New Physics: Models and Searches

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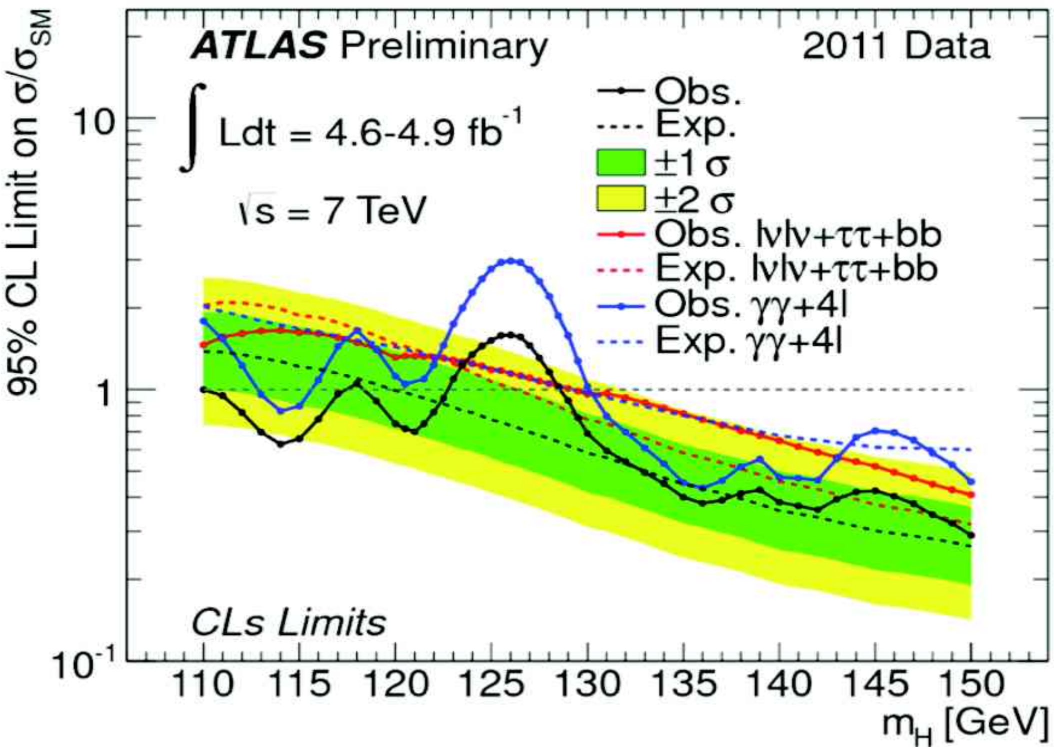
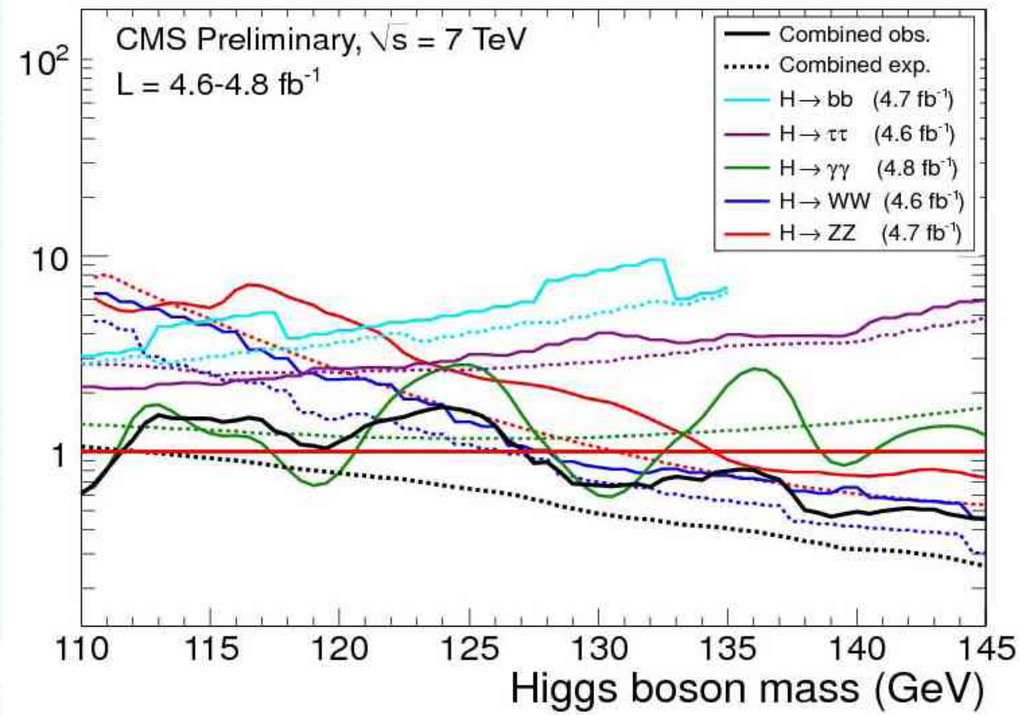
Sussex, March 14, 2012
NexT meeting

OUTLINE

- Introduction: theories and signatures
- Supersymmetry
- Higgsless models
- Models with extra dimensions
- The problem of decoding Theory from the LHC signatures
- Conclusions

News From Moriond 2012

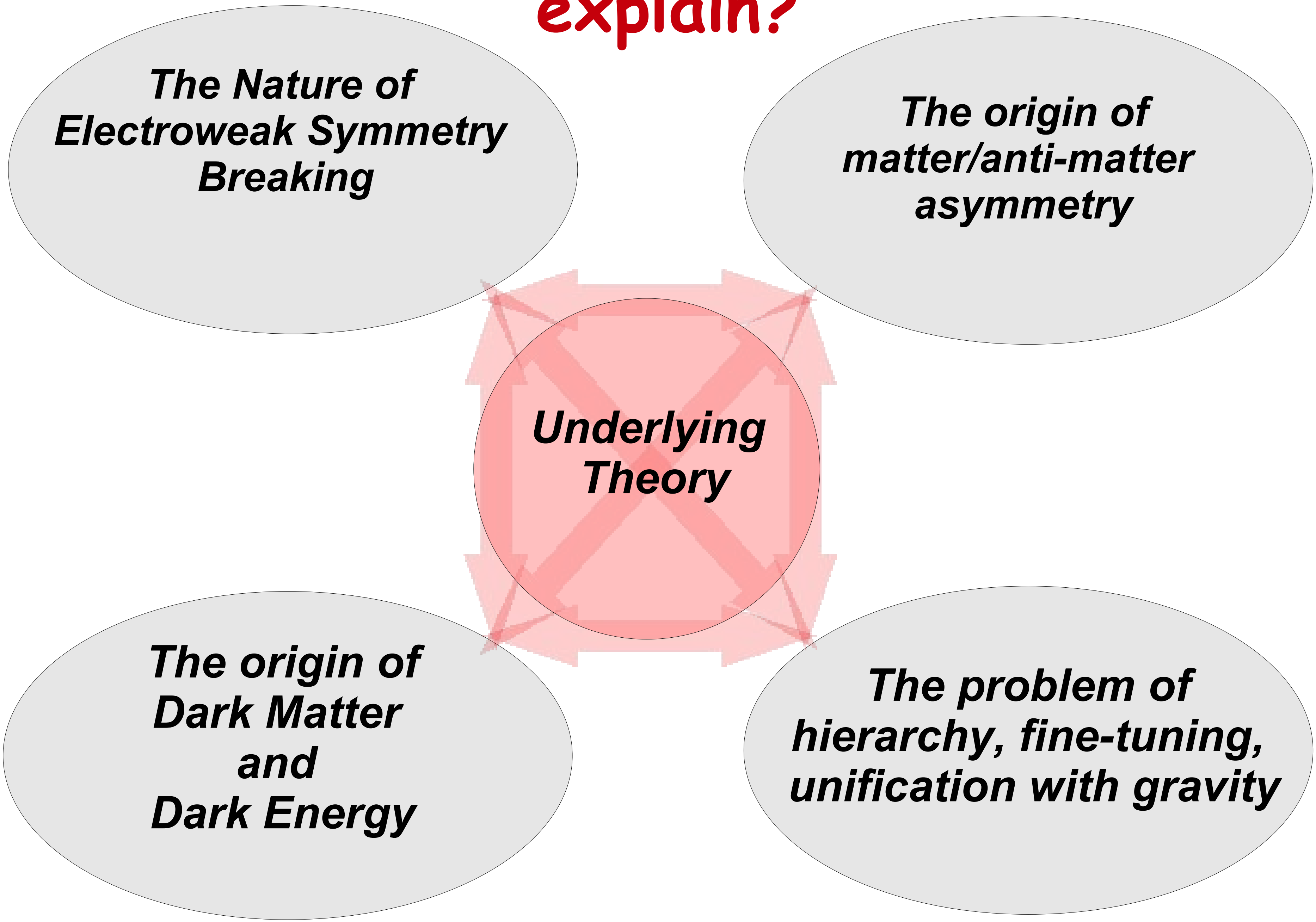




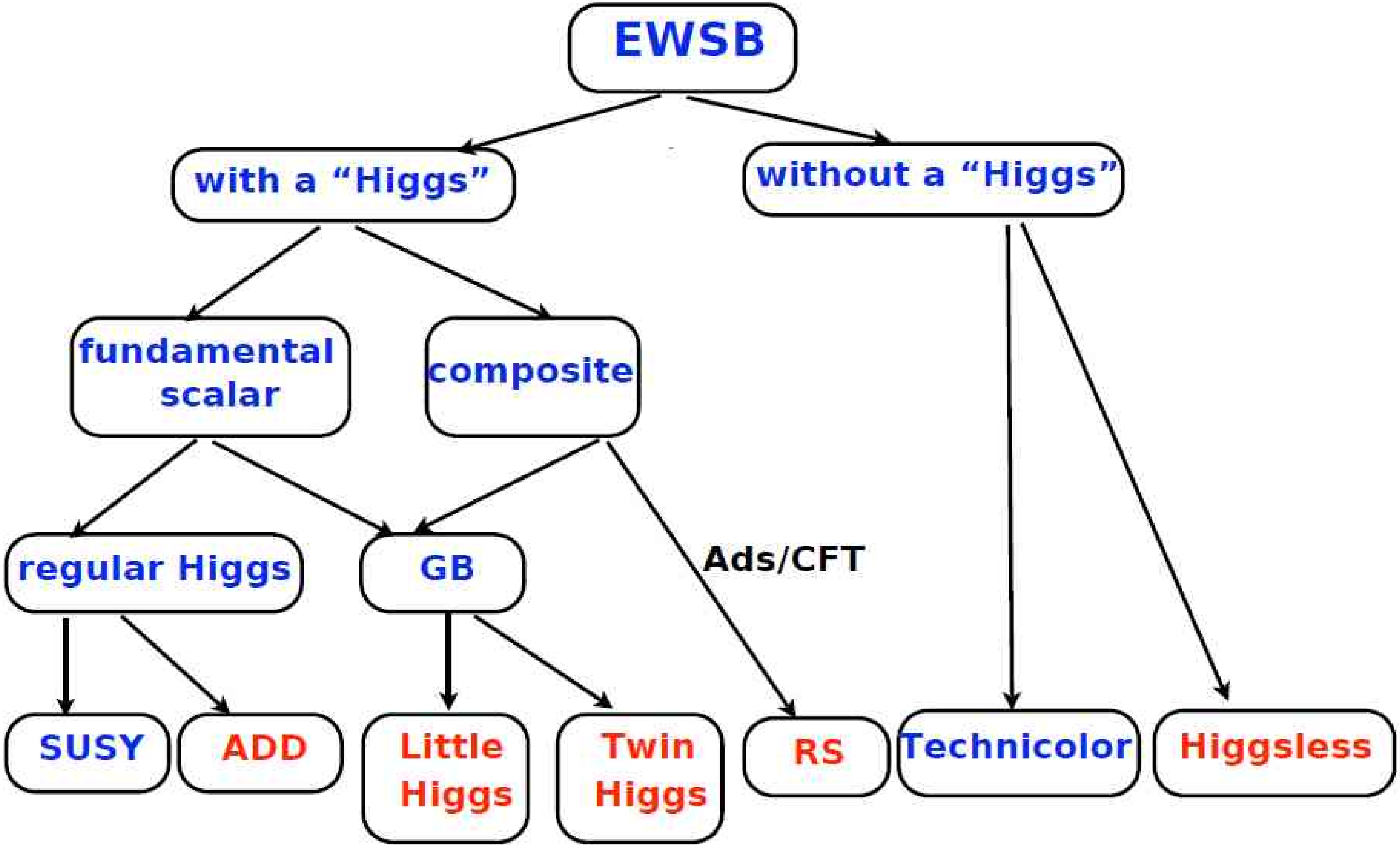
- Excess mainly in two channels $H \to ZZ^{(*)} \to 4l$ and $H \to \gamma\gamma$
  - Combined local significance is 3.4σ at 126 GeV
- No excesses in $H \to WW^{(*)} \to l\nu l\nu$ ($H \to \tau\tau$, $H \to bb$)
  - All channels combined: 2.5σ local significance

- Minimum p-value observed at 125 GeV.
- Global significance 2.1 σ [110-145] GeV (0.8 σ [110-600] GeV).
- Local significance consistent with expected signal from SM.
- Best fit cross section ~1 x SM around 125 GeV.

What do we expect from theory to explain?



Variety of theories with SEWSB



From Sufang Su

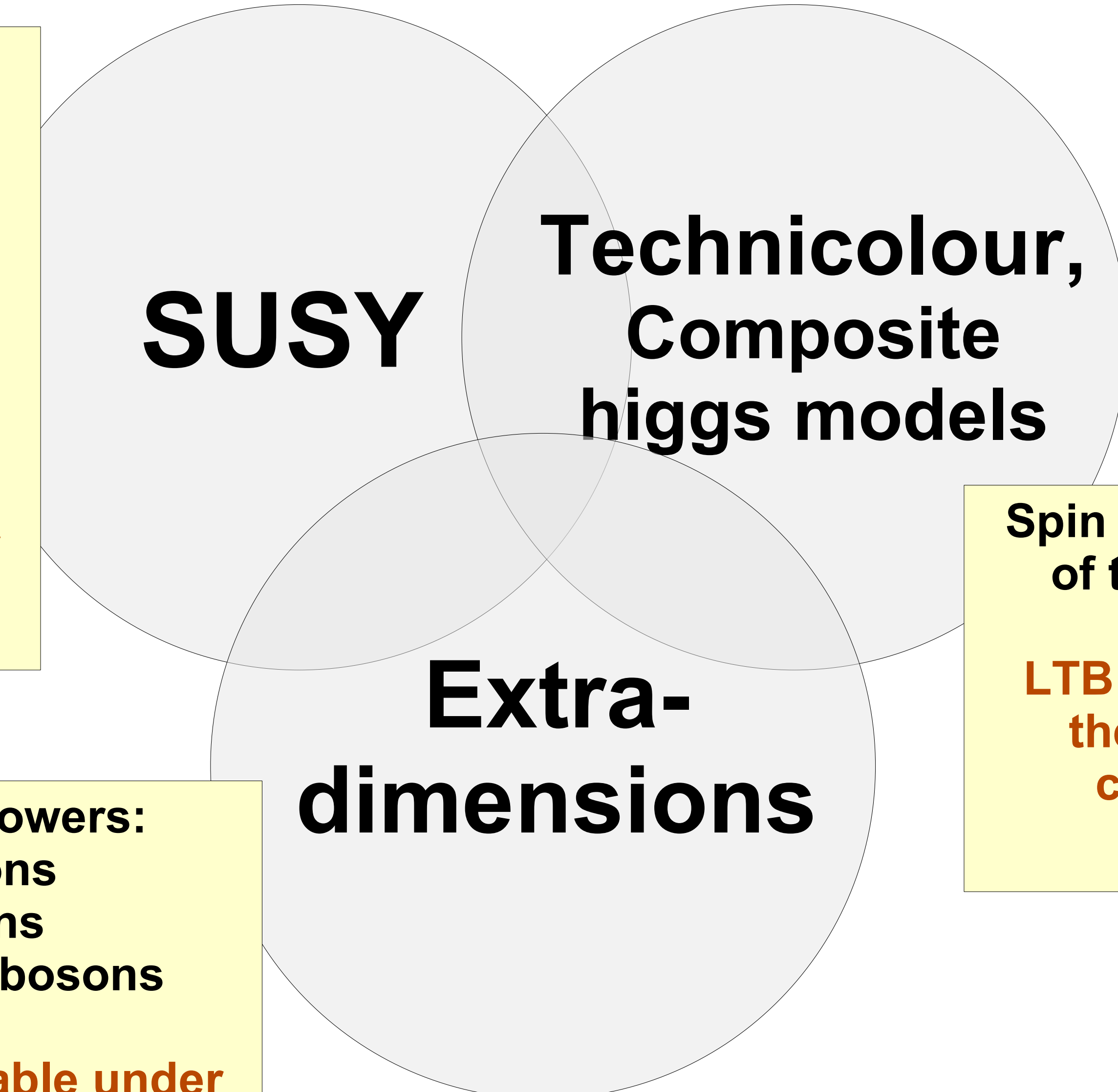
Theories and new particles

SUSY partners

New gauge bosons (USSM, E6SSM)

Exotics – diquarks, LQ (E6SSM)

LSP is stable under the R-parity



Spin 0,1 bound states of techni-quarks:

LTB is stable under the TB number conservation

KK – towers:
KK-gravitons
KK-fermions
KK-gauge bosons

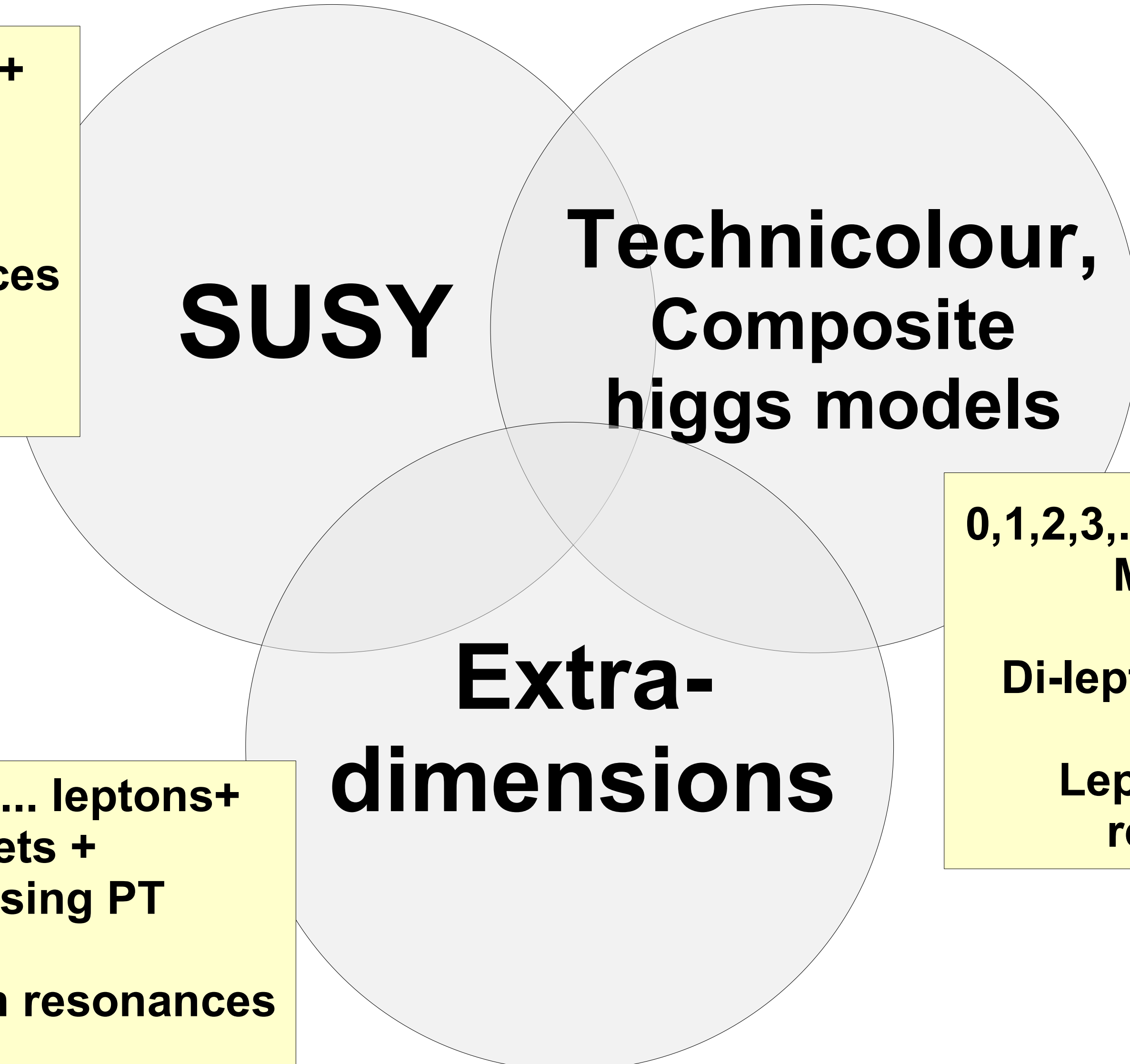
LKP is stable under the KK-parity (UED)

Theories and new signatures

0,1,2,3,... leptons+
jets +
Missing PT

Di-lepton resonances

Same-sign leptons



0,1,2,3,... leptons+ jets +
Missing PT

Di-lepton resonances

Lepton-neutrino
resonances

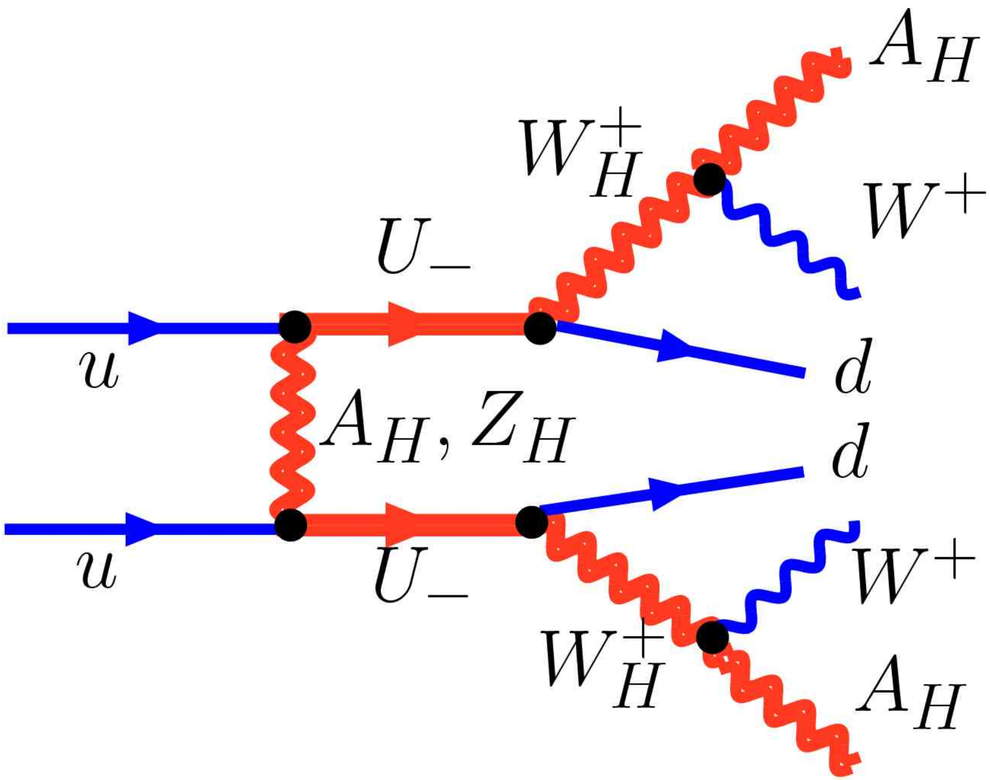
0,1,2,3,... leptons+
jets +
Missing PT

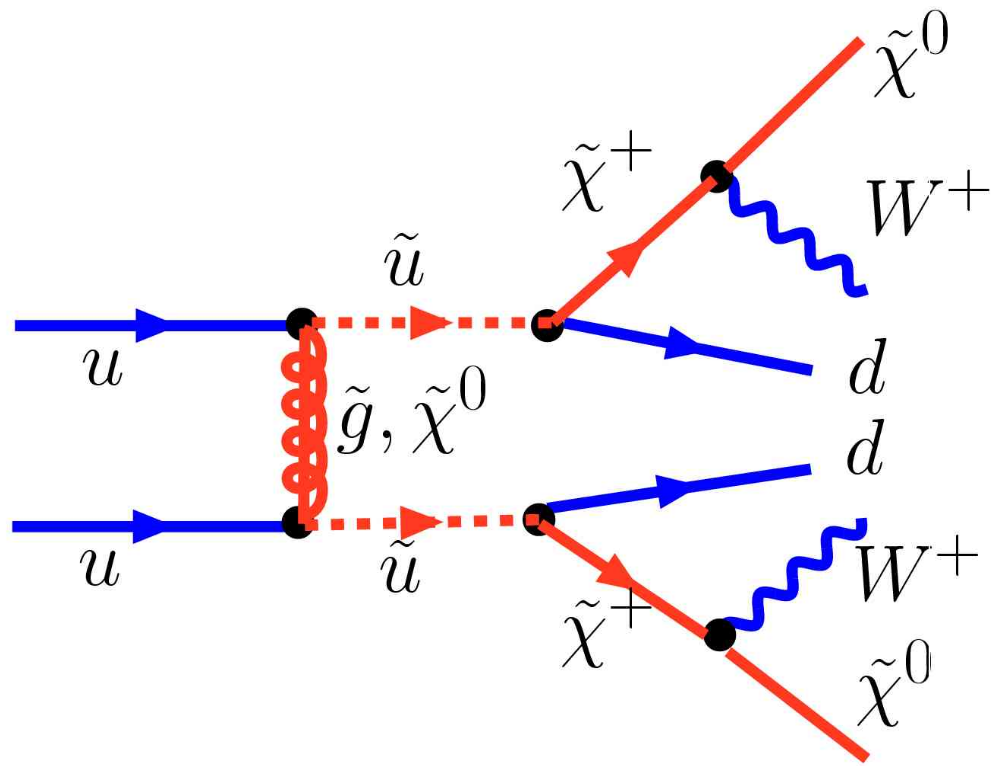
Di-lepton resonances

Same-sign leptons

Signatures can be really similar!

Signatures could look alike indeed!

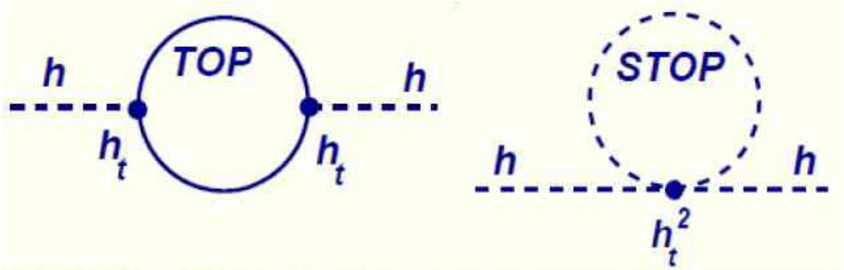




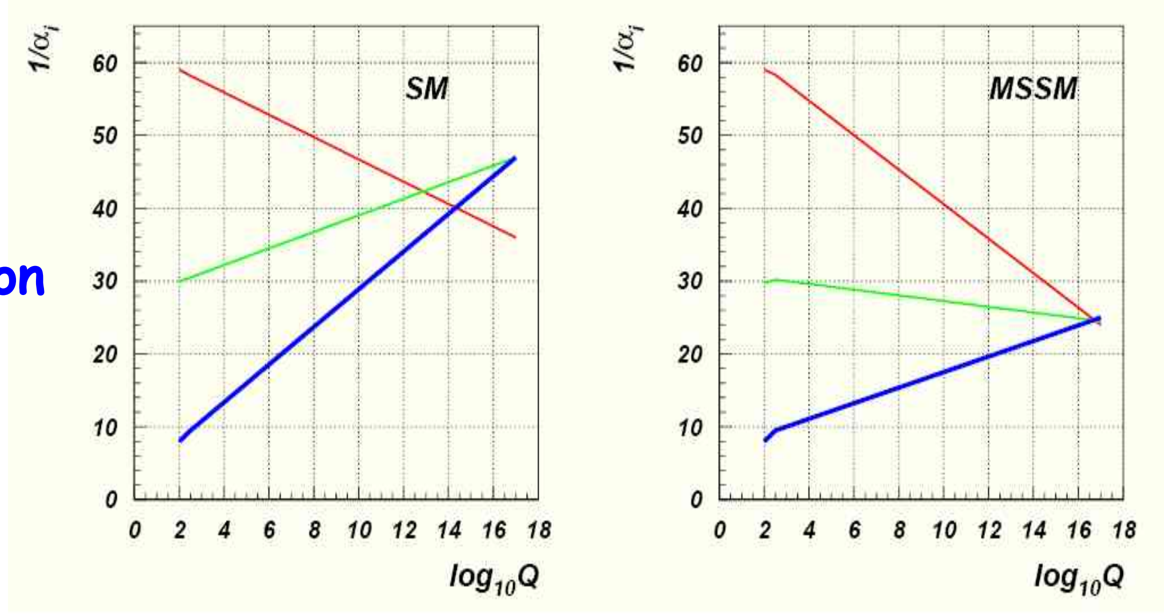
LHT, mUED **SUSY**

Supersymmetry

- Provides good DM candidate – LSP
- CP violation can be incorporated - baryogenesis via leptogenesis
- Radiative EWSB
- Solves fine-tuning problem
- Provides gauge coupling unification
- *local supersymmetry requires spin 2 boson – graviton!*
- *allows to introduce fermions into string theories*



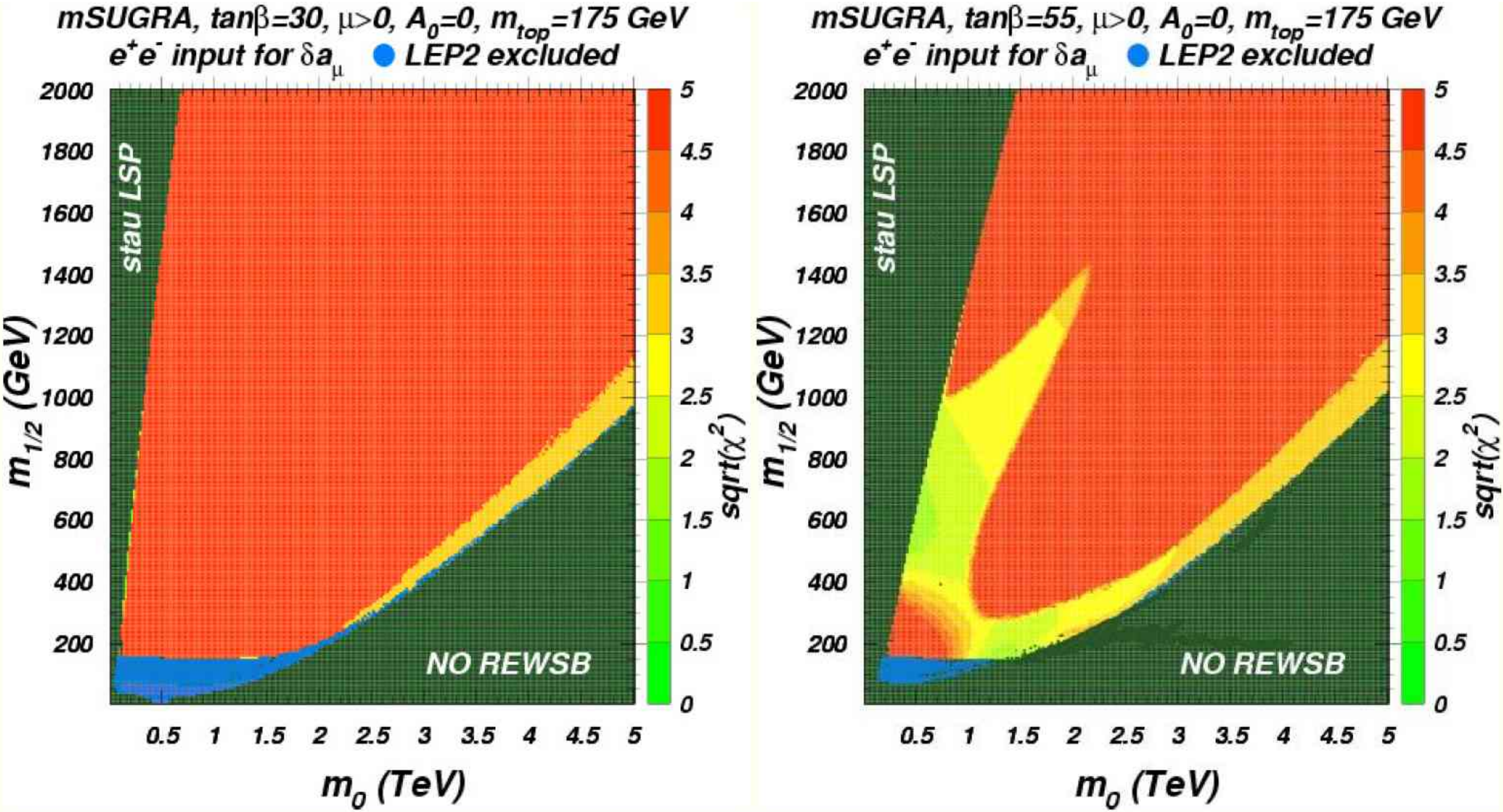
$$\Delta M_H^2 \sim M_{SUSY}^2 \log(\Lambda/M_{SUSY})$$



SUSY was not deliberately designed to solve the SM problems!

Pre LHC mSUGRA $\chi^2 = \chi^2_{\delta a_\mu} + \chi^2_{\Omega h^2} + \chi^2_{b \to s\gamma}$ analysis

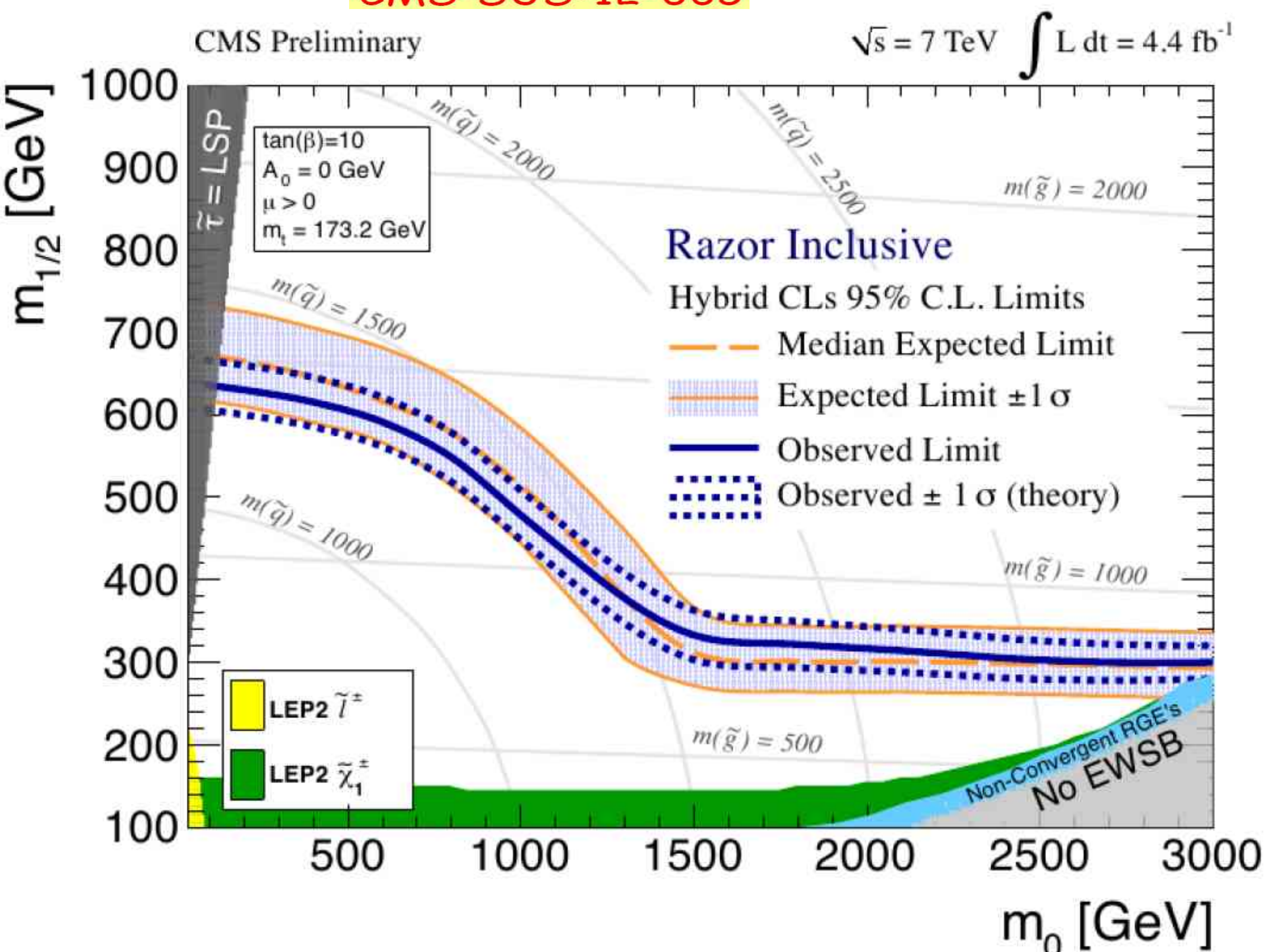
- Δa_μ favors light second generation sleptons, while $BF(b \to s\gamma)$ prefers heavy third generation: hard to realize in mSUGRA model.



Baer, A.B., Krupovnickas, Mustafayev hep-ph/0403214

Limits from LHC for mSUGRA scenario

CMS-SUS-12-005



Combination of 0,1,2 di-lepton signatures:

the razor R: for S/B discrimination

→ sensitive to the ratio of missing and visible momentum

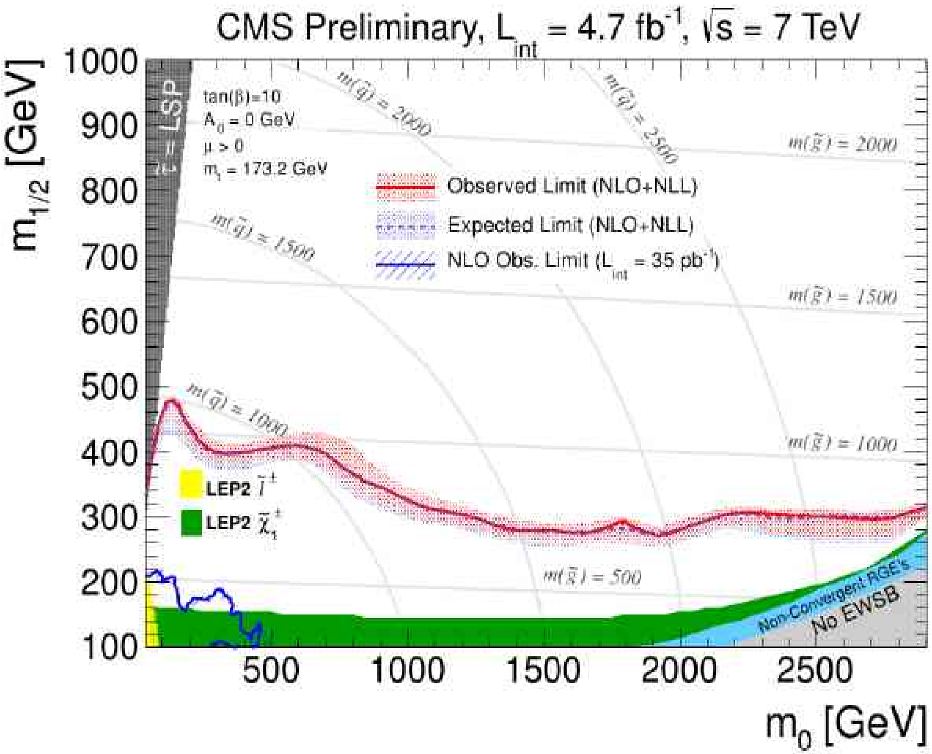
Search with Same-Sign Dileptons

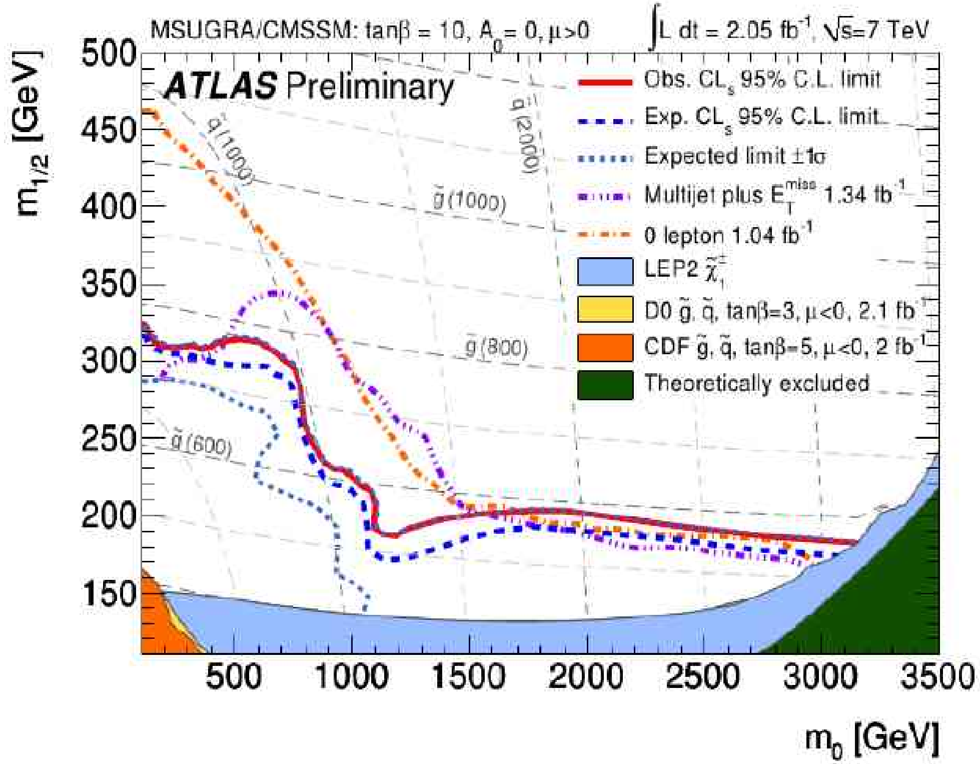
CMS-SUS-11-010

- data agrees with expected background
- results interpreted in CMSSM
  - → also: efficiency model provided for reinterpretation

ATLAS-CONF-2012-004

- 2 SS dileptons ($e^\pm$, $\mu^\pm$)
- MET > 150 GeV, 4 or more jets
- similar background estimates

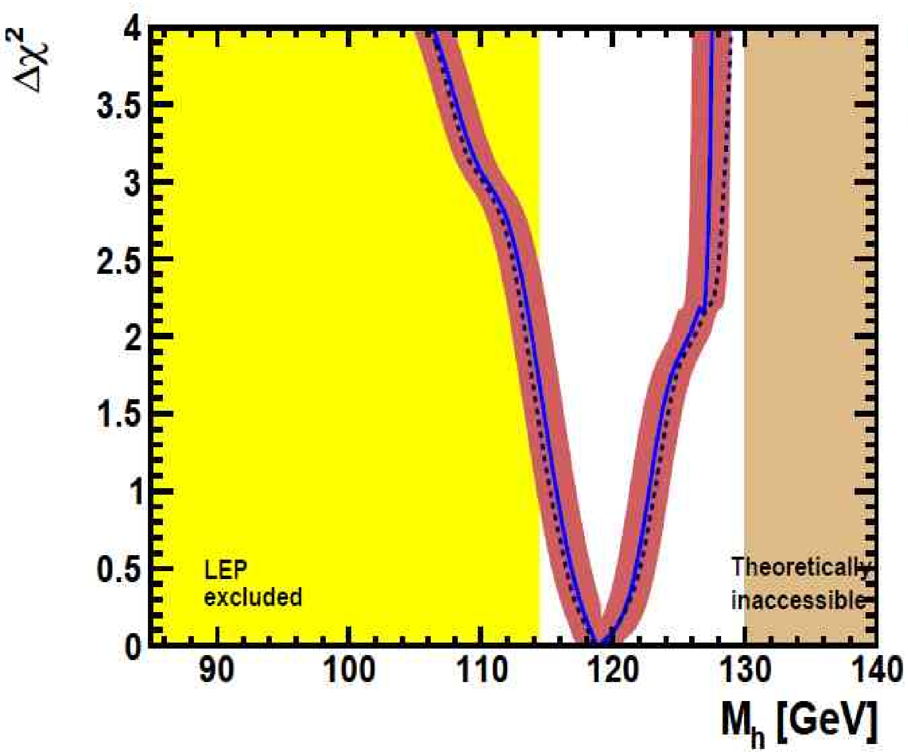


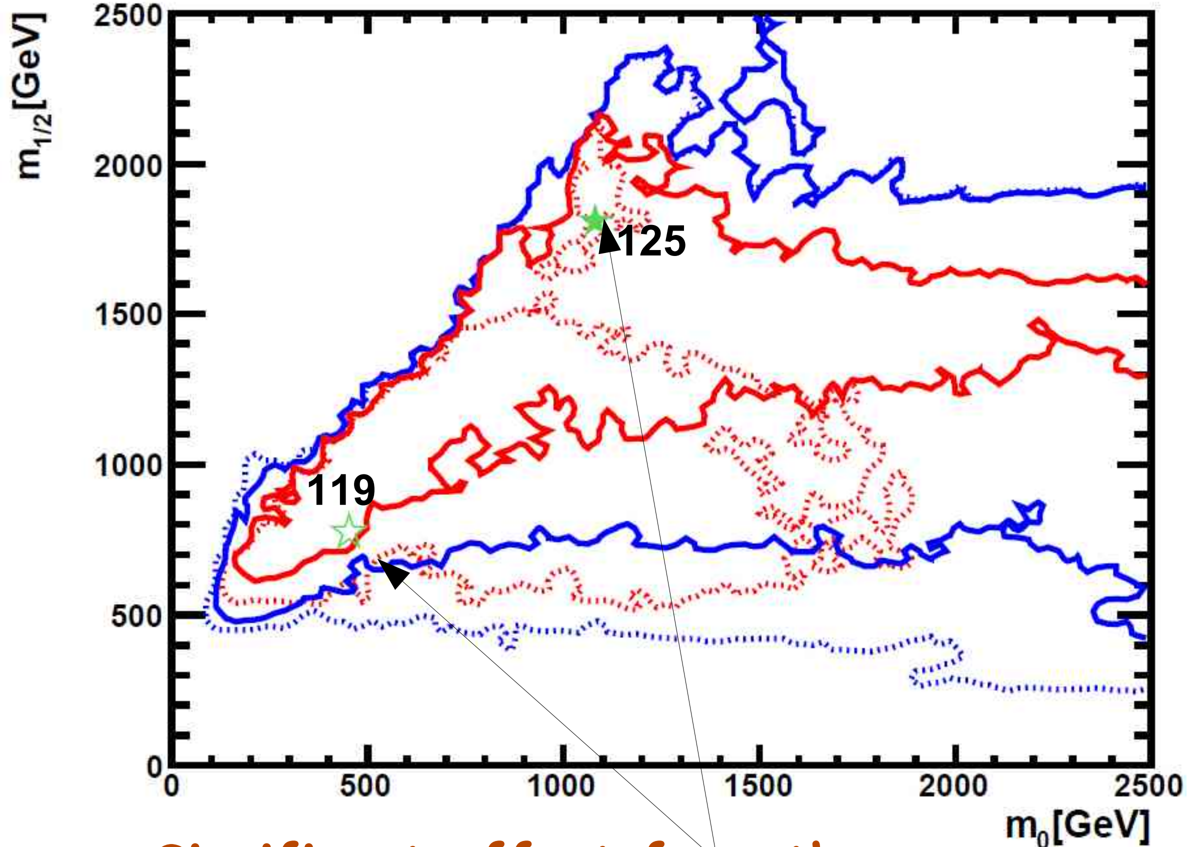


Implications of LHC search for SUSY fits

Buchmueller, Cavanaugh, De Roeck, Dolan, Ellis, Flaecher, Heinemeyer, Isidori, Marrouche, Martınez, Santos, Olive, Rogerson, Ronga, de Vries, Weiglein, arXiv:1112.3564

Global frequentist fits to the CMSSM using the MasterCode framework





Lower corners of m_0 and $m_{1/2}$ are excluded

Significant effect from the Mh=125 GeV assumption

Interpreting LHC SUSY searches in the phenomenological MSSM (pMSSM)

C.F. Berger et al., "SUSY without prejudice" arXiv:0812.0980

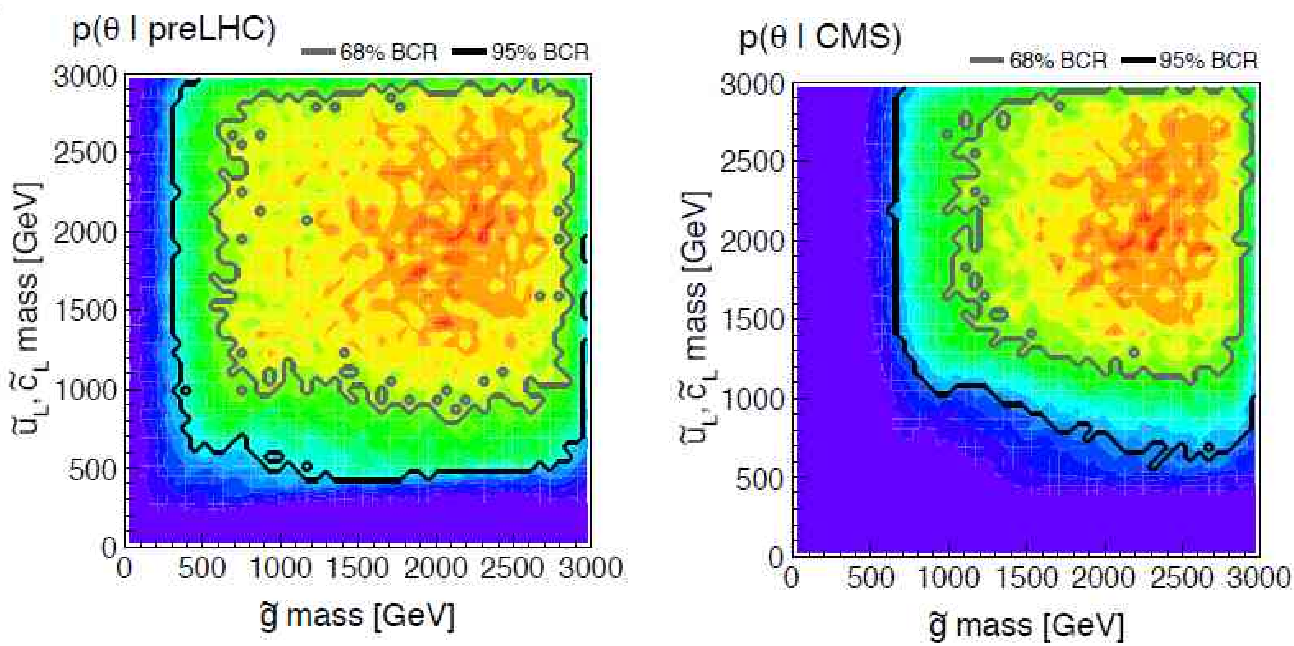
Sekmen, Kraml, Lykken, Moortgat, Padhi, Pape,Pierini, Prosper,Spiropulu, arXiv:1109.5119

The pMSSM is a 19-dimensional parametrization of the MSSM that captures most of its phenomenological features. It encompasses and goes beyond a broad range of more constrained SUSY models.

- Parameters defined at the weak scale

Assumptions: no new CP phases, flavor-diagonal sfermion mass matrices and trilinear couplings, 1st/2nd generation degenerate and A-terms negligible, lightest neutralino is the LSP.

- the gaugino mass parameters M_1, M_2, M_3;
- the ratio of the Higgs VEVs $\tan\beta = v_2/v_1$;
- the higgsino mass parameter μ and the pseudo-scalar Higgs mass m_A;
- 3 trilinear couplings A_t, A_b and A_τ
- 10 sfermion mass parameters $m_{\tilde{F}}$, where $\tilde{F} = \tilde{Q}_1, \tilde{U}_1, \tilde{D}_1, \tilde{L}_1, \tilde{E}_1, \tilde{Q}_3, \tilde{U}_3, \tilde{D}_3, \tilde{L}_3, \tilde{E}_3$ (imposing $m_{\tilde{Q}_1} \equiv m_{\tilde{Q}_2}$, $m_{\tilde{L}_1} \equiv m_{\tilde{L}_2}$, etc.),



E6SSM – as a consistent solution of the μ-problem

One of the ways to solve the μ-problem is to add $\lambda S H_u H_d$ **with** $\langle S \rangle = \frac{s}{\sqrt{2}} \sim m_{\mathrm{soft}} \sim 1\mathrm{TeV} \quad \Rightarrow \quad \mu = \frac{\lambda s}{\sqrt{2}}$

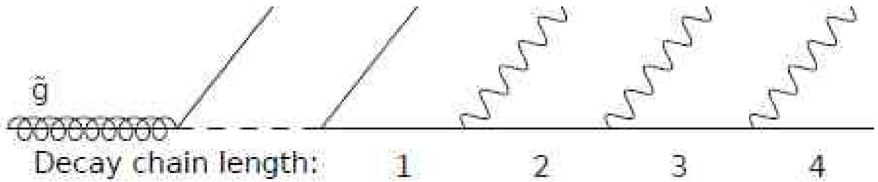
- **NMSSM:** A cubic term, S^3, is also added, breaking the U(1) down to a discrete Z_3. This could lead to cosmological domain walls and overclosure of the Universe.
- **USSM:** The U(1) is gauged and a massive Z' appear. However, the theory is not anomaly free.
- **E$_6$SSM:** The gauged U(1) is a remnant of a broken E_6. Anomaly cancellation is assured by having particles in complete **27**s of E_6 at the TeV scale.

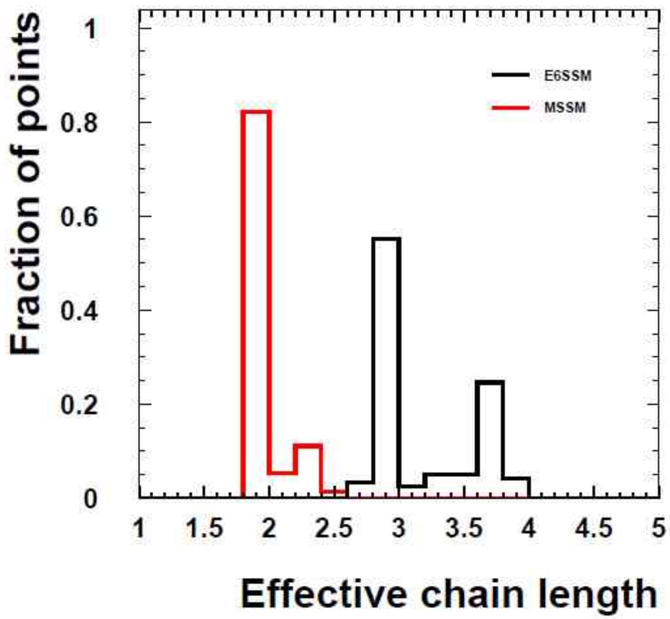
Only the third generation H_d, H_u and S get VEVs and can be identified with the MSSM (USSM) states. The first two inert generations of the Higgs sector are still important.

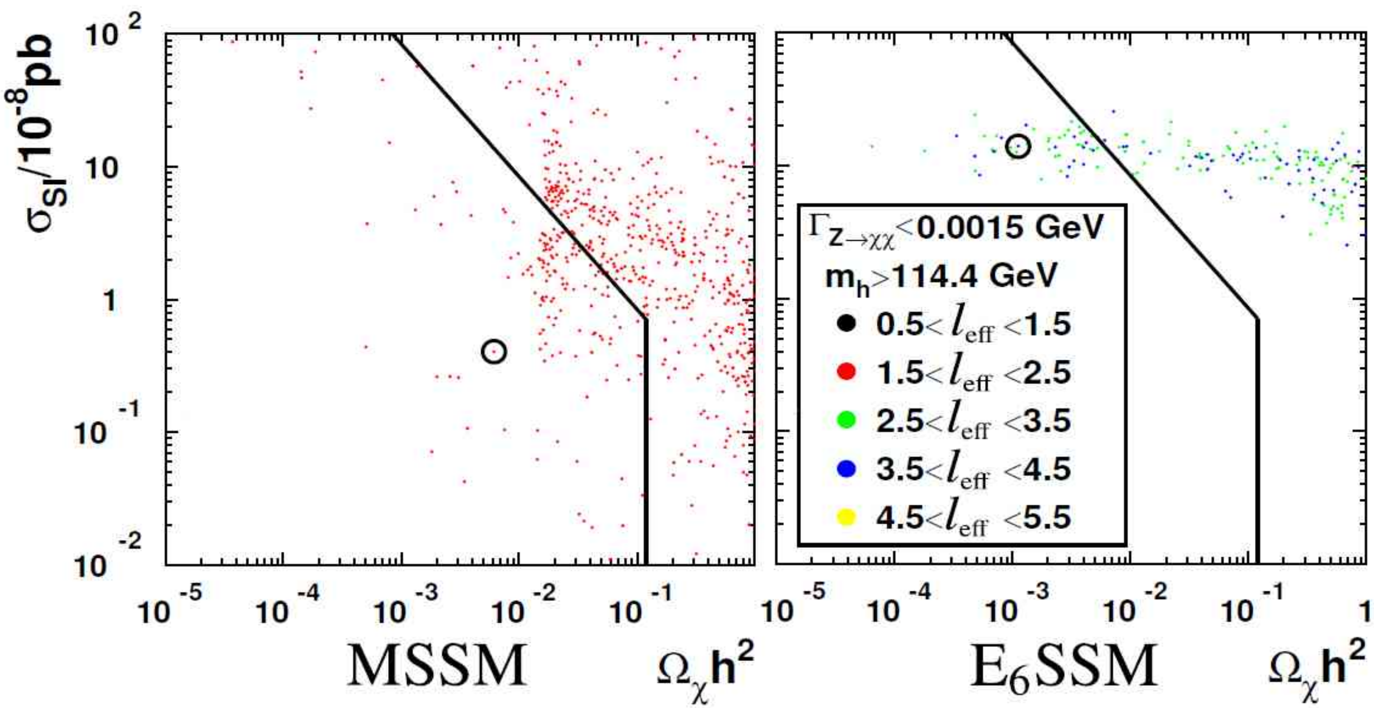
$$\tilde{\chi}^0_{\mathrm{int}} = (\underbrace{\overbrace{\tilde{B}\ \tilde{W}^3\ \tilde{H}^0_d\ \tilde{H}^0_u}_{\text{MSSM}}\ |\ \tilde{S}\ \tilde{B}'}^{\text{USSM}}\ |\ \overbrace{\tilde{H}^0_{d2}\ \tilde{H}^0_{u2}\ \tilde{S}_2\ |\ \tilde{H}^0_{d1}\ \tilde{H}^0_{u1}\ \tilde{S}_1}^{\text{inert E}_6\text{SSM states}})^T$$

King,Moretti,Nevzorov '05

Gluino decay length as a key feature of E6SSM







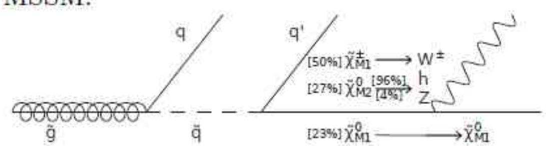
$$l_{\text{eff}} = \sum_l l \cdot P(l)$$

- The gluino as well as the bino- and wino-like states are matched between the models
- The E_6SSM has two light neutralinos below the MSSM spectrum

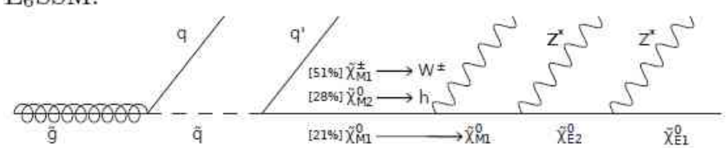
A.B., Hall, King, Svantesson arXiv:1203.2495

Difference in gluino decay length allows to distinguish E6SSM!

MSSM:

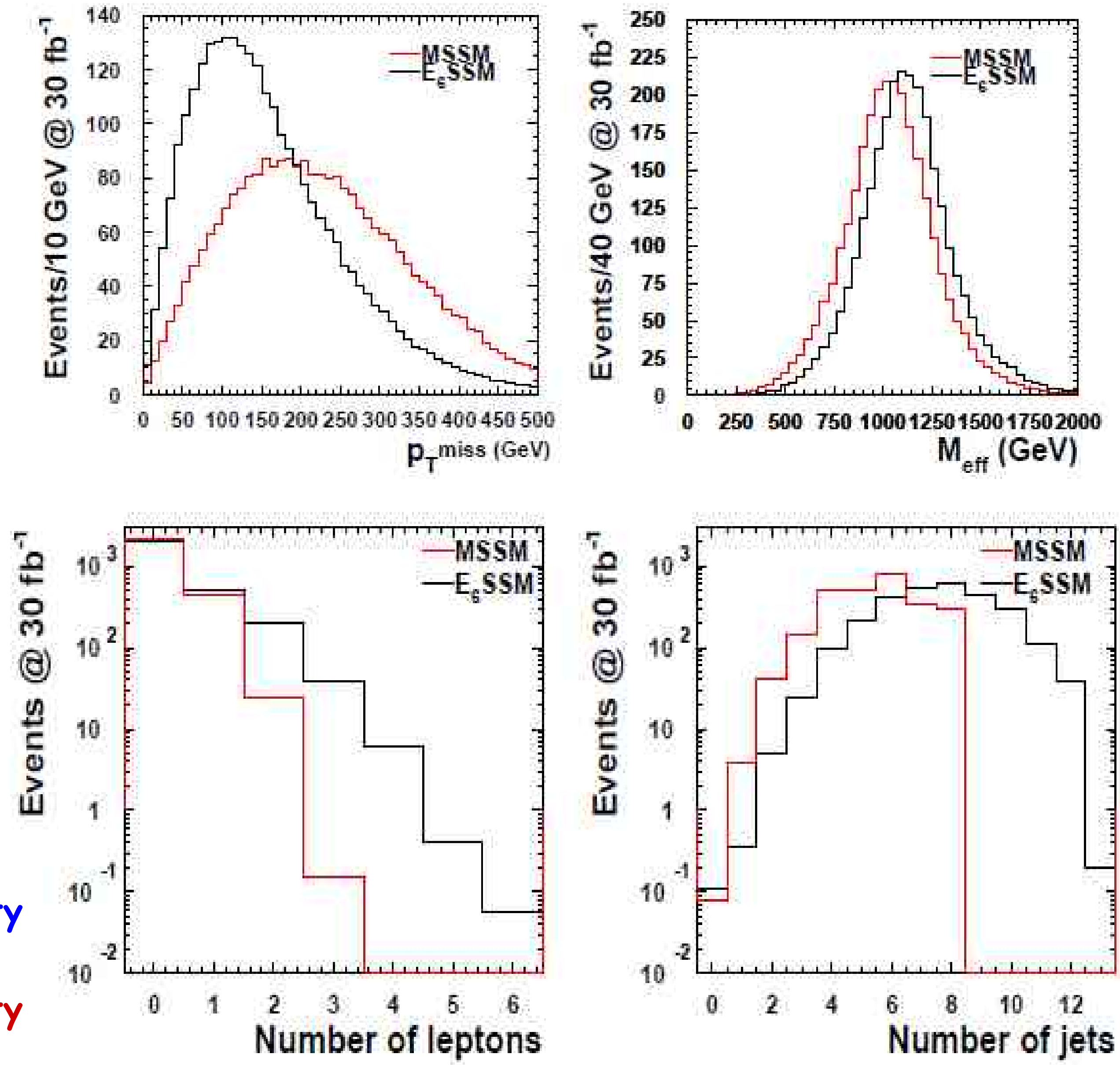


E_6SSM:



	MSSM	E_6SSM	
$\tan\beta$	10	1.77	
λ	-	0.55	
s	-	5418	[GeV]
μ	1578	(2107)	[GeV]
A	-2900	-2200	[GeV]
M_A	302.5	2736	[GeV]
M_1	150	150	[GeV]
M_2	285	300	[GeV]
$M_{1'}$	-	151	[GeV]
$m_{\tilde{g}}$	700	700	[GeV]
$P(l=1)$	0.231	$< 10^{-9}$	
$P(l=2)$	0.769	$< 10^{-4}$	
$P(l=3)$	0	0.287	
$P(l=4)$	0	0.782	
$P(l=5)$	0	0.005	
Ωh^2	0.00628	0.00114	
σ_{SI}	0.04×10^{-8}	15.3×10^{-8}	[pb]

	MSSM	E_6SSM	
$\tilde{\chi}^0_{M1}$	148.7	148.6	[GeV]
$\tilde{\chi}^0_{M2}$	302.2	294.8	[GeV]
$\tilde{\chi}^0_{M3}$	1582	1459	[GeV]
$\tilde{\chi}^0_{M4}$	1584	1468	[GeV]
$\tilde{\chi}^\pm_{M1}$	302.2	298.7	[GeV]
$\tilde{\chi}^\pm_{M2}$	1584	1440	[GeV]
$\tilde{\chi}^0_{U1}$	-	1254	[GeV]
$\tilde{\chi}^0_{U2}$	-	1420	[GeV]
$\tilde{\chi}^0_{E1}$	-	62.7	[GeV]
$\tilde{\chi}^0_{E2}$	-	62,8	[GeV]
$\tilde{\chi}^0_{E3}$	-	119.9	[GeV]
$\tilde{\chi}^0_{E4}$	-	121.1	[GeV]
$\tilde{\chi}^0_{E5}$	-	183.1	[GeV]
$\tilde{\chi}^0_{E6}$	-	184.4	[GeV]
$\tilde{\chi}^\pm_{E1}$	-	109.8	[GeV]
$\tilde{\chi}^\pm_{E2}$	-	117.8	[GeV]
h	124.4	125.4	[GeV]



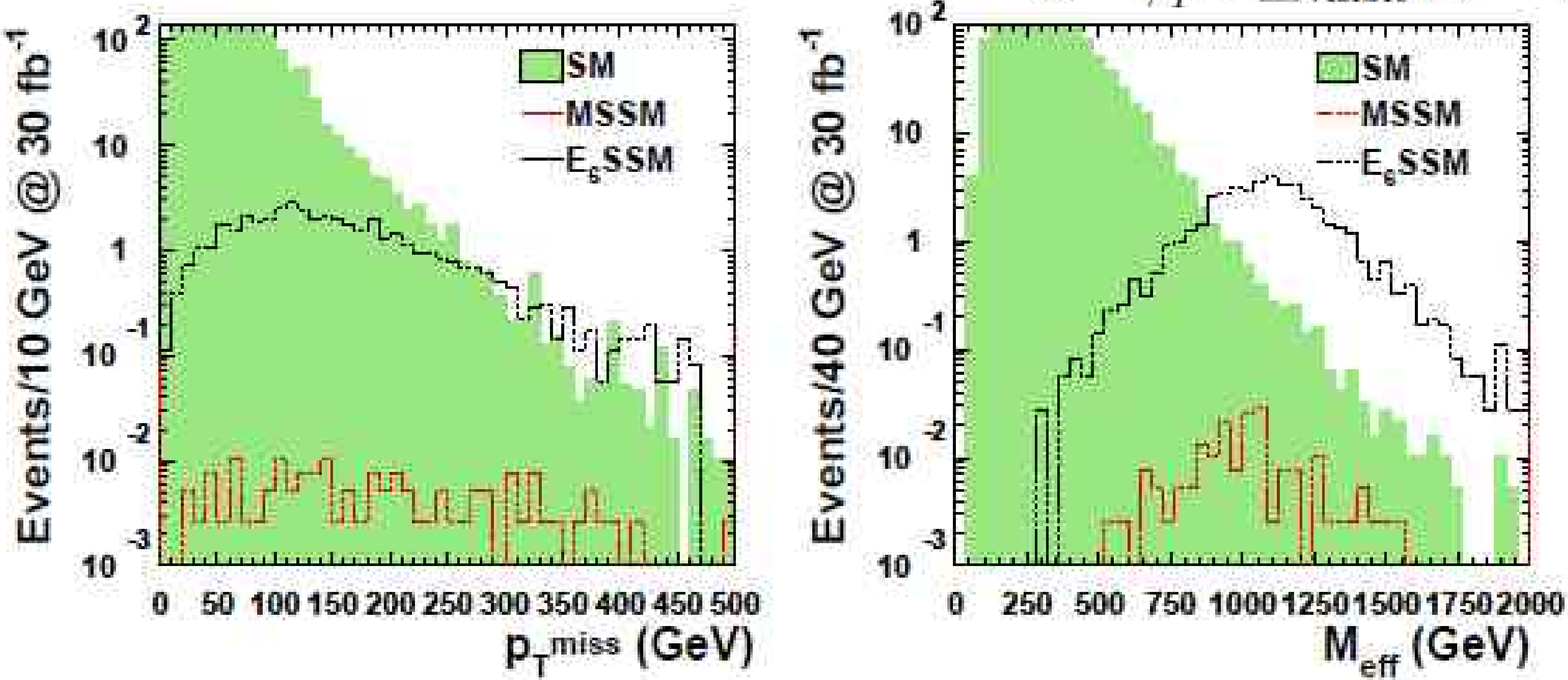
MSSM: bigger missing PT, smaller released energy & lepton/jet multiplicity

E6SSM: smaller missing PT, bigger released energy & lepton/jet multiplicity

A.B., Hall, King, Svantesson arXiv:1203.2495

3-lepton signature is enhanced in E6SSM vs MSSM

$$M_{\rm eff} = \not{p}_T + \sum\nolimits_{\rm visible} |p_T^{\rm visible}|$$



- pT> 275 GeV, Meff > 900 GeV : S = 36.4 ev, B=5.0 ev, ~ 8σ execess
- Gluino mass limits are model dependent! These specic features of the E6-inspired models should be taken into account for the experimental searches.
- This could provide dierent limits for the E6SSM gluino, as compared to the MSSM, or perhaps even to an earlier SUSY discovery.

A.B., Hall, King, Svantesson arXiv:1203.2495

Higgsless Theories

$$\varphi(x) = exp\left(i\frac{\pi^a(x)\tau^a}{v}\right)\left(\begin{array}{c} 0 \\ (v+h(x))/\sqrt{2} \end{array}\right)$$

$$\varphi(x) = exp\left(\Sigma(x)\right)\left(\begin{array}{c} 0 \\ (v+h(x))/\sqrt{2} \end{array}\right)$$

One can eliminate h(x) and still have EWSB via Sigma term

in the Higgsless model – non-linear Sigma model

$$\mathcal{L}_H \rightarrow \mathcal{L}_\Sigma = \frac{v^2}{4}\mathrm{tr}\left(\left[\mathcal{D}^\mu\Sigma\right]^\dagger \mathcal{D}_\mu\Sigma\right)$$

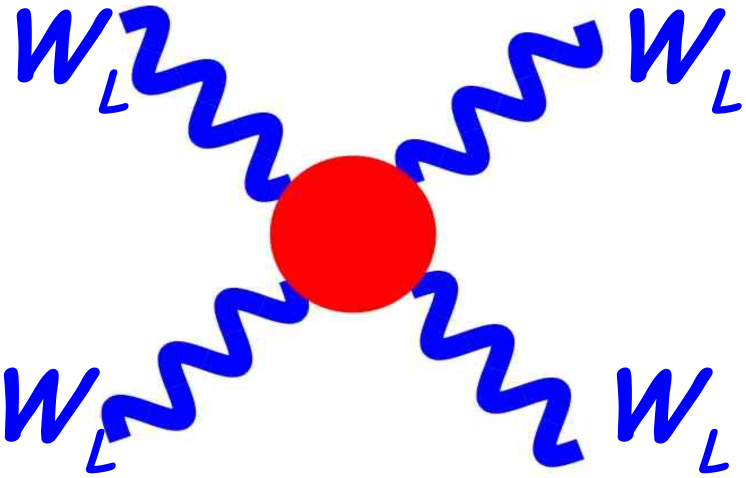
$$|D_\mu\varphi|^2$$

$$= \left(0 \quad v/\sqrt{2}\right)\left|\frac{g}{\sqrt{2}}W^+\sigma^+ + \frac{g}{\sqrt{2}}W^-\sigma^- + \frac{g}{2}W^0\sigma^3 + \frac{g'}{2}B\right|^2 \left(\begin{array}{c} 0 \\ v/\sqrt{2} \end{array}\right)$$

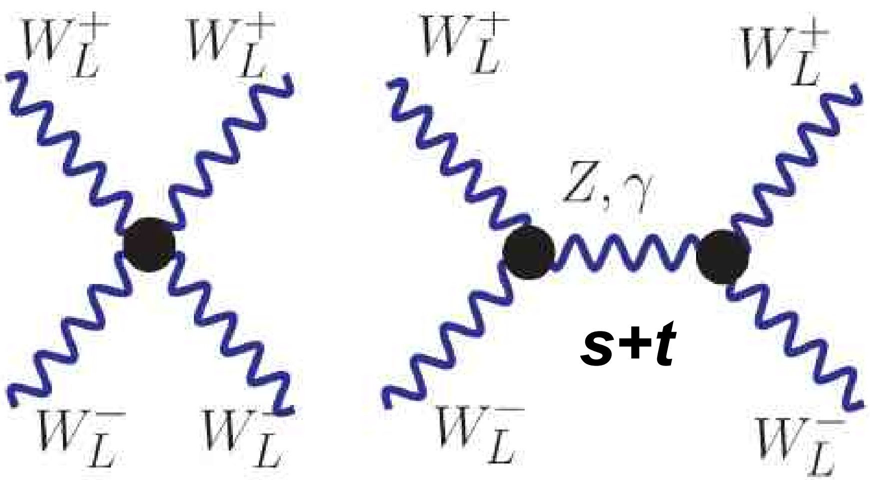
$$= \frac{v^2}{4}\left[g^2W^+W^- + \frac{1}{2}(-gW^0 + g'B)^2\right]$$

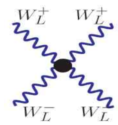
Electroweak Symmetry Breaking without Higgs boson but within the Electroweak theory

The Loss of Unitarity and EW precision data is the main worry!

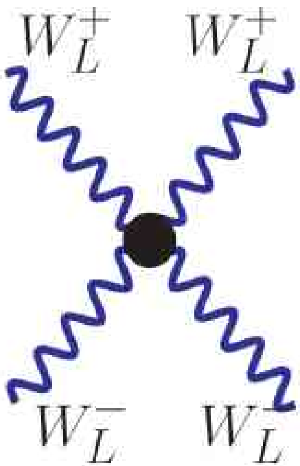


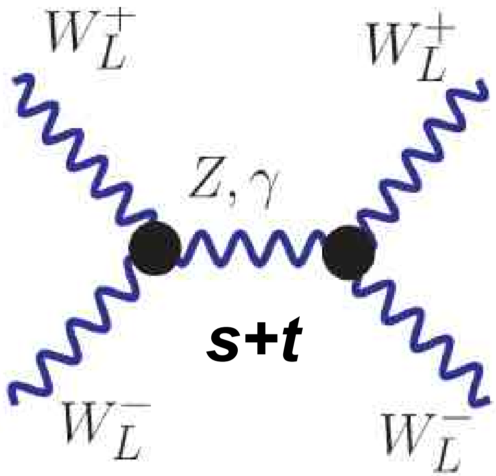
Unitarity with and without Higgs boson

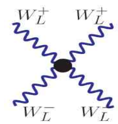


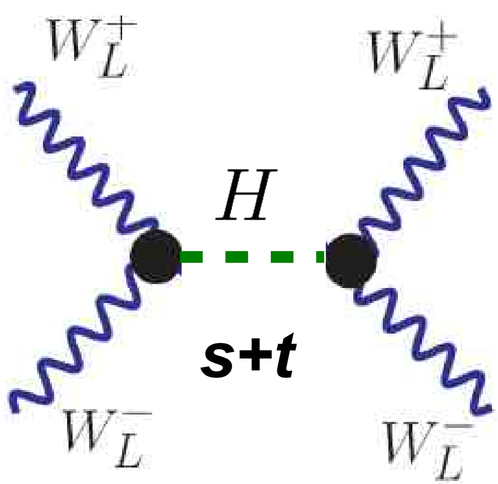
Graphs	$g^2 \frac{E^4}{m_w^4}$	$g^2 \frac{E^2}{m_w^2}$
	$-3 + 6\cos\theta + \cos^2\theta$	$+2 - 6\cos\theta$
s	$-4\cos\theta$	$-\cos\theta$
t	$+3 - 2\cos\theta - \cos^2\theta$	$-\frac{3}{2} + \frac{15}{2}\cos\theta$
Sum	0	$+\frac{1}{2} + \frac{1}{2}\cos\theta$

Unitarity with and without Higgs boson





Graphs	$g^2 \frac{E^4}{m_w^4}$	$g^2 \frac{E^2}{m_w^2}$
	$-3 + 6\cos\theta + \cos^2\theta$	$+2 - 6\cos\theta$
s	$-4\cos\theta$	$-\cos\theta$
t	$+3 - 2\cos\theta - \cos^2\theta$	$-\frac{3}{2} + \frac{15}{2}\cos\theta$
Sum	0	$+\frac{1}{2} + \frac{1}{2}\cos\theta$



$$-\frac{1}{2} - \frac{1}{2}\cos\theta$$

$$0$$

If no Higgs $\Rightarrow \mathcal{O}(E^2) \Rightarrow E < \sqrt{8\pi}v \simeq 1.2\,\mathrm{TeV}$

SM Higgs vs Technicolor

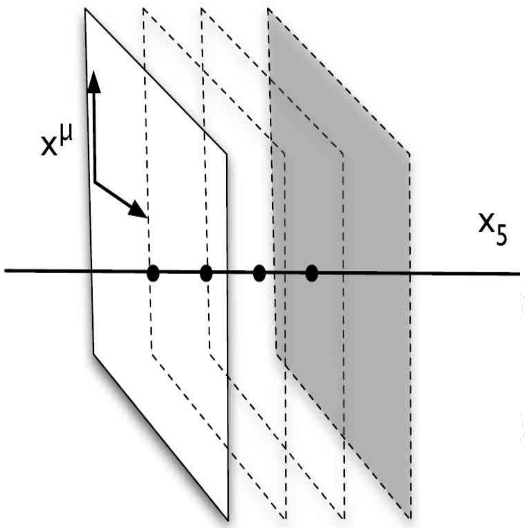
- simple and economical
- GIM mechanism, no FCNC problems, EW precision data are OK for preferably light Higgs boson
- SM is established, perfectly describes data
- fine-tuning and naturalness problem; triviality problem
- there is no example of fundamental scalar
- Scalar potential parameters and yukawa couplings are inputs

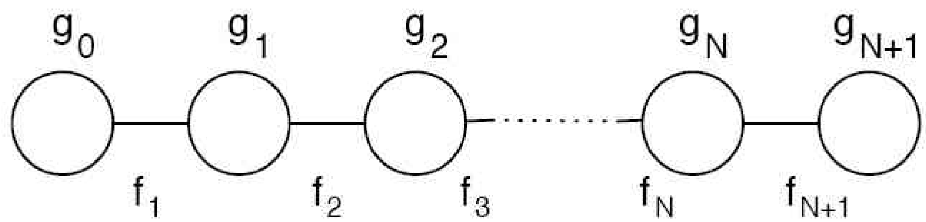
- complicated at the effective theory level
- FCNC constraints require walking, potential tension with EW precision data
- no viable ETC model suggested yet, work in progress
- no fine-tuning, the scale is dynamically generated
- Superconductivity and QCD are examples of dynamical symmetry breaking
- parameters of low-energy effective theory are derived once underlying ETC is constructed

How one can preserve unitarity without Higgs ?

DECONSTRUCTION

moose diagram can be interpreted as the discretization of a continuum gauge theory in 5D along a fifth dimension

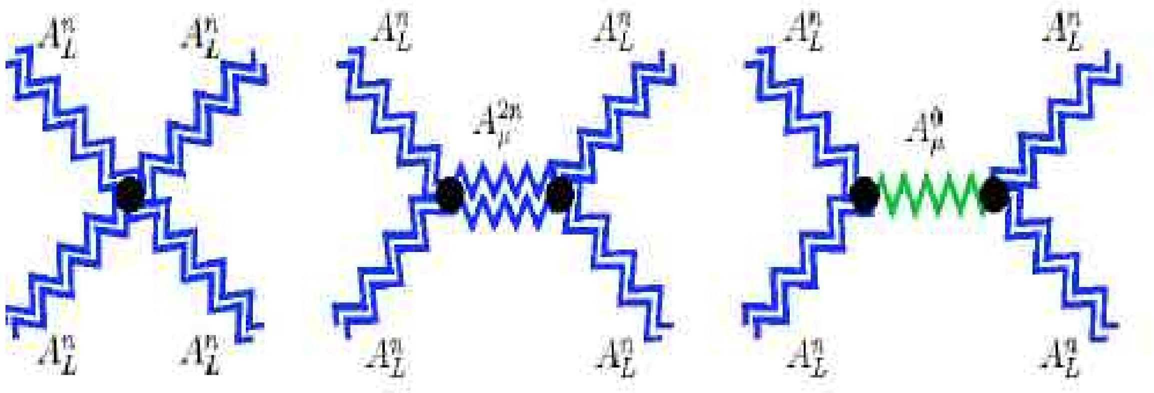




- Discretize fifth dimension
- 4D gauge group at each site
- Nonlinear sigma model link fields
- To include warping: vary f_j
- For spatially dependent coupling: vary g_k
- Continuum Limit: take N → infinity
- Finite N, a 4D theory w/o 5D constraints

Arkani-Hamed, Georgi, Cohen & Hill, Pokorski, Wang

Conflict S and Unitarity



- Z' resonance unitarizes WW scattering, similar to what Higgs boson does in SM
  (Chivukula,He,Dicus)

- Z' mass is bounded from above: $m_{Z_1} < \sqrt{8\pi}\, v$

- ... and yields too much a value of S-paramet $\alpha S \geq \frac{4 s_Z^2 c_Z^2 M_Z^2}{8\pi v^2} = \frac{\alpha}{2}$

  [Chivukula, Simmons, He, Kurachi,Tanabashi]

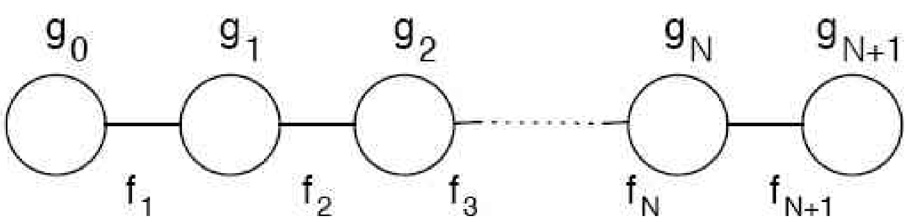
- Solution – delocalization of the fermions:
  mixing of "brane" and "bulk" modes!

[Cacciapaglia, Csaki, Grojean, Reece,Terning; Foadi Gopalakrishna, Schmidt]

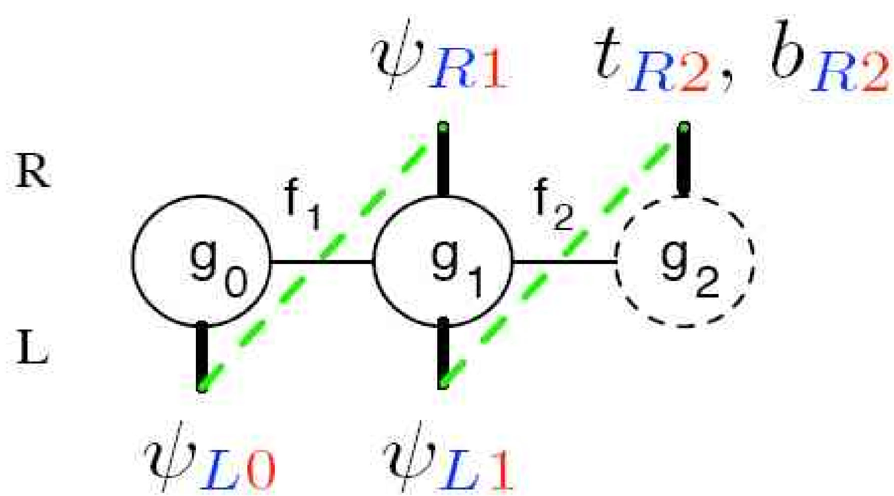
- Alternatively there could be a large contribution to T parameter

Three site model (TSM)

simplest, realistic, highly deconstructed, higgsless



Discretized 5th dimension written in the language of 'theory space'
[Arkani-Hammed, Georgi, Cohen; Hill, Pokorski, Wang]



$$SU(2) \times SU(2) \times U(1)$$

[Chivukula, Coleppa, Di Chiara, Simmons '06]

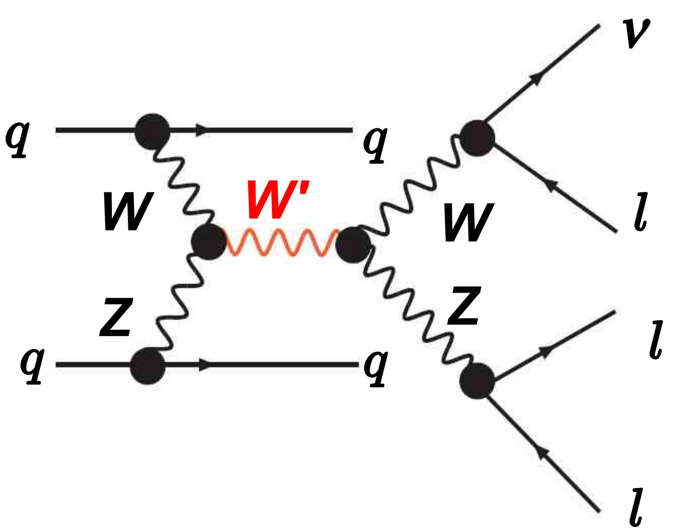
gauge bosons: photon, Z, W, Z', W'

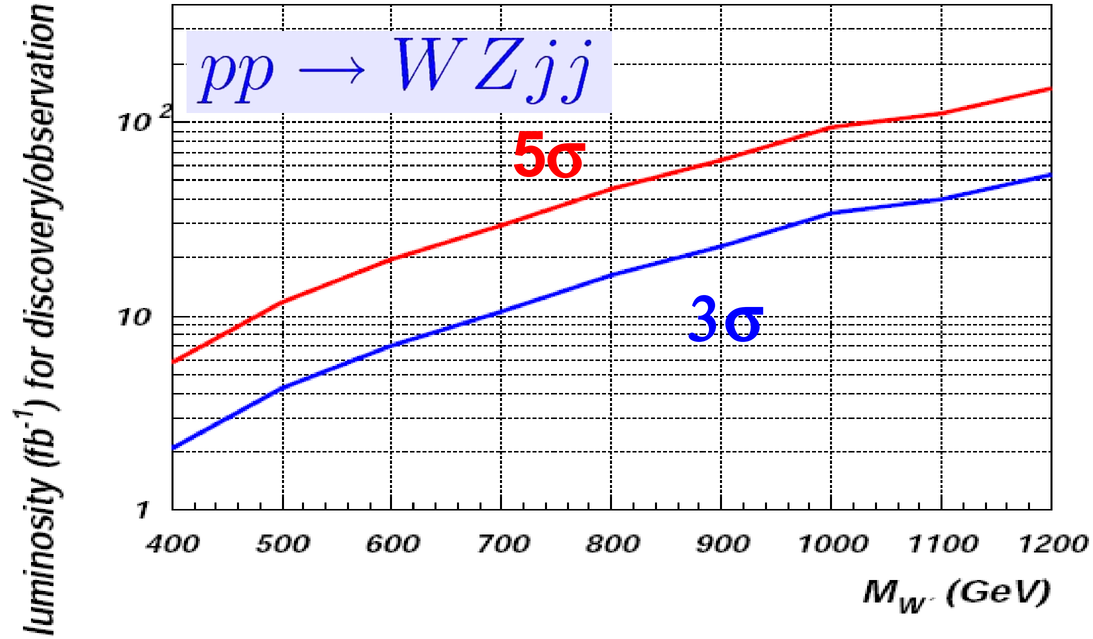
gauge sector is the BESS model
[Casalbuoni, De Curtis, Dominici, Gatto '85]

fermions: ***u, d, c, s, t, b***
U, D, C, S, T, B
plus leptons

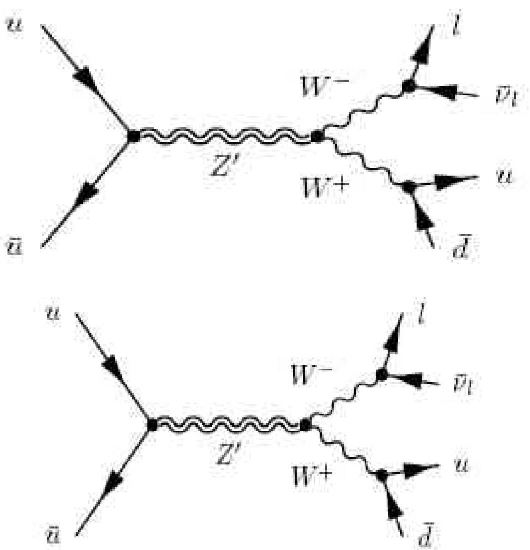
LHC reach for WZ->W' process

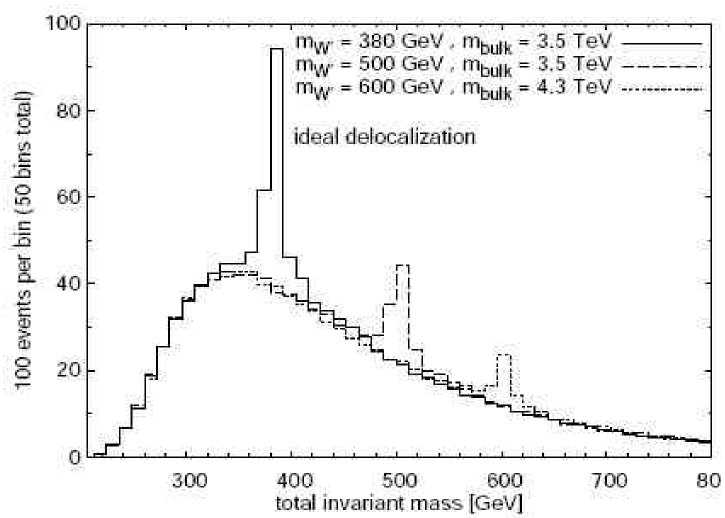
[AB, Chivukula, Christensen, He, Kuang, Pukhov, Qi, Simmons, Zhang '07]

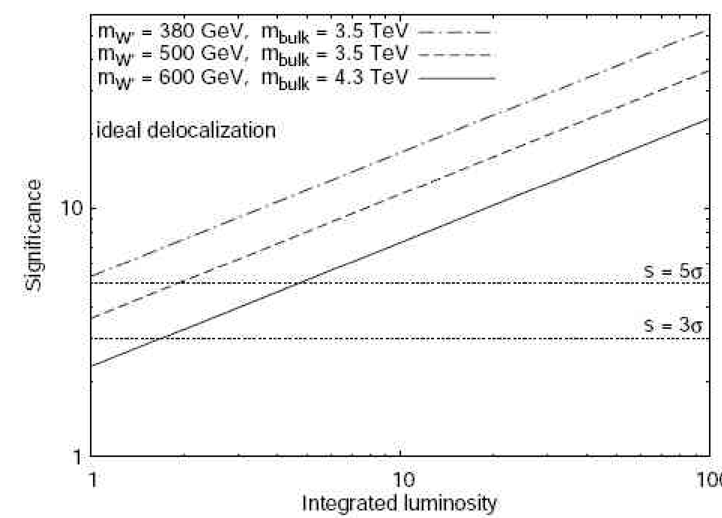




LHC reach for s-channel Z' and W' [Ohl,Speckner '08]







Beyond the 3-site model

there is an increasing progress in Higgsless models and Technicolor models

equivalent description on the languages of Deconstructon and Technicolor

[Barbieri, Isidori, Rychkov,Trincherini '08]

The Higgsless 4-site Linear Moose model

equivalent to

Next to Minimal Walking Technicolor (NMWT)

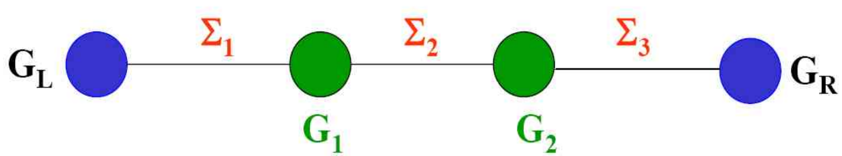
$N_c = 3, N_f = 2$

in the two-index symmetric

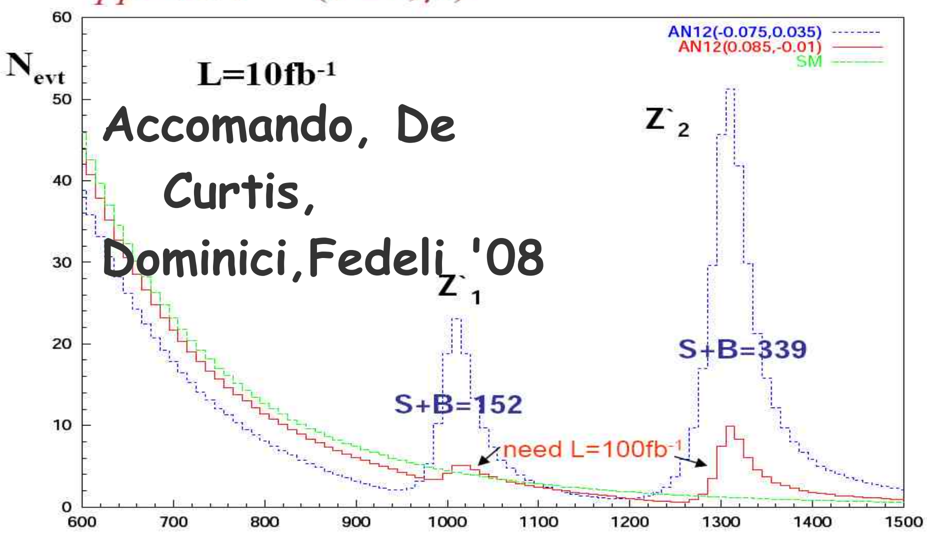
$SU(2)_L$ X $SU(2)_R$ –> $SU(2)_V$

two triplets of heavy mesons

$R_1^{\pm}(R_2^{\pm})$ and $R_1^0(R_2^0)$



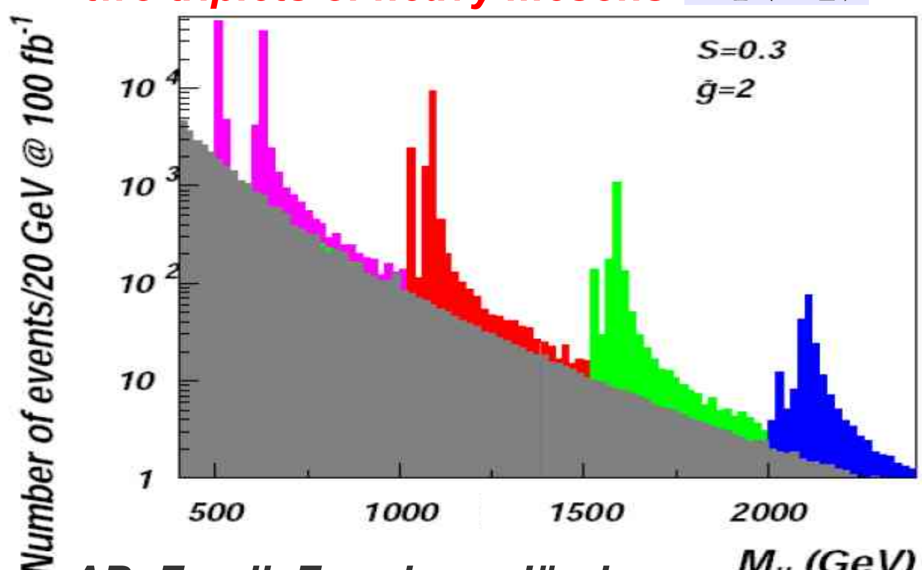
$pp \to l^+l^-$ $(l = e, \mu)$



Accomando, De Curtis, Dominici,Fedeli '08

S+B=#evts(M$\pm$ 3Γ)

M_{INV}(ll) [GeV]

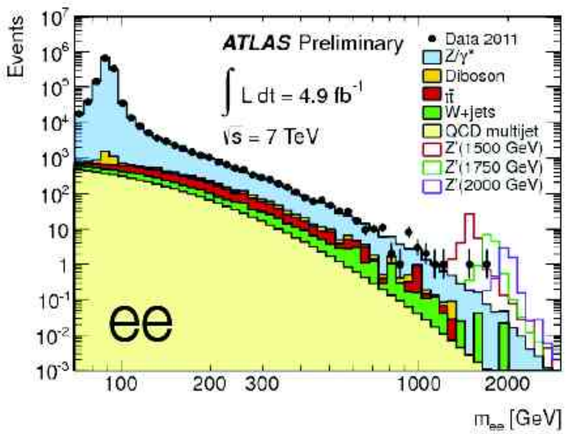


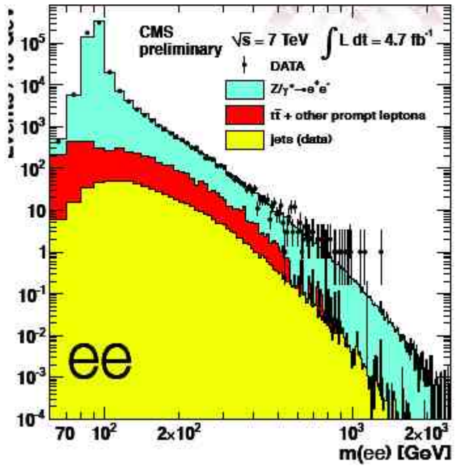
AB, Foadi, Frandsen, Järvinen, Pukhov, Sannino '08

Z' is not necessarily fermiophobic! Complementarity of DY di-lepton and di-boson channels

Experimental search for di-lepton resonances

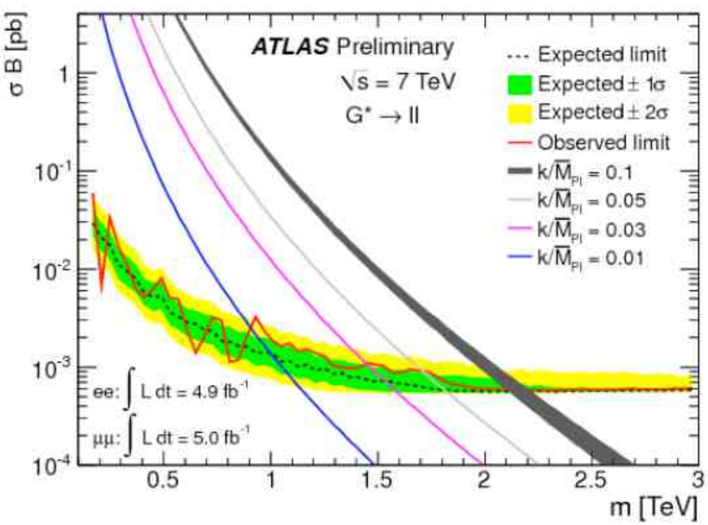
Edward Moyse **"Searches for Resonances at the LHC"** Rencontres de Moriond - Mar 10 2012

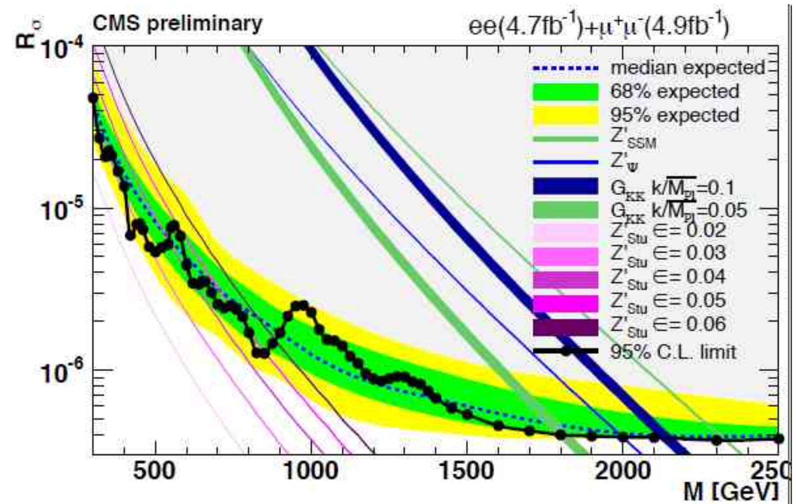




Dilepton - limits

	mass Z'_{SSM} (TeV)	mass RS G_{KK} (TeV)
ATLAS	<2.21	<2.16 for $k/\overline{M}_{PL}$=0.1
CMS	<2.32	< 1.81 (2.14) for $k/\overline{M}_{PL}$=0.05 (0.1)





CMS PAS EXO-11-019

- ***Provides access to different BSM models***
- ***One of the highest priority search channel***
- ***Should be used for interpretation of TC/3site models***

Cu-Cd language for Z' production

parton-level cross section takes a form

$$\hat{\sigma}(q\bar{q} \to Z') = \frac{\pi}{12} g_1^2 [(g_V^q)^2 + (g_A^q)^2]$$

while the hadron-level production and decay process is described by

$$\sigma_{l^+l^-} \approx \frac{\pi}{48s} \left[c_u w_u(s, M_{Z'}^2) + c_d w_d(s, M_{Z'}^2) \right]$$

[Carena, Daleo, Dobrescu, Tait '04]

$$c_u = \frac{g'^2}{2} ({g_V^u}^2 + {g_A^u}^2) Br(\ell^+\ell^-)$$

$$c_d = \frac{g'^2}{2} ({g_V^d}^2 + {g_A^d}^2) Br(\ell^+\ell^-)$$

$w_u(s, M_{Z'}^2)$ and $w_d(s, M_{Z'}^2)$

are defined by

$\left(\frac{dL_{u\bar{u}}}{dM_{Z'}^2}\right)$ and $\left(\frac{dL_{d\bar{d}}}{dM_{Z'}^2}\right)$

specific model is entirely encoded in Cu and Cd

w_u and w_d are defined by collider energy and $M_{Z'}$

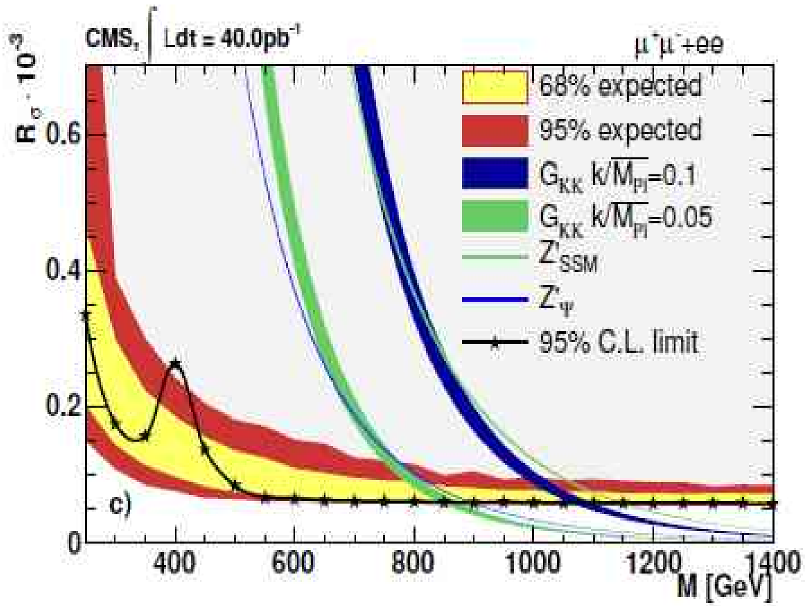
Limits for E6/GLR/GSM classes of models

Experimental limit is translated into Cu-Cd plane

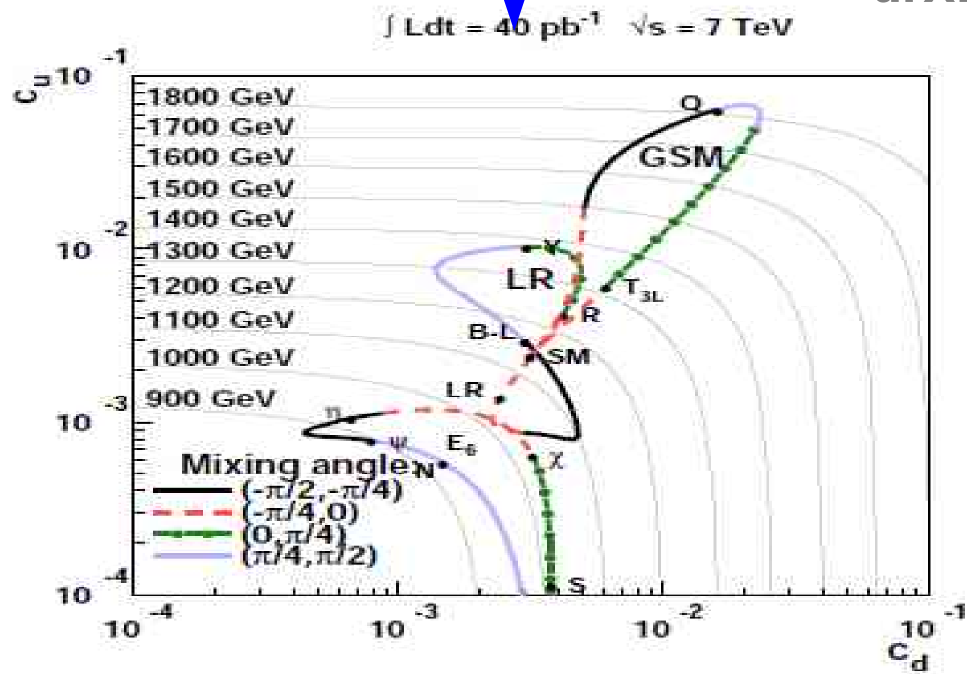
Parametrized E6/GLR/GSM models are presented by continuous contours in the Cu-Cd plane

Thus one can visualise and establish limits for the whole continuous class of models!

Accomando, A.B., Fedeli, King, Shepherd-Themistocleous
http://arxiv.org/pdf/1010.6058



arXiv:1103.0981



Search for $W' \to \ell\nu$ ($\ell = e, \mu$)

CMS PAPER EXO-11-024

$\mathcal{L} = 4.7\ \text{fb}^{-1}$

Models and interpretations

- $W - W'$ interferences considered (left-handed W')
- UED: $W'_{KK}(n = 2, 4, ..)$ (coupling to SM fermions)

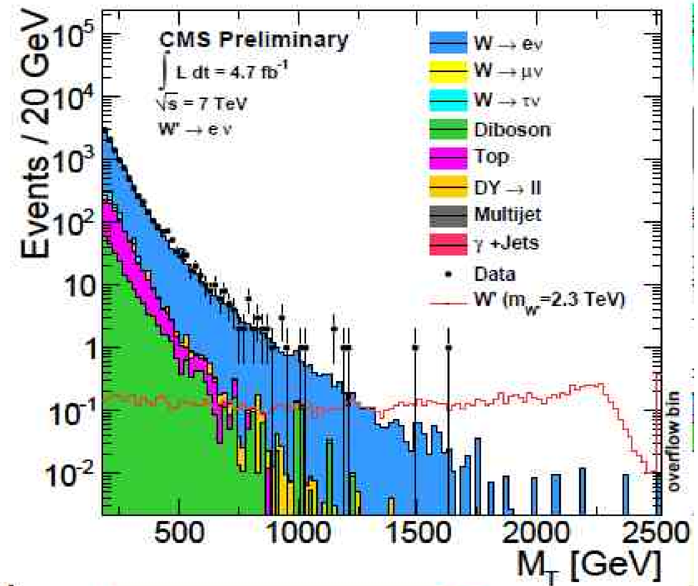
Lepton channels $\ell = e, \mu$ (+ E_T^{miss})

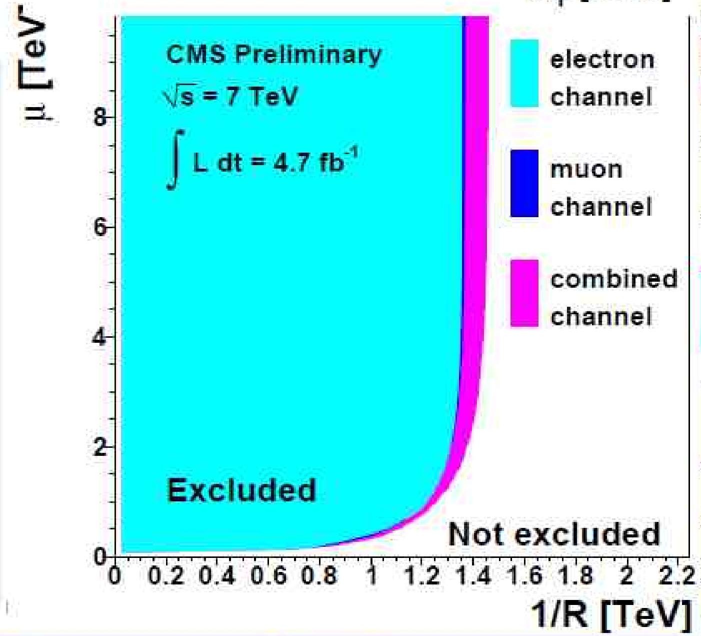
- W boson transverse mass reconstruction

$$M_T = \sqrt{2 \cdot {}^{\ell}_{T} \cdot E_T^{\text{miss}} \cdot (1 - \cos \Delta\phi_{\ell,\nu})}$$

Bayesian exclusion limits at 95% C.L.

- Higher order EW corrections (not plotted) at high masses reduce interference effects
- Limit on $m_{W'}$ (right-handed): 2.5 TeV, on $m_{W'}$ (left-handed): 2.63 TeV [2.43 TeV] for constructive [destructive] $W - W'$ interference
- Universal Extra Dimension re-interpretation: Limits in terms of ED Radius R and Dirac mass term μ No sensitivity to $n \geq 4$ modes (yet)



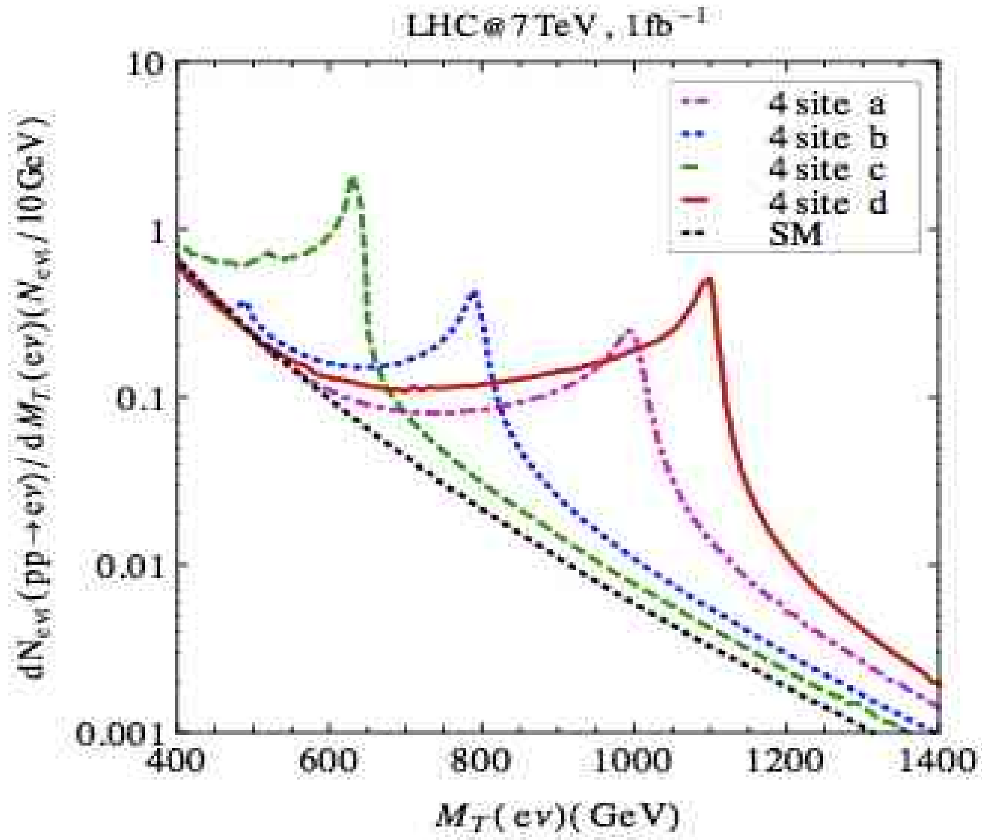


Extension for the case of two degenerate resonances

[Accomando, Becciolini, De Curtis, Dominici, Fedeli, Shepherd-Themistocleous '10/11]

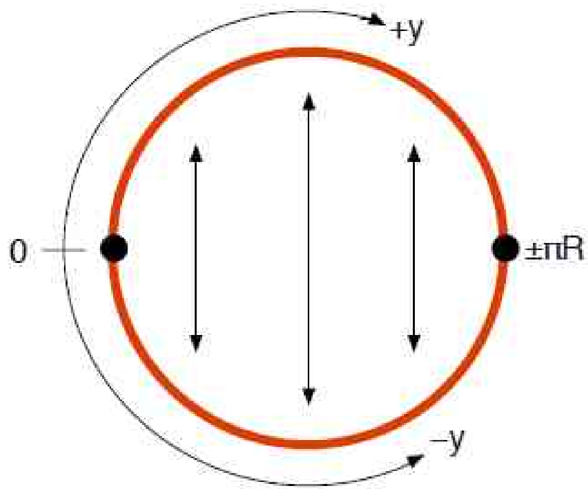
4 Benchmark scenarios

	z	$M_{W1,W2}$(GeV)	$\Gamma_{W1,W2}$(GeV)	$a_{W1,W2}$
a	0.4	410,1000	3.5,24.8	-0.027,0.23
b	0.6	486,794	5.7,15.9	-0.052,0.18
c	0.8	518,636	5.4,2.6	-0.058,0.13
d	0.95	1019,1101	9.4,13.5	-0.062,0.26



Models with extra-dimensions

- ADD, Randal-Sundrum, Universal Extra Dimensions (UED)
- Part of string theory
- Extend symmetry (bosonic space-time)
- Provide Dark Matter (UED)
- UED
  - *All fields propagate in the bulk*



$S^1/\mathcal{Z}_2$ orbifold

$SU(3) \times SU(2) \times U(1)$

SM Gauge group

$$\psi^{R,L}(x) \to \psi^{\pm}(x,y)$$
$$A_\mu(x) \to A_M(x,y)$$
$$\phi(x) \to \phi(x,y)$$

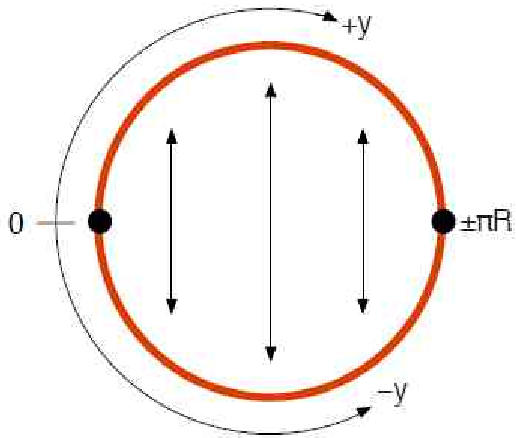
SM field content

brane localised terms are zero at the cutoff scale

Models with extra-dimensions

- ADD, Randal-Sundrum, Universal Extra Dimensions (UED)
- Part of string theory
- Extend symmetry (bosonic space-time)
- Provide Dark Matter (UED)
- UED
  - ***All fields propagate in the bulk***
    - Choose action of $\mathbb{Z}_2$ reflection on Dirac fermions:

$$\psi_\pm(y) \mapsto \psi'_\pm(-y) = \pm\gamma^5\psi_\pm(y)$$



    - If we identify $y \sim -y$ then we require $\psi'_\pm(y) = \psi_\pm(y)$, so

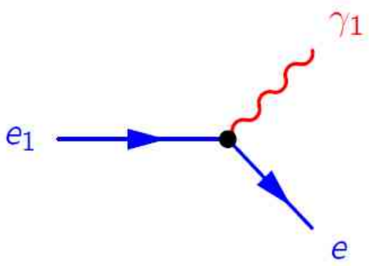
$$\psi_\pm(y) = \psi_0^{R,L} + \sum_n \left(\psi_n^{R,L}\cos_n + \psi_n^{L,R}\sin_n\right)$$

    - KK number broken to KK parity, $(-1)^n$: LKP is stable

UED: the role of the radiative corrections

At tree level, a particle's nth KK level mass is given by

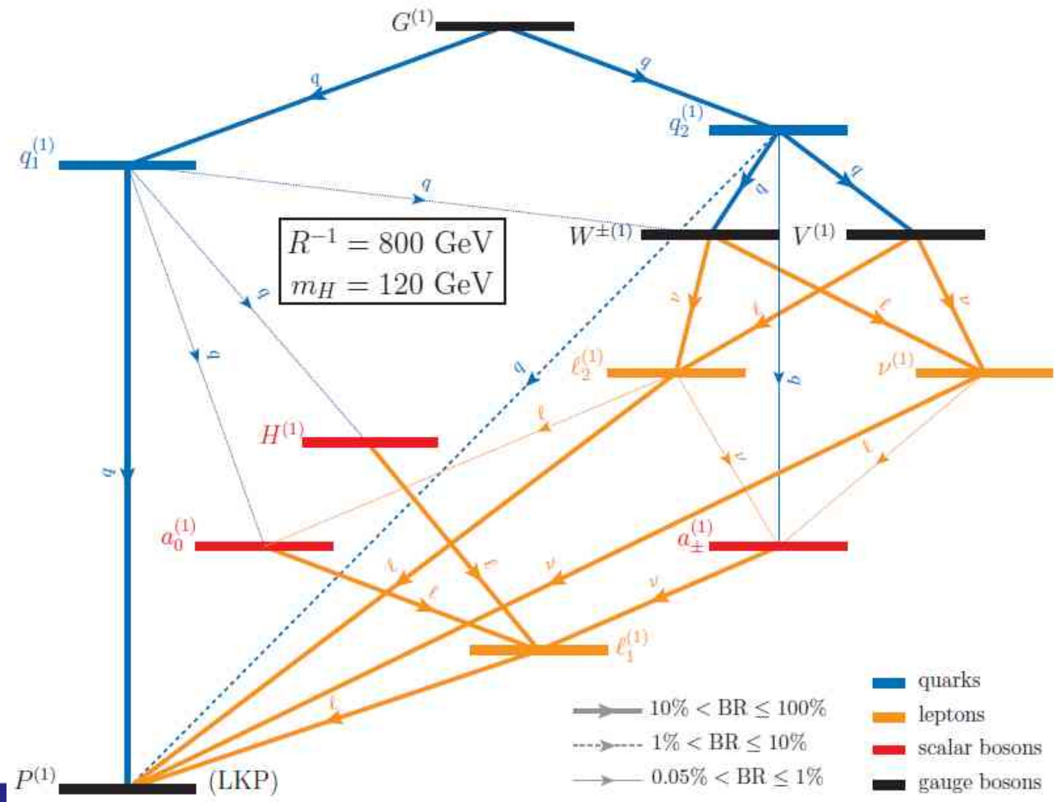
$$m_n = \frac{n}{R} + m \text{ (fermions)}; \quad m_n = \sqrt{\left(\frac{n}{R}\right)^2 + m^2} \text{ (bosons)}$$



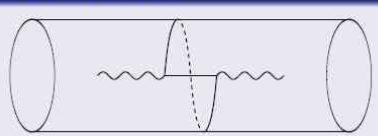
$$\frac{1}{R} + m_e \overset{!}{>} m_e + \sqrt{\frac{1}{R^2}}$$

The $n = 1$ electron is stable $\Rightarrow$ Charged dark matter!

Radiative corrections in 5D can be categorised as either bulk or brane corrections Cheng, Matchev, Konstantin and Schmaltz, 2002 [arxiv:hep-ph/0204342]



Bulk corrections



The two particles in a loop each pass through one of the boundary points

$$\delta m_n = A\frac{1}{R^2}$$

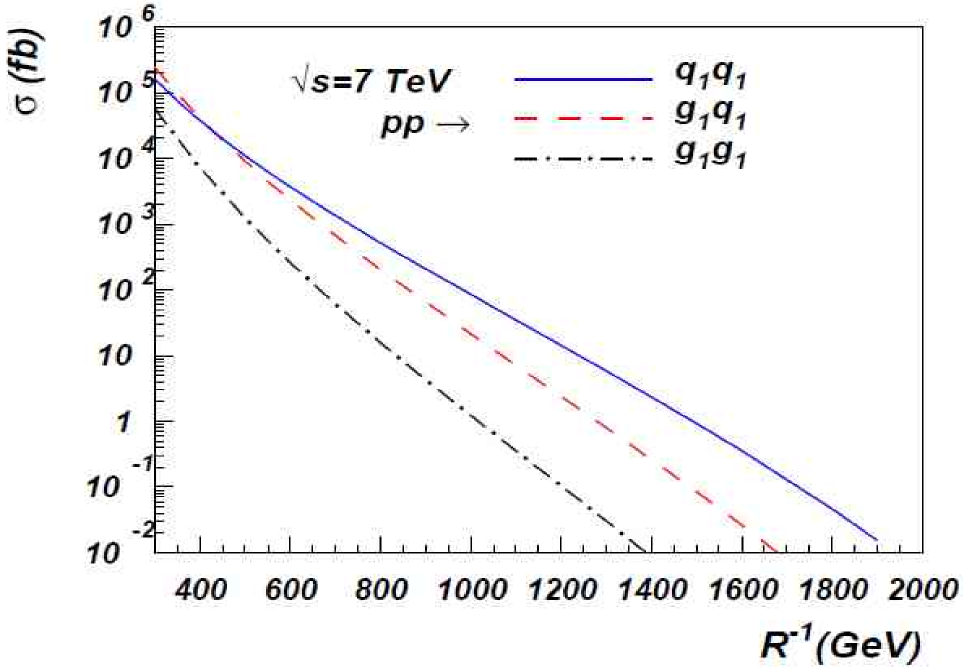
Orbifold corrections

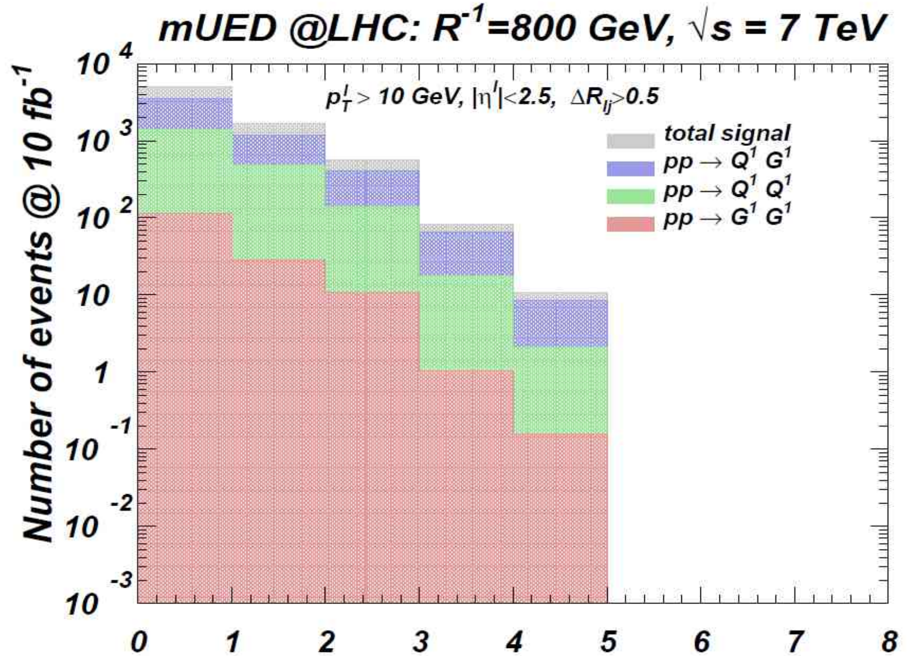
Only one of the particles passes through a boundary point

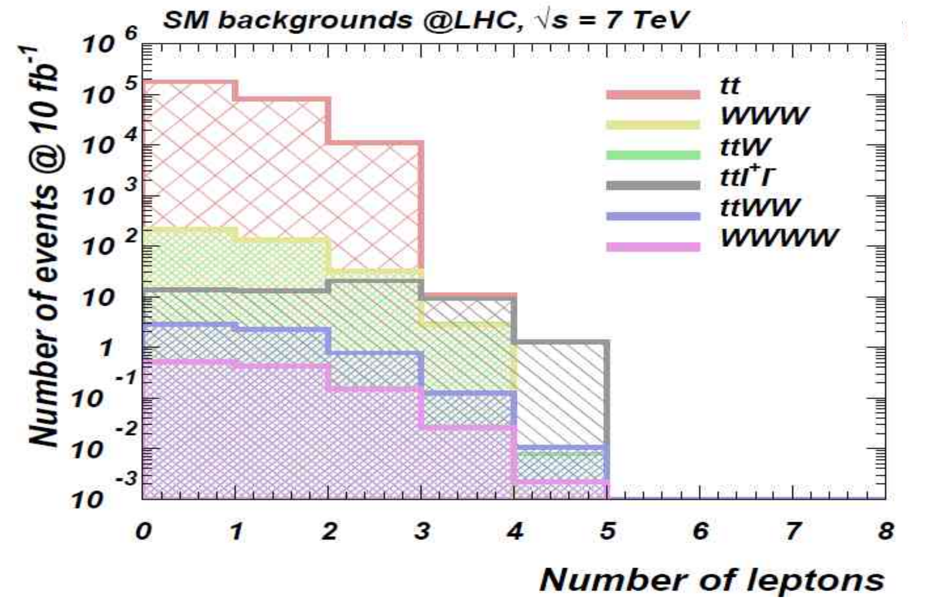
$$\delta m_n = B\frac{n}{R}\ln\frac{\Lambda^2}{\mu^2} \text{ (fermions)}$$

$$\delta m_n^2 = B\frac{n^2}{R^2}\ln\frac{\Lambda^2}{\mu^2} \text{ (bosons)}$$

mUED collider phenomenology

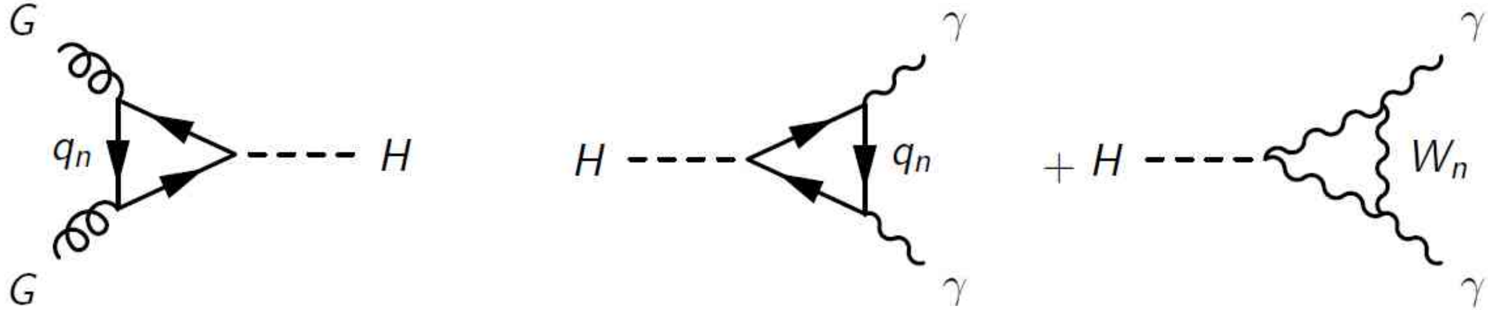


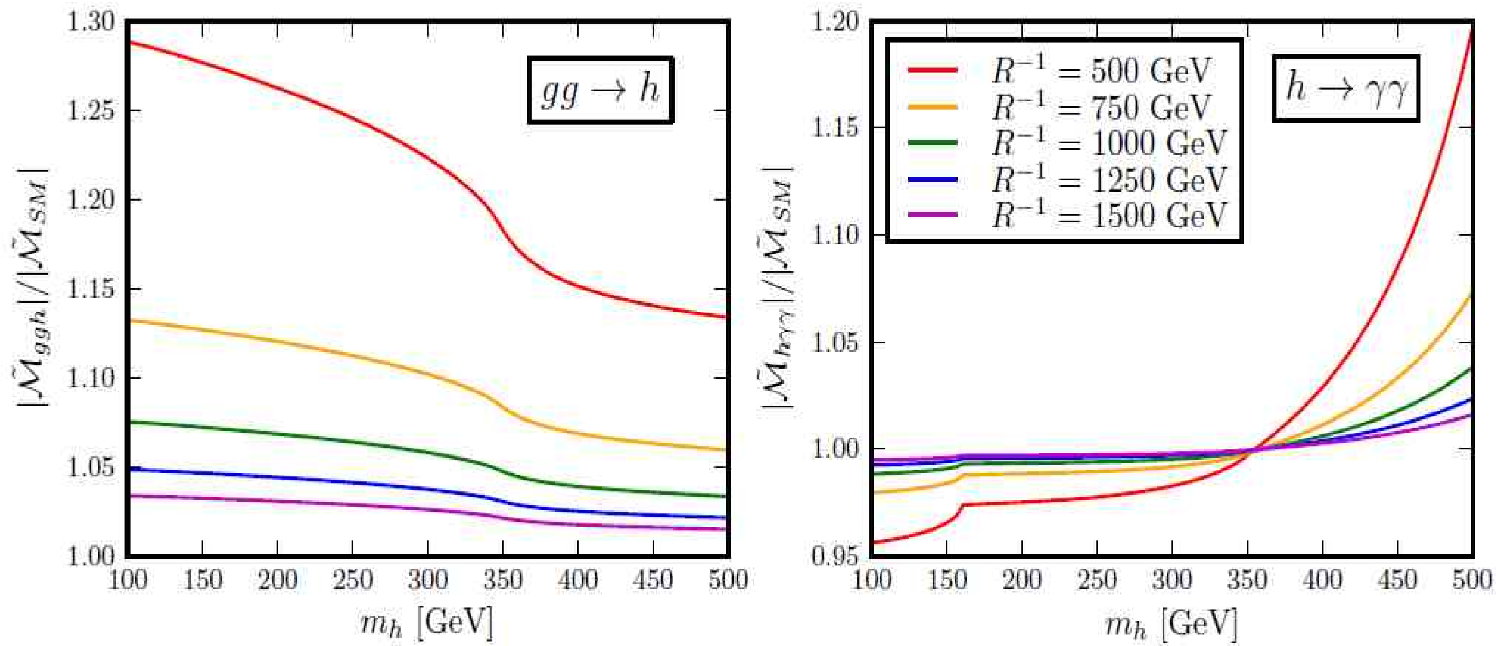




- Small mass gap (as compared to MSSM) - lower missing PT (similar to E6SSM)
- Since KK-quarks are lighter than KK-gluons, the leading production channel is QQ,QG production
- Quite a few PHENO papers, but there is no experimental limits
- 3-lepton signature – one of the most promising ones

The role of the Higgs searches in constraining of the mUED model

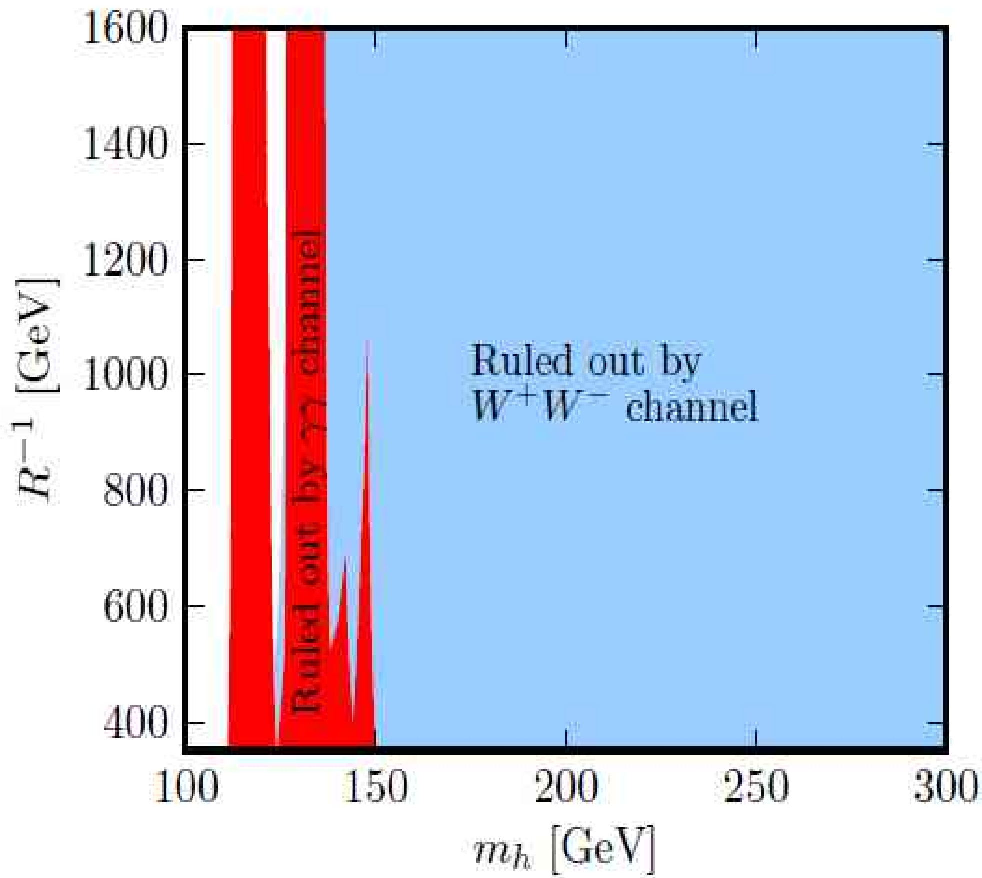


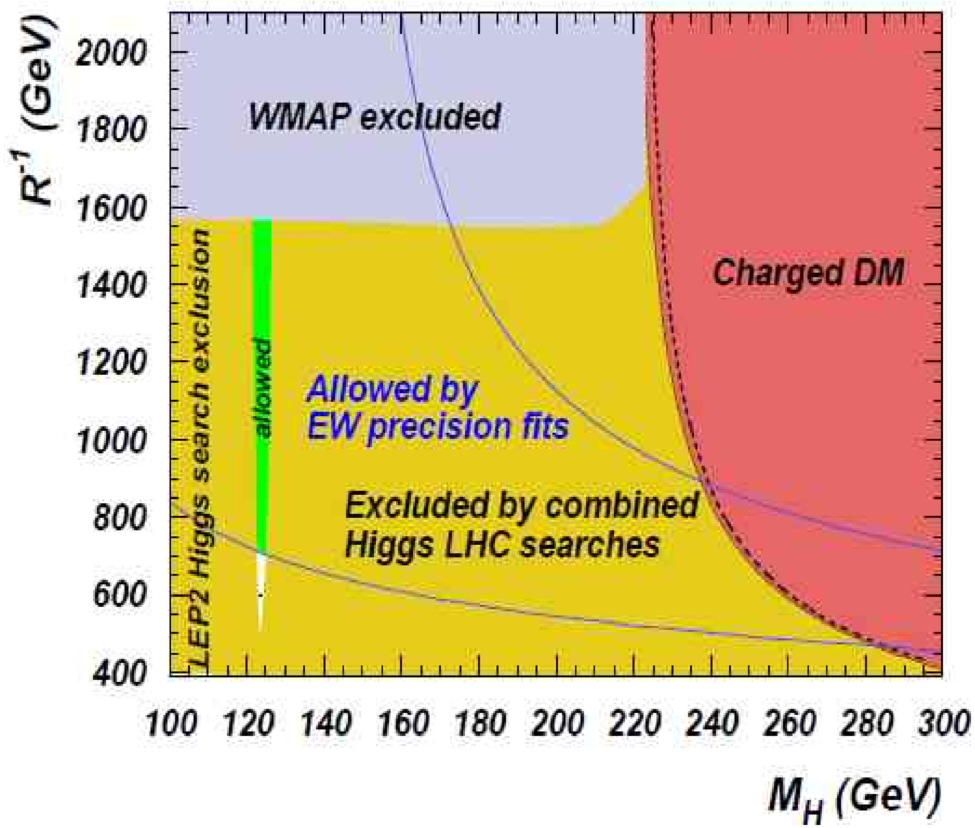


A.B., Belanger, Brown, Kakizaki, Pukhov '12

- Production is enhanced
- Decay is slightly suppressed
- Overall, the GG->H->γγ is enhanced
- GG->H->γγ was independently evaluated in all details
  (was done previously by Ellis, Gaillard, Nanopolous, '76)

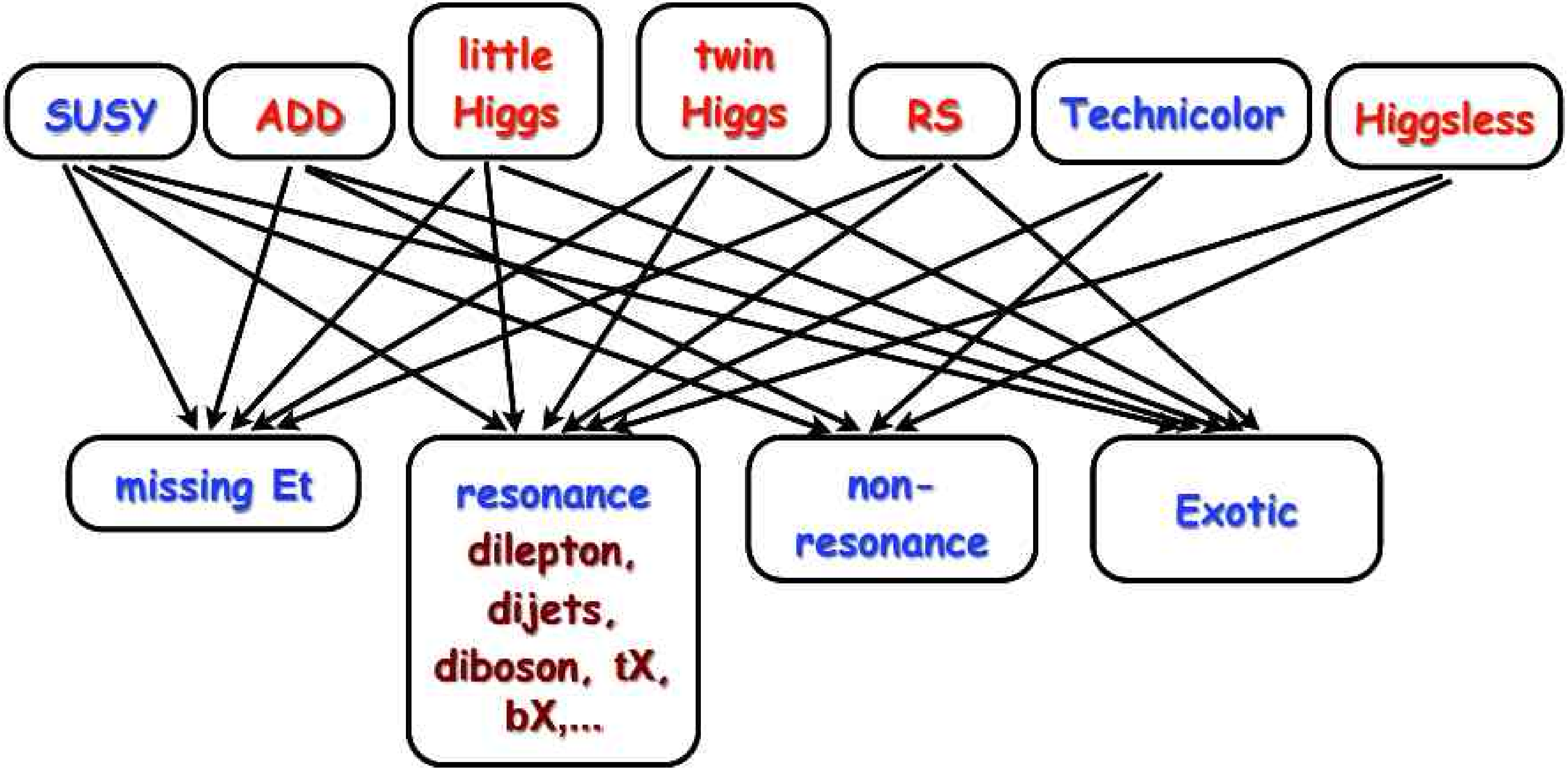
The role of the Higgs searches in constraining of the mUED model





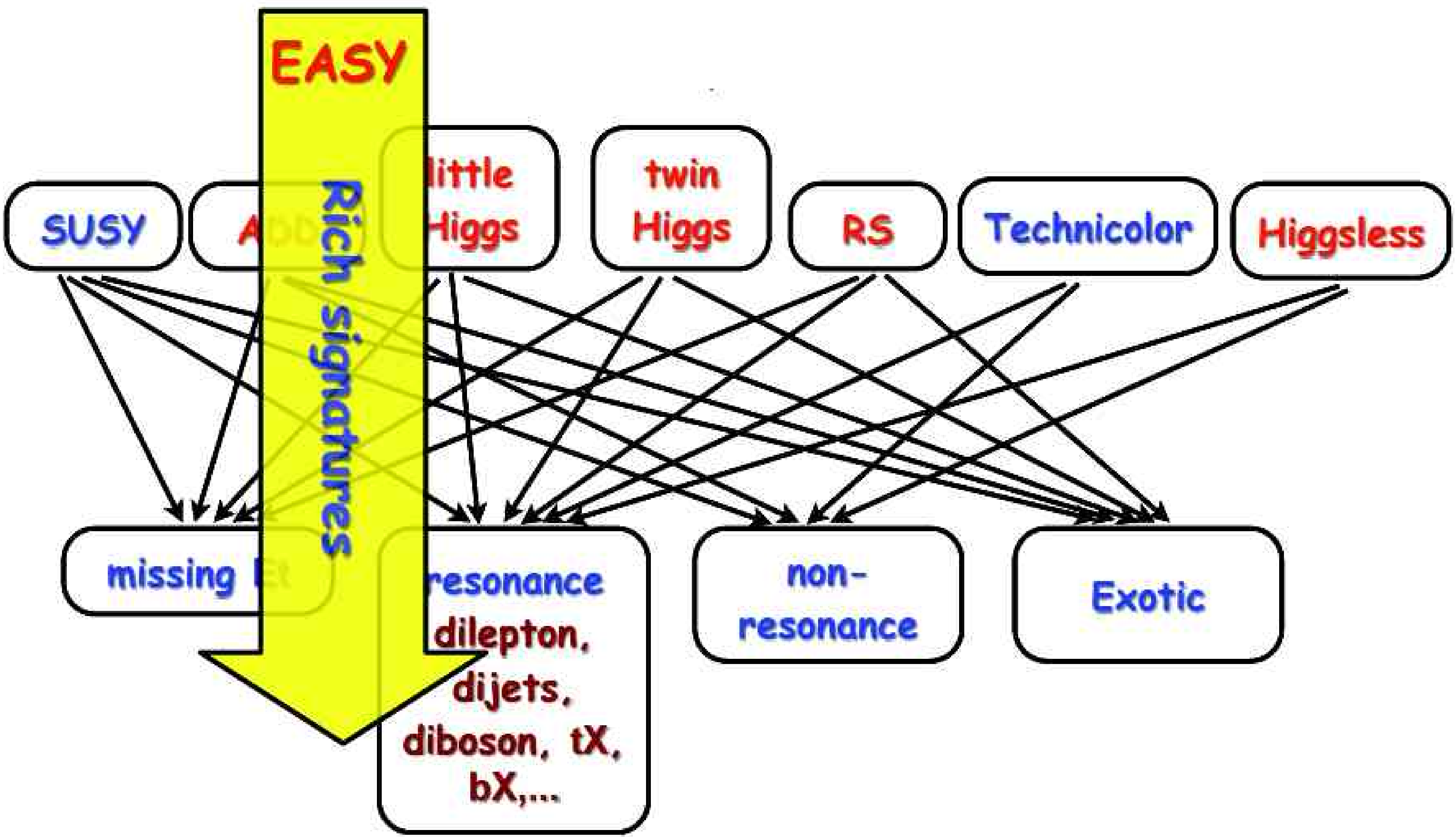
- Same channels ($\gamma\gamma$ and WW) from CMS/ATLAS are combined
- R^{-1}<500 is excluded at 95% CL
- overall, the GG->H->$\gamma\gamma$ is enhanced
- Narrow window around 125+/-3 GeV is left

What we should really worry about?



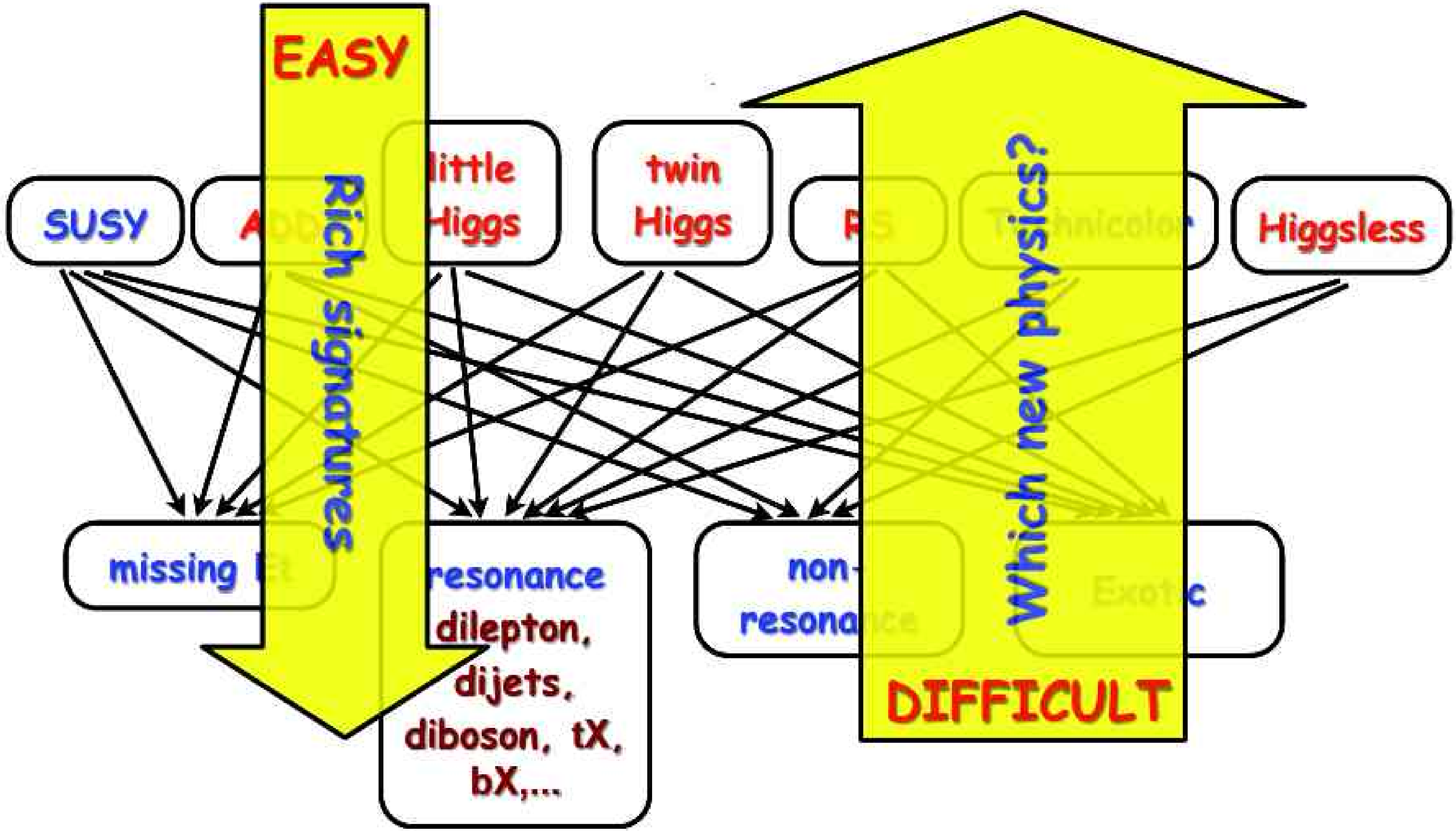
From Sufang Su

What we should really worry about?



From Sufang Su

What we should really worry about?



From Sufang Su

High Energy Physics Model Database

https://hepmdb.soton.ac.uk/

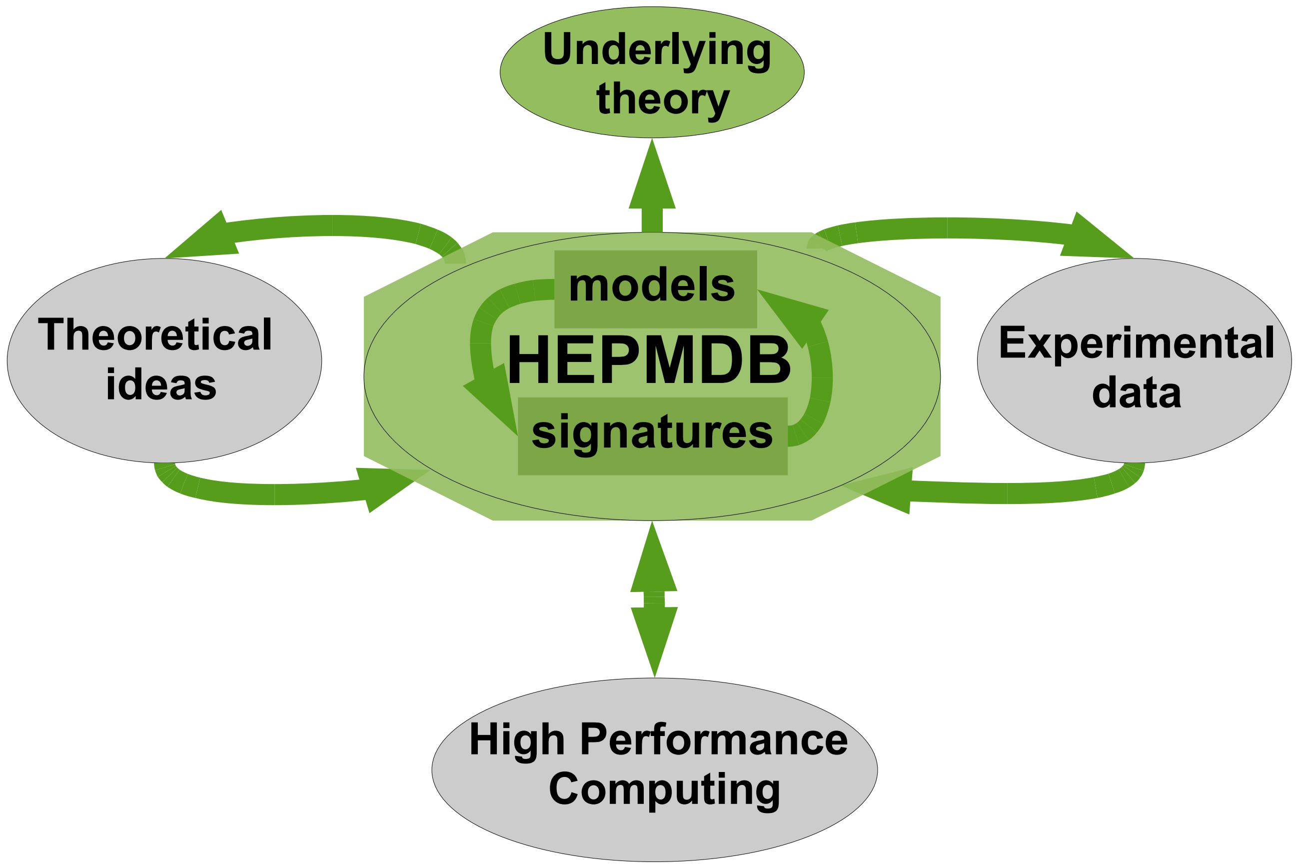
- **Developed at Southampton with support from IPPP, Durham**
  as a result of ideas discussed in the context of the "Dictionary of LHC signatures", at the FeynRules workshop (April, 2010) and at the Mini-Workshop on Dynamical Symmetry Breaking models and tools (July 2010)
- **Further discussed at Les Hocuhes Workshop, June 201**

High Energy Physics Model Database – HEPMDB. Towards decoding of the underlying theory at the LHC.

Maksym Bondarenko[1], Alexander Belyaev[1,2], Lorenzo Basso[1,2,3], Edward Boos[4], Vyacheslav Bunichev[4], R. Sekhar Chivukula[5], Neil D. Christensen[6], Simon Cox[7], Albert De Roeck[8], Stefano Moretti[1,2], Alexander Pukhov[4], Sezen Sekmen[8], Andrei Semenov[9], Elizabeth H. Simmons[5], Claire Shepherd-Themistocleous[2], Christian Speckner[3]

Abstract

We present here the first stage of development of the High Energy Physics Model Data-Base (HEPMDB) which is already a convenient centralized storage environment for HEP models, and can accommodate, via web interface to the HPC cluster, the validation of models, evaluation of LHC predictions and event generation-simulation chain. The ultimate goal of HEPMDB is perform an effective LHC data interpretation isolating the most successful theory for explaining the LHC observations.


Underlying theory
Theoretical ideas
models
HEPMDB
signatures
Experimental data
High Performance Computing

Conclusions

- All three main classes of theories SUSY, Higgsless, ExD (and their mixture, if you like) are not excluded by data! More models (E6SSM, UED, WTC/4site) should be considered for the experimental analysis/constraints
- Their phenomenology is very rich, but decoding back from signatures is problematic. One of the powerful tools which would be able to perform this decoding is HEPMDB
- Even if the Higgs boson is found, how we can check that this is SM Higgs boson and not the Technipion from TC? We need to look at Higgs boson couplings!
- The study of WW/WZ scattering is challenging but would provide the most unambiguous story about the Higgs, since it would tests (essentially) only HWW and HZZ couplings