McDONNELL CENTER
FOR THE SPACE SCIENCES

A Tale of Two Anomalies: from LHCb to ANITA

Speaker: Yicong Sui

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

27th International Conference on Supersymmetry and Unification of Fundamental Interactions
May 20-24th, 2019

Introduction of B-anomaly

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

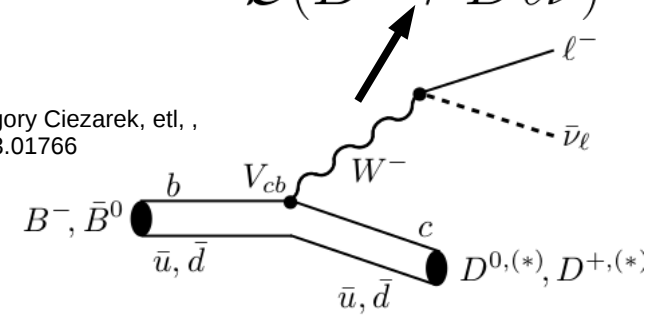
$$\begin{aligned} \text{BaBar, Belle} &: \ \ell = e, \mu \\ \text{LHCb} &: \ \ell = \mu \end{aligned}$$

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle}: \ \ell = e, \mu$$
$$\text{LHCb}: \ \ell = \mu$$

Gregory Ciezarek, etl, , 1703.01766

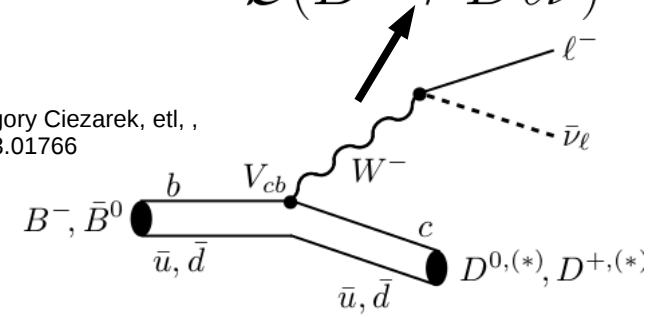


Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle}: \ \ell = e, \mu$$
$$\text{LHCb}: \ \ell = \mu$$

Gregory Ciezarek, etl, , 1703.01766



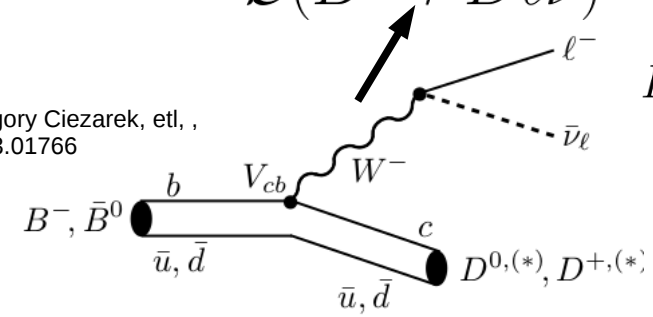
$$R_D^{\mathrm{SM}} = 0.299 \pm 0.003 \qquad R_{D^*}^{\mathrm{SM}} = 0.257 \pm 0.003$$

Florian U. Bernlochner, etl, 1703.05330

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle}: \ \ell = e, \mu$$
$$\text{LHCb}: \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\text{exp}}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\text{exp}}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

PDG2018

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

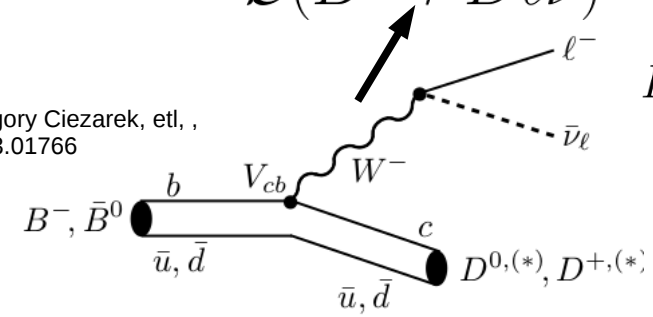
Florian U. Bernlochner, etl, 1703.05330

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle}: \ \ell = e, \mu$$

$$\text{LHCb}: \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

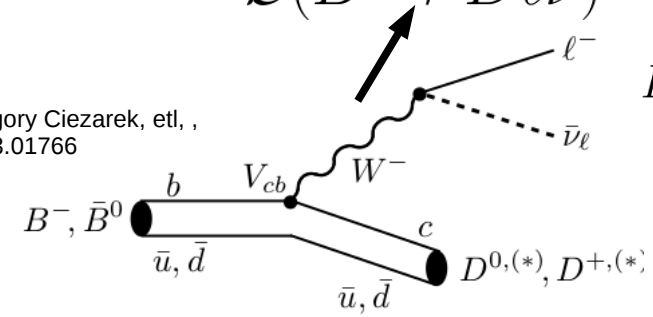
$$2.4\sigma$$

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle} : \ \ell = e, \mu$$

$$\text{LHCb} : \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

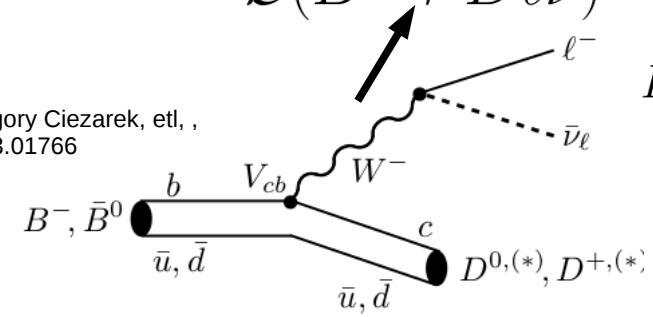
2.4σ

$$R_K = \frac{\mathcal{B}(B \to K\mu\bar{\mu})}{\mathcal{B}(B \to Ke\bar{e})} \qquad R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\bar{\mu})}{\mathcal{B}(B \to K^*e\bar{e})}$$

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle} : \ \ell = e, \mu$$
$$\text{LHCb} : \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

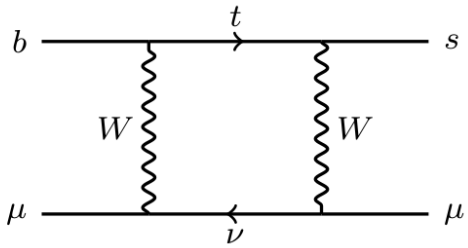
PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

2.4σ

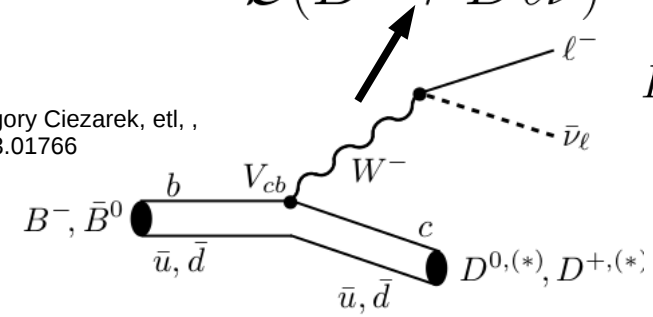
$$R_K = \frac{\mathcal{B}(B \to K\mu\bar{\mu})}{\mathcal{B}(B \to Ke\bar{e})} \qquad R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\bar{\mu})}{\mathcal{B}(B \to K^*e\bar{e})}$$



Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle} : \ \ell = e, \mu$$
$$\text{LHCb} : \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

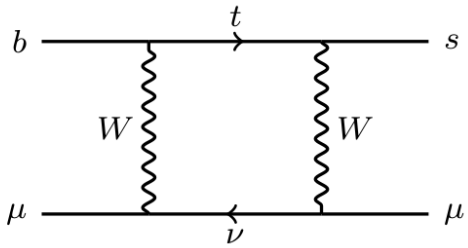
PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

2.4σ

$$R_K = \frac{\mathcal{B}(B \to K\mu\bar{\mu})}{\mathcal{B}(B \to Ke\bar{e})} \qquad R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\bar{\mu})}{\mathcal{B}(B \to K^*e\bar{e})}$$



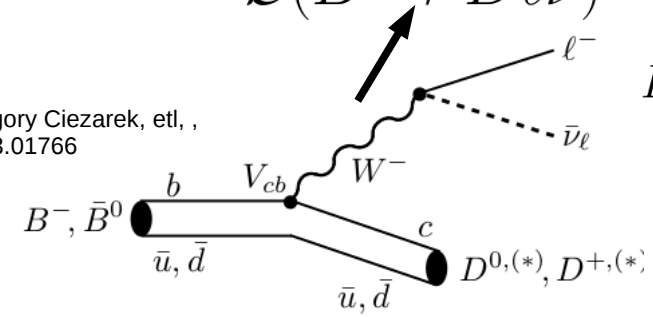
$$R_{K^*}^{\text{SM}}|_{q^2 \in [0.045, 1.1]\ \text{GeV}} = 0.906 \pm 0.028. \qquad R_{K^*}^{\text{SM}}|_{q^2 \in [1.1, 6]\ \text{GeV}} = R_K^{\text{SM}} = 1.00 \pm 0.01.$$

Marzia Bordone, Gino Isidori, Andrea Pattori, 1605.07633

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle} : \ \ell = e, \mu$$
$$\text{LHCb} : \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

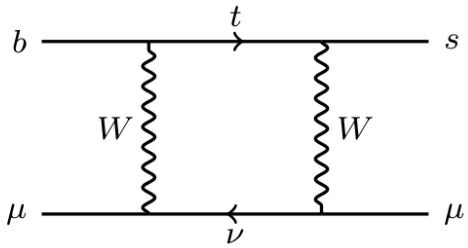
PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

2.4σ

$$R_K = \frac{\mathcal{B}(B \to K\mu\bar{\mu})}{\mathcal{B}(B \to Ke\bar{e})} \qquad R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\bar{\mu})}{\mathcal{B}(B \to K^*e\bar{e})}$$



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

LHCb collaboration, 1903.09252

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

LHCb collaboration, 1705.05802

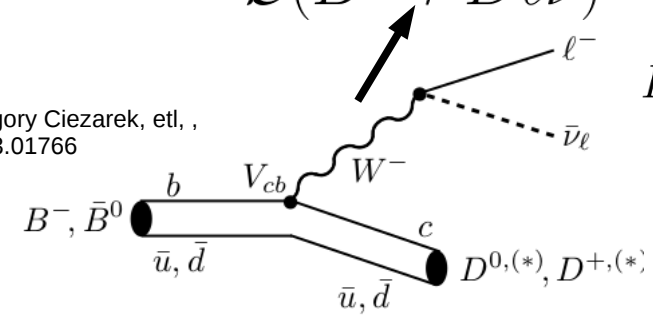
$$R_{K^*}^{\text{SM}}|_{q^2 \in [0.045, 1.1]\ \text{GeV}} = 0.906 \pm 0.028. \qquad R_{K^*}^{\text{SM}}|_{q^2 \in [1.1, 6]\ \text{GeV}} = R_K^{\text{SM}} = 1.00 \pm 0.01.$$

Marzia Bordone, Gino Isidori, Andrea Pattori, 1605.07633

Introduction of B-anomaly

$$R_D = \frac{\mathcal{B}(B \to D\tau\bar{\nu})}{\mathcal{B}(B \to D\ell\bar{\nu})} \qquad R_{D^*} = \frac{\mathcal{B}(B \to D^*\tau\bar{\nu})}{\mathcal{B}(B \to D^*\ell\bar{\nu})}$$

$$\text{BaBar, Belle} : \ \ell = e, \mu$$
$$\text{LHCb} : \ \ell = \mu$$



Gregory Ciezarek, etl, , 1703.01766

$$R_D^{\exp}|_{\text{means}} = 0.407 \pm 0.039 \pm 0.024 \qquad R_{D^*}^{\exp}|_{\text{means}} = 0.304 \pm 0.013 \pm 0.007$$

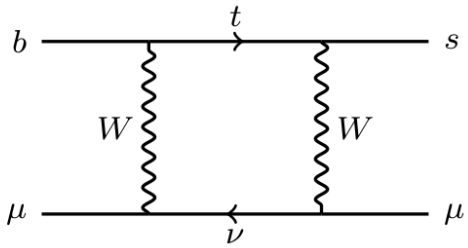
PDG2018

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

Florian U. Bernlochner, etl, 1703.05330

2.4σ

$$R_K = \frac{\mathcal{B}(B \to K\mu\bar{\mu})}{\mathcal{B}(B \to Ke\bar{e})} \qquad R_{K^*} = \frac{\mathcal{B}(B \to K^*\mu\bar{\mu})}{\mathcal{B}(B \to K^*e\bar{e})}$$



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

LHCb collaboration, 1903.09252

2.5σ

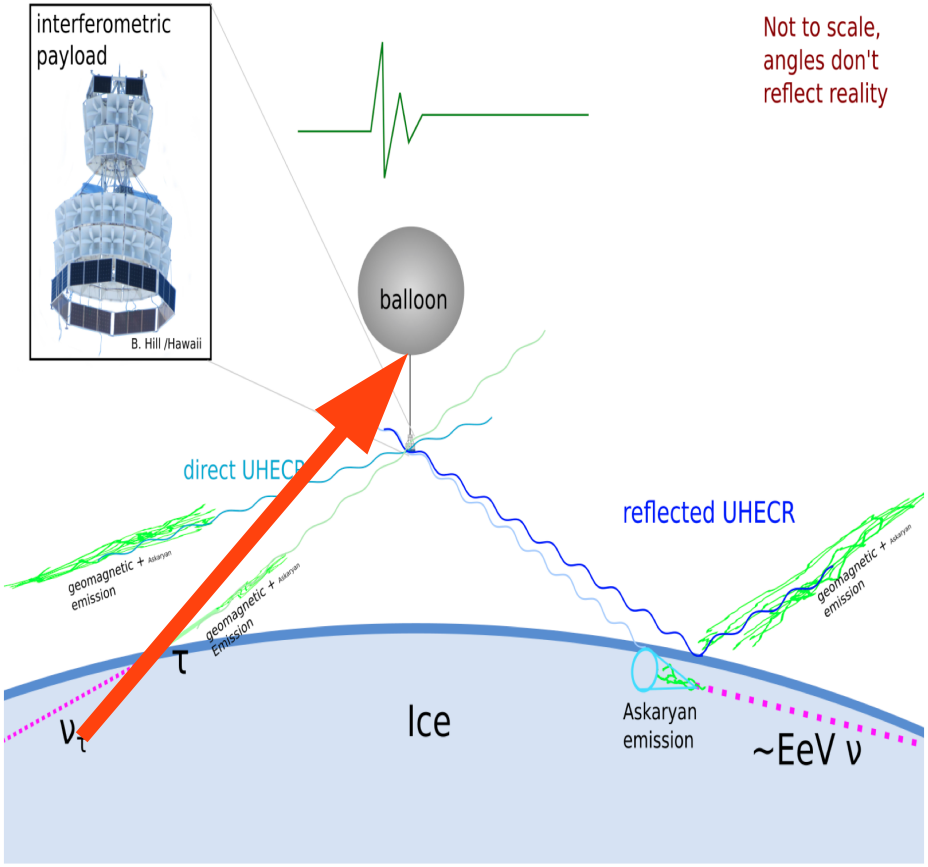
$$R_{K^*} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03, & \text{for } 0.045\,\text{GeV}^2 < q^2 < 1.1\,\text{GeV}^2, \\ 0.69^{+0.11}_{-0.07} \pm 0.05, & \text{for } 1.1\,\text{GeV}^2 < q^2 < 6\,\text{GeV}^2, \end{cases}$$

LHCb collaboration, 1705.05802

$$R_{K^*}^{\text{SM}}|_{q^2 \in [0.045, 1.1]\ \text{GeV}} = 0.906 \pm 0.028. \qquad R_{K^*}^{\text{SM}}|_{q^2 \in [1.1, 6]\ \text{GeV}} = R_K^{\text{SM}} = 1.00 \pm 0.01.$$

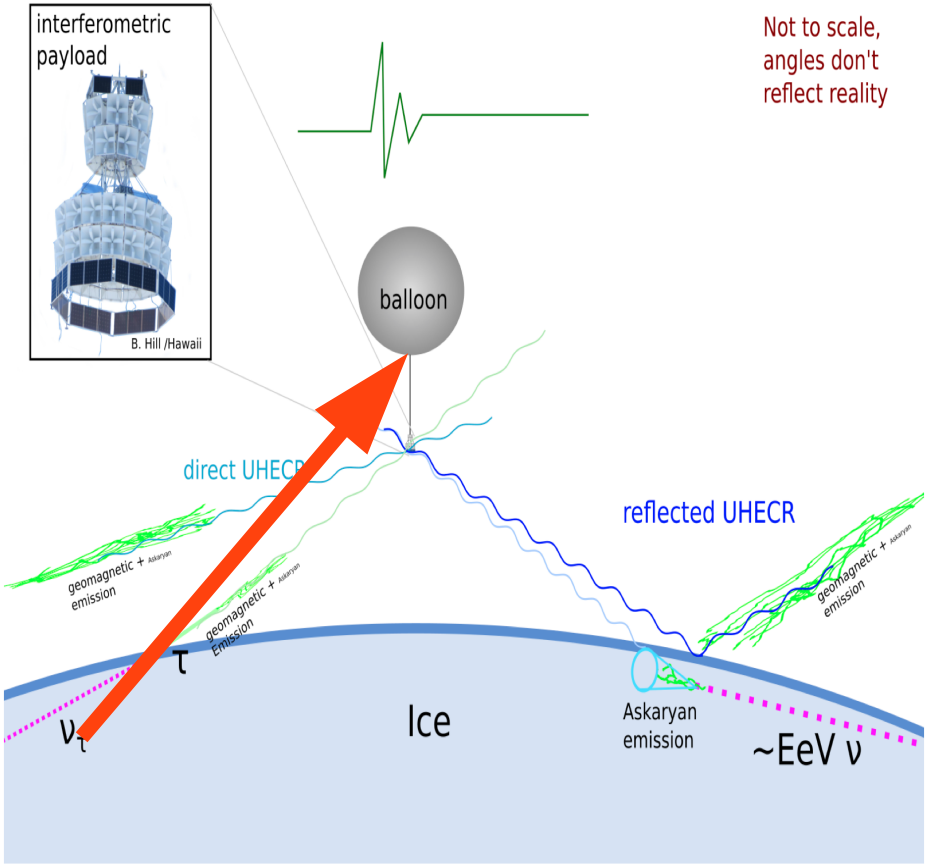
Marzia Bordone, Gino Isidori, Andrea Pattori, 1605.07633

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

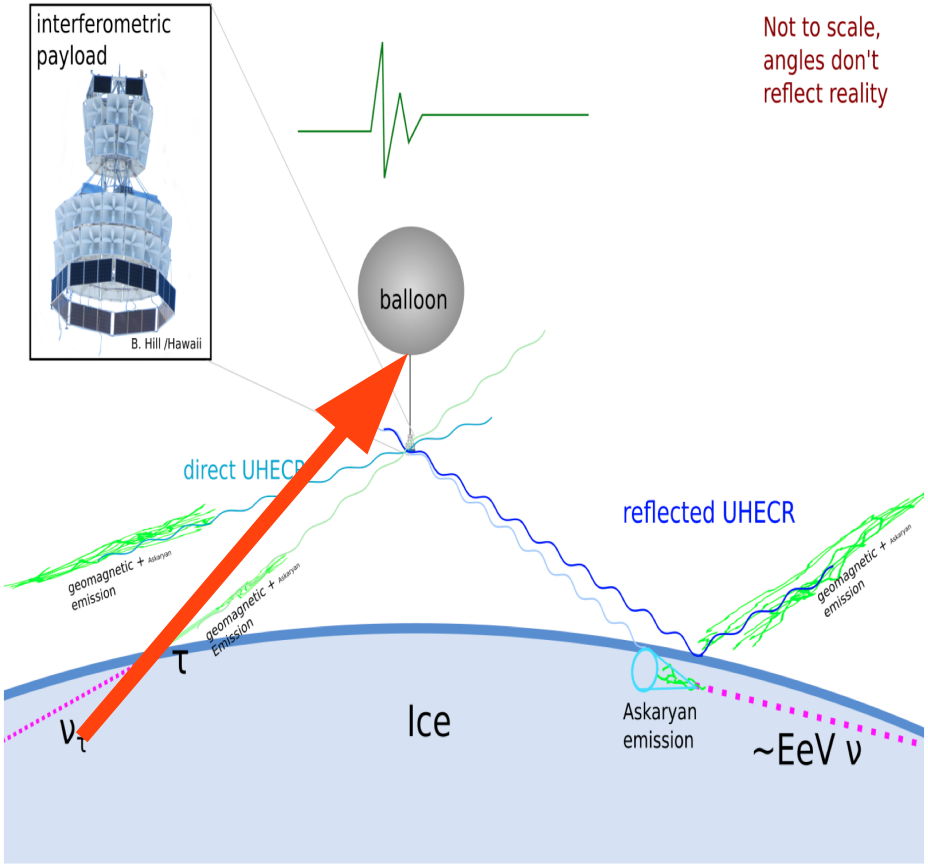
TABLE I: *ANITA-I,-III anomalous upward air showers.*

event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
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

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

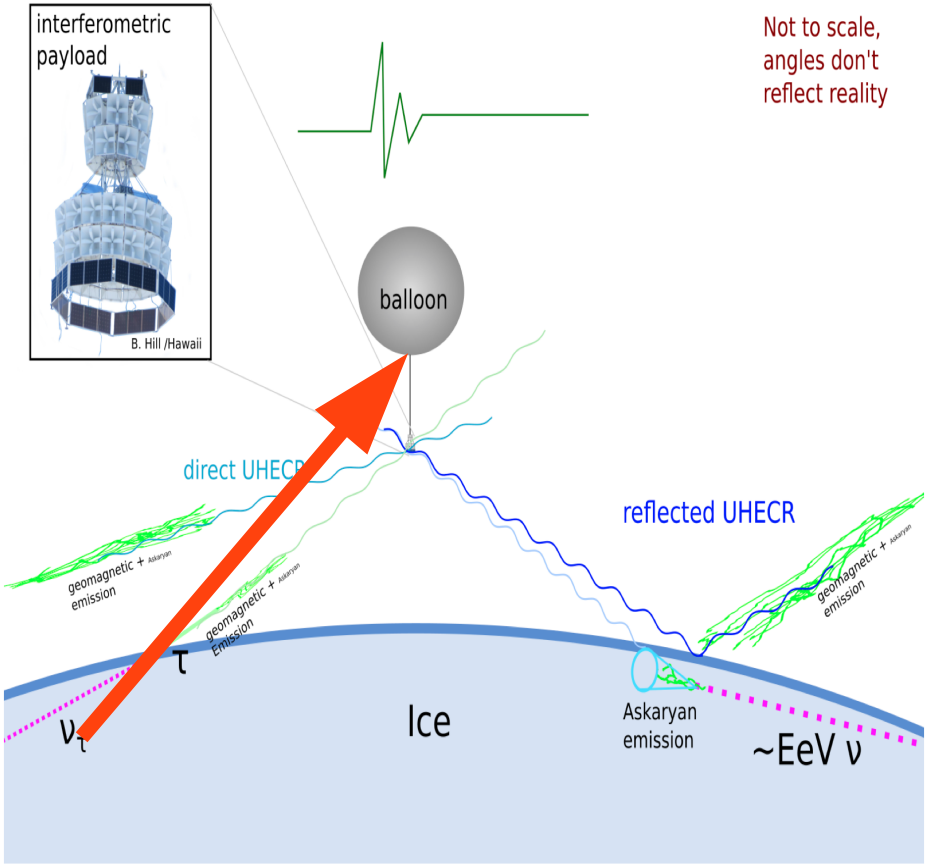
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°, 159.62 \pm 0.7°$	$-35.0 \pm 0.3°, 61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
$E_{shower}^{(3)}$	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1.Large Elevation Angle, going upwards.
2.No Polarity Reverse Relative to Geomagnetic Field.
3.Both have large energy~0.5EeV
4.Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

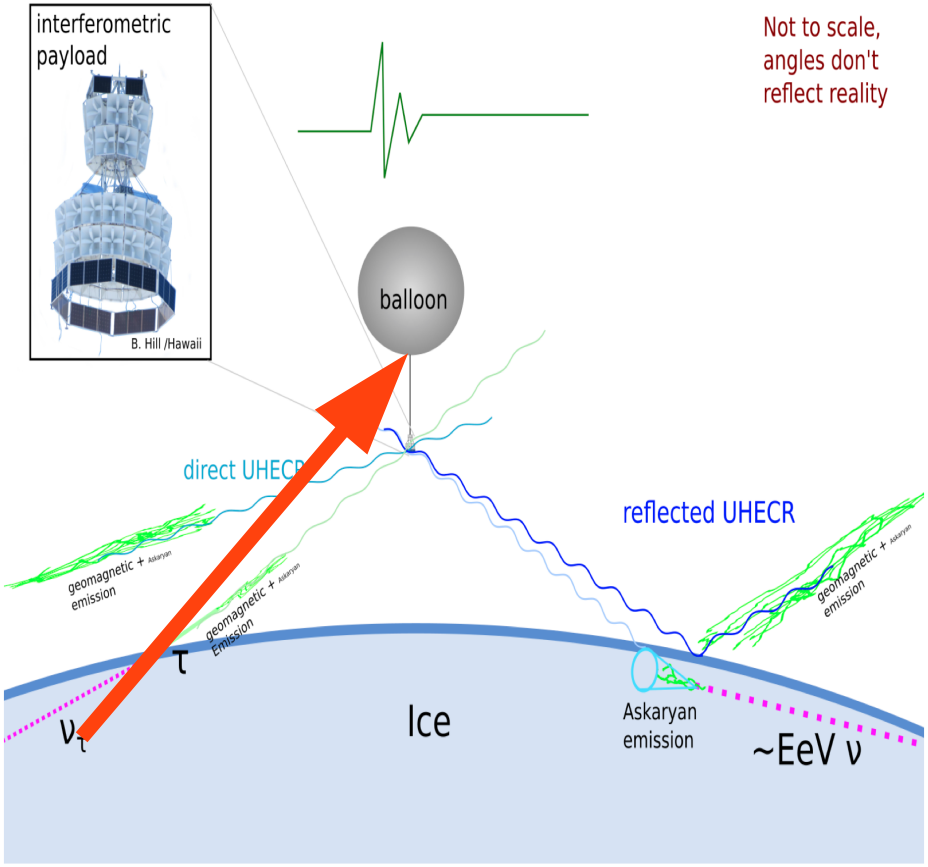
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3^\circ$, $159.62 \pm 0.7^\circ$	$-35.0 \pm 0.3^\circ$, $61.41 \pm 0.7^\circ$
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

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1. Large Elevation Angle, going upwards.
2. No Polarity Reverse Relative to Geomagnetic Field.
3. Both have large energy~0.5EeV
4. Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

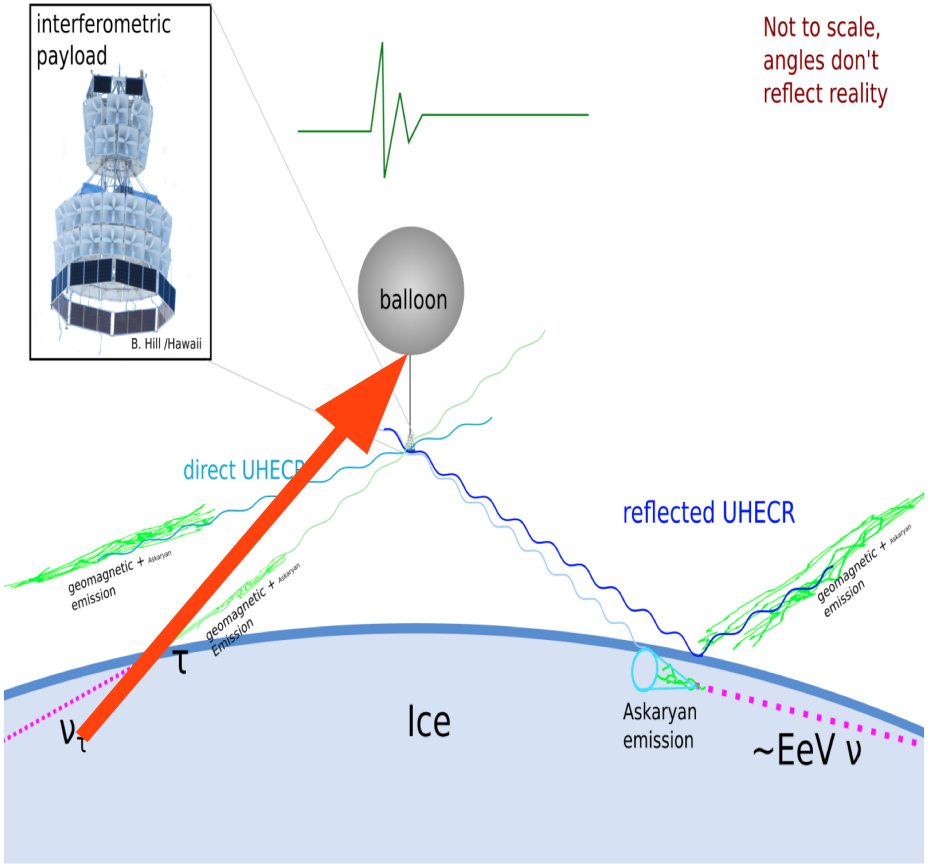
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°$, $159.62 \pm 0.7°$	$-35.0 \pm 0.3°$, $61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
E_{shower}[3]	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1. Large Elevation Angle, going upwards.
2. No Polarity Reverse Relative to Geomagnetic Field.
3. Both have large energy~0.5EeV
4. Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

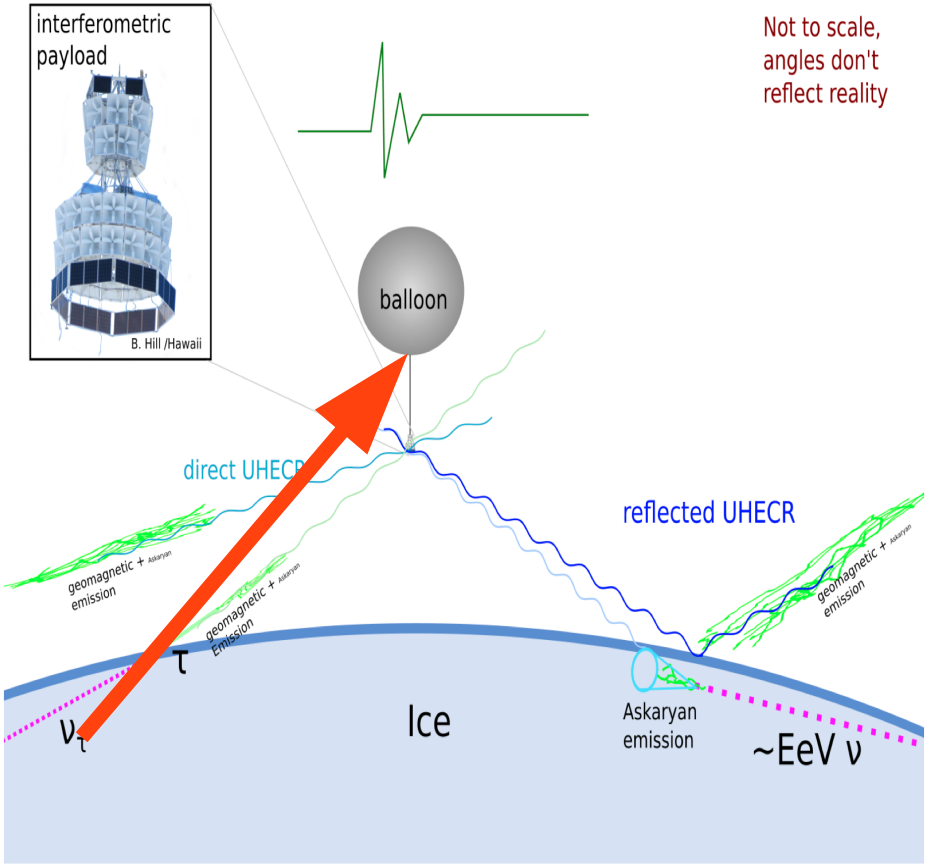
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3^\circ$, $159.62 \pm 0.7^\circ$	$-35.0 \pm 0.3^\circ$, $61.41 \pm 0.7^\circ$
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

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1. Large Elevation Angle, going upwards.
2. No Polarity Reverse Relative to Geomagnetic Field.
3. Both have large energy~0.5EeV
4. Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

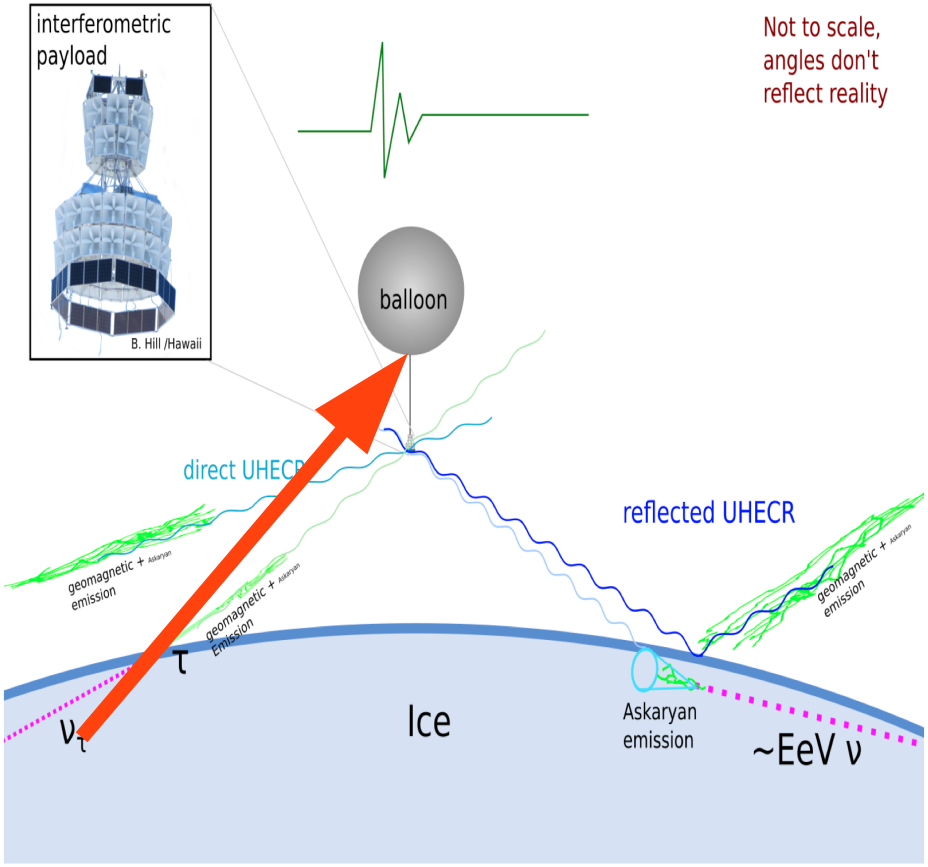
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°$, $159.62 \pm 0.7°$	$-35.0 \pm 0.3°$, $61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
E_{shower}[3]	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1.Large Elevation Angle, going upwards.
2.No Polarity Reverse Relative to Geomagnetic Field.
3.Both have large energy~0.5EeV
4.Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

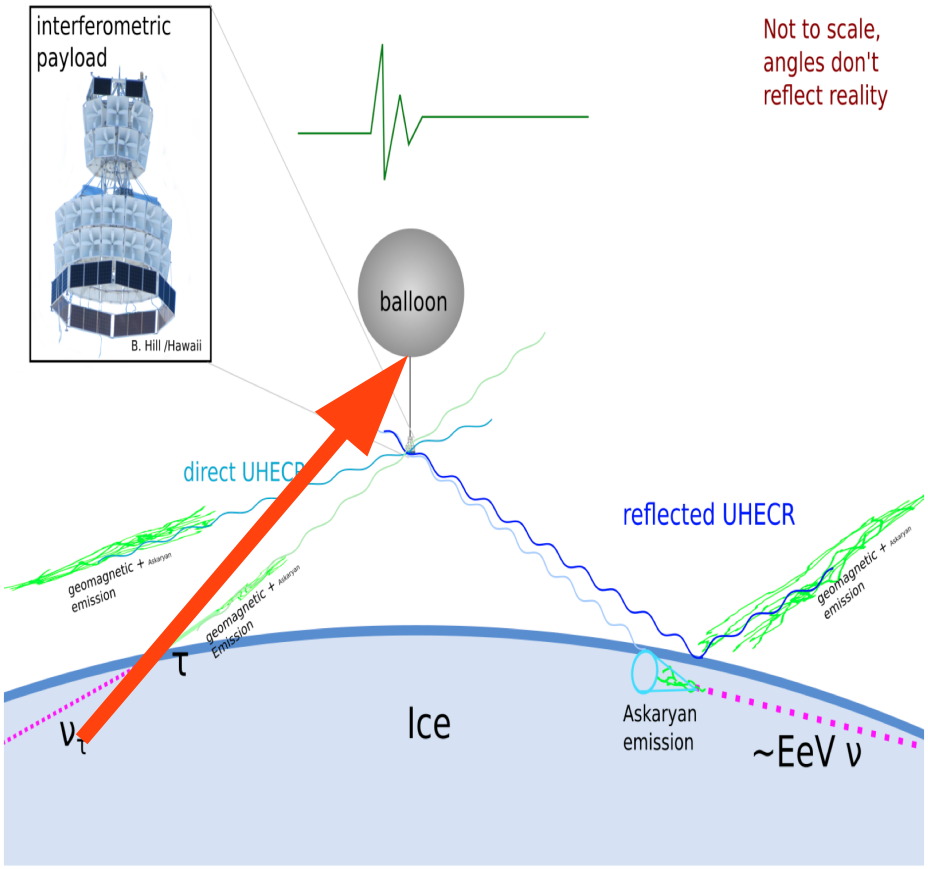
event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
Lat., Lon.[1]	-82.6559, 17.2842	-81.39856, 129.01626
Altitude	2.56 km	2.75 km
Ice depth	3.53 km	3.22 km
El., Az.	$-27.4 \pm 0.3°$, $159.62 \pm 0.7°$	$-35.0 \pm 0.3°$, $61.41 \pm 0.7°$
RA, Dec[2]	282.14064, +20.33043	50.78203, +38.65498
E_{shower}[3]	0.6 ± 0.4 EeV	$0.56^{+0.3}_{-0.2}$ EeV

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1.Large Elevation Angle, going upwards.
2.No Polarity Reverse Relative to Geomagnetic Field.
3.Both have large energy~0.5EeV
4.Both interpreted as tau events by ANITA

Introduction of ANITA anomaly



Not to scale, angles don't reflect reality

R ~ 6400 km
D = 2R cos(θ) > 5700 km
ℓ_{SM} ~ 300 km (in rock)

The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
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

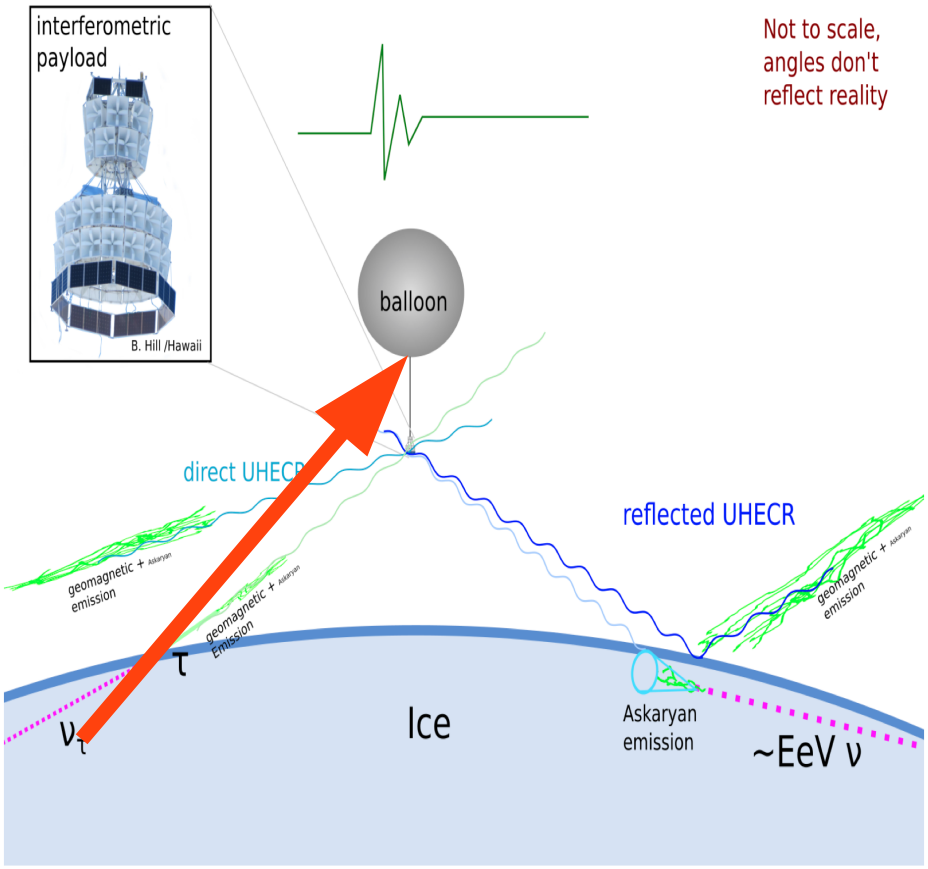
[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1.Large Elevation Angle, going upwards.
2.No Polarity Reverse Relative to Geomagnetic Field.
3.Both have large energy~0.5EeV
4.Both interpreted as tau events by ANITA

Introduction of ANITA anomaly

$P_{survival} \sim 10^{-6}$



Not to scale, angles don't reflect reality

R ~ 6400 km
D = 2R cos(θ) > 5700 km
ℓ_{SM} ~ 300 km (in rock)

The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
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.	$-27.4 \pm 0.3^\circ$, $159.62 \pm 0.7^\circ$	$-35.0 \pm 0.3^\circ$, $61.41 \pm 0.7^\circ$
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

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1.Large Elevation Angle, going upwards.
2.No Polarity Reverse Relative to Geomagnetic Field.
3.Both have large energy~0.5EeV
4.Both interpreted as tau events by ANITA

Introduction of ANITA anomaly

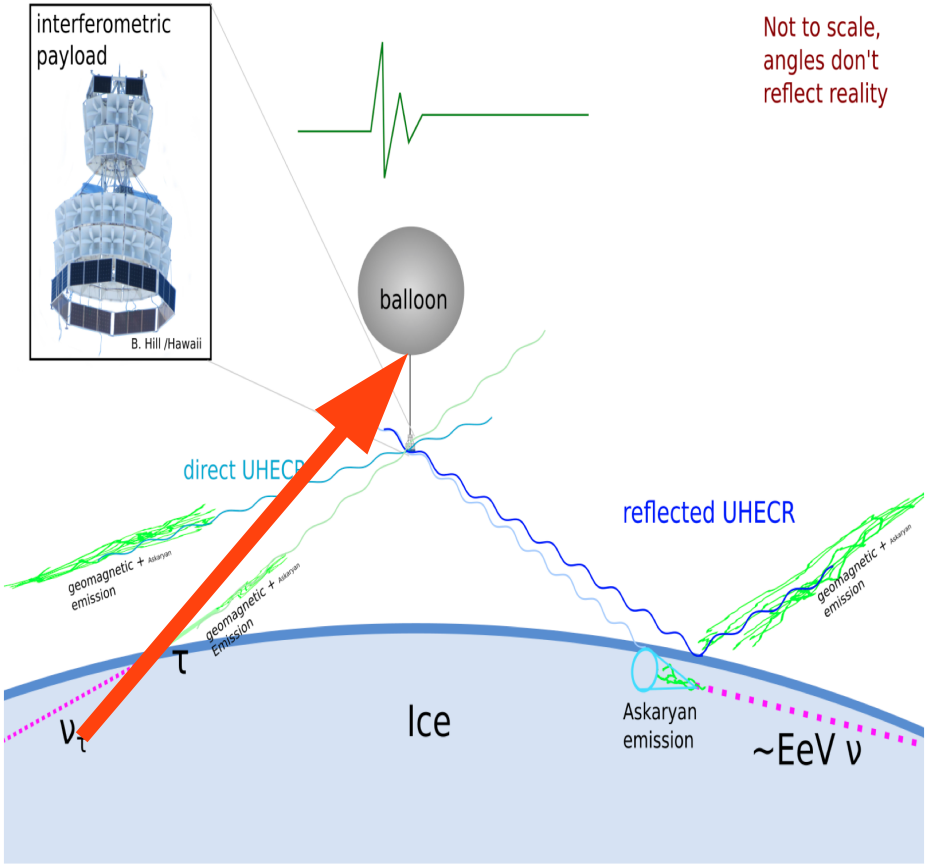
$P_{survival} \sim 10^{-6}$

$= 0.0001\%$

R ~ 6400 km

D = 2R cos(θ) > 5700 km

ℓ_{SM} ~ 300 km (in rock)



The ANITA detection concepts, figure from Cosmin Deaconu

TABLE I: *ANITA-I,-III anomalous upward air showers.*

event, flight	3985267, ANITA-I	15717147, ANITA-III
date, time	2006-12-28,00:33:20UTC	2014-12-20,08:33:22.5UTC
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

[1] Latitude, Longitude of the estimated ground position of the event.
[2] Sky coordinates projected from event arrival angles at ANITA.
[3] For upward shower initiation at or near ice surface.

Table from ANITA, 1803.05088

Properties of the anomalous upward events
1. Large Elevation Angle, going upwards.
2. No Polarity Reverse Relative to Geomagnetic Field.
3. Both have large energy~0.5EeV
4. Both interpreted as tau events by ANITA

New Phyiscs Interpretation to ANITA-anomaly

New Phyiscs Interpretation to ANITA-anomaly

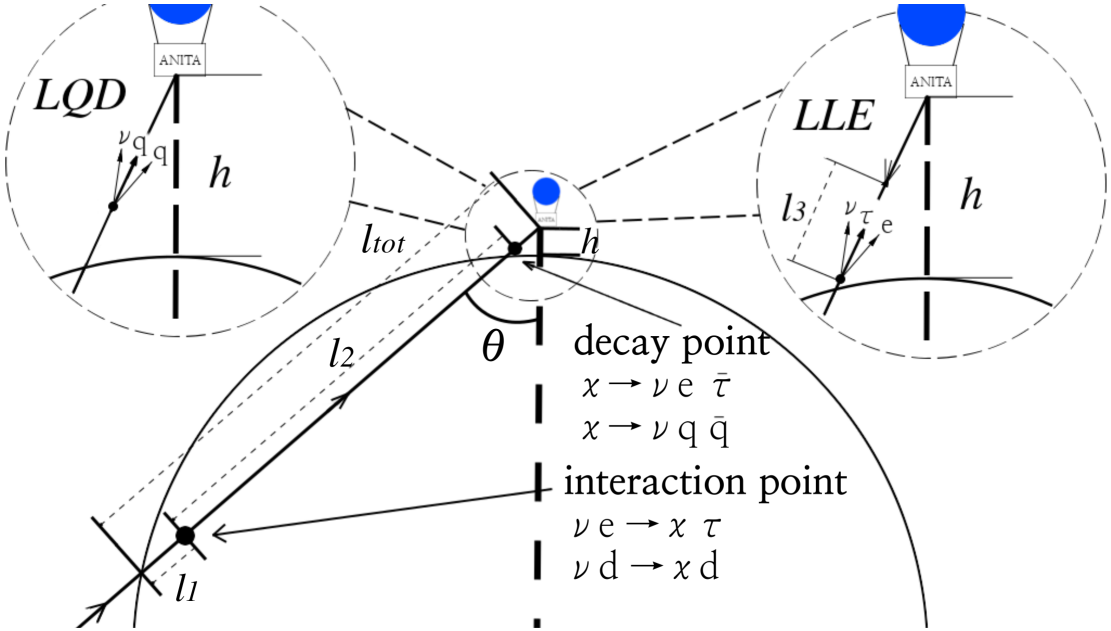
Long-lived neutral particle χ + TeV level mediator particle

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

New Phyiscs Interpretation to ANITA-anomaly

Long-lived neutral particle χ + TeV level mediator particle

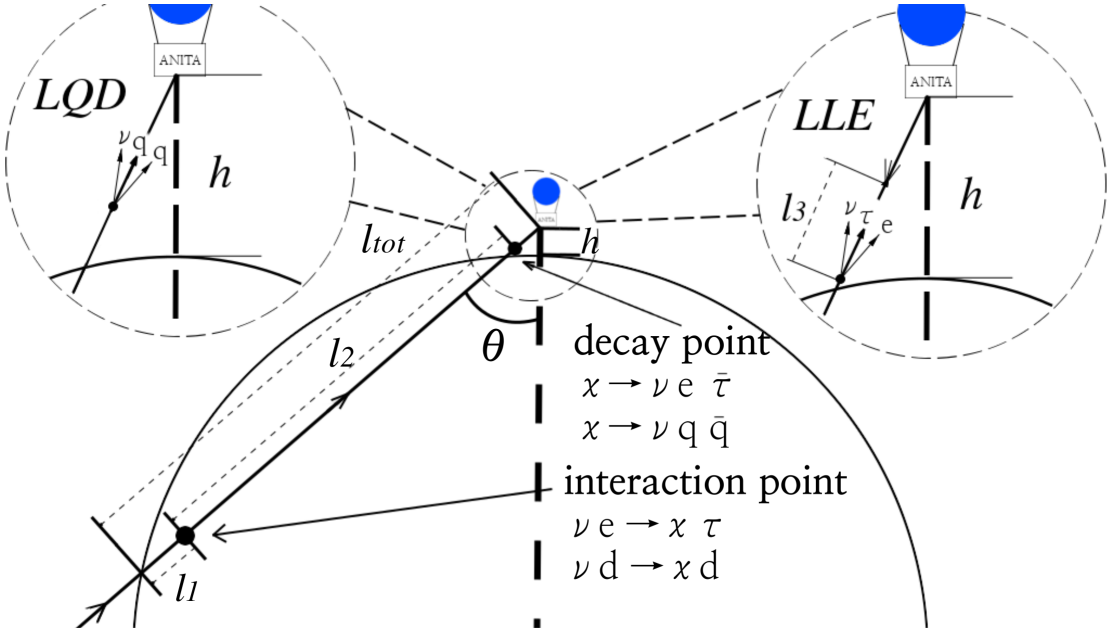
Jack Collins and Bhupal Dev, **Yicong Sui**, 1810.08479

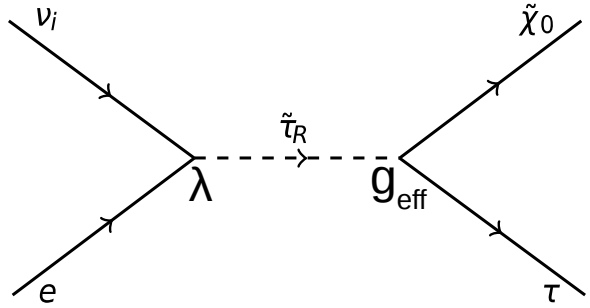


New Phyiscs Interpretation to ANITA-anomaly

Long-lived neutral particle χ + TeV level mediator particle

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



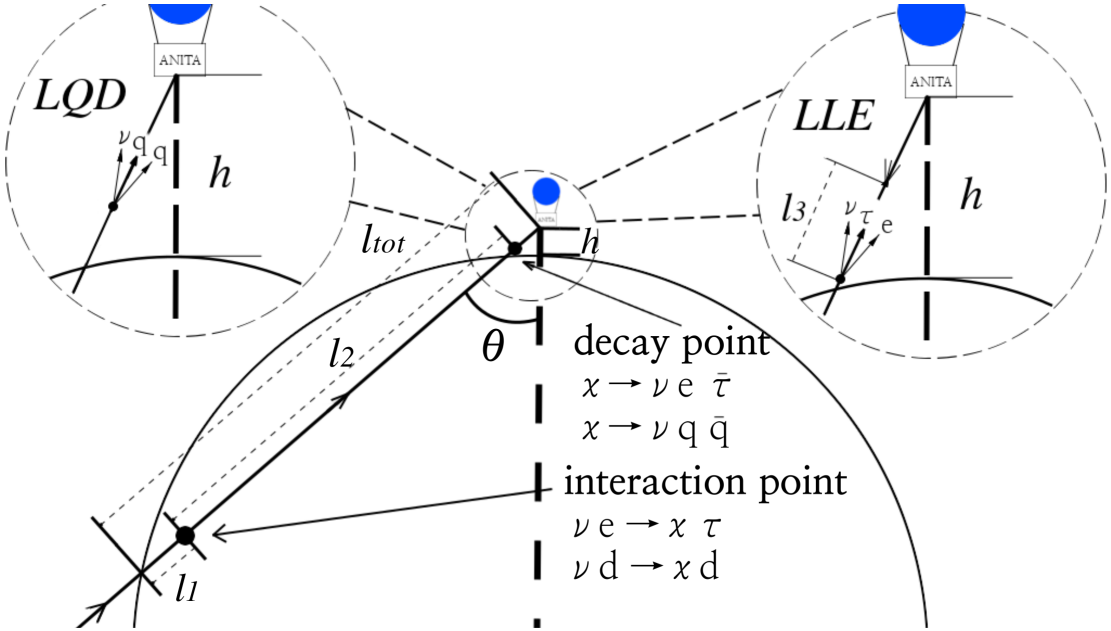


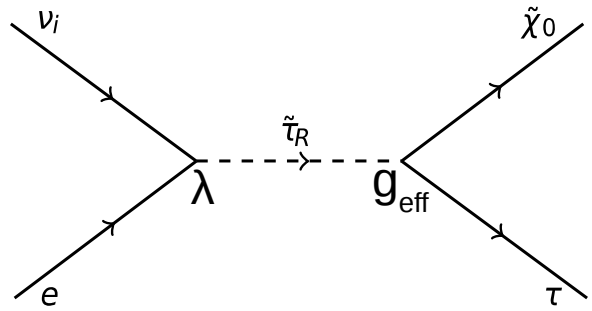
M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
P. S. Bhupal Dev, Dilip Kumar Ghosh, Werner Rodejohann.1605.09743

New Phyiscs Interpretation to ANITA-anomaly

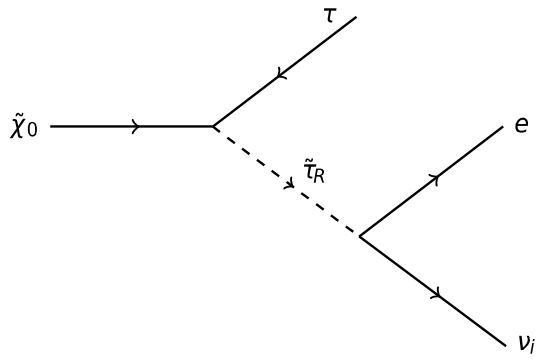
Long-lived neutral particle χ + TeV level mediator particle

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





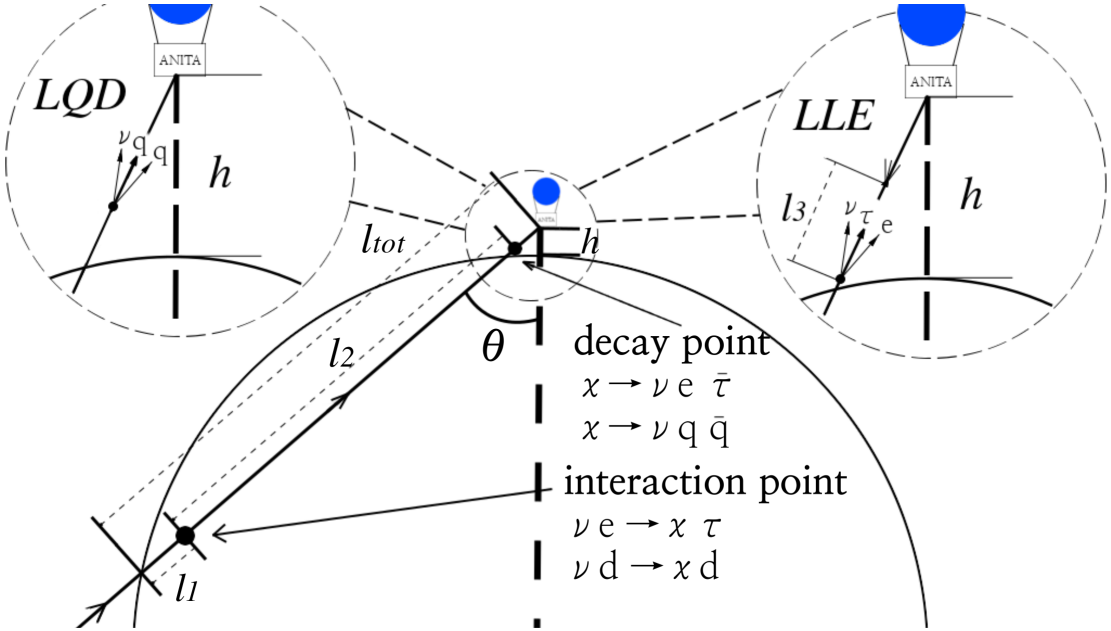
M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
P. S. Bhupal Dev, Dilip Kumar Ghosh, Werner Rodejohann.1605.09743

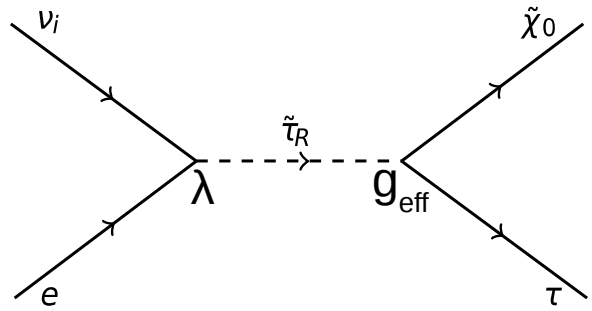


New Phyiscs Interpretation to ANITA-anomaly

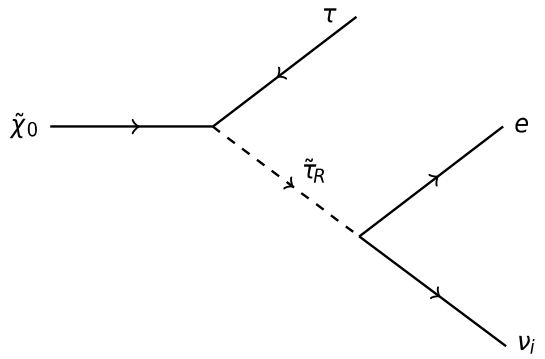
Long-lived neutral particle χ + TeV level mediator particle

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





M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
P. S. Bhupal Dev, Dilip Kumar Ghosh, Werner Rodejohann.1605.09743

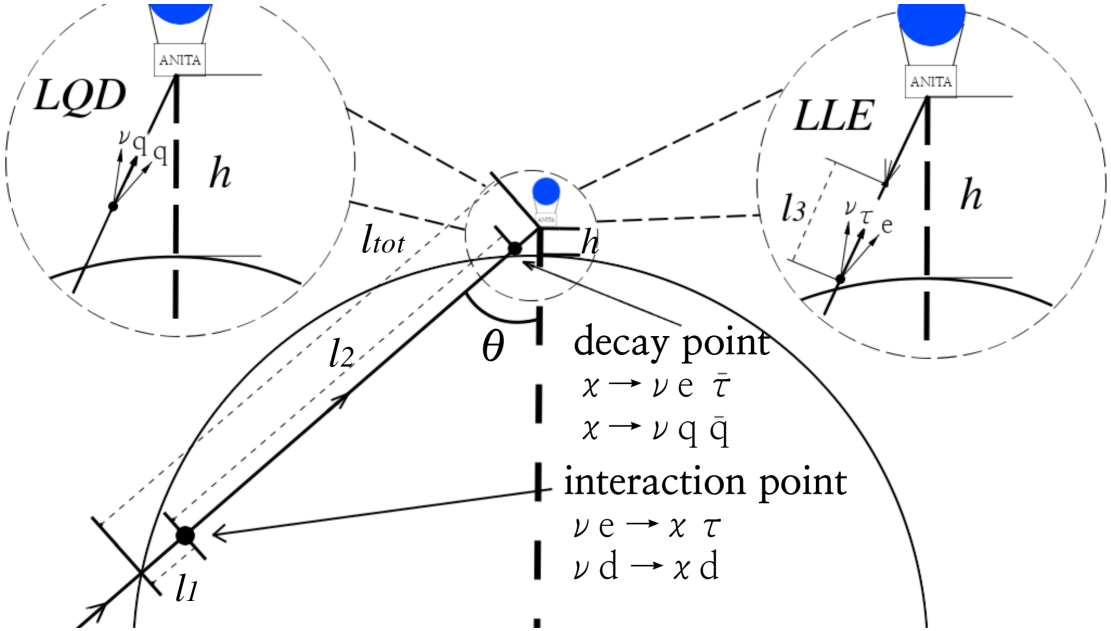


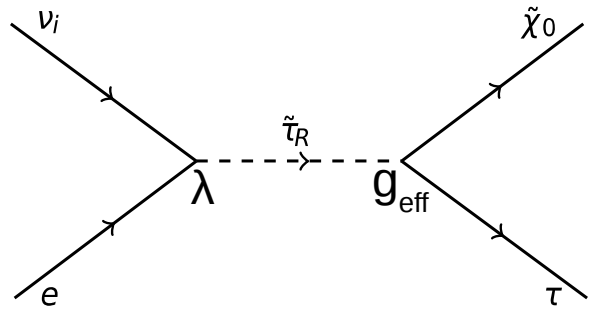
RPV-SUSY

New Phyiscs Interpretation to ANITA-anomaly

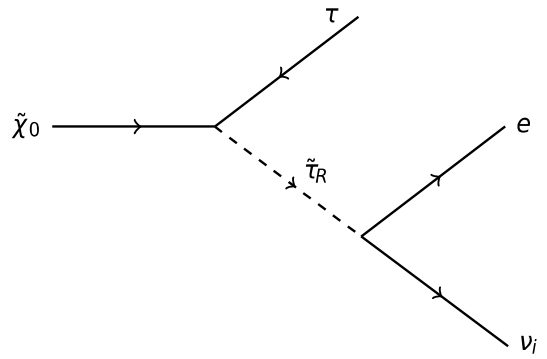
Long-lived neutral particle χ + TeV level mediator particle

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





M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
P. S. Bhupal Dev, Dilip Kumar Ghosh, Werner Rodejohann.1605.09743



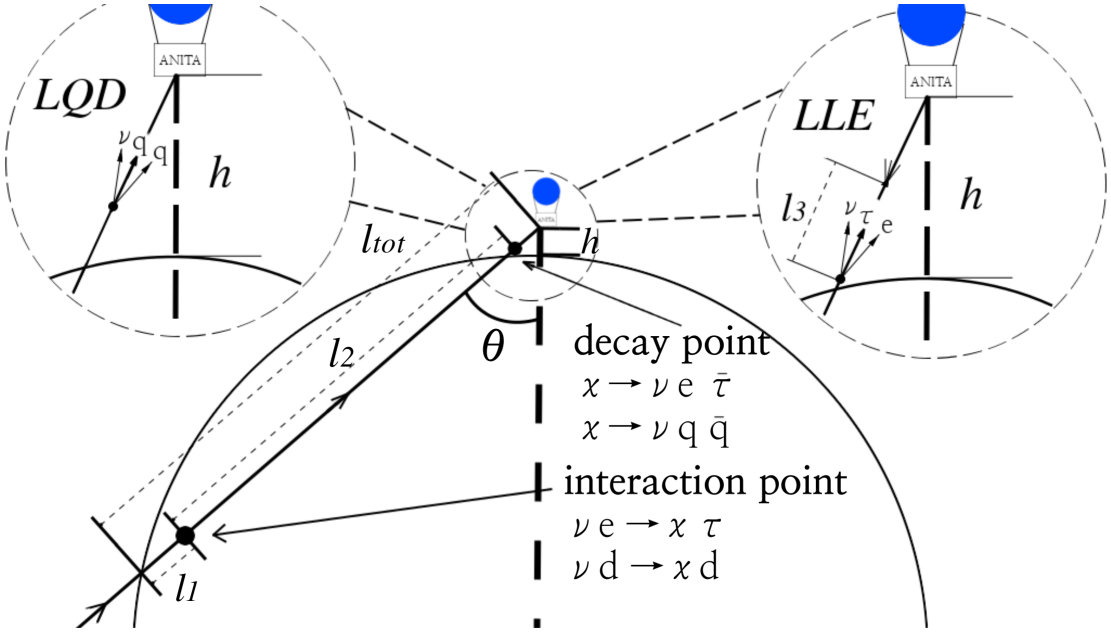
RPV-SUSY

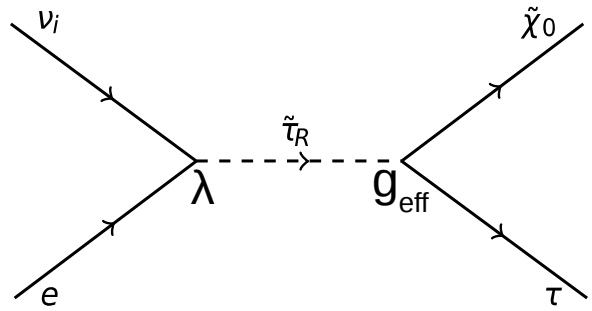
$$W_{RPV} = \lambda_{ijk} L^i L^j \bar{E}^k + \lambda'_{ijk} L^i Q^j \bar{D}^k + \lambda''_{ijk} \bar{U}^i \bar{D}^j \bar{D}^k$$

New Phyiscs Interpretation to ANITA-anomaly

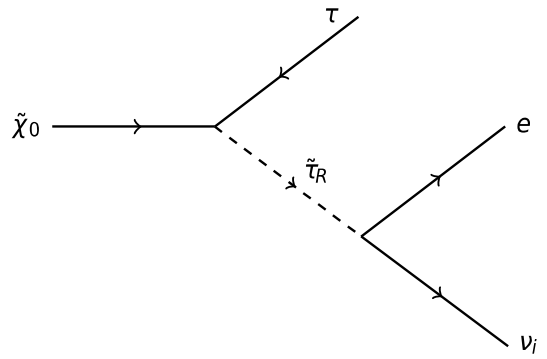
Long-lived neutral particle χ + TeV level mediator particle

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





M. Carena, D. Choudhury, S. Lola, C. Quigg, Hep-ph/9804380;
P. S. Bhupal Dev, Dilip Kumar Ghosh, Werner Rodejohann.1605.09743

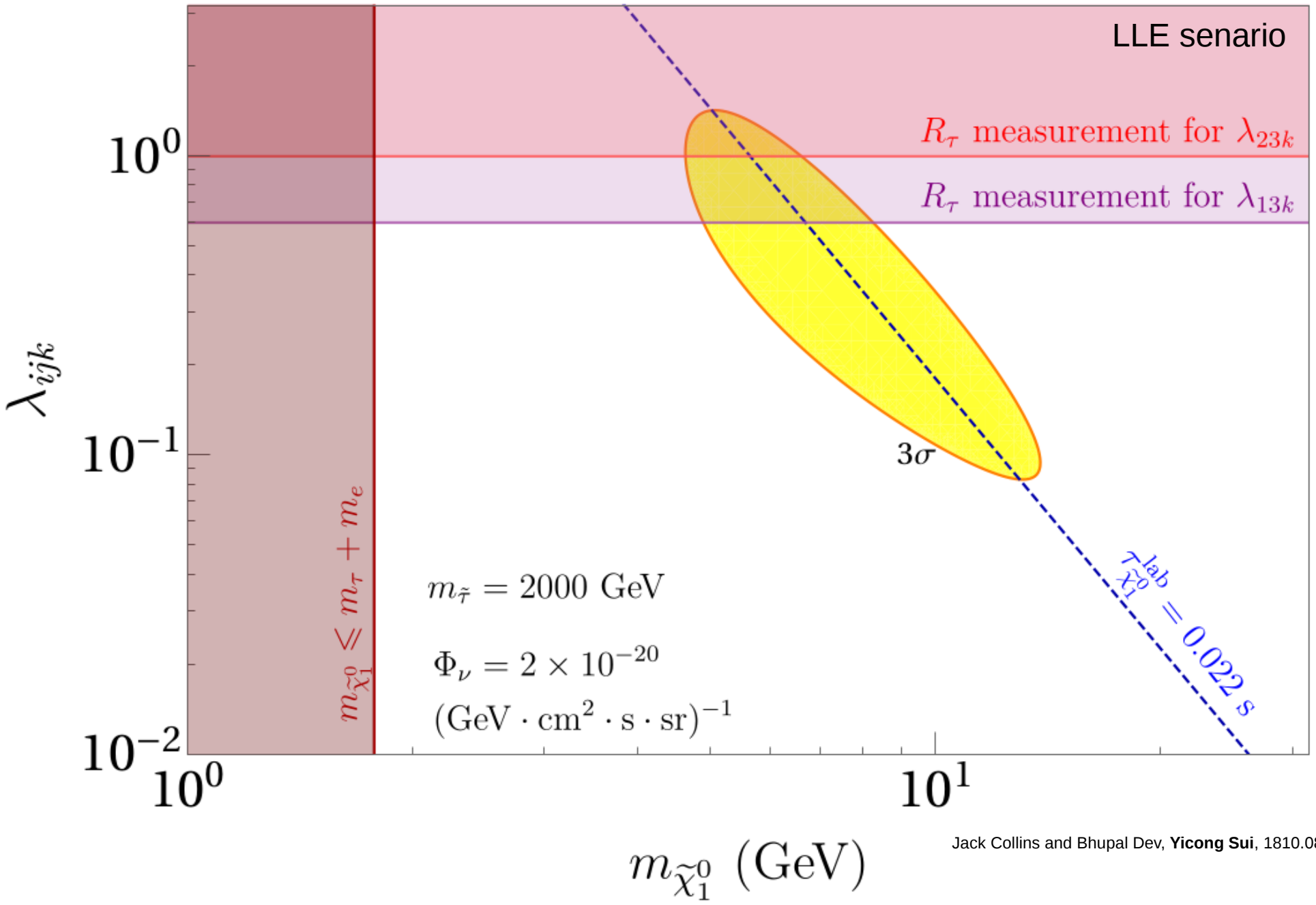


RPV-SUSY

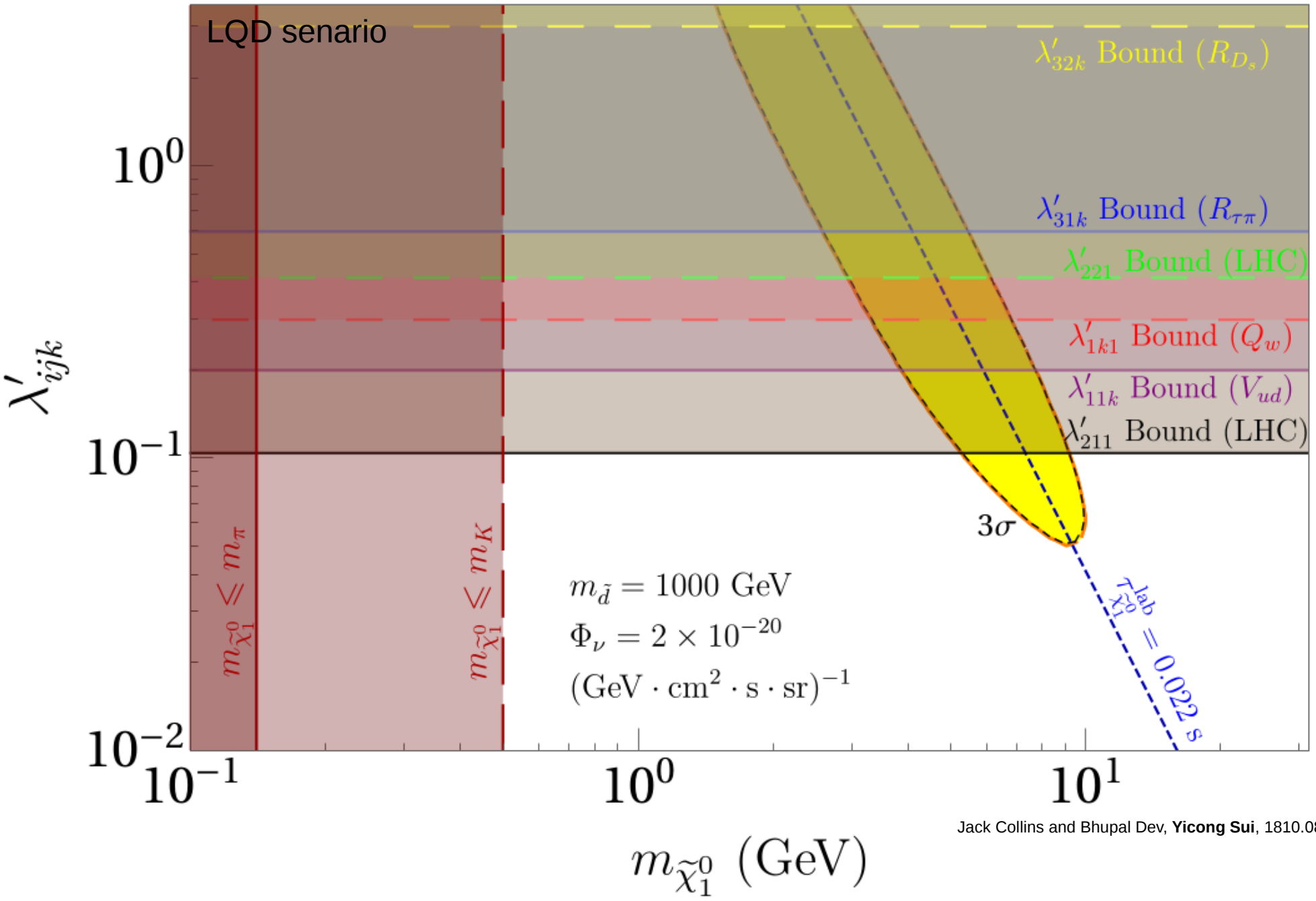
$$W_{RPV} = \lambda_{ijk} L^i L^j \bar{E}^k + \lambda'_{ijk} L^i Q^j \bar{D}^k + \lambda''_{ijk} \bar{U}^i \bar{D}^j \bar{D}^k$$

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

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



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



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

RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

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

RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

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

RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

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

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

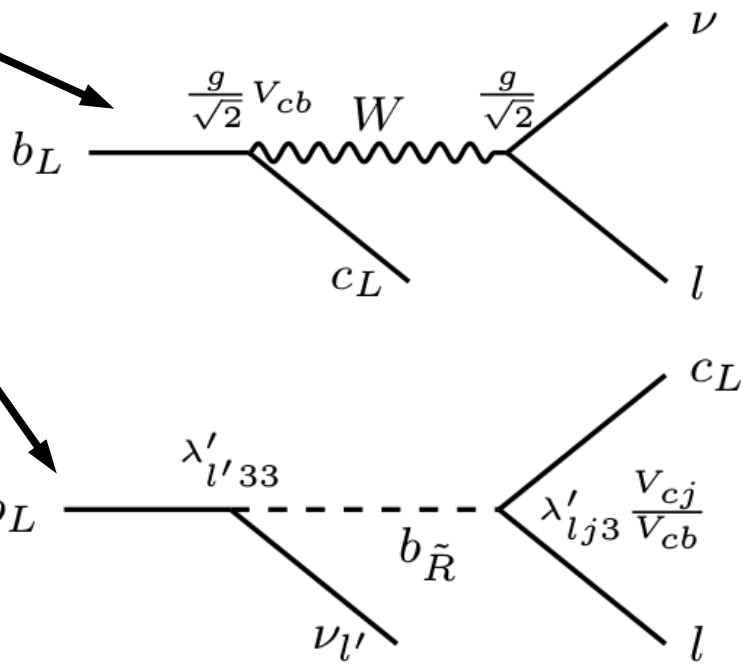
N.G. Deshpande, Xiao-Gang He, 1608.04817
W. Altmannshofer, P. S. Bhupal Dev and A. Soni, 1704.06659
Sokratis Trifinopoulos, 1807.01638

RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

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

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

N.G. Deshpande, Xiao-Gang He, 1608.04817
W. Altmannshofer, P. S. Bhupal Dev and A. Soni, 1704.06659
Sokratis Trifinopoulos, 1807.01638



RPV-SUSY Interpretation to B-anomaly: R_D R_{D^*}

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

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

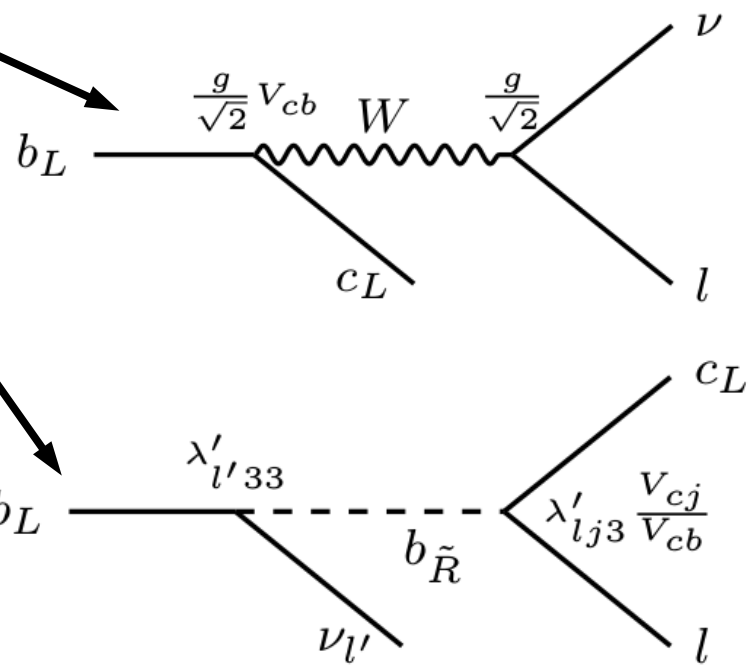
N.G. Deshpande, Xiao-Gang He, 1608.04817
W. Altmannshofer, P. S. Bhupal Dev and A. Soni, 1704.06659
Sokratis Trifinopoulos, 1807.01638

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

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

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

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



RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

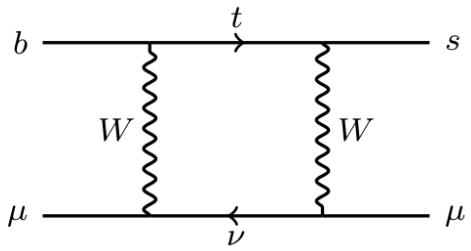
$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$



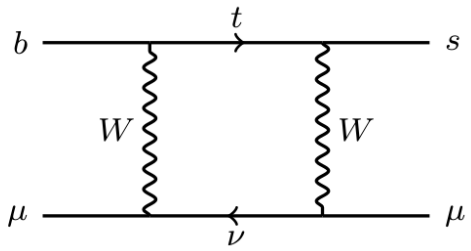
RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

$$\mathcal{H}_{\text{eff}} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

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



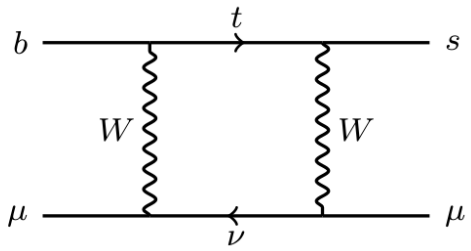
RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

$$\mathcal{H}_{\text{eff}} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

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



RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

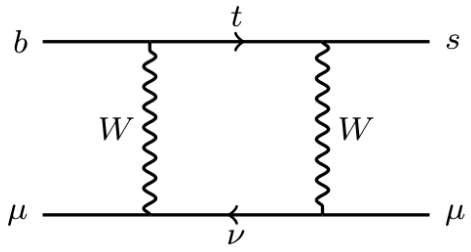
Diganta Das, Chandan Hati, Girish Kumar, and Namit Mahajan, 1705.09188
Kevin Earla, Thomas Gr´egoirea, 1806.01343

$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

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

$$(\delta C_9)^\mu = -(\delta C_{10})^\mu = \frac{m_t^2}{m_{\tilde{b}_R}^2}\frac{|\lambda'_{233}|^2}{16\pi\alpha_{\rm em}} - \frac{v^2}{16m_{\tilde{b}_R}^2}\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$
$$- \frac{v^2}{16(m_{\tilde{t}_L}^2 - m_{\tilde{\nu}_\tau}^2)}\log\left(\frac{m_{\tilde{t}_L}^2}{m_{\tilde{\nu}_\tau}^2}\right)\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$



$$X_{bs} = \sum_{i=1}^{3}\lambda'_{i33}\lambda'_{i23}\ ,\ X_{\mu\mu} = \sum_{j=1}^{3}|\lambda'_{2j3}|^2$$

RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

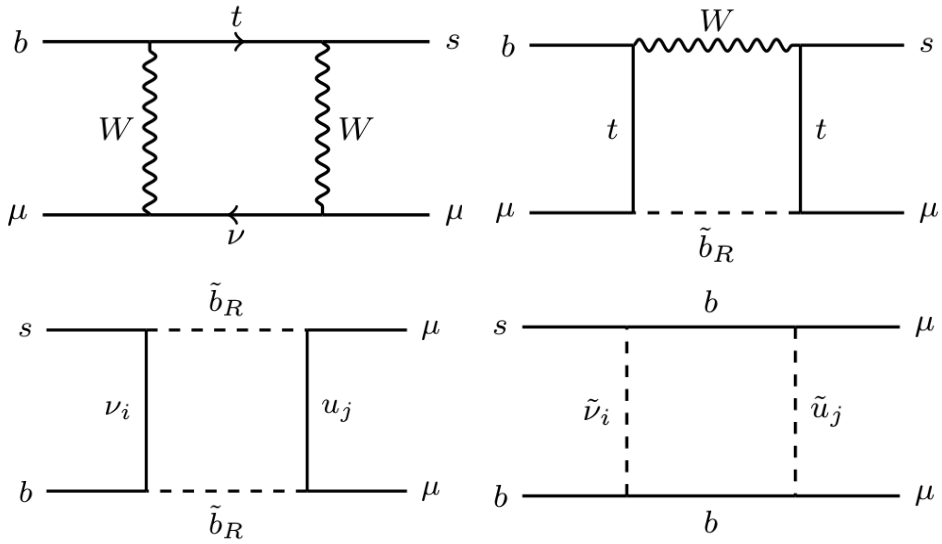
$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^*\sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

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

$$(\delta C_9)^\mu = -(\delta C_{10})^\mu = \frac{m_t^2}{m_{\tilde{b}_R}^2}\frac{|\lambda'_{233}|^2}{16\pi\alpha_{\rm em}} - \frac{v^2}{16m_{\tilde{b}_R}^2}\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$
$$- \frac{v^2}{16(m_{\tilde{t}_L}^2 - m_{\tilde{\nu}_\tau}^2)}\log\left(\frac{m_{\tilde{t}_L}^2}{m_{\tilde{\nu}_\tau}^2}\right)\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$

$$X_{bs} = \sum_{i=1}^{3}\lambda'_{i33}\lambda'_{i23}\ ,\ X_{\mu\mu} = \sum_{j=1}^{3}|\lambda'_{2j3}|^2$$



RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

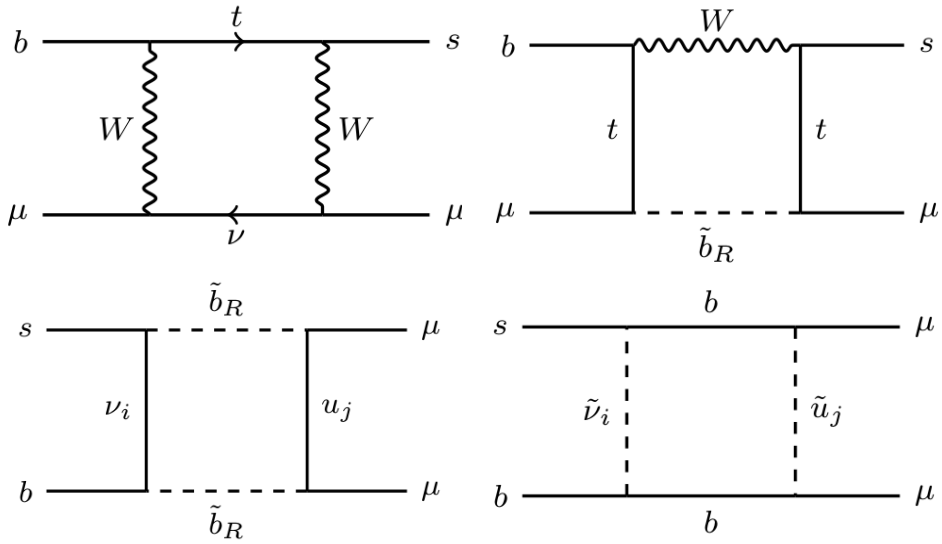
$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

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

$$(\delta C_9)^\mu = -(\delta C_{10})^\mu = \frac{m_t^2}{m_{\tilde{b}_R}^2}\frac{|\lambda'_{233}|^2}{16\pi\alpha_{\rm em}} - \frac{v^2}{16m_{\tilde{b}_R}^2}\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$
$$- \frac{v^2}{16(m_{\tilde{t}_L}^2 - m_{\tilde{\nu}_\tau}^2)}\log\left(\frac{m_{\tilde{t}_L}^2}{m_{\tilde{\nu}_\tau}^2}\right)\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$

$$X_{bs} = \sum_{i=1}^{3}\lambda'_{i33}\lambda'_{i23}\ ,\ X_{\mu\mu} = \sum_{j=1}^{3}|\lambda'_{2j3}|^2$$



RPV-SUSY Interpretation to B-anomaly: R_K R_{K^*}

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

$$\mathcal{H}_{\rm eff} = \frac{4G_F}{\sqrt{2}}\frac{\alpha}{4\pi}V_{tb}V_{ts}^* \sum_{i=9,10}(C_i\mathcal{O}_i + C_i'\mathcal{O}_i')$$

$$\mathcal{O}_{9(10)} = (\bar{s}_L\gamma^\mu b_L)(\bar{\ell}\gamma_\mu(\gamma_5)\ell),$$
$$\mathcal{O}'_{9(10)} = (\bar{s}_R\gamma^\mu b_R)(\bar{\ell}\gamma_\mu(\gamma_5)\ell)$$

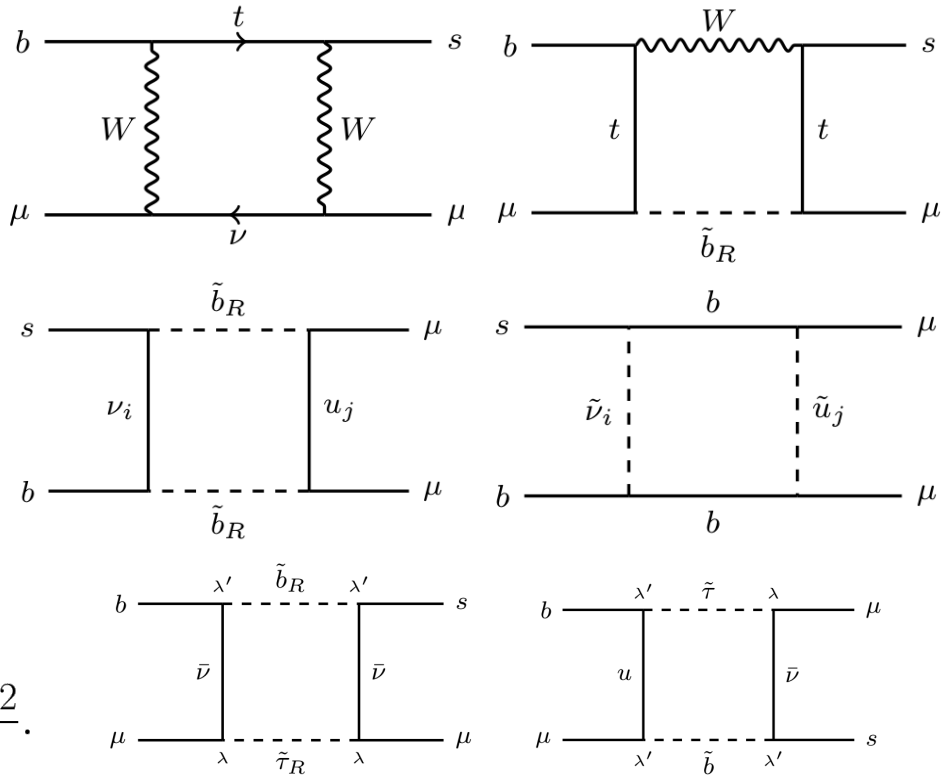
$$W_{RPV} = \lambda_{ijk}L^iL^j\bar{E}^k + \lambda'_{ijk}L^iQ^j\bar{D}^k + \lambda''_{ijk}\bar{U}^i\bar{D}^j\bar{D}^k$$

$$(\delta C_9)^\mu = -(\delta C_{10})^\mu = \frac{m_t^2}{m_{\tilde{b}_R}^2}\frac{|\lambda'_{233}|^2}{16\pi\alpha_{\rm em}} - \frac{v^2}{16m_{\tilde{b}_R}^2}\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$
$$- \frac{v^2}{16(m_{\tilde{t}_L}^2 - m_{\tilde{\nu}_\tau}^2)}\log\left(\frac{m_{\tilde{t}_L}^2}{m_{\tilde{\nu}_\tau}^2}\right)\frac{X_{bs}X_{\mu\mu}}{e^2V_{tb}V_{ts}^*}$$

$$X_{bs} = \sum_{i=1}^{3}\lambda'_{i33}\lambda'_{i23}\ ,\ X_{\mu\mu} = \sum_{j=1}^{3}|\lambda'_{2j3}|^2$$

Fourth Term

$$= -\frac{v^2\ \log\left(\frac{m_{\tilde{b}_R}^2}{m_{\tilde{\tau}_R}^2}\right)}{8(m_{\tilde{b}_R}^2 - m_{\tilde{\tau}_R}^2)}\frac{\lambda'_{323}\lambda'_{333}\lambda^2_{323} + \lambda'_{333}\lambda'_{223}\lambda'_{233}\lambda_{232}}{e^2V_{tb}V_{ts}^*}.$$



Sokratis Trifinopoulos, 1807.01638

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

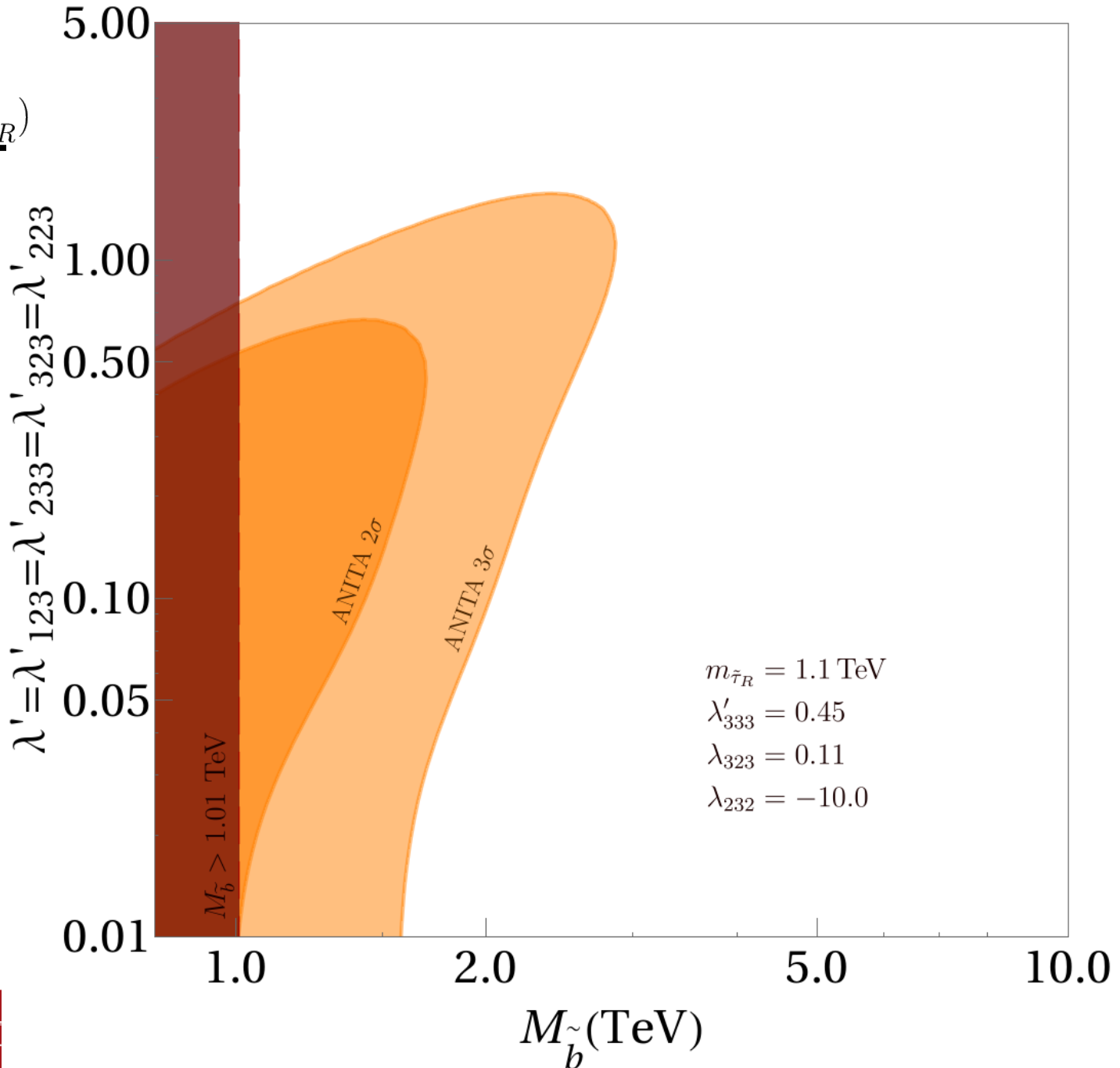
$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters



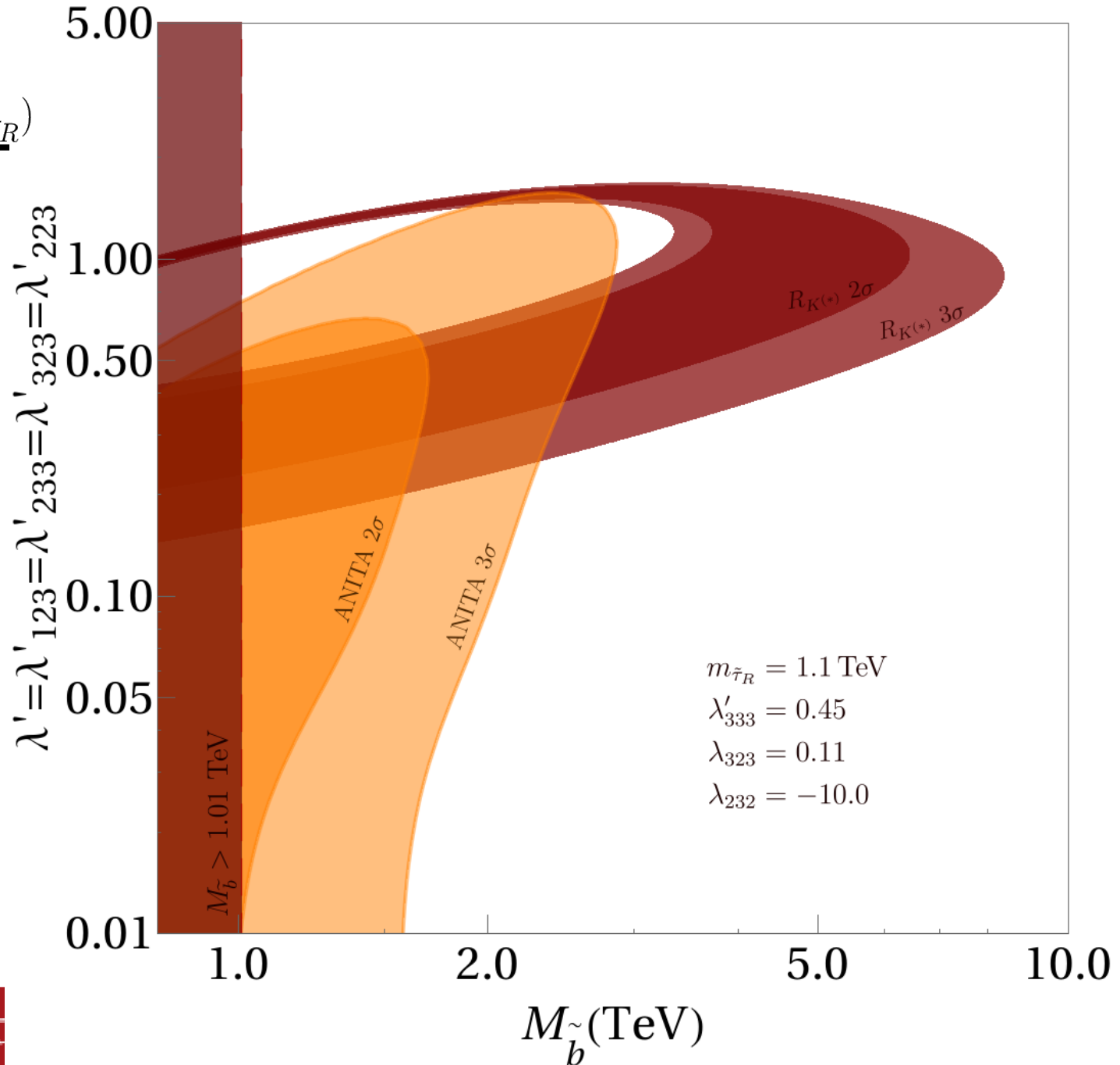
$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters



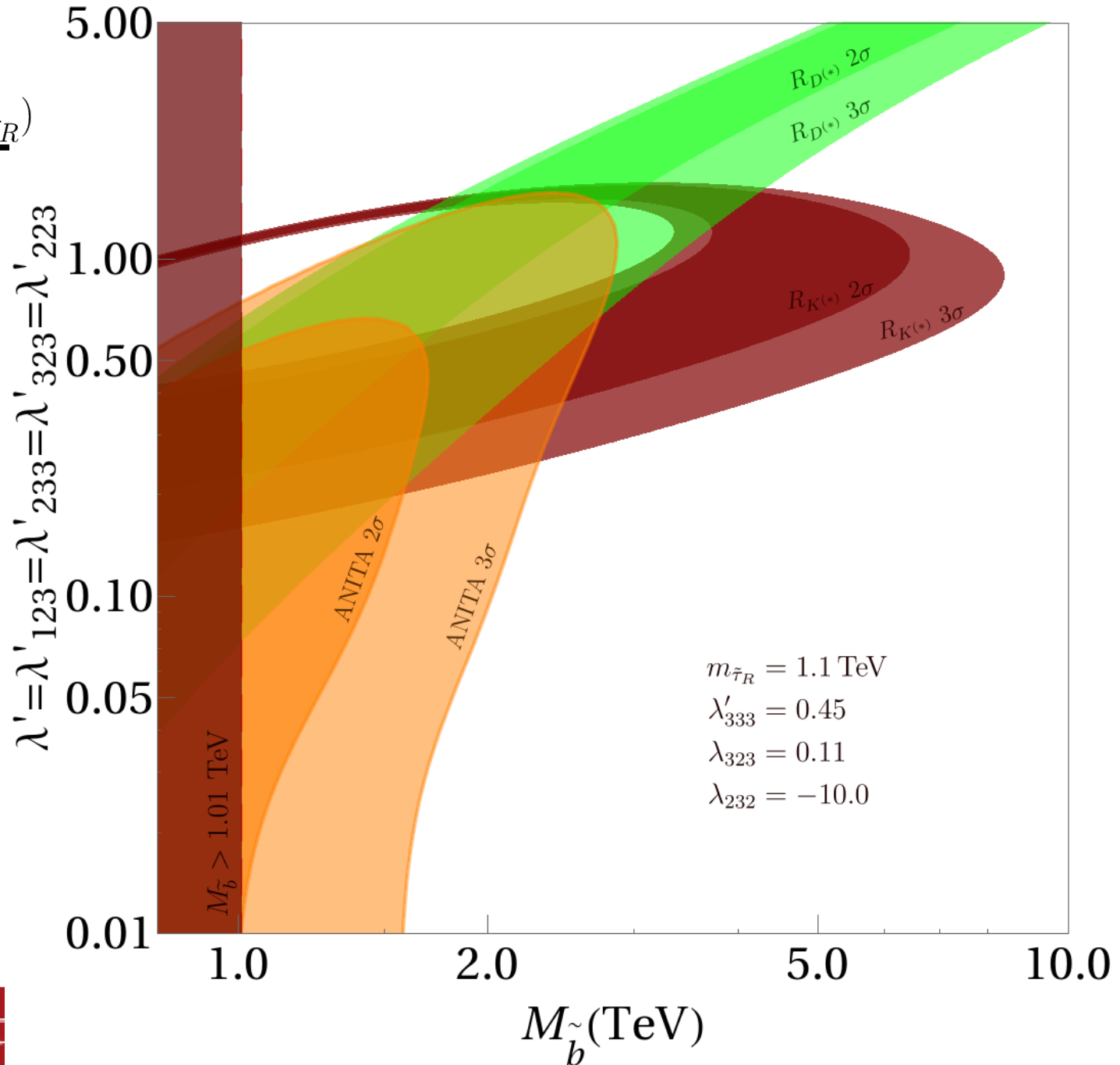
$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

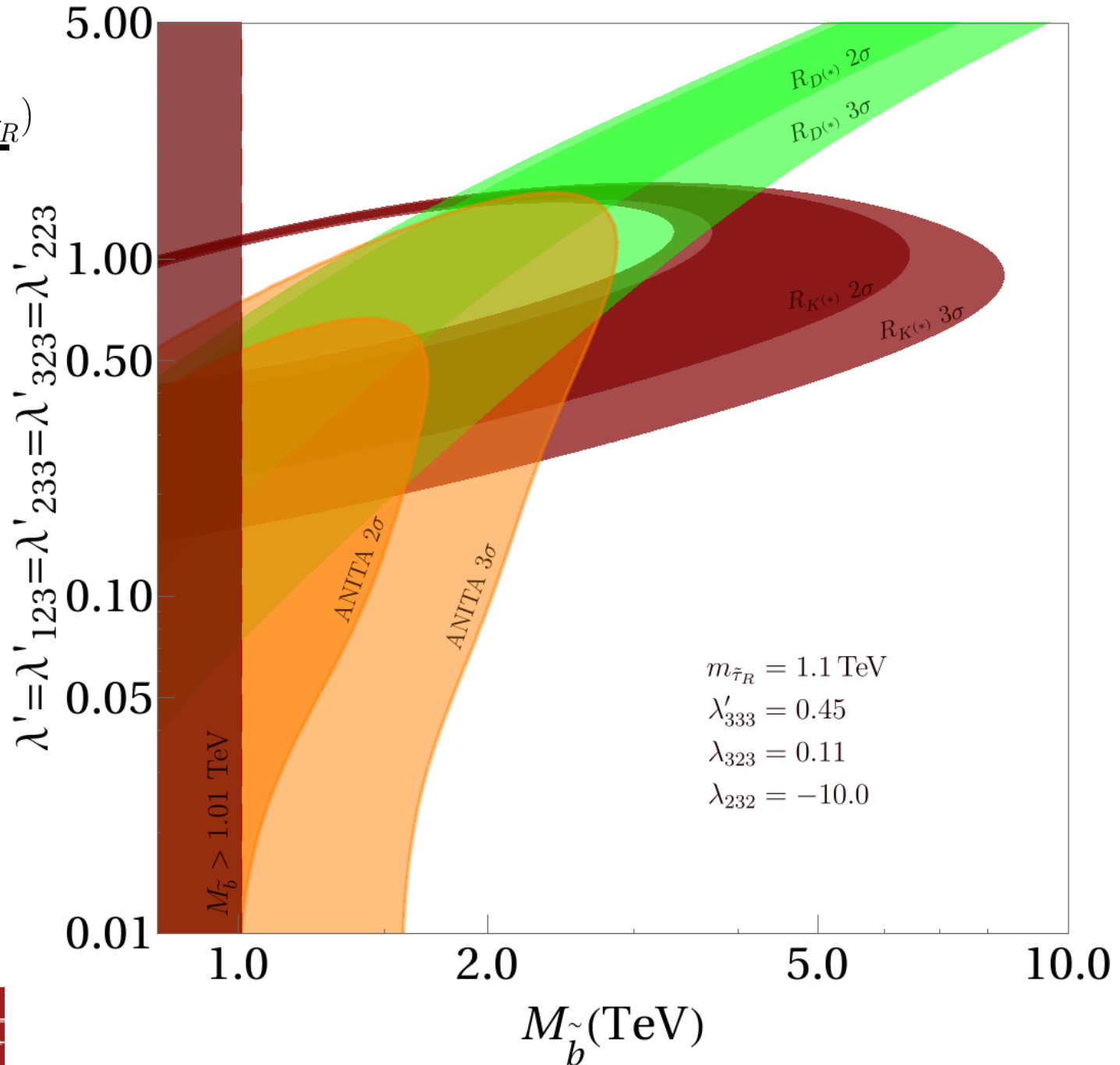
$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

Possible Constraints



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

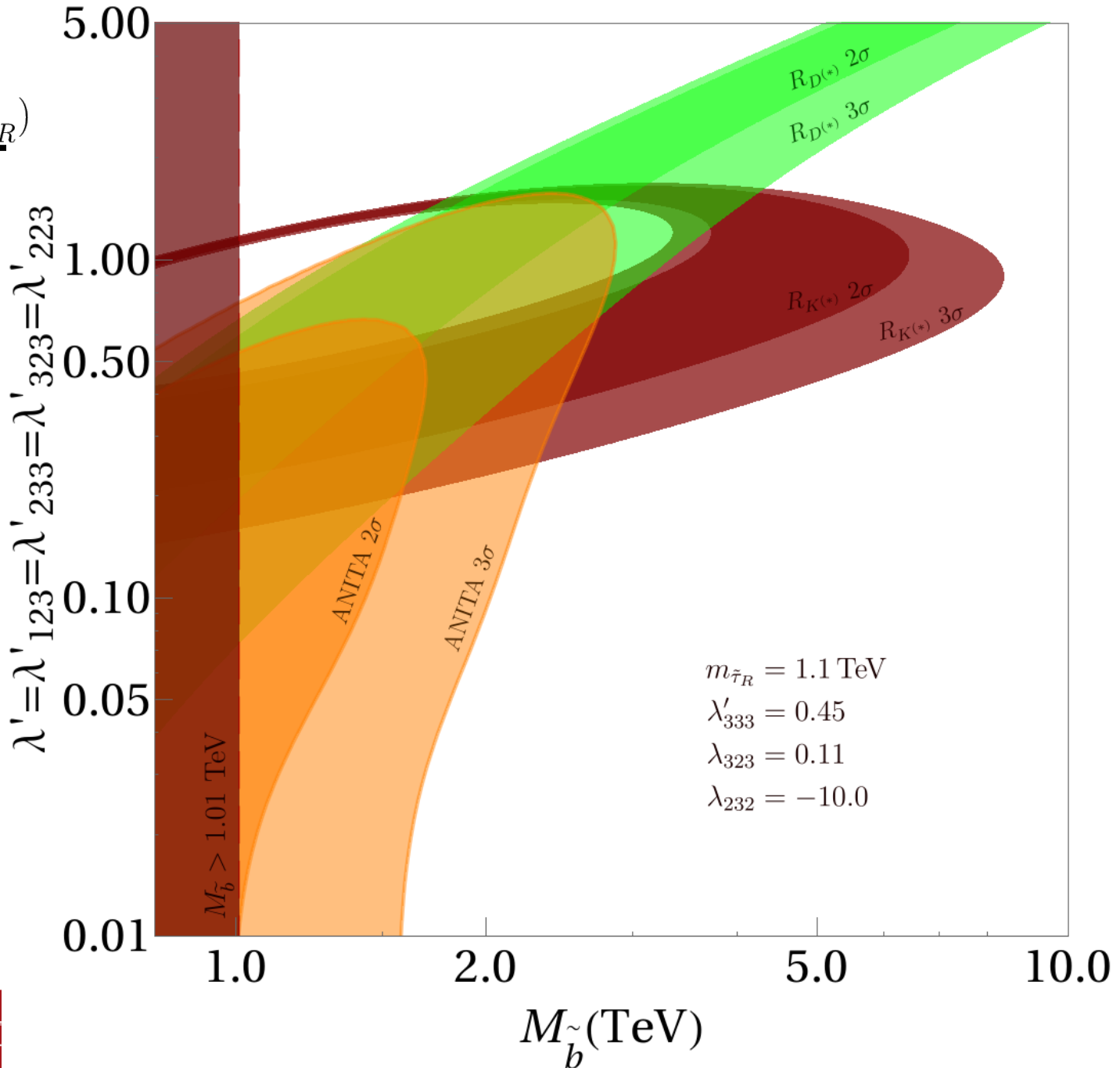
independents

parameters

Possible Constraints

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

Sokratis Trifinopoulos, 1807.01638



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

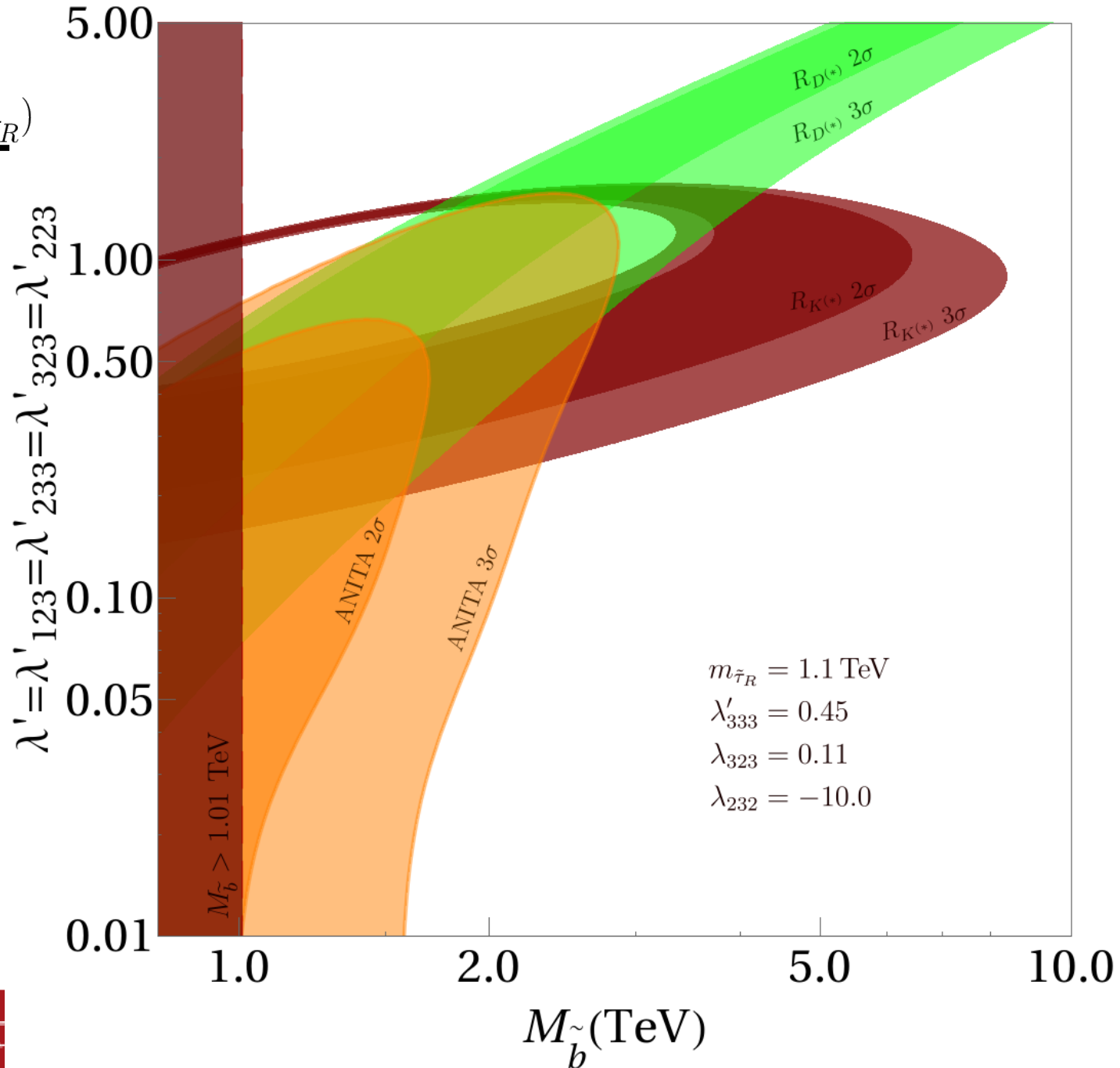
Possible Constraints

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

Sokratis Trifinopoulos, 1807.01638

$$R_{B\to\tau\nu} < 1.12$$

Heavy Flavor Averaging Group, etl, 1612.07233



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

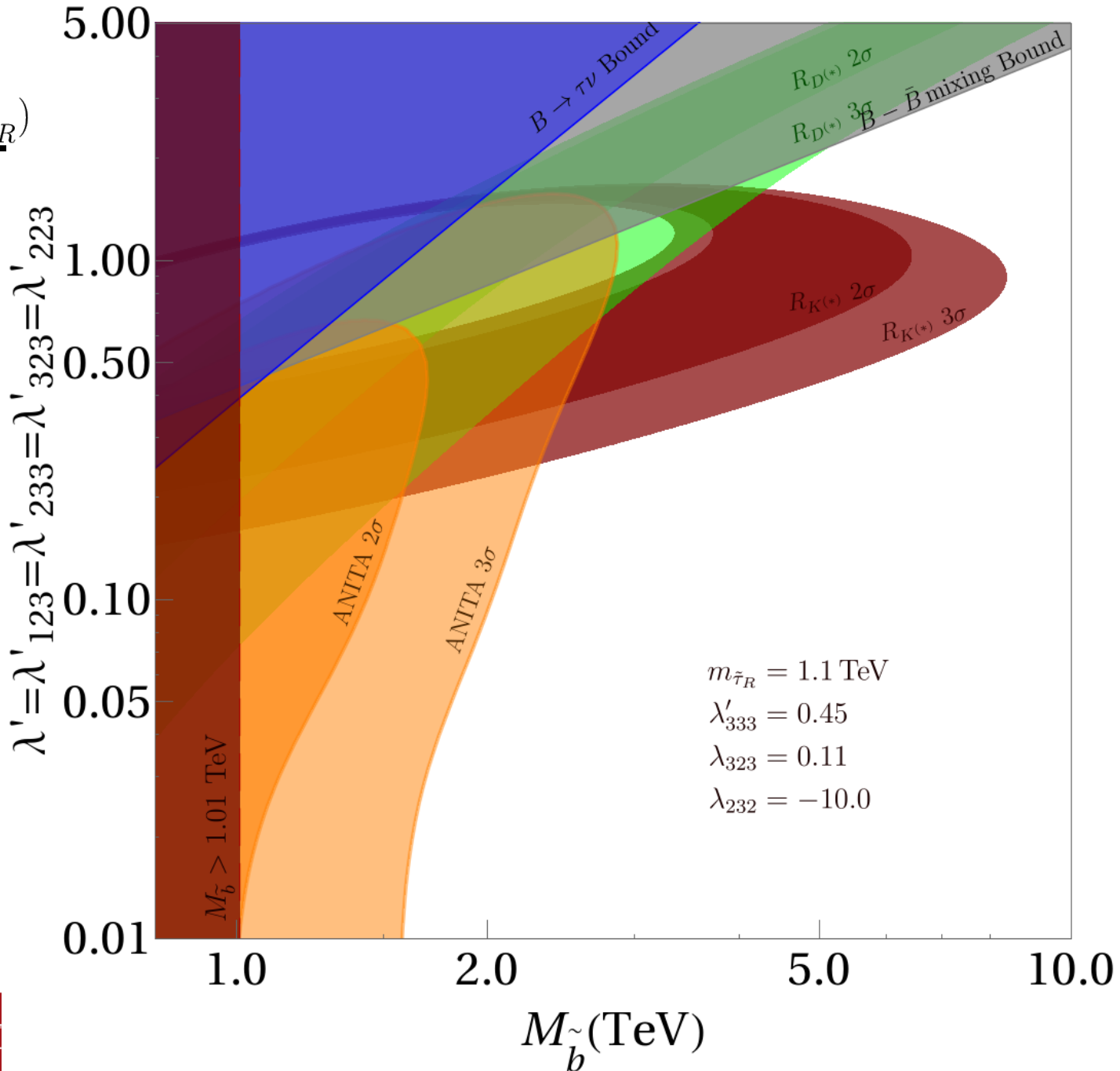
Possible Constraints

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

Sokratis Trifinopoulos, 1807.01638

$$R_{B\to\tau\nu} < 1.12$$

Heavy Flavor Averaging Group, etl, 1612.07233



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

Possible Constraints

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

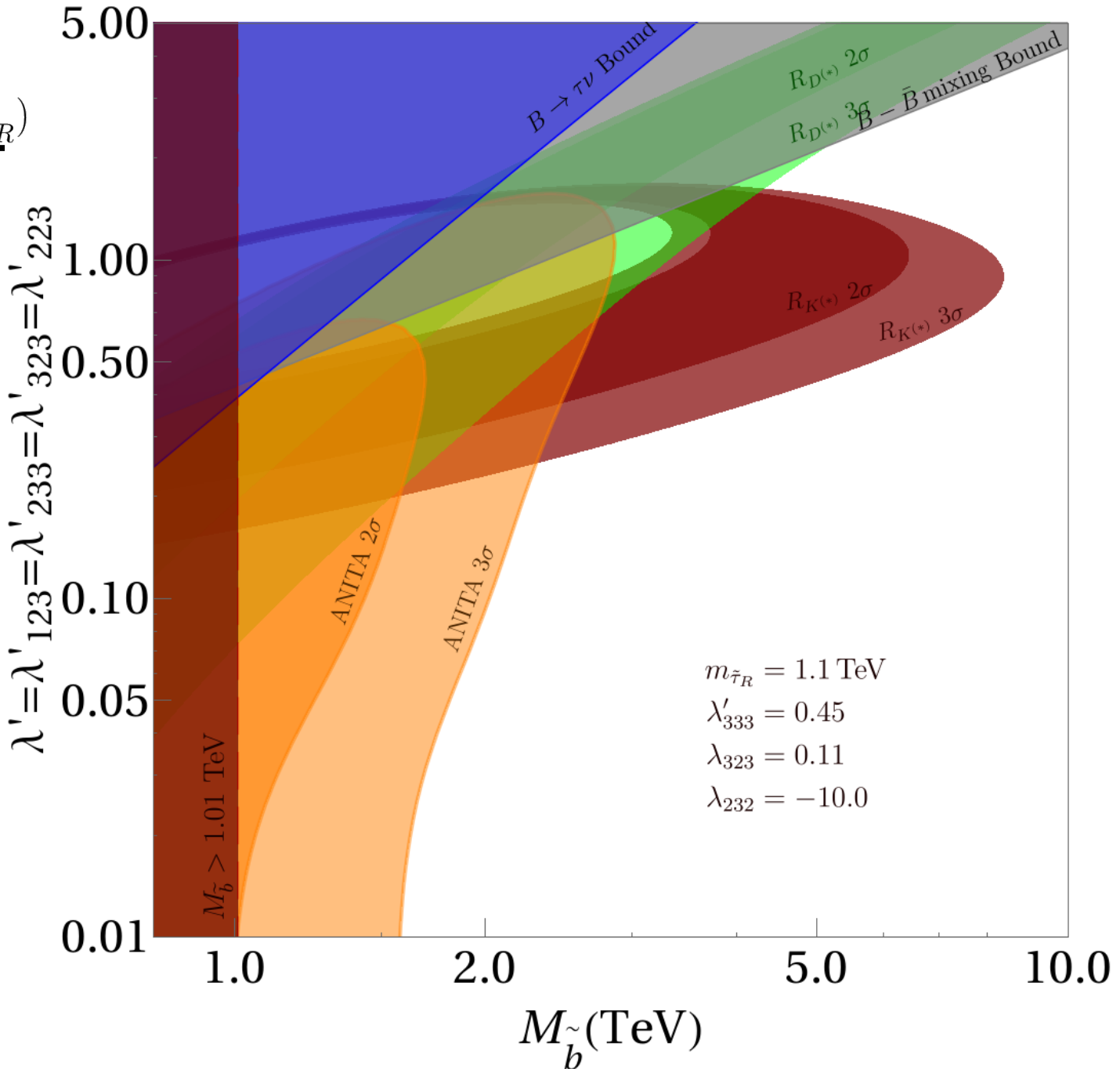
Sokratis Trifinopoulos, 1807.01638

$$R_{B\to\tau\nu} < 1.12$$

Heavy Flavor Averaging Group, etl, 1612.07233

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

Dario Buttazzo, etl, 1706.07808



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

Possible Constraints

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

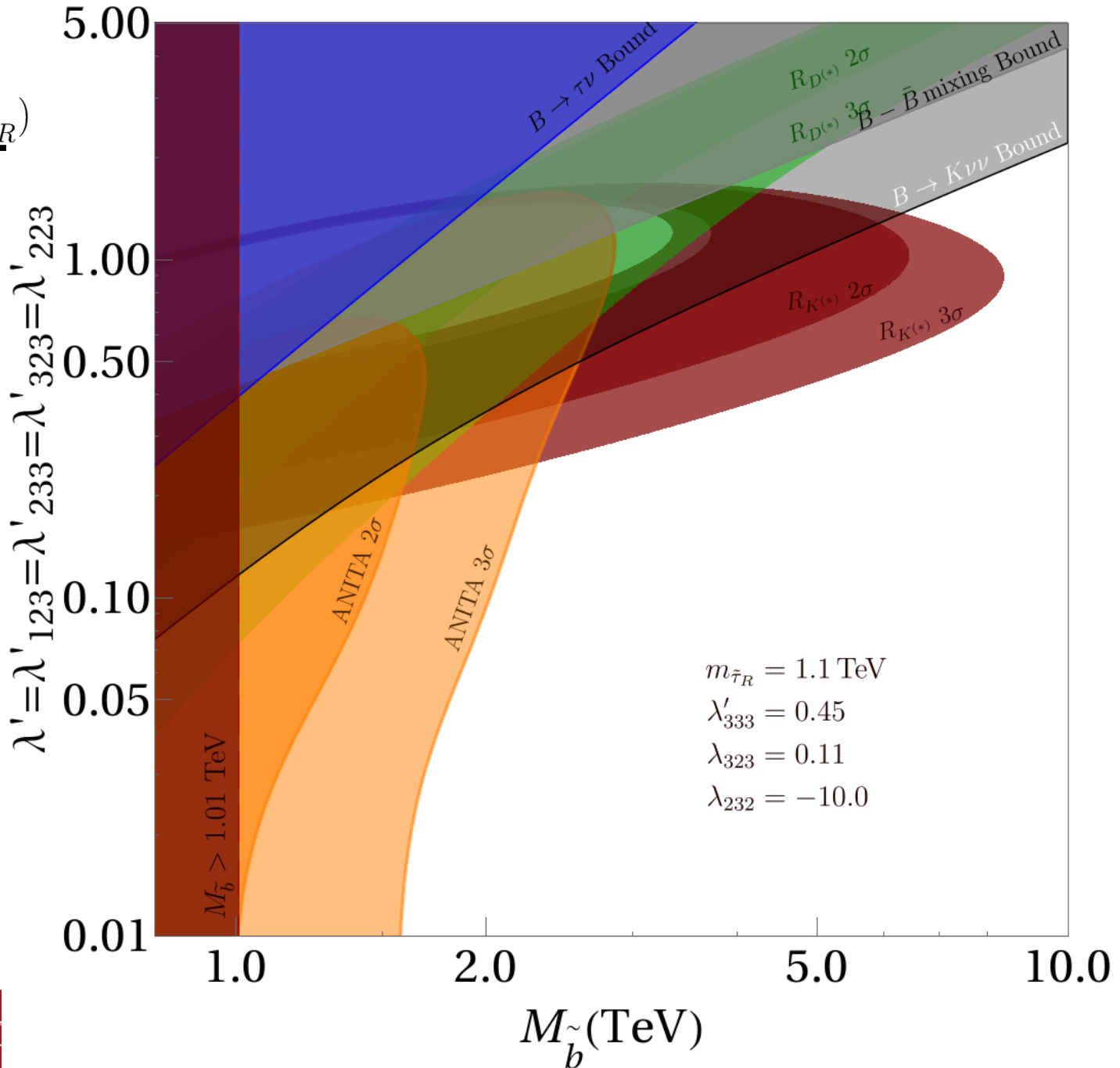
Sokratis Trifinopoulos, 1807.01638

$$R_{B\to\tau\nu} < 1.12$$

Heavy Flavor Averaging Group, etl, 1612.07233

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

Dario Buttazzo, etl, 1706.07808



$$\lambda'_{123} = \lambda'_{233} = \lambda'_{223} = \lambda'_{323} \equiv \lambda' \neq 0$$

$$\lambda'_{333} \neq 0 \;\; \lambda_{323} \neq 0 \;\; \lambda_{232} \neq 0$$

$$(\lambda', m_{\tilde{b}_R}, \lambda'_{333}, \lambda_{323}, \lambda_{232}, m_{\tilde{\tau}_R})$$

independents

parameters

Possible Constraints

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

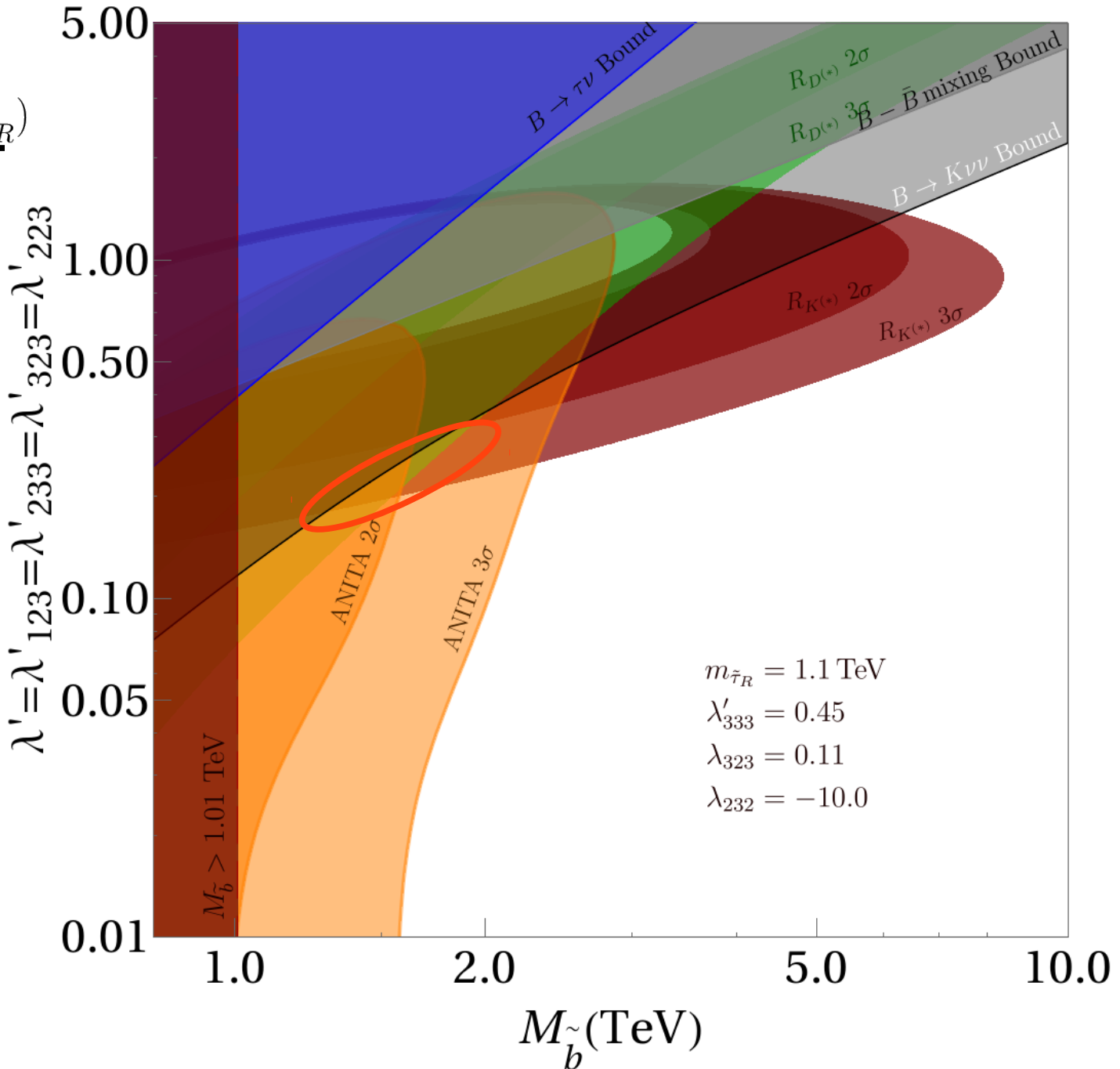
Sokratis Trifinopoulos, 1807.01638

$$R_{B\to\tau\nu} < 1.12$$

Heavy Flavor Averaging Group, etl, 1612.07233

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

Dario Buttazzo, etl, 1706.07808



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

Anita, Anomaly

B, Anomaly

Hey, B. Are we related?


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

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

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

1706.07808 eq 50

BK slides-Constraints

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

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

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

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

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

1706.07808 eq 50

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

$$R_{B\to\tau\nu} < 1.12$$

1807.01638

BK slides-Constraints

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

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

1706.07808 eq 50

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

$$R_{B\to\tau\nu} < 1.12$$

1807.01638

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

$$\Delta M_B = \frac{2m_B F_B^2}{3}\left|P_1^{VLL}\frac{\lambda'_{i23}\lambda'_{i33}\lambda'_{j33}\lambda'_{j23}}{128\pi^2 m^2_{\tilde{b}_R}}\right|$$

BK slides-Constraints

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

$$R_{B\to K^{(*)}\nu\bar{\nu}} < 5.2$$

1706.07808 eq 50

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

$$R_{B\to\tau\nu} < 1.12$$

1807.01638

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

$$\Delta M_B = \frac{2m_B F_B^2}{3}\left|P_1^{VLL}\frac{\lambda'_{i23}\lambda'_{i33}\lambda'_{j33}\lambda'_{j23}}{128\pi^2 m^2_{\tilde{b}_R}}\right|$$

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

1807.01638