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FPCP 2019, Victoria

Lepton non-universality in B-decays in minimal leptoquark models

Michal Malinský
IPNP, Charles University in Prague

in collaboration with
T. Faber, M. Hudec, Y. Liu, H. Kolešová, W. Porod, F. Staub

based on:
Phys.Lett. B787 (2018) 159-166, arXiv:1902.04470 [hep-ph]

B decay anomalies from the BSM perspective

For intro see the talks by R. Alonso, M. Patel, M. Sevior, I. Carli,...

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  (many options; what does it really mean if a particular setting works/fails?)

  Hundreds of refs come here...

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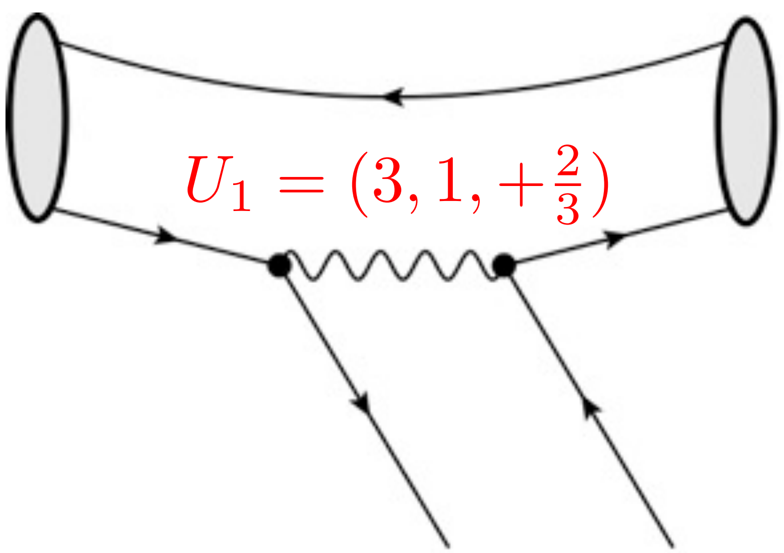

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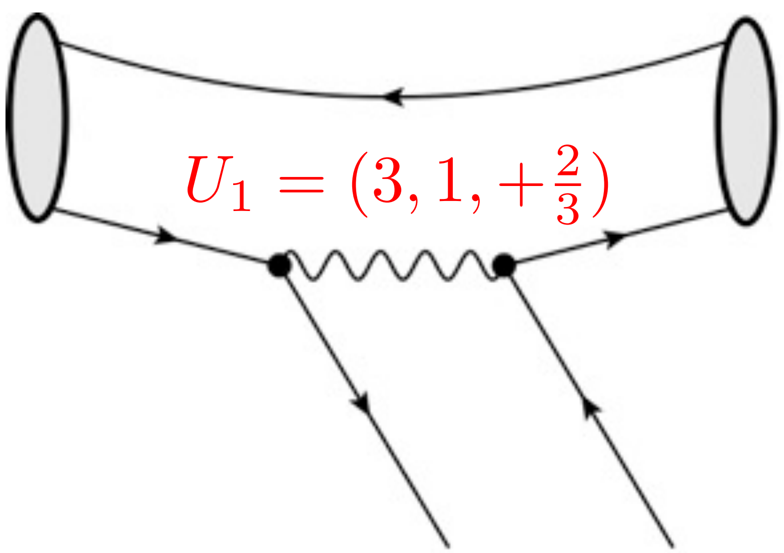

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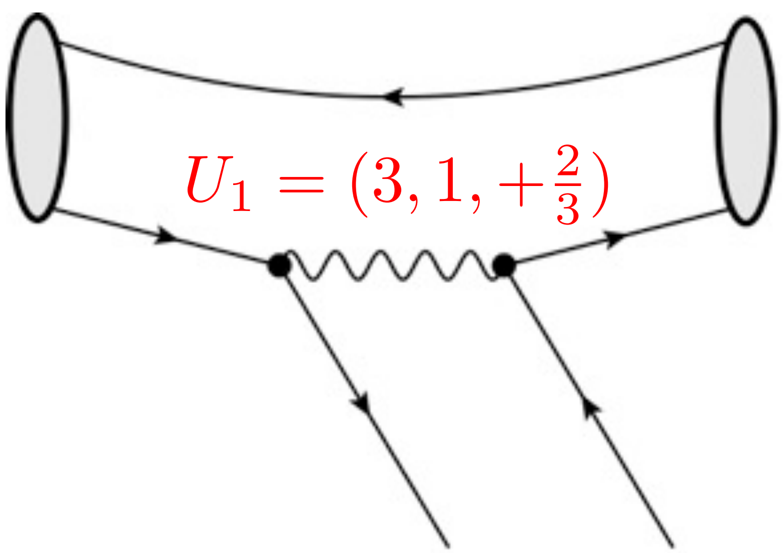

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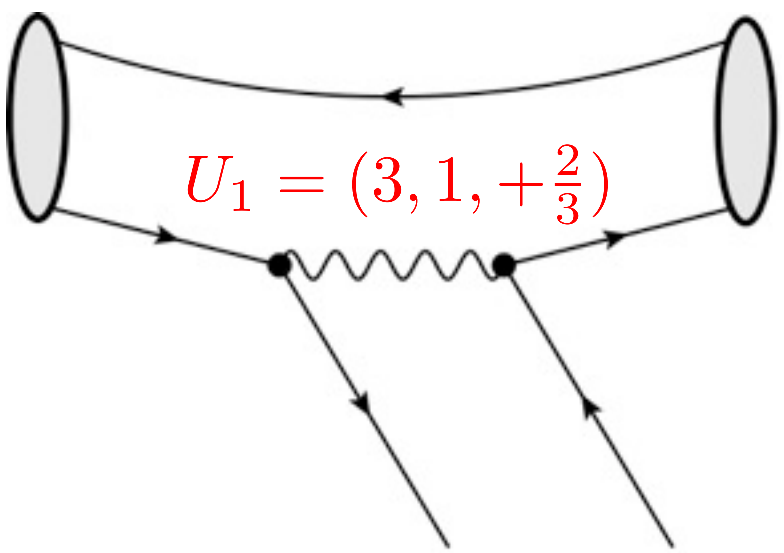

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WRONG AT THE RIGHT MOMENT = testable!

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Minimal potentially realistic gauge theory with leptoquarks

- With RH neutrinos $B-L$ is gaugeable
- $U(1)_Y \subset U(1)_R \otimes U(1)_{BL}$
- $SU(3)_c \otimes U(1)_{BL} \subset SU(4)_C$

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scalar gluons: $(8,2,+\tfrac{1}{2})$; $\tilde{R}_2$: $(\overline{3},2,-\tfrac{1}{6})$; R_2: $(3,2,+\tfrac{7}{6})$

Light leptoquarks in the 421 model?

U_1 vector leptoquark:

- **couplings are strongly constrained** by the gauge structure (unitarity of the CC)
  (can be cheated a bit if heavy extra vector-like matter was employed)

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Not really suitable for the B anomalies in the minimal LQ model!

(even for maximal couplings allowed by the 421 symmetry)

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Can one perhaps do better with scalars?

- Unitarity constraints do not apply to scalar (Yukawa) couplings!

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Only one of the *R*-LQs can be light, ***$R_{D^{(*)}}$* can not be addressed at all...**

T. Faber at al., Phys.Lett. B787 (2018) 159-166

$R_{K(*)}$ from light scalar leptoquarks in the 421 model?

$\tilde{R}_2$ **scalar:**

- Known to be problematic - single coupling, $R_{K^*} > 1$ (+nucleon decays)

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How about enhancing the denominator rather than arranging subtle negative interference effects in the numerator?

$$\frac{\Gamma(\bar{B} \to \bar{K}^{(*)}\mu^+\mu^-)}{\Gamma(\bar{B} \to \bar{K}^{(*)}e^+e^-)}$$

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Phenomenology of a light R_2 scalar

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Yukawa couplings in the "physical" basis:

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Constraints:

- LFV if different columns combine
- LFUV if any two columns differ

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$$\mathcal{L}_{\mathrm{R}_2} = \overline{\hat{d}_L}\, \hat{Y}_4^{de}\, \hat{e}_R\, R_2^{+2/3} + \overline{\hat{u}_L}\, V_{\mathrm{CKM}} \hat{Y}_4^{de}\, \hat{e}_R\, R_2^{+5/3} + \mathrm{h.c.}$$

Yukawa couplings in the "physical" basis:

$$\hat{Y}_4^{de} = \begin{pmatrix} y_{de} & y_{d\mu} & y_{d\tau} \\ y_{se} & y_{s\mu} & y_{s\tau} \\ y_{be} & y_{b\mu} & y_{b\tau} \end{pmatrix}$$

$K_L \to \mu e, B \to \ell\ell'$

Constraints:

- LFV if different columns combine
- LFUV if any two columns differ

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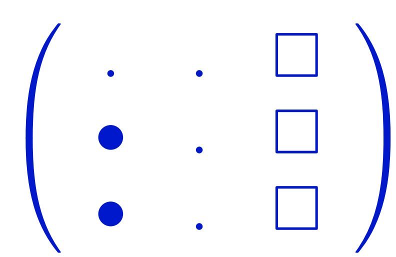

Safest to have zero muon column!

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Phenomenology of a light R_2 scalar in the 421 model

The 421 gauge structure:

$$\hat{Y}_4^{de} = \sqrt{\frac{3}{2}} \frac{1}{v_{\rm ew} \cos\beta} \left(\hat{M}_d U_d - V_d \hat{M}_e \right)$$

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$$\hat{Y}_4^{de} = \sqrt{\frac{3}{2}} \frac{\sqrt{1+\tan^2\beta}}{v_{\mathrm{ew}}} \begin{pmatrix} V_{11}\,(m_{\mathrm{d}} - m_{\mathrm{e}}) & V_{12}\,(m_{\mathrm{d}} - m_{\mu}) & V_{13}\,(m_{\mathrm{d}} - m_{\tau}) \\ V_{21}\,(m_{\mathrm{s}} - m_{\mathrm{e}}) & V_{22}\,(m_{\mathrm{s}} - m_{\mu}) & V_{23}\,(m_{\mathrm{s}} - m_{\tau}) \\ V_{31}\,(m_{\mathrm{b}} - m_{\mathrm{e}}) & V_{32}\,(m_{\mathrm{b}} - m_{\mu}) & V_{33}\,(m_{\mathrm{b}} - m_{\tau}) \end{pmatrix}$$

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Impossible to suppress entirely the 2nd column!

- issues with $K_L \to \mu e, R_{K^{(*)}}, \mu \to e\gamma$, etc.

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Phenomenology of a light R_2 scalar in the 421 model

Asymmetric Yukawas:

$$U_d = \begin{pmatrix} 0 & 1 & 0 \\ 1/\sqrt{2} & 0 & 1/\sqrt{2} \\ 1/\sqrt{2} & 0 & -1/\sqrt{2} \end{pmatrix}, \qquad V_d = \begin{pmatrix} -\cos\phi & 0 & -\sin\phi \\ \sin\phi & 0 & -\cos\phi \\ 0 & 1 & 0 \end{pmatrix}$$

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- Besides R_K and R_{K^*} we expect large residual effects in the tau sector!

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A smoking gun in the LFV tau decays?

$\mathrm{BR}(\tau \to e\,\ell^+\ell^-) \leq 2.7\times10^{-8}$

$\mathrm{BR}(\tau \to e\gamma) \leq 3.3\times10^{-8}$

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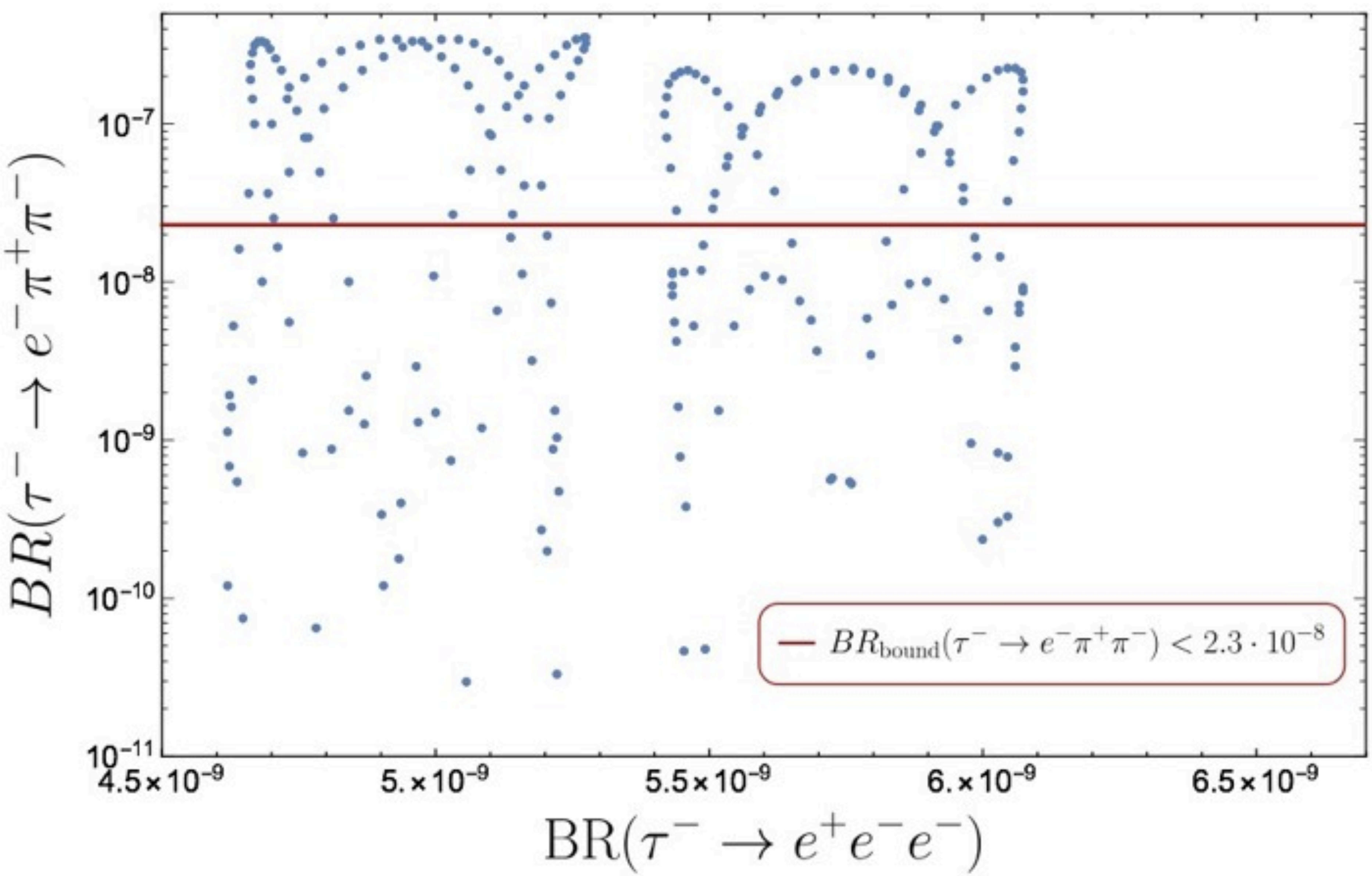

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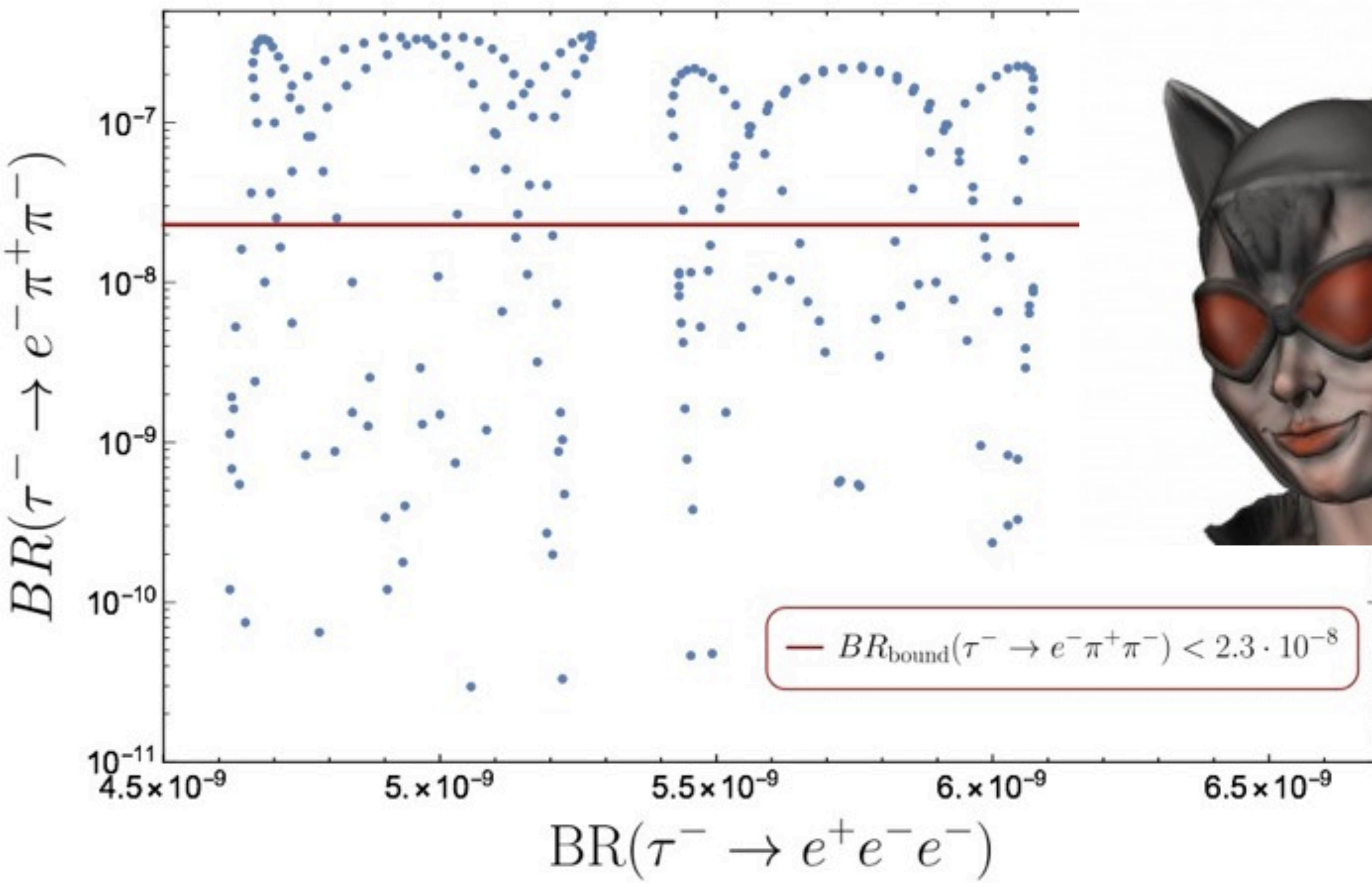

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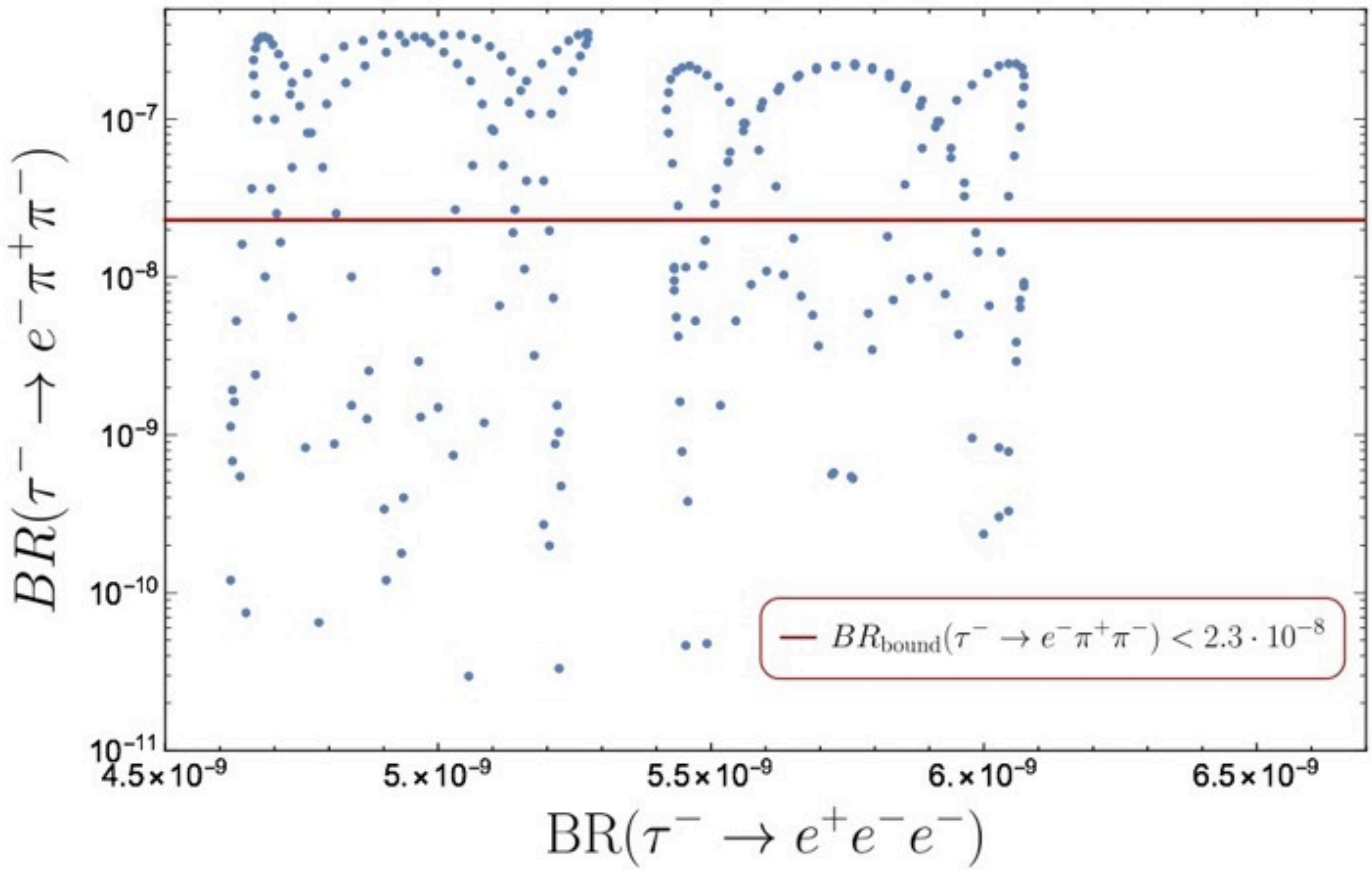

Conclusions, outlook

The minimal potentially realistic leptoquark model can account for the $R_{K^{(*)}}$ anomalies and be compatible with all other SM pre/post-dictions

Smoking-gun signals in LFV tau decays!

Thank you for your kind attention!