New Physics Mixing angles from Penguin Decays

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Work in Collaboration with
S. Descotes-Genon & J. Matias

III Jornadas CPAN - Barcelona, November 2, 2011

Testing the SM with Flavor & Measuring NP

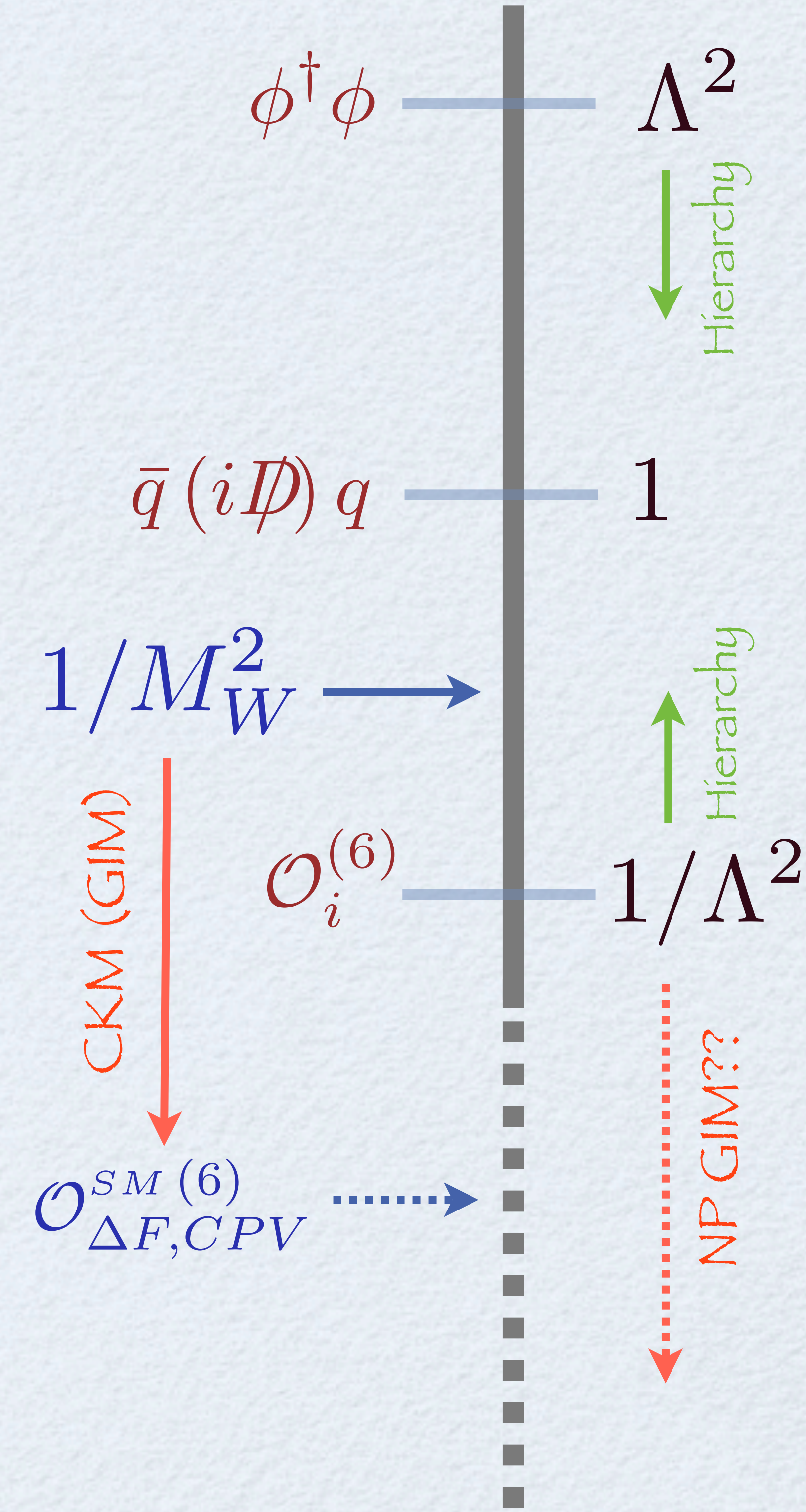
$$\mathcal{L} = \mathcal{L}^{SM} + \sum_n \frac{c_i}{\Lambda^n} \mathcal{O}_i^{(n)}$$

NP is out there, but...
How "natural" is it?

CKM very good for 1st, 2nd gens.
(NP flavor problem)

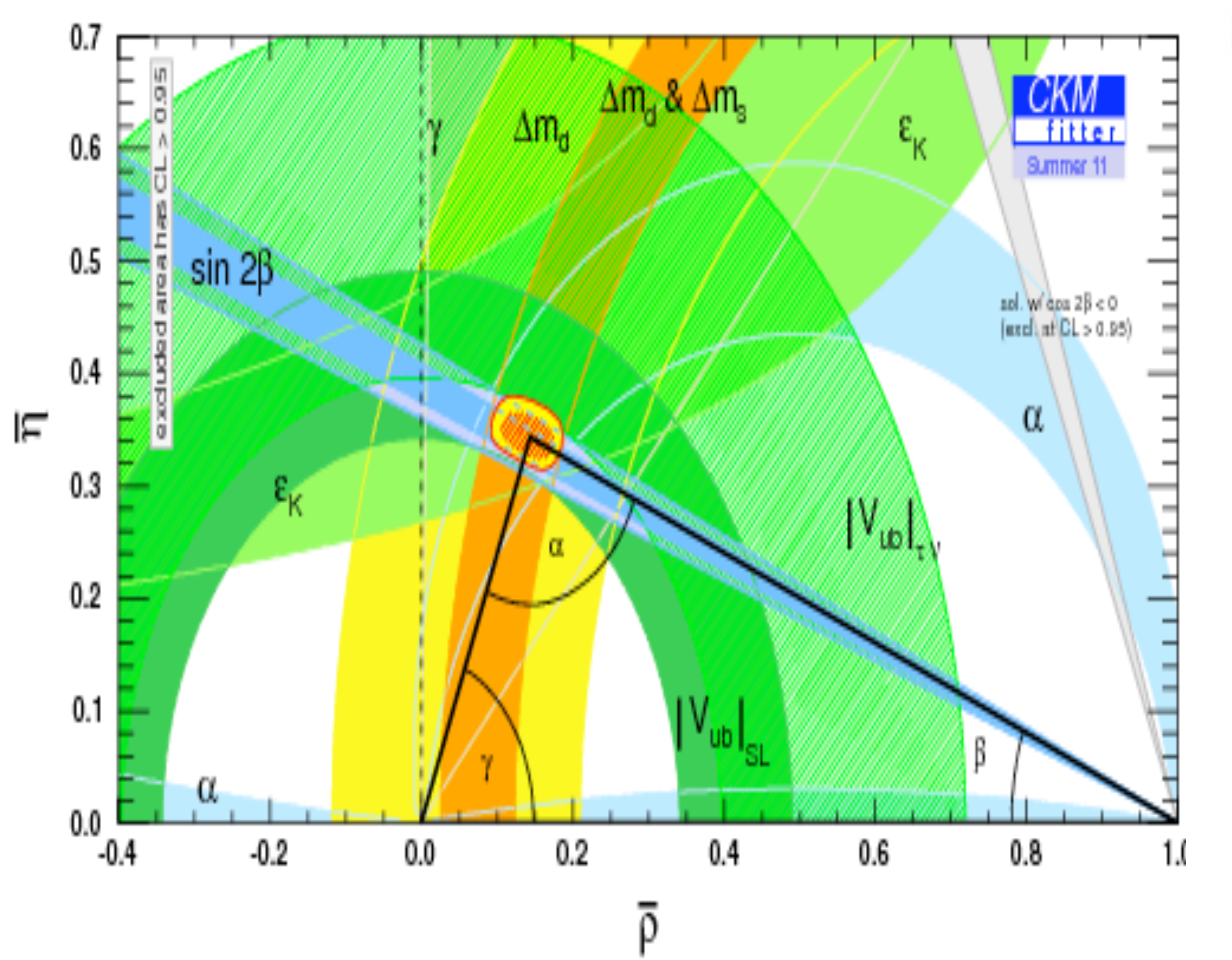
Bs still unexplored ---> LHCb!!

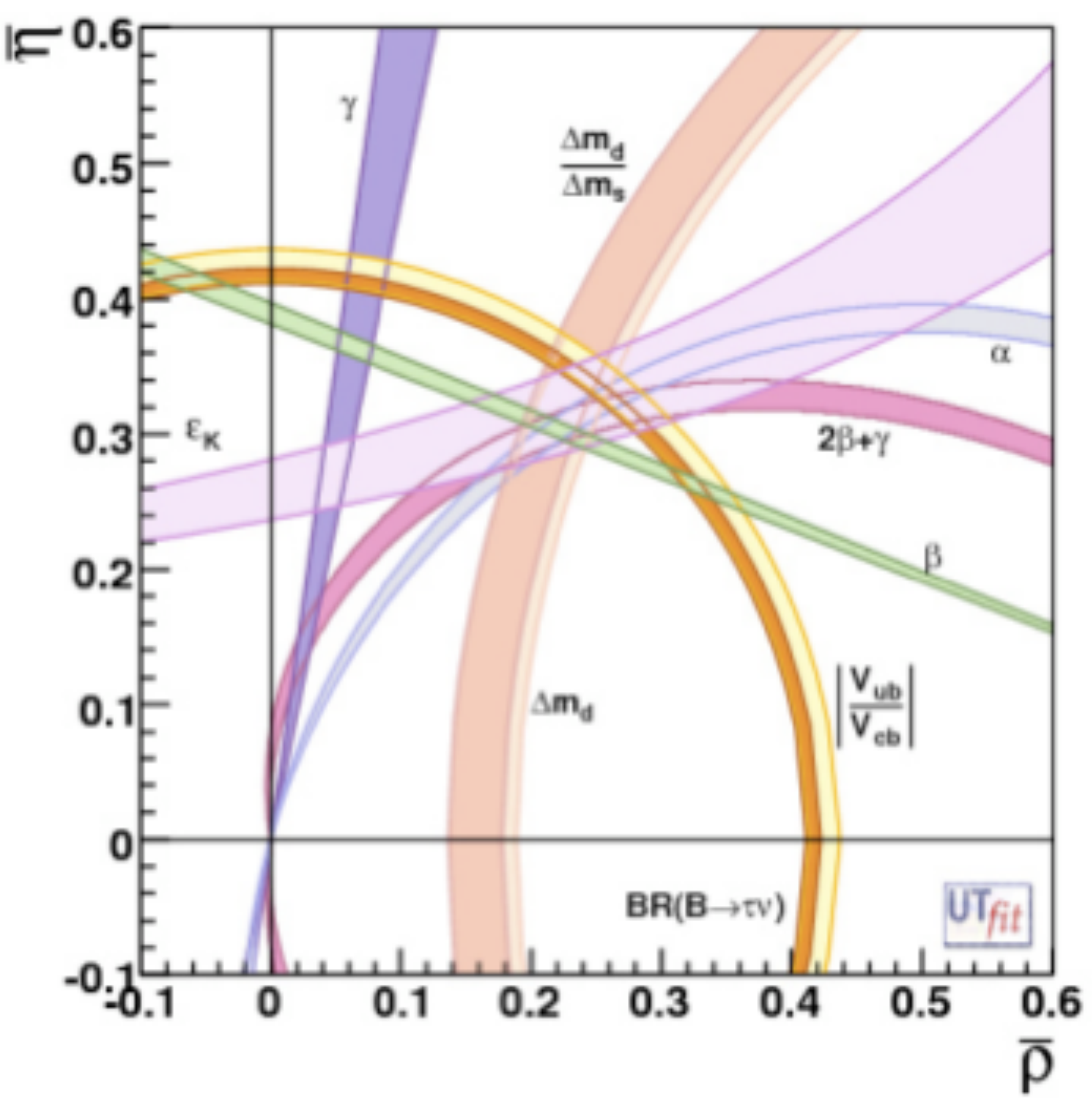
Hints of NP: Dimuon asymmetry, $B \to \tau\nu$, Bd mixing angle...



New Physics in 4 Points

1. Test of the SM through the UT





But... Where is the NP??

2. Fits: Predictions *vs* Measurements

Observable	Prediction	Measurement	Pull (σ)
$\gamma\ [^\circ]$	69.6 ± 3.1	74 ± 11	-0.4
$\alpha\ [^\circ]$	85.4 ± 3.7	91.4 ± 6.1	-0.8
$\sin 2\beta$	0.771 ± 0.036	0.654 ± 0.026	$+2.6$
$\lvert V_{ub}\rvert\ [10^{-3}]$	3.55 ± 0.14	3.76 ± 0.20	-0.9
$\lvert V_{cb}\rvert\ [10^{-3}]$	42.69 ± 0.99	40.83 ± 0.45	$+1.6$
$\varepsilon_K\ [10^{-3}]$	1.92 ± 0.18	2.23 ± 0.010	-1.7
$BR(B \to \tau\nu)\ [10^{-4}]$	0.805 ± 0.071	1.72 ± 0.28	-3.2
$\Delta m_s\ [\mathrm{ps}^{-1}]$	17.77 ± 0.12	18.3 ± 1.3	-0.4
$\beta_s [^\circ]$	1.08 ± 0.04	Tevatron	$+2.1$
$\Delta\Gamma_s\ [\mathrm{ps}^{-1}]$	0.11 ± 0.02	average	
$A_{\mu\mu}\ [10^{-4}]$	-1.7 ± 0.5	-95.7 ± 29.0	$+3.2$

[Ciuchini, Stocchi,2011]

Prediction: Remove from the fit the constrain being tested

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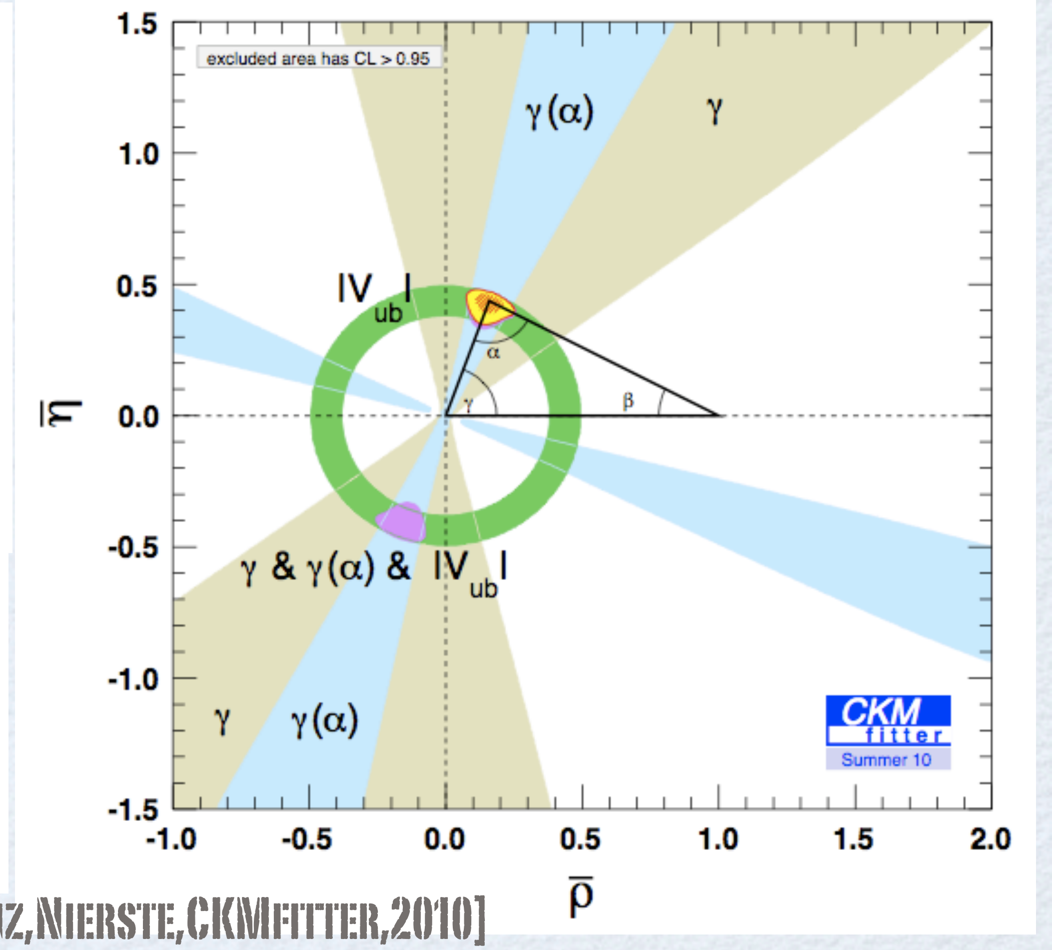
[Ciuchini, Stocchi,2011]

Still... Where is (and how much is) the NP??

3. Disentangling SM + NP

Use only inputs not affected by **NP in the MIXING**

Quantity	central $\pm CL \equiv 1\sigma$	$\pm CL \equiv 2\sigma$	$\pm CL \equiv 3\sigma$
A	$0.801^{+0.024}_{-0.017}$	$0.801^{+0.034}_{-0.026}$	$0.801^{+0.043}_{-0.036}$
λ	$0.22542^{+0.00077}_{-0.00077}$	$0.2254^{+0.0015}_{-0.0015}$	$0.2254^{+0.0023}_{-0.0023}$
$\bar\rho$	$0.159^{+0.036}_{-0.035}$	$0.159^{+0.070}_{-0.067}$	$0.16^{+0.14}_{-0.10}$
$\bar\eta$	$0.438^{+0.019}_{-0.029}$	$0.438^{+0.033}_{-0.069}$	$0.438^{+0.047}_{-0.113}$
α [deg] (!)	79^{+22}_{-15}	79^{+37}_{-24}	79^{+50}_{-31}
β [deg] (!)	$27.2^{+1.1}_{-3.1}$	$27.2^{+2.0}_{-6.0}$	$27.2^{+2.8}_{-9.1}$
γ [deg] (!)	$70.0^{+4.3}_{-4.5}$	$70.0^{+8.5}_{-9.2}$	70^{+13}_{-20}



[Lenz,Nierste,CKMfitter,2010]

Genuine SM values if no NP in decay

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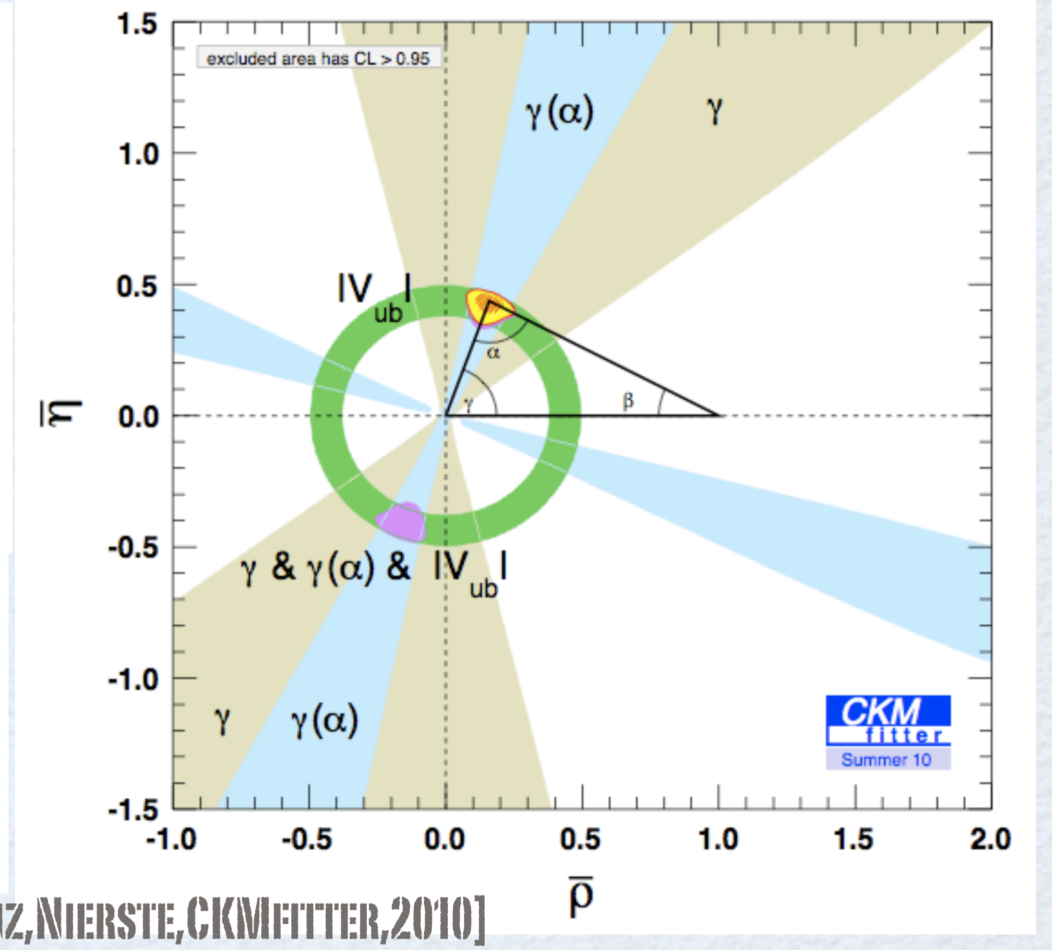

[LENZ,NIERSTE,CKMFITTER,2010]

Genuine SM values if no NP in decay

NP --> Compare SM with FULL ϕ_d

4. *Measuring* NP

OBJECTIVE:

MEASURE $\phi_{d,s}^{NP}$

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SIMPLE

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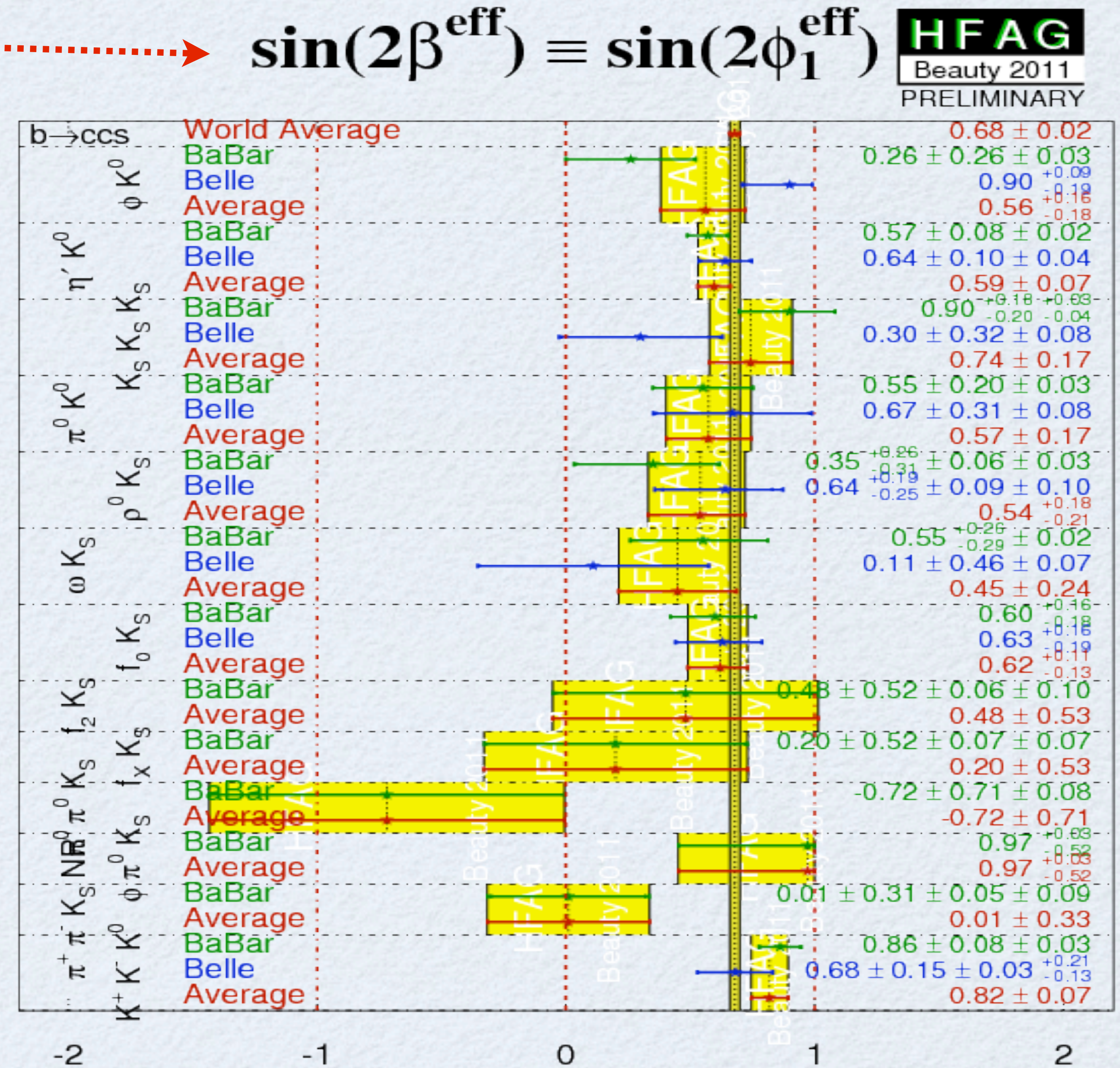
Th. CLEAN

Hadronic $B_{d,s}$-decays & $B_{d,s}$ mixing

?



Hadronic $B_{d,s}$-decays & $B_{d,s}$ mixing

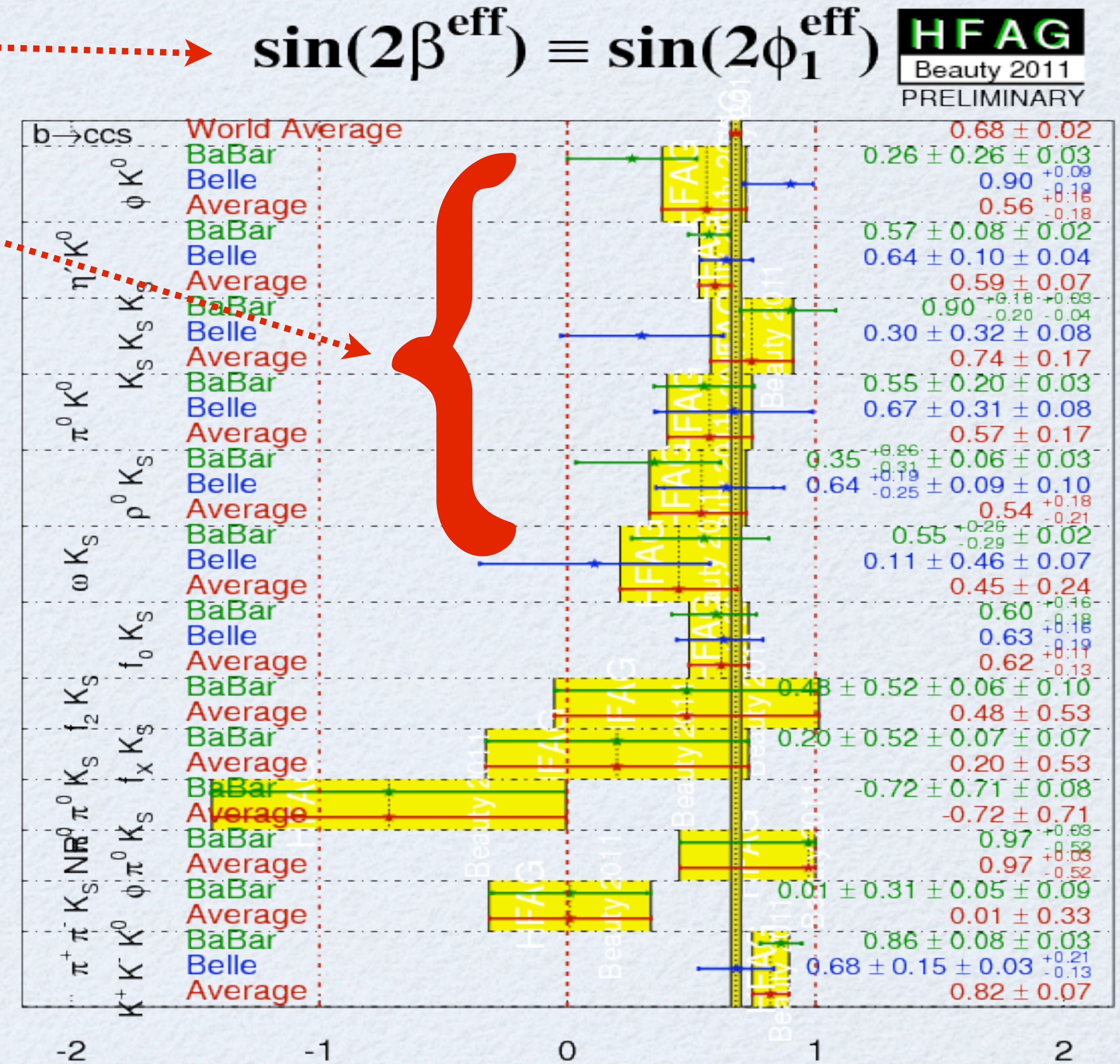
?

Relationship?

$$\eta_f A_{mix} = \sin\left(2\beta^{\text{eff}}\right)$$

β^{eff} **DIFFERENT**

for each decay



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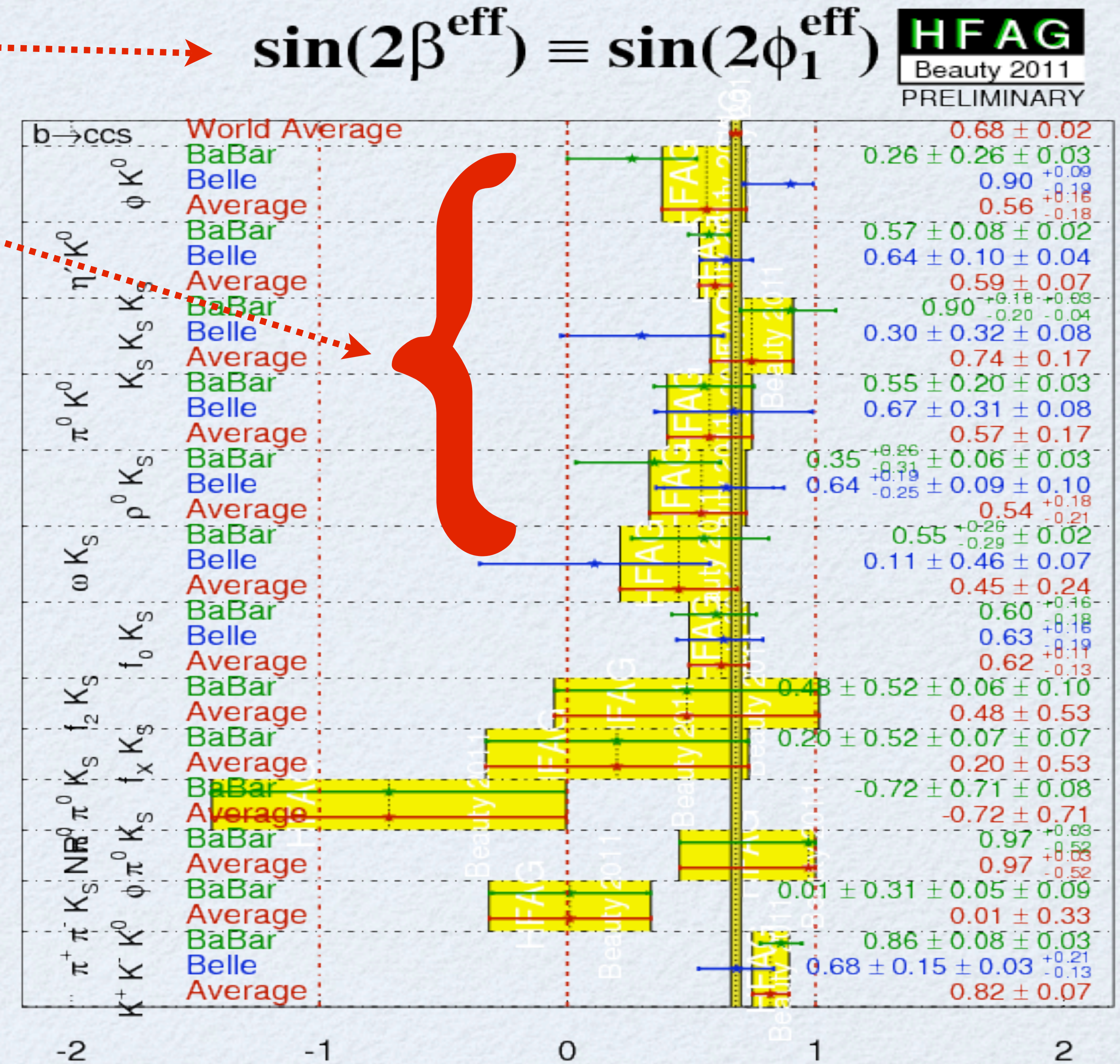


$$\eta_f A_{mix} = \sin\left(2\beta^{\rm eff}\right)$$

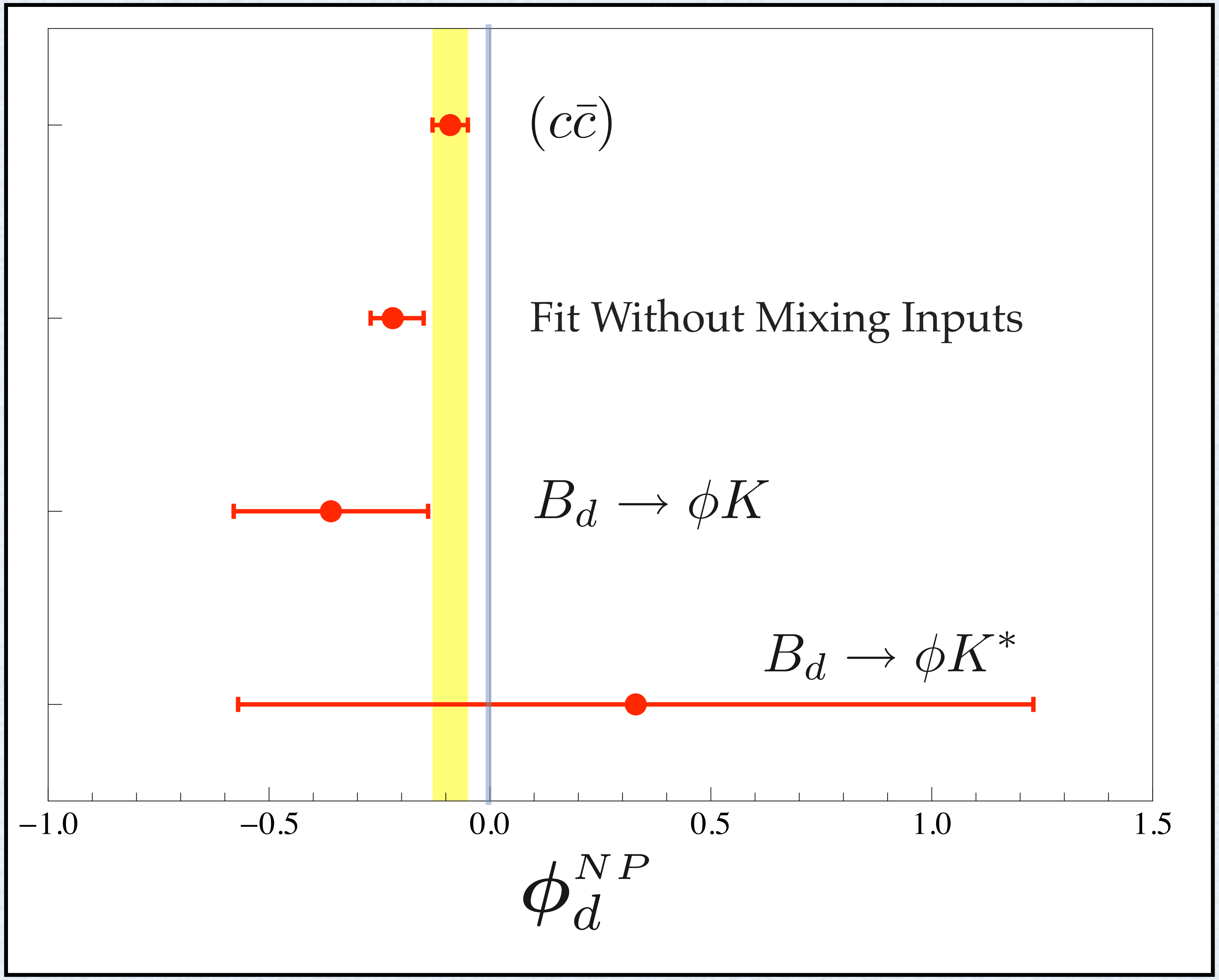
$\beta^{\rm eff}$ **DIFFERENT** for each decay

We Must:

1) Compute WELL each decay

2) Transparent presentation of information

Anticipated Results:



S. Descotes-Genon, J. Matias, J.Virto

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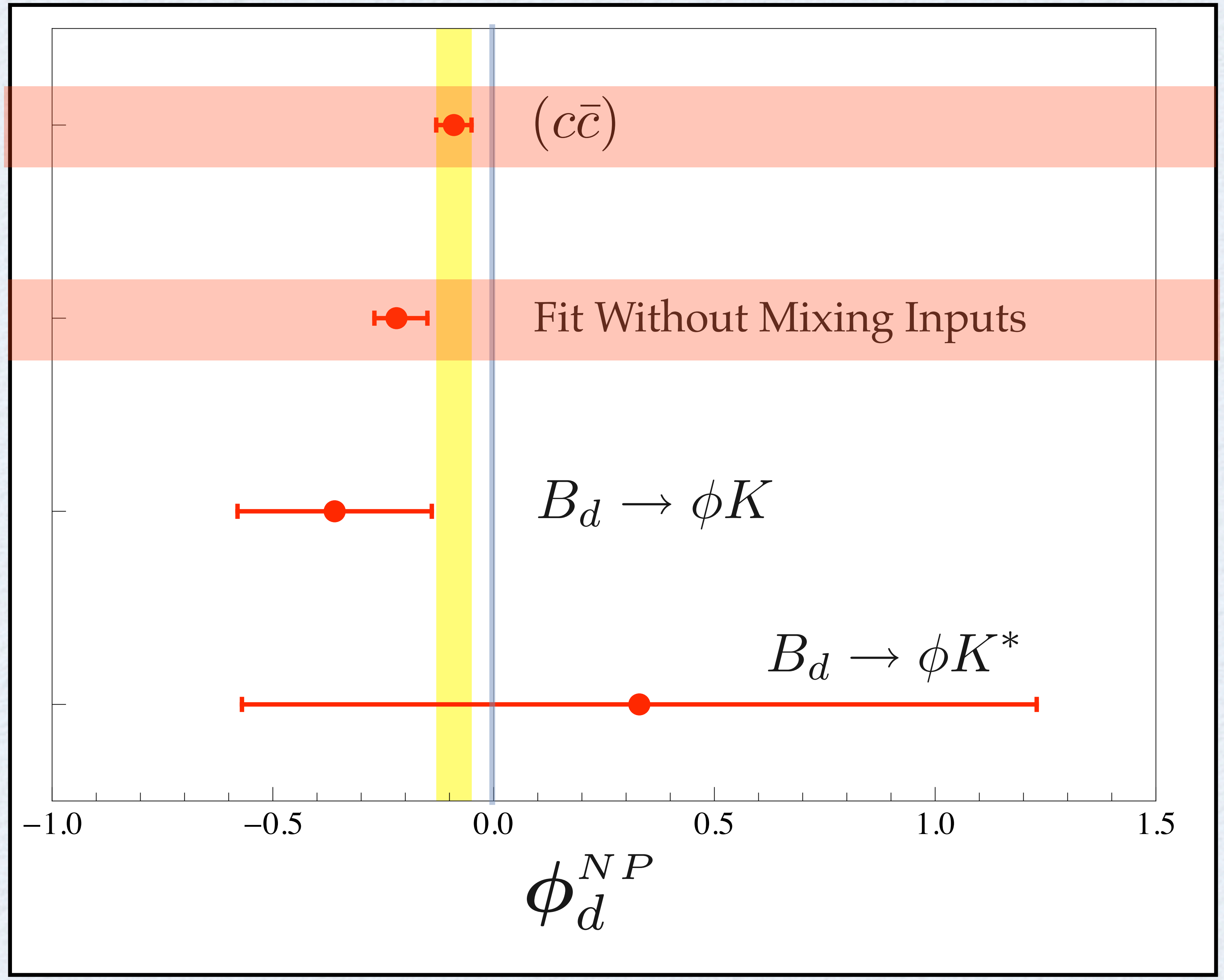

NP in MIXING

S. DESCOTES-GENON, J. MATIAS, J.VIRTO

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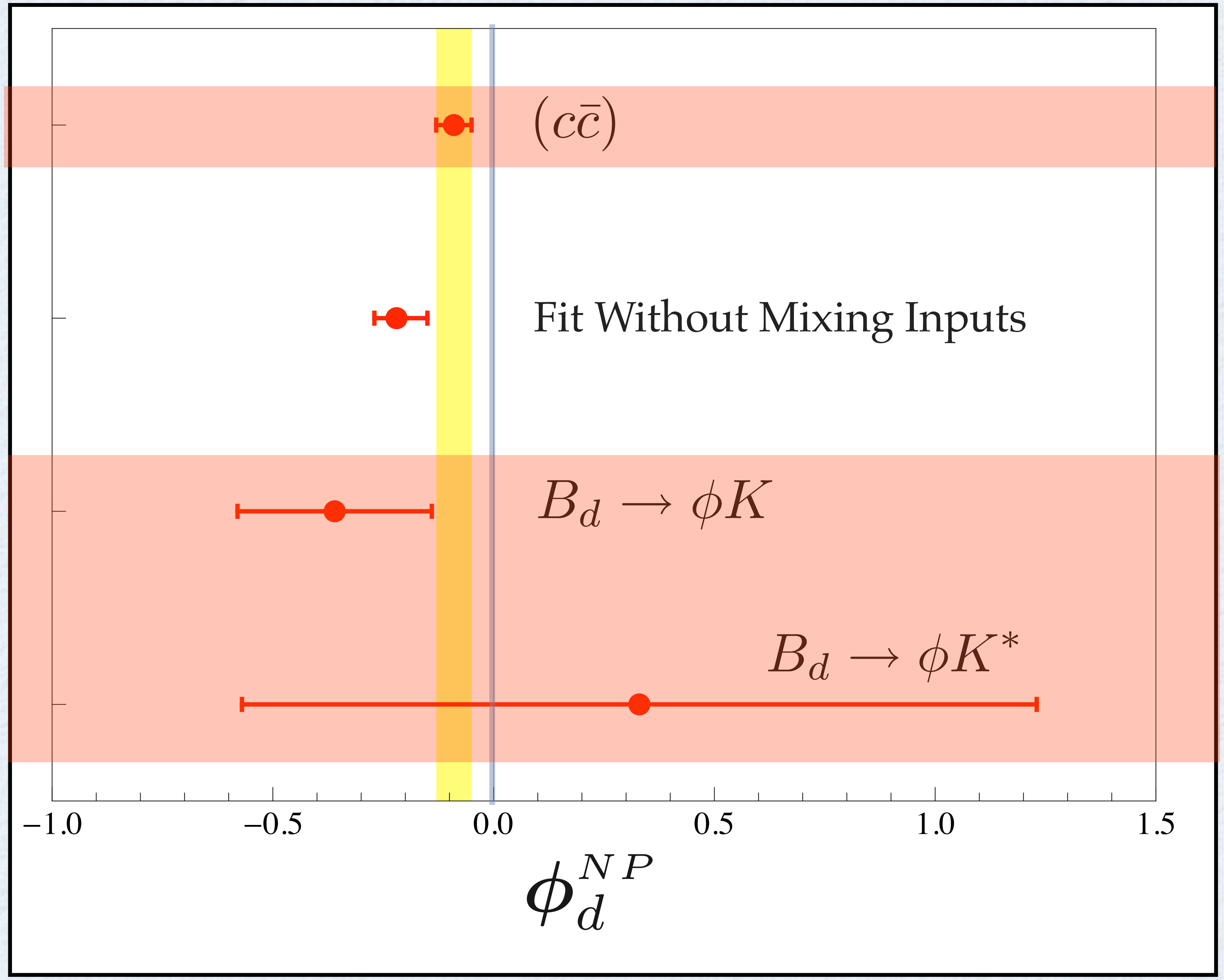

NP in DECAY

S. Descotes-Genon, J. Matias, J.Virto

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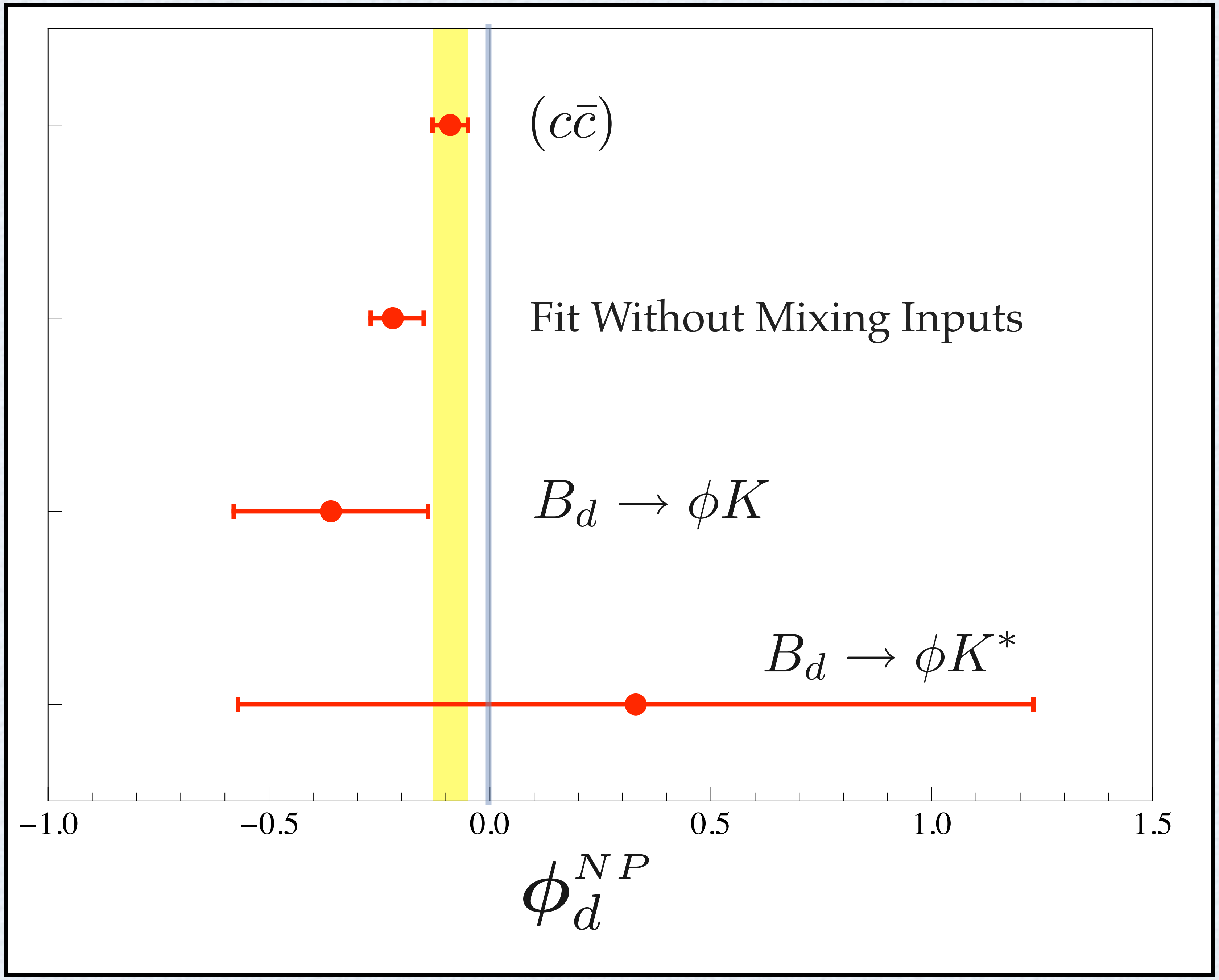

S. Descotes-Genon, J. Matias, J.Virto

Objective:

- Fill out this plot with other decays

- Squeeze Errors (Th + Exp)

$$B_{Q} \longrightarrow M_1 M_2 \ (b \longrightarrow q)$$

Amplitude for hadronic B decay:

$$A(\bar{B}_Q \to M_1 M_2) = -\lambda_u^{(q)}\, T - \lambda_c^{(q)}\, P$$

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 # *Amplitude for hadronic B decay:*

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 # *CKM structure:* $\lambda_u^{(q)} = V_{ub}V_{uq}^* \; , \; \lambda_c^{(q)} = V_{cb}V_{cq}^*$

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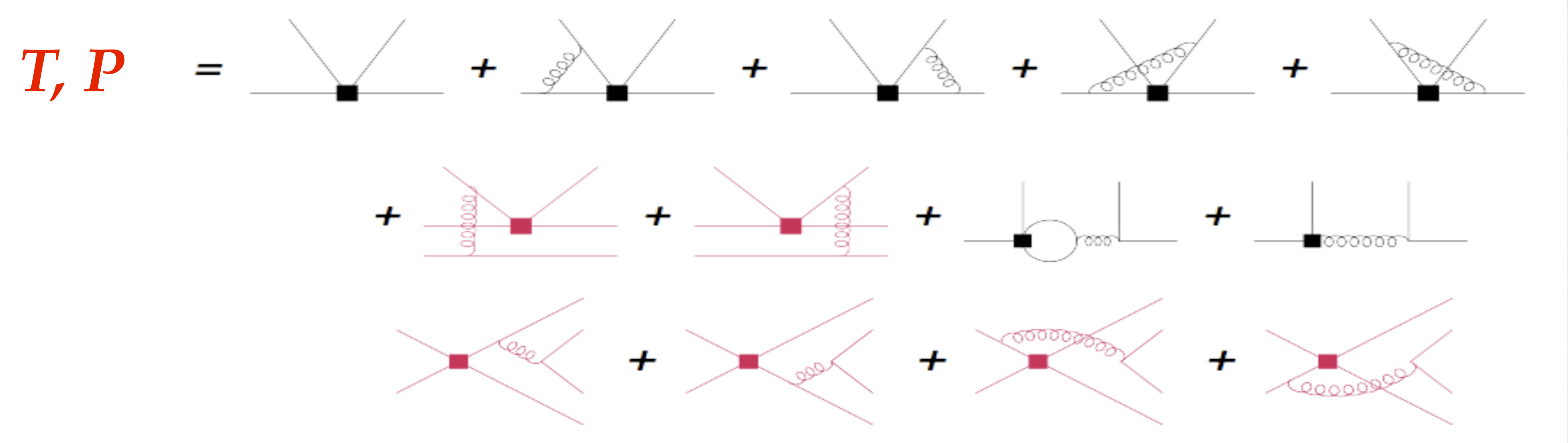
 # HME from QCD Factorization:



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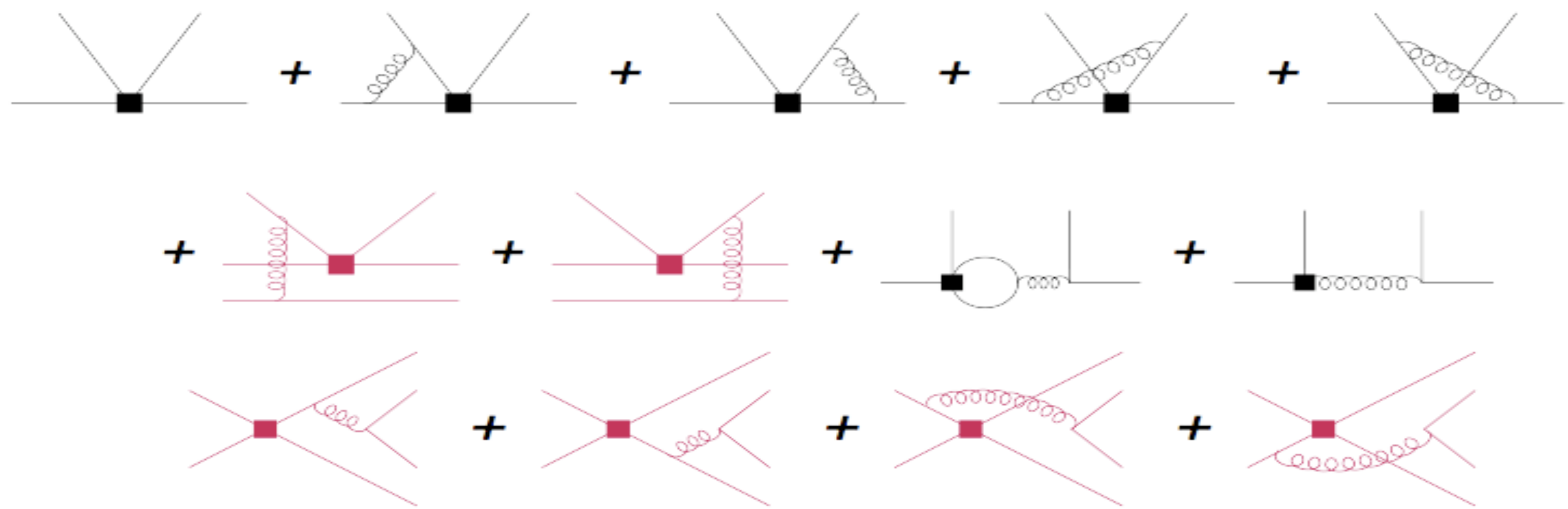
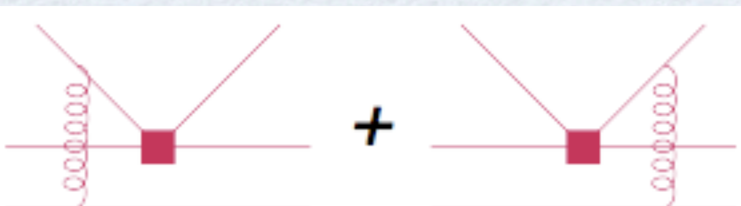
HME from QCD Factorization:

$T, P =$



IR (end-point) divergencies:



$$\supset \int_0^1 \frac{dy}{\bar{y}} \Phi_{m_1}(y) = \Phi_{m_1}(1) X_H^{M_1} + \text{finite}$$

$B_Q \to M_1 M_2 \; (b \to q)$

Amplitude for hadronic B decay:

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HME from QCDF: ***T, P IR-div $\Rightarrow$ Modeling $\Rightarrow$ Uncertainties***

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HME from QCDF: *T, P IR-div* $\Rightarrow$ *Modeling* $\Rightarrow$ *Uncertainties*

KEY IDEA: Descotes-Genon, Matias, Virto, Phys.Rev.Lett. 97 (2006) 061801

$$\Delta \equiv T - P$$ *is FREE from IR divergencies**

* *For a list of selected penguin decays (see later)*

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$\Delta \equiv T - P$ *is FREE from IR divergencies**

If we can use Δ as the ONLY theoretical input
we obtain more RELIABLE and PRECISE predictions

* *For a list of selected penguin decays (see later)*

Channel	$\lvert\Delta\rvert$ (10^{-7} GeV)	$C \times BR$ (10^{-9} GeV^2)
$B_d \to KK$	(3.23 ± 1.16)	(29.8 ± 21.9)
$B_s \to KK$	(3.05 ± 1.11)	(1.21 ± 0.89)
$B_d \to \phi K$	(2.32 ± 1.00)	(0.74 ± 0.64)
$B_d \to K^* K^*$	(1.85 ± 0.93)	(9.37 ± 9.53)
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$B_s \to \phi K^*$	(1.87 ± 0.94)	(8.80 ± 8.96)
$B_s \to \phi\phi$	(3.86 ± 2.09)	(0.92 ± 1.00)

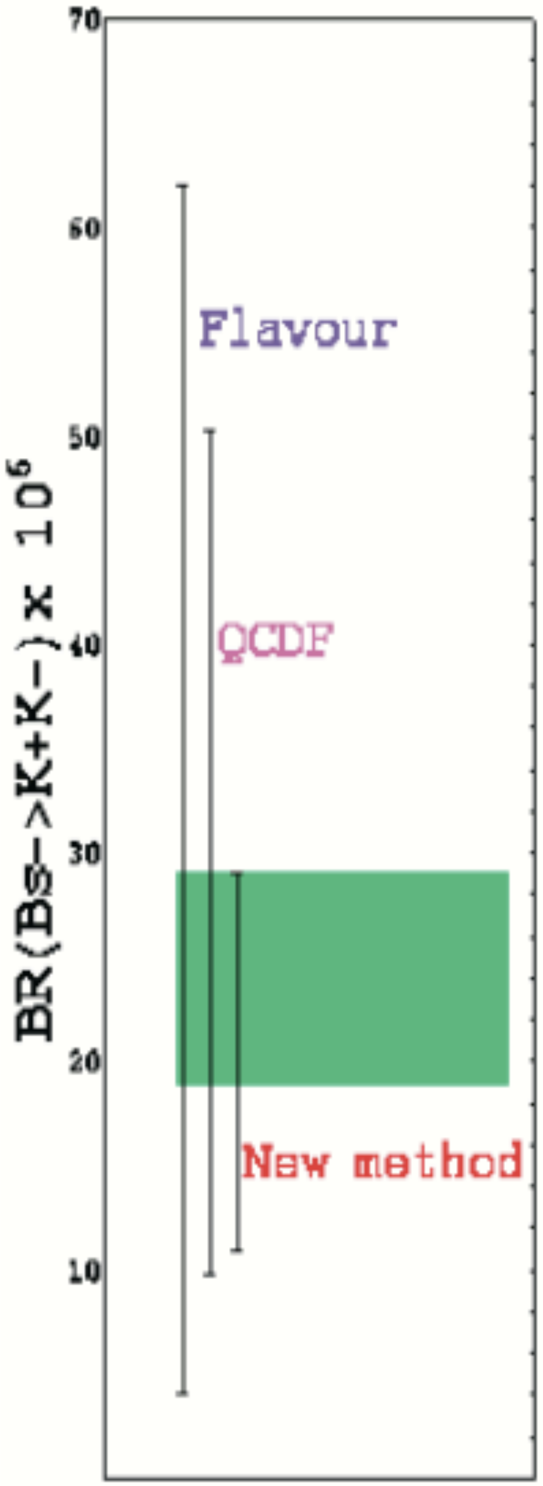
- Our method was used to predict BR's and Asymmetries in $B_s \to K^+K^-$ and $B_s \to K^0\bar{K}^0$.

  (Descotes-Genon, Matias, Virto, *Phys.Rev.Lett* **97** 061801 (2006))

  The outcome was quite promising.

- SU(3) methods suffer from large experimental uncertainties and cannot estimate SU(3)-breaking.

- QCDF has trouble with chirally enhanced $1/m_b$ suppressed contributions, which have to be modelled and introduce huge uncertainties.



EQUATION:

$$B_Q \longrightarrow M_1 M_2 \; (b \longrightarrow q)$$

$$\boxed{\Phi_{Qq} = 2\beta_Q - 2\beta_q + \phi_Q^{\mathrm{NP}}}$$

(= ϕ^{NP} if Q=q)

$$\boxed{\begin{aligned} &2g_{ps}|\Delta|^2|\lambda_c^{(q)}|^2 \sin^2\beta_q \\ &\quad = BR(1 - \eta_f \sin\Phi_{Qq} A_{\mathrm{mix}} + \eta_f \cos\Phi_{Qq} A_{\Delta\Gamma}) \end{aligned}}$$

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Theory

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Theory **Experiment**

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Theory

Experiment

SM Fit *

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Theory **Experiment** **SM Fit *** **OUTPUT**

The Method

FORMULA:

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$$2g_{ps}|\Delta|^2|\lambda_c^{(q)}|^2 \sin^2\beta_q = BR(1 - \eta_f \sin\Phi_{Qq} A_{\mathrm{mix}} + \eta_f \cos\Phi_{Qq} A_{\Delta\Gamma})$$

$$\sin\Phi_{Qq} \;=\; z\,\eta_f \hat{A}_{\mathrm{mix}} \pm \sqrt{1-z^2}\,\eta_f \hat{A}_{\Delta\Gamma}$$

$$\hat{A}^2_{mix} + \hat{A}^2_{\Delta\Gamma} = 1$$

Where:

$$z = (1-C)/\sqrt{1-A^2_{dir}}$$

$$C = \frac{2\,g_{ps}\,|\lambda_c|^2 \sin^2\beta_q\,|\Delta|^2}{BR}$$

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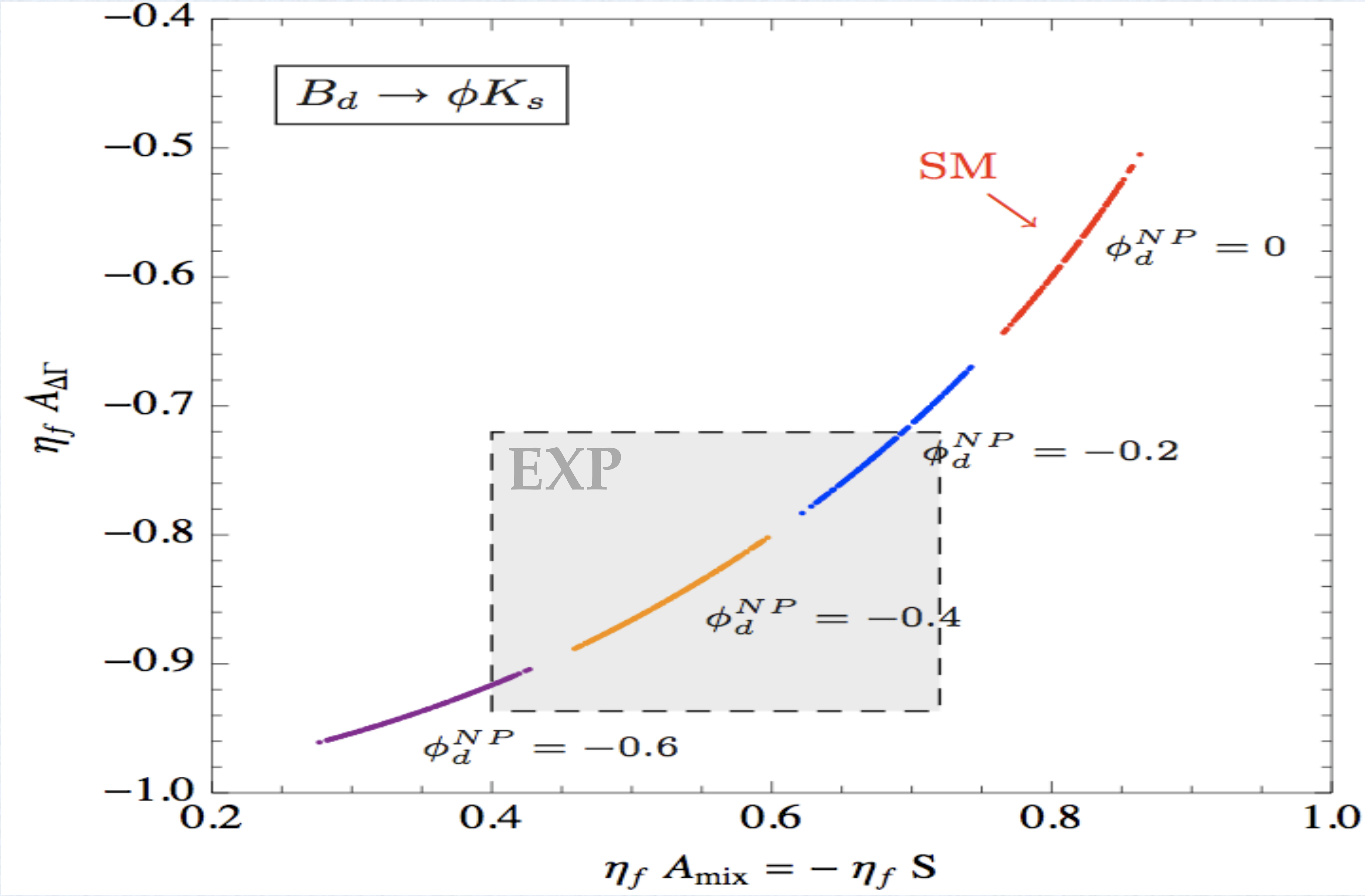

$$\boxed{\phi^{NP}_{d,\ \mathrm{aver}} = -0.36 \pm 0.22}$$

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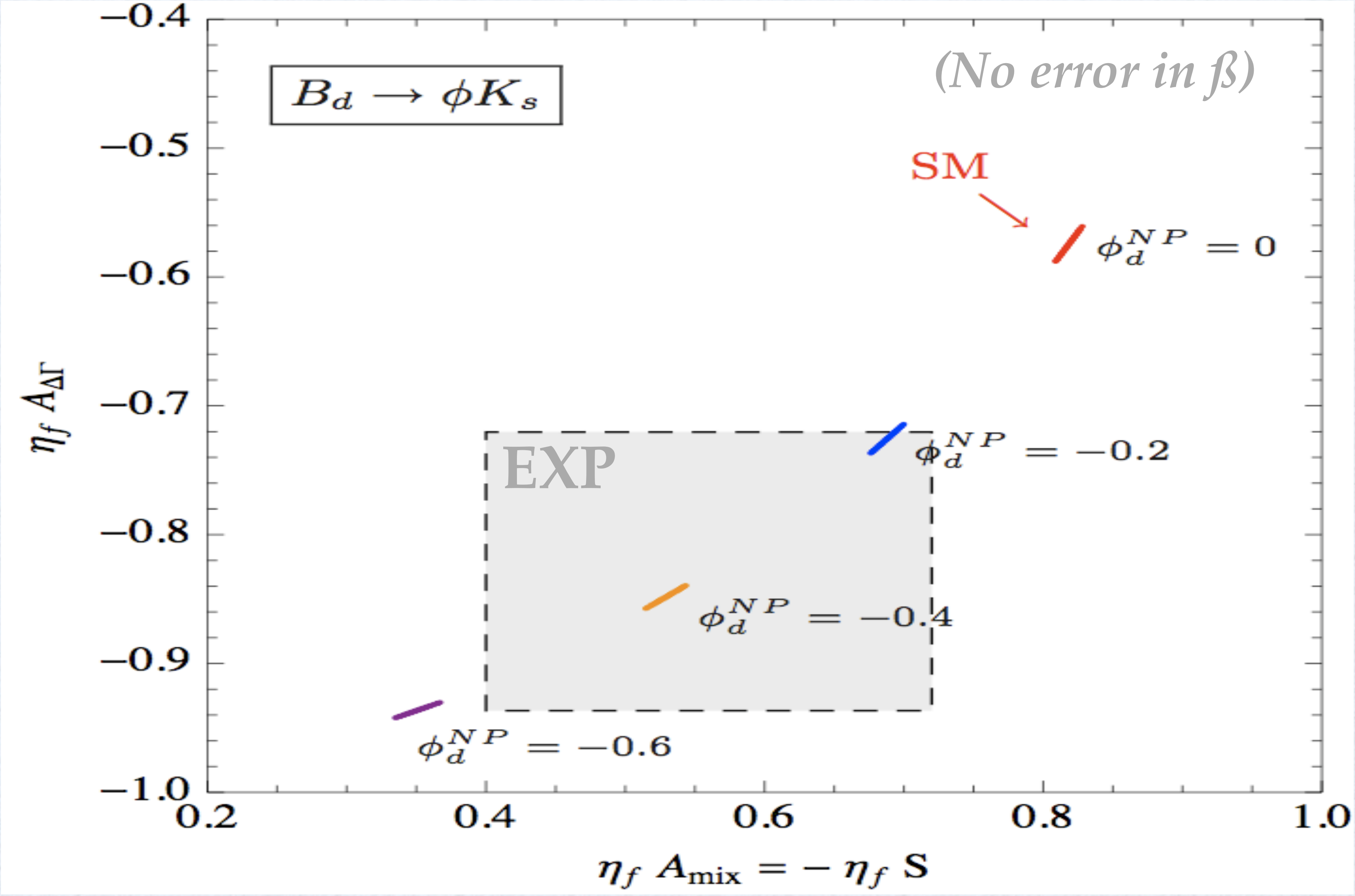

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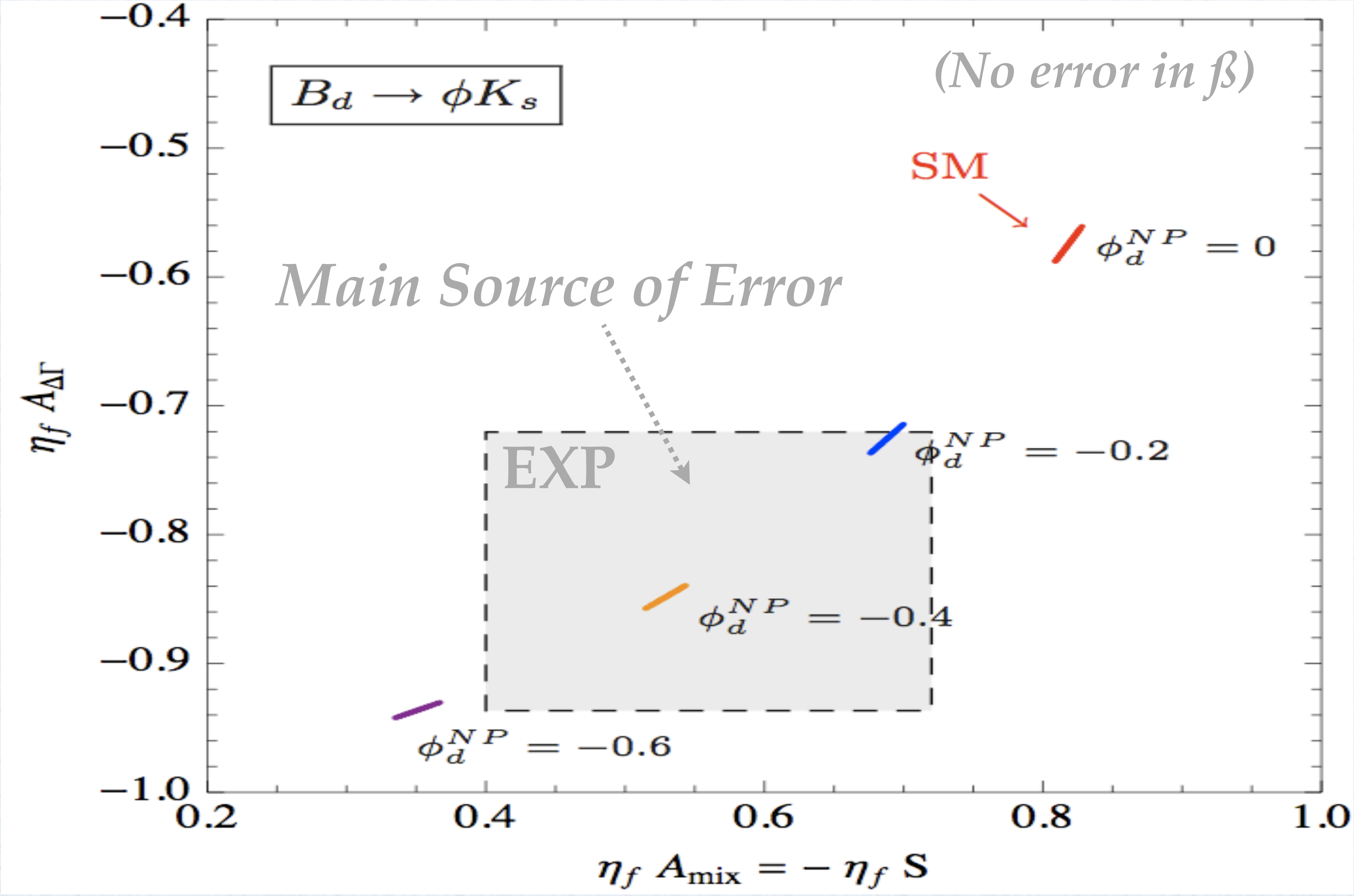
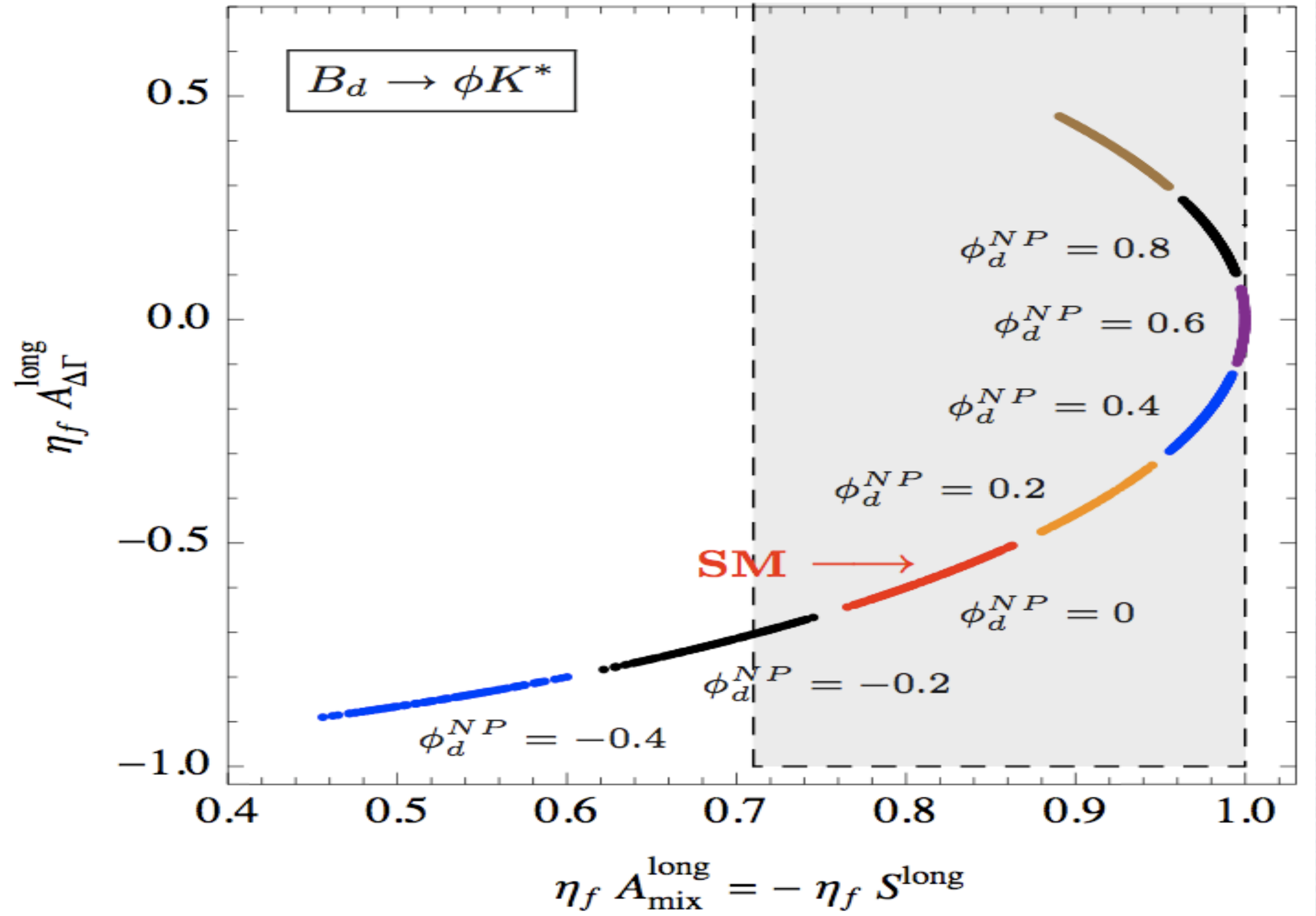
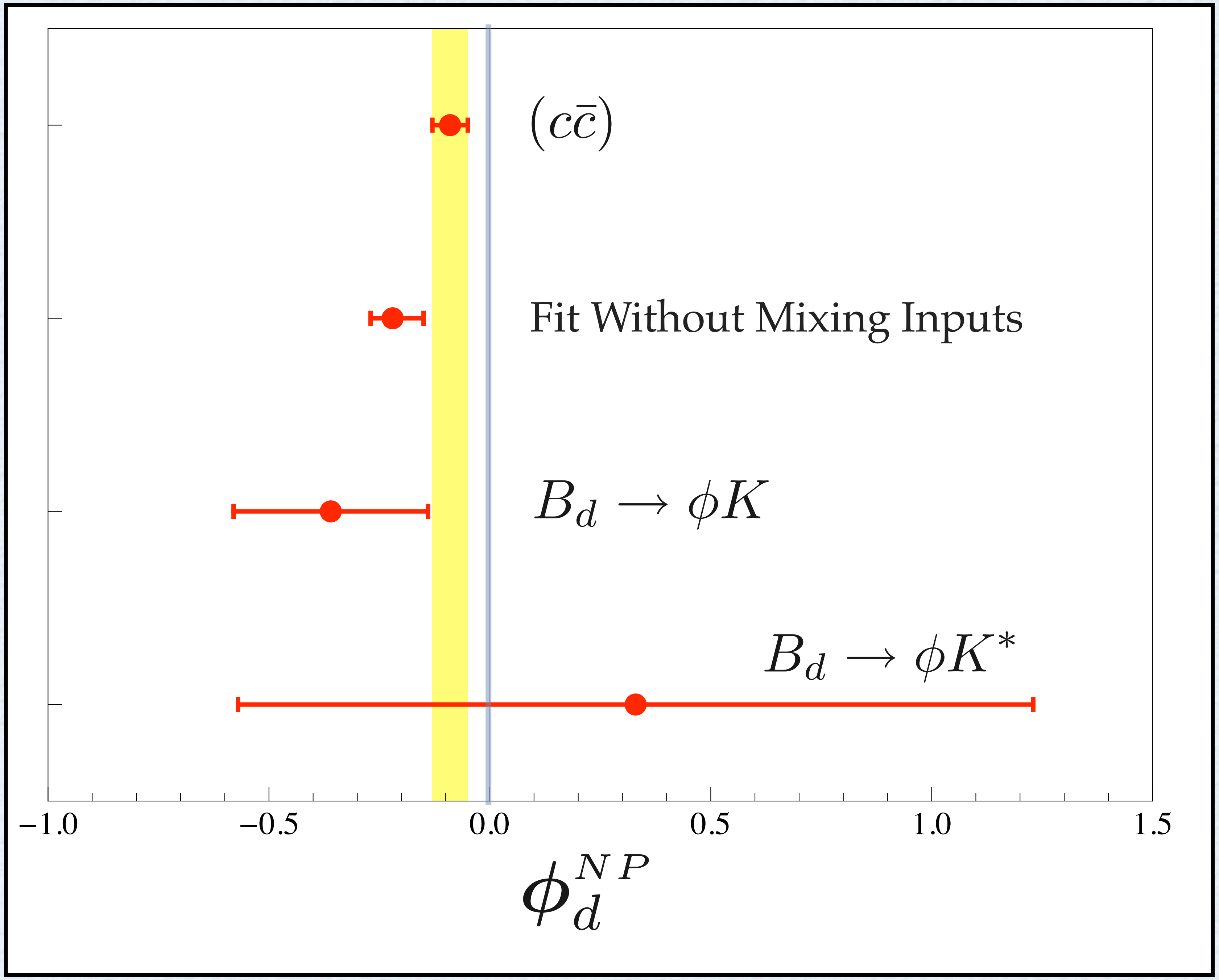


$$\boxed{\phi_{d,\ \rm aver}^{NP} = -0.36 \pm 0.19}$$

EXAMPLE 2:



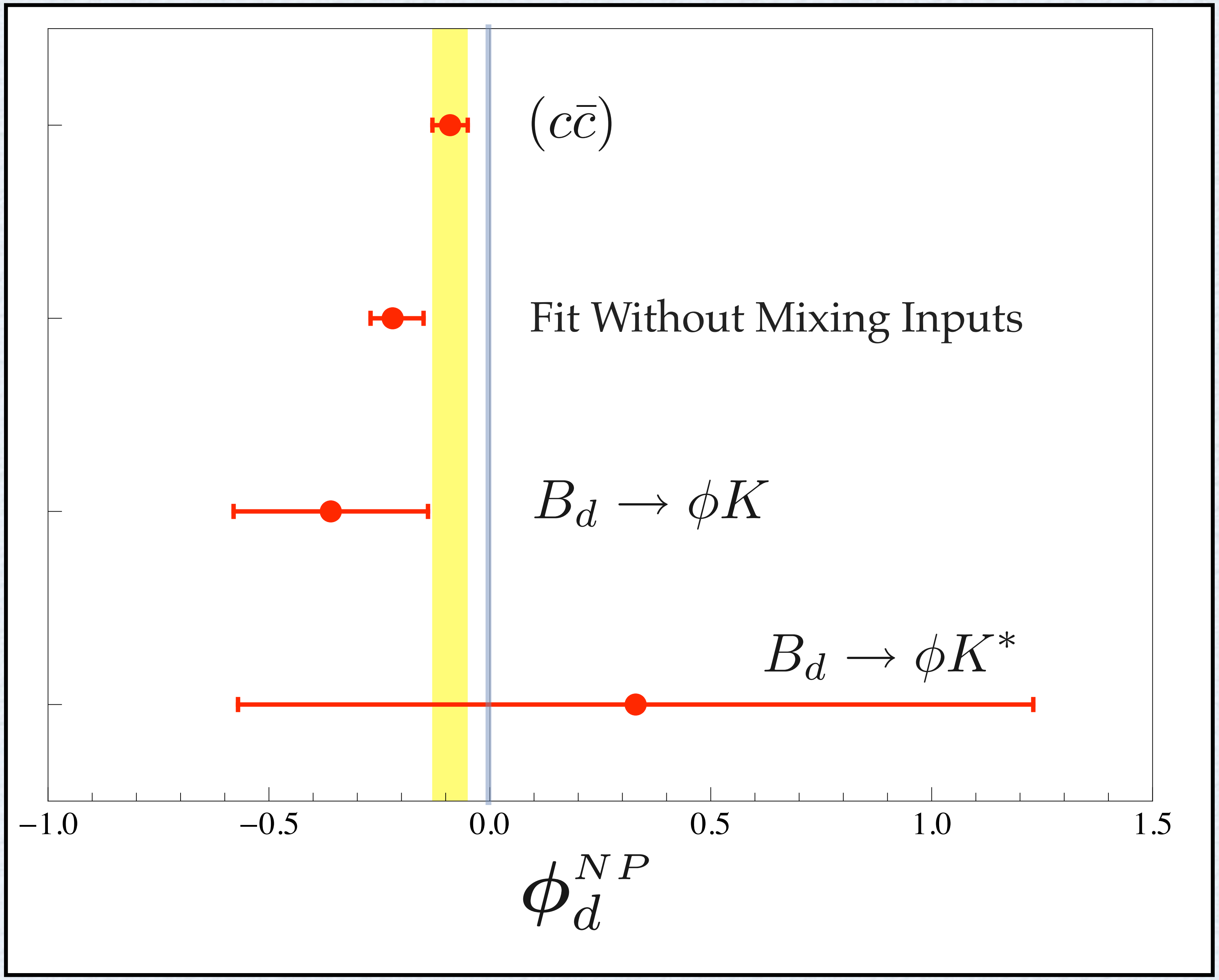
$$\phi_{d,\ av}^{NP} = 0.33 \pm 0.90$$



Include:

$B_d \to K^0 \bar{K}^0$

$B_d \to K^{0*} \bar{K}^{0*}$



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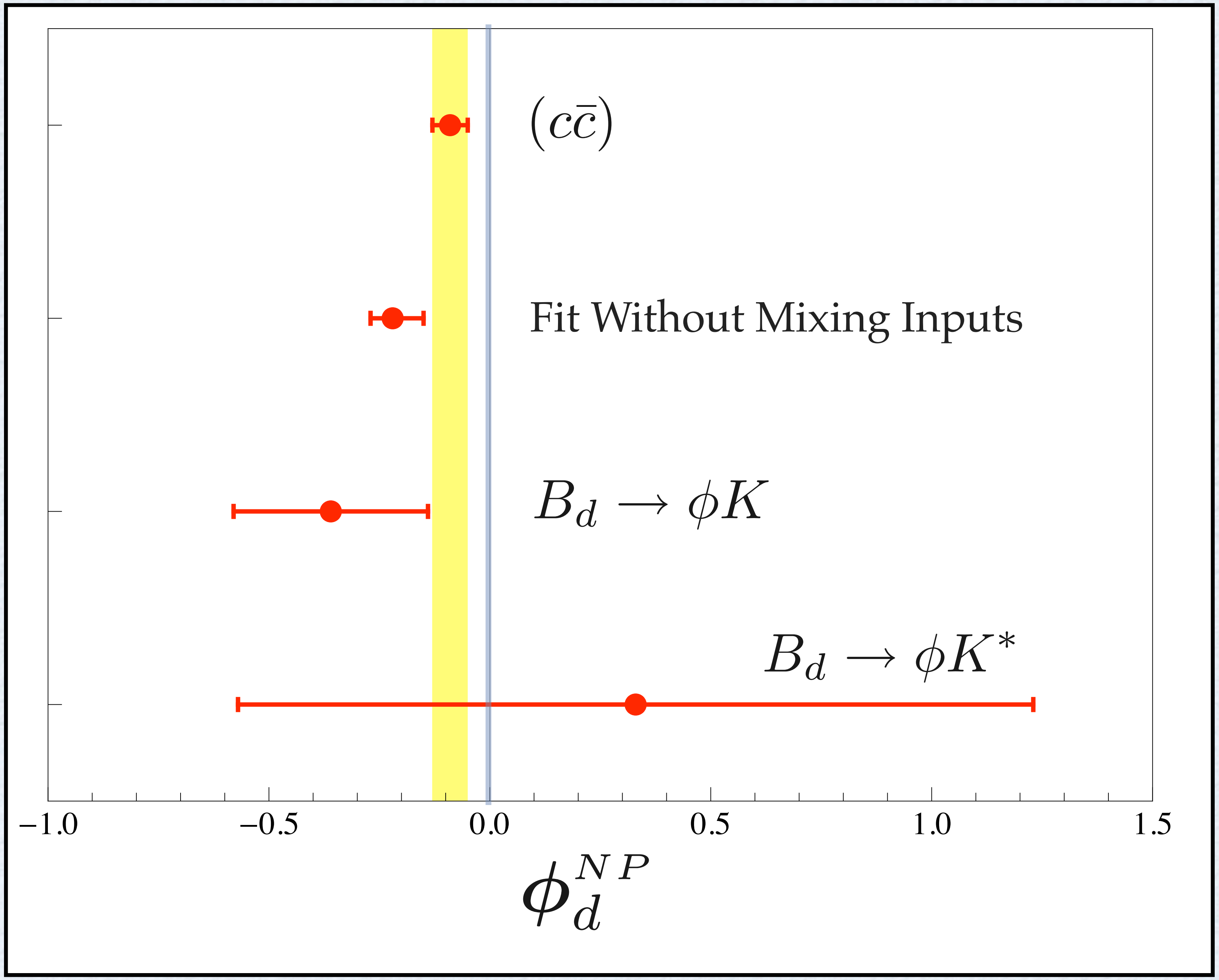
SIMPLE

Th. CLEAN



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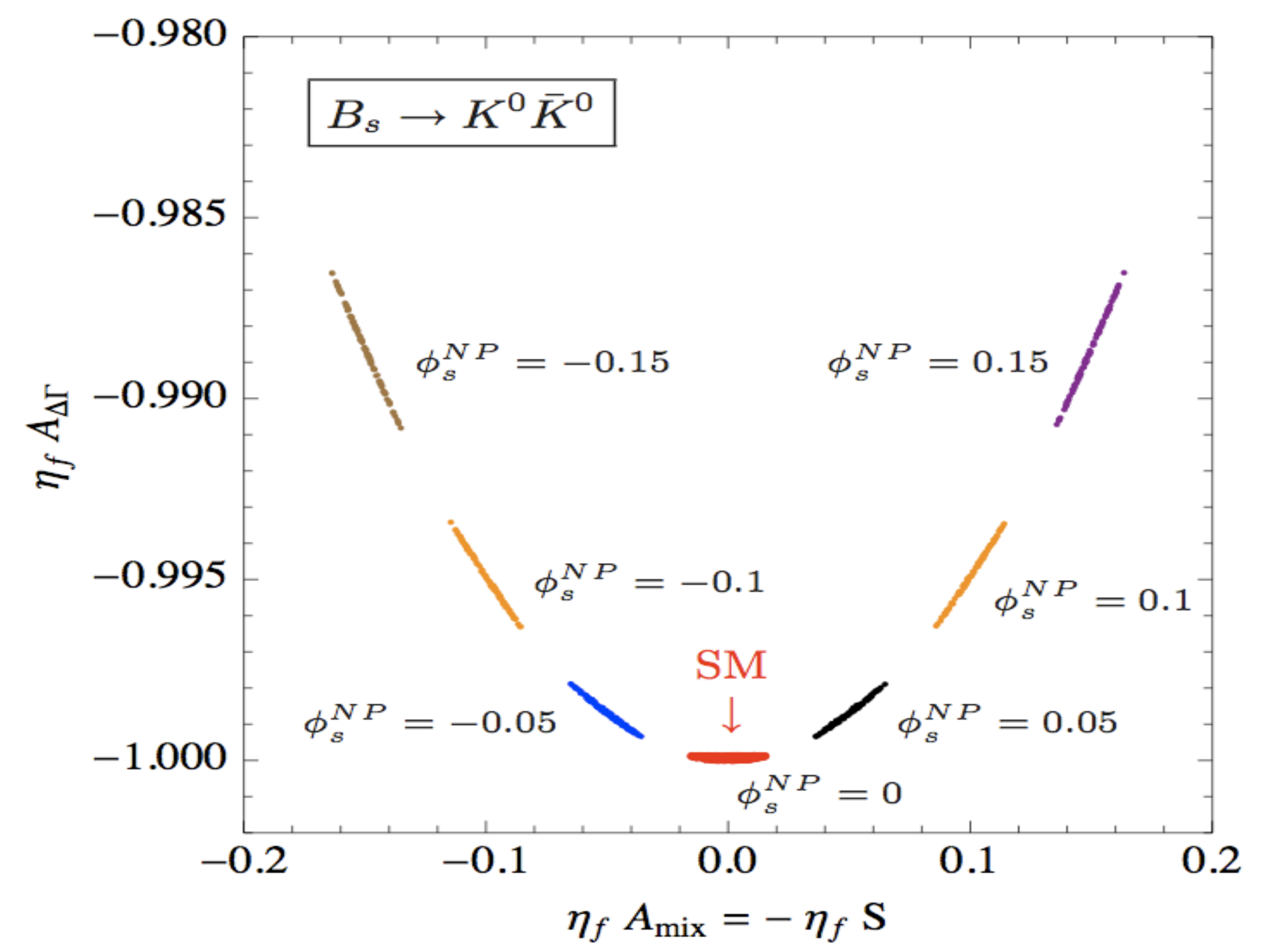
SIMPLE

Th. CLEAN

The same for ϕ_s^{NP}!!!

EXAMPLE 3:


$B_s \to K^0 \bar{K}^0$
−0.980
−0.985
−0.990
−0.995
−1.000
$\eta_f\, A_{\Delta\Gamma}$
−0.2
−0.1
0.0
0.1
0.2
$\eta_f\, A_{\mathrm{mix}} = -\,\eta_f\, \mathrm{S}$
$\phi_s^{NP} = -0.15$
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$\phi_s^{NP} = 0.1$
$\phi_s^{NP} = -0.05$
$\phi_s^{NP} = 0.05$
SM
$\phi_s^{NP} = 0$

With our method we can also give a SM prediction for Rsd:

$$R_{sd} \equiv \frac{BR^{\text{long}}(B_s \to K^{*0}\bar{K}^{*0})}{BR^{\text{long}}(B_d \to K^{*0}\bar{K}^{*0})}$$

$$\boldsymbol{R_{sd}^{\text{DMV}} = 16.4 \pm 5.2}$$

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***LHCb**: New data on this NEXT WEEK!*

(don't miss Paula Alvarez's Talk)

SUMMARY

 # Theoretically CLEAN hadronic quantity: $\Delta \equiv T - P$

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$$\boxed{\sin\Phi_{Qq} = z\,\eta_f \hat{A}_{\rm mix} \pm \sqrt{1-z^2}\,\eta_f \hat{A}_{\Delta\Gamma}}$$

EXACT FORMULA

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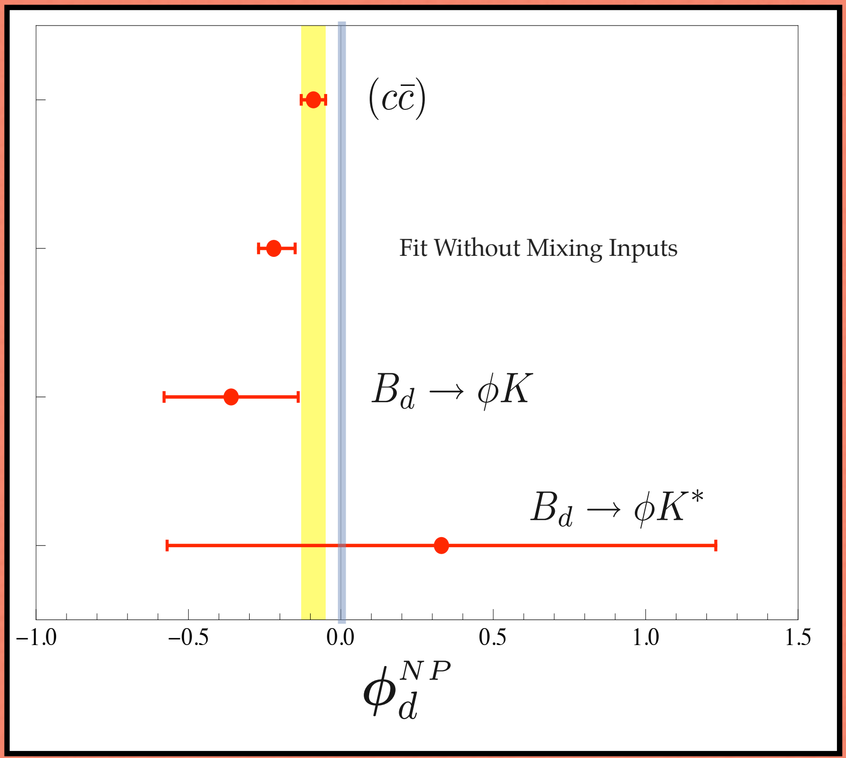

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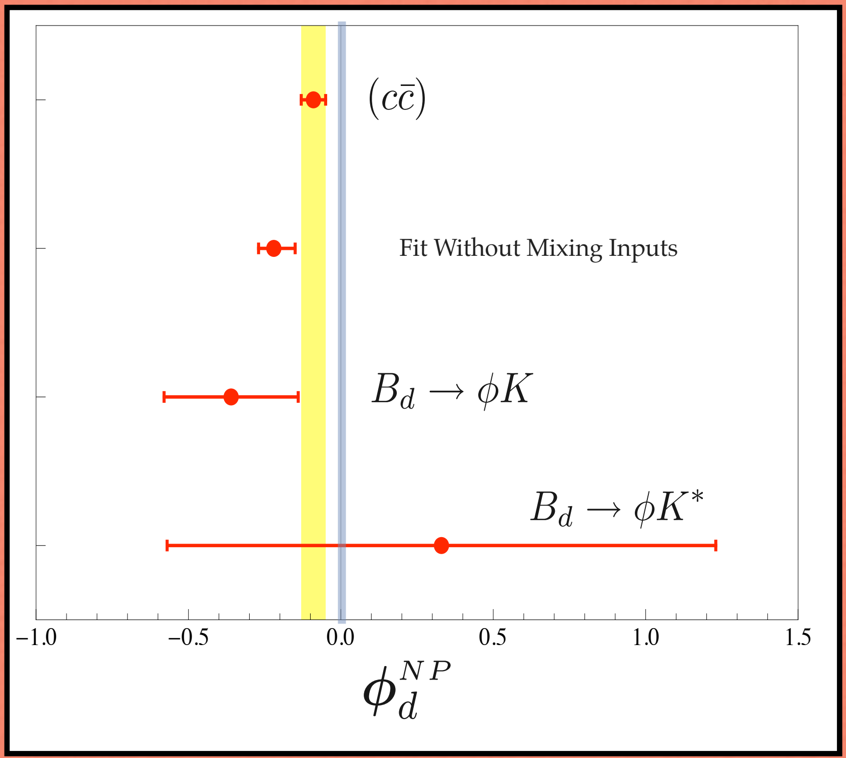

 # Objectives: *Complete the list of Decays*

The same for ϕ_s^{NP}

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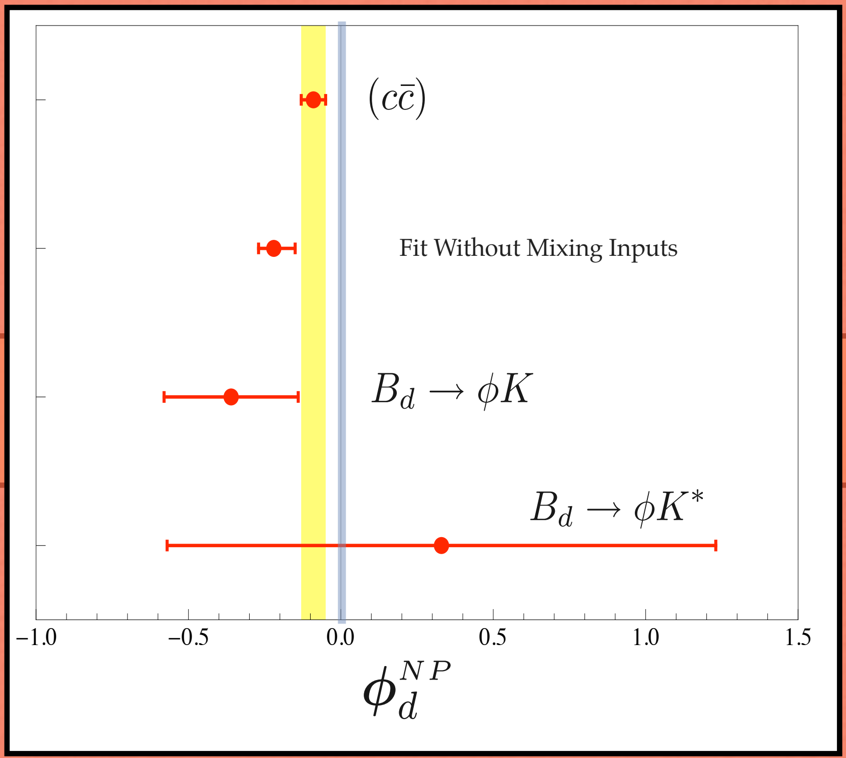

Objectives: Complete the list of Decays

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Results for $B_s \to K^{0*} \bar{K}^{0*}$

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$$R_{sd}^{\rm QCDF} = 13.8 \pm 19.2$$

LHCb ---> very soon

BACK-UP

Longitudinal Observables

We have therefore the relationships

$$BR = \frac{1}{2}\frac{1}{\Gamma_{\text{total}}}(\bar{\Gamma}+\Gamma)\ , \qquad \mathcal{A}_{CP} = \frac{\bar{\Gamma}-\Gamma}{\bar{\Gamma}+\Gamma}\ ,$$
$$f_L = \frac{1}{2}(f_L^+ + f_L^-)\ , \qquad \mathcal{A}_{CP}^0 = \frac{f_L^+ - f_L^-}{f_L^+ + f_L^-}\ . \tag{45}$$

and we can easily define the longitudinal observables in terms of these observables

$$BR^{\text{long}} = BR \cdot f_L \cdot [1 + \mathcal{A}_{CP}^0 \cdot \mathcal{A}_{CP}]\ , \tag{46}$$
$$A_{\text{dir}}^{\text{long}} = -\frac{\mathcal{A}_{CP}^0 + \mathcal{A}_{CP}}{1 + \mathcal{A}_{CP}^0 \cdot \mathcal{A}_{CP}}\ , \tag{47}$$
$$A_{\text{mix}}^{\text{long}} = \eta\sqrt{1 - (A_{\text{dir}}^{\text{long}})^2}\,\sin(2\beta + \arg(A_0/\bar{A}_0))\ , \tag{48}$$
$$A_{\Delta\Gamma}^{\text{long}} = -\eta\sqrt{1 - (A_{\text{dir}}^{\text{long}})^2}\,\cos(2\beta + \arg(A_0/\bar{A}_0))\ , \tag{49}$$

LHCb for Rsd

$$R_{sd}^{\mathrm{DMV}} = 16.4 \pm 5.2$$

$$R_{sd}^{\mathrm{QCDF}} = 13.8 \pm 19.2$$

LHCb Direct Meas. $R_{sd}^{exp-I} = (8.1 \pm 3.3) \times \left(\frac{f_L(B_s)}{0.31}\right) = 8.1 \pm 4.7$

LHCb with D π $R_{sd}^{exp-II} = (7.6 \pm 3.2) \times \left(\frac{f_L(B_s)}{0.31}\right) = 7.6 \pm 4.5$