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Flavour in the era of the LHC

A Model-Independent Analysis of New Physics Contributions in $|\Delta F| = 2$ transitions

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on behalf the CKMfitter group

Outline – New Physics in $|\Delta F|=2$ transitions

Part I. Introduction.

Part II. Exploring New Physics in B_d mixing.

Basic inputs.

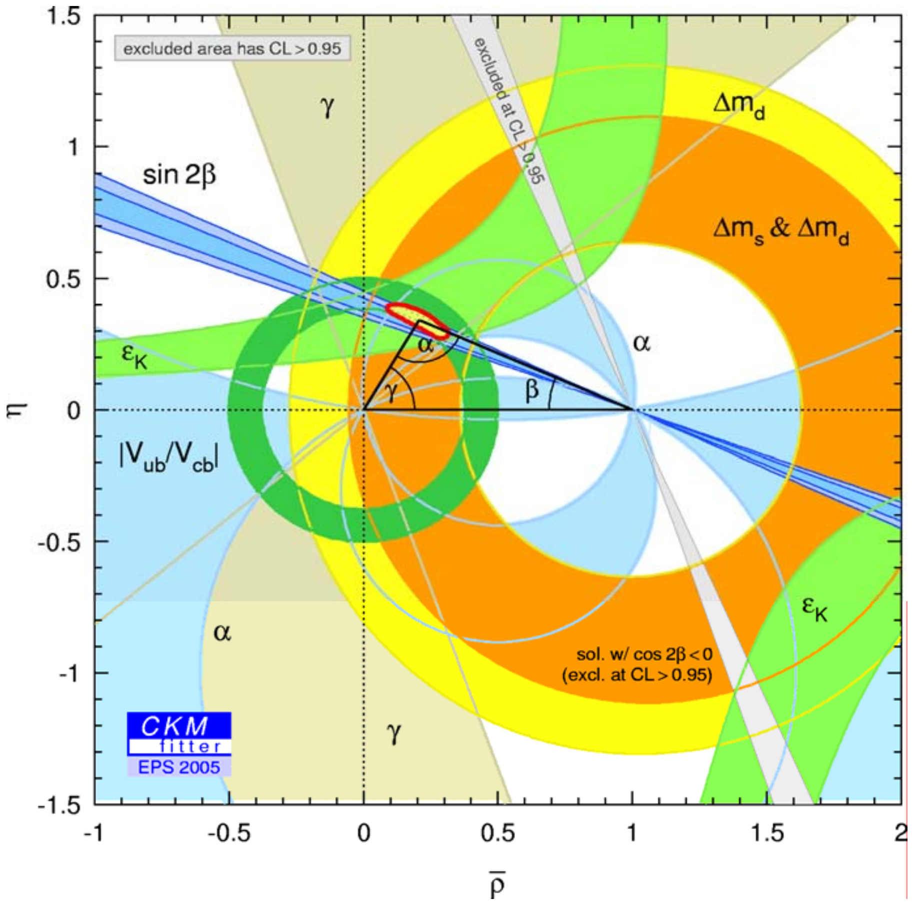
Adding γ and α measurements.

Adding a_{SL} contribution.

Part III. Exploring New Physics in K mixing.

Part IV. Prospective for New Physics in the B_s mixing.

Quality of CKM Standard fit



⇔Standard Model accommodates *successfully* all the present flavour data.

There is no need *a priori* for NP contributions in tree-mediated flavour changing processes.

Modelling New Physics in $|\Delta B|=2$

Is there still room for new physics ?

Follow the strategy developed in the paper:
The CKMfitter group, Eur. Phys. J. C41 (2005)
Past & present attempts (a selection of)
Soares, Wolfenstein, Phys. Rev. D47 (1993)
Grossman, Nir, Worah, Phys. Lett. B407 (1996)
Laplace, Ligeti, Nir, Perez, Phys. Rev. D65 (2002)
Ciuchini et al., hep-ph/0307195
Bona et al., hep-ph/0509219

Assumption ⇔ no NP in tree-mediated decay amplitudes:
$|V_{ub}|/|V_{cb}|$ and γ are the main inputs constraining the CKM parameters.

Introduce NP in $\Delta B=2$ transitions accounted for model-independently through two additional parameters.

$$r_d^2 e^{i2\theta_d} = \frac{\langle B^0 | H_{eff}^{full} | \overline{B}^0 \rangle}{\langle B^0 | H_{eff}^{SM} | \overline{B}^0 \rangle}$$

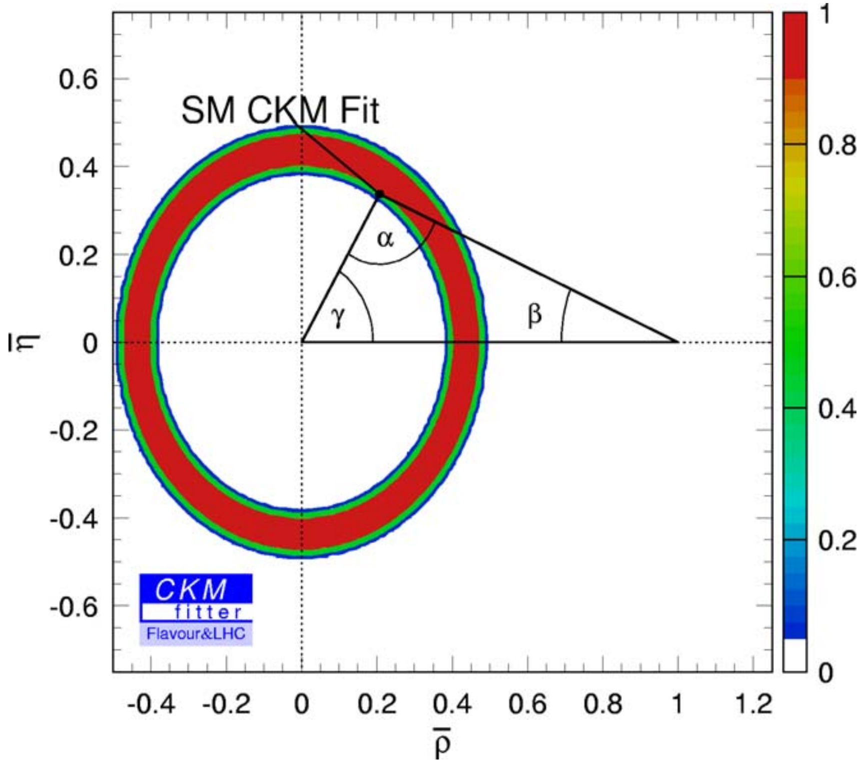
NP in B_d-$\overline{B}_d$ mixing (I)

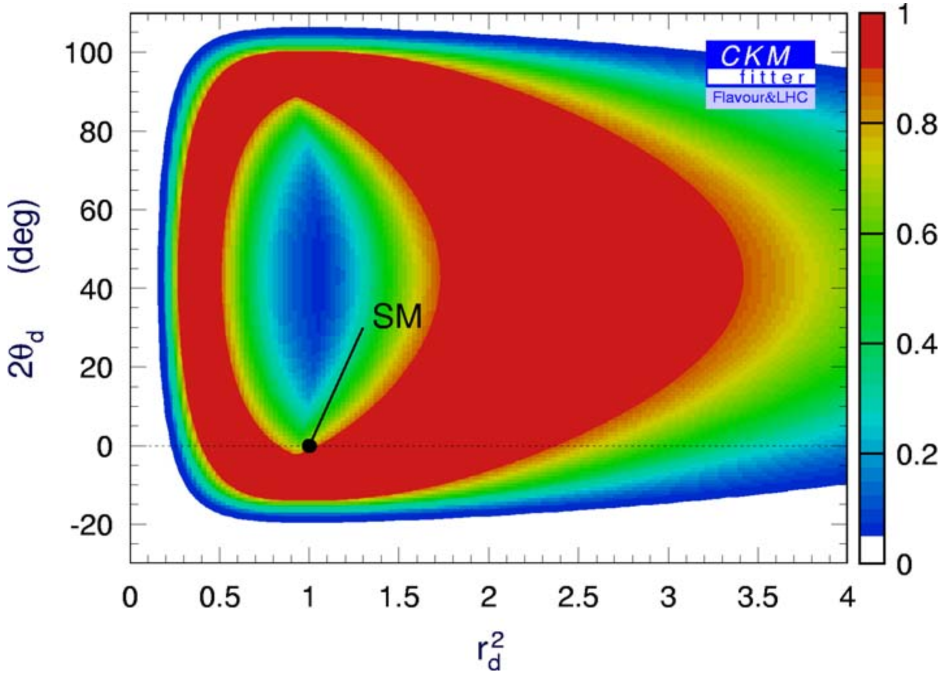
$\rightarrow |V_{ub}|, |V_{cb}|$ ⇔ Remove b-> sγ component from the inclusive V_{ub} average $V_{ub}=(4.15 \pm 0.12 \pm 0.23).10^{-3}$

$\rightarrow r_d^2 \Delta m_d$

$\rightarrow \sin(2\beta + 2\theta_d)$

$\rightarrow \cos(2\beta + 2\theta_d)$





- The SM value on $2\theta_d=0$ is at the border of the CL_{Max} region.
- Shows slight disagreement between V_{ub} and $\sin(2\beta)$.
- Any region with $2\theta_d > \pi/2$ is discarded.

NP in B_d-$\overline{B}_d$ mixing (II)

⇔ Adding γ measurements.

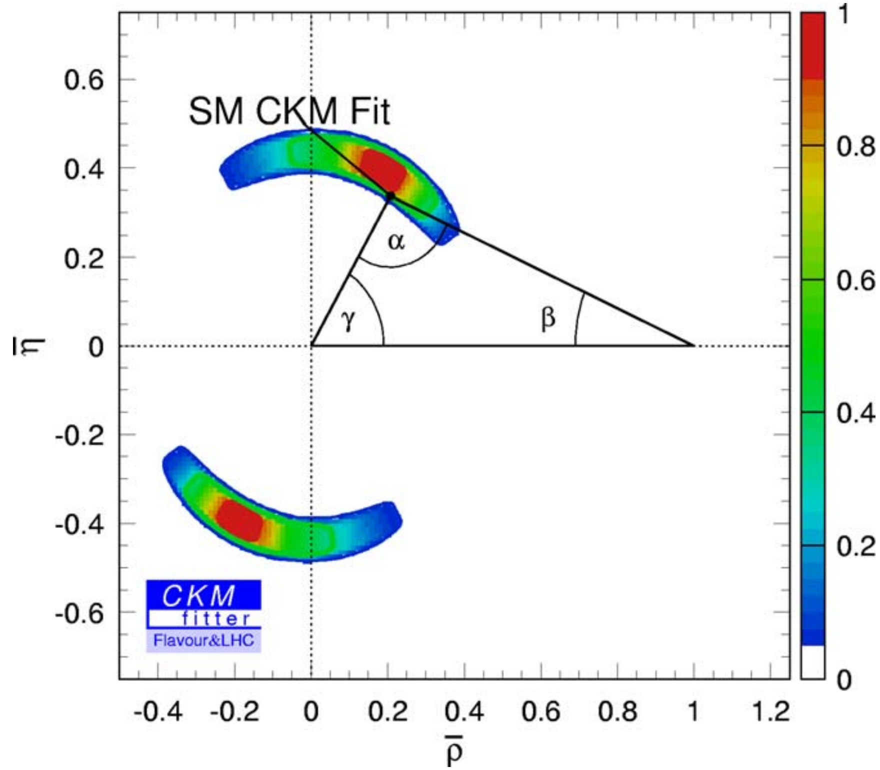
→ $|V_{ub}|/|V_{cb}|$

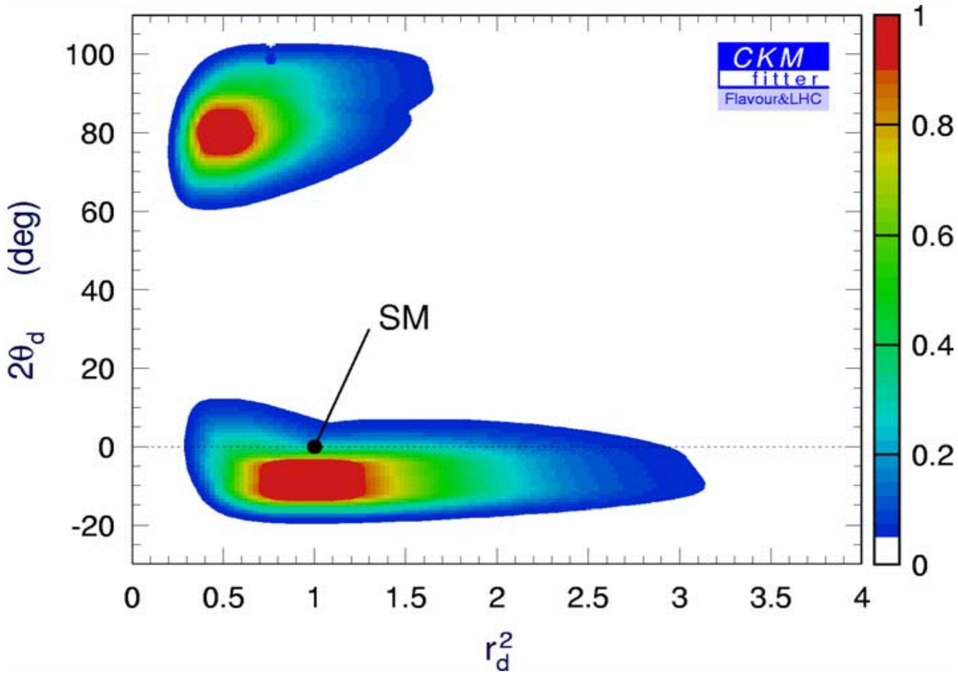
→ $r_d^2 \Delta m_d$

→ $\sin(2\beta + 2\theta_d)$

→ $\cos(2\beta + 2\theta_d)$

→ $\gamma \quad (ADS + GLW + GGSZ)$





- V_{ub} and γ constrain the CKM parameters.

- Two solutions for NP parameters emerge.

NP in B_d-$\overline{B}_d$ mixing (III)

⇔ Adding α measurements.

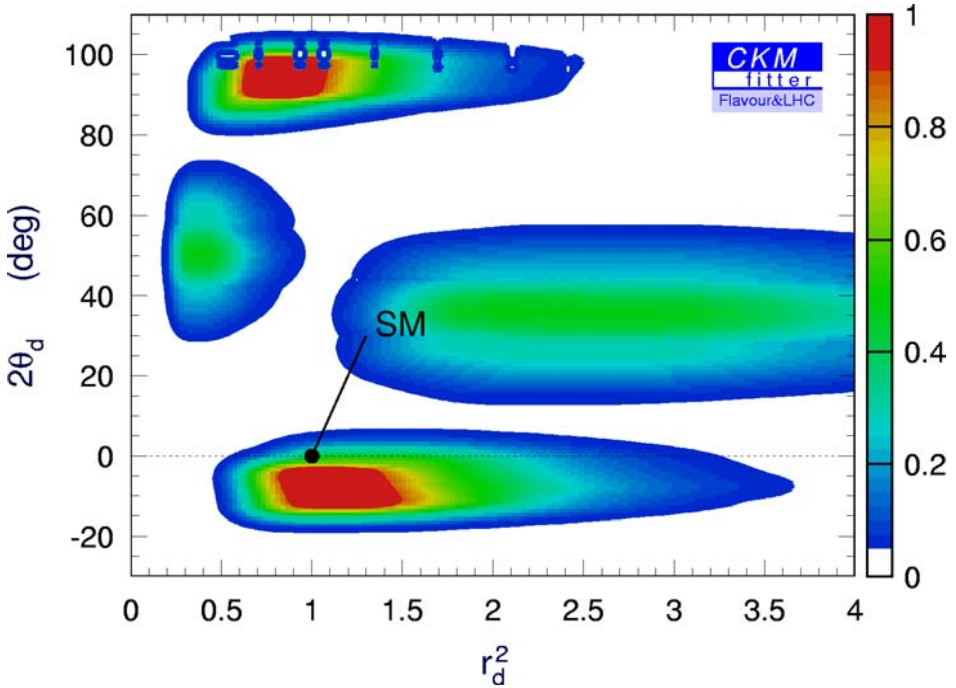
$\rightarrow |V_{ub}|/|V_{cb}|$

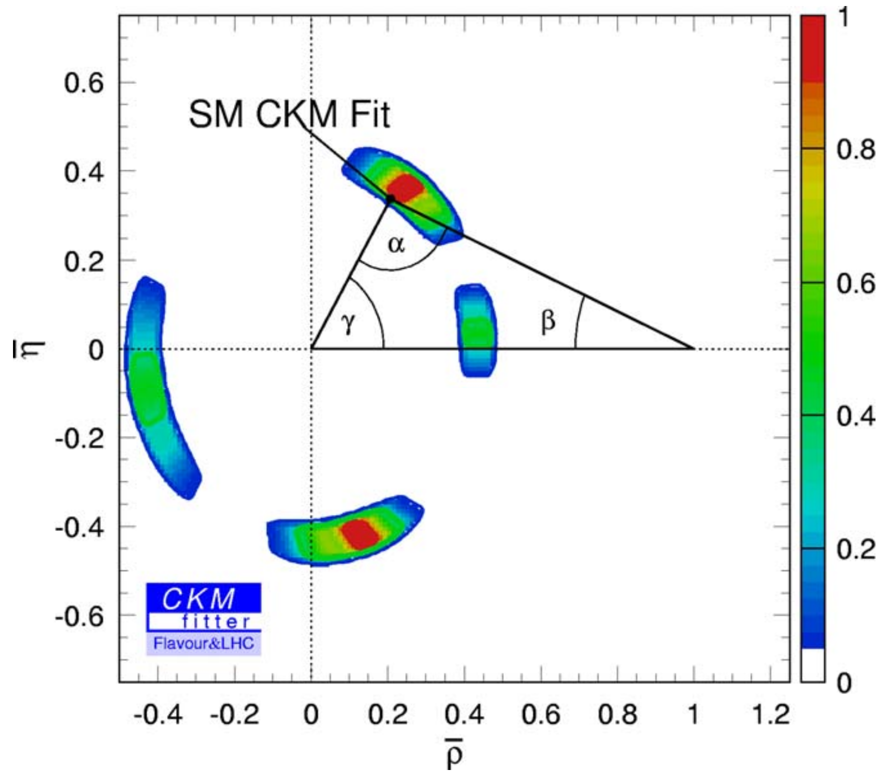
$\rightarrow r_d^2 \Delta m_d$

$\rightarrow \sin(2\beta + 2\theta_d)$

$\rightarrow \cos(2\beta + 2\theta_d)$

$\rightarrow \sin(2\beta + 2\theta_d + 2\gamma)$



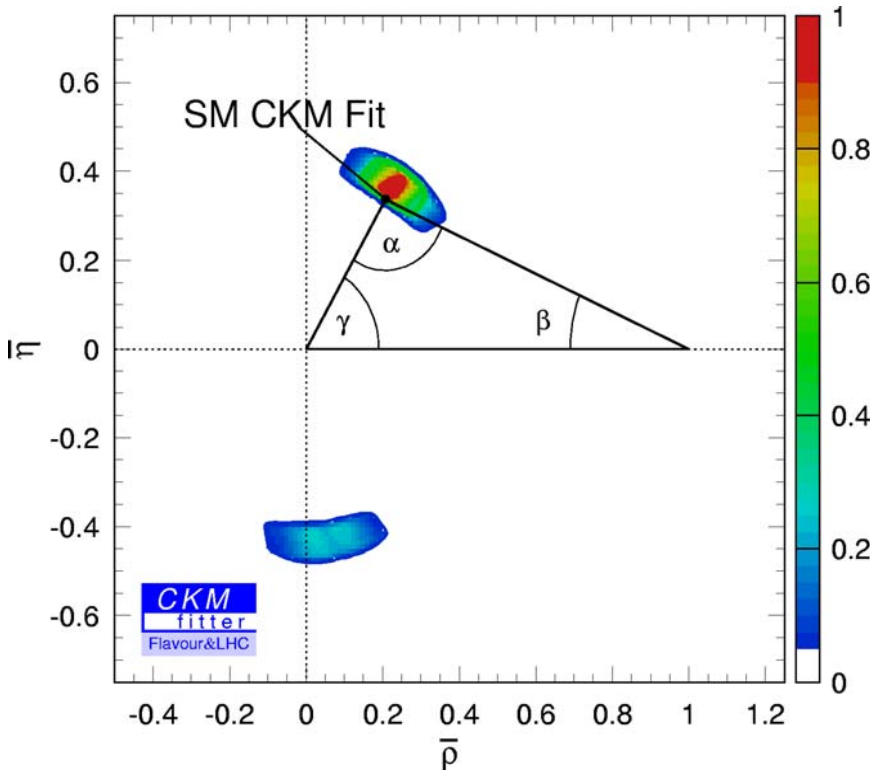


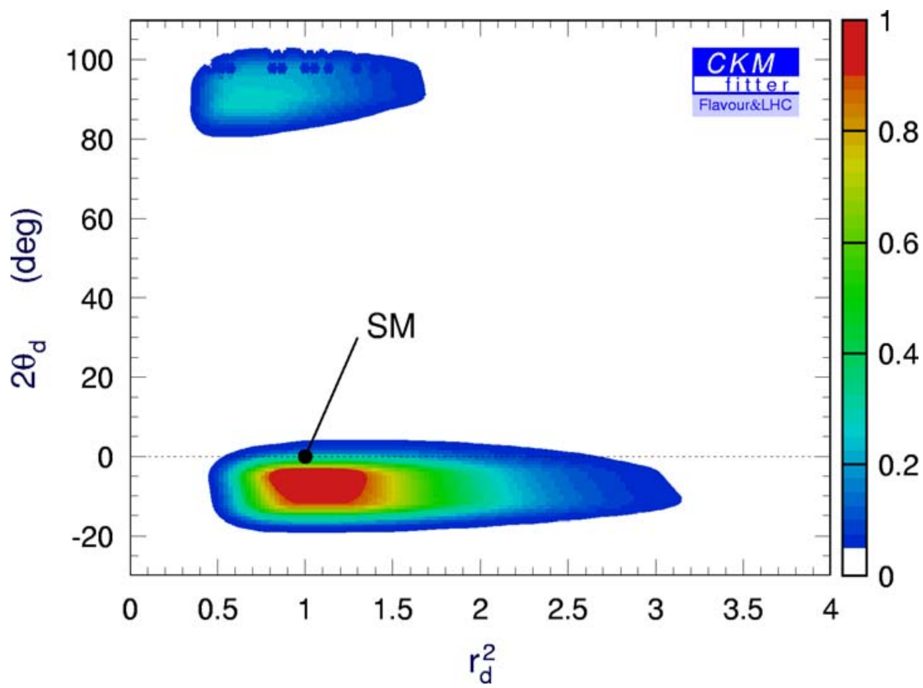
The α constraint (w/o γ) displays also four solutions.

⇔ Reinforce the SM region but the preferred NP region is not the one defined by γ.

NP in B_d-$\overline{B}_d$ mixing (IV)

- $\rightarrow |V_{ub}|/|V_{cb}|$
- $\rightarrow r_d^2 \Delta m_d$
- $\rightarrow \sin(2\beta + 2\theta_d)$
- $\rightarrow \cos(2\beta + 2\theta_d)$
- $\rightarrow \gamma \quad (ADS + GLW + GGSZ)$
- $\rightarrow \sin(2\beta + 2\theta_d + 2\gamma)$





γ and α are of major importance in constraining the NP parameters.

NB: $\sin(2\beta+2\theta_d+\gamma)$ is not included. (almost no influence.)

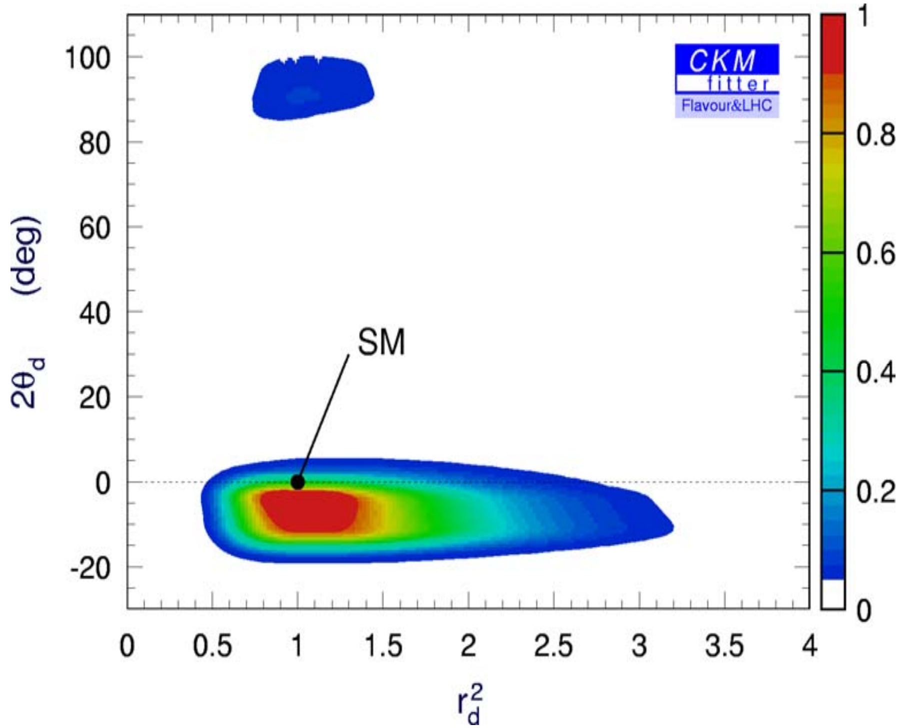
NP in B_d-$\bar{B}_d$ mixing a_{SL} in the game

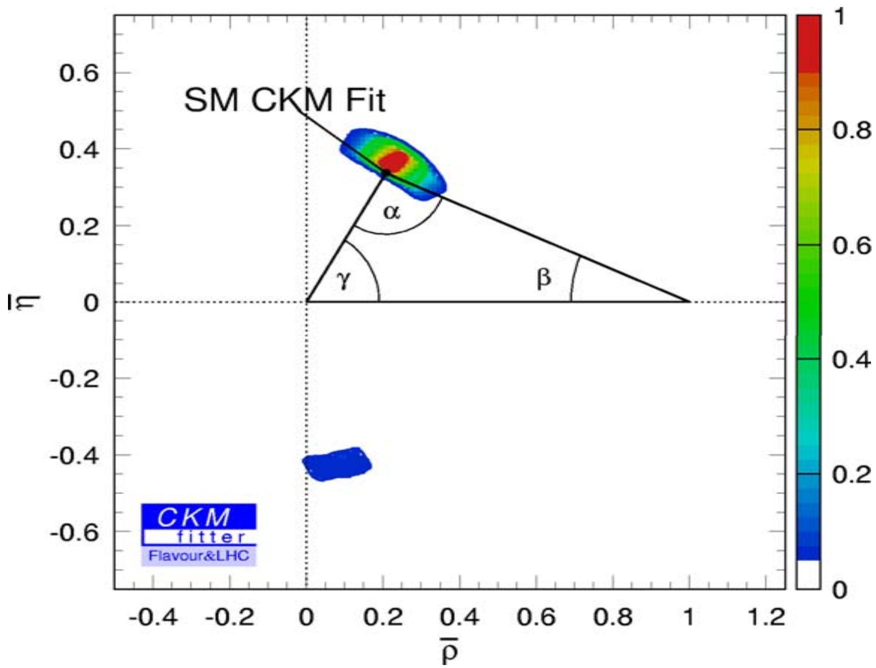
$$a_{SL} = -\mathrm{Re}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\sin 2\theta_d}{r_d^2} + \mathrm{Im}\left(\frac{\Gamma_{12}}{M_{12}}\right)^{SM} \frac{\cos 2\theta_d}{r_d^2}$$

(Γ_{12}/M_{12} is considered here at Leading Order)

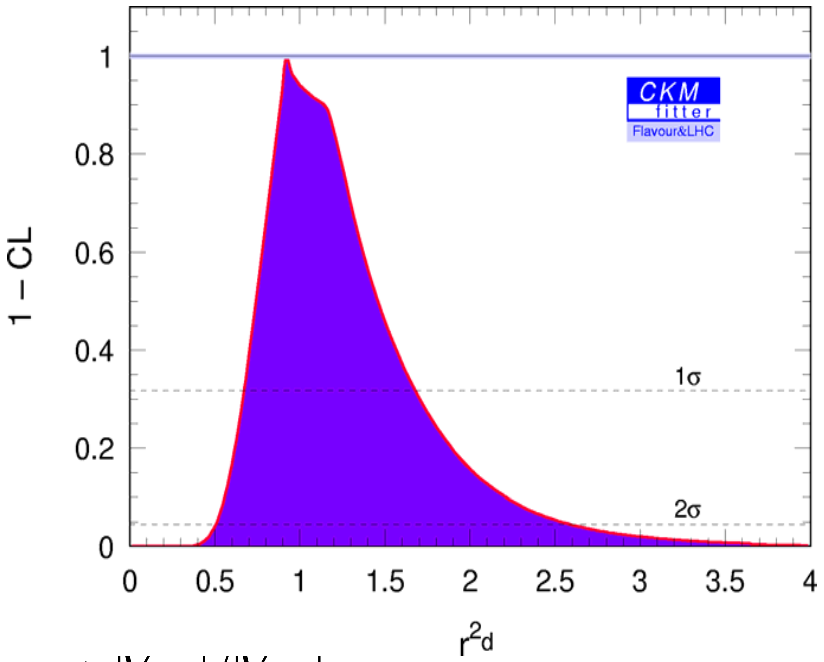
Though the experimental precision is far from the prediction, a_{SL} is a crucial input for constraining NP parameters. Only observable depending on both r_d^2 and $2\theta_d$.

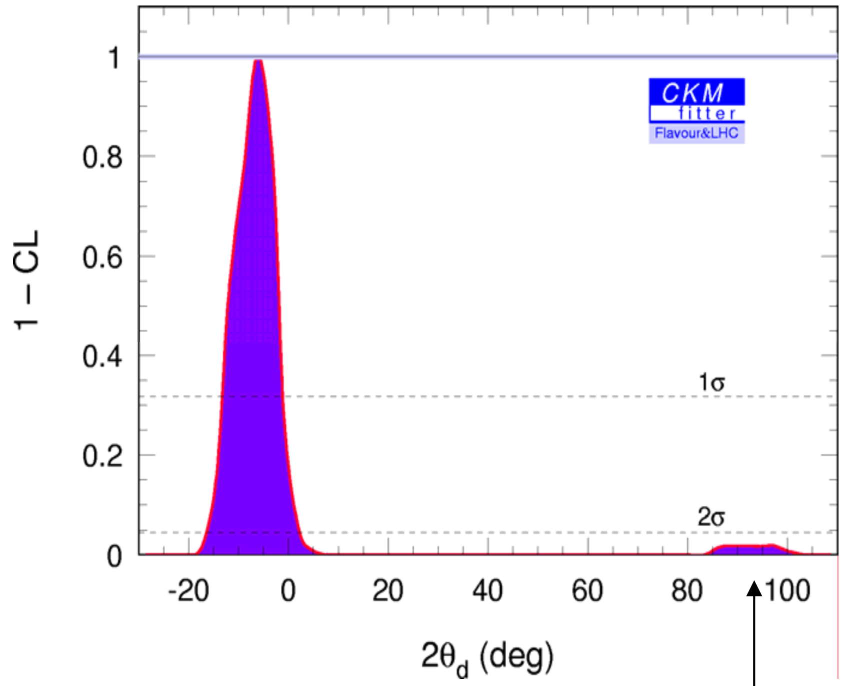
$a_{SL} = -0.0026 \pm 0.0067$ (HFAG 2005)





NP parameters extraction





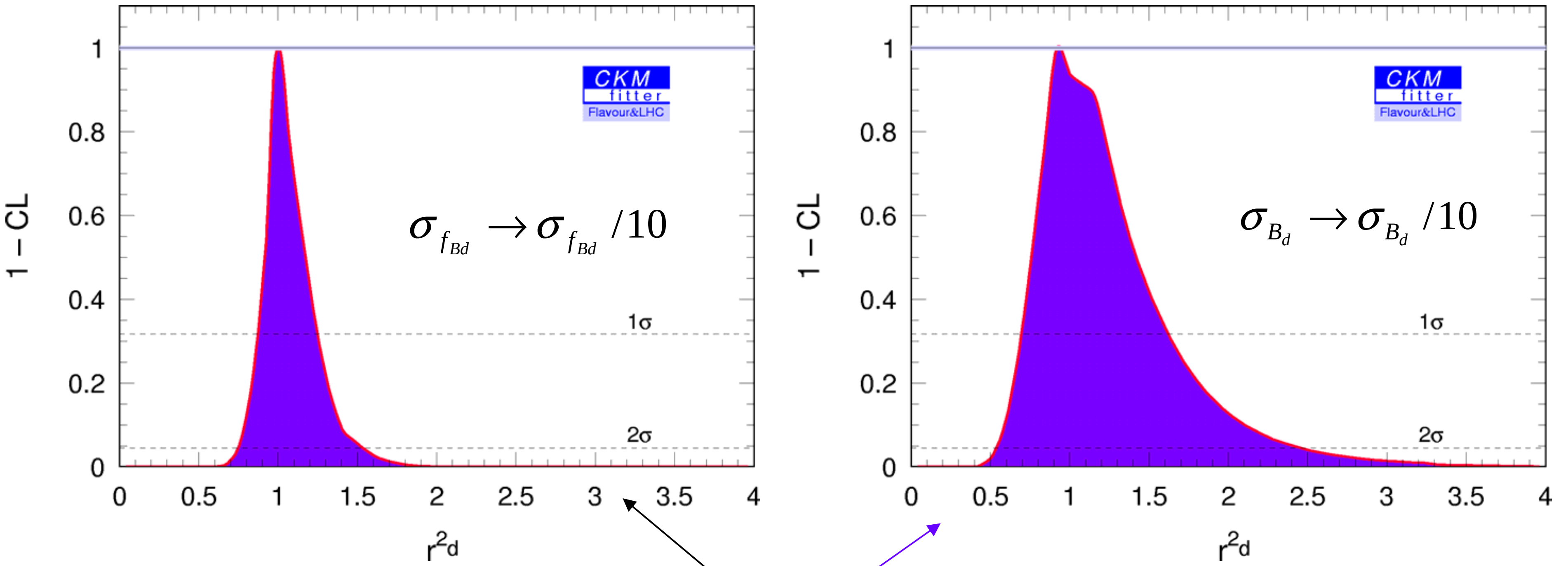
- $\rightarrow |V_{ub}|/|V_{cb}|$
- $\rightarrow r_d^2 \Delta m_d$
- $\rightarrow \sin(2\beta + 2\theta_d)$
- $\rightarrow \cos(2\beta + 2\theta_d)$
- $\rightarrow \gamma \quad (ADS + GLW + GGSZ)$
- $\rightarrow \alpha \quad \sin(2\beta + 2\theta_d + 2\gamma)$
- $\rightarrow a_{\mathrm{SL}}$

$$\begin{cases} r_d^2 = 0.92^{+0.73}_{-0.23} \\ 2\theta_d = -5.3^{+3.2}_{-8.8} \ \text{deg} \end{cases}$$

(Uncertainties are given at 1σ)

The NP solution at π/2 has 1-CL < 3%.

Influence of non-pert. hadronic parameters in Δm_d



$$\Delta m_d = \frac{G_F{}^2}{6\pi^2} \eta_B m_{B_d} f_{B_d}{}^2 B_d m_W{}^2 S(x_t) \left| V_{td} V_{tb}{}^* \right| r_d{}^2$$

- As far as the lattice uncertainties are considered, fB_d is the relevant parameter to improve.
- A factor 2 has important impact. A factor 10 is not decisive with the current experimental uncertainties of the observables.

Alternative parametrization of NP in |ΔB|=2

Isolate the pure NP contribution from (SM+NP) terms:

$$M_{12} = M_{12\,SM}(1+h_d e^{2i\sigma_d})$$

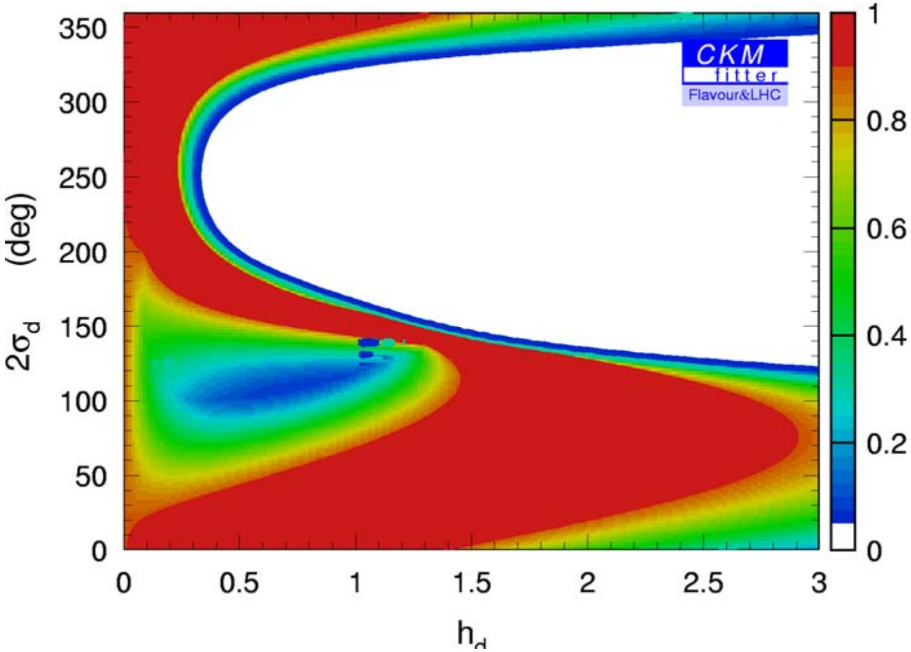
Agashe et al. hep-ph/0509117

$$\Delta m_d = \left|1+h_d e^{2i\sigma_d}\right| \Delta m_d^{\ SM}$$

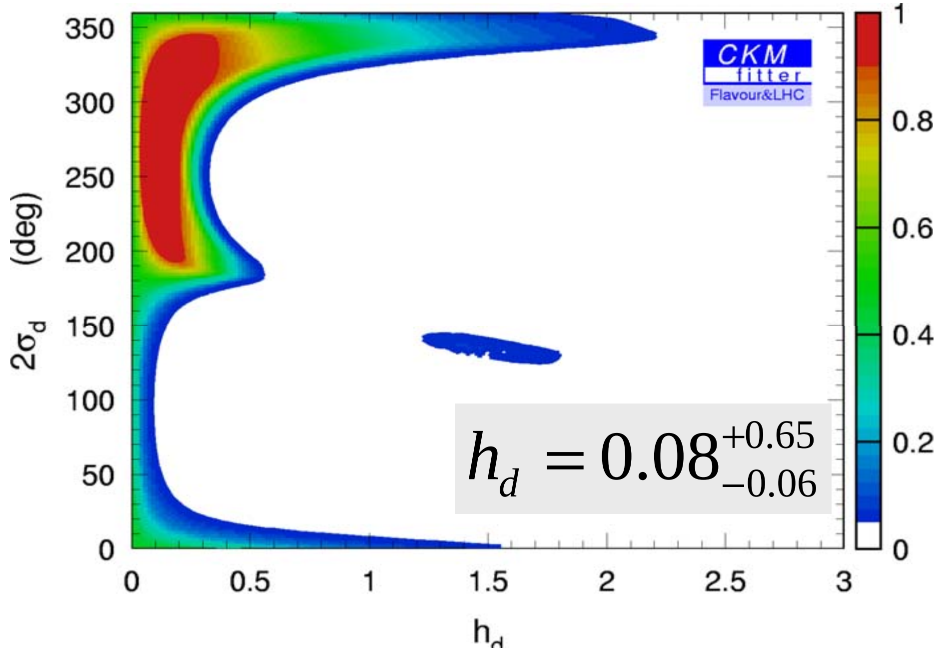
$$2\beta \rightarrow 2\beta + Arg(1+h_d e^{2i\sigma_d})$$

$$a_{SL} = \mathrm{Im}\left(\frac{\Gamma_{12}^{\ SM}}{M_{12}^{\ SM}(1+h_d e^{2i\sigma_d})}\right)$$

Without γ, α and a_{SL} constraints



With γ, α and a_{SL} constraints



Allowing in addition NP in K-$\overline{K}$ mixing (I)

$$r_K = \frac{\mathrm{Im}\left\langle K^0 \middle| H_{eff}^{full} \middle| \overline{K}^0 \right\rangle}{\mathrm{Im}\left\langle K^0 \middle| H_{eff}^{SM} \middle| \overline{K}^0 \right\rangle}$$

$\rightarrow |V_{ub}|/|V_{cb}|$

$\rightarrow r_d^2 \Delta m_d$

$\rightarrow \sin(2\beta + 2\theta_d)$

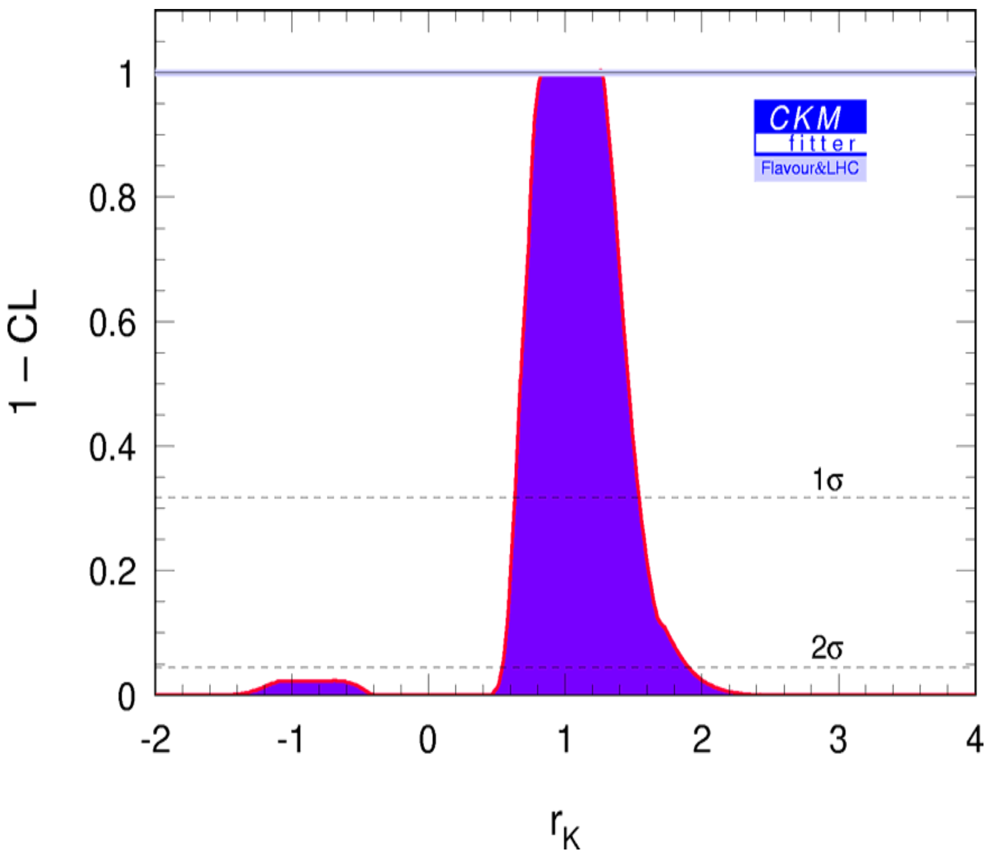
$\rightarrow \cos(2\beta + 2\theta_d)$

$\rightarrow \gamma \; (ADS + GLW + GGSZ)$

$\rightarrow \alpha \quad \sin(2\beta + 2\theta_d + 2\gamma)$

$\rightarrow a_{SL}$

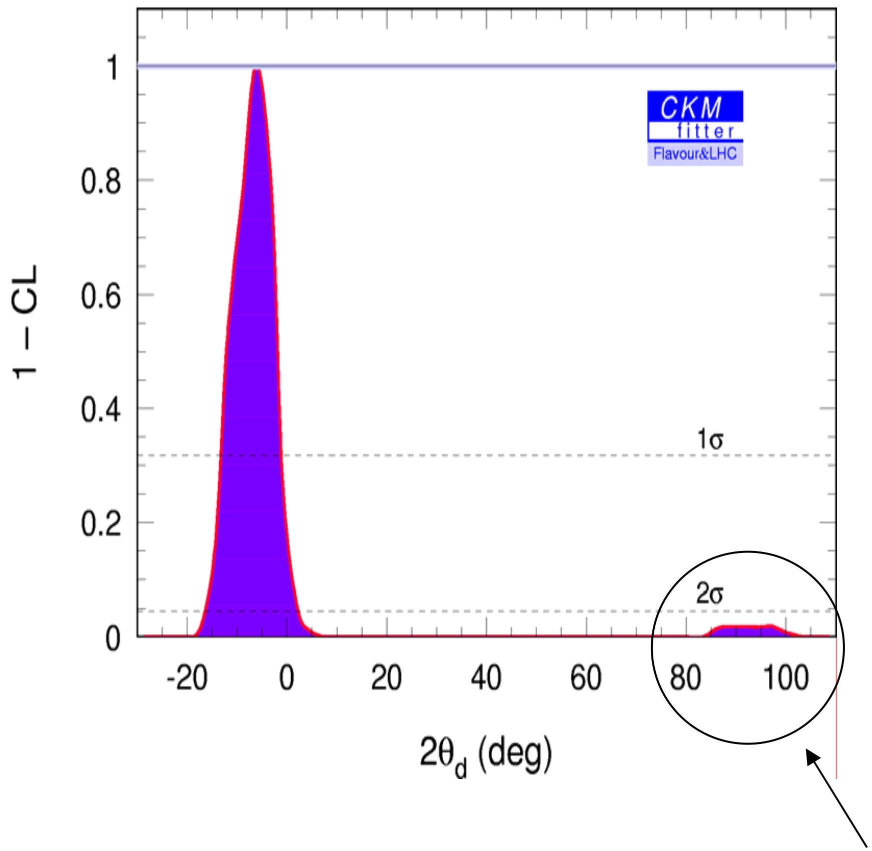
$\rightarrow r_K \varepsilon_K$

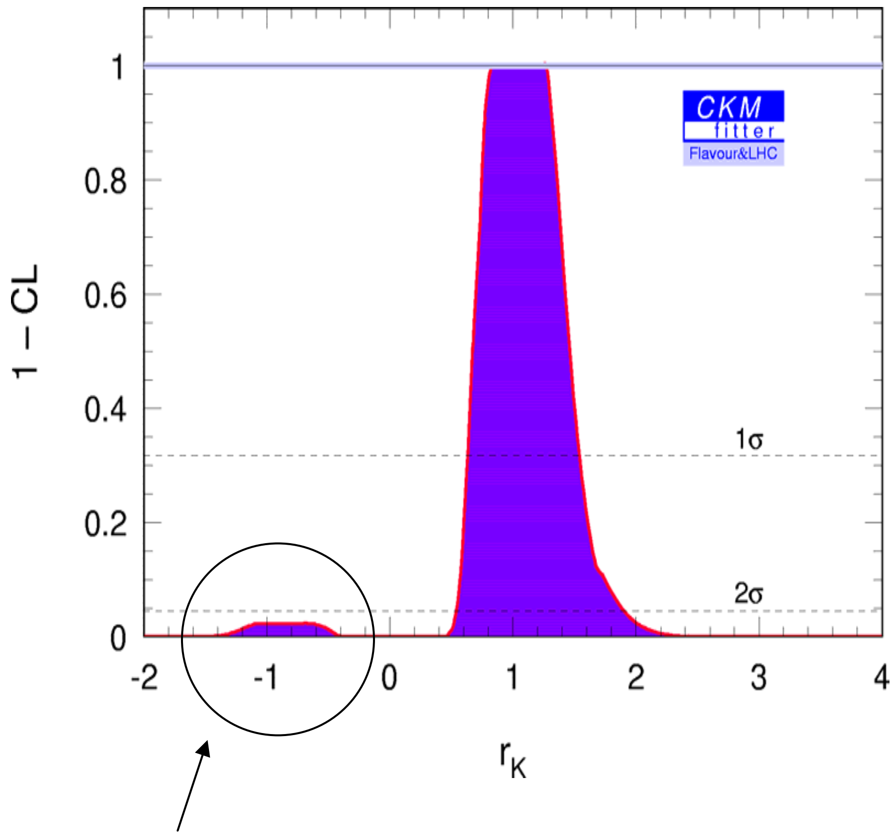


(1σ)

$$\begin{cases} r_d^2 = 0.92^{+0.76}_{-0.25} \\ 2\theta_d = -4.8^{+4.1}_{-9.1} \text{ deg} \\ r_K = 1.09^{+0.45}_{-0.46} \end{cases}$$

Allowing in addition NP in K-$\bar{K}$ mixing (II)

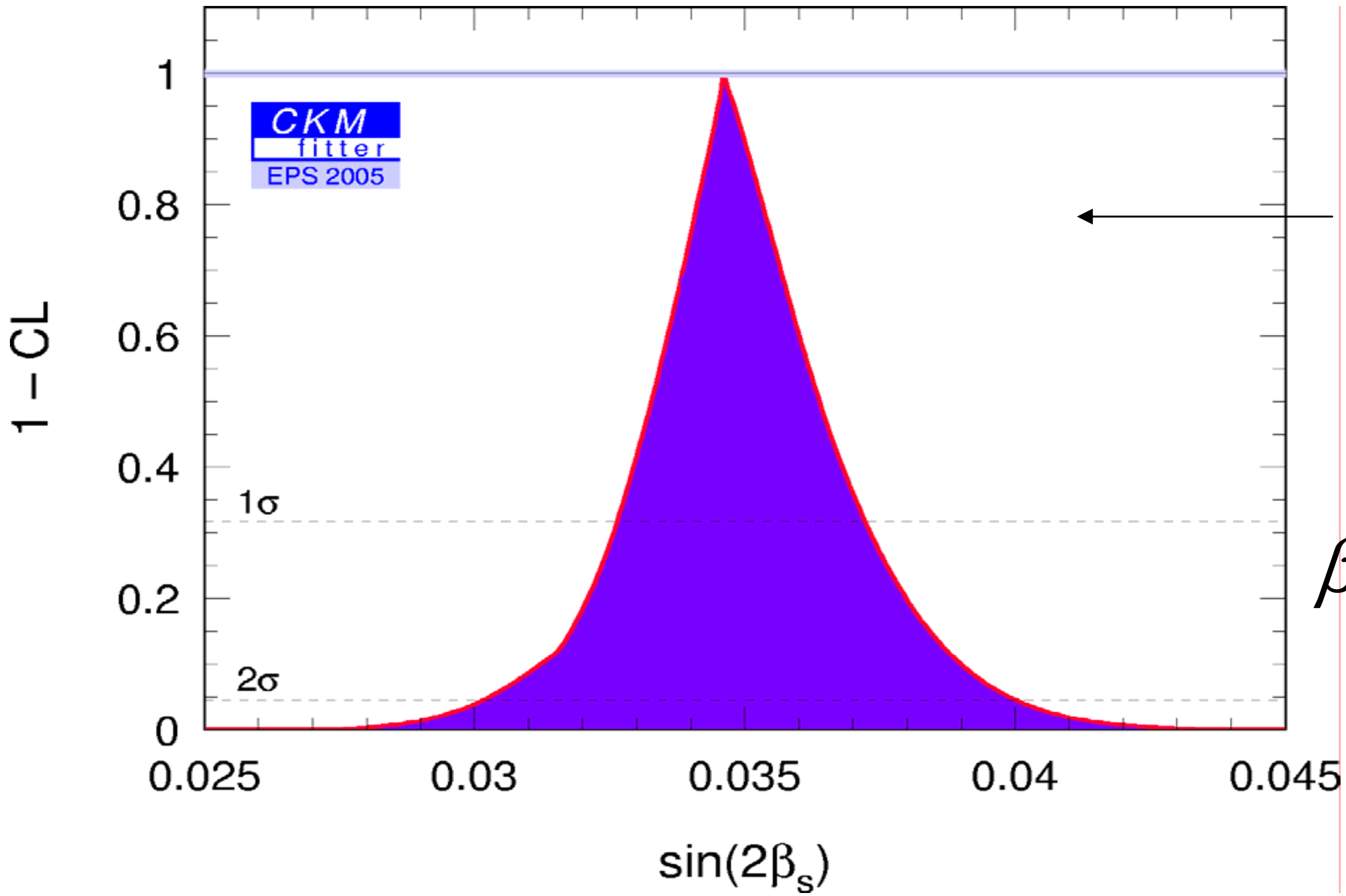




The NP region at $2\theta_d = \pi/2$ in B_d mixing implies also NP in K mixing corresponding to $\varepsilon_K < 0$

NP in B_s mixing Prospective study (I)

The angle governing the mixing in the B_s system is already known to good precision in the SM



$\beta_s \sim \lambda^2\eta + o(\lambda^4)$ can be extracted from the global Standard Model fit.

$$\beta_s = \arg\left(-\frac{V_{cb}V_{cs}^*}{V_{tb}V_{ts}^*}\right)$$

$\sin(2\beta_s) = 0.0363 \pm 0.0025$

NP in B_s mixing Prospective study (I)

NP in B_s mixing ($\Delta B=2$ and $\Delta S=2$) is accounted for model-independently through two additional parameters, akin to the B_d system :

$$r_s^2 e^{i2\theta_s} = \frac{\langle B_s^0 | H_{eff}^{\text{full}} | \overline{B}_s^0 \rangle}{\langle B_s^0 | H_{eff}^{\text{SM}} | \overline{B}_s^0 \rangle}$$

- LHCb expected sensitivities correspond to 2 fb^{-1} (See Talks of O.Schneider & L.Fernandez):

$\rightarrow \Delta m_s = 20.000 \pm 0.011\ \text{ps}^{-1}$ from $B_s \rightarrow D_s \pi$

$\rightarrow A_{mix} = \sin(2\beta_s) = 0.036 \pm 0.028$

from combined $B_s \rightarrow J/\Psi\Phi,\ B_s \rightarrow J/\Psi\eta$ and $B_s \rightarrow \eta_c \phi$

$\rightarrow \gamma - 2\beta_s = 57 \pm 14$ deg from $B_s \rightarrow D_s K$

$\rightarrow \gamma = 59 \pm 8$ deg from $B_d \rightarrow D^{(*)} K$

$\rightarrow r_s^2 \Delta m_s$

$\rightarrow \sin(2\beta_s + 2\theta_s)$

$\rightarrow \sin(2\beta_s + 2\theta_s - \gamma)$

NP in B_s mixing Prospective study (II)

$\rightarrow |V_{ub}|/|V_{cb}|$

$\rightarrow r_d^2 \Delta m_d$

$\rightarrow \sin(2\beta + 2\theta_d)$

$\rightarrow \cos(2\beta + 2\theta_d)$

$\rightarrow \gamma \quad (ADS + GLW + GGSZ)$

$\oplus$ Adding LHCb sensitivity

$\rightarrow \alpha \quad \sin(2\beta + 2\theta_d + 2\gamma)$

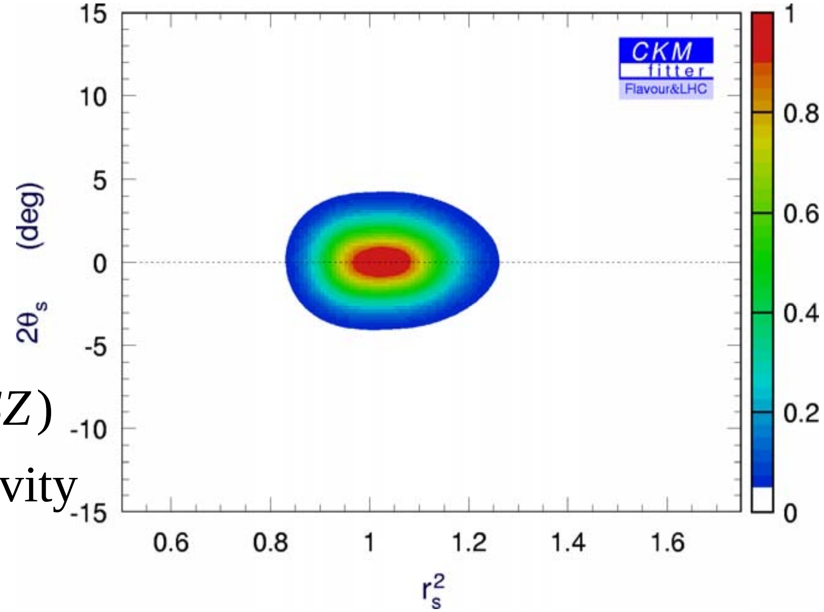
$\rightarrow a_{SL}$

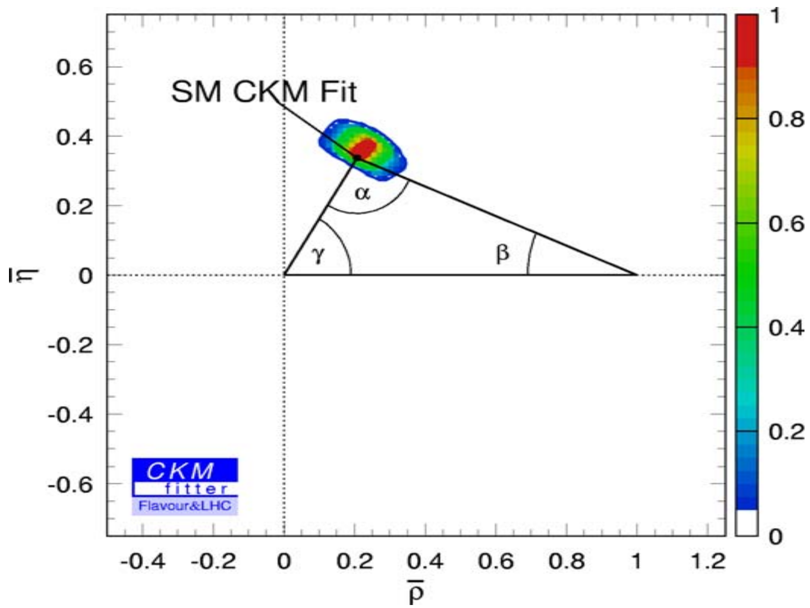
$\rightarrow r_K^2 \varepsilon_K$

$\rightarrow r_s^2 \Delta m_s$

$\rightarrow \sin(2\beta_s + 2\theta_s)$

$\rightarrow \sin(2\beta_s + 2\theta_s - \gamma)$





(1σ)

$$r_s^2 = 1.01^{+0.11}_{-0.09}$$

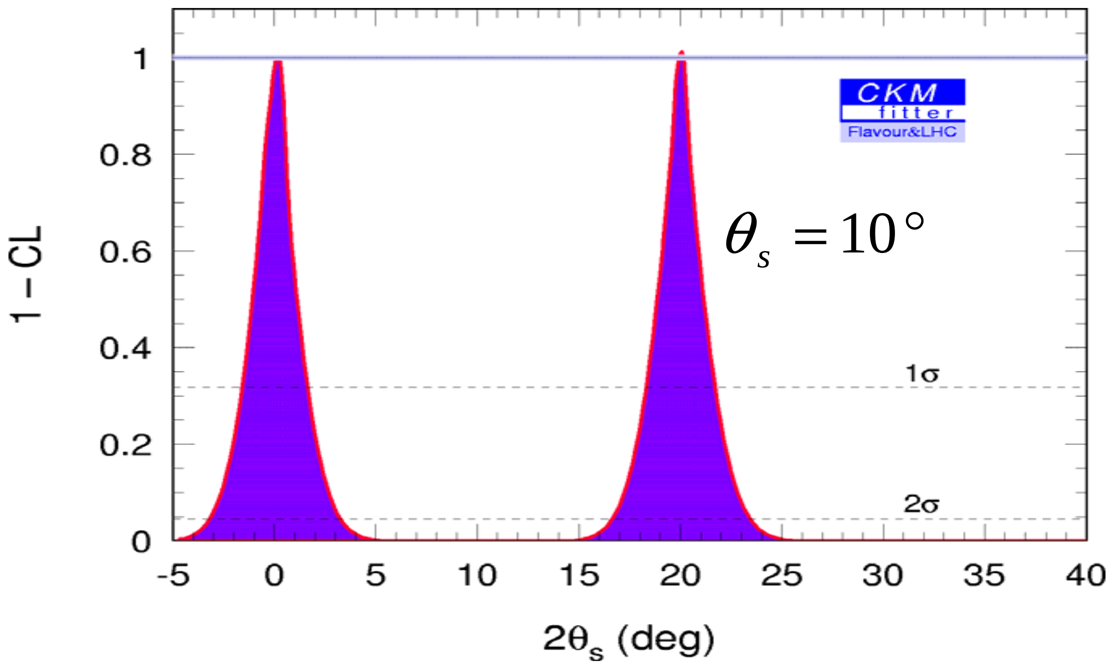
$$2\theta_s = 0.1^{+1.6}_{-1.7} \text{ deg}$$

CONCLUSIONS

- B_d mixing: which room for new physics ? ... Not much.

- K mixing: the only constraint is from ε_K ⇔ under constrained pb as far as specific NP phase & modulus are considered.

- B_s mixing: LHCb will immediately see NP if O(10°).



APPENDIX

I

Main inputs to the fit

$|V_{ub}|$ (average) = $(4.15 \pm 0.12 \pm 0.23).10^{-3}$

$|V_{cb}|$ (incl) = $(41.58 \pm 0.45 \pm 0.58).10^{-3}$

$|V_{cb}|$ (excl) = $(41.4 \pm 2.1).10^{-3}$

$|\varepsilon_K|$ = $(2.282 \pm 0.017).10^{-3}$

Δm_d = (0.509 ± 0.004) ps^{-1}

$\sin(2\beta)$ = 0.687 ± 0.032

$S^{+-}_{\pi\pi}$ = -0.50 ± 0.12
$C^{+-}_{\pi\pi}$ = -0.37 ± 0.10
$C^{00}_{\pi\pi}$ = -0.28 ± 0.39
$B_{\pi\pi,\text{all charge}}$ Inputs to isospin analysis
$S^{+-}_{\rho\rho,L}$ = -0.22 ± 0.22
$C^{+-}_{\rho\rho,L}$ = -0.02 ± 0.17
$B_{\rho\rho,L,\text{all charge}}$ Inputs to isospin analysis
$B \rightarrow \rho\pi \rightarrow 3\pi$ Time dependent Dalits analysis

$B \rightarrow D^{(*)} K^{(*)(-)}$ Inputs to GLW,ADS & GGSZ analysis

Δm_K = $(3.490 \pm 0.006).10^{-12}$ MeV

B_K = $0.79 \pm 0.04 \pm 0.09$

m_{K^+} = (493.677 ± 0.016) MeV

f_K = 159.8 ± 1.5 MeV

η_{tt} = 0.5765 ± 0.0065

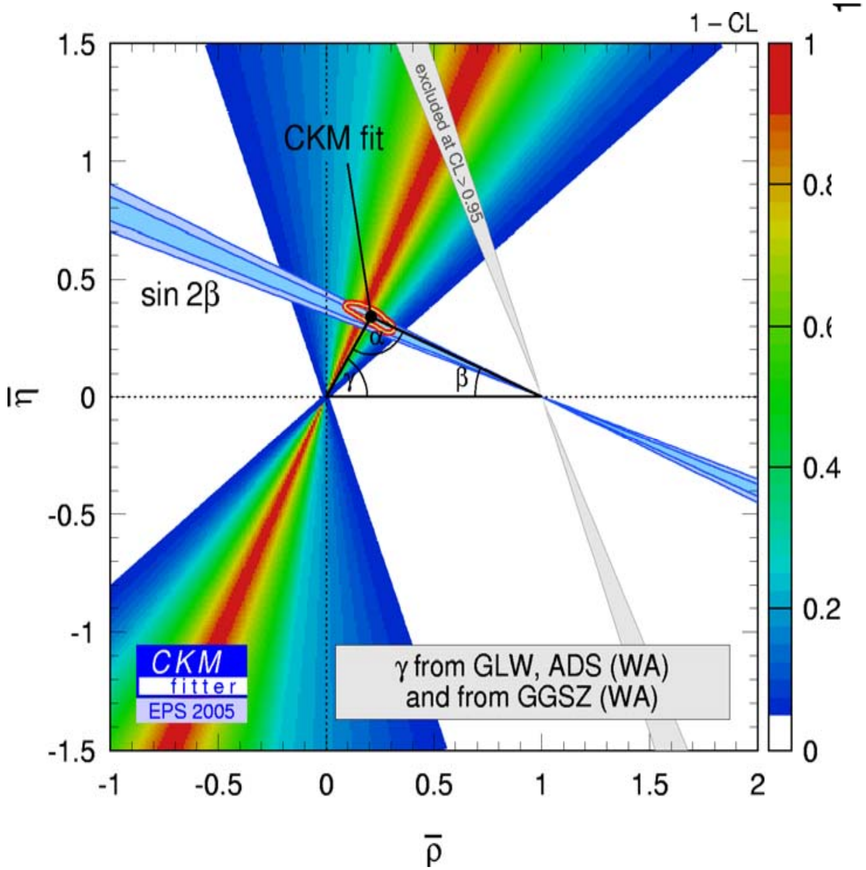
η_{ct} = 0.47 ± 0.04

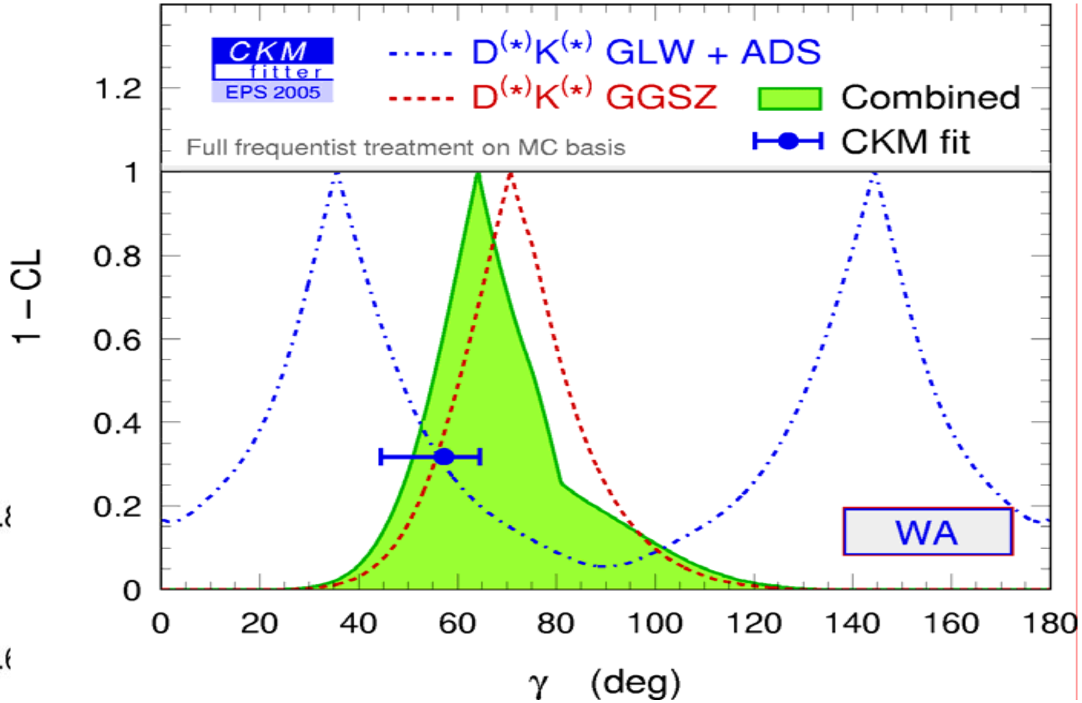
$\eta_B(\overline{MS})$ = 0.551 ± 0.007

$f_{Bd}\sqrt{B_d}$ = $(223 \pm 33 \pm 12)$ MeV

a_{SL} = -0.0026 ± 0.0067

γ measurements



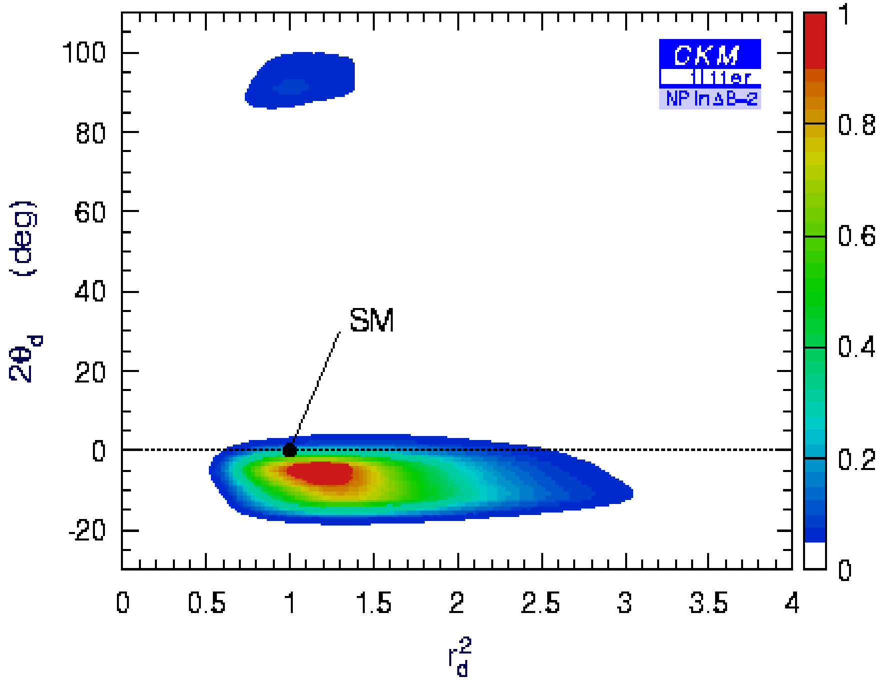


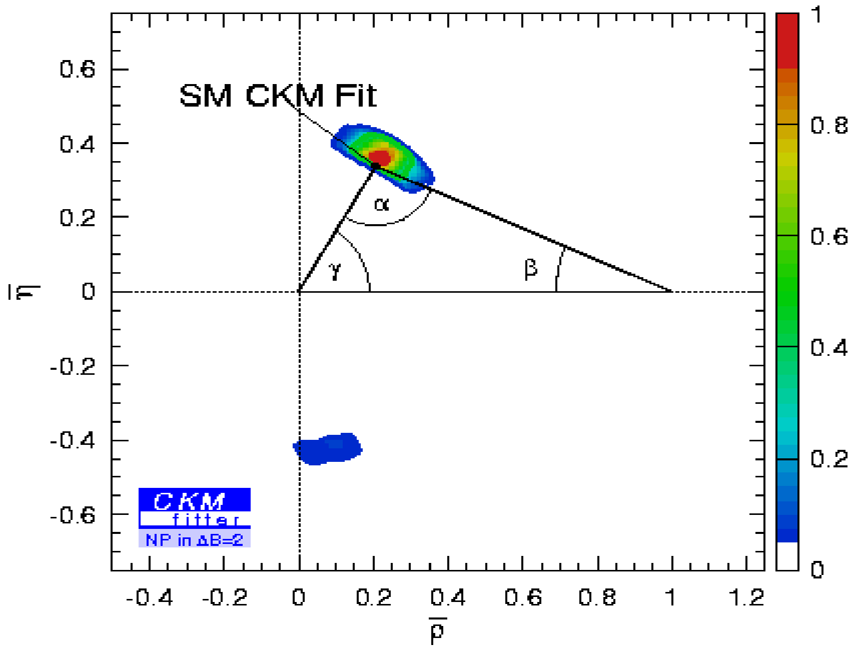
III

Adding $B \to \tau\nu$

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

← With Δm_d, remove the f_B dependence





- Powerful in the future for constraining the SM region.
- Potential annihilation by means of H^+ prevents for considering this input in the analysis.