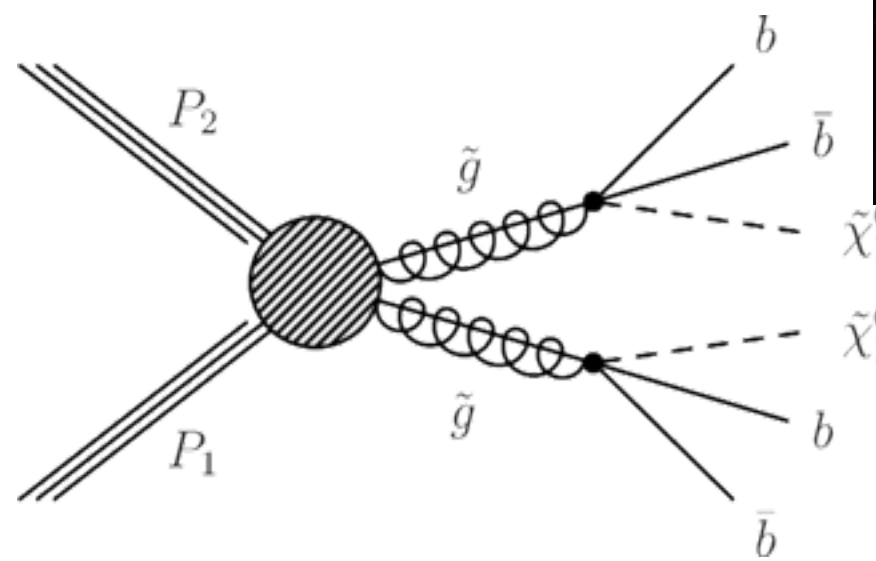
Supersymmetry Results from Run2 at CMS

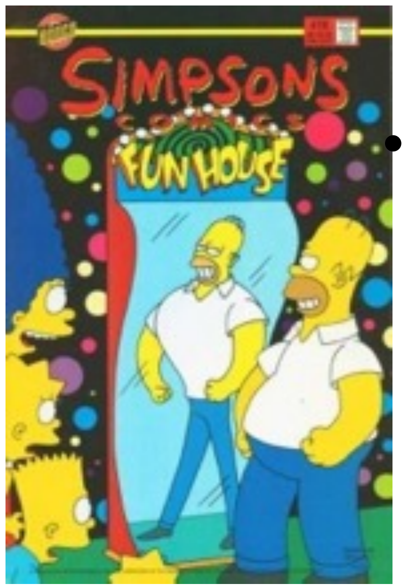
Rishi Patel On Behalf of the CMS Collaboration

Lake Louise 2016 Winter Institute

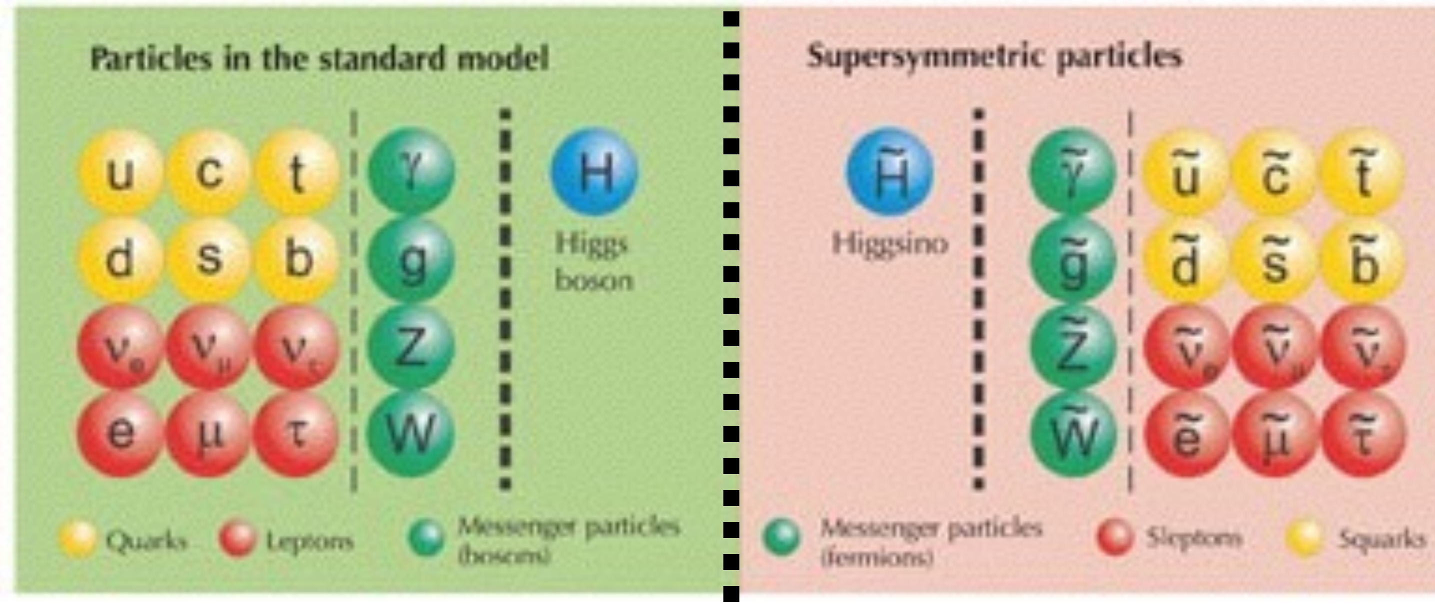


Supersymmtery at a Glance

Fermions ⟷ Bosons

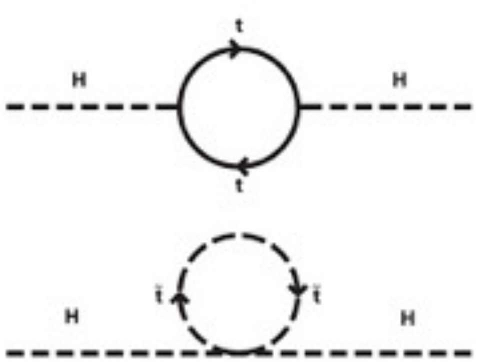


- SUSY breaking pushes SUSY particles to larger masses



- Winos, Zino, photinos, Higgsinos can mix to give Charginos and a Neutralino (DM candidate?)

<u>"Natural" SUSY</u>



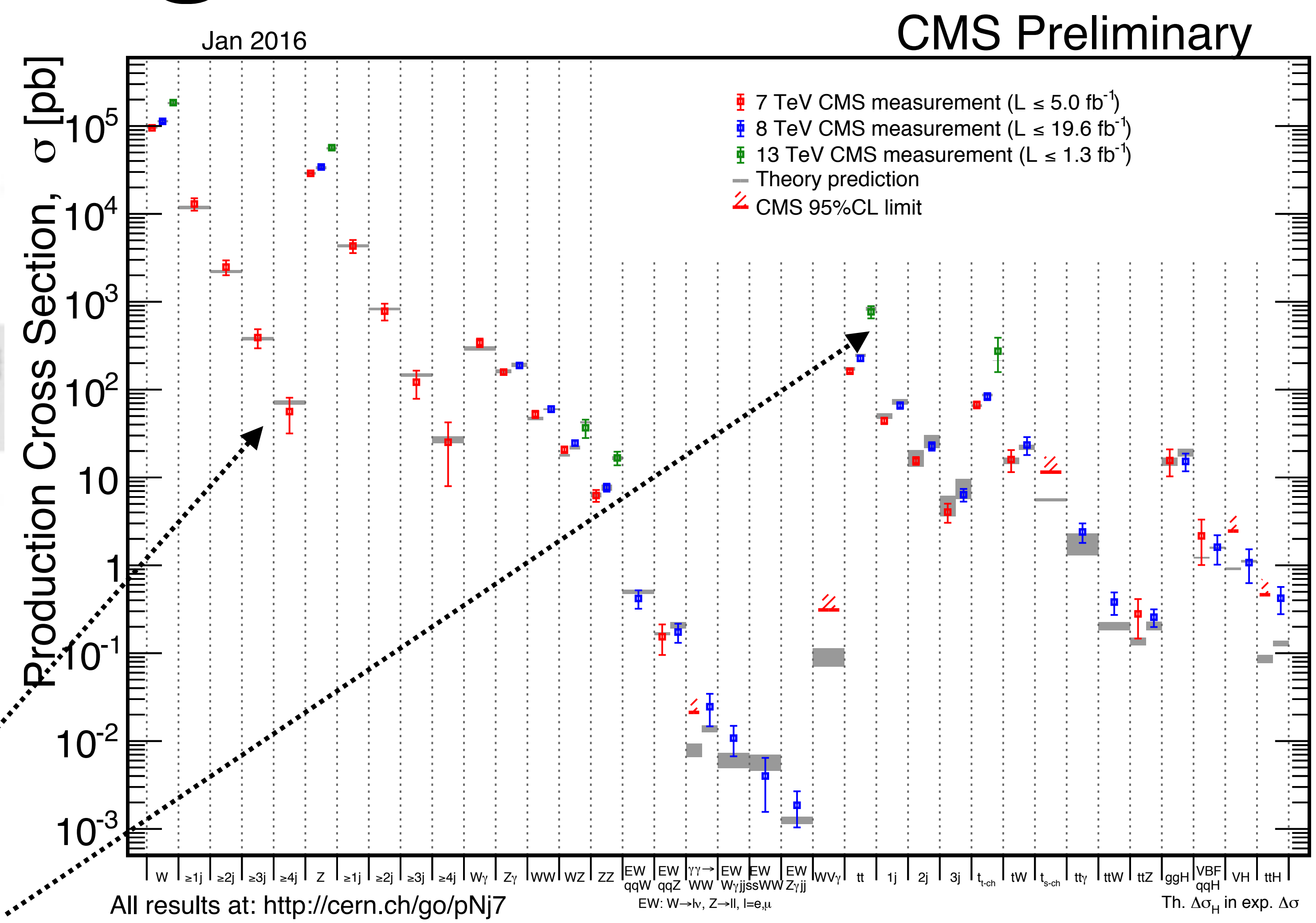
- Light stop could be the key: bosonic loop cancels the fermionic loop

<u>Possible SUSY scenarios with the Usual Suspects:</u>

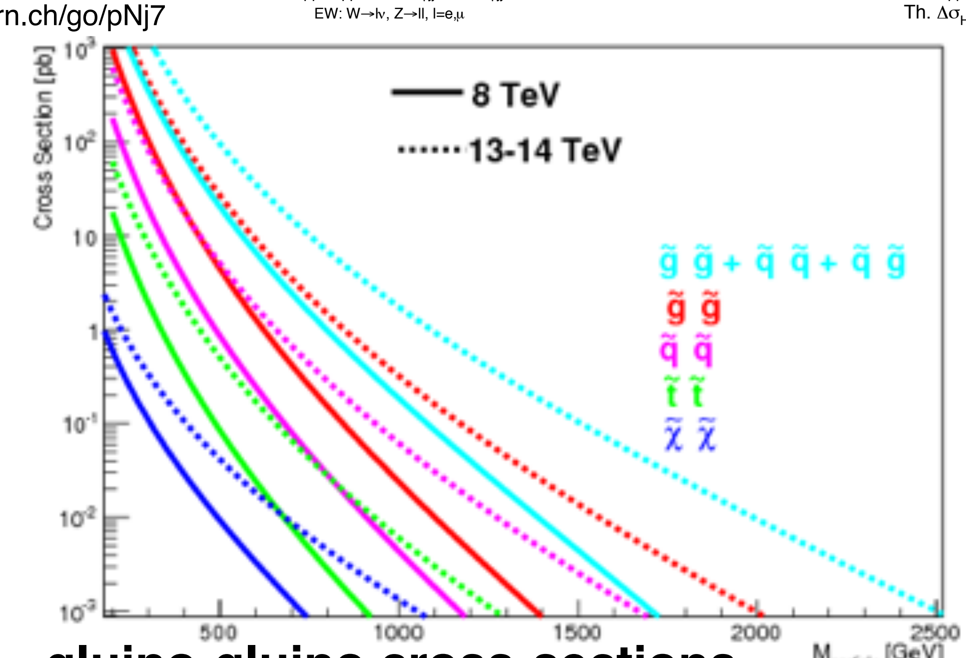
- Neutralino is stable
- GMSB: Neutralino Decays to a Gravitino
- R-parity violation: Neutralino decays to SM particles

The Tough Part!

- SUSY is buried underneath heaps of standard model backgrounds



- General search strategy: Look for SUSY in the **extreme tails of SM processes**:
  - Requiring large jet multiplicity plummets the bkg xsec by orders of magnitude
  - Requiring b-tagged jets shapes the bkg. composition to mainly be top production
- Tricky Part: In these extreme tails, it is important to **precisely measure the backgrounds** for discovery potential e.g. :
  - Observe 7 events and predict only 2.5 background, Poisson probability P(n>=7, μ=2.5)=0.014
  - Observe 7events and predict 2.5±1.9 P(n>=7, μ=2.5+1.9)=0.17



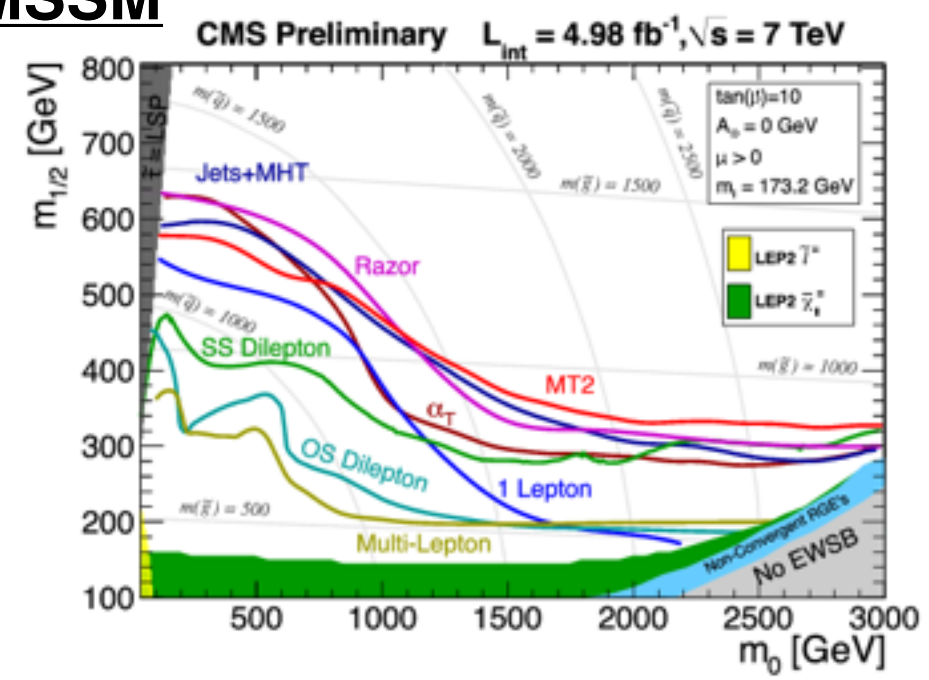
gluino-gluino cross-sections less than 0.4pb for larger than TeV mass

SUSY Search Strategies

- **Constrained models**: Many searches can be motivated by specific SUSY scenarios with constraints: 'Natural' stop mass, DM relic density, R-parity violation/conservation

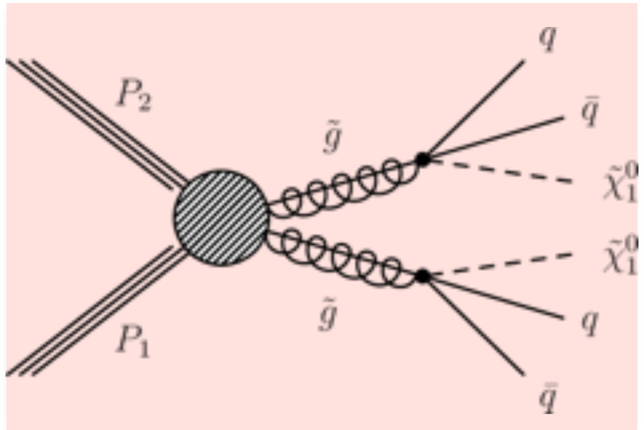
- Pro: **If you find something**, you can look for other predictions in the same model
- CONs: **If you don't** then it is difficult to re-interpret the experimental results in a new model, so you need multiple analyses with the same signature but different interpretations

cMSSM

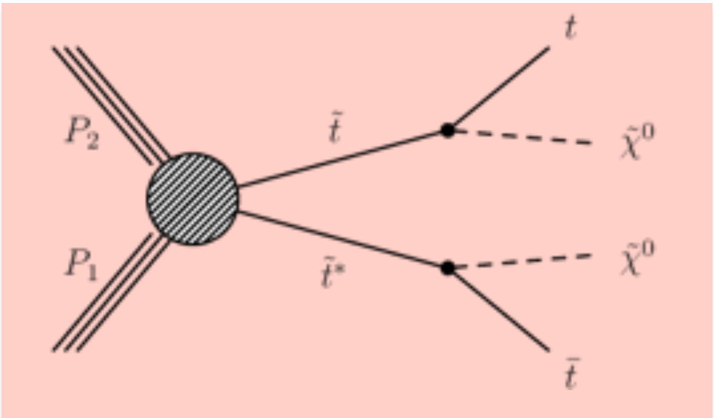


- Experimentally SUSY can encompass a broad class of new physics models: **Be inclusive** and look for "generic" experimental signatures :

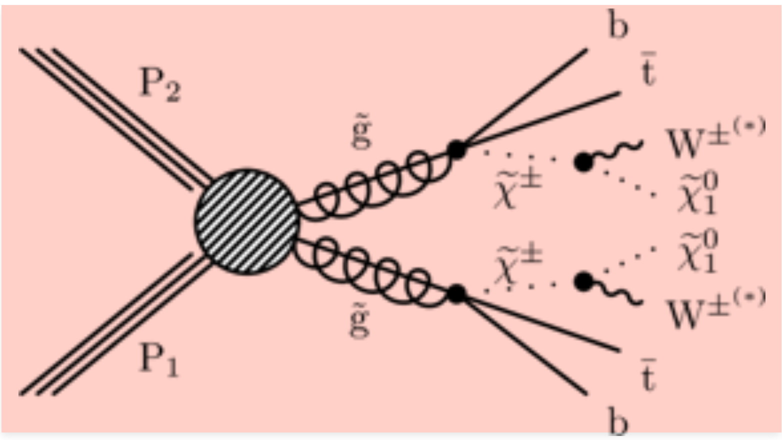
Strong Production gluinos **Strong Production squarks**



Direct cascade
of colored particles
Hadronic Final States



Fully Hadronic Final state,
Single Lepton, (OS)Di-lepton

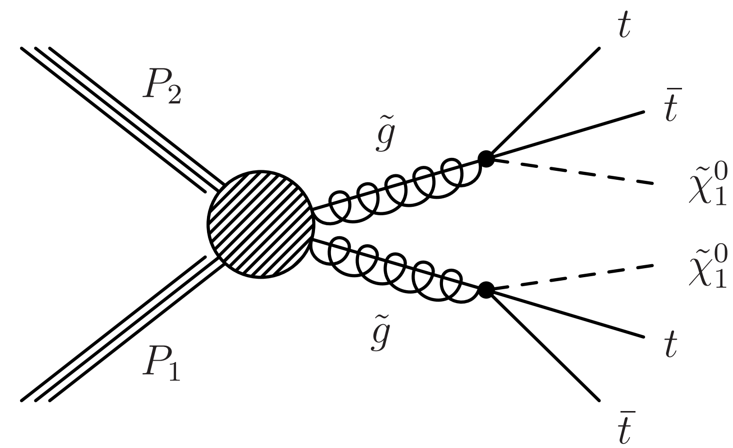


Fully Hadronic Final state,
Single Lepton, (SS)Di-lepton,
multiple-leptons

Can also combine independent signatures

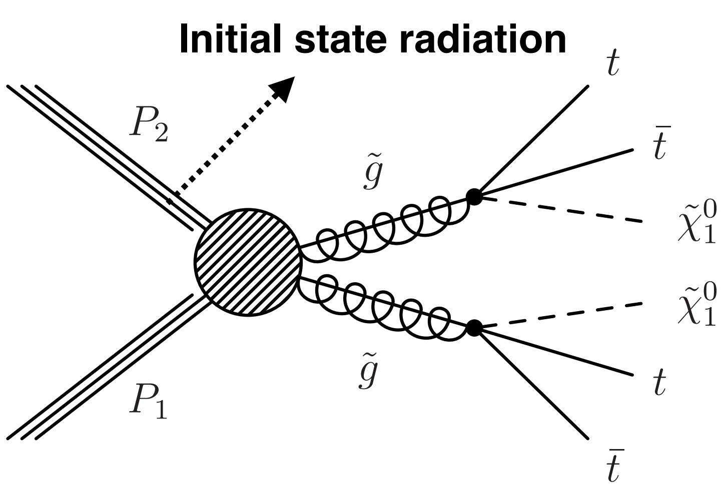
Simplified Model Space

- Defined by a small set of particles and their sequence of production and decay chains.
  - **<u>Main Free Parameter</u>**: SUSY Particle masses
- Each SMS model is designed to encompass a large chunk of phase space for a given signal topology
  Example (T. Rex of SMS T1tttt)

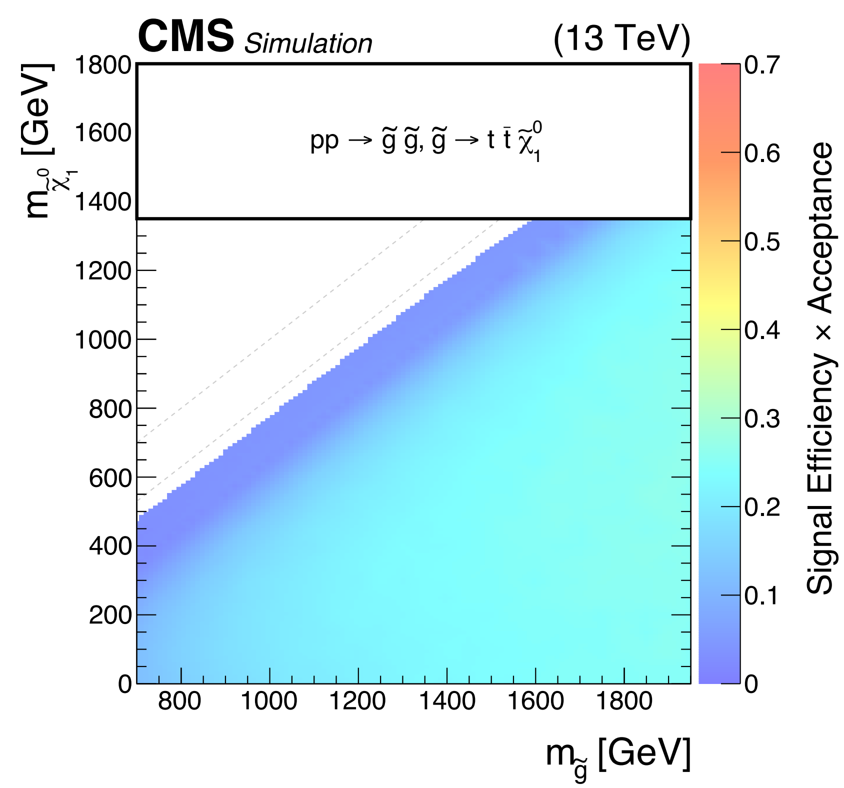


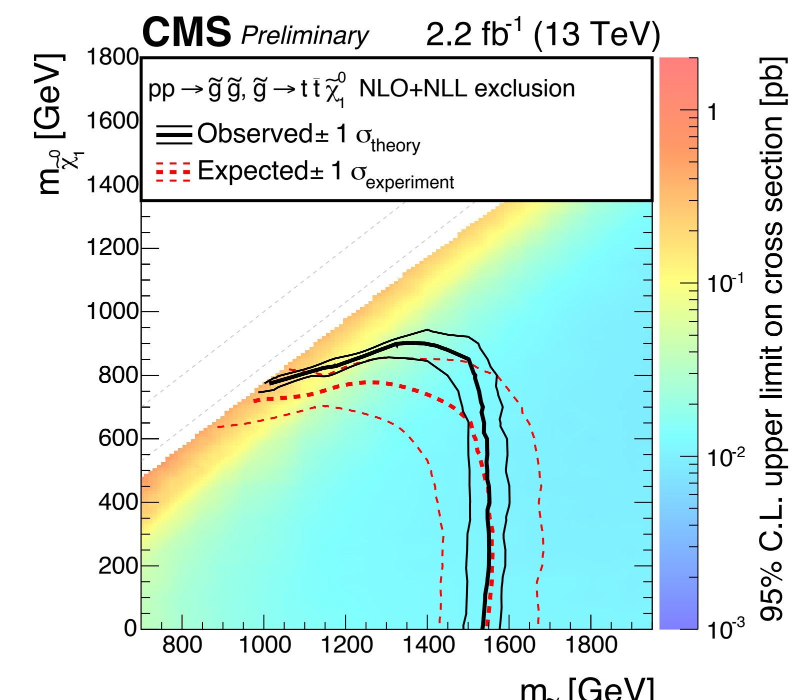
Signal Efficiency varies across the plane of SUSY particle masses, as the signal topology changes:

Closer to the diagonal where the particle masses are comparable, signal acceptance is lower:



boosts the decay products

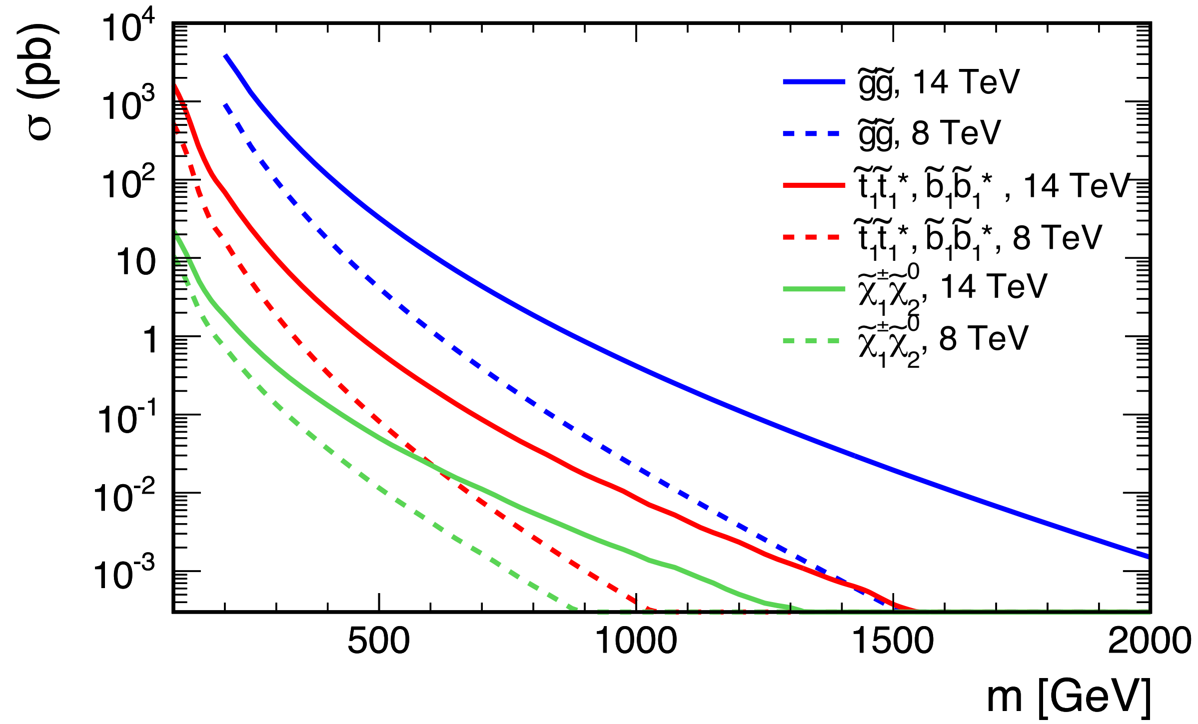




The upper limits are computed with a reference cross-section for each mass point. They can be re-intrepreted given the particle masses, and production σ x BR.

Overview Of Inclusive SUSY Analyses

- **Three Complementary searches** targeting **hadronic final states:**
  - CMS-PAS-SUS-15-002 Missing Transverse Momentum
  - CMS-PAS-SUS-15-003 Transverse Mass
  - CMS-PAS-SUS-15-005 αT QCD-multijet discriminator



Main backgrounds:

- Momentum imbalance that comes from detector mis-measurement in QCD multi-jet processes
- Standard Model processes with genuine momentum imbalance: **W+Jets,top pairs, Z decays to Neutrinos**

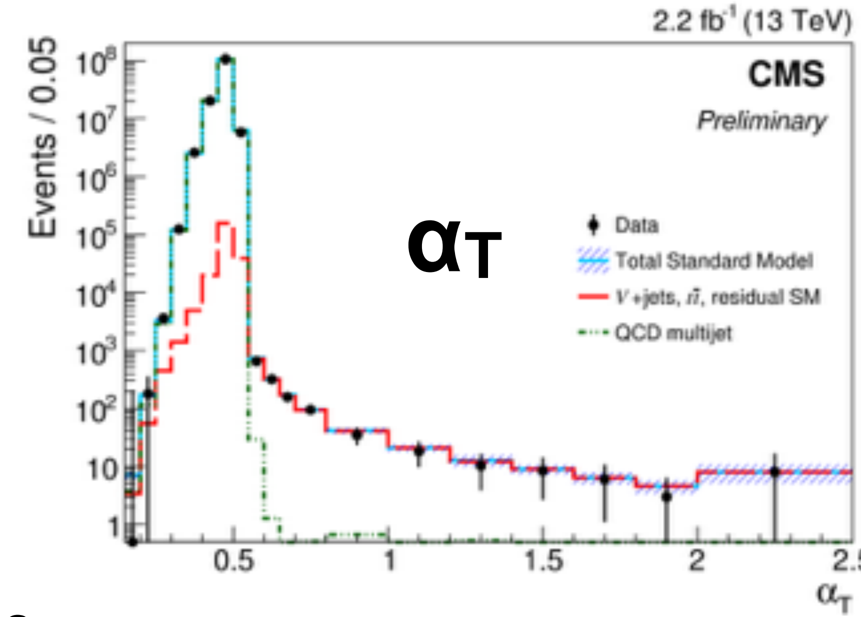
- **Searches with Single Lepton and Jets :** CMS-PAS-SUS-15-004 , CMS-PAS-SUS-15-007
- **Same-Sign Dileptons** General new physics signature with di-boson bkgs: CMS-PAS-SUS-15-008
- **Opposite Sign Dileptons** focus on a GMSB model with on-shell and off-Shell Z-boson: CMS-PAS-SUS-15-008

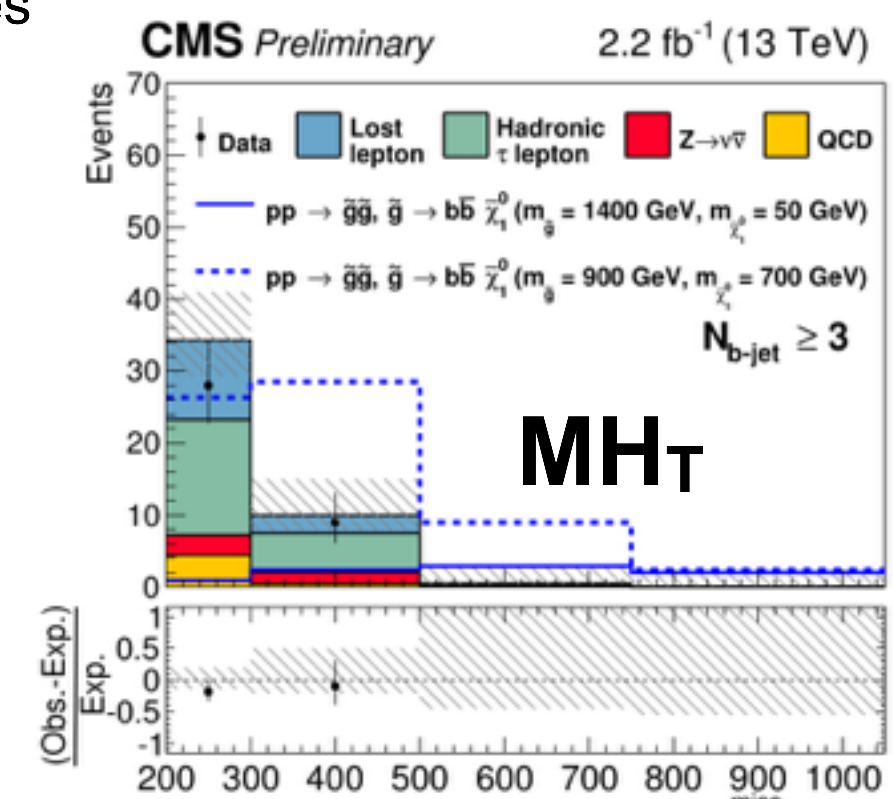
Upper Limits are placed for strongly produced gluino pairs which has the largest boost in xsec increasing the sqrt(s)

Fully Hadronic Searches

Signal Regions for each Search:

- **α_T** is a variable designed to be highly correlated with jet energy mis-measurements to give strong rejection power against the QCD bkg
- **MH_T** is the momentum imbalance from jets: **MH_T** >200GeV suppresses some QCD jets along with a cut on the azimuthal distance between the jet and the Missing Energy.
- **MT_2** was designed to measure the mass of pair produced SUSY particles. **MT_2**> 200GeV also suppresses QCD multi-jets and also processes with lower missing energy

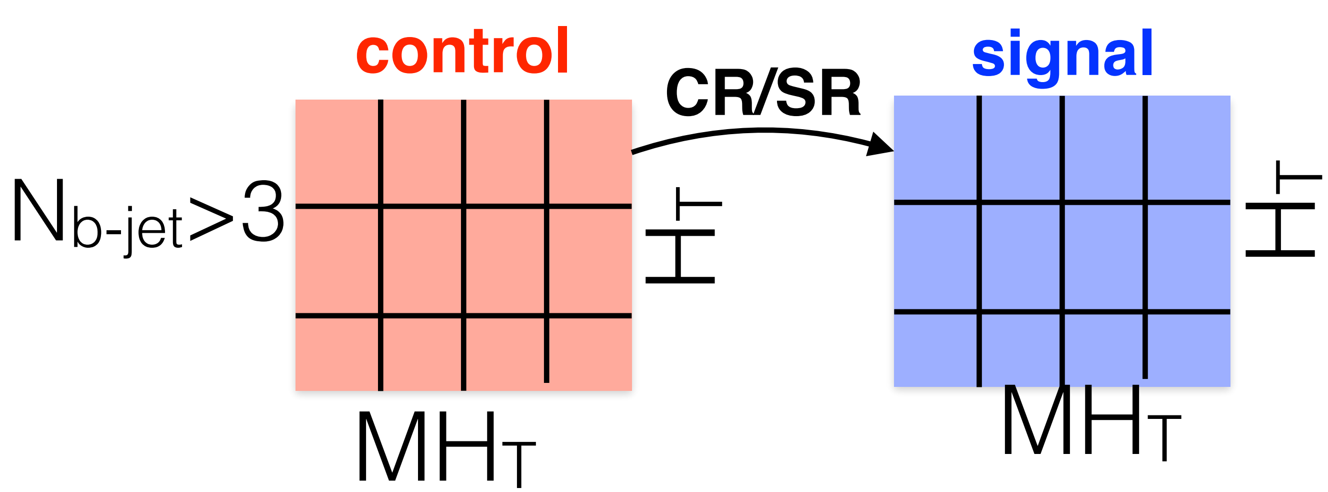




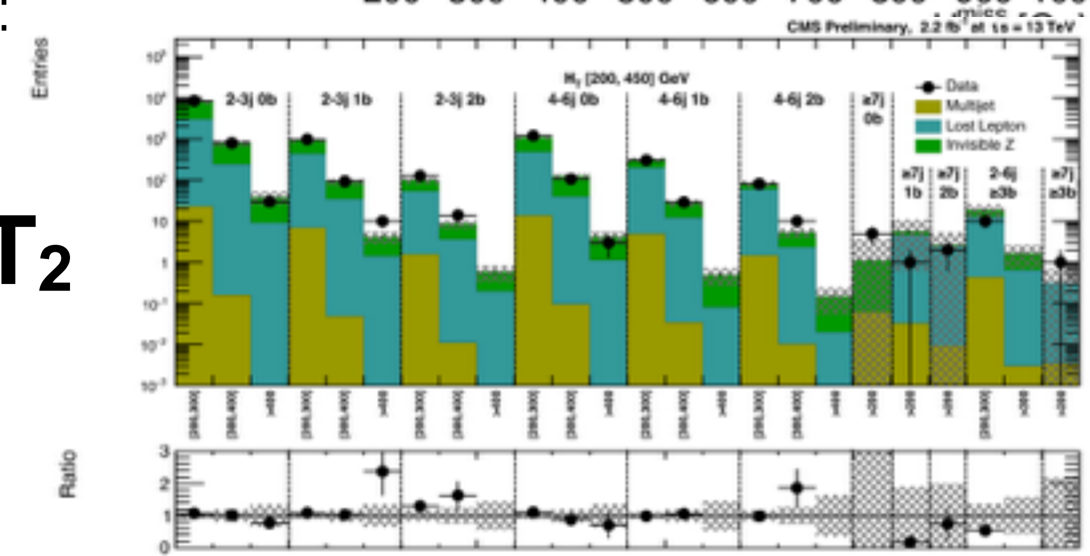
To Maximize Sensitivity:

The signal region is categorized in jet multiplicity, b-quark multiplicity, and Sum (scalar jet pT) HT

Bkg is measured in bins of signal topology e.g:



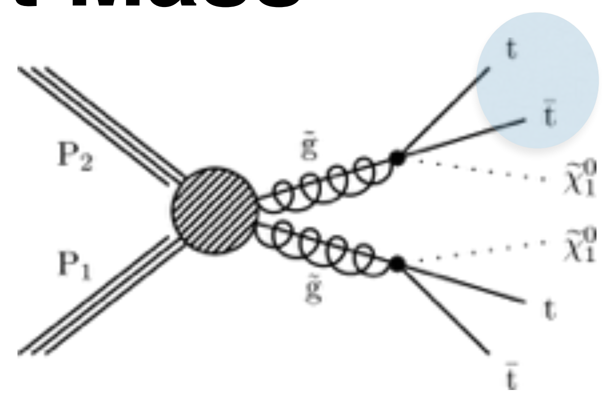
MT_2

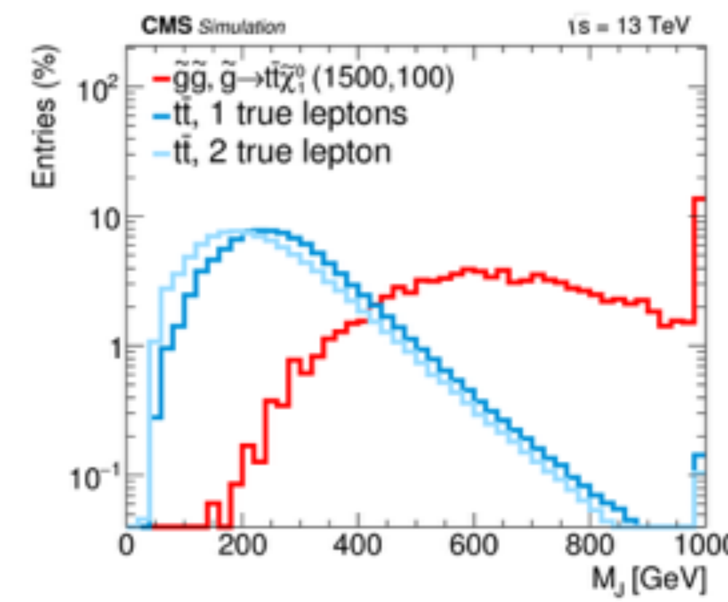


Inclusive Searches With A Lepton

Sum Jet Mass

- Cluster jets in a large cone compute the jet mass. Sum the jet masses. Gives strong discrimination from top-production backgrounds.

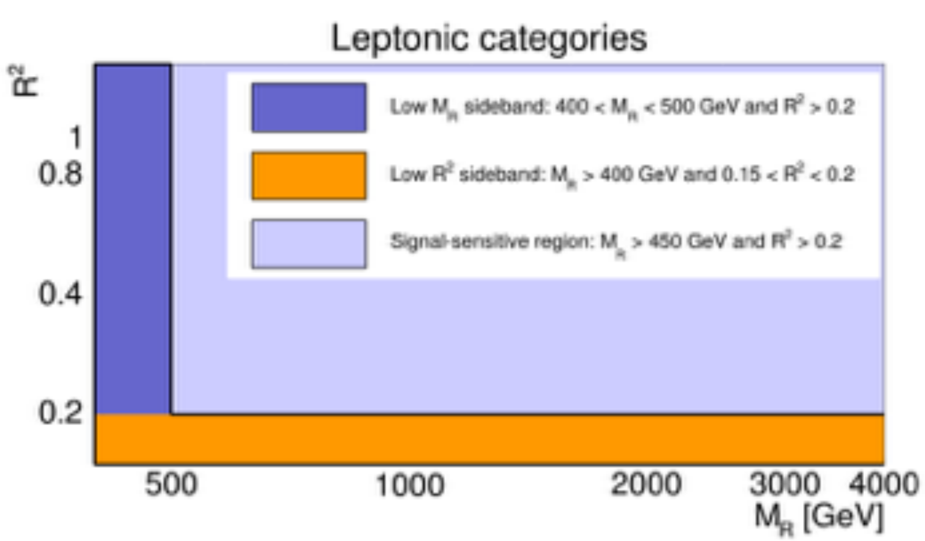


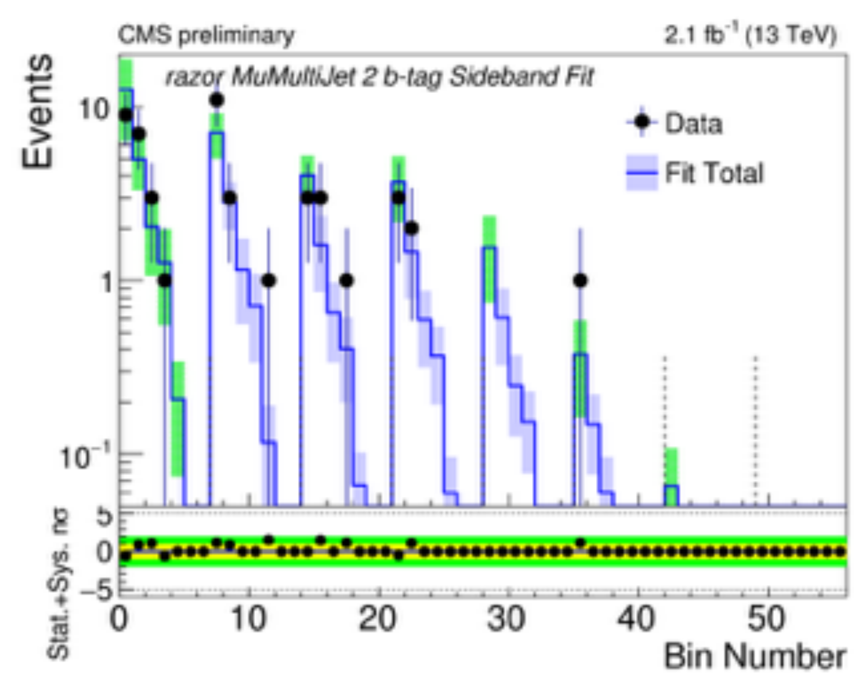


- Jet mass and transverse mass of the lepton is uncorrelated so the background can be measured by extrapolating from two side band regions

RAZOR

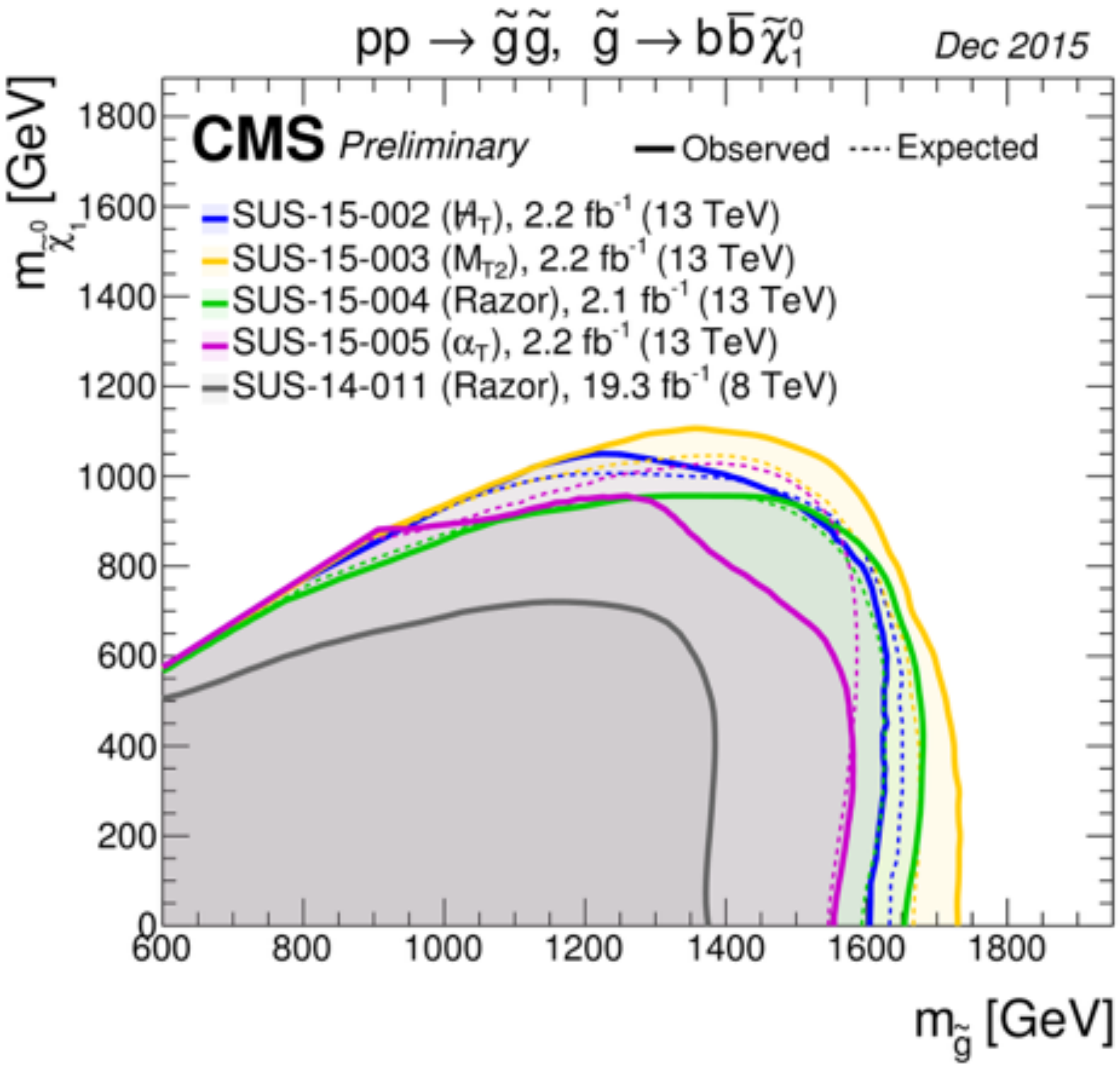
- Performs a 2D Likelihood fit for fully hadronic events and single lepton events with jets

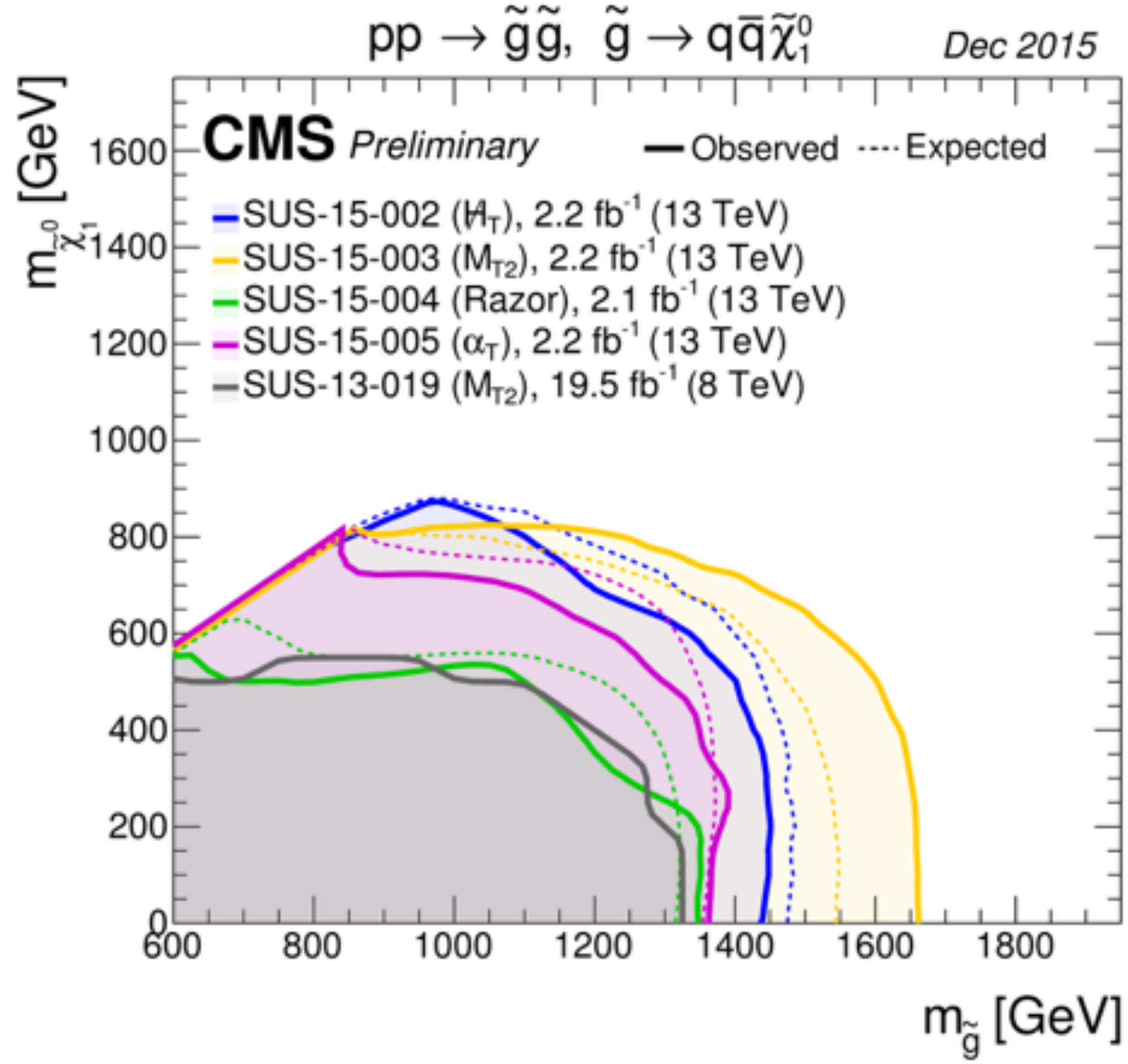




Fully Hadronic Search Results

No Sign of New Physics **Yet**

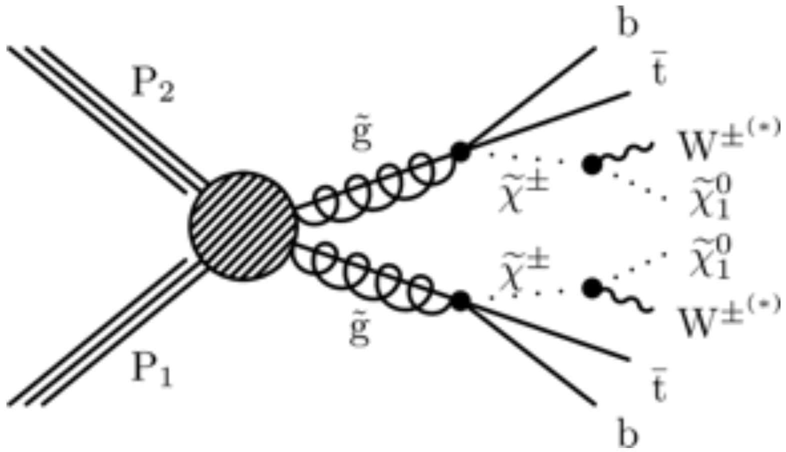


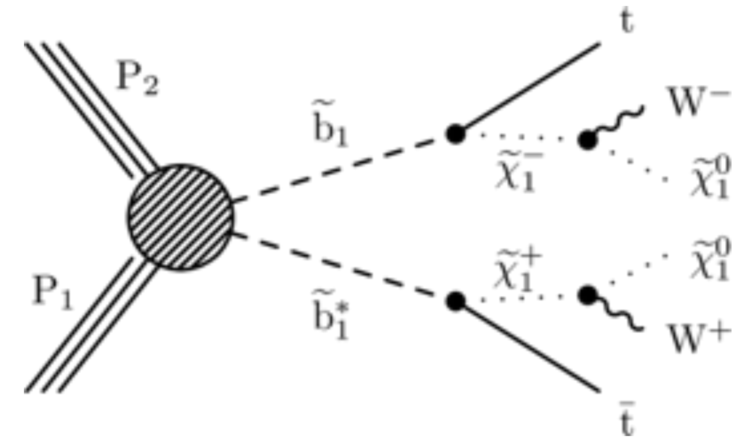


- Exclusion extends out to 1.7 TeV Gluino masses for Neutralino masses below 600 GeV for the heavy flavor decay chain
- Light flavor decay chain extends out 1625 GeV for Neutralino masses below 500 GeV

Same-sign Dilepton Searches

Broad range of Signatures: W's and tops can give SS letpon final states

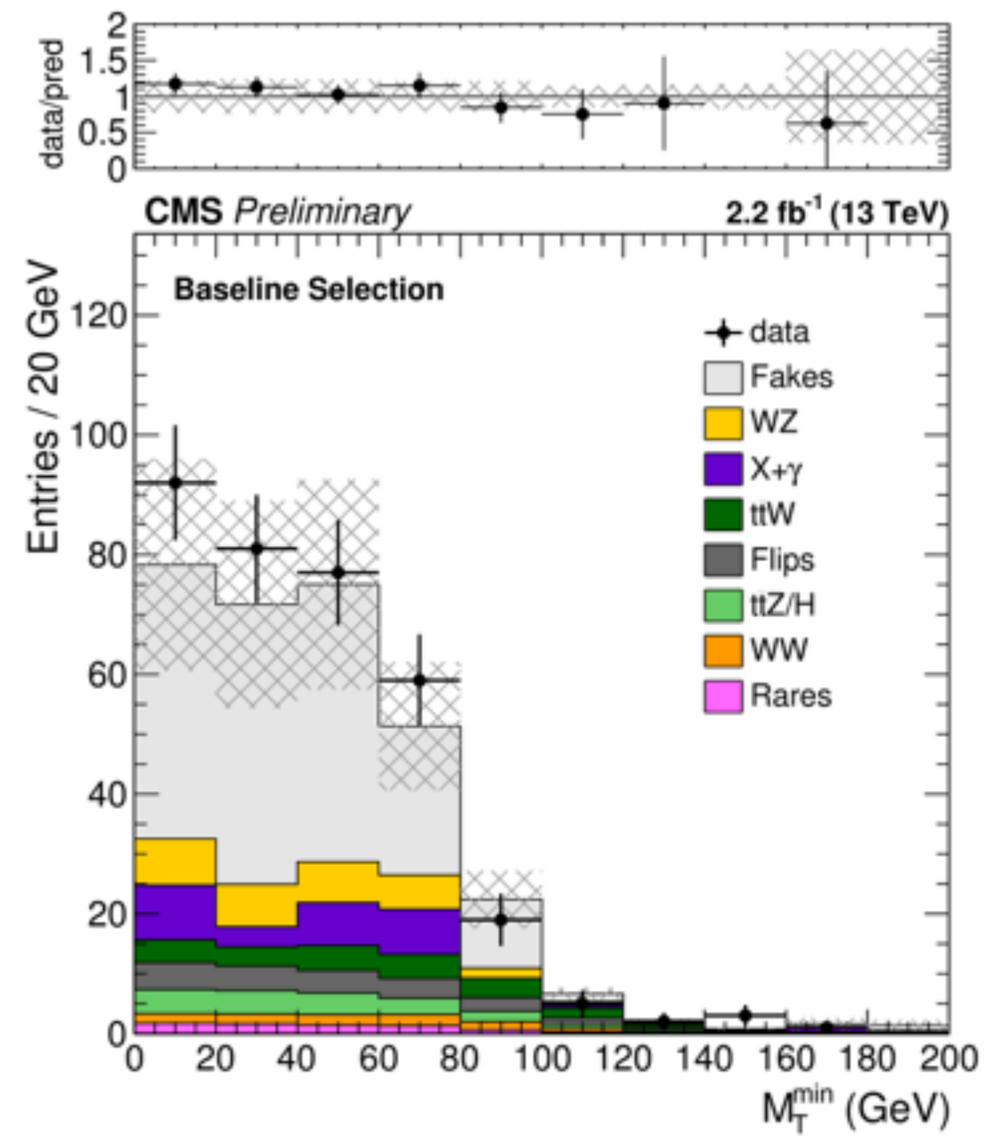




Main Backgrounds:

- SM processes with SS dileptons have relatively low cross-sections: WZ, ttW
- Non-prompt leptons (from mesons), mis-identified hadrons, electrons from photon conversions
  - These are measured in a QCD rich region with single leptons using the ratio of leptons passing a tight selection to those that pass a loose one
- Charge misidentification in opposite sign dileptons

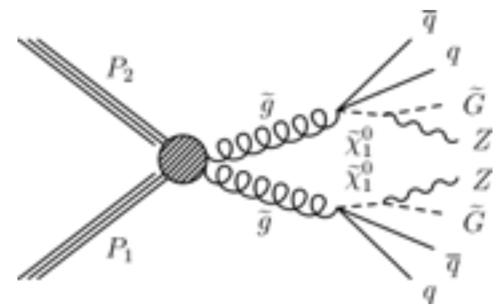
5D Search Region : MET, HT, b-tags, NJets, mT



Opposite-sign Dilepton Searches

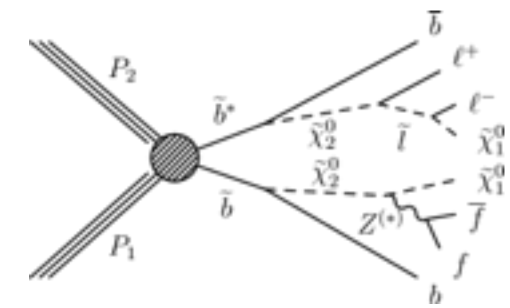
- 8TeV results:
  - CMS observed a 2.6σ excess in the off-shell Z edge search
  - Atlas observed 3.0σ in the on-shell Z region
    - (CMS added this signal region to cross-check)

On-shell Z



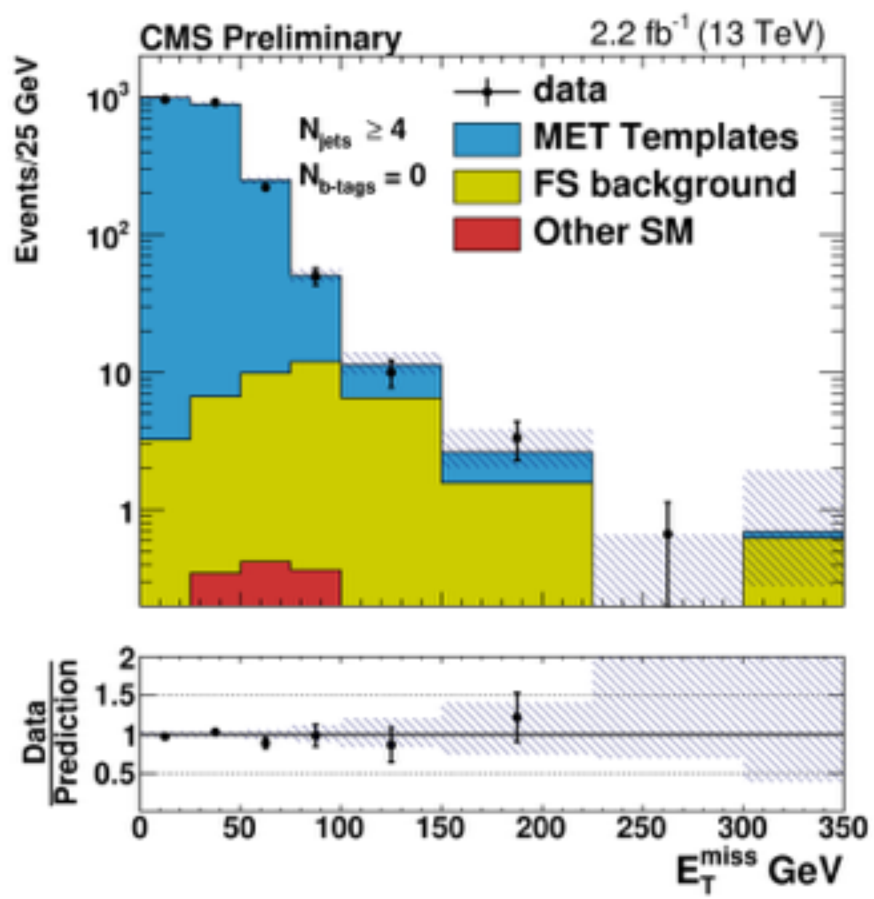
- expect an excess of events compatible with the Z-mass

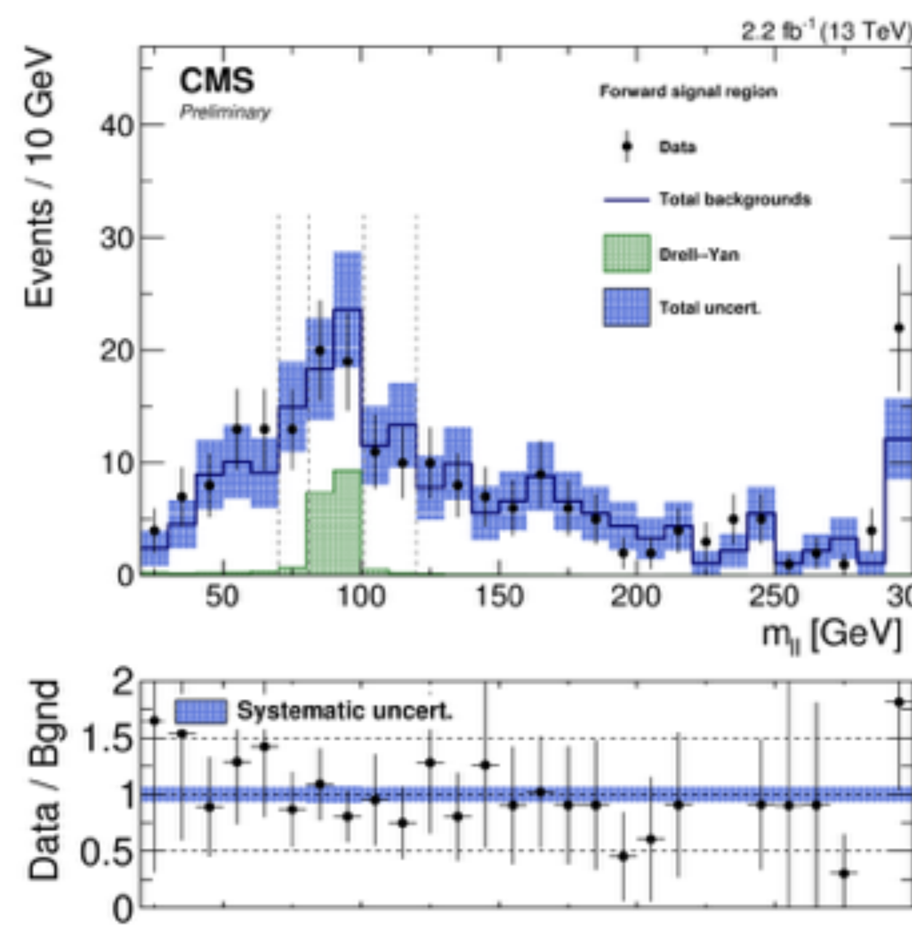
Off-shell Z



- Produces a kinematic edge in di-lepton mass

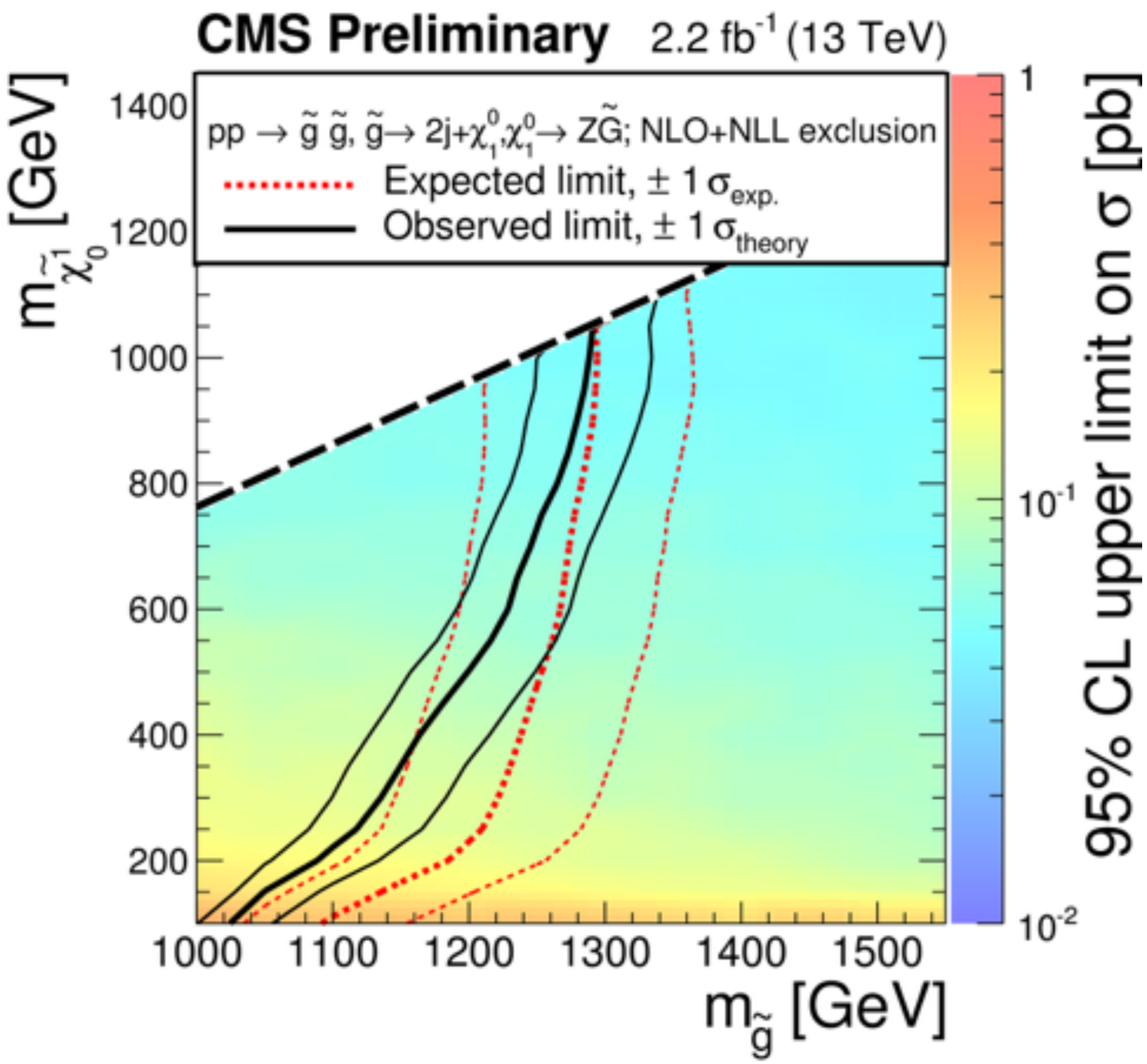
- The most current CMS results disfavor the signal hypothesis, data is consistent with the backgrounds



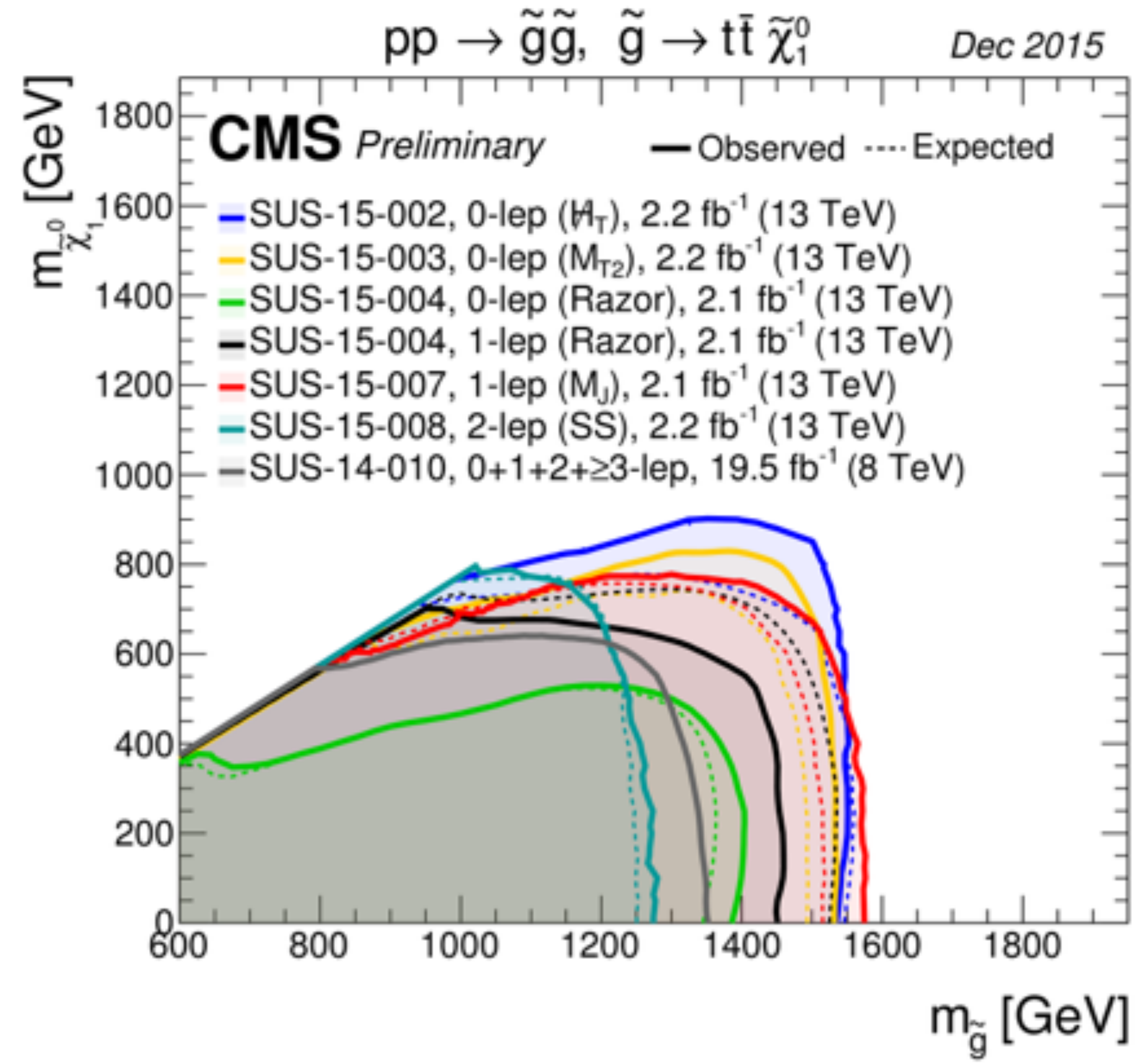


Inclusive Results

No Sign of New Physics **Yet**



- The on Z-search excludes up to 1250 GeV gluino masses for large neutralino mass



- Exclusion extends out to just below 1.6 TeV Gluino masses for Neutralino masses below 600 GeV

Summary

- No SUSY YET

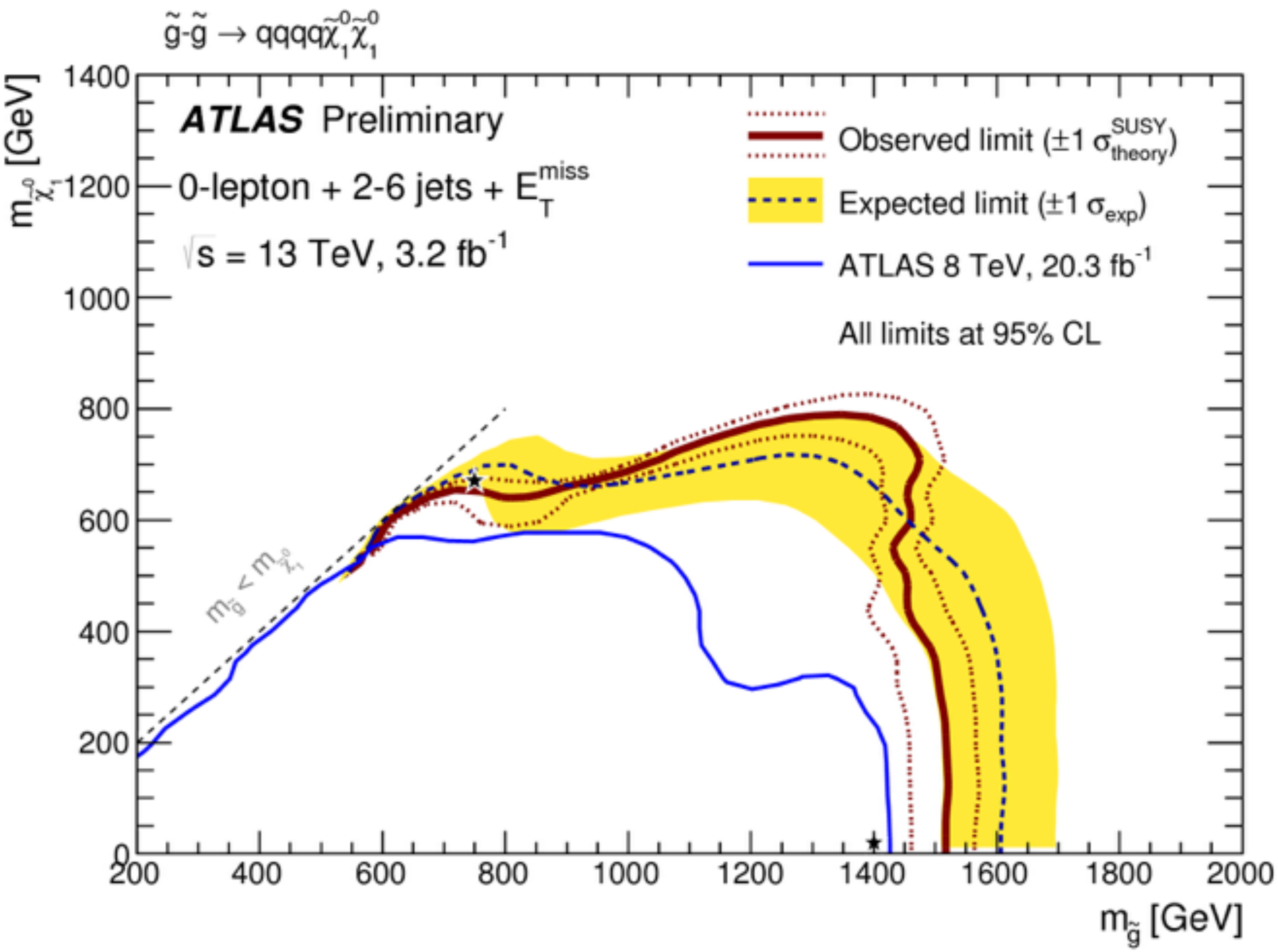
- CMS Searches for SUSY cover a vast amount of phase space
  - Many final states: Jets, b-quark multiplicity, missing energy, single leptons, di-leptons

"We still haven't found your pants, sir."

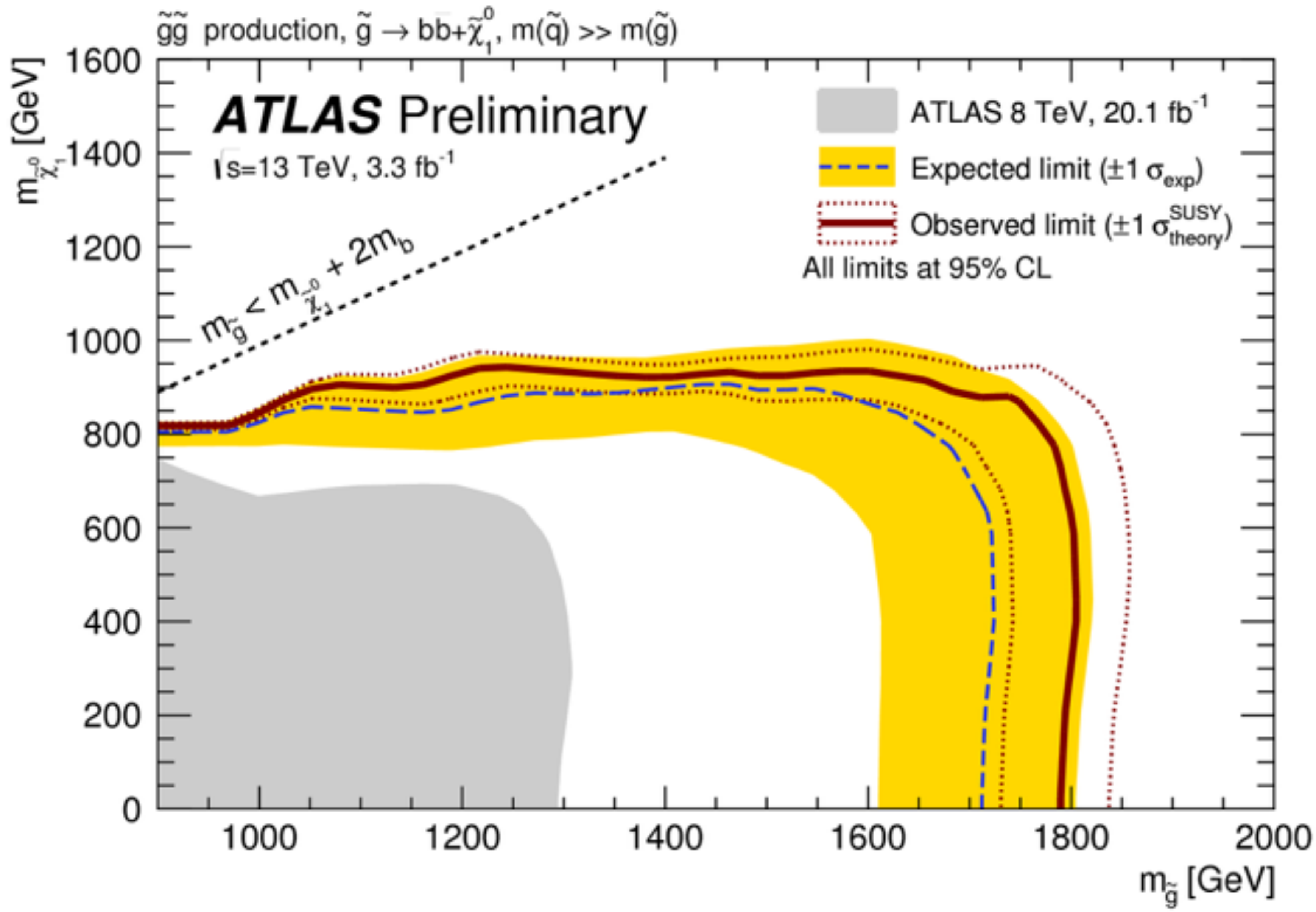
- A large part of the phase space for gluino-pair production is excluded with 2.2/fb of data
  - The full combination of 8TeV results excluded up to 1350GeV Gluino mass
  - Analyses with 13TeV exclude up to 1625 to 1700 GeV

ATLAS PLOTS FOR COMPARISON

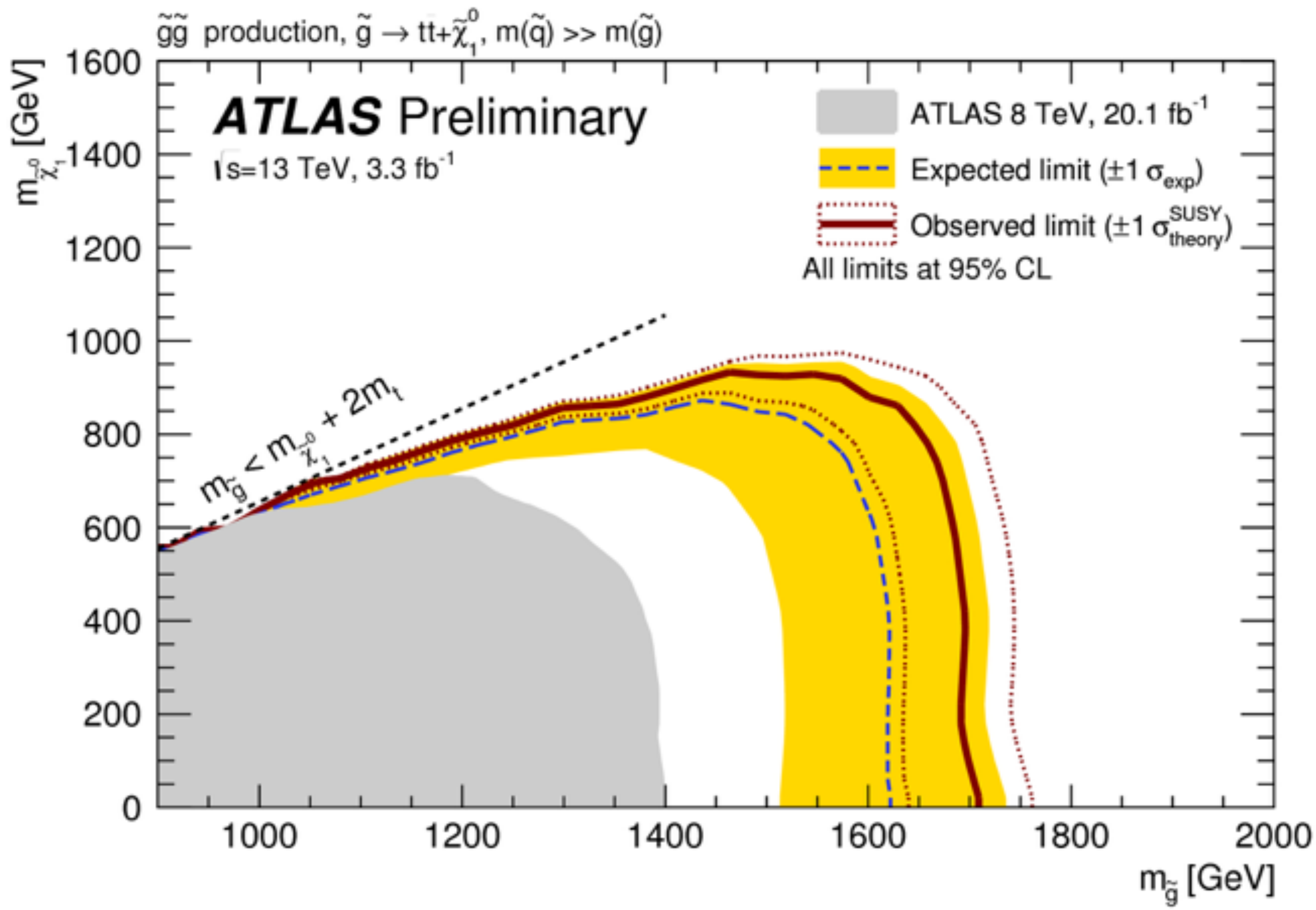
Cascade to Light quarks



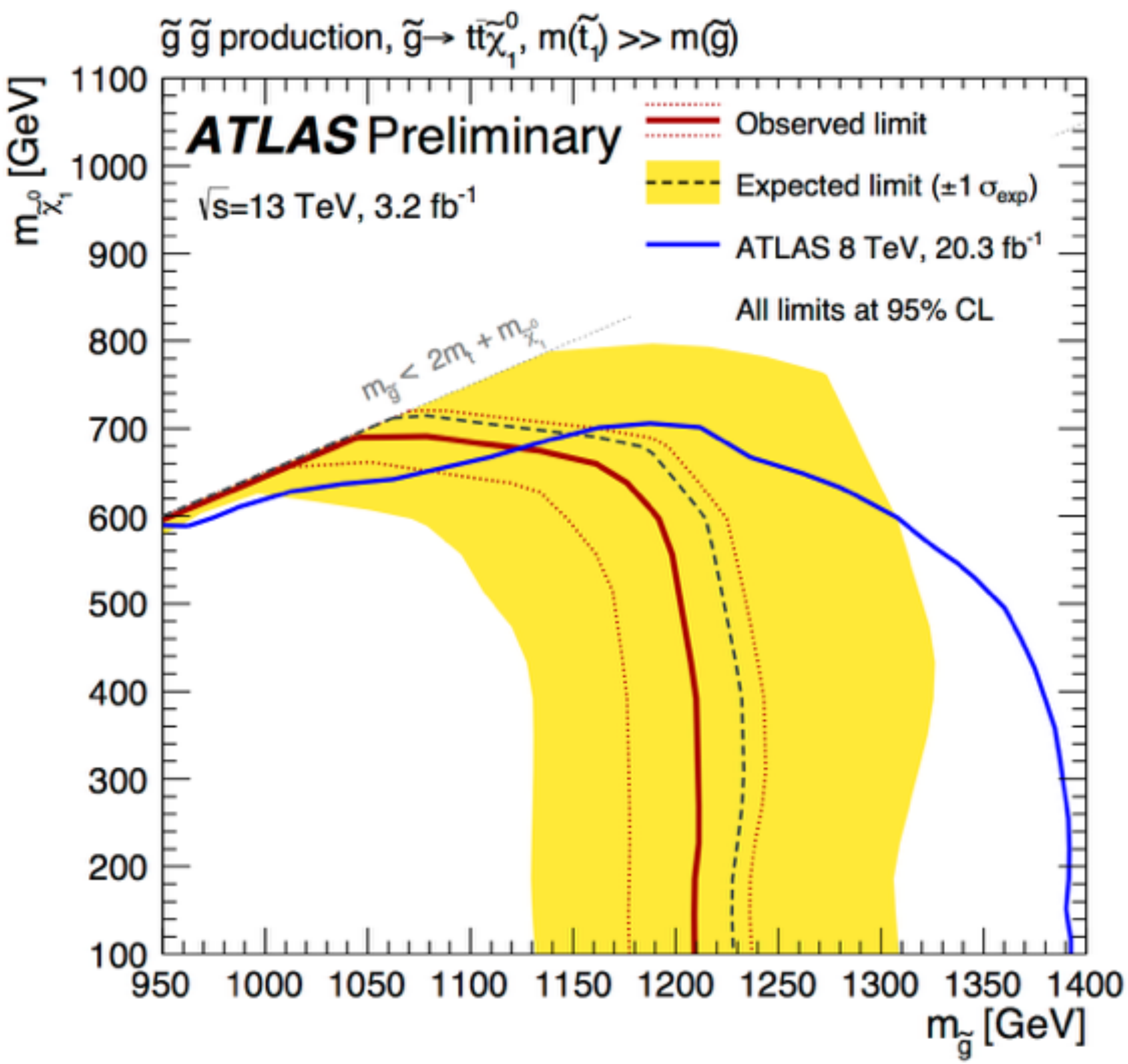
Cascade to b-quarks



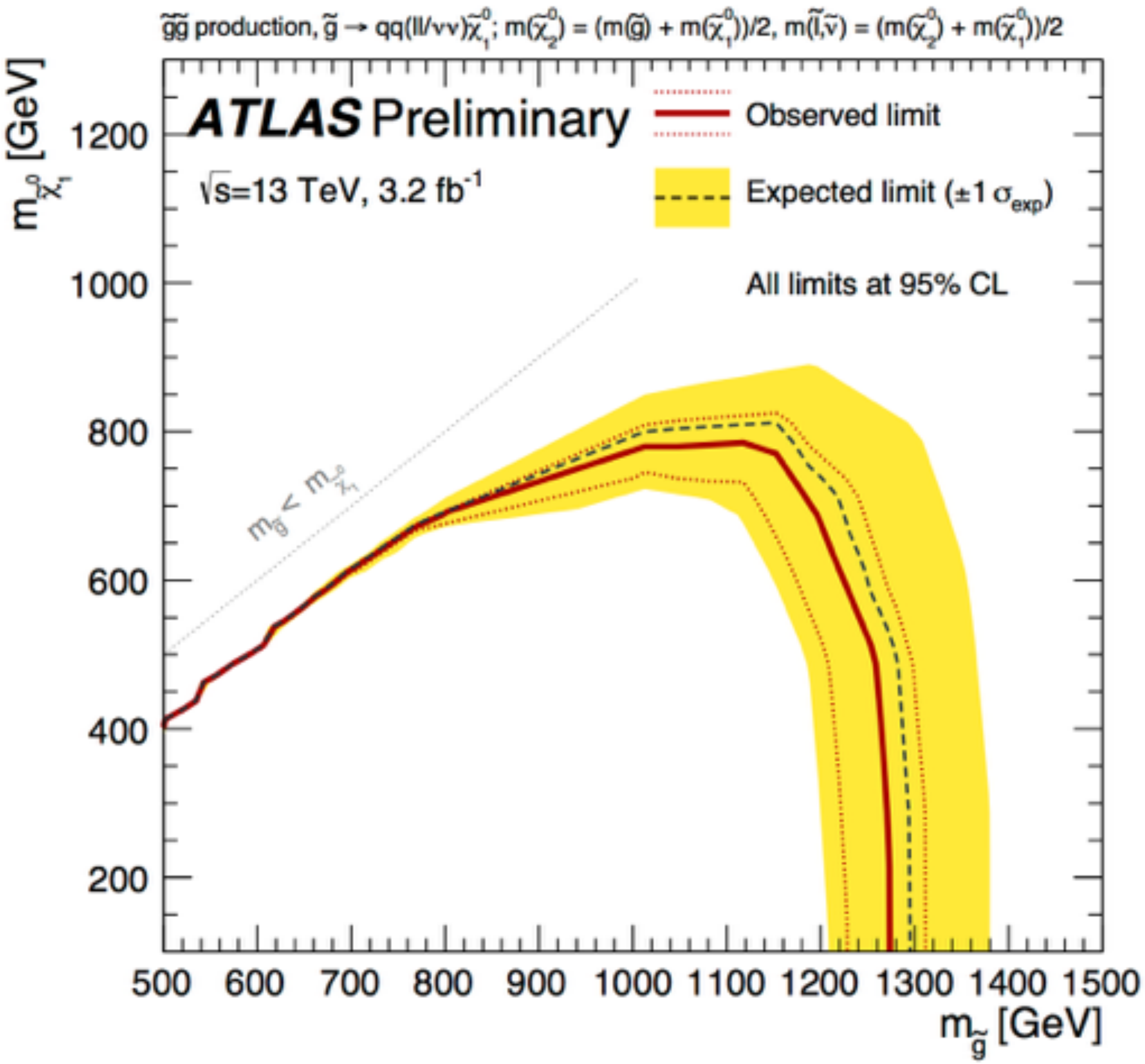
Cascade to t-quarks



Same Sign Di-leptons: top-quarks



Same Sign Di-leptons: W bosons



Opposite Sign Di-leptons