Is Lepton Flavour Universality **Violation** a hint on nonunitary New Physics Couplings?

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Based on: `arXiv:1907.05511` with C. Hati, J. Orloff and A. M. Teixeira

Novembre 5, 2019

Motivation

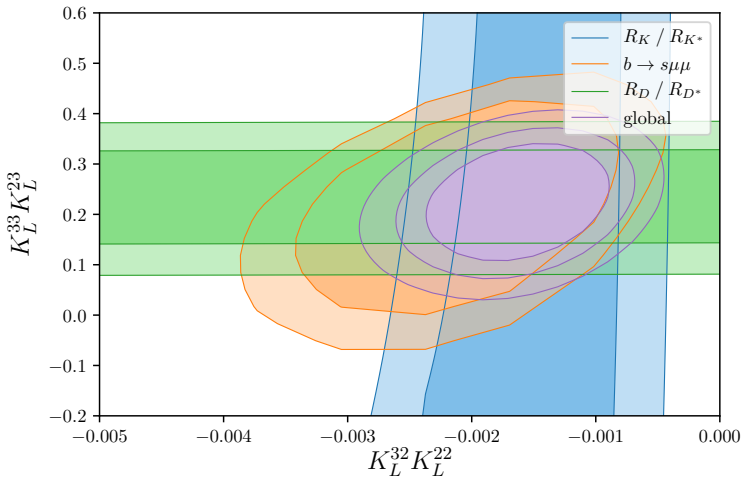
Deviations in charged and neutral current B-meson decays persist
$\Rightarrow$ pointing towards Lepton Flavour Universality **Violation**

In particular: deviations in $R_{D^{(*)}} = \frac{\mathrm{BR}(B \to D^{(*)} \tau \nu)}{\mathrm{BR}(B \to D^{(*)} \ell \nu)}$ and $R_{K^{(*)}} = \frac{\mathrm{BR}(B \to K^{(*)} \mu\mu)}{\mathrm{BR}(B \to K^{(*)} ee)}$ exceed 3σ

Explanations:

Z', (scalar) LQs, composite Higgs, RPV SUSY.../
TeV-scale V_1-leptoquark appealing NP scenario

$$\mathcal{L} \supset V_1^\mu \left(\bar{d}_L^i \gamma_\mu \boldsymbol{K_L^{ik}} \ell_L^k + \bar{u}_L^j V_{ji}^\dagger \gamma_\mu \boldsymbol{K_L^{ik}} U_{kj}^{\mathrm{P}} \nu_L^j \right)$$



$\Rightarrow$ Taking V_1-model coupled to all (q, ℓ)-generations in a consistent framework

See also talks by Adam Morrris, Peter Stangl, Olcyr Sumensari, Karim Trabelsi, Andreas Crivellin

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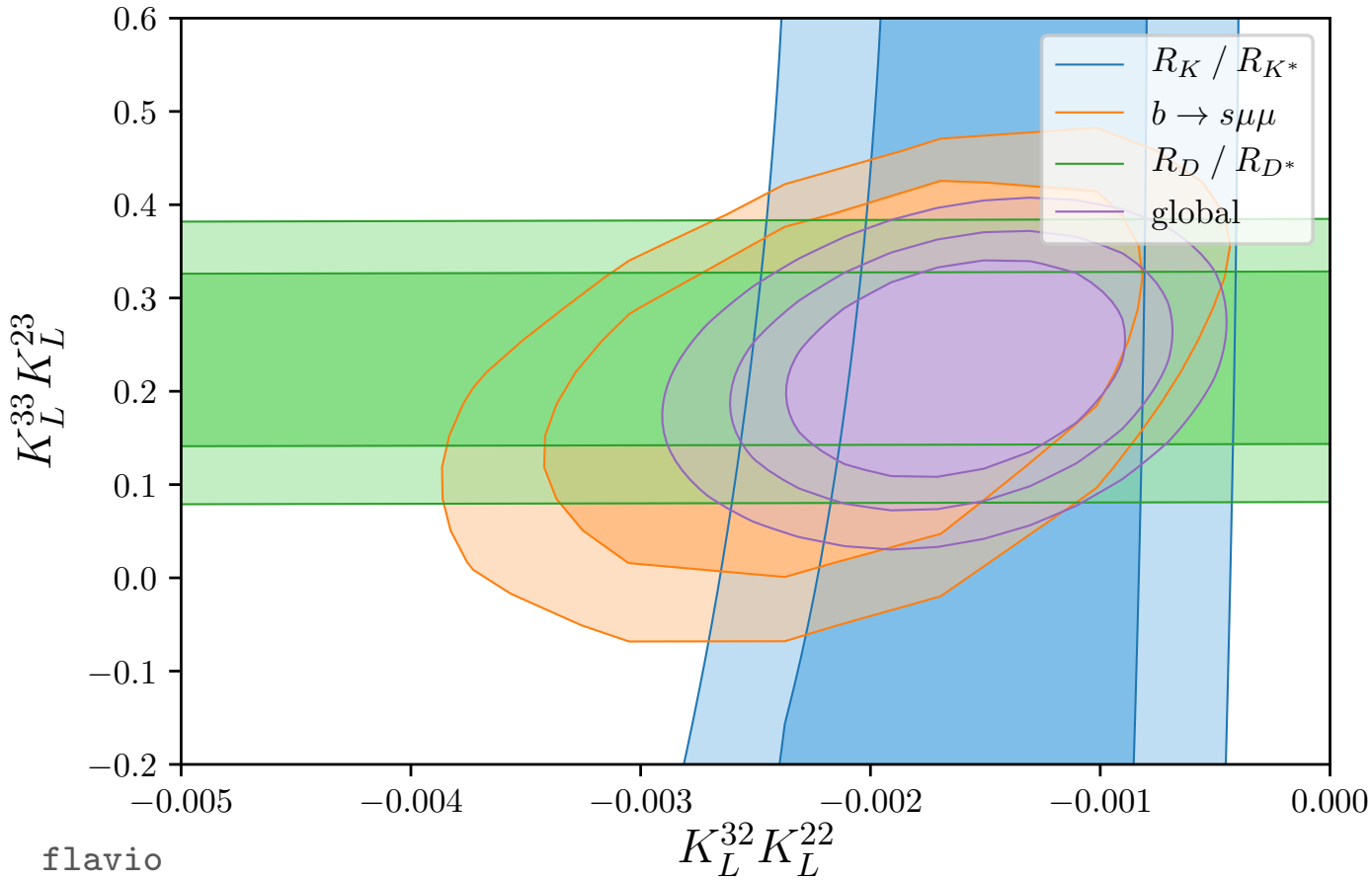

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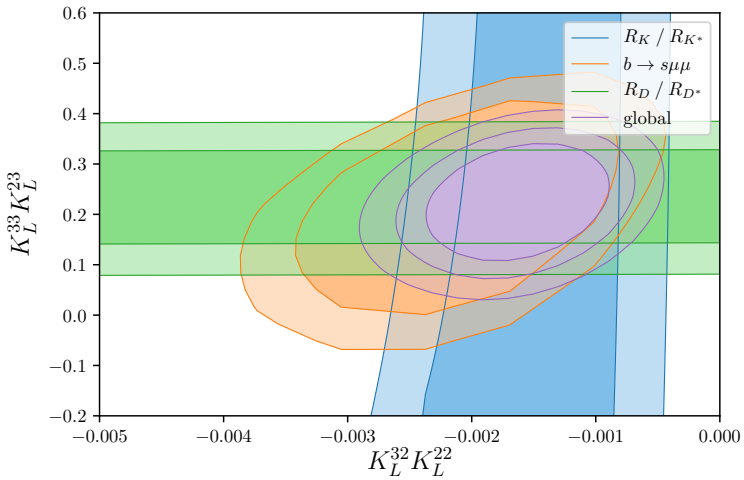

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In analogy to neutrino physics, the mixing matrices get enlargened: *[arXiv:0709.2220]*

$$U_L^\ell = \begin{pmatrix} A & R \\ B & S \end{pmatrix} \begin{pmatrix} V_0 & \mathbf{0} \\ \mathbf{0} & \mathbf{1} \end{pmatrix}$$

In case of $n = 3$ generations:

$$\begin{pmatrix} A & R \\ B & S \end{pmatrix} = \mathcal{R}_{56}\mathcal{R}_{46}\mathcal{R}_{36}\mathcal{R}_{26}\mathcal{R}_{16}\mathcal{R}_{45}\mathcal{R}_{35}\mathcal{R}_{25}\mathcal{R}_{15}\mathcal{R}_{34}\mathcal{R}_{24}\mathcal{R}_{14}$$

$$\begin{pmatrix} V_0 & \mathbf{0} \\ \mathbf{0} & \mathbf{1} \end{pmatrix} = \mathcal{R}_{23}\mathcal{R}_{13}\mathcal{R}_{12}$$

Defining **semi-unitary** rectangular matrix:

$$K_L^{q\ell} = (K_1, K_2) = \frac{\kappa_L}{\sqrt{2}}(A\,V_0, R)$$

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effective LQ-q-ℓ couplings $K_L^{q\ell}$ parametrised via **non-unitary matrix** (from mixing with heavy states)

$\Rightarrow$ Induce **LFUV structure** in $C_{9,10}^{ij;\ell\ell'}$ **Wilson coefficients** (tree-level):

$$C_{9,10}^{ij;\ell\ell'} = \mp \frac{\pi}{\sqrt{2} G_F \alpha V_{3j} V_{3i}^*} \frac{1}{m_U^2} K_L^{i\ell'} K_L^{j\ell *}$$

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$\Rightarrow$ Required mixing pattern could induce nonuniversal $Z \to \ell\ell^{(\prime)}$

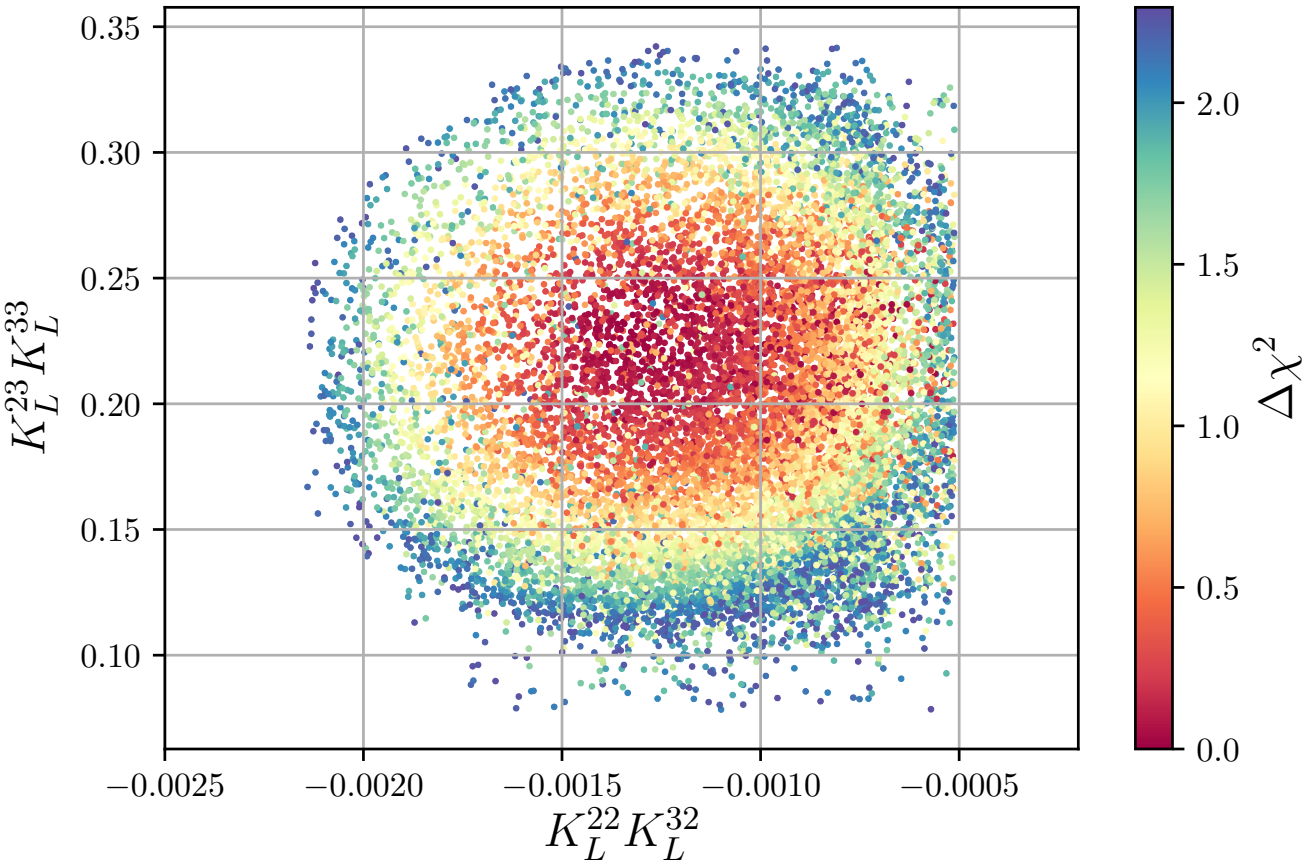
$\rightsquigarrow$ VL leptons have to be $SU(2)_L$-**doublets!!**

$\Rightarrow$ $R_{K^{(*)}}$ and $R_{D^{(*)}}$ can be explained, tight constraints from **cLFV**, **EWPO**, Collider...

Results

Random scan, taking all SM-(q, ℓ)-couplings of V_1 into account, complying with all constraints:

$m_V \sim 1.5\,\mathrm{TeV}$ & $n = 3$ generations of **VL leptons**



Results

Observables taken into account:

cLFV: $(\mu - e)$-conversion, $\ell \to \ell'\gamma$, $\ell \to \ell'\ell'\ell'$, $\tau \to (\rho, \phi)\ell$

LFV: $B_{d,s} \to \ell^{\pm}\ell'^{\mp}$, $K_L \to \mu^{\pm}e^{\mp}$, $B \to (K, K^*, \pi)\ell^{\pm}\ell'^{\mp}$, $K \to \pi\ell^{\pm}\ell'^{\mp}$, $(B \to K\nu\bar{\nu}$, $K \to \pi\nu\bar{\nu})$

EWPO: g_V^{ℓ}, g_A^{ℓ}, Γ_Z^{ℓ}, $Z \to \ell\ell^{(\prime)}$

Likelihood includes:

LFC: $B_{d,s} \to \mu\mu$, $B_s \to \phi\mu\mu$, $B \to K^{(*)}\mu\mu$, $B \to K^{(*)}ee$, $B \to D^{(*)}\tau\nu$

LFU: $R_{K^{(*)}}$, $R_{D^{(*)}}$, angular Observables and Asymmetries in $b \to s\ell\ell$ à la P_5'

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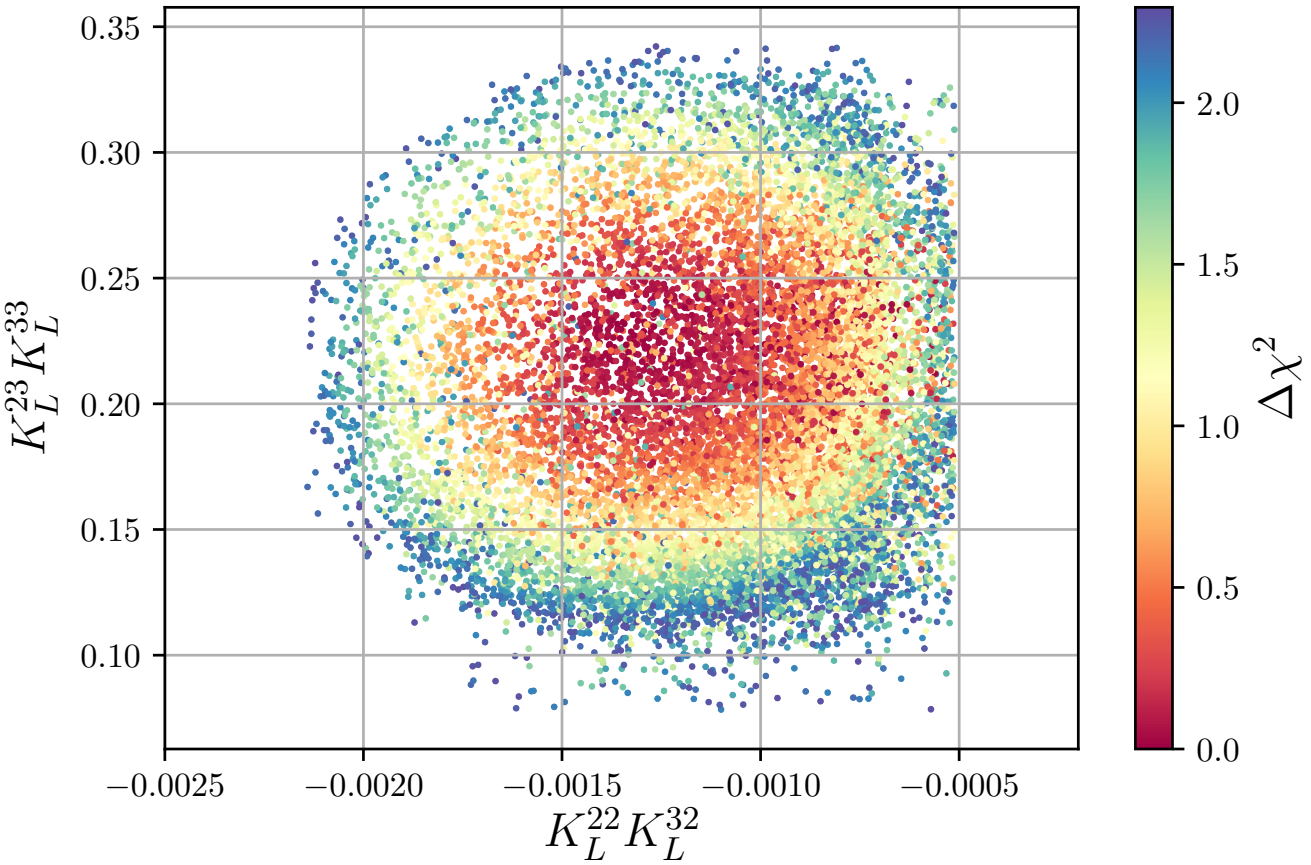

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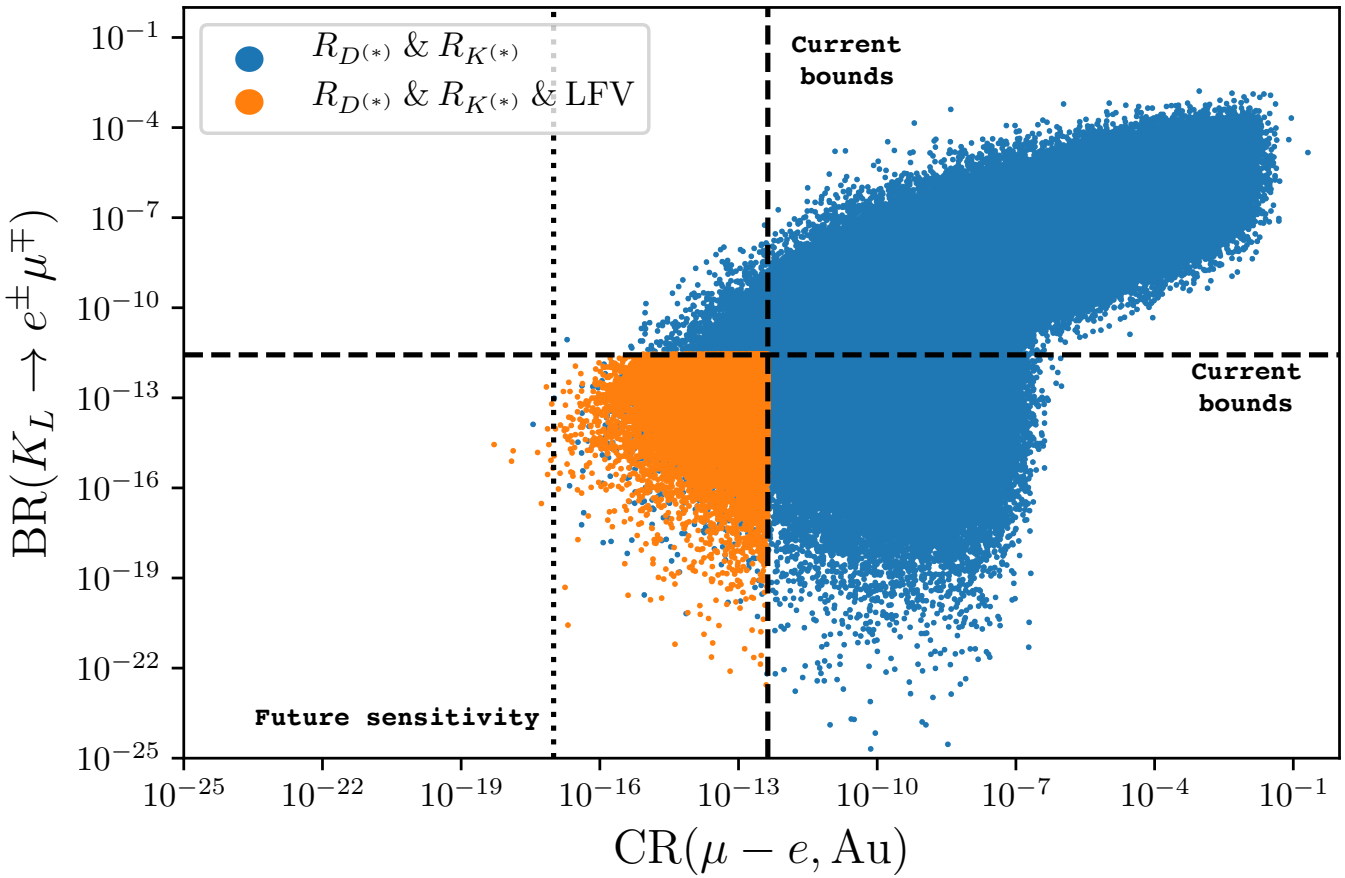
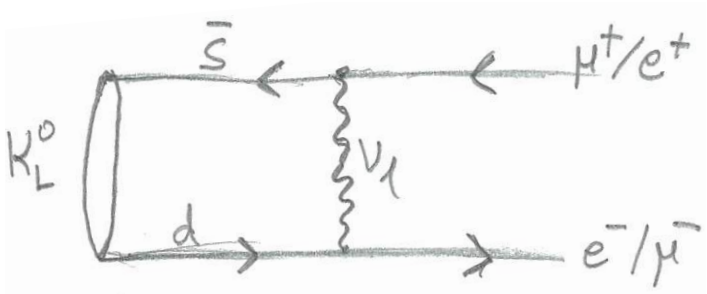
Confrontation with the most constraining observables:

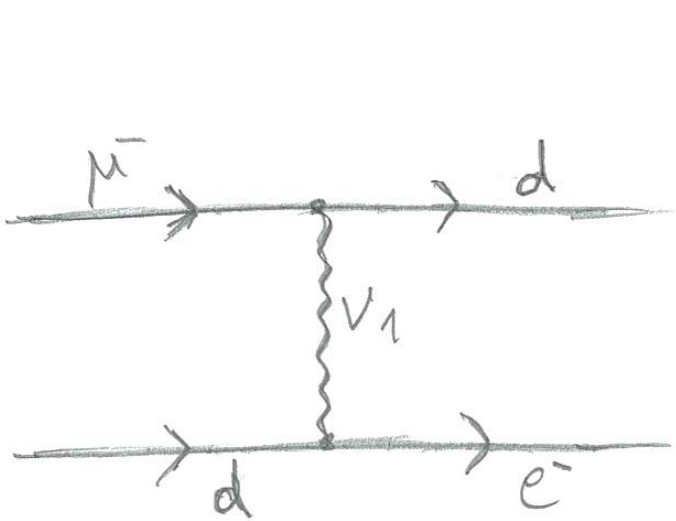


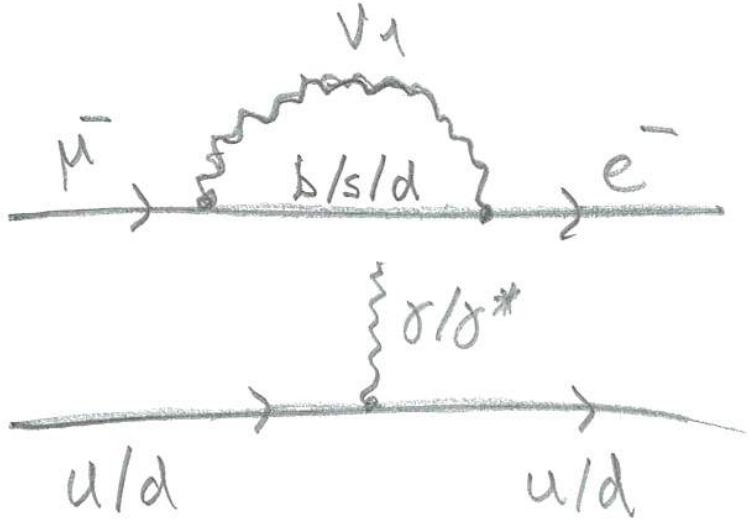
Results

Why are the LFV constraints so severe?

$\Rightarrow$ Contributions are on **tree** level:







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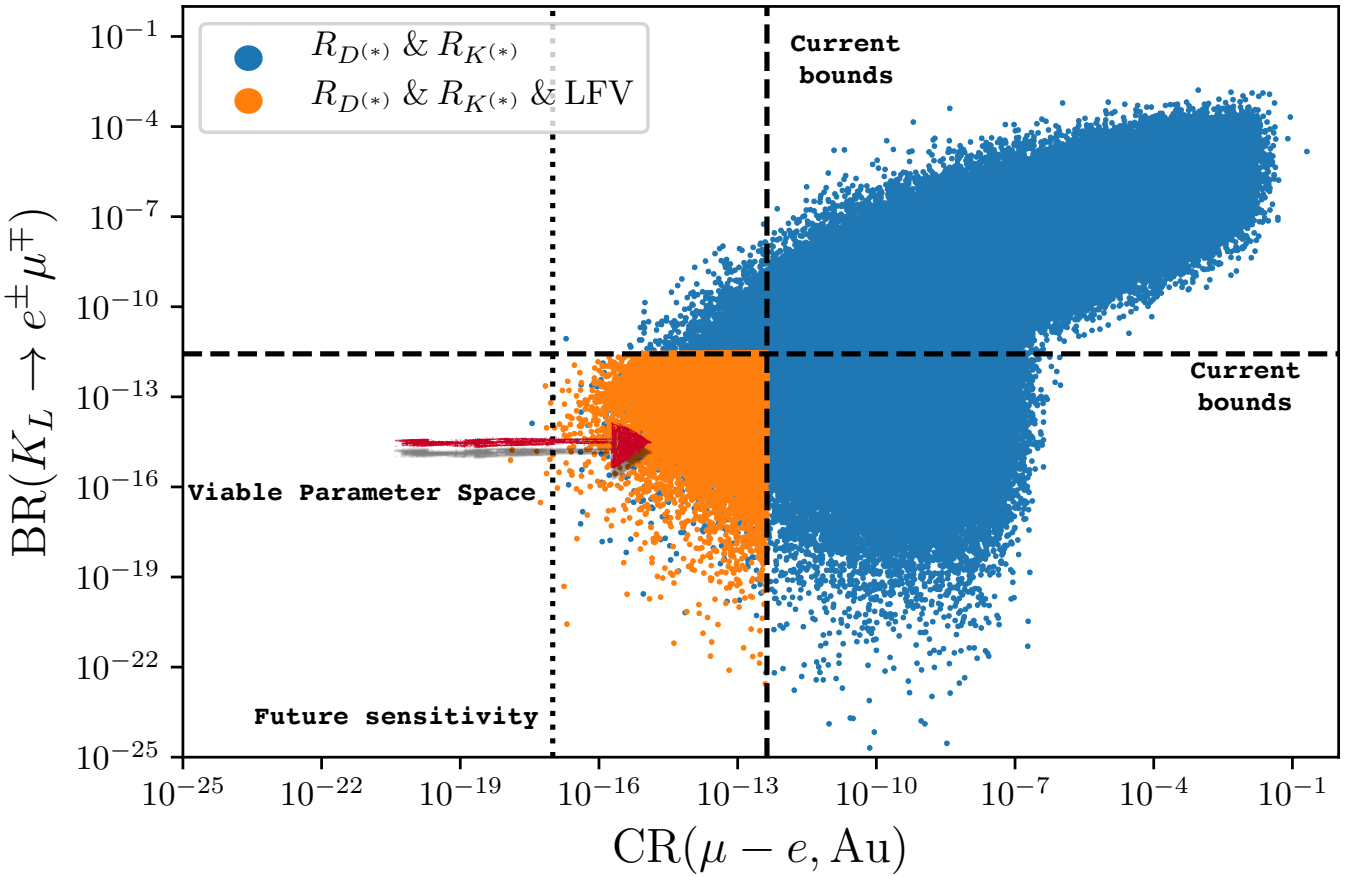

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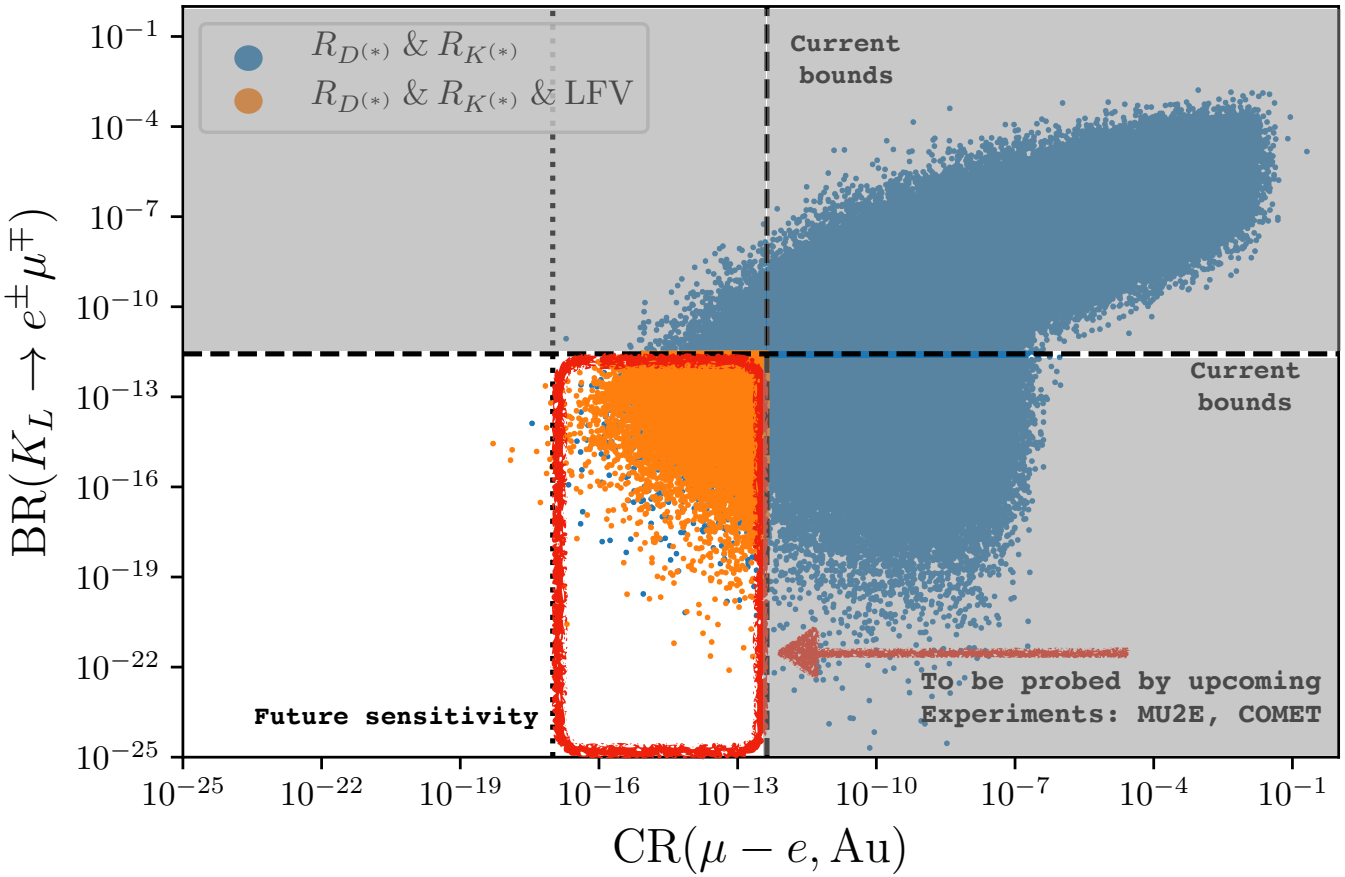

Conclusion

- V_1-leptoquark offers viable explanation for both of the B-anomalies
- 3 generations of **VL leptons** needed to comply with **cLFV** constraints
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- Large region of the **parameter space** to be probed in the near **FUTURE!**

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Thank you!

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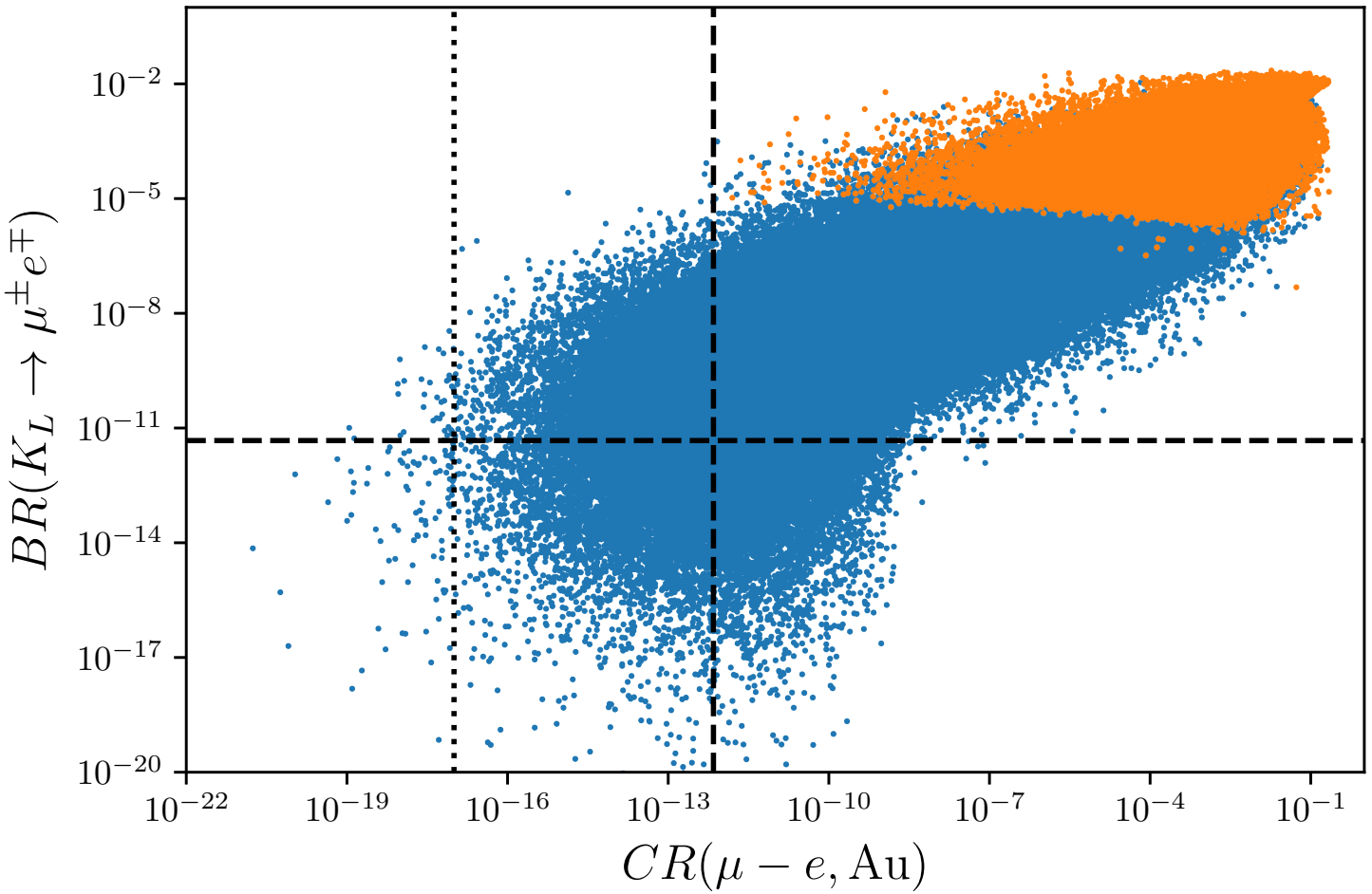
10^{-2}
10^{-5}
10^{-8}
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$BR(K_L \to \mu^{\pm} e^{\mp})$
10^{-22}
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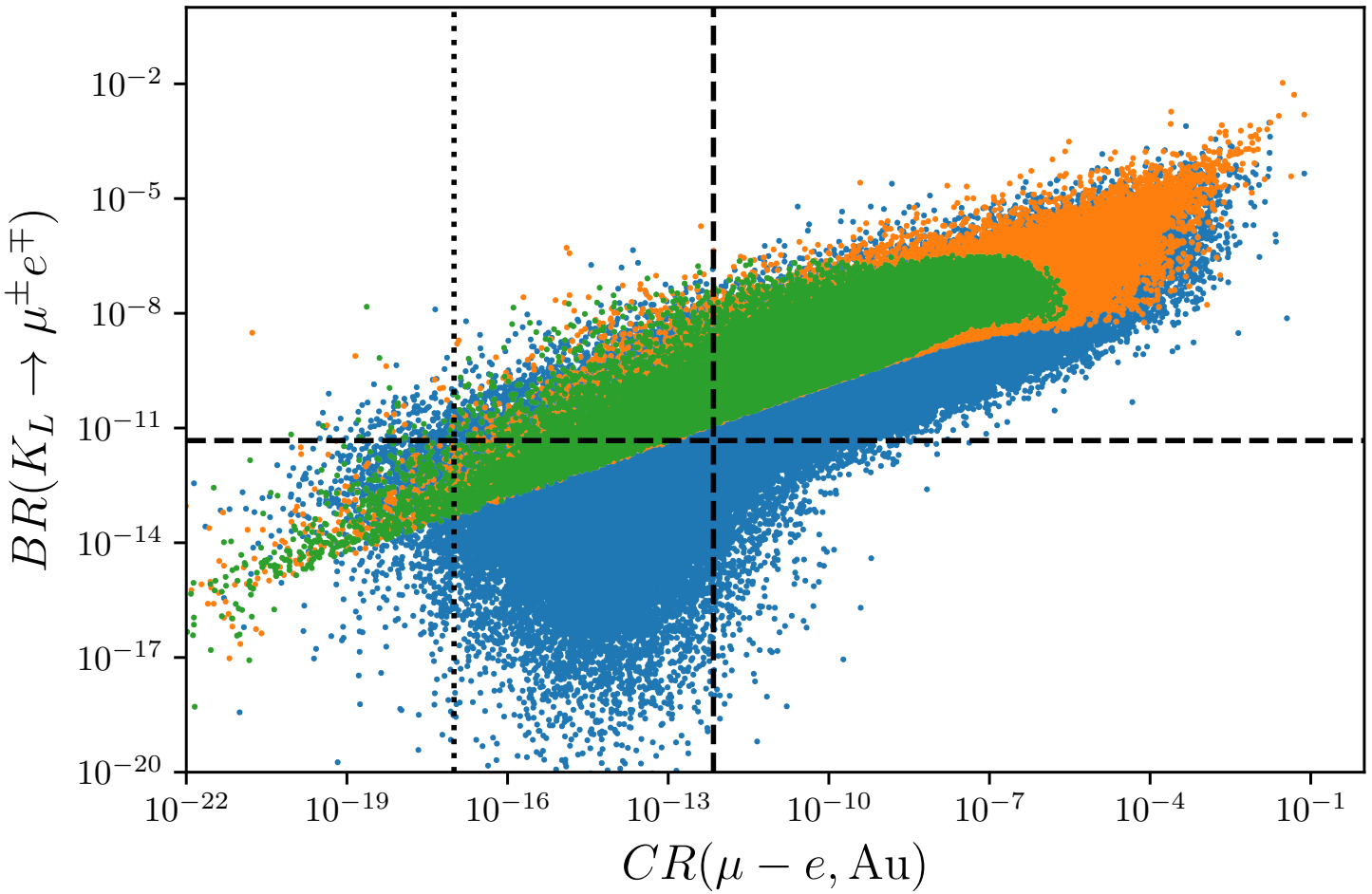
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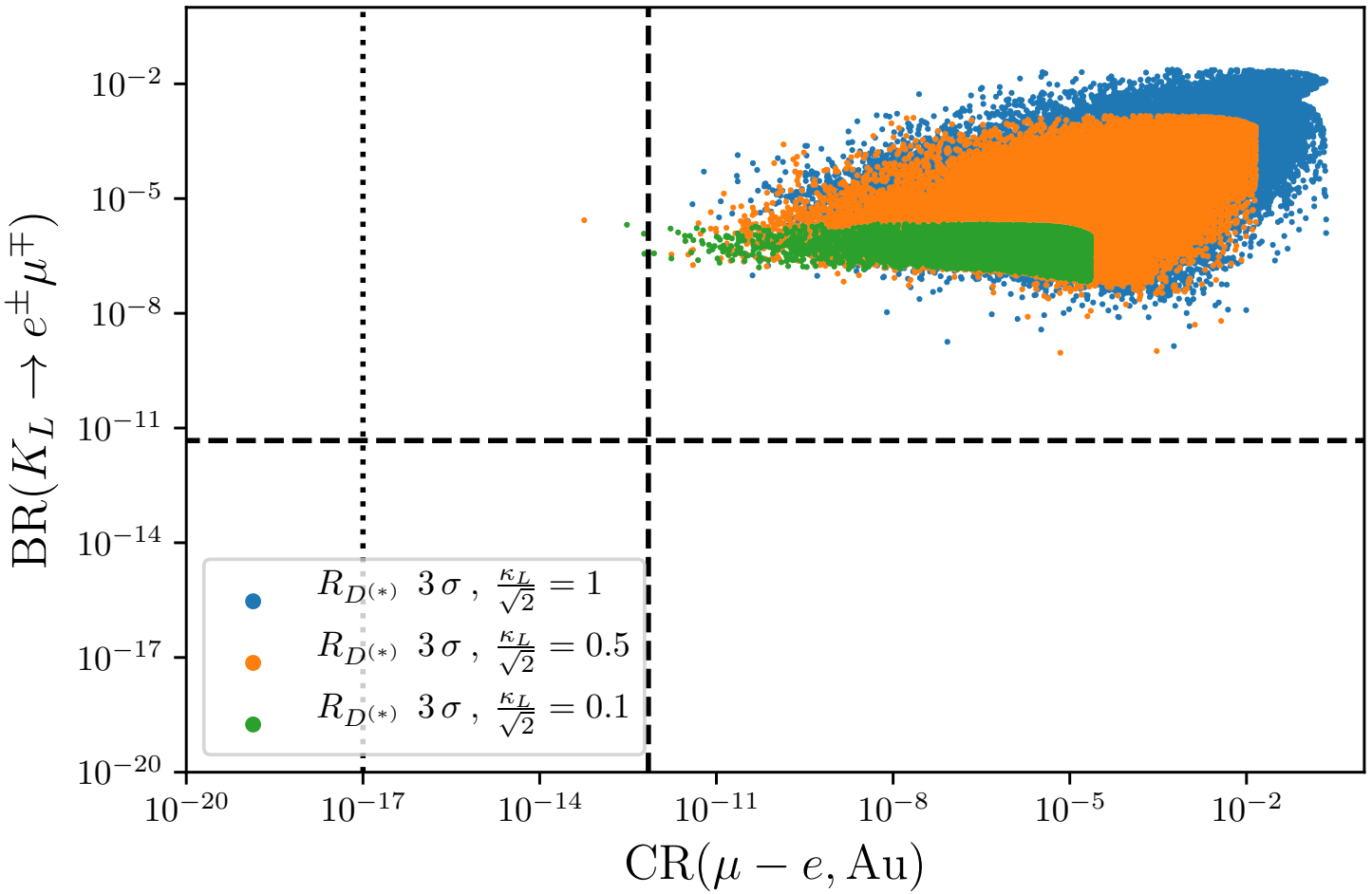
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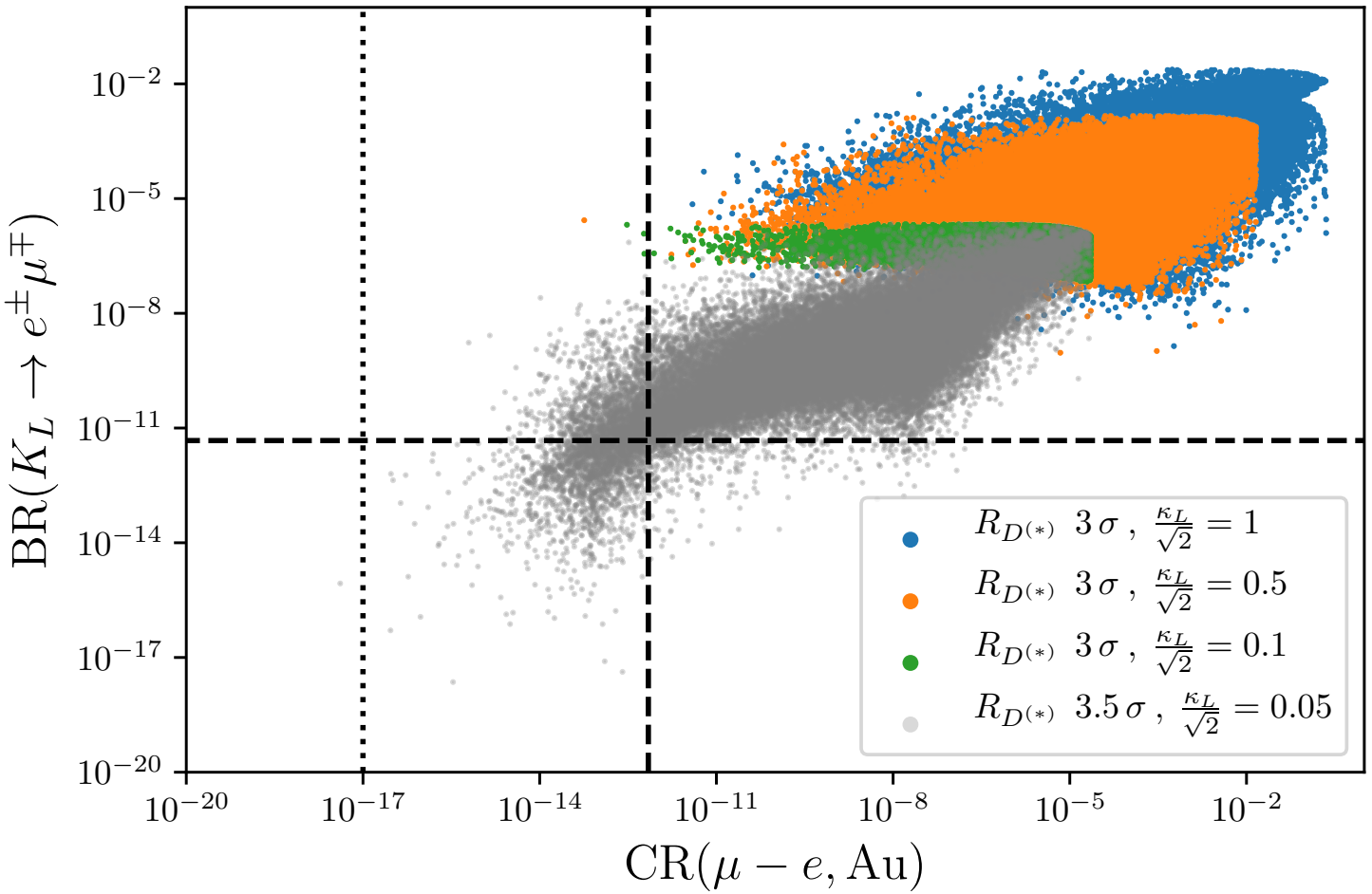
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