Searches for gluino, stop and sbottom production in channels with b-jets and E_T^{miss} at CMS

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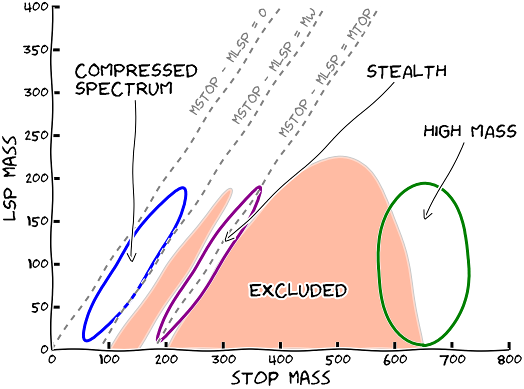
CMS
Compact Muon Solenoid

Scope

Many searches for gluino, stop and sbottom production have been performed with the 8 TeV CMS data. This talk will cover recent results in final states with b-tagged jets and E_T^{miss}, in particular focusing on specific corners of SUSY space.

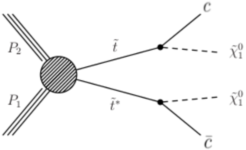


In addition we consider a natural SUSY scenario with a compressed chargino-neutralino spectrum.

Targeting compressed spectra using monojet topology

SUS-13-009

For a very compressed spectrum the stop decay products, e.g. $\tilde{t}_1 \to c\tilde{\chi}_1^0$, are very soft, and thus hard to detect.
$\Rightarrow$ Exploit the possible presence of a hard ISR jet and large E_T^{miss}



Monojet selection

- $E_T^{miss} > 250$ GeV
- $p_T(j_1) > 110$ GeV
- max 2 jets with $p_T > 60$ GeV
- no leptons
- $\Delta\phi(j_1, j_2) < 2.5$

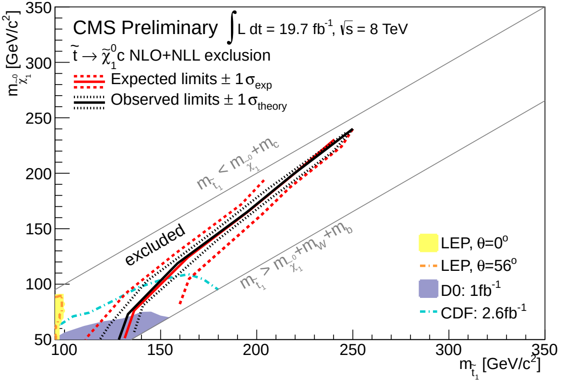
Backgrounds

- Main backgrounds: $Z \to \nu\nu$+jets and $W \to l\nu$+jets
- These are estimated using control regions in data
- Smaller backgrounds are taken from MC, with 50% uncertainty

Inclusive signal regions: $p_T(j_1) > 250, 300, 350, 400, 450, 500, 550$ GeV.
Good agreement between data and prediction is found.

Targeting compressed spectra using monojet topology

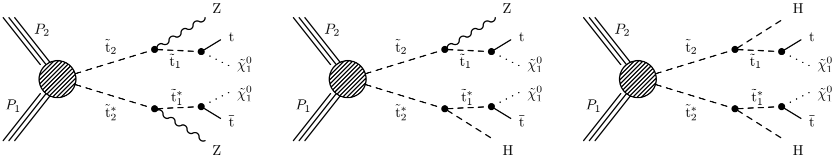
SUS-13-009



- Stop masses up to 250 GeV are excluded for $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} < 10$ GeV
- Results can be generalized to $\tilde{t}_1 \to x\tilde{\chi}_1^0$, where x is any decay product invisible to the monojet selection

Targeting stealth stops using final states with h or Z

SUS-13-024 arXiv:1405.3886 [hep-ex]



- By considering $\tilde{t}_2$ production we can target the region where $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \approx m_t$
- Assume $\mathcal{B}(\tilde{t}_2 \to h\tilde{t}_1) + \mathcal{B}(\tilde{t}_2 \to Z\tilde{t}_1) = 100\%$
- Use combination of number of mutually exclusive analyses: $1, 2, \geq 3$ leptons, multiple b jets and moderate E_T^{miss}

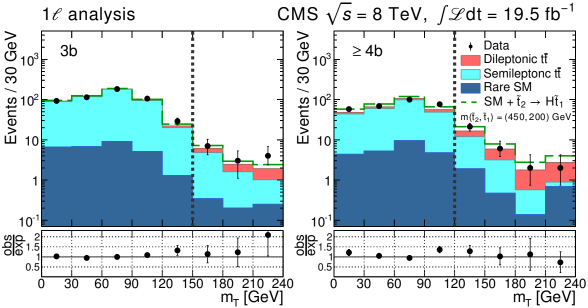
N_ℓ	Veto	$N_{\text{b jets}}$	N_{jets}	E_T^{miss} [GeV]	Additional requirements [GeV]
1	track or τ_h	$=3$ ≥ 4	≥ 5 ≥ 4	≥ 50	$m_T > 150$ $m_T > 120$
2 OS	extra e/μ	$= 3$ ≥ 4	≥ 5 ≥ 4	≥ 50	$N_{bb} = 1$ with $100 \leq m_{bb} \leq 150$, $N_{bb} \geq 2$
2 SS	extra e/μ	$=1$ ≥ 2	$[2,3], \geq 4$	$[50,120], \geq 120$	for low/high-p_T: $H_T \in [200,400], \geq 400$
≥ 3	—	$= 1$ $= 2$ ≥ 3	$[2,3], \geq 4$ ≥ 3	$[50,100], [100,200], \geq 200$	for on/off-Z: $H_T \in [60,200], \geq 200$

Targeting stealth stops using final states with h or Z

SUS-13-024 arXiv:1405.3886 [hep-ex]

One lepton analysis

- Targets $h \to b\bar{b}$ signature
- Main background is $t\bar{t}$, with extra bjet from mistag or gluon splitting
- $m_T = \sqrt{2p_T^l p_T^\nu[1 - \cos(\phi^l - \phi^\nu)]}$ is required to be large
- Use low m_T control region to normalize shape
- Apply (small) scale factors derived in low n_{bjet} region to correct m_T tail



Targeting stealth stops using final states with h or Z

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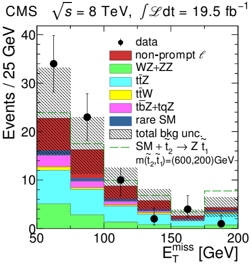
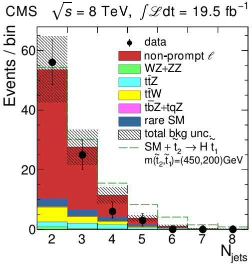
On-Z



Off-Z



Three lepton analysis

- Sensitive to all three processes with leptons from Z or $h \to WW, ZZ$
- On-Z region most sensitive for on-shell Z
- Off-Z region sensitive to off-shell Z and/or h
- Background from WZ+jets is supressed by b-jet requirement, remaining background mainly from rare processes or non-prompt leptons
  - WZ and ZZ background is estimated from simulation and validated with control regions
  - Non-prompt background is estimated using the measured (in data) probability for a lepton from B-hadron decay to pass the analysis criteria

Targeting stealth stops using final states with h or Z

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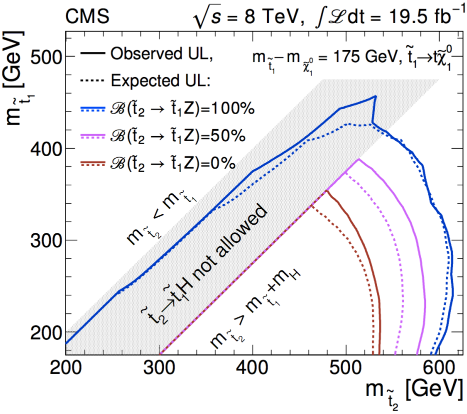
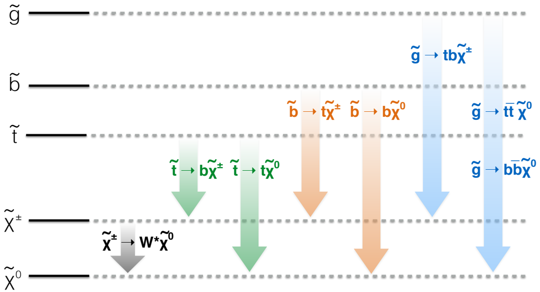


- Background prediction is consistent with observation across all search bins
- Largest discrepancy is 1.6σ local significance
- 3 lepton regions most sensitive
- 1,2 lepton regions mostly sensitive to hh final states
- Limit becomes weaker as branching fraction to h increases

$\Rightarrow$ Exclude $\tilde{t}_2$ masses below approximately 575 GeV for $\tilde{t}_1$ masses below 400 GeV.

Focus on Natural SUSY spectrum

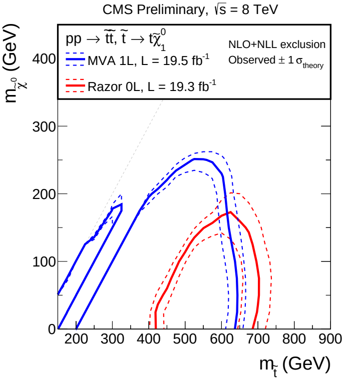


- gluino mass of O(TeV)
- lighter sbottom and stop
- lighter nearly degenerate chargino and neutralino triplet (5 GeV splitting)
- all other sparticles decoupled

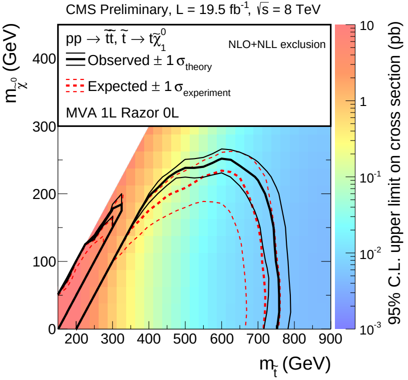
In this talk a new combined result (SUS-14-011) between the Razor and single lepton BDT analyses is shown for stop production in this natural SUSY model.
The Razor analysis also provides an interpretation for gluino production in this framework. The talk by K. Goebel (SUSY Phenomenology session) covers the Razor search and interpretation for $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$, whereas this talk covers the summary across all considered decay modes.

Targeting high mass stop with new combination

SUS-14-011



$\Rightarrow$



Combination of

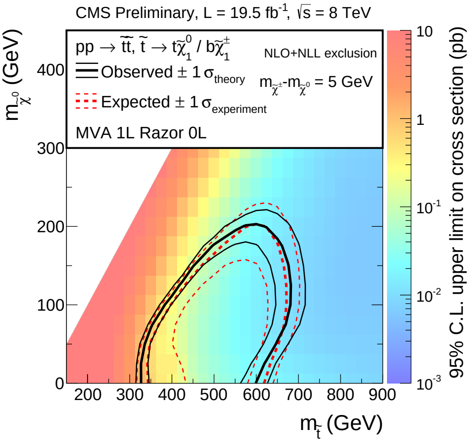
- Razor hadronic box, SUS-13-004
- Single lepton BDT, SUS-13-011

$\Rightarrow$

Highest stop mass limit to date assuming 100% branching ratio for $\tilde{t}_1 \rightarrow t\tilde{\chi}^0_1$.
Stop masses up to 750 GeV are excluded for LSP mass of 100 GeV.

Branching ratio independent result for stop production

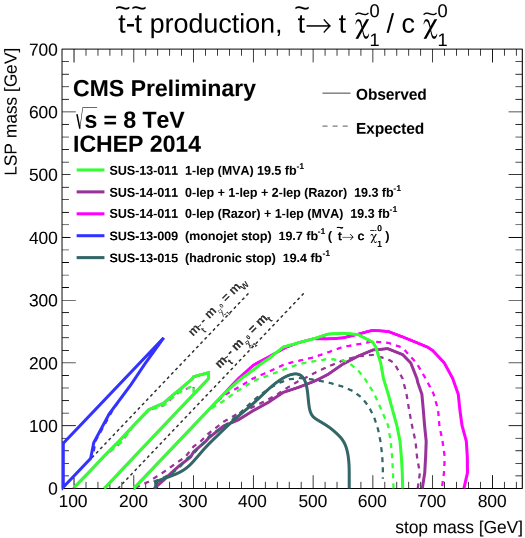
SUS-14-011



- Only decay modes $\tilde{t}_1 \to t\tilde{\chi}^0_1$ and $\tilde{t}_1 \to b\tilde{\chi}^\pm_1$ are open ($m_{\tilde{\chi}^\pm_1} - m_{\tilde{\chi}^0_1} = 5$ GeV)
- For each mass point, scan $\mathcal{B}(\tilde{t}_1 \to t\tilde{\chi}^0_1)$ from 0 to 100% and take worst upper limit on cross section
- Compare that UL to stop production cross section to get a limit

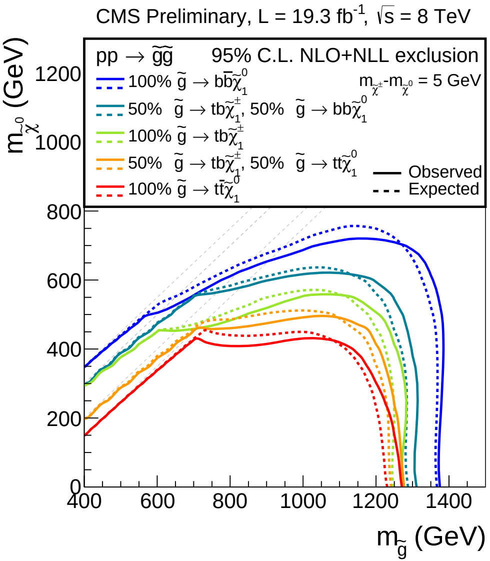
⇒ For an LSP mass of 100 GeV, stop masses between 380 and 675 GeV are excluded, regardless of the branching ratio to $t\tilde{\chi}^0_1$ and $b\tilde{\chi}^\pm_1$.

Summary of stop production



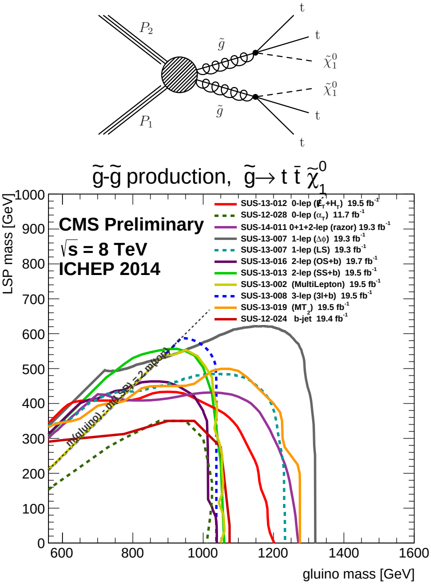
Summary of gluino production

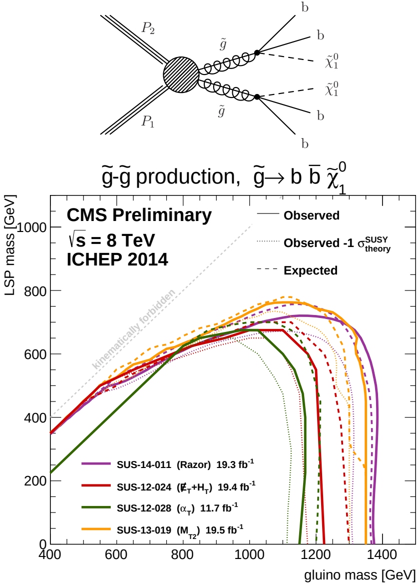
SUS-14-011 Razor – Natural SUSY scenario



- Limits for mixed branching ratios lie within 100% $\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ and 100% $\tilde{g} \to b\bar{b}\tilde{\chi}^0_1$ contours
- Gluino masses smaller than 1275 – 1375 GeV are excluded for LSP mass of 100 GeV
- Greater number of top quarks ⇒ Weaker limit
- In context of this natural SUSY simplified model, the limit for 100% $\tilde{g} \to t\bar{t}\tilde{\chi}^0_1$ is a conservative, branching ratio independent limit

Summary of gluino production



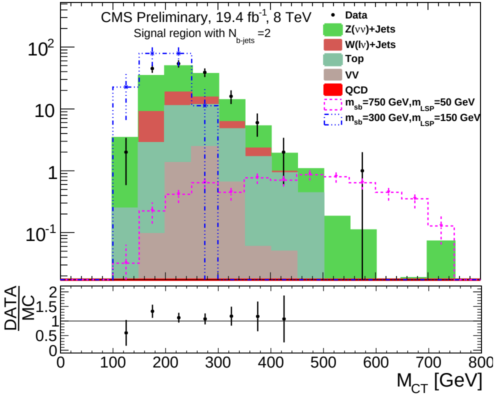


Direct sbottom production

SUS-13-018

Selection

- 2 jets with $p_T > 70$ GeV
- no additional jets with $p_T > 50$ GeV
- at least 1 b-jet
- no leptons
- $H_T > 250$ GeV
- $E_T^{miss} > 175$ GeV
- $\Delta\phi(j_1, j_2) < 2.5$
- $m_T(j_2, E_T^{miss}) > 200$ GeV



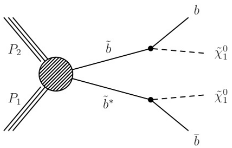
Signal regions defined using b-jet multiplicity and contranverse mass:

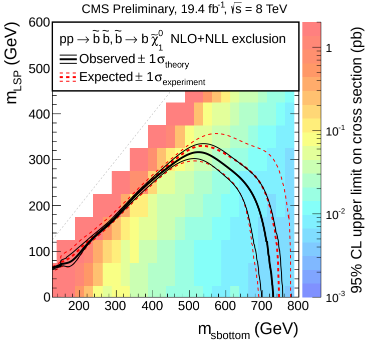
$$M_{CT}^2(j_1, j_2) = [E_T(j_1) + E_T(j_2)]^2 - [\vec{p}_T(j_1) + \vec{p}_T(j_2)]^2 = 2p_T(j_1)p_T(j_2)(1 + \cos\Delta\phi(j_1, j_2))$$

M_{CT}^2 has endpoint at $(m_{\tilde{b}}^2 - m_{\tilde{\chi}_1^0}^2)/m_{\tilde{b}}$

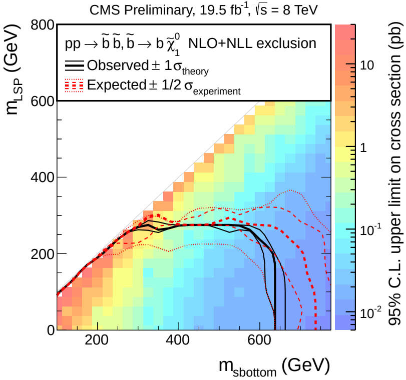
Summary of direct sbottom production

SUS-13-018, SUS-13-019





Dedicated direct sbottom search using M_{CT} (SUS-13-018)

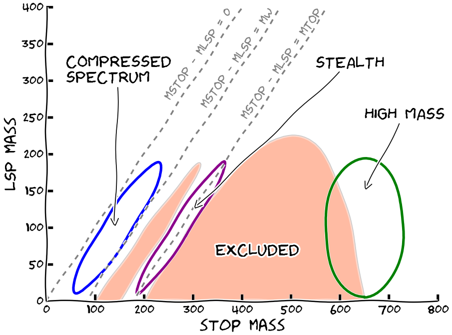


M_{T2} analysis (SUS-13-019), explained in talk by K. Goebel

- Sensitivity up to 740 GeV in sbottom mass
- M_{T2} analysis also sensitive to very compressed region

Conclusion

- We have searched for deviations from the standard model in many final states and many kinematic regions.
- No significant deviations have been found so far and we have thus put constraints on the SUSY parameter space.



There are however still many places where new physics could be hiding!

$\Rightarrow$ Stay tuned for the next run!

BACKUP

SUS-13-009: Background prediction

$Z \rightarrow \nu\nu$ estimation

Select sample of $Z \rightarrow \mu\mu$ events:

- 2 muons with $p_T > 20$ GeV
- $60 < m_{\mu\mu} < 120$ GeV

Compute number of $Z \rightarrow \nu\nu$ events

$$N(Z \rightarrow \nu\nu) = \frac{N^{obs} - N^{bgd}}{A \times \epsilon} \cdot R$$

with A the acceptance, ϵ the selection efficiency, and R the ratio of branching fractions

$W \rightarrow l\nu$ estimation

Select sample of $W \rightarrow \mu\nu$ events:

- 1 muon with $p_T > 20$ GeV
- $50 < m_T < 100$ GeV

Compute number of 'lost' muon events:

$$N_{lost\,\mu} = \frac{N^{obs} - N^{bgd}}{A' \times \epsilon'} \times (1 - A_\mu \epsilon_\mu)$$

Similar procedure for electrons and hadronic taus

SUS-13-024: Background prediction

- Main backgrounds are estimated using control regions in data
- Rare backgrounds (e.g. $t\bar{t}Z, t\bar{t}W$) are taken from simulation with 50% uncertainty on cross section

1 lepton, 2 OS leptons

Background: $t\bar{t}$:

- ≥ 3 bjets are possible if additional jets are mistagged or come from gluon splitting
- data/simulation scale factors derived from $t\bar{t}$ control region
- main uncertainty: limited # events in control region

2 SS leptons

Non-prompt leptons:

- evaluate using loose lepton sample
- scale by probability of loose lepton to pass tight selection

Charge misidentification:

- Use OS $ee, e\mu$
- weight by probability of electron charge misassignment (p_T, η dependent)

3 leptons

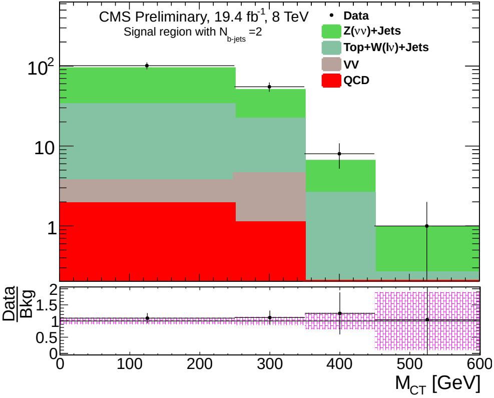
Non-prompt leptons:

- estimate prob. for lepton from b decay to pass tight req.
- apply this to ≥ 3 lepton region where isolation is inverted for one lepton

Genuine leptons

- estimate from simulation
- validate with control regions

SUS-13-018: Selection and backgrounds



Backgrounds

- $Z \to \nu\nu$+jets
- $t\bar{t}$, single top, $W \to l\nu$+jets, where lepton (e, μ) is misidentified, non-isolated, out of acceptance, or where τ decays hadronically
- QCD multijet
- Estimated using data control regions

SUS-13-004: Selection

Table 1: Lepton, b-tag, kinematic, and jet multiplicity requirements for each of the ten boxes in the razor analysis. The boxes are listed in decreasing hierarchy rank. The ranking is introduced to unambiguously associate an event to a box.

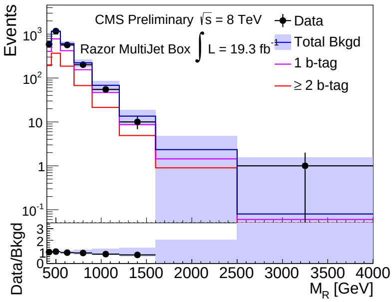
Requirements				
Box	lepton	b-tag	kinematic	jet
Dilepton Boxes				
MuEle	$\geq$ 1 tight electron and $\geq$ 1 loose muon	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	$\geq$ 2 jets
MuMu	$\geq$ 1 tight muon and $\geq$ 1 loose muon	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	$\geq$ 2 jets
EleEle	$\geq$ 1 tight electron and $\geq$ 1 loose electron	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	$\geq$ 2 jets
Single Lepton Boxes				
MuMultiJet	$\geq$ 1 tight muon	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	$\geq$ 4 jets
MuJet	$\geq$ 1 tight muon	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	2 or 3 jets
EleMultiJet	$\geq$ 1 tight electron	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	$\geq$ 4 jets
EleJet	$\geq$ 1 tight electron	$\geq$ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	2 or 3 jets
Hadronic Boxes				
MultiJet	none	$\geq$ 1 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 550$ GeV or $R^2 > 0.3$)	$\geq$ 4 jets
2b-Jet	none	$\geq$ 2 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 550$ GeV or $R^2 > 0.3$)	2 or 3 jets

$$M_R = \sqrt{(p_{j1} + p_{j2})^2 - (p_z^{j1} + p_z^{j2})^2}$$

$$M_R^T = \sqrt{\frac{E_T^{miss}(p_T^{j1}+p_T^{j2}) - \vec{E}_T^{miss}\cdot(\vec{p}_T^{\,j1}+\vec{p}_T^{\,j2})^2}{2}}, \qquad R = \frac{M_R^T}{M_R}$$

SUS-13-004: Background prediction

- Parametrize background with well-validated functional form
- Fit to sideband region and extrapolate to signal region
- No significant deviation from data is seen
- Combine all boxes to set limits



SUS-13-011: Selection and background prediction

Eur. Phys. J. C 73 (2013) 2677

Baseline

- $\geq$ 4 jets
- $\geq$ 1 b-jets
- 1 lepton
- $E_T^{miss} > 100$ GeV
- $M_T > 120$ GeV

BDT signal regions

- E_T^{miss}
- M_{T2}^W
- hadronic top χ^2
- H_T^{ratio}
- bjet p_T
- min $\Delta\phi$

Background prediction

- Main background: $t\bar{t}$ to dilepton
- Normalize MC in the low M_T region
- M_T shape is verified in various control regions and small corrections are applied
- rare backgrounds taken directly from MC