B → K

Hints of New Physics in b→s transitions

(or)

Looking for New Physics in Flavour Physics in quark sector

Achille Stocchi
LAL Orsay
Université Paris Sud/IN2P3-CNRS

24 September 2008
DESY-Zeuthen

UTfit

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

www.utfit.org

Flavour Physics in the *Standard Model* (SM) in the quark sector:

~ half of the *Standard Model*

10 free parameters

6 quarks masses

4 CKM parameters

Wolfenstein parametrization : $\boldsymbol{\lambda}$,**A**, $\boldsymbol{\bar{\rho}}$, $\boldsymbol{\bar{\eta}}$

$\boldsymbol{\eta}$ responsible of CP violation in SM

In the Standard Model, charged weak interactions among quarks are codified in a 3 X 3 unitarity matrix : the **CKM Matrix**.

The existence of this matrix conveys the fact that the quarks which participate to weak processes are a linear combination of mass eigenstates

The fermion sector is poorly constrained by SM + Higgs Mechanism

mass hierarchy and CKM parameters

The Unitarity Triangle

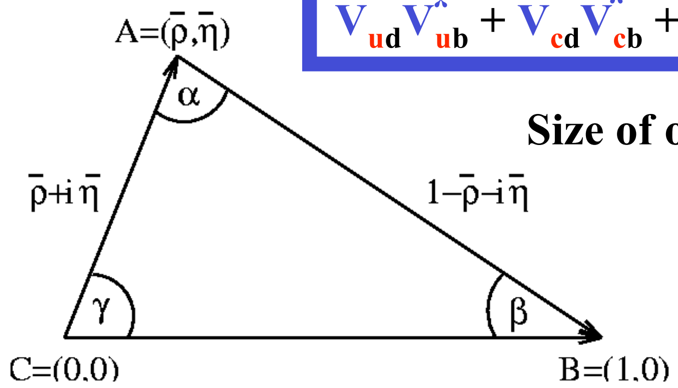
The CKM is unitary

CKM matrix

Wolfenstein parameterization:

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

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



Size of order $\lambda^3 : \lambda^3 : \lambda^3$

$$\overline{AB} = \frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*} = \sqrt{(1-\bar{\rho})^2 + \bar{\eta}^2} = \frac{1}{\lambda}\left|\frac{V_{td}}{V_{cb}}\right| \sim \frac{1}{\lambda}\left|\frac{V_{td}}{V_{ts}}\right|$$

$$\overline{AC} = \frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*} = \sqrt{\bar{\rho}^2 + \bar{\eta}^2} = \left(1 - \frac{\lambda^2}{2}\right)\frac{1}{\lambda}\left|\frac{V_{ub}}{V_{cb}}\right|$$

$$\beta = \arg\left(\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right) = \operatorname{atan}\left(\frac{\bar{\eta}}{(1-\bar{\rho})}\right)$$

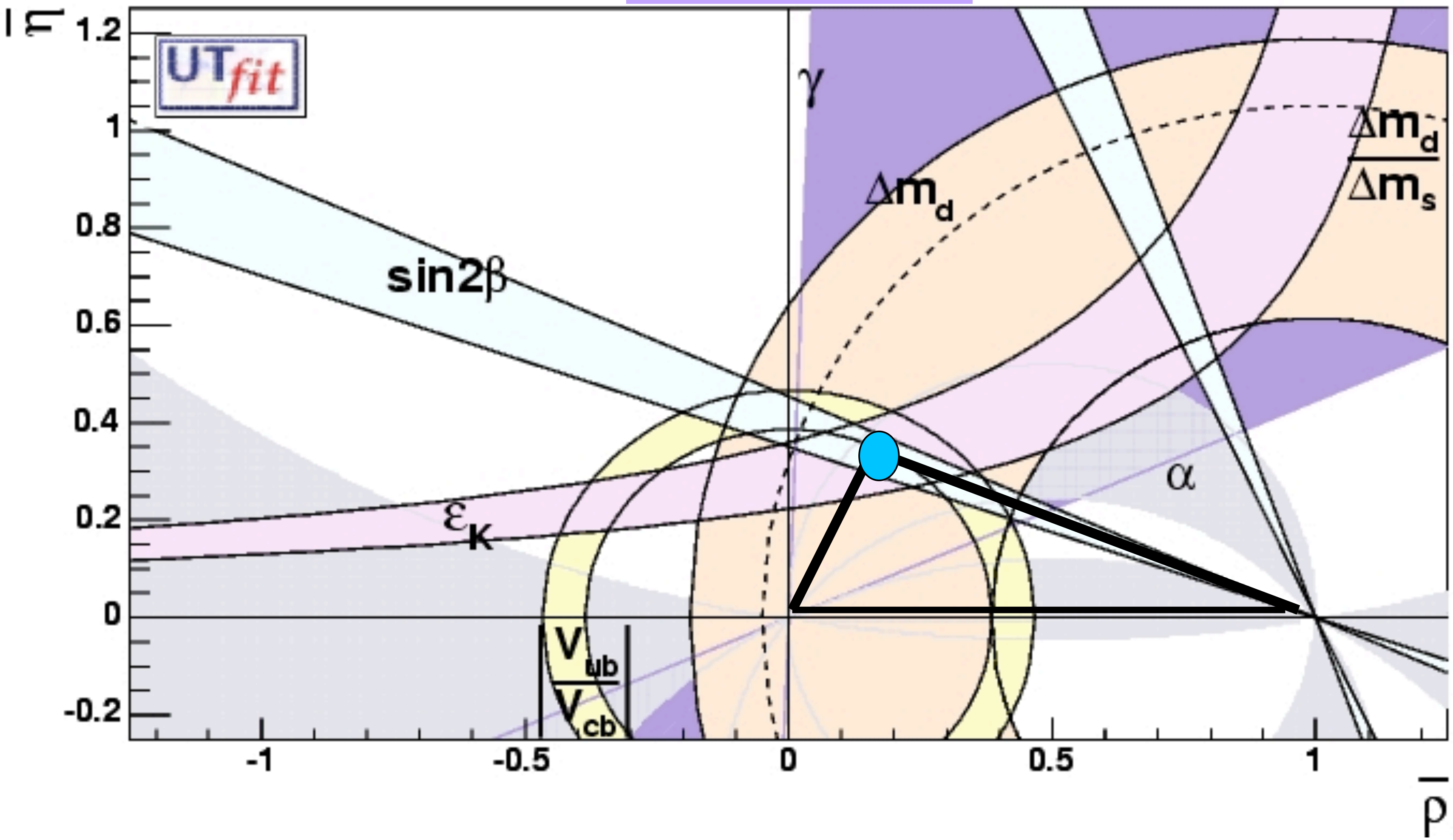
$$\gamma = \arg\left(\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) = \operatorname{atan}\left(\frac{\bar{\eta}}{\bar{\rho}}\right)$$

$$\alpha + \beta + \gamma = \pi$$

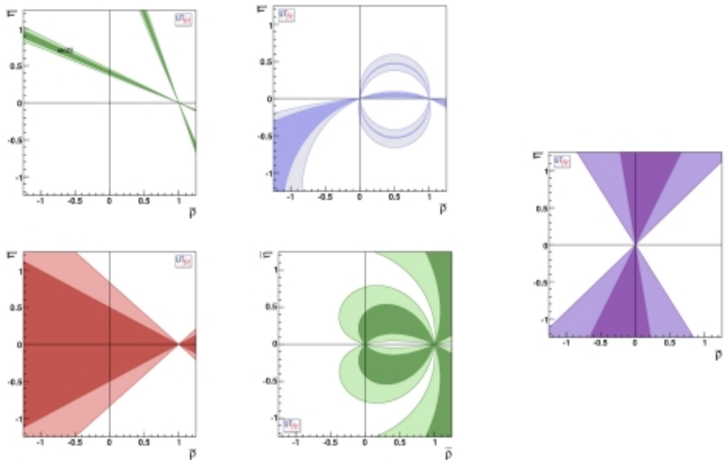
(b→u)/(b→c)	$\bar{\rho}^2 + \bar{\eta}^2$	**f_+,F(1),…**
Δm_d	$(1-\bar{\rho})^2 + \bar{\eta}^2$	$f_{B_d}^2 B_{B_d}$
$\Delta m_d / \Delta m_s$	$(1-\bar{\rho})^2 + \bar{\eta}^2$	ξ
ε_K	$\bar{\eta}[(1-\bar{\rho}) + P]$	B_K
β	$\operatorname{atan}(\bar{\eta}/(1-\bar{\rho}))$	-
γ	$\operatorname{atan}(\bar{\eta}/\bar{\rho})$	-

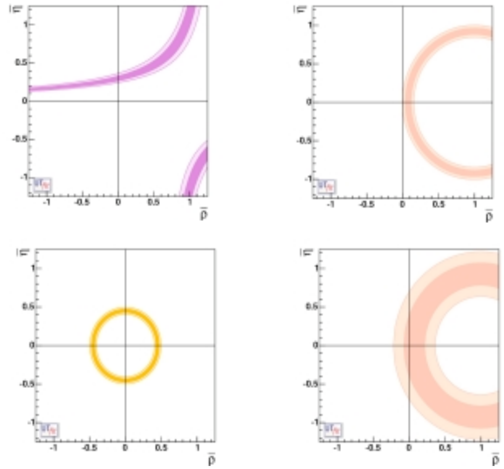
An example on how to fit the UT parameters and fit new physics

B→DK : ϕ_3/γ



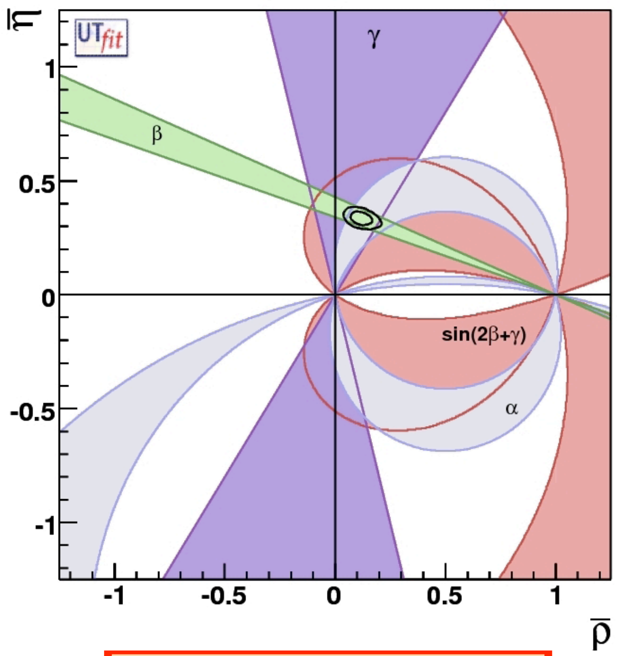
Fit with the Standard Model (SM)





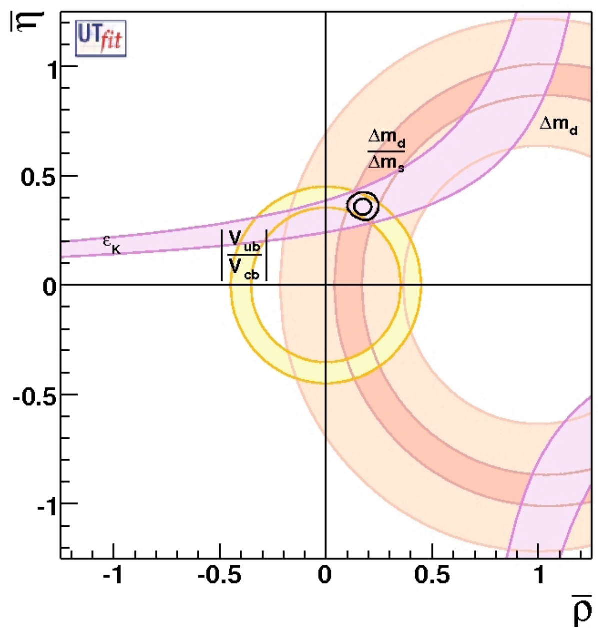
function(ρ,η….)

Angles



$\rho = \mathbf{0.120 \pm 0.034}$

$\eta = \mathbf{0.335 \pm 0.020}$



Sides + ε_K

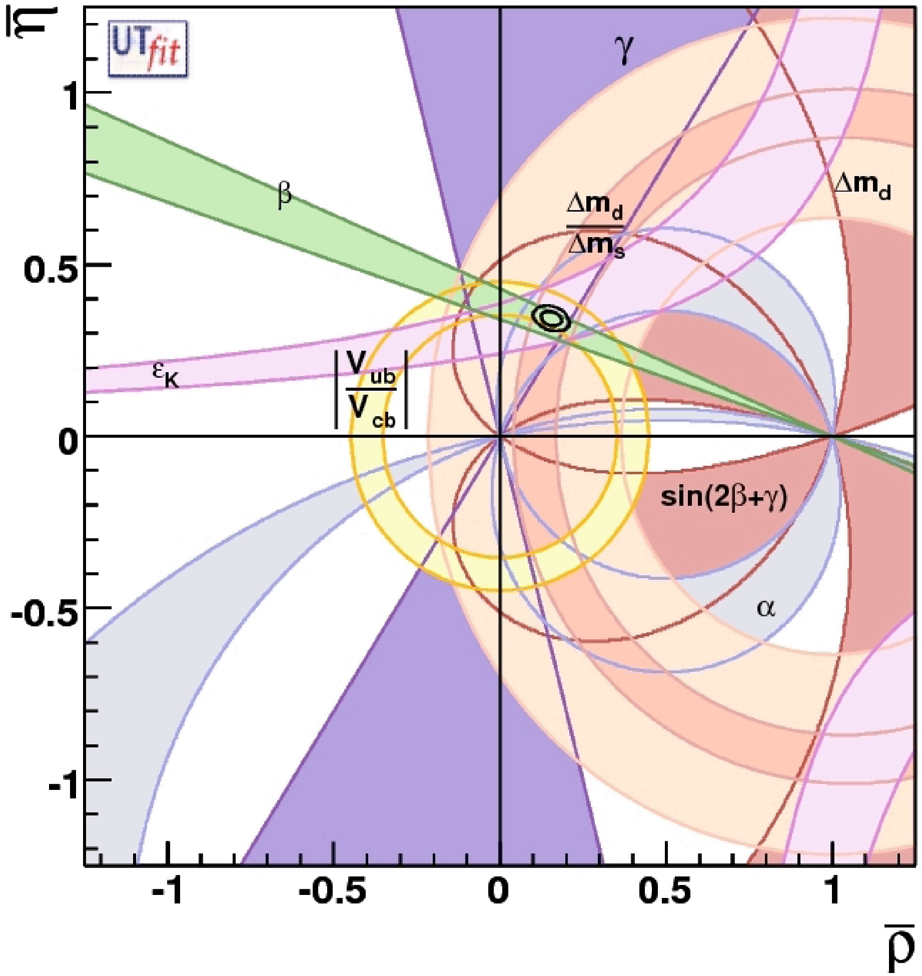
$\rho = \mathbf{0.175 \pm 0.027}$

$\eta = \mathbf{0.360 \pm 0.023}$

SM Fit

Global Fit

$\Delta m_d, \Delta m_s, V_{ub}, V_{cb}, \varepsilon_k + \cos 2\beta + \beta + \alpha + \gamma + 2\beta + \gamma$



Tremendous success of the CKM picture

$\overline{\rho} = 0.155 \pm 0.022$

$\overline{\eta} = 0.342 \pm 0.014$

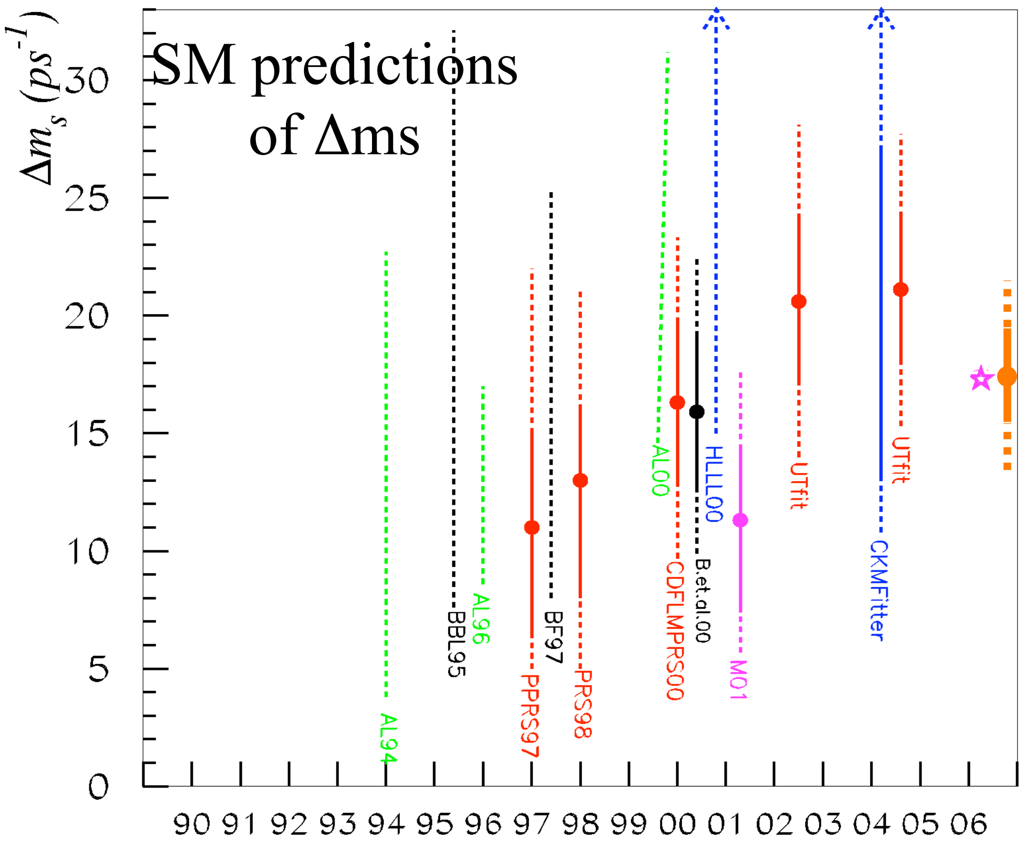
Should we stop here ?

How to look for NP ?
And in case of no observation to establish how much room is left for NP effects…?

Long story…
Some example in next 4 transparencies..

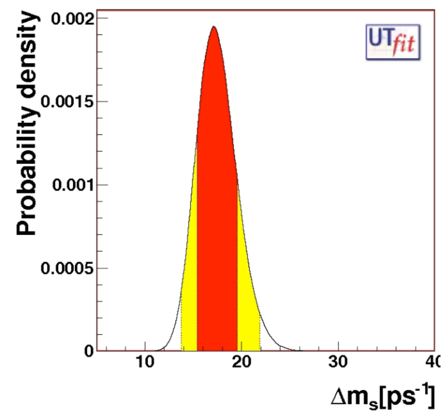
some specific example of NP tests..

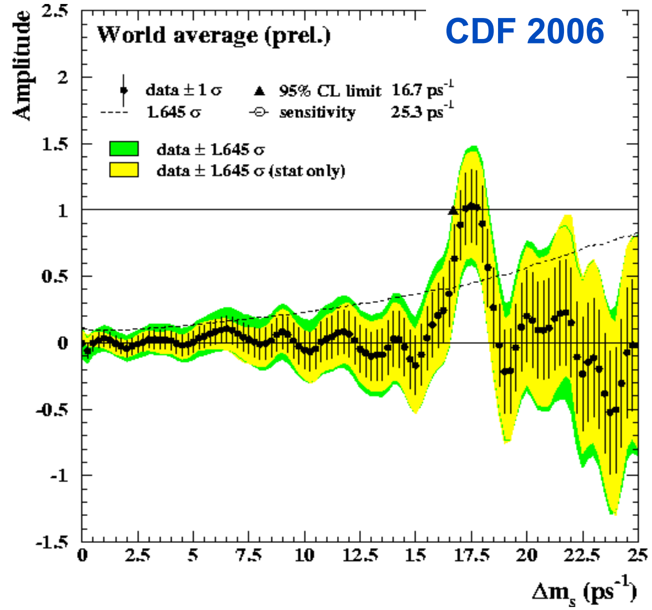
Δm_s



SM expectation

$\Delta m_s = (17.5 \pm 2.1\ )\ ps^{-1}$



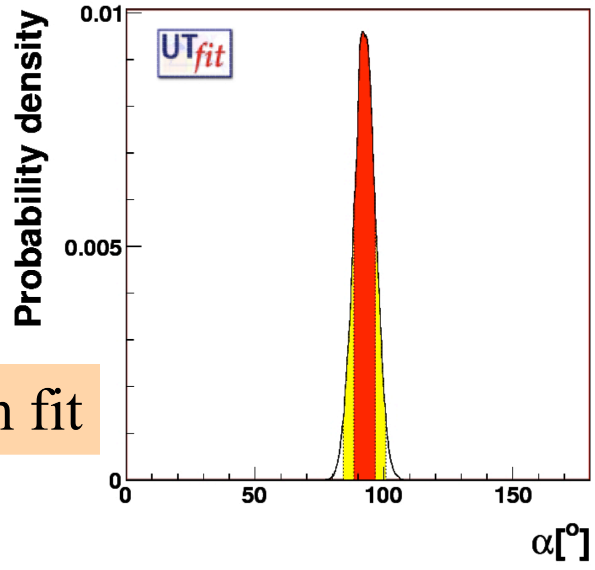


CDF only : signal at 5σ

$\Delta\ m_s = (17.77 \pm 0.12)\ ps^{-1}$

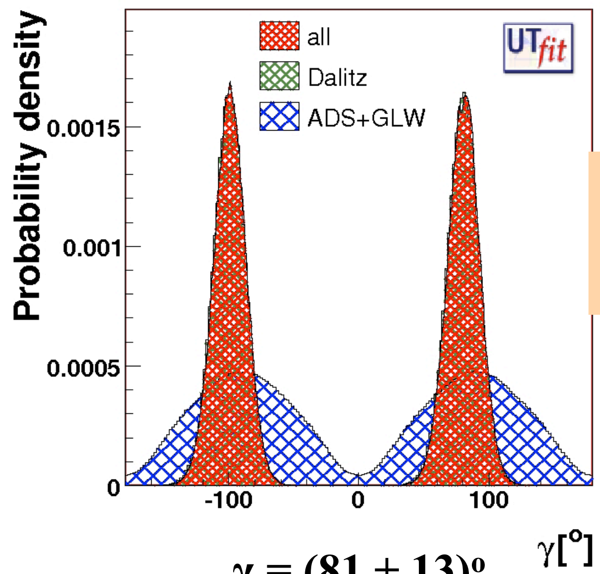
Tevatron results
Limited by Lattice calculations

γ



From fit

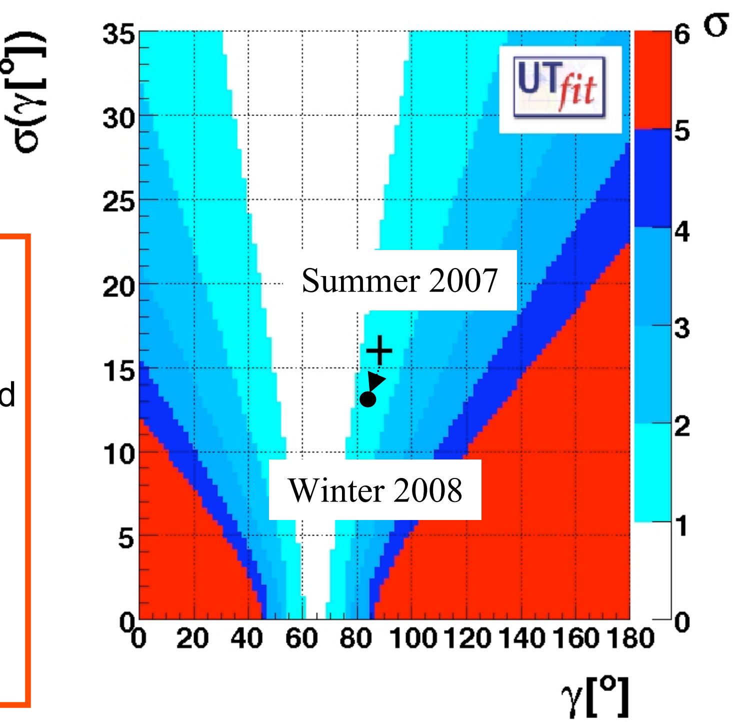
$\gamma = (64.0 \pm 3.0)^{o}$



Direct measurement

$\gamma = (81 \pm 13)^{o}$

(up to π ambiguity)



Legenda

agreement between the predicted values and the measurements at better than :

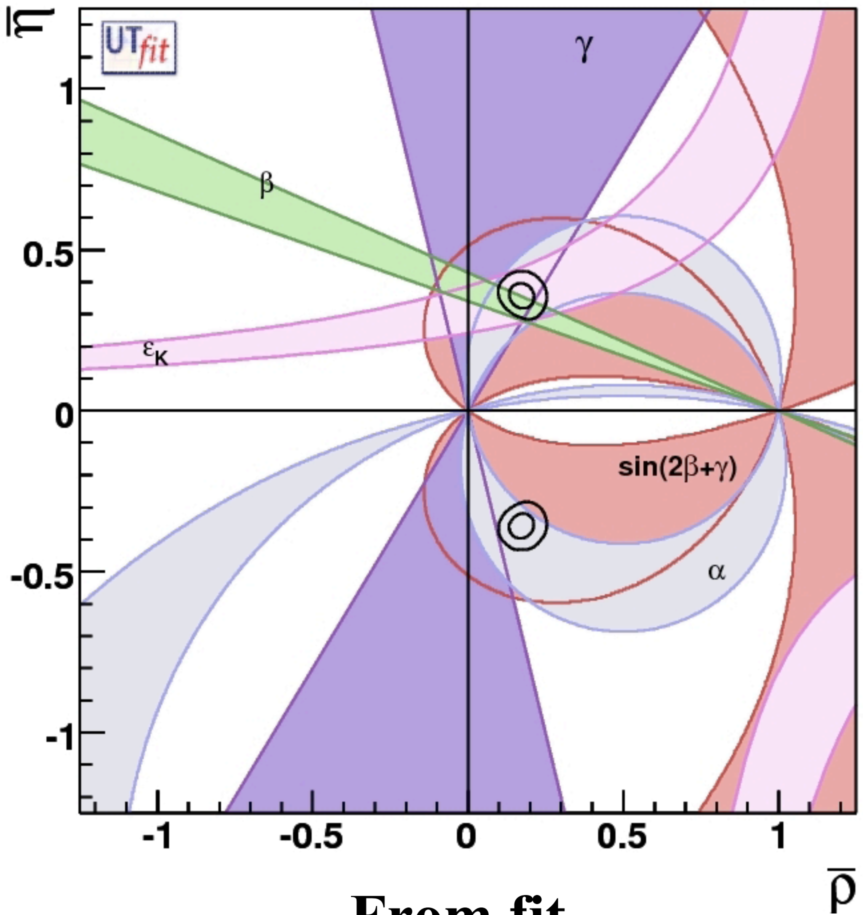
1σ 3σ 5σ

2σ 4σ 6σ

B factories results

LHCb expected to contribute

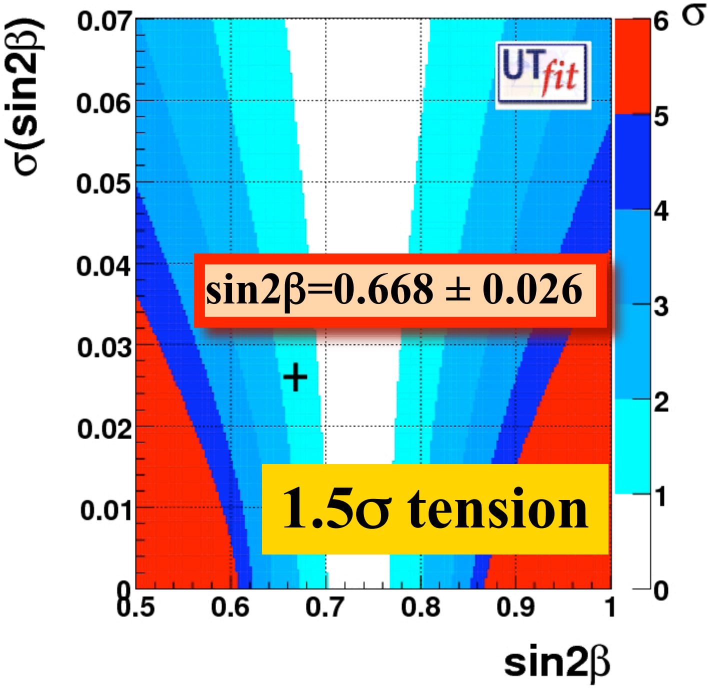
$\sin 2\beta$ vs V_{ub}

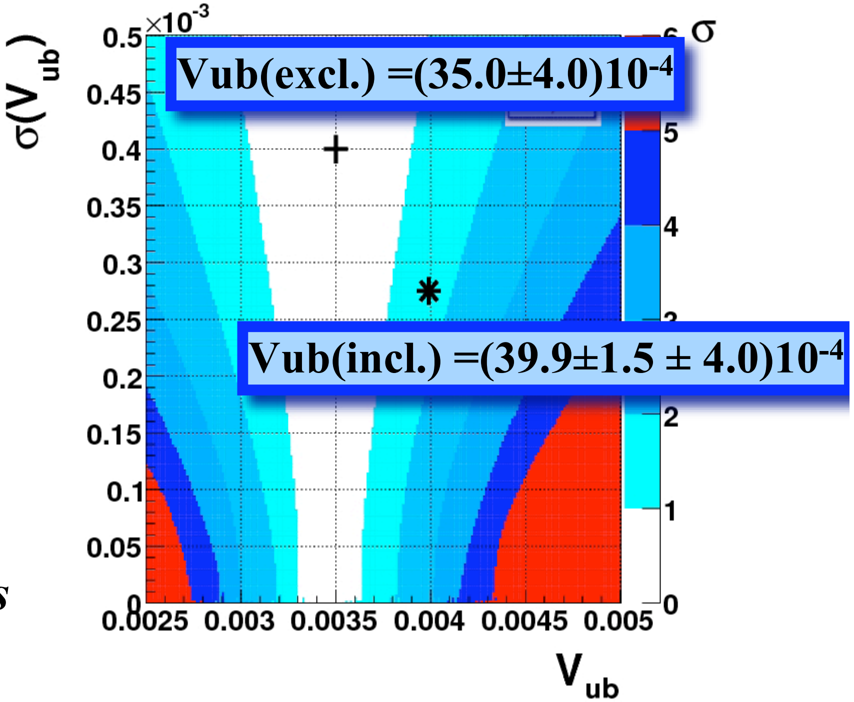


From fit

$\sin 2\beta = 0.736 \pm 0.034$

$V_{ub} = (34.8 \pm 1.6) 10^{-4}$





B factories results

Flavour Physics measure

coupling $\frac{|\delta|}{\Lambda_{eff}}$

Mass scale

NP physics could be always arround the corner

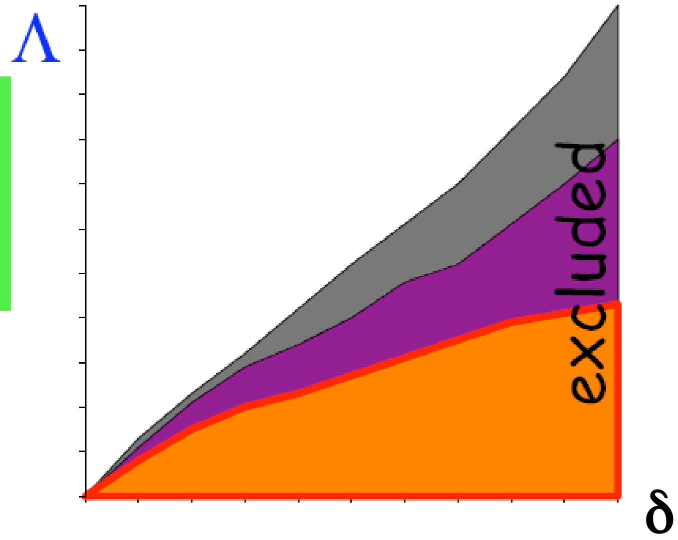
WHAT IS REALLY STRANGE IS
THAT WE DID NOT SEE ANYTHING….

With masses of New Particles at few hundred GeV
effects on measurable quantities should be important

Problem known as the FLAVOUR PROBLEM

Λ_{eff} <~ 1TeV + flavour-mixing protected by additional symmetries (as MFV)

Couplings can be still large if Λ_{eff} > 1..10..TeV



If there is NP at scale Λ, it will generate new operator of dimension D with coefficients proportional to Λ^{4-D}

only operator of D=6 contribute. So that in fact you have a dependence on $1/\Lambda^2$

Today we concentrate on a
Model Independent fit to $\Delta F=2$ observable
which show a 2.5σ evidence of NP
in the $b \rightarrow s$ transitions

Fit in a NP model independent approach

ΔF=2

Parametrizing NP physics in ΔF=2 processes

$$\boxed{C_q e^{2i\phi_d} = \frac{Q^{NP}_{\Delta B=2} + Q^{SM}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}}$$

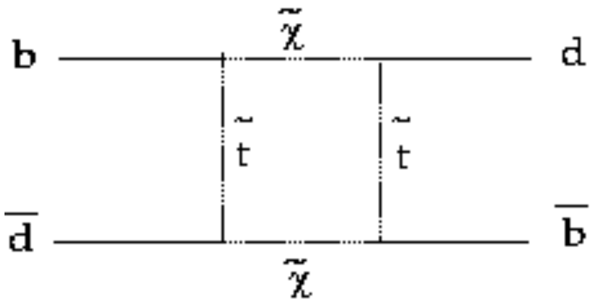
Soares, Wolfenstein PRD47;
Deshpande,Dutta, Oh PRL77;
Silva, Wolfenstein PRD55;
Cohen et al. PRL78;
Grossman, Nir, Worah PLB407;
Ciuchini et al. @ CKM Durham

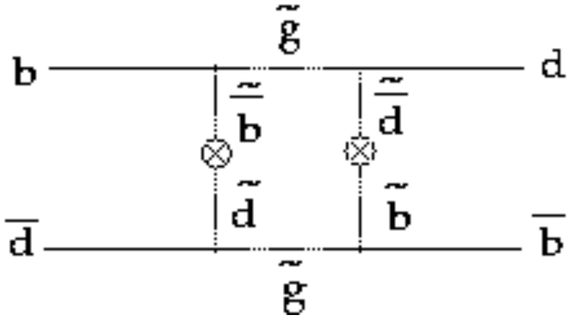
$\Delta m_d^{EXP} = C_{B_d} \Delta m_d^{SM}$	$f(\rho,\eta,C_{B_d},QCD..)$
$A_{CP}(J/\Psi,K^0) = \sin(2\beta + 2\phi_{B_d})$	$f(\rho,\eta,\phi_{B_d})$
$\alpha^{EXP} = \alpha^{SM} - \phi_{B_d}$	$f(\rho,\eta,\phi_{B_d})$
$\lvert\varepsilon_K\rvert^{EXP} = C_\varepsilon \lvert\varepsilon_K\rvert^{SM}$	$f(\rho,\eta,C_\varepsilon,QCD..)$
$\Delta m_s^{EXP} = C_{B_s} \Delta m_s^{SM}$	$f(\rho,\eta,C_{Bs},QCD..)$
$A_{CP}(J/\Psi,\phi) = \sin(2\beta_s - 2\phi_{B_s})$	$f(\rho,\eta,\phi_{B_s})$
...	

To help with a more specific example :

Using the example of the Supersymmetry

Example for B oscillations (FCNC-$\Delta B=2$) :





$$\left|\frac{Q^{NP}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}\right| \leq p_r \quad \rightarrow \quad \frac{|\delta_{bq}|}{\Lambda_{eff}} \leq \sqrt{p_r}\,\frac{|V^*_{tb}V_{tq}|}{M_W}$$

p_r upper limit of the relative contribution of NP

δ_{bd} NP physics coupling

Λ_{eff} NP scale (masses of new particles)

If couplings ~ 1

$\delta_{bq} \sim 1$ $\Lambda_{eff} \sim 10/\sqrt{p_r}$ TeV

$\delta_{bs} \sim 1$ $\Lambda_{eff} \sim 2/\sqrt{p_r}$ TeV

all possible intermediate possibilities

$\delta_{bq} \sim 0.1$ $\Lambda_{eff} \sim 1/\sqrt{p_r}$ TeV

$\delta_{bs} \sim 0.1$ $\Lambda_{eff} \sim 0.2/\sqrt{p_r}$ TeV

Minimal Flavour Violation

$$\delta_{q'd} \approx V^*_{tq'}V_{td}$$

(couplings small as CKM elements)

$\Lambda_{eff} \sim 0.08/\sqrt{p_r}$ TeV

Oversimplified picture : for a quantitative analysis see for instance

UTfit collaboration

JHEP 0803:049,2008 *arXiv:0707.0636*

Constraints

		ρ , η	C_d	φ_d	C_s	φ_s	$C_{\varepsilon K}$
Tree processes	γ (DK)	X					
	V_{ub}/V_{cb}	X					
1↔3 family	Δm_d	X	X				
	ACP (J/Ψ K)	X		X			
	ACP (Dπ(ρ),DKπ)	X		X			
	A_{SL}		X	X			
	α (ρρ,ρπ,ππ)	X		X			
	A_{CH}		X	X	X	X	
2↔3 family	$\Delta\Gamma_s/\Gamma_s$				X	X	
	Δm_s				X		
	ASL(Bs)				X	X	
	ACP (J/Ψ φ)	~X				X	
1↔2 familiy	ε_K	X					X

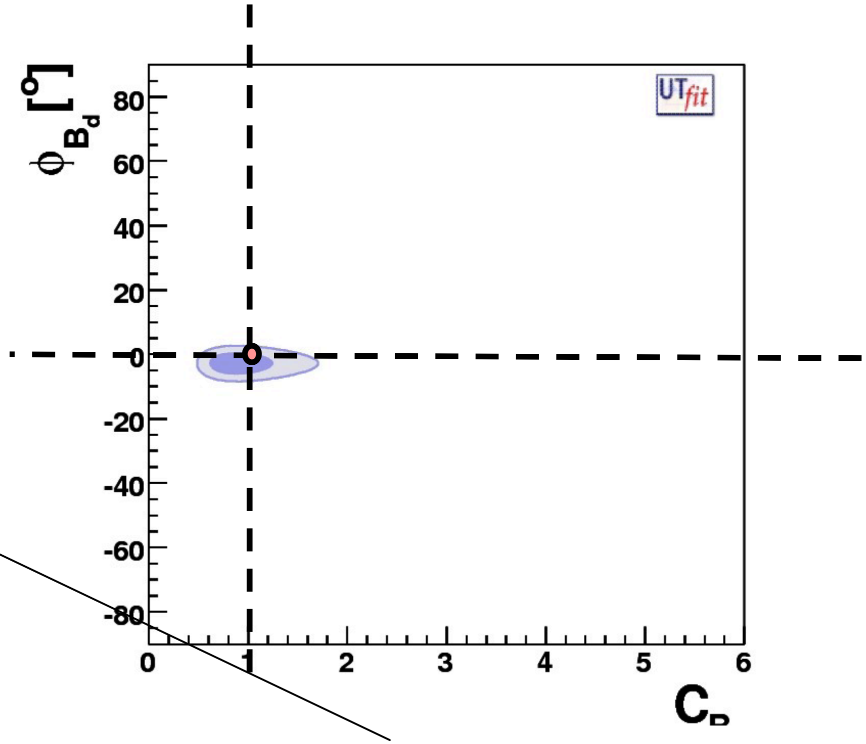
5 new free parameters
C_s,φ_s B_s mixing
C_d,φ_d B_d mixing
$C_{\varepsilon K}$ K mixing

Today :
fit possible with <u>10 contraints</u>
and <u>7 free parameters</u>
(ρ, η, C_d,φ_d ,C_s,φ_s, $C_{\varepsilon K}$)

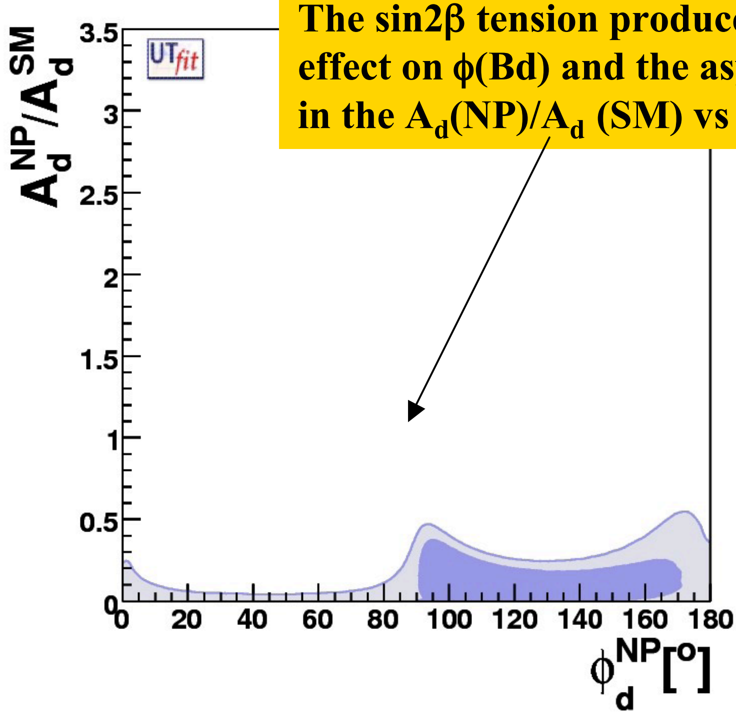
B_d

$C_{Bd} = 0.96 \pm 0.23$

$\phi_{Bd} = -(2.9 \pm 1.9)^o$



The sin2β tension produces a 1.5σ effect on ϕ(Bd) and the asymmetry in the A_d(NP)/A_d (SM) vs ϕ(NP) plot



A_{NP}/A_{SM} vs ϕ_{NP}

$$C_{B_d} e^{2i\phi_{B_d}} = \frac{A_{\rm SM} e^{2i\beta} + A_{\rm NP} e^{2i(\beta+\phi_{\rm NP})}}{A_{\rm SM} e^{2i\beta}}$$

With present data A_{NP}/A_{SM}=0 @ 1.5σ

A_{NP}/A_{SM} ~1 only if ϕ_{NP}~0
A_{NP}/A_{SM} ~0-30% @95% prob.

B_d

Actual sensitivity
for a generic NP phase
in the Bd sector
$r = A_{NP}/A_{SM} \sim 10\text{-}15\%$

This is not yet a prove that if NP should be MFV violating

Just for showing the link between precision and mass scale

$$\left|\frac{Q^{NP}_{\Delta B=2}}{Q^{SM}_{\Delta B=2}}\right| \le r \quad \rightarrow \quad \frac{|\delta_{bq}|}{\Lambda_{eff}} \le \sqrt{r}\,\frac{|V^*_{tb}V_{tq}|}{M_W}$$

r upper limit of the relative contribution of NP

δ_{bd} NP physics coupling

Λ_{eff} NP scale (masses of new particles)

Take a case where $\delta_{q'd} \approx V^*_{tq'}V_{td}$ ➡ $\Lambda_{eff} \sim 80/\sqrt{r}$ GeV ➡ $\Lambda_{eff} \sim (200\text{-}250)$ GeV

MORE PRECISION IS NEEDED

B_s sector : very recent results

B_s

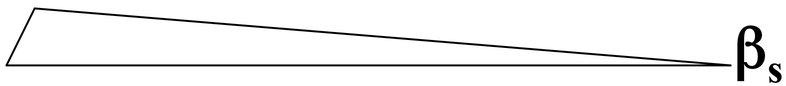
	ρ , η	C_d	φ_d	C_s	φ_s	
A_{CH}		X	X	X	X	**D0,CDF (2006-2007)**
$\tau(Bs)$,$\Delta\Gamma_s/\Gamma_s$				X	X	**CDF, D0, LEP**
Δm_s				X		**CDF (~2006),D0, LEP**
ASL(Bs)				X	X	**D0 (2007)**
ACP (J/Ψ φ)	~X				X	**D0,CDF (2007-2008)**

The realm of Tevatron

$$\beta_s = \arg\left(\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right) = (1.03 \pm 0.06)^\circ$$

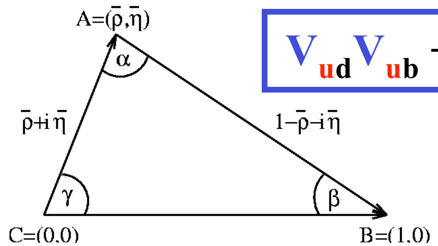
$$\mathbf{V_{td}V_{cd} + V_{ts}V_{cs} + V_{tb}V_{cb} = 0}$$

$\lambda^2\ \lambda^4\ \lambda^4$



Recall that in B_d sector

$$\beta = \arg\left(\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}\right) = (21.8 \pm 0.7)^\circ$$



$$\mathbf{V_{ud}V_{ub} + V_{cd}V_{cb} + V_{td}V_{tb} = 0}$$

$\lambda^3\ \lambda^3\ \lambda^3$

ϕ_s vs of $\Delta\Gamma_s$ using $B_s \rightarrow J/\psi\phi$

Nota bene
for the experimental result
$\phi_s = -2\beta_s$

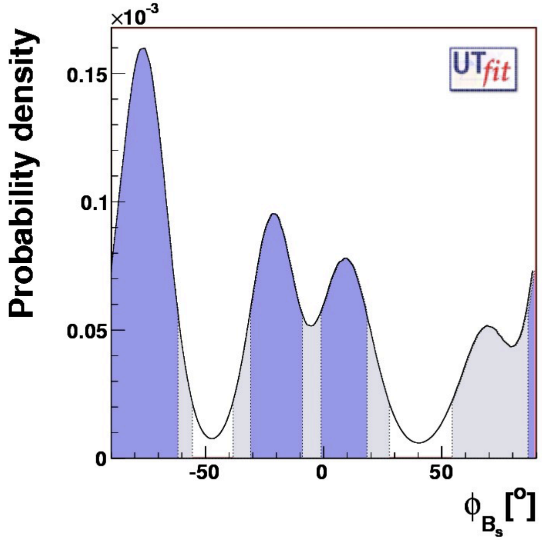
Angular (θ,φ,ψ) analysis as a function of the **proper time**.
Similar to measurement of β in $B_d \rightarrow J/\psi\ K^*$.
Respect to the B_d case, there is additional sensitivity because of $\Delta\Gamma_s$ term

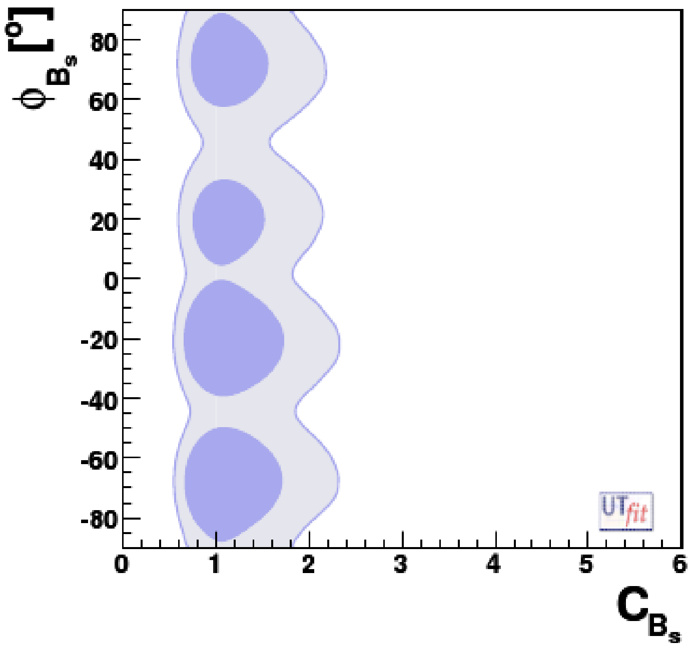
$$
\begin{aligned}
\frac{d^4\Gamma}{dt\,d\cos\theta\,d\varphi\,d\cos\psi} \propto \\
& 2\cos^2\psi(1-\sin^2\theta\cos^2\varphi)|A_0(t)|^2 \\
& +\sin^2\psi(1-\sin^2\theta\sin^2\varphi)|A_\parallel(t)|^2 \\
& +\sin^2\psi\sin^2\theta|A_\perp(t)|^2 \\
& +(1/\sqrt{2})\sin 2\psi\sin^2\theta\sin 2\varphi\,\mathrm{Re}(A_0^*(t)A_\parallel(t)) \\
& +\ (1/\sqrt{2})\sin 2\psi\sin 2\theta\cos\varphi\,\mathrm{Im}(A_0^*(t)A_\perp(t)) \\
& -\ \sin^2\psi\sin 2\theta\sin\varphi\,\mathrm{Im}(A_\parallel^*(t)A_\perp(t)).
\end{aligned}
$$

Dunietz,Fleisher and Nierste
Phys.ReV D63:114015,2001

Experimentally θ and φ are well determined from the μ from J/ψ
ψ is the decay plane between the J/ψ and the ϕ.

Winter 2007

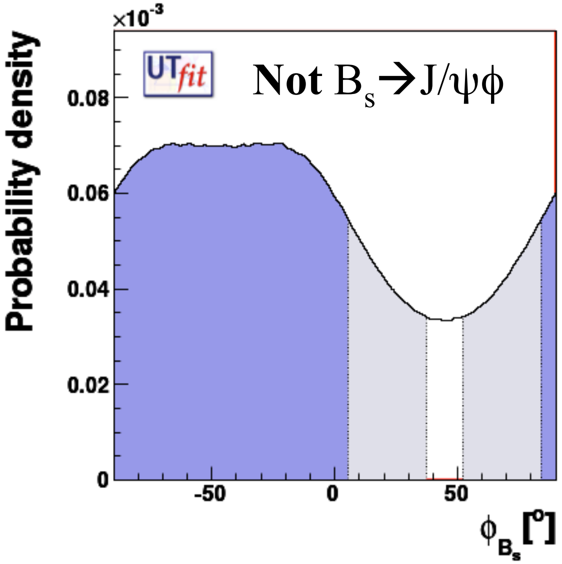


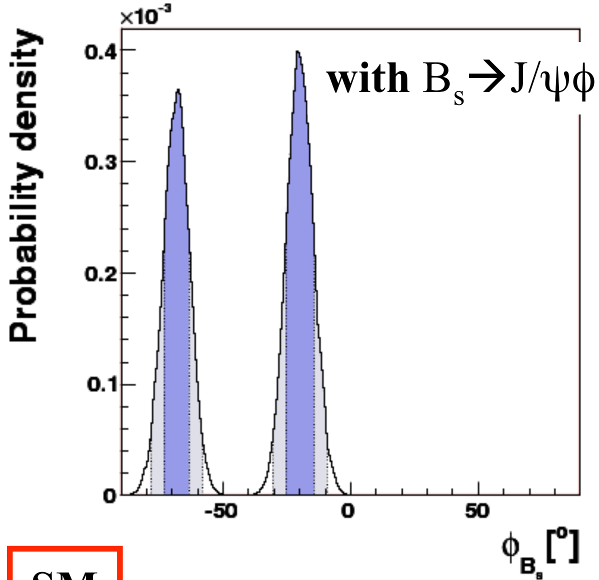


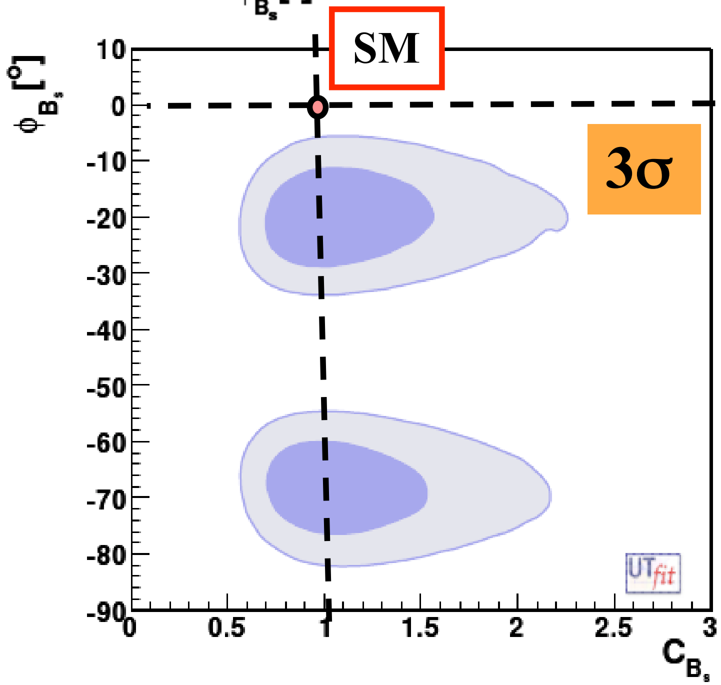
C(Bs) = 1.11 ± 0.32

φ(Bs) = (-69±14)º U (-20±14)º U (20±5)º U (72±8)º

Before ICHEP 2008



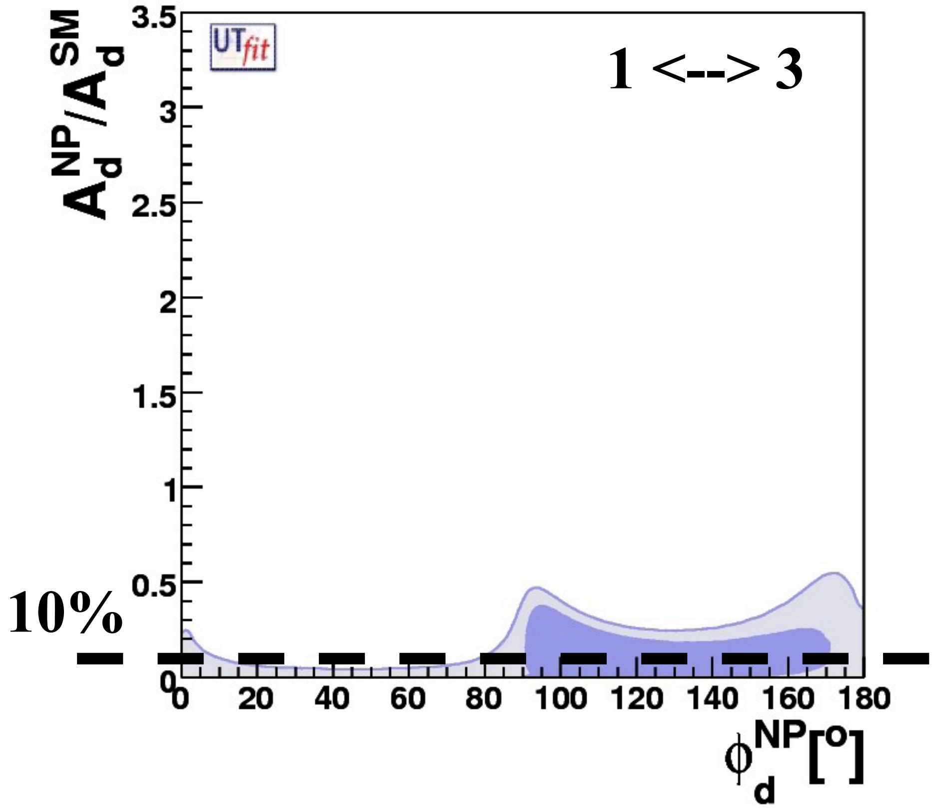


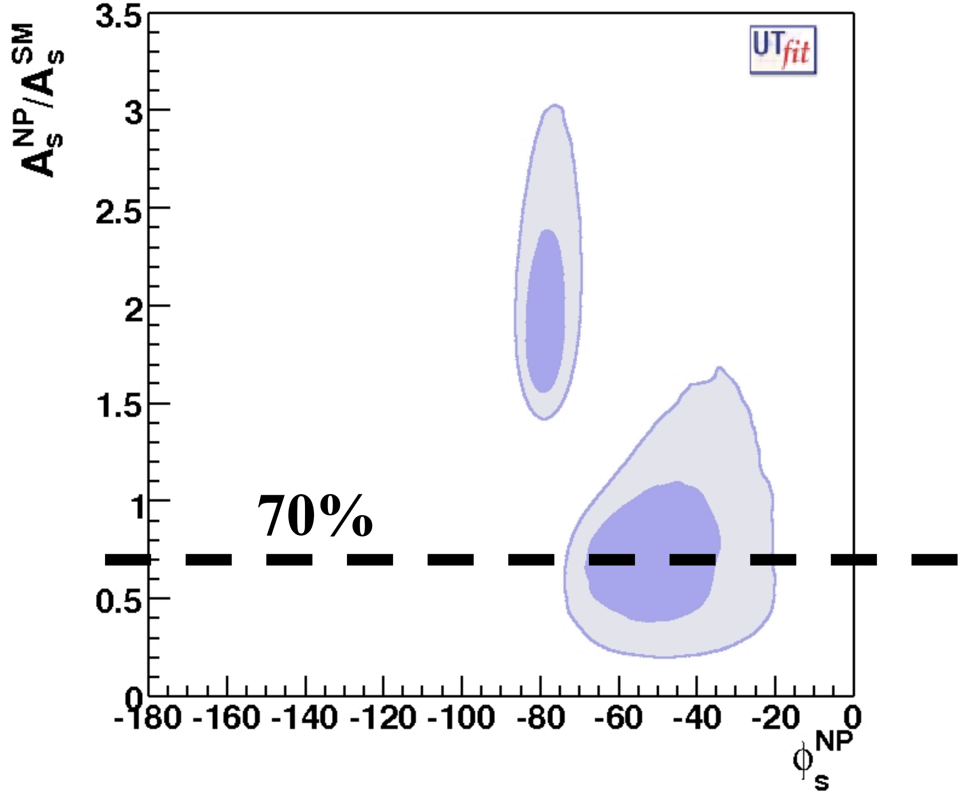


C(Bs)=1.07±0.29

φ(Bs)=(-19.9±5.6)oU(-68.2±4.9)º

B_d 1 <--> 3 vs **B_s 2 <--> 3**



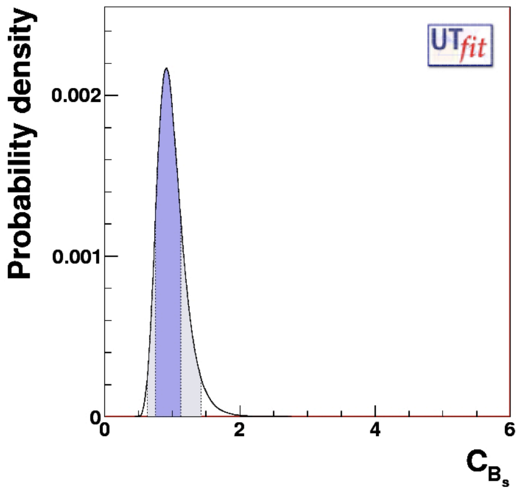


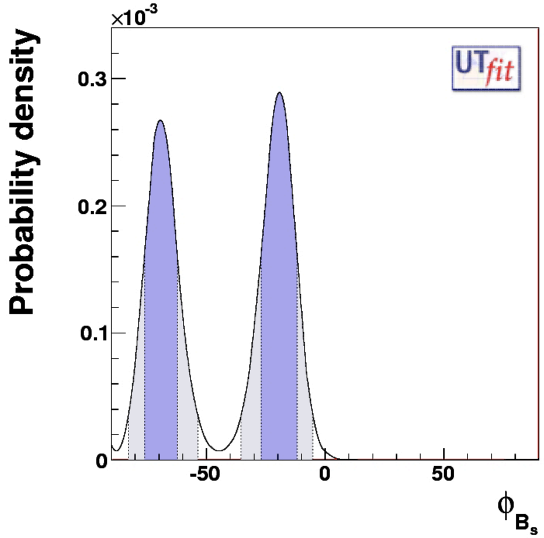
A_{NPd}/A_{SMd}~0.1 and A_{NPs}/A_{SMs}~0.7

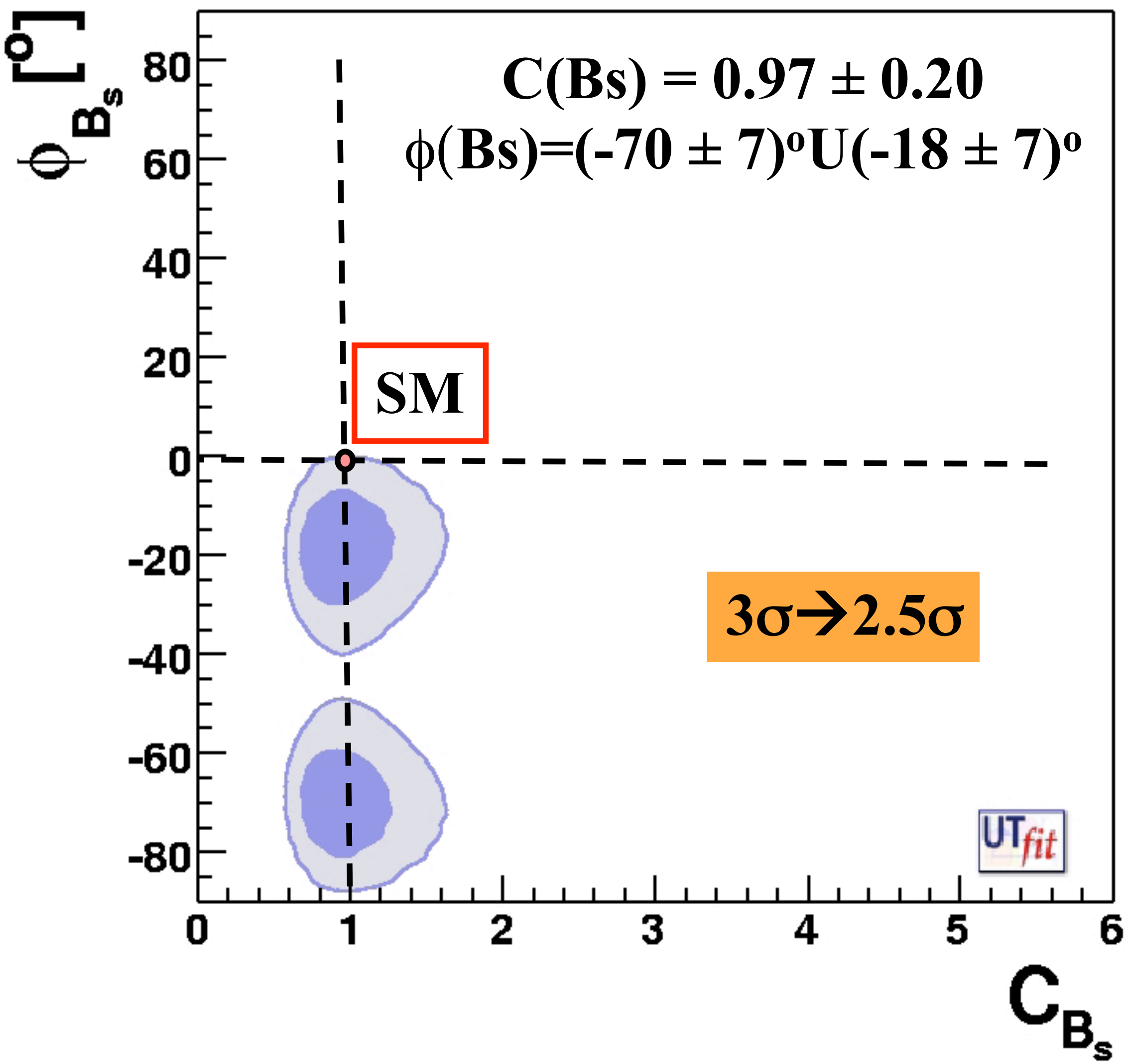
correspond to $A_{NPd}/A_{NPs}\sim \lambda^2$ i.e. to an additional λ suppression.

After ICHEP 2008-CKM2008

ICHEP 2008. D0 released the likelihood without assumptions on the strong phases



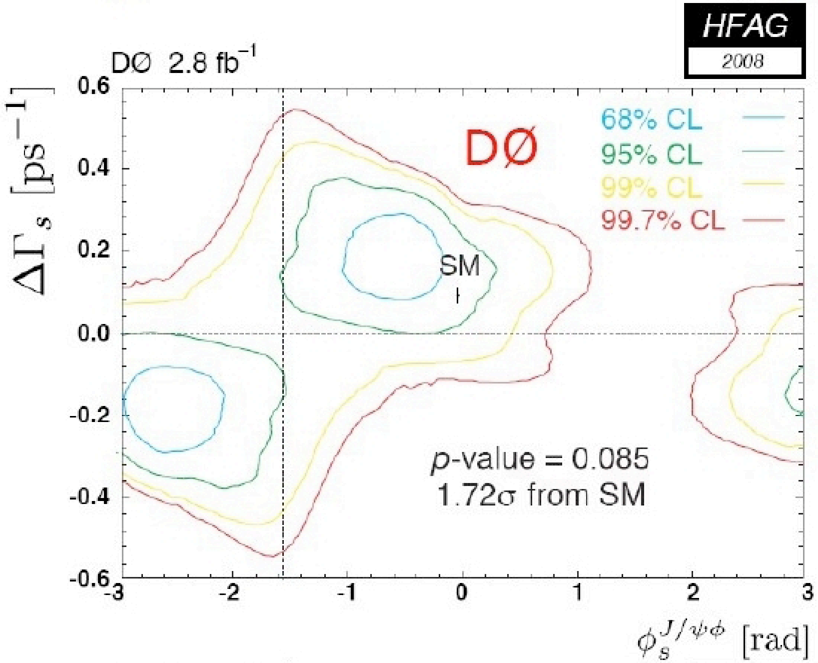


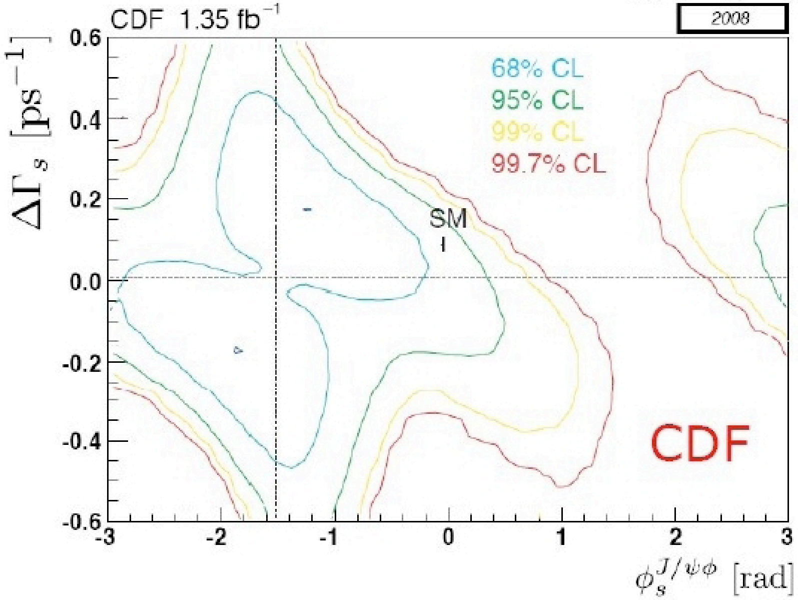


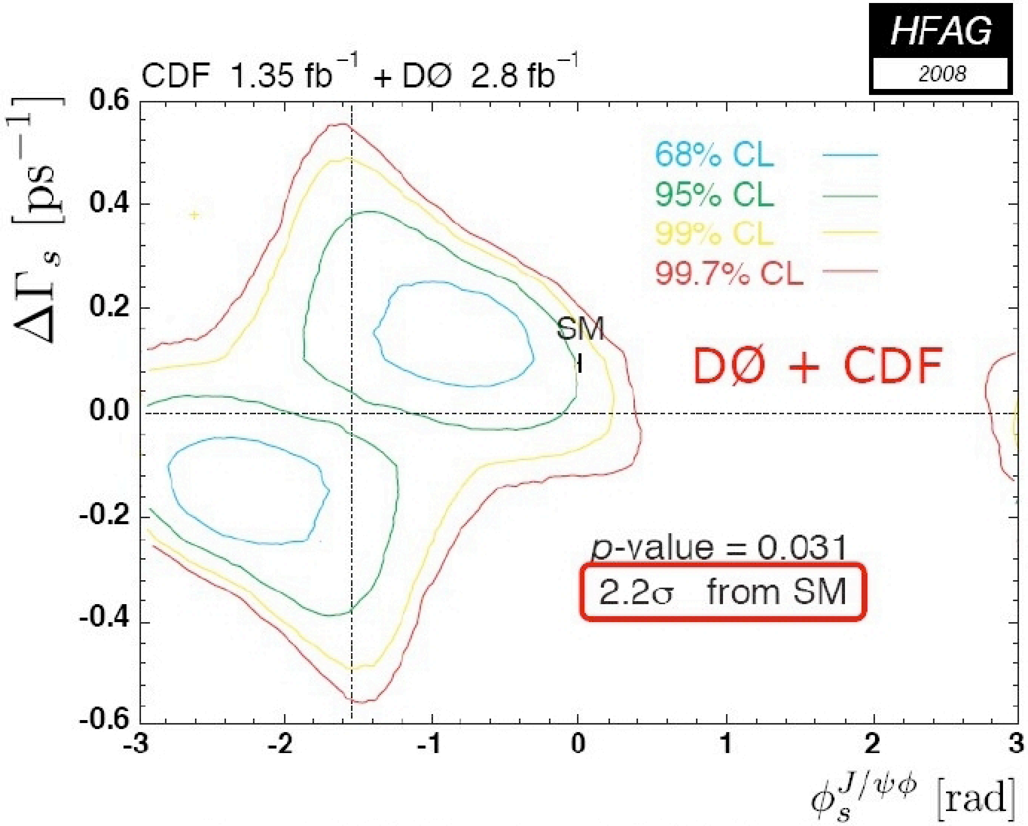
New CDF data not included:

new CDF likelihood "not ready yet" SM compatibility decreased in the CDF analysis

Here the results from HFAG. Without additional constraints







$\phi_s = -2.37\,^{+0.38}_{-0.27}$ rad, $\quad -0.75\,^{+0.27}_{-0.38}$ rad

$\Delta\Gamma_s = -0.150\,^{+0.066}_{-0.059}$ ps^{-1}, $\quad 0.150\,^{+0.059}_{-0.066}$ ps^{-1}

90% C.L. 1-d regions:

$\phi_s \in [-2.85, -1.65], \quad [-1.47, -0.29]$

$\Delta\Gamma_s \in [-0.265, -0.036], \quad [0.036, 0.265]$

See Diego Tonello (CDF), Lars Sonnenschein (D0) CKM08 Rome

This result, if confirmed, will imply

:

- of course → NP physics

- NP not Minimal Flavour Violation
(large couplings..new particles not necessary below the TeV scale

- NP model must explain why effects on B_d (which can still be as large as 20%) and K systems are smaller

1 <-> 2: strong suppression

1 <-> 3: ≤ O(10%)

2 <-> 3: O(1)

this pattern is not unexpected in flavour models and in SUSY-GUTs

→ Flavour physics central
- B_d sector, for $\Delta F=2$ but also $\Delta F=1$ $b \rightarrow s$ transitions
- K sector
- of course B_s sector

See next page

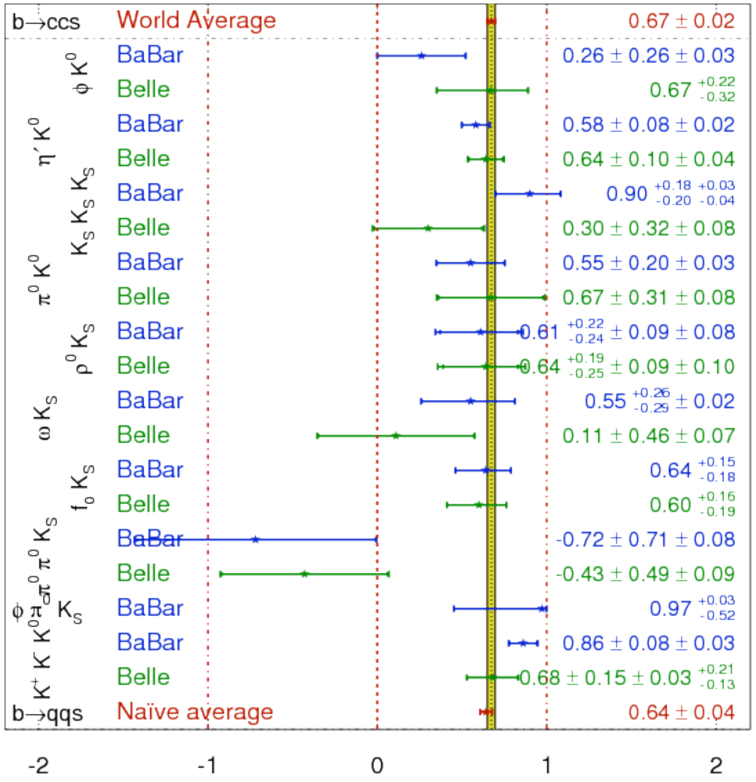
PRECISION IS NEEDED

$\Delta F=1$

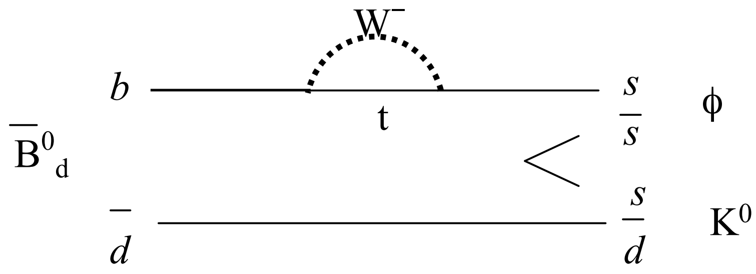
b→ s transitions are very sensitive to NP contributions ($\Delta F=1$)

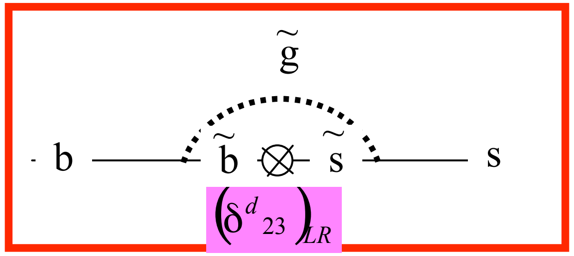
$\sin(2\beta^{eff}) \equiv \sin(2\phi_1^{eff})$

HFAG CKM2008 PRELIMINARY

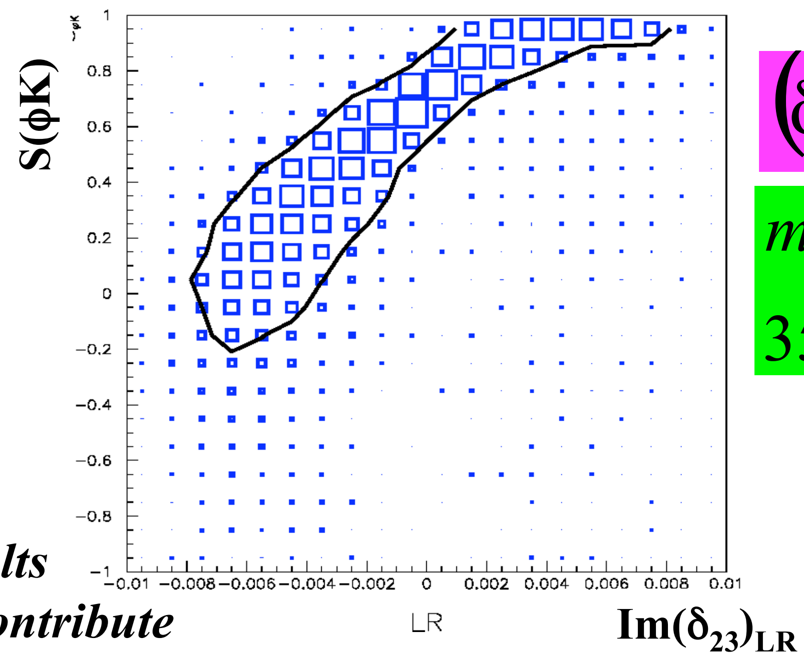


The disagreement is much reduced





New Physics contribution (2-3 families)



$(\delta^d_{23})_{LR}$

$m_{\tilde{q}} = m_{\tilde{g}}$

350 GeV

CFMS

PRECISION IS NEEDED

B factories results

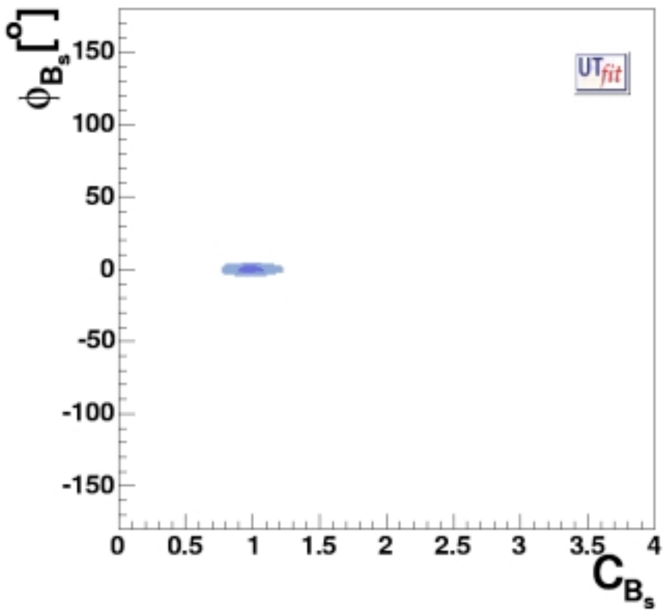
SuperB expected to contribute

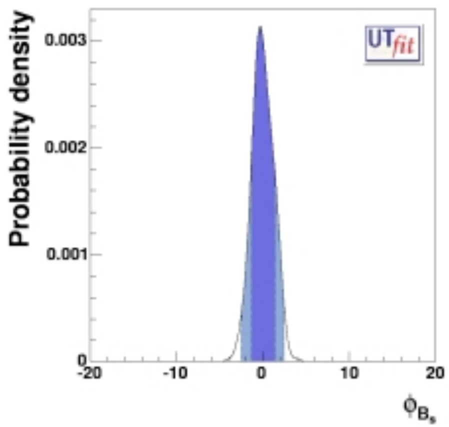
- **D0 and CDF will update their results. They have not used entire dataset.**

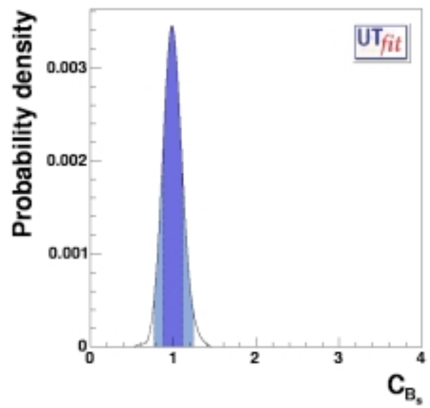
If the NP phase stay so large they could observe it with the full/final dataset

- **φ_s is a golden measurement for LHCb**

Simulation done with $4fb^{-1}$.







$\varphi_{Bs} = (0.0 \pm 1.3)^o$ $C_{Bs} = 0.99 \pm 0.12$

But also with much less data, LHCb can observe the effect if will stay so large

New studies show that (end 2009 ?)

LHCb with 0.5fb-1 → $\sigma(\phi Bs) = 0.06$

ATLAS with 2.5fb-1 → $\sigma(\phi Bs) = 0.16$

See Gaia Lanfranchi CKM08/Rome

Flavour physics in the quark sector is in his mature age

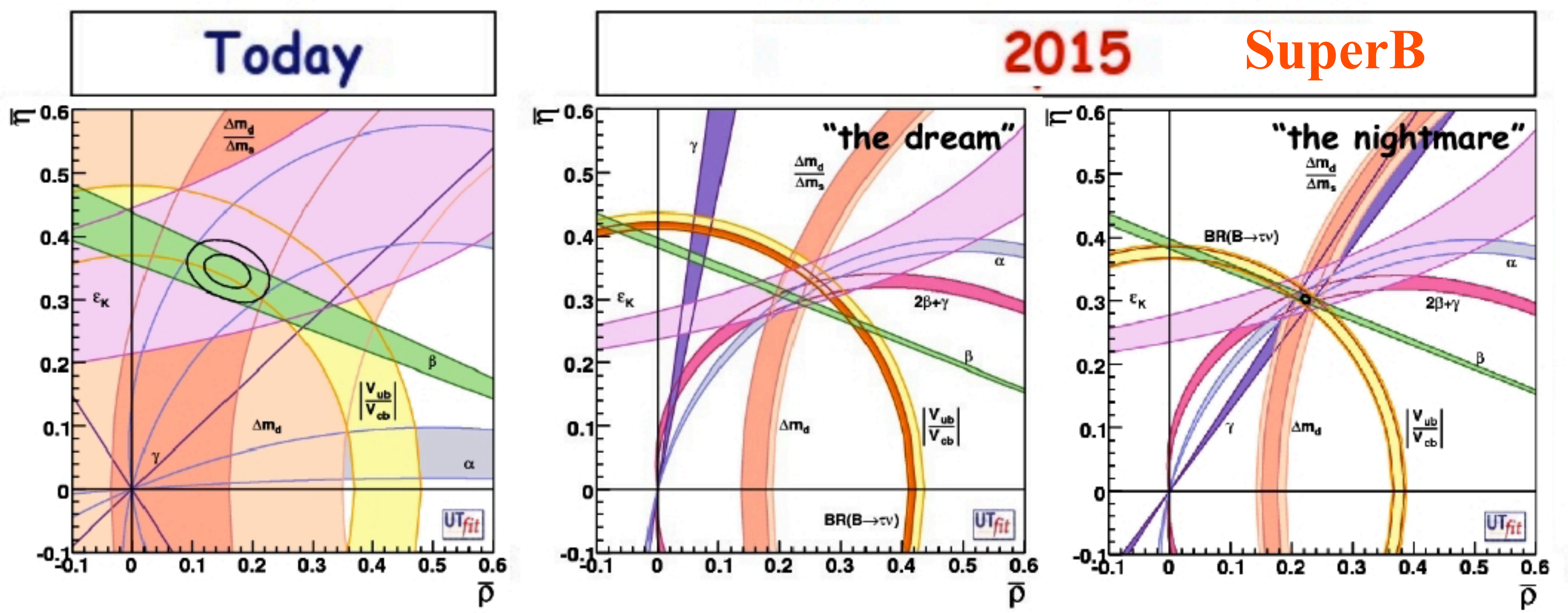
In b→d transitions NP effect are "confined" to be at order less ~10-15% !

New data from Tevatron show ~2.5σ discrepancy from SM in b→s transitions

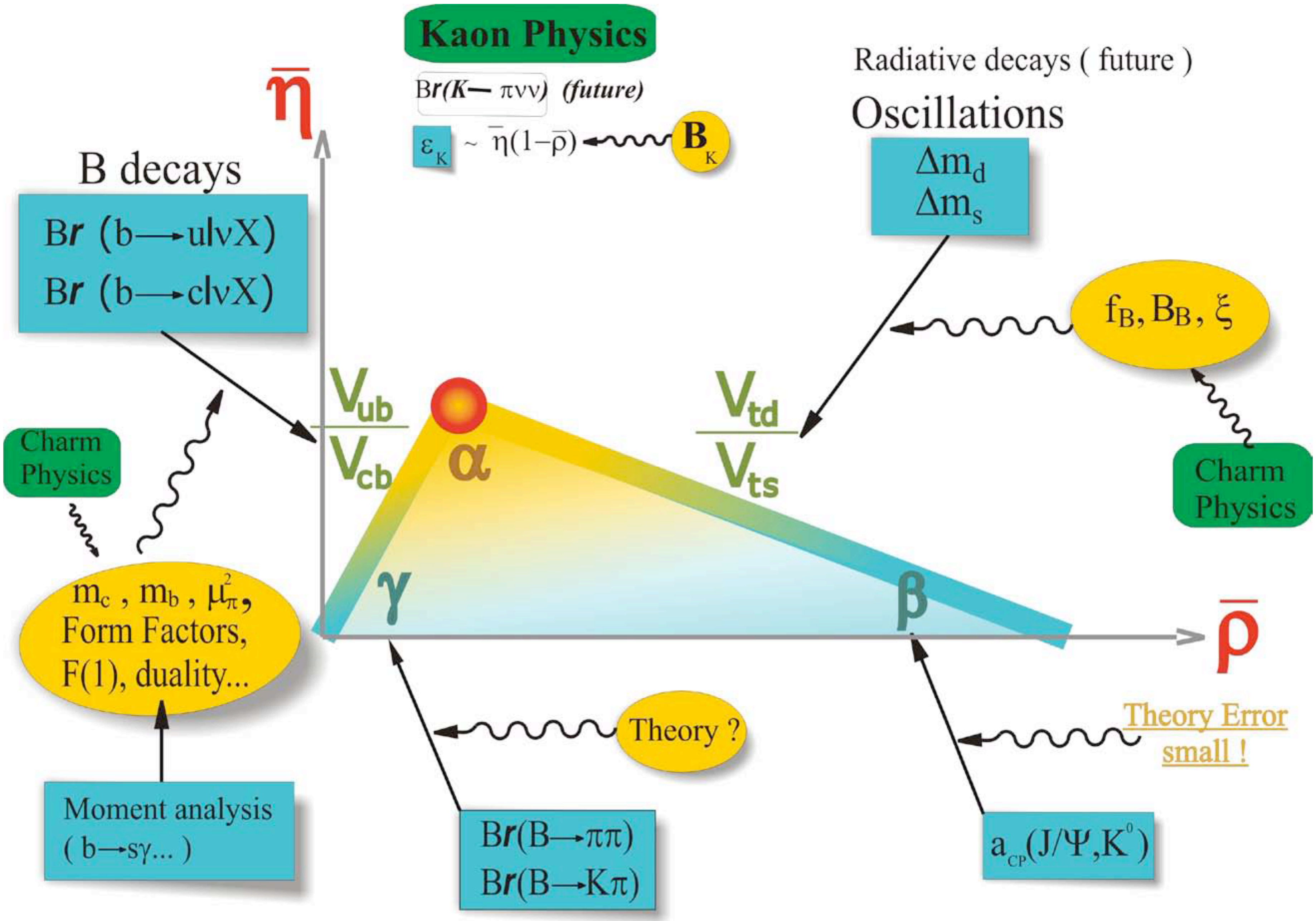
If confirmed would implies NP and not Minimal Flavour Violation

Tevatron (with full statistics) and LHCb will clarify the discrepancy

Flavour Physics is alive more than ever to look for NP beyond SM

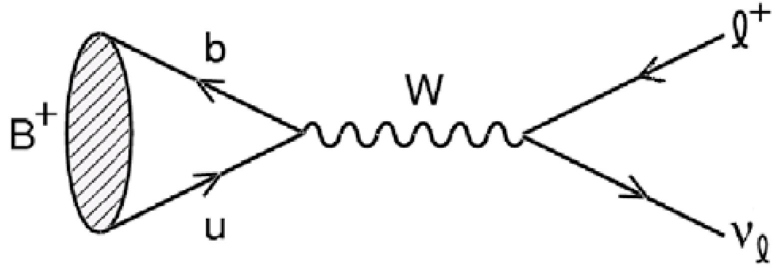


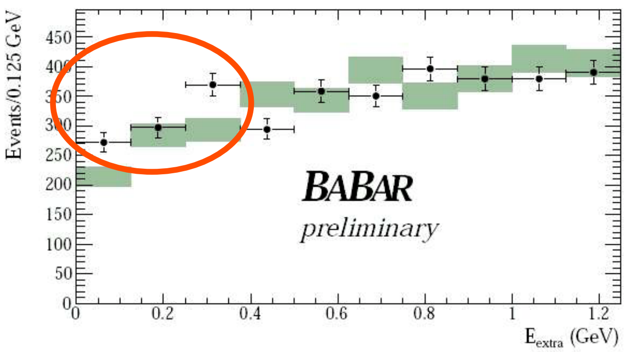
BACKUP MATERIAL

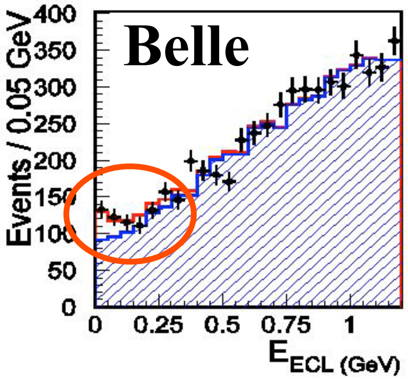

Kaon Physics
Br(K— πνν) (future)
ε_K ~ η̄(1−ρ̄)
B_K
Radiative decays (future)
Oscillations
Δm_d
Δm_s
B decays
Br (b→ulνX)
Br (b→clνX)
η̄
f_B, B_B, ξ
V_ub / V_cb
α
V_td / V_ts
Charm Physics
Charm Physics
γ
β
ρ̄
m_c , m_b , μ_π^2,
Form Factors,
F(1), duality...
Theory ?
Theory Error small !
Moment analysis
(b→sγ...)
Br(B→ππ)
Br(B→Kπ)
a_CP(J/Ψ,K^0)

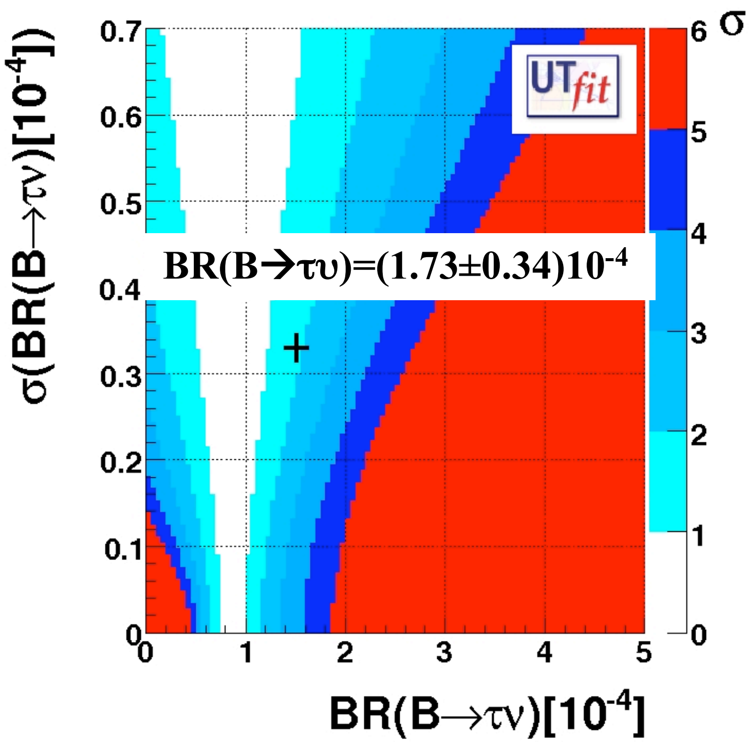
B → τν

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









B factories results
SuperB expected to contribute

The problem of particle physics today is :
where is the NP scale $\Lambda \sim 0.5, 1 \ldots 10^{16}$ TeV

The quantum stabilization of the Electroweak Scale
suggest that $\Lambda \sim 1$ TeV
LHC will search on this range

What happens if the NP scale is at 2-3..10 TeV
…naturalness is not at loss yet…

Flavour Physics explore also this range

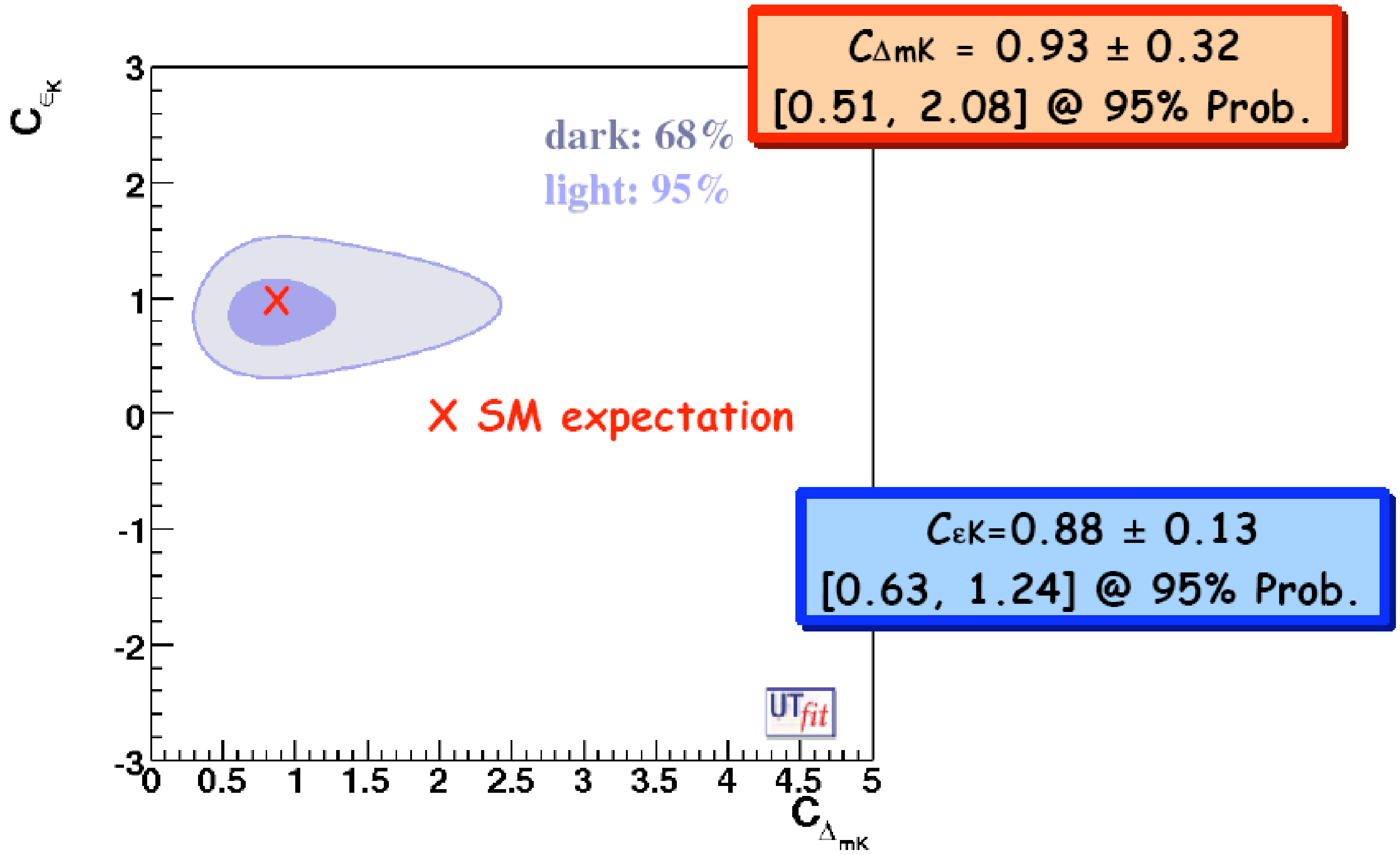
We want to perform flavour measurements such that :
- if NP particles are discovered at LHC we able study the flavour structure of the NP
- we can explore NP scale beyond the LHC reach

$$\frac{|\delta_{bq}|}{\Lambda_{eff}}$$

If there is NP at scale Λ, it will generate new operator of dimension D with coefficients proportional to Λ^{4-D}

You could demonstrate that only operator of D=6 contribute
So that in fact you have a dependence on $1/\Lambda^2$

Kaon sector



$C_{\Delta mK}$ = 0.93 ± 0.32
[0.51, 2.08] @ 95% Prob.
dark: 68%
light: 95%
X SM expectation
$C_{\varepsilon K}$=0.88 ± 0.13
[0.63, 1.24] @ 95% Prob.
C_{ε_K}
$C_{\Delta_{mK}}$
UTfit

$$A_{\mathrm{SL}} \equiv \frac{\Gamma(\bar{B}^0 \to \ell^+ X) - \Gamma(B^0 \to \ell^- X)}{\Gamma(\bar{B}^0 \to \ell^+ X) + \Gamma(B^0 \to \ell^- X)}$$
$$= -\mathrm{Re}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{\mathrm{SM}} \frac{\sin 2\phi_{B_d}}{C_{B_d}} + \mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{\mathrm{SM}} \frac{\cos 2\phi_{B_d}}{C_{B_d}}$$

$$\tau_{B_s}^{FS} = \frac{1}{\Gamma_s} \frac{1 - \left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}{1 + \left(\frac{\Delta\Gamma_s}{2\Gamma_s}\right)^2}$$

Flavour specific final states

$$A_{CH} = \frac{1}{4}\left(A_{SL}^d + \frac{f_s}{f_d}\frac{\chi_{s0}}{\chi_{d0}} A_{SL}^s\right)$$

$$\overset{(-)}{\chi_q} = \frac{\frac{\Delta\Gamma_q}{\Gamma_q}^2 + 4\frac{\Delta m_q}{\Gamma_q}^2}{\frac{\Delta\Gamma_q}{\Gamma_q}^2(\overset{(-)}{z_q} - 1) + 4(2\overset{(-)}{z_q} + \frac{\Delta m_q}{\Gamma_q}^2(1 + \overset{(-)}{z_q}))}$$

With $z = |q/p|^2$ and $\bar{z} = |p/q|^2$

$$\frac{\Delta\Gamma_q}{\Delta m_q} = -2\frac{\kappa}{C_{B_q}}\left\{\cos(2\phi_{B_q})\left(n_1 + \frac{n_6 B_2 + n_{11}}{B_1}\right) - \frac{\cos(\phi_q^{\mathrm{SM}} + 2\phi_{B_q})}{R_t^q}\left(n_2 + \frac{n_7 B_2 + n_{12}}{B_1}\right) + \frac{\cos(2(\phi_q^{\mathrm{SM}} + \phi_{B_q}))}{R_t^{q^2}}\right.$$
$$\left.\left(n_3 + \frac{n_8 B_2 + n_{13}}{B_1}\right) + \cos(\phi_q^{\mathrm{Pen}} + 2\phi_{B_q})\, C_q^{\mathrm{Pen}}\left(n_4 + n_9\frac{B_2}{B_1}\right) - \cos(\phi_q^{\mathrm{SM}} + \phi_q^{\mathrm{Pen}} + 2\phi_{B_q})\frac{C_q^{\mathrm{Pen}}}{R_t^q}\left(n_5 + n_{10}\frac{B_2}{B_1}\right)\right\}$$

NLO calculation of the matrix element of B meson mixing

Ciuchini et al. JHEP 0308:031,2003.

$$|A_{0,\parallel}(t)|^2 = |A_{0,\parallel}(0)|^2 \left[\mathcal{T}_+ \pm e^{-\overline{\Gamma}t} \sin\phi_s \sin(\Delta M_s t)\right],$$

$$|A_\perp(t)|^2 = |A_\perp(0)|^2 \left[\mathcal{T}_- \mp e^{-\overline{\Gamma}t} \sin\phi_s \sin(\Delta M_s t)\right],$$

$$\mathrm{Re}(A_0^*(t)A_\parallel(t)) = |A_0(0)||A_\parallel(0)| \cos(\delta_2 - \delta_1) \times \left[\mathcal{T}_+ \pm e^{-\overline{\Gamma}t} \sin\phi_s \sin(\Delta M_s t)\right],$$

Tagging is important to separate the time evolution of mesons produced as Bs or anti-Bs. In this way we obtain direct sensitivity to CP-violating phase. This phase enters with terms proportional to **cos(2β$_s$) and sin(2β$_s$).** Analyses which do not use flavour tagging are sensitive to |cos(2β$_s$)| and |sin(2β$_s$)|, leading to a four-fold ambiguities in the determination of φ_s.

$$\mathrm{Im}(A_0^*(t)A_\perp(t)) = |A_0(0)||A_\perp(0)|| \times [e^{-\overline{\Gamma}t}(\pm \sin\delta_2 \cos(\Delta M_s t) \mp \cos\delta_2 \sin(\Delta M_s t) \cos\phi_s) - (1/2)(e^{-\Gamma_H t} - e^{-\Gamma_L t}) \sin\phi_s \cos\delta_2],$$

$$\mathrm{Im}(A_\parallel^*(t)A_\perp(t)) = |A_\parallel(0)||A_\perp(0)| \times [e^{-\overline{\Gamma}t}(\pm \sin\delta_1 \cos(\Delta M_s t) \mp \cos\delta_1 \sin(\Delta M_s t) \cos\phi_s) - (1/2)(e^{-\Gamma_H t} - e^{-\Gamma_L t}) \sin\phi_s \cos\delta_1],$$

where $\mathcal{T}_\pm = (1/2)\left[(1 \pm \cos\phi_s)e^{-\Gamma_L t} + (1 \mp \cos\phi_s)e^{-\Gamma_H t}\right].$

Only two-fold ambiguity

Ambiguity for

$\phi_s \to \pi - \phi_s$, $\Delta\Gamma_s \to -\Delta\Gamma_s$,

$\cos(\delta_1 - \delta_2) \to -\cos(\delta_1 - \delta_2)$

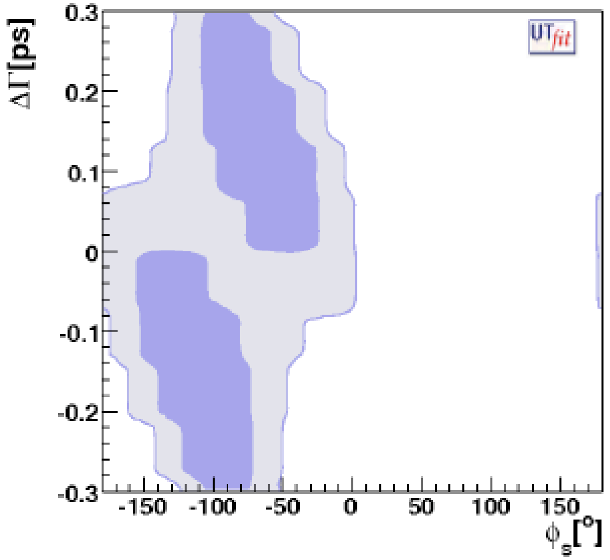
TeVatron results

LHCb expected to contribute

Before ICHEP2008

1.35 fb^{-1}

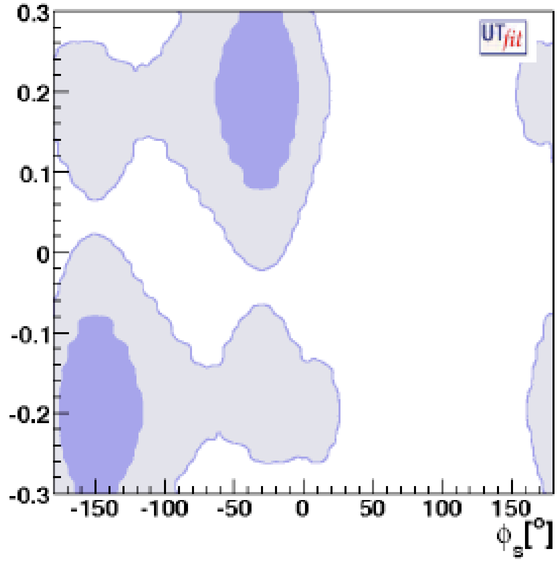
CDF tagged measurement



directly from the Likelihood given by CDF

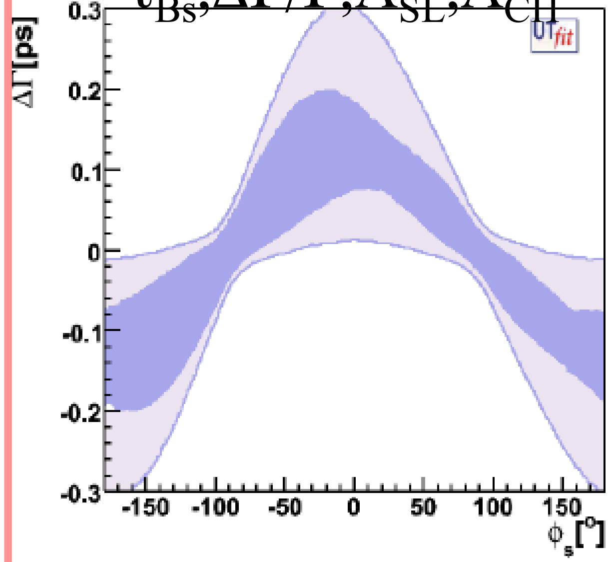
2.8 fb^{-1}

D0 tagged measurement



No likelihood available from D0 Conservative approach used (for details see appendix)

Other measurements τ_{Bs},$\Delta\Gamma/\Gamma$,A_{SL},A_{CH}

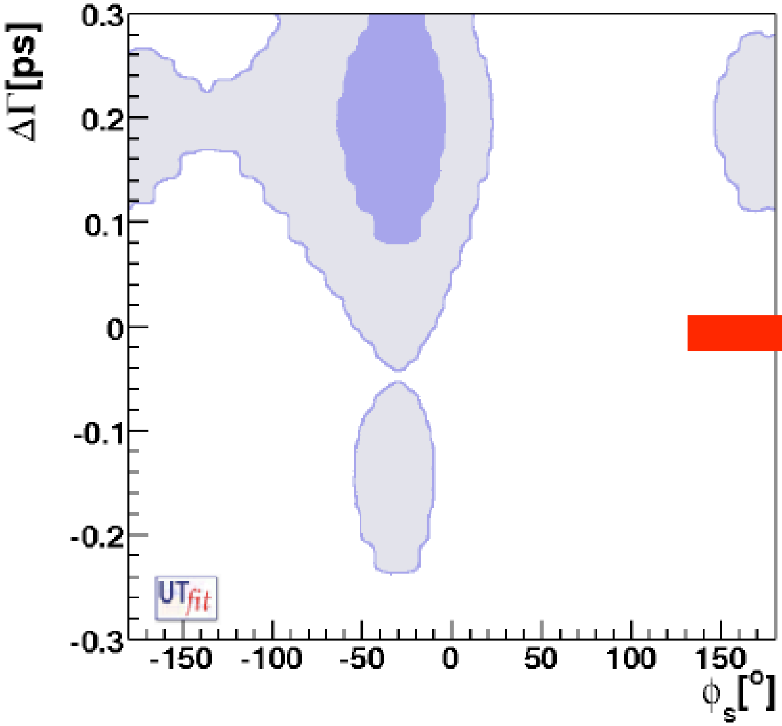


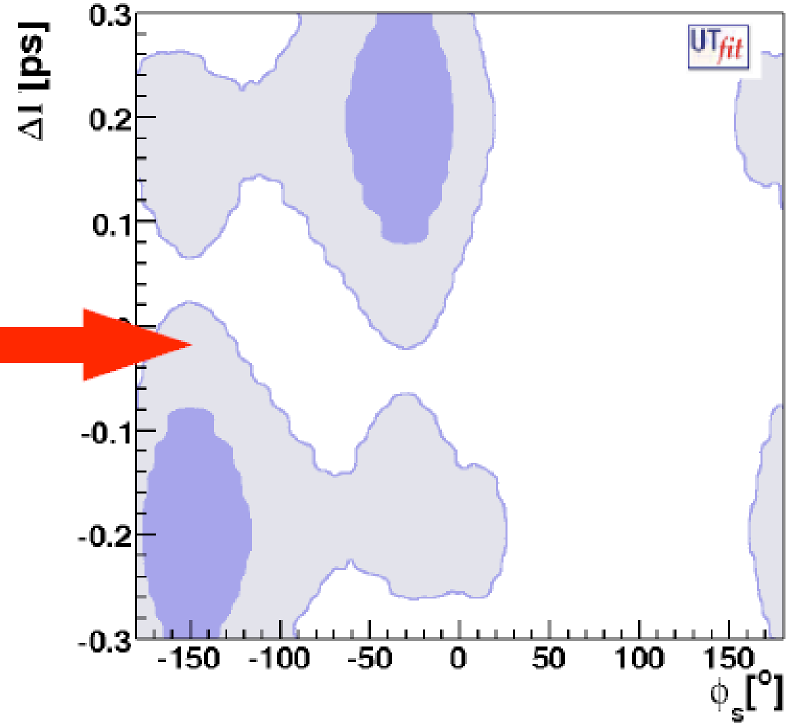
All available measured used with and up-to-date hadronic parameters

Notice that the two measurements are in agreement

Other measurements are also important

Modeling D0 data (I)





D0 data → **Used by UTFit**

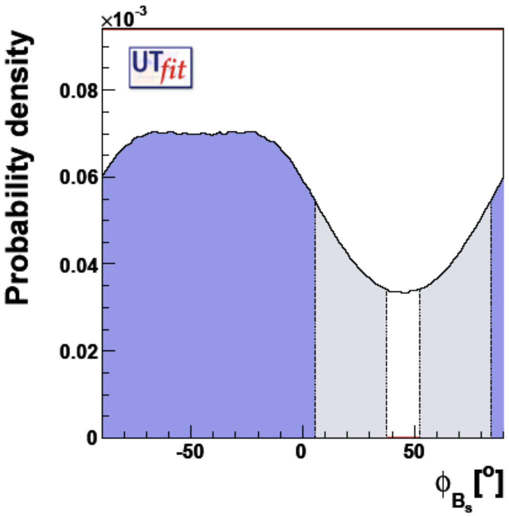
Strong phase taken also From $B_d \rightarrow J/\psi\ K^* + SU(3)$

NO AMBIGUITY

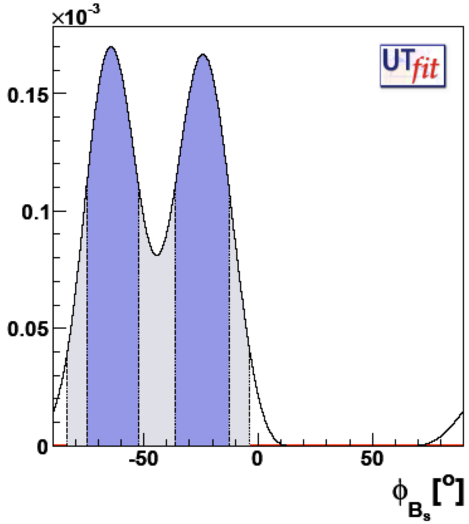
The problem is that the singlet Component of the f is ignored.

WE REINTRODUCE THE AMBIGUITY (mirroring the likelihood)

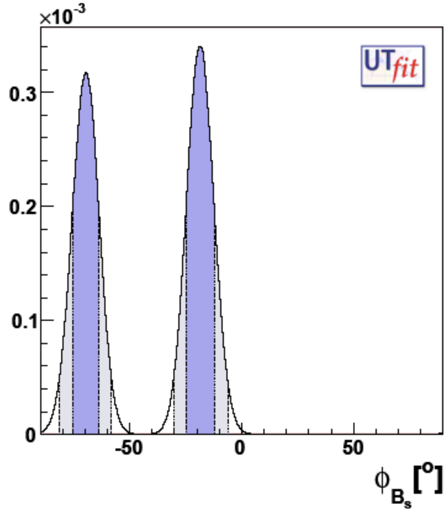
- **Stability of the result, who is contributing more ?**
- **Is an evidence….How many sigmas ?**



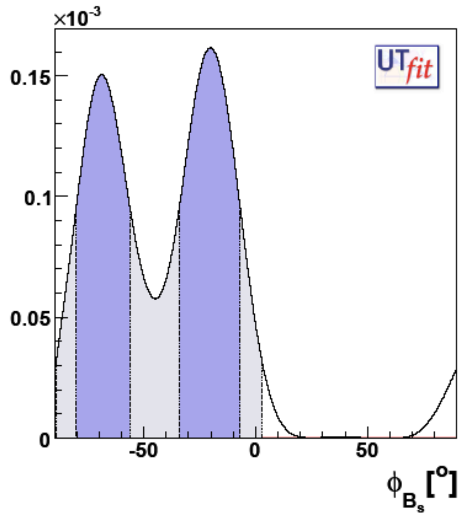
Without tagged analyses D0 and CDF



Including only CDF



Including only D0 Gaussian



Including only D0 likelihood profile

Depending of the approach used (for treating D0 data) φ_s is away from zero from 3σ up to 3.7σ.

Modeling D0 data (II)

TABLE I: Summary of the likelihood fit results for three cases: free ϕ_s, ϕ_s constrained to the SM value, and $\Delta\Gamma_s$ constrained by the expected relation $\Delta\Gamma_s^{SM} \cdot |\cos(\phi_s)|$.

	free ϕ_s	$\phi_s \equiv \phi_s^{SM}$	$\Delta\Gamma_s^{th}$
$\overline{\tau}_s$ (ps)	1.52±0.06	1.53±0.06	1.49±0.05
$\Delta\Gamma_s$ (ps^{-1})	0.19±0.07	0.14±0.07	0.083 ± 0.018
$A_\perp(0)$	0.41±0.04	0.44±0.04	0.45±0.03
$\lvert A_0(0)\rvert^2 - \lvert A_{\parallel}(0)\rvert^2$	0.34±0.05	0.35±0.04	0.33±0.04
δ_1	−0.52±0.42	−0.48±0.45	−0.47±0.42
δ_2	3.17±0.39	3.19±0.43	3.21±0.40
ϕ_s	$-0.57^{+0.24}_{-0.30}$	$\equiv -0.04$	−0.46 ± 0.28
ΔM_s (ps^{-1})	$\equiv$ 17.77	$\equiv$ 17.77	$\equiv$ 17.77

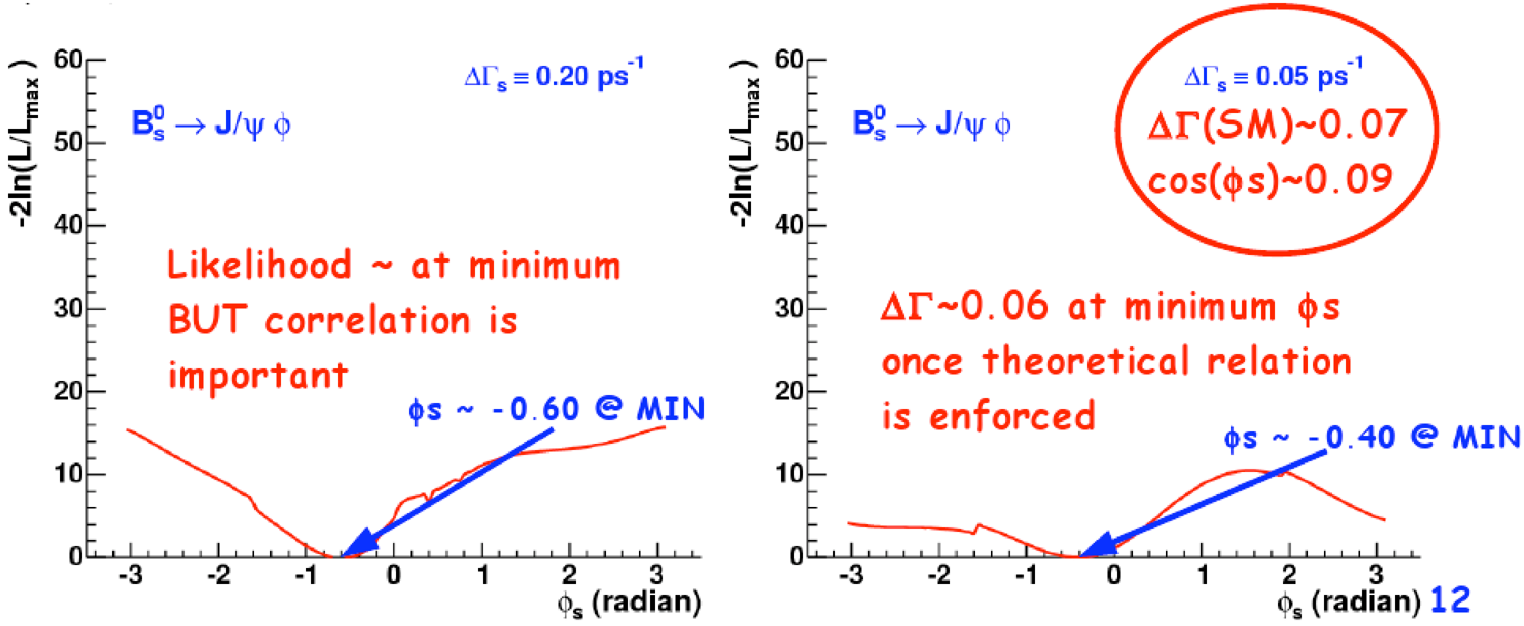
DEFAULT METHOD

We have the results with 7x7 correlation matrix. Fit at 7 parameters→ we extract 2 parameters ($\Delta\Gamma_s$ and φ_s).

Two others approach used to include non-Gaussian tails:

-Scale errors such they agree with the quoted “2σ” ranges
-Use the 1D profile likelihood given by D0 (fig 2).

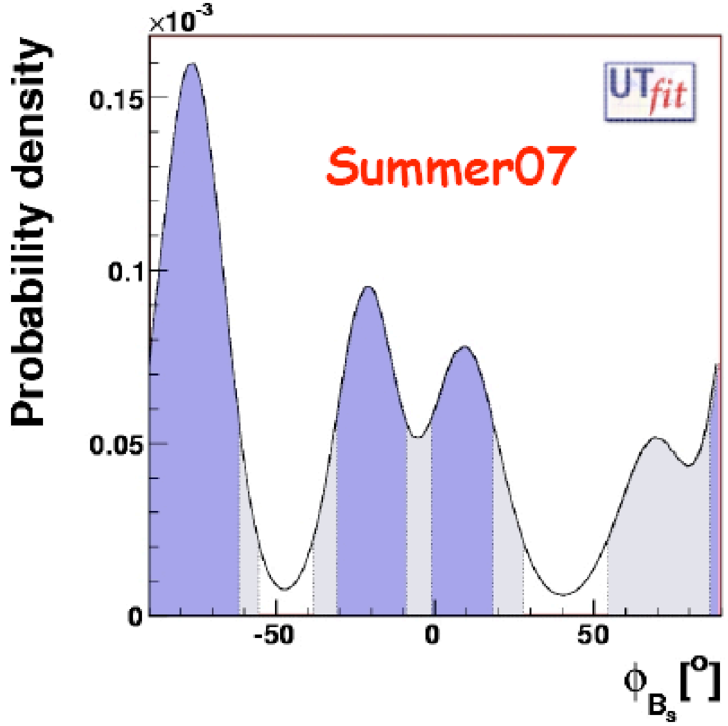
ICHEP 2008. D0 released the likelihood without assumption on the strong phases

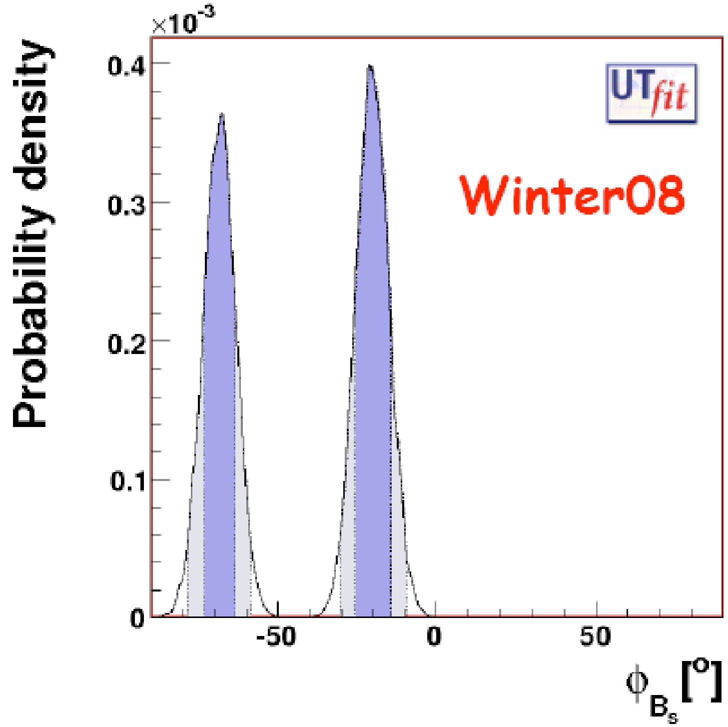


12

Move from $1.35\mathrm{fb}^{-1} \rightarrow 2.8\mathrm{fb}^{-1}$

Evolution of this result

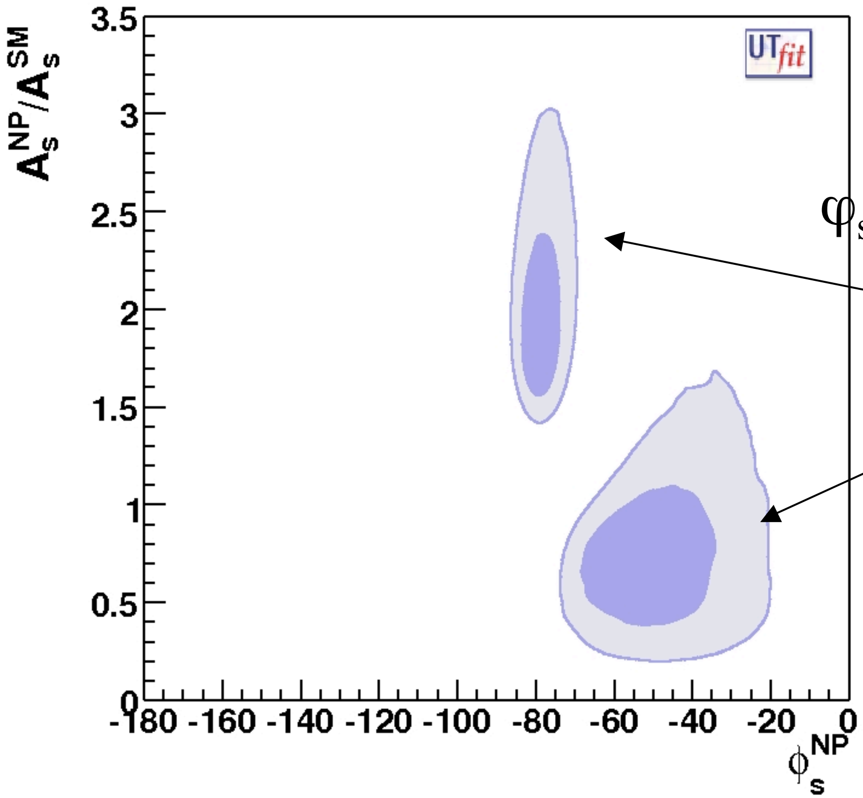




The two most probable peaks of last summer are now enhanced

Looking at the result with a different parametrization

$$C_{Bs}e^{2i\varphi_{Bs}} = \frac{A_{SM}e^{-2i\beta_s} + A_{NP}e^{-2i(\varphi_s^{NP}-\beta_s)}}{A_{SM}e^{-2i\beta_s}}$$



$\varphi_s \sim -70^o$

Solution corresponding to

$\varphi_s \sim -20^o$

A_s^{NP} / A_s^{SM}= (0.73 ± 0.35)

φ_s^{NP} = (-51 ± 11)^o

$$
\begin{aligned}
&\hat{B}_K = 0.75 \pm 0.07 \,, \\
&f_{B_s} = 245 \pm 25 \text{ MeV} \quad , \quad f_B = 200 \pm 20 \text{ MeV} \quad , \quad f_{B_s}/f_B = 1.21 \pm 0.04 \,, \\
&f_{B_s}\sqrt{\hat{B}_{B_s}} = 270 \pm 30 \text{ MeV} \quad , \quad f_B\sqrt{\hat{B}_{B_d}} = 225 \pm 25 \text{ MeV} \quad , \quad \xi = 1.21 \pm 0.04 \,, \\
&\hat{B}_{B_d} = \hat{B}_{B_s} = 1.22 \pm 0.12 \quad , \quad \hat{B}_{B_s}/\hat{B}_{B_d} = 1.00 \pm 0.03 \,, \\
&|V_{cb}| \text{ (excl.)} = (39.2 \pm 1.1) \cdot 10^{-3} \quad , \quad |V_{ub}| \text{ (excl.)} = (35.0 \pm 4.0) \cdot 10^{-4} \,.
\end{aligned}
$$

These averages can be compared with the previous ones used by UTfit

$$
\begin{aligned}
&\hat{B}_K = 0.79 \pm 0.04 \pm 0.08 \,, \\
&f_{B_s} = 230 \pm 30 \text{ MeV} \quad , \quad f_B = 189 \pm 27 \text{ MeV} \quad , \quad f_{B_s}/f_B = 1.22^{+0.05}_{-0.06} \,, \\
&f_{B_s}\sqrt{\hat{B}_{B_s}} = 262 \pm 35 \text{ MeV} \quad , \quad f_B\sqrt{\hat{B}_{B_d}} = 214 \pm 38 \text{ MeV} \quad , \quad \xi = 1.23 \pm 0.06 \,, \\
&\hat{B}_{B_d} = 1.28 \pm 0.05 \pm 0.09 \quad , \quad \hat{B}_{B_s}/\hat{B}_{B_d} = 1.02 \pm 0.02^{+0.06}_{-0.02} \,, \\
&|V_{cb}| \text{ (excl.)} = (39.1 \pm 0.6 \pm 1.7) \cdot 10^{-3} \quad , \quad |V_{ub}| \text{ (excl.)} = (34.0 \pm 4.0) \cdot 10^{-4} \,.
\end{aligned}
$$