Prospects for Electroweakino Discovery at 100 TeV

Stefania Gori, Sunghoon Jung, Lian-Tao Wang, James Wells
(arXiv:1410.6287)

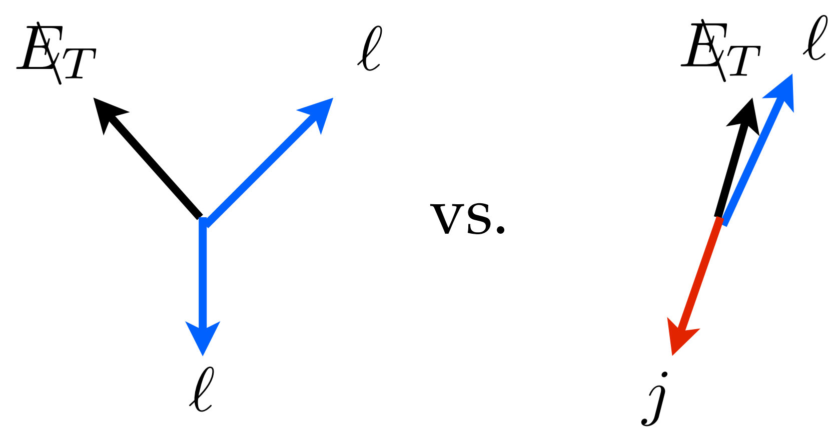
Higgs and BSM at 100 TeV

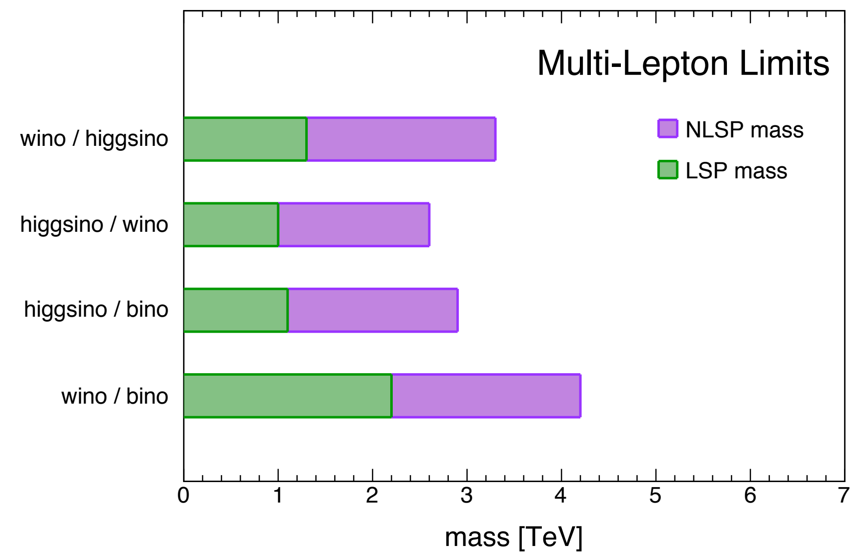
ML, Lian-Tao Wang (arXiv:1404.0682)

Asher Berlin, Tongyan Lin, ML, Lian-Tao Wang (arXiv:1502.05044)

Outline

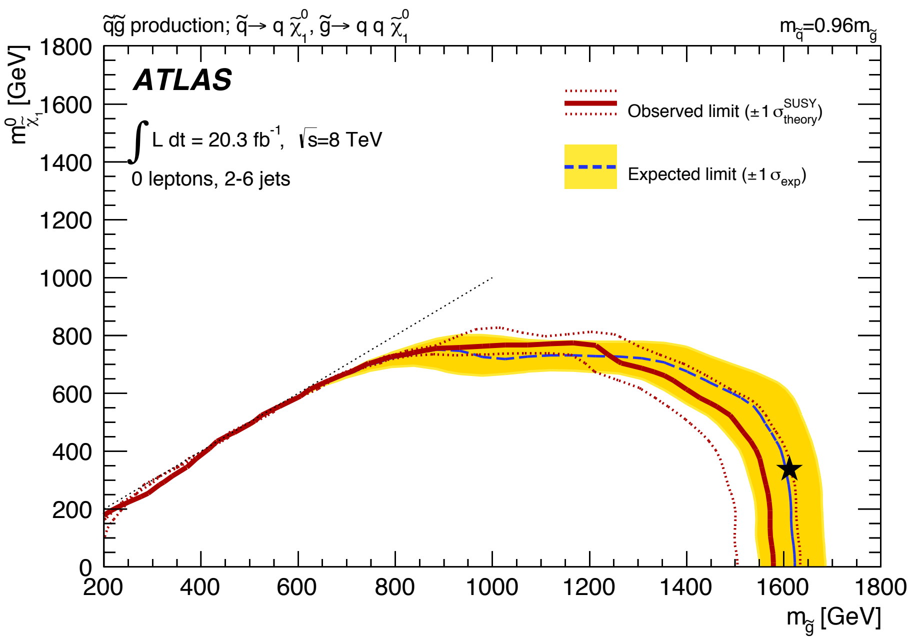
- Motivation
- Multi-lepton searches
- Prospects for discovery

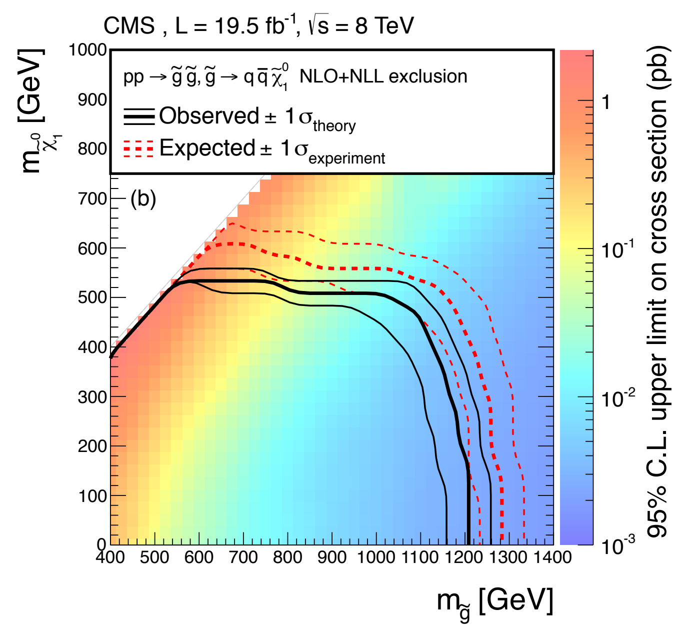




Motivation

- Increasing bounds on colored SUSY particles



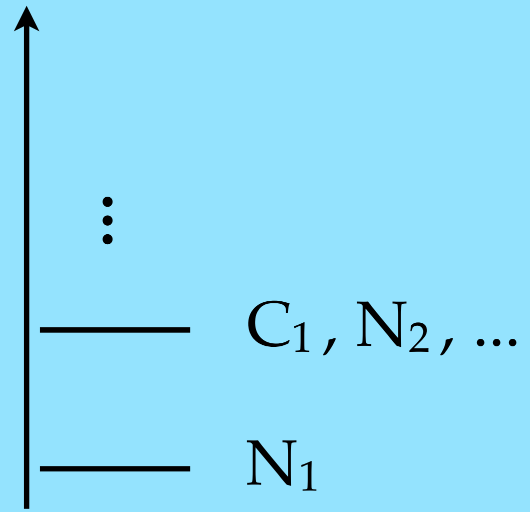


- Maybe only electroweakinos in the low energy spectrum

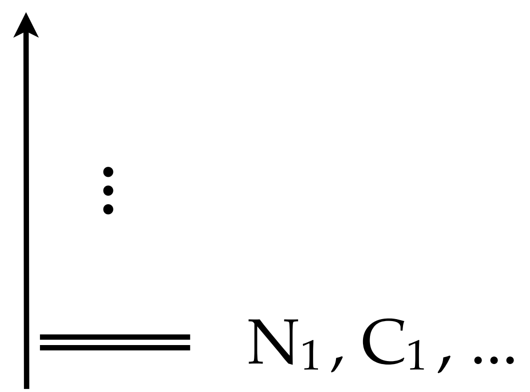
- LHC has limited reach for directly produced electroweak particles

Electroweakino Searches

- Electroweakino Cascades ($\not\!\!E_T$ + leptons)
  - Multi-lepton: 3ℓ
  - Multi-lepton: OSDL
  - Multi-lepton: SSDL



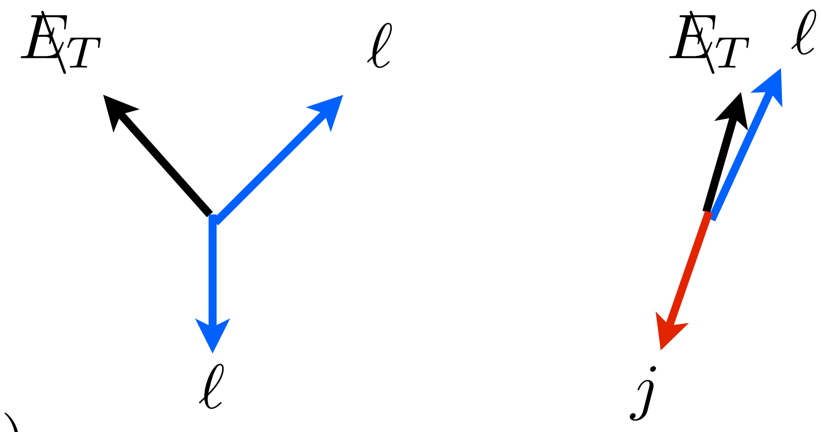
- Compressed Region ($\not\!\!E_T$ + ISR)
  - Disappearing Tracks
  - Vector Boson Fusion

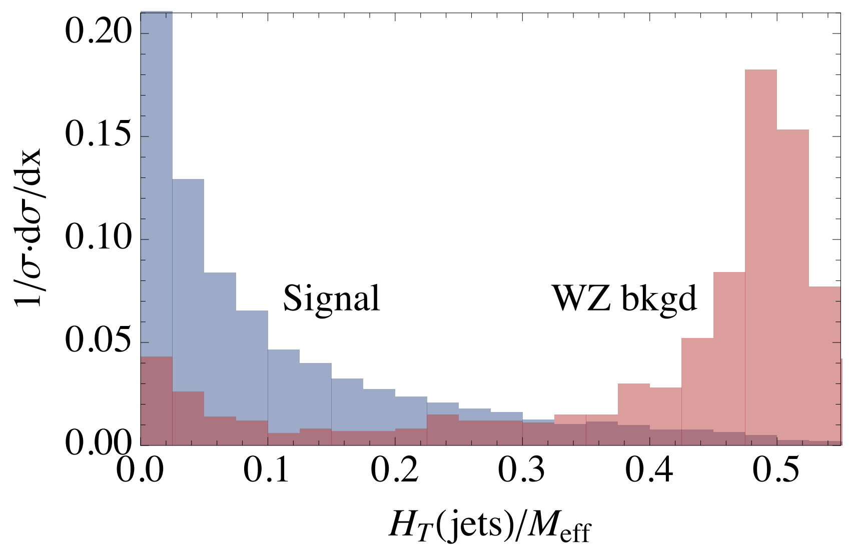


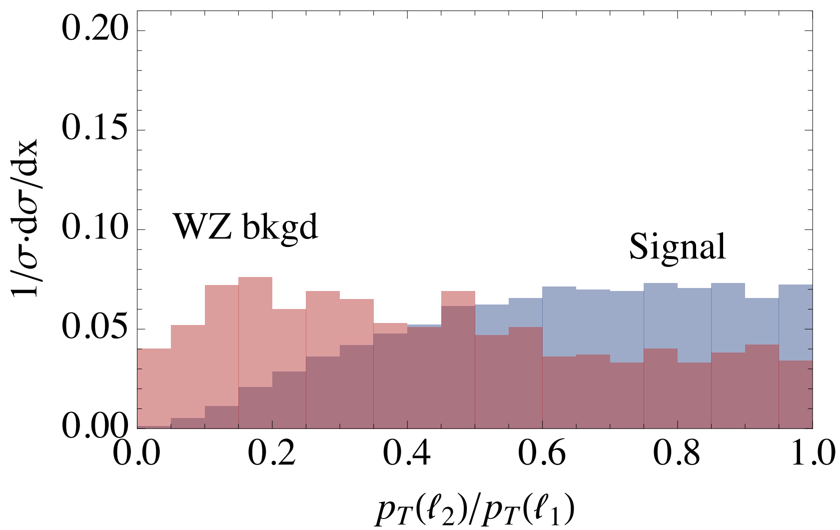
Multi-lepton: 3ℓ

- Signal: WZ
- Background: WZ, Wγ, (ttV, WWW)
- Variables:

$\not{E}_T,\ M_T,\ M'_{\rm eff},\ H_T/M_{\rm eff},\ p_T(\ell_1)/p_T(\ell_2)$



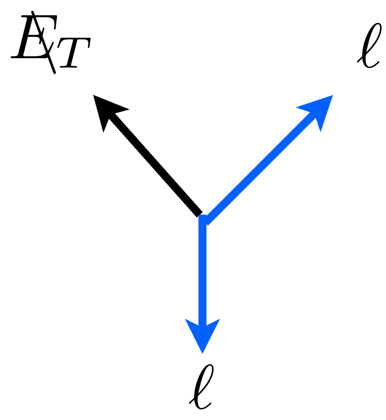


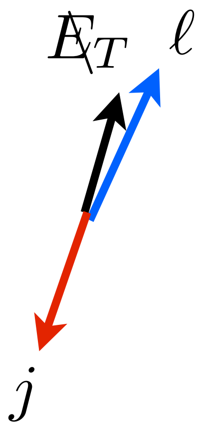


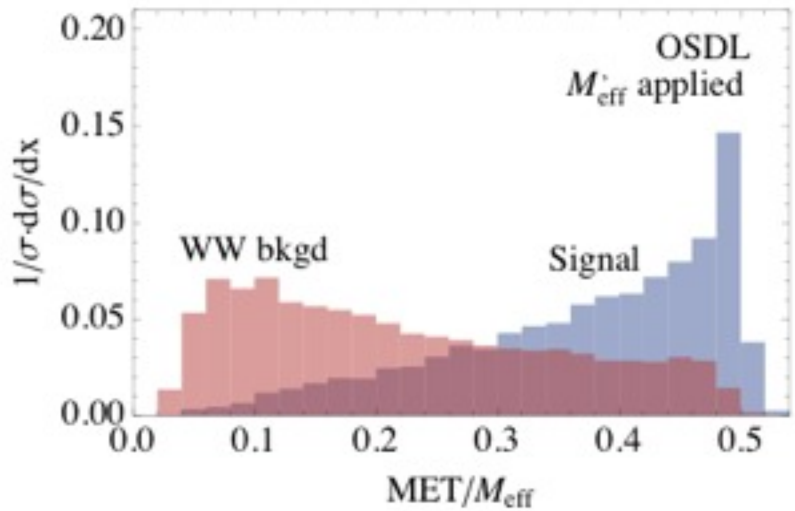
Multi-lepton: OSDL

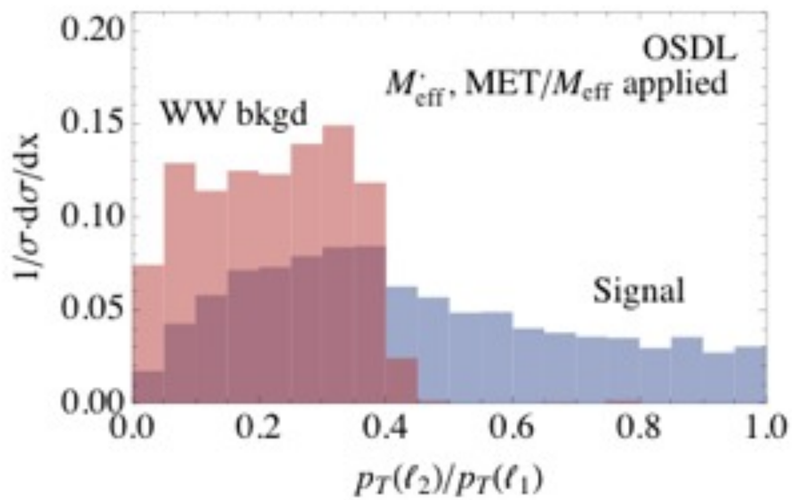
- Signal: W^+W^-
- Background: W^+W^-, (WZ)
- Variables:

$$M_T,\ M'_{\rm eff},\ \not{E}_T/M_{\rm eff},\ p_T(\ell_1)/p_T(\ell_2)$$





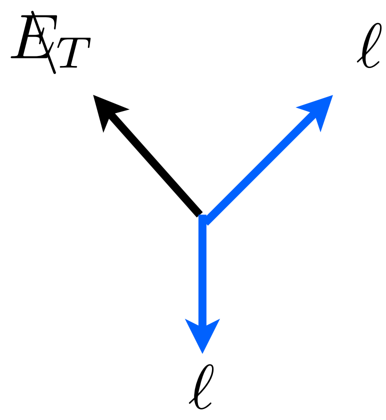


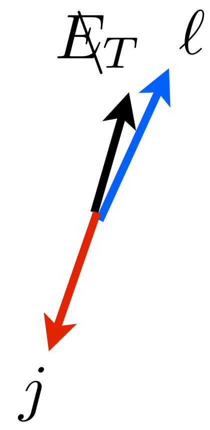


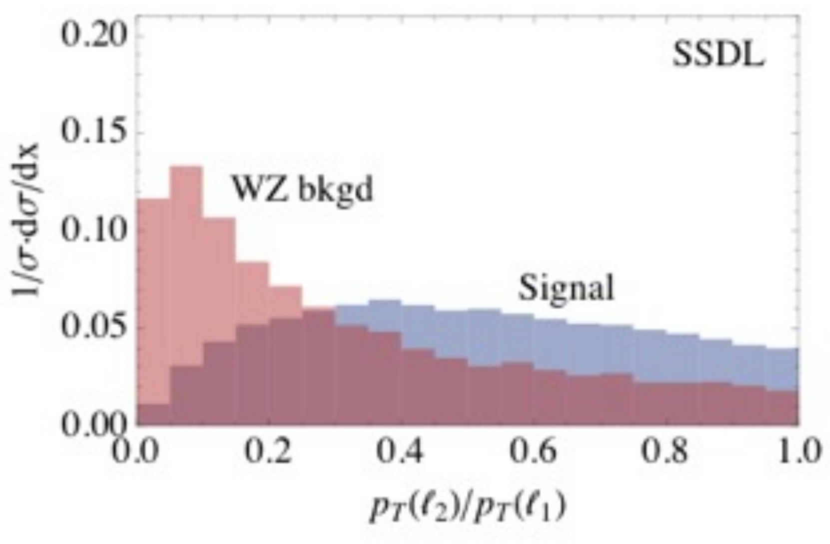
Multi-lepton: SSDL

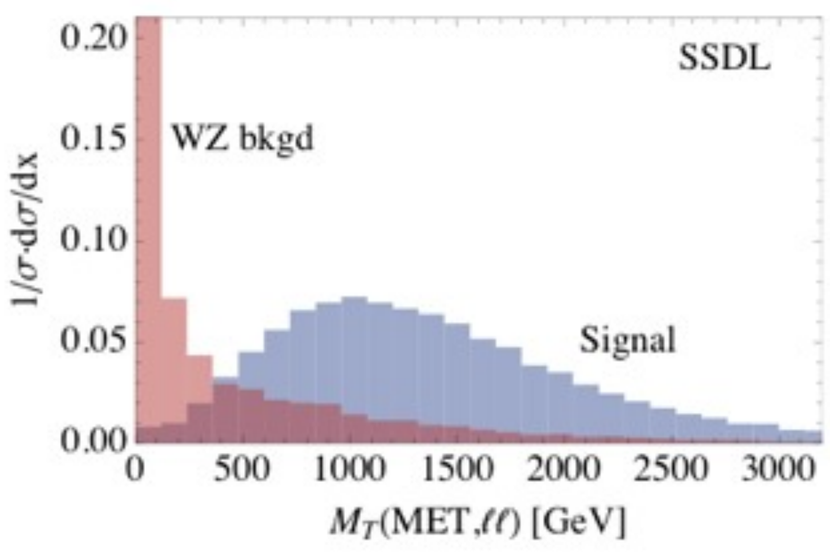
- Signal: $W^{\pm}W^{\pm}$, WZ
- Background: WZ, fakes, mis-IDs, ...
- Variables:

$$M_T,\ M'_{\rm eff},\ \not{E}_T/M_{\rm eff},\ p_T(\ell_1)/p_T(\ell_2)$$







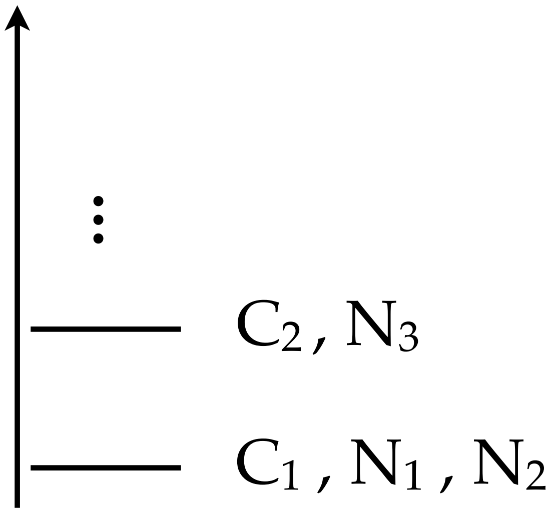


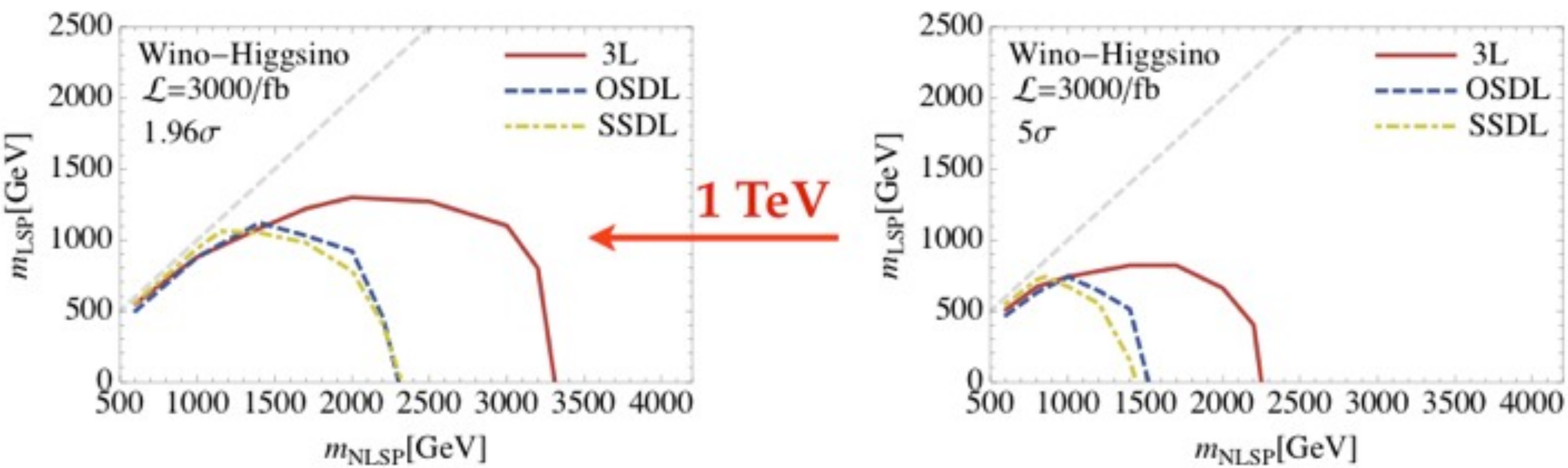
Simulation

- MadGraph 5 + Pythia 6
- MLM matching +1 jet
- Leptons: $p_T > 15$ GeV and $|\eta| < 2.5$
- Jets: $p_T > 30$ GeV and $|\eta| < 2.5$
- Lepton efficiencies, but no detector smearing
- Leptons separated by $\Delta R \geq 0.05$
- m(SFOS) > 12 GeV

1: Wino / Higgsino

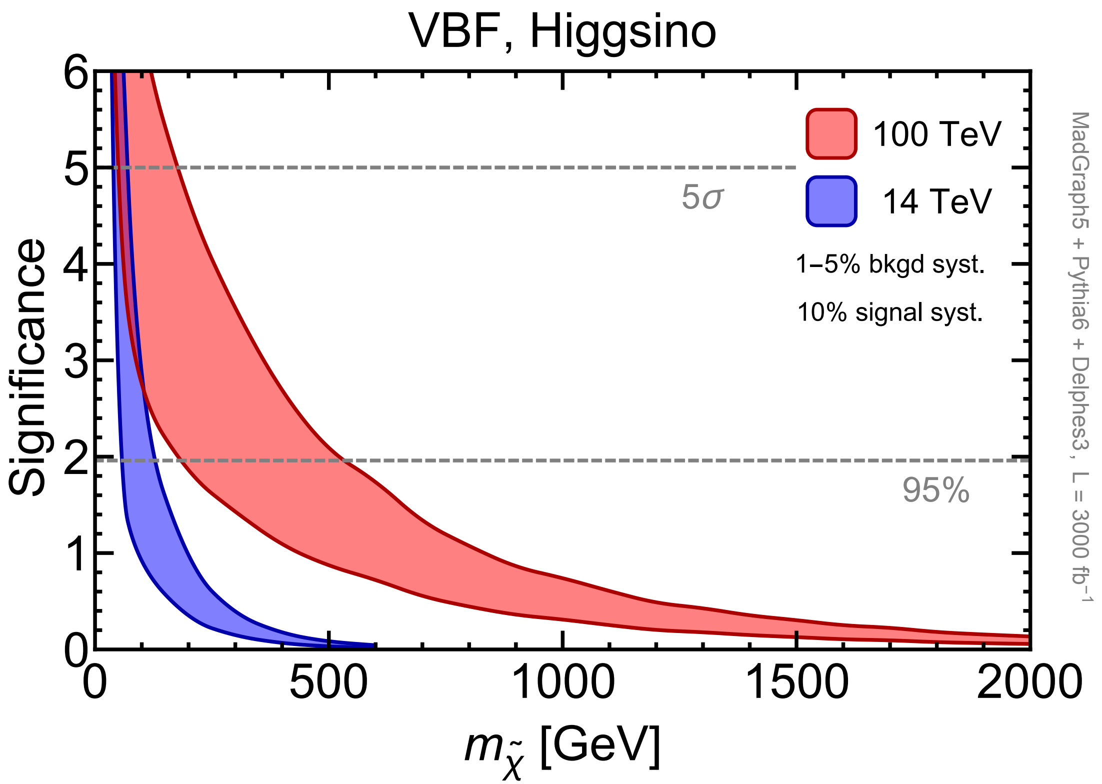
- Rate ~ wino production
- $BR(N_3 \to N_{1,2}\, h) \simeq 1/3$
- $BR(N_3 \to N_{1,2}\, Z) \simeq 1/3$
- $BR(N_3 \to C_1\, W) \simeq 1/3$

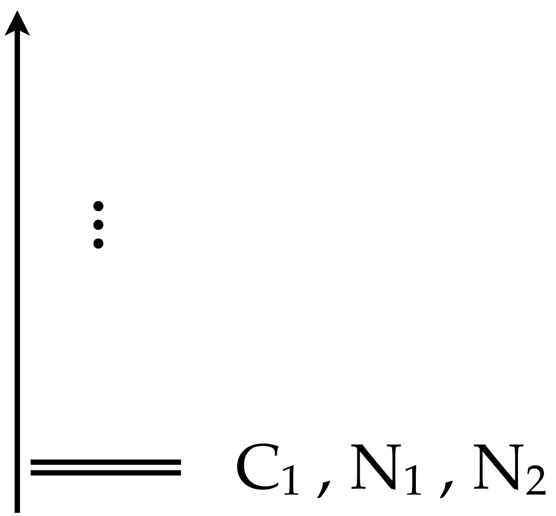




Aside: Higgsinos

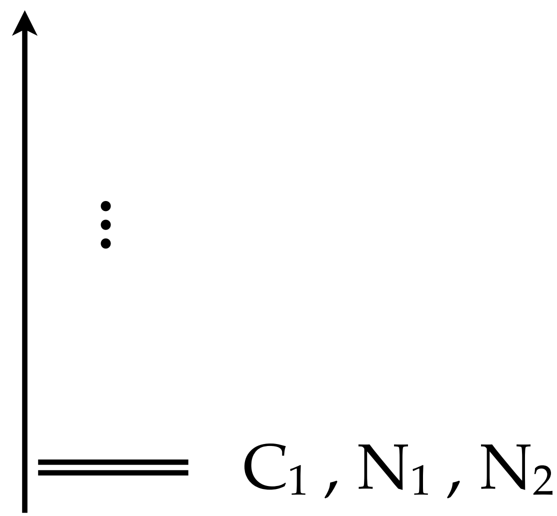
- Other Higgsino probes:
  - Reach in monojet: ~850 GeV
  - Reach in VBF: ~500 GeV

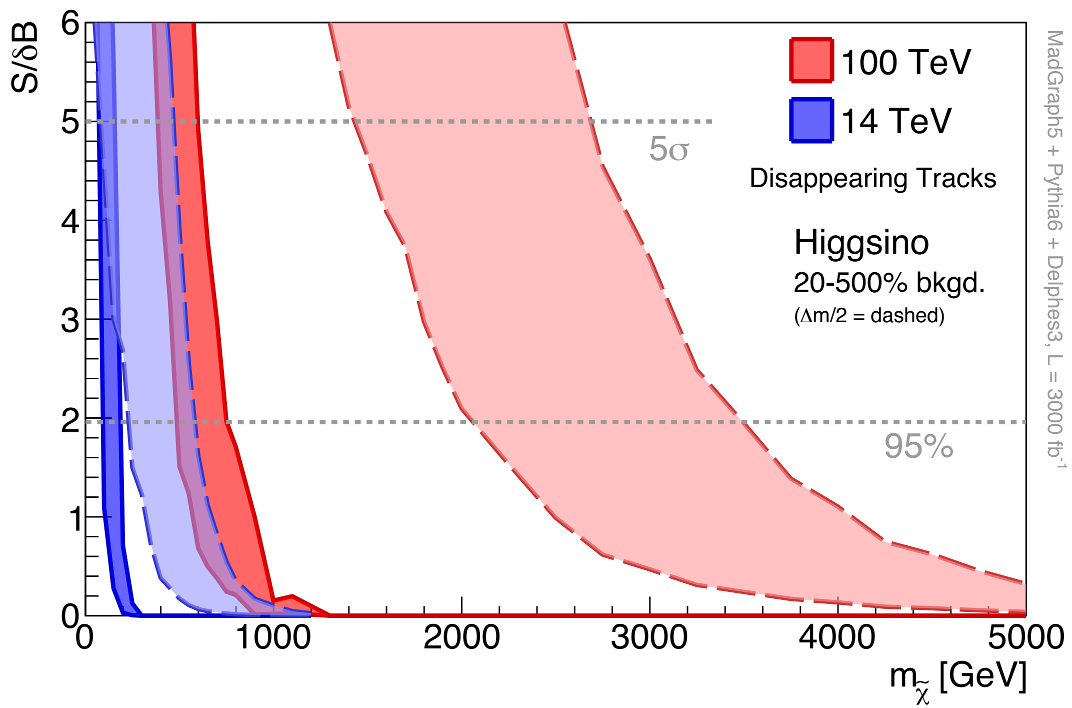




Aside: Higgsinos

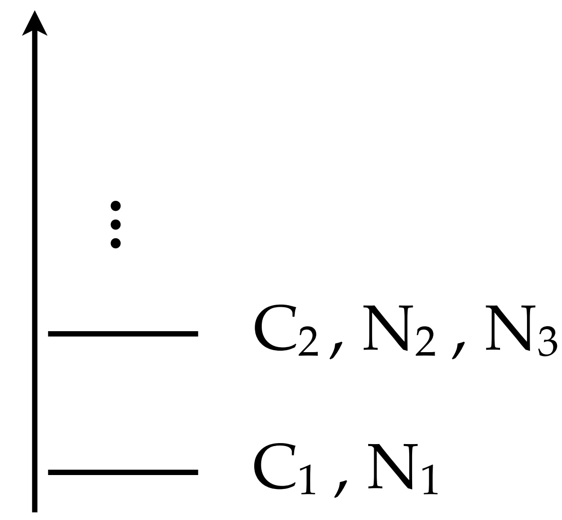
- Reach in disappearing tracks: ~ 500 - 700 GeV
- Radiative splitting ~ $\alpha m_z \sim 355 \text{ MeV}$
- Also dim-5: $\frac{c}{M}(h^\dagger \tilde{H}_u)(h\tilde{H}_d) \sim \frac{m_Z^2}{M}$

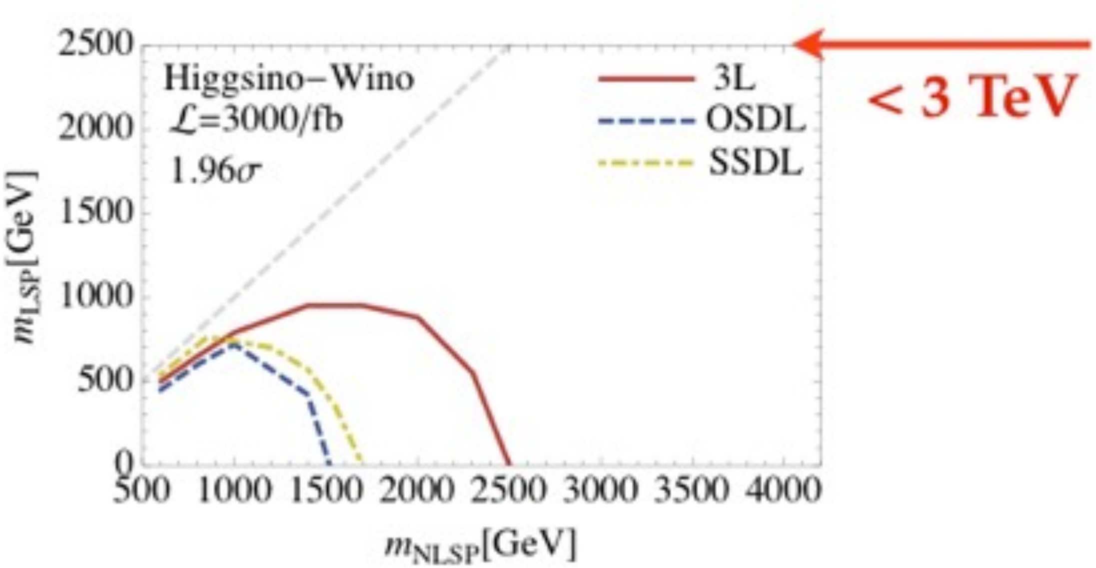


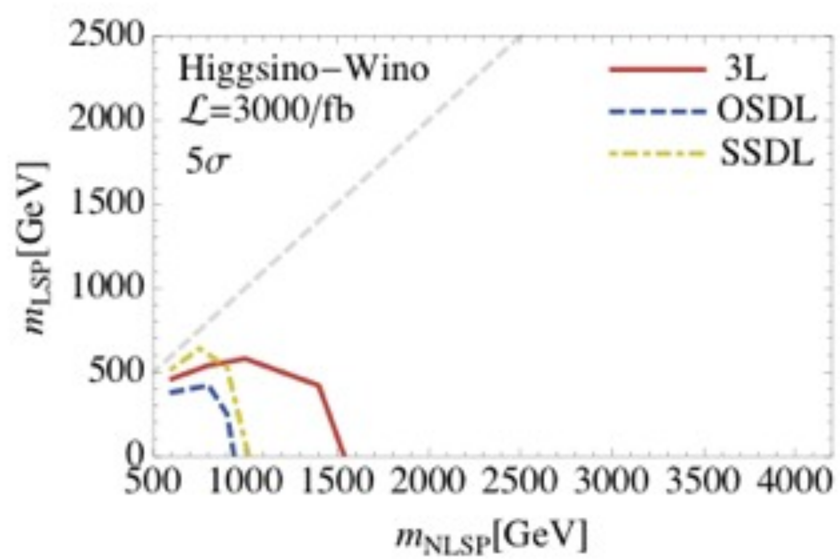


2: Higgsino / Wino

- Rate ~ Higgsino production
- $BR(N_{2,3} \to N_1\, h) \simeq 1/4$
- $BR(N_{2,3} \to N_1\, Z) \simeq 1/4$
- $BR(N_{2,3} \to C_1\, W) \simeq 1/2$



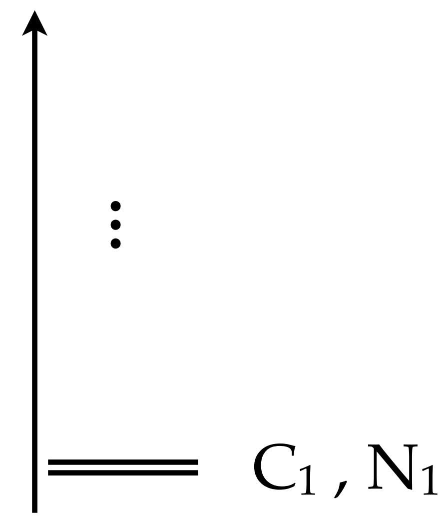




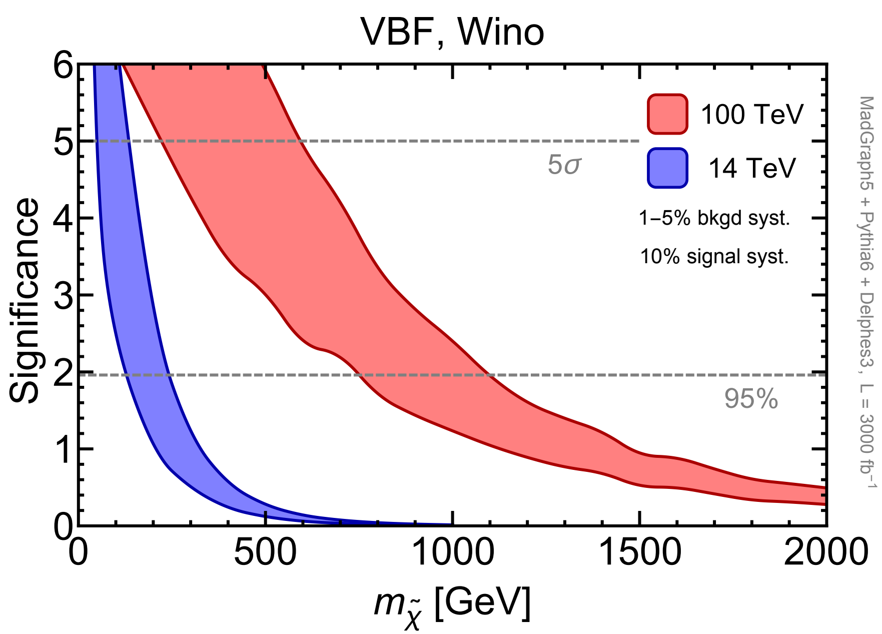
Aside: Winos

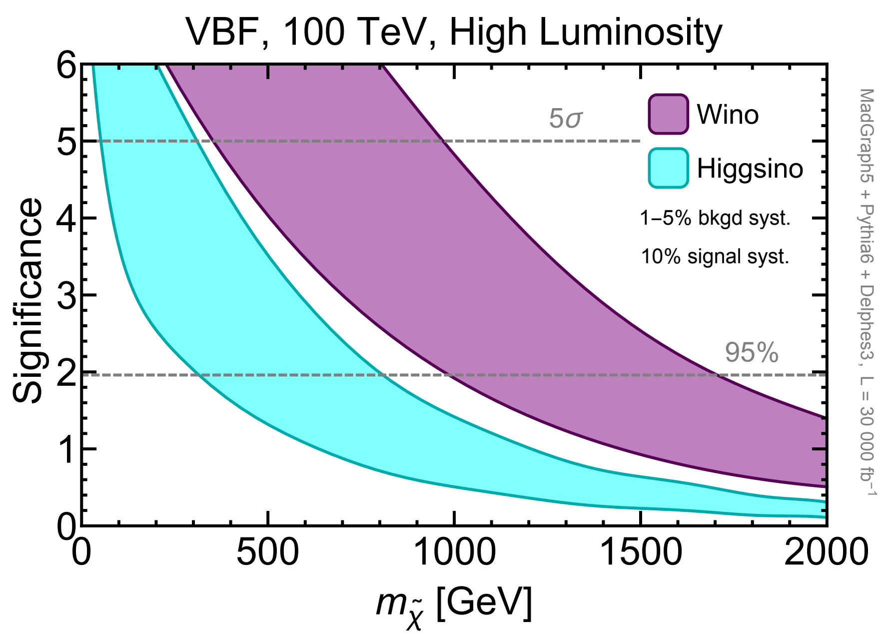
- Other wino probes:
  - Reach in monojet: ~1.4 TeV
  - Reach in VBF: ~1.1 TeV

See also Cirelli, Sala, Taoso (arXiv:1407.7058)



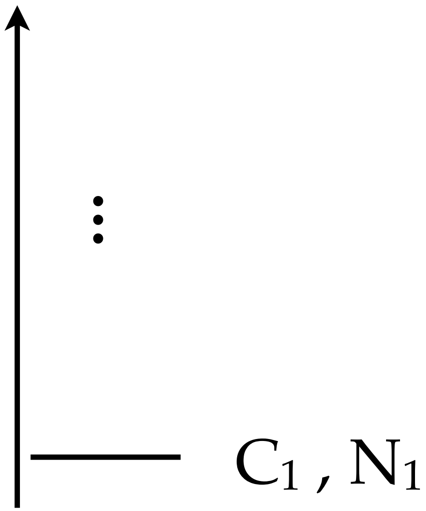
3 ab^{-1} → **30 ab^{-1}**

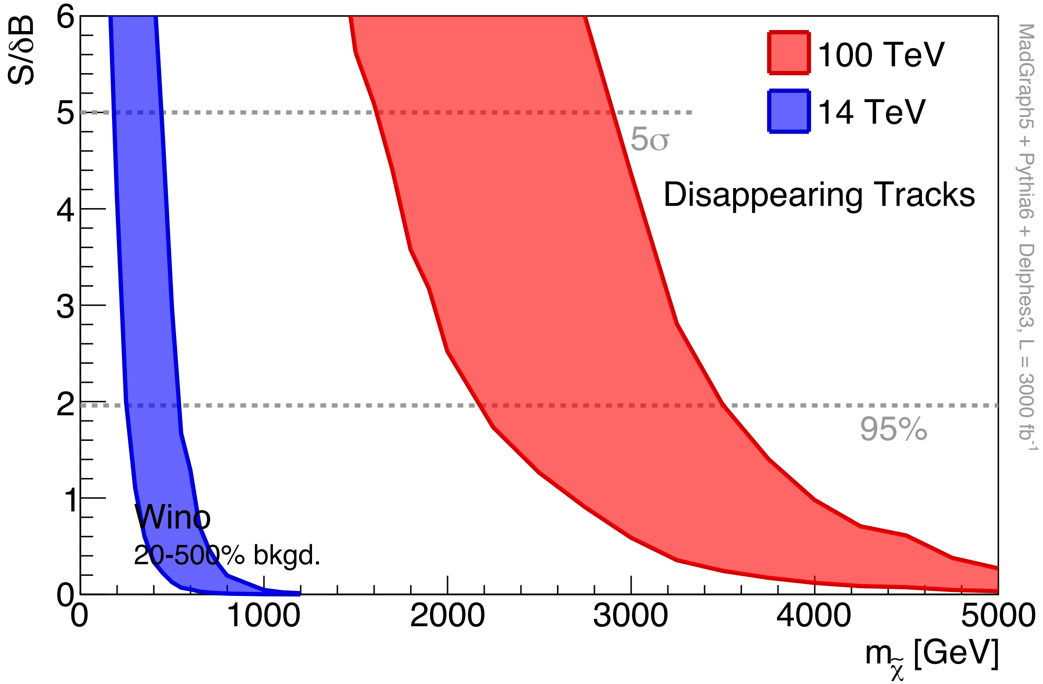




Aside: Winos

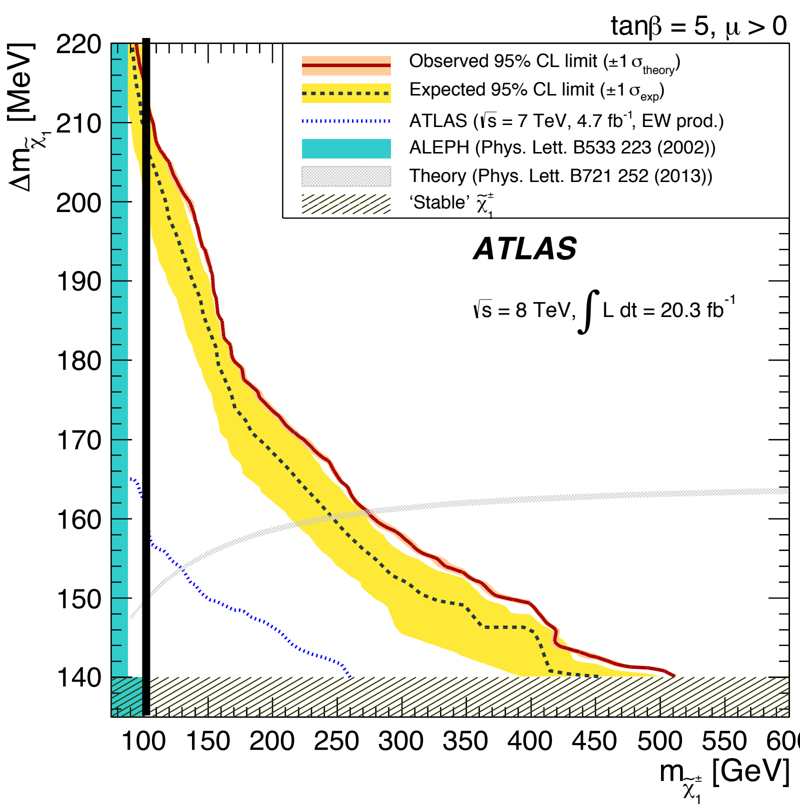
- Reach in disappearing tracks: ~ 2 - 3.5 TeV
- Radiative splitting ~ $\alpha m_z \sim 166\ \text{MeV}$
- Lowest is dim-7: $\frac{c}{M^3}(h^\dagger \tilde{W} h)^2 \sim \frac{m_z^4}{M^3}$

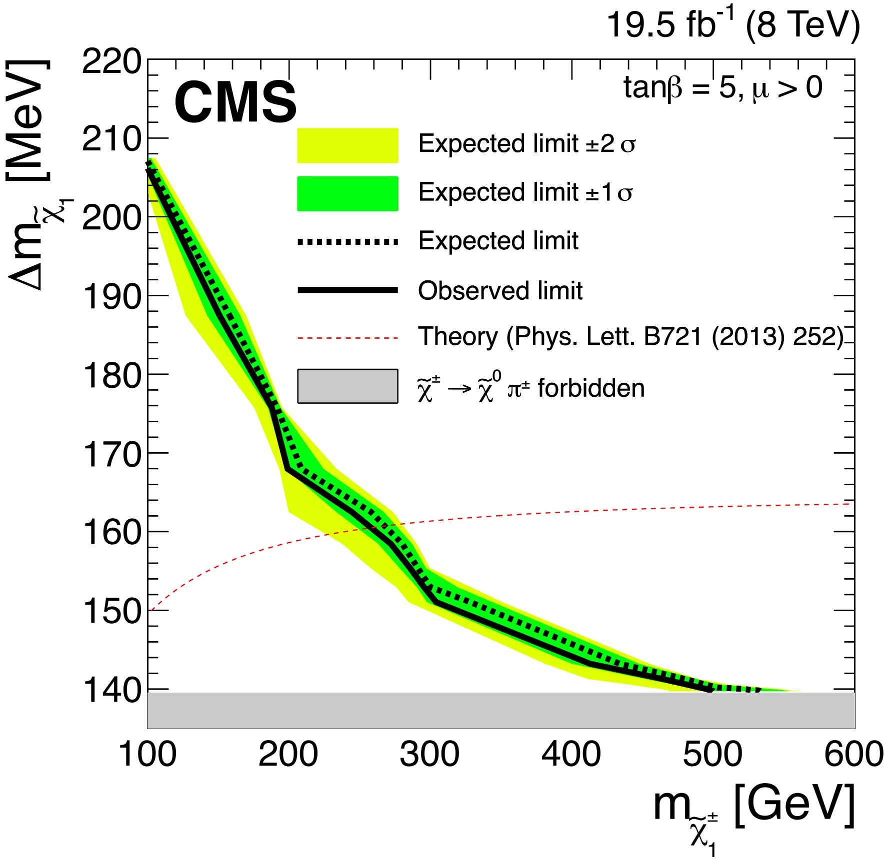




Aside: Winos

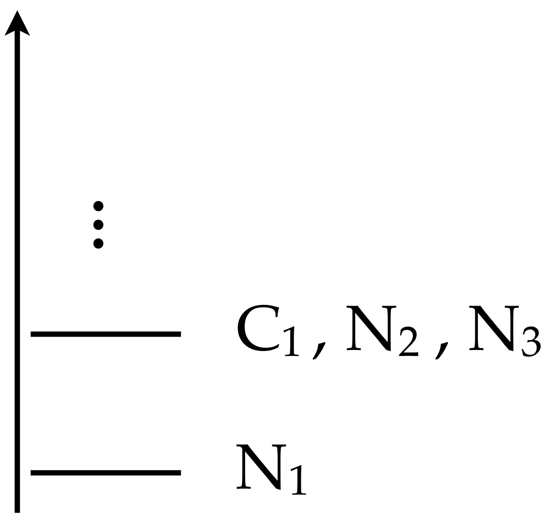
- Limit already **270 GeV** at 8 TeV with 20 fb^{-1}
- ATLAS (arXiv:1310.3675)
- CMS (arXiv:1411.6006)

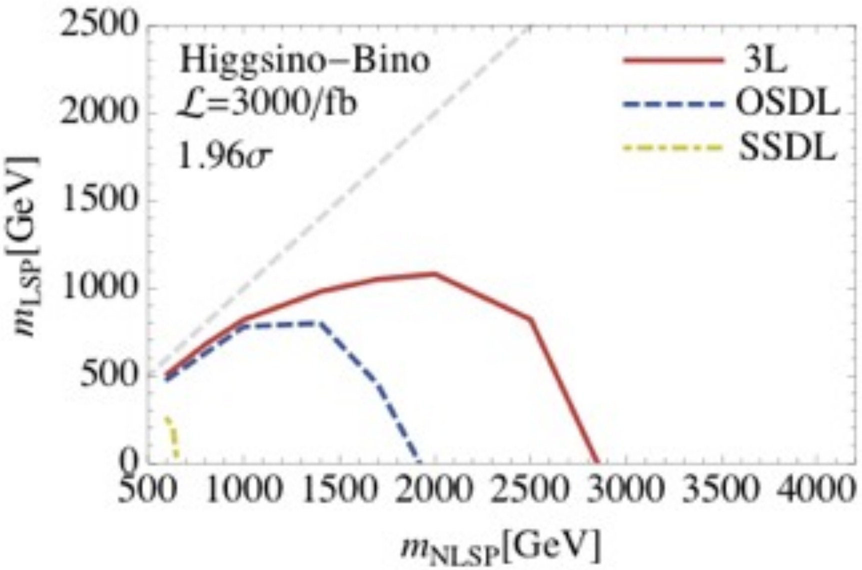


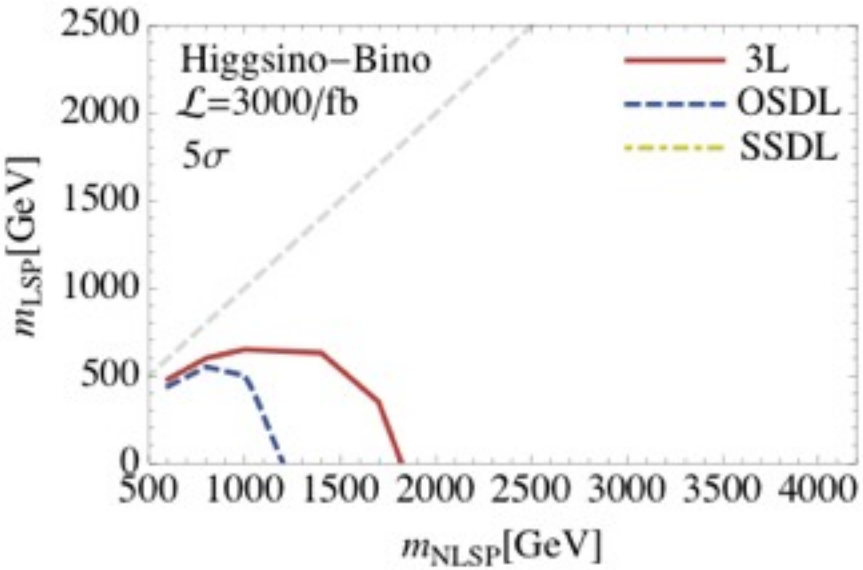


3: Higgsino / Bino

- Rate ~ Higgsino production
- $BR(N_{2,3} \rightarrow N_1\, h) \simeq 1/2$
- $BR(N_{2,3} \rightarrow N_1\, Z) \simeq 1/2$



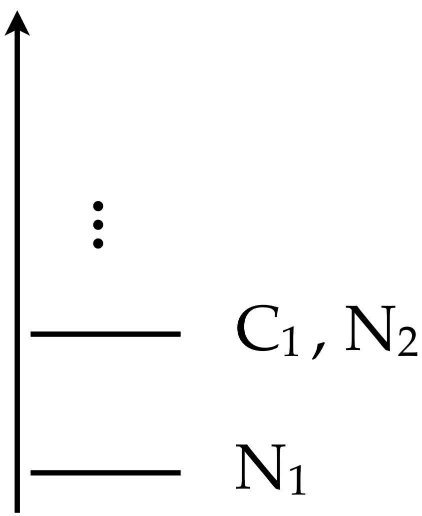




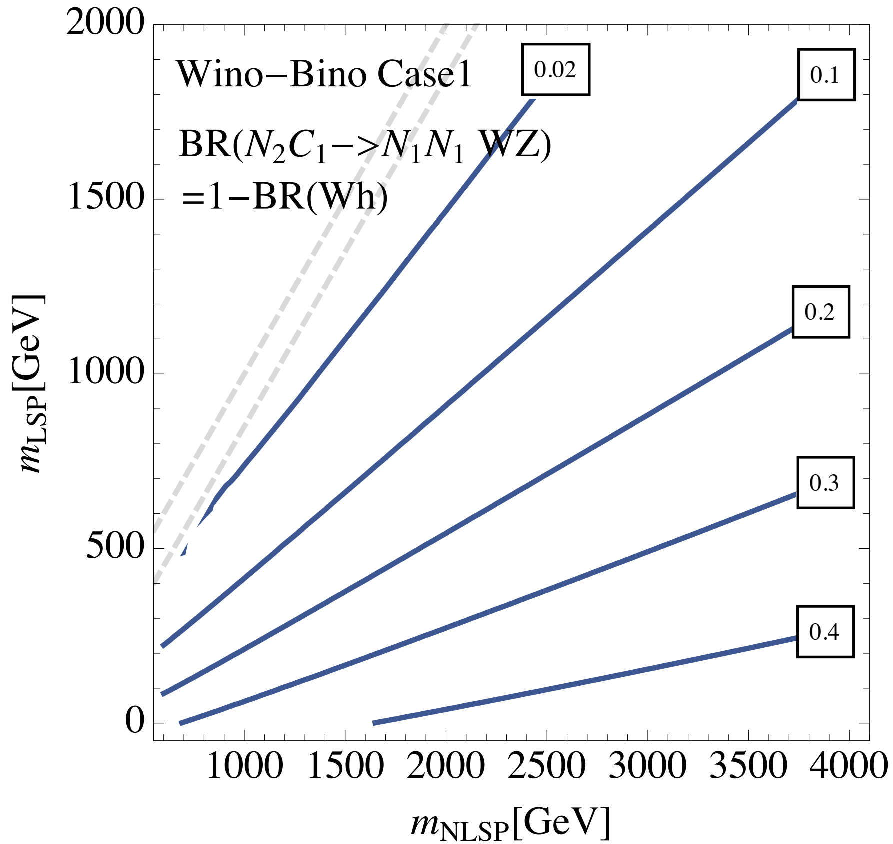
4: Wino / Bino

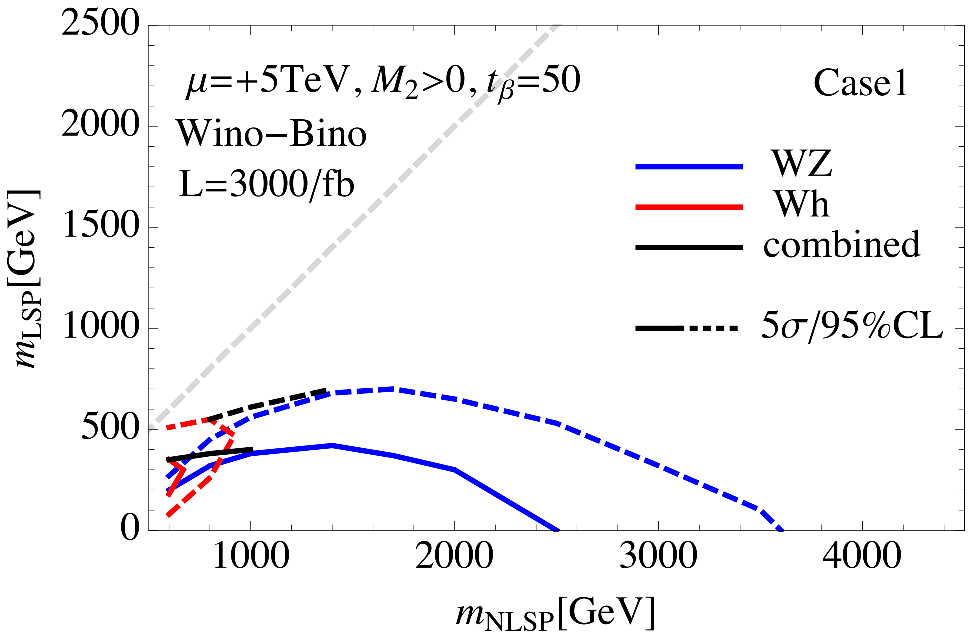
- BRs depend on t_β, $\text{sign}(\mu M_2)$, $\text{sign}(M_2 M_1)$

$$\frac{\Gamma(\tilde{W}^0 \to \tilde{B}^0 Z)}{\Gamma(\tilde{W}^0 \to \tilde{B}^0 h)} \simeq \frac{c_{2\beta}^2 M_2^2}{(2\mu s_{2\beta} + M_2 + M_1)^2 (1 + 2M_1/M_2)} \simeq \frac{M_2^2}{4\mu^2 t_{2\beta}^2}$$



- Case 1: (50, +, +)



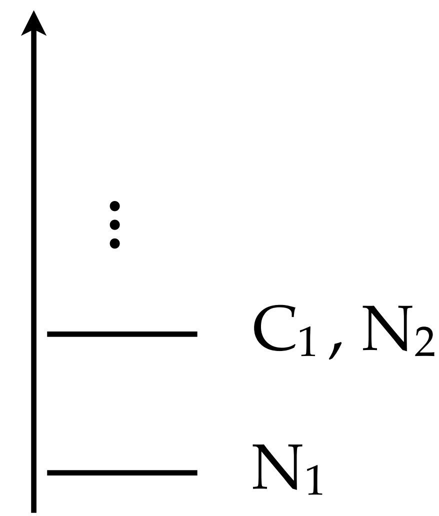


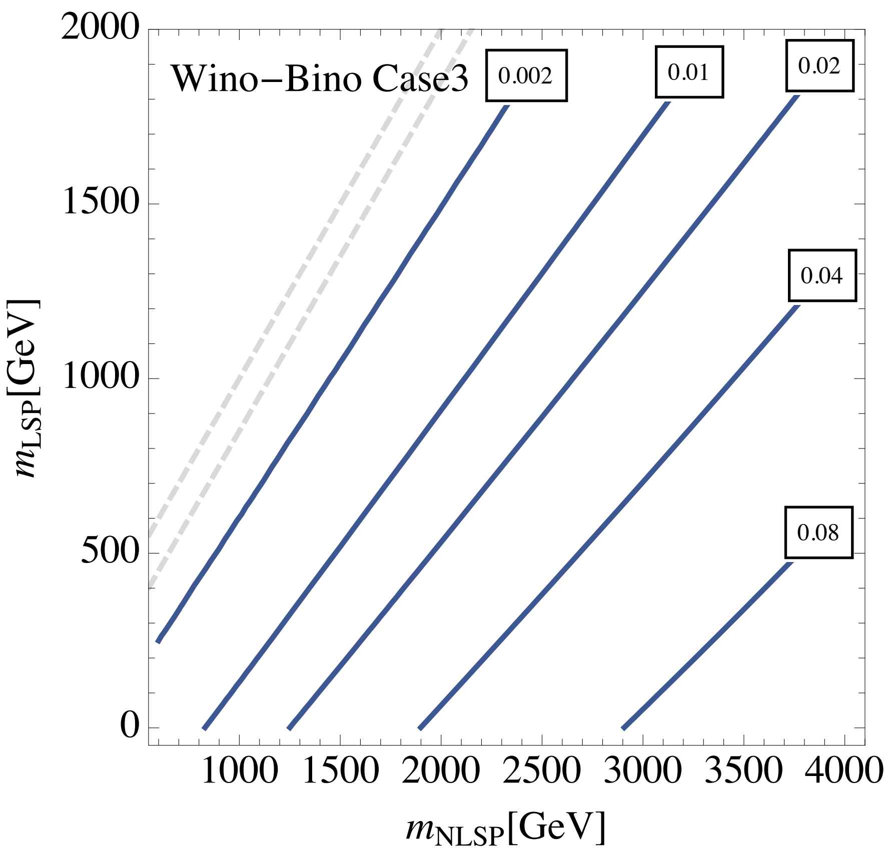
4: Wino / Bino

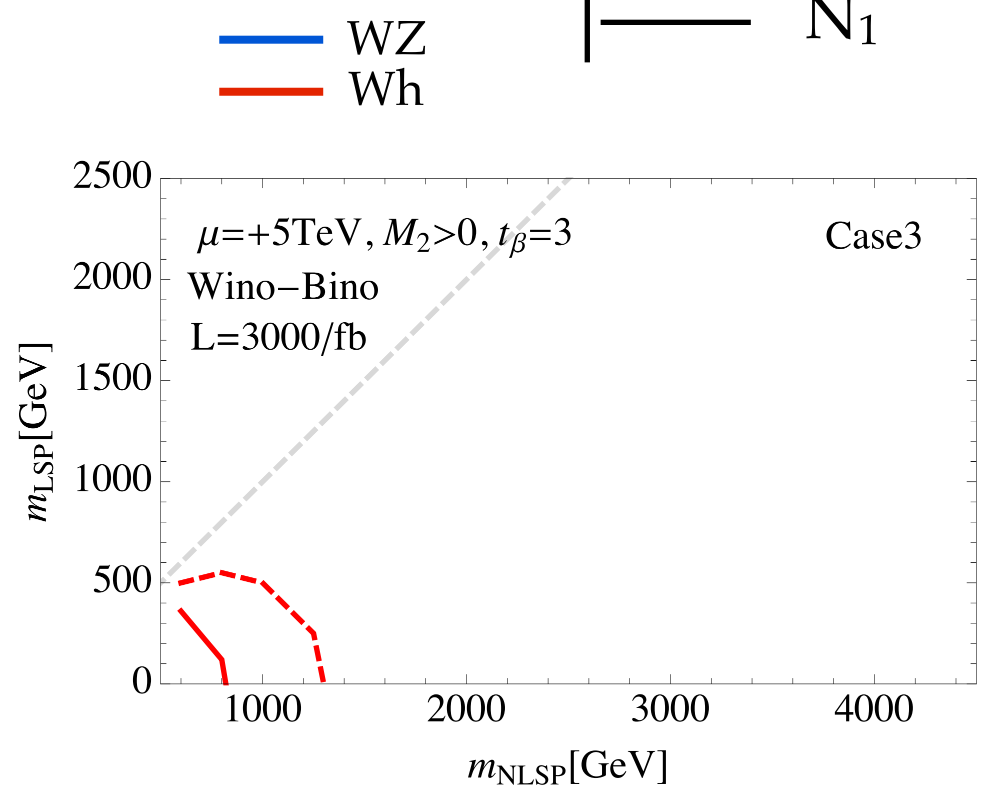
- BRs depend on $t_\beta,\ \text{sign}(\mu M_2),\ \text{sign}(M_2 M_1)$

$$\frac{\Gamma(\tilde{W}^0 \to \tilde{B}^0 Z)}{\Gamma(\tilde{W}^0 \to \tilde{B}^0 h)} \simeq \frac{c_{2\beta}^2 M_2^2}{(2\mu s_{2\beta} + M_2 + M_1)^2 (1 + 2M_1/M_2)} \simeq \frac{M_2^2}{4\mu^2 t_{2\beta}^2}$$

- Case 3: (3, +, +)





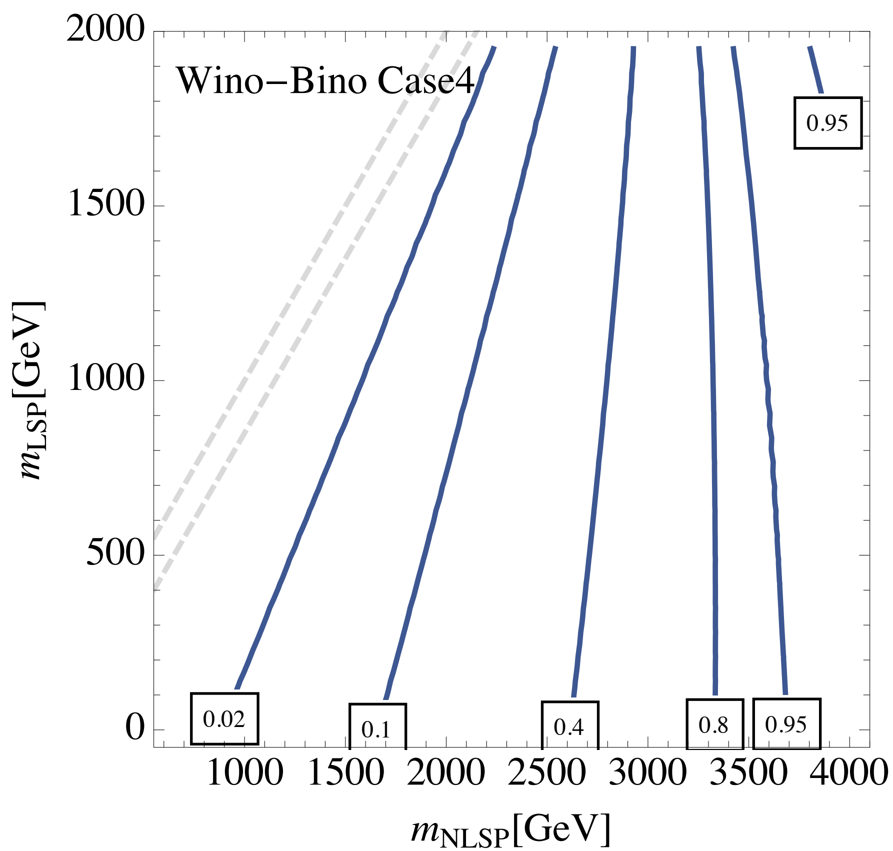


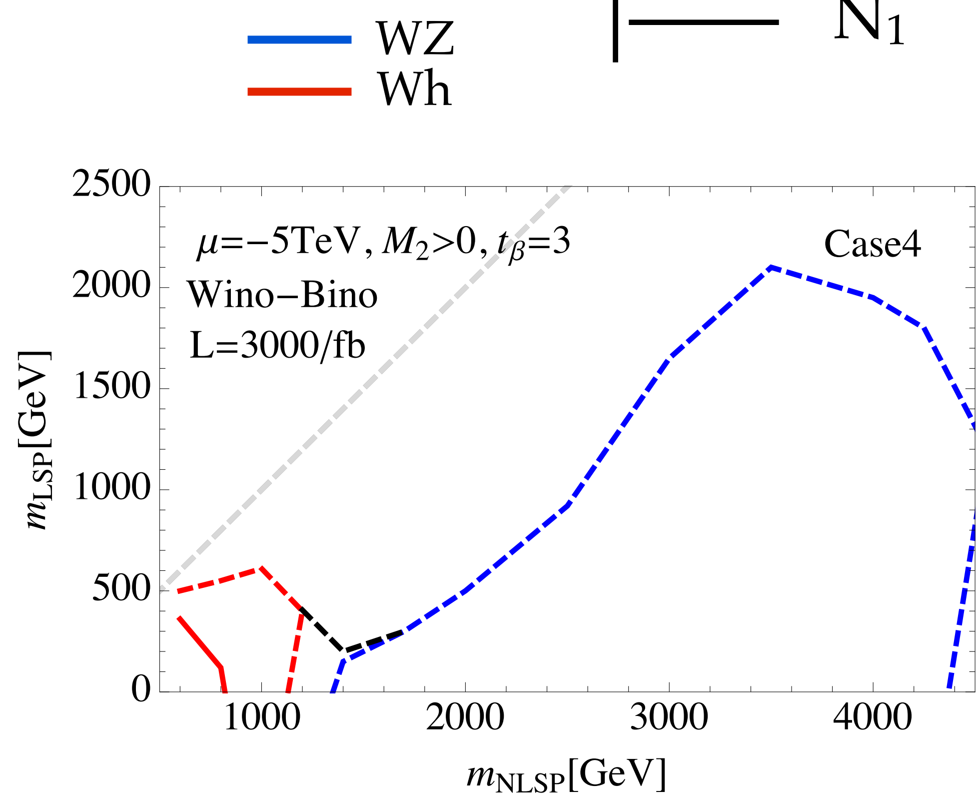
4: Wino / Bino

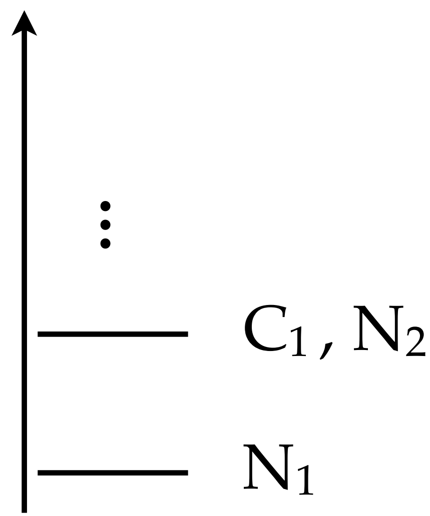
- BRs depend on $t_\beta,\ \mathrm{sign}(\mu M_2),\ \mathrm{sign}(M_2 M_1)$

$$\frac{\Gamma(\tilde{W}^0 \to \tilde{B}^0 Z)}{\Gamma(\tilde{W}^0 \to \tilde{B}^0 h)} \simeq \frac{c_{2\beta}^2 M_2^2}{(2\mu s_{2\beta} + M_2 + M_1)^2(1 + 2M_1/M_2)}$$

- Case 4: (3, -, +)







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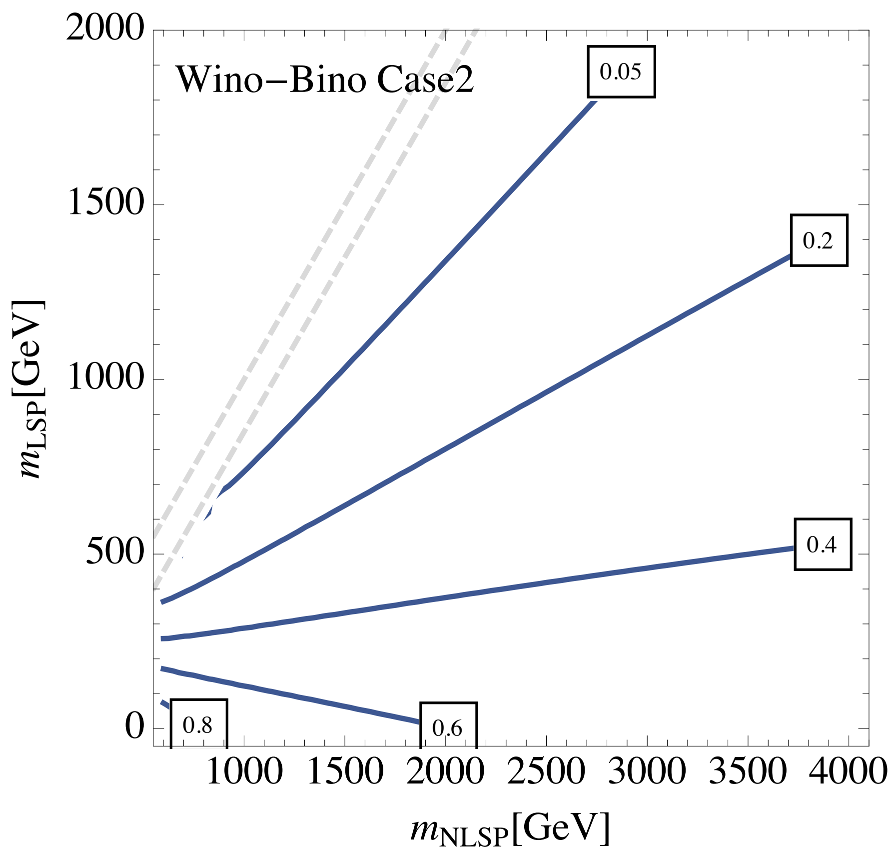
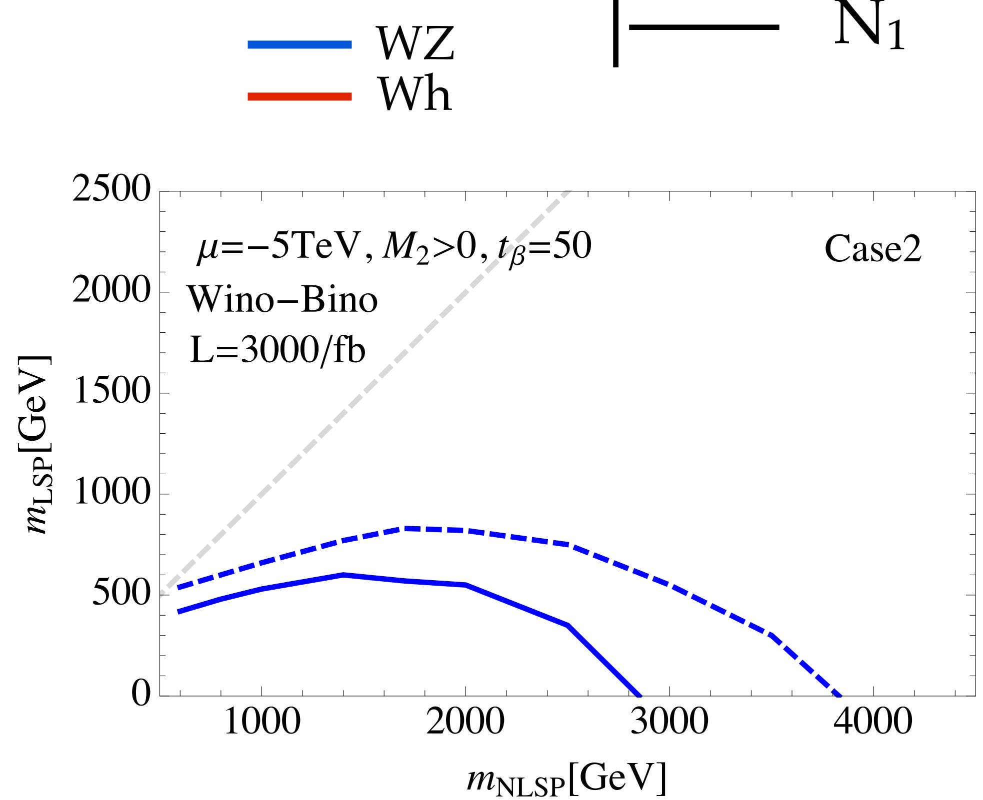
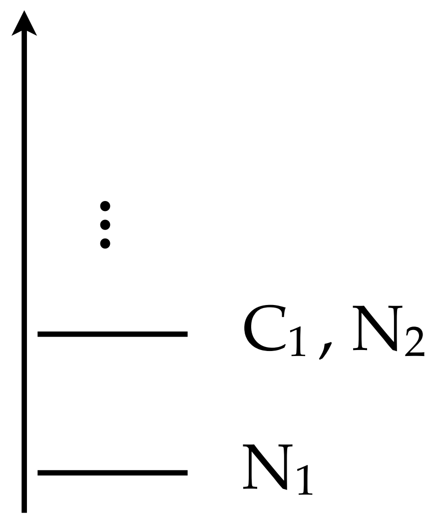
- Case 2: (50, -, +)





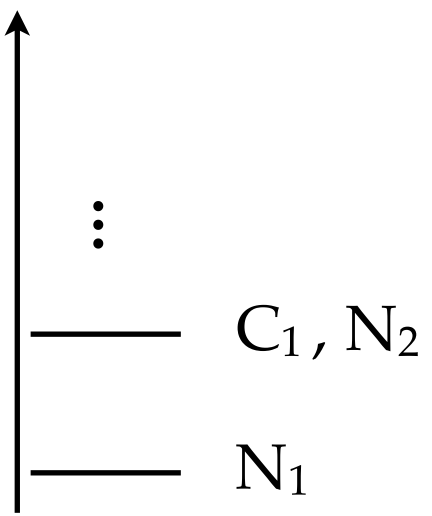


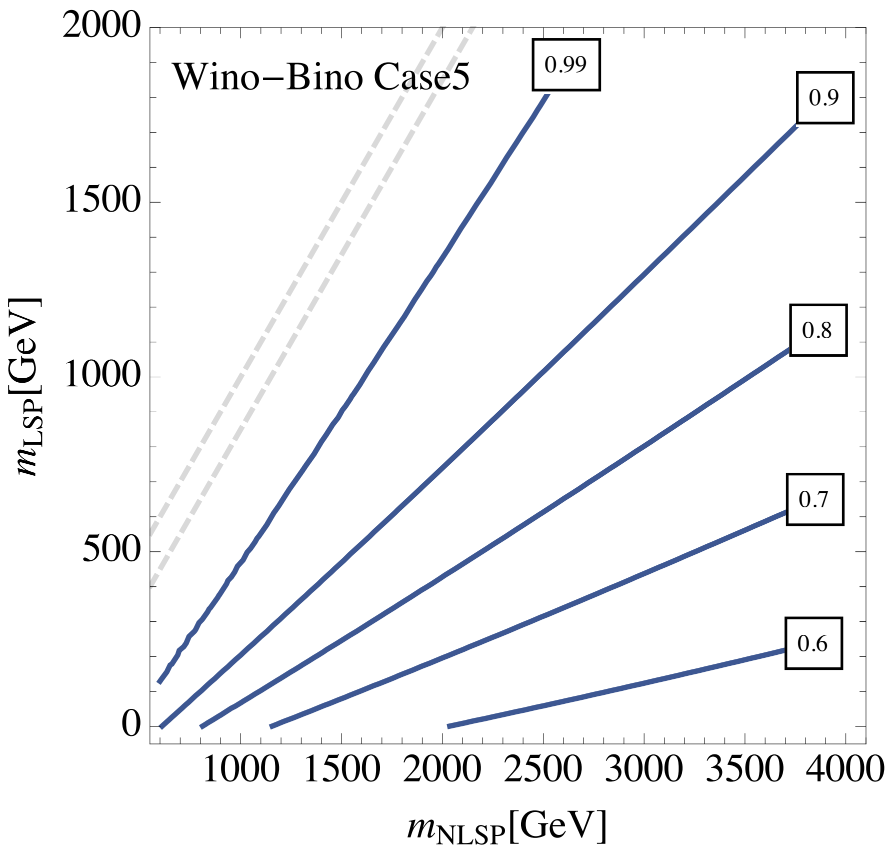
4: Wino / Bino

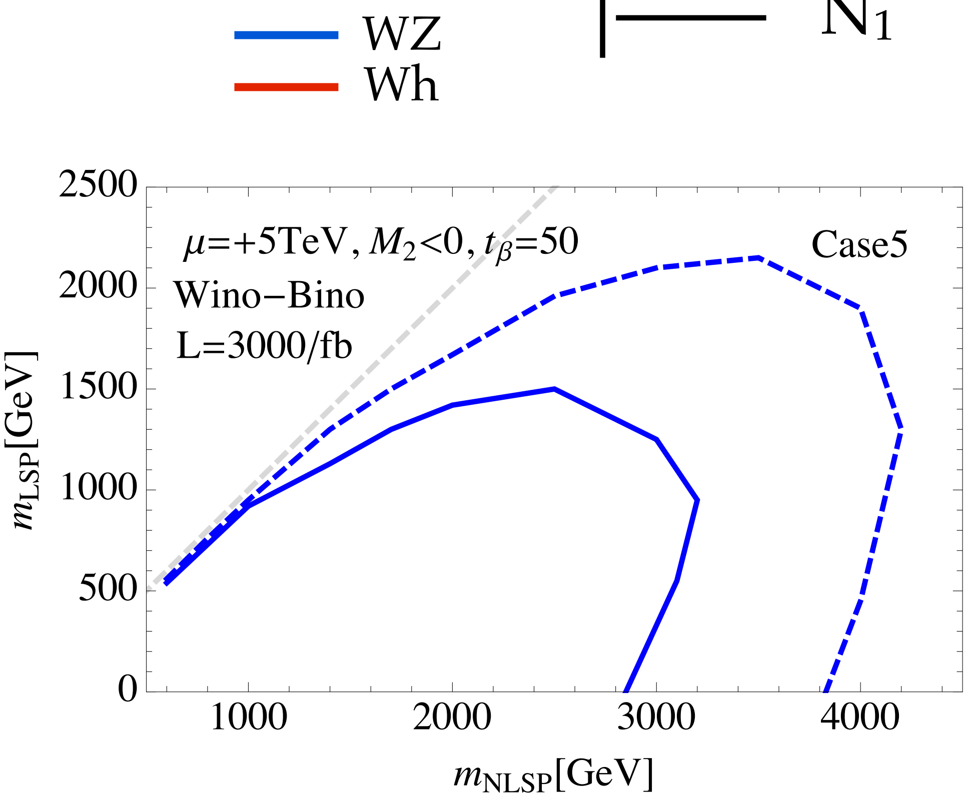
- BRs depend on $t_\beta,\ \mathrm{sign}(\mu M_2),\ \mathrm{sign}(M_2 M_1)$

$$\frac{\Gamma(\tilde{W}^0 \to \tilde{B}^0 Z)}{\Gamma(\tilde{W}^0 \to \tilde{B}^0 h)} \simeq \frac{c_{2\beta}^2 M_2^2}{(2\mu s_{2\beta} + M_2 + M_1)^2 (1 + 2M_1/M_2)}$$

- Case 5: (50, -, -)







4: Wino / Bino

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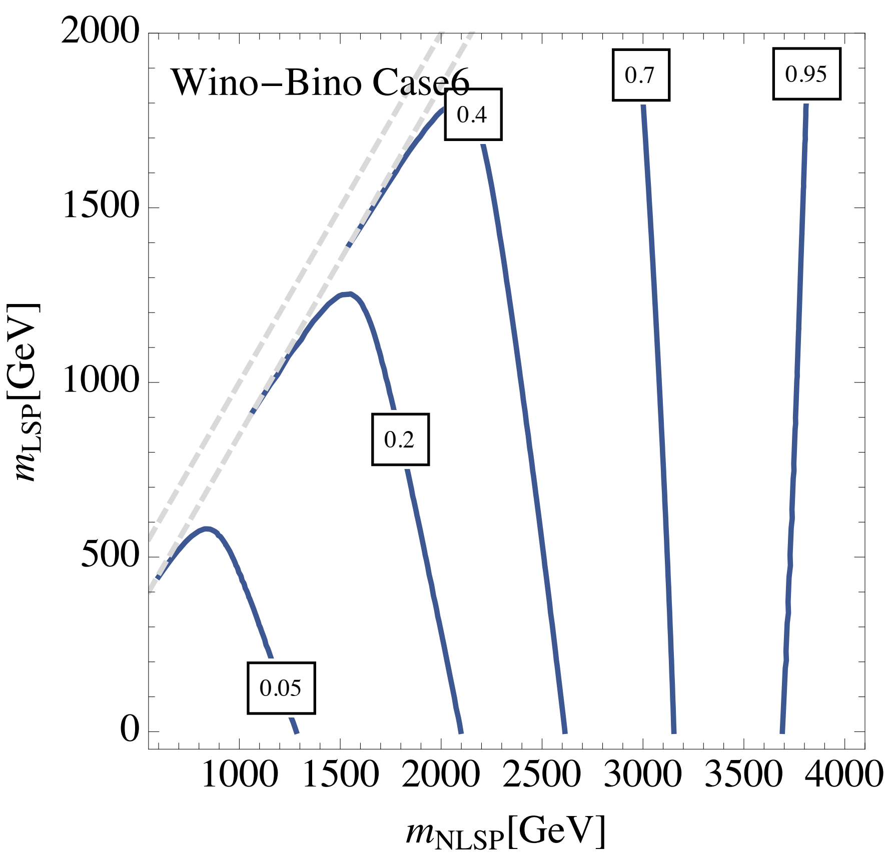
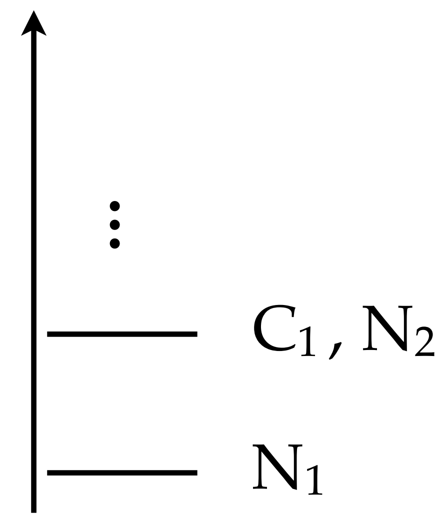
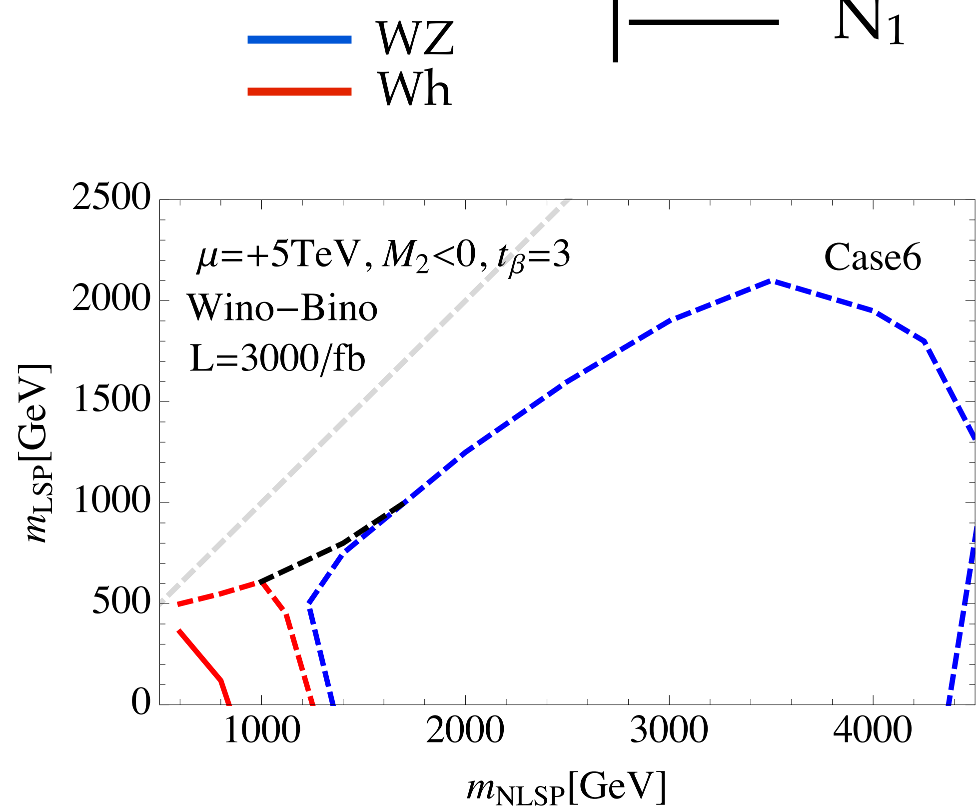
- Case 6: (3, -, -)

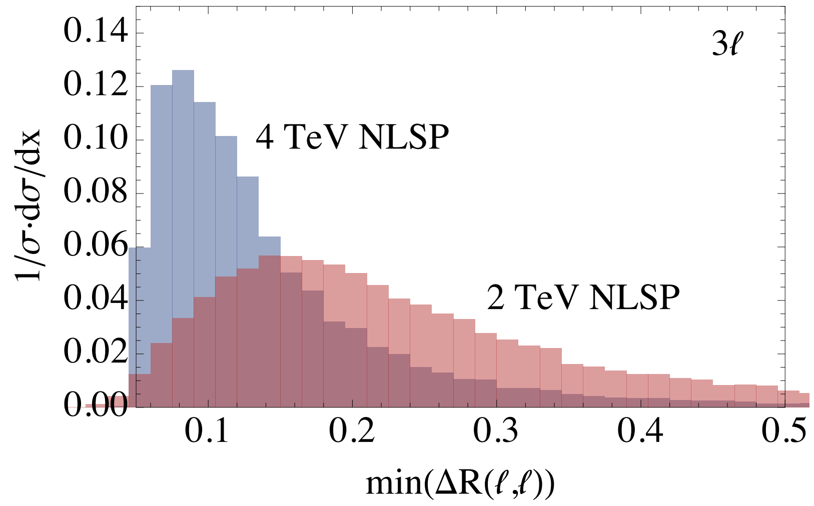


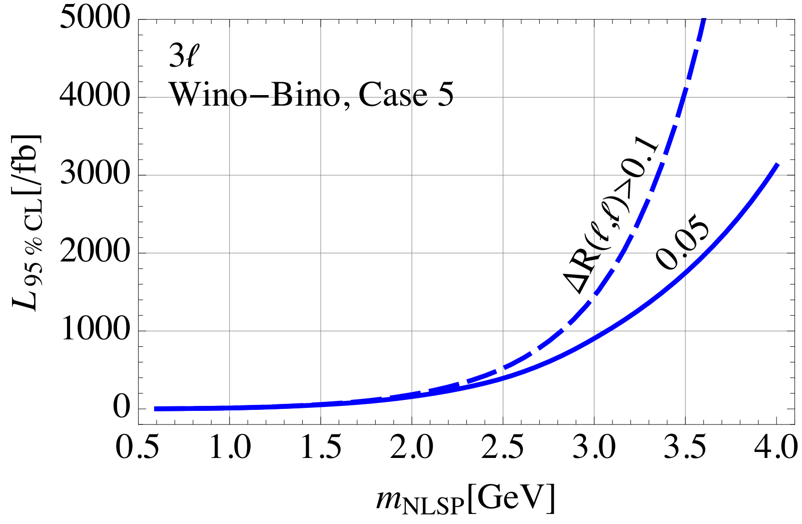




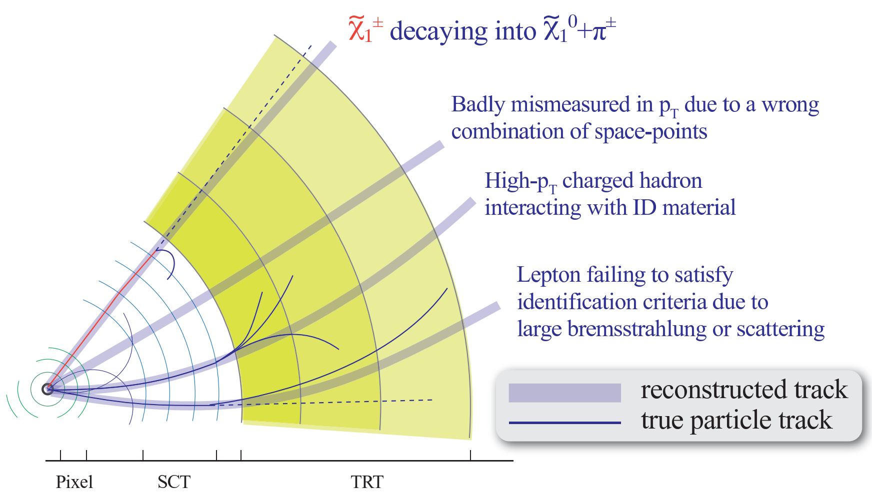
Detector Wishlist

- High resolution for leptons





- Redundant tracker



- High η calorimeter *not* required for electroweakinos

(but is useful for resonances)

Ismail, Low, ML, Wang, in preparation

Summary

- Multi-lepton searches leverage large masses and large mass splittings
- At 100 TeV reach is into the TeV range
- Goldstone equivalence often applies to BR's