

3rd generation SUSY searches in CMS

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04.03.2013



IN2P3
Les deux infinis



ipnl

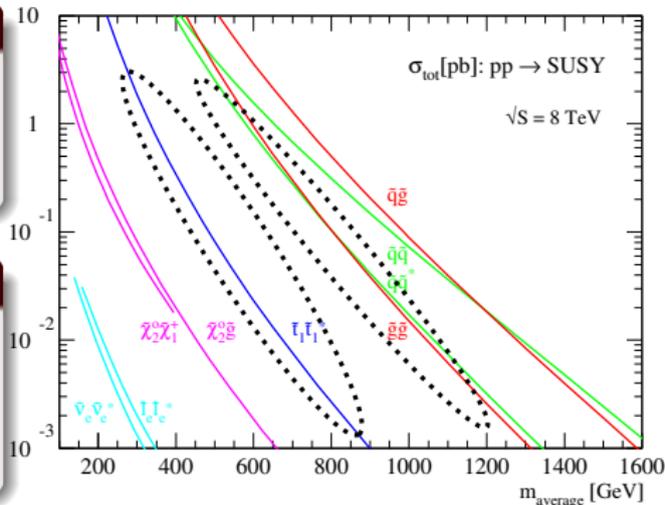


Productions modes

- Gluinios mediated
- Direct squarks production
- Inclusive searches

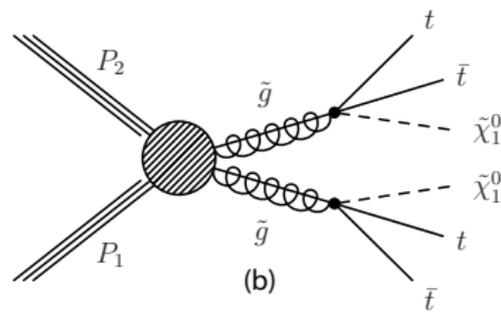
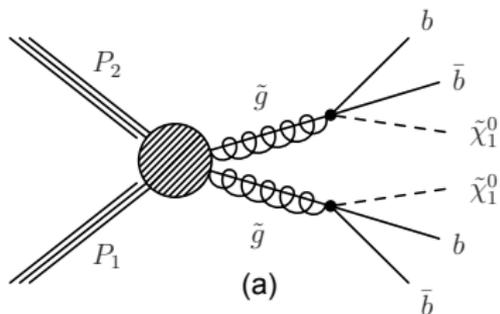
Stop decay modes

- 2 body decay $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0, \tilde{t}_1 \rightarrow b\tilde{\chi}_1^+$
- 3 body decay $\tilde{t}_1 \rightarrow bl\tilde{\nu}$
- 4 body decay $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^0 f\bar{f}'$

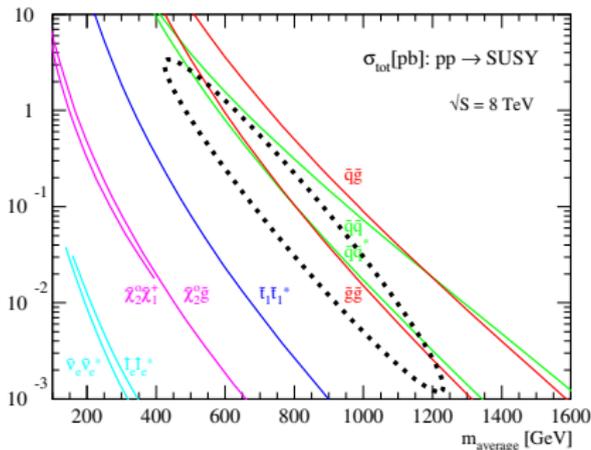


Final states signatures from cascade decays

- Large hadronic activity measured with $H_T = \sum_{i=1}^{N_{jets}} E_T^i$
- Rich in tops (Semi leptonic, dileptonic and hadronic channels)
- Many jets and several bjets (Combined Secondary Vertex method)
- $\cancel{E}_T = -|\sum \vec{E}_T^i|$ (from escaping LSP)
- + Analysis oriented discriminators ($\alpha_T, M_T, \delta\phi(W, l)\dots$).



Glauinos mediated production



SUS-13-007 @ 8TeV 19.4 fb^{-1}

Only 1 decay mode

- $pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0 \rightarrow t\bar{t}\tilde{\chi}^0 t\bar{t}\tilde{\chi}^0$

Selection

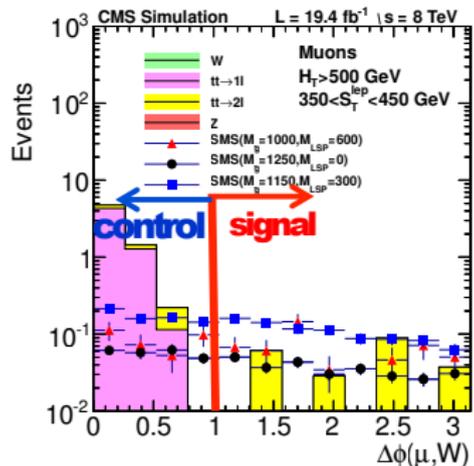
- exactly 1 isolated e or μ ($P_t > 20 \text{ GeV}$)
- N PF jets $\geq 6 \rightarrow$ ~~ttbar~~ background
- N b-jets $\geq 2 \rightarrow$ ~~non ttbar~~ background
- $H_T \geq 500 \text{ GeV}$
- $S_T^{lep} = \sqrt{p_T(W)^2 + M_T(W)^2}$ bins

In SM, high \cancel{E}_T from W (ν) very boosted \rightarrow small and peaked $\Delta\phi$

In SUSY, high \cancel{E}_T from LSPs
no ϕ correlation with lepton \rightarrow flat $\Delta\phi$

2 independant analysis methods

- Lepton Spectrum method:
Predict \cancel{E}_T distribution from SM processes lepton P_T spectrum
- Delta Phi method:
Use correlation between W and lepton direction as discriminator ($\Delta\phi(W, l)$)



Single isolated lepton, multiple jets and b-tags

Estimation of SM background

- $R_{CS} = \frac{N_{sig}}{N_{control}} = \frac{N \text{ events with } \Delta\phi > 1}{N \text{ events with } \Delta\phi < 1}$ from MC
- $N_{SM}^{pred}(\Delta\phi > 1) = R_{CS} \cdot N_{data}(\Delta\phi < 1)$
- R_{CS} from MC are $\sim 10\%$ too small (evaluated in fewer b-tag region)
→ additional corr factor $k_{CS}(N_{bjets})$

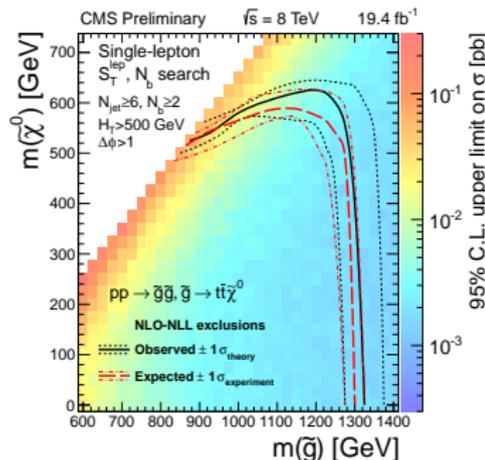
Muons R_{CS} ($N_b = 1$)

S_T^{lep}	control	signal	R_{CS}
[250,350]	192	9	0.005 ± 0.02
[350,450]	55	2	0.004 ± 0.03
>450	10	0	<0.1

Yields for $N_{jet} \geq 6$ Nb-jets=2 (μ channel)

S_T^{lep}	SR pred	SR obs
[250,350]	6.00 ± 2.4	9
[350,450]	1.37 ± 1.1	2
>450	0.0 ± 0.7	0

SUS-13-007 @ 8TeV 19.4 fb^{-1}



Excluded masses

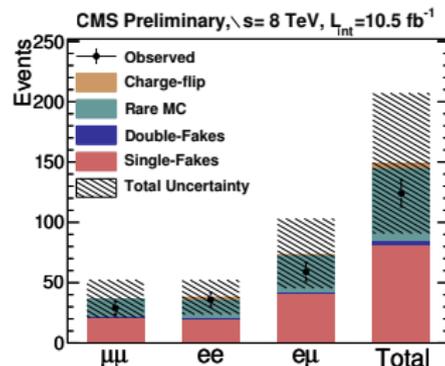
- $\Delta\phi$ Exclusion: Mgluino < 1350 GeV and MLSP < 600 GeV
- LS Exclusion Mgluino < 1200 GeV and MLSP 450 GeV

2 same sign isolated lepton, 2 bjets and \cancel{E}_T

SUS-12-029 @ 8TeV 10.5 fb^{-1}

Selection

- 2 same sign e or μ ($P_T(l) > 20 \text{ GeV}$)
very rare in SM \rightarrow sensitive to new physics
- N PF b jets ≥ 2 ($P_T(\text{jet}) > 40 \text{ GeV}$) \rightarrow non- $t\bar{t}$
- 3rd l veto when $M(l_i, l_j) \sim M_Z \rightarrow WZ, ZZ$
- additional \cancel{E}_T and H_T bins \rightarrow 9 SR



Main backgrounds

- Fake leptons : leptons from misidentified hadrons, electrons from unidentified γ conversion...
- Rare SM processes : with high P_T iso lepton and 2 b jets $\rightarrow t\bar{t}W, t\bar{t}Z, t\bar{t}WW...$
- Charge flips : electron charge misreconstructed due to bremsstrahlung.

2 same sign isolated lepton, 2 bjets and \cancel{E}_T

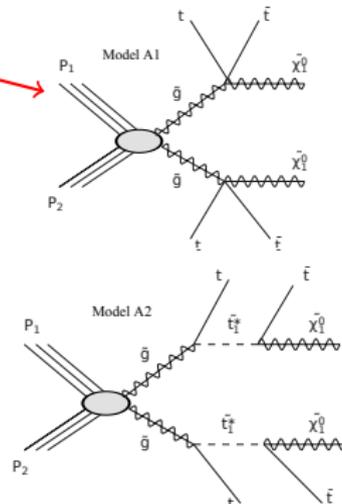
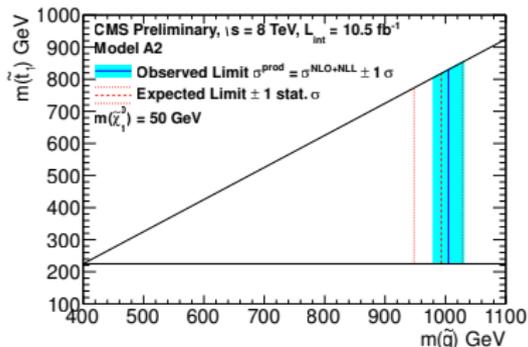
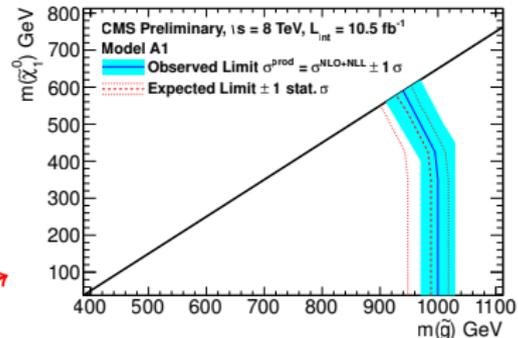
SUS-12-029 @ 8TeV 10.5 fb^{-1}

Main results

- limit on same sign tt X-section (95% CL)
 $\sigma(pp \rightarrow \bar{t}t) + \sigma(pp \rightarrow tt) < 0.87 pb$
 $\sigma(pp \rightarrow tt) < 0.30 pb$
- $M(\text{gluinos}) < 970 \text{ GeV}$ $M(\text{LSP}) < 580 \text{ GeV}$

Decay modes

- A1 $pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0 t\bar{t}\tilde{\chi}^0$ (3Body)
- A2 $pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0 t\bar{t}\tilde{\chi}^0$ (2Body)



2 same sign isolated lepton, 2 bjets and \cancel{E}_T

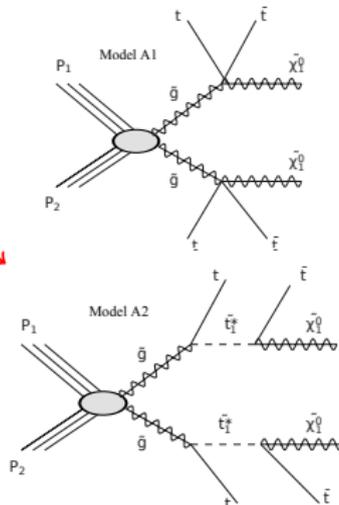
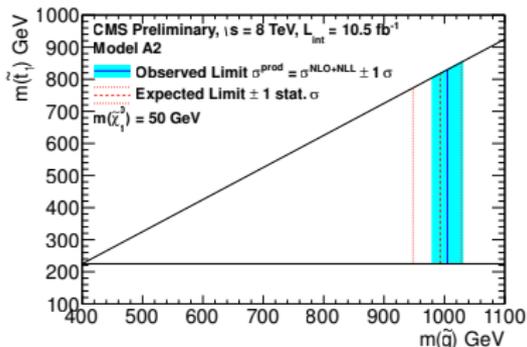
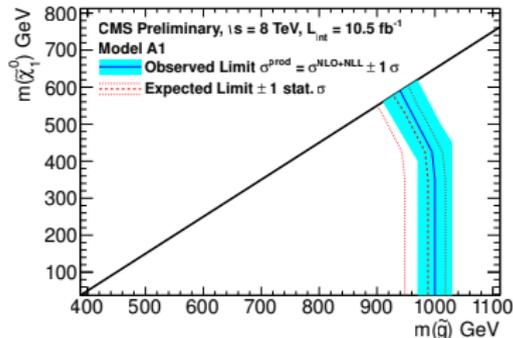
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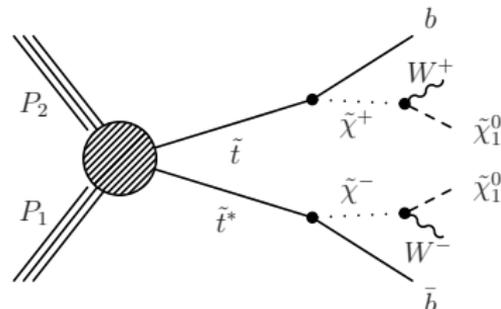
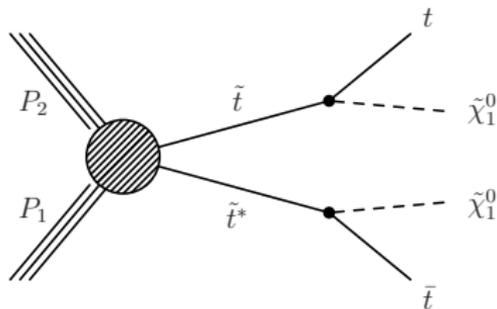
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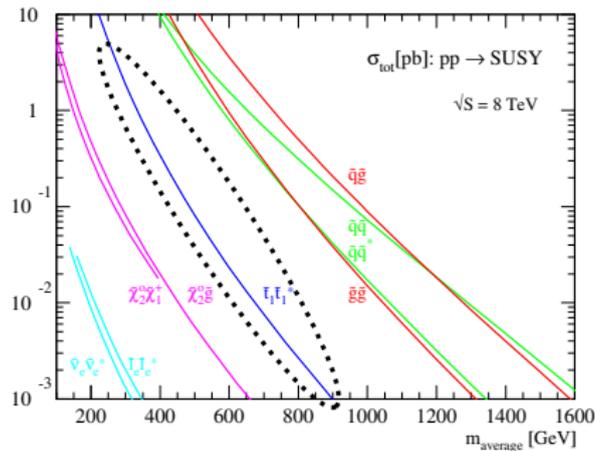
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Direct stop and bottom production

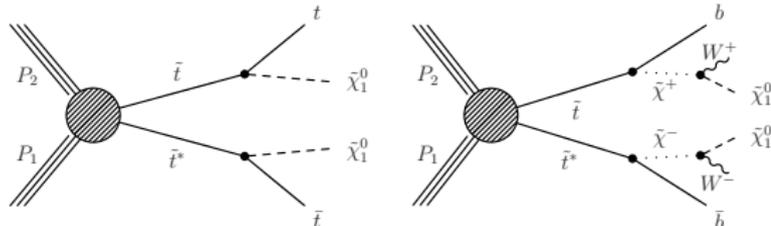
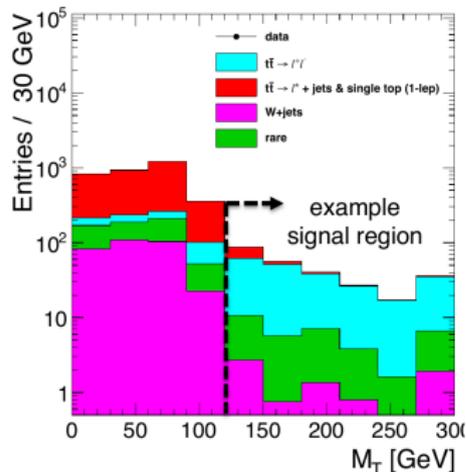


Single isolated lepton, jets and large \cancel{E}_T

SUS-12-023 @ 8TeV 9.7 fb^{-1}

Selection

- exactly 1 e/μ ($P_T(l) \geq 30 GeV$)
- N PF jets ≥ 4 ($P_T^{jets} \geq 30 GeV$)
- $N_{bjets} \geq 1$
- $M_T > 120 GeV$
- $\cancel{E}_T > 150 GeV$
- 7 SR in the (\cancel{E}_T, M_T) plan
- several CR to validate predictions in SR



$$M_T = \sqrt{2\cancel{E}_T p_T^l [1 - \cos(\Delta\phi(l, \cancel{E}_T))]}$$

Decay modes

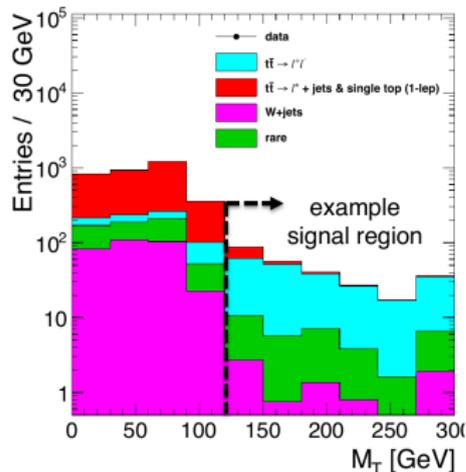
- $\tilde{t} \rightarrow t\tilde{\chi}_1^0 \rightarrow bW\tilde{\chi}_1^0$
- $\tilde{t} \rightarrow b\tilde{\chi}_1^+ \rightarrow bW\tilde{\chi}_1^0$

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SUS-12-023 @ 8TeV 9.7 fb^{-1}

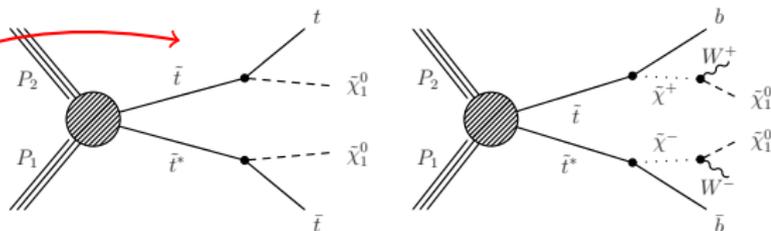
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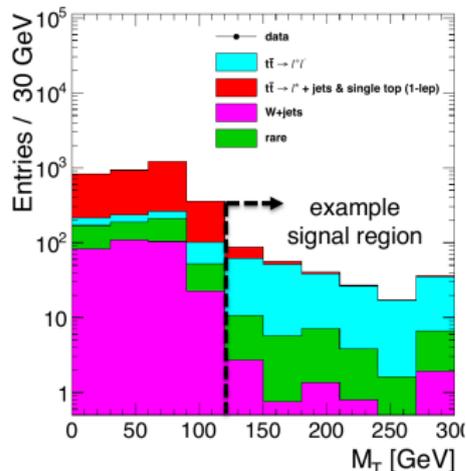
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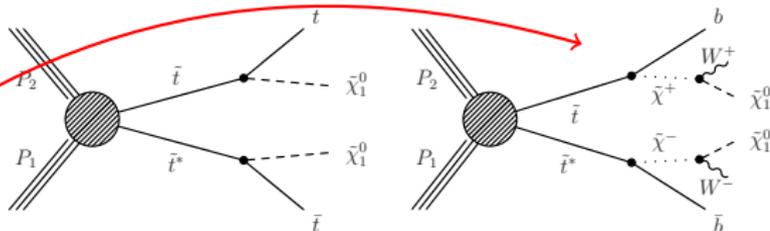
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$$M_T = \sqrt{2 \cancel{E}_T p_T^l [1 - \cos(\Delta\phi(l, \cancel{E}_T))]}$$

Single isolated lepton, jets and large \cancel{E}_T SUS-12-023 @ 8TeV 9.7 fb^{-1}

Background uncertainties snapshot (in %)

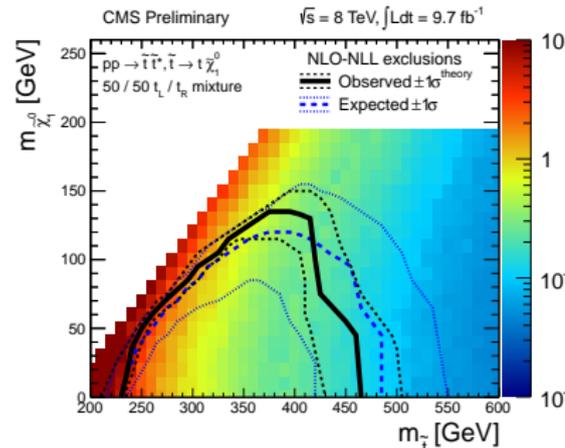
Source	SRA	SRD	SRG
M_T peak data and MC (stat)	0.9	4.7	15.4
W+jets cross section	1.7	3.9	5.1
K_3 and K_4 N_{jets} scale fact	1.9	2.1	1.8
$t\bar{t} \rightarrow ll$ (CR4 and CR5 tests)	3.1	17.3	24.5
2nd lepton veto	1.2	1.4	1.2
$t\bar{t} \rightarrow ll$ (stat)	1.2	5.1	13.6
top tail-to-peak ratio	12.5	6.5	6.0
W+jets tail-to-peak ratio	6.4	6.6	17.6
rare cross sections	2.0	4.9	7.6
total	14.9	21.8	38.2

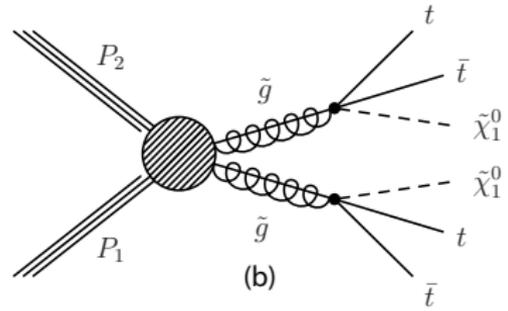
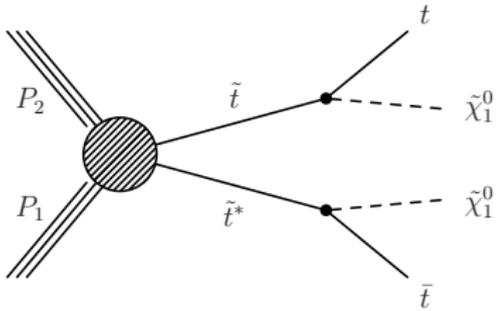
Muon+electron channel yields

Process	SRA	SRD	SRG
$t\bar{t} \rightarrow ll$	579 ± 38	39 ± 10	3.5 ± 1.8
$t\bar{t} \rightarrow l$ +jets & singletop	256 ± 131	7.7 ± 5.1	0.8 ± 1.0
W+jets	33.5 ± 8.2	2.0 ± 1.0	0.3 ± 0.4
Rare processes	59 ± 29.5	7.7 ± 3.9	1.1 ± 0.6
total	927 ± 138	56 ± 12	5.7 ± 2.2
data	861	61	3

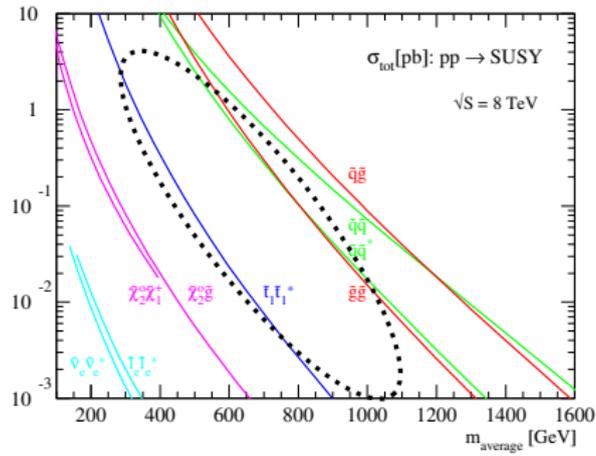
Main results: excluded masses

- $\tilde{t} \rightarrow t\tilde{\chi}_1^0$:
stop mass in range 230-460 GeV
neutralino mass < 130 GeV
- $\tilde{t} \rightarrow b\tilde{\chi}_1^+$:
stop mass in range 150-430 GeV
neutralino mass < 140 GeV





Inclusive searches



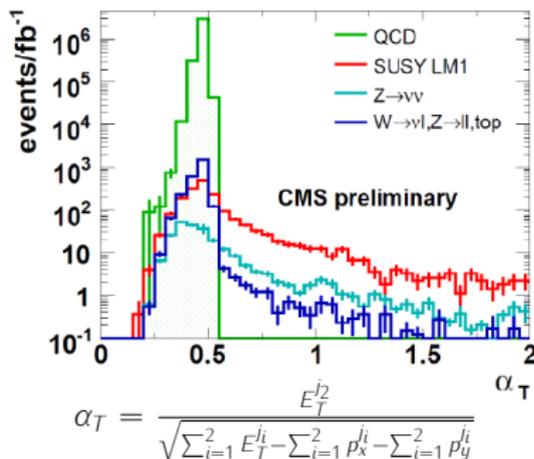
All hadronic search using btagging and α_T SUS-12-028 @ 8TeV 11.7 fb⁻¹

Inclusive search

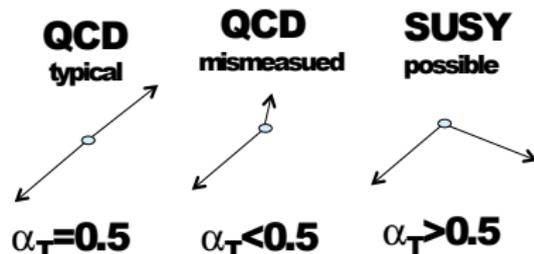
- $pp \rightarrow \tilde{g}\tilde{g} \rightarrow q\tilde{q}\tilde{\chi}^0 q\tilde{q}\tilde{\chi}^0$
- $pp \rightarrow \tilde{q}\tilde{q} \rightarrow q\tilde{\chi}^0 \bar{q}\tilde{\chi}^0$
- $pp \rightarrow \tilde{b}\tilde{b} \rightarrow b\tilde{\chi}^0 \bar{b}\tilde{\chi}^0$
- $pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\tilde{\chi}^0 t\tilde{\chi}^0$
- $pp \rightarrow \tilde{g}\tilde{g} \rightarrow b\bar{b}\tilde{\chi}^0 b\bar{b}\tilde{\chi}^0$

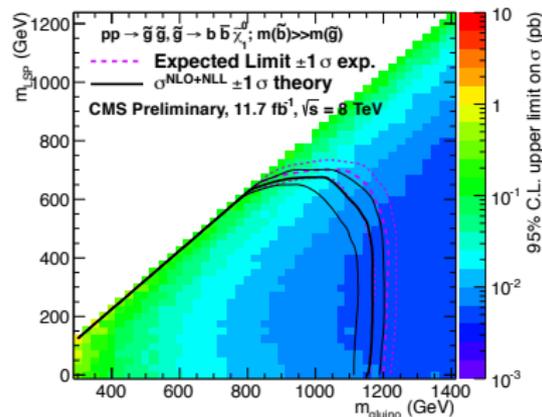
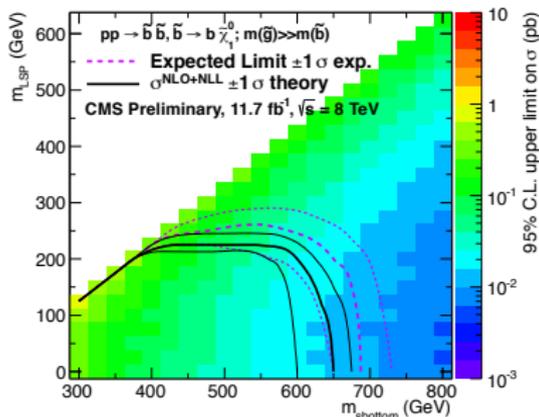
Selection

- $H_T \geq 275\text{GeV} + \text{bins}$
- N_{bjets} bins [0,1,2,3 and 4]
- $2 \leq N_{\text{jets}} \leq 3$ or $N_{\text{jets}} \geq 4$
($P_T(\text{jets}) \geq 50\text{GeV}$)
- $\alpha_T > 0.55$



E_T^{jet} is the transverse energy of the least energetic jet
(if $N_{\text{jets}} > 2$ an equivalent dijet system is formed)



All hadronic search using btagging and α_T 

Main results

Production/decay	n_{jet}	n_b	$m_{q(\tilde{g})}^{best}$ (GeV)	m_{LSP}^{best} (GeV)
$pp \rightarrow \tilde{g}\tilde{g} \rightarrow q\bar{q}\tilde{\chi}^0 q\bar{q}\tilde{\chi}^0$	≥ 4	0	~ 950	~ 450
$pp \rightarrow \tilde{q}\tilde{q} \rightarrow q\tilde{\chi}^0 \bar{q}\tilde{\chi}^0$	2–3	0	~ 775	~ 325
$pp \rightarrow \tilde{b}\tilde{b} \rightarrow b\tilde{\chi}^0 \bar{b}\tilde{\chi}^0$	2–3	1,2	~ 600	~ 200
$pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\tilde{\chi}^0 \bar{t}\tilde{\chi}^0$	≥ 4	2,3, ≥ 4	~ 975	~ 325
$pp \rightarrow \tilde{g}\tilde{g} \rightarrow b\tilde{\chi}^0 \bar{b}\tilde{\chi}^0$	≥ 4	2,3, ≥ 4	~ 1125	~ 650

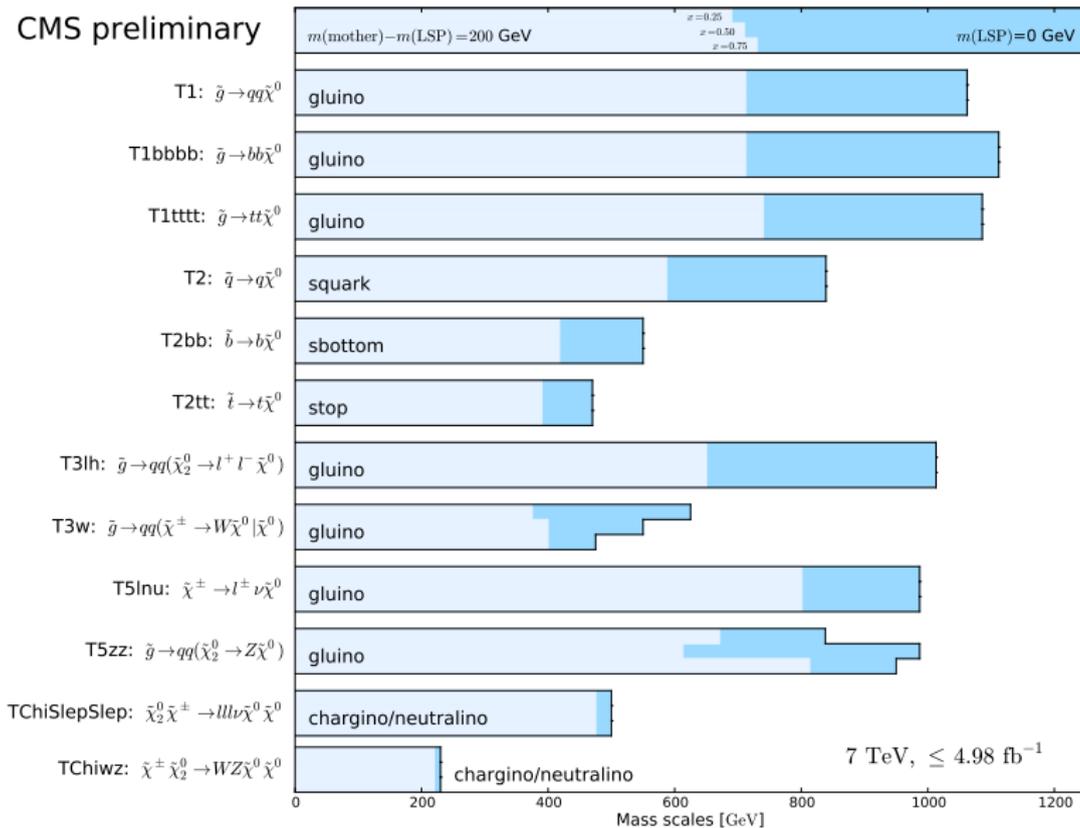
Conclusions

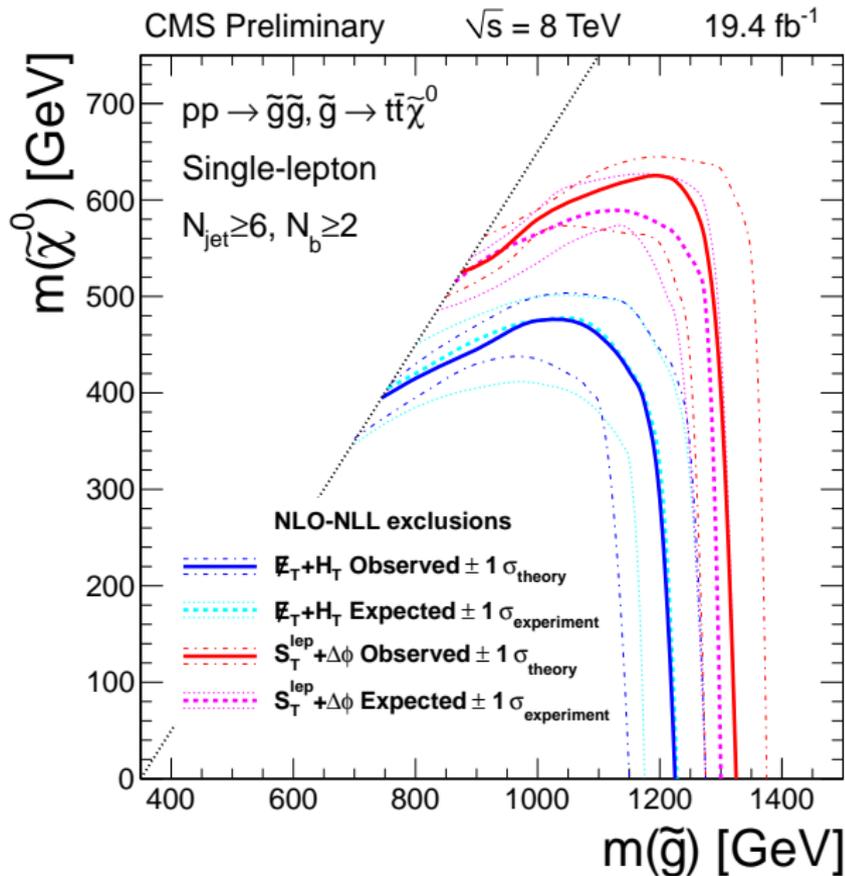
- Many final states, search regions and discriminators but still no SUSY in sight.
- No significant excess observed in many different channels.
- Very stringent limits already obtained on strong SUSY production.
- Limits get close to 10% fine tuning on Z mass (0.6 TeV stop, 1.4 TeV Gluino).
- Natural SUSY quite constrained but still alive

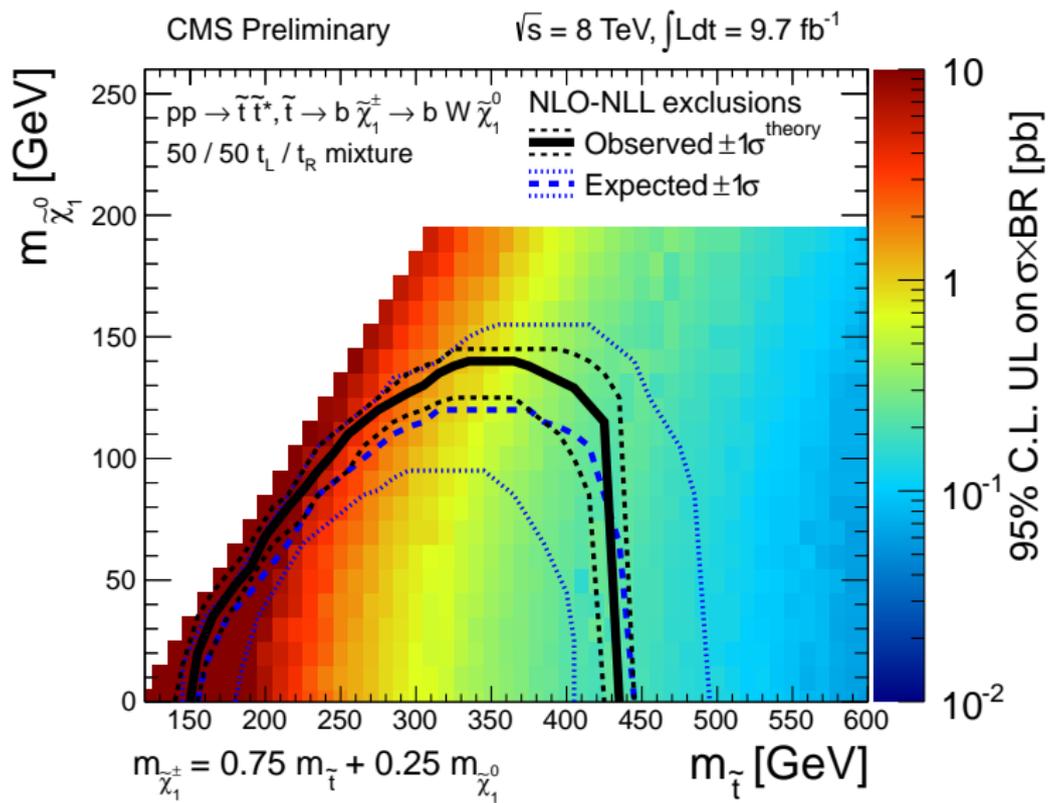
Perspectives

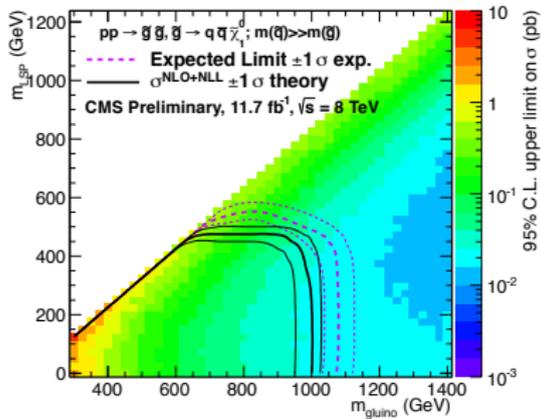
- Combination of direct and gluinos mediated production results under discussion.
- Many analyses are still processing 2012 dataset, stay tuned for future results.
- Add tau for leptonic channel searches.
- Adapt current analyses and be prepared for ~ 13 TeV runs.

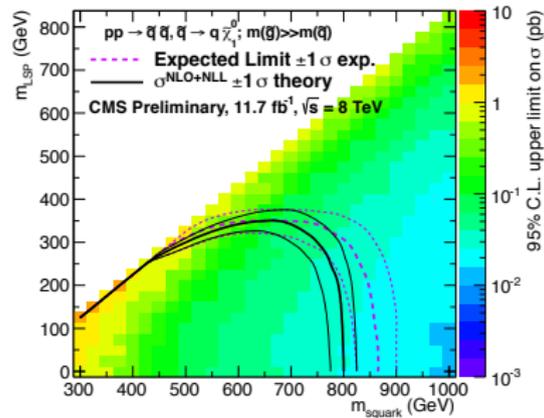
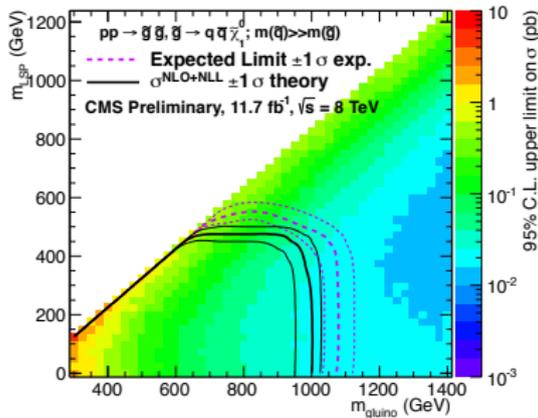
CMS preliminary



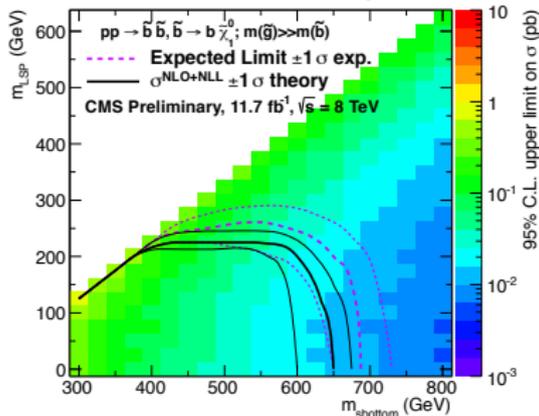
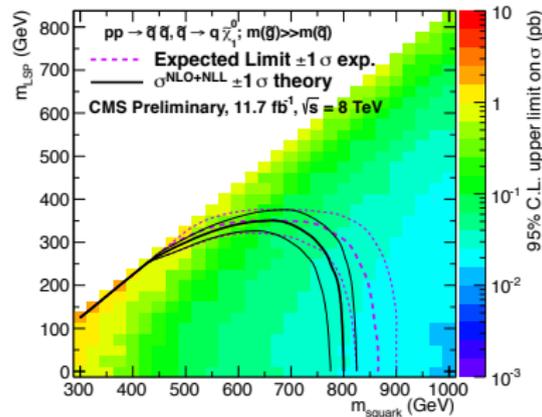
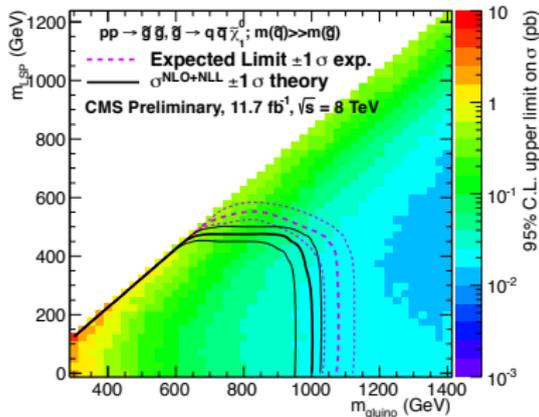




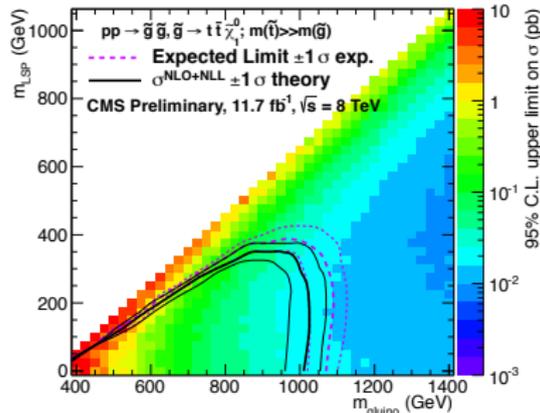
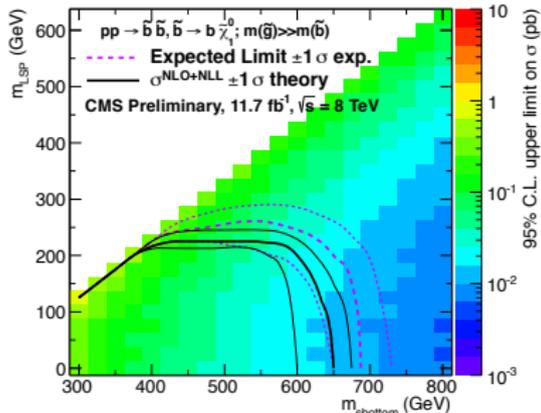
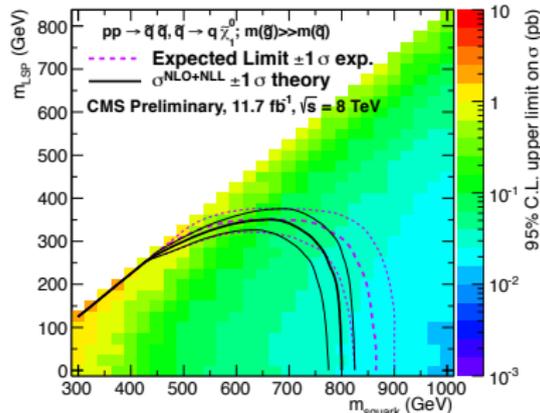
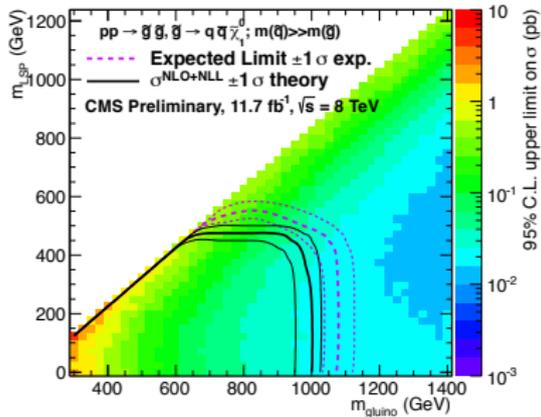
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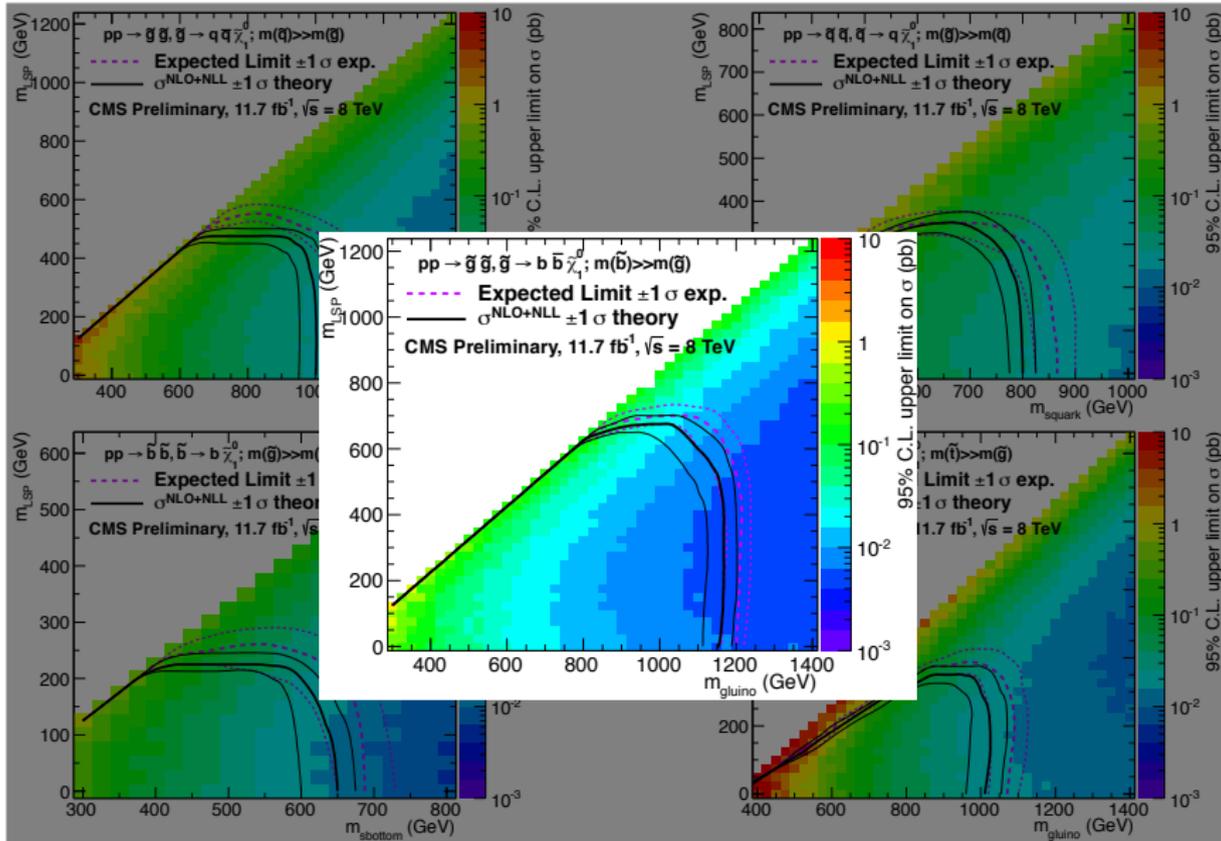
All hadronic search using btagging and α_T



All hadronic search using btagging and α_T



All hadronic search using btagging and α_T



Acceptance mainly due to high- p_T ISR jet(s)



One possible choice: stability of EW scale (identified by MZ) w.r.t. model parameters [Nucl. Phys. B306 (63-76) (1987)]

$$m_Z^2 = -2\mu^2 + 2 \frac{m_{H_d}^2 - \tan^2 \beta m_{H_u}^2}{\tan^2 \beta - 1}$$

$$\max_{a_i} \left(\left| \frac{a_i}{m_Z^2} \frac{\partial m_Z^2(a_i)}{\partial a_i} \right| \right) < \Delta$$

model parameters
↑
↓
tolerated fine tuning