Searches for electroweak production of supersymmetric gauginos and sleptons with the ATLAS detector

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Outlook:

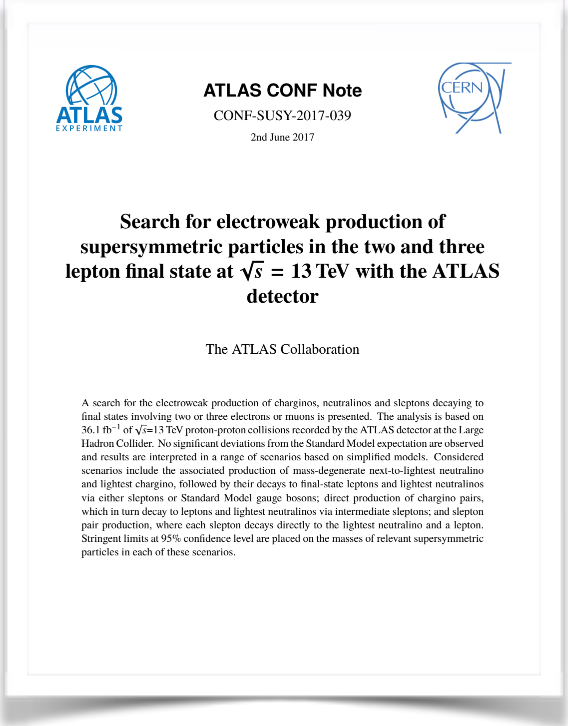
(I) Introduction

(II) Search for electroweak SUSY with 2/3 leptons

(III) Electroweak di-tau analysis

(IV) Search for EW SUSY with disappearing-tracks

(V) Summary



ATLAS CONF Note

CONF-SUSY-2017-039

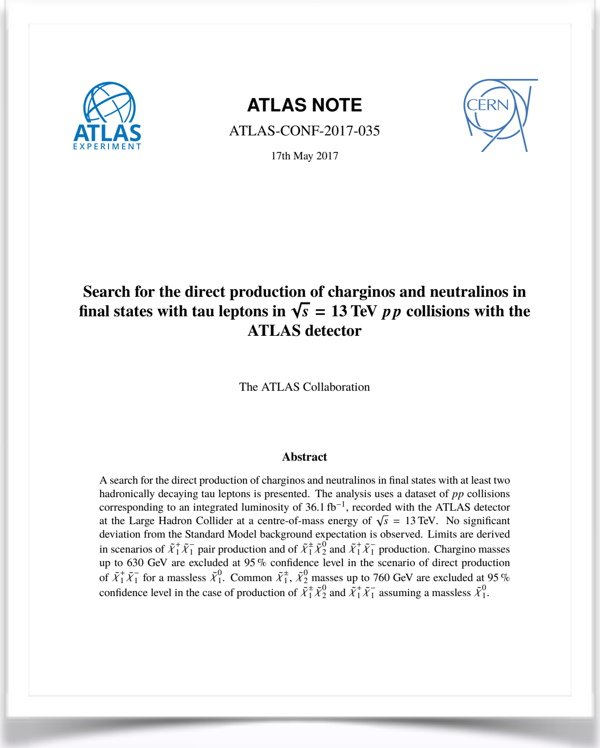
2nd June 2017

Search for electroweak production of supersymmetric particles in the two and three lepton final state at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

A search for the electroweak production of charginos, neutralinos and sleptons decaying to final states involving two or three electrons or muons is presented. The analysis is based on 36.1 fb^{-1} of $\sqrt{s}$=13 TeV proton-proton collisions recorded by the ATLAS detector at the Large Hadron Collider. No significant deviations from the Standard Model expectation are observed and results are interpreted in a range of scenarios based on simplified models. Considered scenarios include the associated production of mass-degenerate next-to-lightest neutralino and lightest chargino, followed by their decays to final-state leptons and lightest neutralinos via either sleptons or Standard Model gauge bosons; direct production of chargino pairs, which in turn decay to leptons and lightest neutralinos via intermediate sleptons; and slepton pair production, where each slepton decays directly to the lightest neutralino and a lepton. Stringent limits at 95% confidence level are placed on the masses of relevant supersymmetric particles in each of these scenarios.

ATLAS-CONF-2017-039



ATLAS NOTE

ATLAS-CONF-2017-035

17th May 2017

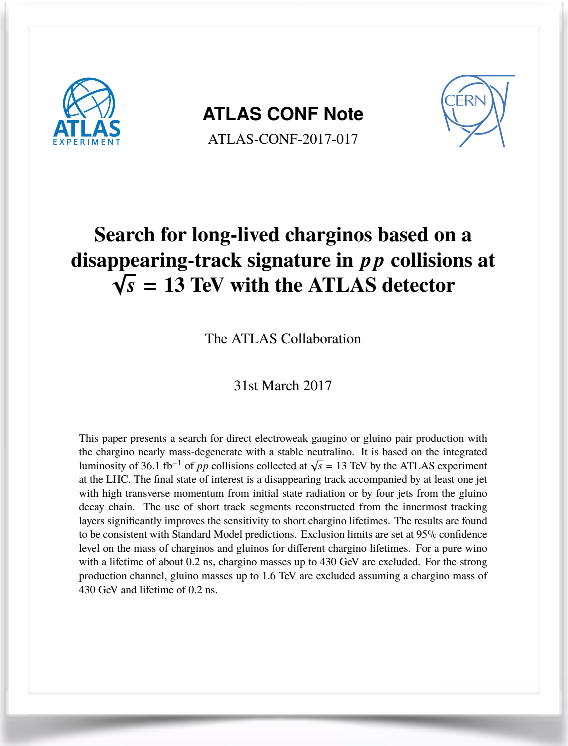
Search for the direct production of charginos and neutralinos in final states with tau leptons in $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector

The ATLAS Collaboration

Abstract

A search for the direct production of charginos and neutralinos in final states with at least two hadronically decaying tau leptons is presented. The analysis uses a dataset of pp collisions corresponding to an integrated luminosity of 36.1 fb^{-1}, recorded with the ATLAS detector at the Large Hadron Collider at a centre-of-mass energy of $\sqrt{s}$ = 13 TeV. No significant deviation from the Standard Model background expectation is observed. Limits are derived in scenarios of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ pair production and of $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ and $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production. Chargino masses up to 630 GeV are excluded at 95 % confidence level in the scenario of direct production of $\tilde{\chi}_1^+\tilde{\chi}_1^-$ for a massless $\tilde{\chi}_1^0$. Common $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$ masses up to 760 GeV are excluded at 95 % confidence level in the case of production of $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ and $\tilde{\chi}_1^+\tilde{\chi}_1^-$ assuming a massless $\tilde{\chi}_1^0$.

ATLAS-CONF-2017-035



ATLAS CONF Note

ATLAS-CONF-2017-017

Search for long-lived charginos based on a disappearing-track signature in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

31st March 2017

This paper presents a search for direct electroweak gaugino or gluino pair production with the chargino nearly mass-degenerate with a stable neutralino. It is based on the integrated luminosity of 36.1 fb^{-1} of pp collisions collected at $\sqrt{s}$ = 13 TeV by the ATLAS experiment at the LHC. The final state of interest is a disappearing track accompanied by at least one jet with high transverse momentum from initial state radiation or by four jets from the gluino decay chain. The use of short track segments reconstructed from the innermost tracking layers significantly improves the sensitivity to short chargino lifetimes. The results are found to be consistent with Standard Model predictions. Exclusion limits are set at 95% confidence level on the mass of charginos and gluinos for different chargino lifetimes. For a pure wino with a lifetime of about 0.2 ns, chargino masses up to 430 GeV are excluded. For the strong production channel, gluino masses up to 1.6 TeV are excluded assuming a chargino mass of 430 GeV and lifetime of 0.2 ns.

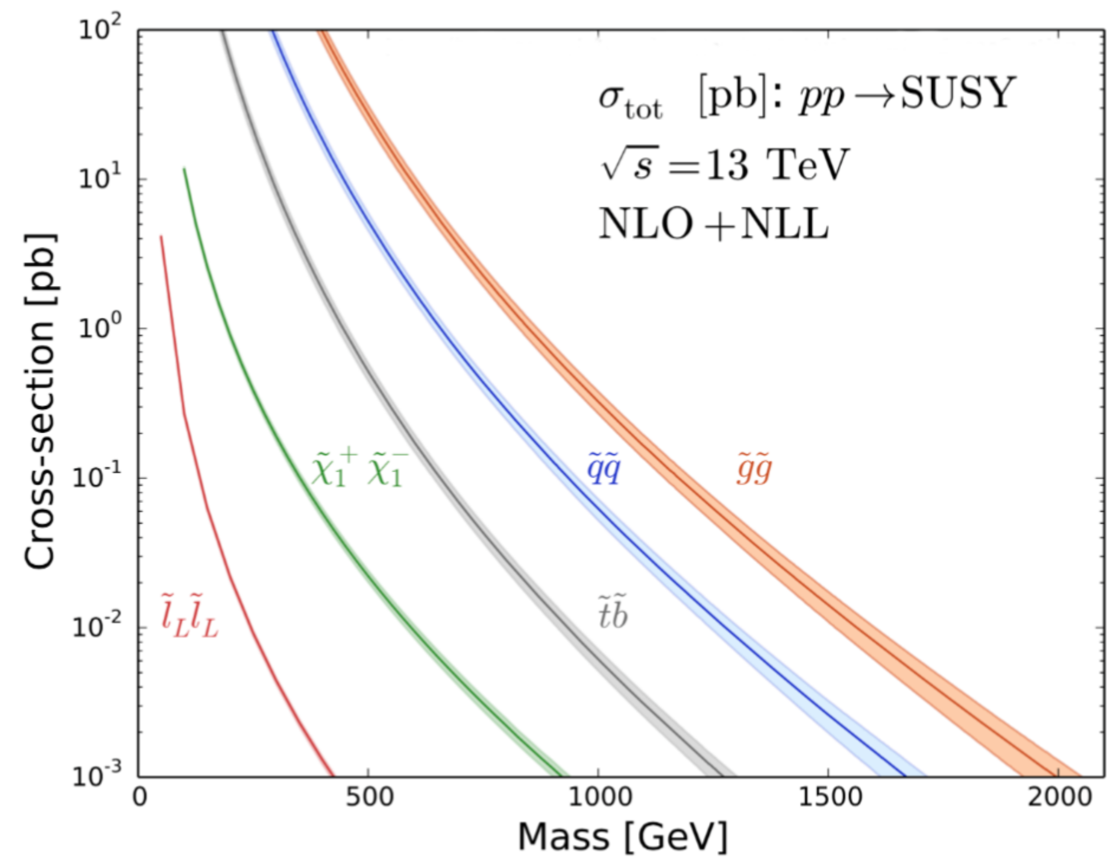
ATLAS-CONF-2017-017

Electroweak SUSY

- ***Gauginos*** mix to charged and uncharged mass-eigenstates (***neutralinos/charginos***).
- ***Sleptons*** are the superpartners of the left- and right-handed SM leptons.
- Strong production of SUSY particles (via squarks & gluinos) at the LHC has higher cross-sections than electroweak (EW) processes.
- However, direct production of electroweak particles can dominate if the masses of the gluinos and squarks are significantly higher.
- The purely leptonic signatures can more easily be separated from strong SM processes.
- Will address latest results of EW SUSY searches in this talk.

Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	+1	$H_u^0\ H_d^0\ H_u^+\ H_d^-$	$h^0\ H^0\ A^0\ H^\pm$
squarks	0	−1	$\widetilde{u}_L\ \widetilde{u}_R\ \widetilde{d}_L\ \widetilde{d}_R$	(same)
			$\widetilde{s}_L\ \widetilde{s}_R\ \widetilde{c}_L\ \widetilde{c}_R$	(same)
			$\widetilde{t}_L\ \widetilde{t}_R\ \widetilde{b}_L\ \widetilde{b}_R$	$\widetilde{t}_1\ \widetilde{t}_2\ \widetilde{b}_1\ \widetilde{b}_2$
sleptons	0	−1	$\widetilde{e}_L\ \widetilde{e}_R\ \widetilde{\nu}_e$	(same)
			$\widetilde{\mu}_L\ \widetilde{\mu}_R\ \widetilde{\nu}_\mu$	(same)
			$\widetilde{\tau}_L\ \widetilde{\tau}_R\ \widetilde{\nu}_\tau$	$\widetilde{\tau}_1\ \widetilde{\tau}_2\ \widetilde{\nu}_\tau$
neutralinos	1/2	−1	$\widetilde{B}^0\ \widetilde{W}^0\ \widetilde{H}_u^0\ \widetilde{H}_d^0$	$\widetilde{N}_1\ \widetilde{N}_2\ \widetilde{N}_3\ \widetilde{N}_4$
charginos	1/2	−1	$\widetilde{W}^\pm\ \widetilde{H}_u^+\ \widetilde{H}_d^-$	$\widetilde{C}_1^\pm\ \widetilde{C}_2^\pm$
gluino	1/2	−1	$\widetilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	−1	$\widetilde{G}$	(same)

EW



https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections
arXiv:1206.2892

How do we search for SUSY?

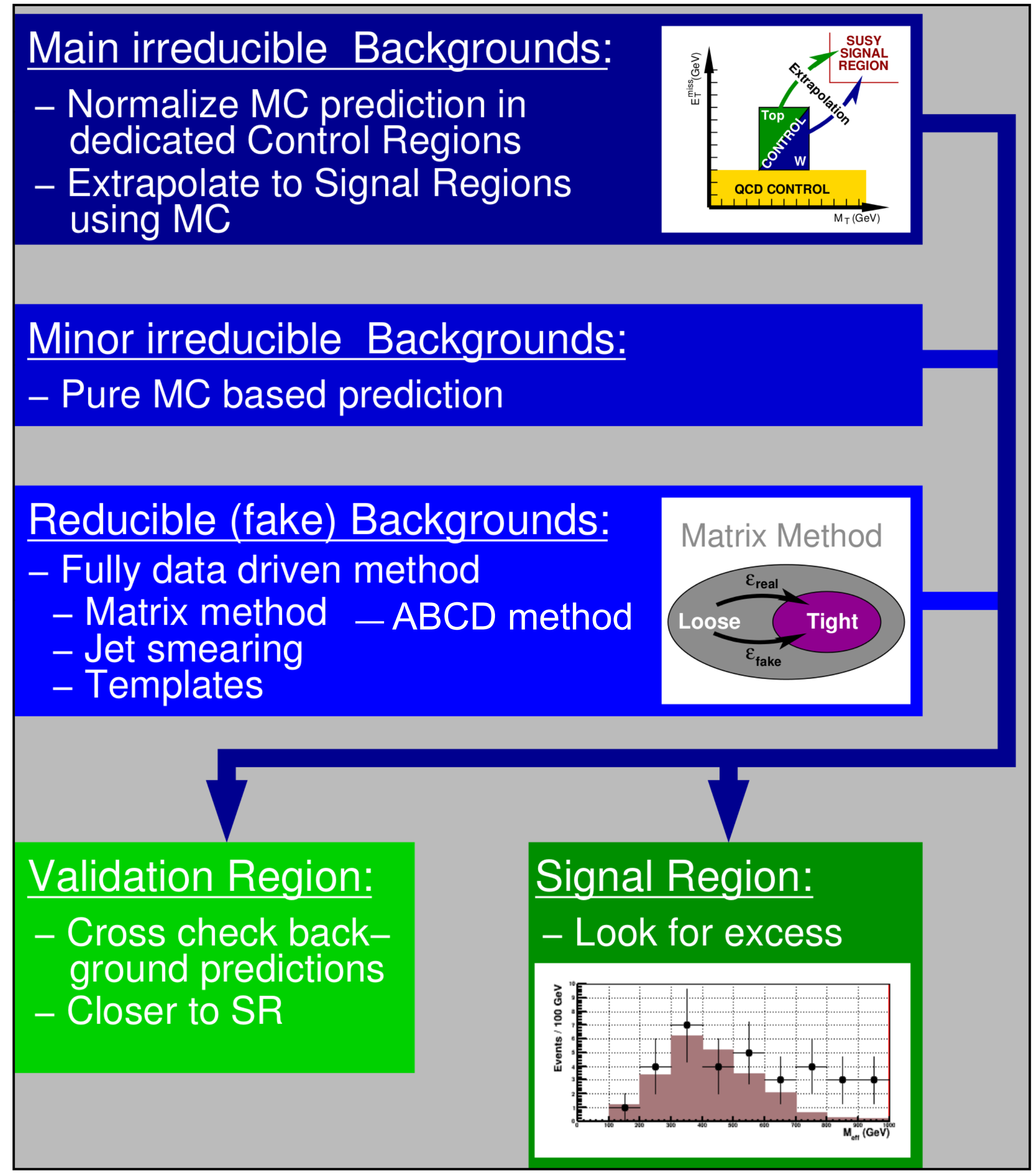
- Define signal region (SR). Using variables which discriminate signal from SM background.
- Missing energy E_T^{miss}, effective mass m_{eff}, stransverse mass m_{T2}

$$E_T^{miss} = -\sum_{i \in ev.} p_T^i \qquad m_{eff} = \sum_i p_T^i + E_T^{miss}$$

$$m_{T2} = \min_{\mathbf{q}_T} \left[\max \left(m_T(\mathbf{p}_T^{\ell 1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell 2}, \mathbf{p}_T^{miss} - \mathbf{q}_T) \right) \right]$$

$$m_T(\mathbf{p}_T, \mathbf{q}_T) = \sqrt{2(p_T q_T - \mathbf{p}_T \cdot \mathbf{q}_T)}$$

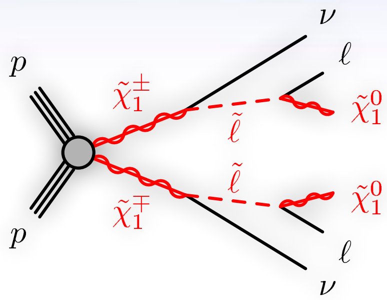
- Irreducible backgrounds: Monte Carlo normalised in control region (CR) or pure MC.
- Reducible backgrounds: Data-driven or semi data-driven approches.
- Validation regions (VR) to verify the background estimation.



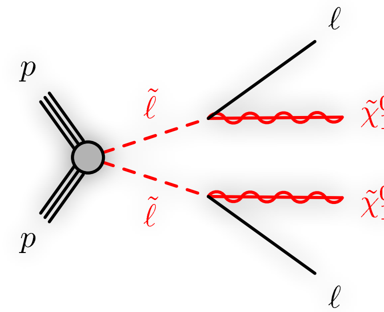
from Marc Hohlfelds talk at SUSY13 (link)

electroweak 2/3 lepton analysis

- Search for EW production of charginos/neutralinos or sleptons with two or three leptons and E_T^{miss} in the final state.
- Three different signal region types:



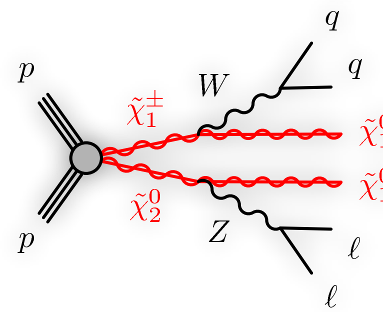
(a)



(b)

(I) **2l+0jets channel:** $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{l}\,\tilde{l}$ pair production (a,b)

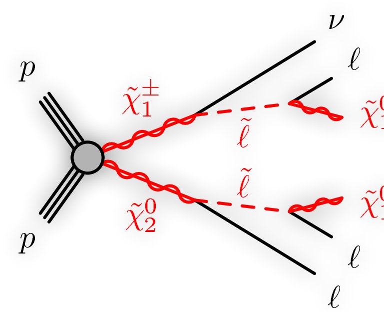
- Separated in same-flavour (ee+$\mu\mu$) and different-flavour ($e\mu$) categories.
- Binned in m_{T2} and m_{ll} for exclusion (inclusive for discovery).



(c)

(II) **2l+jets channel:** $\tilde{\chi}_1^+\tilde{\chi}_2^0$ production (decay via $Z\to ll$, $W\to qq$) (c)

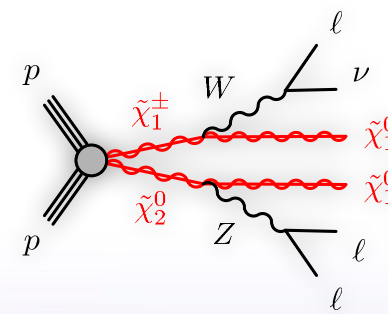
- Using separate SR for different $\Delta m(\tilde{\chi}_1^{\pm},\tilde{\chi}_1^0)$: high, low or intermediate.
- Cuts on m_{ll} and angular variables of leptons to reconstruct W, Z bosons.



(d)

(III) **3l channel:** $\tilde{\chi}_1^+\tilde{\chi}_2^0$ production (slepton mediated or via $Z\to ll$, $W\to lv$) (d,e)

- Select same-flavour opposite-sign (SFOS) lepton pairs.
- SR binned in m_{SFOS} , E_T^{miss} or m_{T2} (depending on the targeted model).



(e)

Background estimation:

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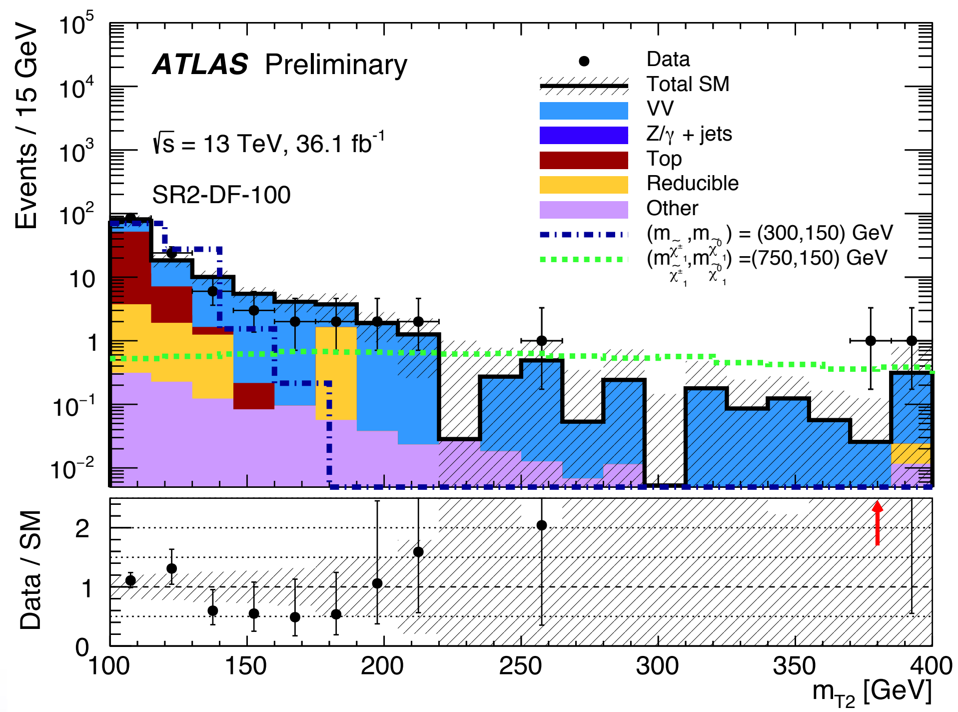
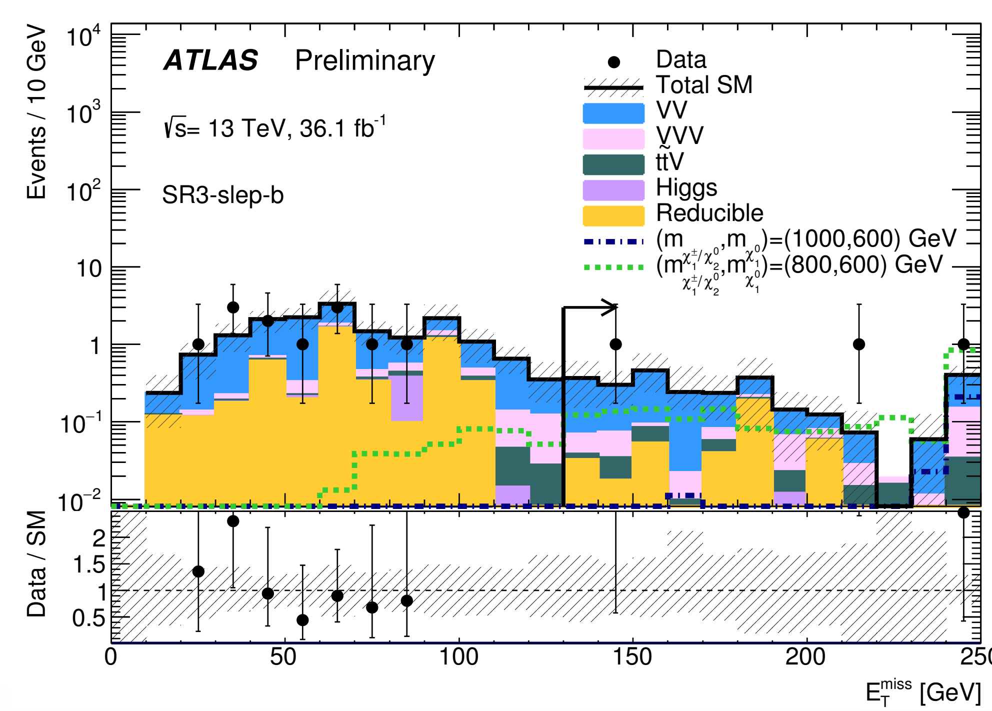
- *tt+Wt* and diboson backgrounds are predicted from MC but normalised to data in control regions. For *3l* channel, the fake-factor method is used.
- *Z/γ*+jets is estimated with a γ+jets data sample with corrections for the different *Z* vs. γ boson p_T applied (γ+jets template). Relevant only for 2*l*+jets.
- Fakes/non-prompt leptons are estimated with matrix-method for *2l*+0jets and *2l*+jets channel. Fake-factor method for *3l* channel.
- Smaller backgrounds are estimated purely from MC.
- Validation regions to verify background prediction.

Background estimation summary			
Channel	2ℓ+0jets	2ℓ+jets	3ℓ
Fake leptons	Matrix method (MM)		Fake factor method (FF)
$t\bar{t} + Wt$	CR	MC	FF
VV	CR	MC	CR (WZ-only)
Z/γ+jets	MC	γ+jet template	FF
Higgs/ VVV/ top+V	MC		



m_{T2} distribution in a 2*l*+0jets SR with m_{T2} >100 GeV



E_T^{miss} distribution in a 3*l* SR with E_T^{miss} >130 GeV

Electroweak 2/3L analysis

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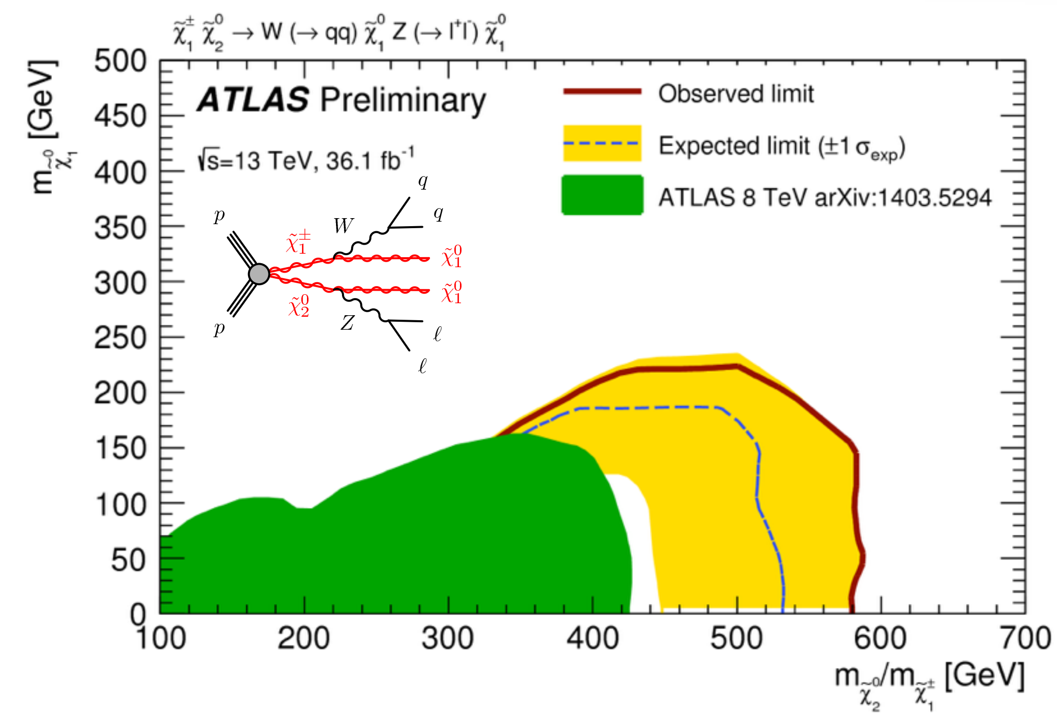
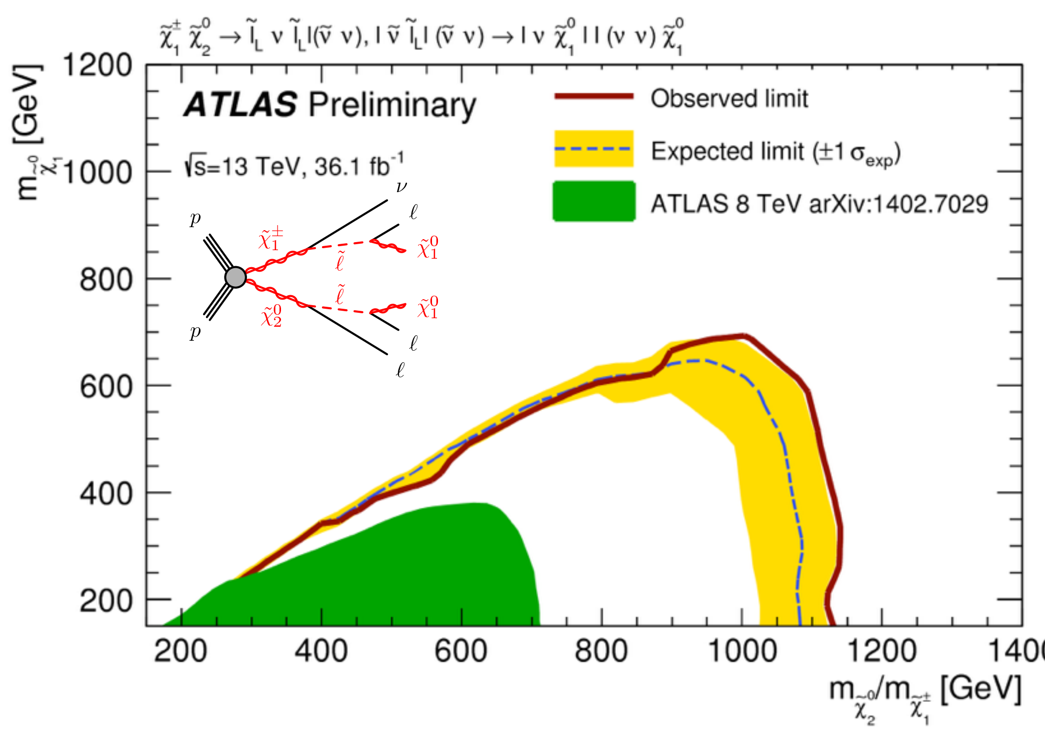
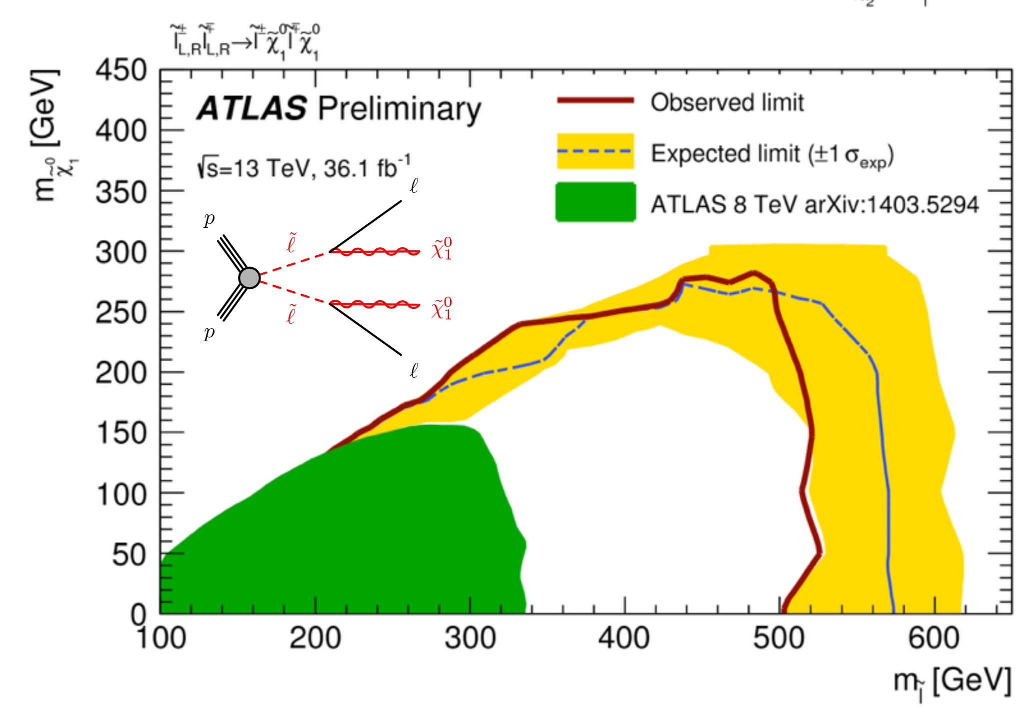
Results and interpretations:

- Analysed full 2015+2016 dataset (36.1 fb^{-1}).
- No significant excess above the SM expectation is observed in any of the signal regions.
- Results can be used to derive limits on gaugino & slepton masses in targeted SUSY models.
- Can exclude gaugino masses up to ≈ 1.1 TeV and slepton masses up to ≈ 500 GeV.







Observed and expected exclusion limits on the degenerated $\tilde{\chi}_2^0$,$\tilde{\chi}_1^\pm$ masses, the slepton mass and the $\tilde{\chi}_1^0$ mass. All limits are computed at 95% CL. The 8 TeV results are shown in green.

electroweak di-tau analysis

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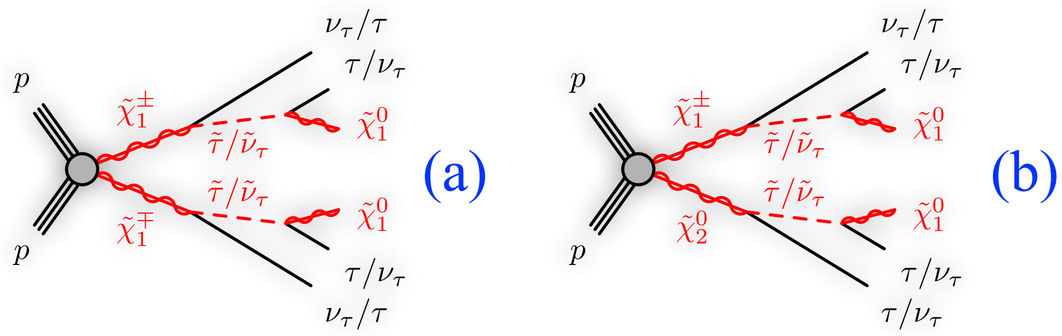
- Search for production of charginos/neutralinos with tau leptons and E_T^{miss} in the final state.
- Looking at scenarios with chargino pair production (a) and production of mass-degenerated chargino/neutralino pair (b).
- Two-step decay mediated by superpartners of tau/tau-neutrino. Same final state ($\tau \rightarrow hadr.$)
- Two signal regions for high and low $\Delta m(\tilde{\chi}_1^{\pm},\tilde{\chi}_1^{0})$: **SR-lowMass, SR-highMass**.

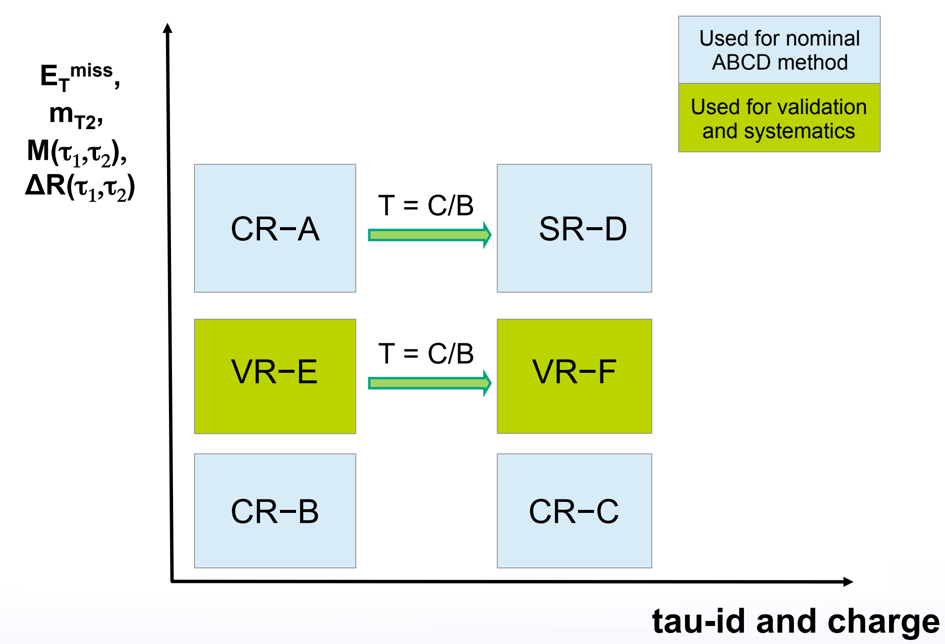


SR-lowMass	SR-highMass	
at least one opposite sign tau pair		
b-jet veto		
Z-veto		
at least two medium tau candidates	at least one medium and one tight tau candidates	
	$m(\tau_1,\tau_2) > 110$ GeV	
$m_{T2} > 70$ GeV	$m_{T2} > 90$ GeV	
di-tau+E_T^{miss} trigger	di-tau+E_T^{miss} trigger	asymmetric di-tau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

Signal region definitions for SR-low/highMass

Background estimation:

- ABCD method for multi-jet background: Two uncorrelated variables which discriminate CR from SR.
- Regions defined by tau quality/charge and kinematic variables, like E_T^{miss}, m_{T2}.
- Extrapolation using $N_A = N_C/N_B$
- W+jets: Predicted from MC but normalised in dedicated CR enriched with $W \rightarrow \tau\nu$ events.
- Other backgrounds: Estimated purely from MC.



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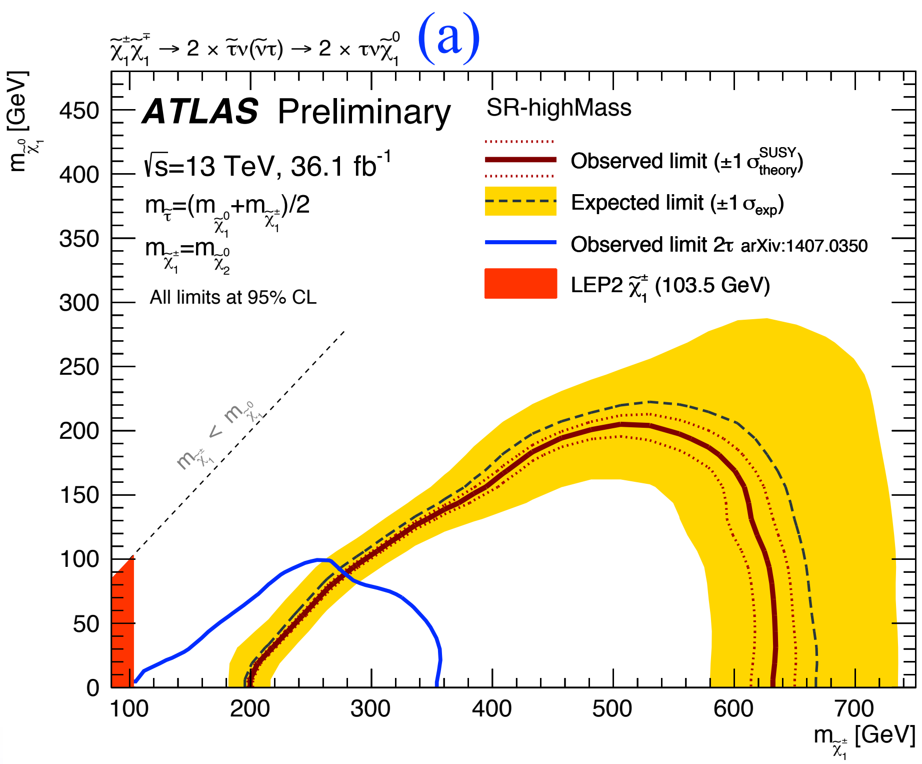
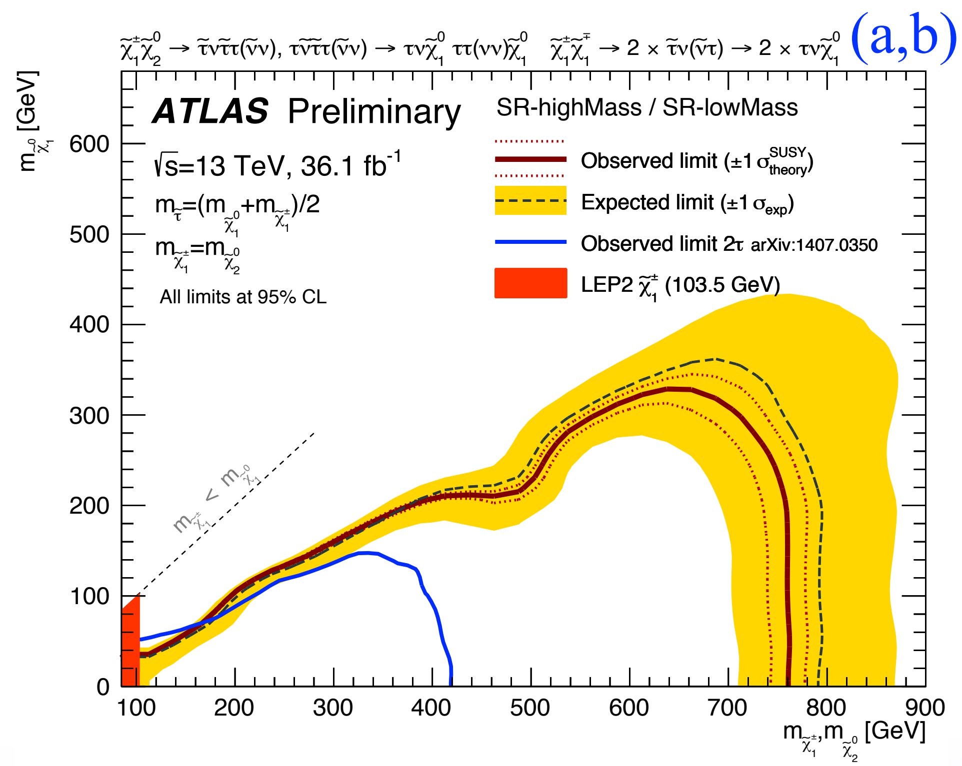
Results and interpretations:

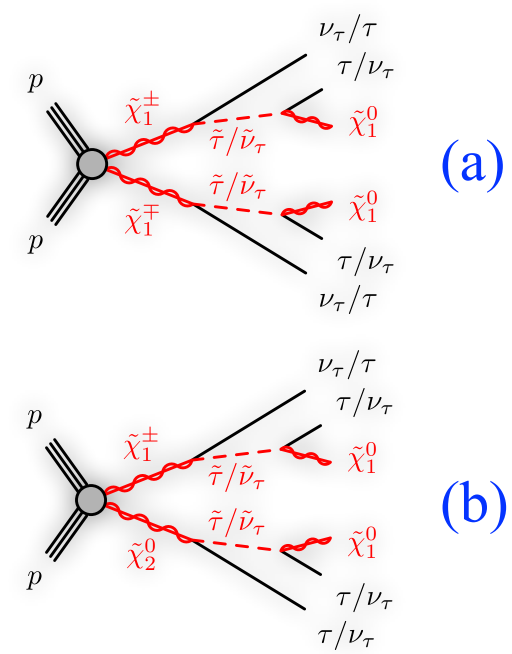
- Observed event yields for 36.1 fb^{-1} show no significant excess above the SM prediction.
- Set exclusion limits on chargino and neutralino masses for the given SUSY benchmark models.
- Left plot considers only $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production and SR-highMass. Right plot uses both SR and includes also $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production.
- Exclude gaugino masses up to 750 GeV.

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	11.6 ± 2.6	11.8 ± 2.8
Reference point 2	10.0 ± 2.1	11.4 ± 2.6
p_0	0.5	0.3
Expected σ_{vis}^{95} [fb]	$0.31^{+0.12}_{-0.08}$	$0.17^{+0.08}_{-0.05}$
Observed σ_{vis}^{95} [fb]	0.26	0.20

Observed and expected events in SR







Observed and expected exclusion limits on chargino/neutralino masses for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_2^0,\tilde{\chi}_1^\pm$ production disappearing-track analysis

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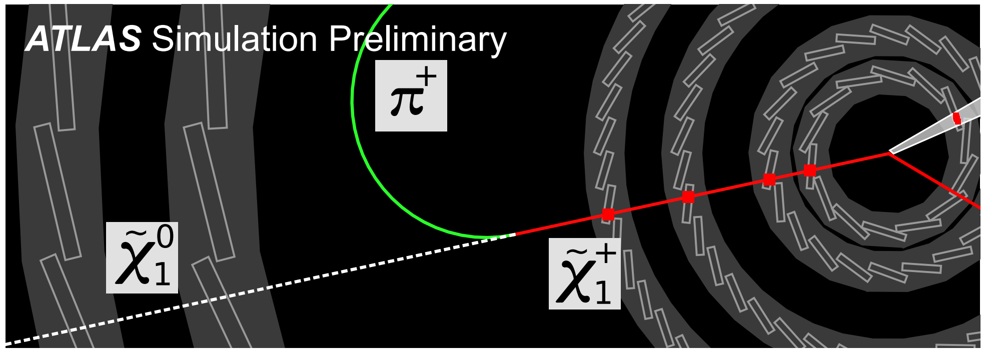
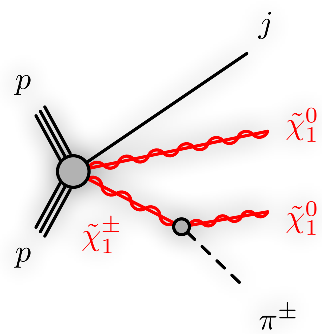
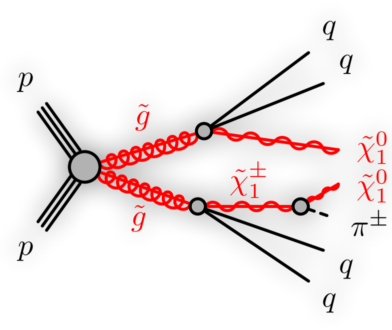


- Search for long-lived charginos based on a disappearing-track signature.
- If $\Delta m(\tilde{\chi}_1^{\pm},\tilde{\chi}_1^{0})$ is very small, charginos can have a measurable lifetime (0.1 - 0.3 ns) and decay while penetrating the pixel layers
- Pure-wino LSP: $\Delta m \approx 160$ MeV.
- Low momentum $\pi^{\pm}$ (not reconstructed) and $\tilde{\chi}_1^0$ $\Rightarrow$ disappearing track in ID.
- Sensitive to $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{0}$ production with ISR jet and $\tilde{\chi}_1^{\pm} \rightarrow \tilde{\chi}_1^{0}\,\pi^{\pm}$ visible as disappearing-track (a) $\tilde{g}\tilde{g}$ production (b).

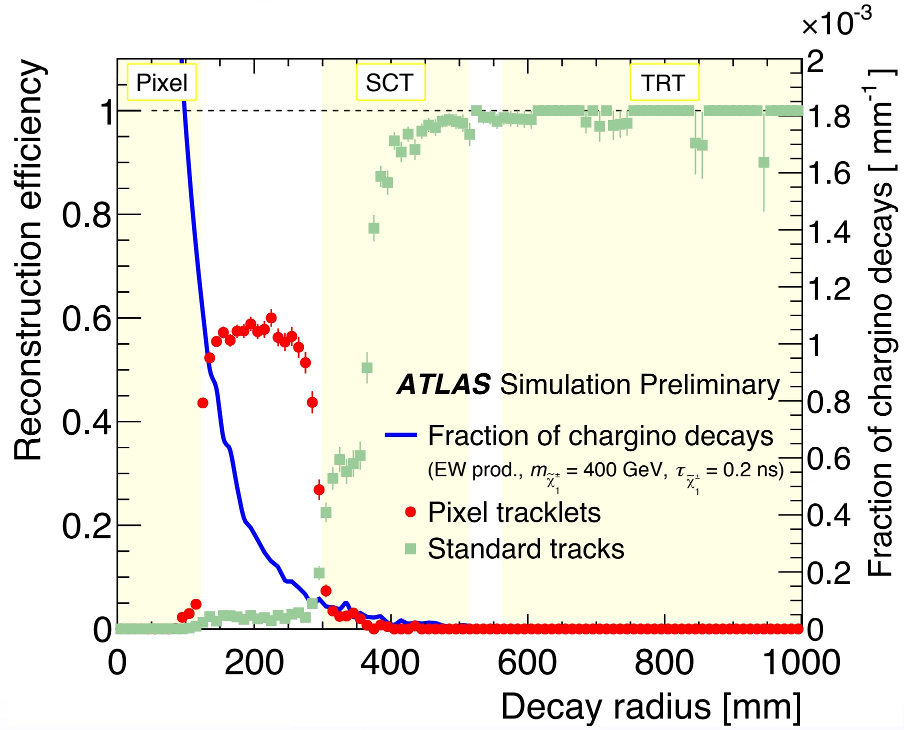


(a)



(b)

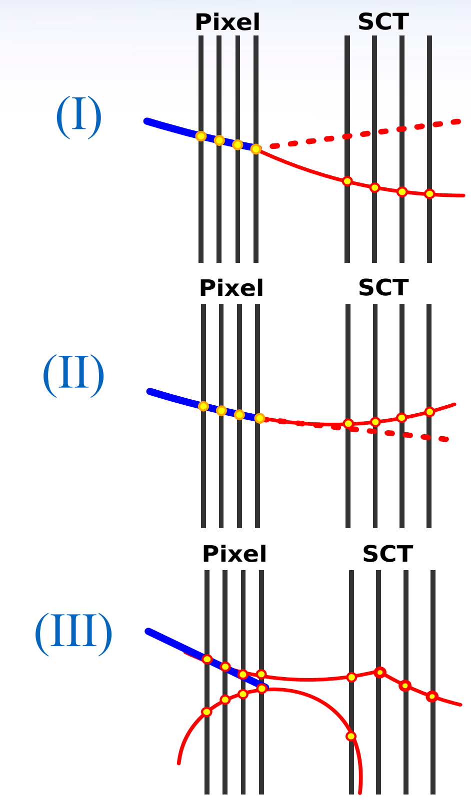
- **Disappearing condition:** Tracking algorithm with shorter tracks than standard tracks (tracklets). Looking for tracklets with hits only in pixel-detector (pixel tracklets).
- Improve efficiency for meta-stable charginos by $\approx 50\%$.
- Possible since Run II $\rightarrow$ new insertable b-layer (IBL).
- SR selection: Disappearing-track + jet ($p_T > 140$ GeV) + $E_T^{miss} > 140$ GeV.



$\tilde{\chi}_1^{\pm}$ reco. efficiency vs. decay radius

Background estimation:

- No prompt SM background, but several other sources of disappearing-tracks.
  - (I) Hard-scattered hadrons estimated with sample of non-scattered hadrons and a track-smearing function.
  - (II) Leptonic bremsstrahlung taken from 1-lepton CR weighted with lepton mis-identification probabilities.
  - (III) Close-by tracks are extrapolated from CR with inverse IP requirement: $|d_0|/\sigma(d_0) > 10$.



Interpretation:

- No significant excess above SM background prediction for 36.1 fb^{-1}.
- Set exclusion limit depending on chargino lifetime τ.
- Can exclude masses up to 550 GeV for $\tau(\tilde{\chi}_1^{\pm}) \approx 1$ ns.
- Around 430 GeV for pure-wino LSP scenario.

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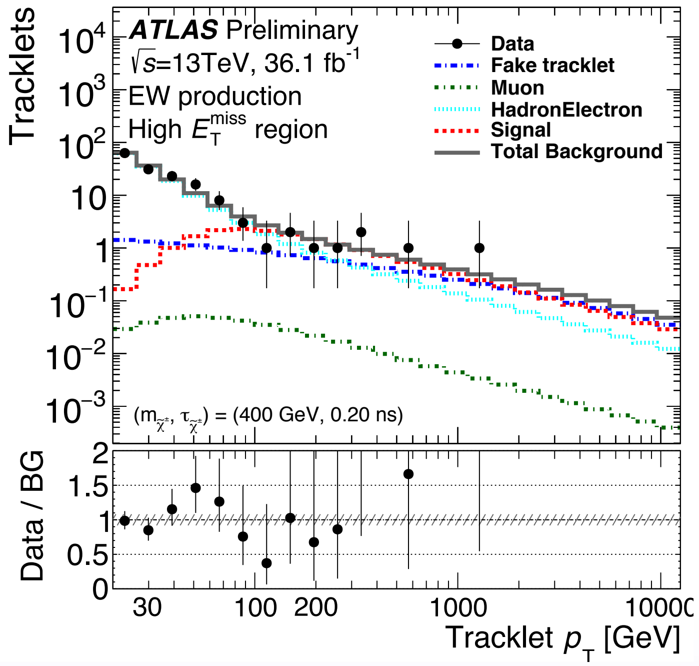
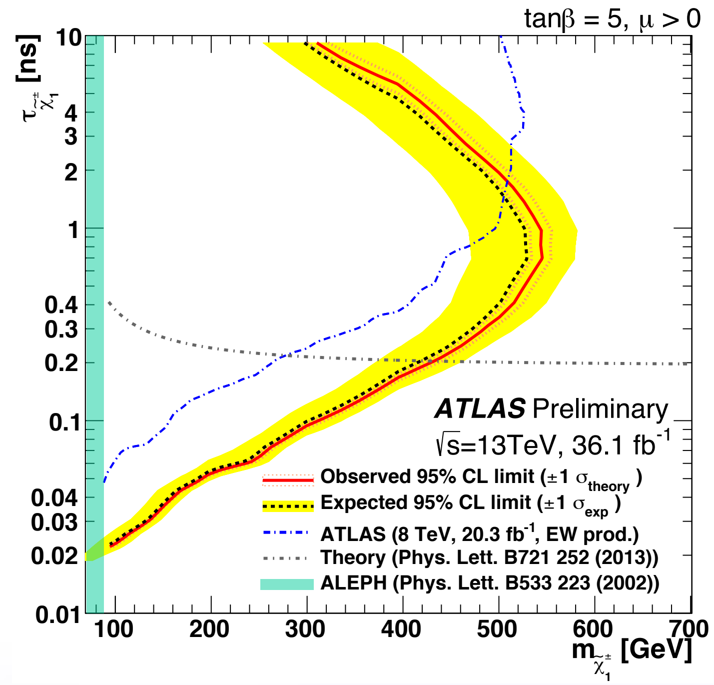


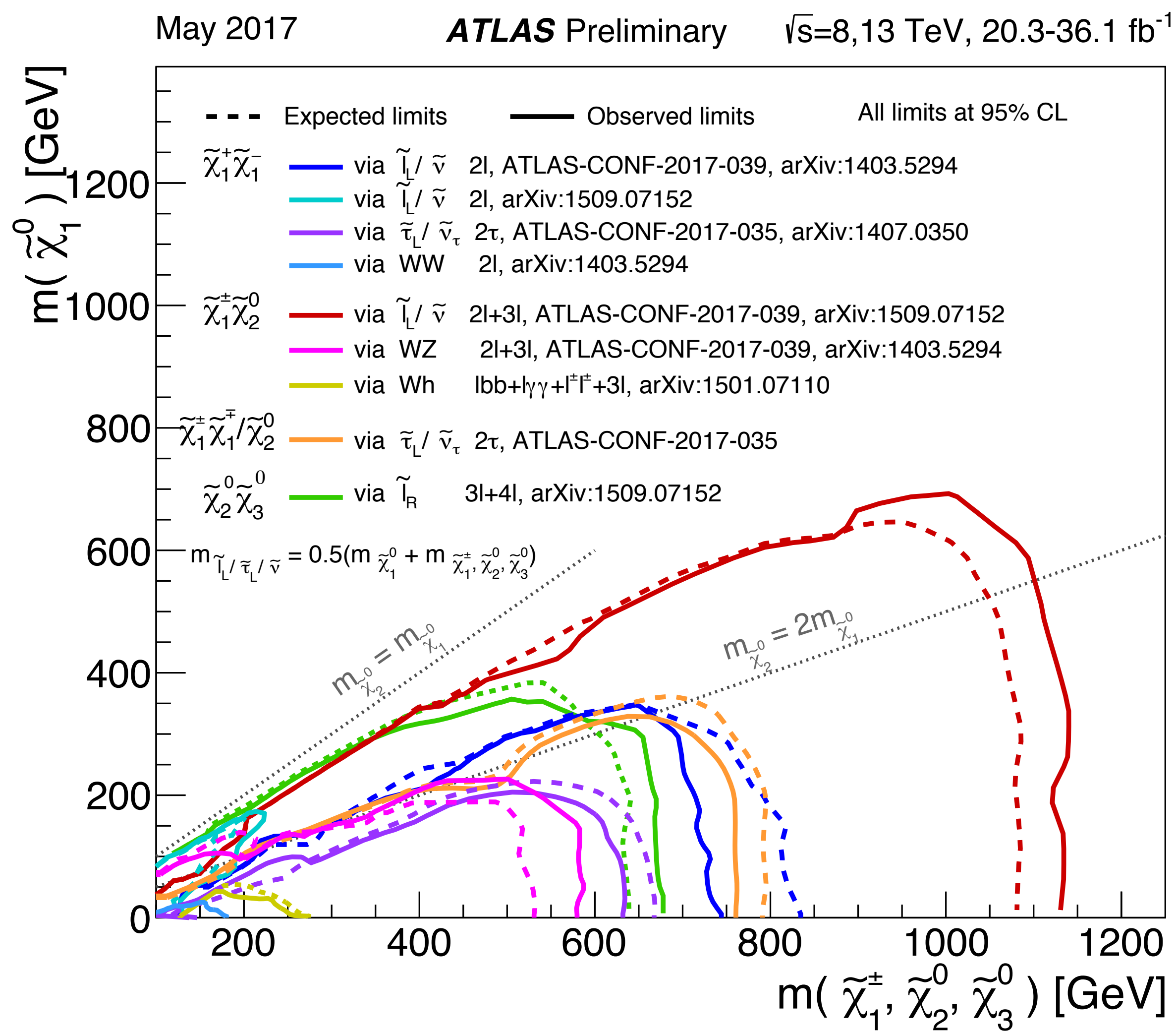
Dis. tracklet p_T spectrum



Exclusion limit on $\tilde{\chi}_1^{\pm}$ vs. τ

Summary:

- Electroweak SUSY searches can be interesting if masses of gluinos & squarks are significantly larger than the EW particles.
- Presented different searches for EW production of gauginos and sleptons at ATLAS.
- 2/3 lepton search: Three different search channels inspired by five different models (blue, red, pink).
- Di-tau search: Interpretation for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production with two taus in final state (violet).
- Disappearing-tracks: Strong constraints on long-lived charginos.
- A lot of other searches for EW SUSY ongoing. ⇒ Many new results soon.



Summary plot showing exclusion limits from several electroweak SUSY searches

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/SUSY

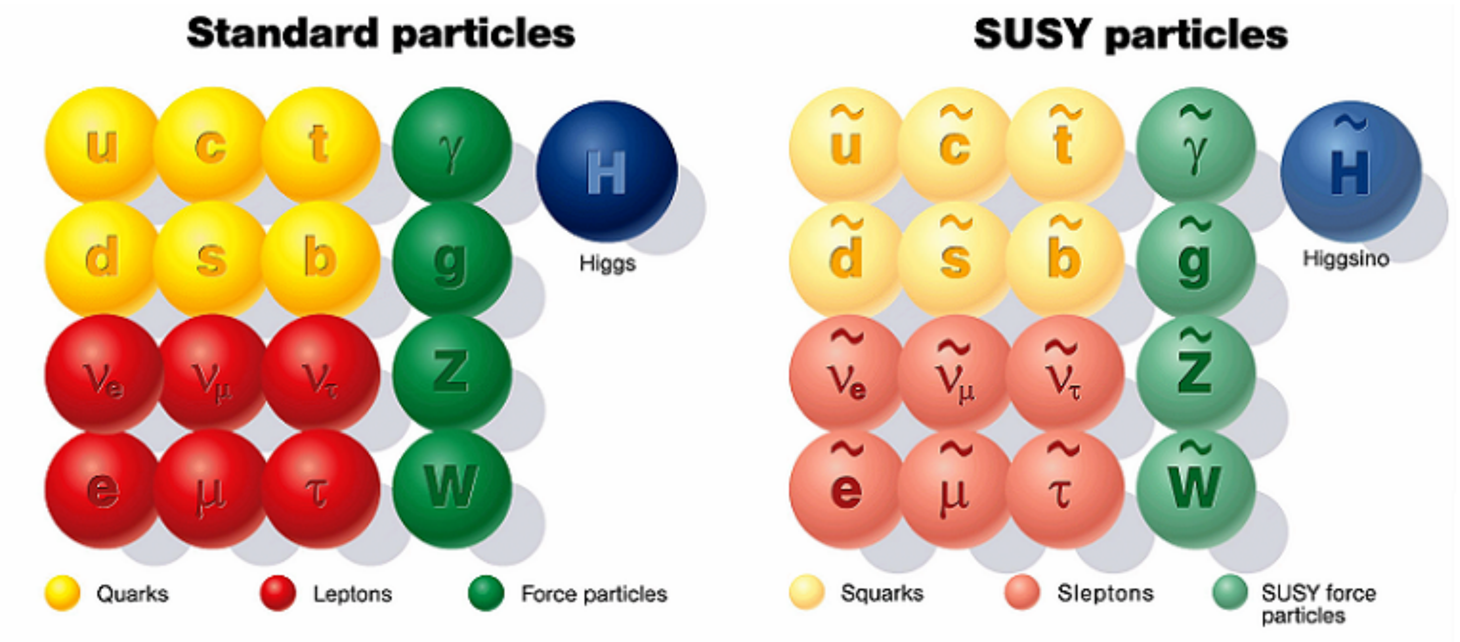
Backup

- Supersymmetry (SUSY) is a spacetime symmetry that relates bosons, which have an integer-valued spin and fermions, which have a half-integer spin.
- Each fermion/boson is associated with a boson/fermion, known as its *superpartner*, which spin differs by a half-integer.
- Since the superpartners cannot have the same masses as the SM particles, SUSY must be a broken theory.

$$Q|boson\rangle = |fermion\rangle$$
$$Q|fermion\rangle = |boson\rangle$$

$$R = (-1)^{3(B-L)+2S}$$

B: baryon no, L: lepton no, S: spin
SM particles : R = +1
SUSY particles: R = −1



- Supersymmetry provides a solution for the Hierarchy problem (quadratic divergences to the Higgs boson mass are cancelled by SUSY terms).
- Postulate new quantum number: *R-parity*
- If R-parity is conserved, the lightest supersymmetric particle (LSP) is stable. Thus, it can be a suitable candidate for Dark Matter.

Electroweak 2/3L analysis

- Definitions of the binned and inclusive signal regions for the $2l$+0jets, $2l$+jets and $3l$ channel.

2ℓ+0jets binned signal region definitions			
m_{T2}[GeV]	$m_{\ell\ell}$ [GeV]	SF bin	DF bin
100-150	111-150	SR2-SF-a	SR2-DF-a
	150-200	SR2-SF-b	
	200-300	SR2-SF-c	
	> 300	SR2-SF-d	
150-200	111-150	SR2-SF-e	SR2-DF-b
	150-200	SR2-SF-f	
	200-300	SR2-SF-g	
	> 300	SR2-SF-h	
200-300	111-150	SR2-SF-i	SR2-DF-c
	150-200	SR2-SF-j	
	200-300	SR2-SF-k	
	> 300	SR2-SF-l	
> 300	> 111	SR2-SF-m	SR2-DF-d
2ℓ+0jets inclusive signal region definitions			
> 100	> 111	SR2-SF-loose	-
> 130	> 300	SR2-SF-tight	-
> 100	-	-	SR2-DF-100
> 150	-	-	SR2-DF-150
> 200	-	-	SR2-DF-200
> 300	-	-	SR2-DF-300

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2ℓ+jets signal region definitions				
	SR2-int	SR2-high	SR2-low-2J	SR2-low-3J
$n_{\text{non}-b-\text{tagged jets}}$	≥ 2		2	3-5
$m_{\ell\ell}$ [GeV]	81-101		81-101	86-96
m_{jj} [GeV]	70-100		70-90	70-90
E_T^{miss} [GeV]	>150	> 250	>100	>100
p_T^Z [GeV]	>80		> 60	> 40
p_T^W [GeV]	>100			
m_{T2} [GeV]	>100			
$\Delta R_{(jj)}$	<1.5			<2.2
$\Delta R_{(\ell\ell)}$	<1.8			
$\Delta\phi_{(\vec{E}_T^{\text{miss}},Z)}$			< 0.8	
$\Delta\phi_{(\vec{E}_T^{\text{miss}},W)}$	0.5-3.0		> 1.5	< 2.2
E_T^{miss}/p_T^Z			0.6 – 1.6	
E_T^{miss}/p_T^W			< 0.8	
$\Delta\phi_{(\vec{E}_T^{\text{miss}},\text{ISR})}$				> 2.4
$\Delta\phi_{(\vec{E}_T^{\text{miss}},\text{jet1})}$				> 2.6
$E_T^{\text{miss}}/\text{ISR}$				0.4-0.8
$\lvert\eta(Z)\rvert$				< 1.6
p_T^{jet3} [GeV]				> 30

3ℓ binned signal region definitions							
m_{SFOS} [GeV]	E_T^{miss} [GeV]	$p_T^{\ell_3}$ [GeV]	$n_{\text{non}-b-\text{tagged jets}}$	m_T^{min} [GeV]	$p_T^{\ell\ell\ell}$ [GeV]	p_T^{jet1} [GeV]	Bins
<81.2	> 130	20-30		> 110			SR3-slep-a
		> 30					SR3-slep-b
>101.2	> 130	20-50		> 110			SR3-slep-c
		50-80					SR3-slep-d
		> 80					SR3-slep-e
81.2-101.2	60-120		0	> 110			SR3-WZ-0Ja
	120-170						SR3-WZ-0Jb
	> 170						SR3-WZ-0Jc
81.2-101.2	120-200		≥ 1	> 110	< 120	> 70	SR3-WZ-1Ja
	> 200			110-160			SR3-WZ-1Jb
		> 35		> 160			SR3-WZ-1Jc

- Definition of the control- and validation regions used for the ABCD method.

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 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 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 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

- Definition of the regions W-CR and W-VR.

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

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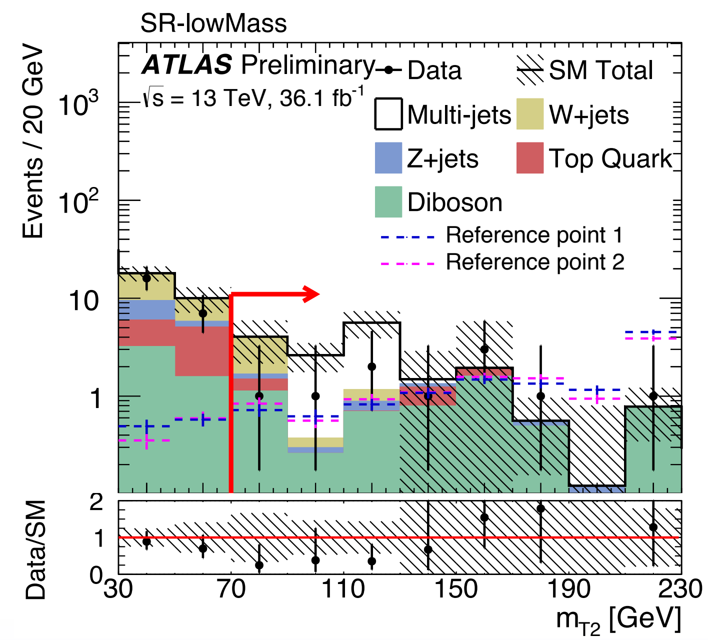
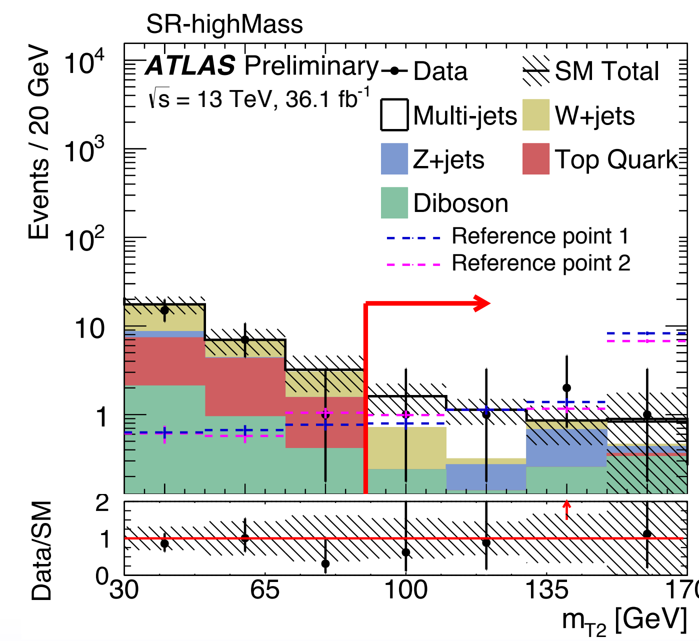
- The m_{T2} distribution of SR-lowMass (l) and SR-highMass (r) before the m_{T2} requirement.





- Observed and total expected events in electroweak and strong search channel.

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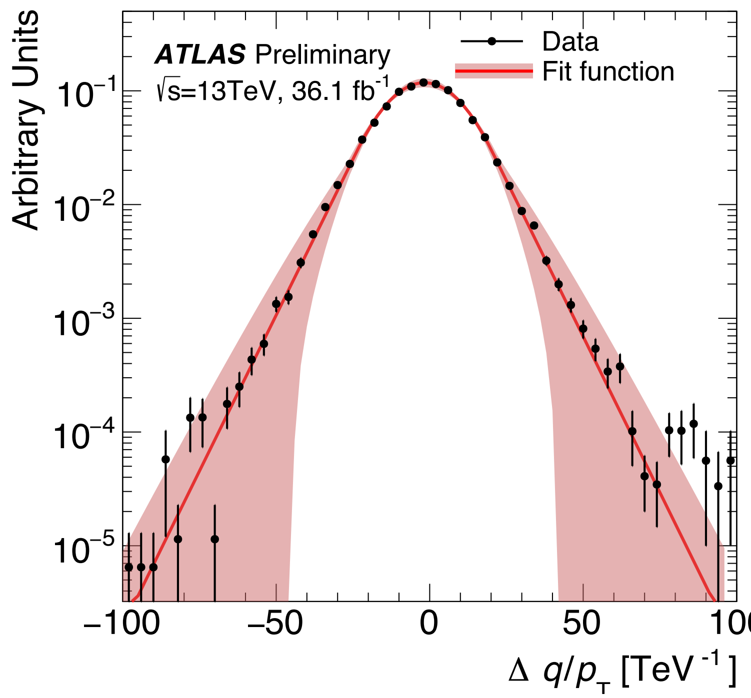
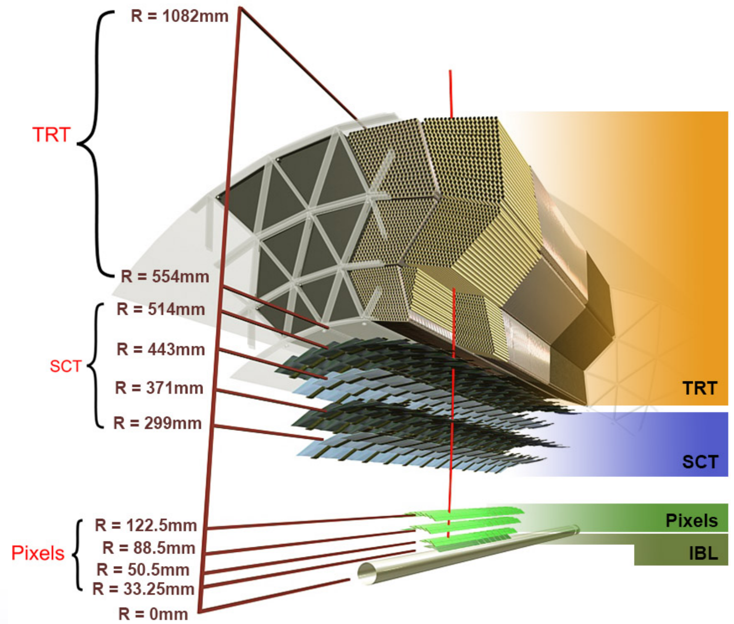
High E_T^{miss} region	Electroweak channel	Strong channel
	$(m_{\tilde{\chi}_1^\pm}, \tau_{\tilde{\chi}_1^\pm})$ =(400 GeV, 0.2 ns)	$(m_{\tilde{g}}, m_{\tilde{\chi}_1^\pm}, \tau_{\tilde{\chi}_1^\pm})$ =(1600 GeV, 500 GeV, 0.2 ns)
Number of observed events with $p_T > 100$ GeV		
Observed	9	2
Number of expected events with $p_T > 100$ GeV		
Hadron+electron background	6.1 ± 0.6	2.08 ± 0.35
Muon background	0.1549 ± 0.0022	0.0385 ± 0.0005
Fake background	5.5 ± 3.3	0.0 ± 0.8
Total background	11.8 ± 3.1	2.1 ± 0.9
Expected signal	10.4 ± 1.7	4.1 ± 0.5
CL_b	0.39	0.702
Observed $\sigma_{vis}^{95\%}$ [fb]	0.22	0.14
Expected $\sigma_{vis}^{95\%}$ [fb]	$0.24^{+0.10}_{-0.07}$	$0.11^{+0.06}_{-0.04}$

- Resolution smearing-function. Diff. of q/p_T between standard tracks and pixel tracklets.



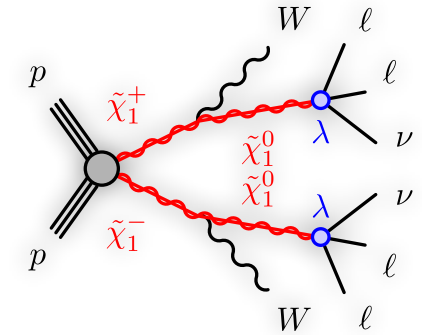
- Schematic layout of the ATLAS Inner Detector with the new IBL (r).



ATLAS-CONF-2016-075

- Search for supersymmetry in events with four or more leptons.
- Inspired by $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production scenario with RPV decay chain (λ_{121}, λ_{122} couplings).
- Two signal regions are defined: A general one **SR-A** and one with a higher m_{eff} cut **SR-B**.

Sample	$N(e, \mu)$ signal	$N(e, \mu)$ loose	Z boson	m_{eff} [GeV]
SRA	>= 4	>= 0	veto	> 600
CR-SRA	= 2	>= 2	veto	> 600
SRB	>= 4	>= 0	veto	> 900
CR-SRB	= 2	>= 2	veto	> 900
VR	>= 4	>= 0	veto	< 600
CR-VR	= 2	>= 2	veto	< 600

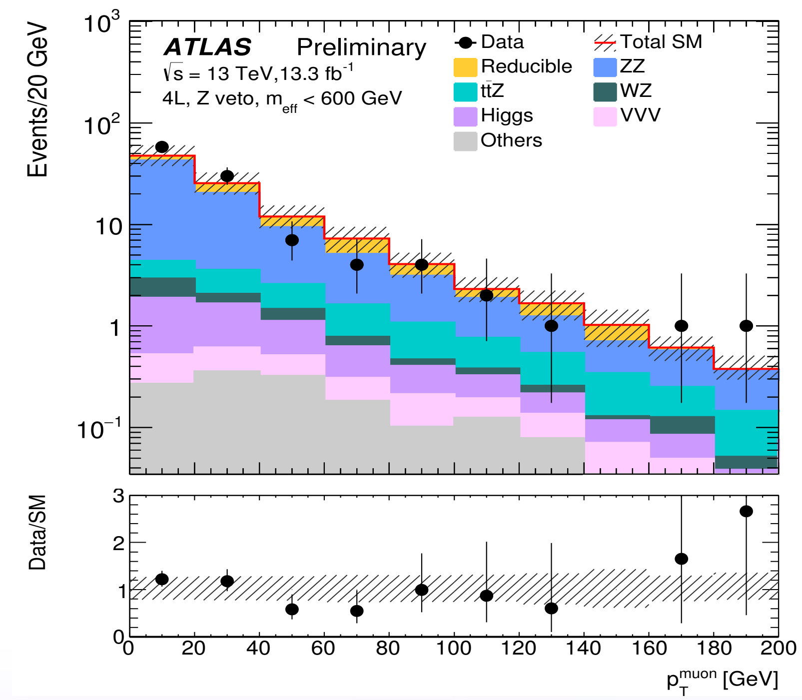


Background estimation:

- Irreducible background (4 prompt leptons) is estimated with MC (mainly *ttZ, ZZ,* Higgs).
- Background with ≥ 2 fake leptons is predicted with fake-factor method:

$$N_{\mathrm{red}}^{\mathrm{SR}} = [N_{\mathrm{data}}^{\mathrm{CR}} - N_{\mathrm{irr,1\text{-}fake}}^{\mathrm{CR}}] \times F_{w,1} \times F_{w,2}$$

- Estimation is checked in VR (SR with reverted m_{eff} cut).
- Uncertainty of this method is ≈ 50% (dominated by stat. uncertainty in CR).
- Total uncertainty in SR: 20% - 30%.



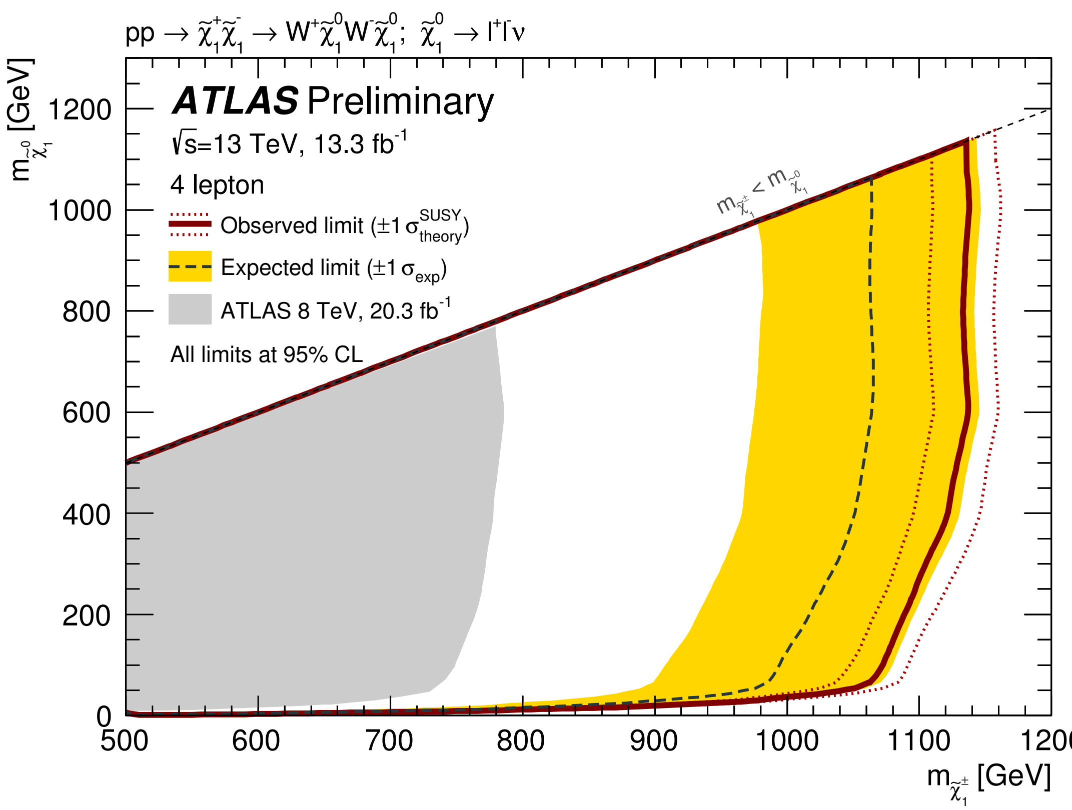
Muon p_T distribution in VR

Results and interpretation:

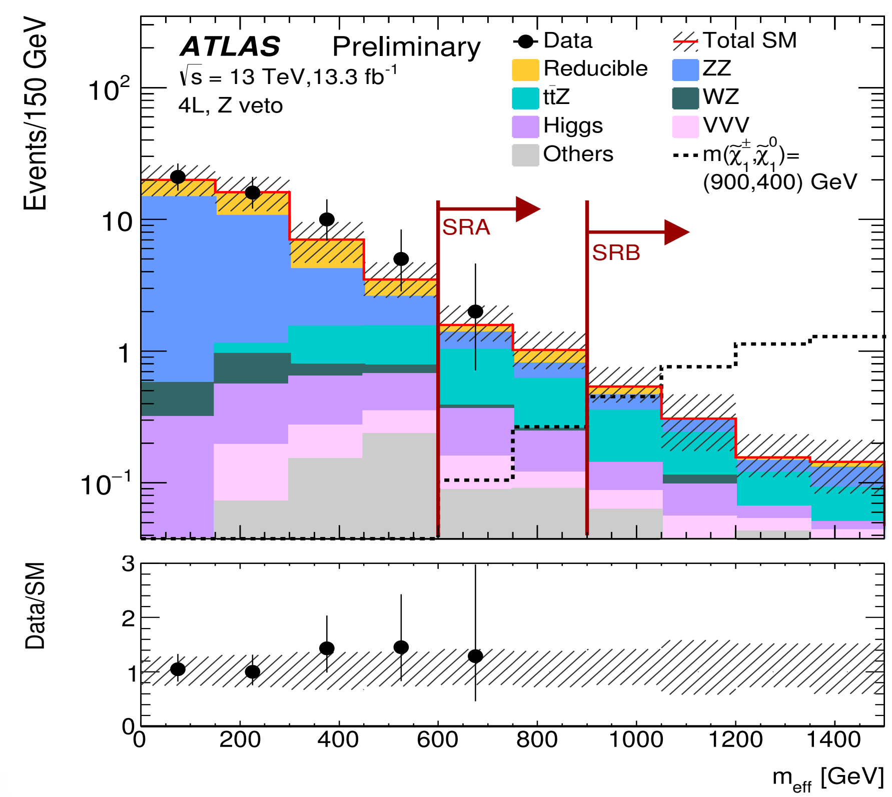
ATLAS-CONF-2016-075

- No significant excess over the SM prediction in SR for 13.3 fb^{-1} (only 2015 data).
- Can derive exclusion limits for $\tilde{\chi}_1^+ \tilde{\chi}_1^- \rightarrow W^+ \tilde{\chi}_1^0 \, W^- \tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \rightarrow l^+ l^- \nu$ scenario.
- Excluding chargino masses up to ≈ 1.15 TeV and neutralino masses up to ≈ 1.1 TeV.

Sample	VR	SRA	SRB
Irreducible			
ZZ	29 ± 5	0.6 ± 0.4	0.20 ± 0.19
$t\bar{t}Z$	2.05 ± 0.24	1.43 ± 0.23	0.47 ± 0.09
Higgs	1.7 ± 1.4	0.4 ± 0.4	0.11 ± 0.11
VVZ	0.72 ± 0.14	0.31 ± 0.06	0.123 ± 0.027
Others	0.28 ± 0.07	0.32 ± 0.04	0.181 ± 0.022
1-fake ℓ reducible	1.14 ± 0.07	0.168 ± 0.018	0.069 ± 0.014
2-fake ℓ reducible	16 ± 6	0.48 ± 0.24	0.11 ± 0.05
Σ SM	51 ± 6	3.6 ± 0.6	1.26 ± 0.26
Data	53	2	0



Observed and expected exclusion limits (at 95% CL) on chargino/neutralino masses.



m_{eff} distribution in SR (without m_{eff} cut)