Cornering natural SUSY with $\sqrt{s} = 13$ TeV data

Les Rencontres de Moriond

EW Interactions and Unified Theories

La Thuile, Italy 18-25 March 2017

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On behalf of the ATLAS and CMS collaborations

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Supersymmetry and Naturalness

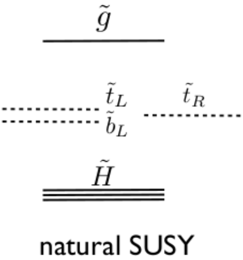
The most studied extension of the SM among any BSM theory. Advantages:

- Could solve the hierarchy problem through the one loop stop correction;
- Could unify the fundamental interactions of nature;
- Could provide a dark matter candidate, if R-Parity is conserved;

- Naturalness requierement by the tree-level relation in MSSM:

$$\frac{-m_Z^2}{2} = |\mu|^2 + m_{H_u}^2$$

- *stops expected to be light (<∼ 1 TeV);*
- *higgsinos with masses below 350 GeV;*
- *a not too heavy gluino;*

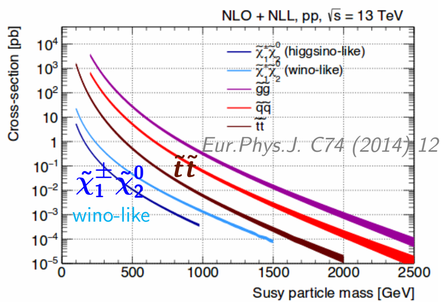


10.1007/JHEP09(2012)035,arXiv:1110.6926 [hep-ph]

Overview

Analyses covered

- $\tilde{t}\tilde{t}$
- $\tilde{b}\tilde{b}$
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$
  Compressed spectra
  $(\Delta m = m_{\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} < 30\text{ GeV})$



ATLAS

- $\tilde{t}$ 0-lepton (**ATLAS-CONF-2017-020**)
- $\tilde{t}_2 \to \tilde{t}_1\ Z/H$ (**ATLAS-CONF-2017-013**)
- $\tilde{t}$ 1-lepton R-Parity Violation(**ATLAS-CONF-2017-013**)

Link to ATLAS public results

CMS

- $\tilde{t}$ 0-lepton (**SUS-16-049**)
- $\tilde{t}$ 2-leptons (**SUS-17-001**)
- 2-soft-leptons (**SUS-16-042**)
- $HH \to 4b$ (**SUS-16-044**)
- $\tilde{b}$ 0-lepton (**SUS-16-032**)
- $\tilde{b}\ h \to \gamma\gamma$ (**SUS-16-045**)

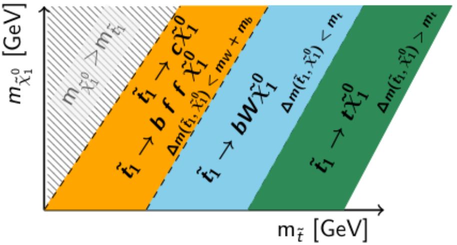
Link to CMS public results

... from stops ...

... to sbottoms ...

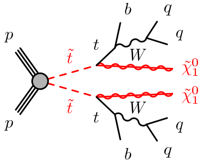
The stop searches: $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$

- **High mass region**
  $\Delta m > m_t$
  - boosted topologies
- **Intermediate region**
  $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) < m_t$
  - Examine "3-body-decays"
- **Compressed region**
  $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) < m_W + m_b$
  - Examine "4-body-decays"
  - Challenging region due to the soft products of the decays
  - high background rates
  - $\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$ challenging due to charm tagging



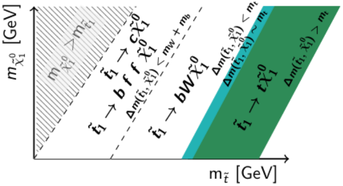
- Dedicated searches based on the *lepton multiplicities*

ATLAS Stop *0-lepton* *ATLAS-CONF-2017-020*



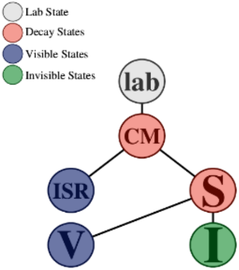
High mass - $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) > m_t$

- 2 inclusive SRs targeting different $\Delta m = m_{\tilde{t}} - m_{\tilde{\chi}_1^0}$ with 3 subcategories based on $t-$tagged and $W-$tagged jets (**TT, TW, T0**)
- Disctriminant variables: $m^{0,1}_{jet,R=1.2}$, $m_T^{b,min}$, $m_T^{b,max}$, E_T^{miss}
- Main background contribution comes $Z(\nu\nu) + jets$, followed by $t\bar{t}V$ (where $V = W,\ Z$) and $t\bar{t}$

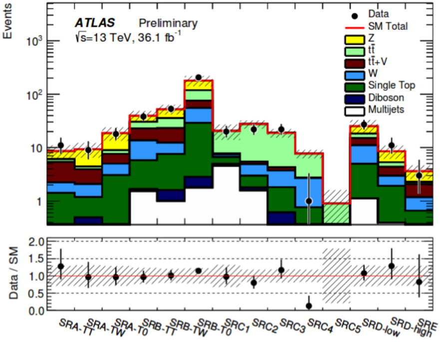


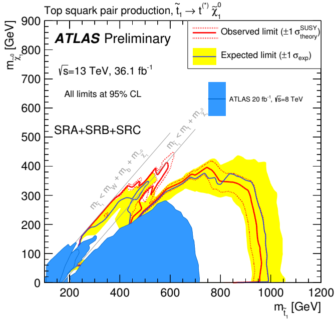
$\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_t$

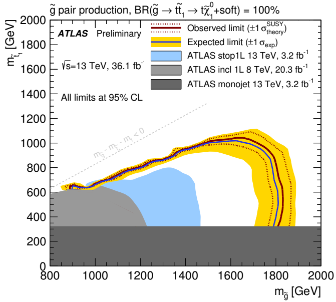
- Based on Recursive Jigsaw Reconstruction (RJR) by requiring an Initial State Radiation jet
- SRs binned in RISR ($\equiv E_T^{miss}/p_T^{ISR} \sim m_{\tilde{\chi}_1^0}/m_{\tilde{t}}$)
- Main background contribution $t\bar{t}$



ATLAS Stop 0L - Results *ATLAS-CONF-2017-020*





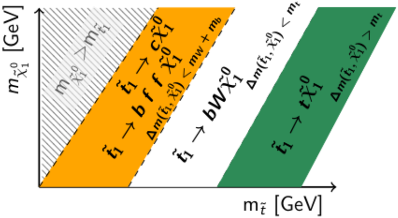


- Top left: Data and Standard Model (SM) predictions in Signal Regions (SRs)
- 95% CL limits in the mass planes $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ for $\tilde{t}_1 \to t\tilde{\chi}_1^0$ (top right) and $m_{\tilde{g}} - m_{\tilde{t}_1}$ (bottom right) in fully hadronic final states

CMS Stop *0-lepton* CMS-SUS-16-049

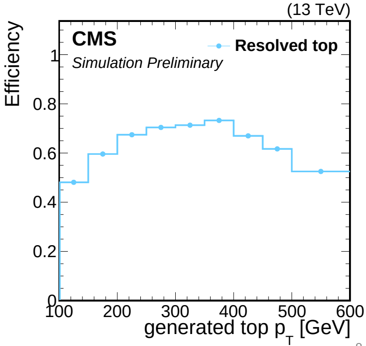
High $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$

- Search regions are defined from different requirements on $m_T(b_{1,2}, E_T^{\text{miss}})$, $t/W-$tagged jets, N_{jets}, "resolved-top", E_T^{miss}
- 51 disjoint search regions



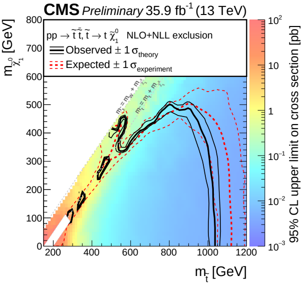
Low $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$

- ISR approach
- 53 disjoint regions
- Developmet of a novel soft $b-$tagging algorithm based on the presence of a secondary vertex for recovering $b-$tagged below $p_T(b) < 20$ GeV

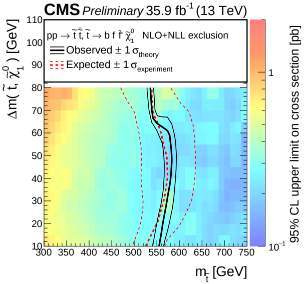


CMS Stop *0-lepton* - Results *SUS-16-049*

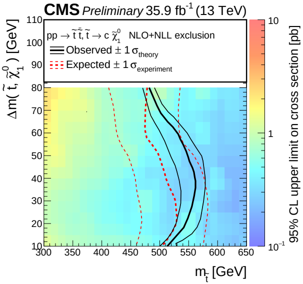
High mass



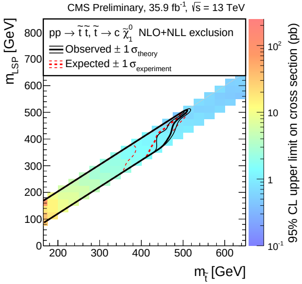
four-body-decay



charm-tagged



- 95% CL exclusion limits on $pp \rightarrow \tilde{t}_1 \tilde{t}_1$ in three different topologies;
- High mass region: $m_{\tilde{t}_1}$ up to 1.04 TeV and $m_{\tilde{\chi}^0_1}$ up to 500 GeV are probed;
- Low mass region ($\Delta m(\tilde{t}_1, \tilde{\chi}^0_1) < m_W$): $m_{\tilde{t}_1}$ up to 580 GeV are probed for $m_{\tilde{\chi}^0_1}$ of 540 GeV;
- Bottom exclusion taken from *SUS-16-032*. Mass splits up to 10 GeV have been probed.



CMS Stop *two-lepton* CMS-SUS-17-001

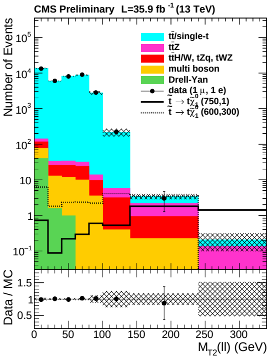
- Searches based on different flavors of m_{T2} calculation ($m_{T2}(\ell\ell)$, $m_{T2}(b\ell b\ell)$);

$$M_{T2}(\ell\ell) = \min_{\vec{p}_{T1}^{miss} + \vec{p}_{T2}^{miss} = \vec{E}_T^{miss}} \left(\max \left[M_T(\vec{p}_T^{vis1}, \vec{p}_{T1}^{miss}), M_T(\vec{p}_T^{vis2}, \vec{p}_{T2}^{miss}) \right] \right)$$

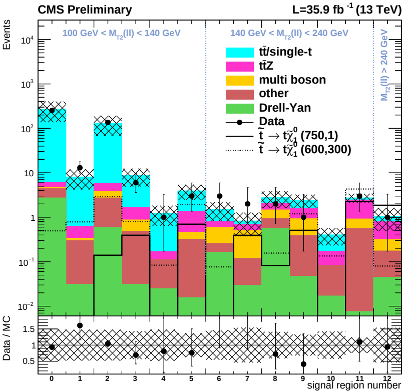
- Construct 12 disjoint SRs based on E_T^{miss}, $m_{T2}(\ell\ell)$ and $m_{T2}(b\ell b\ell)$
  - Dominant background in low m_{T2} region comes from single top and $t\bar{t}$
  - In high m_{T2} regions $t\bar{t} + X$ has significant contributions with $t\bar{t}Z(\nu\nu)$ being the dominant one. CRs defined in

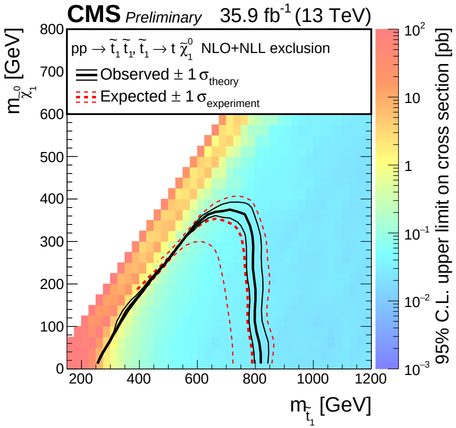
$$pp \to t\bar{t}Z \to (t \to b\ell^{\pm}\nu)(t \to bjj)(Z \to \ell\ell)$$

leptons	2 (e or μ), opposite charge
$m(ll)$	≥ 20
$\lvert M_Z - m(ll) \rvert$	$> 15\,\text{GeV}$, same flavor only
N_{jets}	≥ 2
N_{bjets}	≥ 1
E_T^{miss}	> 80 GeV
S	$> 5\,\text{GeV}^{1/2}$
$\cos\Delta\phi(E_T^{miss}, j_1)$	< 0.80
$\cos\Delta\phi(E_T^{miss}, j_2)$	< 0.96



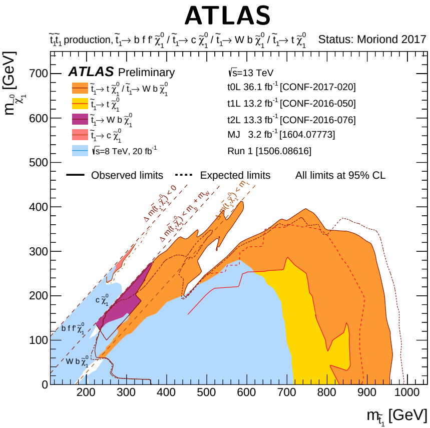
CMS Stop *two-lepton* CMS-SUS-17-001

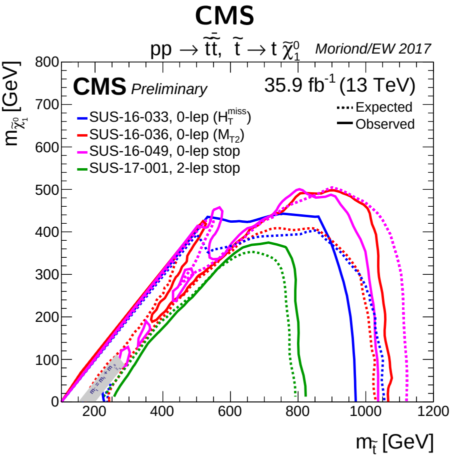




- Observation agrees within errors with the Standard Model expectations
- 95% CL exclusion limits on the mass plane $m_{\tilde{t}_1} - m_{\tilde{\chi}^0_1}$
- Interpretations on $\tilde{t} \to b\tilde{\chi}^{\pm}_1, \tilde{\chi}^{\pm}_1 \to W^{\pm}\tilde{\chi}^0_1$ are also available

Summary of $\tilde{t}_1 \to t\tilde{\chi}_1^0$ searches



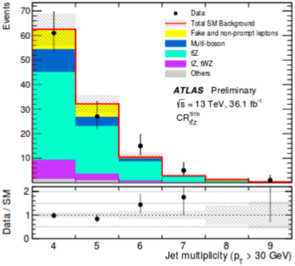


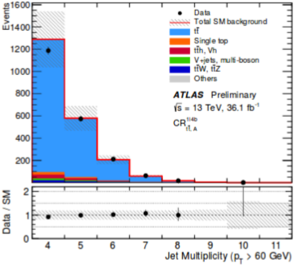
- Updated results from CMS are expected in time for Moriond QCD

Complementary models studied from ATLAS and CMS

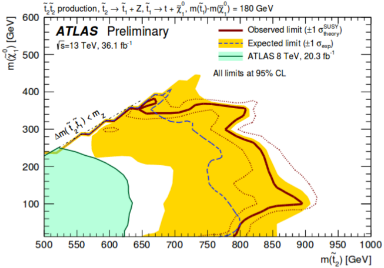
ATLAS $\tilde{t}$ Z/H *ATLAS-CONF-2017-019*

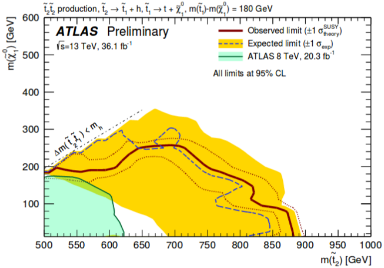
- Searches for $\tilde{t}$ production with Higgs (h) or Z bosons
- $\tilde{t}_1 \to t\tilde{\chi}_2^0,\ \tilde{\chi}_2^0 \to h/Z\tilde{\chi}_1^0$
- $\tilde{t}_2 \to h/Z\tilde{t}_1,\ \tilde{t}_1 \to t\tilde{\chi}_1^0$. Provide additional sensitivity in the region $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_t$
- Final states considered:
  - three-leptons plus a $b-$tag jet ($3\ell 1b$), aiming at top squark decays involving Z boson
    - Dominant backgrounds: $t\bar{t}Z,\ WZ$.
  - one-lepton plus four $b - tag$ jet ($1\ell 4b$), targeting top squark decays involving Higgs boson
    - Dominant background: $t\bar{t}$;
  - Three overlapped SRs targeting different mass splits ($m_{\tilde{t}_2} - m_{\tilde{\chi}_1^0}$) have been designed for each final-state

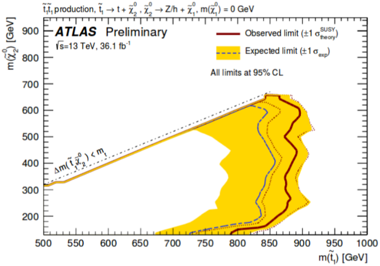




ATLAS $\tilde{t}$ Z/H *ATLAS-CONF-2017-019*



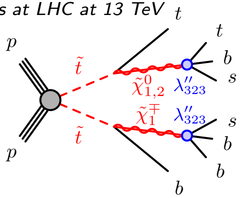




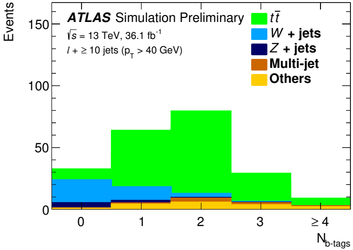
- **Top:** 95% CL exclusion limits on $m_{\tilde{t}_2} - m_{\tilde{\chi}_1^0}$ for a fixed $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} = 180$ GeV, assuming BR($\tilde{t}_2 \to Z\tilde{t}_1$)=1 (**left**) BR($\tilde{t}_2 \to h\tilde{t}_1$)=1 (**right**)
- **Bottom right**: 95% CL exclusion limits on $m_{\tilde{t}_1} - m_{\tilde{\chi}_2^0}$ for $m_{\tilde{\chi}_1^0} = 0$ GeV, assuming a BR($\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0$)=0.5 and BR($\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$)=0.5

ATAS Stop RPV *ATLAS-CONF-2017-013*

Discussed in Emma's talk: Pushing limits on generic squarks and gluinos at LHC at 13 TeV



- Stop Searches performed in R-Parity Violation models
- Final-state examined: $1\ell + jets$ final state
- SRs are binned in jet multiplicity with the lower one being at five-jets
- Dominant backgrounds in $N_{b-tag} = 0$ are $t\bar{t} + jets$ and $W + jets$ while for $N_{b-tag} > 0$ the dominant source is $t\bar{t} + jets$



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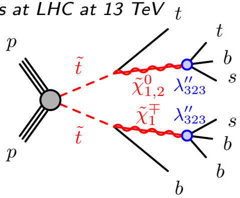

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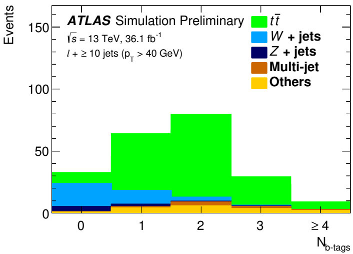
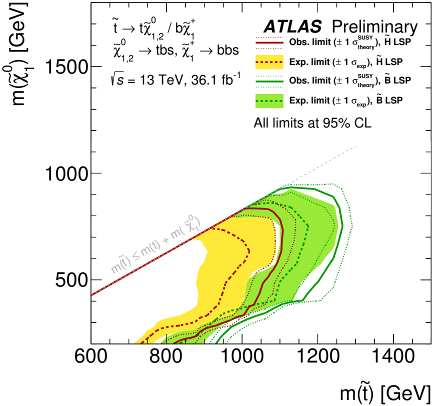


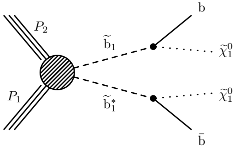


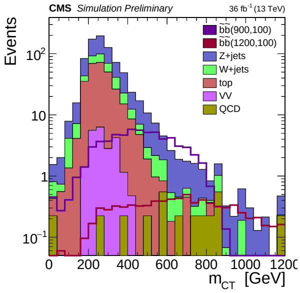
... from stops ...

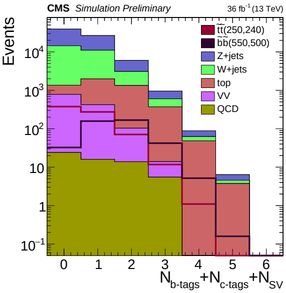
... to sbottoms ...

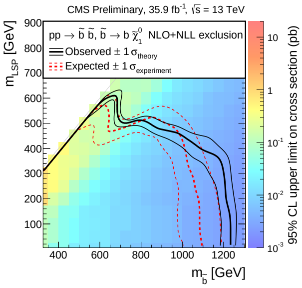
CMS Sbottom searches *CMS-SUSY-16-032*

- Non-compressed ($\Delta m(\tilde{b}_1, \tilde{\chi}_1^0)$ >150 GeV):
  - Main discriminants: Min[$M_T(j_1, E_{\rm T}^{\rm miss}), M_T(j_2, E_{\rm T}^{\rm miss})$], cotransverse mass ($m_{CT}$) and H_T (scalar sum of the two leading jets)
  - SRs binned in m_{CT} and H_T
- Compressed ($\Delta m(\tilde{b}_1, \tilde{\chi}_1^0)$ <150 GeV):
  - Based on an ISR jet recoiling against $\boldsymbol{E_{\rm T}^{\rm miss}}$.
  - Compressed SRs are binned in $E_{\rm T}^{\rm miss}$ and $b/c-$tag jet multiplicity



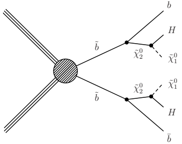


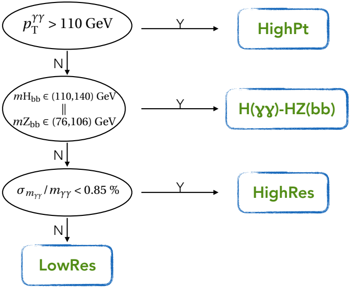




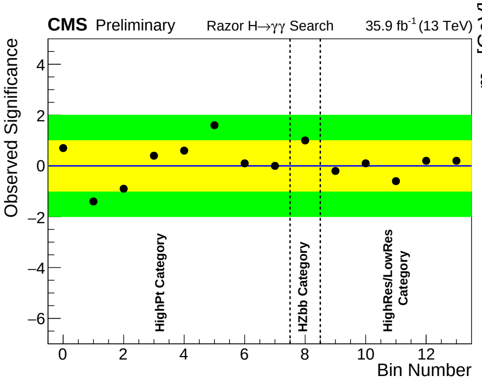
CMS search in razor+$H \to \gamma\gamma$ (sbottom) CMS-SUY-16-045

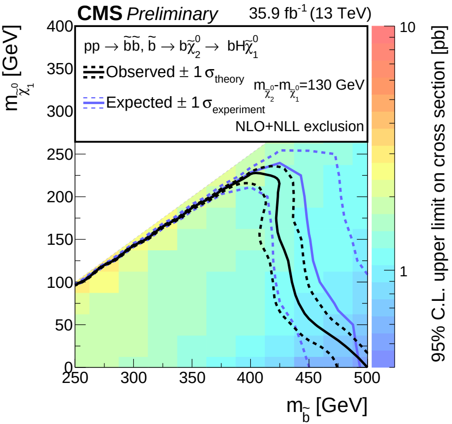
- In the MSSM Higgs bosons may be produced through the cascade decays of heavier *s*particles;
- Search performed in $H \to \gamma\gamma$ decay-mode and in association with at least one jet
- Approach based on razor variables and the momentum and mass resolution of the diphoton system
- Two main classes of background:
  - SM Higgs (taken from MC)
  - non-resonant QCD estimated from a data-driven technique by fitting the $\gamma\gamma$ mass distribution (dominant systematic uncertainty arises from normalization and shape of that function)





CMS search in razor+$H \to \gamma\gamma$ (sbottom) CMS-SUY-16-045



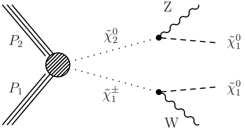


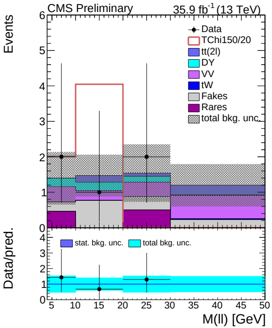
- Left: Observed significance in units of standard deviations per search region; The yellow and green bands represent the 1σ and 2σ regions, respectively.
- Right: 95% CL exclusion limits on the mass plane $m_{\tilde{b}} - m_{\tilde{\chi}_1^0}$

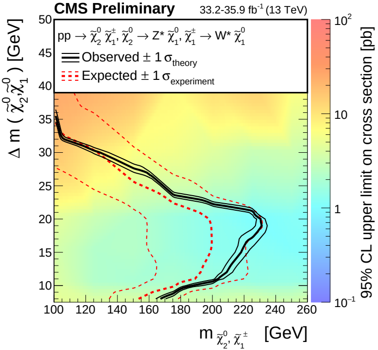
Compressed Electroweakino searches

CMS *two-soft-lepton* *CMS-PAS-SUS-16-048*

- Naturalness imposes constraints on the masses of higgsinos
- Light higgsinos would likely have a compressed mass spectrum
- Experimentaly challenging signature: **Muons p_T down to 3.5 GeV has been considered**
- Results interpreted in the context of direct $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ (cross sections based on Wino scenario)







Summary

- Both experiments have a rich program on the SUSY production of 3^{rd} generation squarks;
- Both experiments improved the object reconstruction and identification to obtain sensitivities in very challenging regions in the mass plane $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$
- Advanced techniques have also been employed to gain sensitivity in the different regions;
- Current searches explore a wide range of final states and topologies;
- All searches produced null results so far;
- More data are expected to be collected in the upcoming years, stay tuned and you never know what the data might be hiding!

Thank you

Back-up

Background estimation strategies

SUSY searches heavily rely on our understanding of the Standard Model processes

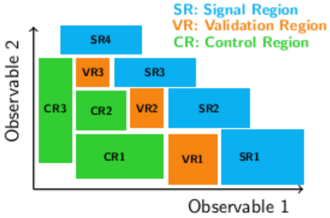
Reducible background

Receives contributions from non-prompt leptons. Estimation based on data-driven techniques (Matrix Method, Fake Factor);

Irreducible backgrounds

Normalize Monte Carlo predictions ($t\bar{t}$, VV, ..) to data in dedicated Control Regions (CR);

- Extracted Normalization Factor (NF) is validated in Validation Regions(VR);
- Final background estimation comes from a simultaneous likelihood fit of Signal Regions and CR;



Backgrounds producing "fake" $E_{\mathrm{T}}^{\mathrm{miss}}$ due to jet mismeasurement

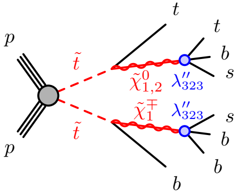
Contributions from this category are suppressed by requiring the jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ to not point in the same direction ($\Delta\phi(jets, E_{\mathrm{T}}^{\mathrm{miss}})$)

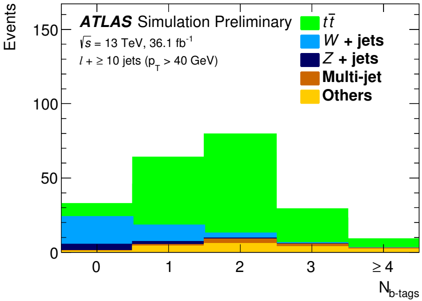
Small backgrounds

Contributions from these sources ara takes directly from Monte Carlo predictions.

ATAS Stop RPV *ATLAS-CONF-2017-013*

- Searches performed for right-handed $\tilde{t}$ pair production with the $\tilde{t}$ decaying to a bino or higgsino $\tilde{\chi}_1^0$;
- $\tilde{\chi}_1^0$ undergoes RPV decays with a non-zero λ''_{323} ($\approx \mathcal{O}(10^{-1} - 10^{-2})$)
- Final-state examined: $1\ell + jets$ final state
- Three sets of jet p_T thresholds (40, 60, 80) have been considered to provide sensitivity to a broad range of possible signals
- SRs are binned in jet multiplicity with the lower one being at five-jets
- Dominant backgrounds in $N_{b-tag} = 0$ are $t\bar{t} + jets$ and $W + jets$ while for $N_{b-tag} > 0$ the dominant source is $t\bar{t} + jets$





ATAS Stop RPV *ATLAS-CONF-2017-013*

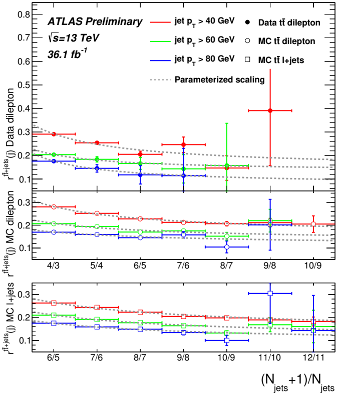
- $t\bar{t}$ + *jets* estimation based on a data-driven technique. Extraction of an initial template of the $b-$tag multiplicity spectrum in events with five jets and the parameterization of the evolution of this template to higher jet multiplicities.

$$N_{j,b}^{t\bar{t}+\text{jets}} = N_j^{t\bar{t}+\text{jets}} \cdot f_{j,b}$$

$$f_{(j+1),b} = f_{j,b} \cdot x_0 + f_{j,(b-1)} \cdot x_1 + f_{j,(b-2)} \cdot x_2$$

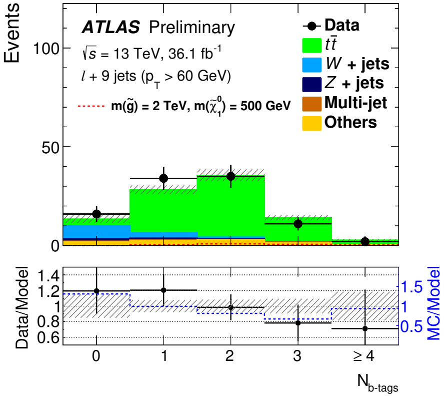
  where x_i describe the probability of one additional jet to be either not $b-$tagged (x_0), $b-$tagged (x_1) or $b-$tagged and leading to a second $b-$tagged jet to move into the fiducial acceptance (x_2)

- Validation of the jet-scaling parameterization in dileptonic $t\bar{t}$ events

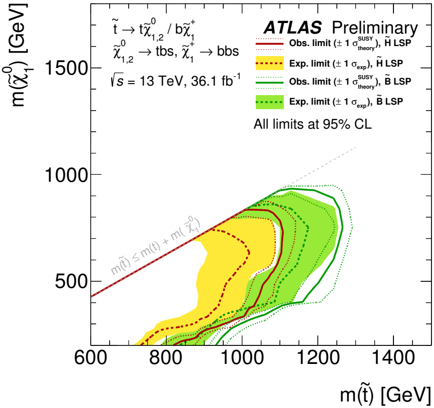


ATAS Stop RPV *ATLAS-CONF-2017-013*

- Right: Expected SM background and observation in different $b-$tag multiplicities in $\ell + 9jets$ final state



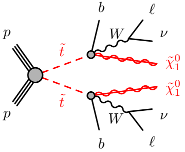
- Left: 95% CL limits on the mass plane $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0}$ for pure bino or pure higgsino $\tilde{\chi}_1^0$

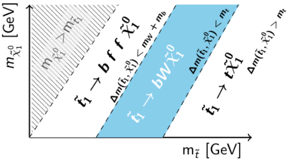


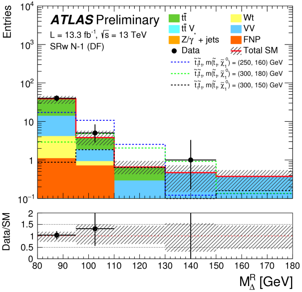
ATLAS Stop *two-leptons* *ATLAS-CONF-2016-076*

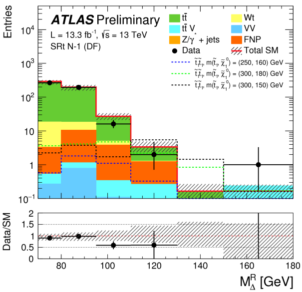
..highlights from 2016 summer confereces

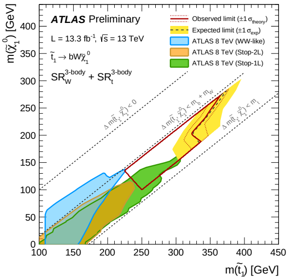
- Examining $\tilde{t}_1$ pair production in three-body-decays;
- Searches based on super-razor variables;
- Particularly sensitvite in $m_W + m_b < \Delta m(\tilde{t}_1, \tilde{\chi}_1^0) < m_t$
- Two dedicated SRs, one for $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_W$ and the other $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \sim m_t$





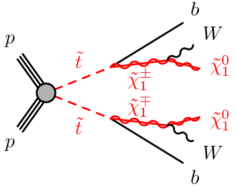






$\tilde{t} \to b\tilde{\chi}_1^{\pm},\ \tilde{\chi}_1^{\pm} \to W\tilde{\chi}_1^{0}$

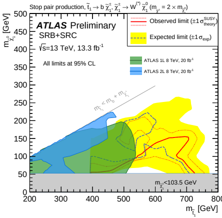
...motivated by gaugino universality



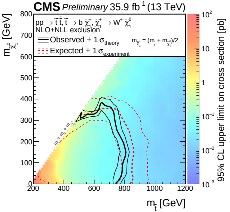
Searches based on fully hadronic final states

ATLAS-CONF-2016-077 CMS-SUS-16-049

ATLAS



CMS



ATLAS assumption:

$m_{\tilde{\chi}_1^{\pm}} = 2 \times m_{\tilde{\chi}_1^0}$

CMS assumption:

$m_{\tilde{\chi}_1^{\pm}} = (m_{\tilde{t}_1} + m_{\tilde{\chi}_1^0})/2$

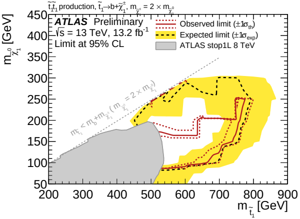
Searches based on *one-lepton* final states

ATLAS-CONF-2016-050

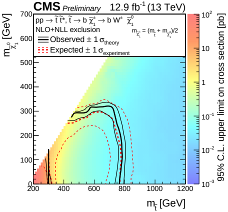
CMS-PAS-SUS-16-028

To be updated from both experiments

ATLAS



CMS



ATLAS Sbottom searches *Eur. Phys. J. C (2016) 76:547*

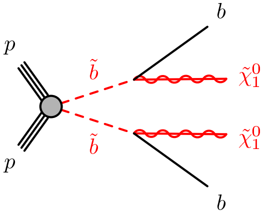
highlights from 2015 data sample

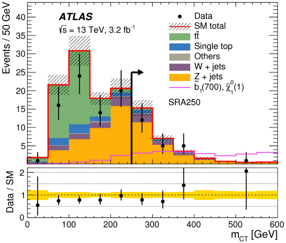
- Searches for $\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$;
- Examining final states with exactly two b-tag jets and E_T^{miss}
- Main discriminant variable:

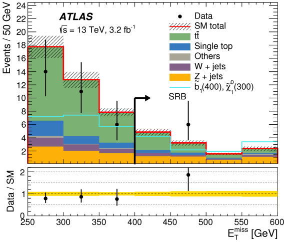
$$m_{CT}^2(v_1, v_2) = [E_T(v_1) + E_T(v_2)]^2 - [\mathbf{p}_T(v_1) - \mathbf{p}_T(v_2)]^2$$

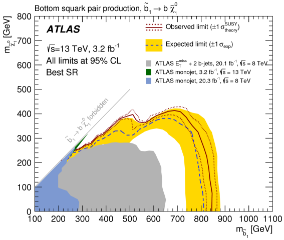
- Bound for $\tilde{b}$ is given by:

$$m_{CT}^{max} = (m_{\tilde{b}_1}^2 - m_{\tilde{\chi}_1^0}^2)/m_{\tilde{b}_1}$$







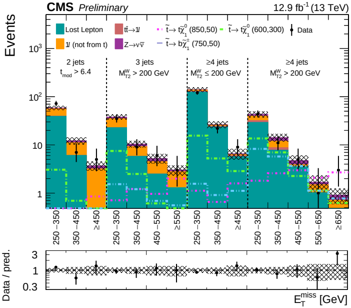


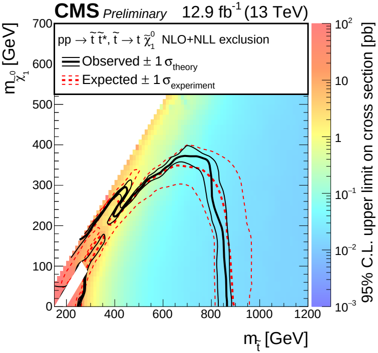
CMS Stop *one-lepton* CMS-PAS-SUS-16-028

New results will be available on Moriond QCD

- Four main SRs with different N_{jets} and M_{T2}^{W} requirements which are then binned in $E_{\mathrm{T}}^{\mathrm{miss}}$
- Main discriminants:
  M_{T2}^{W} : the information from on-shell $W-$boson is included in the m_{T2} calculator
  Modified topness variable t_{mod} for further background rejection

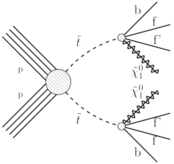
N_{jets}	M_{T2}^{W} [GeV]	t_{mod}	$E_{\text{T}}^{\text{miss}}$ [GeV]				
$=2$		>6.4	250–350	350–450	>450		
$=3$	>200		250–350	350–450	450–550	>550	
≥ 4	≤ 200		250–350	350–450	>450		
≥ 4	>200		250–350	350–450	450–550	550–650	>650



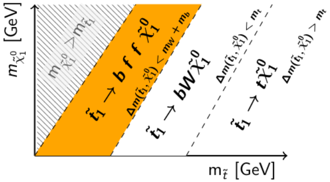


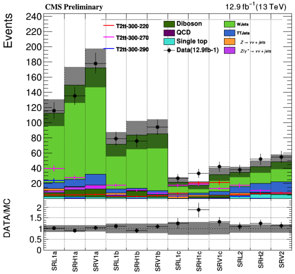
CMS Stop *one-soft-lepton* CMS-PAS-SUS-16-031

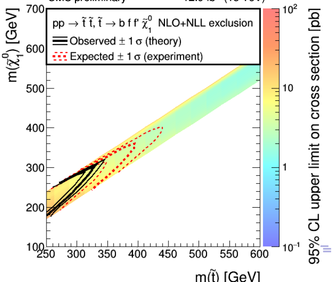
- Direct $\tilde{t}_1 \tilde{t}_1$ production with subsequent four-body-decays;
- Exploring the very-low p_T region of leptons



Variable	SR1a–c, CR1a–c	SR2, CR2	CR($t\bar{t}$)
E_T^{miss} (GeV)	>300	>300	>200
H_T (GeV)	>400	-	>300
p_T(ISR jet) (GeV)	>100	>325	>100
Number of hard jets	≤2	≤2	≤2
$\Delta\phi$(hard jets) (rad)	<2.5	<2.5	<2.5
Number of b jets	0	≥1 soft 0 hard	(≥1 soft and ≥1 hard) or (≥2 hard)
$p_T(l)$ (GeV)	[5, 12][12, 20][20, 30] (SR) >30 (CR)	[5, 12][12, 20][20, 30] (SR) >30 (CR)	>5
$\|\eta(l)\|$	<1.5	<2.4	<2.4
$Q(l)$	−1 (a,b) any (c)	any	any
Lepton rejection	no τ, or additional l with $p_T > 20$ GeV		
m_T (GeV)	<60 (a), 60–95 (b), >95 (c)	-	-



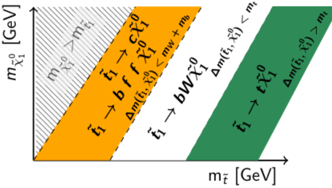


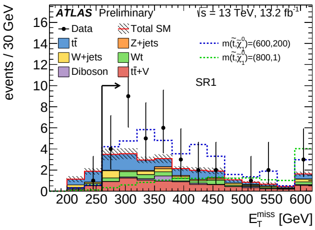


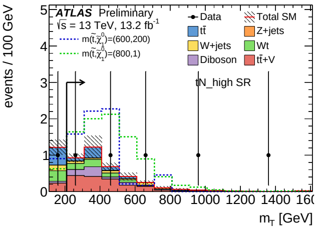
ATLAS Stop *1-lepton* *ATLAS-CONF-2016-050*

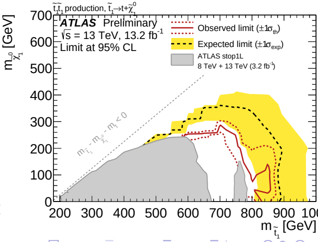
..highlights from 2016 summer confereces

- **SR1** targets low mass splittings (decay products are fully resolved)
- **tN_high** targets the high mass region
- $m_T = \sqrt{2 p_T^{\ell} E_{\mathrm{T}}^{\mathrm{miss}} (1 - cos(\Delta\phi))}$
- asymmetric-m_{T2} is used to reject $t\bar{t}$ events where one lepton is not reconstructed;
- *topness:* a minimising χ^2−type function quantifying the compatibility with a dileptonic $t\bar{t}$ event









CMS Razor+$H \to \gamma\gamma$ *CMS-SUS-16-045*

Table 1: A summary of the search region bins in each category is presented. The functional form used to model the non-resonant background is also listed. An exponential function of the form e^{-ax} is denoted as "single-exp"; a linear combination of two independent exponential functions of the form e^{-ax} and e^{-bx} is denoted as "double-exp"; a modified exponential function of the form e^{-ax^b} is denoted as "mod-exp"; and a Bernstein polynomial of degree n is denoted by "poly-n".

Bin Number	Category	M_R (GeV) Bin	R^2 Bin	Non-Resonant Bkg Model
0	HighPt	600 - ∞	0.025 - ∞	single-exp
1	HighPt	150 - 600	0.130 - ∞	single-exp
2	HighPt	1250 - ∞	0.000 - 0.025	single-exp
3	HighPt	150 - 450	0.000 - 0.130	poly-3
4	HighPt	450 - 600	0.000 - 0.035	poly-3
5	HighPt	450 - 600	0.035 - 0.130	single-exp
6	HighPt	600 - 1250	0.000 - 0.015	double-exp
7	HighPt	600 - 1250	0.015 - 0.025	single-exp
8	H($\gamma\gamma$)-H/Z(bb)	150 - ∞	0.000 - ∞	single-exp
9	HighRes	150 - 250	0.000 - 0.175	mod-exp
10	HighRes	150 - 250	0.175 - ∞	single-exp
11	HighRes	250 - ∞	0.05 - ∞	single-exp
12	HighRes	250 - 600	0.000 - 0.05	poly-2
13	HighRes	600 - ∞	0.000 - 0.05	single-exp
9	LowRes	150 - 250	0.000 - 0.175	poly-3
10	LowRes	150 - 250	0.175 - ∞	single-exp
11	LowRes	250 - ∞	0.05 - ∞	poly-2
12	LowRes	250 - 600	0.000 - 0.05	mod-exp
13	LowRes	600 - ∞	0.000 - 0.05	single-exp