A Tale of Two Anomalies: from LHCb to ANITA

Speaker: Yicong Sui

In collaboration with:
Wolfgang Altmannshofer, Bhupal Dev, Amarjit Soni

Introduction of B-anomaly

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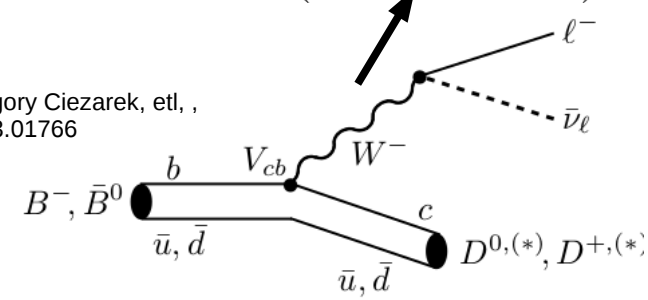
Gregory Ciezarek, etl, ,
1703.01766



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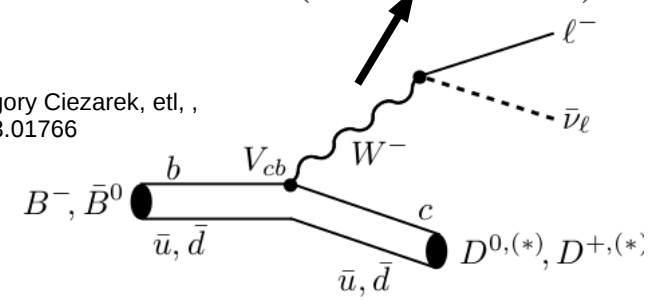

$$R_D^{\rm SM} = 0.299 \pm 0.003 \qquad R_{D^*}^{\rm SM} = 0.257 \pm 0.003$$

Florian U. Bernlochner, etl, 1703.05330

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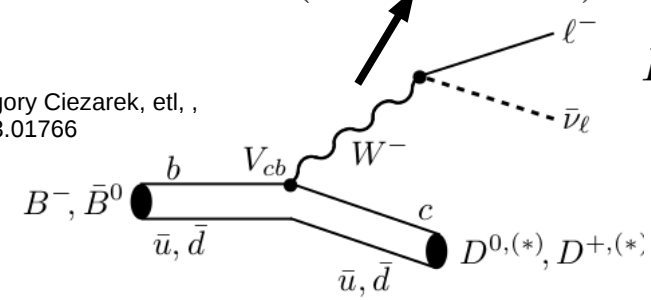

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PDG2018

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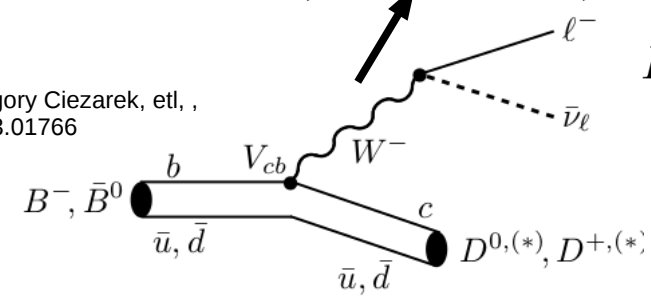

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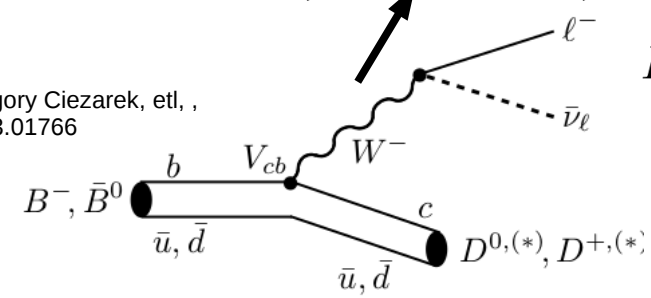

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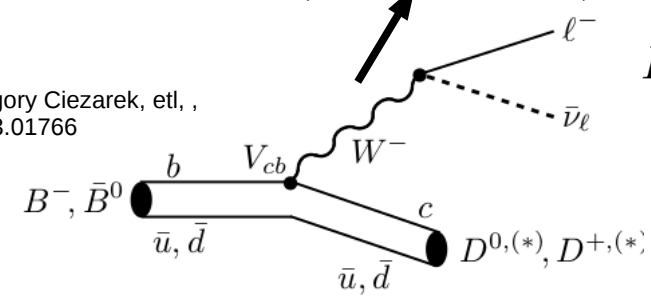

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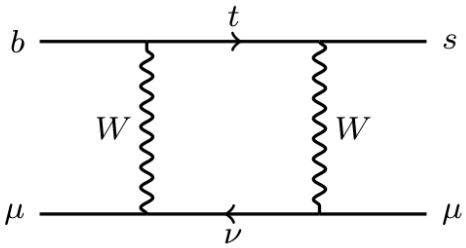

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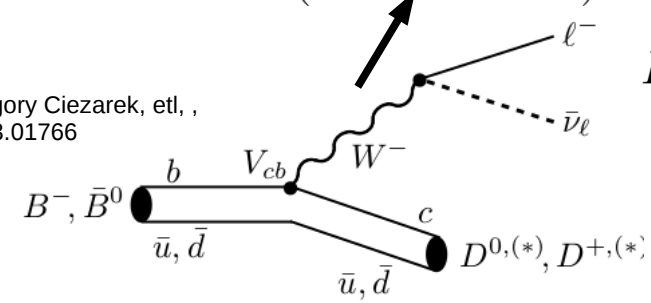

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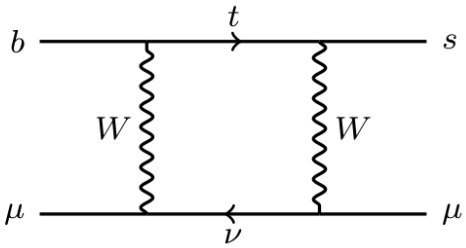

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Marzia Bordone, Gino Isidori, Andrea Pattori, 1605.07633

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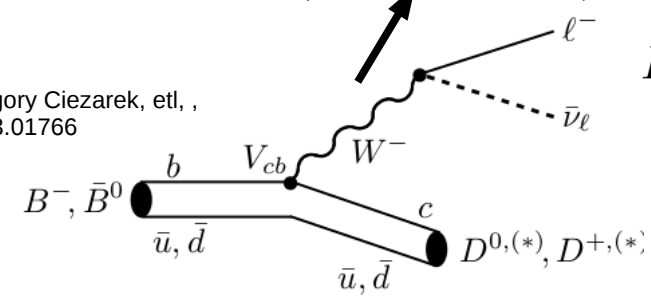

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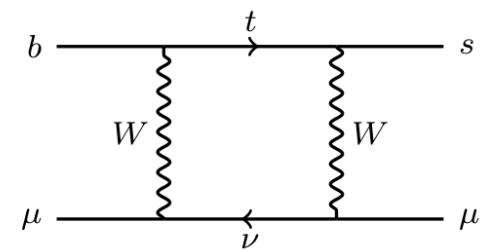

$$R_K = 0.846\ ^{+0.060}_{-0.054}\ ^{+0.016}_{-0.014}, \qquad \text{for } 1.1\,\text{GeV}^2 < q^2 < 6\,\text{GeV}^2$$

LHCb collaboration, 1903.09252

$$R_{K^*} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03, & \text{for } 0.045\,\text{GeV}^2 < q^2 < 1.1\,\text{GeV}^2, \\ 0.69^{+0.11}_{-0.07} \pm 0.05, & \text{for } 1.1\,\text{GeV}^2 < q^2 < 6\,\text{GeV}^2, \end{cases}$$

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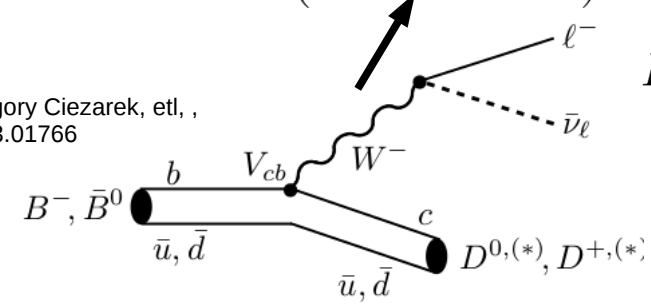

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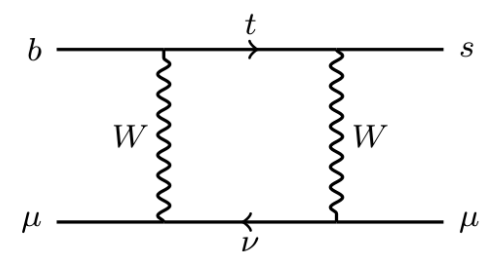

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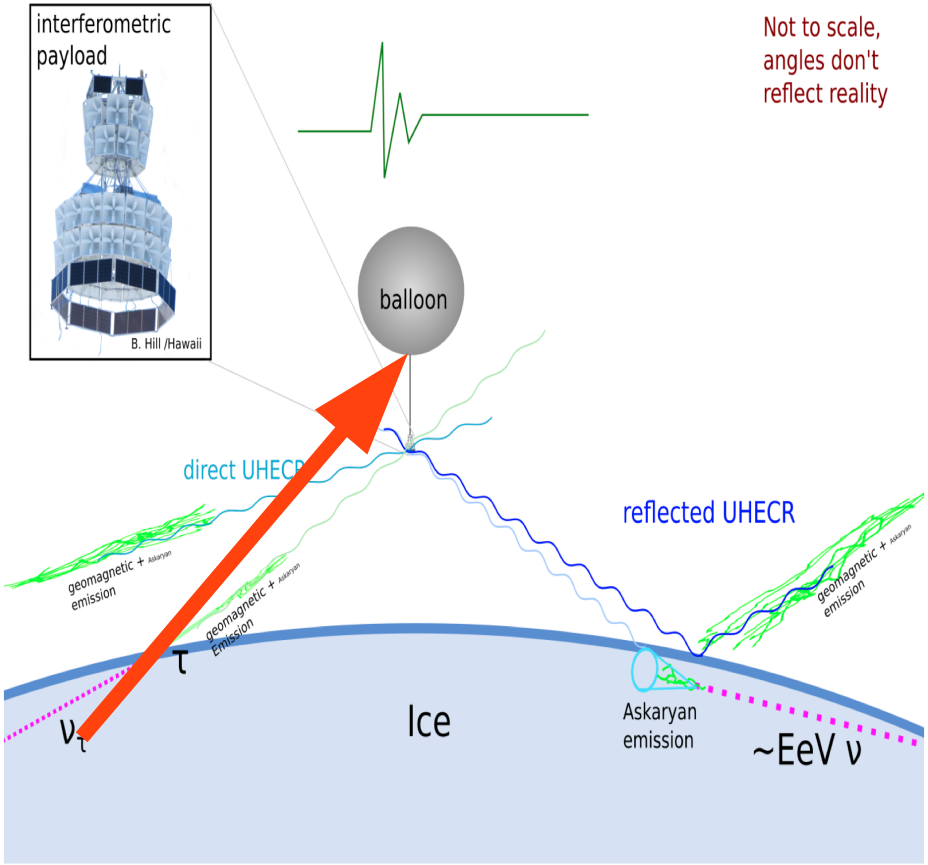
Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

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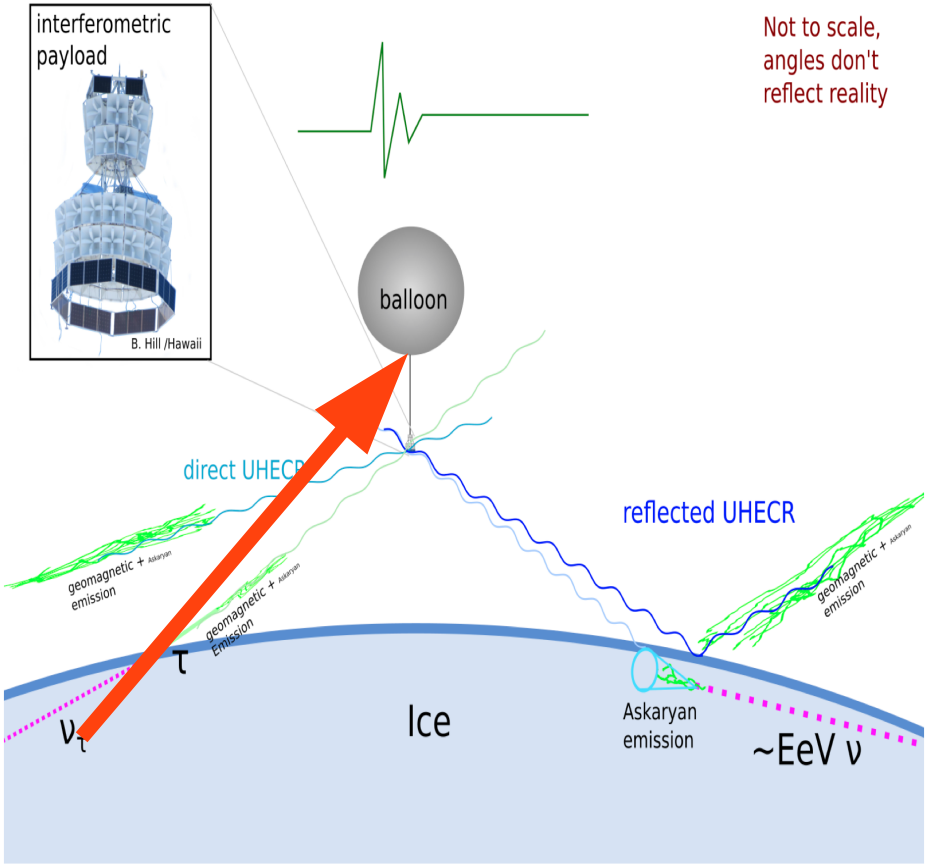

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Lat., Lon.(1)	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°, 159.62 \pm 0.7°$	$-35.0 \pm 0.3°, 61.41 \pm 0.7°$
RA, Dec(2)	282.14064, +20.33043	50.78203, +38.65498
E_{shower} (3)	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

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Table from ANITA, 1803.05088

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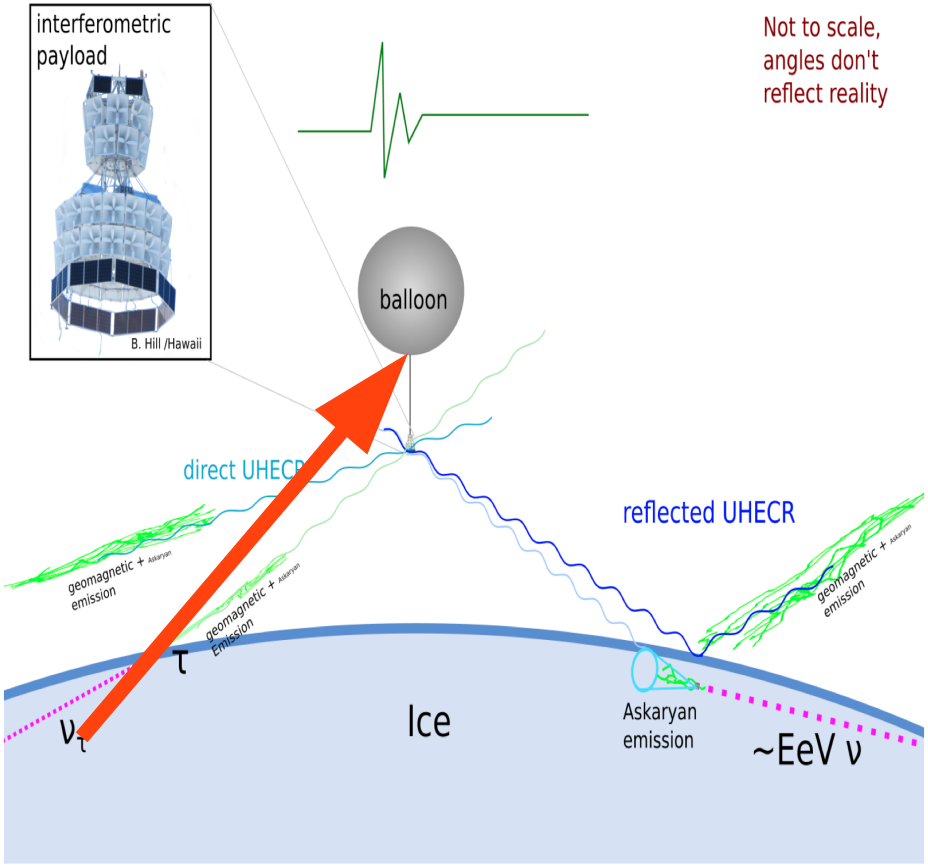

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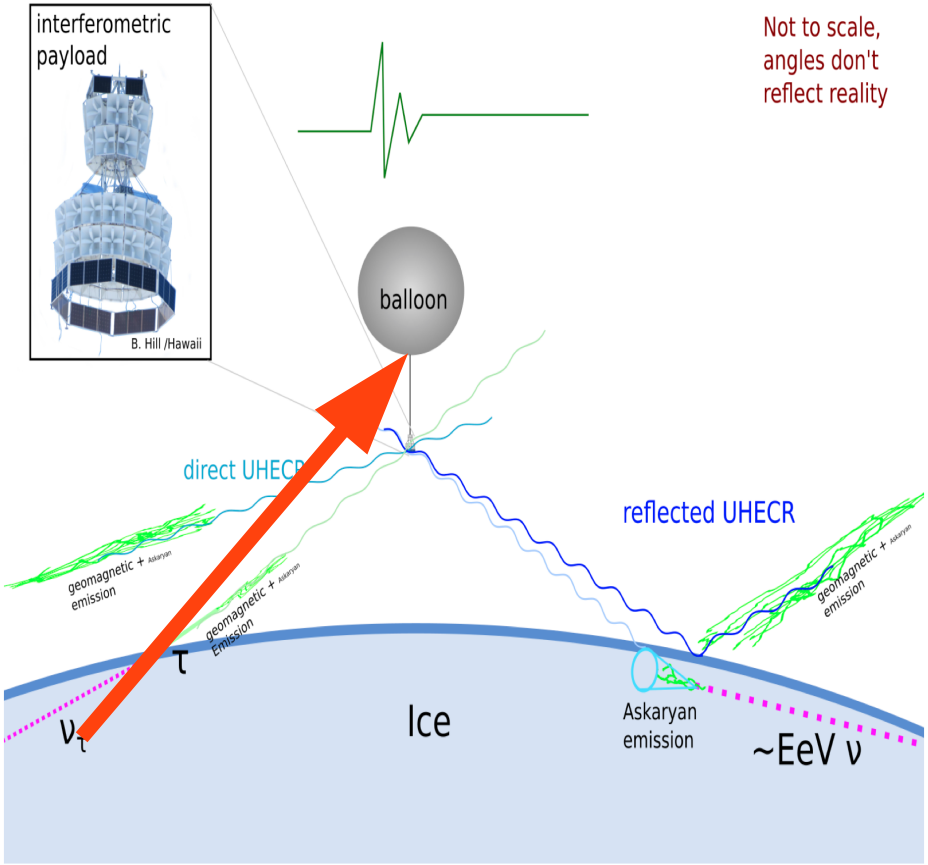

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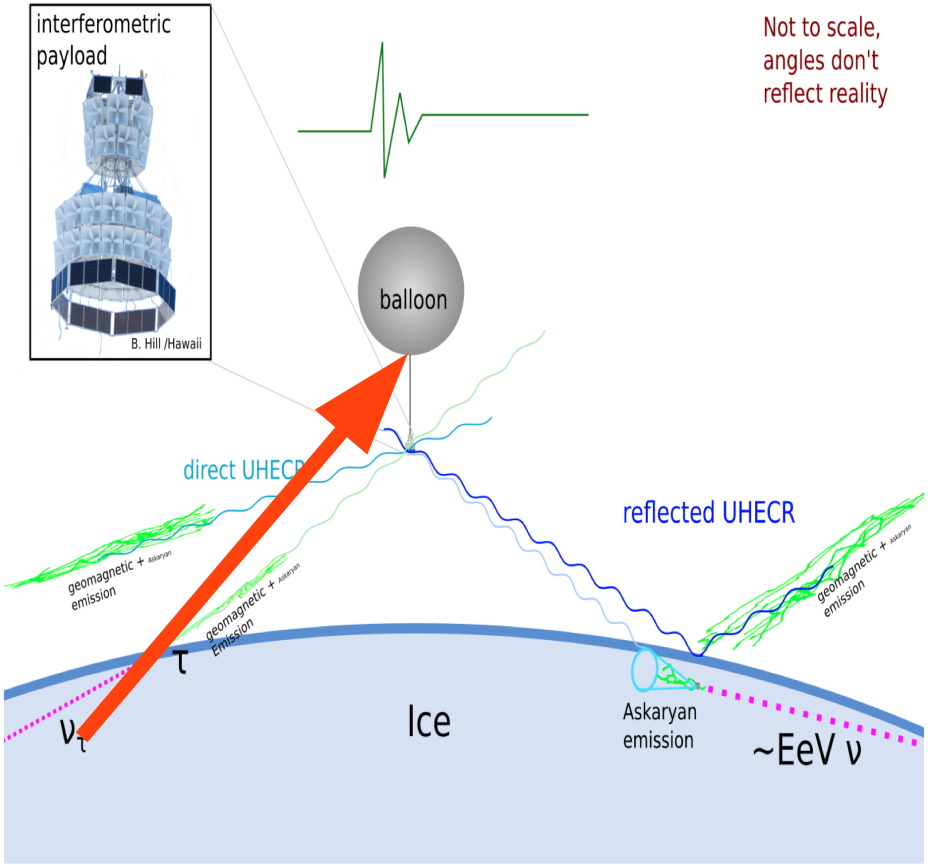

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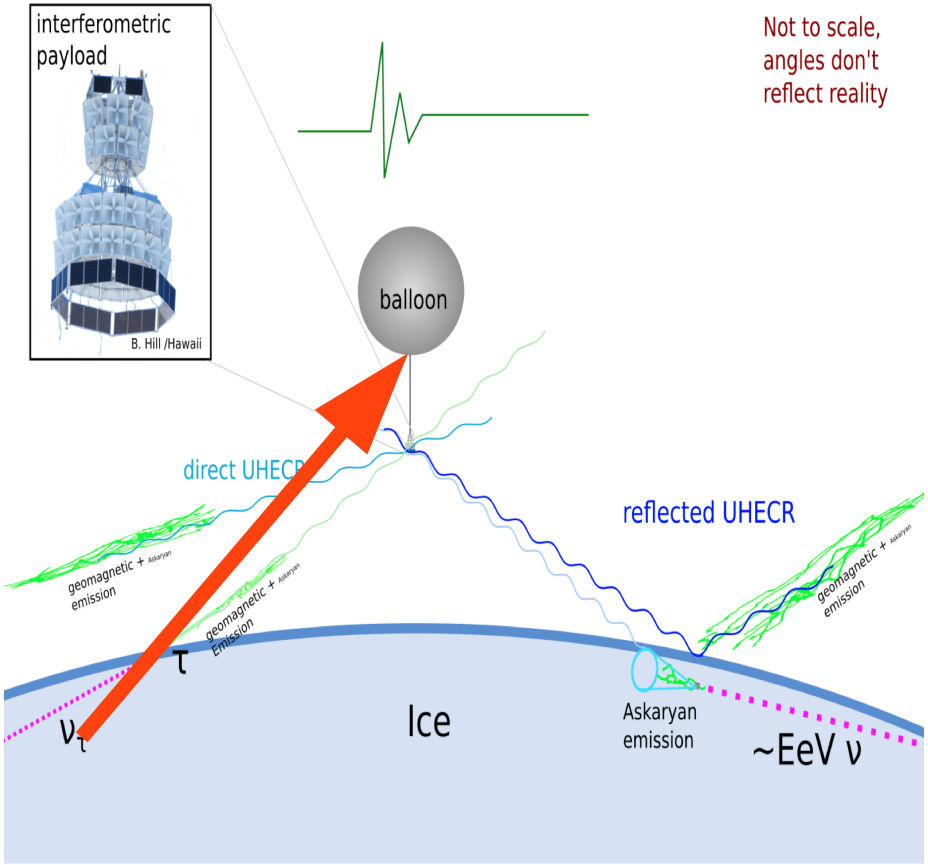

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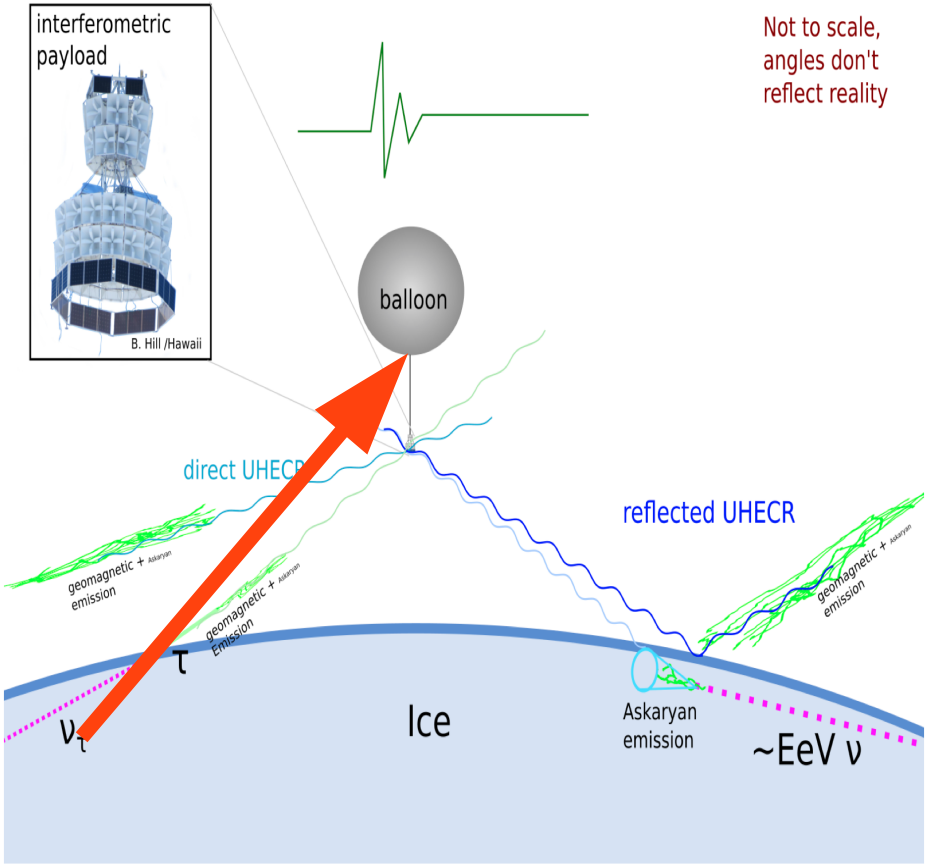

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Ice depth	3.53 km	3.22 km
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RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
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Table from ANITA, 1803.05088

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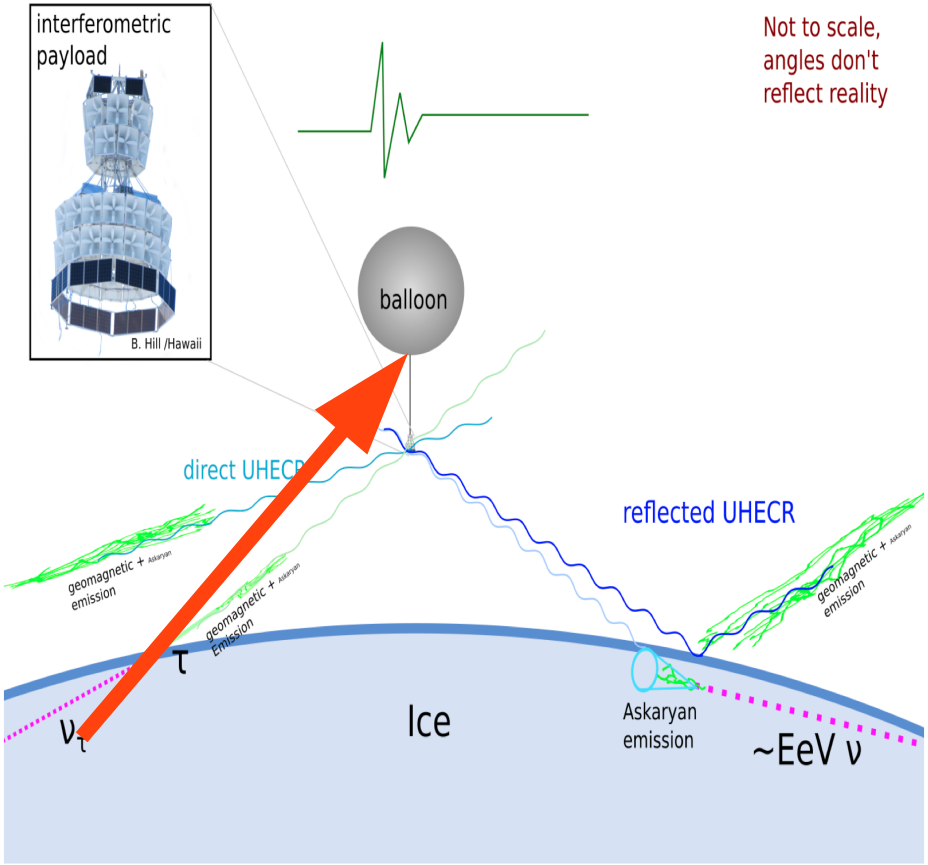
Introduction of ANITA anomaly



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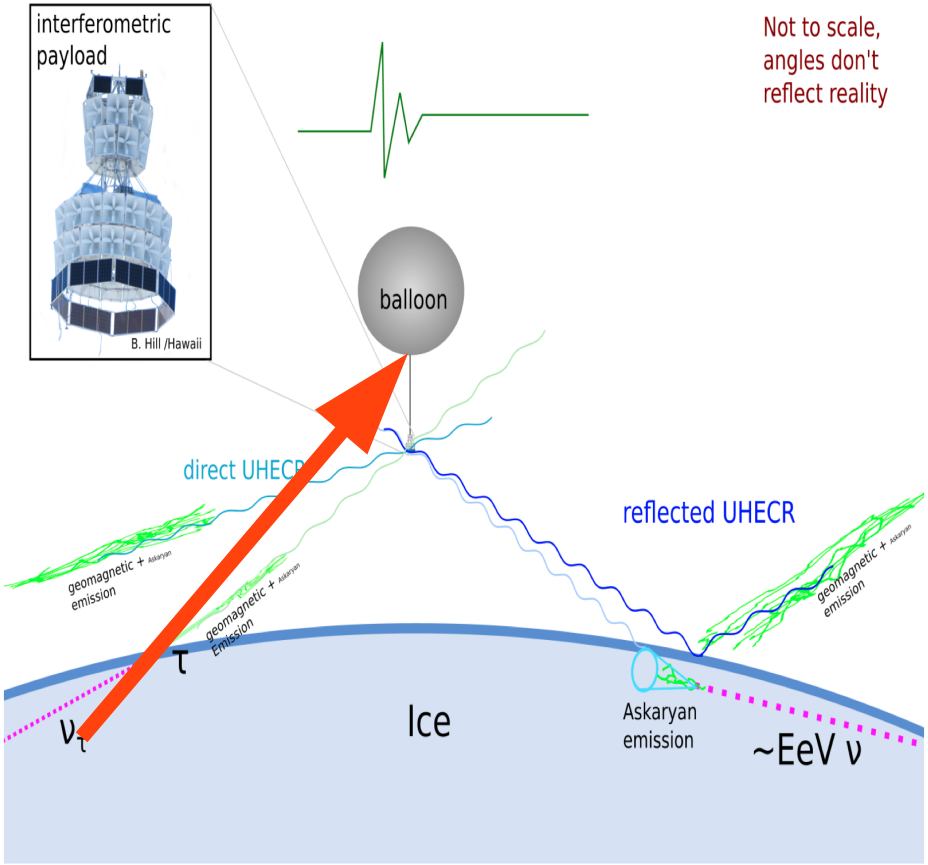

Not to scale, angles don't reflect reality

R ~ 6400 km
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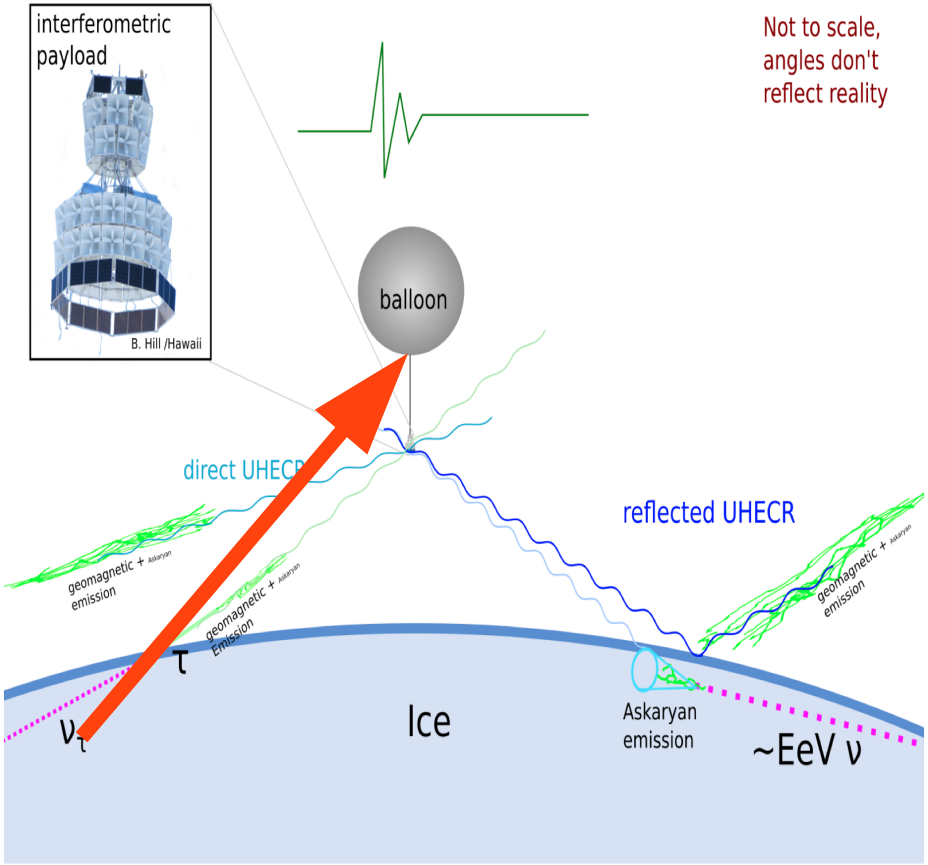
$P_{survival} \sim 10^{-6}$



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$= 0.0001\%$

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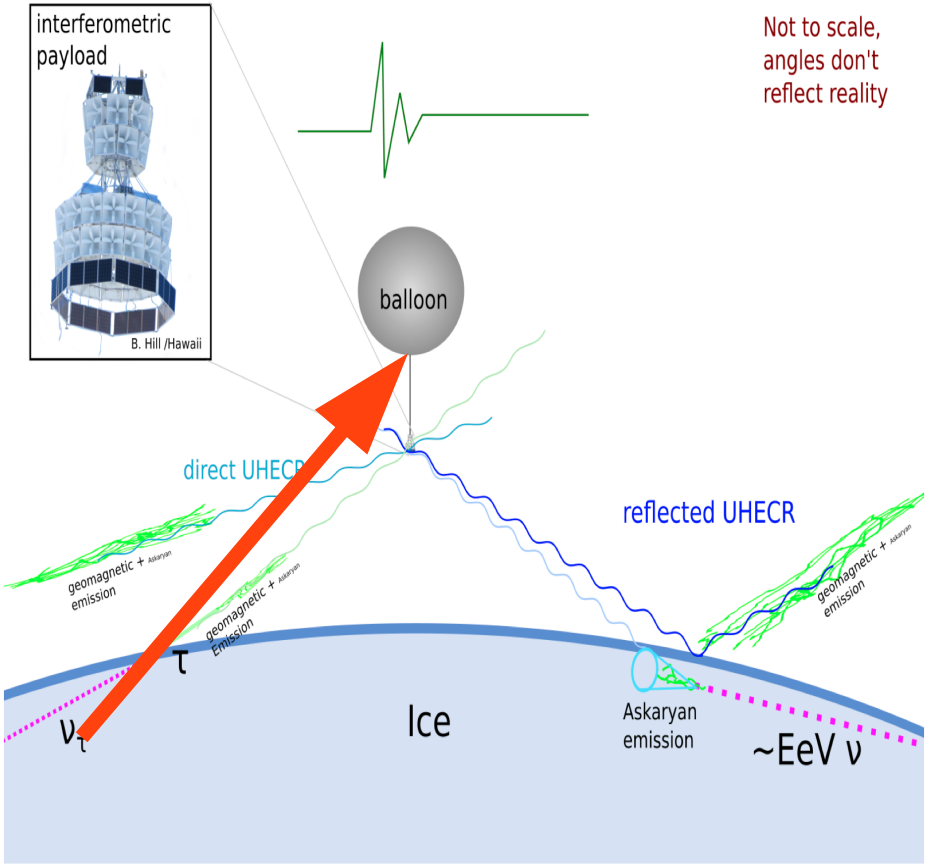

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New Phyiscs Interpretation to ANITA-anomaly

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Long-lived neutral particle χ + TeV level mediator particle

Jack Collins and Bhupal Dev, **Yicong Sui**, 1810.08479

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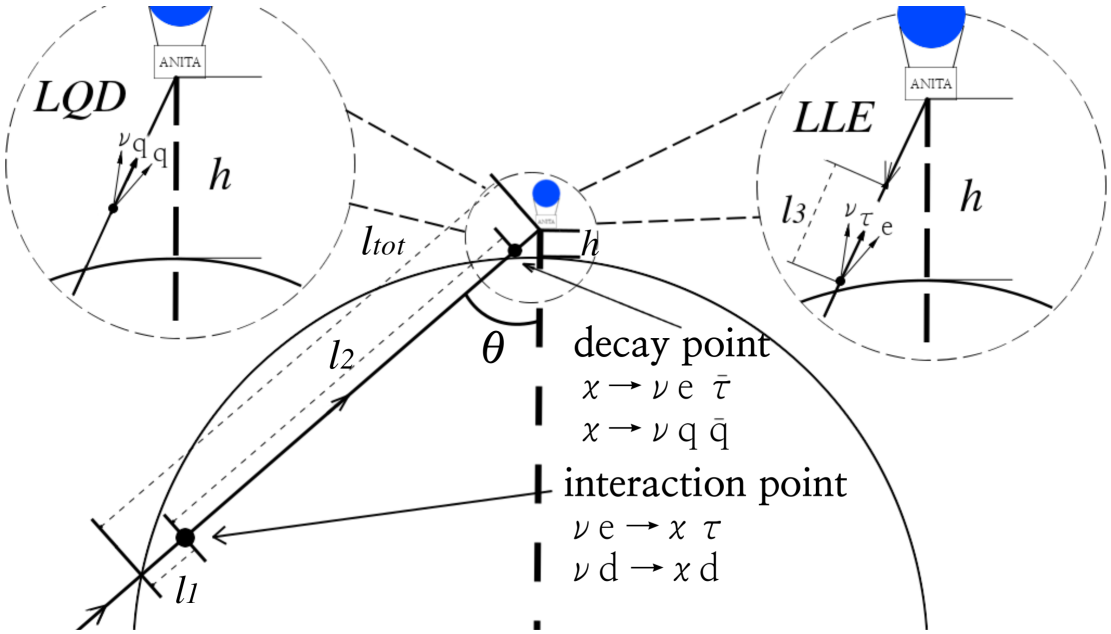

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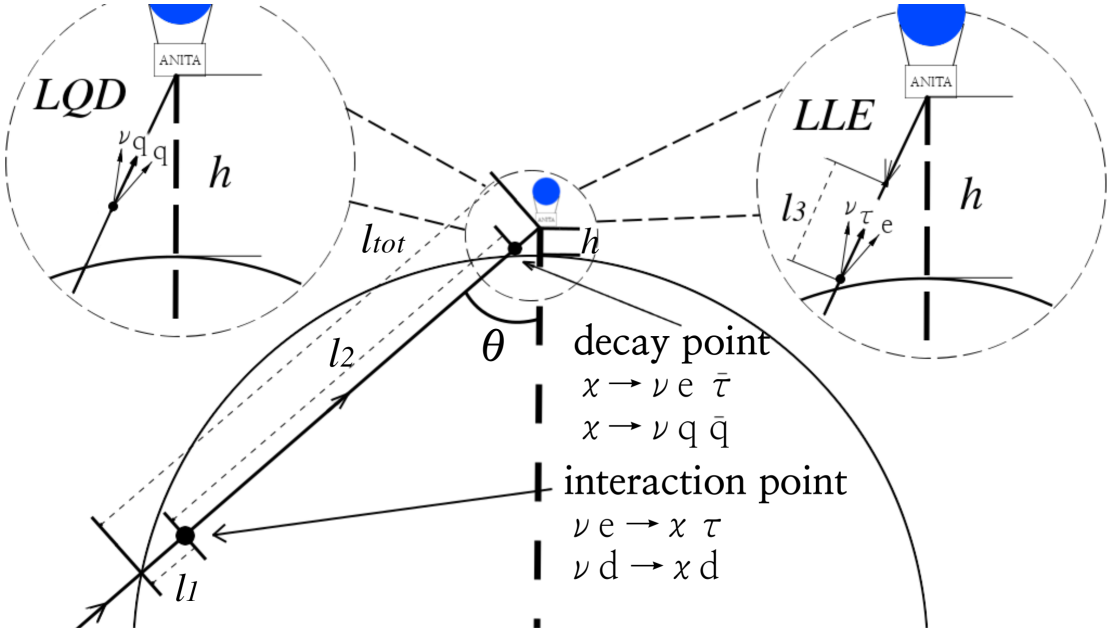

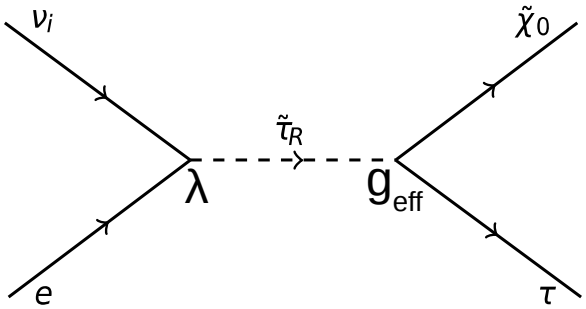

M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
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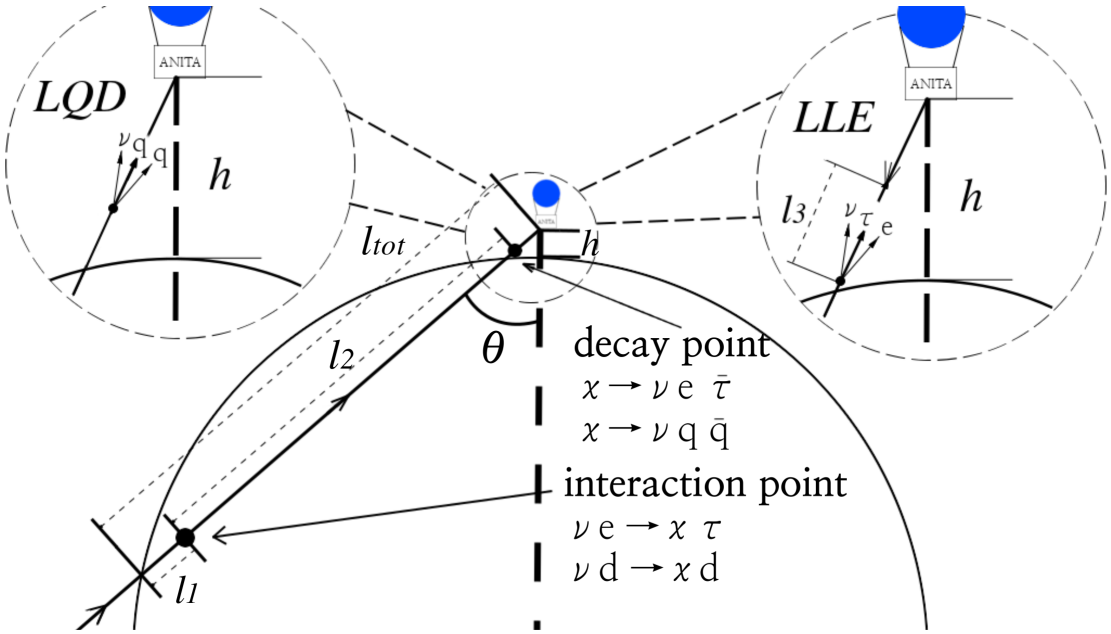

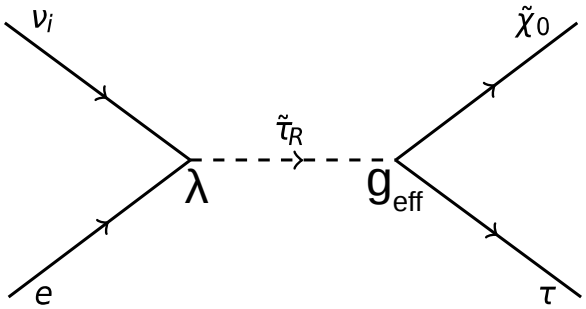

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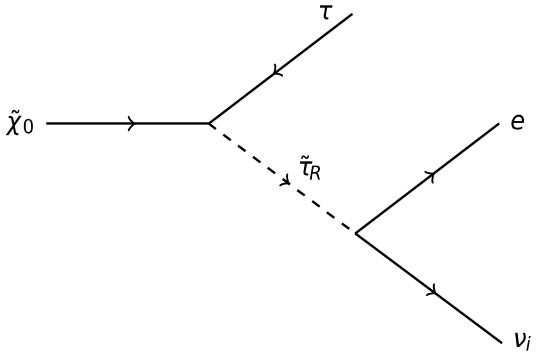

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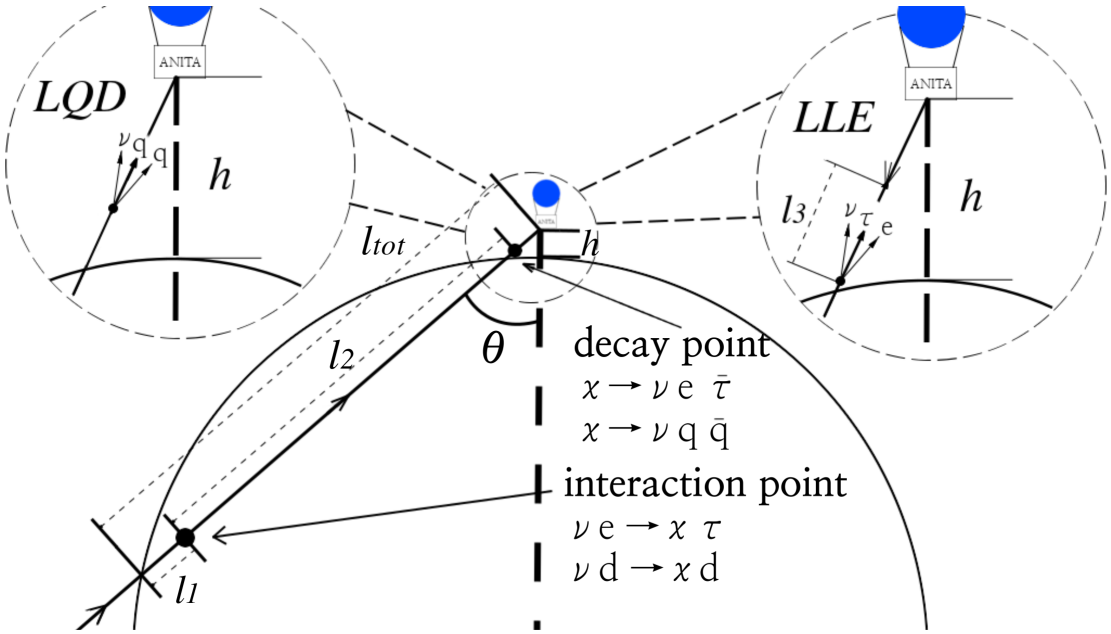

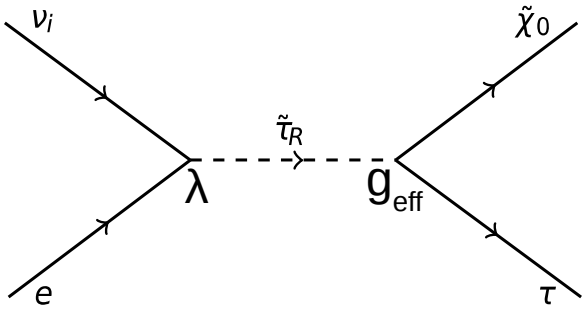

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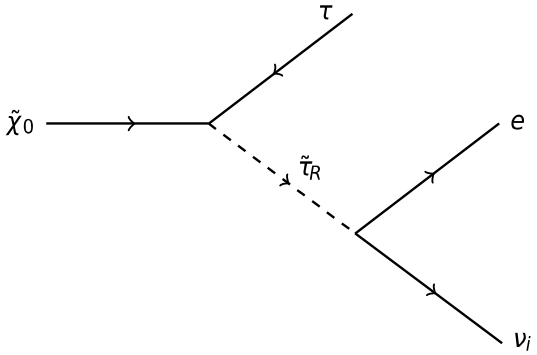

RPV-SUSY

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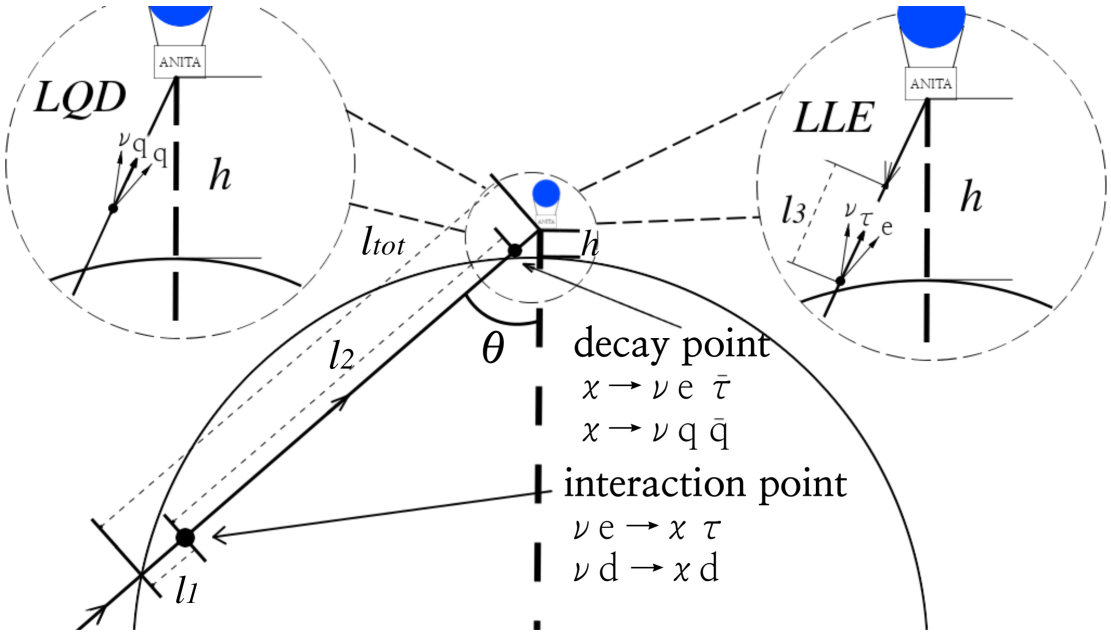

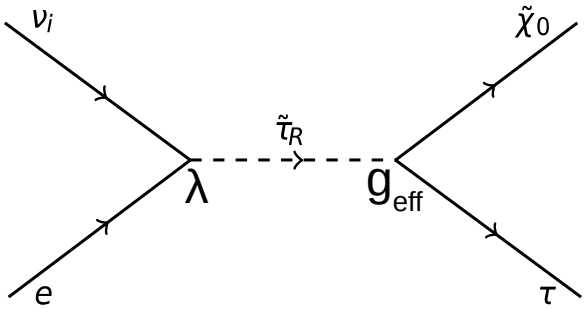

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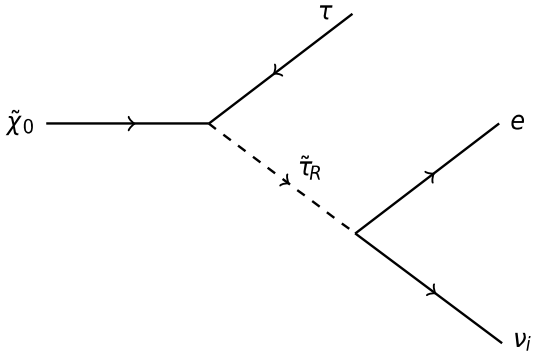

RPV-SUSY

$$W_{RPV} = \lambda_{ijk} L^i L^j \bar{E}^k + \lambda'_{ijk} L^i Q^j \bar{D}^k + \lambda''_{ijk} \bar{U}^i \bar{D}^j \bar{D}^k$$

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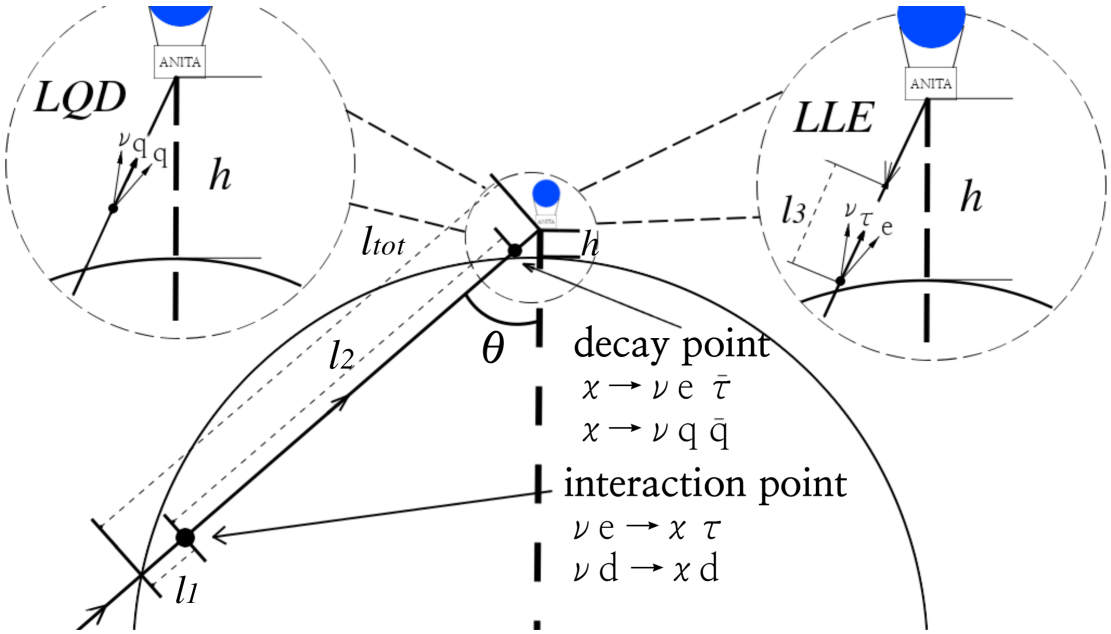

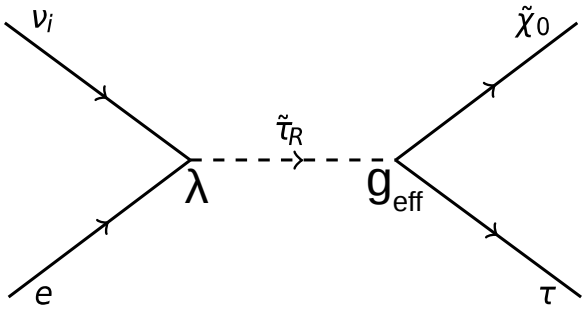

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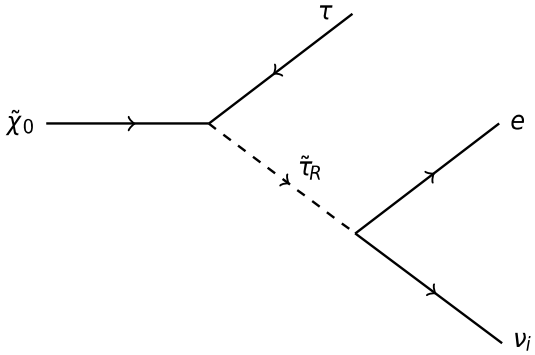

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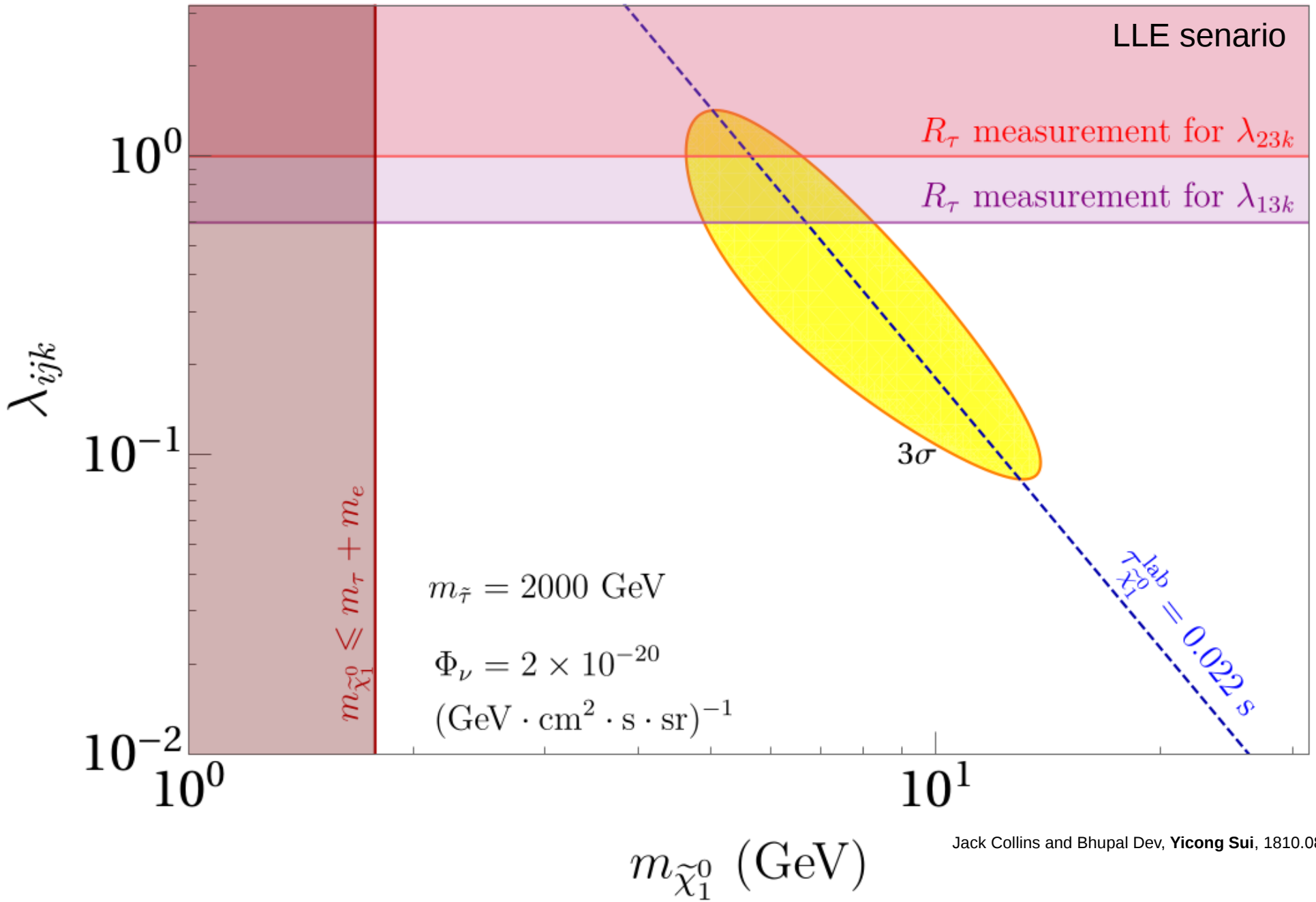
$$\begin{aligned}\sigma_{\rm RPV} &= \frac{8\pi}{M_{\tilde{\tau}}^2} {\rm Br}[\tilde{\tau} \to \nu + e] \cdot {\rm Br}[\tilde{\tau} \to \chi + \tau] \\ &= \frac{8\pi}{M_{\tilde{\tau}}^2} \frac{|\lambda|^2}{|\lambda|^2 + g_{eff}^2} \frac{g_{eff}^2}{|\lambda|^2 + g_{eff}^2}\end{aligned}$$

$$\Gamma(\chi \to \tau e \nu) \sim \frac{3\alpha \lambda_{i31}^2}{128\pi^2} \frac{M_\chi^5}{M_{\tilde{\tau}}^4}$$



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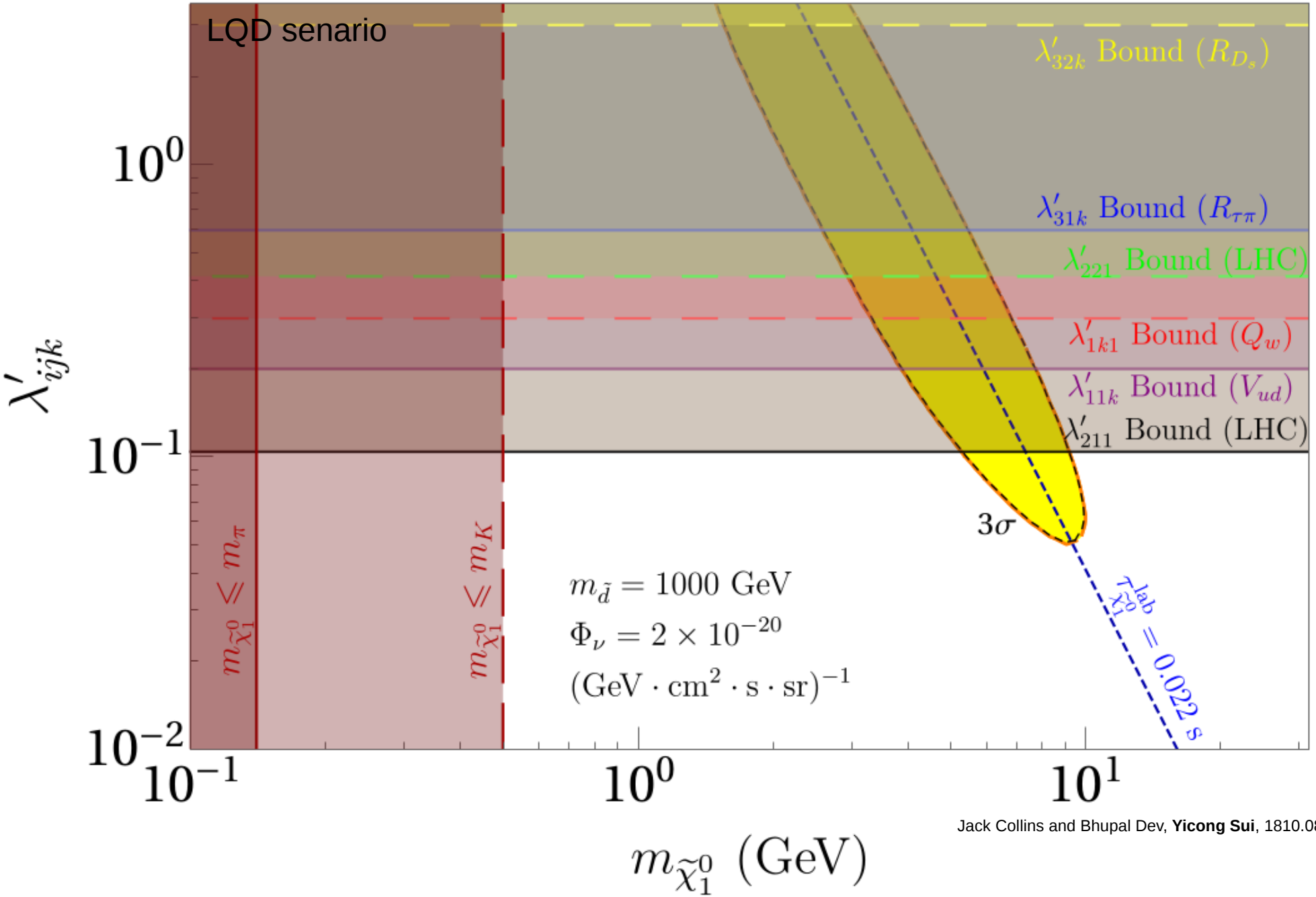

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$$\mathcal{L}(b \to c\ell_l \bar{\nu}_{l'}) = -\frac{4G_F}{\sqrt{2}} V_{cb} (\delta_{ll'} + \Delta^c_{ll'}) \bar{\ell}^l_L \gamma^\mu \nu^{l'}_L \bar{c}_L \gamma^\mu b_L \qquad \Delta^c_{ll'} = \sum_{j=1}^{3} \frac{\sqrt{2}}{4G_F} \frac{\lambda'_{l'33} \lambda'_{lj3}}{2m^2_{\tilde{b}_R}} \frac{V_{cj}}{V_{cb}}$$

N.G. Deshpande, Xiao-Gang He, 1608.04817
W. Altmannshofer, P. S. Bhupal Dev and A. Soni, 1704.06659
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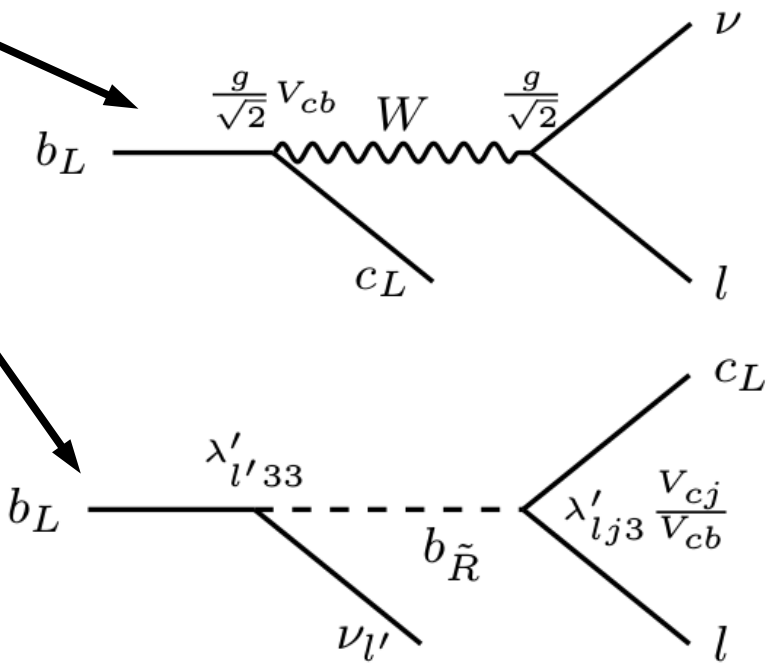

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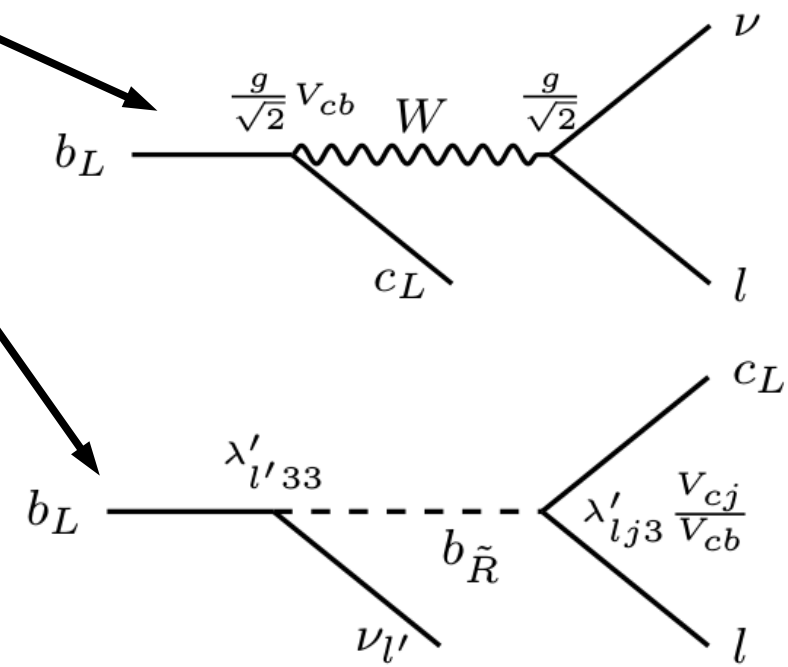
$$\frac{R_D}{R_D^{\rm SM}} = \frac{R_{D^*}}{R_{D^*}^{\rm SM}} = \left| 1 + \frac{v^2}{2m^2_{\tilde{b}_R}} {\rm Re}(X_c^\tau - X_c^{\mu \text{ or } <e,\mu>}) \right|^2$$

$$X_c^\tau = (\sum_{i=1}^{3} \lambda'_{i33}) \left(\lambda'_{333} + \lambda'_{323} \frac{V_{cs}}{V_{cb}} + \lambda'_{313} \frac{V_{cd}}{V_{cb}} \right)$$

$$X_c^\mu = (\sum_{i=1}^{3} \lambda'_{i33}) \left(\lambda'_{233} + \lambda'_{223} \frac{V_{cs}}{V_{cb}} + \lambda'_{213} \frac{V_{cd}}{V_{cb}} \right) \Big|_{\rm LHCb}$$

$$X_c^{<e,\mu>} = (\sum_{i=1}^{3} \lambda'_{i33}) \frac{1}{2} \sum_{i=1}^{2} \left(\lambda'_{i33} + \lambda'_{i23} \frac{V_{cs}}{V_{cb}} + \lambda'_{i13} \frac{V_{cd}}{V_{cb}} \right) \Big|_{\rm BarBar+Belle}$$



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Diganta Das, Chandan Hati, Girish Kumar, and Namit Mahajan, 1705.09188
Kevin Earla, Thomas Gr´egoirea, 1806.01343

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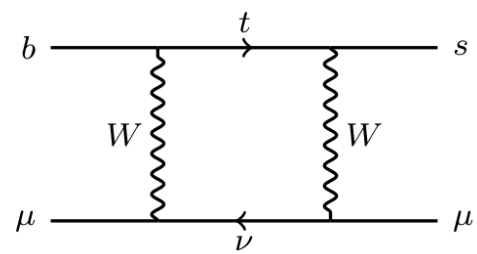

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Diganta Das, Chandan Hati, Girish Kumar, and Namit Mahajan, 1705.09188
Kevin Earla, Thomas Gr´egoirea, 1806.01343

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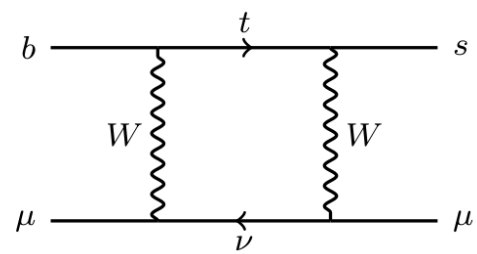

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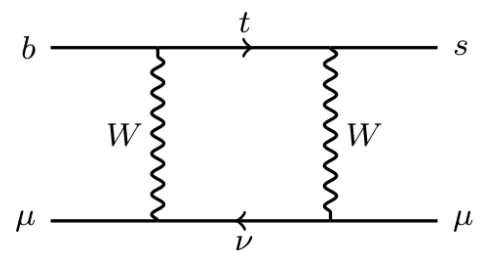

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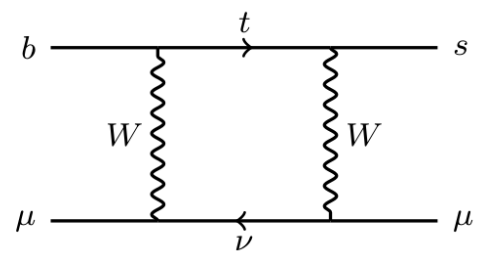

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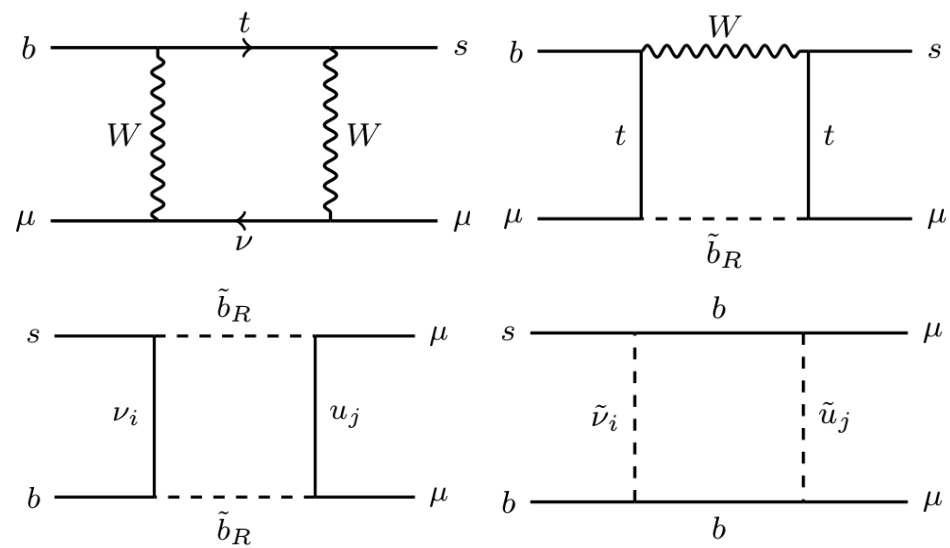

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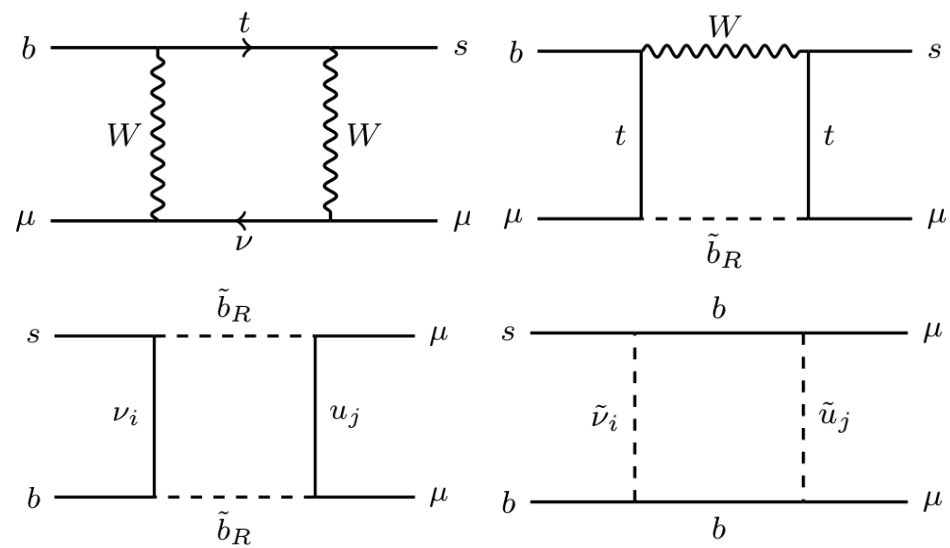

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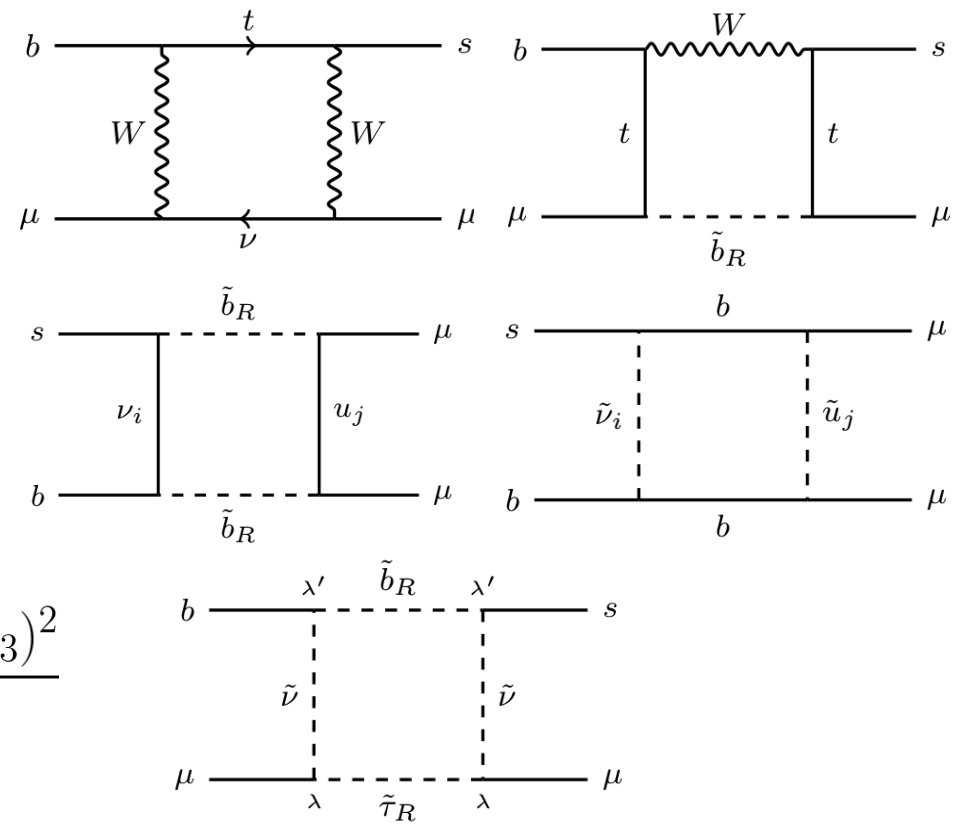

$$\text{Fourth Term} = -\frac{v^2\log\left(\frac{m_{\tilde{b}_R}^2}{m_{\tilde{\tau}_R}^2}\right)}{8(m_{\tilde{b}_R}^2 - m_{\tilde{\tau}_R}^2)}\frac{\lambda'_{323}\lambda'_{333}(\lambda_{323})^2}{e^2V_{tb}V_{ts}^*}$$

Sokratis Trifinopoulos, 1807.01638

Anita, Anomaly

B, Anomaly

Hey, B. Are we related?

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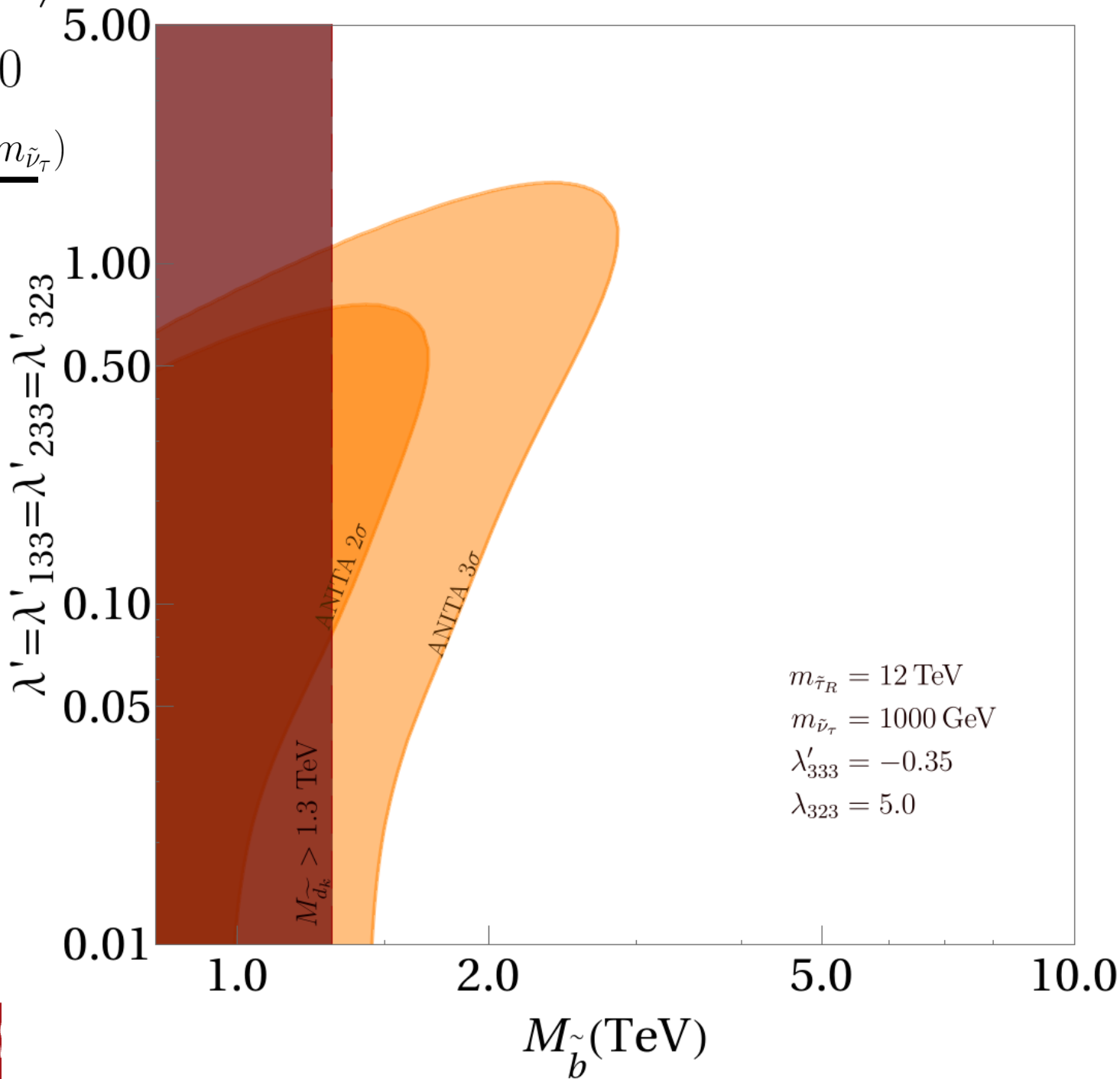

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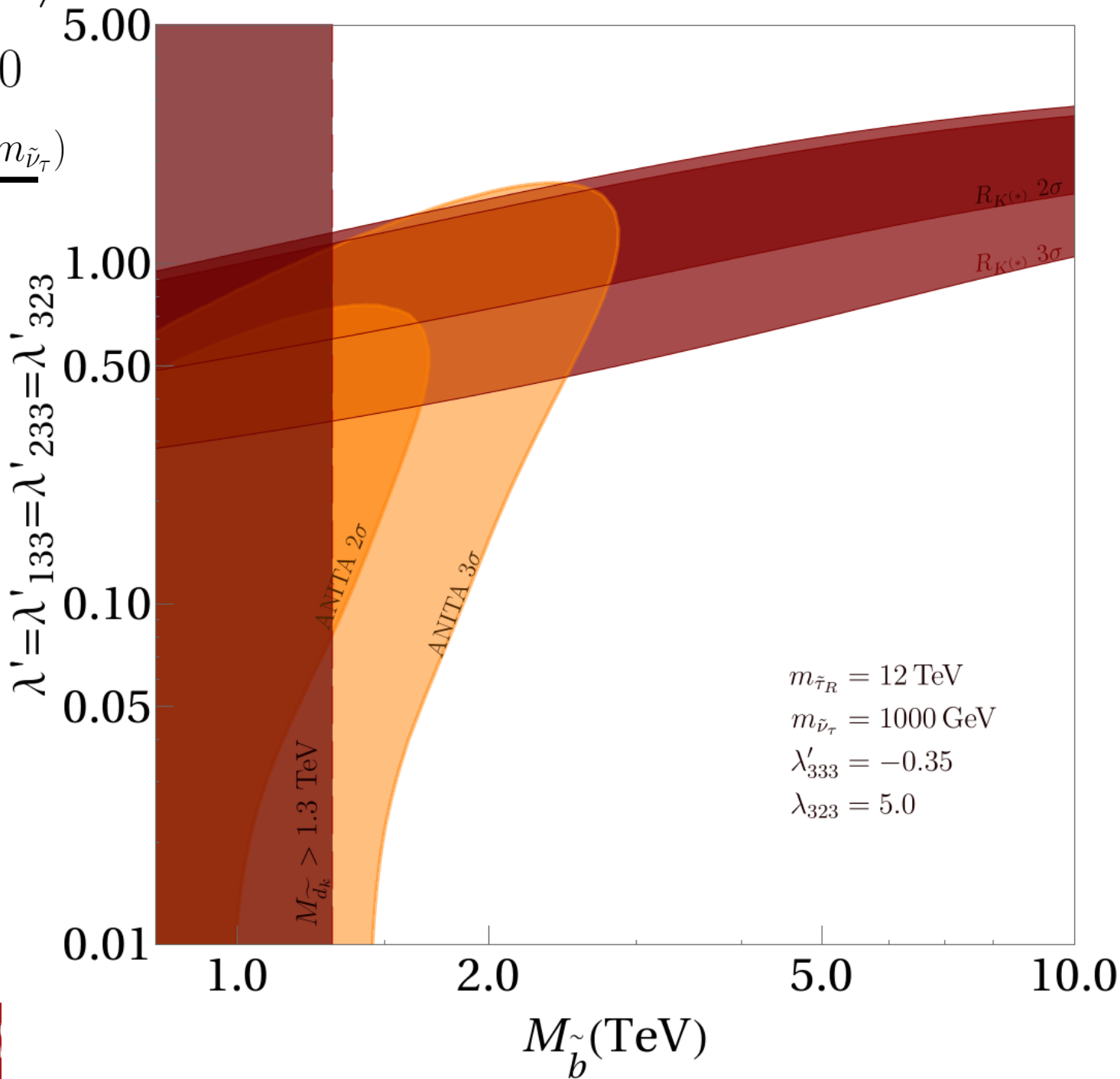

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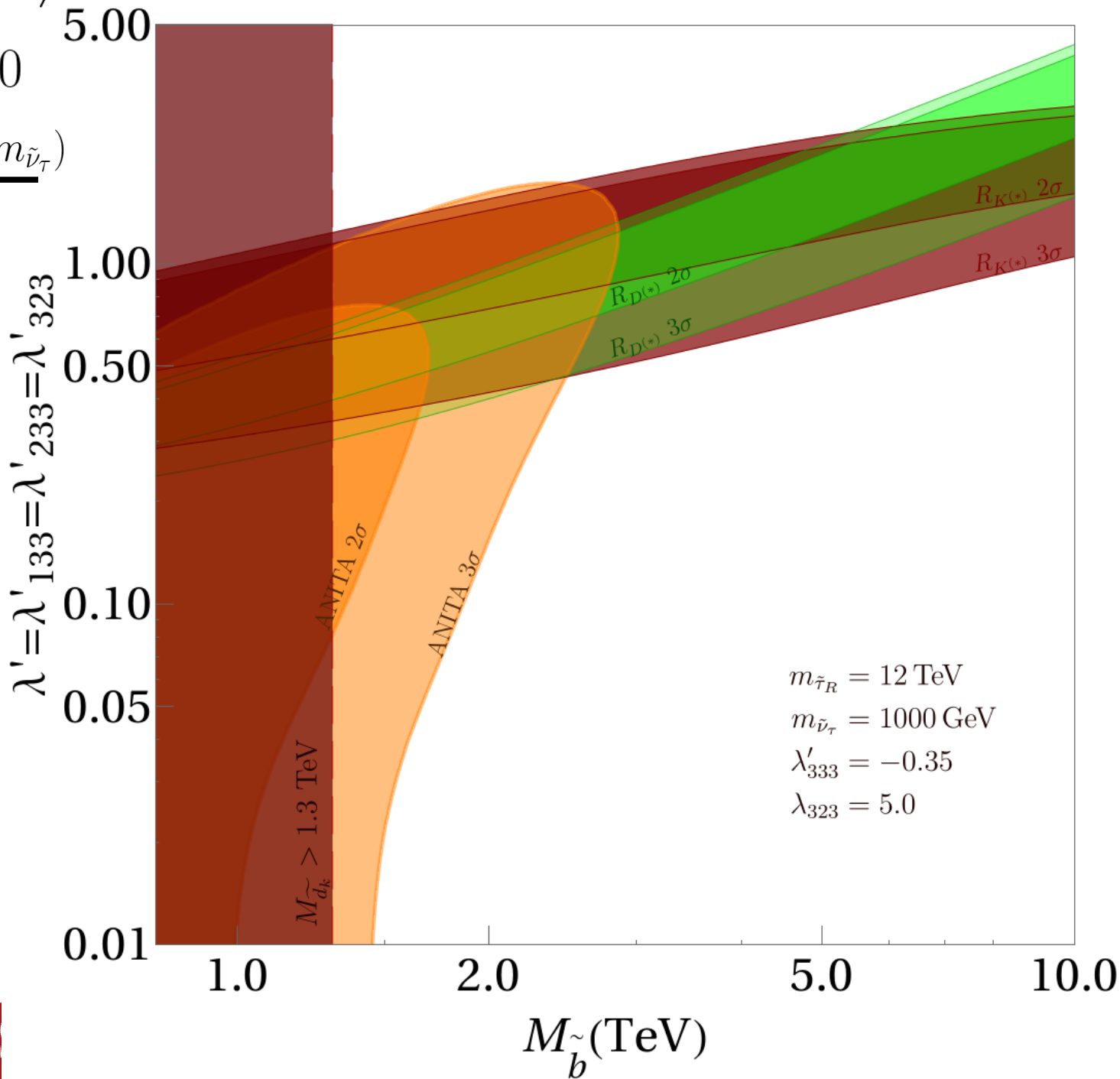

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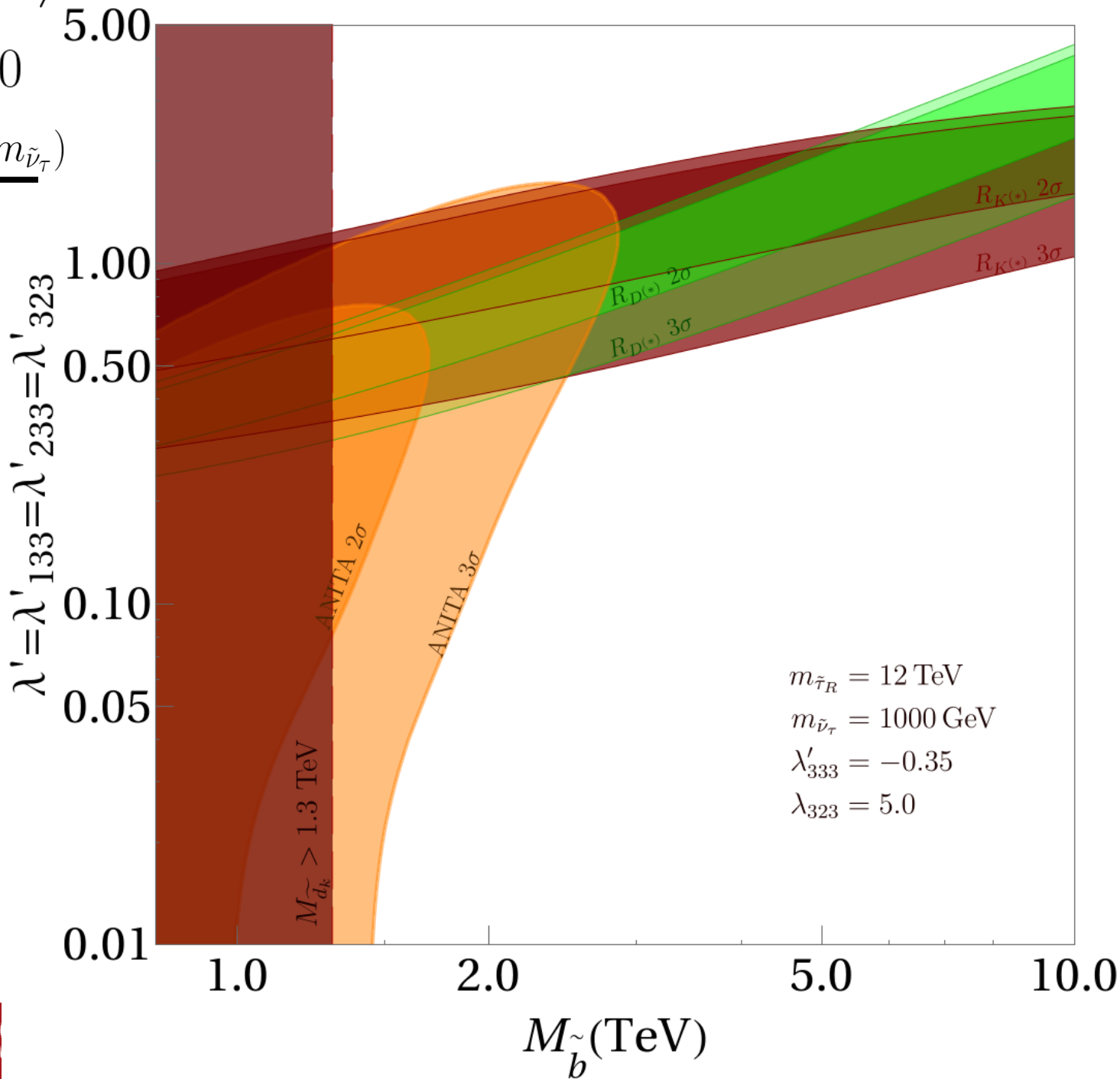

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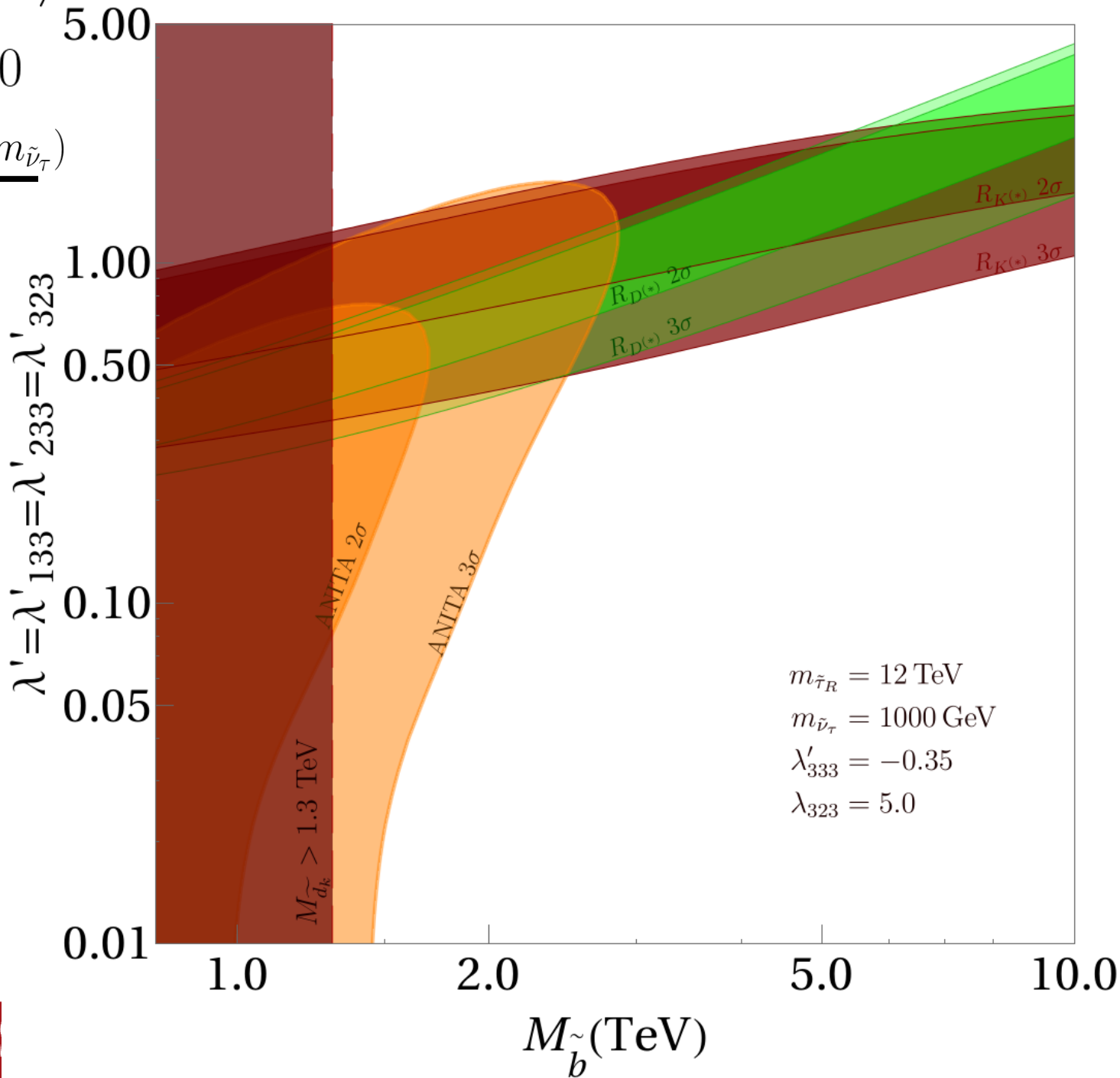
$$\Delta M_B < 2.73 \times 10^{-12}$$

Sokratis Trifinopoulos, 1807.01638



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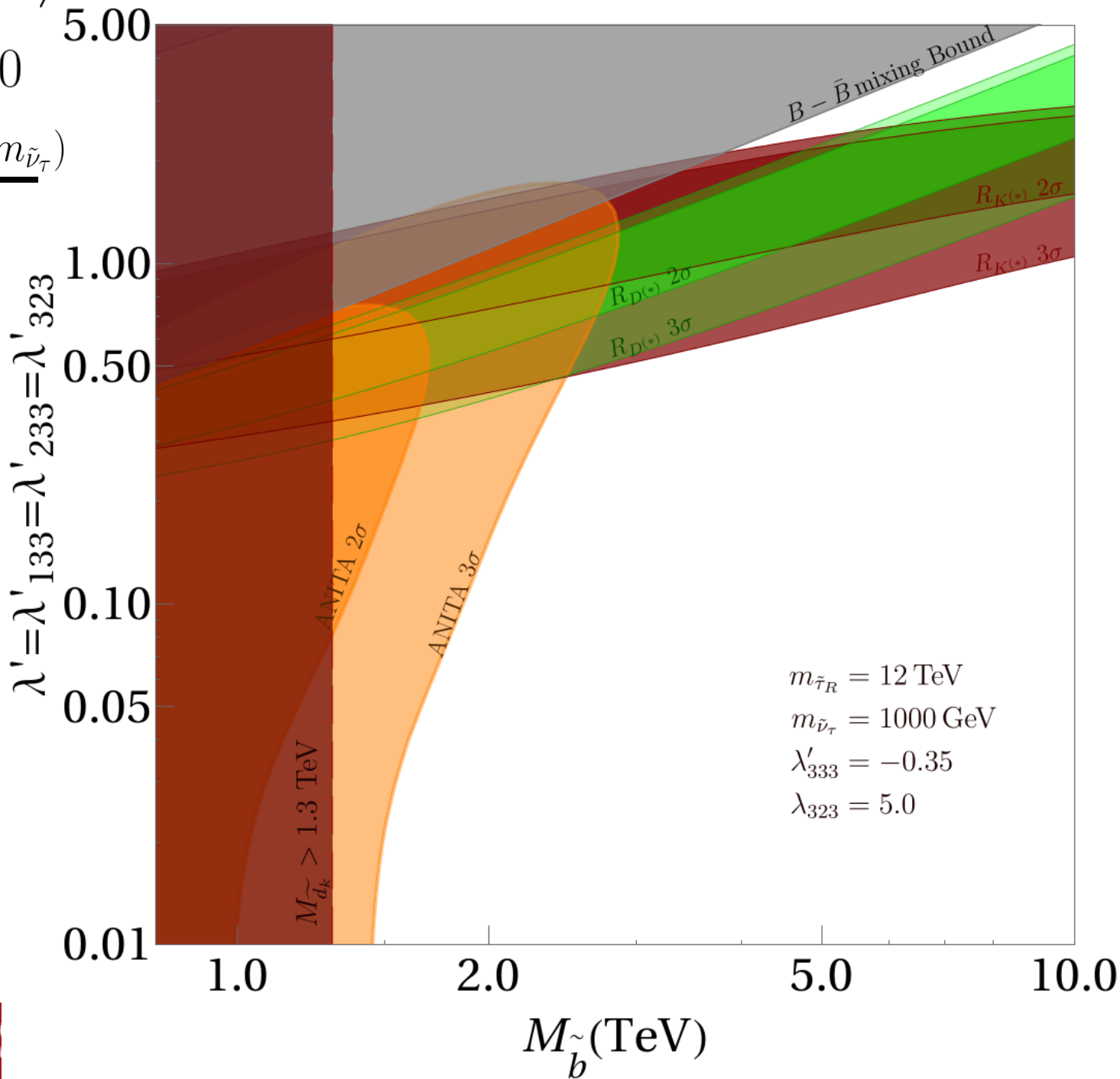

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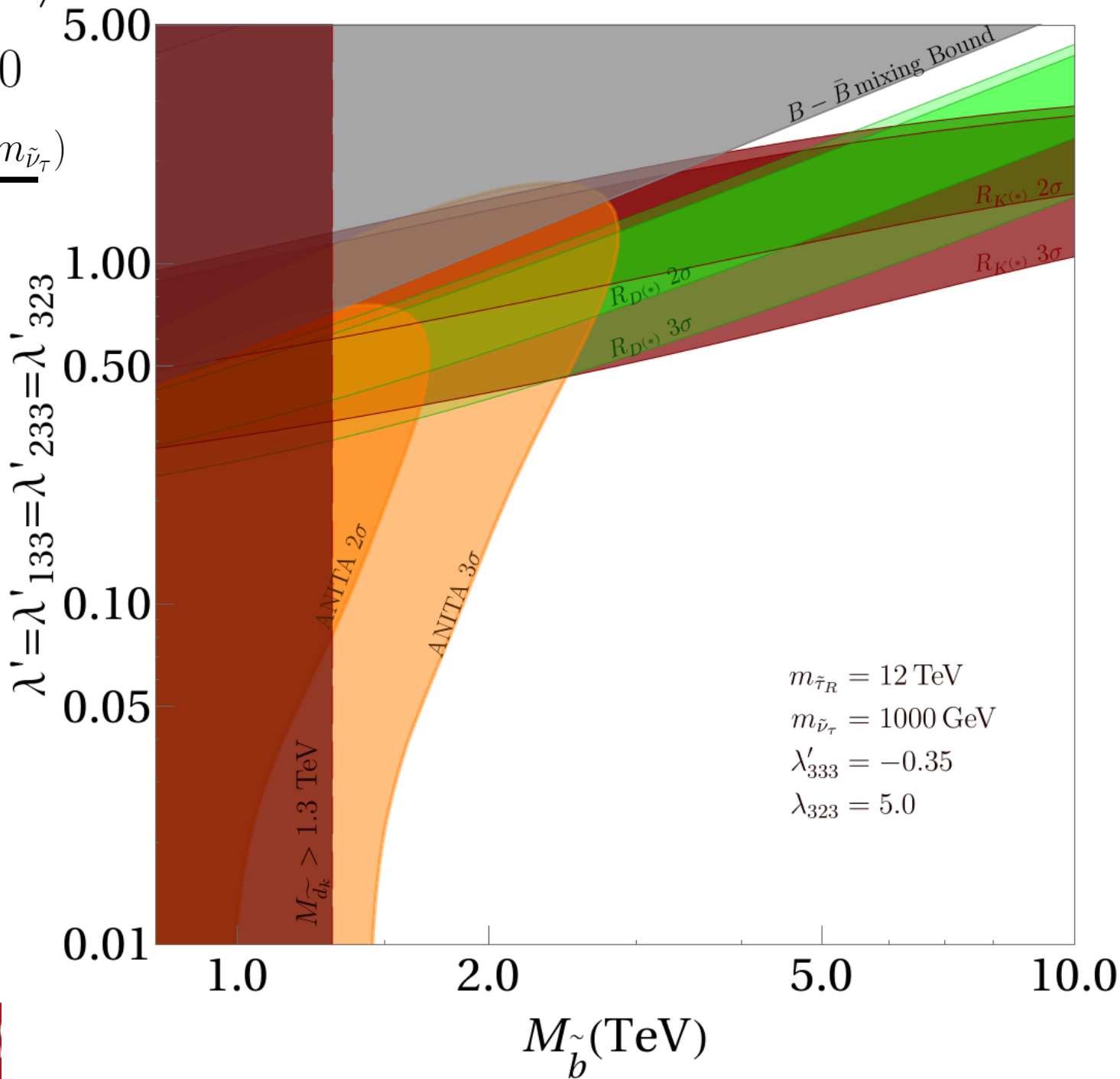
Dario Buttazzo, etl, 1706.07808



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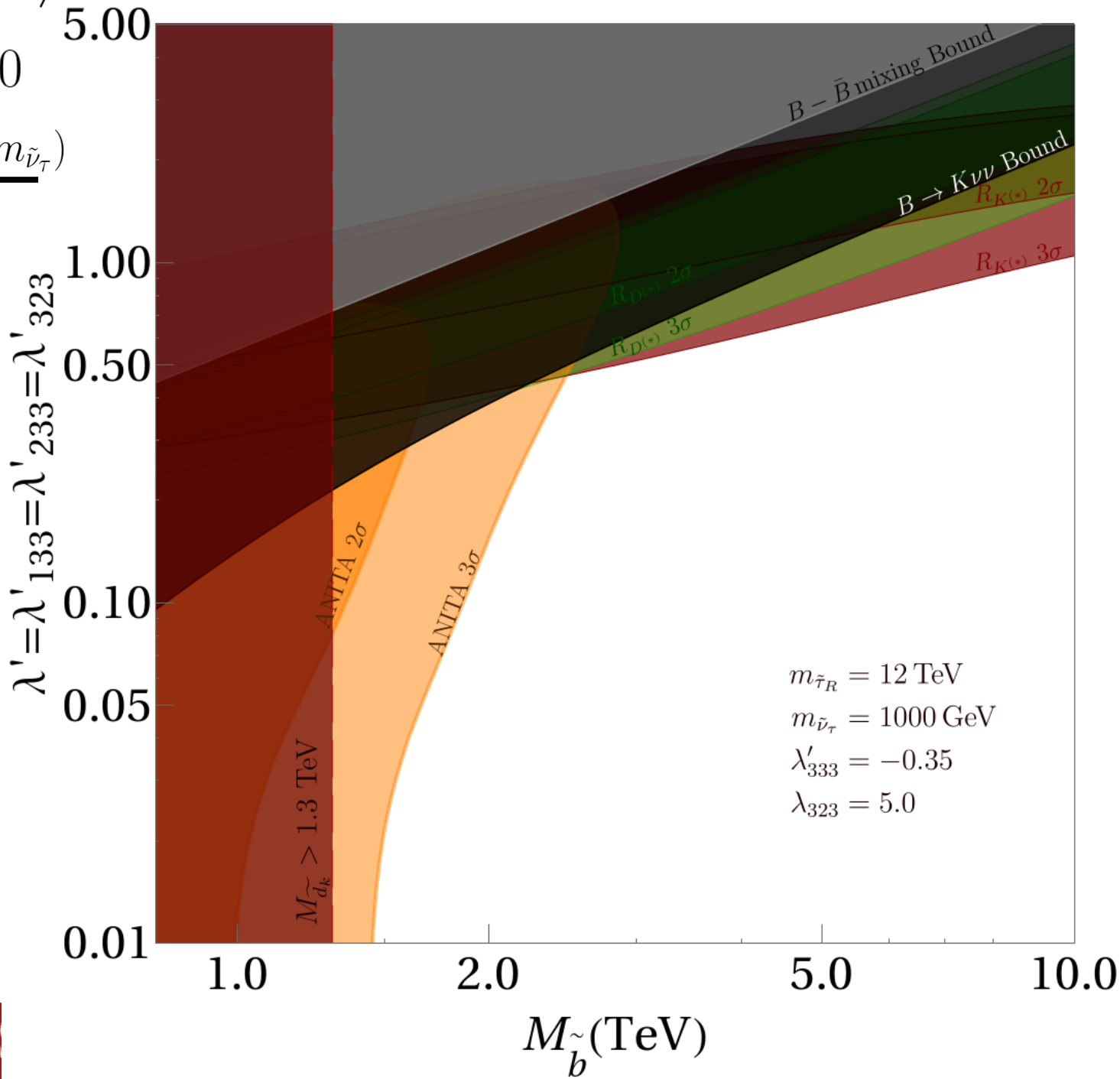

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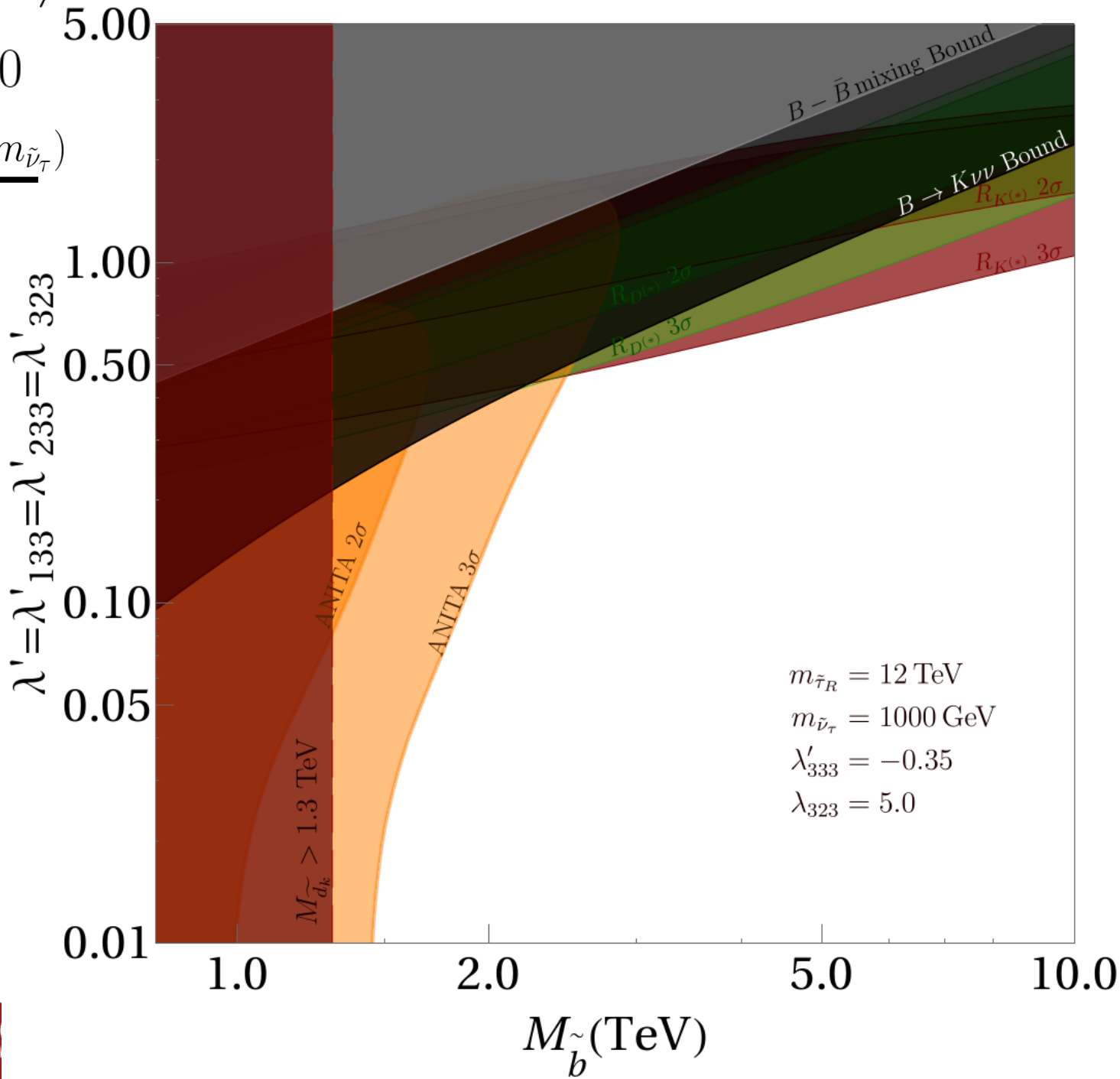
Heavy Flavor Averaging Group, etl, 1612.07233



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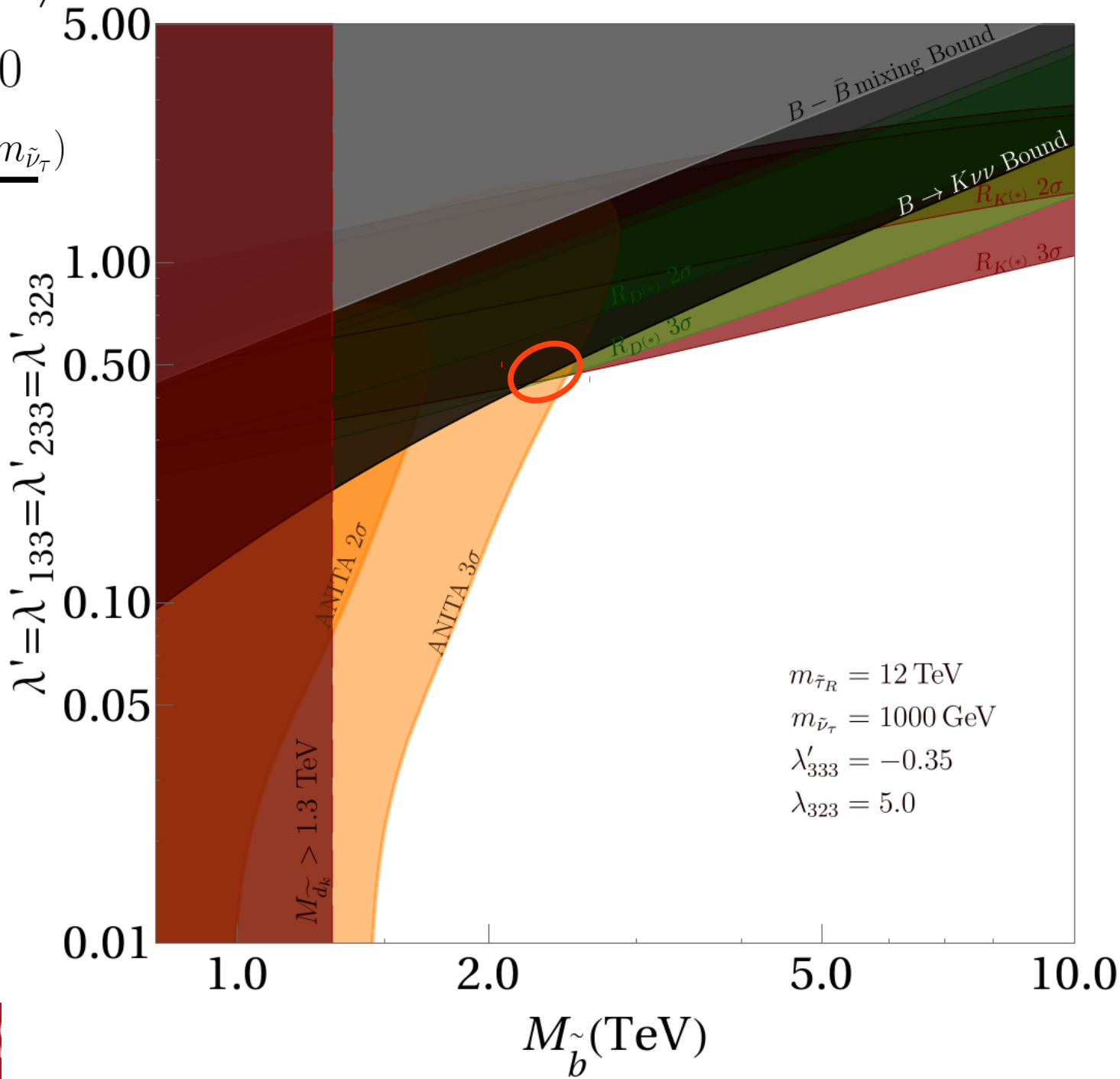

Conclusion:

1. Under the framework of RPV-SUSY, ANITA anomaly has quite large parameter space, which is in the simlar range demanded by RD and RK.

2. Rk Rk* and RD RD* anomalies could be explained simultaneously after a “fourth term” is included in the traditional RPV-SUSY Rk Rk* expression.

3. Under the simplified parameter setup, we find that there exist parameter spaces that could satisfy RK-RD-ANITA altogether.

4. Relaxing the parameter setup and letting more lambda’ running free could possibly lead to larger preferred region for the parameters.

5. This framework could also be expanded to include muon g-2 anomaly

Thank you

BK slides-Constraints

BK slides-Constraints

$$R_{B\to K^{(*)}\nu\bar{\nu}} = \sum_{i=i'=1}^{3} \frac{1}{3}\left|1+\frac{\Delta^{\rm RPV}_{\nu_i\bar{\nu}'_i}}{Xt\,V^*_{ts}V_{tb}}\right|^2 + \sum_{i\neq i'}\frac{1}{3}\left|\frac{\Delta^{\rm RPV}_{\nu_i\bar{\nu}'_i}}{Xt\,V^*_{ts}V_{tb}}\right|^2 \qquad \Delta^{\rm RPV}_{\nu_i\bar{\nu}'_i} = \frac{\pi s_W^2}{\sqrt{2}G_F\alpha}\left|-\frac{\lambda'_{i33}\lambda'_{i'23}}{2m^2_{\tilde{b}_R}}\right|$$

BK slides-Constraints

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1706.07808 eq 50

BK slides-Constraints

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1706.07808 eq 50

$$R_{B\to\tau\nu} = \left[1+\frac{\sqrt{2}}{8G_F\,m^2_{\tilde{b}_R}}\left(\lambda'_{333}\lambda'_{323}\frac{V_{us}}{V_{ub}}+\lambda'^2_{333}\right)\right]^2$$

BK slides-Constraints

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1706.07808 eq 50

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$\mathrm{B}-\bar{\mathrm{B}}$ mixing

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$$\Delta M_B < 2.73\times 10^{-12}$$

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