Inclusive and Electroweakino SUSY search with leptons

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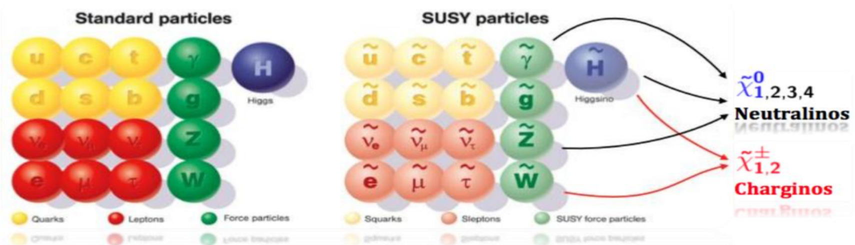
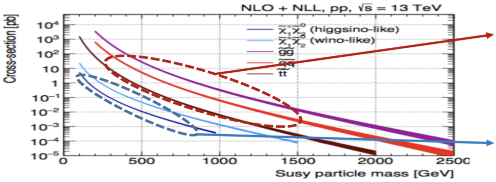
Introduction



- The Supersymmetry is a well motivated and favored extension of the Stand Model (SM):
  - ◇ Solves hierarchy problem, provides dark matter candidate, helps with the GUT…
- Basically have 2 production ways:



SUSY strong production:
- Squark & gluino production
- Relative larger cross-section
- Larger SUSY particle mass

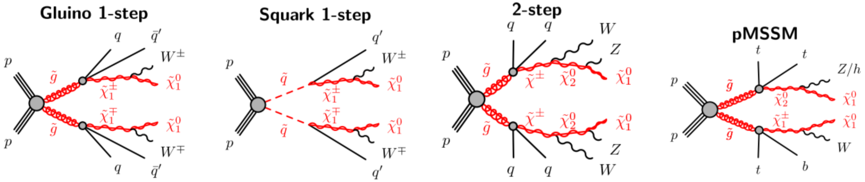
ElecktroWeak sector (EWK):
- Chargino & sleptons production
- Smaller cross-section
- Lower hadronic background

- This talk will focus on the public results of SUSY search with 1L+jets (**1708.08232**) , SS/3L+jets, (**1706.03731**) and Di-Tau (**1708.07875**) at ATLAS during run2

Inclusive search with 1L+jets:

Analysis Overview:

- **Signature**: 1L+jets+MET, decay from gluinos or squarks produced in a strong interaction
- **Dominant backgrounds** (W+jets and ttbar) are studied in dedicated control regions (CR); others are estimated via Monte Carlo (MC) simulations
- The contributions in signal regions (SRs) are derived using a **simultaneously fit**



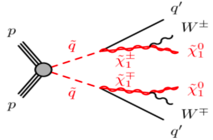
Inclusive search with 1L+jets:

Signal Regions:

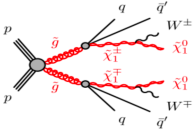
- Defined for different signal models aiming for different mass regions:

	Compressed region	High-x region	Low-x region	High mass region
SR	**2J**	**4J high-x**	**4J low-x**	**6J**
N_ℓ		$= 1$		
p_{T}^{ℓ} [GeV]	$> 7(6)$ for $e(\mu)$ and $< \min(5 \cdot N_{\mathrm{jet}}, 35)$	> 35	> 35	> 35
N_{jet}	≥ 2	4–5	4–5	≥ 6
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 430	> 300	> 250	> 350
m_{T} [GeV]	> 100	> 450	150–450	> 175
Aplanarity	–	> 0.01	> 0.05	> 0.06
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.25	> 0.25	–	–
$N_{b-\mathrm{jet}}$ (excl)		$= 0$ for b-veto, ≥ 1 for b-tag		
m_{eff} [GeV] (excl)	3 bins $\in [700{,}1900]$ + $[> 1900]$	2 bins $\in [1000{,}2000]$ + $[> 2000]$	2 bins $\in [1300{,}2000]$ + $[> 2000]$	3 bins $\in [700{,}2300]$ + $[> 2300]$
m_{eff} [GeV] (disc)	> 1100	> 1500	$> 1650(1300)$ for gluino (squark)	$> 2300(1233)$ for gluino (squark)

Squark 1-step



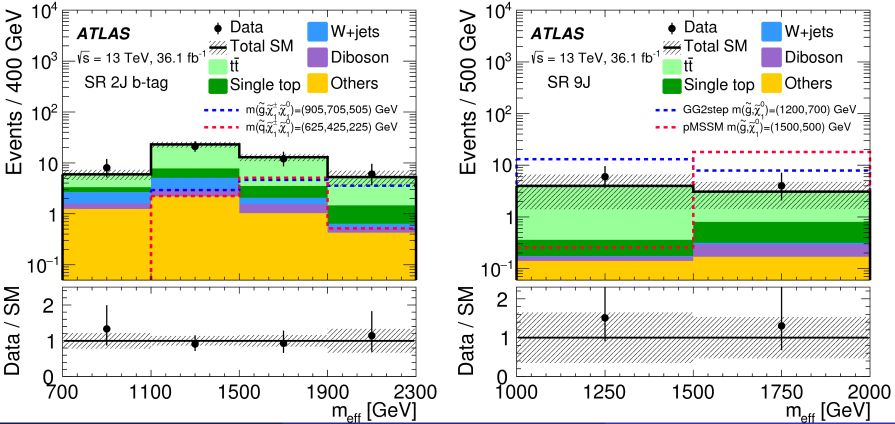
Gluino 1-step



Inclusive search with 1L+jets:

Background estimation:

- **BKGs in 2-6J SR**:
  - ◇ Dominant backgrounds (ttbar, single top and W+Jets): semi-data driven method used, "object replacement method" as cross check
  - ◇ Small backgrounds (ttV, Z+Jets and diboson): estimated by MC directly
  - ◇ Fakes are negligible due to the stringent selection on MET
- **BKGs in 9J SR**: ABCD method

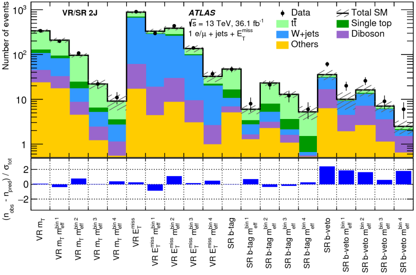


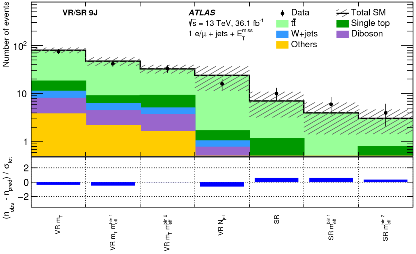
Inclusive search with 1L+jets:

Systematic uncertainties:

- Experimental systematics:
  - Object scale factors, ES, ER, MET, b-tagging efficiencies, etc...
- Theoretical uncertainties:
  - uncertainties from SM samples modeling etc...
- Method uncertainties: Coming from the methods we used to estimate the backgrounds

Results:



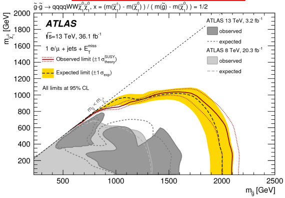


- Good agreement between data and bkgs
- No significant excess observed

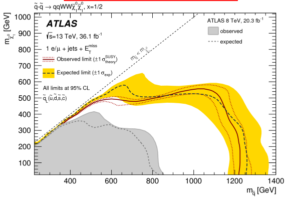
Inclusive search with 1L+jets:

Results:

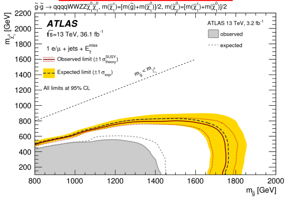
GG 1-step X=1/2



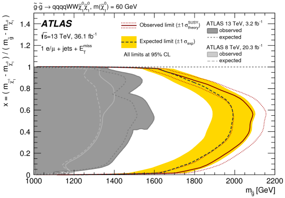
SS1-step X=1/2



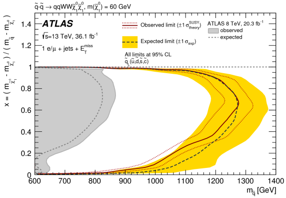
GG 2-step WZ



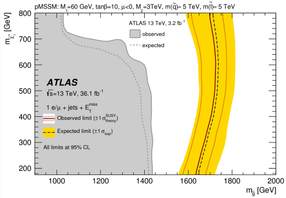
GG 1-step grid-x



SS1-step grid-x



pMSSM



- Limits up to 2.1 TeV in gluino and 1.25 TeV in squark mass have been excluded
- Limits up tp 1.8 TeV (2-step grid) and 1.7 TeV (pMSSM grid) have been excluded

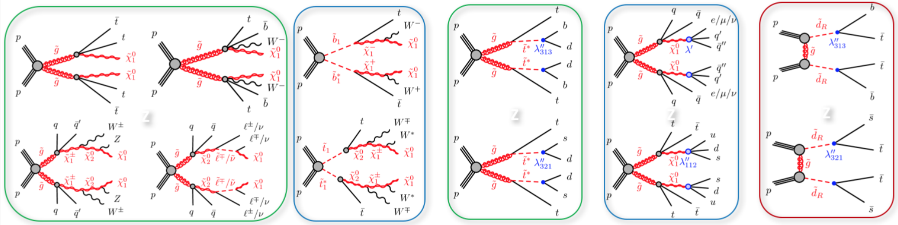
Inclusive search with SS/3L+jets:

Analysis Overview:

- **Signature**: Same sign or 3L+jets+MET, decays from gluino or squarks produced in strong interaction, can be studied in both RPC and RPV scenarios
- **Dominant backgrounds**: reducible and irreducible backgrounds are estimated using data-driven and MC method separately
- The contributions in signal regions (SRs) are derived using a simultaneously fit

Signal Regions:

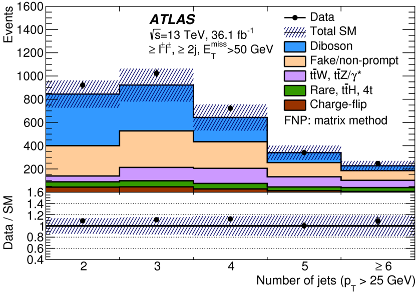
- **13 SRs** designed for **7 RPC** SUSY scenarios including NUHM2: (left 2 columns)
- **6 SRs** designed for **6 RPV** SUSYS scenarios: (right 3 columns)

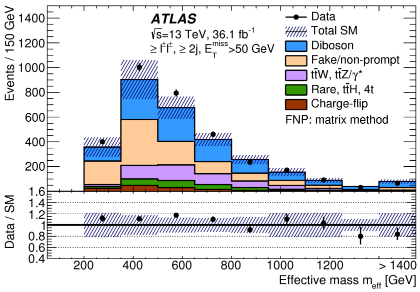


- Mainly use NLep, NBJet, NJet, MET, Meff and MET/Meff to optimise SRs

Background Estimation:

- Irreducible background (ttV, VV, rare): estimated via MC simulation directly
- reducible backgrounds:
  - Charge-flip: Estimated via a data-driven method
  - Fakes or non-prompt (FNP) leptons: "matrix method" and "MC Template" method are used, final yields coming from weighted average of the two results

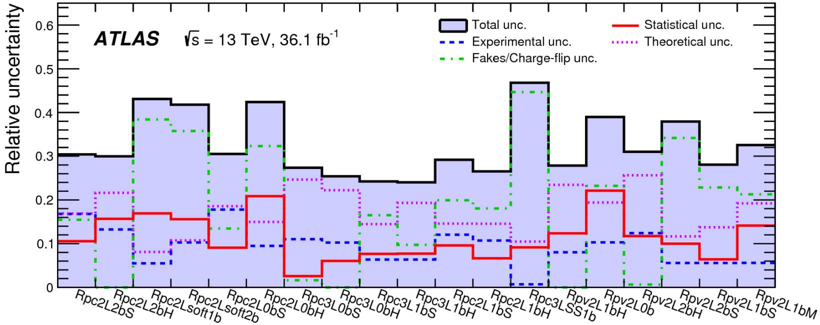




Inclusive search with SS/3L+jets:

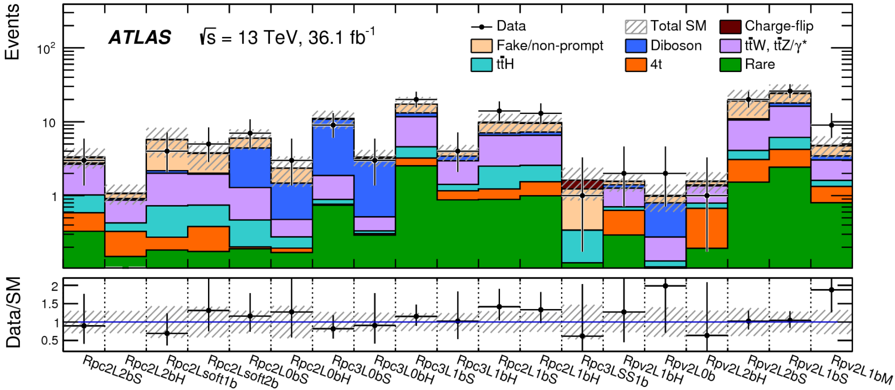
Systematic uncertainties:

- uncertainties range from 25% to 45%, depending on the SRs
- Dominant uncertainties come from fakes/CF and theoretical uncertainties



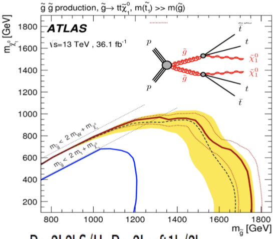
Results:

- No significant excess in any of the SRs
- All divergences are within 2 σ

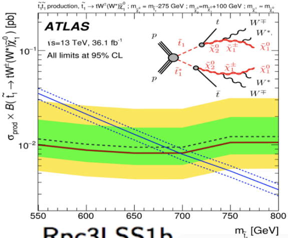


Inclusive search with SS/3L+jets:

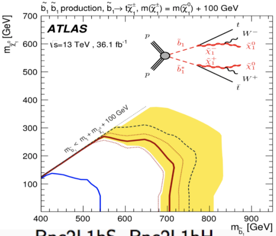
- Exclusion limits for RPC: Gluino up to 1.5 TeV, Sbottom up to 700 GeV, Stop up to 700 GeV, LSP up to 1.2 TeV are excluded



Rpc2L2bS/H, Rpc2Lsoft1b/2b



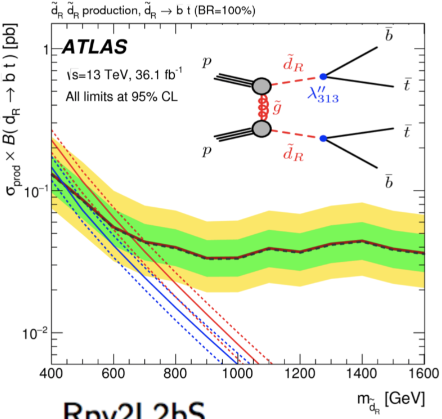
Rpc3LSS1b



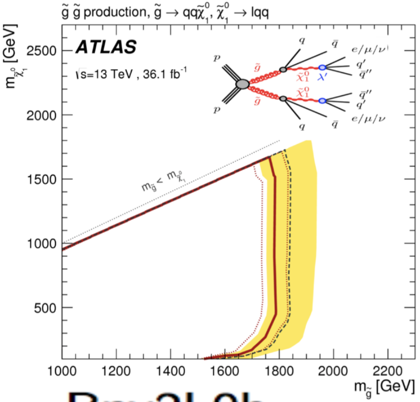
Rpc2L1bS, Rpc2L1bH

Inclusive search with SS/3L+jets:

- Exclusion limits for RPV: Gluino up to 1.3 TeV, $\tilde{d}_R$ up to 500 GeV are excluded



Rpv2L2bS

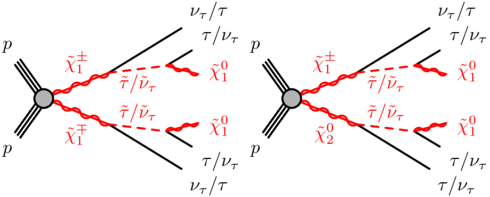


Rpv2L0b

EWK search with DiTau:

Analysis Overview:

- Model: Two simplified models of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ (C1C1) and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ (C1N2) direct production decay via mediated $\tilde{\tau}/\tilde{\nu_\tau}$ are considered in this search
- Signature: $\geq$ 2 hadronic τ, low jet multiplicity and large MET



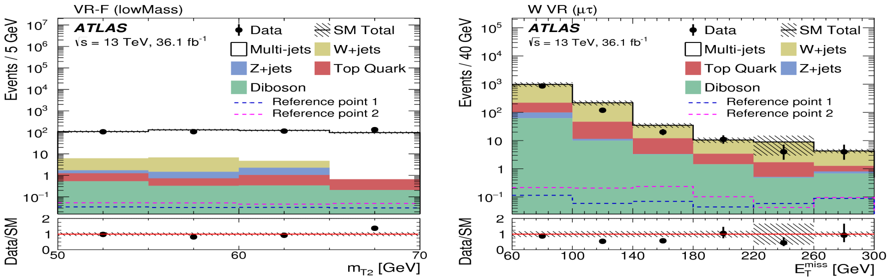
Signal Regions:

- Two SRs are designed aiming for two different mass split region:

SR-lowMass	SR-highMass	
At least one opposite-sign tau pair		
b-jet veto		
Z-veto		
At least two medium tau candidates	at least one medium and one tight tau candidates	
–	$m(\tau_1,\tau_2) > 110$ GeV	
$m_{T2} > 70$ GeV	$m_{T2} > 90$ GeV	
Di-tau+E_T^{miss} trigger	di-tau+E_T^{miss} trigger	asymmetric di-tau trigger
$E_T^{miss} > 150$ GeV	$E_T^{miss} > 150$ GeV	$E_T^{miss} > 110$ GeV
$p_{T,\tau_1} > 50$ GeV	$p_{T,\tau_1} > 80$ GeV	$p_{T,\tau_1} > 95$ GeV
$p_{T,\tau_2} > 40$ GeV	$p_{T,\tau_2} > 40$ GeV	$p_{T,\tau_2} > 65$ GeV

Background Estimation:

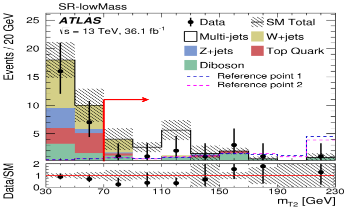
- Reducible backgrounds: $\geq$1 fake tau
  - multi-jet: estimated via ABCD method:
  - w+jets: normalized in a CR to data
- Irreducible backgrounds (VV, ZJets, and Top processes): estimated via MC simulation



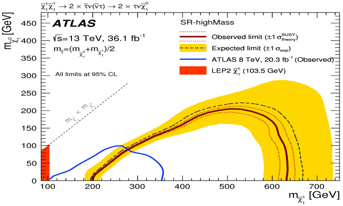
EWK search with DiTau:

Results:

- No excess observed in SRs

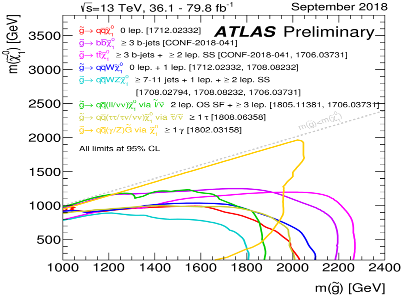


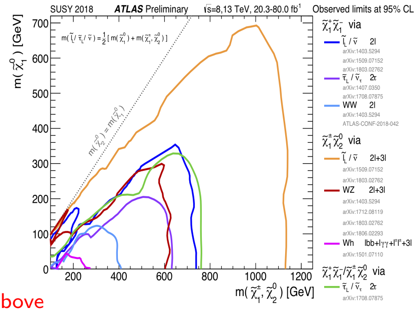
- C1C1: C1 up to 630 GeV are excluded for a massless LSP
- C1N2: C1/N2 up to 760 GeV are excluded for a massless LSP



Summary & Outlook:

Summary:



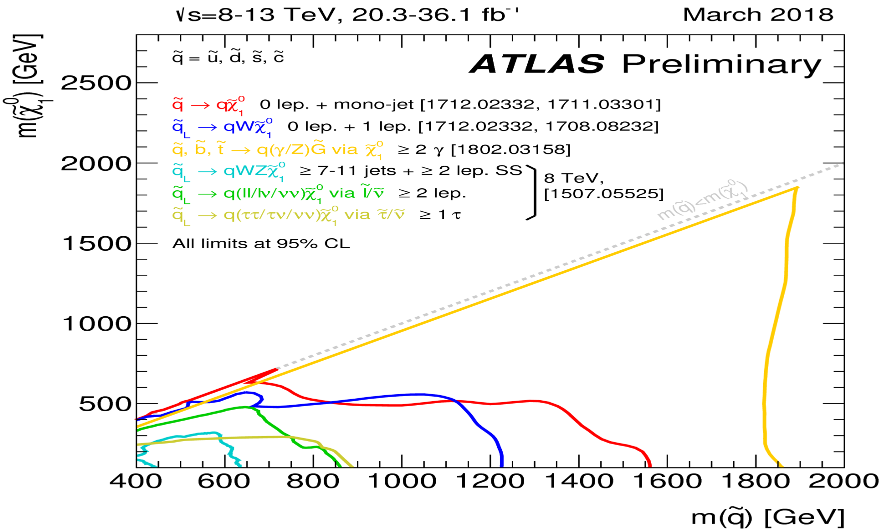


- No excess observed in all search channels above
- Gluino masses up to ∼2 TeV are excluded
- $\tilde{q}$ masses up to ∼1 TeV are excluded
- $\tilde{t}/\tilde{b}$ masses up to ∼700 GeV are excluded
- C1/N2 masses up to ∼700 GeV are excluded

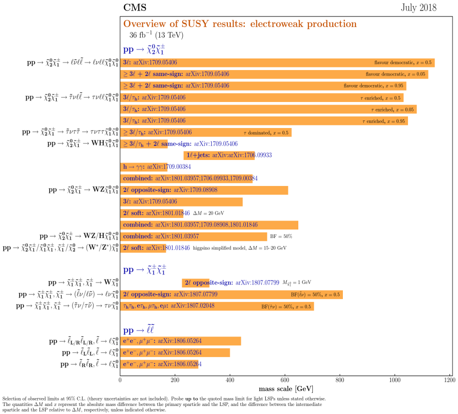
Outlook: Will update all resutls with end of run2 data ($\sim 140\ fb^{-1}$)

Back Up

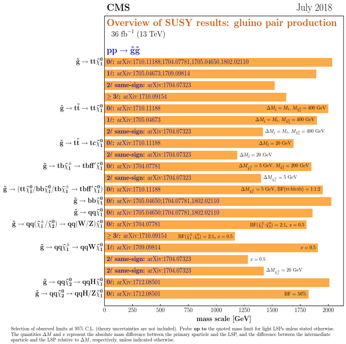
ATLAS Summary:



CMS Summary:

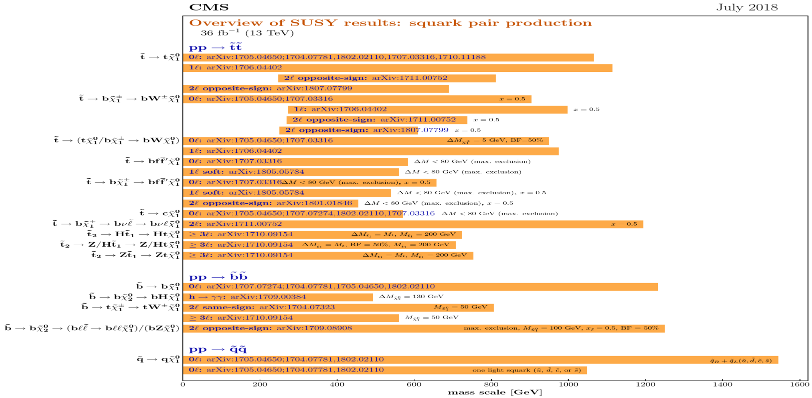


CMS
July 2018
Overview of SUSY results: electroweak production
36 fb^{-1} (13 TeV)
pp → $\tilde\chi^0_2\tilde\chi^\pm_1$
3ℓ: arXiv:1709.05406
≥ 3ℓ + 2ℓ same-sign: arXiv:1709.05406
3ℓ/τ_h: arXiv:1709.05406
≥ 3ℓ/τ_h: arXiv:1709.05406
≥ 3ℓ/τ_h + 2ℓ same-sign: arXiv:1709.05406
1ℓ(+jets: arXiv:arXiv:1706.09933
h → γγ: arXiv:1709.00384
combined: arXiv:1801.03957;1706.09933,1709.00384
2ℓ opposite-sign: arXiv:1709.08908
3ℓ: arXiv:1709.05406
2ℓ soft: arXiv:1801.01846
combined: arXiv:1801.03957;1709.08908,1801.01846
combined: arXiv:1801.03957
2ℓ soft: arXiv:1801.01846 higgsino simplified model, ΔM = 15–20 GeV
pp → $\tilde\chi^\pm_1\tilde\chi^\pm_1$
2ℓ opposite-sign: arXiv:1807.07799
pp → $\tilde\ell\tilde\ell$
$e^+e^-, \mu^+\mu^-$: arXiv:1806.05264
mass scale [GeV]
Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe up to the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.



CMS
July 2018
Overview of SUSY results: gluino pair production
36 fb^{-1} (13 TeV)
pp → $\tilde g\tilde g$
0ℓ: arXiv:1710.11188;1704.07781,1705.04650,1802.02110
1ℓ: arXiv:1705.04673;1709.09814
2ℓ same-sign: arXiv:1704.07323
≥ 3ℓ: arXiv:1710.09154
0ℓ: arXiv:1710.11188
1ℓ: arXiv:1705.04673
0ℓ: arXiv:1704.07781
0ℓ: arXiv:1705.04650;1704.07781,1802.02110
1ℓ: arXiv:1709.09814
0ℓ: arXiv:1712.08501
mass scale [GeV]
Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe up to the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.

CMS Summary:

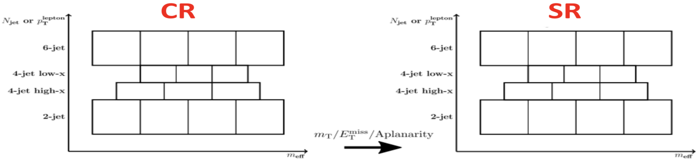


Selection of observed limits at 95% C.L. (theory uncertainties are not included). Probe **up to** the quoted mass limit for light LSPs unless stated otherwise. The quantities ΔM and x represent the absolute mass difference between the primary sparticle and the LSP, and the difference between the intermediate sparticle and the LSP relative to ΔM, respectively, unless indicated otherwise.

Inclusive search with 1L+jets:

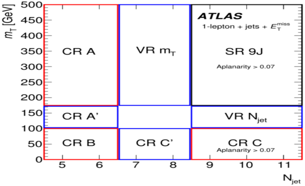
Background estimation:

- BKGs in 2-6J SR:
  - ◇ Dominant backgrounds (ttbar, single top and W+Jets):
    - ○ use semi-data driven method
    - ○ "object replacement method" is developed independently for cross-check
  - ◇ Small backgrounds (ttV, Z+Jets and diboson) are estimated by MC directly
  - ◇ Fakes are negligible due to the stringent selection on MET



extrapolate bin-by-bin in $m_{\rm eff}$

- BKGs in 9J SR: ABCD method used to reduce the dependence on the mismodelling of additional jets



$$
\begin{aligned}
N^{\rm est}_{\rm SR_{9J}} &= f_{\rm closure}\cdot\frac{N^{\rm obs}_{\rm CR_A}}{N^{\rm obs}_{\rm CR_B}}\cdot N^{\rm obs}_{\rm CR_C}\\
&= N^{\rm sim}_{\rm SR_{9J}}\cdot\left(\frac{N_{\rm CR_A}}{N_{\rm CR_B}}N_{\rm CR_C}\right)^{\rm obs}\Big/\left(\frac{N_{\rm CR_A}}{N_{\rm CR_B}}N_{\rm CR_C}\right)^{\rm sim}\\
&= N^{\rm sim}_{\rm SR_{9J}}\cdot\underbrace{\frac{N^{\rm obs}_{\rm CR_C}}{N^{\rm sim}_{\rm CR_C}}}_{\mu_{\rm C}}\cdot\underbrace{\frac{\left(\frac{N_{\rm CR_A}}{N_{\rm CR_B}}\right)^{\rm obs}}{\left(\frac{N_{\rm CR_A}}{N_{\rm CR_B}}\right)^{\rm sim}}}_{\mu_{\rm A/B}},
\end{aligned}
$$

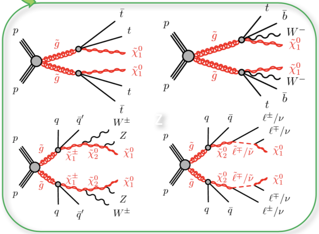
Inclusive search with SS/3L+jets:

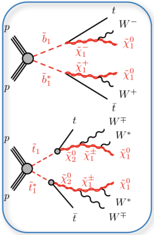
Analysis Overview:

- Signature: Same sign or 3L+jets+MET, decays from gluino or squarks produced in strong interaction, can be studided in both RPC and RPV scenarios
- Dominant backgrounds: reducible (charge-flip & fakes) and irreducible (ttV & VV) backgrounds are estimated using data-driven and MC method separately
- The contributions in signal regions (SRs) are derived using a simulations fit

Signal Regions: RPC

- Thirteen SRs designed for six RPC SUSY scenarios including a model with non-universal Higgs masses with two extra parameters (NUHM2):
  - Four scenarios focus on gluino pair production
  - Two scenarios focus on direct production of 3rd generation squark-antisquark pairs





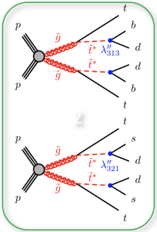
Using b-jets, E_T^{miss} ,m_{eff} and E_T^{miss}/m_{eff} to optimise SRs

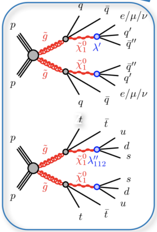
Signal region Name	$N_{\text{leptons}}^{\text{signal}}$	$N_{b-\text{jets}}$	N_{jets}	$p_{\text{T,jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\text{T}}^{\text{miss}}/m_{\text{eff}}$	Other	Targeted Signal
Rpc2L2bS	≥ 2SS	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	–	Fig. 1a
Rpc2L2bH	≥ 2SS	≥ 2	≥ 6	> 25	–	> 1800	> 0.15	–	Fig. 1a, NUHM2
Rpc2Lsoft1b	≥ 2SS	≥ 1	≥ 6	> 25	> 100	–	> 0.3	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100$ GeV	Fig. 1b
Rpc2Lsoft2b	≥ 2SS	≥ 2	≥ 6	> 25	> 200	> 600	> 0.25	$20,10 < p_{\text{T}}^{\ell_1}, p_{\text{T}}^{\ell_2} < 100$ GeV	Fig. 1b
Rpc2L0bS	≥ 2SS	$= 0$	≥ 6	> 25	> 150	–	> 0.25	–	Fig. 1c
Rpc2L0bH	≥ 2SS	$= 0$	≥ 6	> 40	> 250	> 900	–	–	Fig. 1c
Rpc3L0bS	≥ 3	$= 0$	≥ 4	> 40	> 200	> 600	–	–	Fig. 1d
Rpc3L0bH	≥ 3	$= 0$	≥ 4	> 40	> 200	> 1600	–	–	Fig. 1d
Rpc3L1bS	≥ 3	≥ 1	≥ 4	> 40	> 200	> 600	–	–	
Rpc3L1bH	≥ 3	≥ 1	≥ 4	> 40	> 200	> 1600	–	–	
Rpc2L1bS	≥ 2SS	≥ 1	≥ 6	> 25	> 150	> 600	> 0.25	–	Fig. 1e
Rpc2L1bH	≥ 2SS	≥ 1	≥ 6	> 25	> 250	–	> 0.2	–	Fig. 1e
Rpc3LSS1b	$\geq \ell^{\pm}\ell^{\pm}\ell^{\pm}$	≥ 1	–	–	–	–	-	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1f

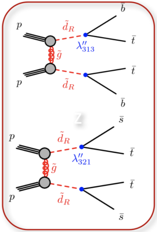
Inclusive search with SS/3L+jets:

Signal Regions: RPV

- Six SRs designed for RPV scenarios:
  - Two scenarios focus on gluinos and squarks decay directly to top quarks
  - Two scenarios target on gluino decays into a neutralino which further decays to SM particles via a non-zero λ' or λ'' RPV coupling
  - Two scenarios consider Pair-production of right-handed same-sign down squarks







Using b-jets, E_T^{miss} ,m_{eff} and E_T^{miss}/m_{eff} to optimise SRs

Signal region Name	$N_{\mathrm{leptons}}^{\mathrm{signal}}$	$N_{b-\mathrm{jets}}$	N_{jets}	$p_{\mathrm{T,jet}}$ [GeV]	$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	m_{eff} [GeV]	$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	Other	Targeted Signal
Rpv2L1bH	≥ 2SS	≥ 1	≥ 6	> 50	–	> 2200	–	–	Figs. 1g,1h
Rpv2L0b	$= 2$SS	$= 0$	≥ 6	> 40	–	> 1800	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1i
Rpv2L2bH	≥ 2SS	≥ 2	≥ 6	> 40	–	> 2000	–	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV	Fig. 1j
Rpv2L2bS	$\geq \ell^-\ell^-$	≥ 2	≥ 3	> 50	–	> 1200	–		Fig. 1k
Rpv2L1bS	$\geq \ell^-\ell^-$	≥ 1	≥ 4	> 50	–	> 1200	–	–	Fig. 1l
Rpv2L1bM	$\geq \ell^-\ell^-$	≥ 1	≥ 4	> 50	–	> 1800	–	–	Fig. 1l

Inclusive search with SS/3L+jets:

Background Estimation:

- Irreducible background: SM process with SS/3L in the final state
  - Estimate from pure MC samples
  - Since diboson and $t\bar{t}V$ events are the main backgrounds in the signal regions
  - Dedicated validation regions (VR) are defined to verify the background predictions from the simulation.

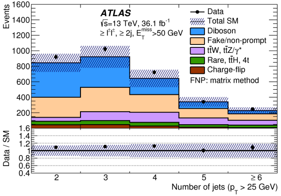
Validation Region Name	$N_{\text{lepton}}^{\text{signal}}$	$N_{b-\text{jets}}$	N_{jets}	$p_{\text{T,jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	Other
$t\bar{t}W$	$=2SS$	≥ 1	≥ 4 ($e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$) ≥ 3 ($\mu^{\pm}\mu^{\pm}$)	> 40 > 25	> 45	> 550	$p_{\text{T}}(\ell_2) > 40$ GeV $\sum p_T^{b-jet} / \sum p_T^{jet} > 0.25$
$t\bar{t}Z$	≥ 3 ≥ 1 SFOS pair	≥ 1	≥ 3	> 35	–	> 450	$81 < m_{\text{SFOS}} < 101$ GeV
$WZ4$j	$= 3$	$= 0$	≥ 4	> 25	–	> 450	$E_{\text{T}}^{\text{miss}} / \sum p_T^{\ell} < 0.7$
$WZ5$j	$= 3$	$= 0$	≥ 5	> 25	–	> 450	$E_{\text{T}}^{\text{miss}} / \sum p_T^{\ell} < 0.7$
$W^{\pm}W^{\pm}jj$	$=2SS$	$= 0$	≥ 2	> 50	> 55	> 650	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV $p_{\text{T}}^{\ell_2} > 30$ GeV $\Delta R_{\eta}(\ell_{1,2}, j) > 0.7$ $\Delta R_{\eta}(\ell_1, \ell_2) > 1.3$
All VRs	Veto events belonging to any SR						

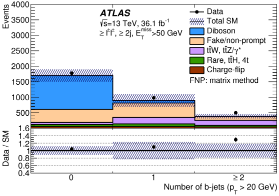
Validation Regions	$t\bar{t}W$	$t\bar{t}Z$	$WZ4$j	$WZ5$j	$W^{\pm}W^{\pm}jj$
$t\bar{t}Z/\gamma^*$	6.2 ± 0.9	123 ± 17	17.8 ± 3.5	10.1 ± 2.3	1.06 ± 0.22
$t\bar{t}W$	19.0 ± 2.9	1.71 ± 0.27	1.30 ± 0.32	0.45 ± 0.14	4.1 ± 0.8
$t\bar{t}H$	5.8 ± 1.2	3.6 ± 1.8	1.8 ± 0.6	0.96 ± 0.34	0.69 ± 0.14
$t\bar{t}t\bar{t}$	1.02 ± 0.22	0.27 ± 0.14	0.04 ± 0.02	0.03 ± 0.02	0.03 ± 0.02
$W^{\pm}W^{\pm}$	0.5 ± 0.4	$--$	$--$	$--$	26 ± 14
WZ	1.4 ± 0.8	29 ± 17	200 ± 110	70 ± 40	27 ± 14
ZZ	0.04 ± 0.03	5.5 ± 3.1	22 ± 12	9 ± 5	0.53 ± 0.30
Rare	2.2 ± 0.5	26 ± 13	7.3 ± 2.1	3.0 ± 1.0	1.8 ± 0.5
Fake/non-prompt leptons	18 ± 16	22 ± 14	49 ± 31	17 ± 12	13 ± 10
Charge-flip	3.4 ± 0.5	$--$	$--$	$--$	1.74 ± 0.22
Total SM background	57 ± 16	212 ± 35	300 ± 130	110 ± 50	77 ± 31
Observed	71	209	257	106	99

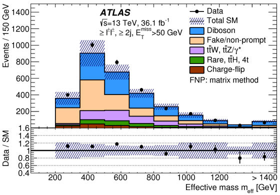
- reducible backgrounds:
  - Charge-flip:
    - Mainly caused by bremmstrahlung of the origin electron interact with detector materials
    - A data-driven method is used, $w_{flip} = \xi_1(1-\xi_2) + (1-\xi_1)\xi_2$, ξ means charge-flip rate extracted from $Z/\gamma^\star \to ee$ data sample
  - Fakes or non-prompt (FNP) leptons: two data-driven methods are used, final yields coming from weighted average of teh two results
    - Matrix method: Relates the prompt and FNP events with tight and loose-not-tight leptons and fake/real efficiency (ϵ/ξ)

$$\begin{pmatrix} n_{pass} \\ n_{fail} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ \frac{1-\epsilon}{\epsilon} & \frac{1-\xi}{\xi} \end{pmatrix} \begin{pmatrix} n_{real} \\ n_{fake} \end{pmatrix}$$

    - MC Template: 6 CRs are defined to re-weight MC to match the data, 5 categories to classfiy events



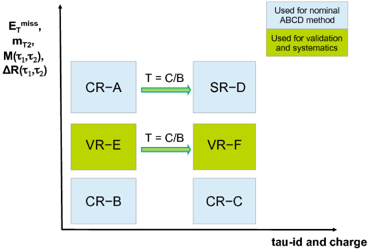




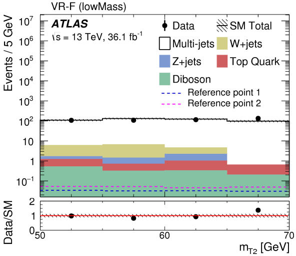
EWK search with DiTau:

Background Estimation:

- Reducible backgrounds: $\geq$1 fake tau
  - multi-jet: estimated via ABCD method:
    - Techs: Exclusive CRs and VRs are defined in 2D plane as a function of 2 sets of uncorrelated variables, contributions in SRs extracted from correspondig CRs
  - Results: Good agreement between bkgs and data in VRs

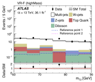


SR	Sample	CR-B	CR-C	CR-A	T = C/B	Multi-jet in SR-D
lowMass	**Data**	**556**	**674**	**8**	1.16 ± 0.07	4.3 ± 4.0
	Z+jets	3.4 ± 2.1	19 ± 5	0.8 ± 0.4		
	W+jets	8.9 ± 1.8	20 ± 5	1.8 ± 1.0		
	Diboson	0.94 ± 0.12	3.3 ± 0.2	0.29 ± 0.07		
	Top	1.61 ± 0.30	4.7 ± 0.5	1.4 ± 1.1		
	Multi-jet	*541 ± 24*	*627 ± 27*	*3.7 ± 1.6*		
	Reference point 1	0.06 ± 0.01	0.16 ± 0.02	1.68 ± 0.16		
highMass	**Data**	**1565**	**836**	**5**	0.43 ± 0.04	1.3 ± 1.1
	Z+jets	56 ± 31	93 ± 42	0.02 ± 0.29		
	W+jets	151 ± 22	125 ± 17	1.1 ± 0.4		
	Diboson	9.6 ± 1.1	20.5 ± 2.0	0.8 ± 0.4		
	Top	9.2 ± 1.5	25.4 ± 3.4	0.01 ± 0.01		
	Multi-jet	*1340 ± 50*	*570 ± 50*	*3.1 ± 0.6*		
	Reference point 2	0.53 ± 0.08	2.37 ± 0.21	1.92 ± 0.16		



CR-A	SR-D (SR-lowMass)
Di-tau+E_T^{miss} trigger	
≥ 2 loose tau leptons (SS)	≥ 2 medium tau leptons (OS)
$m(\tau_1,\tau_2)$ < 250 GeV	–
$\Delta R(\tau_1,\tau_2)$ > 1.5	–
E_T^{miss} > 150 GeV	E_T^{miss} > 150 GeV
m_{T2} > 70 GeV	m_{T2} > 70 GeV
VR-E	**VR-F**
Di-tau trigger	
≥ 2 loose tau leptons (SS)	≥ 2 medium tau leptons (OS)
$m(\tau_1,\tau_2)$ < 250 GeV	–
$\Delta R(\tau_1,\tau_2)$ > 1.5	–
E_T^{miss} > 40 GeV	E_T^{miss} > 40 GeV
50 < m_{T2} < 70 GeV	50 < m_{T2} < 70 GeV
CR-B	**CR-C**
Di-tau trigger	
≥ 2 loose tau leptons (SS)	≥ 2 medium tau leptons (OS)
$m(\tau_1,\tau_2)$ < 250 GeV	–
$\Delta R(\tau_1,\tau_2)$ > 1.5	–
E_T^{miss} > 40 GeV	E_T^{miss} > 40 GeV
20 < m_{T2} < 50 GeV	20 < m_{T2} < 50 GeV

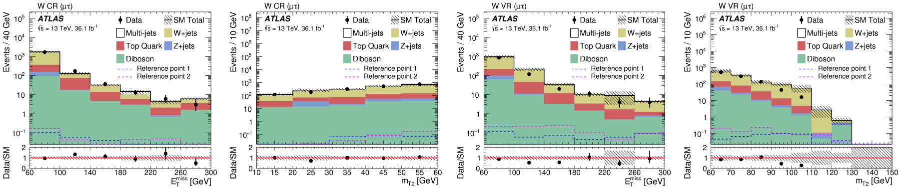
CR-A	SR-D (SR-highMass)
Di-tau+E_T^{miss} or asymmetric di-tau trigger	
≥ 2 loose tau leptons (OS)	≥ 2 medium tau leptons (OS)
< 1 medium tau < 1 tight tau leptons	≥ 1 tight tau lepton
$\Delta R(\tau_1,\tau_2)$ > 1.8	–
E_T^{miss} > 110 GeV	E_T^{miss} > 110 GeV
m_{T2} > 90 GeV	m_{T2} > 90 GeV
VR-E	**VR-F**
Di-tau or asymmetric di-tau trigger	
≥ 2 loose tau leptons (OS)	≥ 2 medium tau leptons (OS)
< 1 medium tau < 1 tight tau leptons	≥ 1 tight tau lepton
$\Delta R(\tau_1,\tau_2)$ > 1.8	–
E_T^{miss} > 40 GeV	E_T^{miss} > 40 GeV
60 < m_{T2} < 90 GeV	60 < m_{T2} < 90 GeV
CR-B	**CR-C**
Di-tau or asymmetric di-tau trigger	
≥ 2 loose tau leptons (OS)	≥ 2 medium tau leptons (OS)
< 1 medium tau < 1 tight tau leptons	≥ 1 tight tau
$\Delta R(\tau_1,\tau_2)$ > 1.8	–
E_T^{miss} > 40 GeV	E_T^{miss} > 40 GeV
10 < m_{T2} < 60 GeV	10 < m_{T2} < 60 GeV



Background Estimation:

- Reducible backgrounds: $\geq$1 fake tau
  - ◇ w+jets: A dedicated CR with high purity and low signal contamination is used to normalize to data. A VR is used to validate this method

<table>
<tr><th>W-CR</th><th>W-VR</th></tr>
<tr><td colspan="2">One isolated muon and one medium tau lepton with opposite sign</td></tr>
<tr><td colspan="2">b-jet veto</td></tr>
<tr><td colspan="2">$m(\mu,\tau) > 70$ GeV</td></tr>
<tr><td colspan="2">$E_{\mathrm{T}}^{\mathrm{miss}} > 60$ GeV</td></tr>
<tr><td colspan="2">$50 < m_{\mathrm{T},\mu} < 150$ GeV</td></tr>
<tr><td colspan="2">$m_{\mathrm{T},\mu} + m_{\mathrm{T},\tau} > 80$ GeV</td></tr>
<tr><td>$0.5 < \Delta R(\mu,\tau) < 3.5$</td><td>$0.5 < \Delta R(\mu,\tau) < 4.5$</td></tr>
<tr><td>$10 < m_{\mathrm{T2}} < 60$ GeV</td><td>$m_{\mathrm{T2}} > 60$ GeV</td></tr>
</table>



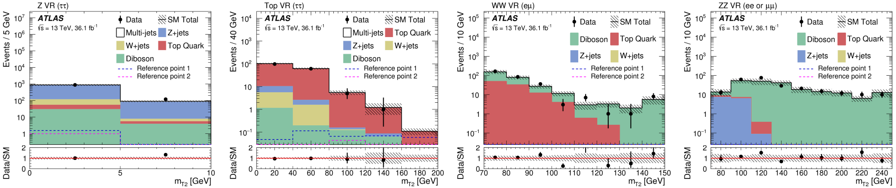
EWK search with DiTau:

Background Estimation:

- Irreducible backgrounds: VV, ZJets, and Top processes
  - ◇ Estimated via MC directly
  - ◇ Dedicated VRs are defined to validate them

Z-VR	Top-VR
At least one opposite-sign tau lepton pair	
Tau $p_{\mathrm{T}} > 50$, 40 GeV	
$E_{\mathrm{T}}^{\mathrm{miss}} > 60$ GeV	
At least two medium tau leptons	at least one medium and one loose tau lepton
b-jet veto	at least one *b*-jet
$m_{\mathrm{T2}} < 10$ GeV	$m_{\mathrm{T2}} > 10$ GeV
	m_{CT} top-tagged

WW-VR	*ZZ*-VR
One opposite-sign lepton (e or μ) pair	
μ $p_{\mathrm{T}} > 30$ GeV, e $p_{\mathrm{T}} > 40$ GeV	
Jet veto	
$m_{\ell\ell} > 50$ GeV	
$E_{\mathrm{T}}^{\mathrm{miss}} > 50$ GeV	
$m_{\mathrm{T},\mu} > 100$ GeV	
$m_{\mathrm{T2}} > 70$ GeV	
Two isolated leptons (e or μ) with different flavour	two isolated leptons (e or μ) with same flavour
m_{CT} top tag veto	$\Delta R(\ell, \ell) < 1.5$
	$\lvert m_{\ell\ell} - m_Z \rvert < 15$ GeV

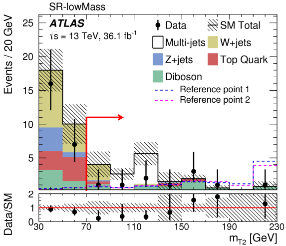


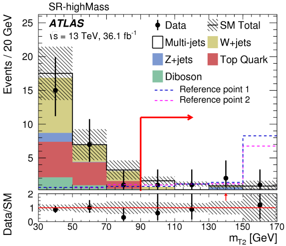
EWK search with DiTau:

Results:

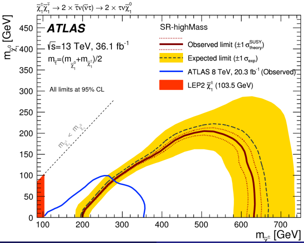
- No excess observed in SRs

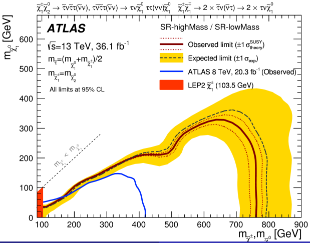
SM process	SR-lowMass	SR-highMass
Diboson	5.9 ± 2.2	1.0 ± 0.8
W+jets	1.8 ± 1.1	0.7 ± 0.5
Top quark	1.2 ± 1.0	$0.03^{+0.26}_{-0.03}$
Z+jets	$0.6^{+0.7}_{-0.6}$	0.6 ± 0.5
Multi-jet	4.3 ± 4.0	1.3 ± 1.1
SM total	14 ± 6	3.7 ± 1.4
Observed	10	5
Reference point 1	11.8 ± 2.8	11.6 ± 2.6
Reference point 2	11.4 ± 2.6	10.0 ± 2.1
p_0	0.5	0.3
Expected $\sigma_{\rm vis}^{95}$ [fb]	$0.31^{+0.12}_{-0.08}$	$0.17^{+0.08}_{-0.05}$
Observed $\sigma_{\rm vis}^{95}$ [fb]	0.26	0.20





- C1C1: C1 up to 630 GeV are excluded for a massless LSP
- C1N2: C1/N2 up to 760 GeV are excluded for a massless LSP





Systematic Uncertainty:

- Main sources:
  - Experimental: Mainly coming from TauID, pile-up, and object's energy scales and energy resolutions
  - Theoretical: Mainly coming from theory uncertainties in MC samples, the choice of QCD normalization scale and resummation scale
  - Uncertainties in ABCD method

Source of systematic uncertainty	SR-lowMass	SR-highMass
Normalisation uncertainties of the multi-jet background	32	32
Statistical uncertainty of MC samples	18	24
Multi-jet estimation	14	13
Pile-up reweighting	8	8
Jet energy scale and resolution	11	4
Tau identification and energy scale	6	8
$E_{\mathrm{T}}^{\mathrm{miss}}$ soft-term resolution and scale	2	6
Total	40	38

THE END