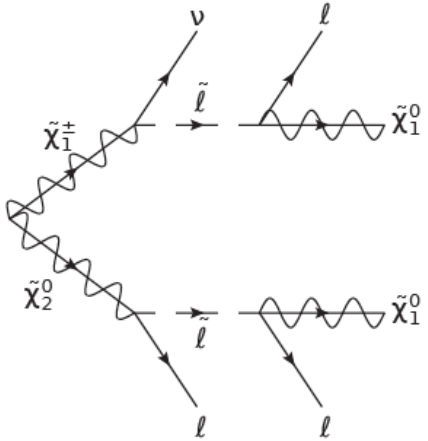
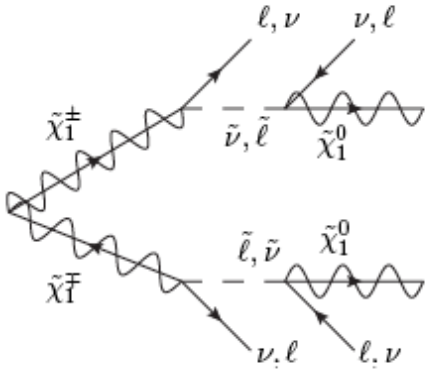
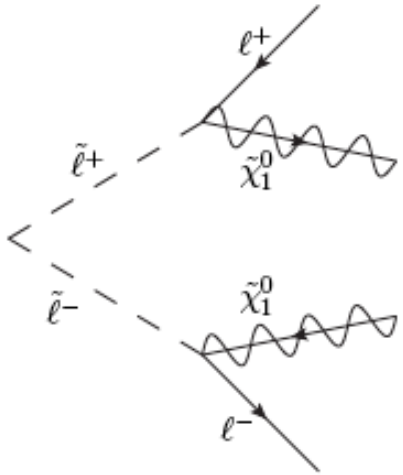
Searches for direct supersymmetric gaugino and slepton pair production in final states with leptons with the ATLAS detector







Janet Dietrich
DESY

LHC discussion
21.01.2013

HELMHOLTZ ASSOCIATION

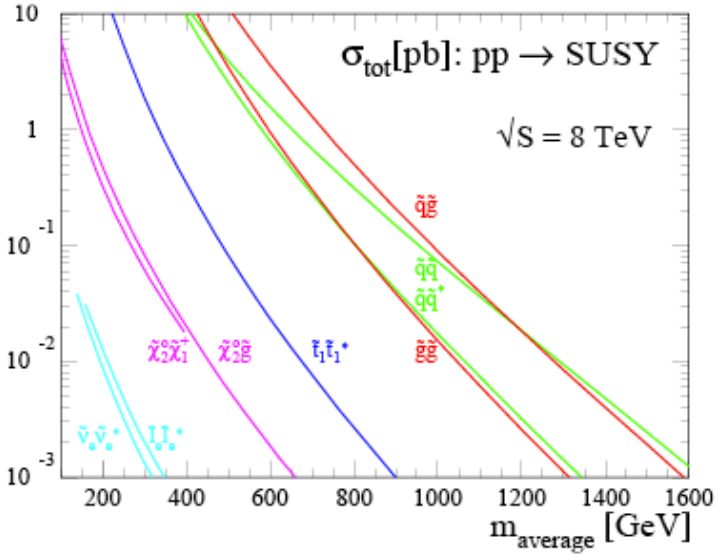
DESY

Motivation

- if coloured SUSY particles ($\tilde{g}$, $\tilde{q}$) are very massive while non-coloured SUSY particles are light
- → weak gauginos (charginos $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^{\pm}$ or neutralinos $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\chi}_3^0$, $\tilde{\chi}_4^0$) and sleptons ĩ may dominate the SUSY production at the LHC
- limits on squark/gluino masses are being pushed higher and naturalness favours gaugino masses around 100 GeV

search for events with missing transverse energy E_T^{miss} and leptons (electrons and muons)

Present the results for the 2 leptons analysis (7TeV 4.7 fb^{-1} arXiv: 1208.2884, PLB 718 (2013) 879) and
3 lepton analysis (8TeV 13fb^{-1} ATLAS-CONF-2012-154)



2(3)-LEPTON SUSY SEARCHES

Looking for events with exactly 2(3) leptons (e or μ) (+ jets) and missing transverse energy 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}

- **transverse mass m_T**: $$m_{\mathrm{T}} = \sqrt{2 \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot p_{\mathrm{T}}^{\ell} \cdot (1 - \cos\Delta\phi_{\ell, E_{\mathrm{T}}^{\mathrm{miss}}})}$$

  3lepton: use lepton not included in lepton pair with invariant mass closest to nominal Z-boson mass

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

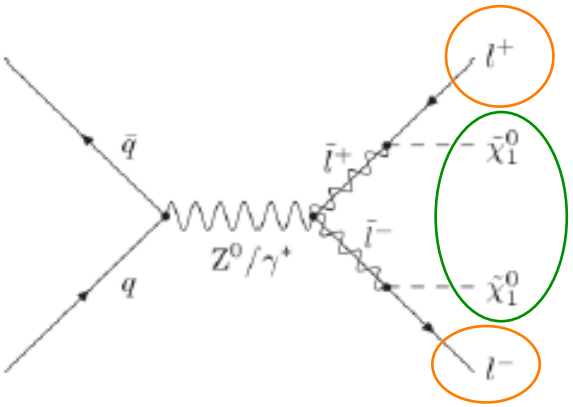
  based on transverse mass

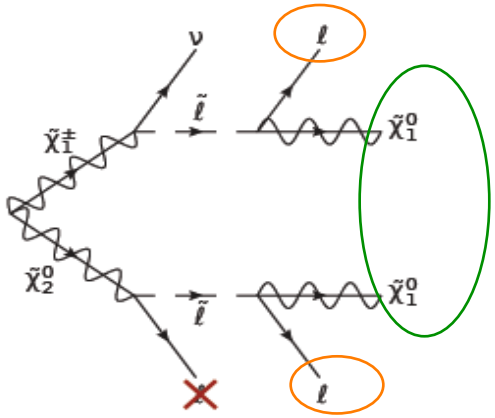
defined for events with pair-produced identical particles, where each decays into 2 particles out of which ones goes undetected

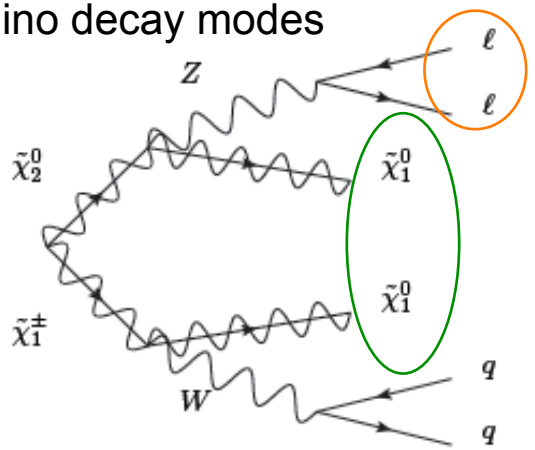
DESY

2-LEPTON SUSY SEARCHES

- define same charge (SS) and opposite charge (OS) signal regions depending on the SUSY process
- four SR are optimized for slepton production and different gaugino decay modes







2 lepton opposite charge
2 lepton OS with
m(l,l)>20 GeV
jet veto
Z mass veto
$E_T^{miss, rel}$ > 50 GeV
stransverse mass
m_{T2}> 90 GeV

m_{T2}

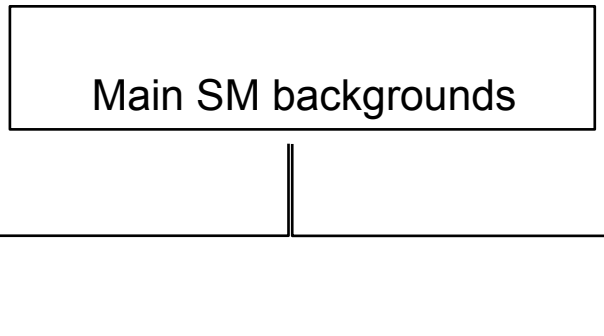
3 lepton final state
1 lepton not reconstr./out of acceptance
2lepton + OS or SS with
m(l,l)>20 GeV
jet veto
Z mass veto in OS
$E_T^{miss, rel}$ > 100 GeV

OS jveto/SS jveto

2 lepton opposite charge
2 lepton OS with
m(l,l)>20 GeV
≥ 2 jets
Z mass veto
$E_T^{miss, rel}$ > 50 GeV
bjet + top veto

2jets

SM BACKGROUNDS- 2 LEPTON



OS signal regions

“real” SM backgrounds:
Fully leptonic top-antitop pairs, single top, Z/γ* + jets, diboson (WW, WZ, ZZ)

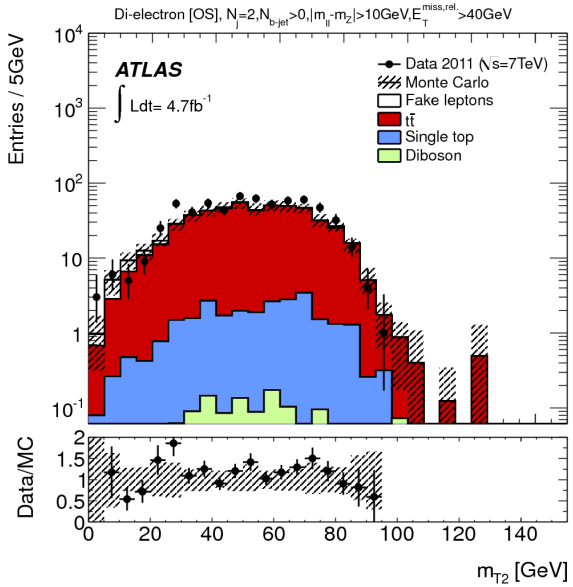
retrieved from data in dedicated control regions by normalizing MC to data and extrapolation to the SR based on MC derived transfer factors
or using MC simulation only
(WW in SR: m_{T2})

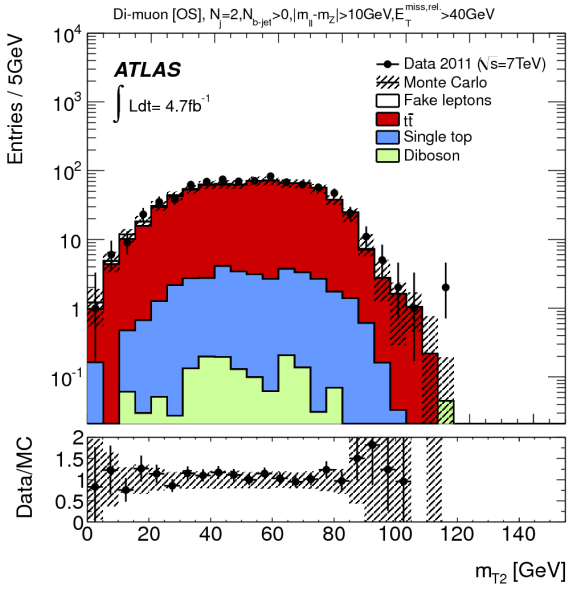
SS signal regions

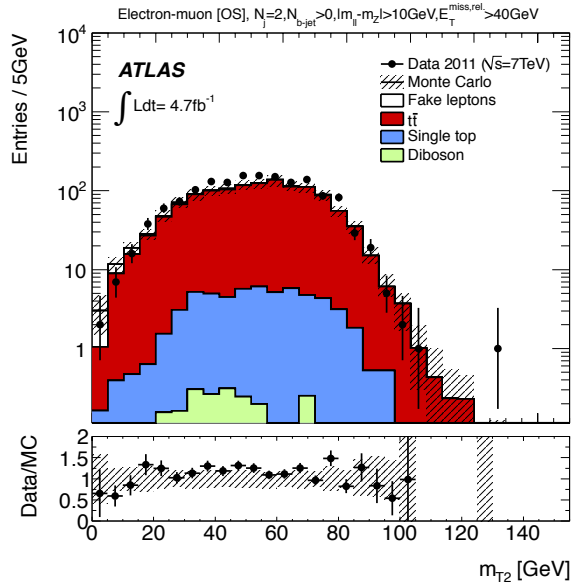
“fake” (or reducible) SM backgrounds from multi-jets /W+jets:

consists of events with non-prompt leptons originating from jets or conversion estimated with data-driven “matrix method”
→categorize events according to lepton id criteria, use efficiency /fake rate to obtain the fake contribution in SR

SM BACKGROUNDS- 2 LEPTON t-tbar/single top







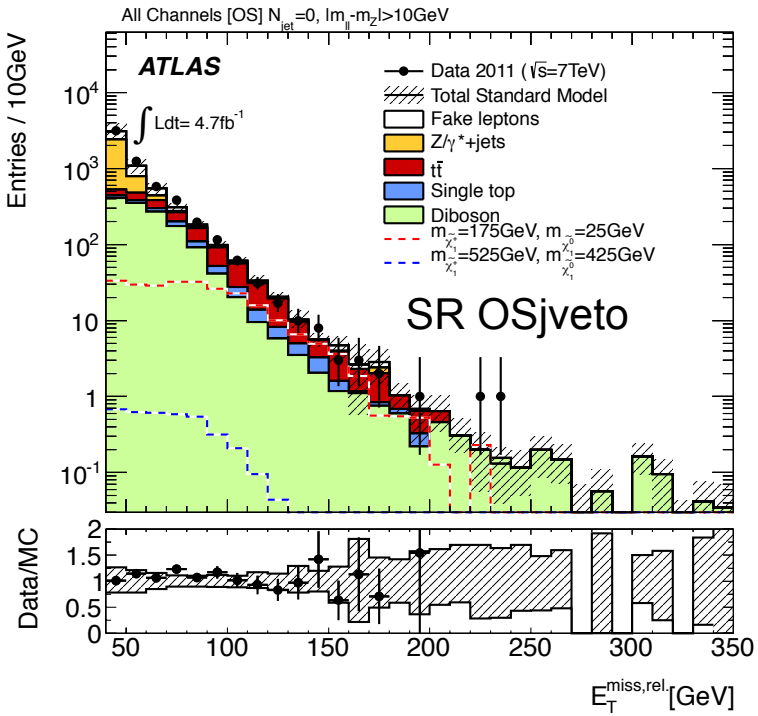
top CR:
≥ 2 signal jets + ≥ 1 b-tagged jet +$E_T^{miss,\,rel}$ cut

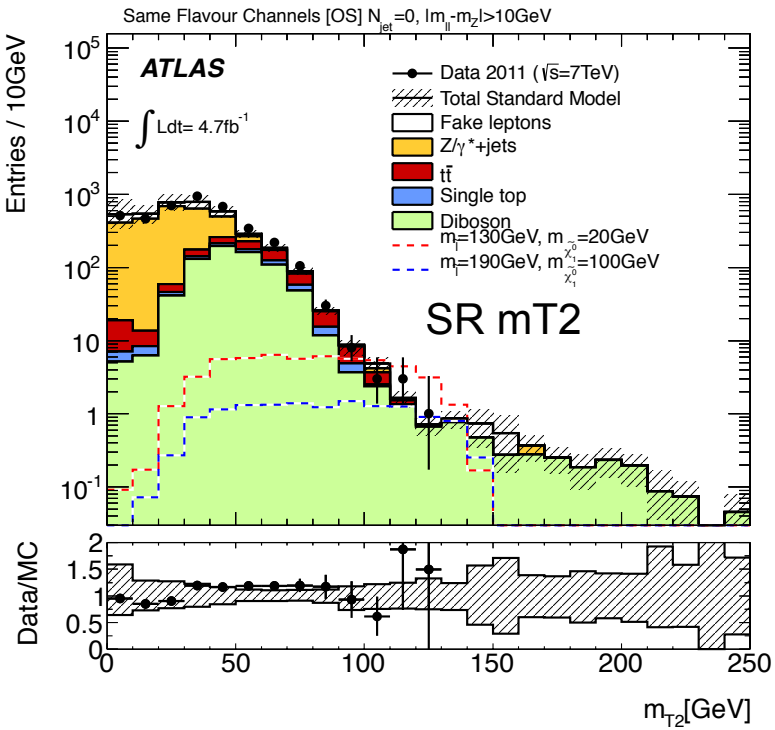
data driven estimate using different CRs:

$$N_{top}^{SR} = \left(N_{data}^{CR} - N_{non-top\ MC}\right) \times \left(\frac{N_{top}^{SR}}{N_{top}^{CR}}\right)_{MC} \times SF_T$$

SF corrects differences in jet-veto efficiencies data and MC

RESULTS -2 Lepton 7TeV 4.7 fb^{-1}





No significant excess is found in any SR!

Signal Region	Background	Data
m_{T2}	$32.8 \pm 3.2 \pm 6.3$	24
OSjveto	$161.7 \pm 6.7 \pm 30.8$	139
SSjveto	$11.0 \pm 1.5 \pm 3.9$	9
2jets	$65.5 \pm 4.0 \pm 31.8$	78

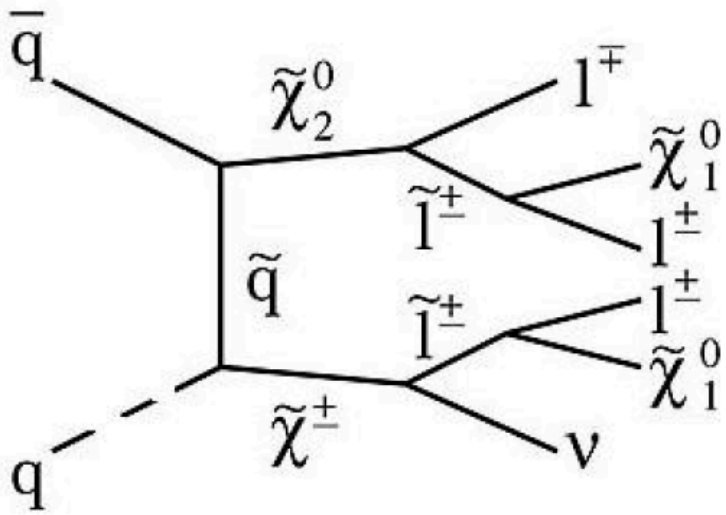
2011 Data, $\sqrt{s} = 7$ TeV

$\int \mathcal{L} dt = 4.7$ fb^{-1}

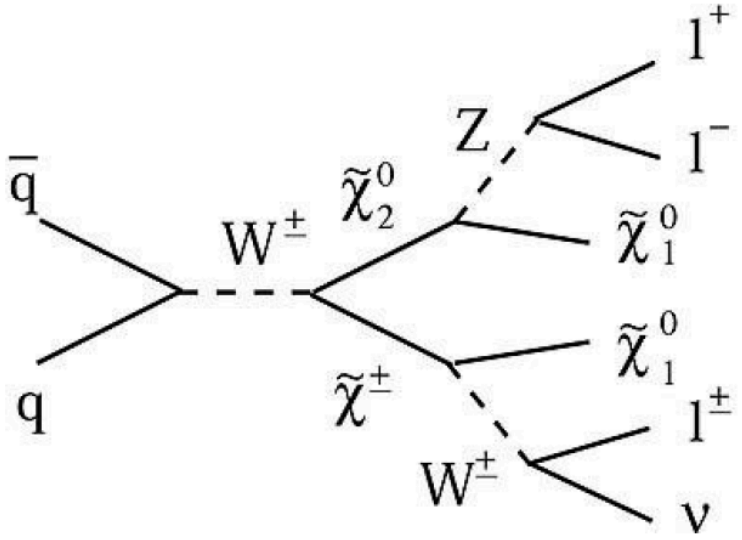
arXiv:1208.2884

3-LEPTON SUSY SEARCHES

- require exactly three leptons with at least one pair of same-flavour opposite sign (SFOS) with m_{SFOS}> 12 GeV (to suppress background from low-mass resonances)



neutralino decay via intermediate sleptons or off-shell Z-bosons



neutralino decay via on-shell Z-bosons with large E_T^{miss}

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

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

- note: no SR defined addressing the scenarios with neutralino decaying via on-shell Z boson with intermediate E_T^{miss}

3-LEPTON SUSY SEARCHES

> require exactly three leptons of same-flavour opposite sign (SFOS) with m_{SFOS}> 12 GeV

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

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

"Z-depleted" regions
2 SRs with similar cuts – SR1b with tighter cuts to enhance sensitivity for large mass splitting scenarios between heavy gauginos and LSP

"Z-enriched" region
neutralino decay via on-shell Z-bosons

3 leptons opposite charge

Z mass veto
E_T^{miss} > 75 GeV
no b-tagged jets

no transverse mass m_T cut	m_T> 110 GeV
lepton p_T> 10 GeV	3 lepton p_T> 30 GeV
SR1a	SR1b

3 lepton opposite charge

Z-candidate: $|m_{SFOS}-m_Z| < 10$ GeV
E_T^{miss} > 120 GeV
any number of b-jets

m_T> 110 GeV → supress WZ

lepton p_T> 10 GeV

SR2

SM BACKGROUNDS- 3 LEPTON

- **“reducible” fake background**

  at least one fake object:

  lepton from semilept. decay of heavy-flavour quark, lepton from misidentified light-flavour quark or gluon jet (light-flavour) or electron from isolated photon conversion

  SM backgrounds: single- and pair-production of top-quark, WW or W/Z production in association with jets or photons

  dominant component: top-antitop pair production, Z + jets

  → determined with matrix method

SM BACKGROUNDS- 3 LEPTON

- **irreducible "real"** backgrounds:

  3 isolated "real" leptons in decay mode

  SM backgrounds:

  diboson (WZ, ZZ), triboson (WWW, ZZZ, ZWW) and top-antitop W/Z production

  → determined using MC approach

  → lepton/jet selection efficiencies are corrected to account differences with respect to data

  dominant component: WZ

  determination via semi-data driven approach

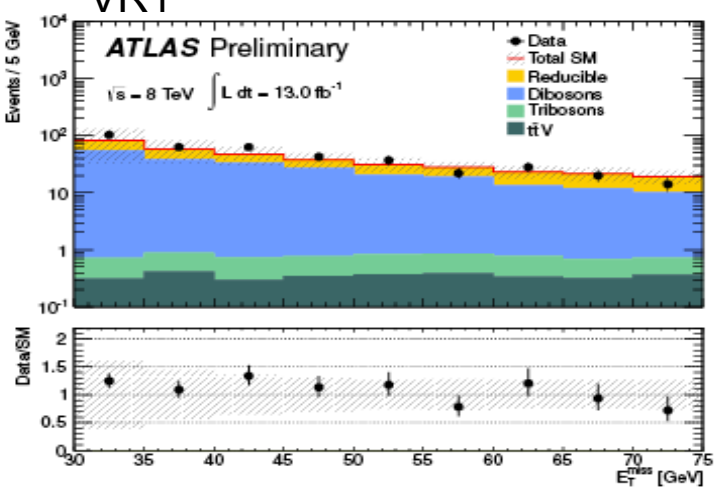
  → define a CR with high WZ purity (95%)

  and fit MC to data

  → test the background prediction in

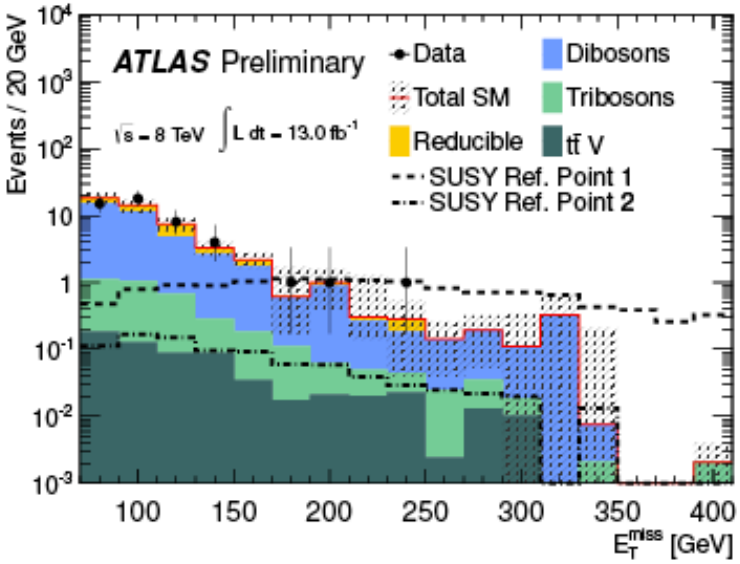
  validation regions (VR)

VR1

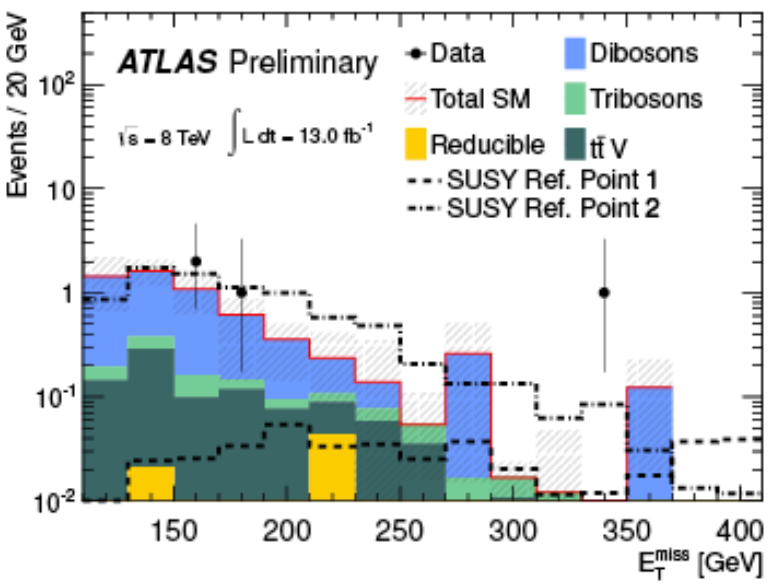


RESULTS -3 Lepton 8TeV 13 fb^{-1}

SR1a



SR2



No significant excess is found in any SR!

Signal Region	Background	Data
SR1a	50 ± 8	48
SR1b	3.1 ± 1.0	4
SR2	$6.1^{+2.0}_{-1.2}$	4

2012 Data, $\sqrt{s} = 8$ TeV
$\int \mathcal{L} dt = 13$ fb^{-1}
ATLAS-COM-CONF-2012-192

SUSY Ref. Point 1: $m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_1^0}, m_{\tilde{\ell}_L}, m_{\tilde{\chi}_1^0} = 500, 500, 250, 0\,\text{GeV}$

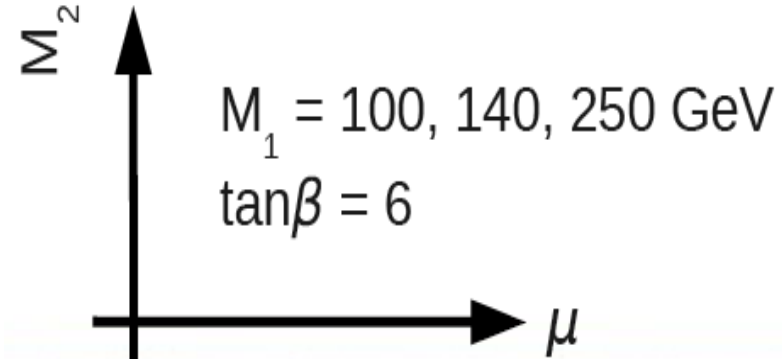
SUSY Ref. Point 2: $m_{\tilde{\chi}_1^\pm}, m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_1^0} = 250,\ 250,\ 0\,\text{GeV}$

SUSY MODELS

pMSSM models

- the mixing for the $\tilde{\chi}_i^{\pm}$ and $\tilde{\chi}_j^0$ depends on the gaugino masses M_1, M_2 + higgs mass parameter tanβ and ratio of vacuum exp. value μ of the Higgs doublets
- gluino/squark masses, left-handed sleptons > 2TeV
- right-handed sleptons (incl. staus) are assumed to be degenerated + mass set: $m_{\tilde{\ell}} = \frac{m_{\tilde{\chi}_1^0} + m_{\tilde{\chi}_2^0}}{2}$
- 3lep: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production via s-channel exchange of a virtual gauge boson
- grids are parameterized in M_1,M_2 and μ
- σ = 0.5pb…100 pb

(M_1 = 250 GeV, low M_2, μ)



SUSY MODELS

Simplified models

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

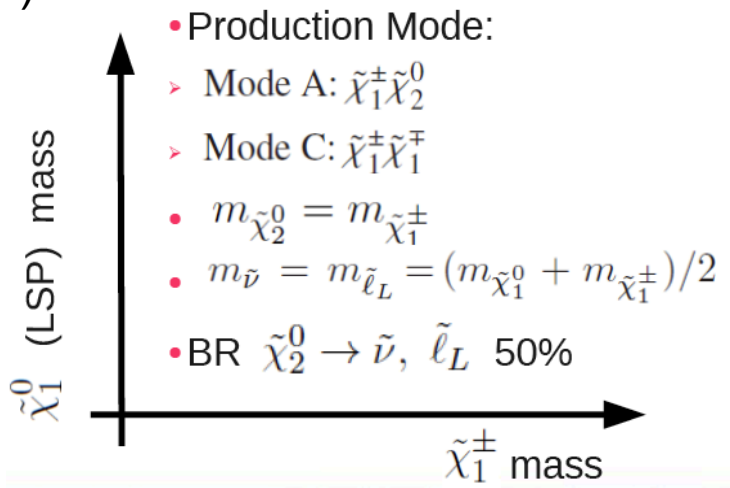
mass and decay modes of $\tilde{\chi}_1^{\pm}\ \tilde{\chi}_2^0, \tilde{\chi}_1^0,\ \tilde{\nu},\ \tilde{\ell}_L$

- $\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}$ are set to be wino-like and mass degenerated, $\tilde{\chi}_1^0$ set to be bino-like
- BR for decays in higgs bosons is set to 0
- σ = 3pb (chargino 50GeV)… < 0.2 pb (200GeV)
- decay modes:

- via sleptons (50% BR)

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

- via Z and W boson

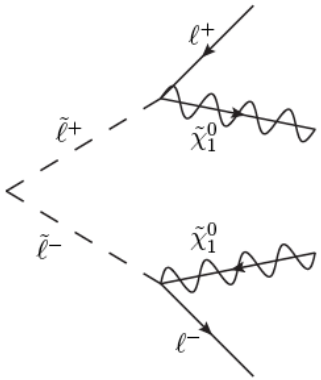


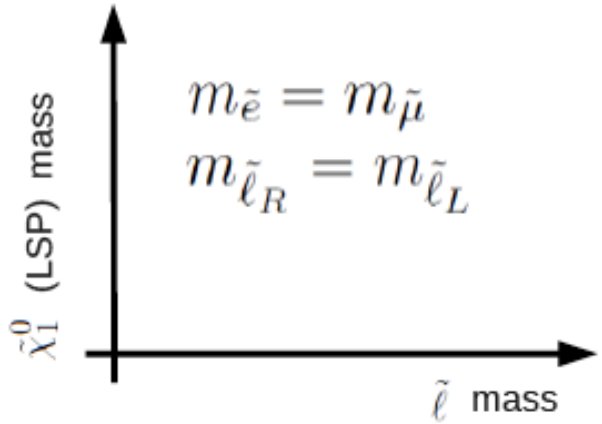
SUSY MODELS

Direct slepton models

- only for 2-lepton analyses
- direct production of sleptons, models based on pMSSM, but left-handed sleptons are included via: $m_{\tilde{\ell}_L} = m_{\tilde{\ell}_R}$
- 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 70-190 GeV

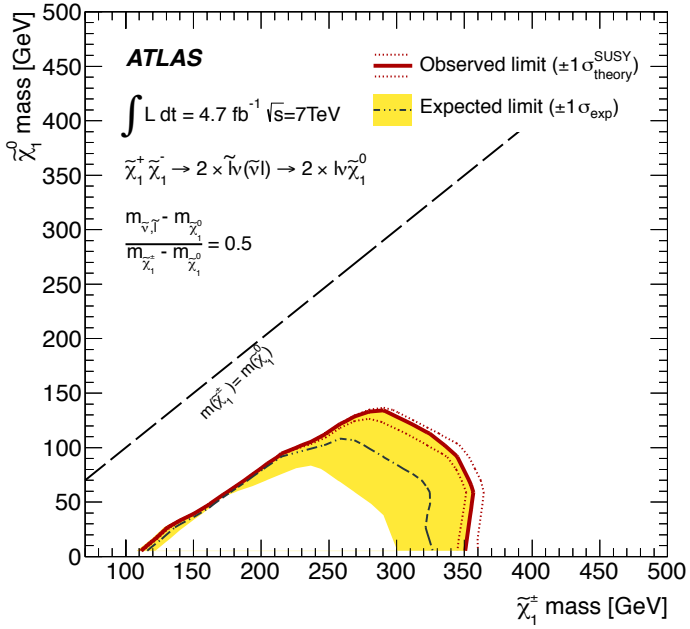
  $m_{\tilde{\ell}} > m_{\tilde{\chi}_1^0} + 30\ \mathrm{GeV}$
- $\tilde{\chi}_1^0$ is bino-like (μ large) and varied by scanning M_1 in range 20-160 GeV
- σ = 0.05…3.9 pb



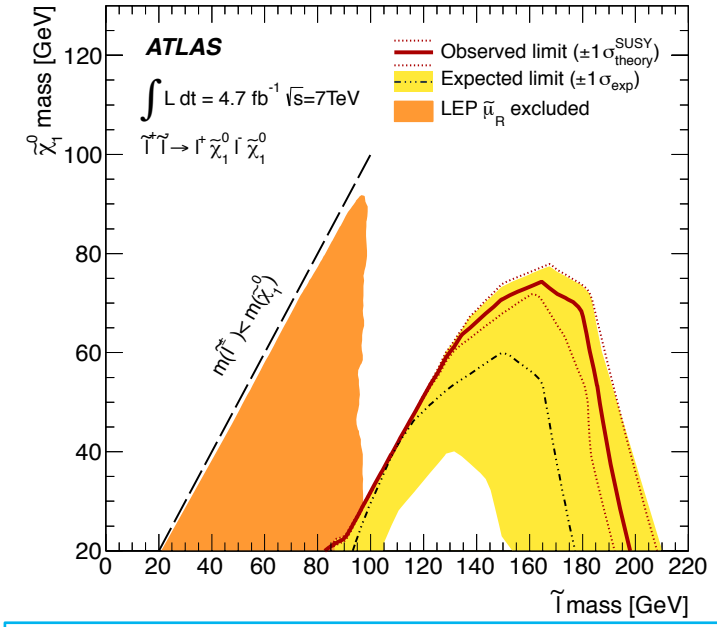


2 LEPTON EXCLUSION LIMITS

simplified model grid



slepton grid



- chargino masses between 110 and 330 GeV are excluded for a neutralino mass of 10 GeV
- best limit with SR m_{T2} ($\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$ prod. limits)
- earlier gaugino searches focused on $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production

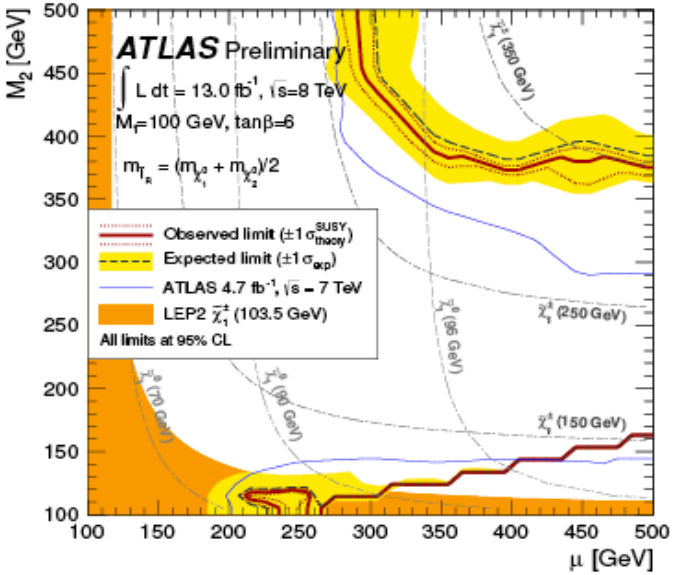
→new mass limit on chargino 1 mass independent of the neutralino 2 mass

- limits based on m_{T2} signal region results sensitivity decreases with m_{NLSP}-m_{LSP} need considerable mass gap to the LSP
- slepton masses between 90-185 GeV for 20 GeV neutralinos are excluded 60 GeV neutralino 1→ slepton masses between 150-170 GeV)

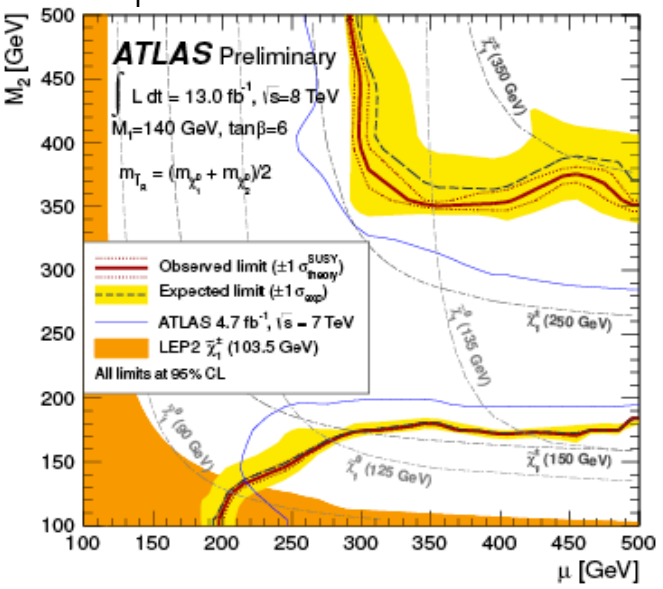
DESY

3 LEPTON EXCLUSION LIMITS

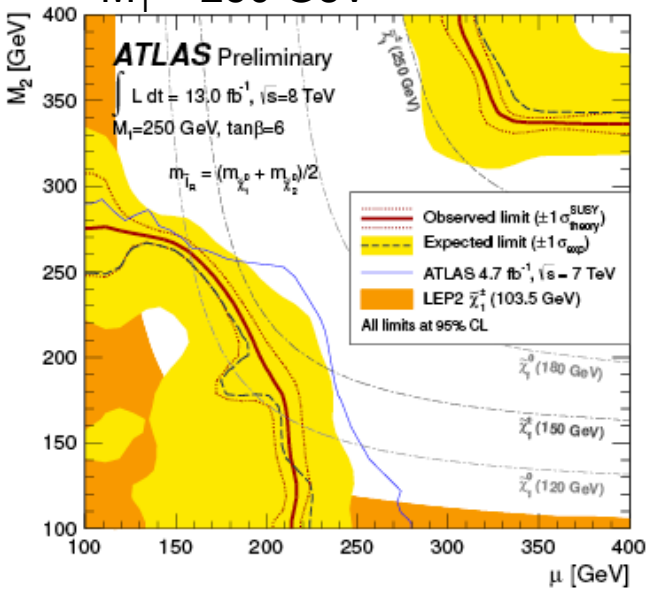
M_1 = 100 GeV



M_1 = 140 GeV



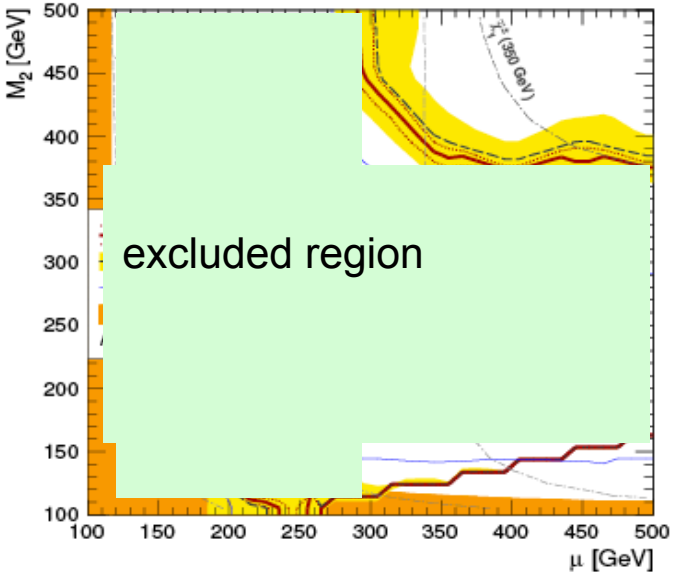
M_1 = 250 GeV



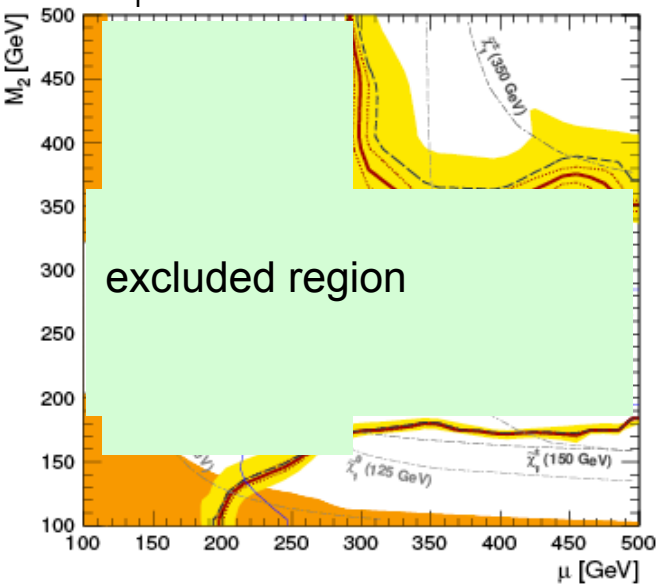
- 95% exclusion limits for chargino-neutralino production in the pMSSM grids for M_1= 100, 140 and 250 GeV, tanβ = 6 and light sleptons
- limits are optimized using in each grid point the CL values from the most sensitive SR
- SR1a/SR1b provide best sensitivity (targets small/large mass splitting between heavy gauginos and LSP)

3 LEPTON EXCLUSION LIMITS

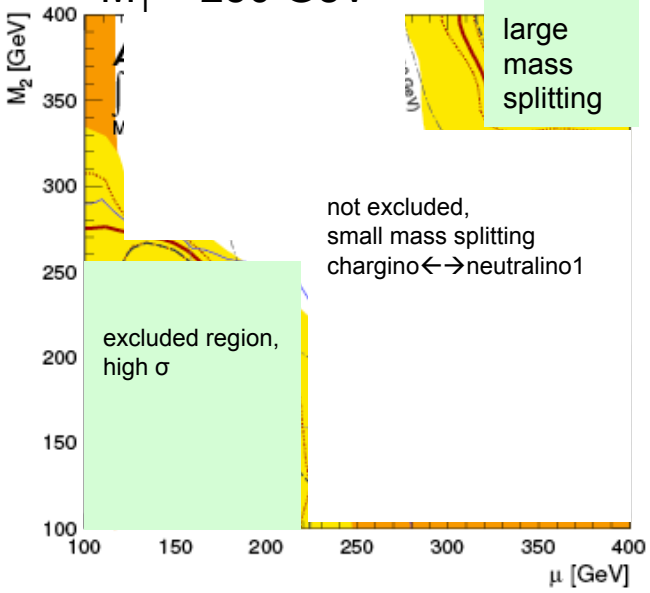
M_1 = 100 GeV



M_1 = 140 GeV



M_1 = 250 GeV

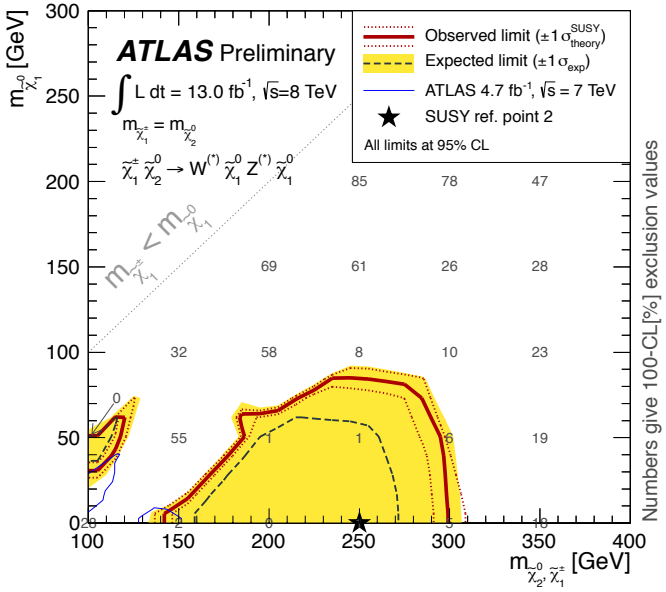


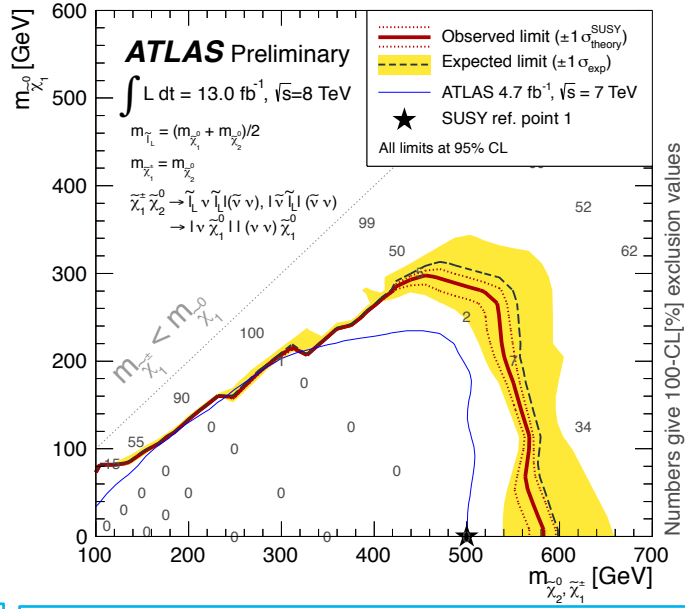
- for a defined M_1 SUSY prod. σ decrease with increasing M_2 and μ →less stringent limits at high values of M_2 and μ
- small mass splitting between $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$ at low M_2 and high μ → low analysis sensitivity
- if μ> M_2 ,M_1 : gaugino mass is independent of μ

  constant analysis sensitivity

3 LEPTON EXCLUSION LIMITS

95% CL limit contours for chargino and neutralino production in the simplified model scenario with intermediate gauge boson decay (left) and intermediate slepton decay (right)





- SR1a provides best sensitivity for small neutralino mass differences, SR2 is best for region far from diagonal (high E_T^{miss})
- degenerated chargino1 and neutralino 2 masses up to 300 GeV are excluded for large mass differences from neutralino1

- SR1b provides best sensitivity
- degenerated chargino1 and neutralino2 masses up to 580 GeV are excluded for large mass differences from the neutralino1(and light slepton masses)

★ SUSY reference point 2: $m_{\tilde{\chi}_1^\pm} = 250\,\text{GeV}$, $m_{\tilde{\chi}_2^0} = 250\,\text{GeV}$, $m_{\tilde{\chi}_1^0=0}\,\text{GeV}$.

SUMMARY

- dedicated searches for slepton/gaugino production in final states with 2/3 leptons have been performed with the ATLAS detector
- searches are complementary and optimized independently
- good agreement between ATLAS data and Standard Model prediction is observed, no significant excess was found
- ATLAS limits for slepton and chargino/neutralino production are set using full 2011 data (2-lepton search) and 13 fb^{-1} 2012 data (3-lepton search)
- new results will be published in the next months –including all 2012 data ($21fb^{-1}$)

DESY