



3rd generation SUSY searches at CMS

Florent Lacroix
(U. of California Riverside)
on behalf of the CMS collaboration

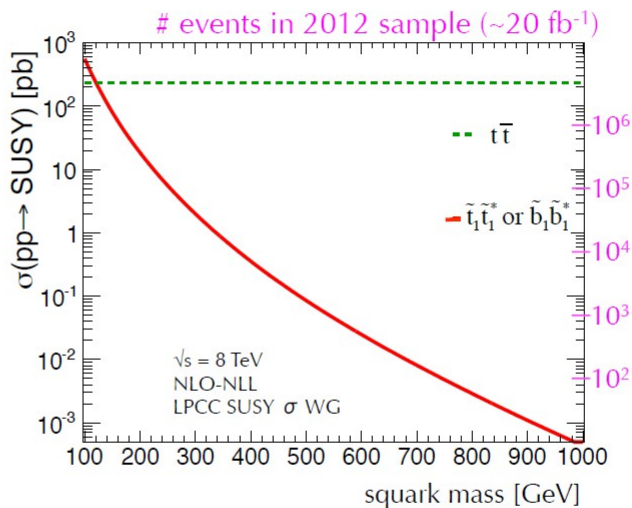
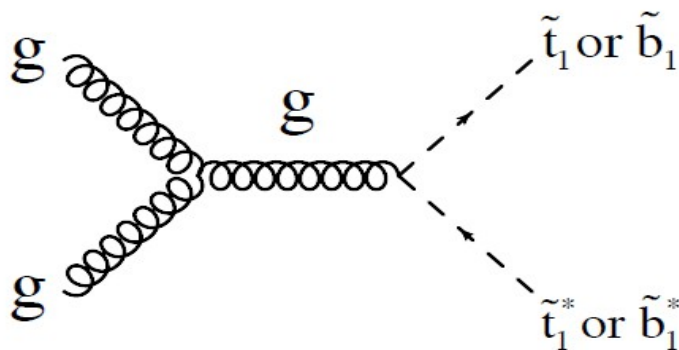
3rd generation susy

- Motivations:
 - Naturalness usually requires low squark mass (<1 TeV) to cancel radiation corrections to Higgs masses.
 - 3rd generation quarks can be lighter than all squarks due to large mixing.
- CMS has a broad 8 TeV 3rd generation search program:
 - Diverse selection of signal topologies, classified in produced sparticles and decay channels;
 - Inclusive and dedicated searches, spanning many decay signatures (lepton multiplicity).
- Interpretation of analyses are made with Simplified Model Spectra.
- No significant excess observed, so results are interpreted as limits.

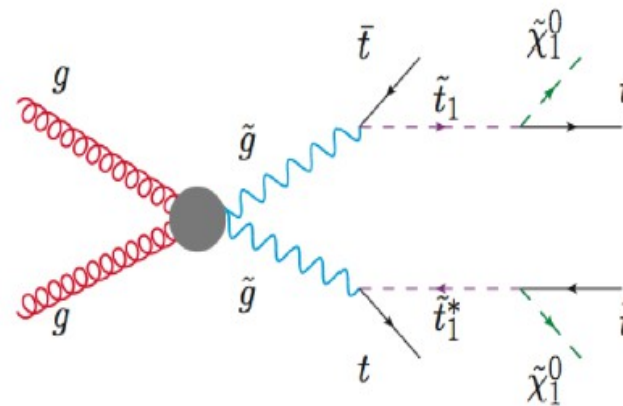
Production mechanisms

- Stop and sbottom quarks can be produced in LHC collisions via:
 - Direct squark pair production by gg fusion or $q\bar{q}$ annihilation;
 - Gluino mediated production.

Direct production



Gluino mediated production

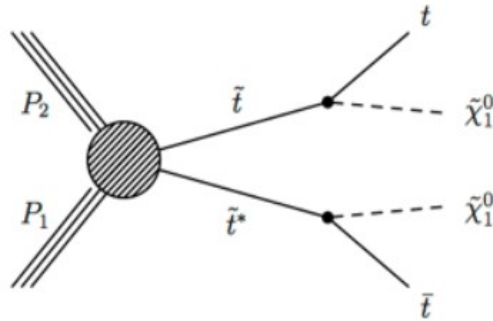


- Production cross-section rapidly falls with mass.
- ~ 100 events expected in 8 TeV dataset for 700 GeV squarks in direct production.

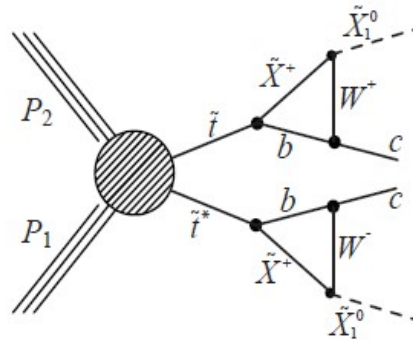
Direct stop production

Light stop

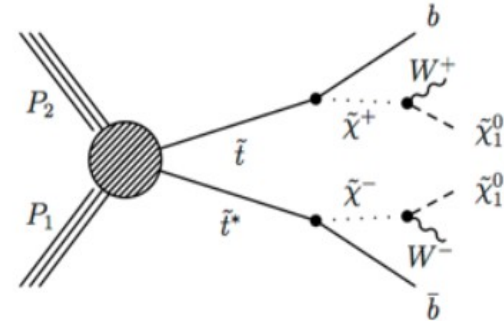
Direct LSP decay



c through loop



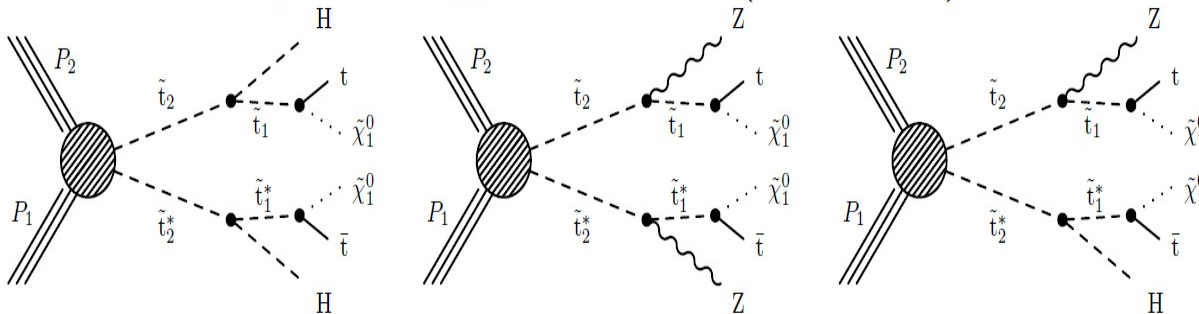
Chargino decay



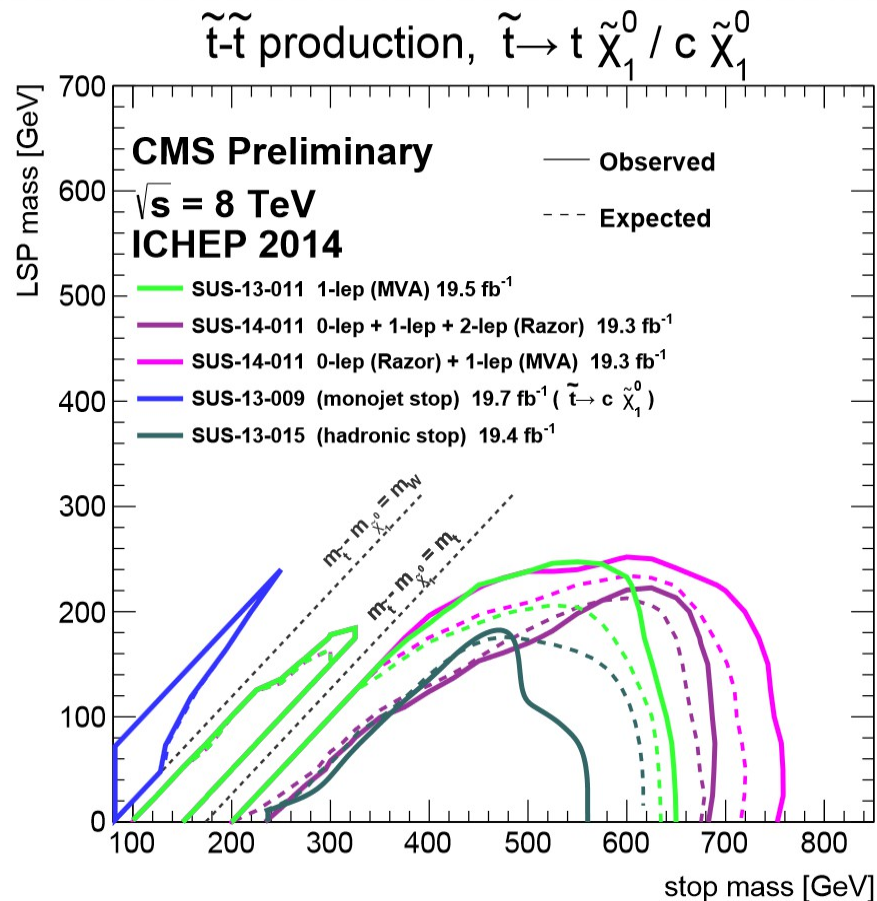
- Direct LSP decay: Hadronic (SUS-13-015), Inclusive Razor (SUS-13-004), Inclusive MT2 (SUS-13-019) and 1 lepton (SUS-13-011).
- Razor and 1 lepton combination (SUS-14-011).
- C through loop: monojet (SUS-13-009).
- Chargino decay: 1 lepton (SUS-13-011).

Heavy stop

Stop2 with Higgs and Z bosons (SUS-13-024)



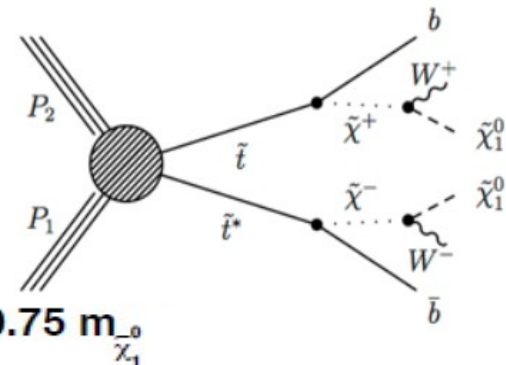
Light stop $\tilde{t} \rightarrow t \tilde{\chi}_1^0 / c \tilde{\chi}_1^0$ results



- 1 lepton: using BDTs optimized for the different Δm regions.
- Razor: cf “Inclusive susy searches at CMS” talk by Lukas Vanelderen.
- Monojet: charm jets very soft and LSPs back to back, so require hard ISR jet recoiling against MET from the LSPs.
- Hadronic stop: jet+met cut and count analysis using a top tagger.

Chargino decay results

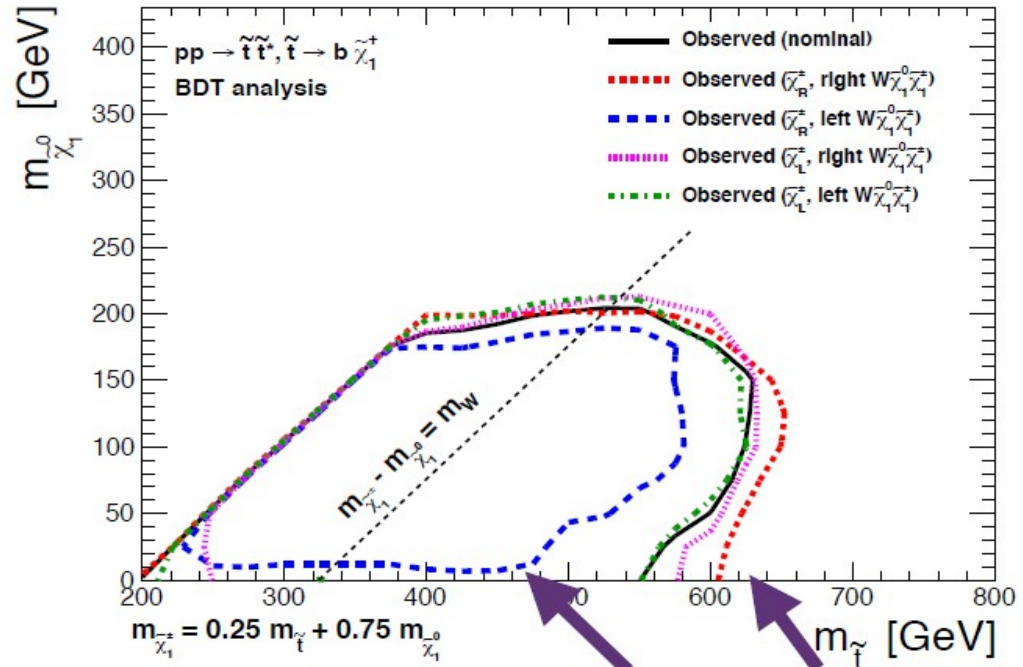
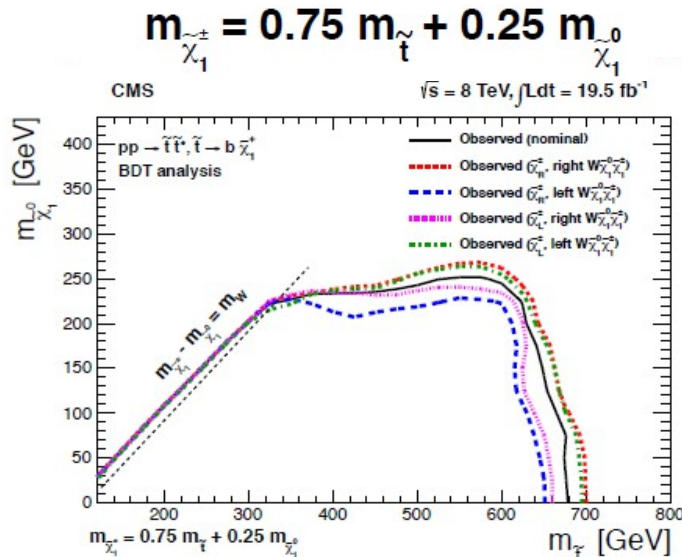
- 1 lepton analysis (SUS-13-011)
- Stop to chargino decay is probed with 3 different mass relations.
- Sensitivity dependent on assumptions on chargino polarization and left/right handedness of $W\chi_1^0\chi_1^\pm$ coupling.



$$m_{\tilde{\chi}_1^\pm} = 0.25 m_{\tilde{t}} + 0.75 m_{\tilde{\chi}_1^0}$$

CMS

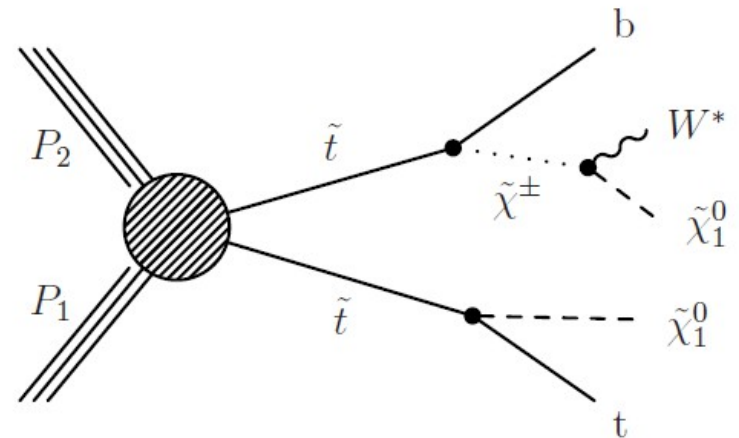
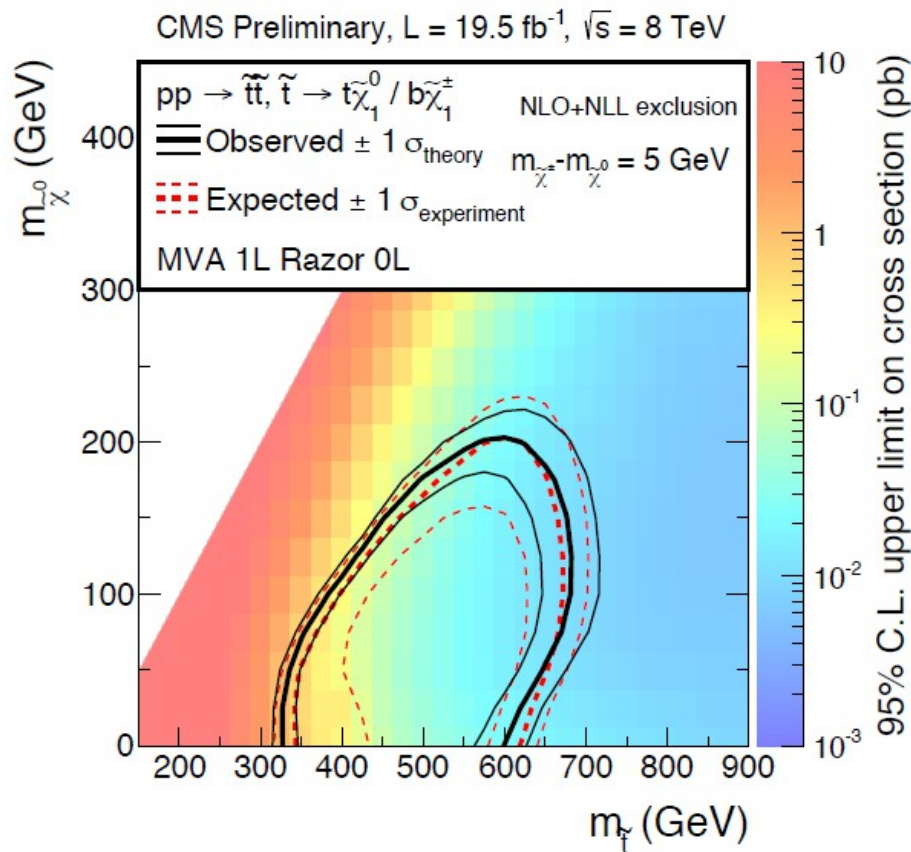
$\sqrt{s} = 8 \text{ TeV}, \int \mathcal{L} dt = 19.5 \text{ fb}^{-1}$



Different polarizations

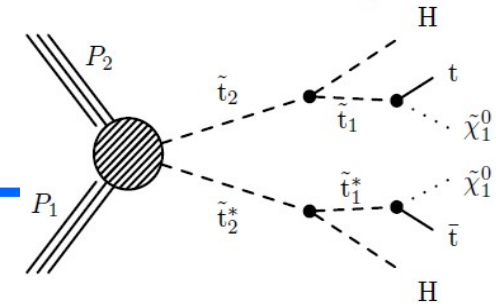
Other interpretation with chargino

- Other interpretation of the Razor/1-lep combination:
 - Allow the stop to decay into $b\tilde{\chi}^\pm$ with $m(\tilde{\chi}^\pm) - m(\tilde{\chi}_1^0) = 5 \text{ GeV}$
 - Results in a virtual W



- Results independent of the branching ratio ($\tilde{t} \rightarrow t\tilde{\chi}_1^0$) choice

Heavy stop results

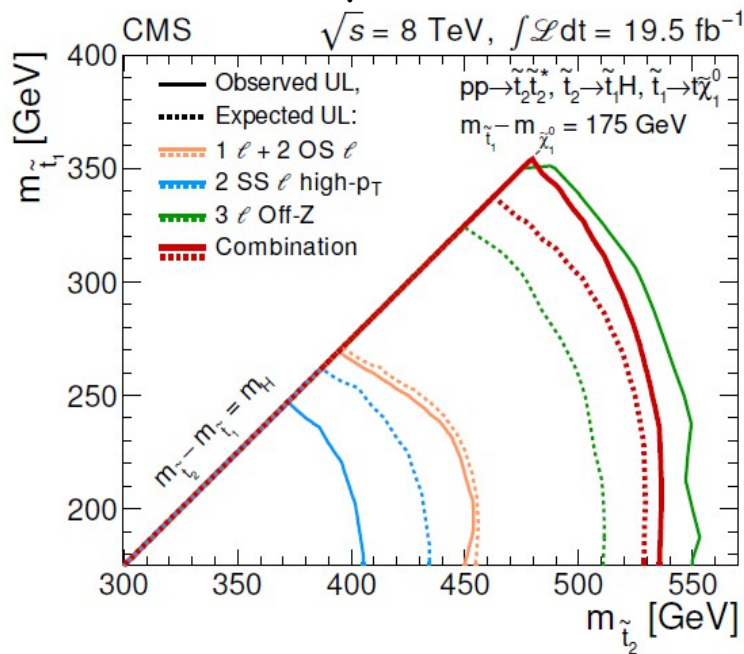


Heavy stop analyses:

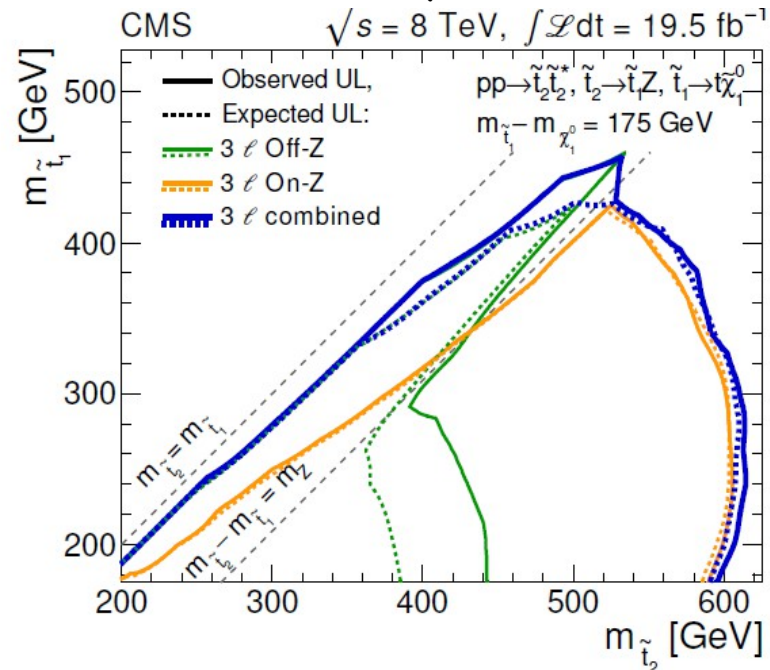
- 1 lepton + 2 OS leptons (SUS-13-021)
- 2 SS leptons (SUS-13-013)
- 3 leptons (SUS-13-008)

Combination (SUS-13-024)

Decay with H



Decay with Z

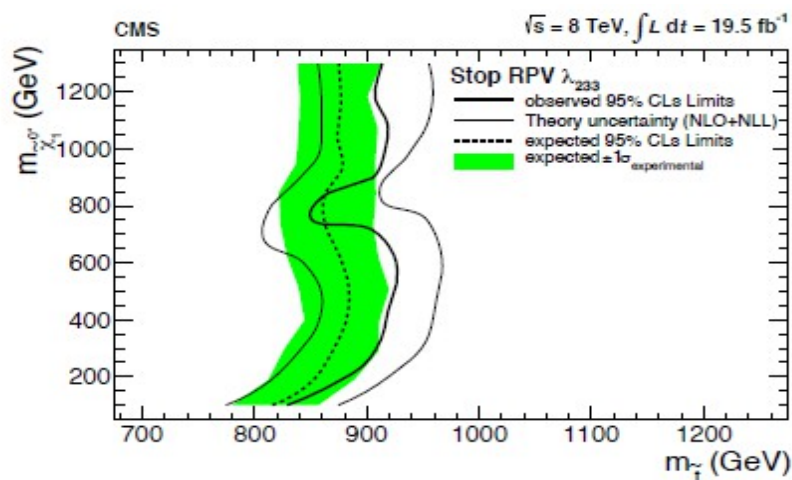
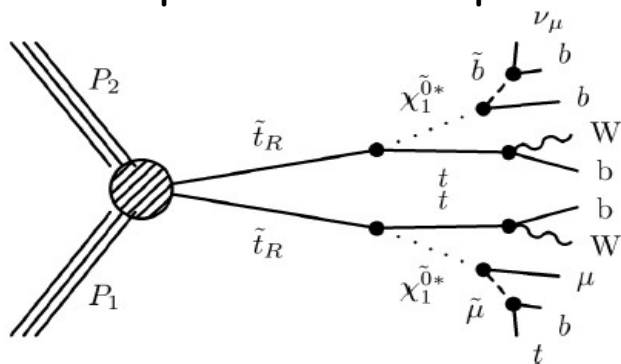


Mixed branching ratio scenario results also available in SUS-13-024.

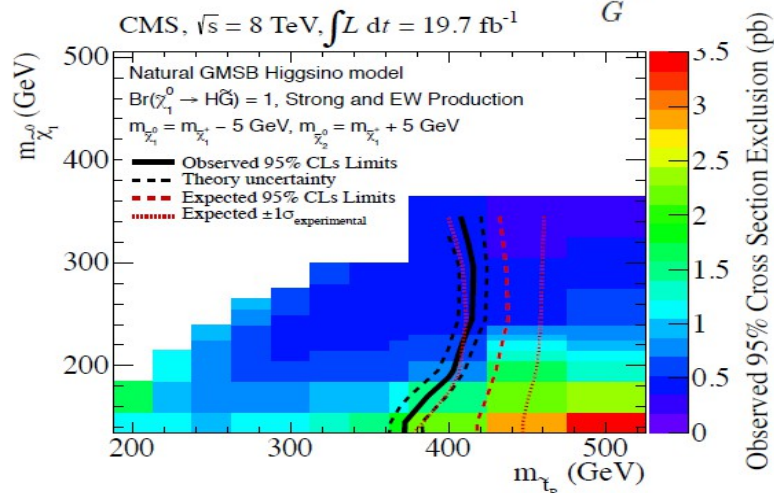
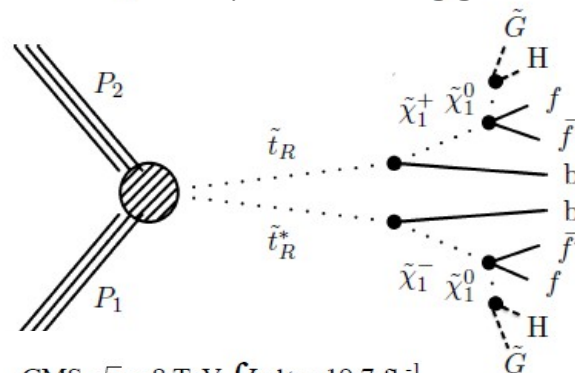
Other direct stop searches

- RPV stop search (SUS-13-003)
 - Multiple R-parity violating topologies are considered
- Gauge Mediated Susy Breaking stop search (SUS-13-014 and SUS-13-008)
 - Direct production of stop with higgsino as NLSP
 - NLSP decays into $H + \tilde{G}$ or $Z + \tilde{G}$

Example of RPV stop signal

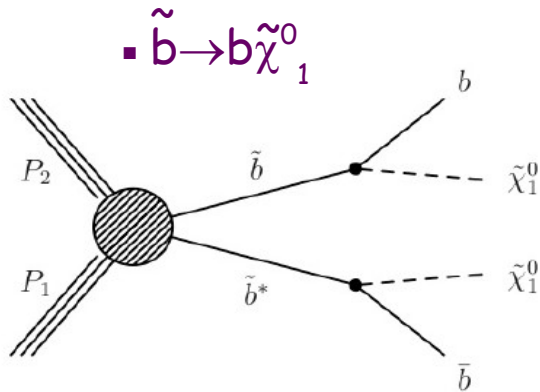


GMSB Stop with Higgs boson

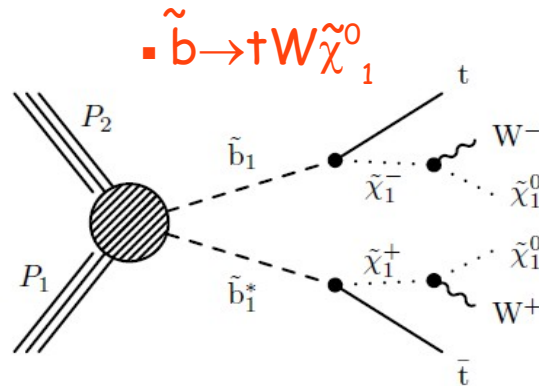


Direct sbottom production

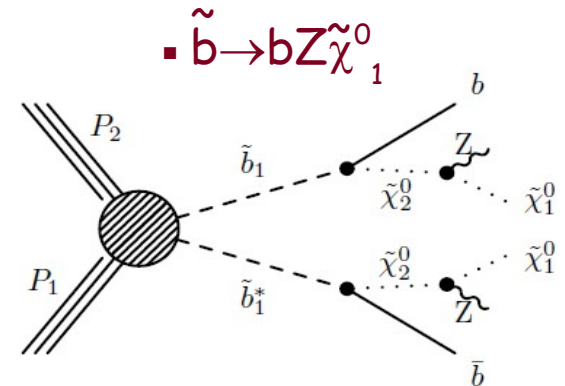
- 3 sbottom decays:



- (b) jets+HT+MET (SUS-13-018).
- Inclusive MT2 (SUS-13-019).

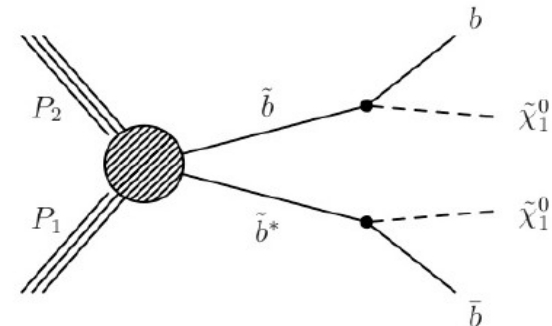


- Multilepton (SUS-13-002)
- SS-l+jets+MET (SUS-13-013).
- 3l+bjets+MET (SUS-13-008).



- 3l+bjets+MET (SUS-13-008).

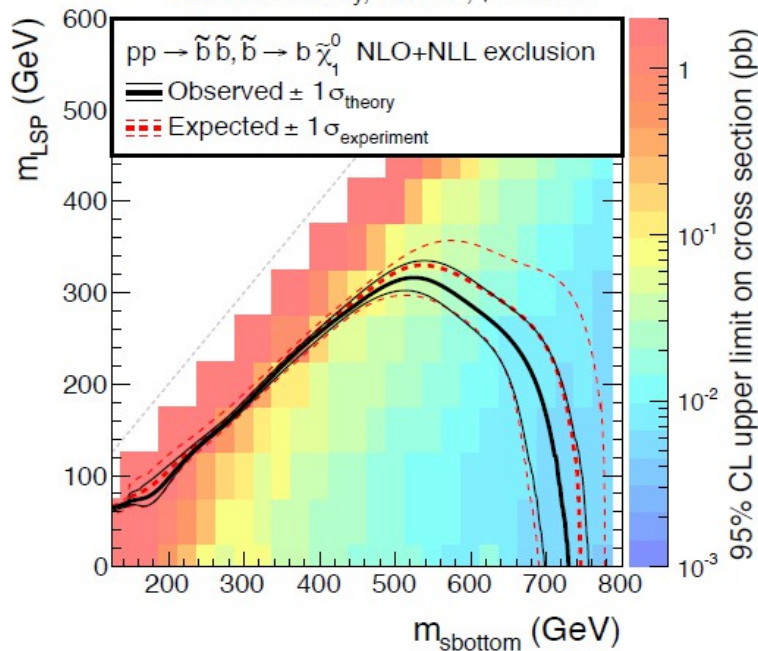
Direct sbottom results



- Mass limit using dedicated sbottom search

SUS-13-018

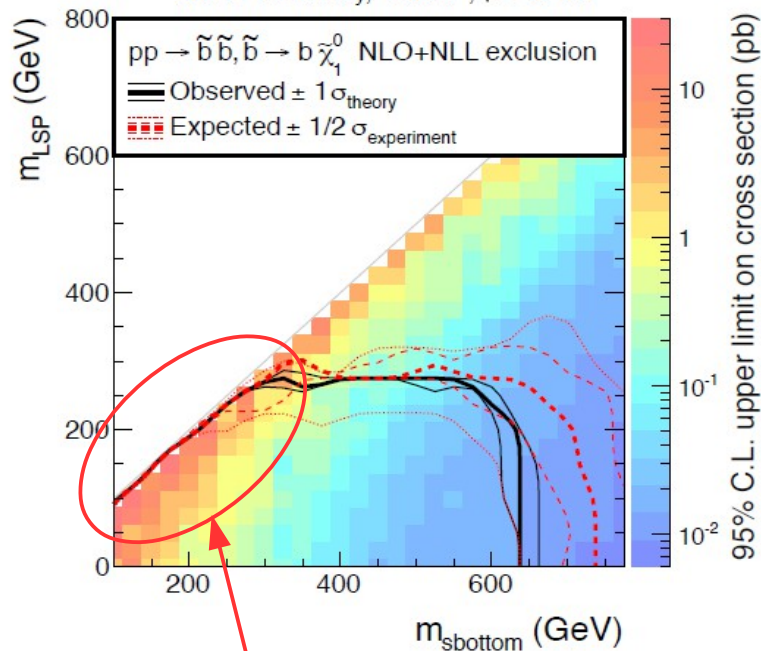
CMS Preliminary, 19.4 fb⁻¹, $\sqrt{s} = 8$ TeV



- Mass limit using inclusive M_{T2} analysis

SUS-13-019

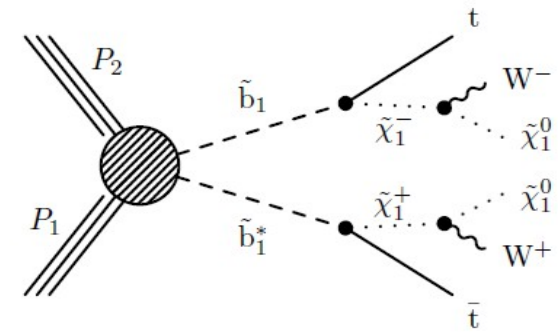
CMS Preliminary, 19.5 fb⁻¹, $\sqrt{s} = 8$ TeV



Sensitive to compressed spectra.

sbottom to tWX results

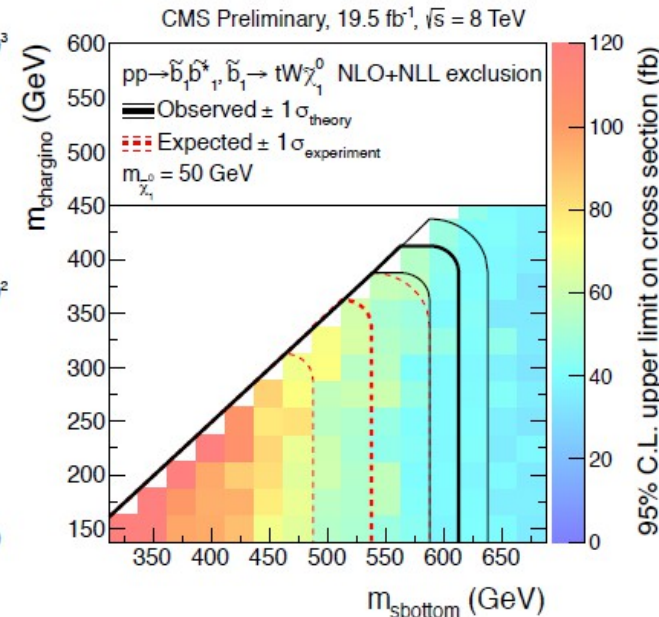
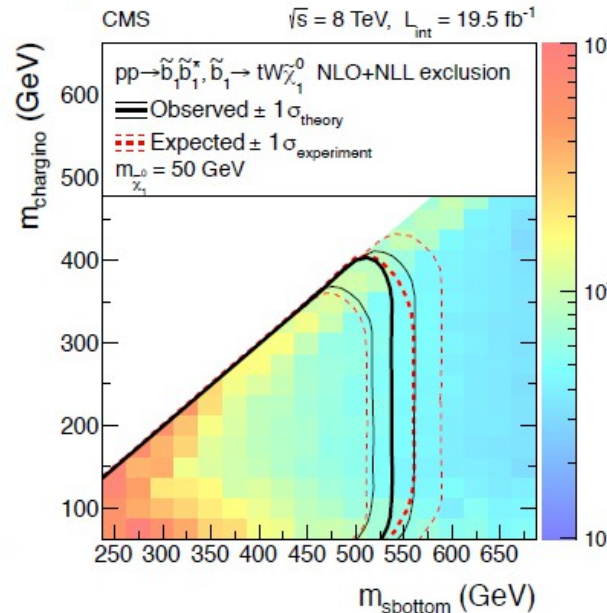
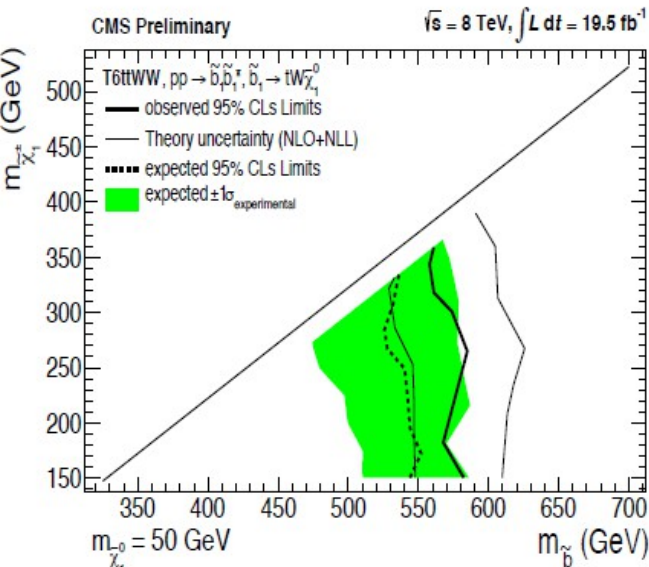
- multilepton search
- same-sign dilepton search
- three lepton search



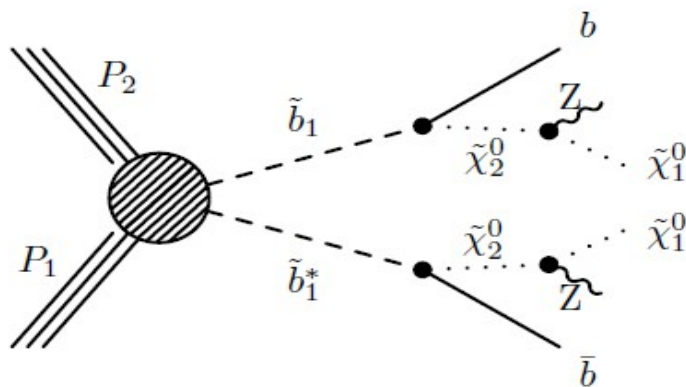
SUS-13-002

JHEP 01 (2014) 163

SUS-13-008



sbottom to bZX results

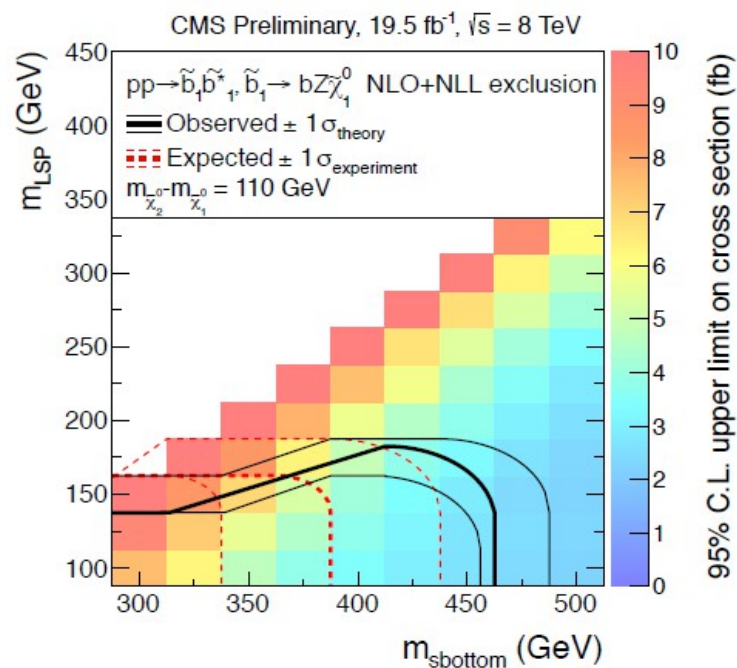


- $m(\tilde{\chi}_2^0) - m(\tilde{\chi}_1^0) = 110 \text{ GeV}$

\Rightarrow only $\tilde{\chi}_2^0 \rightarrow Z\tilde{\chi}_1^0$ is allowed, $\tilde{\chi}_2^0 \rightarrow h\tilde{\chi}_1^0$ is closed.

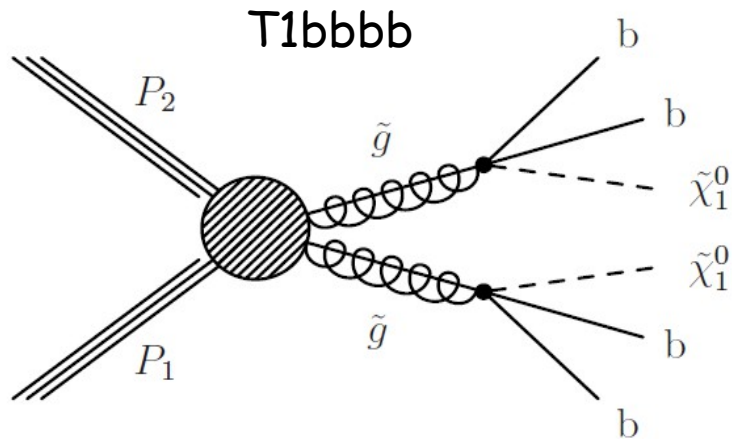
- 3 leptons analysis:
- Small backgrounds
- Main SM background is diboson, suppressed by requiring at least 1 btag jet.
- After btag, non-prompt and mis-identified leptons (estimated from data Control Samples) and rare processes like $t\bar{t}Z$ (estimated from MC).

SUS-13-008

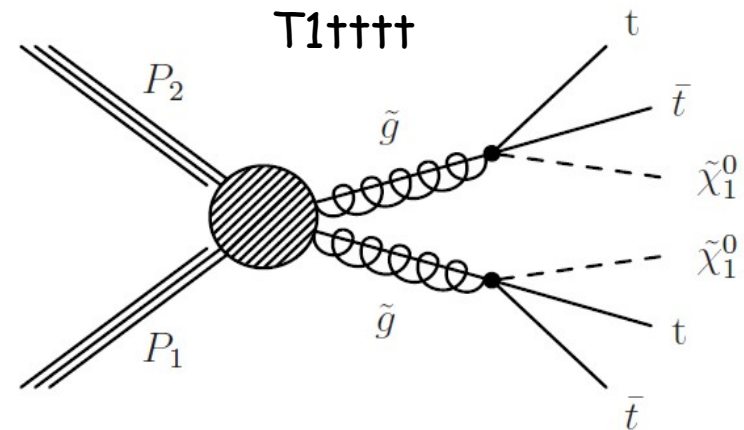


Glino mediated production

- Gluinos can decay via a virtual stop or a virtual sbottom.



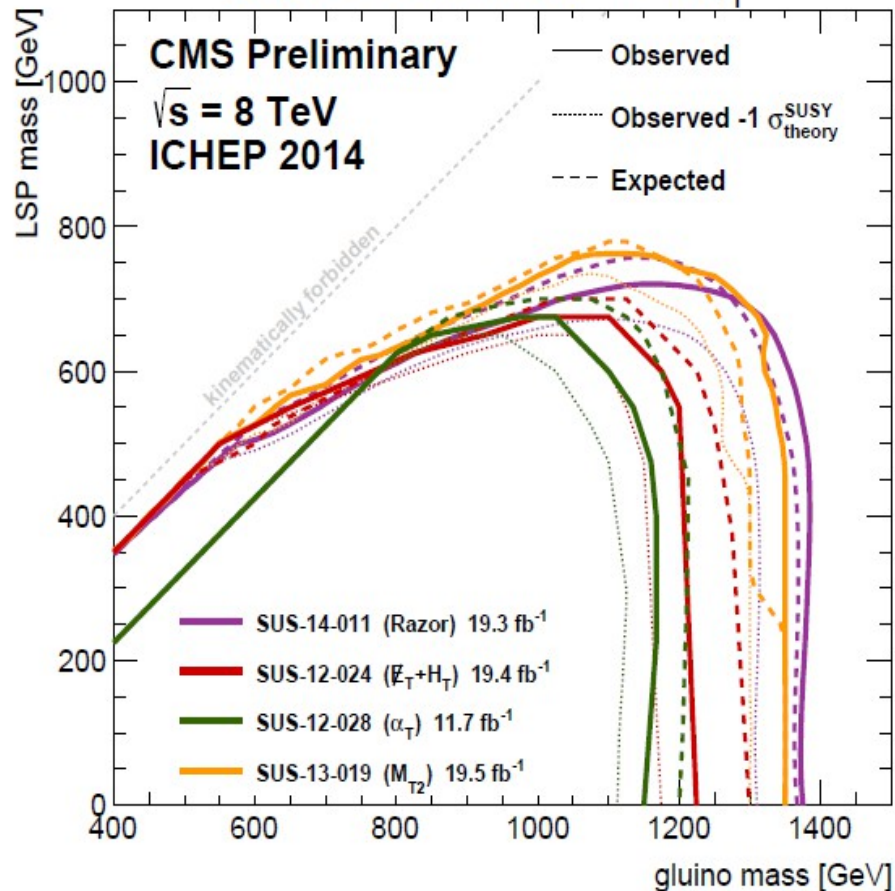
- Purely hadronic final state.
- Razor, MET+HT, alphaT, MT2.



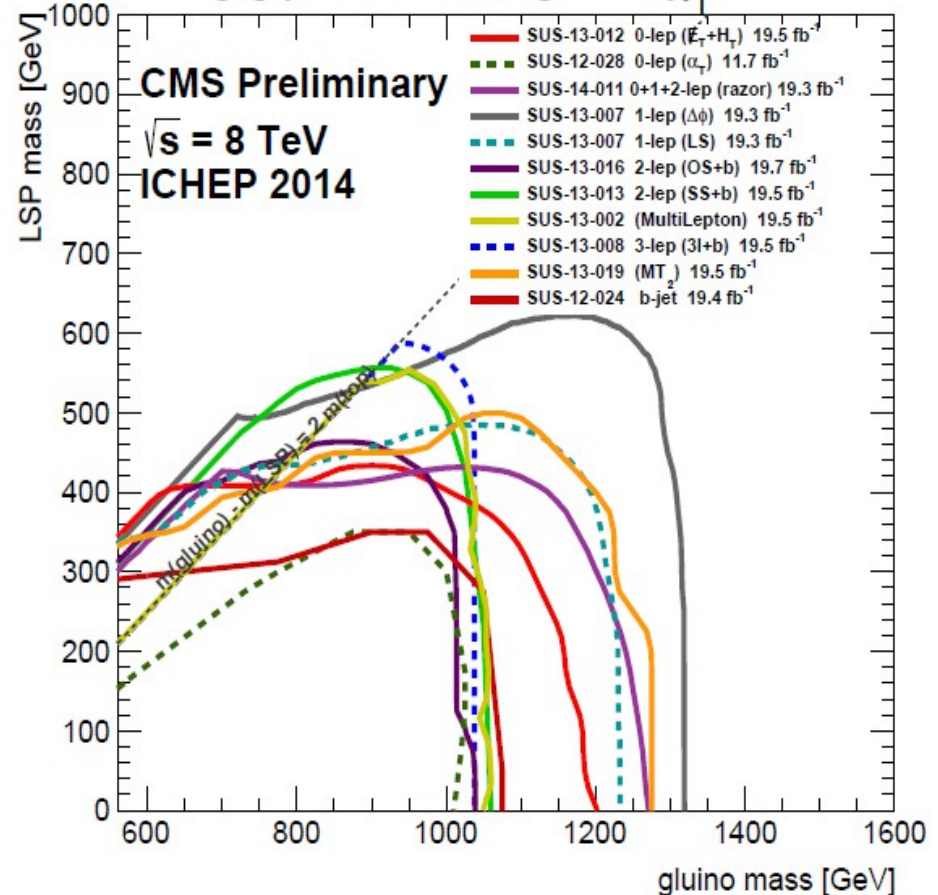
- All lepton multiplicities.
- 0-lep (Razor, MET+HT, α_T , MT2)
- 1-lep ($\Delta\phi$, LS)
- 2-lep (OS, SS)
- 3-lep (≥ 3 , 3l+b)

Gluino mediated results

$\tilde{g}\text{-}\tilde{g}$ production, $\tilde{g} \rightarrow b \bar{b} \tilde{\chi}_1^0$

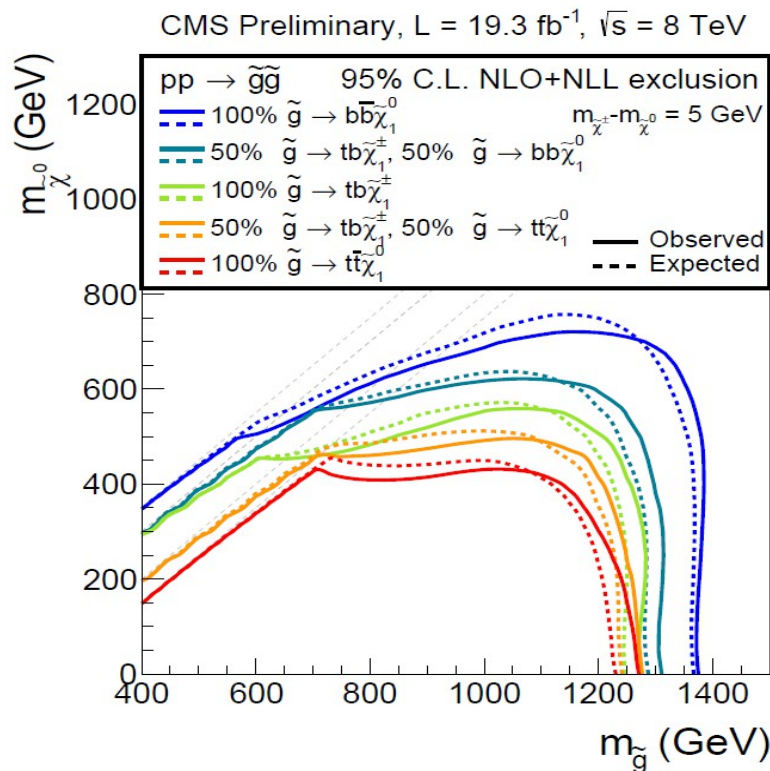
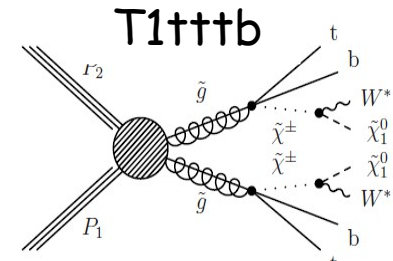
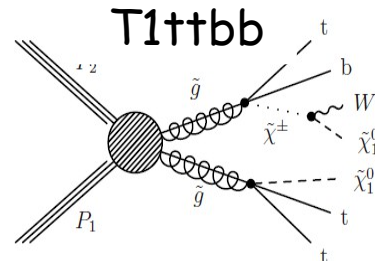
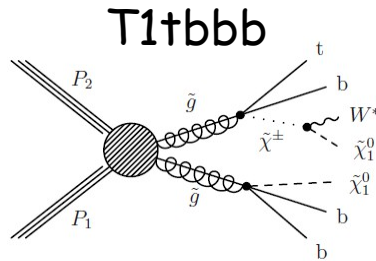


$\tilde{g}\text{-}\tilde{g}$ production, $\tilde{g} \rightarrow t \bar{t} \tilde{\chi}_1^0$



Mixed branching ratios

- Mixed branching ratios are also possible:

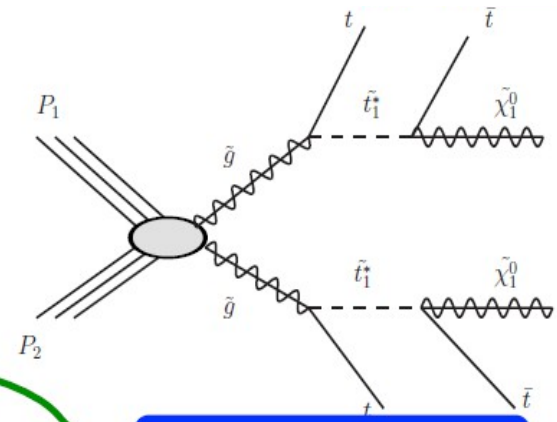


- Studied by the razor analysis (SUS-14-011):
- Limits for mixed branching ratios lie within 100% $\tilde{g} \rightarrow b\bar{b}\tilde{\chi}_1^0$ and 100% $\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$ contours.
- Greater number of top quarks \Rightarrow weaker limit
- T1tttt is a conservative branching ratio independent limit.

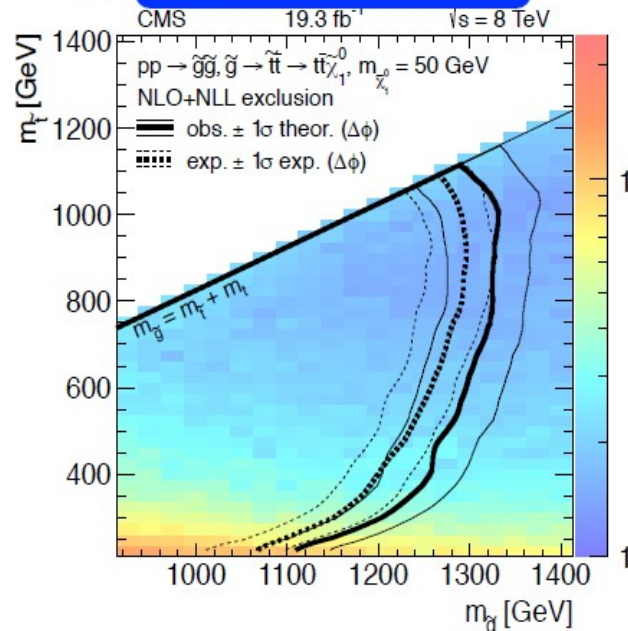
Gluino decays via on-shell stop

- 3 analyses interpret their results in term on on-shell stop:

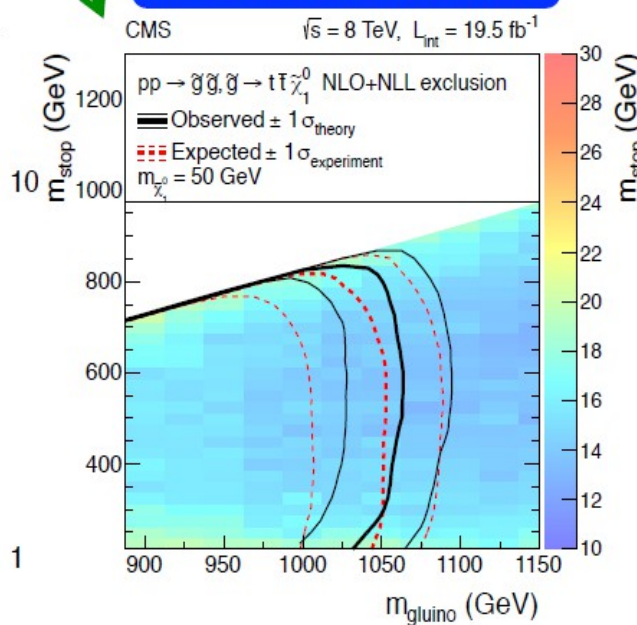
- single lepton search
- same-sign dilepton search
- three lepton search



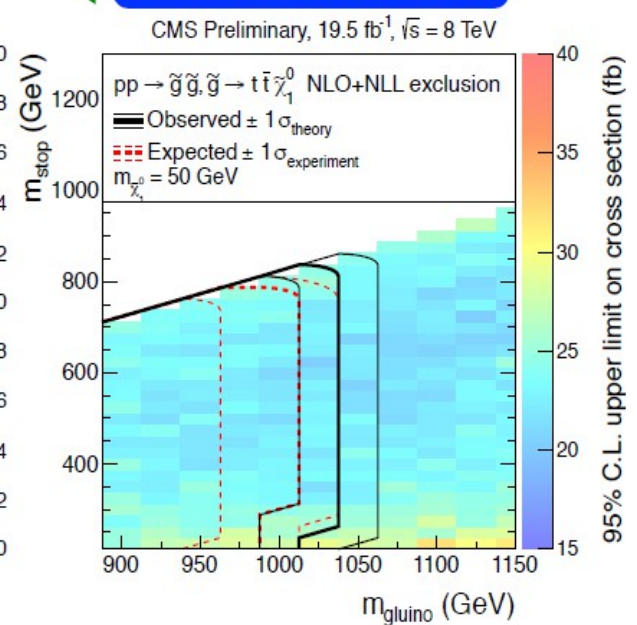
SUS-13-007



JHEP 01 (2014) 163



SUS-13-008



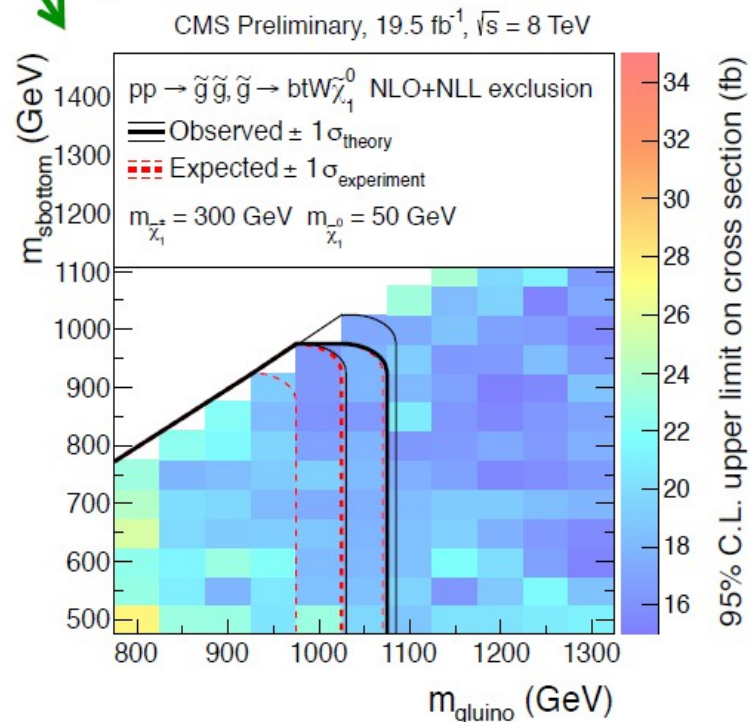
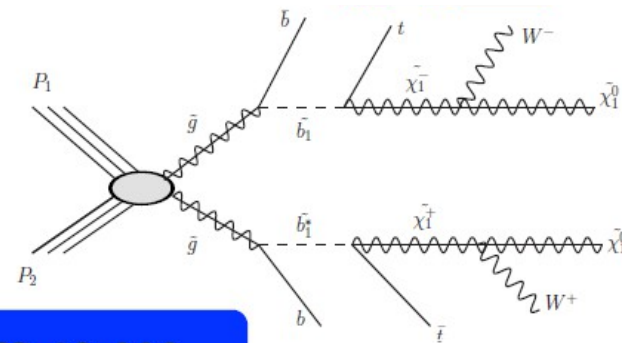
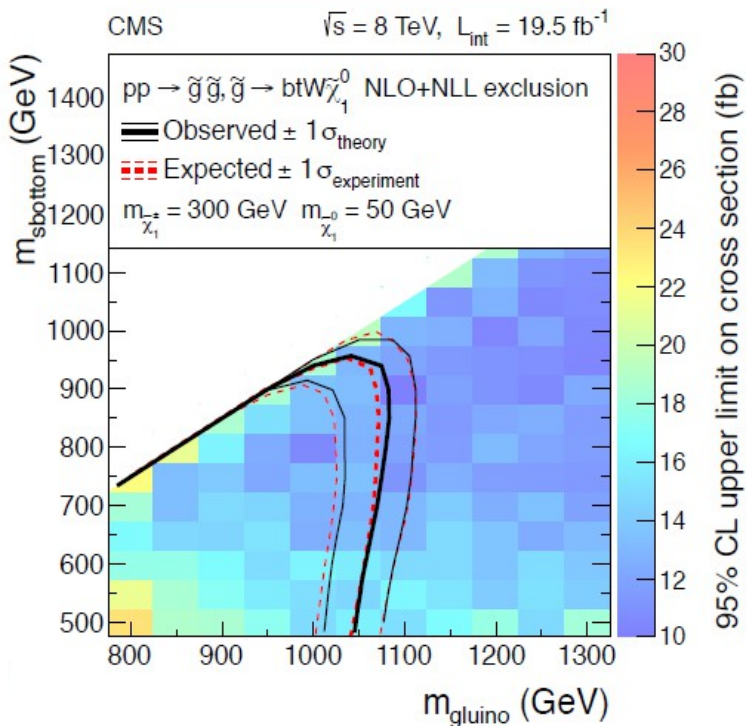
Gluino decays via on-shell sbottom

- 2 analyses interpret their results in term on on-shell sbottom:

- same-sign dilepton search
- three lepton search

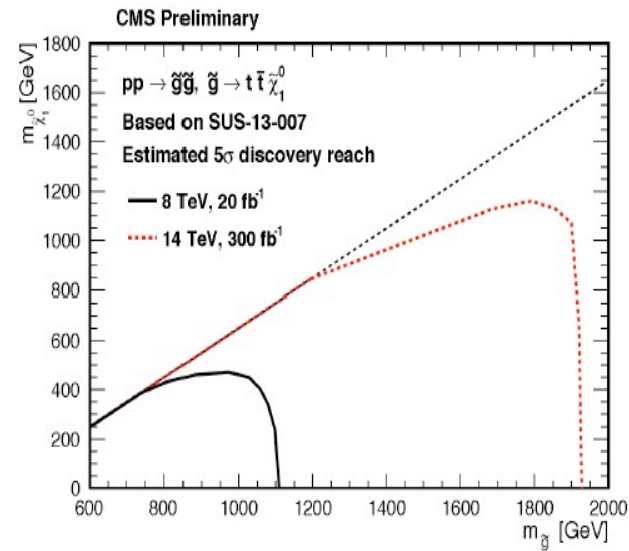
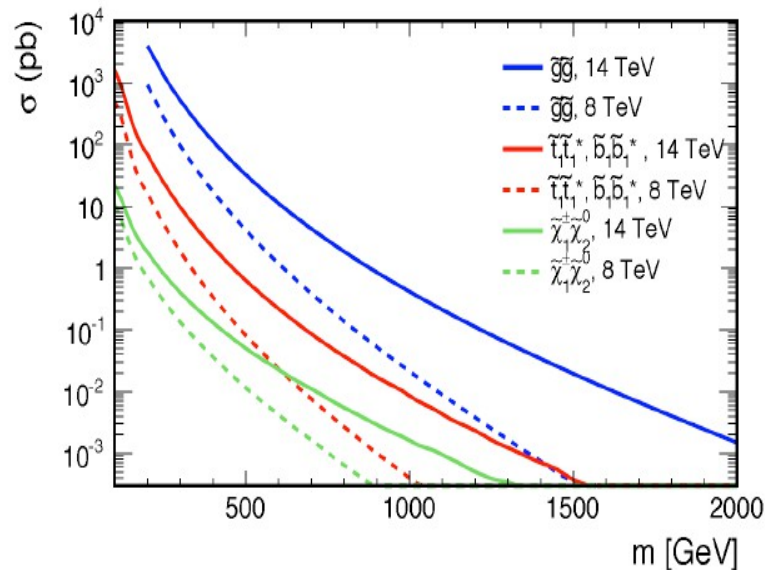
JHEP 01 (2014) 163

SUS-13-008



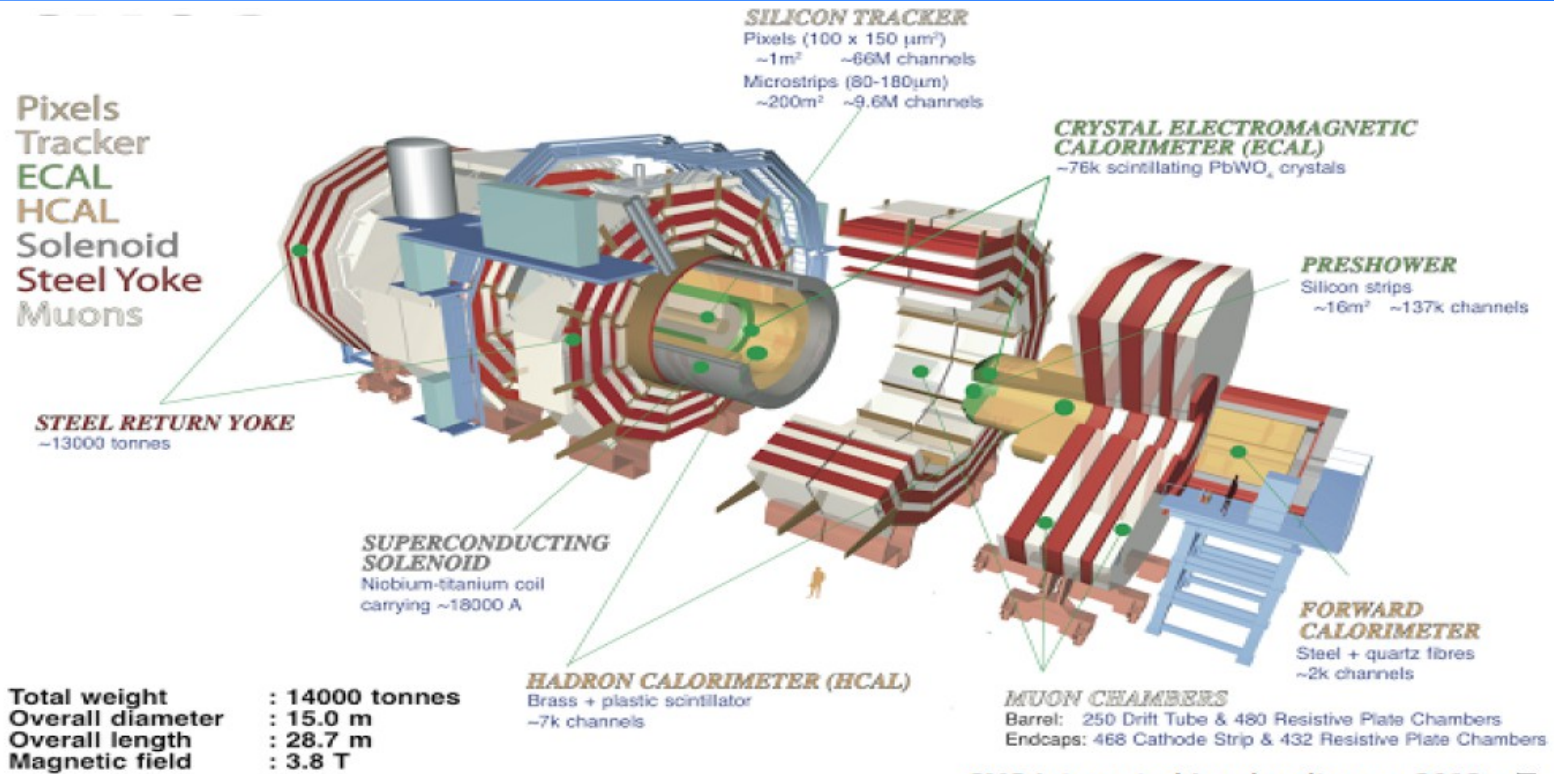
Conclusions / Outlook

- A variety of 3rd generation susy searches have been successfully performed in CMS with the 8 TeV data.
- No excess have been observed so far, but the step to 13 TeV is a significant one, so stay tuned!

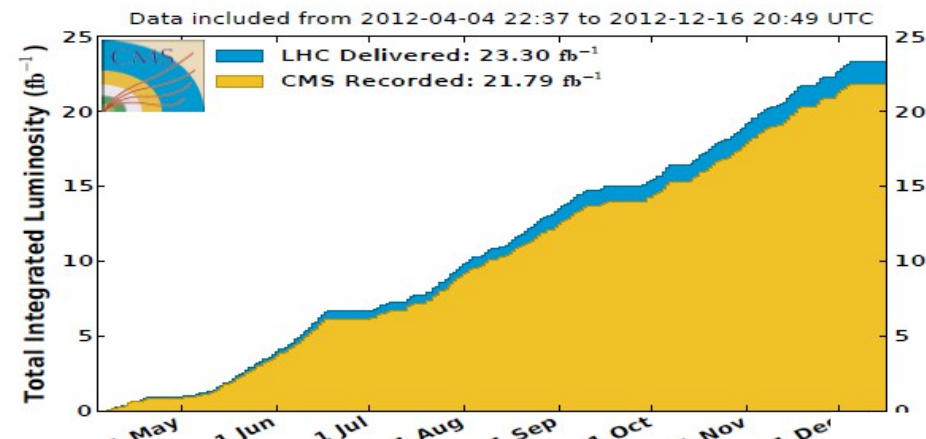


BACK UP SLIDES

CMS detector

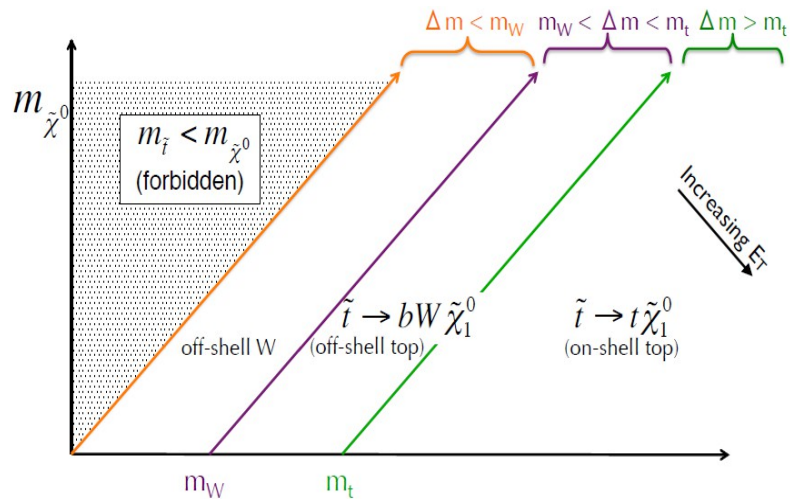


CMS Integrated Luminosity, pp, 2012, $\sqrt{s} = 8\text{ TeV}$

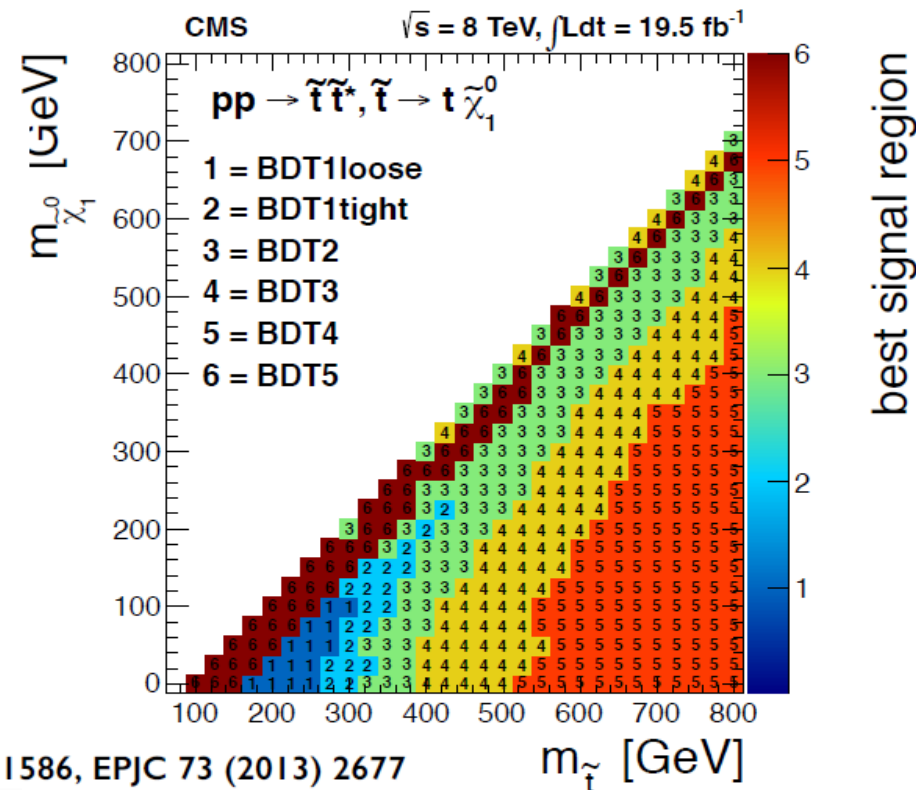
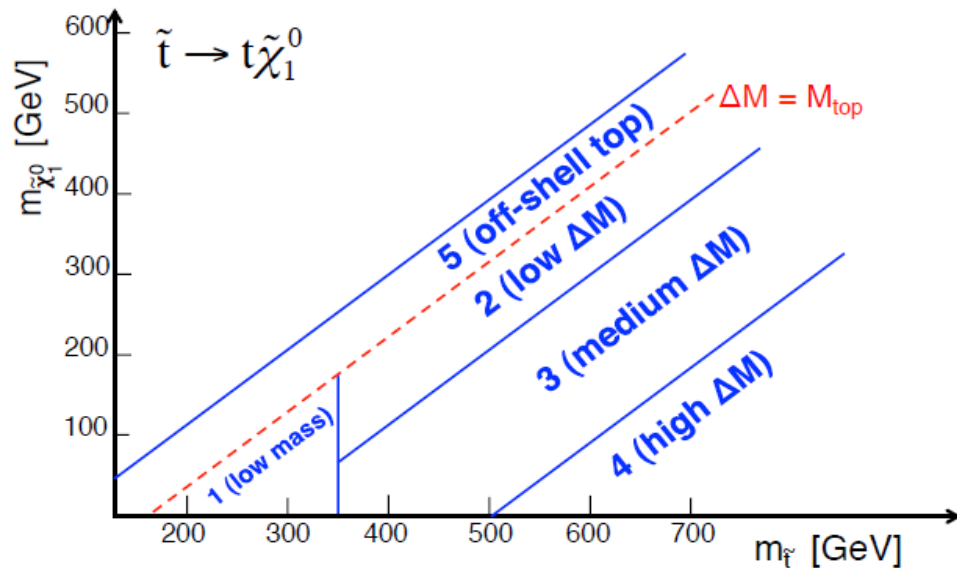


Parameter	Nominal	2012
\sqrt{s}	14 TeV	8 TeV
bunches	2808×2808	1374×1374
protons /bunch	1.15×10^{11}	1.7×10^{11}
spacing	25 ns (40 MHz)	50 ns (20 MHz)
$\mathcal{L} (\text{cm}^{-2} \text{s}^{-1})$	10^{34}	7.7×10^{33}

Direct stop: 1-lepton analysis



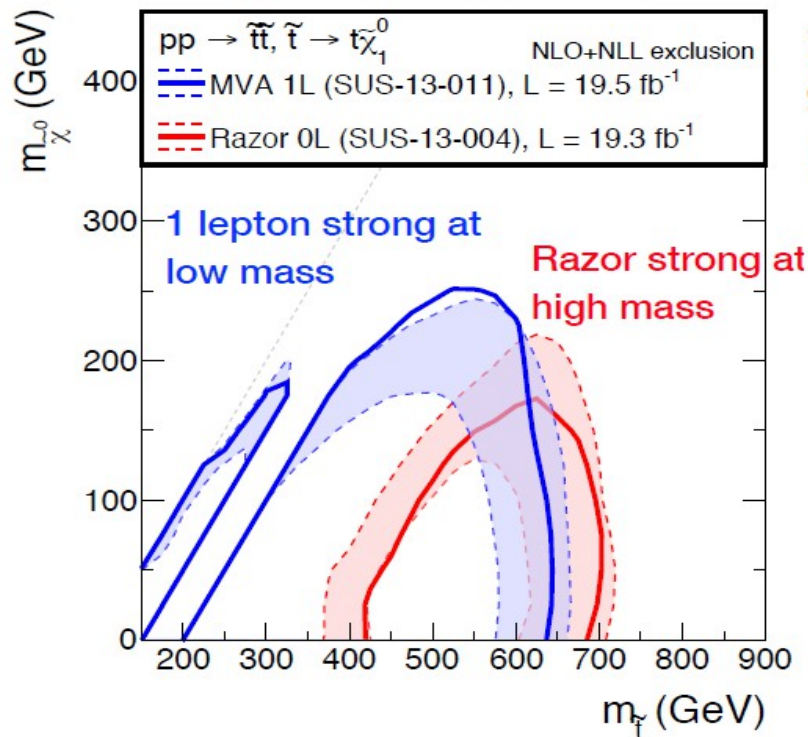
- Preselection: exactly 1 lepton, at least 4 jets, at least 1 bjet, $MET > 100$ GeV.
- Signal region: $M_T > 120$ GeV.



Light stop combination results

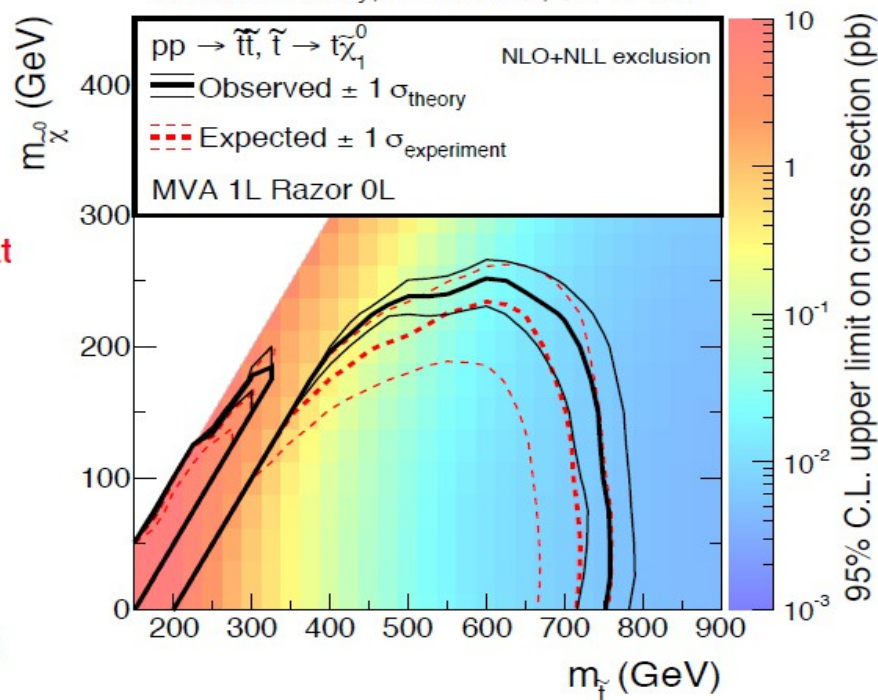
SUS-14-011

CMS Preliminary, $\sqrt{s} = 8$ TeV



combined result

CMS Preliminary, $L = 19.5 \text{ fb}^{-1}$, $\sqrt{s} = 8$ TeV



Topologies with different non-0 RPV terms

