Third-Family Quark–Lepton Unification and Electroweak Precision Tests

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[2302.11584]

Rencontres de Physique de la Vallée d'Aoste - La Thuile - March 2023

4321 model

[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368, 1805.09328; Greljo, Stefanek, 1802.04274; Cornella, Fuentes-Martin, Isidori 1903.11517]

See Joe Davighi's talk

Third-family quark-lepton unification:

$$\Psi_{L/R} = \begin{pmatrix} Q^1_{L,R} \\ Q^2_{L,R} \\ Q^3_{L,R} \\ L_{L,R} \end{pmatrix}$$

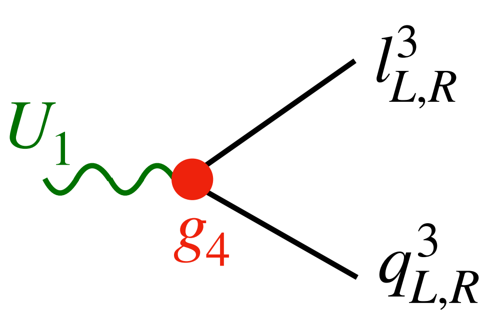
$$SU(3)_h \rightarrow SU(3)_c$$

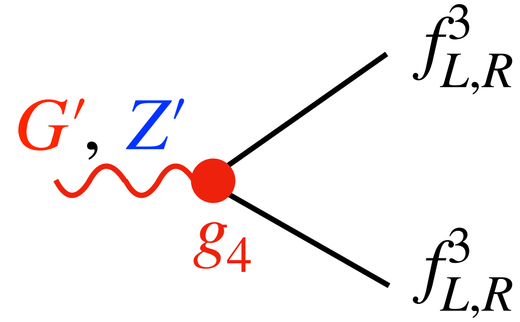
$$SU(3)_h \subset SU(4)_h, \quad U(1)_{(B-L)_h} \subset SU(4)_h$$

$$SU(4)_h \times SU(3)_l \times SU(2)_L \times U(1)_{R+\frac{(B-L)_l}{2}} \xrightarrow{\sim \text{TeV}} SU(3)_c \times SU(2)_L \times U(1)_Y$$

$$U(1)_{(B-L)_h} \longrightarrow U(1)_Y$$

$$+ \quad U_1 \sim (\mathbf{3},\mathbf{1})_{2/3}, \quad G' \sim (\mathbf{8},\mathbf{1})_0, \quad Z' \sim (\mathbf{1},\mathbf{1})_0$$





$$g_4 \gg g_3$$

$$\Downarrow$$

$$g_s \approx g_3$$
$$g_h^{G'} \approx g_4$$
$$g_l^{G'} \approx g_s^2/g_4$$

LHC bounds:
$$M_{G'} \gtrsim 3 - 3.5\,\text{TeV}$$

[Cornella, Faroughy, Fuentes-Martin, Isidori, Neubert, 2103.16558]

Accidental $U(2)$ flavor symmetry

4321 fermion content (I)

1st & 2nd families	$q_L^{1,2},\ \ell_L^{1,2}$	$u_R^{1,2}$	$d_R^{1,2},\ e_R^{1,2}$
3rd family	$\psi_L \sim \begin{pmatrix} q_L^3 \\ \ell_L^3 \end{pmatrix}$	$\psi_R^+ \sim \begin{pmatrix} u_R^3 \\ \nu_R^3 \end{pmatrix}$	$\psi_R^- \sim \begin{pmatrix} d_R^3 \\ e_R^3 \end{pmatrix}$

1 VL fermion

$$\chi_{L/R} = \begin{pmatrix} Q_{L/R} \\ L_{L/R} \end{pmatrix} \sim (4,1,2)_0$$

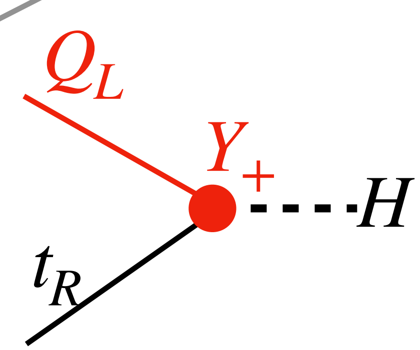
$\langle \Omega_3 \rangle$: $q_L^2 \to c_q q_L^2 + s_q Q_L$

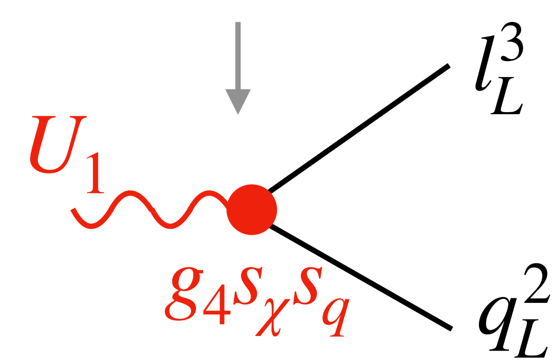
$\langle \Omega_{15} \rangle$: $\begin{pmatrix} Q_L \\ L_L^3 \end{pmatrix} \to \begin{pmatrix} Q_L \\ c_\chi L_L - s_\chi \ell_L^3 \end{pmatrix}$

2-VLF mixing (s_q)

3-VLF mixing (χ)

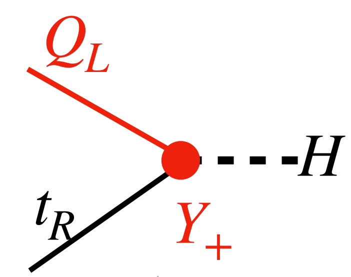
$$y_t V_{cb} = Y_+ s_q$$

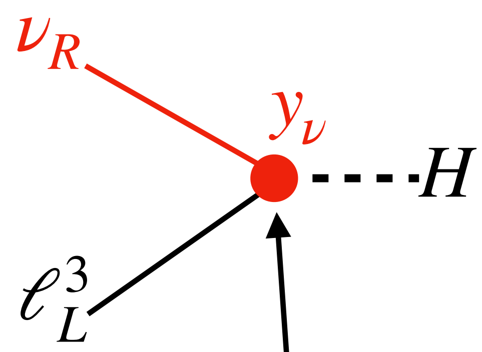




[Crosas, Isidori, JML, Selimović, Stefanek, 2203.01952]

4321 fermion content (II)





3-VLF mixing

$$\begin{pmatrix} t_R \\ \nu_R \end{pmatrix} + \begin{pmatrix} q_L^3 \\ c_\chi \ell_L^3 + s_\chi L_L^3 \end{pmatrix} + \begin{pmatrix} Q_L \\ c_\chi L_L - s_\chi \ell_L^3 \end{pmatrix} \longrightarrow \boxed{y_\nu = y_t \cos(\chi) - Y_+ \sin(\chi)}$$

1 singlet fermion $\boxed{S_L}$ $\sim (1,1,1)_0 \quad \mathscr{L} \supset \lambda_S \bar{S}_L \Omega_1 \Psi_R \xrightarrow{\langle \Omega_1 \rangle} \mathscr{L} \supset m_R \bar{S}_L \nu_R$

$$\nu_L^3 \rightarrow c_\nu \nu_L^3 + s_\nu S_L$$

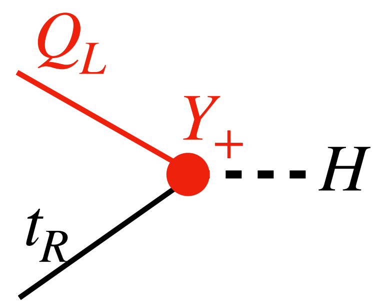
$$(s_\nu = y_\nu v_{\mathrm{EW}} / m_R)$$

[Crosas, Isidori, JML, Selimović, Stefanek, 2203.01952]

[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

Relevant parameters for this analysis

- $\Lambda_U \longrightarrow \sqrt{2}\, m_{U_1}/g_4$
- $Y_+,\ s_q \longrightarrow$



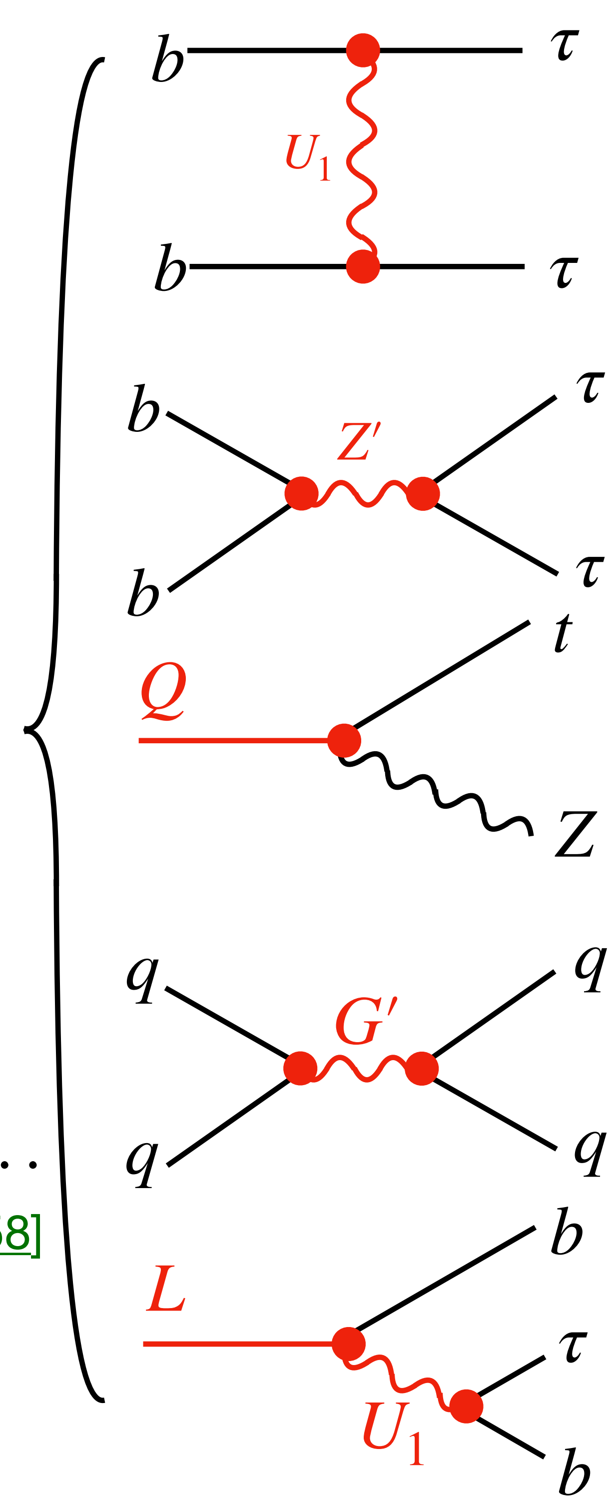
$\left(Y_+ s_q = y_t V_{cb}\right) \longrightarrow$ 2-VLF mixing

- $\chi \longrightarrow$ 3-VLF mixing
- $m_{Q,L} \longrightarrow Q,\ L$
- $m_R \longrightarrow (\nu_R, S_L)$
- $m_{U_1,G',Z'} \longrightarrow U_1,\ G',\ Z'$

Phenomenology

- $b \to c\tau\nu$ physics $(R_{D^{(*)}}, R_{\Lambda_c})$
- EWPO
- LFUV in τ decays
  [Allwicher, Isidori, Selimović, 2109.03833]
- High p_T at LHC
- Other $q_3 \to q_2$ transitions:
  - $B_s \to \tau\tau$, $B \to K\nu\nu$, $B \to K\tau\tau$, B_s mixing, etc…
  [Cornella, Faroughy, Fuentes-Martin, Isidori, Neubert, 2103.16558]
- $q_2 \to q_1$ transitions:
  - $K \to \pi\nu\nu$, K, D mixing
  [Crosas, Isidori, JML, Selimović, Stefanek, 2203.01952]

[Haisch, Schnell, Schulte, 2209.12780]



See Uli Haisch's talk

$m_Q > 1.5$ TeV
95 % CL

Phenomenology

[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

- $b \to c\tau\nu$ physics $(R_{D^{(*)}},\ R_{\Lambda_c})$
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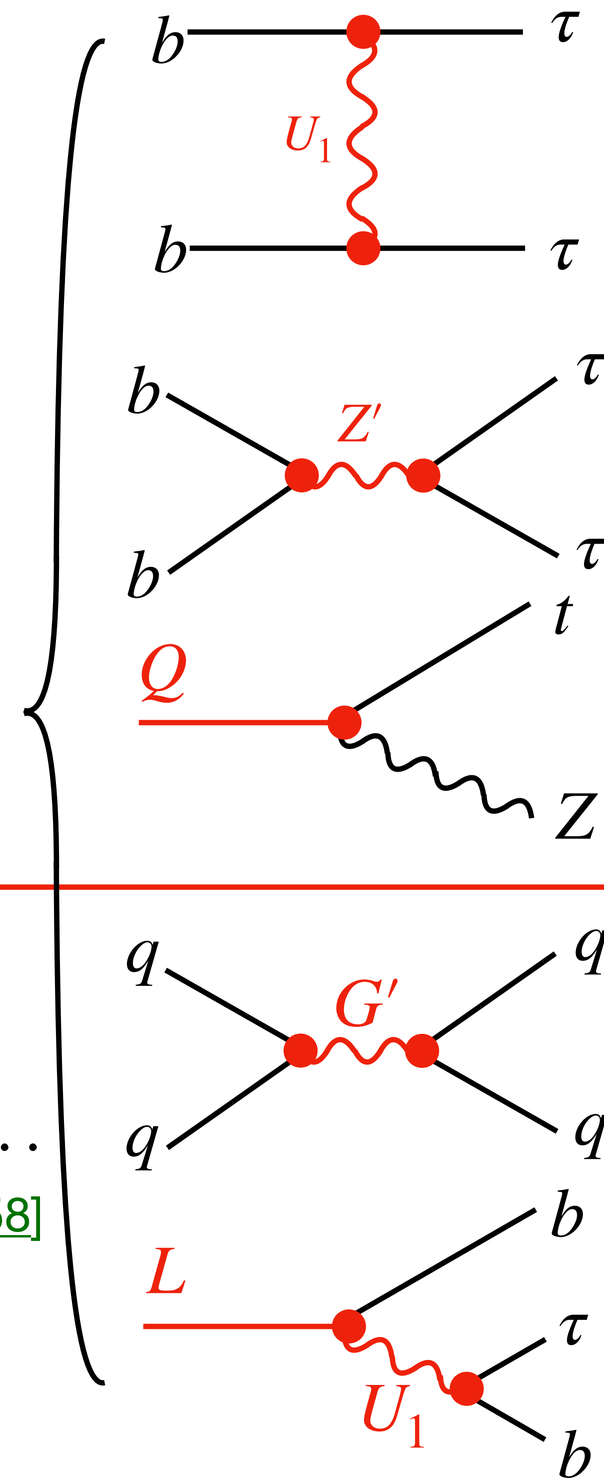

See Uli Haisch's talk

HighPT [2207.10756] (see Lukas's talk)

$m_Q > 1.5$ TeV 95 % CL

- Other $q_3 \to q_2$ transitions:
  - $B_s \to \tau\tau$, $B \to K\nu\nu$, $B \to K\tau\tau$, B_s mixing, etc…
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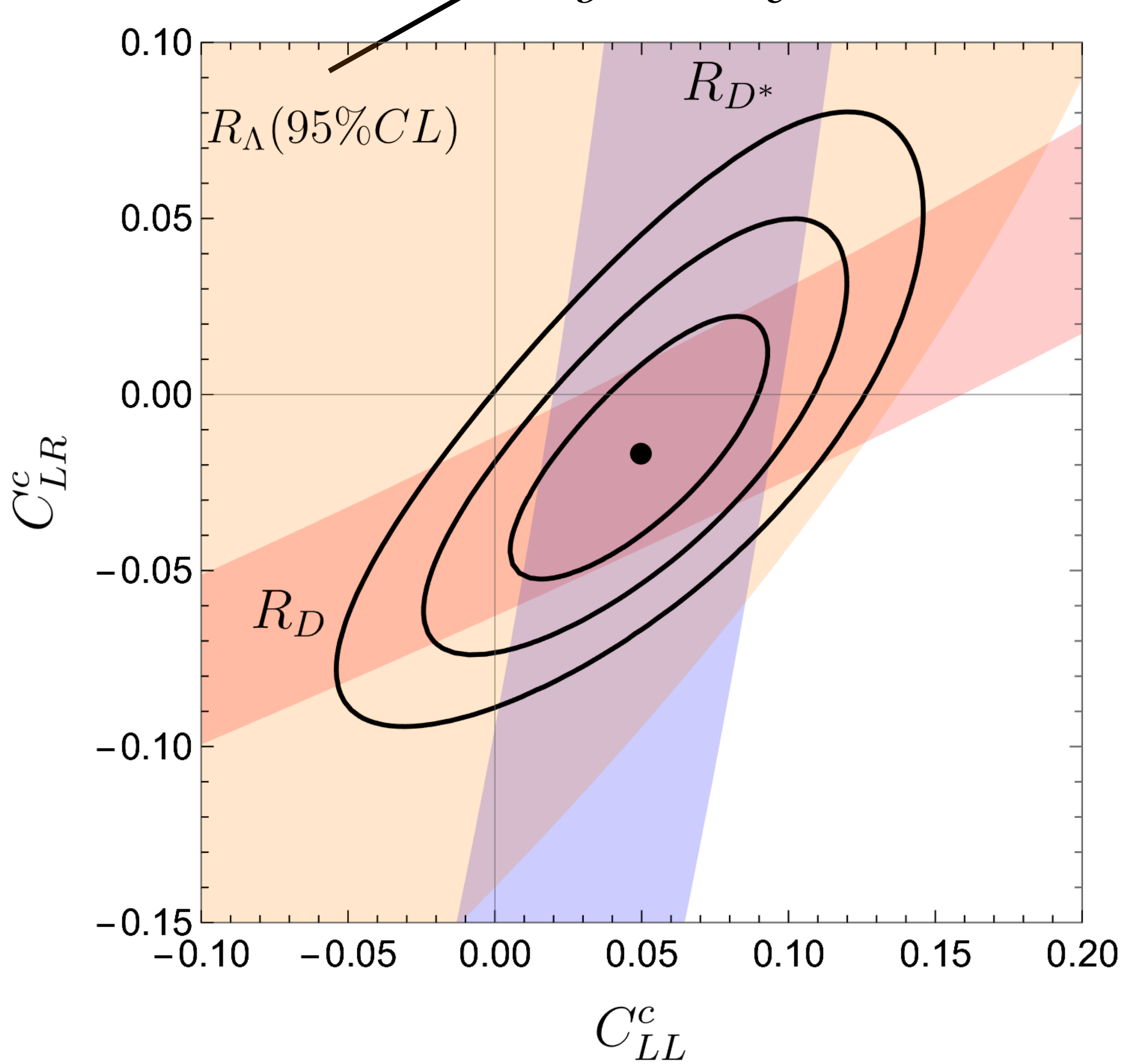
[J. Aebischer, G. Isidori, M. Pesut, B. Stefanek, F. Wilsch, 2210.13422]

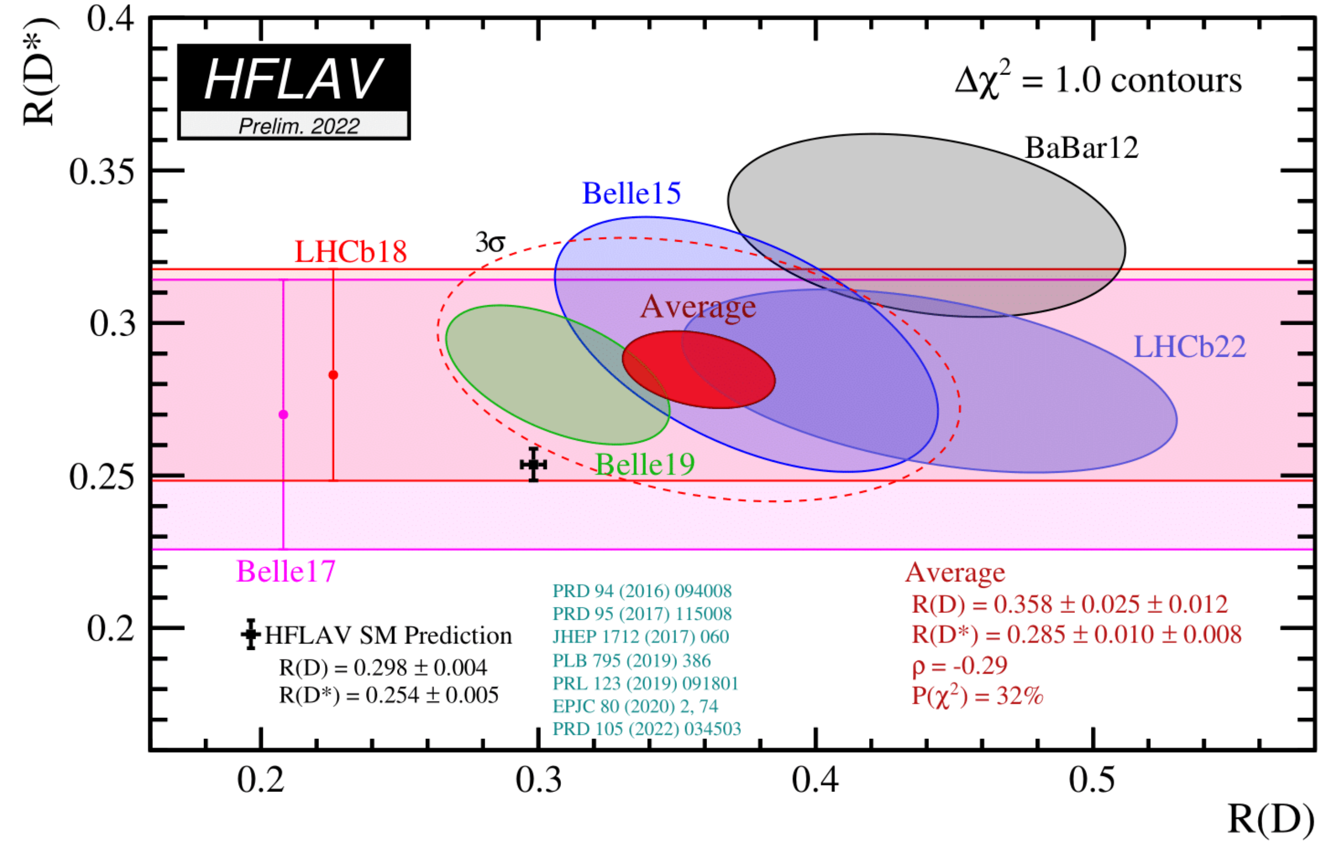
$b \to c\tau\nu$ data

$$R_{D^{(*)}} = \frac{Br(B \to D^{(*)}\tau\nu)}{Br(B \to D^{(*)}l\nu)}$$

$\sim 3.2\sigma$

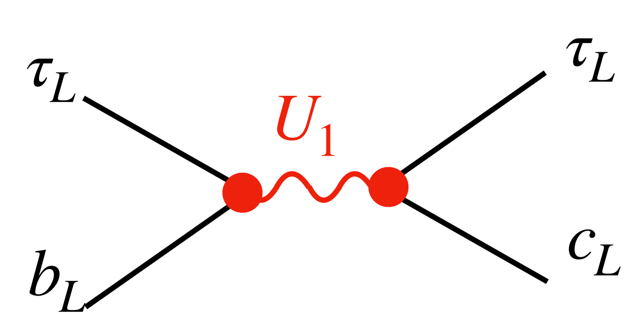
$\Lambda_b \to \Lambda_c\tau\nu$

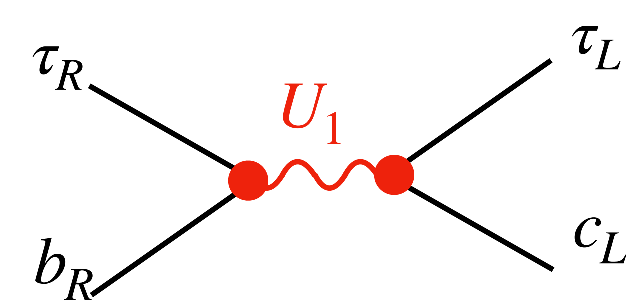




$$\mathscr{L} \supset \frac{2}{v^2}V_{cb}\Big[\left(1 + C^c_{LL}\right)(\bar{c}_L\gamma_\mu b_L)(\bar{\tau}_L\gamma^\mu\nu_L)$$

$$-2C^c_{LR}(\bar{c}_L b_R)(\bar{\tau}_L\nu_L)\Big]$$

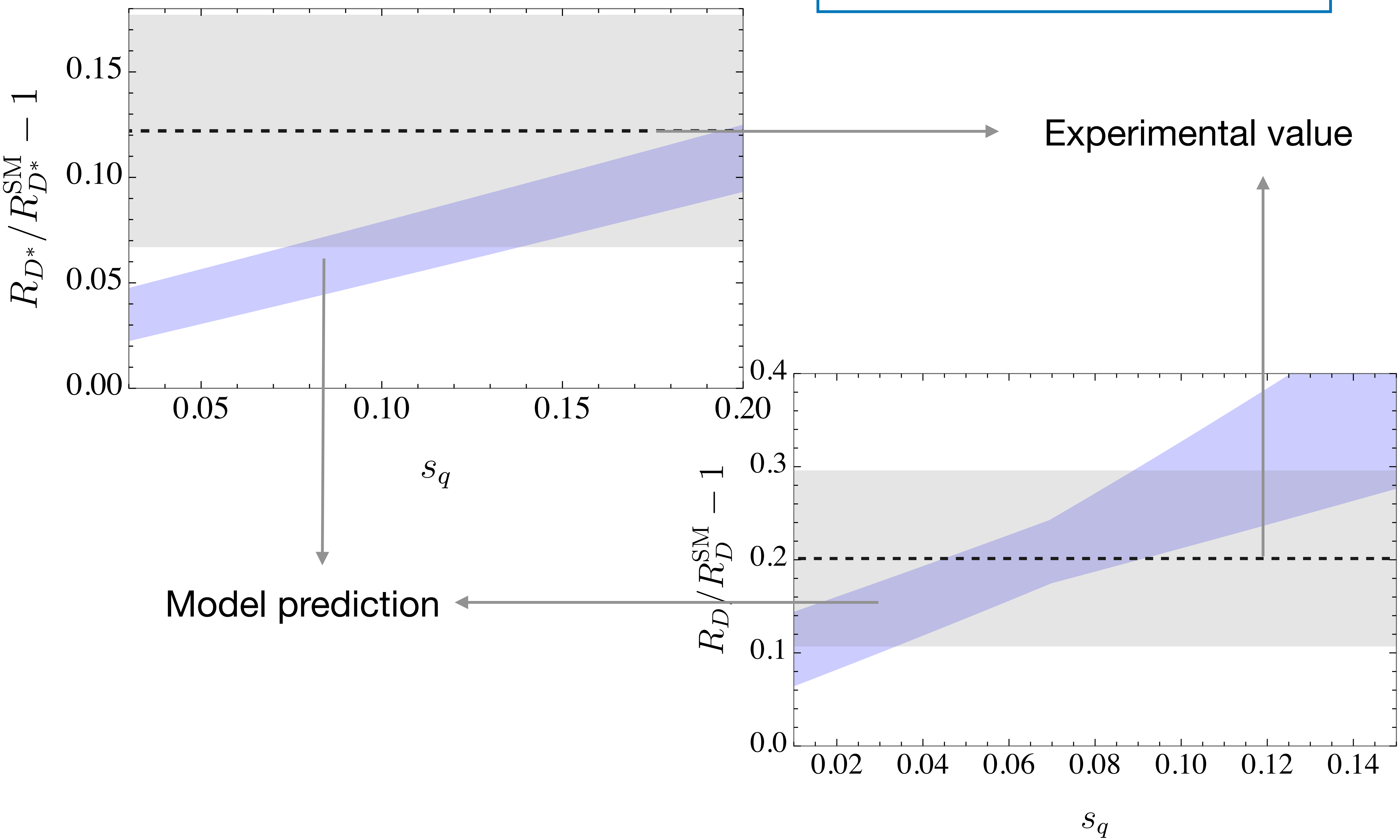




$$C^c_{LL} \propto \frac{s_q}{\Lambda_U^2}\sin(\chi)\cos(\chi) \qquad C^c_{LR} \propto \frac{s_q}{\Lambda_U^2}\sin(\chi)$$

$b \to c\tau\nu$ data

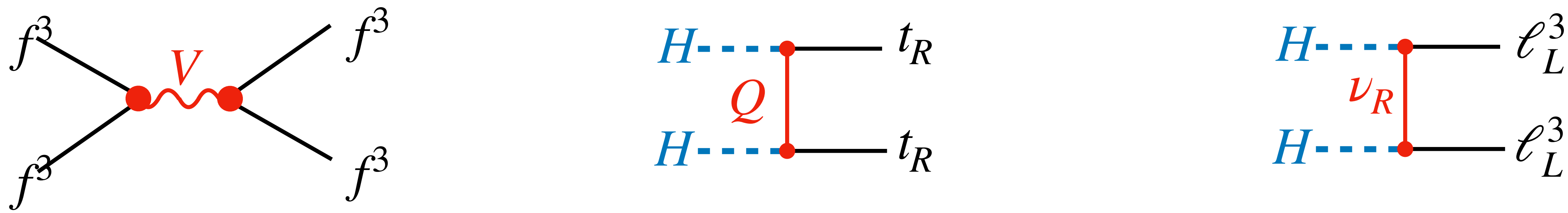
$$\Lambda_U = \sqrt{2}\, m_{U_1}/g_4 = 1.5\,\text{TeV}$$



SMEFT

- One-loop matching in g_4, Y_+, y_t, g_s to the relevant SMEFT operators:

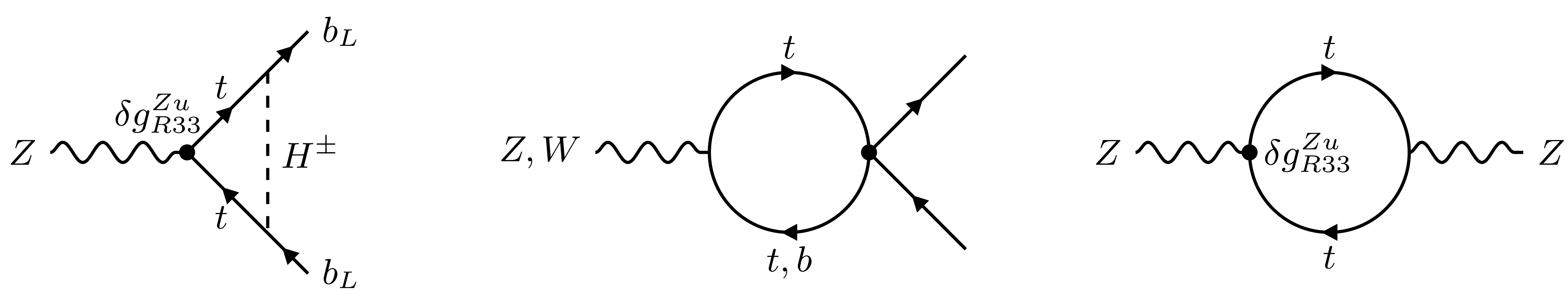
Tree level matching:



$\rightarrow C_{ff}\,(\bar{f}^3 f^3)(\bar{f}^3 f^3)$ $\quad\rightarrow C_{Hu}\,(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{t}_R\gamma^\mu t_R)$ $\quad\rightarrow C_{H\ell}\left((H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{\ell}^3_L\gamma^\mu \ell^3_L) - (H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{\ell}^3_L\tau_I\gamma^\mu \ell^3_L)\right)$

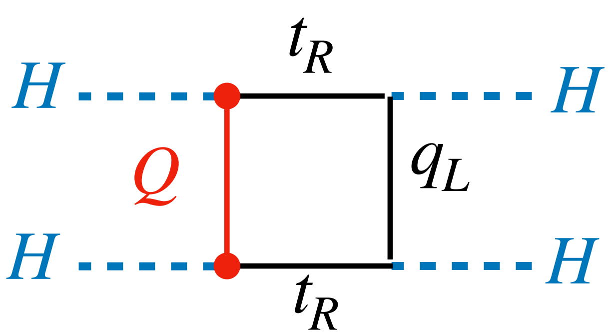
- Running at one loop from UV scale to EW.

- To keep consistency with the one-loop matching, calculation of the EW observables at one-loop in y_t, g_s :



EW: Universal contributions

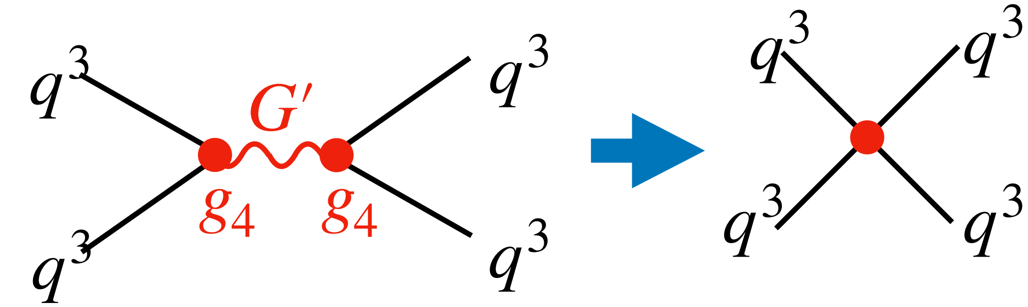
$$\mathscr{L} \supset C_{HD} |H^\dagger D_\mu H|^2$$

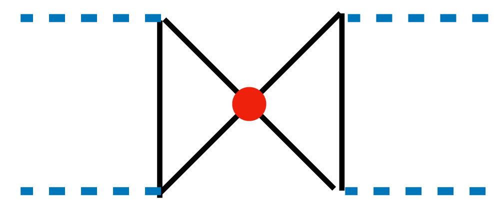


$\propto Y_+^2 / m_Q^2$

$\left(Y_+ s_q = y_t V_{cb} \right)$

$(C_{Hu} \to C_{HD})$ + 1-loop matching

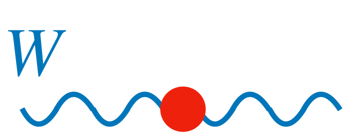




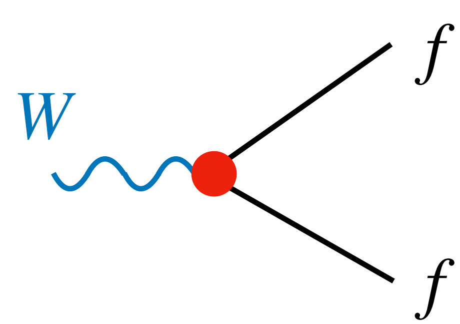
$\propto 1/\Lambda_U^2$

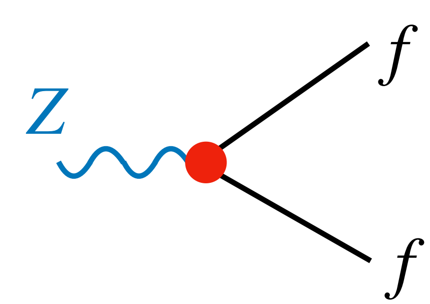
$$C_{uu} + C_{qq} \to C_{Hu} + C_{Hq}^{(1)} \to C_{HD}$$

m_W



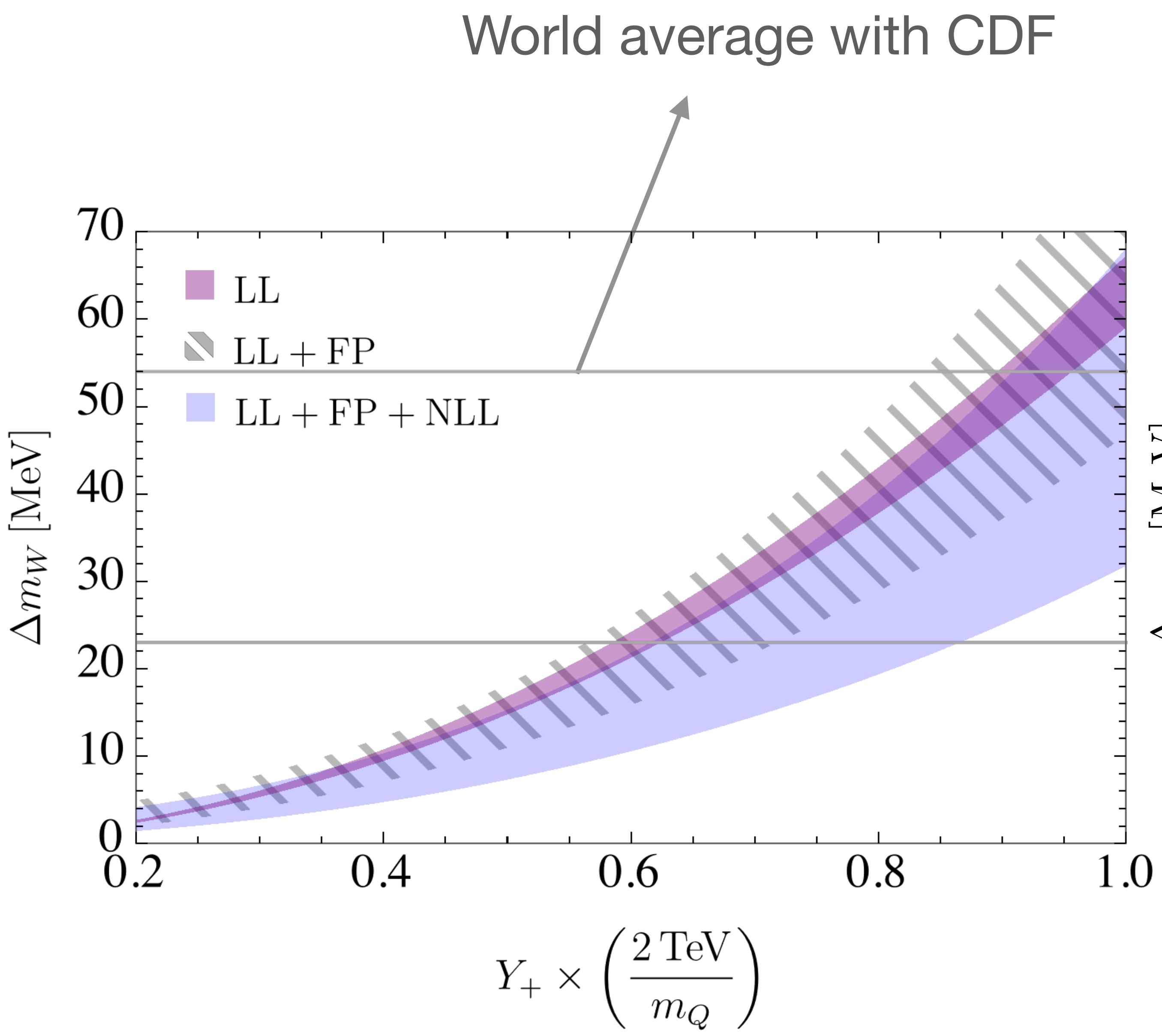
Universal coupling modification



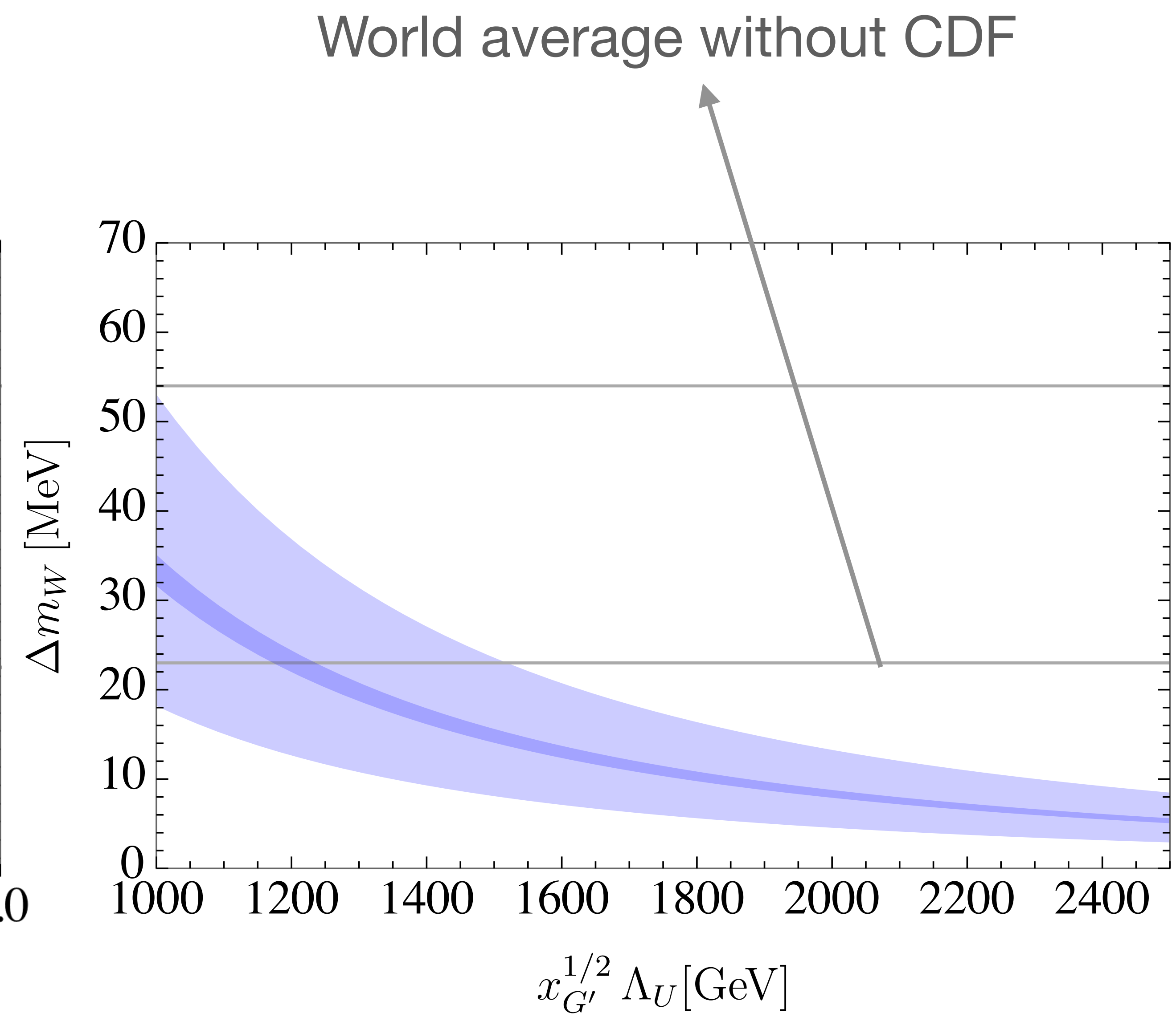


[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

EW: Universal contributions



VLF sector

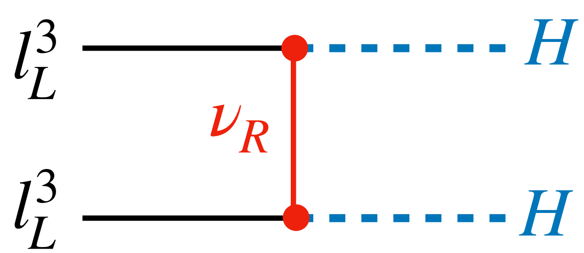


Coloron sector

[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

EW: Non-Universal contributions

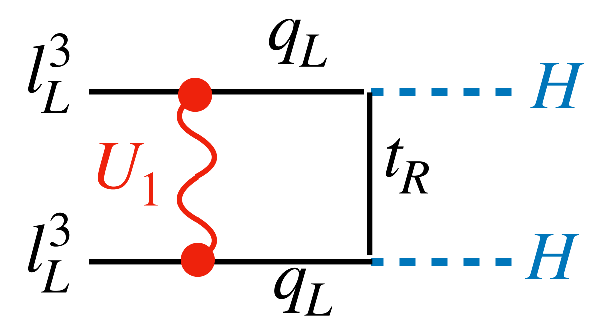
$$\mathscr{L} \supset C_{Hl}^{(1)}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{\ell}_L^3\gamma^\mu\ell_L^3) + C_{Hl}^{(3)}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{\ell}_L^3\tau_I\gamma^\mu\ell_L^3)$$



$\propto y_\nu^2/m_R^2$

$(y_\nu = c_\chi y_t - s_\chi Y_+)$

Tree-level + LL running ($C_{H\ell} \to C_{H\ell}$)



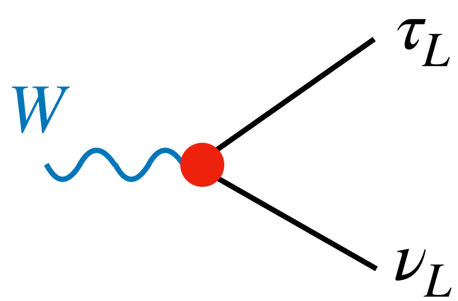
$\propto c_\chi^2/\Lambda_U^2$

($C_{lq} \to C_{H\ell}$) + 1-loop matching (+ NLL)

$$C_{H\ell}^{(1)} = -\,C_{H\ell}^{(3)}$$

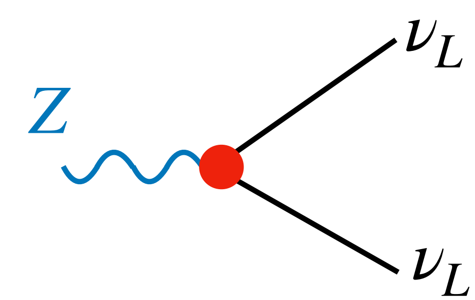
(Only broken by small g_2 effects and negligible NLL)

$W\tau\nu_\tau$



LFUV in τ-decays

$Z\nu_\tau\nu_\tau$



[Allwicher, Isidori, Selimović, 2109.03833]

Global fit

- Global likelihood:

$$\chi^2 = \chi^2_{b\to c\tau\nu} + \chi^2_{\mathrm{EWPO}} + \chi^2_{\tau\text{-LFU}} + \chi^2_{\text{high-}p_T}$$

- Fixed parameters:

$$\chi = 60^{\mathrm{o}},\ m_L = 1\,\mathrm{TeV},\ m_R = 1.5\,\mathrm{TeV},\ m_U = 3\,\mathrm{TeV},\ m_{G'} = 3.5\,\mathrm{TeV},\ m_{Z'} = 3\,\mathrm{TeV}$$

- Two fits:

m_W without CDF

$$m_W^{\mathrm{exp}} = (80.379 \pm 0.012)\mathrm{GeV}$$

Parameter	Best-fit point	1σ interval
Λ_U	1.61 TeV	$[1.46, 1.86]$ TeV
m_Q	$m_Q \to \infty$	$[2.31, \infty)$ TeV
Y_+	0.36	$[0.26, 0.56]$

$$\chi^2_{\mathrm{SM}} - \chi^2_{\mathrm{BFP}} = 12.3\ (2.4\sigma)$$

m_W with CDF

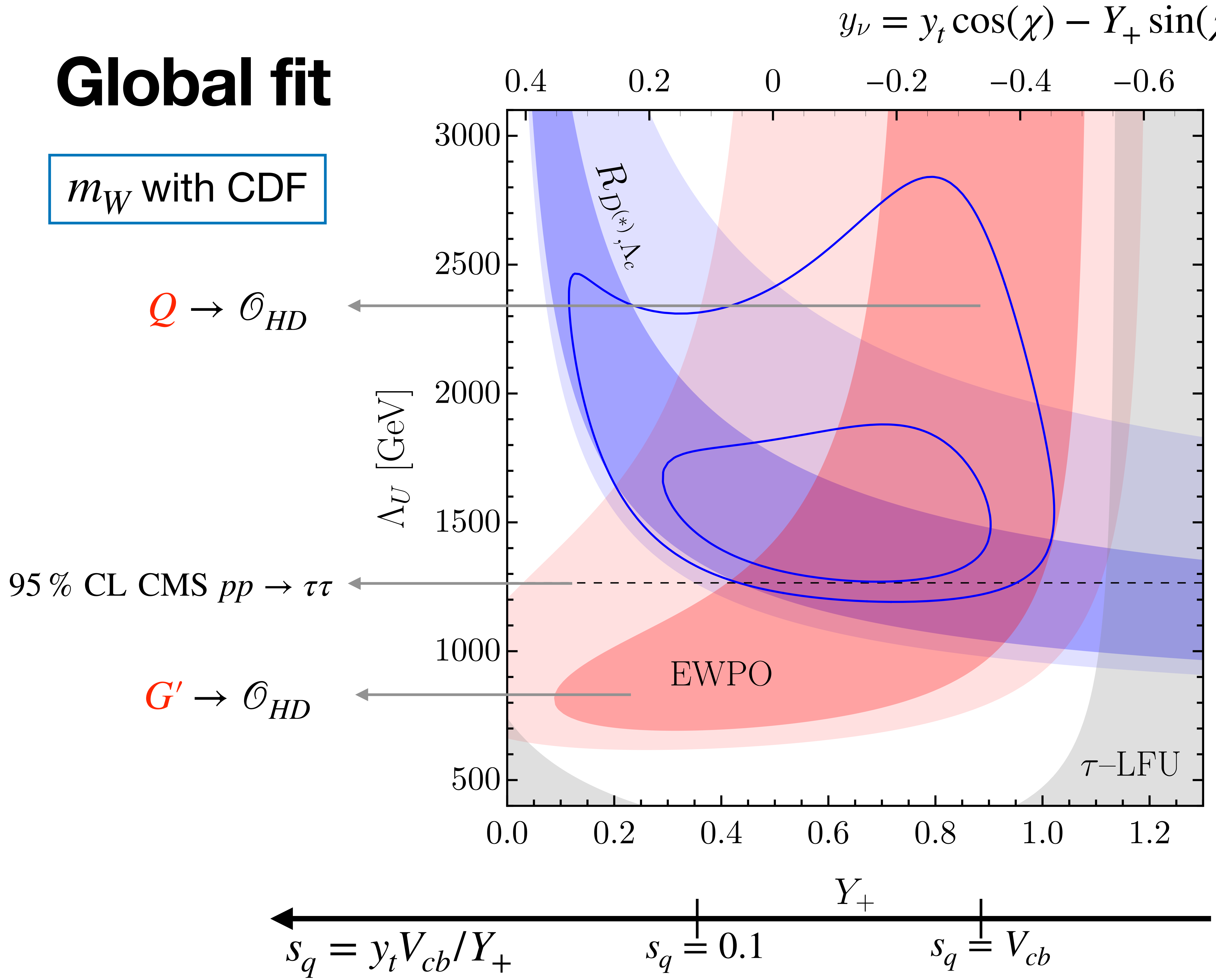
$$m_W^{\mathrm{exp}} = (80.410 \pm 0.015)\mathrm{GeV}$$

Parameter	Best-fit point	1σ interval
Λ_U	1.46 TeV	$[1.32, 1.68]$ TeV
m_Q	2.08 TeV	$[1.43, 4.72]$ TeV
Y_+	0.65	$[0.43, 0.83]$

$$\chi^2_{\mathrm{SM}} - \chi^2_{\mathrm{BFP}} = 15.4\ (2.9\sigma)$$

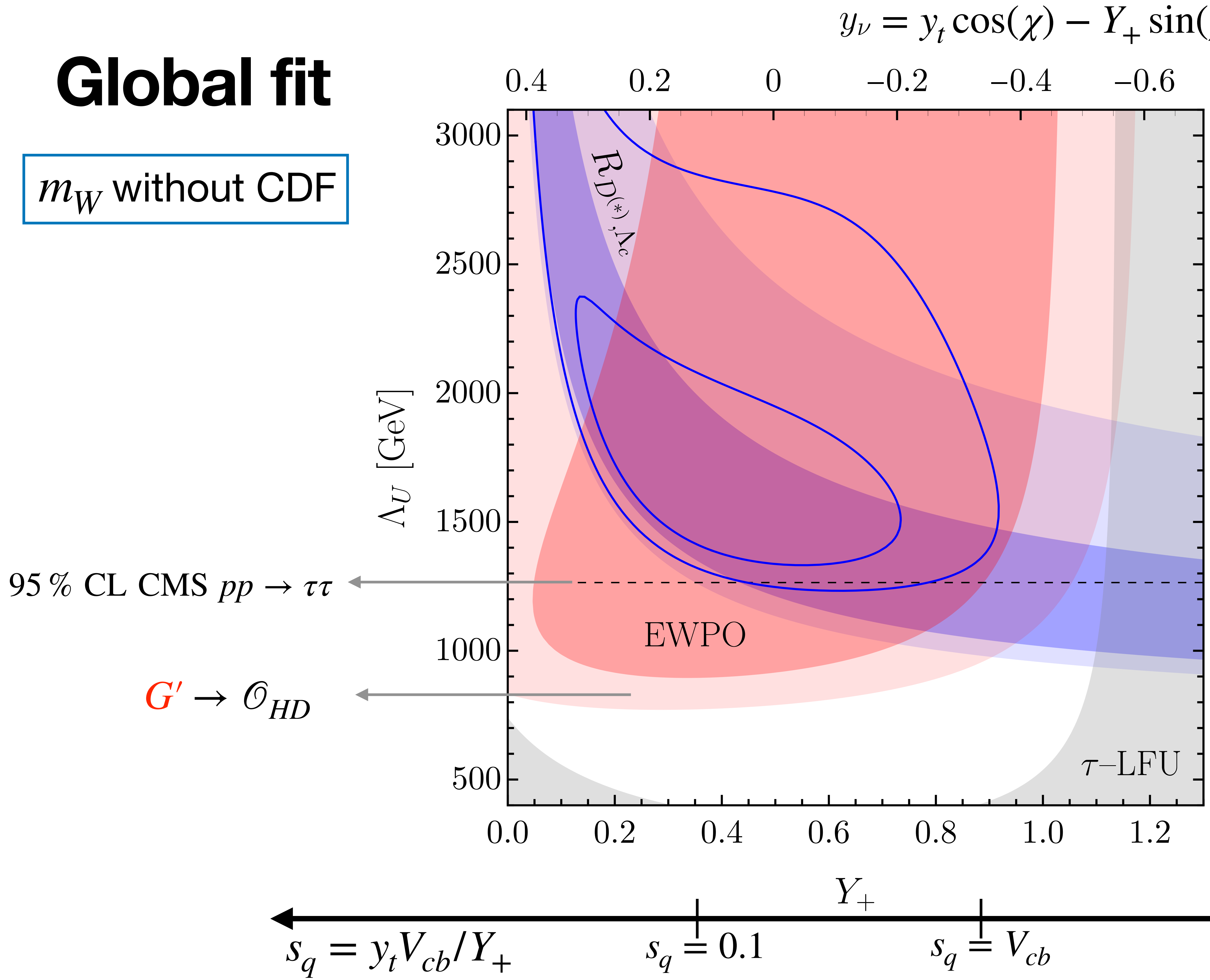
Global fit

m_W with CDF



Global fit

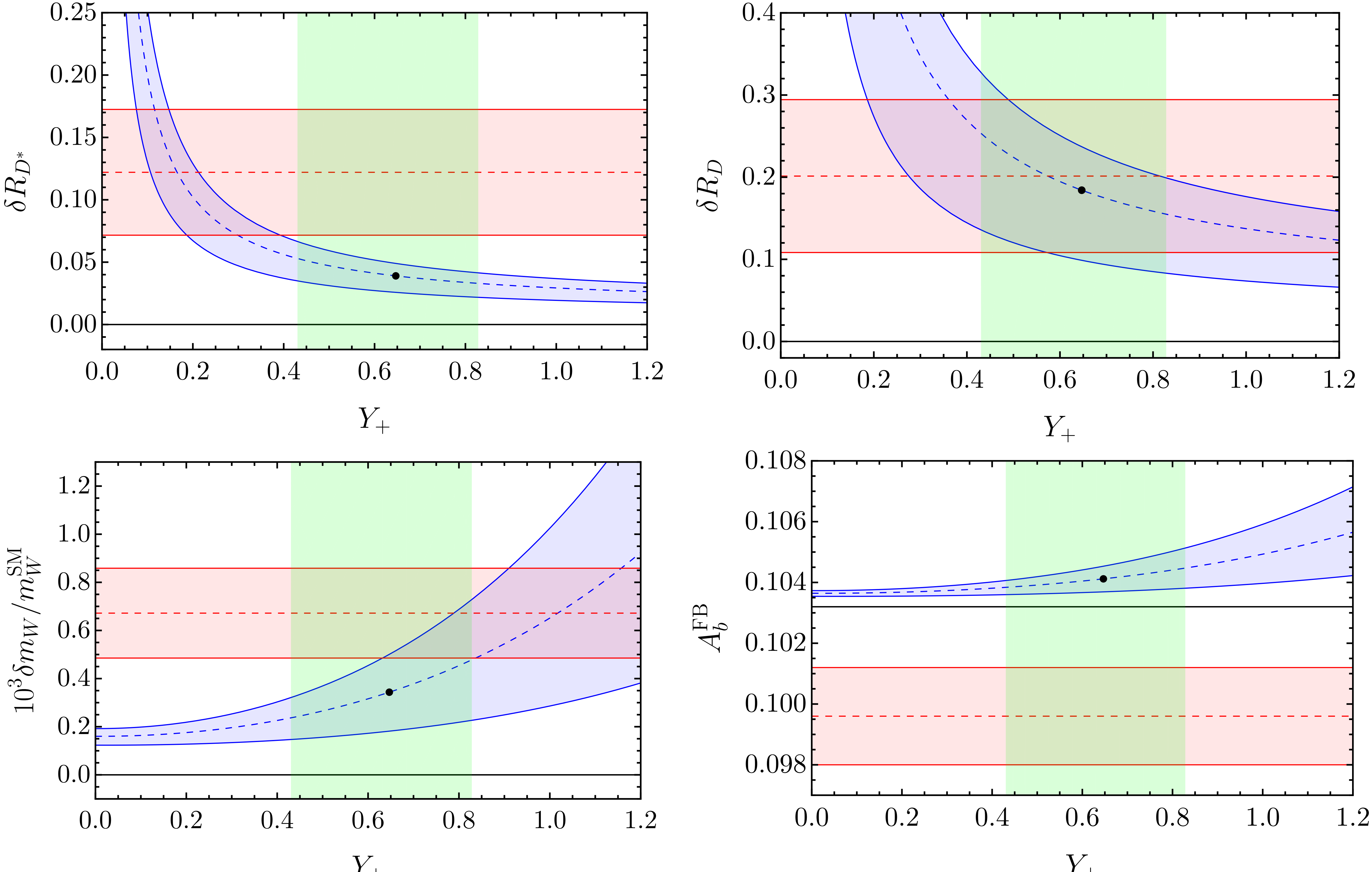
m_W without CDF



[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

Global fit

m_W with CDF



Conclusions

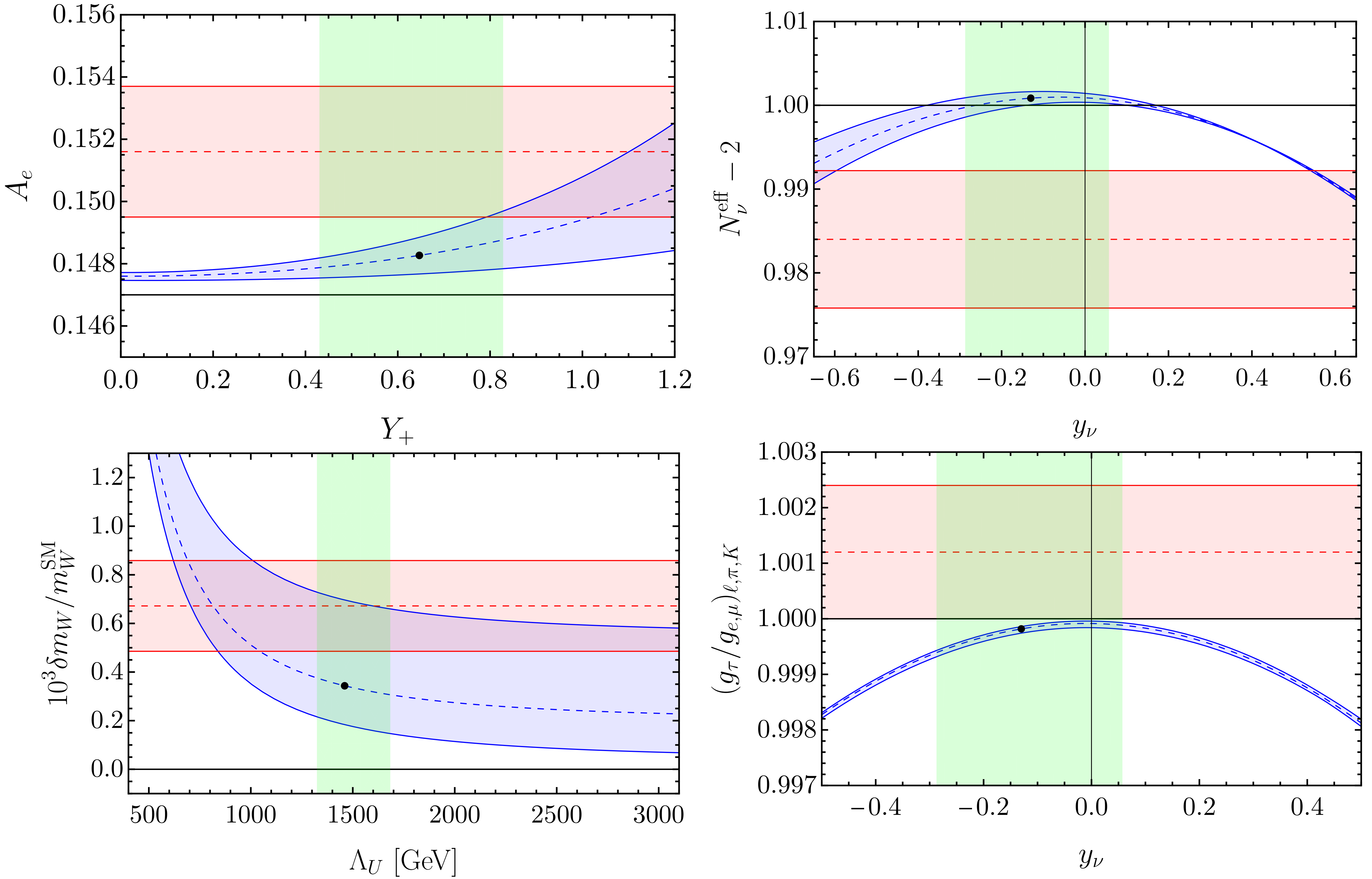
- Quark-lepton unification of the third family at the TeV scale could be the infrared limit of a natural solution to the flavor puzzle.
- Apart from a rich B-physics pheno, the model has an interesting impact on EW physics.
- We find that the new colored states generate large universal contributions at the loop level.
- Higher order effects can play a key role.
- These results have a wider range of applicability: VLF, extended gauge groups, or inverse-seesaw mechanism.

Thank you!

[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

Backup: Global fit

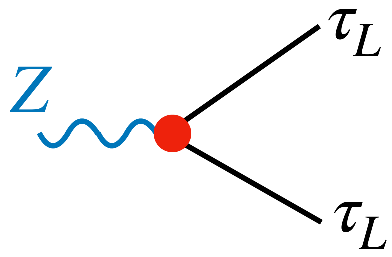
m_W with CDF

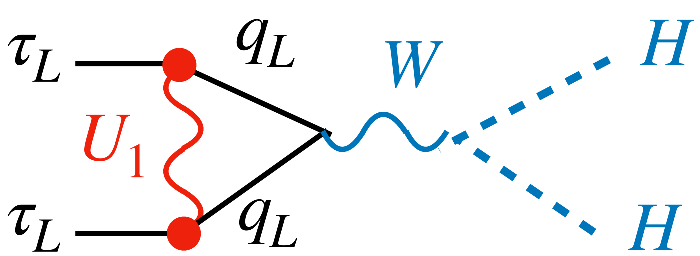


[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

Backup: Other EW observables

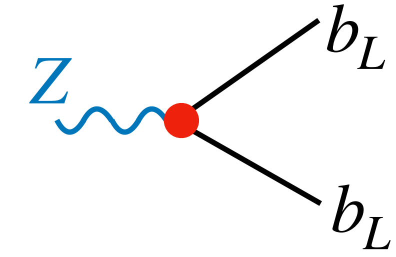
$Z\tau_L\tau_L$

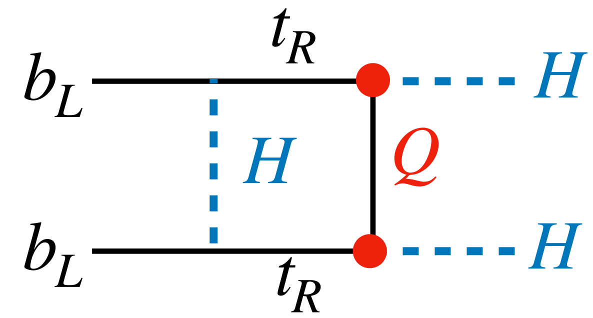




$$\mathscr{L} \supset C^{(3)}_{H\ell}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{\ell}^3_L\tau_I\gamma^\mu\ell^3_L)$$

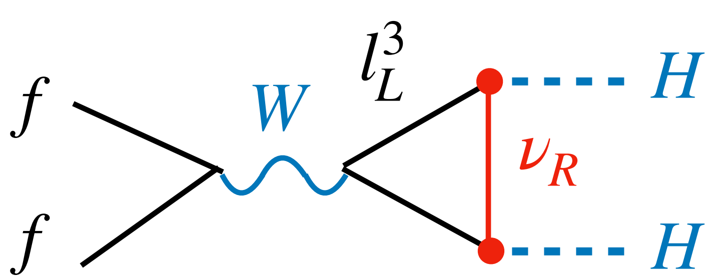
Zb_Lb_L





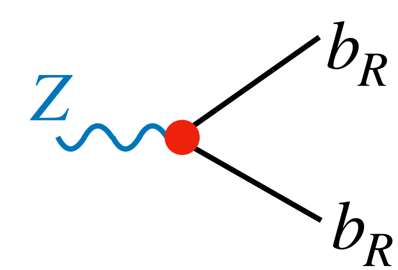
$$\mathscr{L} \supset C^{(1)}_{Hq}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}^3_L\gamma^\mu q^3_L)$$

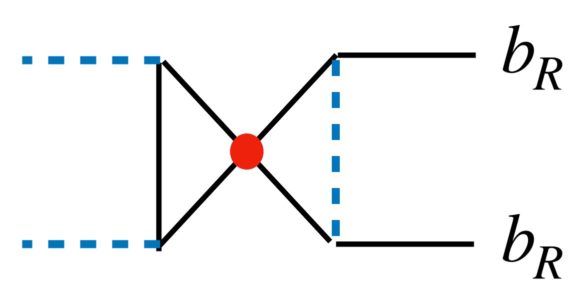
Universal coupling modification



$$\mathscr{L} \supset C^{(3)U}_{H\ell}(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{\ell}_L\tau_I\gamma^\mu\ell_L)$$

Zb_Rb_R





$$\mathscr{L} \supset C_{Hb}(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{b}_R\gamma^\mu b_R)$$

Backup: EW observables

Observable	Experimental value	SM prediction	Definition
Γ_Z [GeV]	2.4955 ± 0.0023 [4, 28]	2.4941	$\sum_f \Gamma(Z \to f\bar{f})$
$\sigma_{\rm had}$ [nb]	41.4802 ± 0.0325 [4, 28]	41.4842	$\frac{12\pi}{m_Z^2}\frac{\Gamma(Z\to e^+e^-)\Gamma(Z\to q\bar{q})}{\Gamma_Z^2}$
R_e	20.804 ± 0.050 [4]	20.734	$\frac{\sum_q \Gamma(Z\to q\bar{q})}{\Gamma(Z\to e^+e^-)}$
R_μ	20.785 ± 0.033 [4]	20.734	$\frac{\sum_q \Gamma(Z\to q\bar{q})}{\Gamma(Z\to \mu^+\mu^-)}$
R_τ	20.764 ± 0.045 [4]	20.781	$\frac{\sum_q \Gamma(Z\to q\bar{q})}{\Gamma(Z\to \tau^+\tau^-)}$
$A_{\rm FB}^{0,e}$	0.0145 ± 0.0025 [4]	0.0162	$\frac{3}{4}A_e^2$
$A_{\rm FB}^{0,\mu}$	0.0169 ± 0.0013 [4]	0.0162	$\frac{3}{4}A_e A_\mu$
$A_{\rm FB}^{0,\tau}$	0.0188 ± 0.0017 [4]	0.0162	$\frac{3}{4}A_e A_\tau$
R_b	0.21629 ± 0.00066 [4]	0.21581	$\frac{\Gamma(Z\to b\bar{b})}{\sum_q \Gamma(Z\to q\bar{q})}$
R_c	0.1721 ± 0.0030 [4]	0.17222	$\frac{\Gamma(Z\to c\bar{c})}{\sum_q \Gamma(Z\to q\bar{q})}$
$A_b^{\rm FB}$	0.0996 ± 0.0016 [4, 29]	0.1032	$\frac{3}{4}A_e A_b$
$A_c^{\rm FB}$	0.0707 ± 0.0035 [4]	0.0736	$\frac{3}{4}A_e A_c$
A_e	0.1516 ± 0.0021 [4]	0.1470	$\frac{\Gamma(Z\to e_L^+e_L^-)-\Gamma(Z\to e_R^+e_R^-)}{\Gamma(Z\to e^+e^-)}$
A_μ	0.142 ± 0.015 [4]	0.1470	$\frac{\Gamma(Z\to \mu_L^+\mu_L^-)-\Gamma(Z\to \mu_R^+\mu_R^-)}{\Gamma(Z\to \mu^+\mu^-)}$
A_τ	0.136 ± 0.015 [4]	0.1470	$\frac{\Gamma(Z\to \tau_L^+\tau_L^-)-\Gamma(Z\to \tau_R^+\tau_R^-)}{\Gamma(Z\to \tau^+\tau^-)}$
A_e	0.1498 ± 0.0049 [4]	0.1470	$\frac{\Gamma(Z\to e_L^+e_L^-)-\Gamma(Z\to e_R^+e_R^-)}{\Gamma(Z\to e^+e^-)}$
A_τ	0.1439 ± 0.0043 [4]	0.1470	$\frac{\Gamma(Z\to \tau_L^+\tau_L^-)-\Gamma(Z\to \tau_R^+\tau_R^-)}{\Gamma(Z\to \tau^+\tau^-)}$
A_b	0.923 ± 0.020 [4]	0.935	$\frac{\Gamma(Z\to b_L\bar{b}_L)-\Gamma(Z\to b_R\bar{b}_R)}{\Gamma(Z\to b\bar{b})}$
A_c	0.670 ± 0.027 [4]	0.668	$\frac{\Gamma(Z\to c_L\bar{c}_L)-\Gamma(Z\to c_R\bar{c}_R)}{\Gamma(Z\to c\bar{c})}$
A_s	0.895 ± 0.091 [30]	0.936	$\frac{\Gamma(Z\to s_L\bar{s}_L)-\Gamma(Z\to s_R\bar{s}_R)}{\Gamma(Z\to s\bar{s})}$
R_{uc}	0.166 ± 0.009 [9]	0.1722	$\frac{\Gamma(Z\to u\bar{u})+\Gamma(Z\to c\bar{c})}{2\sum_q \Gamma(Z\to q\bar{q})}$

Observable	Experimental value	SM prediction
m_W [GeV]	80.379 ± 0.012 [9]	80.356
Γ_W [GeV]	2.085 ± 0.042 [9]	2.088
${\rm Br}(W \to e\nu)$	0.1071 ± 0.0016 [5]	0.1082
${\rm Br}(W \to \mu\nu)$	0.1063 ± 0.0015 [5]	0.1082
${\rm Br}(W \to \tau\nu)$	0.1138 ± 0.0021 [5]	0.1081
${\rm Br}(W \to \mu\nu)/{\rm Br}(W \to e\nu)$	0.982 ± 0.024 [32]	1.000
${\rm Br}(W \to \mu\nu)/{\rm Br}(W \to e\nu)$	1.020 ± 0.019 [12]	1.000
${\rm Br}(W \to \mu\nu)/{\rm Br}(W \to e\nu)$	1.003 ± 0.010 [13]	1.000
${\rm Br}(W \to \tau\nu)/{\rm Br}(W \to e\nu)$	0.961 ± 0.061 [9, 31]	0.999
${\rm Br}(W \to \tau\nu)/{\rm Br}(W \to \mu\nu)$	0.992 ± 0.013 [14]	0.999
$R_{Wc} \equiv \frac{\Gamma(W\to cs)}{\Gamma(W\to ud)+\Gamma(W\to cs)}$	0.49 ± 0.04 [9]	0.50

[V. Breso-Pla, A. Falkowski, M. Gonzalez-Alonso, 2103.12074]

[Allwicher, Isidori, JML, Selimović, Stefanek, 2302.11584]

Backup: Running

$$\mathcal{A}(\mu) = \frac{y_t(\mu)^2}{16\pi^2}\mathcal{A}_t + \frac{g_s(\mu)^2}{16\pi^2}\mathcal{A}_s + \frac{g_L(\mu)^2}{16\pi^2}\mathcal{A}_L + \dots$$

- RGE: $$\mu\frac{d}{\mu}\mathcal{C}(\mu) = \mathcal{A}(\mu)\,\mathcal{C}(\mu)$$
- Integration:

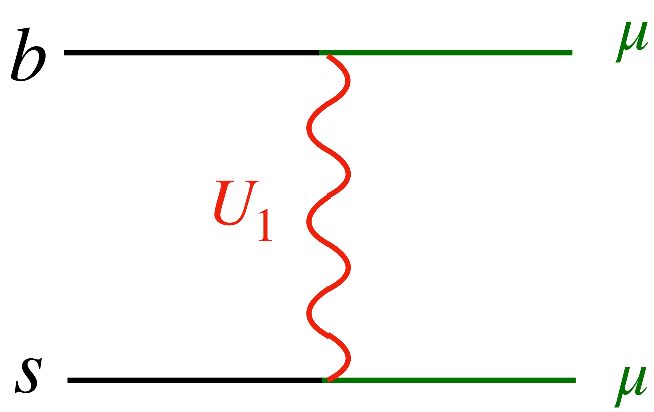
$$\begin{aligned}\mathcal{C}(\mu) &= \mathcal{P}\int_{\mu_0}^{\mu} \exp \mathcal{A}(\mu)\, d\log\mu\, \mathcal{C}(\mu_0)\\ &= \left(\mathbb{1} + \int_{\mu_0}^{\mu} d\log\mu\, \mathcal{A}(\mu) + \int_{\mu_0}^{\mu} d\log\mu_1 \int_{\mu_0}^{\mu_1} d\log\mu_2 \mathcal{A}(\mu_1)\mathcal{A}(\mu_2) + \dots\right)\mathcal{C}(\mu_0)\end{aligned}$$

- Top Yukawa running: $$\begin{aligned}\mathcal{C}(\mu) - \mathcal{C}(\mu_0) &= \frac{1}{16\pi^2}\mathcal{A}_t\mathcal{C}(\mu_0)\int_{\mu_0}^{\mu} y_t(\mu)^2 d\log\mu\\ &= \frac{\bar{y}_t^2}{16\pi^2}\mathcal{A}_t\mathcal{C}(\mu_0)\log\frac{\mu}{\mu_0}\,,\end{aligned}$$

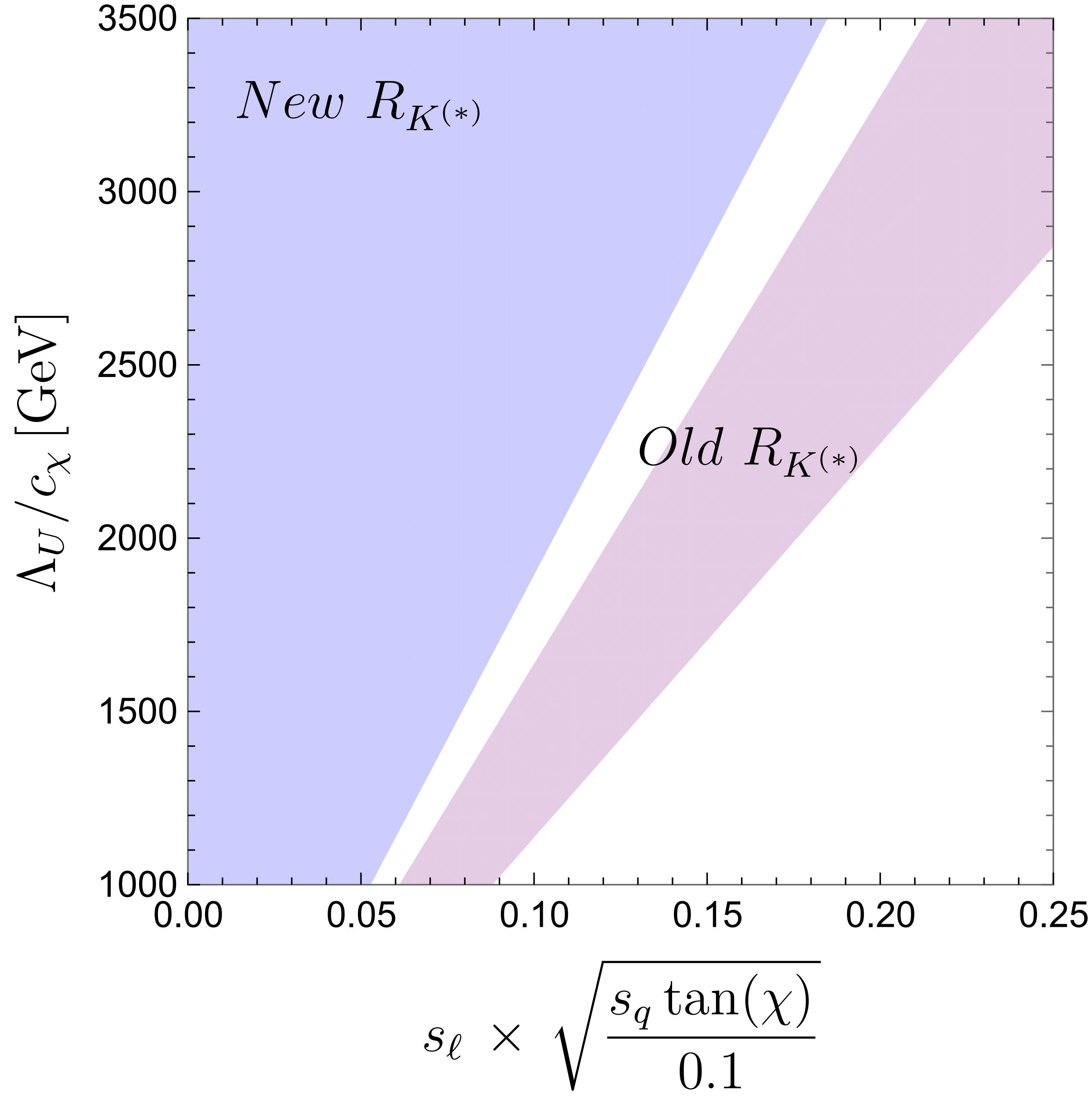
$$\bar{y}_t^2 = \frac{1}{\log\frac{\mu}{\mu_0}}\int_{\mu_0}^{\mu} d\log\mu'\, y_t^2(\mu')$$ ➡ $$\bar{y}_t \approx 0.87$$

Backup: $R_{K^{(*)}}$

$$R_{K^{(*)}} = \frac{Br(B \to K^{(*)}\mu\mu)}{Br(B \to K^{(*)}ee)}$$

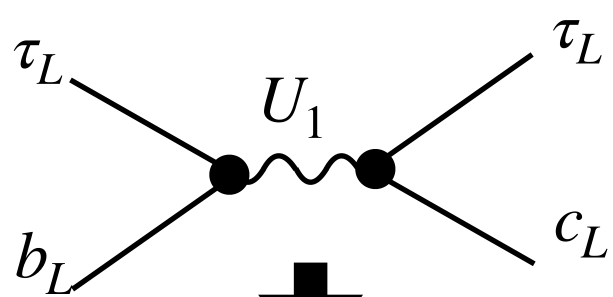


$$\propto \frac{s_q\, s_l^2}{\Lambda_U^2} \sin(\chi)\cos(\chi)$$

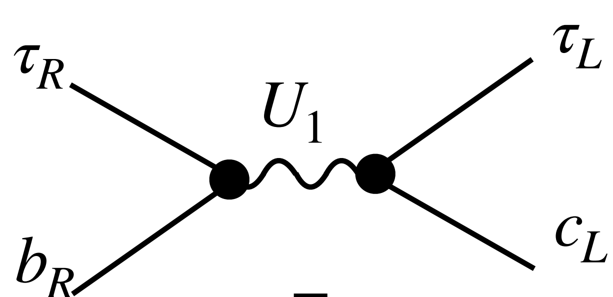


Backup: $R_{D^{(*)}}$

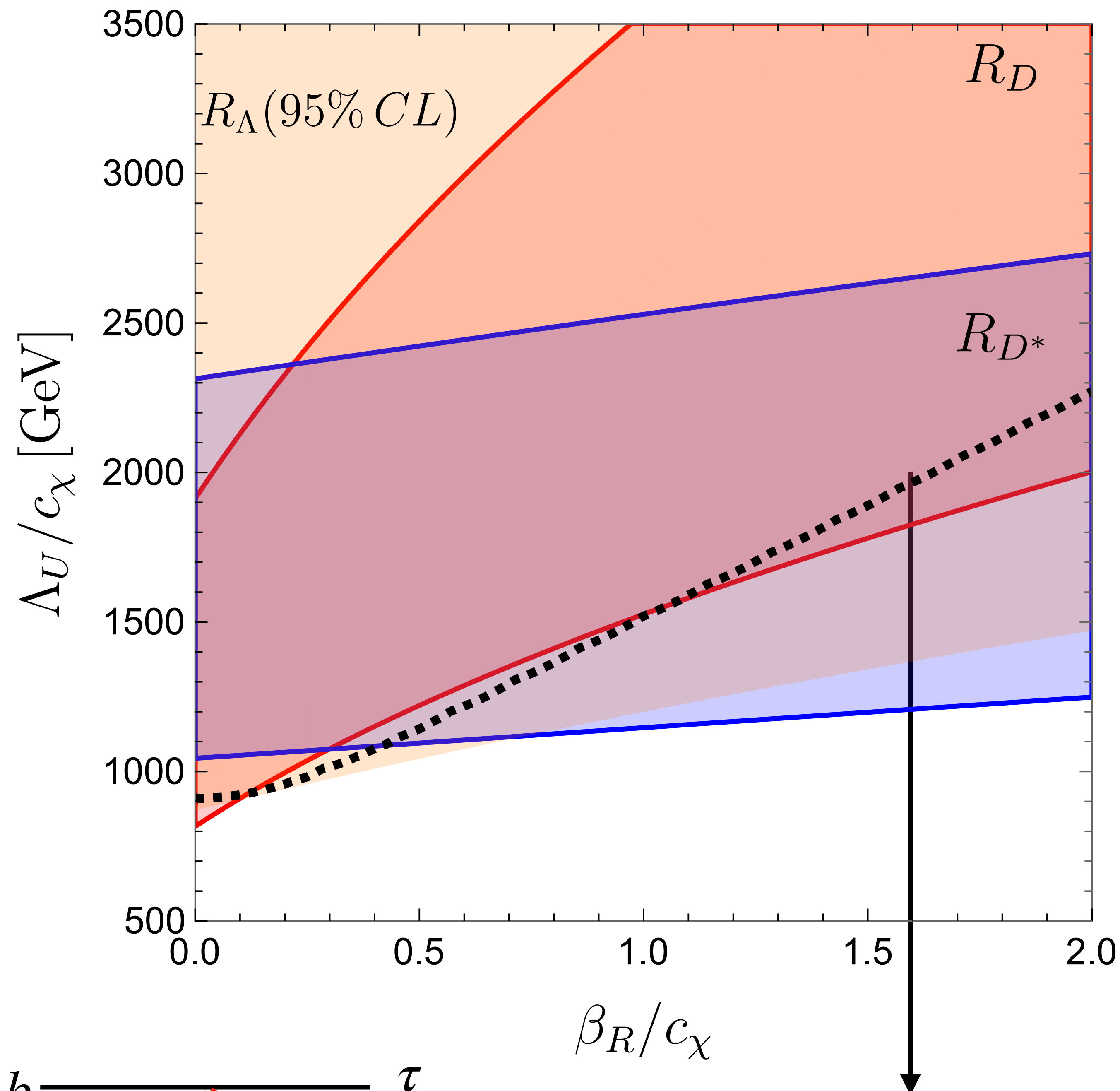
$s_q \tan(\chi) = 0.1 \approx 2.4 V_{cb}$

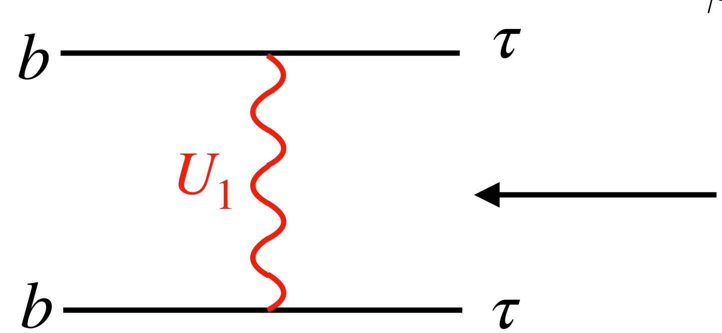


$$C^c_{LL} \propto \frac{s_q}{\Lambda^2}$$



$$C^c_{LR} \propto \frac{\beta_R s_q}{\Lambda_U^2}$$





95% CL CMS exclusion limits on $pp \to \tau\tau$

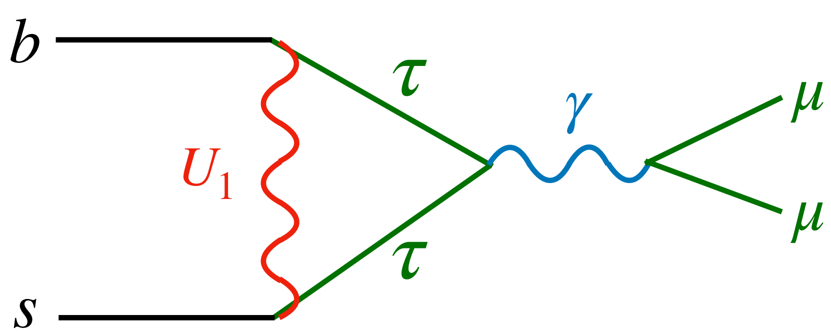
[W. Altmannshofer, P. Stangl, 2103.13370]

Backup: $b \to s\mu\mu$

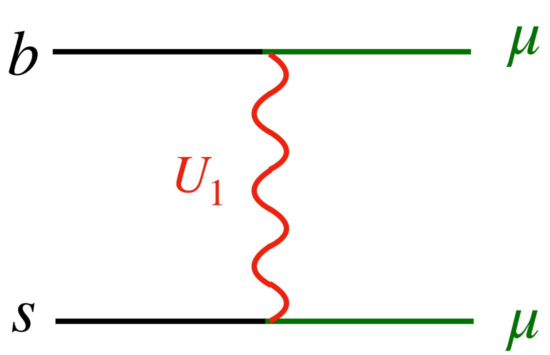
$B \to K^*\mu\mu$

$$\mathscr{L} \supset \frac{2}{v^2} V_{ts}^* V_{tb}\, C_9 (\bar{s}_L \gamma^\mu b_L)(\mu \gamma_\mu \mu)$$

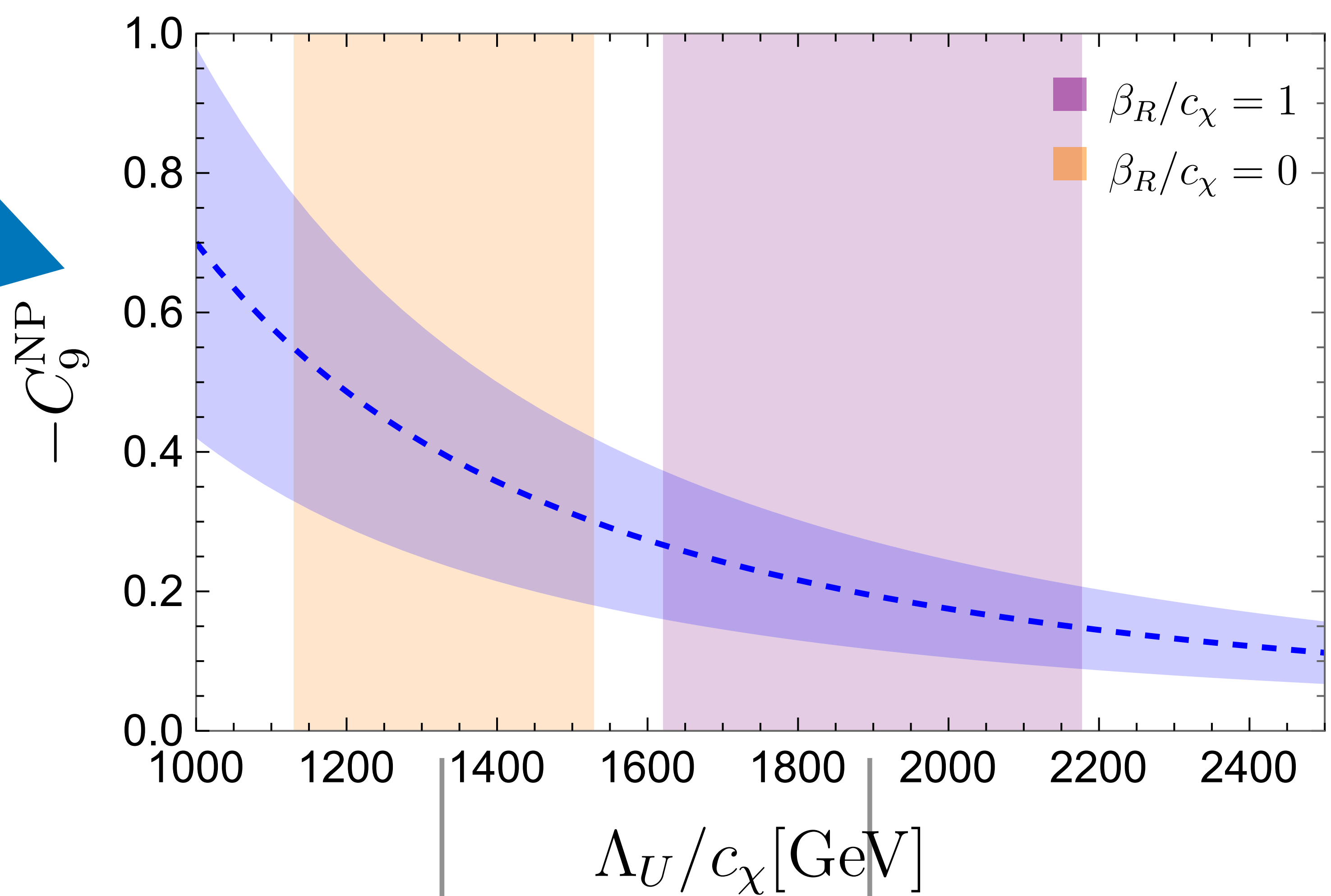
$$C_9^{\rm NP} = -0.75 \pm 0.23 \;\; (\sim 3.4\sigma)$$



$\sim \frac{s_q}{\Lambda_U^2} \times$ loop (Universal)

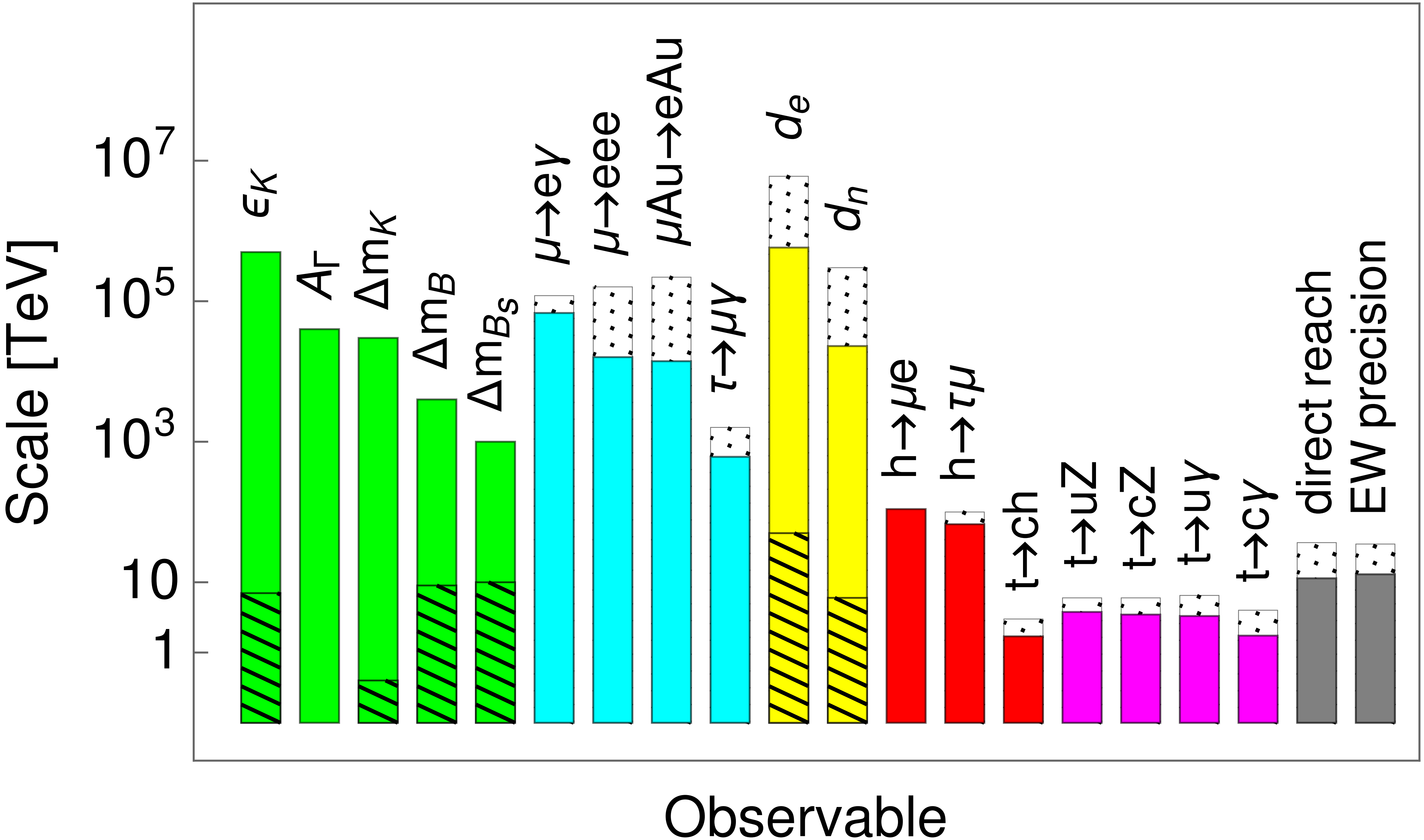


$\sim \frac{s_q s_l^2}{\Lambda_U^2}$



$b \to c\tau\nu$ preferred regions for $s_q \tan(\chi) = 0.1$

Backup: Flavor bounds on NP

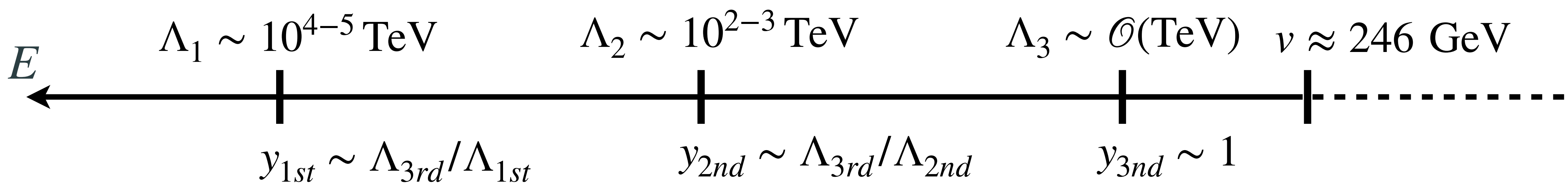


[Physics Briefing Book, 1910.11775]

[Dvali, Shiftman, hep-ph/0001072,Panico, Pomarol, 1603.06609;
Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368; Barbieri, 2103.15635]

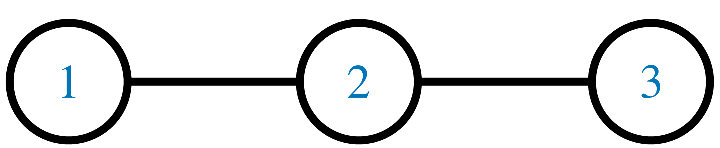
Backup: Multiscale flavor

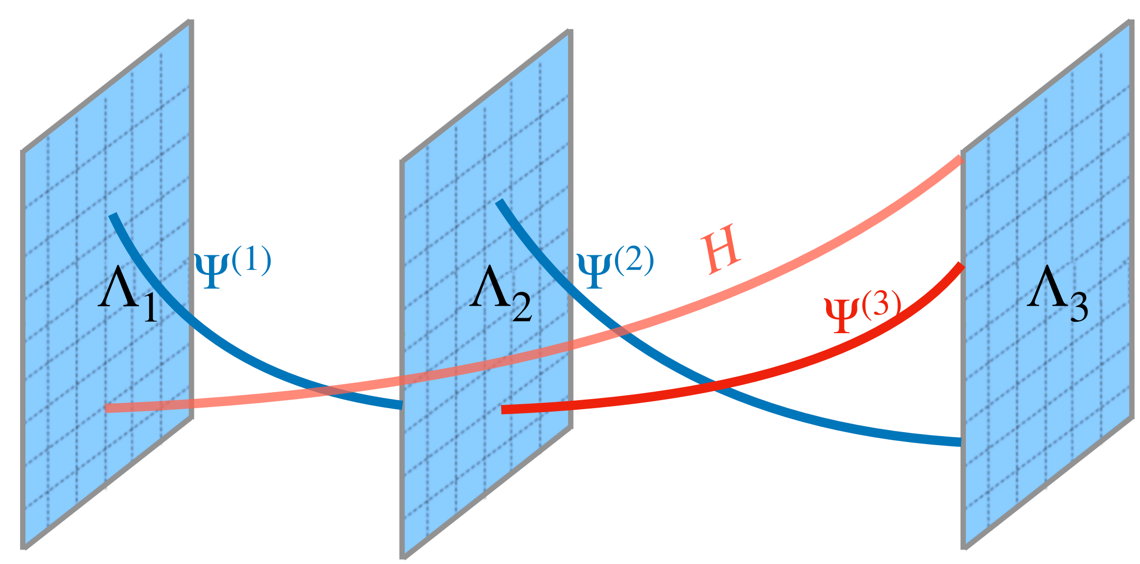
- Safe solution to the flavor puzzle: multiscale origin of the flavor hierarchies.



Gauge deconstruction

Extra-dimensions ⟷ (dual) Composite dynamics





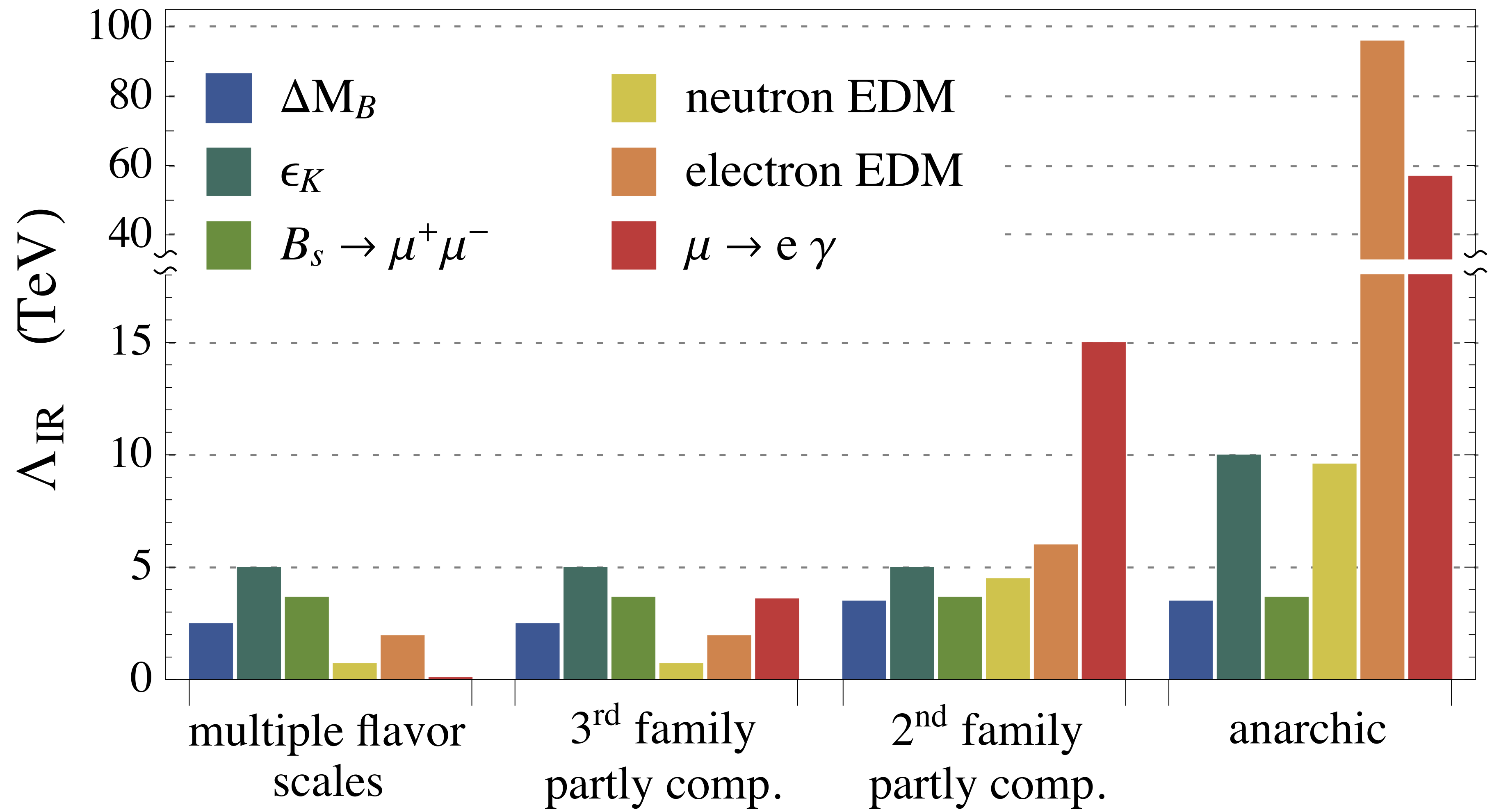
[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368]

[Fuentes-Martin, Isidori, JML, Selimovic, Stefanek, 2203.01952]

Backup: Composite models

[Panico, Pomarol, 1603.06609]

- Example in composite models/RS:

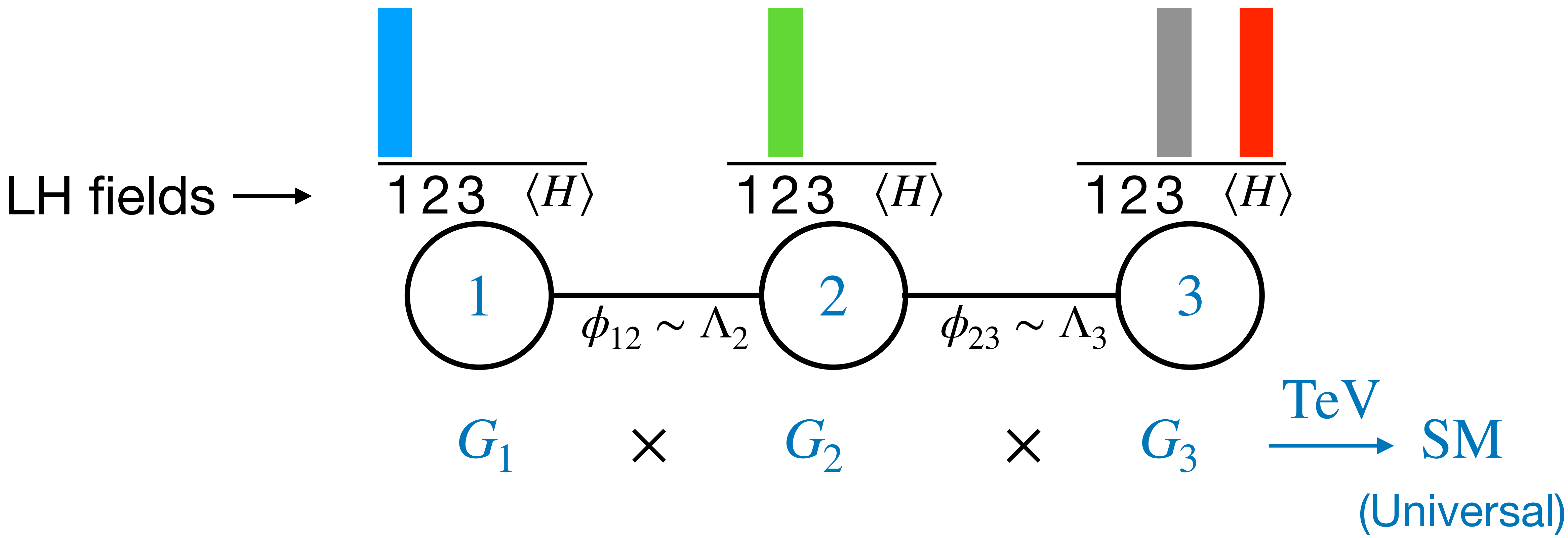


Dangerous dipoles (among others) generated at the IR scale

$$\sim \frac{g_*^2}{16\pi^2}\frac{m_e}{\Lambda_{\rm IR}^2}\,\bar{e}_L\sigma_{\mu\nu}e_R F^{\mu\nu}$$

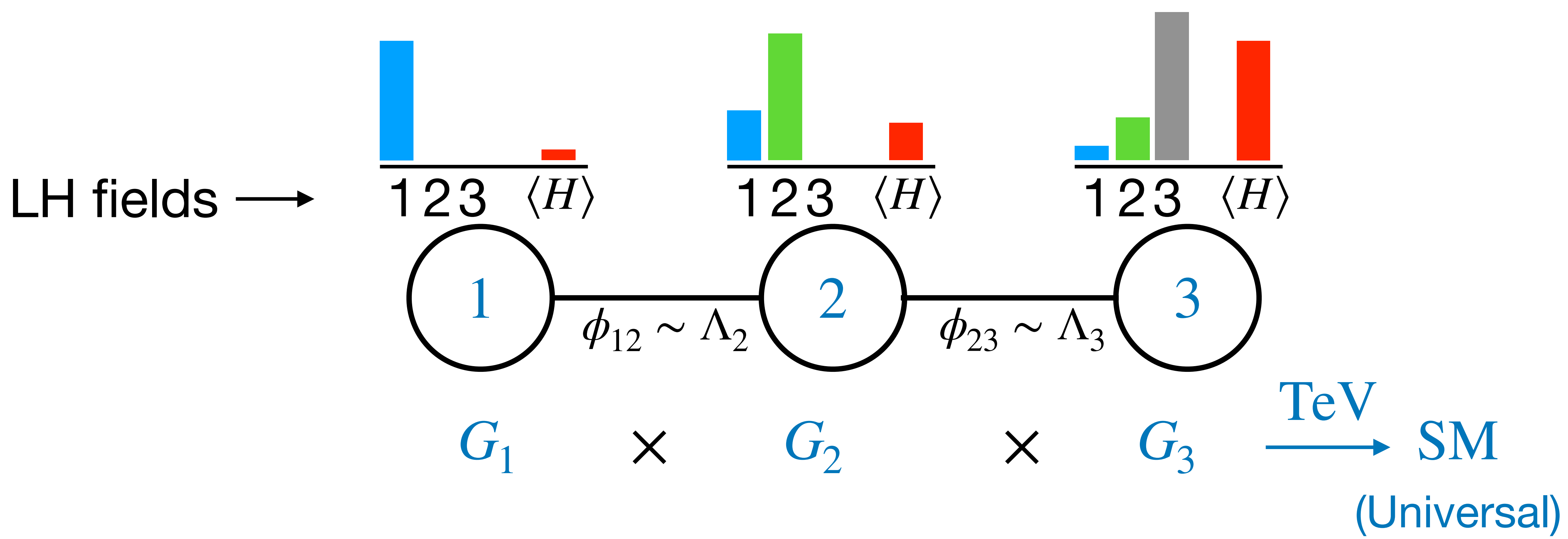
[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368, Allwicher, Isidori, Thomsen, 2011.01946]

Backup: Deconstructing flavor



[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368, Allwicher, Isidori, Thomsen, 2011.01946]

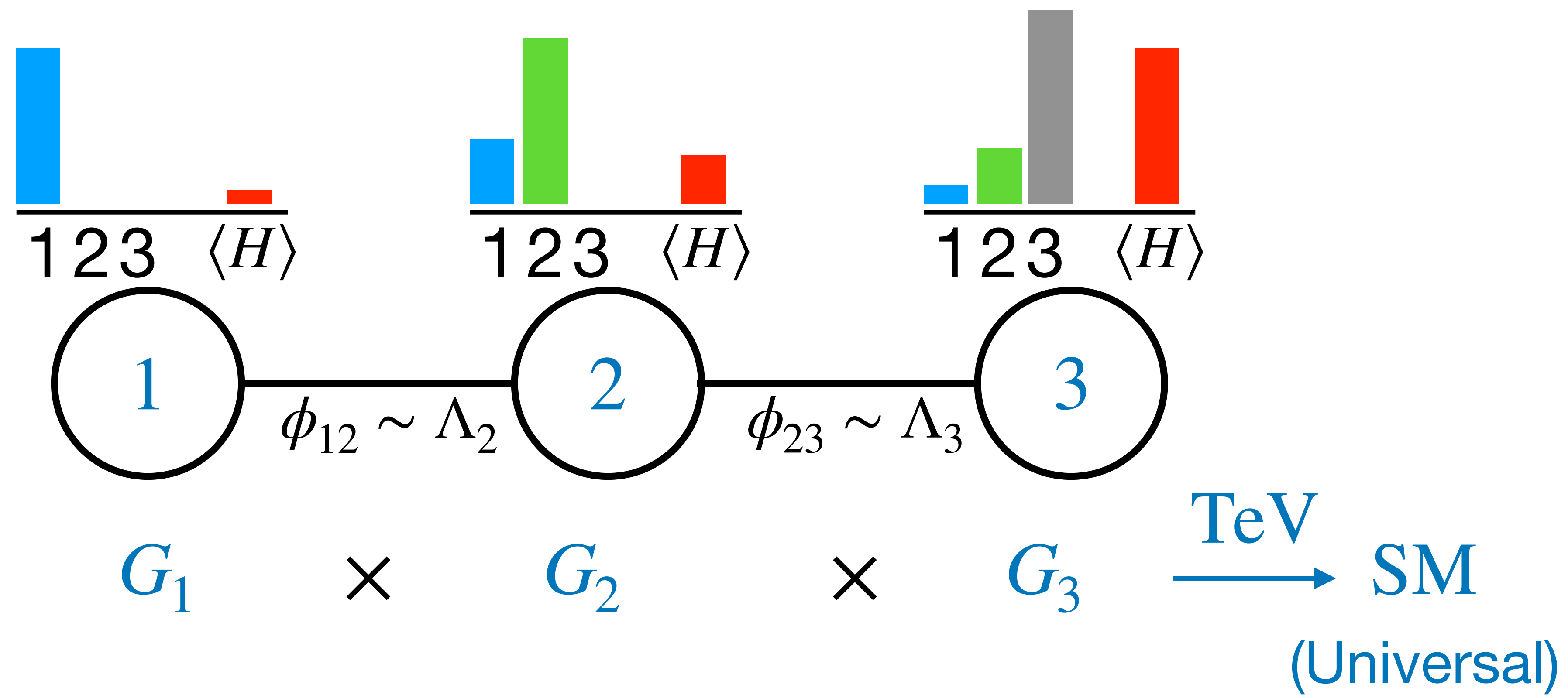
Backup: Deconstructing flavor



[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368, Allwicher, Isidori, Thomsen, 2011.01946]

Backup: Deconstructing flavor

LH fields ⟶



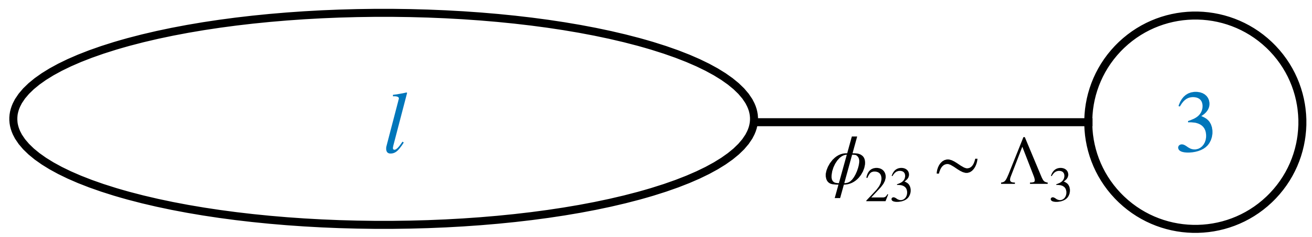
- Only rotations in the LH sector ➡ **No RH or scalar FCNC** ✔

[Crosas, Isidori, JML, Selimović, Stefanek, 2203.01952]

[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368,
Allwicher, Isidori, Thomsen, 2011.01946]

Backup: Gauge deconstruction

- From the TeV scale, we see…



$$\mathrm{SM}_l \quad \times \quad G_3 \xrightarrow{\mathrm{TeV}} \mathrm{SM}$$

(Universal)

- Emerging flavor symmetry:

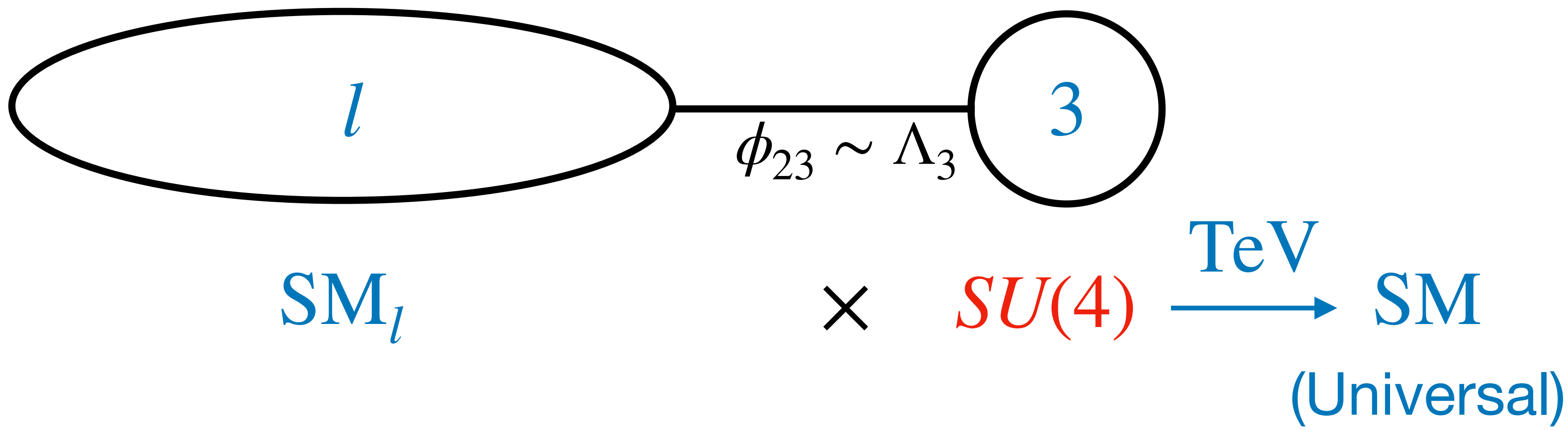
$$\boxed{U(2)}$$

(Only broken minimally in the LH sector)

[Bordone, Cornella, Fuentes-Martin, Isidori, 1712.01368,
Allwicher, Isidori, Thomsen, 2011.01946]

Backup: Gauge deconstruction

- From the TeV scale, we see…



- Emerging flavor symmetry:

$U(2)$

(Only broken minimally in the LH sector)