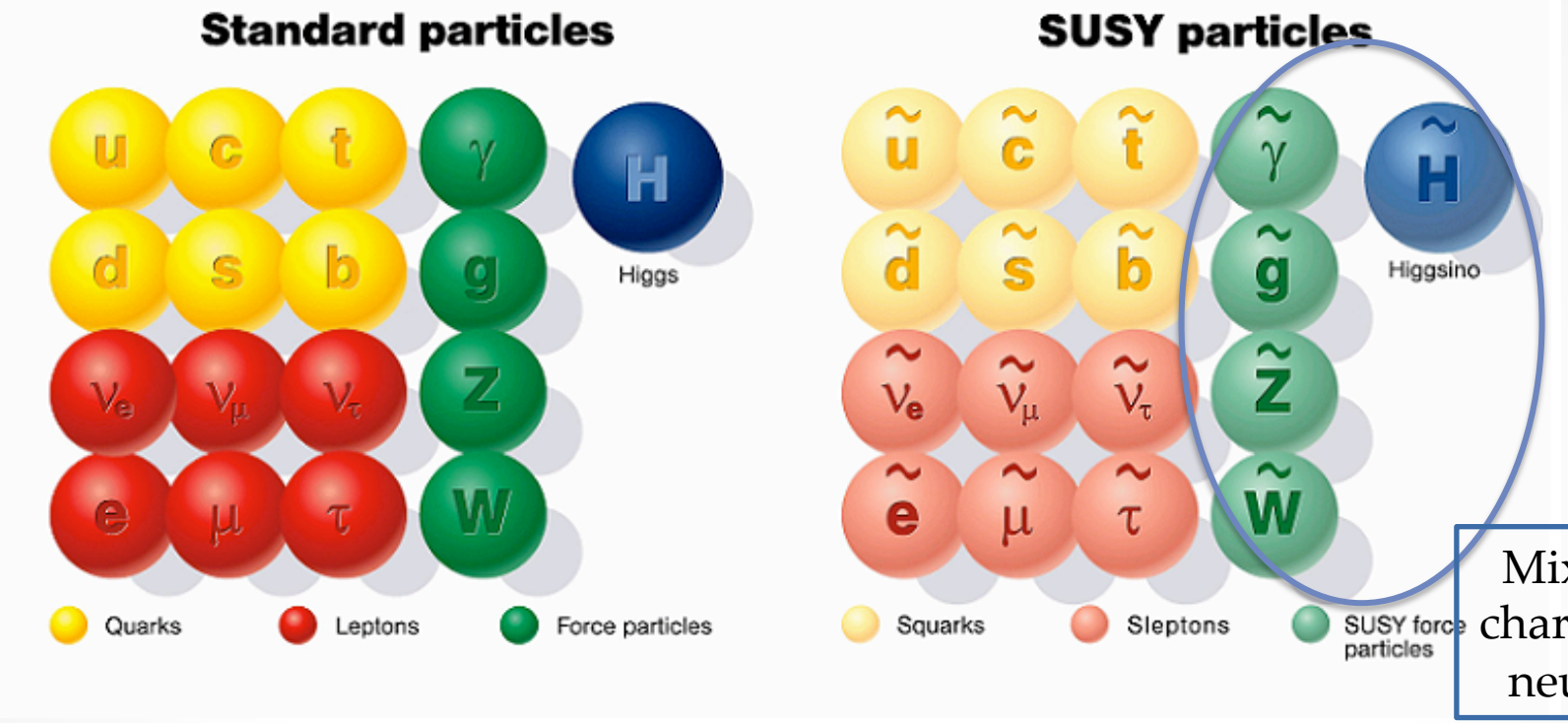
3rd Generation SUSY Searches at CMS

Daryl Hare, Fermilab
On behalf of the CMS Collaboration

Outline

- SUSY in 30 seconds
- Why do we care about 3rd Gen?
- Recent Publications:
  - Inclusive Search in Hadronic Final States using MT2 (arXiv: 1502.04358)
  - Razor Variables in Events with B-tagged Jets (arXiv:1502.00300)
  - Search with b Jets Plus 4 W Bosons (arXiv:1412.4109)
- Conclusions

SUSY Overview



Mix to form charginos and neutralinos

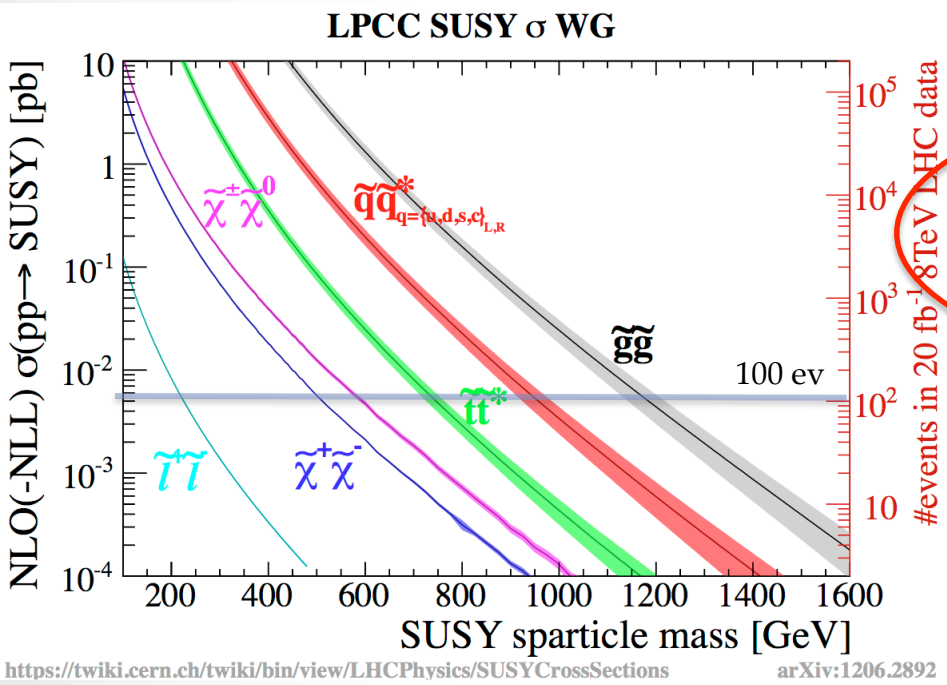
- Spin based symmetry relating fermions and bosons

SM fermions ⟷ SUSY bosons → squarks and sleptons stop and sbottom

SM bosons ⟷ SUSY fermions → gluinos, charginos, and neutralinos

- Unification of forces at GUT scale

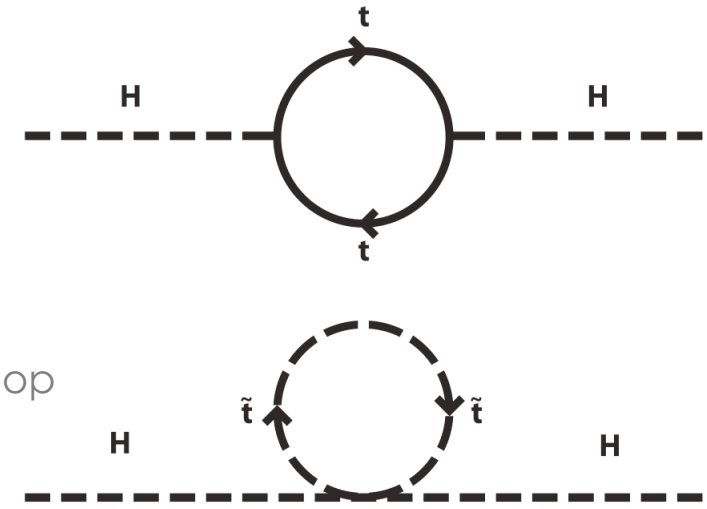
SUSY Production at LHC



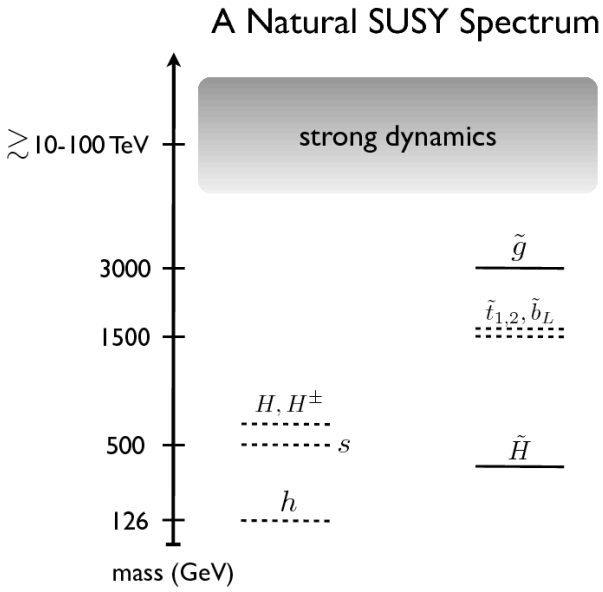
[arXiv 1206.2892]

- Gluinos, 1st and 2nd gen squarks have highest cross sections
- Third generation squarks
  - Must be light for naturalness
  - Highly motivated discovery potential from 125 GeV Higgs
- ElectroWeak production
  - Charginos, neutralinos, and sleptons
  - Small cross sections
  - Feasible discovery potential if squarks and gluinos are simply too heavy

Natural SUSY

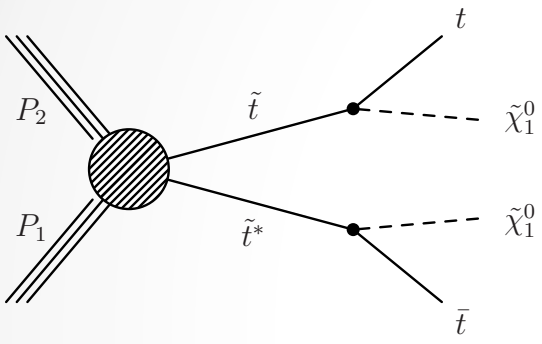


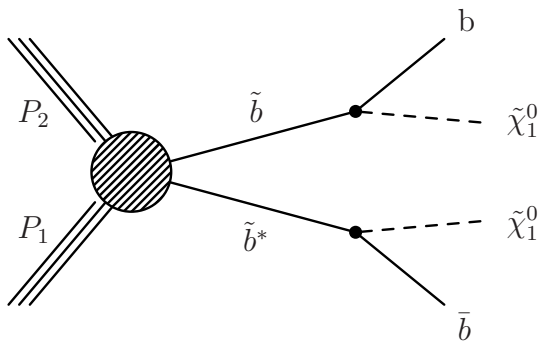
- Hierarchy problem
  - Unnatural cancelations to the Higg's mass loop corrections to get a low mass Higgs
- SUSY provides a natural cancellation **assuming** superpartner masses are not too large
  - SUSY is a broken symmetry
  - If this breaking is not "soft", large Higgs mass corrections terms are introduced
- Natural SUSY
  - 3rd Gen SUSY is O(TeV)
    - High Yukawa coupling means these provide most dangerous mass corrections
  - stop/sbottom produced directly or via light gluino
  - 1st/2nd generation squarks can still be very heavy
  - **Discovery of 125 GeV Higgs boson suggests Natural SUSY may be within our reach at the LHC**

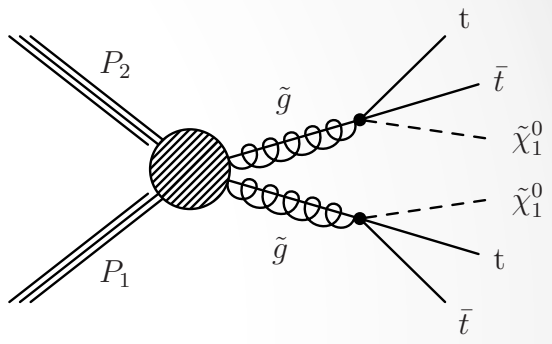


All Hadronic Inclusive Search

CMS Collaboration
arXiv: 1502.04358
19.5 fb^{-1}



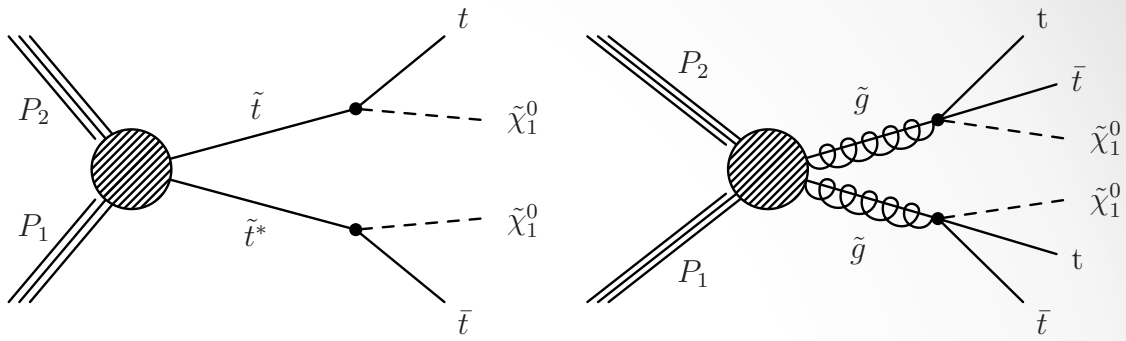




- Fully hadronic final state
- Require high Stransverse mass, M_{T2}, to discriminate signal
  - Stransverse mass – using visible objects and MET, recreate transverse mass of 2 parent particles
- This talk focusing on 3rd Generation Signatures
  - Inclusive search includes direct squark production, gluino pair production, and H->bb decay within the SUSY cascade decay

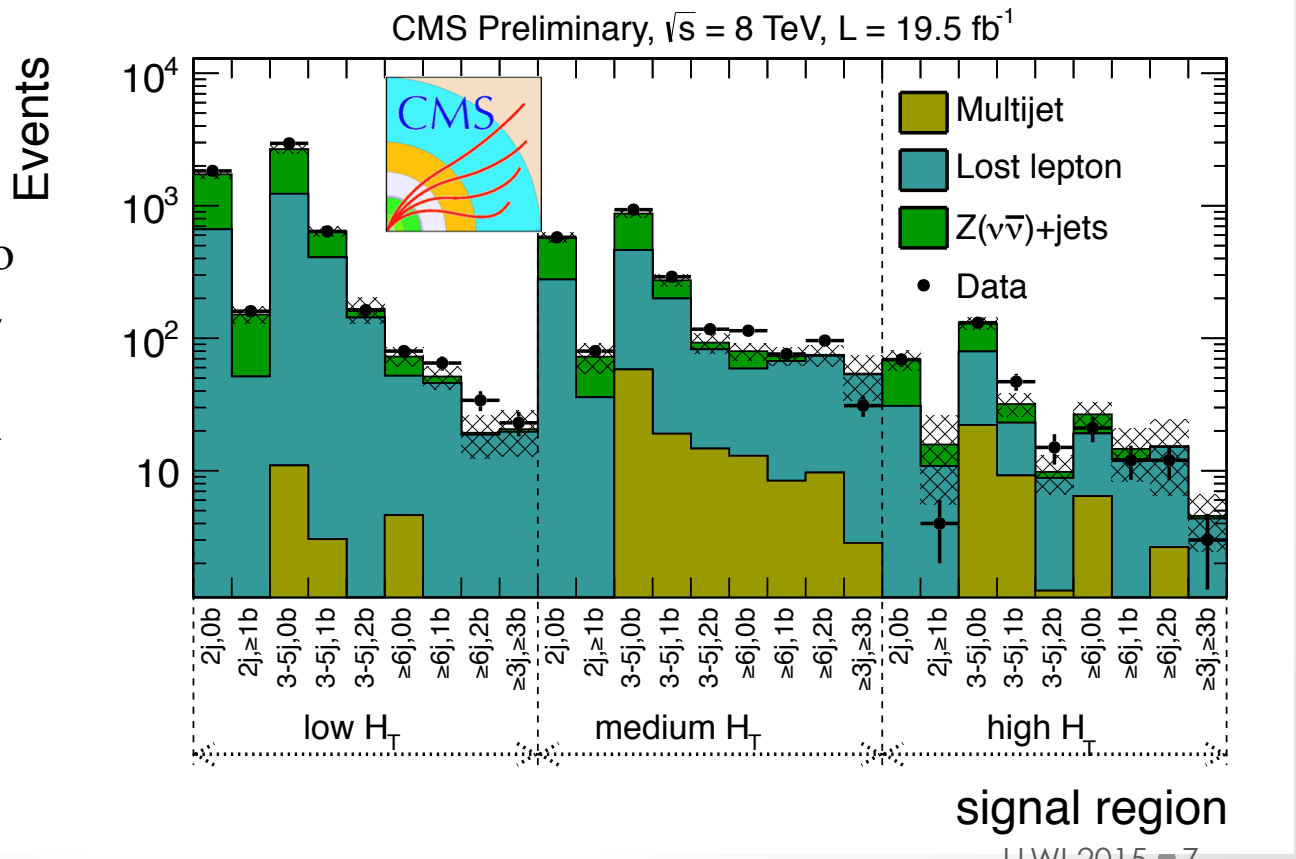
All Hadronic Inclusive Search

CMS Collaboration
arXiv: 1502.04358
19.5 fb^{-1}



RESULTS

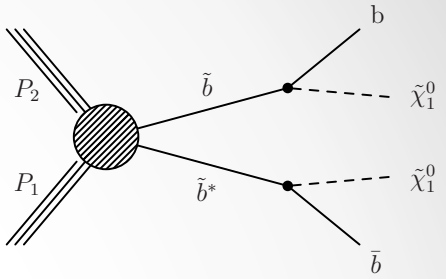
Inclusive searches tend to give multiple signal bins, each optimized for various simplified model



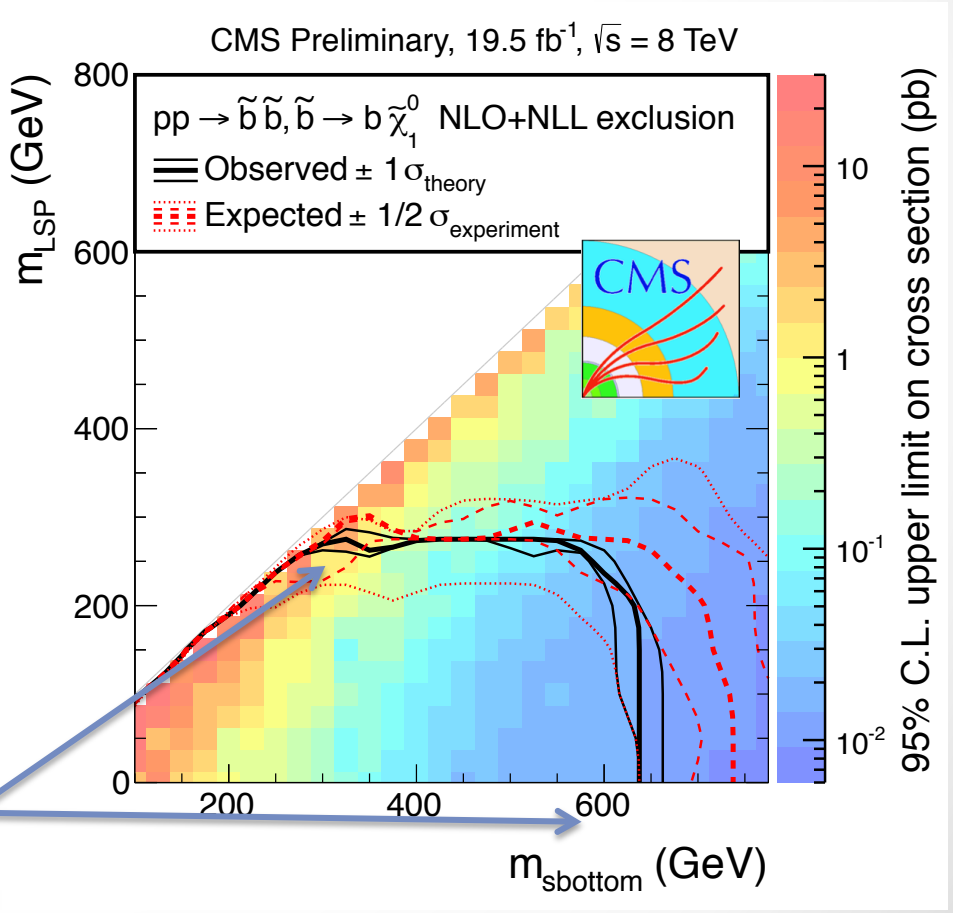
All Hadronic Inclusive Search

CMS Collaboration
arXiv: 1502.04358
19.5 fb^{-1}

Limits (Simplified Models):



- Simplifed Models
  - Assume limited new particles to produce topological signal
  - Shown as M_{LSP} vs M_{SUSY}
  - 95% CL upper limits shown
  - Usually assume 100% BR
  - Color map shows cross section limits
  - Diagonals show kinematic limits (usually assume on-shell production)

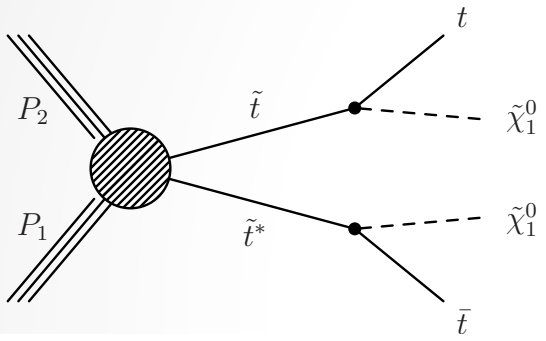


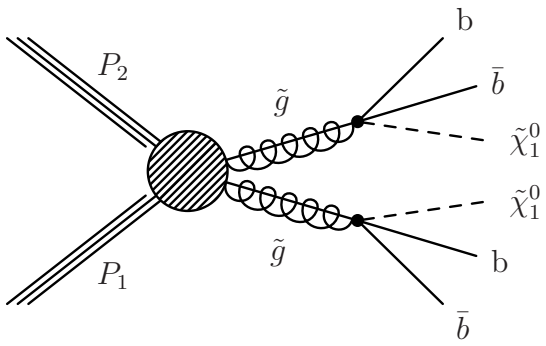
Exclusion up to:
M_{squark} < ~600 GeV
M_{LSP} < ~300 GeV

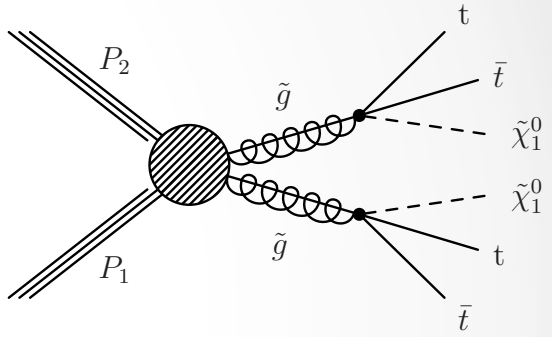
All Hadronic Inclusive Search

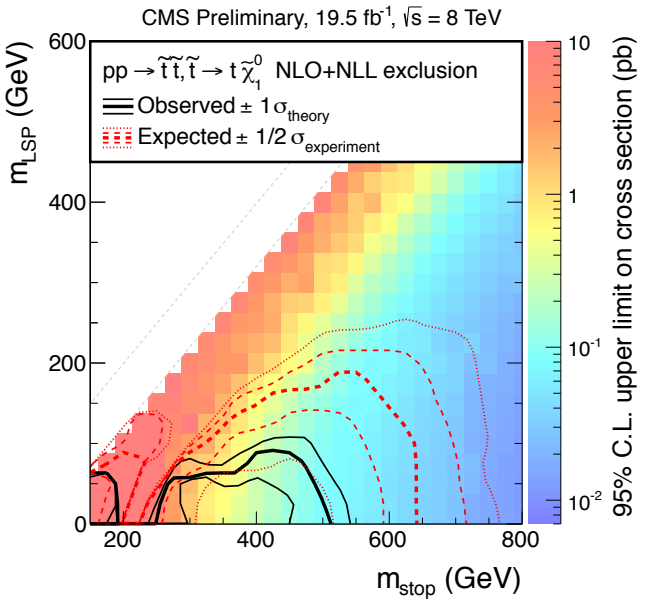
CMS Collaboration
arXiv: 1502.04358
19.5 fb^{-1}

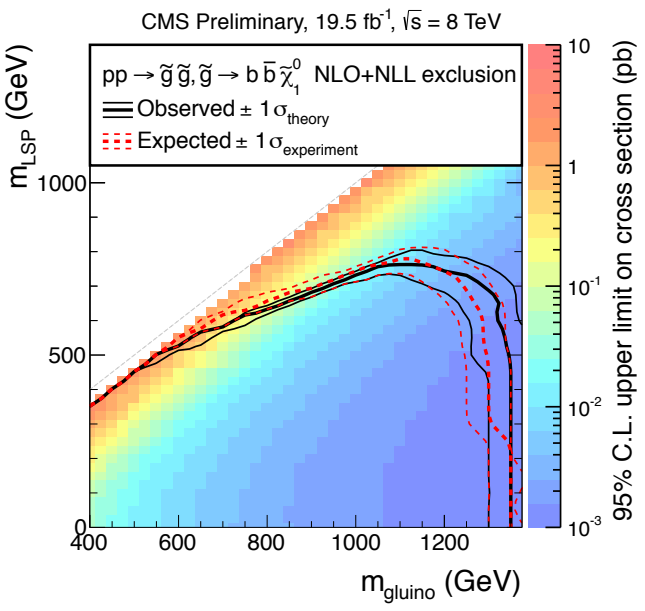
Limits: Simplified Models

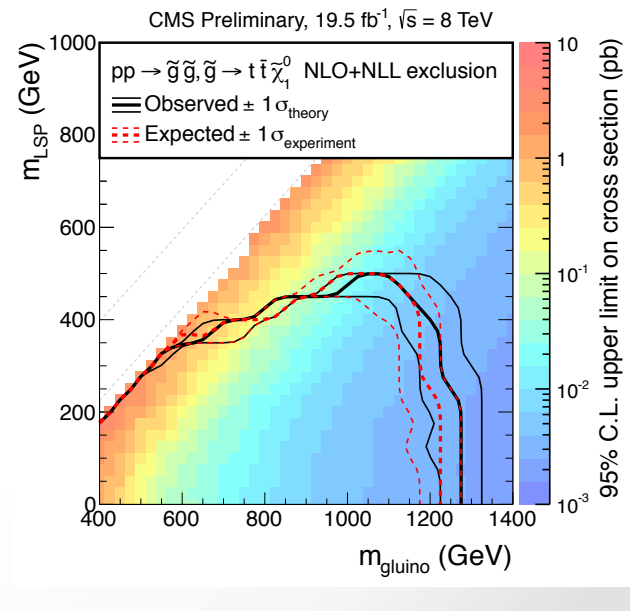


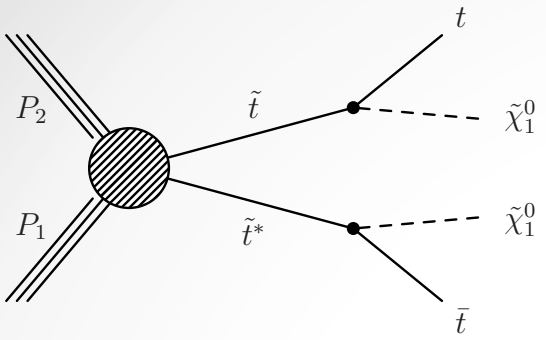












CMS collaboration
arXiv 1502.00300
19.3 fb^{-1}

Razor with b's

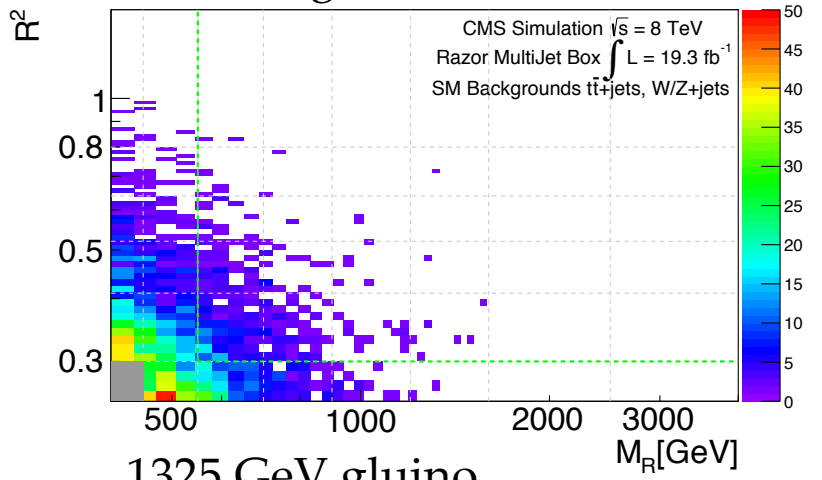
- Razor variables designed to ID two squarks which each decay to a quark and a stable neutralino
- Event is classified into two megajets
  - Chosen to minimize the invariant mass of the megajets summed in quadrature
- Look for a peaking signal in R^2 vs M_R

$$M_R = \sqrt{\left(\left|\vec{p}^{\,j_2}\right| + \left|\vec{p}^{\,j_2}\right|\right)^2 - \left(p_z^{j_1} + p_z^{j_2}\right)^2}$$

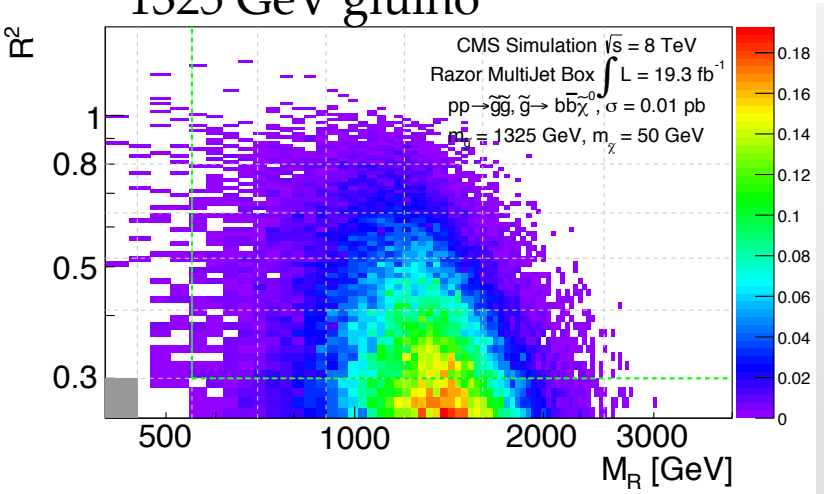
$$R = \frac{M_T^R}{M_R}$$

$$M_T^R = \sqrt{\frac{E_T^{miss}\left(p_T^{j_1} + p_T^{j_2}\right) - \vec{p}_T^{\,miss} \cdot \left(\vec{p}_T^{\,j_1} + \vec{p}_T^{\,j_2}\right)}{2}}$$

SM Background:



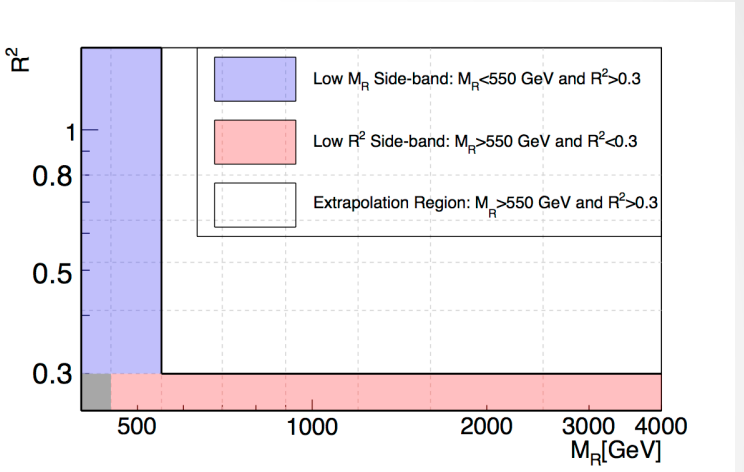
1325 GeV gluino

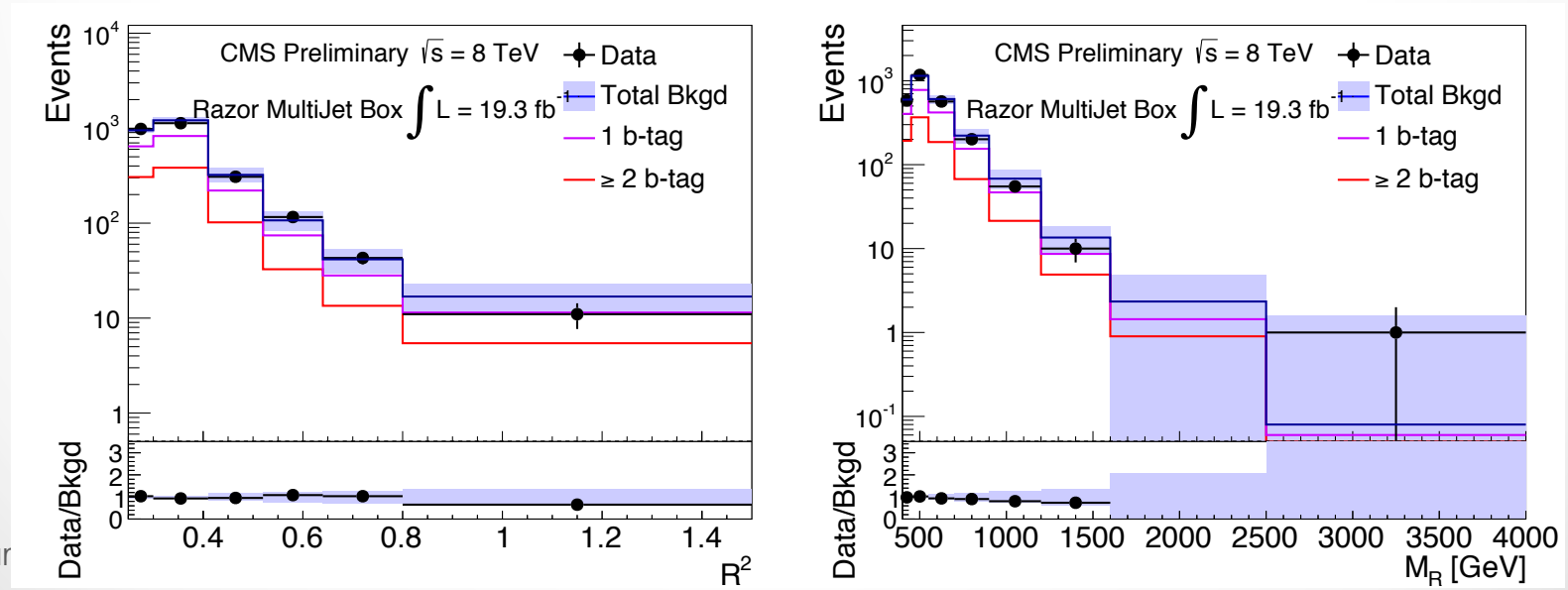


CMS collaboration
arXiv:1502.00300
19.3 fb^{-1}

Razor with b's

- Events sorted into exclusive signal boxes based on number of leptons and jets.
- Background estimated with a simultaneous fit of R^2 and M_R

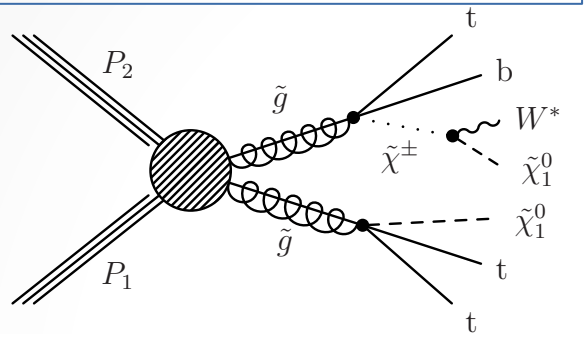


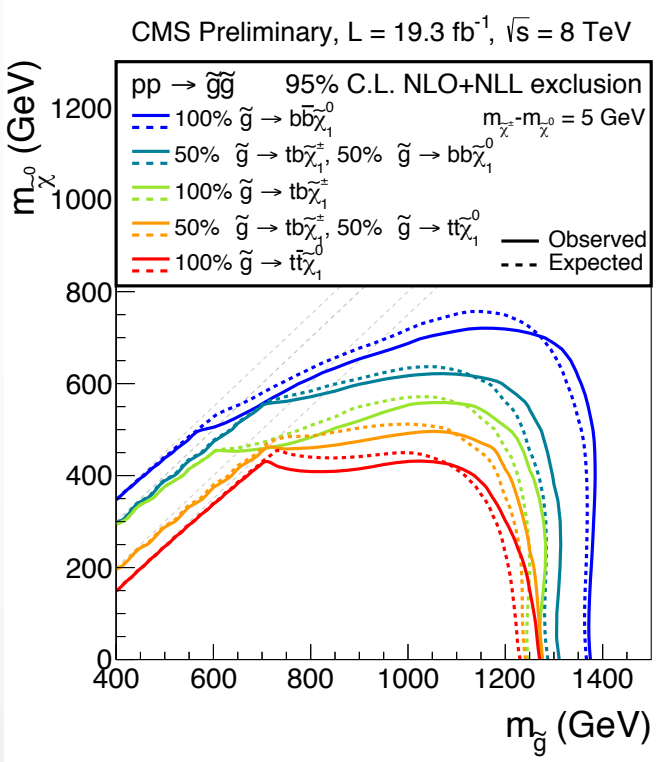


Razor with b's

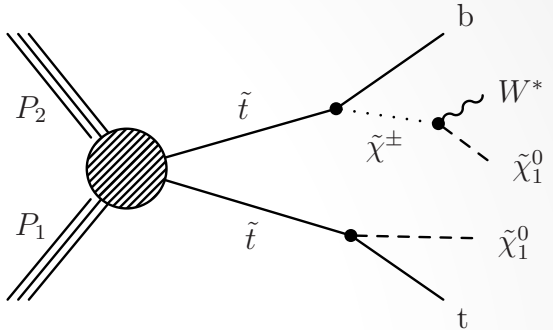
CMS collaboration
arXiv:1502.00300
19.3 fb^{-1}

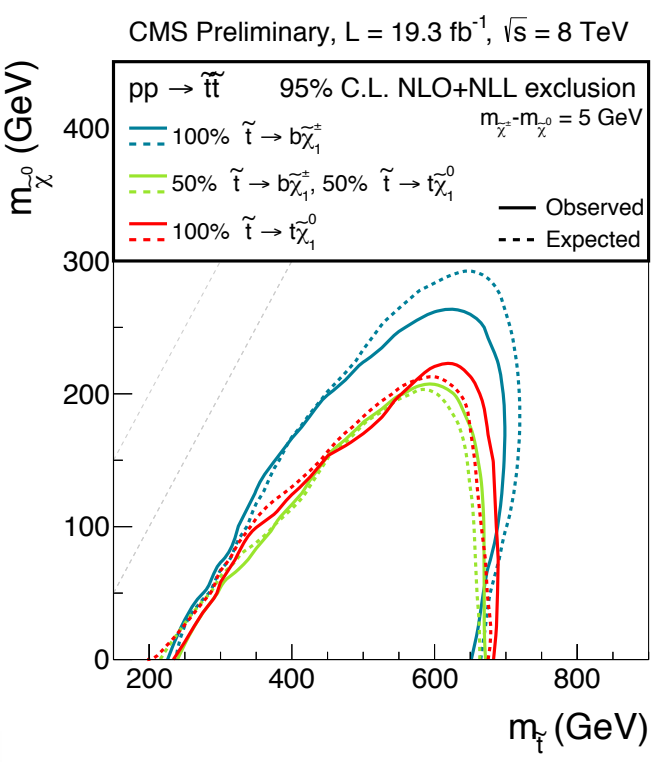
Gluino Mediated





Direct Production

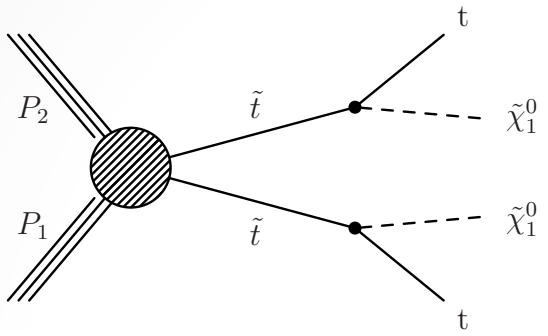


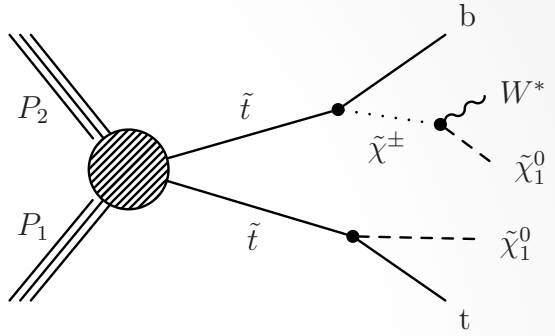


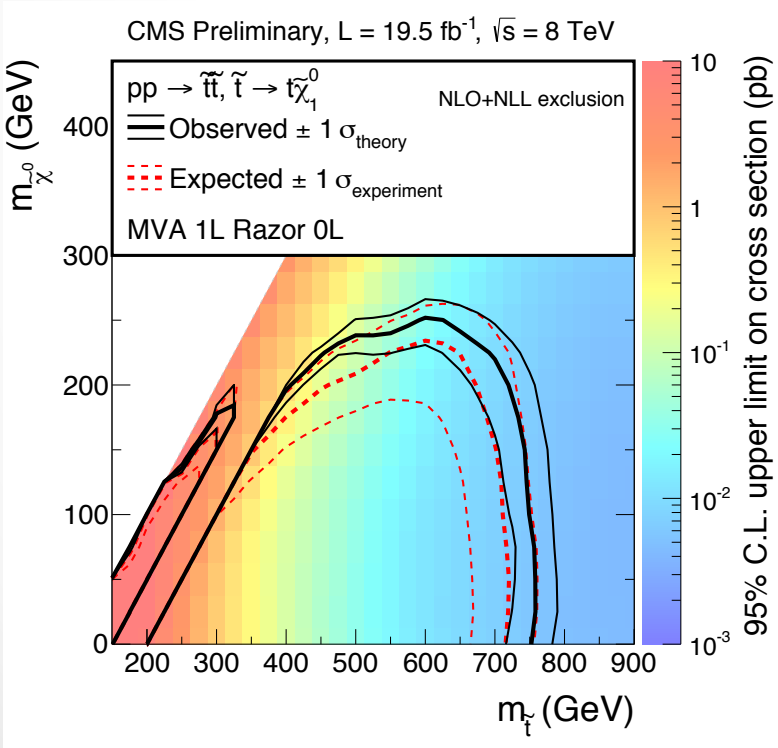
Razor with b's

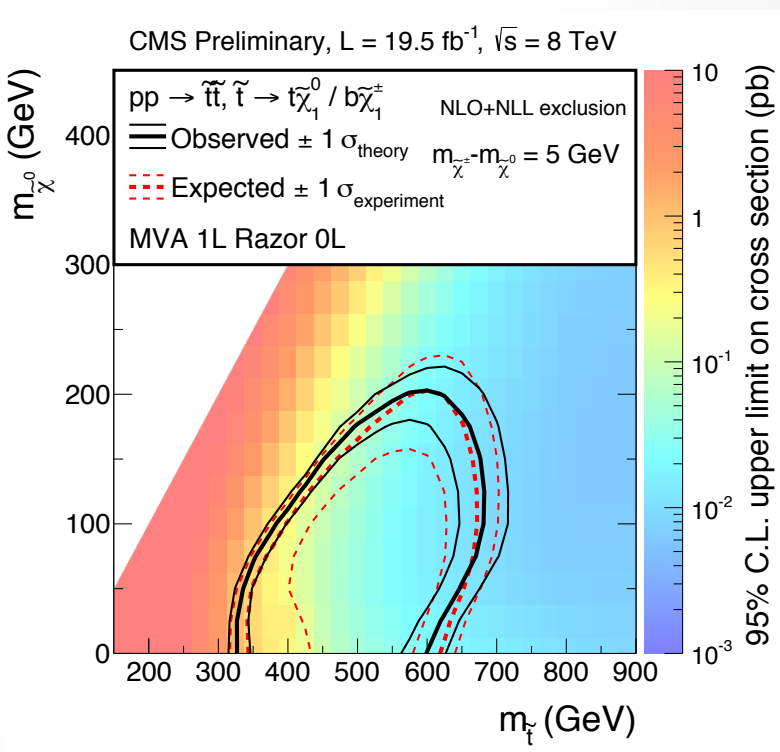
CMS collaboration
arXiv:1502.00300
19.3 fb^{-1}

Combining Razor 0l with exclusive MVA 1l analysis:







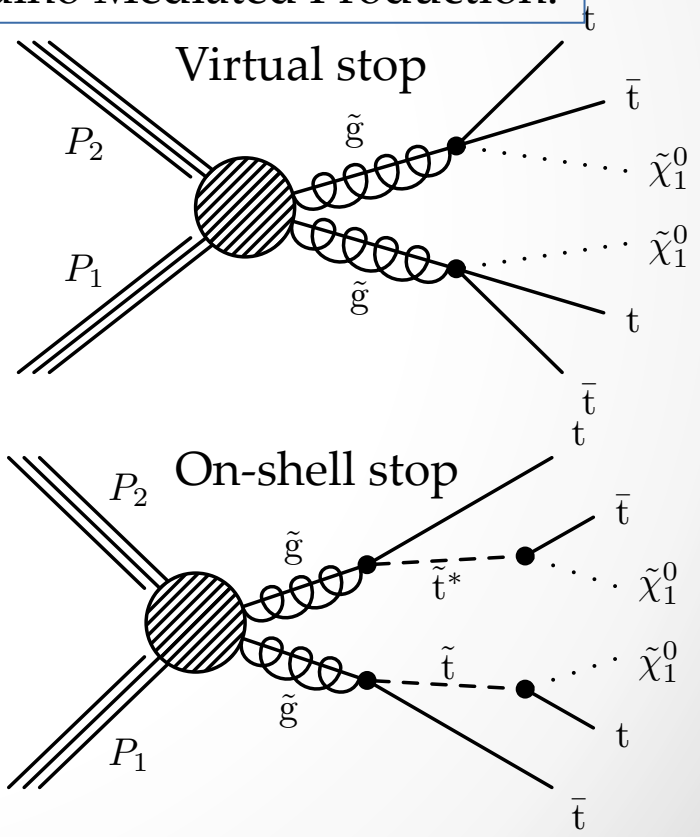


CMS Collaboration
arXiv:1412.4109
19.5 fb^{-1}

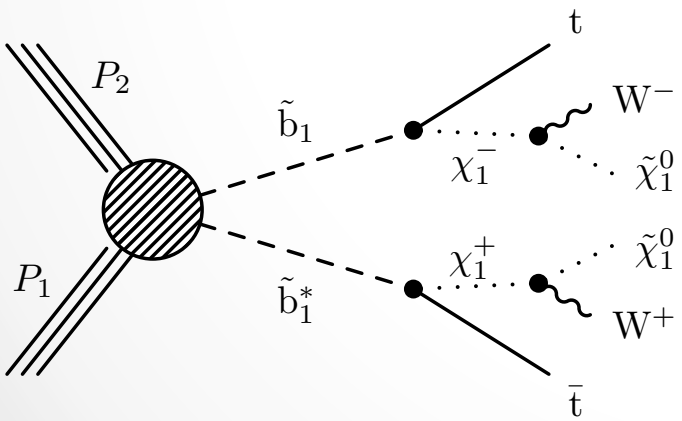
b Jets and 4 W's

- Combination of 5 individual searches categorized by leptonic content of event:
  - Fully Hadronic
  - Single-lepton
  - Same-sign dilepton
  - Opposite-sign dilepton
  - Multilepton

Gluino Mediated Production:



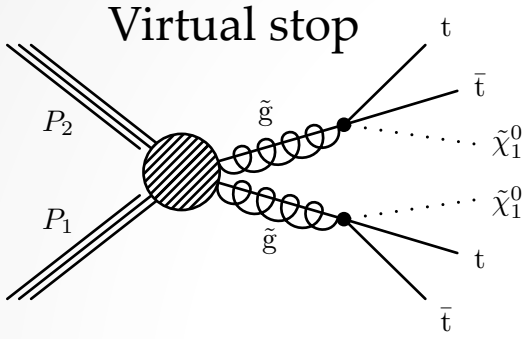
Sbottom Pair Production:



b Jets and 4 W's

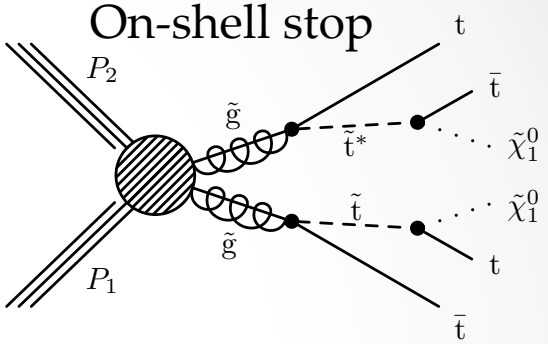
CMS Collaboration
arXiv:1412.4109
19.5 fb^{-1}

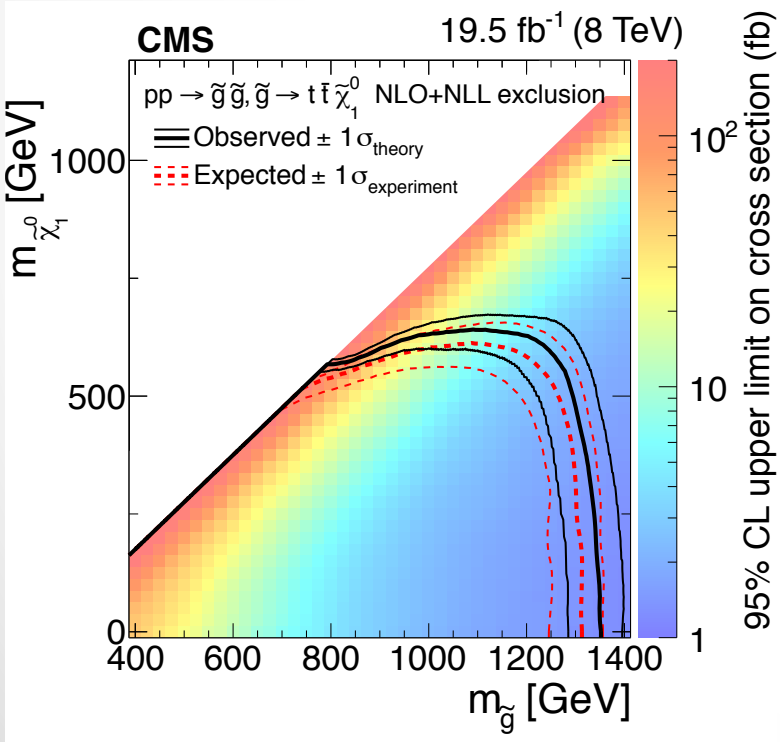
Virtual stop

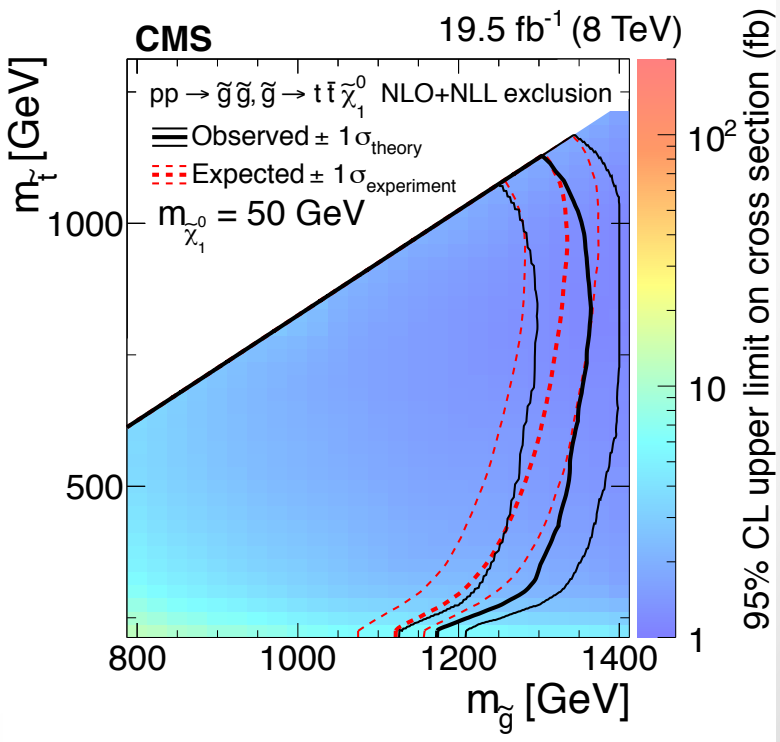


Gluino exclusion of 1280 GeV

On-shell stop



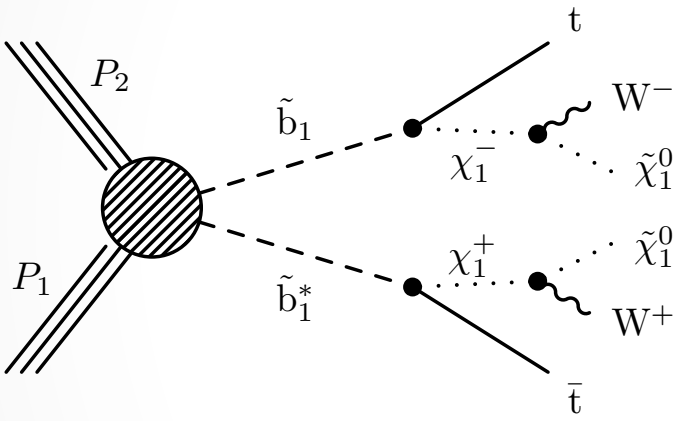




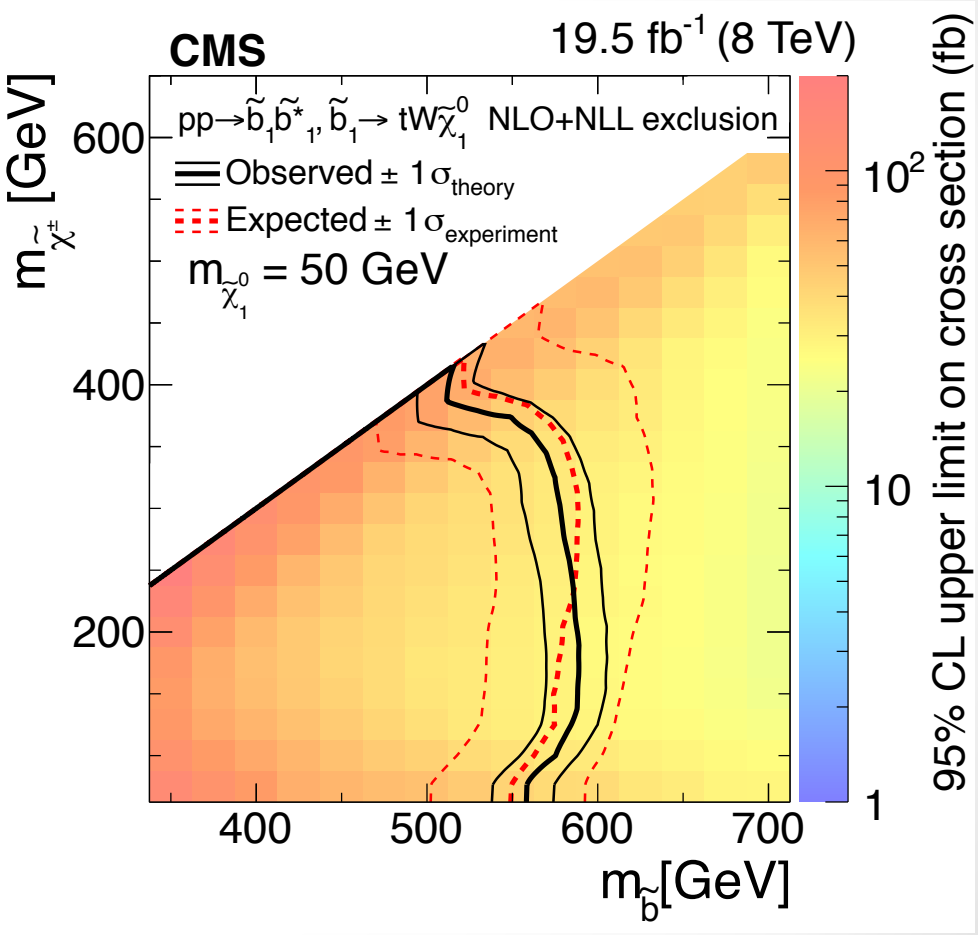
CMS Collaboration
arXiv:1412.4109
19.5 fb^{-1}

b Jets and 4 W's

Sbottom Pair Production:



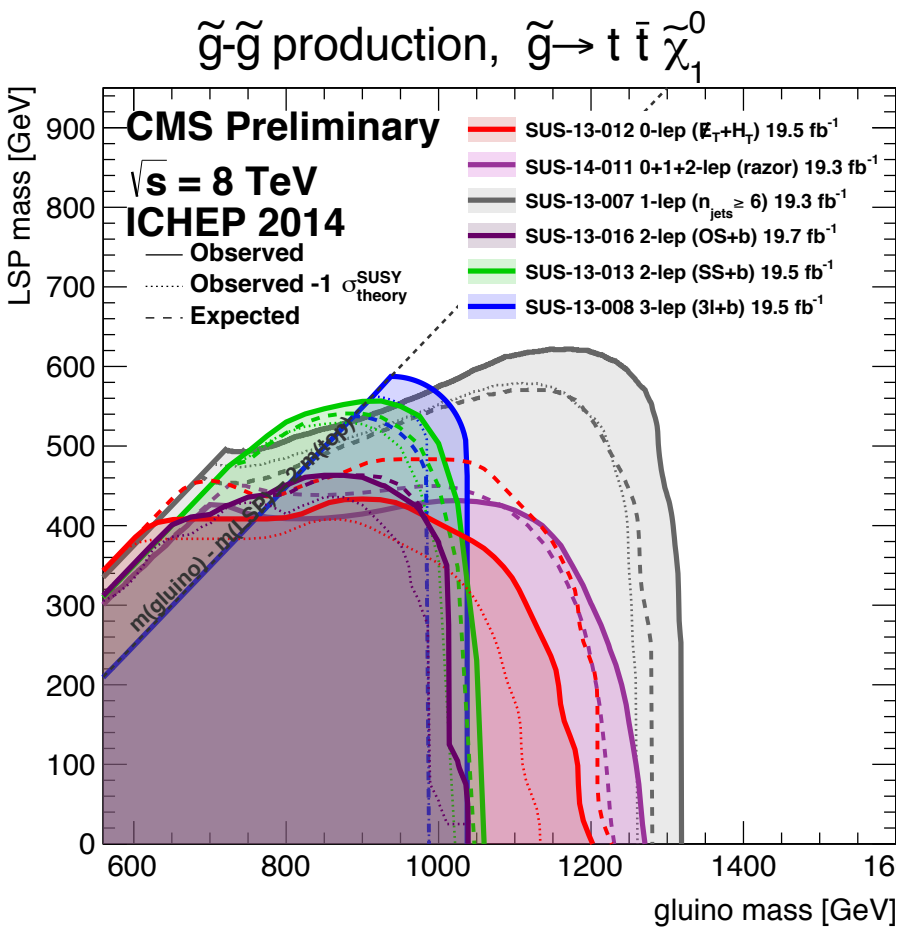
Sbottom exclusion of 570 GeV

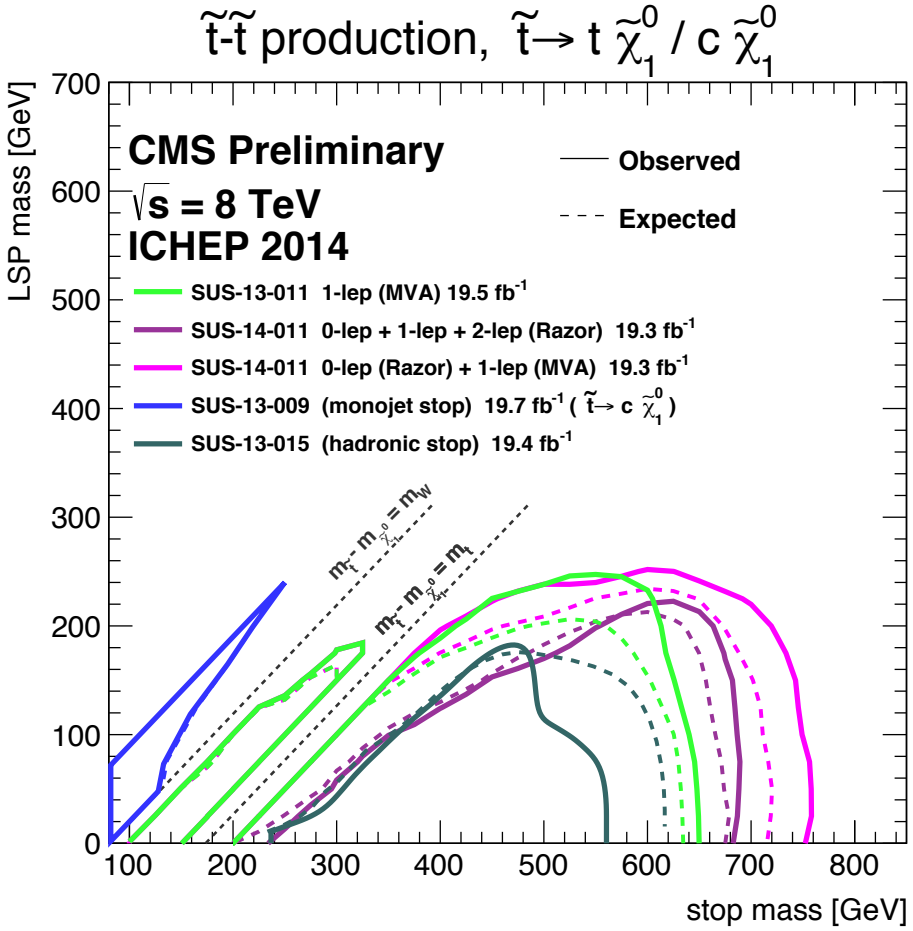


Combined Exclusion

Gluino Mediated

Direct Stop Production





Conclusions

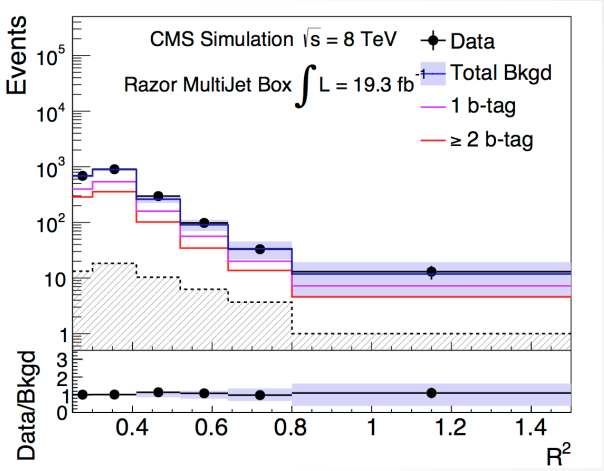
- Strong program of third generation SUSY searches at CMS
  - Focused on latest results here, but very broad program at CMS
  - No significant excess over the Standard Model prediction has been observed so far
- Natural SUSY is still viable
  - But we've certainly constrained the phase space available to it
  - How constrained are we?
    - Fine tuning: SM $\approx 10^{-32}$ SUSY with current exclusion $\approx 10^{-(1\text{-}2)}$
    - Coincidences at the level of 10% happen in nature
- Run II begins soon at $\sqrt{s}$ = 13 TeV
  - Preparing analysis now for quick turn around on new data
  - Exciting future at the LHC

Backup

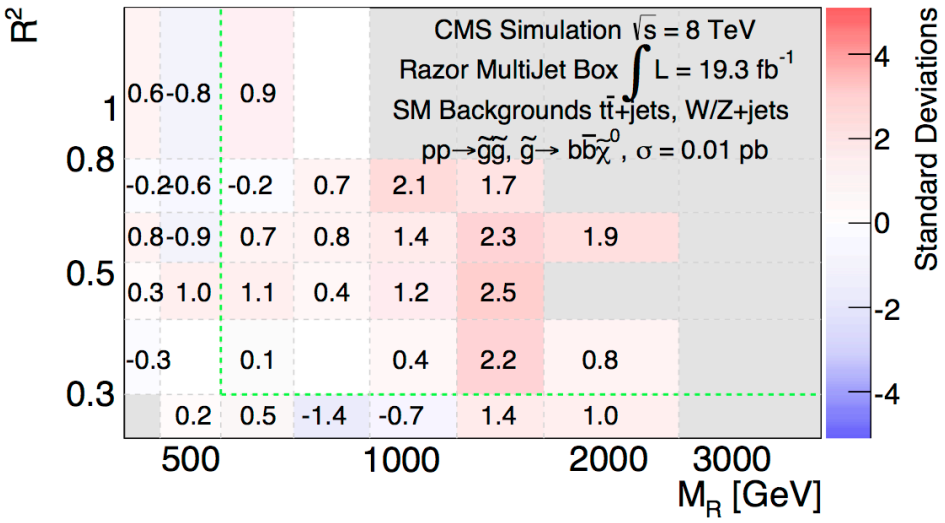
CMS collaboration
arXiv:1502.00300
19.3 fb^{-1}

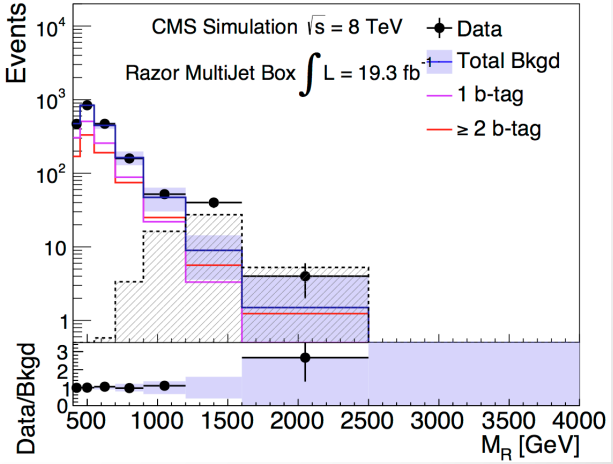
Razor with b's

- Test background fit with injected signal (σ =0.01 pb)
  - M_{gluino} = 1350 GeV, $M_{neutralino}$ = 50 GeV
- Signal contamination in sideband has negligible effect on background shape
- Excess still observed near M_R ~ 1500



PSUEDODATA





Razor with b's

CMS collaboration
arXiv:1502.00300
19.3 fb^{-1}

Just focusing on squark production