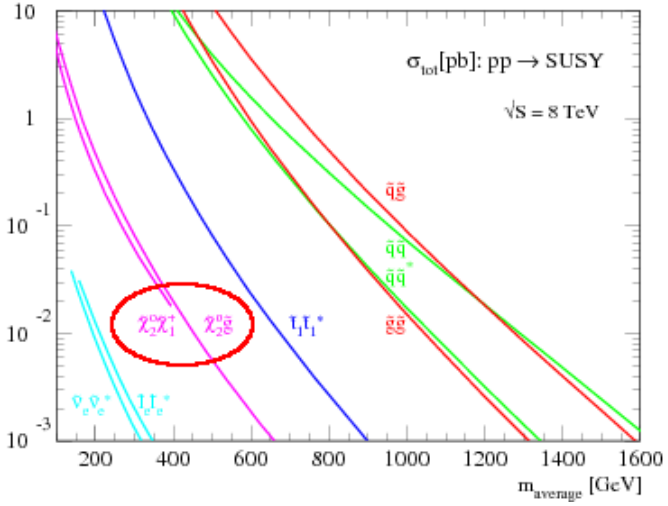
Searches for chargino, neutralino and slepton production with CMS

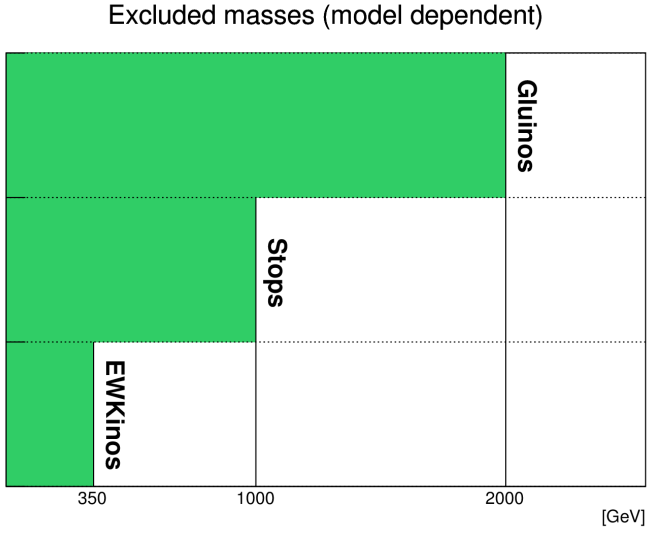
Basil Schneider on behalf of the CMS Collaboration

26th International Conference on Supersymmetry and Unification of Fundamental Interactions (SUSY)
24 July 2018

The Case For Electroweak SUSY

- Classic naturalness arguments require light gluinos, stops, higgsinos
- Gluinos and stops with largest cross section, strong exclusion exist





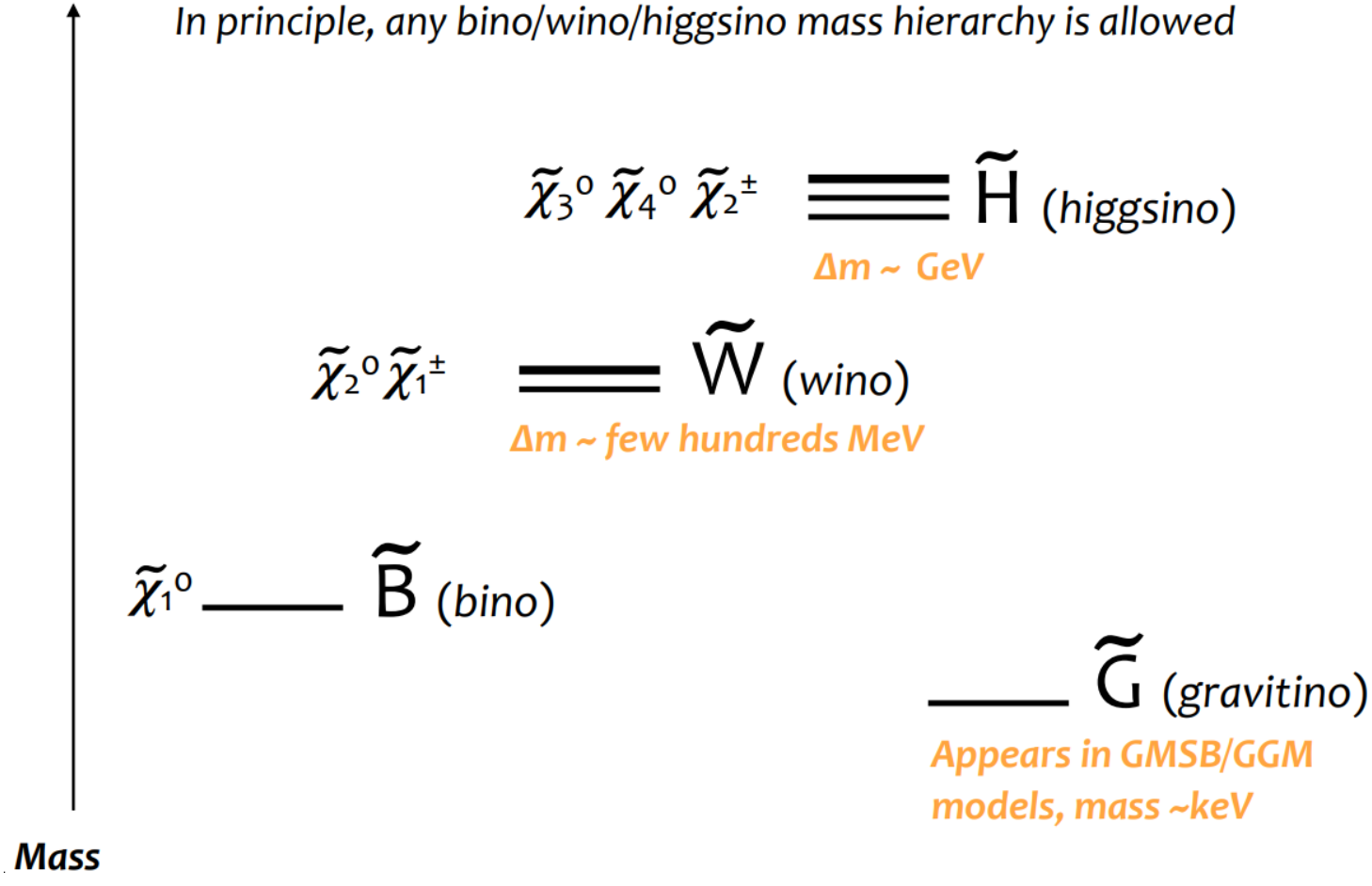
Only higgsinos enter higgs mass at tree level

tree-level:

$$-\frac{m_Z^2}{2} = |\mu^2| + m_{H_u}^2 + \mathcal{O}\left(\frac{1}{\tan^2\beta}\right)$$

→ Electroweak SUSY dominant process at LHC?

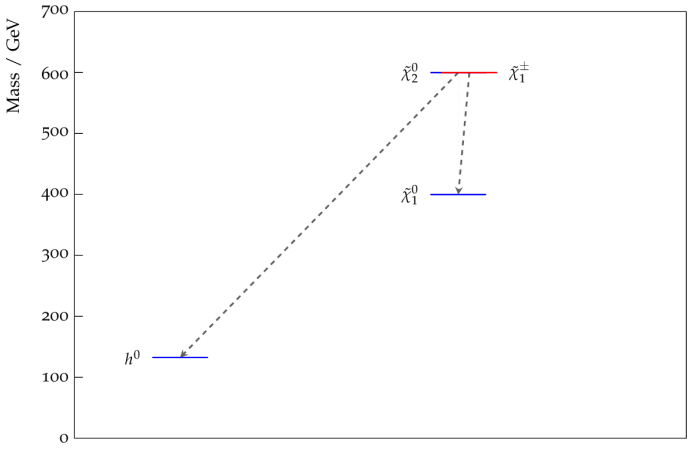
Electroweak Mass Parameters



Electroweak Mass Hierarchy

Mostly two mass hierarchies considered

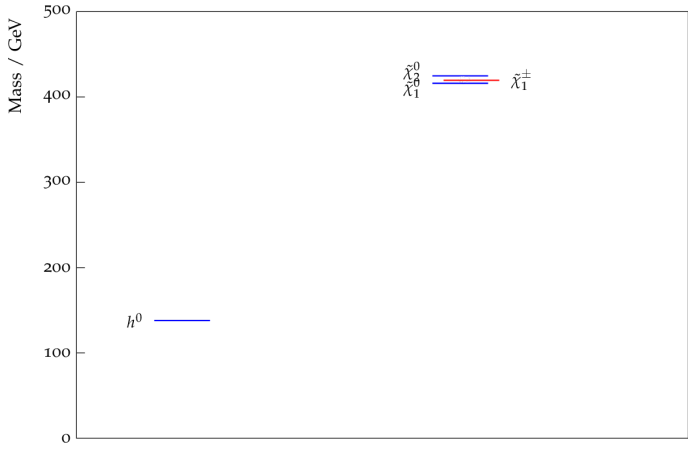
$$\tilde{B} < \tilde{W} \ll \tilde{H}$$



- Bino-like LSP and Wino-like NLSP
- Mass difference can be large $\rightarrow$ heavy objects
- Associated $\tilde{\chi}_2^0\tilde{\chi}_1^\pm$ with highest SUSY EWK cross section

Optimal case

$$\tilde{H} \ll \tilde{B} < \tilde{W}$$

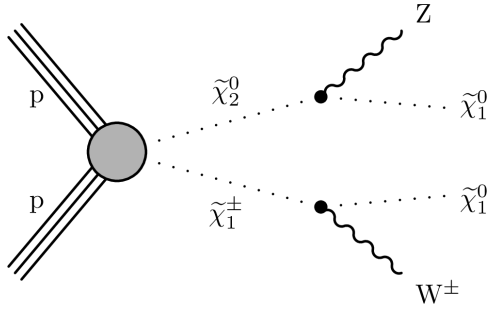


- Natural (higgsino mass $\lesssim$ 400 GeV)
- Compressed mass spectrum, leading to low p_T^{miss}, soft decay products
- Smaller cross section

Natural case

Electroweak Signatures

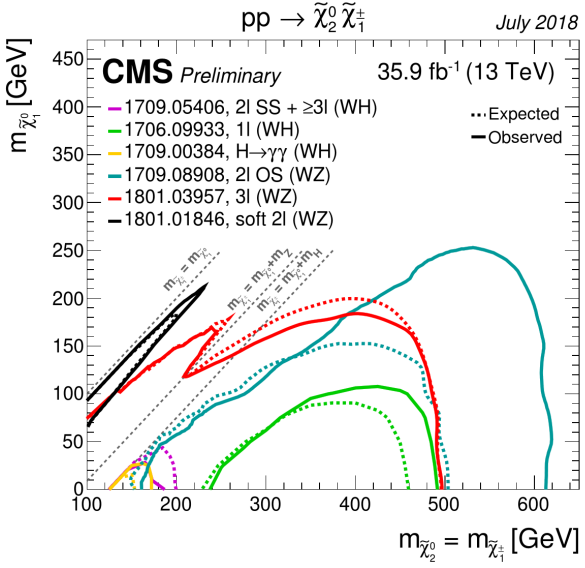
- Searches optimized on Simplified Models
- Decay to leptons, vector bosons, higgses
- Clean experimental signatures
- Hadronic activity only due to bosonic decay products or initial state radiation
- 2d scan in sparticle masses



Flagship analyses using on-shell bosons, where at least one decays to high p_T leptons like

- $WZ : 2\ell$ + jets + p_T^{miss}
- $WZ : 3\ell + p_T^{\text{miss}}$
- $Wh : 1\ell + bb + p_T^{\text{miss}}$

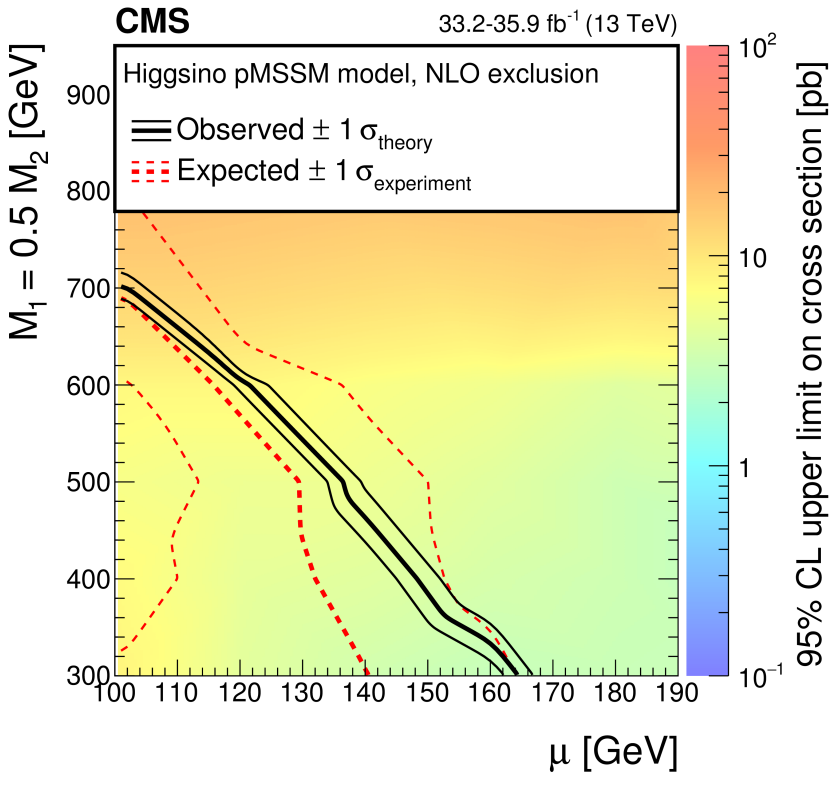
set very strong limits in their corresponding models. Today I will focus on analyses targeting signatures with soft leptons, challenging S/B, and signals with small cross sections



Fermilab

Model Dependency

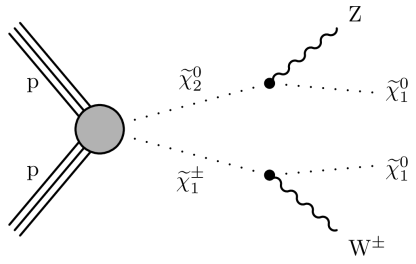
- Simplified Models are an excellent tool to systematically search for physics BSM
- They target a very specific process
- For gluinos, this often works very well
- In the electroweak (and stop) sector, things are a bit more delicate
- One needs to consider additional variables under which limits have been set:
  - couplings
  - cross sections
  - mass splitting
  - masses of other particles
  - ...
- It is therefore important to also look at more generic models (like the pMSSM with low $\tilde{B}$, $\tilde{W}$ and $\tilde{H}$ here, from the soft opposite sign lepton search)

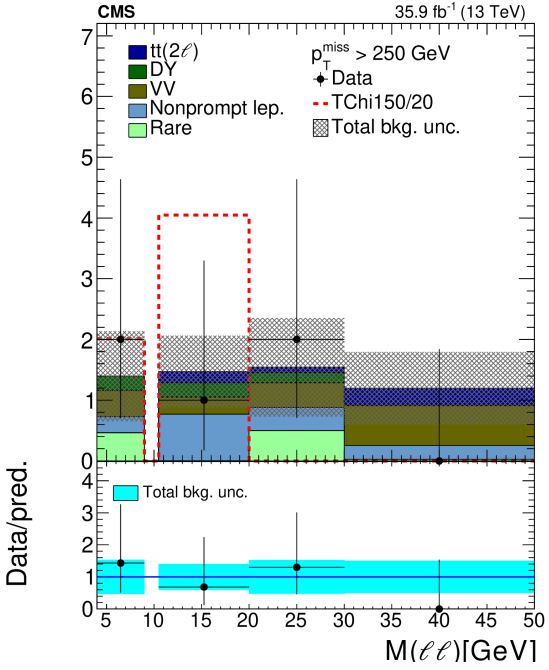


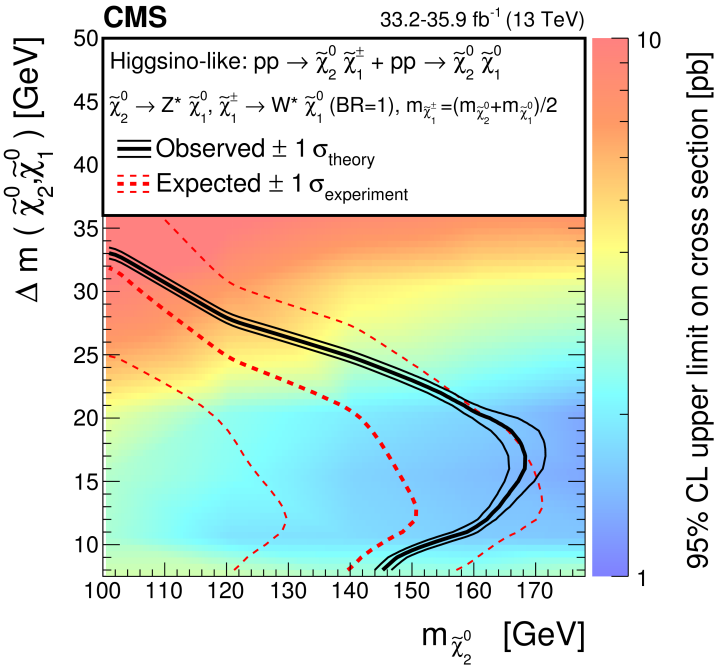
Fermilab

Soft Opposite Sign Lepton Search

- Targets compressed scenarios
- Select 2 leptons with $p_T \in [5, 30]$ GeV
- Events need to recoil against initial state radiation jet to pass trigger requirements
- Dominated by diboson and "fake" lepton background

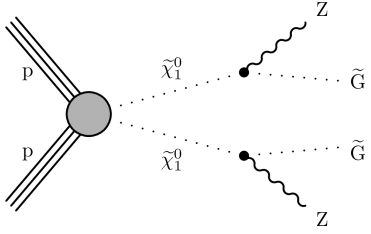


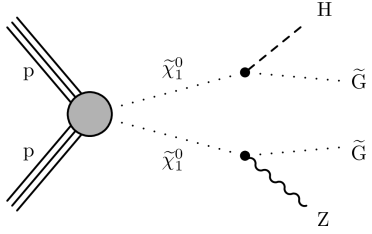


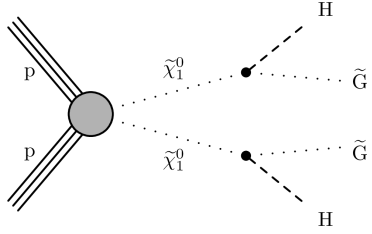


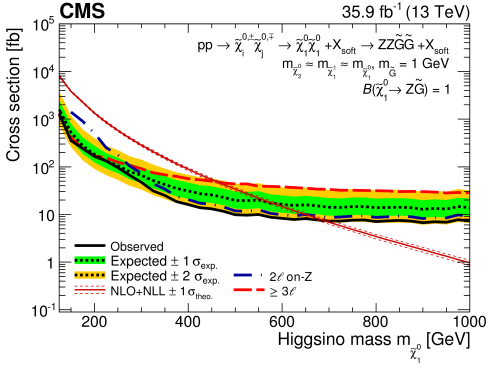
Different Decay Channels

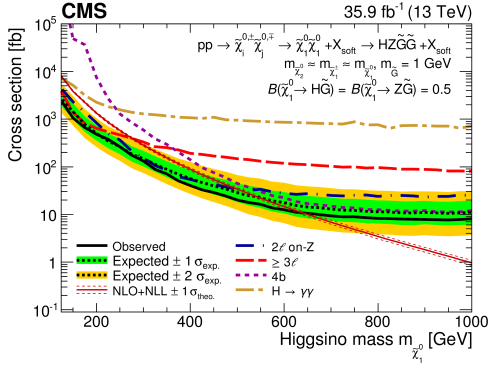
- In R-Parity conserved SUSY, we produce two SUSY particles per vertex
- Often these particles are the same, and often we assume they decay in the same way
- Consider higgsino $\tilde{\chi}_1^0$ production with decay to gravitino
- Decays via Z and H are possible
- Many different final states combined to set limits

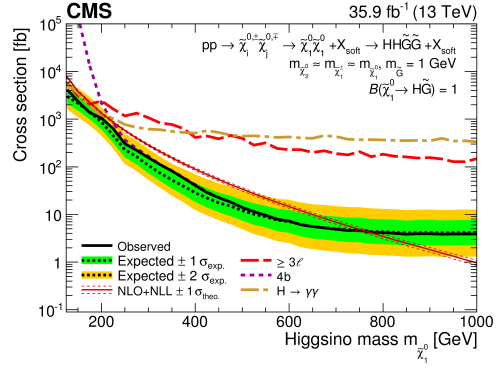








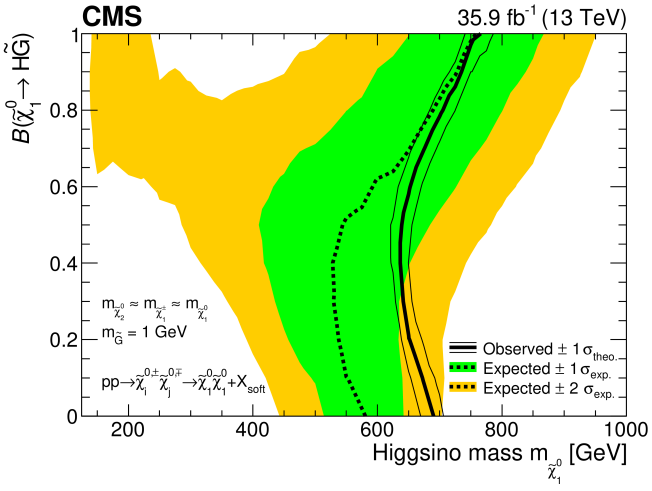


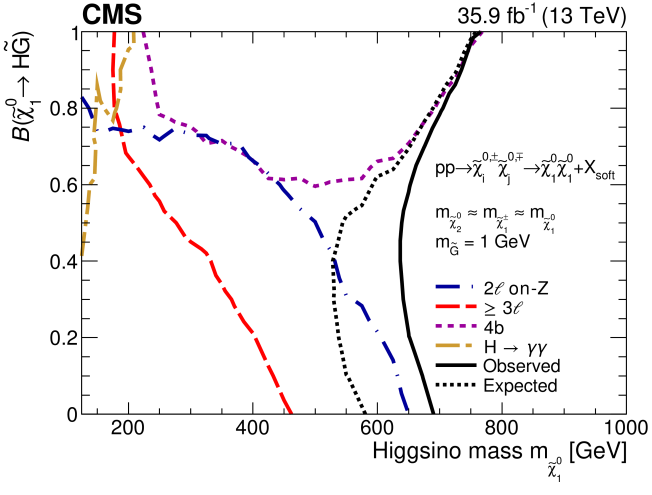


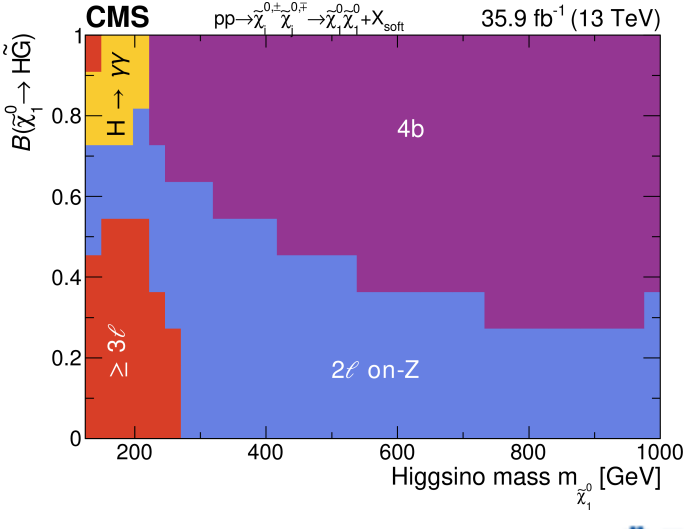
Fermilab

GMSB Combination

- Combined exclusion in higgsino mass vs. branching fraction
- Four final states contribute:
  - 4 b mesons
  - 3 or more leptons
  - 2 leptons with invariant mass close to Z
  - $H \to \gamma\gamma$



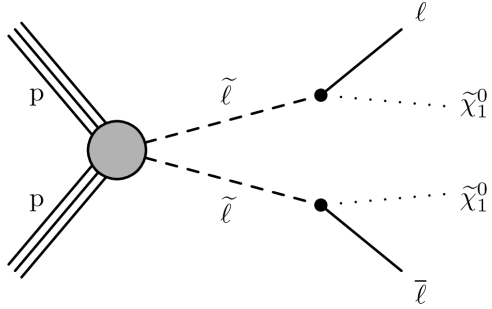




Fermilab

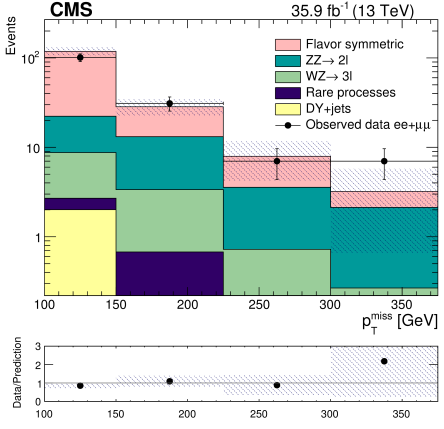
Search For Light Sleptons

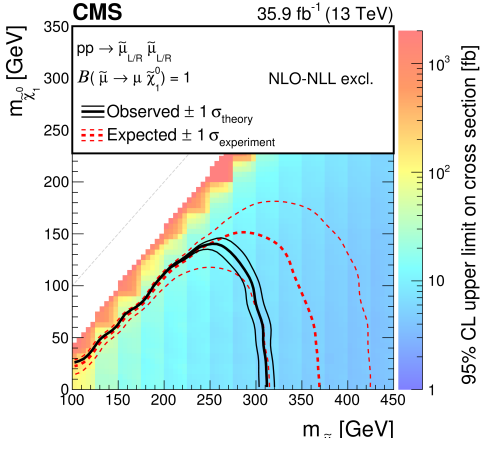
- Direct slepton production clean signature
- Select events with
  - exactly two leptons, $m_{\ell\ell} \neq m_Z$
  - Split into dielectron and dimuon regions
  - no hadronic activity
  - $M_{T2} > 90$ GeV to suppress $t\bar{t}$ and WW
- Bin in p_T^{miss}
- Interpret results separately for light selectrons and smuons, consider right-handed, left-handed and mixed production

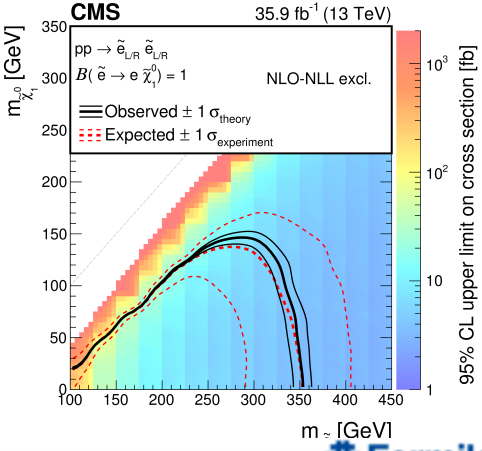


$$M_{\mathrm{T2}} = \min_{\vec{p}_{\mathrm{T}}^{\,\mathrm{miss}(1)} + \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}(2)} = \vec{p}_{\mathrm{T}}^{\,\mathrm{miss}}} \left[\max\left(M_{\mathrm{T}}^{(1)}, M_{\mathrm{T}}^{(2)} \right) \right]$$

$$M_{\mathrm{T}}^{(i)} = \sqrt{2 p_{\mathrm{T}}^{\mathrm{vis}} p_{\mathrm{T}}^{\mathrm{miss}(i)} (1 - \cos(\Delta\phi))}$$







Fermilab

Conclusions

- Strong limits exist in colored SUSY sector
- Electroweak limits are not only weaker ...
- ... they are also much more model dependent (e.g depend on specific mass splittings, couplings, mass of other particles, ...)

- Very few results from the vast SUSY search program at CMS shown:
- Soft opposite sign lepton search is sensitive to low mass higgsinos, limits depend on mass splitting, excluded up to 170 GeV
- GMSB combination of four final states exploring decays to higgs and Z bosons, excluding higgsinos up to 750 GeV
- Search for light sleptons, excluding selectrons up to 350 GeV and smuons up to 310 GeV

- Many avenues remain unexplored
- CMS is continuously developing new ideas to check in all corners of the available data!