# Phenomenology of 5d supersymmetry

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# The essential points!

- Top-down: Fundamental theories at high scale are generally higher dimensional and *often* contain SUSY at lower scale.
  Bottom-up: Supersymmetry breaking may be triggered by extra-d.
- MSSM embedded in $S^1/Z_2$. Orbifolding gives chiral fermions. Zero modes correspond to 4d MSSM.
- 5d $N = 1 \Rightarrow$ 4d $N = 2$: $(Q, Q^c)$. In the 5d bulk $N = 2$, but at the orbifold fixed points $N = 1$.
- How to break $N = 1$ brane SUSY? SS mechanism (Pomarol, Quiros, von Gersdorff, ..),$S^1/(Z_2 \times Z_2')$ (Barbieri, Hall, Nomura), brane-bulk interface dynamics (Mirabelli, Peskin, ...) distant source (Kaplan, Kribs, Schmaltz).
- We assume a common scalar mass ($m_0$), common gaugino mass ($M_{1/2}$), and vary them in the range $c/R$, with $c = [0.1 - 1.0]$. Run them down from $\Lambda \sim 20$ TeV with power law scaling with KK thresholds. Confront with low energy observables (DM, $b \to s\gamma$, $(g-2)_\mu$,..).

# Multiplet structures and locations

Vector and matter hypermultiplets:

$$V \equiv \begin{pmatrix} A_\mu & \phi \\ \lambda & \psi \end{pmatrix}, \qquad \Psi \equiv \begin{pmatrix} \phi_L & \phi_R \\ \psi_L & \psi_R \end{pmatrix}$$

- If all generation matters access bulk, *pert. gauge unification* requires $R^{-1} > 10^{10}$ GeV. Third generation better be in bulk to drive EWSB. First two generations kept at brane. For $R^{-1} = 1$ TeV, pert. gauge coupl unification at 30 TeV.
- Yukawa interaction confined at the brane, otherwise it will break $N = 2$ bulk SUSY.
- Yukawa couplings become non-perturbative near $\Lambda \sim 20$ TeV.

$N = 2$ yields a massive representation of SUSY. This mass is like central charge which is not renormalized. As a consequence, no wave-function renormalization of matter/Higgs hypermultiplets from bulk interaction (Dienes, Dudas, Gherghetta '98, Barbieri, Ferrara, Maiani, Palumbo, Savoy '82).

$$\beta_t^0 = \frac{y_t}{16\pi^2}\left[6y_t^* y_t + y_b^* y_b - \frac{16}{3}g_3^2 - 3g_2^2 - \frac{13}{15}g_1^2\right], \qquad \tilde{\beta}_t = \beta_t^0(g_i \to 0)$$

# KK decompositions of superfields

Every field is either $Z_2$ even or $Z_2$ odd.

$$\begin{pmatrix} A_\mu \\ \lambda \end{pmatrix} \equiv \mathcal{V}(x,y) = \frac{\sqrt{2}}{\sqrt{2\pi R}}\mathcal{V}^{(0)}(x) + \frac{2}{\sqrt{2\pi R}}\sum_{n=1}^{\infty}\mathcal{V}^{(n)}(x)\cos\frac{ny}{R}\,,$$

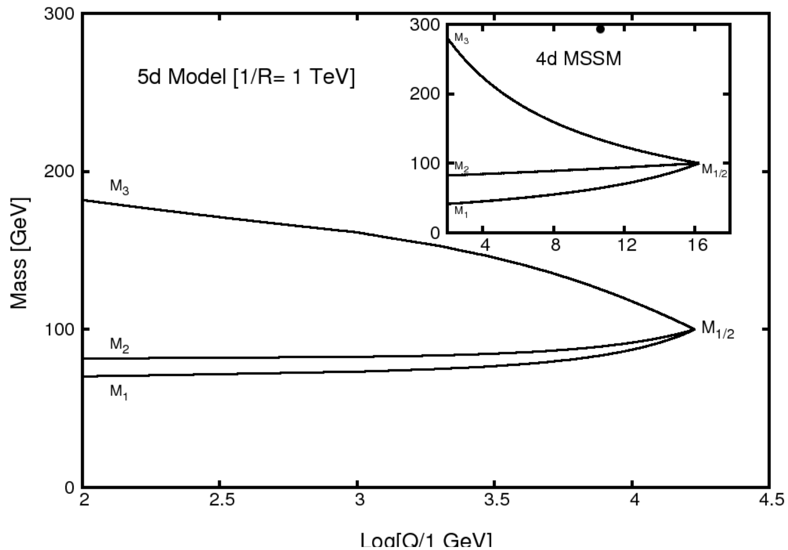
$$\begin{pmatrix} \phi \\ \psi \end{pmatrix} \equiv \Phi(x,y) = \frac{2}{\sqrt{2\pi R}}\sum_{n=1}^{\infty}\Phi^{(n)}(x)\sin\frac{ny}{R}\,,$$

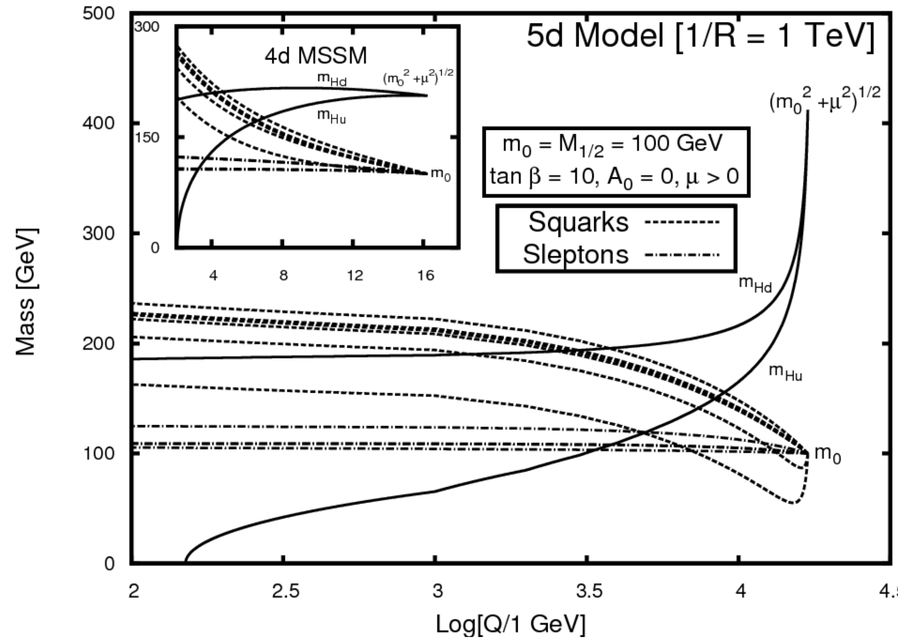
$$\begin{pmatrix} \phi_L \\ \psi_L \end{pmatrix} \equiv \mathcal{F}_L(x,y) = \frac{\sqrt{2}}{\sqrt{2\pi R}}\mathcal{F}_L^{(0)}(x) + \frac{2}{\sqrt{2\pi R}}\sum_{n=1}^{\infty}\mathcal{F}_L^{(n)}(x)\cos\frac{ny}{R}\,,$$

$$\begin{pmatrix} \phi_R \\ \psi_R \end{pmatrix} \equiv \mathcal{F}_R(x,y) = \frac{2}{\sqrt{2\pi R}}\sum_{n=1}^{\infty}\mathcal{F}_R^{(n)}(x)\sin\frac{ny}{R}\,.$$

- Doubling of fermionic contributions in bulk,
- At the brane the odd wave-functions vanish.

# gauginos, scalars, radiative EWSB



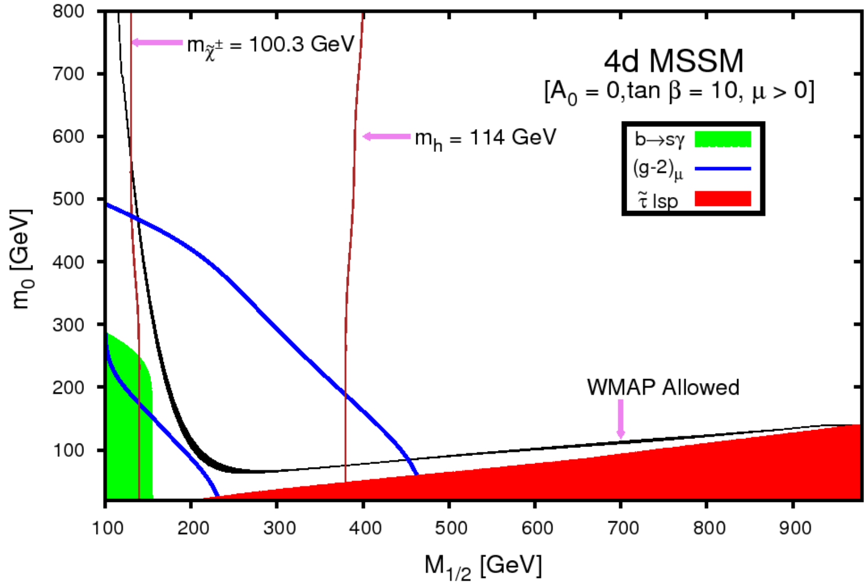



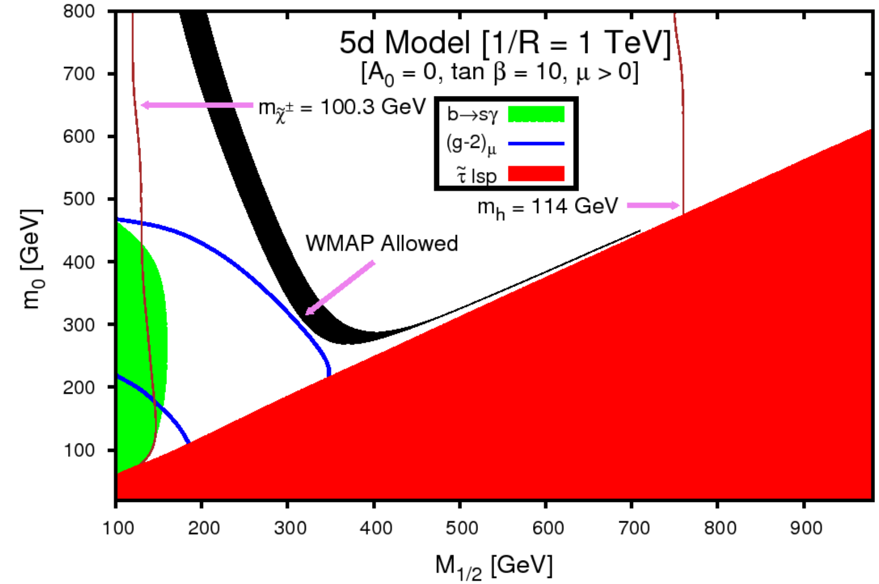

$$\frac{\partial X}{\partial t} = \beta_X\,, \quad \text{where} \;\; \beta_X = \beta_{0X} + n\tilde{\beta}_X\,.$$

$M_1, M_2, M_3 \;\sim\; (0.4, 0.8, 3.0) \times M_{1/2}$ (in 4d) , $\quad (0.7, 0.8, 2.0) \times M_{1/2}$ (in 5d)

$m^2_{\tilde{Q}_3} \;\sim\; m_0^2 + 5.5 M_{1/2}^2$ (in 4d) , $\quad m_0^2 + 3.5 M_{1/2}^2$ (in 5d)

# $m_0$–$M_{1/2}$ plots




- 3 DM candidates: $\tilde{N}_1$ (LSP), $\gamma_1$, $\tilde{\gamma}_1$. If KK parity is *not* conserved, then the usual LSP is the only candidate.
- Above plots drawn using micrOMEGAS.

# In Future....

- Estimate limits on $R^{-1}$ with MSSM in mind. Present limit in UED: $R^{-1} > 600$ GeV from all sorts of electroweak processes. We expect that the bound will be relaxed.
- Include the KK one-loop effects in the processes encoded in microOMEGAS.
- Tackle all 3 DM's together to obtain the allowed zone.
- ......