New bounds on sneutrino masses through collider searches

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Introduction

- Among least-constrained sparticles are the sneutrinos
  - LEP-I measurement nearly 30 years-old (!)
  - $m_{\tilde{\nu}} > 44.7 \text{ GeV } (N(\tilde{\nu}) = 3)$
- Various models can accommodate the sneutrino as the LSP or NLSP
  - If the sneutrino is the LSP, then it will be invisible in the detector
  - If it is the NLSP, it will decay invisibly
- Place generic bounds on sneutrino masses from two sources
  - Model-independent bound by investigating couplings in the Higgs sector
  - Repurposing mono-boson LHC searches

Introduction

- The bottom line:

Place model-independent bounds on sneutrino masses

Couplings in the Higgs sector

Repurposed mono-boson LHC search

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Couplings in the Higgs sector

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Sneutrino MSSM Higgs constrains

- Left-handed charged sleptons are (nearly) mass degenerate with the sneutrinos due to the single soft mass parameter
- Mass separation comes from D-terms when Higgs VEVs are inserted

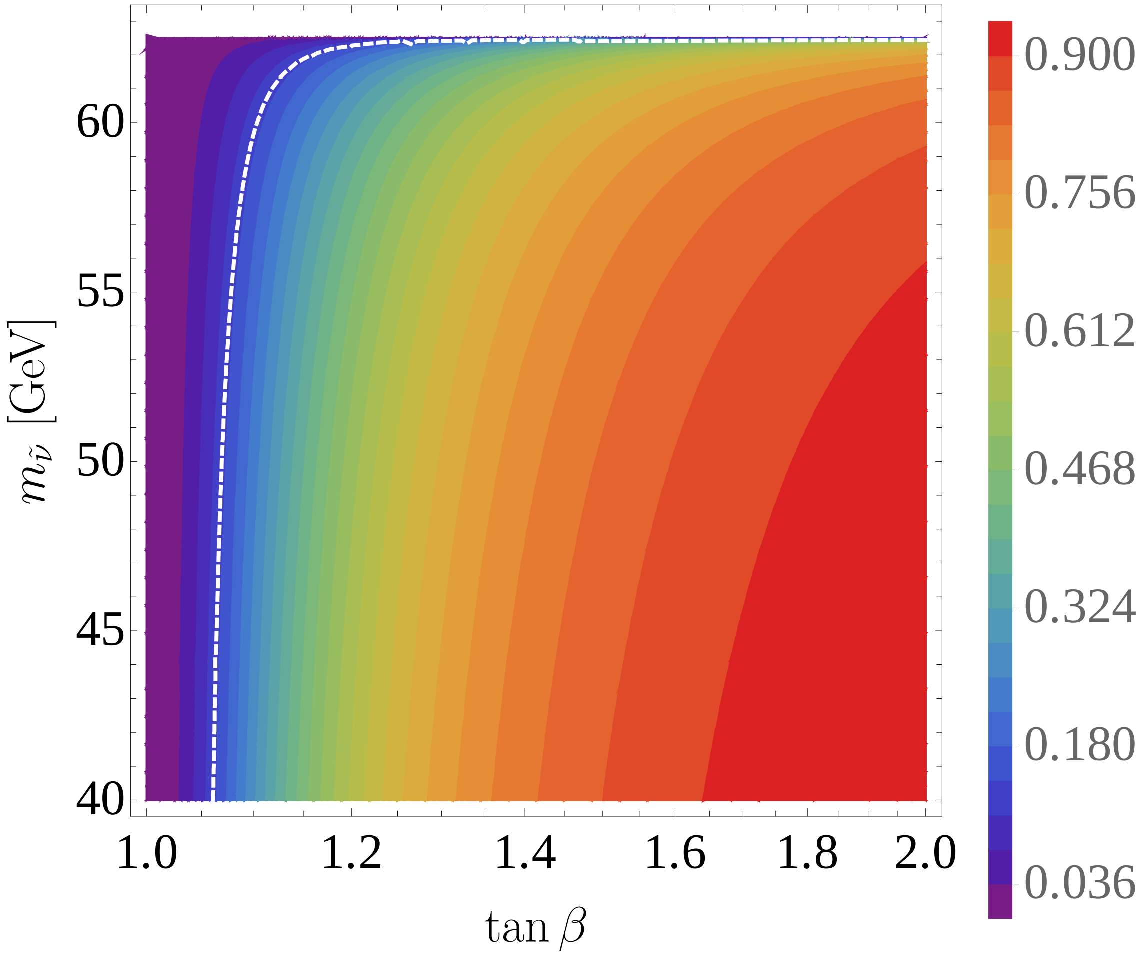
$$\Delta m := m_{\tilde{e}} - m_{\tilde{\nu}} = -\frac{m_W^2 \cos 2\beta}{m_{\tilde{e}} + m_{\tilde{\nu}}}$$

- Higgs couples to sneutrinos through tri-linear couplings

$$V_{\tilde{\ell}} = m_{\tilde{\nu}}^2 |\tilde{\nu}|^2 + m_{\tilde{e}}^2 |\tilde{e}|^2 + A_{\tilde{\nu}} h |\tilde{\nu}|^2 \qquad A_{\tilde{\nu}} = \frac{g m_Z^2}{2 m_W} \sin(\alpha + \beta)$$

$$\mathrm{Br}(h \to \mathrm{inv}) := \frac{\Gamma(h \to \tilde{\nu}\tilde{\nu}^*)}{\Gamma_h} \sim 390 \times \left(\frac{4.07\ \mathrm{MeV}}{\Gamma_h}\right) \left(\frac{|A_{\tilde{\nu}}|}{100\ \mathrm{GeV}}\right)^2 \times N_{\tilde{\nu}} \sqrt{1 - \frac{4 m_{\tilde{\nu}}^2}{m_h^2}}$$

Sneutrino MSSM Higgs constrains



- Current limit is BF ~ 0.13
- Sneutrino lighter than half the Higgs mass is excluded

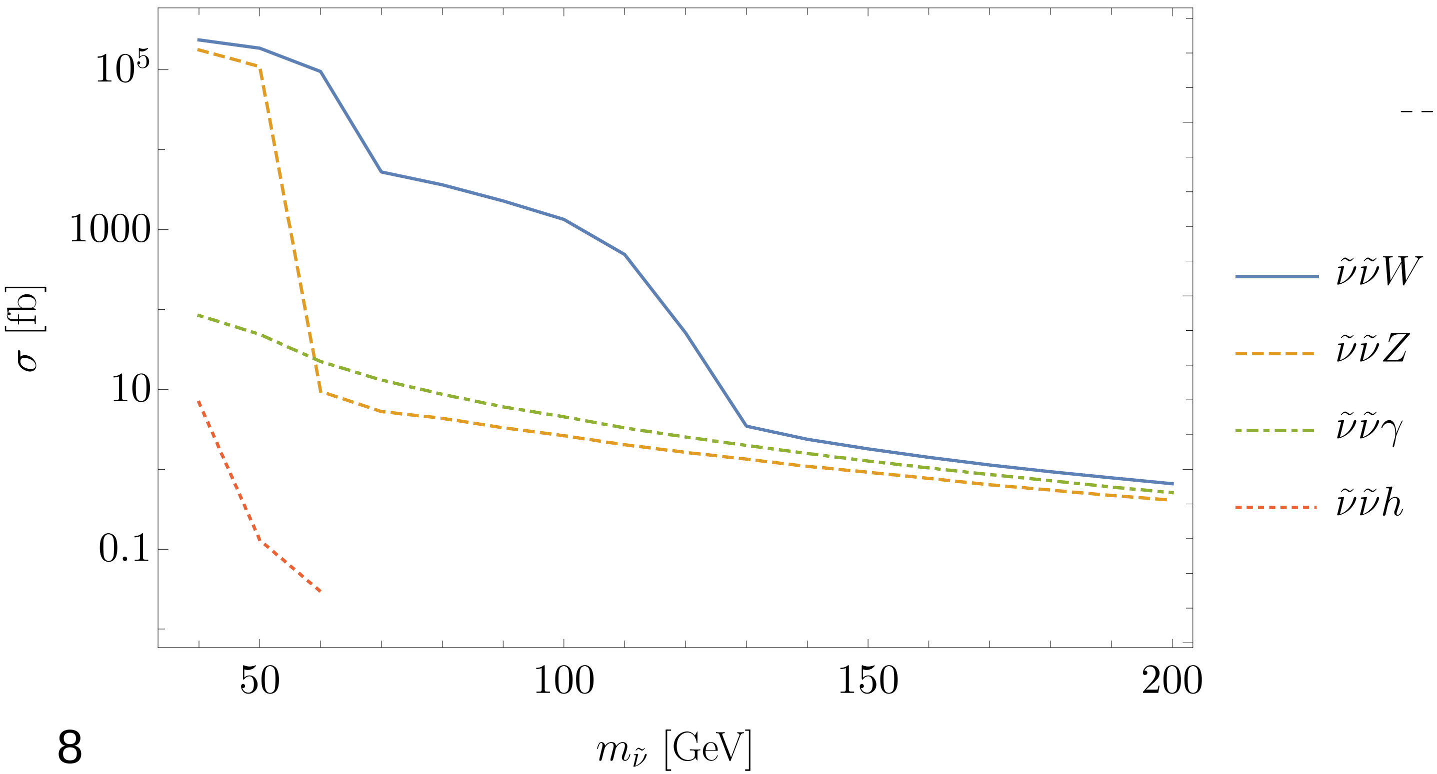
Place model-independent bounds on sneutrino masses

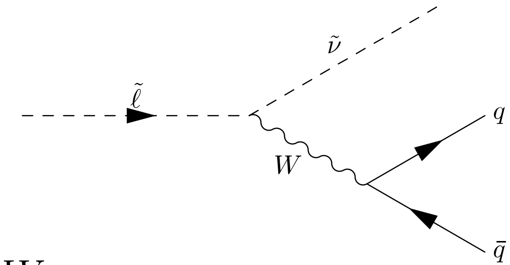
Couplings in the Higgs sector

Repurposed mono-boson LHC search

Vector boson processes

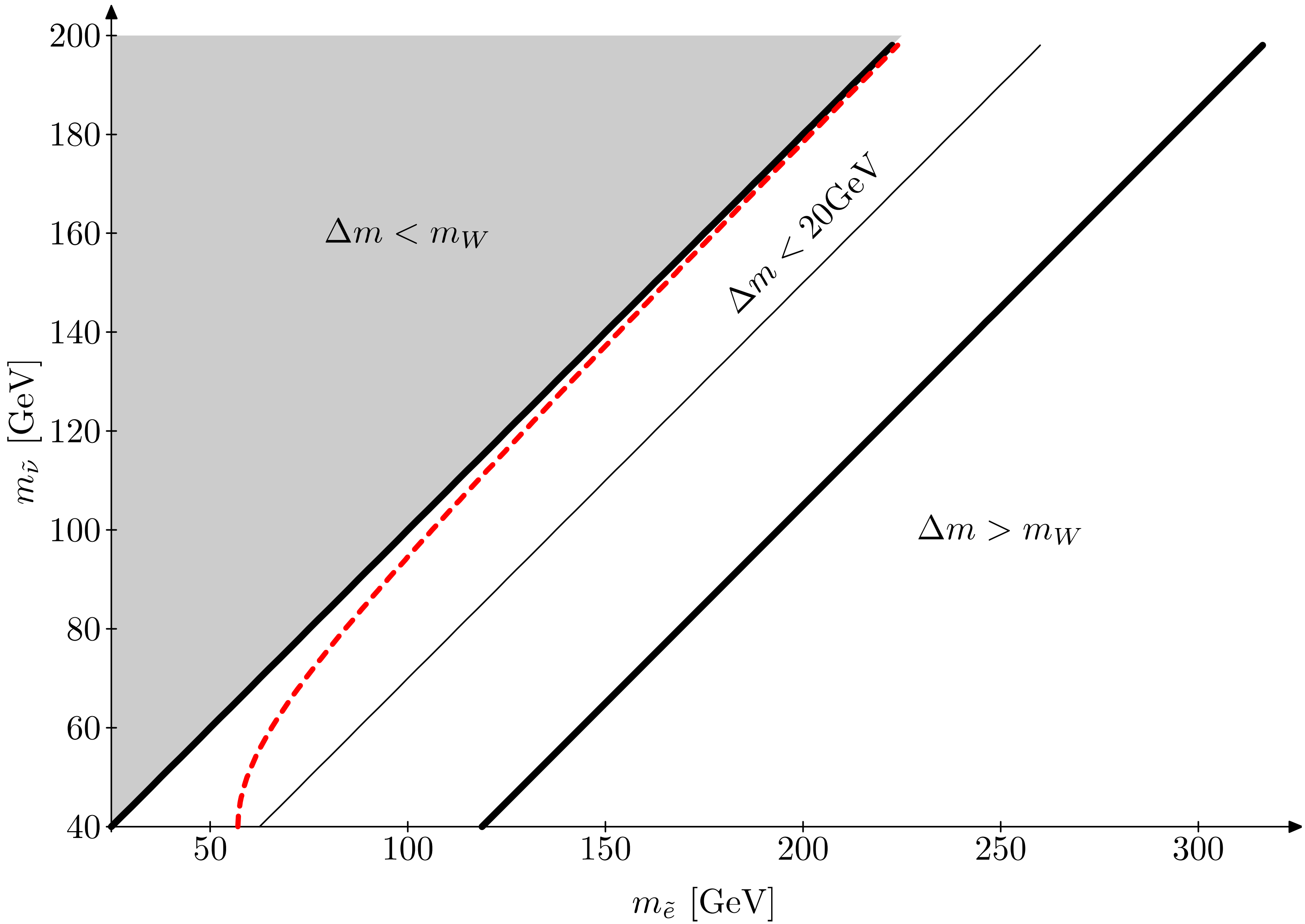
- ISR gluon events have greatest cross-section
  - And greatest background—SNR does not look promising
- Turn instead to FSR/ISR electroweak events
  - Vector mono-boson events with a hadronic v-tag





Processes by region

- Three regions to consider



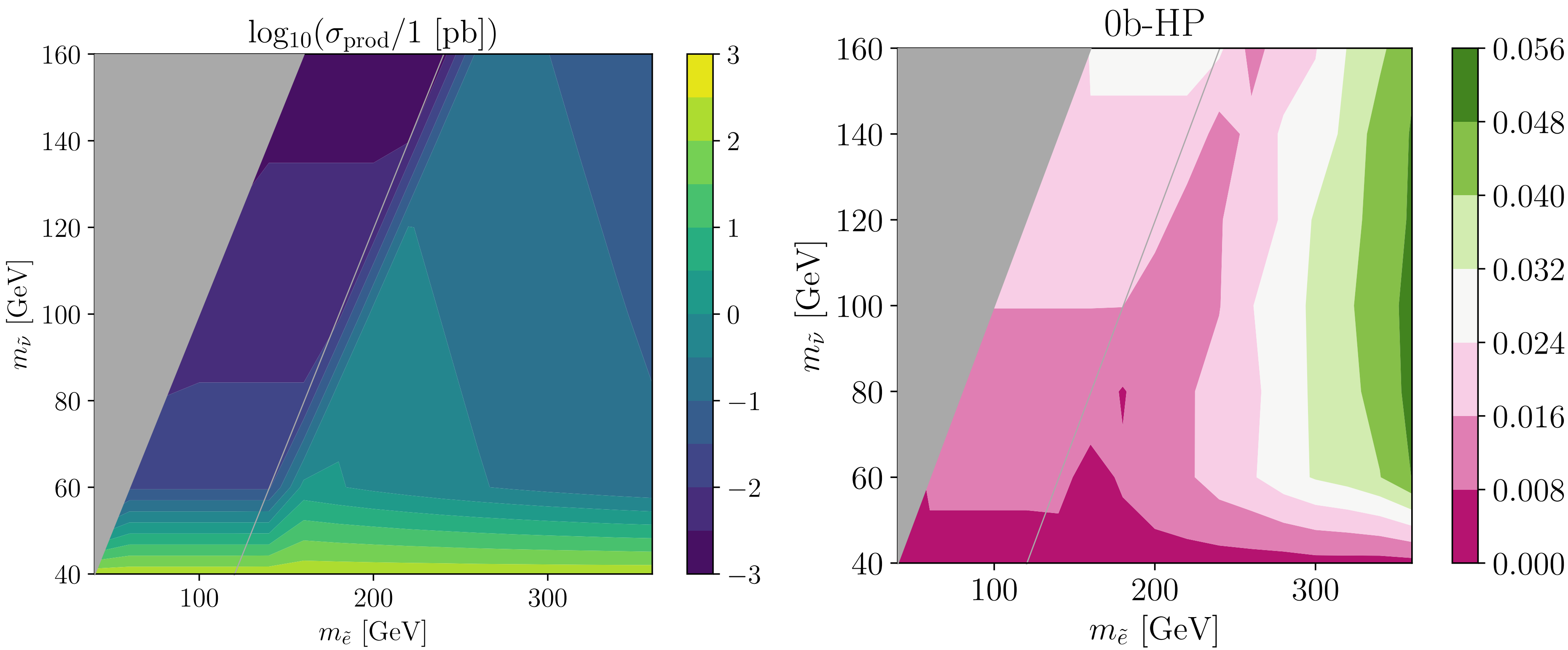
ATLAS search

- Hadronically decaying vector bosons → 1 or 2 jets
  - Number depends on topology
- Jets are classified by number of *b* quarks
- Resolved topology → two well-separated jets (R = 0.4)
  - These arise from vector bosons with relatively low boosts
- Merged topology → one large-radius jet (R = 1.0)
  - Further classified into ‘high-purity’ or ‘low-purity’ regions (HP and LP, respectively)

LHC constraints

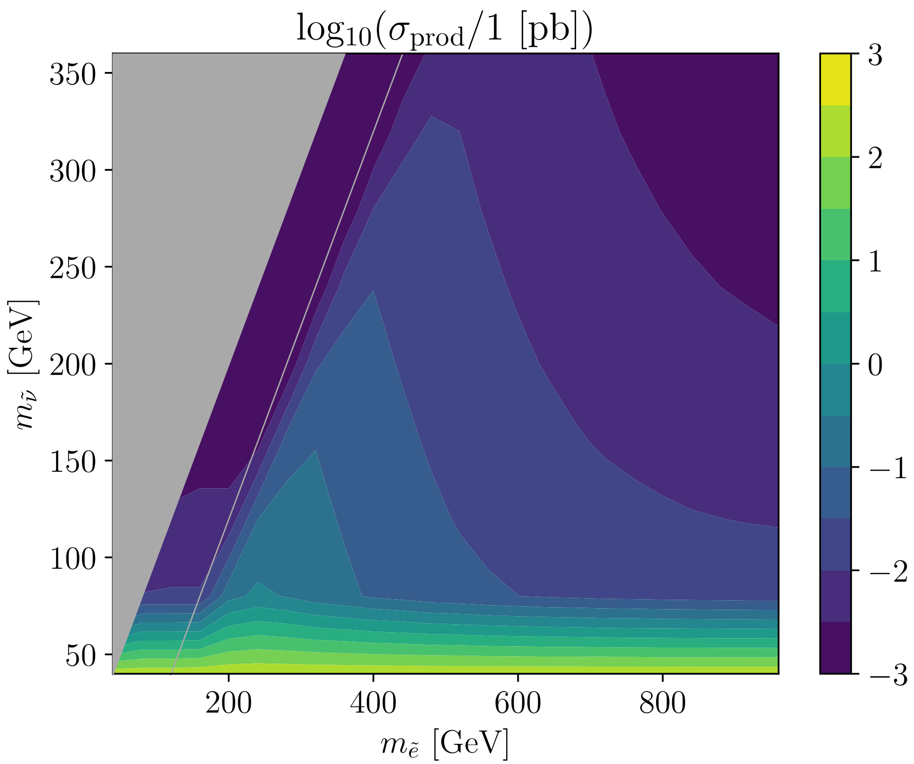
	Merged topology				Resolved topology	
E_T^{miss}	> 250 GeV				> 150 GeV	
Jets, leptons	≥ 1J, 0ℓ				$\geq 2j$, 0ℓ	
b-jets	no b-tagged jets outside of J				≤ 2 b-tagged small-R jets	
Multijet suppression	$\Delta\phi(\vec{E}_T^{\text{miss}},\ J \text{ or } jj) > 2\pi/3$ $\min_{i=1,2,3}\left[\Delta\phi(\vec{E}_T^{\text{miss}}\ j_i)\right] > \pi/9$ $\lvert\vec{p}_T^{\text{ miss}}\rvert > 30$ GeV or ≥ 2 b-jets $\Delta\phi(\vec{E}_T^{\text{miss}}, \vec{p}_T^{\text{ miss}}) < \pi/2$					
Signal properties					$p_T^{j_1} > 45$ GeV $\sum_i p_T^{j_i} > 120\ (150)$ GeV for 2 (≥ 3) jets	
Signal region	0b-HP	0b-LP	1b-HP	1b-LP	0b-Res	1b-Res
J or jj	HP	LP	HP	LP	$\Delta R_{jj} < 1.4$ and $m_{jj} \in [65, 105]$ GeV	
b-jet	no b-jet	no b-jet	1 b-jet	1 b-jet	no b-jet	1 b-jet

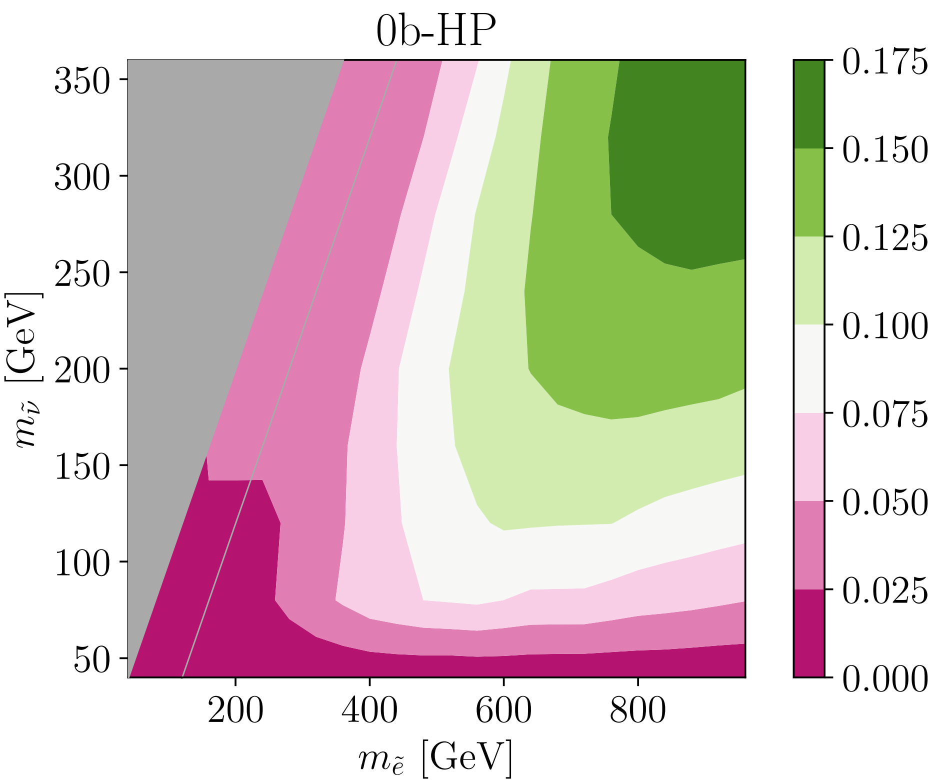
Cross sections & Efficiencies



$$\sqrt{s} = 13\ \text{TeV}$$

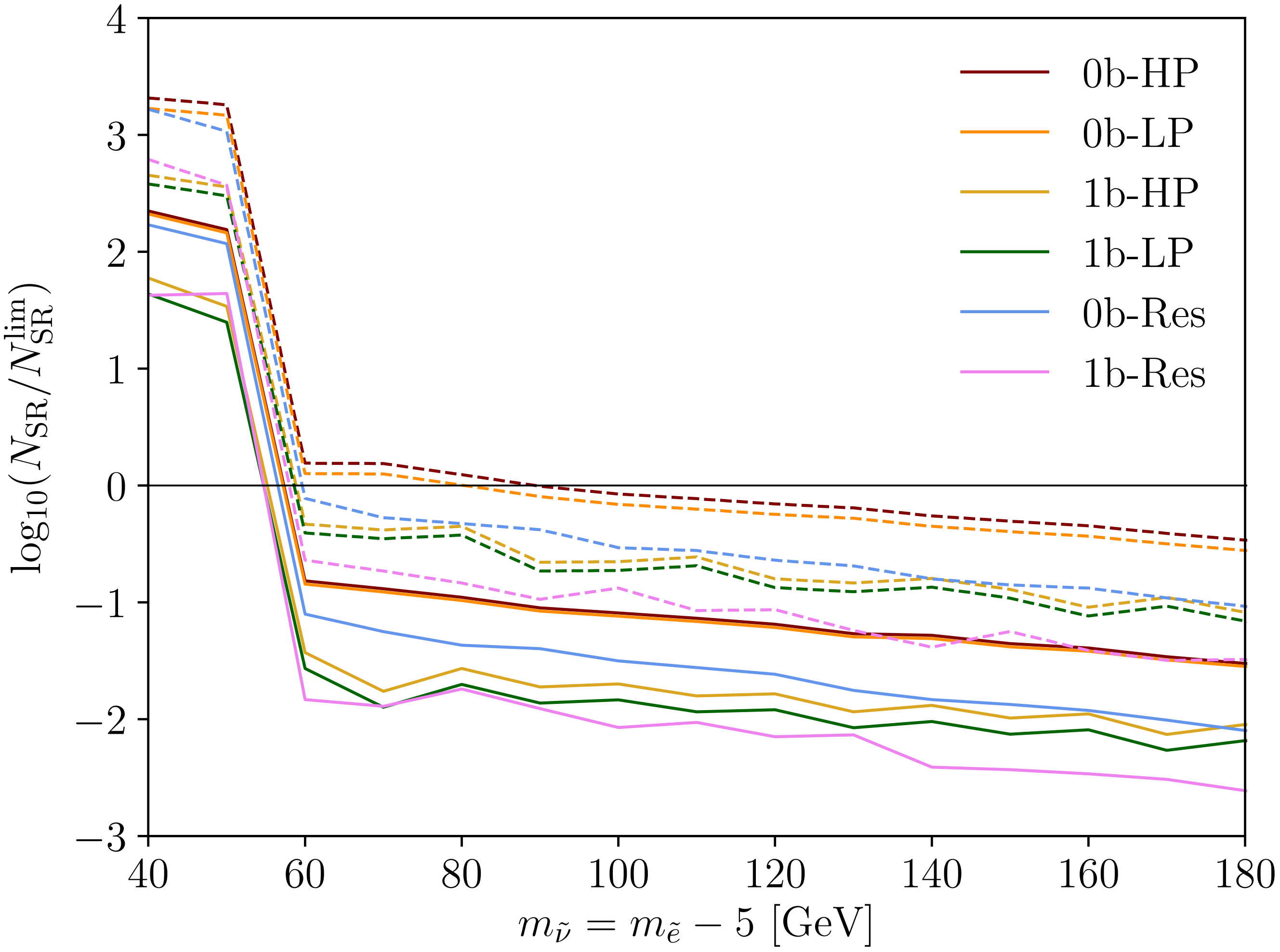
Cross sections & Efficiencies





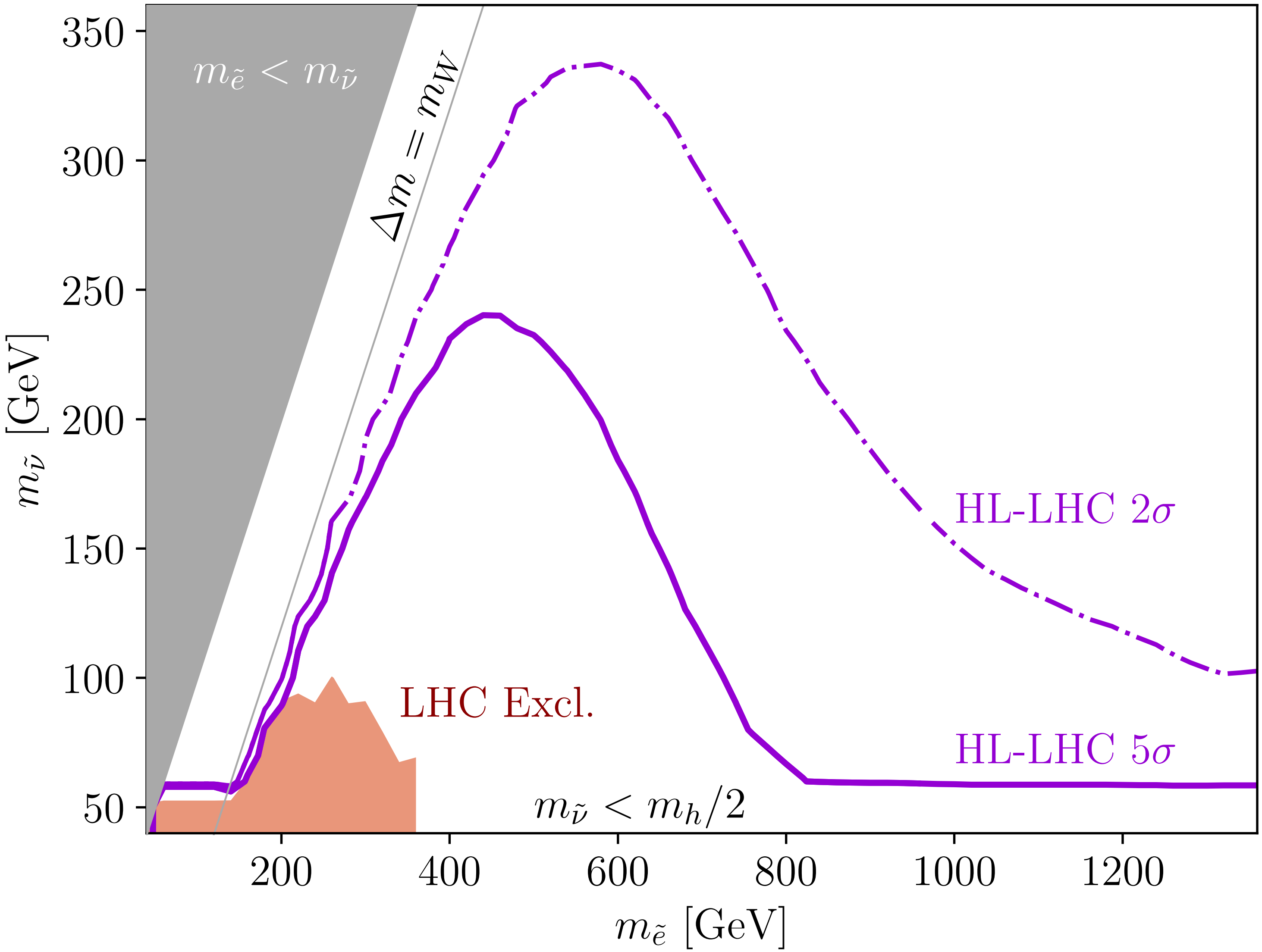
$$\sqrt{s} = 14\ \text{TeV}$$

Results



- Solid lines = 13 TeV signal region
- Dashed lines = 14 TeV signal region
- Black line = experimental limit
- Strongest constraint comes from the 0b-HP channel
- $m_{\tilde{\nu}} \sim 90$ GeV

Results


$m_{\tilde{e}} < m_{\tilde{\nu}}$
$\Delta m = m_W$
HL-LHC 2σ
HL-LHC 5σ
LHC Excl.
$m_{\tilde{\nu}} < m_h/2$
350
300
250
200
150
100
50
200
400
600
800
1000
1200
$m_{\tilde{\nu}}$ [GeV]
$m_{\tilde{e}}$ [GeV]

Summary

- Sneutrino (N)LSP models remain as least-constrained BSM scenarios
- Challenging scenario to constrain
- Derive bounds from Higgs-sector couplings and repurposed mono-boson LHC searches
- Higgs bound is $m_{\tilde{\nu}} > \frac{m_h}{2}$
- HL-LHC bound is $m_{\tilde{\nu}} \sim 90\ \mathrm{GeV}$

Thank you!

Extra Slides

Sneutrino (N)LSP models

- There exist many scenarios where sneutrinos are the lightest or next-to-lightest sparticle
- In the LSP case, we consider a scenario where the sneutrino does not constitute a sizable fraction of dark matter
  - Strong constraints from direct detection
- In the NLSP case, lighter sparticles, such as the gravitino or axino are required

Sneutrino general mass constraints

- Many non-SUSY extensions of the SM contain sleptons
  - Can increase mass separation between sleptons and sneutrinos with extra SU(2) breaking
  - e.g., Dirac gaugino models