Same-sign dibosons from SUSY models with light higgsinos

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EW-inos

- Typically in phenomenological analysis higgsino mass parameter μ is considered larger than gaugino masses $|M_{1,2}|$
  $\Rightarrow$ $\widetilde{Z}_1$ is bino, $\widetilde{Z}_2, \widetilde{W}_1$ are winos and $\widetilde{Z}_3, \widetilde{Z}_4, \widetilde{W}_2$ are higginos
  $\Rightarrow$ search for $\widetilde{Z}_2\widetilde{W}_1$ and $\widetilde{W}_1\widetilde{W}_1$

- If $|\mu| \ll |M_{1,2}|$ then $\widetilde{Z}_1, \widetilde{Z}_2, \widetilde{W}_1$ are higgsinos, $\widetilde{Z}_3$ is bino and $\widetilde{Z}_4, \widetilde{W}_2$ are winos
  $\Rightarrow$ search for $\widetilde{Z}_2\widetilde{W}_1$ and $\widetilde{W}_1\widetilde{W}_1$ is very difficult because mass gaps are small, ~5-20 GeV

- Such light higgsinos appear in
  - Hyperbolic branch/focus point (HB/FP)
  - Models of "natural SUSY"

Fine-tuning

- Minimization condition for higgs scalar potential

$$\boxed{\frac{M_Z^2}{2} = \frac{(m_{H_d}^2 + \Sigma_d^d) - (m_{H_u}^2 + \Sigma_u^u)\tan^2\beta}{\tan^2\beta - 1} - \mu^2}$$

- Require all terms on RHS comparable to LHS

  $\Rightarrow$ fine-tuning measure $\Delta_{EW} \equiv max(C_i)/(M_Z^2/2)$

- To make dependence on high scale Λ explicit

$$m_{H_{u,d}}^2 = m_{H_{u,d}}^2(\Lambda) + \delta m_{H_{u,d}}^2$$

- Terms $\delta m_{H_{u,d}}^2$ contain dependence of type $\log(\Lambda^2/m_{SUSY}^2)$
- For $\Lambda \sim M_{GUT} - M_{Pl}$ logs are ~60

  $\Rightarrow$ very large fine-tuning 0.1-0.01%

Fine-tuning (cont.)

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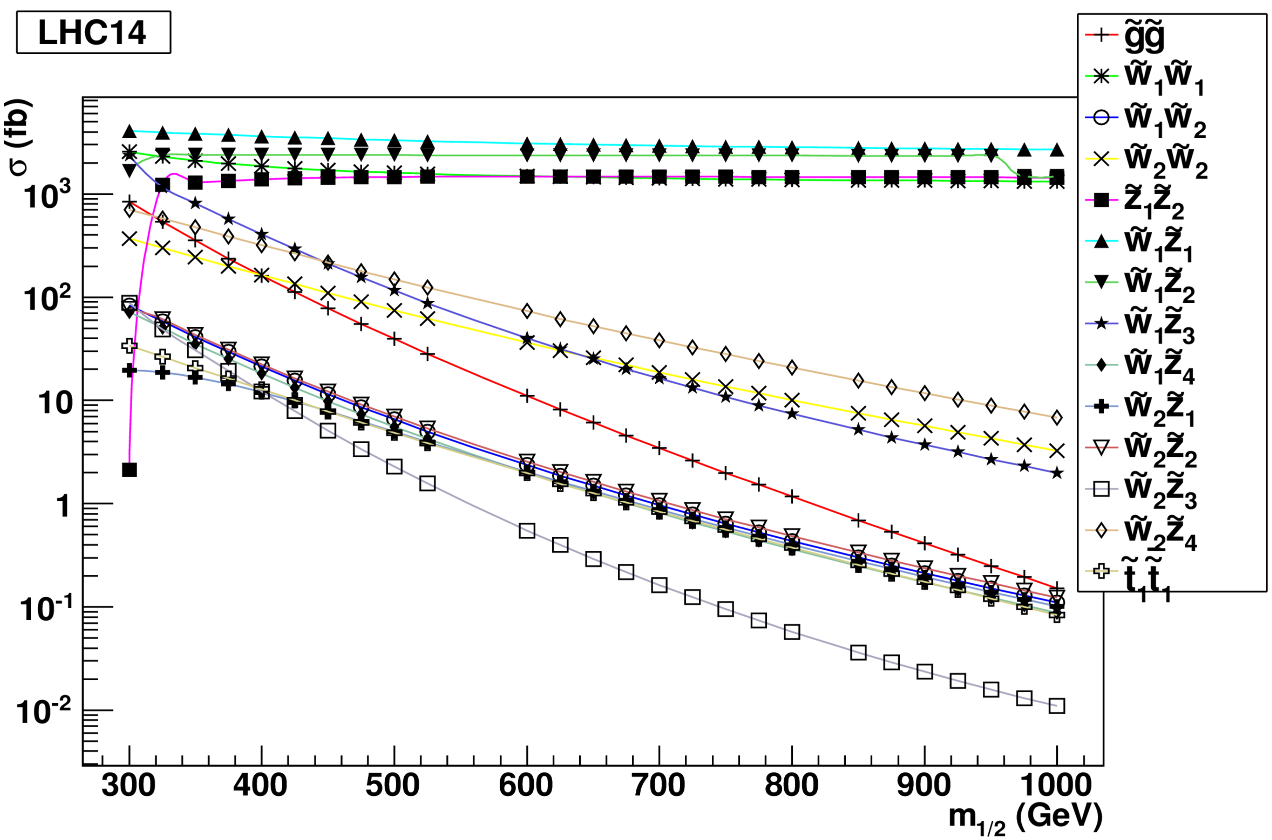
- Logs can (partially) cancel against $m_{H_{u,d}}^2(\Lambda)$ terms:
  - HB/FP region [Feng et al]
  - MMAMSB for special value of α [Nilles, Lebedev, Ratz '05]
- Δ_{EW} is a lower bound on fine-tuning for any model with similar sparticle spectrum
- Typically Σ_u^u dominates leading to stops/sbottoms ≤ 500 GeV. Can be relaxed by cancellations - RNS model (see P.Huang talk)
- Low $\mu \sim 100 - 300\, GeV$ is necessary condition for naturalness.

EW-inos in RNS

- Consider RNS model realized in NUHM2 with
  $m_{1/2}, m_0 = 5TeV, A_0 = -1.6m_0, \tan\beta = 15, \mu = 150GeV, m_A = 1TeV$
- Sizeable production cross section (~10-100 fb) for $\widetilde{Z}_4\widetilde{W}_2$ and $\widetilde{W}_2\widetilde{W}_2$



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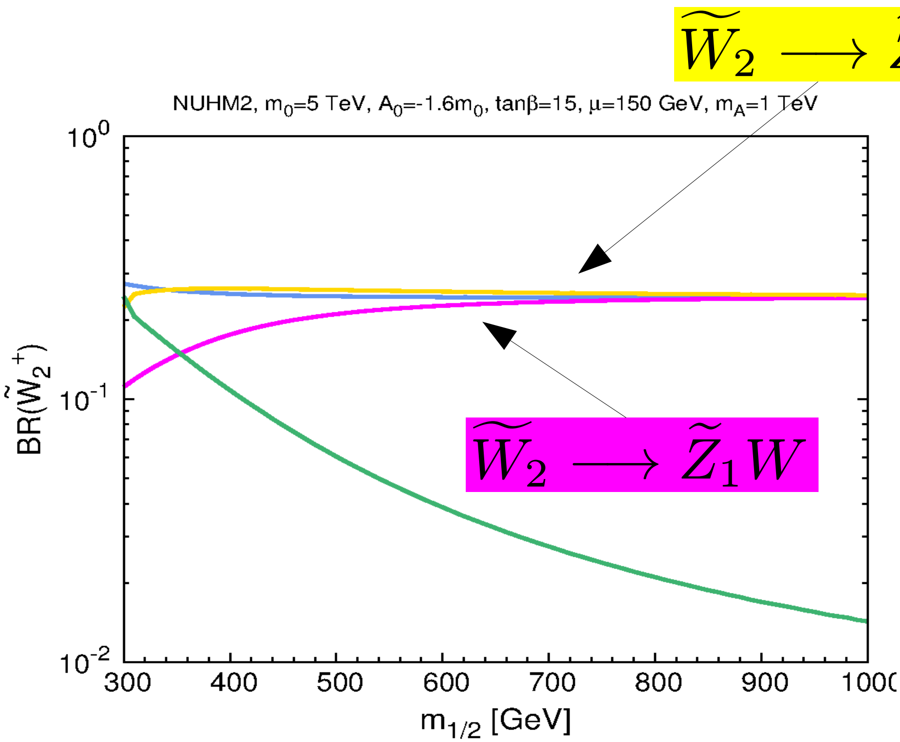

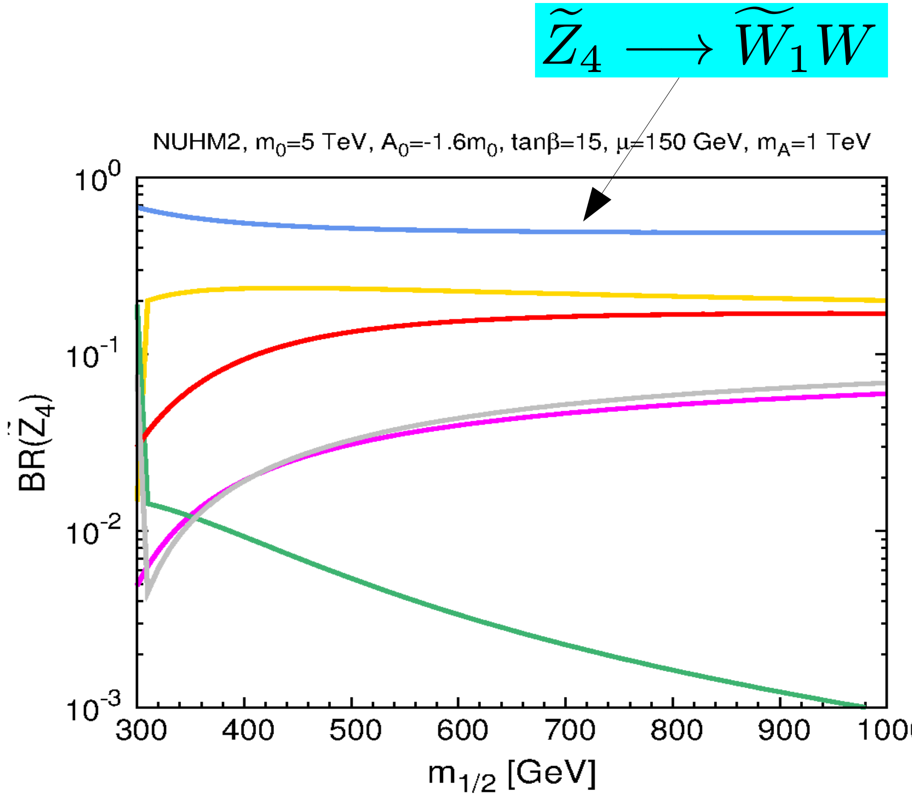

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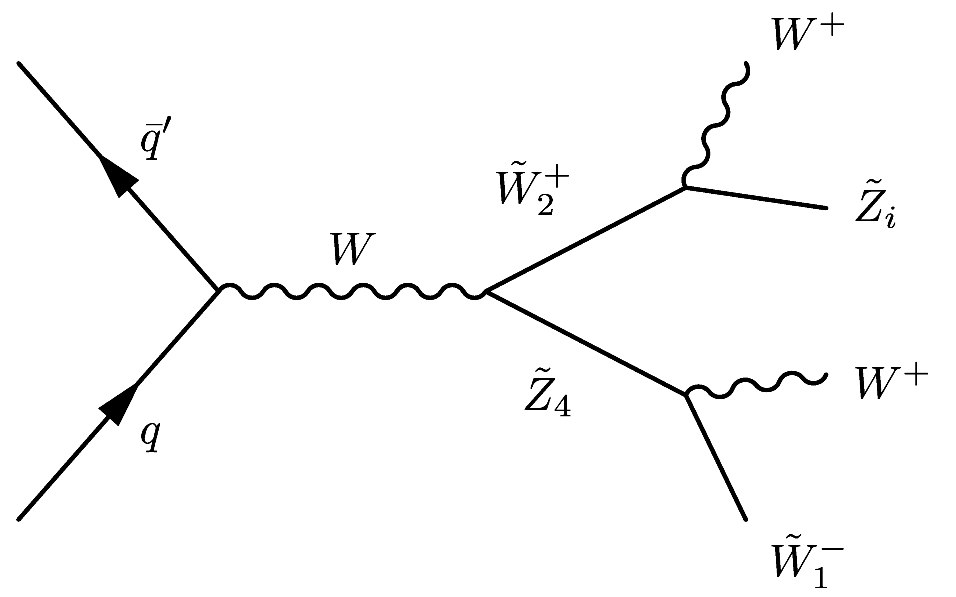
- Each decay into W about 50%
- Two W's are not charge correlated
- Same-sign WW is novel signature, charcteristic of light higgsinos



Backgrounds

- No 2->2 SM production for same-sign WW
- Lowest order SM processes (~350 fb)

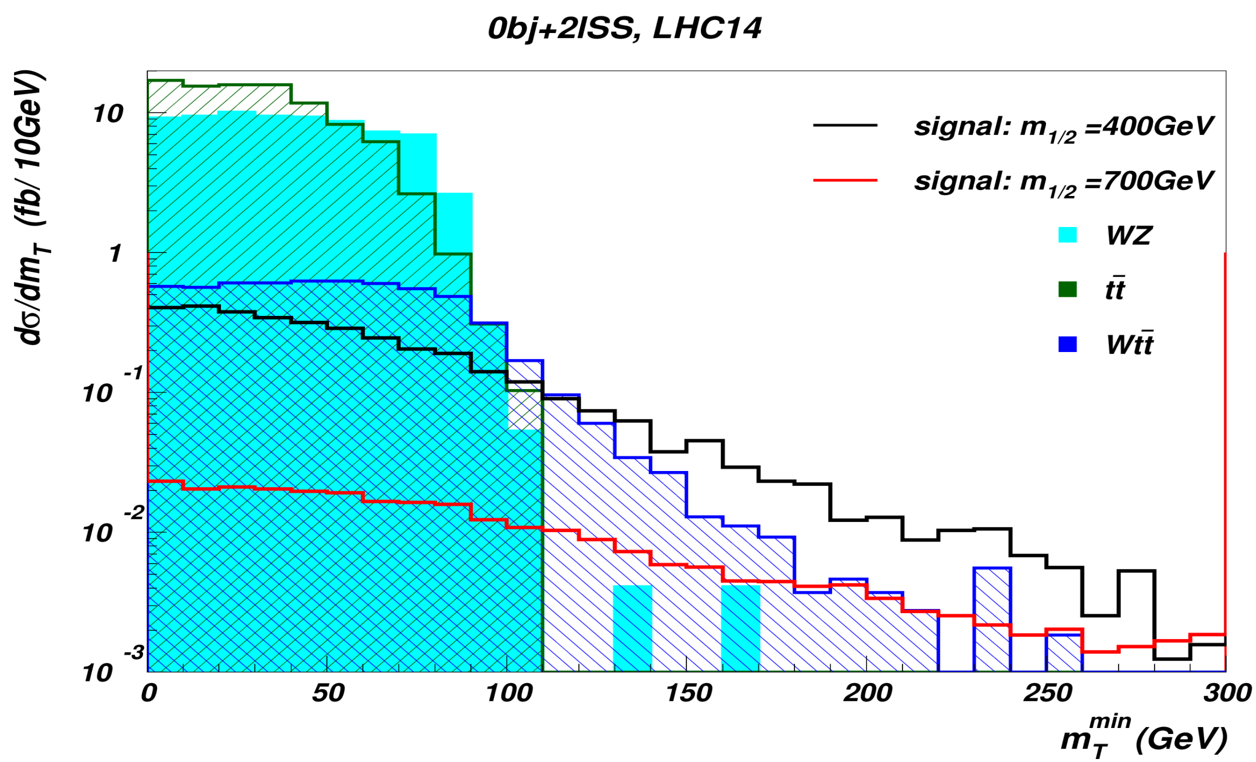
  $$uu \longrightarrow W^+W^+dd \text{ and } dd \longrightarrow W^-W^-uu$$

  produce forward jets and have low MET
- Two overlapping events; low pt W-bosons
- Double parton scattering (~4 fb); low pt W-bosons
- Di-leptons: $t\bar{t}$, $t\bar{t}W$ and $4t$
- Tri-lepton bkgd's: WZ and $t\bar{t}Z$

Cuts

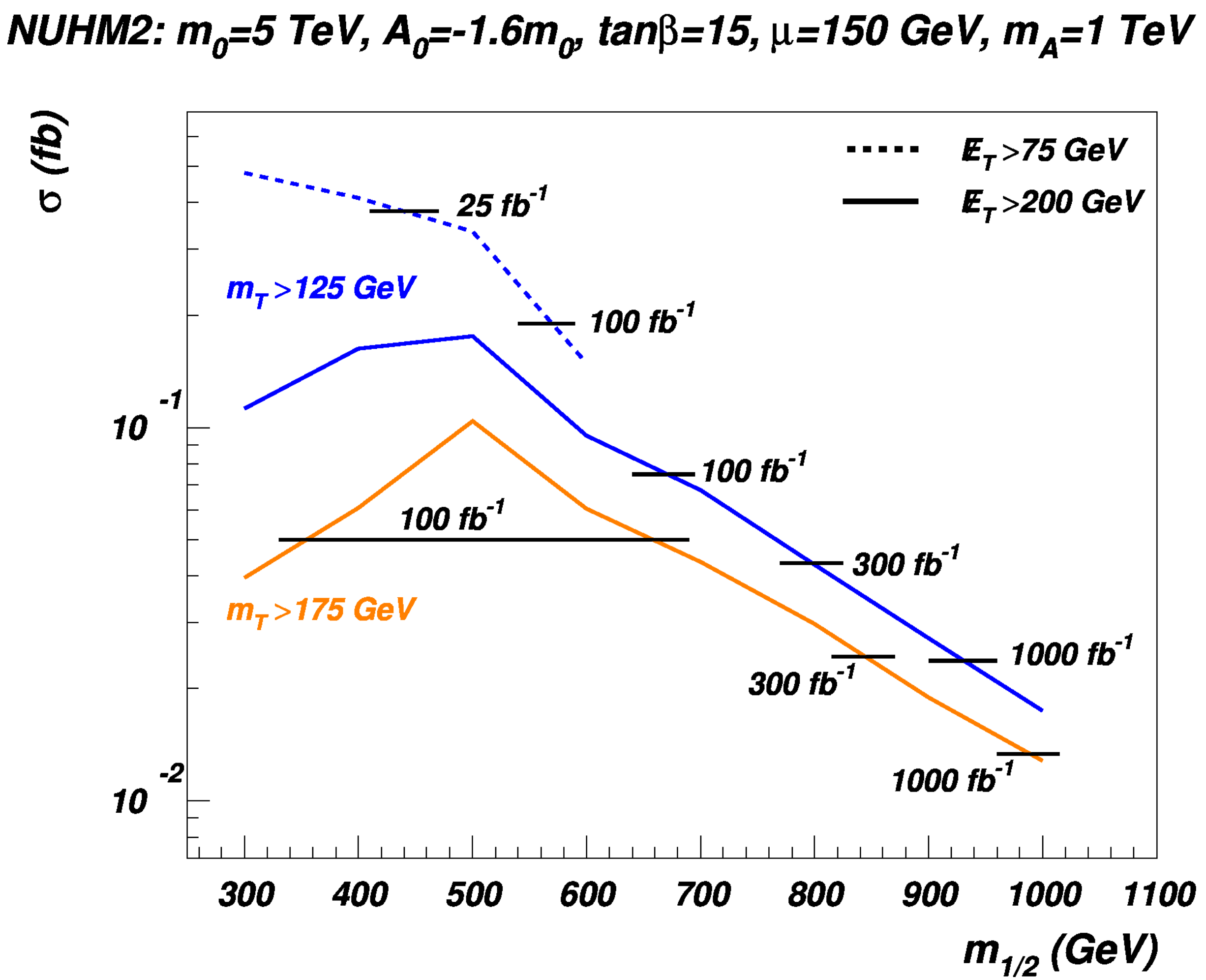
- b-jet veto (60% eff.)
- 2 isolated same-sign leptons $p_T(l_1) > 20GeV,\ p_T(l_2) > 10GeV$
- $m_T^{min} \equiv \min\left[m_T(l_1, \not{E}_T), m_T(l_2, \not{E}_T)\right] > 125GeV$

  removes WZ and ttbar due to kinematic cutoff for on-shell W
- MET>200GeV



Same-sign dibosons at LHC14

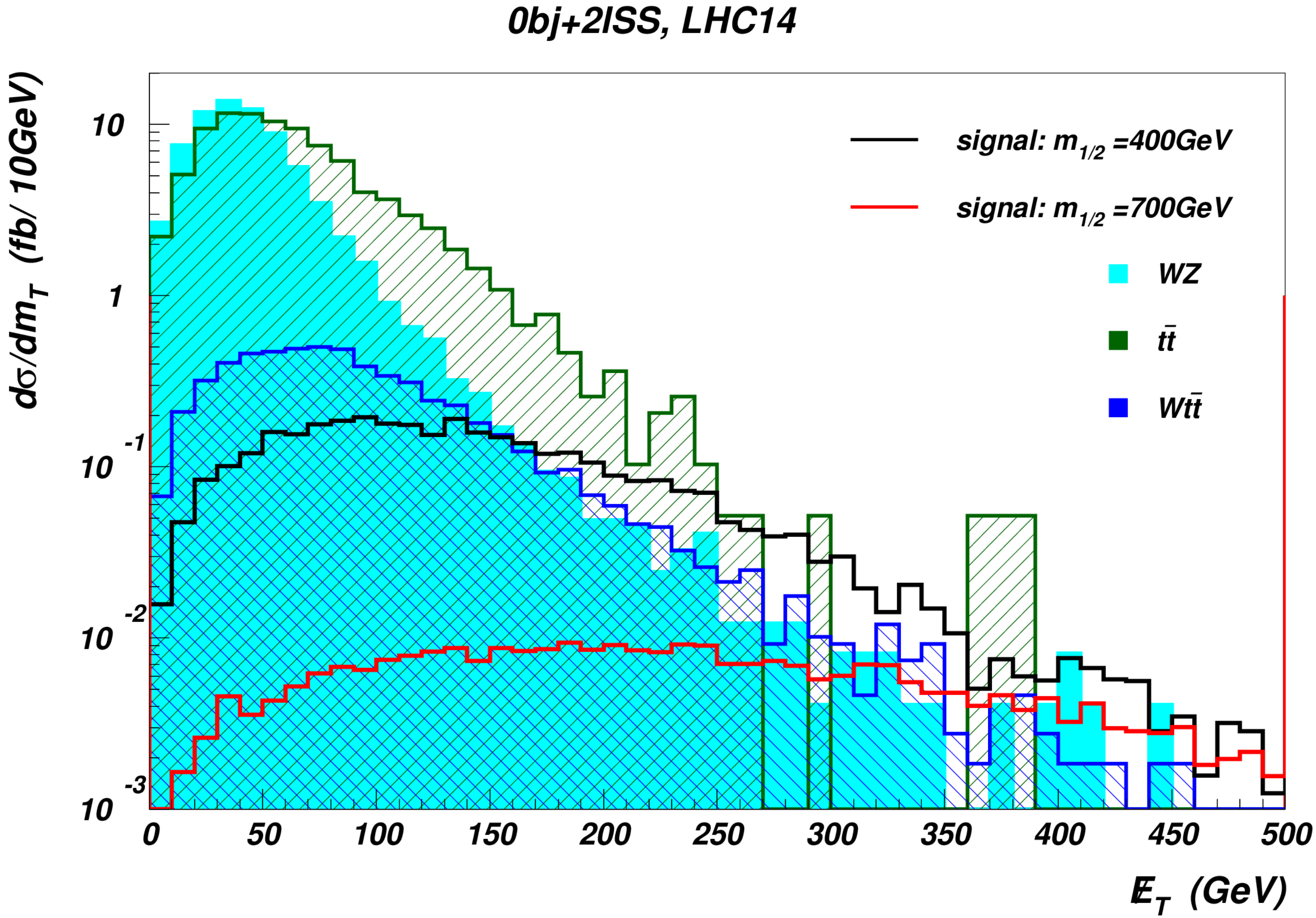
- Reach for 100/fb extends $m_{1/2} \sim 680 GeV$
- Corresponds to gluino mass ~1.6TeV, which is the same as reach for direct gluino production (if gaugino masses unify)
- For larger lumin. ssWW reach exceeds direct gluino production reach
- Can get sizable reach for 25/fb with softer cuts
- Independent of gluino search!



Conclusions

- Small μ is necessary, but not sufficient, condition for naturalness.
- In such models, the lighter chargino and neutralinos are higgsino-like. They are difficult to detect at LHC due to low visible energy release from their decays.
- $\widetilde{Z}_4, \ \widetilde{W}_2$ are wino-like, produced at substantial rate and decay dominantly to vector bosons.
- Same-sign diboson production $W^{\pm}W^{\pm}+\not{E}_T$ is a novel signature characteristic of light higgsino scenario. It depends only on EW-ino spectrum.
- For 100/fb (1000/fb) this SS diboson should be observable at LHC14 for wino masses up to 550 (800) GeV.
- Larger reach than in canonical trilepton channel.
- Assuming gaugino mass unification, SS dibosons extend LHC SUSY reach well beyond conventional gluino pair production searches.

MET distributions



Reach in trileptons at LHC14