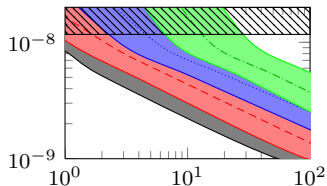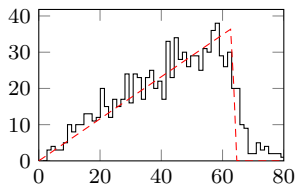# Higgsinos with broken R-parity at the LHC.

Jan Hajer
Across the TeV frontier with the LHC
International School Cargese, August 23, 2012

Higgsinos with broken R-parity at the LHC

> **Higgsino World**
  - Mono-jet Signal
  - Detectability

> **R-Parity Violation**
  - Displaced Higgsino Decays
  - Discovery Reach

Higgsino World

> The Superpotential W and the soft SUSY breaking Lagrangian $\mathcal{L}_{\text{soft}}$ of the MSSM are

$$W = \mu H_u H_d + \lambda^u_{ij} q_i u^c_j H_u + \lambda^d_{ij} d^c_i q_j H_d + \lambda^e_{ij} l_i e^c_j H_d \ ,$$

$$-\mathcal{L}_{\text{soft}} = m^2_u H^\dagger_u H_u + m^2_d H^\dagger_d H_d + (B H_u H_d + \text{h.c.})$$
$$+ \widetilde{m}^2_{li} \widetilde{l}^\dagger_i \widetilde{l}_i + \widetilde{m}^2_{ei} \widetilde{e}^{c\dagger}_i \widetilde{e}^c_i + \widetilde{m}^2_{qi} \widetilde{q}^\dagger_i \widetilde{q}_i + \widetilde{m}^2_{ui} \widetilde{u}^{c\dagger}_i \widetilde{u}^c_i + \widetilde{m}^2_{di} \widetilde{d}^{c\dagger}_i \widetilde{d}^c_i$$
$$+ \frac{1}{2} \left(M_1 \widetilde{B} \widetilde{B} + M_2 \widetilde{W} \widetilde{W} + M_1 \widetilde{g} \widetilde{g} + \text{h.c.} \right) + \text{trilinear } A \text{ terms} \ .$$

> The supersymmetric Higgsino mass parameter μ is, in general, independent of the soft SUSY breaking masses.

> In certain hybrid mediation models the μ parameter can be gravity mediated and the soft SUSY breaking masses gauge mediated.

> Hence one can end up with models in which the Higgsinos have masses of order $100\,\text{GeV}$ (and a small mass splitting) and the rest of the supersymmetric spectrum is above $1\,\text{TeV}$.
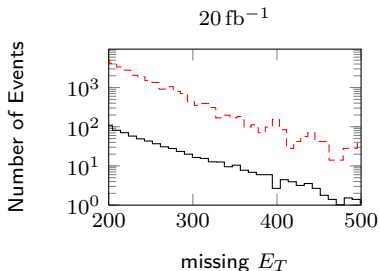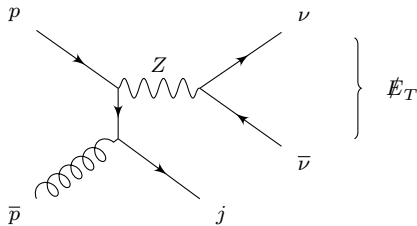
Mono-jet Signal

> In such a model the usual SUSY decay chains are not accessible.
> Electroweak production of Higgsinos is dominant.
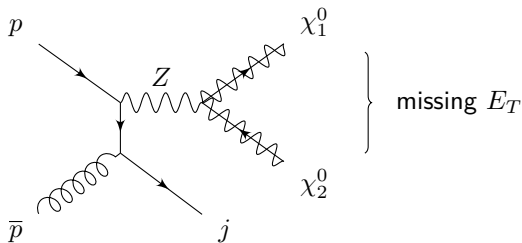
> An additional jet leads to an missing E_T signature.

Detectability

> The SM background to such an mono-jet event is an invisibly decaying Z-boson with a jet.

> There is no possibility to find the signal in this background.
> Hence, SUSY might be right around the corner but invisible.

R-Parity Violation

> R-parity distinguishes between SM and SUSY particles.

> If R-parity is broken, in general, many new parameter are introduced.

$$\Delta W = \mu_i H_u l_i + \frac{1}{2}\lambda_{ijk} l_i e_j^c l_k + \lambda'_{ijk} d_i^c q_j l_k + \lambda''_{ijk} u_i^c d_j^c d_k^c \ ,$$

$$-\Delta\mathcal{L} = B_i H_u \tilde{l}_i + \left(m_{id}^2 \tilde{l}_i^\dagger H_d + \text{h.c.} \right) + \text{trilinear terms} \ .$$

> In the case of bilinear R-parity violation, one introduces only the bilinear terms.

> The lepton number violating trilinear terms are generated at loop level.

> It turns out that it is possible to explain experiments in terms of just one R-parity breaking parameter ζ.

> In order to ensure a consisted cosmology we restrict ζ to be $10^{-8} \gtrsim \zeta \gtrsim 10^{-16}$.

Displaced Higgsino Decays

> Now the lightest Higgsino decays with a minimal decay-length of order 50 cm.
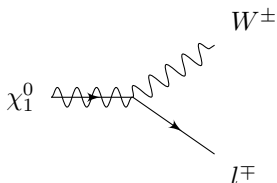
> The most dangerous backgrounds are di-boson and top pair production.
> However, due to the large decay length we are able to separate these background from the signal.
> And we are left with cosmics and detector effects as major background, wich we can not simulate.

Discovery Reach

> If we live in a Higgsino world with broken R-parity we might be able to see this in the near future
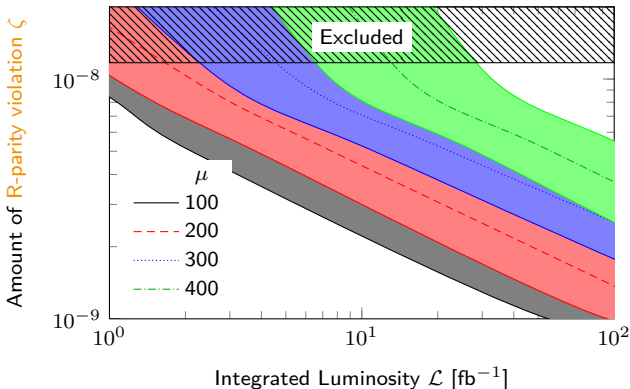
> With enough events it is possible to reconstruct the lightest Higgsino mass.

Mass

Integrated Luminosity $\mathcal{L}$ [fb^{-1}]

Conclusion
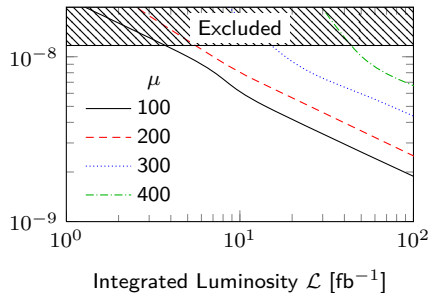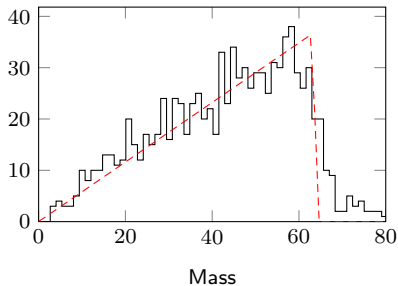
> In hybrid mediation models the Higgsino mass can be considerably lighter than the rest of the SUSY spectrum.

> It is very challenging to find such Higgsinos.

> If R-parity is broken the Higgsinos would decay and could be observable.

Thank You