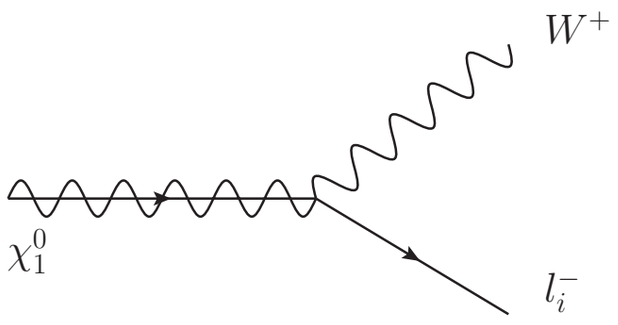
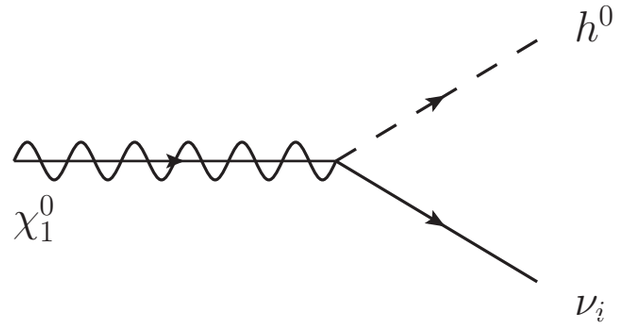
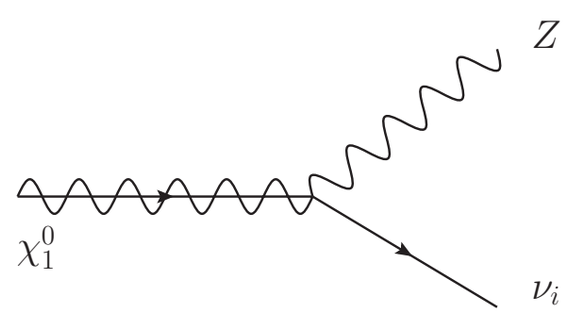
Gravitinos and hidden SUSY at the LHC.







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based on :

JHEP 1201 (2012) 122
JHEP 1109 (2011) 119
JHEP 1010 (2010) 061
and ongoing work

Collaborators: W. Buchmüller, F. Brümmer, J. Hajer, J. Schmidt

Implications of LHC Results for TeV-Scale Physics Workshop
CERN, 29.03.2012

HELMHOLTZ ASSOCIATION

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Outline

- Gravitino Cosmology
- Gravitinos and Higgsino World
- Gravitino Dark Matter and R-parity Violation
- Neutralino NLSP Decays at the LHC
- Summary

Experimental Facts

- Possible heuristic : Evaluate experimental facts and find the simplest theory predicting the observed results.

Experimental Observation	Theoretical Explanation
Neutrino Oscillations (Neutrino Mass)	Seesaw Extension of the SM
Dark Matter	New (super) weakly interacting massive Particle
Matter-Antimatter Asymmetry	Leptogenesis
No evidence for New Physics so far & Higgs mass ~ 125 GeV @ LHC	?

Neutrino Mass ⟺ **Lepto-genesis**

Gravitino Cosmology

- Supersymmetry is so far the best motivated extension of the SM.

- The existence of gravitino, gauge fermion of SUGRA, is unequivocal prediction of locally supersymmetric extensions of SM.

- Leptogenesis requiers high temperature in the universe leading to production of gravitinos from thermal bath via SQCD 2->2 scattering.

- Problems:
  - Heavy gravitino: Late time decays during BBN spoil its success.
  - Light stable gravitino: Too high abundance leads to overclosure of the universe.

Gravitino Cosmology II

> Possible solutions to the gravitino problem leading to consistent cosmology:

Gravitino (heavy) LSP / Gravitino DM

↓

NLSP Problem

NLSP->Gravitino decays are suppressed and can spoil BBN

↓

Small R-parity Violation

NLSP decays before BBN
Lifetime of gravitino longer than age of the universe

Super-heavy Gravitino

↓

Gravitino decays

↓

WIMP DM

Non-thermally produced higgsino DM

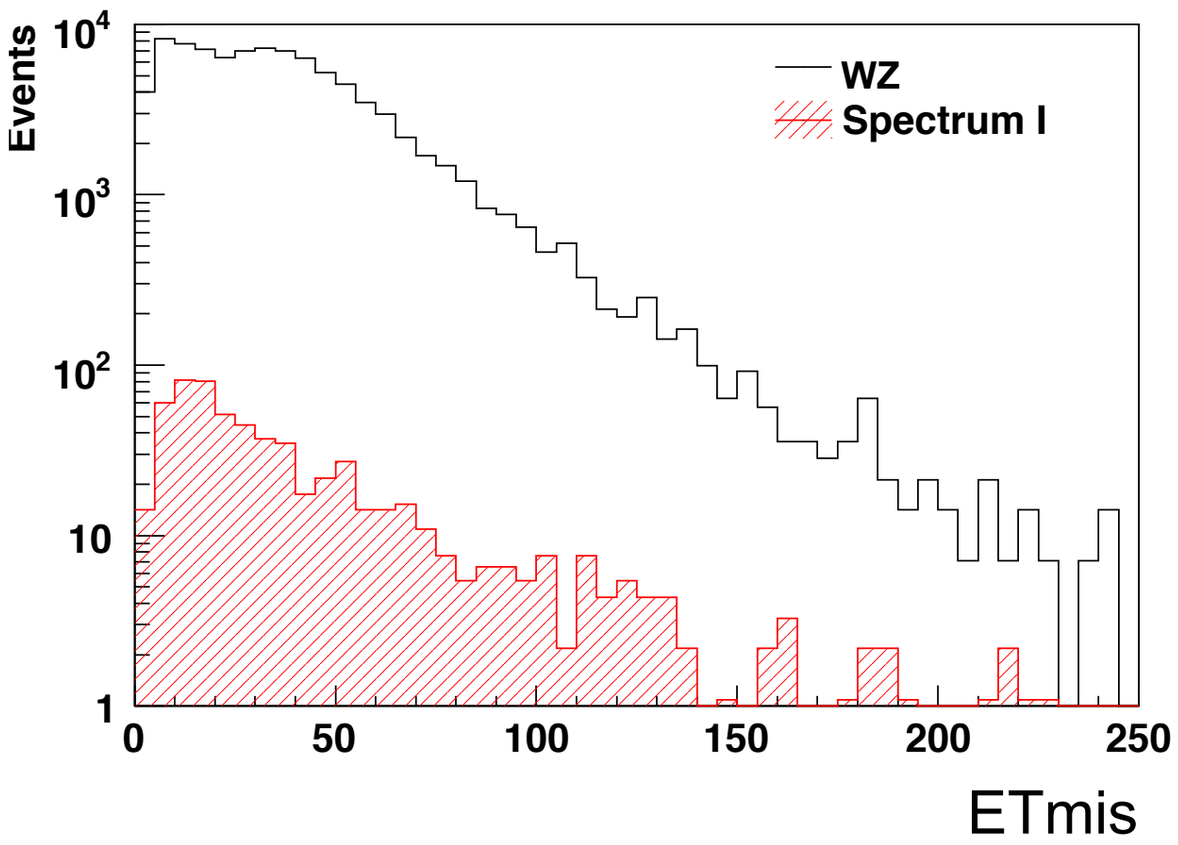
LHC Nightmare from Higgsino World

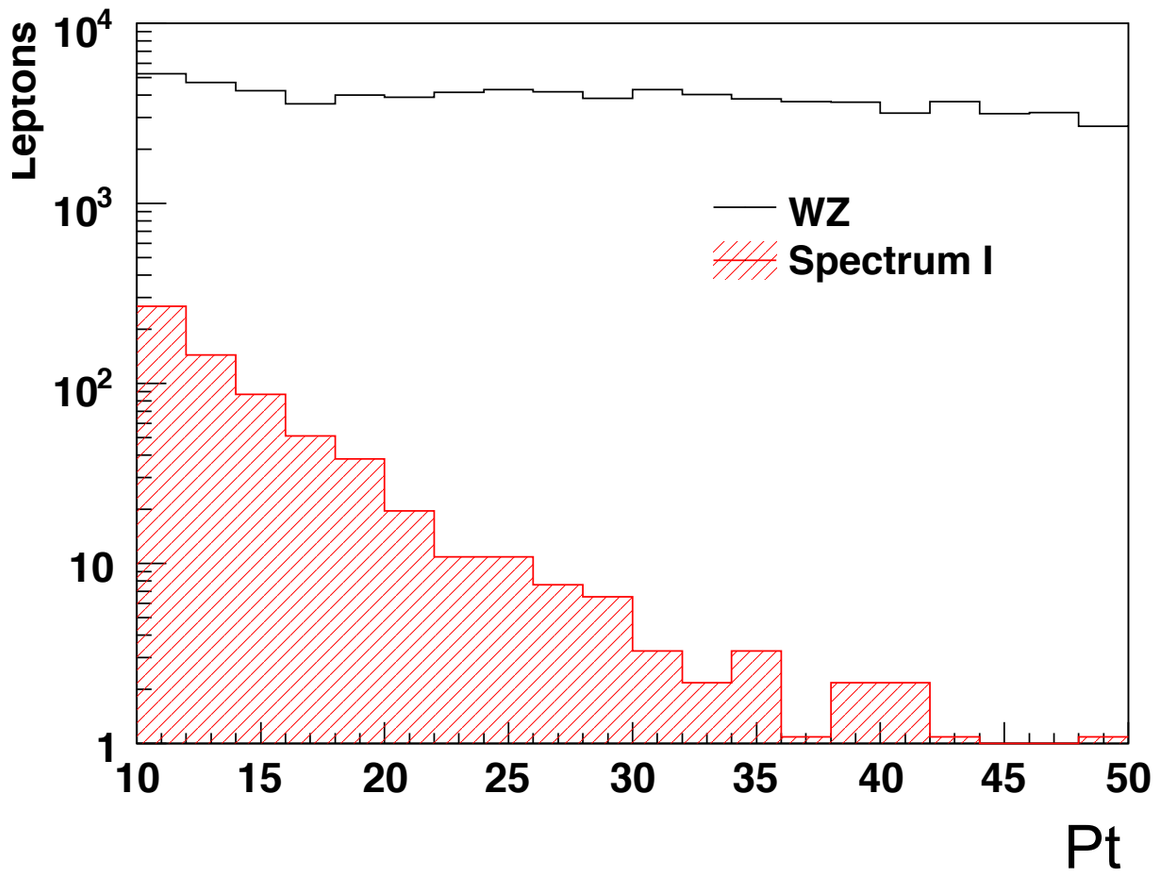
- Why is SUSY not found so far ?
- SUSY signals depend on the nature of the LSP !
- Consider a scenario where:
  - Gravitino is either super-heavy or the LSP
  - Neutralino is the (N)LSP and higgsino-like
  - Charginos are mass-degenerate with neutralinos
  - Higgs mass around 125 GeV
  - All colored particles are inaccessible at the LHC

- This scenario is motivated by higher dimensional GUTs if gravitino is the LSP (Brümmer/Buchmüller ’11).
- If gravitino is super-heavy such spectrum can occur in anomaly mediation scenarios (Jeong et al. ’11) .

A Challenge for the LHC

- LHC discovery is very challenging, see also work by (Baer/Barger/Huang '11)
- Linear Collider can find them

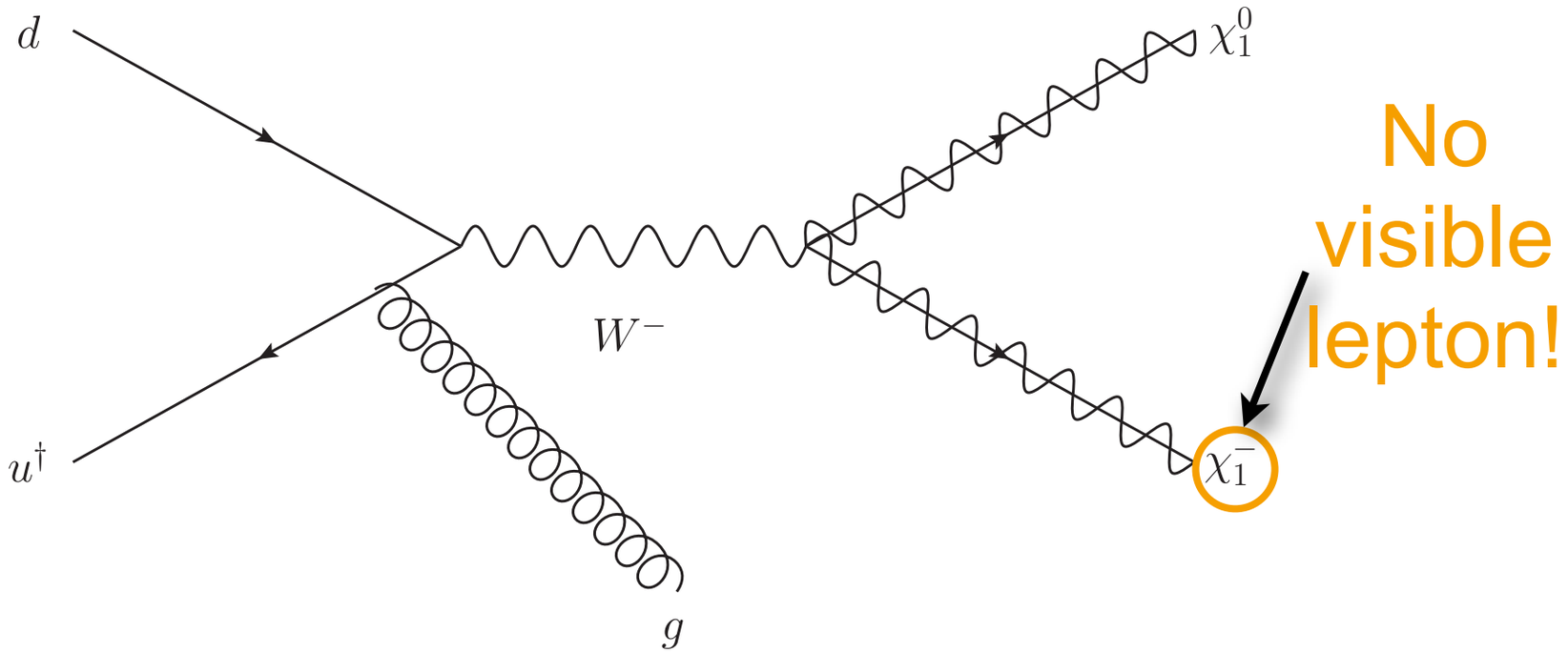




ETmis spectrum and Pt spectrum of leptons
after *DELPHES* simulation

Monojets at the LHC

- If there is initial state radiation with significant Pt -> Monojet signature!



- Need to perform a study with real detector simulation software !
- Maybe limits at higgsinos from monojets ?
- See Steve Worm‘s talk at Moriond.

Gravitino DM and R-parity Violation

- Small R-parity violation: leads to consistent cosmology.
- Possible NLSP: neutralino.
- RPV will lead to gravitino and neutralino decays which are governed by the same parameter: ζ.
- Cosmological constraints:
  - RPV terms violate lepton number L ➔ RPV should not wash out baryon asymmetry.
  - NLSP should decay before BBN.

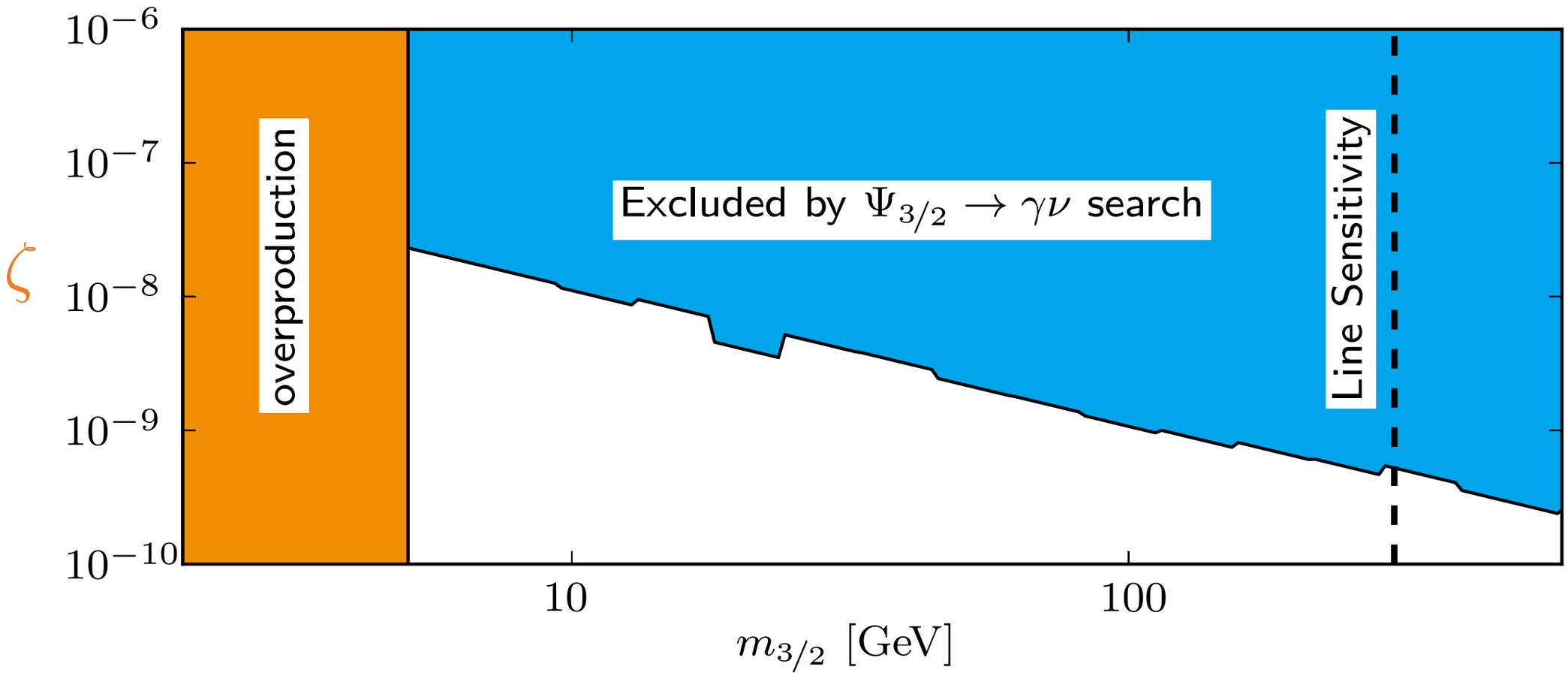
$$10^{-13} < \zeta < 10^{-7}$$

BBN
(Buchmüller et al ‘07)

Washout
(Endo et al ‘10)

Constraints from Fermi - LAT

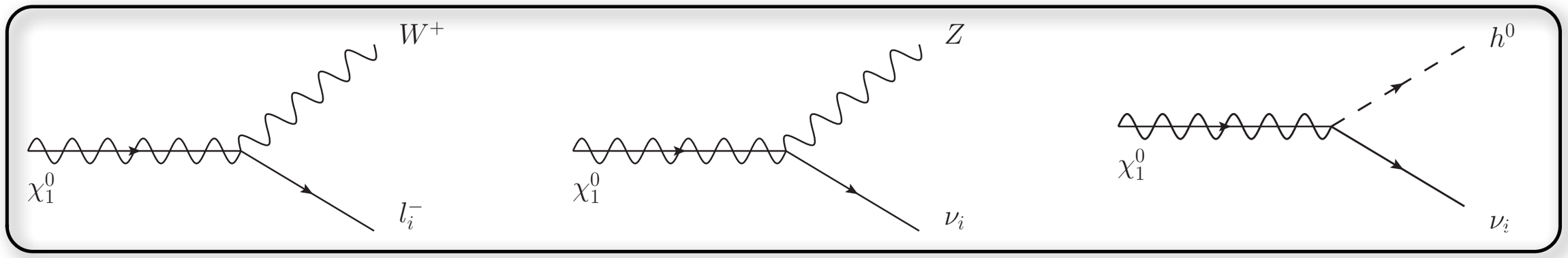
- Detection of gravitino decays is possible with gamma rays.
- Absence of signal at Fermi - LAT leads to an upper bound of $\zeta = 3 \times 10^{-8}$



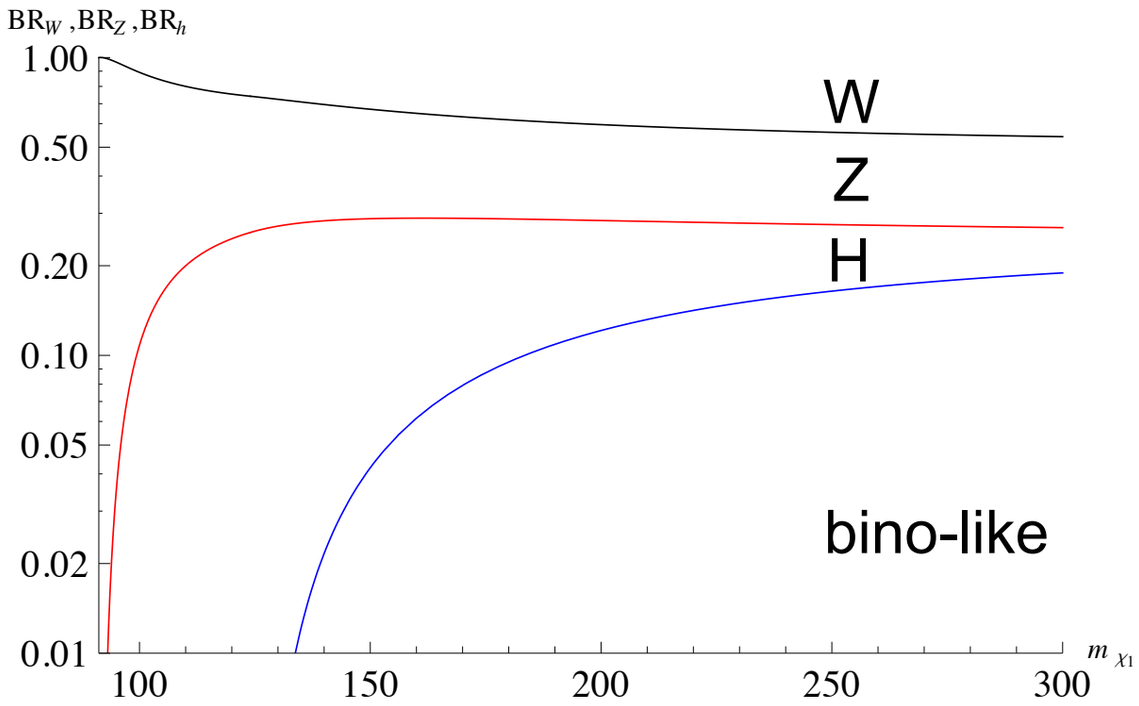
- Taken from (Vertongen/Weniger '11).

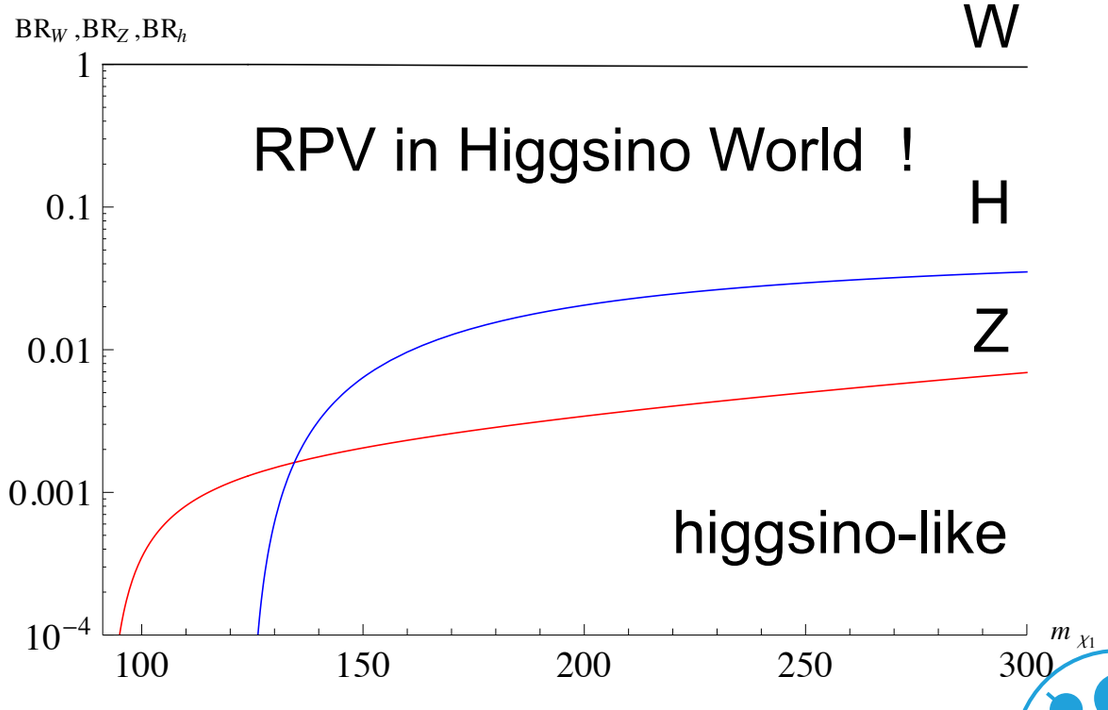
Neutralino NLSP at the LHC

- If mass > 100 GeV decays into charged lepton and W, neutrino and Z or neutrino and Higgs (if kinematically allowed).



- Branching ratios depend on the neutralino wavefunction.





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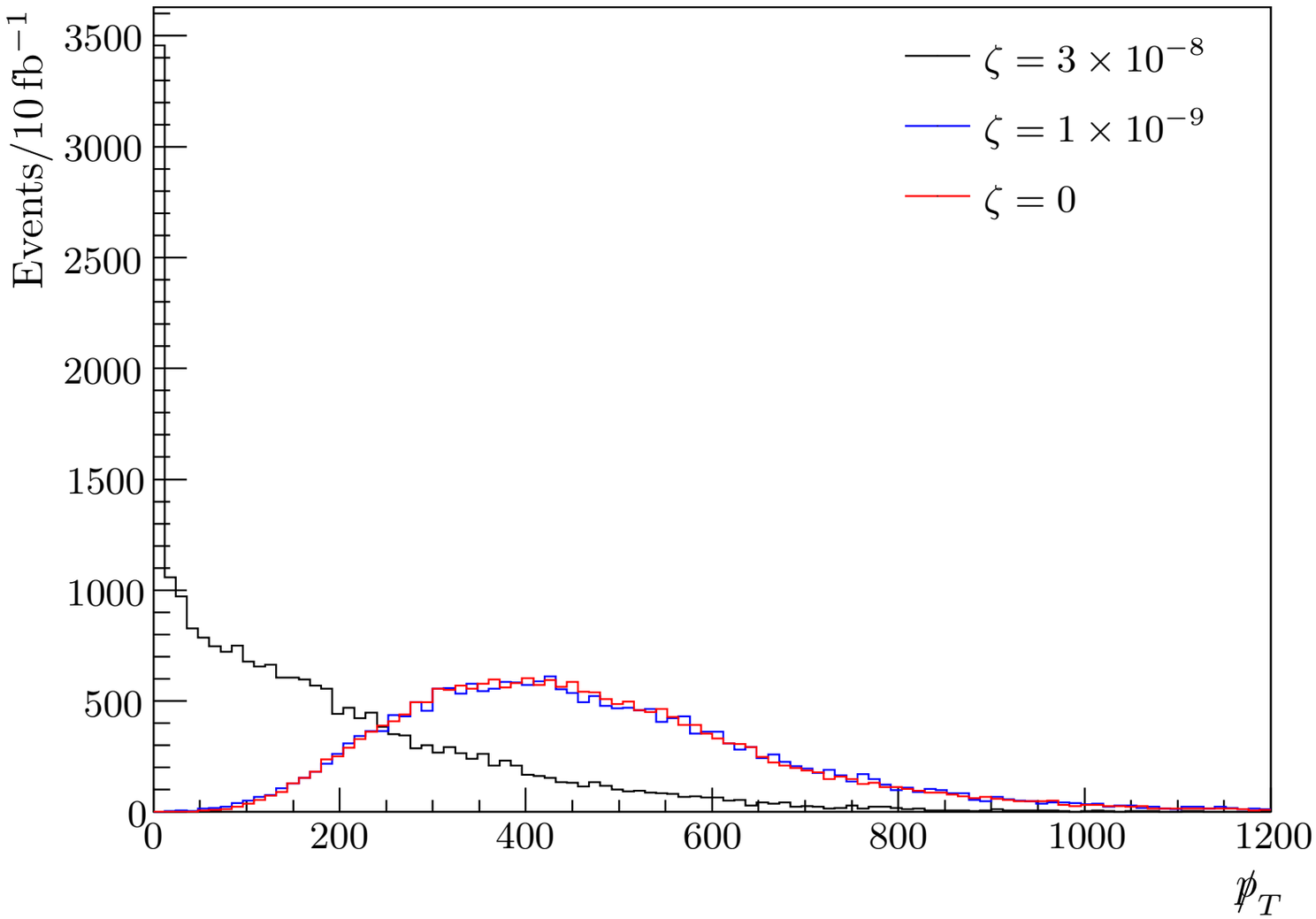
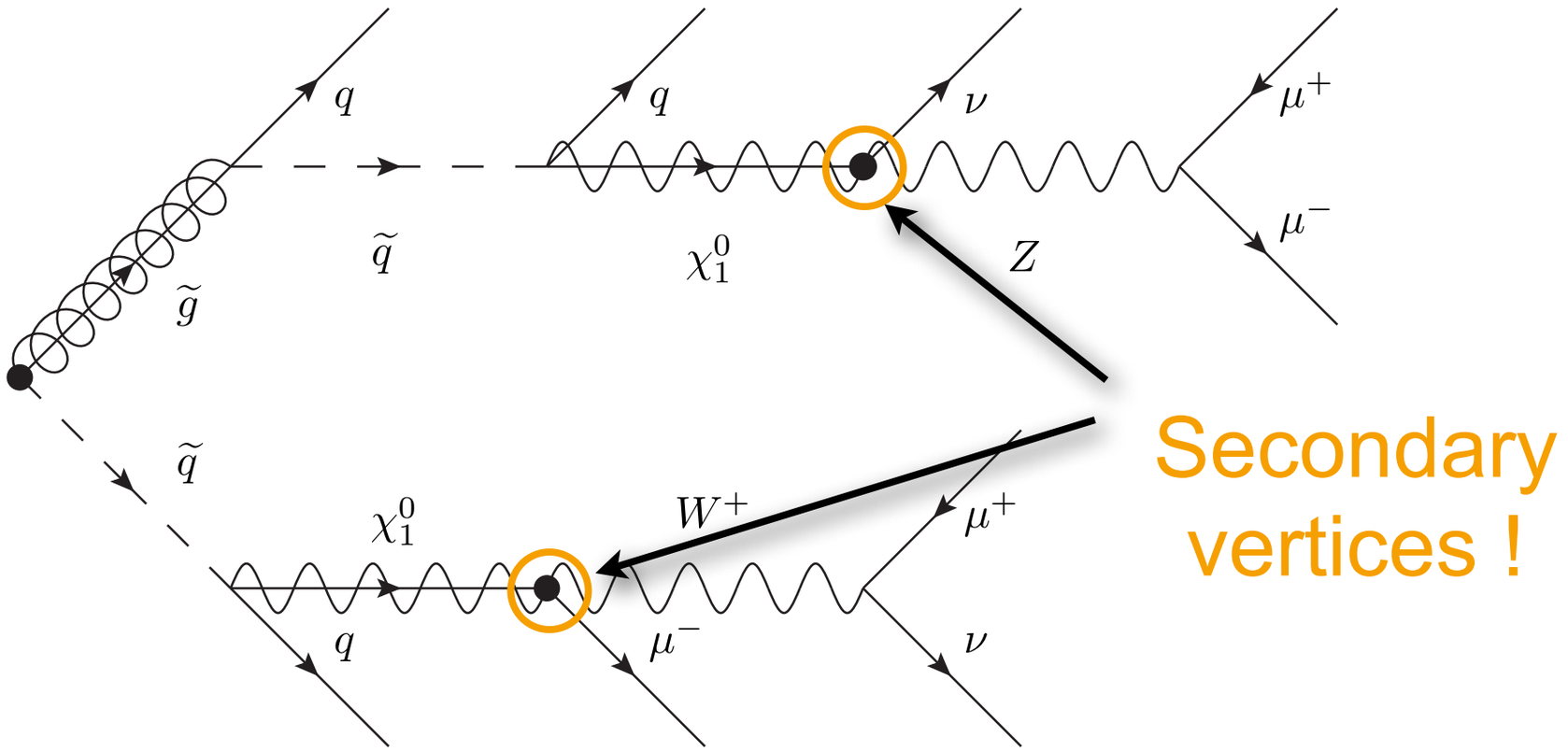
Hidden Signals at the LHC

> Be aware that the MET signal can be altered by R-parity violation:



> and SUSY be again potentially hidden !

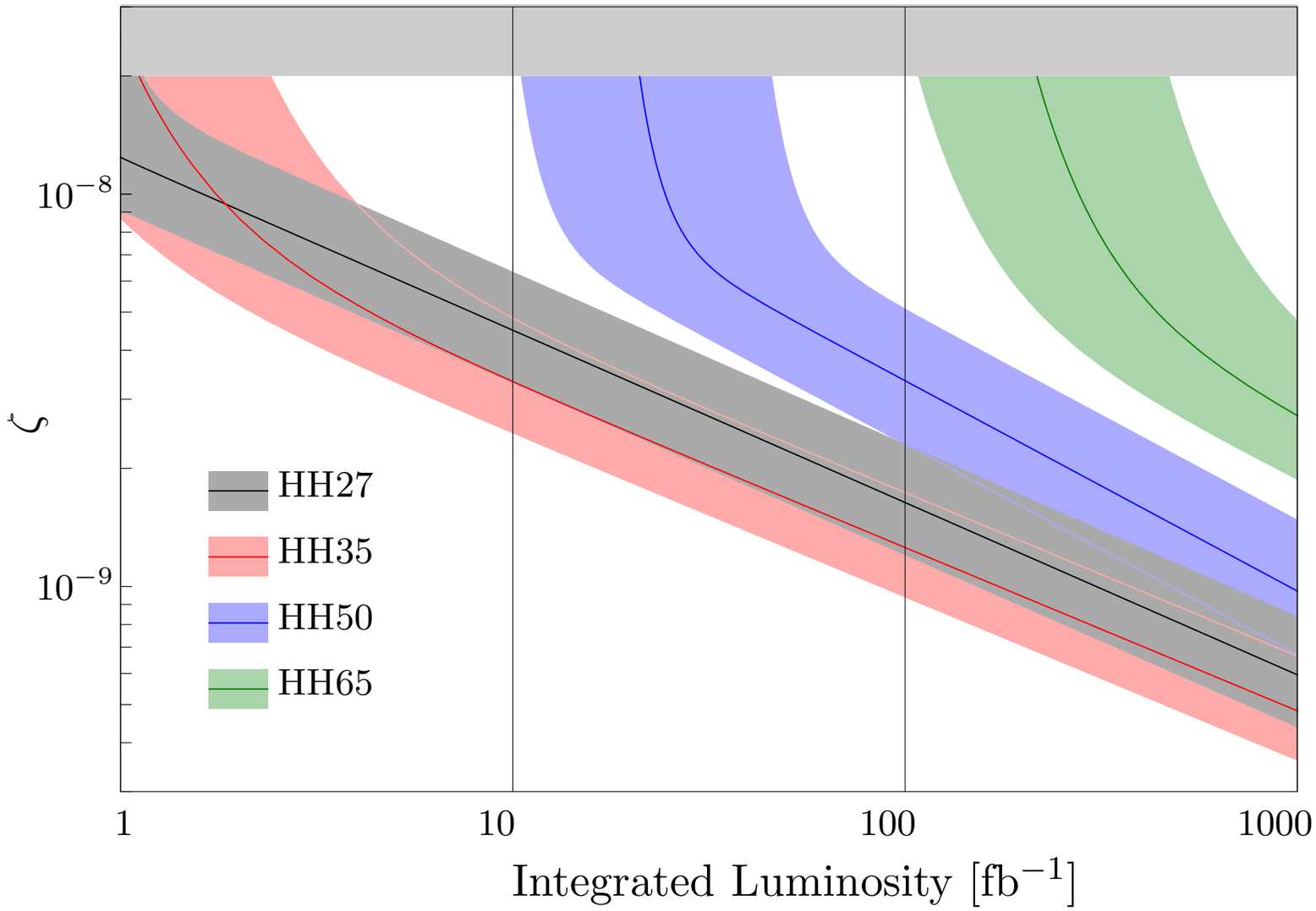
Event Topology



Secondary vertices !

- Assumed bino-like NLSP
- Generated 10 inverse femtobarns of events for 7 TeV LHC + *DELPHES*
- Looking for events with two muons from secondary vertex!

Discovery Reach



- Bands represent different assumptions about the background.
- Probing RPV beyond Fermi-LAT.

Summary

- SUSY can be hidden in the LHC data
- Either detectable only via monojets in higgsino world
- Or via secondary vertices if RPV and gravitino DM
- However in latter case signals in gamma rays expected
- Higgsino NLSP with RPV also possible

Bibliography

- M. Bolz, A.Brandenburg, and W. Buchmüller, Nucl. Phys. B 606 (2001) 518
- J. Pradler, and F. D. Steffen, Phys. Rev. D 75 023509 (2007)
- S. Weinberg, Phys. Rev. Lett 49 (1982) 1303
- T. Gherghetta, G.F. Giudice, J. D. Wells, Nucl. Phys. B. 559 (1999)
- W. Buchmüller, V. Domcke, K. Schmitz, arXiv:1203.0285 [hep-ph]
- F. Brümmer and W. Buchmüller, JHEP 0711 (2011) 010
- K. S. Jeong, M. Shimosuka and M. Yamaguchi, arxiv:1112:5293 [hep-ph]
- H. Baer, V. Barger, and P. Huang, JHEP 1111 (2011) 031
- W. Buchmüller et al., JHEP 0307 (2007) 037
- M. Endo, K. Hamaguchi and S. Iwamoto, JCAP 1002 (2010) 032
- G. Vertongen and C. Weniger, JCAP 1105 (2011) 027

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