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Unitarity Triangle Analysis (UTA) within and beyond the SM:

(on behalf of the UTfit Collaboration)

www.utfit.org

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

Status of the UTA within the Standard Model (SM)

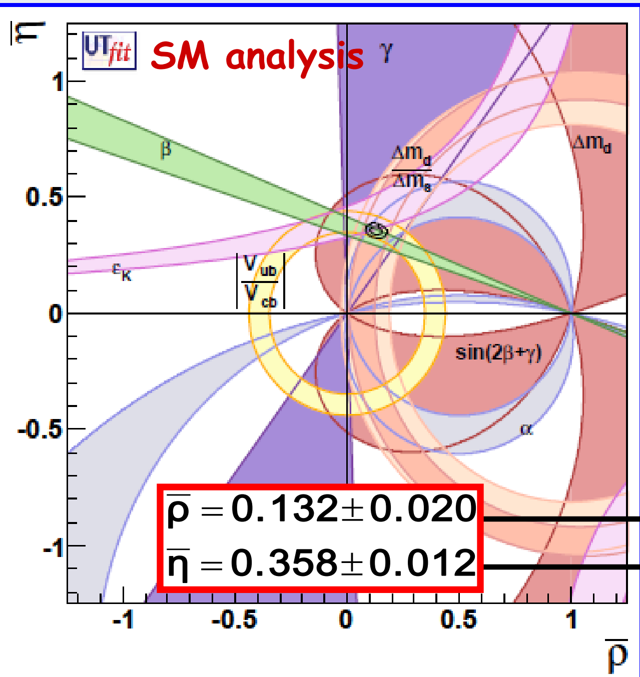
→ high precision and global success (but few tensions: $BR(B \to \tau\, \nu)$, $\sin(2\beta)$, ε_K)

Status of the UTA beyond the SM

→ news on the hint of New Physics (NP) in the B_s system

Cecilia Tarantino
Università Roma Tre and INFN

The UTA within the Standard Model



~16%

~ 3%

The experimental constraints:

$$\varepsilon_K, \Delta m_d, \left|\frac{\Delta m_s}{\Delta m_d}\right|, \left|\frac{V_{ub}}{V_{cb}}\right|$$

⇨ relying on theoretical calculations of hadronic matrix elements

$$\sin 2\beta, \cos 2\beta, \alpha, \gamma (\ \ 2\beta + \gamma)$$

⇨ independent from theoretical calculations of hadronic parameters

overconstrain the CKM parameters consistently

The UTA has established that the CKM matrix is the dominant source of flavour mixing and CP violation

From a closer look

From the UTA
(excluding its exp. constraint) → Prediction

	Prediction	Measurement	Pull
$\sin 2\beta$	0.771 ± 0.036	0.654 ± 0.026	2.6 ←
γ	$69.6° \pm 3.1°$	$74° \pm 11°$	<1
α	$85.4° \pm 3.7°$	$91.4° \pm 6.1°$	<1
$\|V_{cb}\| \cdot 10^3$	42.69 ± 0.99	40.83 ± 0.45	+1.6
$\|V_{ub}\| \cdot 10^3$	3.55 ± 0.14	3.76 ± 0.20	<1
$\varepsilon_K \cdot 10^3$	1.92 ± 0.18	2.230 ± 0.010	-1.7 ←
$BR(B \to \tau \nu) \cdot 10^4$	0.805 ± 0.071	1.72 ± 0.28	-3.2 ←

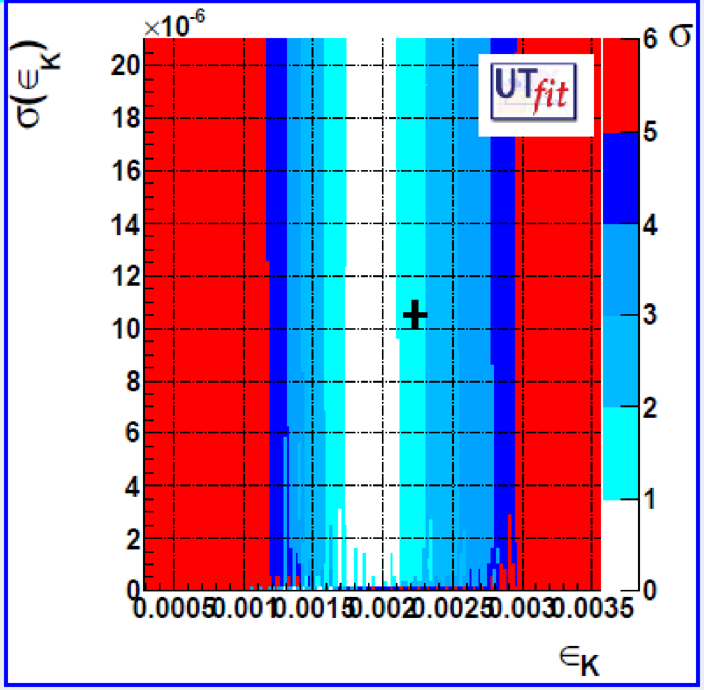
ε_K

Buras&Guadagnoli (0805.3887)+Buras&Guadagnoli&Isidori (1002.3612):

decrease of the SM prediction of ε_K by ~6%

$$\epsilon_K = \sin\phi_\epsilon e^{i\phi_\epsilon}\left[\frac{\mathrm{Im}M_{12}^{(6)}}{\Delta m_K} + \rho\xi\right]$$

Long-distance



Improved accuracy in B_K from Lattice QCD,
thanks to the continuum limit in unquenched studies
(smaller though compatible values w.r.t few years ago)

$$\hat{B}_K = 0.731(7)(35)$$

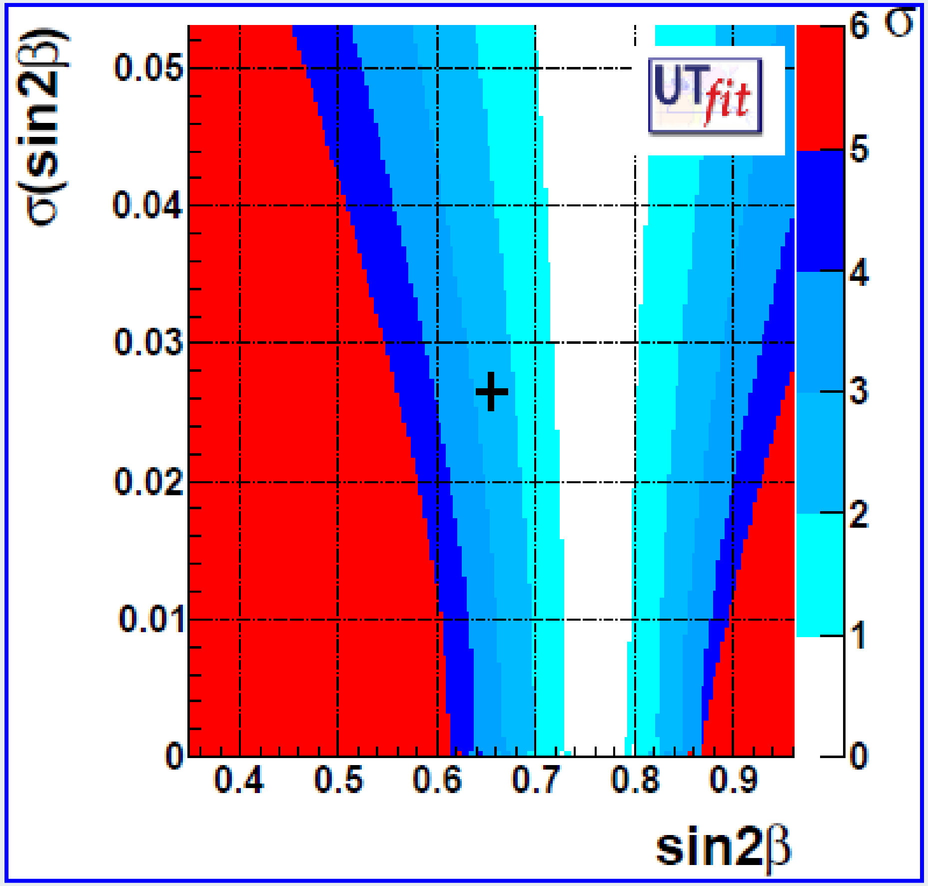
Average by V.Lubicz in PoS Lattice09 (1004.3473)

Lattice '96	$\hat{B}_K = 0.90 \pm 0.03 \pm 0.15$
Lattice '00	$\hat{B}_K = 0.86 \pm 0.06 \pm 0.14$
Lattice '05	$\hat{B}_K = 0.79 \pm 0.04 \pm 0.08$
Lattice '08	$\hat{B}_K = 0.723 \pm 0.037$

NEWS:
Brod&Gorbahn (1007.0684): NNLO QCD analysis of the charm-top contribution in box diagrams
(3% enhancement of ε_K)

NEXT FUTURE:
Further few percents could come from dimension-8 operators: ~m_K^2/m_c^2 corrections (calculation in progress)

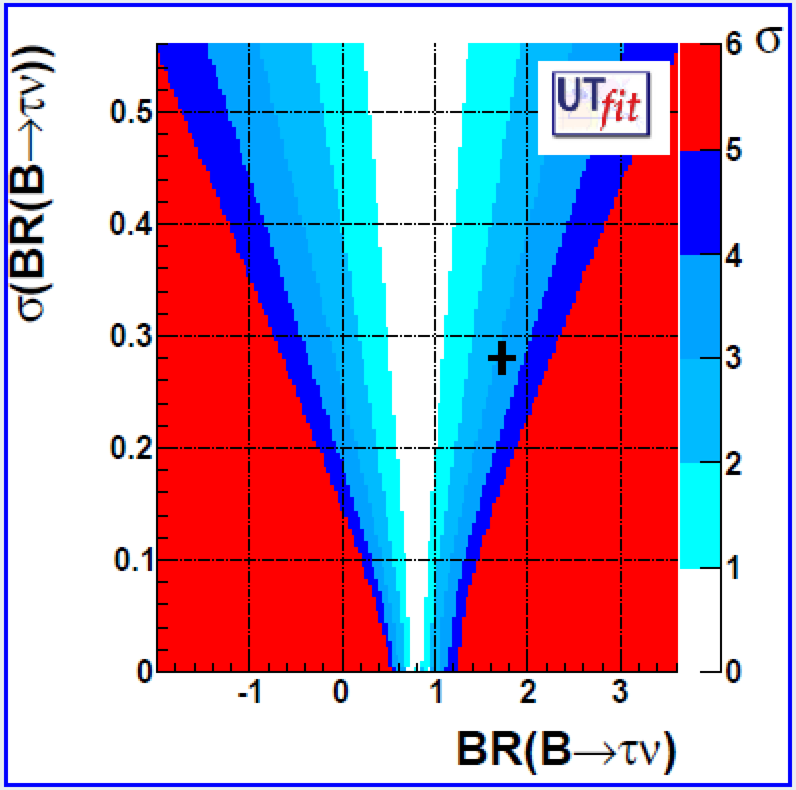
sin2β



The indirect determination of sin(2β) turns out to be at ~2.6 σ from the experimental measurement (the theory error in the extraction from $B \rightarrow J_{\psi} K_S$ is well under control)

$B \to \tau\nu$

$BR(B \to \tau\nu)_{SM} = (0.805\ \ 0.071) \cdot 10^{-4}$
[UTfit, update of 0908.3470]
turns out to be smaller by ~3.2 σ than the experimental value
$BR(B \to \tau\nu)_{exp} = (1.72 \pm 0.28) \cdot 10^{-4}$



The experimental state of the art

BaBar Semileptonic tag (0912.2453)
BaBar Hadronic tag (0708.2260)
[new result is available since YESTERDAY: see talk by Guglielmo De Nardo]

Belle Semileptonic tag (1006.4201) **[full data set analysis is on the way: see talk by Jacek Stypula]**
Belle Hadronic tag (hep-ex/0604018)

$$BR(B \to \tau\nu) = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

- **$BR(B \to \tau\nu)_{exp}$ prefers a large value for $|V_{ub}|$** (**f_B under control and improved by the UTA**)
- **But a shift in the central value of $|V_{ub}|$ would not solve the β tension**

the debate on V_{ub} (excl. vs incl, various models…) is not enough to explain all

The UTA beyond the Standard Model

Update of UTfit 0909.5065

UTfit

Model-independent UTA: bounds on deviations from the SM (+CKM)

- Parametrize generic NP in $\Delta F=2$ processes, in all sectors
- Use all available experimental info
- Fit simultaneously the CKM and NP parameters

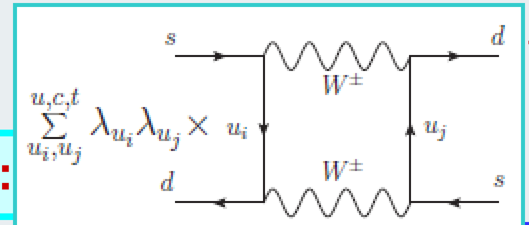
From this (NP) analysis:

$$\bar\rho = 0.135 \pm 0.040$$
$$\bar\eta = 0.374 \pm 0.026$$

In good agreement with the results from the SM analysis

$$\bar\rho = 0.132 \pm 0.020$$
$$\bar\eta = 0.358 \pm 0.012$$

NP contributions in the mixing amplitudes:



$$H^{\Delta F=2} = m + \frac{i}{2}\Gamma \qquad A = m_{12} = \langle M | m | \bar{M} \rangle \qquad \Gamma_{12} = \langle M | \Gamma | \bar{M} \rangle$$

K mixing amplitude (2 real parameters):

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

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

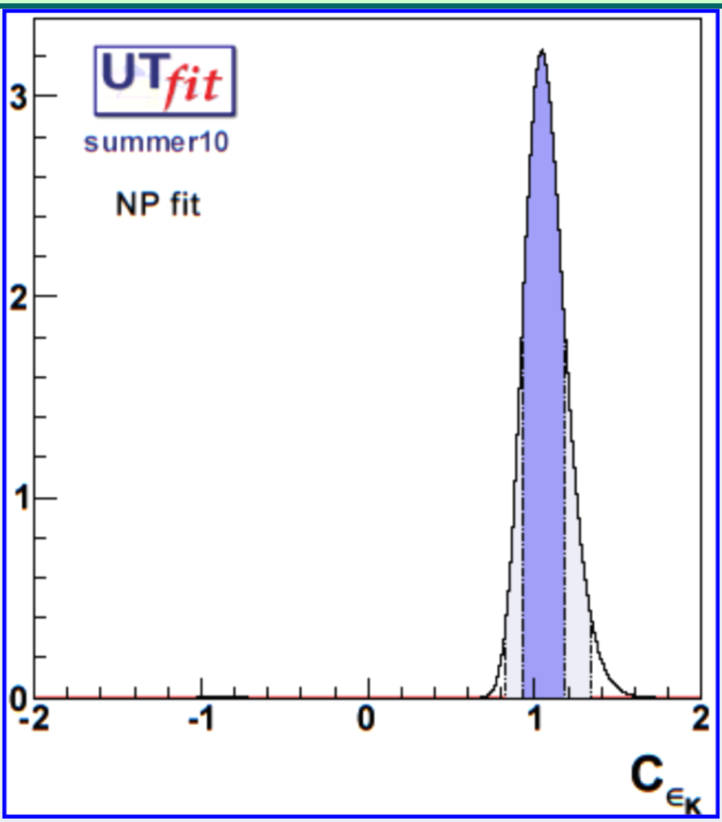
$$A_q e^{2i\phi_q} = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_q^{SM}} = \left(1 + \frac{A_q^{NP}}{A_q^{SM}} e^{2i(\phi_q^{NP} - \phi_q^{SM})}\right) A_q^{SM} e^{2i\phi_q^{SM}}$$

SM	→	SM+NP
$(V_{ub}/V_{cb})^{SM}$, γ^{SM}	tree level	$(V_{ub}/V_{cb})^{SM}$, γ^{SM}
β^{SM}, α^{SM}, Δm_d	*Bd Mixing*	$\beta^{SM}+\phi_{Bd}$, $\alpha^{SM}-\phi_{Bd}$, $C_{Bd}\Delta m_d$
Δm_s^{SM}, $-\beta_s^{SM}$	*Bs Mixing*	$C_{Bs}\Delta m_s^{SM}$, $-\beta_s^{SM}+\phi_{Bs}$
ε_K^{SM}, Δm_K^{SM}	*K Mixing*	$C_{\varepsilon K}\,\varepsilon_K^{SM}$, $C_{\Delta mK}\,\Delta m_K^{SM}$

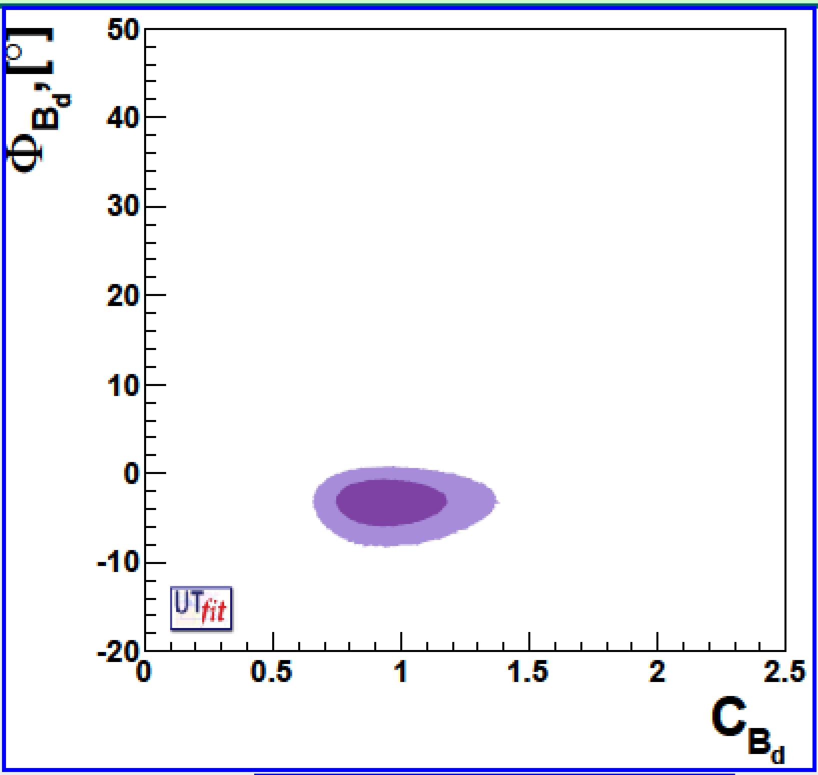
Results for the K and B_d mixing amplitudes

For K-$\bar{K}$ mixing, the NP parameters are found in agreement with the SM expectations

For B_d-$\bar{B}_d$ mixing, the mixing phase ϕ_{Bd} is found 1.8 σ away from the SM expectation (reflecting the tension in sin2β)



$$C_{\varepsilon_K} = 1.05 \pm 0.12$$
$$([0.82, 1.34] \leftrightarrow 95\%)$$



$$C_{B_d} = 0.95 \pm 0.14$$
$$([0.70, 1.27] \leftrightarrow 95\%)$$
$$\Phi_{B_d} = (-3.1 \pm 1.7)^\circ$$
$$([-7.0, 0.1]^\circ \leftrightarrow 95\%)$$

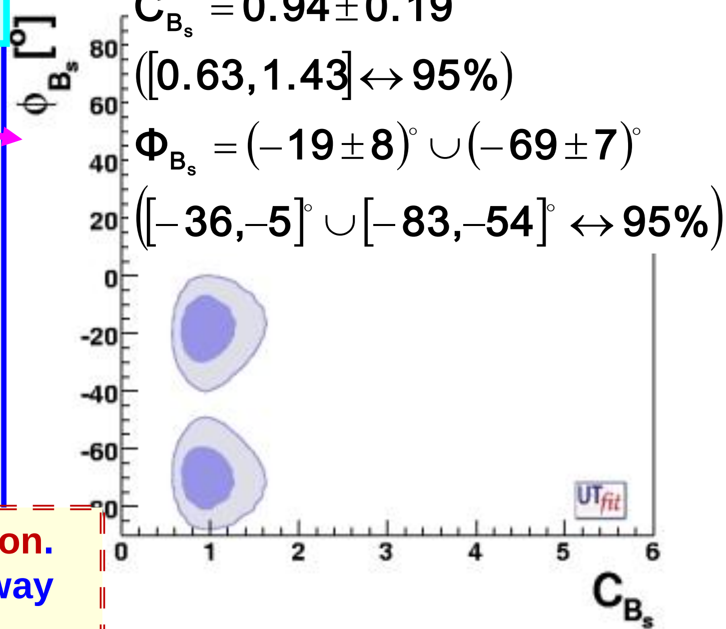
Results for the B_s mixing amplitude: INTERESTING NEWS ⟹ NEW QUESTION MARKS

In 2009, by combining CDF and DØ results for ϕ_{Bs}:

UTfit: 2.9σ (update of 0803.0659)
HFAG: 2.2σ (0808.1297)
CKMfitter: 2.5σ (0810.3139)
Tevatron B w.g.: 2.1σ (http://tevbwg.fnal.gov)

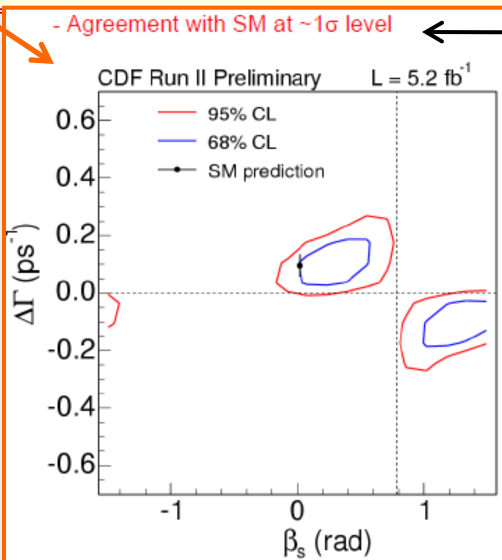
More than 2σ deviation for every statistical approach!

$C_{B_s} = 0.94 \pm 0.19$
$([0.63, 1.43] \leftrightarrow 95\%)$
$\Phi_{B_s} = (-19 \pm 8)^\circ \cup (-69 \pm 7)^\circ$
$([-36,-5]^\circ \cup [-83,-54]^\circ \leftrightarrow 95\%)$



In 2010, two surprising news:

The new CDF measurement reduces the significance of the deviation.
The likelihood is not yet available, a CDF Bayesian study is underway
See talk by Gavril Giurgiu

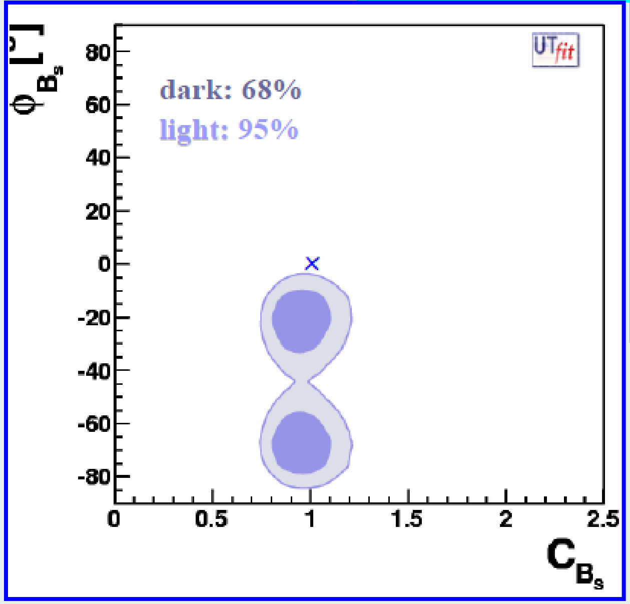


← Before it was 1.8 σ

The new DØ measurement of $a_{\mu\mu}$ points to large β_s but also to large $\Delta\Gamma_s$ requiring a non-standard Γ_{12} ?!?!?
If confirmed, two (UNLIKELY) explantions:
- Huge (tree-level-like) NP contributions in Γ_{12} (a factor 2.5: why only in Γ_{12}??)
- Bad failure of the OPE in Γ_{12} (while in Γ_{11} (b-hadron lifetimes) works well)

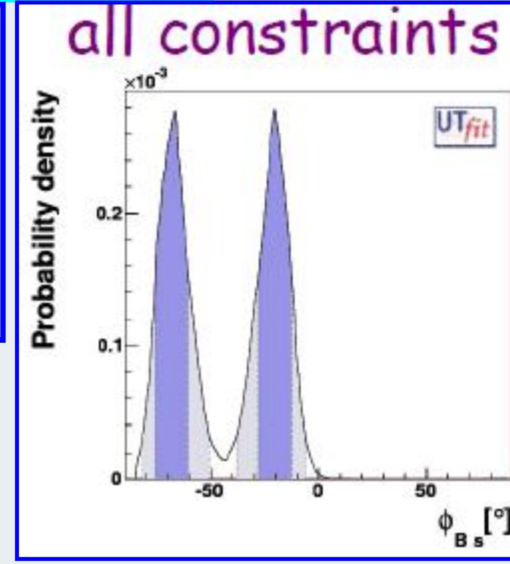
See talks by Bruce Hoeneisen and by Gilad Perez

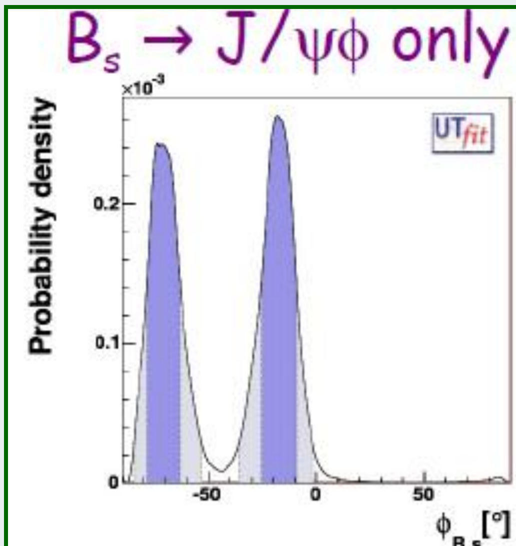
Updated Results including NEW DØ results
(new CDF results are not yet available)

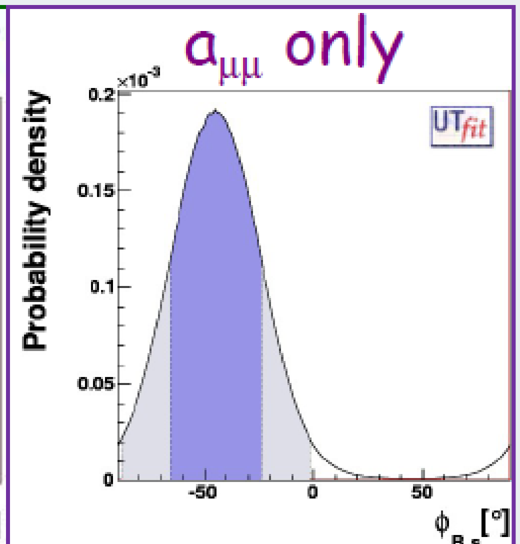


$$C_{B_s} = 0.95 \pm 0.10$$
$$([0.78, 1.16] \leftrightarrow 95\%)$$
$$\Phi_{B_s} = (-20 \pm 8)^\circ \cup (-68 \pm 8)^\circ$$
$$([-38, -6]^\circ \cup [-81, -51]^\circ \leftrightarrow 95\%)$$

Deviation from the SM at 3.1σ







$a_{\mu\mu}$ and $B_s \to J/\Psi\ \phi$ point to large but different values of ϕ_{Bs} (N.B. the UTA beyond the SM allows for NP in loops only, i.e. tree-level NP in Γ_{12} is not allowed)

Further confirmations from experiments are looked forward!

Some information and propaganda:

New UTfit website is now available at

www.utfit.org