

20 Ways to Solve the Hierarchy Problem

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Aspen 2017: From the LHC to Dark Matter and Beyond



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20 Increasingly Crazy Ideas About the Hierarchy Problem

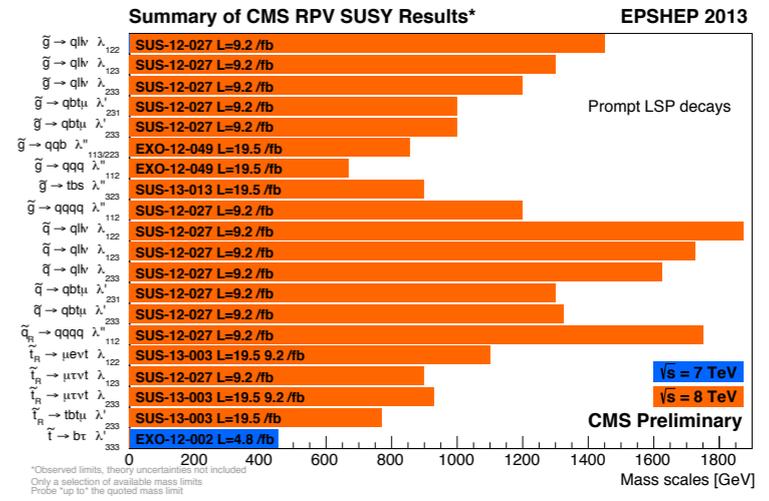
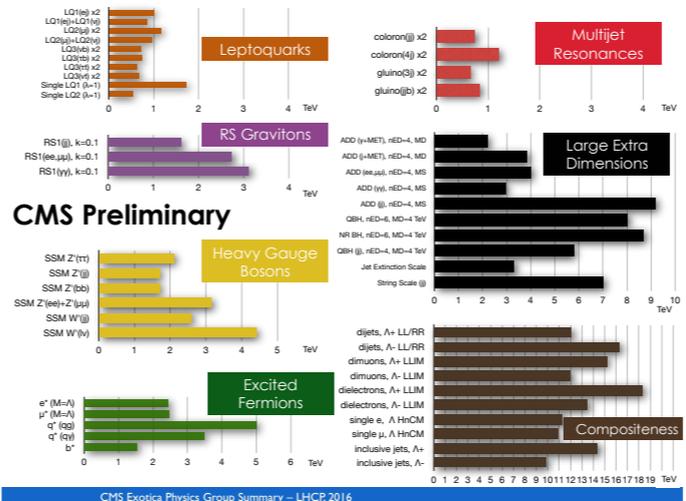
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Model	ℓ, γ	Jets†	E_{miss}^{min}	$[L dt] [fb^{-1}]$	Limit	Reference
Extra dimensions	ADD $G_{KK} + g/q$	≥ 1	Yes	3.2	M_{KK} mass 6.50 TeV	$n=2$ 1604.07773
	ADD non-resonant $\ell\ell$	≥ 1	Yes	20.3	M_{KK} mass 4.70 TeV	$n=3 \text{ HLZ}$ 1407.2410
	ADD QBH $\rightarrow \ell q$	≥ 1	Yes	20.3	M_{KK} mass 3.2 TeV	$n=6$ 1311.2008
	ADD QBH	≥ 1	Yes	15.7	M_{KK} mass 8.7 TeV	ATLAS-CONF-2016-089
	ADD BH high Σp_T	≥ 1	Yes	20.3	M_{KK} mass 8.2 TeV	$n=6, M_{2,0} = 3 \text{ TeV}$ not BH
	ADD BH multijet	≥ 3	Yes	3.6	M_{KK} mass 9.55 TeV	$n=6, M_{2,0} = 3 \text{ TeV}$ not BH
	RST $G_{KK} \rightarrow \ell\ell$	≥ 1	Yes	20.3	G_{KK} mass 2.68 TeV	$k/M_{2,0} = 0.1$ 1405.4123
	RST $G_{KK} \rightarrow \gamma\gamma$	≥ 1	Yes	3.2	G_{KK} mass 3.2 TeV	$k/M_{2,0} = 0.1$ 1608.0303
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq/\nu\nu$	≥ 1	Yes	13.2	G_{KK} mass 1.24 TeV	$k/M_{2,0} = 1.0$ ATLAS-CONF-2016-082
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbb$	≥ 1	Yes	13.3	G_{KK} mass 360-860 GeV	$k/M_{2,0} = 1.0$ ATLAS-CONF-2016-049
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	≥ 1	Yes	13.3	Z' mass 4.05 TeV	ATLAS-CONF-2016-045
	SSM $Z' \rightarrow \tau\tau$	≥ 1	Yes	19.5	Z' mass 2.02 TeV	1502.07177
	Leptophobic $Z' \rightarrow bb$	≥ 2	Yes	3.2	Z' mass 1.5 TeV	1603.08791
	SSM $W' \rightarrow \ell\nu$	≥ 1	Yes	13.3	W' mass 4.74 TeV	ATLAS-CONF-2016-061
	HVT $W' \rightarrow WZ \rightarrow qq\nu$ model A	≥ 1	Yes	13.2	W' mass 2.4 TeV	ATLAS-CONF-2016-082
	HVT $W' \rightarrow WZ \rightarrow qq\nu$ model B	≥ 1	Yes	15.5	W' mass 3.0 TeV	ATLAS-CONF-2016-055
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel	Yes	3.2	V' mass 2.21 TeV	1607.05621
	LRSM $W'_2 \rightarrow tb$	≥ 1	Yes	20.3	W' mass 1.92 TeV	1410.4103
	LRSM $W'_3 \rightarrow tb$	≥ 1	Yes	20.3	W' mass 1.78 TeV	1408.0396
	CI	CI $qq\nu$	≥ 2	Yes	15.7	A mass 19.9 TeV
CI $\ell\ell qq$		≥ 2	Yes	3.2	A mass 25.2 TeV	$\beta_{SM} = -1$ 1607.03669
DM	Axial-vector mediator (Dirac DM)	≥ 1	Yes	3.2	m_A mass 1.0 TeV	1604.07773
	Axial-vector mediator (Dirac DM)	≥ 1	Yes	3.2	m_A mass 710 GeV	1604.01306
LQ	Scalar LQ 1 st gen	≥ 2	Yes	3.2	LQ mass 1.1 TeV	1605.06035
	Scalar LQ 2 nd gen	≥ 2	Yes	3.2	LQ mass 1.05 TeV	1605.06035
Heavy quarks	VLQ $TT \rightarrow H + X$	≥ 2	Yes	20.3	T mass 825 GeV	T in (TB) doublet 1505.04306
	VLQ $YY \rightarrow Wb + X$	≥ 1	Yes	20.3	Y mass 776 GeV	Y in (BY) doublet 1505.04306
	VLQ $BB \rightarrow Hb + X$	≥ 2	Yes	20.3	B mass 739 GeV	isospin singlet 1409.5001
	VLQ $QQ \rightarrow Wq + X$	≥ 2	Yes	20.3	Q mass 785 GeV	B in (BY) doublet 1509.04261
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	≥ 1	Yes	3.2	q^* mass 4.4 TeV	only u^* and d^* , $A = m(q^*)$ 1512.05910
	Excited quark $q^* \rightarrow qg$	≥ 1	Yes	15.7	q^* mass 5.6 TeV	only u^* and d^* , $A = m(q^*)$ ATLAS-CONF-2016-089
	Excited quark $q^* \rightarrow q\ell$	≥ 1	Yes	8.8	q^* mass 2.3 TeV	only u^* and d^* , $A = m(q^*)$ ATLAS-CONF-2016-080
	Excited quark $q^* \rightarrow Wt$	≥ 1	Yes	20.3	q^* mass 1.9 TeV	$\xi_u = \xi_d = 1$ 1510.02664
Other	LSTC $\gamma\gamma \rightarrow W\gamma$	≥ 1	Yes	20.3	γ mass 960 GeV	$m(W_{\gamma}) = 2.4 \text{ TeV}$ no mixing 1407.8150
	LRSM Majorana ν	≥ 1	Yes	20.3	$\tilde{\nu}$ mass 570 GeV	$D\tilde{\nu}$ production, BR($\tilde{\nu} \rightarrow \nu\tilde{g}$) 1506.06200

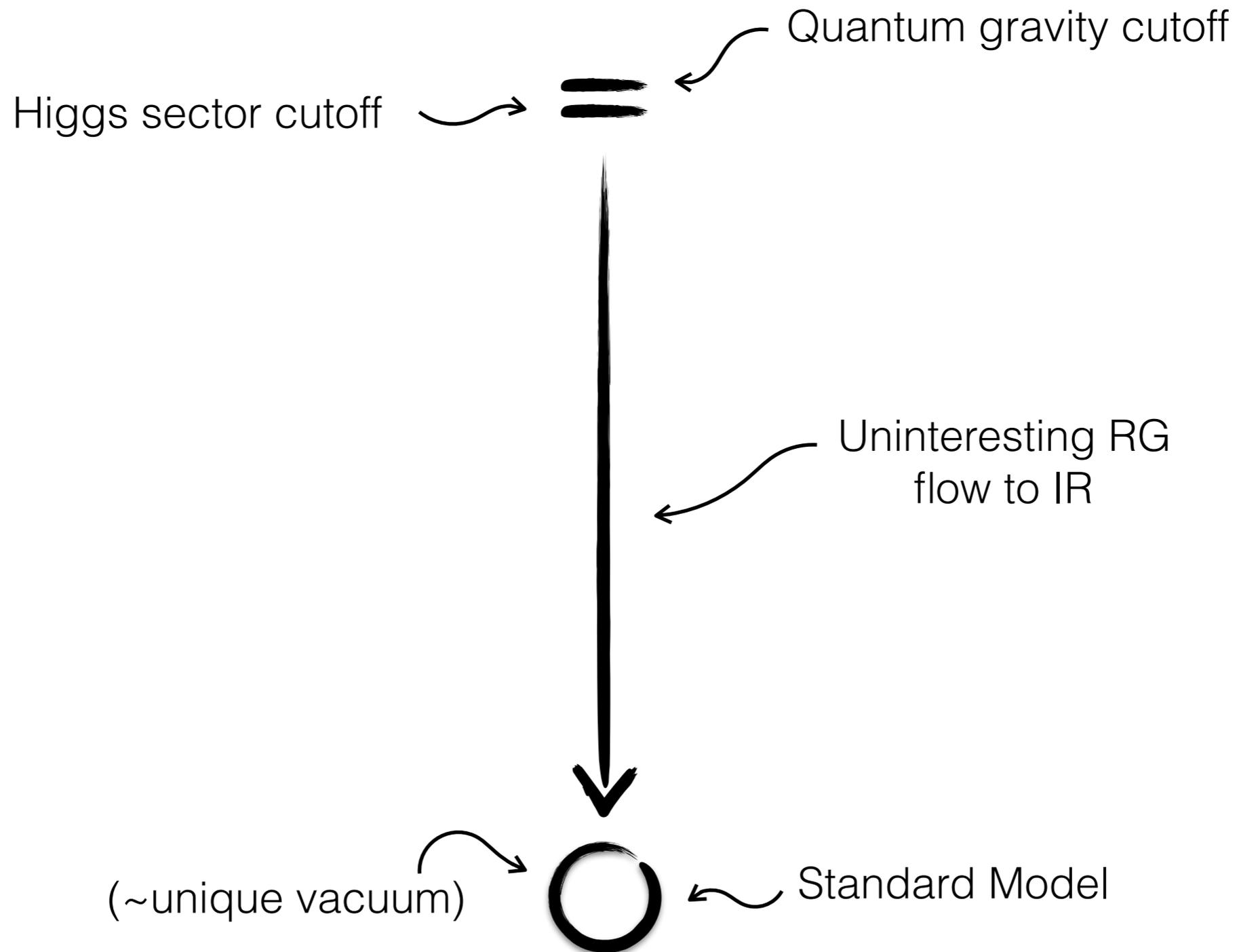
We (collectively) spend most of our time looking for solutions to the hierarchy problem



Model	ℓ, μ, τ, γ	Jets	E_{miss}^{min}	$[L dt] [fb^{-1}]$	Mass limit	Reference	
Indirect Searches	MSUGRA/CMSSM	$0-3 \mu, 1-2 \tau$	≥ 2 jets	Yes	20.3	\tilde{g} mass 129 TeV	
	$\tilde{g} \rightarrow q\bar{q}$	≥ 1	Yes	13.2	\tilde{g} mass 1.34 TeV	1507.05235	
	$\tilde{g} \rightarrow t\bar{t}$ (compressed)	≥ 1	Yes	3.2	\tilde{g} mass 810 GeV	ATLAS-CONF-2016-078	
	$\tilde{g} \rightarrow b\bar{b}$	≥ 1	Yes	13.2	\tilde{g} mass 1.46 TeV	ATLAS-CONF-2016-078	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	13.2	\tilde{g} mass 1.80 TeV	ATLAS-CONF-2016-078	
	$\tilde{g} \rightarrow \gamma\gamma$	≥ 1	Yes	13.2	\tilde{g} mass 1.7 TeV	ATLAS-CONF-2016-078	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	13.2	\tilde{g} mass 1.6 TeV	ATLAS-CONF-2016-037	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	13.2	\tilde{g} mass 1.6 TeV	ATLAS-CONF-2016-037	
	GMSB (NLSP)	$1-2 \mu, 0-1 \tau$	≥ 2 jets	Yes	3.2	\tilde{g} mass 5.0 TeV	1507.05235
	GGM (higgsino NLSP)	0	≥ 2 jets	Yes	3.2	\tilde{g} mass 1.60 TeV	1506.01950
1 st gen. squarks & gluinos	$\tilde{g} \rightarrow q\bar{q}$	≥ 1	Yes	14.8	\tilde{g} mass 1.29 TeV	ATLAS-CONF-2016-052	
	$\tilde{g} \rightarrow t\bar{t}$	≥ 1	Yes	14.8	\tilde{g} mass 1.29 TeV	ATLAS-CONF-2016-052	
	$\tilde{g} \rightarrow b\bar{b}$	≥ 1	Yes	20.1	\tilde{g} mass 1.37 TeV	1407.0830	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	3.2	\tilde{g} mass 940 GeV	1608.08772	
	$\tilde{g} \rightarrow \gamma\gamma$	≥ 1	Yes	13.2	\tilde{g} mass 325-985 GeV	ATLAS-CONF-2016-037	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	13.2	\tilde{g} mass 300-721 GeV	1209.2162, ATLAS-CONF-2016-077	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	13.2	\tilde{g} mass 205-930 GeV	1508.08816, ATLAS-CONF-2016-077	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	13.2	\tilde{g} mass 90-323 GeV	1604.07773	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	13.2	\tilde{g} mass 130-600 GeV	1403.5292	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	13.3	\tilde{g} mass 286-716 GeV	ATLAS-CONF-2016-038	
EW direct	$\tilde{g} \rightarrow q\bar{q}$	≥ 1	Yes	20.3	\tilde{g} mass 326-620 GeV	1508.08816	
	$\tilde{g} \rightarrow t\bar{t}$	≥ 1	Yes	20.3	\tilde{g} mass 90-325 GeV	1403.5294	
	$\tilde{g} \rightarrow b\bar{b}$	≥ 1	Yes	13.3	\tilde{g} mass 940 GeV	ATLAS-CONF-2016-036	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	14.8	\tilde{g} mass 590 GeV	ATLAS-CONF-2016-039	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	13.3	\tilde{g} mass 1.0 TeV	ATLAS-CONF-2016-036	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	13.3	\tilde{g} mass 425 GeV	1403.5294, 1432.3709	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	20.3	\tilde{g} mass 270 GeV	1507.07110	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	20.3	\tilde{g} mass 115-370 GeV	1403.5294	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	20.3	\tilde{g} mass 835 GeV	1507.05425	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	20.3	\tilde{g} mass 590 GeV	1507.05425	
Long-lived particles	Direct $\tilde{g} \rightarrow q\bar{q}$ prod., long-lived \tilde{g}	≥ 1 jet	Yes	20.3	\tilde{g} mass 270 GeV	1518.3675	
	Direct $\tilde{g} \rightarrow t\bar{t}$ prod., long-lived \tilde{g}	≥ 1 jet	Yes	18.4	\tilde{g} mass 485 GeV	1508.05352	
	Stable, stopped \tilde{g} production	≥ 1 jets	Yes	27.9	\tilde{g} mass 850 GeV	1511.0534	
	Stable \tilde{g} production	≥ 1 jets	Yes	3.2	\tilde{g} mass 1.34 TeV	1606.01929	
	Metastable \tilde{g} production	≥ 1 jets	Yes	3.2	\tilde{g} mass 1.37 TeV	1604.04820	
	GMSB, stable \tilde{g} prod., long-lived \tilde{g}	≥ 1 jet	Yes	19.1	\tilde{g} mass 537 GeV	1411.6736	
	GMSB, $\tilde{g} \rightarrow \ell\bar{\ell}$, long-lived \tilde{g}	≥ 1 jet	Yes	20.3	\tilde{g} mass 440 GeV	1403.5292	
	$\tilde{g} \rightarrow \ell\bar{\ell}$, long-lived \tilde{g}	≥ 1 jet	Yes	20.3	\tilde{g} mass 1.0 TeV	1504.05162	
	$\tilde{g} \rightarrow W\ell$, long-lived \tilde{g}	≥ 1 jet	Yes	20.3	\tilde{g} mass 1.0 TeV	1504.05162	
	$\tilde{g} \rightarrow \ell\bar{\ell}$, long-lived \tilde{g}	≥ 1 jet	Yes	20.3	\tilde{g} mass 1.9 TeV	1607.08739	
RPV	Bilinear RPV CMSSM	$0-3 \mu, 0-3 \tau$	Yes	3.2	\tilde{g} mass 1.45 TeV	1404.2930	
	$\tilde{g} \rightarrow q\bar{q}$	≥ 1	Yes	13.3	\tilde{g} mass 1.14 TeV	ATLAS-CONF-2016-075	
	$\tilde{g} \rightarrow t\bar{t}$	≥ 1	Yes	20.3	\tilde{g} mass 450 GeV	1403.5294	
	$\tilde{g} \rightarrow b\bar{b}$	≥ 1	Yes	20.3	\tilde{g} mass 1.38 TeV	ATLAS-CONF-2016-037	
	$\tilde{g} \rightarrow WZ$	≥ 1	Yes	14.8	\tilde{g} mass 1.33 TeV	ATLAS-CONF-2016-037	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	14.8	\tilde{g} mass 1.70 TeV	ATLAS-CONF-2016-034	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	14.8	\tilde{g} mass 1.4 TeV	ATLAS-CONF-2016-034	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	15.4	\tilde{g} mass 816 GeV	ATLAS-CONF-2016-034	
	$\tilde{g} \rightarrow W\ell$	≥ 1	Yes	20.3	\tilde{g} mass 850-910 GeV	ATLAS-CONF-2016-034	
	$\tilde{g} \rightarrow \ell\bar{\ell}$	≥ 1	Yes	20.3	\tilde{g} mass 94-110 TeV	ATLAS-CONF-2016-015	

We have yet to find evidence for these solutions. (not for lack of outstanding experimental effort) Natural question: *have we exhausted the solutions?*

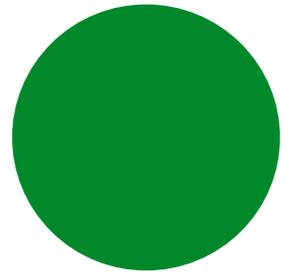
The Hierarchy Problem



m_H is not technically natural

\Rightarrow hierarchy problem

Adding a symmetry



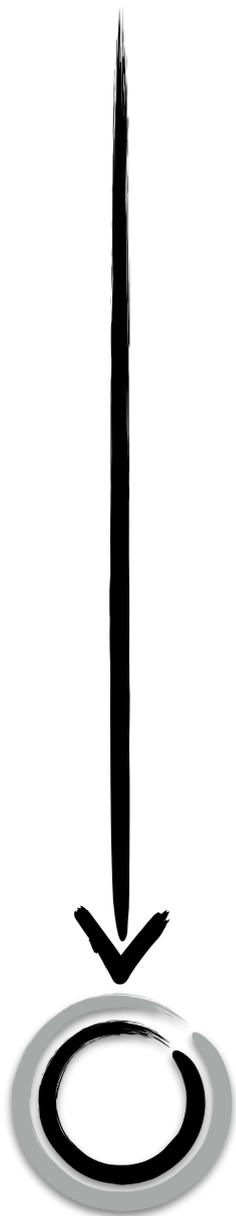
...and breaking it softly

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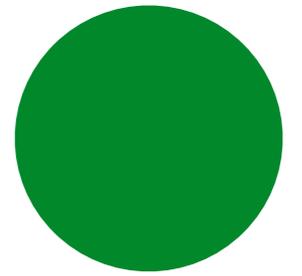
1. Supersymmetry
2. Global symmetry
3. Discrete subgroups thereof
("neutral naturalness")

Experimental signals: partner particles

- The familiar host of prompt signals (with or without missing energy)
- Rich variety of displaced decays (RPV, fraternal twin higgs, folded SUSY, ...)



Lowering the cutoff



...in diverse dimensions

4. RS / Technicolor

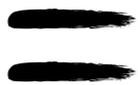
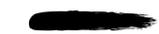
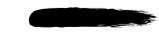
5. LED / 10^{32} x SM

6. LST / Clockwork

7. Classicalization

Experimental signals: resonances

- Primary distinctions are in spacing & coupling of resonances
- Potential goldmine of unexplored signals for LST — e.g. perturbative string excitations



Selecting a vacuum



Vacuum is one of many; end up in observed vacuum through dynamical process or anthropic constraint.

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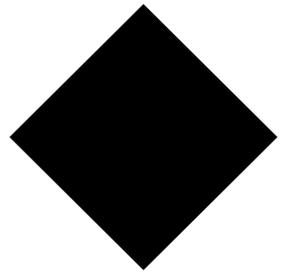


8. Anthropic (pressure)
9. Relaxation (dynamics)
10. Naturalness (reheating)

Experimental signals: Diverse, but typically

- Cosmology (Bubble collisions; axions; contributions to N_{eff} and Σm_ν)
- Exotic LHC signals (displaced decays, hidden sector confinement, ...)

Complicating the flow



SM is reached from some intermediate fixed point where, say, a generalized Veltman condition is satisfied

$$\delta m_H^2 = \sum_i c_i \frac{g_{i,*}^2}{16\pi^2} \Lambda_i^2 = 0$$

This is the sense in which

11. Conformal symmetry

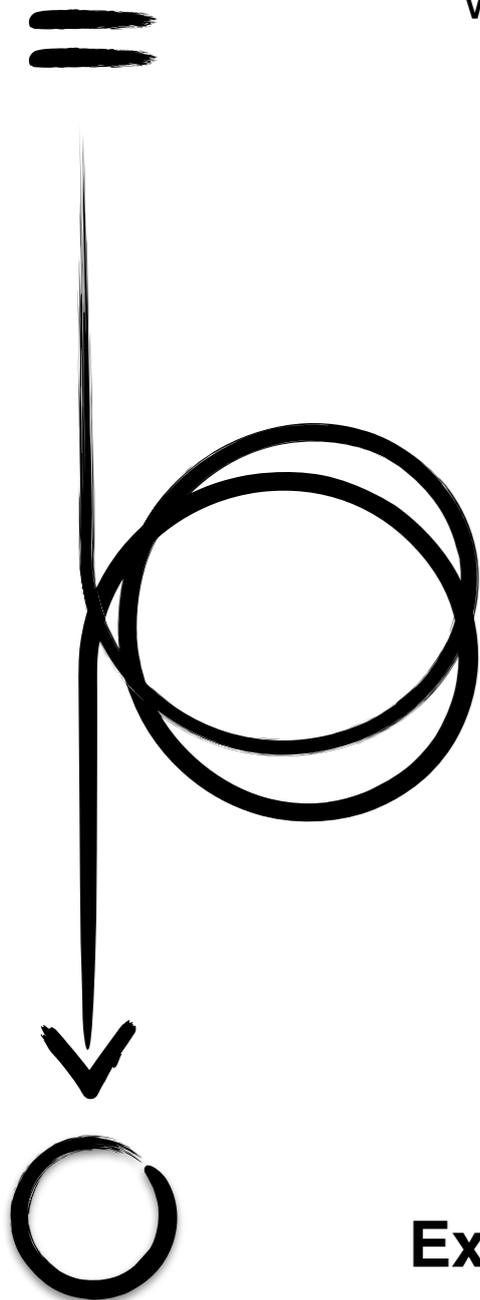
could address the hierarchy problem

Top-down: Embed SM in orbifold of N=4 SYM
[Frampton, Vafa '99; Csaki, Skiba, Terning '99]

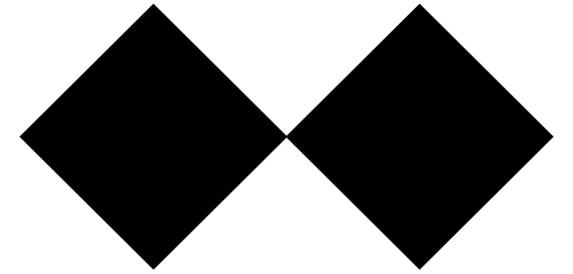
Bottom-up: "Little conformal symmetry"
[Houtz, Colwell, Terning '16]

A challenge: how do fixed point couplings know about UV scale?

Experimental signals: Not fully understood, but expect new particles w/ SM quantum numbers around the TeV scale. Novelty is that their statistics, representations & couplings differ from more familiar solutions.



Exploding the cutoff



Gravity doesn't provide a UV scale & the SM takes care of itself

12. Asymptotic fragility

[Dubovsky, Gorbenko, Mirbabayi '13]

13. Agravity [Salvio, Strumia '14]

Scale M_{Pl} not associated with relevant operator becoming strong, not "felt" by non-grav physics.

At low energies, looks like IR CFT perturbed by irrelevant operators.

At high energies there is no UV fixed point; cannot define local observables.

Example in 2d, no proposal for 4d.

Gravity has no intrinsic length scale and is "renormalizable"

$$S \sim \int d^4x \sqrt{g} \left(\frac{R^2}{f_1^2} + \frac{\frac{1}{3}R^2 - R_{\mu\nu}^2}{f_2^2} + \dots \right)$$

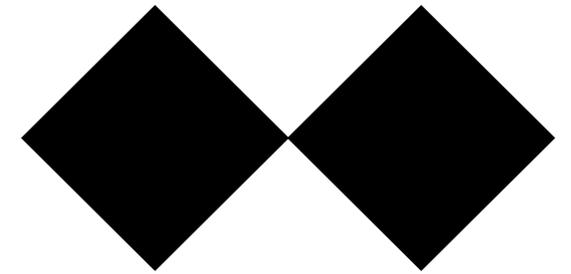
(E-H term via vev of some field)

Can be re-written in terms of 2-deriv fields w/ ghosts. Like Lee-Wick (next slide) but **not obvious that ghosts are innocuous here**

Experimental signals: Details of gravity sector might be irrelevant. Crucially, must render SM couplings asymptotically free. Not a property of the SM itself, so entails low-scale unification (~ 10 TeV)

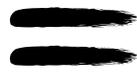


Not actually the SM



Maybe our IR theory is not actually the SM

Might help if: introduces states of non-positive norm



14. Lee-Wick (higher derivative scalar)

[Grinstein, O'Connell, Wise '06]

15. Non-compact gauge group?

[Please give me a hat tip if it works '17]

Higher-derivative theory,

$$\sim \frac{1}{2} \partial_\mu \phi \partial^\mu \phi - \frac{1}{2M^2} (\partial^2 \phi)^2 + \dots$$

improves UV convergence of diagrams

Can write in terms of a normal scalar plus a new field with wrong-sign quadratic action

$$-\frac{1}{2} \partial_\mu \tilde{\phi} \partial^\mu \tilde{\phi} + \frac{1}{2} M^2 \tilde{\phi}^2 + \dots$$

Can be defined in a unitary, Lorentz-invariant manner with only microscopic acausality

Cosmology may be a bit wacky.

Usually restrict to compact simple subalgebras & U(1)'s to guarantee positive-norm states.

Then EWK group definitely SU(2)xU(1)

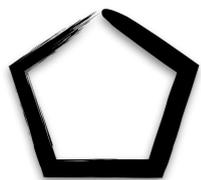
But [Tseytlin '95] a 4d gauge theory of a non-semisimple Lie algebra can be fully renormalized at 1 loop, finite S-matrix; negative-norm state factorizes

E.g. gauge theory based on E_2^C

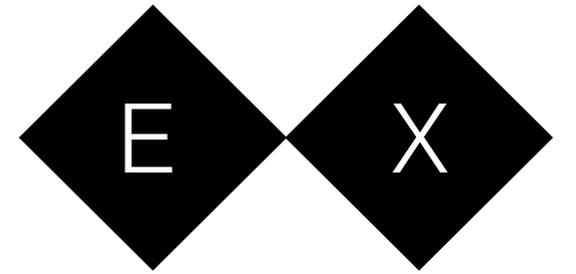
$$[e_3, e_i] = \epsilon_{ij} e_j \quad [e_i, e_j] = \epsilon_{ij} e_4$$

$$[e_4, e_i] = [e_4, e_3] = 0 \quad i, j = 1, 2$$

Special limit of SU(2) x [U(1) ghost factor]



Connecting UV & IR



Essential feature of the hierarchy problem is that the UV doesn't know about the IR... unless it does?

Two “theories” exhibiting UV/IR mixing:
Quantum gravity & non-commutative field theory

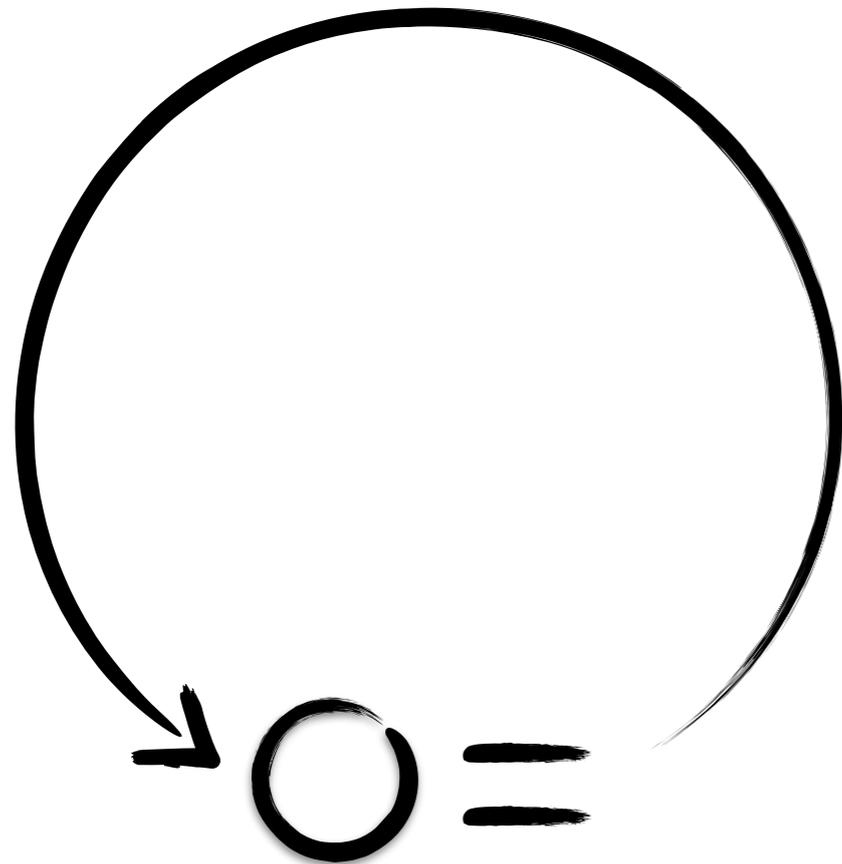
QG (cartoon version): probe spacetime with sufficiently energetic particles, make a black hole.
More energetic particles → bigger black hole.

NCQFT (cartoon version): non-commutativity of the form $[x^\mu, x^\nu] = i\Theta^{\mu\nu}$, qualitatively a space-space uncertainty principle.

Two ways to put this to work for hierarchy problem:

16. Weak gravity conjecture

17. Non-commutative SM



A UV/IR “Solution”: Weak gravity

Weak gravity conjecture: an abelian gauge theory must contain a state of charge q and mass m satisfying $q > \frac{m}{M_{Pl}}$

Justification: consider BH of charge Q , mass M decaying to this particle

particles produced = Q/q

Conservation of energy: $mQ/q < M$

Then BH satisfies

$$Z = Q M_{Pl}/M < z = q M_{Pl}/m$$

Extremal BH ($Z=1$) stable unless there exists a state with $z > 1$

$\Rightarrow q > m/M_{Pl}$ to avoid BH remnants, in conflict w/ holography

Connection to the weak scale

[Cheung, Remmen '14]

Charge SM fermions under weakly gauged (unbroken) $U(1)_{B-L}$
(bounds currently $q \lesssim 10^{-24}$). Cancel anomalies with RHN ν_R

Neutrino mass is $y_\nu H \bar{L} \nu_R \rightarrow m_\nu \sim y_\nu v$ so $m_\nu \sim 0.1$ eV, $q \gtrsim 10^{-29}$

For fixed yukawa, if v were any larger, WGC would be violated
Physics in the UV needs to know about the IR scale v .

A UV/IR “Solution”: NCQFT

Extensive literature starting with [\[Minwalla, Seiberg, Van Raamsdonk '99\]](#)

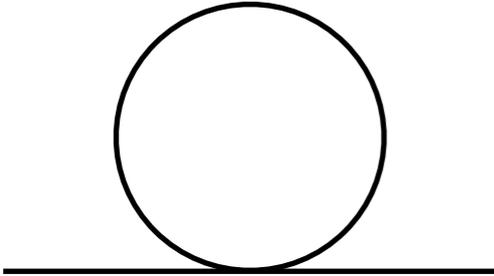
Noncommutativity manifested
by star product

$$(\phi_1 \star \phi_2)(0) = e^{i\Theta^{\mu\nu} \partial_\mu^y \partial_\nu^z} \phi_1(y) \phi_2(z) \Big|_{y=z=0}$$

Consider just ϕ^4 in $d=4$:

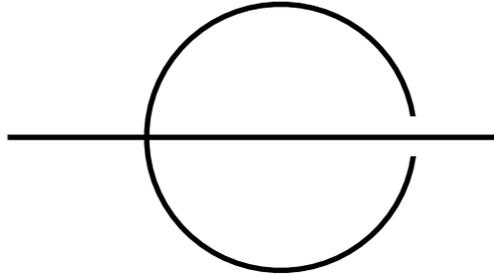
$$\mathcal{L} = \frac{1}{2} (\partial_\mu \phi)^2 + \frac{1}{2} m^2 \phi^2 + \frac{1}{4!} g^2 \phi \star \phi \star \phi \star \phi$$

Now there are “planar” and “non-planar” diagrams.
E.g. at one loop



$$\sim \int \frac{d^4 k}{k^2}$$

UV divergent as usual



$$\sim \int \frac{d^4 k}{k^2} e^{ip\Theta k} \sim \frac{1}{\Theta^2 p^2}$$

IR divergence!

Can define a suitable noncommutative SM [\[Calmet et al '01\]](#)

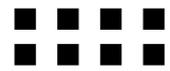
Strongly constrained by Lorentz violation

Far from an actual proposal to solve the hierarchy problem, but...

????????????????



Things I can't (yet) cleanly compartmentalize



18. Tune the CC to set the weak scale

[Arvanitaki, Dimopoulos, Gorbenko, Huang, Van Tilburg '16]

19. Massless moduli from explicitly broken SUSY

[Dong, Freedman, Zhao '14, '15]

20. Self-organized criticality

Example: explicit marginal SUSY breaking involving $U(1)_R$ gauge fields on bdy of AdS_3

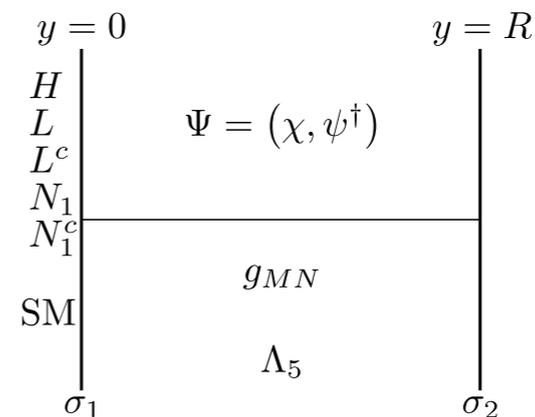
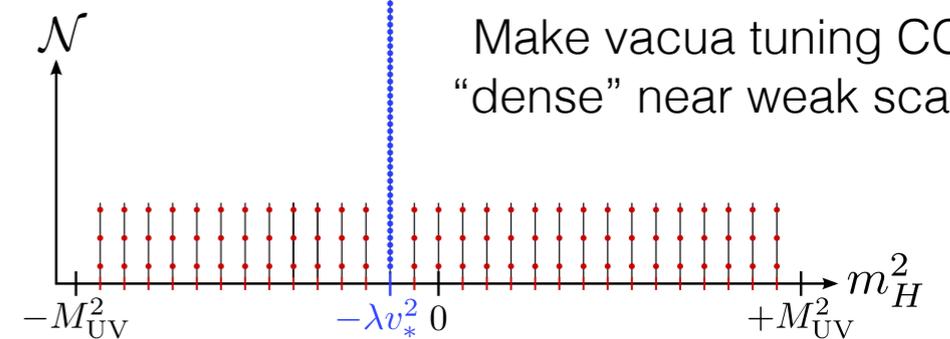
$$\delta S \sim \int_{bdy} A \wedge \tilde{A} \sim \int d^2 z J(z) \tilde{J}(\bar{z})$$

Induces splitting in R-charged multiplets.
Feed to R-neutral multiplets w/ yukawa

$$\lambda \phi_N \phi_R^\dagger \phi_R$$

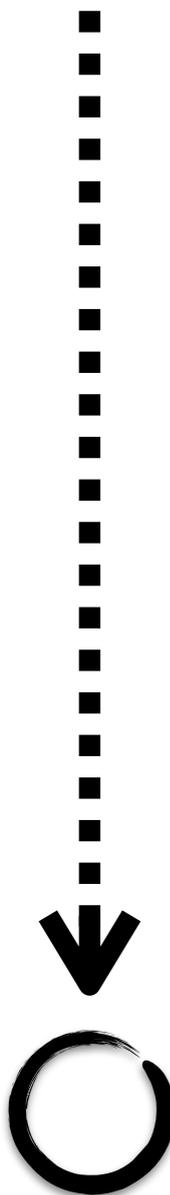
R-neutral scalars are massless to all orders

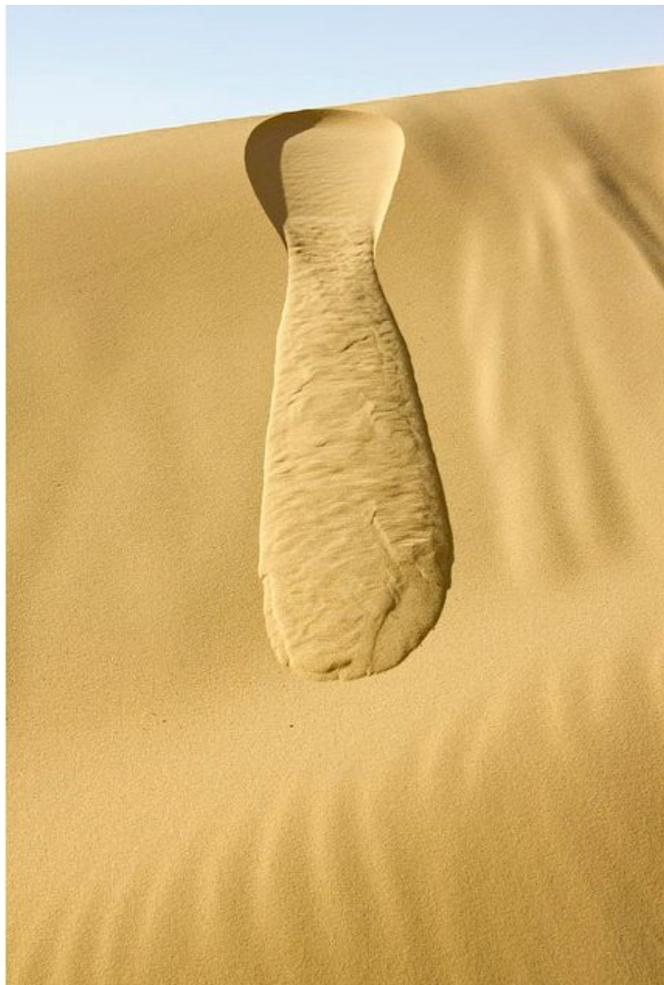
Analogous to $y_t^2 m_t^2 - y_{\tilde{t}}^2 m_{\tilde{t}}^2 = 0$



Signals

- Vector-like leptons (direct search, Higgs invisible width, precision electroweak)
- Super-light radion ($O(10^{-10})$ eV)





A ??? Solution: Self-Organized Criticality

Some systems evolve into critical states on their own.
Wouldn't that be nice?

Canonical example: Sandpile. Initially dynamics of individual grains. Critical slope \rightarrow one grain causes avalanche; correlations far larger than individual grains.

The QFT analog of SOC has been called:

- A free scalar field
- The (2,0) theory in 6d
- A classical FT w/ dissipation
- Soft gluons
- The relaxion
- "A terrible idea"

All of these in some sense true, but it's time to figure out which senses give novel, functional solutions to the hierarchy problem

Conclusions

- Electroweak hierarchy problem remains one of the biggest motivations for physics beyond the SM.
- Close to comprehensively understanding what conventional solutions look like & searching accordingly. Should obviously keep searching for these as hard as possible, but...
- ...at some point **data** tells us that we should look more closely at truly unconventional solutions. Most of these are a way of making sense of the failure of Wilsonian EFT.
- Promising places to look: conformal symmetry; naive IR pathologies; UV/IR mixing. But who am I to say? Lots to explore.
- Experimental possibilities potentially vast.

Thank you!