SUSY Searches at the LHC

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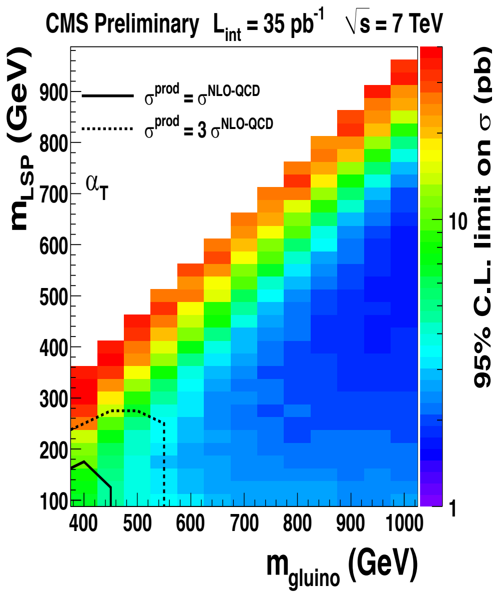
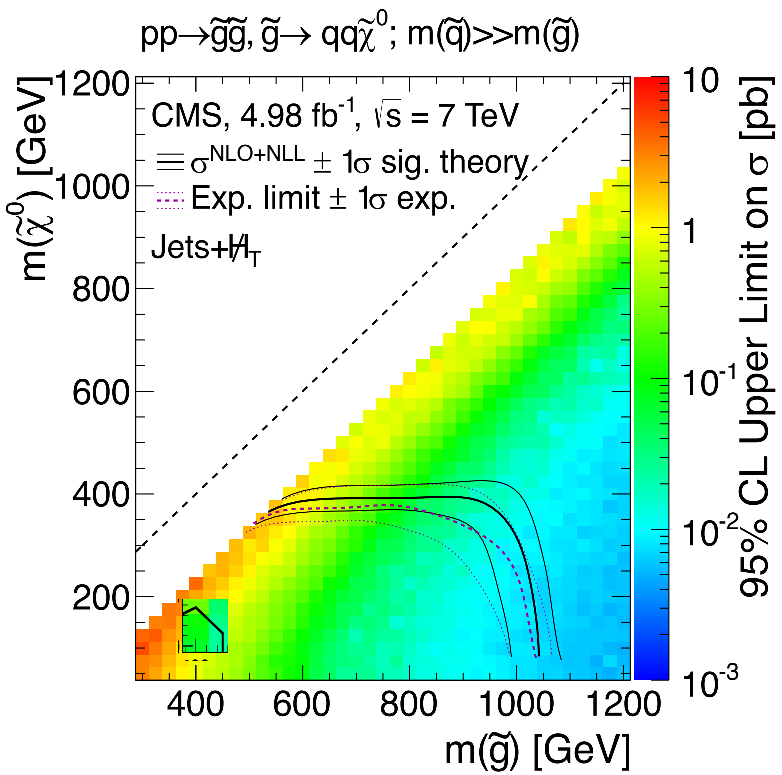
Gluino Mass Reach

2010:



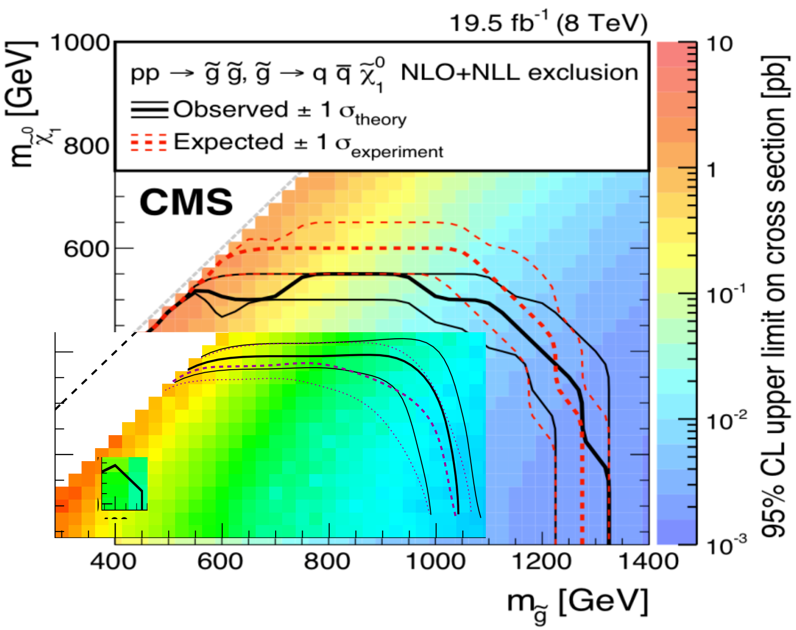
Gluino Mass Reach

2011:



Gluino Mass Reach

2012:



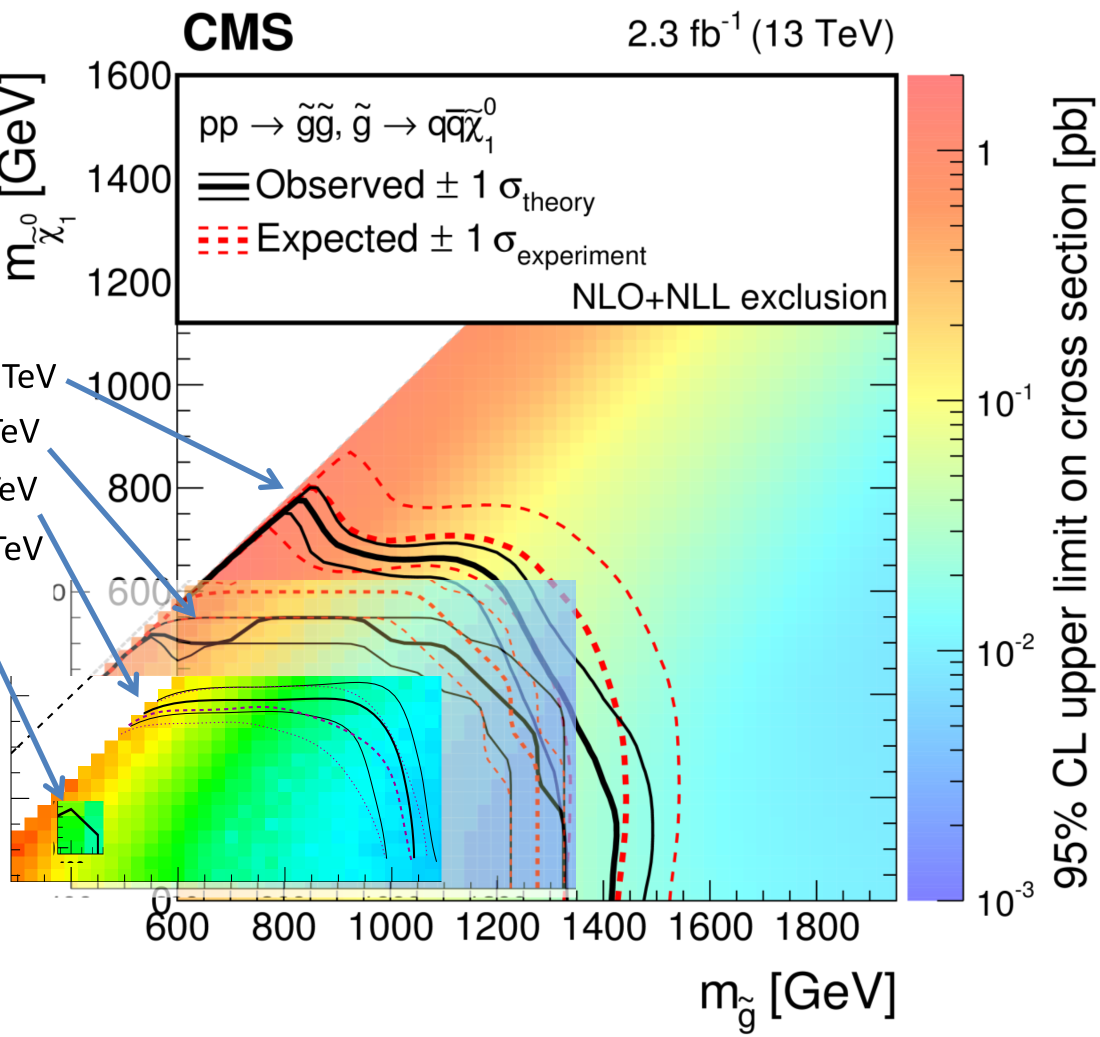
Gluino Mass Reach

2015: 2 fb^{-1} @13 TeV

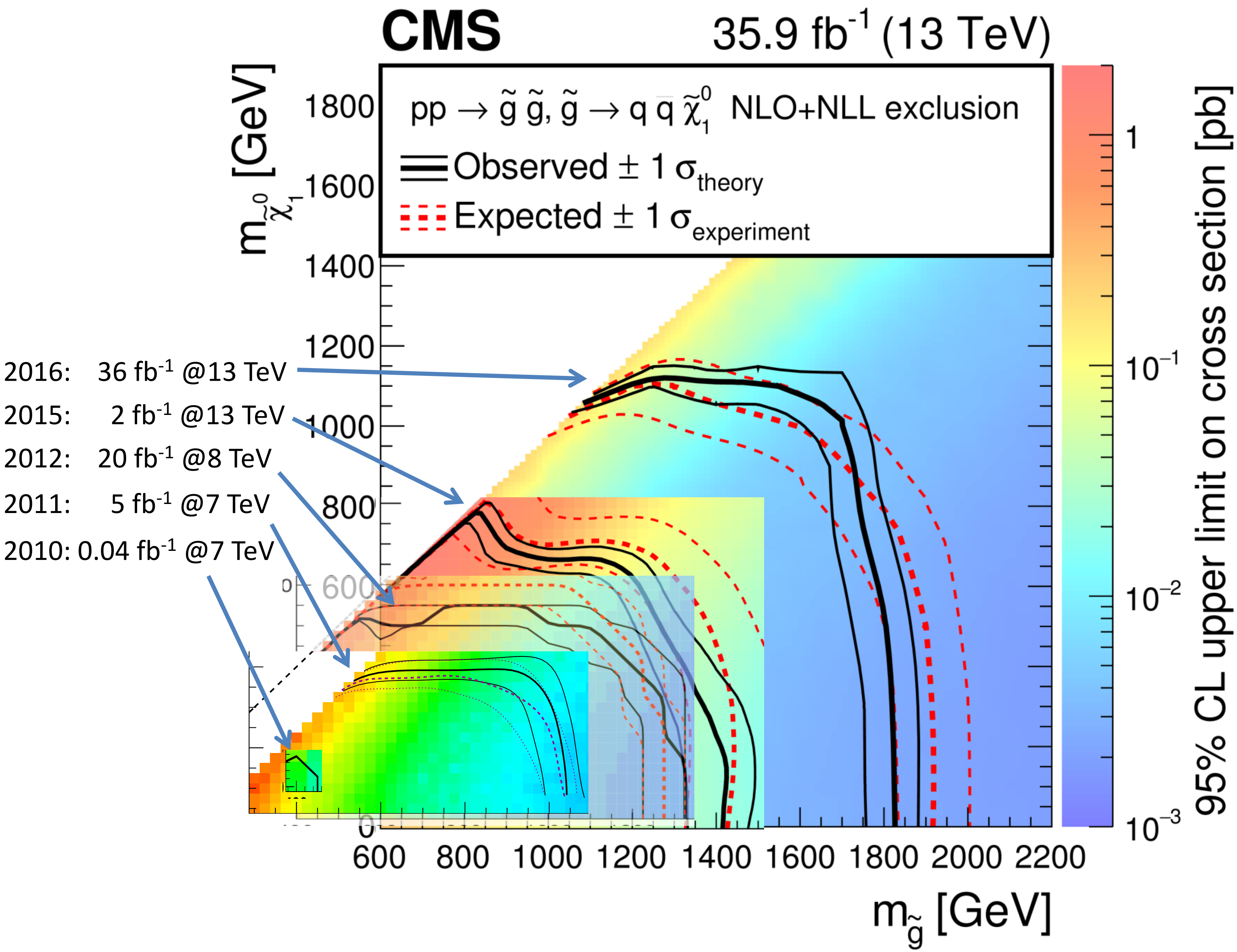
2012: 20 fb^{-1} @8 TeV

2011: 5 fb^{-1} @7 TeV

2010: 0.04 fb^{-1} @7 TeV

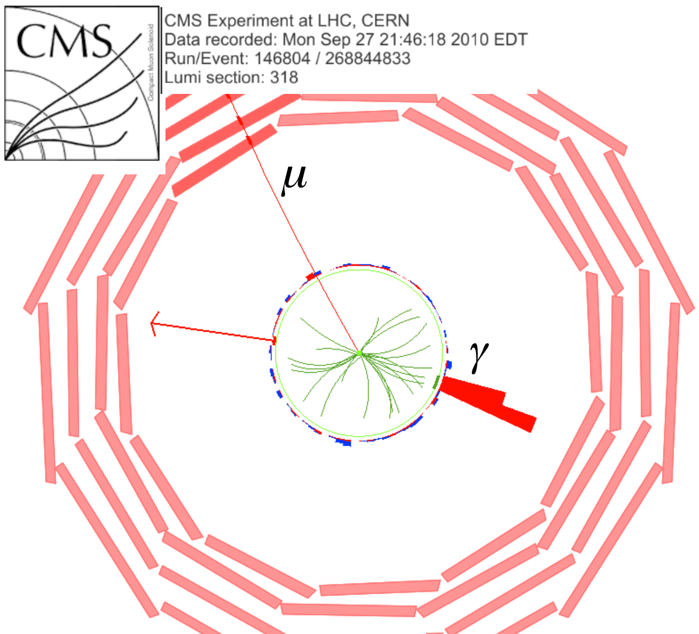


Gluino Mass Reach

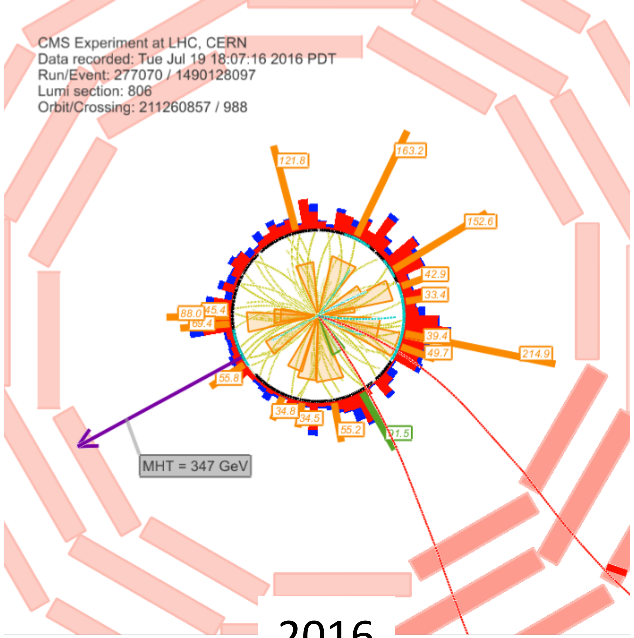


SUSY at the LHC

- Despite lack of observation, have made huge of progress in SUSY searches
  - Generally very inclusive searches with broad reach
  - Sophisticated analysis techniques, robust background predictions, comprehensive interpretation techniques, searching further in kinematic tails, …

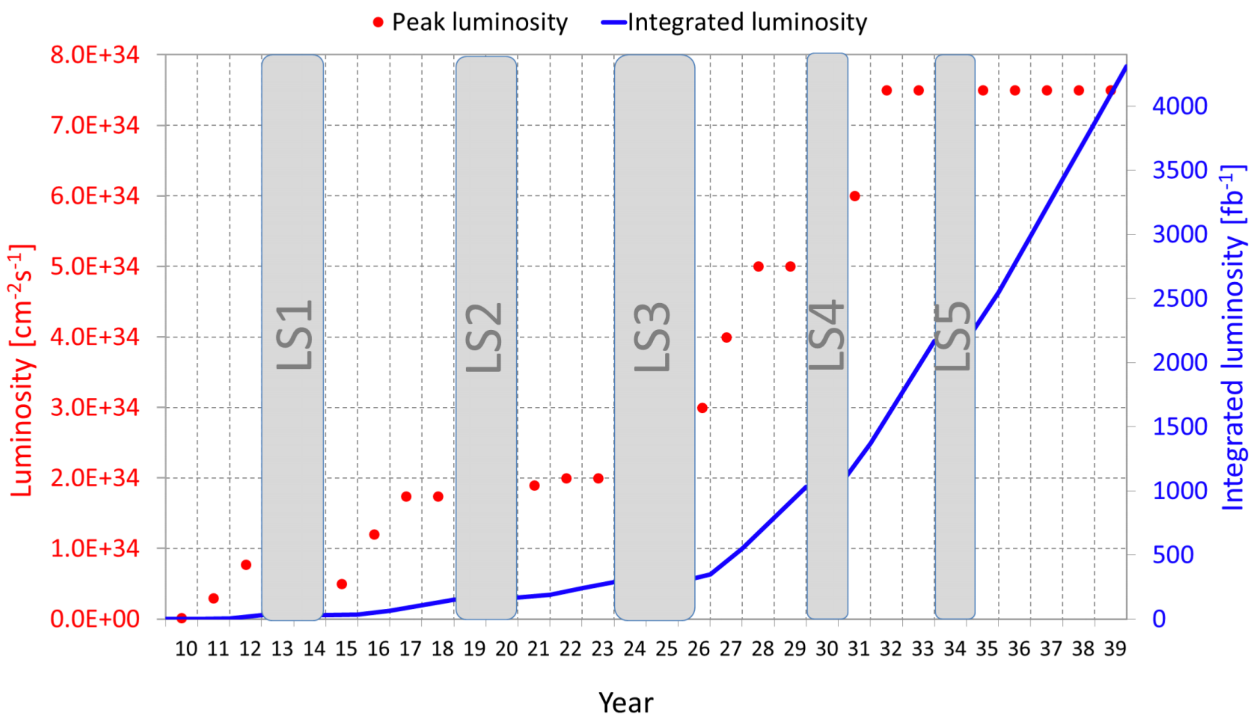


2010



2016

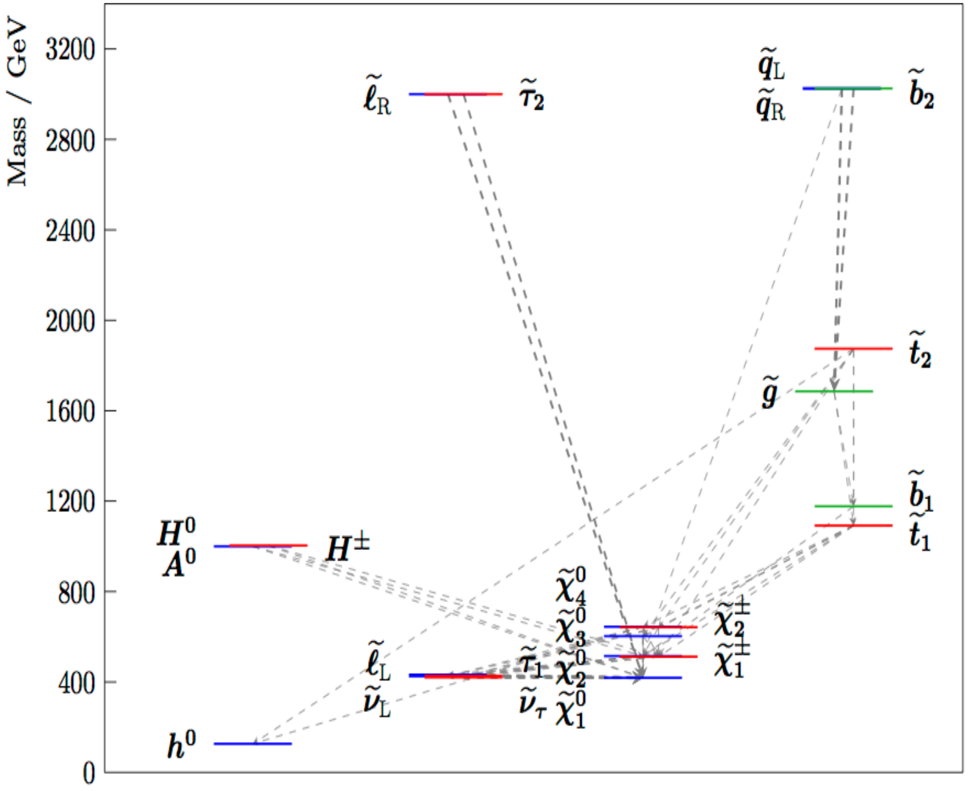
Some paths forward



- The era of large jumps in energy or luminosity is over (for awhile!)
- This talk: My view of ways to push beyond the inclusive, high p_T SUSY searches
  - Digging deeper under background
  - Targeting more specific signatures
  - New experimental techniques
  - More comprehensive searches

Digging Under Background

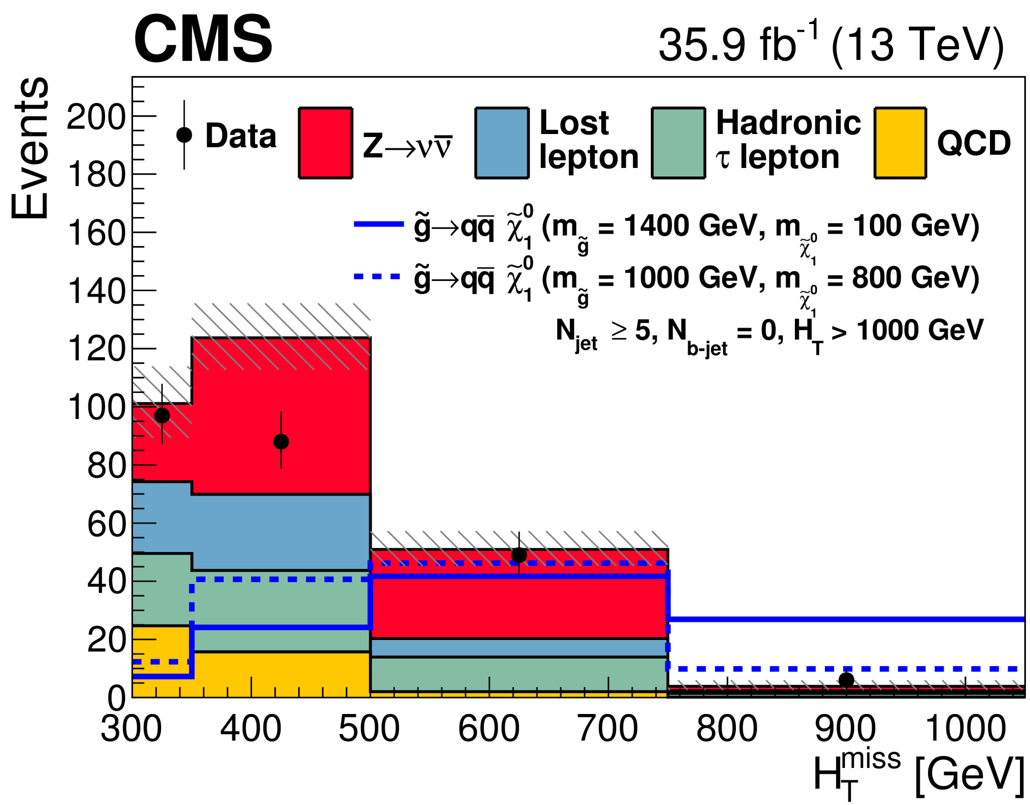
- SUSY can give a remarkably wide range of potential signatures
  - Essentially anything from the SM + missing energy
  - CMS and ATLAS have recent and ongoing searches in just about every combination imaginable
- https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults



An example SUSY spectrum

Digging Under Background

- Traditional approach is to look in extreme tails of kinematic distributions

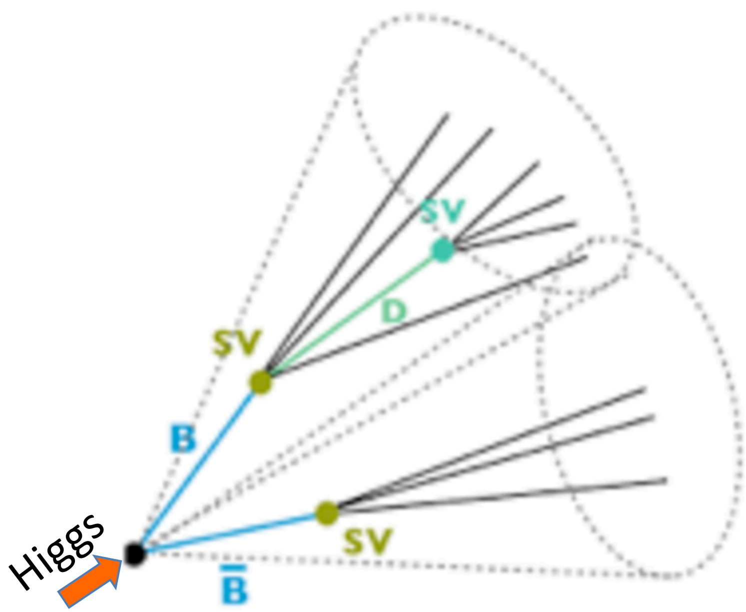


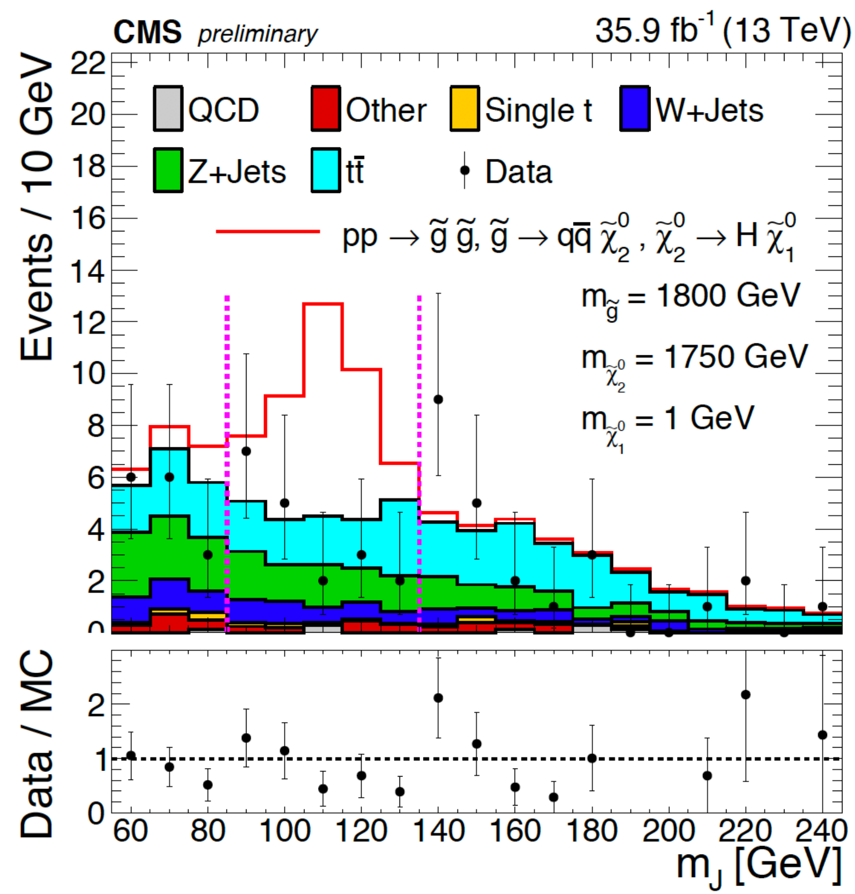
- But signals could be hiding in the bulk with lower rates
- Another option is to use new unique signatures to beat down backgrounds in these cases
- Will give two examples from canonical multi-jet signals

Boosted Object Tagging

- High p_T $H \rightarrow bb$ decay with small opening angle
- Use large angle jets to capture full Higgs decay
- Identify Higgs tags by presence of two displaced subjets
- Jet mass shows clear peaking structure

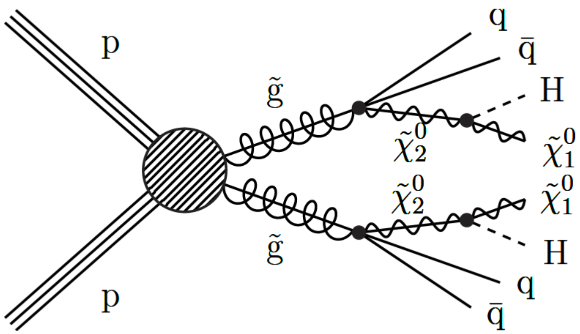
CMS-SUS-17-006
PRL 120, 241801 (2018)

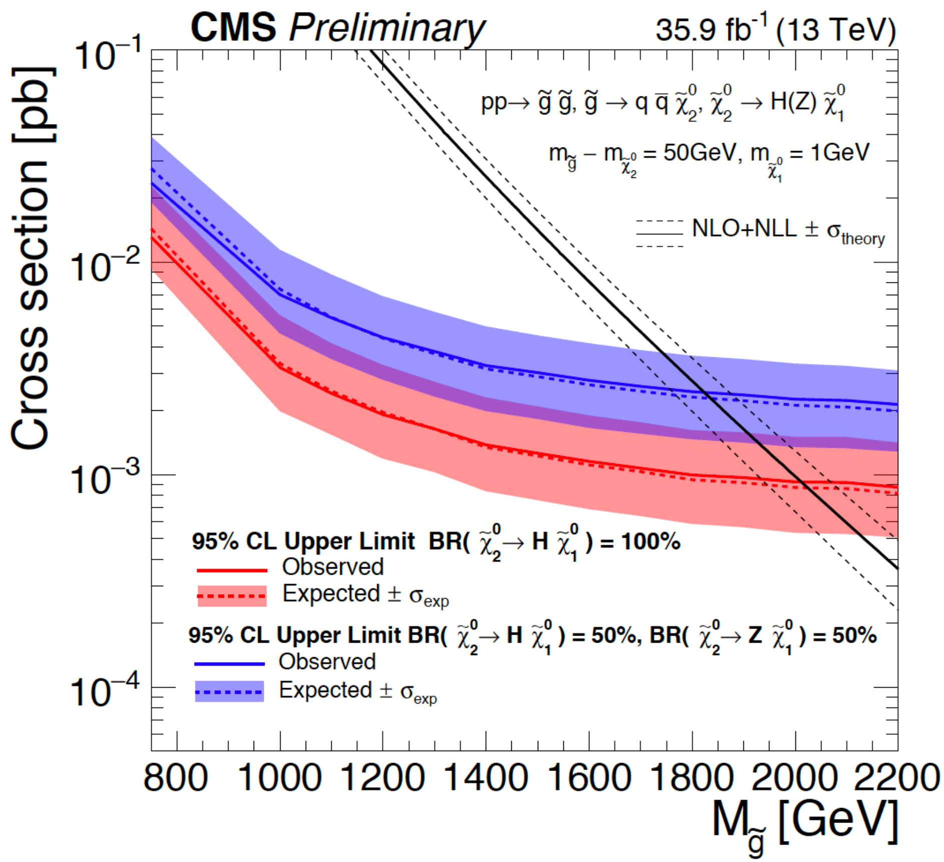




Boosted Higgs Search

- Select events with 1 or 2 Higgs tags and large missing energy
  - 2 AK8 jets with p_T > 300 GeV
  - MET > 300 GeV
- Backgrounds predicted from mass and bb-tag sidebands in data
- Interpret in gluino decay model with mass splittings that give high p_T Higgs bosons

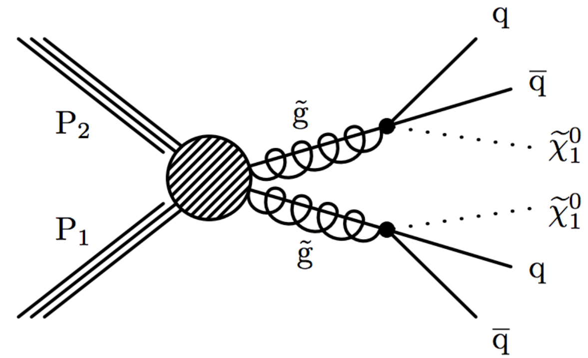


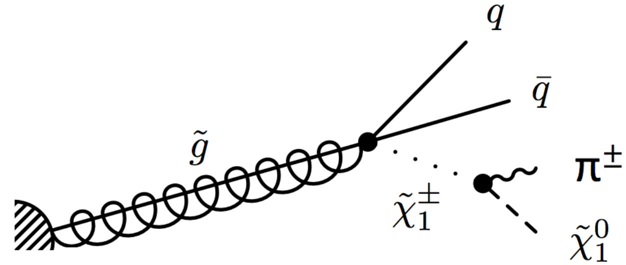


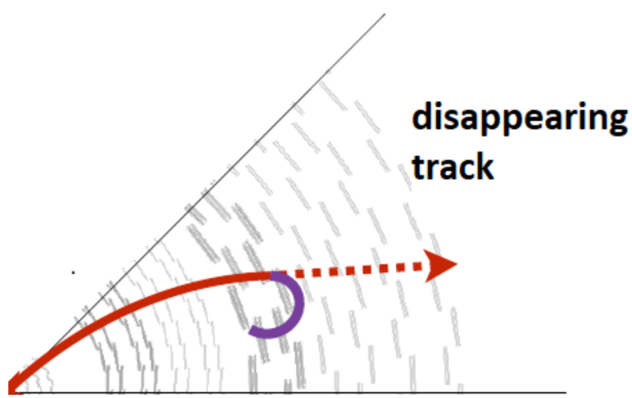
Disappearing tracks

CMS-SUS-19-005

- Typical SUSY decay ends with LSP
- Consider instead if a chi1+ sits just above the chi0
  - As is typical with Wino or Higgsino-like LSPs
- Small mass splitting between chi1+ and chi0 order(100 MeV)
  - Can result in long-lived chi1+ with limited phase space for decay
  - Decays through a pi+ which is too soft to detect and a chi0
- Can select for “disappearing tracks”
  - Well reconstructed track in the inner layers of the tracker
  - Require at least two outer tracker layers missing hits
  - Categorize by length of observed track to catch a range of lifetimes

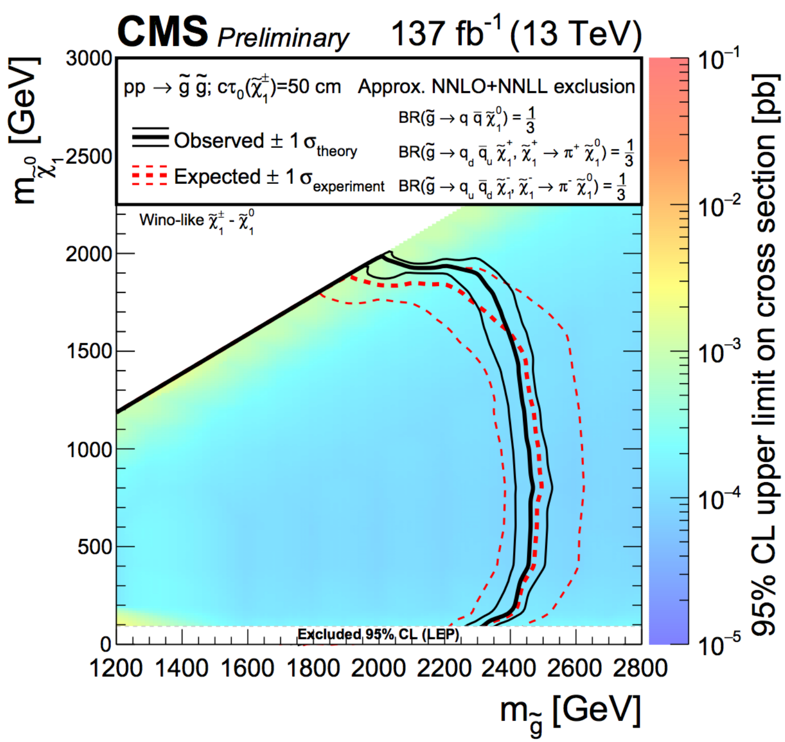


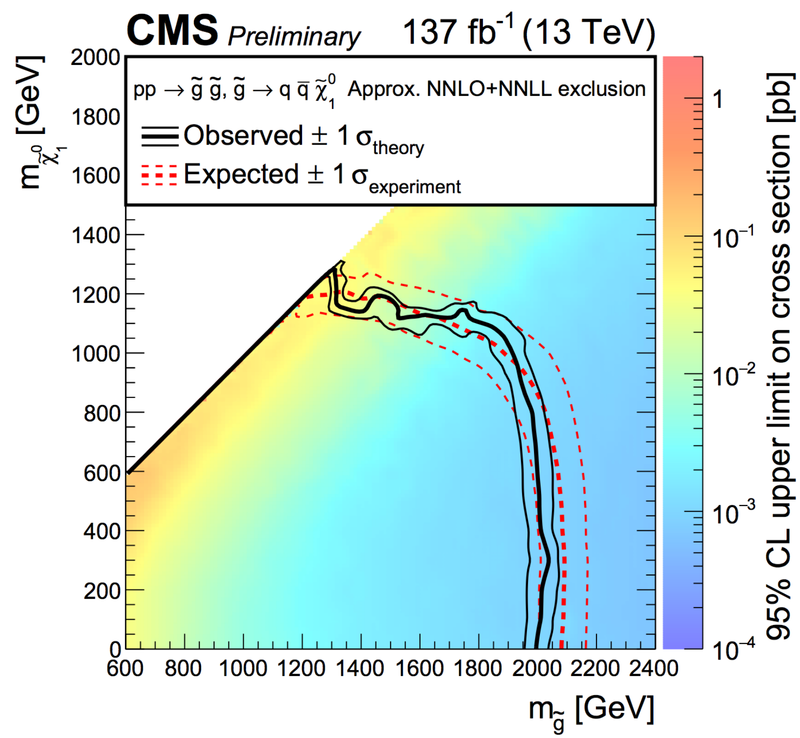




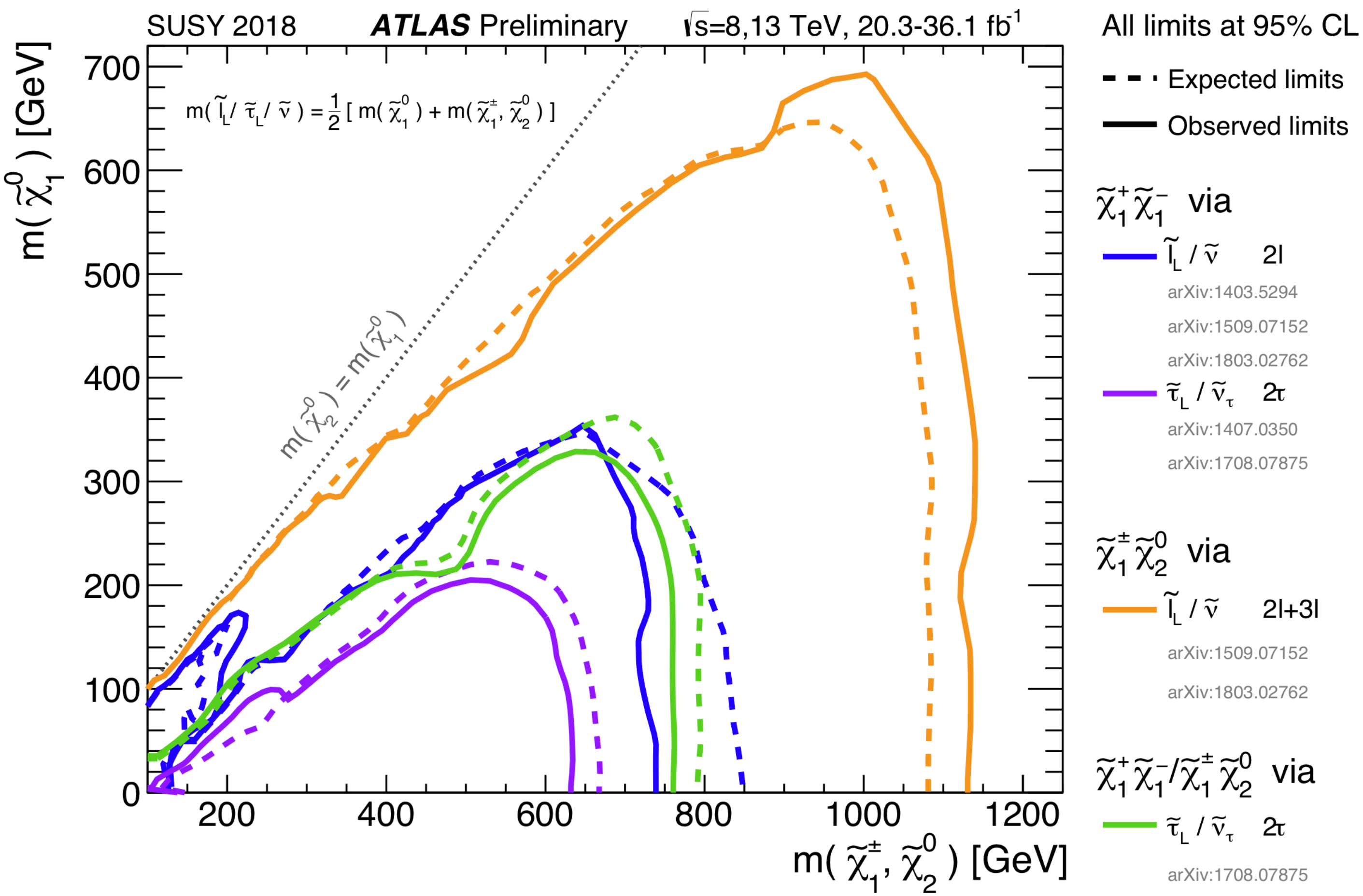
Disappearing tracks

- Search binned in jet multiplicity, HT, and disappearing track pT
- No significant excess observed in any search bin
- Limits extended by ~400 GeV compared to case without long-lived chargino





Targeting Corners

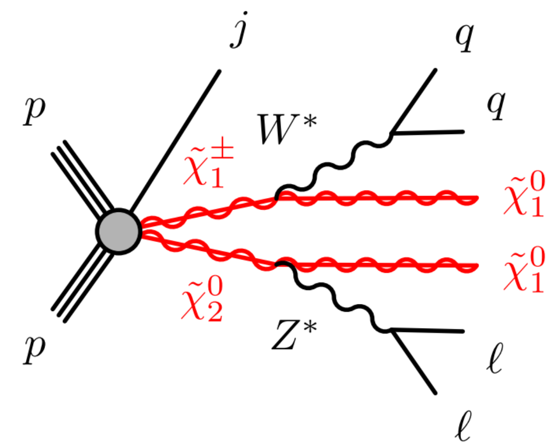


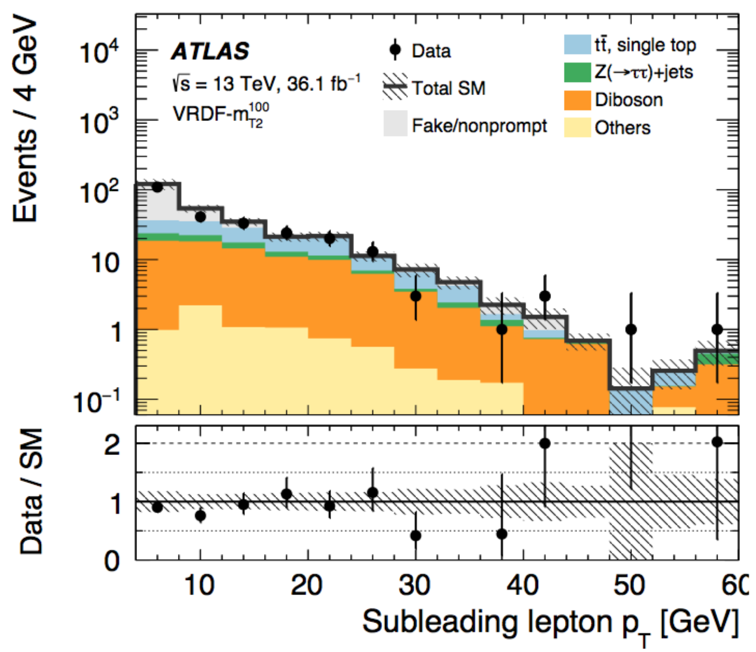
- Broad inclusive searches can leave gaps in sensitivity in challenging regions
  - Dedicated searches extend and complete the coverage

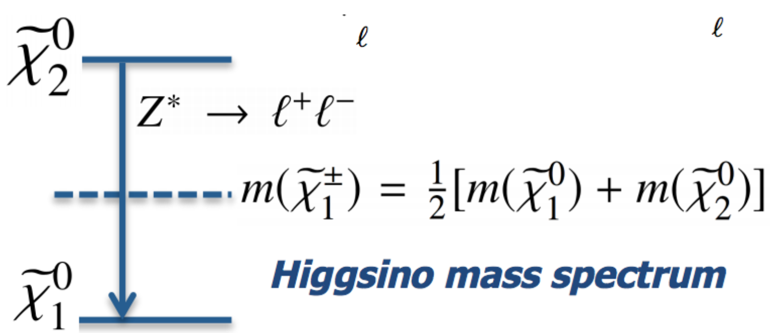
Higgsinos with low p_T leptons

PRD 97, 052010 (2018)

- Target compressed scenarios through low p_T leptons from far offshell W* and Z* decays
- Stretching detector capabilities to reconstruct electrons (muons) down to 4 (4.5) GeV

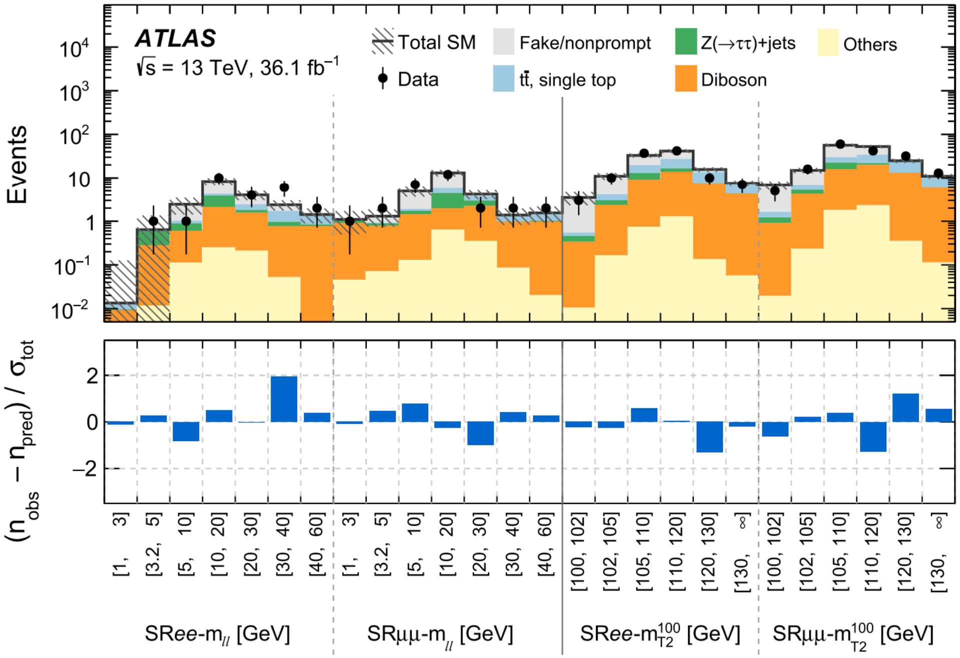


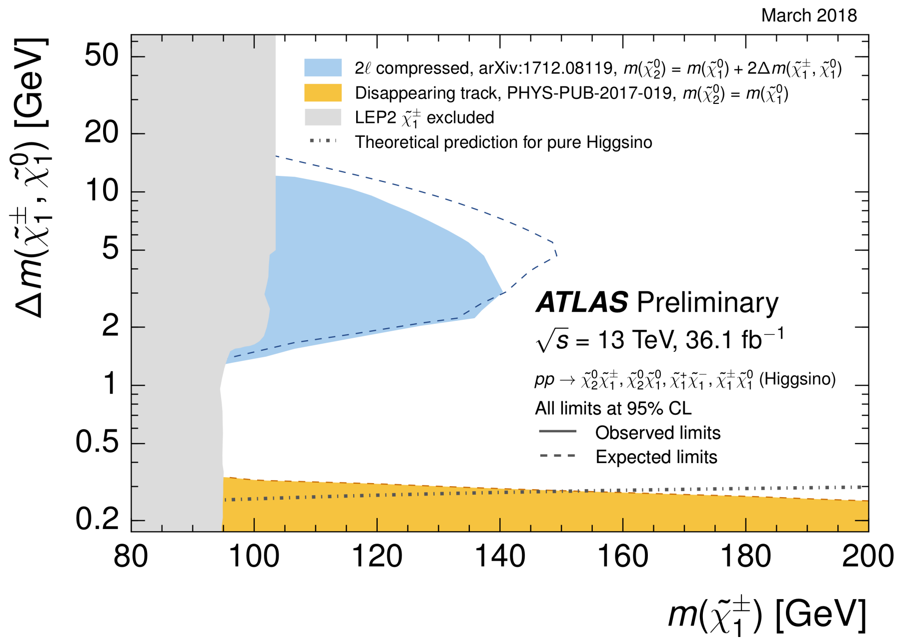




Higgsinos with low p_T leptons

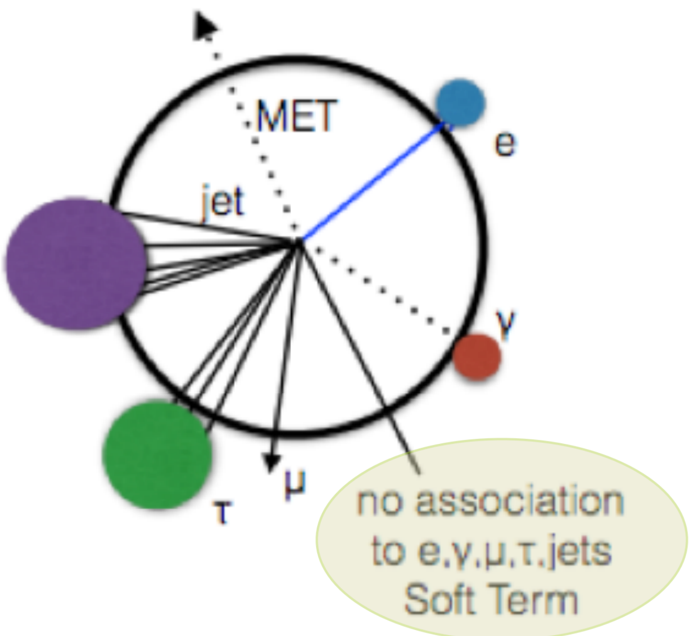
- Difficult search with backgrounds from many different sources and detailed detector response to understand
- No excess observed
- Interpret results in EW-ino mass vs mass splitting





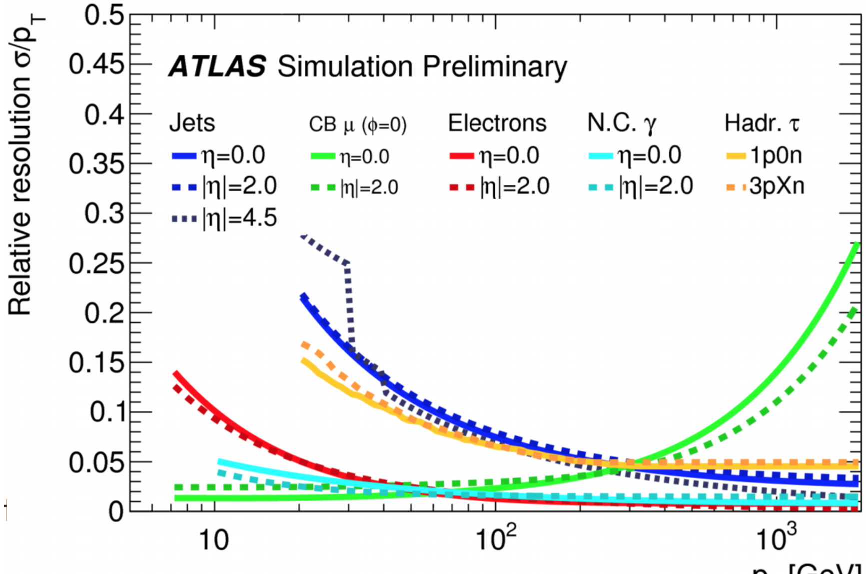
New experimental techniques

- Missing Energy is the hallmark signature for SUSY and other dark matter searches



ATLAS-CONF-2018-038

- Normally computed as the vector sum of observed energy deposits in the detector
- But not all energy deposits are measured with equal resolution
- Can exploit this with "MET significance"

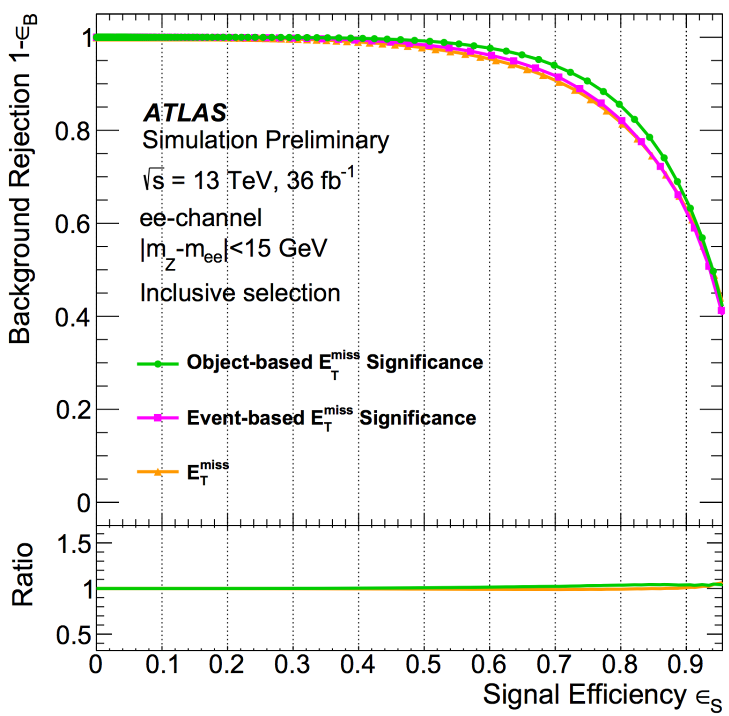


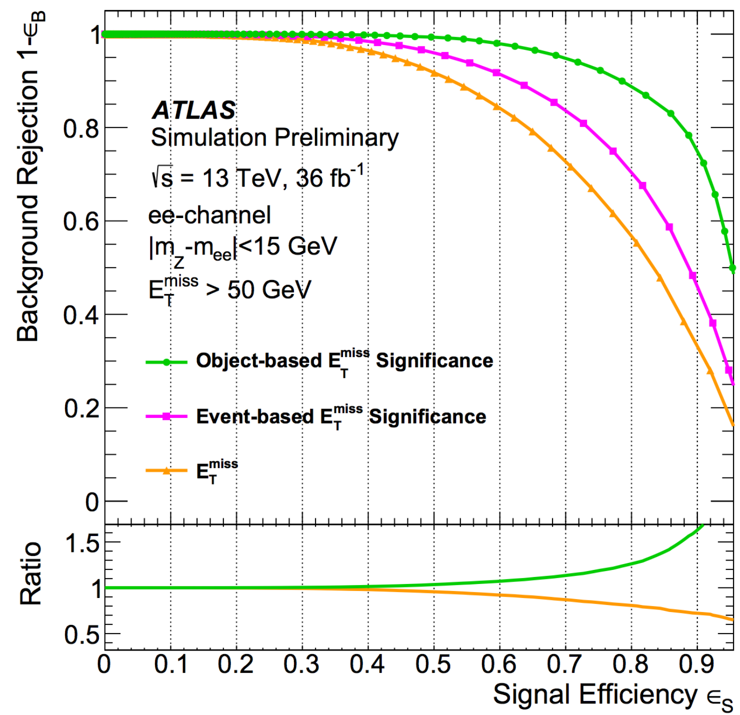
ATLAS-CONF-2018-038

MET significance

- Compute as $$\mathcal{S} = \frac{\left|E_{\mathrm{T}}^{\mathrm{miss}}\right|}{\sqrt{\sigma_L^2\left(1-\rho_{LT}^2\right)}}$$

- Evaluate performance in simulated Z→ee events as background and ZZ→(ee)(neutrinos) as signal

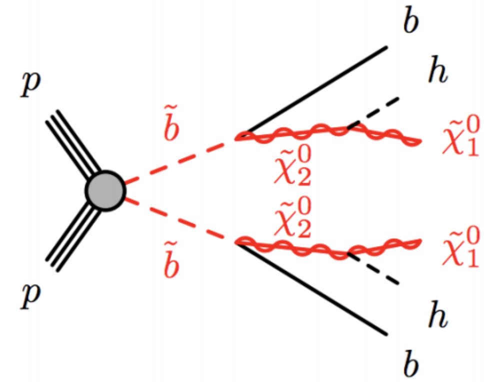


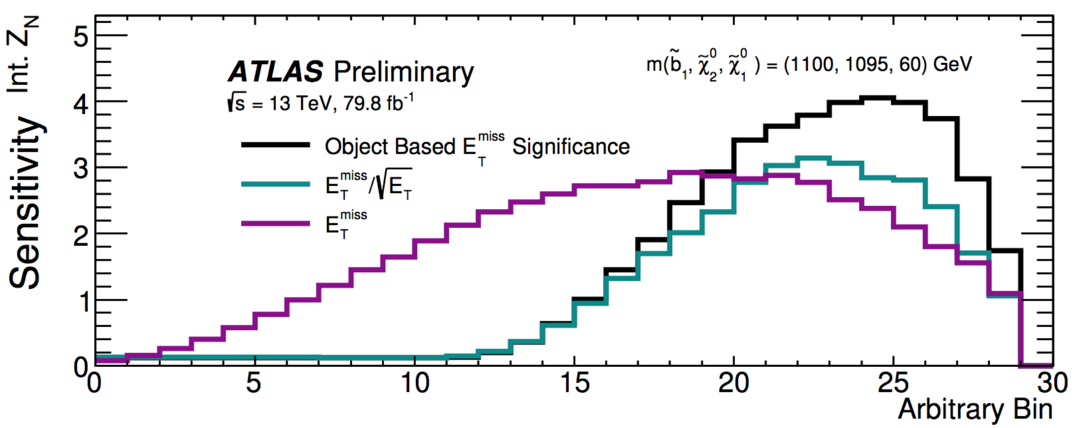


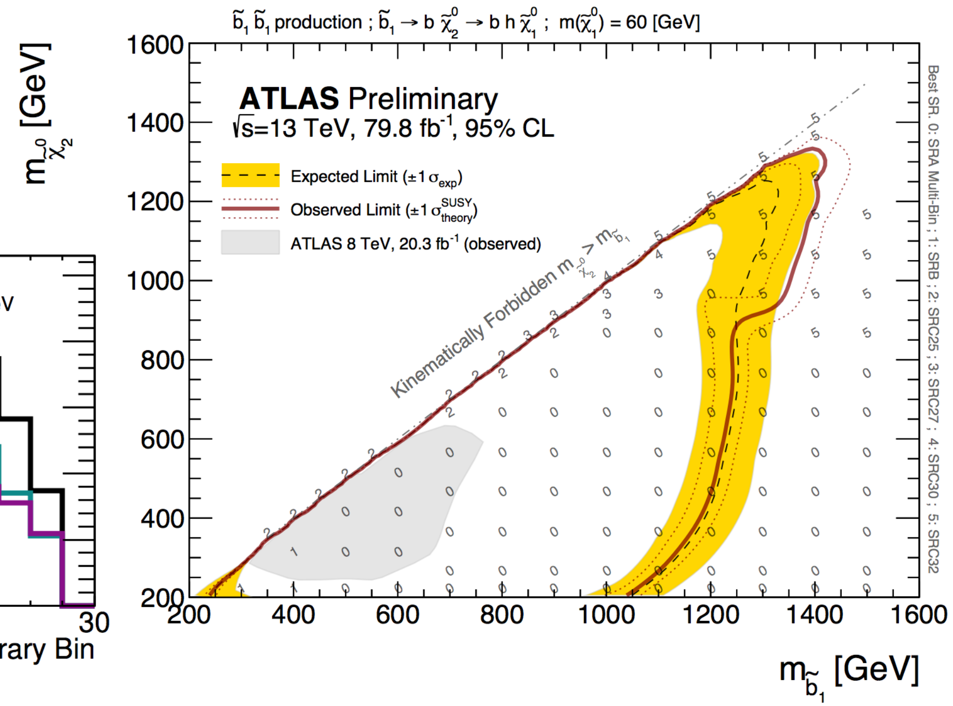
sbottom decays through Higgs

ATLAS-CONF-2018-040

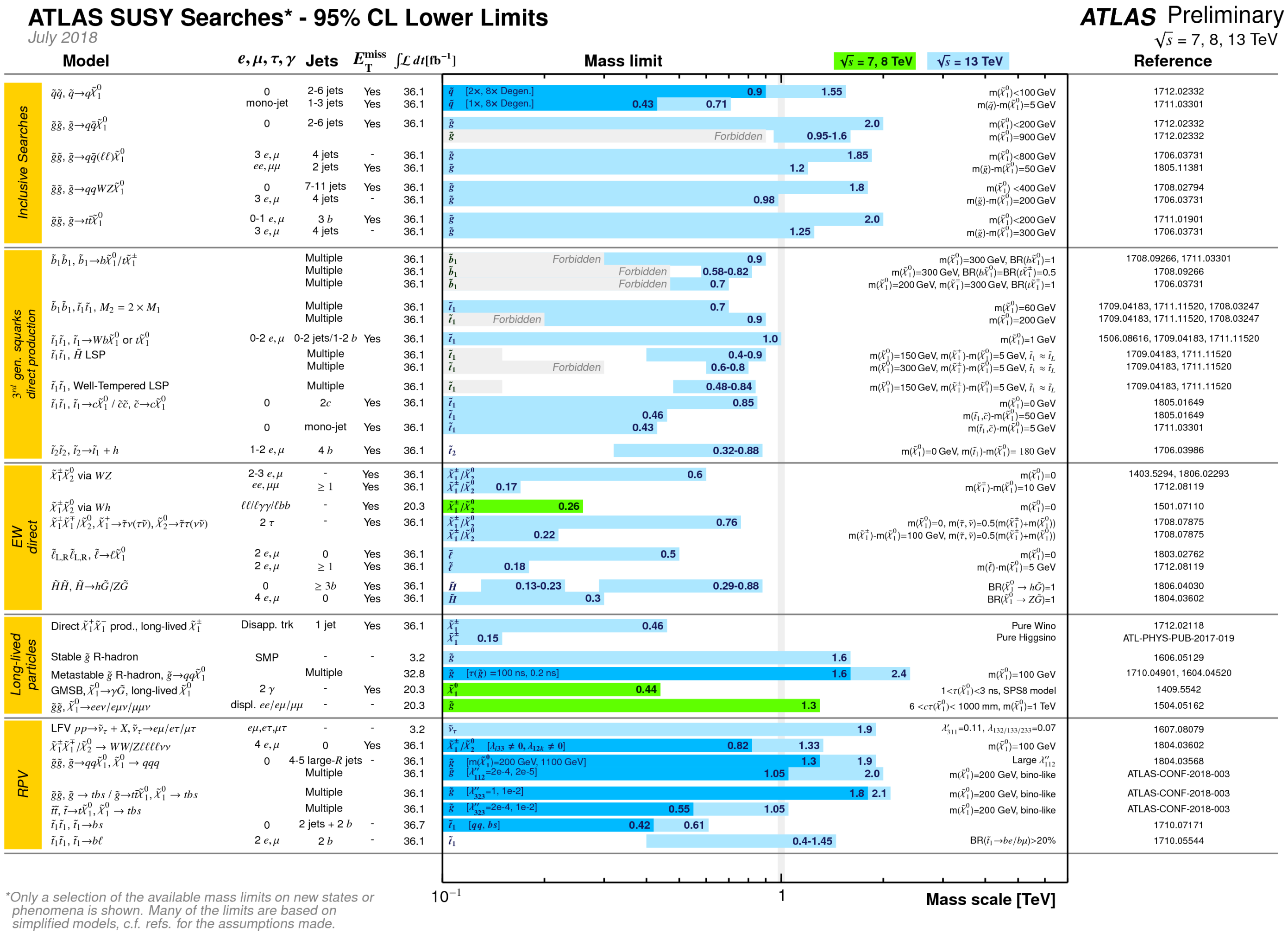
- Search in multi-b plus missing energy final state (up to 6 b's!)
- Exploits MET significance as main search variable
- Can boost expected sensitivity from 3 to 4 sigma in most favorable phase space







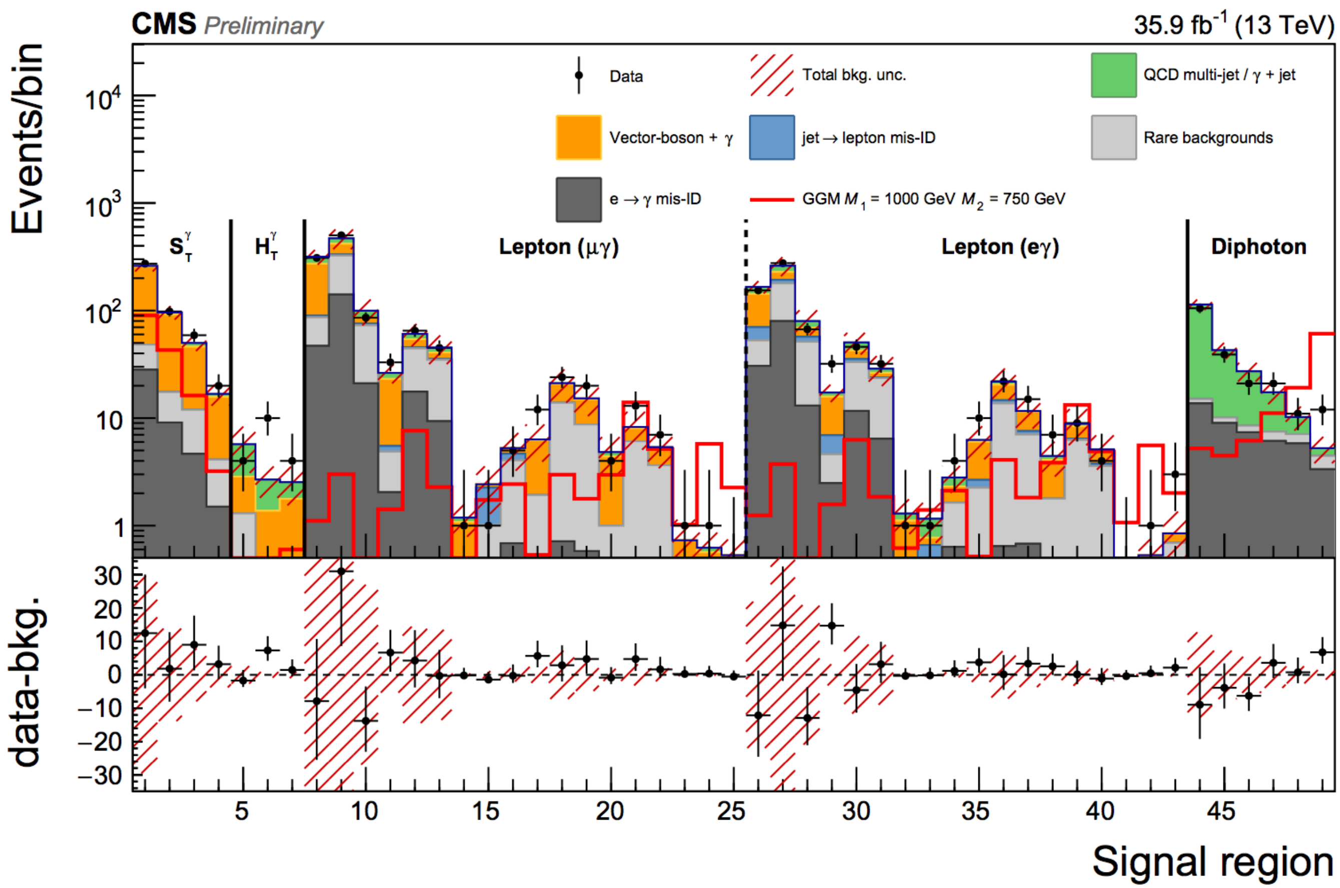
More comprehensive results



- Would like to turn wide collection of individual searches into more comprehensive statement about progress and viable parameter space

GMSB photon combination

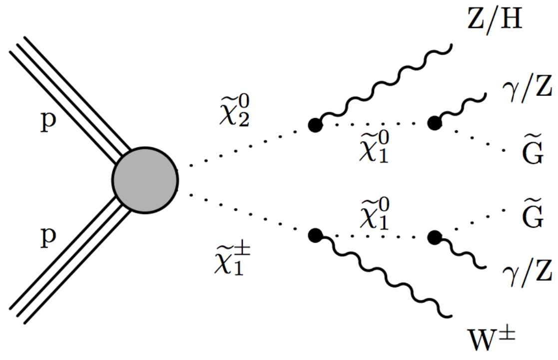
- New effort combines results from variety of searches with photons
- Aim to understand global reach for searches sensitive to similar models

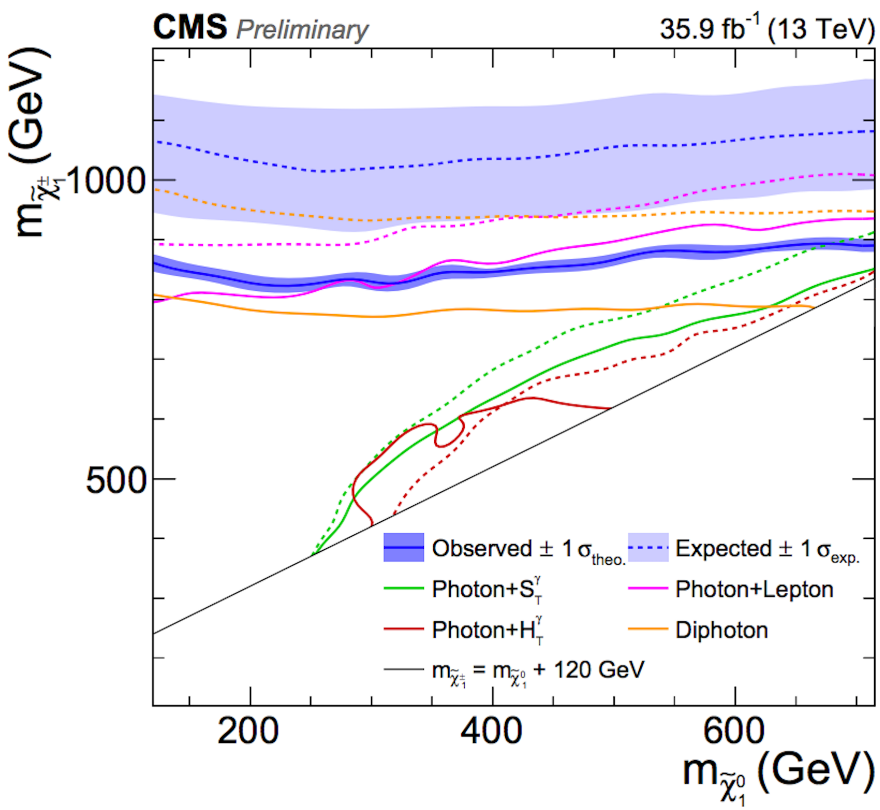


CMS-SUS-18-005

GMSB photon combination

- Consider gauge mediated full SUSY model
  - Decouple squarks and gluinos
  - Include full range of NLSP composition, which drives the NLSP branching ratios
- Complementarity between di-photon and photon + lepton searches
- Also small consistent excess between them…





Conclusions

- Lots of progress in LHC SUSY searches
- But still no signs of new physics
- The low hanging fruit has been picked
- Further progress requires new approaches, techniques, and final states
- But there are still lots of fruitful new ideas coming out of LHC SUSY searches
- And more to come with the full Run 2 dataset