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New explanations of the Flavour Anomalies

Moriond EW, La Thuile, 22.03.2017

Outline

- Introduction:

  New Physics and Flavour anomalies

  – $b \to s\mu\mu$

  – $b \to c\tau\nu$

  – $h \to \tau\mu$

  – a_μ
- NP explanations for the anomalies
- Heavy new scalars and fermions
- Conclusions

Finding NP in Flavour Observables

- At colliders one produces many (up to 10^{14}) heavy quarks or leptons and measures their decays into light flavours

Experiment

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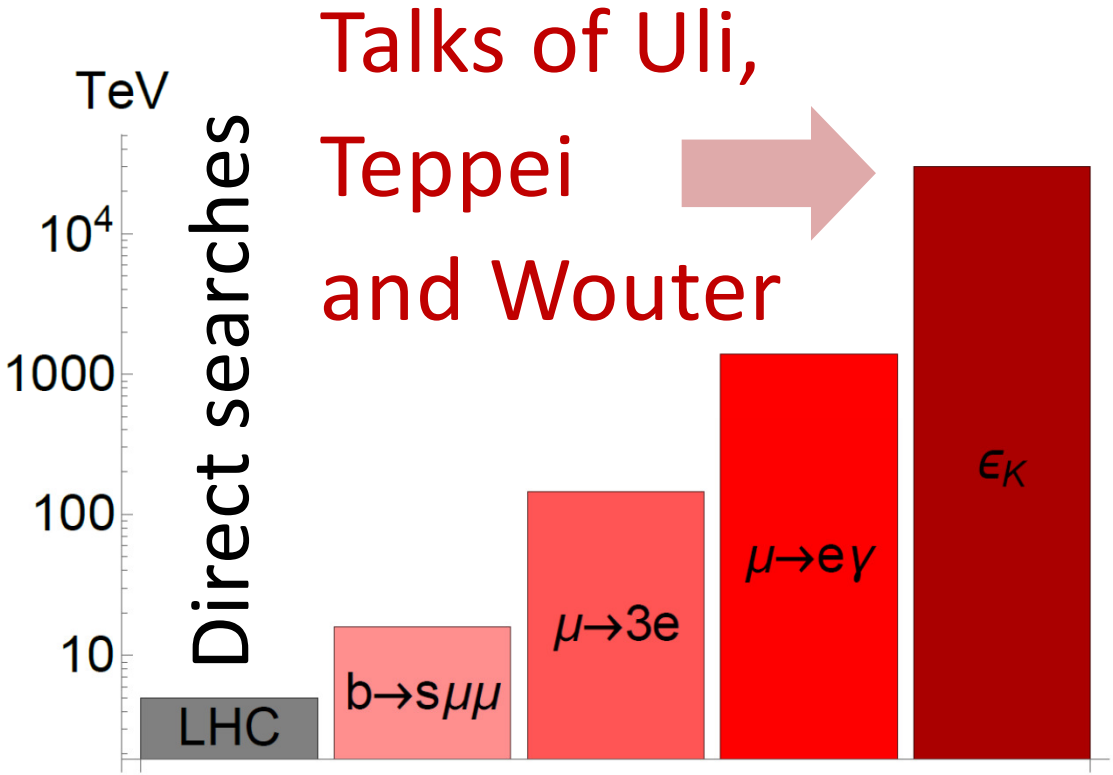
Standard Model

New Physics

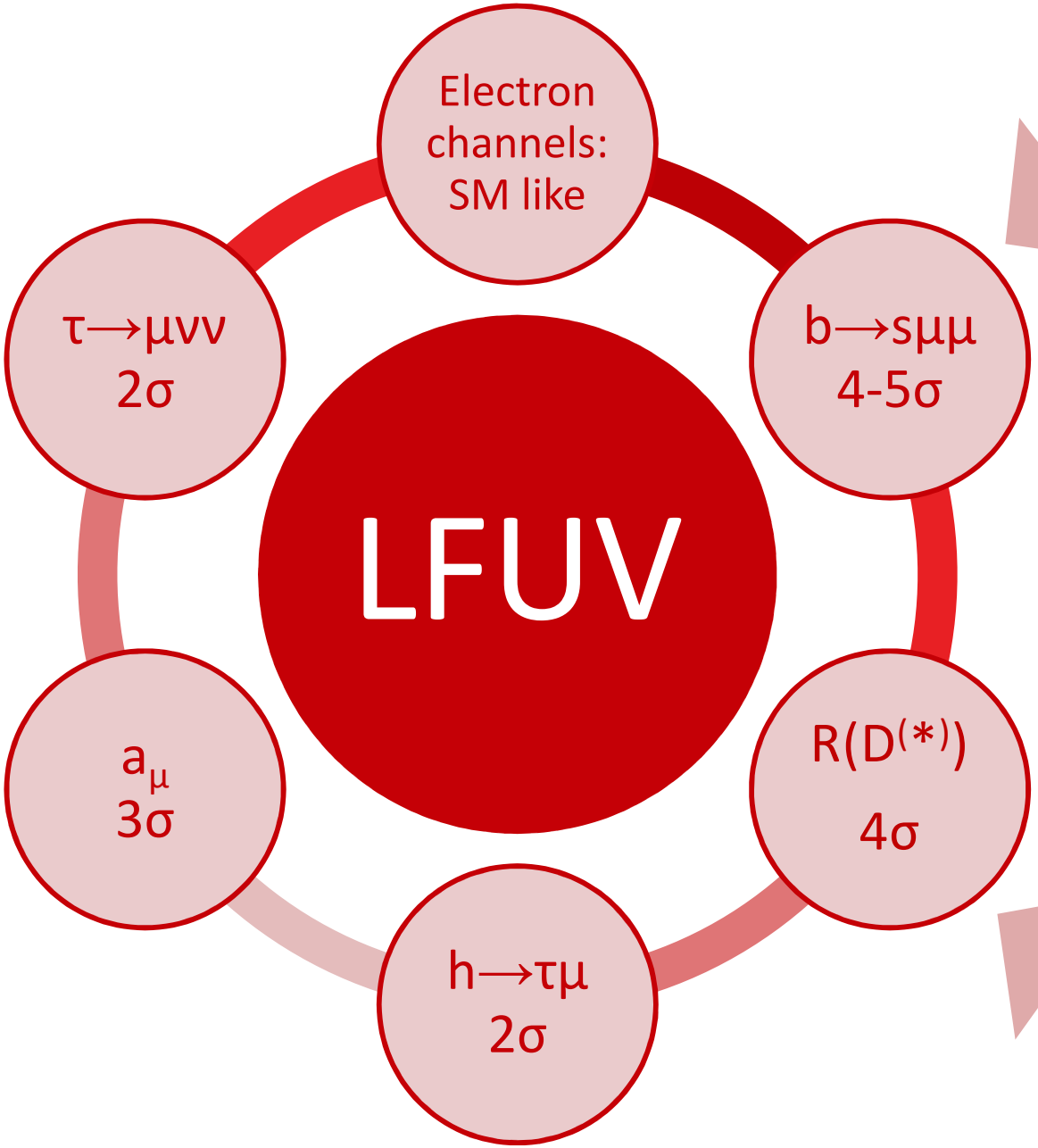


Talks of Uli, Teppei and Wouter

Flavour observables

Flavour observables are sensitive to higher energy scales than collider searches

Hints for LFUV



Talk of Quim

Lepton Flavour Universality Violation (LFUV)

Talk of Jorge

a_μ explanations

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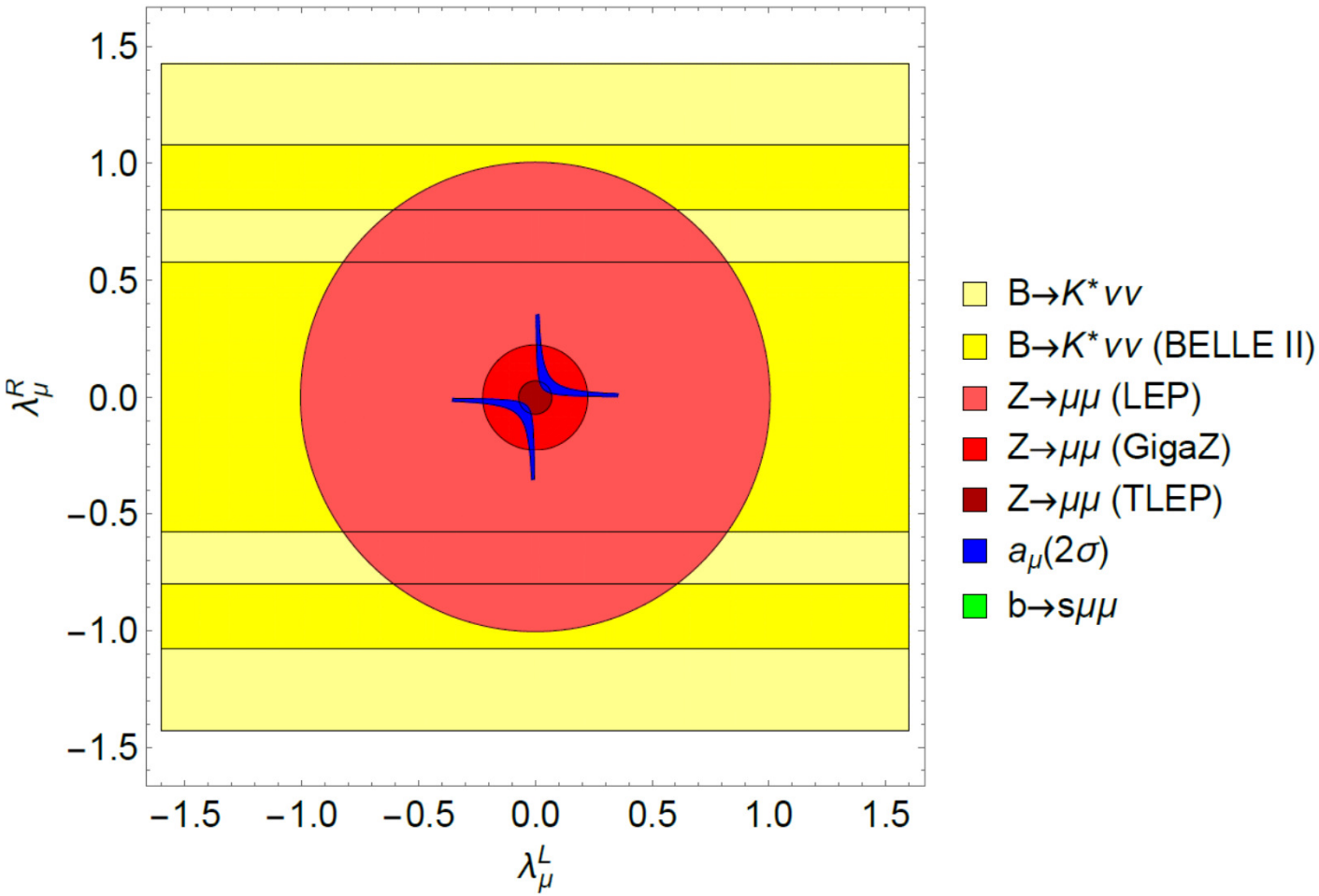
- MSSM e.g. D. Stockinger, hep-ph/0609168
  - tan(ß) enhanced slepton loops
- Scalars e.g. A. Broggio et at. arXiv:1409.3199
  A.C. et al. arXiv:1507.07567
  - Light scalars with enhanced muon couplings
- Z' e.g. W. Altmannshofer, C. Chen, P.S.B. Dev, A. Soni, arXiv:1607.06832
  - Very light with τμ couplings (m_τ enhancement)
- Leptoquarks e.g. A. Djouadi, T. Kohler, M. Spira, J. Tutas, Z.Phys. C46 (1990)
  - m_t enhaned effects E. Leskow, A.C., G. D'Ambrosio, D. Müller arXiv:1612.06858

Chiral enhancement or very light particles

Scalar Leptoquarks in a_μ

- Chirally enhanced effects via top-loops



$\lambda_\mu^{L,R}$

Left-, right-handed muons-top coupling

E. Leskow, A.C., G. D'Ambrosio, D. Müller arXiv:1612.06858

Z→μμ at future colliders

h→τμ explanation

- Can be explained in the effective field theory approach by

R. Harnik, J. Kopp, and J. Zupan, 1209.1397.
G. Blankenburg, J. Ellis, and G. Isidori, 1202.5704.
S. Davidson and P. Verdier, 1211.1248.

$$Q_{e\phi}^{fi} = \ell_f \phi e_i \phi^\dagger \phi$$

- No dominant contribution from vector-like fermions

A. Falkowski, D. M. Straub, and A. Vicente, 1312.5329

Extended Higgs sector

J. Heeck et al. 1412.3671
A. Greljo et al. arXiv:1502.07784
A. C. et al. arXiv:1501.00993
.....
.....

R(D) & R(D*) explanations

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- Charged scalars
  - Problems with angular distributions
- W'
  - UV complete model difficult
  - Strong constraints from direct LHC searches
- Leptoquark
  - Strong signals in $qq \to \tau\tau$ searches

→ Talk of Olcyr

Explanation difficult

b→sμμ explanations

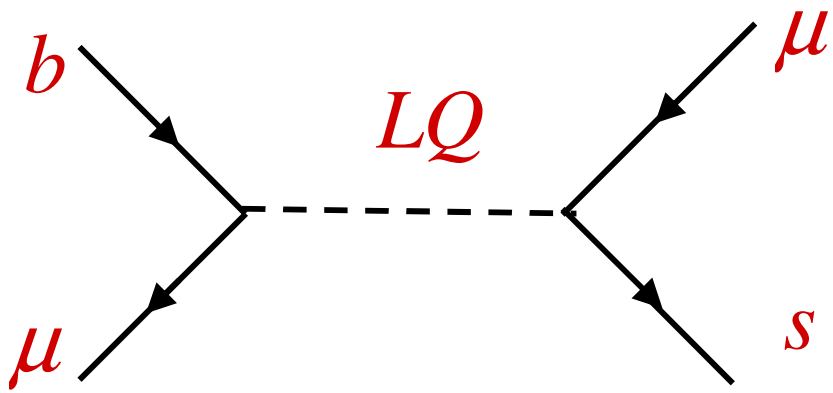
- Z'

Talks of Giuliano and Javier

U. Haisch et al. 1308.1959, Buras et al. 1311.6729
W. Altmannshofer et al. 1403.1269, AC. et al. 1501.00993, ...

- Leptoquarks

Gudrun Hiller, Martin Schmaltz.
arXiv:1411.4773
B. Gripaios, M. Nardecchia, S.A. Renner.
arXiv:1412.1791
D. Bečirević, N. Košnik, O. Sumensari,
R. Zukanovich Funchal, arXiv:1608.07583
L. Calibbi, AC. T. Ota, PRL 2015
...

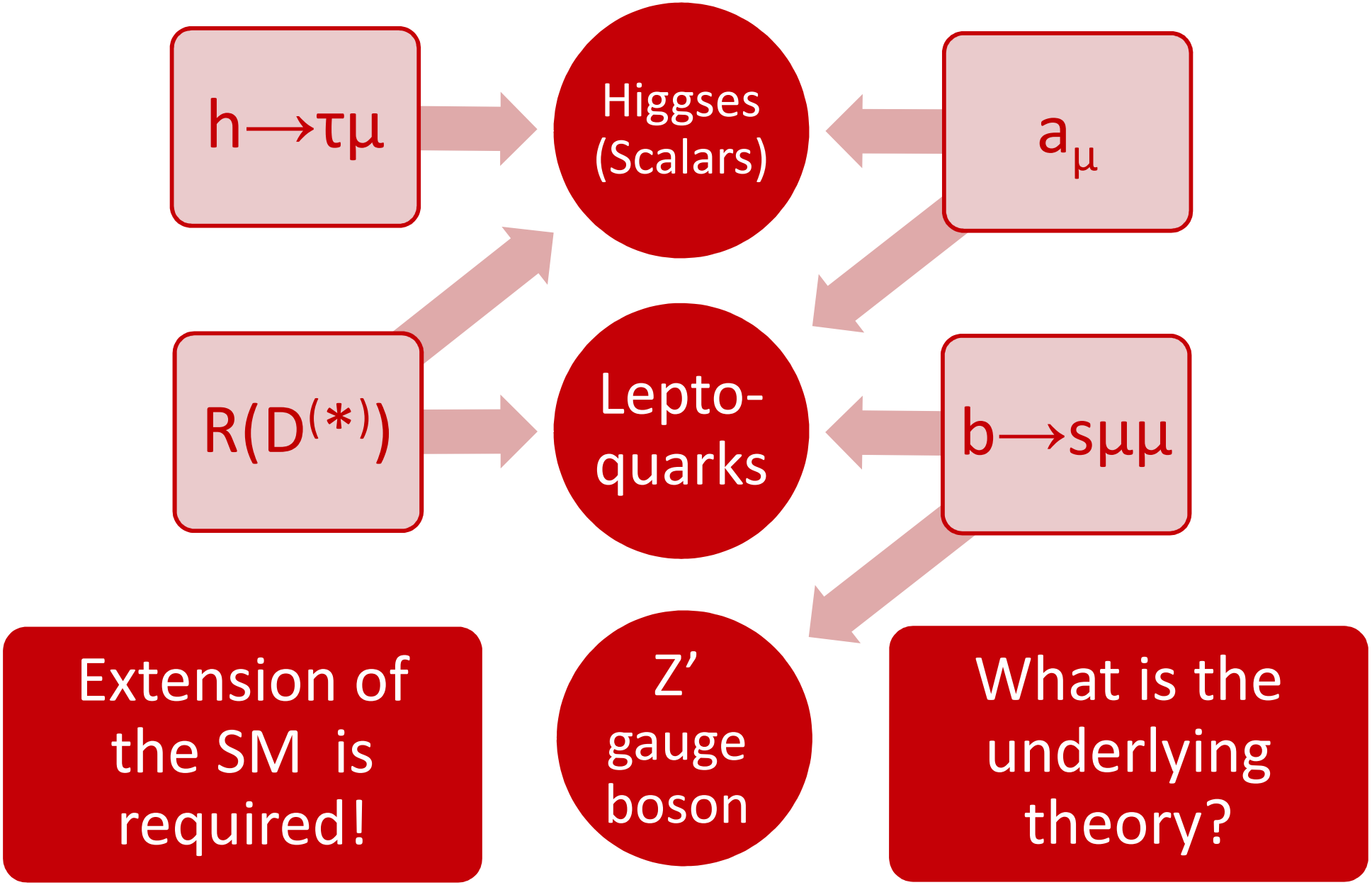


- Loop effects

B. Gripaios, M. Nardecchia, S. Renner, arXiv:1509.05020

Even high scale NP explanations possible

Implications for New Particles



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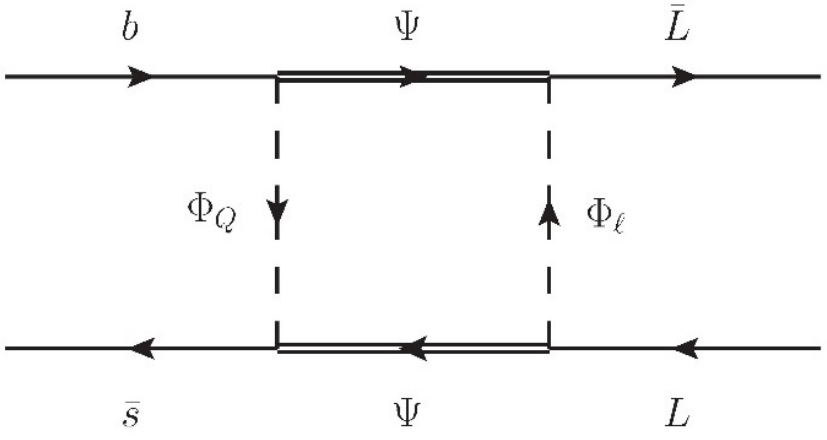
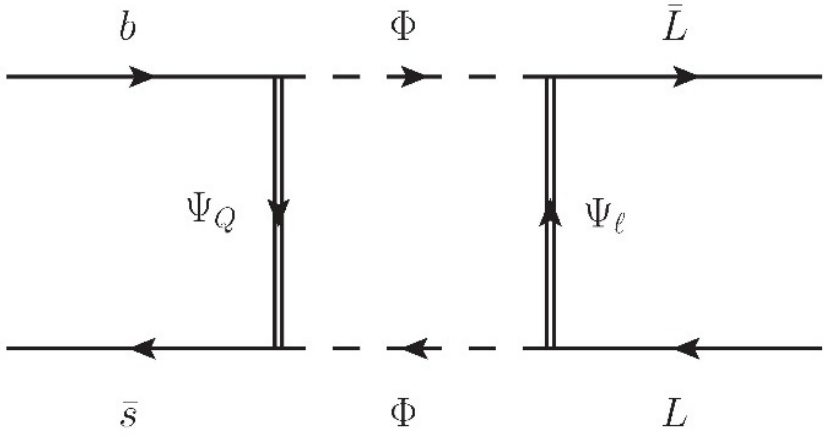
Heavy new sclars and fermions In $b \to s\mu\mu$

Pere Arnan, A.C., Lars Hofer and Federico Mescia, arXiv:1608.07832

New Scalars and Fermions in b→sμμ





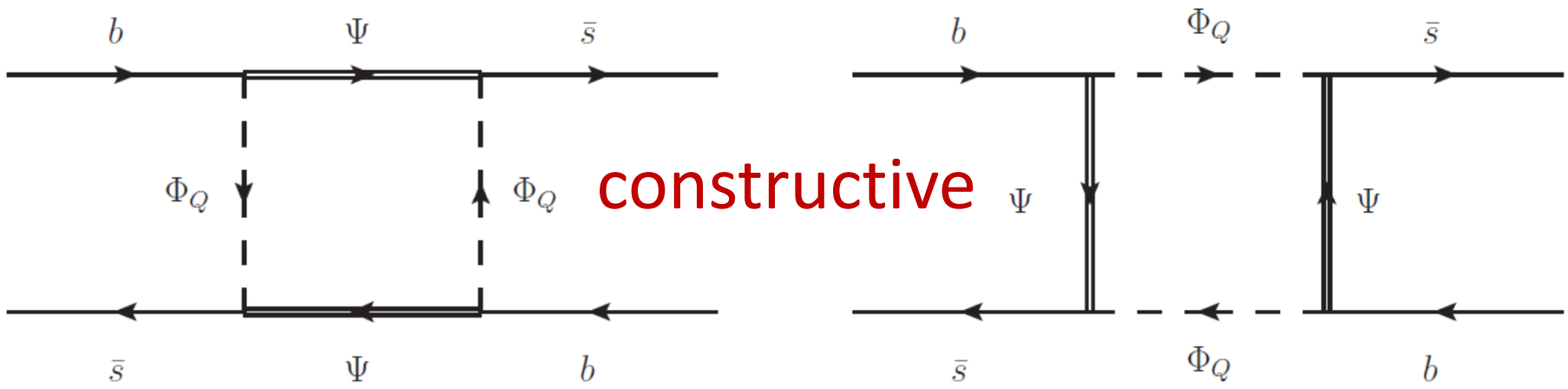
- Possible representations

$SU(2)$	Φ_Q, Ψ_Q	Φ_ℓ, Ψ_ℓ	Ψ, Φ
I	2	2	1
II	1	1	2
III	3	3	2
IV	2	2	3
V	3	1	2
VI	1	3	2

$SU(3)$	Φ_Q, Ψ_Q	Φ_ℓ, Ψ_ℓ	Ψ, Φ
A	3	1	1
B	1	$\bar{3}$	3
C	3	8	8
D	8	$\bar{3}$	3

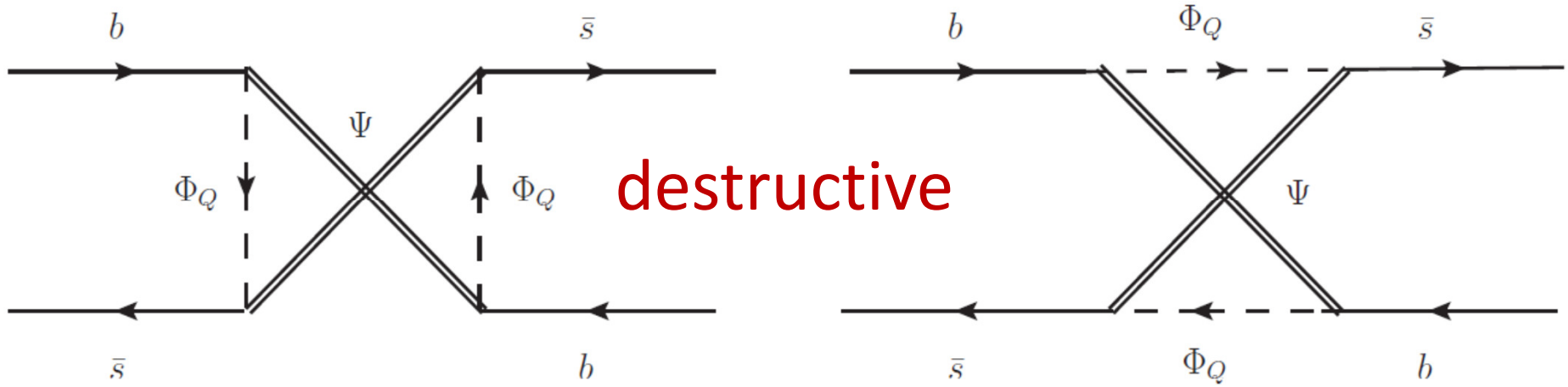
2x6x4 possibilities

Constraints from B_s mixing



Lattice results prefers destructive interference MILC, 1602.03560

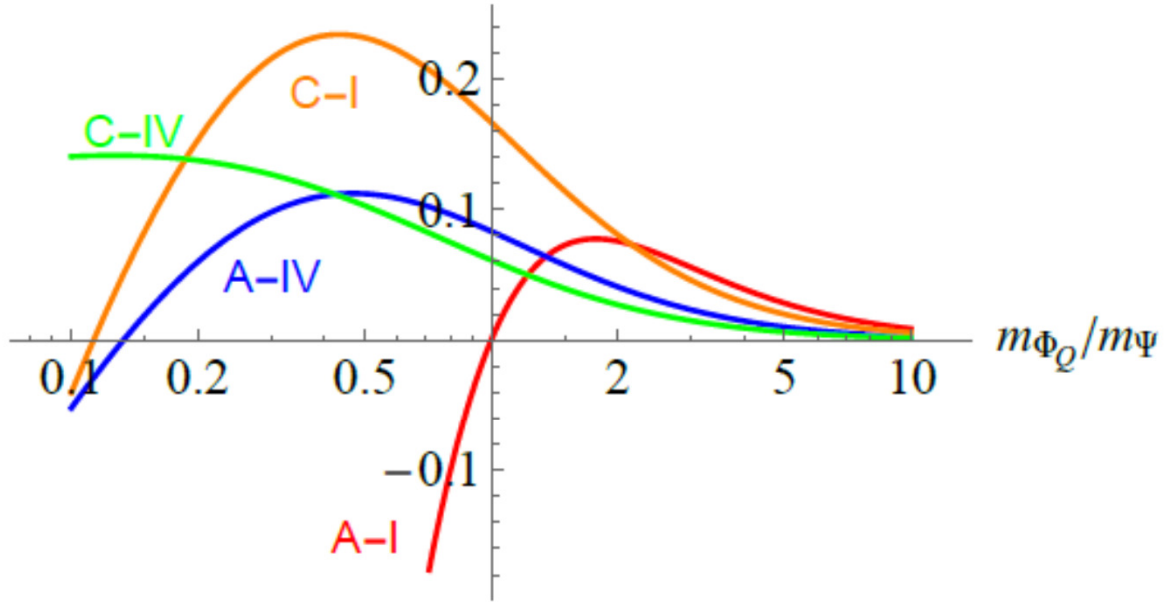
- Majorana representations



Destructive interference with Majorana fermions

b→sμμ and B_s mixing

Relative effect in B_s mixing

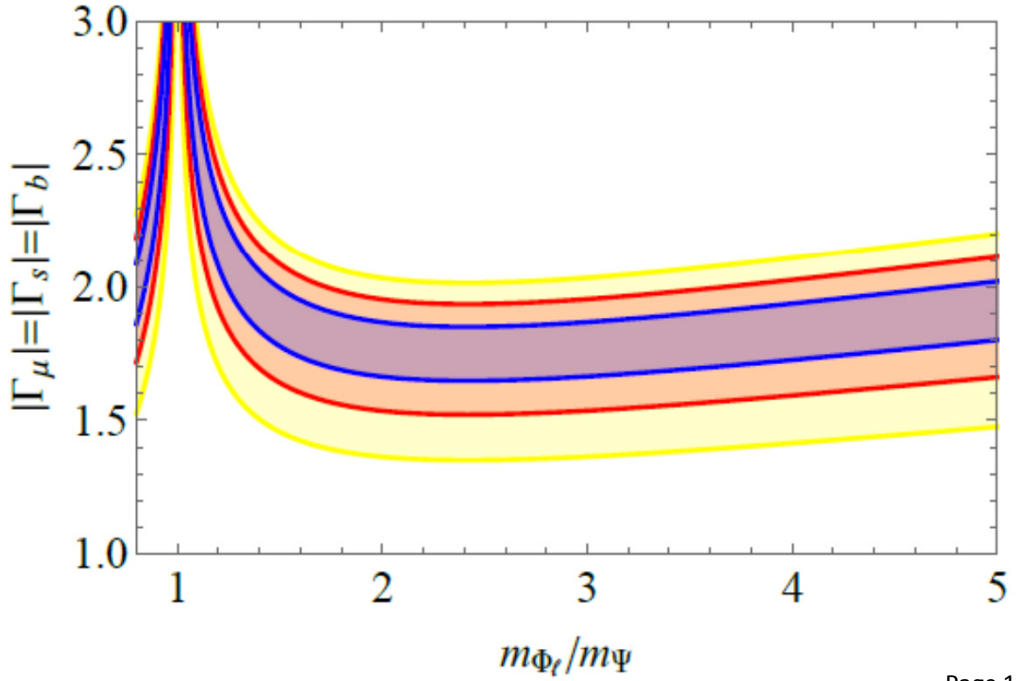


b→sμμ

3σ

1σ

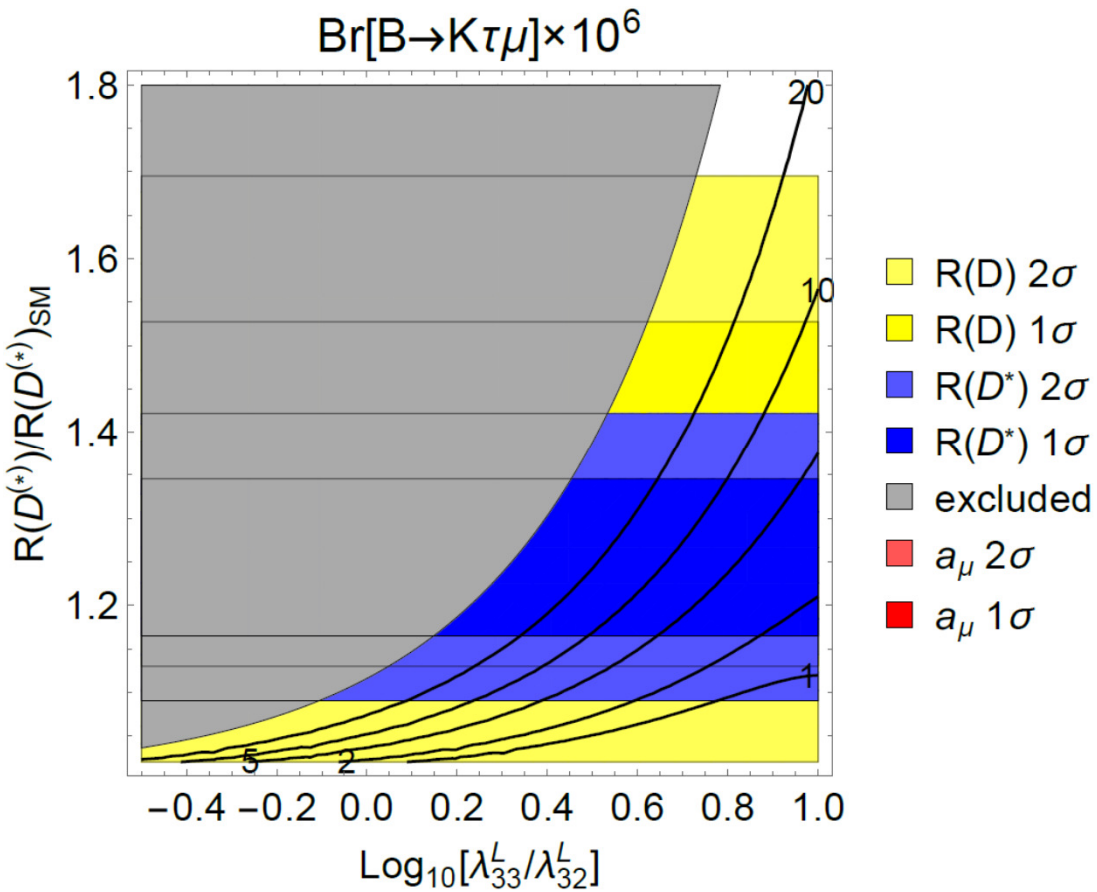
2σ

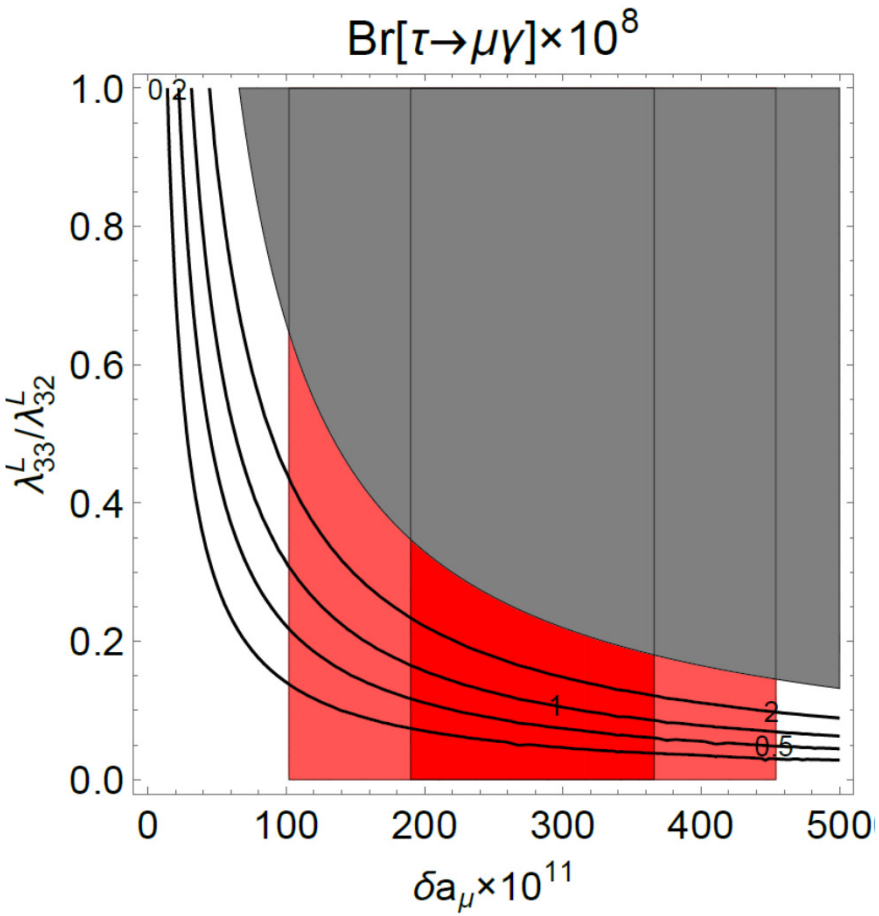


Explanation with O(1) couplings

$R(D^{(*)})$ and $b \to s\mu\mu$ with Leptoquarks

- Scalar leptoquark singlet + triplet with Y=-2/3
- Cancelation in $b \to s\nu\nu$ imposed



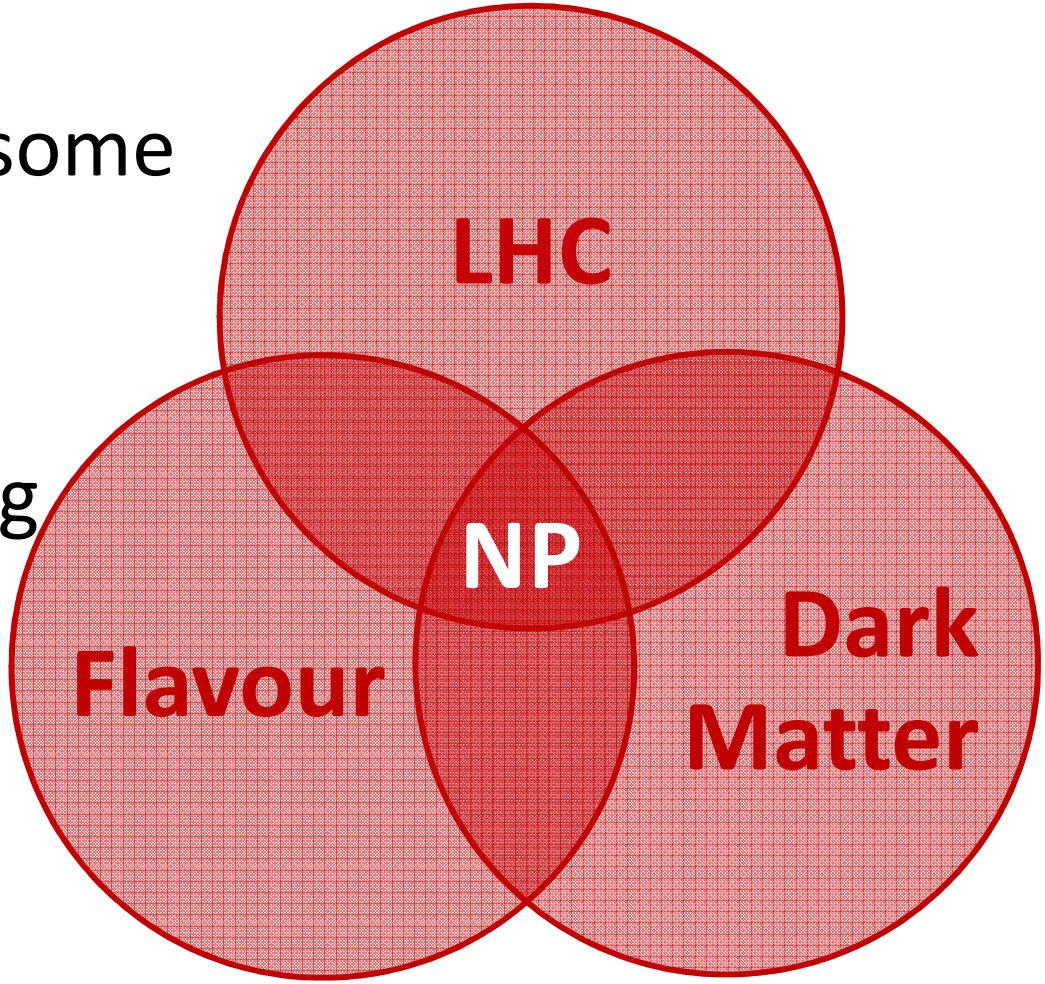


AC, D. Mueller, T. Ota, arXiv:1703._____

Weak collider bounds

Conclusions

- Intriguing hints for Lepton Flavour Universality violating New Physics
- NP models can explain some of the anomalies simultaneously
- Confirming or disproving the anomalies makes a model selection
- Predictions for flavor and LHC observables



Exiting times in flavour physics are ahead of us!