Non-SUSY Scenarios for TeV Scale Physics

Summary Talk, Les Houches Workshop, May 2005

Maxim Perelstein, Cornell U.

Towards a Classification of Models

- A large number of non-SUSY models for TeV-scale physics have been proposed
- We concentrated on models with extra dimensions (other interesting alternatives also exist - I'll mention one)
- Divide models into broad classes (nb: many variations exist within each class, but phenomenological differences between classes >> within class)

Classification Criteria

- Who lives in the extra dimensions? [gravity only=G, all matter=M] (a huge variety of intermediate cases is possible but not particularly well motivated)
- What is the curvature of the metric in XD? [flat=F, curved=C] (curved usually means AdS slice)
- How is the electroweak symmetry broken? [H=Higgs, S=strong dynamics]

Classification of XD Models

- Large Extra Dimensions [ADD, or GODs]: GFH (or GFS)
- Warped Extra Dimension [RS1]: GCH
- Universal Extra Dimension(s) [UED]: MFH
- Warped XD with Matter in the Bulk [RSMB]: MCH
- Higgsless Models [HL]: MCS

Everybody Loves SUSY!

‘cause There’s Something About SUSY

- Many reasons to love SUSY, but the main three are probably: (1) solves the hierarchy problem; (2) gauge coupling unification; and (3) contains a WIMP dark matter candidate
- Alternative models are more motivated if they reproduce all or some of these successes
- How do our 5 models fare?

Scorecard for Xtra Dim

	hierarchy	unification	WIMP
ADD	-	-	-
RS1	+	-	-
UED	+?	-	+
RSMB	+	+	+
HL	+	+?	+?

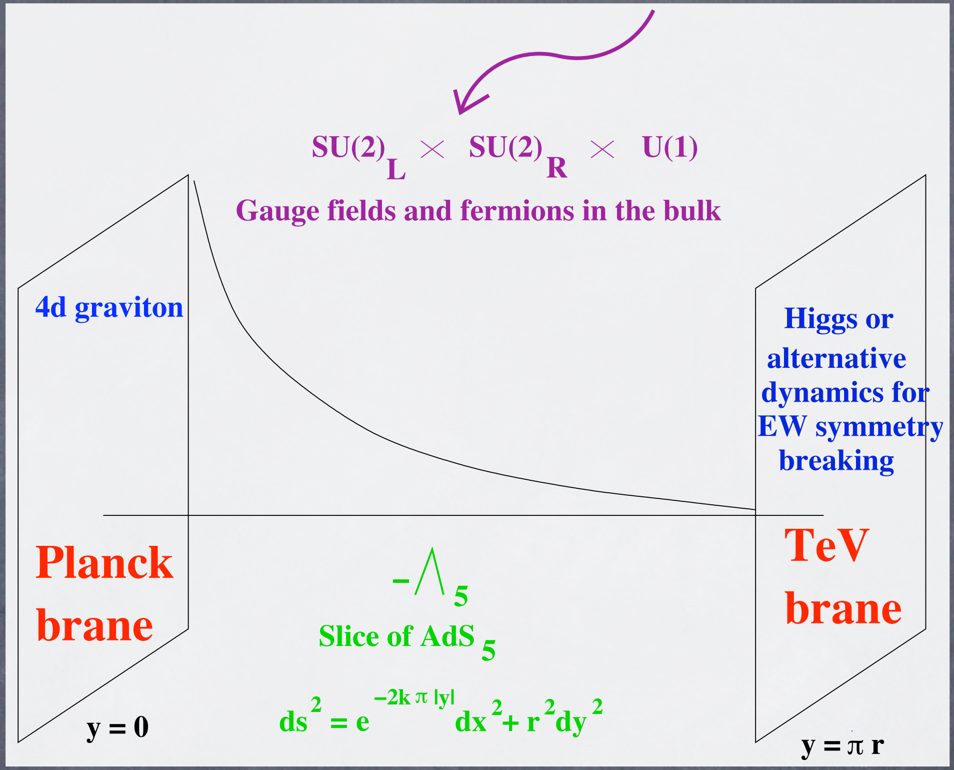
Some Conclusions

- The early models (ADD, RS1, UED) provide good "strawman" scenarios for experiments looking for gravity and matter in XD
- They are not "state-of-the-art" in XD model building
- Newer models are better motivated - more phenomenological studies should be done [e.g. MC tool development]
- Classification is INCOMPLETE - more work is needed!

Particle physics model building in warped space

2005 FAVOURITE SET-UP:

- ✔ hierarchy pb
- ✔ fermion masses
- ✔ High scale unification
- ✔ FRW cosmology



Now embed this into a GUT + solve proton stability

→

- ✔ Dark matter

[Servant's talk]

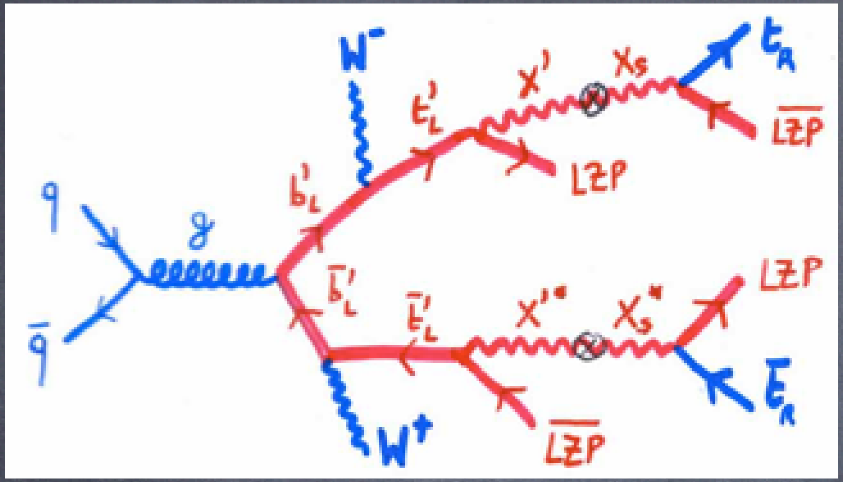
Non-SUSY BSM Talks

- Geraldine Servant [Saclay] - WIMPs in UED and RSMB models
- Bogdan Dobrescu [Fermilab] - UED Review
- Giacomo Cacciapaglia [Cornell] - Review of Higgsless models
- MP - Collider Phenomenology of Higgsless and Little Higgs Models

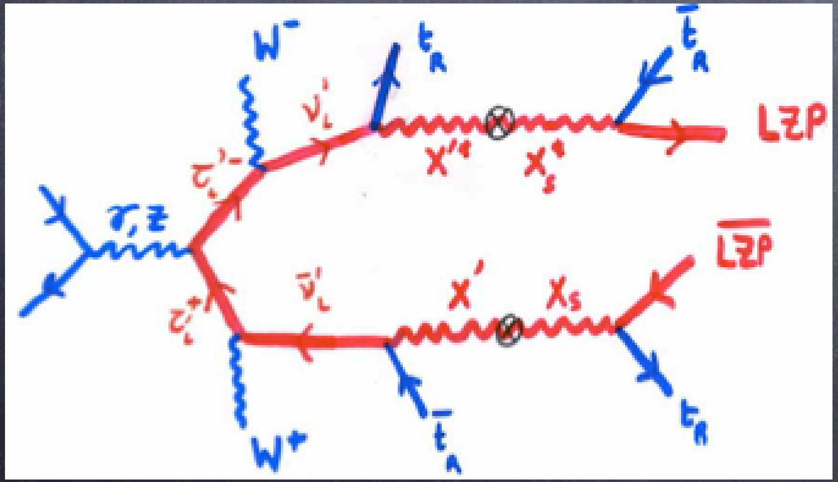
+ contributions from Ferrag+Jinnouchi+Sridhar and Mahmoudi+Sridhar

	LKP	LZP	LSP
nature	gauge boson	Dirac fermion	Majorana fermion
symmetry	KK parity $(-1)^n$	Z_3 $B - \frac{(n_c - \bar{n}_c)}{3}$	R-parity $(-1)^{3(B-L)+2S}$
		related to proton stability	related to proton stability
mass range	~600-1000 GeV	20 GeV-few TeV	~50 GeV-1 TeV
annihilation cross section	s-wave	s-wave	helicity suppressed (p-wave)
favourite detection	✔ LHC ✔ Indirect detection	✔ Direct detection! ✔ LHC! ✔ Indirect detection ! entire parameter space is testable	✔ LHC

Collider Signatures: examples



→ 4 W + 2 b+ $\not{E}_T$



→ 6 W + 4 b+ $\not{E}_T$

[Servant's talk]

UED: Why 6D is Better

[Dobrescu's talk]

- Global SU(2)w anomaly cancellation requires 3 mod 3 quark and lepton generations!
- Gravitational anomaly cancellation in 6D requires one right-handed neutrino per generation (only Dirac masses allowed)
- Proton lifetime is naturally sufficiently long

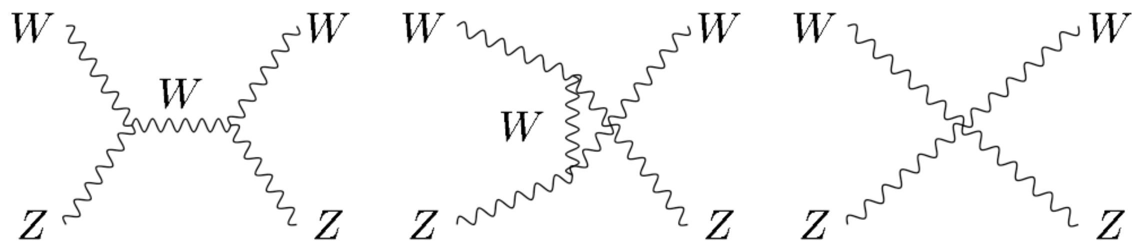
Higgsless Models

- Randall-Sundrum setup with SM fermions and gauge fields in the bulk
- Dynamical EW symmetry breaking on TeV brane (”boundary conditions breaking”)
- Extended 5D gauge group $SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ guarantees custodial SU(2) in 4D
- Unitarity violation postponed until ~5-10 TeV by virtue of 5D locality and gauge invariance-- no large contributions to precision electroweak observables

[Cacciapaglia’s talk]

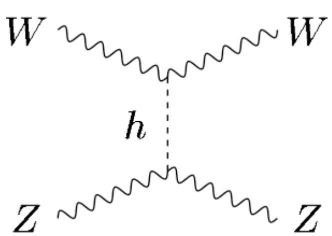
Example: Unitarity in $W_L^{\pm} Z_L \to W_L^{\pm} Z_L$ Scattering

SM sans Higgs:



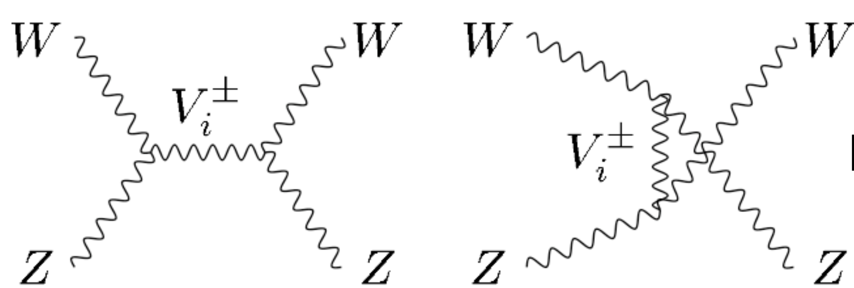
$$\mathcal{M} \propto E^2$$

SM:



$$\mathcal{M} \propto E^0\,!$$

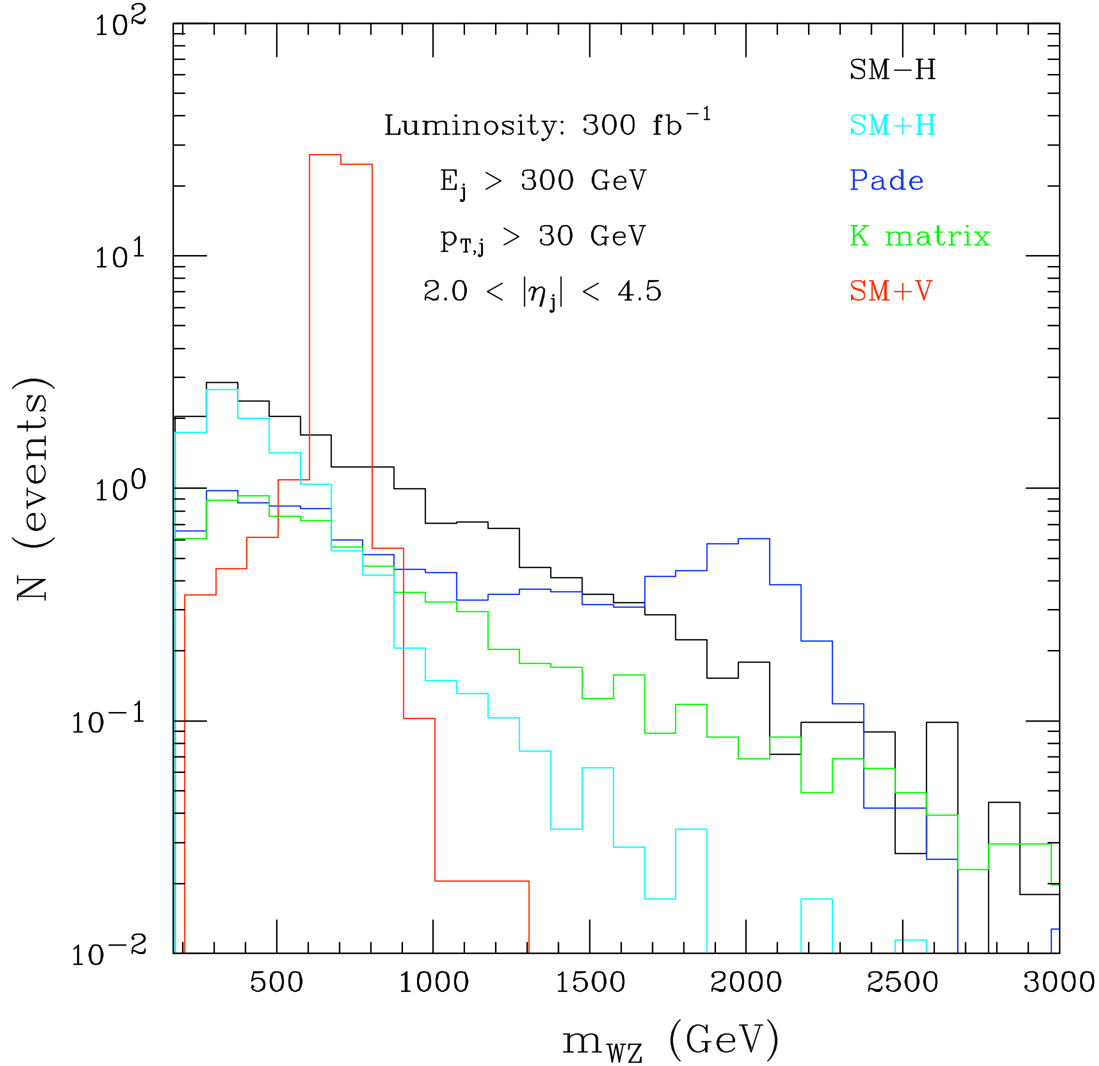
Higgsless:



$$\mathcal{M} \propto E^0\,!$$

[Perelstein's talk]

HL models predict a resonance in WZ channel, mass < 1 TeV



Number of events in 2j+3l+Et_miss channel at the LHC

[Perelstein's talk]

Virtual effects of gravitons in the production of diphotons at the LHC are analysed with the idea of probing the parameter space of the Randall-Sundrum (RS) model.

The masses of the $h_{\mu\nu}^{(\vec{n})}$ are given by

$$M_n \;=\; x_n \mathcal{K}\; e^{-\pi \mathcal{K} R_c} \tag{1}$$

where the x_n are the zeros of the Bessel function $J_1(x)$ of order unity, $\mathcal{K}i$ is the curvature of the extra dimension and R_c is the radius of compactifion.

The parameters of the model can be written as

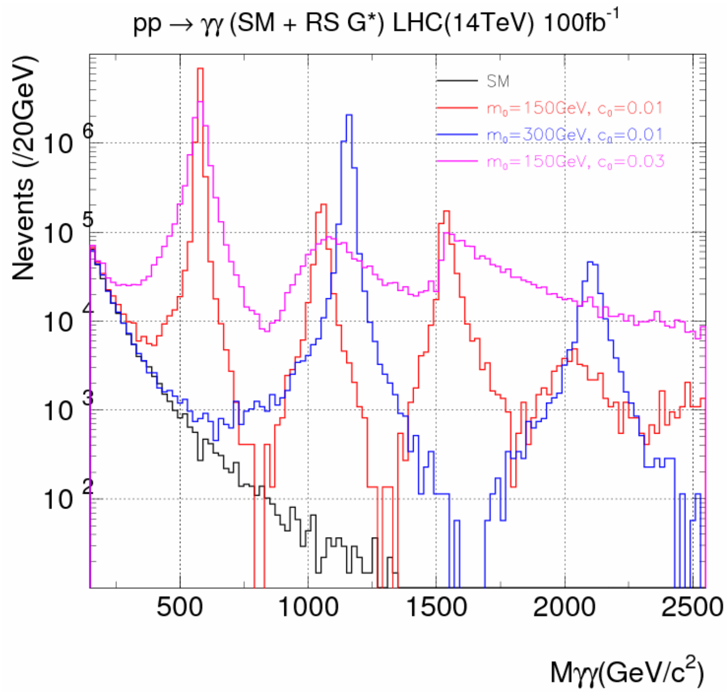
$$\begin{aligned} m_0 &= \mathcal{K} e^{-\pi \mathcal{K} R_c} \\ c_0 &= \mathcal{K}/M_P \end{aligned} \tag{2}$$

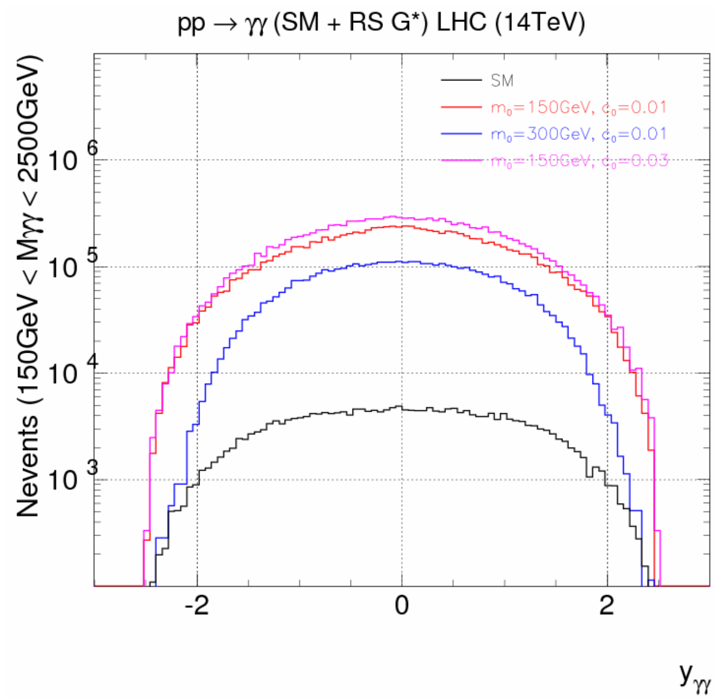
where m_0 is a scale of the dimension of mass and sets the scale for the masses of the KK excitations, and c_0 is an effective coupling. The interaction of massive KK gravitons with matter is given by

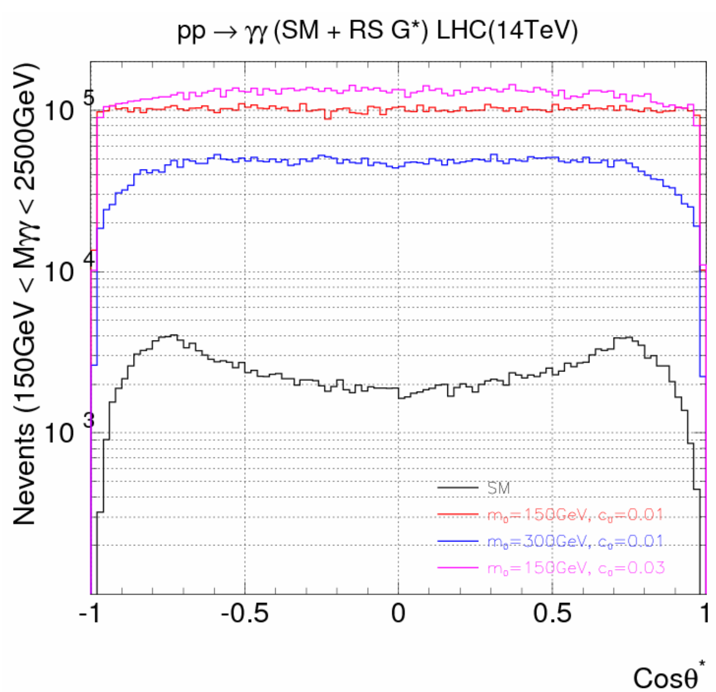
$$\mathcal{L}_{int} = -\sqrt{8\pi}\frac{c_0}{m_0}\sum_{n}^{\infty} T^{\mu\nu}(x) h_{\mu\nu}^{(n)}(x)\ . \tag{3}$$

We display the distributions in the invariant mass of the photon pair, the rapidity of the pair and the sub-procees c.m. angle.

[Ferrag+Jinnouchi+Sridhar's contribution]







Tool: PYTHIA6.210 (G* implemented)
+ ATLFAST2.53 ($|\eta_\gamma|<2.5$)
PDF: CTEQ6M
Pt cut (generator) > 50GeV
$\sigma(gg \rightarrow \gamma\gamma)$ / $\sigma(qq \rightarrow \gamma\gamma)$ = 1~4 %

S. Ferrag, O. Jinnouchi, K. Sridhar
May 20th, 2005 Les Houches

Non-commutative GUTS and neutrino physics

F. Mahmoudi and K. Sridhar

- We consider anomaly cancellation in GUTs defined on a non-commutative space-time.

- For the SU(5) group the $\bar{\mathbf{5}} + \mathbf{10}$ fermion representation is not anomaly-free.

- On the other hand, the SO(10) group is naturally preferred because the 16-dimensional fermion representation is anomaly-free.

- Also observation of neutrino oscillations favour SO(10) GUTs because the right-handed neutrino appears in the 16 dimensional representation.

- Thus it seems that the GUT group preferred by low-enery neutrino phenomenology is also favoured by NC space-time.

- We propose to study a SO(10) theory breaking to the SM via a Pati-Salam LR symmetry group. We also assume that the non-commutativity is a high energy phenomenon and the space-time becomes commutative at the scale of either GUT breaking or LR symmetry breaking. We then propose to study the implications of the NC GUTs for neutrino phenomenology.