BSM Theory Overview

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Dissecting the LHC results
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The ideal world:

The real world:

Higgs couplings!

Flavour!

No DM!

EWPTs!

Top couplings!

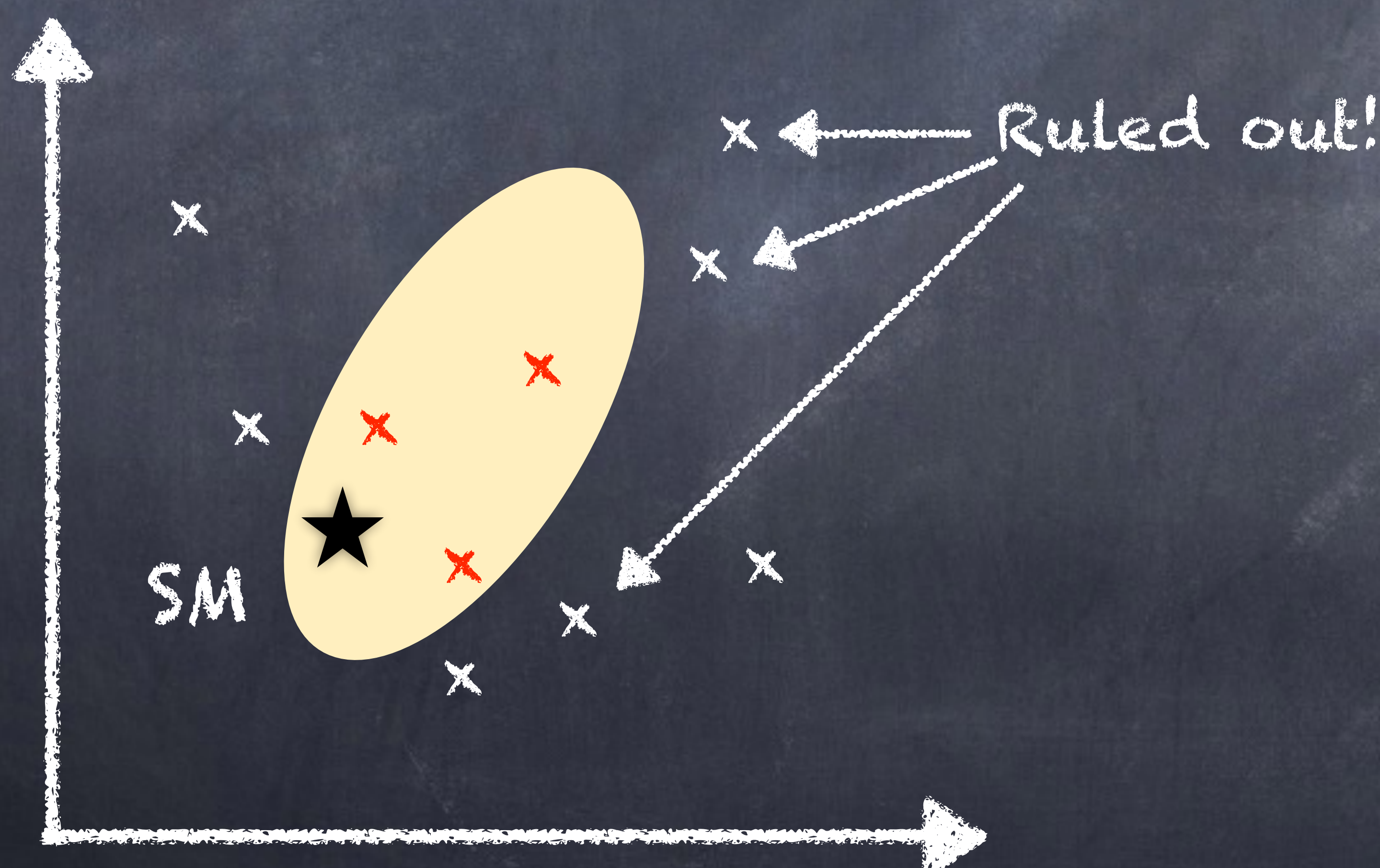
Struggling to put together a model in the midst of "buzzers"!

No bumps!

Higgs mass!

What is our job?

- Models can be ruled out, but cannot be proven right!



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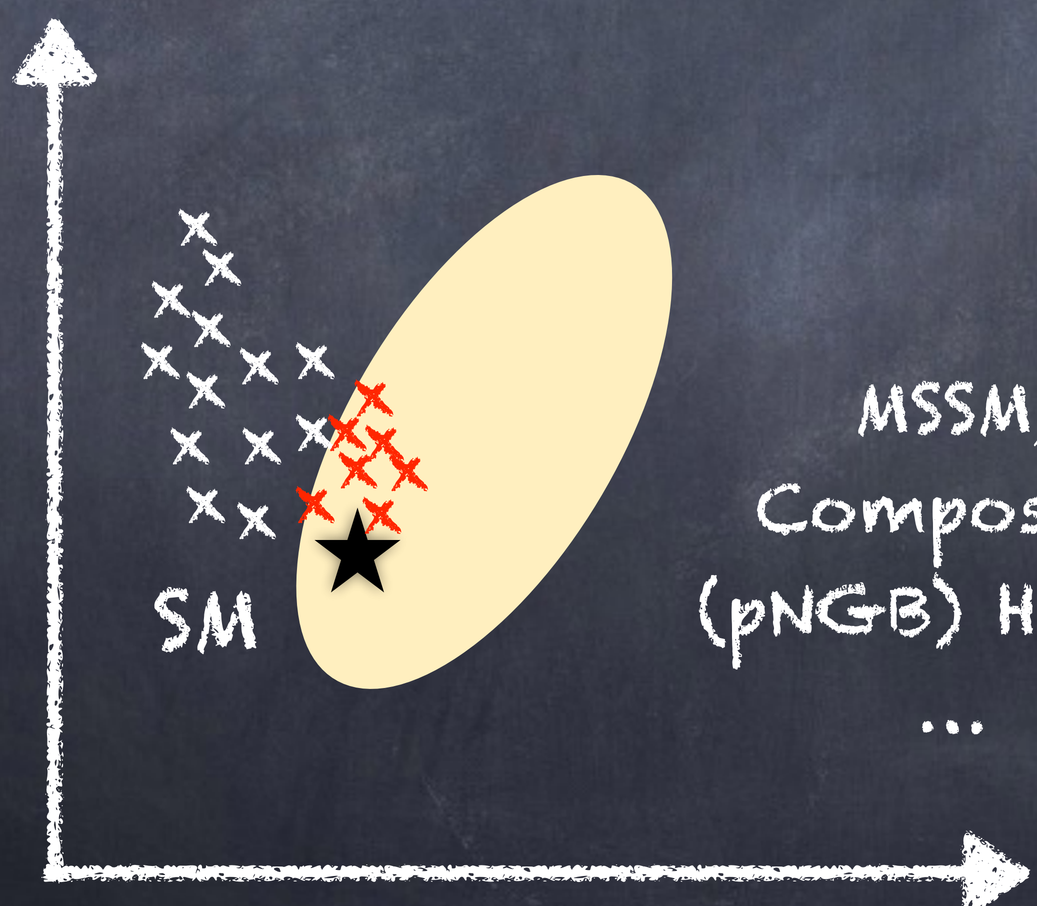


MSSM,
Composite
(pNGB) Higgs,
...

Class A:

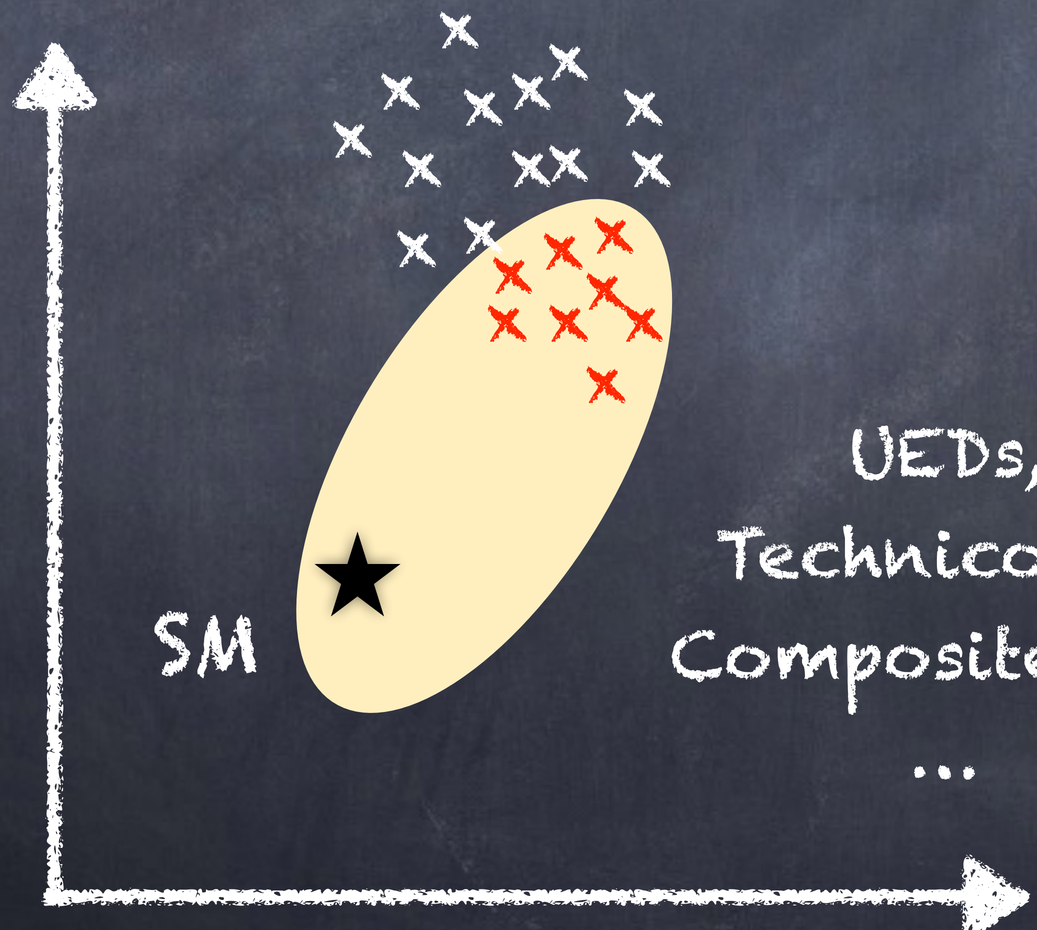
Parameter space connected to the SM prediction

↓

Cannot be ruled out!

What is our job?

- Models can be ruled out, but cannot be proven right!



UEDs,
Technicolor,
Composite DM,
...

Class B:

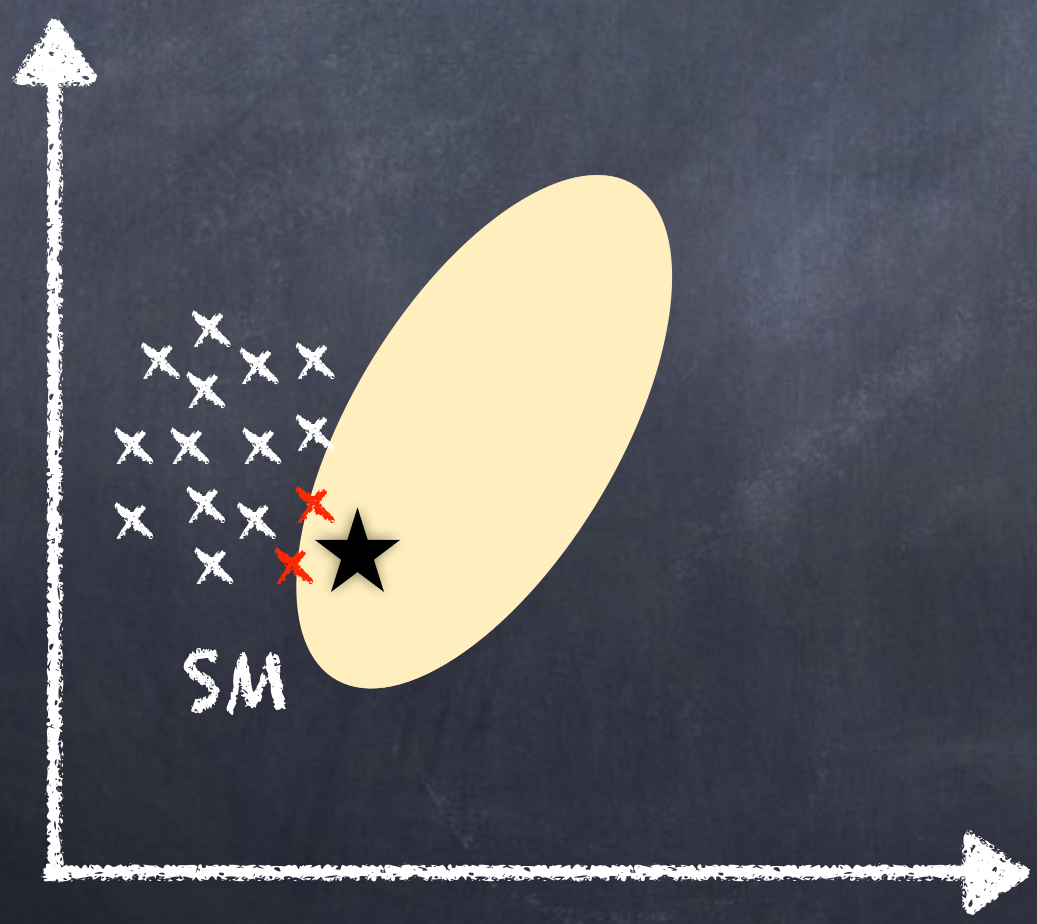
Parameter space disconnected from SM prediction

↓

Can be ruled out!

What is our job?

- Models can be ruled out, but cannot be proven right!



Grey zone:

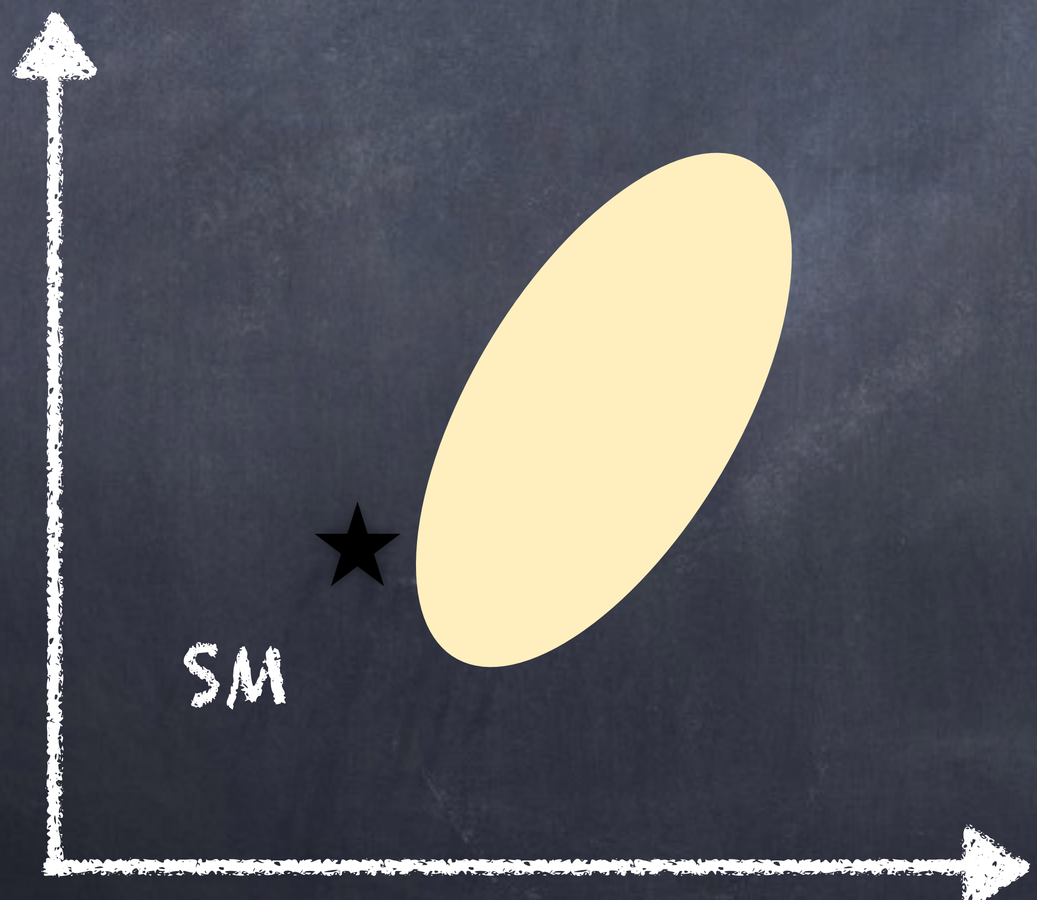
Fine tuning?

Personal taste?

How close to
the decoupling limit?

What is our job?

- Models can be ruled out, but cannot be proven right!



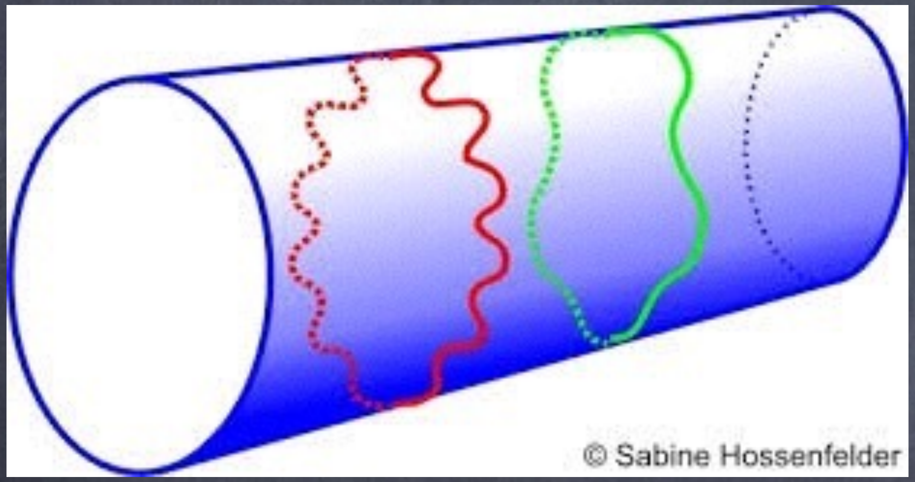
BSM dream:

The SM itself can be excluded!

Are we there yet?
No...

Class B: UEDs

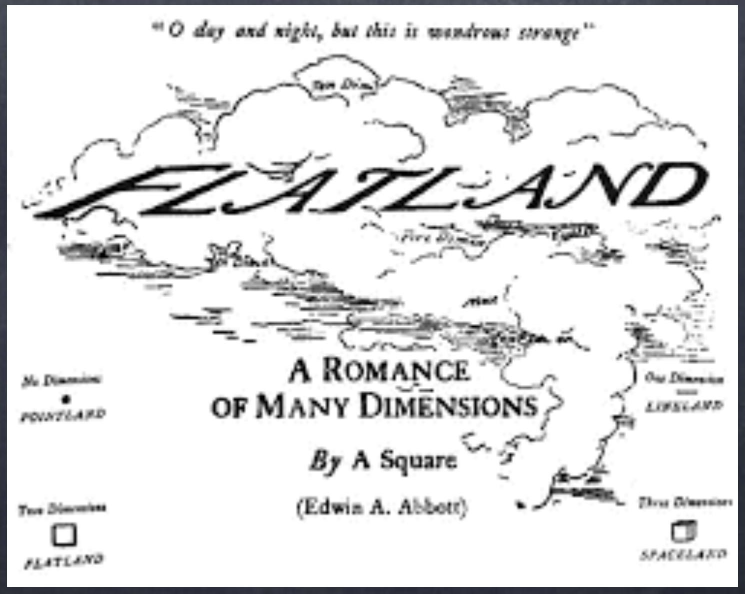
- Model of Dark Matter based on extra dimensions!



XD fields -> tower of KK states

frequencies -> KK masses

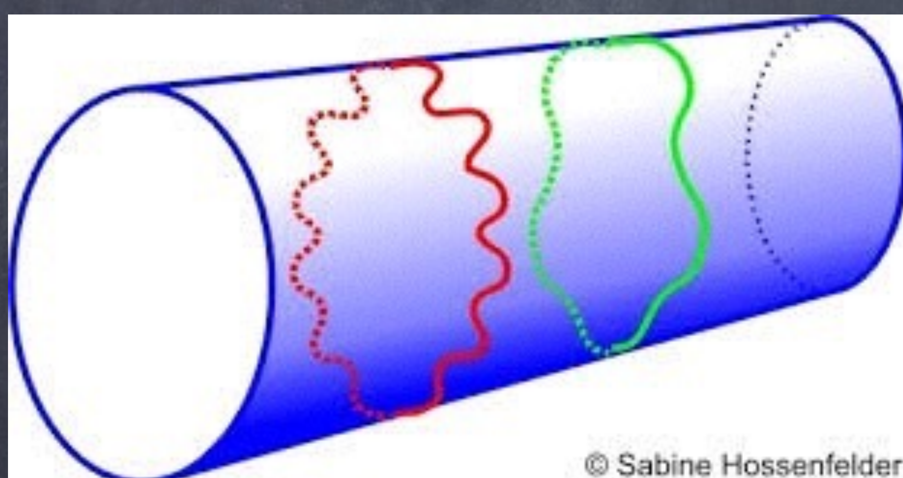
geometry -> KK parities



Class B: UEDs

- Model of Dark Matter based on extra dimensions!

1702.00410



Mass splitting crucially depends on the "cut-off" of the theory.

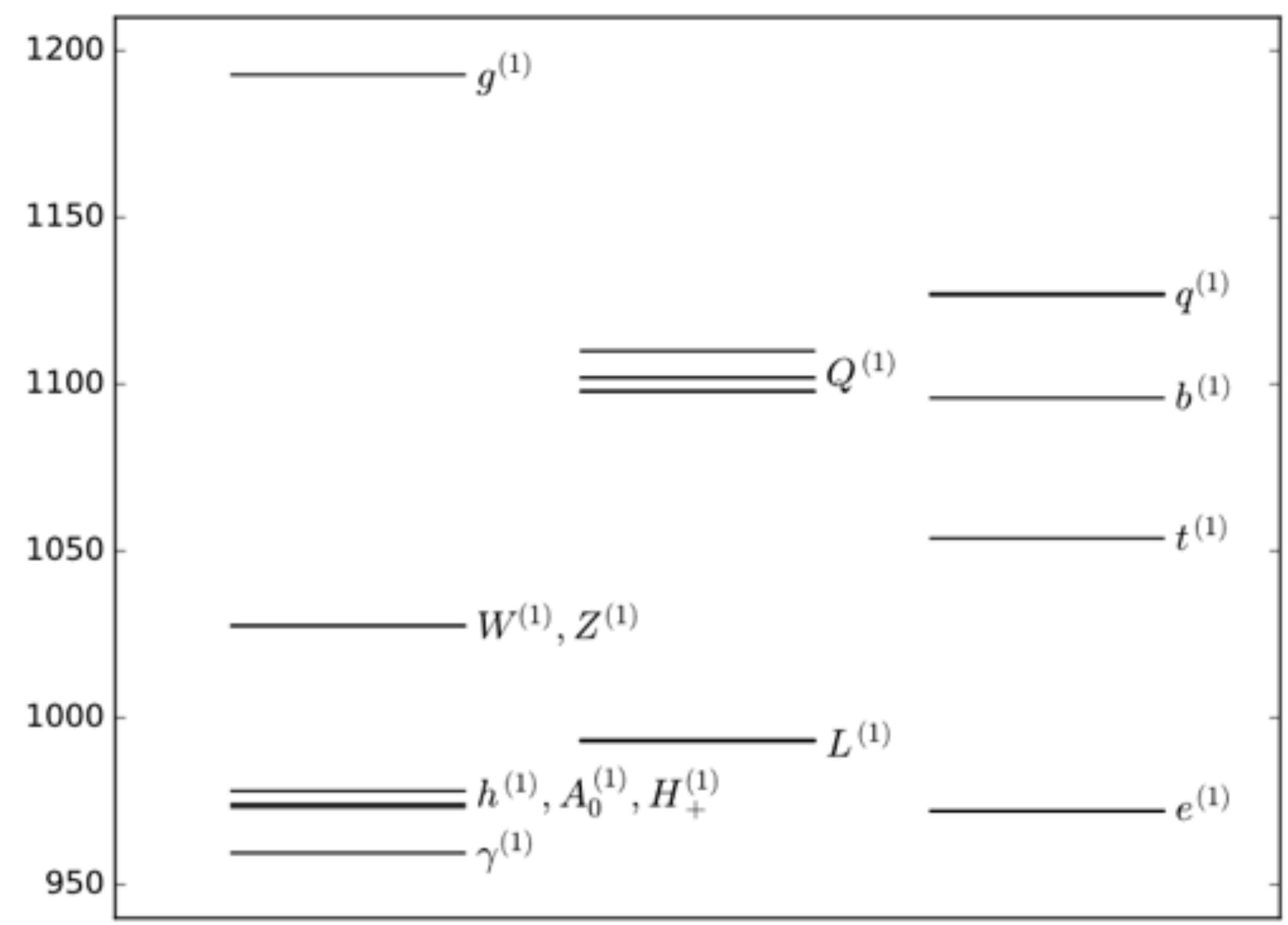
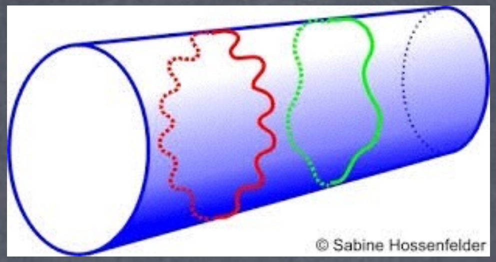


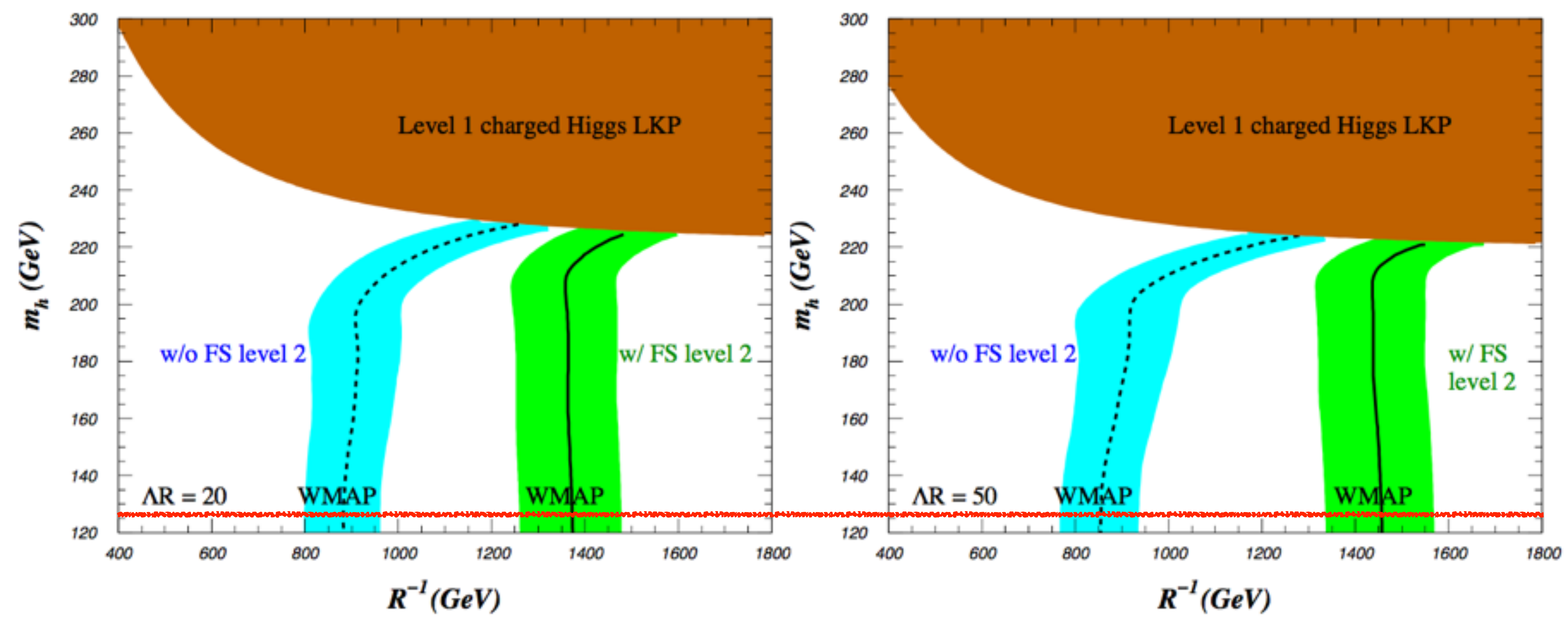
FIG. 1. Loop corrected KK mass spectrum in MUED for R^{-1}=960 GeV, ΛR=30 and m_h=125 GeV.

Class B: UEDs

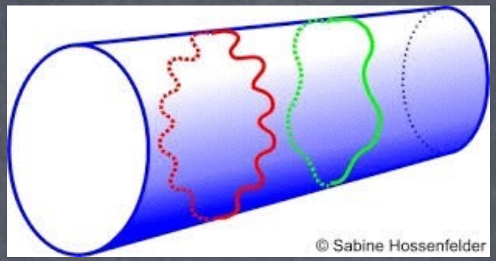


- Model of Dark Matter based on extra dimensions!

1012.2577



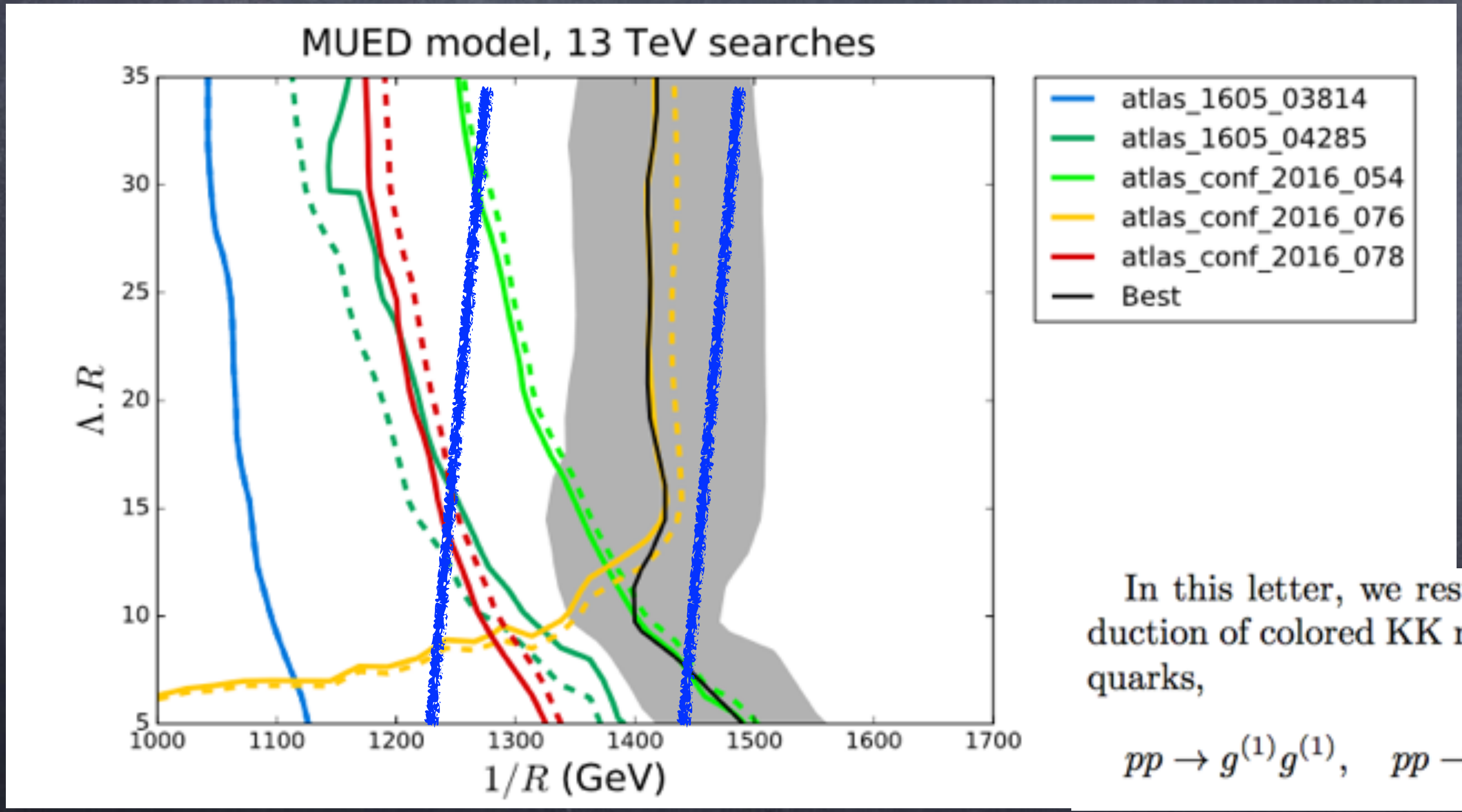
Class B: UEDs



- Model of Dark Matter based on extra dimensions!

1702.00410

On the verge of exclusion!

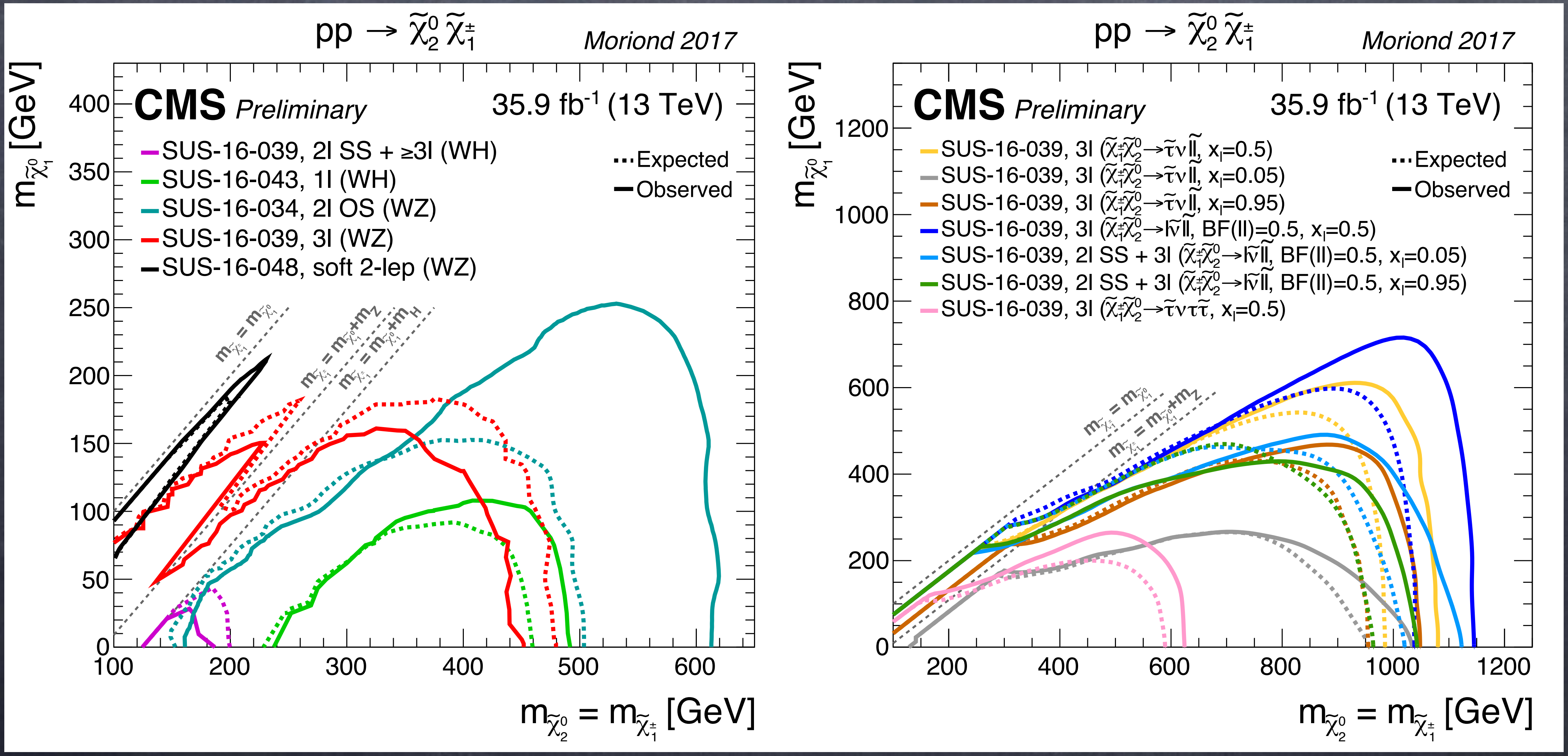


In this letter, we restrict ourselves to the strong production of colored KK modes such as KK gluons and KK quarks,

$$pp \to g^{(1)}g^{(1)}, \quad pp \to Q_i^{(1)}Q_j^{(1)}, \quad pp \to g^{(1)}Q_j^{(1)}, \quad (1)$$

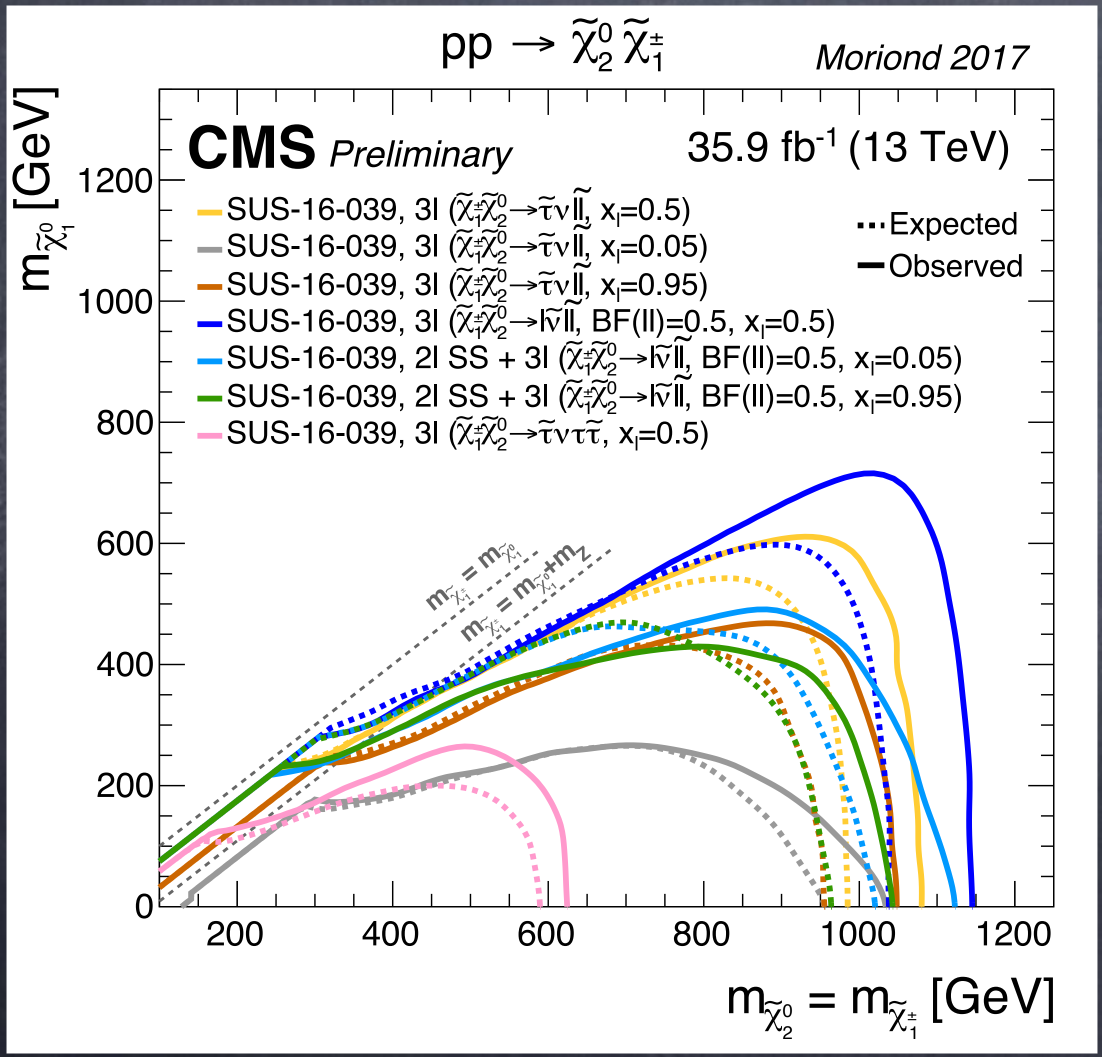
Class A: MSSM

- Moriond bounds on EW-inos



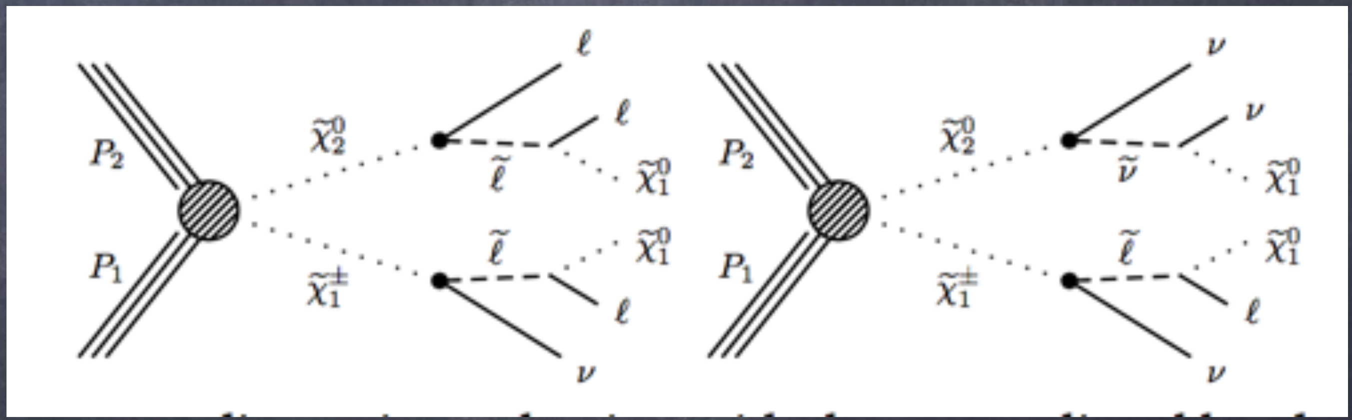
Class A: MSSM

- Moriond bounds on EW-inos



The bounds are impressive, however...

those are for Simplified Models!



- Production sensitive to the details of the model;
- Decays assumed @ 100%!

Beware of Simplified Models!

- Simplified models are designed for simplifying exp. analyses!
- Bound on S.M.s cannot be used to give general conclusions on models!

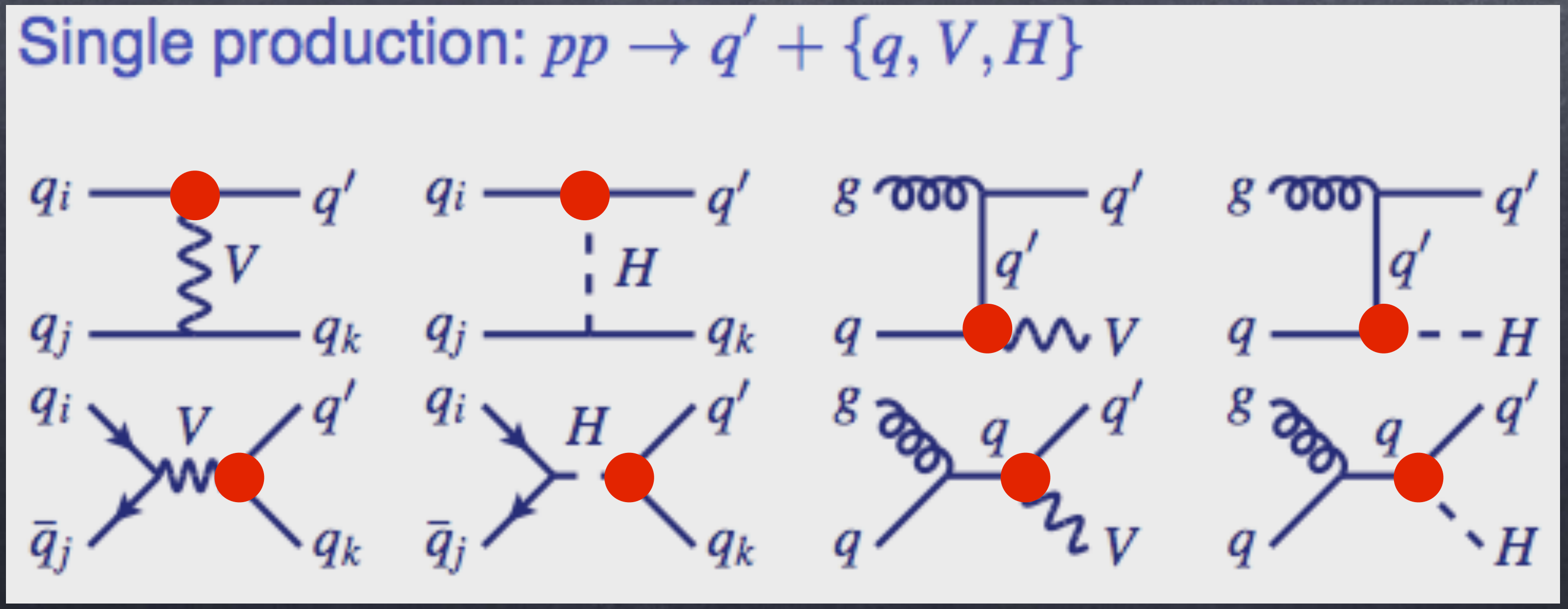
The case of VLQs, aka Top partners

- VLQs are non-chiral quarks that mix to the SM ones via Higgs couplings!

	u W	u Z	u H	d W	d Z	d H
T(2/3)		Y	Y	Y		
B(-1/3)	Y				Y	Y
X(5/3)	Y					
Y(-4/3)				Y		

The case of VLQs, aka Top partners

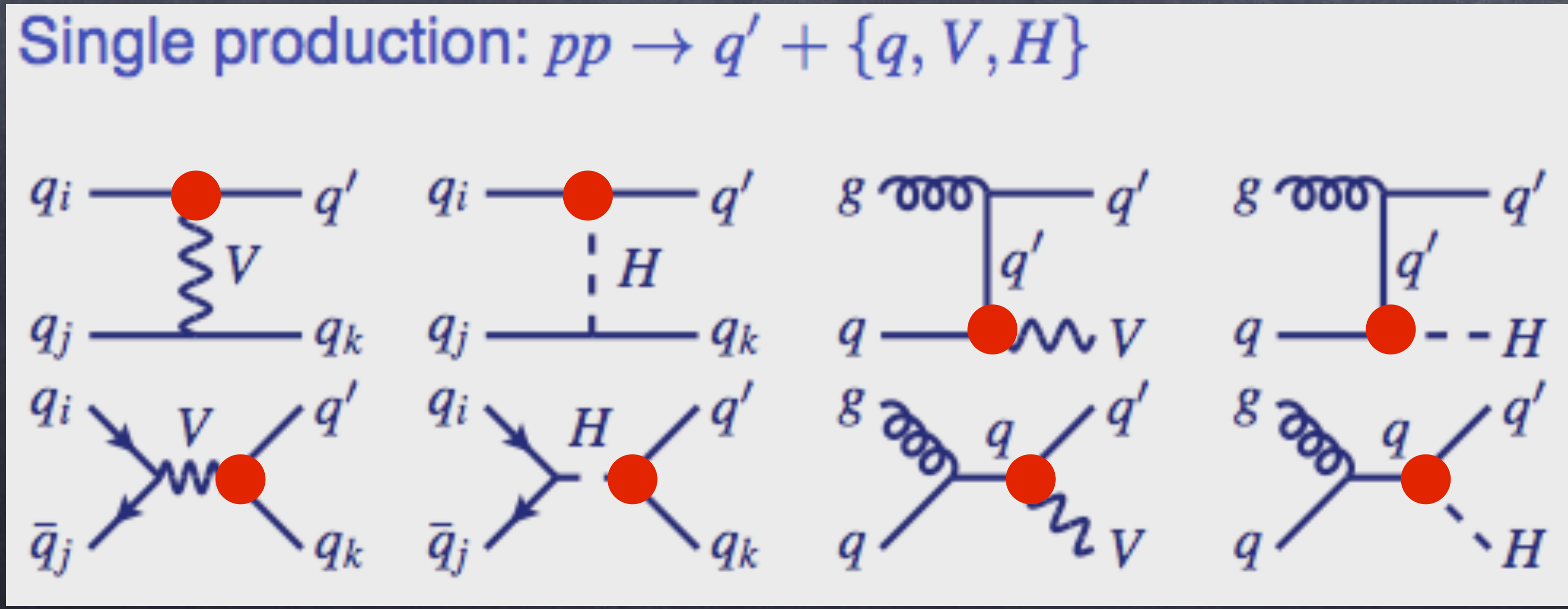
- BRs depend on the model.
- QCD pair-production is model-independent!
- Single production is not:



The case of VLQs, aka Top partners

$$-\hat{\kappa}_T \; H \; \bar{T}_R u_L + \frac{g}{2\cos\theta_W}\tilde{\kappa}_T \; Z_\mu \; \bar{T}_L \gamma^\mu u_L + \frac{g}{\sqrt{2}}\kappa_T \; W^+_\mu \; \bar{T}_L \gamma^\mu d_L$$

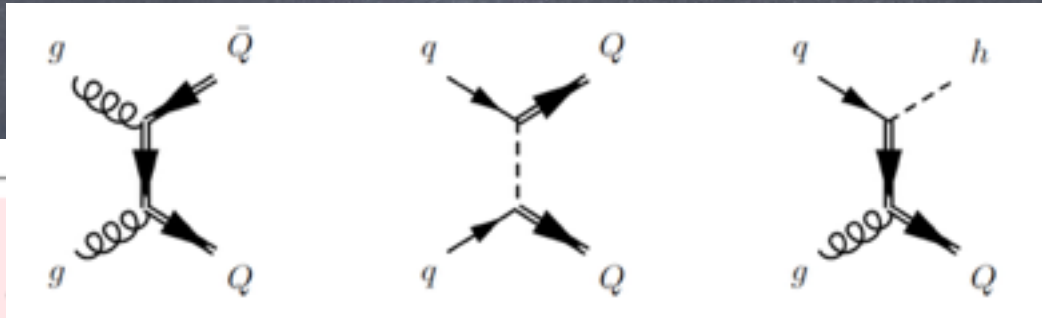
Couplings can be expressed in terms of the BRs, plus an overall coupling strength!
BRs and Single Productions are correlated!

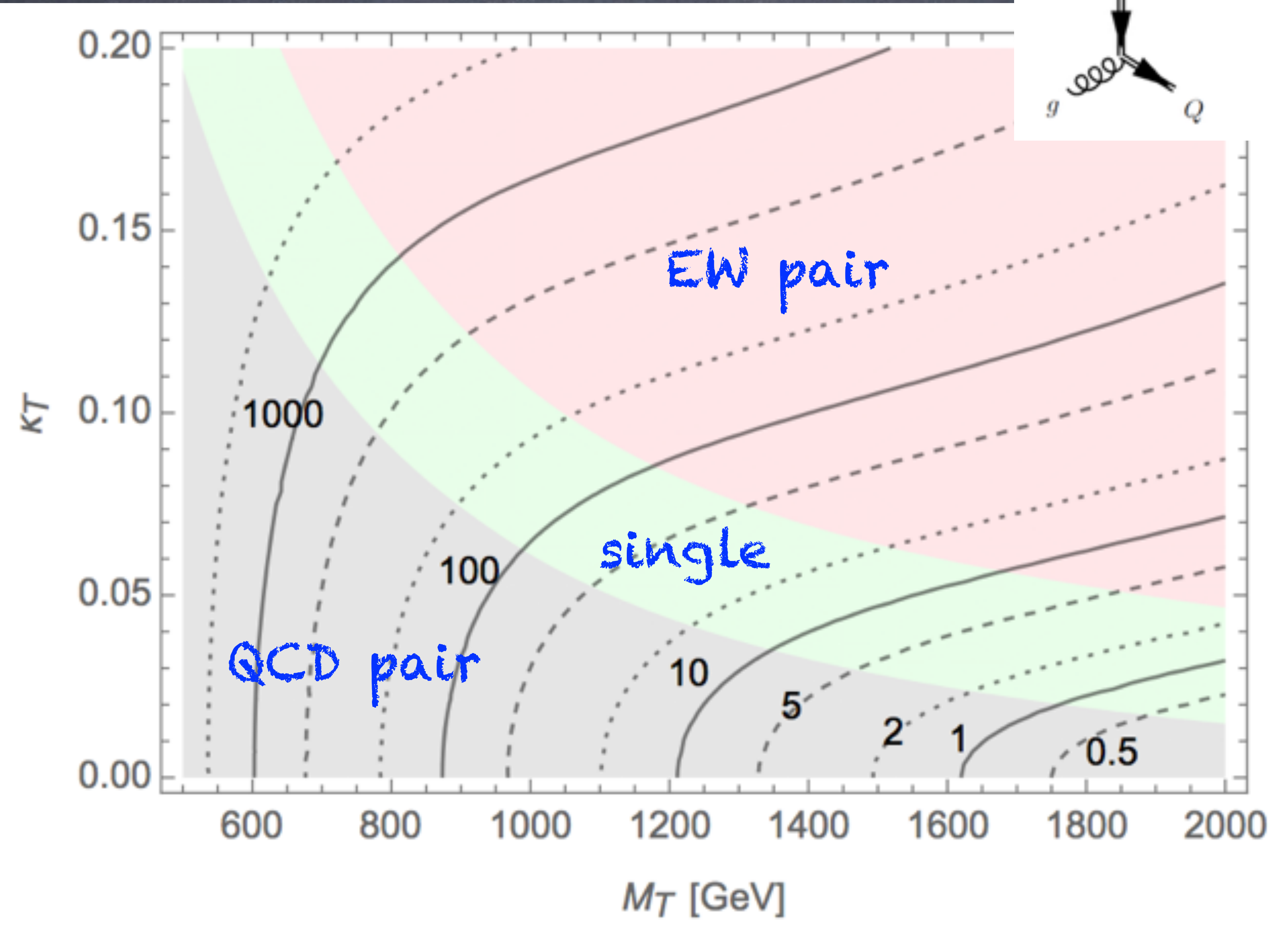


The case of VLQs, aka Top partners

- BRs depend on the model.
- QCD pair-production is model-independent!
- Single production is not:
- EW pair production may be important!

The case of VLQs, aka Top partners

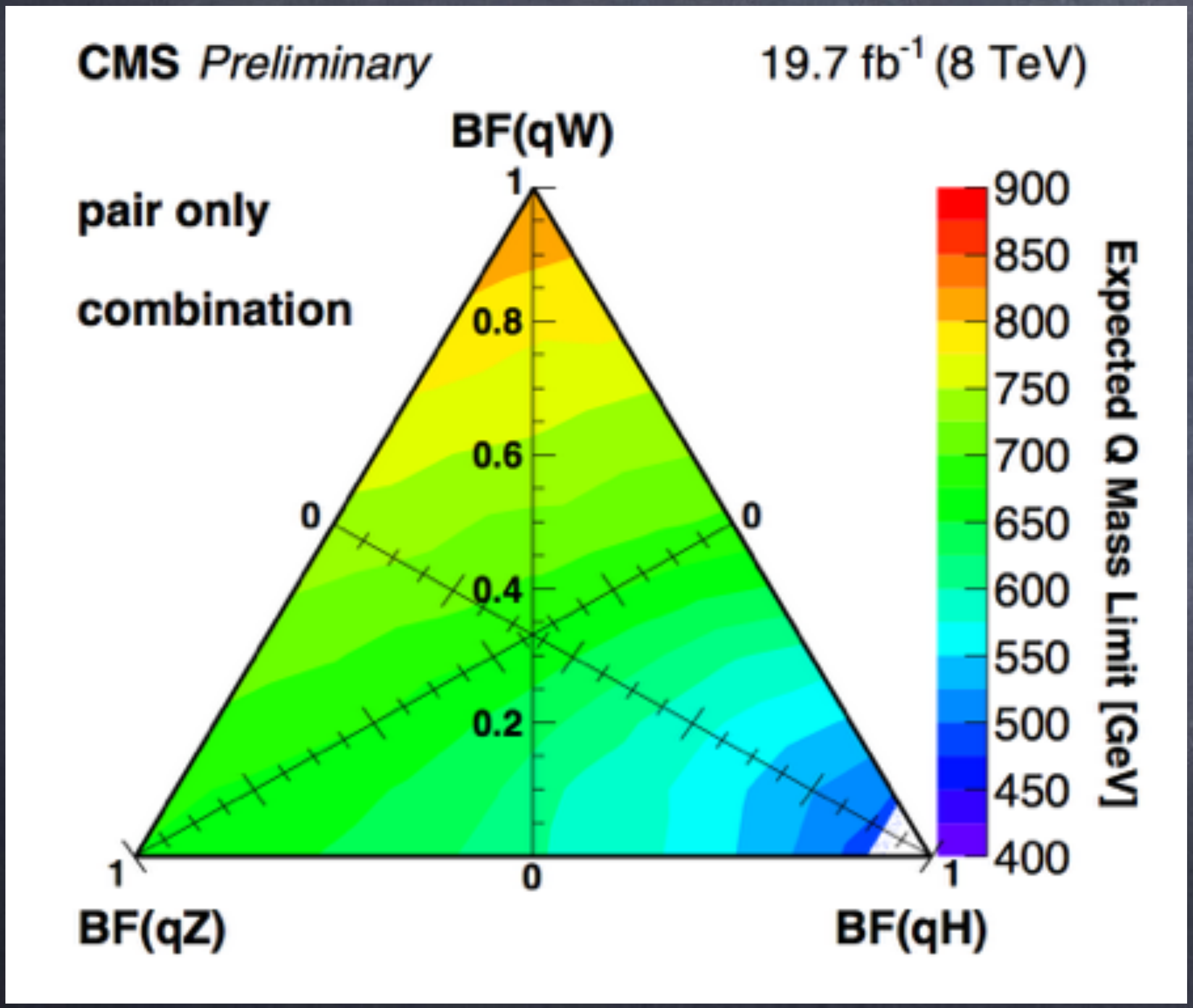


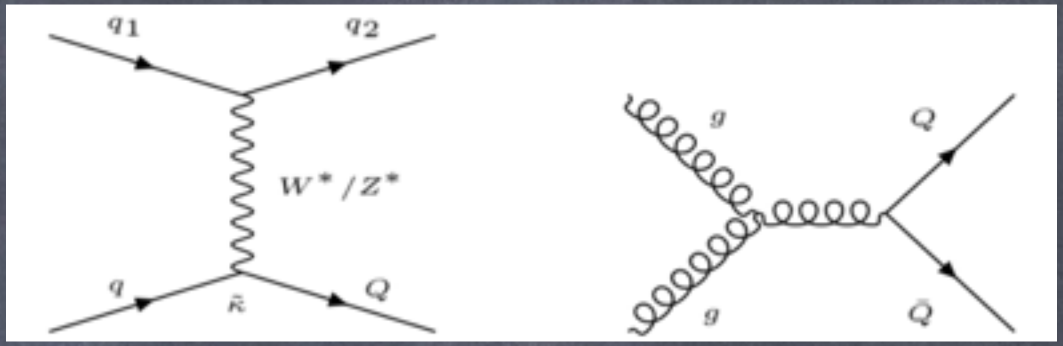


$$\kappa_T \frac{m_T}{v_{\rm SM}}\ \bar{Q}hq + h.c.$$

The case of VLQs, aka Top partners

CMS-PAS-B2G-12-016



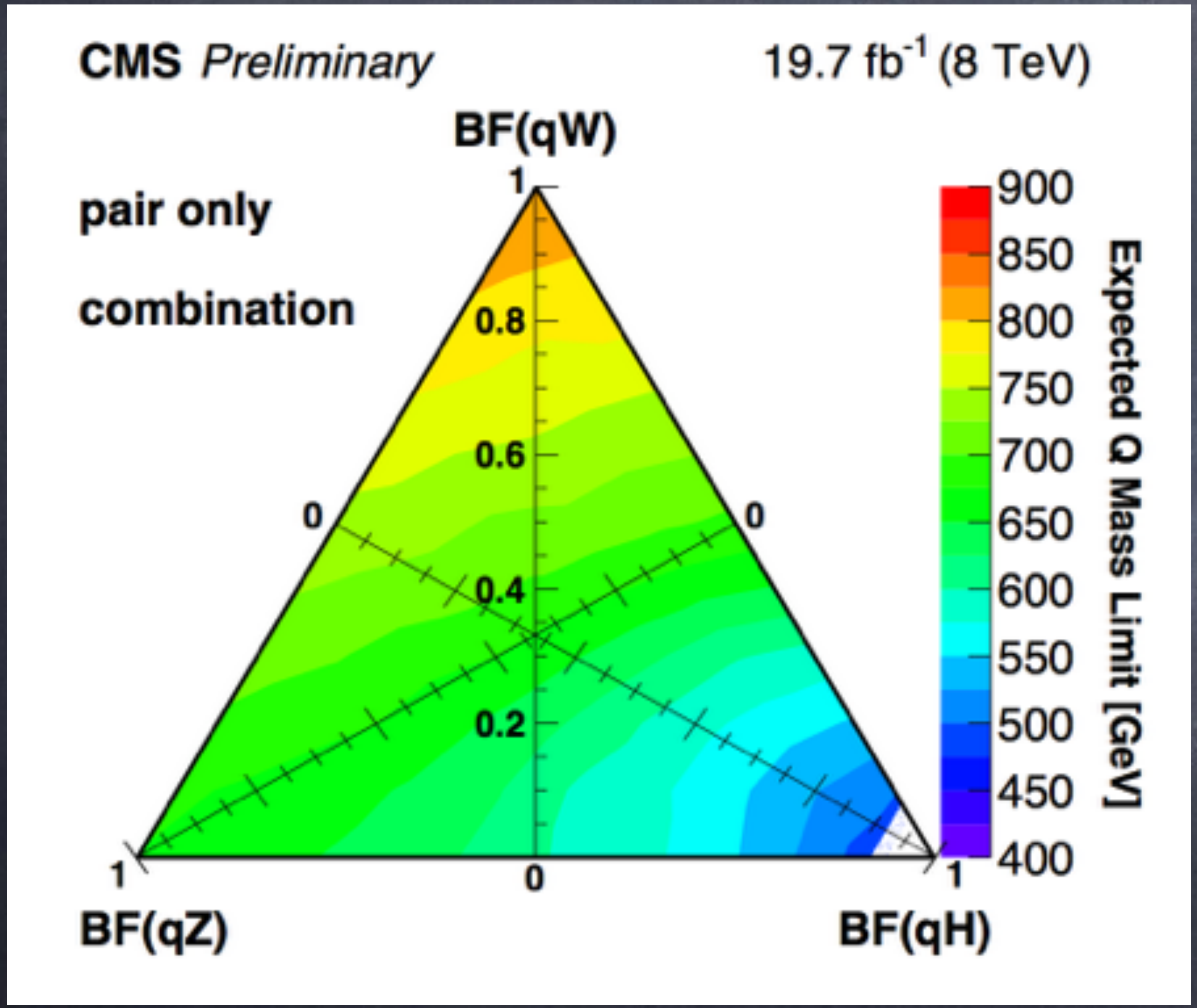


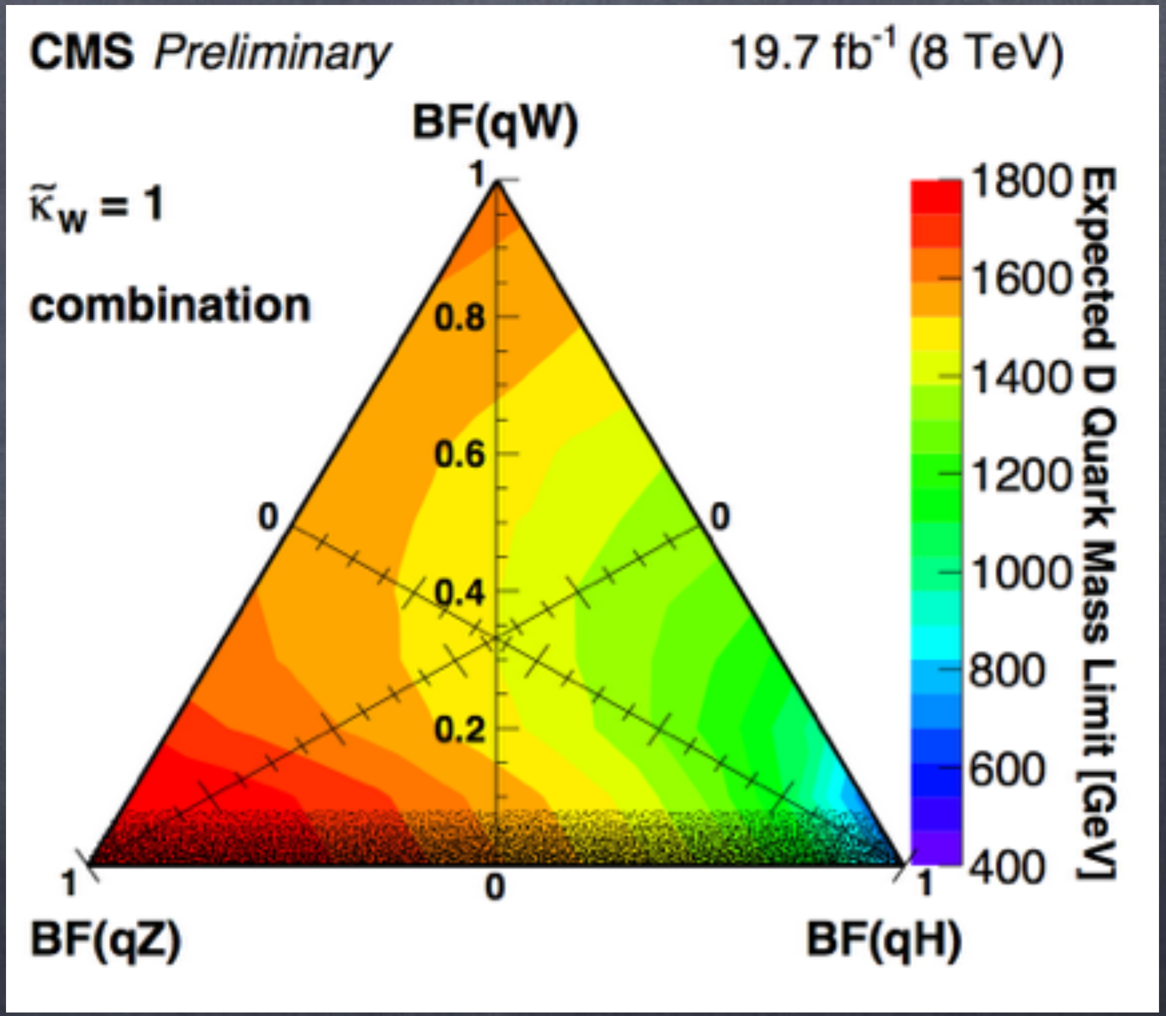
Full coverage of BR combinations.

Bounds are very sensitive to the BRs, ranging from less then 400 GeV to 800 GeV.

The case of VLQs, aka Top partners

CMS-PAS-B2G-12-016





pp -> Q jet added in.

The case of VLQs, aka Top partners

CMS-PAS-B2G-12-016

- Strategy allows fill coverage.
- Small improvements needed (fix overall coupling instead of kappa_W)
- QCD@NLO, other single channels, EW pair can be easily included.
- Are we really complete and fool-proof?

The case of VLQs, aka Top partners

- Exotic decay channels may be present:

E.g., non-minimal composite Higgs models.

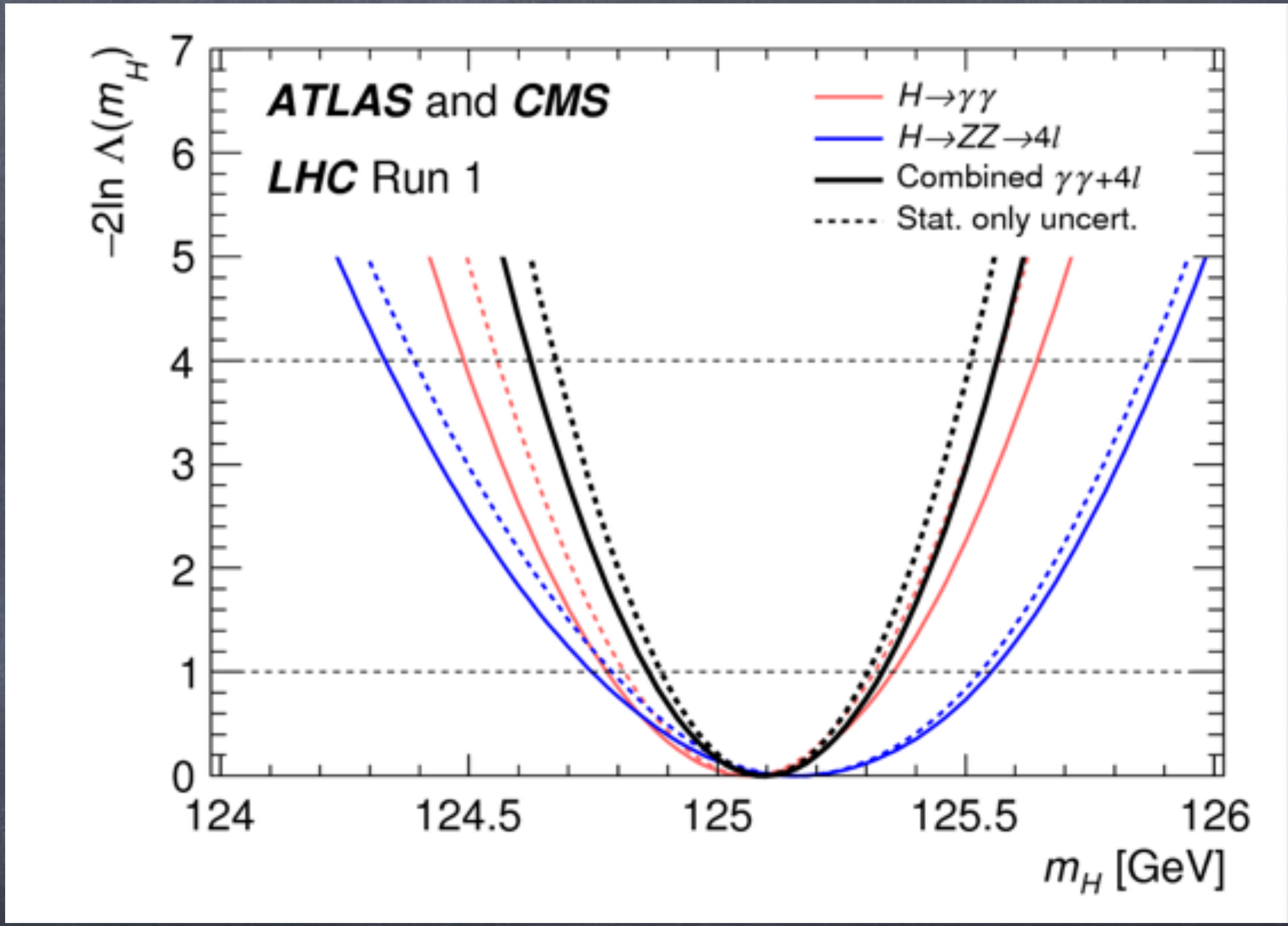
- Long-lived (i.e. MET)
- Decay to pair of gauge bosons (WZW anomaly)
- Decay into di-top

Theory: what have we learnt so far?

- There is a Higgs: what do we really know about it?
- Do we still need BSM physics?
- How can we rule out our favourite model(s)?

What do we know about H?

- The mass has been precisely measured!



$$125.09 \pm 0.21(\mathrm{stat}) \pm 0.11(\mathrm{syst})$$

What do we know about H?

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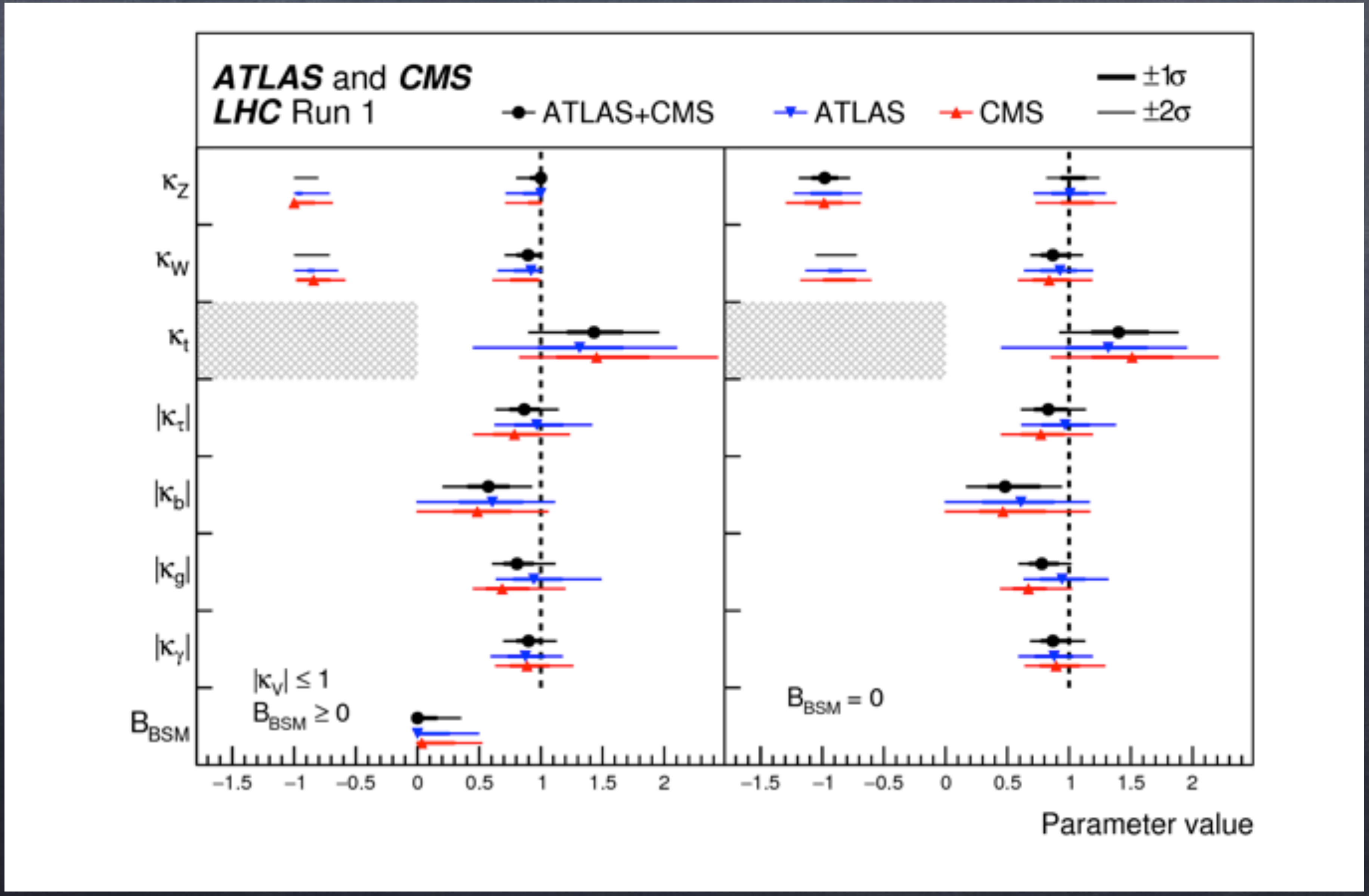
- The couplings follow the SM expectations:



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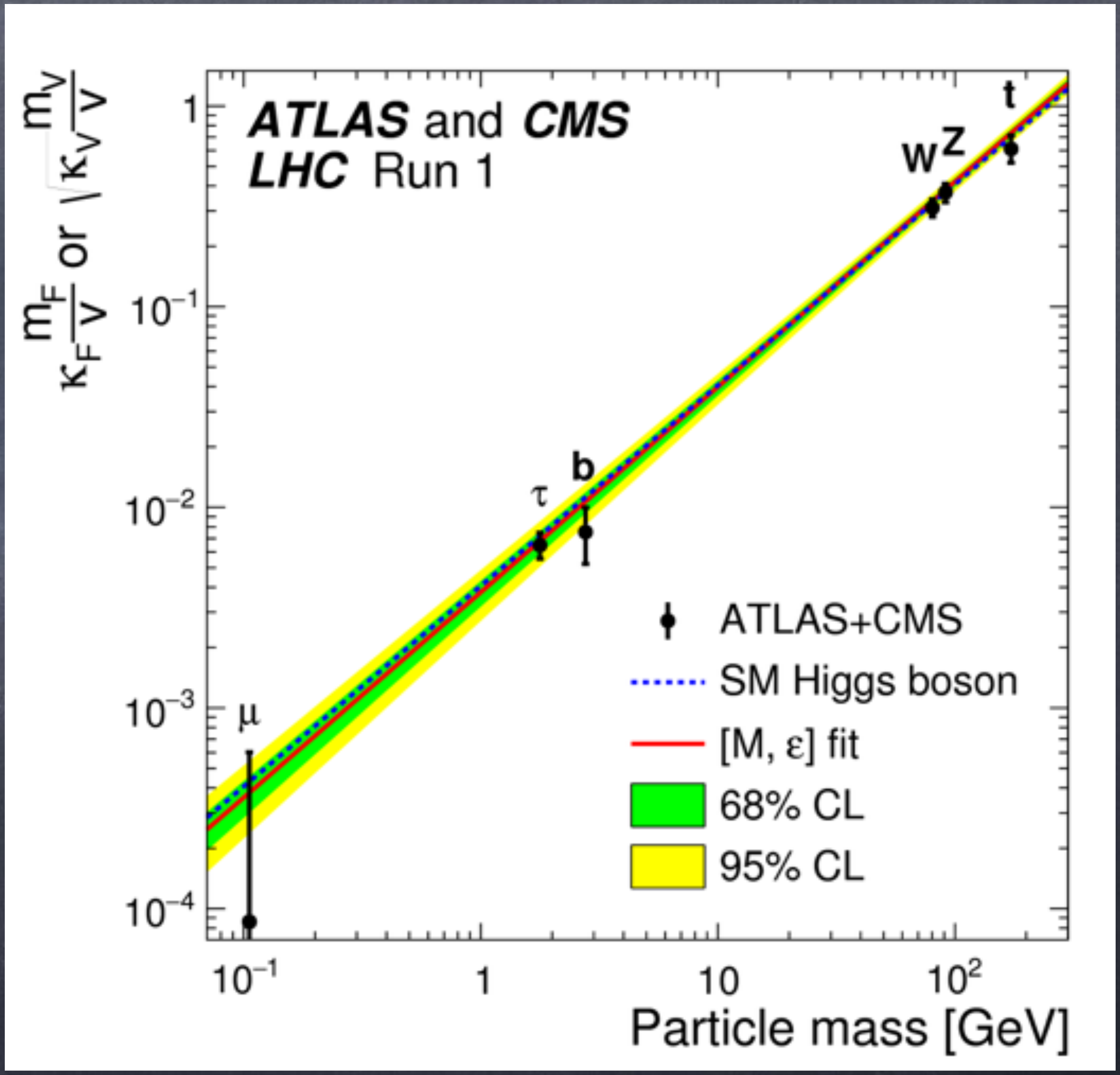


What do we know about H?

- The mass has been precisely measured!
- The couplings follow the SM expectations: being proportional to mass.
- The uncertainties are still large!
- Coupling measurements are always subject to model assumptions!!!

Run I

Decay channel	ATLAS+CMS	ATLAS	CMS
$\mu^{\gamma\gamma}$	$1.14\ ^{+0.19}_{-0.18}$ $\left(^{+0.18}_{-0.17}\right)$	$1.14\ ^{+0.27}_{-0.25}$ $\left(^{+0.26}_{-0.24}\right)$	$1.11\ ^{+0.25}_{-0.23}$ $\left(^{+0.23}_{-0.21}\right)$
μ^{ZZ}	$1.29\ ^{+0.26}_{-0.23}$ $\left(^{+0.23}_{-0.20}\right)$	$1.52\ ^{+0.40}_{-0.34}$ $\left(^{+0.32}_{-0.27}\right)$	$1.04\ ^{+0.32}_{-0.26}$ $\left(^{+0.30}_{-0.25}\right)$
μ^{WW}	$1.09\ ^{+0.18}_{-0.16}$ $\left(^{+0.16}_{-0.15}\right)$	$1.22\ ^{+0.23}_{-0.21}$ $\left(^{+0.21}_{-0.20}\right)$	$0.90\ ^{+0.23}_{-0.21}$ $\left(^{+0.23}_{-0.20}\right)$
$\mu^{\tau\tau}$	$1.11\ ^{+0.24}_{-0.22}$ $\left(^{+0.24}_{-0.22}\right)$	$1.41\ ^{+0.40}_{-0.36}$ $\left(^{+0.37}_{-0.33}\right)$	$0.88\ ^{+0.30}_{-0.28}$ $\left(^{+0.31}_{-0.29}\right)$
μ^{bb}	$0.70\ ^{+0.29}_{-0.27}$ $\left(^{+0.29}_{-0.28}\right)$	$0.62\ ^{+0.37}_{-0.37}$ $\left(^{+0.39}_{-0.37}\right)$	$0.81\ ^{+0.45}_{-0.43}$ $\left(^{+0.45}_{-0.43}\right)$
$\mu^{\mu\mu}$	$0.1\ ^{+2.5}_{-2.5}$ $\left(^{+2.4}_{-2.3}\right)$	$-0.6\ ^{+3.6}_{-3.6}$ $\left(^{+3.6}_{-3.6}\right)$	$0.9\ ^{+3.6}_{-3.5}$ $\left(^{+3.3}_{-3.2}\right)$

What do we know about H?

- Theoretical Modelling, i.e. the Standard Model Higgs

$$\mathcal{L}_{\text{Higgs}} = (D_\mu \phi)^\dagger (D^\mu \phi) + \mu^2 \phi^\dagger \phi - \lambda \, (\phi^\dagger \phi)^2$$

"wrong sign"

It well describes
the symmetry breaking,
but no dynamical
insight!

$$\tau^i = \frac{\sigma^i}{2}$$

Pauli matrices

$$\phi = e^{i\pi^i \tau^i} \cdot \begin{pmatrix} 0 \\ v + \frac{h}{\sqrt{2}} \end{pmatrix}$$

$$v = \frac{\mu}{\sqrt{2\lambda}} \sim 246 \ \text{GeV}$$

What do we know about H?

$$\mathcal{L}_{\text{Higgs}} = (D_\mu\phi)^\dagger (D^\mu\phi) + \mu^2\ \phi^\dagger\phi - \lambda\ (\phi^\dagger\phi)^2$$

- Custodial symmetry as a lucky accident:

$$\phi = \begin{pmatrix} \varphi_u \\ \varphi_d \end{pmatrix} \qquad \tilde{\phi} = (i\sigma^2)\cdot\phi^* = \begin{pmatrix} \varphi_d^* \\ -\varphi_u^* \end{pmatrix}$$

Both transform as doublets of SU(2) [pseudo-real irrep]

- We can rewrite the Lagrangian as:

$$\Phi = \begin{pmatrix} \tilde{\phi}\ \phi \end{pmatrix} = \begin{pmatrix} \varphi_d^* & \varphi_u \\ -\varphi_u^* & \varphi_d \end{pmatrix} \qquad \mathcal{L}_{\text{Higgs}} = \frac{1}{2}\text{Tr}\left[(D_\mu\Phi)^\dagger(D^\mu\Phi)\right] + \frac{\mu^2}{2}\text{Tr}\left[\Phi^\dagger\Phi\right] + \ldots$$

$$\Phi \to U_L\cdot\Phi\cdot U_R^\dagger$$

uncovers a "hidden" invariance under a global SU(2)L x SU(2)R broken to SU(2)D by the VEV

What do we know about H?

- Non-linear description:

$$\Sigma = e^{i\pi^i\tau^i}\cdot\begin{pmatrix}0\\ v\end{pmatrix} \qquad \mathcal{L}_{NL} = f(h)\,(D_\mu\Sigma)^\dagger(D^\mu\Sigma) - V(h)$$

- Goldstones transform as a triplet of SU(2)D.
- The coupling of h to gauge bosons ARE proportional to the mass (but not determined).
- However: trilinear h coupling is not determined!

Do we still need BSM?

We have a pretty good idea of the mechanism

But, we dont know how to protect it:

$$\delta m_h^2 \sim \frac{g^2}{16\pi^2} M_{\rm NPh}^2$$

Do we still need BSM?

Fact:

we have been working on the same ideas for the last 30-40 years!

Supersymmetry

(Strong) dynamics

Do we still need BSM?

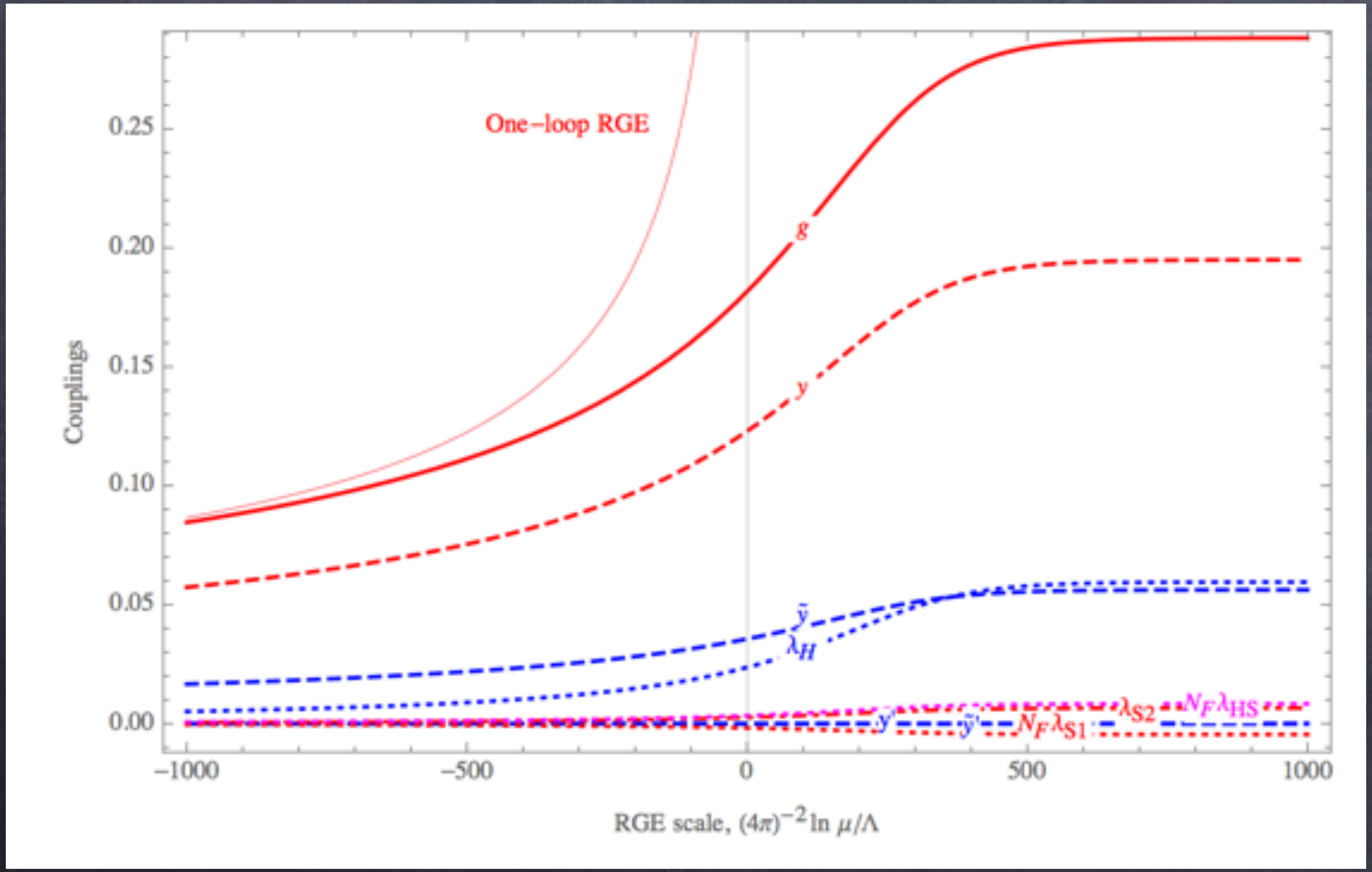
No judgement: I'm playing devil's advocate!

Recent New Ideas:

- Scale invariance: only true at classical level.
- Relaxion: classical field evolution imposed (tautologic fault!)
- Warped extra dimensions: exponentiation of large scale hierarchies.
- Asymptotic Safe theories: still under study (see 1701.01453) - no realistic example!

Do we still need BSM?

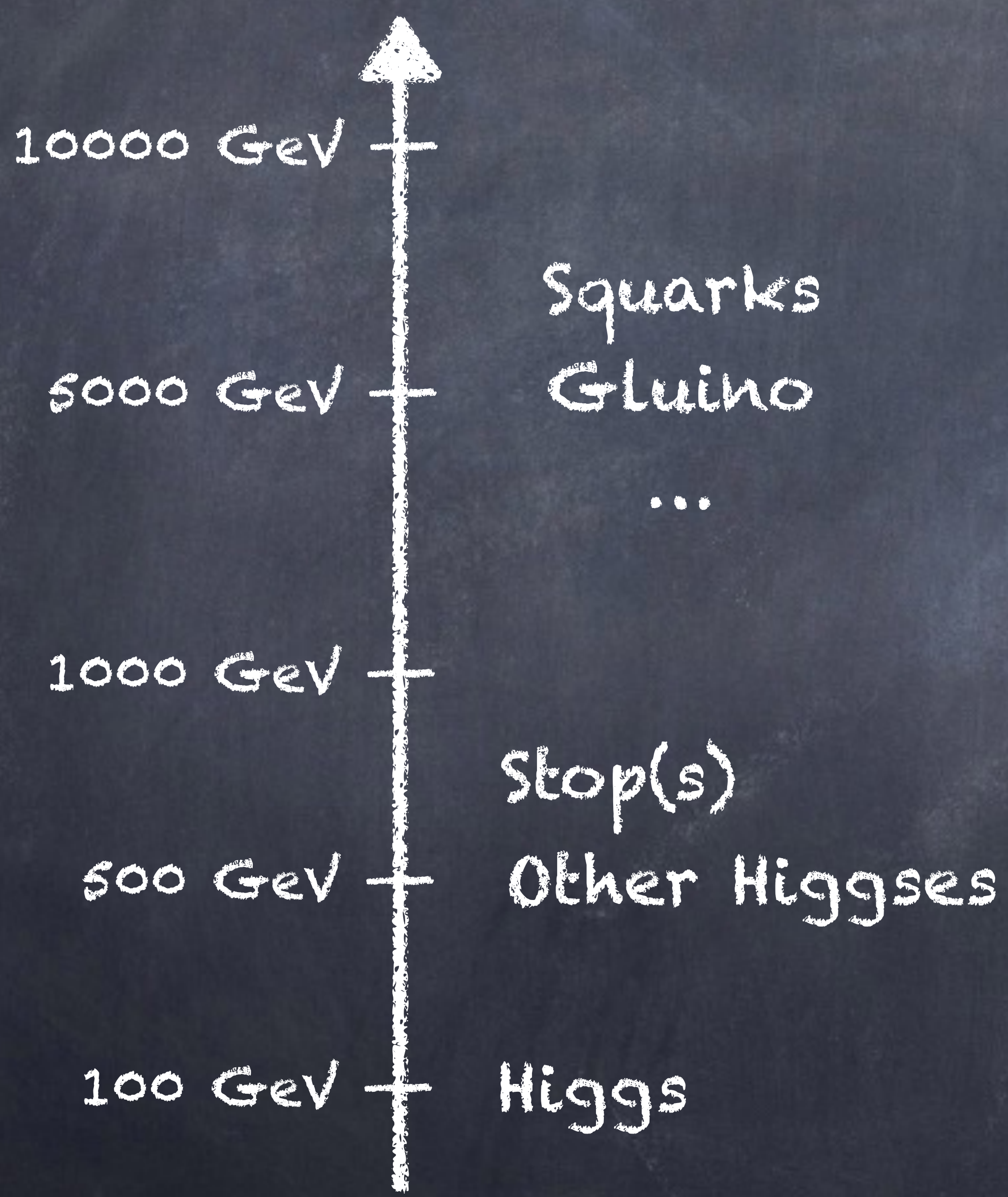
- Asymptotic Safe theories: still under study (see 1701.01453)



Interacting UV fixed point!

Claim that scalar masses can be natural, i.e. quantum corrections proportional to the mass itself!

How can we rule out our favourite model(s)?



"Natural" SUSY spectrum

- Higgs decoupling limit: SM-like light Higgs
- Light-ish stops
- Other sparticles above TeV scale

How can we rule out our favourite model(s)?

10000 GeV — Resonances: Z', ...

5000 GeV

Top partners

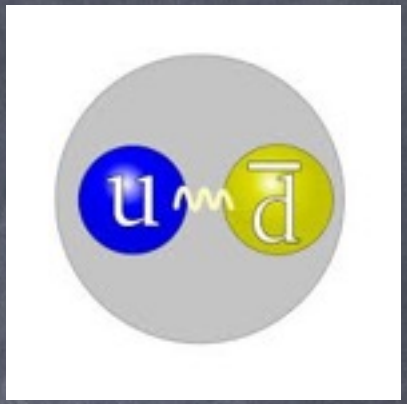
1000 GeV

f - comp. scale

500 GeV — Extra scalars?

100 GeV — Higgs

Compositeness



- Higgs close to SM-like

$$\frac{g_{hVV}}{g_{hVV}^{SM}} \sim \cos\theta \sim 1 - \frac{1}{2}\sin^2\theta$$

$$\sin\theta \sim \frac{v}{f} < 0.2$$

(EW precision)

The hot potato: flavour!

1501.03818, ...

100,000 TeV	Λ_{flavour}	Light flavours	
		near-conformal dynamics	
10 TeV	$\Lambda \sim 4\pi f$	Vectors	+ top mixing
1 TeV	f	Condensation scale (extra pions)	+ top partners
100 GeV	$v_{\text{SM}} \sim f \sin\theta$	EWSB	

The hot potato: flavour!

1501.03818, ...

100,000 TeV	$\Lambda_{\text{fl...ur}}$	...ght flavou...	
1... TeV			+ top m...ing
1 TeV	f	...ond... ...on scale (extra ...ions)	+ top partners
100 GeV	$v_{\text{SM}} \sim f \sin\theta$	EWSB	

New Physics
most likely to show-up
in flavour?

A fermionic theory of top partners

$\mathcal{G}_{\rm TC}$: rep R rep R′ 1312.5330, 1604.06467

Q χ $T' = QQ\chi$ or $Q\chi\chi$

SM : EW colour + hypercharge

global : $\langle QQ \rangle \neq 0$ a) $\langle \chi\chi \rangle \neq 0$

$\downarrow$

coloured pNGBs
di-boson

pNGB Higgs
DM?

b) $\langle \chi\chi \rangle = 0$

light top partners
from t Hooft anomaly
conditions?

Global symmetries

More precisely, the global symmetries are:

$$SU(N_Q) \times SU(N_\chi) \times U(1)_Q \times U(1)_\chi$$

WZW term:

$$\mathcal{L} \supset \frac{g_i^2}{32\pi^2} \frac{\kappa_i}{f_a} \, a \, \epsilon^{\mu\nu\alpha\beta} G^i_{\mu\nu} G^i_{\alpha\beta} \,,$$

Coefficients depend
on the underlying dynamics!

G = A, W, Z, g !!!

1512.04508

Anomalous U(1) -> heavy η'

Orthogonal U(1) -> pNGB a

Decays and production
only via WZW anomaly.

Model zoology

1604.06467

$G_{\rm HC}$	ψ	χ	Restrictions	$-q_\chi/q_\psi$	Y_χ	Non Conformal	Model Name
	Real	Real	SU(5)/SO(5) $\times$ SU(6)/SO(6)				
$SO(N_{\rm HC})$	$5 \times \mathbf{S}_2$	$6 \times \mathbf{F}$	$N_{\rm HC} \geq 55$	$\frac{5(N_{\rm HC}+2)}{6}$	1/3	/	
$SO(N_{\rm HC})$	$5 \times \mathbf{Ad}$	$6 \times \mathbf{F}$	$N_{\rm HC} \geq 15$	$\frac{5(N_{\rm HC}-2)}{6}$	1/3	/	
$SO(N_{\rm HC})$	$5 \times \mathbf{F}$	$6 \times \mathbf{Spin}$	$N_{\rm HC} = 7, 9$	$\frac{5}{6}, \frac{5}{12}$	1/3	$N_{\rm HC} = 7, 9$	M1, M2
$SO(N_{\rm HC})$	$5 \times \mathbf{Spin}$	$6 \times \mathbf{F}$	$N_{\rm HC} = 7, 9$	$\frac{5}{6}, \frac{5}{3}$	2/3	$N_{\rm HC} = 7, 9$	M3, M4
	Real	Pseudo-Real	SU(5)/SO(5) $\times$ SU(6)/Sp(6)				
$Sp(2N_{\rm HC})$	$5 \times \mathbf{Ad}$	$6 \times \mathbf{F}$	$2N_{\rm HC} \geq 12$	$\frac{5(N_{\rm HC}+1)}{3}$	1/3	/	
$Sp(2N_{\rm HC})$	$5 \times \mathbf{A}_2$	$6 \times \mathbf{F}$	$2N_{\rm HC} \geq 4$	$\frac{5(N_{\rm HC}-1)}{3}$	1/3	$2N_{\rm HC} = 4$	M5
$SO(N_{\rm HC})$	$5 \times \mathbf{F}$	$6 \times \mathbf{Spin}$	$N_{\rm HC} = 11, 13$	$\frac{5}{24}, \frac{5}{48}$	1/3	/	
	Real	Complex	SU(5)/SO(5) $\times$ SU(3)^2/SU(3)				
$SU(N_{\rm HC})$	$5 \times \mathbf{A}_2$	$3 \times (\mathbf{F}, \overline{\mathbf{F}})$	$N_{\rm HC} = 4$	$\frac{5}{3}$	1/3	$N_{\rm HC} = 4$	M6
$SO(N_{\rm HC})$	$5 \times \mathbf{F}$	$3 \times (\mathbf{Spin}, \overline{\mathbf{Spin}})$	$N_{\rm HC} = 10, 14$	$\frac{5}{12}, \frac{5}{48}$	1/3	$N_{\rm HC} = 10$	M7
	Pseudo-Real	Real	SU(4)/Sp(4) $\times$ SU(6)/SO(6)				
$Sp(2N_{\rm HC})$	$4 \times \mathbf{F}$	$6 \times \mathbf{A}_2$	$2N_{\rm HC} \leq 36$	$\frac{1}{3(N_{\rm HC}-1)}$	2/3	$2N_{\rm HC} = 4$	M8
$SO(N_{\rm HC})$	$4 \times \mathbf{Spin}$	$6 \times \mathbf{F}$	$N_{\rm HC} = 11, 13$	$\frac{8}{3}, \frac{16}{3}$	2/3	$N_{\rm HC} = 11$	M9
	Complex	Real	SU(4)^2/SU(4) $\times$ SU(6)/SO(6)				
$SO(N_{\rm HC})$	$4 \times (\mathbf{Spin}, \overline{\mathbf{Spin}})$	$6 \times \mathbf{F}$	$N_{\rm HC} = 10$	$\frac{8}{3}$	2/3	$N_{\rm HC} = 10$	M10
$SU(N_{\rm HC})$	$4 \times (\mathbf{F}, \overline{\mathbf{F}})$	$6 \times \mathbf{A}_2$	$N_{\rm HC} = 4$	$\frac{2}{3}$	2/3	$N_{\rm HC} = 4$	M11
	Complex	Complex	SU(4)^2/SU(4) $\times$ SU(3)^2/SU(3)				
$SU(N_{\rm HC})$	$4 \times (\mathbf{F}, \overline{\mathbf{F}})$	$3 \times (\mathbf{A}_2, \overline{\mathbf{A}}_2)$	$N_{\rm HC} \geq 5$	$\frac{4}{3(N_{\rm HC}-2)}$	2/3	$N_{\rm HC} = 5$	M12
$SU(N_{\rm HC})$	$4 \times (\mathbf{F}, \overline{\mathbf{F}})$	$3 \times (\mathbf{S}_2, \overline{\mathbf{S}}_2)$	$N_{\rm HC} \geq 5$	$\frac{4}{3(N_{\rm HC}+2)}$	2/3	/	
$SU(N_{\rm HC})$	$4 \times (\mathbf{A}_2, \overline{\mathbf{A}}_2)$	$3 \times (\mathbf{F}, \overline{\mathbf{F}})$	$N_{\rm HC} = 5$	4	2/3	/	

Model zoology

G_{HC}	ψ	χ	Restrictions	$-q_\chi/q_\psi$	Y_χ	Non Conformal	Model Name
	Pseudo-Real	Real	$SU(4)/Sp(4) \times SU(6)/SO(6)$				
$Sp(2N_{\text{HC}})$	$4 \times \mathbf{F}$	$6 \times \mathbf{A}_2$	$2N_{\text{HC}} \leq 36$	$\frac{1}{3(N_{\text{HC}}-1)}$	$2/3$	$2N_{\text{HC}} = 4$	M8
$SO(N_{\text{HC}})$	$4 \times \mathbf{Spin}$	$6 \times \mathbf{F}$	$N_{\text{HC}} = 11, 13$	$\frac{8}{3}, \frac{16}{3}$	$2/3$	$N_{\text{HC}} = 11$	M9

Defines $\tan\zeta$

Theory confines!

$T' = \psi\psi\chi$

Note: there is enough baryons to give mass to the top (and bottom) only!

Example of predictions: di-boson resonances

1610.06591

	Pseudo-Real	Real	SU(4)/Sp(4) × SU(6)/SO(6)				
$Sp(2N_{\rm HC})$	$4 \times \mathbf{F}$	$6 \times \mathbf{A}_2$	$2N_{\rm HC} \leq 36$	$\frac{1}{3(N_{\rm HC}-1)}$	$2/3$	$2N_{\rm HC} = 4$	M8
$SO(N_{\rm HC})$	$4 \times \mathbf{Spin}$	$6 \times \mathbf{F}$	$N_{\rm HC} = 11, 13$	$\frac{8}{3}, \frac{16}{3}$	$2/3$	$N_{\rm HC} = 11$	M9

The EFT is the same!

Numerical value of couplings:

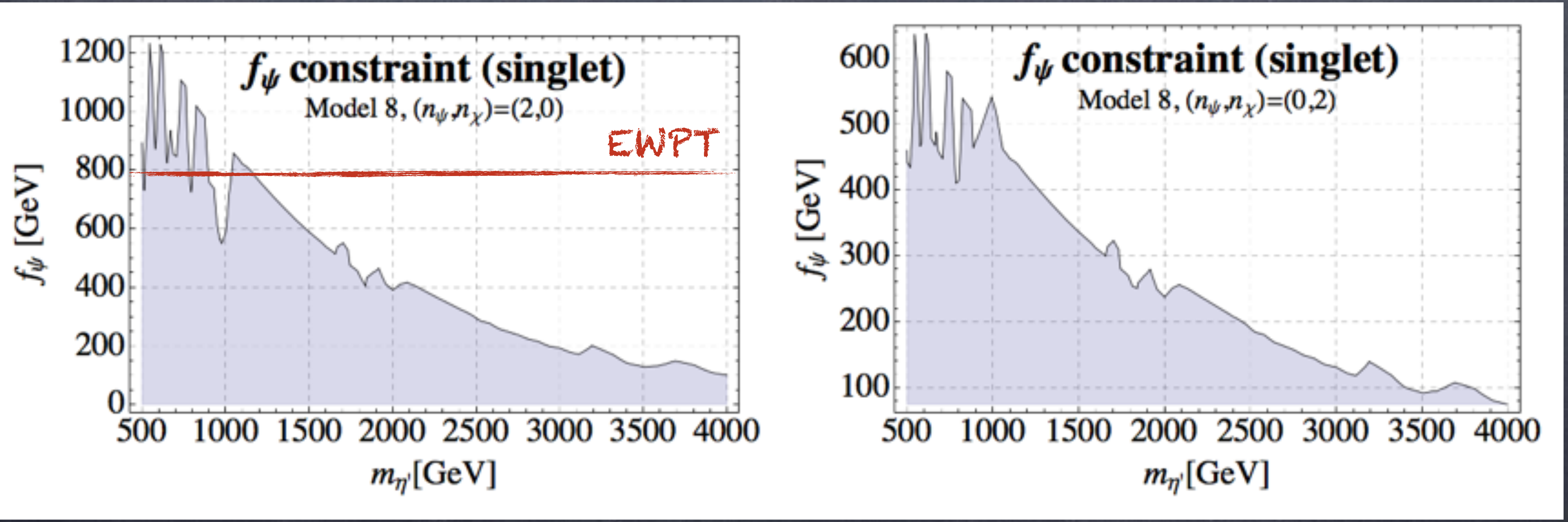
Model		κ_g	$\frac{\kappa_W}{\kappa_g}$	$\frac{\kappa_B}{\kappa_g}$	$\frac{C_t}{\kappa_g}$ (2,0)	$\frac{C_t}{\kappa_g}$ (0,2)	$\tan\zeta$
M8	a	$-0.77(-0.39)$	$-1.2(-2.5)$	$1.5(0.17)$	$-1.2(-2.5)$	$0.40(0.40)$	
	η'	$1.9(2.0)$	$0.20(0.096)$	$2.9(2.8)$	$0.20(0.0.96)$	$0.40(0.40)$	-0.41
	π_8	7.1	0	1.3	0	0.40	
M9	a	$-4.3(-2.7)$	$-0.55(-2.4)$	$2.1(0.26)$	$-0.068(-0.30)$	$0.18(0.18)$	
	η'	$1.3(3.6)$	$5.8(1.3)$	$8.5(4.0)$	$0.73(0.16)$	$0.18(0.18)$	-3.26
	π_8	$16.$	0	1.3	0	0.18	

Assuming $f_a = f_\psi = f_\chi$

Model M8

1610.06591

"a" too light for the LHC! $\left.\frac{m_a}{m_{\eta'}}\right|_{\max} = 0.20$



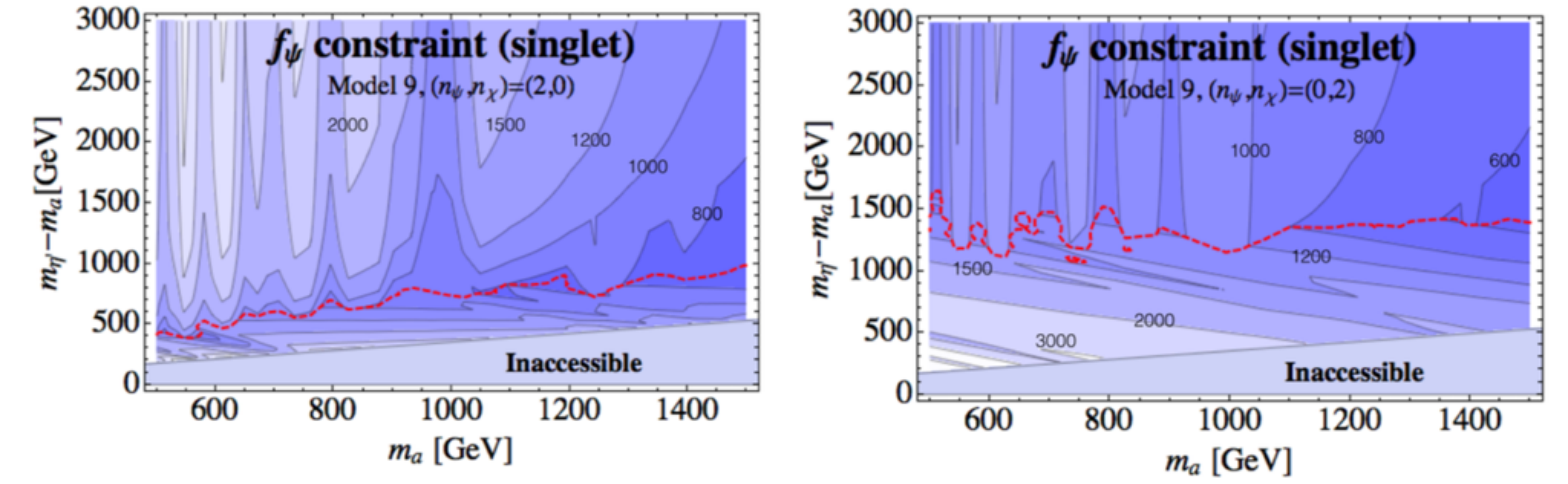
For light masses: bounds competitive with EW precision!

Larger top couplings: reduced diboson rates due to tt BR.

Model M9

$$\left.\frac{m_a}{m_{\eta'}}\right|_{\max} = 0.74$$

1610.06591



Above red line, bound driven by "a"!

Bounds stronger than EW precision in most of the parameter space!

Let's bet: which model will be ruled out first?

Supersymmetry?

Composite (pNGB) Higgs?

(please, add your model)

Bonus

The hot potato: flavour!

100,000 TeV	Λ_{flavour}	Scale of fermion mass generation
		How can this hierarchy be generated?
10 TeV	$\Lambda \sim 4\pi f$	Vector resonances, ...
1 TeV	f	Condensation scale (extra pions)
100 GeV	$v_{\text{SM}} \sim f \sin\theta$	EWSB

Higgs

$$\mathcal{L}_{\text{fermions}} = \frac{1}{\Lambda_{\text{fl.}}^2}(\psi\psi)(q_L^c q_R)$$

$$+\frac{1}{\Lambda_{\text{fl.}}^2}(q_L^c q_R)(q_L^c q_R) + \frac{1}{\Lambda_{\text{fl.}}^2}(\psi\psi)^2$$

FCNCs

Higgs mass

$$m_{\text{top}} \sim \frac{(4\pi f)^3}{\Lambda_{\text{fl.}}^2}\sin\theta$$

Too small!

The hot potato: flavour!

100,000 TeV	Λ_{flavour}	Scale of fermion mass generation
		Intermediate conformal region
10 TeV	$\Lambda \sim 4\pi f$	Vector resonances, ...
1 TeV	f	Condensation scale (extra pions)
100 GeV	$v_{\text{SM}} \sim f \sin\theta$	EWSB

$$(\psi\psi) \to \mathcal{O}_H$$

$$\dim[\mathcal{O}_H] = d_H$$

effective Yukawa:

$$\frac{1}{\Lambda_{\text{fl.}}^{d-1}} \mathcal{O}_H q_L^c q_R$$

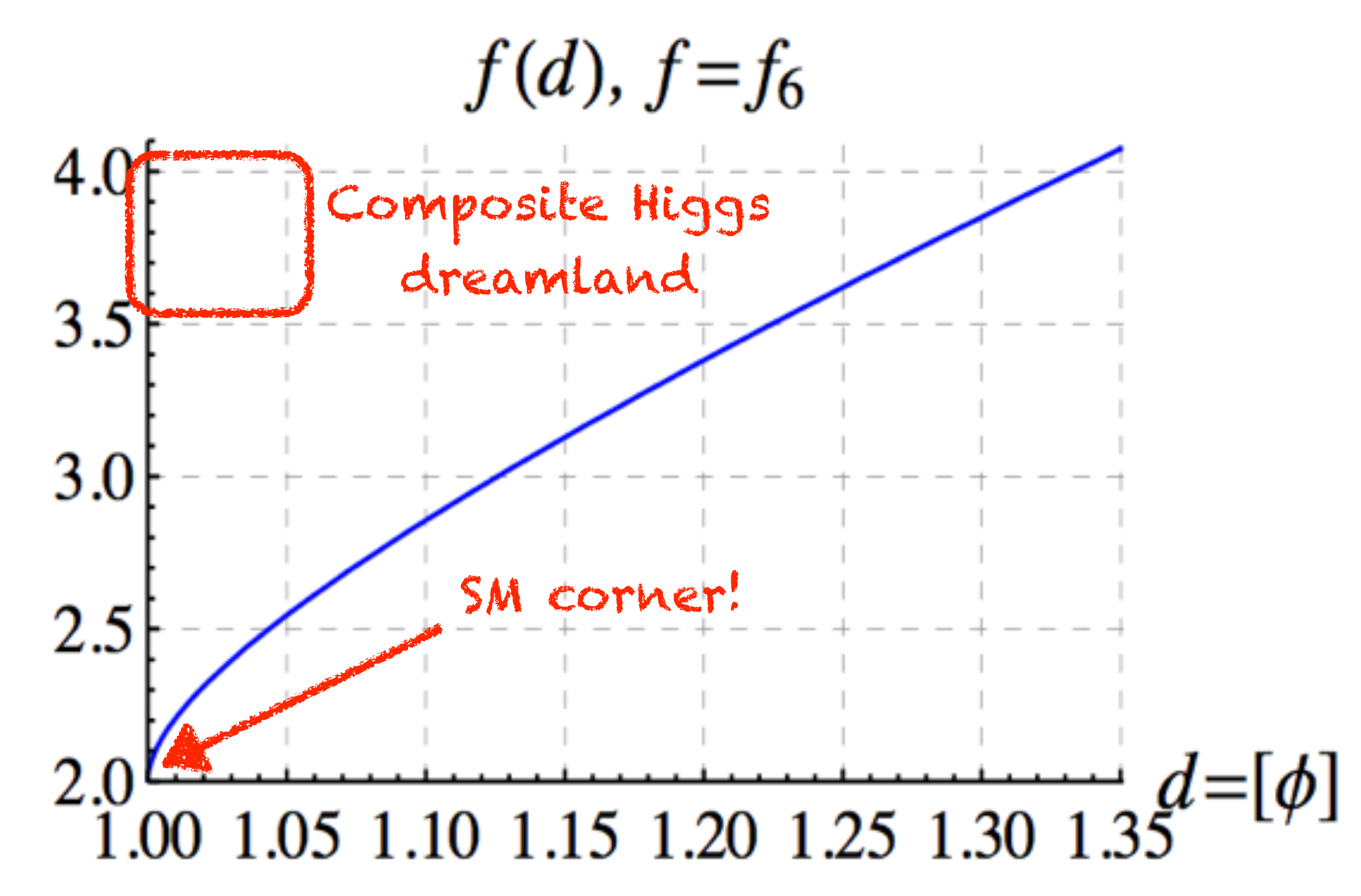
$$m_{\text{top}} \sim \left(\frac{4\pi f}{\Lambda_{\text{fl.}}}\right)^{d-1} 4\pi f \sin\theta$$

$$d \sim 1.$$

A no-go theorem?

Bounds on the dimensions of scalar operators can be extracted using bootstrap techniques!

Rattazzi, Rychkov, Tonni, Vichi 0807.0004



$$\phi \equiv \mathcal{O}_H$$

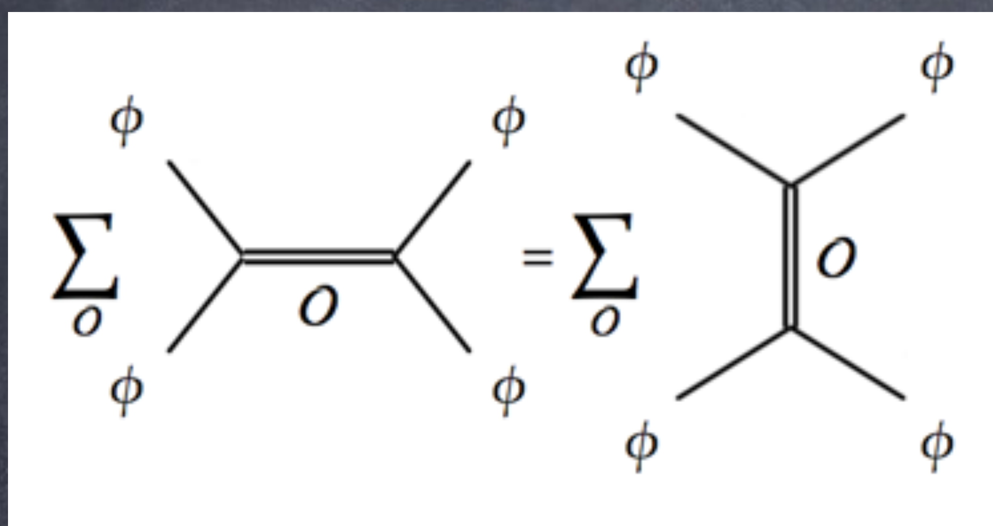
$$d[\phi^2]_{\min} < f(d)$$

Higgs mass operator!

$$\Delta m_H^2 \sim \left(\frac{4\pi f}{\Lambda_{\text{fl.}}}\right)^{d-4} f^2$$

A no-go theorem?

Q: does the bound apply to the Higgs?



$$(\psi^i\psi^j) = \phi^{ij}$$

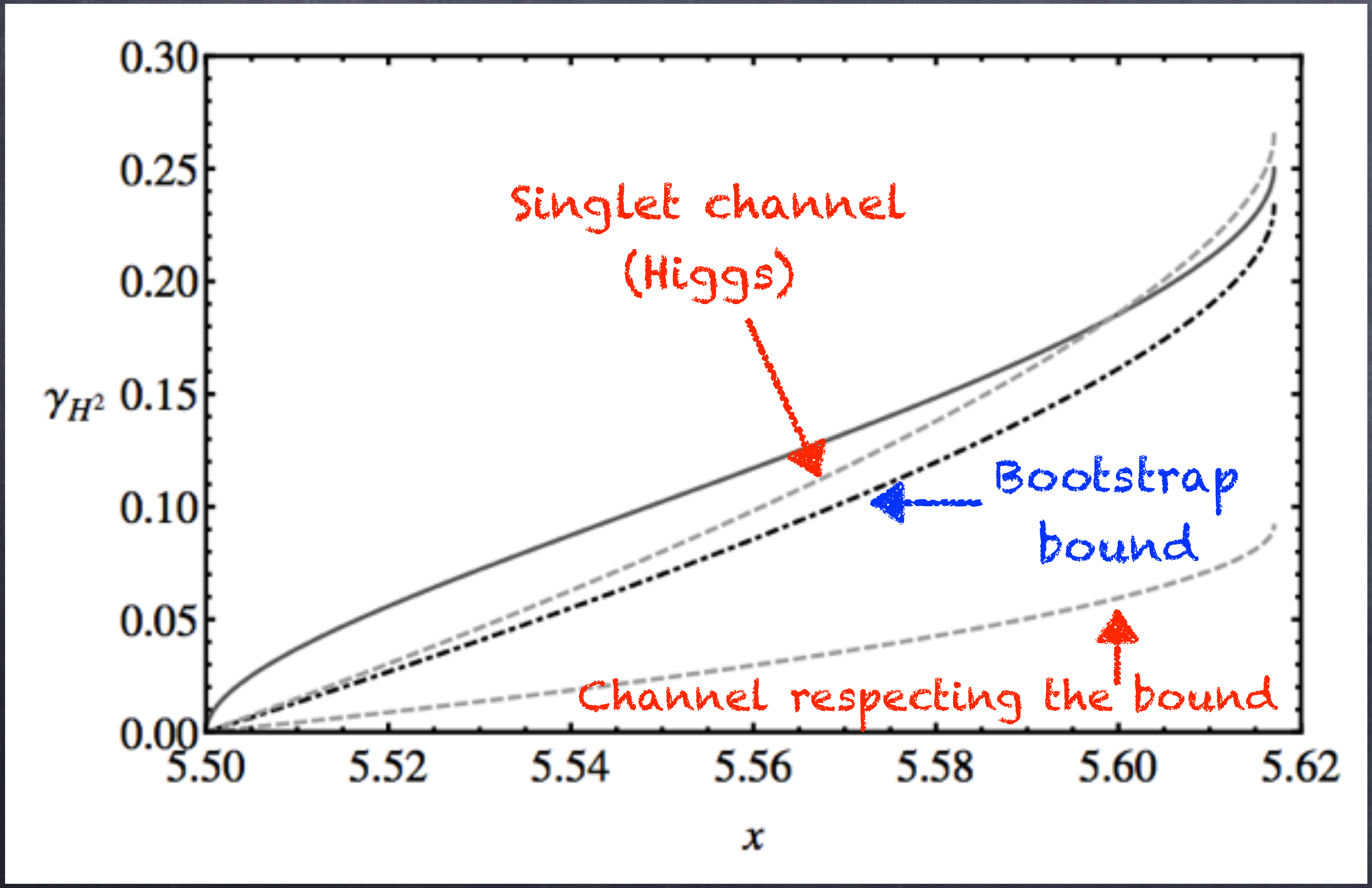
The scalar operator has
flavour indices:
many by-linear ops appear!

The bound applies to the one
with lowest dimension!

A no-go theorem? No...

Q: does the bound apply to the Higgs?

Antipin, Mølgaard, Sannino 1406.6166



Gauge-Yukawa theory
with weakly-coupled
fixed point.

Dimensions are calculable
(but small...)

The hot potato: flavour!

100.000 TeV	Λ_{flavour}	Light fermions
		Conformal region
Λ_{top}		
10 TeV	$\Lambda \sim 4\pi f$	Vector resonances, ...
1 TeV	f	Condensation scale (extra pions)
100 GeV	$v_{\text{SM}} \sim f \sin\theta$	EWSB

Multi-scale model

$$m_c \sim \left(\frac{4\pi f}{\Lambda_{\text{fl.}}}\right)^{d-1} 4\pi f \sin\theta$$

$$\Downarrow$$

$$\sim 0.01 \Rightarrow d \sim 1.5$$

Still, for the top, one would need:

$$\Lambda_{\text{top}} \sim 4\pi f$$

The partial compositeness paradigm

Kaplan Nucl.Phys. B365 (1991) 259

$$\frac{1}{\Lambda_{\text{fl.}}^{d-1}}\mathcal{O}_H q_L^c q_R \qquad \Delta m_H^2 \sim \left(\frac{4\pi f}{\Lambda_{\text{fl.}}}\right)^{d-4} f^2$$

Both irrelevant if

we assume: $d_H > 1$ $\quad d_{H^2} > 4$

Let's postulate the existence of fermionic operators:

$$\frac{1}{\Lambda_{\text{fl.}}^{d_F-5/2}}(\tilde{y}_L\, q_L\mathcal{F}_L + \tilde{y}_R\, q_R\mathcal{F}_R)$$

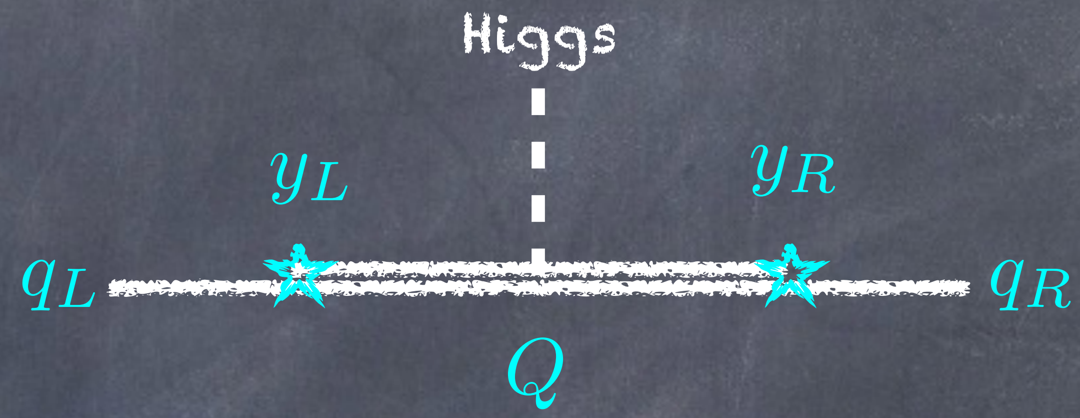
$$\downarrow$$

This dimension is not related to the Higgs!

$f(y_L\, q_L Q_L + y_R\, q_R Q_R)$ with $y_{L/R} f \sim \left(\frac{4\pi f}{\Lambda_{\text{fl.}}}\right)^{d_F-5/2} 4\pi f$

The partial compositeness paradigm

$$f(y_L\, q_L Q_L + y_R\, q_R Q_R)$$



$$m_q \sim \frac{y_L y_R f^2}{M_Q^2} f \sin\theta$$

$$M_Q \sim f \Rightarrow y_L, y_R \sim 1$$

Top can cancel top loop, PUVC

$$M_Q \sim 4\pi f \Rightarrow y_L, y_R \sim 4\pi$$