LIO International Conference on
“Asymptotic safety in Quantum Field Theory: Grand Unification"

Directions for Model Building
beyond Asymptotic Freedom

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running couplings

quantum fluctuations modify interactions
couplings depend on energy

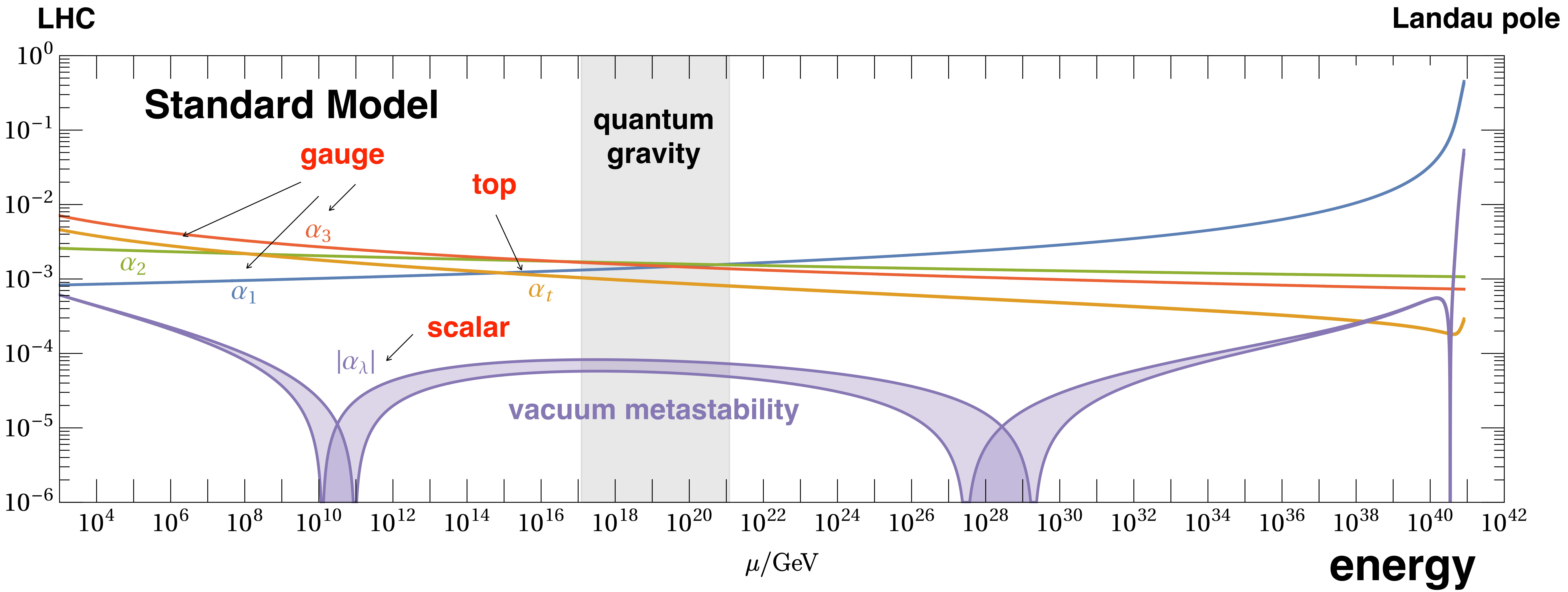
$$\mu \frac{d\alpha}{d\mu} = \beta(\alpha)$$

fluctuations	$\hbar$
energy scale	μ
couplings	$\alpha(\mu)$

QFT provides
us with

predictions into regions where we cannot (yet) make measurements

where are we?



$$\alpha_\lambda = \frac{\lambda}{(4\pi)^2}$$

Higgs quartic

Uncertainty bands:
1-sigma top pole mass

$$m_t = 172.76 \pm 0.30\ \mathrm{GeV}$$

G Hiller, T Hoehne, DF Litim, T Steudtner, **Portals into Higgs Vacuum Stability** 2207.07737

SM vacuum stability

Higgs discovery ’12: **SM vacuum metastability** Buttazzo et al ’13

revisiting vacuum stability ’24: **matching observables to MSbar**

at least 2L + 3L QCD Martin, Patel ‘18

RG running

4L gauge + 5L QCD Davies, Herren, Poole, Steinhauer, Thomsen ’19
Baikov et al ’16, , Herzog et al ’17, Luthe et al ‘17

3L Yukawa + 3L quartic (+4L QCD) Chetyrkin, Zoller ’13-’16
Bednyakov et al ’12-‘14

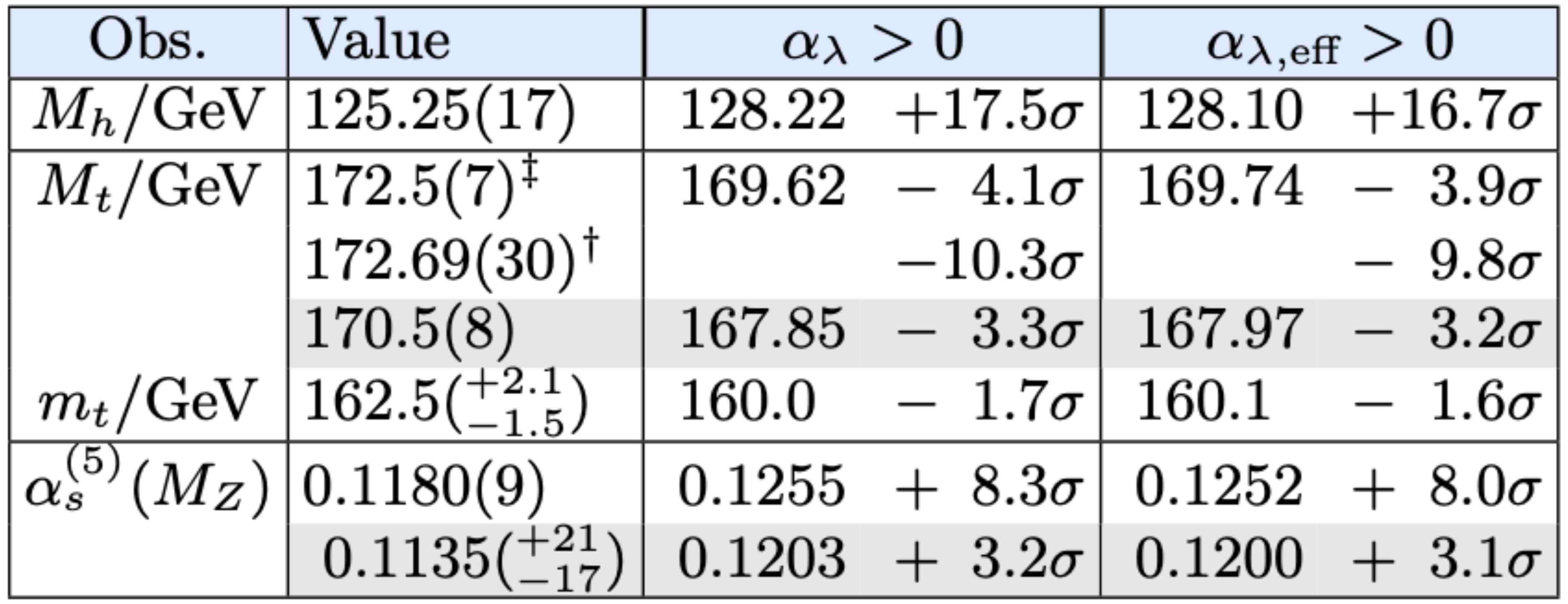
effective potential

3L (4L QCD) + RG improvement Ford, Jack, Jones ’92, Martin ’13-‘17

PDG 2023 update

→

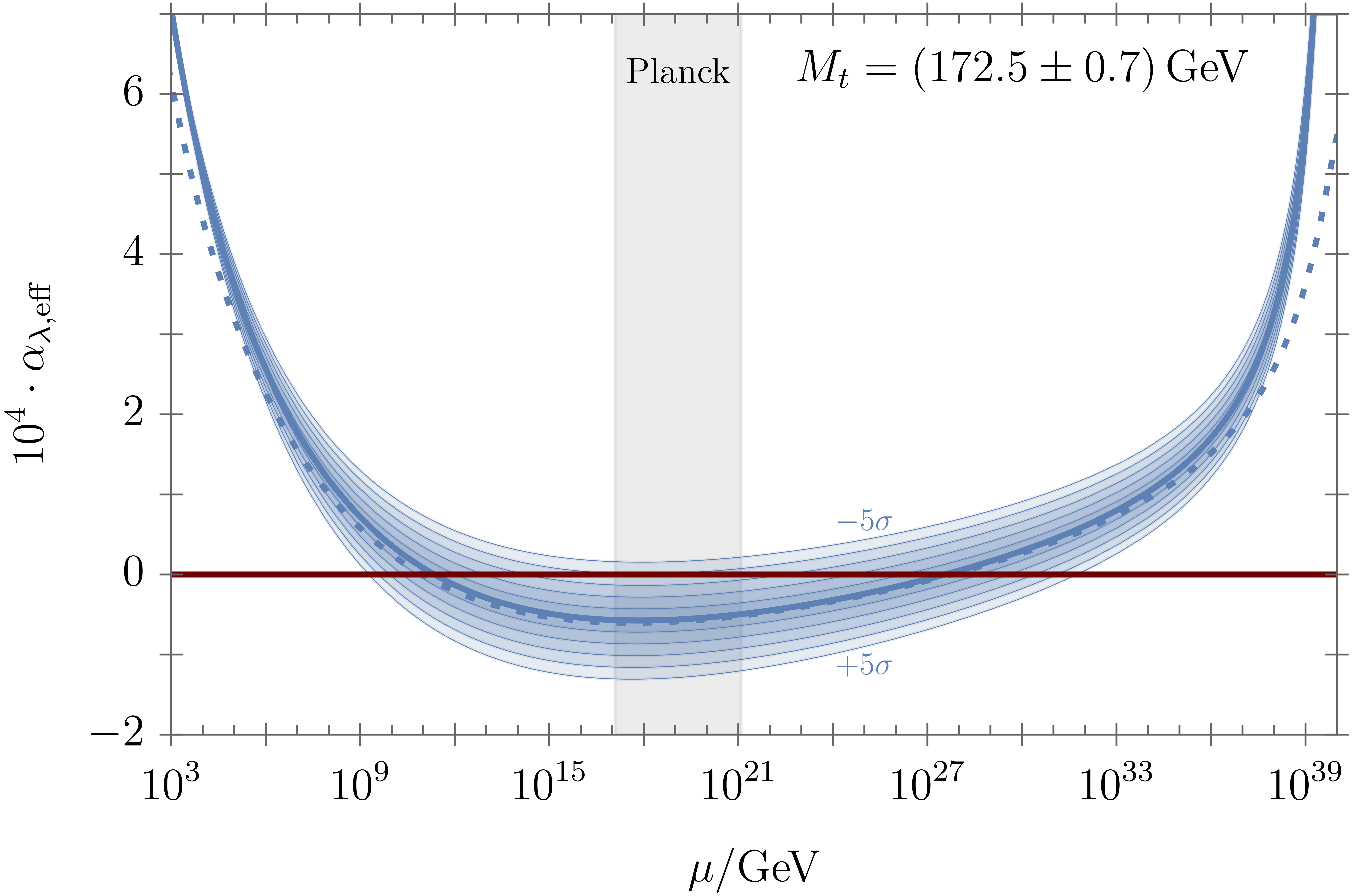
→



Obs.	Value	$\alpha_\lambda > 0$		$\alpha_{\lambda,\mathrm{eff}} > 0$	
M_h/GeV	$125.25(17)$	128.22	$+17.5\sigma$	128.10	$+16.7\sigma$
M_t/GeV	$172.5(7)^\ddagger$	169.62	$-\ 4.1\sigma$	169.74	$-\ 3.9\sigma$
	$172.69(30)^\dagger$		-10.3σ		$-\ 9.8\sigma$
	$170.5(8)$	167.85	$-\ 3.3\sigma$	167.97	$-\ 3.2\sigma$
m_t/GeV	$162.5(^{+2.1}_{-1.5})$	160.0	$-\ 1.7\sigma$	160.1	$-\ 1.6\sigma$
$\alpha_s^{(5)}(M_Z)$	$0.1180(9)$	0.1255	$+\ 8.3\sigma$	0.1252	$+\ 8.0\sigma$
	$0.1135(^{+21}_{-17})$	0.1203	$+\ 3.2\sigma$	0.1200	$+\ 3.1\sigma$

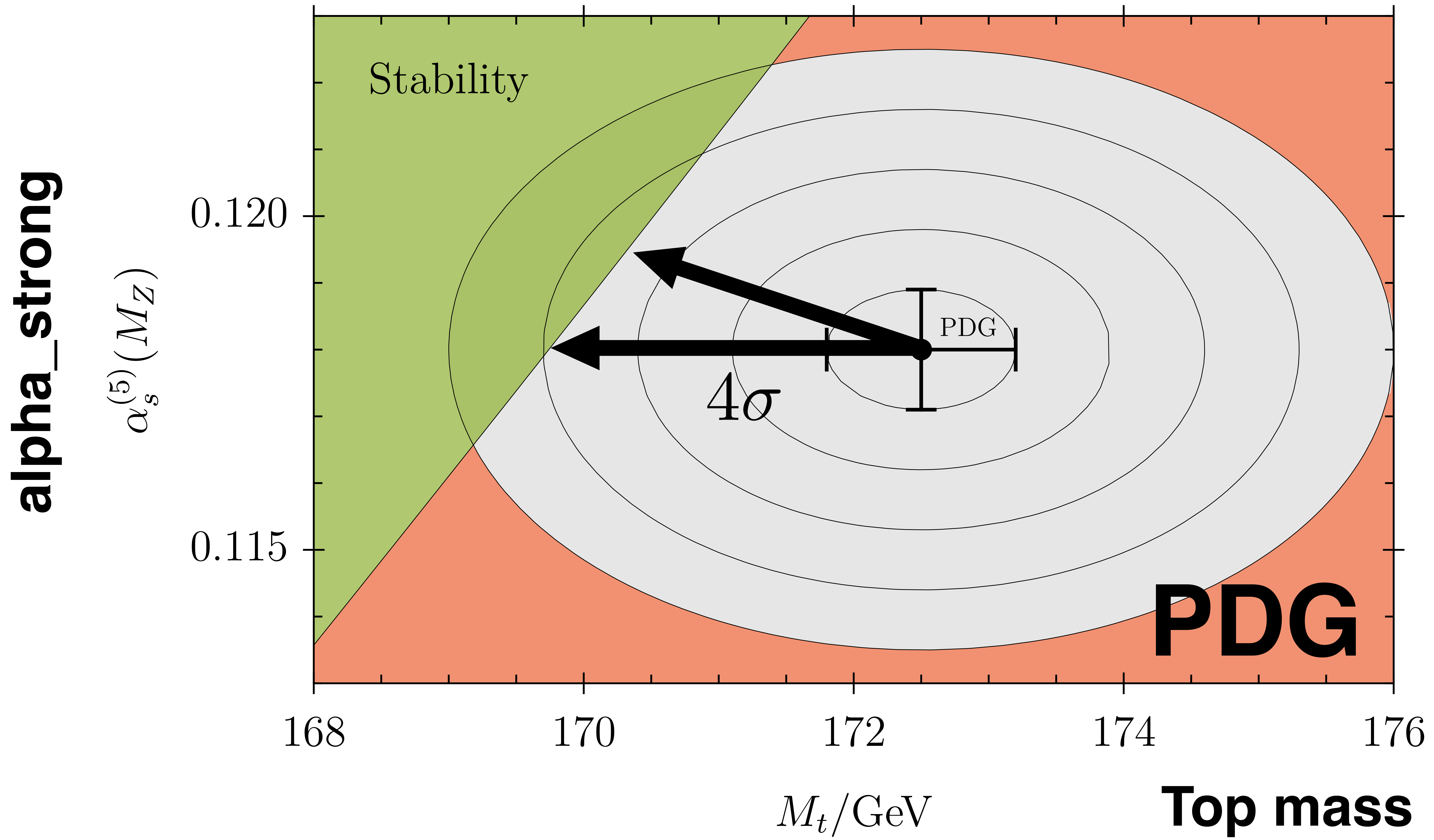
G Hiller, T Hoehne, DF Litim, T Steudtner, **Vacuum stability in the SM and beyond** 2401.08811

SM vacuum stability



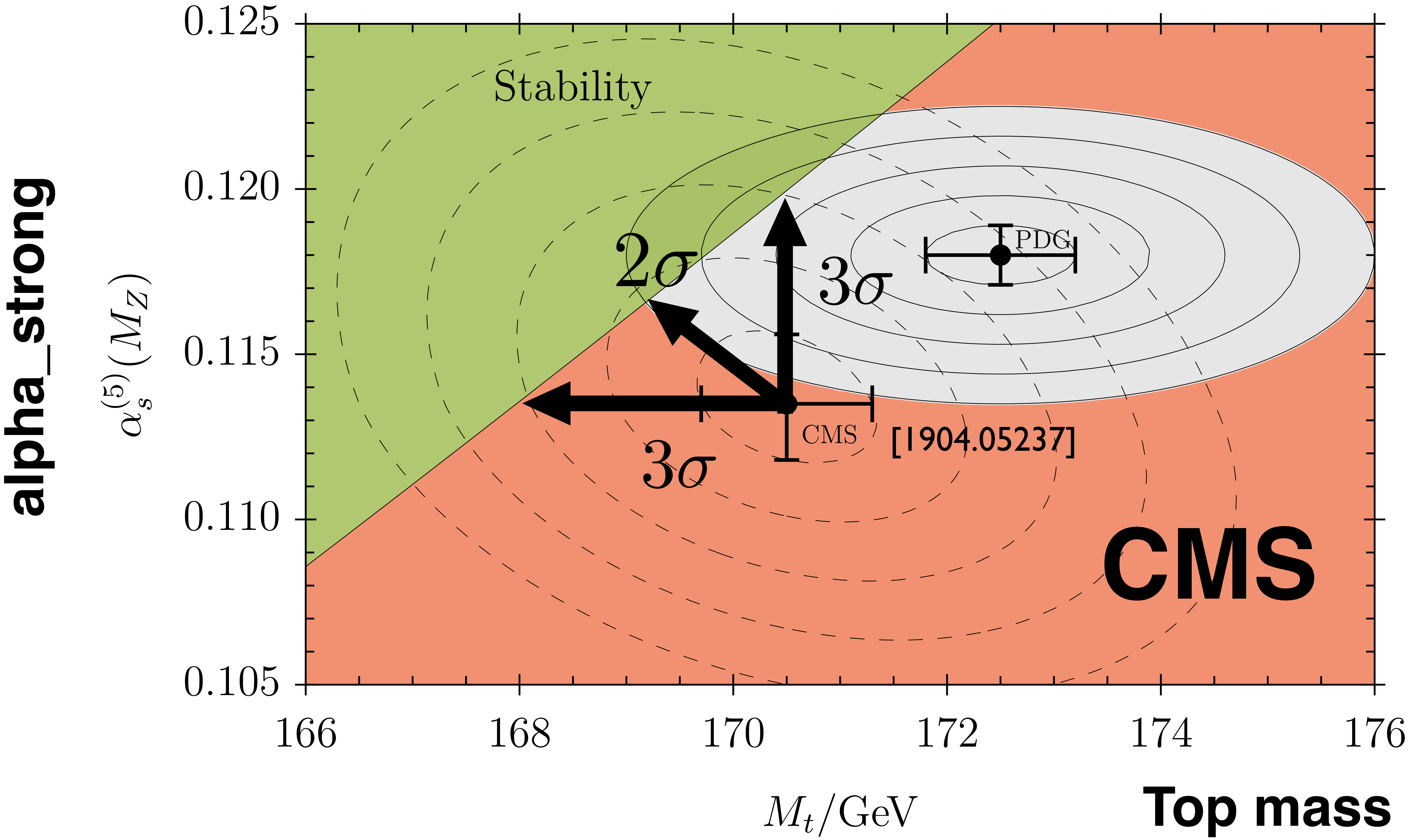
G Hiller, T Hoehne, DF Litim, T Steudtner, **Vacuum stability in the SM and beyond** 2401.08811

SM vacuum stability



G Hiller, T Hoehne, DF Litim, T Steudtner, **Vacuum stability in the SM and beyond** 2401.08811

correlations



G Hiller, T Hoehne, DF Litim, T Steudtner, **Vacuum stability in the SM and beyond** 2401.08811

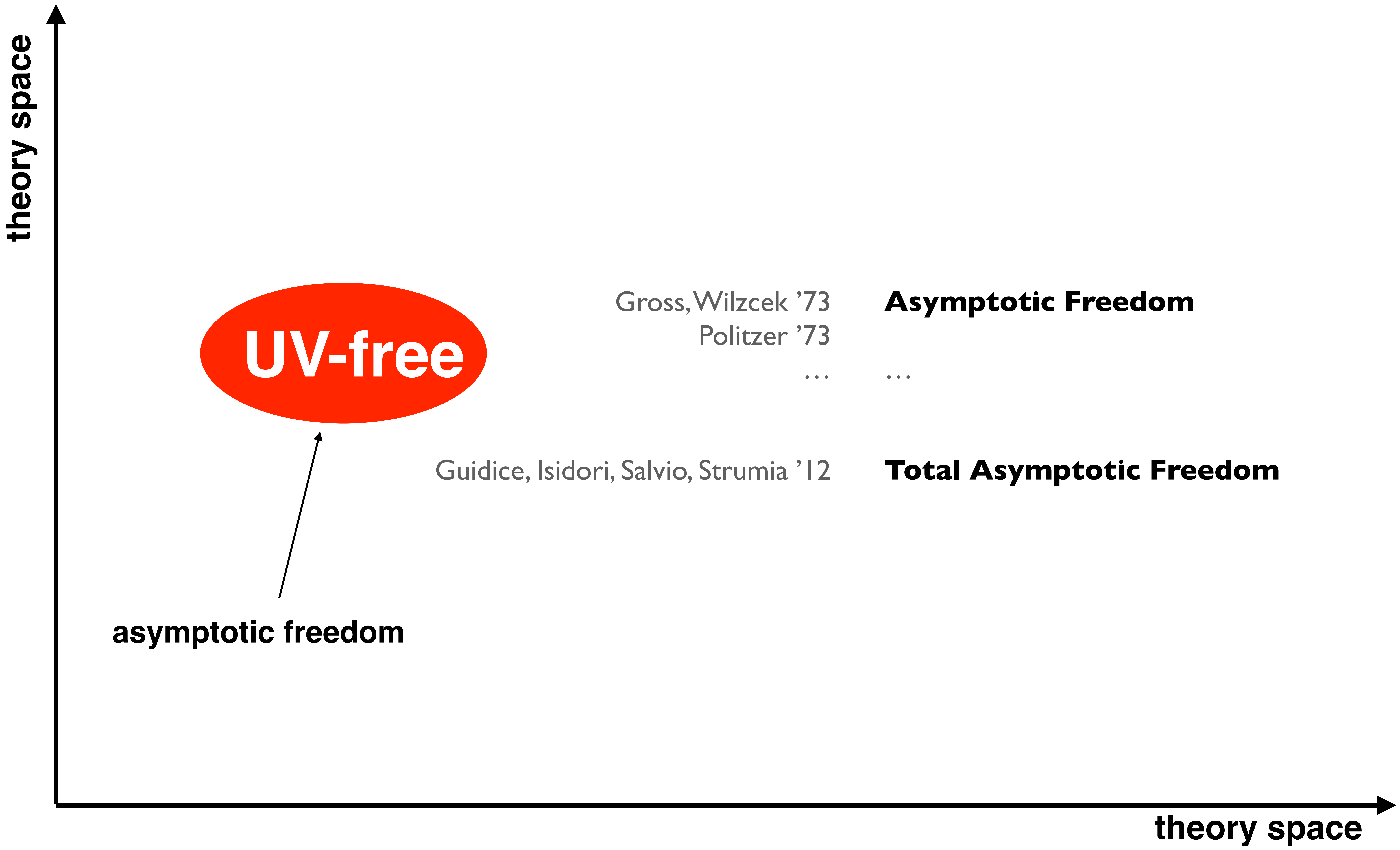
today:

new directions for model building

bottom-up “Planck-safe”

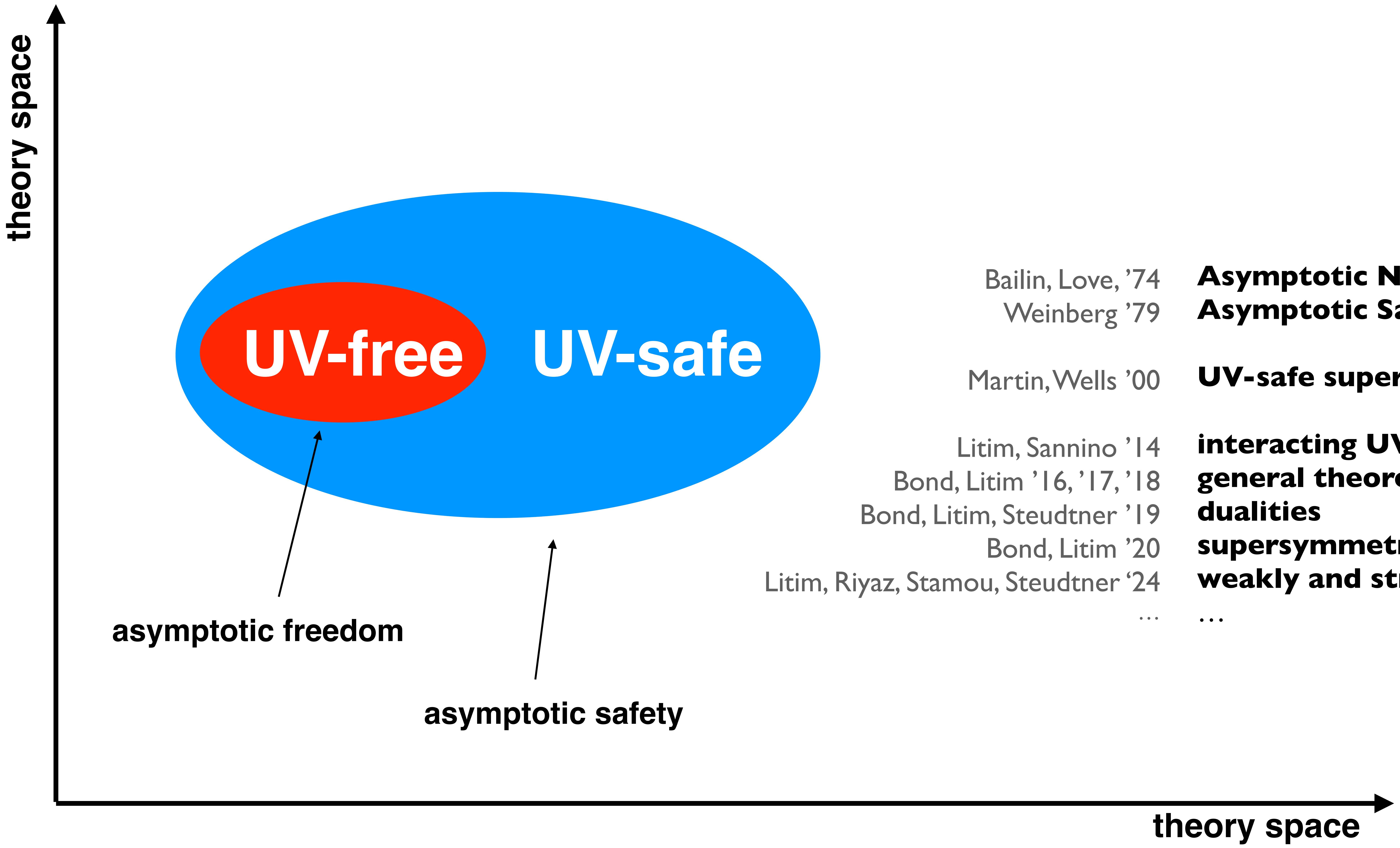
top-down “UV safe”

Top-Down



Gross, Wilzcek ’73	**Asymptotic Freedom**
Politzer ’73	
…	…
Guidice, Isidori, Salvio, Strumia ’12	**Total Asymptotic Freedom**

Top-Down



theory space

UV-free

UV-safe

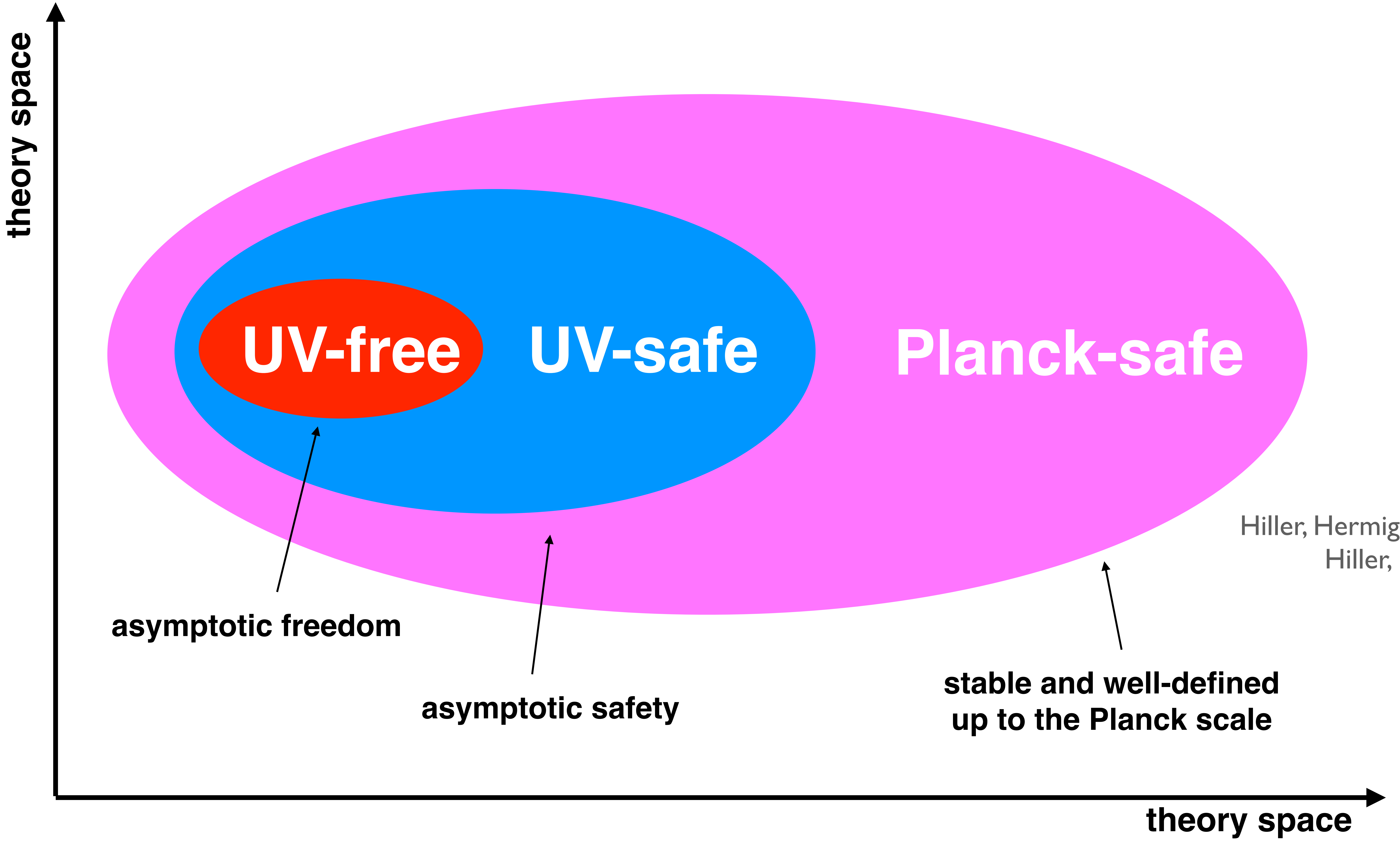
asymptotic freedom

asymptotic safety

theory space

Bailin, Love, '74	**Asymptotic Near-Freedom**
Weinberg '79	**Asymptotic Safety**
Martin, Wells '00	**UV-safe supersymmetry**
Litim, Sannino '14	**interacting UV fixed points in 4d QFTs**
Bond, Litim '16, '17, '18	**general theorems**
Bond, Litim, Steudtner '19	**dualities**
Bond, Litim '20	**supersymmetry**
Litim, Riyaz, Stamou, Steudtner '24	**weakly and strongly coupled FPs**
…	**…**

Bottom-Up



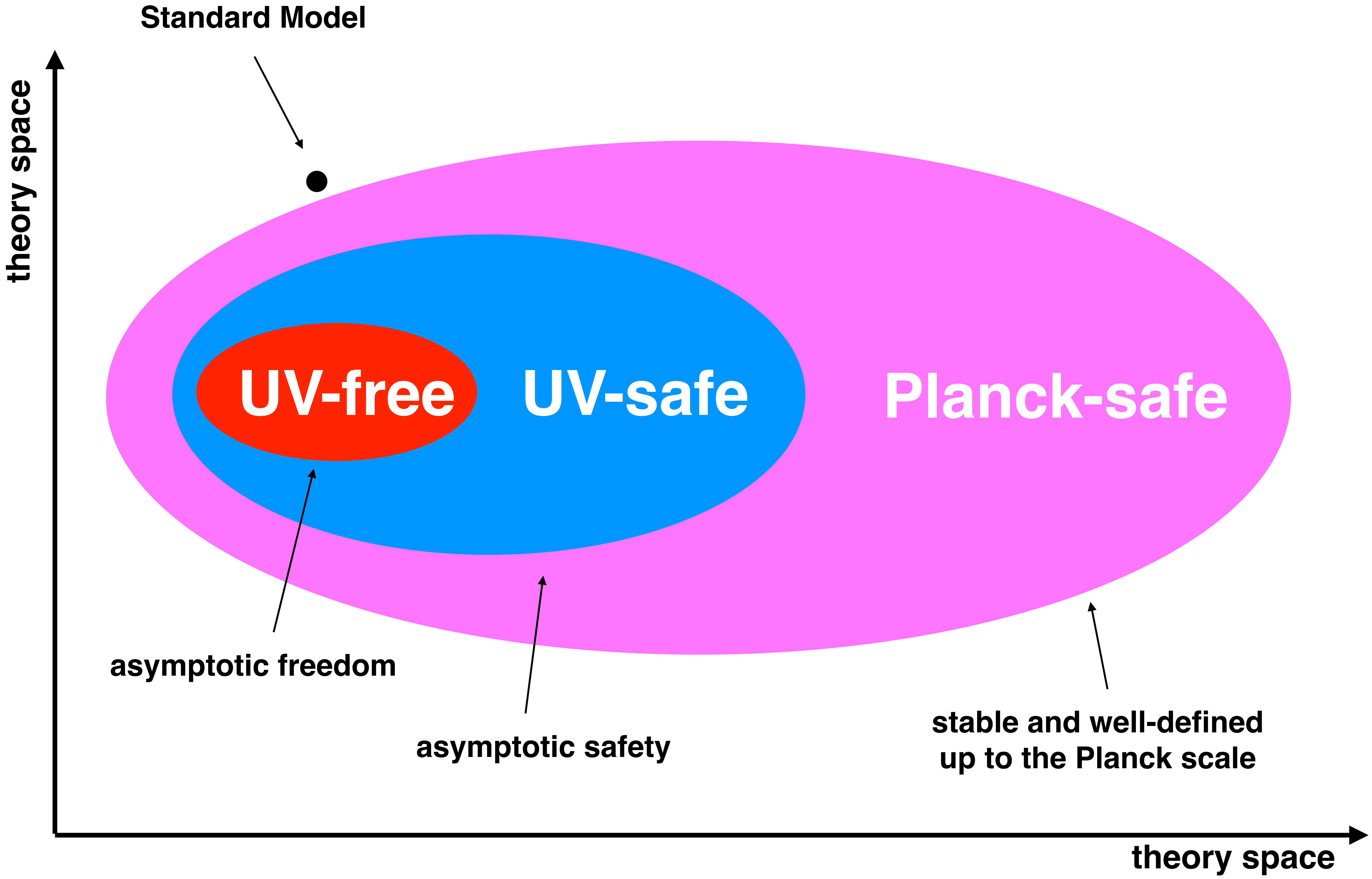
asymptotic freedom

asymptotic safety

stable and well-defined
up to the Planck scale

Hiller, Hermigos-Feliu, Litim, Steudtner ’19, ’20
Hiller, Hoehne, Litim, Steudtner ’22-’24

Bottom-Up



Standard Model
theory space
UV-free
UV-safe
Planck-safe
asymptotic freedom
asymptotic safety
stable and well-defined
up to the Planck scale
theory space

Bottom-Up

Q: What does it take to

achieve vacuum stability?

… and make it safely up to
the Planck scale?

Portals into Stability

Gauge Portals

Portals into Stability

Gauge Portals

$$\mathcal{L} \supset \bar{\psi} i \not{D} \psi$$

Vectorlike Fermions (VLFs)

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

charges (Y_F, d_2, d_3)

mass M_F

multiplicity N_F

$\longrightarrow$ **modified RG running**

``minimally invasive’’

Portals into Stability

Gauge Portals

$$\mathcal{L} \supset \bar{\psi} i \not{D} \psi$$

Yukawa Portals

$$\mathcal{L} \supset -\underbrace{\kappa}_{\text{Yukawa}}\, \underbrace{\bar{\psi}}_{\text{VLFs}}\, \underbrace{H}_{\text{Higgs}}\, \underbrace{f_{\text{SM}}}_{\text{SM fermion}}$$

→ new interactions

→ new RG beta functions
modified RG running

Portals into Stability

Gauge Portals

$$\mathcal{L} \supset \bar{\psi} i \not{D} \psi$$

Yukawa Portals

$$\mathcal{L} \supset -\kappa \, \bar{\psi} \, H \, f_{\mathrm{SM}}$$

Higgs Portals

$$\mathcal{L} \supset \sum_i \delta_i \, (H^\dagger H)(S_i^\intercal S_i)$$

Portals

Higgs

BSM scalars

⟶ **new scalars**

⟶ **new interactions**

⟶ **new RG beta functions**
modified RG running

Portals into Stability

Gauge Portals

$$\mathcal{L} \supset \bar{\psi} i \not{D} \psi$$

Yukawa Portals

$$\mathcal{L} \supset -\kappa \, \bar{\psi} \, H \, f_{\mathrm{SM}}$$

Higgs Portals

$$\mathcal{L} \supset \sum_i \delta_i \, (H^\dagger H)(S_i^\intercal S_i)$$

and more…

How do they work?

Study RG running of couplings

Matching: $$\alpha^{\text{BSM}}_{1,2,3,t,b,\lambda}(\mu_0) = \alpha^{\text{SM}}_{1,2,3,t,b,\lambda}(\mu_0)$$

scale of new physics

Tools:

- **ARGES** Litim, Steudtner '21
- **RGBeta** Thomsen '22
- **Pyr@te3** Sartore, Schienbein '20
- **Sarah4** Staub '13

here: complete 2-loop

Gauge Portals

1-loop running

$$\beta_i \approx -B_i\,\alpha_i^2$$

SM **BSM**

$$\begin{aligned} B_1 &= -\tfrac{41}{3} - \delta B_1\,, \\ B_2 &= \ \ \tfrac{19}{3} - \delta B_2\,, \\ B_3 &= \ \ 14 - \delta B_3\,, \end{aligned}$$

$$\mathcal{L}_{\rm BSM} \supset \bar\psi\,(i\not{D} - M_F)\,\psi$$

$$\begin{aligned} \delta B_1 &= \tfrac{8}{3} N_F\, d_2\, d_3\, Y_F^2 \\ \delta B_{2,3} &= \tfrac{8}{3} N_F\, d_{3,2}\, S_2(d_{2,3}) \end{aligned}$$

Gauge Portals

1-loop running

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Three key effects

$$\Lambda > \mu_0$$

$$\xrightarrow{\text{gauge}} \qquad \alpha_i(\Lambda) - \alpha_i^{\rm SM}(\Lambda) \geq 0$$

Gauge Portals

1-loop running

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Three key effects

$$\Lambda > \mu_0$$

$$\xrightarrow{\text{gauge}} \qquad \alpha_i(\Lambda) - \alpha_i^{\rm SM}(\Lambda) \geq 0$$

$$\xrightarrow{\text{top}} \qquad \alpha_t(\Lambda) - \alpha_t^{\rm SM}(\Lambda) < 0$$

$$\beta_t \approx \alpha_t \left[9\,\alpha_t - \tfrac{17}{6}\,\alpha_1 - \tfrac{9}{2}\,\alpha_2 - 16\,\alpha_3\right]$$

Gauge Portals

1-loop running

$$\beta_i \approx -B_i\,\alpha_i^2$$

SM **BSM**

$$\begin{aligned} B_1 &= -\tfrac{41}{3} - \delta B_1\,,\\ B_2 &= \tfrac{19}{3} - \delta B_2\,,\\ B_3 &= 14 - \delta B_3\,, \end{aligned}$$

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Three key effects

$$\Lambda > \mu_0$$

$$\xrightarrow{\text{gauge}} \quad \alpha_i(\Lambda) - \alpha_i^{\rm SM}(\Lambda) \geq 0$$

$$\xrightarrow{\text{top}} \quad \alpha_t(\Lambda) - \alpha_t^{\rm SM}(\Lambda) < 0$$

$$\xrightarrow{\text{Higgs}} \quad \alpha_\lambda(\Lambda) - \alpha_\lambda^{\rm SM}(\Lambda) > 0$$

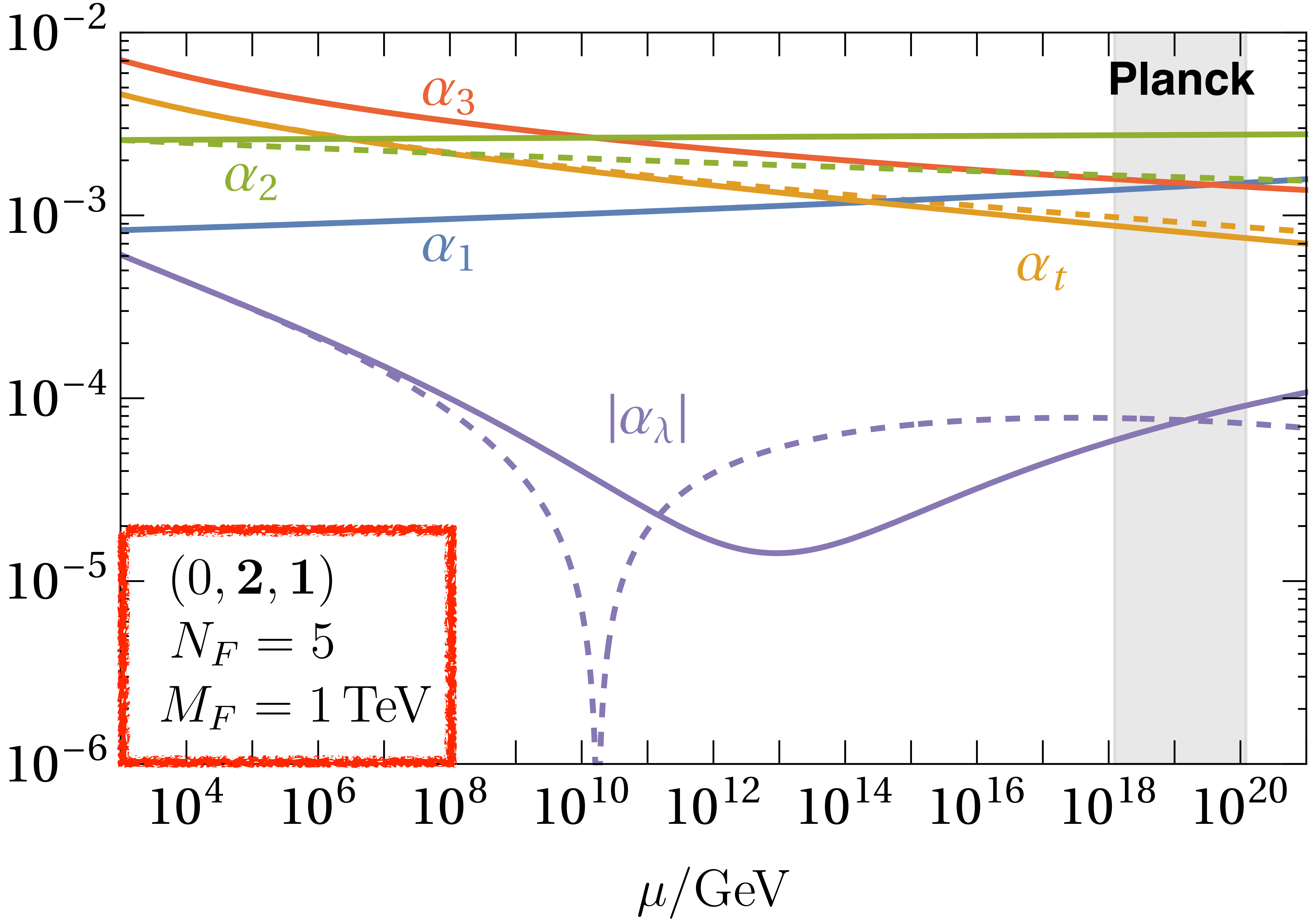
$$\beta_\lambda \approx \tfrac{3}{8}\left[\alpha_1^2 + 2\,\alpha_1\alpha_2 + 3\,\alpha_2^2\right] - 6\,\alpha_t^2$$

Why?

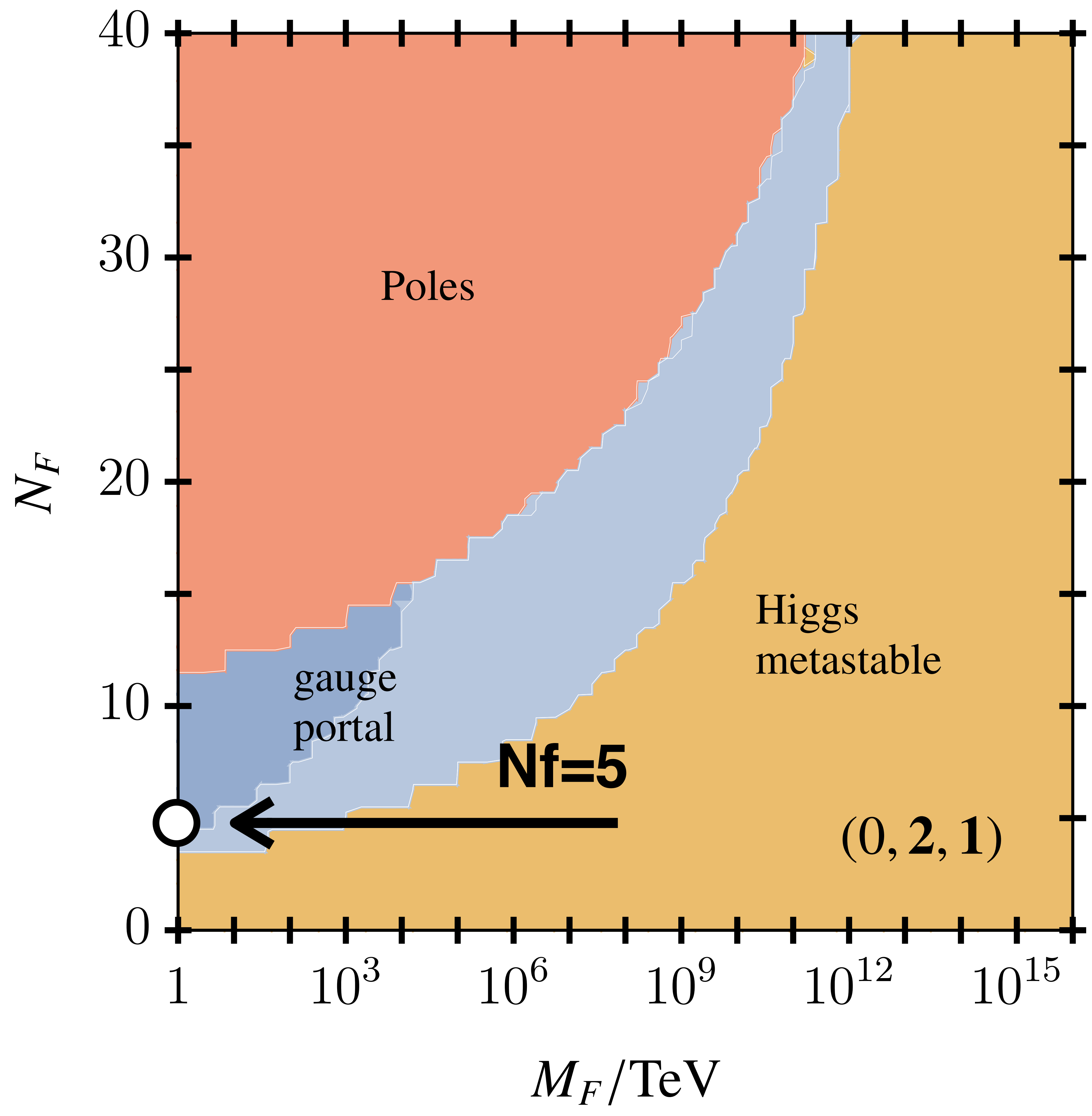
$$
\begin{aligned}
\alpha_\lambda(\Lambda) - \alpha_\lambda^{\mathrm{SM}}(\Lambda) \approx & +\tfrac{3}{8}\alpha_1^2(\mu_0)\left[\alpha_1(\mu_0) + \alpha_2(\mu_0)\right] \overset{\textbf{Hypercharge}}{\boxed{\delta B_1}} \ln^2\left(\frac{\Lambda}{\mu_0}\right) \\
& +\tfrac{3}{8}\alpha_2^2(\mu_0)\left[\alpha_1(\mu_0) + 3\alpha_2(\mu_0)\right] \overset{\textbf{Weak}}{\boxed{\delta B_2}} \ln^2\left(\frac{\Lambda}{\mu_0}\right) \\
& +32\,\alpha_t^2(\mu_0)\,\alpha_3^2(\mu_0) \overset{\textbf{Strong}}{\boxed{\delta B_3}} \ln^3\left(\frac{\Lambda}{\mu_0}\right)
\end{aligned}
$$

All three gauge portals enhance the quartic

weak portal

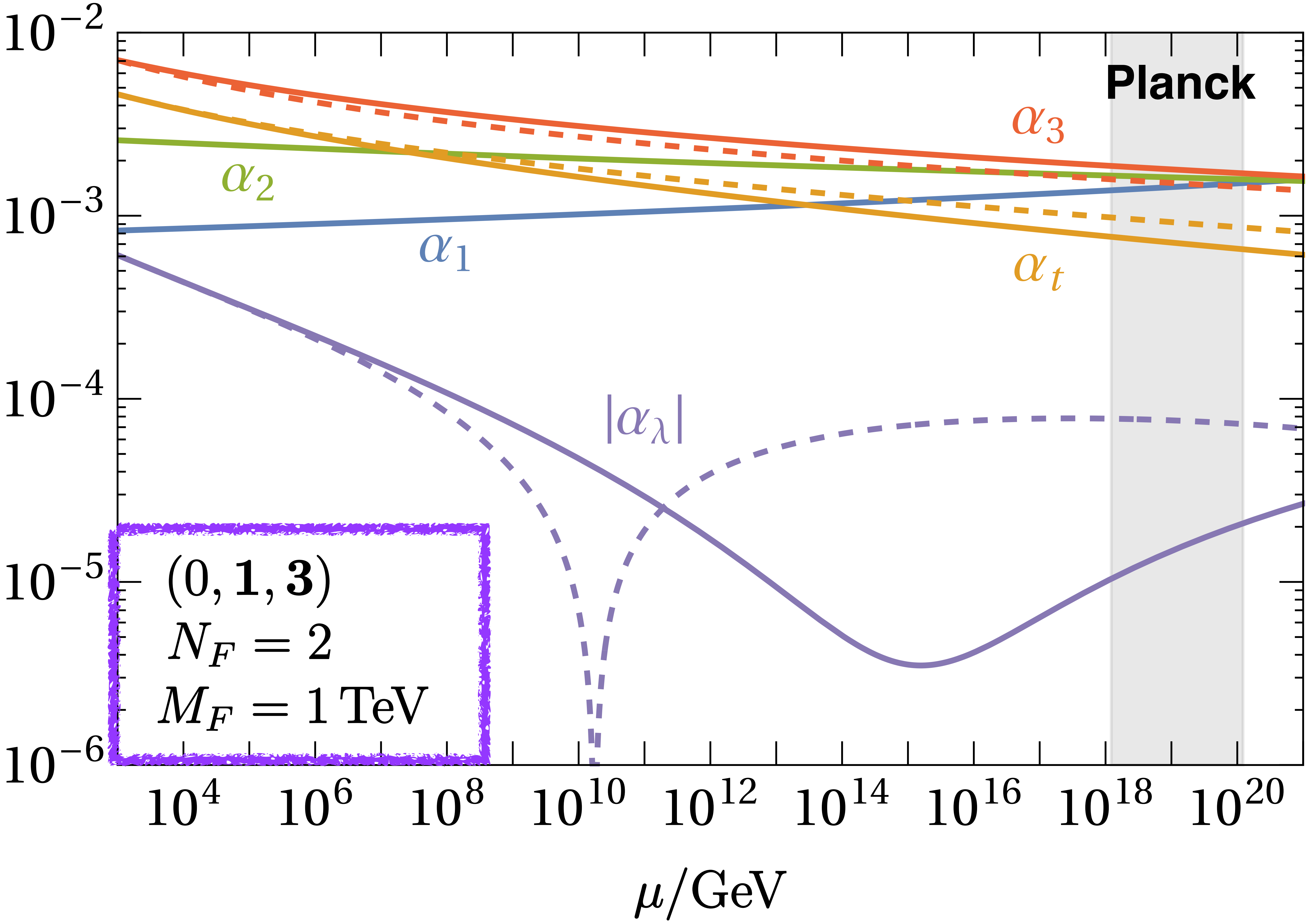


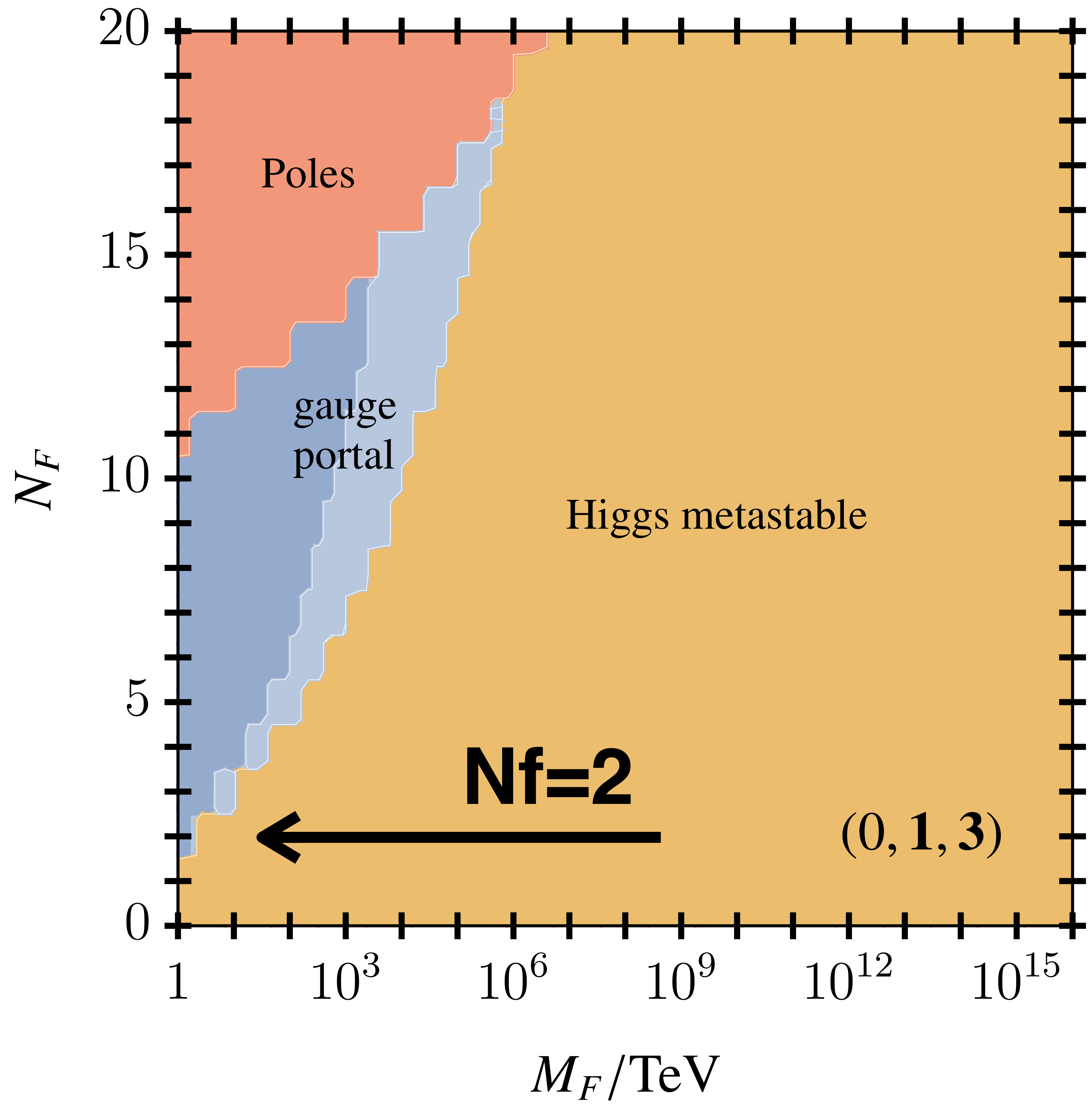
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{4}
10^{6}
10^{8}
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
μ/GeV
Planck
α_3
α_2
α_1
α_t
$|\alpha_\lambda|$
$(0,\mathbf{2},\mathbf{1})$
$N_F = 5$
$M_F = 1\,\mathrm{TeV}$



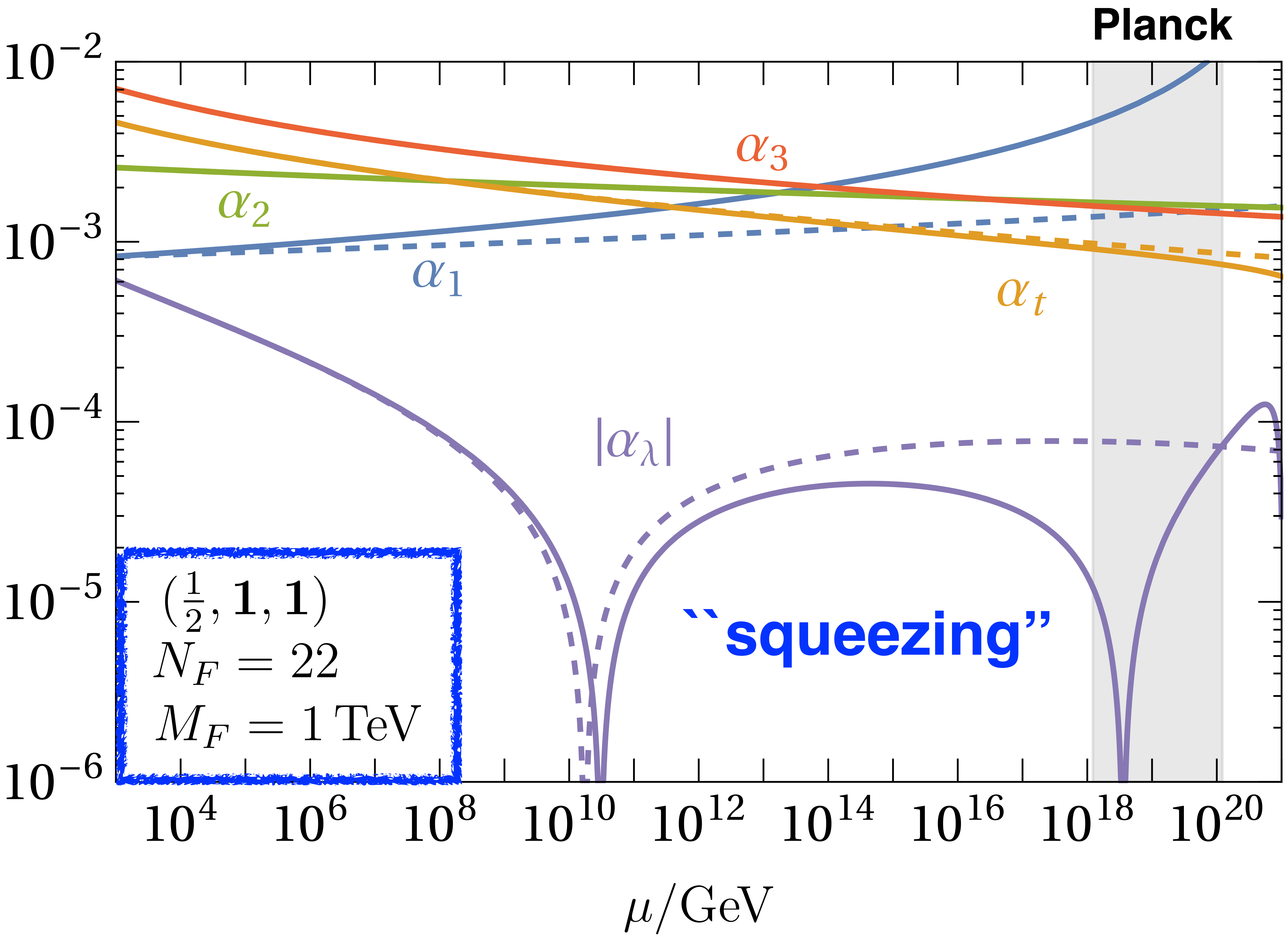
40
30
20
10
0
N_F
1
10^{3}
10^{6}
10^{9}
10^{12}
10^{15}
M_F/TeV
Poles
gauge portal
Higgs metastable
Nf=5
$(0,\mathbf{2},\mathbf{1})$

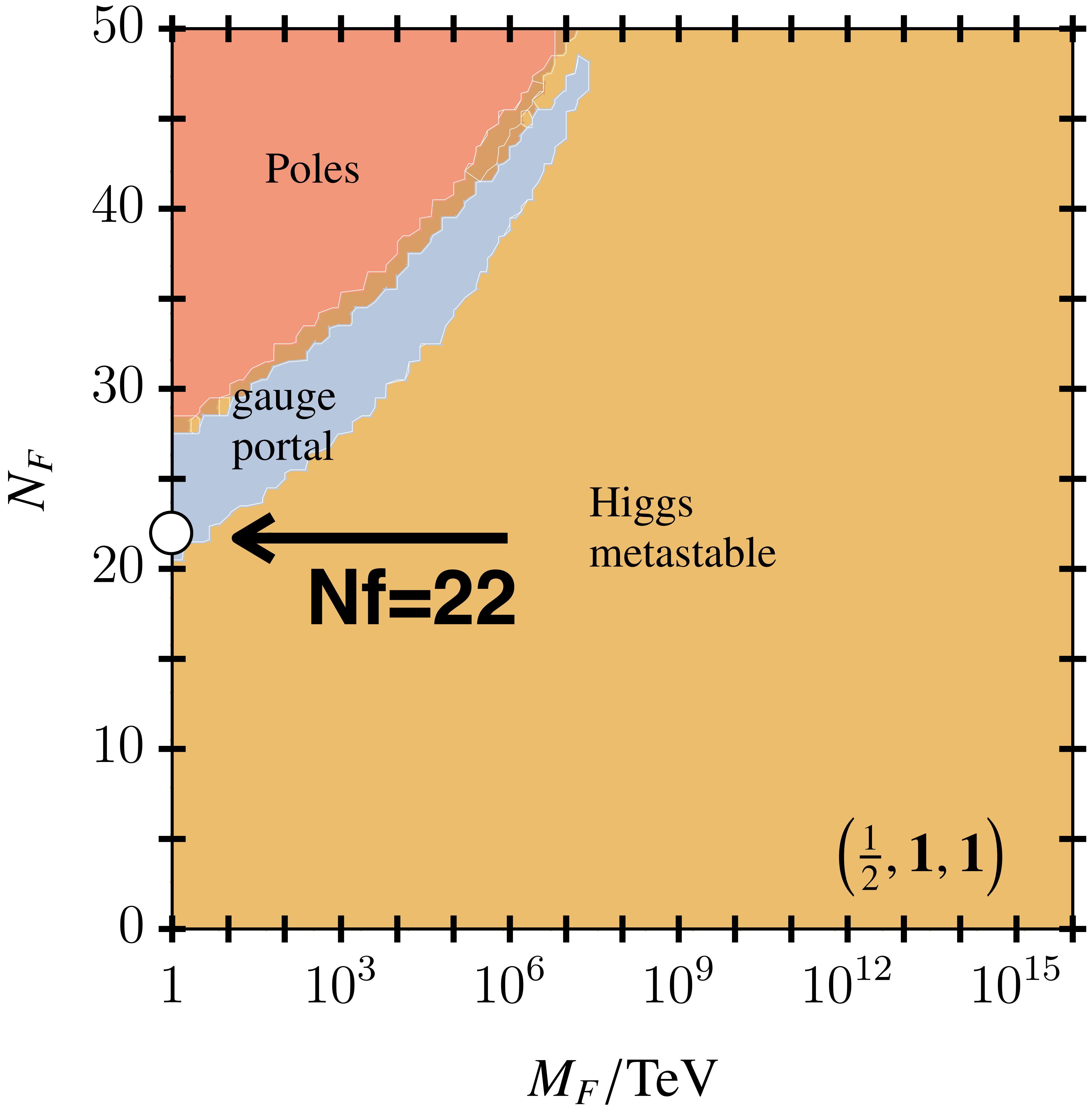
strong portal



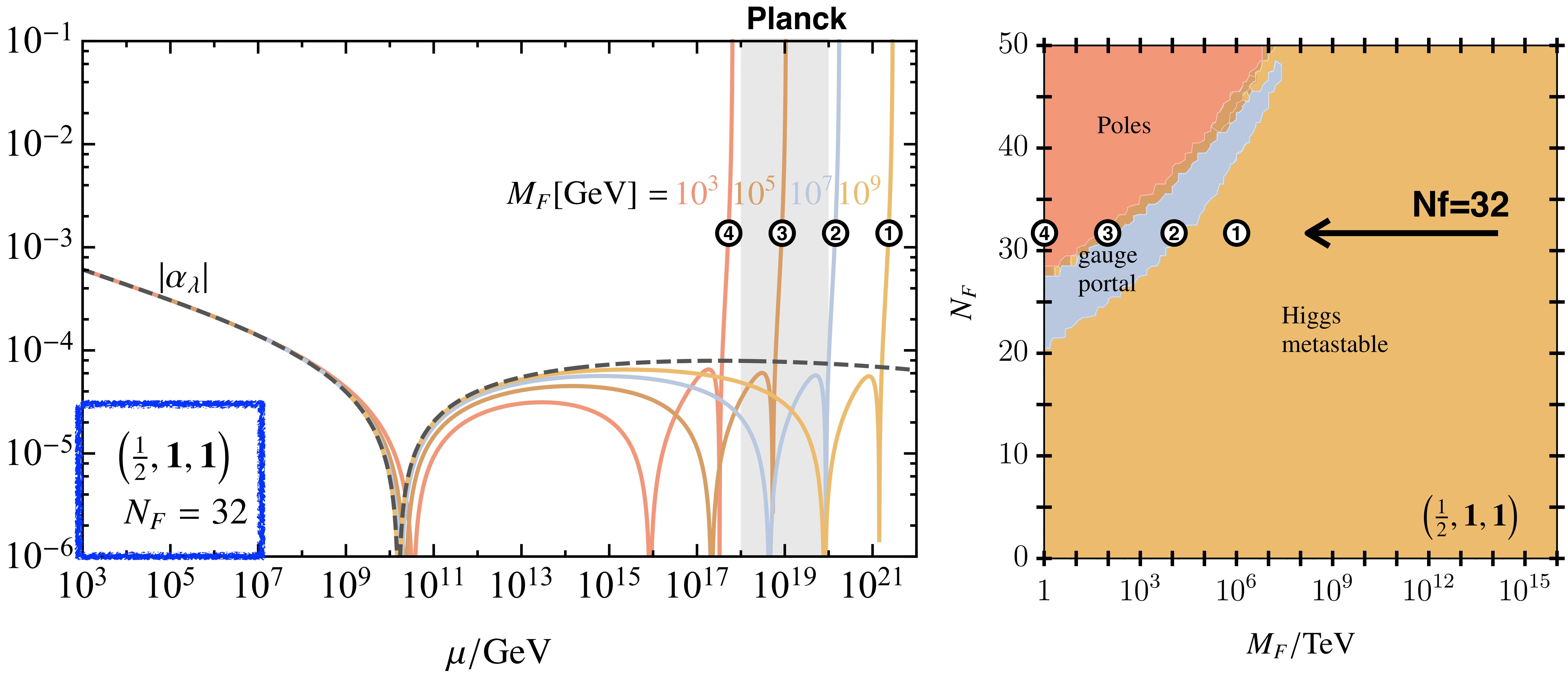


hypercharge portal





hypercharge portal

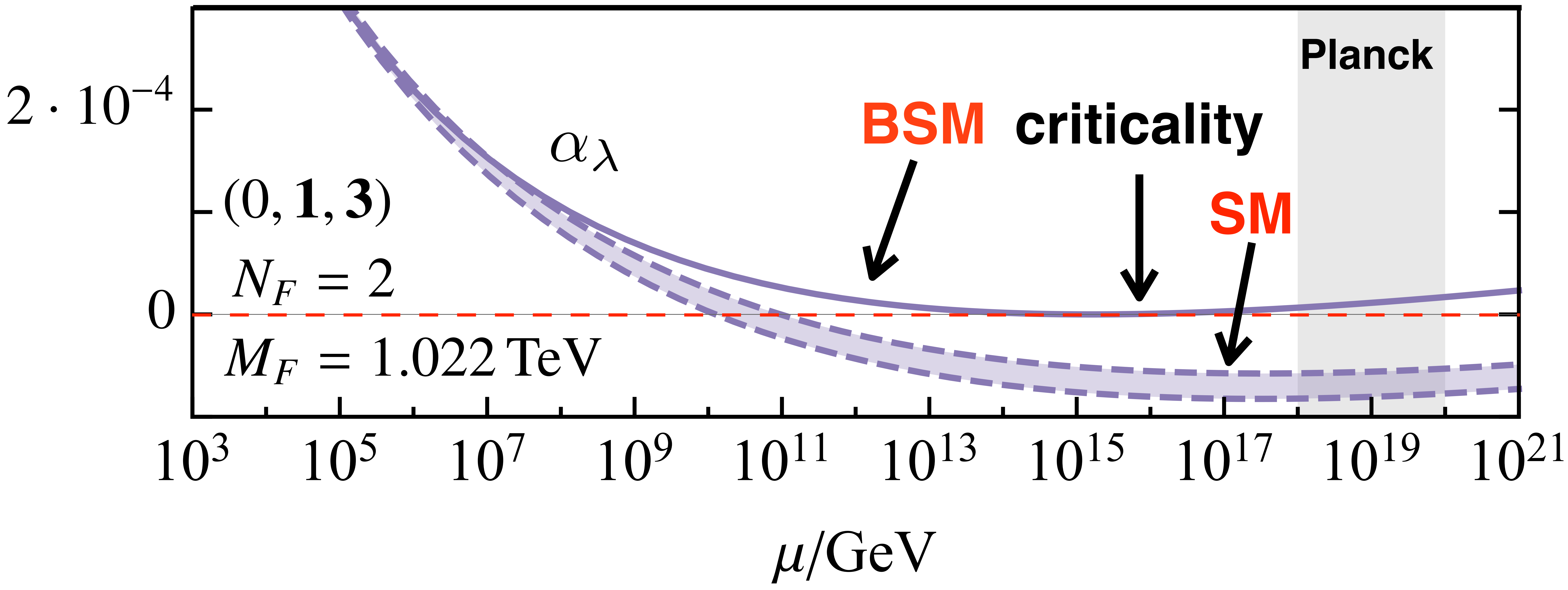


Higgs Criticality

Criticality: $\lambda|_{\mu_{\rm crit}} = 0 \quad \text{and} \quad \beta_\lambda|_{\mu_{\rm crit}} = 0$

[SM $\beta_\lambda|_{\mu=M_{\rm Pl}} \approx 0 \quad \text{and} \quad \lambda|_{\mu=M_{\rm Pl}} \approx 0 \quad \text{within} \quad \mathcal{O}(10^{-4})$]

[Buttazzo et al '13]



Result:

$$\frac{\mu_{\rm crit}}{\rm GeV} \approx 10^{11} - 10^{15}$$

typical GUT scale
not Planck scale

Yukawa Portals

Main new RG effect

``good'' ``bad''

$$\beta_\lambda = \beta_\lambda^{\rm SM} + I_{\kappa\lambda}\,\alpha_\kappa\,\alpha_\lambda - I_{\kappa\kappa}\,\alpha_\kappa^2 + \mathcal{O}(2\text{-loop})$$

Yukawa

$$\alpha_\lambda = \frac{\lambda}{(4\pi)^2}$$

$$\alpha_\kappa = \frac{\kappa^2}{(4\pi)^2}$$

Competition!

Who wins?

Yukawa Portals

all 13 possibilities

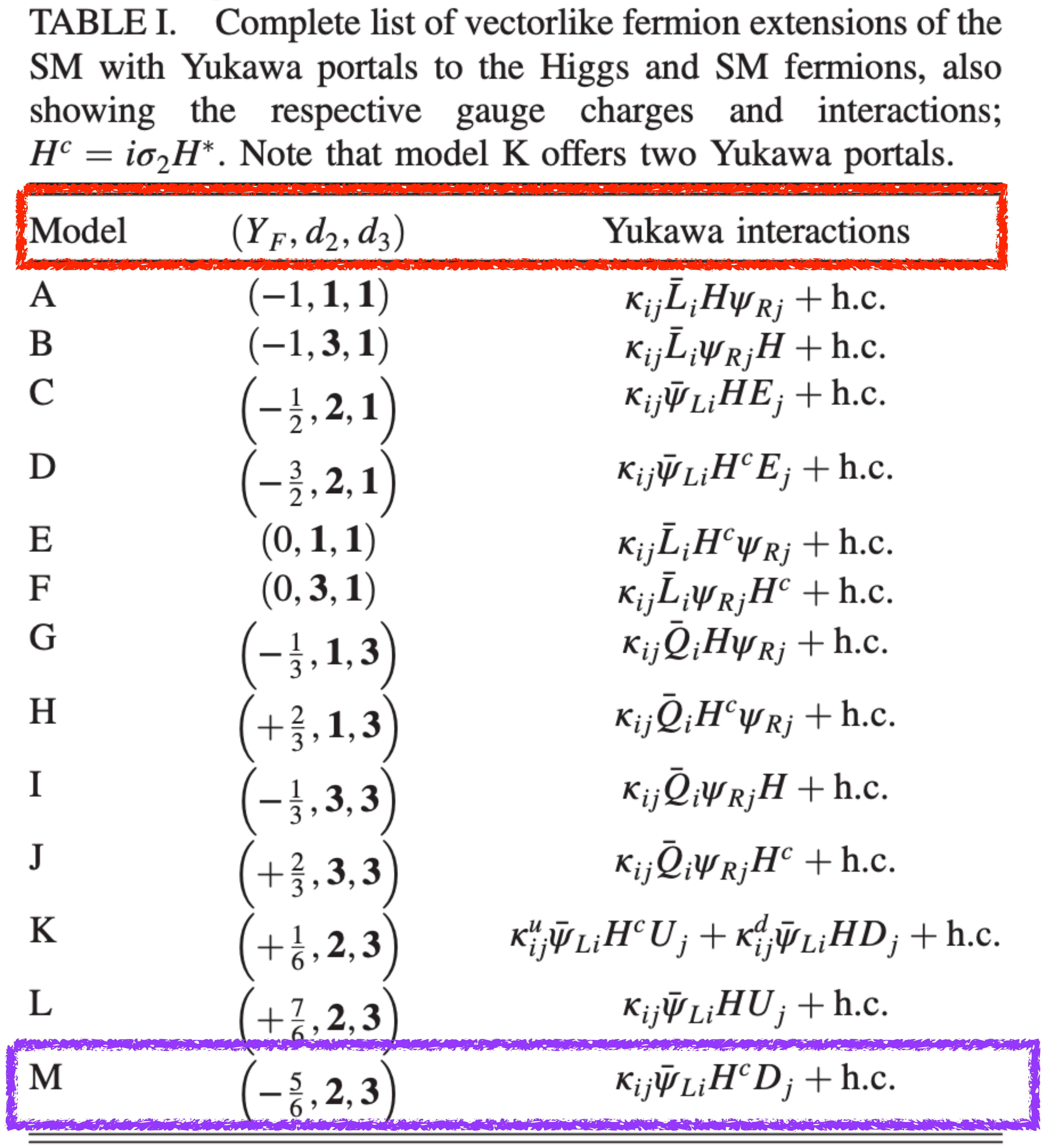
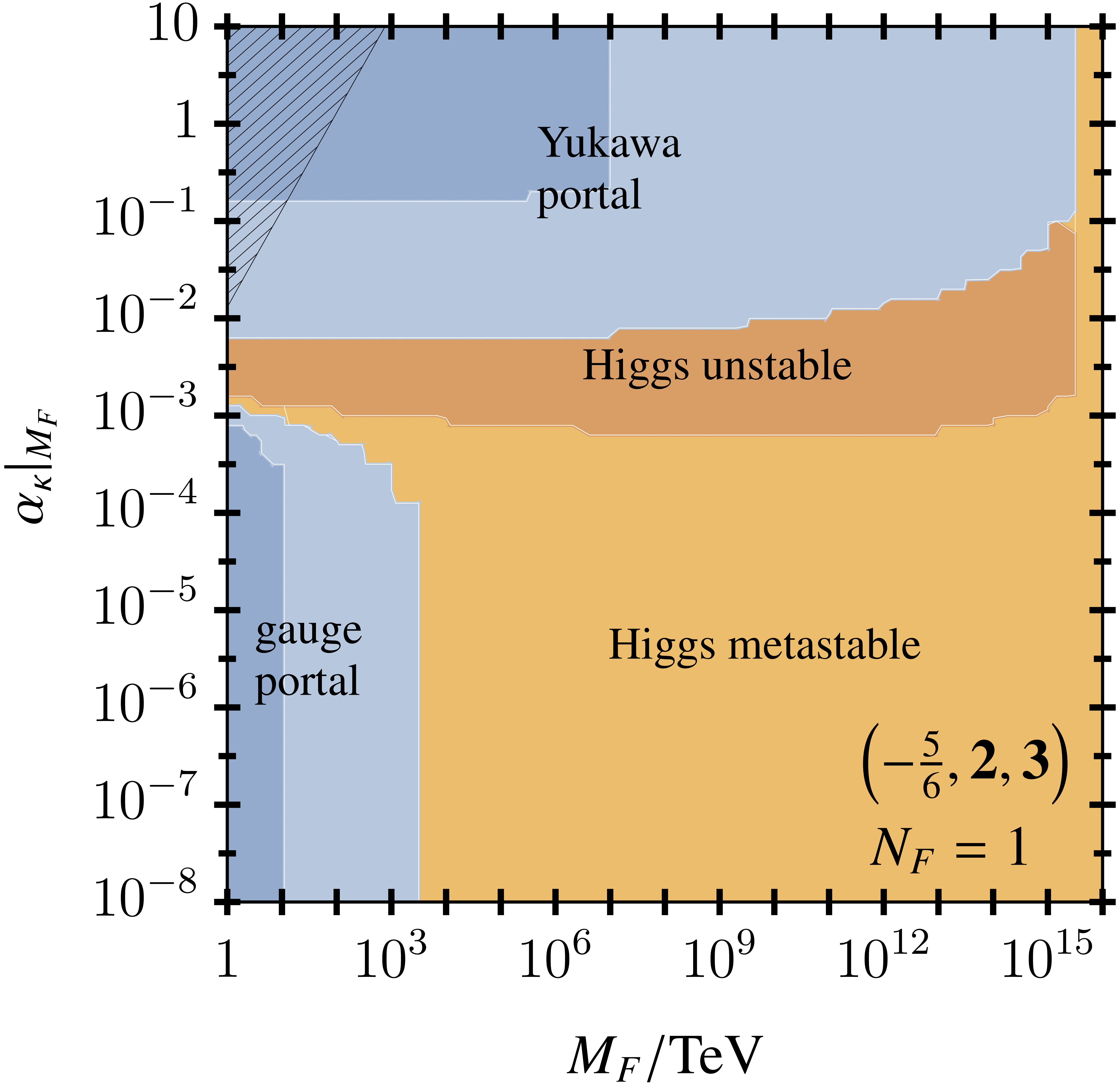


TABLE I. Complete list of vectorlike fermion extensions of the SM with Yukawa portals to the Higgs and SM fermions, also showing the respective gauge charges and interactions; $H^c = i\sigma_2 H^*$. Note that model K offers two Yukawa portals.

Model	(Y_F, d_2, d_3)	Yukawa interactions
A	$(-1, \mathbf{1}, \mathbf{1})$	$\kappa_{ij}\bar{L}_i H \psi_{Rj} + \text{h.c.}$
B	$(-1, \mathbf{3}, \mathbf{1})$	$\kappa_{ij}\bar{L}_i \psi_{Rj} H + \text{h.c.}$
C	$\left(-\frac{1}{2}, \mathbf{2}, \mathbf{1}\right)$	$\kappa_{ij}\bar{\psi}_{Li} H E_j + \text{h.c.}$
D	$\left(-\frac{3}{2}, \mathbf{2}, \mathbf{1}\right)$	$\kappa_{ij}\bar{\psi}_{Li} H^c E_j + \text{h.c.}$
E	$(0, \mathbf{1}, \mathbf{1})$	$\kappa_{ij}\bar{L}_i H^c \psi_{Rj} + \text{h.c.}$
F	$(0, \mathbf{3}, \mathbf{1})$	$\kappa_{ij}\bar{L}_i \psi_{Rj} H^c + \text{h.c.}$
G	$\left(-\frac{1}{3}, \mathbf{1}, \mathbf{3}\right)$	$\kappa_{ij}\bar{Q}_i H \psi_{Rj} + \text{h.c.}$
H	$\left(+\frac{2}{3}, \mathbf{1}, \mathbf{3}\right)$	$\kappa_{ij}\bar{Q}_i H^c \psi_{Rj} + \text{h.c.}$
I	$\left(-\frac{1}{3}, \mathbf{3}, \mathbf{3}\right)$	$\kappa_{ij}\bar{Q}_i \psi_{Rj} H + \text{h.c.}$
J	$\left(+\frac{2}{3}, \mathbf{3}, \mathbf{3}\right)$	$\kappa_{ij}\bar{Q}_i \psi_{Rj} H^c + \text{h.c.}$
K	$\left(+\frac{1}{6}, \mathbf{2}, \mathbf{3}\right)$	$\kappa^u_{ij}\bar{\psi}_{Li} H^c U_j + \kappa^d_{ij}\bar{\psi}_{Li} H D_j + \text{h.c.}$
L	$\left(+\frac{7}{6}, \mathbf{2}, \mathbf{3}\right)$	$\kappa_{ij}\bar{\psi}_{Li} H U_j + \text{h.c.}$
M	$\left(-\frac{5}{6}, \mathbf{2}, \mathbf{3}\right)$	$\kappa_{ij}\bar{\psi}_{Li} H^c D_j + \text{h.c.}$

Yukawa Portals



Model M

$\kappa\,\overline{\psi}_L H^c D_{\mathbf{3}}$

Higgs Portals

$$\mathcal{L} \supset \sum_i \delta_i \, (H^\dagger H)(S_i^\intercal S_i)$$

Main new RG effect

``good”

$$\beta_\lambda = \beta_\lambda^{\rm SM} + \sum_i 2\, N_i \, \alpha_{\delta_i}^2$$

$$\alpha_\lambda(\Lambda) - \alpha_\lambda^{\rm SM}(\Lambda) \propto \sum_i 2\, N_i \, \alpha_{\delta_i}^2 \; > 0$$

genuine uplift

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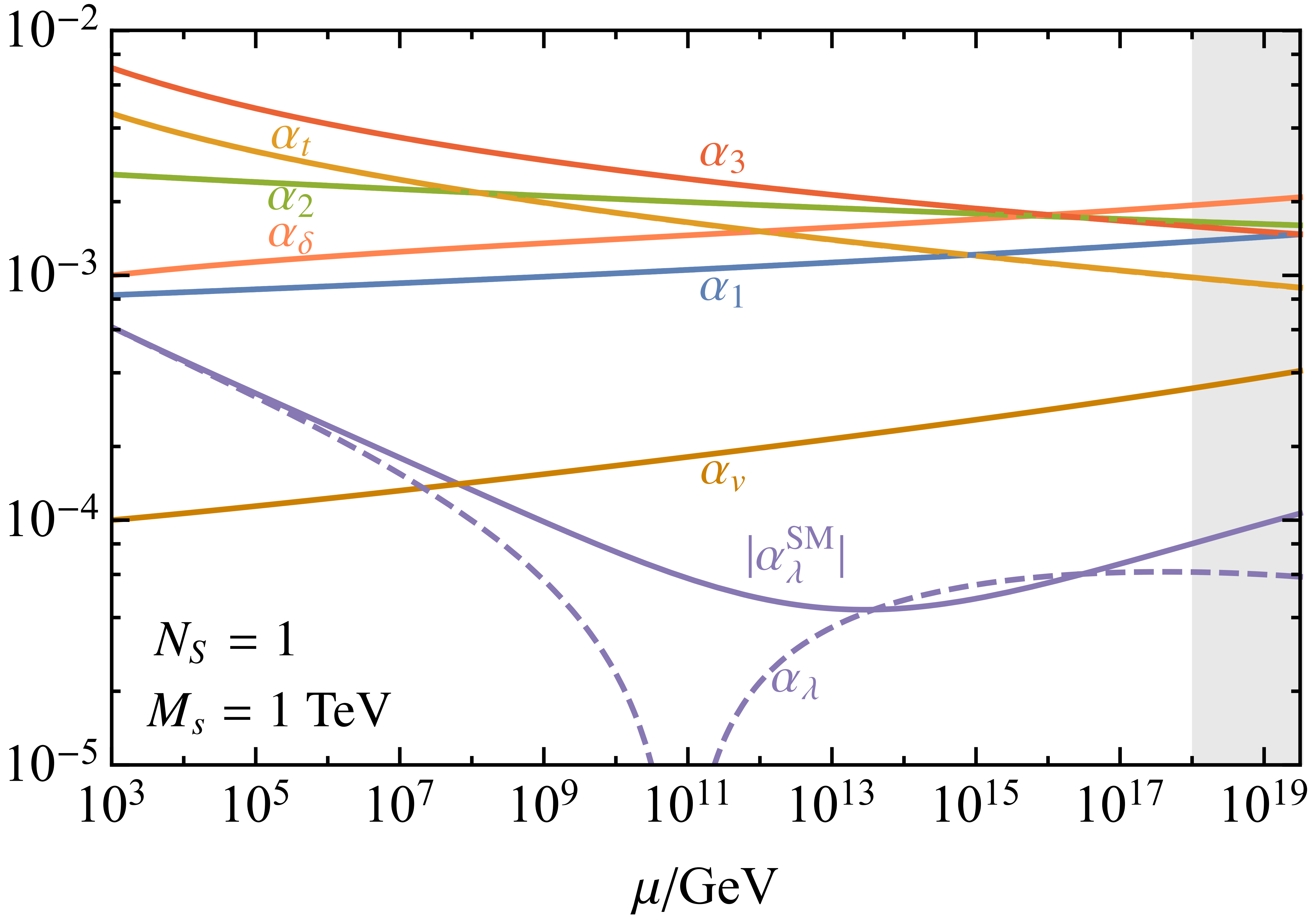
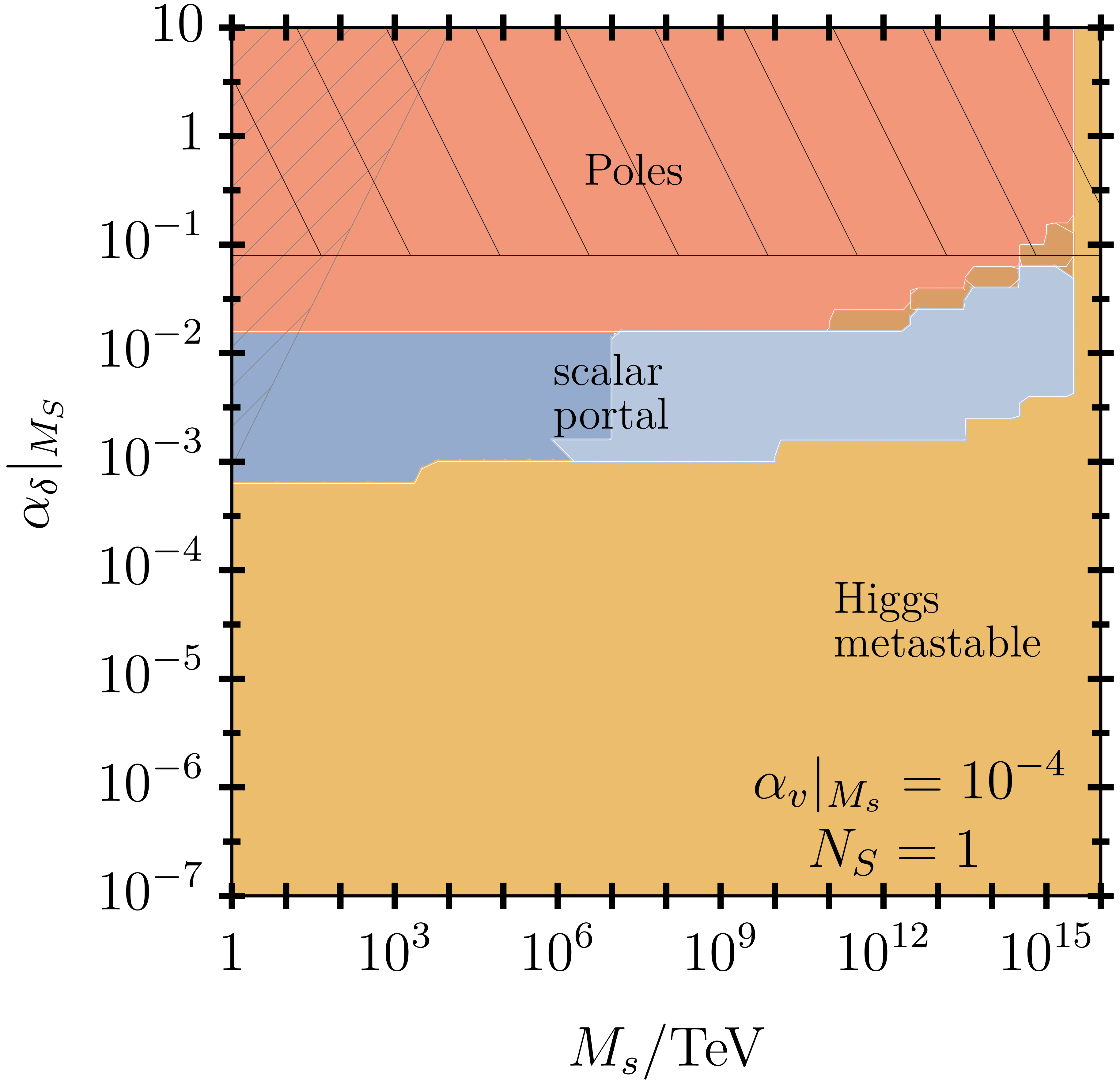
Higgs Portals

single real BSM scalar





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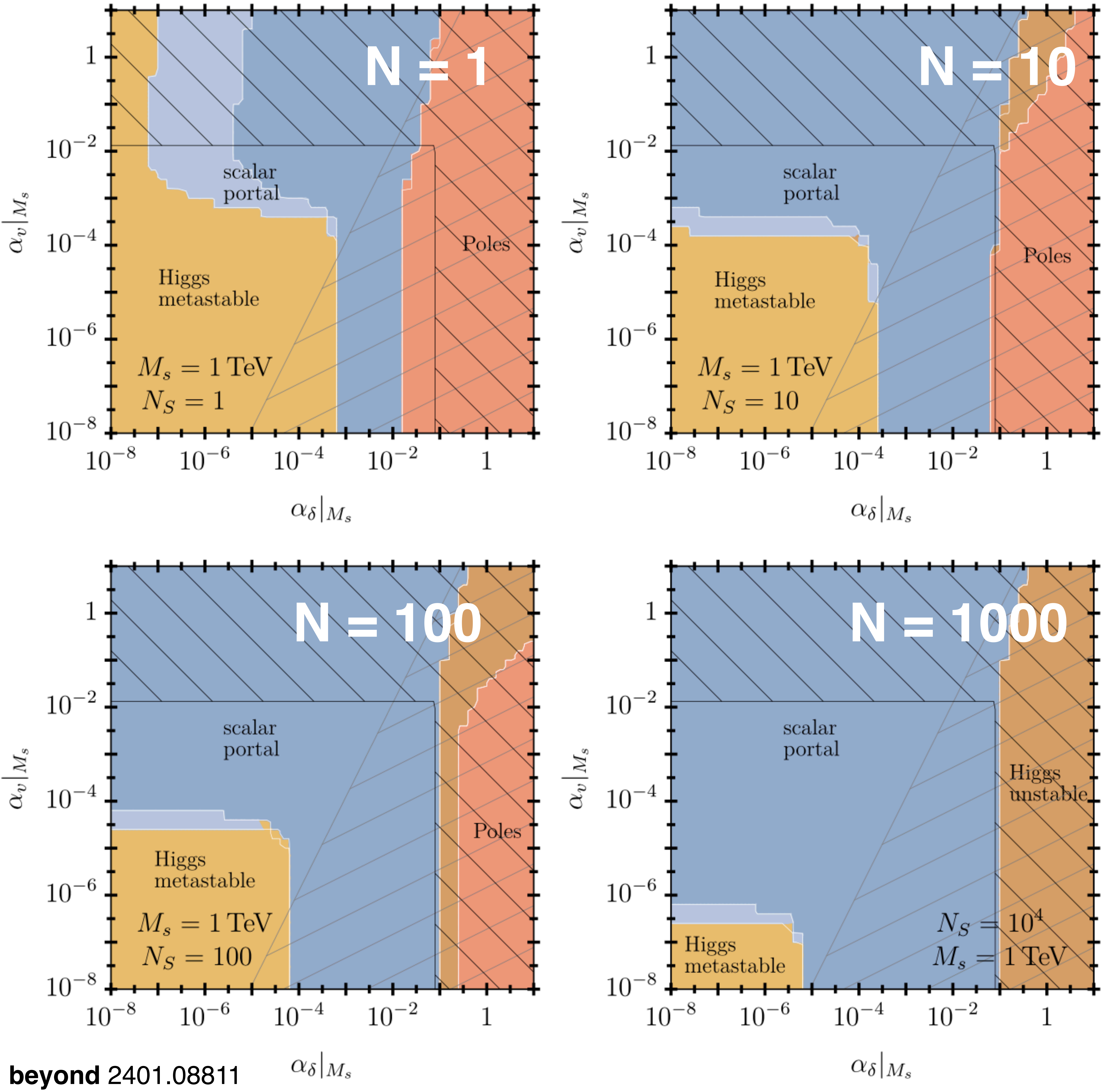
Higgs Portals

O(N) BSM scalars

M = 1 TeV

adding more scalars enhances the range for stability



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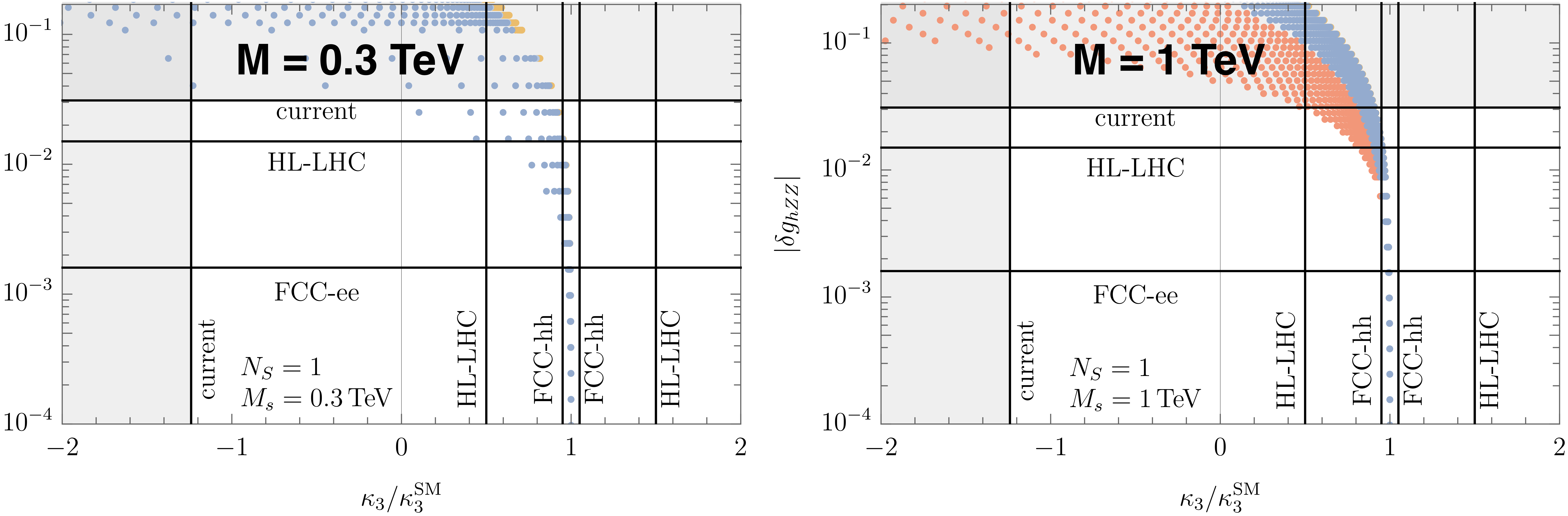
Higgs Portals

Signatures

BSM scalar obtains VEV
modified hZZ, 3h vertices → FCC-ee



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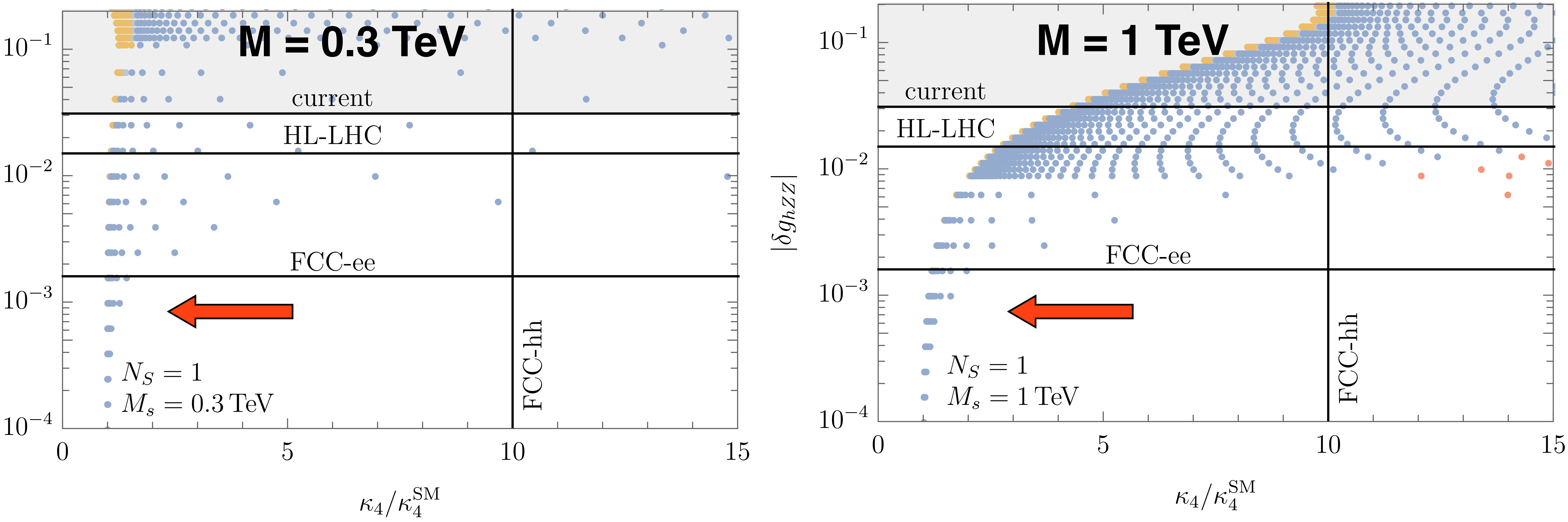
Higgs Portals

Signatures

BSM scalar obtains VEV
modified 4h vertices → **FCC-ee**
FCC-hh



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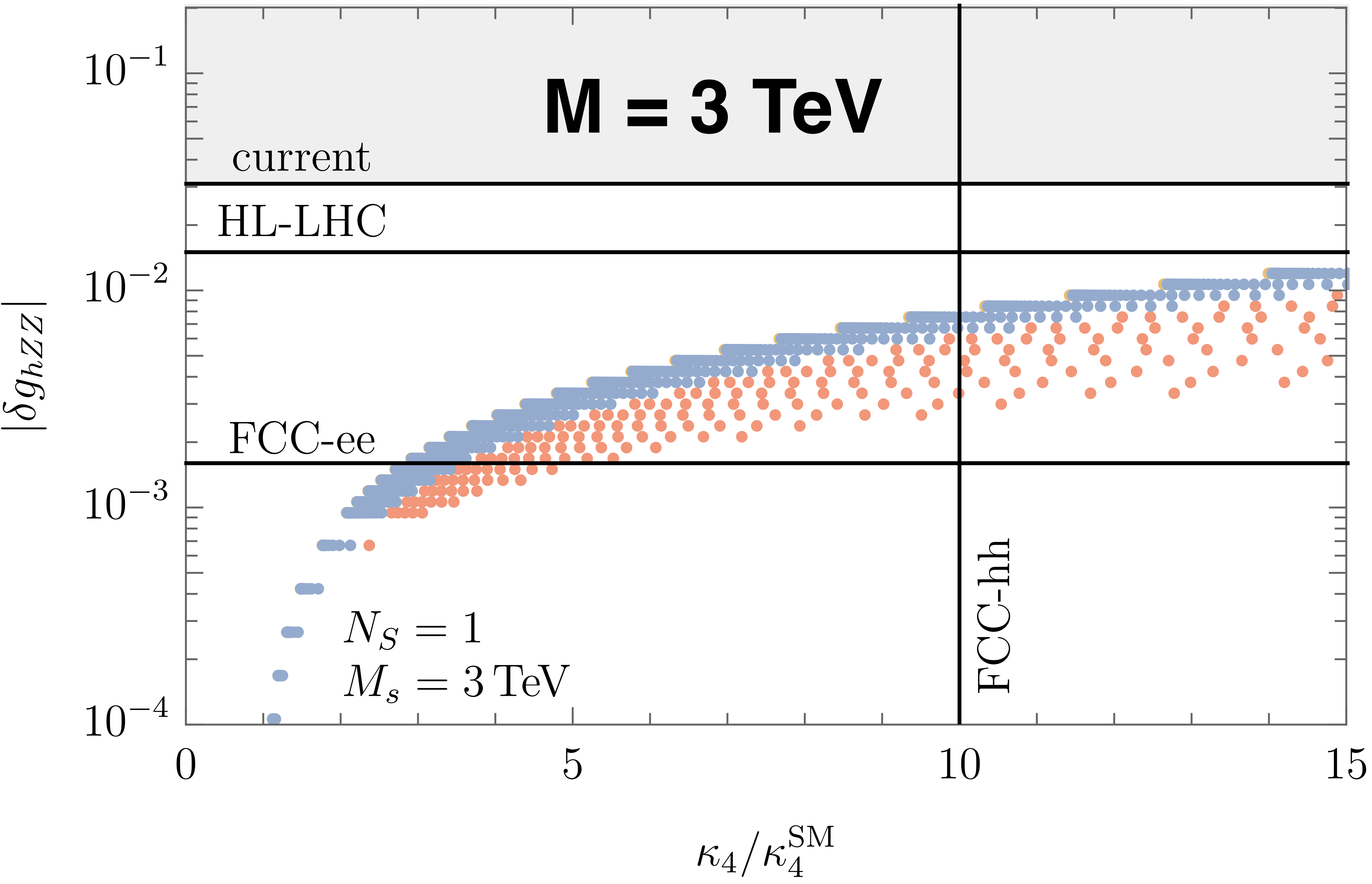
Higgs Portals

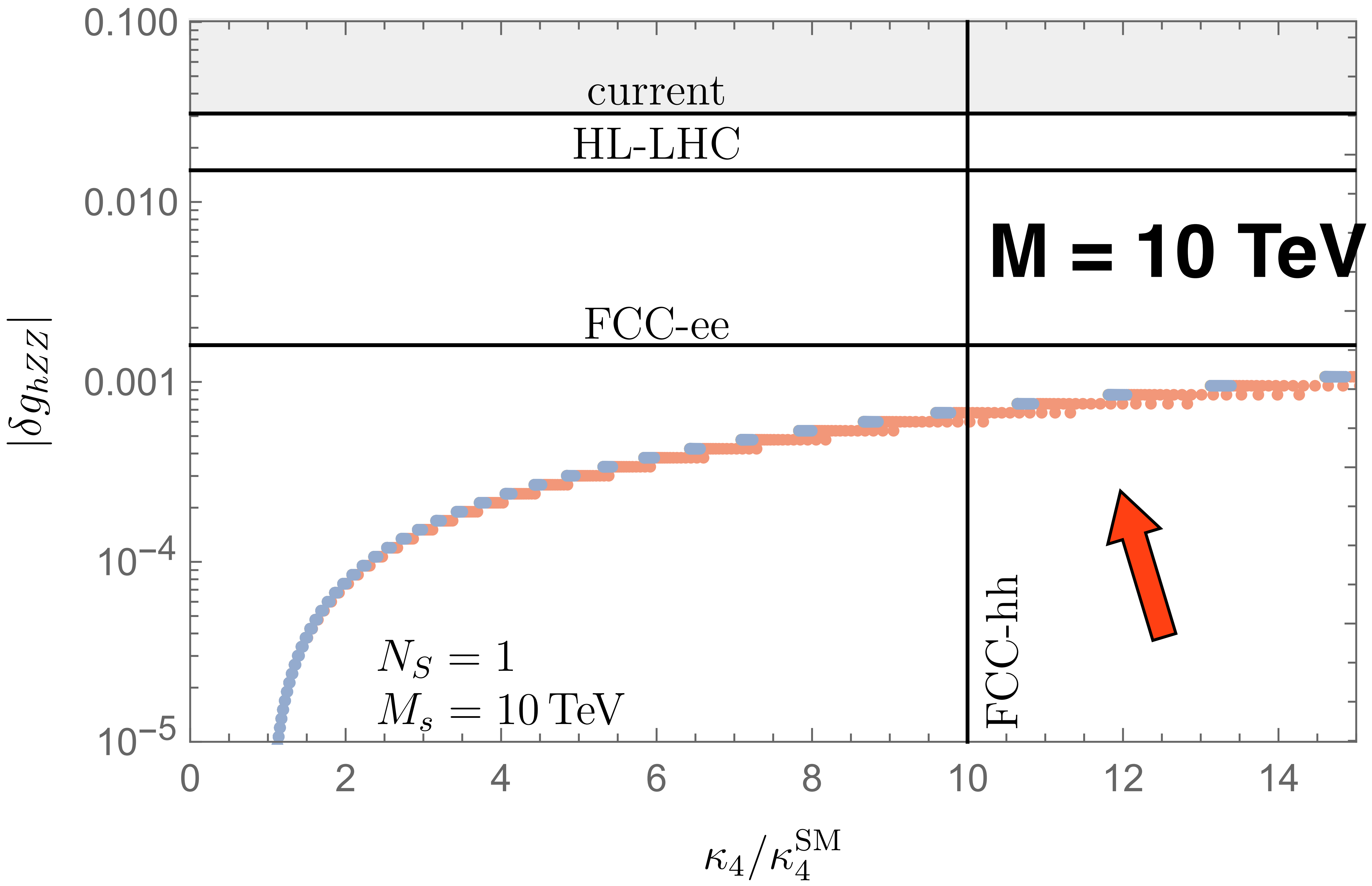
Signatures

BSM scalar obtains VEV

modified 4h vertices

higher mass → FCC-hh O(1) effects





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Top-Down

Q: What does it take to

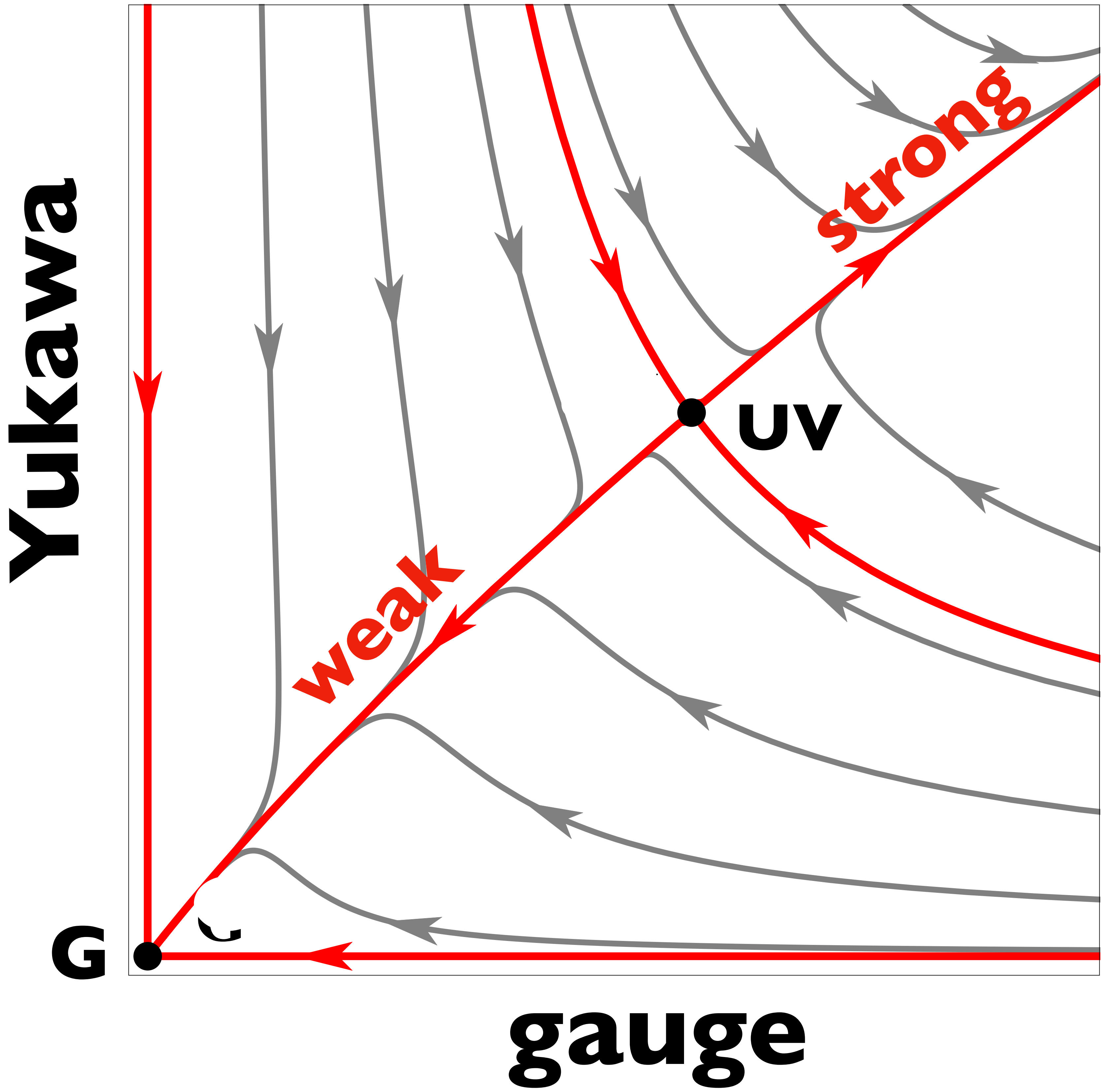
achieve UV-safe theories

… beyond asymptotic freedom?

Top-Down

rigorous fixed points in 4d:

exist for **weakly coupled gauge theories with matter**



SU(N) + Diracs
+ mesons

SO(N) + Majoranas
+ mesons

Sp(N) + Majoranas
+ mesons

DF Litim, F Sannino, **Asymptotic safety guaranteed,** 1406.2337
AD Bond, DF Litim, G Medina Vazquez, T Steudtner, **Conformal window for asymptotic safety**, 1710.07615
AD Bond, DF Litim, T Steudtner, **Asymptotic safety with Majorana fermions and new large N equivalences** 1911.11168

Top-Down

rigorous UV fixed points in 4d:

exist for **weakly coupled gauge non-SUSY theories with matter**

exist for **weekly and strongly coupled SUSY theories**

UV fixed points with SUSY and MSSM extensions

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

why no Susy UV fixed point

superfield anomalous dimension

$$2d_R|\gamma_R|^2 = d_G\,B\,\alpha_* + \mathcal{O}(B\alpha_*^2, \alpha_*^3)$$

asymptotic freedom: B > 0

no asymptotic freedom: B < 0

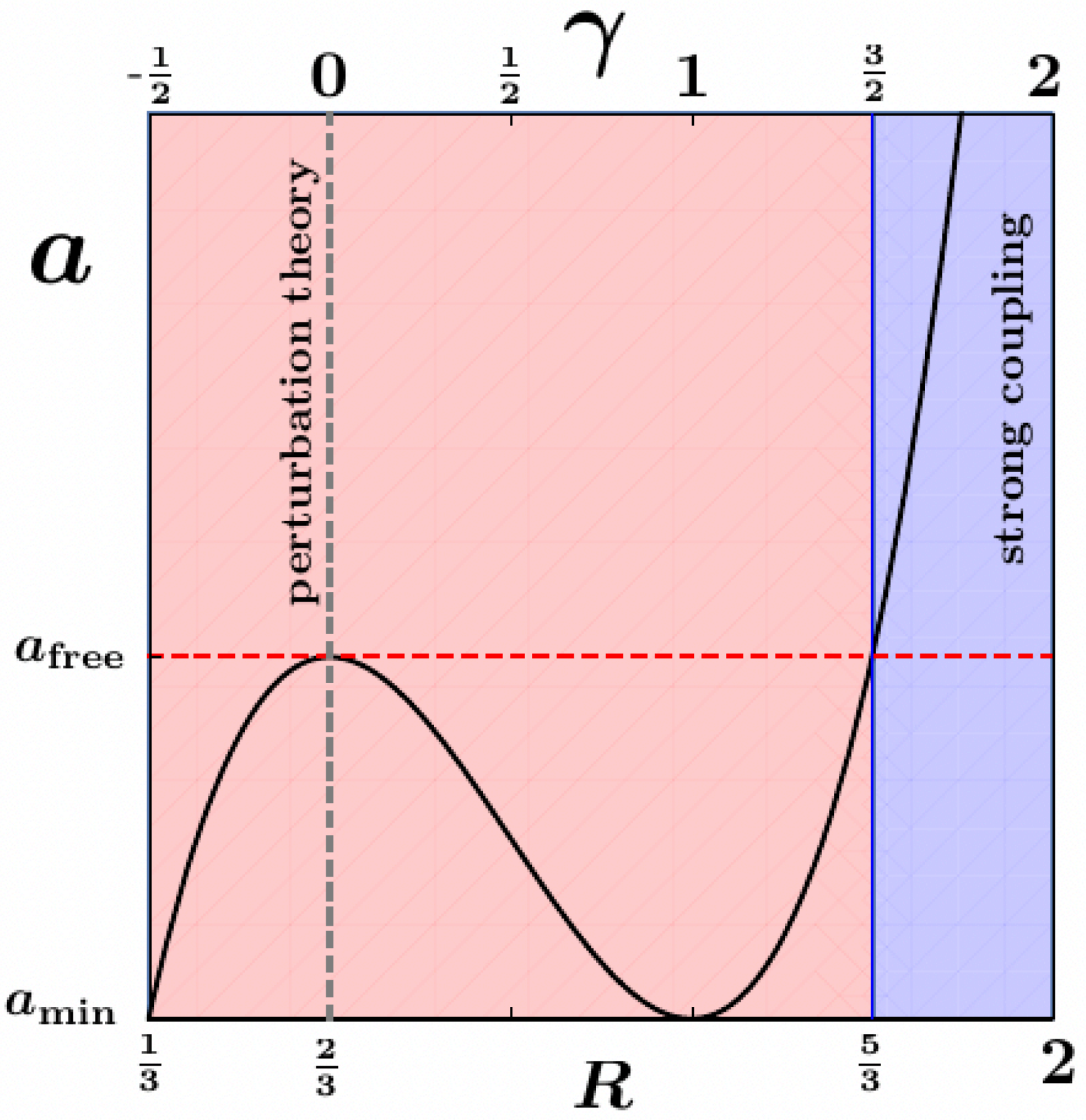
→ **fixed point requires AF**

UV fixed point cannot arise

S Martin, J Wells, hep-ph/0011382/PRD

why ~~no~~ Susy UV fixed point

strong coupling?



why ~~no~~ Susy UV fixed point

superfield anomalous dimension

$$2d_R|\gamma_R|^2 = d_{G_i}\, B_i\, \alpha_i^* + \mathcal{O}(B\alpha_*^2, \alpha_*^3)$$

remedy:

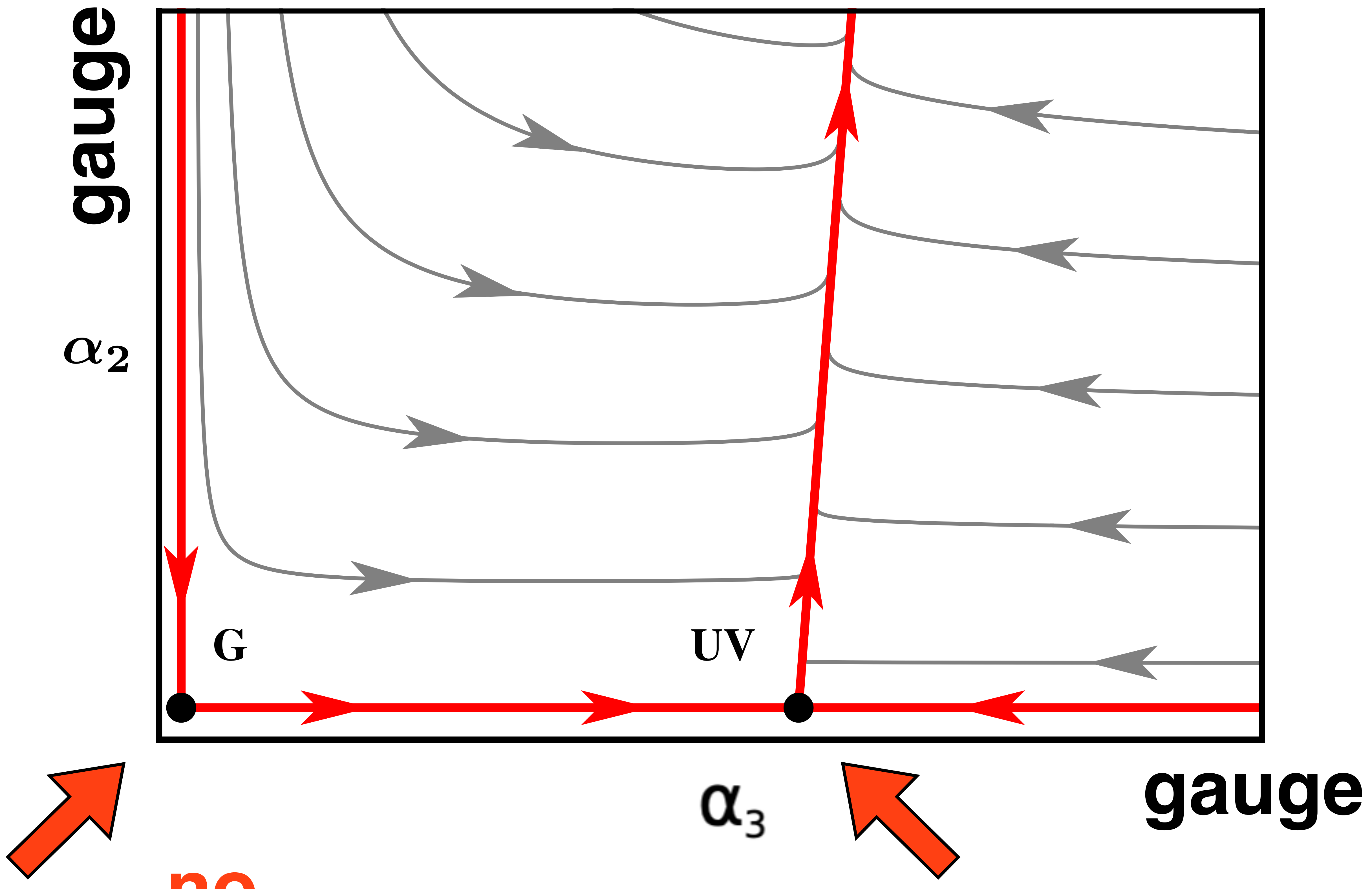
semi-simple susy gauge theories

some $B_i < 0$ a possibility

→ **UV fixed points can arise**

AD Bond, DF Litim, 1709.06953/PRL

Susy UV fixed points



no asymptotic freedom

e.g. MSSM

interacting UV fixed point

template:

SU(N) x SU(M)
+ chiral superfields
+ superpotential

AD Bond, DF Litim, **Asymptotic Safety Guaranteed in Supersymmetry,** 1709.06953 (PRL)
Asymptotic Safety Guaranteed for Strongly Coupled Gauge Theories, 2202.08223 (PRD)

MSSM extensions

concrete: MSSM + new quark singlets Q
+ new leptons L
+ superpotential Y_ijk

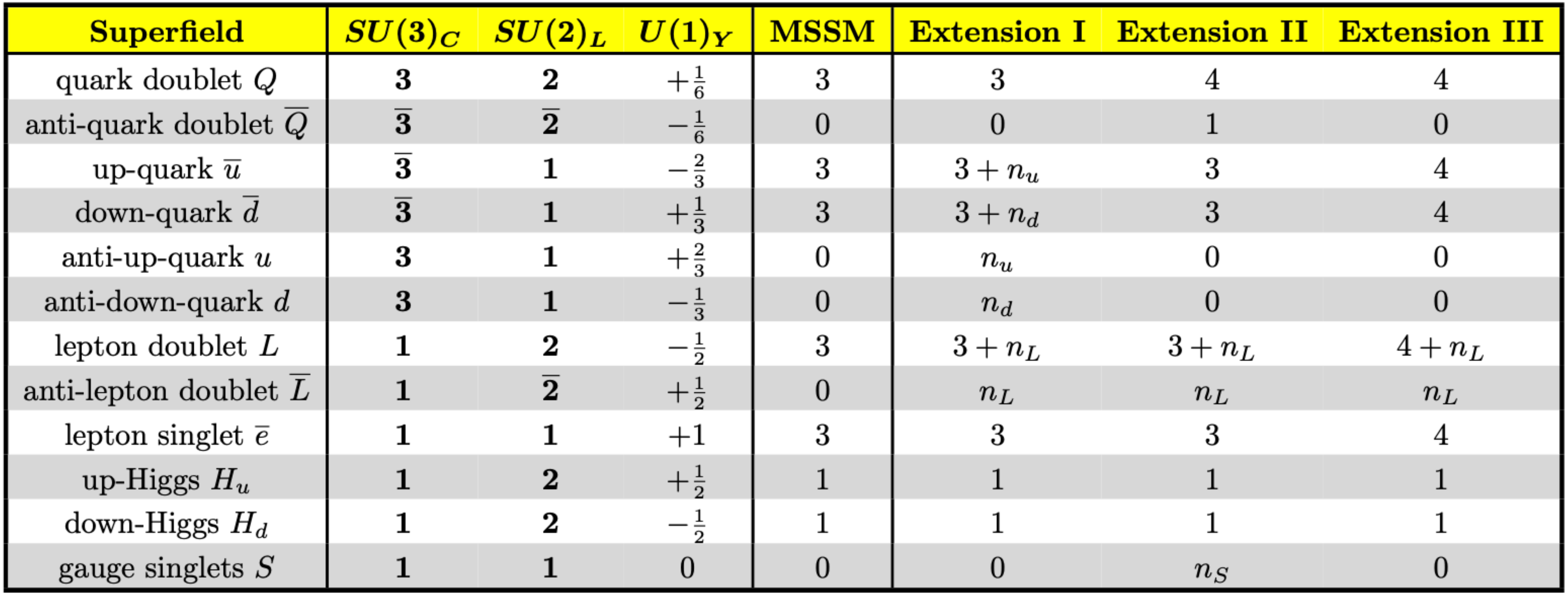
$$W_1 = Y^{ijk}\overline{d}_i Q_j L_k + \overline{Y}^{ijk}\overline{u}_i Q_j \overline{L}_k + x_b\, y_b \overline{d}_3 Q_3 H_d + x_t\, y_t \overline{u}_3 Q_3 H_u \ ,$$

2 Loop RGEs

scan over 212k models
approx 100 UV fixed points

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

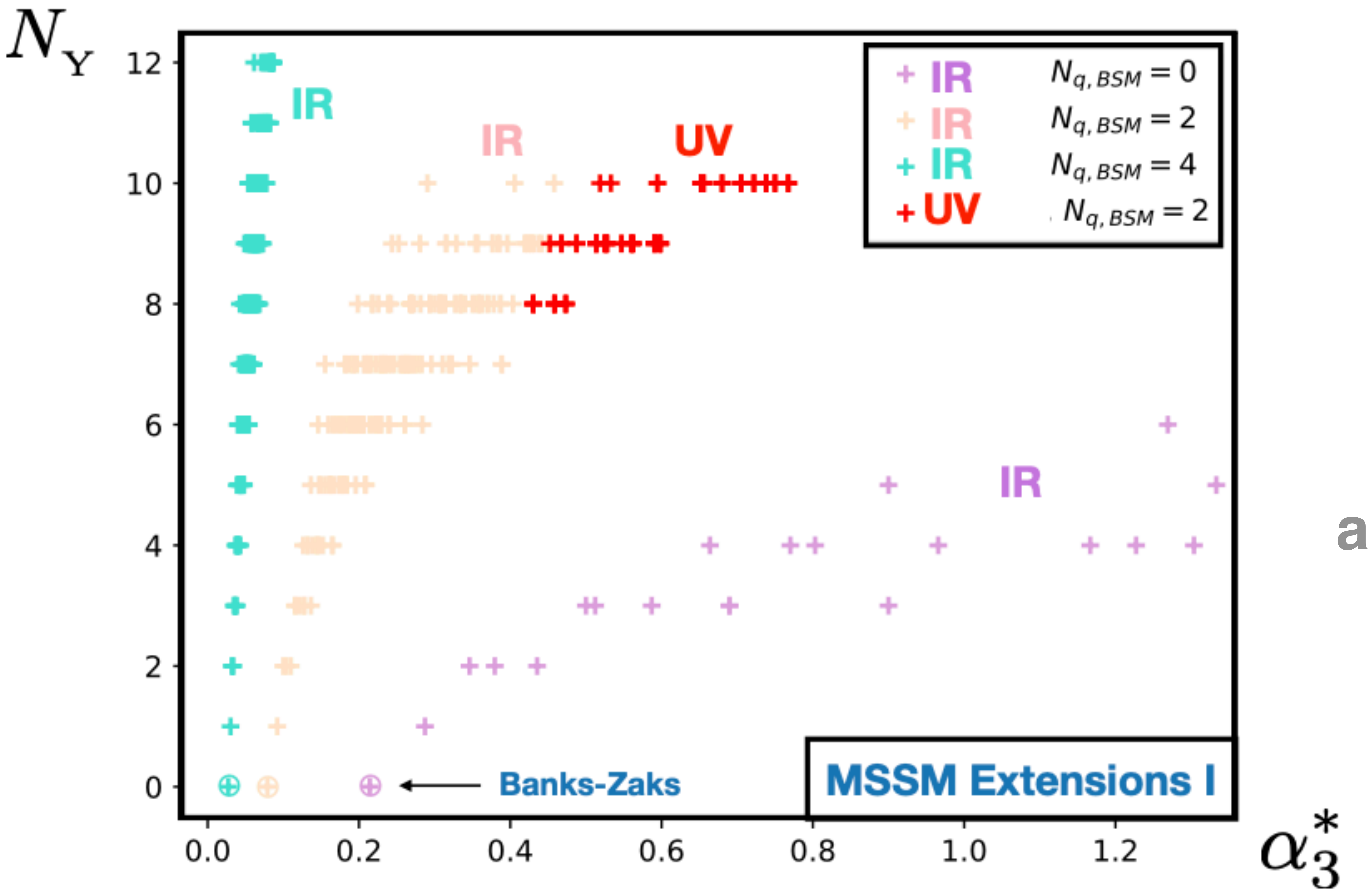
MSSM extensions



Superfield	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	MSSM	Extension I	Extension II	Extension III
quark doublet Q	$\mathbf{3}$	$\mathbf{2}$	$+\frac{1}{6}$	3	3	4	4
anti-quark doublet $\overline{Q}$	$\overline{\mathbf{3}}$	$\overline{\mathbf{2}}$	$-\frac{1}{6}$	0	0	1	0
up-quark $\overline{u}$	$\overline{\mathbf{3}}$	$\mathbf{1}$	$-\frac{2}{3}$	3	$3+n_u$	3	4
down-quark $\overline{d}$	$\overline{\mathbf{3}}$	$\mathbf{1}$	$+\frac{1}{3}$	3	$3+n_d$	3	4
anti-up-quark u	$\mathbf{3}$	$\mathbf{1}$	$+\frac{2}{3}$	0	n_u	0	0
anti-down-quark d	$\mathbf{3}$	$\mathbf{1}$	$-\frac{1}{3}$	0	n_d	0	0
lepton doublet L	$\mathbf{1}$	$\mathbf{2}$	$-\frac{1}{2}$	3	$3+n_L$	$3+n_L$	$4+n_L$
anti-lepton doublet $\overline{L}$	$\mathbf{1}$	$\overline{\mathbf{2}}$	$+\frac{1}{2}$	0	n_L	n_L	n_L
lepton singlet $\overline{e}$	$\mathbf{1}$	$\mathbf{1}$	$+1$	3	3	3	4
up-Higgs H_u	$\mathbf{1}$	$\mathbf{2}$	$+\frac{1}{2}$	1	1	1	1
down-Higgs H_d	$\mathbf{1}$	$\mathbf{2}$	$-\frac{1}{2}$	1	1	1	1
gauge singlets S	$\mathbf{1}$	$\mathbf{1}$	0	0	0	n_S	0

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

MSSM extensions



scan over 212k models
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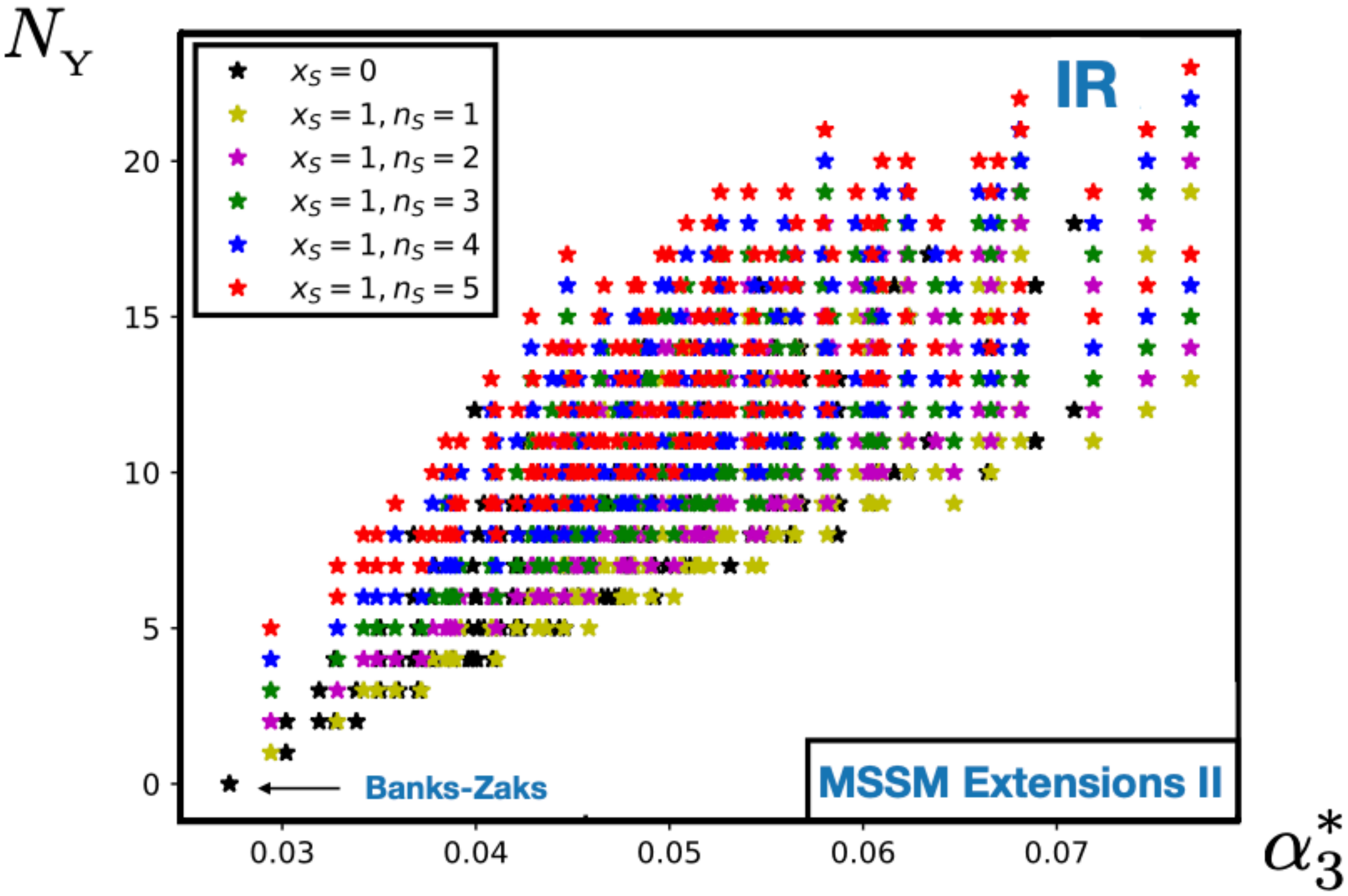
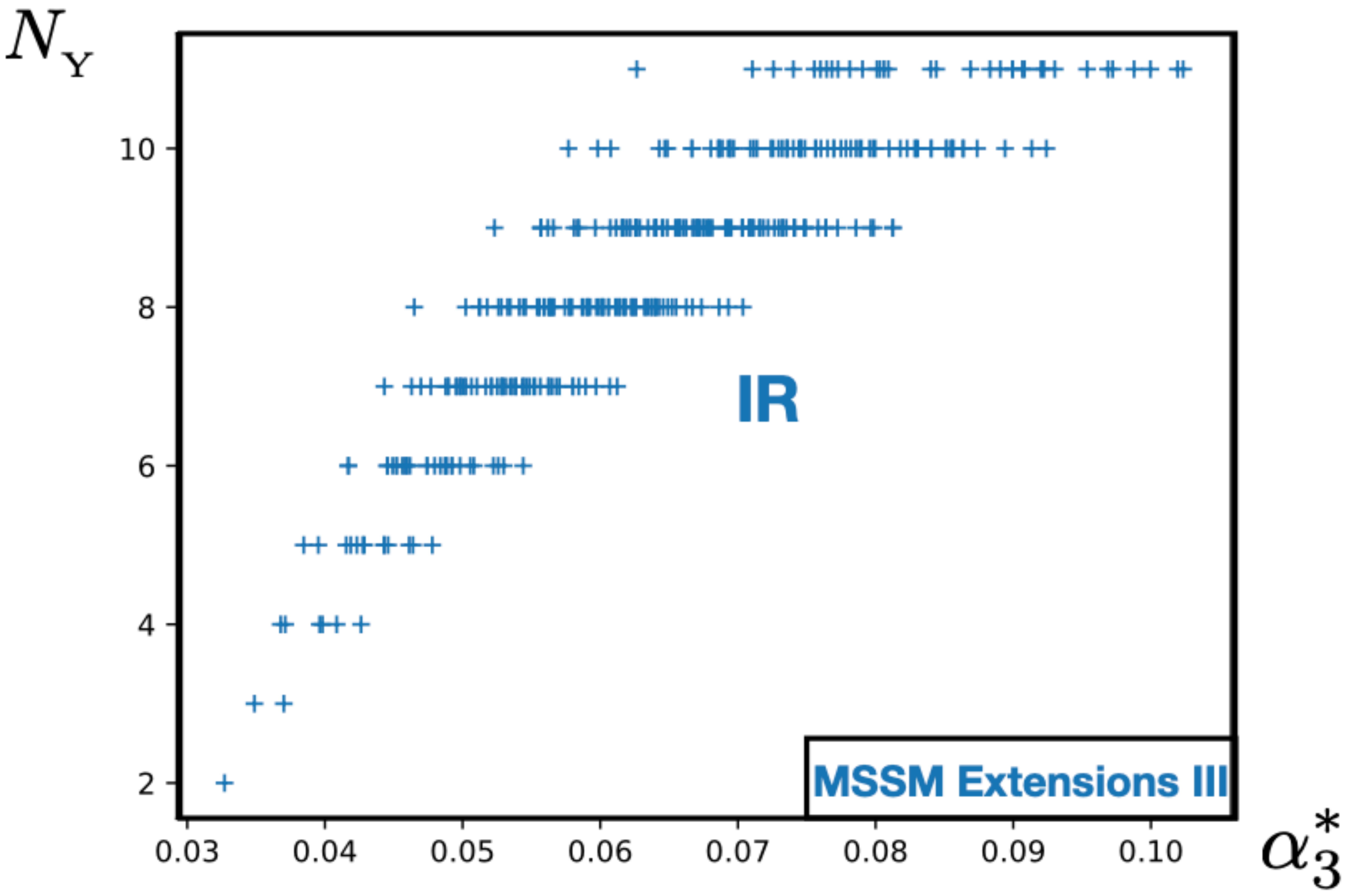
MSSM extensions



G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

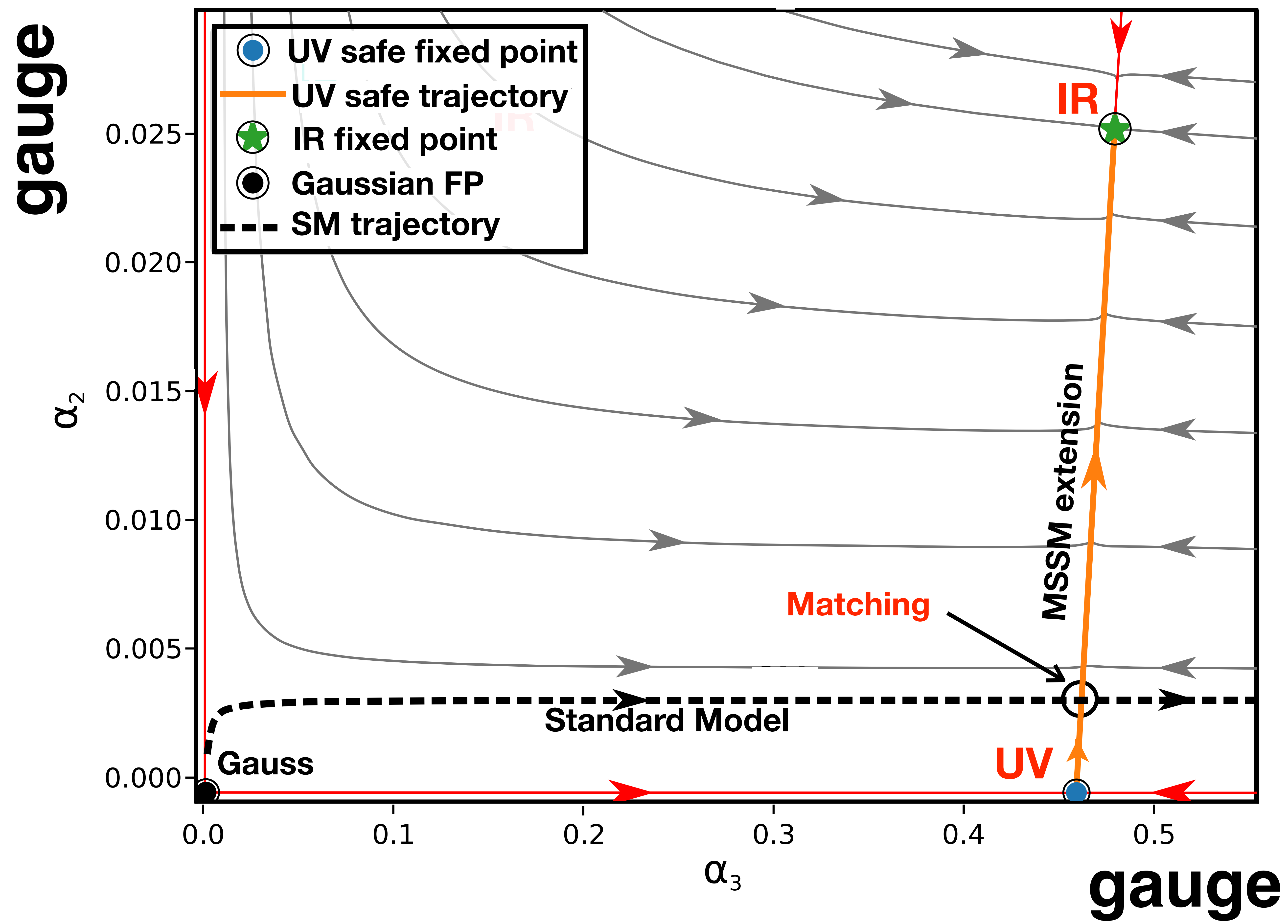
MSSM extensions



G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

MSSM extensions

MSSM + new quark singlets
+ new leptons + superpotential

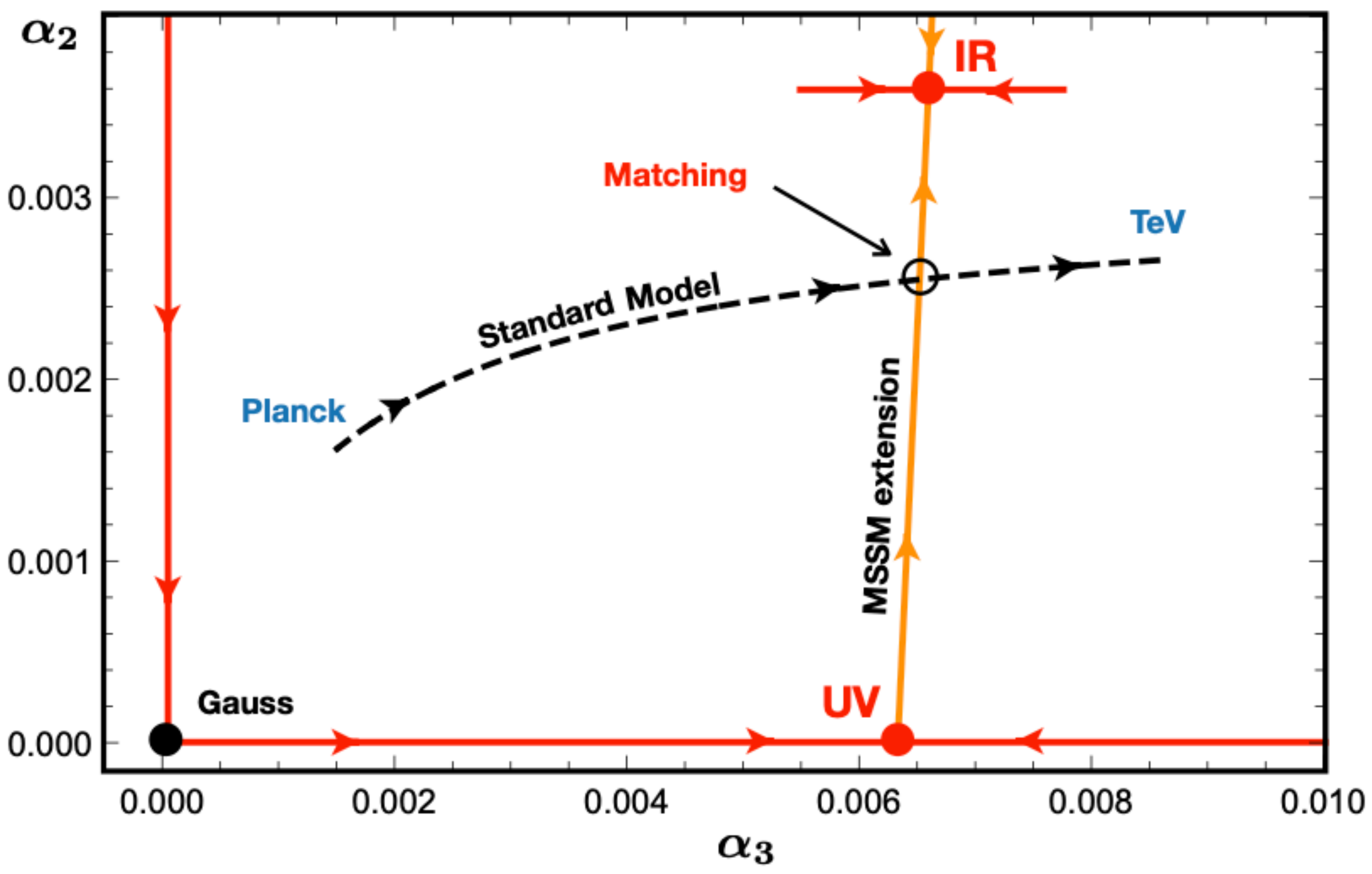


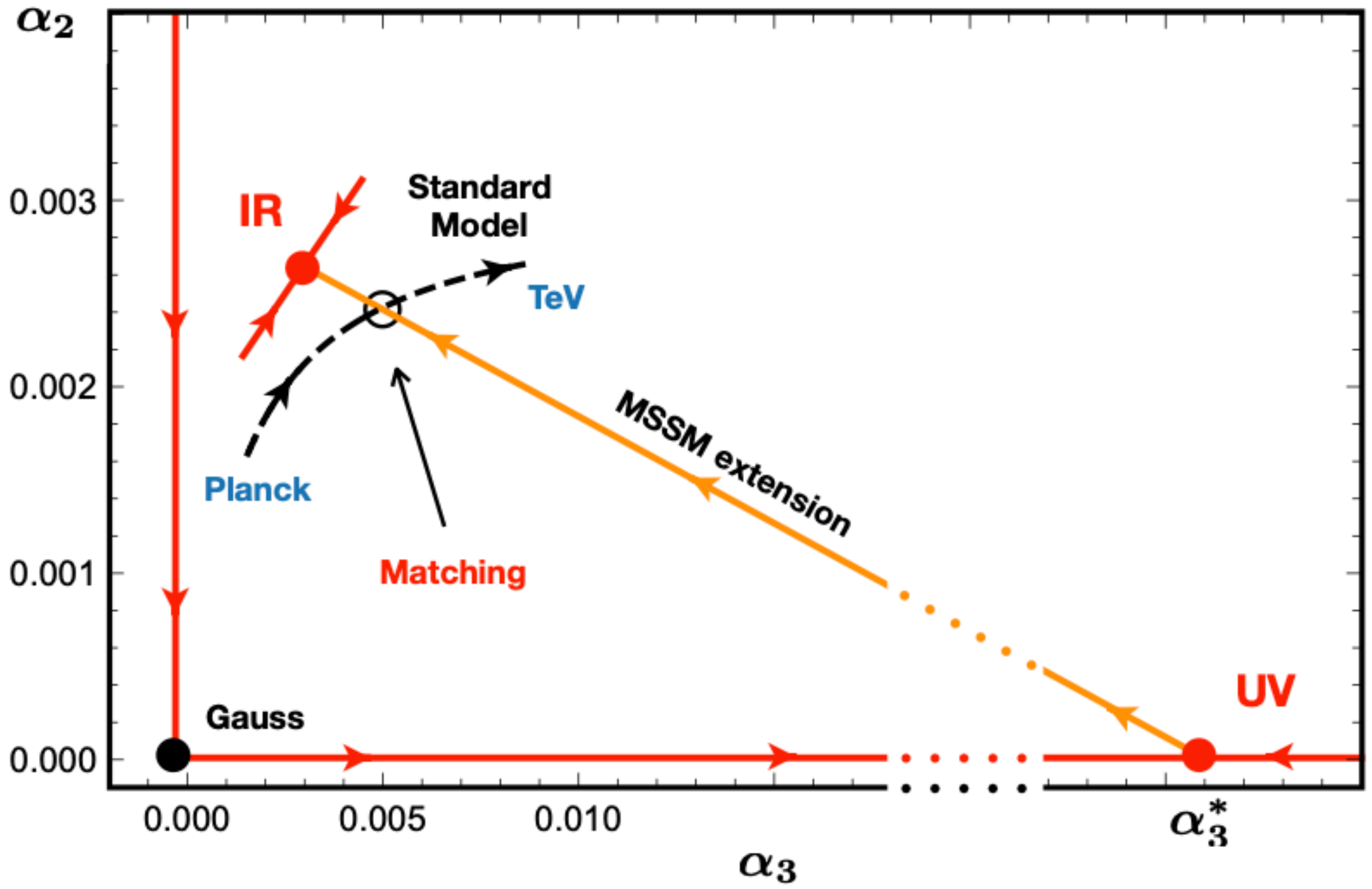
nearly works:
matching scale
too low (1 GeV)

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

MSSM extensions

Effects that could help:





non-perturbative study required

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

Conclusions

Quo vadis model building?

Bottom-Up

turn SM metastability into BSM task

various portals, constraining power
new BSM matter as light as TeV
can be searched for at colliders

Top-Down

new opportunities from UV fixed points

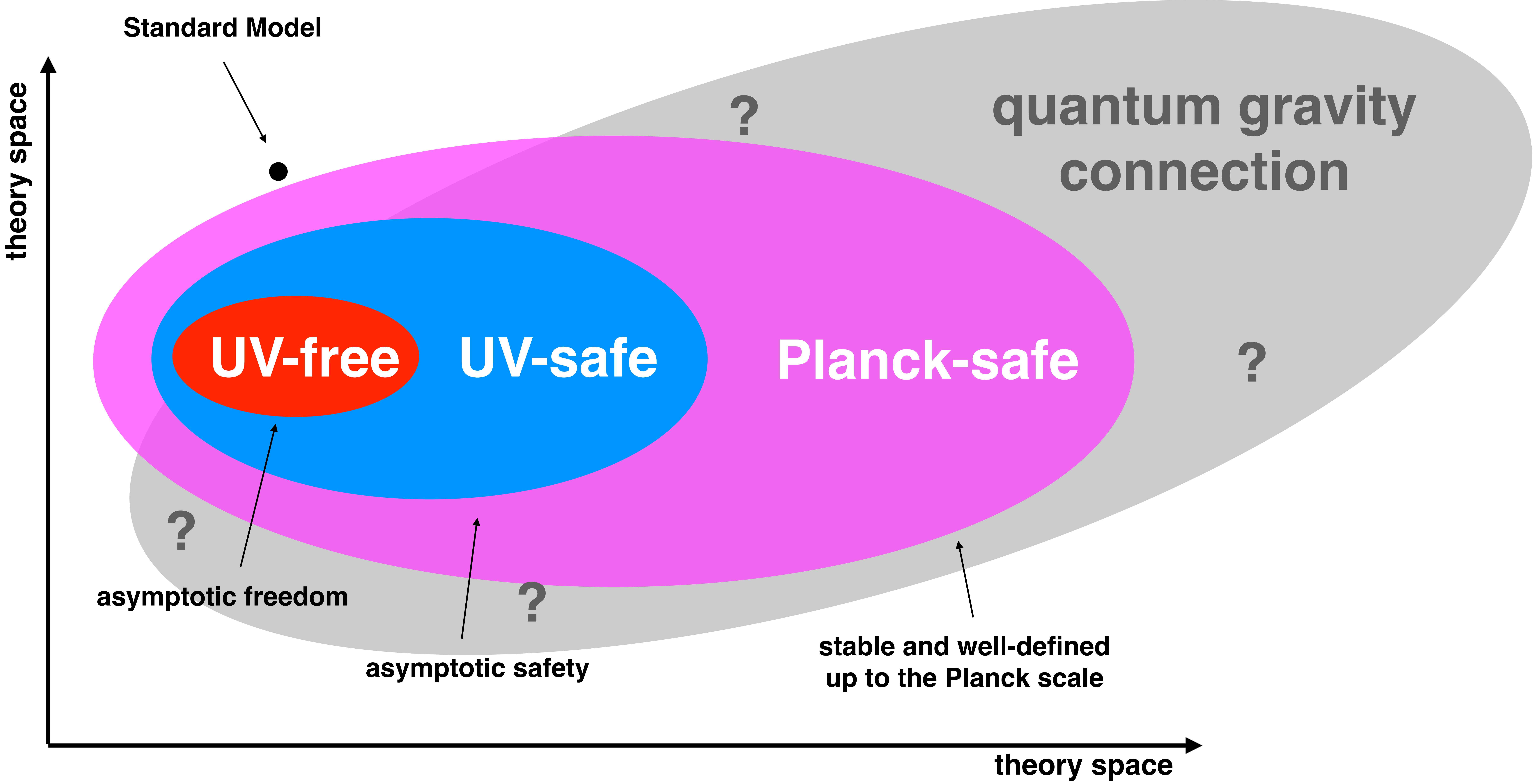
exploit ideas beyond asymptotic freedom

Outlook

“quantum gravity connection”

learn how quantum gravity kicks in
constraining power

Outlook


Standard Model
theory space
quantum gravity connection
?
UV-free
UV-safe
Planck-safe
?
?
?
asymptotic freedom
asymptotic safety
stable and well-defined up to the Planck scale
theory space

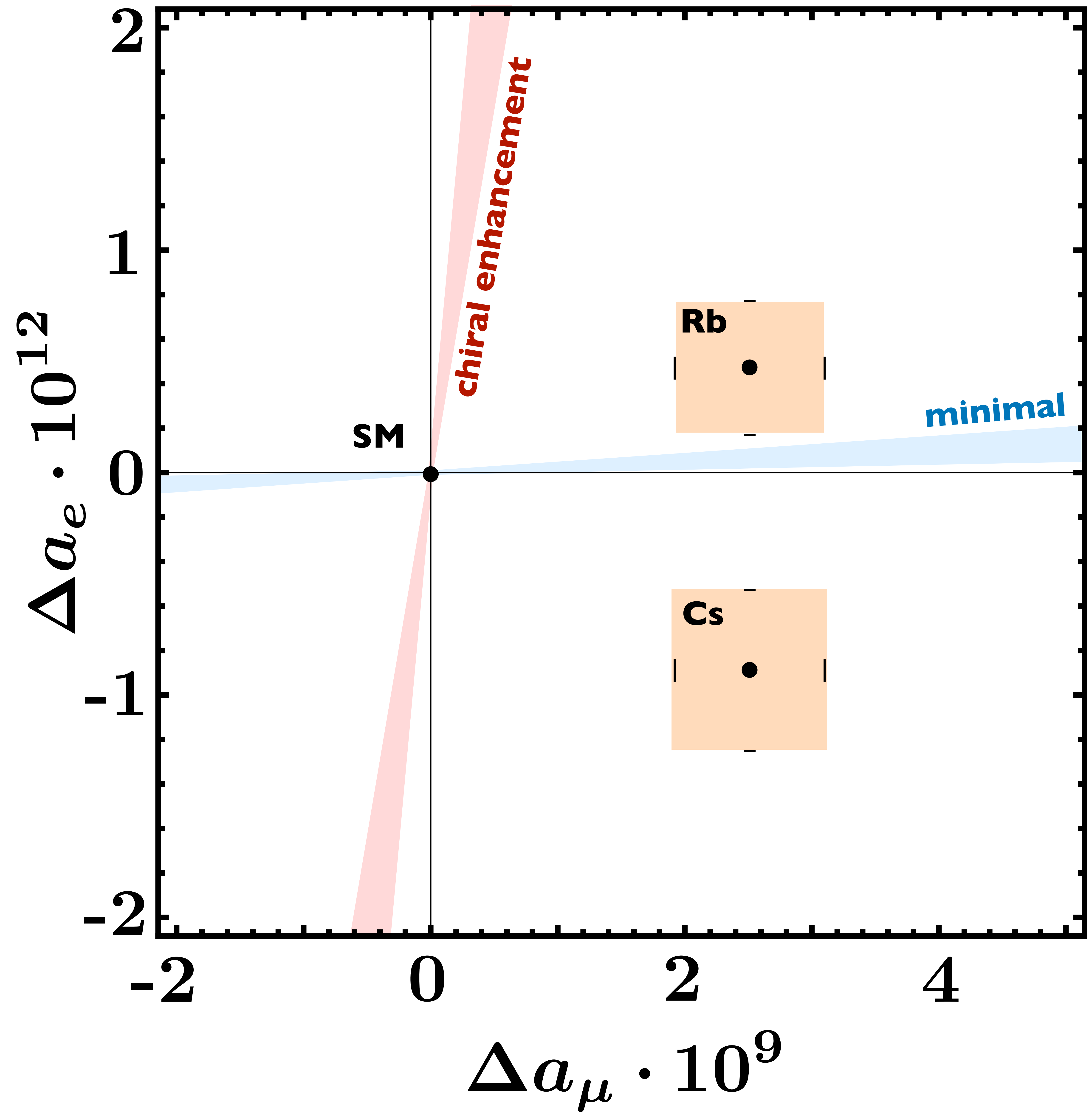
Thank you!

electron and muon anomalous magnetic moments

A Bond, G Hiller, K Kowalska, DF Litim,
Directions for model building from asymptotic safety, JHEP1708 (2017) 004

G Hiller, C Hermigos-Feliu, DF Litim, T Steudtner,
Asymptotically safe extensions of the Standard Model and their flavour phenomenology 1905.11020
Anomalous magnetic moments from asymptotic safety 1910.14062
Model building from asymptotic safety with Higgs and flavour portals 2008.08606

AMMs



a puzzle …

AMMs

what’s the new physics?

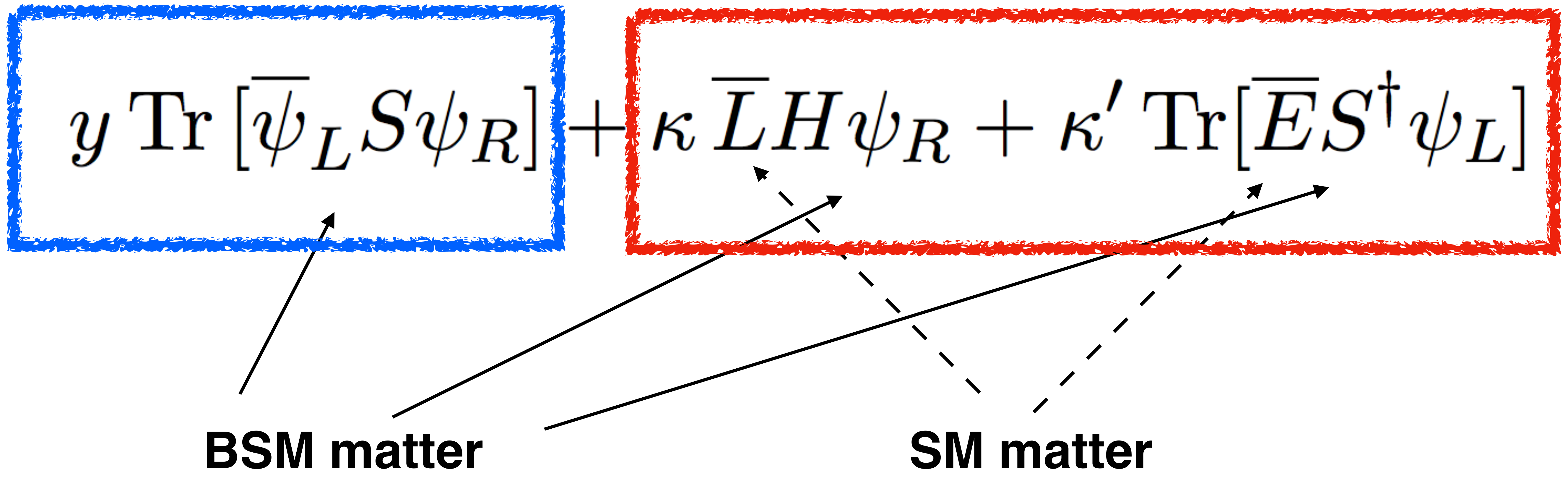
to date: about < 100 BSM models can explain the muon and electron data simultaneously

All but ONE treat electrons and muons differently
i.e. **break lepton universality manifestly**

AMMs

inspired by UV fixed point:

matrix scalar field S
Nf = 3 vector-like fermions
new Yukawas + portal interactions



$$\boxed{y\,\mathrm{Tr}\,[\overline{\psi}_L S \psi_R]} + \boxed{\kappa\,\overline{L} H \psi_R + \kappa'\,\mathrm{Tr}[\overline{E} S^\dagger \psi_L]}$$

feature 1: lepton universality intact

identify SM flavour symmetry
with BSM flavour symmetry

$$\kappa_{ij} = \kappa\,\delta_{ij}$$

AMMs

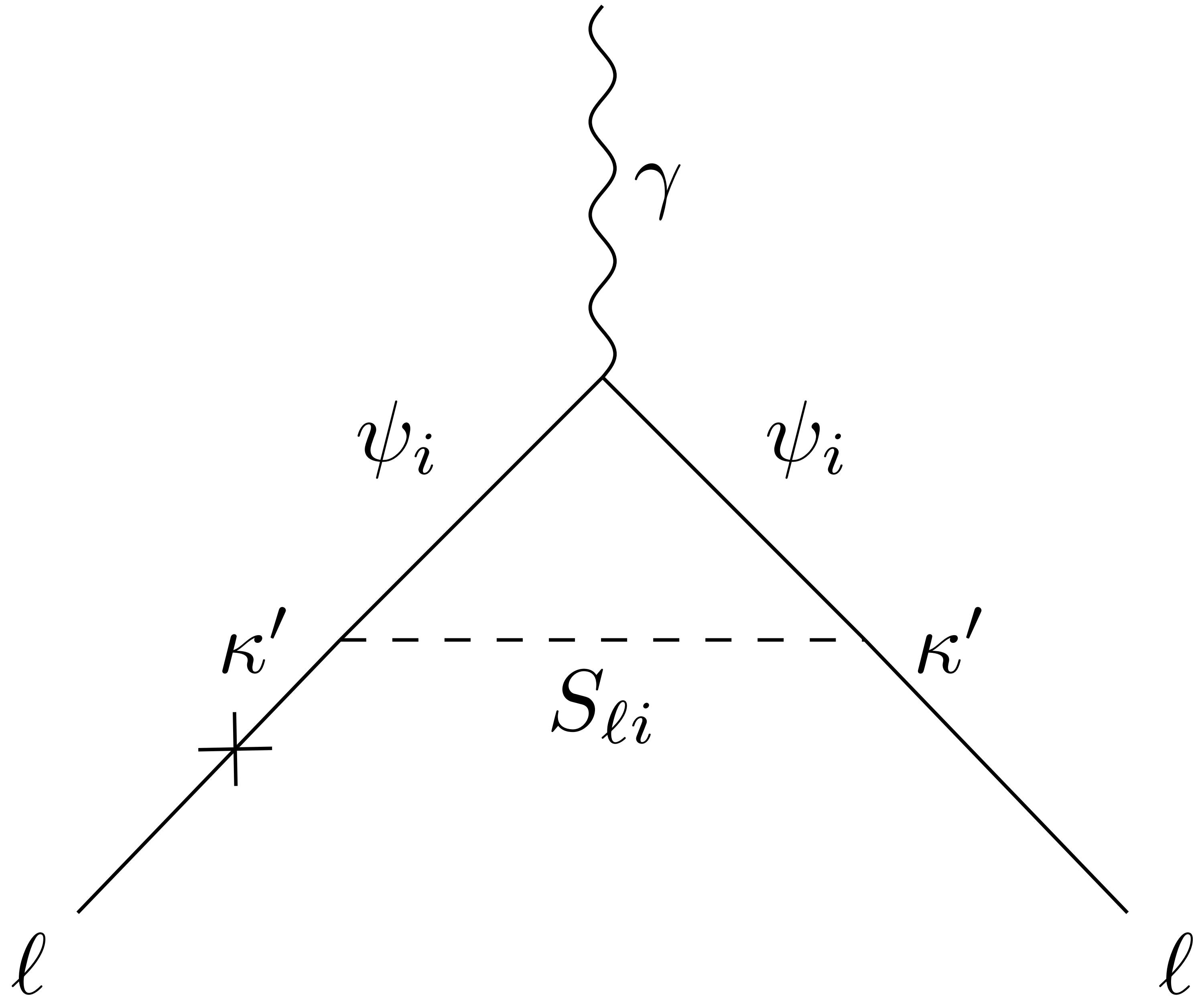
inspired by UV fixed point:

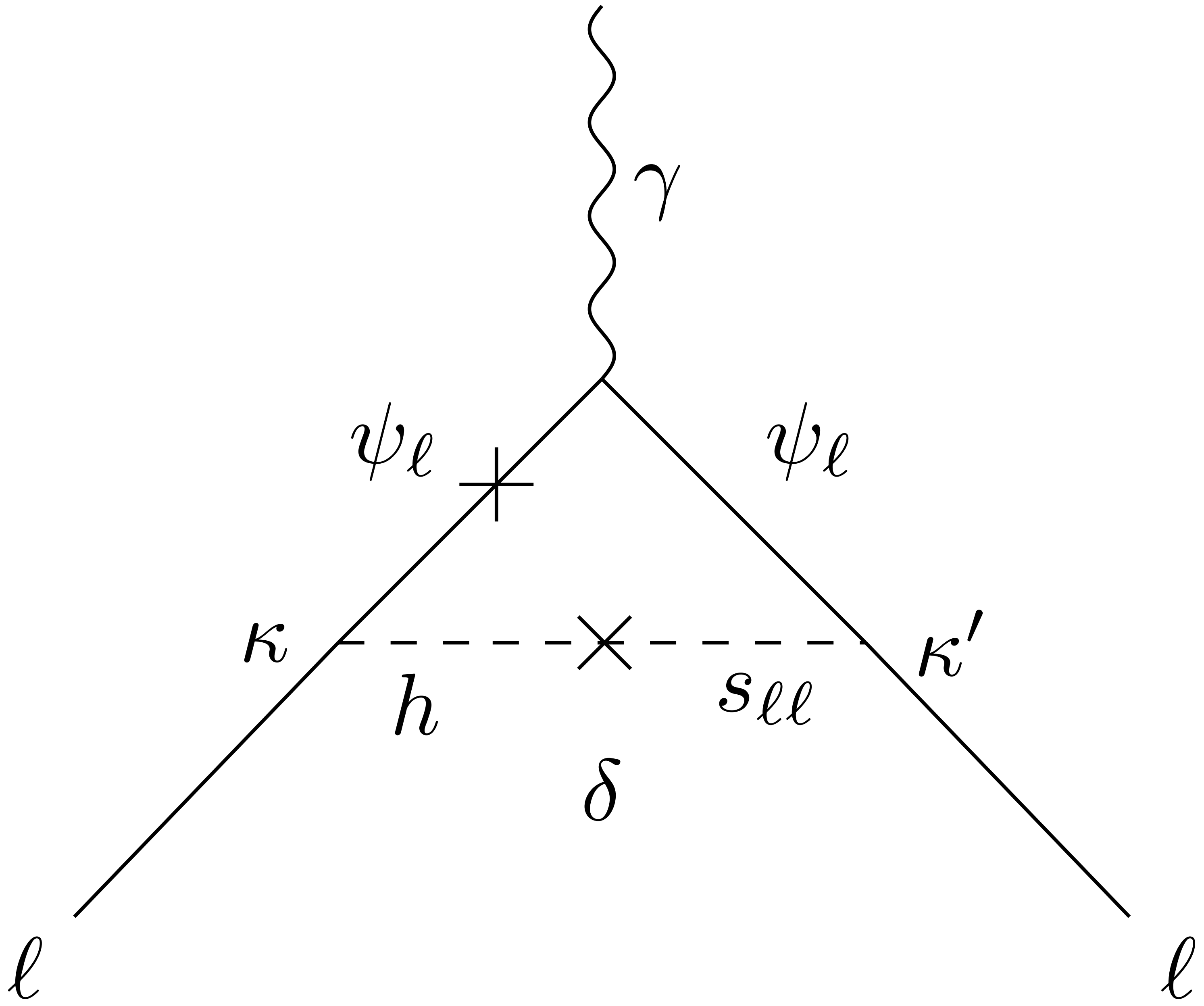
matrix scalar field S
Nf = 3 vector-like fermions
new Yukawas + portal interactions

$$\boxed{y\,\mathrm{Tr}\,[\overline{\psi}_L S \psi_R]} + \boxed{\kappa\,\overline{L} H \psi_R + \kappa'\,\mathrm{Tr}[\overline{E} S^\dagger \psi_L]}$$

feature 2: **BSM Yukawas can explain anomalous magnetic moments**

AMMs





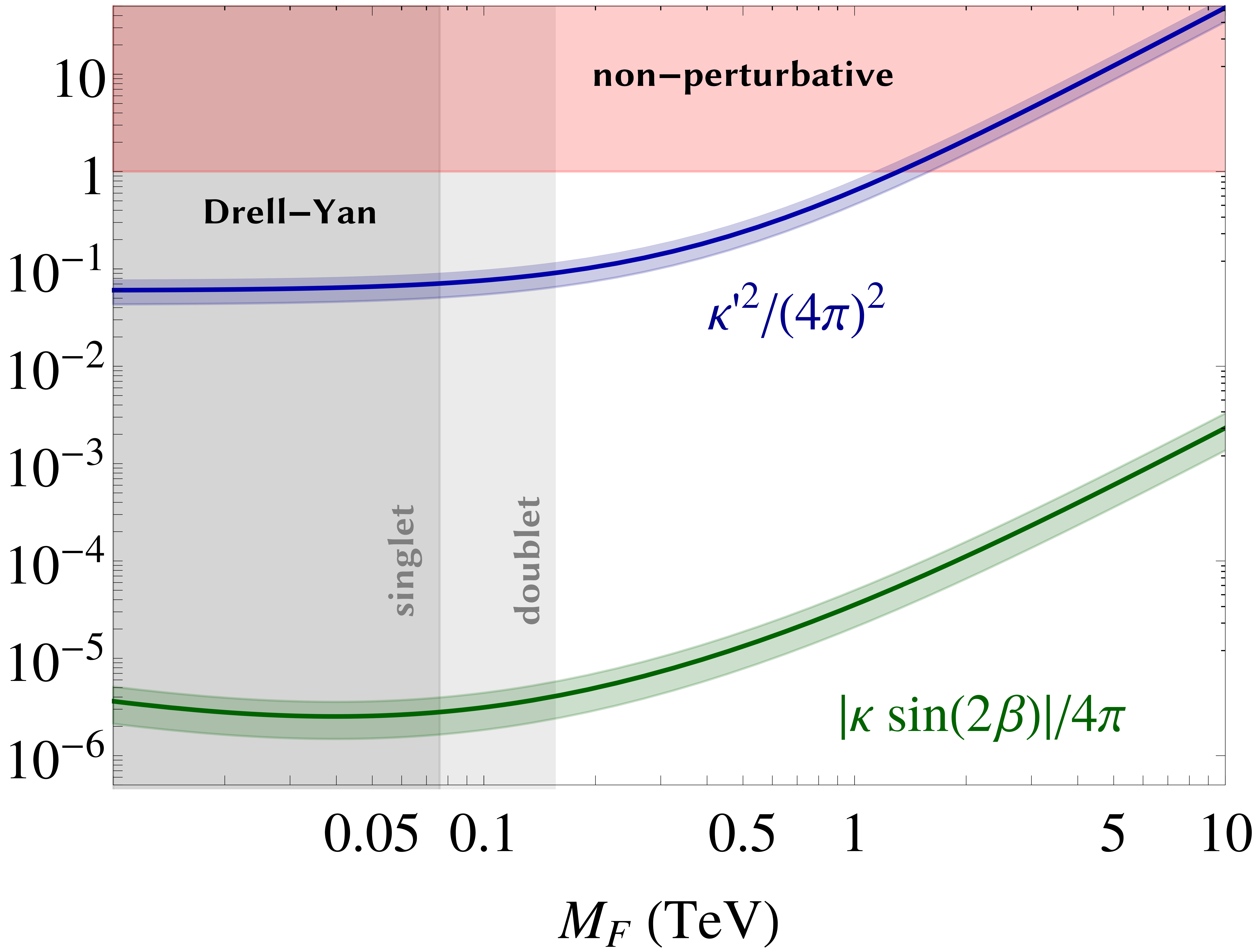
“minimal”

“chirally enhanced”

$$\boxed{\sim (m_e/m_\mu)^2}$$

$$\boxed{\sim (m_e/m_\mu)}$$

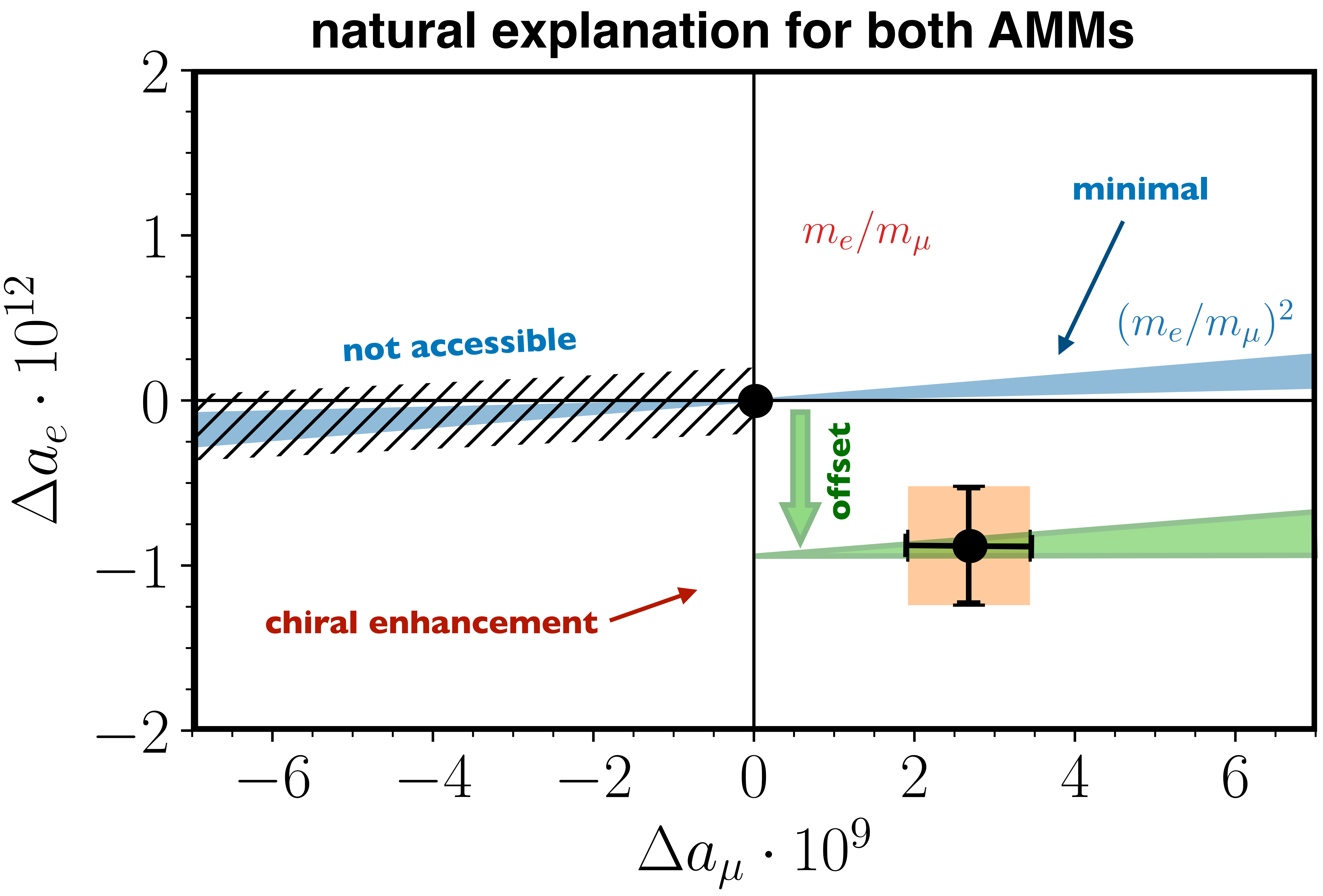
AMMs



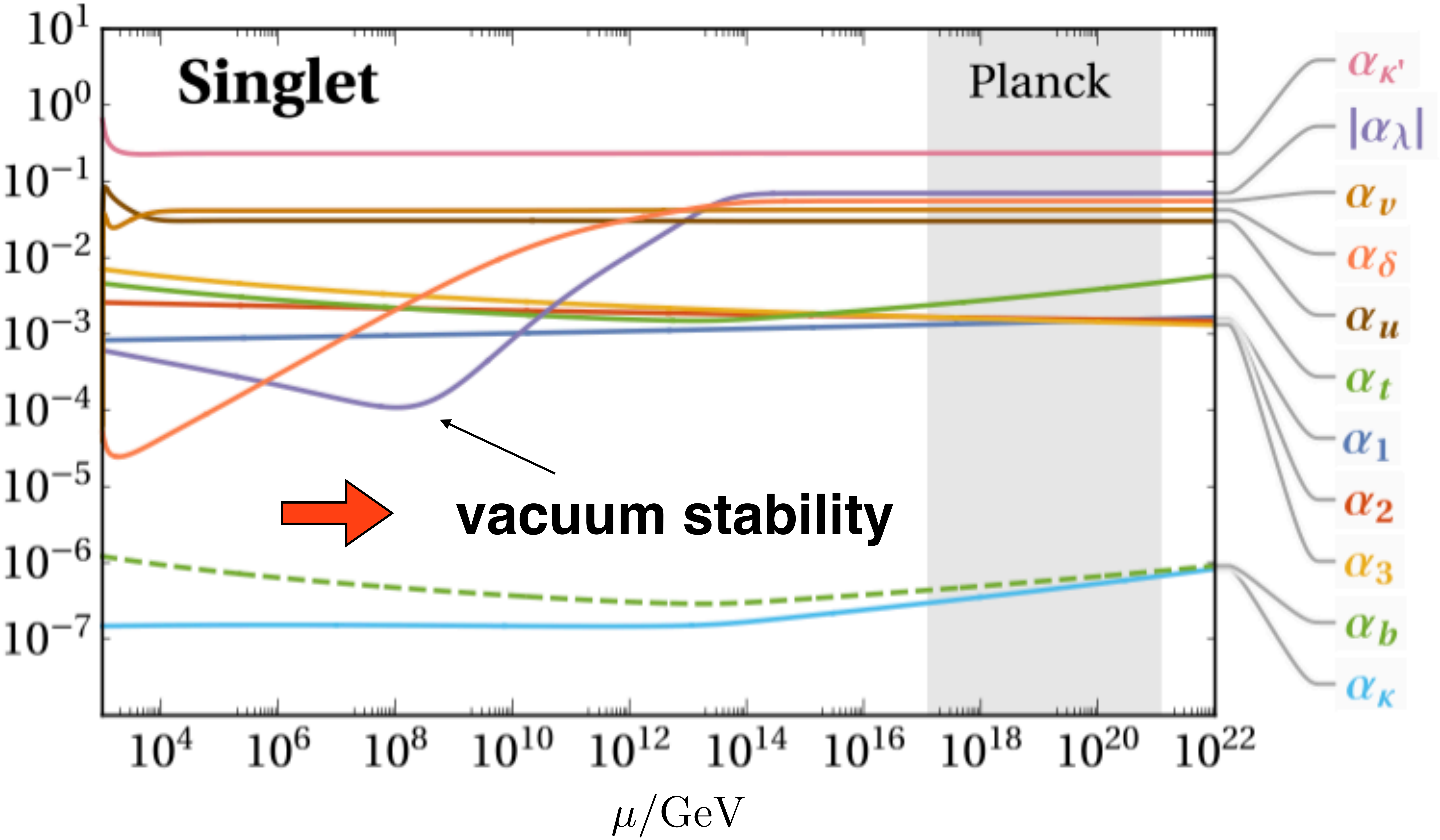
G Hiller, C Hermigos-Feliu, DF Litim, T Steudtner, **Anomalous magnetic moments from asymptotic safety** 1910.14062

Model building from asymptotic safety with Higgs and flavour portals 2008.08606

AMMs

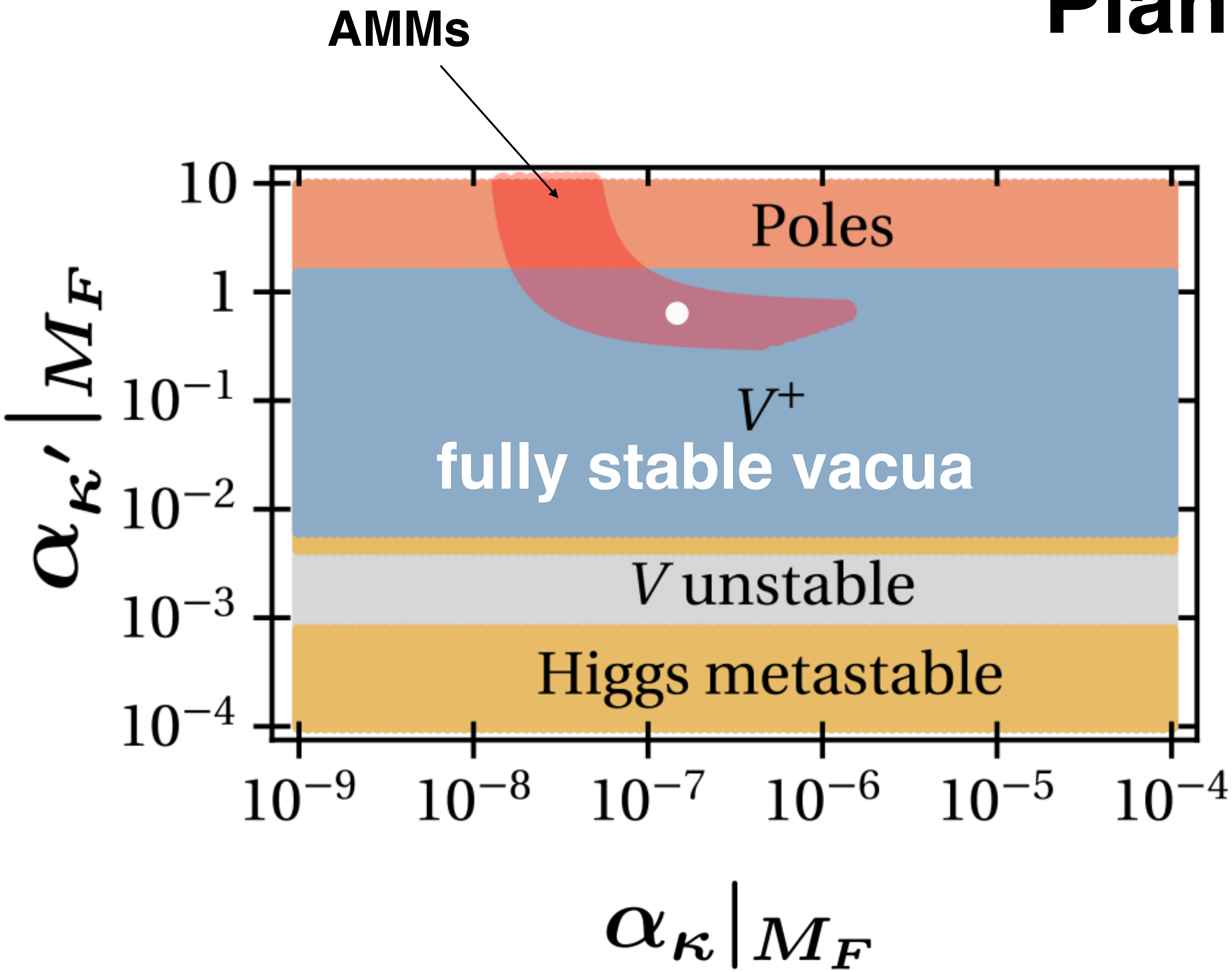

natural explanation for both AMMs
minimal
m_e/m_μ
$(m_e/m_\mu)^2$
not accessible
offset
chiral enhancement
$\Delta a_e \cdot 10^{12}$
$\Delta a_\mu \cdot 10^9$
2
1
0
-1
-2
-6
-4
-2
0
2
4
6

what’s more

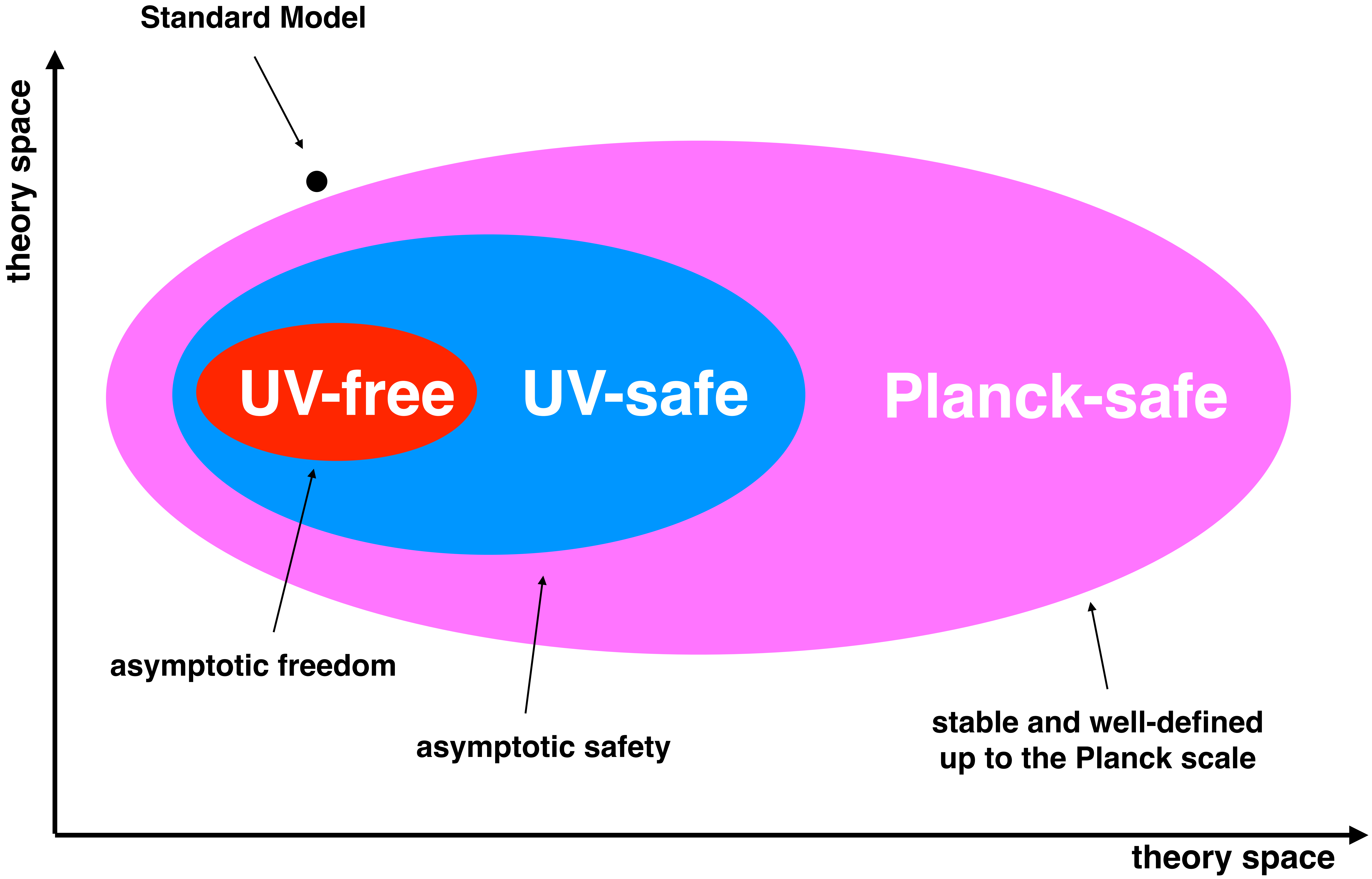


➡ **vacuum stability**

“Planck safe”


AMMs
Poles
V^+
fully stable vacua
V unstable
Higgs metastable
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-9}
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
$\alpha_{\kappa'}|_{M_F}$
$\alpha_\kappa|_{M_F}$

Conclusions



extra material

UV fixed points and MSSM extensions

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

why no Susy UV fixed point

superfield anomalous dimension

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asymptotic freedom: B > 0

no asymptotic freedom: B < 0

⇒ **fixed point requires AF**

UV fixed point cannot arise

S Martin, J Wells, hep-ph/0011382/PRD

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remedy:

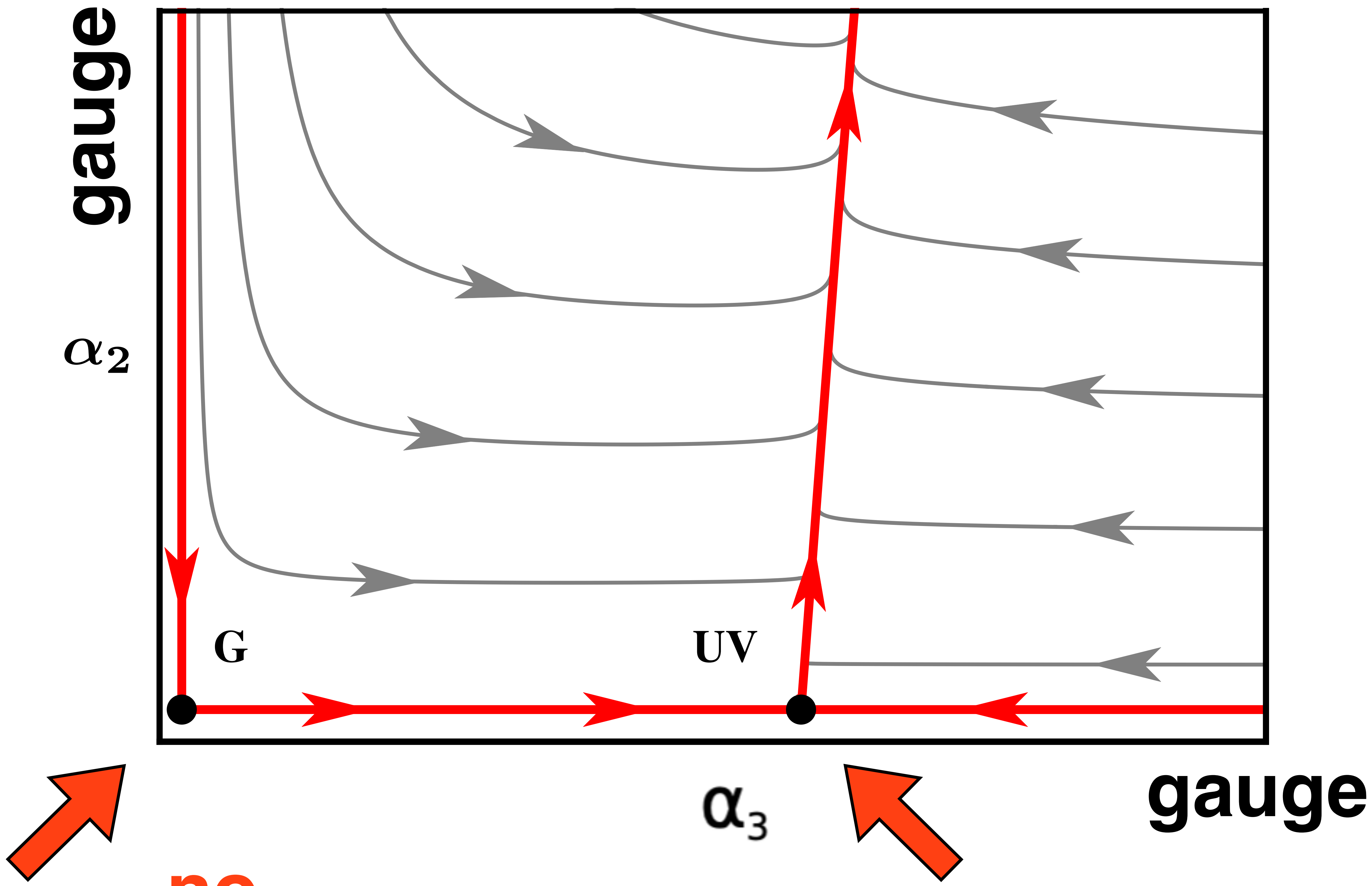
semi-simple susy gauge theories

some $B_i < 0$ a possibility

→ **UV fixed points can arise**

AD Bond, DF Litim, 1709.06953/PRL

Susy UV fixed points



no
asymptotic
freedom

e.g. MSSM

interacting
UV fixed point

template:

SU(N) x SU(M)
+ chiral superfields
+ superpotential

AD Bond, DF Litim, **Asymptotic Safety Guaranteed in Supersymmetry,** 1709.06953 (PRL)
Asymptotic Safety Guaranteed for Strongly Coupled Gauge Theories, 2202.08223 (PRD)

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2 Loop RGEs

scan over 212k models
approx 100 UV fixed points

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MSSM extensions

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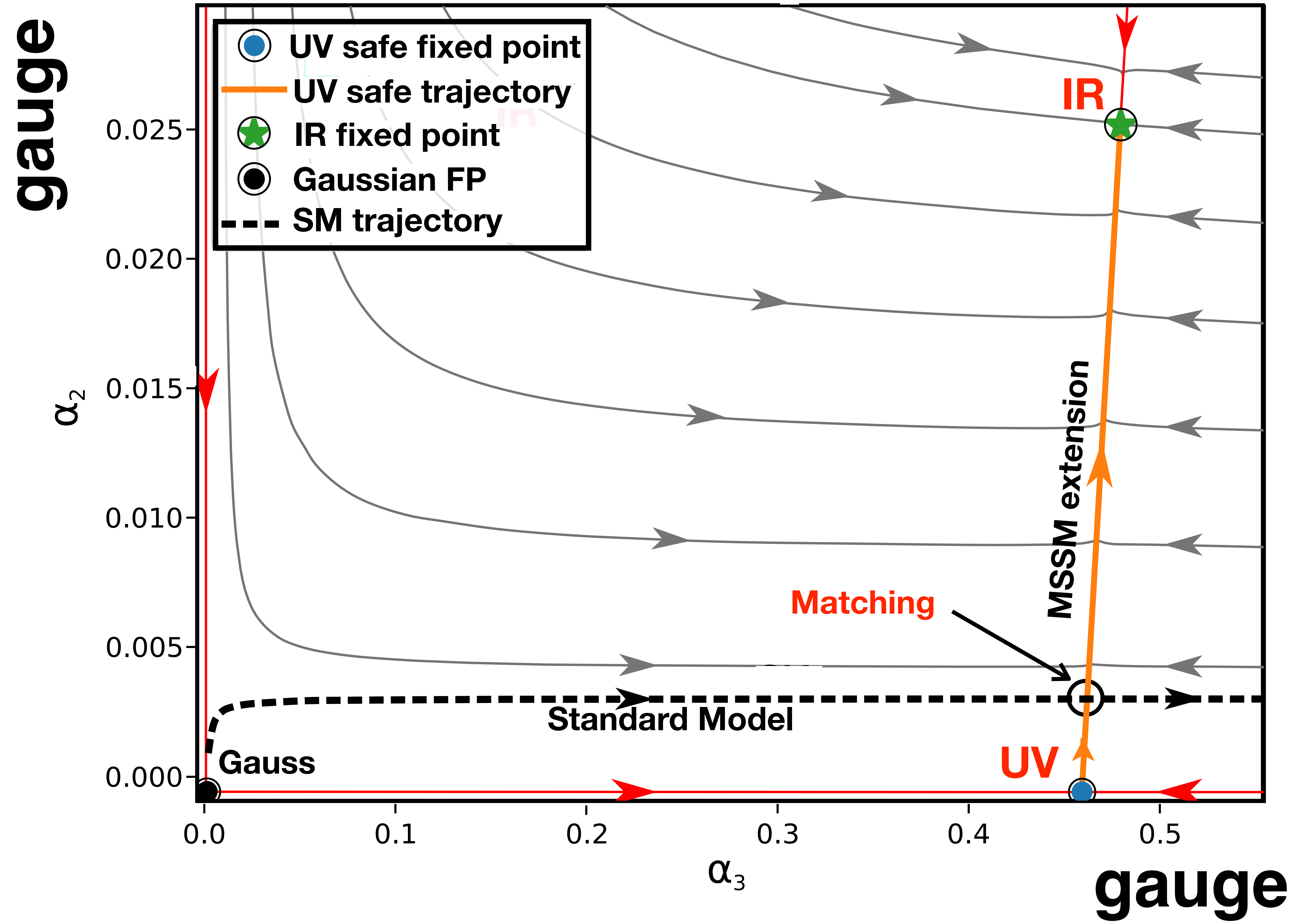


nearly works:
matching scale
too low (1 GeV)

G Hiller, D Litim, K Moch, **FPs in supersymmetric extensions of the Standard Model** 2202.01264 (EPJC)

Top-Down

template UV

Lagrangian

$$L_{\rm YM} = -\frac{1}{2}{\rm Tr}\, F^{\mu\nu} F_{\mu\nu}$$

SU(N)

$$L_F = {\rm Tr}\left(\overline{Q}\, i\not{D}\, Q\right)$$

$$L_Y = y\,{\rm Tr}\left(\overline{Q}\, H\, Q\right)$$

fermions

$$L_H = {\rm Tr}\,(\partial_\mu H^\dagger\, \partial^\mu H)$$

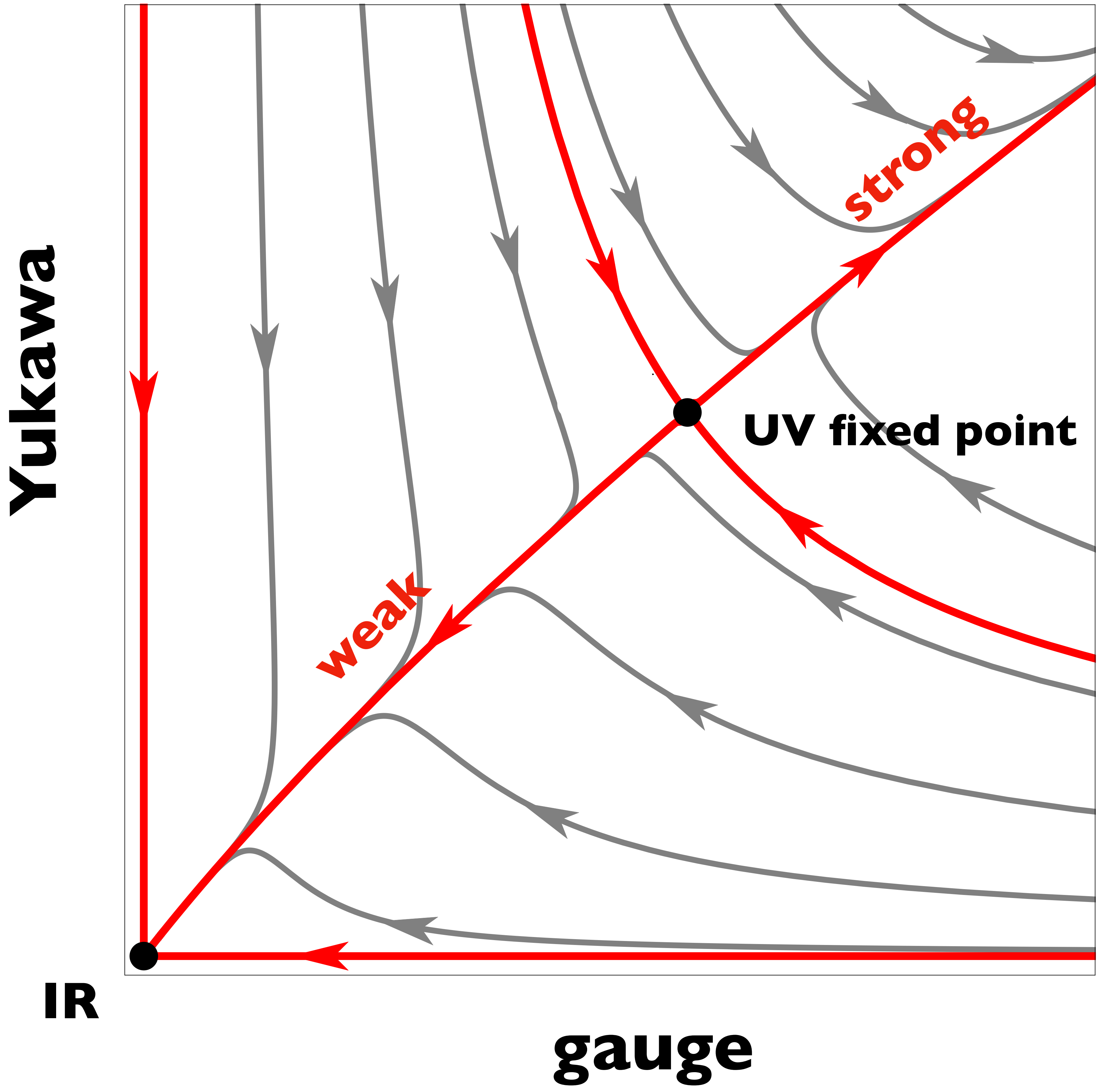
$$L_U = -u\,{\rm Tr}\,(H^\dagger H)^2$$

$$L_V = -v\,({\rm Tr}\, H^\dagger H)^2\,.$$

scalars

scalars are "meson-like", H_ij

no asymptotic freedom, yet, stable and predictive
"UV complete"



DF Litim, F Sannino, **Asymptotic Safety Guaranteed,** 1406.2337 (JHEP)