Flavor anomalies from asymptotic safety

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arXiv: 2007.03567 (accepted to EPJC)

Annual Department Seminar

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National
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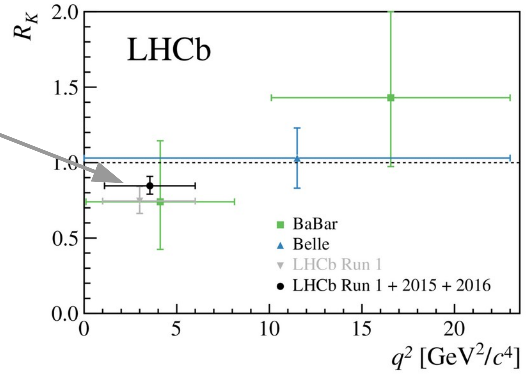
Flavor anomalies in b to s

(recap from last year’s Seminar)

- **lepton-flavor universality violation (LHCb: ~2.5 σ)**

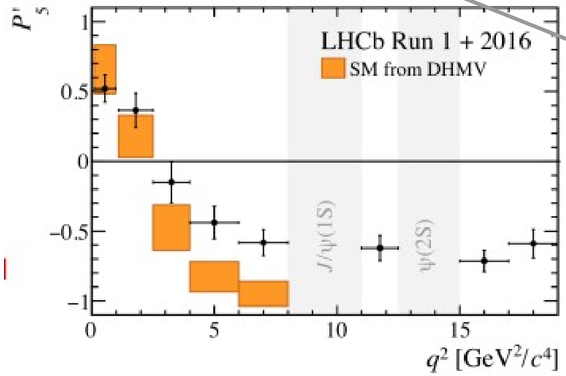
$$R_K = \frac{\mathrm{BR}(B^+ \to K^+ \mu^+ \mu^-)}{\mathrm{BR}(B^+ \to K^+ e^+ e^-)}$$

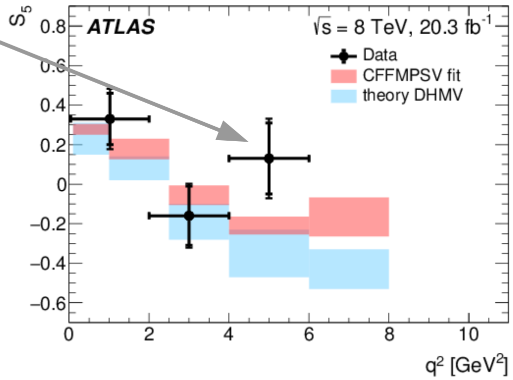
$$R_{K^*} = \frac{\mathrm{BR}(B^0 \to K^{0*} \mu^+ \mu^-)}{\mathrm{BR}(B^0 \to K^{0*} e^+ e^-)}$$



- **deviations in angular observables (LHCb: ~2.5 σ)**

$$B^0 \to K^{0*} \mu^+ \mu^-$$





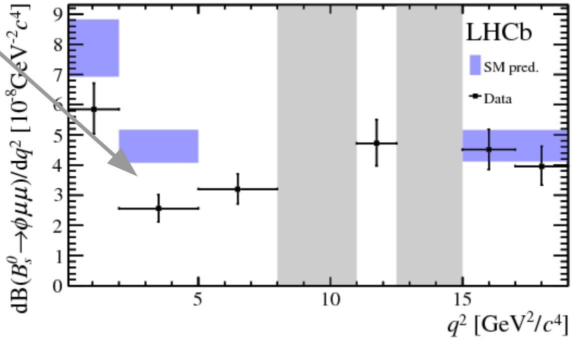
- **deviations in branching ratios (LHCb: ~2-3.5 σ)**

$$B^0 \to K^{0*} \mu^+ \mu^-$$

$$B^0 \to K^0 \mu^+ \mu^-$$

$$B_s^0 \to \phi \mu^+ \mu^-$$

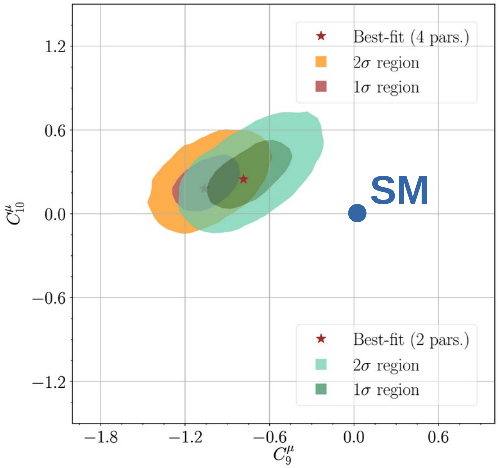
$$\Lambda_b^0 \to \Lambda \mu^+ \mu^-$$



New Physics explanations

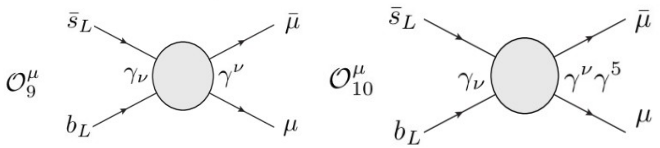
- 140 observables with experimental + theoretical correlations
- GLOBAL FIT

K.Kowalska, D.Kumar, E.M.Sessolo, Eur.Phys.J. C79 (2019) no.10, 840



New Physics in the muon sector?

EFT approach:



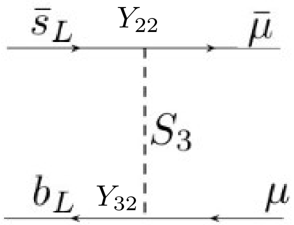
$$\Longrightarrow C_9^{\mu},\ C_{10}^{\mu}$$

pull of the best-fit point: **5.1 σ**

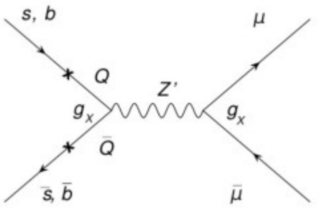
Bayes factor NP vs Standard Model: **10^5 to 1** (“decisive”)

NP models:

$$C_9^{\mu} = -C_{10}^{\mu} = \frac{\pi v_h^2}{V_{33}V_{32}^{*}\alpha_{\text{em}}}\boxed{\frac{\hat{Y}_{32}^{L}\hat{Y}_{22}^{L*}}{m_{S_3}^2}}$$



leptoquarks

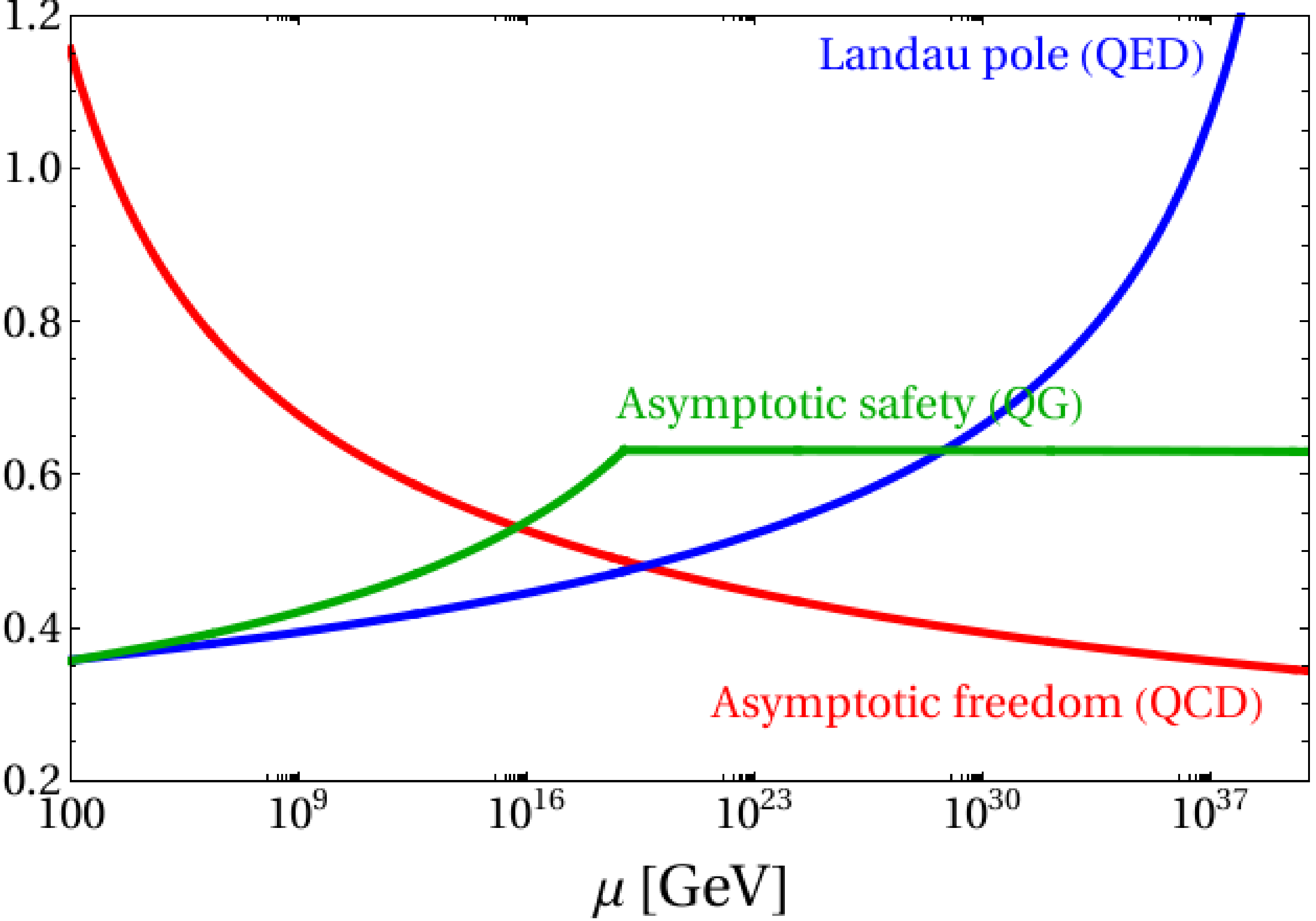


Z’ with VL fernions

Problem: we know only coupling/mass ratio → no prediction for the NP scale

Question: how to get a prediction? → asymptotic safety

Asymptotic behaviours



g → ∞

g ≠ 0*

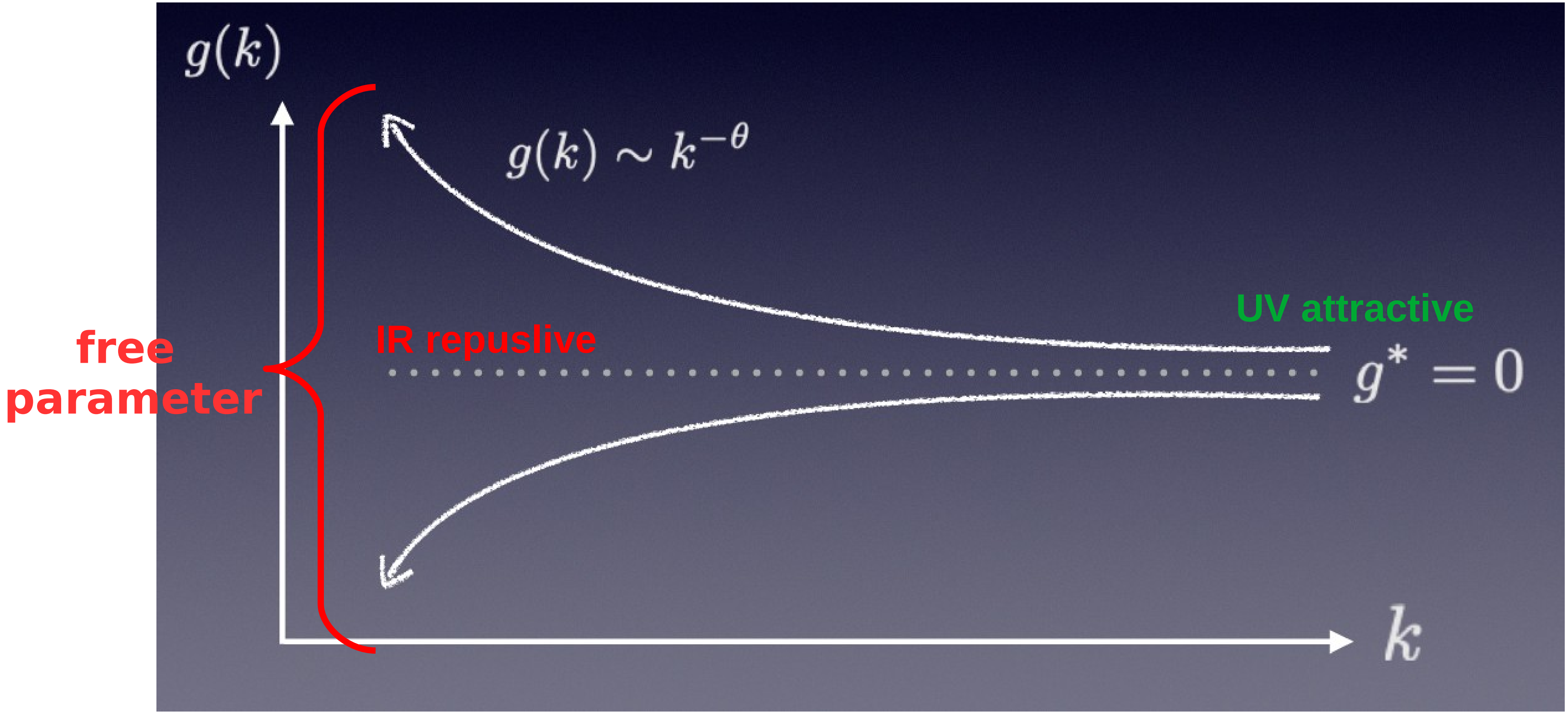
g = 0*

$$\beta_g(g^*) = 0$$

fixed point *g*
in the RGE flow

Relevant couplings

critical exponent θ > 0



free parameter

IR repuslive

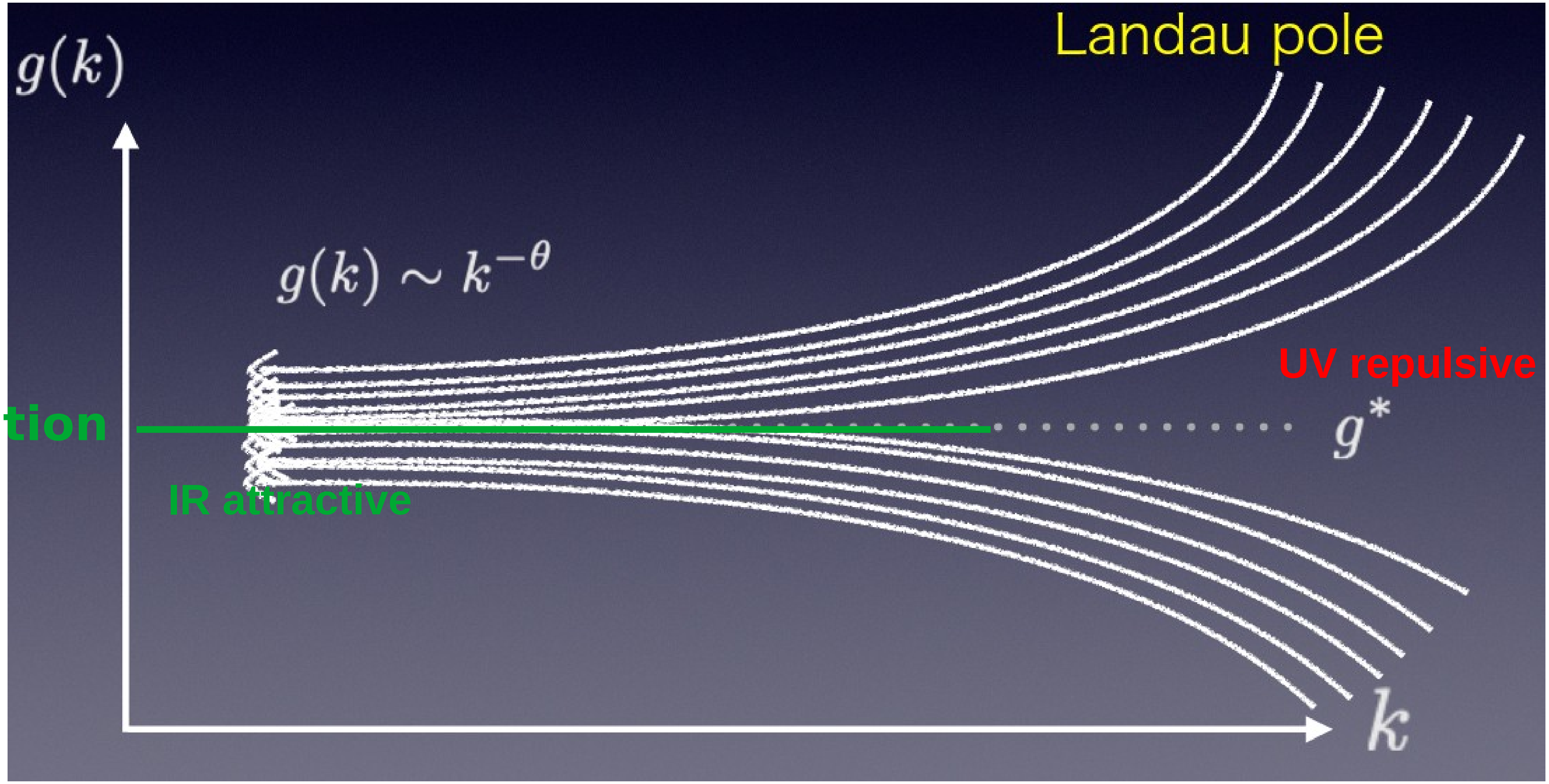
UV attractive

M.Yamada, HECA seminar, 08.10.2019

Relevant couplings are free parameters of the theory

Irrelevant couplings

critical exponent θ < 0



M.Yamada, HECA seminar, 08.10.2019

Irrelevant couplings provide **predictions**

Asymptotic safety – how to make it happen

$$\boxed{\beta_g(g^*) = 0}$$

- 1 vs 2 loop cancellation (ex. A.Bond, G.Hiller, K.Kowalska, D.Litim, JHEP 1708 (2017) 004)
- resummation of perturbative expansion (ex. K.Kowalska, E.M.Sessolo, JHEP 1804 (2018) 027)
- quantum gravity → this talk

for example in the SM: - Higgs quartic (M.Shaposhnikov, C.Wetterich, *Phys.Lett.B 683 (2010) 196-200)*,
- top Yukawa (A.Eichhorn, A.Held, *Phys.Lett. B 777 (2018) 217-221*)

SM + leptoquark + gravity

System of beta functions to solve:

$$\begin{cases} \beta_g = \beta_g^{\mathrm{SM+NP}} - g\, f_g \\ \beta_y = \beta_y^{\mathrm{SM+NP}} - y\, f_y \end{cases}$$

gravity contributions

$$\underbrace{g_Y\,,\ g_2,\ g_3,}_{\text{gauge}}\ \underbrace{y_t,\ y_b,\ V_{33},}_{\text{SM Yukawa}}\ \underbrace{\hat{Y}^L_{22},\ \hat{Y}^L_{32}}_{\text{LQ Yukawa}}$$

Leptoquark Yukawa matrix

$$\begin{pmatrix} d & s & b \end{pmatrix} \begin{pmatrix} 0 & 0 & 0 \\ 0 & \hat{Y}^L_{22} & 0 \\ 0 & \hat{Y}^L_{32} & 0 \end{pmatrix} \begin{pmatrix} e \\ \mu \\ \tau \end{pmatrix}$$

UV fixed-point:

SM: $g_3^* = 0,\ g_2^* = 0,\ g_Y^* = 0.48,\ y_t^* = 0,\ y_b^* = 0.03,\ V_{33} = 0$

LQ: $\hat{Y}^{L*}_{22} = 0,\ \hat{Y}^{L*}_{32} = 0.19 \xrightarrow{\text{irrelevant}}$ low-scale predictions

Prediction for the LQ mass

$$C_9^\mu = -C_{10}^\mu = \frac{\pi v_h^2}{V_{33}V_{32}^*\alpha_{\rm em}} \frac{\hat{Y}_{32}^{L}\hat{Y}_{22}^{L*}}{m_{S_3}^2}$$

0.03

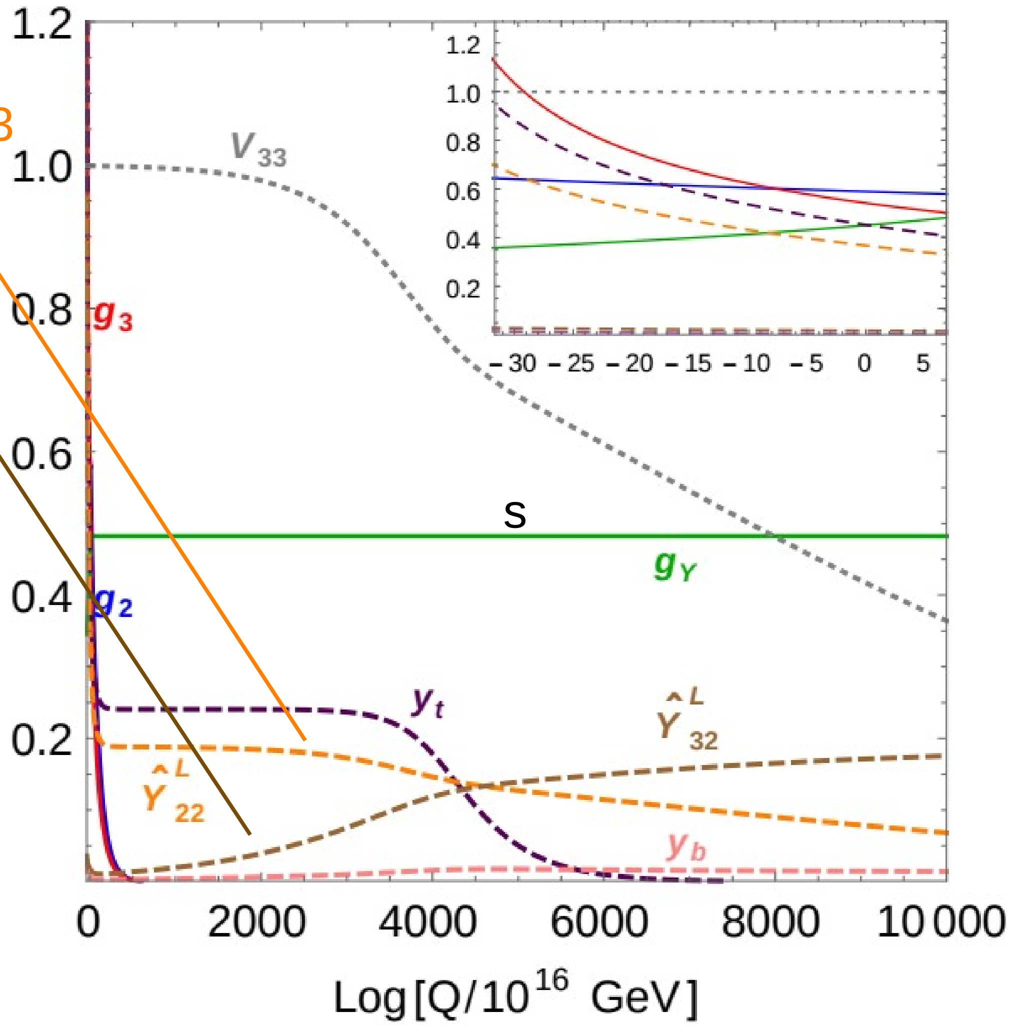
0.63

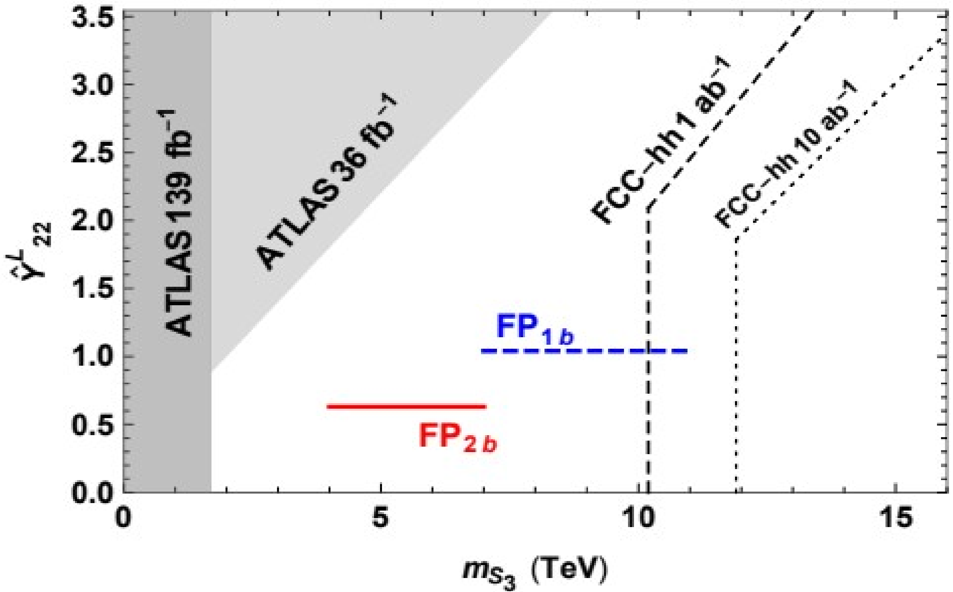
global fits:

$$C_9^\mu = -C_{10}^\mu \in (-0.7, -0.3)$$

$$\boxed{M_{S_3} \in (4,7)\,\mathrm{TeV}}$$

Mass predicted !





In the reach of the FCC!

To take home

- Asymptotic safety can enhance predictivity of the BSM models

- Single leptoquark extensions of the SM with AS predicts the LQ mass between 4 and 7 TeV, in the reach of FCC

- Asymptotic safety can provide a theoretical guidance for future experiments

- Other applications (anomalous magnetic moments, dark matter – work in progress)