Very informal[2] discussion about the recent Tevatron results on CPV in Bs mixing

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Andreas Weiler (CERN)

[2]Disclaimer: We apologize in advance for not including complete references. Slides intended as basis for discussion and **not** as a review talk.

Some references.

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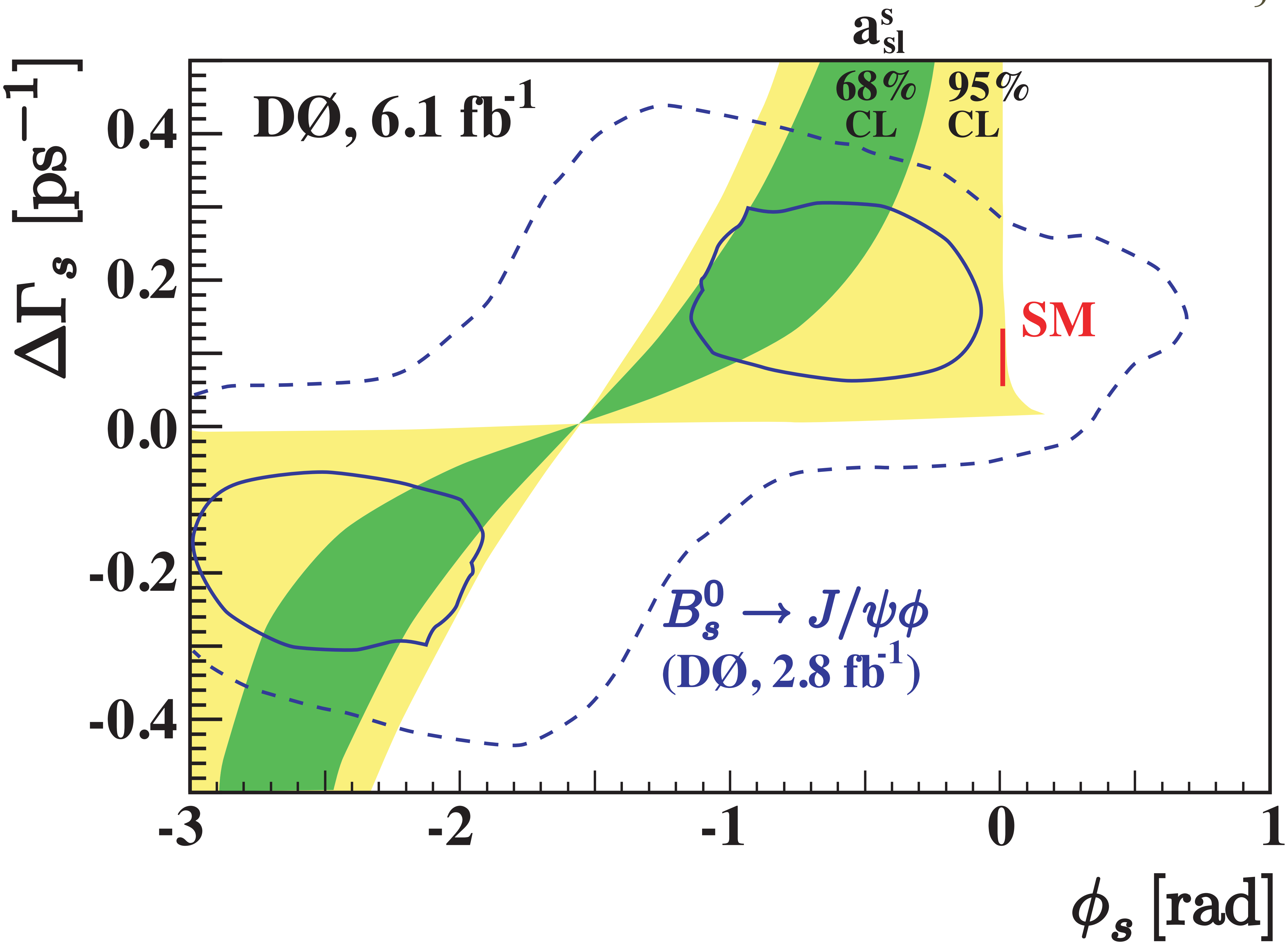
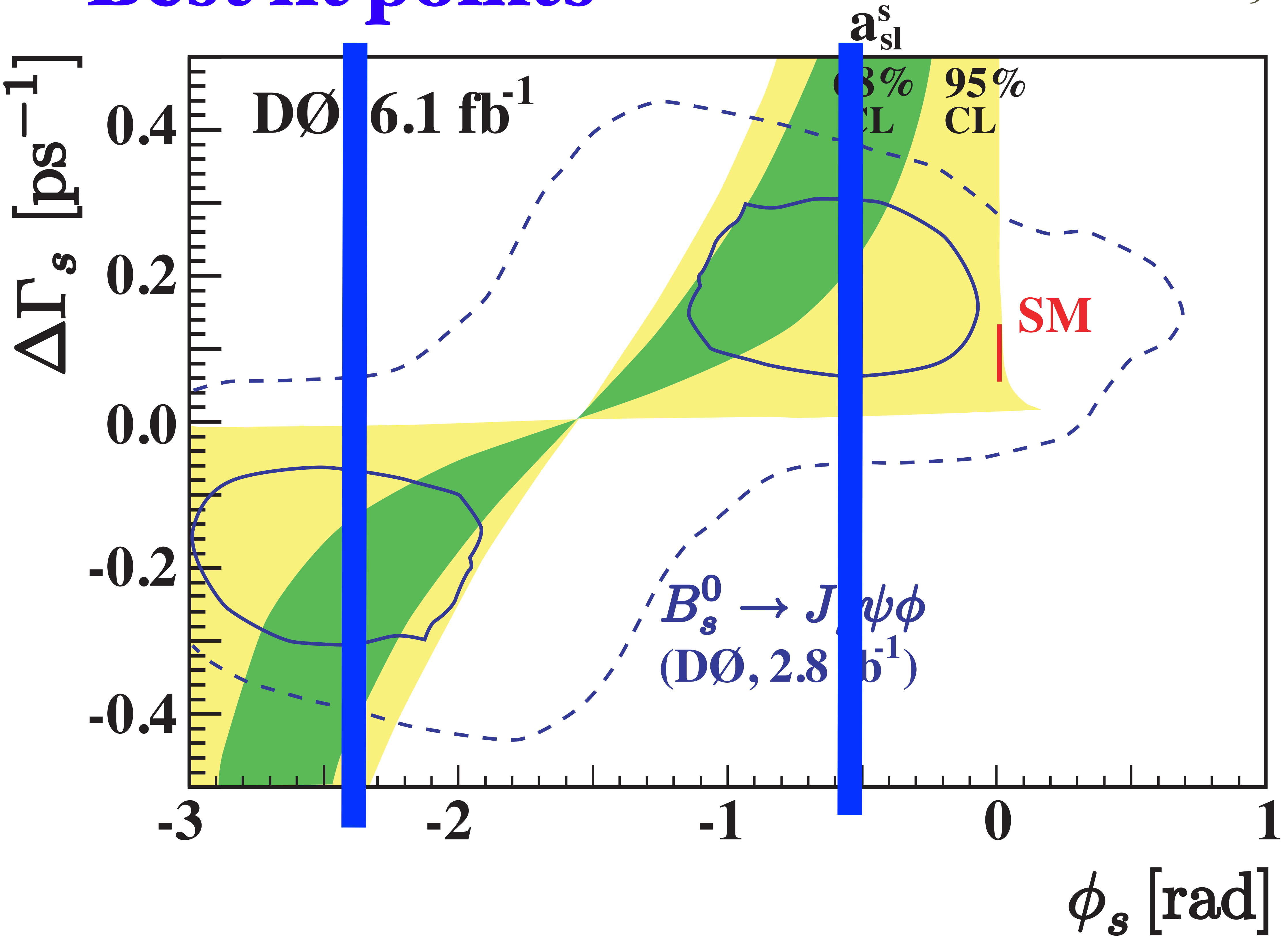
arXiv:1005.2757



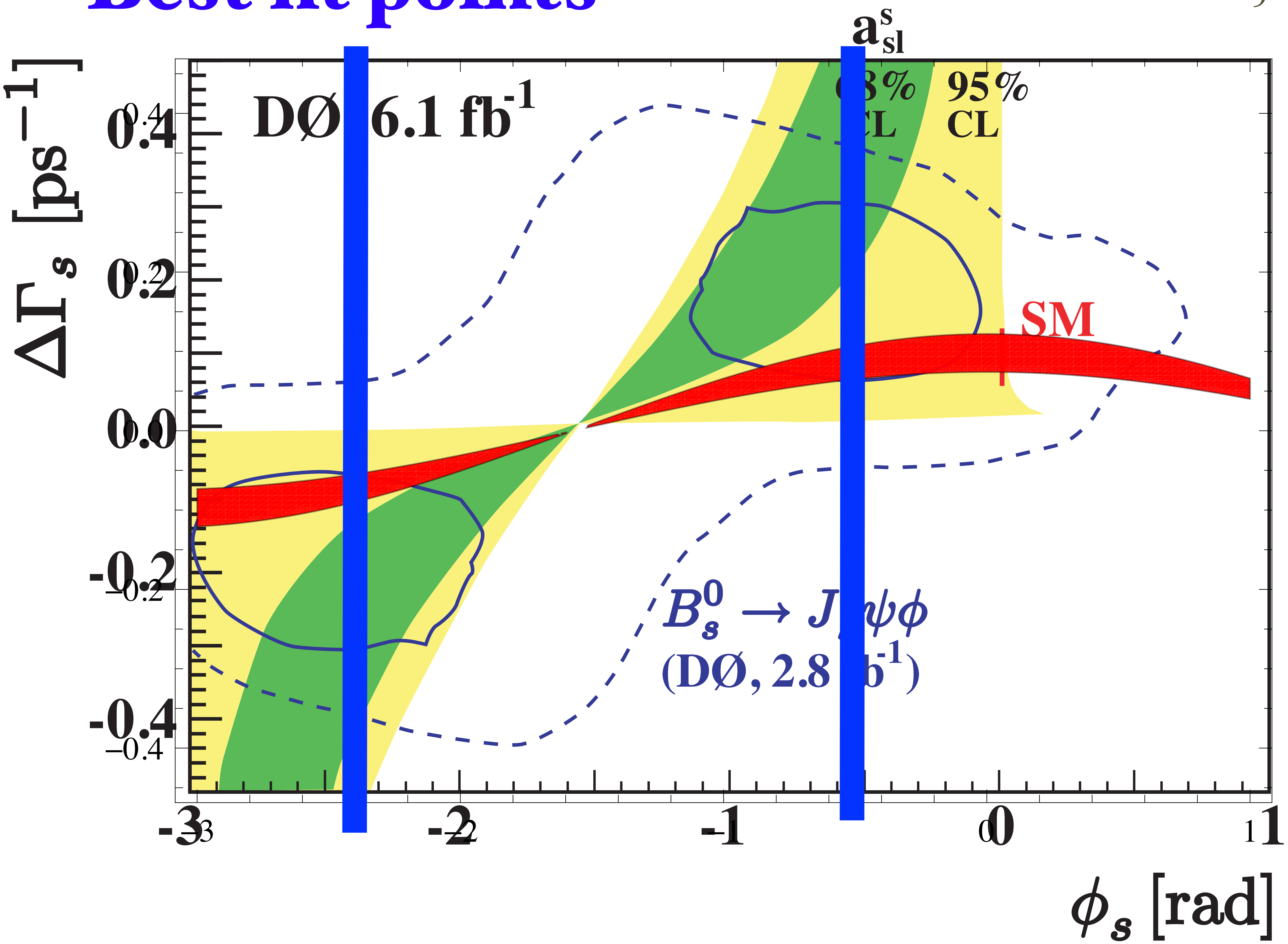
Best fit points

arXiv:1005.2757



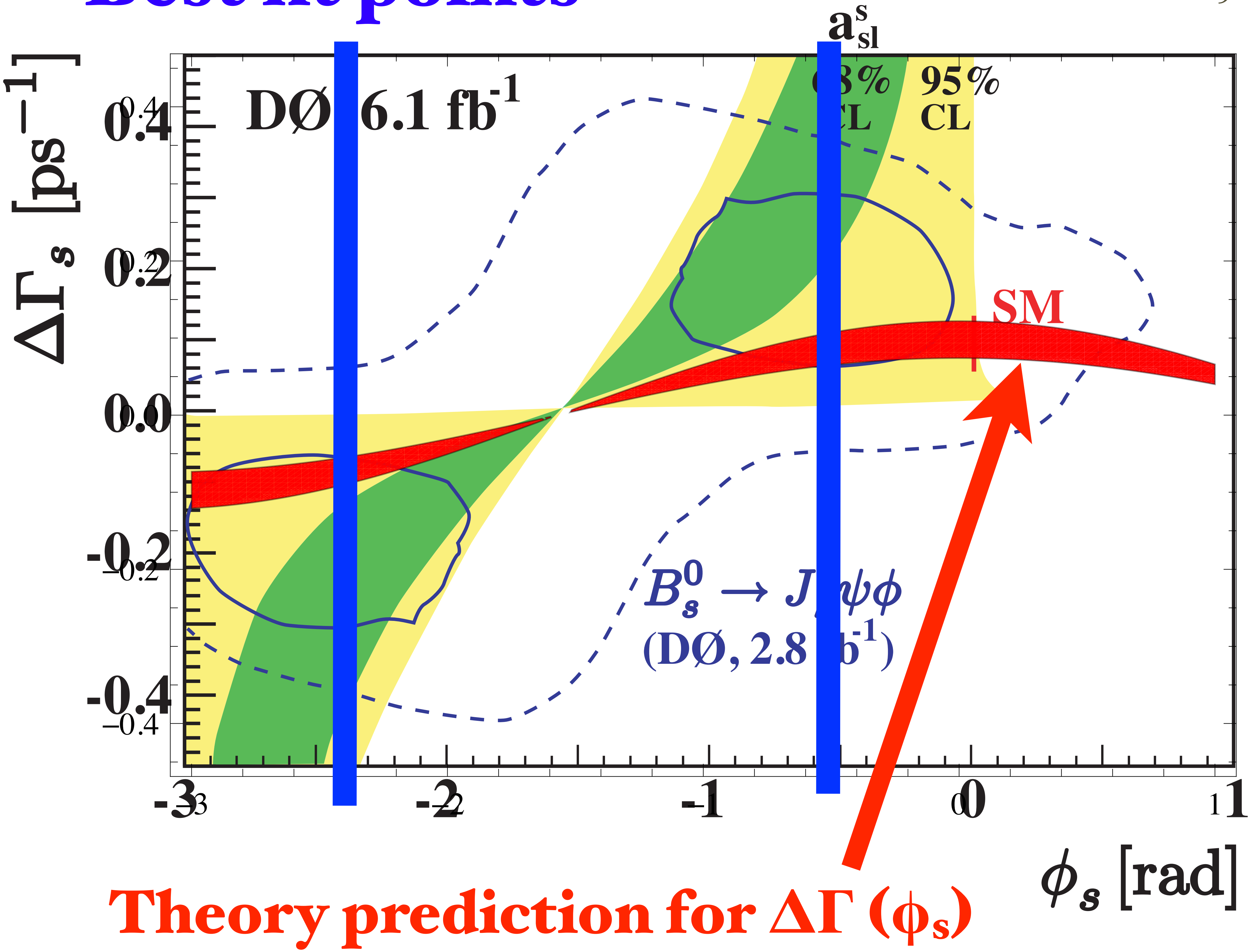
Best fit points

arXiv:1005.2757



Best fit points

arXiv:1005.2757



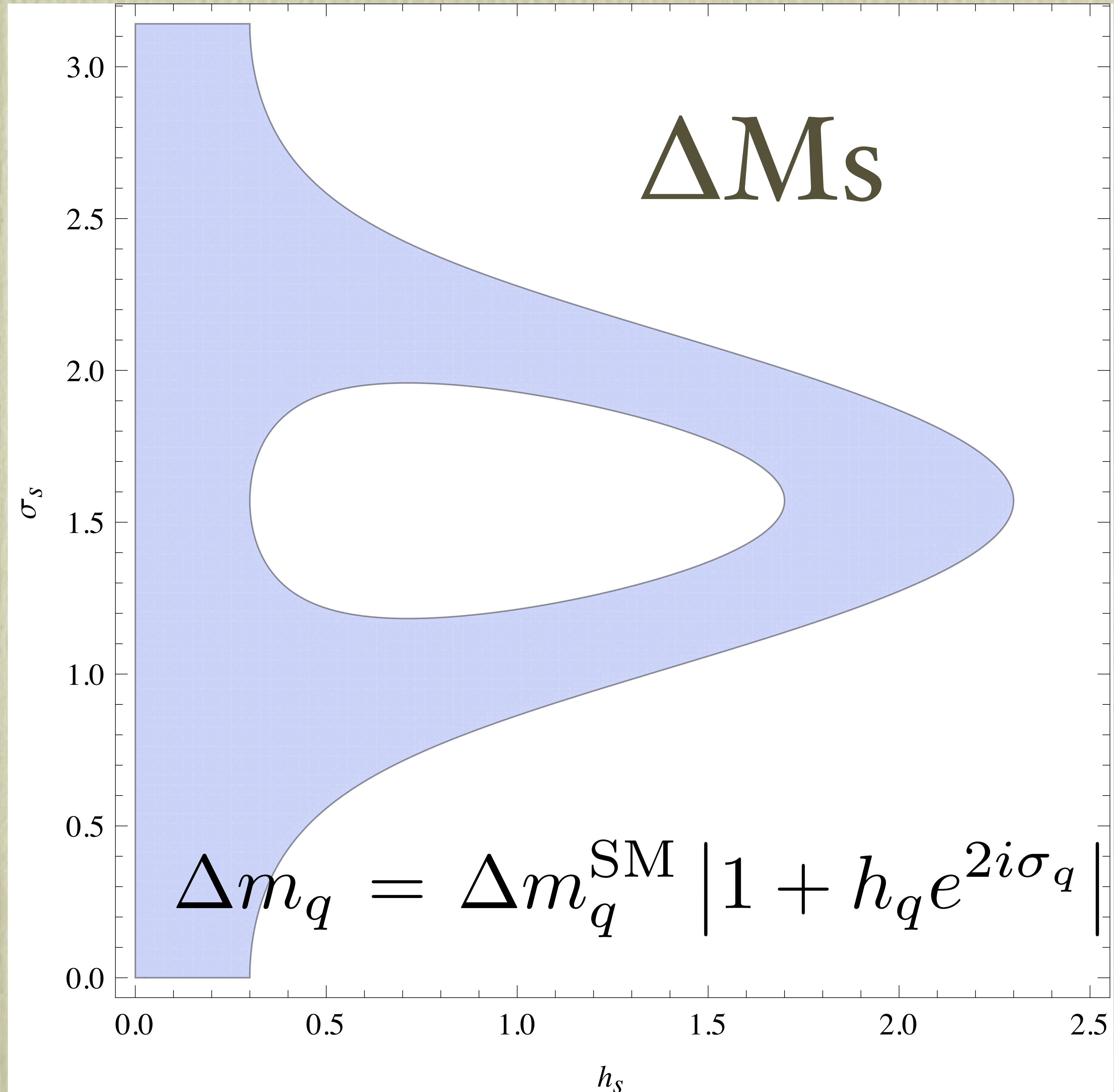
$$\Delta\Gamma_q = 2\left|\Gamma_q^{12}\right| \cos\phi_q \quad {}_3\, |\Gamma_{12}^s|^{SM} = (0.049 \pm 0.012)\mathrm{ps}^{-1}$$

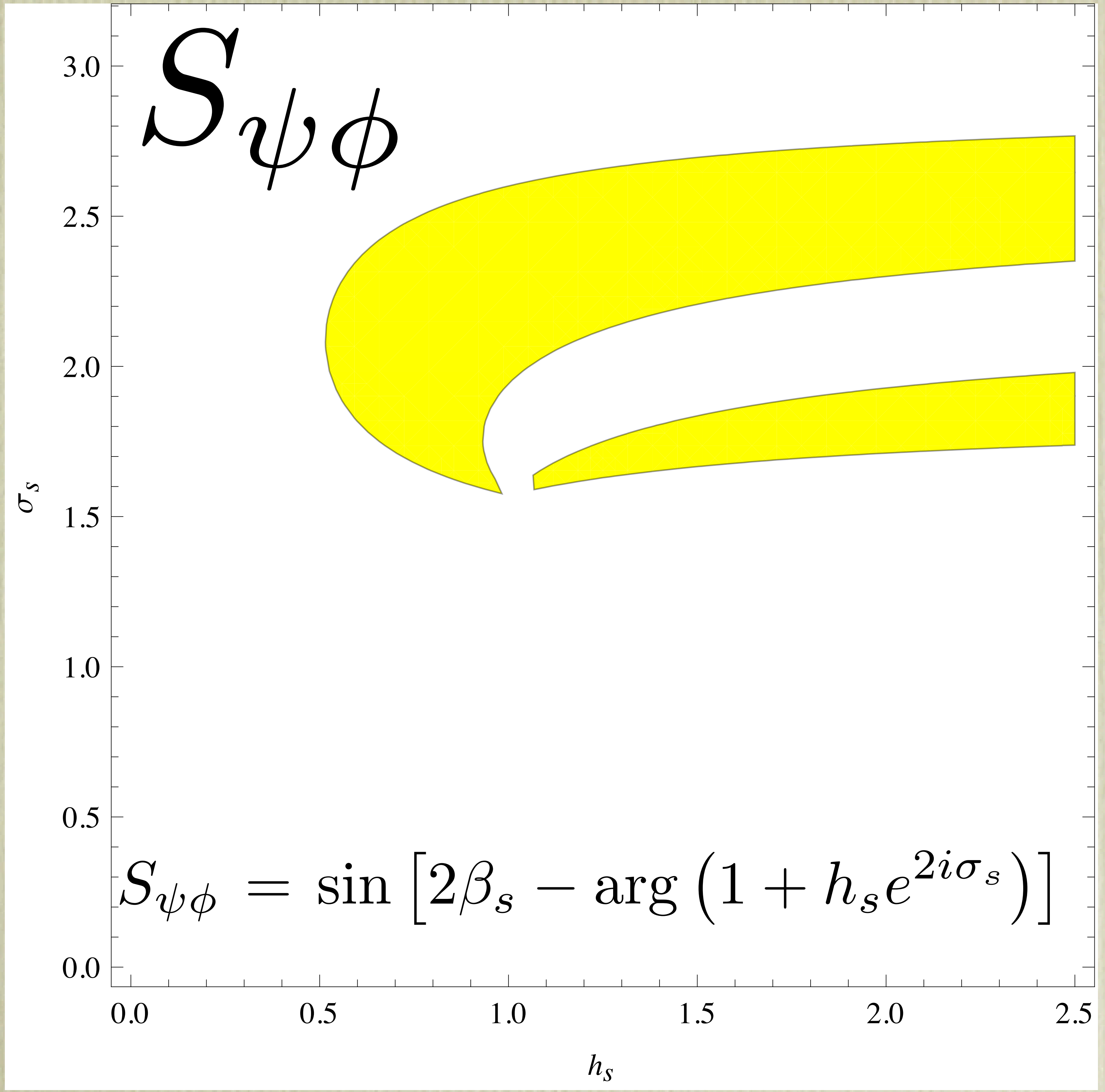
Do the B_s data give a consistent picture?

Disclaimer: home-made plots, intended
to further understanding (~ 1 sigma regions).
For statistically significant analysis look elsewhere
(Experiments, UTfit, CKMfitter, Ligeti et al, ...) .

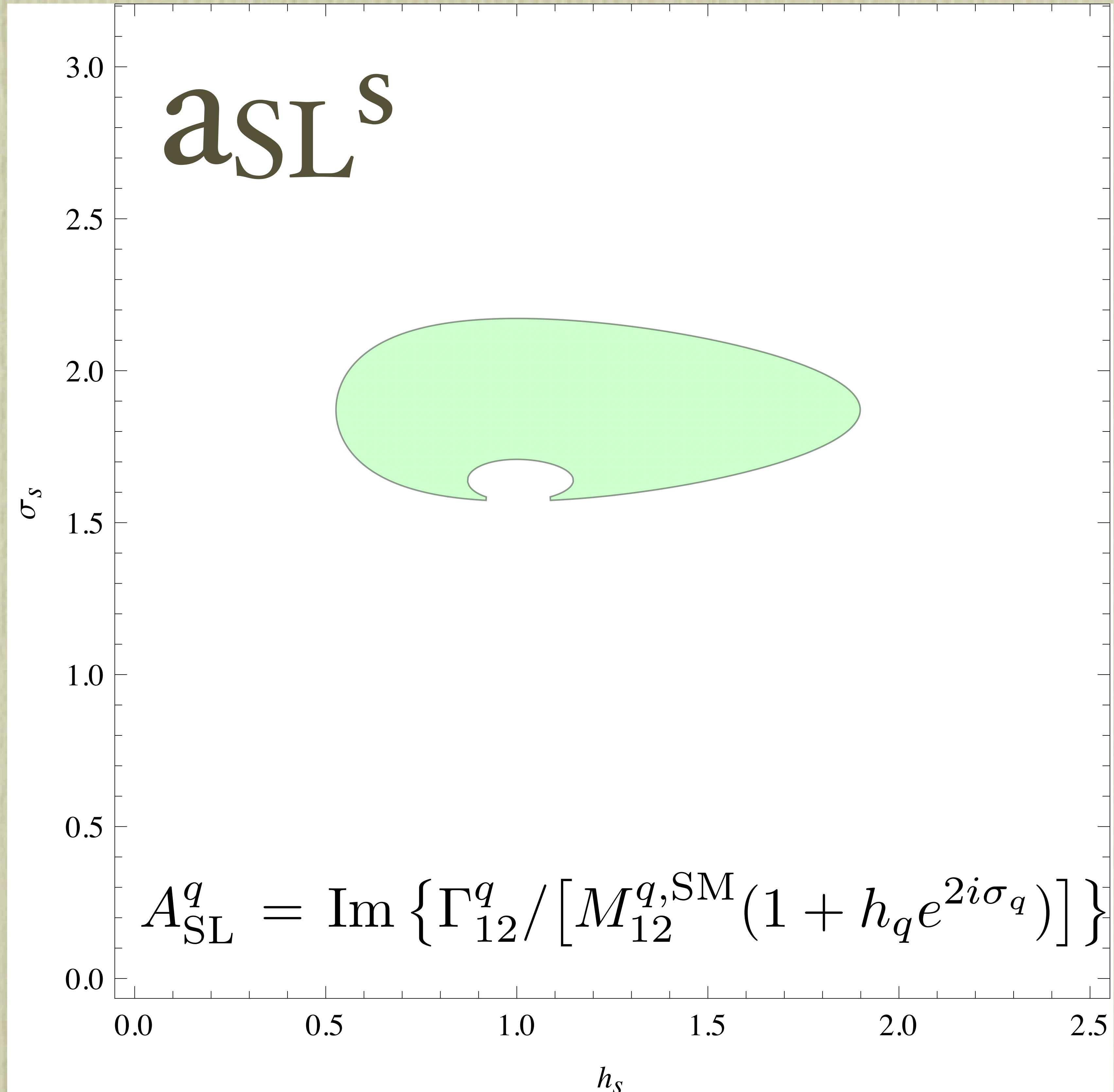
Main players, see Gudrun's introduction

$$\begin{aligned}
\Delta m_q &= \Delta m_q^{\rm SM} \left|1 + h_q e^{2i\sigma_q}\right| , \\
\Delta\Gamma_s &= \Delta\Gamma_s^{\rm SM} \, \cos\left[\,\arg\left(1 + h_s e^{2i\sigma_s}\right)\right] , \\
A_{\rm SL}^q &= {\rm Im}\left\{\Gamma_{12}^q / \left[M_{12}^{q,{\rm SM}}(1 + h_q e^{2i\sigma_q})\right]\right\} , \\
S_{\psi K} &= \sin\left[2\beta + \arg\left(1 + h_d e^{2i\sigma_d}\right)\right] , \\
S_{\psi\phi} &= \sin\left[2\beta_s - \arg\left(1 + h_s e^{2i\sigma_s}\right)\right] .
\end{aligned}$$


ΔMs
$\Delta m_q = \Delta m_q^{\rm SM} \left|1 + h_q e^{2i\sigma_q}\right|$
σ_s
h_s
0.0
0.5
1.0
1.5
2.0
2.5
3.0

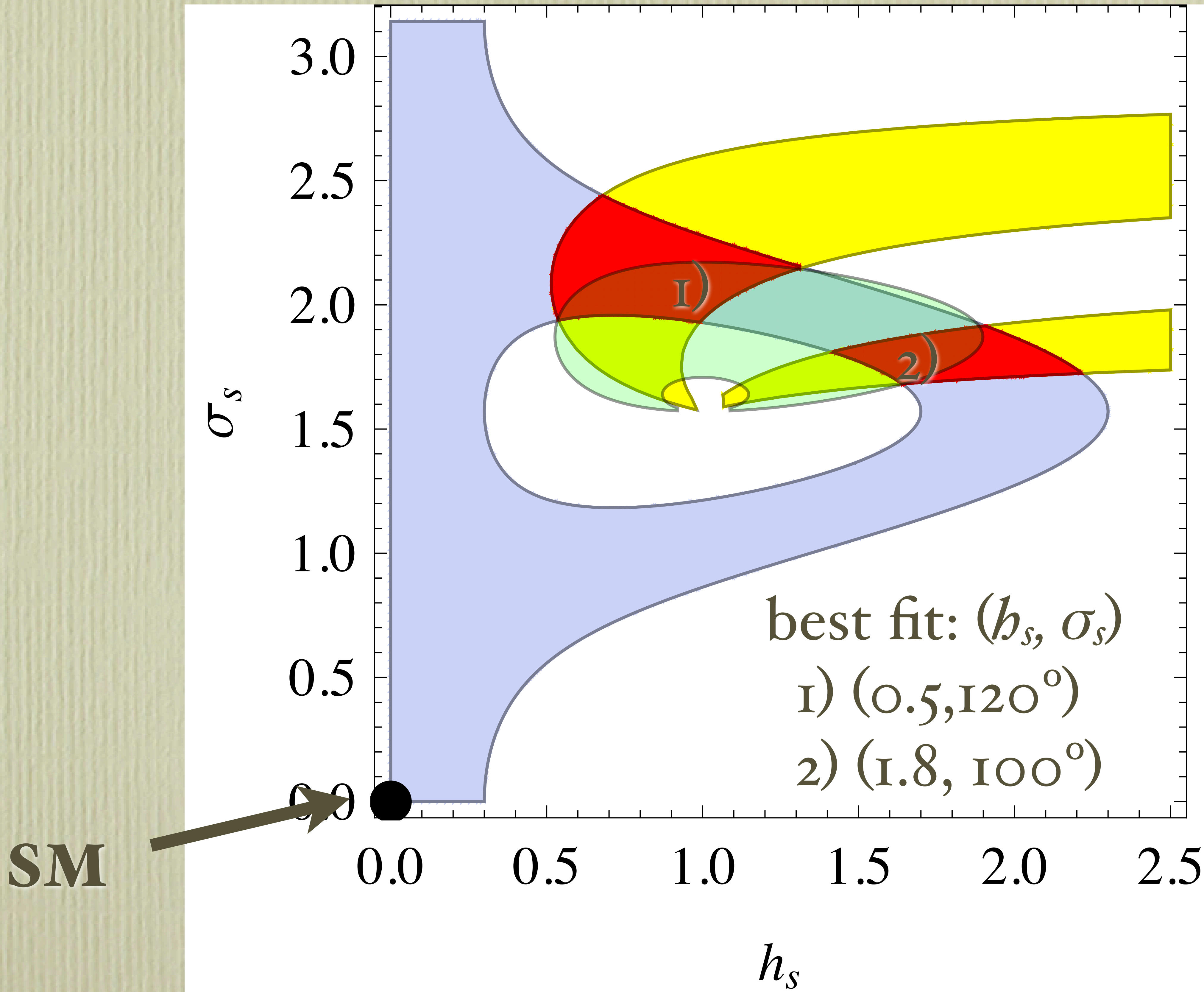


combined DØ/CDF (w/o new CDF)



$a_{SL}{}^{s}$
$A_{\rm SL}^{q} = {\rm Im}\left\{\Gamma_{12}^{q}/\left[M_{12}^{q,{\rm SM}}(1+h_q e^{2i\sigma_q})\right]\right\}$
σ_s
h_s
0.0
0.5
1.0
1.5
2.0
2.5
3.0

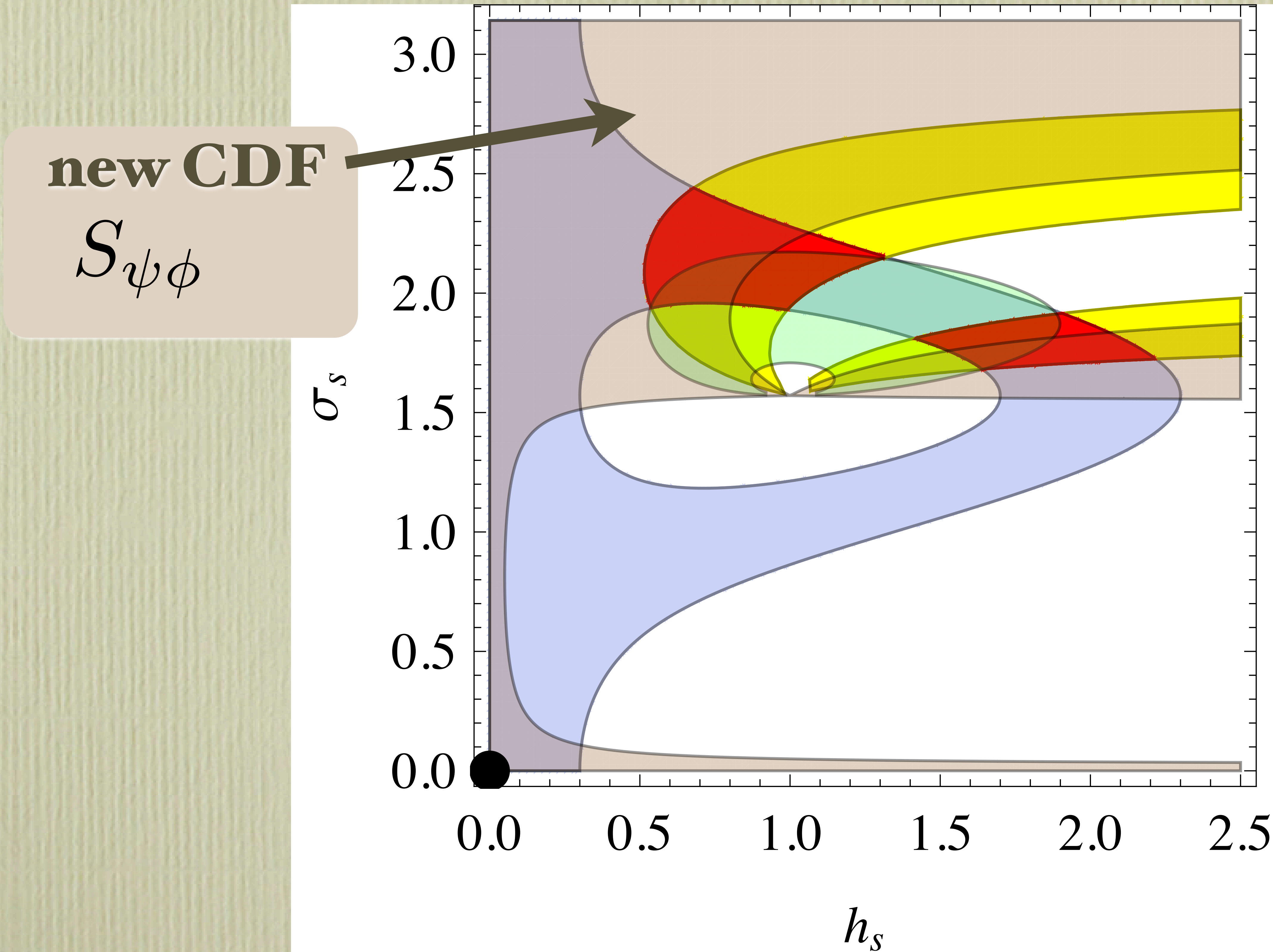
new DØ

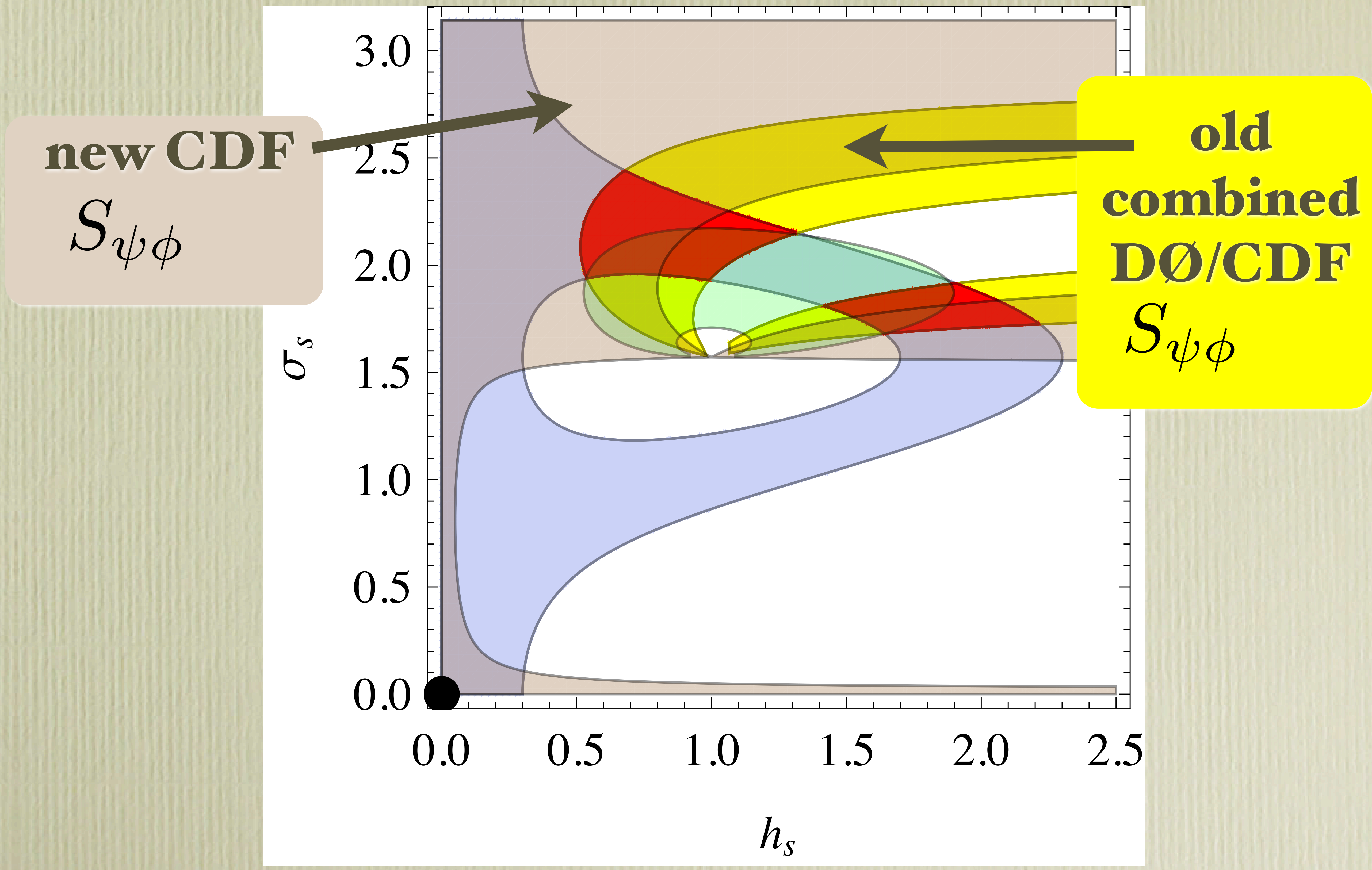


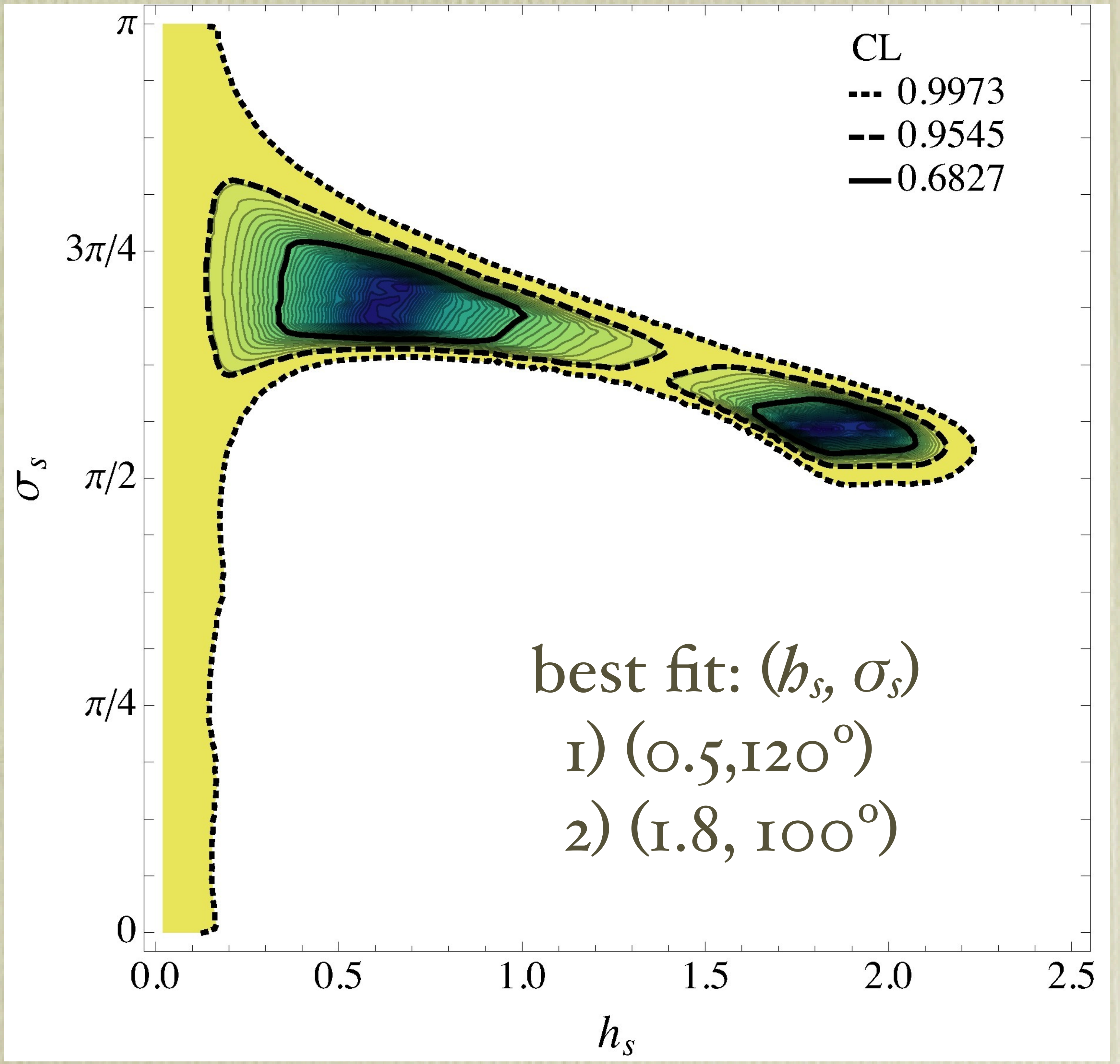
3.0
2.5
2.0
1.5
1.0
0.5
0.0
σ_s
0.0
0.5
1.0
1.5
2.0
2.5
h_s
1)
2)
best fit: (h_s, σ_s)
1) (0.5,120°)
2) (1.8, 100°)
SM

Including the recent CDF result for $S_{\psi\phi}$ ....

ref. FPCP 2010

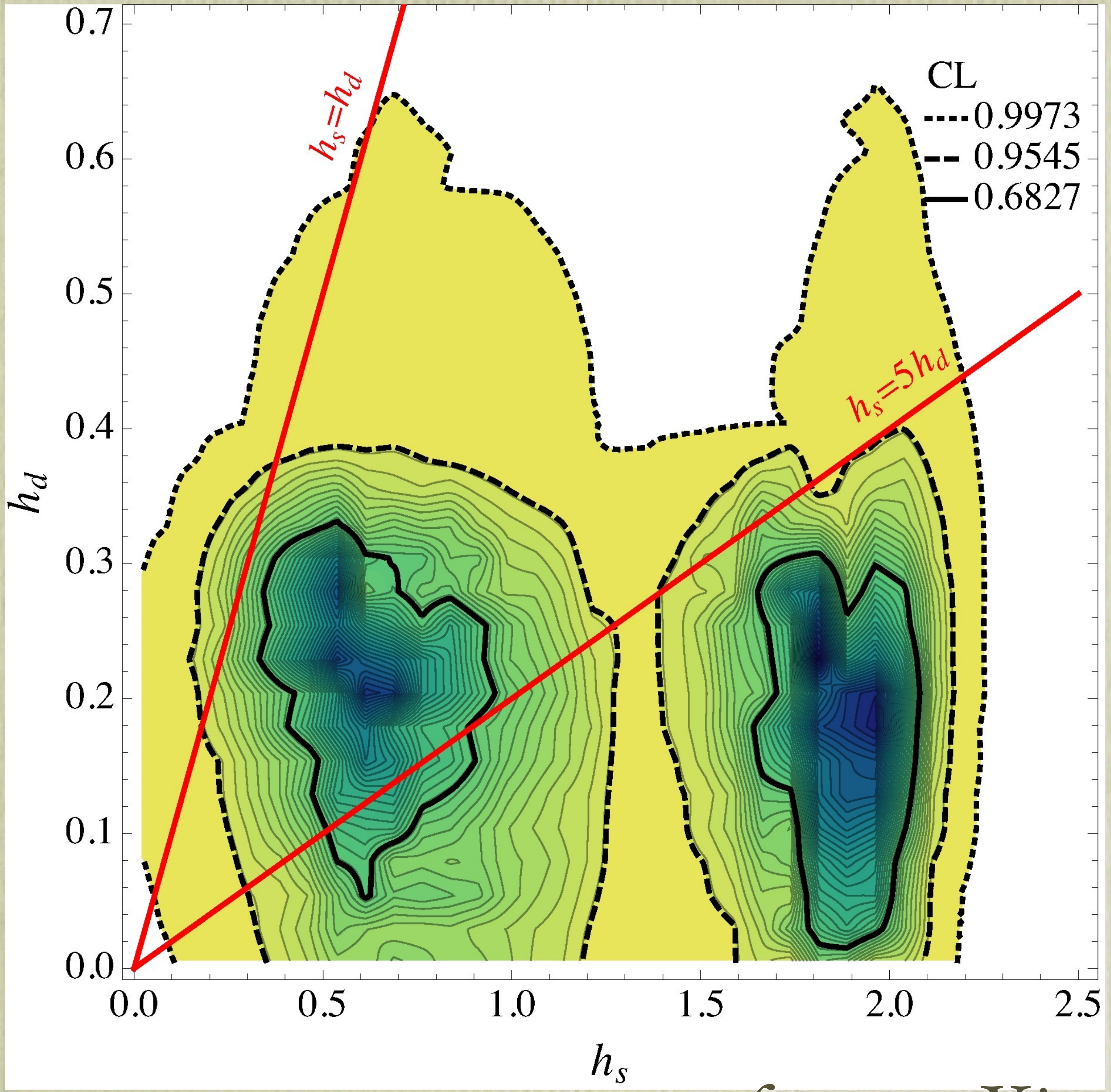

new CDF
$S_{\psi\phi}$
3.0
2.5
2.0
1.5
1.0
0.5
0.0
σ_s
0.0
0.5
1.0
1.5
2.0
2.5
h_s


new CDF
$S_{\psi\phi}$
old
combined
DØ/CDF
$S_{\psi\phi}$
σ_s
h_s
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5



from: arXiv 1006.0432

B_d vs. B_s system



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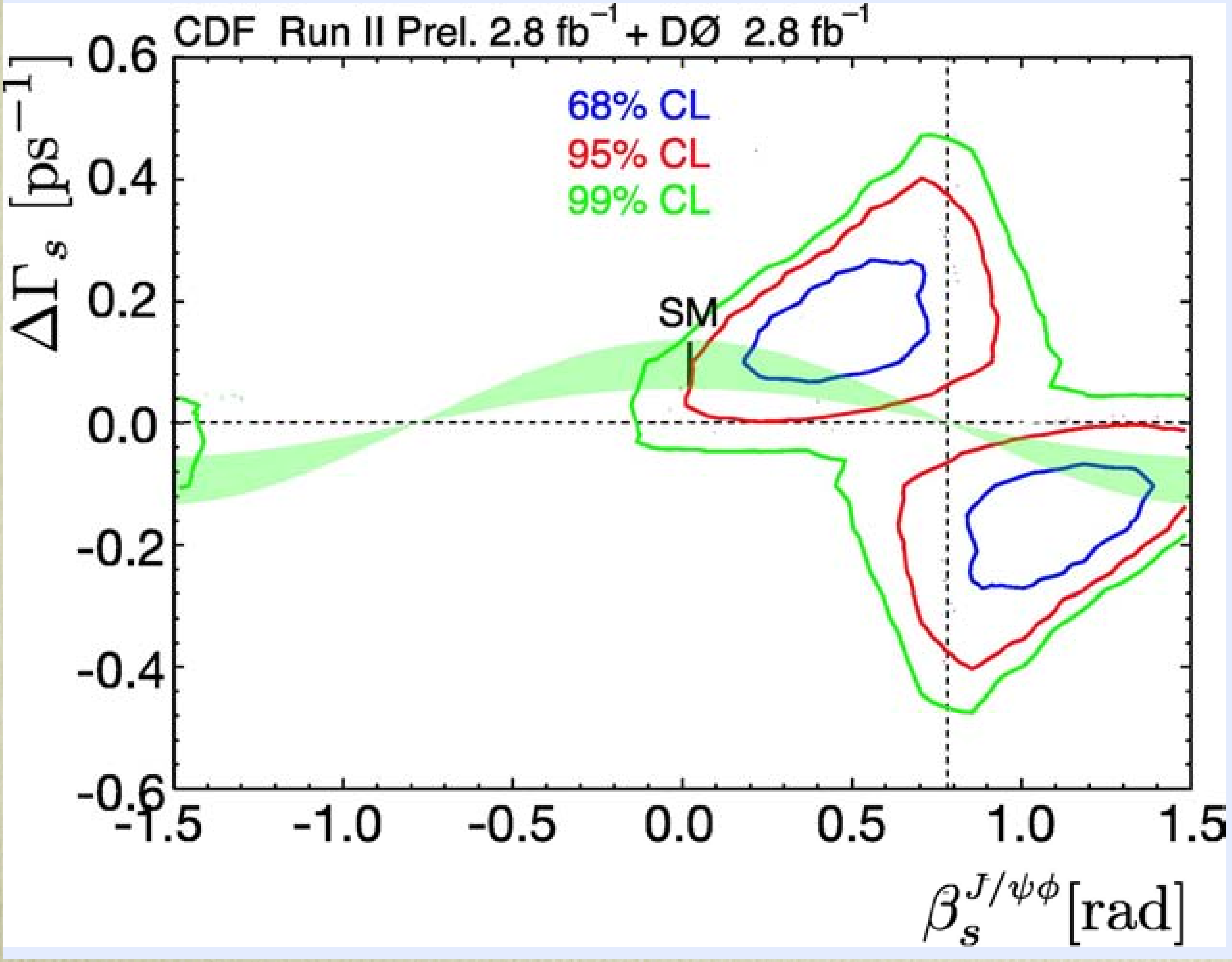
Why are theorists slightly worried?

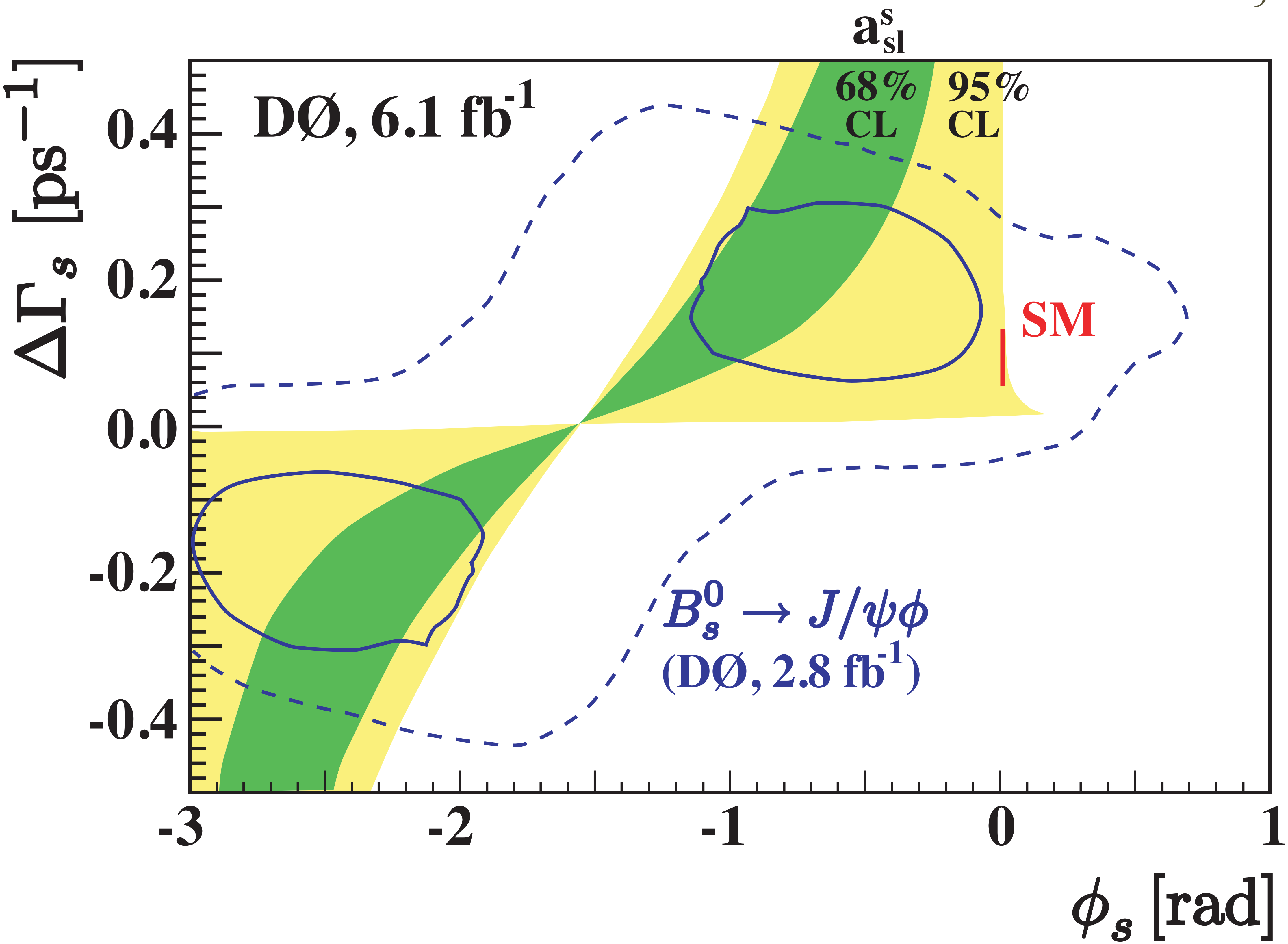

CDF Run II Prel. 2.8 fb^{-1} + DØ 2.8 fb^{-1}
68% CL
95% CL
99% CL
SM
$\Delta\Gamma_s$ [ps^{-1}]
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
$\beta_s^{J/\psi\phi}$[rad]

$$\Delta M_s = 2|M_{12}^s|$$

$$\Delta\Gamma_s = 2|\Gamma_{12}^s| \cos\phi^s$$

$$a_{\mathrm{sl}}^q = \frac{|\Gamma_{12}^q|}{|M_{12}^q|} \sin\phi^q$$

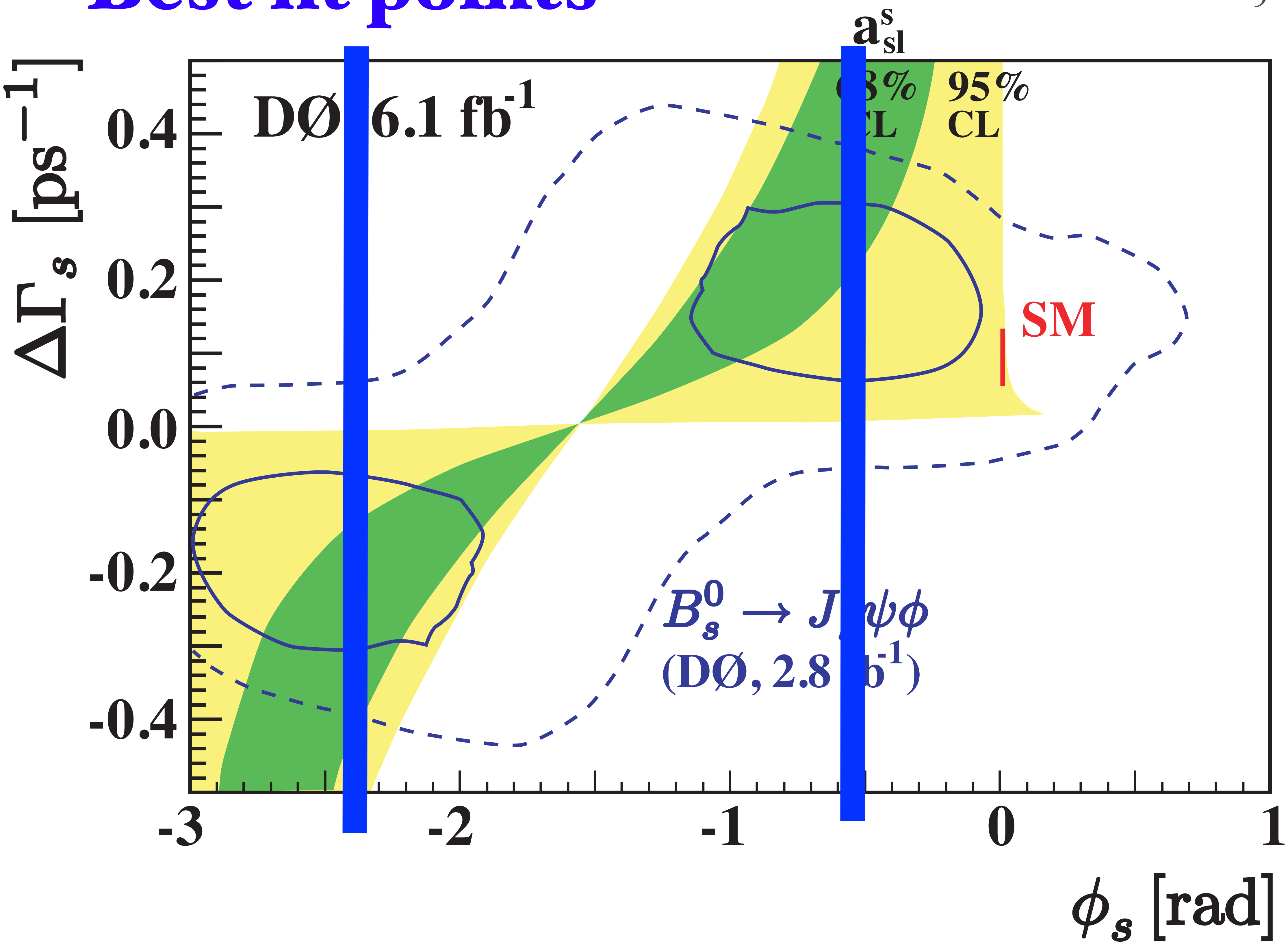
$$(a_{sl}^s)^{exp} = \frac{\Delta\Gamma_s}{\Delta M_s^{exp}} \tan\phi_s$$



a_{sl}^s
68% CL
95% CL
DØ, 6.1 fb^{-1}
0.4
0.2
0.0
-0.2
-0.4
$\Delta\Gamma_s$ [ps^{-1}]
SM
$B_s^0 \rightarrow J/\psi\phi$
(DØ, 2.8 fb^{-1})
-3
-2
-1
0
1
ϕ_s [rad]

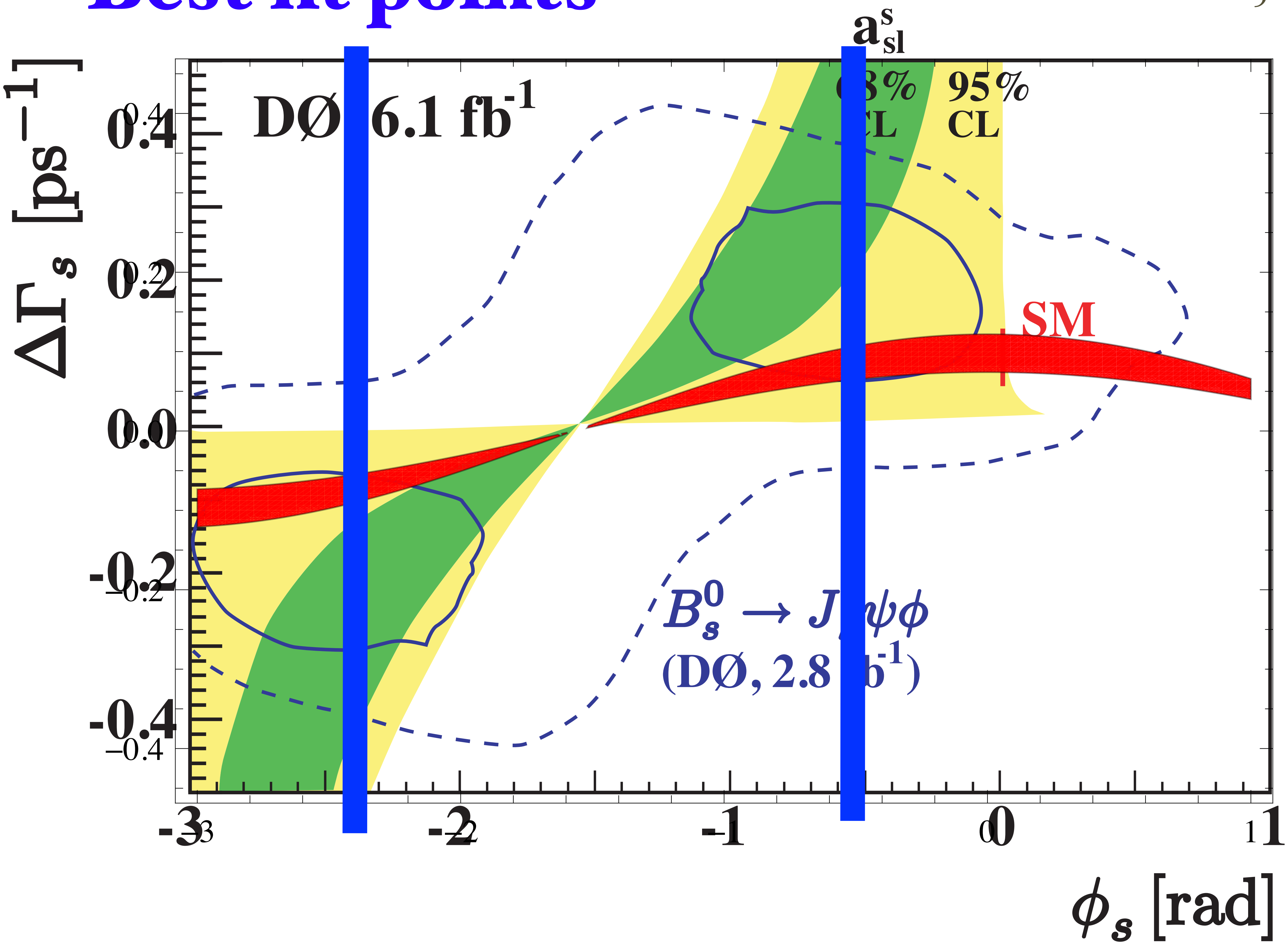
Best fit points

arXiv:1005.2757



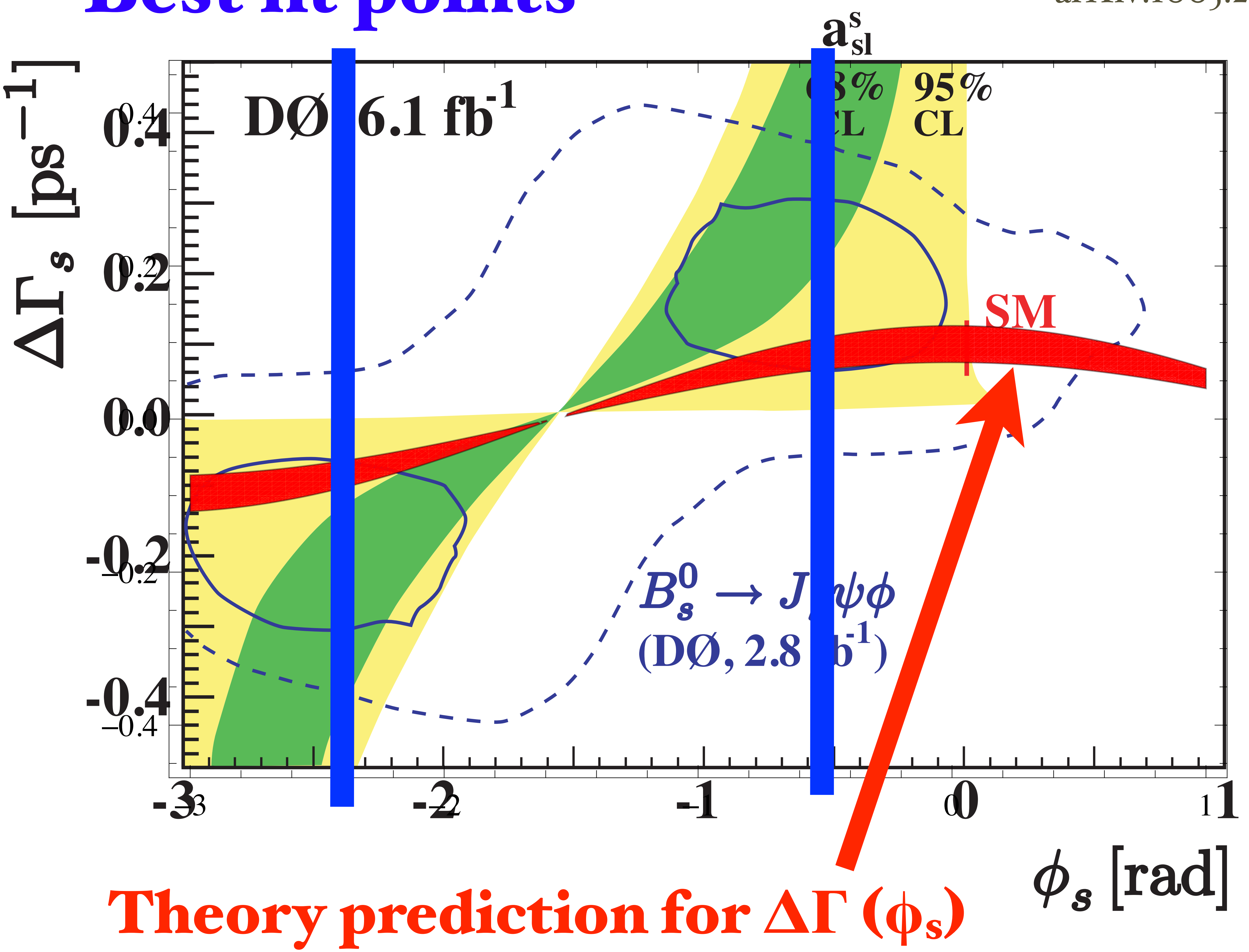
Best fit points

arXiv:1005.2757



Best fit points

arXiv:1005.2757



$$\Delta\Gamma_q = 2\left|\Gamma_q^{12}\right| \cos\phi_q$$

$$|\Gamma_{12}^s|^{SM} = (0.049 \pm 0.012)\text{ps}^{-1}$$

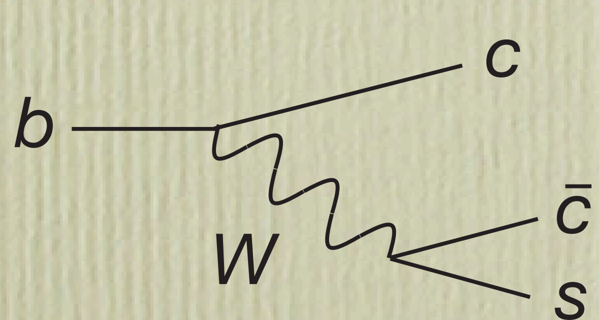
Discussion about $|\Gamma_{12}|$

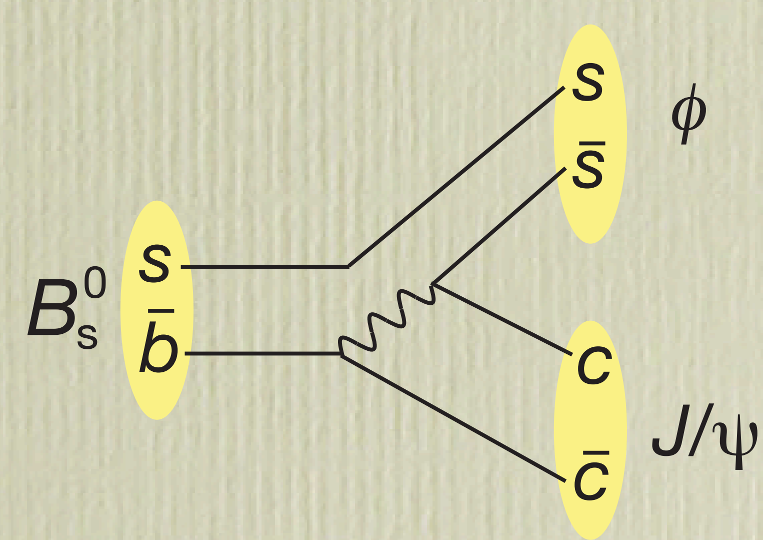
$$i\,\frac{\mathrm{d}}{\mathrm{d}\,t}\begin{pmatrix}|B(t)\rangle\\|\overline{B}(t)\rangle\end{pmatrix}=\left(M-i\,\frac{\Gamma}{2}\right)\begin{pmatrix}|B(t)\rangle\\|\overline{B}(t)\rangle\end{pmatrix}$$

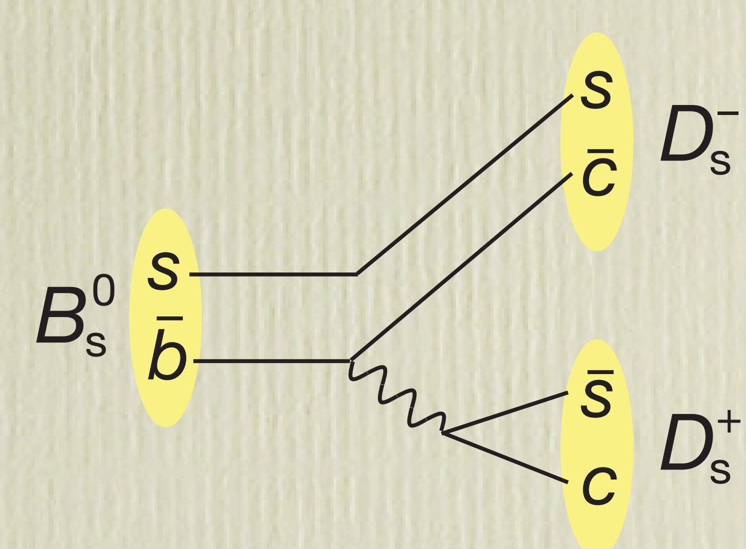
$$\phi=\arg\left(-\frac{M_{12}}{\Gamma_{12}}\right)$$

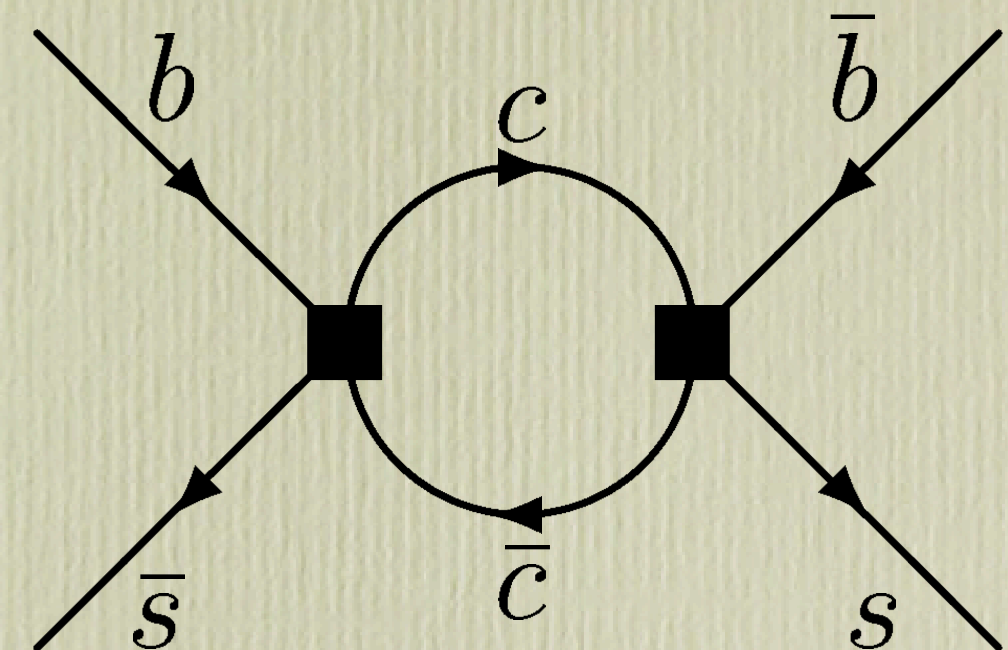
$$\Delta m=2\,|M_{12}|\left[1+\mathcal{O}\left(\left|\frac{\Gamma_{12}}{M_{12}}\right|^2\right)\right],$$

$$\Delta\Gamma=2\,|\Gamma_{12}|\cos\phi\left[1+\mathcal{O}\left(\left|\frac{\Gamma_{12}}{M_{12}}\right|^2\right)\right].$$









$$\Gamma_{12} = \frac{1}{2m_{B_s}} \sum_X (2\pi)^4\, \delta^4(p_{B_s} - p_X)\, \langle B_s|\, H^{|\Delta B|=1}\, |X\rangle\, \langle X|\, H^{|\Delta B|=1}\, |\overline{B}_s\rangle$$

$$= \frac{1}{2m_{B_s}} \,\mathrm{Im}\, \langle B_s|\, i \int \mathrm{d}^4x\, T\left\{H^{|\Delta B|=1}(x)\, H^{|\Delta B|=1}(0)\right\} |\overline{B}_s\rangle\,.$$

Exclusive determination

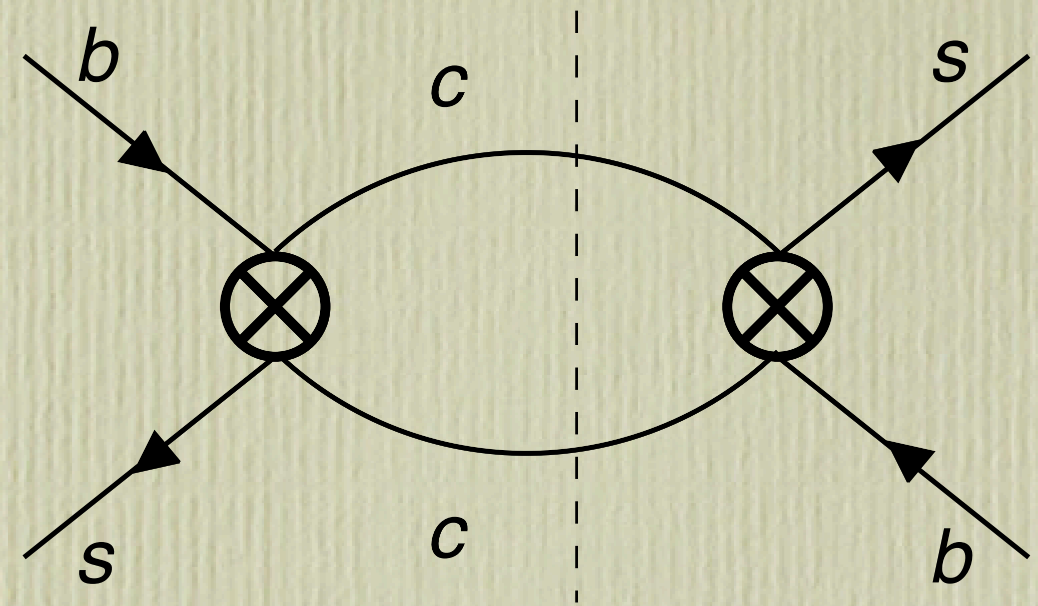
Decay mode	Contribution to $\Delta\Gamma/\Gamma$(%)
$B_1 \to D_s\bar{D}_s$	3.13
$B_1 \to D_s^*\bar{D}_s^*$	7.04
$B_1 \to D_s\bar{D}_s^* + \bar{D}_sD_s^*$	4.40
$B_2 \to D_s\bar{D}_s^* + \bar{D}_sD_s^*$	0.02
$B_2 \to D_s^*\bar{D}_s^*$	0.19
$B_1 \to \eta_c\eta$	0.13
$B_1 \to \eta_c\eta'$	0.01
$B_1 \to \psi\eta$	0.06
$B_1 \to \psi\eta'$	0.00
$B_1 \to \eta_c\varphi$	0.05
$B_1 \to \psi\varphi$	0.31
$B_2 \to \psi\varphi$	0.01
$B_1 \to \psi'\eta$	0.02
$B_1 \to \psi'\eta'$	0.00
$B_1 \to \psi'\varphi$	0.21
$B_2 \to \psi'\varphi$	0.01
$B_1 \to \chi\eta$	0.01
$B_1 \to \chi\eta'$	0.00
$B_1 \to \chi\varphi$	0.02
$B_2 \to \chi\varphi$	0.00

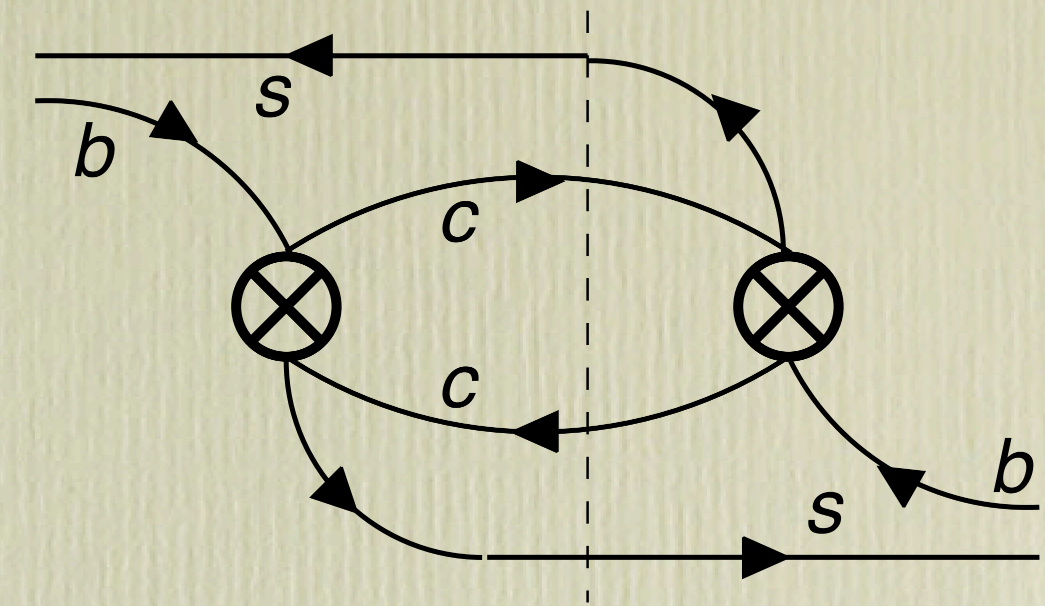
$$(\Delta\Gamma/\Gamma)_{\text{exclusive}} \cong 0.15$$

Aleksan et. al. '93

Use quark-hadron duality

- Observe: $m_B >> \Lambda_{QCD}$





$$\Delta\Gamma_s = \left(\frac{f_{B_s}}{240\,\mathrm{MeV}}\right)^2 \Big[(0.105 \pm 0.016)B + (0.024 \pm 0.004)\tilde{B}'_S$$
$$- \Big((0.030 \pm 0.004)B_{\tilde{R}_2} - (0.006 \pm 0.001)B_{R_0} + 0.003 B_R\Big)\Big]\ \mathrm{ps}^{-1}$$

Lenz&Nierste ’06, many others

Exhausting ranges in ΔΓ: can we explain it?

$$\Delta\Gamma_s = \left(\frac{f_{B_s}}{240\,\mathrm{MeV}}\right)^2 \Big[(0.105 \pm 0.016)B + (0.024 \pm 0.004)\tilde{B}'_S - \Big((0.030 \pm 0.004)B_{\tilde{R}_2} - (0.006 \pm 0.001)B_{R_0} + 0.003 B_R\Big)\Big]\ \mathrm{ps}^{-1}$$

Hadronic inputs needed

We don't dare to disclose our experimental numerics.

$$M_{12}^{d,s} = \left(M_{12}^{d,s}\right)^{\rm SM} \left(1 + h_{d,s}\, e^{2i\sigma_{d,s}}\right)$$

Maurizio sometimes used an alternative parameterization:

$$1 + h_s e^{2i\sigma_s} \equiv C_{B_s} e^{2i\varphi_{B_s}}$$

$$
\begin{aligned}
\Delta m_q &= \Delta m_q^{\rm SM} \left|1 + h_q e^{2i\sigma_q}\right|, \\
\Delta\Gamma_s &= \Delta\Gamma_s^{\rm SM} \, \cos\left[\,\arg\left(1 + h_s e^{2i\sigma_s}\right)\right], \\
A_{\rm SL}^q &= {\rm Im}\left\{\Gamma_{12}^q / \left[M_{12}^{q,{\rm SM}} (1 + h_q e^{2i\sigma_q})\right]\right\}, \\
S_{\psi K} &= \sin\left[2\beta + \arg\left(1 + h_d e^{2i\sigma_d}\right)\right], \\
S_{\psi\phi} &= \sin\left[2\beta_s - \arg\left(1 + h_s e^{2i\sigma_s}\right)\right].
\end{aligned}
$$

Alternative: marginalize over

$|\Gamma_{12}|$ = 0.0 ... 0.25 1/ps

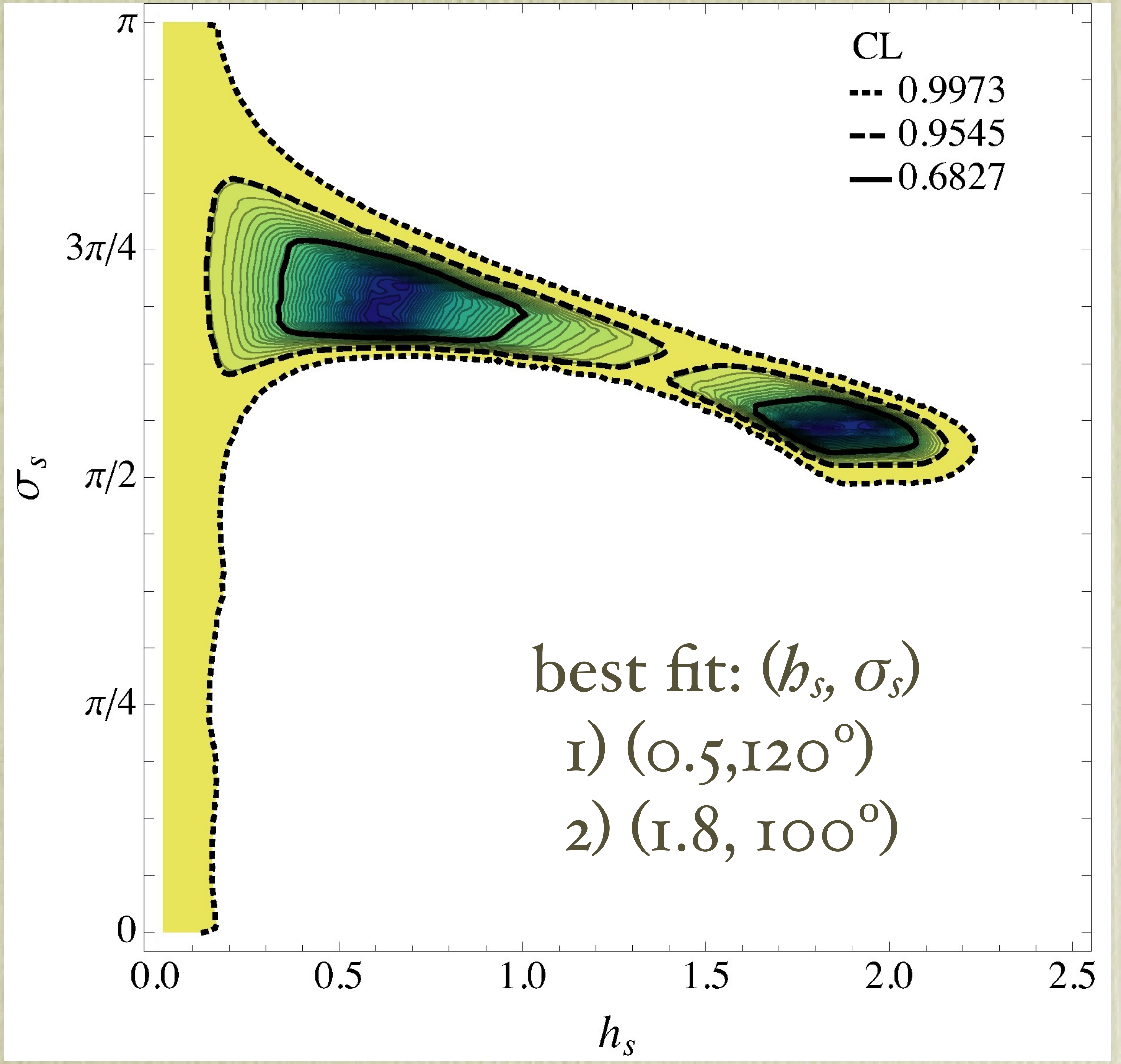
vs $|\Gamma^s_{12}|^{\rm SM} \;=\; (0.049 \pm 0.012) {\rm ps}^{-1}$

at best-fit points need

$|\Gamma_{12}|^{fit}$ = 2.5 x $|\Gamma_{12}|^{theory}$

If we don't do this, discrepancy remains, but fit worse.

from: arXiv 1006.0432



from: arXiv 1006.0432

New (light) physics in $|\Gamma_{12}|$?

$$O^s_{\rm NP} = \bar{b}s\,\bar{\psi}\psi \qquad \frac{\left|\Gamma_{12}^{\rm NP}\right|}{\left|\Gamma_{12}^{\rm SM}\right|} \sim \left(\frac{C^s_{\rm NP}}{|V_{\rm cb}|}\right)^2 \frac{\sqrt{1-2m_\psi/m_b}}{\sqrt{1-2m_c/m_b}}\,.$$

Allowed operators			
B_s		B_d	
$O^s_{\rm NP}$	Constr Γ	$O^d_{\rm NP}$	Constr Γ
$\bar{b}s\bar{u}u$	$K^+\pi^-$, $K^+\pi^0$	$\bar{b}d\bar{u}u$	$\pi^+\pi^-$, $\pi^+\pi^0$
$\bar{b}s\bar{d}d$	$K^0\pi^+$, $K^+\pi^0$	$\bar{b}d\bar{d}d$	$\pi^+\pi^0$
$\bar{b}s\bar{c}c$		$\bar{b}d\bar{c}c$	$X_d\gamma$
$\bar{b}s\bar{s}s$	ϕK^0	$\bar{b}d\bar{s}s$	$\bar{K}^0K^+$, $K^0\bar{K}^0$, $\phi\pi^+$
$\bar{b}s\bar{e}e$	$K^{(*)}e^+e^-$	$\bar{b}d\bar{e}e$	$(\pi,\rho)e^+e^-$
$\bar{b}s\bar{\mu}\mu$	$K^{(*)}\mu^+\mu^-$	$\bar{b}d\bar{\mu}\mu$	$(\pi,\rho)\mu^+\mu^-$
$\bar{b}s\bar{\tau}\tau$		$\bar{b}d\bar{\tau}\tau$	$\tau^+\tau^-$
$\bar{b}s\bar{\nu}\nu$	$K^{(*)}\bar{\nu}\nu$	$\bar{b}d\bar{\nu}\nu$	$(\pi,\rho)\bar{\nu}\nu$
		$\bar{b}d\bar{s}d$	$\bar{K}^0\pi^+$ (unobserved)
		$\bar{b}d\bar{d}s$	$K^0\pi^+$
		$\bar{b}d\bar{c}u$	$D^0\pi^+$
		$\bar{b}d\bar{u}c$	

arXiv 1006.1629

2 Possibilities

$$(\bar{b}_L s_L)(\bar{c}_R c_R)$$

$$(\bar{b} s)(\bar{\tau}\tau)$$

Constrain using life-time ratios

$$\frac{\tau(B_s)}{\tau(B_d)} = 1 \pm O(1\%)\,.$$

theory prediction

$$\frac{\tau(B_s)}{\tau(B_d)} = 0.965 \pm 0.017$$

exp result. At 2 sigma - 5 % possible

New physics proposals

Expect daily updates on the arXiv.

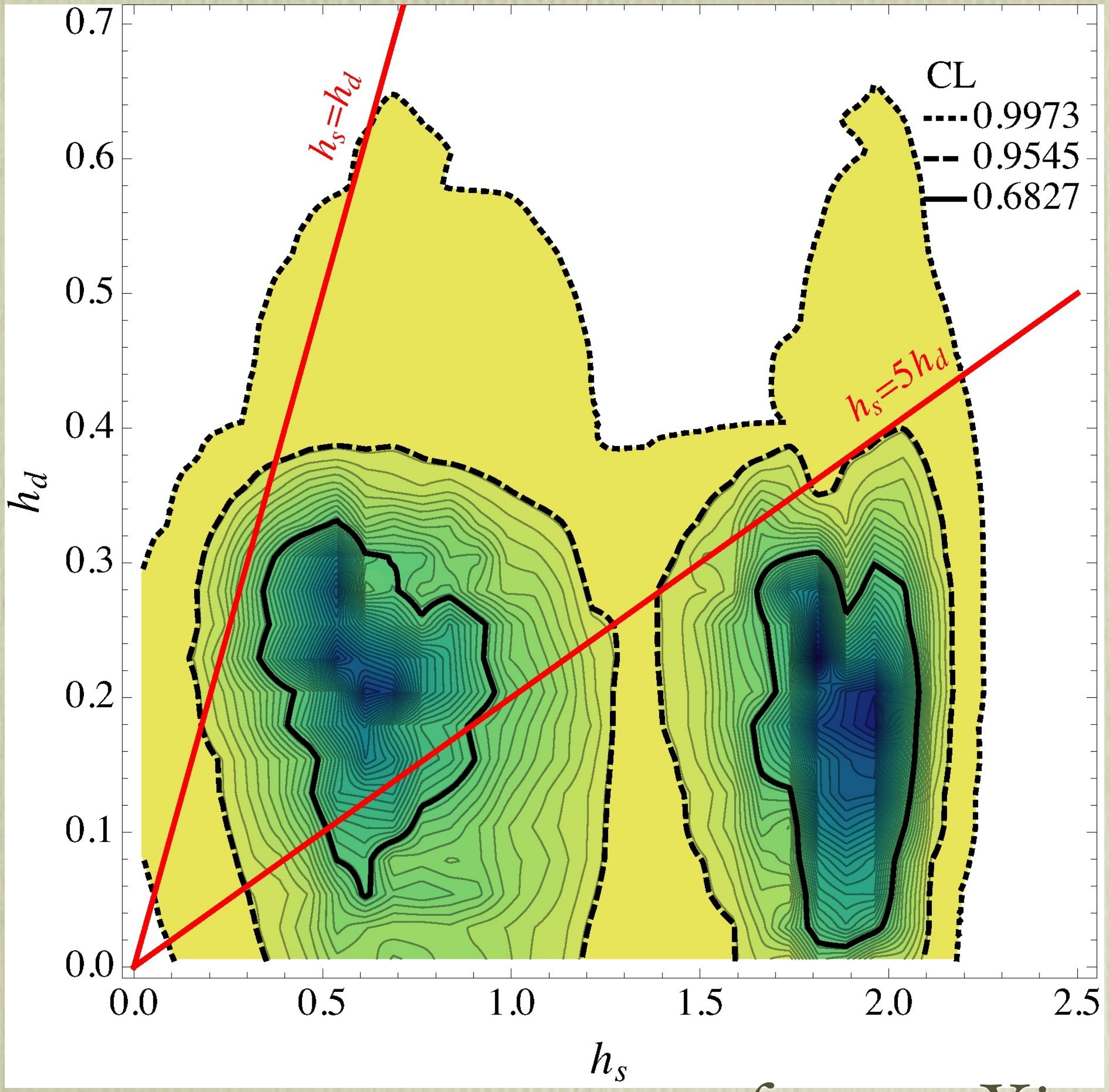
We won't attempt an overview.

2 criteria (apart from new CP phases):

I) need to suppress new physics
- O(1) SM (dress with CKM factors if E~TeV...)

II) don't spoil B_d consistency

B_d vs. B_s system



from: arXiv 1006.0432

Summary

- Recent findings in CPV in B_s mixing are intriguing
- The theory prediction for $\Delta\Gamma$ clashes with the recent Tevatron data
- Assuming $|\Gamma_{12}|$ theoretically much more uncertain than previously thought: data shows consistent (S_{psiphi} vs a_{sl}^s) deviation from the SM
- If $|\Gamma_{12}|$ theoretically under control, consistency suggests new, very light physics to enhance $\Delta\Gamma$
- Could a_{sl}^s be due to non-B physics?