CKM Fits:
Standard Model and New Physics

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On behalf of the CKMfitter group
http://ckmfitter.in2p3.fr

The CKM Matrix: The Four Parameters

$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

Consider the Wolfenstein parametrization as in EPJ C41:1-131,2005 : unitarity-exact and phase convention independent.

$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2} \,, \qquad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2} \quad \text{and} \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

✓ λ is measured from $|V_{ud}|$ and $|V_{us}|$ in nuclear decays and semileptonic kaon decays, resp.
✓ A is determined from $|V_{cb}|$ and λ.
✓ The last two parameters are to be determined from angles and sides measurements of the CKM unitarity triangle.

The CKM Matrix: The Four Parameters

STANDARD MODEL FIT

Inputs:

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

Δm_d

Δm_s

$B \to \tau\nu$

$|\varepsilon_K|$

$\sin 2\beta$

α

γ

CP-conserving Observables

CP-violating Observables

For a complete review of the inputs used in these analyses, please refer to Lacker @ FPCP07

NP IN ΔF=2 FIT

Assumptions:

1. NP only in short distance part of the mixing
2. CKM matrix still unitary
3. Decays b in $q_1q_2q_3$ are SM (V_{ub}, γ, α (knowing β))

$$\frac{\left\langle B_q^0 \middle| H_{eff}^{SM+NP} \middle| \overline{B}_q^0 \right\rangle}{\left\langle B_q^0 \middle| H_{eff}^{SM} \middle| \overline{B}_q^0 \right\rangle} = r_q^2 e^{i2\theta_q} = 1 + h_q e^{i2\sigma_q}$$

The theory for all processes w/ mixing is modified accordingly, e.g sin(2β) becomes sin($2\beta+2\theta_d$).
In addition to the inputs on the left, consider $a_{SL}(d)$ and $a_{SL}(s)$ plus $\Delta\Gamma(s)$.

CKM Global Fit Inputs (selection of) : $|V_{ub}|$

$|V_{ub}|$ is one of the basic (hence critical) ingredients of all the CKM fits (SM and NP). Its measurement results from the average of exclusive and inclusive measurements in semileptonic decays of b hadrons.

$| V_{ub}| \, [10^{-3}] = 3.50 \pm 0.10_{\mathrm{exp}} \pm 0.47_{\mathrm{theo}}$(exclusive, includes revised HPQCD)
$| V_{ub}| \, [10^{-3}] = 4.52 \pm 0.09_{\mathrm{exp}} \pm 0.44_{\mathrm{theo}}$(inclusive, using HFAG06)

Our average :

$| V_{ub}| \, [10^{-3}] = 4.03 \pm 0.09_{\mathrm{exp}} \pm 0.44_{\mathrm{theo}}$

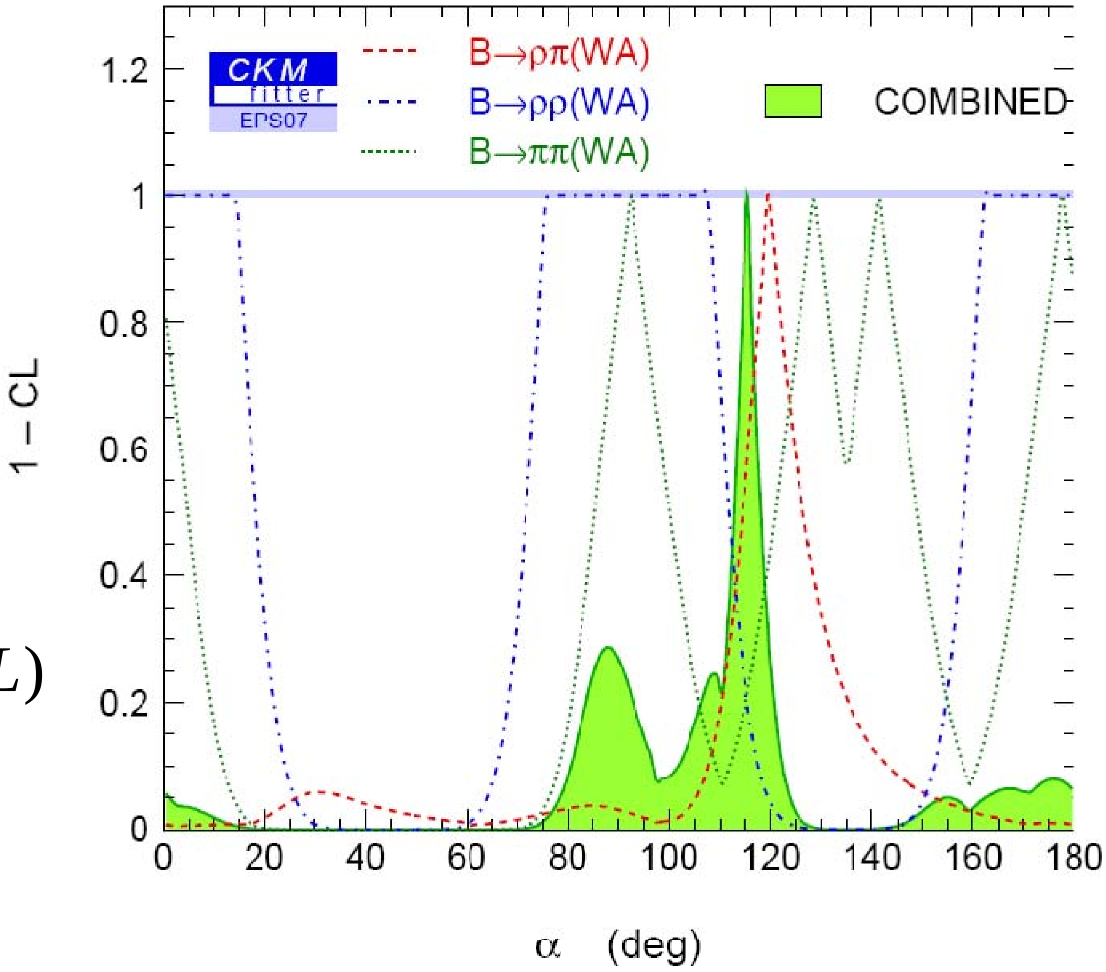
The high value of the inclusive determination is in slight disagreement with the indirect measurement/prediction in SM from sin 2β. Note : the uncertainty on m_b might be underestimated (cf Matthias Neubert's talk @ FPCP07) which would result in improving the agreement between both determinations. So does the global fit …

Today, exclusive determination contributes at the same level as inclusive in the average. Wait for new HFAG averages.

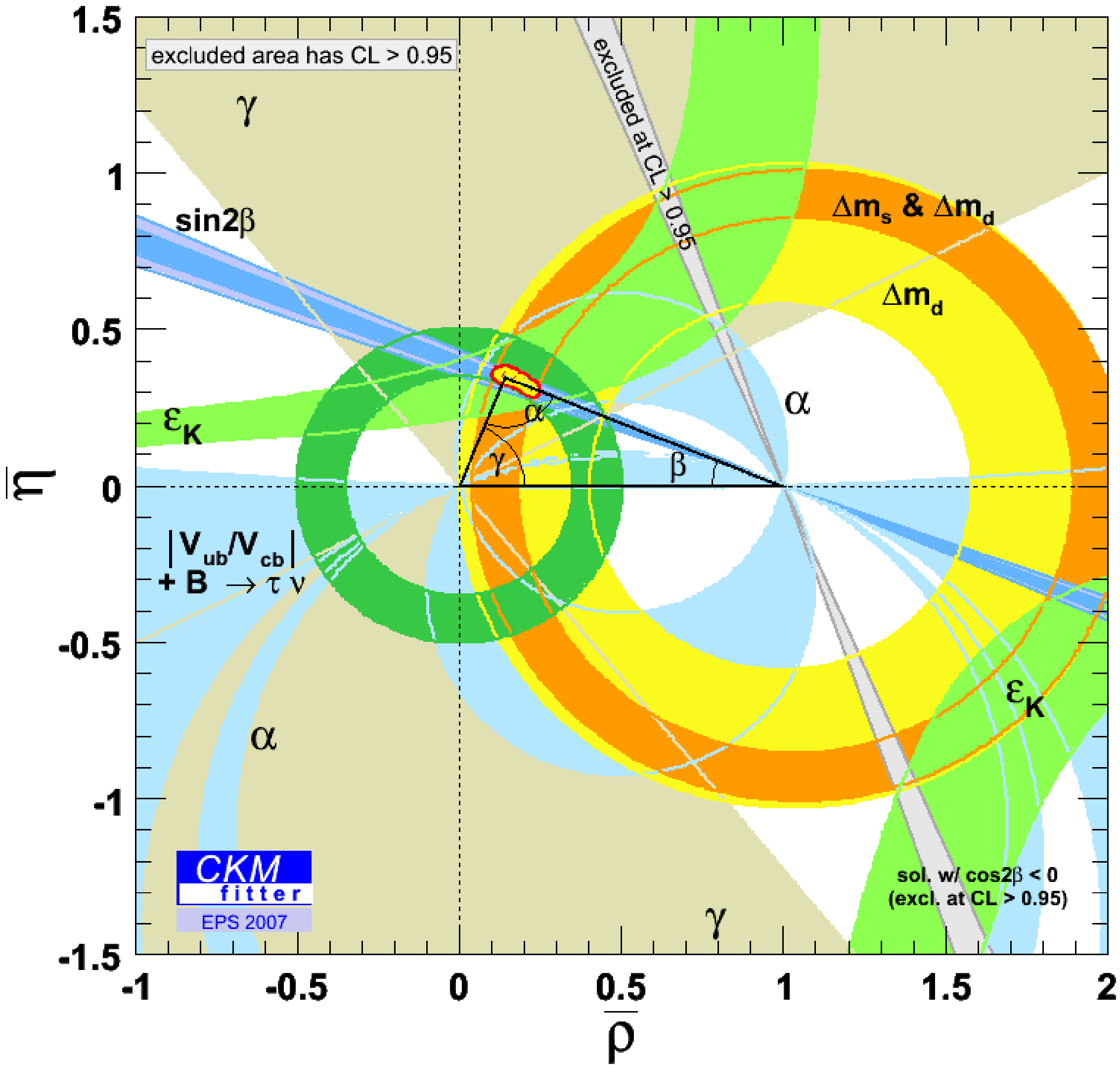
CKM Global Fit Inputs (selection of) : α

Combination of Belle and Babar measurements in charmless B decays $\pi\pi$,$\rho\rho$ and $\rho\pi$.

$$\alpha = 115.5^{+8.6}_{-37.5} \ \mathrm{deg}\ (95\%\,CL)$$



Overall Picture



Inputs:

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

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$B \to \tau\nu$

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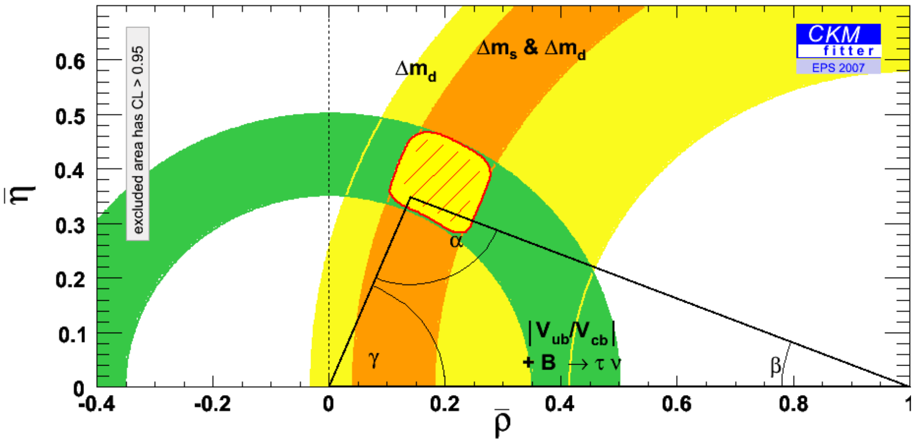
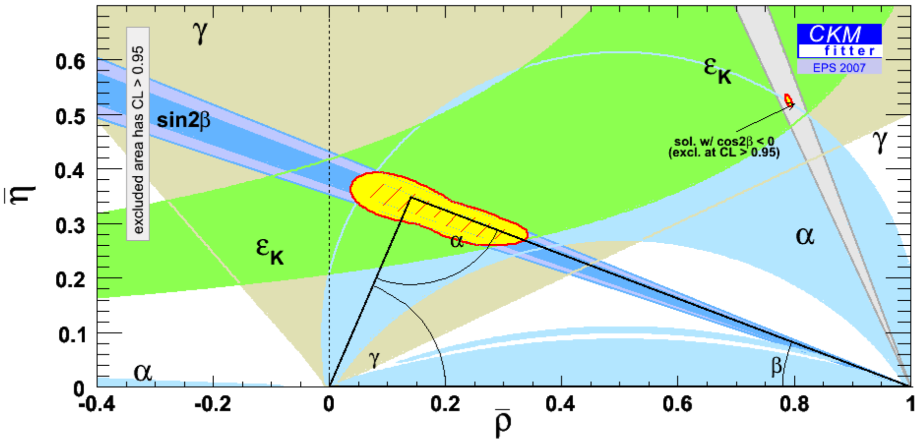
α

γ

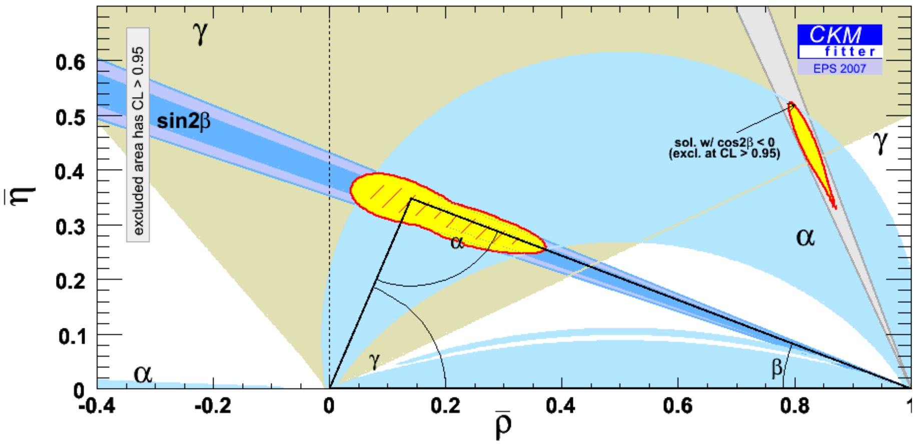
The global CKM fit: Testing the CKM Paradigm



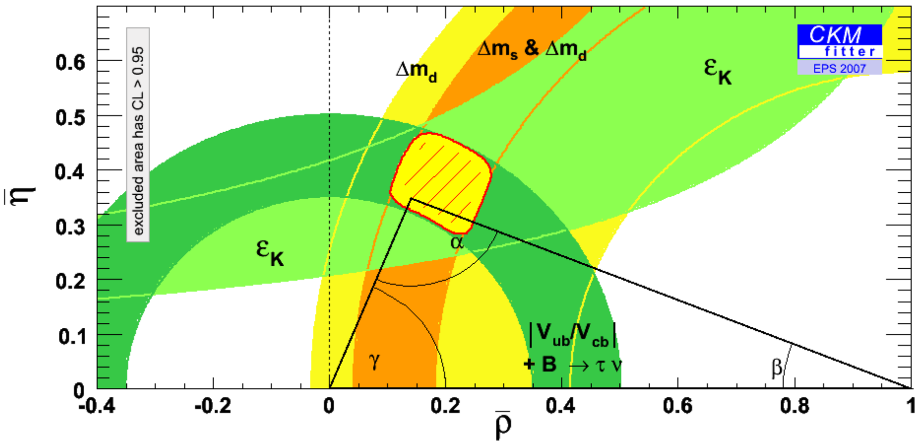
CP-Conserving observables imply CP violation.



CP-Violating observables stresses the same feature

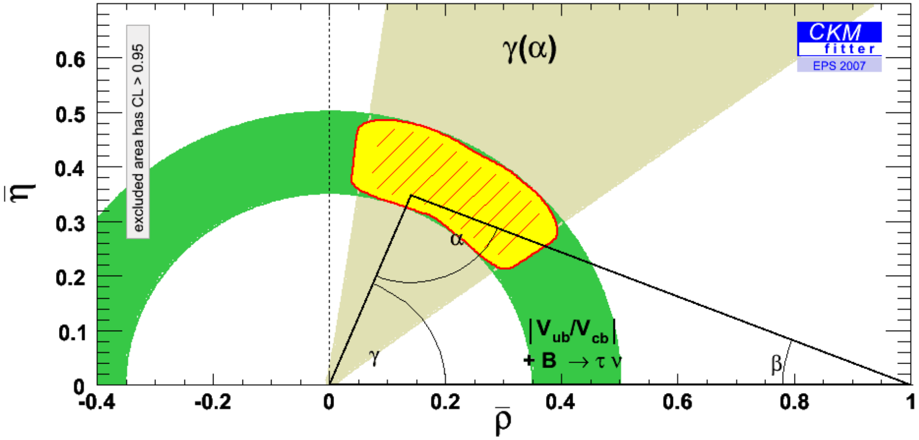


Angles (small theoretical uncertainties)

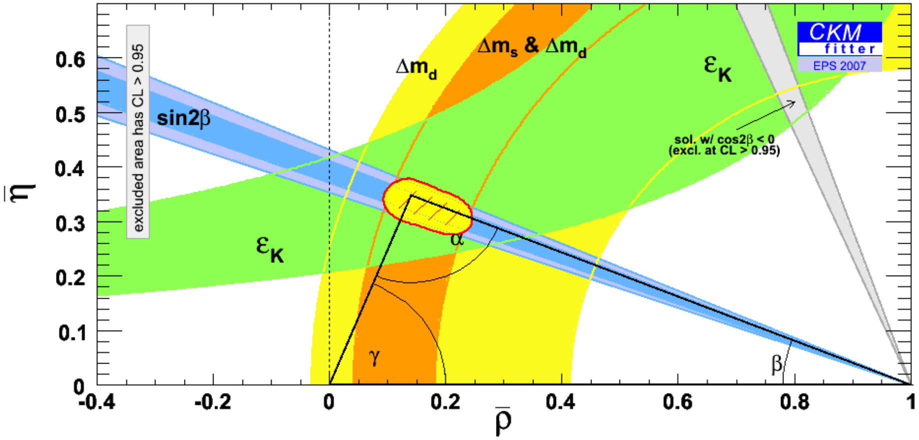


No angles (large theoretical uncertainties)

The global CKM fit: Testing the CKM Paradigm (cont.)



Observables w/ Tree processes



Observables involving Loops

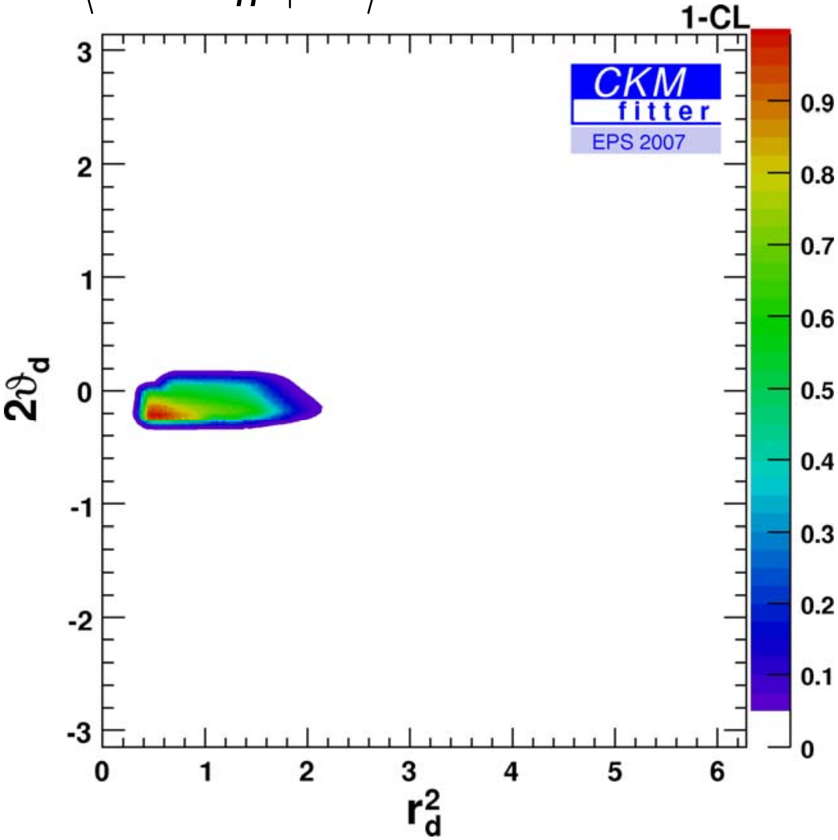
Assuming there is no NP in ΔI=3/2 b→d EW penguin amplitude. Use α with β (charmonium) to produce a new γ Tree.

Even if we are not entered a precision era, the CKM mechanism IS the dominant source of CP violation, enough to accommodate within the Standard Model the whole set of Observables.

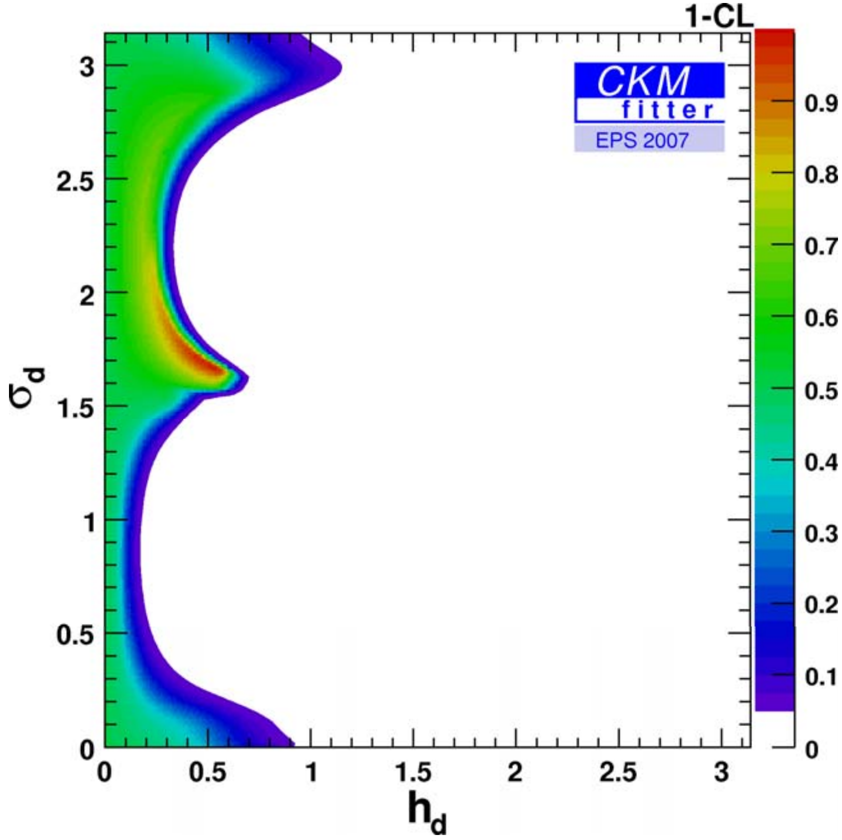
As a consequence, the space left to NP in B_d system IS strongly constrained.

NP in B_d System

$$\frac{\langle B_q^0 | H_{eff}^{SM+NP} | \overline{B}_q^0 \rangle}{\langle B_q^0 | H_{eff}^{SM} | \overline{B}_q^0 \rangle} = r_q^2 e^{i2\theta_q} = 1 + h_q e^{i2\sigma_q}$$



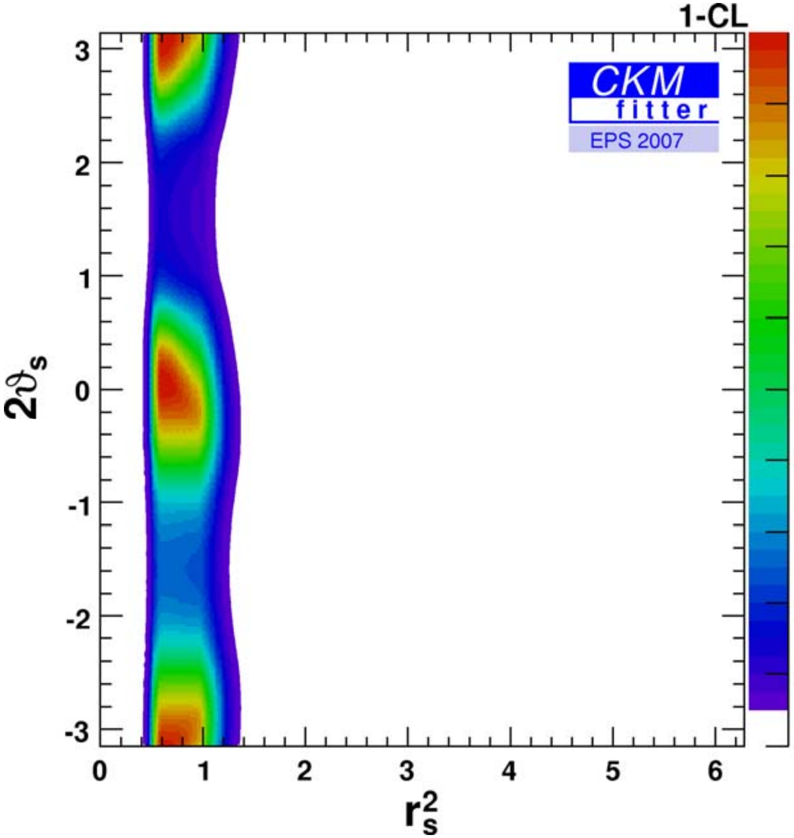
Not much room left for NP in $\Delta F|_d=2$.



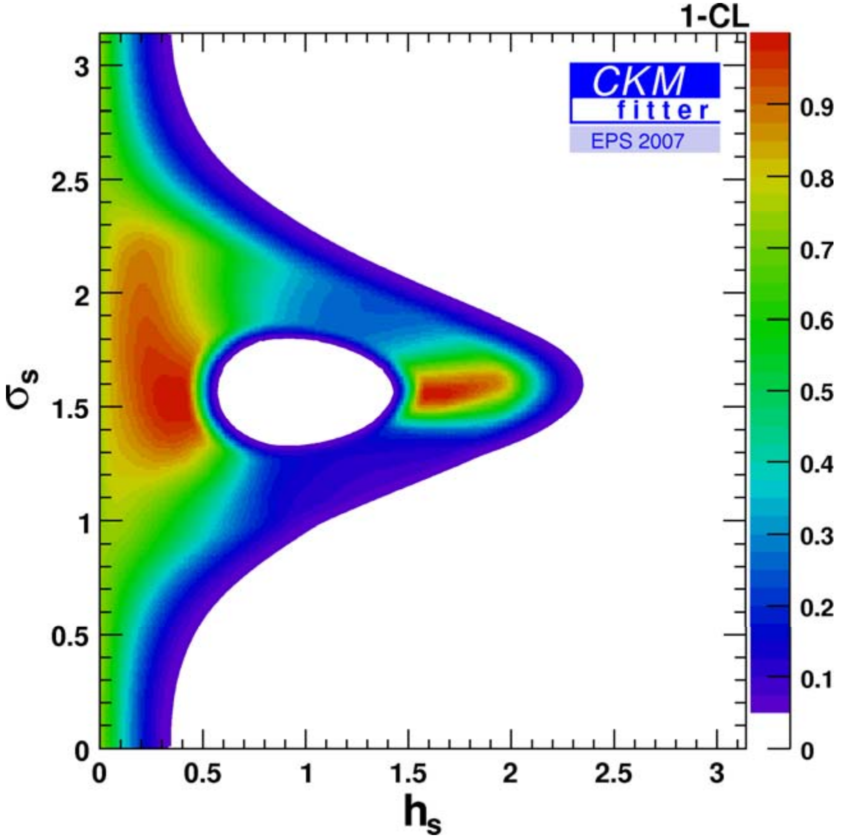
The preferred regions of parameter space (maximum 1-CL) are displaced w.r.t the SM one. Reflects the V_{ub} vs sin (2β) tension.

NP in B_s System

Δm_s, $\Delta\Gamma_s$ and A^s_{SL}



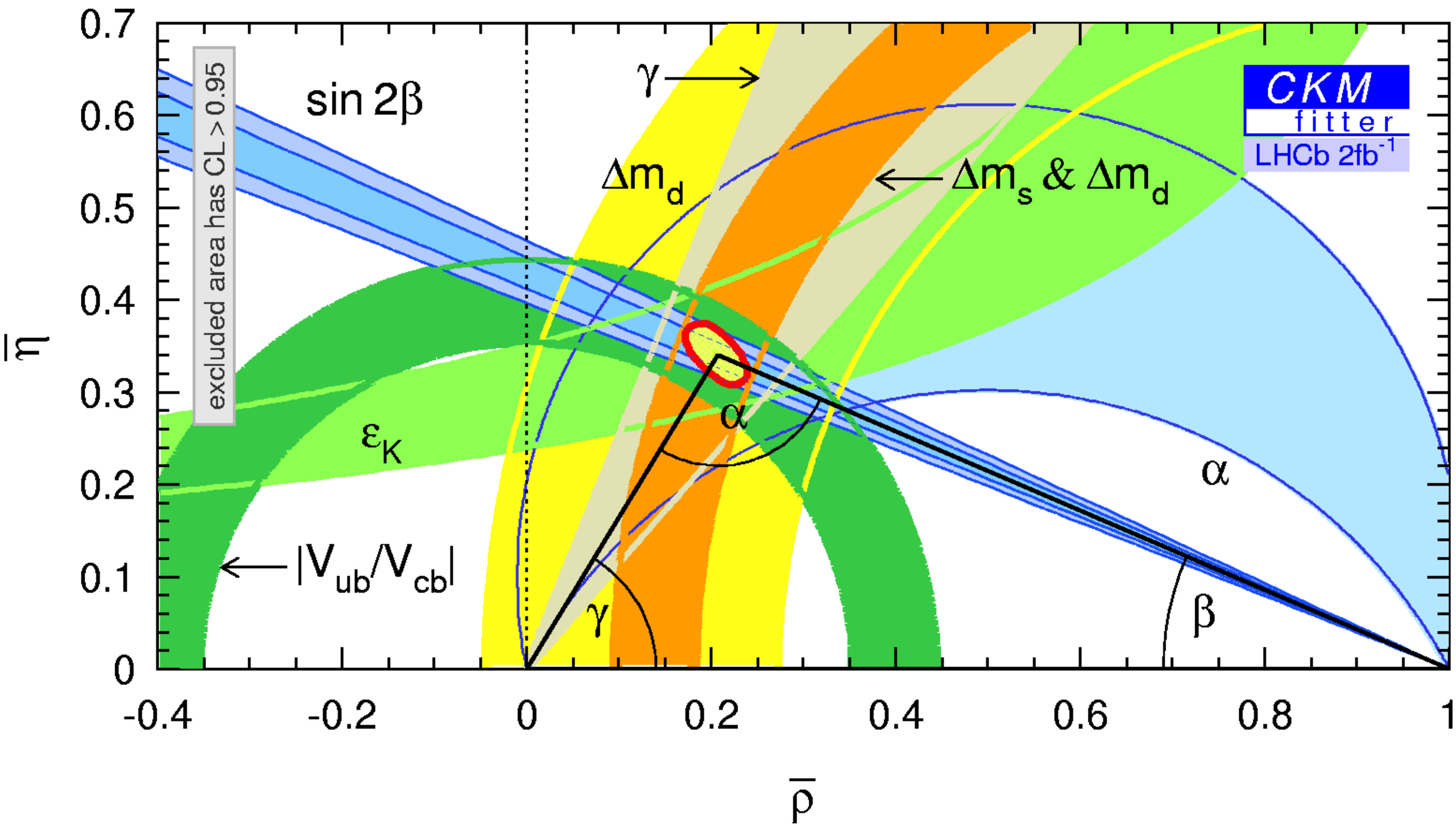
First constraint for NP in the B_s sector come from the Tevatron. Still plenty of room for NP.



$h_s \leq 3$ while $h_d \leq 1$

Large theoretical uncertainties: LQCD

Towards the precision era : LHCb 2 fb^{-1} EPS 2009 ?



Assumptions:
LHCb TDR

$\sigma(\Delta m_s)=0.01$

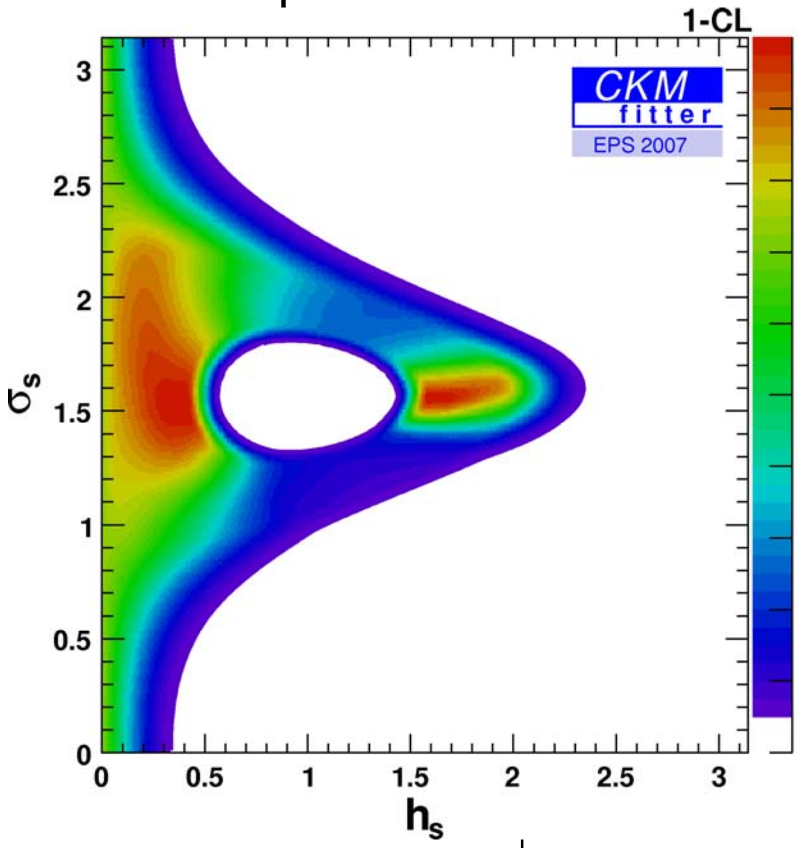
$\sigma(\sin 2\beta)=0.02$

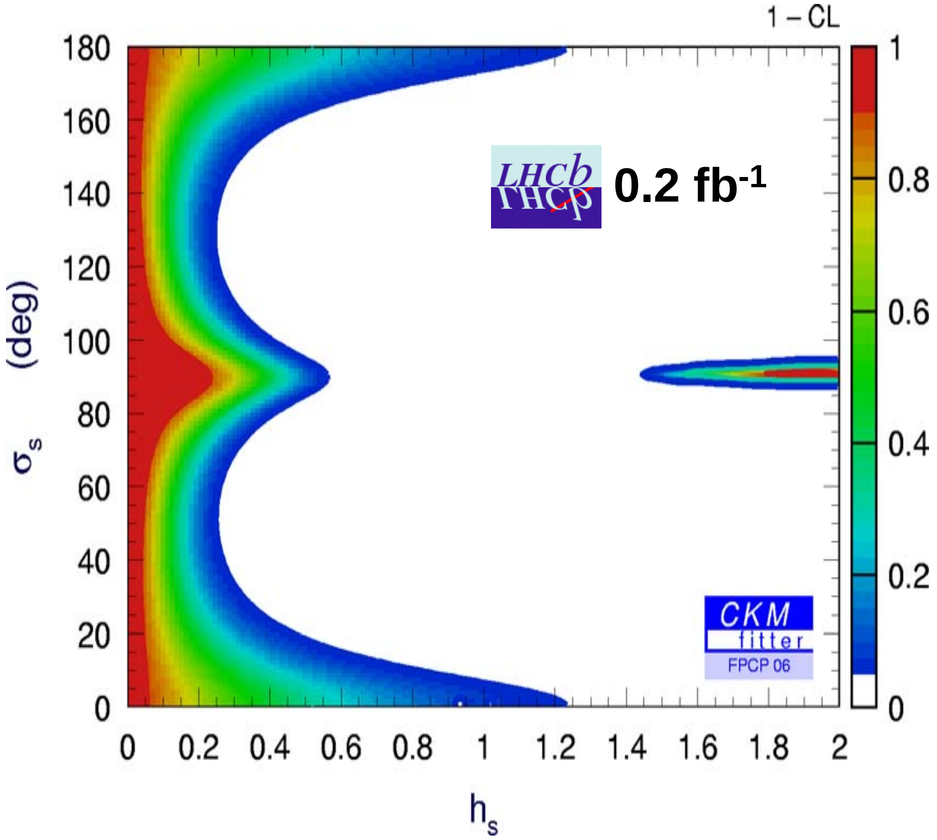
$\sigma(\alpha) = 10^\circ$

$\sigma(\gamma) = 5^\circ$

Towards the precision era : LHCb 0.2 fb^{-1} EPS2009

β_s is precisely predicted in the Standard Model. LHCb can rapidly constrain NP parameters thanks to Bs decays in $J/\Psi\,\Phi$ for instance. Hopefully it won't be that Standard picture.





assumptions:

$\sigma(\Delta m_s)$= 0.035

$\sigma(\sin 2\beta_s)$=0.09

Conclusions

1. The CKM mechanism faced a great success in describing flavor dynamics of many constraints from vastly different scales. It's the dominant source of CP violation in B system. The BaBar and Belle experiments provided fantastic measurements in that respect.

2. Stringent constraints on NP, established in a model-independent manner in $\Delta F=2$ transitions , are already existing in the B_d system. The Tevatron measurements in the B_s sector start to constraint NP in the Bs sector.

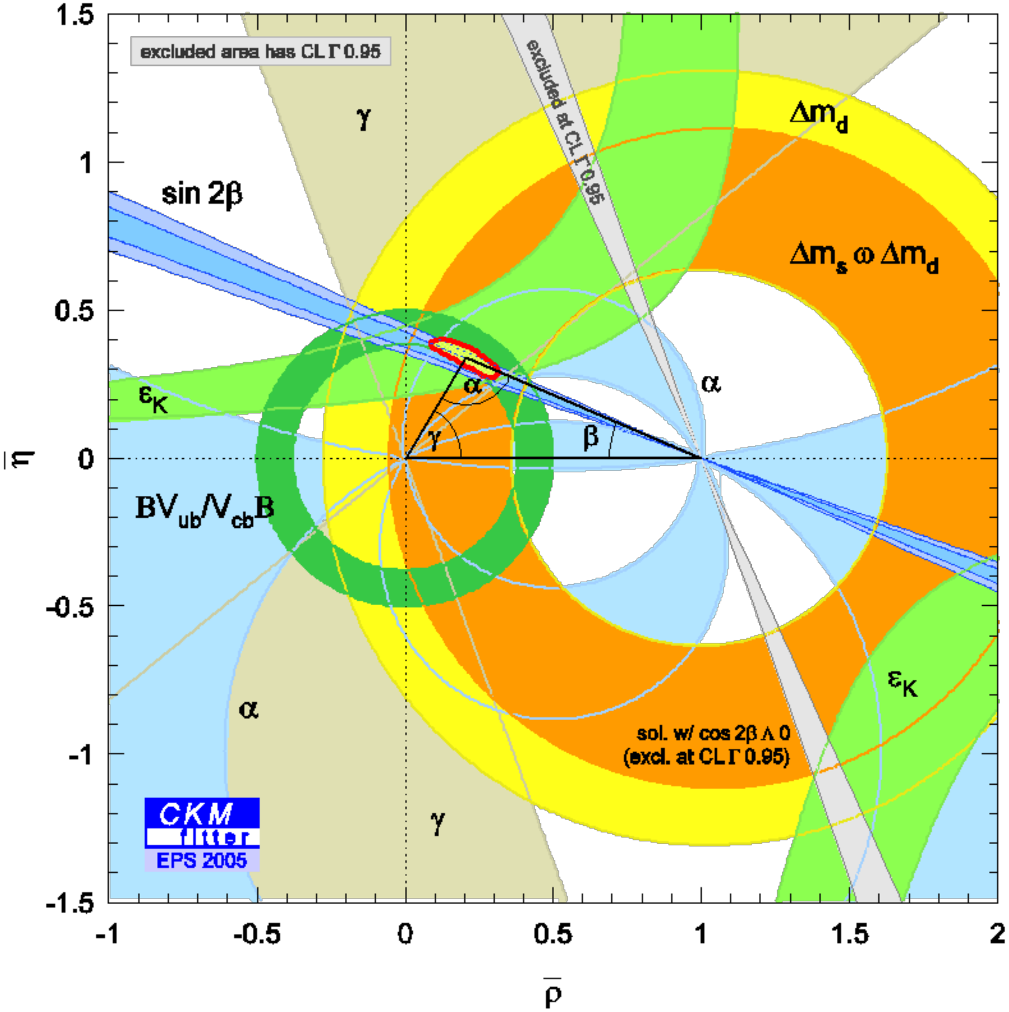
3. We are not entered the precision era yet. A precise/O(5%) γ measurement is around thanks to the LHCb experiment. The step forward for improving α measurement is more delicate.

4. The B_s system is a basically new territory to explore. B_s transitions might be powerful probes for NP.

Back Up Slides.

Overall Picture

the global CKM fit



Inputs:

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

Δm_d

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$B \to \tau\nu$

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α

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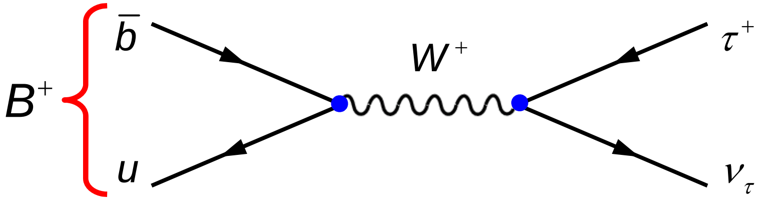
3. NP : $B^+ \to \tau^+ \nu_\tau$

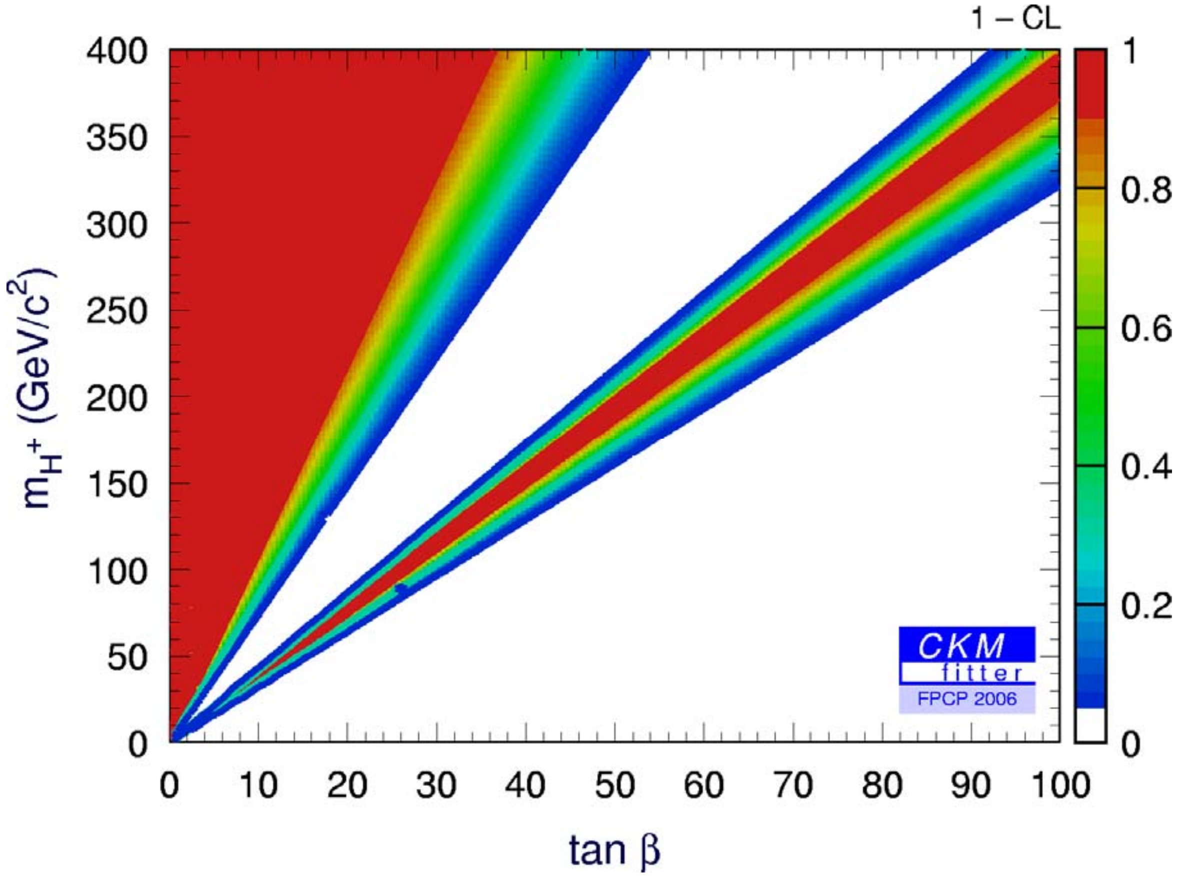


In addition, decay mediated by a charged Higgs.

$$BF(B^+ \to \tau^+ \nu_\tau) =$$

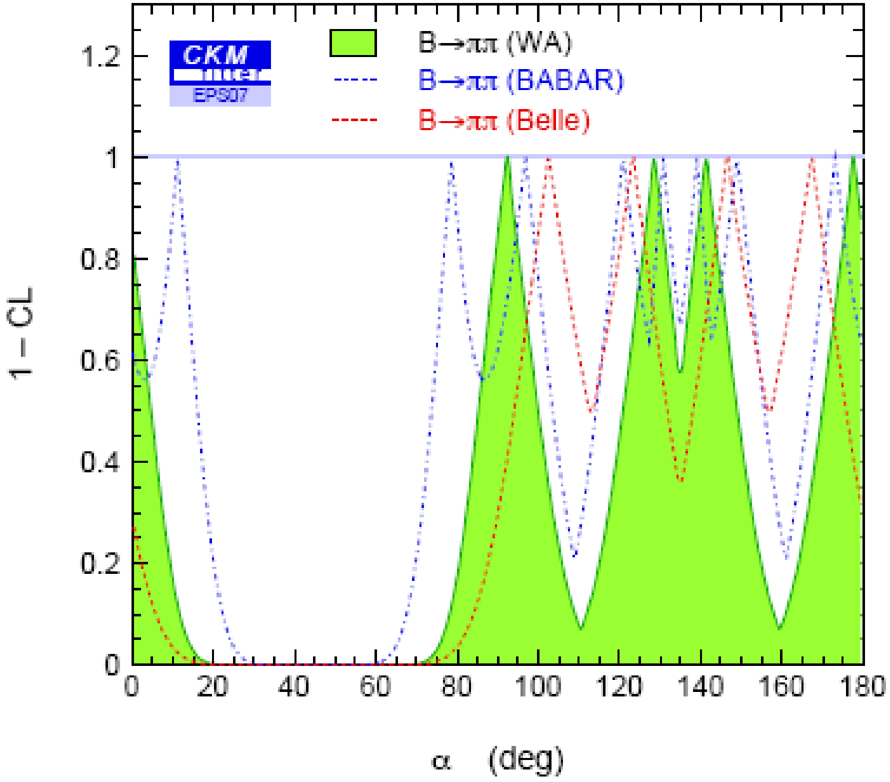
$$BF(B^+ \to \tau^+ \nu_\tau)_{SM} \times c_H$$

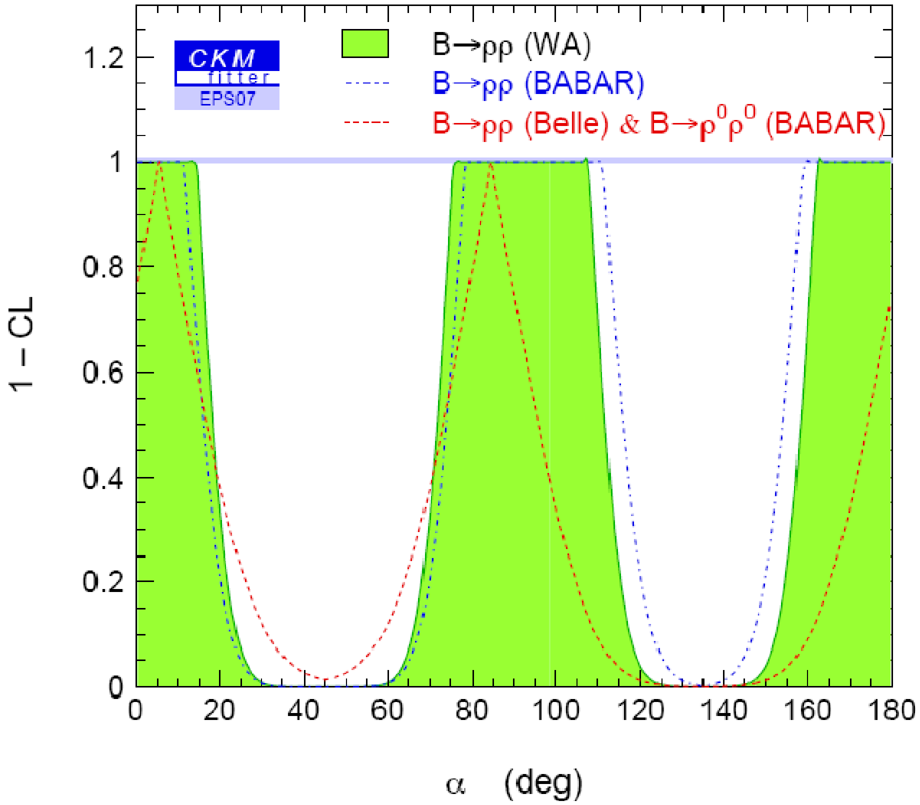
$$c_H = (1 - \frac{m_B^2}{m_H^2}) \tan^2 \beta$$



CKM Global Fit Inputs (selection of) : α

Combination of Belle and Babar measurements in charmless B decays $\pi\pi$,$\rho\rho$ and $\rho\pi$.

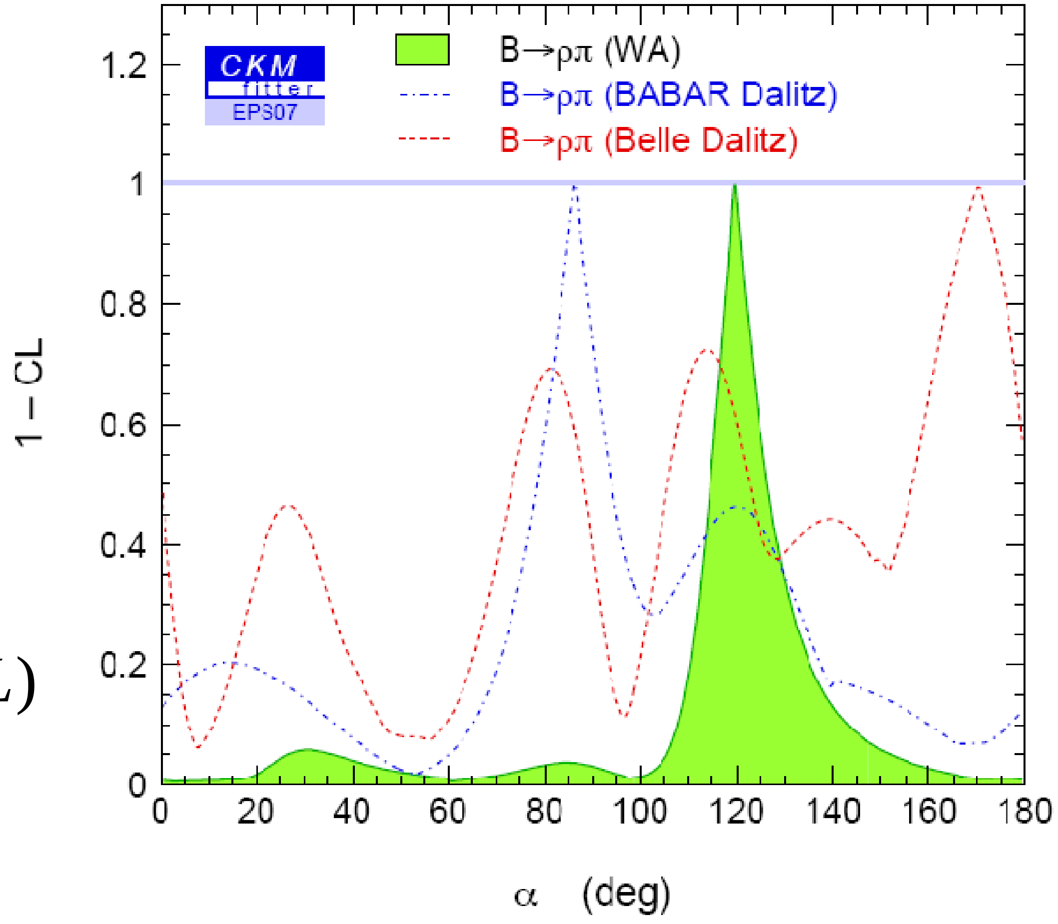




$$\alpha = 115.5^{+8.6}_{-37.5} \ \text{deg}\ (95\% \, CL)$$

CKM Global Fit Inputs (selection of) : α

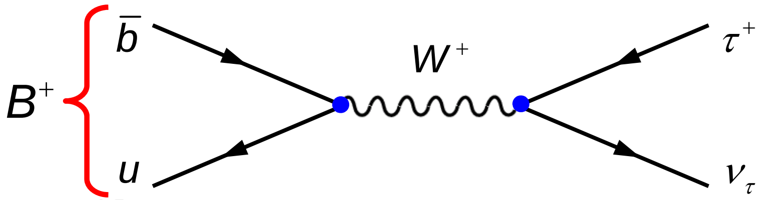
Combination of Belle and Babar measurements in charmless B decays ππ,ρρ and ρπ.



$$\alpha = 115.5^{+8.6}_{-37.5} \ \text{deg}\ (95\%\,CL)$$

$B^+ \to \tau^+\nu_\tau$

- helicity-suppressed annihilation decay sensitive to $f_B \times |V_{ub}|$
- Powerful <u>together</u> with Δm_d : removes f_B (Lattice QCD) dependence
- Sensitive to charged Higgs replacing the W propagator



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