Searches for electroweak supersymmetric particles with the ATLAS detector in pp collisions at $\sqrt{s}$ = 8TeV

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8th July 2013

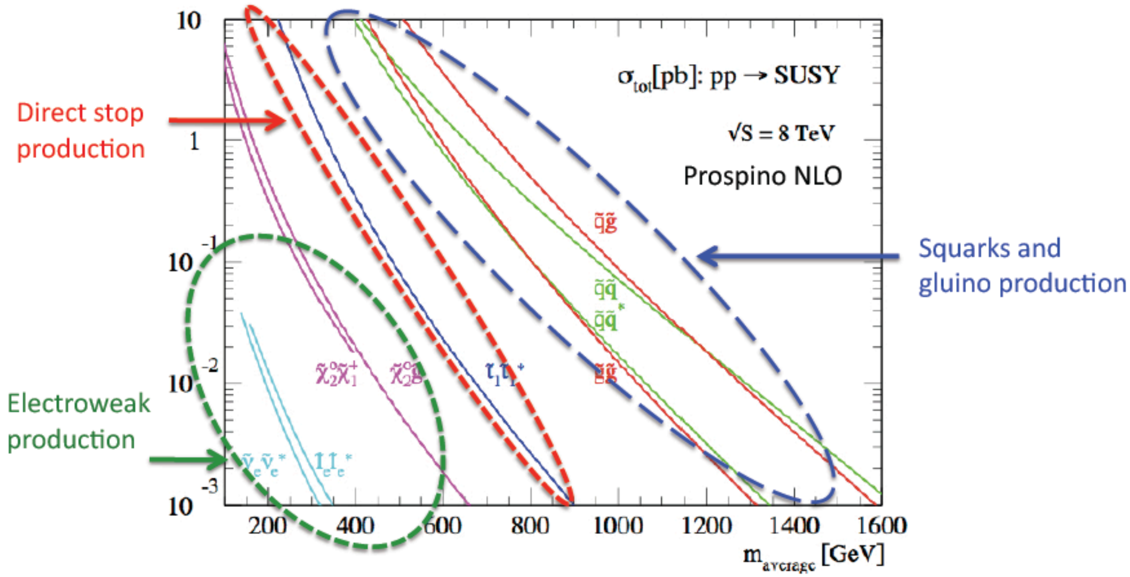
HELMHOLTZ
ASSOCIATION

DESY

ATLAS SUSY SEARCHES

The ATLAS SUSY group has a well defined strategy to search for SUSY, based on phenomenology oriented searches:

- gluino and 1st generation squarks
- 3rd generation squarks
- electroweak SUSY
  (chargino, neutralino, sleptons)



- R-parity violating scenarios and long-lived particles

Latest ATLAS latest results

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2012 data (8 TeV)

Short Title of the CONF note	Date	√s (TeV)	L (fb^{-1})
1-2 leptons + 3-6 jets + Etmiss [Incl. strong production, mUED] NEW	05/2013	8	20.3
0-1 leptons + >=3 b-jets + Etmiss [3rd gen. squarks] NEW	05/2013	8	20.1
Long-lived sleptons NEW	06/2013	8	15.9
Long-lived stopped gluinos R-hadrons NEW	06/2013	7+8	27.9
2 leptons + Etmiss [EW production]	05/2013	8	20.3
0 leptons + 2-6 jets + Etmiss [Incl. strong production]	05/2013	8	20.3
0 leptons + 7-10 jets + Etmiss [Incl. strong production]	05/2013	8	20.3
0 leptons + 2 b-jets + Etmiss [Sbottom/stop]	05/2013	8	20.1
2 leptons (+ jets) + Etmiss [Medium stop]	05/2013	8	20.3
1 lepton + 4(1 b-)jets + Etmiss [Medium / heavy stop]	03/2013	8	20.7
3 leptons + Etmiss [EW production]	03/2013	8	20.7
4 leptons + Etmiss [EW production, RPV]	03/2013	8	20.7
0 lepton + 6 (2 b-)jets + Etmiss [Heavy stop]	03/2013	8	20.5
Z + b-jet + jets + Etmiss [Stop in GMSB, stop2]	03/2013	8	20.7
1-2 taus + jets + Etmiss [GMSB]	03/2013	8	20.7
2 taus + Etmiss [EW production]	03/2013	8	20.7
2 same-sign leptons + 0-3 b-jets + Etmiss	03/2013	8	20.7

17 new conference notes public with 20 fb^{-1}

+

1 CONF notes + 1 paper in ATLAS approval

Plan about 3-5 summary papers with 8 TeV data this summer/early autumn!

Latest ATLAS results

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New results that are discussed today!

Plan about 5 summary papers with 8 TeV data this summer/early autumn!

PHYSICS MOTIVATION

- in SUSY scenarios with heavy squarks and gluinos while non-coloured SUSY particles are light, weak gauginos (charginos, neutralinos) and sleptons $\tilde{l}$ may dominate the SUSY production at the LHC
- naturalness favours gaugino masses around 100 GeV
- gauginos can decay via sleptons or via

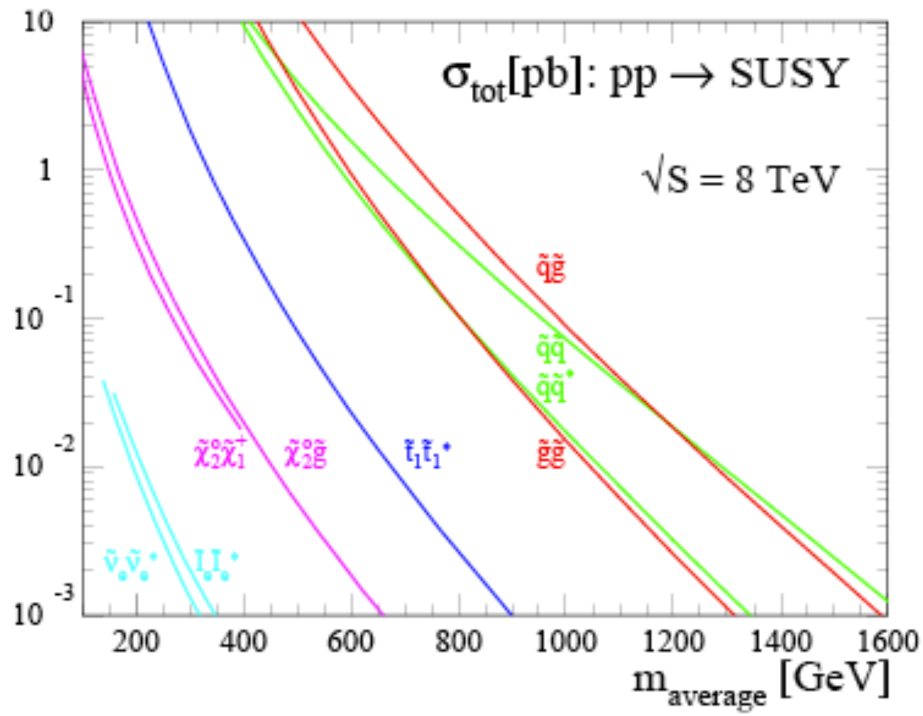
  Standard Model gauge boson

  → defined SRs to cover both scenarios
- relatively clean signature:

  → missing transverse energy E_T^{miss} signature

  from LSP

  → low hadronic activity



- all results are interpreted in simplified models

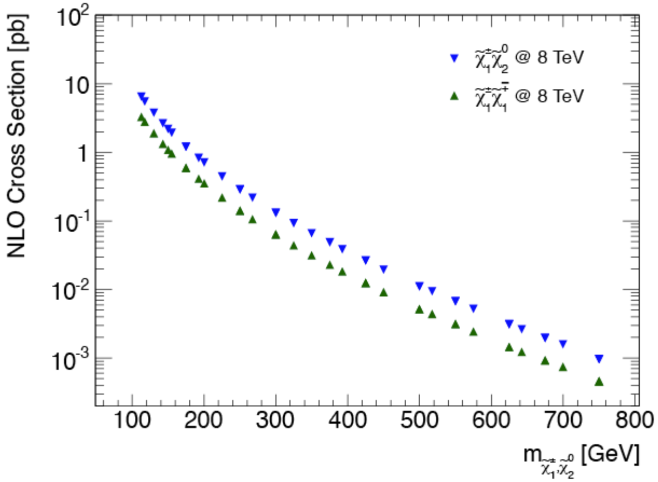
2 LEPTON (electron, muon) + 0 jets

ATLAS-CONF-2013-049

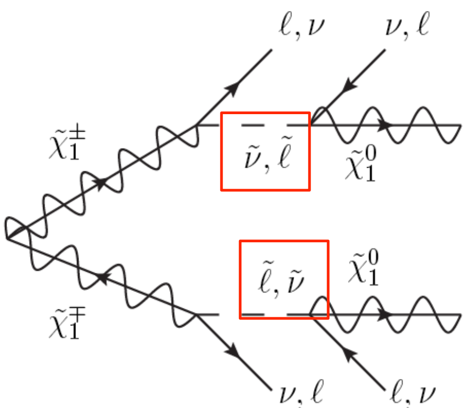
Searches for direct slepton-pair and chargino-pair production in final states with two opposite-sign leptons, missing transverse momentum and no jets in 20 fb^{-1} of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector

SUSY MODELS

chargino1-chargino1 production

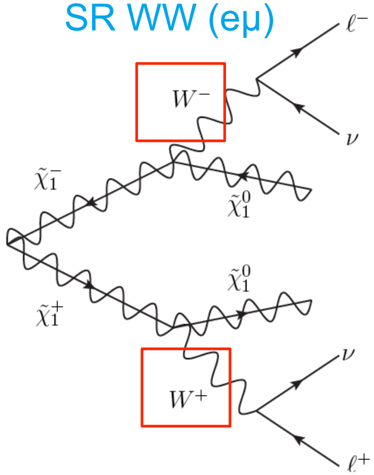


SR m_{T2} (ee, μμ, eμ)



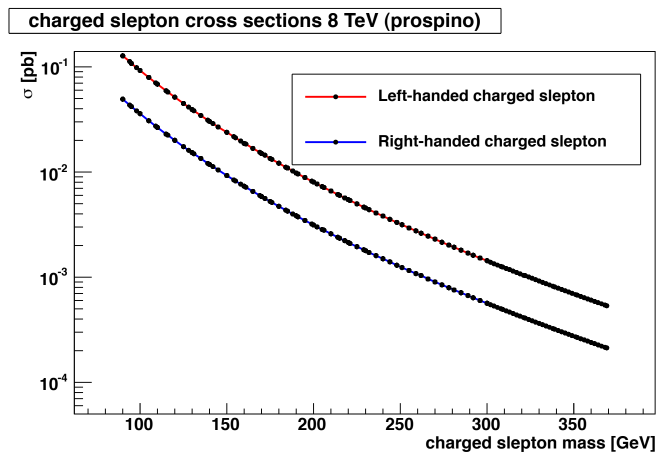
via intermediate sleptons

SR WW (eμ)

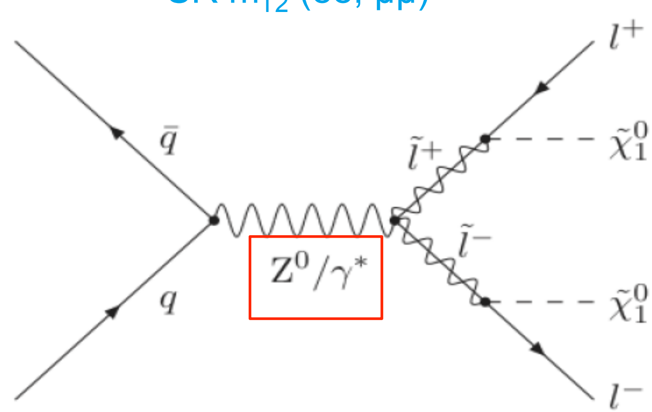


with on-shell W decays

slepton pair production



SR m_{T2} (ee, μμ)



via virtual Z

SIGNAL REGIONS

process

Targeted Process		Signal Region
Two Leptons	$\tilde{\ell}^{\pm}\tilde{\ell}^{\mp} \to \ell^{\pm}\tilde{\chi}_1^0 + \ell^{\mp}\tilde{\chi}_1^0$	SR-m_{T2}
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \to \ell^{\pm}\nu\tilde{\chi}_1^0 + \ell^{\mp}\nu\tilde{\chi}_1^0$	SR-m_{T2}
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \to W^{\pm}\tilde{\chi}_1^0 + W^{\mp}\tilde{\chi}_1^0 \to \ell^{\pm}\nu\tilde{\chi}_1^0 + \ell^{\mp}\nu\tilde{\chi}_1^0$	SR-WW

final selection in all SR

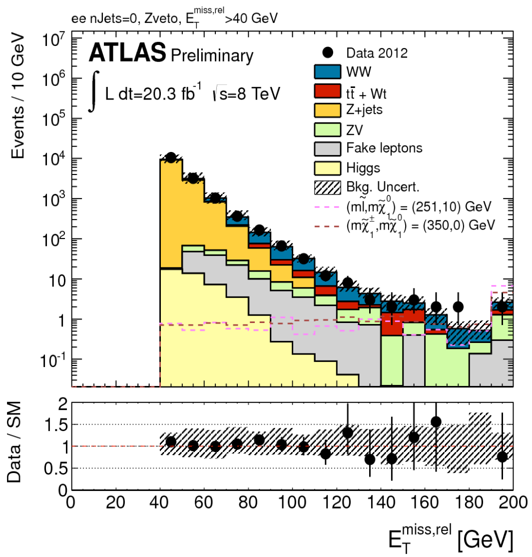
= 2 signal leptons with opposite charge (eμ only for SRWW) + trigger + m(l,l) > 20 GeV + jet veto

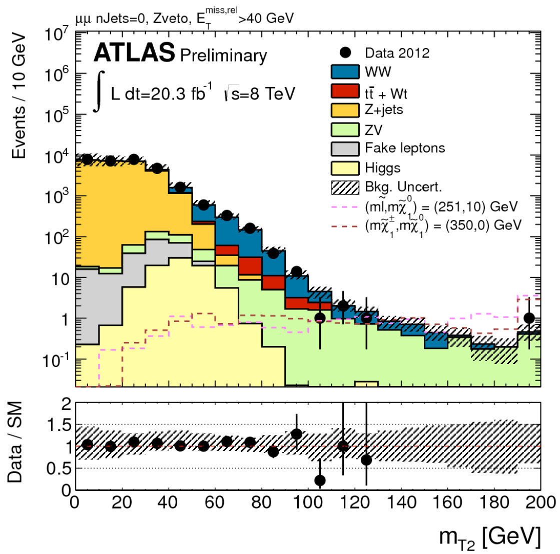
	SR-$m_{T2,90}$	SR-$m_{T2,110}$	SR-WWa	SR-WWb	SR-WWc
lepton flavour	$e^+e^-, \mu^+\mu^-, e^{\pm}\mu^{\mp}$		$e^{\pm}\mu^{\mp}$		
$p_T^{\ell 1}$	—		> 35 GeV		
$p_T^{\ell 2}$	—		> 20 GeV		
$m_{\ell\ell}$	Z veto		< 80 GeV	< 130 GeV	—
$p_{T,\ell\ell}$	—		> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_T^{\text{miss,rel}}$	> 40 GeV		> 70 GeV	—	
m_{T2}	> 90 GeV	> 110 GeV	—	> 90 GeV	> 100 GeV

SRWW: SRWWa for off-shell WW production, SRWWb, SRWWc for higher C1-N1 mass splitting
only eμ channel considered due to lack of Z+jets background

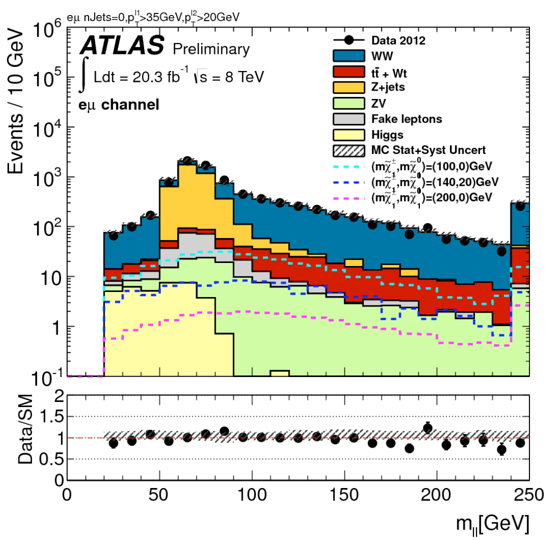
SRm_{T2} : SR$m_{T2,90}$ for small C1 masses, SR$m_{T2,110}$ for higher C1 masses and slepton pair production
slepton pair production only ee/μμ channel

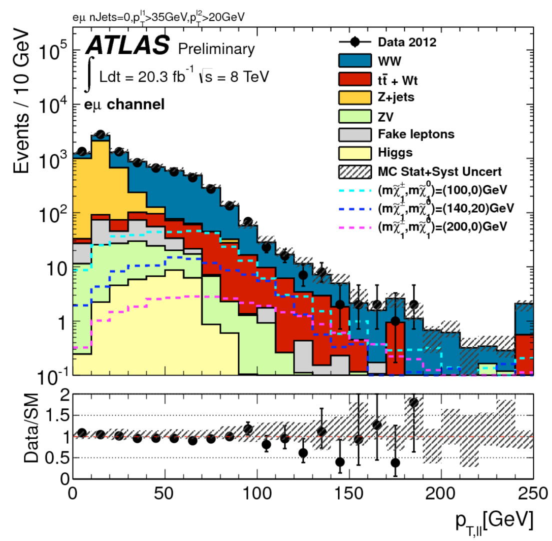
SIGNAL REGIONS



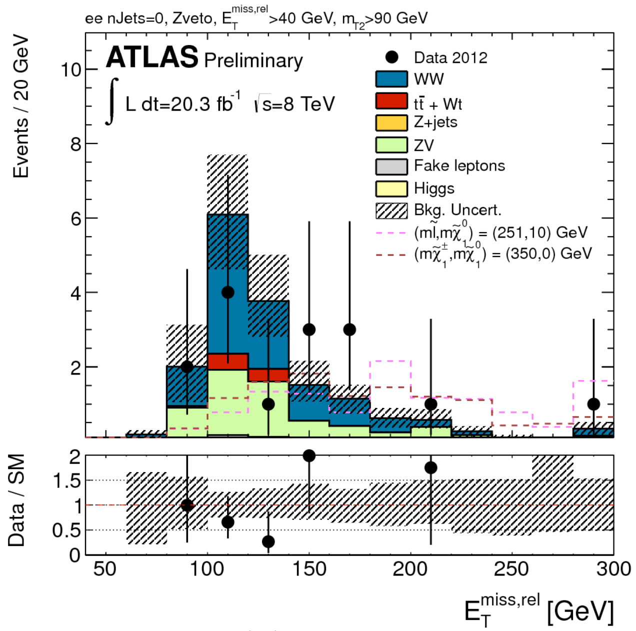


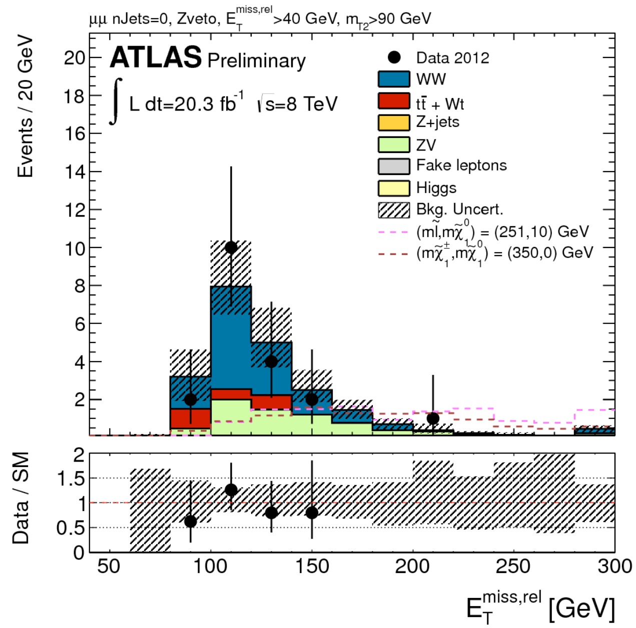
results for SRm_{T2} before applying m_{T2} cut

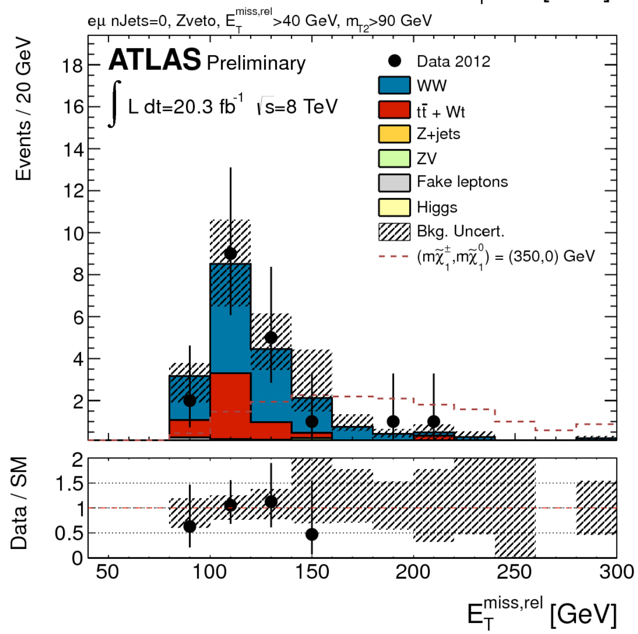




results for SRWW after applying p_T (lep) cuts



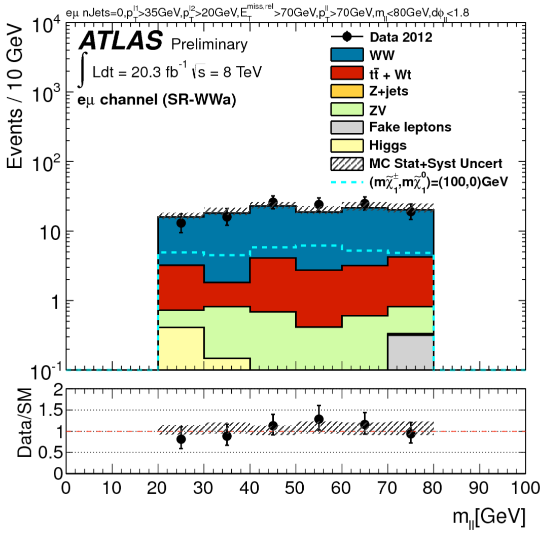


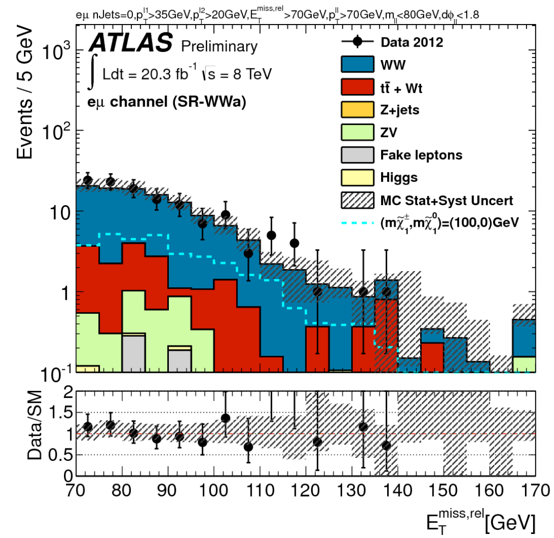


$E_T^{miss,\,rel}$ distribution for SR$m_{T2,\,90}$

in the ee, μμ, eμ channel

RESULTS - SRWW

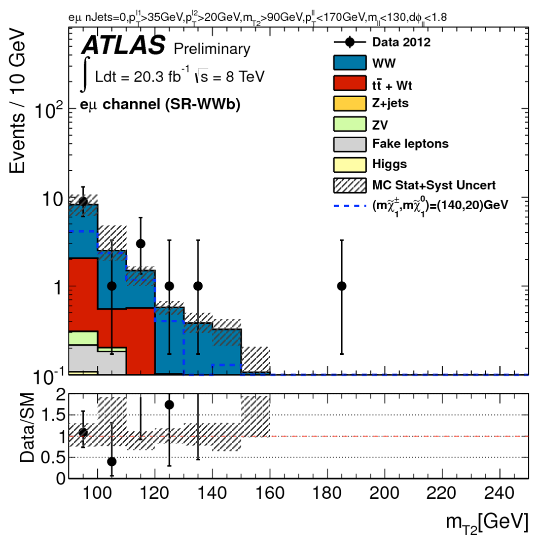


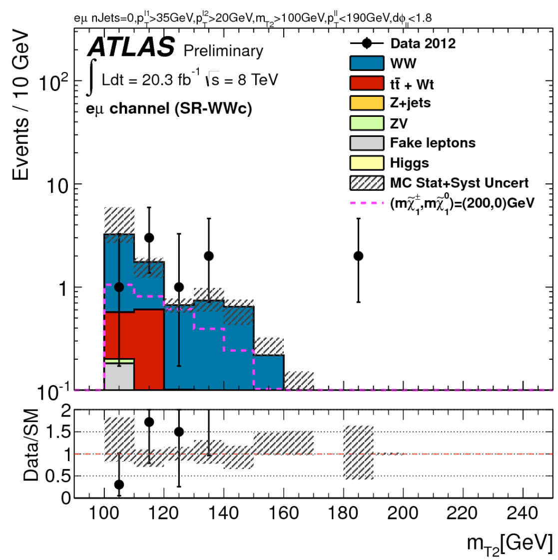


top:

m_{ll}, $E_T^{miss,\ rel}$

distribution for SRWWa





bottom:

m_{T2} distribution for

SRWWb, SRWWc

SM BACKGROUNDS

Irreducible backgrounds with two isolated real leptons:

- dominating background processes: ttbar, single top Wt, WW
- sizeable after pre-selection: WZ, ZZ

→ define CR and determine scaling factors to scale MC in SR

- small contributions from Z + jets and Higgs

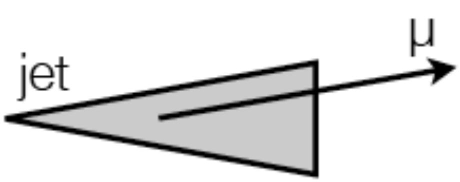
→ modeled with MC

Reducible background with 1 (or 2) fake lepton:

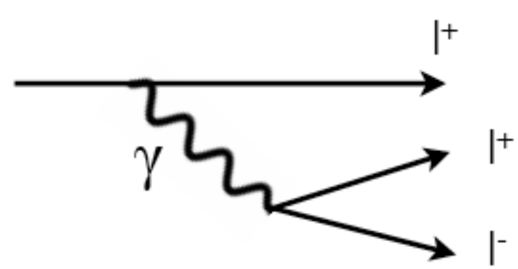
- non-prompt leptons originating from light /heavy jets or from conversion mis-identified as real leptons from W, Z or leptonic tau decays
- tiny contribution for SRs

→ modeled with Matrix Method

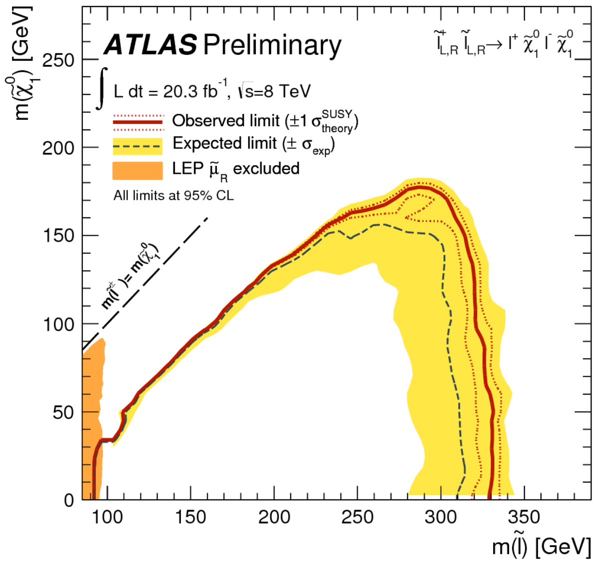
LF/HF fakes from jets

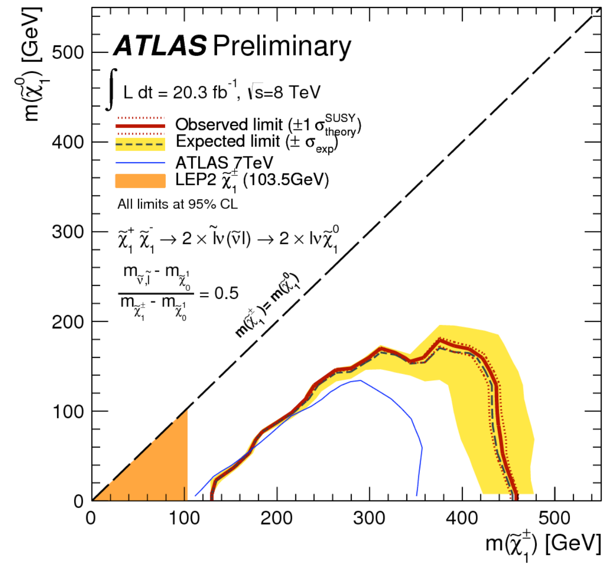


conversion leptons from photon radiation



RESULTS - SRm_{T2}

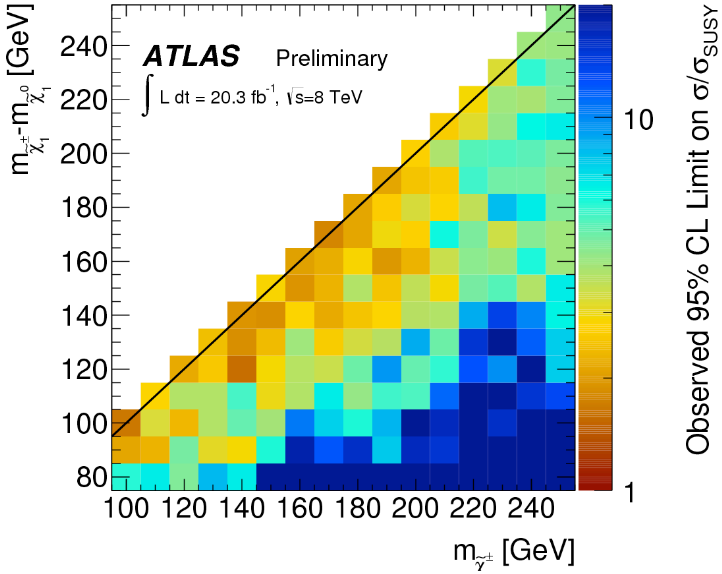


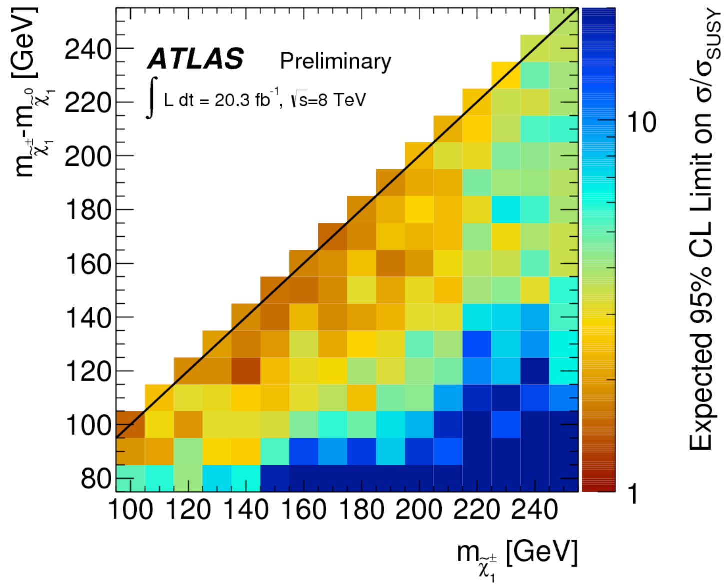


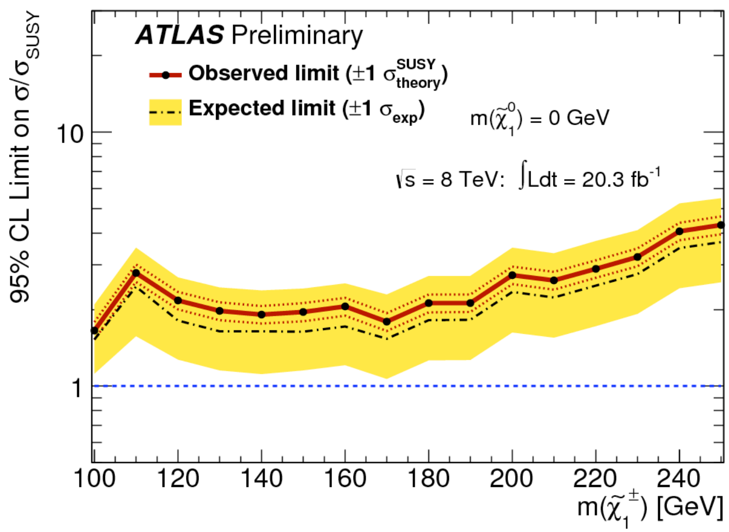
- observed and expected 95% CLs for right- and left-handed $\tilde{l}$:

  slepton masses between 90-320 GeV are excluded for massless neutralinos
- for a 100 GeV neutralino, slepton masses between 160-320 GeV are excluded
- chargino-chargino pair production 95% CLs limits:

  chargino masses between 130-450 GeV are excluded for 20 GeV neutralinos







- observed and expected 95% CLs limits of cross-sections obtained from SRWWa-c and of cross-sections as a function of chargino masses (normalized to cross-sections) for simplified models with bino-like neutralinos and wino-like charginos
- excluded cross-section is above the model cross section by a factor of 1.9-2.8 in a chargino mass range 100-190 GeV and degrades gradually to 4.7 at a chargino mass of 250 GeV

best result for model with chargino mass= 100 GeV, σ_{SUSY}=1.79

≥ 2 TAUS

ATLAS-CONF-2013-028:

Search for electroweak production of supersymmetric particles in final states with at least two hadronically decaying taus and missing transverse momentum with the ATLAS detector in proton-proton collisions at $\sqrt{s} = 8$ TeV

SUSY MODELS

chargino1-chargino1 production

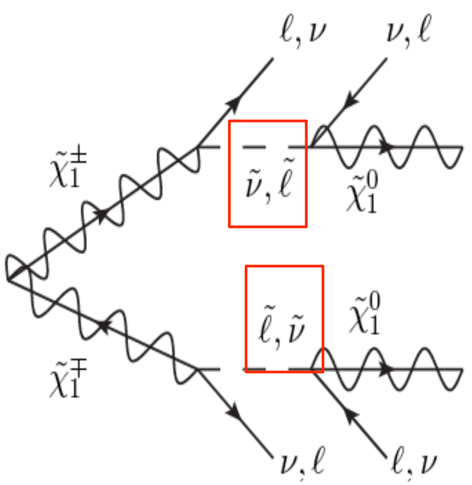
$$\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp} \rightarrow 2\times \tilde{\tau}\nu(\tilde{\nu}\tau) \rightarrow 2\times \tau\nu\tilde{\chi}_1^0$$

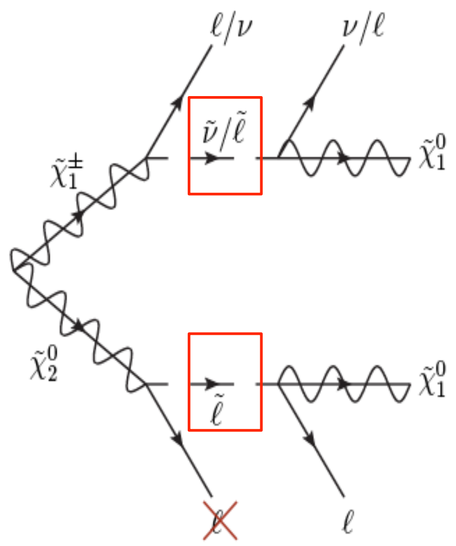
Chargino1-neutralino1 production

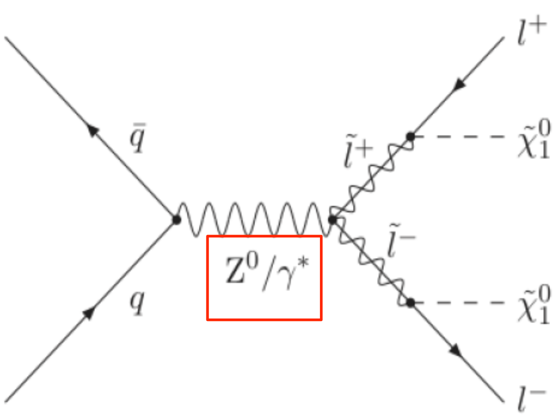
$$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0 \rightarrow \tilde{\tau}_L\nu(\tau\tilde{\nu})\ \tilde{\tau}_L\tau \rightarrow \tau\nu\tilde{\chi}_1^0\ \tau\tau\tilde{\chi}_1^0$$

slepton pair production

$$\tilde{\tau}^{\pm}\tilde{\tau}^{\mp} \rightarrow 2\times \tau\tilde{\chi}_1^0$$







via intermediate sleptons

via virtual Z

SIGNAL REGIONS

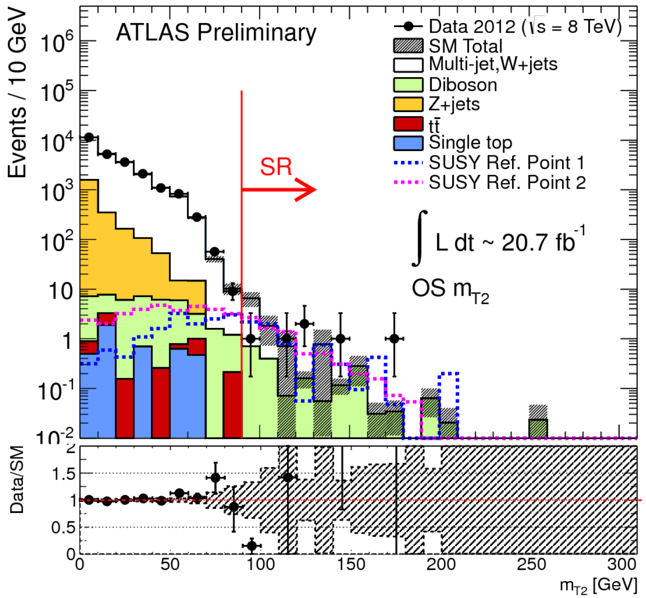
final selection in all SR

≥ 2 taus with opposite charge with p_T(tau1) > 40 GeV, p_T (tau2) > 25 GeV + trigger (di-tau or MET trigger) + veto additional leptons

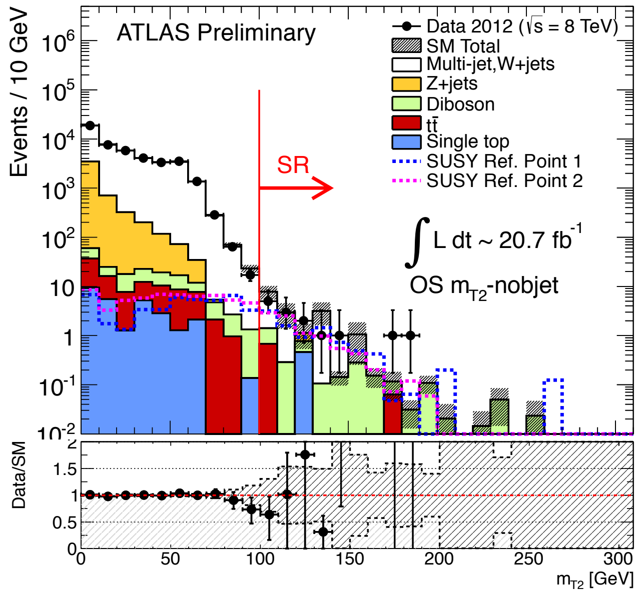
Signal region	requirements
OS m_{T2}	at least 1 OS tau pair jet veto Z-veto $E_T^{miss} > 40$ GeV $m_{T2} > 90$ GeV
OS m_{T2}-nobjet	at least 1 OS tau pair b-jet veto Z-veto $E_T^{miss} > 40$ GeV $m_{T2} > 100$ GeV

→ SR m_{T2}-nobjet: b-jet veto to suppress top background
→ m_{T2} is calculated among all OS tau pairs and the one with the largest value is selected

SIGNAL REGIONS



m_{T2} distribution for SR OS-m_{T2}.
The stacked histograms show the expected backgrounds. The white histogram represents the multi-jet and W+jets contribution



m_{T2} distribution for SR OS-m_{T2}nobjet
The stacked histograms show the expected backgrounds. The white histogram represents the multi-jet and W+jets contribution obtained from data

SM BACKGROUNDS

Irreducible backgrounds with two real taus:

- small contribution
- dominating background processes: diboson,

  top production (ttbar, single top ttbar, single top Wt, ttbar +V),

  Z+jets

→

modeled with MC
correct MC for differences in tau-ID efficiency and trigger efficiency

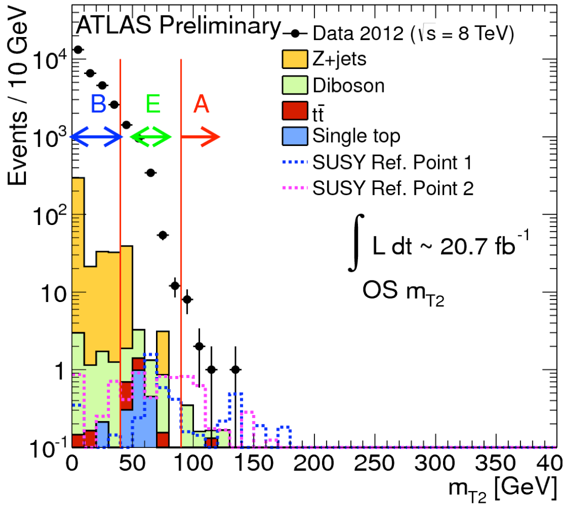
Reducible background with ≥ fake taus:

- dominant background in the SRs (75-80%)
- mis-identified jets from multi-jet and W + jets processes

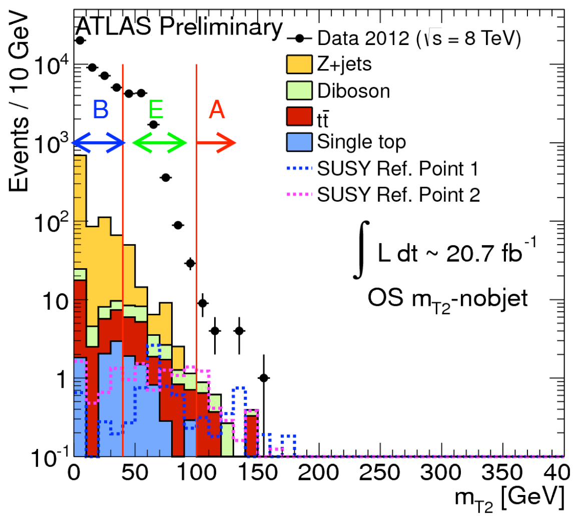
→

modeled with "ABCD" method (3 CR, 1 SR are selected in a plane defined by two weak correlated variables: tau-ID-m_{T2})
control of the method in two validation regions

CONTROL REGIONS

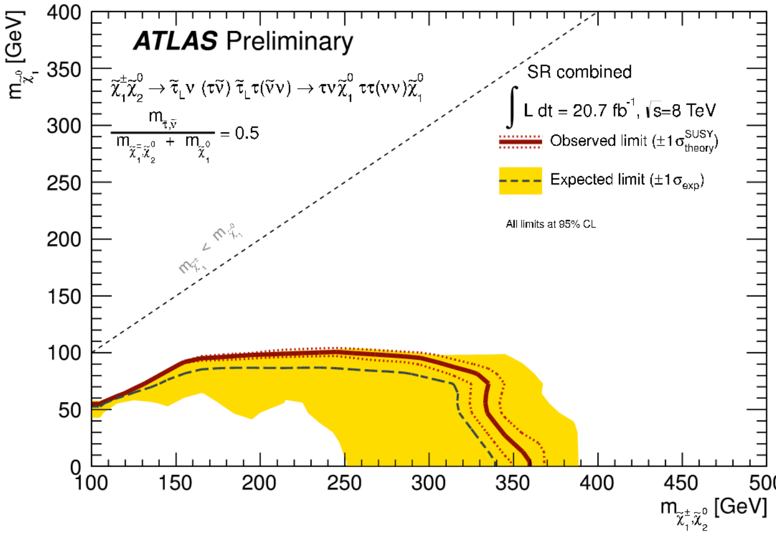


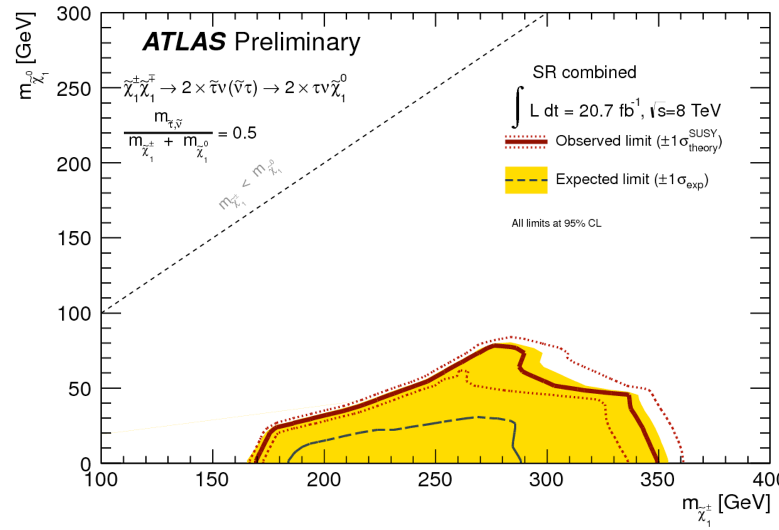
m_{T2} distribution after requiring at least two loose but not tight taus in the multi-jet and W+jets background CRs corresponding to SR OS-m_{T2}



m_{T2} distribution after requiring at least two loose but not tight taus in the multi-jet and W+jets background CRs corresponding to SR OS-mt2-nobjet

RESULTS





- 95% CL exclusion limits for simplified Models with chargino-neutralino production (left) and with chargino-chargino production (right)
- SR with the best expected limit at each point is used
- chargino masses up to 350 GeV are excluded for a massless lightest neutralino in the scenario of direct production of wino-like chargino pairs decaying into the lightest neutralino via an intermediate on-shell tau slepton
- in the case of pair production of degenerate charginos and next-to-lightest neutralinos, masses up to 330 (300) GeV are excluded for lightest neutralino masses below 50 (100) GeV

CROSS-SECTION LIMITS

• model-independent upper limits at 95% CL are placed on the visible cross section of new physics processes:

Signal Region	$\langle\epsilon\sigma\rangle^{95}_{\text{obs}}$[fb]	S^{95}_{obs}	S^{95}_{exp}	CL_B	$p(s=0)$
SR-OSm_{T2}	0.27	5.6	$8.9^{+2.7}_{-3.2}$	0.14	0.42
SR-OSm_{T2}-nobjet	0.50	10.4	$10.4^{+0.6}_{-1.7}$	0.48	0.39

- due to the low cross-section compared to electroweak production, the analysis has low sensitivity to the direct production of tau sleptons:

  → best upper limit on the production cross-section is found for a stau mass of 140 GeV

  and neutralino 1 mass of 10 GeV:

  theoretical cross section at NLO is 0.04 pb, excluded cross section is 0.17 pb

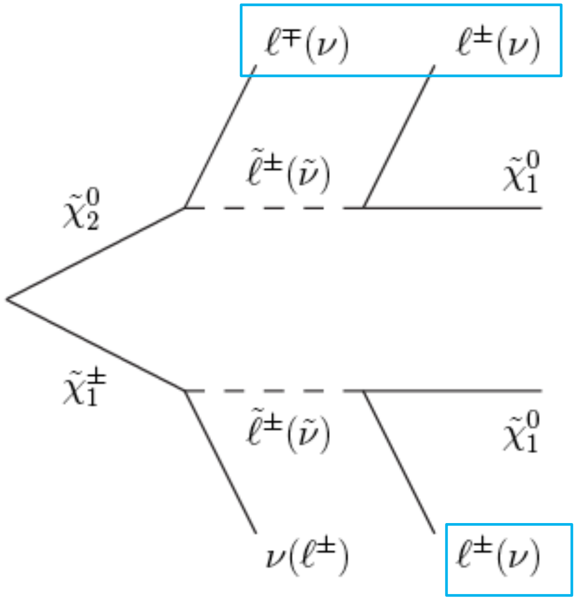
3 LEPTON (electron, muon)

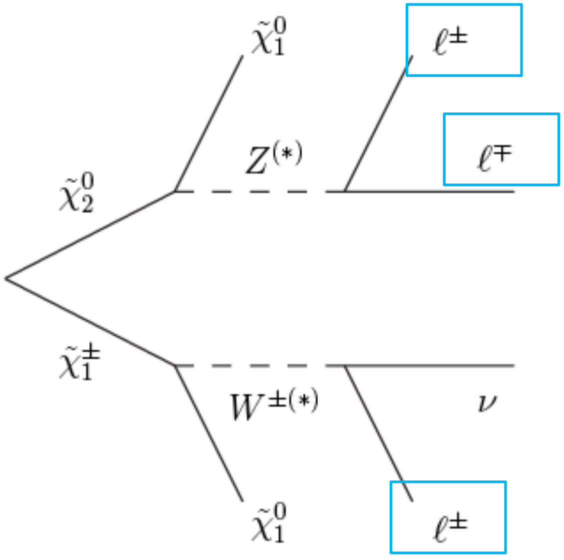
ATLAS-CONF-2013-035:

Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in 21 fb^{-1} of pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector

SUSY MODELS

chargino-neutralino production





neutralino decay via sleptons

$$\tilde{\chi}_2^0 \to \tilde{\ell}\bar{\ell} \to \ell\bar{\ell}\tilde{\chi}_1^0$$

neutralino decay via gauge bosons

$$\tilde{\chi}_2^0 \to Z\tilde{\chi}_1^0 \to \ell\bar{\ell}\tilde{\chi}_1^0$$

SIGNAL REGIONS

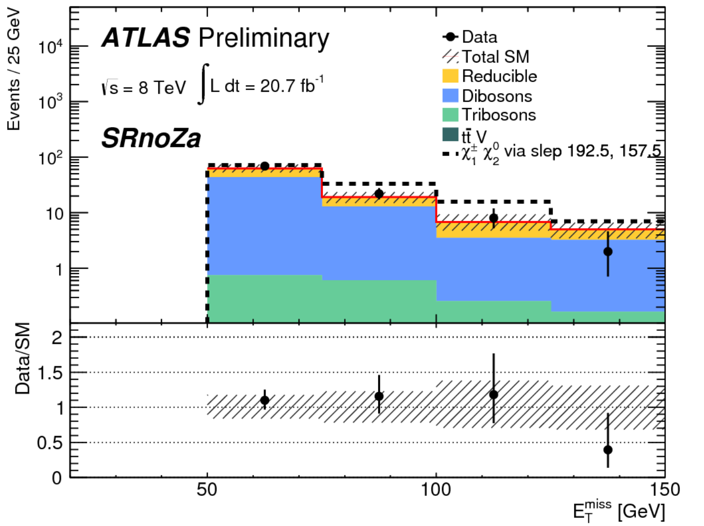
final selection in all SR

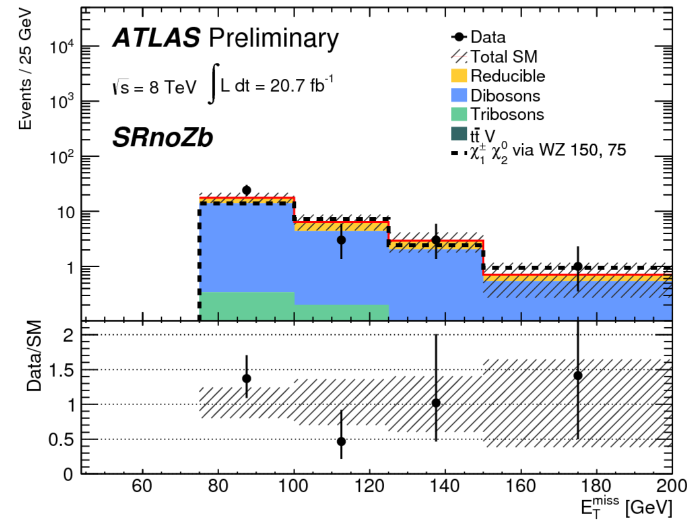
= 3 signal leptons with 1 lepton pair opposite charge + trigger + m(l,l) > 12 GeV + b-jet veto

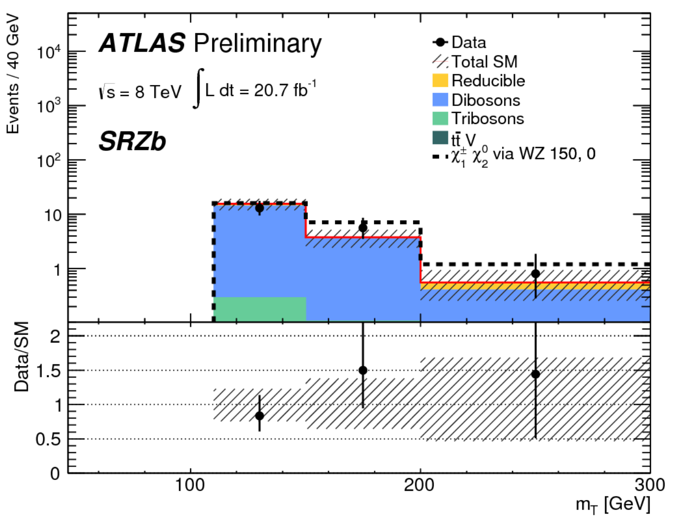
	Z depleted			Z enriched		
Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
m_{SFOS} [GeV]	<60	60–81.2	<81.2 or >101.2	81.2–101.2	81.2–101.2	81.2–101.2
E_T^{miss} [GeV]	>50	>75	>75	75–120	75–120	>120
m_T [GeV]	–	–	>110	<110	>110	>110
p_T 3^{rd} ℓ [GeV]	>10	>10	>30	>10	>10	>10
SR veto	SRnoZc	SRnoZc	–	–	–	–
Target	**Low mass splitting**	**No-slep off-shell Z**	**Slepton bulk**	**WZ-like**	**No-slep on-shell Z**	**No-slep bulk**

Z depleted: target neutralino decays via intermediate sleptons or off-shell Z-bosons
Z enriched: target decays via on-shell Z-boson
m_T cut to suppress WZ background

RESULTS







E_T^{miss}, distribution in SRnoZa,b

m_T distribution in SRnoZb

SM BACKGROUNDS

Irreducible backgrounds with three isolated real leptons:

main background: WZ

→ - define CR and determine scaling factors
- test background prediction in validation regions

diboson (WW, ZZ), triboson (WWW, ZZZ, ZWW) and

top-antitop W/Z production

→ modeled with MC, correct for b-jet efficiency

Reducible background with one or 2 fake lepton:

leptons from a semileptonic decay of heavy-flavour quarks,

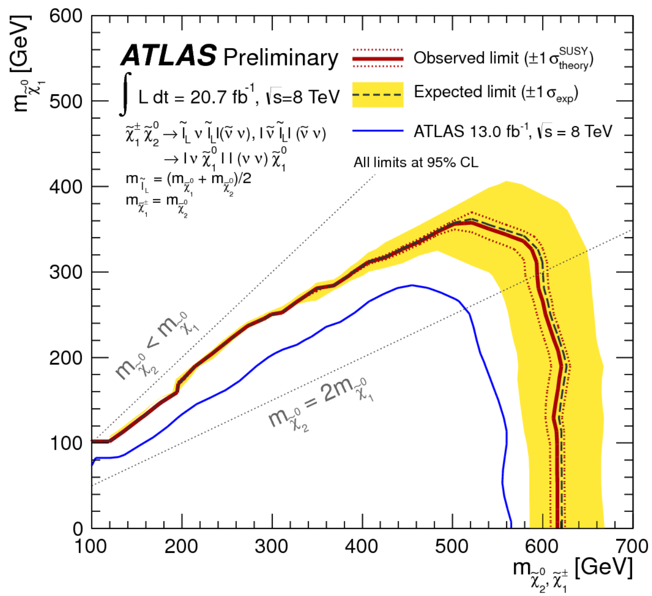
lepton from misidentified light-flavour quark or gluon jet or

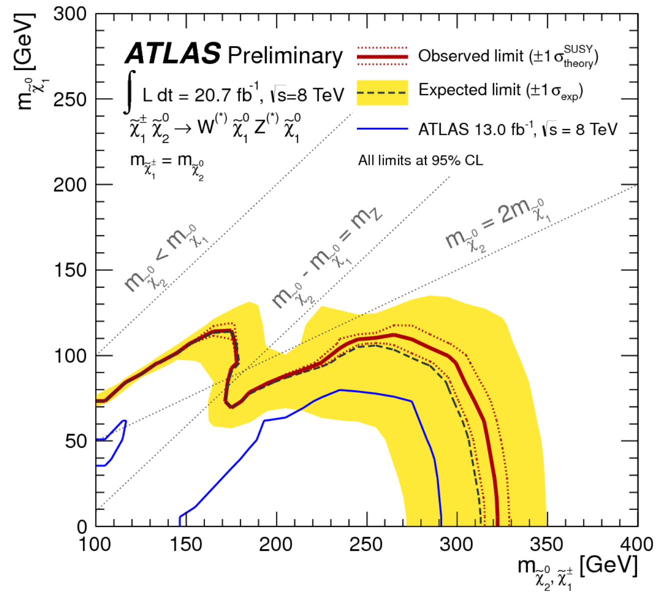
electron from photon conversion in single- and pair-

production of top quarks, WW, W+ jets, Z+jets

→ modeled with Matrix Method

RESULTS





- observed and expected 95% CL limit contours for chargino and neutralino production in the simplified model scenario with (left) decay via sleptons and (right) decay via gauge bosons
- left plot: regions SRnoZa, SRnoZb and SRnoZc provide the best sensitivity to the simplified models with intermediate slepton decays, chargino masses up to 600 GeV are excluded
- right plot: signal region SRnoZa has the best sensitivity for small mass differences between the two lightest neutralinos→ region close to diagonal, SRZa, SRZb and SRZc are sensitive to the area far from the diagonal

  → chargino masses up to 315GeV are excluded for large mass differences with the neutralino mass

SUMMARY

- Dedicated searches for slepton/gaugino production in final states with 2 leptons have been performed with the ATLAS detector with 20 fb^{-1} of 8TeV data.
- Searches are complementary and optimized independently.
- Good agreement between ATLAS data and Standard Model prediction is observed, no significant excess was found.
- New ATLAS limits for slepton and chargino/neutralino production are set.

BACKUP

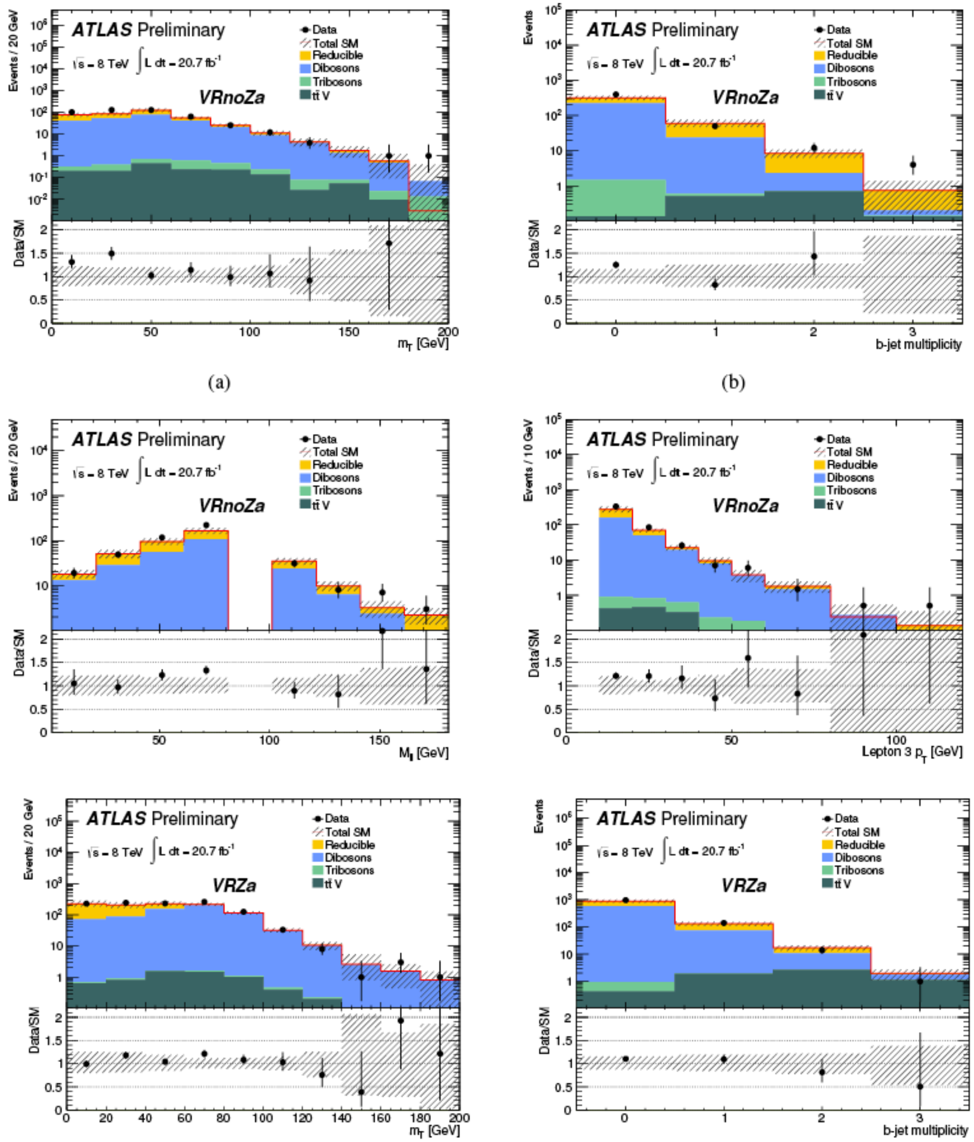
3 LEPTON ANALYSIS

Table 2: The selection requirements of the validation regions. All regions require exactly three signal leptons and a same-flavour opposite-sign (SFOS) lepton pair. Events that contain a SFOS lepton pair with a mass less than 12 GeV are rejected. The mass of the SFOS lepton pair closest to the Z-boson mass is denoted by m_{SFOS}.

Selection	VRnoZa	VRnoZb	VRZa	VRZb
m_{SFOS} [GeV]	<81.2 or >101.2	<81.2 or >101.2	81.2–101.2	81.2–101.2
b-jet	veto	request	veto	request
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	35–50	>50	30–50	>50
Dominant process	WZ^*, Z^*Z^*, Z^*+jets	$t\bar{t}$	WZ, Z+jets	WZ

Selection	VRnoZa	VRnoZb	VRZa	VRZb
Tri-boson	1.4 ± 1.4	0.5 ± 0.5	0.6 ± 0.6	0.26 ± 0.26
ZZ	$(1.3 \pm 0.9) \times 10^2$	4.5 ± 2.8	108 ± 23	6.9 ± 2.2
$t\bar{t}V$	2.9 ± 1.2	21 ± 7	7.4 ± 2.6	26 ± 8
WZ	110 ± 21	34 ± 15	$(5.5 \pm 0.9) \times 10^2$	$(1.4 \pm 0.4) \times 10^2$
Σ SM irreducible	$(2.4 \pm 0.9) \times 10^2$	60 ± 16	$(6.6 \pm 0.9) \times 10^2$	$(1.7 \pm 0.4) \times 10^2$
SM reducible	$(1.5 \pm 0.6) \times 10^2$	$(0.7 \pm 0.4) \times 10^2$	$(3.8 \pm 1.4) \times 10^2$	27 ± 13
Σ SM	$(3.9 \pm 1.1) \times 10^2$	$(1.3 \pm 0.5) \times 10^2$	$(10.4 \pm 1.7) \times 10^2$	$(2.0 \pm 0.4) \times 10^2$
Data	463	141	1131	171

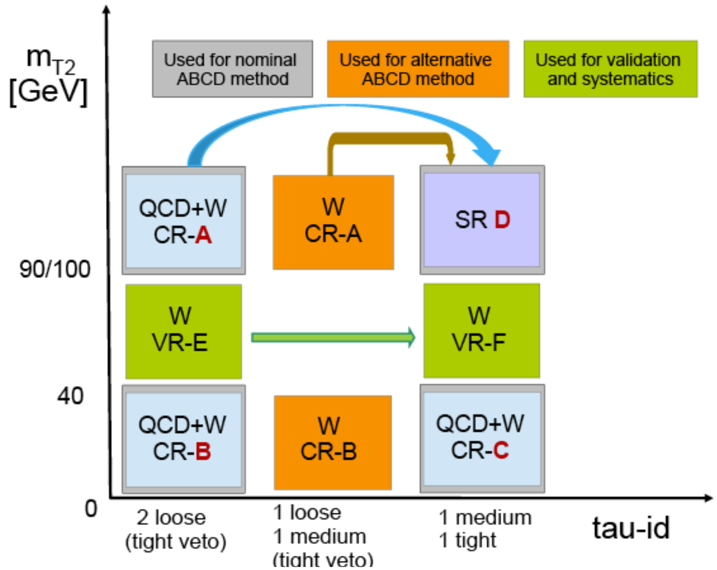
VALIDATION REGION- 3 LEPTON ANALYSIS



3 LEPTON ANALYSIS

Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
Tri-boson	1.7 ± 1.7	0.6 ± 0.6	0.8 ± 0.8	0.5 ± 0.5	0.4 ± 0.4	0.29 ± 0.29
ZZ	14 ± 8	1.8 ± 1.0	0.25 ± 0.17	8.9 ± 1.8	1.0 ± 0.4	0.39 ± 0.28
$t\bar{t}V$	0.23 ± 0.23	0.21 ± 0.19	$0.21^{+0.30}_{-0.21}$	0.4 ± 0.4	0.22 ± 0.21	0.10 ± 0.10
WZ	50 ± 9	20 ± 4	2.1 ± 1.6	235 ± 35	19 ± 5	5.0 ± 1.4
Σ SM irreducible	65 ± 12	22 ± 4	3.4 ± 1.8	245 ± 35	20 ± 5	5.8 ± 1.4
SM reducible	31 ± 14	7 ± 5	1.0 ± 0.4	4^{+5}_{-4}	1.7 ± 0.7	0.5 ± 0.4
Σ SM	**96 ± 19**	**29 ± 6**	**4.4 ± 1.8**	**249 ± 35**	**22 ± 5**	**6.3 ± 1.5**
Data	**101**	**32**	**5**	**273**	**23**	**6**
p_0-value	0.41	0.37	0.40	0.23	0.44	0.5
N_{signal} excluded (exp)	39.3	16.3	6.2	67.9	13.2	6.7
N_{signal} excluded (obs)	41.8	18.0	6.8	83.7	13.9	6.5
σ_{visible} excluded (exp) [fb]	1.90	0.79	0.30	3.28	0.64	0.32
σ_{visible} excluded (obs) [fb]	2.02	0.87	0.33	4.04	0.67	0.31

SM BACKGROUNDS



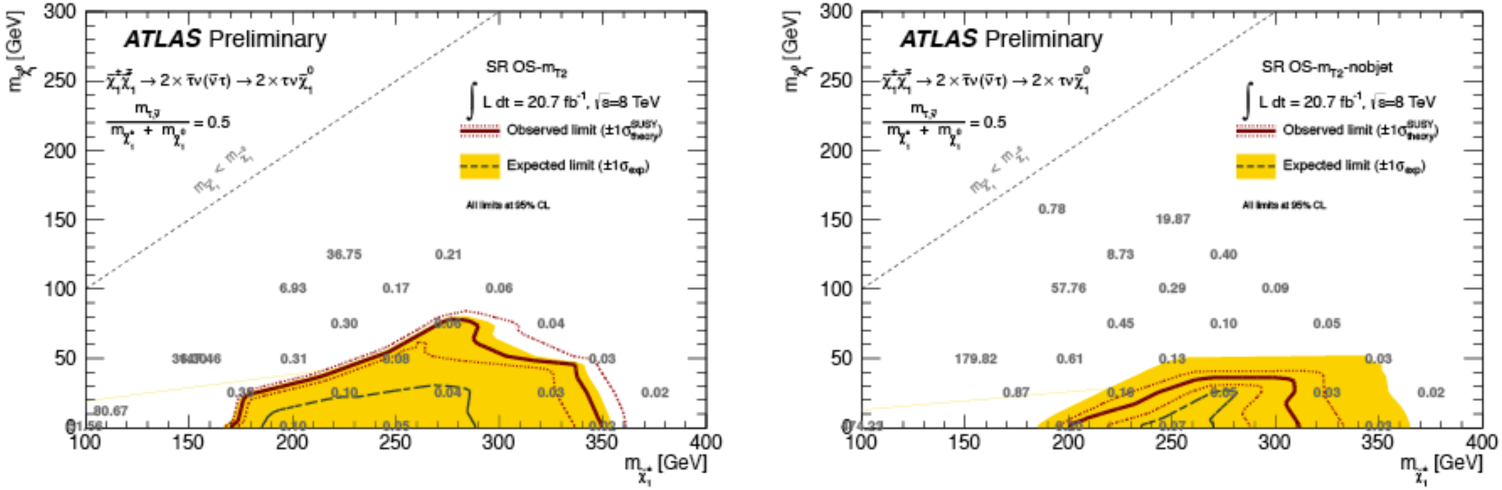
Regions	multi-jet and W+jets background control region			Signal region
	A	B	C	D
OS m_{T2}	m_{T2}> 90 GeV E_T^{miss}> 40 GeV ≥ 2 loose taus tight tau veto	m_{T2}< 40 GeV E_T^{miss}> 40 GeV ≥ 2 loose taus tight tau veto	m_{T2}< 40 GeV E_T^{miss}> 40 GeV ≥ 1 medium tau ≥ 1 tight tau	m_{T2}> 90 GeV E_T^{miss}> 40 GeV ≥ 1 medium tau ≥ 1 tight tau
OS m_{T2}-nobjet	m_{T2}> 100 GeV E_T^{miss}> 40 GeV ≥ 2 loose taus tight tau veto	m_{T2}< 40 GeV E_T^{miss}> 40 GeV ≥ 2 loose taus tight tau veto	m_{T2}< 40 GeV E_T^{miss}> 40 GeV ≥ 1 medium tau ≥ 1 tight tau	m_{T2}> 100 GeV E_T^{miss}> 40 GeV ≥ 1 medium tau ≥ 1 tight tau

RESULTS tau channels

Syst. Sources	SR OS-m_{T2}	SR OS-m_{T2}-nobjet
Correlation	5%	1%
Transfer factor difference	15%	24%
Subtraction of other backgrounds	2%	6%
Number of events in Region A	31%	27%
Total	35%	37%

SM process	SR OS m_{T2}	SR OS m_{T2} -nobjet
top	0.2 ± 0.5 ± 0.1	1.6 ± 0.8 ± 1.2
Z+jets	0.28 ± 0.26 ± 0.23	0.4 ± 0.3 ± 0.3
diboson	2.2 ± 0.5 ± 0.5	2.5 ± 0.5 ± 0.9
multi-jet & W+jets	8.4 ± 2.6 ± 1.4	12 ± 3 ± 3
SM total	11.0 ± 2.7 ± 1.5	17 ± 4 ± 3
data	6	14
SUSY Ref. point 1	6.8 ± 1.0	9.2 ± 1.2
SUSY Ref. point 2	7.5 ± 0.7	8.9 ± 0.7

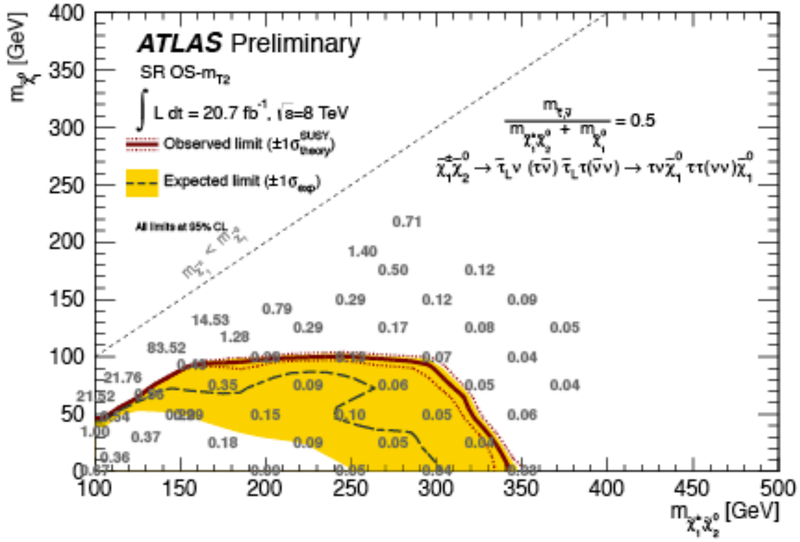
RESULTS tau channels



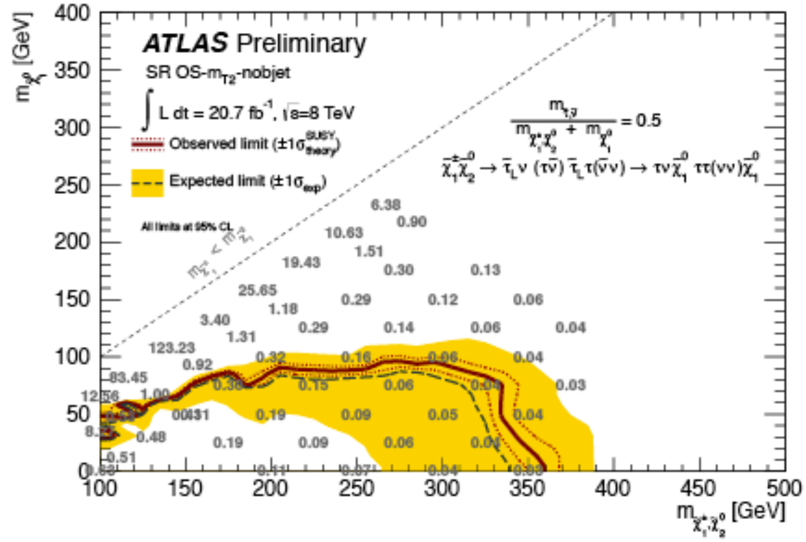
(a) SR OS-m_{T2} (b) SR OS-m_{T2}-nobjet

Figure 9: 95% CL exclusion limits for a Simplified Model with chargino-chargino production, for the SR OS-m_{T2} (a) and the SR OS-m_{T2}-nobjet (b). The dashed lines show the 95% CL expected limits. The solid band around the expected limit shows the $\pm 1\sigma$ result where all uncertainties, except those on the signal cross-sections, are considered. The $\pm 1\sigma$ lines around the observed limit represent the results obtained when moving the nominal signal cross-section up and down by the $\pm 1\sigma$ theoretical uncertainty. The overlaid numbers give the observed upper limit on the signal cross section, in pb.

RESULTS tau channels



(a) SR OS-m_{T2}



(b) SR OS-m_{T2}-nobjet

Figure 8: 95% CL exclusion limits for a Simplified Model with chargino-neutralino production, for the SR OS-m_{T2} (a) and the SR OS-m_{T2}-nobjet (b). The dashed lines show the 95% CL expected limits. The solid band around the expected limit shows the $\pm 1\sigma$ result where all uncertainties, except those on the signal cross-sections, are considered. The $\pm 1\sigma$ lines around the observed limit represent the results obtained when moving the nominal signal cross-section up and down by the $\pm 1\sigma$ theoretical uncertainty. The overlaid numbers give the observed upper limit on the signal cross section, in pb.

OBJECTS

E_T^{miss}:

- E_T^{miss} becomes $E_T^{miss,rel}$: $$E_{\mathrm{T}}^{\mathrm{miss,rel}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$

ΔΦ=azimutal angle between the direction of E_T^{miss} vector and the nearest lepton or jet

→ reduce the impact of events where an object is badly reconstructed such that it is aligned with E_T^{miss}

- **stransverse mass m_{T2}**: $$m_{\mathrm{T2}} = \min_{\mathbf{q}_{\mathrm{T}}+\mathbf{r}_{\mathrm{T}}=\mathbf{p}_{\mathrm{T}}^{\mathrm{miss}}} \left[\max\left(m_T(\mathbf{p}_{\mathrm{T}}^{\ell_1}, \mathbf{q}_{\mathrm{T}}), m_T(\mathbf{p}_{\mathrm{T}}^{\ell_2}, \mathbf{r}_{\mathrm{T}})\right)\right]$$

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

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

based on transverse mass

defined for events with pair-produced identical particles, where each decays into 2 particles

out of which ones goes undetected

OBJECTS

- The stransverse mass m_{T2} is defined for pair produced particles that each decay to two particles, out of which one goes undetected.
- If the undetected particles are massless, the two-lepton m_{T2} distribution (for $\tilde{\ell}$ pair production) has an endpoint given by

$$m_{\mathrm{T2}}^2 = m_{\tilde{\ell}}^2 - m_{\tilde{\chi}_1^0}^2 + \frac{m_{\tilde{\ell}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{\ell}}} \left(\sqrt{\left(\frac{m_{\tilde{\ell}}^2 + m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{\ell}}} \right)^2 - m_{\tilde{\chi}_1^0}^2} - \frac{m_{\tilde{\ell}}^2 + m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{\ell}}} \right)$$

- It can be shown that this equation simplifies to $\approx m_{\tilde{\ell}} - m_{\tilde{\chi}_1^0}$.
- In particular, m_{T2} is a powerful tool rejecting WW background, since the WW m_{T2} distribution will end at the W mass.
- *J.Phys. G29 (2003) 2343-2363, Phys.Lett. B463 (1999) 99-103.*

MATRIX METHOD

- takes care of fake leptons from W+jets, semi leptonic ttbar, single top t- and s-channel or multi-jets
- employs a set of linear equations relating kinematic properties of the leptons to be real (R) or fake (F)
- number of observed events with one (or two) fakes is extracted from this system of linear equations relating the number of events with 1(2) additional signal (tight T) or tagged lepton (loose L) candidates to the number of events with 1(2) additional candidates that are either real or fake candidates
- coefficients of the linear equations are functions of real-lepton id efficiencies r (obtained from MC simulation + scaled to account differences to data) and fake-object misidentification probabilities (f)

$$\begin{pmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{pmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \cdot \begin{pmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{pmatrix}$$

- fake rate depends of the type of fake and the process that produced the fake

→ fake rates are obtained from MC simulated samples and corrected for differences between data and MC in each signal and validation region

- weighted average fake efficiency for a generic region XR:

$$f^{l}_{XR} = \sum_{i,XR} (sf^{i} \times R^{i}_{XR} \times f^{i})$$

sf^i : scaling factor for lepton fake type (HF, conversion)
R^i_{XR}: fraction of type iin region XR
f^i : fake efficiency for type i, parametrized as a function of p_T

MATRIX METHOD

- Define a set of tight and loose object selection criteria.
- Determine the *real efficiency* r, i.e the probability for a real, prompt lepton to pass the tight selection. This is done using real data.
- Determine the *fake rate* f, i.e the probability for a fake, non-prompt lepton to pass the tight selection. This is done using MC truth.
- Let N_{TT} denote the number of events with two tight leptons, N_{TL} the number of events with one tight and one loose lepton and so on.
- Let N_{RR} denote the number of events with two real leptons, N_{RF} the number of events with one real and one fake lepton and so on.
- The number of events with at least one fake lepton is found by inverting the matrix below. For 3-Lepton, the method is applicable under the assumption that the leading lepton is always real.

$$\begin{pmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{pmatrix} = \begin{bmatrix} r_1 r_2 & r_1 f_2 & f_1 r_2 & f_1 f_2 \\ r_1(1-r_2) & r_1(1-f_2) & f_1(1-r_2) & f_1(1-f_2) \\ (1-r_1)r_2 & (1-r_1)f_2 & (1-f_1)r_2 & (1-f_1)f_2 \\ (1-r_1)(1-r_2) & (1-r_1)(1-f_2) & (1-f_1)(1-r_2) & (1-f_1)(1-f_2) \end{bmatrix} \cdot \begin{pmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{pmatrix}$$

MATRIX METHOD

- Use isolation to define "loose" and "tight" leptons
  - "tight" (T) are the signal leptons
  - "loose" (L) leptons have more relaxed isolation requirements
    - electrons: `medium++` and no isolation
    - muons: no isolation
- The fake rate f is the probability that a loose fake lepton passes tight
  - $f(e(p_{\mathrm{T}})) = \sum_{i \in \mathrm{QCD,\ conv}} f_i(p_{\mathrm{T}}) w_i(p_{\mathrm{T}}) s_i(p_{\mathrm{T}})$
  - f_i Measured for $E_T^{\mathrm{miss,\ rel}} < 50$ GeV, Z mass, == 2 μ, >=1 el with $m_T < 40$ GeV in MC
  - Compared with rates in fake-rich control regions $\rightarrow s_i$
  - Weighted average for each SR used in estimate $\rightarrow w_i$
- The real efficiency $r = (N_T/N_L)_{|m_{\ell\ell} - m_Z| < 5 \text{ GeV}}$

$$\begin{bmatrix} N_{TT} \\ N_{TL} \\ N_{LT} \\ N_{LL} \end{bmatrix} = \begin{bmatrix} rr & rf & fr & ff \\ r(1-r) & r(1-f) & f(1-r) & f(1-f) \\ (1-r)r & (1-r)f & (1-f)r & (1-f)f \\ (1-r)(1-r) & (1-r)(1-f) & (1-f)(1-r) & (1-f)(1-f) \end{bmatrix} \begin{bmatrix} N_{RR} \\ N_{RF} \\ N_{FR} \\ N_{FF} \end{bmatrix}$$

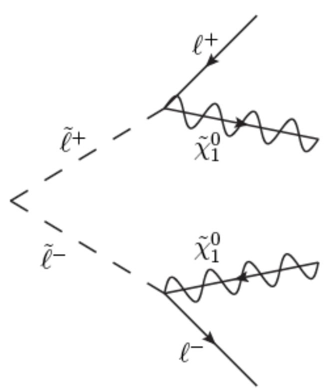
$$N_{TT}^{RF} = r_1 f_2 N_{LL}^{RF}, \; N_{TT}^{FR} = f_1 r_2 N_{LL}^{FR}, \; N_{TT}^{FF} = f_1 f_2 N_{LL}^{FF}$$

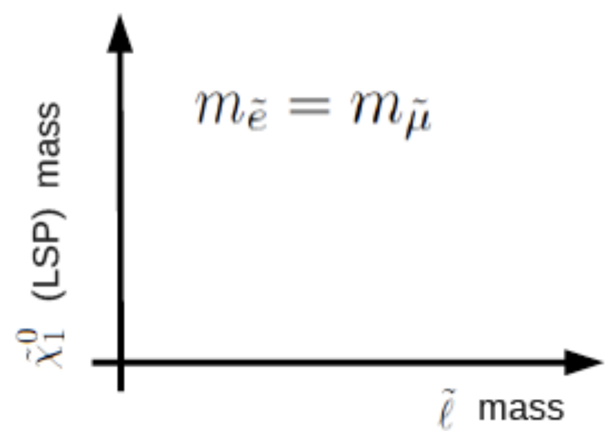
SUSY MODELS

Direct slepton models

- direct production of sleptons, models based on pMSSM
- grid with left-handed and right-handed sleptons (both have same mass), no sneutrinos
- all gauginos masses – except for LSP set to 2.5 TeV
- models contain only selectrons and smuons $m_{\tilde{e}} = m_{\tilde{\mu}}$ in range 90-370 GeV

  step size: $m_{\tilde{\ell}} \geq m_{\tilde{\chi}_1^0} + 30\ \mathrm{GeV}$
- $\tilde{\chi}_1^0$ is bino-like (μ large) and varied by scanning M_1 in range 0-200 GeV
- σ = 127…0.5 fb for left-handed sleptons, σ = 49 to 0.2 fb for right-handed sleptons, independently of the neutralino mass as the slepton mass : 90 to 369 GeV





SUSY MODELS

Simplified models

- minimal particle content necessary to produce SUSY-like events
- parameterization in SUSY particles masses; only free parameter are:

neutralino 1 mass, slepton mass, sneutrino mass and chargino mass

- BR for decays in higgs bosons is set to 0
- Squarks are set to be very heavy
- charginos are pair produced via s-channel + exchange a virtual gauge boson
- decay modes:

\- via on-shell charged left-handed sleptons – including staus and sneutrinos with equal BR:

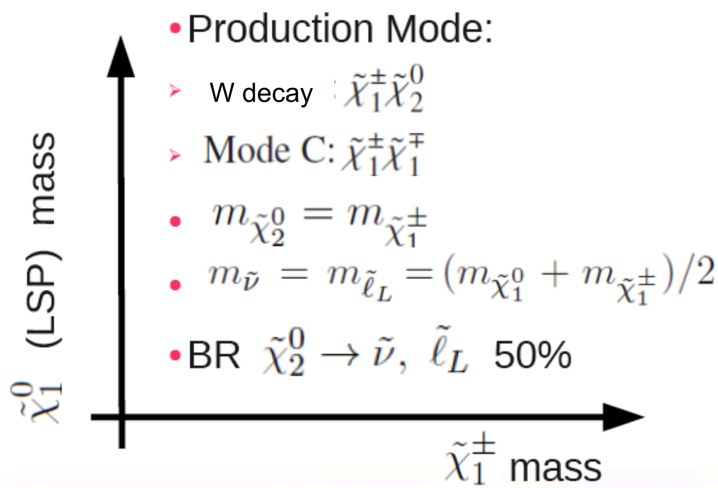
$$m_{\tilde{\nu}} = m_{\tilde{\ell}_L} = (m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_1^\pm})/2.$$

cross section assuming chargino is about 95% wino-like

σ=5 pb (chargino mass = 100 GeV) …σ=0.35 pb

(chargino masses > 200 GeV

\- via Z and W boson (W decay)



DESY

SUSY MODELS

Chargino-to-W scenario

- mass grid in chargino-neutralino1 mass plane in 10 GeV steps from (100,0) to chargino mass – neutralino mass > 80 GeV
- BR assumes 100%
- Bino-like LSP, wino-like chargino
- charged higgs very heavy→ decay only via W
- small higgsino component is allowed

GMSB model:

- LSP= gravitino, NLSP
- gauginos are higgsino-like: chargino with mass = 110 GeV, m (neutralino1)= 113 GeV, m(chargino 2) = 130 GeV
- 25% of the production xsection from chargino-chargino production (σ= 1.3 pb), 50% from chargino-neutralino channel (σ=2.4 pb)
- neutralino→ W chargino decay is possible

→ chargino-neutralino, chargino-chargino channels result in the same experimental signature

→ production xsection can be added

- main decays: chargino→ W gravitino (BF 100%) and neutralino→ W chargino

DATA-MC SAMPLES | TRIGGER

- **Data**:

  full 8 TeV 2012 corresponding to 20.3 fb^{-1}

- **MC (most important ones)**:

  TOP: ttbar, Wt with MC@NLO (Powheg/Alpgen for cross checks)

  ttbar + boson with Madgraph (LO xsection scaled to NLO via k-factor)

  WW: WW w/ Powheg (Sherpa for cross checks), WW via gluon fusion w/ gg2WW

  ZV: ZW/ZZ w/ Powheg (Sherpa for cross checks), ZZ via gluon fusion w/ gg2ZZ

  VVV: WWW, WWZ and ZZZ w/ Madgraph

  Higgs: Associated production modes (WH, ZH) w/ Pythia and the VBF, ggF w/ Powheg

- **SUSY Signal:**

  all signal samples are generated w/ Herwig++, cross-sections are computed with prospino

- **Trigger**:

  symmetric and asymmetric di-electron, di-muon and asymmetric electron-muon trigger

  no trigger simulation is used, trigger weights are applied to MC

RESULTS - SRWW

- results are consistent between Standard Model predictions, no excess observed
- set limits on the visible cross section for new physics

SM process	SR OS m_{T2}	SR OS m_{T2} -nobjet
top	$0.2 \pm 0.5 \pm 0.1$	$1.6 \pm 0.8 \pm 1.2$
Z+jets	$0.28 \pm 0.26 \pm 0.23$	$0.4 \pm 0.3 \pm 0.3$
diboson	$2.2 \pm 0.5 \pm 0.5$	$2.5 \pm 0.5 \pm 0.9$
multi-jet & W+jets	$8.4 \pm 2.6 \pm 1.4$	$12 \pm 3 \pm 3$
SM total	$11.0 \pm 2.7 \pm 1.5$	$17 \pm 4 \pm 3$
data	6	14
SUSY Ref. point 1	6.8 ± 1.0	9.2 ± 1.2
SUSY Ref. point 2	7.5 ± 0.7	8.9 ± 0.7

RESULTS - SRWW

- results are consistent between Standard Model predictions, no excess observed
- set limits on the visible cross section for new physics

	SR-WWa	SR-WWb	SR-WWc
Observed	123	16	9
Background total	117.9 ± 14.6	13.6 ± 2.3	7.4 ± 1.5
Top	15.2 ± 6.6	2.7 ± 1.1	1.0 ± 0.7
WW	98.6 ± 14.6	10.2 ± 2.1	5.9 ± 1.3
ZV ($V = W$ or Z)	3.4 ± 0.8	$0.26^{+0.31}_{-0.26}$	0.29 ± 0.14
Higgs	0.76 ± 0.14	0.21 ± 0.06	0.10 ± 0.04
fake	$0.02^{+0.33}_{-0.02}$	$0.26^{+0.30}_{-0.26}$	$0.12^{+0.17}_{-0.12}$
Signal expectation			
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (100, 0)$ GeV	31	N/A	N/A
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (140, 20)$ GeV	N/A	8.2	N/A
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (200, 0)$ GeV	N/A	N/A	3.3
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (110, 113)$ GeV	18	4.3	N/A
Observed $\sigma^{95}_{\rm vis}$ (fb)	1.94	0.58	0.43
Expected $\sigma^{95}_{\rm vis}$ (fb)	$1.77^{+0.66}_{-0.49}$	$0.51^{+0.21}_{-0.15}$	$0.37^{+0.18}_{-0.11}$

RESULTS - SRm_{T2}

SR-$m_{T2,90}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	15	19	19	53
Background total	16.6 ± 2.3	20.7 ± 3.2	22.4 ± 3.3	59.7 ± 7.3
WW	9.3 ± 1.6	14.1 ± 2.2	12.6 ± 2.0	36.1 ± 5.1
ZV ($V = W$ or Z)	6.3 ± 1.5	0.8 ± 0.3	7.3 ± 1.7	14.4 ± 3.2
Top	$0.9^{+1.1}_{-0.9}$	5.6 ± 2.1	2.5 ± 1.8	8.9 ± 3.9
Higgs	0.11 ± 0.04	0.19 ± 0.05	0.08 ± 0.04	0.38 ± 0.08
Fake	$0.00^{+0.18}_{-0.00}$	$0.00^{+0.14}_{-0.00}$	$0.00^{+0.15}_{-0.00}$	$0.00^{+0.28}_{-0.00}$
Signal expectation				
$(m_{\tilde{\ell}}, m_{\tilde{\chi}_1^0}) = (191, 90)$ GeV	21.6	0	21.6	43.2
$(m_{\tilde{\ell}}, m_{\tilde{\chi}_1^0}) = (251, 10)$ GeV	12.2	0	12.5	24.7
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (350, 0)$ GeV	11.7	16.6	10.5	38.8
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (425, 75)$ GeV	4.3	6.7	4.4	15.4
Observed $\sigma^{95}_{\rm vis}$ (fb)	0.44	0.51	0.47	0.81
Expected $\sigma^{95}_{\rm vis}$ (fb)	$0.50^{+0.22}_{-0.15}$	$0.57^{+0.25}_{-0.17}$	$0.58^{+0.25}_{-0.17}$	$1.00^{+0.41}_{-0.28}$
SR-$m_{T2,110}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	4	5	4	13
Background total	6.1 ± 2.2	4.4 ± 2.0	6.3 ± 2.4	16.9 ± 6.0
WW	2.7 ± 1.5	3.6 ± 2.0	2.9 ± 1.6	9.1 ± 4.9
ZV ($V = W$ or Z)	2.7 ± 1.4	0.2 ± 0.1	3.4 ± 1.8	6.3 ± 3.3
Top	0.7 ± 0.7	0.6 ± 0.4	0.0 ± 0.0	1.3 ± 1.0
Higgs	0.05 ± 0.03	0.12 ± 0.04	0.05 ± 0.02	0.22 ± 0.05
Fake	$0.00^{+0.09}_{-0.00}$	$0.00^{+0.13}_{-0.00}$	$0.00^{+0.12}_{-0.00}$	$0.00^{+0.28}_{-0.00}$
Signal expectation				
$(m_{\tilde{\ell}}, m_{\tilde{\chi}_1^0}) = (191, 90)$ GeV	12.3	0	12.0	24.3
$(m_{\tilde{\ell}}, m_{\tilde{\chi}_1^0}) = (251, 10)$ GeV	10.5	0	11.2	21.7
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (350, 0)$ GeV	9.5	14.0	8.7	32.2
$(m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}) = (425, 75)$ GeV	3.7	1.1	3.8	8.5
Observed $\sigma^{95}_{\rm vis}$ (fb)	0.27	0.35	0.28	0.54
Expected $\sigma^{95}_{\rm vis}$ (fb)	$0.33^{+0.16}_{-0.10}$	$0.33^{+0.16}_{-0.09}$	$0.33^{+0.16}_{-0.10}$	$0.62^{+0.23}_{-0.16}$

- results are consistent between Standard Model predictions, no excess observed
- set limits on the visible cross section for new physics

OBJECT SELECTION

I

Cleaning cuts: PV with ≥ 5 tracks, bad jet veto, cosmic muon rejection, reject events with LarError, TileError, Tile saturation, Tile hot spot, veto against incomplete events

E_T^{miss}: RefFinalEgamma10NoTau

II

baseline electrons
medium++ quality
author 1 or 3
p_T > 10 GeV, |η| < 2.47

baseline muons
STACO loose
combined or segment tagged
p_T > 10 GeV, |η| < 2.4

baseline jets
anit-kt LC topo, R = 0.4
p_T > 20 GeV, |η| < 4.5

III

overlap removal
discard softer electron if ΔR(e1, e2) < 0.1
discard jet if ΔR(e, j) < 0.2, discard electron if ΔR(e, j) < 0.4, discard muon if ΔR(μ, j) < 0.4
discard electron and muon if ΔR(e, μ) < 0.1
discard muons if ΔR(μ1, μ2) < 0.05

IV

signal electron
tight quality
pTcone30/p_T < 0.16
ETcone30/p_T < 0.18
$|z_0 \sin\Theta|$ < 0.4 mm
(pileup corrected)
d_0 significance < 0.5

signal muons
pTcone30/p_T < 0.12
$|z_0 \sin\Theta|$ < 1 mm
(pileup corrected)
d_0 significance < 0.3

signal jets Veto

Central jets C20:
p_T > 20 GeV, |η| < 2.4, non-b-tagged (MV1@ 80%), |JVF| >0 if p_T < 50 GeV

B- jets B20:
p_T > 20 GeV, |η| < 2.4, b-tagged (MV1@80%)

Forward jets F30:
p_T > 30 GeV, 2.4 < |η| < 4.5, non-b-tagged

DATA DRIVEN BACKGROUND ESTIMATION

- define different CR and calculate a scaling factor S = $(N^{CR} - N^{CR}_{other})/(N^{CR}_{B,MC})$
- number of SR events: $N^{SR}_{B} = \left[\frac{N^{CR} - N^{CR}_{other}}{N^{CR}_{B,MC}}\right] \times \left(N^{SR}_{B,MC}\right)$

SR	SR-$m_{T2,90}$	SR-$m_{T2,110}$	SR-WWa	SR-WWb	SR-WWc
***WW* CR**					
lepton flavour	$e^{\pm}\mu^{\mp}$		$e^{\pm}\mu^{\mp}$		
$m_{\ell\ell}$	Z veto		—		
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_{T}^{miss,rel}$	> 40 GeV		< 70 GeV	—	
m_{T2}	50–90 GeV		—	< 90 GeV	
Top CR					
b-tagged jets	≥ 1		≥ 1		
signal jets	≥ 2		≥ 1		
lepton flavour	$e^{+}e^{-}, \mu^{+}\mu^{-}, e^{\pm}\mu^{\mp}$		$e^{\pm}\mu^{\mp}$		
$m_{\ell\ell}$	Z veto		< 80 GeV	< 130 GeV	
$p_{T,\ell\ell}$	—		> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_{T}^{miss,rel}$	> 40 GeV		> 70 GeV	—	
m_{T2}	—		—	> 90 GeV	> 100 GeV
***ZV* CR**					
lepton flavour	$e^{+}e^{-}, \mu^{+}\mu^{-}$		not defined		
$m_{\ell\ell}$	Z select				
$E_{T}^{miss,rel}$	> 40 GeV				
m_{T2}	> 90 GeV	> 110 GeV			

DESY

HISTFITTER

$$\mathcal{L}(\mu, \vec{\theta}) = P(N|\mu_{\mathrm{SIG}} s + \sum_{m}^{N_{\mathrm{bkg}}} b_m) \times N(\tilde{\theta}|\theta)$$

HISTFITTER

$$CL_s \equiv \frac{p_{S+BG}}{1 - p_{BG}}$$

For each signal region, a simultaneous likelihood fit [74] to the signal regions and the control regions is performed to normalise the top, WW and ZV (in the case of SR-m_{T2} only) background estimates and to determine or limit a potential signal contribution. The inputs to the fit are:

- For each control region, the observed number of events in the top, WW and ZV and the expected background estimate from simulation.
- The expected background in the signal regions for all processes determined from simulation.
- The fake-lepton background estimate in the signal regions as described in Section 6.4.

The event count in each control and signal region is treated with a Poisson probability density function. The systematic uncertainties on the expected background yields are included as nuisance parameters, constrained to be Gaussian with a width determined from the size of the uncertainty. Correlations in the nuisance parameters between the control and signal regions, and background processes are taken into account. The Poisson probability density function also includes free parameters to scale the expected contribution from top, WW and, where relevant, ZV in the control regions. A likelihood is formed as the product of these probability density functions and the constraints on the nuisance parameters. The free parameters and the nuisance parameters are adjusted to maximise the likelihood.

DATA-MC SAMPLES

- **Data**:

  full 8 TeV 2012 corresponding to 20.3 fb^{-1}

- **MC**:

  TOP: ttbar with MC@NLO (Powheg/Alpgen for cross checks)

  ttbar + boson with Madgraph (LO xsection scaled to NLO via k-factor)

  WW: WW w/ Powheg (Sherpa for cross checks), WW via gluon fusion w/ gg2WW

  Z+jets: Alpgen+Pythia for mll> 60 GeV and Sherpa (mll<60GeV)

  Z+V: WZ/ZZ w/ Powheg (Sherpa for cross checks), ZZ via gluon fusion w/ gg2ZZ

  W+jets: w/ Sherpa (used only in the MC-only results)

  Fakes: Data Driven (used in the final result)

  VVV: WWW, WWZ and ZZZ w/ Madgraph

  Higgs: Associated production modes (WH, ZH) w/ Pythia and the VBF, ggF w/ Powheg

- **SUSY Signal:**

  All signal samples are generated w/ Herwig++, cross-sections are computed with prospino

TRIGGER

trigger	L1	Offline p_T Threshold
EF_2e12Tvh_loose1	L1_2EM10VH	$p_T(e_1) > 14$ GeV, $p_T(e_2) > 14$ GeV
EF_e24vh_medium1_e7_medium1	L1_EM18VH	$p_T(e_1) > 25$ GeV, $p_T(e_2) > 8$ GeV
EF_2mu13	L1_2MU10	$p_T(\mu_1) > 14$ GeV, $p_T(\mu_2) > 14$ GeV
EF_mu18_tight_mu8_EFFS	L1_MU15	$p_T(\mu_1) > 18$ GeV, $p_T(\mu_2) > 8$ GeV
EF_e12Tvh_medium1_mu8	L1_EM10VH_MU6	$p_T(e) > 14$ GeV, $p_T(\mu) > 8$ GeV
EF_mu18_tight_e7_medium1	L1_MU15	$p_T(e) > 8$ GeV, $p_T(\mu) > 18$ GeV

- used symmetric and asymmetric di-lepton trigger
- 2-D parameter phase space defined by the p_T of the two leptons is split into several regions
- most efficient trigger requirement is used in each region
- no trigger simulation is used, trigger weights are applied to MC
- dimuon trigger: efficiency 52% (77%) - 80% (98%) in barrel region (end-caps), lowest efficiency from symmetric trigger
- dielectron trigger: efficiency 85-98%, lowest efficiency from asymmetric trigger in end-cap region
- el-muon trigger: efficiency 65%-82%

SYSTEMATICS

- The following sources of systematic uncertainty are considered (where applicable).

- Luminosity
- Cross section
- Jet Energy Scale
- Jet Energy Resolution
- Trigger Reweighting
- b-tag Efficiency
- Generator
- Parton Shower
- PDF

- Electron Efficiency
- Electron Energy Resolution
- Electron Energy Scale
- Muon Efficiency
- Muon Energy Resolution
- Muon Energy Scale
- Muon MS Momentum
- Muon ID Momentum