# A closer look at the $R_D$ and $R_{D^*}$ anomalies

Based on arXiv:1610.03038,
in collaboration with
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LFV/LFUV - Why and How?
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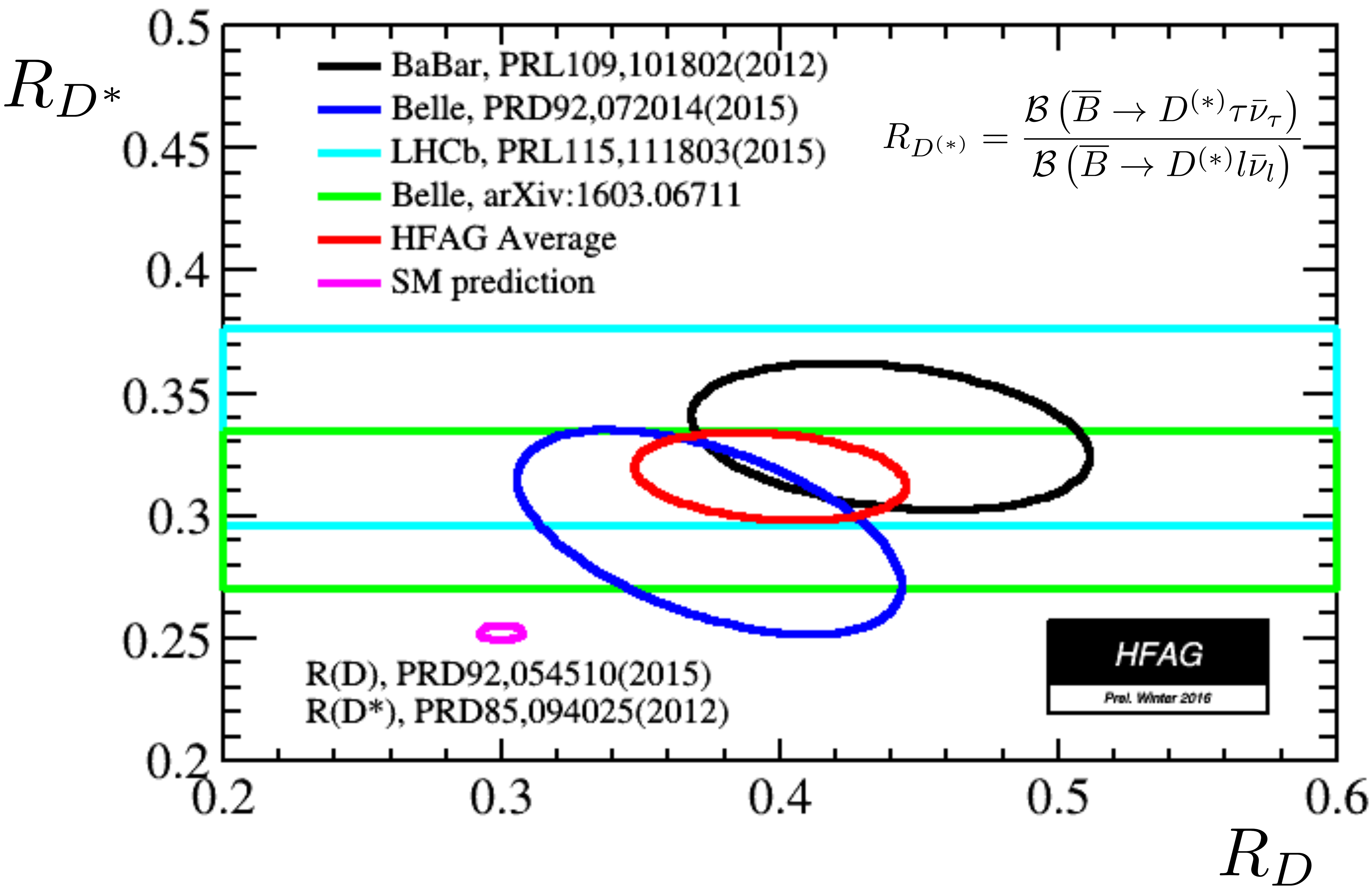
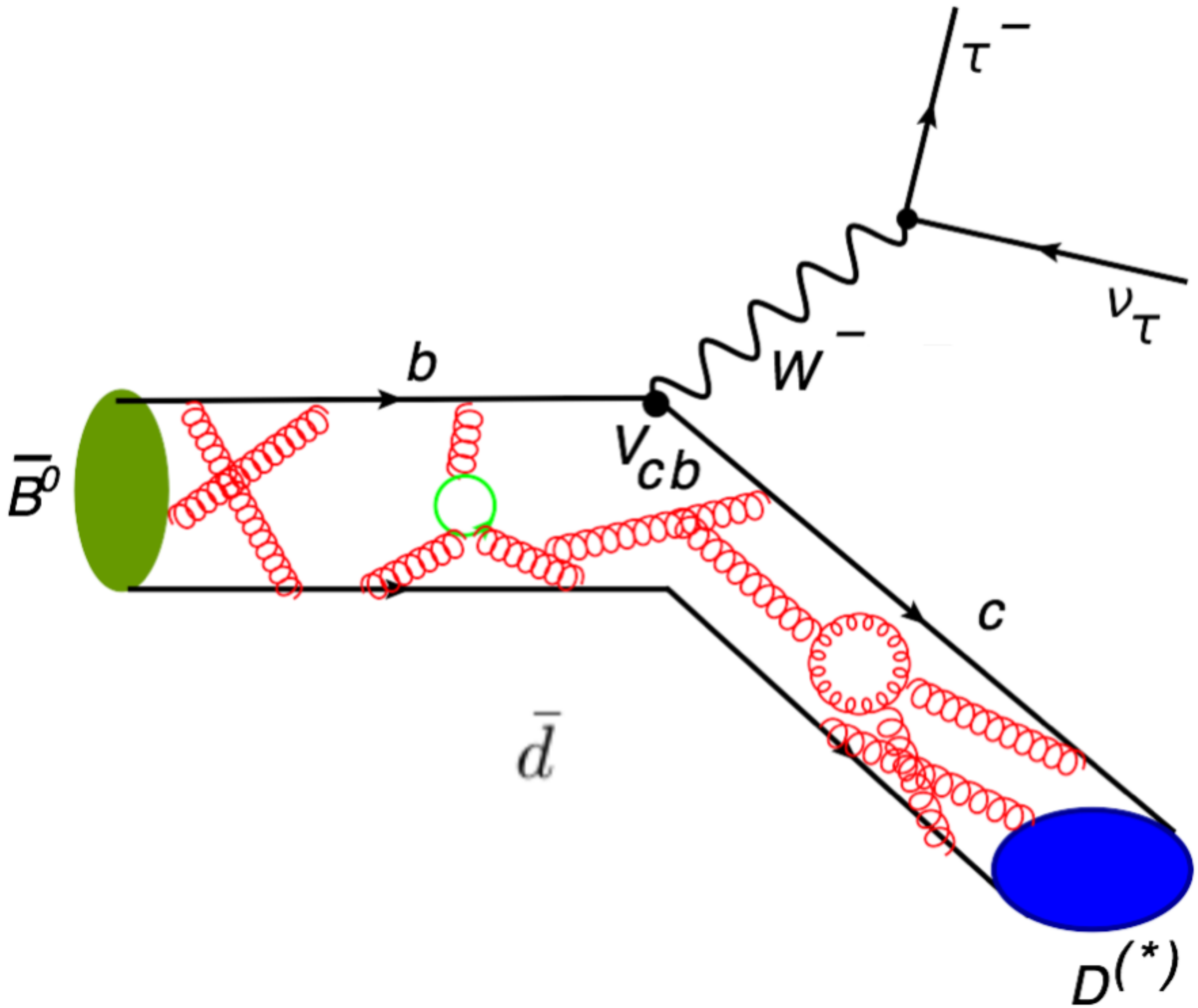
# Motivation




Deviation from the SM is at the $4\sigma$ level

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




$$q = p_\tau + p_{\nu_\tau}$$
$$= p_{\bar{B}^0} - p_{D^{(*)}}$$

# $\overline{B} \to D$ Form Factors

$$\langle D(p_D, M_D)|\bar{c}\gamma^\mu b|\bar{B}(p_B, M_B)\rangle = F_+(q^2)\left[(p_B + p_D)^\mu - \frac{M_B^2 - M_D^2}{q^2}q^\mu\right] + F_0(q^2)\frac{M_B^2 - M_D^2}{q^2}q^\mu$$

$$\langle D(p_D, M_D)|\bar{c}\gamma^\mu\gamma_5 b|\bar{B}(p_B, M_B)\rangle = 0$$

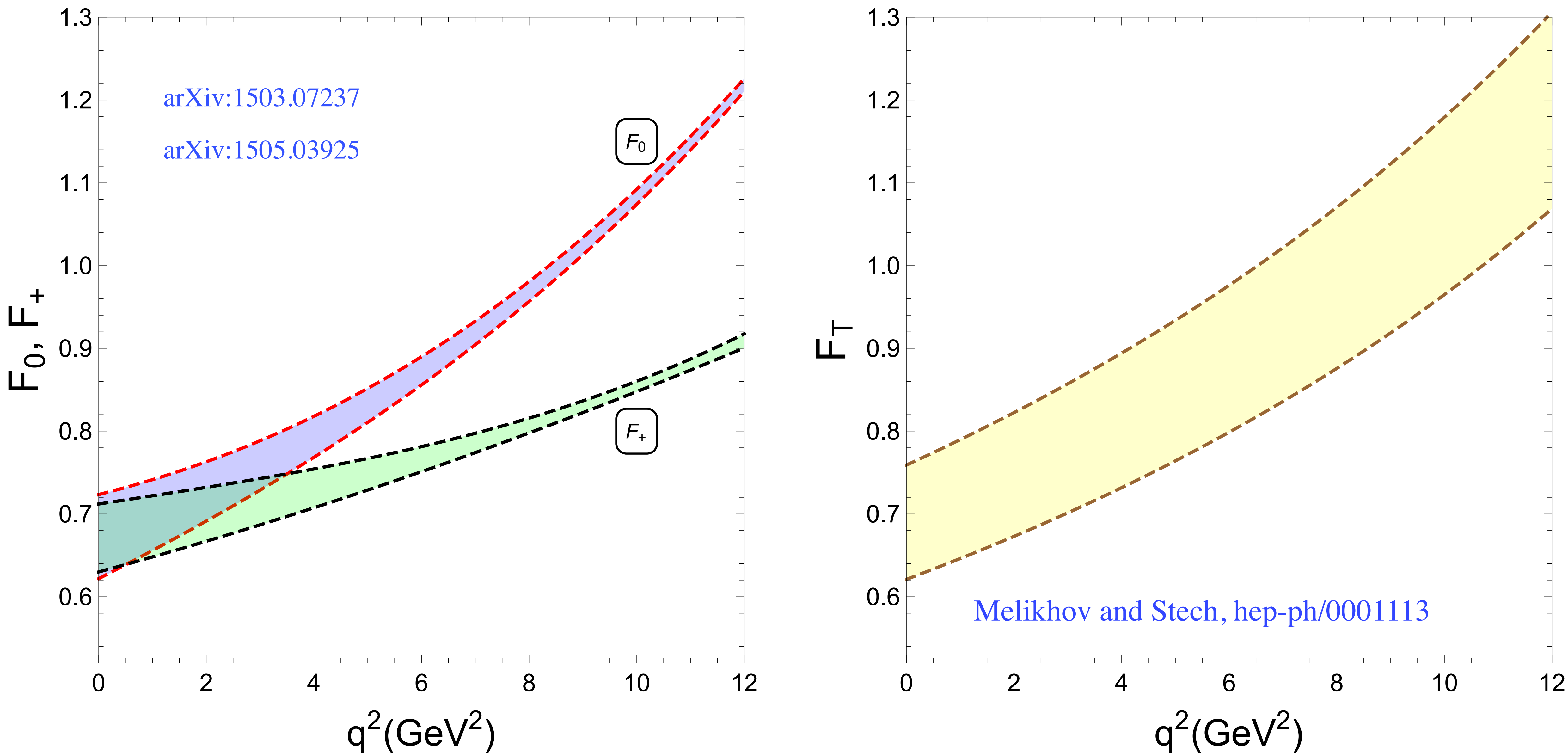
$$\langle D(p_D, M_D)|\bar{c}b|\bar{B}(p_B, M_B)\rangle = F_0(q^2)\frac{M_B^2 - M_D^2}{m_b - m_c}$$

$$\langle D(p_D, M_D)|\bar{c}\gamma_5 b|\bar{B}(p_B, M_B)\rangle = 0$$

$$\langle D(p_D, M_D)|\bar{c}\sigma^{\mu\nu} b|\bar{B}(p_B, M_B)\rangle = -i(p_B^\mu p_D^\nu - p_B^\nu p_D^\mu)\frac{2F_T(q^2)}{M_B + M_D}$$

$$\langle D(p_D, M_D)|\bar{c}\sigma^{\mu\nu}\gamma_5 b|\bar{B}(p_B, M_B)\rangle = \varepsilon^{\mu\nu\rho\sigma}p_{B\rho}p_{D\sigma}\frac{2F_T(q^2)}{M_B + M_D}$$

# $\overline{B} \to D$ Form Factors



# $\overline{B} \to D^*$ Form Factors

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}\gamma_\mu b|\bar{B}(p_B, M_B)\rangle = i\varepsilon_{\mu\nu\rho\sigma}\epsilon^{\nu*}p_B^\rho p_{D^*}^\sigma \frac{2V(q^2)}{M_B + M_{D^*}}$$

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}\gamma_\mu\gamma_5 b|\bar{B}(p_B, M_B)\rangle = 2M_{D^*}\frac{\epsilon^*.q}{q^2}q_\mu A_0(q^2) + (M_B + M_{D^*})\Big[\epsilon_\mu^* - \frac{\epsilon^*.q}{q^2}q_\mu\Big]A_1(q^2)$$
$$-\frac{\epsilon^*.q}{M_B + M_{D^*}}\Big[(p_B + p_{D^*})_\mu - \frac{M_B^2 - M_{D^*}^2}{q^2}q_\mu\Big]A_2(q^2)$$

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}b|\bar{B}(p_B, M_B)\rangle = 0$$

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}\gamma_5 b|\bar{B}(p_B, M_B)\rangle = -\epsilon^*.q\,\frac{2M_{D^*}}{m_b + m_c}A_0(q^2)$$

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}\sigma_{\mu\nu} b|\bar{B}(p_B, M_B)\rangle = -\varepsilon_{\mu\nu\alpha\beta}\Big[-\epsilon^{\alpha*}(p_{D^*} + p_B)^\beta T_1(q^2)$$
$$+\frac{M_B^2 - M_{D^*}^2}{q^2}\epsilon^{*\alpha}q^\beta\left(T_1(q^2) - T_2(q^2)\right)$$
$$+2\frac{\epsilon^*.q}{q^2}p_B^\alpha p_{D^*}^\beta\left(T_1(q^2) - T_2(q^2) - \frac{q^2}{M_B^2 - M_{D^*}^2}T_3(q^2)\right)\Big]$$

$$\langle D^*(p_{D^*}, M_{D^*})|\bar{c}\sigma_{\mu\nu}q^\nu b|\bar{B}(p_B, M_B)\rangle = -2\varepsilon_{\mu\nu\rho\sigma}\epsilon^{*\nu}p_B^\rho p_{D^*}^\sigma T_1(q^2)$$

# Summary of experimental measurements

| List of Observables | | | |
|---|---|---|---|
| Observable | Experimental Results | | SM Prediction |
| | Experiment | Measured value | |
| $R_D$ | Belle | $0.375 \pm 0.064 \pm 0.026$ | $0.299 \pm 0.011$ |
| | BaBar | $0.440 \pm 0.058 \pm 0.042$ | $0.300 \pm 0.008$ |
| | HFAG average | $0.397 \pm 0.040 \pm 0.028$ | $\mathbf{0.300^{+0.012}_{-0.011}}$ |
| $R_{D^*}$ | Belle | $0.293 \pm 0.038 \pm 0.015$ | $0.252 \pm 0.003$ |
| | Belle | $0.302 \pm 0.030 \pm 0.011$ | $\mathbf{0.254 \pm 0.004}$ |
| | BaBar | $0.332 \pm 0.024 \pm 0.018$ | |
| | LHCb | $0.336 \pm 0.027 \pm 0.030$ | |
| | HFAG average | $0.316 \pm 0.016 \pm 0.010$ | |
| | Belle | $0.276 \pm 0.034\ ^{+0.029}_{-0.026}$ | |
| | Our average | $0.310 \pm 0.017$ | |
| $\mathcal{B}(\overline{B} \to D\tau\bar{\nu}_\tau)$ | BaBar | $1.02 \pm 0.13 \pm 0.11$ % | $\mathbf{0.633 \pm 0.016}$ % |
| $\mathcal{B}(\overline{B} \to D^*\tau\bar{\nu}_\tau)$ | BaBar | $1.76 \pm 0.13 \pm 0.12$ % | $\mathbf{1.27 \pm 0.09}$ % |
| $\mathcal{B}(\overline{B} \to Dl\bar{\nu}_l)$ | HFAG average | $2.13 \pm 0.03 \pm 0.09$ % | $\mathbf{2.11^{+0.09}_{-0.11}}$ % |
| $\mathcal{B}(\overline{B} \to D^*l\bar{\nu}_l)$ | HFAG average | $4.93 \pm 0.01 \pm 0.11$ % | $\mathbf{5.04^{+0.44}_{-0.35}}$ % |
| $P_\tau(\overline{B} \to D\tau\bar{\nu}_\tau)$ | | | $0.325 \pm 0.009$<br>$\mathbf{0.325^{+0.013}_{-0.014}}$ |
| $P_\tau(\overline{B} \to D^*\tau\bar{\nu}_\tau)$ | Belle | $-0.44 \pm 0.47\ ^{+0.20}_{-0.17}$ | $-0.497 \pm 0.013$<br>$\mathbf{-0.497 \pm 0.008}$ |
| $\mathcal{A}_{FB}^{D}$ | | | $\mathbf{-0.360^{+0.002}_{-0.001}}$ |
| $\mathcal{A}_{FB}^{D^*}$ | | | $\mathbf{0.064 \pm 0.014}$ |

# Operator basis

$$\mathcal{L}_{\rm eff}^{b\to c\,\ell\,\nu} = \frac{2G_F V_{cb}}{\sqrt{2}} \Big( C_9^{cb\ell}\,\mathcal{O}_9^{cb\ell} + C_9^{cb\ell\,\prime}\,\mathcal{O}_9^{cb\ell\,\prime} + C_{10}^{cb\ell}\,\mathcal{O}_{10}^{cb\ell} + C_{10}^{cb\ell\,\prime}\,\mathcal{O}_{10}^{cb\ell\,\prime}$$
$$+ \quad C_s^{cb\ell}\,\mathcal{O}_s^{cb\ell} + C_s^{cb\ell}\,\mathcal{O}_s^{cb\ell\,\prime} + C_p^{cb\ell}\,\mathcal{O}_p^{cb\ell} + C_p^{cb\ell\,\prime}\,\mathcal{O}_p^{cb\ell\,\prime}$$
$$+ \quad C_T^{cb\ell}\,\mathcal{O}_T^{cb\ell} + C_{T5}^{cb\ell}\,\mathcal{O}_{T5}^{cb\ell} \Big)$$

$$\mathcal{O}_9^{cb\ell} = [\bar c\,\gamma^\mu\,\mathrm{P}_L\,b][\bar\ell\,\gamma_\mu\,\nu]$$
$$\mathcal{O}_{10}^{cb\ell} = [\bar c\,\gamma^\mu\,\mathrm{P}_L\,b][\bar\ell\,\gamma_\mu\gamma_5\,\nu]$$
$$\mathcal{O}_s^{cb\ell} = [\bar c\,\mathrm{P}_L\,b][\bar\ell\,\nu]$$
$$\mathcal{O}_p^{cb\ell} = [\bar c\,\mathrm{P}_L\,b][[\bar\ell\,\gamma_5\,\nu]$$
$$\mathcal{O}_T^{cb\ell} = [\bar c\,\sigma^{\mu\nu}\,b][\bar\ell\,\sigma_{\mu\nu}\,\nu]$$

$$\mathcal{O}_9^{cb\ell\,\prime} = [\bar c\,\gamma^\mu\,\mathrm{P}_R\,b][\bar\ell\,\gamma_\mu\,\nu]$$
$$\mathcal{O}_{10}^{cb\ell\,\prime} = [\bar c\,\gamma^\mu\,\mathrm{P}_R\,b][\bar\ell\,\gamma_\mu\gamma_5\,\nu]$$
$$\mathcal{O}_s^{cb\ell\,\prime} = [\bar c\,\mathrm{P}_R\,b][\bar\ell\,\nu]$$
$$\mathcal{O}_p^{cb\ell\,\prime} = [\bar c\,\mathrm{P}_R\,b][[\bar\ell\,\gamma_5\,\nu]$$
$$\mathcal{O}_{T5}^{cb\ell} = [\bar c\,\sigma^{\mu\nu}\,b][\bar\ell\,\sigma_{\mu\nu}\gamma_5\,\nu]$$

$$\begin{aligned}\epsilon_{\mu\nu\alpha\beta}[\bar c\,\sigma^{\mu\nu}\,b][\bar\ell\,\sigma^{\alpha\beta}\,\nu] &= -2i\mathcal{O}_{T5}^{cb\ell}\\ [\bar c\,\sigma^{\mu\nu}\gamma_5\,b][\bar\ell\,\sigma_{\mu\nu}\gamma_5\,\nu] &= \mathcal{O}_T^{cb\ell}\\ [\bar c\,\sigma^{\mu\nu}\gamma_5\,b][\bar\ell\,\sigma_{\mu\nu}\,\nu] &= \mathcal{O}_{T5}^{cb\ell}\,.\end{aligned}$$

# Operator basis

$$\mathcal{O}^{cb\ell}_{\rm VL} = [\bar{c}\,\gamma^\mu\, b][\bar{\ell}\,\gamma_\mu\, P_L\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm AL} = [\bar{c}\,\gamma^\mu\,\gamma_5\, b][\bar{\ell}\,\gamma_\mu\, P_L\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm SL} = [\bar{c}\, b][\bar{\ell}\, P_L\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm PL} = [\bar{c}\,\gamma_5\, b][[\bar{\ell}\, P_L\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm TL} = [\bar{c}\,\sigma^{\mu\nu}\, b][\bar{\ell}\,\sigma_{\mu\nu}\, P_L\,\nu]$$

$$\mathcal{O}^{cb\ell}_{\rm VR} = [\bar{c}\,\gamma^\mu\, b][\bar{\ell}\,\gamma_\mu\, P_R\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm AR} = [\bar{c}\,\gamma^\mu\,\gamma_5\, b][\bar{\ell}\,\gamma_\mu\, P_R\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm SR} = [\bar{c}\, b][\bar{\ell}\, P_R\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm PR} = [\bar{c}\,\gamma_5\, b][[\bar{\ell}\, P_R\,\nu]$$
$$\mathcal{O}^{cb\ell}_{\rm TR} = [\bar{c}\,\sigma^{\mu\nu}\, b][\bar{\ell}\,\sigma_{\mu\nu}\, P_R\,\nu]$$

SM: $C^{cb\ell}_{\rm VL} = 1, C^{cb\ell}_{\rm AL} = -1$

$$C^{cb\ell}_{\rm VL} = \frac{1}{2}\left(C^{cb\ell}_9 - C^{cb\ell}_{10} + C^{cb\ell\,\prime}_9 - C^{cb\ell\,\prime}_{10}\right)$$
$$C^{cb\ell}_{\rm AL} = \frac{1}{2}\left(-C^{cb\ell}_9 + C^{cb\ell}_{10} + C^{cb\ell\,\prime}_9 - C^{cb\ell\,\prime}_{10}\right)$$
$$C^{cb\ell}_{\rm SL} = \frac{1}{2}\left(C^{cb\ell}_s - C^{cb\ell}_p + C^{cb\ell\,\prime}_s - C^{cb\ell\,\prime}_p\right)$$
$$C^{cb\ell}_{\rm PL} = \frac{1}{2}\left(-C^{cb\ell}_s + C^{cb\ell}_p + C^{cb\ell\,\prime}_s - C^{cb\ell\,\prime}_p\right)$$
$$C^{cb\ell}_{\rm TL} = \left(C^{cb\ell}_T - C^{cb\ell}_{T5}\right)$$

$$C^{cb\ell}_{\rm SR} = \frac{1}{2}\left(C^{cb\ell}_s + C^{cb\ell}_p + C^{cb\ell\,\prime}_s + C^{cb\ell\,\prime}_p\right)$$
$$C^{cb\ell}_{\rm PR} = \frac{1}{2}\left(-C^{cb\ell}_s - C^{cb\ell}_p + C^{cb\ell\,\prime}_s + C^{cb\ell\,\prime}_p\right)$$
$$C^{cb\ell}_{\rm VR} = \frac{1}{2}\left(C^{cb\ell}_9 + C^{cb\ell}_{10} + C^{cb\ell\,\prime}_9 + C^{cb\ell\,\prime}_{10}\right)$$
$$C^{cb\ell}_{\rm AR} = \frac{1}{2}\left(-C^{cb\ell}_9 - C^{cb\ell}_{10} + C^{cb\ell\,\prime}_9 + C^{cb\ell\,\prime}_{10}\right)$$
$$C^{cb\ell}_{\rm TR} = \left(C^{cb\ell}_T + C^{cb\ell}_{T5}\right)$$

*We provide analytical expressions for all the operators, for the first time in the literature!*

## Operators → Amplitudes

$$\mathcal{O}^{cb\ell}_{\rm VL} = [\bar{c}\,\gamma^{\mu}\,b][\bar{\ell}\,\gamma_{\mu}\,P_L\,\nu] \qquad \overline{B} \to D^{(*)}\tau\bar{\nu}_{\tau}$$

$$\mathcal{O}^{cb\ell}_{\rm AL} = [\bar{c}\,\gamma^{\mu}\,\gamma_5\,b][\bar{\ell}\,\gamma_{\mu}\,P_L\,\nu] \qquad \overline{B} \to D^{*}\tau\bar{\nu}_{\tau}$$

$$\mathcal{O}^{cb\ell}_{\rm SL} = [\bar{c}\,b][\bar{\ell}\,P_L\,\nu] \qquad \overline{B} \to D\tau\bar{\nu}_{\tau}$$

$$\mathcal{O}^{cb\ell}_{\rm PL} = [\bar{c}\,\gamma_5\,b][[\bar{\ell}\,P_L\,\nu] \qquad \overline{B} \to D^{*}\tau\bar{\nu}_{\tau}$$

$$\mathcal{O}^{cb\ell}_{\rm TL} = [\bar{c}\,\sigma^{\mu\nu}\,b][\bar{\ell}\,\sigma_{\mu\nu}\,P_L\,\nu] \qquad \overline{B} \to D^{(*)}\tau\bar{\nu}_{\tau}$$

→ The two decays $\overline{B} \to D^{*}\tau\bar{\nu}_{\tau}$ and $\overline{B} \to D\tau\bar{\nu}_{\tau}$ are in general theoretically independent

# Observables

$$\frac{d^2\mathcal{B}_\ell^{D^{(*)}}}{dq^2\, d(\cos\theta)} = \mathcal{N}\, |p_{D^{(*)}}| \left(a_\ell^{D^{(*)}} + b_\ell^{D^{(*)}} \cos\theta + c_\ell^{D^{(*)}} \cos^2\theta\right)$$

$$\mathcal{B}_\ell^{D^{(*)}} = \int \mathcal{N}\, |p_{D^{(*)}}| \left(2a_\ell^{D^{(*)}} + \frac{2}{3} c_\ell^{D^{(*)}}\right) dq^2$$

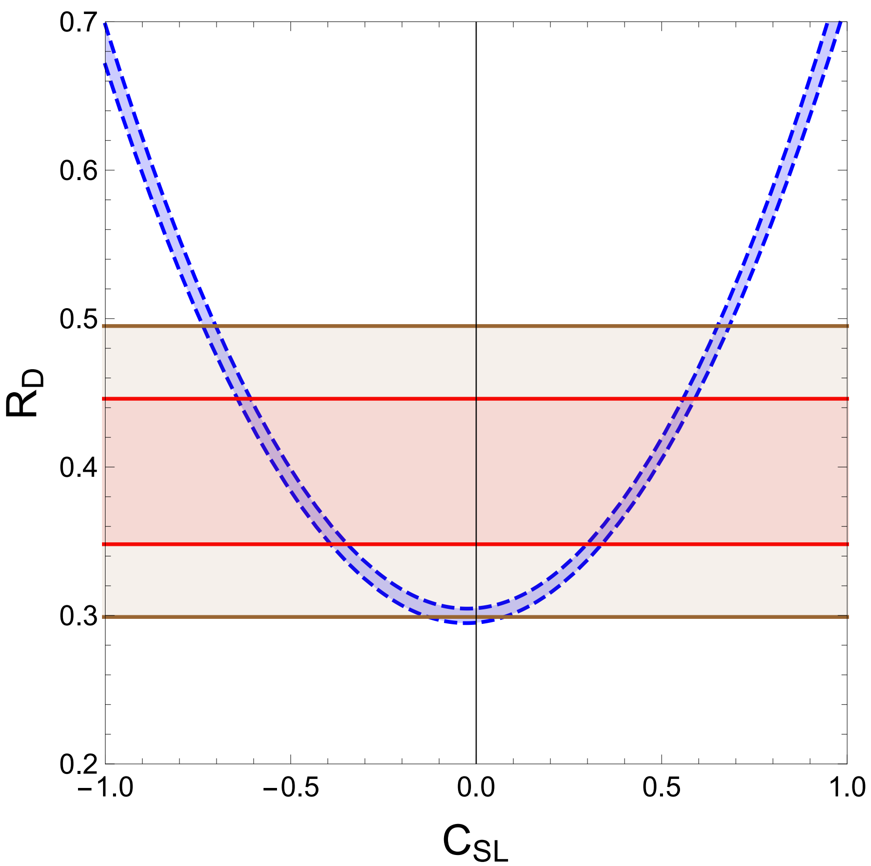
$$R_{D^{(*)}} = \frac{\mathcal{B}\left(\overline{B} \to D^{(*)}\tau\bar{\nu}_\tau\right)}{\mathcal{B}\left(\overline{B} \to D^{(*)} l\bar{\nu}_l\right)}$$

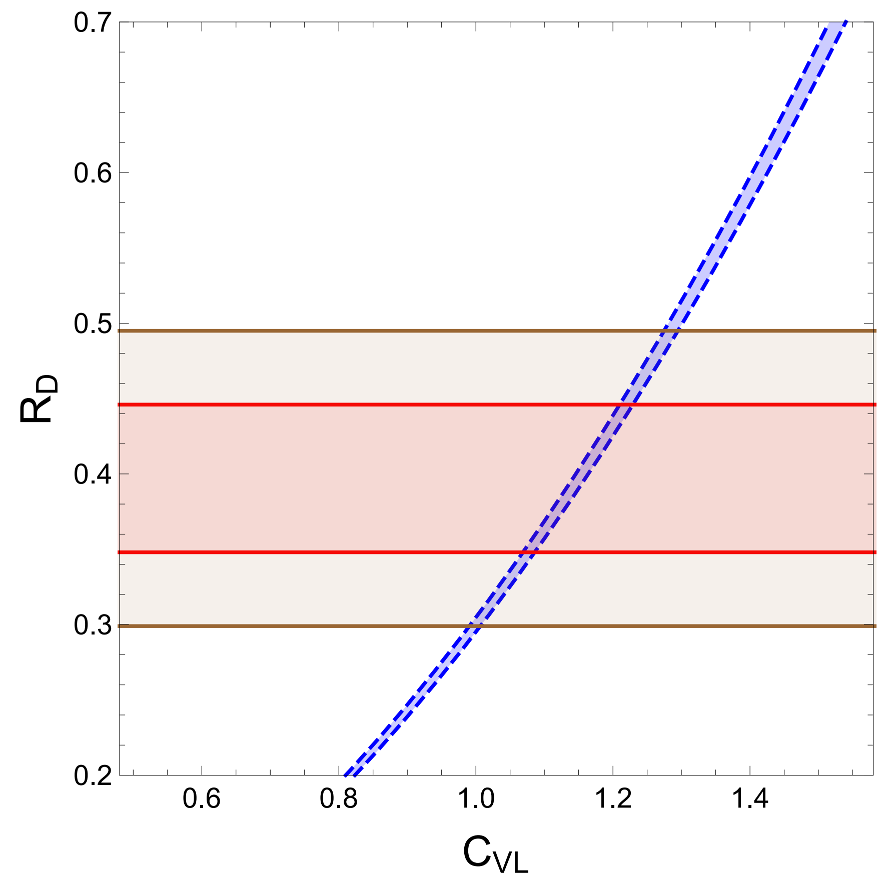
$$R_{D^{(*)}}[q^2\ \mathrm{bin}] = \frac{\mathcal{B}_\tau^{D^{(*)}}[q^2\ \mathrm{bin}]}{\mathcal{B}_l^{D^{(*)}}[q^2\ \mathrm{bin}]}$$

$$P_\tau(D^{(*)}) = \frac{\Gamma_\tau^{D^{(*)}}(+) - \Gamma_\tau^{D^{(*)}}(-)}{\Gamma_\tau^{D^{(*)}}(+) + \Gamma_\tau^{D^{(*)}}(-)}$$

$$\mathcal{A}_{FB}^{D^{(*)}} = \frac{\int b_\tau^{D^{(*)}}(q^2)dq^2}{\Gamma^{D^{(*)}}}$$

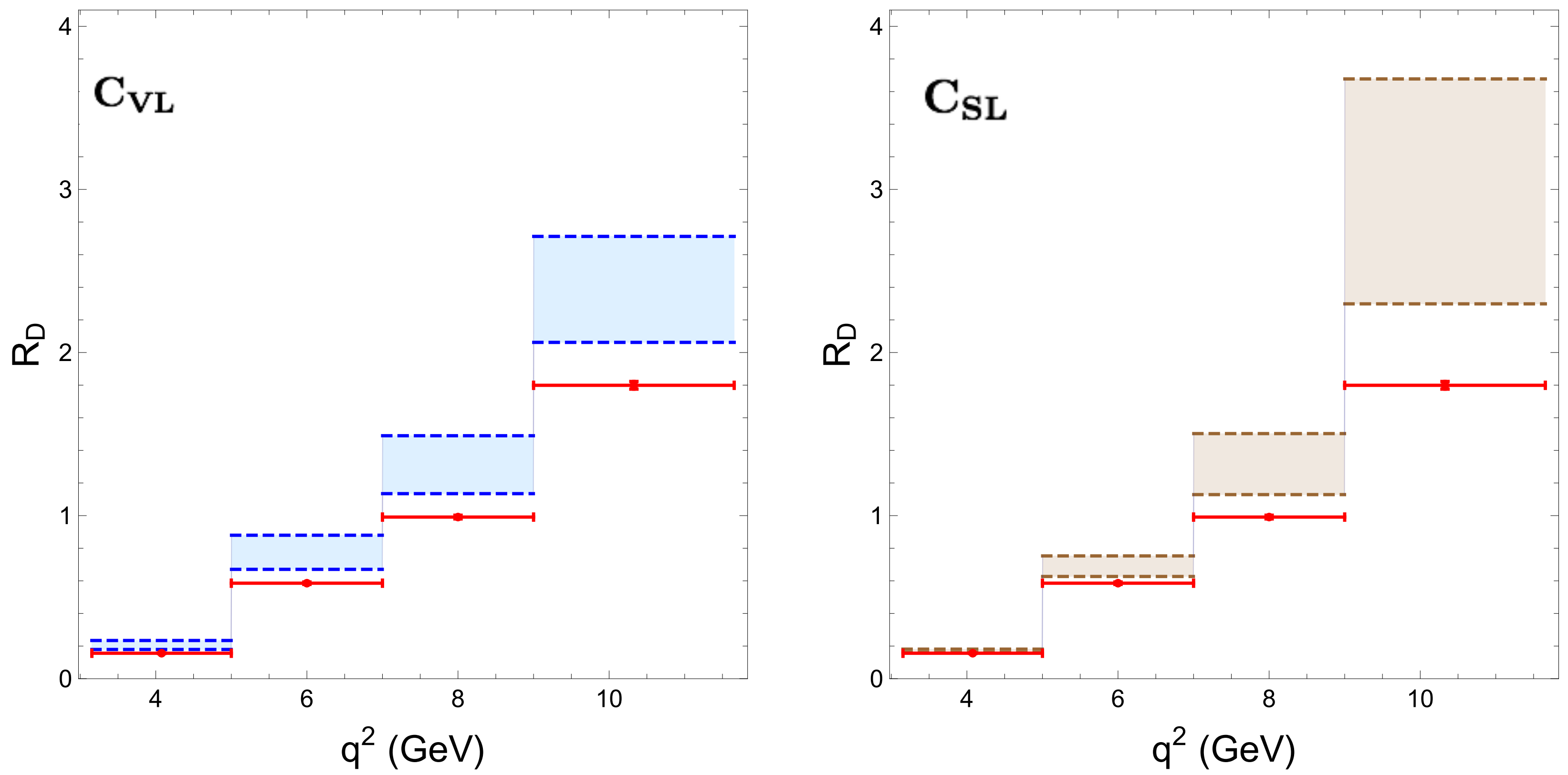
# Explaining $R_D$




| | | SM | $\mathbf{C_{VL}}$ $(\mathbf{C_{SL}} = 0)$ | $\mathbf{C_{SL}}$ $(\mathbf{C_{VL}} = 1)$ |
|---|---|---|---|---|
| | $1\sigma$ range of the WC | | [1.073, 1.222] | [−0.656, −0.342] [0.296, 0.596] |
| | $P_\tau(D)$ | [0.313, 0.336] | [0.313, 0.336] | [0.408, 0.556] |
| | $\mathcal{A}_{FB}^D$ | [−0.361, −0.358] | [−0.361, −0.358] | [−0.168, −0.022] [−0.450, −0.428] |
| $R_D$ [bin] | $[m_\tau^2 - 5]$ GeV$^2$ | [0.154, 0.158] | [0.178, 0.236] | [0.161, 0.181] |
| | $[5 - 7]$ GeV$^2$ | [0.578, 0.593] | [0.665, 0.888] | [0.626, 0.752] |
| | $[7 - 9]$ GeV$^2$ | [0.980, 1.003] | [1.127, 1.505] | [1.125, 1.502] |
| | $[9 - (M_B - M_D)^2]$ GeV$^2$ | [1.776, 1.823] | [2.049, 2.741] | [2.294, 3.669] |

# Explaining $R_D$



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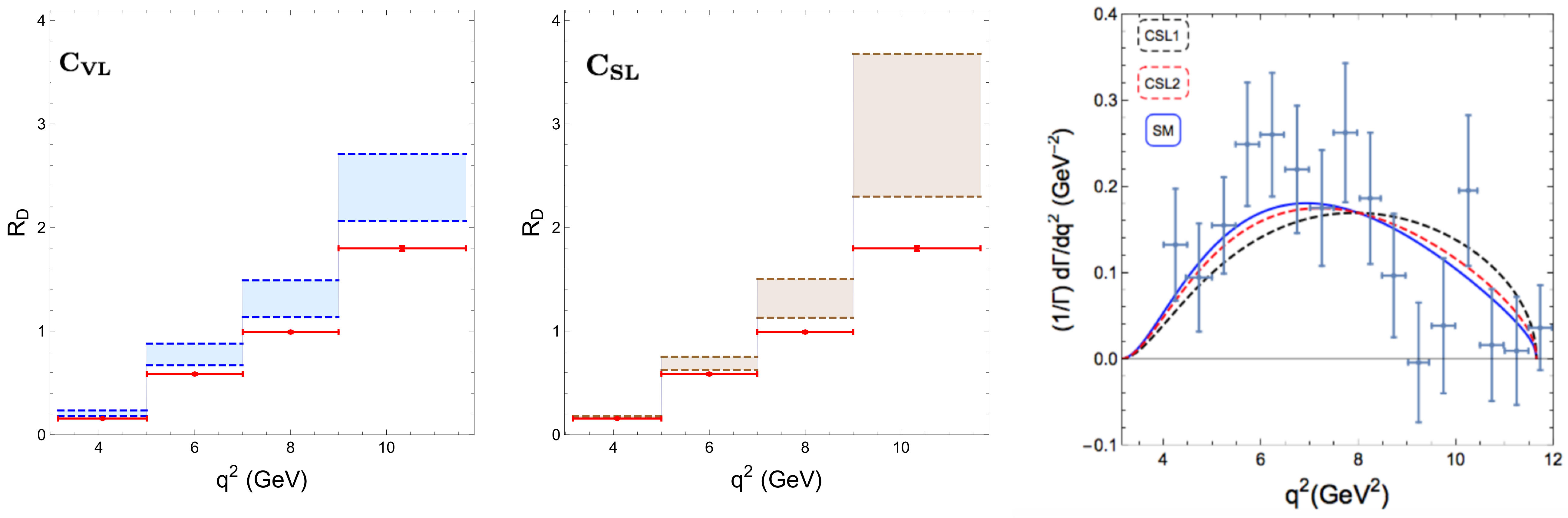

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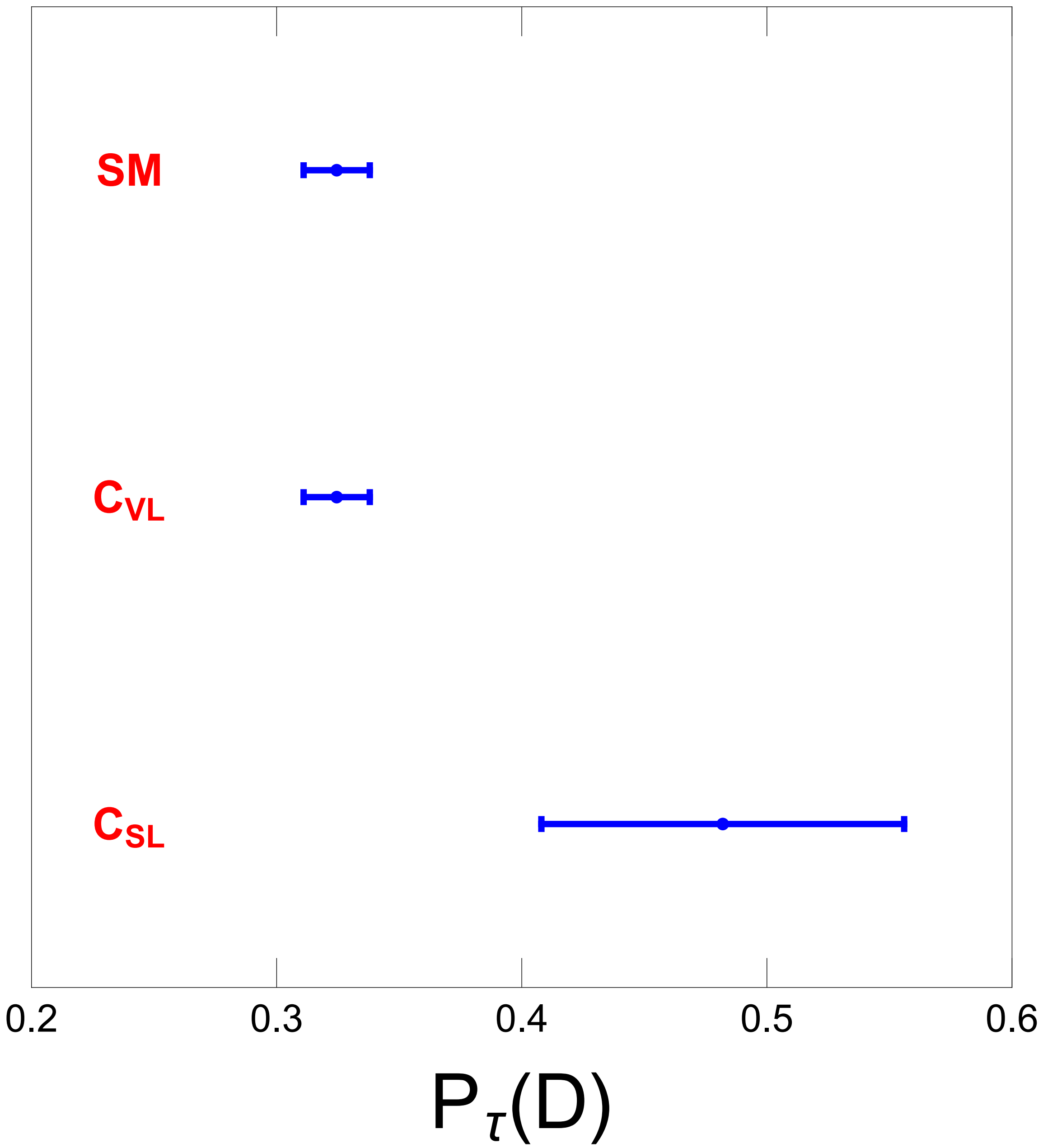

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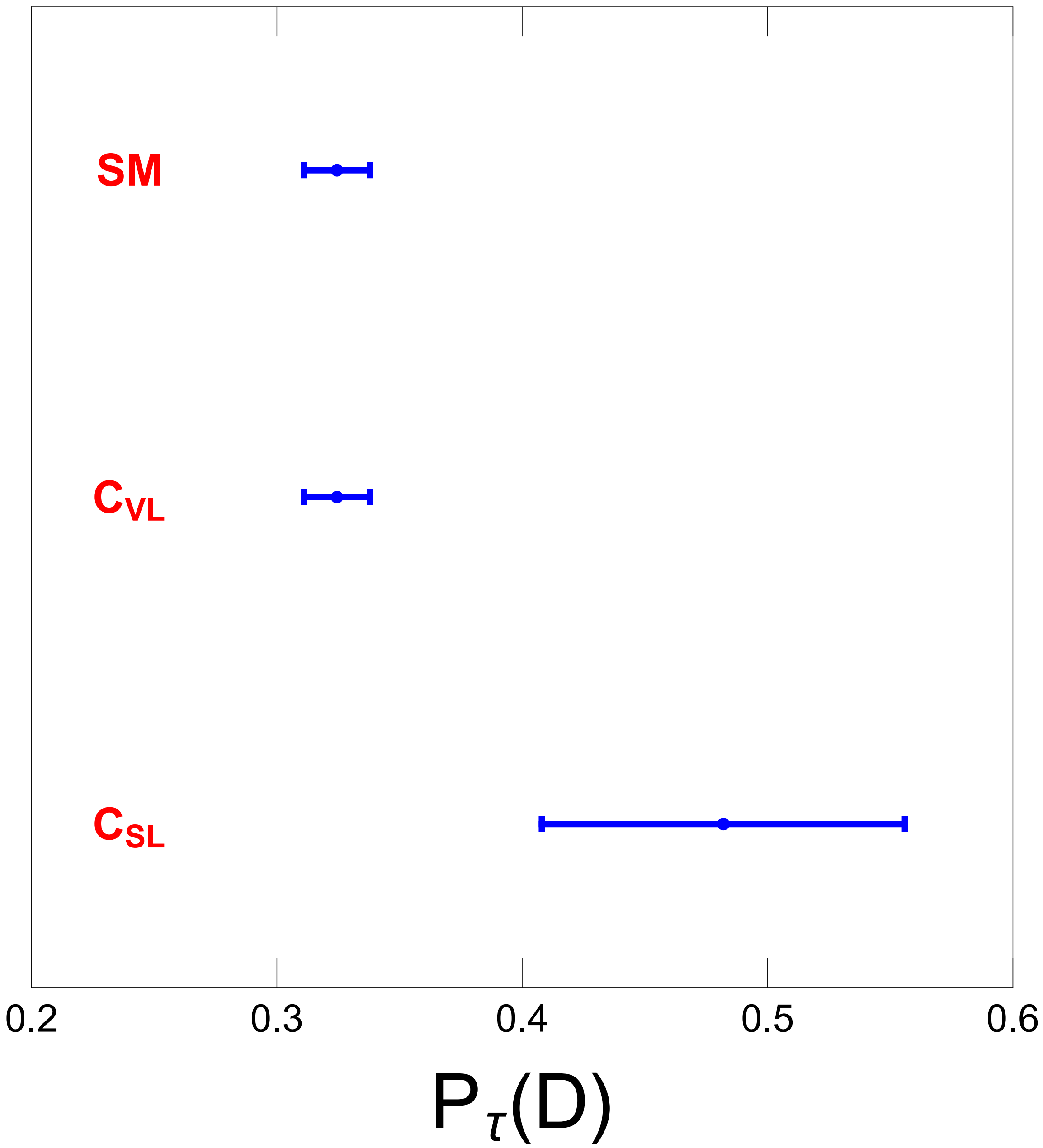
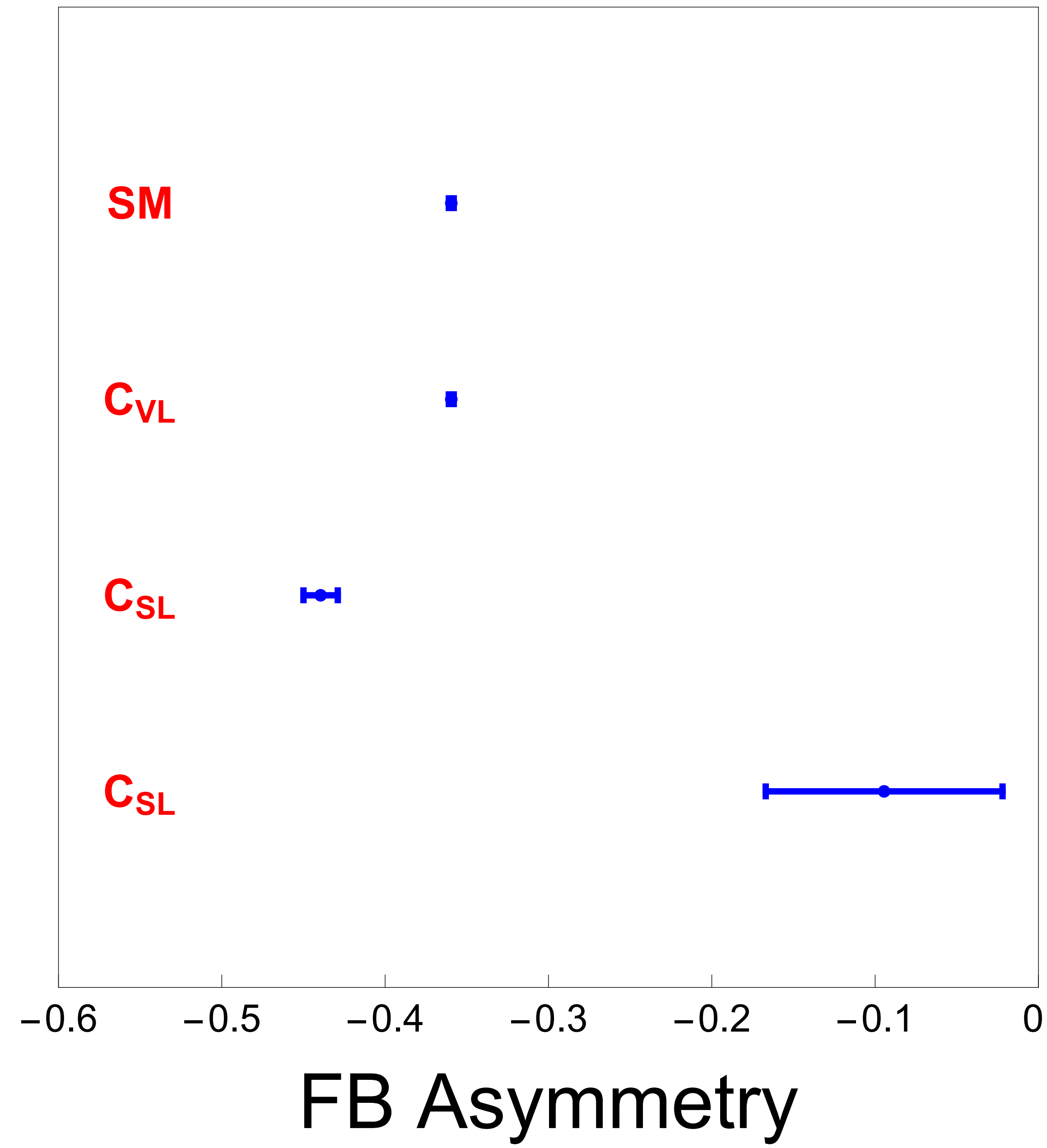
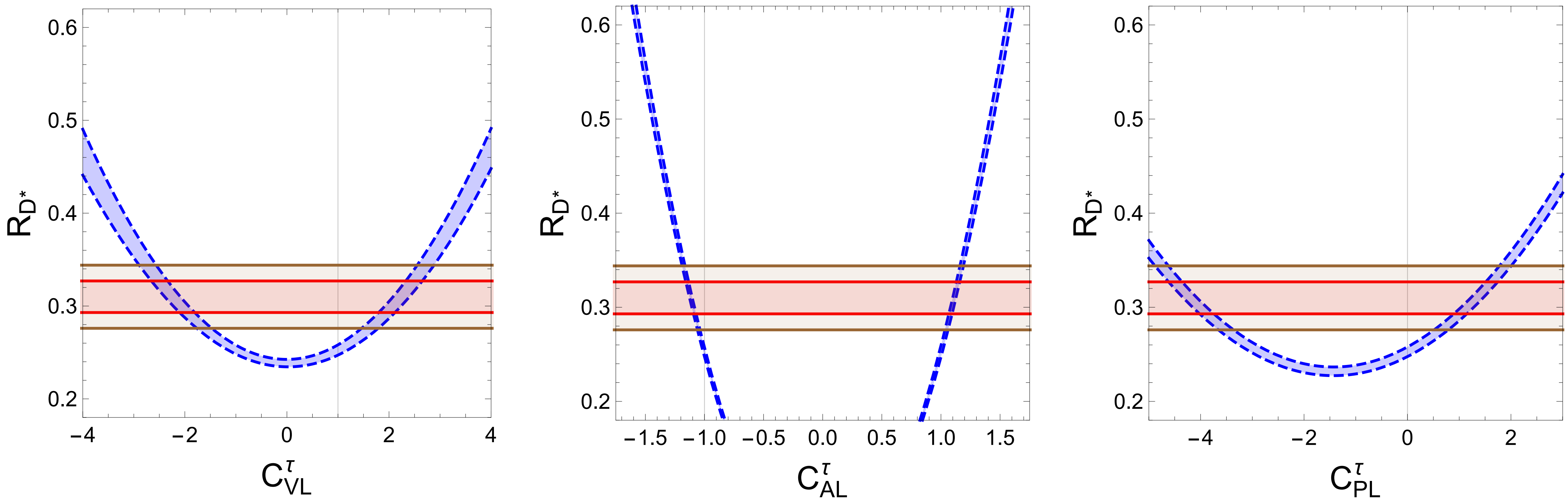


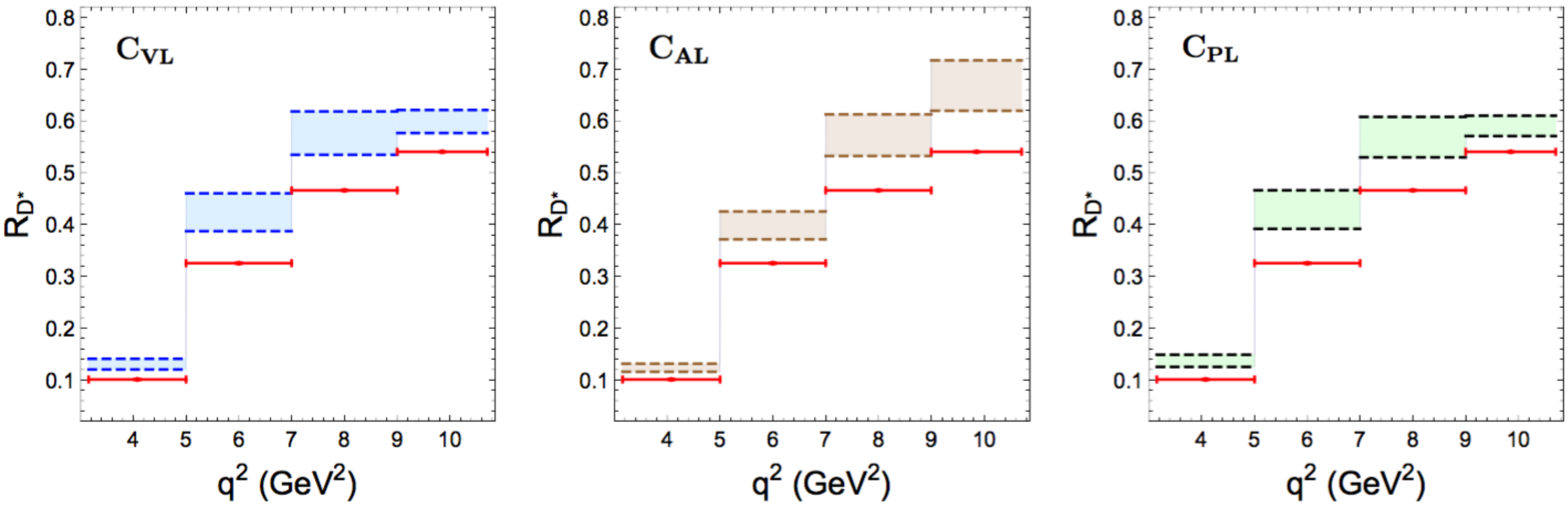



# Explaining $R_{D^*}$

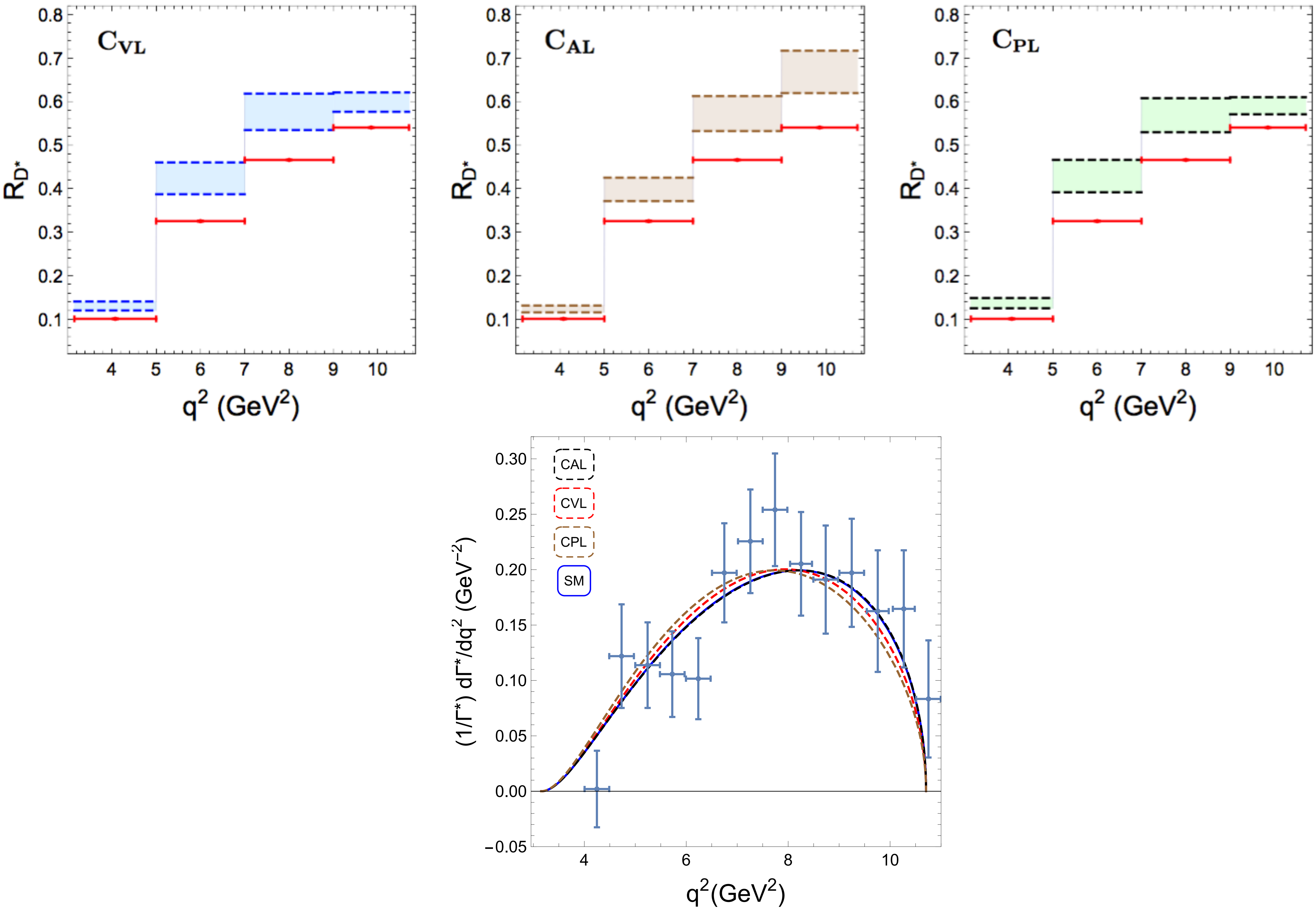



| | | SM | $\mathbf{C_{VL}}$<br>$\mathbf{C_{AL,PL}} = -1, 0$ | $\mathbf{C_{AL}}$<br>$\mathbf{C_{VL,PL}} = 1, 0$ | $\mathbf{C_{PL}}$<br>$\mathbf{C_{VL,AL}} = 1, -1$ |
|---|---|---|---|---|---|
| | Range in WC | | [1.856, 2.569] | [−1.149, −1.073] | [0.890, 1.583] |
| | $P_\tau(D^*)$ | [−0.505, −0.490] | [−0.530, −0.509] | [−0.505, −0.488] | [−0.322, −0.144] |
| | $\mathcal{A}_{FB}^{D^*}$ | [0.050, 0.078] | [0.191, 0.297] | [0.028, 0.062] | [−0.078, −0.007] |
| $R_{D^*}$ [bin] | $[m_\tau^2 - 5]$ GeV$^2$ | [0.103, 0.105] | [0.120, 0.140] | [0.116, 0.132] | [0.124, 0.148] |
| | $[5 - 7]$ GeV$^2$ | [0.331, 0.336] | [0.387, 0.457] | [0.373, 0.425] | [0.390, 0.465] |
| | $[7 - 9]$ GeV$^2$ | [0.475, 0.479] | [0.535, 0.613] | [0.535, 0.613] | [0.534, 0.610] |
| | $[9 - (M_B - M_{D^*})^2]$ GeV$^2$ | [0.554, 0.556] | [0.577, 0.619] | [0.621, 0.710] | [0.571, 0.611] |

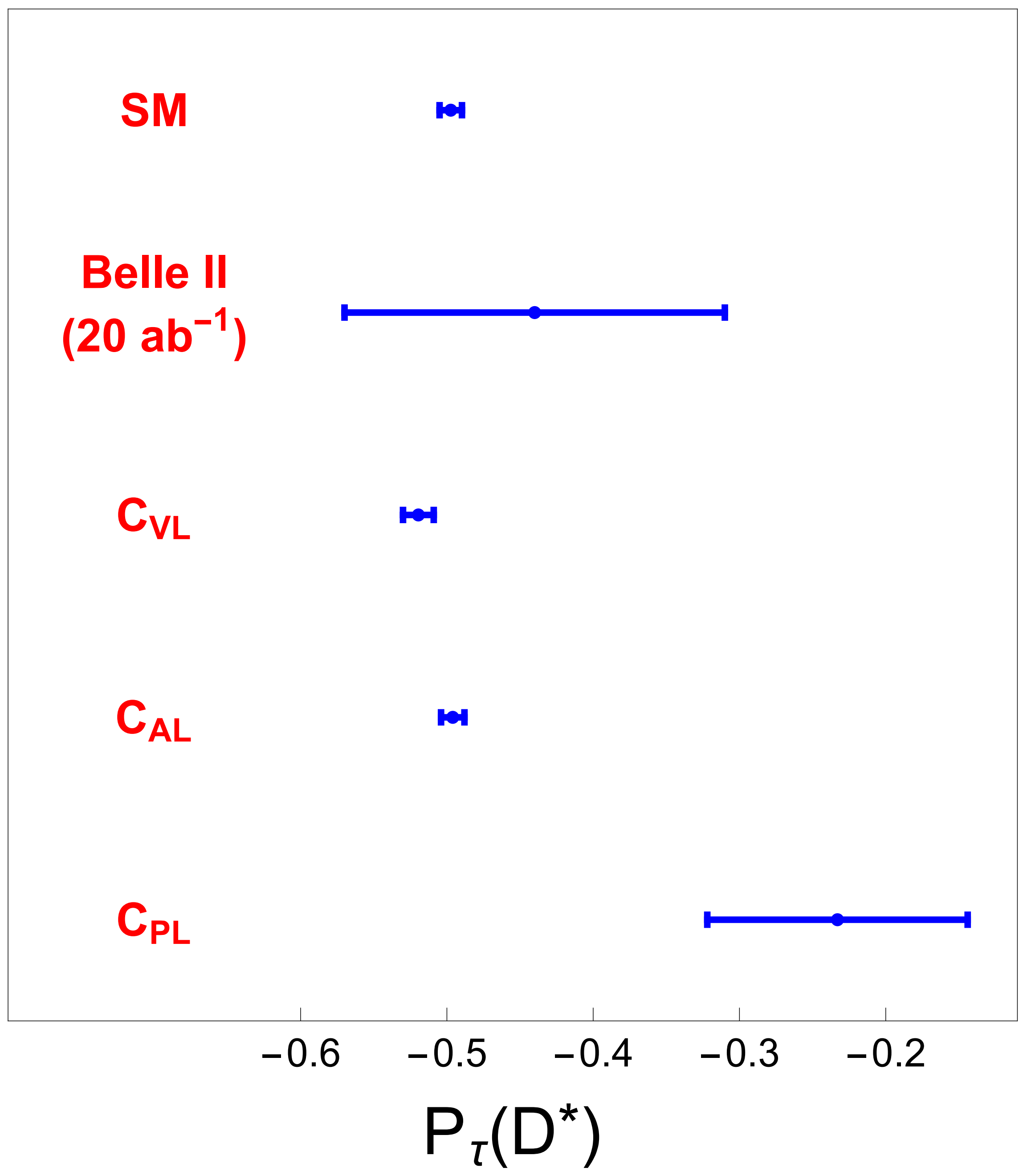
# Explaining $R_{D^*}$



# Explaining $R_{D^*}$



# Distinguishing the various operators



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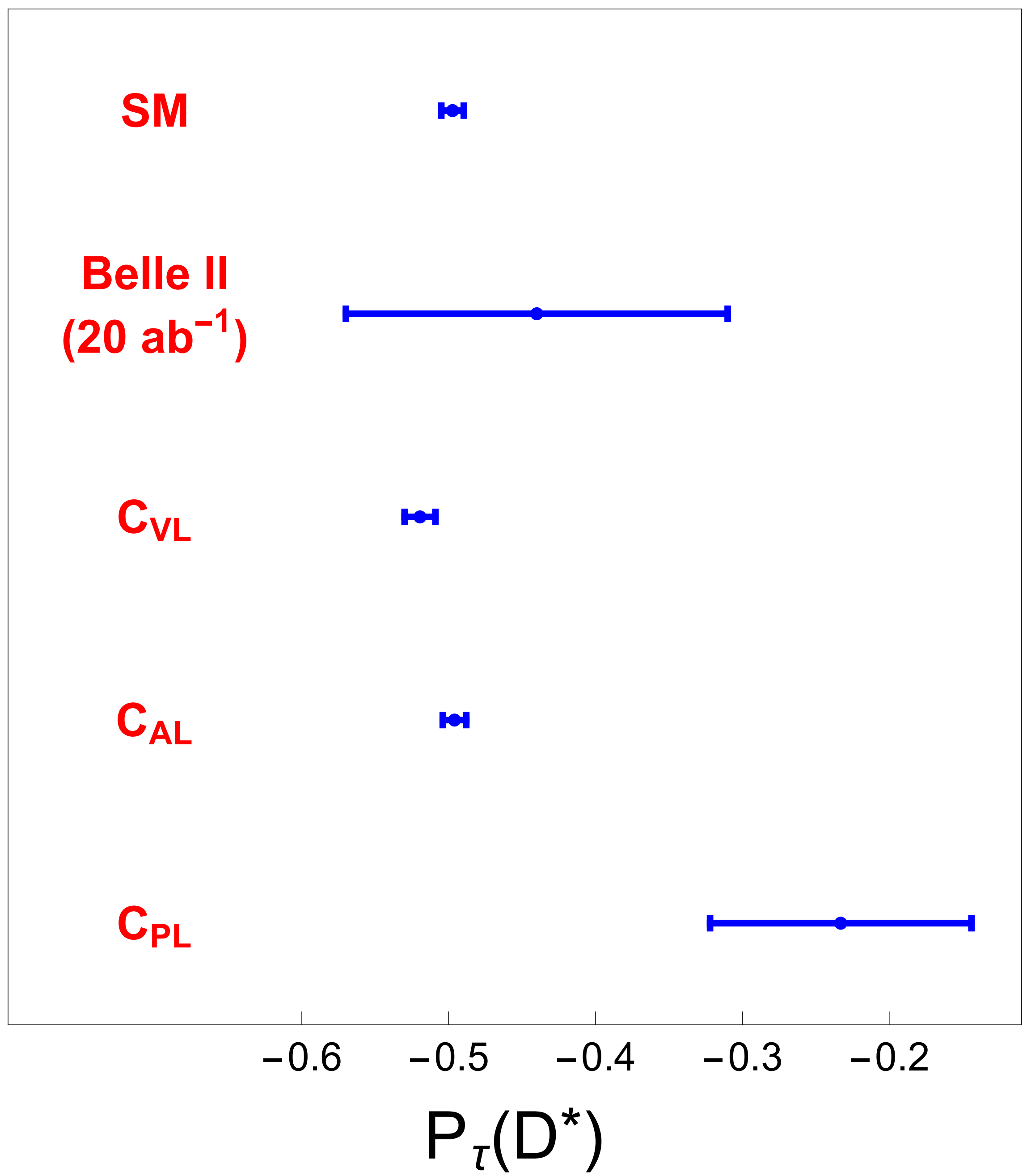
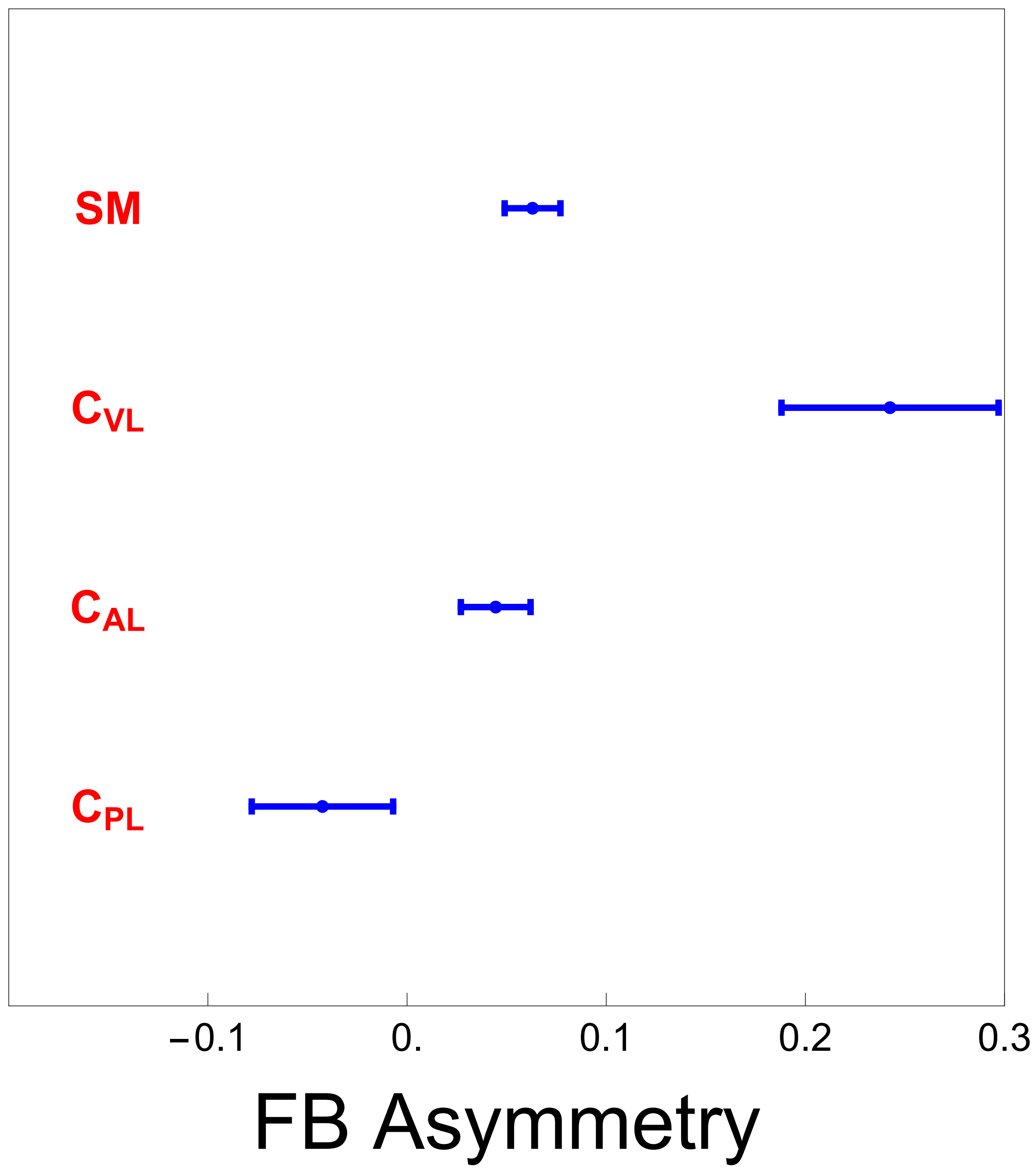
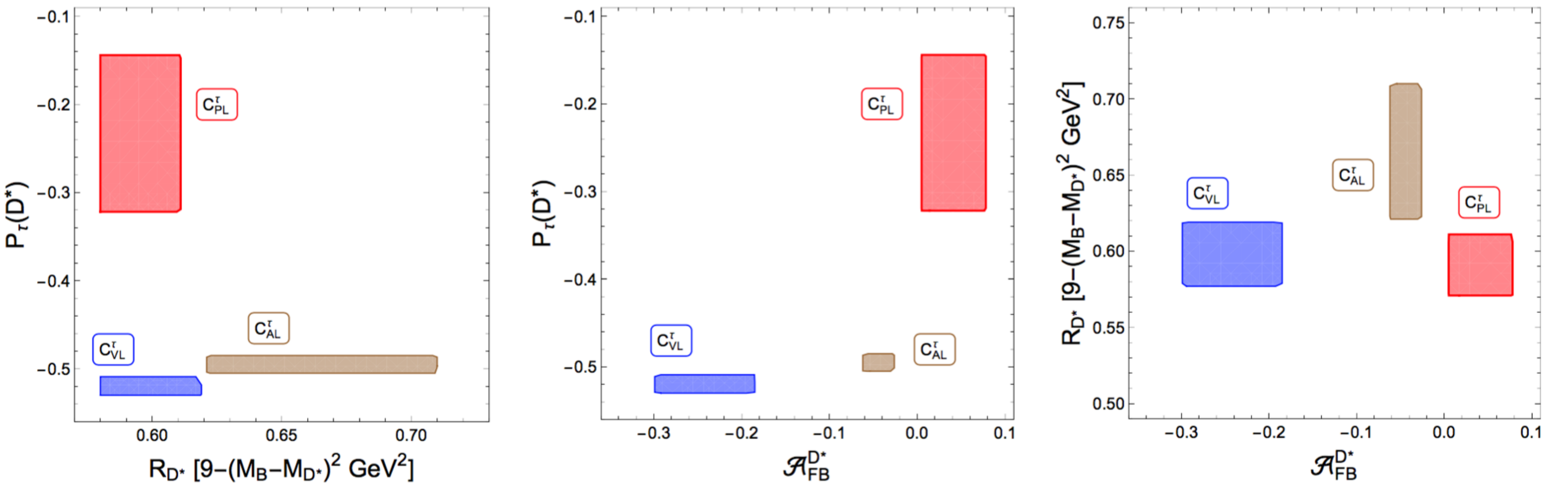


# Distinguishing the various operators



# Explaining $R_D$ and $R_D^*$ together

$\mathcal{O}^{cb\ell}_{\rm VL} = [\bar{c}\,\gamma^\mu\, b][\bar{\ell}\,\gamma_\mu\, P_L\, \nu]$ $\quad \overline{B} \to D^{(*)}\tau\bar{\nu}_\tau$

$\mathcal{O}^{cb\ell}_{\rm AL} = [\bar{c}\,\gamma^\mu\,\gamma_5\, b][\bar{\ell}\,\gamma_\mu\, P_L\, \nu]$ $\quad \overline{B} \to D^{*}\tau\bar{\nu}_\tau$

$\mathcal{O}^{cb\ell}_{\rm SL} = [\bar{c}\, b][\bar{\ell}\, P_L\, \nu]$ $\quad \overline{B} \to D\tau\bar{\nu}_\tau$

$\mathcal{O}^{cb\ell}_{\rm PL} = [\bar{c}\,\gamma_5\, b][[\bar{\ell}\, P_L\, \nu]$ $\quad \overline{B} \to D^{*}\tau\bar{\nu}_\tau$

$\mathcal{O}^{cb\ell}_{\rm TL} = [\bar{c}\,\sigma^{\mu\nu}\, b][\bar{\ell}\,\sigma_{\mu\nu}\, P_L\, \nu]$ $\quad \overline{B} \to D^{(*)}\tau\bar{\nu}_\tau$

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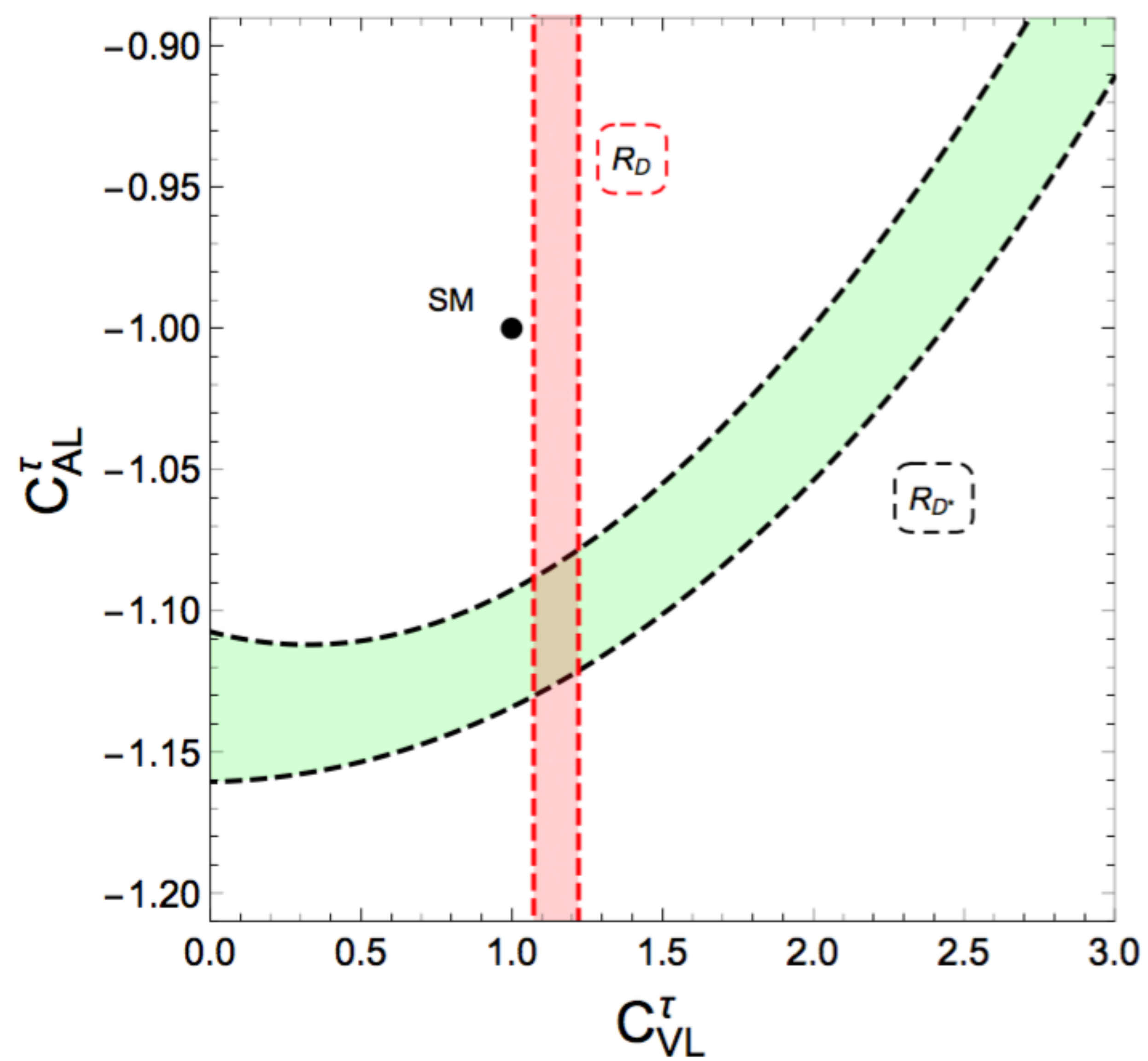
$\mathbf{C_{SL}}$ : [-0.656, -0.342]
[0.296, 0.596]

$\mathbf{C_{PL}}$ : [0.937, 1.710]

# Explaining $R_D$ and $R_D^*$ together




| $C^{\tau}_{VL}$ $\in$ [1.073, 1.222] | $P_{\tau}(D^*)$ $\in$ [-0.507, -0.489] | $R_{D^*}$ [bin] | | | |
|---|---|---|---|---|---|
| | | $[m_\tau^2 - 5]$ GeV$^2$ | $[5-7]$ GeV$^2$ | $[7-9]$ GeV$^2$ | $[9-(M_B - M_{D^*})^2]$ GeV$^2$ |
| $C^{\tau}_{AL}$ $\in$ [-1.144, -1.067] | $\mathcal{A}_{FB}^{D^*}$ $\in$ [0.055, 0.092] | [0.116, 0.131] | [0.373, 0.426] | [0.535, 0.609] | [0.616, 0.706] |

# Explaining $R_D$ and $R_D^*$ together

A minimum value of $C^{\tau}_{VL} \approx -C^{\tau}_{AL} \approx 1.07$ can explain both $R_D$ and $R_{D^*}$

$$\rightarrow \quad \frac{g^2_{NP}}{\Lambda^2}\,[\bar{c}\gamma^{\mu}\mathrm{P}_L b]\,[\bar{\ell}\,\gamma_{\mu}\mathrm{P}_L\,\nu]$$

$$\rightarrow \quad \Lambda \approx g_{\mathrm{NP}}\, 2.25\ \mathrm{TeV}$$