Constraints on the CKM Matrix

FPCP - Vancouver - April 12th, 2006

Jérôme Charles (CPT - Marseille)

for the CKMfitter group

Eur. Phys. J. C41 (2005); http://ckmfitter.in2p3.fr

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le Triangle d'Unitarité sous toutes les coutures

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The Unitarity Triangle

unitarity-exact and convention-independent version of the Wolfenstein parametrization

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

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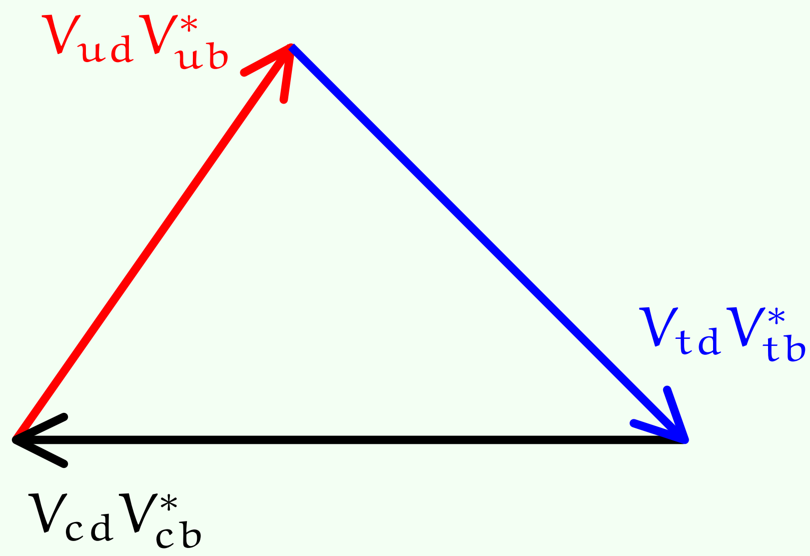
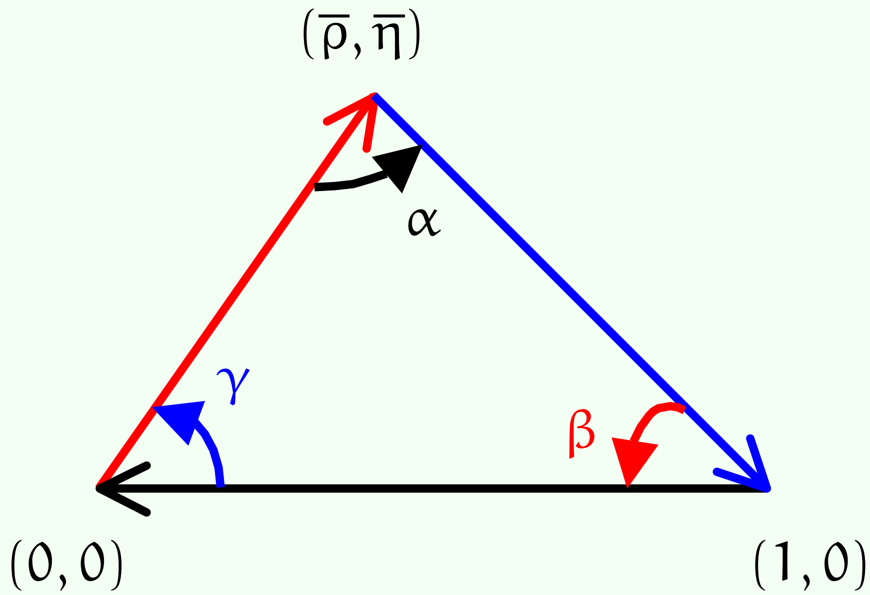
there is no need to stop at $\mathcal{O}(\lambda^4)$!

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





The global CKM fit

uses all constraints on which we think we have a good theoretical control

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$|V_{ud}|, |V_{us}|, |V_{cb}|$ PDG06

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$\|V_{ud}\|, \|V_{us}\|, \|V_{cb}\|$	PDG06	
ε_K	exp: KTeV/KLOE, theo: CKM05	$B_K = 0.79 \pm 0.04 \pm 0.09$
$\|V_{ub}\|$	PDG06	excl. $(3.94 \pm 0.28 \pm 0.51) \times 10^{-3}$
		incl. $(4.45 \pm 0.23 \pm 0.39) \times 10^{-3}$
Δm_d	exp: last WA, theo: CKM05	$\xi = 1.24 \pm 0.04 \pm 0.06$
Δm_s	exp: you guess, theo: CKM05	$f_{B_{B_s}} \sqrt{B_s} = 271 \pm 38$ GeV

note: we have splitted errors into stat. $\pm$ theo.

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β	last WA	
α	exp: last WA, theo: $\pi\pi$, $\rho\pi$, $\rho\rho$ and SU(2)	
γ	exp: last WA, theo: GLW/ADS/GGSZ	

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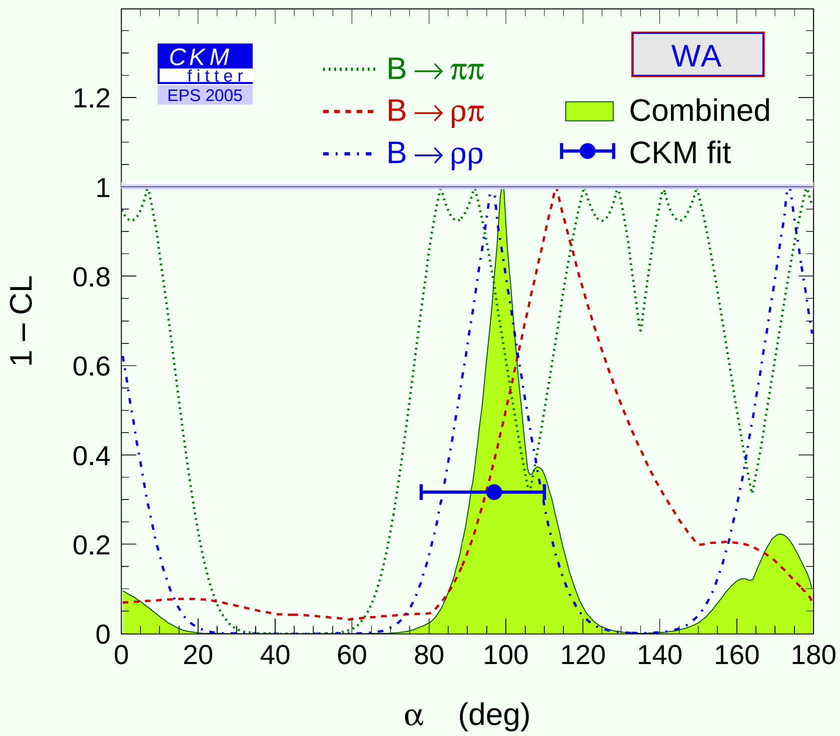
$B \to \tau\nu$	exp: last WA, theo: CKM03-05	$f_{B_d} = 190 \pm 25 \pm 9$ MeV

note: we have splitted errors into stat. $\pm$ theo.

More on selected inputs...

the angle α

the best constraint comes from the $\rho\rho$ modes; thanks to the BaBar update on $\rho^+\rho^0$ the data are now fully compatible with a closed isospin triangle



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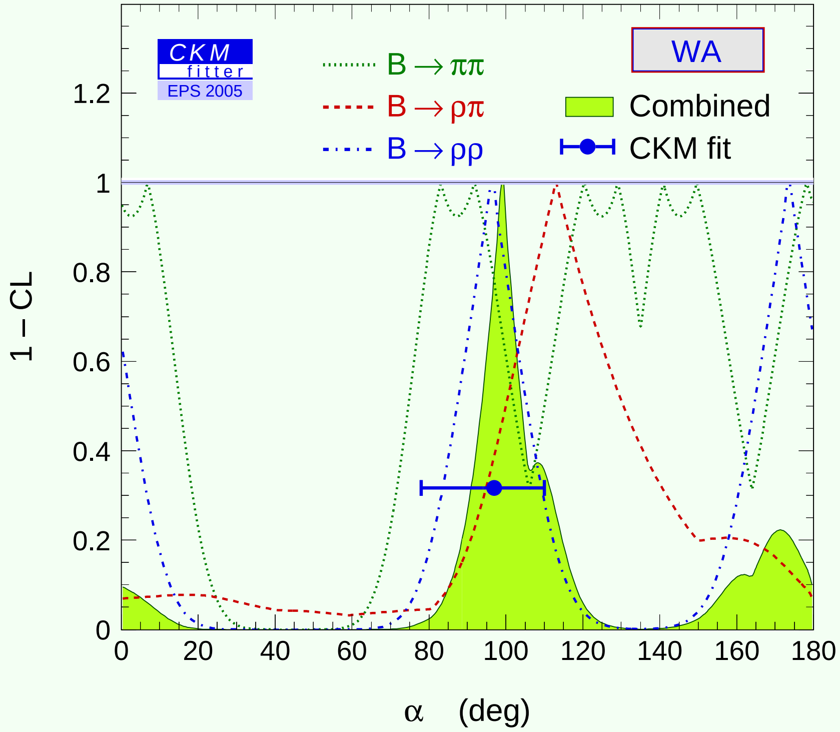
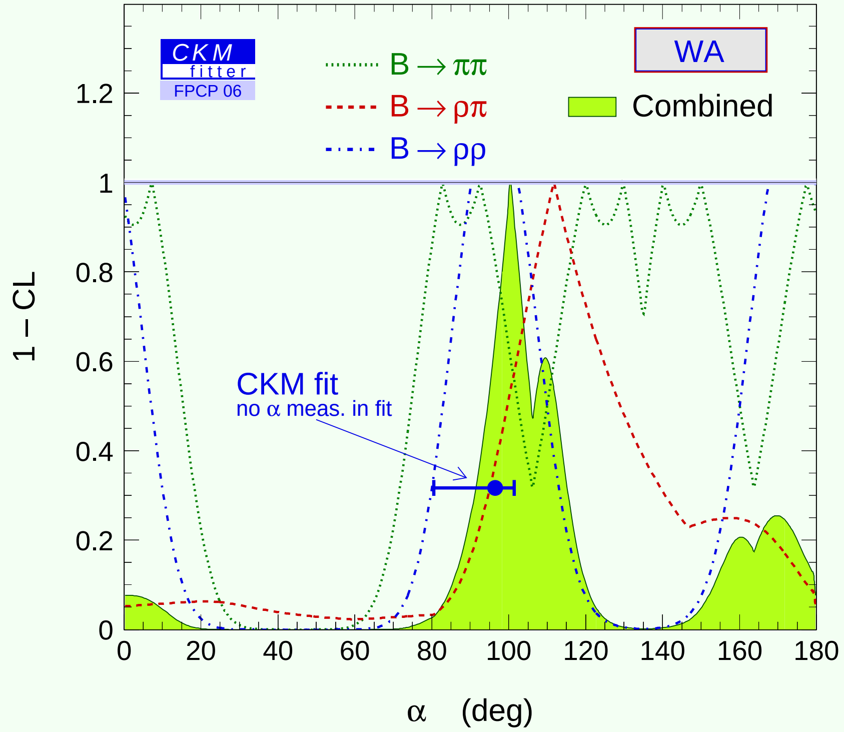
new average $\alpha = (100.2^{+15.0}_{-8.8})^\circ$





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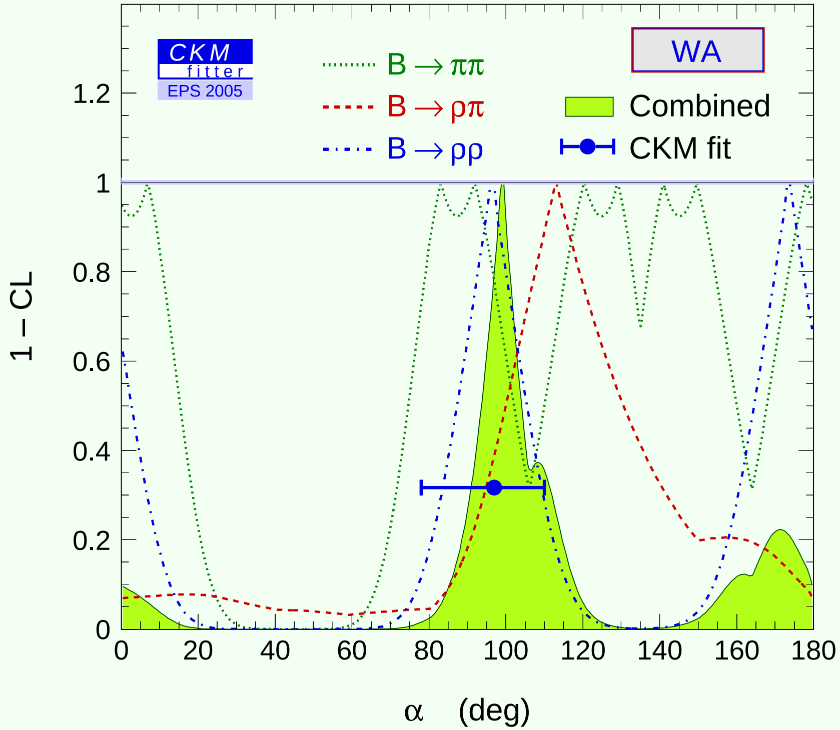

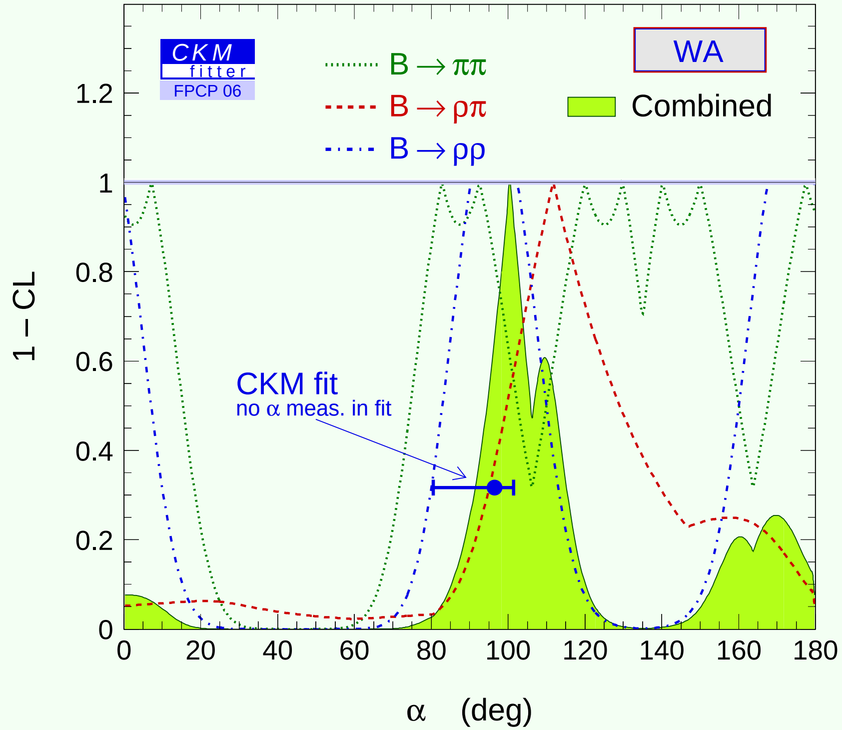

waiting for Belle: Dalitz $\rho\pi$, and $\rho^0\rho^0$ modes !

…more on selected inputs…

the angle γ (preliminary)

the analysis is non trivial: naive interpretation of χ^2 in terms of the error function underestimates the error on γ because of the bias on r_B due to $r_B > 0$; both Babar and Belle use their own frequentist approach, while we use a different one

meanwhile the central value of r_B has decreased since last summer

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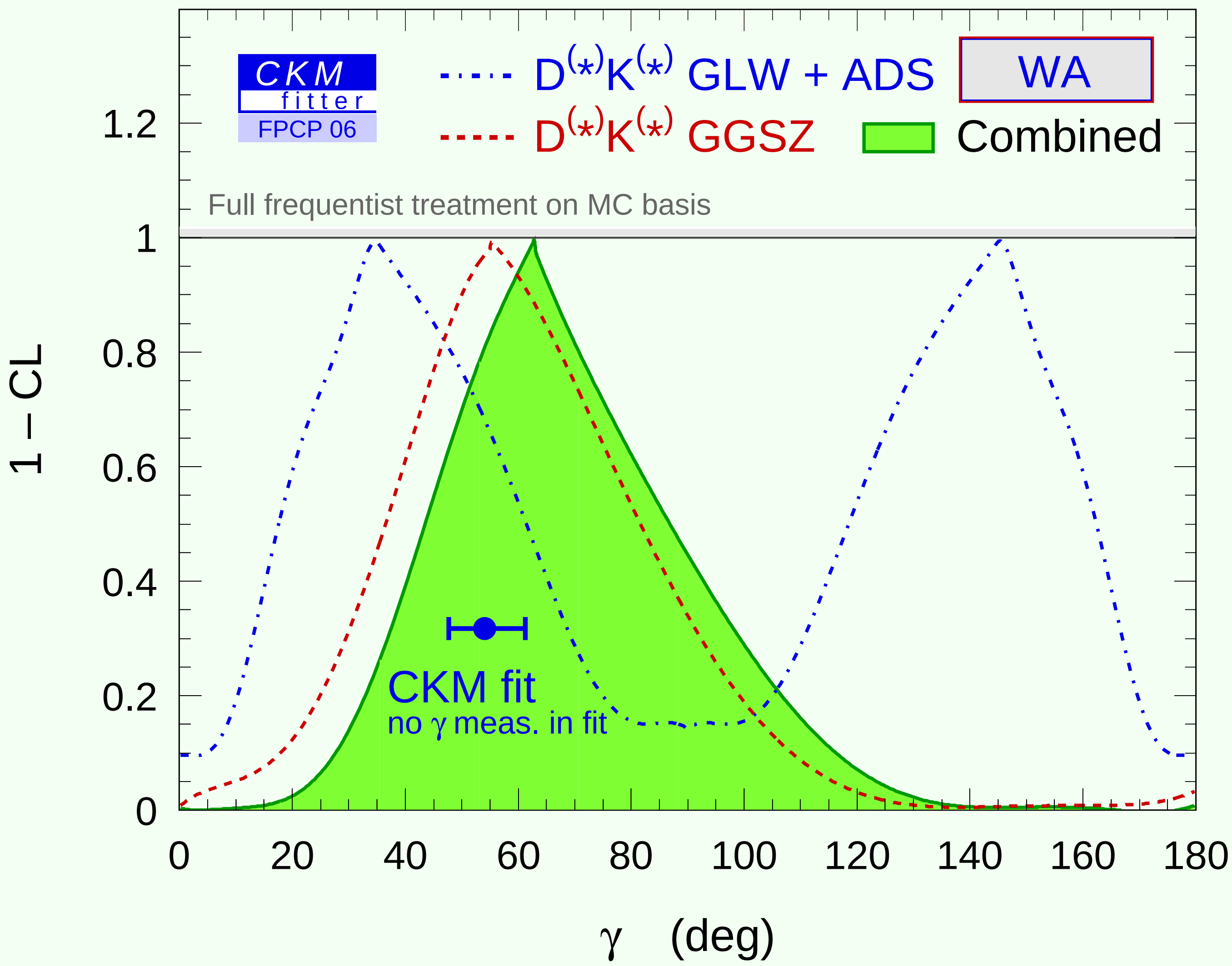
we find a somewhat looser constraint, with $\gamma = (62^{+35}_{-25})^\circ$



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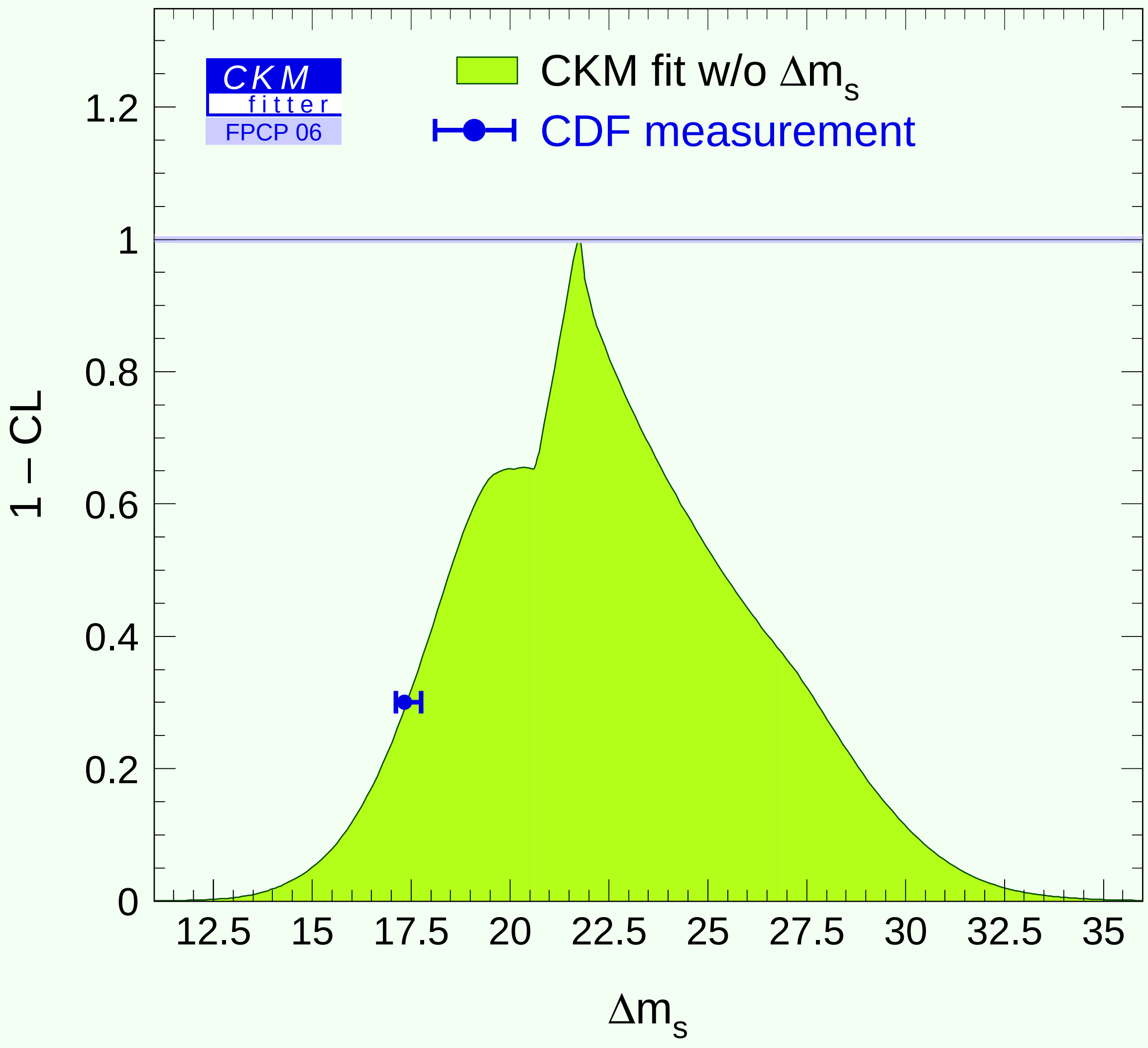
just look at this plot !



...more on selected inputs

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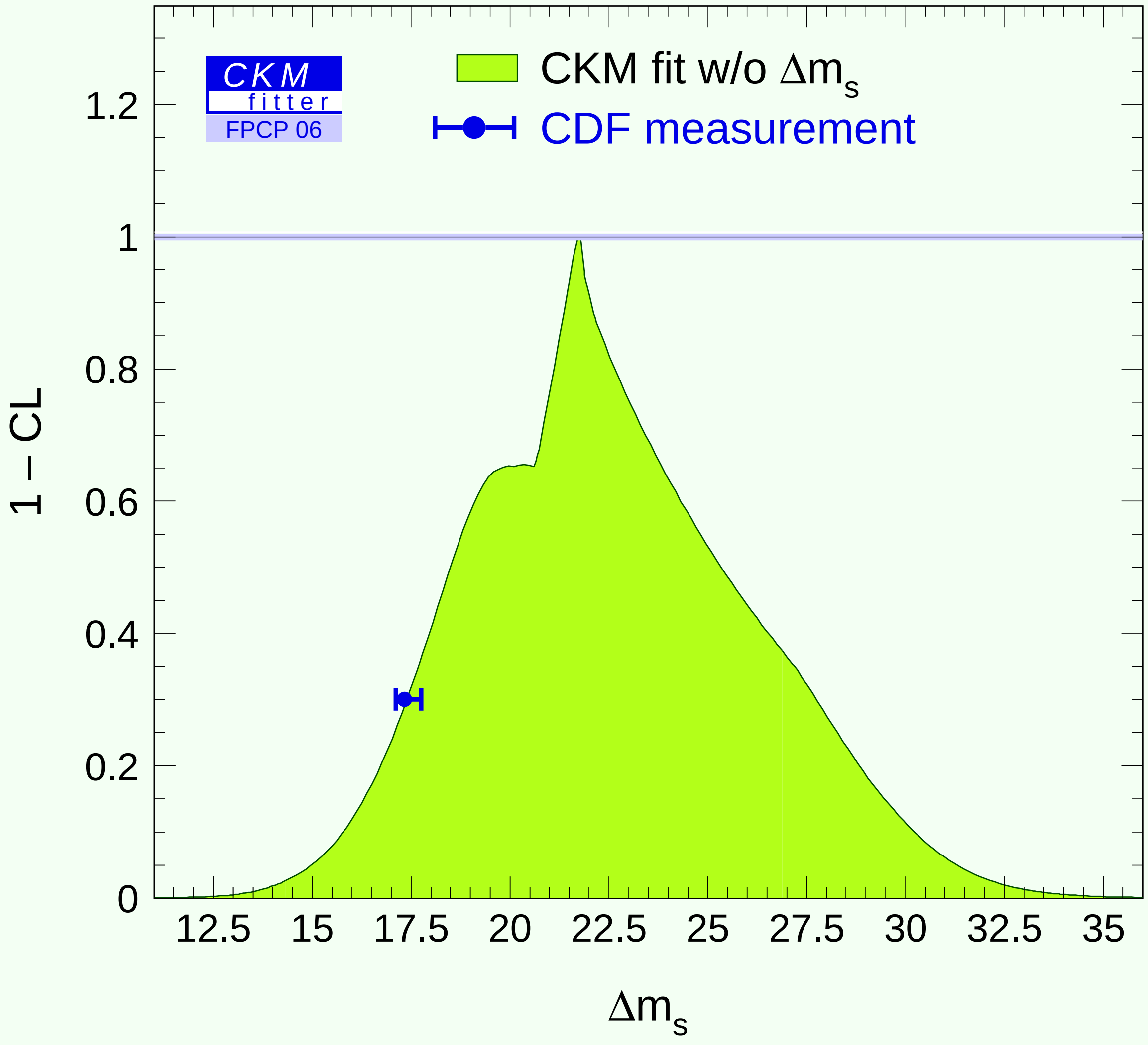
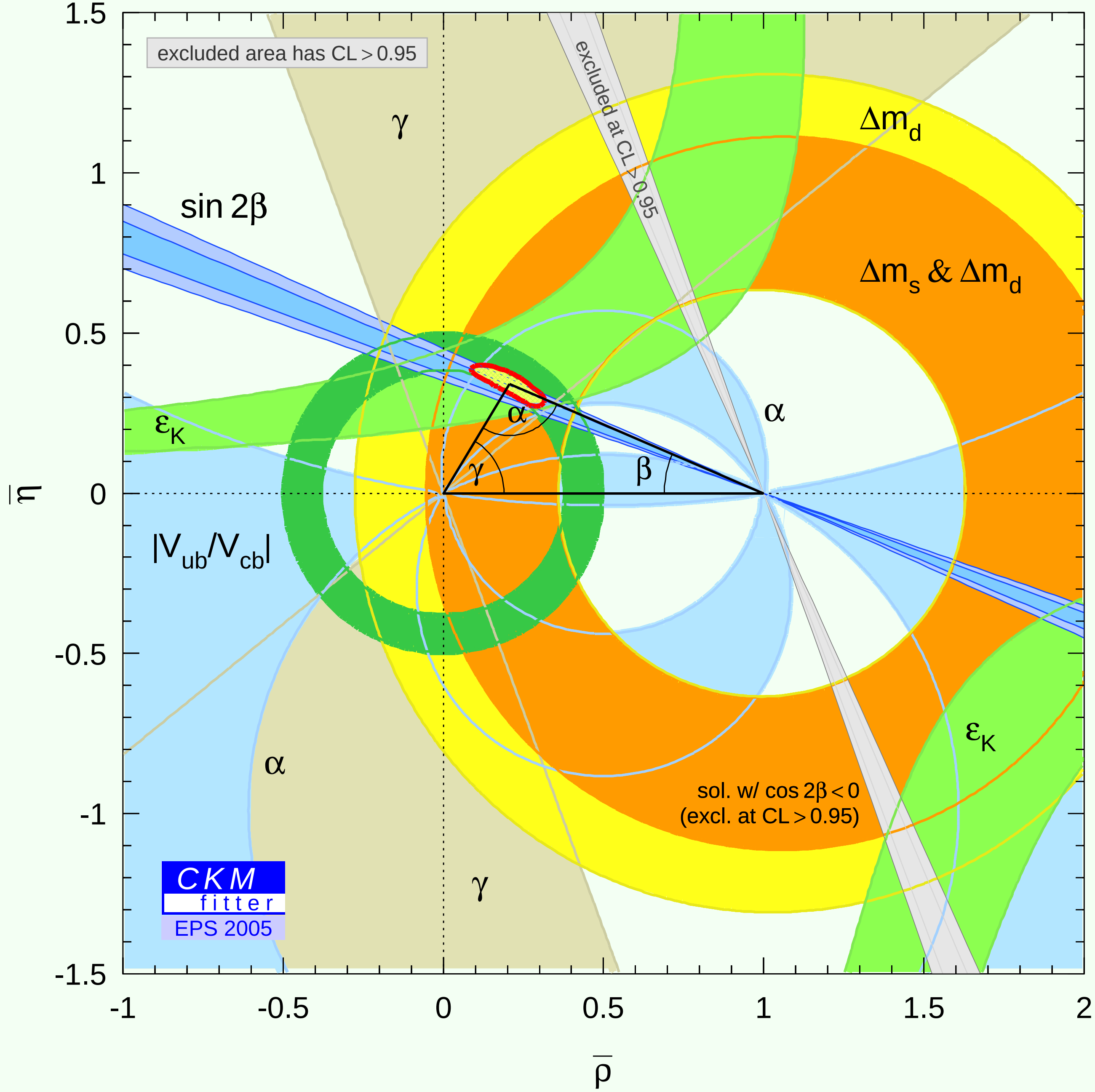
just look at this plot !

however, the measured likelihood function has a complicated structure and does not contain enough information to perform a full frequentist analysis

it would be great to provide us with a Confidence Level curve, or even better, the PDF$(\Delta m_{s\,meas} | \Delta m_{s\,true})$



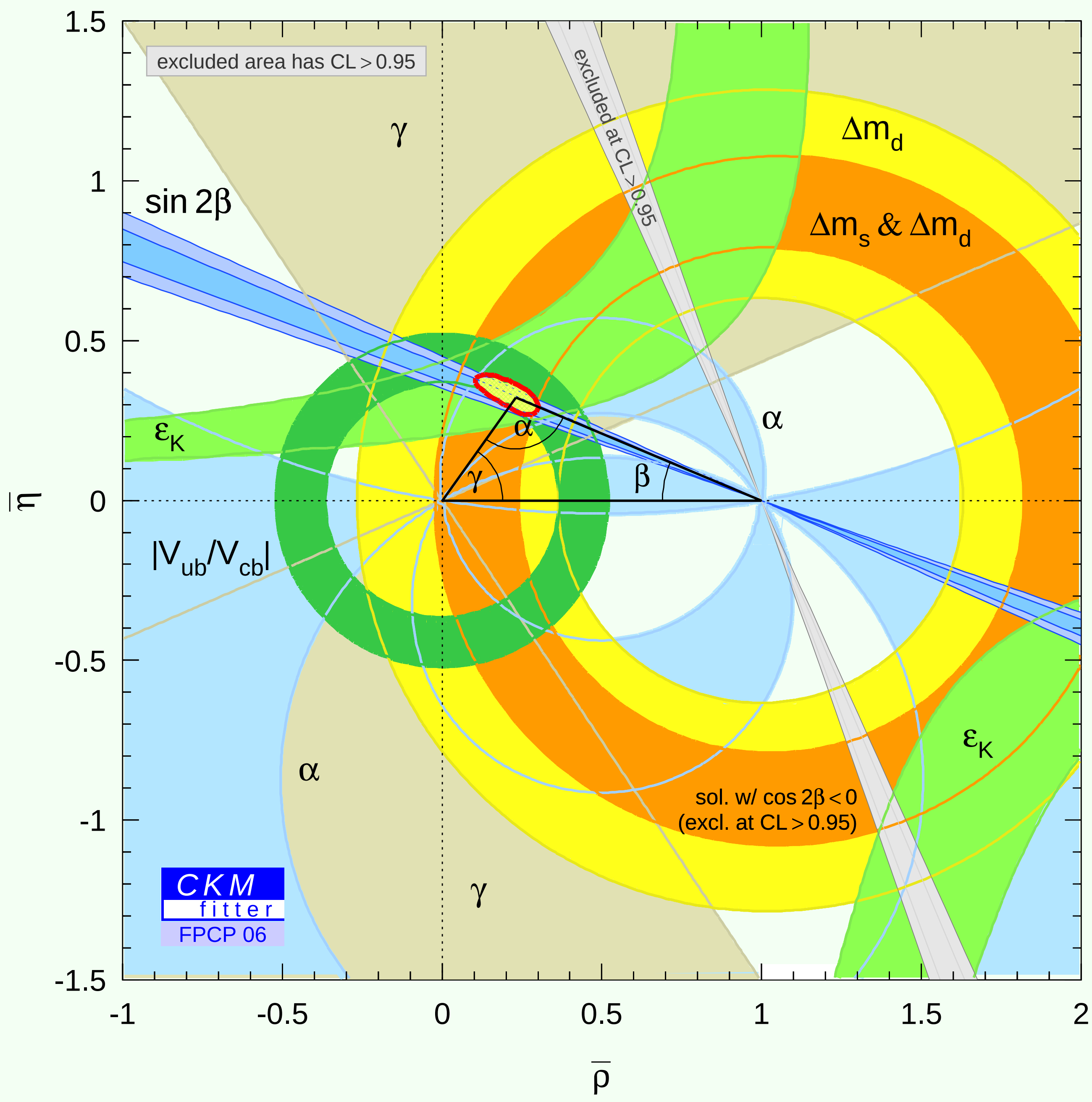
The global CKM fit: results…



EPS05

all constraints together

The global CKM fit: results...

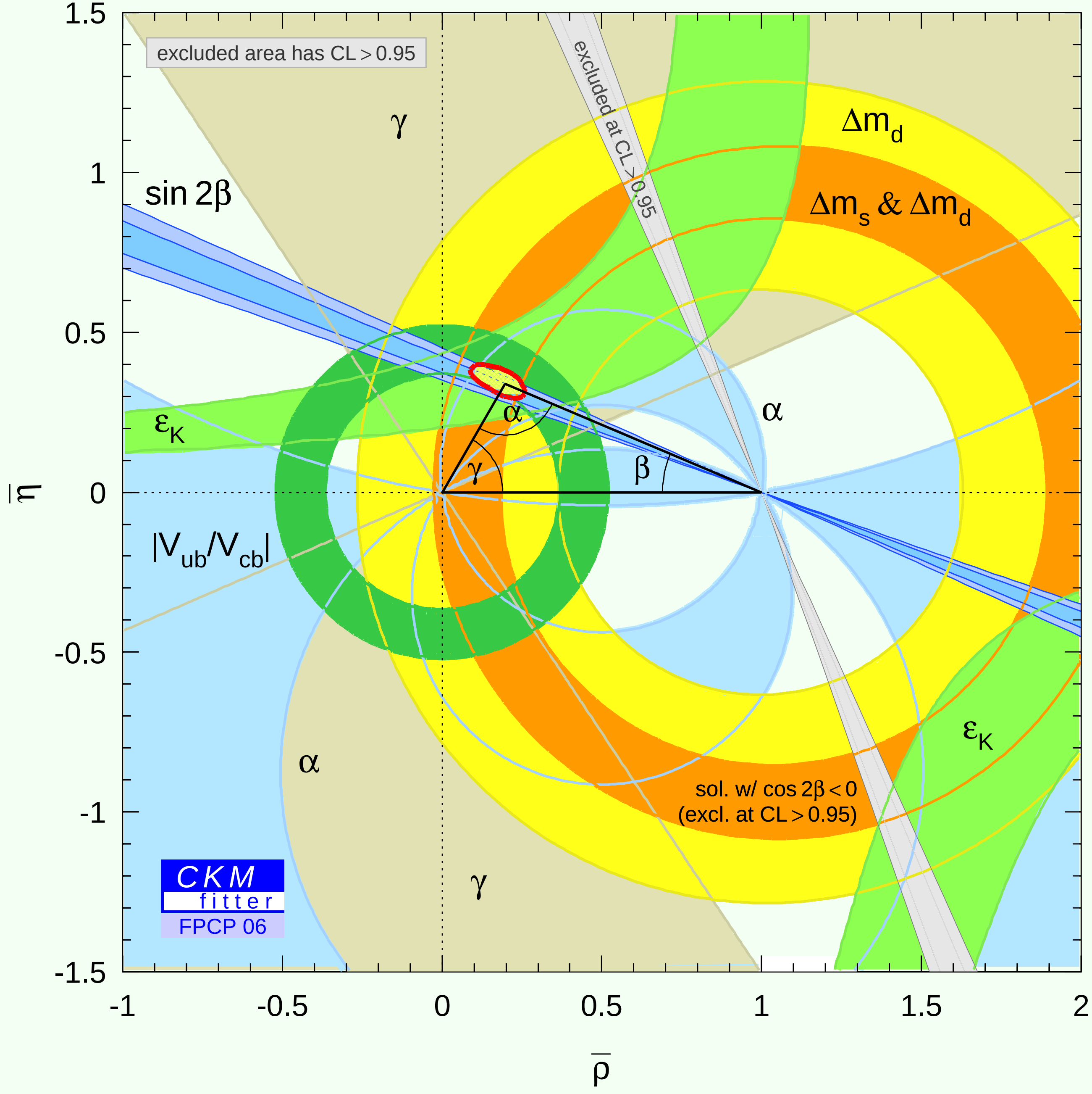


FPCP06

without Δm_s(CDF)

all constraints together

The global CKM fit: results!



FPCP06

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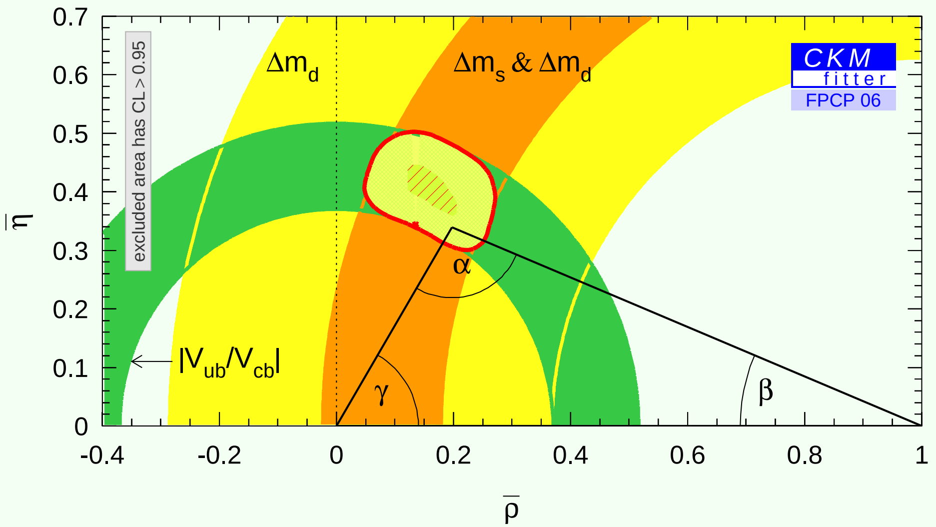
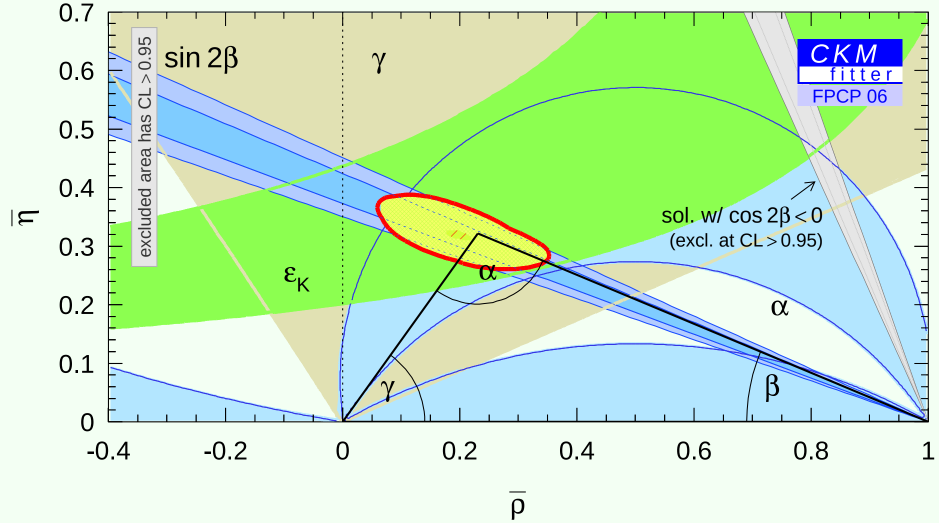
all constraints together

Testing the CKM paradigm

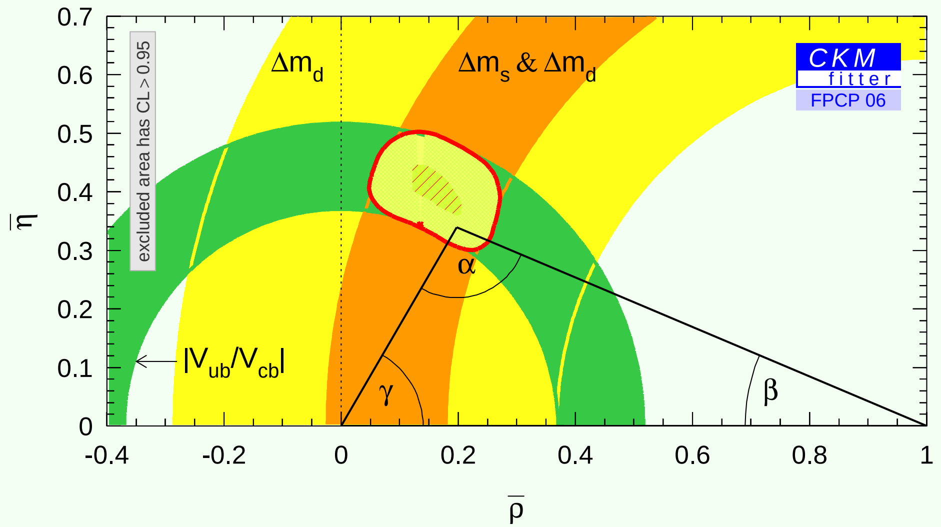


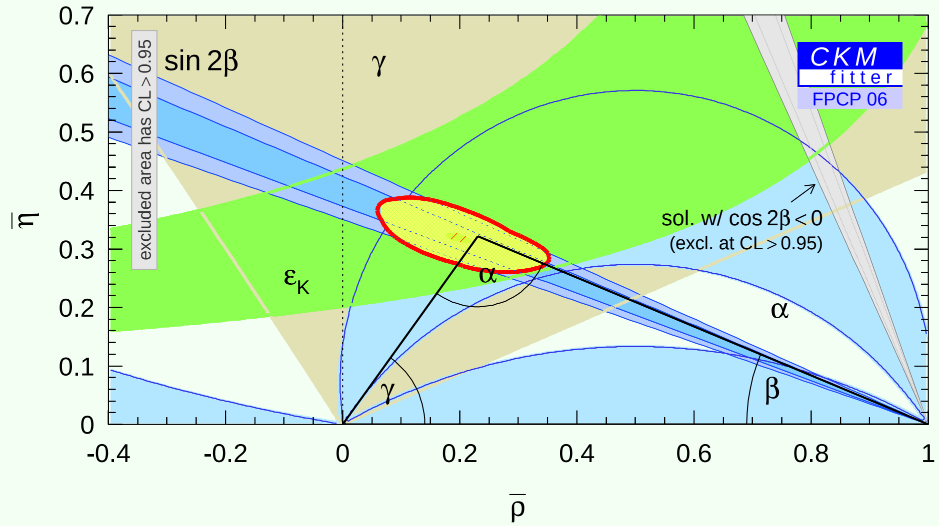


CP-conserving...

...vs. CP-violating

Testing the CKM paradigm





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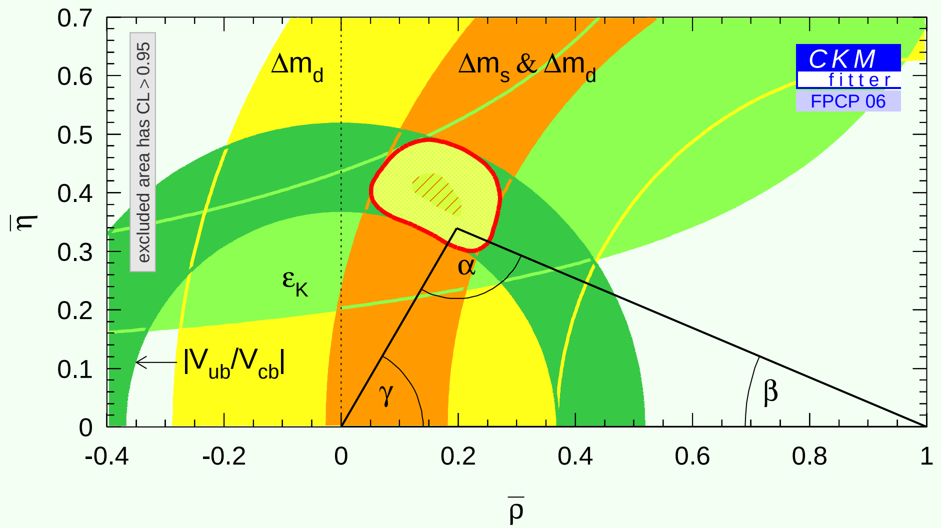
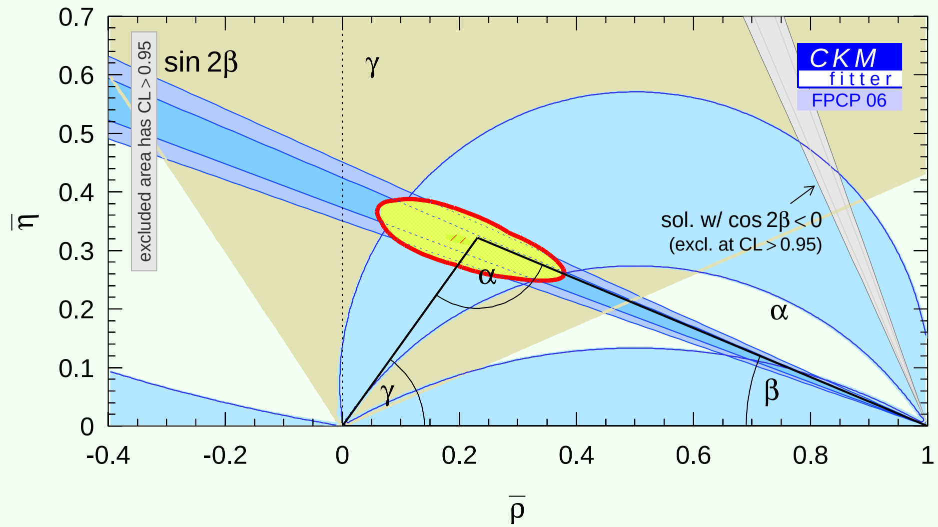
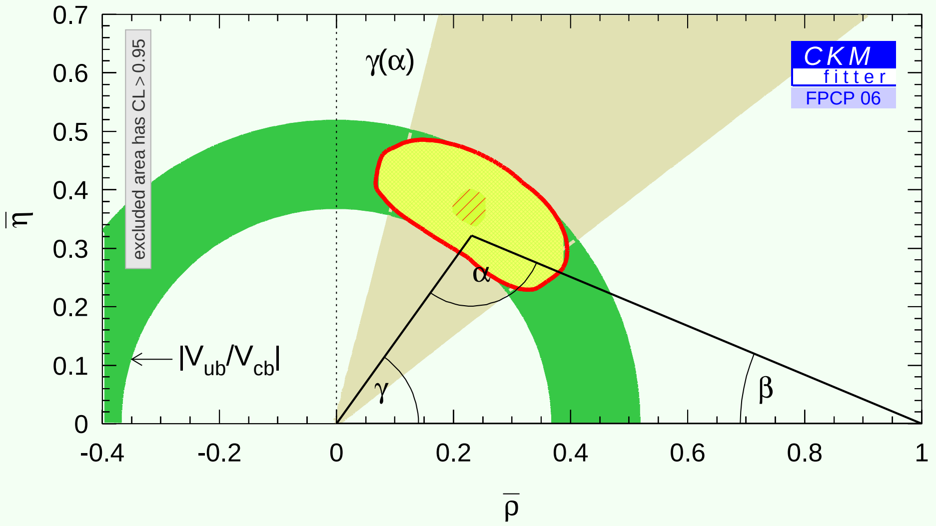


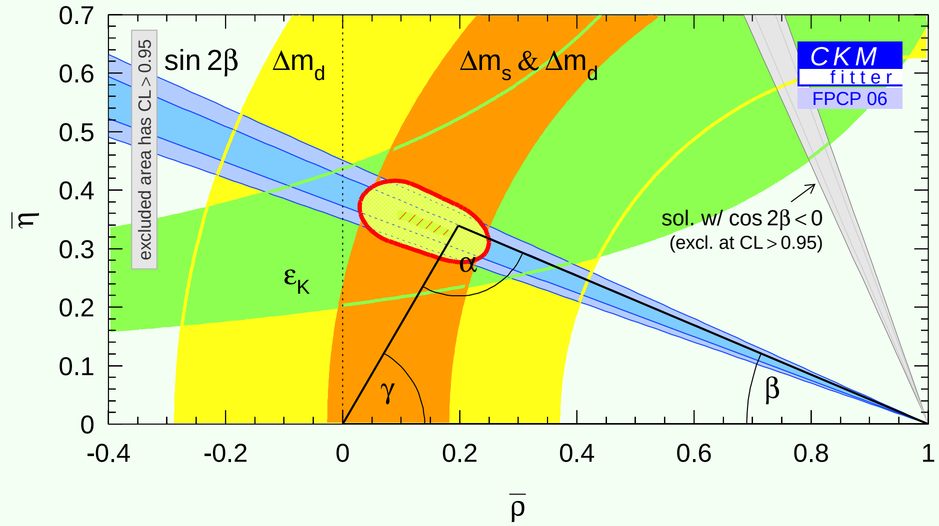


no angles (with theory). . .

. . .vs. angles (without theory)

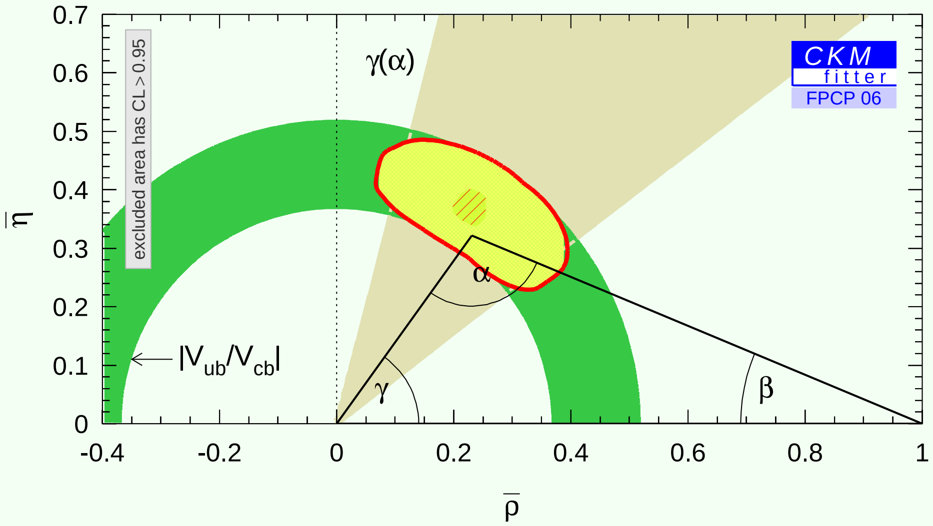
Testing the CKM paradigm

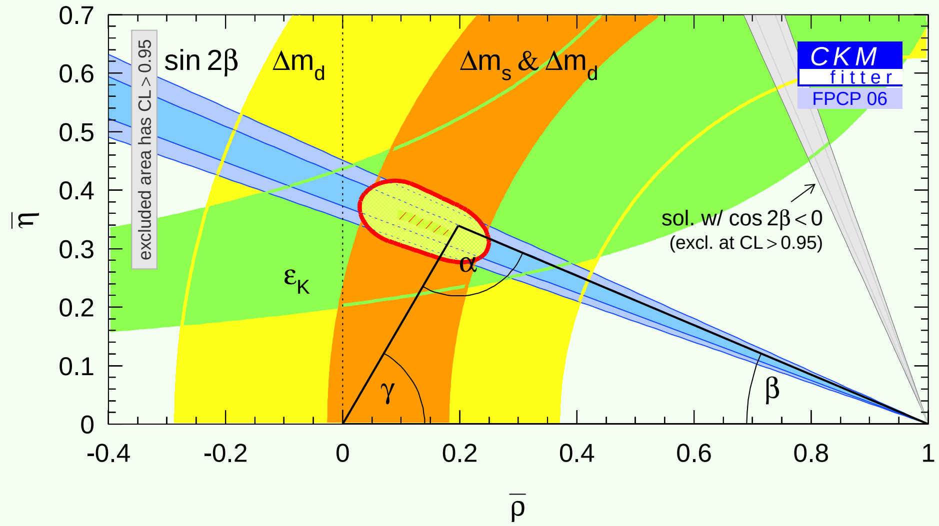




tree... ...vs. loop

Testing the CKM paradigm



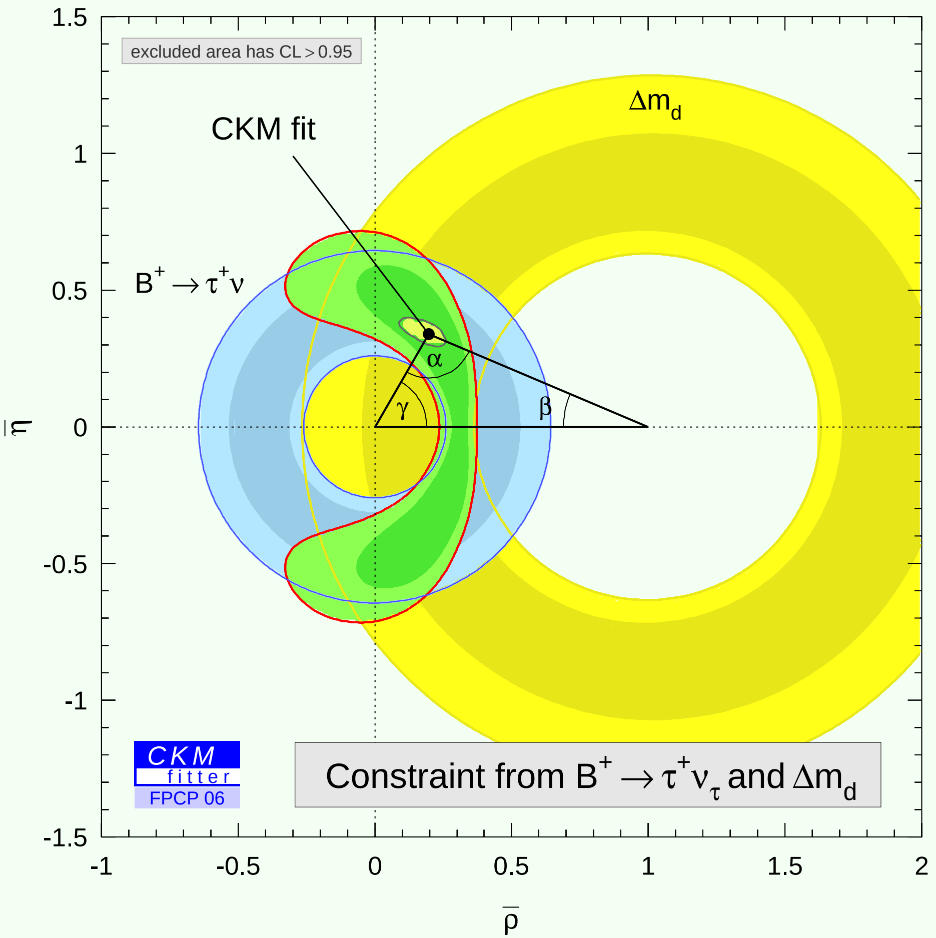


tree... ...vs. loop

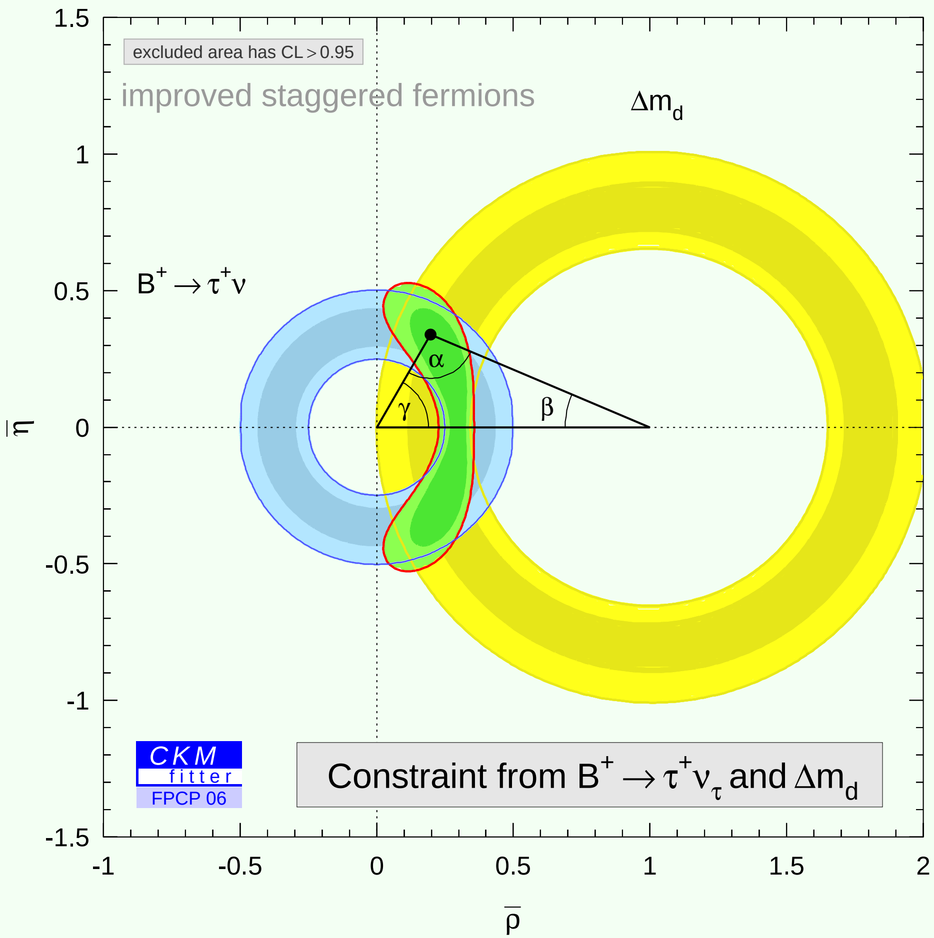
the $(\bar\rho, \bar\eta)$ plane is not the whole story, still the overall agreement is impressive !

Theoretical uncertainties...

all non angle measurements uncertainties are now dominated by theory; however a lot of progress in analytical calculations and lattice simulations has been made recently



using traditional approaches



using improved staggered fermions

and theoretical correlations

from Okamoto et al. (2005), splitting into stat. ± theo.

$$\begin{aligned} f_{B_d} &= 216 \pm 22 \text{ MeV} \\ f_{B_s}/f_{B_d} &= 1.20 \pm 0.03 \\ B_{B_d} &= 1.257 \pm 0.095 \pm 0.021 \\ B_{B_s} &= 1.313 \pm 0.093 \pm 0.014 \end{aligned}$$

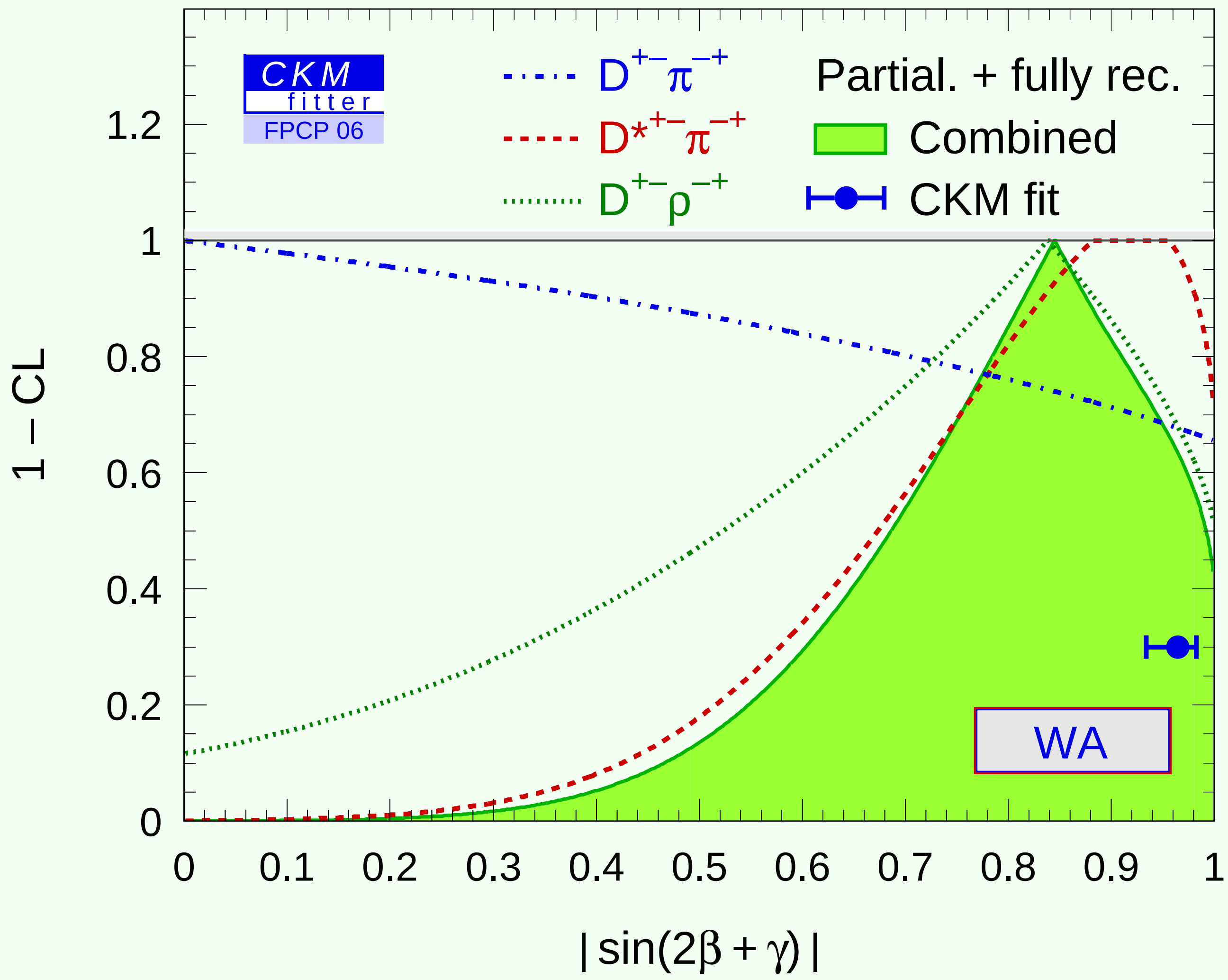
leads to $\xi = 1.226 \pm 0.071 \pm 0.033$ and $f_{B_d}\sqrt{B_{B_d}} = 242 \pm 26 \pm 2$ MeV, while

$$\begin{aligned} f_{B_d} &= 216 \pm 22 \text{ GeV} \\ f_{B_s}/f_{B_d} &= 1.20 \pm 0.03 \\ B_{B_s} &= 1.313 \pm 0.093 \pm 0.014 \\ B_{B_s}/B_{B_d} &= 1.044 \pm 0.023 \pm 0.027 \end{aligned}$$

leads to $\xi = 1.226 \pm 0.035 \pm 0.031$, $f_{B_d}\sqrt{B_{B_d}} = 242 \pm 26 \pm 9$ MeV and $B_{B_d} = 1.258 \pm 0.094 \pm 0.045$

$|\sin(2\beta+\gamma)|$

from $b \to c\bar{u}d,\ u\bar{c}d$



Selected fit predictions

the Wolfenstein parameters

$$\lambda = 0.2272^{+0.0010}_{-0.0010} \qquad A = 0.809^{+0.014}_{-0.014}$$

$$\bar{\rho} = 0.197^{+0.026}_{-0.030} \qquad \bar{\eta} = 0.339^{+0.019}_{-0.018}$$

the Jarlskog invariant

$$J = (3.05 \pm 0.18) \times 10^{-5}$$

the UT angles

$$\alpha = (97.3^{+4.5}_{-5.0})^\circ \qquad \beta = (22.86^{+1.00}_{-1.00})^\circ \qquad \gamma = (59.8^{+4.9}_{-4.1})^\circ$$

$B_s - \bar{B}_s$ mixing

$$\Delta m_s = 17.34^{+0.49}_{-0.20}\ \mathrm{ps}^{-1}$$

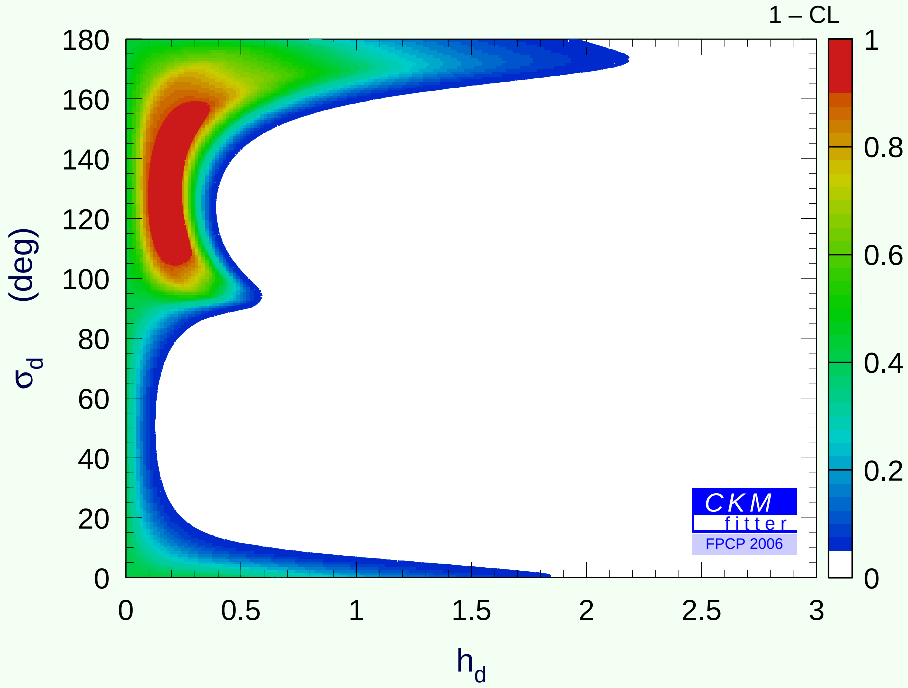
B leptonic decay

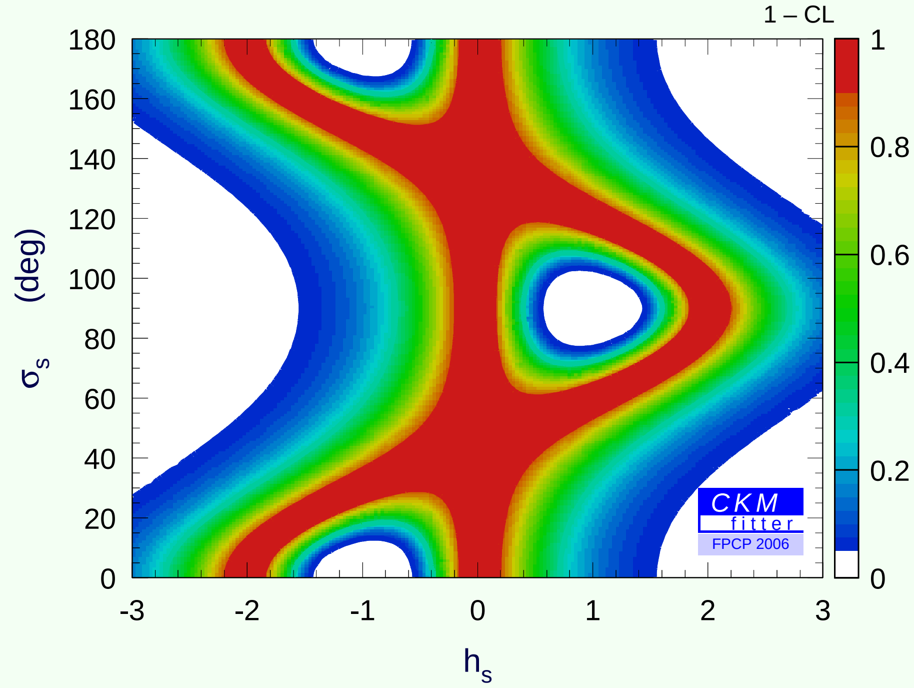
$$\mathcal{B}(B \to \tau\nu) = (9.7 \pm 1.3) \times 10^{-5}$$

New Physics in mixing

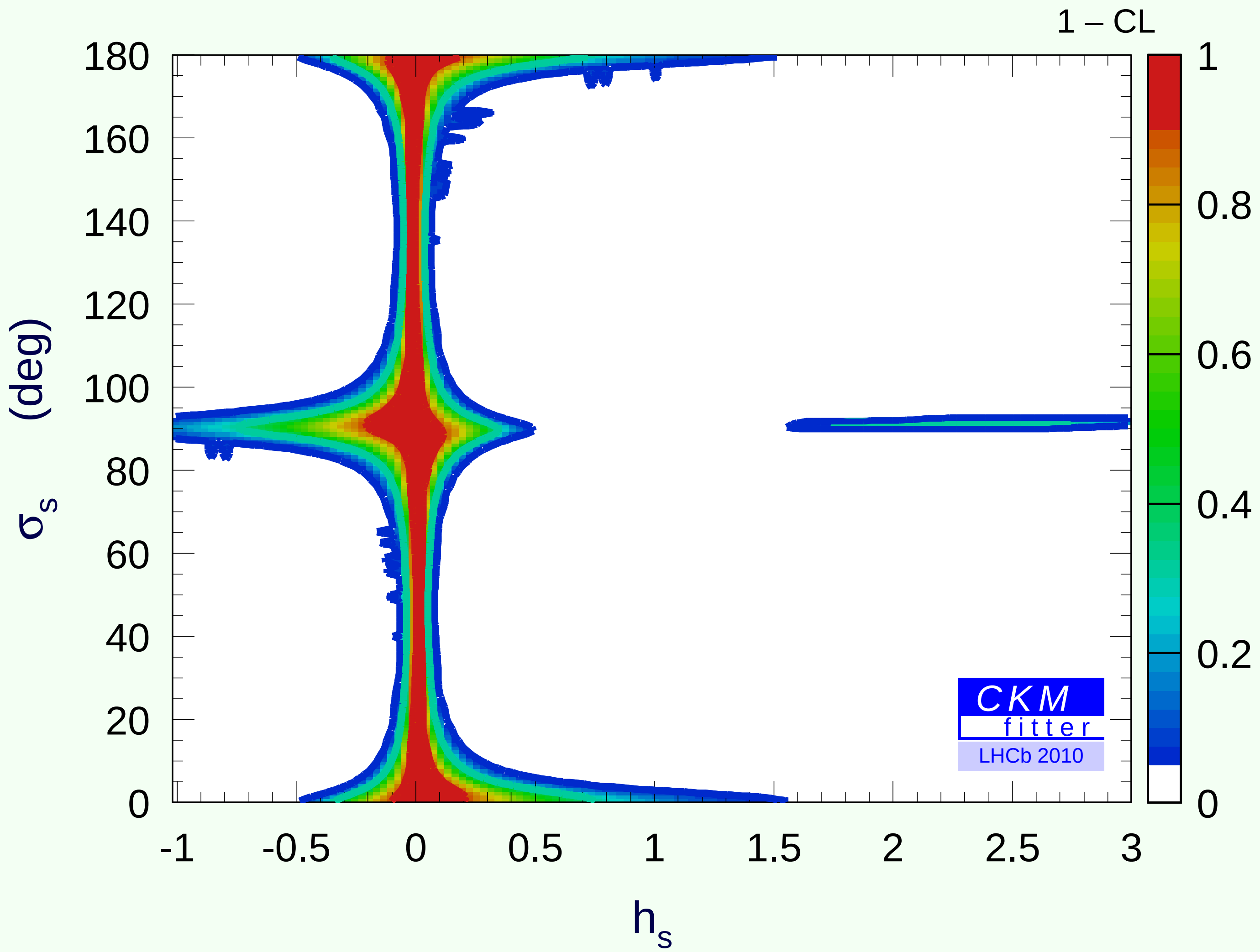
model-independent parametrization

$$\langle B_q \,|\, \mathcal{H}^{SM+NP}_{\Delta B=2} \,|\, \bar{B}_q \rangle \equiv \langle B_q \,|\, \mathcal{H}^{SM}_{\Delta B=2} \,|\, \bar{B}_q \rangle \times (1 + h_q\, e^{2i\sigma_q})$$



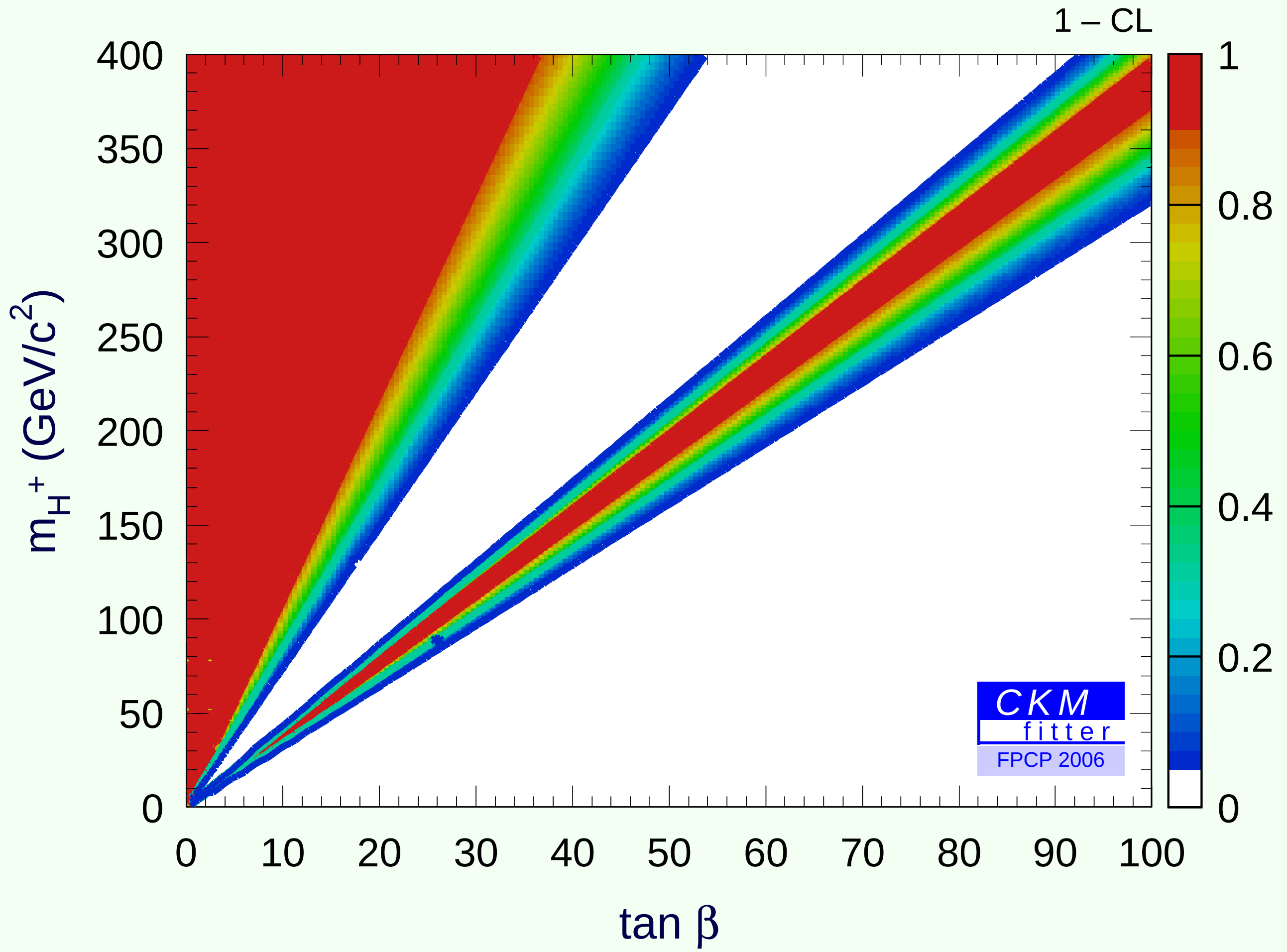


assuming $\Delta m_s = 20.000 \pm 0.011\ \mathrm{ps}^{-1}$ and $\sin 2\beta_s = 0.036 \pm 0.028$ (one year LHCb running)



Constraint on supersymmetric charged Higgs

from $B \to \tau\nu$



The Unitarity Triangle from flavor SU(3)

JC, A. Höcker, J. Malclès, J. Ocaríz, to appear

most of SU(3)-based analyses of charmless $B \to \pi\pi, K\pi, K\bar{K}$ decays neglect annihilation/exchange topologies

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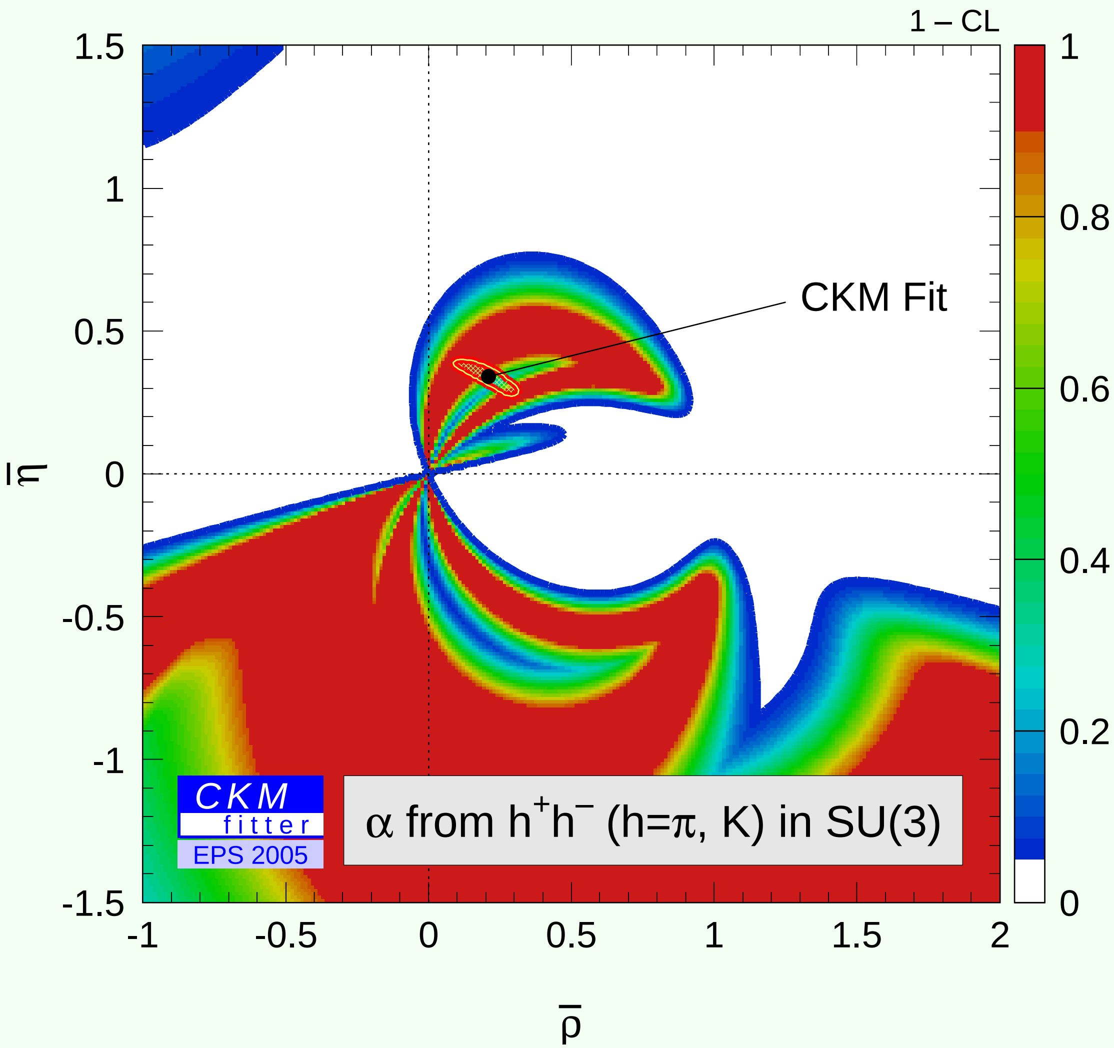
this assumption is not mandatory !

"α" from

$B \to \pi^+\pi^-, K^+\pi^-, K^+K^-$



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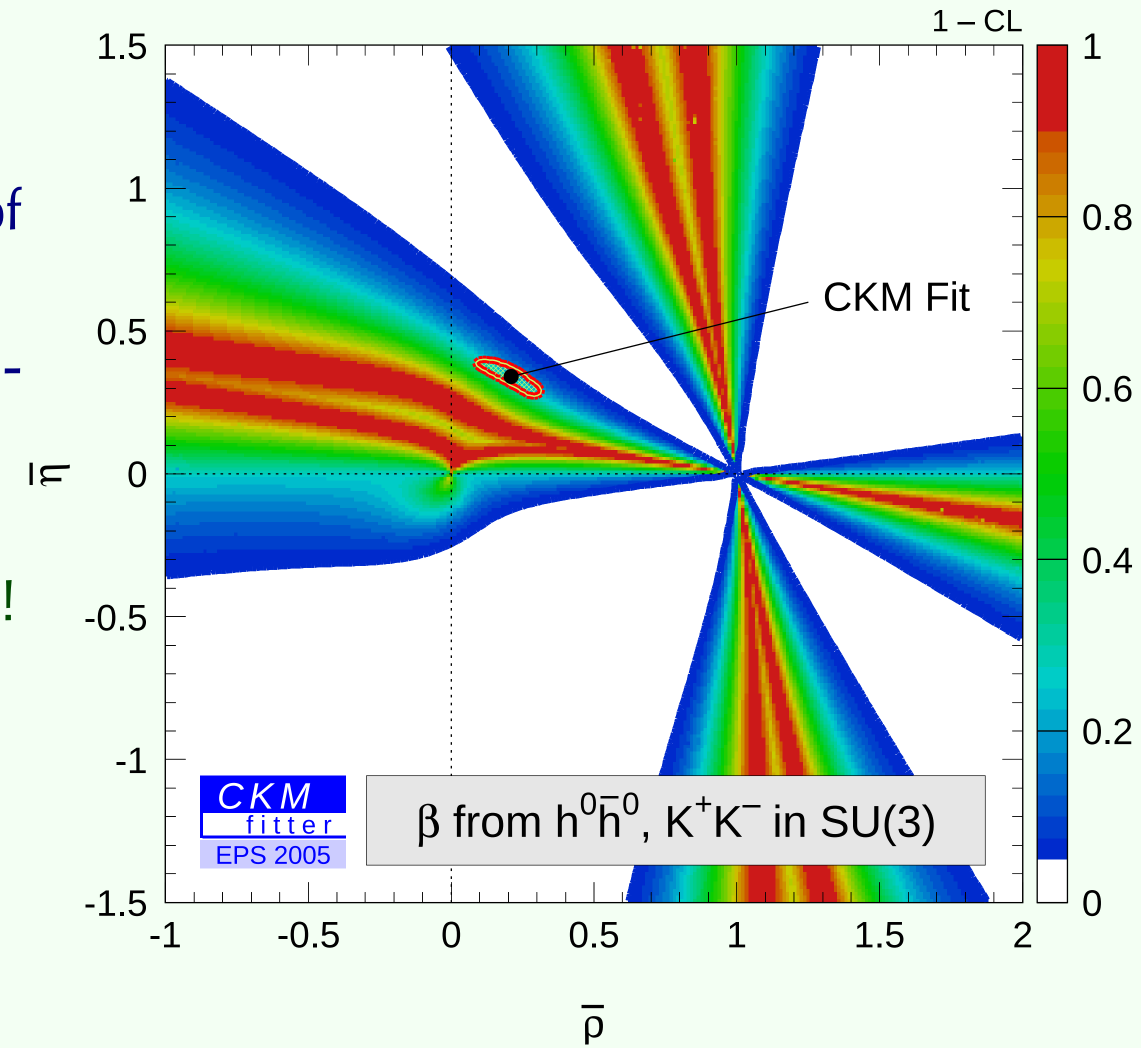
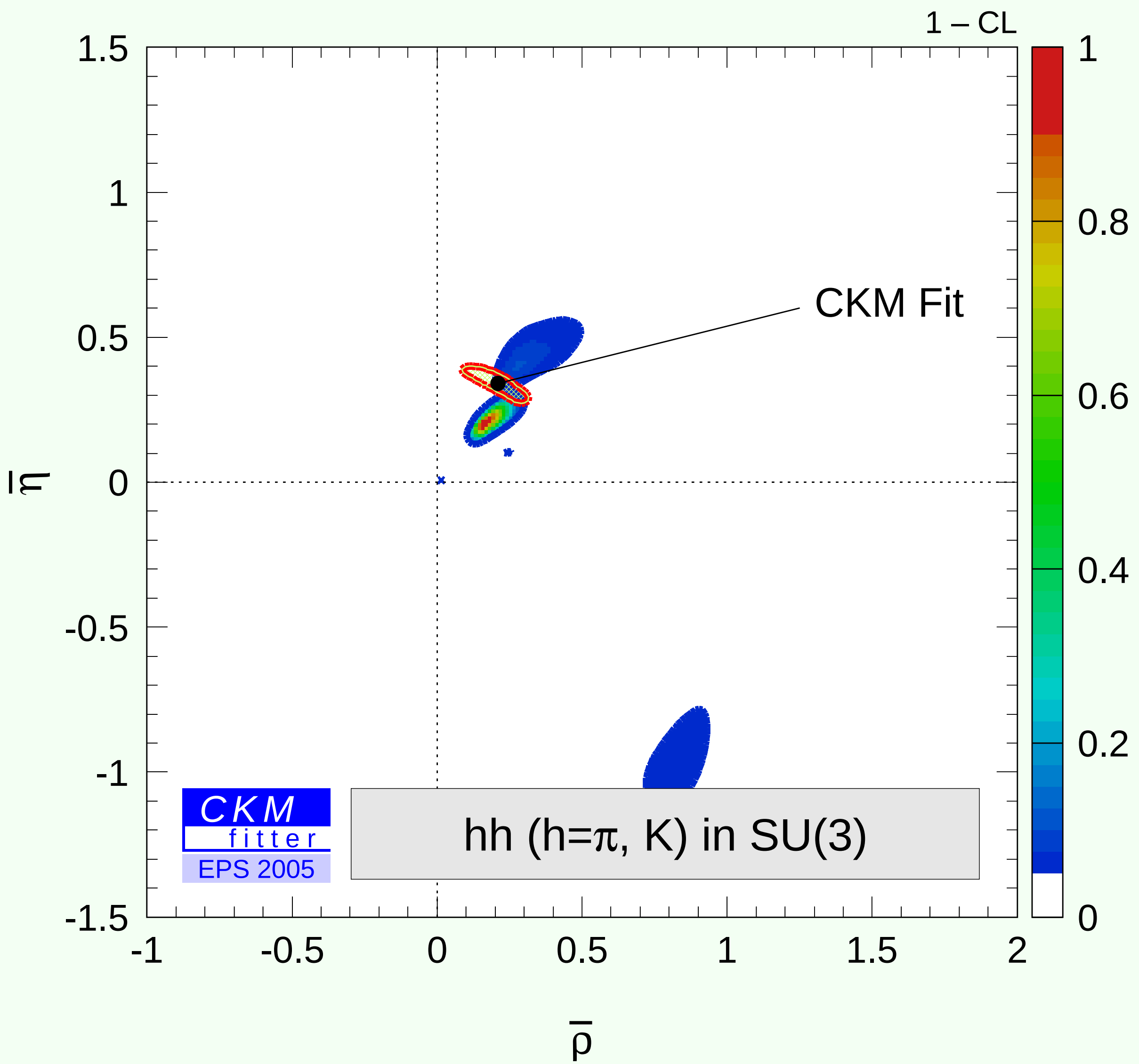
"β" from

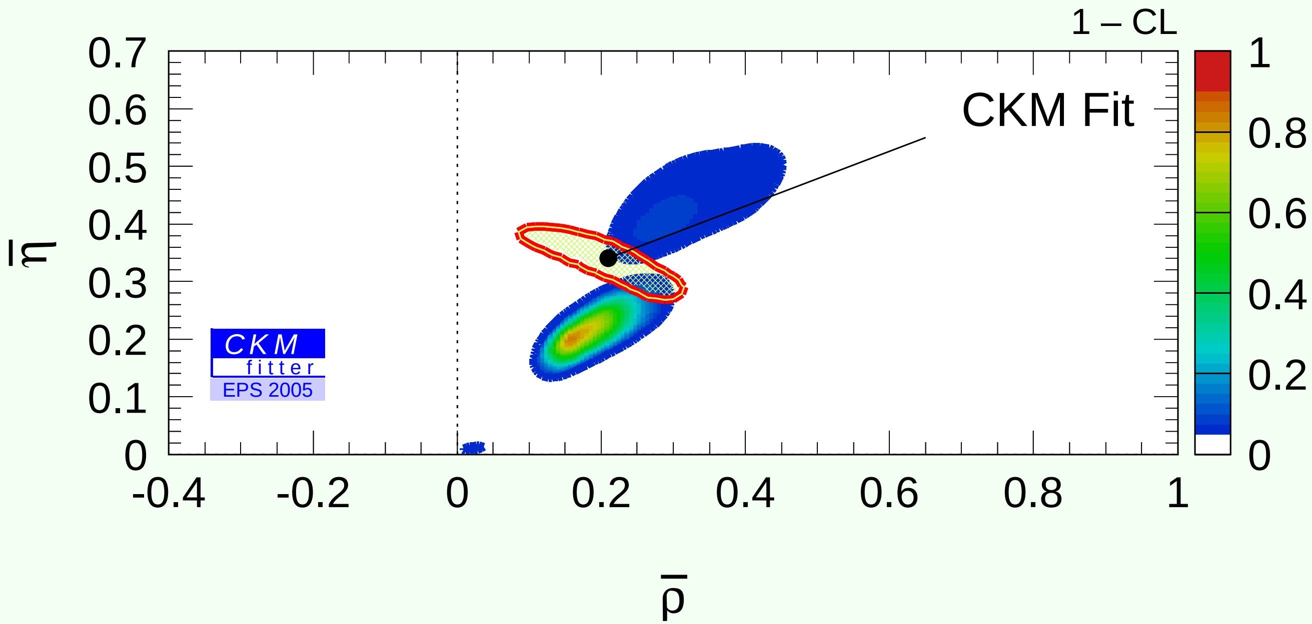
$B \to K_S\pi^0, \pi^0\pi^0, K^+K^-$

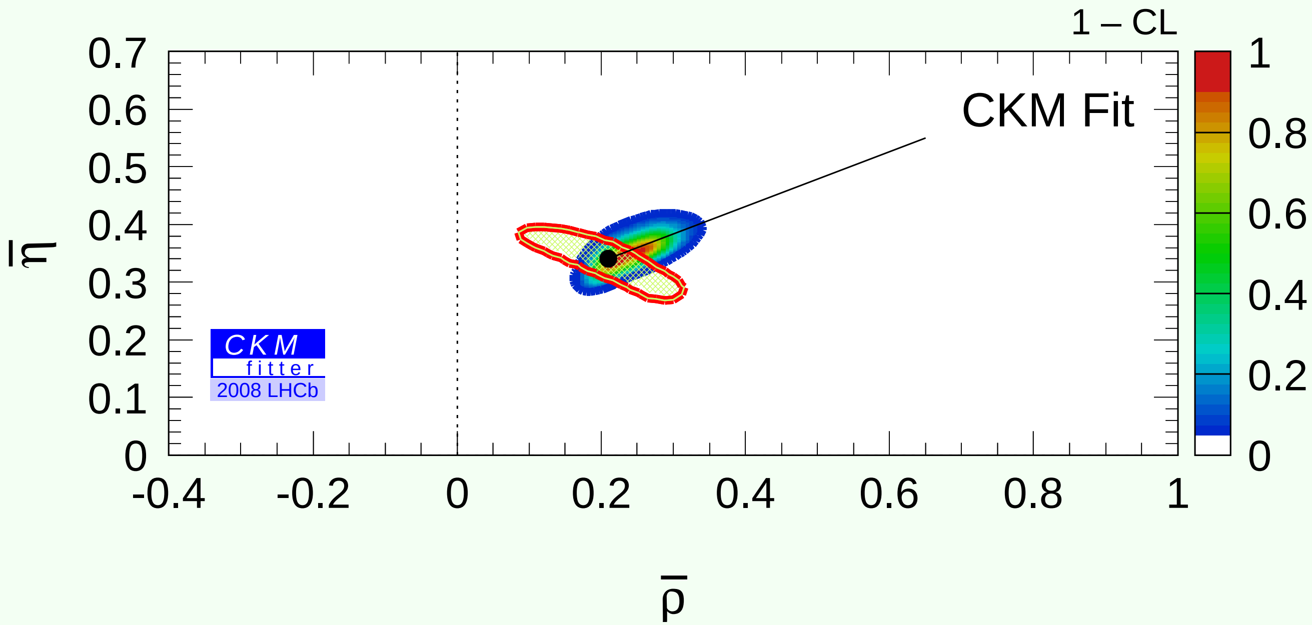


using all $B \to PP$ observables (today)



using all $B \to PP$ observables (today $\to$ tomorrow)

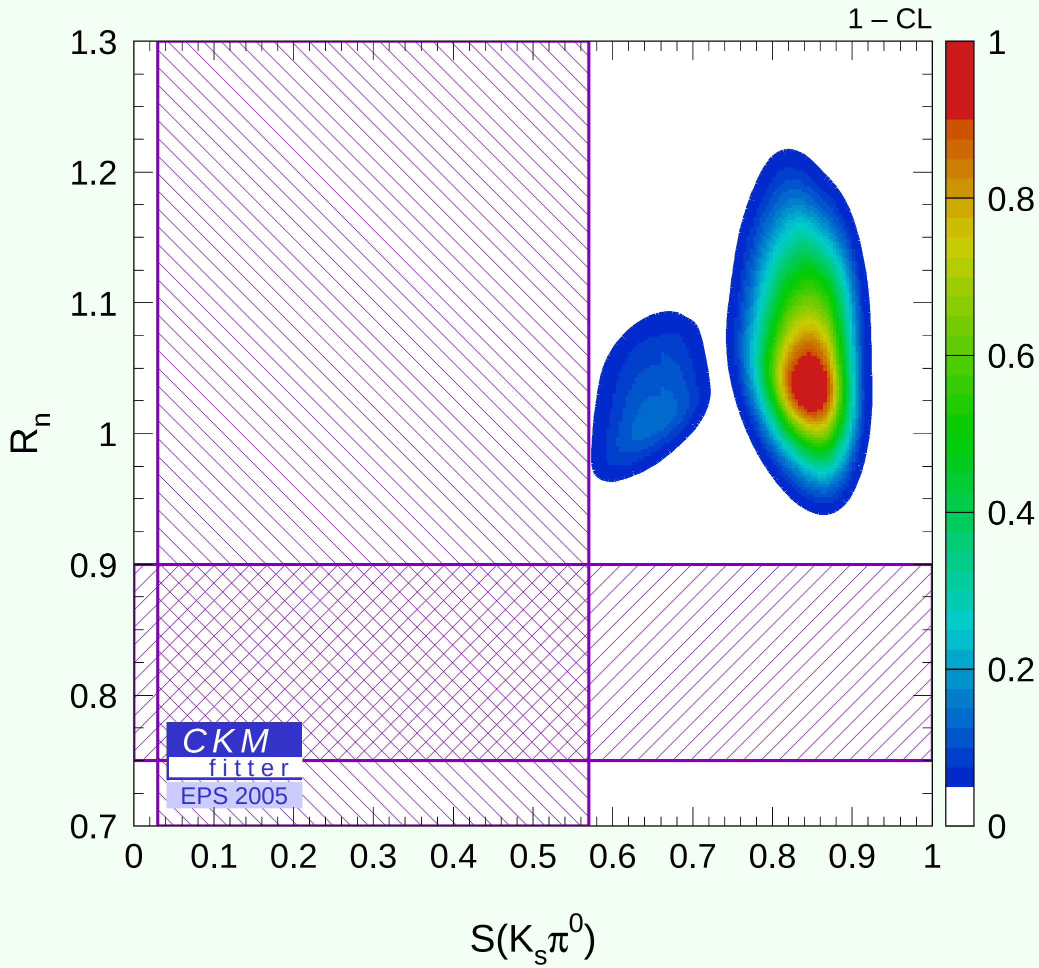




Depuzzling $B \to K\pi$

using $(\bar{\rho}, \bar{\eta})_{SM}$ and all $B \to PP$ observables, except $BR(B \to K^+\pi^-)$, $BR(B \to K^0\pi^0)$ and $S(K_S\pi^0)$

$$R_n = BR(K^+\pi^-)/\left(2BR(K^0\pi^0)\right)$$



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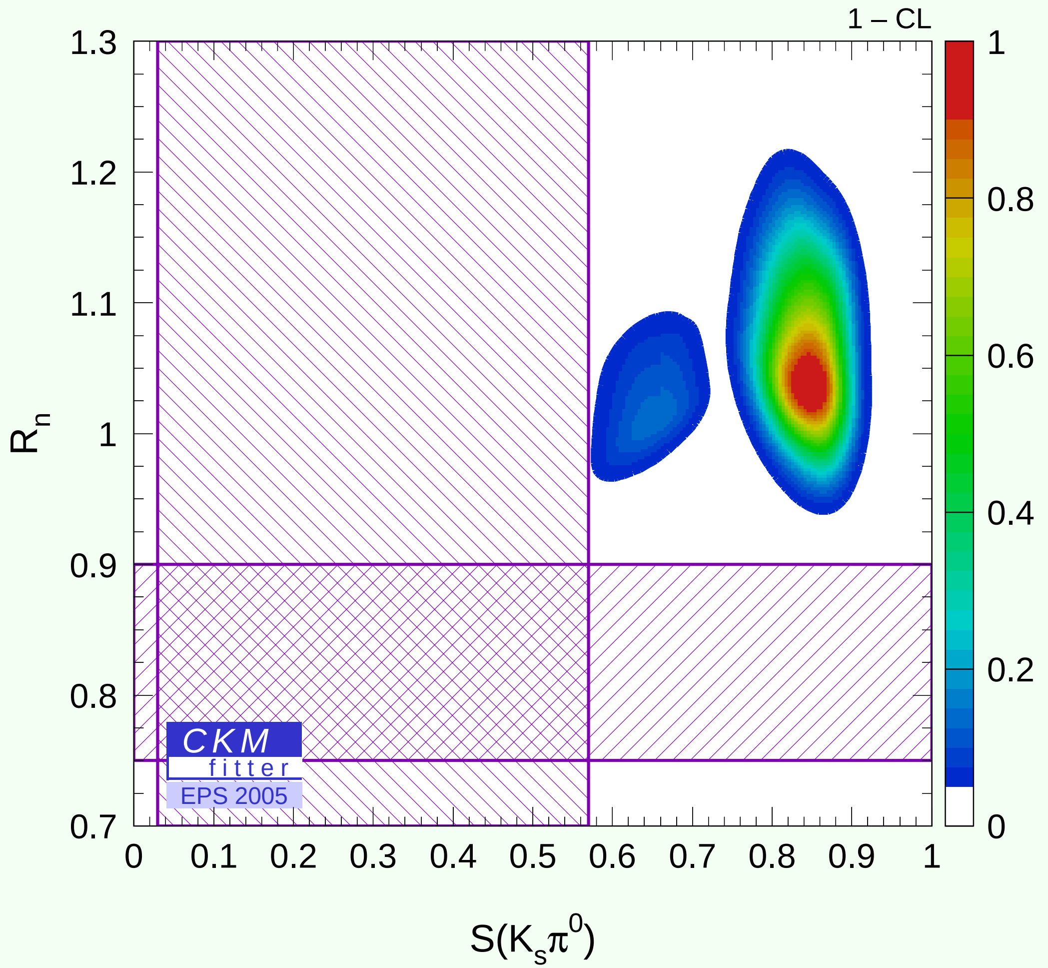
$$R_n = BR(K^+\pi^-)/\left(2BR(K^0\pi^0)\right)$$

a $\sim 2\sigma$ effect !



Conclusion

congratulations to

Conclusion

congratulations to

BaBar ?...

Conclusion

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BaBar ?. . .

Belle ?. . .

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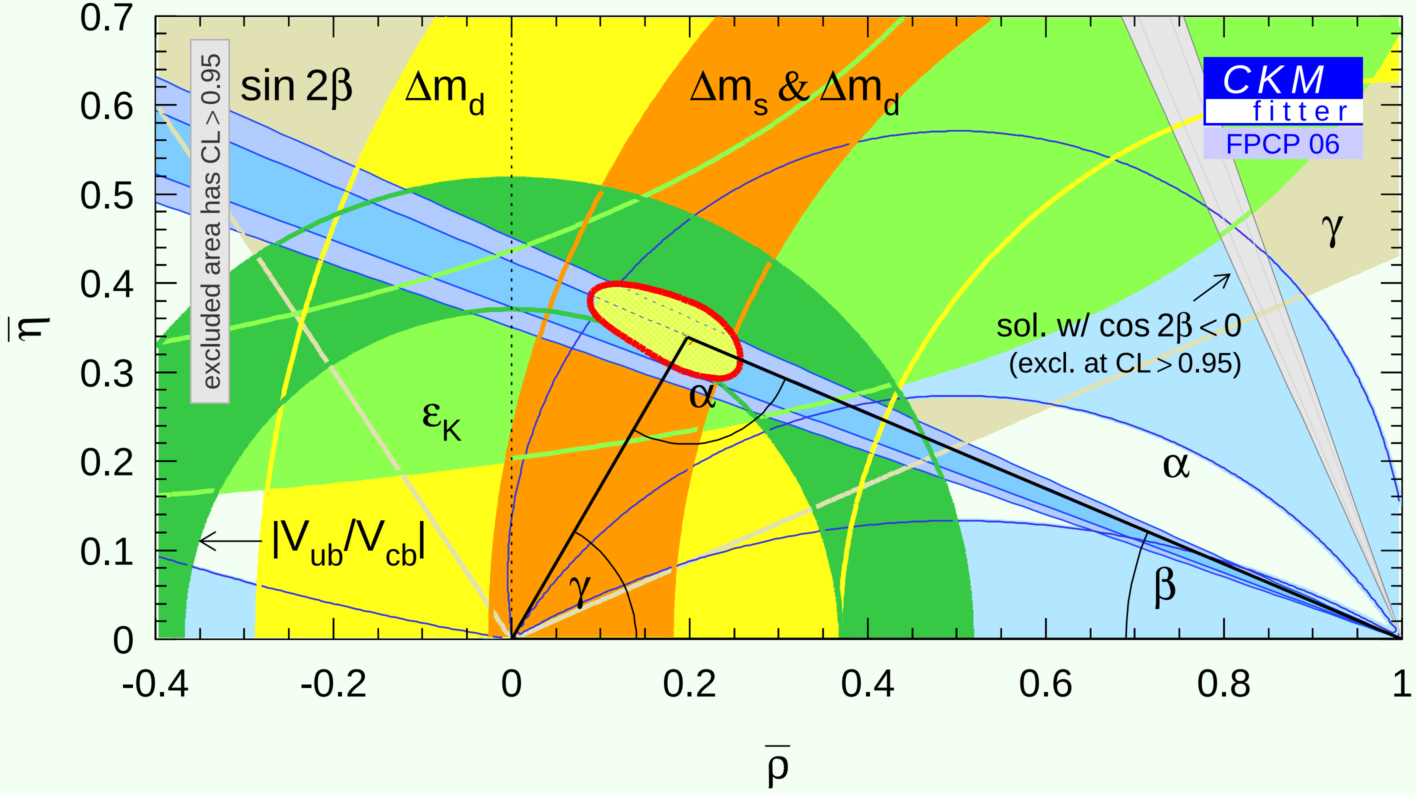
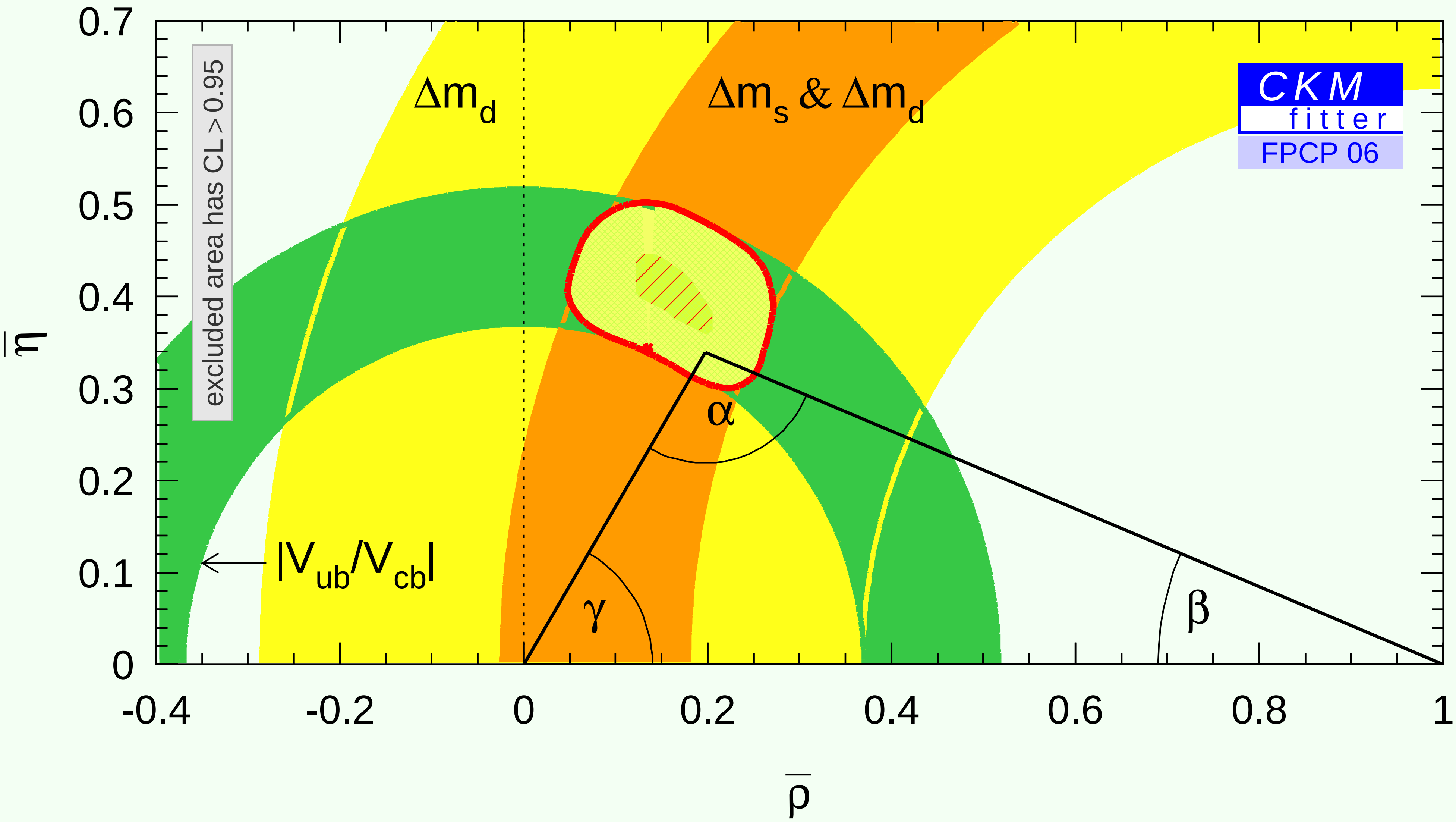
. . . to Standard Model of course



backup

The CKM movie



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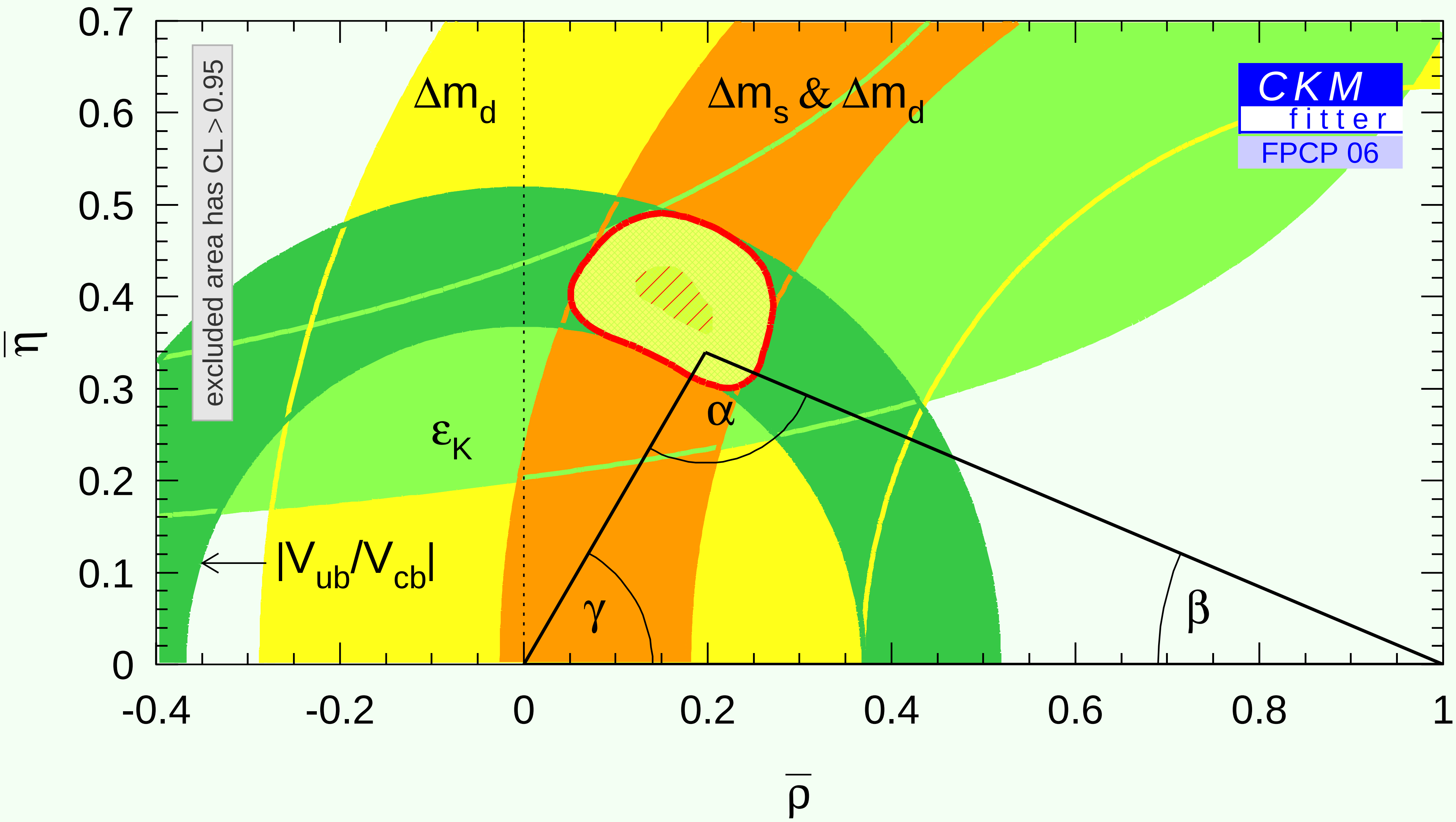

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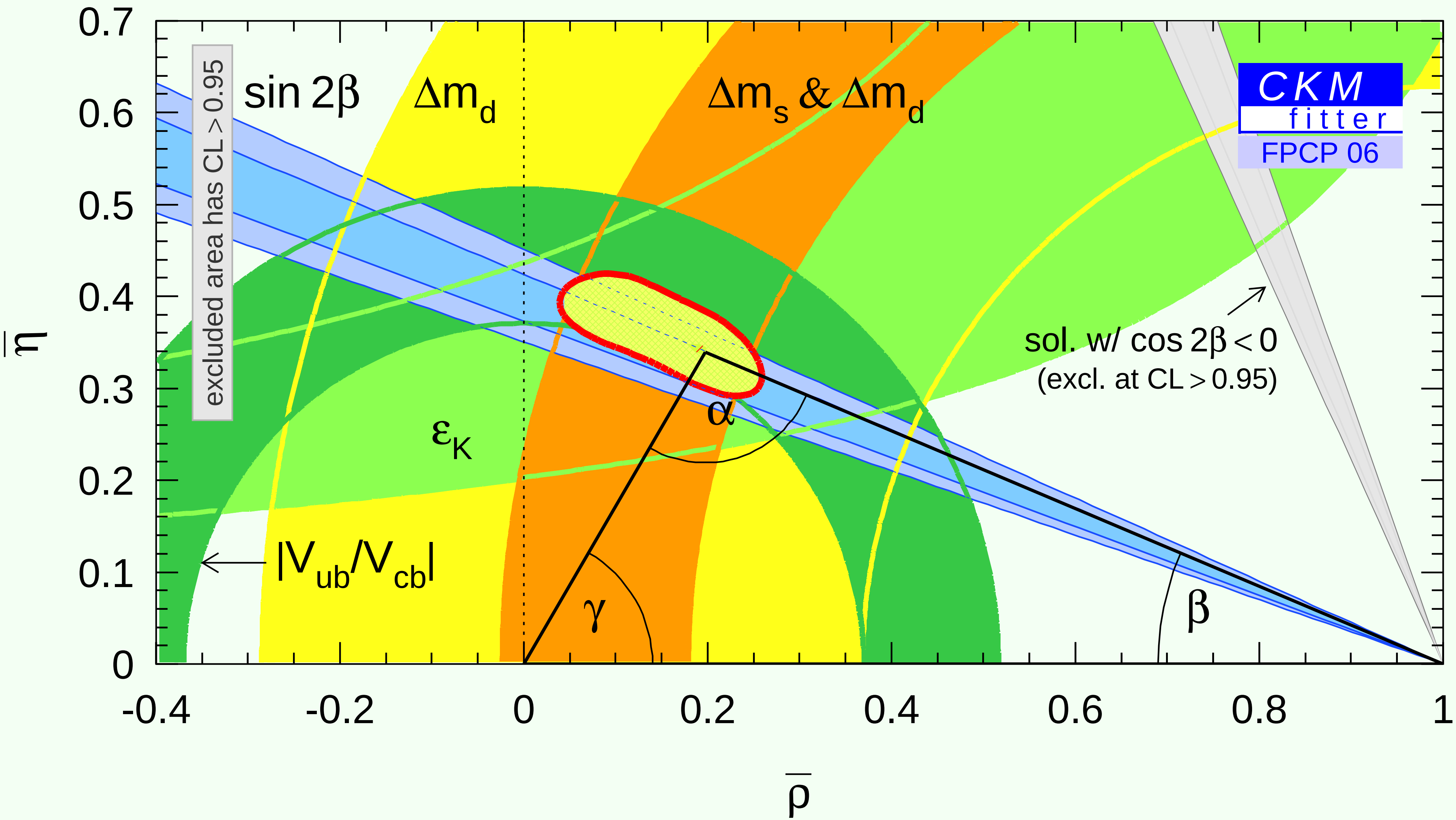
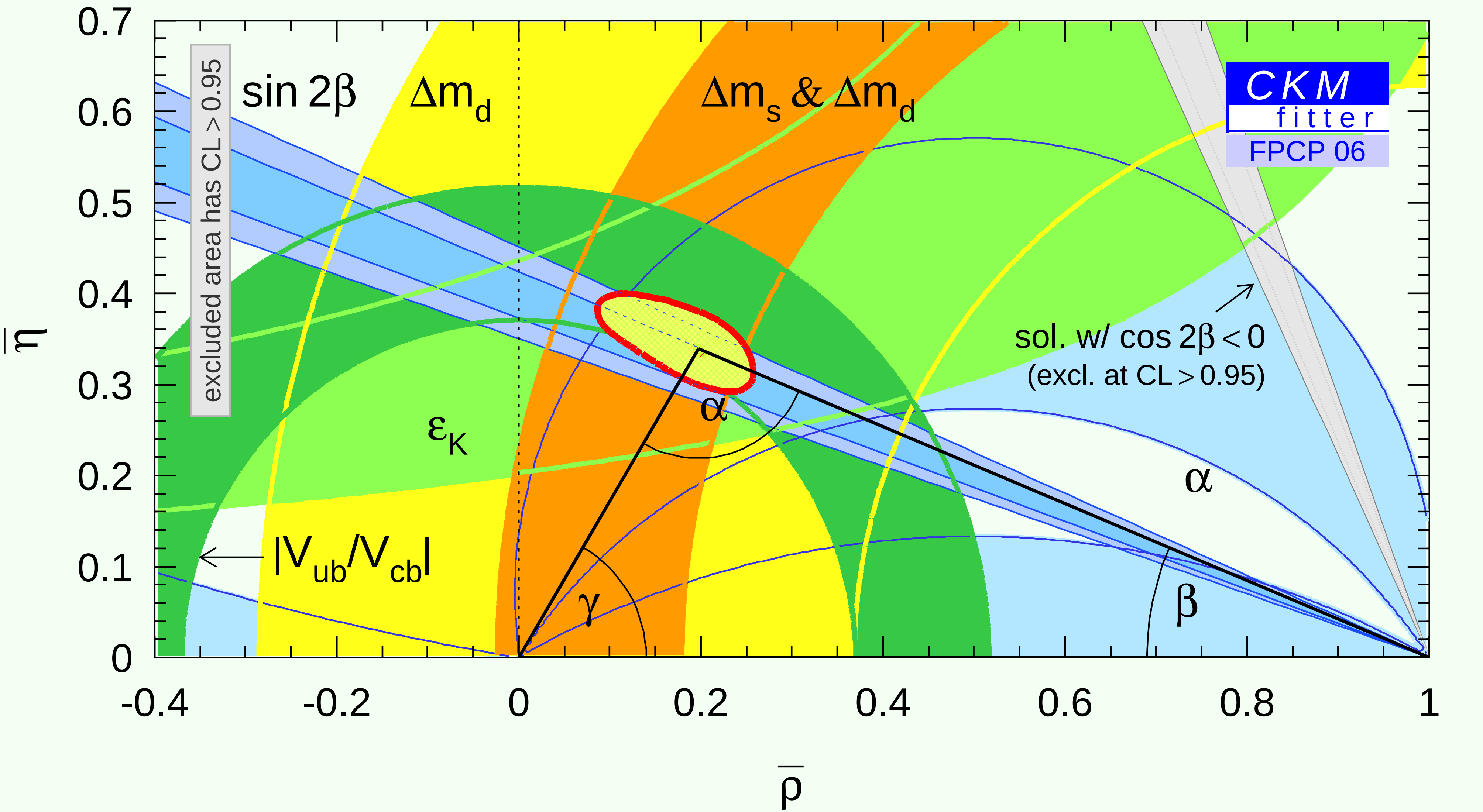


The CKM movie



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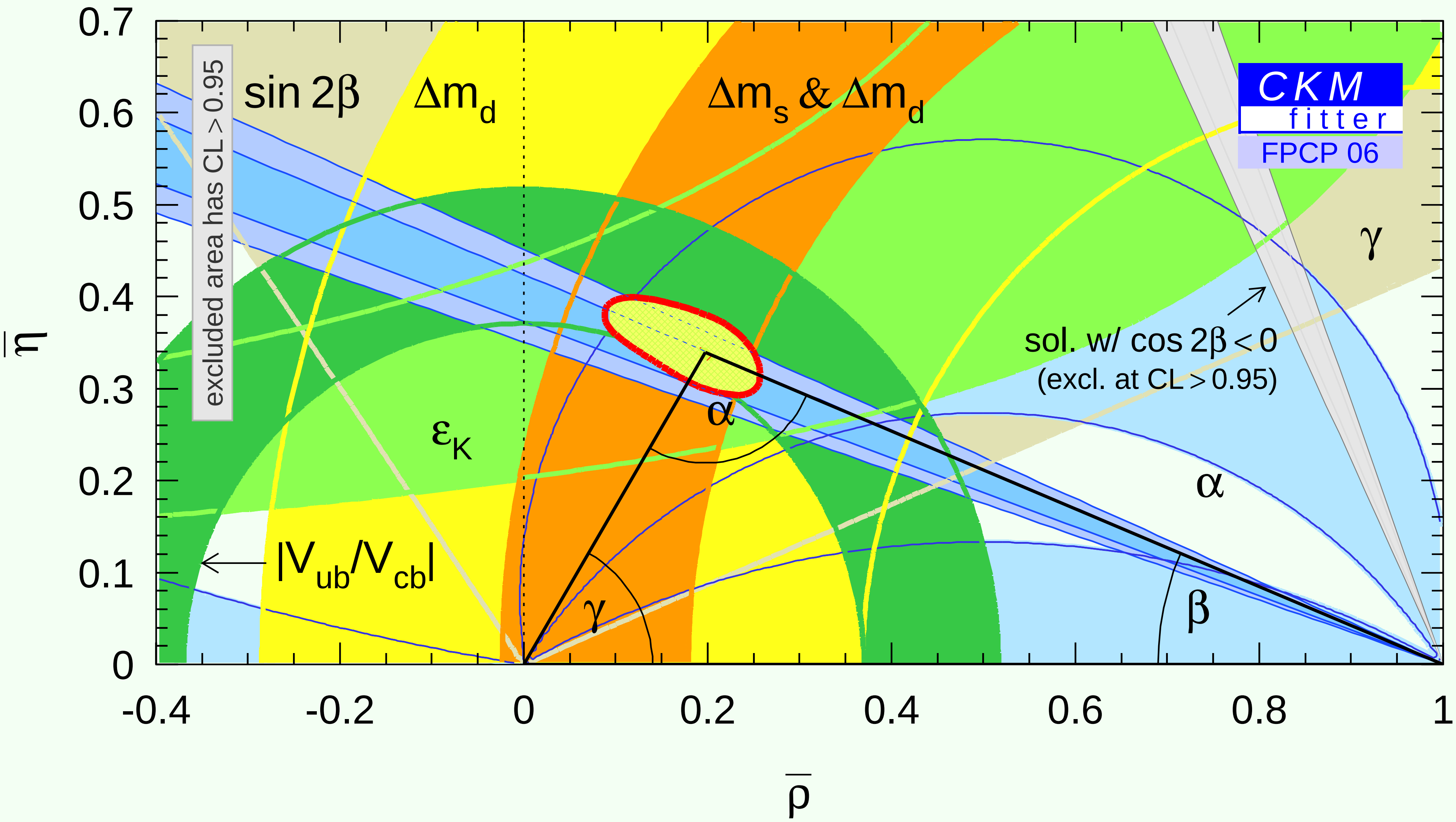

The statistical method to extract γ

the observables depend on γ and μ where $\mu = (r_B, \delta)$

1. minimize $\chi^2(\gamma, \mu)$ with respect to μ and substract the minimum $\rightarrow \Delta\chi^2(\gamma)$
2. assume that the true value of μ is $\mu_t \rightarrow$ PDF$\left[\Delta\chi^2(\gamma) \,|\, \gamma, \mu_t\right]$
3. compute $(1 - \mathrm{CL})_{\mu_t}(\gamma)$ via toy Monte-Carlo
4. maximize with respect to $\mu_t \rightarrow (1 - \mathrm{CL})(\gamma)$

this is a quite general, but very expensive, procedure; coverage must be checked

before we assumed that μ_t was given by the value that minimizes $\chi^2(\gamma, \mu)$ on the real data: studies have shown us that this can lead to an underestimate of the error