The CKM matrix :

Status and sensitivity to New Physics

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On behalf of the CKMfitter group

CKM fitter

EPS 09

http://ckmfitter.in2p3.fr

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H. Lacker	ATLAS & BABAR	Humboldt	Berlin
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V. Niess	LHCb	LPC	Clermont-Ferrand
J. Ocariz	BABAR	LPNHE	Paris
S. T'Jampens	LHCb	LAPP	Annecy-le-Vieux
V. Tisserand	BABAR	LAPP	Annecy-le-Vieux
K. Trabelsi	Belle	KEK	Tsukuba

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This talk

- **Introduction**

- **The CKM Global Fit as of Summer 2009**
    - **Experimental, theoretical inputs, results**

- **Selected topics from the CKM global fit**

    - α **,** ε_K **,** V_{ub} **,** β **and** $B \to \tau\nu$
    - **will skip NP in** $B_{(s)}$ **mixing**

- **A hint on the future : CKM from rare kaon decays**

- **Conclusions**

The CKM Matrix

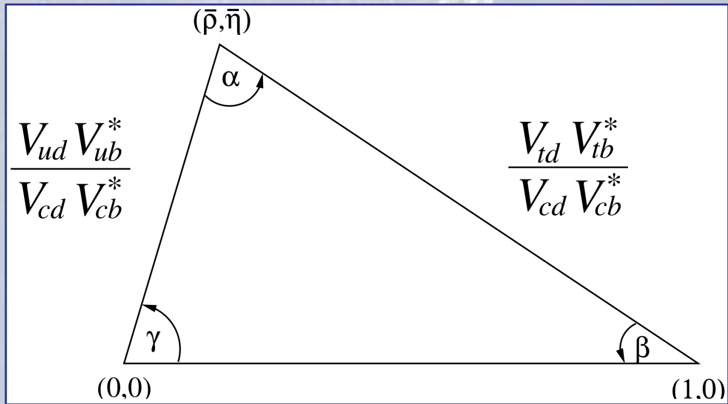
$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}$$

$$A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2}$$

$$\overline{\rho} + i\overline{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

The CKM Matrix:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix}_J = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}_M$$



Unitary-exact, phase independent Wolfenstein parametrisation :

V_{ud} , V_{us} **and** V_{cb} **determine** A **and** λ

$\overline{\rho}+i\overline{\eta}$ **are determined from the angles and sides of the UT**

Inputs to the global CKM fit

Parameter	*Experimental source*	*Method, theoretical parameters, references*
$\|V_{ud}\|$	Superallowed b decays	*Towner & Hardy*, PRC 77, 025501 (2008)
$\|V_{us}\|$	K_{l3} (WA Flavianet)	$f_+^{K\pi}(0)=0.964(5)$
$\|V_{cb}\|$	HFAG incl.+excl. $B\to X_c l n$	
$\|V_{ub}\|$	HFAG incl.+excl. $B\to X_d l n$	OOA : $3.87(9)(46)\times10^{-3}$
Δm_d	WA HFAG B_d- $\bar{B}_d$ mixing	OOA : B_{Bs}/B_{Bd}= 1.05(2)(5) + f_{Bs} + f_{Bd}
Δm_s	CDF B_s- $\bar{B}_s$ mixing	OOA : B_{Bs}= 1.23(3)(5) + f_{Bs} + f_{Bd}
$B^-\to\tau^-\nu$	WA: BaBar/Belle	OOA : f_{Bs}/f_{Bd}= 1.196(8)(23) & f_{Bs}= 228(3)(17)
$\|\varepsilon_K\|$	K^0- $\bar{K}^0$ (KLOE, KTeV)	OOA : B_K= 0.721(5)(40)
β	WA HFAG	
α	WA $\pi\pi/\rho\pi/\rho\rho$	isospin SU(2)
γ	WA HFAG $B^-\to D^{(*)}K^{(*)-}$	GLW/ADS/GGSZ

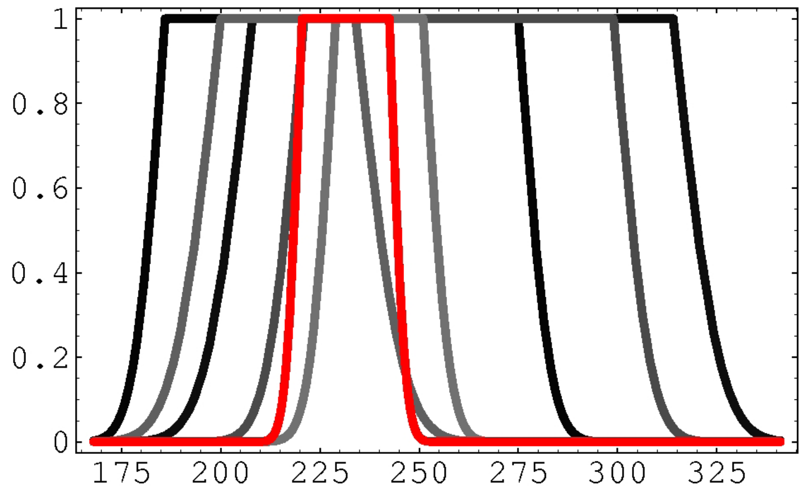
Frequentist hypothesis-testing approach :

confidence intervals obtained through $\Delta\chi^2$

dedicated RFit scheme for theoretical uncertainties

The RFit statistical scheme, OOA

- theoretical uncertainties are bounded over a range without any preference
- minimisation explores uniformly the theoretical parameter space



OOA for *Bs* decay constant

Reference	N_f	Mean	Stat	Syst
CP-PACS01	2	242	9	$^{+53}_{-34}$
MILC02	2	217	6	$^{+58}_{-31}$
JLQCD03	2	215	9	$^{+19}_{-15}$
HPQCD03	2+1	260	7	39
FNAL-MILC07∗	2+1	240	5	26
Our average		228	3	17

In presence of multiple, different estimations of theoretical parameters,

we use the ``educated RFit'' approach to obtain Our Own Averages (OOA) :

- **central values : weighted average from statistical errors only**
- **statistical errors : combination of statistical errors**
- **theoretical errors : use the RFit range for the most precise input**

The Global CKM fit : result

INPUTS :

$|V_{ud}|, |V_{us}|, |V_{cb}|,$

$|V_{ub}|, BR(B^- \to \tau^- \nu),$

$\Delta m_d, \Delta m_s,$

$|\varepsilon_K|,$

α, β, γ

RESULTS :

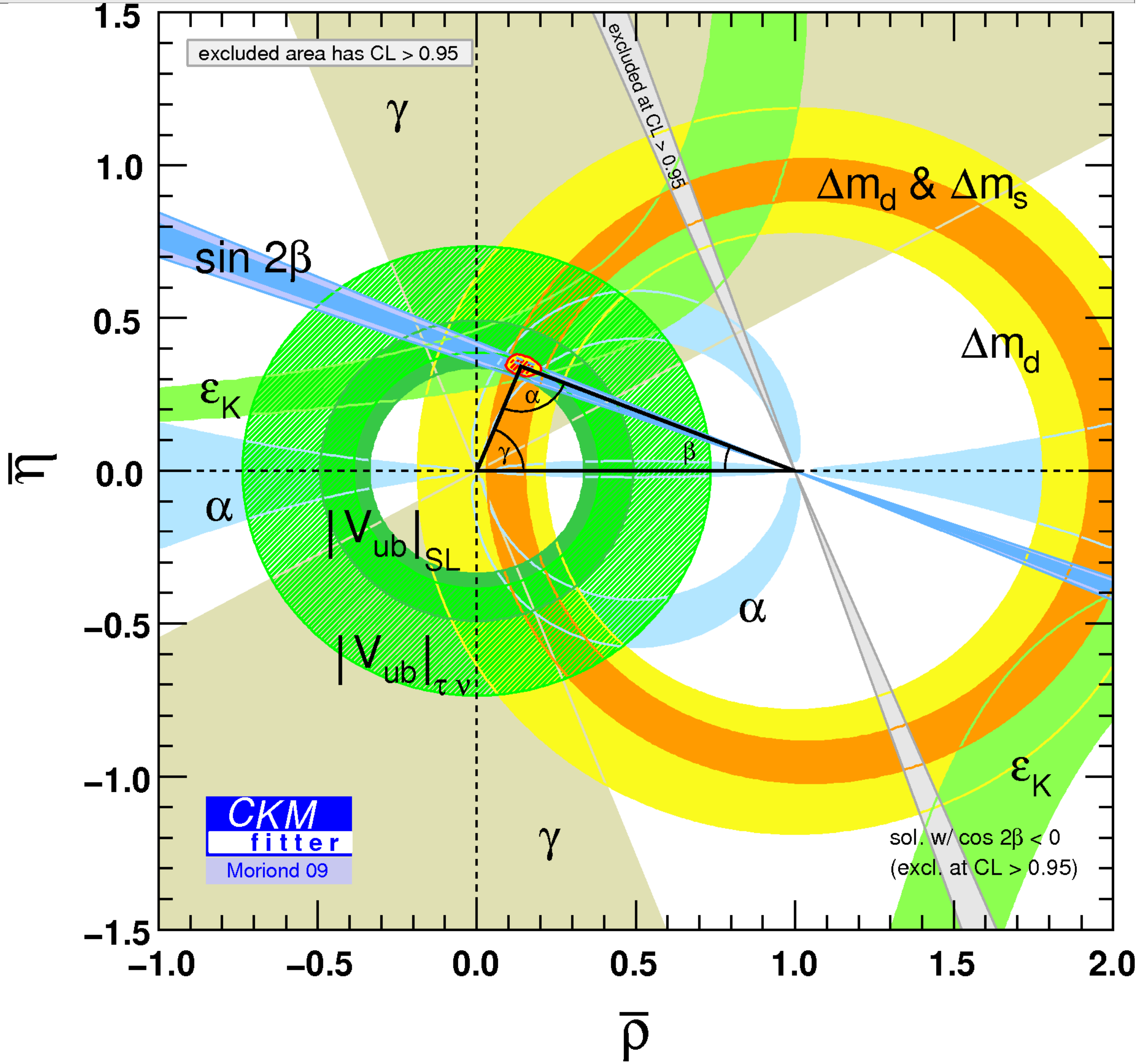
$$A = 0.812^{+0.010}_{-0.024}$$

$$\lambda = 0.2252 \pm 0.0008$$

$$\bar{\rho} = 0.139^{+0.025}_{-0.027}$$

$$\bar{\eta} = 0.341^{+0.016}_{-0.015}$$

(68%C.L.)



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Overall consistency at 95% C.L.

Global fit p-value : 45% (0.8σ)

Fit dominated by :

sin2β , Δmd/Δms , α

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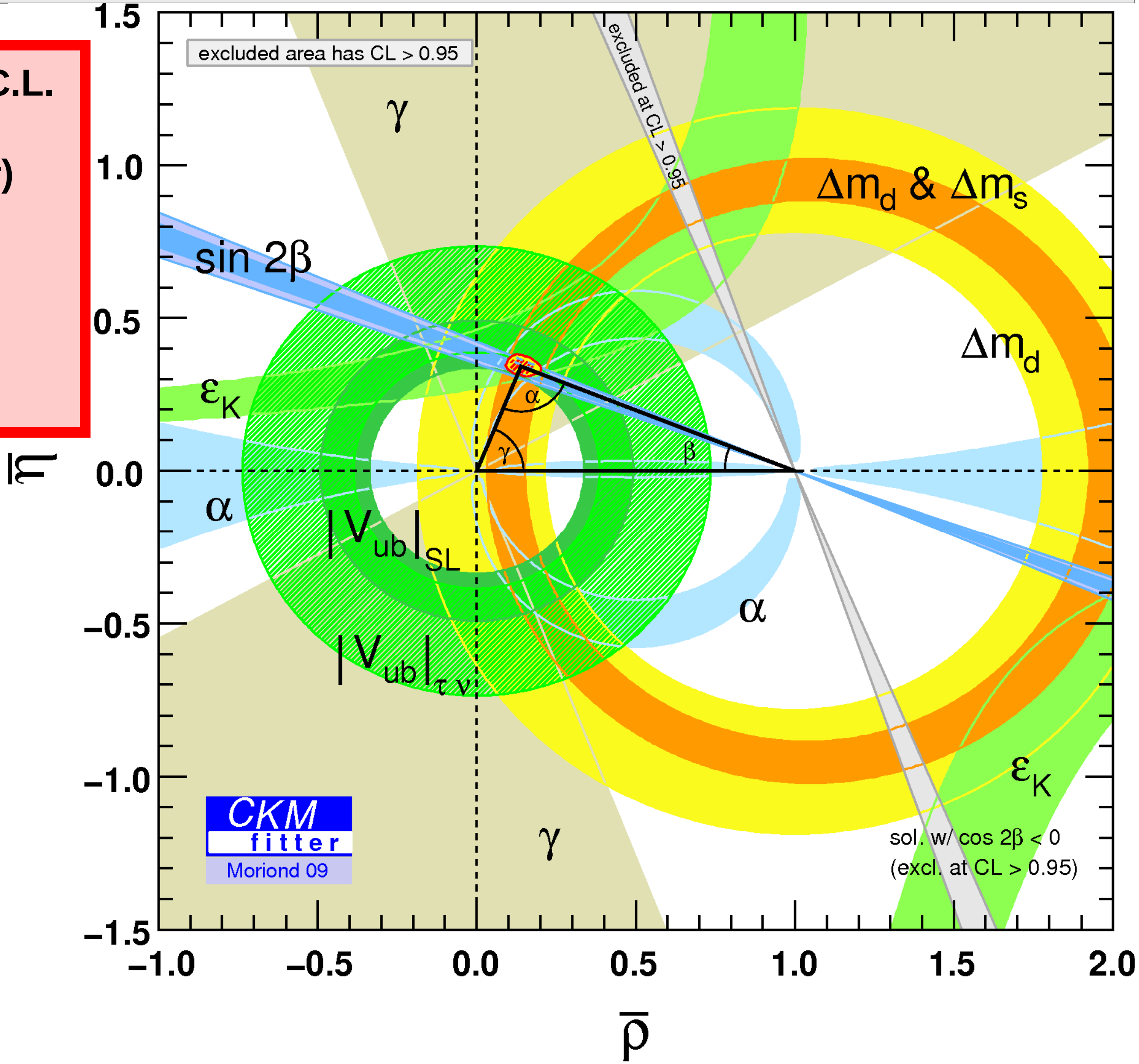

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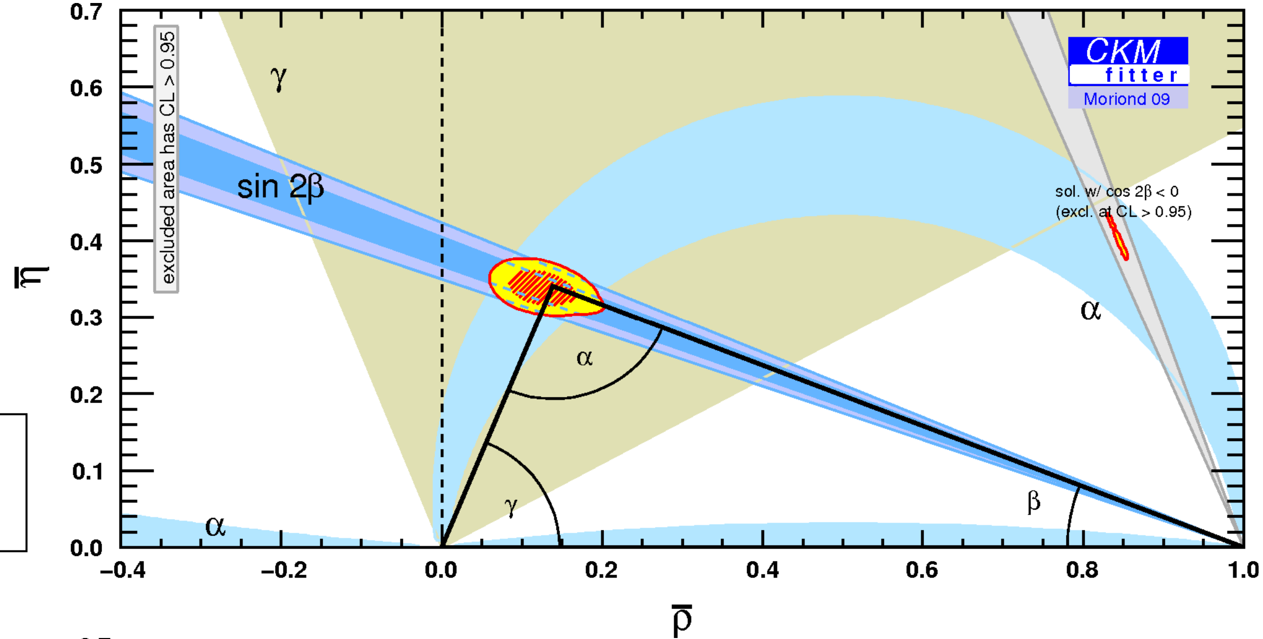
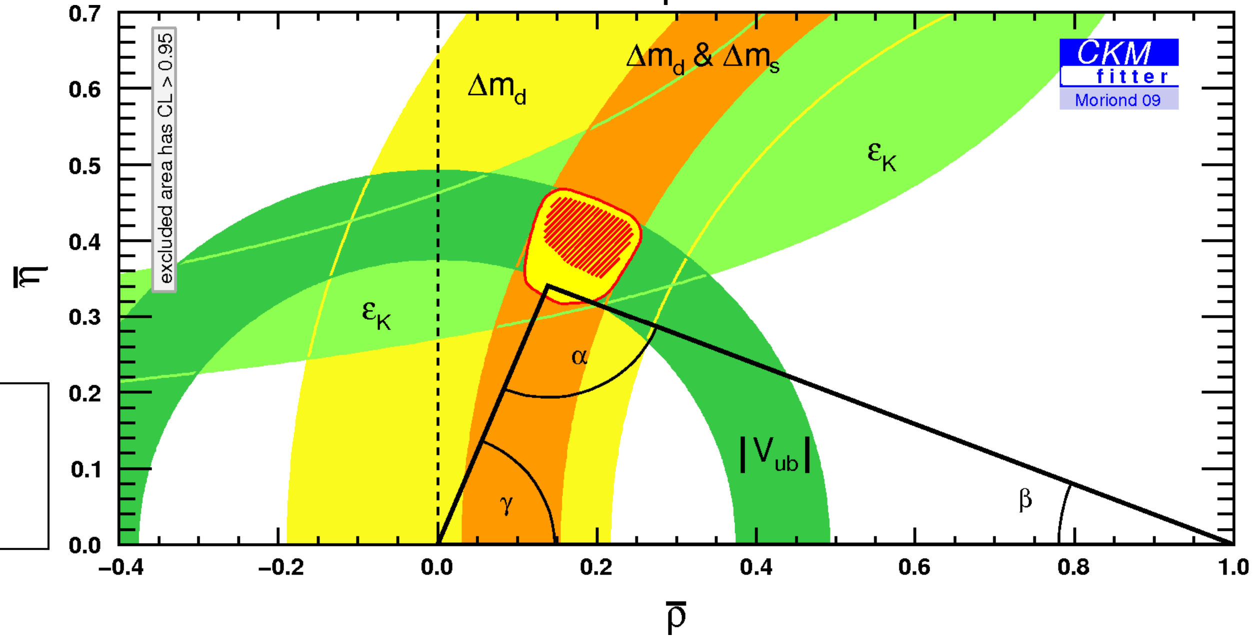
Using CKM angles as only inputs…



Excluding CKM angles

from the inputs …



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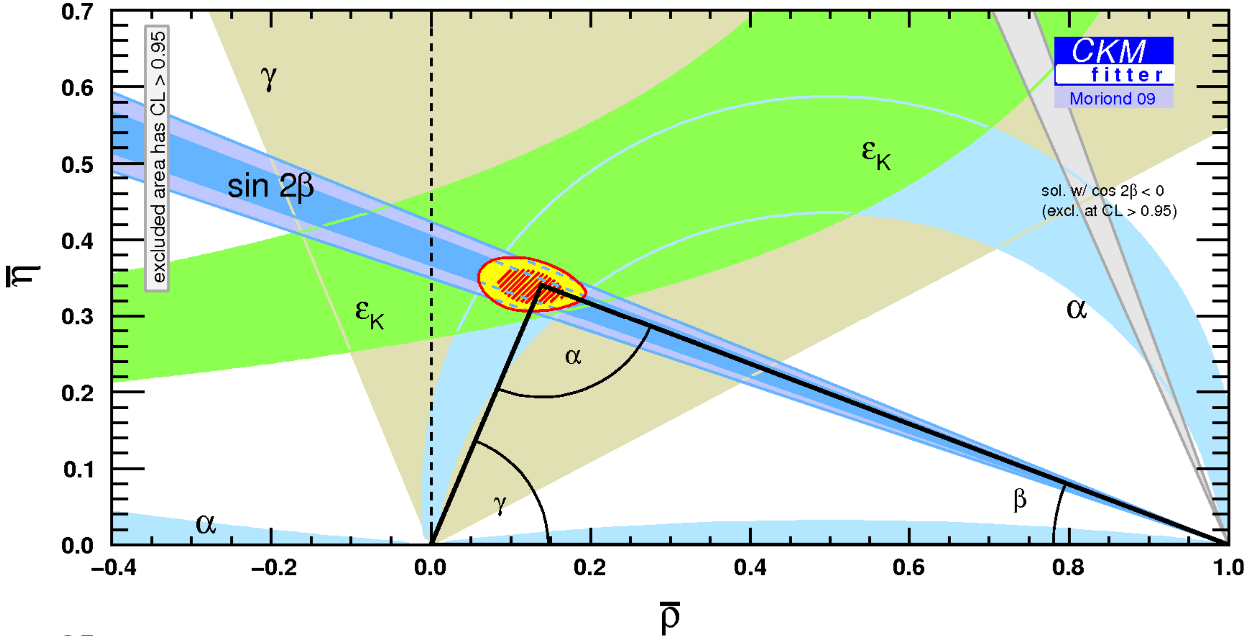

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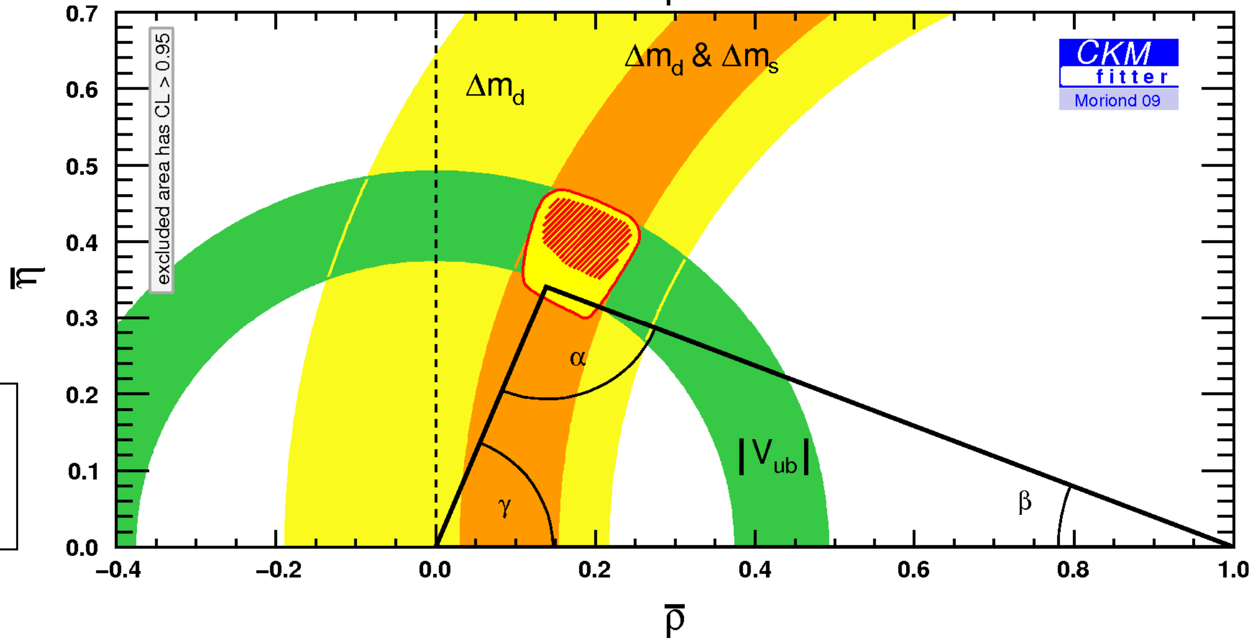

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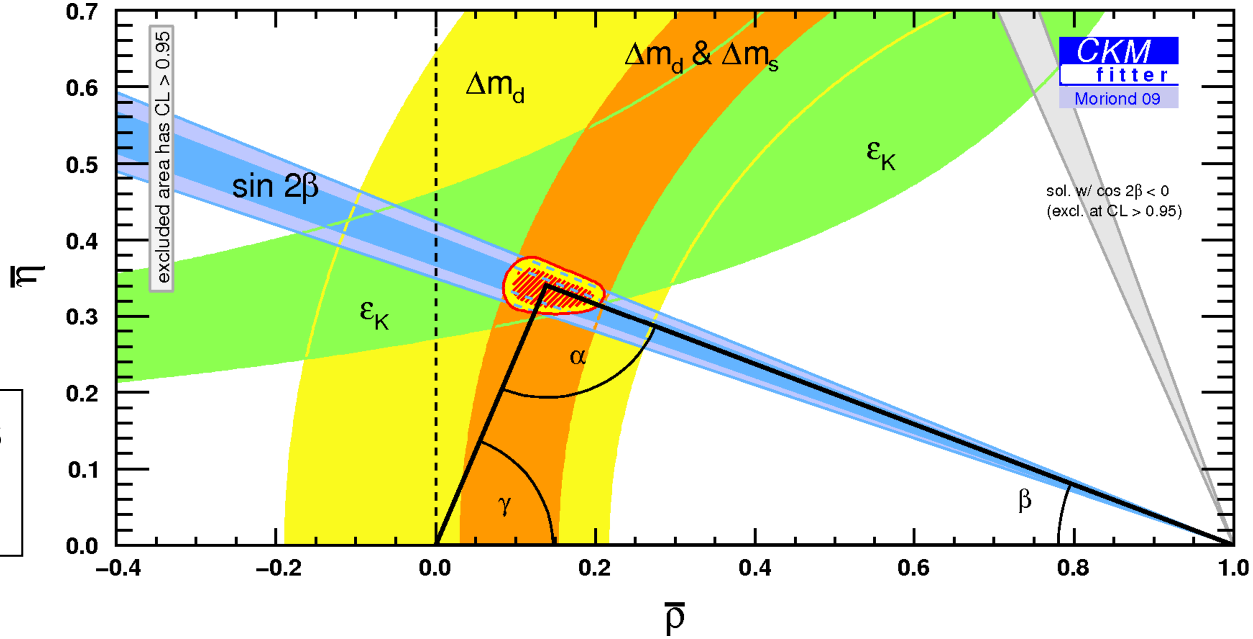
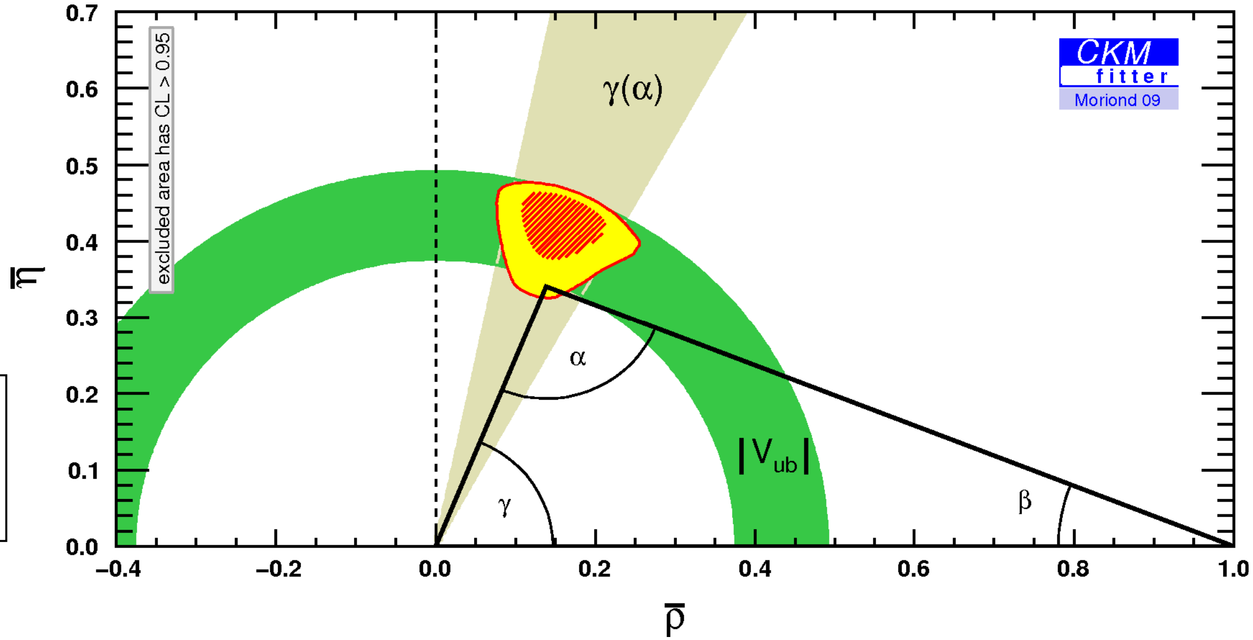


Using Loop-level processes as only inputs…



Using Tree-level processes as only inputs …

The Global CKM fit : results

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The inputs for the global fit (pdf).

- Wolfenstein parameters
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Wolfenstein parameters and Jarlskog invariant:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
A	0.8116 [+0.0097 -0.0241]	0.812 [+0.019 -0.036]	0.812 [+0.029 -0.045]
λ	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
ρbar	0.139 [+0.025 -0.027]	0.139 [+0.053 -0.040]	0.139 [+0.073 -0.052]
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J $[10^{-5}]$	2.92 [+0.15 -0.15]	2.92 [+0.30 -0.19]	2.92 [+0.45 -0.23]

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Observable	Central ± 1 σ	± 2 σ	± 3 σ
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sin 2β (meas. not in the fit)	0.817 [+0.026 -0.040]	0.817 [+0.039 -0.114]	0.817 [+0.052 -0.171]
|sin (2β+γ)|	0.934 [+0.023 -0.030]	0.934 [+0.039 -0.051]	0.934 [+0.049 -0.071]
α [deg]	90.6 [+3.8 -4.2]	90.6 [+7.5 -6.3]	90.6 [+10.2 -8.2]
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α [deg] (dir. meas.)	89.0 [+4.4 -4.2]	89.0 [+9.1 -8.3] || 178.3 [+1.7 -5.6] || 0 [+5 -0]	89 [+21 -13] || 178.3 [+1.7 -13.8] || 0 [+12 -0]
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R_u	0.368 [+0.015 -0.013]	0.368 [+0.030 -0.022]	0.368 [+0.045 -0.030]
R_t	0.926 [+0.027 -0.025]	0.926 [+0.040 -0.053]	0.926 [+0.052 -0.072]

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$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]

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…but prefers a larger value (more on this later)

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|sin (2β+γ)|	0.934 [+0.023 -0.030]	0.934 [+0.039 -0.051]	0.934 [+0.049 -0.071]
α [deg]	90.6 [+3.8 -4.2]	90.6 [+7.5 -6.3]	90.6 [+10.2 -8.2]
α [deg] (meas. not in the fit)	95.6 [+3.3 -8.8]	95.6 [+5.2 -11.8]	95.6 [+6.8 -13.9]
α [deg] (dir. meas.)	89.0 [+4.4 -4.2]	89.0 [+9.1 -8.3] || 178.3 [+1.7 -5.6] || 0 [+5 -0]	89 [+21 -13] || 178.3 [+1.7 -13.8] || 0 [+12 -0]
β [deg]	21.58 [+0.91 -0.81]	21.6 [+1.8 -1.4]	21.6 [+2.8 -1.9]
β [deg] (meas. not in the fit)	27.4 [+1.3 -1.9]	27.4 [+2.0 -5.0]	27.4 [+2.8 -7.3]
β [deg] (dir. meas.)	21.07 [+0.90 -0.88]	21.1 [+1.8 -1.7]	21.1 [+2.8 -2.6]
γ [deg]	67.8 [+4.2 -3.9]	67.8 [+6.3 -8.0]	67.8 [+8.2 -10.6]
γ [deg] (meas. not in the fit)	67.8 [+4.2 -3.9]	67.8 [+6.3 -8.0]	67.8 [+8.2 -10.6]
γ [deg] (dir. meas.)	70 [+27 -30]	70 [+44 -41]	70 [+60 -52] || 131.14 [+0.18 -0.25]
R_u	0.368 [+0.015 -0.013]	0.368 [+0.030 -0.022]	0.368 [+0.045 -0.030]
R_t	0.926 [+0.027 -0.025]	0.926 [+0.040 -0.053]	0.926 [+0.052 -0.072]

UT_s apex and angle:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$\rho_s$bar	-0.0074 [+0.0014 -0.0013]	-0.0074 [+0.0022 -0.0029]	-0.0074 [+0.0028 -0.0040]
$\eta_s$bar	-0.01821 [+0.00081 -0.00085]	-0.0182 [+0.0013 -0.0017]	-0.0182 [+0.0018 -0.0026]
$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]

The Global CKM fit : discussion on α

file:///C:/Documents%20a...

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

CKMfitter global fit results:

The inputs for the global fit (pdf).

- Wolfenstein parameters
- UT angles and sides
- UT_s angle and apex
- CKM elements
- Theory parameters
- Rare branching fractions ($B\to l\nu$, $B\to ll$)

Wolfenstein parameters and Jarlskog invariant:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
A	0.8116 [+0.0097 -0.0241]	0.812 [+0.019 -0.036]	0.812 [+0.029 -0.045]
λ	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
ρbar	0.139 [+0.025 -0.027]	0.139 [+0.053 -0.040]	0.139 [+0.073 -0.052]
ηbar	0.341 [+0.016 -0.015]	0.341 [+0.032 -0.025]	0.341 [+0.048 -0.034]
J [10^{-5}]	2.92 [+0.15 -0.15]	2.92 [+0.30 -0.19]	2.92 [+0.45 -0.23]

UT angles and sides:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
sin 2α	-0.02 [+0.15 -0.13]	-0.02 [+0.22 -0.26]	-0.02 [+0.28 -0.35]
sin 2α (meas. not in the fit)	-0.20 [+0.30 -0.11]	-0.20 [+0.41 -0.17]	-0.20 [+0.48 -0.23]
sin 2β	0.684 [+0.023 -0.021]	0.684 [+0.046 -0.035]	0.684 [+0.068 -0.049]
sin 2β (meas. not in the fit)	0.817 [+0.026 -0.040]	0.817 [+0.039 -0.114]	0.817 [+0.052 -0.171]
|sin (2β+γ)|	0.934 [+0.023 -0.030]	0.934 [+0.039 -0.051]	0.934 [+0.049 -0.071]
α [deg]	90.6 [+3.8 -4.2]	90.6 [+7.5 -6.3]	90.6 [+10.2 -8.2]
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β [deg]	21.58 [+0.91 -0.81]	21.6 [+1.8 -1.4]	21.6 [+2.8 -1.9]
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γ [deg]	67.8 [+4.2 -3.9]	67.8 [+6.3 -8.0]	67.8 [+8.2 -10.6]
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$\eta_s$bar	-0.01821 [+0.00081 -0.00085]	-0.0182 [+0.0013 -0.0017]	-0.0182 [+0.0018 -0.0026]
$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]

The Global CKM fit : discussion on α

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

CKMfitter global fit results:

The inputs for the global fit (pdf).

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- UT angles and sides
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- CKM elements
- Theory parameters
- Rare branching fractions ($B \to l\nu$, $B \to ll$)

CKM angle α now measured with a ~4° accuracy !

Wolfenstein parameters and Jarlskog invariant:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
A	0.8116 [+0.0097 -0.0241]	0.812 [+0.019 -0.036]	0.812 [+0.029 -0.045]
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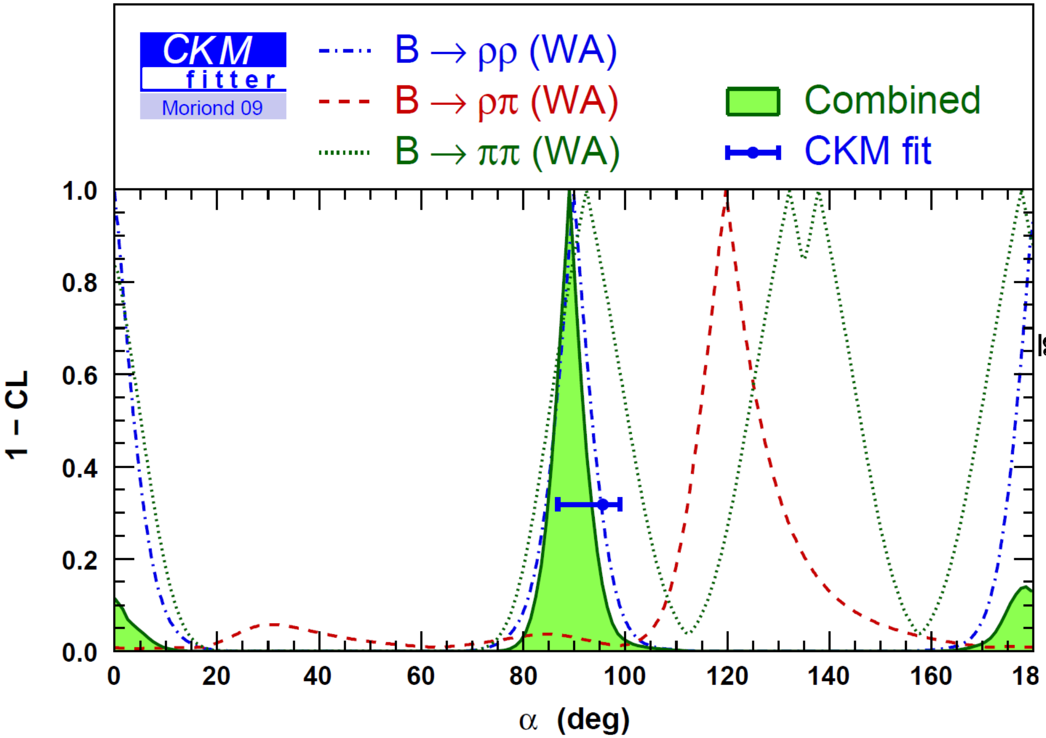
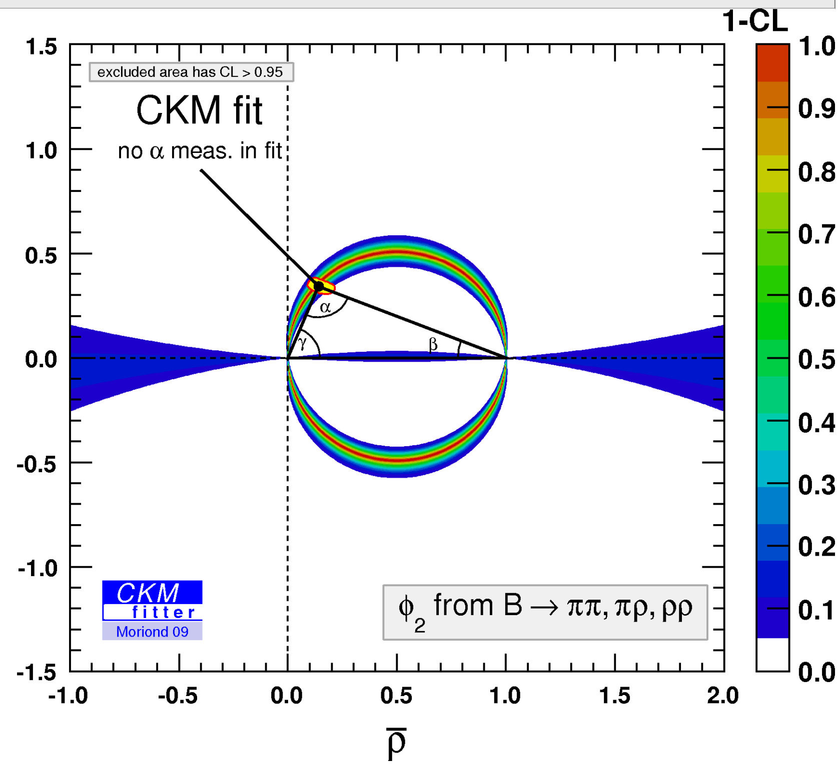
$\eta_s$bar	-0.01821 [+0.00081 -0.00085]	-0.0182 [+0.0013 -0.0017]	-0.0182 [+0.0018 -0.0026]
$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]

The Global CKM fit : discussion on α

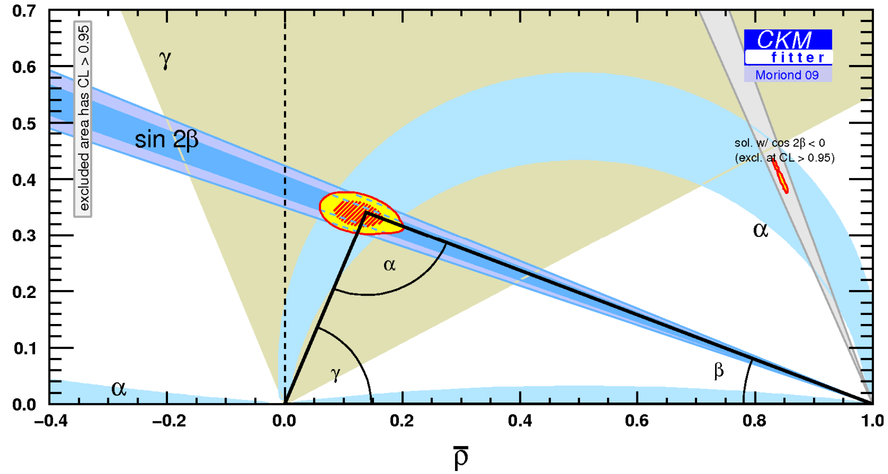




3 contributions to α :

- **Isospin analysis of B→ππ , B→ρρ**
- **Time-dependent Dalitz analysis of B→ρπ**

The dominant contribution is B→ρρ



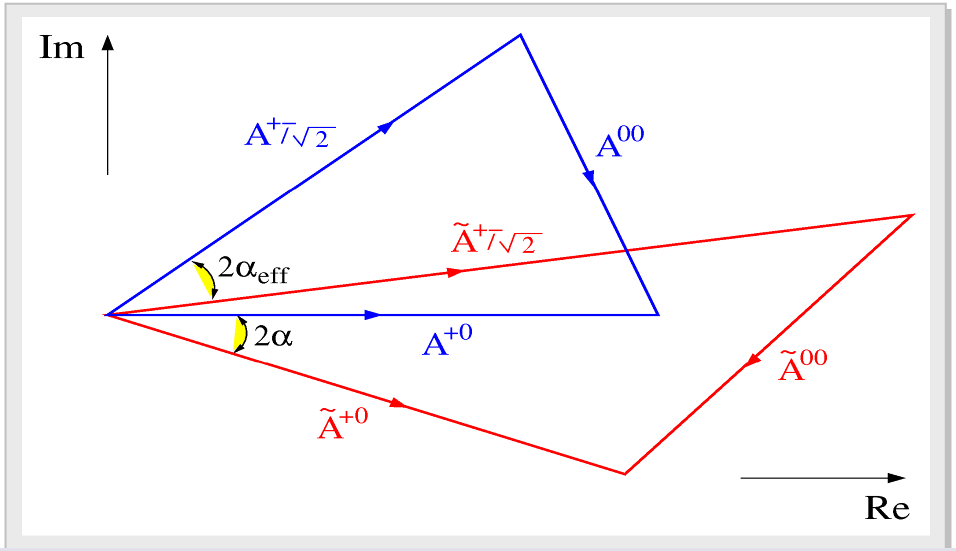
α from isospin analyses

Triangular relation on amplitudes :

$$A^{+-} - \sqrt{2}A^{+0} + \sqrt{2}A^{00} = 0$$

(plus a similar relation for the CP-conjugated amplitudes)

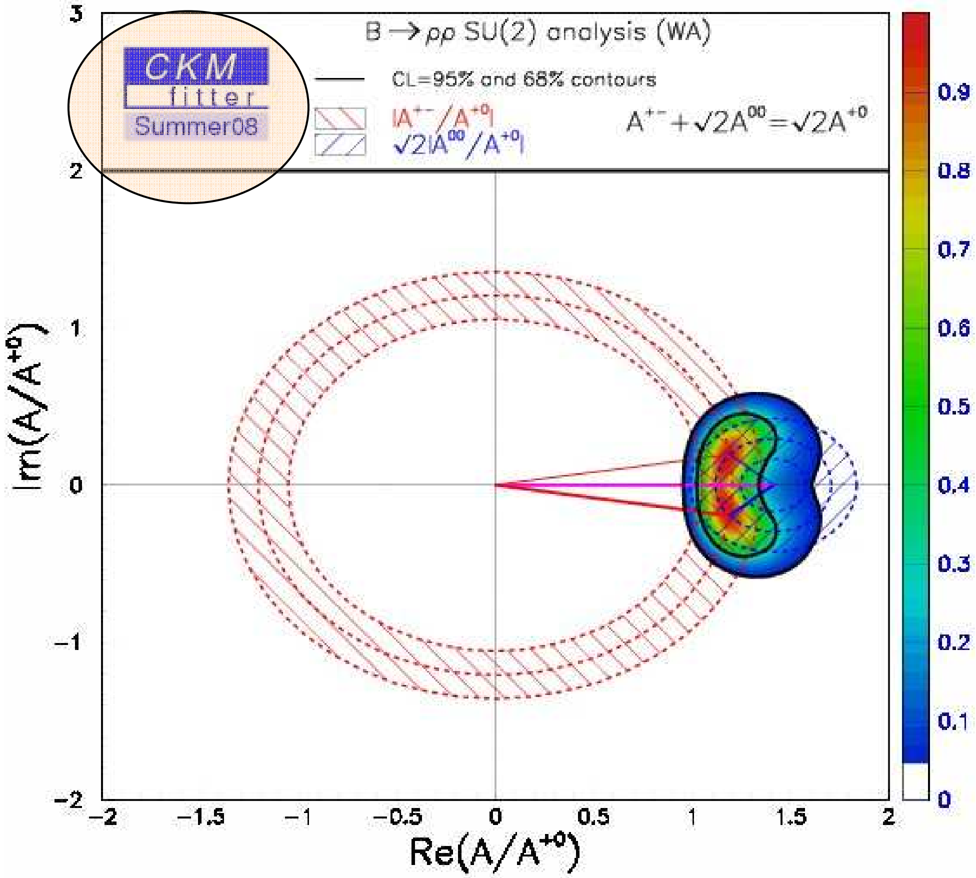
- neglect EW penguins
  - shifts α by ~ 2º
  - A+0 pure tree : no DCPV
  - testable against data
- neglect isospin-breaking effects

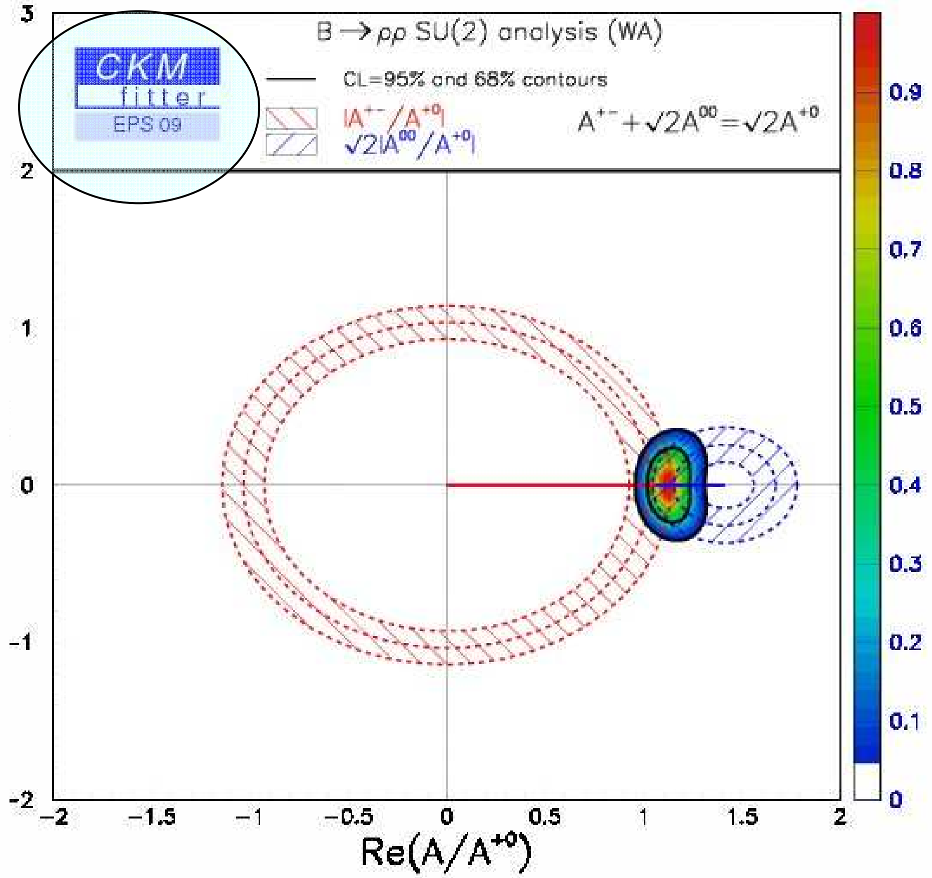


α can be resolved up to an 8-fold ambiguity within [0,π]

Unknowns	Observables	Constraints	Account
α, T^{+-}, P^{+-}, T^{+0}, P^{+0}, T^{00}, P^{00}	B^{+-}, $S_{\pi\pi}$, $C_{\pi\pi}$ B^{+0}, A_{CP} B^{00}, (S_{00}), C_{00}	2 isospin triangles and one common side	13 unknowns – 7 observables – 5 constraints – 1 global phase = 0 ☺

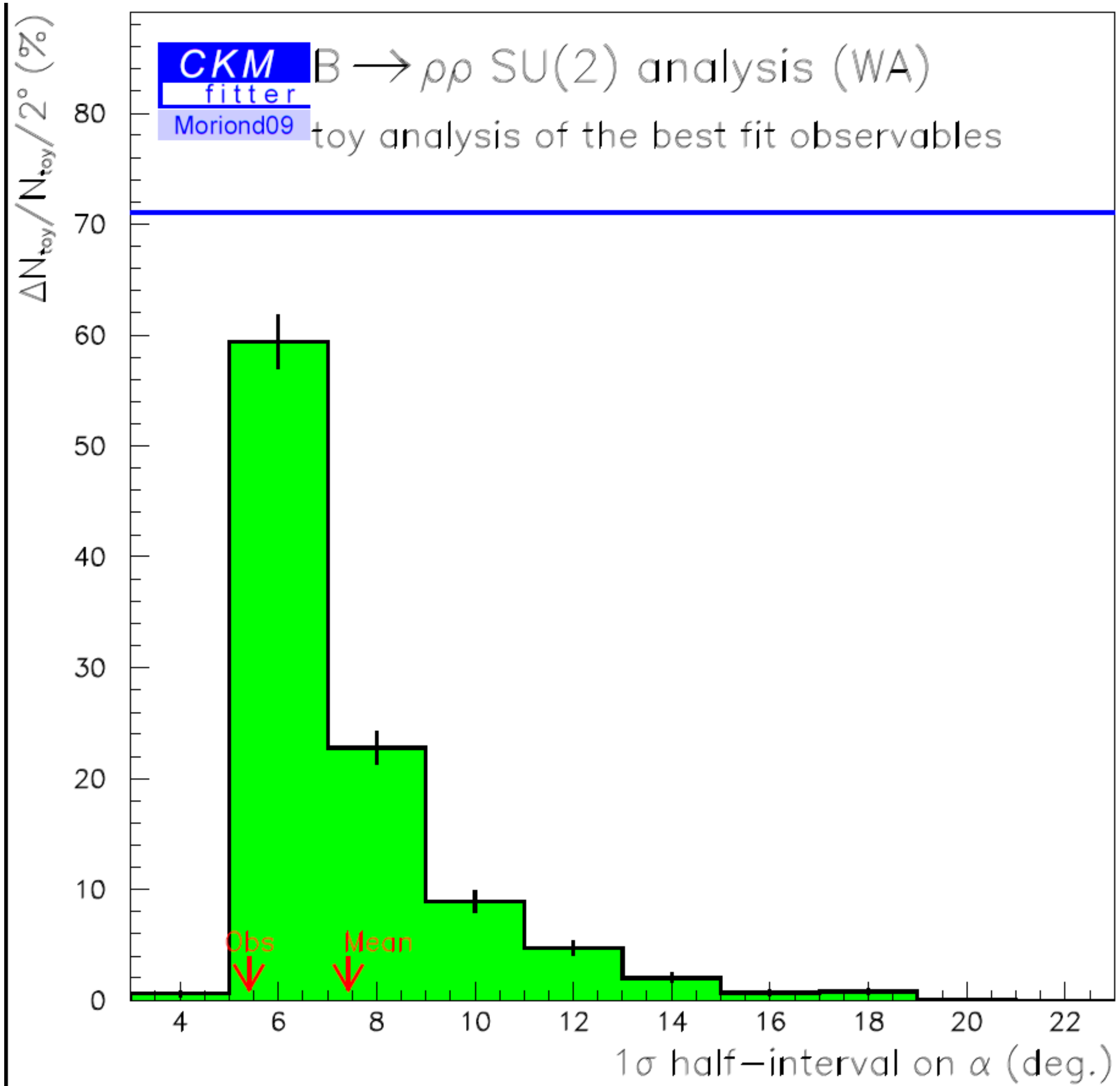
Both B and B isospin triangles do not close (consistent within errors)
mirror solutions are degenerated in a single peak





$$\delta\alpha = (0.5^{+12.6}_{-5.5})^\circ \quad \rightarrow \quad (1.4 \pm 3.7)^\circ$$
$$\alpha = (90.9^{+6.7}_{-14.9})^\circ \quad \rightarrow \quad (89.9 \pm 5.4)^\circ$$

Isospin analysis of B→ρρ *: the lucky shot*



34% of the triangles close

Long asymmetric tail (20°) where pseudo-mirror solutions kick in

Average toy error is 7.5° (observed: 5.4°)

68% of the toys have a larger error than the data

Isospin analysis of $B \to \rho\rho$ *: breaking effects*

At this level of accuracy, consider potential isospin-breaking effects :

- **ρ/ω mixing**
- **finite ρ width**
- **EPWs**
- **…**

Test **4%,** 10% and 15% violation of the triangular relation with arbitrary additional amplitude:

$\Rightarrow A^{+0} \to A^{+0} + \Delta A^{+0}$

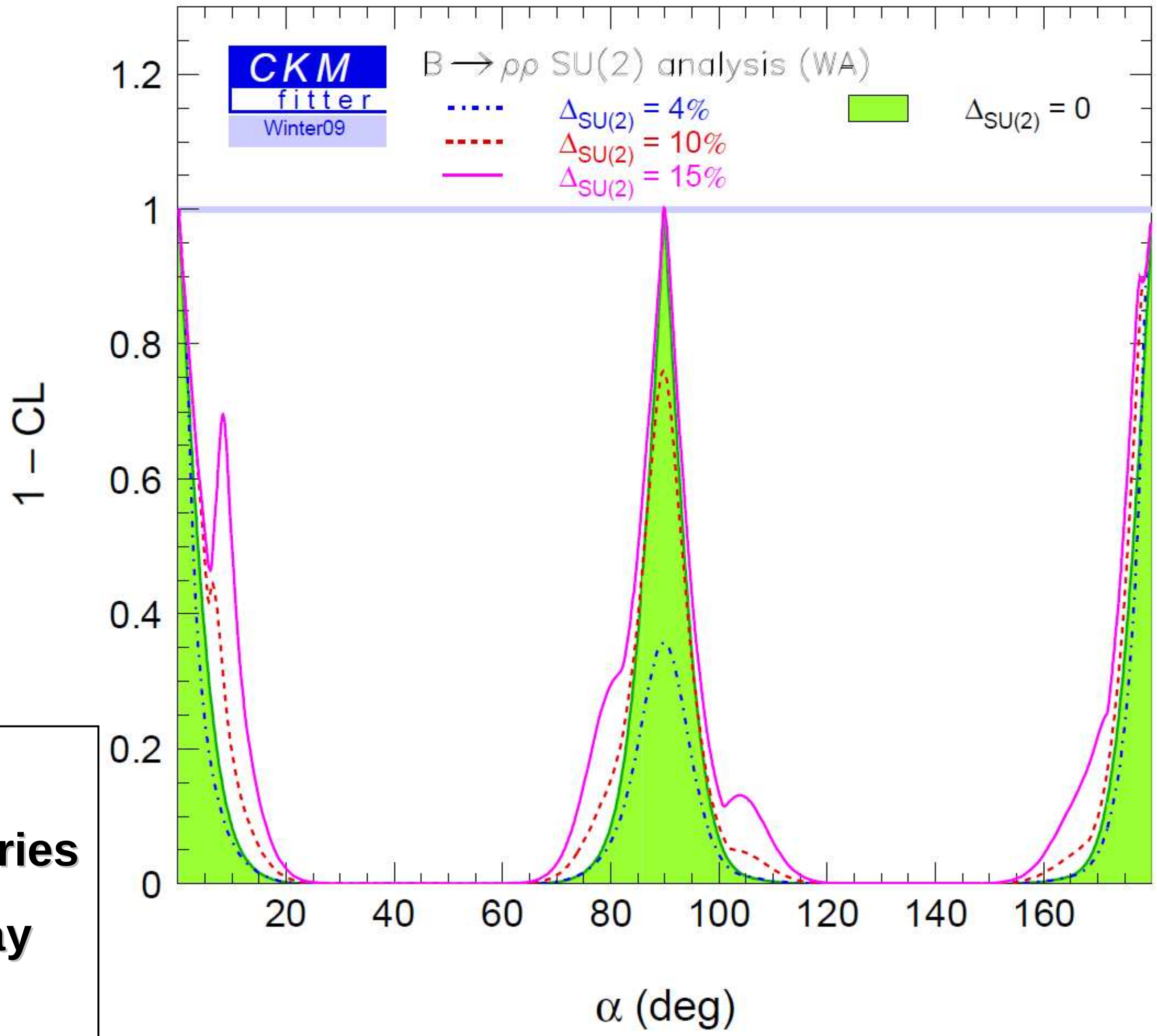
Small values of isospin breaking do not change the pattern.

Similar issue :

f^{+-}/f^{00} normalisation at B factories

A 6.5% (2.4σ) effect as of today

… similar conclusion



The Global CKM fit : discussion on Vub

file:///C:/Documents%20a...

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

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Observable	Central ± 1 σ	± 2 σ	± 3 σ
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$\eta_s$bar	-0.01821 [+0.00081 -0.00085]	-0.0182 [+0.0013 -0.0017]	-0.0182 [+0.0018 -0.0026]
$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]
sin $2\beta_s$	0.0361 [+0.0017 -0.0016]	0.0361 [+0.0035 -0.0027]	0.0361 [+0.0051 -0.0036]

CKM elements:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$\|V_{ud}\|$	0.97430 [+0.00019 -0.00019]	0.97430 [+0.00038 -0.00038]	0.97430 [+0.00057 -0.00057]
$\|V_{us}\|$	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
$\|V_{ub}\|$	0.00350 [+0.00015 -0.00014]	0.00350 [+0.00029 -0.00022]	0.00350 [+0.00044 -0.00029]
$\|V_{cb}\|$	0.04117 [+0.00038 -0.00115]	0.04117 [+0.00077 -0.00161]	0.0412 [+0.0011 -0.0019]
$\|V_{ud}\|$ (meas. not in the fit)	0.97444 [+0.00028 -0.00028]	0.97444 [+0.00055 -0.00056]	0.97444 [+0.00082 -0.00084]
$\|V_{us}\|$ (meas. not in the fit)	0.2257 [+0.0011 -0.0011]	0.2257 [+0.0022 -0.0023]	0.2257 [+0.0033 -0.0034]
$\|V_{ub}\|$ (meas. not in the fit)	0.00350 [+0.00015 -0.00016]	0.00350 [+0.00029 -0.00029]	0.00350 [+0.00045 -0.00040]
$\|V_{cb}\|$ (meas. not in the fit)	0.04399 [+0.00069 -0.00397]	0.0440 [+0.0014 -0.0047]	0.0440 [+0.0024 -0.0052]
$\|V_{cd}\|$	0.22508 [+0.00082 -0.00082]	0.2251 [+0.0016 -0.0016]	0.2251 [+0.0025 -0.0025]
$\|V_{cs}\|$	0.97347 [+0.00019 -0.00019]	0.97347 [+0.00039 -0.00038]	0.97347 [+0.00058 -0.00057]
$\|V_{td}\|$	0.00859 [+0.00027 -0.00029]	0.00859 [+0.00042 -0.00049]	0.00859 [+0.00056 -0.00064]
$\|V_{ts}\|$	0.04041 [+0.00038 -0.00115]	0.04041 [+0.00076 -0.00162]	0.0404 [+0.0011 -0.0019]
$\|V_{tb}\|$	0.999146 [+0.000047 -0.000016]	0.999146 [+0.000065 -0.000032]	0.999146 [+0.000078 -0.000048]

Theory parameters:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
Δm_d [ps^{-1}] (meas. not in the fit)	0.563 [+0.068 -0.076]	0.56 [+0.11 -0.13]	0.56 [+0.16 -0.16]
Δm_s [ps^{-1}] (meas. not in the fit)	17.6 [+1.7 -1.8]	17.6 [+3.2 -3.5]	17.6 [+4.2 -4.5]
ε_K [10^{-3}] (meas. not in the fit)	2.06 [+0.47 -0.53]	2.06 [+0.62 -0.64]	2.06 [+0.77 -0.75]
m_c [GeV/c^2] (meas. not in the fit)	1.44 [+0.43 -0.40]	1.44 [+0.52 -0.56]	1.44 [+0.62 -0.73]
m_t [GeV/c^2] (meas. not in the fit)	160 [+13 -10]	160 [+44 -14]	160 [+60 -17]
B_K (lattice value not in the fit)	0.79 [+0.20 -0.12]	0.79 [+0.28 -0.16]	0.79 [+0.37 -0.19]
$\xi_{SU(3)}$ (lattice value not in the fit)	1.188 [+0.059 -0.044]	1.188 [+0.131 -0.085]	1.19 [+0.18 -0.13]

The Global CKM fit : discussion on Vub

■ The *significant* difference between $|V_{ub}|$ derived from inclusive and exclusive $B \to X_u l \nu$ semileptonic measurements drops when treating systematics within the ***Educated RFit*** scheme

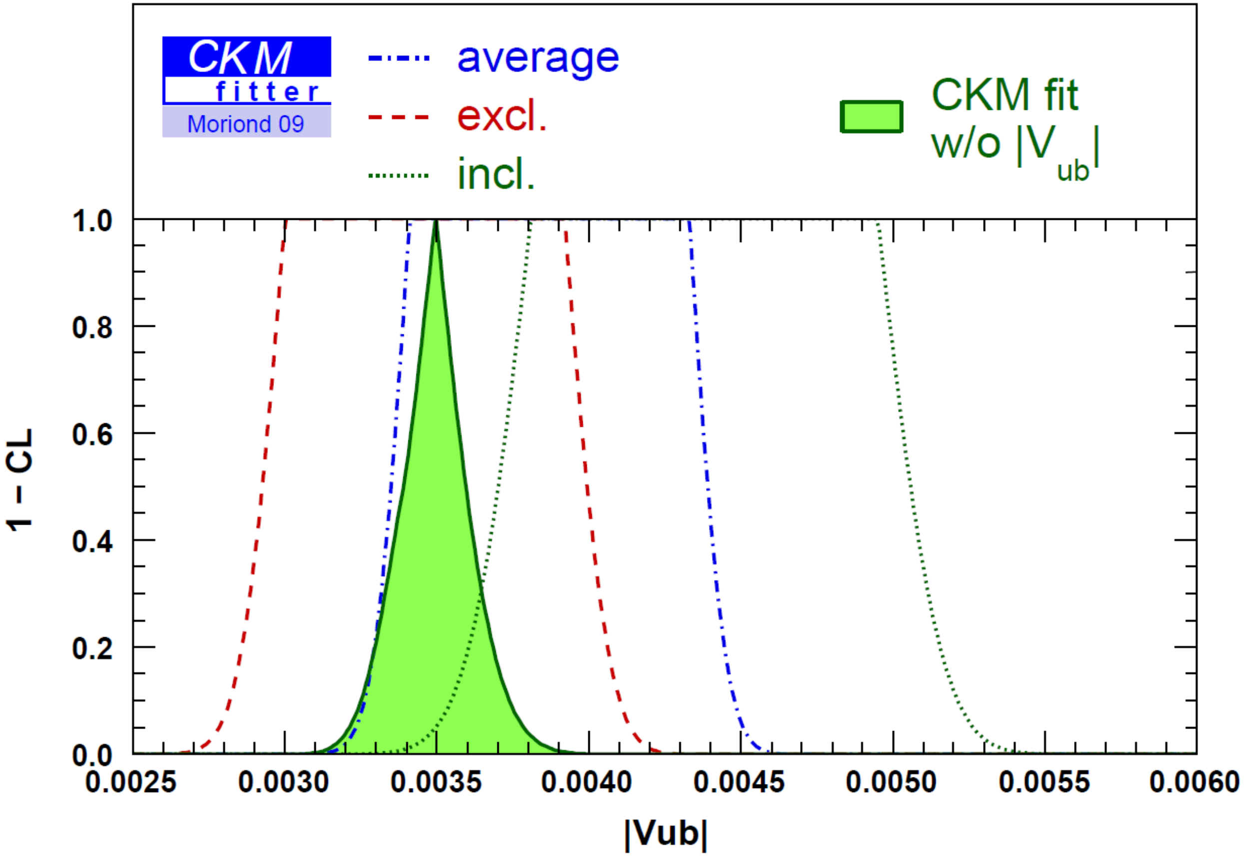
OOA adapted from HFAG summer 08

$|V_{ub}|_{incl.} = 4.38(16)(57)\ 10^{-3}$

$|V_{ub}|_{excl.} = 3.46(11)(46)\ 10^{-3}$

$|V_{ub}| = 3.87(9)(46)\ 10^{-3}$

$\Delta|Vub| = 0.92$, consistent with **OOA** error budget



The Global CKM fit : discussion on ε_K

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$\lvert V_{ud}\rvert$	0.97430 [+0.00019 -0.00019]	0.97430 [+0.00038 -0.00038]	0.97430 [+0.00057 -0.00057]
$\lvert V_{us}\rvert$	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
$\lvert V_{ub}\rvert$	0.00350 [+0.00015 -0.00014]	0.00350 [+0.00029 -0.00022]	0.00350 [+0.00044 -0.00029]
$\lvert V_{cb}\rvert$	0.04117 [+0.00038 -0.00115]	0.04117 [+0.00077 -0.00161]	0.0412 [+0.0011 -0.0019]
$\lvert V_{ud}\rvert$ (meas. not in the fit)	0.97444 [+0.00028 -0.00028]	0.97444 [+0.00055 -0.00056]	0.97444 [+0.00082 -0.00084]
$\lvert V_{us}\rvert$ (meas. not in the fit)	0.2257 [+0.0011 -0.0011]	0.2257 [+0.0022 -0.0023]	0.2257 [+0.0033 -0.0034]
$\lvert V_{ub}\rvert$ (meas. not in the fit)	0.00350 [+0.00015 -0.00016]	0.00350 [+0.00029 -0.00029]	0.00350 [+0.00045 -0.00040]
$\lvert V_{cb}\rvert$ (meas. not in the fit)	0.04399 [+0.00069 -0.00397]	0.0440 [+0.0014 -0.0047]	0.0440 [+0.0024 -0.0052]
$\lvert V_{cd}\rvert$	0.22508 [+0.00082 -0.00082]	0.2251 [+0.0016 -0.0016]	0.2251 [+0.0025 -0.0025]
$\lvert V_{cs}\rvert$	0.97347 [+0.00019 -0.00019]	0.97347 [+0.00039 -0.00038]	0.97347 [+0.00058 -0.00057]
$\lvert V_{td}\rvert$	0.00859 [+0.00027 -0.00029]	0.00859 [+0.00042 -0.00049]	0.00859 [+0.00056 -0.00064]
$\lvert V_{ts}\rvert$	0.04041 [+0.00038 -0.00115]	0.04041 [+0.00076 -0.00162]	0.0404 [+0.0011 -0.0019]
$\lvert V_{tb}\rvert$	0.999146 [+0.000047 -0.000016]	0.999146 [+0.000065 -0.000032]	0.999146 [+0.000078 -0.000048]

Theory parameters:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
Δm_d [ps^{-1}] (meas. not in the fit)	0.563 [+0.068 -0.076]	0.56 [+0.11 -0.13]	0.56 [+0.16 -0.16]
Δm_s [ps^{-1}] (meas. not in the fit)	17.6 [+1.7 -1.8]	17.6 [+3.2 -3.5]	17.6 [+4.2 -4.5]
ε_K [10^{-3}] (meas. not in the fit)	2.06 [+0.47 -0.53]	2.06 [+0.62 -0.64]	2.06 [+0.77 -0.75]
m_c [GeV/c^2] (meas. not in the fit)	1.44 [+0.43 -0.40]	1.44 [+0.52 -0.56]	1.44 [+0.62 -0.73]
m_t [GeV/c^2] (meas. not in the fit)	160 [+13 -10]	160 [+44 -14]	160 [+60 -17]
B_K (lattice value not in the fit)	0.79 [+0.20 -0.12]	0.79 [+0.28 -0.16]	0.79 [+0.37 -0.19]
$\xi_{SU(3)}$ (lattice value not in the fit)	1.188 [+0.059 -0.044]	1.188 [+0.131 -0.085]	1.19 [+0.18 -0.13]
f_{B_s} (lattice value not in the fit)	0.2448 [+0.0099 -0.0103]	0.245 [+0.015 -0.019]	0.245 [+0.019 -0.023]

Rare branching fractions ($B\to l\nu$, $B\to ll$):

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$B(B^+\to\tau\nu)$ [10^{-4}]	0.92 [+0.10 -0.11]	0.92 [+0.19 -0.22]	0.92 [+0.28 -0.26]
$B(B^+\to\tau\nu)$ [10^{-4}] (meas. not in the fit)	0.796 [+0.154 -0.093]	0.80 [+0.26 -0.13]	0.80 [+0.35 -0.17]
$B(B^+\to\tau\nu)$ [10^{-4}] (dir. meas.)	1.73 [+0.35 -0.35]	1.73 [+0.70 -0.70]	1.75 [+1.05 -1.05]
$B(B^+\to\mu\nu)$ [10^{-6}]	0.412 [+0.047 -0.048]	0.412 [+0.086 -0.098]	0.41 [+0.13 -0.12]
$B(B^+\to e\nu)$ [10^{-11}]	0.96 [+0.11 -0.11]	0.96 [+0.20 -0.23]	0.96 [+0.30 -0.28]
$B(B\to e^+e^-)$ [10^{-15}]	2.523 [+0.090 -0.207]	2.52 [+0.18 -0.53]	2.52 [+0.26 -0.62]
$B(B\to\mu^+\mu^-)$[10^{-11}]	10.78 [+0.38 -0.88]	10.78 [+0.75 -2.26]	10.8 [+1.1 -2.6]
$B(B_s\to e^+e^-)$ [10^{-14}]	7.70 [+0.22 -0.62]	7.70 [+0.43 -1.08]	7.70 [+0.64 -1.27]
$B(B_s\to\mu^+\mu^-)$ [10^{-9}]	3.291 [+0.094 -0.267]	3.29 [+0.18 -0.46]	3.29 [+0.27 -0.54]

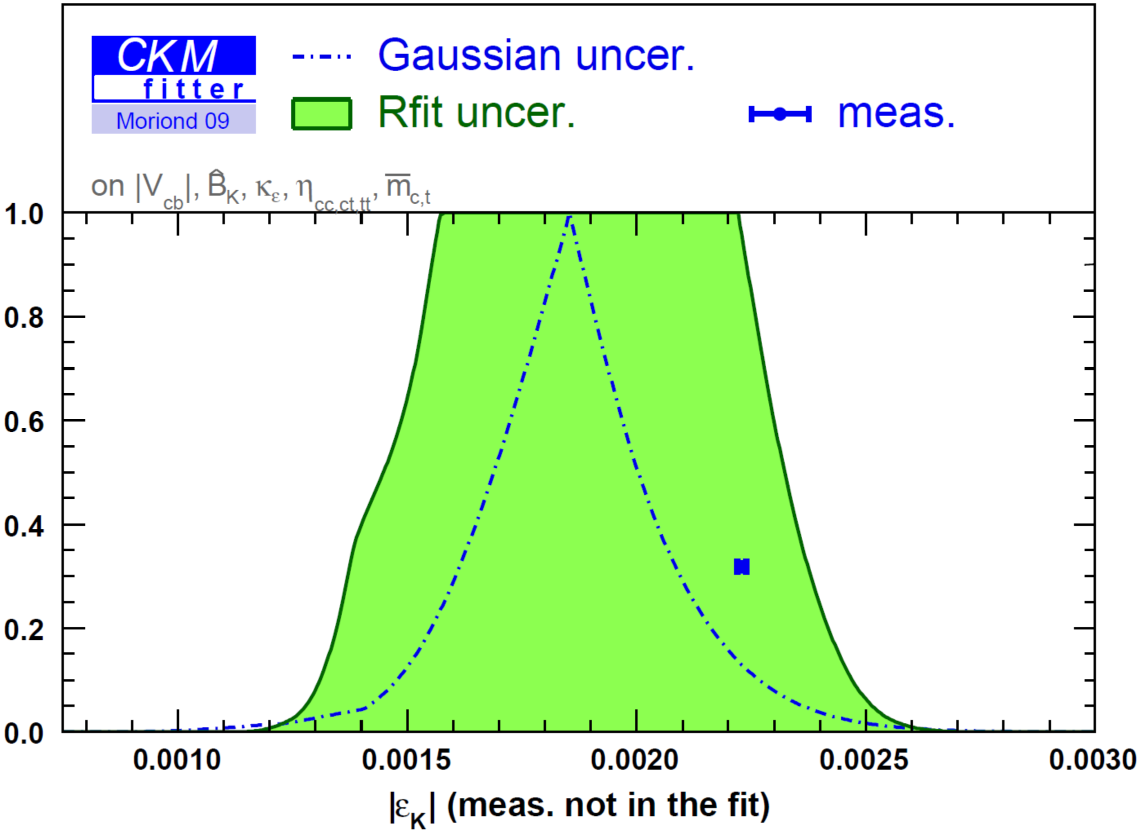
The Global CKM fit : discussion on ε_K

■ Reminder from Buras & Guadagnoli (Phys. Rev. D78, 033005 (2008)): there is an additional suppression factor, κ_ε, to $|\varepsilon_K|$, estimated to be $\kappa_\varepsilon = 0.92(2)$.
⇒ Note that this factor has not yet been accounted for in the Global Fit. Its in the line for next update

■ **Any tension between direct measurement of $|\varepsilon_K|$ and indirect measurement from the global fit (through $\sin(2\beta_{cc})$)?**

⇒ Using **Gaussian distributions** for systematic uncertainties and including the factor $\kappa_\varepsilon = 0.92(2)$ we get **1.5 σ** deviation

⇒ With our ***Educated RFit*** treatment of systematics **no deviation is seen**. The measurement is compatible with our fit best guess considering **uncertainties** on CKM parameters (through **$|V_{cb}|^4 \sim 7\%$**) mainly and hadronic uncertainties from **B_K (~5%)**.



The Global CKM fit : back to β

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

CKM angle β measured with a ~1° accuracy

Indirect constraint has similar precision …

…but prefers a larger value …

CKMfitter global fit results:

The inputs for the global fit (pdf).

- Wolfenstein parameters
- UT angles and sides
- UT_s angle and apex
- CKM elements
- Theory parameters
- Rare branching fractions ($B\to l\nu$, $B\to ll$)

Wolfenstein parameters and Jarlskog invariant:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
A	0.8116 [+0.0097 -0.0241]	0.812 [+0.019 -0.036]	0.812 [+0.029 -0.045]
λ	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
ρbar	0.139 [+0.025 -0.027]	0.139 [+0.053 -0.040]	0.139 [+0.073 -0.052]
ηbar	0.341 [+0.016 -0.015]	0.341 [+0.032 -0.025]	0.341 [+0.048 -0.034]
J $[10^{-5}]$	2.92 [+0.15 -0.15]	2.92 [+0.30 -0.19]	2.92 [+0.45 -0.23]

UT angles and sides:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
sin 2α	-0.02 [+0.15 -0.13]	-0.02 [+0.22 -0.26]	-0.02 [+0.28 -0.35]
sin 2α (meas. not in the fit)	-0.20 [+0.30 -0.11]	-0.20 [+0.41 -0.17]	-0.20 [+0.48 -0.23]
sin 2β	0.684 [+0.023 -0.021]	0.684 [+0.046 -0.035]	0.684 [+0.068 -0.049]
sin 2β (meas. not in the fit)	0.817 [+0.026 -0.040]	0.817 [+0.039 -0.114]	0.817 [+0.052 -0.171]
|sin (2β+γ)|	0.934 [+0.023 -0.030]	0.934 [+0.039 -0.051]	0.934 [+0.049 -0.071]
α [deg]	90.6 [+3.8 -4.2]	90.6 [+7.5 -6.3]	90.6 [+10.2 -8.2]
α [deg] (meas. not in the fit)	95.6 [+3.3 -8.8]	95.6 [+5.2 -11.8]	95.6 [+6.8 -13.9]
α [deg] (dir. meas.)	89.0 [+4.4 -4.2]	89.0 [+9.1 -8.3] || 178.3 [+1.7 -5.6] || 0 [+5 -0]	89 [+21 -13] || 178.3 [+1.7 -13.8] || 0 [+12 -0]
β [deg]	21.58 [+0.91 -0.81]	21.6 [+1.8 -1.4]	21.6 [+2.8 -1.9]
β [deg] (meas. not in the fit)	27.4 [+1.3 -1.9]	27.4 [+2.0 -5.0]	27.4 [+2.8 -7.3]
β [deg] (dir. meas.)	21.07 [+0.90 -0.88]	21.1 [+1.8 -1.7]	21.1 [+2.8 -2.6]
γ [deg]	67.8 [+4.2 -3.9]	67.8 [+6.3 -8.0]	67.8 [+8.2 -10.6]
γ [deg] (meas. not in the fit)	67.8 [+4.2 -3.9]	67.8 [+6.3 -8.0]	67.8 [+8.2 -10.6]
γ [deg] (dir. meas.)	70 [+27 -30]	70 [+44 -41]	70 [+60 -52] || 131.14 [+0.18 -0.25]
R_u	0.368 [+0.015 -0.013]	0.368 [+0.030 -0.022]	0.368 [+0.045 -0.030]
R_t	0.926 [+0.027 -0.025]	0.926 [+0.040 -0.053]	0.926 [+0.052 -0.072]

UT_s apex and angle:

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$\rho_s$bar	-0.0074 [+0.0014 -0.0013]	-0.0074 [+0.0022 -0.0029]	-0.0074 [+0.0028 -0.0040]
$\eta_s$bar	-0.01821 [+0.00081 -0.00085]	-0.0182 [+0.0013 -0.0017]	-0.0182 [+0.0018 -0.0026]
$\beta_s \equiv -\arg(-V_{cs} V^*_{cb}/V_{ts} V^*_{tb})$ [rad]	0.01807 [+0.00086 -0.00081]	0.0181 [+0.0017 -0.0014]	0.0181 [+0.0026 -0.0018]

The Global CKM fit : discussion on $B \to \tau\nu$

file:///C:/Documents%20a...

http://ckmfitter.in2p3.fr/plots_Moriond09/ckmEval_results.html

Observable	Central ± 1 σ	± 2 σ	± 3 σ
$\|V_{ud}\|$	0.97430 [+0.00019 -0.00019]	0.97430 [+0.00038 -0.00038]	0.97430 [+0.00057 -0.00057]
$\|V_{us}\|$	0.22521 [+0.00082 -0.00082]	0.2252 [+0.0016 -0.0016]	0.2252 [+0.0025 -0.0025]
$\|V_{ub}\|$	0.00350 [+0.00015 -0.00014]	0.00350 [+0.00029 -0.00022]	0.00350 [+0.00044 -0.00029]
$\|V_{cb}\|$	0.04117 [+0.00038 -0.00115]	0.04117 [+0.00077 -0.00161]	0.0412 [+0.0011 -0.0019]
$\|V_{ud}\|$ (meas. not in the fit)	0.97444 [+0.00028 -0.00028]	0.97444 [+0.00055 -0.00056]	0.97444 [+0.00082 -0.00084]
$\|V_{us}\|$ (meas. not in the fit)	0.2257 [+0.0011 -0.0011]	0.2257 [+0.0022 -0.0023]	0.2257 [+0.0033 -0.0034]
$\|V_{ub}\|$ (meas. not in the fit)	0.00350 [+0.00015 -0.00016]	0.00350 [+0.00029 -0.00029]	0.00350 [+0.00045 -0.00040]
$\|V_{cb}\|$ (meas. not in the fit)	0.04399 [+0.00069 -0.00397]	0.0440 [+0.0014 -0.0047]	0.0440 [+0.0024 -0.0052]
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m_c [GeV/c^2] (meas. not in the fit)	1.44 [+0.43 -0.40]	1.44 [+0.52 -0.56]	1.44 [+0.62 -0.73]
m_t [GeV/c^2] (meas. not in the fit)	160 [+13 -10]	160 [+44 -14]	160 [+60 -17]
B_K (lattice value not in the fit)	0.79 [+0.20 -0.12]	0.79 [+0.28 -0.16]	0.79 [+0.37 -0.19]
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$B(B^+ \to \tau\nu)$ [10^{-4}] (dir. meas.)	1.73 [+0.35 -0.35]	1.73 [+0.70 -0.70]	1.75 [+1.05 -1.05]
$B(B^+ \to \mu\nu)$ [10^{-6}]	0.412 [+0.047 -0.048]	0.412 [+0.086 -0.098]	0.41 [+0.13 -0.12]
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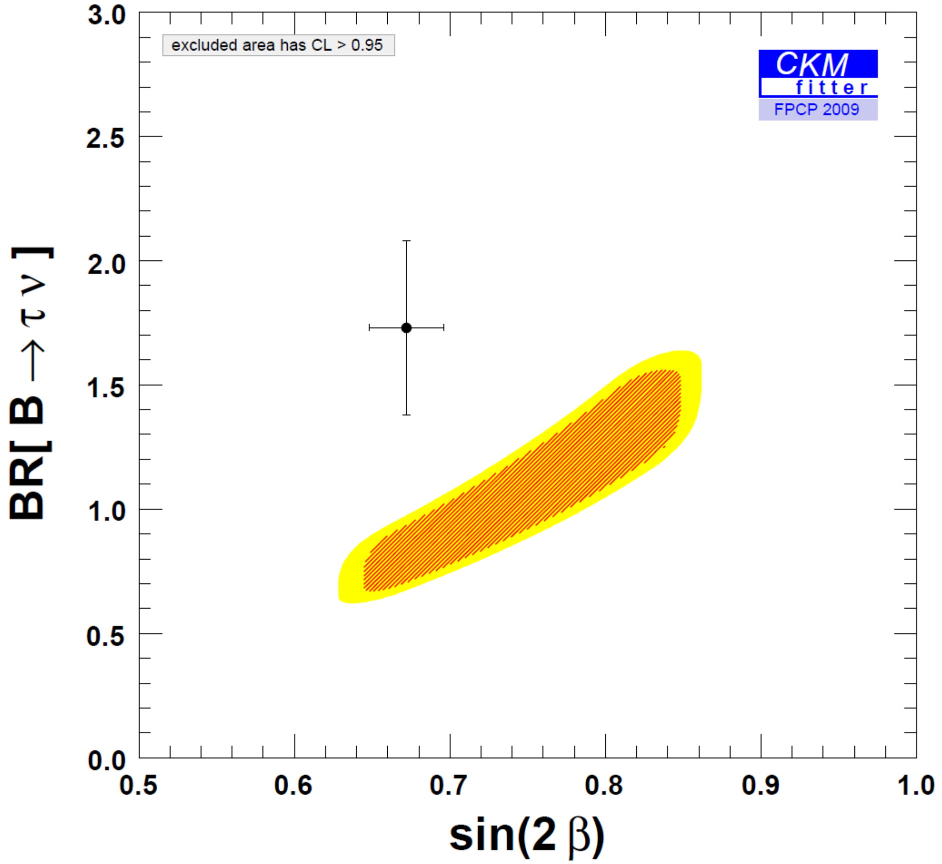
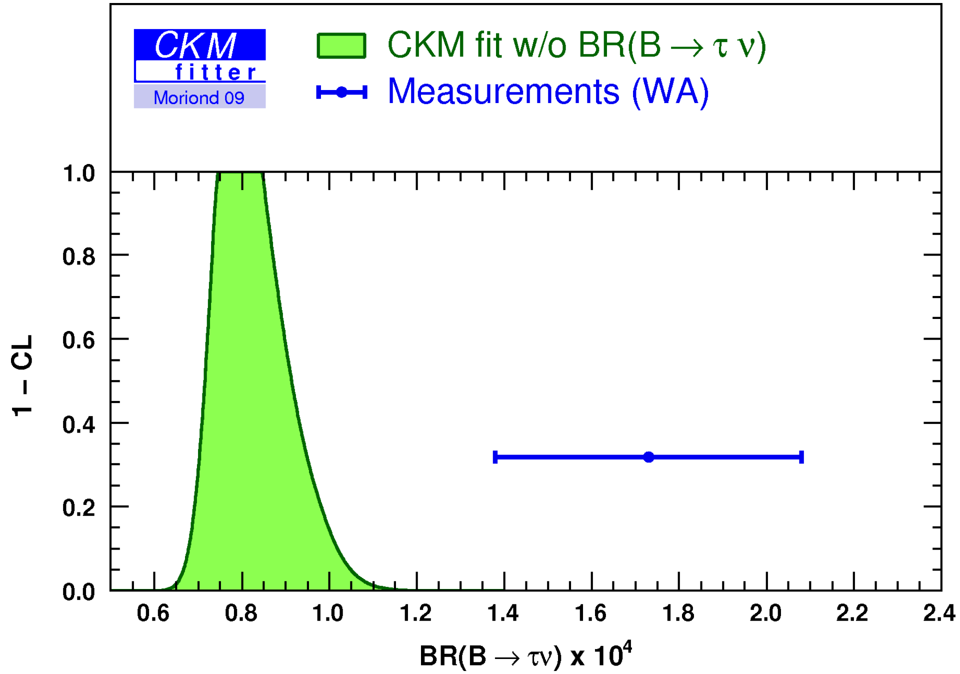
$B(B \to e^+e^-)$ [10^{-15}]	2.523 [+0.090 -0.207]	2.52 [+0.18 -0.53]	2.52 [+0.26 -0.62]
$B(B \to \mu^+\mu^-)$[10^{-11}]	10.78 [+0.38 -0.88]	10.78 [+0.75 -2.26]	10.8 [+1.1 -2.6]
$B(B_s \to e^+e^-)$ [10^{-14}]	7.70 [+0.22 -0.62]	7.70 [+0.43 -1.08]	7.70 [+0.64 -1.27]
$B(B_s \to \mu^+\mu^-)$ [10^{-9}]	3.291 [+0.094 -0.267]	3.29 [+0.18 -0.46]	3.29 [+0.27 -0.54]

The Global CKM fit : β and B→τν





The Global fit χ^2_{min} drops by **~2.4 σ** if taking out sin(2β_{cc}) or B → τ ν.

$$BR(B^+ \rightarrow \tau^+ \upsilon) = G_F^2 \frac{m_B m_\tau^2 \tau_{B^+}}{8\pi} (1 - \frac{m_\tau^2}{m_B^2})^2 |V_{ub}|^2 f_{B_d}^2$$

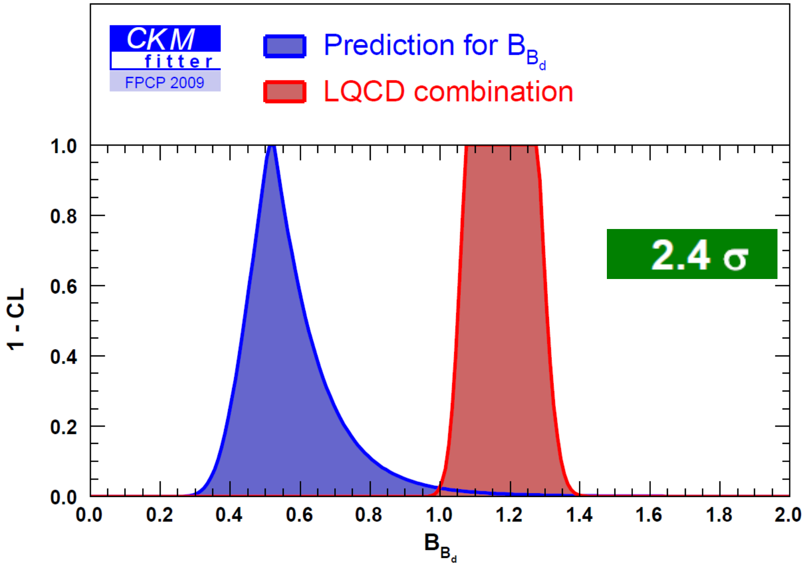
Non-trivial correlation of indirect constraints on β and B→τν …

Can be shown that V_{ub} and f_{Bd} are unrelated to this correlation (next slide)

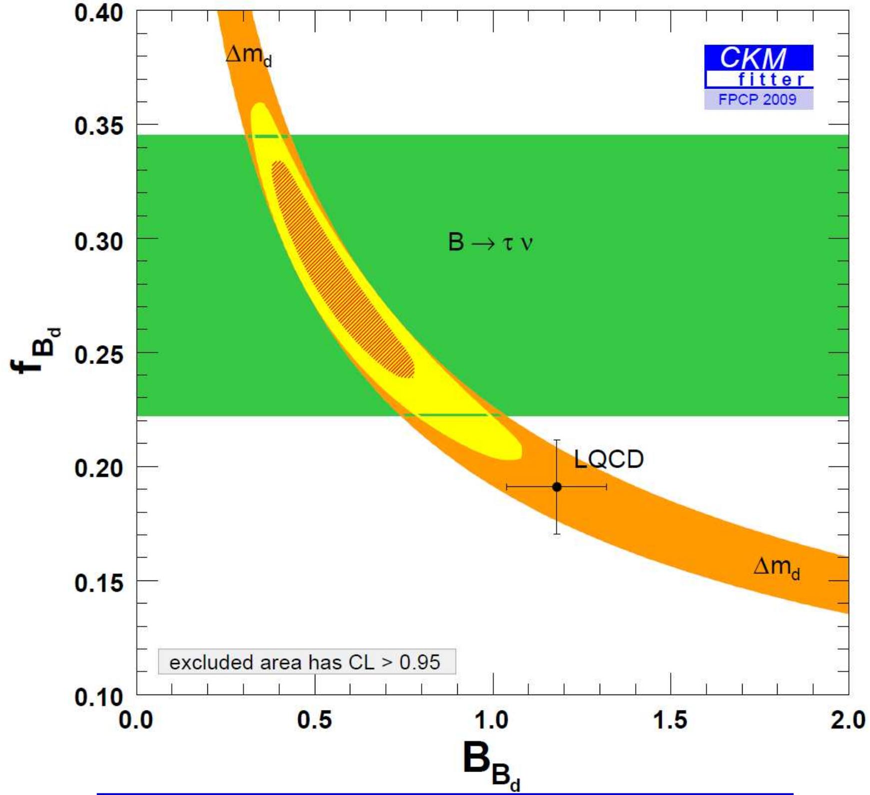
The Global CKM fit : β and B→τν

$$\frac{BR(B^+ \to \tau^+ \nu)}{\Delta m_d} = \frac{3\pi}{4} \frac{m_\tau^2 \tau_{B^+}}{m_W^2 S(x_t)} \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 \frac{\sin^2(\beta)}{\sin^2(\gamma)} \frac{1}{|V_{ud}|^2 B_{B_d}}$$

Theory-free estimation of B_{Bd} and f_{Bd}



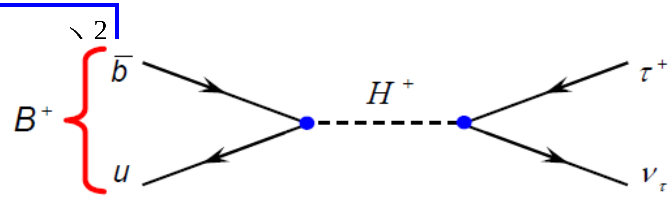
Simultaneous constraint on B_{Bd} and f_{Bd}



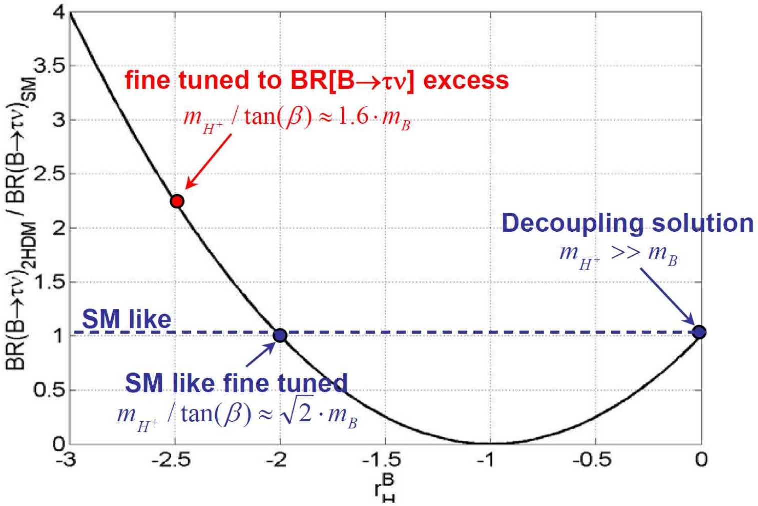
⇒ The global fit is accommodated keeping $f_{Bd}^2 \times B_{Bd} \approx$ const to fit Δm_d while increasing f_{Bd} to fit $B \to \tau\nu$

Beyond the global CKM fit : B→τν

$$BR(B^+\to\tau^+\upsilon)(NP) = BR(B^+\to\tau^+\upsilon)(SM)\times\left(1-\frac{m_B^2}{m_{H^+}^2}\tan\ \ldots\right)^2$$



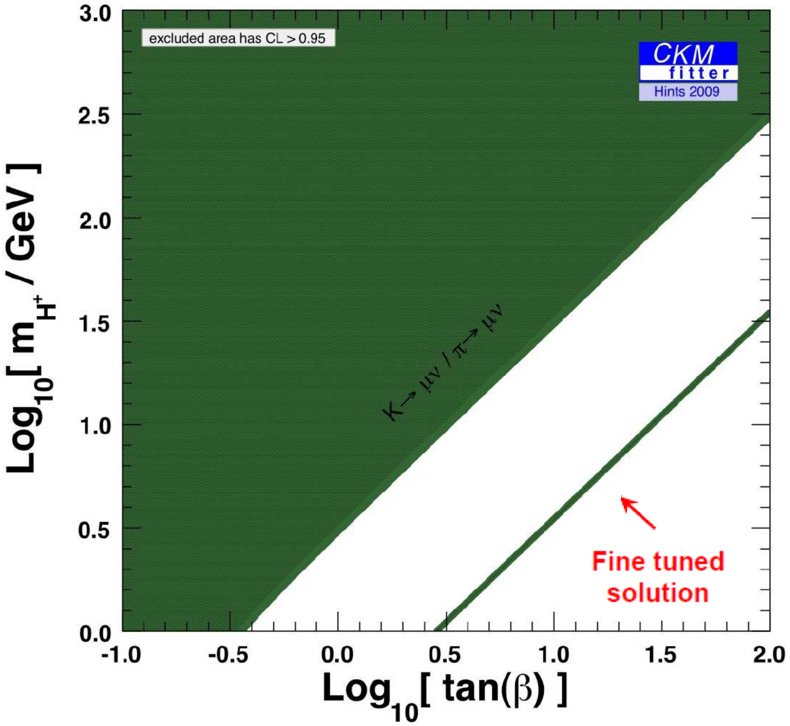
■ **Charged higgs** contribution can modify B[B→τν] as a multiplicative term: $r_H^B \approx -\tan^2(\beta) m_B^2 / m_{H^+}^2$ in **2HDM Type II** model. Note that one would need $r_H^B \approx -2.5$ to fit B[B→τν] (fine tuned solution).



Agreement with the SM can be recovered 2 ways:

• $r_H^B \to 0 \Rightarrow m_{H+}/m_B \to \infty$ irrespective tan(β).
This is the **decoupling solution**

• $r_H^B = -2 \Rightarrow m_{H^+}/\tan(\beta) \approx \sqrt{2}\cdot m_B$; requires a **fine tuning of m_{H+}/tan(β) to the meson mass**.



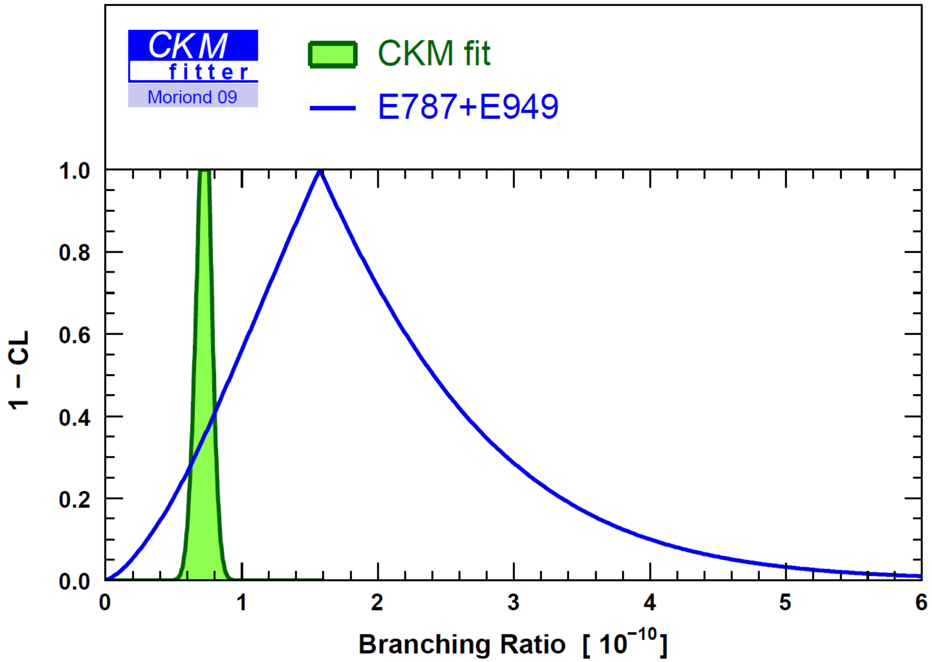
Fine-tuned solution can be ruled out

By using other semileptonic information

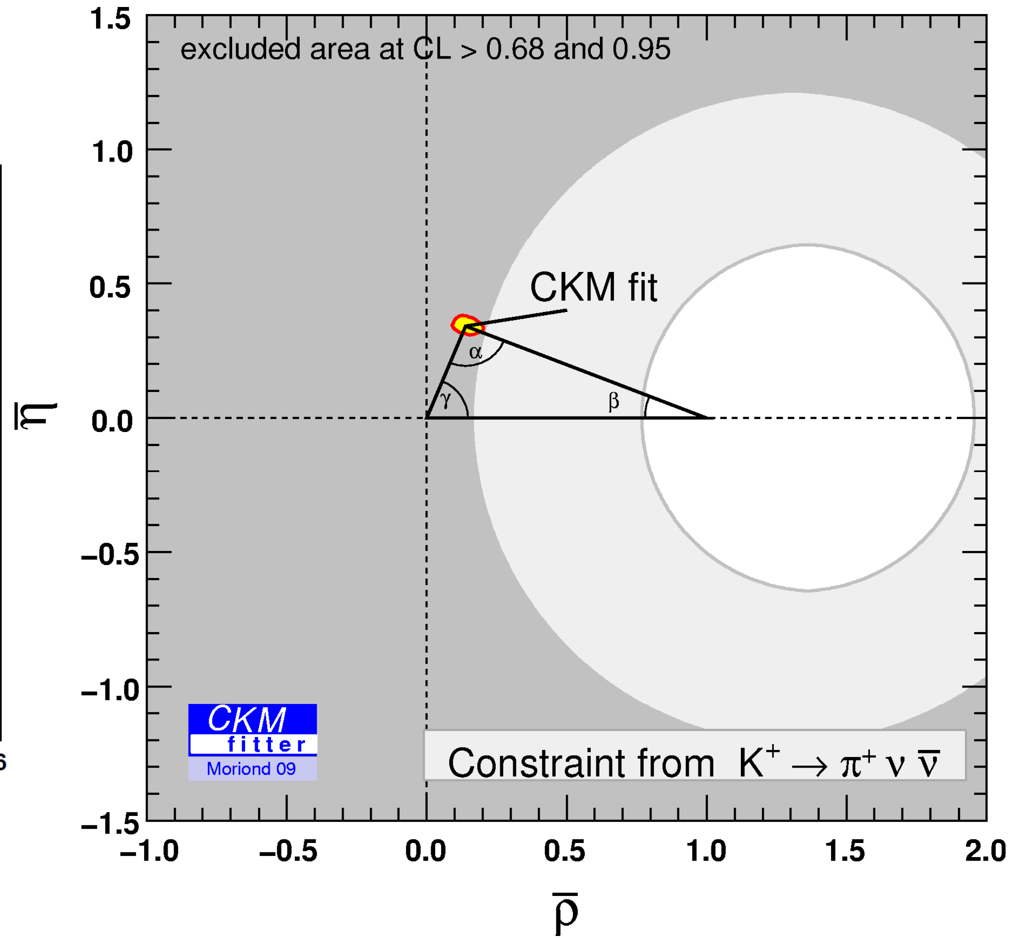
With contributions from R. Camacho

- Recent E949 update (arXiv:0903.0030 with 5 events (& incl. E787)): $(1.73^{+1.15}_{-1.05}) \cdot 10^{-10}$
- BR parameterization as Brod & Gorbahn '08 (PRD 78, 034006)
  NLO QED-QCD & EW corr. to the charm quark contribution
  $\alpha_s(m_Z)=0.1176(20)$ & $m_c(m_c)=1.286(13)(40)$

Charm term Pc(X) controlled at ~few %



$$(0.811^{+0.027}_{-0.021} \pm 0.096) \cdot 10^{-10}$$



A word on the rare kaon decays $K^+ \to \pi^+ \nu\bar{\nu}$ *and* $K_L \to \pi^0 \nu\bar{\nu}$

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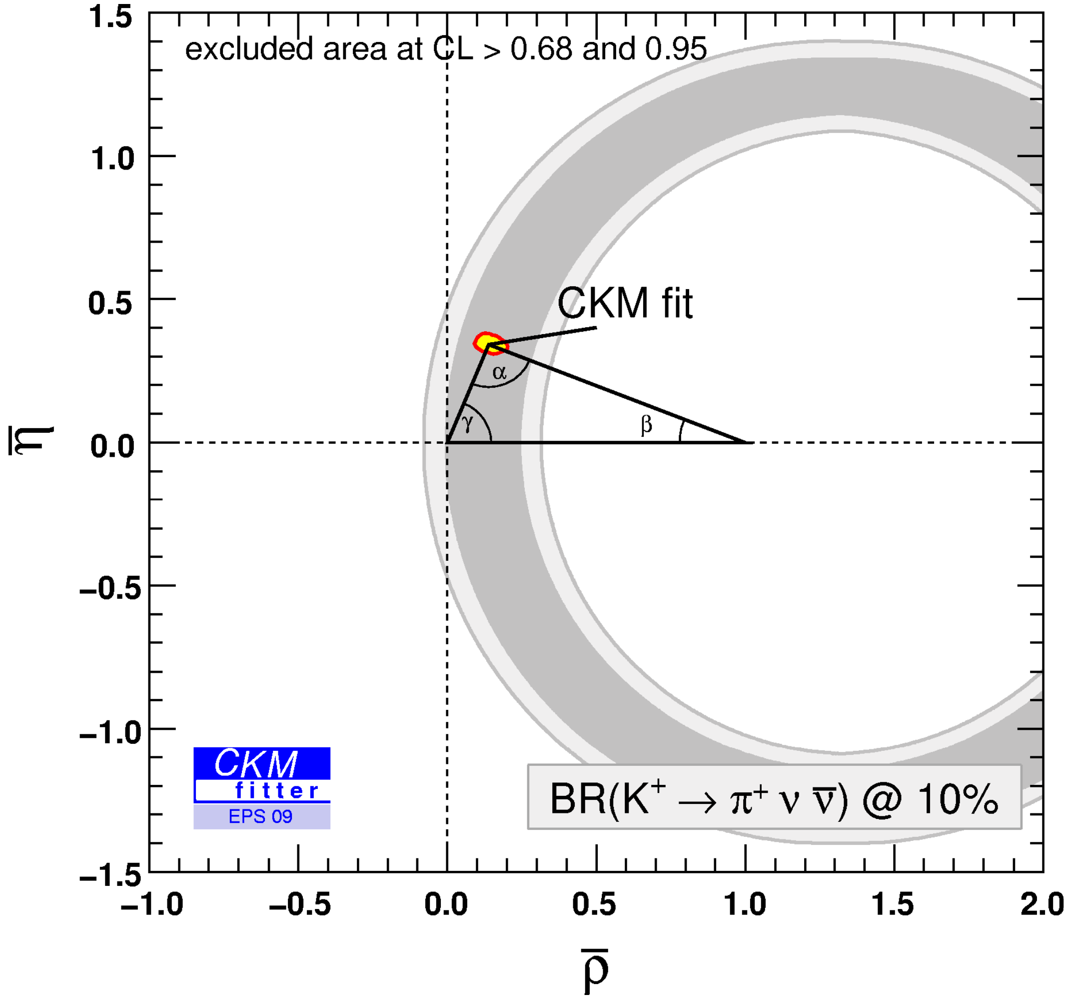
Prospective study : assume

- **$K^+ \to \pi^+ \nu\nu$ measured by NA62 (~10%)**



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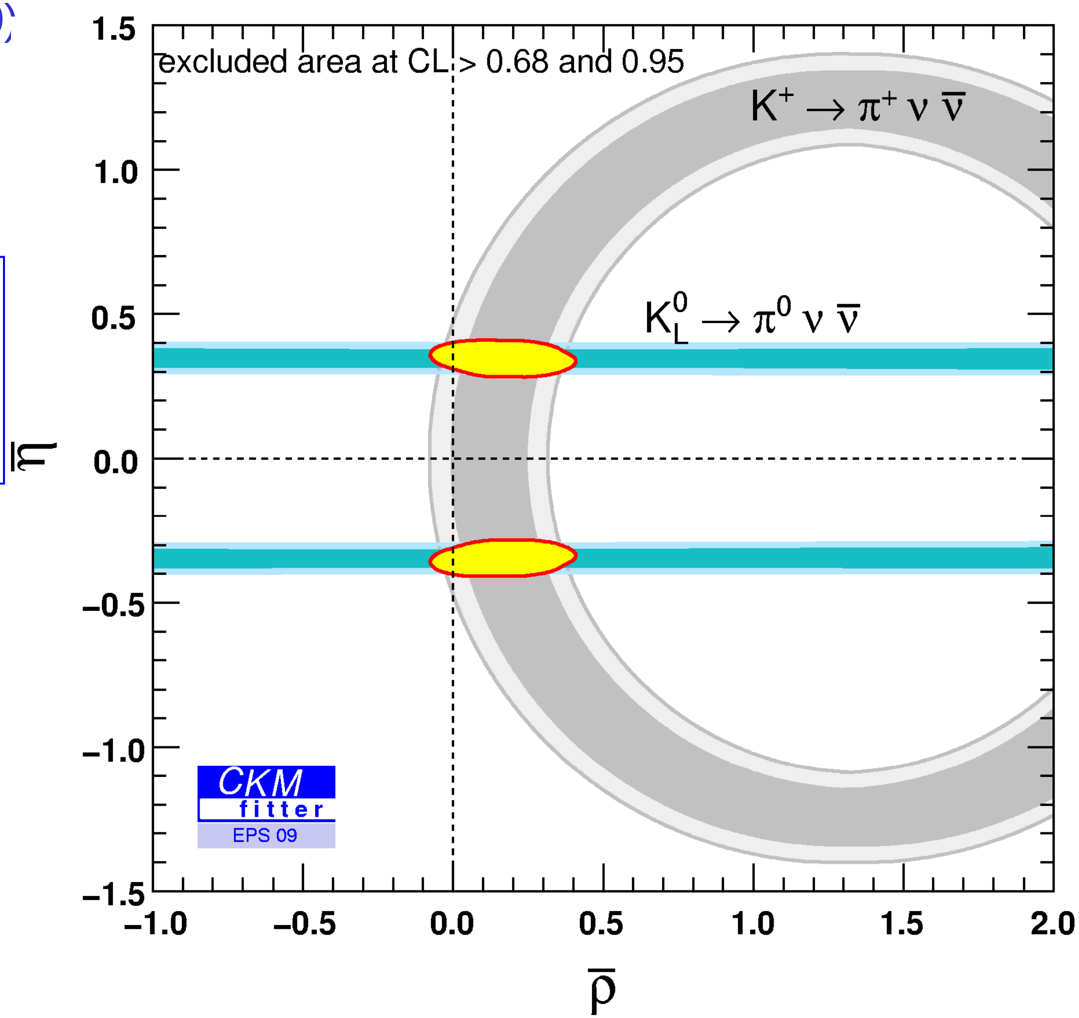

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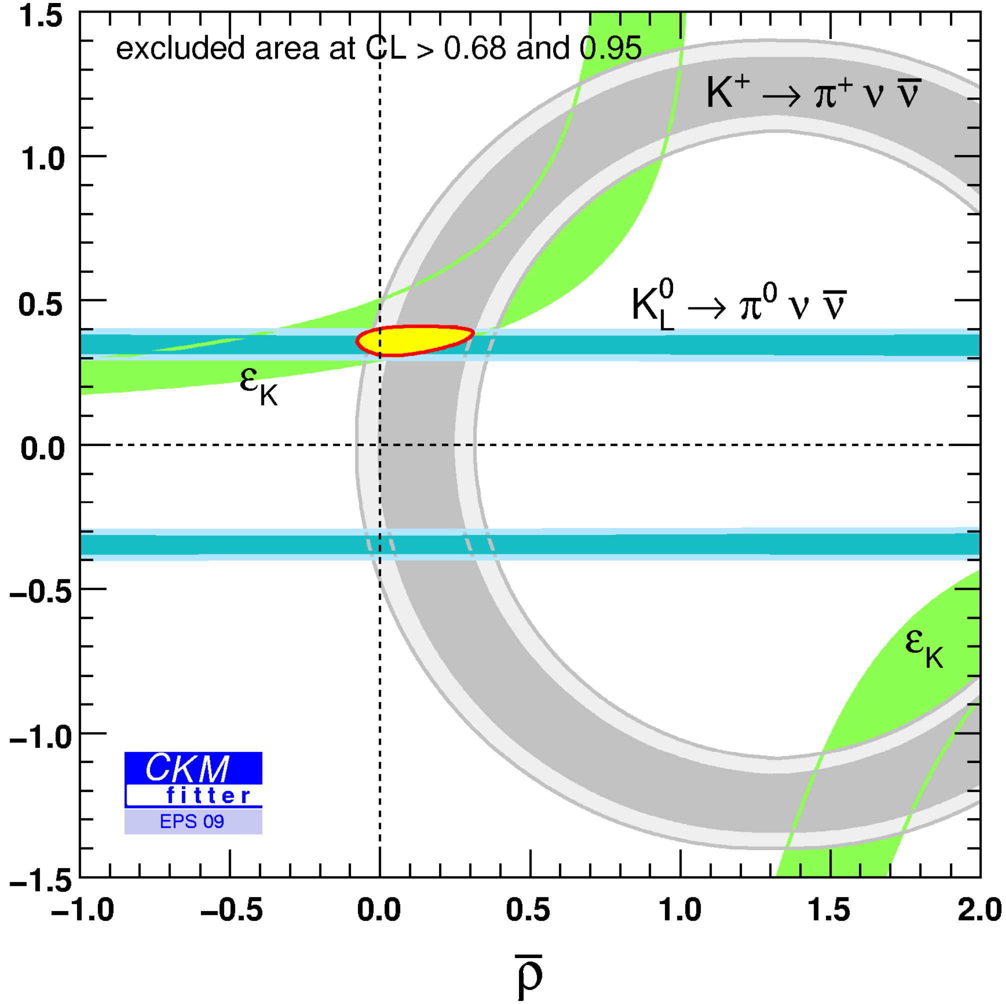

Prospective study : assume

- **$K^+\to\pi^+\nu\nu$ measured by NA62 (~10%)**
- **$K_L\to\pi^0\nu\nu$ measured by J-PARC (~15%)**
- **Use ε_K (and ε'/ε ?) to lift ambiguities**

(pessimistic scenario: no improvement of theoretical errors)

A strong constrain on the CKM matrix only using Kaon inputs

Summary

- KM mechanism at work, main source of CP violation
- Increased precision on α
  - keep an eye on possible non-SU(2) effects
- sin2β vs $B\rightarrow\tau\nu$ (and/or V_{ub} and/or ε_K)
  - issue of hadronic/lattice inputs
- eagerly waiting for updates from B factories
  - γ !
  - new news on $B\rightarrow\tau\nu$?
- Results from TeVatron and soon LHC, to test for NP scenarios
- Support Kaon physics !