Universität
Zürich$^{\text{UZH}}$

Hunting τ loops in $B^+ \to K^+\mu^+\mu^-$

Claudia Cornella
University of Zurich

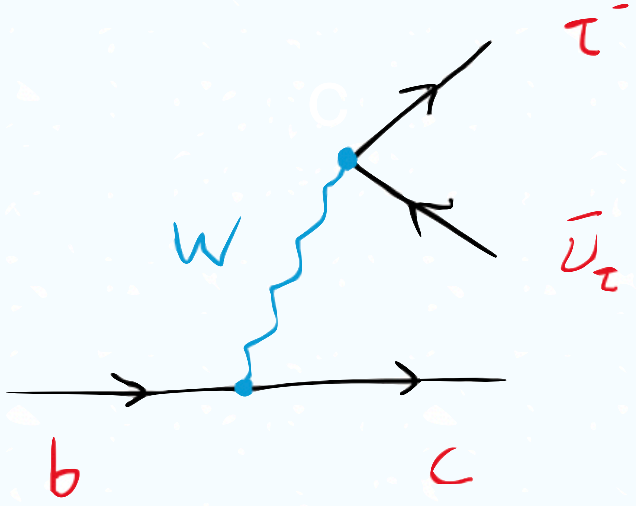
based on ongoing work with G.Isidori, M.König, S. Liechti, P. Owen, N.Serra

Introduction

Flavour anomalies in semileptonic B-decays:

$b \to c\tau\nu$

τ/μ ~~universality~~



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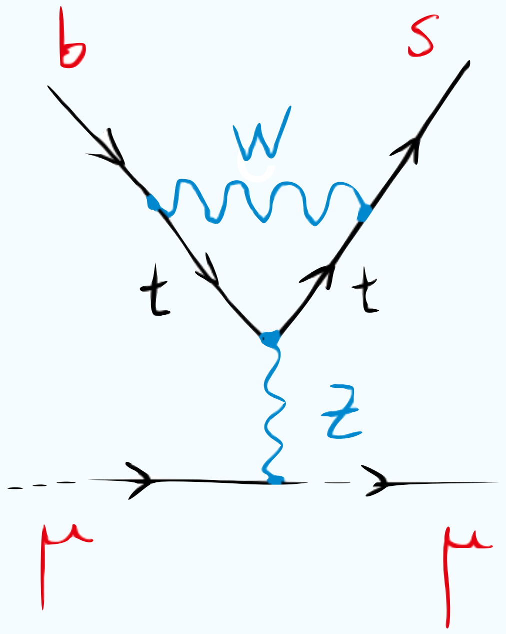

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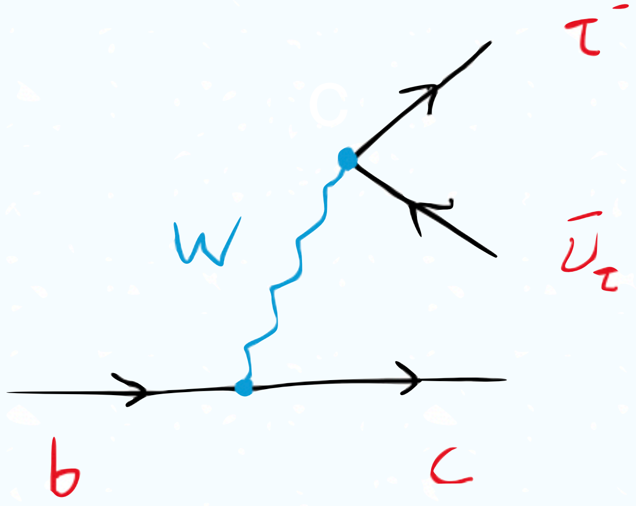

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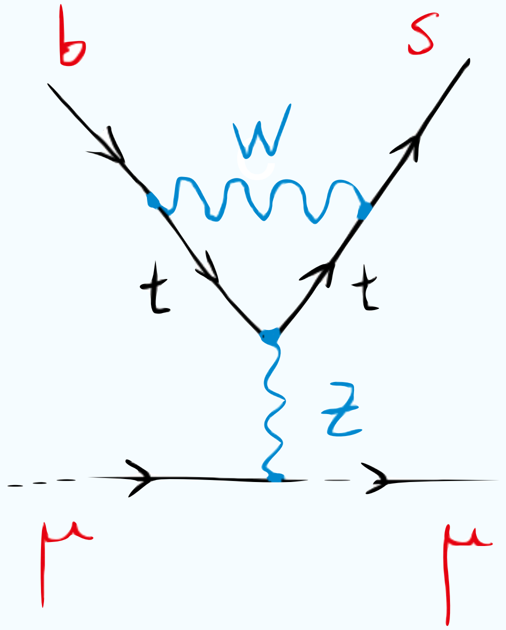

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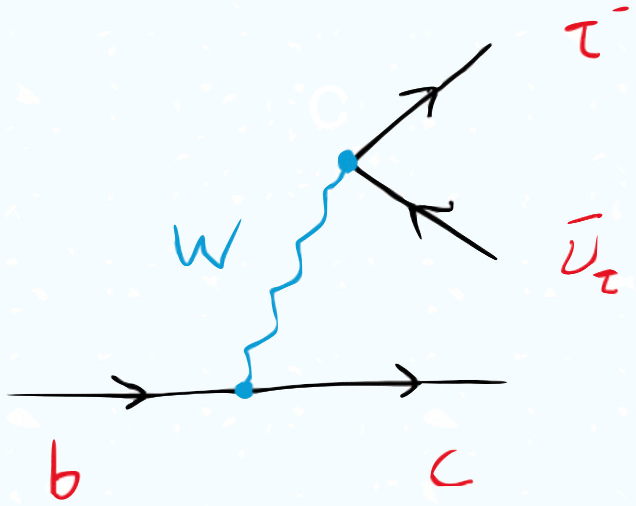

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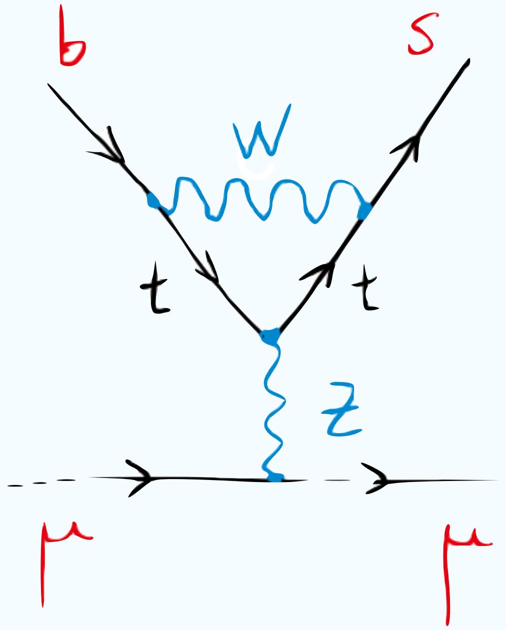

Combined explanation calls for NP coupled dominantly to 3rd generation

General prediction: huge enhancement of $b \to s\tau\tau$ transitions!

Constraining NP in taus…from muons?

Probing $b \to s\tau\tau$ directly is experimentally very challenging:

$B^+ \to K^+\tau^+\tau^-$	$\mathscr{B}_{\text{exp}} < 2.25 \cdot 10^{-3}$	[BaBar]	$\mathscr{B}_{\text{SM}} = 1.2 \cdot 10^{-7}$
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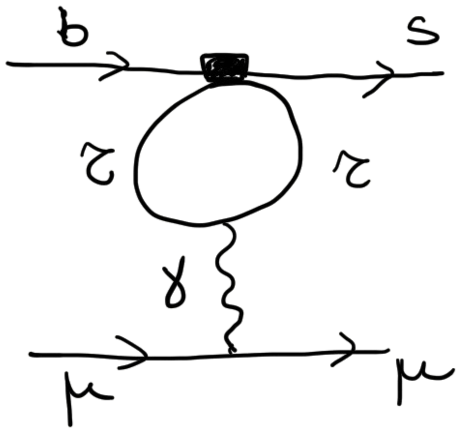

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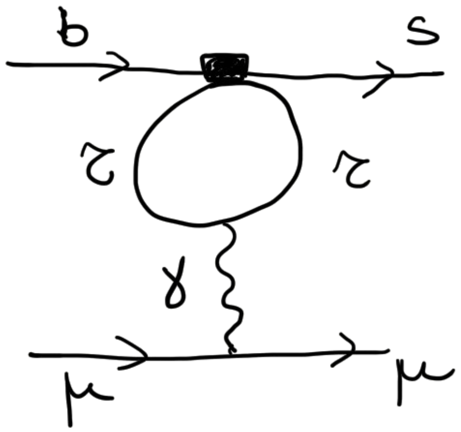

…a solid description of SM spectrum shape in the full q^2 range is needed!

EFT description of $b \to s\ell\ell$

Weak effective Lagrangian: $$\mathscr{L}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_i C_i(\mu)\, O_i\,,$$

SM: $$\left\{ \begin{array}{ll} O_9^\ell = \dfrac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \ell) & O_{10}^\ell = \dfrac{e^2}{16\pi^2} (\bar{s}\gamma_\mu P_L b)(\bar{\ell}\gamma^\mu \gamma_5 \ell) \\ O_7 = \dfrac{e}{16\pi^2} m_b\, (\bar{s}\sigma_{\mu\nu} P_R b)\, F^{\mu\nu} & \\ O_1^q = (\bar{s}\gamma_\mu P_L q)(\bar{q}\gamma^\mu P_L b) & O_2^q = (\bar{s}^\alpha \gamma_\mu P_L q^\beta)(\bar{q}^\beta \gamma^\mu P_L b^\alpha) \end{array} \right.$$

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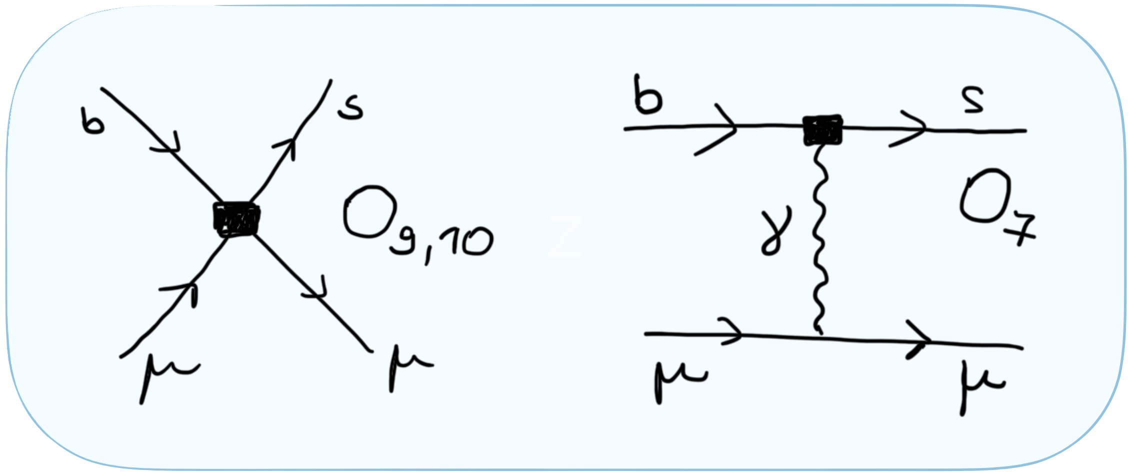

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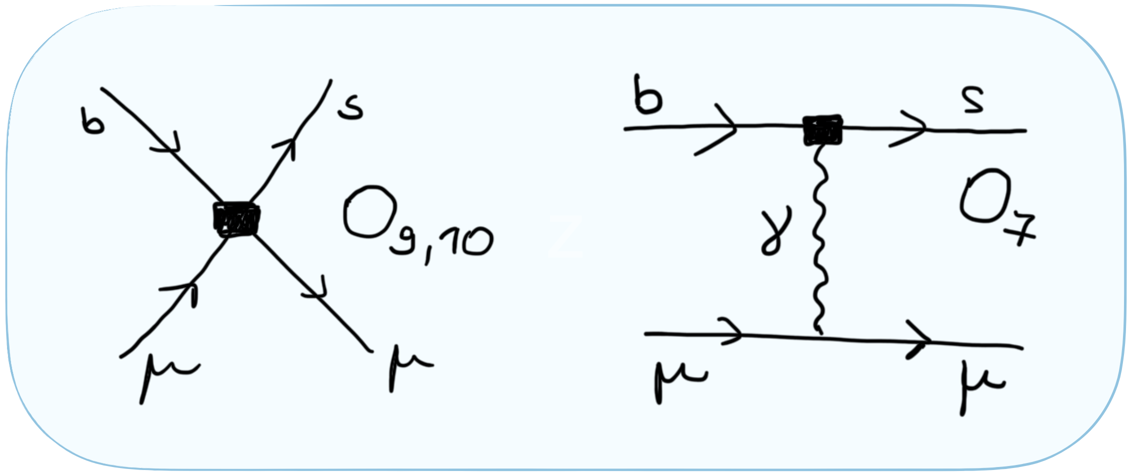

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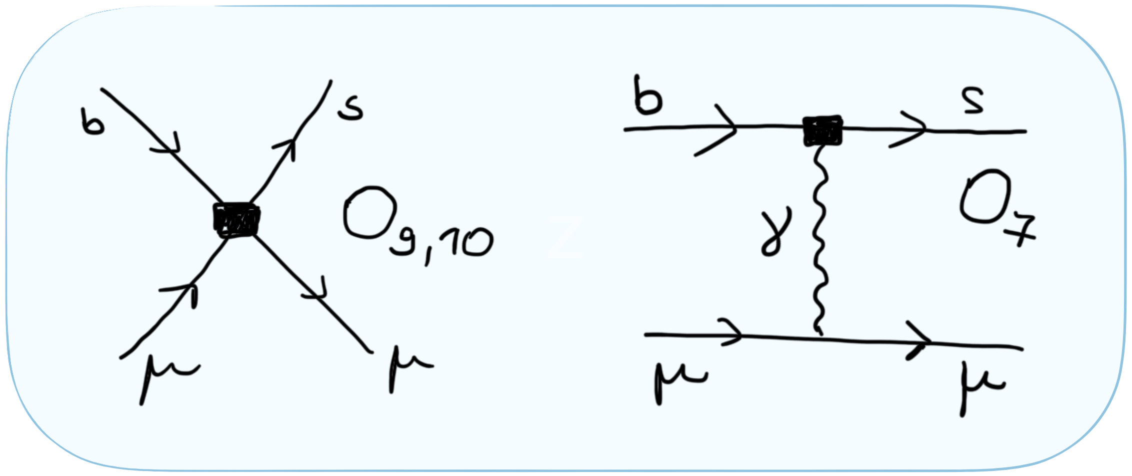

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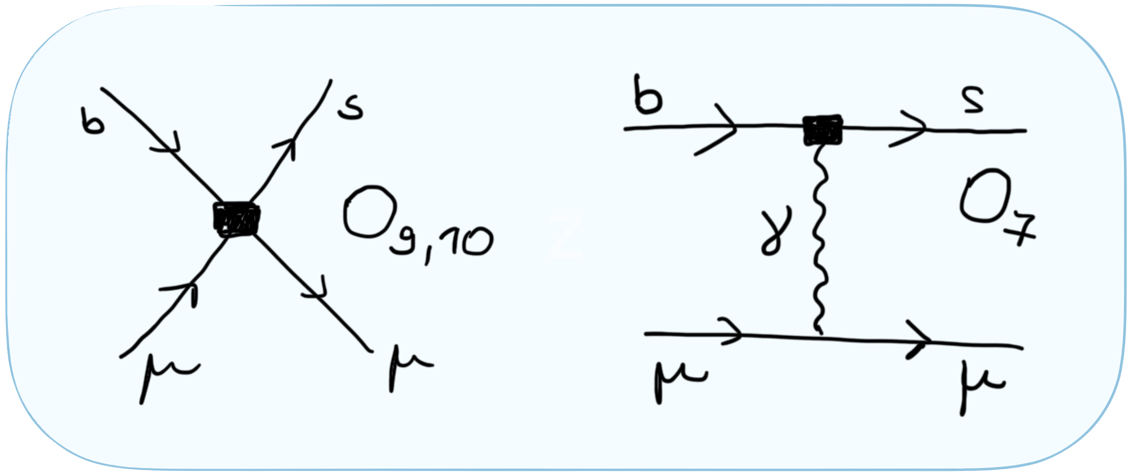

Two ingredients needed:

- $C_i^{SM}(\mu)$
- form factors $f_i(q^2)$ for $B \to K$

Non-local effects: the charm loop

Non-local (long distance) effects arise via 4-quark + chromomagnetic operator. Included via

$$C_9 \rightarrow C_9^{\mathrm{eff}}(q^2) = C_9 + Y(q^2)$$

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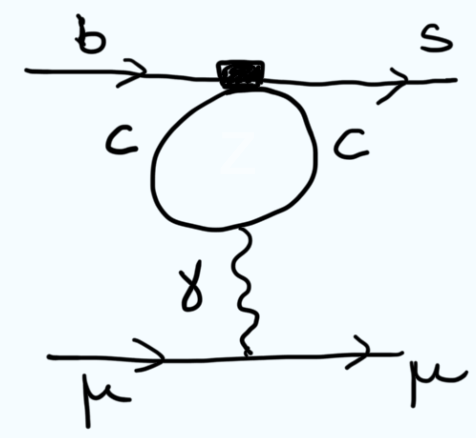

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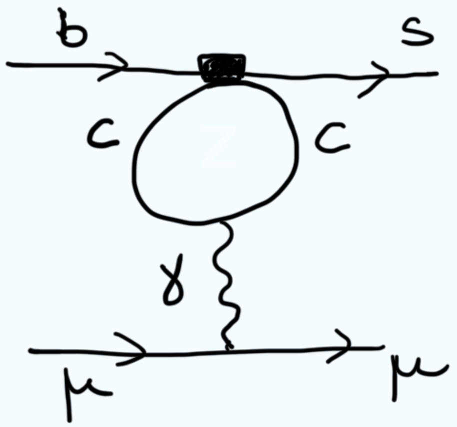
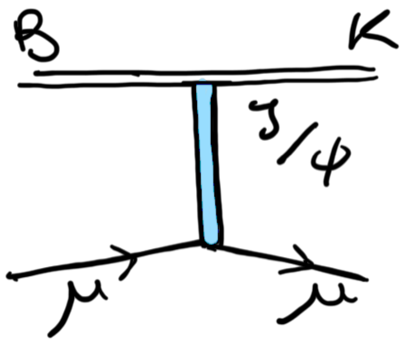


[Semi]perturbative approach valid at low q^2:

Pert. contribution + expansion in $\Lambda^2_{QCD}/(q^2 - 4m_c^2)$

[Khodjamirian et al., 1212.0234]

<u>cannot</u> be applied in the full kinematical range :



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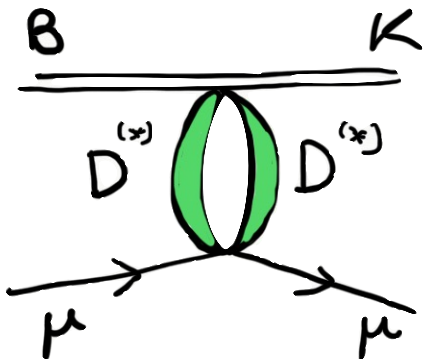

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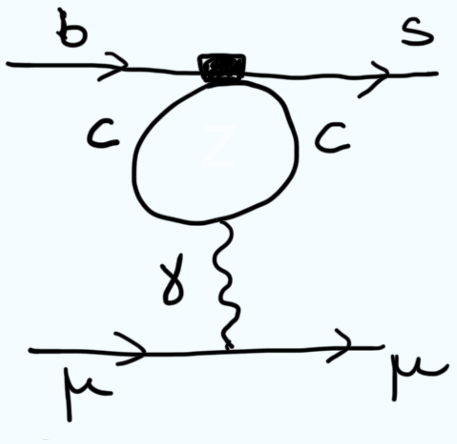

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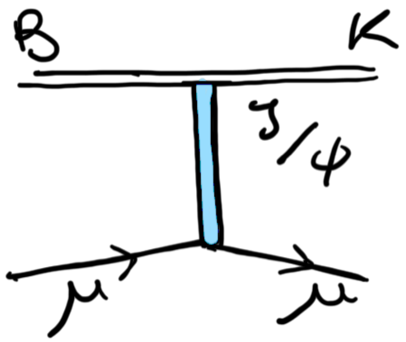

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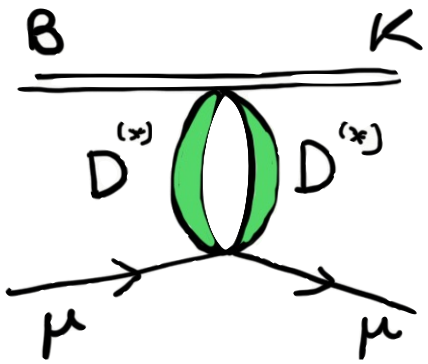

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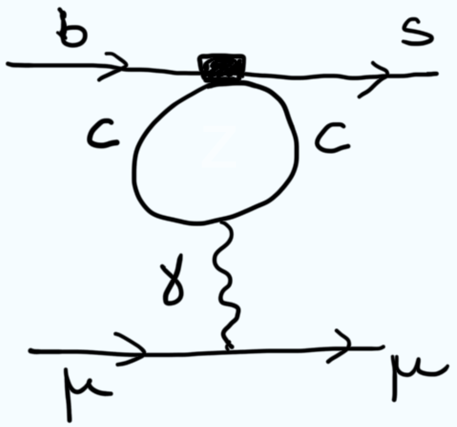

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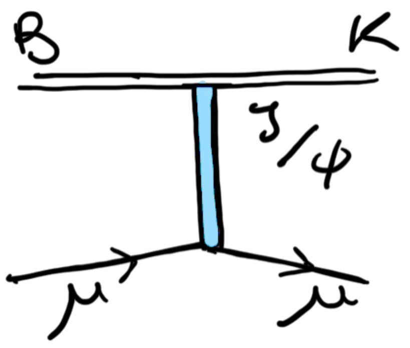

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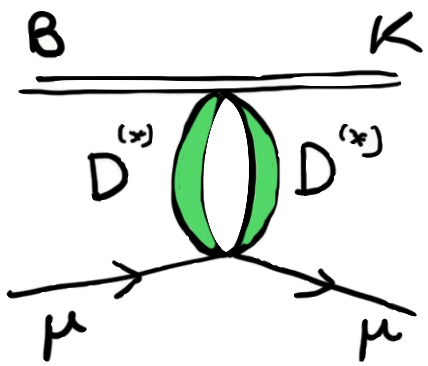

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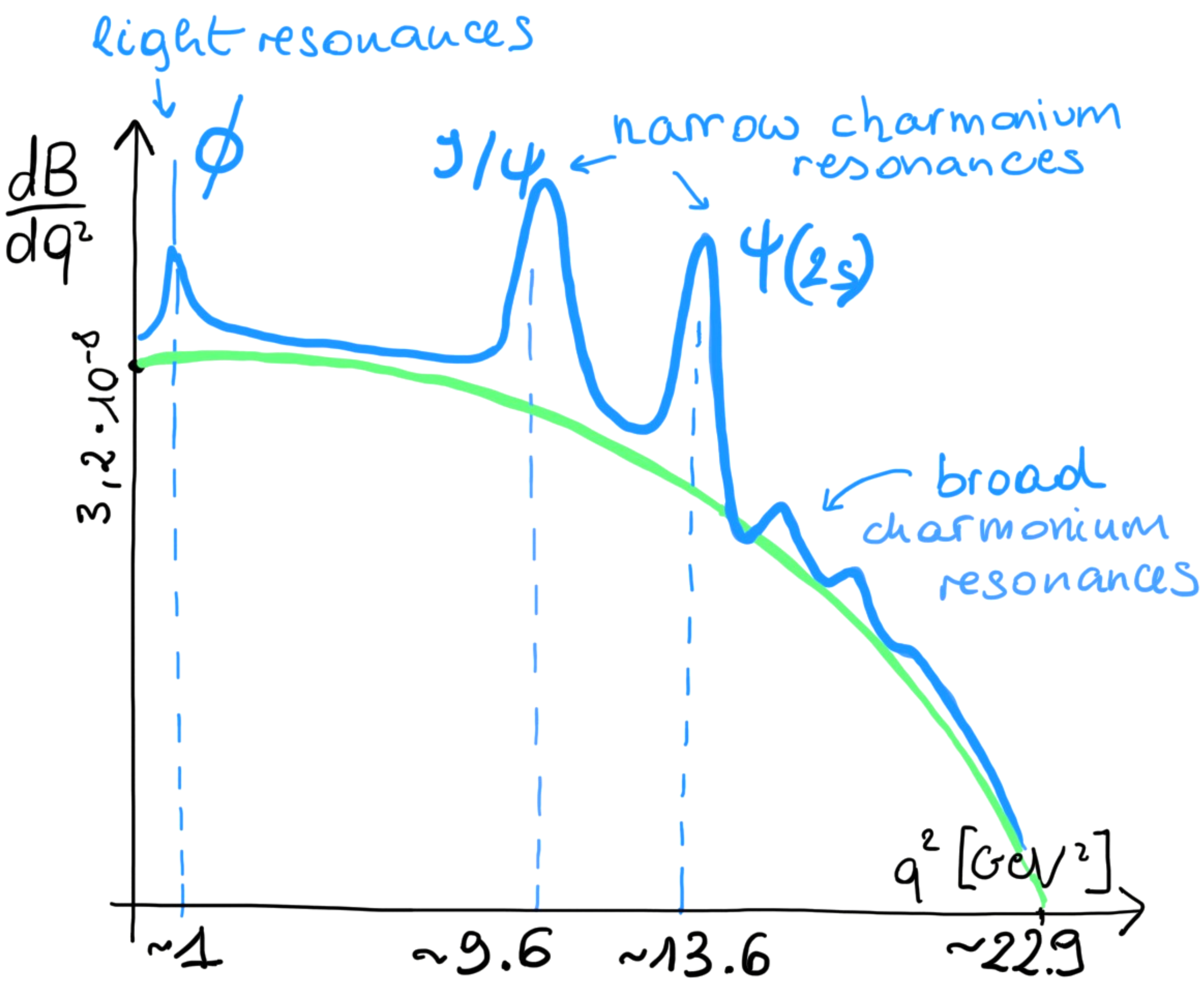
Goal: model long-distance effects at experiments, in the entire spectrum.

Long-distance effects at experiments



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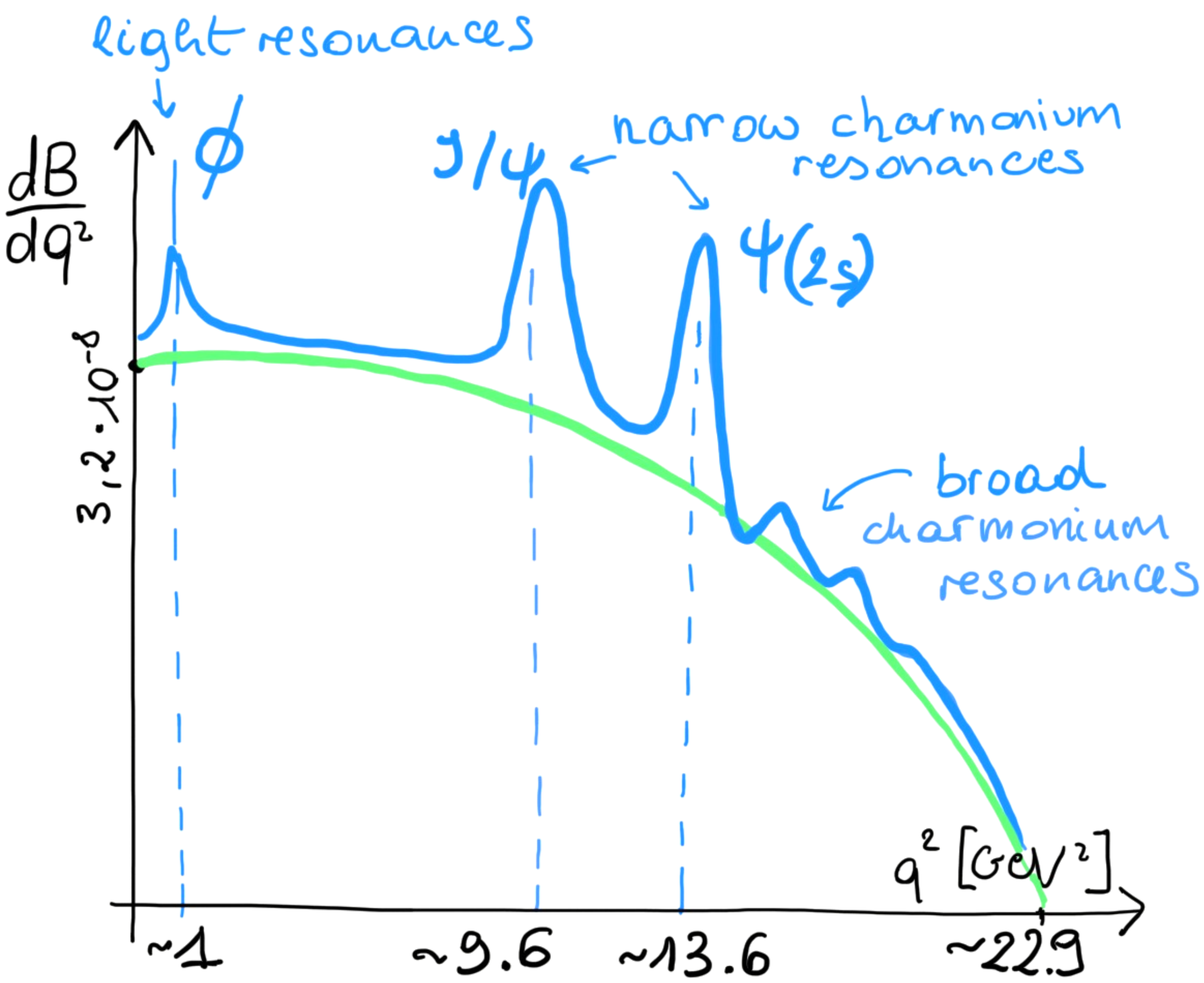

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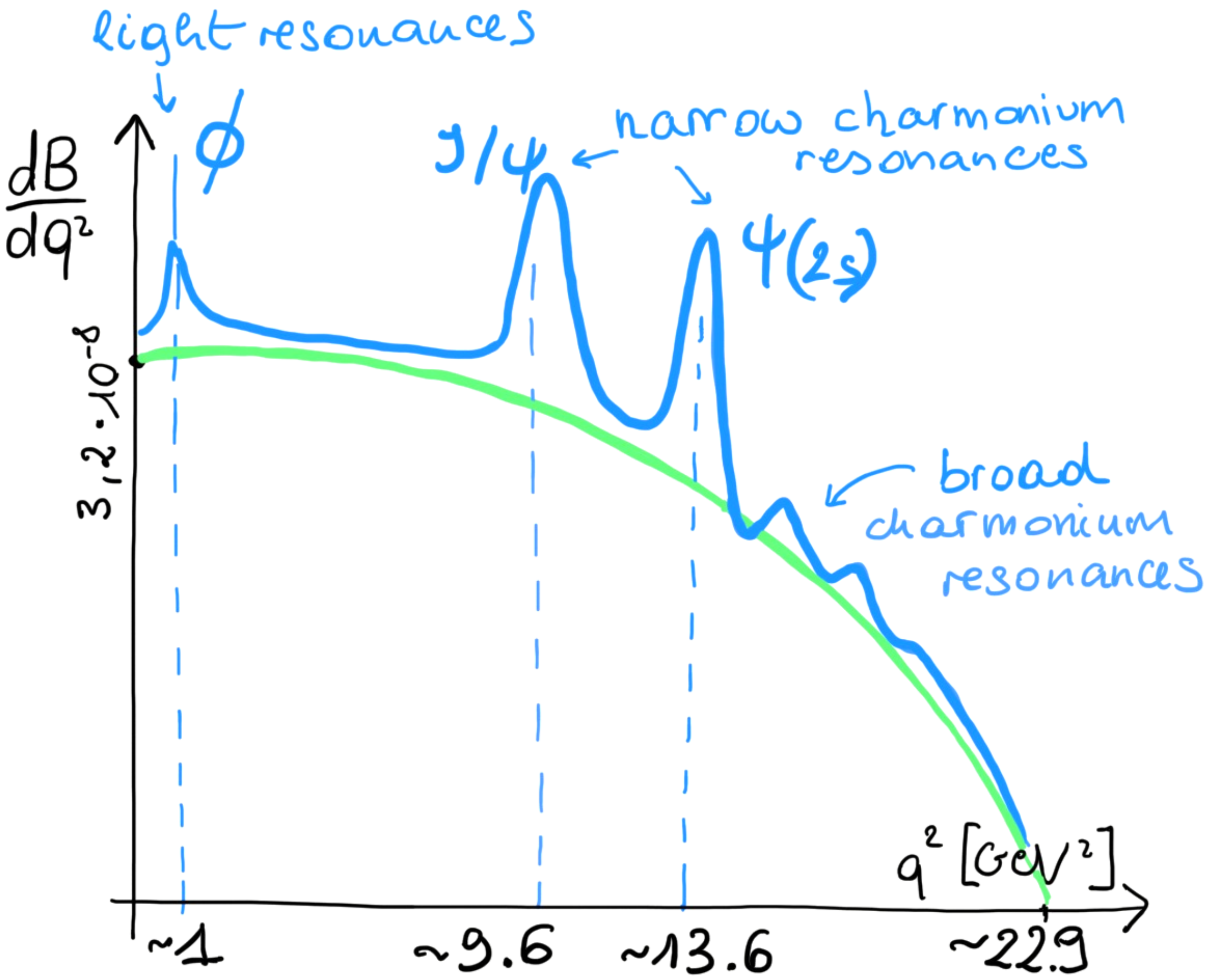

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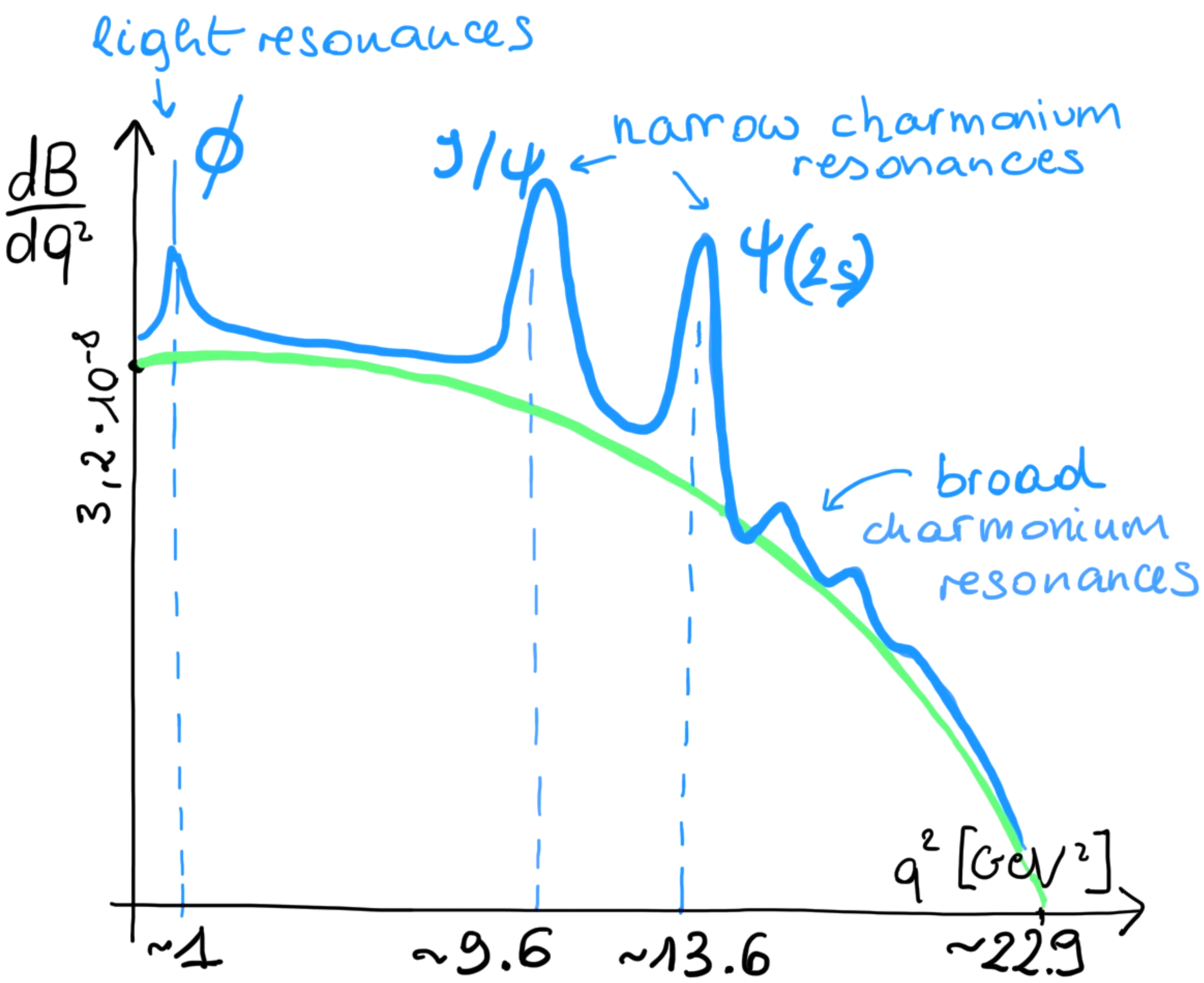
fit parameters

Long-distance effects at experiments



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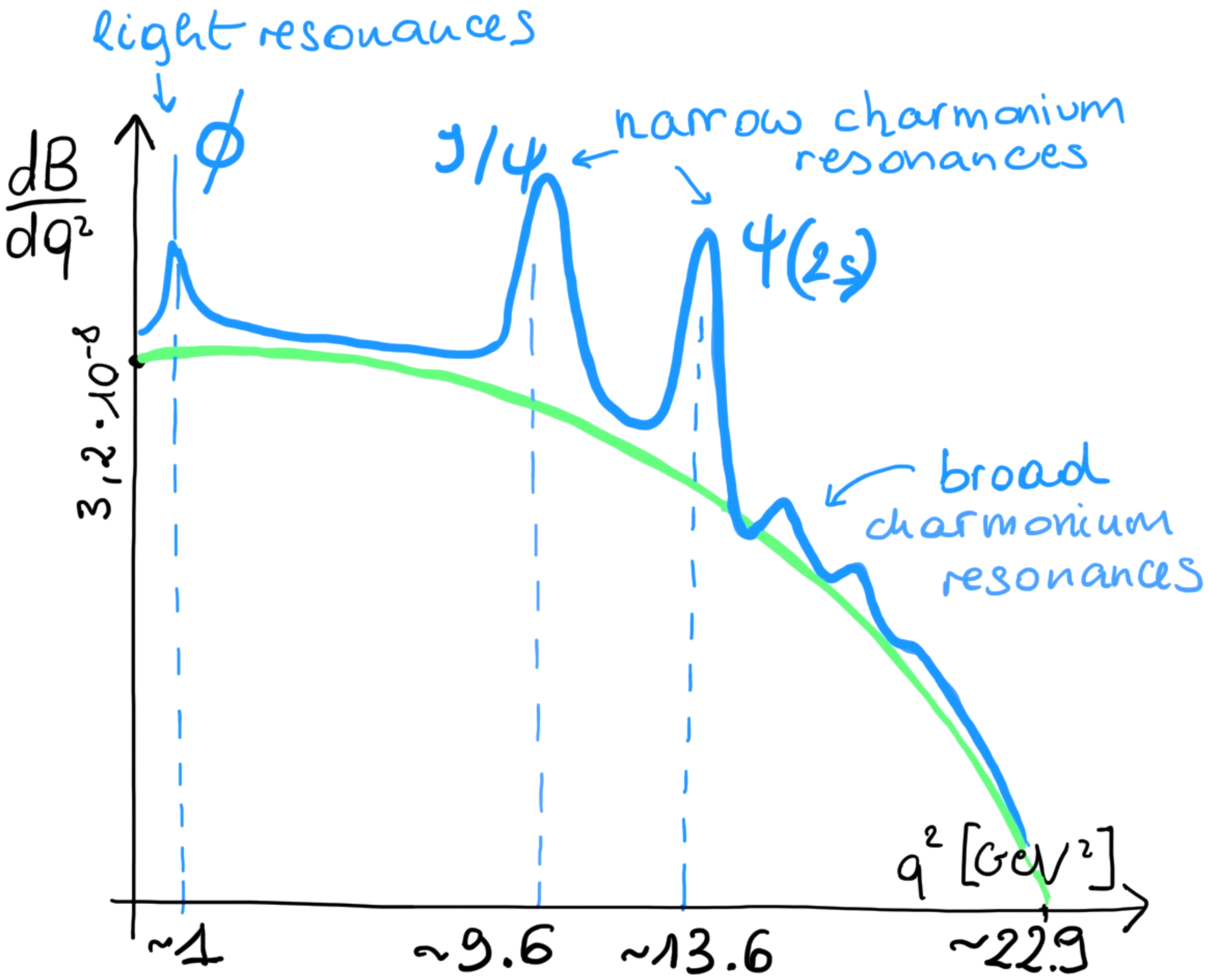

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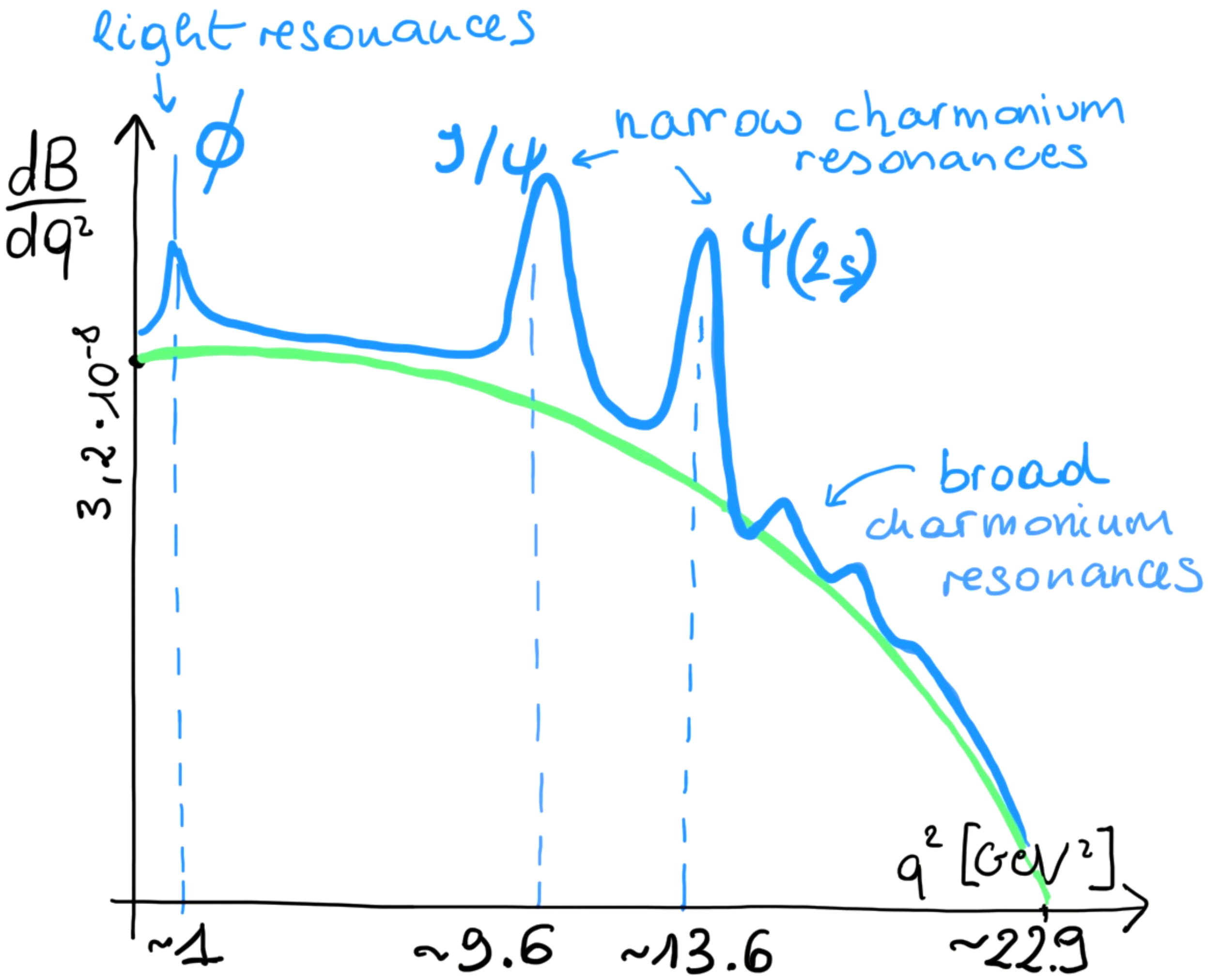

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- extract reliable short-distance info [hence NP!]

Charm loops: resonances

For the charm we employ a dispersive approach, with subtraction in $q^2 = 0$:

$$\Delta Y_{c\bar{c}}(q^2) = \frac{q^2}{\pi}\int_{s_0}^{\infty}\frac{ds}{s}\frac{\rho_{c\bar{c}}(s)}{(s-q^2)}$$

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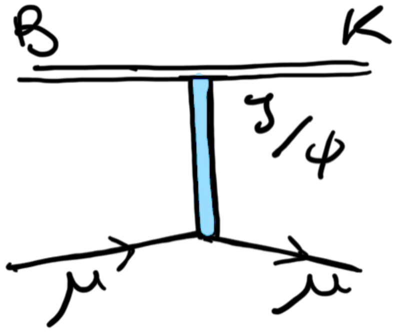

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$$V = J/\psi, \psi(2S), \psi(3770)\,, \psi(4040), \psi(4160), \psi(4415)$$

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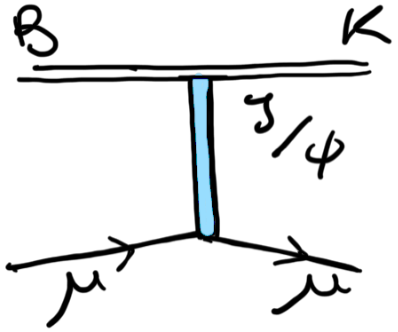
Charmonium resonances:

BW, subtracted in $q^2 = 0$!



$$\Delta Y_{c\bar{c}}^{1\mathrm{P}}(q^2) = \sum_V \eta_V \, e^{i\delta_V} \frac{q^2}{m_V^2} A_V^{\mathrm{res}}(q^2)$$

$$V = J/\psi, \psi(2S), \psi(3770)\,, \psi(4040), \psi(4160), \psi(4415)$$

Charm loops: two-particle states

Two-particle $\bar{c}c$ states:

$$\Delta Y^{2\mathrm{P}}_{c\bar{c}}(q^2) = \sum_{VV'} \eta_{VV'} e^{i\delta_{VV'}} A^{2\mathrm{P}}_{VV'}(q^2) \qquad A^{2\mathrm{P}}_{VV'}(s) = \frac{s}{\pi} \int_{s_0}^{\infty} \frac{d\tilde{s}}{\tilde{s}} \frac{\rho_{VV'}(\tilde{s})}{(\tilde{s} - s)},$$

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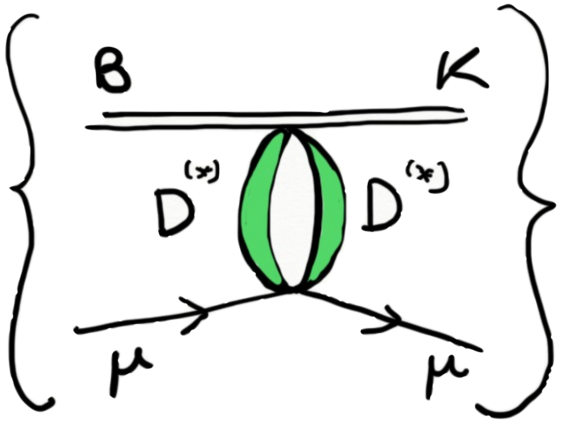
$\rho_{VV'}(s)$ = Im



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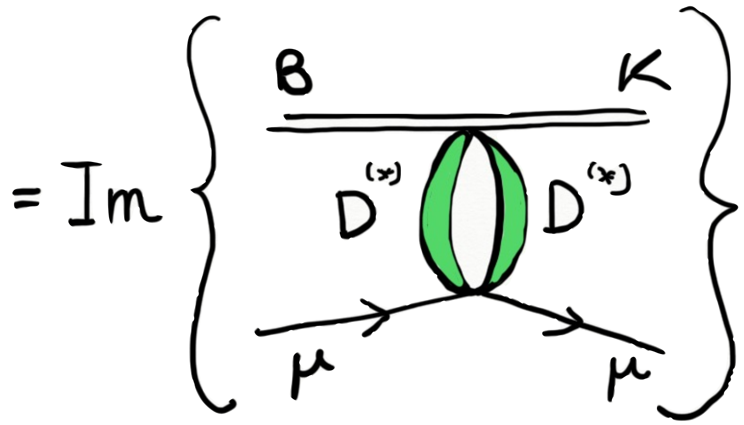

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…estimate from helicity arguments!

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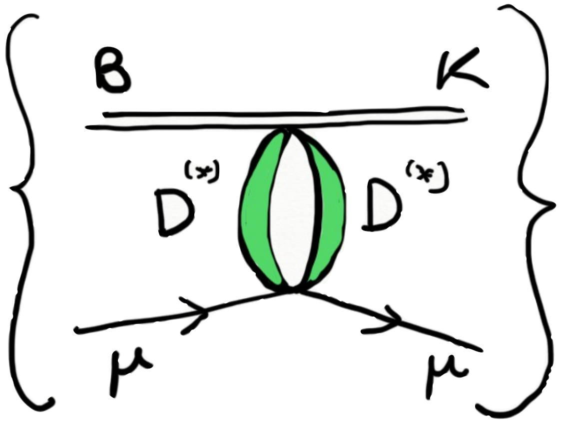

$$= \sum_n c_n^{VV'} \beta^n(4m_{VV'}^2/s) \qquad \beta(\tau) = \sqrt{1 - \tau}$$

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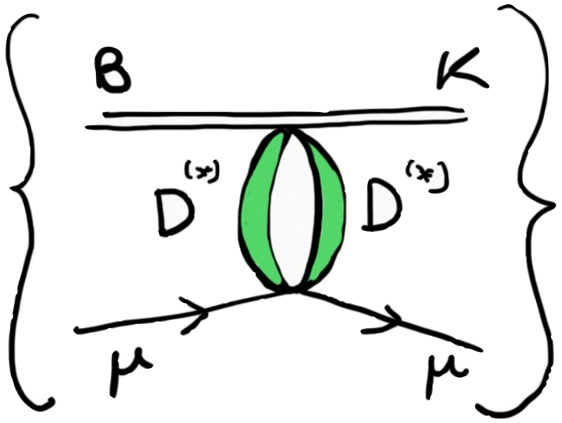

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Keeping leading partial wave only: $\rho_{DD} \sim \beta^3\,,\ \rho_{D^*D^*} \sim \beta^3\,,\ \rho_{DD^*} \sim \beta$

Charm loops: two-particle states

Two-particle $\bar{c}c$ states:

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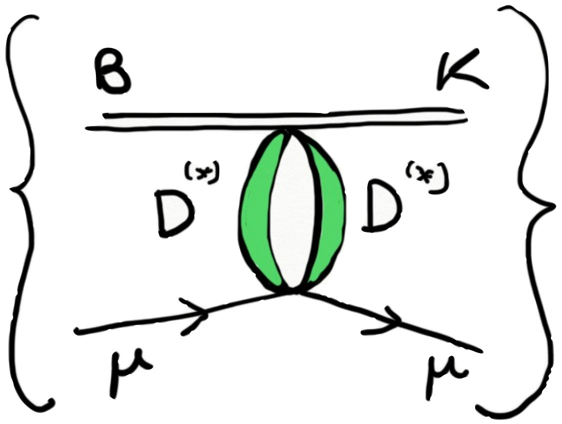

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$$Y^{\rm 1P}_{c\bar{c}}(q^2) + Y^{\rm 2P}_{c\bar{c}}(q^2) \approx Y^{\rm pert}_{c\bar{c}}(q^2) \qquad\qquad q^2 \ll 4m_c^2$$

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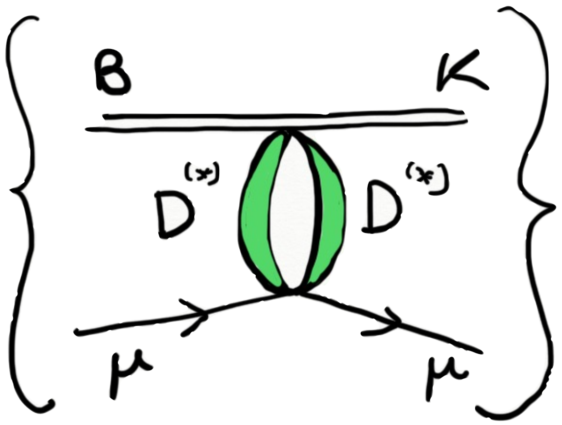

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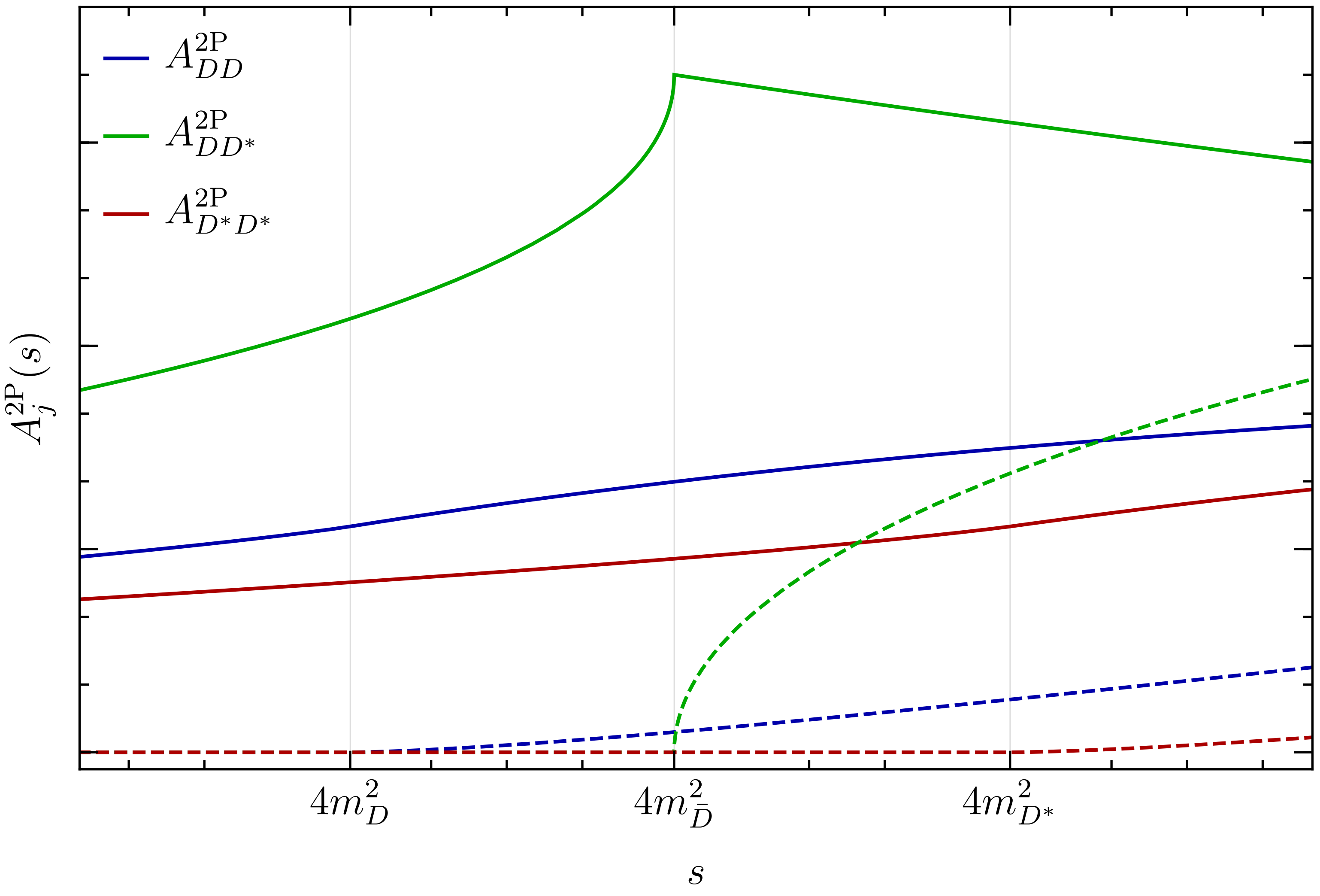
Up contribution is CKM suppressed: only resonances included.

Charm loops: two-particle states



$$\rho_{DD} = \left(1 - \frac{4m_D^2}{s}\right)^{3/2} \qquad \rho_{D^*D} = \left(1 - \frac{4m_{\bar{D}}^2}{s}\right)^{\mathbf{1/2}} \qquad \rho_{D^*D^*} = \left(1 - \frac{4m_{D^*}^2}{s}\right)^{3/2}$$

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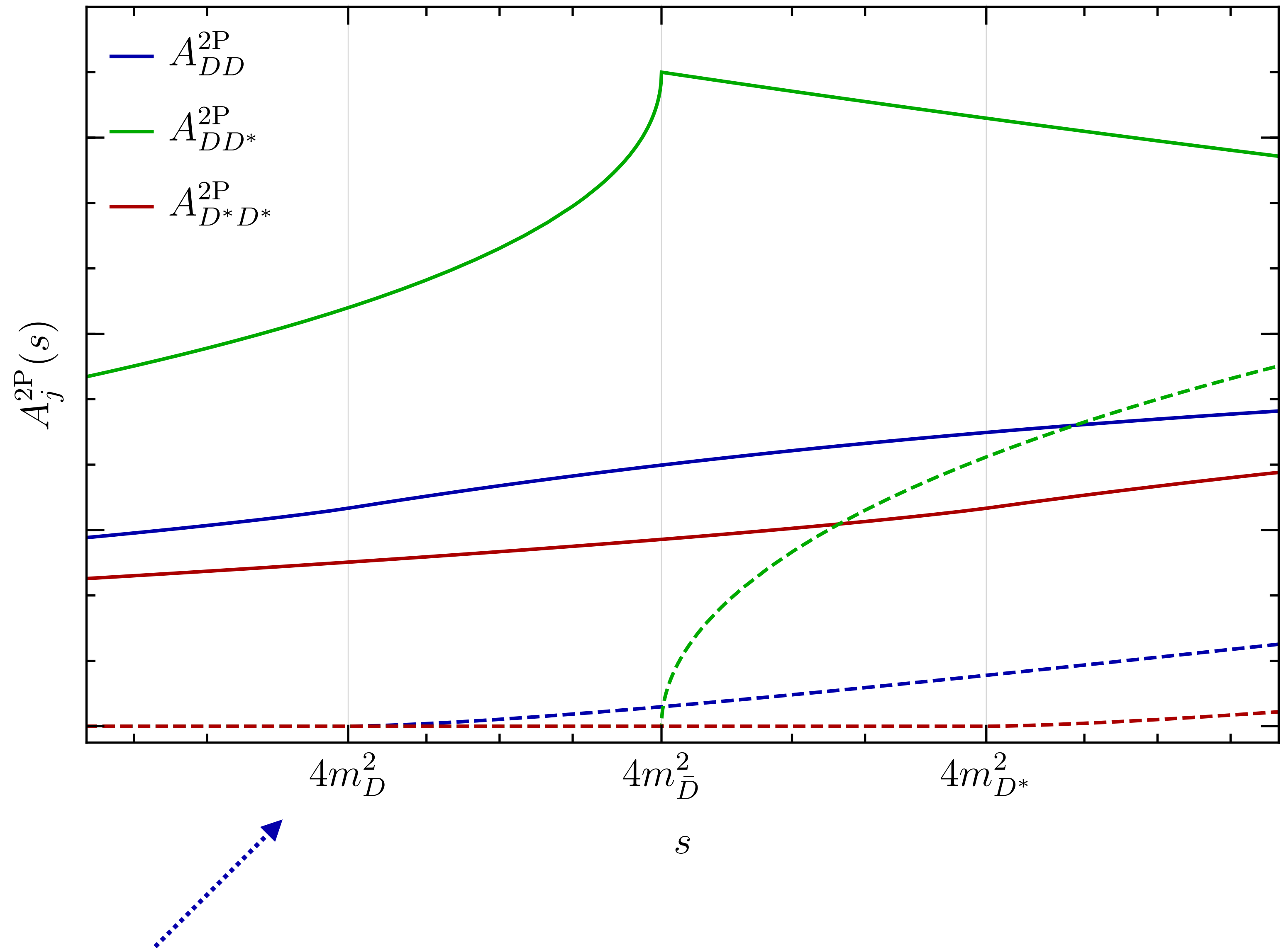

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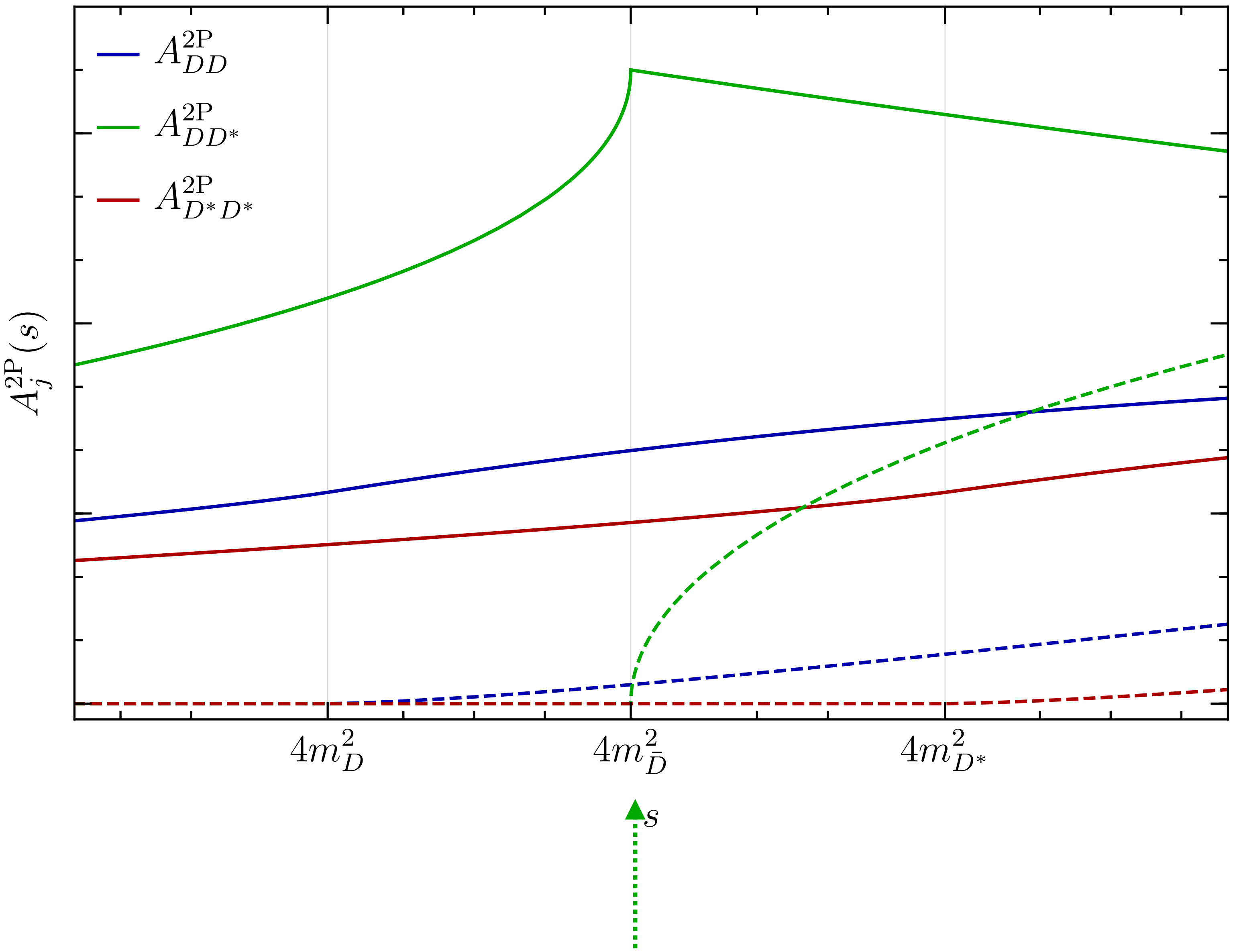

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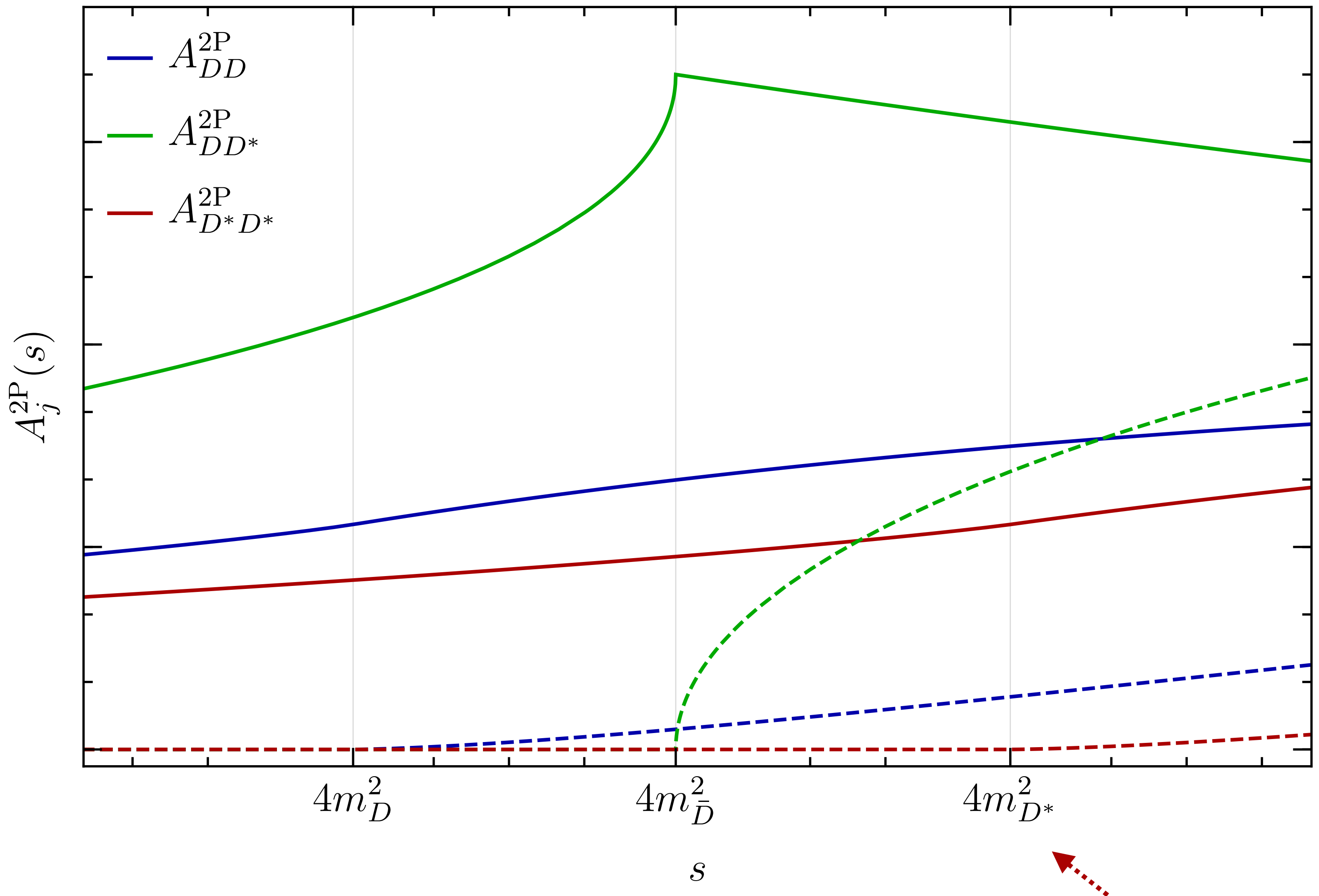

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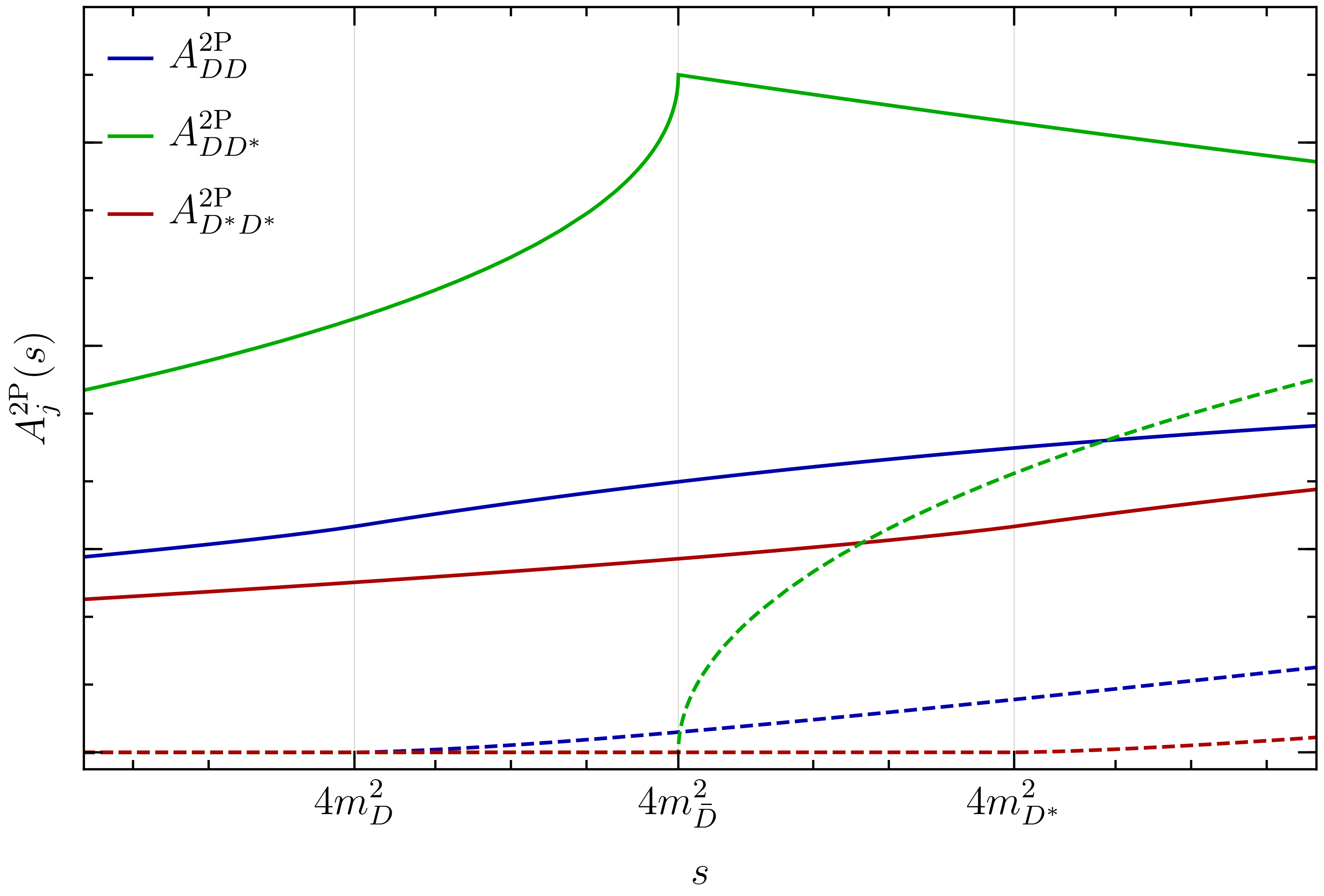

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Our proposal

We parametrise hadronic long-distance contributions as:

$$Y(q^2) = Y_0 + Y_{light}^{1\mathrm{P}}(q^2) + \Delta Y_{c\bar{c}}^{1\mathrm{P}}(q^2) + \Delta Y_{c\bar{c}}^{2\mathrm{P}}(q^2)$$

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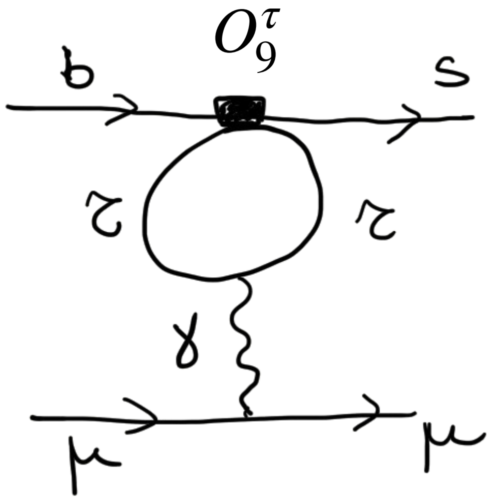
Tau loops in $b \to s\mu\mu$

The tau loop also enters as a q^2-dependent shift in $C_9^{eff}(q^2)$:



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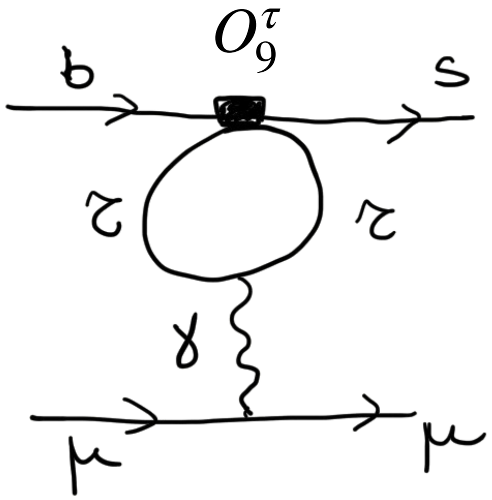

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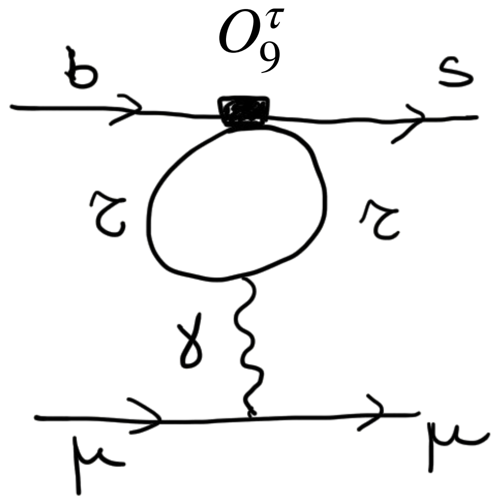

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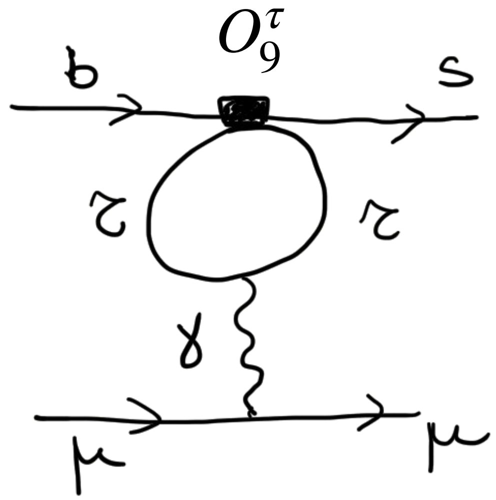

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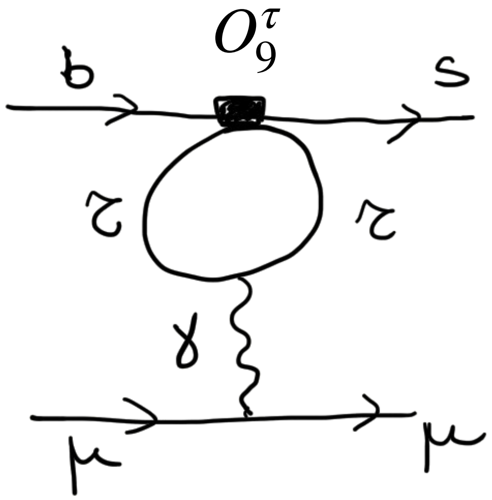

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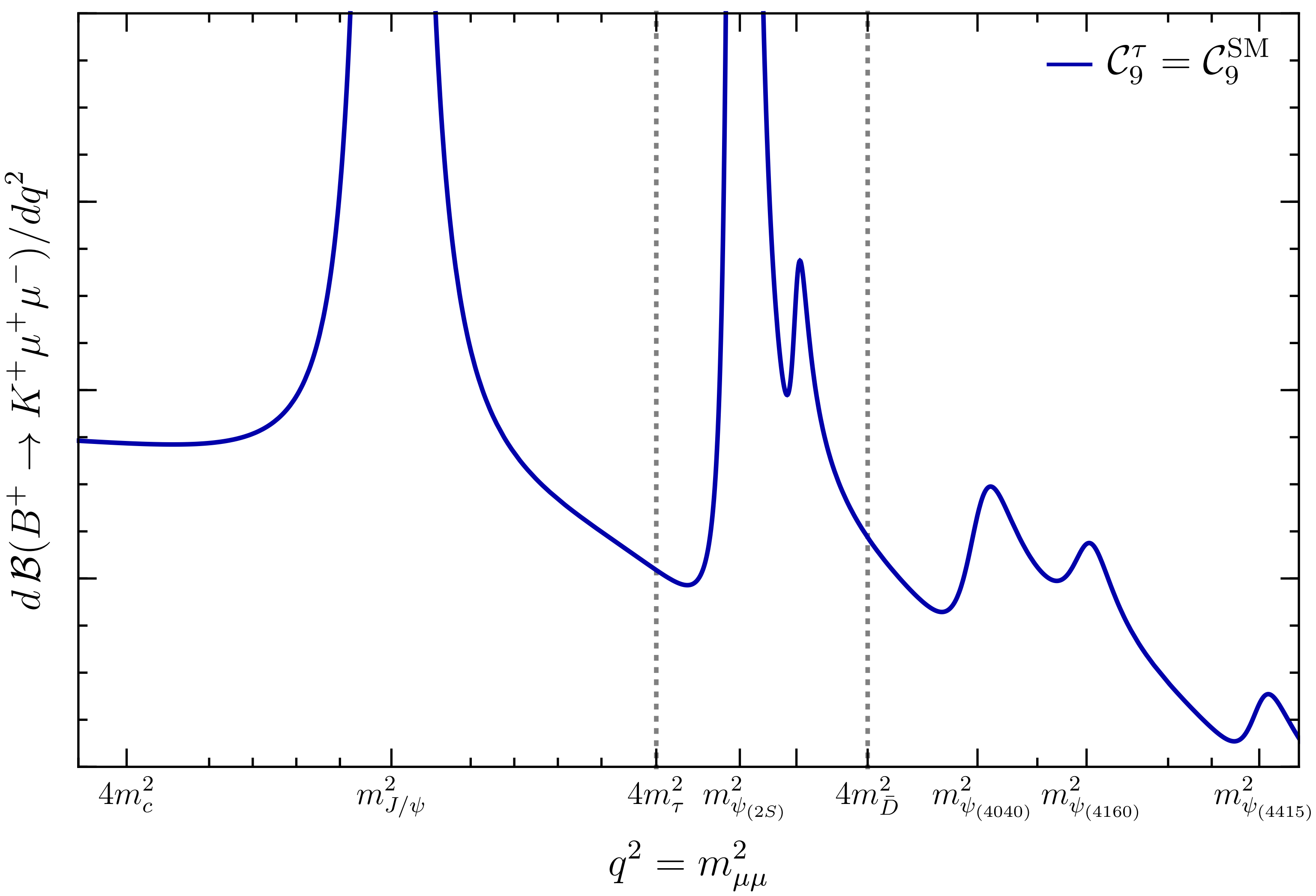

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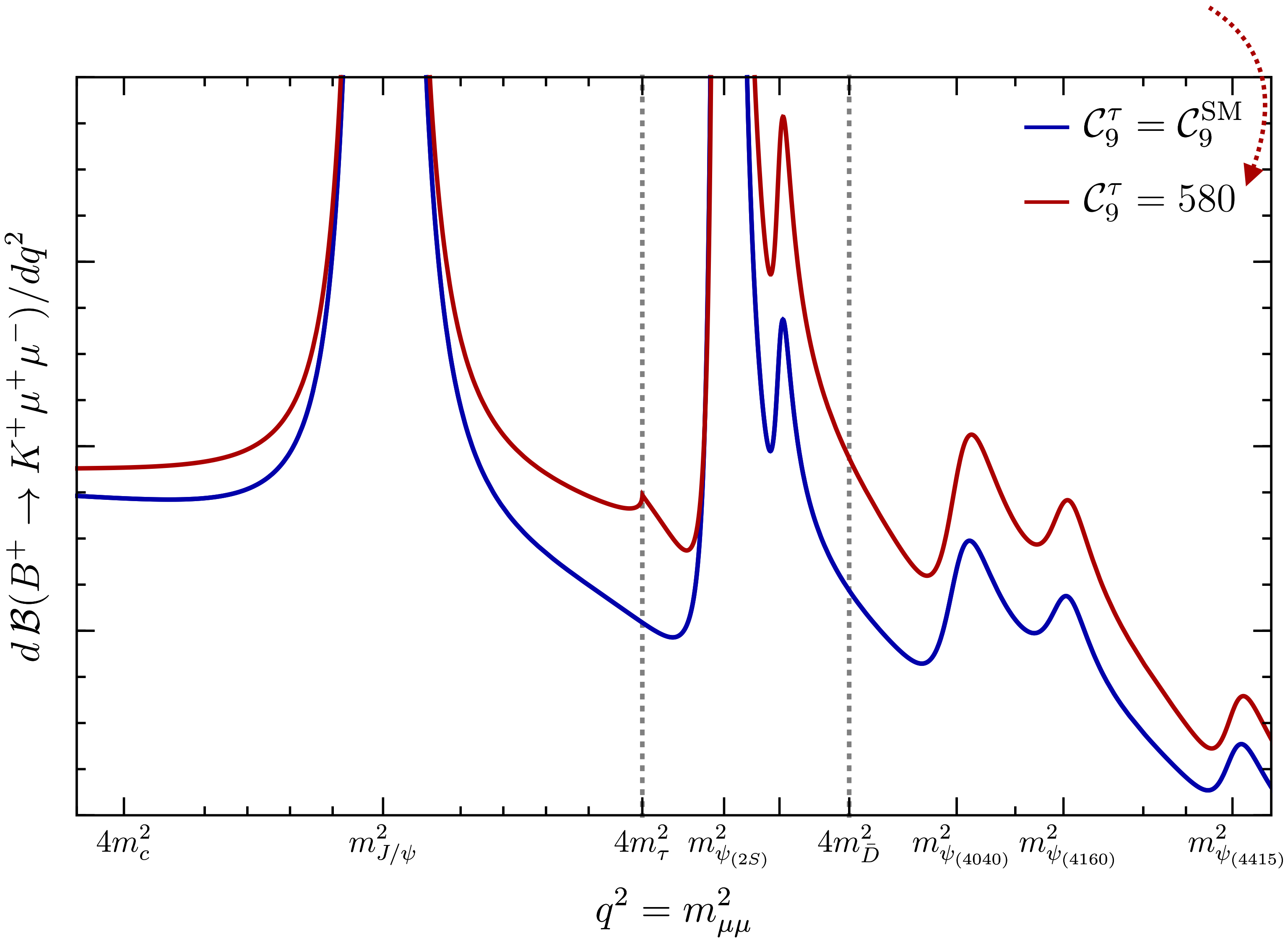

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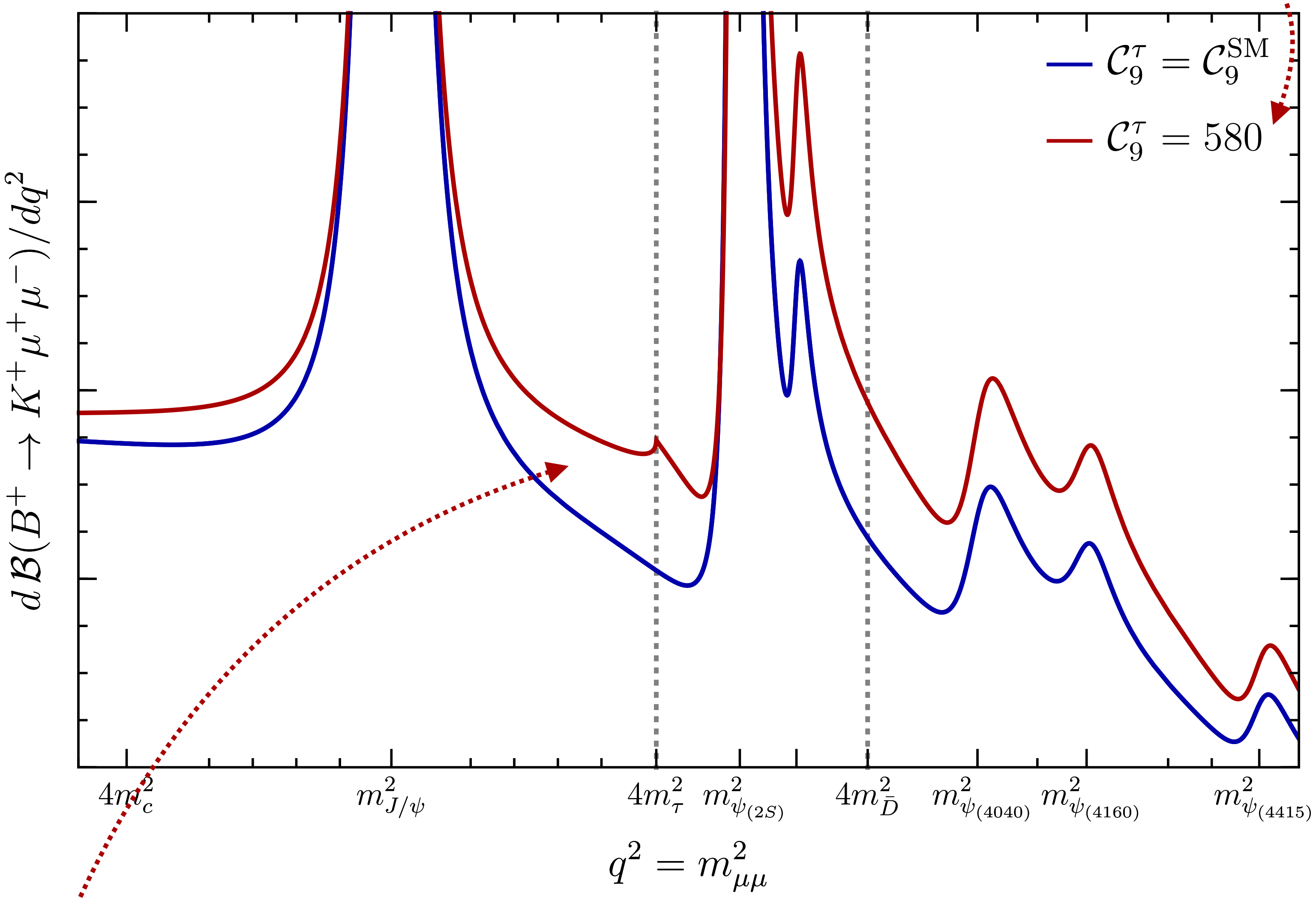

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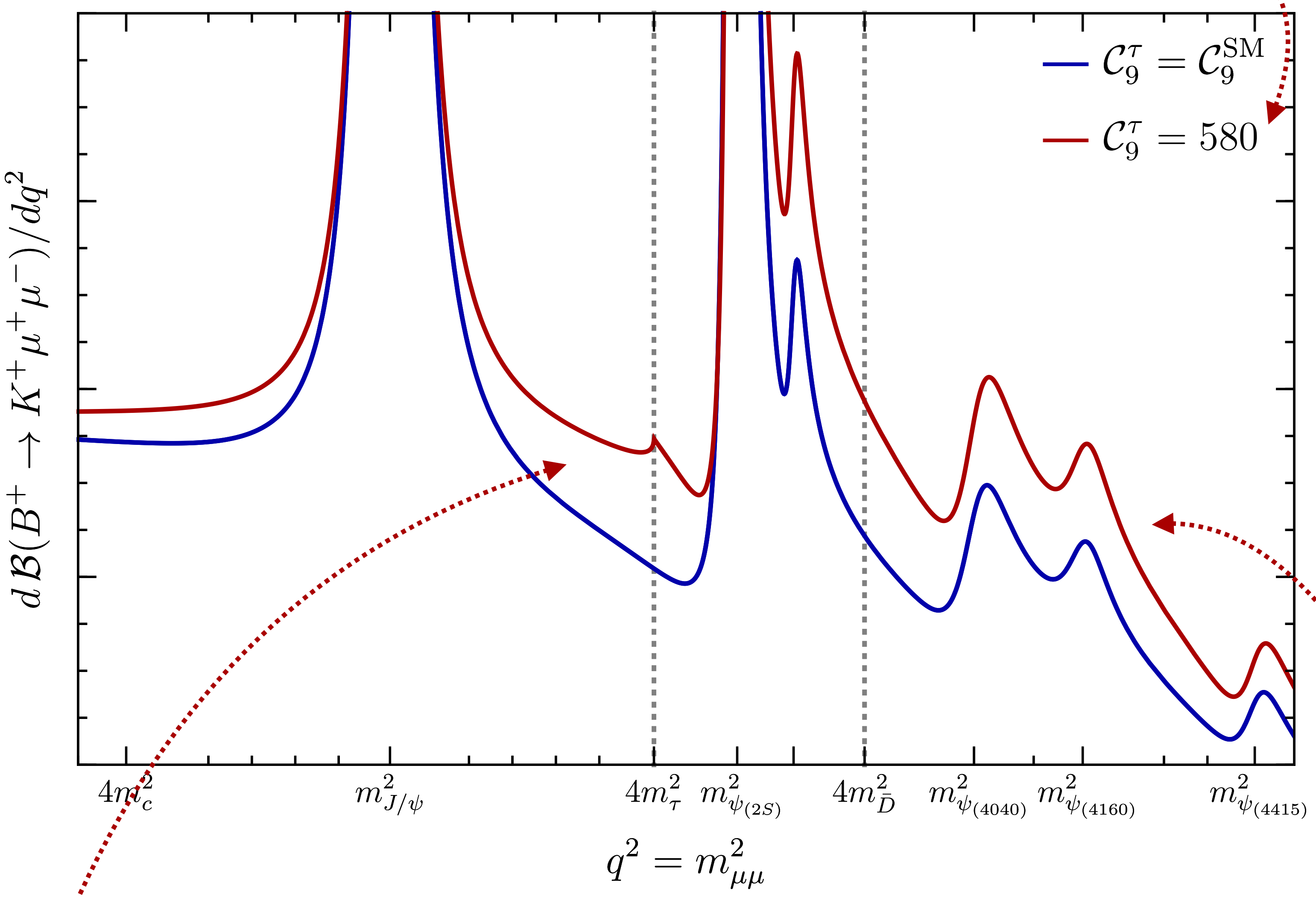

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distortion above and below threshold

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Future projections, assuming FF uncertainty reduced to $30\,\%$:

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Conclusions and outlook

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Thank you!