Electroweak SUSY search with ditau

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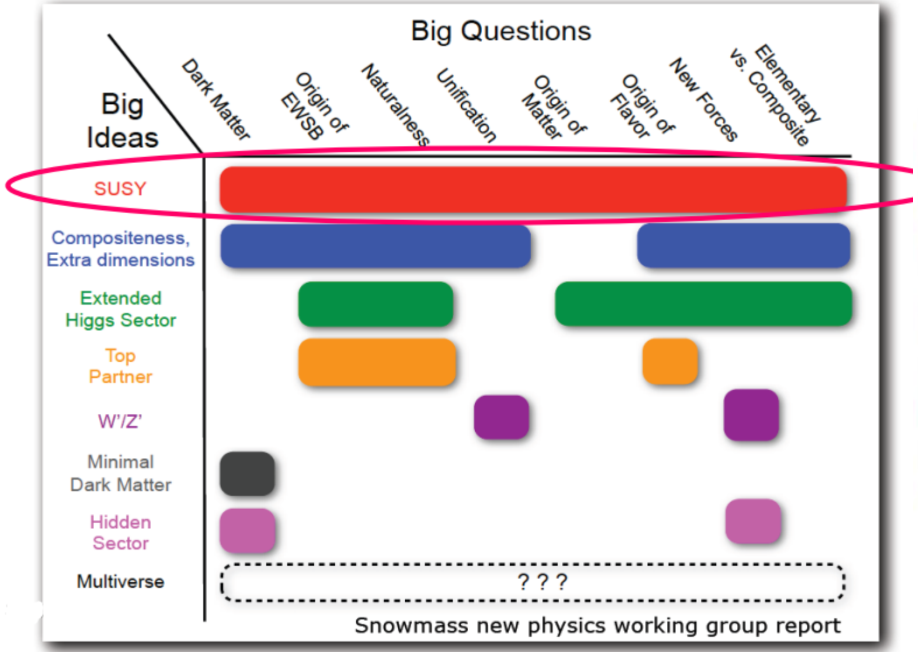
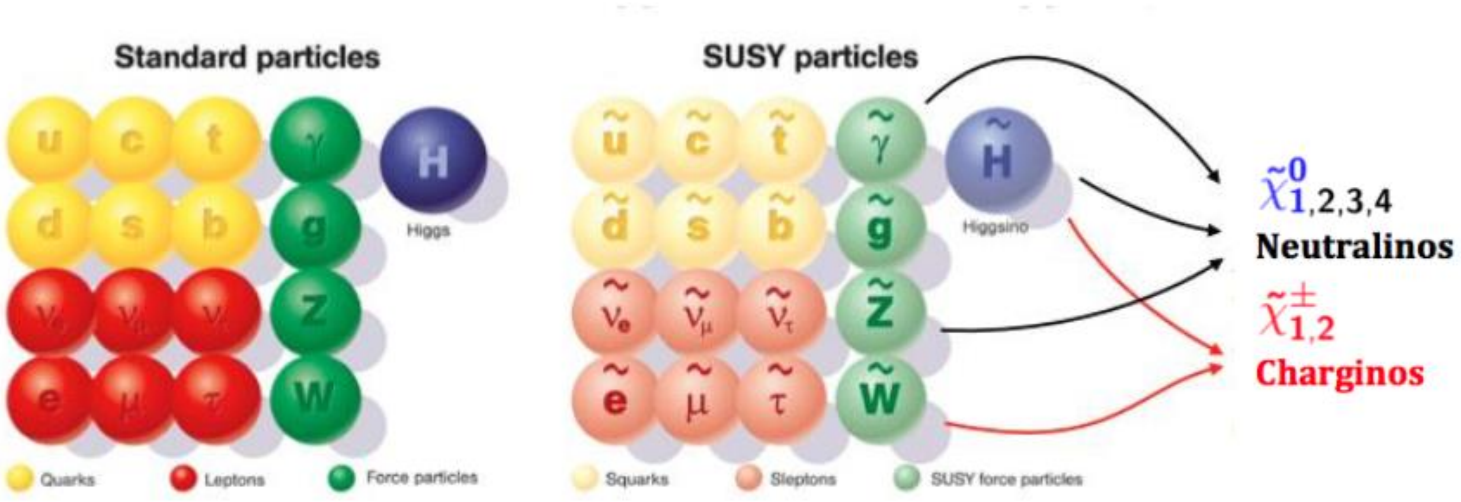
Introduction





- Supersymmetry: one of the most appealing BSM theories
  - Solve problems such as hierarchy problem, grand unification of gauge couplings, dark matter…
- If SUSY is at TeV scale, it will be produced copiously at LHC
- SUSY search is one of the most hot topics at LHC and beyond

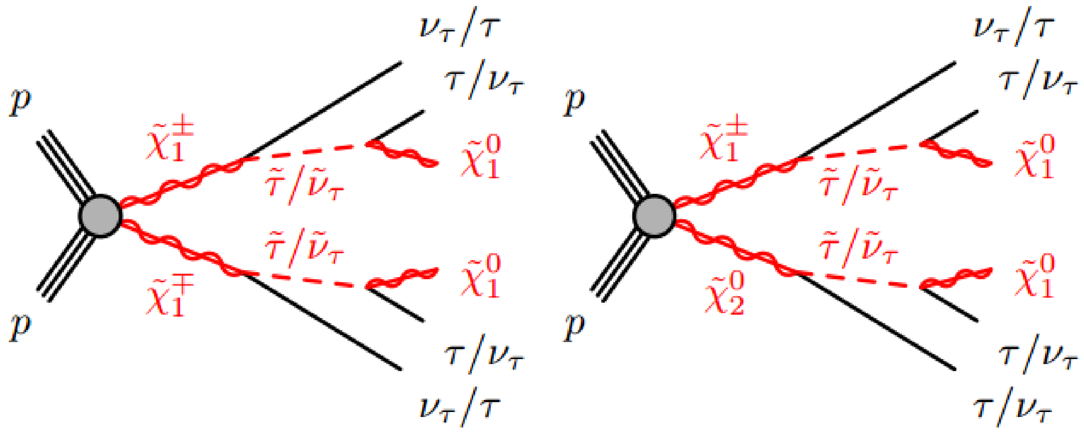
Overview

- **Movitation**

  – If colored sparticles much heavier than EW partners, EWK production may dominant at LHC

  – Light stau models are consistent with current dark matter cosmological observations

  – There is no sensitivity in direct stau at LHC yet, so we only consider charginos and neutralinos productions via stau decay



- **Model:** Two simplified models of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production are considered in this work

- **Signature:** two or more hadronic taus, low jet activity and large MET

- **Data:** 13TeV pp collision data recorded by ATLAS Detector in 2015 and 2016 with integrated luminosity of 36.1 fb^{-1}

Object selection

- Event: At least one reconstructed primary vertex with at least two associated charged-particle tracks with p_T > 400 MeV
- Object:

Electrons	Baseline	Signal
p_T	$p_T > 10$ GeV	$p_T > 25$ GeV
η-acceptance	$\|\eta_{cluster}\| < 2.47$	$\|\eta_{cluster}\| < 2.47$
quality	LooseLH	TightLH
isolation	—	GradientLoose
tracking cuts		$\|d_0/\sigma(d_0)\| < 5$
		$\|z_0 \sin(\theta)\| < 0.5$ mm

Taus	Baseline
p_T	$p_T > 20$ GeV
η-acceptance	$\|\eta\| < 2.5$
n-prongs	1 or 3
quality/jet BDT WP	medium
electron OR	yes

Muons	Baseline	Signal
p_T	$p_T > 10$ GeV	$p_T > 25$ GeV
η-acceptance	$\|\eta\| < 2.7$	$\|\eta\| < 2.7$
quality	xAOD::Muon::Medium	xAOD::Muon::Medium
isolation	—	GradientLoose
tracking cuts		$\|d_0/\sigma(d_0)\| < 3$
		$\|z_0 \sin(\theta)\| < 0.5$ mm

Jets	Baseline	b-jets
Collection	AntiKt4EMTopo	AntiKt4EMTopo
p_T	$p_T > 20$ GeV	$p_T > 20$ GeV
η-acceptance	$\|\eta\| < 2.8$	$\|\eta\| < 2.5$
JVT cut	> 0.59 (or $p_T > 60$ GeV)	> 0.59 (or $p_T > 60$ GeV)
b-tag	–	MV2c10 @ 77 % OP

- The overlap removal for each objects is using SUSY group default recommendation

Signal region definition

- Preselection:
  - Event cleaning
  - At least two taus with opposite sign
  - Pass asymmetric di-tau trigger or di-tau + MET trigger
  - M$\tau\tau$ > 12GeV
- Two SRs: SR-lowMass and SR-highMass are designed to improve the sensitivity of signal models with for different mass difference between the $\tilde{\chi}_1^{\pm}$ and $\tilde{\chi}_1^0$

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	
$m_{\mathrm{T2}} > 70$ GeV	$m_{\mathrm{T2}} > 90$ GeV	
Di-tau+$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger	di-tau+$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger	asymmetric di-tau trigger
$E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV	$E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV	$E_{\mathrm{T}}^{\mathrm{miss}} > 110$ GeV
$p_{\mathrm{T},\tau_1} > 50$ GeV	$p_{\mathrm{T},\tau_1} > 80$ GeV	$p_{\mathrm{T},\tau_1} > 95$ GeV
$p_{\mathrm{T},\tau_2} > 40$ GeV	$p_{\mathrm{T},\tau_2} > 40$ GeV	$p_{\mathrm{T},\tau_2} > 65$ GeV

Mainly use this variable to discriminate the signal and background in SR!

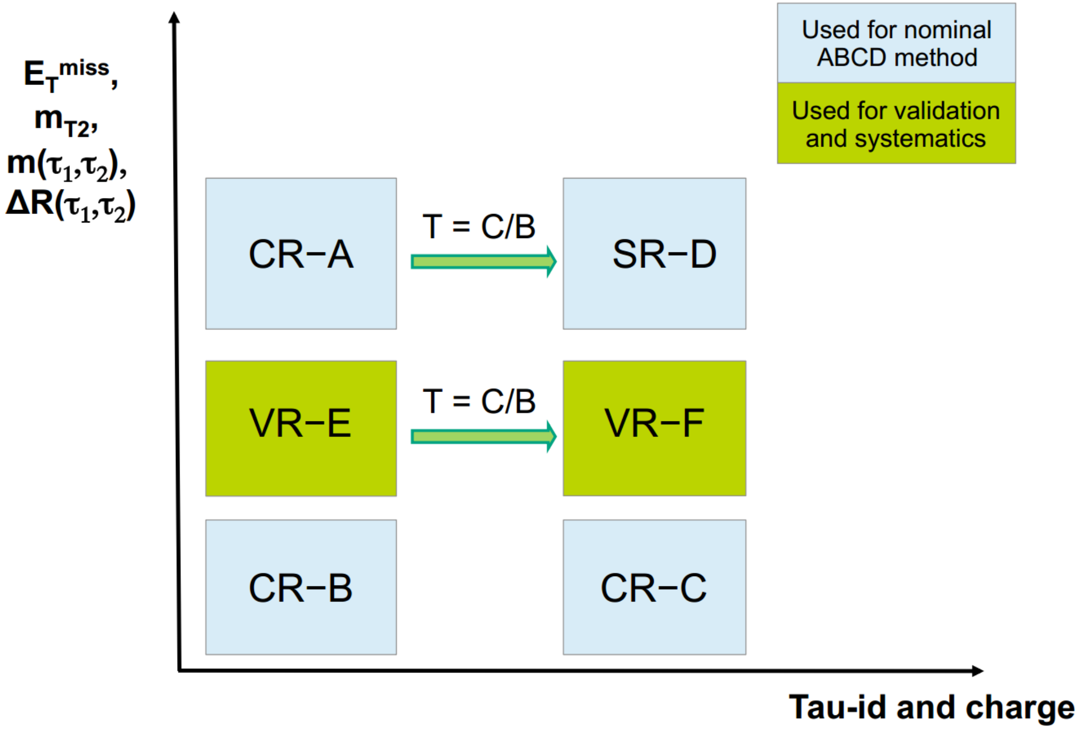
Background estimation

- Reducible backgrounds: (>= 1 fake tau)
  - **Multi-jet background**: Using Data-driven ABCD method
  - **W+jets**: Using a dedicated control region (W-CR) to normalize it to data

- Irreducible background estimation
  - mainly from $t\bar{t}$, single top quark, $t\bar{t}$+V, Z+jets, and diboson (WW, WZ and ZZ)
  - Estimated based on MC simulation
  - Using a dedicated validation region to validate the MC production

multi-jet estimation

- Using ABCD Method
  - Four exclusive regions, labelled as A, B, C, and D are defined in a two-dimensional plane as a function of two (or more) uncorrelated discriminating variables
  - Multi-jet in SR_D = A * TF while TF = C/B
  - Two sets of validation regions (VR), are defined to verify the extrapolation of the ABCD estimation to the SRs and estimate the systematic uncertainty



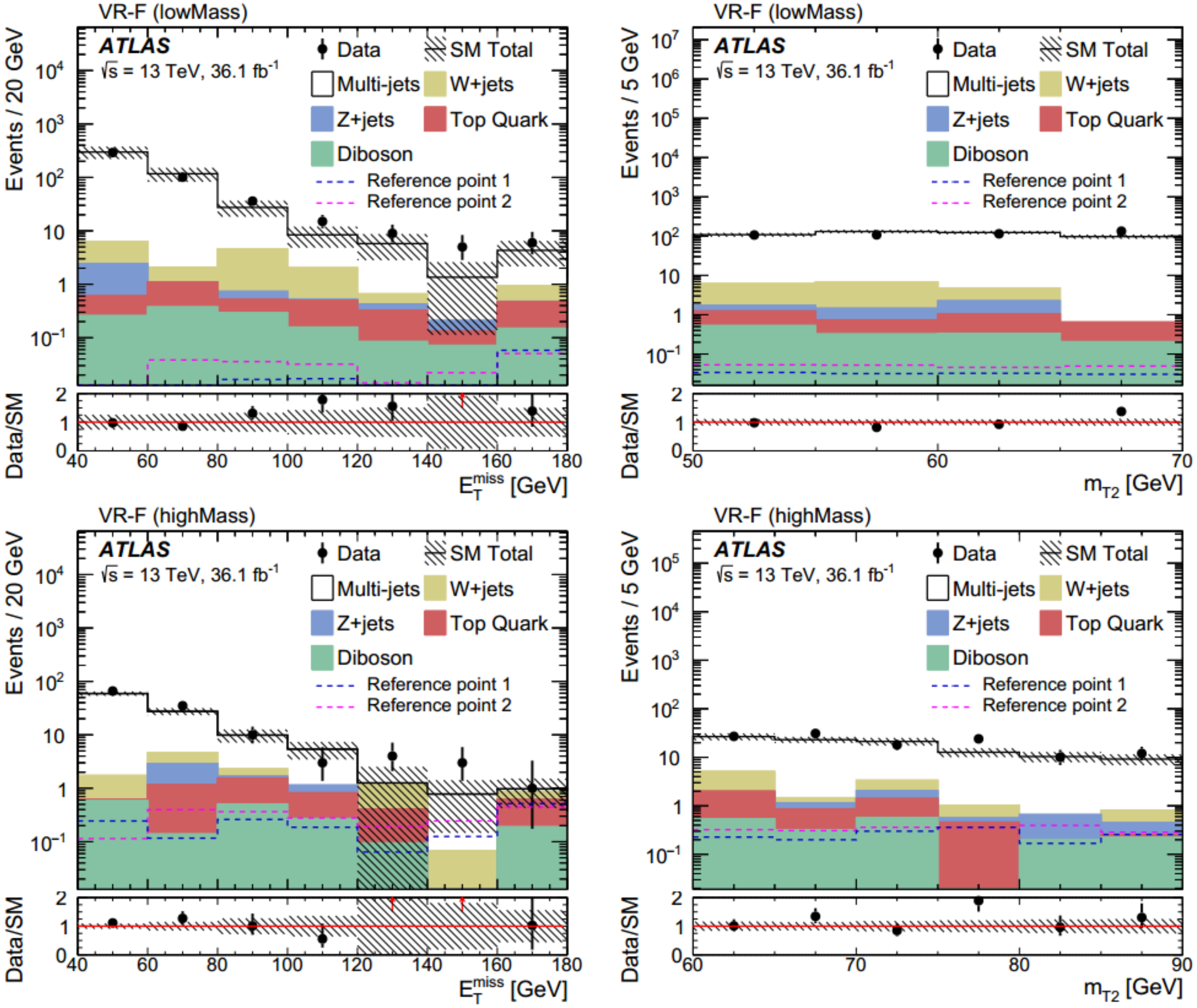
CR – A (lowMass)	SR – D (lowMass)	CR – A (lowMass)	SR – D (highMass)
ditau+MET trigger		ditau+MET or asym ditau trigger	
$\geq$ 2 loose taus (SS) $M(\tau_1,\tau_2) < 250$ GeV $\Delta R(\tau_1,\tau_2) > 1.5$ $E_T^{miss} > 150$ GeV $m_{T2} > 70$ GeV	$\geq$ 2 medium taus (OS) $E_T^{miss} > 150$ GeV $m_{T2} > 70$ GeV	$\geq$ 2 loose taus (OS) < 1 medium 1 tight taus $\Delta R(\tau_1,\tau_2) > 1.8$ $E_T^{miss} > 110$ GeV $m_{T2} > 90$ GeV	$\geq$ 2 medium taus (OS) $\geq$ 1 tight tau $E_T^{miss} > 110$ GeV $m_{T2} > 90$ GeV
VR – E (lowMass)	**VR – F (lowMass)**	**VR – E (lowMass)**	**VR – F (highMass)**
ditau trigger		ditau or asym ditau trigger	
$\geq$ 2 loose taus (SS) $M(\tau_1,\tau_2) < 250$ GeV $\Delta R(\tau_1,\tau_2) > 1.5$ $E_T^{miss} > 40$ GeV $50 < m_{T2} < 70$ GeV	$\geq$ 2 medium taus (OS) $E_T^{miss} > 40$ GeV $50 < m_{T2} < 70$ GeV	$\geq$ 2 loose taus (OS) < 1 medium 1 tight taus $\Delta R(\tau_1,\tau_2) > 1.8$ $E_T^{miss} > 40$ GeV $60 < m_{T2} < 90$ GeV	$\geq$ 2 medium taus (OS) $\geq$ 1 tight tau $E_T^{miss} > 40$ GeV $60 < m_{T2} < 90$ GeV
CR – B (lowMass)	**CR – C (lowMass)**	**CR – B (lowMass)**	**CR – C (highMass)**
ditau trigger		ditau or asym ditau trigger	
$\geq$ 2 loose taus (SS) $M(\tau_1,\tau_2) < 250$ GeV $\Delta R(\tau_1,\tau_2) > 1.5$ $E_T^{miss} > 40$ GeV $20 < m_{T2} < 50$ GeV	$\geq$ 2 medium taus (OS) $E_T^{miss} > 40$ GeV $20 < m_{T2} < 50$ GeV	$\geq$ 2 loose taus (OS) < 1 medium 1 tight taus $\Delta R(\tau_1,\tau_2) > 1.8$ $E_T^{miss} > 40$ GeV $10 < m_{T2} < 60$ GeV	$\geq$ 2 medium taus (OS) $\geq$ 1 tight tau $E_T^{miss} > 40$ GeV $10 < m_{T2} < 60$ GeV

multi-jet estimation - result

- Good data/SM agreement for E_T^{miss} and m_{T2} !
- the signal contamination in CR has been considered in the final combined fit

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		

The predicted MC and data in the multi-jet control regions, MC has included the statistical uncertainties



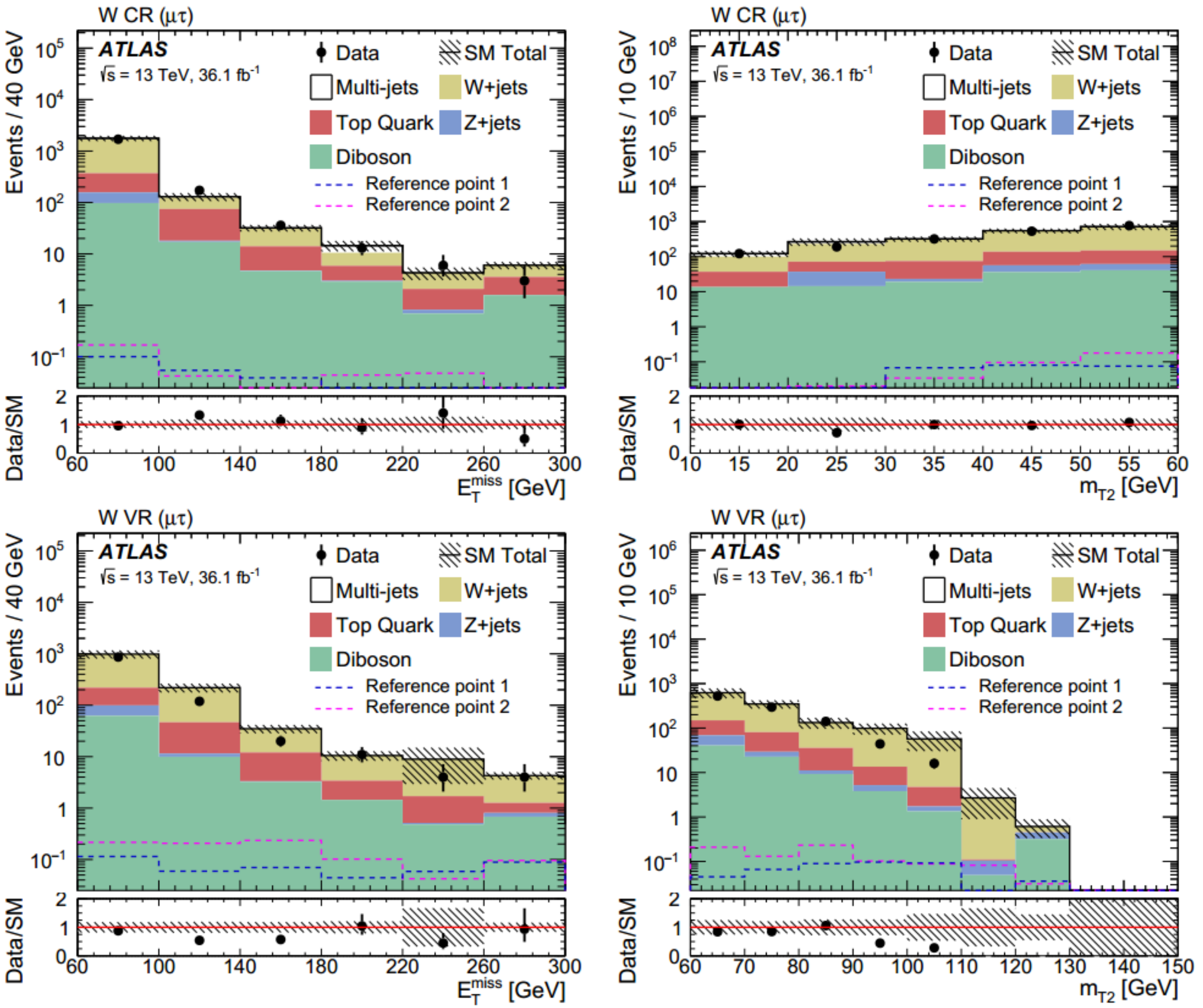
The E_T^{miss} and m_{T2} distributions in the VR-F lowmass(top) and VR-F highmass (bottom) regions

W+jet estimation

- Definition:

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

- High W+jets purity
- The signal contamination in the W-CR and W-VR is negligible
- Agreement between data and SM predictions is observed



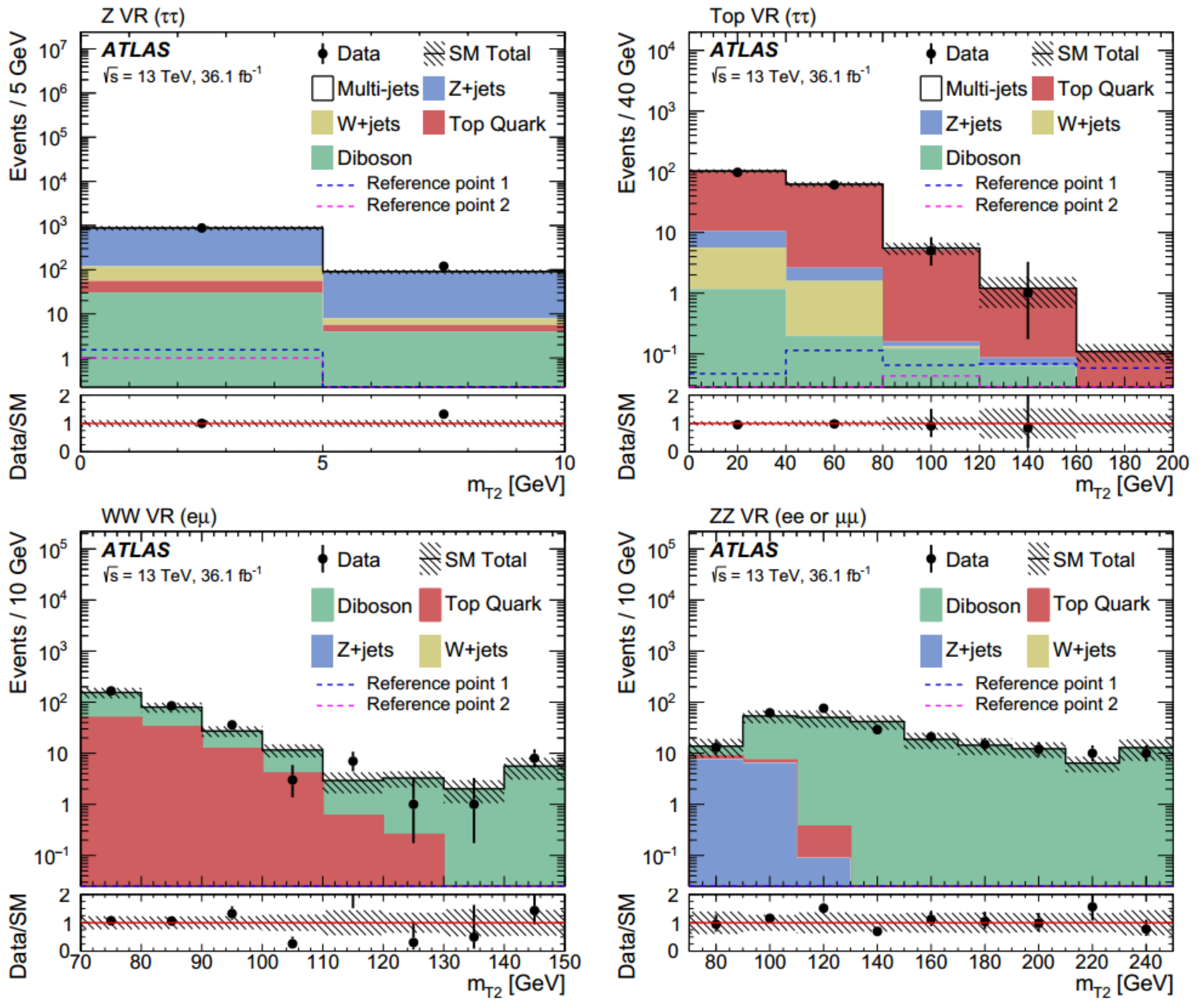
The E_T^{miss} and m_{T2} distributions in the W-CR (top) and W-VR (bottom) regions

Irreducible background estimation

- Use Z-VR, Top-VR, WW-VR and ZZ-VR to validate them

Z-VR	Top-VR
At least one opposite-sign tau lepton pair	
Tau p_T > 50, 40 GeV	
E_T^{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_{T2} < 10 GeV	m_{T2} > 10 GeV
	m_{CT} top-tagged

WW-VR	ZZ-VR
One opposite-sign lepton (e or μ) pair	
μ p_T >30 GeV, e p_T > 40 GeV	
Jet veto	
$m_{\ell\ell}$ > 50 GeV	
E_T^{miss} > 50 GeV	
$m_{T,\mu}$ > 100 GeV	
m_{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



The mT2 distributions in the Z-VR(first), Top-VR(second), WW-VR(third) and ZZ-VR(last)

- High background purity in their validation region
- Agreement between data and SM predictions is observed

Systematic uncertainty

- Main sources
  - Experimental:
    - Mainly from tau lepton identification, pile-up, object energy scale resolution
  - Theoretical
    - Mainly from the choice of QCD renormalisation scale and resummation scale, theory uncertainty in background production
  - Uncertainties in ABCD Method
- The relative systematic uncertainty (%) for background in SR is:

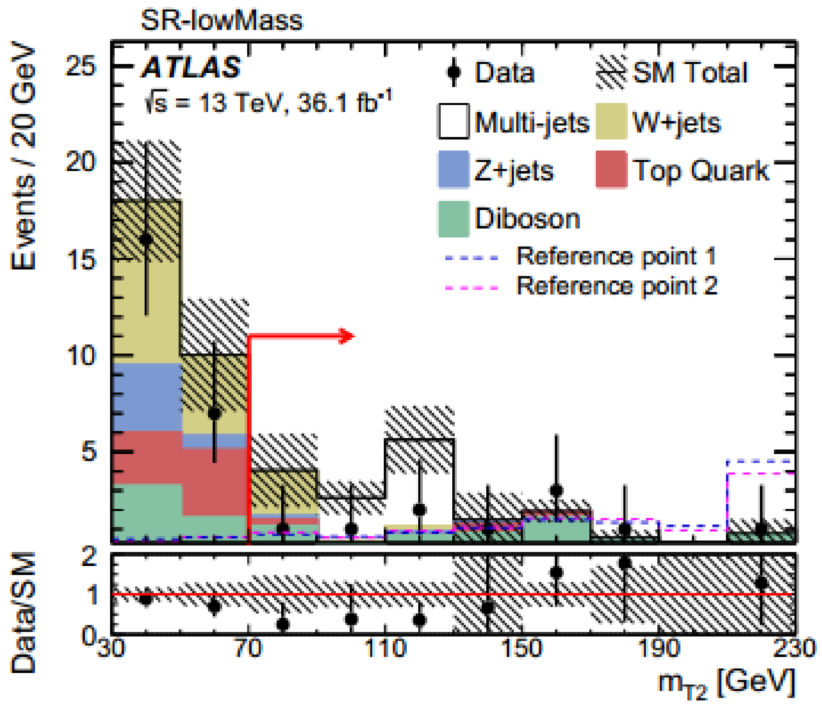
Source of systematic uncertainty	SR-lowMass	SR-highMass
Normalisation uncertainties of the multi-jet background	32	32
Statistical uncertainty of MC samples	18	24
Multi-jet estimation	14	13
Pile-up reweighting	8	8
Jet energy scale and resolution	11	4
Tau identification and energy scale	6	8
E_T^{miss}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

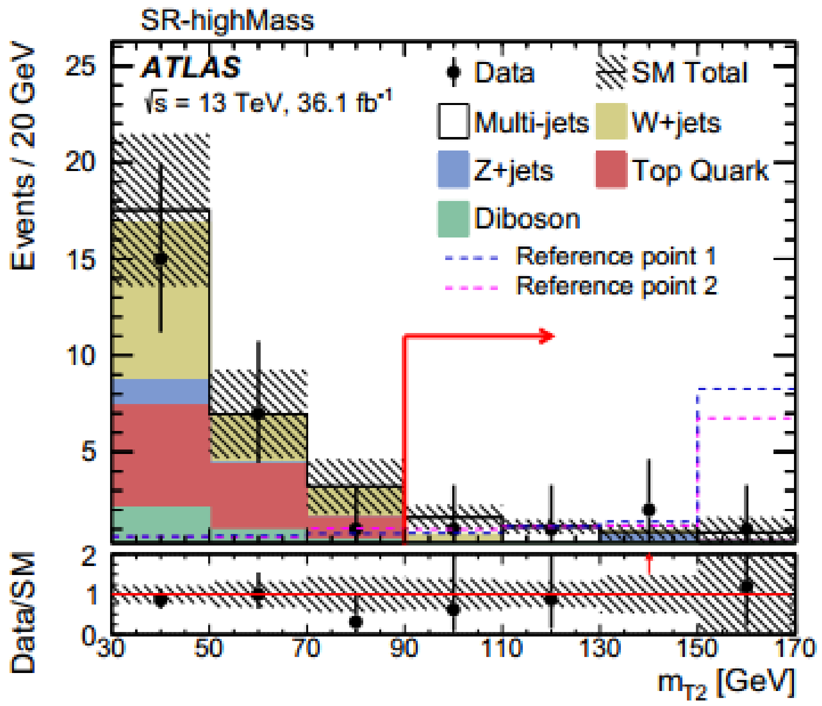
- The total uncertainty in the signal yield for SUSY reference point is about 20% and is mainly from the experimental uncertainty (15%)

Results in Signal Region

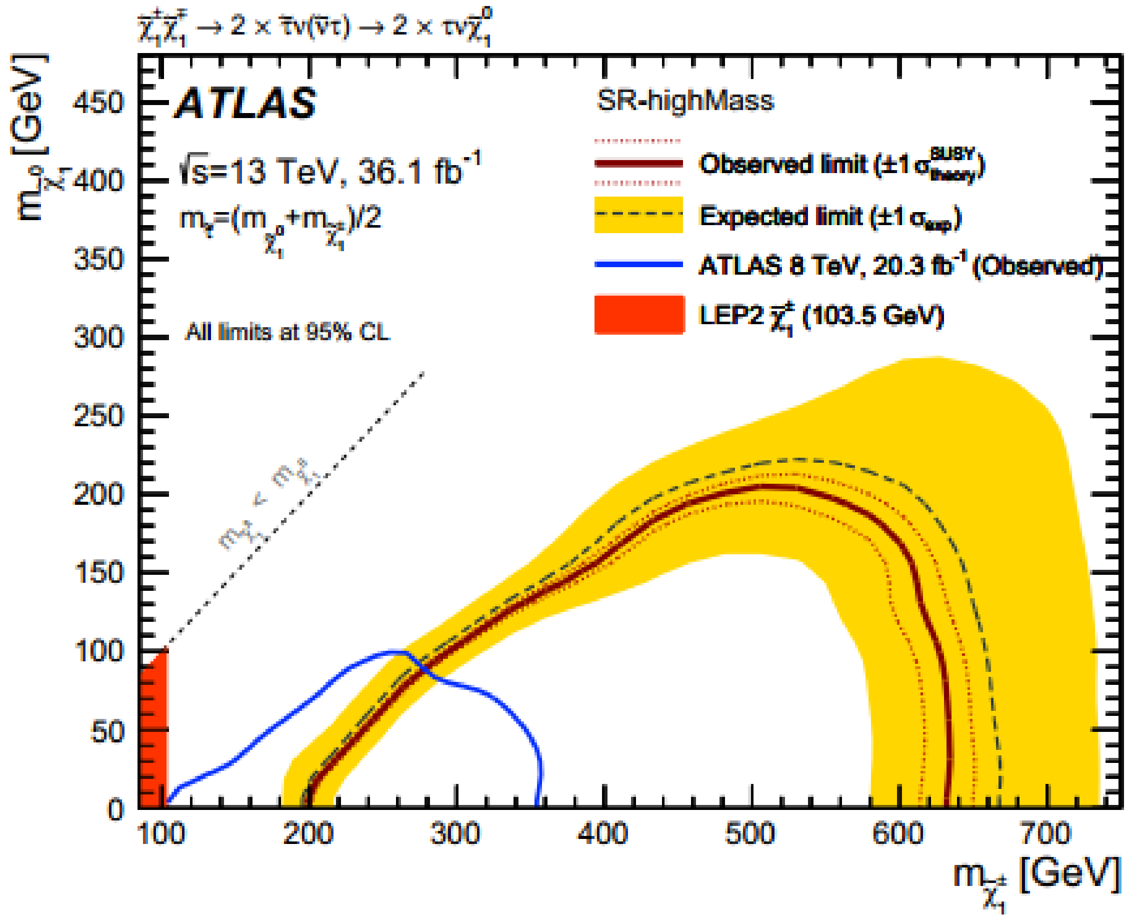
- Dominant backgrounds are diboson and multi-jet
- No excess observed in signal regions

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 $\sigma^{95}_{\rm vis}$ [fb]	$0.31^{+0.12}_{-0.08}$	$0.17^{+0.08}_{-0.05}$
Observed $\sigma^{95}_{\rm vis}$ [fb]	0.26	0.20

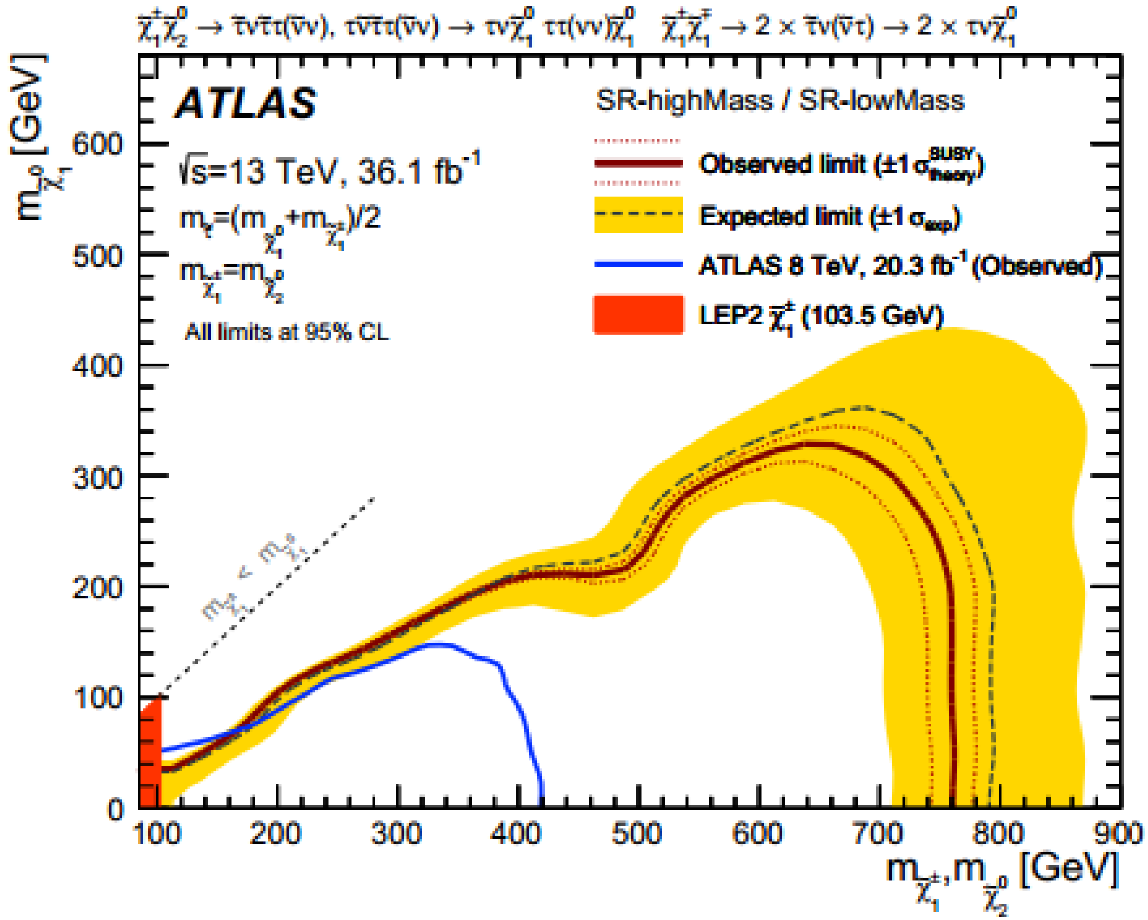




The 95% Confidence level exclusion limit



Limit for pure production of $\tilde{\chi}_1^+\tilde{\chi}_1^-$



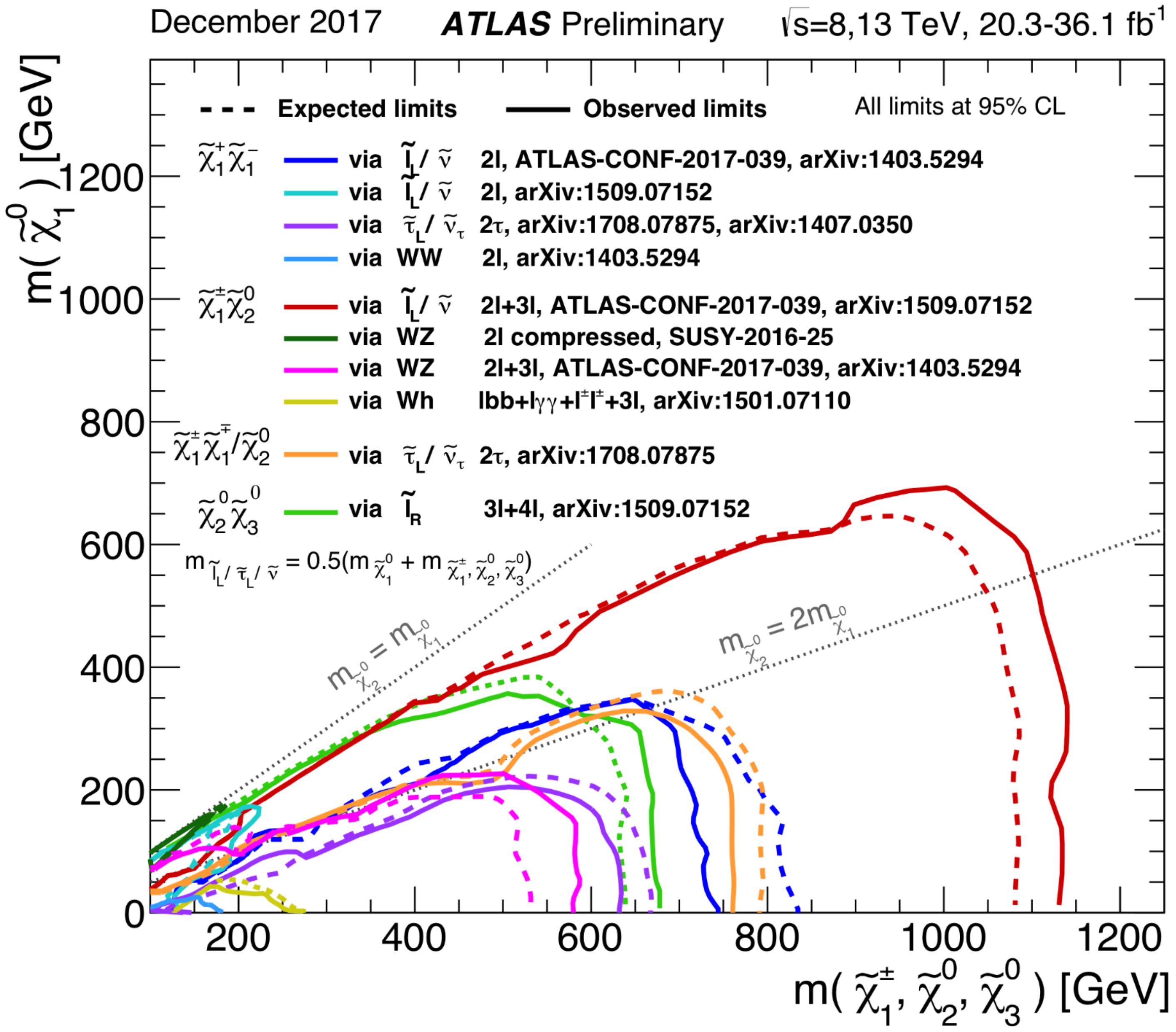
Limit for production of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$

- C1C1: Chargino masses up to 630 GeV are excluded for a massless LSP
- C1N2+C1C1: Chargino/neutralino masses up to 760 GeV are excluded for a massless LSP

Summary and Outlook

- Summary
  - The electroweak SUSY search with at least two hadronically decaying taus in the final state is performed with 2015+2016 data 36.1 fb^{-1}
  - No excess beyond the SM expectation in all signal regions
  - Limits on the chargino/neutralino are significantly extended compared with previous study
  - Paper links at arXiv:1708.07875
- Outlook
  - direct stau: Aiming for 2018 spring/summer conf note, first LHC sensitivity
  - Gaugino with taus: Will update with full run2 data

Summary of Ewk Production



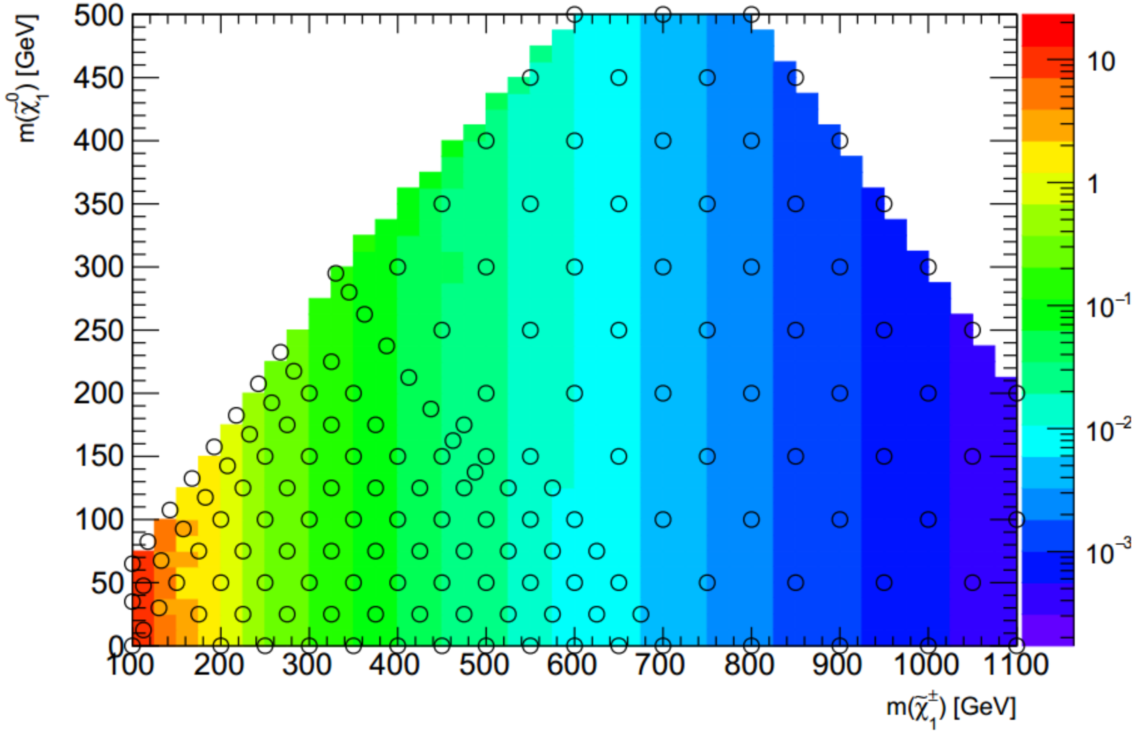
- Powerful exclusions in decays via sleptons and staus (C1/N2 up to 0.6-1.1 TeV)
- Exclusion limits is not so large in decays via bosons

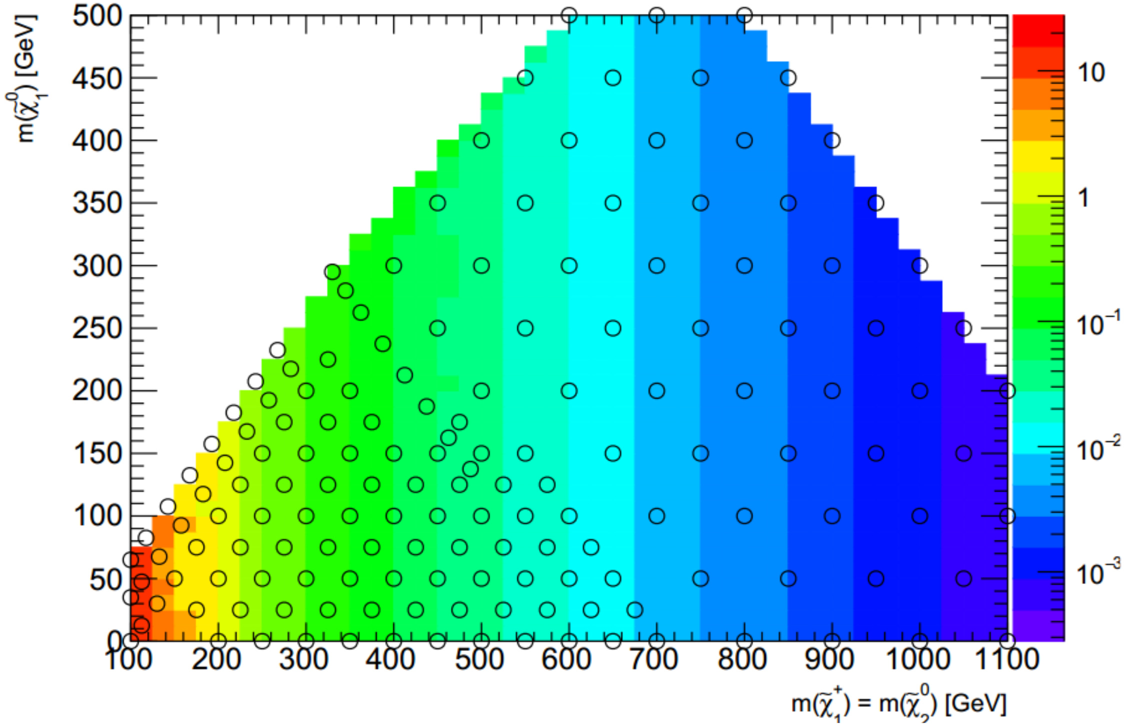
BackUp

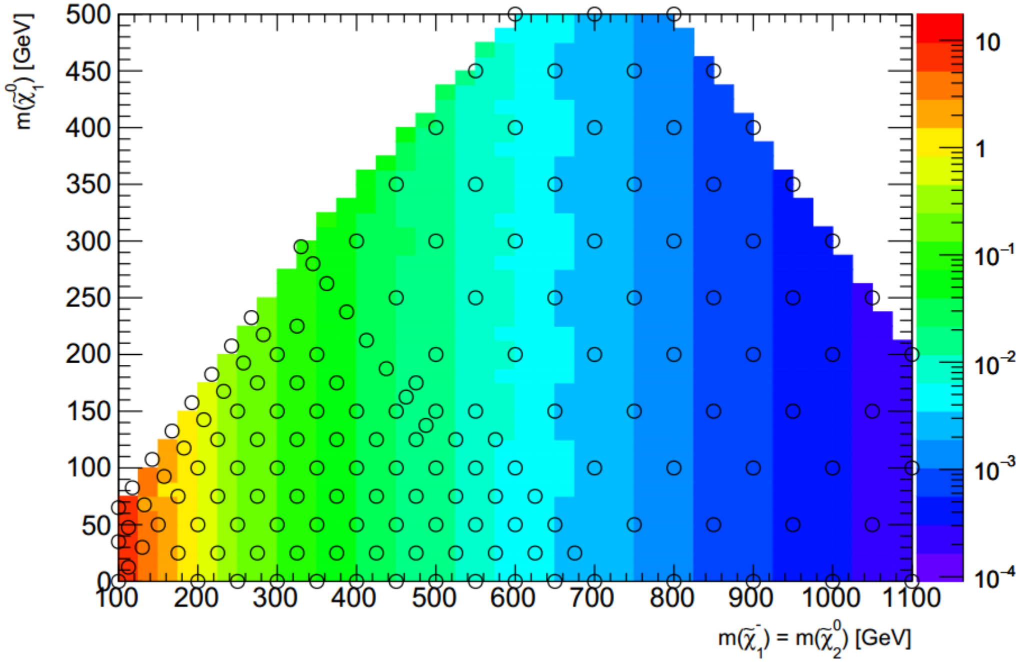
Samples

- Signal grids
  - The charginos and neutralinos decay through intermediate staus with 100% BR to final states containing tau leptons
  - The only free parameters of the considered models are the masses of the SUSY particles
- Data
  - 2015 data(3.19 fb^{-1}) + 2016 data(32.91 fb^{-1})
- MC event generating:
  - W+jets, Z+jets: Shepra 2.2.0 and 2.2.1
  - Diboson: Sherpa 2.2.1 (2.1.1 for with one of the bosons decaying hadronically and the other leptonically)
  - ttV: MadGraphPythia8EvtGen
  - Top: PowhegPythiaEvtGen
  - Signal: MadGraphPythia8EvtGen
- Analysis Release
  - SUSYTools-00-08-55 and AnalysisBase 2.4.28

Crossections







Crossections in pb for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production(left) , $\tilde{\chi}_1^+\tilde{\chi}_2^0$ (upper right)and $\tilde{\chi}_1^-\tilde{\chi}_2^0$ production (lower right). The applied grid points(circle) is also shown here

Trigger

- 2015 data:
  - ditau-trigger: HLT_tau35_medium1_tracktwo_tau25_medium1_tracktwo
  - single muon trigger(Tau-Muon channel): HLT_mu20_iloose_L1MU15
- 2016 data:
  - di-tau + MET trigger: HLT_tau35_medium1_tracktwo _tau25_medium1_tracktwo_xe50
  - asymmetric di-tau trigger : HLT_tau80_medium1_tracktwo_L1TAU60_tau50_medium1_tracktwo_L1TAU12
  - single muon trigger: HLT_mu26_imedium
- To ensure that only events in the plateau region of the trigger are selected, additional requirements are applied

Trigger leg	HLT	Offline
leading tau p_T [GeV]	35	50
2nd leading tau p_T [GeV]	25	40
E_T^{miss} [GeV]	50	150
leading tau p_T [GeV]	80	95
2nd leading tau p_T [GeV]	50	65

Variables Definition

- the "stransverse mass", m_{T2}, which can be shown to have a kinematic endpoint for events where two massive pair produced particles each decay to two objects, one of which is detected (the lepton in our case) and the other escapes undetected (the neutralino) [16, 17]. It is defined as:

$$m_{\mathrm{T2}} = \min_{\mathbf{q}_{\mathrm{T}}} \left[\max \left(m_{\mathrm{T},\tau 1}(\mathbf{p}_{\mathrm{T},\tau 1}, \mathbf{q}_{\mathrm{T}}), m_{\mathrm{T},\tau 2}(\mathbf{p}_{\mathrm{T},\tau 2}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}} - \mathbf{q}_{\mathrm{T}}) \right) \right],$$

  where $\mathbf{p}_{\mathrm{T},\tau 1}$ and $\mathbf{p}_{\mathrm{T},\tau 2}$ are the transverse momenta of the two taus, and $\mathbf{q}_{\mathrm{T}}$ is the transverse vector that minimises the larger of the two transverse masses $m_{\mathrm{T},\tau 1}$ and $m_{\mathrm{T},\tau 2}$. The latter is defined by

$$m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}, \mathbf{q}_{\mathrm{T}}) = \sqrt{2(p_{\mathrm{T}} q_{\mathrm{T}} - \mathbf{p}_{\mathrm{T}} \cdot \mathbf{q}_{\mathrm{T}})}.$$

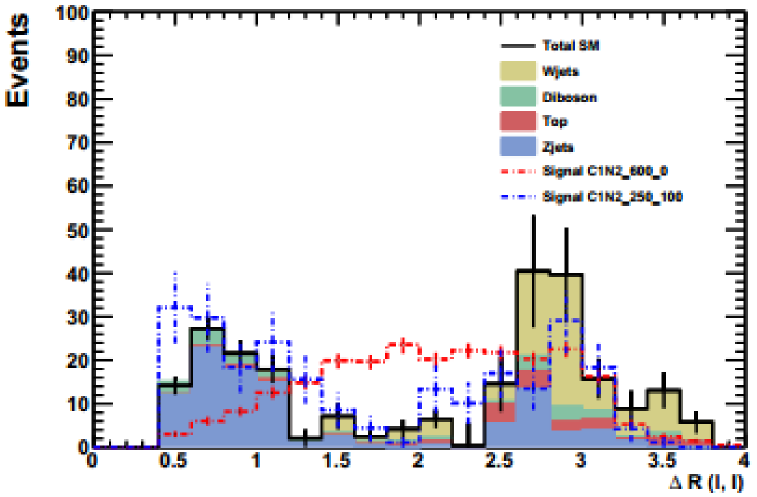
  In events with more than two taus, m_{T2} is calculated using all possible tau pairs and the largest value is chosen (the reason for this choice can be found in Section H.4);

- $m_{T\tau 1} + m_{T\tau 2}$, the sum of the transverse mass values of the leading and next-to-leading taus;

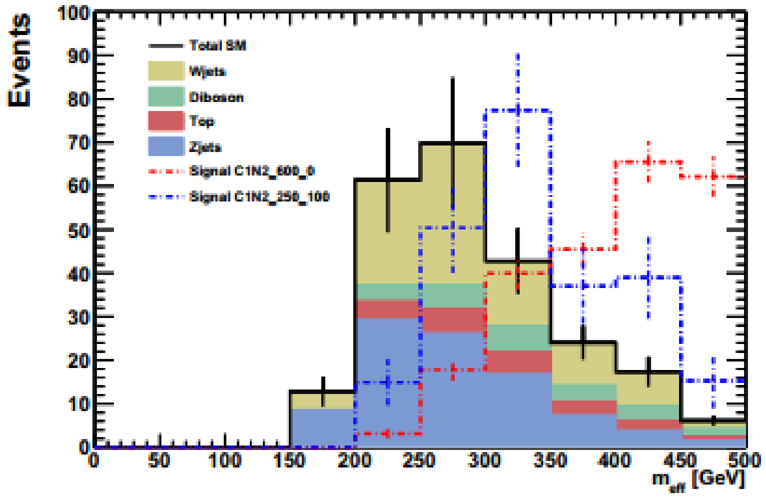
- m_{eff}, the scalar sum of the missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) and the transverse momenta of the leading and next-to-leading taus;

- $\Delta R(\tau, \tau)$, the cone size between the leading and next-to-leading tau. An upper cut on this variable is powerful to discriminate against back-to-back events such as di-jets or Z decays.

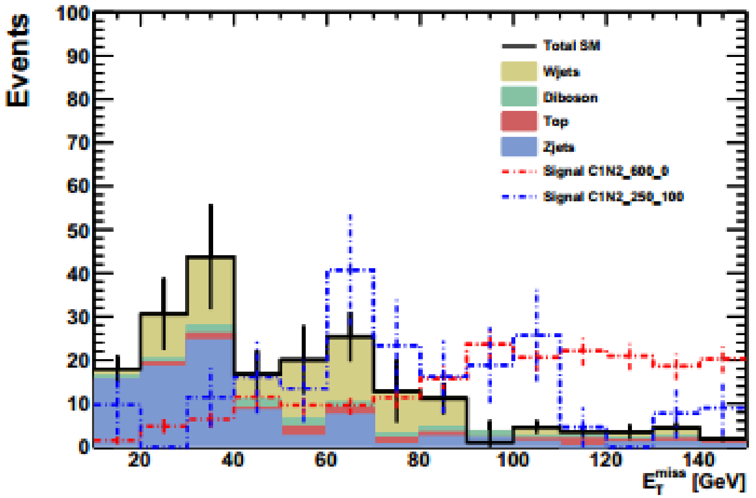
Distributions after pre-selection



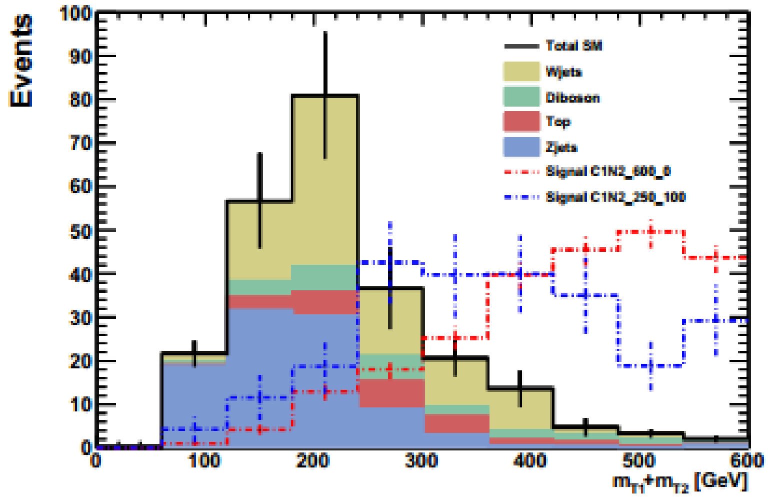
(a) $\Delta R(\tau, \tau)$



(b) m_{eff}

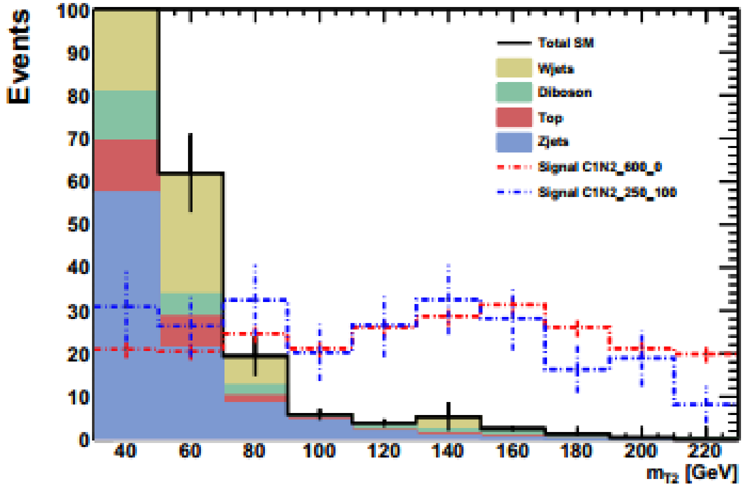


(c) $E_{\mathrm{T}}^{\mathrm{miss}}$

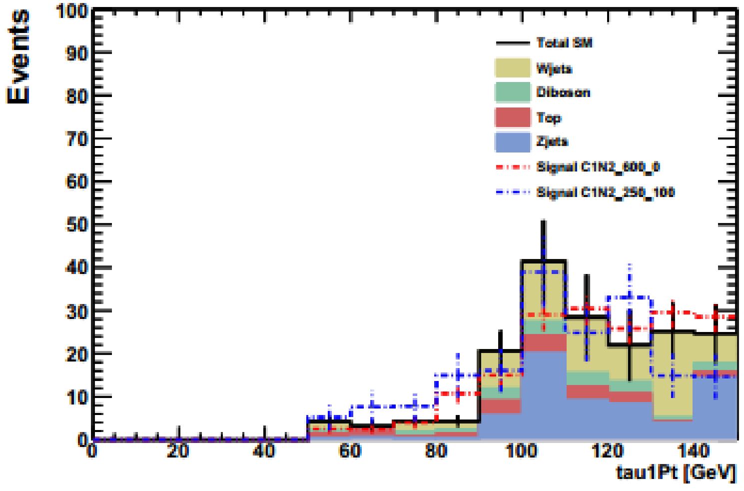


(d) $m_{T\tau1} + m_{T\tau2}$

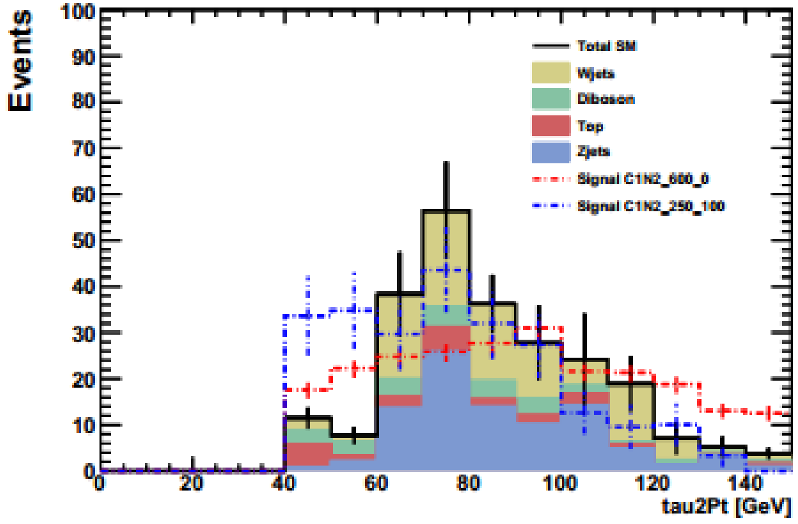
Distributions after pre-selection



(e) m_{T2}



(f) $p_{T\tau 1}$



(g) $p_{T\tau 2}$

SR Definition

- Using $Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2p)$ where $p \propto \int_0^\infty db\, G(b; N_b, \delta b) \sum_{i=N_{s+b}}^{\infty} \frac{e^{-b} b^i}{i!}$
- Requirement:
  - integrated luminosity: 36.5 fb−1 -- systematic uncertainty in the sensitivity calculation: 30%
  - the signal statistical uncertainty is not taken into account
  - Total background statistical uncertainty < 35% and same constraint for diboson background
  - the yields for W+jets background and Z+jets background must be great than 0
  - the total background yield must be greater than 2
  - only MC backgrounds are considered
- Cut Step:

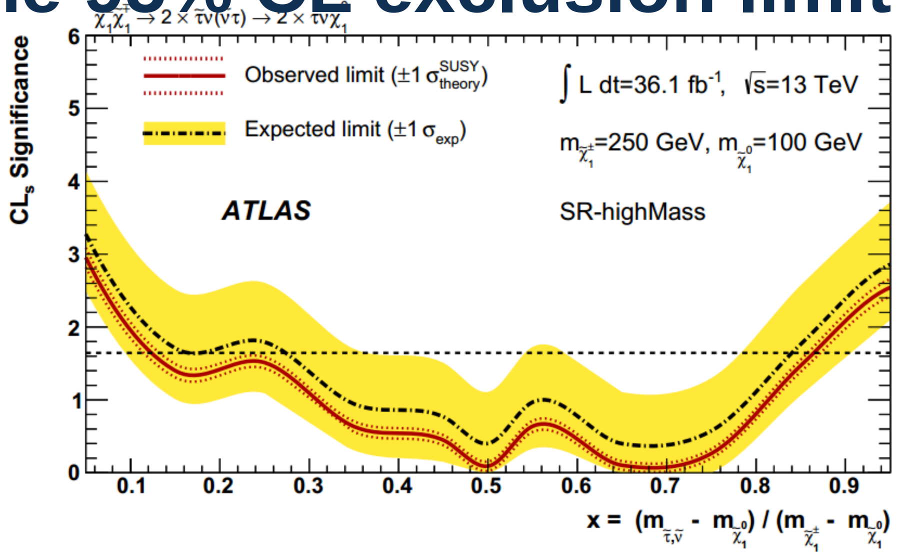
variables	cut values
$E_{\mathrm{T}}^{\mathrm{miss}} >$	80, 90, 100, 110, 120, 130, 140, 150
$m_{\mathrm{T2}} >$	0, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140
$m_{T\tau1} + m_{T\tau2} >$	0, 200, 220, 240, 260, 280, 300, 320, 340, 360
$m_{\mathrm{eff}} >$	0, 200, 220, 240, 260, 280, 300, 320
$\Delta R(\tau, \tau) <$	2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 6 (no cut)
$\tau_1\ p_{\mathrm{T}} >$	50, 60, 70, 80, 90, 100
$\tau_2\ p_{\mathrm{T}} >$	40, 45, 50
jet-veto	yes, no
tau quality	2 medium taus, 1 medium 1 tight taus, 2 tight taus
baseline electron and muon veto	yes, no

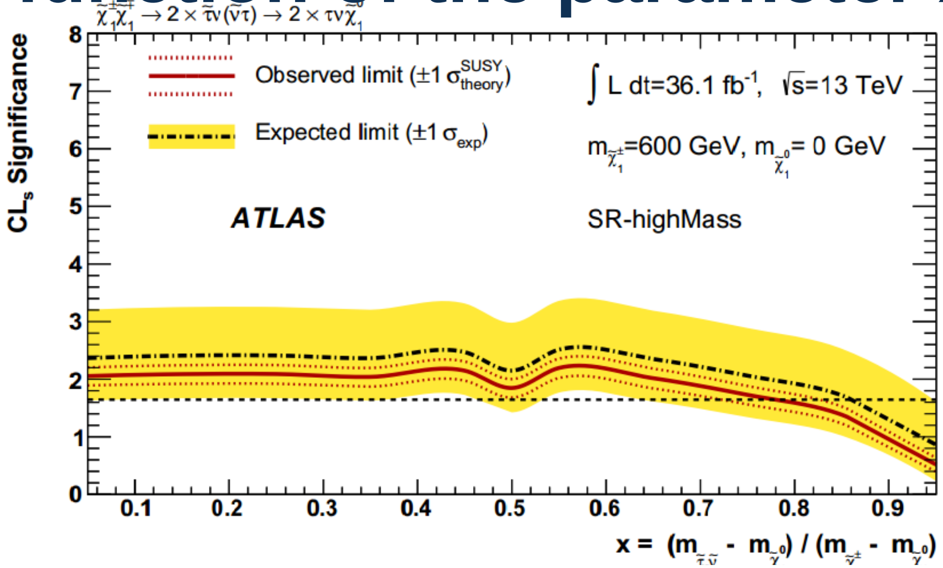
Event yields in the W-CR and W-VR

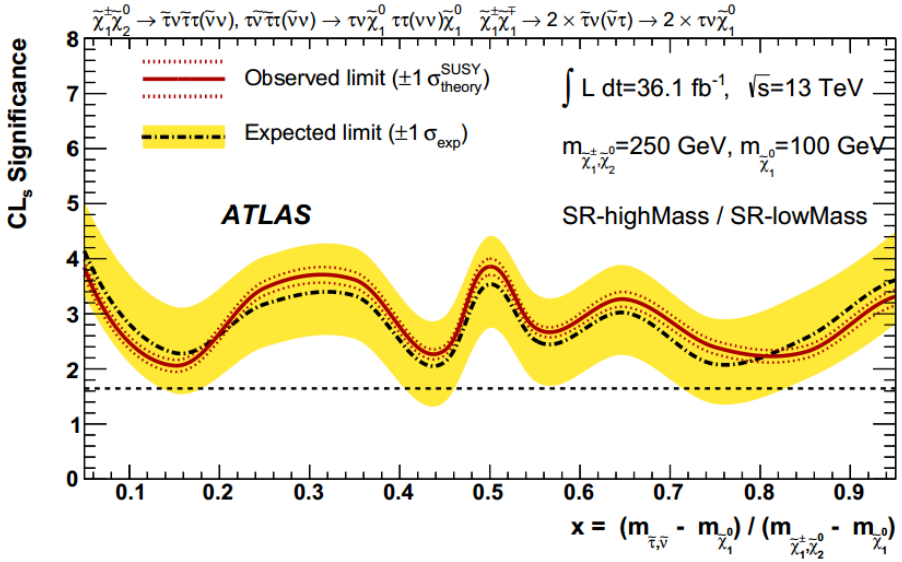
Sample	W-CR	W-VR
Data	1928	1023
SM total	1930 ± 50	1260 ± 440
W+jets	1395 ± 130	980 ± 410
Z+jets	60 ± 28	39 ± 15
Diboson	125 ± 24	78 ± 20
Top quark	290 ± 80	170 ± 60
Multi-jet	60 ± 60	0 ± 100
Reference point 1	0.22 ± 0.07	0.44 ± 0.08
Reference point 2	0.33 ± 0.08	0.87 ± 0.11

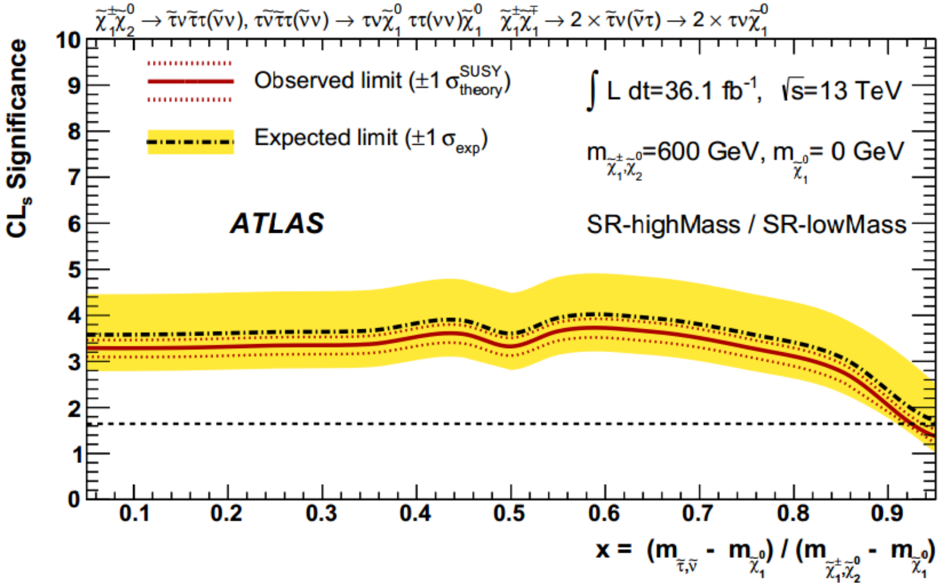
- High W+jets purity
- Agreement between data and SM predictions is observed
- The signal contamination in the W-CR and W-VR is negligible

The 95% CL exclusion limit as a function of the parameter x









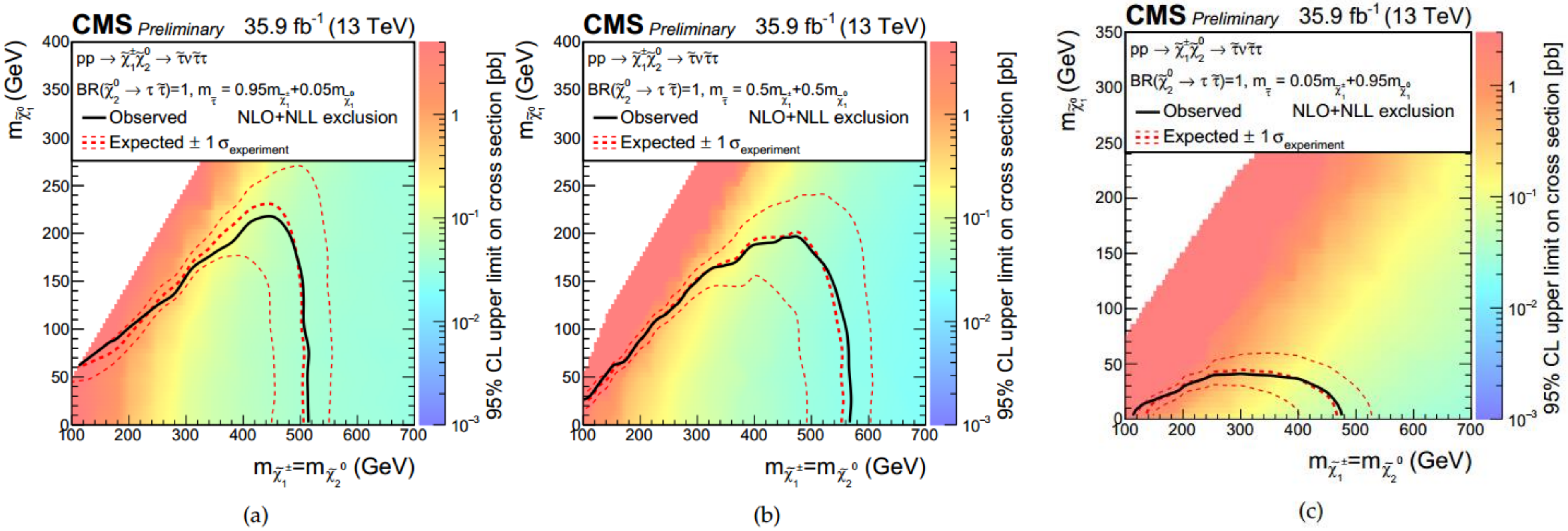
Left is the limit for point ($m(\tilde\chi_1^{\pm};\tilde\chi_2^0)$ = 250 GeV, $m(\tilde\chi_1^0)$ = 100 GeV) and right is which for point ($m(\tilde\chi_1^{\pm};\, \tilde\chi_2^0)$ = 600 GeV, $m(\tilde\chi_1^0)$ = 0) .The top is for $\tilde\chi_1^+\tilde\chi_1^-$ pure production and the bottom is for $\tilde\chi_1^+\tilde\chi_1^-$, $\tilde\chi_1^\pm\tilde\chi_2^0$ combined production

Cutlow

Sample	C1N2	C1C1				
Cuts	(600, 0) GeV	(600, 0) GeV	W+jets	Z+jets	diboson	top
$\geq$ 1 Medium τ, Trigger & offline cuts	32.8 ± 0.626	20.8 ± 0.535	642 ± 73.1	2.94×10^3 ± 171	153 ± 3.6	545 ± 13.2
M(τ1, τ2) > 12 GeV	32.8 ± 0.626	20.8 ± 0.535	642 ± 73.1	2.94×10^3 ± 171	153 ± 3.6	545 ± 13.2
OS	23.4 ± 0.529	20.6 ± 0.532	532 ± 67.2	2.85×10^3 ± 170	132 ± 3.35	487 ± 12.5
B-veto	22 ± 0.511	20 ± 0.523	504 ± 67	2.62×10^3 ± 167	120 ± 3.21	85.8 ± 5.1
Z-veto	21 ± 0.499	19.3 ± 0.515	497 ± 67	2.02×10^3 ± 166	96.9 ± 3.05	82.4 ± 5.01
m_{T2} > 30 GeV	17.5 ± 0.455	16.9 ± 0.481	97.8 ± 15.4	94.9 ± 14.9	26.4 ± 1.78	22.3 ± 2.63
SR-DS: E_T^{miss} > 50 GeV	17 ± 0.448	16.6 ± 0.476	63.6 ± 12.5	24.8 ± 7.02	20.9 ± 1.58	19.1 ± 2.43
jet100 Veto	10.8 ± 0.352	13.6 ± 0.426	46.8 ± 11.9	−0.221 ± 6.61	10.1 ± 1.39	8.71 ± 1.64
τ p_T > 90,40 GeV	10.6 ± 0.35	13.3 ± 0.423	45.8 ± 11.9	−0.221 ± 6.61	9.22 ± 1.36	8.36 ± 1.6
M(τ1, τ2) > 100 GeV	10.3 ± 0.344	12.6 ± 0.411	47 ± 11.8	0.079 ± 6.57	6.77 ± 1.2	8.03 ± 1.57
== 2 Tight τ	4.14 ± 0.217	7.67 ± 0.321	8.11 ± 3.5	−7.07 ± 5.8	2.94 ± 0.76	4.23 ± 1.12
deltaRtt < 3.4	4.07 ± 0.215	7.51 ± 0.317	6.03 ± 3.3	−5.64 ± 5.62	2.66 ± 0.709	2.6 ± 0.86
$m_{T\tau1} + m_{T\tau2}$ > 280 GeV	3.98 ± 0.213	7.31 ± 0.313	2.8 ± 1.77	0.338 ± 0.286	1.5 ± 0.645	1.3 ± 0.563
$m_{T\tau1} + m_{T\tau2}$ > 320 GeV	3.8 ± 0.208	6.93 ± 0.305	3.19 ± 1.49	0.293 ± 0.283	0.417 ± 0.448	0.54 ± 0.354
SR-C1C1: 1T1M τ	16.9 ± 0.447	16.1 ± 0.469	85.7 ± 14	98.9 ± 12.5	24.9 ± 1.71	20.9 ± 2.56
e mu veto	12.2 ± 0.38	16.1 ± 0.469	84 ± 13.9	96.7 ± 12.4	21 ± 1.67	19.2 ± 2.44
τ p_T > 80,40 GeV	12 ± 0.377	15.8 ± 0.465	80.9 ± 13.9	95.5 ± 12.4	18.7 ± 1.64	16.8 ± 2.28
M(τ1, τ2) > 100 GeV	11.7 ± 0.373	14.8 ± 0.449	81.3 ± 13.8	34.9 ± 11.5	13.5 ± 1.46	16.1 ± 2.25
E_T^{miss} > 110 GeV	9.81 ± 0.342	12.4 ± 0.412	10.7 ± 2.71	2.45 ± 1.05	4 ± 0.909	7.42 ± 1.53
m_{T2} > 90 GeV	8.42 ± 0.316	10.3 ± 0.375	0.282 ± 0.168	0.605 ± 0.452	1.24 ± 0.412	0.0336 ± 0.0305
SR-C1N2: 2T τ	12.4 ± 0.384	10.4 ± 0.377	23.3 ± 6.32	65.1 ± 11.6	15.8 ± 1.3	10.6 ± 1.8
τ p_T > 80,40 GeV	12.3 ± 0.381	10.3 ± 0.375	22.8 ± 6.24	64.3 ± 11.6	13.9 ± 1.26	8.63 ± 1.62
M(τ1, τ2) > 70 GeV	12 ± 0.377	9.89 ± 0.368	22.8 ± 6.24	51.7 ± 11.5	9.67 ± 1.13	8.57 ± 1.62
E_T^{miss} > 80 GeV	11.1 ± 0.362	9.15 ± 0.354	4.59 ± 2.24	3.74 ± 1.02	5.39 ± 0.842	3.66 ± 1.05
m_{T2} > 90 GeV	9.12 ± 0.328	7.28 ± 0.316	0.214 ± 0.108	0.535 ± 0.308	1.25 ± 0.431	0.0336 ± 0.0305

CMS Result

- Differences
  - The decay channel of the two tau are $e\tau_H$, $\mu\tau_H$, and $e\mu$ instead of $\tau_H\tau_H$
  - Since there is some change in the background contribution, the definition of SR and the background estimation are not the same
  - Defined many search bins in 0/1 jet catagory



- Expected and observed limits for neutralino-chargino production with decay with different x(0.95, 0.5 and 0.05). No mass point can be excluded for direct stau