

SUSY Breaking with Slepton (N)LSPs

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Based on

W. Buchmüller, J.K., K. Schmidt-Hoberg, JHEP **02** (2006) 069
W. Buchmüller, K. Hamaguchi, J.K., Phys. Lett. **B632** (2006) 366

Outline

- 1 Introduction
- 2 Gaugino Mediation in an Orbifold GUT
- 3 Sparticle Spectrum
- 4 Conclusions

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The Scenario

- **Gravitino** is the **LSP**
 - Only gravitational interaction
- ⇒ **Long-lived NLSP**
- Decays outside detector for $m_{3/2} \gtrsim 10$ keV
 - Lifetime up to a year for heavier gravitinos
- ⇒ Looks like LSP at colliders
- ⇒ LHC experiments might find charged “LSP”, if the NLSP is a charged slepton

Motivation from Cosmology

Constraints on the LSP:

- Observed dark matter density
- Big Bang Nucleosynthesis
- Distortions of the Cosmic Microwave Background

↪ Bounds on gravitino mass and reheating temperature

More restrictive for unstable gravitino

↪ Favored scenario:

- Stable **gravitino LSP**, $m_{3/2} \sim 10 - 100$ GeV
- **Slepton NLSP**

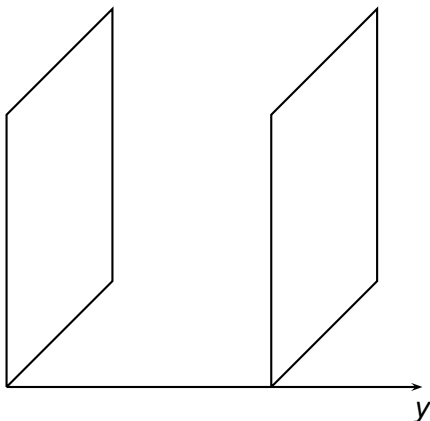
For SUSY breaking by **Gaugino Mediation**:

Gravitino can be LSP, $m_{3/2} \gtrsim 10$ GeV

Gaugino-Mediated Supersymmetry Breaking

Kaplan, Kribs, Schmaltz, Phys. Rev. **D62** (2000)

Chacko, Luty, Nelson, Ponton, JHEP **01** (2000)

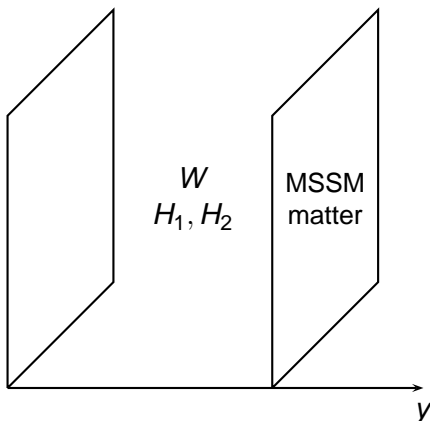


- D dimensions
- 4-dimensional branes

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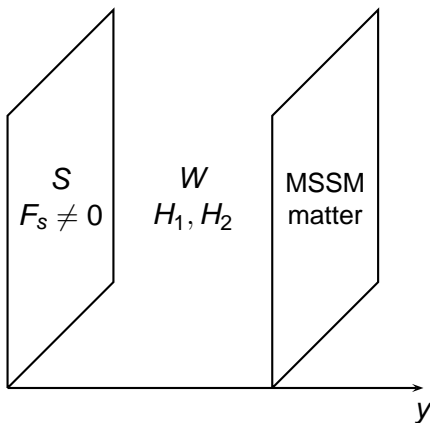


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- Gauge fields in the bulk
- Higgs in bulk or on brane

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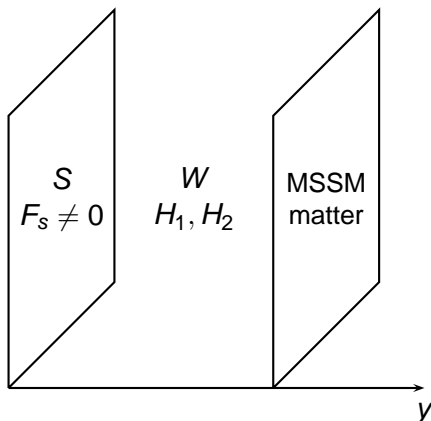


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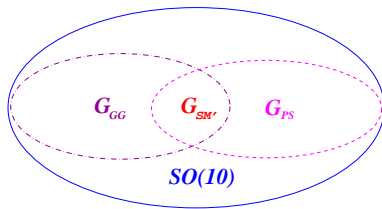
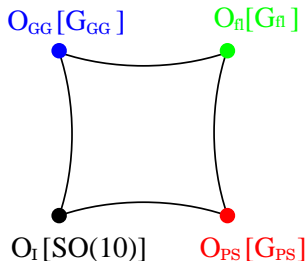
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- 4-dimensional branes
- Gauge fields in the bulk
- Higgs in bulk or on brane
- SUSY broken by vev F_S of gauge singlet S
- Soft masses for gauginos, Higgs, gravitino
- Squark and slepton soft masses ≈ 0
 \rightsquigarrow no **SUSY flavor problem**

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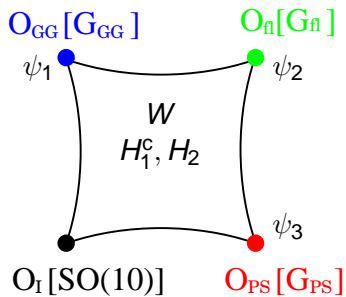
A Concrete Model

Asaka, Buchmüller, Covi, Phys. Lett. **B563** (2003)

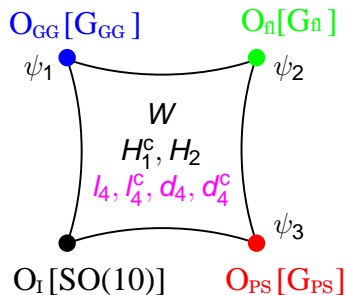
- 6 dimensions
- $SO(10)$ gauge symmetry
- Orbifold $T^2/(\mathbb{Z}_2^I \otimes \mathbb{Z}_2^{PS} \otimes \mathbb{Z}_2^{GG})$
- 4D gauge symmetry: $G_{SM'} = SU(3)_c \otimes SU(2)_L \otimes U(1)_Y \otimes U(1)_X$



Zero Modes



Zero Modes

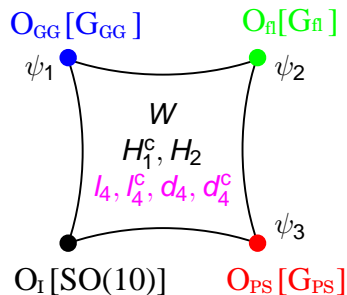


Partial 4th generation in bulk, mixes with brane fields

\Rightarrow MSSM matter: linear combinations of $\psi_1, \psi_2, \psi_3, l_4, l_4^C, d_4, d_4^C$

Couplings restricted by gauge symmetry and 2 global U(1)'s

Zero Modes



Partial 4th generation in bulk, mixes with brane fields

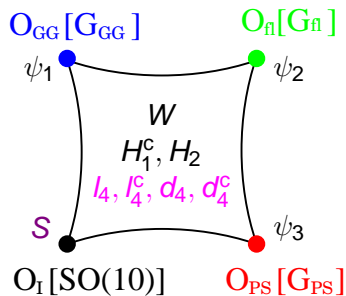
⇒ MSSM matter: linear combinations of $\psi_1, \psi_2, \psi_3, l_4, l_4^C, d_4, d_4^C$

Couplings restricted by gauge symmetry and 2 global U(1)'s

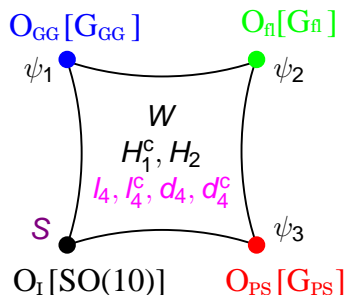
⇒ Realistic mixing pattern:

Large mixings for e_L, ν_L, d_R , Small mixings for d_L, e_R

Supersymmetry Breaking



Supersymmetry Breaking



FCNC danger from coupling of **bulk matter** to S
 \Rightarrow Couplings must be strongly suppressed

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Boundary Conditions at the Compactification Scale

Assuming $M_c \sim M_{\text{GUT}}$:

- Gauge couplings $g_1 = g_2 = g_3 = g \approx \frac{1}{\sqrt{2}}$
- Gaugino masses $M_1 = M_2 = M_3 = m_{1/2}$
- Squark and slepton masses ≈ 0
- Trilinear couplings $A \approx 0$
- Soft Higgs masses $m_{h_1}^2, m_{h_2}^2 \neq 0$ for bulk Higgs fields

Running generates non-zero masses at low energies

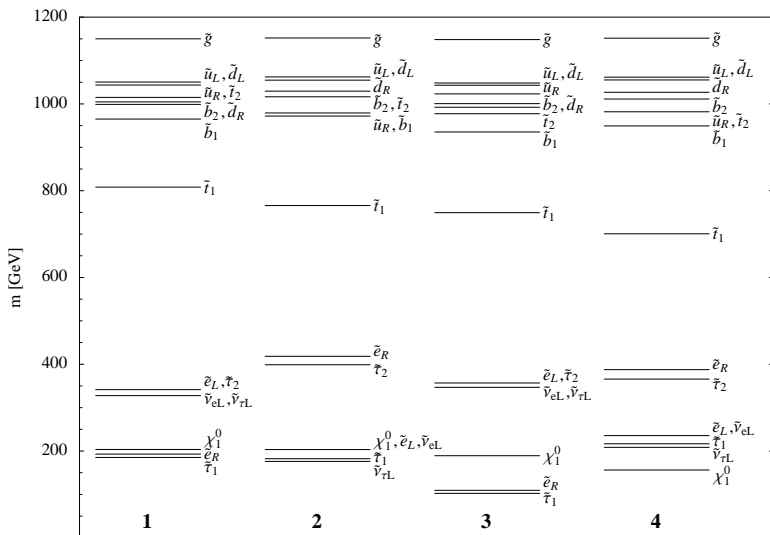
Calculated using SOFTSUSY

Allanach, Comput. Phys. Commun. 143 (2002)

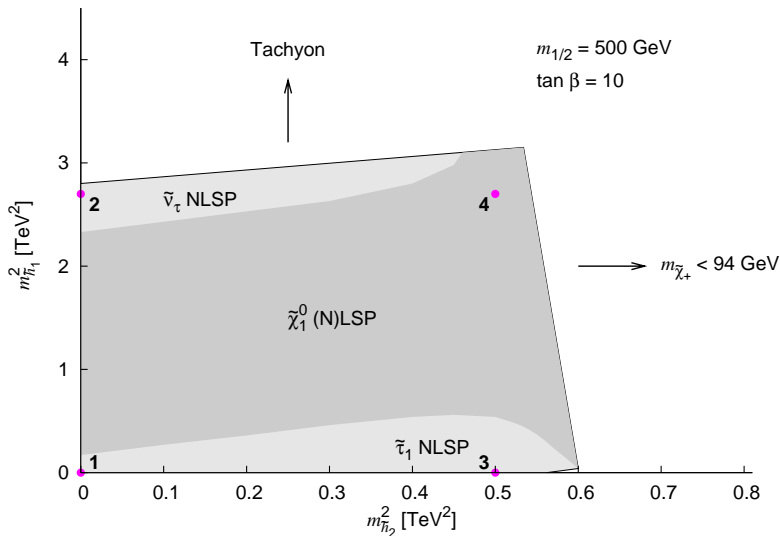
Resulting Slepton Masses

- $m_{\tilde{h}_i}^2 = 0$: Right-handed $\tilde{\tau}$ is the NLSP
Kaplan, Kribs, Schmaltz, Phys. Rev. **D62** (2000)
- $m_{\tilde{h}_1}^2 > m_{\tilde{h}_2}^2$: Heavier RH sleptons, lighter LH ones
 - Neutralino can be lighter than sleptons
Chacko, Luty, Nelson, Ponton, JHEP **01** (2000)
⇒ Gravitino LSP not viable (BBN)
 - **Left-handed** slepton can be the NLSP
Kaplan, Tait, JHEP **06** (2000)

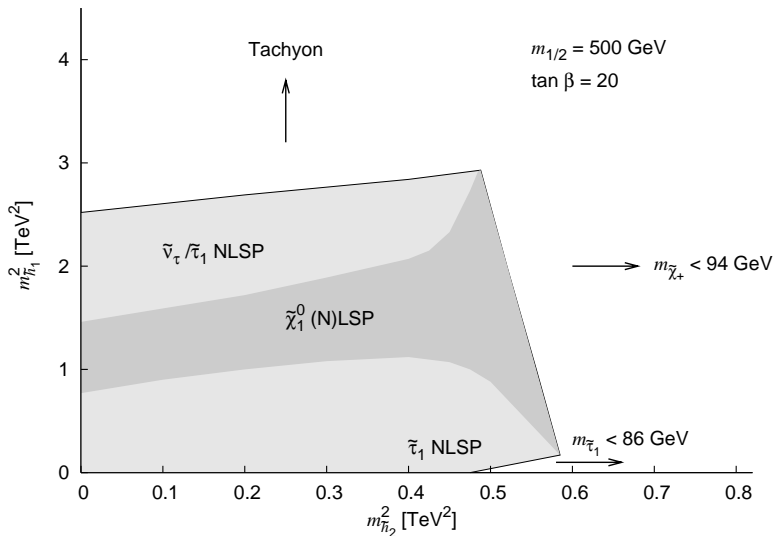
Sparticle Spectrum ($m_{1/2} = 500$ GeV, $\tan \beta = 10$)



Allowed Parameter Space Region



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Conclusions

- Gravitino alternative LSP candidate
- NLSP effectively LSP in collider, unless gravitino very light
- $\tilde{\tau}$ or $\tilde{\nu}$ could be the NLSP
- Scenario can be accommodated in
 - Gaugino Mediation
 - Gravity Mediation
 - Gauge Mediation
- Decays of $\tilde{\tau}$ NLSP into gravitinos may be observable