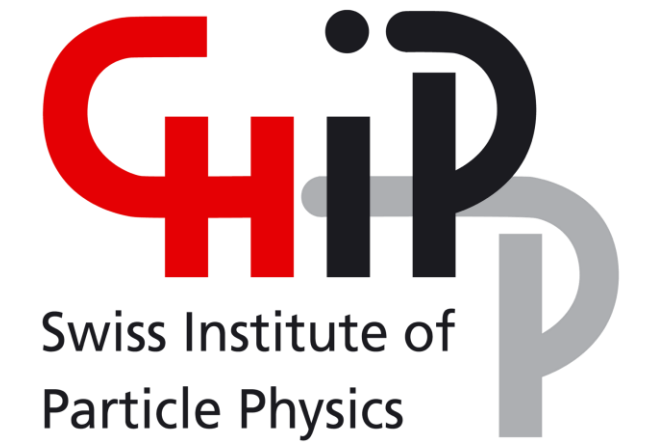




Universität
Zürich^{UZH}

B-anomalies and UV Completion of the SM



CHIPP Winter School of Particle Physics 2022, Jan 16-21 - Adelboden

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Group of Gino Isidori
Universität Zürich



Why UV-complete the SM ?

B-anomalies [\[Sandro's talk\]](#) → Hints of **L**epton **F**lavour **U**niversality **V**iolation in B decays

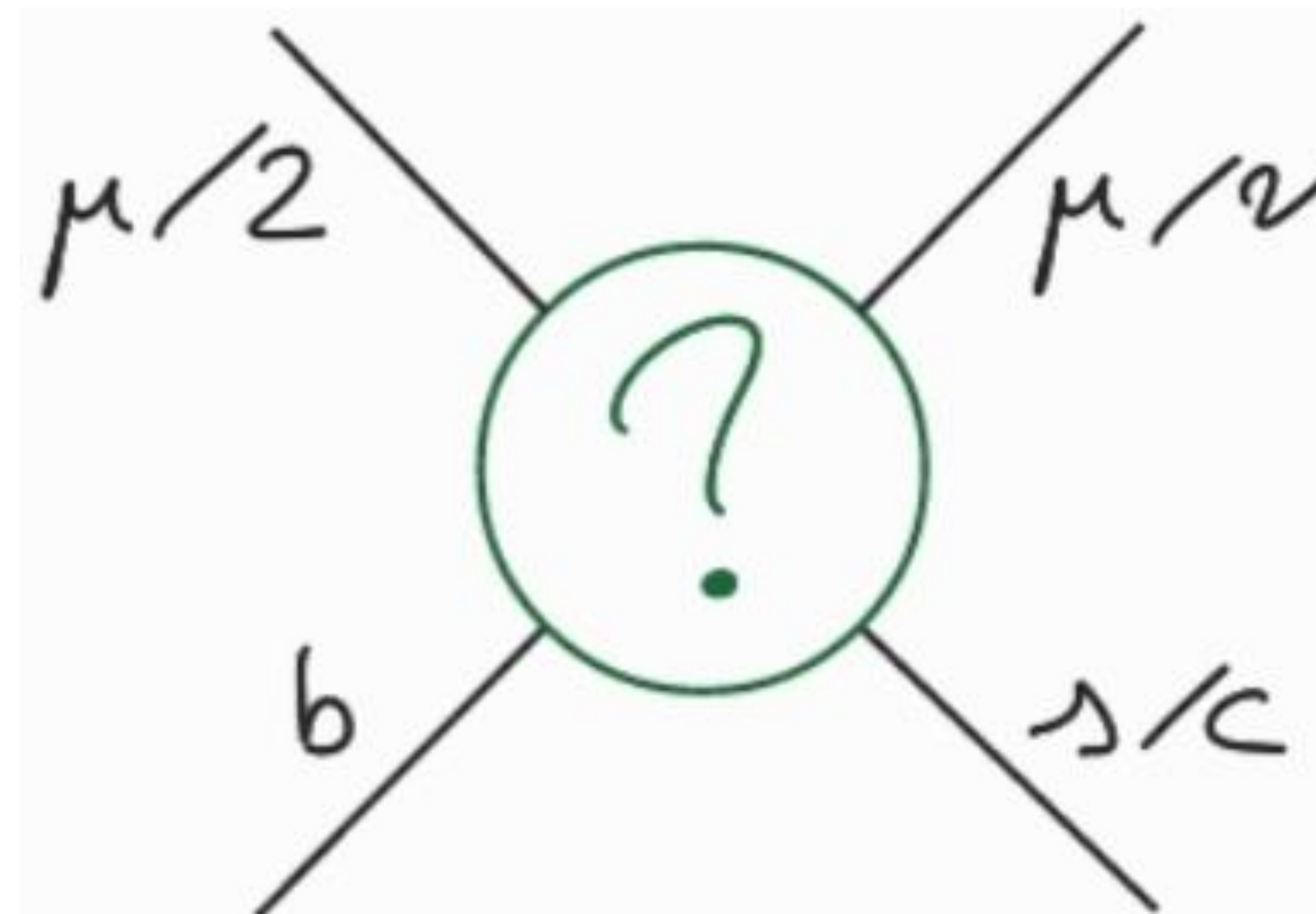
Neutral Currents :

$$b \rightarrow s \ell \ell \quad (\mu \text{ vs } e)$$

Charged Currents :

$$b \rightarrow c \ell \nu_\ell \quad (\tau \text{ vs } \mu, e)$$

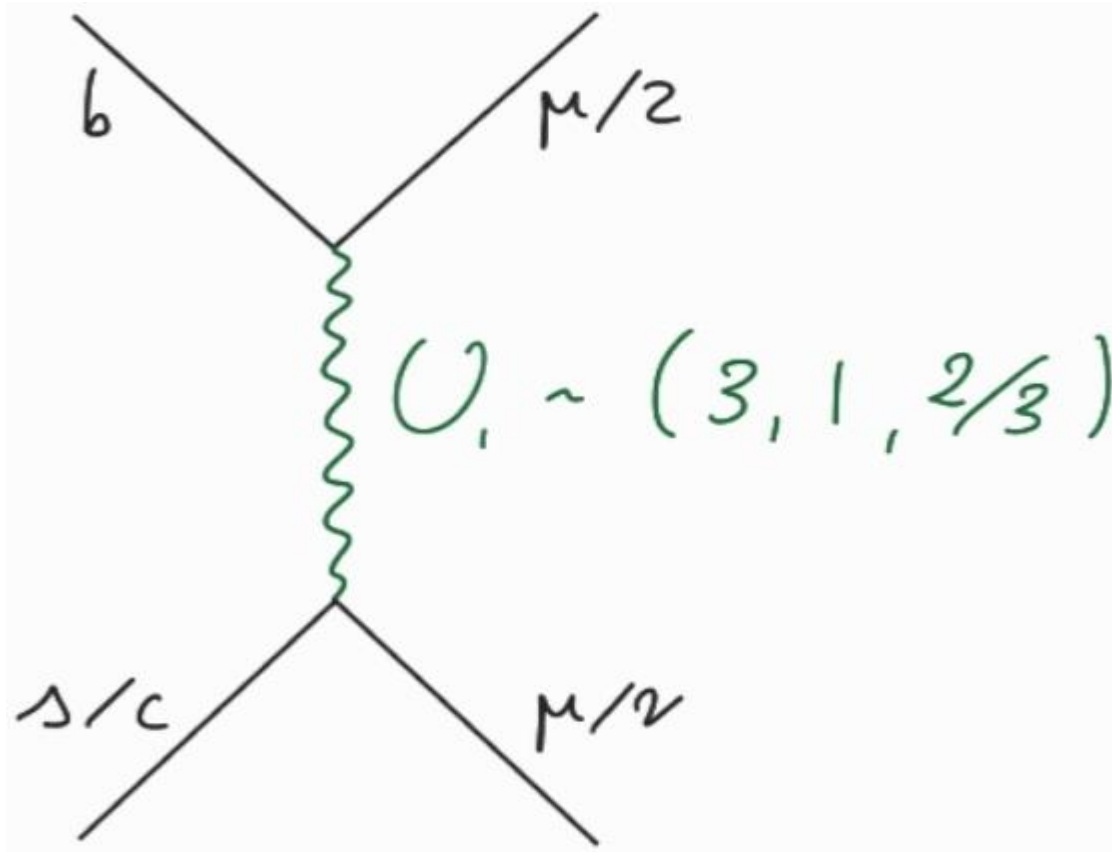
Describe NP effects by EFT operators [\[Julie's talk\]](#) → Which **mediator** generates these operators ?



Mediator and UV completion

Best Single Mediator :

Leptoquark : spin 1,
massive boson



➡ UV completion ?

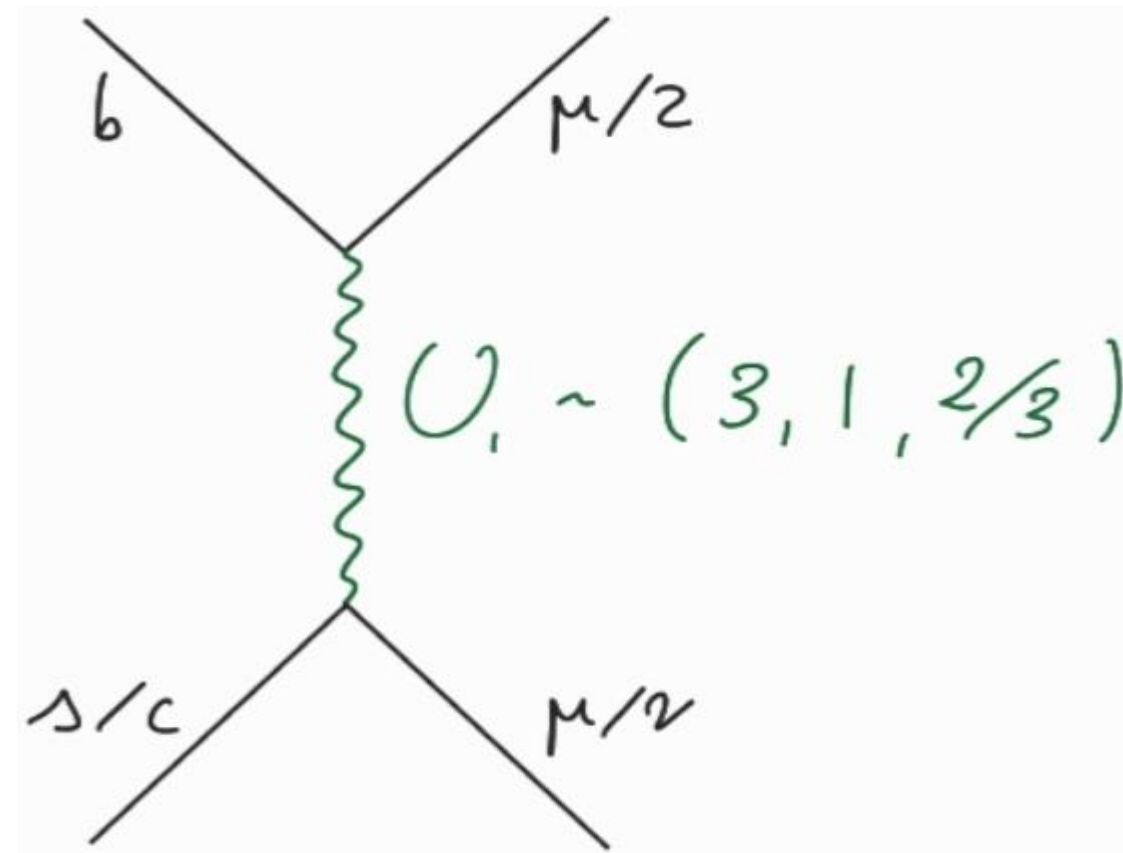
Tree-level NP

Mediator and UV completion

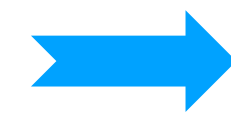
Best Single Mediator :

Flavour non-universal couplings :

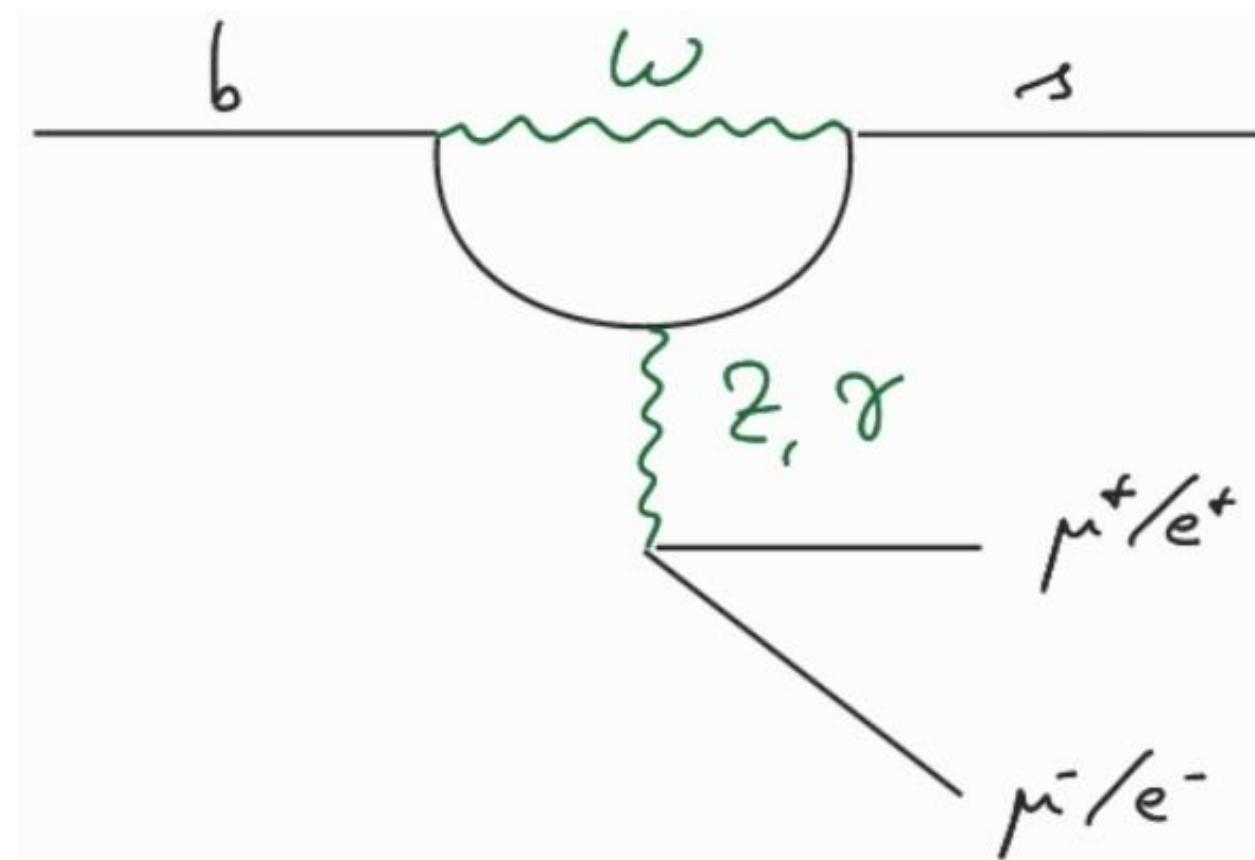
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Tree-level NP

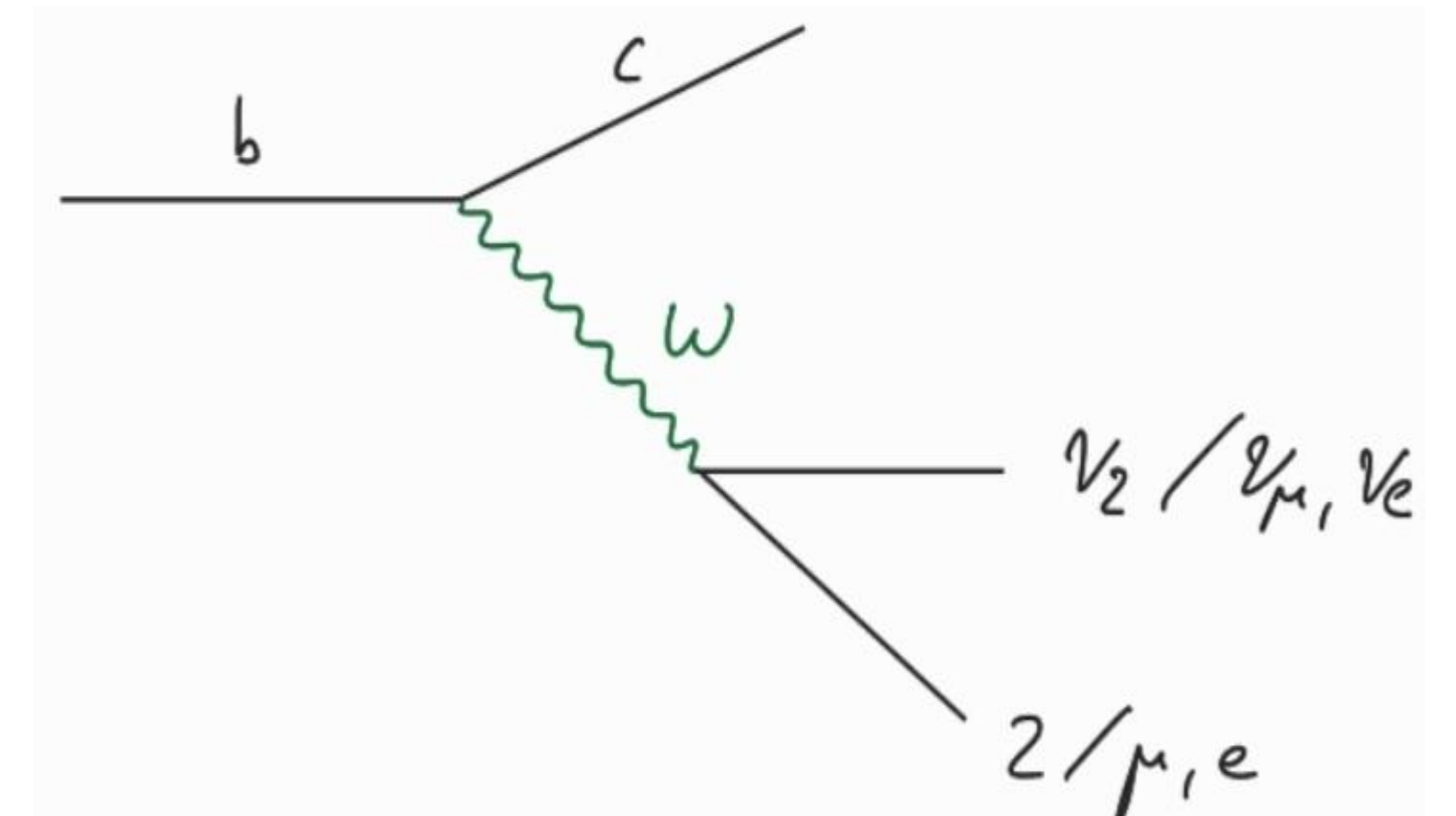


Small coupling with 2nd
family



Loop-suppressed in SM

Large coupling with 3rd
family



Tree-level in SM

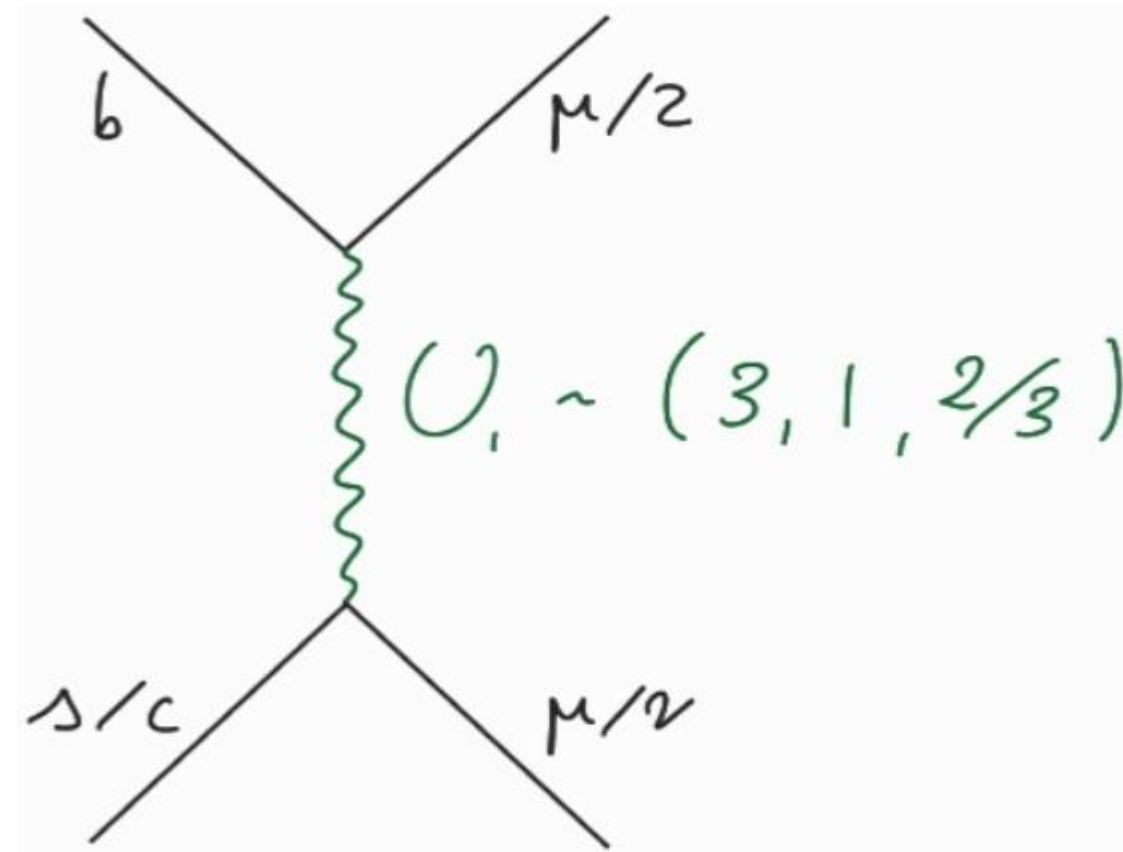
+ List of constraints ($\Delta F=2$ processes, meson decays,...)

Mediator and UV completion

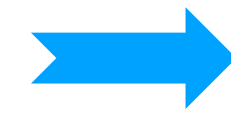
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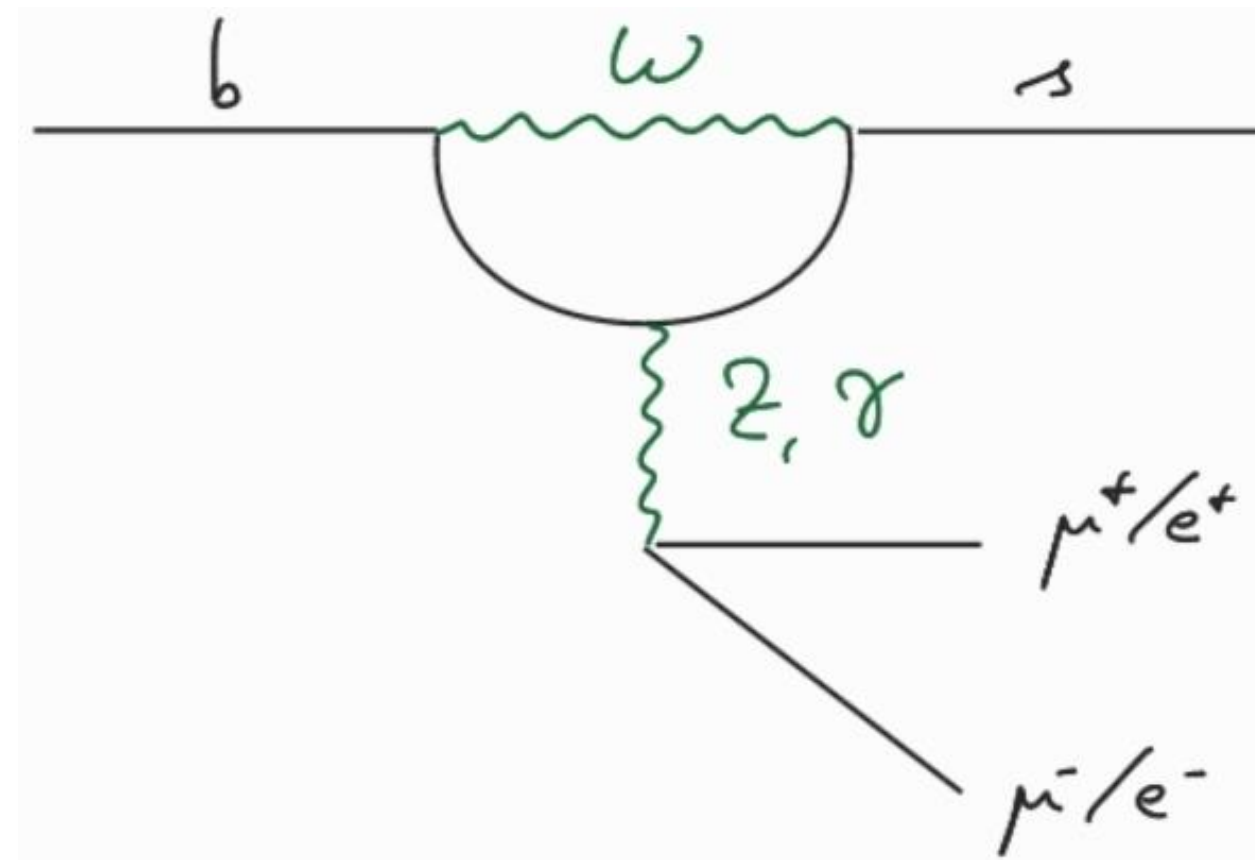
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Tree-level NP

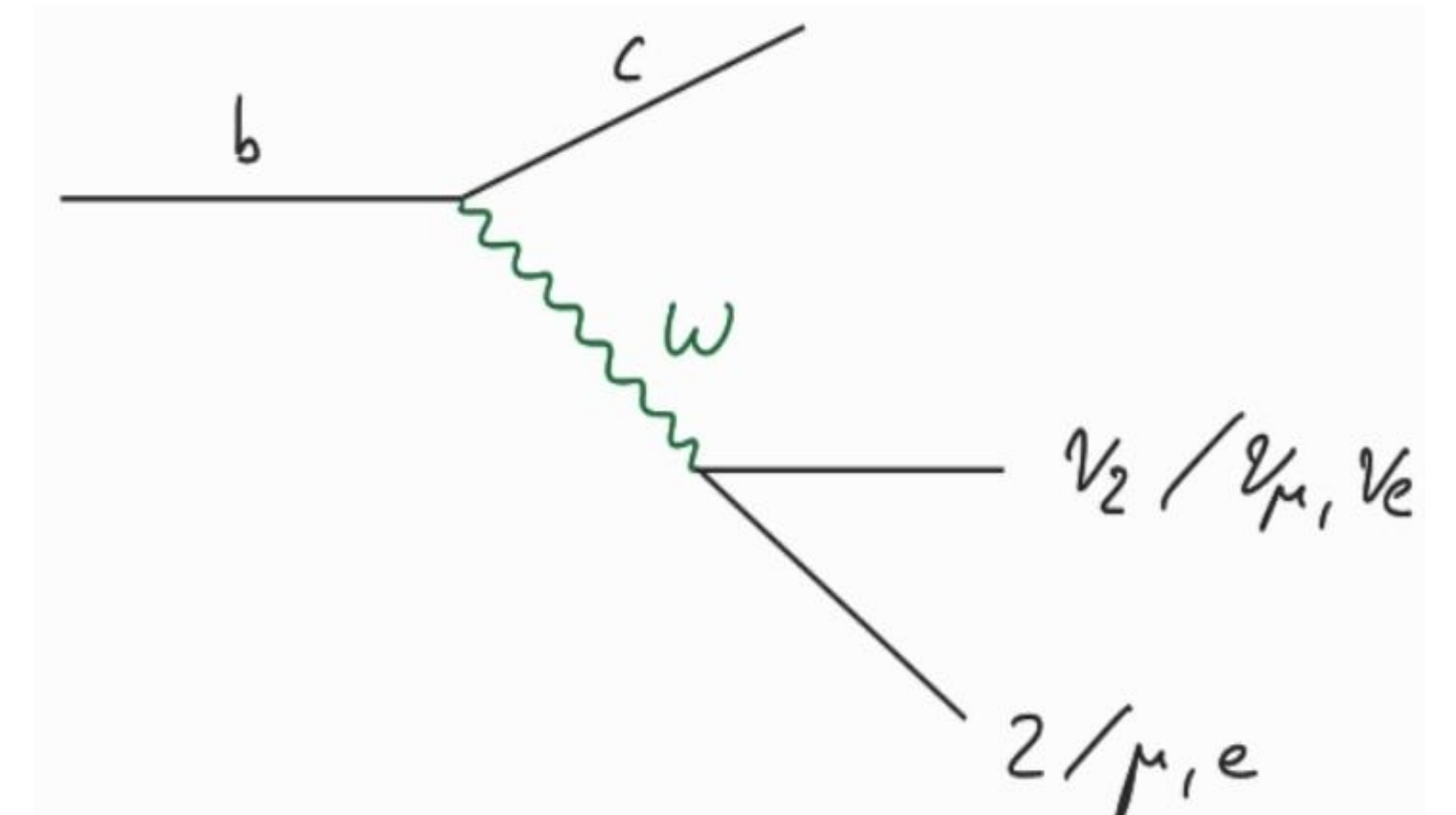


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Tree-level in SM

+ List of constraints ($\Delta F=2$ processes, meson decays,...)

Flavour **Non**-Universal interaction at TeV scale

4321 Models and the Leptoquark

➔ Leptoquark as massive gauge boson from the SSB of the 4321 gauge group

$$SU(4) \times SU(3) \times SU(2)_L \times U(1)'$$

[L.Luzio, A.Greljo,
M.Nardecchia; 1708.08450]

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3rd family ← $SU(4)^h$ × $SU(3)_c^l$ → 1st & 2nd families

Field	$SU(4)^h$	$SU(3)_c^l$	$SU(2)_L$	$U(1)'$
Q_L^l	1	3	2	1/6
Ψ_L^h	4	1	2	0

Accidental $U(2)^5$
symmetry

$$\Psi_L^h = \begin{bmatrix} Q_L \\ Q_L \\ Q_L \\ L_L \end{bmatrix}$$

Originally : Pati-Salam model (1974)
[J.Pati, A.Salam; Phys. Rev. D 11, 703]

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Accidental $U(2)^5$ symmetry

$\langle \Omega^h \rangle$

- Massive vector Leptoquark :
 $U_1 \sim (\mathbf{3}, \mathbf{1}, 2/3)$
- Massive color octet :
 $G' \sim (\mathbf{8}, \mathbf{1}, 0)$
- Massive neutral singlet :
 $Z' \sim (\mathbf{1}, \mathbf{1}, 0)$

$$\Psi_L^h = \begin{bmatrix} Q_L \\ Q_L \\ Q_L \\ L_L \end{bmatrix}$$

$$SU(3)_c \times SU(2)_L \times U(1)_Y$$

Flavour hierarchy

Up-type quark Yukawa Matrix :

$$Y_u \sim \begin{pmatrix} & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \\ \blacksquare & \blacksquare & \blacksquare \end{pmatrix}$$

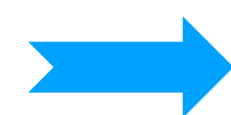
Hierarchical structure

Flavour hierarchy

Up-type quark Yukawa Matrix :

$$Y_u \sim \begin{pmatrix} & & & \\ & \blacksquare & & \\ & & \blacksquare & \\ & & & \blacksquare \end{pmatrix}$$

Hierarchical structure



Similar hierarchy as for the couplings of the Leptoquark to explain the B-anomalies

Flavour hierarchy

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Hierarchical structure



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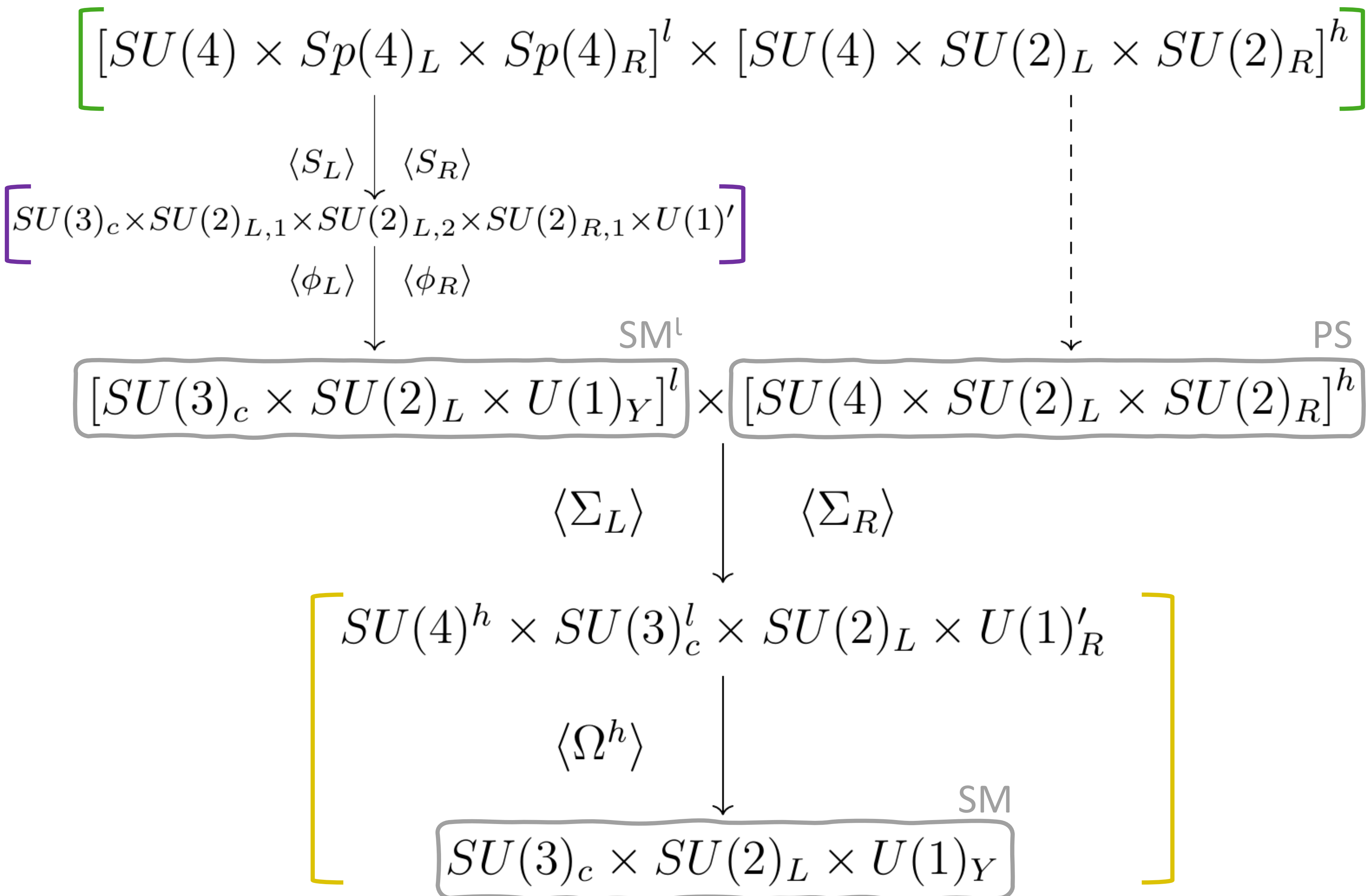


Flavour Non-Universal UV completion at the TeV scale



Simultaneously address the B-anomalies and the flavour hierarchy !

A (short) overview of my current PhD project



- Flavour **non-universal** UV completion
- (Weak) **deconstruction** of the light sector : generate the Yukawa hierarchies
- **4321 breaking** at low energy \rightarrow Leptoquark

Conclusion

B-anomalies + others
(exp. data)

+

Flavour Structure
(theory)

Guiding principles for model
building & UV-completing the SM

Sp(4)-type models

[J.Davighi, G.Isidori, MP; W.I.P]

Sp(6)-type models

[J.Davighi, J. Tooby-Smith; WIP]

PS³-type models

[J.Fuentes-Martin, G.Isidori,
J.Pagès, B.Stefanek;
2012.10492]

Thank you for your attention !

Backup Slides

Sp(2n) in a nutshell

$$\mathrm{Sp}(2n, \mathbb{R}) = \left\{ M \in M_{2n \times 2n}(\mathbb{R}) : M^T \Omega M = \Omega \right\} \quad \Omega = \begin{pmatrix} 0 & I_n \\ -I_n & 0 \end{pmatrix}$$



Only **anomaly-free** gauge group that allows n-family flavour symmetry unification with electroweak symmetry

SU(4) quark & lepton unification

Lie Algebra : $T^T \Omega + \Omega T = 0_{2n \times 2n}$
dimension : $n(2n+1)$



$$\Psi_L^l = \begin{pmatrix} U_{1,L}^r & U_{2,L}^r & D_{1,L}^r & D_{2,L}^r \\ U_{1,L}^g & U_{2,L}^g & D_{1,L}^g & D_{2,L}^g \\ U_{1,L}^b & U_{2,L}^b & D_{1,L}^b & D_{2,L}^b \\ \nu_{1,L} & \nu_{2,L} & e_{1,L} & e_{2,L} \end{pmatrix}$$

Sp(4) flavour & Electroweak unification

Lepton number as the 4th colour

(Light) Fermions in our model :