Search for Electroweak Production of Charginos and Neutralinos in Final States with 2 and 3 Leptons and E_T^{miss} with the ATLAS Experiment

IOP Institute of Physics:
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UNIVERSITY OF SUSSEX

ATLAS EXPERIMENT

CERN

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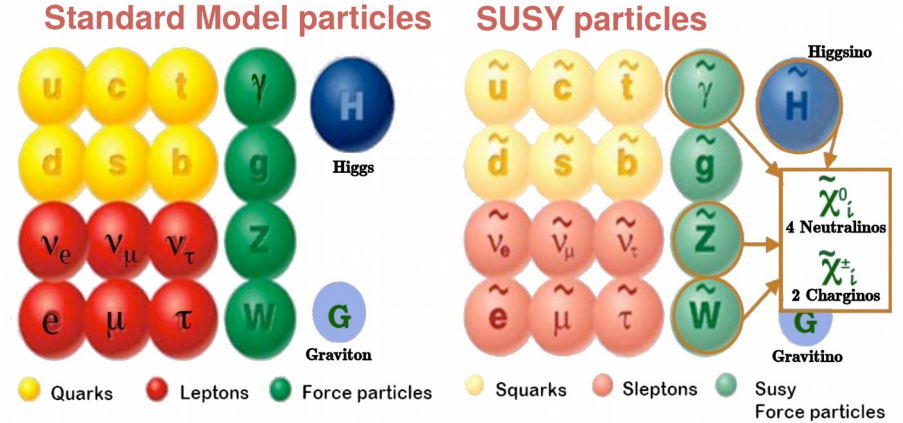
Introduction

- ATLAS search for **EWK direct production** of **Chargino** and **Neutralino**
- **Gauge-** and **Higgs-mediated decays** into final states with missing transverse momentum and:
  - → **Three leptons**
  - → **Two leptons** of the **same charge**
- Overview:
  - Physics scenario and motivation for these searches
  - Analyses strategies for each search
  - Results

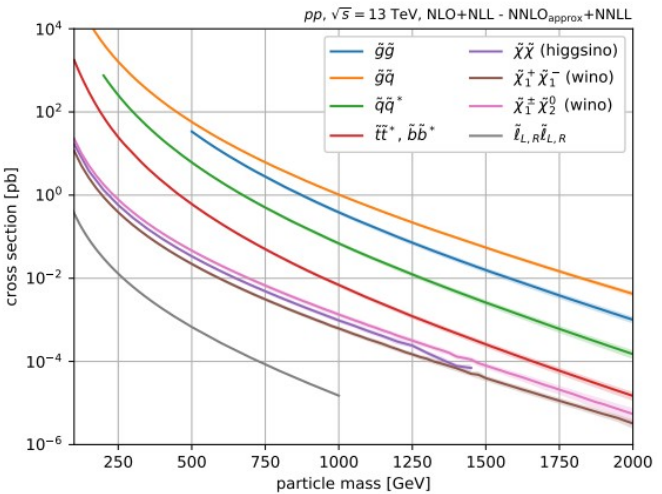
Electroweak SUSY: the physics case



- **Supersymmetry (SUSY)** introduces a **fermion-boson symmetry** ($\Delta s = ½$) in the Standard Model (SM)
- In the **Minimal Supersymmetric SM (MSSM)**, the least number of new particles are predicted
- **Charginos** $\tilde{\chi}_i^{\pm}$ (i=1,2) and **neutralinos** $\tilde{\chi}_j^0$ (j=1,2,3,4) are linear combination of superpartners of gauge and Higgs bosons

  → Produced at the LHC via their **electroweak interaction**

Twiki; Eur.Phys.J.C 73 (2013) 2480



- Given the **existing constraints on squark and gluino masses**
  → Electroweak **chargino/neutralino production** may become the **dominant SUSY mechanism at the LHC**
- $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ **searches** with **boson-mediated decays** to **multileptonic final states**

  → **key analyses to search for SUSY**

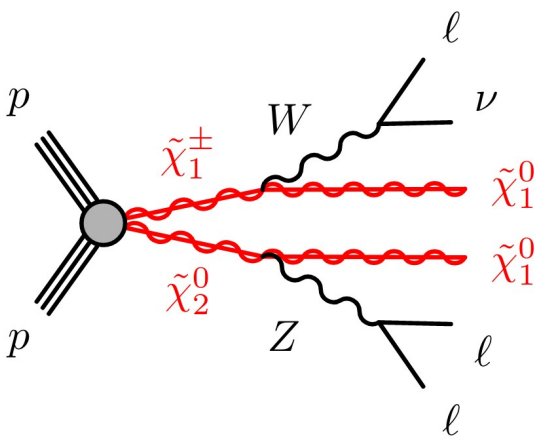
Targeted signal models

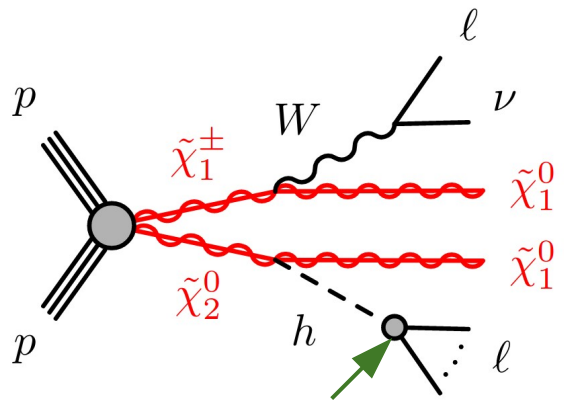
Simplified models assumptions:

- EWK direct production of **Chargino-Neutralino**
- **Wino-Bino** scenario: $|M_1| < |M_2| \ll |\mu|$
- $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ → **Wino-like** and **mass-degenrate**
- $\tilde{\chi}_1^0$ → **Bino-like** and Lightest SUSY Particle (LSP)
- **R-parity** ($P_R = (-1)^{3(B-L)+2s}$) **conservation**:
  → $\tilde{\chi}_1^0$ = LSP → stable → Good **Dark Matter candidate**!
- **SM gauge-** and **SM Higgs-mediated** decays (100% B.R.)

"WZ-3L"

$\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0) \gtrsim m_Z$





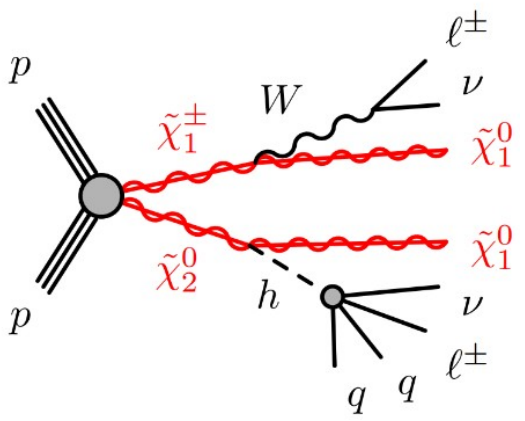
Decay of SM $h \to WW/ZZ/\tau\tau$ ℓ

"Wh-3L"

$\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0) > m_h$

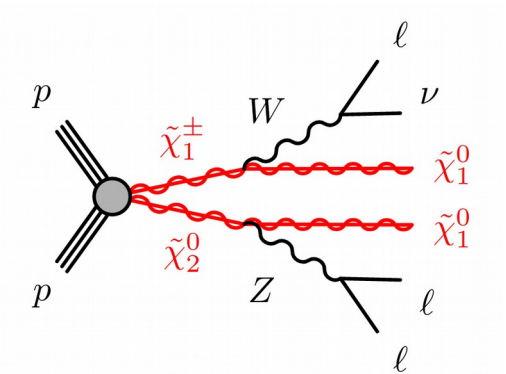
"Wh-SS"

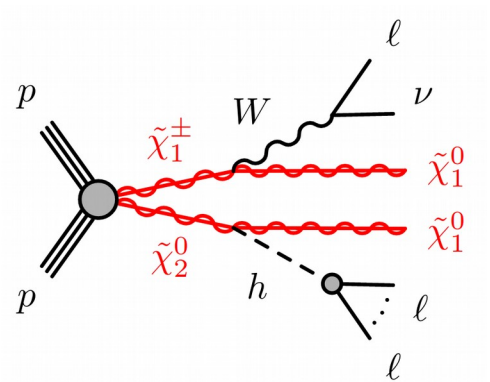
$\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0) > m_h$



Three-lepton searches

New ATLAS analysis (***ATLAS-CONF-2020-015***), using **full Run 2** (139 fb^{-1}) data from √s = 13 TeV pp collisions



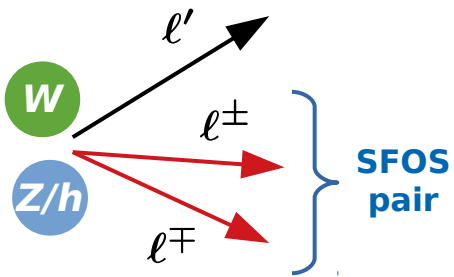


Final state = three isolated leptons (e or μ) + E_T^{miss} + light (non b-tagged jets)

Analysis strategy: *WZ-3L* and *Wh-3L*

- Event selection based on the presence of a **Same-Flavour Opposite-Sign (SFOS)** lepton pair + **one extra lepton**

$n_{SFOS} \geq 1$



- If $|m_{\ell\ell}^{\mathrm{SFOS}} - m_Z| < 15\,\mathrm{GeV}$

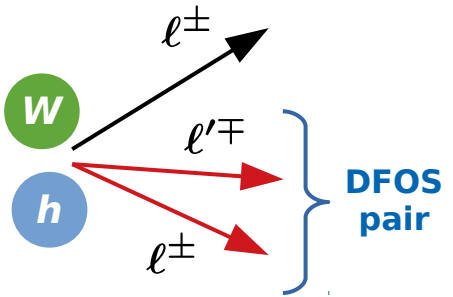
  → Target = ***WZ-3L***

- If $|m_{\ell\ell}^{\mathrm{SFOS}} - m_Z| \geq 15\,\mathrm{GeV}$

  → Target = ***Wh-3L***

- **Signal Regions (SRs)** binned in E_T^{miss}, m_T:
  - **Enhance sensitivity** for different $\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ scenarios
  - Exploit **topologies** with jets from **Initial State Radiation**

$n_{SFOS} = 0$

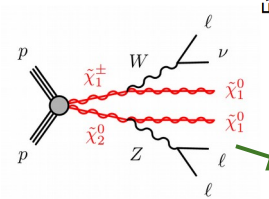


- **Different-Flavour Opposite Sign (DFOS)** lepton pair from SM Higgs decay
- Background suppression with requirements on:
  - **Angular separation between leptons**
  - Binning in jet multiplicity

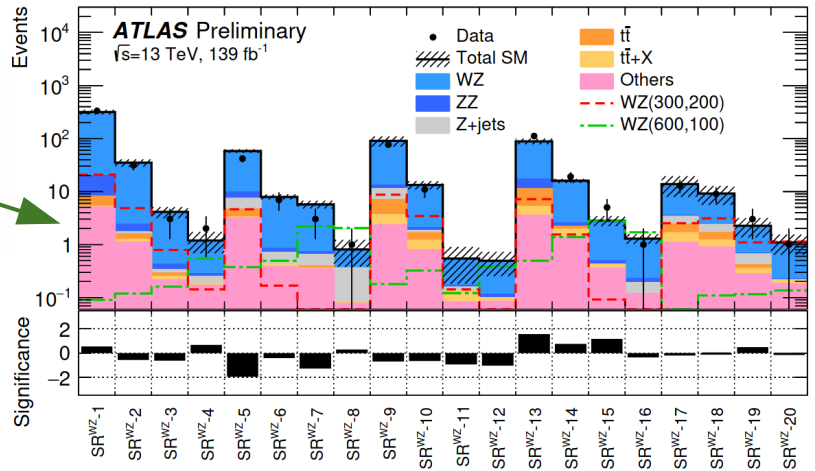
- **Irreducible** backgrounds from: **SM *WZ*** (mainly in SFOS SRs) → MC normalised to data in a Control Region (CR); ***SM Higgs*** and ***Triboson*** processes (mainly in DFOS SRs)
- **Reducible** backgrounds with "fake/non-prompt" leptons from SM ***Z+jets*** (estimated from data) and ***$t\bar{t}$***

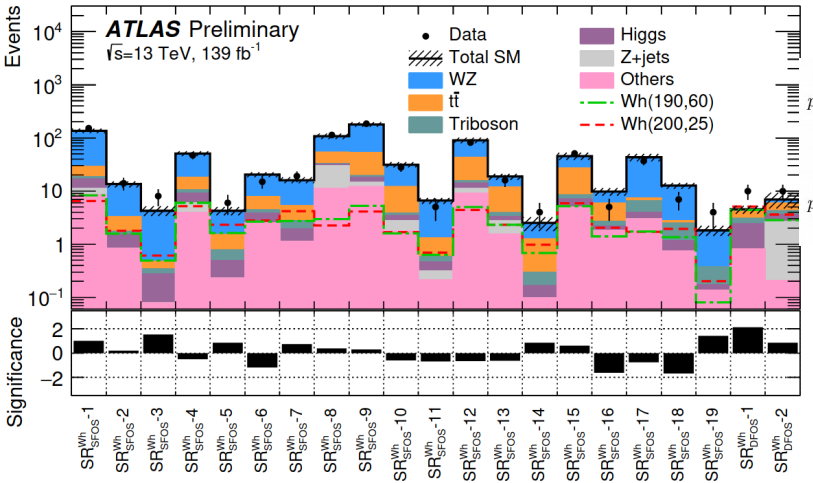
Results: *WZ-3L* and *Wh-3L*

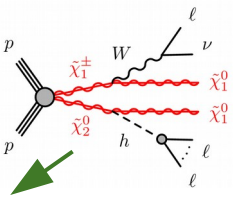
ATLAS-CONF-2020-015



WZ-3L



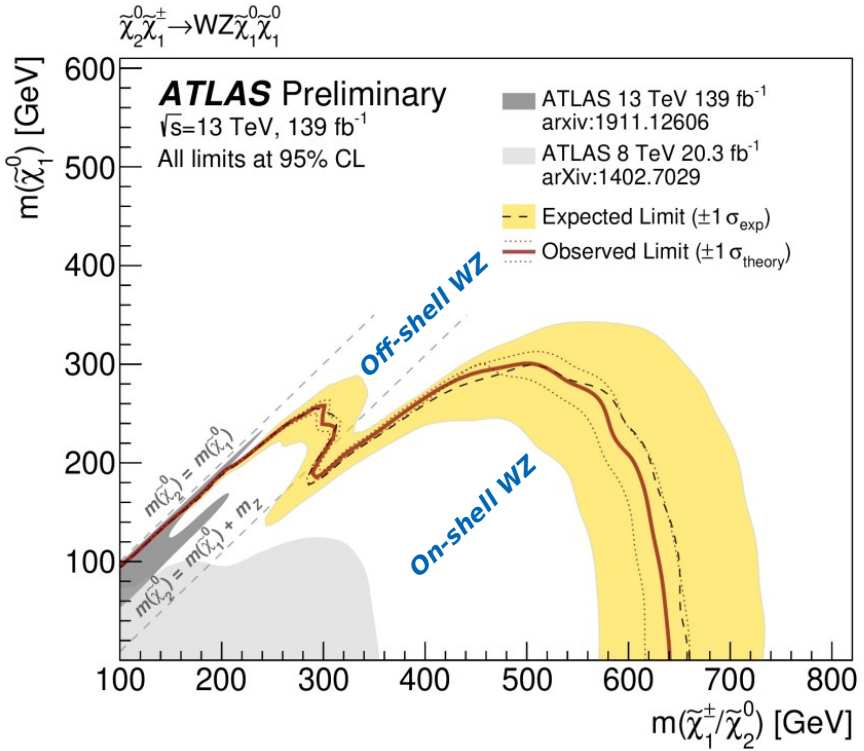


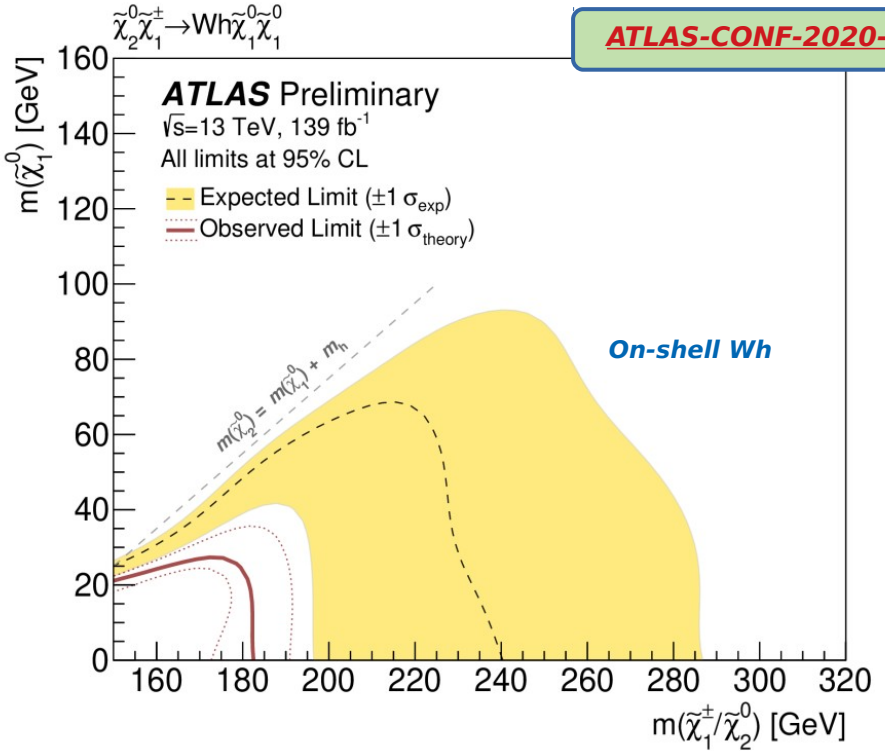


Wh-3L

- Results from 3L search with full Run-2 data (139 fb^{-1})
- Final background estimate from profile log-likelihood fit, simultaneous in all (orthogonal) CRs and SRs
- **No significant deviation from SM** prediction observed

Model-dependent limits: *WZ-3L* and *Wh-3L*

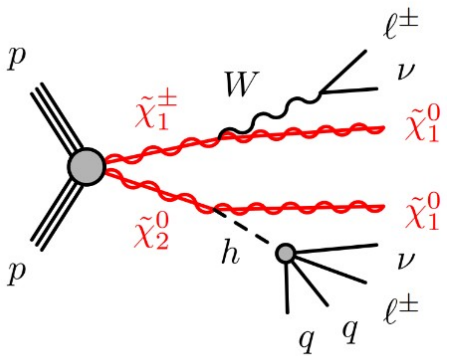




- **95% Confidence Level upper-limits** on $m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0)$ and $m(\tilde{\chi}_1^0)$ using the CL_s prescription
  - For ***WZ*-mediated** models: $m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0)$ excluded up to 640 GeV for $m(\tilde{\chi}_1^0) = 0$, and up to 300 GeV for low $\Delta m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0, \tilde{\chi}_1^0)$
  - For ***Wh*-mediated** model: $m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0)$ excluded up to 185 GeV for $m(\tilde{\chi}_1^0)$ < 20 GeV

Two same-sign leptons search

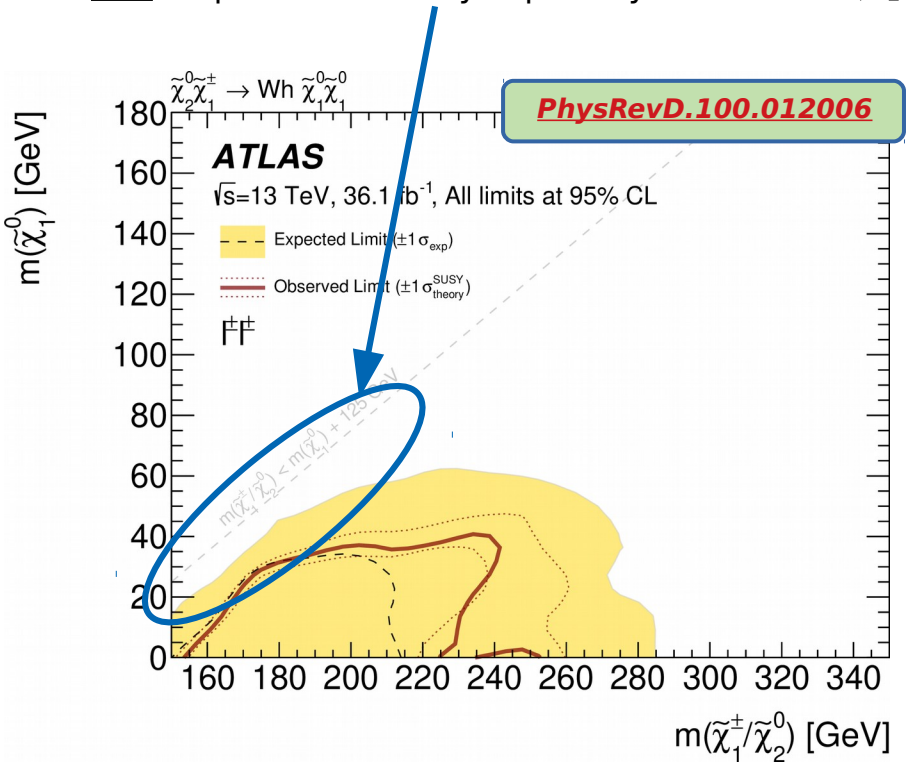
Results available (***PhysRevD.100.012006***) with **partial Run 2** (36.1 fb^{-1}) data from √s = 13 TeV pp collisions



Final state = two isolated same-sign (SS) leptons (e or μ) + E_T^{miss} + light (non b-tagged jets)

Analysis strategy: *Wh-SS*

- First round of analysis with partial Run-2 data (36.1 fb^{-1}) → no excess observed with respect to SM prediction
- **SRs re-optimisation** with full Run-2 statistics, based on cut&count approach on relevant kinematic variables
  - Aim: improve sensitivity especially for low $\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0)$



- $E_T^{miss} \geq 50\,\mathrm{GeV}$ → from neutrinos and neutralinos
- **b-tagged jets veto** → suppression of top background
- Consider **flavour channels**: ***e*±*e*±**, ***e*±*μ*±**, ***μ*±*μ*±**
- Main discriminant against SM background is the **"Stranverse mass"**:

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

  → Useful to target masses of pair-produced particles with invisibly decaying components

- Other variables include m_T^{min} and the missing transverse energy significance
- **SR binned in** E_T^{miss} to target different $\Delta m(\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0, \tilde{\chi}_1^0)$ scenarios

Backgrounds: *Wh-SS*

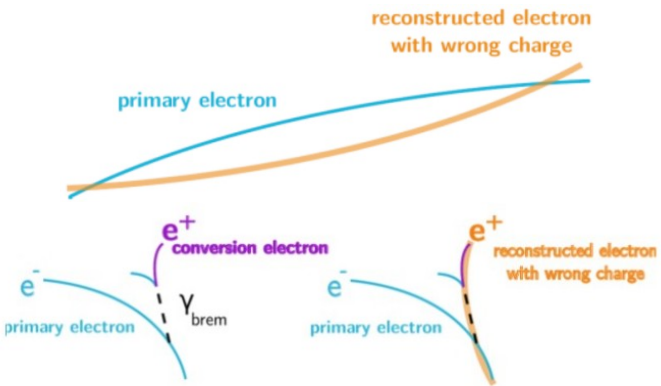
- **Irreducible backgrounds**: SM processes leading to prompt SS leptons

  → Mainly from **di-boson** production such as ***WZ*** processes

  → Other backgrounds include rarer **SM $W^{\pm}W^{\pm}$** processes

Background source	
Prompt Leptons	
Charge-Flip Electrons	
Electrons from photon conversion	
Fake/Non-prompt	Light-Flavour decay
	Heavy-Flavour decay

- **Reducible (or detector) backgrounds**:
  - **Charge-flip** → **opposite-sign** lepton events, such as from **ttbar** or **Z+jets**, being identified as same-sign due to the mis-reconstruction of the charge of one lepton (typically an electron)



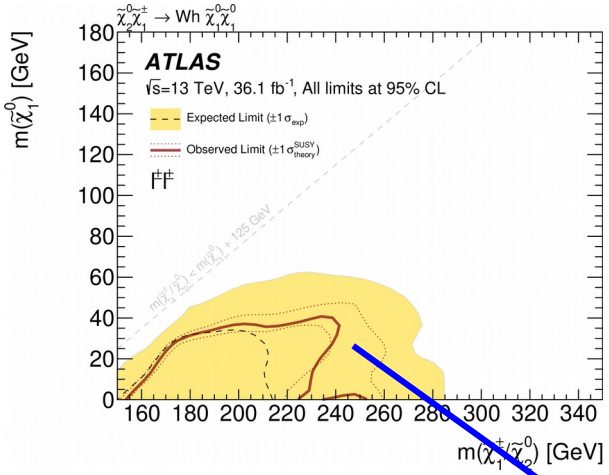
  - **Fake/Non-Prompt**:

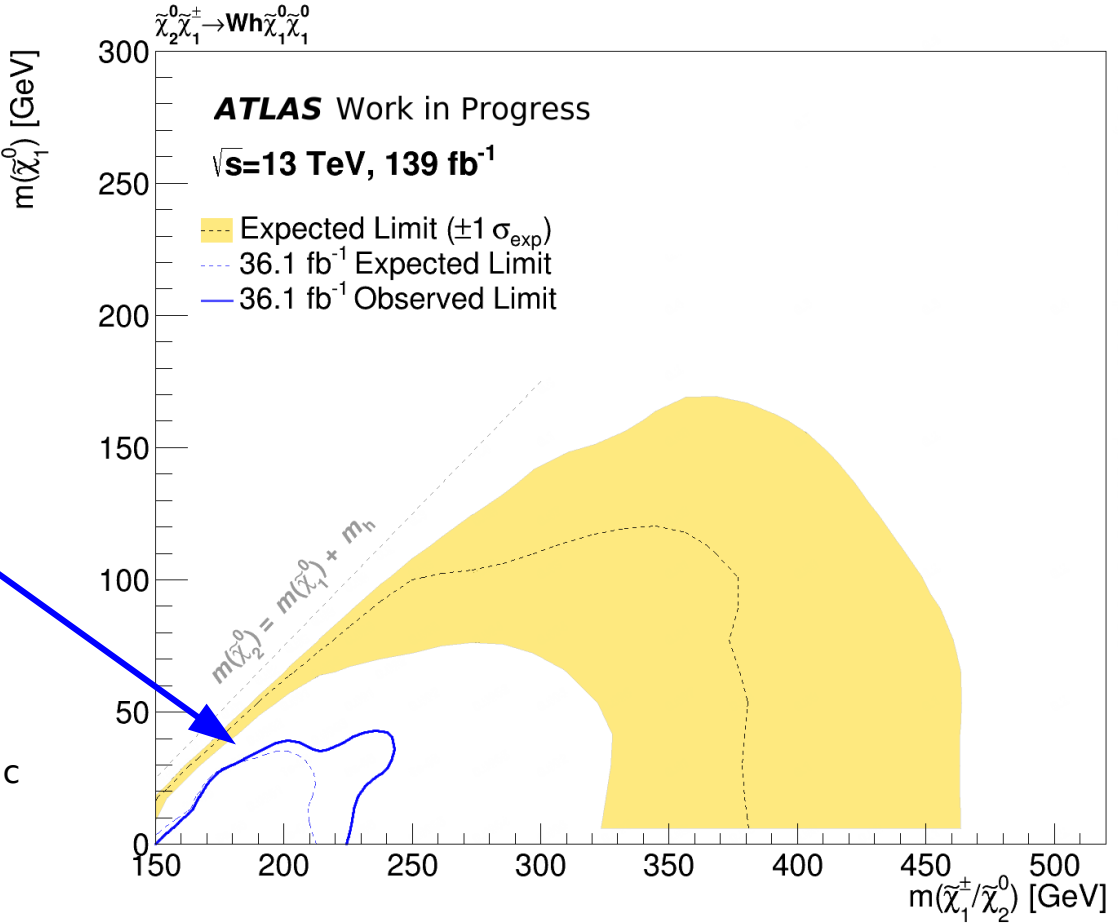
    → **Electrons and muons** from **semi-leptonic decay of heavy-flavour hadrons**, mainly from ***$t\bar{t}$*** or other SM top processes

    → **Light-flavour jets** being mis-identified as **electrons**, from ***W+jets* or *$t\bar{t}$*** events

  - **Electrons** from **ISR** or **FSR photon conversion**

Expected sensitivity: *Wh-SS*





- Expected 95% CL limits after re-optimisation
  - Background from MC and 30% flat systematic
- Significant improvement in signal sensitivity

Conclusions

- ATLAS search for the production of **chargino-neutralino** decaying **via *WZ***, and ***Wh*** into **three light-flavour leptons** and via ***Wh*** into **two same-sign leptons**
- Data **compatible with SM prediction**
- New results on the three-lepton search **significantly extend** known **constraints on charginos and neutralino masses** in the context of the respective simplified models
- Results on the two same-sign leptons search currently available with partial Run-2 data
  - Ongoing search using full Run-2 data → significant **improvement in signal sensitivity**