EPS CONFERENCE ON HIGH ENERGY PHYSICS
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SEARCHES FOR ELECTROWEAK SUSY PRODUCTION AT CMS

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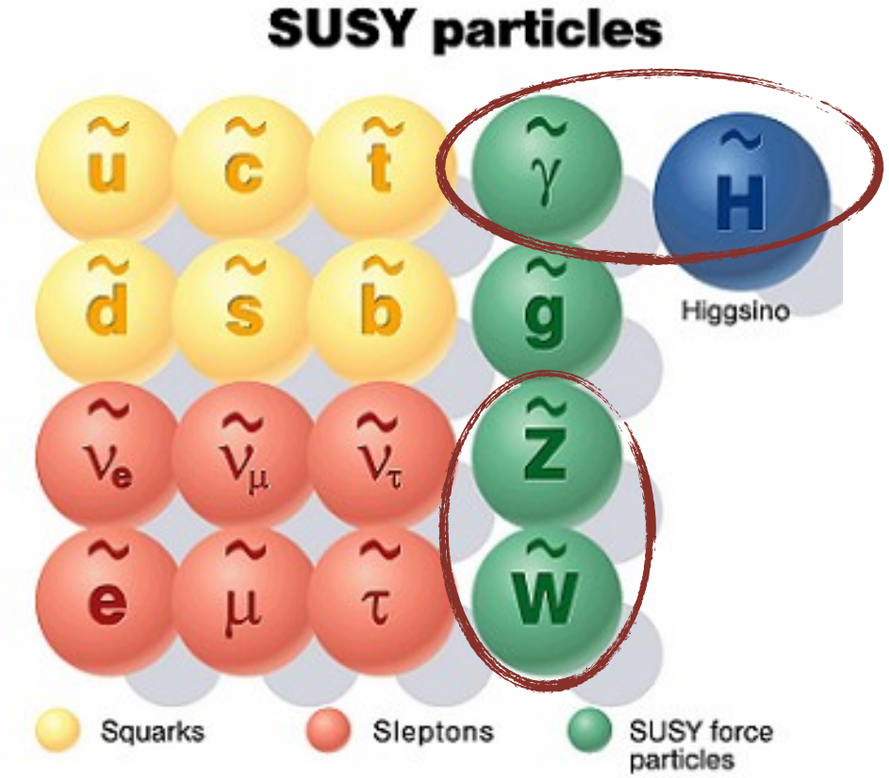
Fermilab.

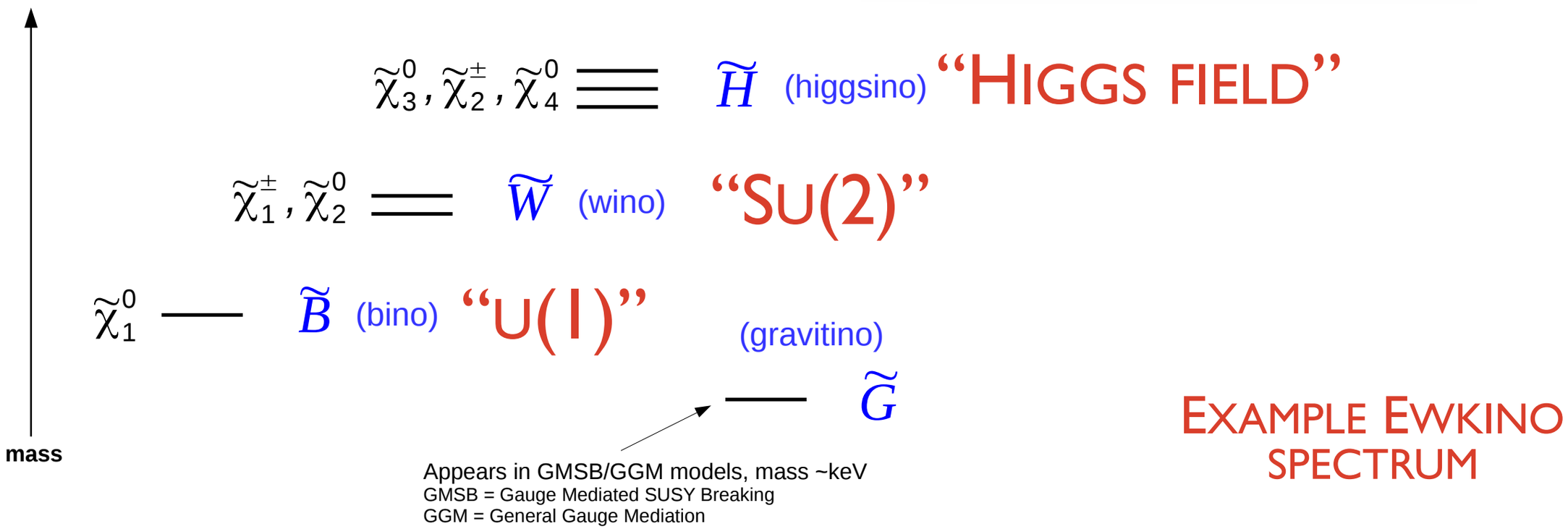
July. 7.2017
on behalf of the CMS Collaboration

Electroweak SUSY

- Searches for SUSY partners of the electroweak sector.
  - The partners of the SM electroweak bosons mix to form mass eigenstates: chargino and neutralinos



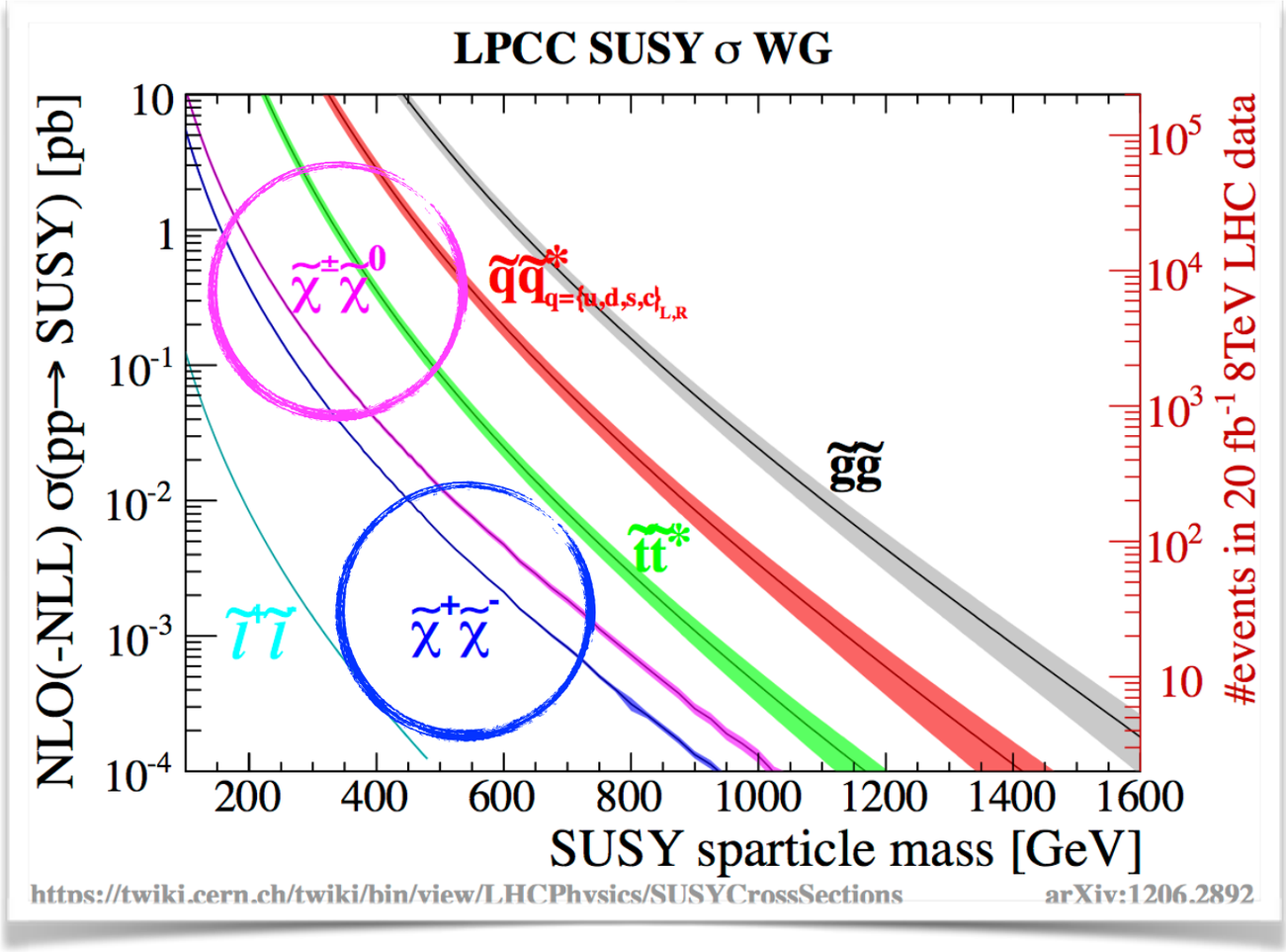
- Naturalness: gaugino mass is of the order of H boson mass



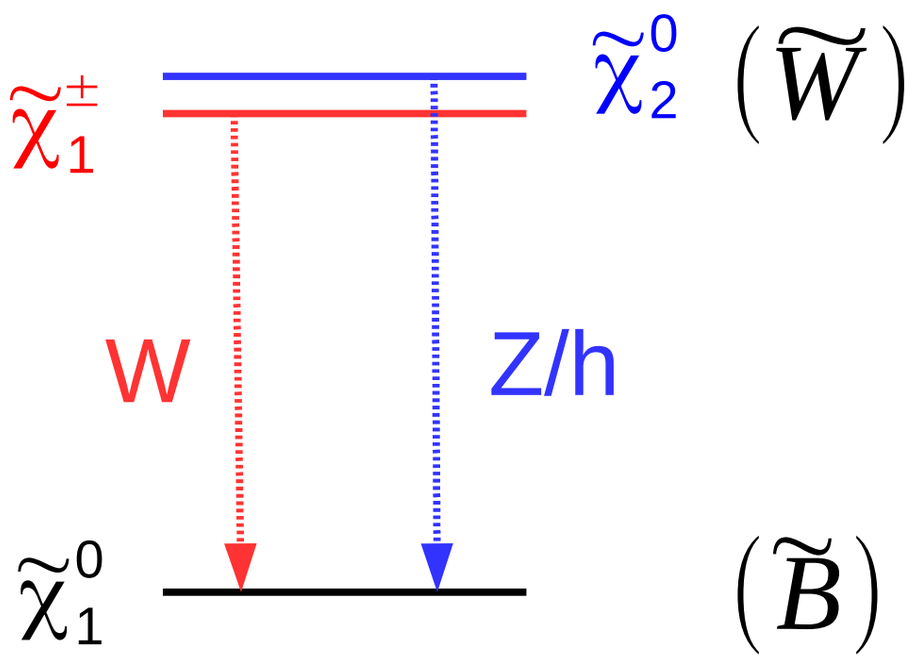
EXAMPLE EWKINO SPECTRUM

Electroweak Production of SUSY

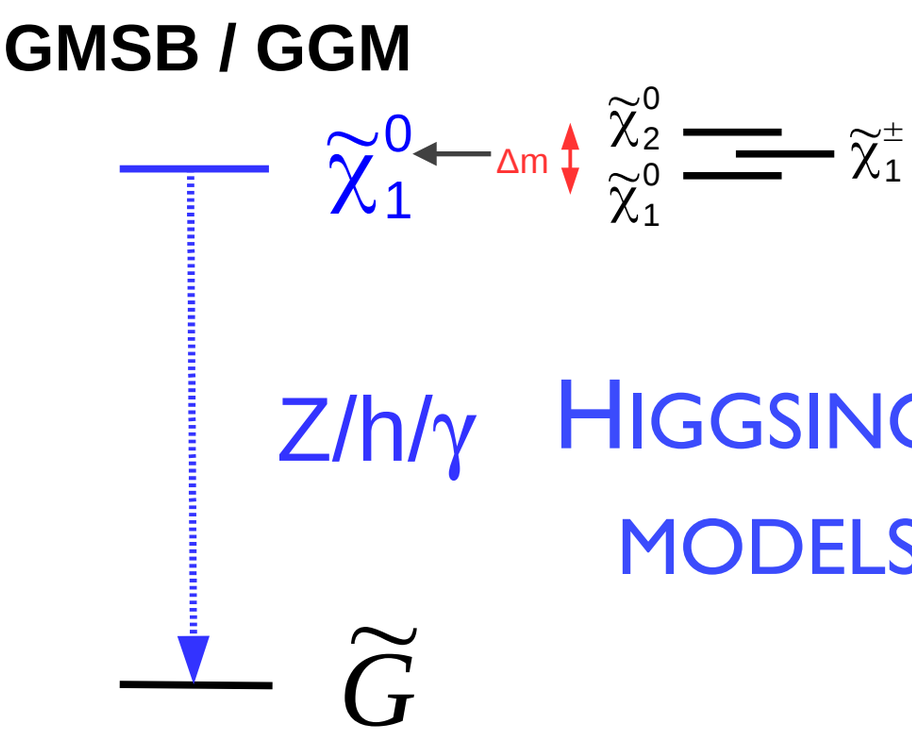
- Less constrained by experimental results due to low production cross section for the same SUSY particle mass
- 35.9 fb-1 proton-proton collision data collected with the CMS detector during 2016 provides unique opportunities to probe SUSY EKW production.
- Performed analyses exploring a large variety of signatures:
  - Will focus on decays through bosons.
  - New! Analyses combination.
  - New! Stau search.



Decays via bosons



WINO MODELS



HIGGSINO-MODELS

- In R-parity conserved models, result in di-boson(W/Z/h/γ) associated with missing transverse momentum (Etmiss)
  - Results in a final state of WH/WZ in Wino Models.
- In GMSB model, mass degenerate $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^0$
  - Enhanced pair production of $\tilde{\chi}_1^0\tilde{\chi}_1^0$
  - Also produce a signature of diboson+missingEt.
  - Results in a final state of ZZ/HZ/HH in higgino models.

Experimental signatures: diboson+MET

- Diboson decay results in different signatures
  - 1L + 2 bTagged jets
  - 4 b Tagged jets
  - Opposite-sign dilepton
  - Inclusive multilepton
  - Soft opposite-sign dilepton
  - H->γγ
- Analyses combined to reach best sensitivities for each decay topology

Search	Signal topology WZ	WH	ZZ	ZH	HH
1ℓ 2b		✓			
4b					✓
2ℓ on-Z	✓		✓	✓	
2ℓ soft	✓				
2ℓ SS, $\geq 3\ell$	✓	✓	✓	✓	✓
H($\gamma\gamma$)		✓		✓	✓

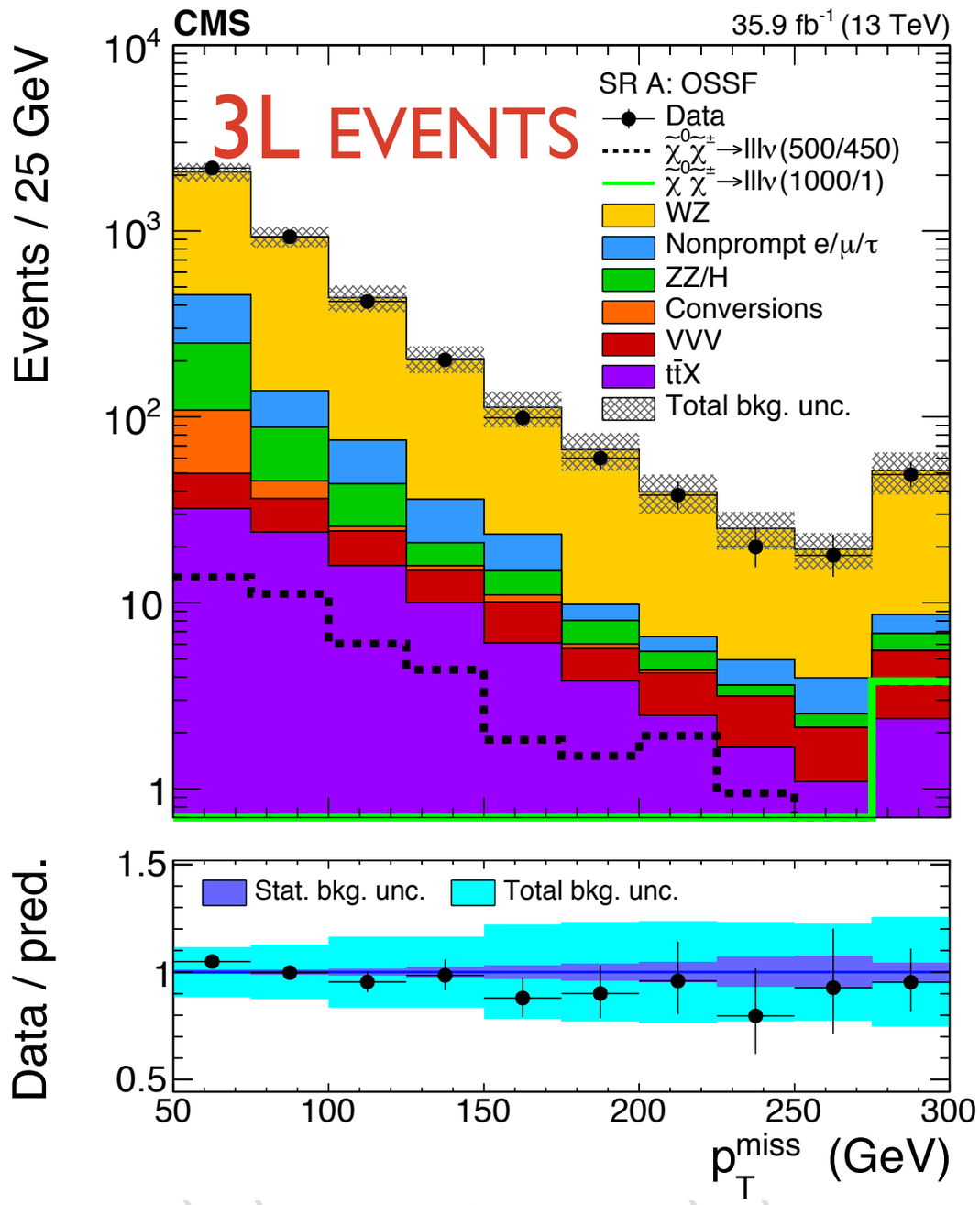
Experimental signatures: diboson+MET

- Diboson decay results in different signatures
  - 1L + 2 bTagged jets
  - 4 b Tagged jets
  - Opposite-sign dilepton
  - Inclusive multilepton
  - Soft opposite-sign dilepton
  - H->γγ
  - See dedicated talks for other analyses.
  - Constantin : compressed
  - Marc: final states with photons

Search	Signal topology WZ	WH	ZZ	ZH	HH
1ℓ 2b		✓			
4b					✓
2ℓ on-Z	✓		✓	✓	
2ℓ soft	✓				
2ℓ SS, $\geq 3\ell$	✓	✓	✓	✓	✓
$H(\gamma\gamma)$		✓		✓	✓

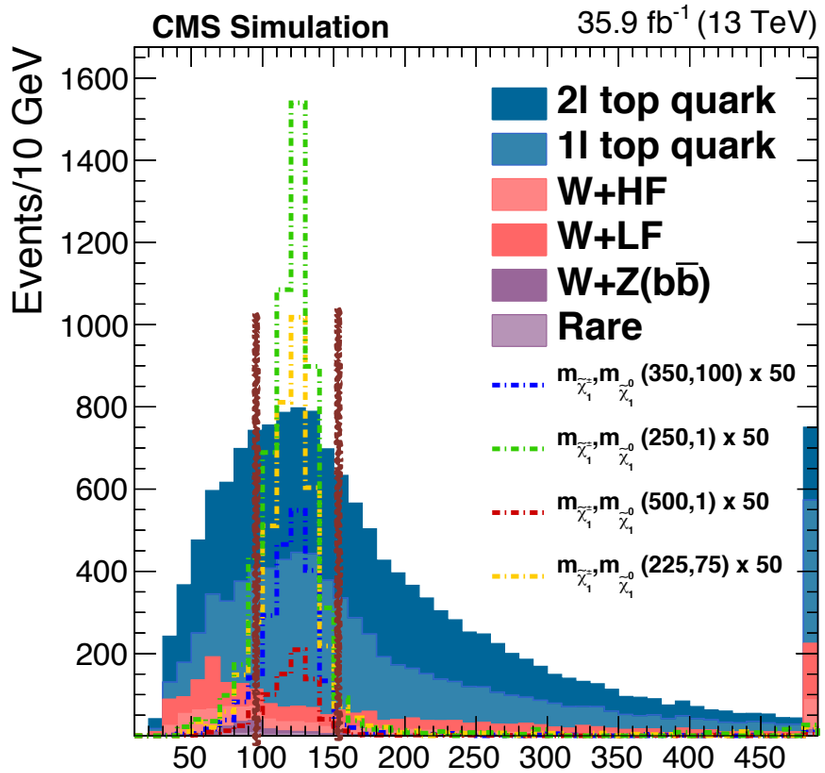
Multilepton Search

- Inclusive search not tied to specific SUSY scenario, many decay topologies result in a multi-lepton final state.
- Event categorization:
  - 2 leptons same-sign, trilepton, multilepton
    - presence / invariant mass (M_{ll}) of OSSF pairs (~ Z-resonances)
    - Other kinematic variables: Etmiss, Mt etc.
    - Total of 158 search bins
- Dedicated poster will be presented next Monday by Constantin.
- Will show the combination results today.

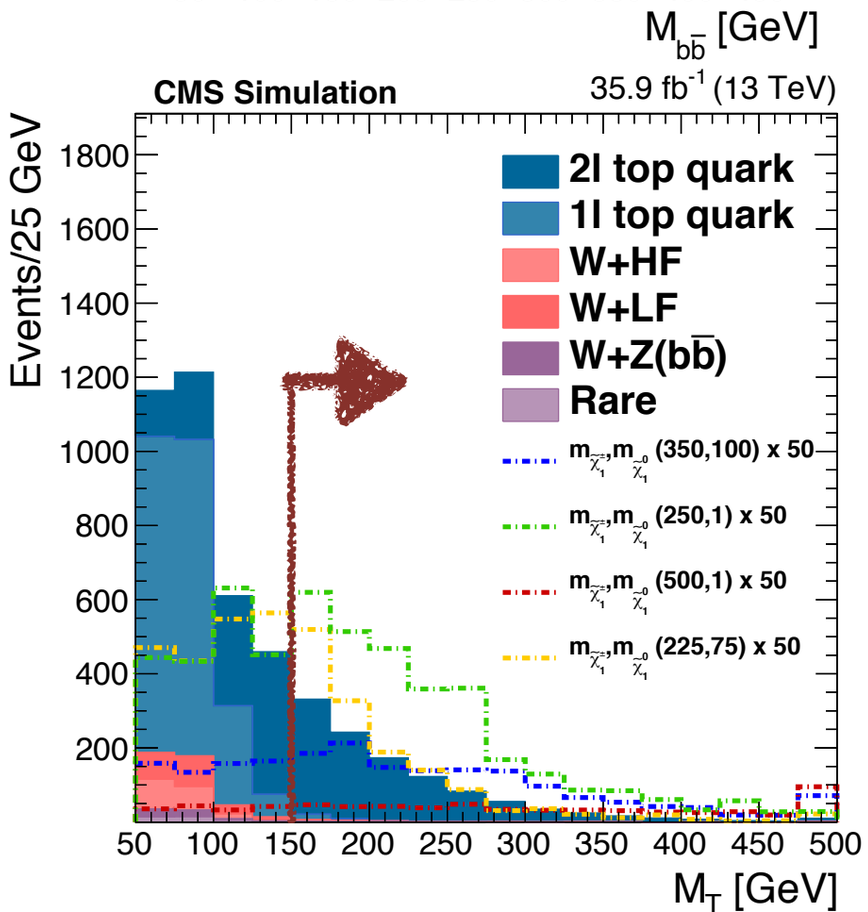


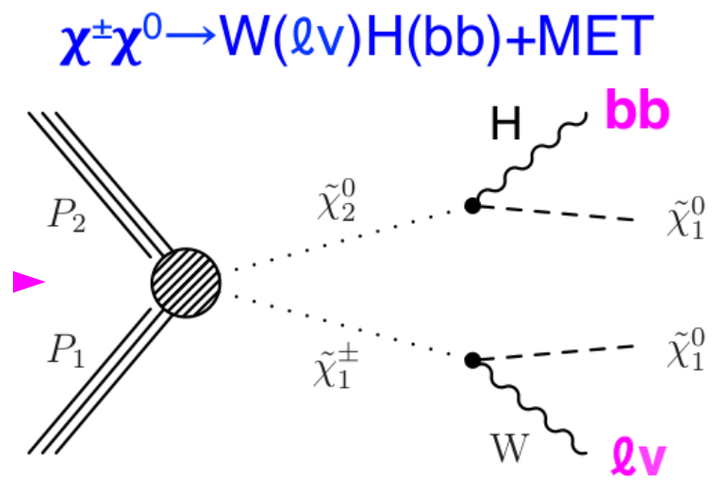
Single-Lepton (e or μ) + bb Search

HIGGS MASS



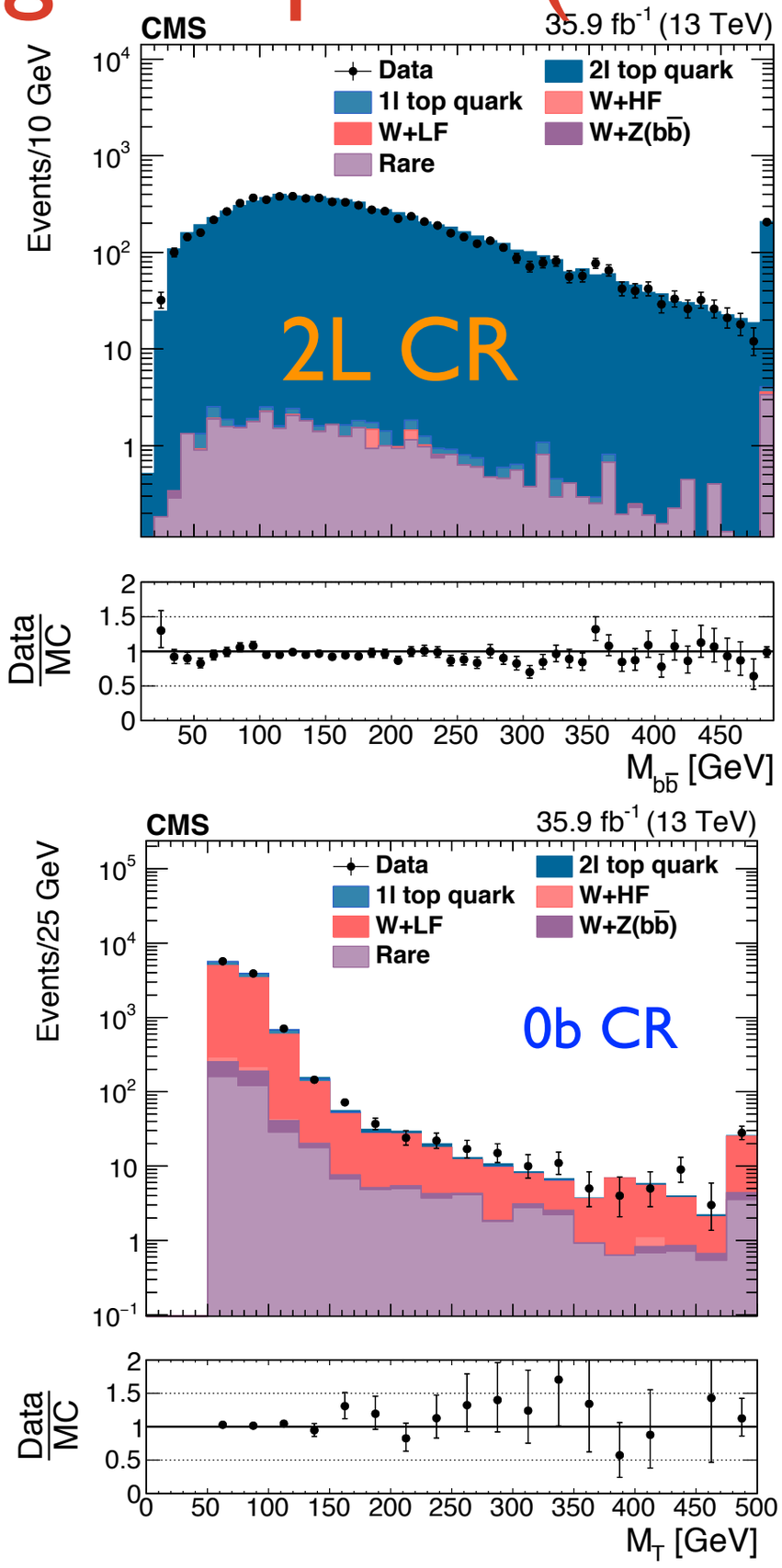
ENDPOINT FOR 1L TTBAR

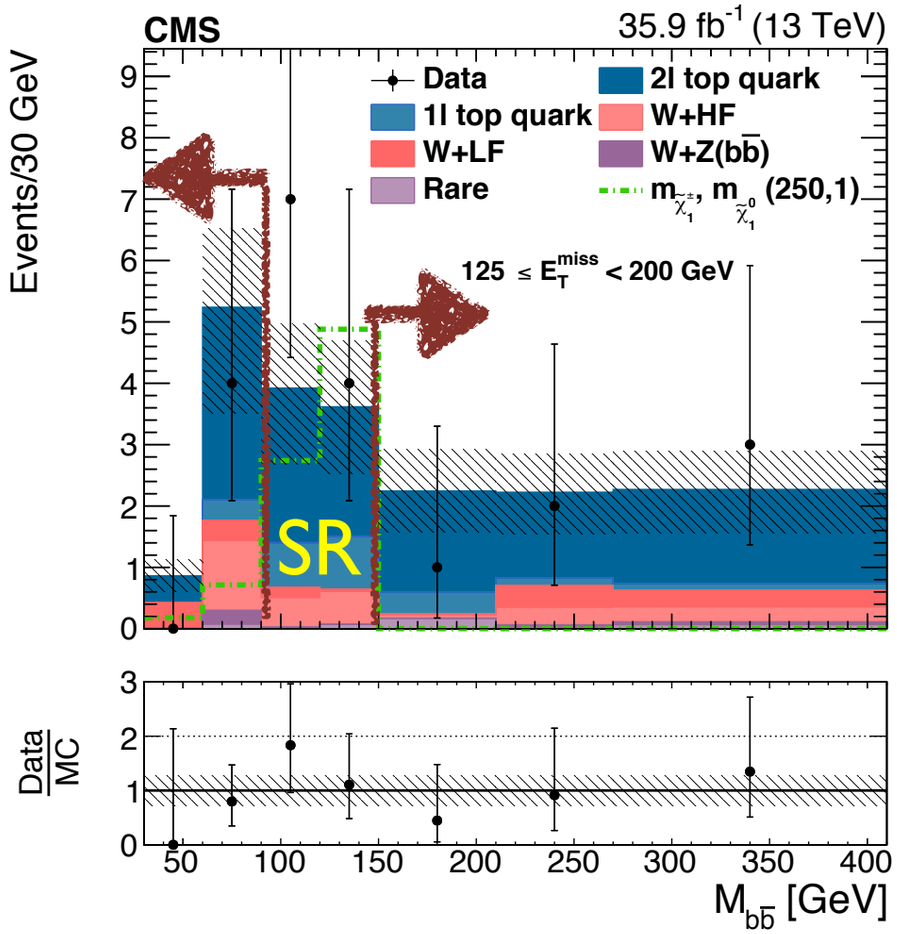




- Targeted search for WH production.
  - Large branching fraction of H->bb
- Require exactly 1L + two bTagged jets
  - Higgs mass peak, endpoint type of variables for background suppression
- Cut and count analysis with two exclusive signal regions binned in MET 125-200 and 200-∞ GeV.

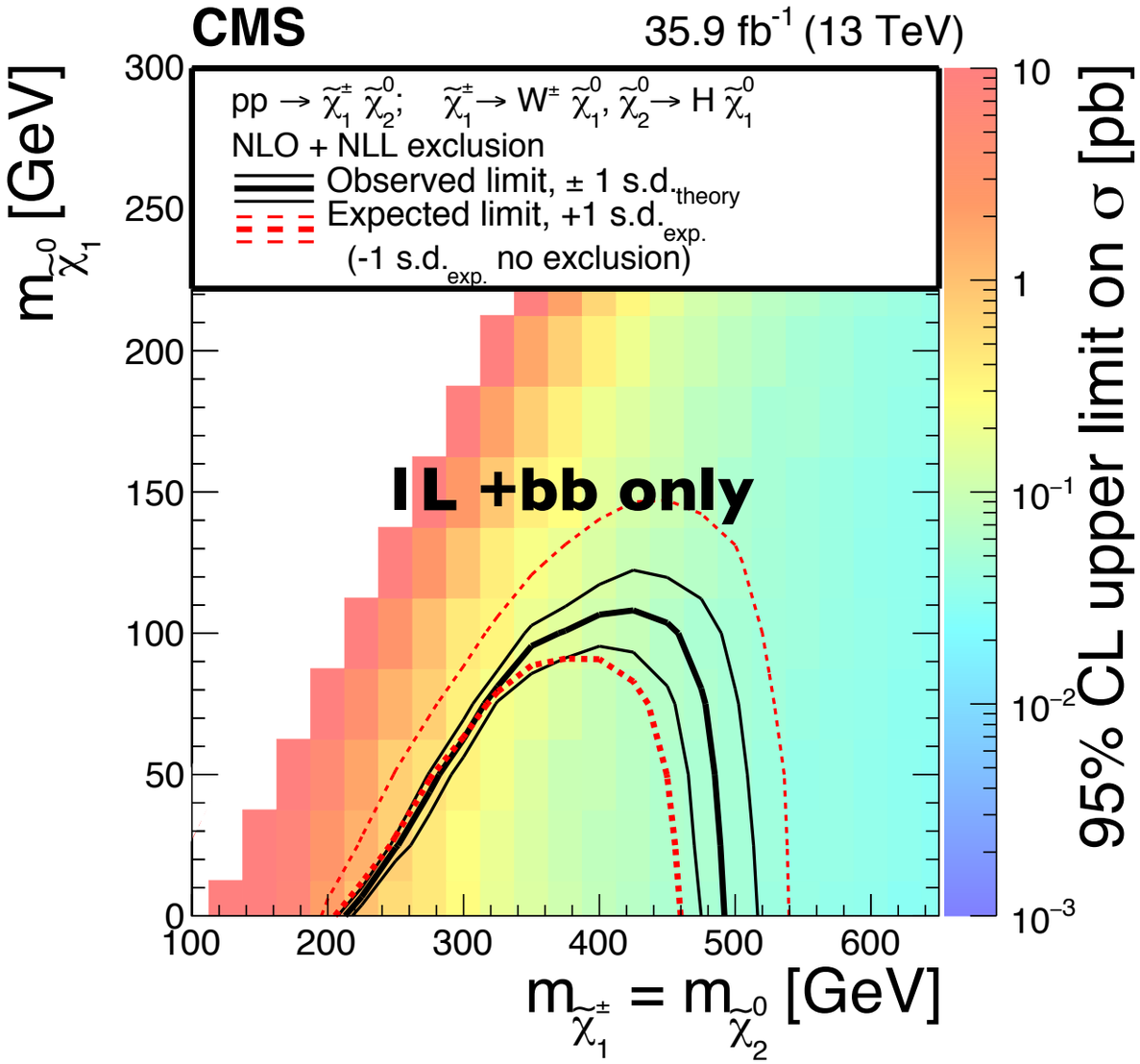
Single-Lepton (e or μ) + bb Search



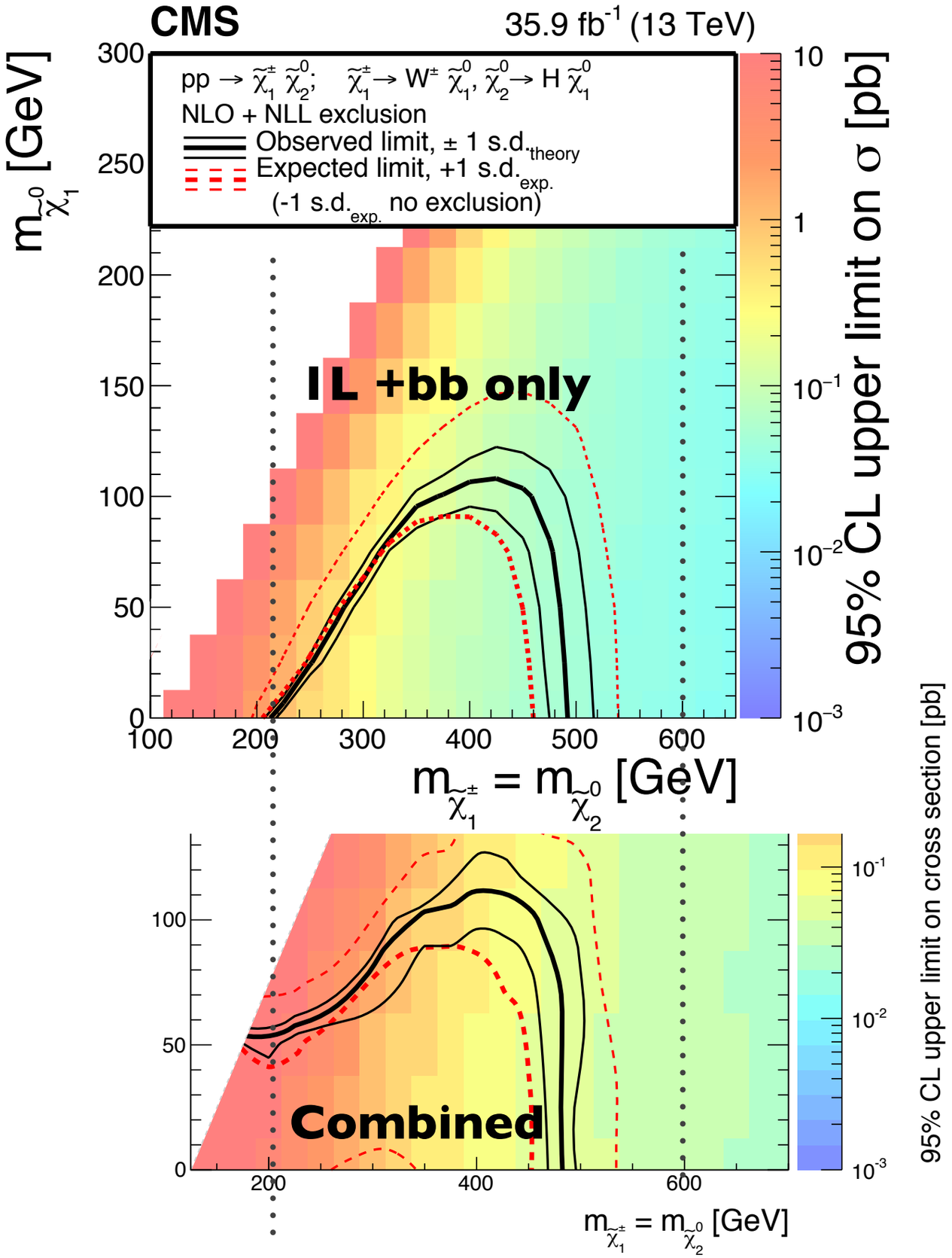


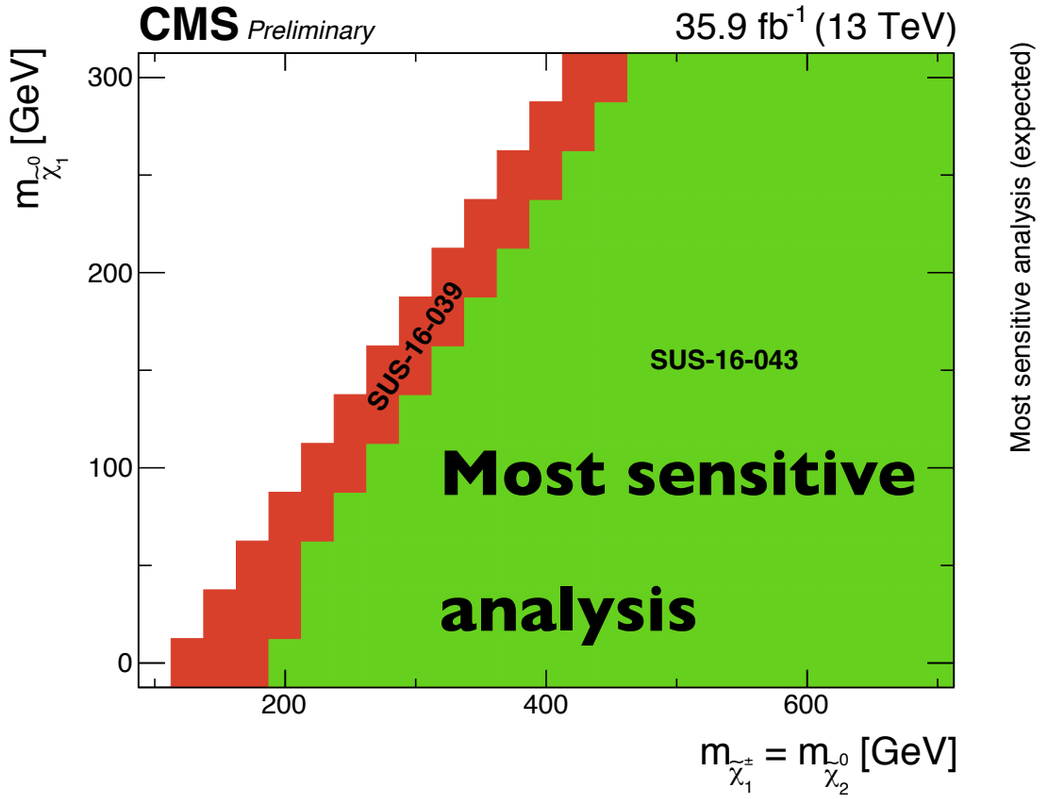
- Robust background estimations using control regions in data.
  - 2L Control region to validate overall TTbar modeling.
  - bjet-vetoed Control region to validate Mt shape and tail modeling.
  - Main background 2L TTbar controlled in higgs mass side band.

Electroweakino combination results —WH



Electroweakino combination results —WH



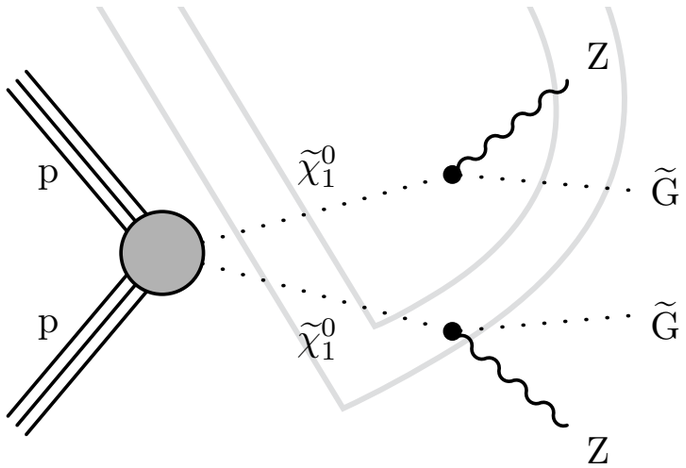


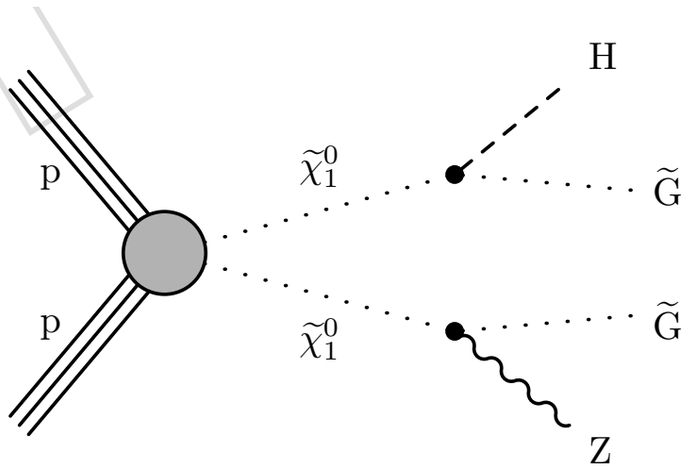
- 8 TeV exclusion: ~200 GeV, huge improvement!
- SUS-16-043: 1L +bb,
  - sensitive in the bulk of the phase space
- SUS-16-039: multilepton
  - sensitive in compressed region.
- Combined limit bridges the gap in the mass plane.

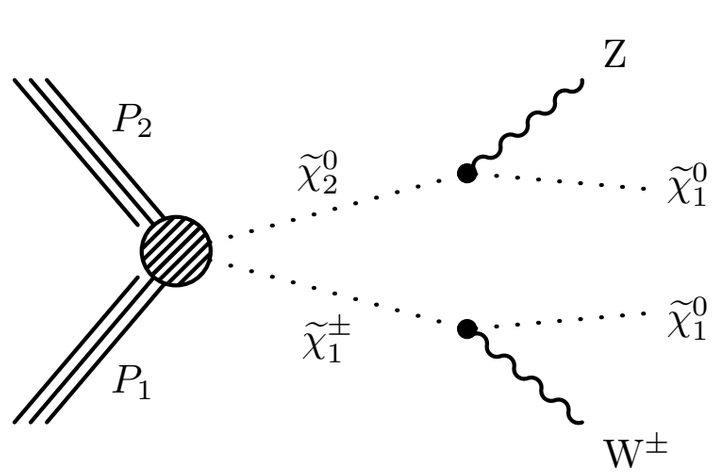
CMS-PAS-SUS-16-034

Opposite-Sign Dilepton Search

- Require 2 opposite-sign same flavor (OSSF) leptons to tag leptonic Z decay.
- Require at least 2 jets from the other boson and large EtMiss from LSP/gravitino.
- Sensitive to models with at least one Z boson.



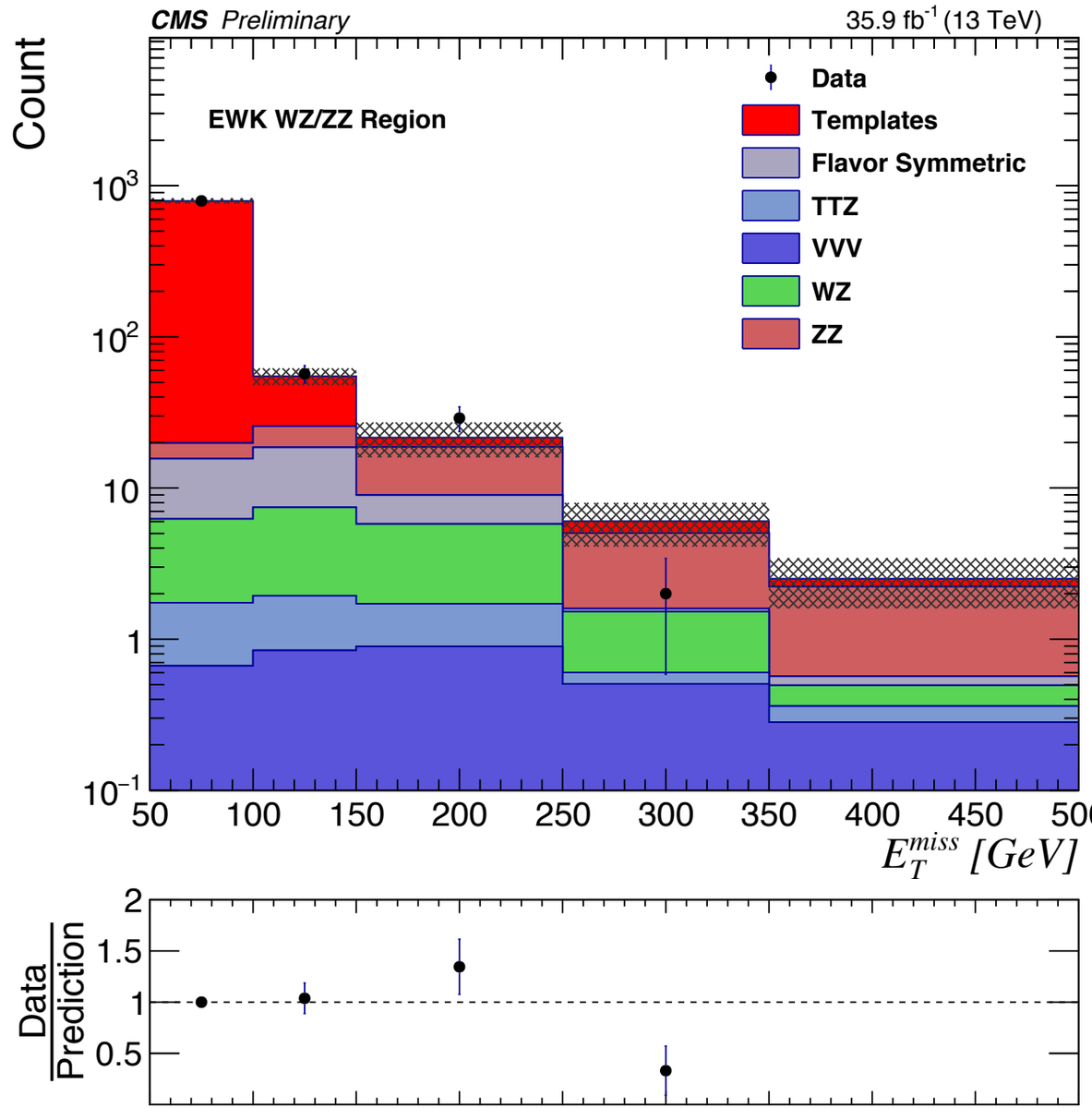




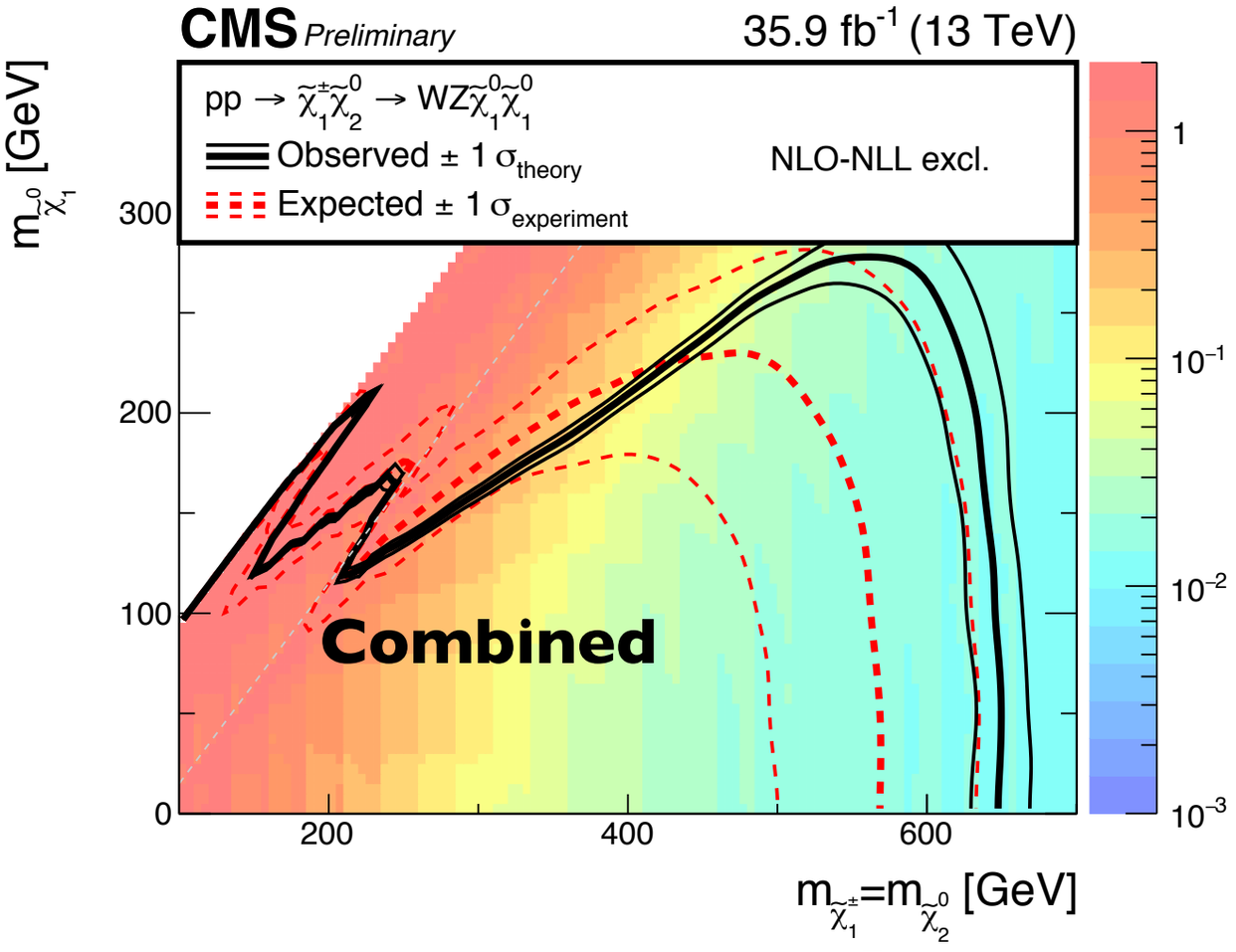
CMS-PAS-SUS-16-034

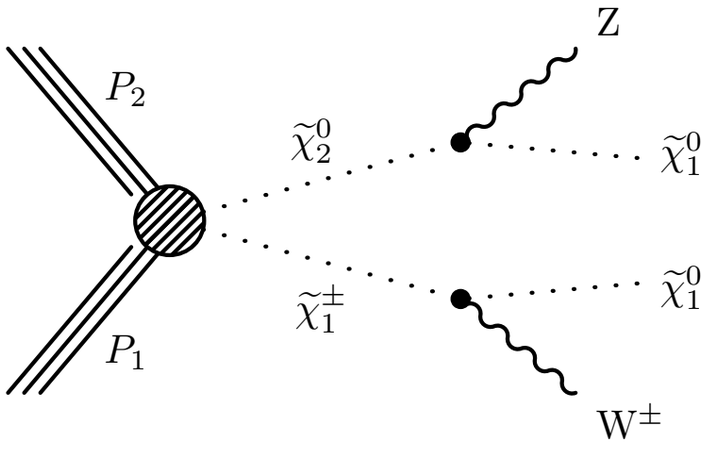
Opposite-Sign Dilepton Search

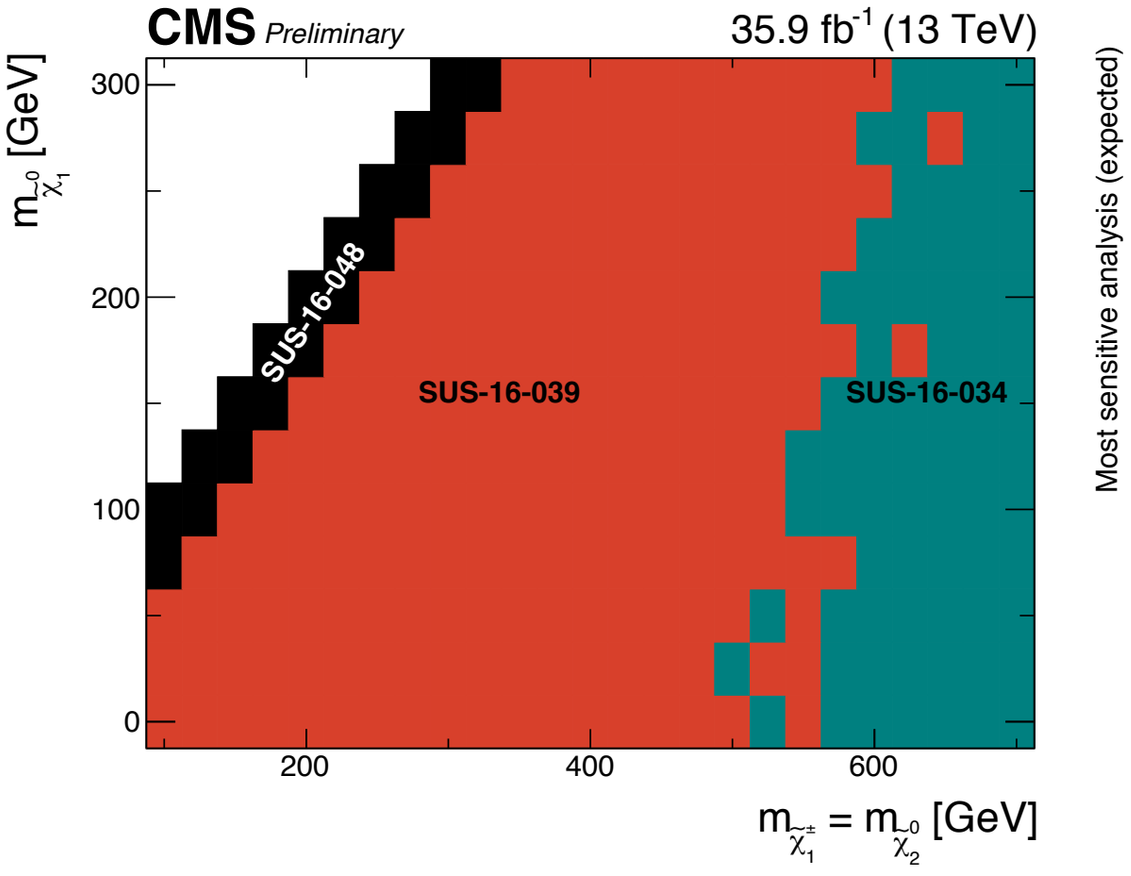
- Backgrounds:
  - Z+jets:
    - ETmiss from jet mismeasurement
    - Predicted using γ+jets events in data.
  - Flavor symmetric:
    - Processes with two W bosons, ttbar
    - N(ee+μμ) = N(eμ+μe)
  - Other backgrounds:
    - Small, taken from MC.
    - WZ/ZZ validated in CRs.



Electroweakino combination results - WZ

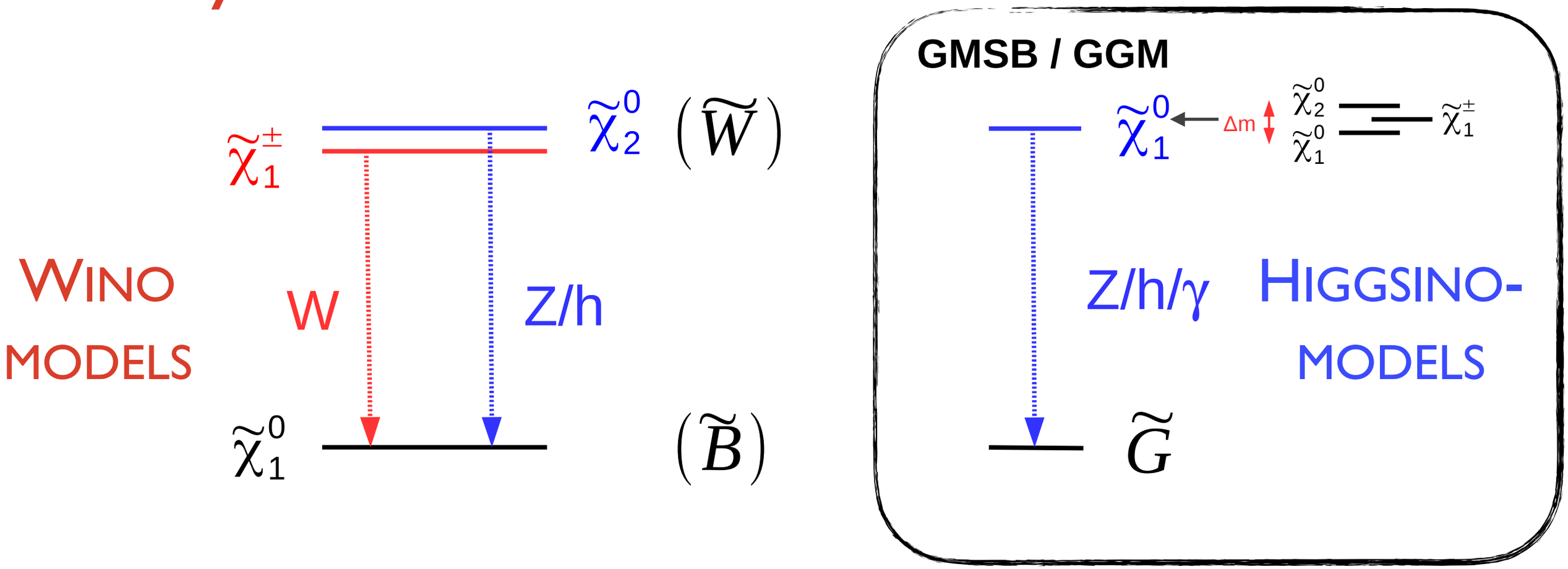






- SUS-16-039: Multilepton
- SUS-16-034: OS 2L
- SUS-16-048: Soft-2lepton(see talk, add link)

Decays via bosons



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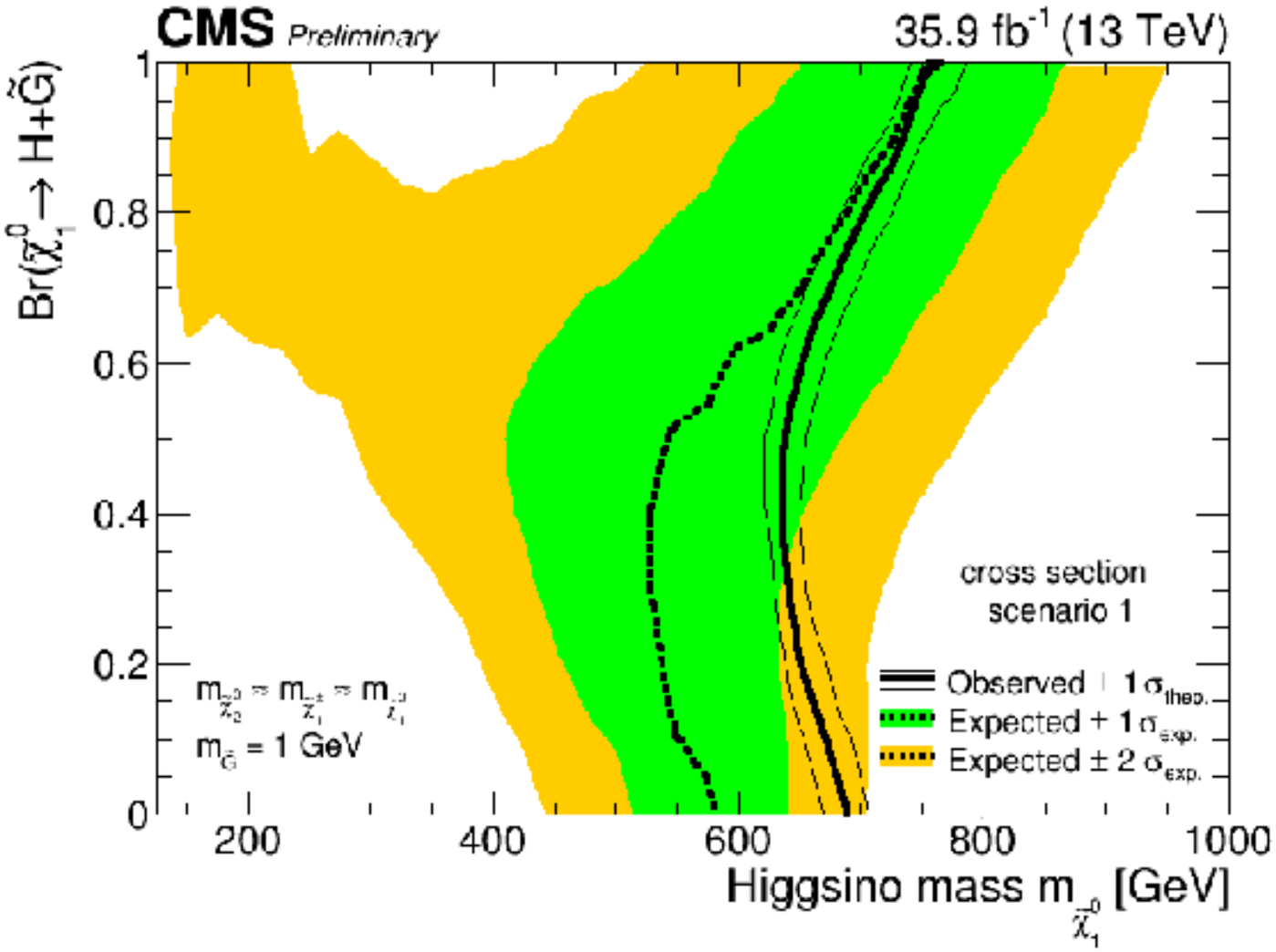
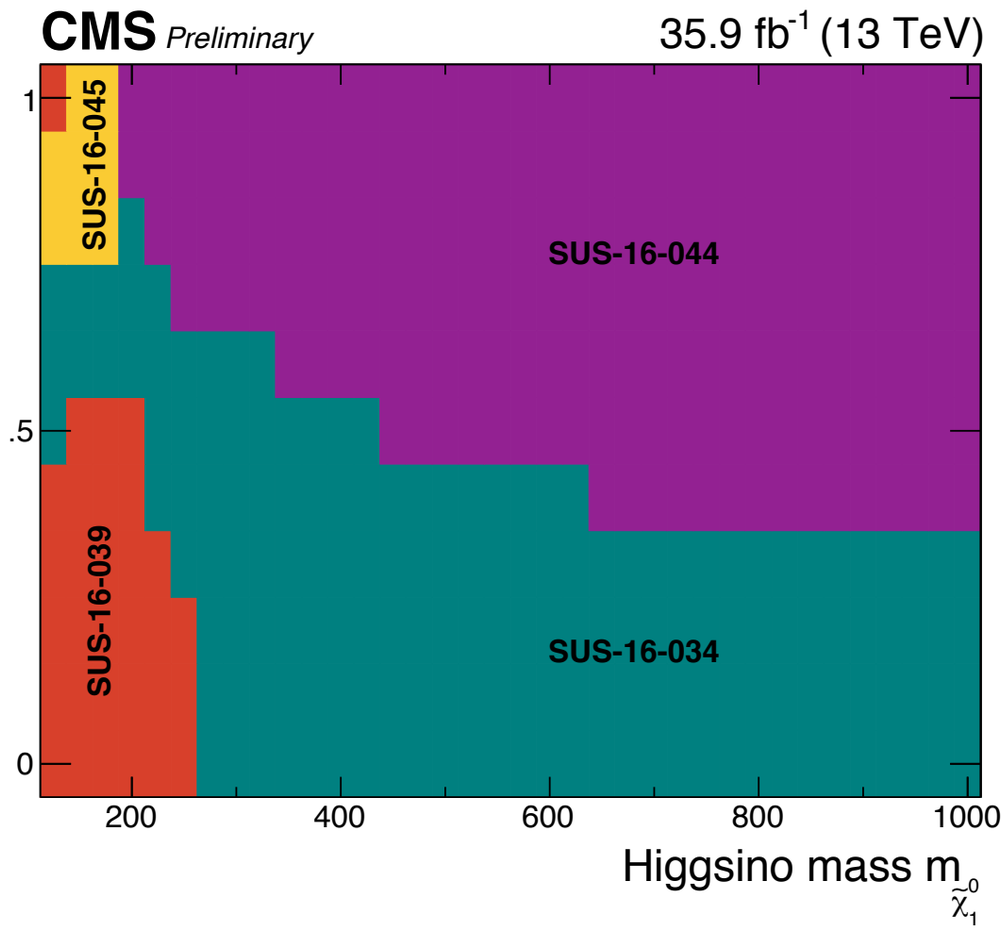
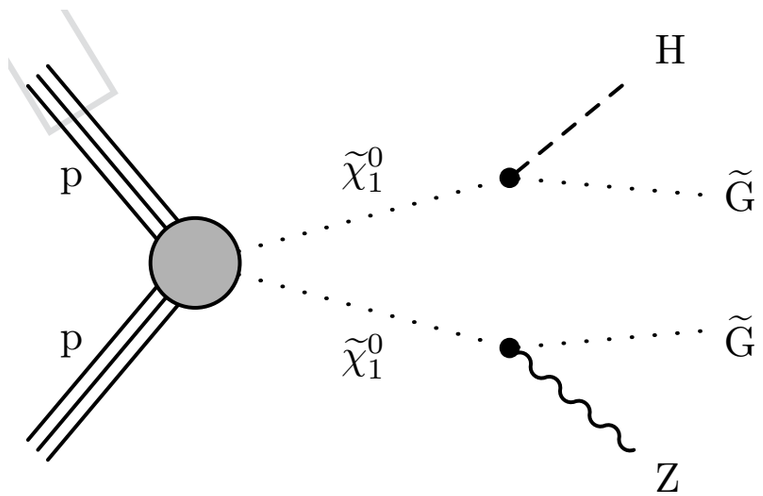
- In GMSB model, mass degenerate $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^0$, and $\tilde{\chi}_1^0$
  - Enhanced pair production of $\tilde{\chi}_1^0\tilde{\chi}_1^0$
  - Also produce a signature of diboson+missingEt.

Electroweakino combination results - HH/ZZ/HZ

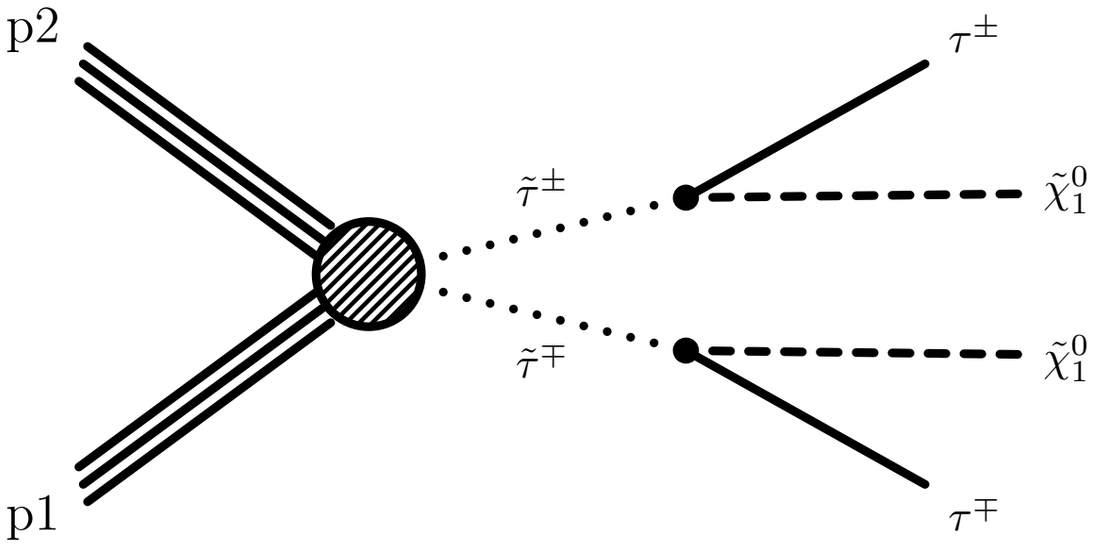


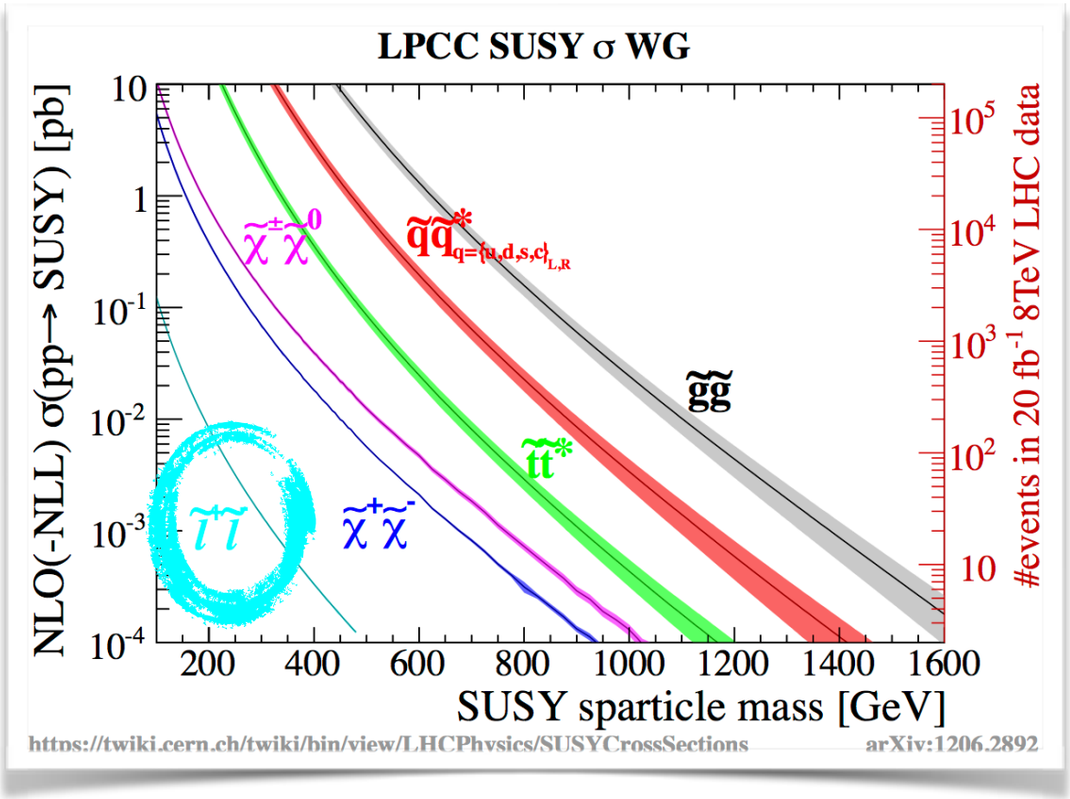




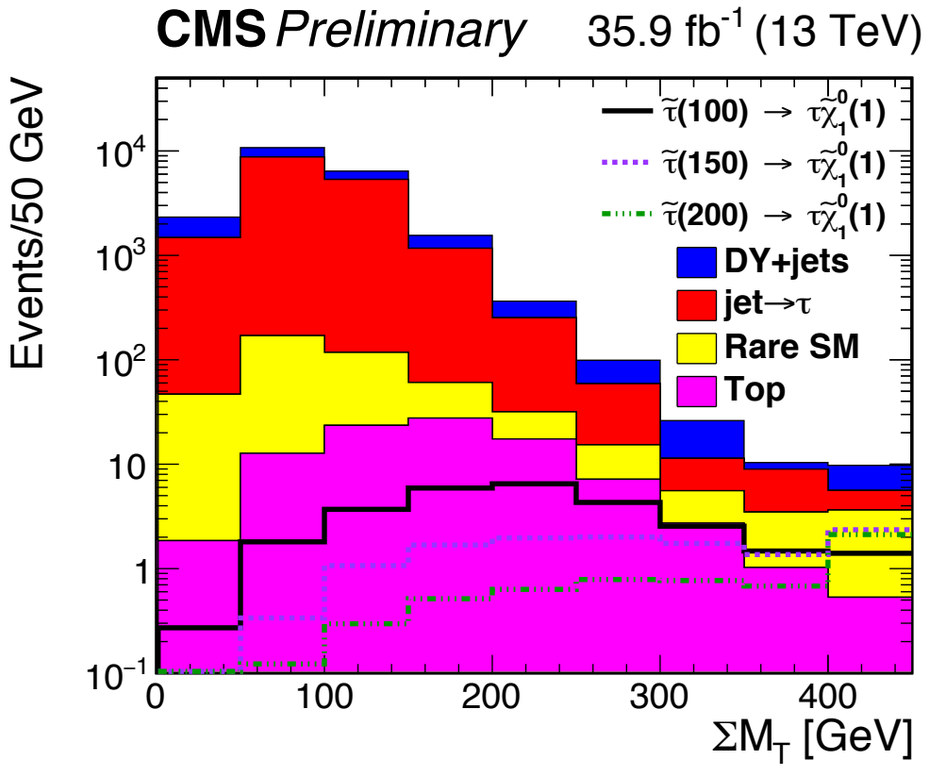
- M(gravitino) = 1 GeV.
- SUS-16-034: OS 2L
- SUS-16-044: HH->4b +MET
- SUS-16-039: Multilepton
- SUS-16-045: 2 photon+MET

Stau search in all hadronic final state





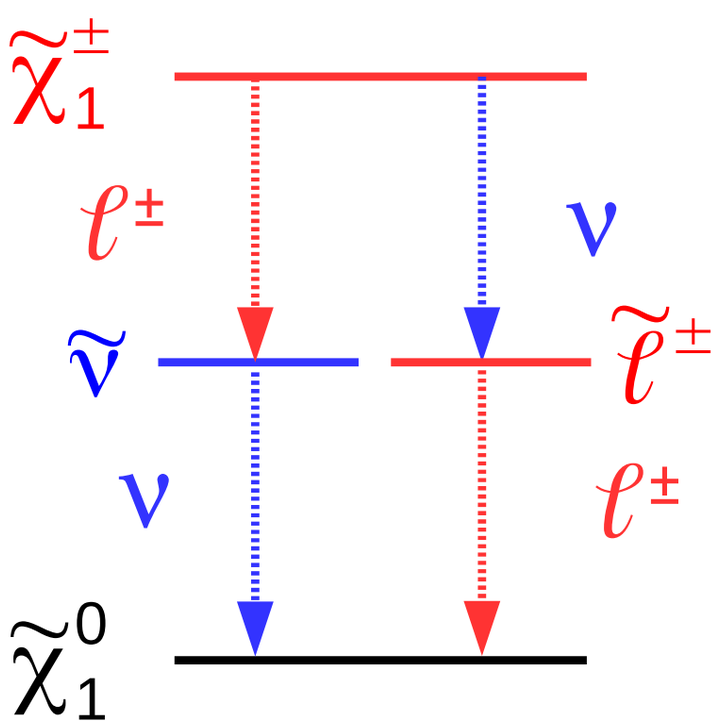
- Started looking at slepton direct production
- Search for two hadronically decaying Taus with large MET.
- The results are interpreted as upper limits on the cross section for tau slepton pair production in different helicity scenarios

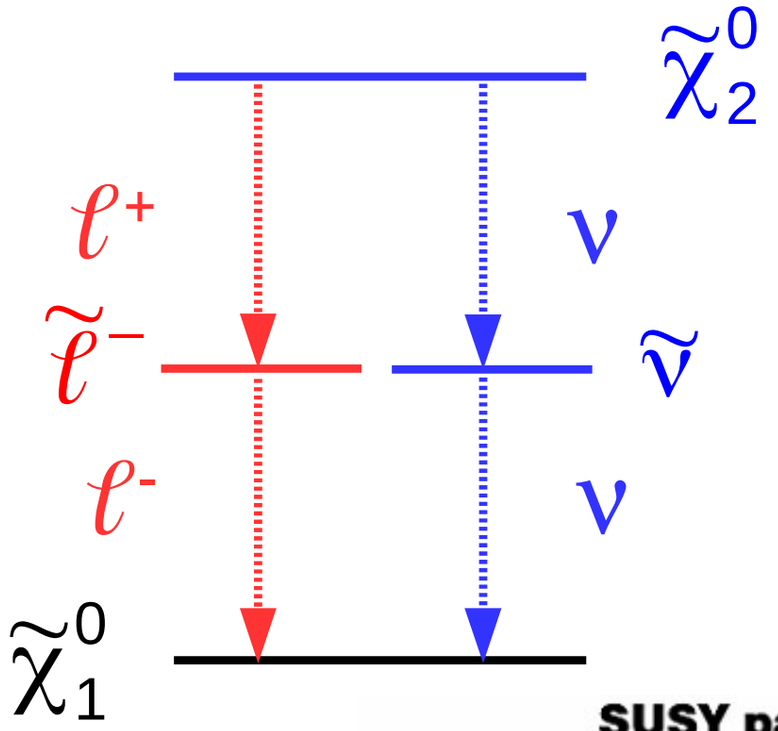


Summary

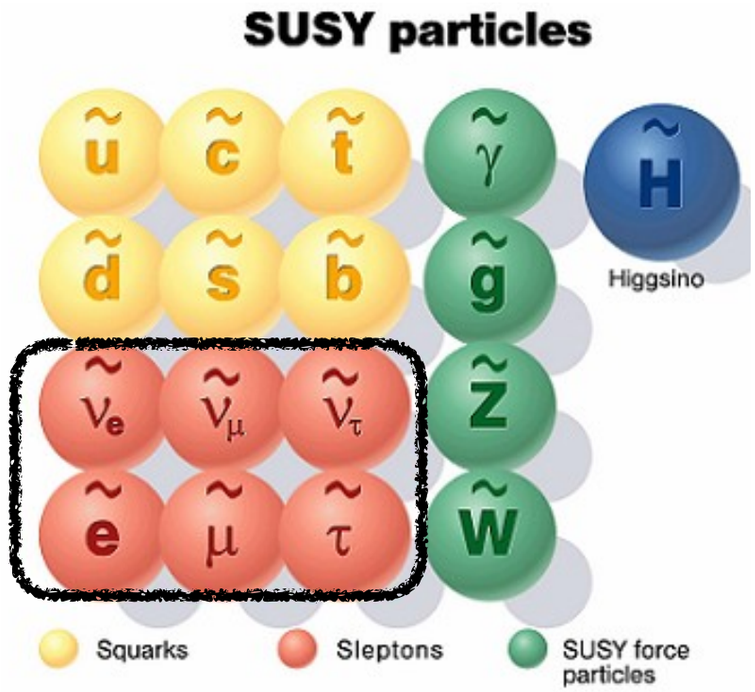
- Excellent performance of LHC in 2016 provided CMS with enough data to search for new physics in yet unprobed regions of phase space
- Extensive search program performed at CMS covering an extensive variety of topologies. Only had time to cover some of them today.
  - Focused on decays via bosons today, see backup and poster for decays via sleptons.
  - Branching ratio dependent limits for wino models.
- No hint for new physics observed, large regions of phase space were excluded. Analysis results combined to reach best exclusion sensitivity.
  - Significant improvement compared to 8 TeV results.
- LHC delivering more pp data in 2017 - stay tuned!

Decays, with Sleptons



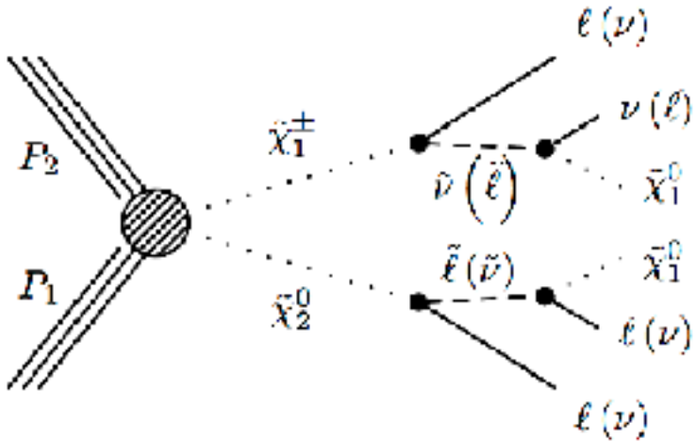


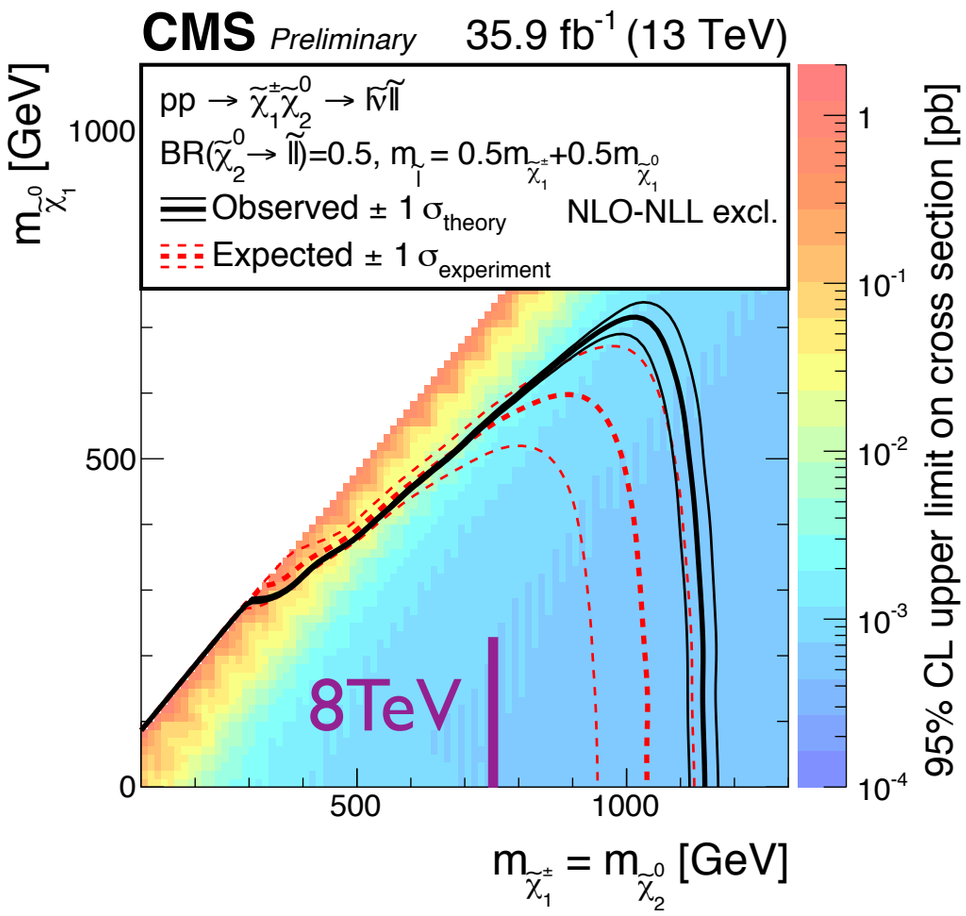
- Decay via SLeptons when sleptons are lighter.
- Signature: Leptons+MET
  - Large branching fraction to leptons.
  - Sensitivity dominated by multilepton analysis.



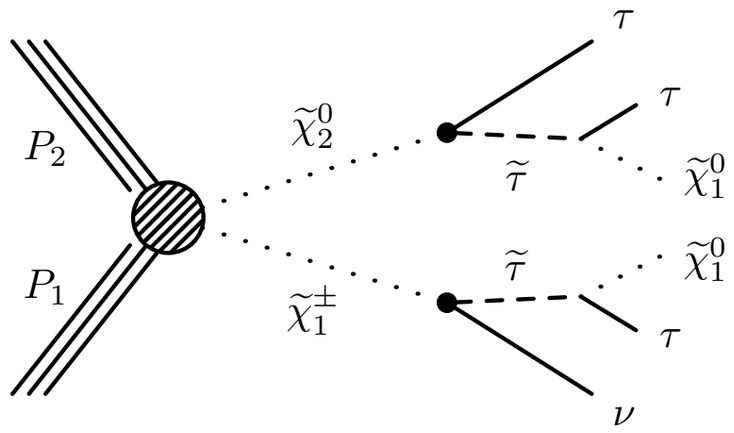
CMS-PAS-SUS-16-039

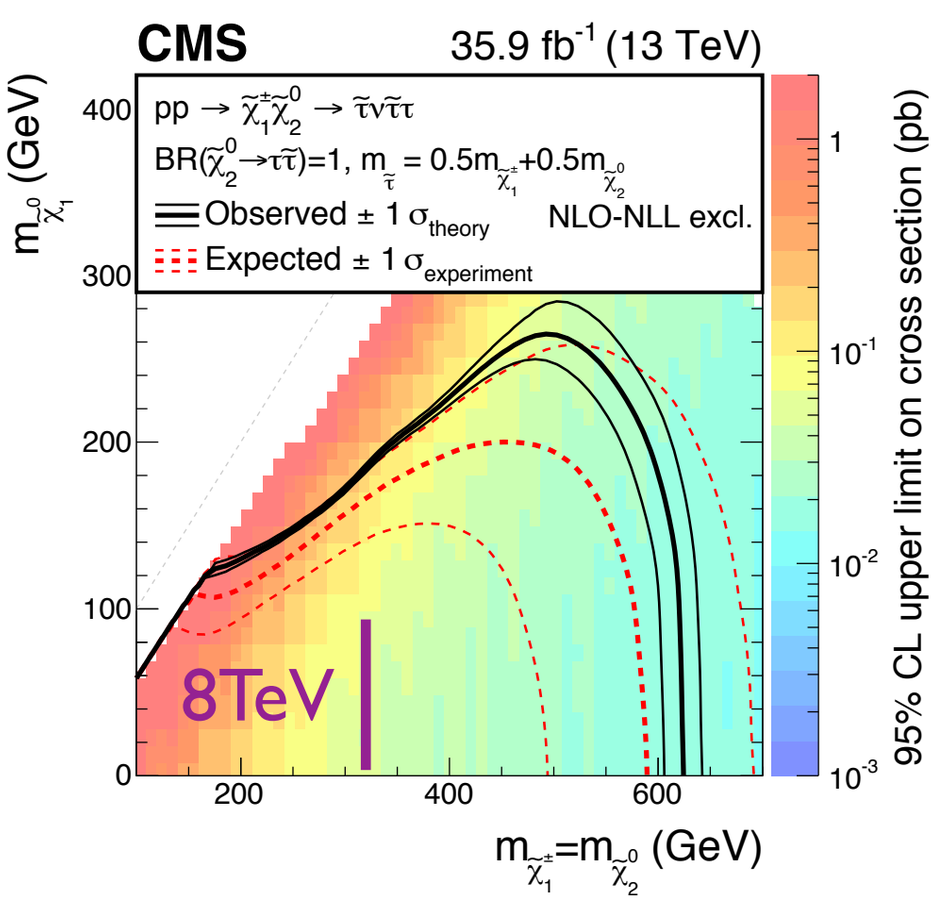
Inclusive Multilepton Search - Limits





light sleptons scenario
flavor-democratic decays

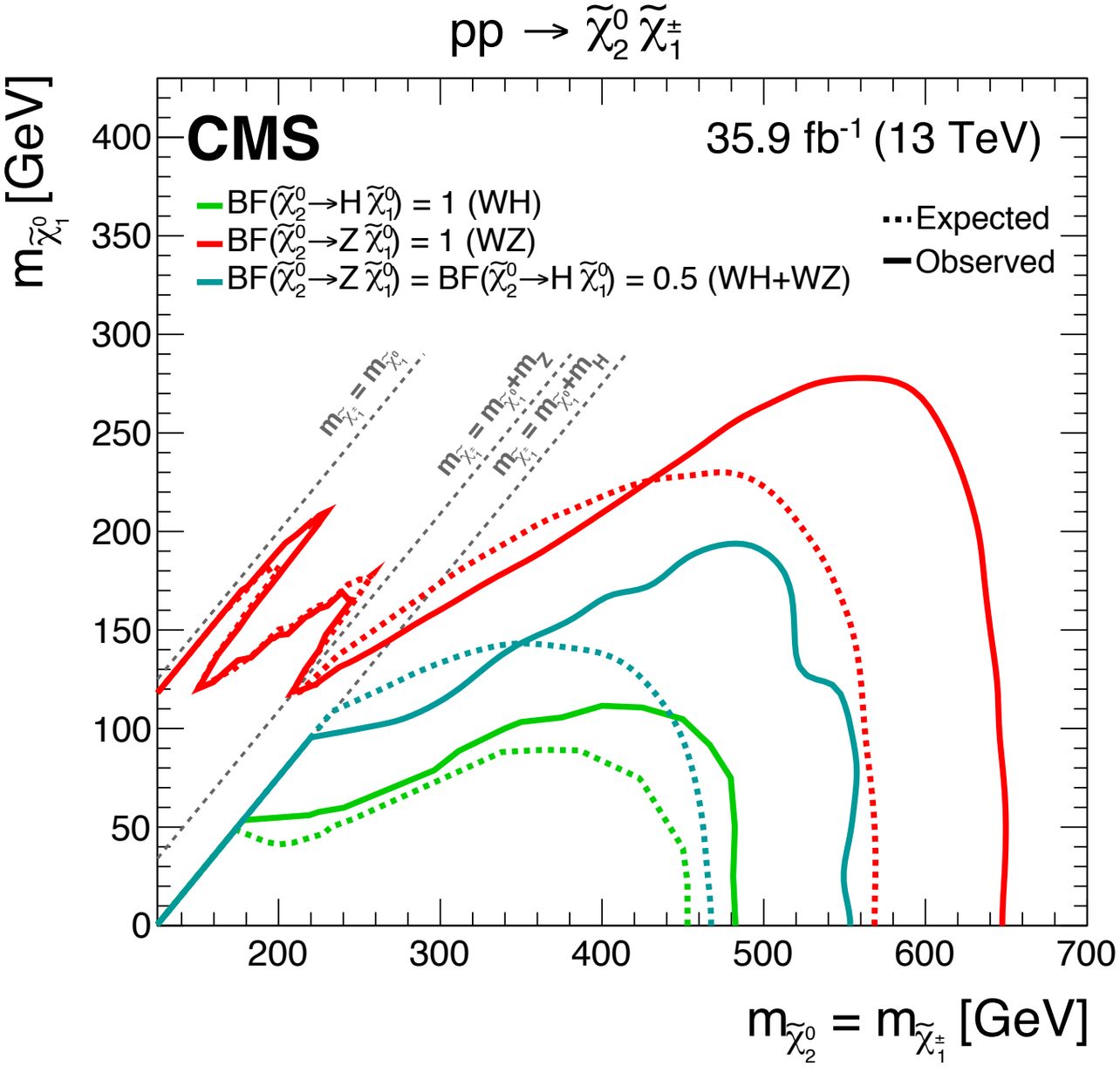


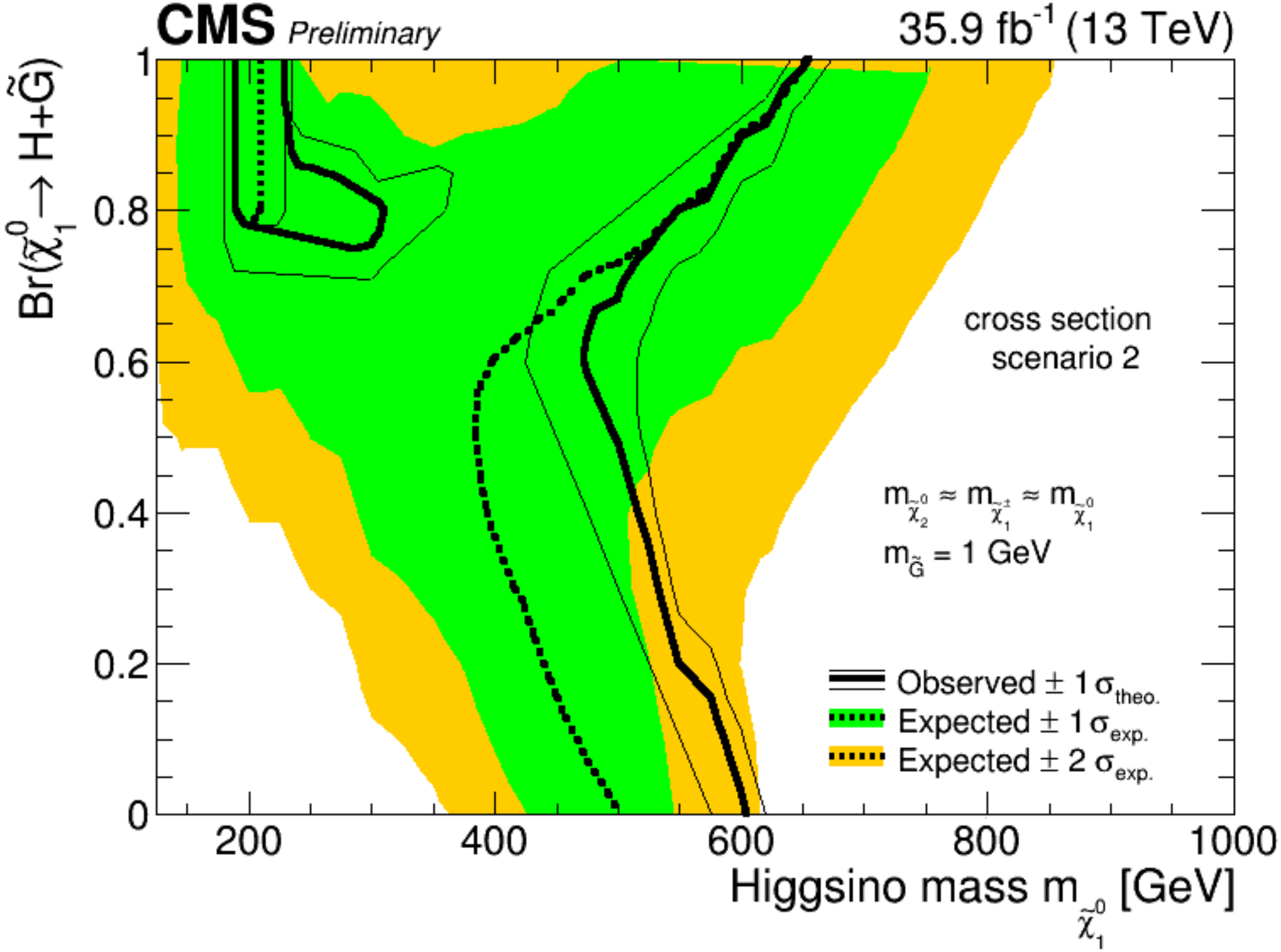


light stau scenario
decays to taus

- Extension of exclusion limit with respect to 8TeV searches up to TeV range

Electroweakino combination results —WZ/WH



- Interpretation with mixed decay senario:
  - 50% WH, 50% WZ

Electroweakino combination results —higgsinos