$\bar{B} \to D^* \tau \bar{\nu}$ における D^* 偏極

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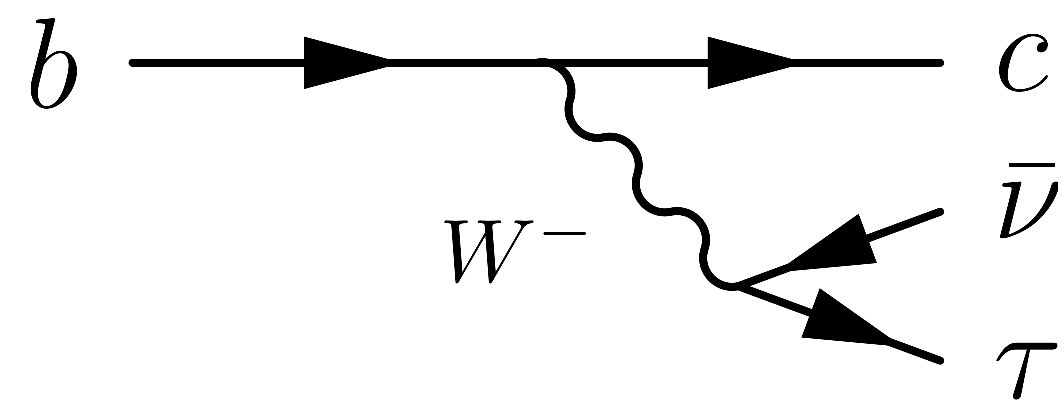
Introduction

Semi-tauonic B decays



$$\bar{B} \to D^{(*)}\tau\bar{\nu}$$

$$\frac{\mathcal{B}(\bar{B} \to D\tau\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D\ell\bar{\nu}_\ell)} = 0.40 \pm 0.08$$

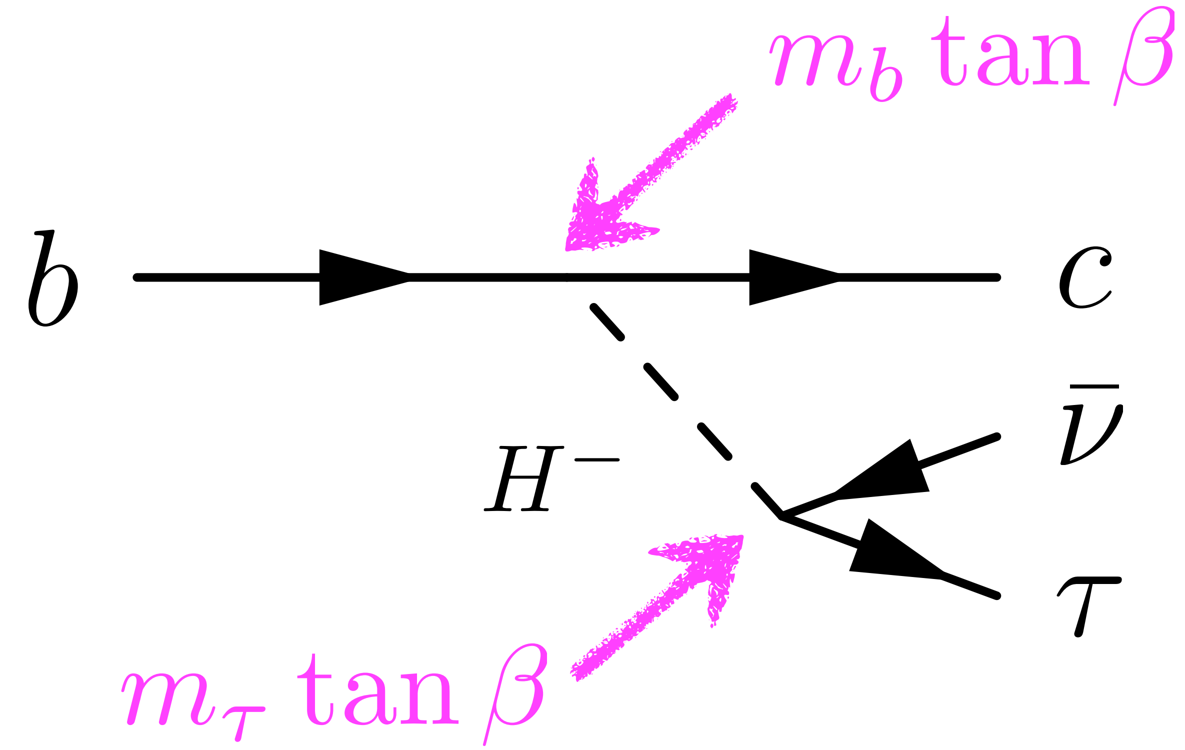
$$\frac{\mathcal{B}(\bar{B} \to D^*\tau\bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^*\ell\bar{\nu}_\ell)} = 0.35 \pm 0.04$$

(BABAR, Belle combined.)

Charged Higgs contribution

W.S. Hou and B. Grzadkowski (1992),
M.T. (1995), ...

Type-II 2HDM (SUSY)



$\propto m_b m_\tau \tan^2\beta$

Sensitive to the charged Higgs if tanβ is large.

D vs D*

	pros	cons
D	simple (2 FFs) sensitive to scalar	less observables less statistics (Br~0.7%)
D*	D* polarization more statistics (Br~1.3%)	complicated (4 FFs) less sensitive to scalar

Form factors in $\bar{B} \to D^* \tau \bar{\nu}$

$$w = v \cdot v'$$

$$\langle D^*(v')|\bar{c}\gamma_\mu b|B(v)\rangle = i h_V(w)\, \varepsilon_{\mu\nu\alpha\beta}\epsilon^{*\nu} v'^\alpha v^\beta$$

$$\begin{aligned}\langle D^*(v')|\bar{c}\gamma_\mu\gamma_5 b|B(v)\rangle &= h_{A_1}(w)\,(1+w)\epsilon^*_\mu \\ &\quad -h_{A_2}(w)\,\epsilon^* \cdot v v_\mu \\ &\quad -h_{A_3}(w)\,\epsilon^* \cdot v v'_\mu\end{aligned}$$

Heavy Quark Limit

$$h_V = h_{A_1} = h_{A_3} = \xi(w),\ \xi(1) = 1$$

$$h_{A_2} = 0$$

Isgur-Wise func.

Parametrization

Caprini et al. (1998)

$$z = \frac{\sqrt{w+1}-\sqrt{2}}{\sqrt{w+1}+\sqrt{2}}, \; r = \frac{m_{D^*}}{m_B}$$

$$h_{A_1}(w) = h_{A_1}(1)\left\{1 - 8\rho^2 z + (53\rho^2 - 15)z^2 - (231\rho^2 - 91)z^3\right\}$$

$$\begin{aligned} R_1(w) &\equiv \frac{h_V(w)}{h_{A_1}(w)} \\ &= R_1(1) - 0.12(w-1) + 0.05(w-1)^2 \\ R_2(w) &\equiv \frac{h_{A_3}(w) + r h_{A_2}(w)}{h_{A_1}(w)} \\ &= R_2(1) + 0.11(w-1) - 0.06(w-1)^2 \end{aligned}$$

$\bar{B} \to D^* \ell \bar{\nu}$ exp. data

$$R_3(w) \equiv \frac{h_{A_3}(w) - r h_{A_2}(w)}{h_{A_1}(w)}$$

$\bar{B} \to D^* \tau \bar{\nu}$ only

Numerical results

Inputs

$$\bar{B} \to D^* \ell \bar{\nu} \quad (\ell = e, \mu)$$

$$\rho^2 = 1.24 \pm 0.04$$

HFAG

$$R_1(1) = 1.41 \pm 0.049$$

$$R_2(1) = 0.844 \pm 0.027$$

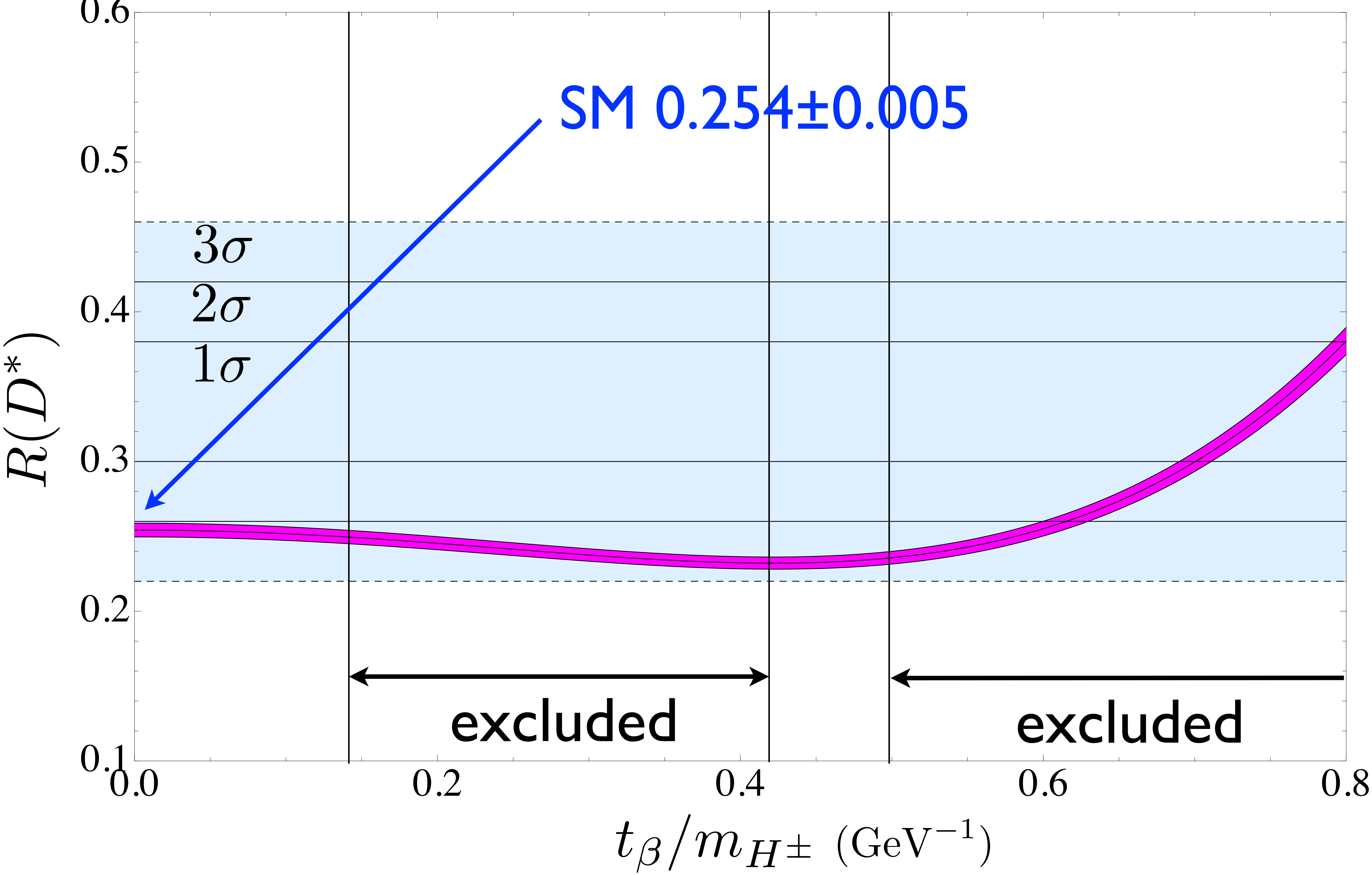
HQET

$$R_3(w) = 1 + a\{0.22 - 0.052(w-1) + 0.026(w-1)^2\}$$

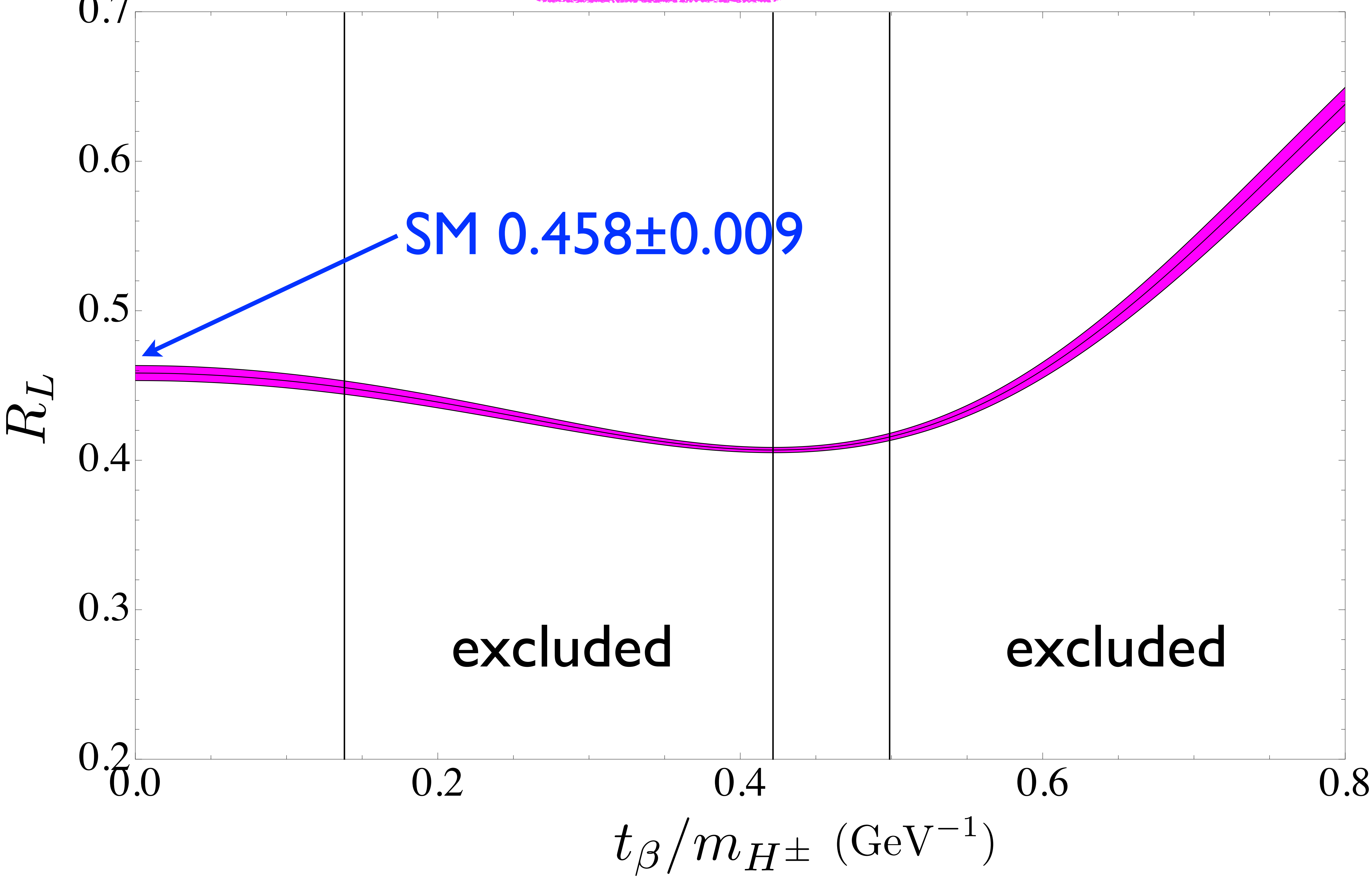
$$a = 1 \pm 0.5$$

Branching fraction (D*)

$$\frac{\mathcal{B}(\bar{B} \to D^* \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D^* \ell^- \bar{\nu}_\ell)}$$



D* polarization $\frac{D_L^*}{D_T^* + D_L^*}$



D^* decay and polarization

Helicity amplitudes

$$\mathcal{M}(D_T^* \to D\pi) \sim Y_{\pm}^1(\theta, \varphi)$$

$$\mathcal{M}(D_L^* \to D\pi) \sim Y_0^1(\theta, \varphi)$$

Angular distribution

$$R_L = \frac{D_L^*}{D_T^* + D_L^*}$$

$$W(\cos\theta) = f(\cos\theta) + (2R_L - 1)g(\cos\theta)$$

$$f(\cos\theta) = \frac{3}{8}(1 + \cos^2\theta), \; g(\cos\theta) = \frac{3}{8}(3\cos^2\theta - 1)$$

Sensitivity

$$S = \left[\int \frac{g^2}{f + (2R_L - 1)g}\, d\cos\theta\right]^{1/2} \Rightarrow \quad \sim 0.66$$

Statistical error: $\delta R_L = \frac{1}{2S\sqrt{N}}$

B factory

$N \sim 500$ → $\delta R_L \sim 0.03$

Super B factory

$N \sim 2 \times 10^4$ → $\delta R_L \sim 5 \times 10^{-3}$

cf. SM prediction: $R_L = 0.458 \pm 0.009$

Summary

- 4 form factors in $\bar{B} \to D^* \tau \bar{\nu}$

  h_{A_1}, R_1, R_2 determined by $\bar{B} \to D^* \ell \bar{\nu}$,

  R_3 determined by HQET.

  Uncertainties are well controlled. $\lesssim 5\%$

- D* polarization

  SM prediction $R_L = 0.458 \pm 0.009$

  B factory $\delta R_L \sim 0.03$

  Super B factory $\delta R_L \sim 5 \times 10^{-3}$

- D* less sensitive to charged Higgs than D.
- But, different dependece on $t_\beta/m_{H^\pm}$.

  → The 2-fold ambiguity can be solved within the semi-tauonic decays.
- D* complementary to D.

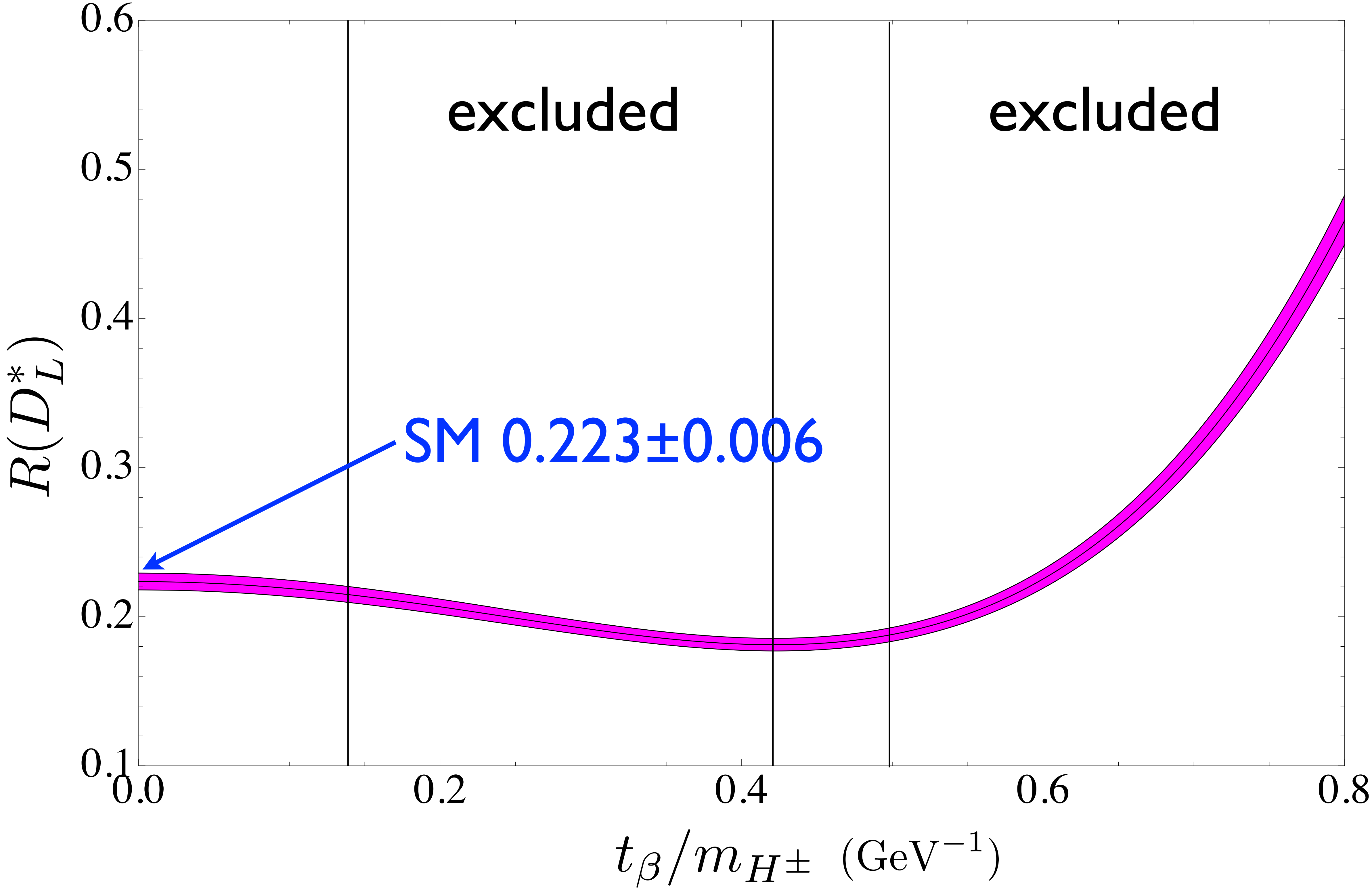
Backup Slides

	$L=0$	$L=1$	$L=2$
$B \to DW^*$	✓	✓	
$B \to D_T^* W^*$	✓	✓	✓
$B \to D_L^* W^*$	✓	✓	✓
$B \to DH^*$	✓		
$B \to D_T^* H^*$			
$B \to D_L^* H^*$		✓	

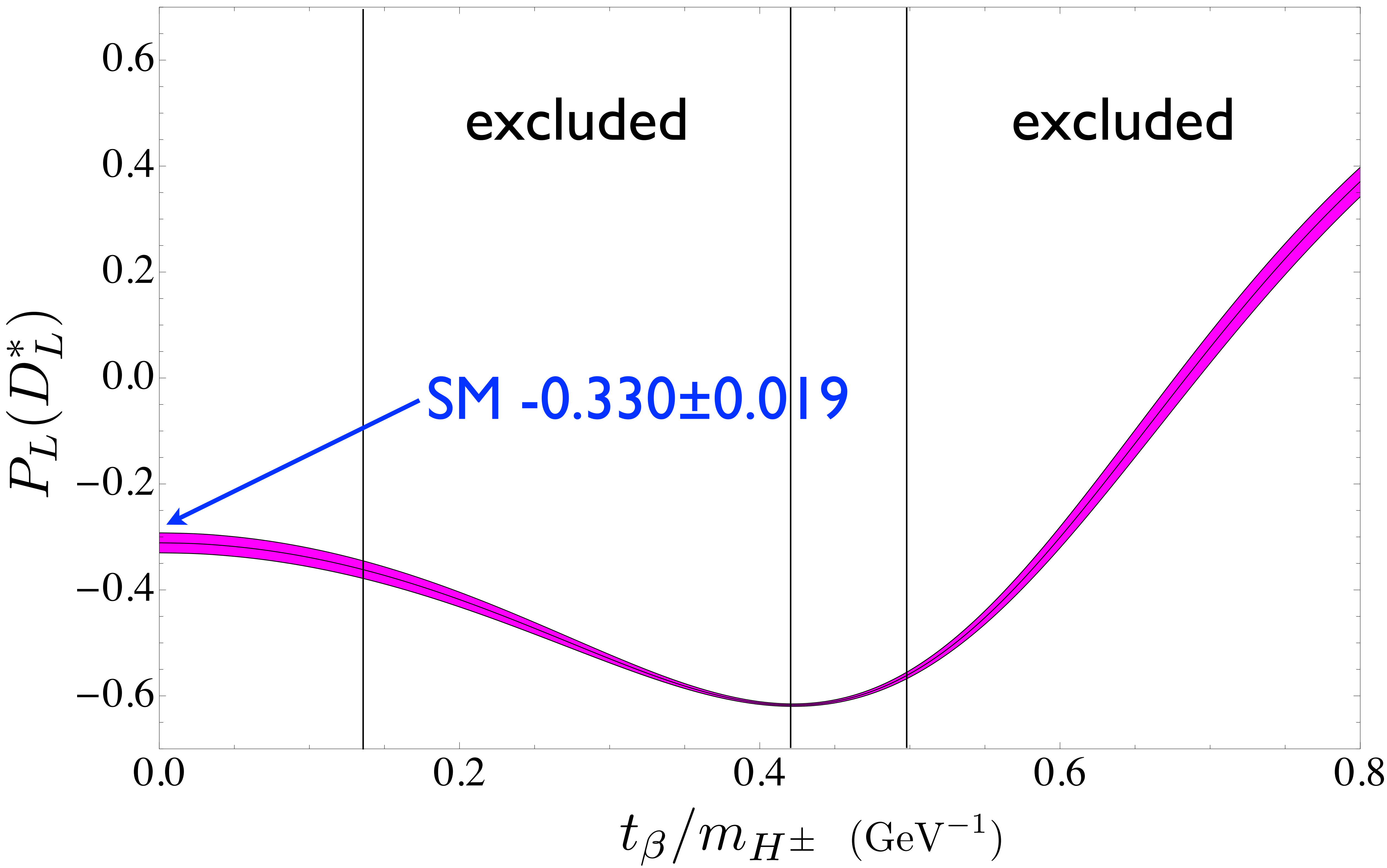
↑ suppressed

Branching fraction (D_L^*)

$$\frac{\mathcal{B}(\bar{B} \to D_L^* \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B} \to D_L^* \ell^- \bar{\nu}_\ell)}$$



Tau longitudinal polarization



Sensitivity to tau polarization

$$S(\tau \to \pi\nu(\ell\bar{\nu}\nu)) \simeq 0.61(0.20)$$

$$\delta P_\tau = \frac{1}{S\sqrt{N}}$$

B factory

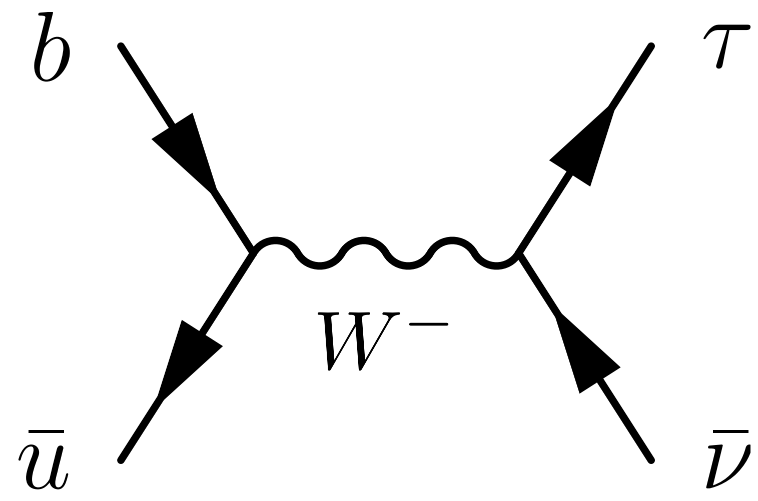
$N \sim 500$ → $\delta P_\tau \sim 0.07(0.22)$

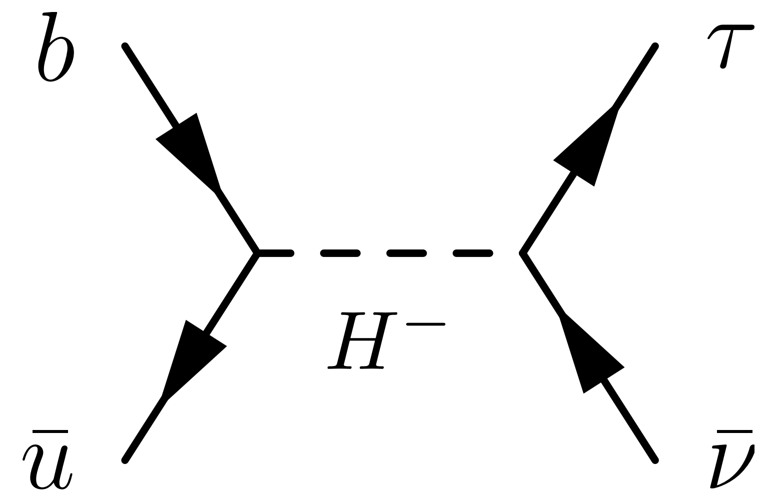
Super B factory

$N \sim 2 \times 10^4$ → $\delta P_\tau \sim 0.01(0.04)$

cf. SM prediction: $P_\tau = -0.330 \pm 0.019$

Pure tauonic B decay $B^- \to \tau\bar{\nu}$





$$\mathcal{B} = (1.67 \pm 0.39) \times 10^{-4}$$

(HFAG)

Uncertainties

$V_{ub}, \ f_B$

Nierste et al.