B-physics anomalies and the flavor problem

Gino Isidori
[*University of Zürich*]

- Introduction
- A closer look to the data
- EFT considerations
- From EFT to simplified models
- Speculations on UV completions
- Conclusions

University of Zurich[UZH]

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Introduction

(*almost*...) all microscopic phenomena we observe in Nature seem to be well described by the SM, a simple and elegant Theory that we continue to call "model" only for historical reasons...

However, despite all its phenomenological successes, the SM has some deep unsolved problems (*hierarchy problem*, *flavor problem*, *neutrino masses, dark-matter, dark energy, inflation*...)

↓

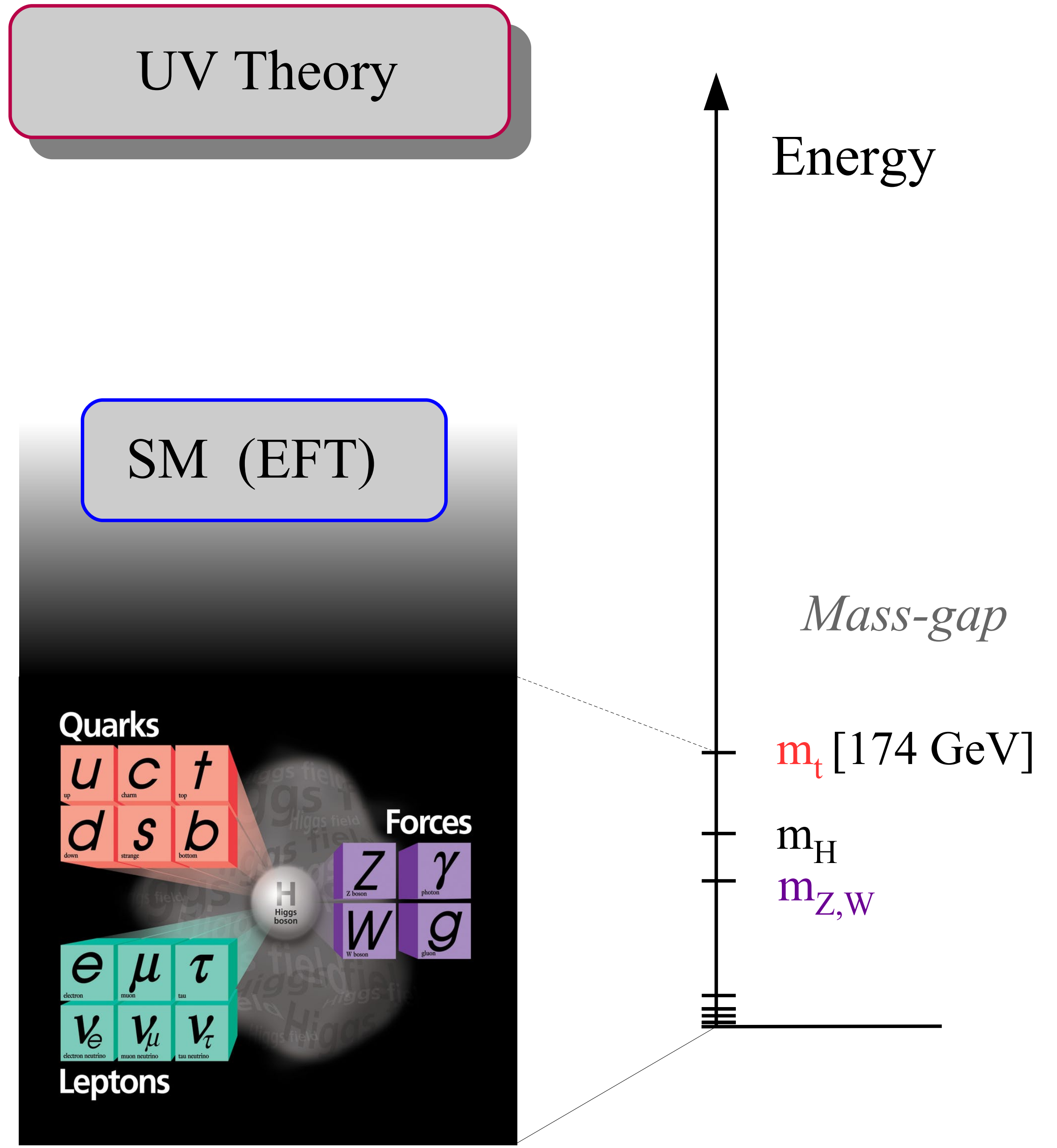
The Standard Model should be regarded as an *Effective Field Theory* (*EFT*)

i.e. the limit (*in the range of energies and effective couplings so far probed*) of a more fundamental theory with new degrees of freedom

Introduction

What we know after the first phase of the LHC is that:

- The Higgs boson is SM-like and is "light" (*completion of the SM spectrum*)
- There is a mass-gap above the SM spectrum



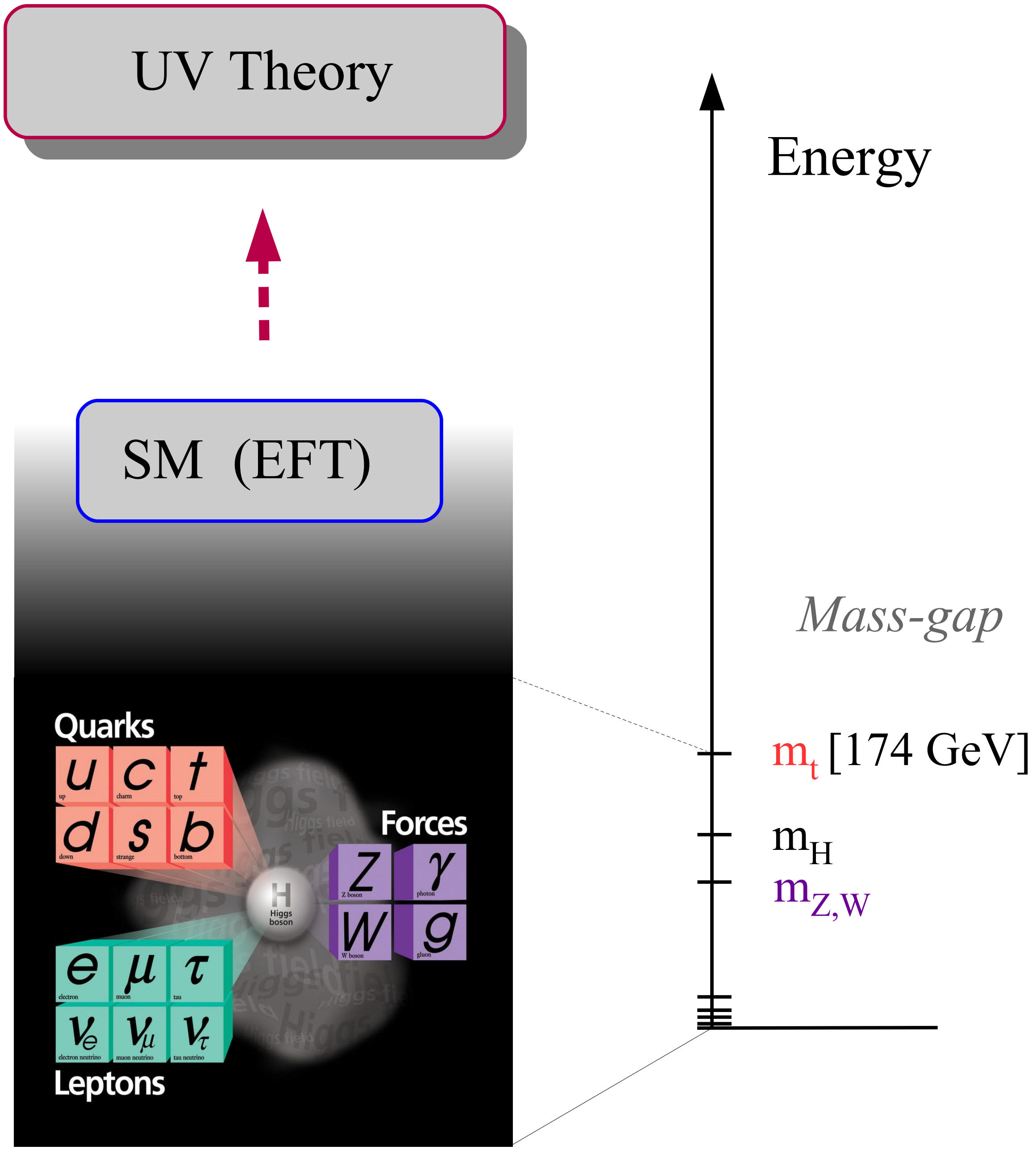
Introduction

What we know after the first phase of the LHC is that:

- The Higgs boson is SM-like and is "light" (*completion of the SM spectrum*)
- There is a mass-gap above the SM spectrum

Reconstructing the UV theory from its low-energy limit is a very difficult problem with no unique solution

[*It took more than 35 years to go from the Fermi Theory to the SM...*]



Introduction

The most interesting hints toward UV dynamics come from possible *un-natural features* of the EFT.

UV Theory

↓

SM (EFT)

Two types of effects in QFT:

$$\mathscr{L}_{\text{SM-EFT}} = \mathscr{L}_{\text{gauge}} + \mathscr{L}_{\text{Higgs}} + \sum_{d,i} \frac{c_i^{[d]}}{\Lambda^{d-4}} O_i^{d\geq 5}$$

Un-natural aspects of low-energy couplings

Violations of accidental symmetries

qualitative UV imprint

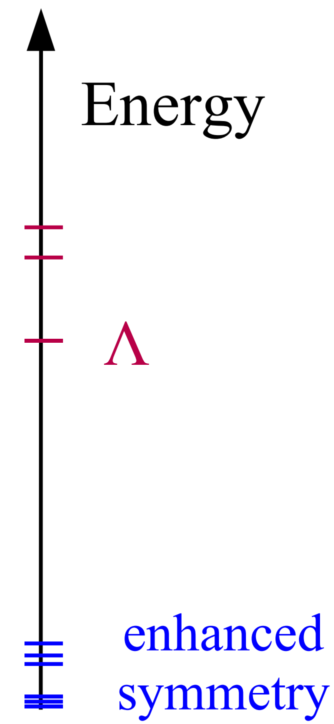
quantitative UV imprint

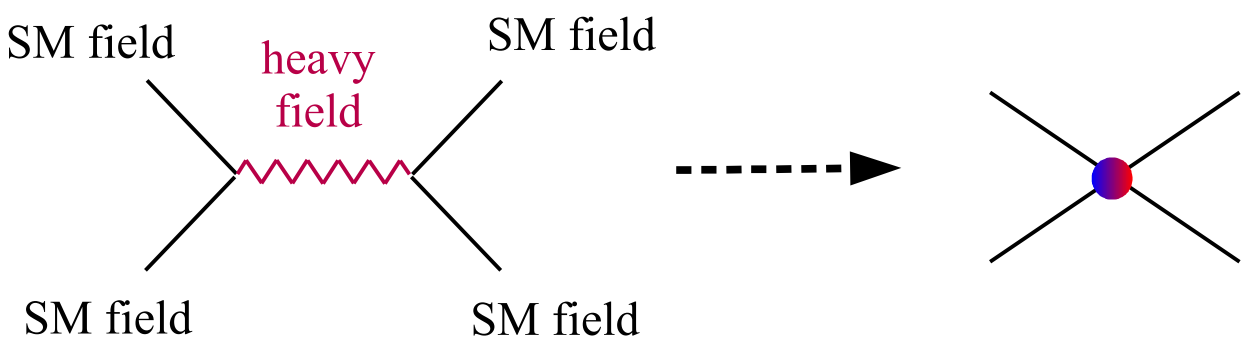
Introduction

$$\mathscr{L}_{\text{SM-EFT}} = \mathscr{L}_{\text{gauge}} + \mathscr{L}_{\text{Higgs}} + \sum_{d,i} \frac{c_i^{[d]}}{\Lambda^{d-4}} O_i^{d\geq 5}$$

If a symmetry arises accidentally in the low-energy theory, we expect it to be violated by higher dim. ops

Violations of accidental symmetries





At large distances, not enough "variables" to describe the violation of the symmetry
[~ *multipole expansion*]

▶ *Introduction*

$$\mathscr{L}_{\text{SM-EFT}} = \mathscr{L}_{\text{gauge}} + \mathscr{L}_{\text{Higgs}} + \sum_{d,i} \frac{c_i^{[d]}}{\Lambda^{d-4}} O_i^{d\geq 5}$$

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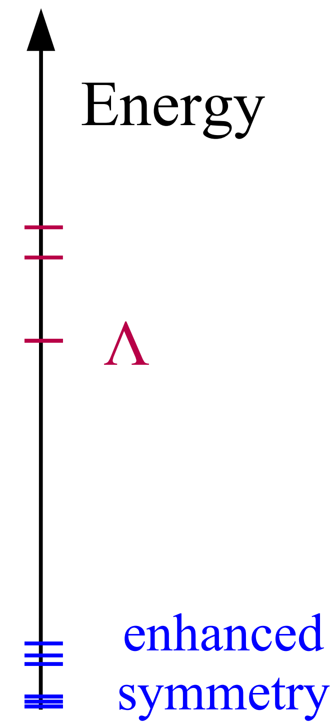
Violations of accidental symmetries



Well-known examples from the past...

Eg: *Low-energy theory:* QED + QCD
Accidental symm.: Flavor [$U(1)^{n_f}$]
Violated by: Weak interactions → $G_F \sim (250\ \text{GeV})^{-2}$

Eg: *Low-energy theory:* SM, 2 generations
Accidental symm.: CP
Violated by: "Super-weak" interactions → $\frac{(G_F m_t V_{ts} V_{td})^2}{4\pi^2} \sim (10^4\ \text{TeV})^{-2}$

Introduction

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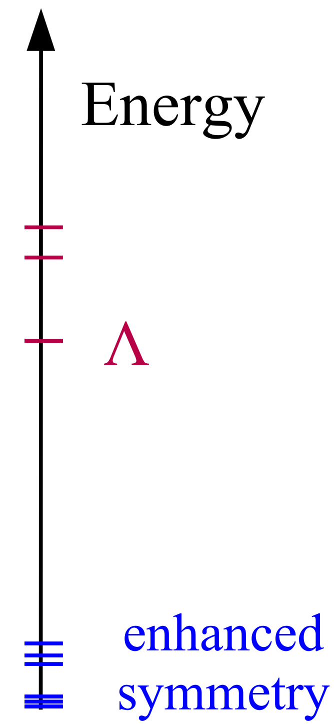

If a symmetry arises accidentally in the low-energy theory, we expect it to be violated by higher dim. ops

Well-known examples from the past...

…the violations of Lepton Flavor Universality recently reported by experiments belong to this category

Introduction

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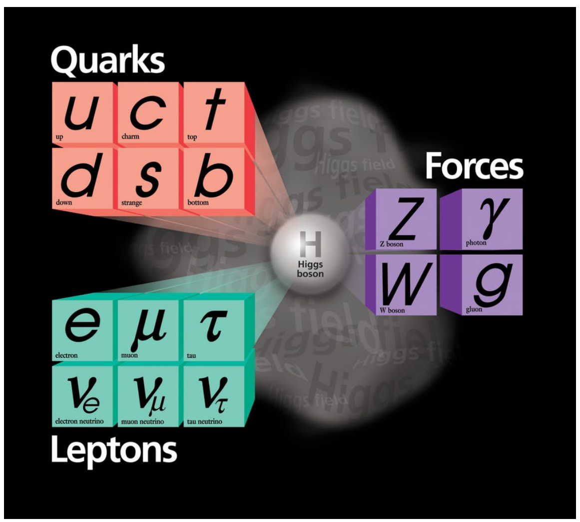
Natural
(fully dictated by gauge symmetry)

Non-trivial
UV imprints

I $m_H^2 H^2$

II $y_{ij}\, \psi_i \psi_j H$

Un-natural aspects of the SM couplings



UV Theory

↓

SM (EFT)

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Natural (*fully dictated by gauge symmetry*) → $\mathcal{L}_{\text{gauge}}$

$\mathcal{L}_{\text{Higgs}}$: Non-trivial UV imprints

Un-natural aspects of the SM couplings

↓

I. Electroweak hierarchy problem

Instability of the Higgs mass under quantum corrections → (*some*) New Physics (*coupled at least to* H & t) in the TeV domain

$$m_H^2\big|_{\Lambda} + \text{NP} \rightarrow m_H^2\big|_{\text{Phys}}$$

$$\Delta m_H^2 \sim \Lambda^2$$

Introduction

$$\mathcal{L}_{\text{SM-EFT}} = \mathcal{L}_{\text{gauge}} + \mathcal{L}_{\text{Higgs}} + \sum_{d,i} \frac{c_i^{[d]}}{\Lambda^{d-4}} O_i^{d\geq 5}$$

Natural (*fully dictated by gauge symmetry*)

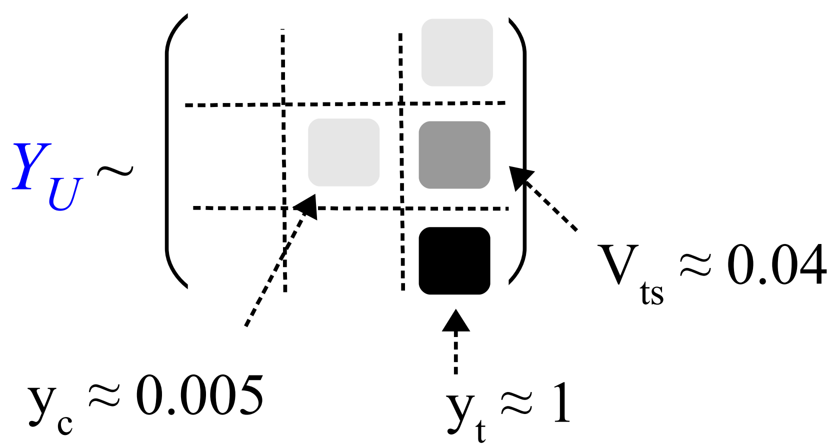
Non-trivial UV imprints

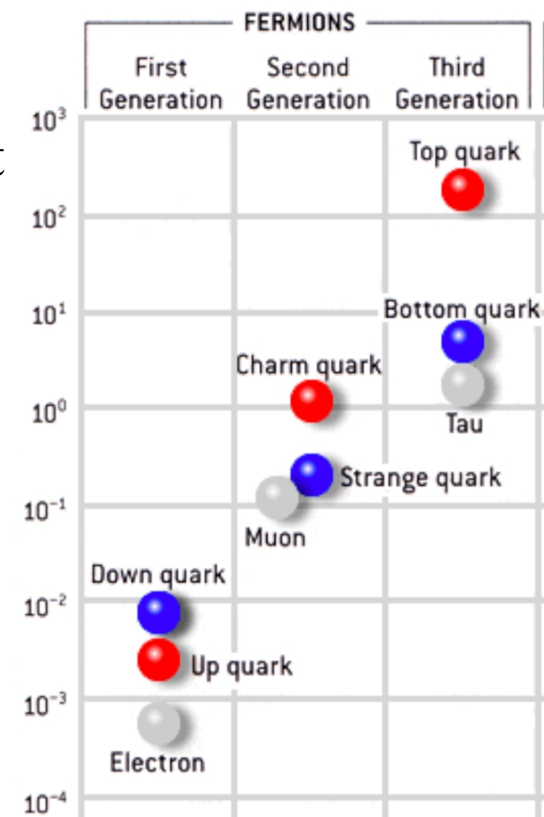
Un-natural aspects of the SM couplings

I. Electroweak hierarchy problem

II. Flavor problem

The entries of the Yukawa couplings span 5 orders of magnitude & do not appear at all accidental:





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Natural (*fully dictated by gauge symmetry*)

Non-trivial UV imprints

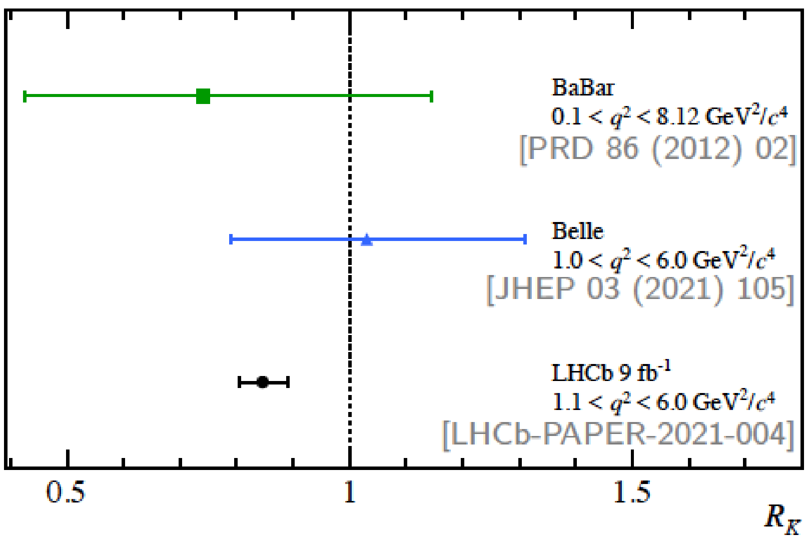
Un-natural aspects of the SM couplings

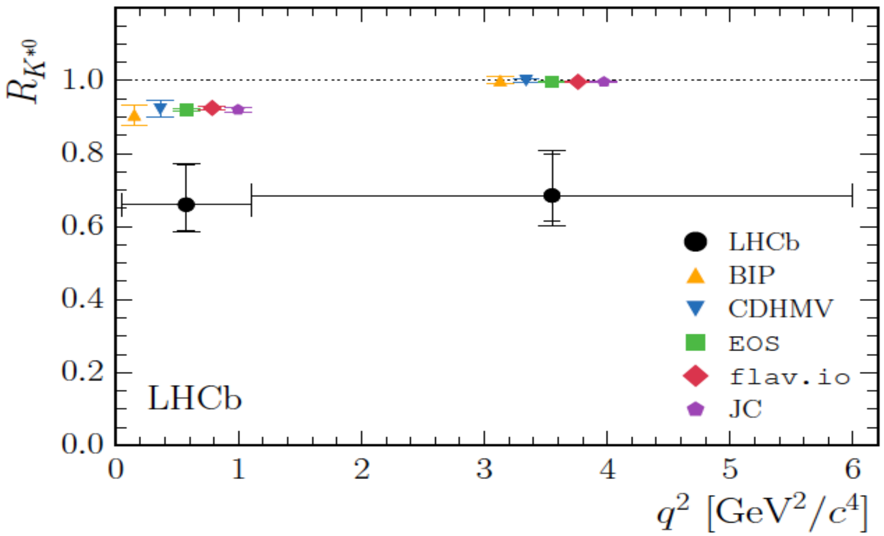
I. Electroweak hierarchy problem — *Instability of the Higgs mass under quantum corrections* → (*some*) New Physics in the TeV domain

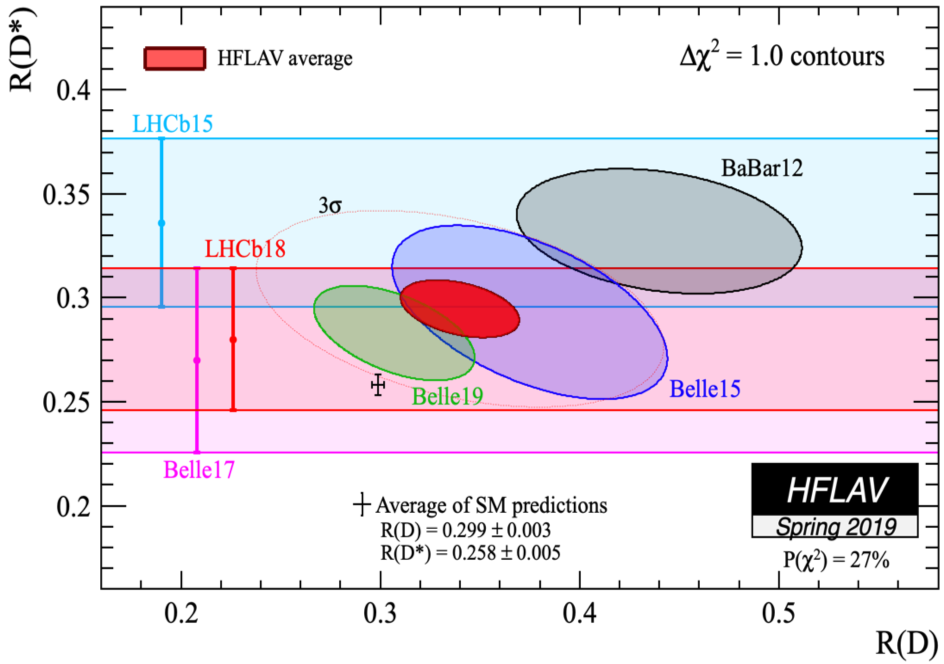
II. Flavor problem — *Un-natural hierarchies in the couplings describing fermion masses* → flavor non-universal dynamics (*at some energy scale*)

As I will argue in the rest of this talk, the violations of LFU suggest to "attack" these two problems together, and not one at a time (*as often done in the past*)

A closer look to the data







A closer look to the data

Since 2013 results in semi-leptonic B decays started to exhibit tensions with the SM predictions connected to a possible violation of Lepton Flavor Universality

More precisely, we seem to observe a different behavior (*beside pure kinematical effects*) of different lepton species in the following processes:

- $b \to s\, l^+ l^-$ (neutral currents): μ vs. e
- $b \to c\, l\nu$ (charged currents): τ vs. light leptons (μ, e)

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N.B: LFU is an accidental symmetry of the SM Lagrangian in the limit where we neglect the lepton Yukawa couplings.

LFU is badly broken in the Yukawa sector: $y_e \sim 3\times10^{-6}$, $y_\mu \sim 3\times10^{-4}$, $y_\tau \sim 10^{-2}$

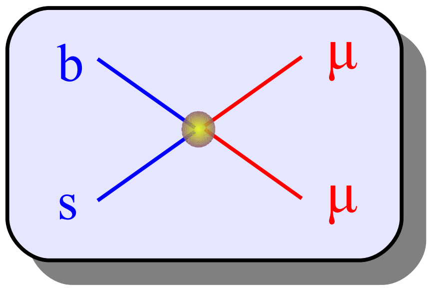
but all the lepton Yukawa couplings are small compared to SM gauge couplings, giving rise to the (*approximate*) universality of decay amplitudes which differ only by the different lepton species involved

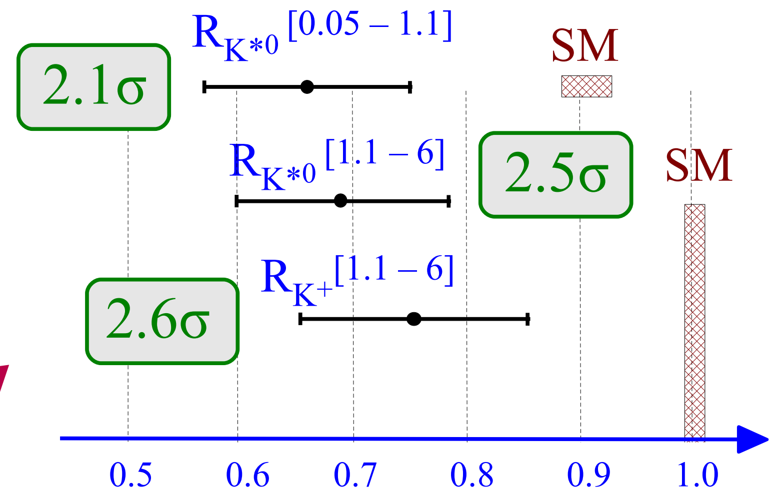
The B-physics anomalies

- $b \to s\, l^+ l^-$ (neutral currents): μ vs. e

High significance: several observables pointing to the same coherent picture [several new results in 2021]

$\Gamma(H_b \to H_s\, \mu\mu)/\Gamma(H_b \to H_s\, ee)$





LFU ratios

[LHCb – Spring 2017]

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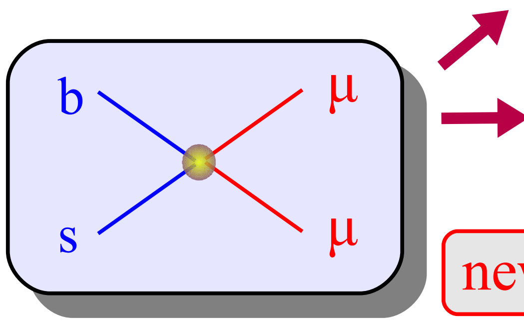

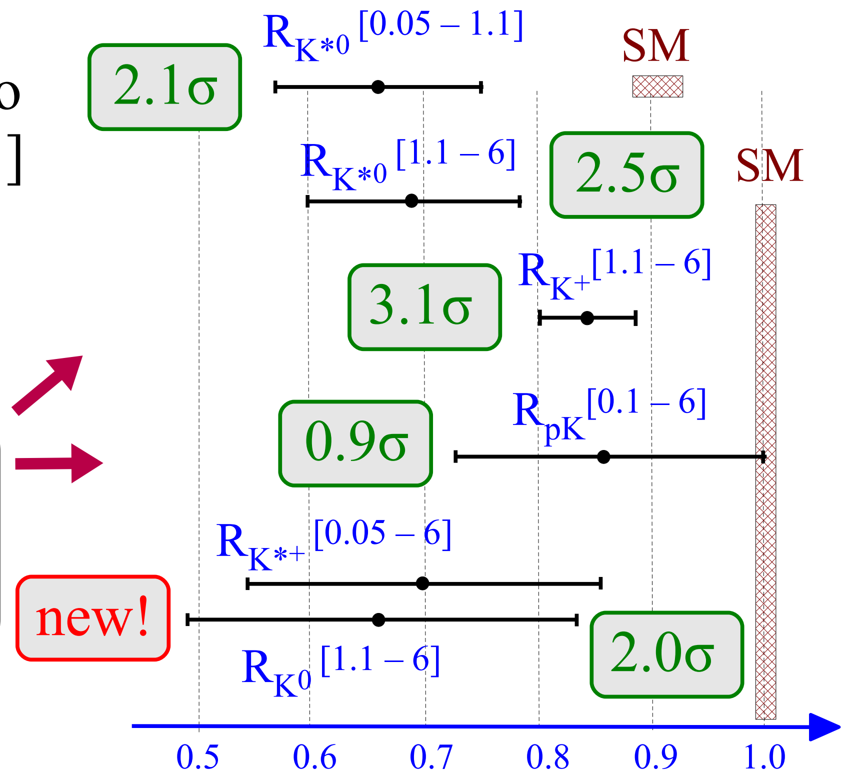

LFU ratios

[LHCb – Autumn 2021]

▶ *The B-physics anomalies*

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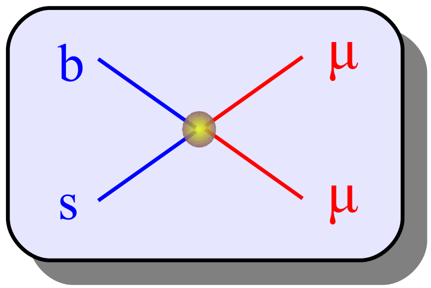

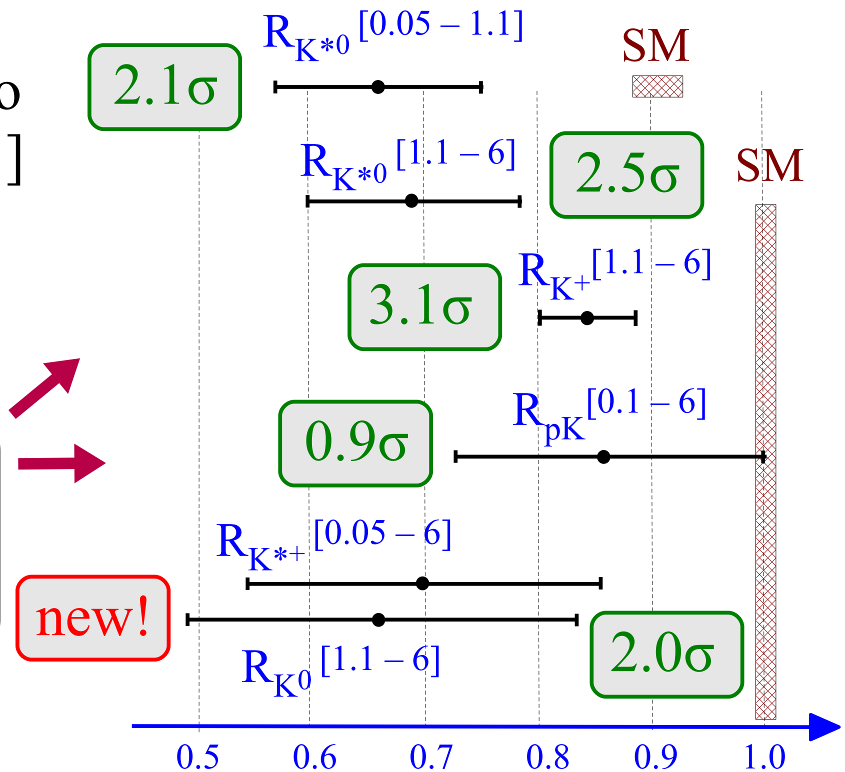

$BR(B_s \to \mu\mu)$

$BR_{exp} = (2.85 \pm 0.32) \times 10^{-9}$ ATLAS+CMS+LHCb '21

$BR_{SM} = (3.66 \pm 0.14) \times 10^{-9}$ 2.3σ

The B-physics anomalies

- $b \rightarrow s\, l^+ l^-$ (neutral currents): μ vs. e

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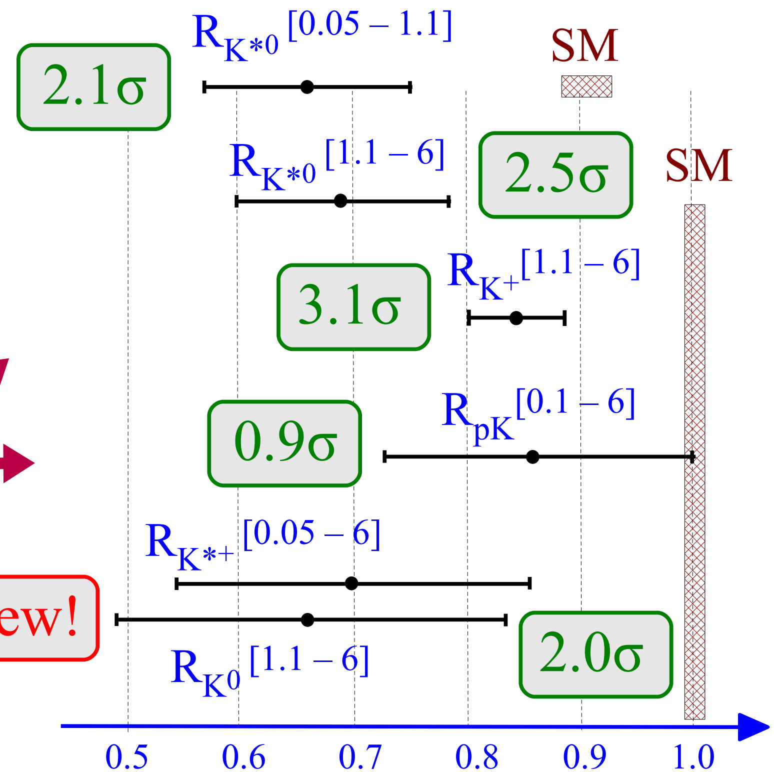
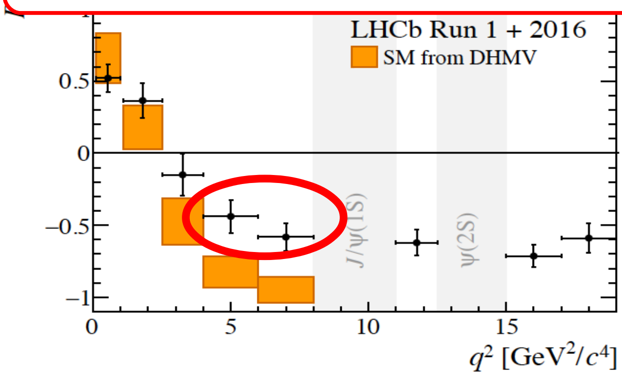
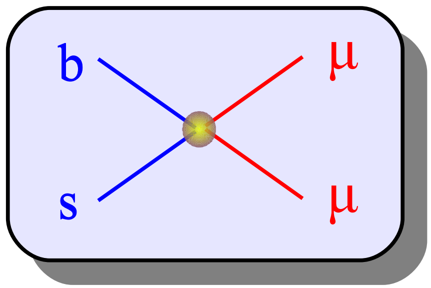
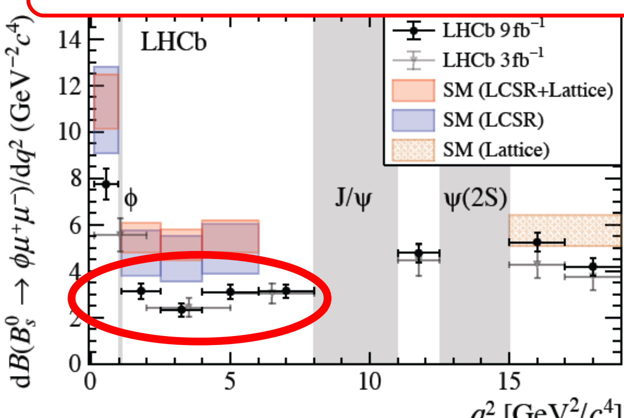


$B \rightarrow K^* \mu\mu$ angular distribution





$B \rightarrow H\, \mu\mu$ branching ratios



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2.3σ

The B-physics anomalies

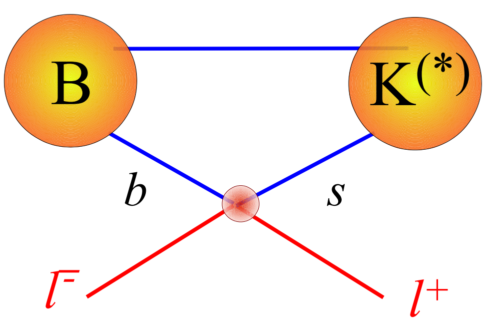
- $b \to s\, l^+ l^-$ (neutral currents): μ vs. e

build an EFT Lagrangian
evolve it down to $\mu \sim m_b$
evaluate hadronic matrix elements

$$\mathcal{L}_{\rm eff} = \frac{4G_F}{\sqrt{2}} V_{tb}^* V_{ts} \sum_i \mathcal{C}_i \mathcal{O}_i$$

FCNC operators:

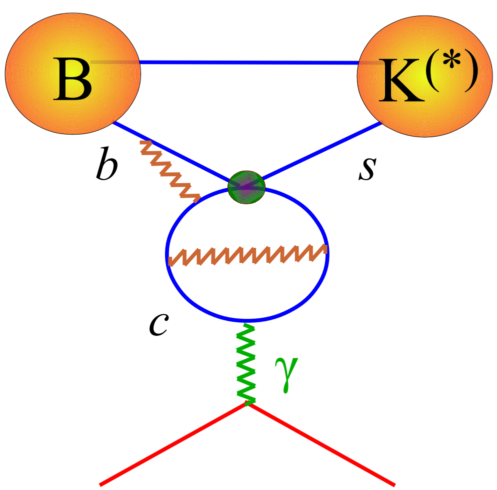
$$\mathcal{O}_{10}^{\ell} = (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \gamma_5 \ell)$$
$$\mathcal{O}_{9}^{\ell} = (\bar{s}_L \gamma_\mu b_L)(\bar{\ell}\gamma^\mu \ell)$$



"easy" & "clean"

Four-quark operators:

$$\mathcal{O}_2 = (\bar{s}_L \gamma_\mu b_L)(\bar{c}_L \gamma_\mu c_L)$$
$$\vdots$$



"difficult"

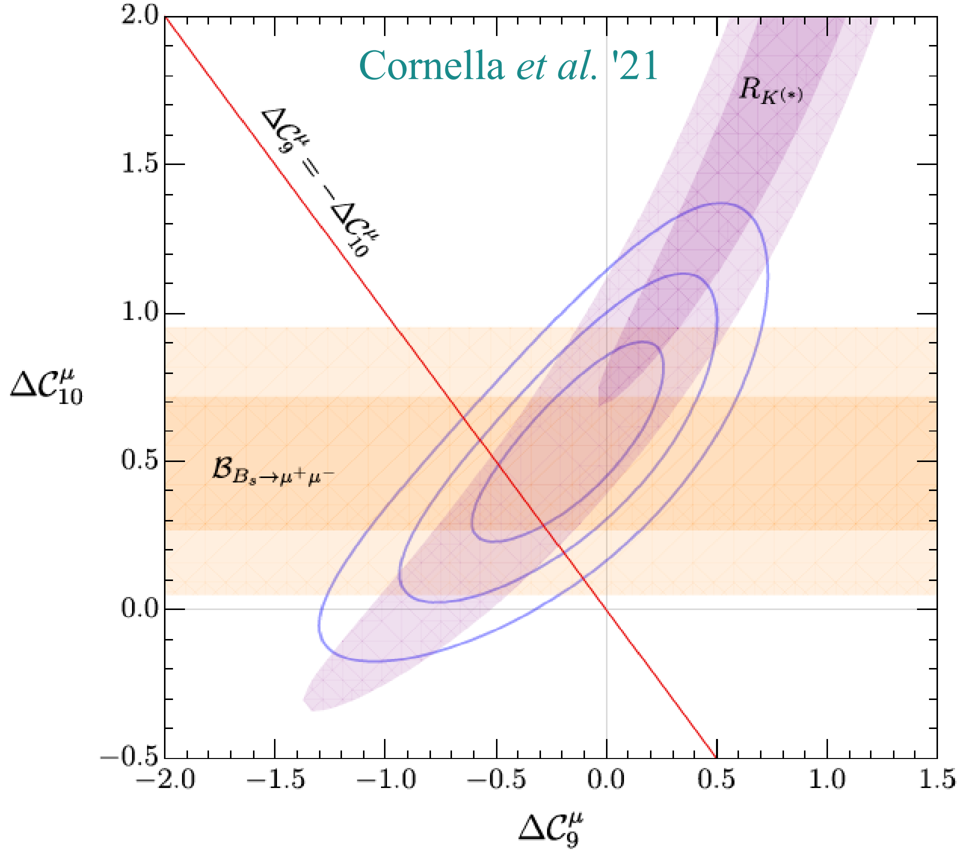
↓

induces $\Delta C_9^{\rm Univ}$

N.B.: long-distance effect cannot induce LFU breaking terms (→ LFU ratios *"clean"*) and cannot induce axial-current contributions (→ $B_s \to \mu\mu$ *"clean"*)

The B-physics anomalies

- $b \to s\, l^+ l^-$ (neutral currents): μ vs. e



Conservative fit using "clean obs." only

5.0σ significance of NP hypothesis $\Delta C_9^\mu = -\Delta C_{10}^\mu$ vs. SM

Clean short-distance effect
$[\Delta C_i^\mu = C_i^\mu - C_i^e]$:

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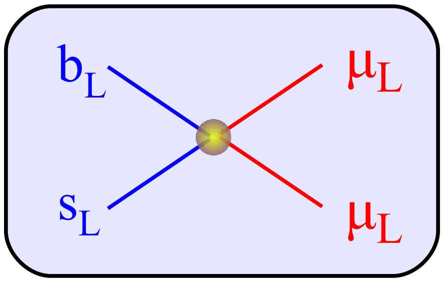
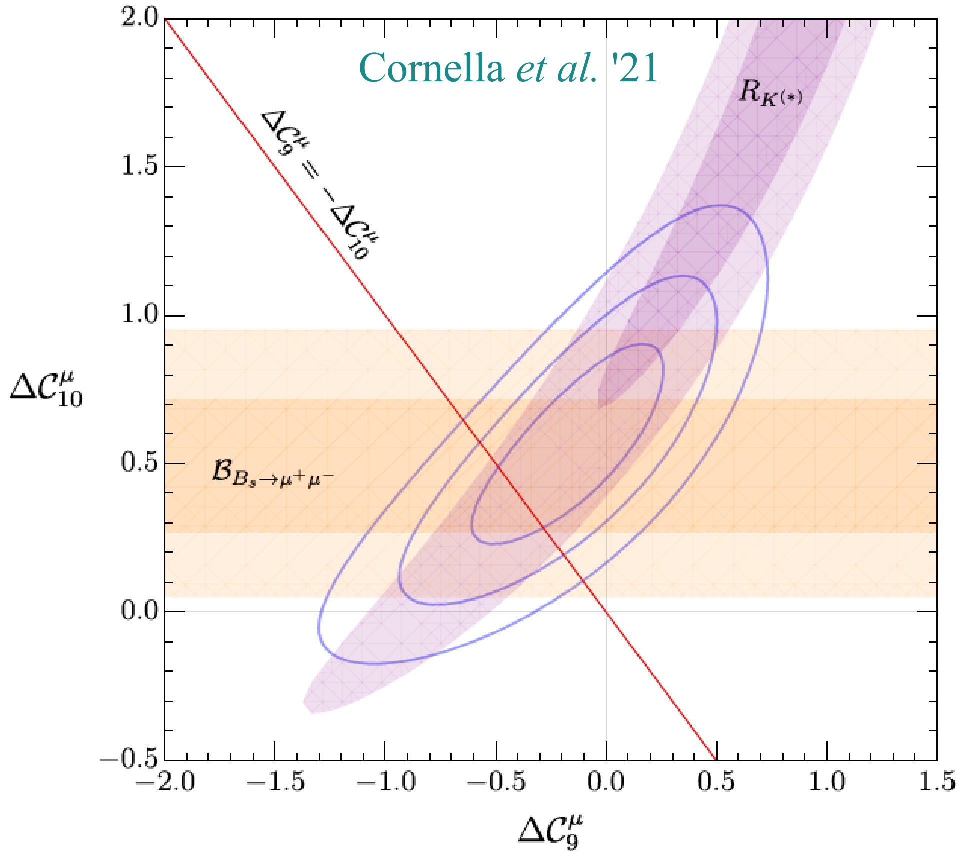
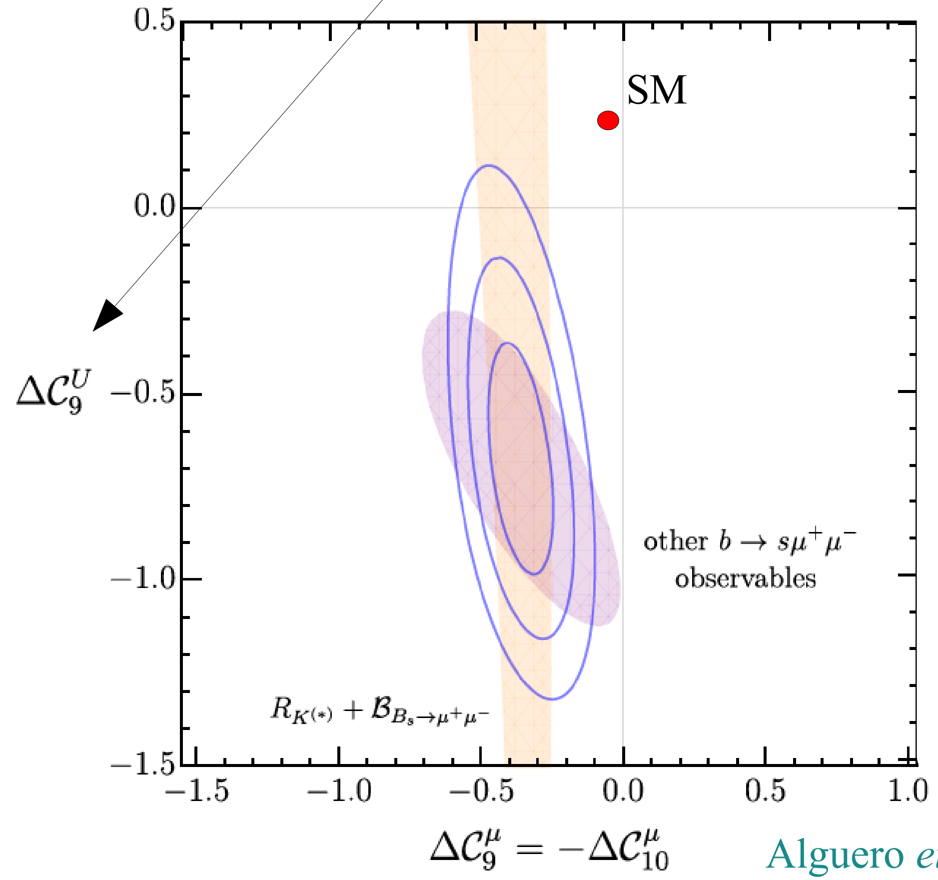


The B-physics anomalies

- $b \rightarrow s\ l^+l^-$ (neutral currents): μ vs. e

Lepton-universal shift to C_9
(*sensitive to charm re-scattering*)





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5.0σ significance of NP hypothesis $\Delta C_9^\mu = -\Delta C_{10}^\mu$ vs. SM

>> 5σ best estimate of charm contribution

Alguero *et al.* '19
Ciuchini *et al.* '20
Li-Sheng *et al.* '21
Altmanshofer & Stangl '21

4.3σ *global significance* of NP (*very conserv. estimate*)

GI, Lancierini Owen, Serra '21

The B-physics anomalies

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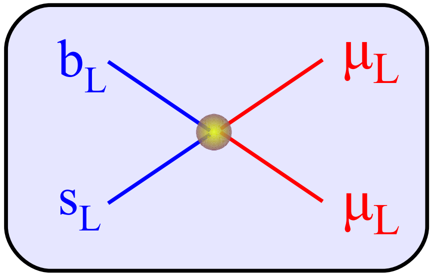
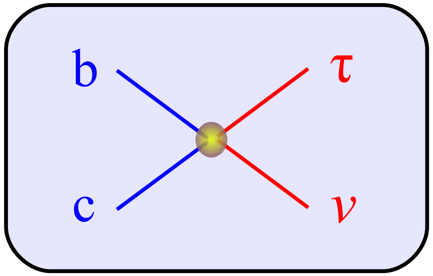
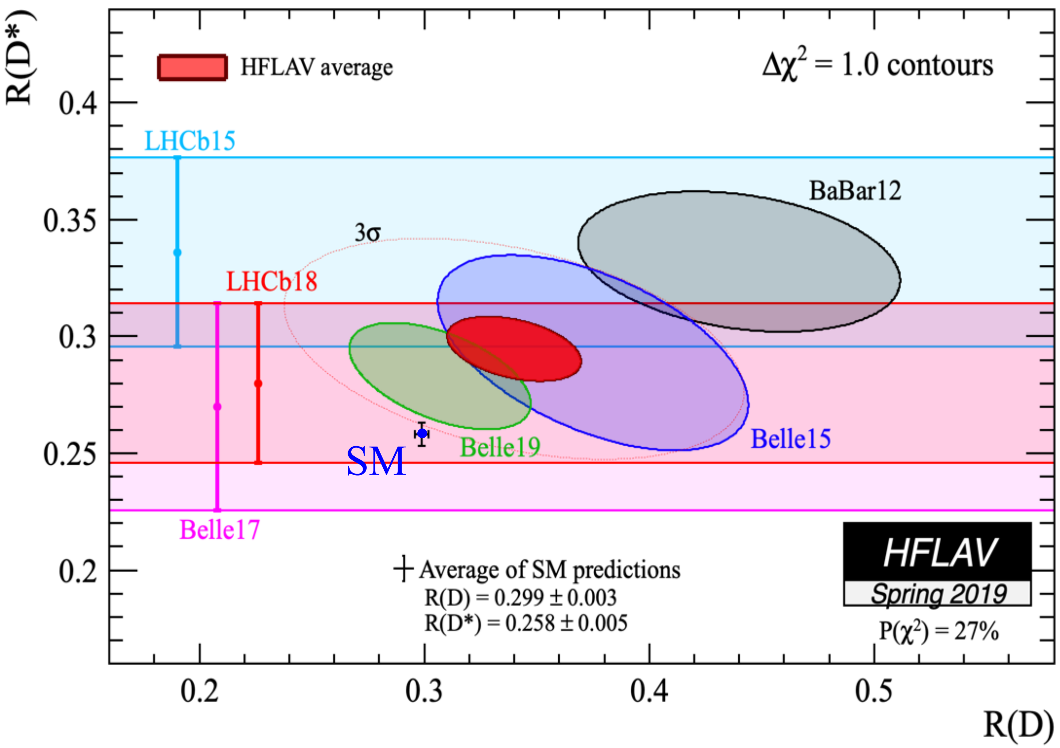


- $b \to c\, l\nu$ (charged currents): τ vs. light leptons (μ, e)



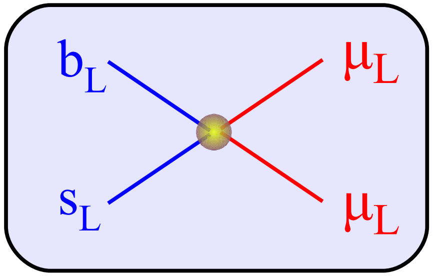


$$R(X) = \frac{\Gamma(B \to X\, \tau\nu)}{\Gamma(B \to X\, l\nu)} \qquad X = D \text{ or } D^*$$

- Clean SM predictions (*uncertainties cancel in the ratios*)
- Consistent results by 3 different exp.ts: 3.1σ excess over SM
- Slower progress

The B-physics anomalies

- $b \to s\, l^+ l^-$ (neutral currents): μ vs. e



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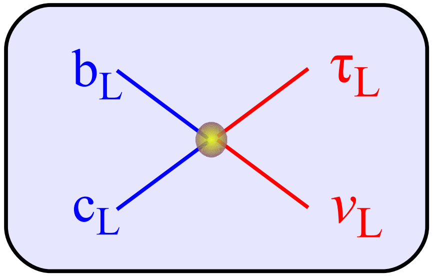

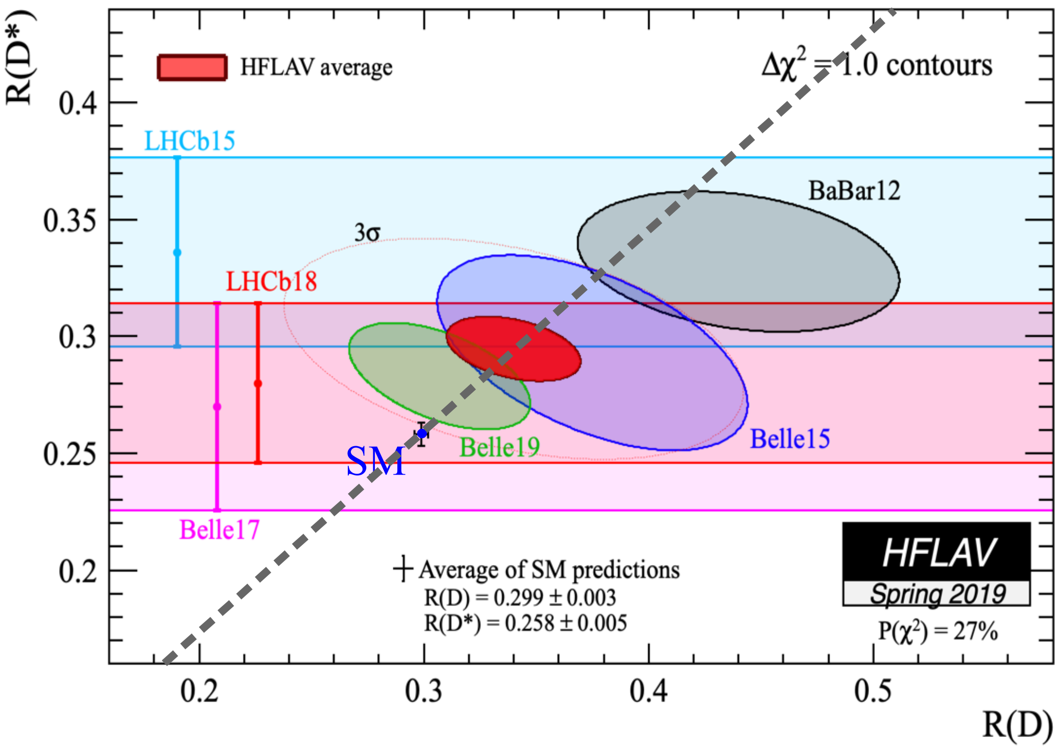

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- Clean SM predictions (*uncertainties cancel in the ratios*)
- Consistent results by 3 different exp.ts: 3.1σ excess over SM
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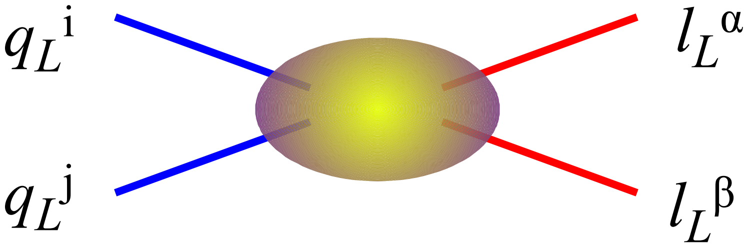
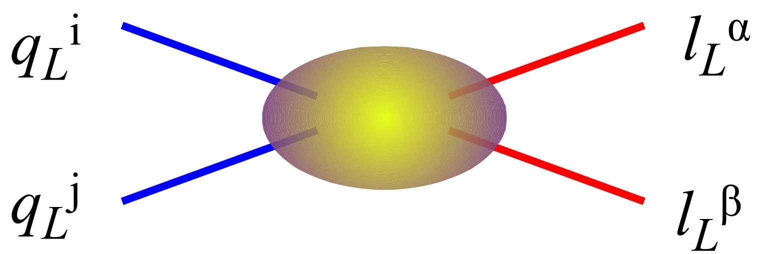
- Large NP effect competing with tree-level SM amplitude
- Left-handed NP amplitude describe well data (*but other options still possible*)

EFT considerations



EFT considerations

- Anomalies are seen only in semi-leptonic (quark×lepton) operators
- We definitely need non-vanishing left-handed current-current operators although other contributions are also possible



Bhattacharya *et al.* '14
Alonso, Grinstein, Camalich '15
Greljo, GI, Marzocca '15
(+many others...)

- Large coupling [*competing with SM tree-level*] in bc → $l_3\, \nu_3$ [R_D, R_{D^*}]
- Small coupling [*competing with SM loop-level*] in bs → $l_2\, l_2$ [R_K, R_{K^*}, ...]

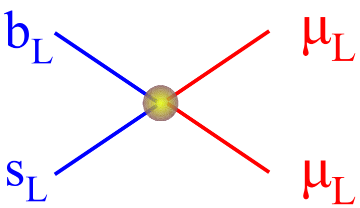
↓

$C_{ij\alpha\beta}$ = large for 3rd generation fields + small terms for 2nd (& 1st) generations → *Link to pattern of the Yukawa couplings !*

EFT considerations

Data point to (short-distance) NP effects in operators of the type

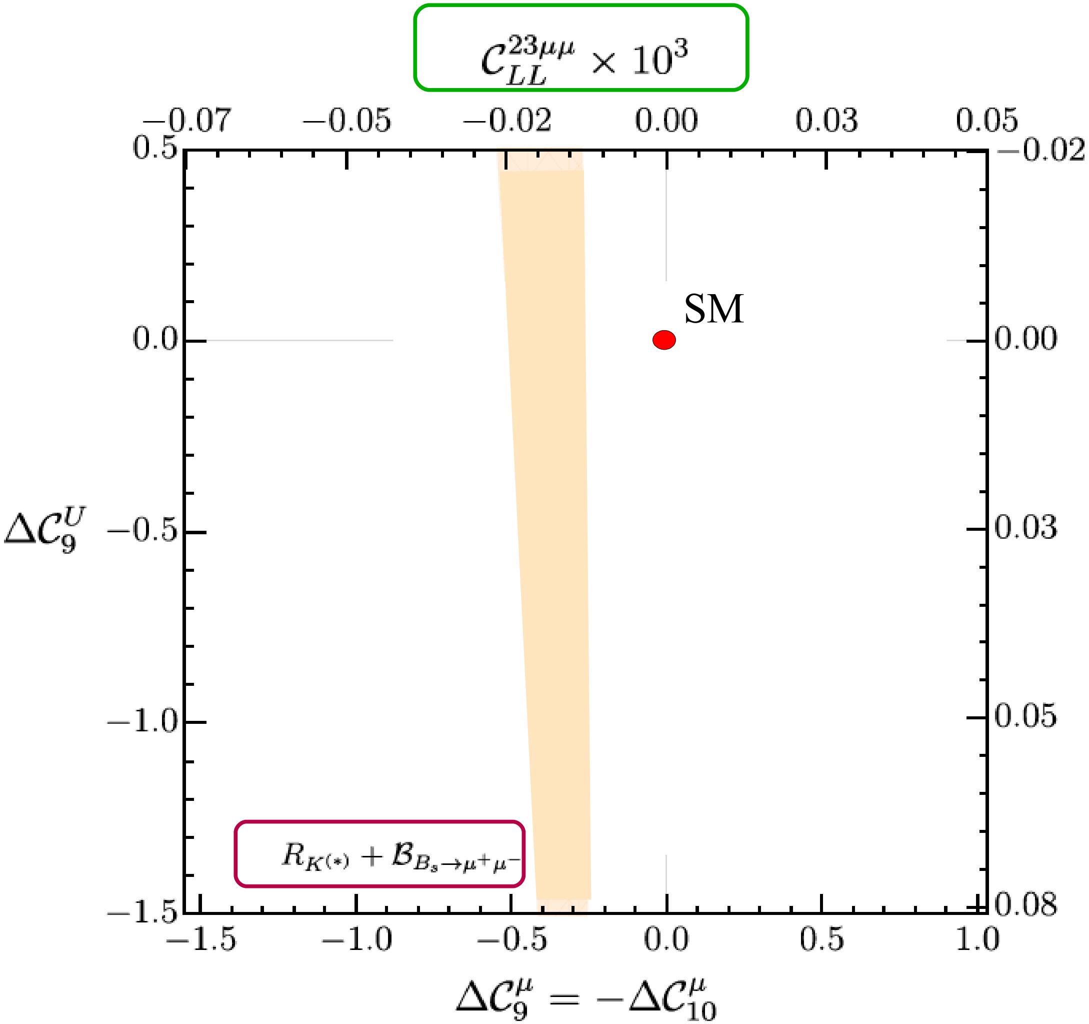
$$\mathcal{O}_{LL}^{ij\alpha\beta} = (\bar{q}_L^i \gamma_\mu \ell_L^\alpha)(\bar{\ell}_L^\beta \gamma_\mu q_L^j)$$



$\sim 4\times10^{-5}\, G_{Fermi}$

super-weak interaction!

$C_{LL}^{23\mu\mu}$ ➡ $\Delta C_9^\mu = -\Delta C_{10}^\mu$



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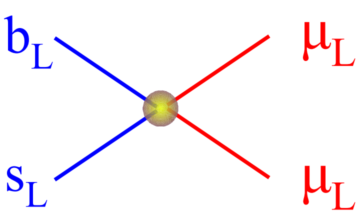
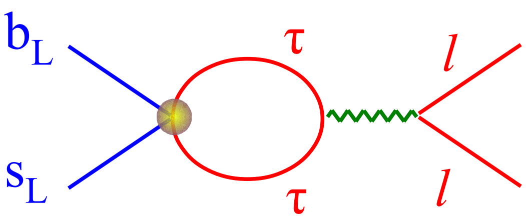
✔ $O(10^{-1})$ suppress. for each 2^{nd} gen. l_L



$\sim 4\times10^{-5}\ G_{Fermi}$

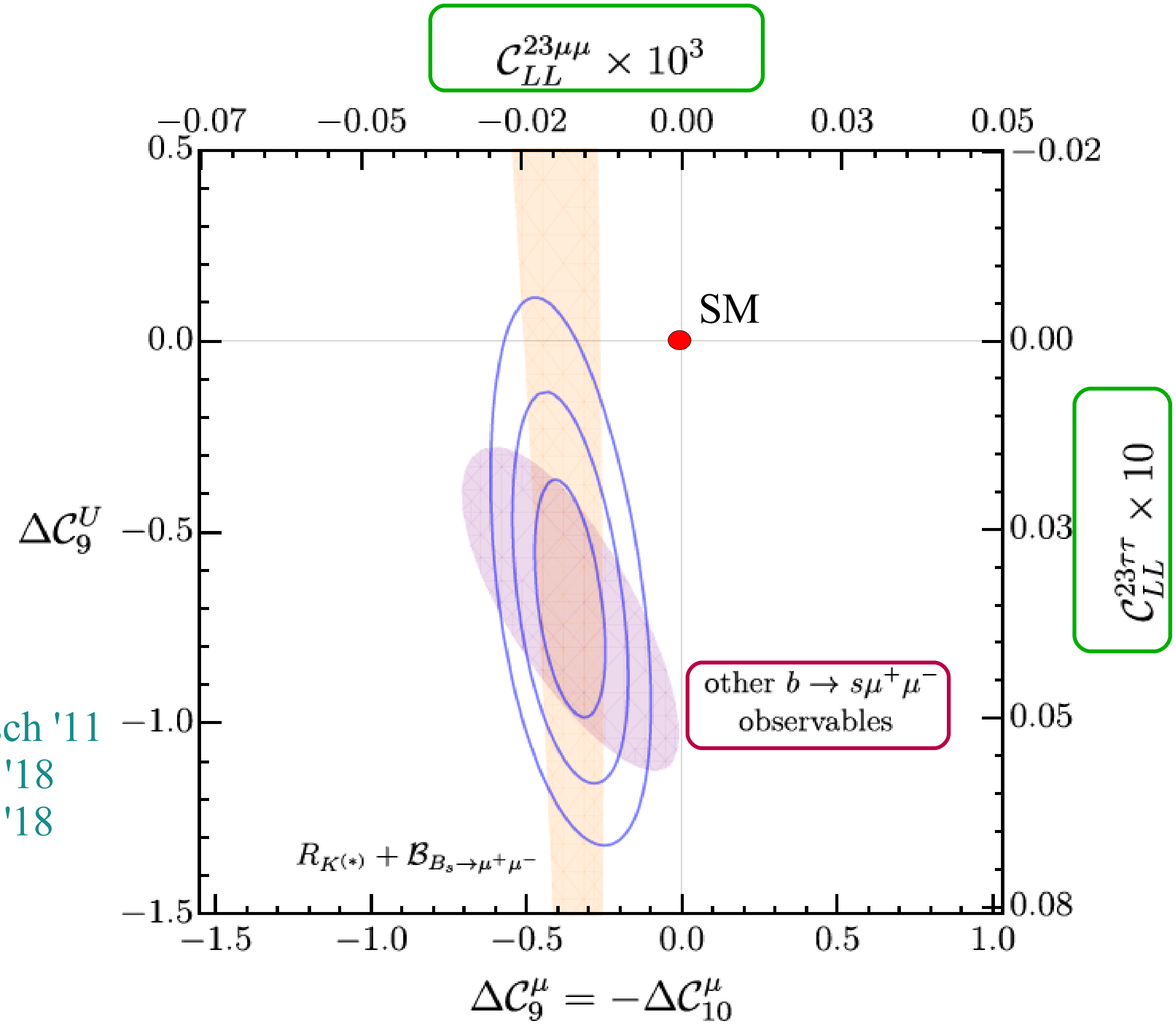
super-weak interaction!

$C_{LL}^{23\mu\mu} \Rightarrow \Delta C_9^\mu = -\Delta C_{10}^\mu$



$C_{LL}^{23\tau\tau} \Rightarrow \Delta C_9^{Univ}$

Bobeth & Haisch '11
Crivellin *et al.* '18
Alguero *et al.* '18

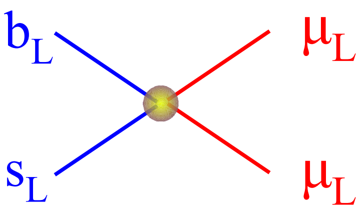


EFT considerations

Data point to (short-distance) NP effects in operators of the type

$$\mathcal{O}_{LL}^{ij\alpha\beta} = (\bar{q}_L^i \gamma_\mu \ell_L^\alpha)(\bar{\ell}_L^\beta \gamma_\mu q_L^j)$$

✔ $O(10^{-1})$ suppress. for each 2nd gen. l_L



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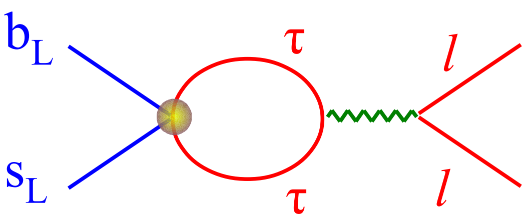
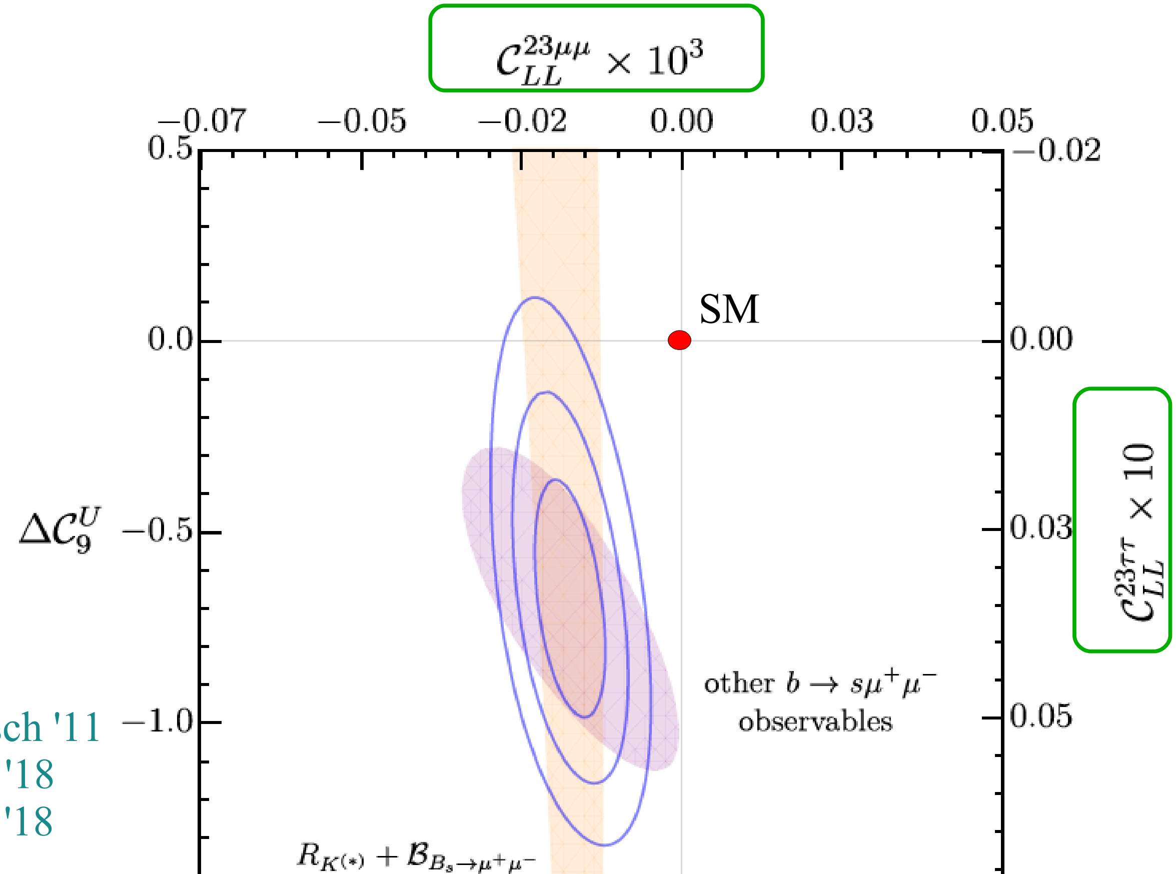


$C_{LL}^{23\tau\tau} \Rightarrow \Delta C_9^{Univ}$

→ Link to CC anomaly

Bobeth & Haisch '11
Crivellin *et al.* '18
Alguero *et al.* '18



Size (and need) of $C^{23\tau\tau}$ pre-dicted from CC before this effect was observed in NC Greljo *et al.* '17

EFT considerations

Data point to (short-distance) NP effects in operators of the type

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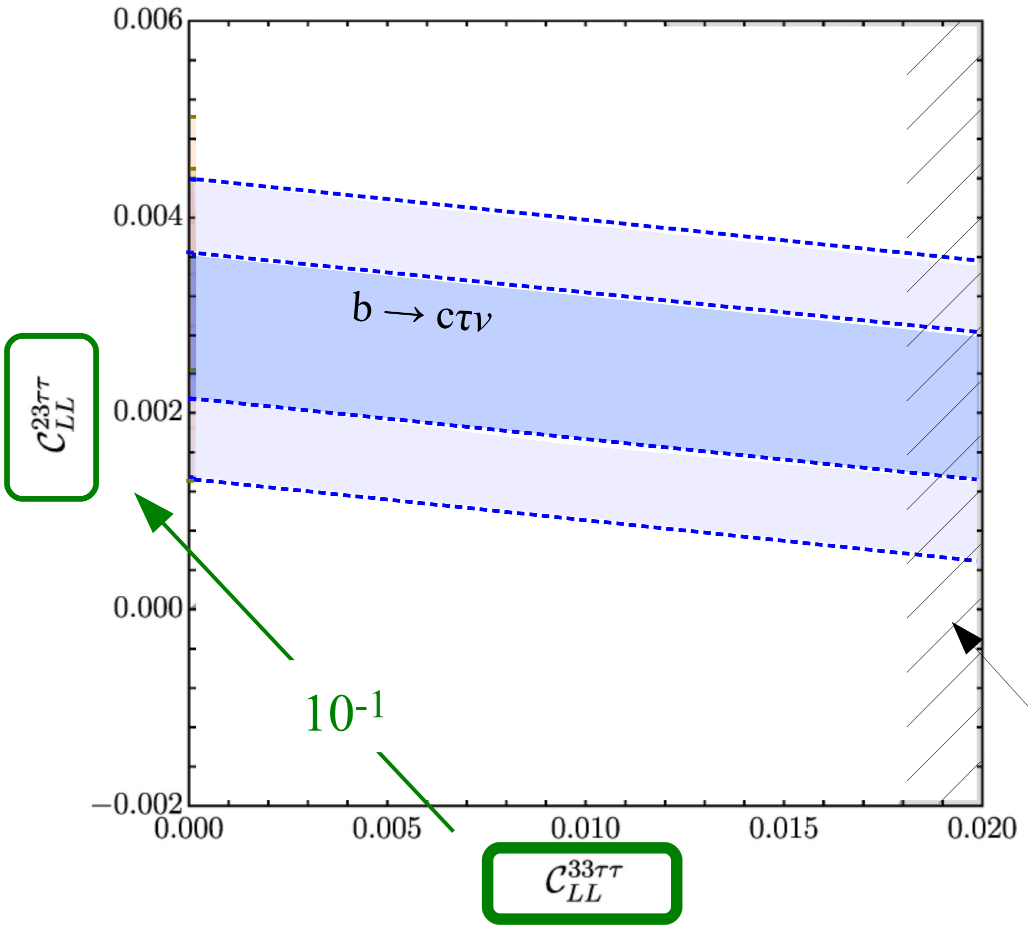
- ✔ O(10^{-1}) suppress. for each 2nd gen. q_L or l_L

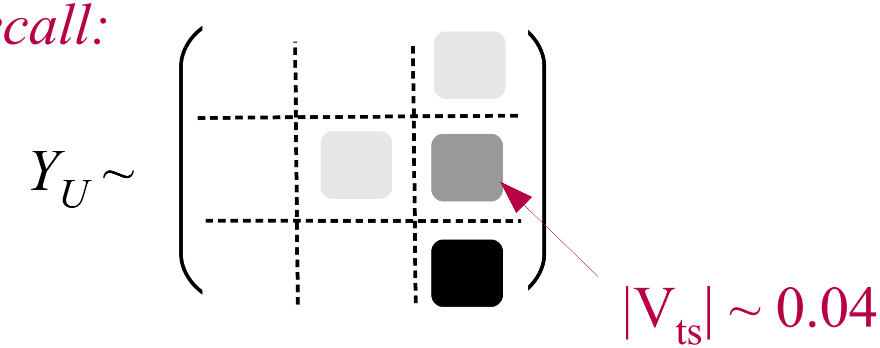
charged-currents:

$$\frac{V_{cb}\,\mathcal{C}_{LL}^{33\tau\tau} + V_{cs}\,\mathcal{C}_{LL}^{23\tau\tau}}{V_{cb}}$$



bounds from high-pT searches

recall:

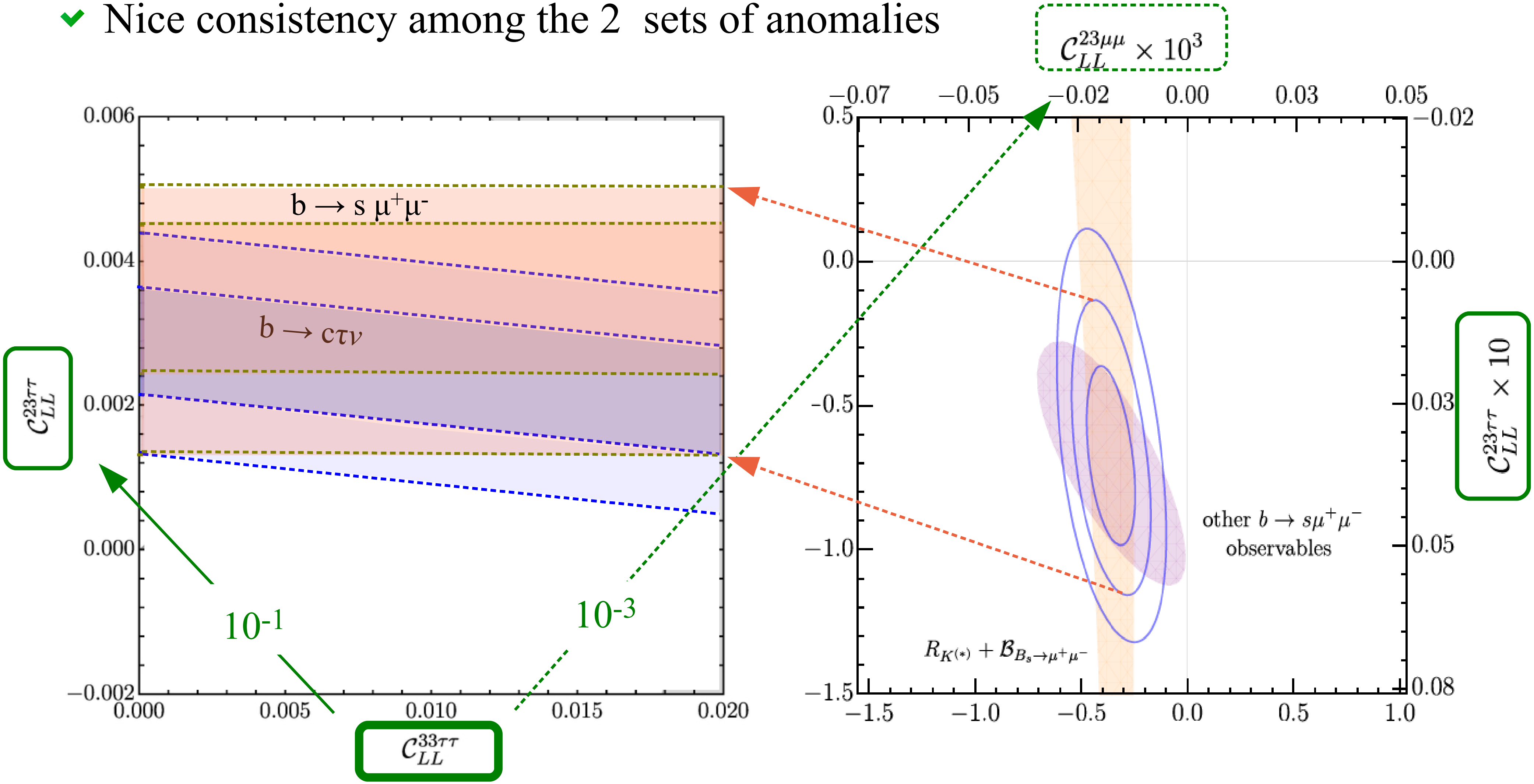


EFT considerations

Data point to (short-distance) NP effects in operators of the type

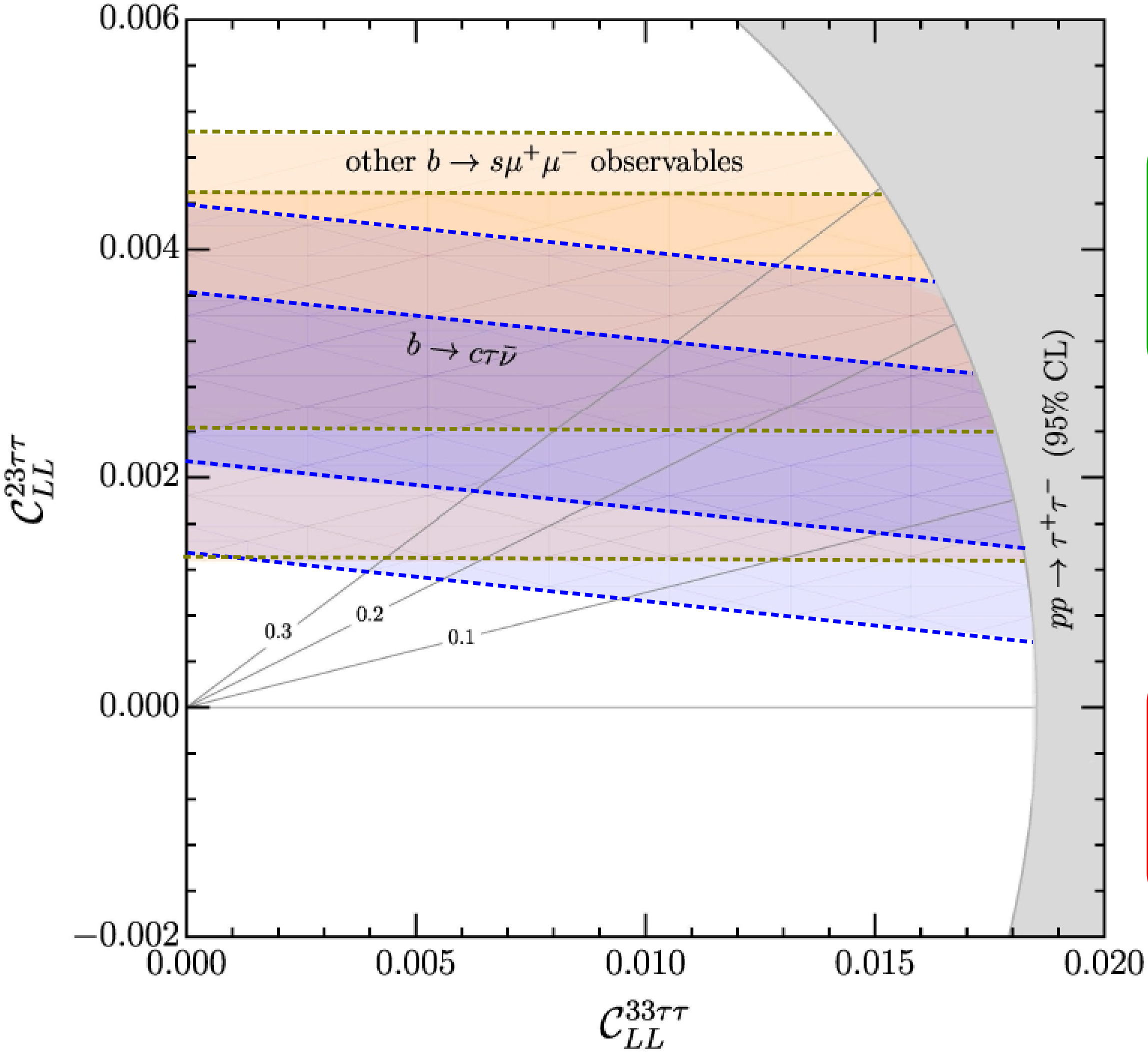
$$\mathcal{O}^{ij\alpha\beta}_{LL} = (\bar{q}^i_L \gamma_\mu \ell^\alpha_L)(\bar{\ell}^\beta_L \gamma_\mu q^j_L)$$

- O(10^{-1}) suppress. for each 2nd gen. q_L or l_L [↔ $|V_{ts}| \sim 0.4\times10^{-1}$]
- Nice consistency among the 2 sets of anomalies



EFT considerations

$$\mathcal{O}_{LL}^{ij\alpha\beta} = (\bar{q}_L^i \gamma_\mu \ell_L^\alpha)(\bar{\ell}_L^\beta \gamma_\mu q_L^j) \quad = \frac{1}{2}\left[\mathcal{O}_{\ell q}^{(1)} + \mathcal{O}_{\ell q}^{(3)}\right]^{ij\alpha\beta}$$



Pattern emerging from data:

- ✔ $O(10^{-1})$ for each 2nd gen. q_L or l_L
- ✔ Nice consistency among the two sets of anomalies

What we do not see (*seem to call for an additional ~ loop suppression*):

- ✖ Four-quarks (ΔF=2)
- ✖ Four-leptons (τ→μνν)
- ✖ Semi-leptonic $O^{(1\text{-}3)}$ (b→sνν)

EFT considerations

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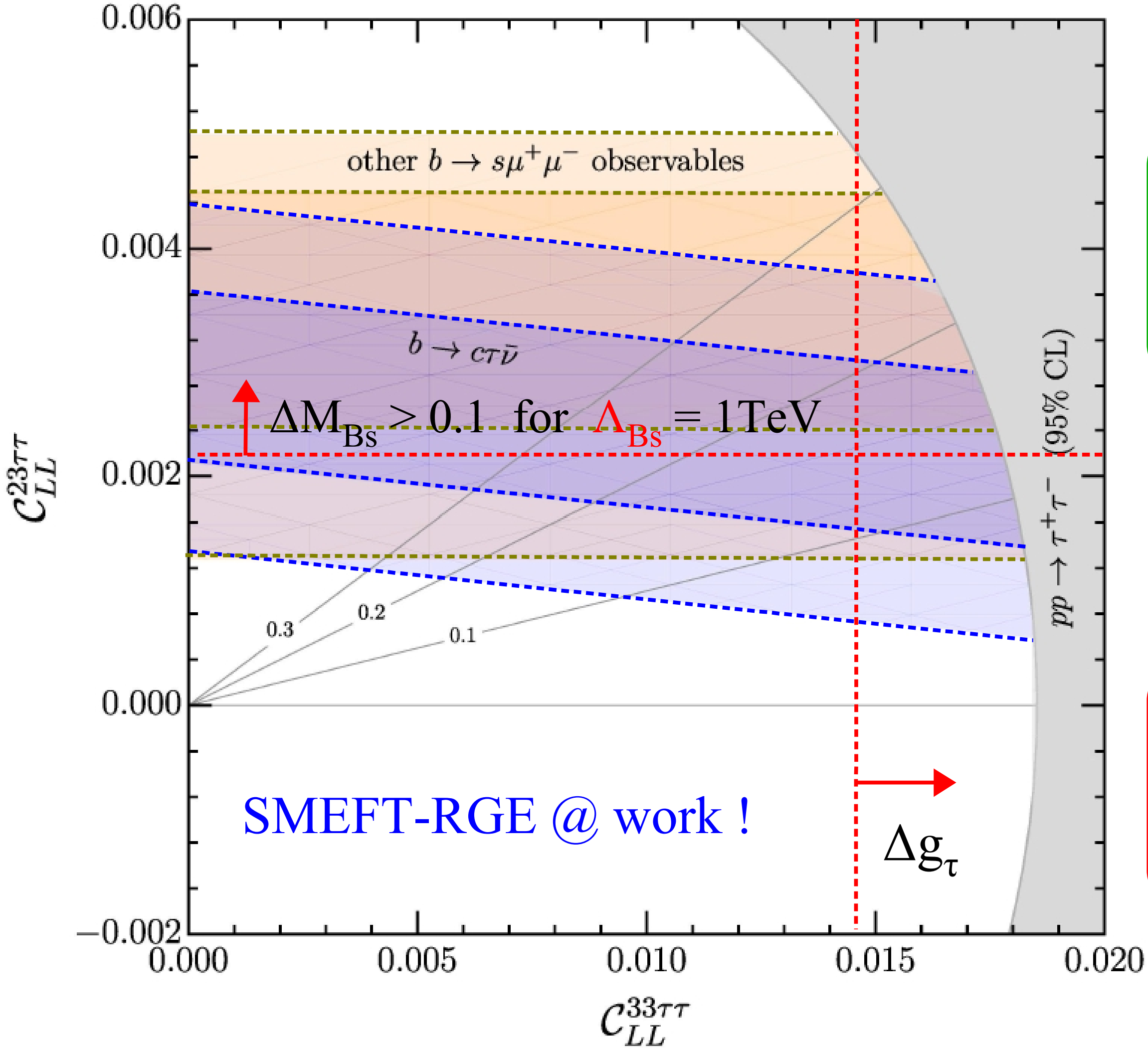

Pattern emerging from data:

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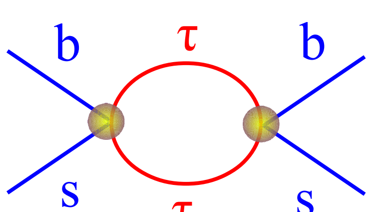
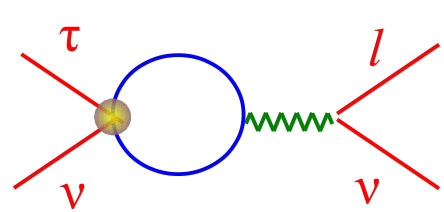
- ✖ Four-quarks ($\Delta F=2$)
- ✖ Four-leptons ($\tau \to \mu\nu\nu$)
- ✖ Semi-leptonic $O^{(1\text{-}3)}$ ($b \to s\nu\nu$)

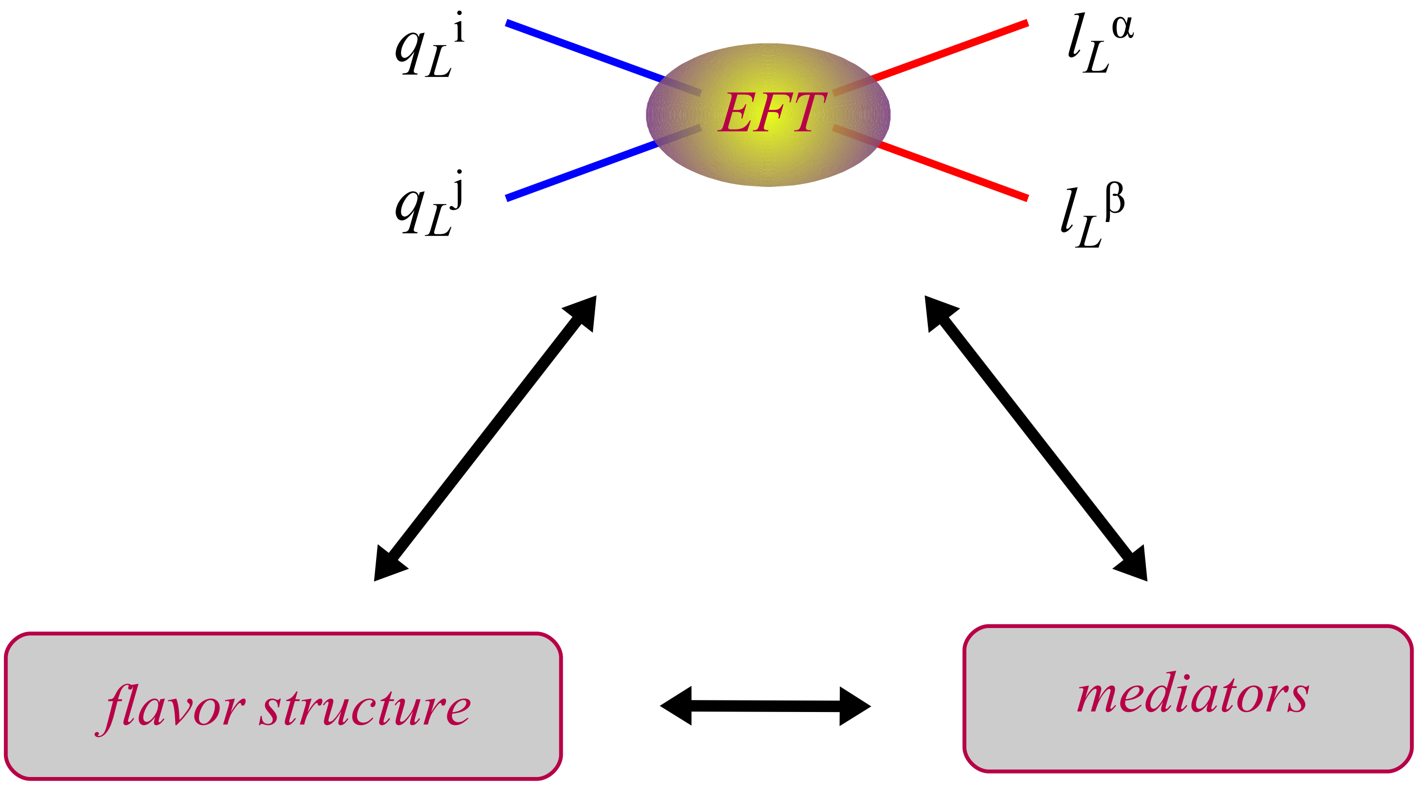


$\Delta M_{Bs} \sim (C^{23\tau\tau})^2\, \Lambda_{Bs}^{\;2}$



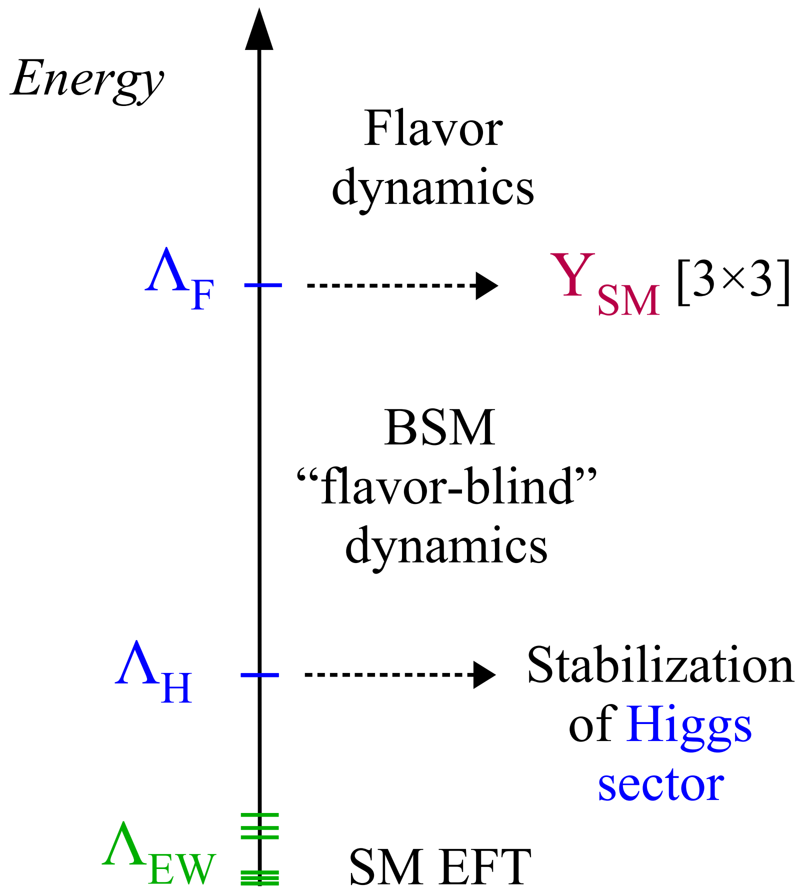
$\Delta g_\tau \sim (C^{33\tau\tau}) \log(\Lambda/m_t)$

From EFT to simplified models



From EFT to simplified models [*the flavor structure*]

The old (MFV) paradigm:



Main idea:

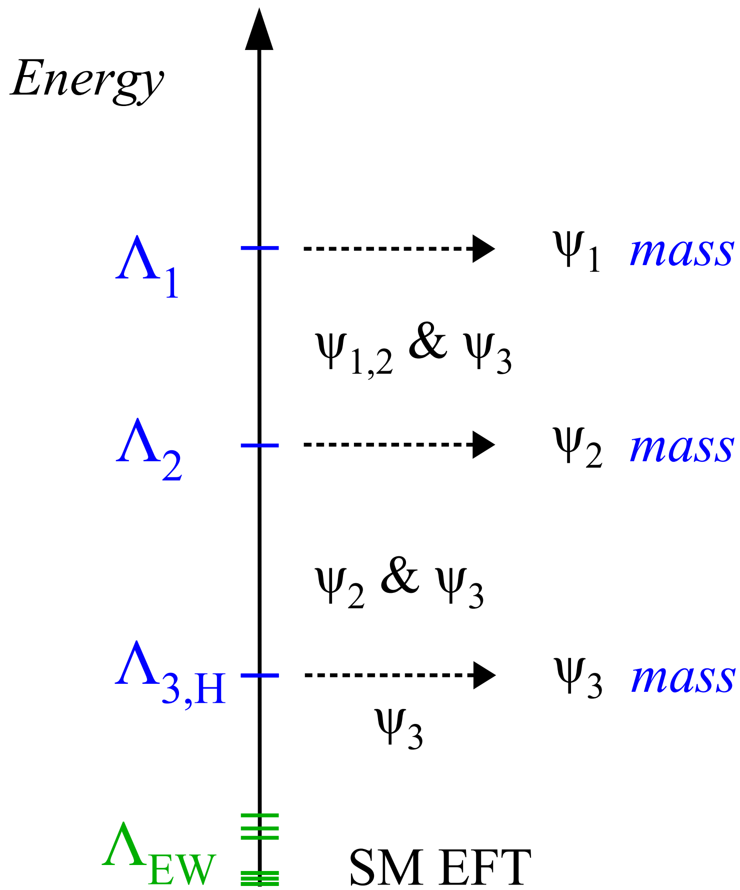
- Concentrate on the Higgs hierarchy problem
- Postpone (*ignore*) the flavor problem

⬇

3 gen. = “identical copies” up to high energies

▶ From EFT to simplified models [*the flavor structure*]

The new paradigm: multi-scale strucutre @ origin of flavor:



Barbieri '21
Allwicher, GI, Thomsen '20
⋮
Bordone *et al.* '17
Panico & Pomarol '16
⋮
Dvali & Shifman '00

Main idea:

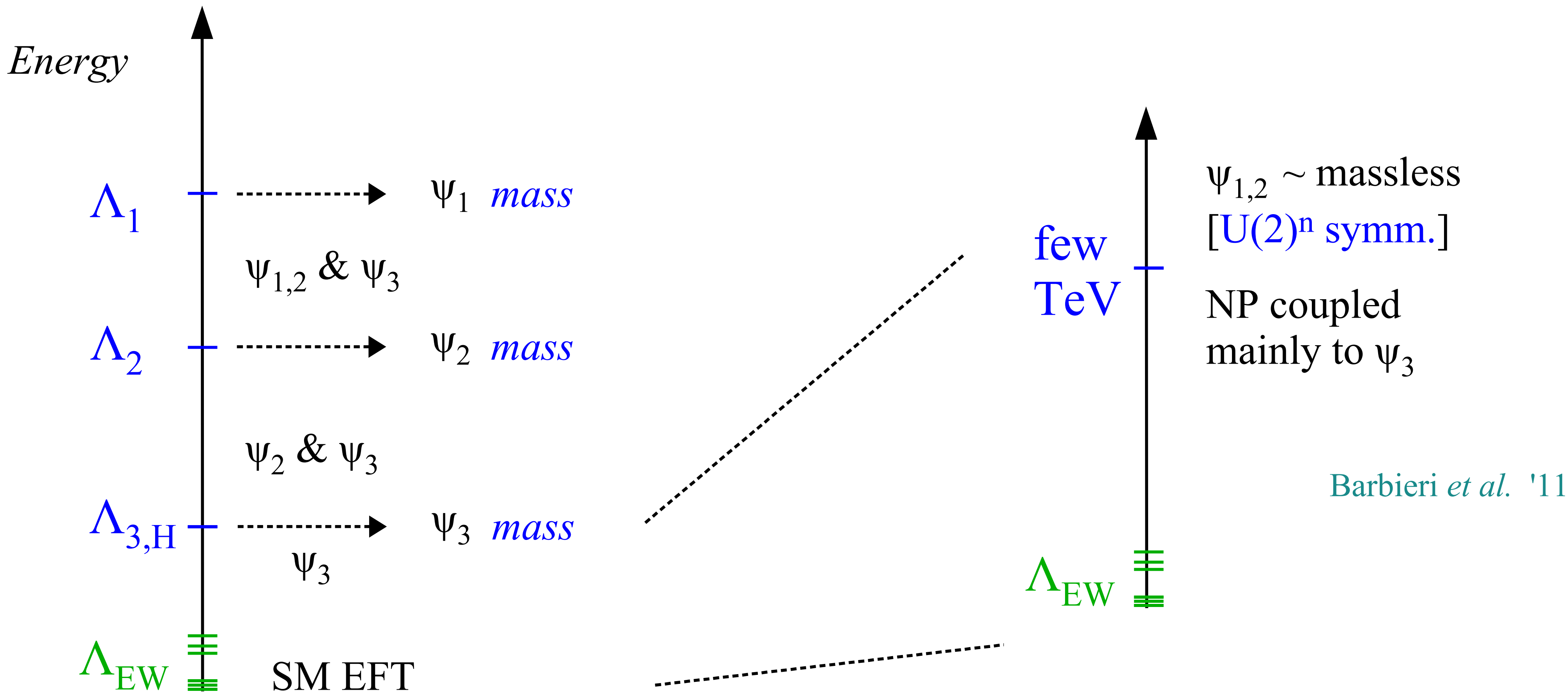
- Flavor non-universal interactions already at the TeV scale:
- 1st & 2nd gen. have small masses because they are coupled to NP at heavier scales

⬇

~~3 gen. = "identical copies" up to high energies~~

From EFT to simplified models [*the flavor structure*]

The new paradigm: multi-scale strucutre @ origin of flavor:



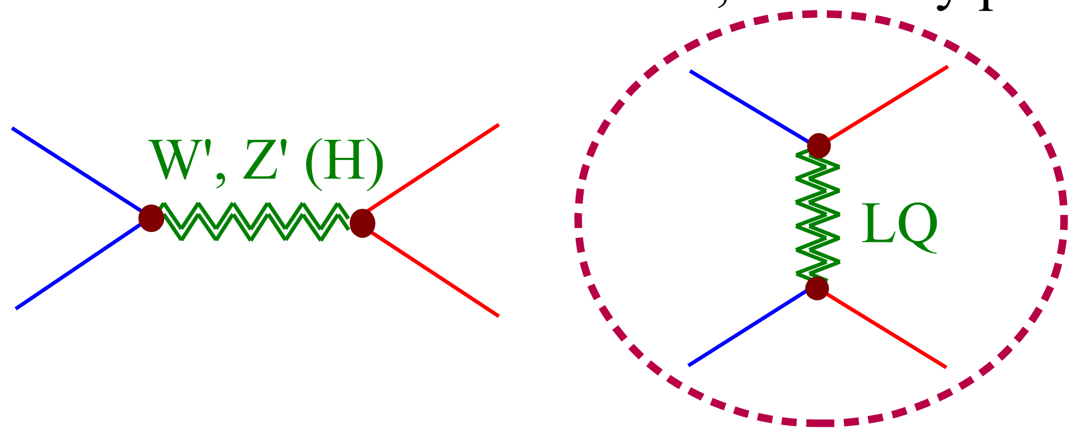
Barbieri *et al.* '11

$$\mathscr{L}_{\text{SM-EFT}} = \mathscr{L}_{\text{gauge}} + \mathscr{L}_{\text{Higgs}} + \mathscr{L}_{Y} + \Sigma_i \frac{1}{\Lambda_i^{d-4}} O_i^{d\geq 5}$$

Non-trivial UV imprints

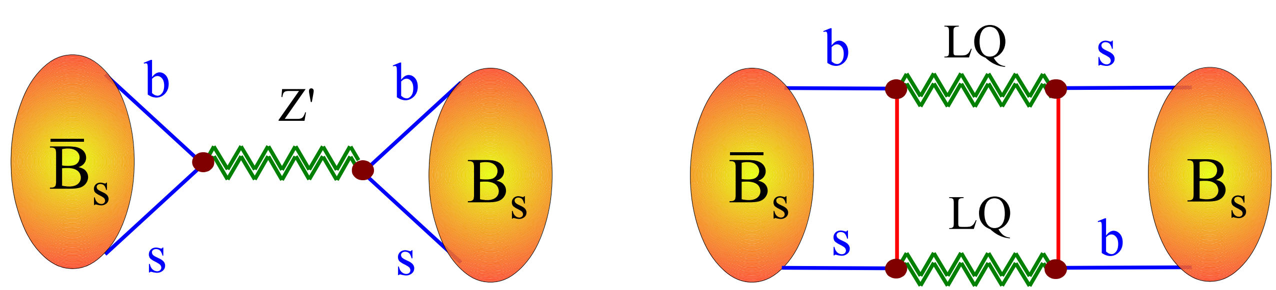
From EFT to simplified models [*the possible mediators*]

Which mediators can generate the effective operators required for by the EFT fit?
If we restrict the attention to tree-level mediators, not many possibilities...



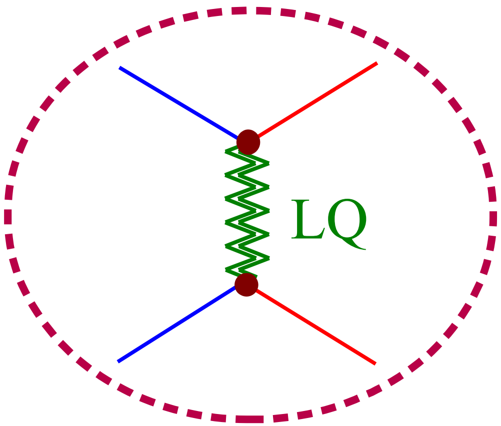
LQ (both scalar and vectors) have two general strong advantages with respect to the other mediators:

I. $\Delta F=2$ & $\tau \to l\nu\nu$



II. Direct searches: 3[rd] gen. LQ are also in better shape as far as direct searches are concerned (*contrary to Z'...*).

From EFT to simplified models [*the possible mediators*]



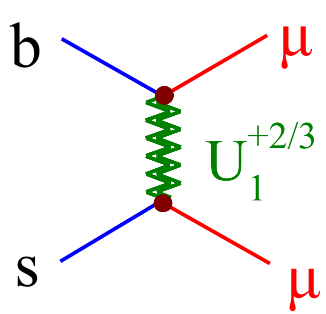
"Renaissance" of LQ models
(*to explain the anomalies, but not only...*):

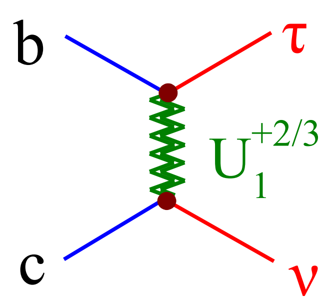
- Scalar LQ as PNG
  Gripaios, '10
  Gripaios, Nardecchia, Renner, '14
  Marzocca '18
- Scalar LQ from GUTs & R̸ SUSY
  Hiller & Schmaltz, '14; Becirevic *et al*. '16,
  Fajfer *et al*. '15-'17; Dorsner *et al*. '17;
  Crivellin *et al*. '17; Altmannshofer *et al*. '17
  Trifinopoulos '18, Becirevic *et al*. '18 + ...
- Vector LQ in GUT gauge models
  Assad *et al*. '17
  Di Luzio *et al*. '17
  Bordone et *al*. '17
  Heeck & Teresi '18
  + ...
- Vector LQ as techni-fermion resonances
  Barbieri *et al*. '15; Buttazzo *et al*. '16,
  Barbieri, Murphy, Senia, '17 + ...
- LQ as Kaluza-Klein excit.
  Megias, Quiros, Salas '17
  Megias, Panico, Pujolas, Quiros '17
  Blanke, Crivellin, '18 + ...

Best option for a combined solution:

- U_1 = $SU(2)_L$ singlet vector

Barbieri, GI, Pattori, Senia '15



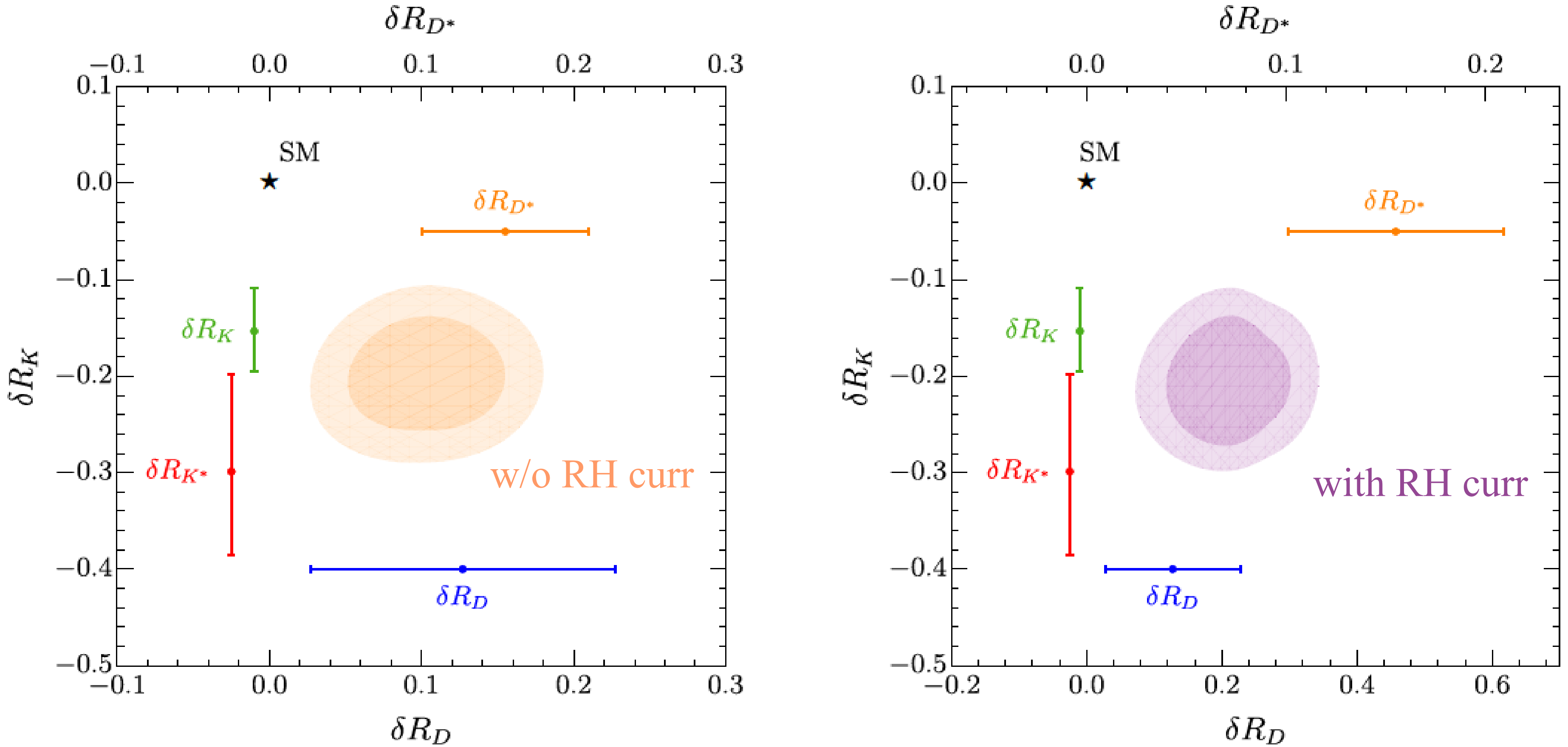


From EFT to simplified models [*the possible mediators*]

Considering the U_1 only

$$\mathscr{L} \supset \frac{g_U}{\sqrt{2}} U_1^\mu \left[\beta_{i\alpha}^L (\bar{q}_L^i \gamma_\mu \ell_L^\alpha) - \beta_{i\alpha}^R (\bar{d}_R^i \gamma_\mu e_R^\alpha) \right] + \text{h.c.}$$

→ excellent description of all available low-energy data:



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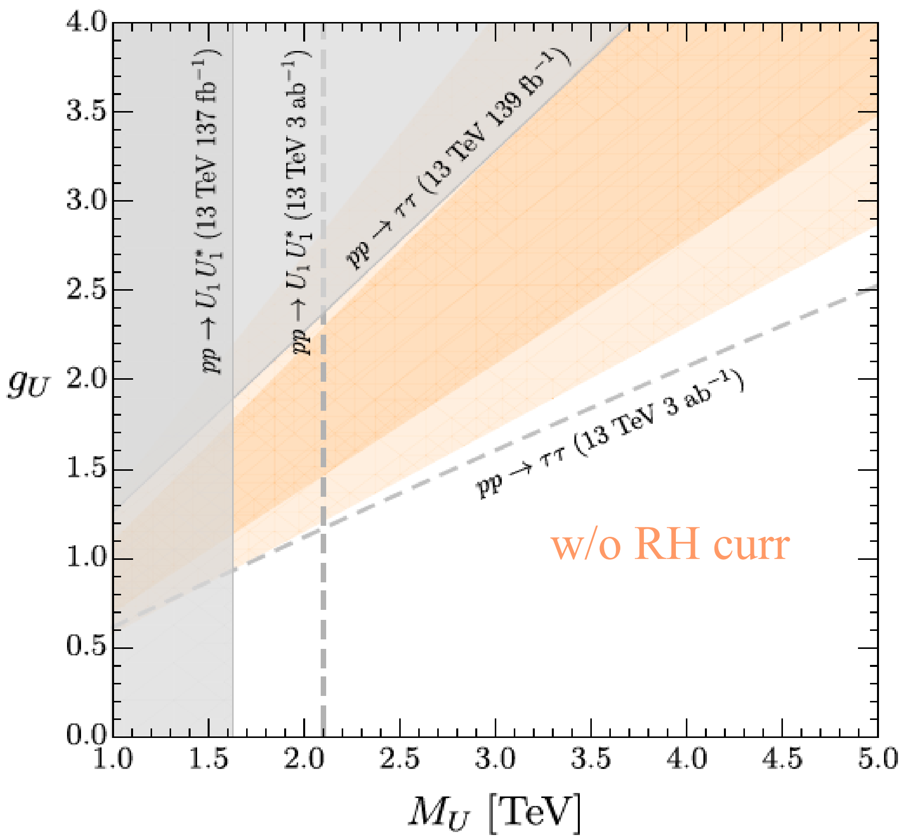
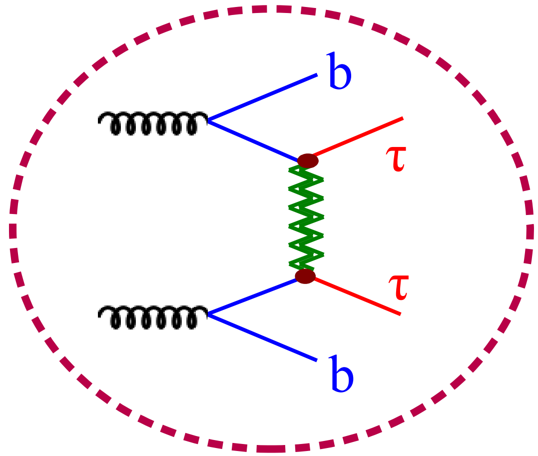
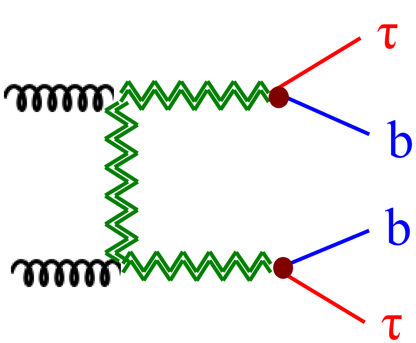
→ excellent description of all available low-energy data
→ consistent with present high-energy data → *signals within the reach of HL-LHC*:





Faroughi, Greljo, Kamenik '16



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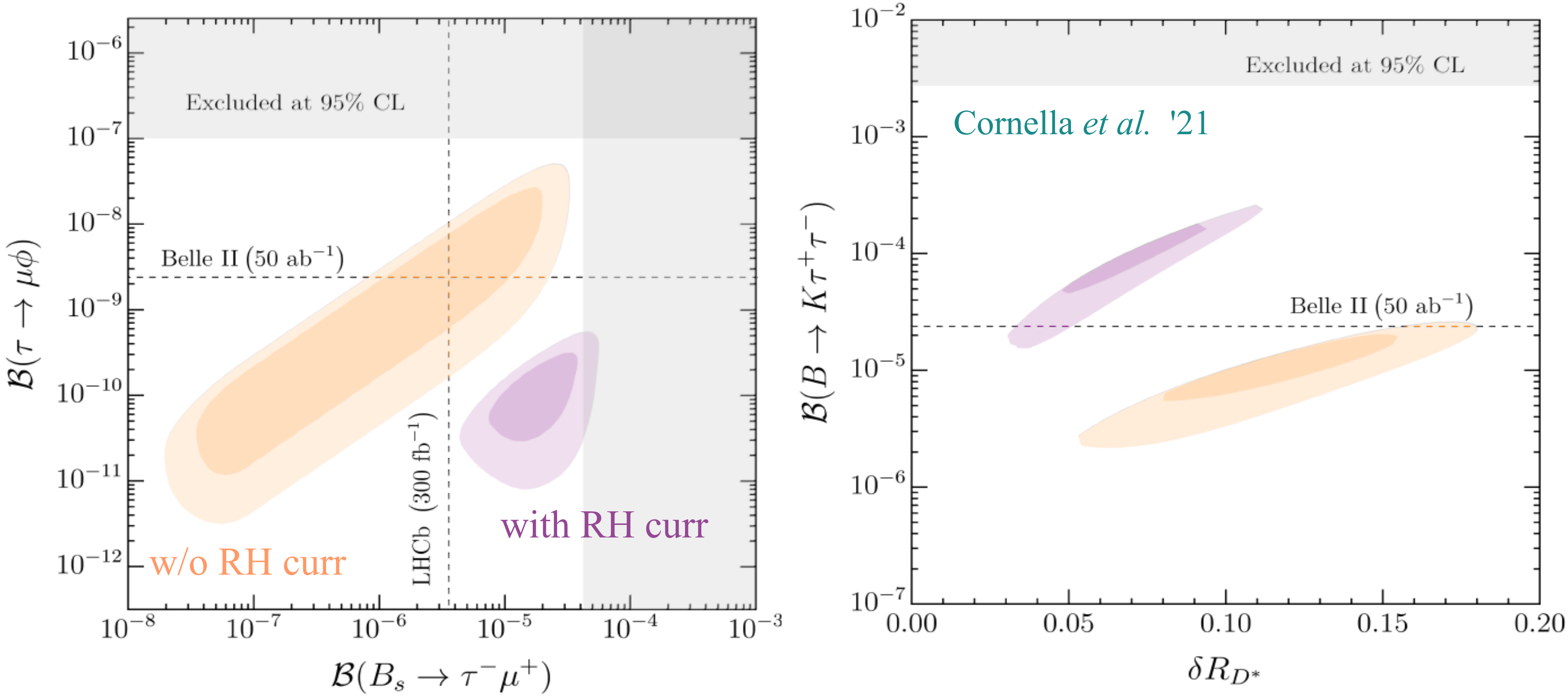
→ excellent description of all available low-energy data
→ consistent with present high-energy data → *signals within the reach of HL-LHC*
→ *interesting implications also for future low-energy searches:*



Speculations on UV completions

▶ *Speculations on UV completions*

First observation: the Pati & Salam group, proposed in the 70's to unify quarks & leptons predicts the only massive LQ that is a good mediator for both anomalies:

Pati-Salam group: $SU(4) \times SU(2)_L \times SU(2)_R$

Fermions in SU(4):

$$\begin{bmatrix} Q_L^{\alpha} \\ Q_L^{\beta} \\ Q_L^{\gamma} \\ L_L \end{bmatrix} \quad \begin{bmatrix} Q_R^{\alpha} \\ Q_R^{\beta} \\ Q_R^{\gamma} \\ L_R \end{bmatrix}$$

Main Pati-Salam idea:
Lepton number as "the 4th color"

The massive LQ [U_1] arise from the breaking $SU(4) \to SU(3)_C \times U(1)_{B-L}$

$$SU(4) \sim \left[\begin{array}{c|c} SU(3)_C & 0 \\ \hline 0 & 0 \end{array}\right] \quad \left[\begin{array}{c|c} 0 & LQ \\ \hline LQ & \end{array}\right] \quad \left[\begin{array}{c|c} \frac{1}{3} & 0 \\ \hline 0 & -1 \end{array}\right]$$

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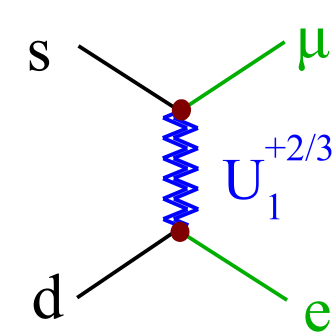
The problem of the "original PS model" are the strong bounds on the LQ couplings to 1st & 2nd generations [e.g. $M > 200$ TeV from $K_L \to \mu e$]

Attempts to solve this problem simply adding extra fermions or scalars

Calibbi, Crivellin, Li, '17;
Fornal, Gadam, Grinstein, '18
Heeck, Teresi, '18



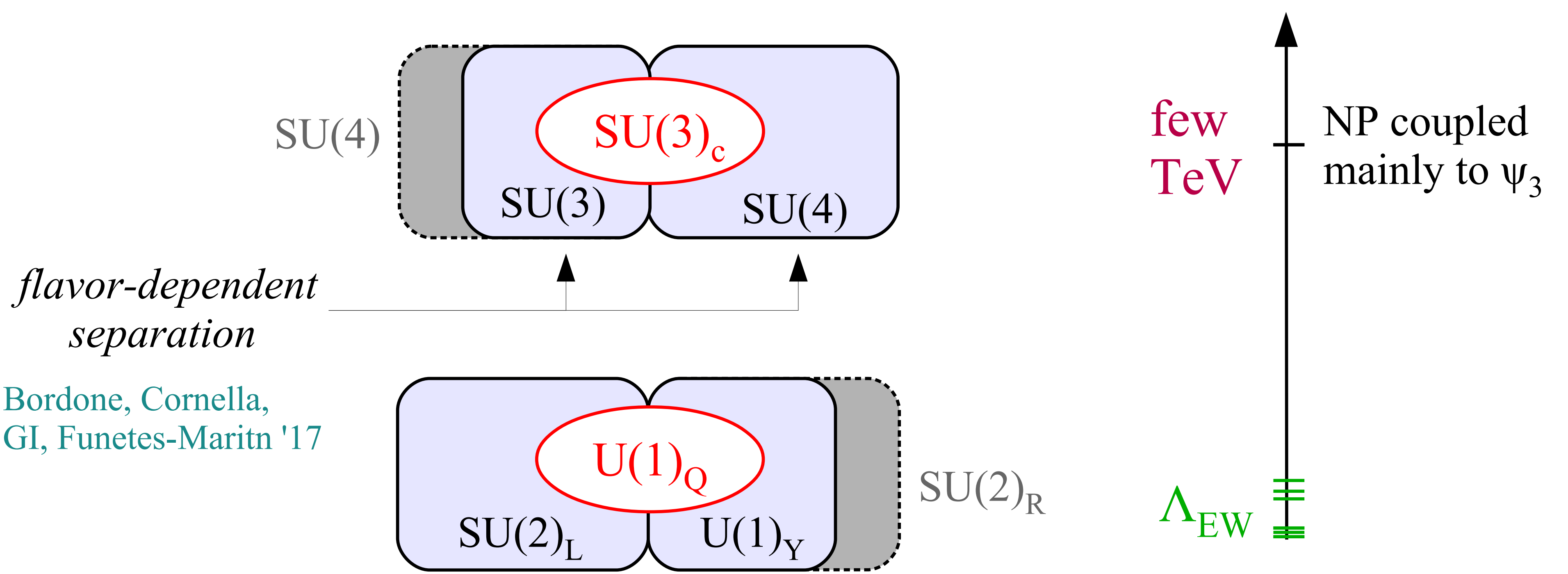
Speculations on UV completions

Second observation: we can "protect" the light families charging under SU(4) only the 3rd gen. or, more generally, "separating" the universal SU(3) component

PS group: $SU(4) \times SU(2)_L \times SU(2)_R$ • *flavor universality*

4321 models: $SU(4) \times SU(3) \times G_{EW} = \begin{cases} SU(2)_L \times SU(2)_R \\ SU(2)_L \times U(1)_Y \end{cases}$

Di Luzio, Greljo, Nardecchia, '17



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$SU(4)\times SU(3)$

- *Non-universality via mixing*

$SU(4)_3\times SU(3)_{1,2}$

- *Accidental* U(2)^5 *flavor symm. in the gauge sect.*

UV completions

$SU(3)\times G_{EW}\times G_{HC}$
Barbieri, Tesi '17

$SU(4)\times SU(3)\times G_{EW}$
Di Luzio, Greljo, Nardecchia, '17

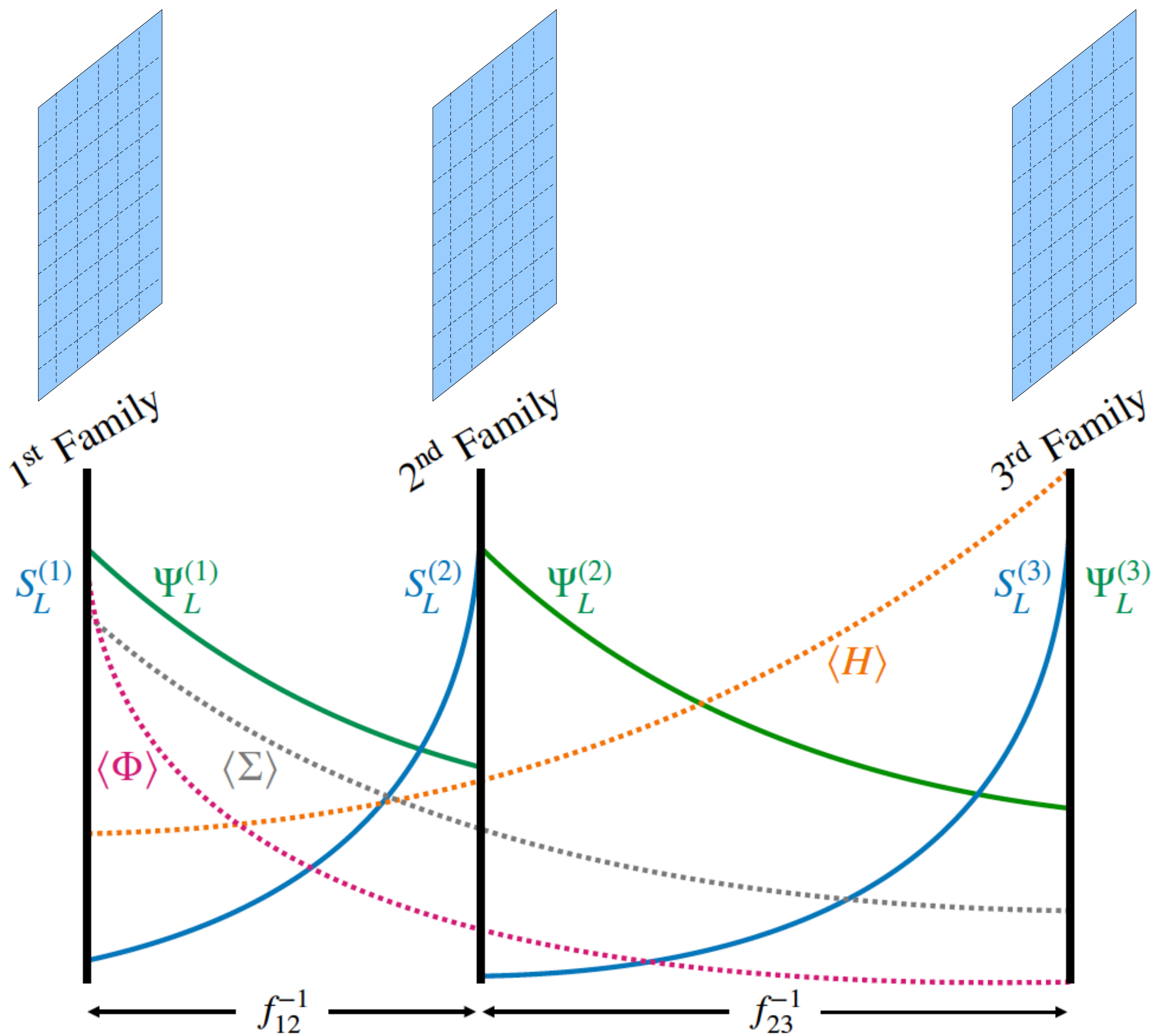
$SU(4)_h\times SU(4)_l\times G_{EW}\times G_{HC}$
Fuentes-Martin & Stangl '20

$[PS]^3 = [SU(4)\times G_{EW}]^3$
Bordone *et al.* '17

$[\,PS\,]_{\text{warped-5d, 3-branes}}$
Fuentes-Martin *et al.* '20 + *work in prog.*

Speculations on UV completions

An ambitious attempt to construct a *full theory of flavor* has been obtained embedding the Pati-Salam gauge group (or variations) into an extra-dimensional construction:



Flavor ↔ special position (*topological defect*) in an extra (compact) space-like dimension

Dvali & Shifman, '00

Higgs and SU(4)-breaking fields with oppositely-peaked profiles, leading to the desired flavor pattern for masses & anomalies

Bordone, Cornella, Fuentes-Martin, GI '17
Fuentes-Martin, GI, Pages, Stefanek '20

Possible to implement anarchic neutrino masses via an inverse see-saw mechanism

Conclusions

- Flavor is an essential ingredient to understand the structure of physics beyond the SM. This statement, which we deduce already by the SM Yukawa structure, is reinforced by the recent anomalies

- The statistical significance of the LFU anomalies is growing: in the $b \to s\ell\ell$ system, the chance this is a pure statistical fluctuation is marginal.

- If combined, the two sets of anomalies point to non-trivial flavor dynamics around the TeV scale, involving mainly the 3rd family → connection to the origin of flavor [multi-scale picture at the origin of flavor hierarchies]

- No contradiction with existing low- & high-energy data, but new non-standard effects should emerge soon in both these areas

↓

Very interesting (near-by!) future...
(both on the exp., the pheno,
and the model-building point of view)