Searches for electroweak production of supersymmetric neutralinos, charginos and sleptons with the ATLAS detector

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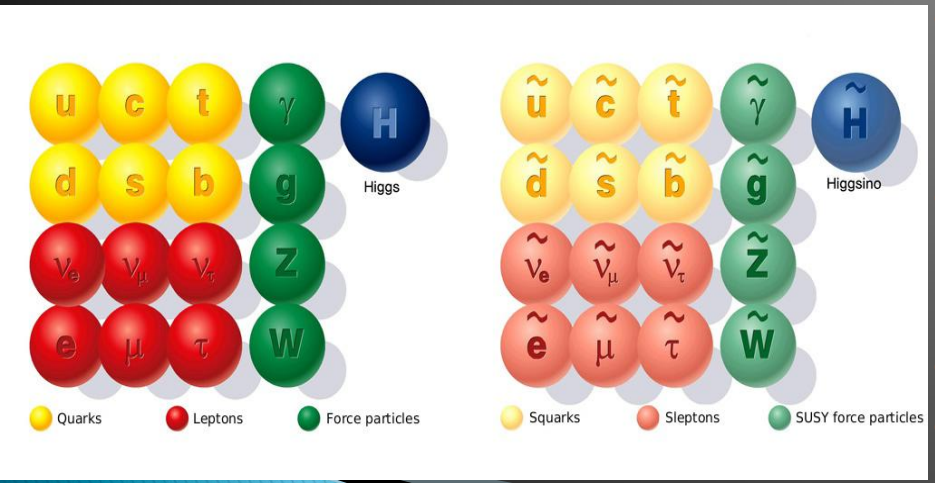
SuperSymmetry

- Is an extension of the Standard Model
  - Solution to the hierarchy problem
  - Gauge coupling unification
  - Can provide dark matter candidate
    - Provided R-parity is conserved



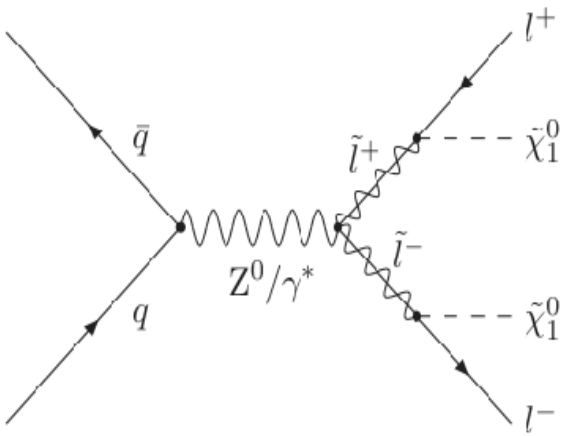
- Each SM particle gets a superpartner
  - Spin differs by half a unit
  - Heavier mass
- Higgs and EW gauge bosons -> gauginos: $(\tilde{\chi}_i^0, \tilde{\chi}_i^\pm)$
  - Neutralinos and Charginos
- Leptons -> Sleptons $(\tilde{\ell})$
- Quarks -> Squarks $(\tilde{q})$
- Gluons -> Gluinos $(\tilde{g})$

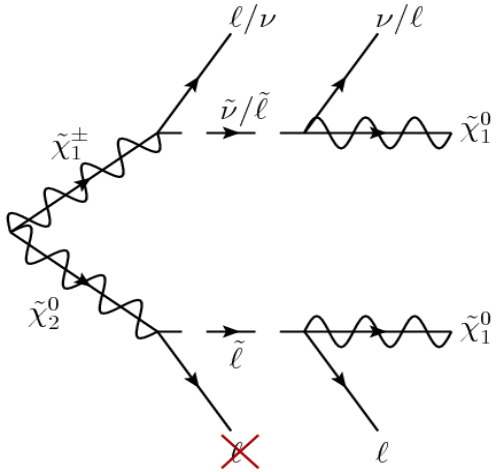
SUSY at LHC

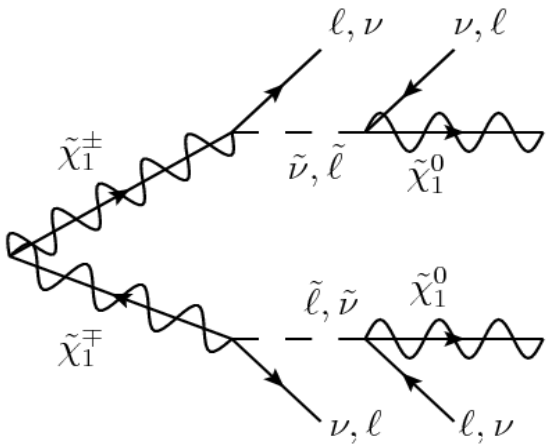
- SUSY particle production channels at LHC:
  - Strongly produced squarks and gluinos, which decays into final states with jets and E_T^{miss} (+leptons/fotons)
  - Electroweak production of neutralinos, charginos and sleptons which decays into final states with multiple leptons and E_T^{miss}
- Natural SUSY predicts light stops and gauginos to cancel divergences in higgs mass
- Charginos, neutralinos and possible sleptons might be light and their production rate sizable at the LHC

2-lepton signal regions

- Look for final states containing exactly 2 leptons and relative missing energy
- Four different signal regions are used
  - Cover both opposite-sign (OS) and same-sign (SS) final states







SR: m_{T2}

$E_T^{miss,rel} > 40$ GeV

Jet Veto

Z-Veto

$m_{T2} > 90$ GeV

SR: OSJVeto,SSJVeto

$E_T^{miss,rel} > 100$ GeV

Jet Veto

Z-Veto in OSJVeto

SR: 2Jets

$E_T^{miss,rel} > 50$ GeV

≥ 2 Jets

Z-Veto

Bjet and Top Veto

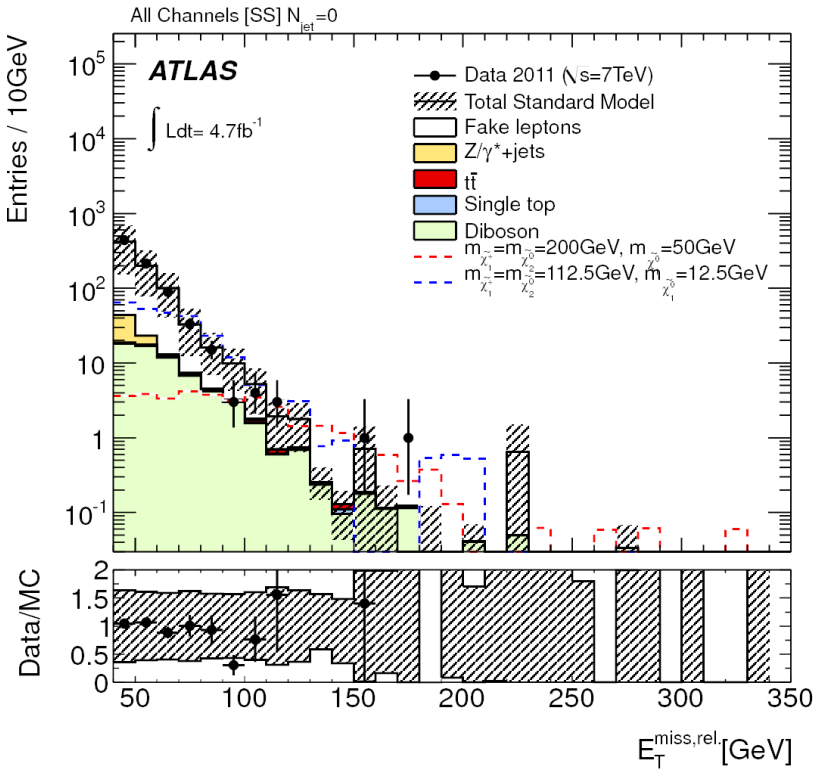
$$m_{T2}^2(\mu_N) \equiv \min_{\mathbf{p}_T^1 + \mathbf{p}_T^2 = \not{\mathbf{p}}_T} \left[\max\{m_T^2(\mathbf{p}_T^1, \mathbf{p}_T^a; \mu_N), m_T^2(\mathbf{p}_T^2, \mathbf{p}_T^b; \mu_N)\}\right]$$

CERN-PH-EP-2012-216

2-lepton results

- The results shown below are for 4.7 fb^{-1} collisions taken at $\sqrt{s} = 7$TeV

- The plot shows the relative missing energy distribution in the SR:SSJVeto channel prior to the final requirement:
$$E_T^{miss,rel} > 100\,\text{GeV}$$
- The main backgrounds are Z+Jets shown in yellow, dibosons (green), and top quark pairs (red) (all MC estimations) Charge flipping and fake leptons (white) (data driven)
- The data/SM agreement is very good

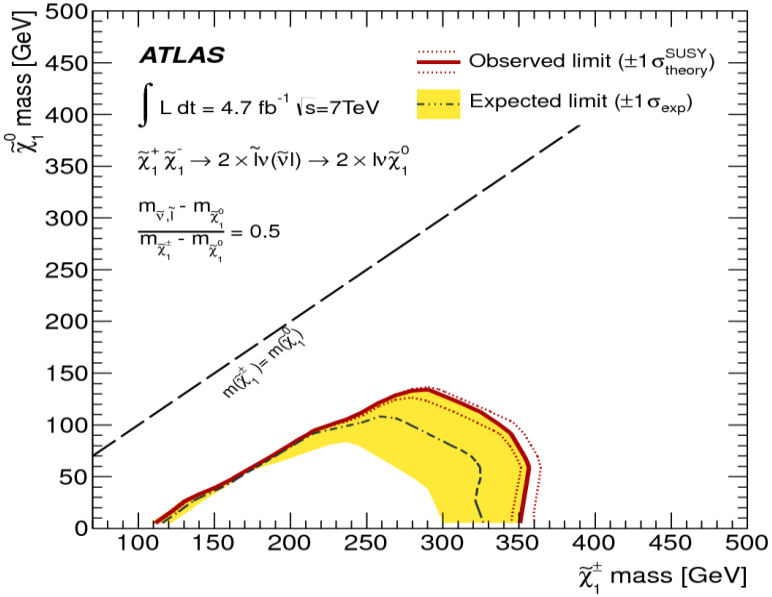


- Two signal points are illustrated
- The hatched band indicates the experimental uncertainties on the background expectation
- The bottom panel shows the distributions of data over SM background ratio.

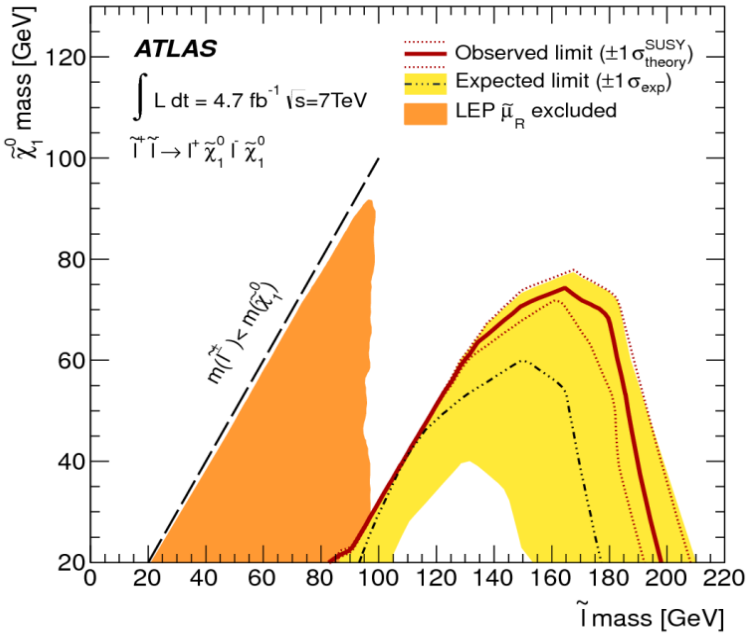
Selection	M_{T2}	OSJVeto	SSJVeto	2Jets
SM	32.8±3.2±6.3	161.7±6.7±30.8	11.0±1.5±3.9	65.5±4.0±31.8
DATA	24	139	9	78

2-lepton exclusion plots

- $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$ production in a simplified model (right)
  - Free parameters: $\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}, \tilde{l}, \tilde{\upsilon}$
  - All other sparticles decoupled
- Chargino masses between 110 and 340 GeV are excluded for a 10 GeV neutralino



- The dashed and solid lines show the 95% CLs expected and observed limits, respectively



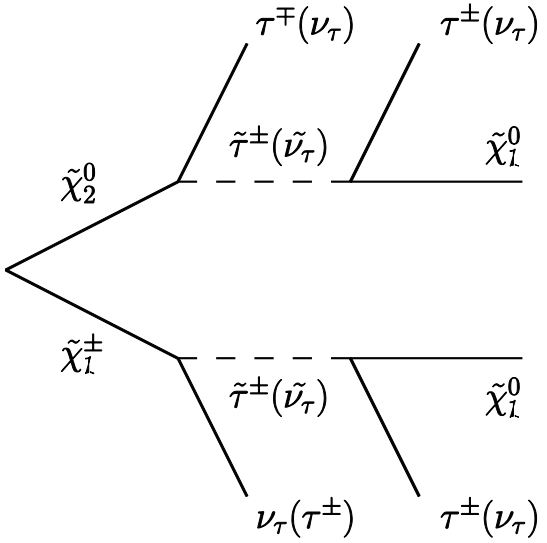
- $\tilde{\ell}^{\pm}$ pair production in the $m_{\tilde{\ell}} - m_{\chi_1^0}$ mass plane for direct slepton production (left)
  - Free parameters: $\tilde{\chi}_1^0, \tilde{l}$
  - All other sparticles decoupled
- $m_{\tilde{e}_L} = m_{\tilde{\mu}_L}$ and excluded between 85 and 195 GeV for a 20 GeV neutralino
- The LEP limit is a conservative limit on slepton pair production: if right-handed slepton masses are excluded, left-handed sleptons of equivalent masses are automatically excluded.

CERN-PH-EP-2012-216

Scenario with taus

- Look for events with at least two hadronically decaying taus and missing transverse momentum
  - At least one of the selected tau pairs have opposite sign
  - Events with additional light leptons are vetoed
  - Z-Veto (invariant mass of at least one of the OS tau pairs within 10 GeV of Z-mass)
- Two signal regions are used

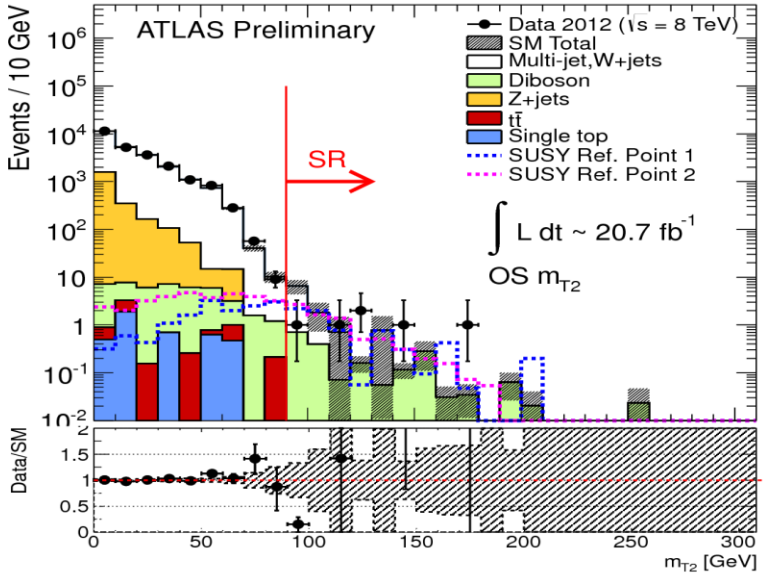
SR: m_{T2}	SR: m_{T2}-nobjet
Jet Veto	*b*-Jet Veto
$E_T^{miss} > 40\,\mathrm{GeV}$	$E_T^{miss} > 40\,\mathrm{GeV}$
$m_{T2} > 90$ GeV	$m_{T2} > 100$ GeV

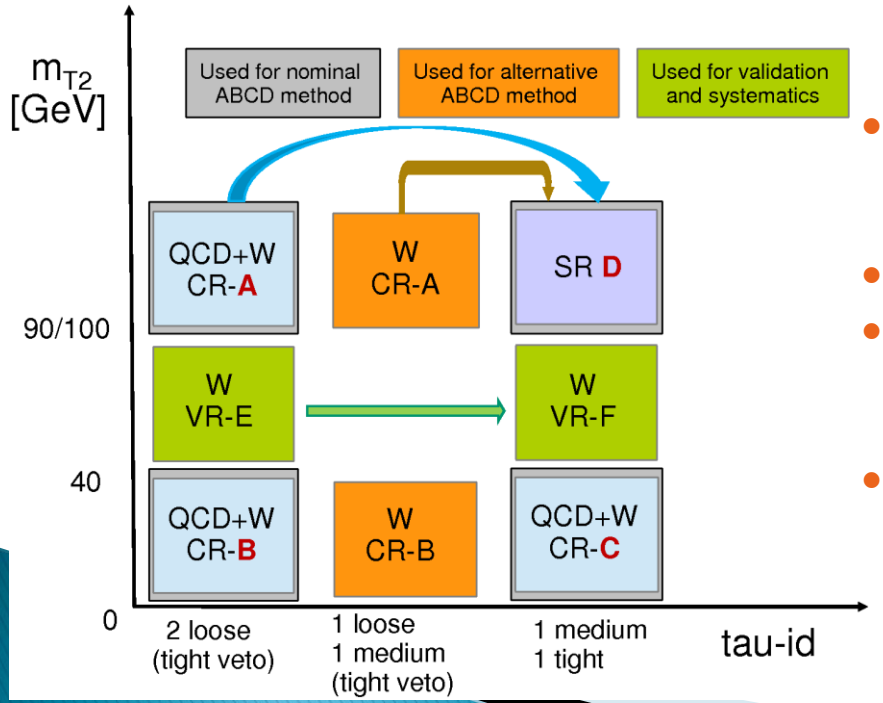


Tau results

- The results shown below are for 20.7 fb^{-1} collisions taken at $\sqrt{s} = 8$ TeV

- The right plot shows the m_{T2} distribution for the SR:m_{T2} channel.
- The main backgrounds are fake taus from W-jets and multi-jets shown in white followed by diboson events shown in green
- The data/SM agreement is very good

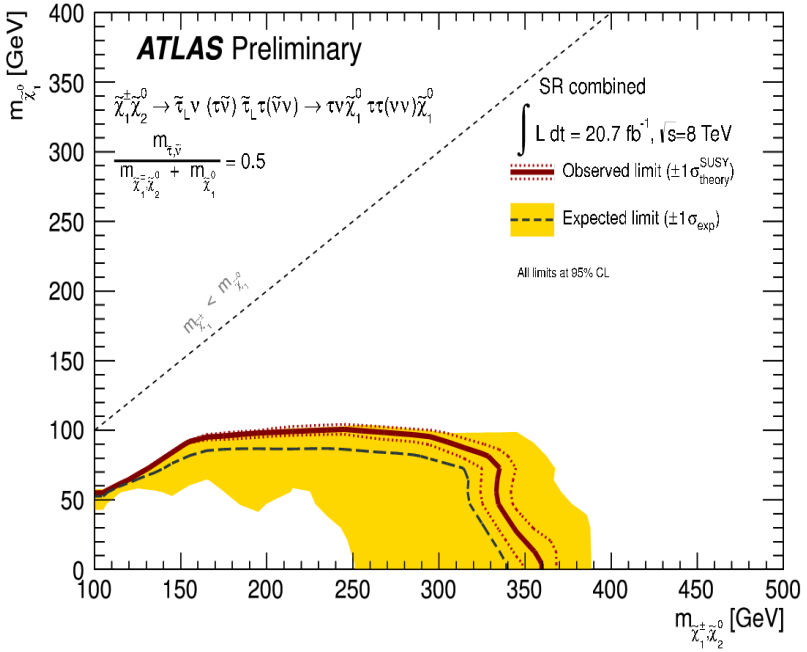


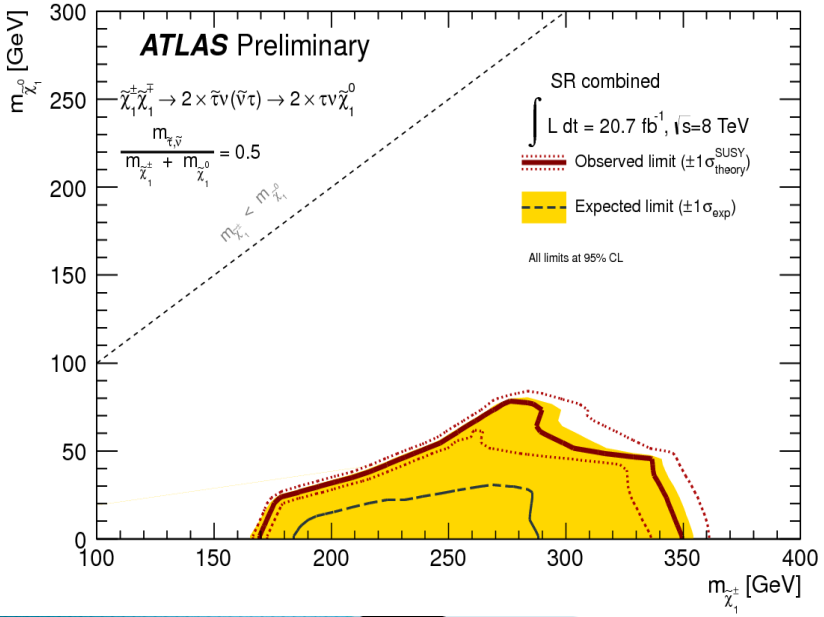


- The left figure shows the overview of the data driven method used to estimate the main backgrounds
- The parameters chosen are weakly correlated
- Ratio of the number of events in Control Region (CR) A and B equals that of SR D to CR C
- Number of SR events can therefore be calculated from number of CR A events normalized to the C and B ratio

Tau exclusions

- The right plot shows the limits from $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ production in a simplified model
- Chargino masses up to 330 (300) GeV are excluded for neutralino masses below 50 (100) GeV

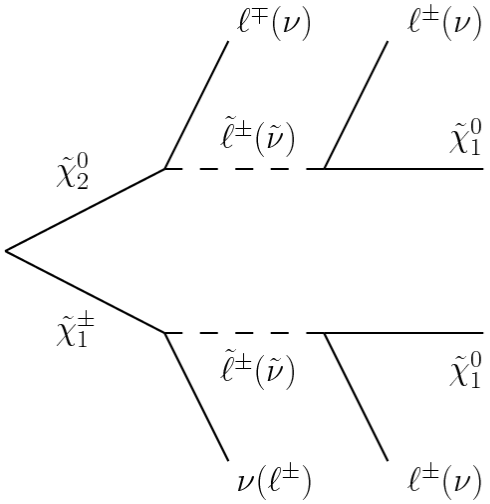


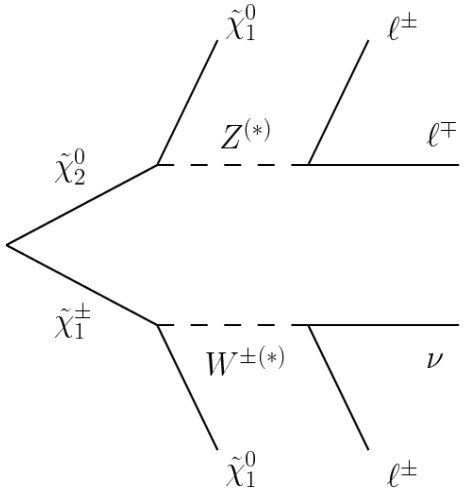


- The left plot shows the limits from $\tilde{\chi}_1^\mp \tilde{\chi}_1^\pm$ production in a simplified model
- Chargino masses up to 350 GeV are excluded for a massless neutralino

3-lepton signal regions

- $\widetilde{\chi}_2^0 \widetilde{\chi}_1^\pm$ production leading to 3 leptons and E_T^{miss}
- Selected events must contain exactly 3 signal leptons and at least one same-flavour opposite-sign lepton (SFOS) pair
  - Any SFOS pair must have an invariant mass > 12 GeV
- No B-jets with P_T > 20 GeV
- Six signal regions were used:
  - Three "Z-depleted" regions with no SFOS pair with and invariant mass within 10 GeV of the Z mass
  - Three "Z-enriched" regions with at least one SFOS pairs invariant mass within 10 GEV of the Z mass





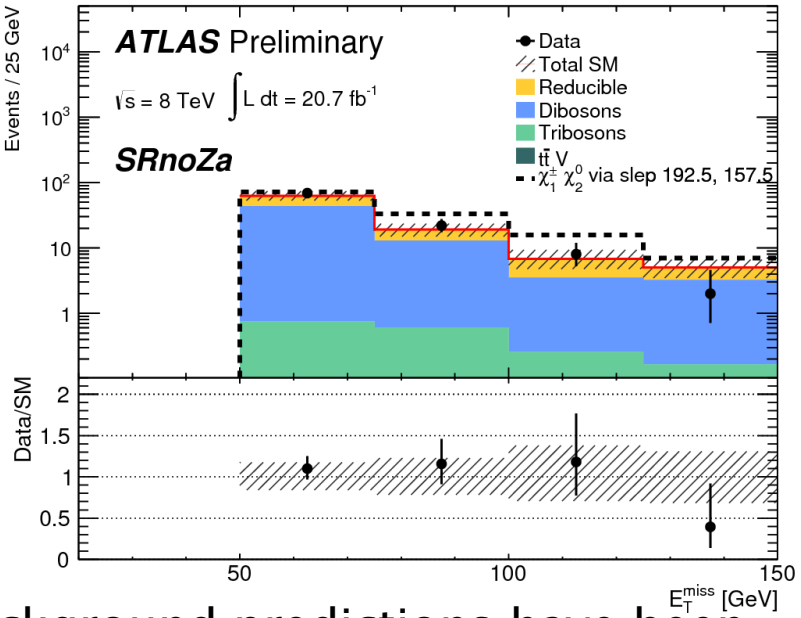
selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
M_{SFOS}	<60	60-81.2	<81.2 or >101.2	81.2-101.2	81.2-101.2	81.2-101.2
E_T miss	>50	>75	>75	75-120	75-120	>120
M_T	-	-	>110	<110	>110	>110
P_T 3rd l	>10	>10	>30	>10	>10	>10

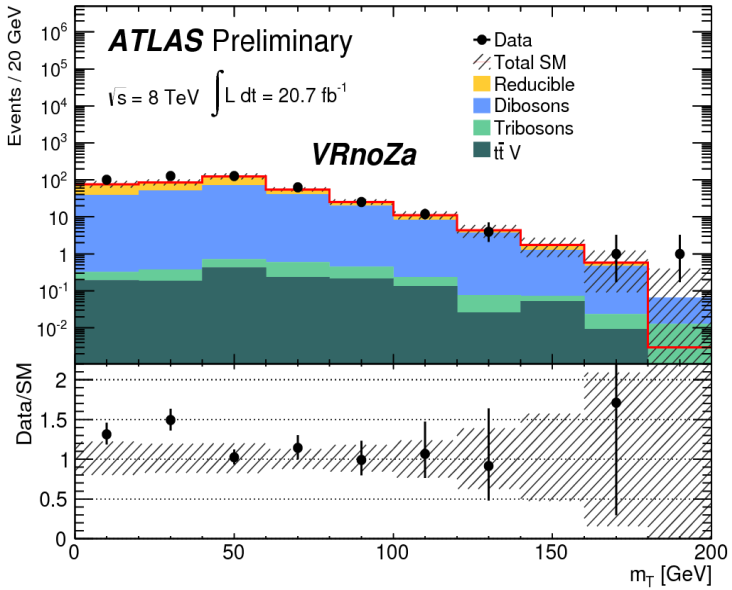
ATLAS-CONF-2013-035

3-lepton results

- The results shown below are for 20.7 fb^{-1} collisions taken at $\sqrt{s} = 8$ TeV

- The right plot shows the E_T^{miss} distribution for events in the SRnoZa channel
- The main backgrounds are irreducible WZ/gamma events and reducible ttbar events
- The data/SM agreement is very good
  - As seen in the table





- The background predictions have been tested in validation regions outside but close to the signal regions
- The left plot shows the m_T distribution for the VRnoZa channel
  - Dominated by WZ

selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
SM	96 ± 19	29 ± 6	4.4 ± 1.8	249 ±35	22 ± 5	6.3 ± 1.5
DATA	101	32	5	273	23	6

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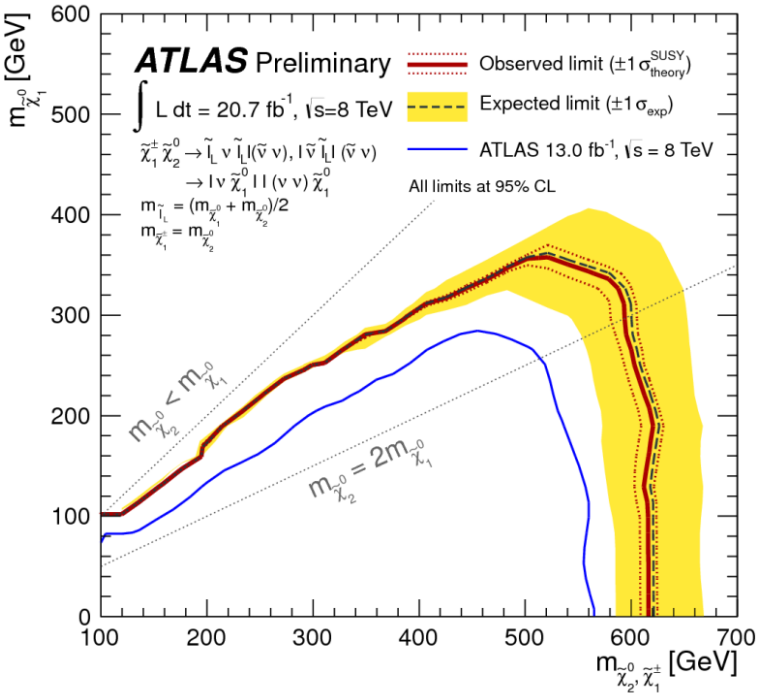
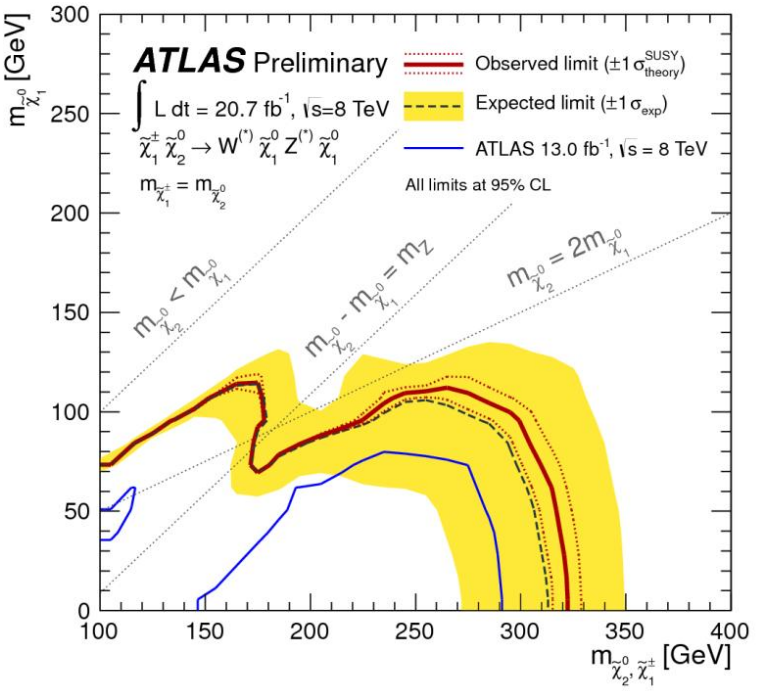
3-lepton exclusion plots

- The interpretation of the results have been made in a simplified model
- The plots show limits from $\tilde{\chi}_2^0 \tilde{\chi}_1^\pm$ production with (left) and without (right) sleptons.



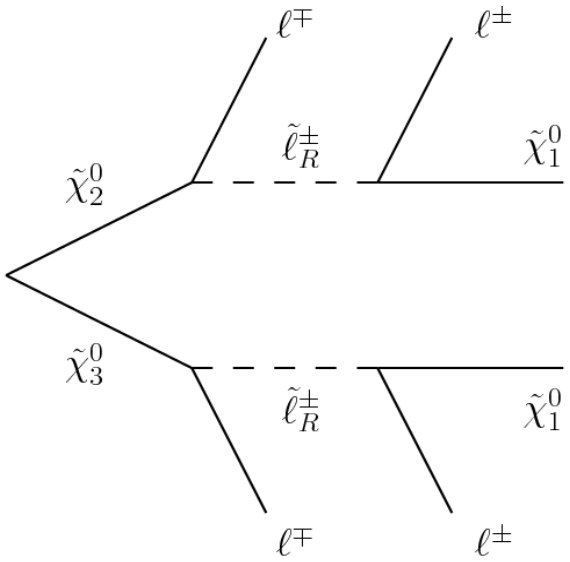


- Chargino masses up to 600 or 315 GeV are excluded if decaying through sleptons or decaying via gauge bosons to a massless lightest neutralino

4-lepton signal regions

- $\tilde{\chi}_2^0 \tilde{\chi}_3^0$ production leading to 4 leptons and E_T^{miss}
  - Only combinations with at least 3 light leptons are considered
  - Invariant mass of all light SFOS lepton pairs > 12 GeV
- Several signal regions are used for R-parity conserved/violated and gauge mediated SUSY
  - Will only cover the R-parity conserved channel here
  - Z veto defined as no light SFOS pairs with an invariant mass between 81.2 and 101.2 GeV

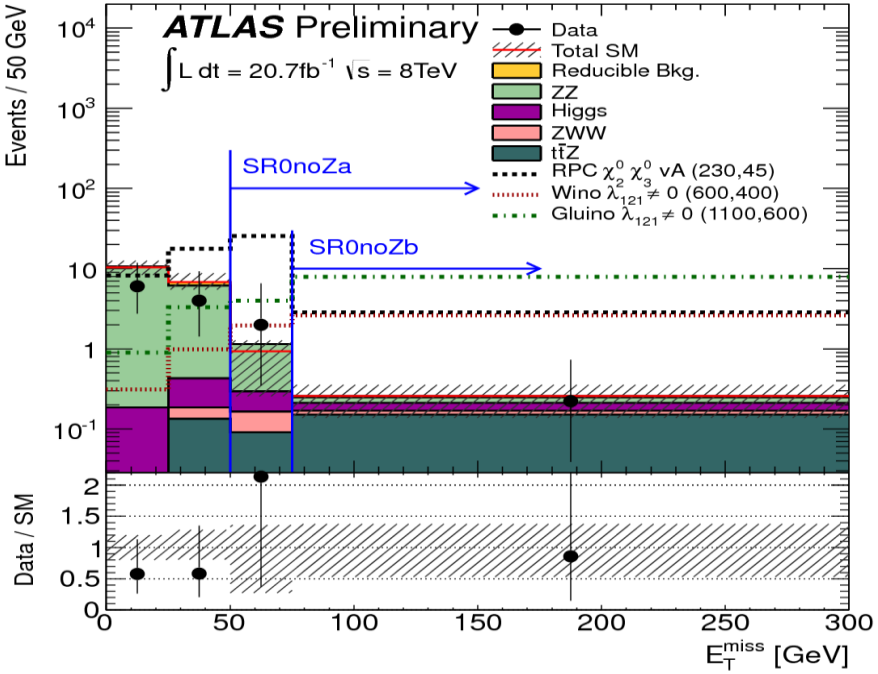
SR: SR0noZa
N(l =e,μ) ≥4
N(τ) ≥0
Z veto
$E_T^{miss} > 50\,GeV$

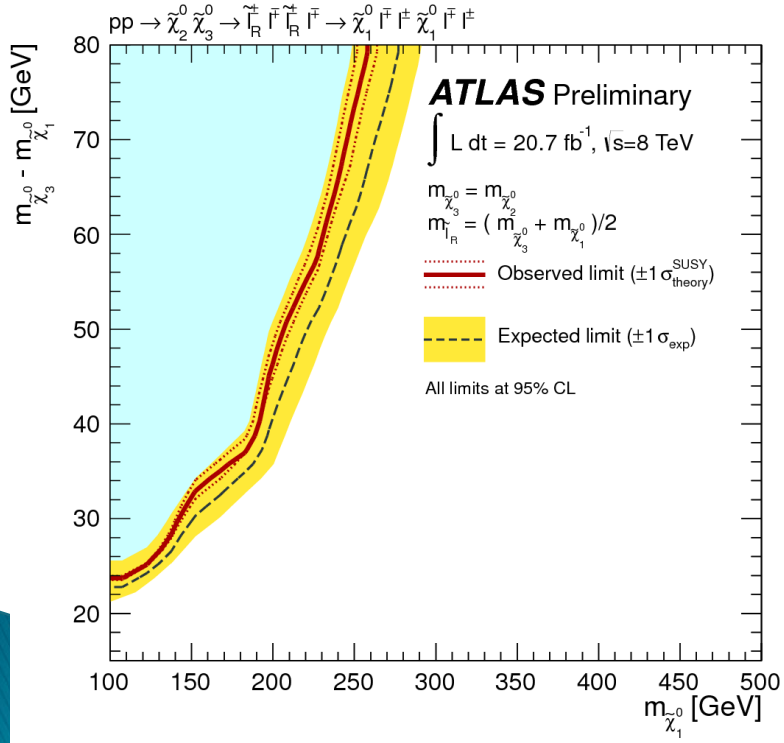


4-lepton results and exclusions

- The results shown below are for 20.7 fb^{-1} collisions taken at $\sqrt{s} = 8$ TeV

- The right plot shows the E_T^{miss} distribution
- The main background is ZZ events shown in green followed by Higgs events in purple
- The data/SM agreement is very good





- The left plot shows the limits from $\tilde{\chi}_2^0 \tilde{\chi}_3^0$ production in a simplified model
- $m_{\tilde{\chi}_1^0} < 250$ GeV is excluded for $\Delta m(\tilde{\chi}_3^0 \tilde{\chi}_1^0) \sim 80\,GeV$

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Summary

- Several searches for gaugino and slepton production with the ATLAS detector were presented
- 20.7 fb^{-1} at 8 TeV taken in 2012 were used except for the 2-lepton case which uses the 4.7 fb^{-1} at 7 TeV taken in 2011(soon to be updated)
- Good agreement between data and standard model predictions is observed in all signal regions
- In simplified models using 3-lepton results chargino/neutralino masses are excluded up to 600 or 315 GeV depending on the decay mode
- From the tau scenario chargino masses up to 330 GeV are excluded for a neutralino below 50 GeV

Backup Slides

$E_T^{miss,rel}$ and m_T

- The relative missing transverse energy $E_T^{miss,rel}$ is determined by finding the $\Delta\phi$ between the E_T^{miss} and the closest signal electron, muon or jet.
- The idea is to reduce the impact of events where an object is badly reconstructed, such that it is aligned with the E_T^{miss}

$$E_T^{miss,rel} = \begin{cases} E_T^{miss} & \text{if } \Delta\phi_{l,j} \geq \pi/2 \\ E_T^{miss} \times \sin\Delta\phi_{l,j} & \text{if } \Delta\phi_{l,j} < \pi/2 \end{cases}$$

- The transverse mass m_T is defined as the transverse mass in the plane formed by the and the lepton not belonging to the SFOS pair that forms the best Z-candidate.

$$m_T = \sqrt{2 \cdot E_T^{miss} \cdot p_T^l \cdot (1 - \cos\Delta\phi_{l,E_T^{miss}})}$$

Systematic uncertainties

- Jet energy scale and resolution
- Electron scale, resolution and efficiency
- Muon scale, resolution, efficiency and momentum
- B-tag efficiency
- Luminosity
- Theory and MC modelling