Theoretical aspects of Beyond the Standard Model physics

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Experimental hot subjects (a very long quest in just few lines)

- Discovery and properties of the Higgs Boson
- The top quark
- Electroweak precision tests
- Flavour measurements
- Neutrino oscillations
- Dark matter content of the universe

Standard Model quite successful on the first 4, way beyond expectations!

Hints for BSM

we have data to explain beyond SM

- neutrinos and flavour hierarchies in the quark/lepton sectors
- dark matter (and dark energy if you dare...)

data to search/fulfill (precision tests, small deviations)

- Higgs boson mass, couplings
- top and flavour data
- EW precision data, etc.

Guidelines for BSM physics

- Top-down
  - Fundamental symmetries ☺
  - Unification of the couplings ☺
  - Unitarity ☺
  - Renormalisability ☺
  - Hierarchies, naturalness, fine-tuning?? etc...

- Bottom-up
  - Dark matter as a WIMP
  - Electroweak precision tests
  - Flavour observables
  - Observation of new particles

Usual list, but realistic model-building not obvious

New Physics @ the TeV scale?

- Electroweak symmetry breaks at energies ~ 100 GeV-1 TeV
- Weakly Interacting Massive Particle needs a mass
- ~ 100 GeV-1 TeV to fit observed Dark Matter density
- WL WL scattering unitarised at energies ~ 1 TeV, by just the Higgs?
- Hierarchy: fine-tuning or Higgs mass must be stabilized by a scale ~ 1 TeV

This makes a few strong hints to go beyond the SM at the TeV scale but...

Constraints from higher dim operators

Unless symmetries/cancellations:

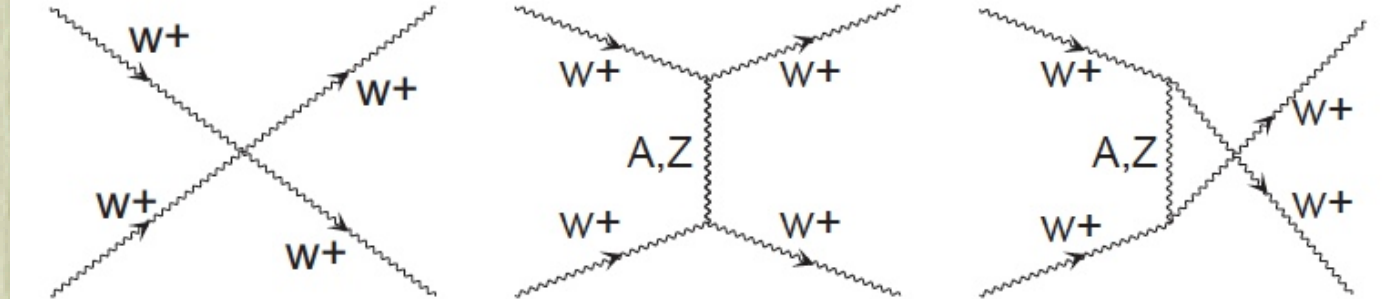
• Baryon Number Violation	$\Lambda \gtrsim 10^{16}$ GeV
• Lepton Number Violation	$\Lambda \gtrsim 10^{15}$ GeV
• Flavour Violation	$\Lambda \gtrsim 10^{6}$ GeV
• CP Violation	$\Lambda \gtrsim 10^{6}$ GeV
• Precision Electroweak	$\Lambda \gtrsim 10^{3}$ GeV
• Contact Operators	$\Lambda \gtrsim 10^{3}$ GeV

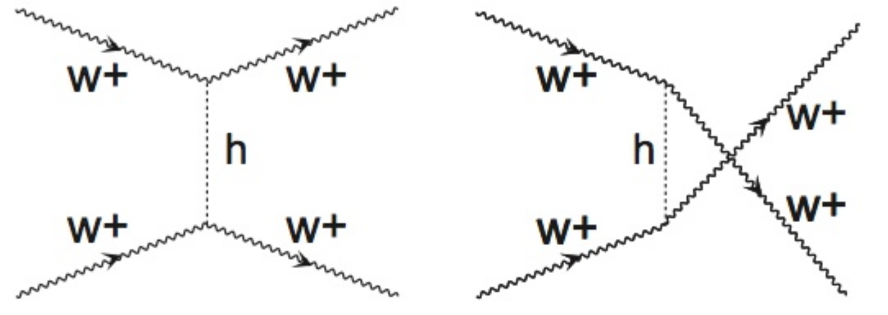
Some ideas behind models

- WW scattering unitarity
- naturalness and vacuum stability
- matter parities
- extra symmetries (space-time, global, gauge)
- compositeness & Technicolor
- extra dimensions

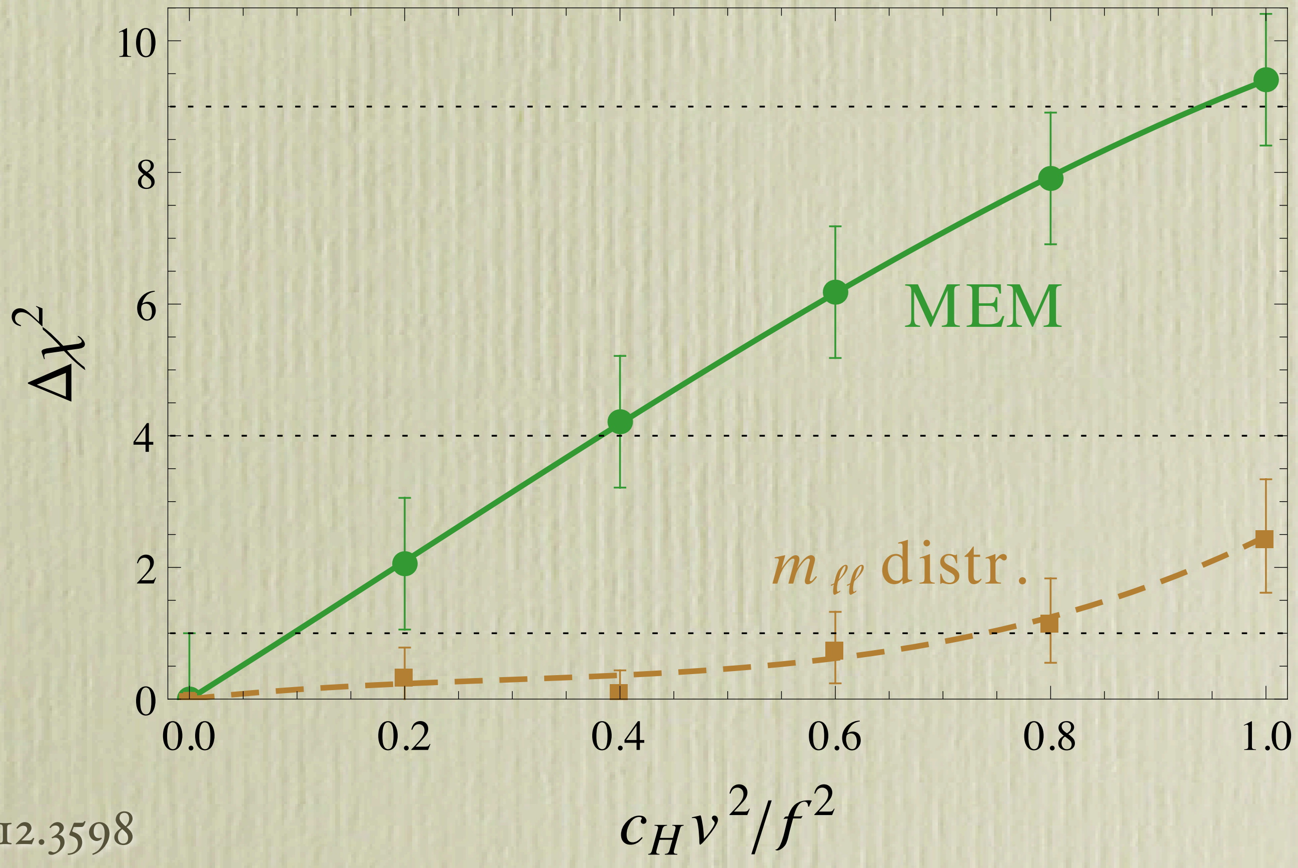
WW and unitarity

- Higgs boson exchange crucial (see Lee, Quigg, Thacker 1977)



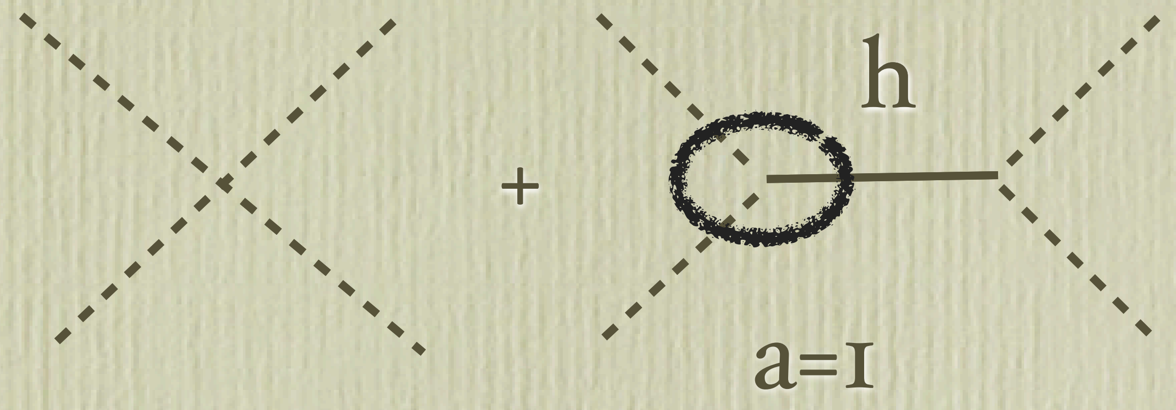


- Now still useful for discriminating models if accurately measured at LHC 14 TeV, example testing 2HDM or effective composite SILH models:



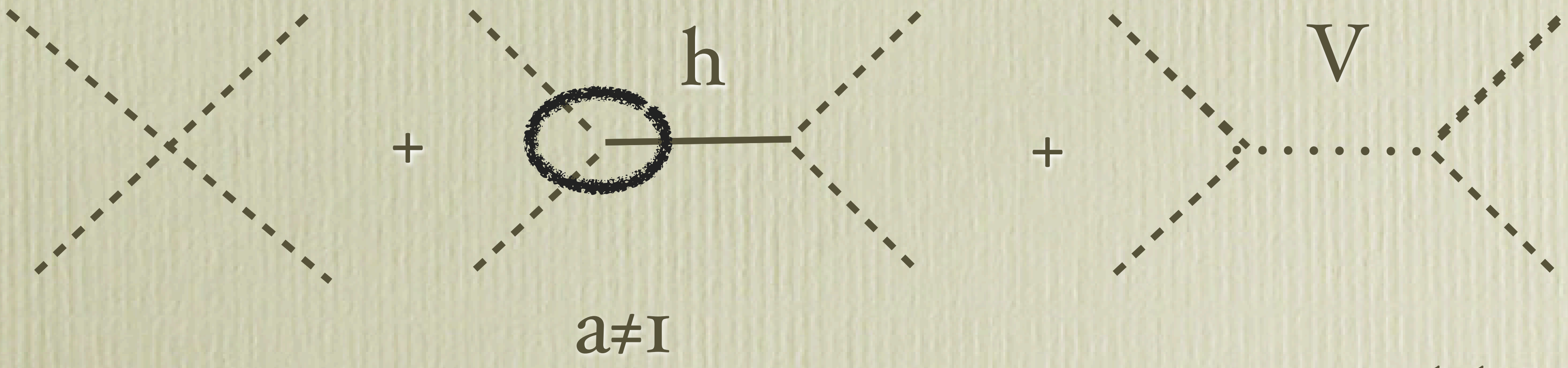
from 1212.3598

Weak or strong EWSB?



weak, SM like

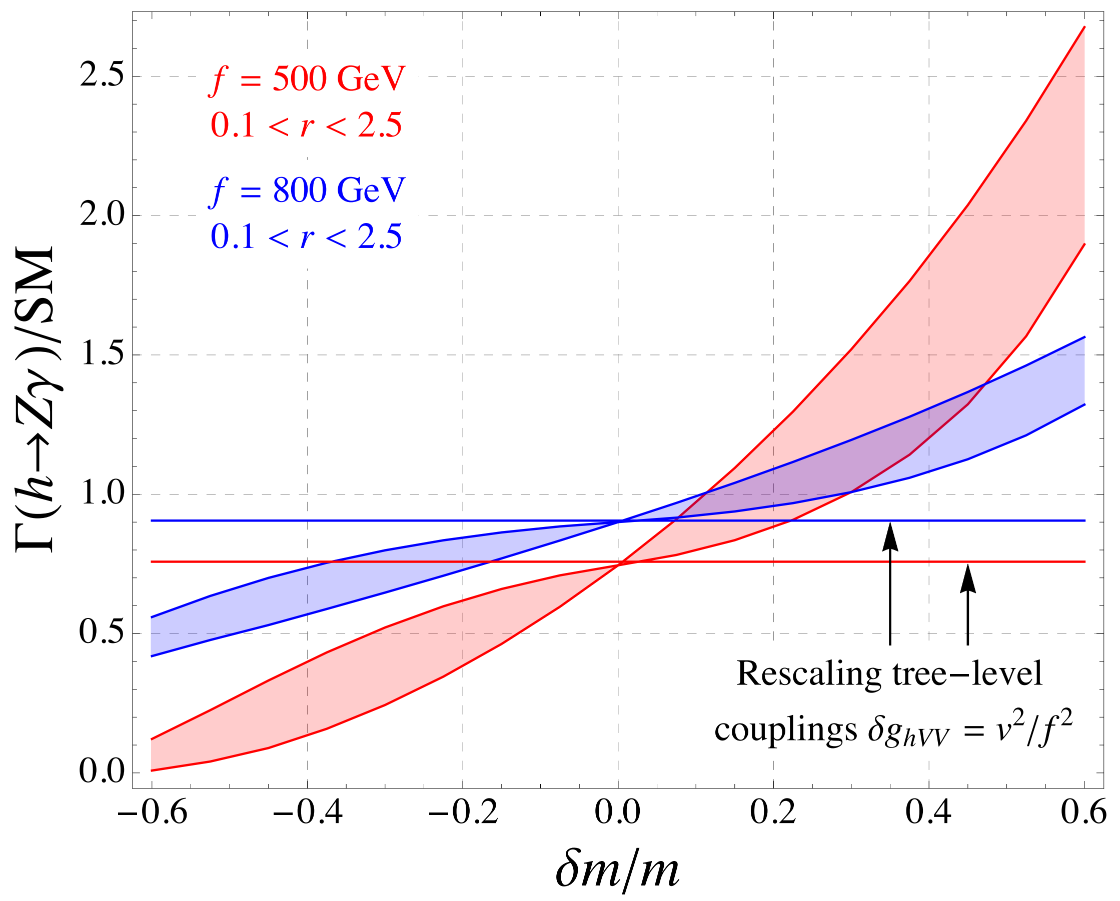
$$A(W_L W_L \to W_L W_L) \sim \frac{E^2}{v^2}(1-a^2) - a^2 \frac{m_h^2}{v^2}\frac{s}{s-m_h^2}$$



strong, composite like

Possible tests weak vs strong

- VV → VV, limited sensitivity at LHC
- h → Z γ, large effect may be possible
- VV → hh, at a e^+e^- collider



see 1305.5251, 1308.2676, 1309.7038

Natural theories

$$m^2 = m_0^2 \left(1 + a(\lambda, g) \log \frac{\Lambda^2}{m_0^2}\right) + b(\lambda, g)\Lambda^2$$

- natural if $b(\lambda,g)=0$ by a symmetry
- can be natural if Λ is a physical cut-off (ex. compositness)
- quasi-natural if $b(\lambda,g)=0$ perturbatively (ex. at one-loop in Little Higgs for top contribution)
- tuned: any special value you like, even $m_0=0$ $\Lambda=0$ (classically conformal)

SM and naturalness

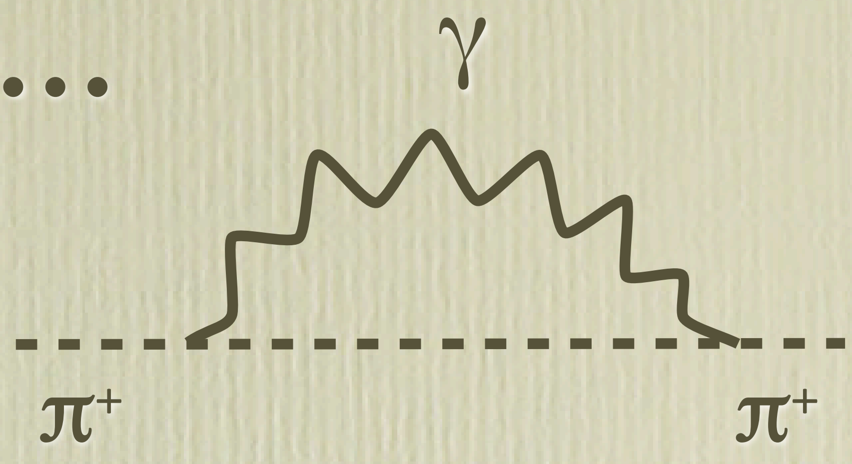
- Naturalness as UV sensitivity of h mass in the SM effective theory (not a principle, just reasonable)

$$\delta M_H^2 \sim \frac{3G_F}{4\pi^2\sqrt{2}}\Lambda^2(4m_t^2 - 2m_W^2 - m_Z^2 - m_H^2)$$

implies $\Lambda \sim 500\ \mathrm{GeV}$

- no new physics (yet) implies it is wrong? Maybe but it works in other cases...

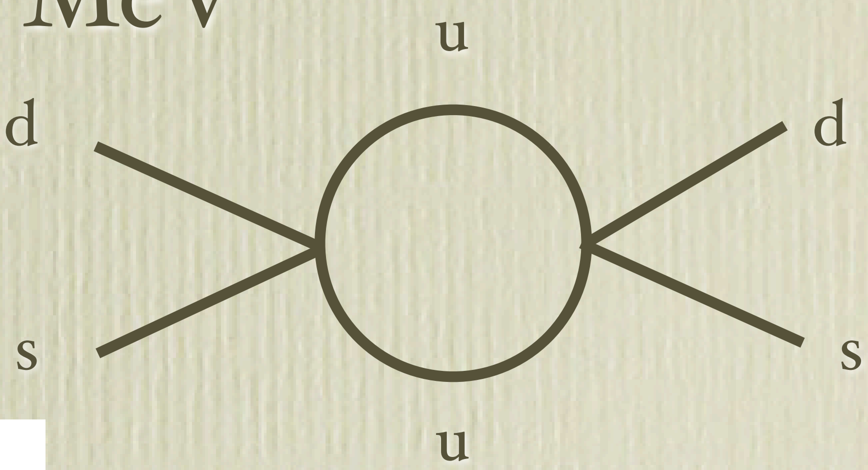
and it works...



- QED pion mass difference

$$\frac{3\alpha}{4\pi}\Lambda^2 < M_{\pi^+}^2 - M_{\pi^0}^2 \quad \rightarrow \quad \Lambda \sim 850 \text{ MeV}$$

new physics: ρ mass at 770 MeV



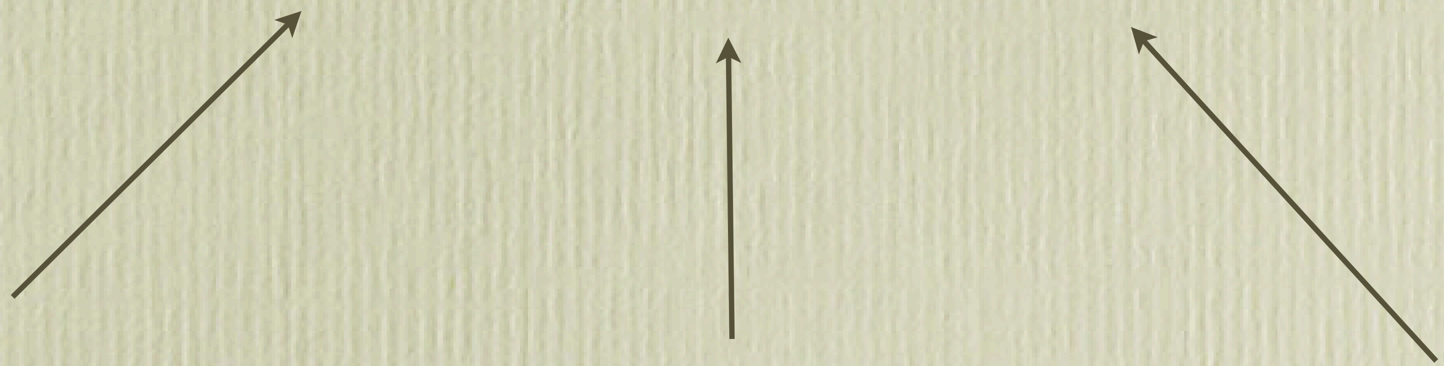
- Neutral kaons mass difference

$$\frac{G_F^2 f_K^2 \sin^2\theta_c}{6\pi^2}\Lambda^2 < \frac{M_{K_L^0} - M_{K_S^0}}{M_{K_L^0}} \quad \rightarrow \quad \Lambda \sim 2 \text{ GeV}$$

new physics: charm quark mass at 1.3 GeV

More general question... if fundamental scalar sector

$$V = \text{constant} + M_H^2|H|^2 + \lambda|H|^4$$



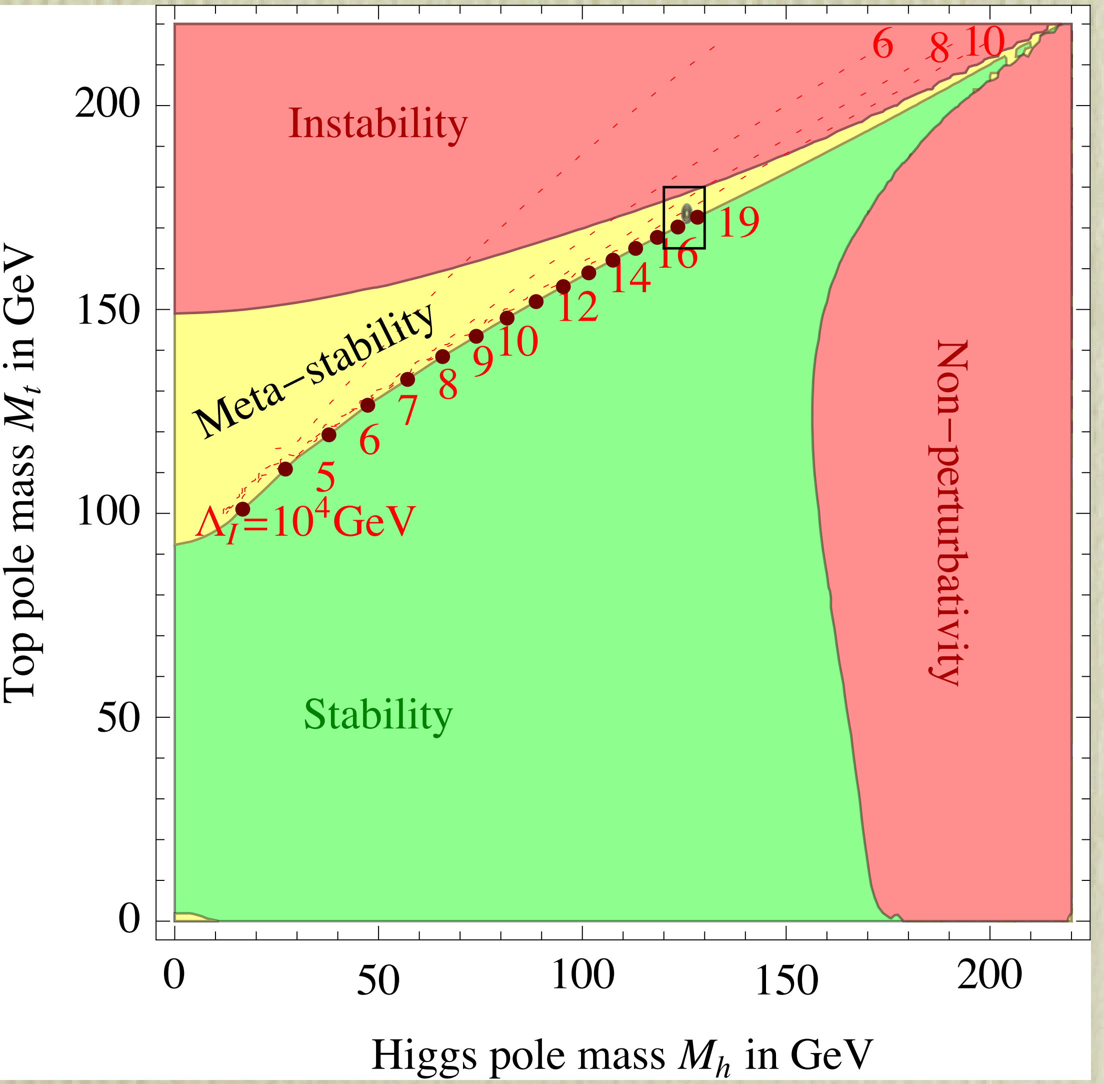
Cosmological constant

Naturalness

Stability

Stability/criticality

- measurement of m_t, m_h allows to “wildly” extrapolate up to 15 orders of magnitude:



Why close to instability?

- not a nonsense as true even at low scale
- maybe not tuned, due to a model?

from 1307.3536

Matter parities

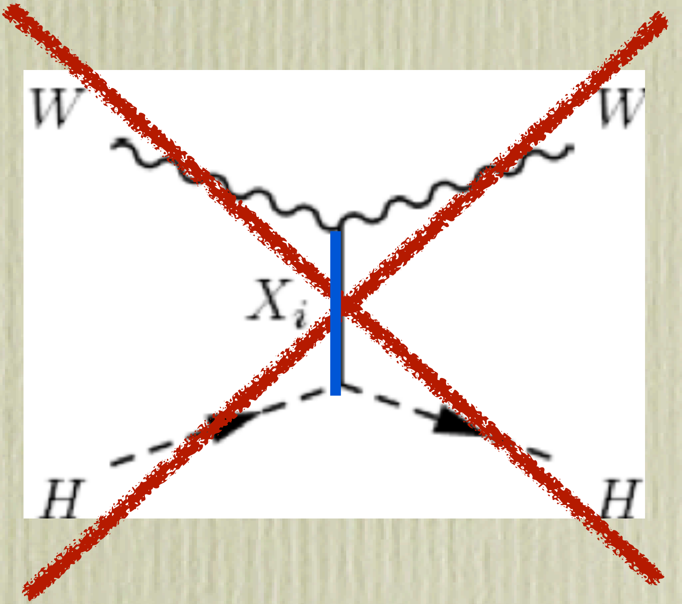
- Many models share a common ingredient: a Matter parity, M-parity, for the new particles X_A, X_B ... or more generally a new global symmetry
- Often known as R-, T-, KK- parity
- Not fundamental, but rather ad hoc
- decay by pairs if initial particles are SM (as M-neutral)
- cannot be resonantly produced
- the lightest M-parity particle is stable (LMP)
- MET (large) at colliders
- once X_i produced (may cascade) decay to X_{LMP}

A well known example is SUSY phenomenology

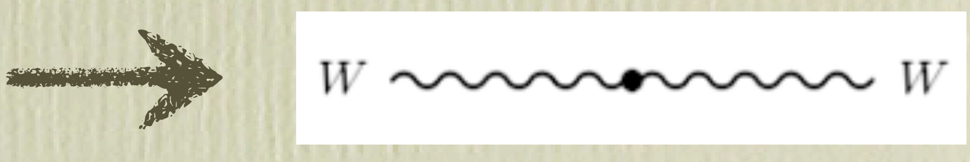
Matter parities and quantum corrections

- corrections to electroweak precision measurements are typically small, just ad-hoc parity or something more fundamental?

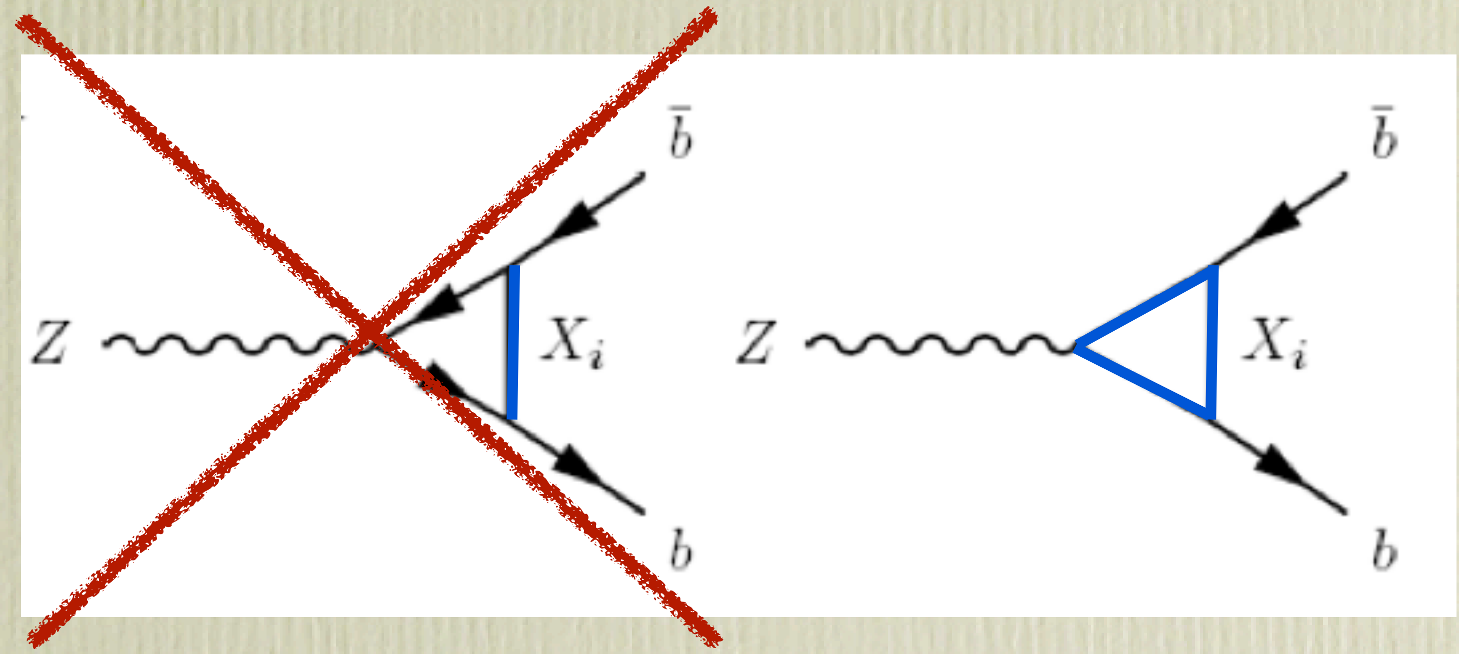
Higher dim. operators are suppressed:



W mass correction



Suppression of loops by a heavy mass :



Typical BSM models under test

- Supersymmetry
- Technicolor/Composite
- Extra dimensions

Supersymmetry

- hierarchy problem
- unification of gauge couplings
- dark matter candidate
- unification with gravity
- essential ingredient in string/brane

MSSM

- MSSM has tuning (direct search limit and H mass & couplings constraints)

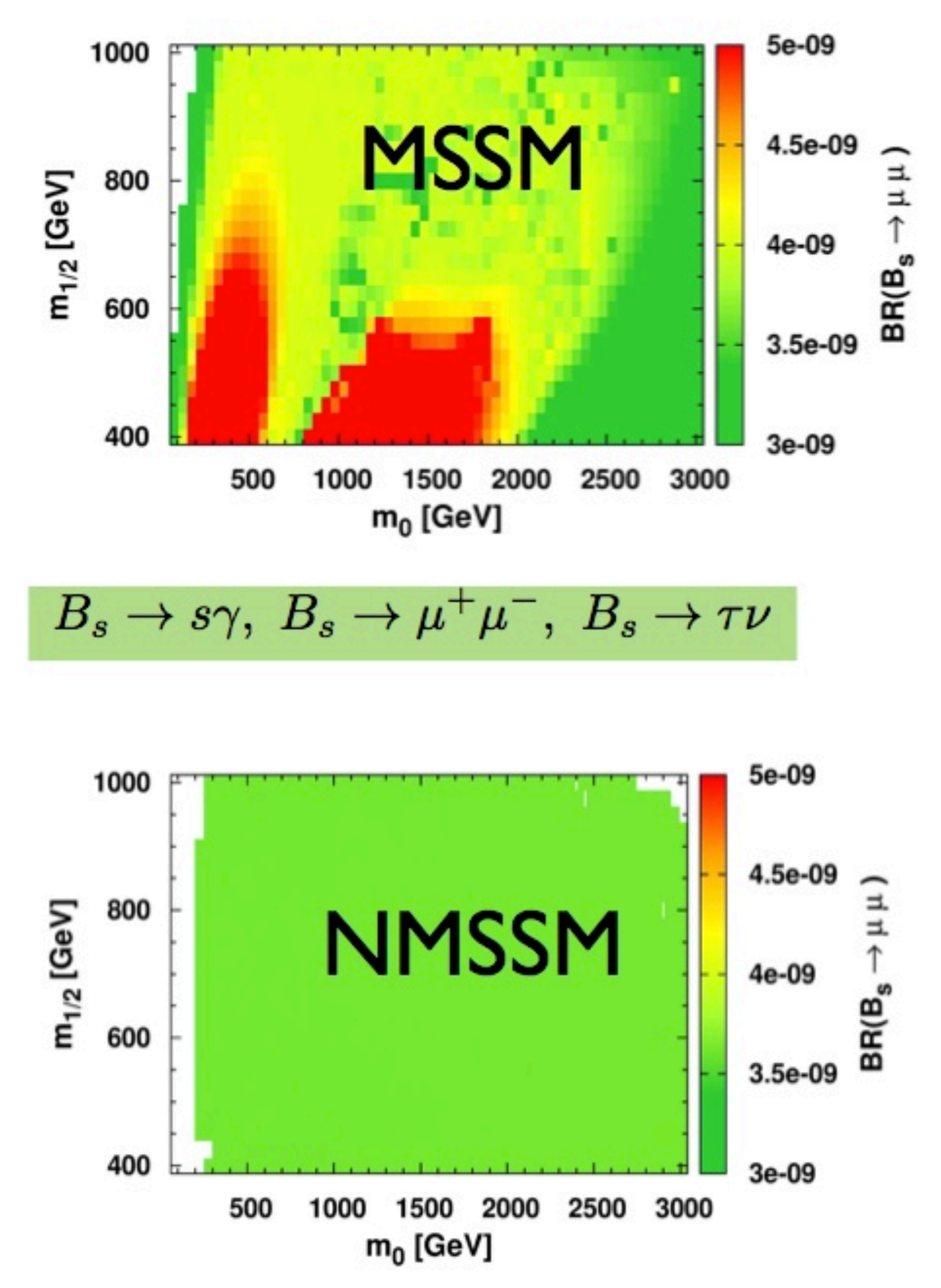
$$\begin{aligned} m_H^2 &= m_Z^2 \cos^2 2\beta + \Delta m_H^2 \\ \Delta m_H^2 &= \frac{3m_t^4}{4\pi^2 v^2}\left[\log\frac{M_S^2}{m_t^2}\left(1-\frac{X_t^2}{12M_S^2}\right)\right] \geq 87 \text{ GeV} \end{aligned}$$

$$X_t = A_t - \mu \cot\beta \qquad M_S^2 = m_{\tilde{t}_1} m_{\tilde{t}_2}$$

maximal mixing

heavy stops, fine tuning O(1%)

more general low scale SUSY



$B_s \to s\gamma,\ B_s \to \mu^+\mu^-,\ B_s \to \tau\nu$

- not limited to artificially very constrained models (mSUGRA, mGMSB, mAMSB, etc.)
- example NMSSM in much better shape than MSSM
- however λ-SUSY (large coupling λ SH_uH_d case of NSSM) partially ruled out, see 1310.0459

from D.Kazakov Morion 13

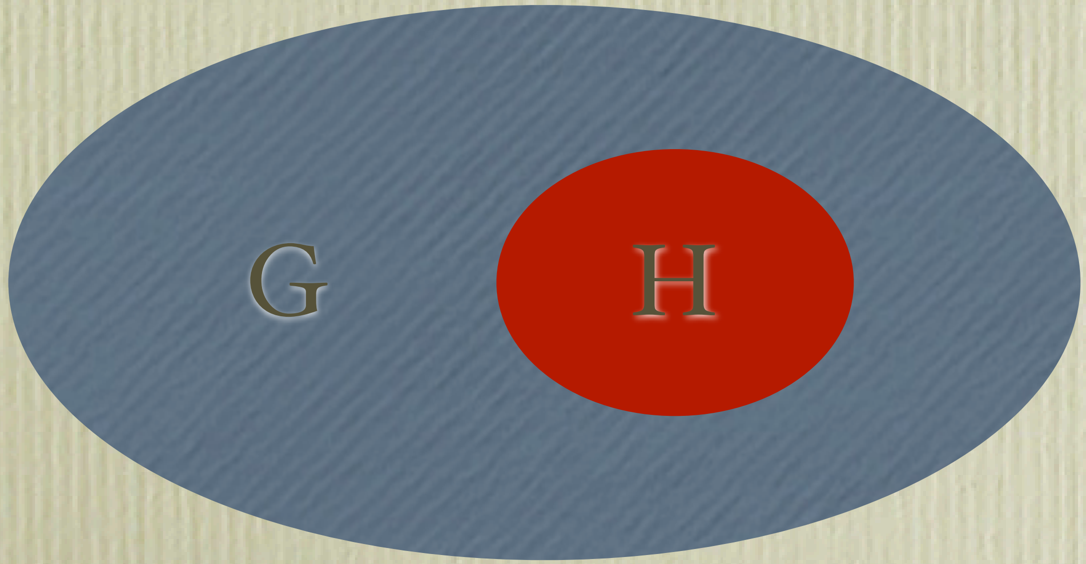
Compositness/Technicolor

- “Composite” models used today in the effective theory meaning
- “Technicolor” used typically for fundamental fermions forming bound states
- naively the S parameter $\approx 4\pi(v/m_\varrho)^2$ implies $m_\varrho \approx 3$ TeV
- The lighter the composites, more they affect Higgs couplings

Composite effective theories

- The Higgs can be a Goldstone boson (massless in the symmetry limit) of a global symmetry
- coset G/H → # Goldstones = dim[G]-dim[H]
  SM ∈ H

Georgi, Kaplan 1980
Arkani-Hamed, Cohen,Georgi 2001
Little Higgs, deconstruction



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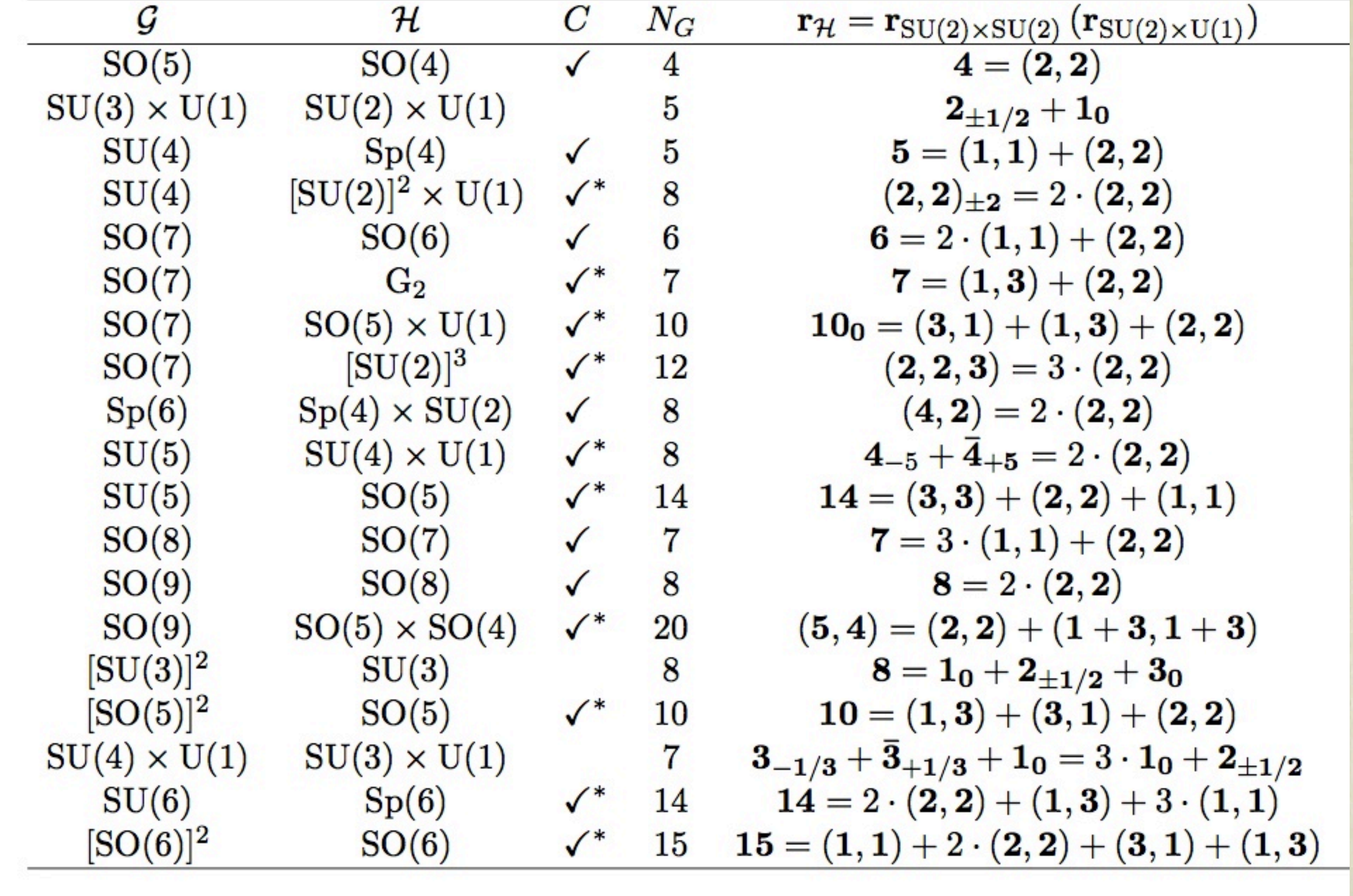
Composite effective theories



$\mathcal{G}$	$\mathcal{H}$	C	N_G	$\mathbf{r}_{\mathcal{H}} = \mathbf{r}_{\mathrm{SU(2)\times SU(2)}}$ $(\mathbf{r}_{\mathrm{SU(2)\times U(1)}})$
$\mathrm{SO(5)}$	$\mathrm{SO(4)}$	✓	4	$\mathbf{4} = (\mathbf{2}, \mathbf{2})$
$\mathrm{SU(3)} \times \mathrm{U(1)}$	$\mathrm{SU(2)} \times \mathrm{U(1)}$		5	$\mathbf{2}_{\pm 1/2} + \mathbf{1}_0$
$\mathrm{SU(4)}$	$\mathrm{Sp(4)}$	✓	5	$\mathbf{5} = (\mathbf{1}, \mathbf{1}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SU(4)}$	$[\mathrm{SU(2)}]^2 \times \mathrm{U(1)}$	✓*	8	$(\mathbf{2}, \mathbf{2})_{\pm 2} = 2 \cdot (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(7)}$	$\mathrm{SO(6)}$	✓	6	$\mathbf{6} = 2 \cdot (\mathbf{1}, \mathbf{1}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(7)}$	G_2	✓*	7	$\mathbf{7} = (\mathbf{1}, \mathbf{3}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(7)}$	$\mathrm{SO(5)} \times \mathrm{U(1)}$	✓*	10	$\mathbf{10}_0 = (\mathbf{3}, \mathbf{1}) + (\mathbf{1}, \mathbf{3}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(7)}$	$[\mathrm{SU(2)}]^3$	✓*	12	$(\mathbf{2}, \mathbf{2}, \mathbf{3}) = 3 \cdot (\mathbf{2}, \mathbf{2})$
$\mathrm{Sp(6)}$	$\mathrm{Sp(4)} \times \mathrm{SU(2)}$	✓	8	$(\mathbf{4}, \mathbf{2}) = 2 \cdot (\mathbf{2}, \mathbf{2})$
$\mathrm{SU(5)}$	$\mathrm{SU(4)} \times \mathrm{U(1)}$	✓*	8	$\mathbf{4}_{-5} + \bar{\mathbf{4}}_{+5} = 2 \cdot (\mathbf{2}, \mathbf{2})$
$\mathrm{SU(5)}$	$\mathrm{SO(5)}$	✓*	14	$\mathbf{14} = (\mathbf{3}, \mathbf{3}) + (\mathbf{2}, \mathbf{2}) + (\mathbf{1}, \mathbf{1})$
$\mathrm{SO(8)}$	$\mathrm{SO(7)}$	✓	7	$\mathbf{7} = 3 \cdot (\mathbf{1}, \mathbf{1}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(9)}$	$\mathrm{SO(8)}$	✓	8	$\mathbf{8} = 2 \cdot (\mathbf{2}, \mathbf{2})$
$\mathrm{SO(9)}$	$\mathrm{SO(5)} \times \mathrm{SO(4)}$	✓*	20	$(\mathbf{5}, \mathbf{4}) = (\mathbf{2}, \mathbf{2}) + (\mathbf{1} + \mathbf{3}, \mathbf{1} + \mathbf{3})$
$[\mathrm{SU(3)}]^2$	$\mathrm{SU(3)}$		8	$\mathbf{8} = \mathbf{1}_0 + \mathbf{2}_{\pm 1/2} + \mathbf{3}_0$
$[\mathrm{SO(5)}]^2$	$\mathrm{SO(5)}$	✓*	10	$\mathbf{10} = (\mathbf{1}, \mathbf{3}) + (\mathbf{3}, \mathbf{1}) + (\mathbf{2}, \mathbf{2})$
$\mathrm{SU(4)} \times \mathrm{U(1)}$	$\mathrm{SU(3)} \times \mathrm{U(1)}$		7	$\mathbf{3}_{-1/3} + \bar{\mathbf{3}}_{+1/3} + \mathbf{1}_0 = 3 \cdot \mathbf{1}_0 + \mathbf{2}_{\pm 1/2}$
$\mathrm{SU(6)}$	$\mathrm{Sp(6)}$	✓*	14	$\mathbf{14} = 2 \cdot (\mathbf{2}, \mathbf{2}) + (\mathbf{1}, \mathbf{3}) + 3 \cdot (\mathbf{1}, \mathbf{1})$
$[\mathrm{SO(6)}]^2$	$\mathrm{SO(6)}$	✓*	15	$\mathbf{15} = (\mathbf{1}, \mathbf{1}) + 2 \cdot (\mathbf{2}, \mathbf{2}) + (\mathbf{3}, \mathbf{1}) + (\mathbf{1}, \mathbf{3})$

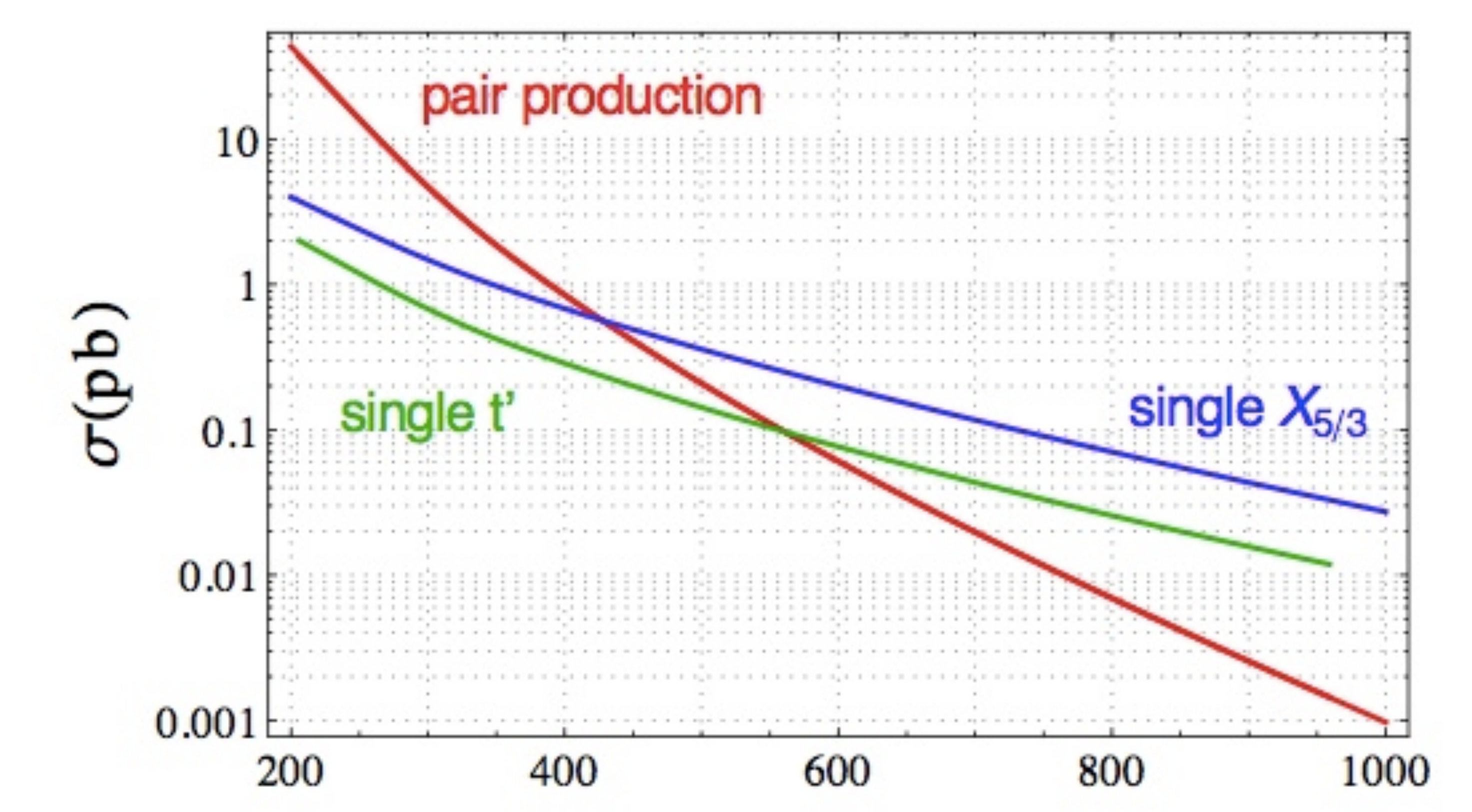
from 1401.2457 Csaki et al.

Compositness and flavour

- Extra vector-like quark multiplets often present (even exotic ones)
- Partial compositness (elementary/composite talk through mixings)
- Anarchic scenario (no hierarchies, SM ones generated by mixings of strongly composite top and elementary light quarks)
- MFV (light quarks strongly composite)

Vector-like quarks

- Unique window to test models (Xdim, composite, Little Higgs, SUSY)
- Reach at LHC substantial and only partially exploited
- Mixings with all the 3 SM generation important (production/decay)
- Single production dominant with present mass bound at LHC (~700 GeV)



see talk by
L.Panizzi

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Mixing structure

- Key assumption: new fermions interact with the SM fermions via Yukawa interactions
- The Q-numbers of the new fermions under the weak $SU(2)_L \times U(1)_Y$ gauge group are limited by interaction with the SM Higgs doublet and one of the SM fermions
- Possible Q-numbers :
- 1 SM-like singlet
- 3 doublets : 1 with SM hypercharge Y, the others Y+/-1
- 2 triplets with Y+/-1
- if more than one VL multiplet, inter-multiplet interactions and more general structure

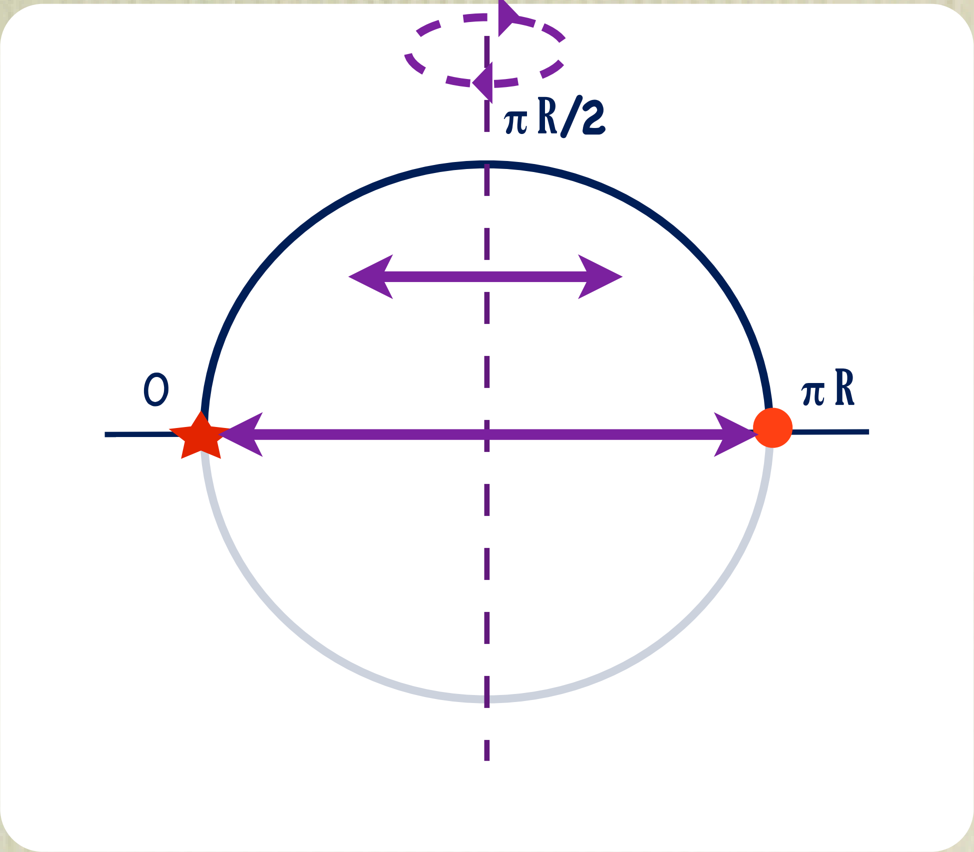
Extra dimensional models

- Typical Scenarios:
    - Large (flat) \ Warped Extra Dimensions
    - only gravity in the bulk, all SM fields in the bulk
- Issues you may explain (or describe geometrically) :
    - Weak scale stability: Gauge-Higgs unification
    - Fermion mass hierarchy, neutrino masses
    - Gauge symmetry breaking, strongly interacting conformal sector
    - Higgs composite models/technicolor

    But : non-renormalizable, often large arbitrariness (localized interactions)

Selecting Xdim models

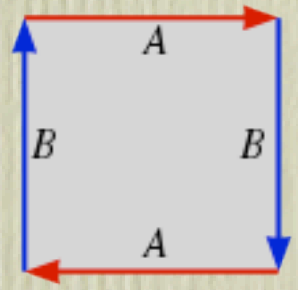
- Many models but a personal view:
  - promote (dark-)Matter parity to a fundamental orbifold symmetry
  - "natural" chiral fermions in the spectrum (no Z_N-type quotient tricks)
  - no fixed points (source of arbitrary localized interactions)

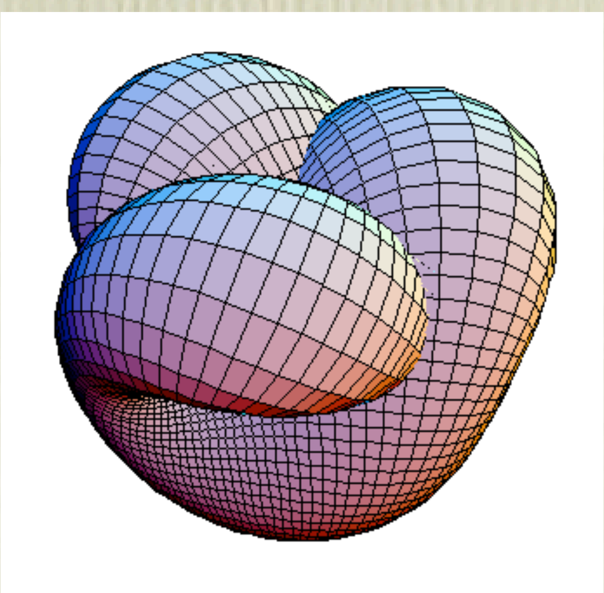


standard orbifold S^1/Z_2, KK-parity ad hoc, fixed points are not the same point!

Orbifolds without fixed points

- One flat X-dim does not have candidates with chiral fermions and no fixed points
- 2 flat X-dim has the 17 wallpaper groups in the plane
  - Only 3 have no fixed points (Torus, Klein bottle, Real Projective Plane)
  - Only 1 has moreover chiral fermions (Real Projective Plane)
  - Isometries of X^n: Noether theorem imposes selection rules

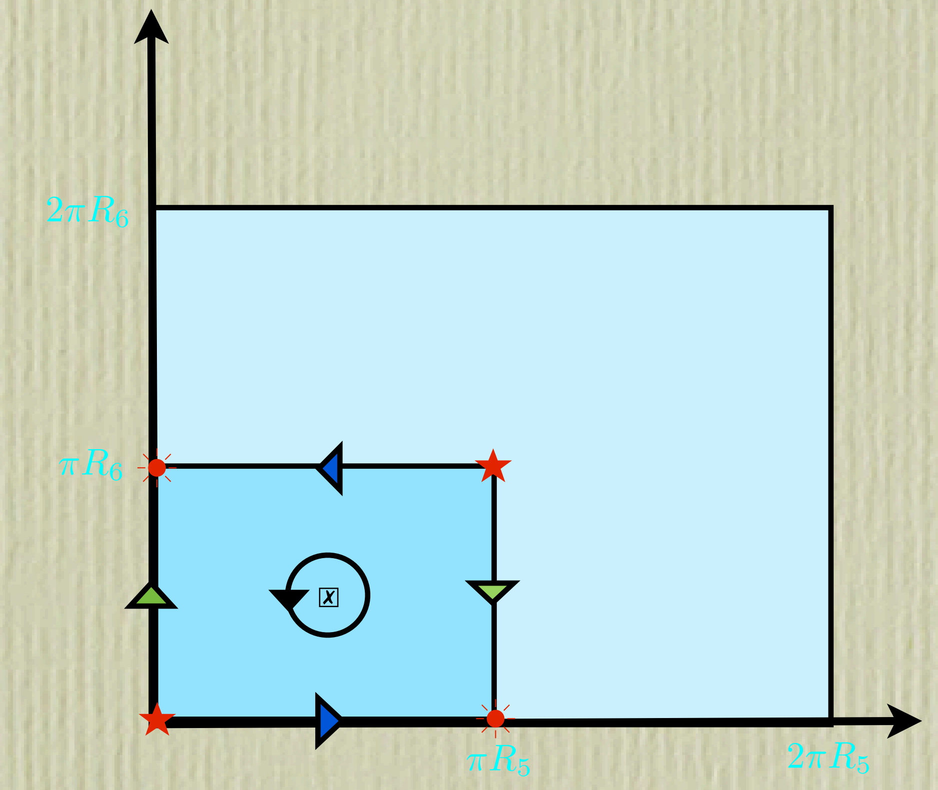




for details 0907.4993
1104.3800, 1210.0384

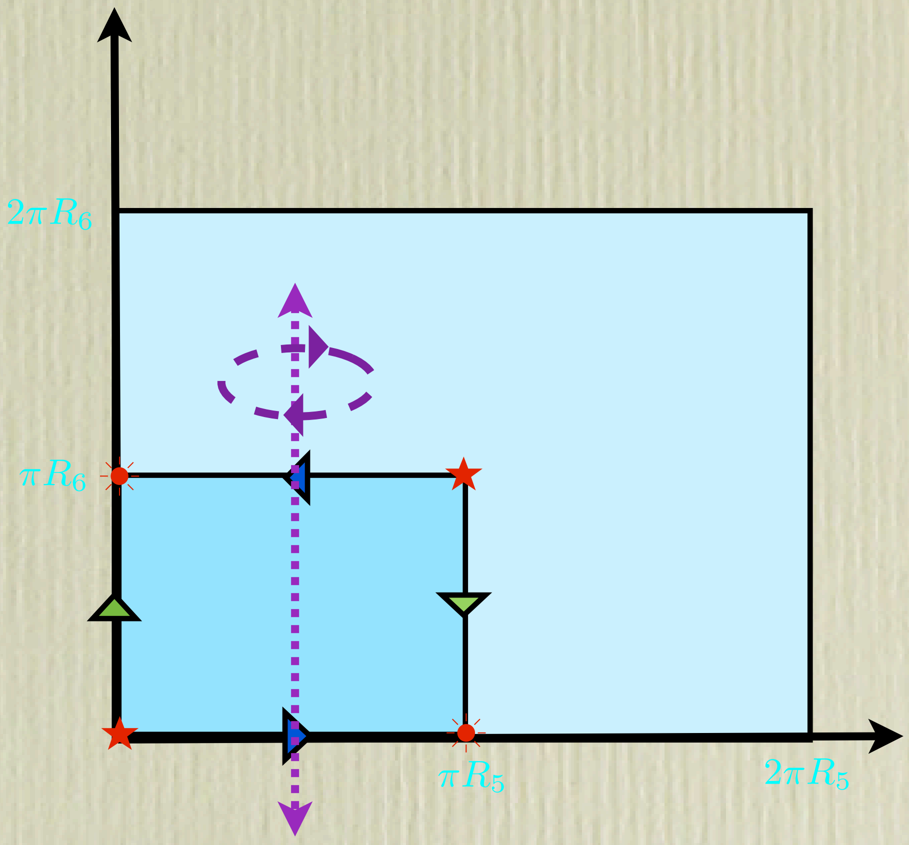
Selection rules in flat RPP

kk-modes (m,n)



$p_{kk}=(-1)^{(m+n)}$

exact symmetry



$p_{kk}=(-1)^{(m)}$

violated by localised interactions

pictures courtesy of G.Cacciapaglia

Beyond flat geometries

- RPP can be obtained from the sphere, but positive curvature implies massive eigenvalues for the Dirac operator. Extra gauge field can compensate the connection...but not than nice!

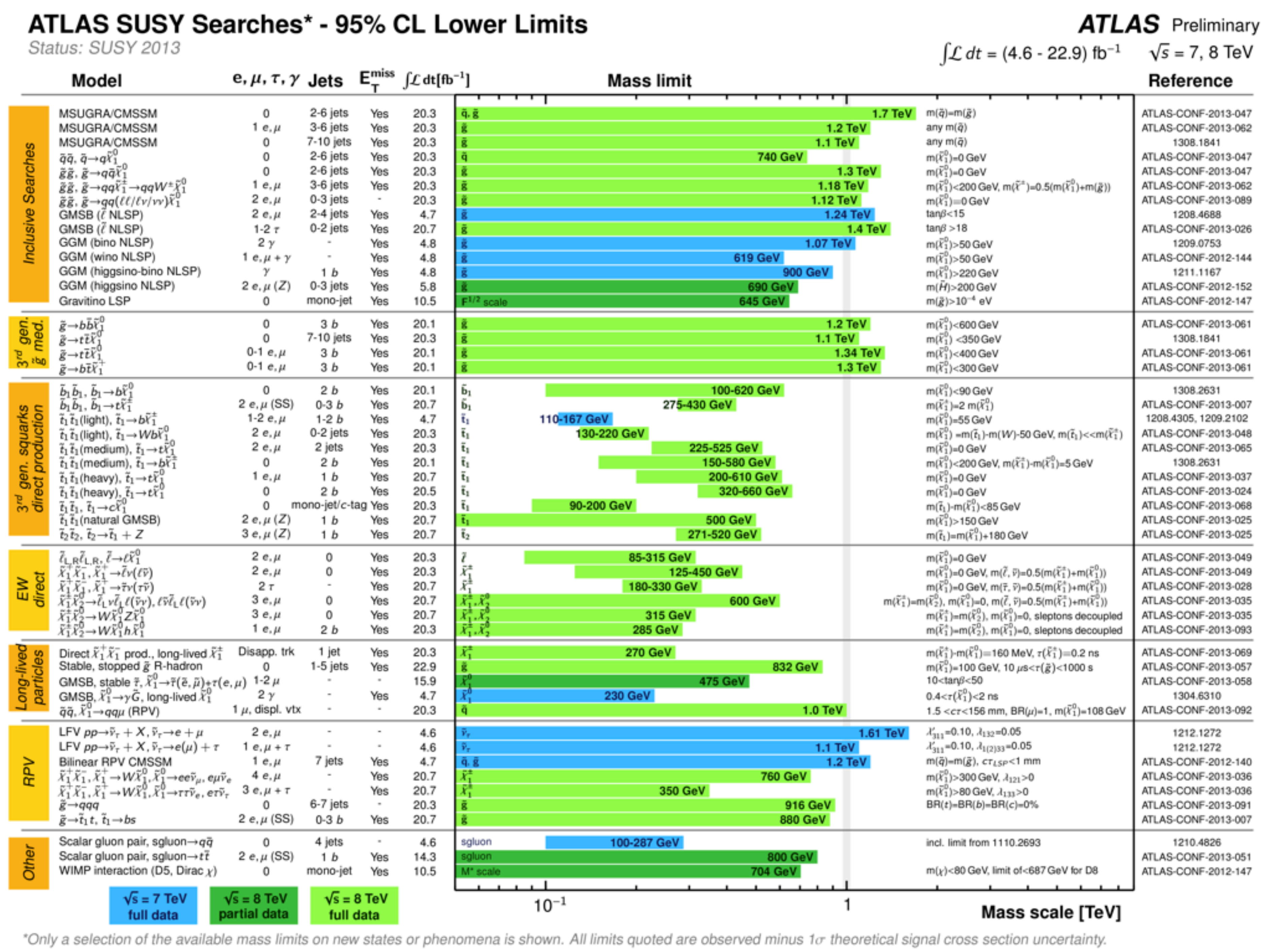
- Negative curvature more interesting (hyperbolic orbifolds $M_4 \times H^d/\Gamma$):
  - massless fermionic modes, large mass gap with KK modes
  - M_p - TeV exponential hierarchy
  - stability of the extra space (rigidity, only radion stabilization)
  - standard Friedman-Roberson-Walker cosmology

see N.Deutschmann's talk

Bump hunt at LHC

- LHC at 7-8 TeV measured the Higgs boson (remember the no-loose "theorem" either Higgs or something else?)
- LHC at 13 TeV, more uncertain discovery of new particles, but well in the TeV range for testing extensions of the EW sector, putting bounds, challenging more naturalness

Example of limits @LHC



ATLAS SUSY Searches* - 95% CL Lower Limits

Status: SUSY 2013

ATLAS Preliminary

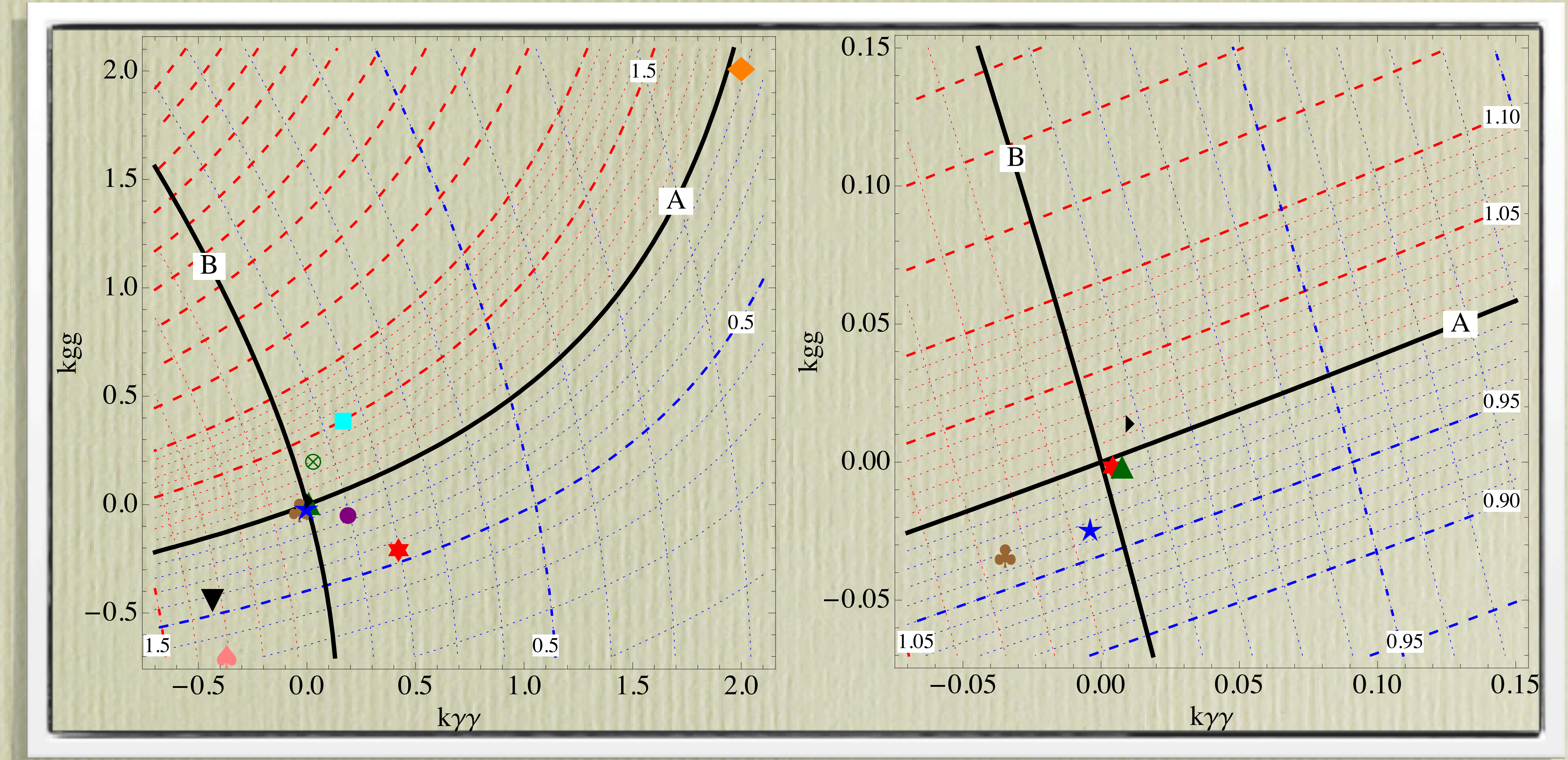
$\int\mathcal{L}\,dt = (4.6 - 22.9)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$	1.7 TeV	$m(\tilde{q})=m(\tilde{g})$	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.2 TeV	any $m(\tilde{q})$	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	any $m(\tilde{q})$	1308.1841
	$\tilde{q}\tilde{q}, \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	740 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g}, \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	1 e,μ	3-6 jets	Yes	20.3	$\tilde{g}$	1.18 TeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}^\pm)=0.5(m(\tilde{\chi}_1^0)+m(\tilde{g}))$	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g}, \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20.3	$\tilde{g}$	1.12 TeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	2 e,μ	2-4 jets	Yes	4.7	$\tilde{g}$	1.24 TeV	$\tan\beta<15$	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$	1.4 TeV	$\tan\beta>18$	ATLAS-CONF-2013-026
	GGM (bino NLSP)	2 γ	-	Yes	4.8	$\tilde{g}$	1.07 TeV	$m(\tilde{\chi}_1^0)>50$ GeV	1209.0753
	GGM (wino NLSP)	1 $e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$	619 GeV	$m(\tilde{\chi}_1^0)>50$ GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$	900 GeV	$m(\tilde{\chi}_1^0)>220$ GeV	1211.1167
	GGM (higgsino NLSP)	2 e,μ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$	690 GeV	$m(\tilde{H})>200$ GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale	645 GeV	$m(\tilde{G})>10^{-4}$ eV	ATLAS-CONF-2012-147
3^{rd} gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.2 TeV	$m(\tilde{\chi}_1^0)<600$ GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)<350$ GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)<400$ GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)<300$ GeV	ATLAS-CONF-2013-061
3^{rd} gen. squarks direct production	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)<90$ GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1\to t\tilde{\chi}_1^\pm$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$	275-430 GeV	$m(\tilde{\chi}_1^\pm)=2\,m(\tilde{\chi}_1^0)$	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$	110-167 GeV	$m(\tilde{\chi}_1^0)=55$ GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	2 e,μ	0-2 jets	Yes	20.3	$\tilde{t}_1$	130-220 GeV	$m(\tilde{\chi}_1^0)=m(\tilde{t}_1)-m(W)-50$ GeV, $m(\tilde{t}_1)<<m(\tilde{\chi}_1^\pm)$	ATLAS-CONF-2013-048
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	2 e,μ	2 jets	Yes	20.3	$\tilde{t}_1$	225-525 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-065
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)<200$ GeV, $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=5$ GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	1 e,μ	1 b	Yes	20.7	$\tilde{t}_1$	200-610 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$	320-660 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1, \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-200 GeV	$m(\tilde{t}_1)-m(\tilde{\chi}_1^0)<85$ GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	2 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_1$	500 GeV	$m(\tilde{\chi}_1^0)>150$ GeV	ATLAS-CONF-2013-025
	$\tilde{t}_2\tilde{t}_2, \tilde{t}_2\to\tilde{t}_1+Z$	3 e,μ (Z)	1 b	Yes	20.7	$\tilde{t}_2$	271-520 GeV	$m(\tilde{t}_1)=m(\tilde{\chi}_1^0)+180$ GeV	ATLAS-CONF-2013-025
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	85-315 GeV	$m(\tilde{\chi}_1^0)=0$ GeV	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm$	125-450 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-049
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	180-330 GeV	$m(\tilde{\chi}_1^0)=0$ GeV, $m(\tilde{\tau},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu), \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	600 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, $m(\tilde{\ell},\tilde{\nu})=0.5(m(\tilde{\chi}_1^\pm)+m(\tilde{\chi}_1^0))$	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	3 e,μ	0	Yes	20.7	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	315 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, sleptons decoupled	ATLAS-CONF-2013-035
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	1 e,μ	2 b	Yes	20.3	$\tilde{\chi}_1^\pm, \tilde{\chi}_2^0$	285 GeV	$m(\tilde{\chi}_1^\pm)=m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)=0$, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$	270 GeV	$m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=160$ MeV, $\tau(\tilde{\chi}_1^\pm)=0.2$ ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)=100$ GeV, 10 μs$<\tau(\tilde{g})<1000$ s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$	475 GeV	$10<\tan\beta<50$	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	4.7	$\tilde{\chi}_1^0$	230 GeV	$0.4<\tau(\tilde{\chi}_1^0)<2$ ns	1304.6310
	$\tilde{q}\tilde{q}, \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$	1.0 TeV	$1.5<c\tau<156$ mm, BR(μ)=1, $m(\tilde{\chi}_1^0)=108$ GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e+\mu$	2 e,μ	-	-	4.6	$\tilde{\nu}_\tau$	1.61 TeV	$\lambda'_{311}=0.10$, $\lambda_{132}=0.05$	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X, \tilde{\nu}_\tau\to e(\mu)+\tau$	1 $e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$	1.1 TeV	$\lambda'_{311}=0.10$, $\lambda_{1(2)33}=0.05$	1212.1272
	Bilinear RPV CMSSM	1 e,μ	7 jets	Yes	4.7	$\tilde{q},\tilde{g}$	1.2 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}<1$ mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu, e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.7	$\tilde{\chi}_1^\pm$	760 GeV	$m(\tilde{\chi}_1^0)>300$ GeV, $\lambda_{121}>0$	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^+\to W\tilde{\chi}_1^0, \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e, e\tau\tilde{\nu}_\tau$	3 $e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$	350 GeV	$m(\tilde{\chi}_1^0)>80$ GeV, $\lambda_{133}>0$	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t, \tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.7	$\tilde{g}$	880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon	100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	2 e,μ (SS)	1 b	Yes	14.3	sgluon	800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale	704 GeV	$m(\chi)<80$ GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

~ 1 TeV but read the fine prints!!! NOT general bounds

Large BSM effects only in few cases



from hep-ph 0901.0927 (in unsuspicious times...)

♦	4th	✻	Littlest Higgs	●	Warped GHU Space	★	Flat GHU
♣	SUSY gold	■	Color Octet	▼	Flat BH with Flavour	●	UED Model
▲	SLH	◣	Lee Wick SM	♠	Warped BH with Flavour		

Sort of conclusion: BSM hints?

- naive/oversimplified models are under serious attack
- Hints may hide in details... Experimental bounds should be kept as general as possible (we may overlook interesting physics)
- model building has new challenges and opportunities