Goldstini Give the Higgs a Boost

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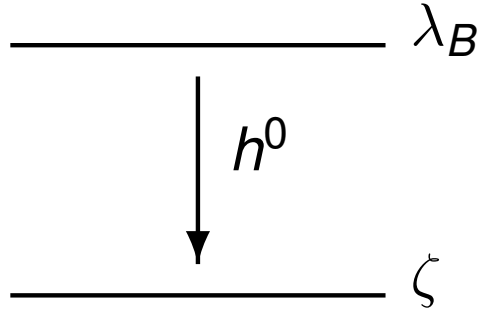
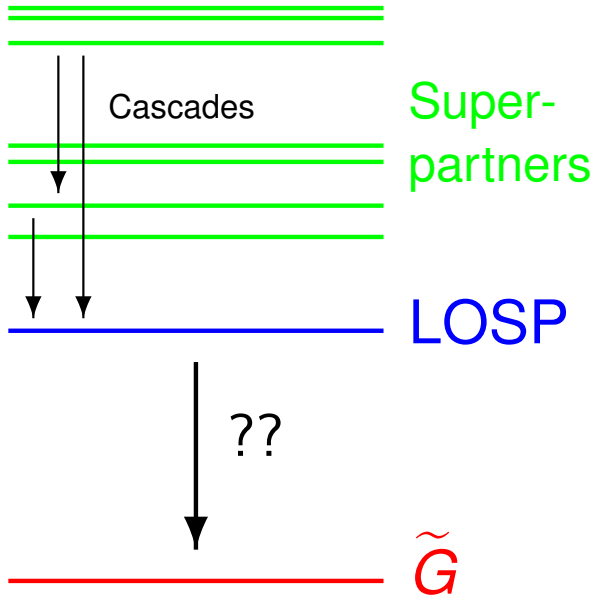
Outline

- Background
  - Lightest Observable-Sector Supersymmetric Particle (LOSP)
  - 'Traditional' LOSP Phenomenology and Decays
- Novel LOSP Decays
  - Multiple Goldstini
  - Counterintuitive Possibility:
  - Br(Pure Bino $\rightarrow h^0 +$ Goldstino) $= 100\%$



The LOSP

- SSM fields in 'observable sector.'
  - Lightest R-parity odd state: LOSP
- SUSY breaking occurs in 'hidden sector(s).'
- In Colliders: pair of cascade decays to two LOSPs.
- Possible LOSP decays are important.
- A 'traditional' scenario: LOSP decays to gravitino.

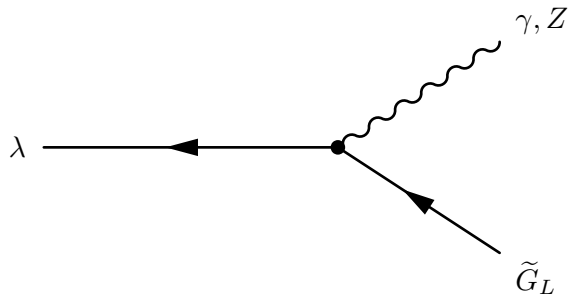


Gravitino couplings

- Super-Higgs mechanism
  - gravitino eats goldstino, gets mass $m_{3/2} = \frac{F}{\sqrt{3}M_{Pl}}$
- Goldstino Equivalence Theorem
  - longitudinal gravitino $\approx$ goldstino
- Goldstino couplings set by supercurrent conservation
  - $\mathcal{L} = \frac{1}{F} j^{\mu} \partial_{\mu} \widetilde{G}_L$
- LOSP decays to its superpartner + gravitino.

Bino LOSP $\rightarrow$ Gravitino decay

- Decay modes of a bino LOSP λ:
  - $\lambda \rightarrow \gamma + \widetilde{G}_L$ ($> 70\%$)
  - $\lambda \rightarrow Z + \widetilde{G}_L$ ($< 30\%$)
- Small admixture of higgsino allows:
  - $\lambda \rightarrow h^0 + \widetilde{G}_L$
  - Tiny Branching Fraction $\sim \frac{m_\lambda^2 m_Z^2}{\mu^4}$



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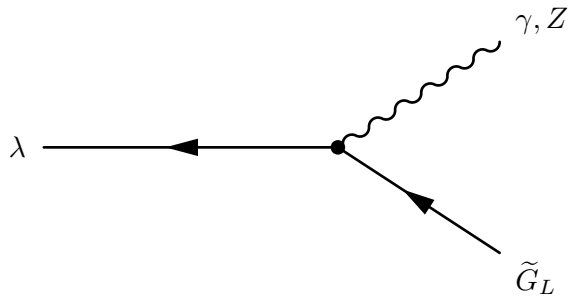
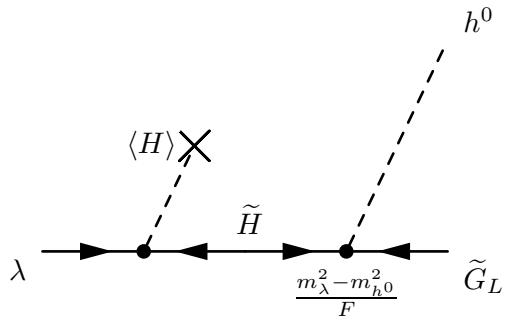
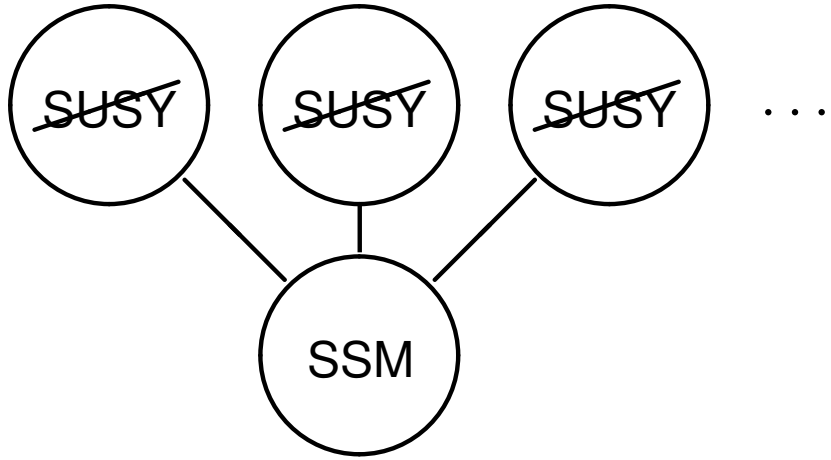
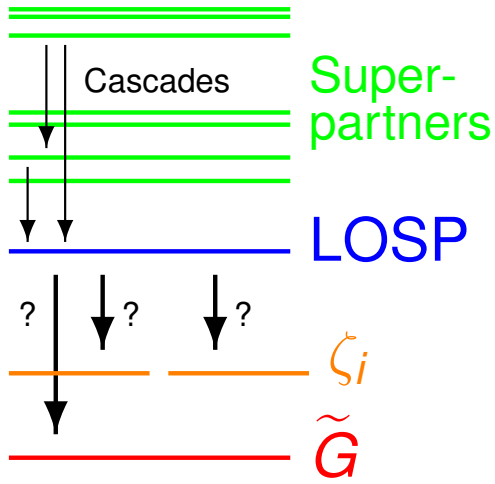




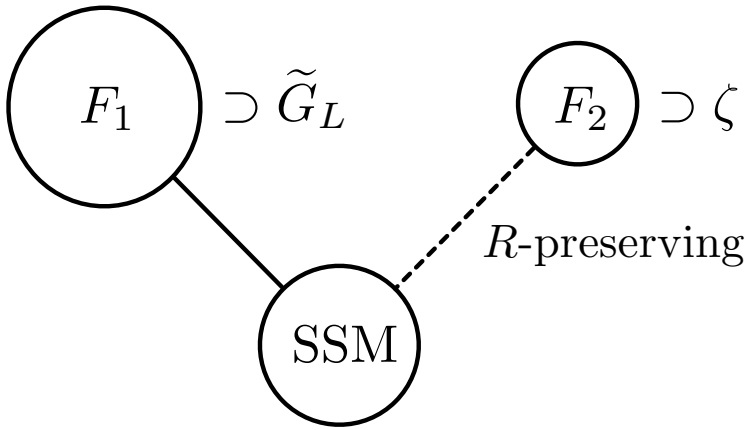
Multiple Goldstini?

- SUSY may be broken in multiple hidden sectors
  [Cheung, Nomura, Thaler '10]
  - Each has its own goldstino
- Gravitino eats one linear combo via Super-Higgs
- Other goldstini (ζ_i) remain in the theory
  - Goldstini mass = $2m_{3/2}$ at tree level
- Goldstini couplings not set by supercurrent conservation!
- Possibility of novel LOSP $\rightarrow$ goldstini decays





Our Model



- Two hidden sectors break SUSY
  - SUSY-breaking scales: $F_1 \gg F_2$
    - ζ couplings $\gg \widetilde{G}_L$ couplings
  - Each contributes to soft SUSY-breaking terms
- Sector 2 respects an R-symmetry
  - no contribution to gaugino masses, or A- or B-terms.

Higgsino Decoupling Limit Effective Field Theory

- Study $\lambda \to X + \zeta$ in Higgsino Decoupling Limit
  - $|\mu|$ (and m_{A^0}) $\gg m_\lambda$
  - λ is predominantly bino
- Integrate out heavy Higgsinos (and scalars) to form EFT
- $m_\lambda/|\mu|$ suppression for higher dim. operators
- What operators allowed for $\lambda \to X + \zeta$?

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HDL-EFT: The Dimension 5 Operator

- Many operators prohibited by R-symmetry:
  - $i\lambda\sigma^{\mu\nu}\zeta F_{\mu\nu}$, $\lambda\zeta\Phi^\dagger\Phi$, etc.
  - Usual decay to photon forbidden!
- Only 1 operator allowed at dimension 5:
  - $\mathcal{O}_R^5 = C_R^5 \frac{\mu}{F_2}\lambda\zeta(H_u \cdot H_d)^*$
  - Allows only $\lambda \to h^0 + \zeta$
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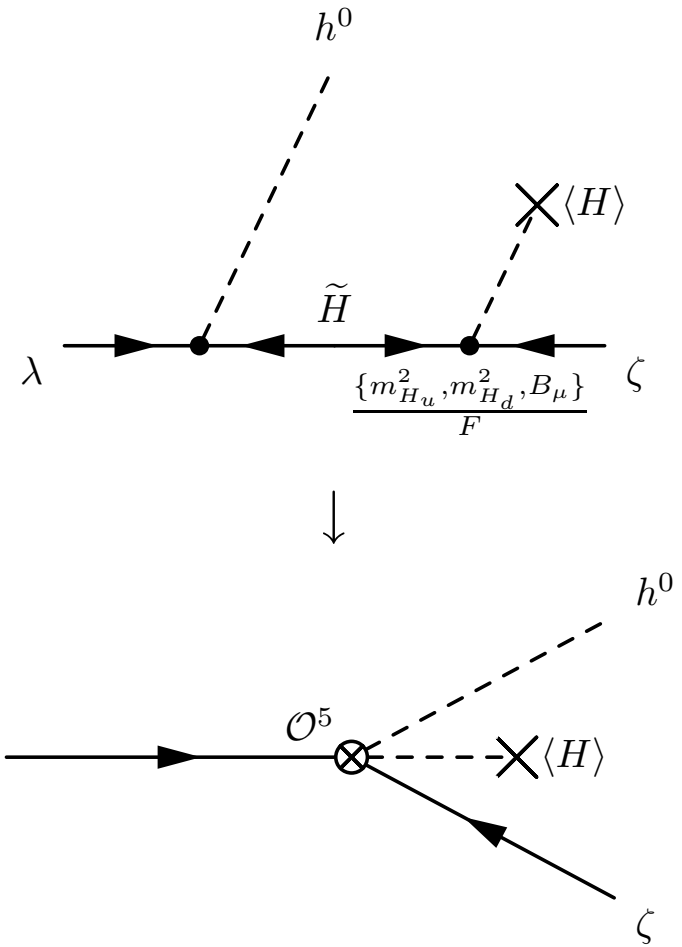

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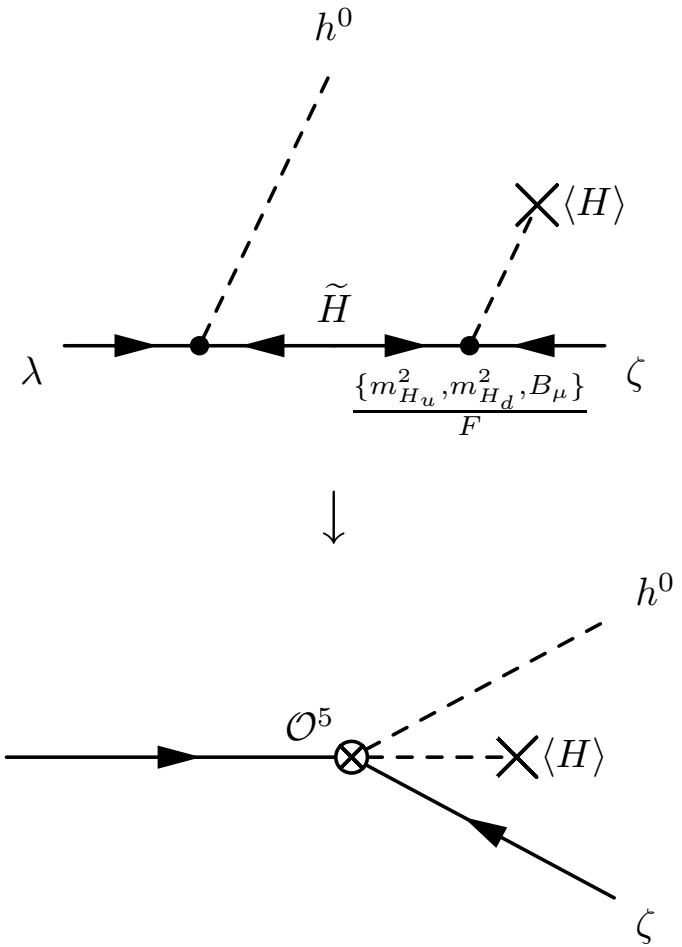
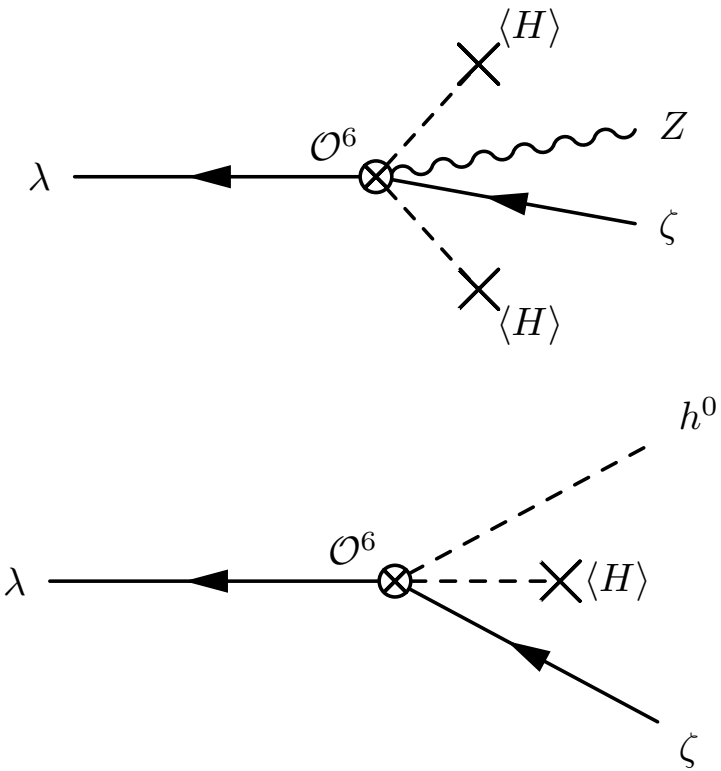


HDL-EFT: Dimension 6 Operators

- Only 'suppressed' by $m_\lambda \tan\beta/|\mu|$
- $\mathcal{O}^6_{\Phi,1} = \frac{C^6_{\Phi,1}}{F_2} i\zeta^\dagger \bar{\sigma}^\mu \lambda \, \Phi^\dagger D_\mu \Phi$
- $\mathcal{O}^6_{\Phi,2} = \frac{C^6_{\Phi,2}}{F_2} i\zeta^\dagger \bar{\sigma}^\mu \lambda \, D_\mu \Phi^\dagger \Phi$
  - Mediates $\lambda \to Z + \zeta$, $\lambda \to h^0 + \zeta$
- Three-body decays generally subdominant



Sanity Check: Does this work for the 'true' goldstino?

- Same power counting would (erroneously) imply substantial $\lambda \longrightarrow h^0 + \widetilde{G}_L$
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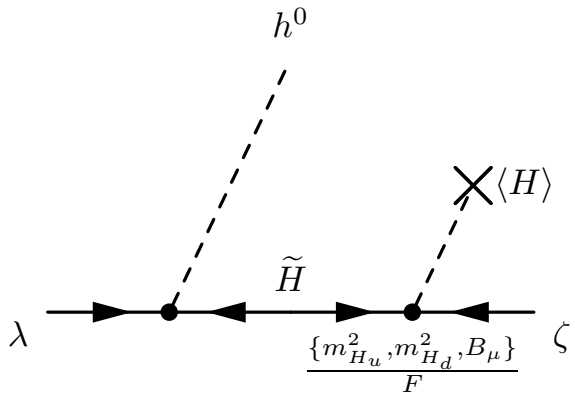

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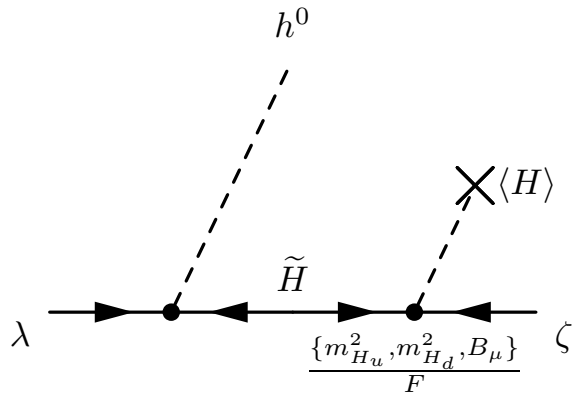
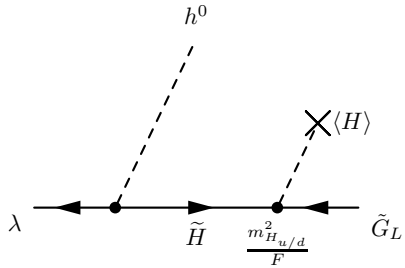
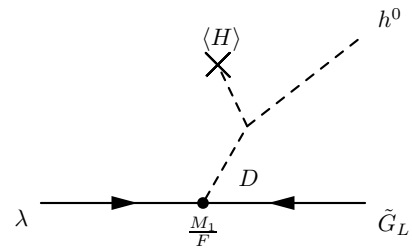
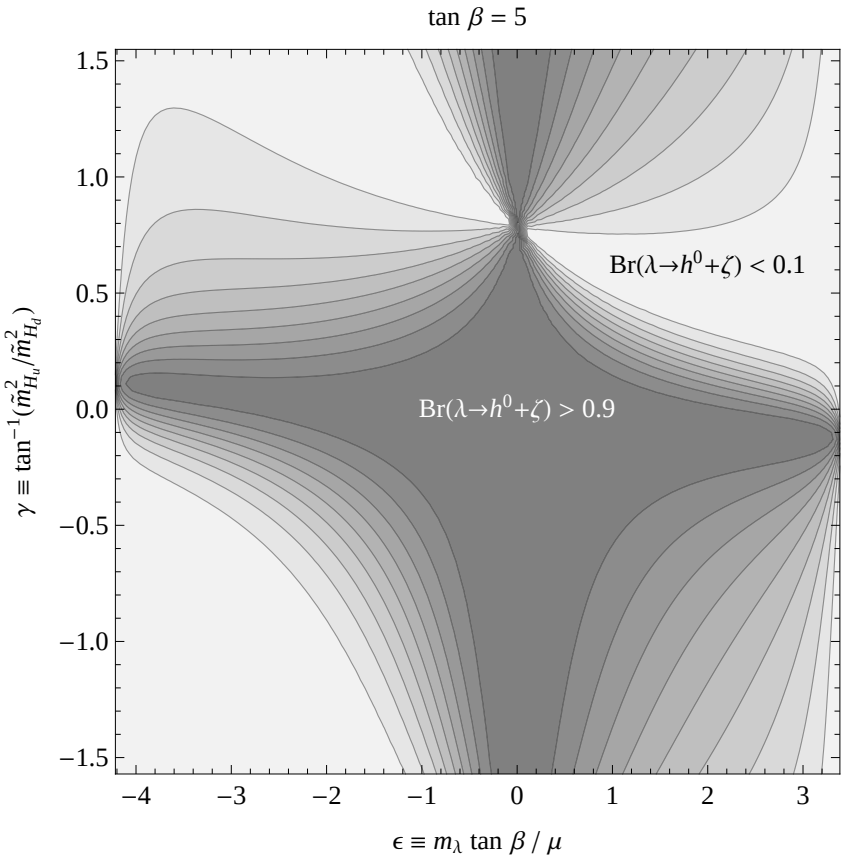






HDL-EFT: Results

- Two dominant decay modes:
  - $\lambda \to h^0 + \zeta$ (dim 5 + dim 6)
  - $\lambda \to Z + \zeta$ (dim 6)
- Higgs mode dominant for small $m_\lambda \tan\beta/\mu$
  - Pure bino ($\mu \to \infty$), only Higgs mode occurs!
- Difermion mode subdominant
- Photon mode at dimension 7 and loop-suppressed



Summary

- Multiple SUSY-breaking sectors, and their associated goldstini, can lead to novel phenomenology at the LHC.

- In particular, a nearly-pure bino LOSP may have a counterintuitively large branching ratio for its decay to a Higgs and an uneaten goldstino.