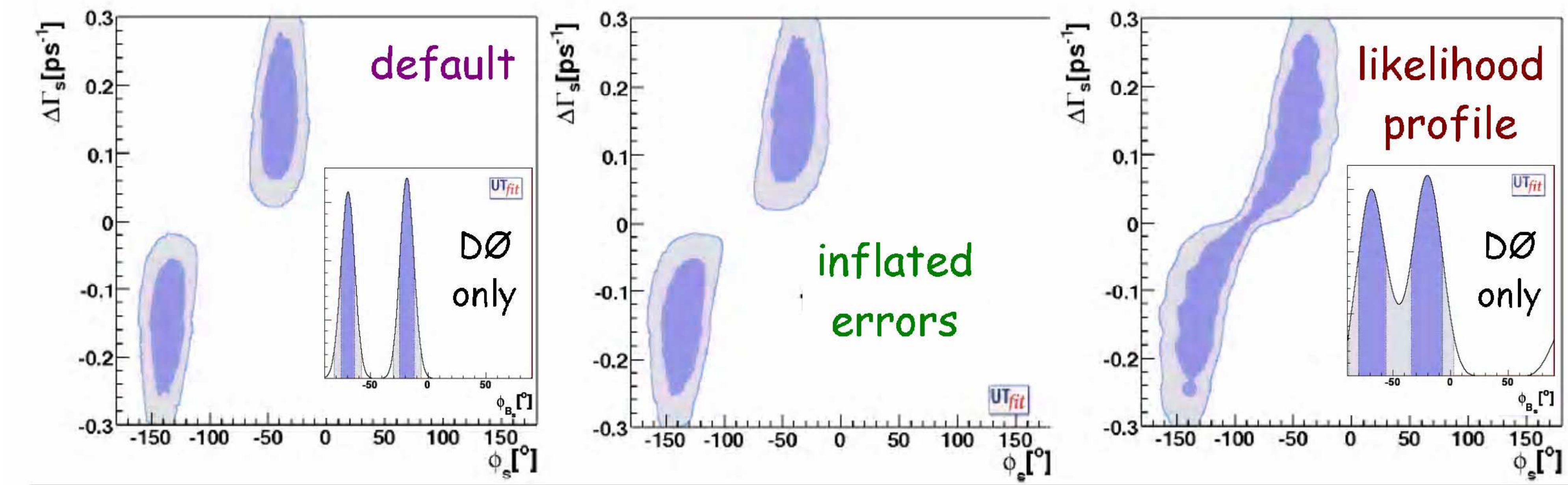
1) scale errors such that they agree with the quoted "2σ" ranges: [-0.06, 1.20] → 0.38



2) use the 1D profile likelihood given by D0.



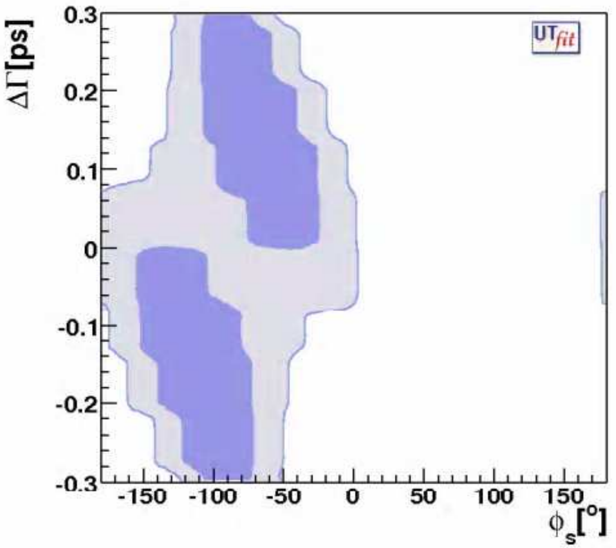
Modeling D0 data (II)



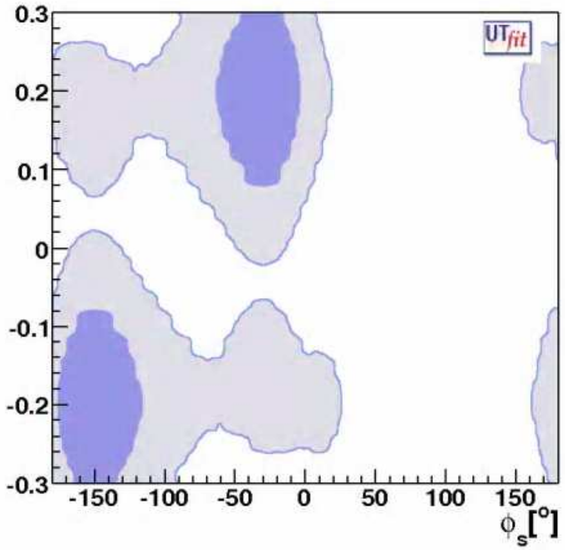
- **In the 3 modelizations we have considered, the probability density is significantly affected just in the region far from the Standard Model solution**

A comment: more than two measurements…

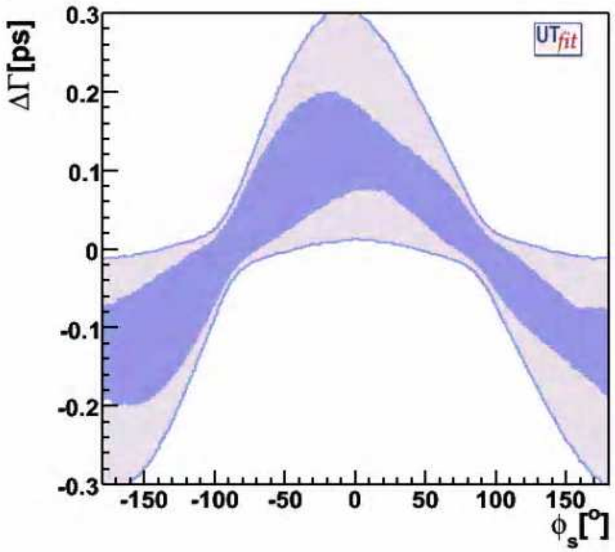
CDF tagged measurement



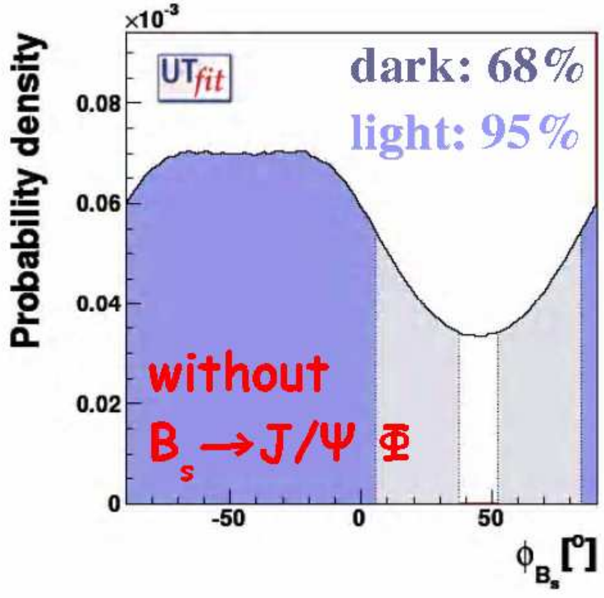
D0 tagged measurement

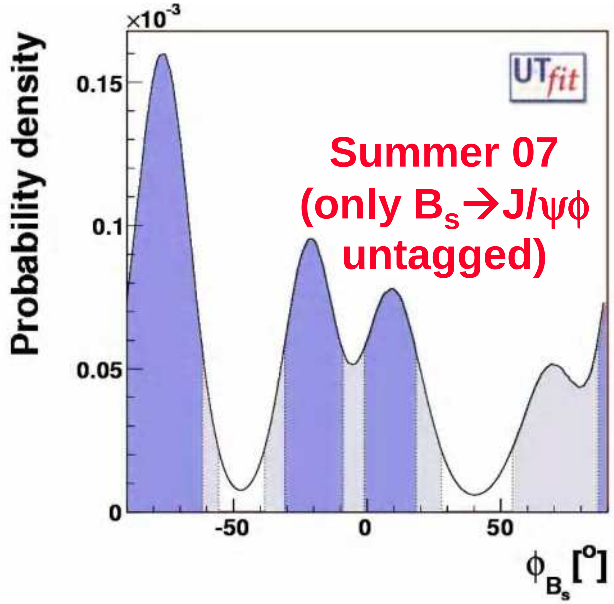


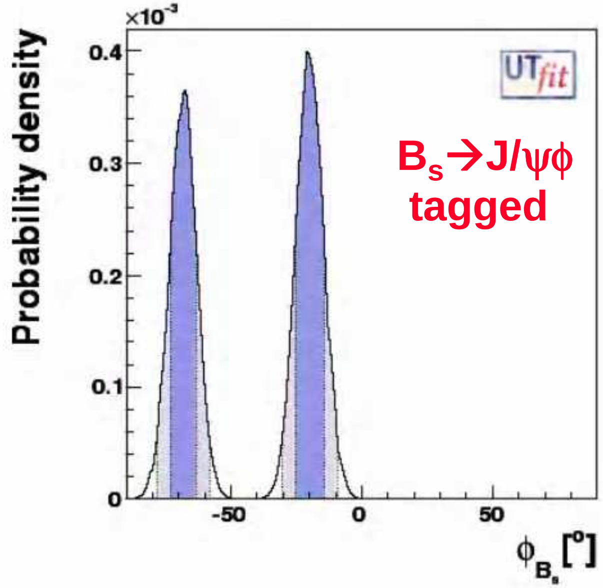
Our analysis (using A_{SL}, A_{CH}, τ_{Bs}, $\Delta\Gamma/\Gamma$)

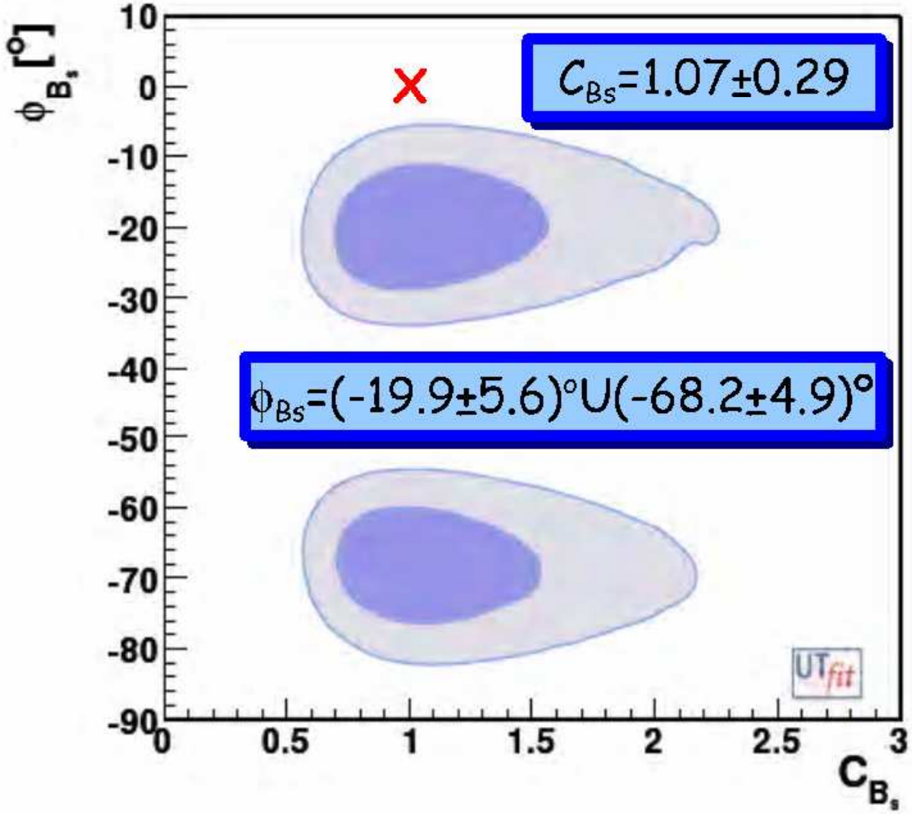


- CDF and D0 measurements consider $\Delta\Gamma$ and β_s as uncorrelated parameters
- In our analysis, we enforce the dependence of $\Delta\Gamma$ from SM and NP parameters
- There is more physics information in our fit than in a simple combination of the two experimental results

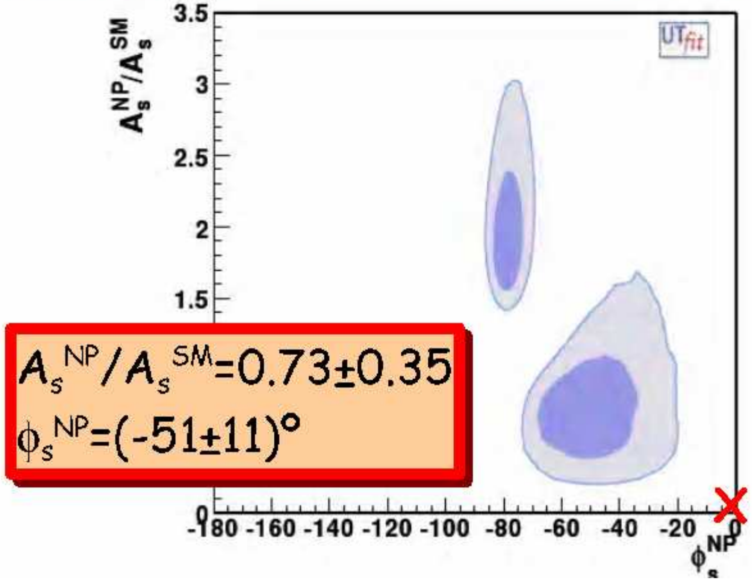








Φ_{Bs} < 0 @99.7% probability
(equivalent to the Gaussian 3σ level)
for any treatment of the DØ data



Conclusions

- The UT apex is nowadays very well known in the Standard Model, but only known at O(10%) in the presence of New Physics in the mixing
- Nevertheless, the inclusion of the Tevatron measurements has led to an evidence of discrepancy with respect to the Standard Model prediction of the B_s mixing phase
- If this evidence will be confirmed by further data…
  - MFV class of models will be ruled out
  - The following pattern of flavour violation in NP would emerge
    - 1 ←→ 2: strong suppression
    - 1 ←→ 3: ≤ O(10%)
    - 2 ←→ 3: O(1)
- Looking forward to new Tevatron results and eventually LHCb to say a final word on this
- A Super B factory would then be very important to enter the 1% era of CKM fits at some point