Search for electroweak production of charginos and neutralinos in multileptonic final states with the ATLAS experiment

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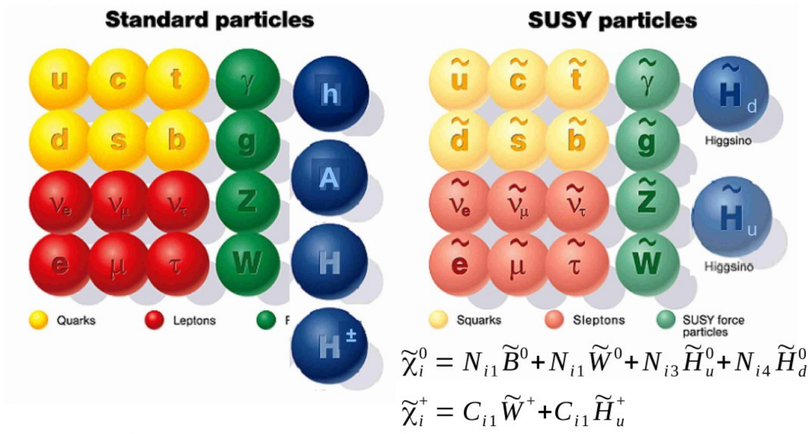
Electroweak SUSY: the physics case

- Supersymmetry (SUSY) introduces a **fermion-boson symmetry** ($\Delta s = \frac{1}{2}$) in the Standard Model (SM) [1]



$$\tilde{\chi}_i^0 = N_{i1}\tilde{B}^0 + N_{i1}\tilde{W}^0 + N_{i3}\tilde{H}_u^0 + N_{i4}\tilde{H}_d^0$$

$$\tilde{\chi}_i^+ = C_{i1}\tilde{W}^+ + C_{i1}\tilde{H}_u^+$$

Particle content of the Minimal Supersymmetric SM

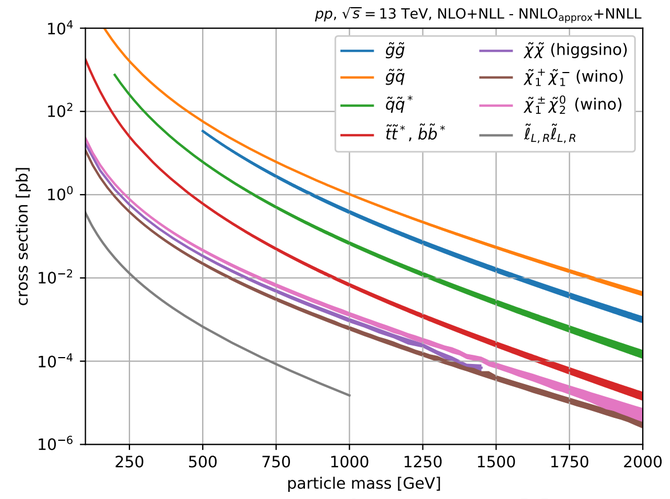
R-Parity
$$P_R = (-1)^{3(B-L)+2s}$$

- If *R-Parity* is conserved $\Rightarrow \tilde{\chi}_1^0$ is stable and a good dark matter candidate

- Mass of strongly interacting $\tilde{q}/\tilde{g}$ excluded up to $\mathcal{O}$(TeV) scale $\Rightarrow \tilde{\chi}_1^\pm \tilde{\chi}_2^0$ may be the **dominant SUSY process**

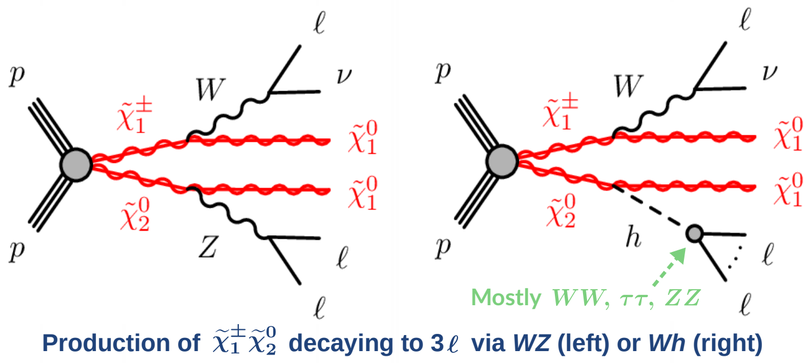
- **Charginos**, $\tilde{\chi}_i^\pm$ (i=1,2), and **neutralinos**, $\tilde{\chi}_j^0$ (j=1,2,3,4), produced and studied via their **electroweak** interaction

- $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0 \rightarrow WZ/h \rightarrow$ **2/3 leptons** are **key analyses to search for SUSY**

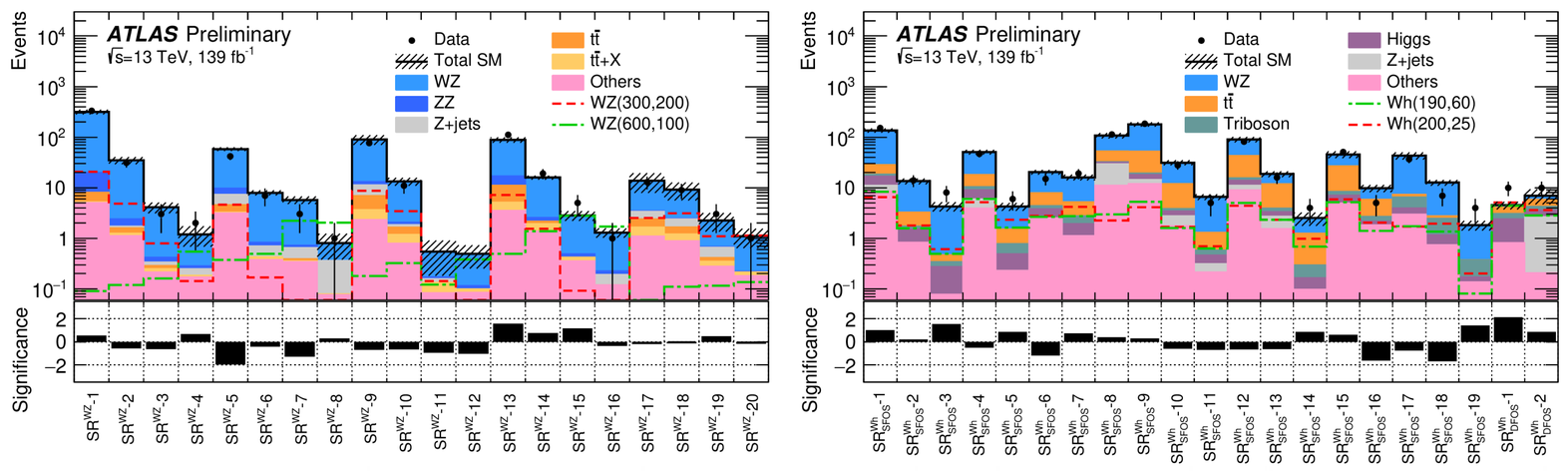


SUSY cross sections at 13 TeV [2]

$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow WZ/h \rightarrow 3\ell$ search



Production of $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ decaying to 3ℓ via *WZ* (left) or *Wh* (right)



Comparison of the observed data and expected SM background yields in the SRs for *WZ* (left) and *Wh* (right) models [4]

Simplified models assumptions:
- *R-Parity* conserving
- $\tilde{\chi}_1^\pm/\tilde{\chi}_2^0 \rightarrow$ Wino-like; $\tilde{\chi}_1^0 \rightarrow$ Bino-like
- $m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_2^0) > m(\tilde{\chi}_1^0)$
- On-shell decays to $W/Z/h$, with 100% BR

3 isolated *e* or *μ* + E_T^{miss} + light (not b-tagged) jets

SIGNAL SEARCH STRATEGY		TARGET
≥1 Same Flavour Opposite Sign (SFOS) lepton pair + 1 extra lepton	m_Z compatible with $m_{\ell\ell}^{SFOS}$	*WZ*
	m_Z non compatible with $m_{\ell\ell}^{SFOS}$	*Wh*
1 Different Flavour Opposite Sign (DFOS) + 1 Same Flavour Same Sign (SFSS) lepton pairs		*Wh*

Irreducible backgrounds (e.g. prompt leptons from SM *WZ*) normalised to data in dedicated **Control Regions (CRs)**

Estimation of **reducible** (fake/non-prompt leptons from SM *Z*+jets or $t\bar{t}$) backgrounds with **data-driven techniques**

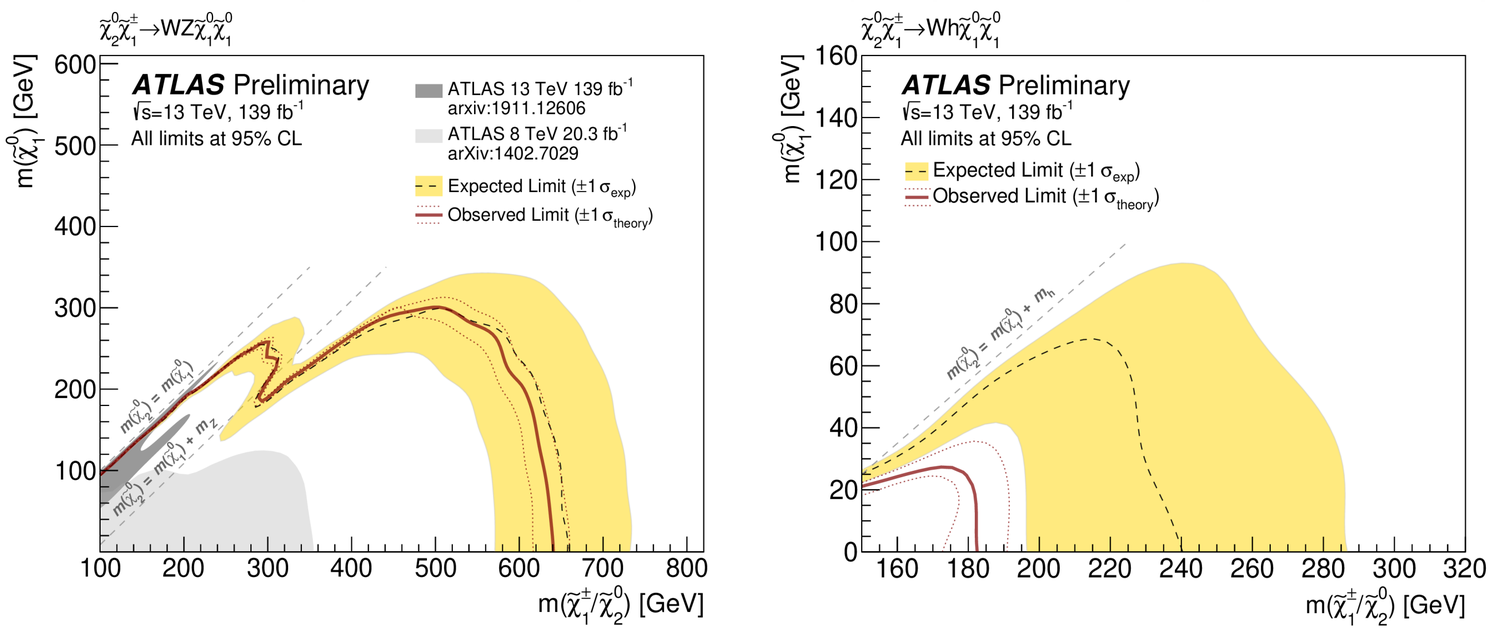
Validate background modeling in search-like **Validation Regions (VRs)**

Sophisticated multi-bin **Signal Regions (SRs)** optimised on signals

- All SRs/CRs/VRs are **orthogonal** to each other
- Final background estimate from **profile log-likelihood fit**, simultaneous in all CRs and SRs

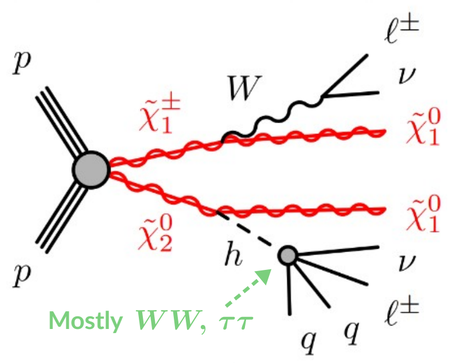
- Full Run 2 analysis recently released [4]

- No significant deviation from SM observed → upper limits on $m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0)$ and $m(\tilde{\chi}_1^0)$ using the CL_s prescription



Limits at 95% CL for *WZ* (left) and *Wh* (right) models in the 3ℓ channel [4]

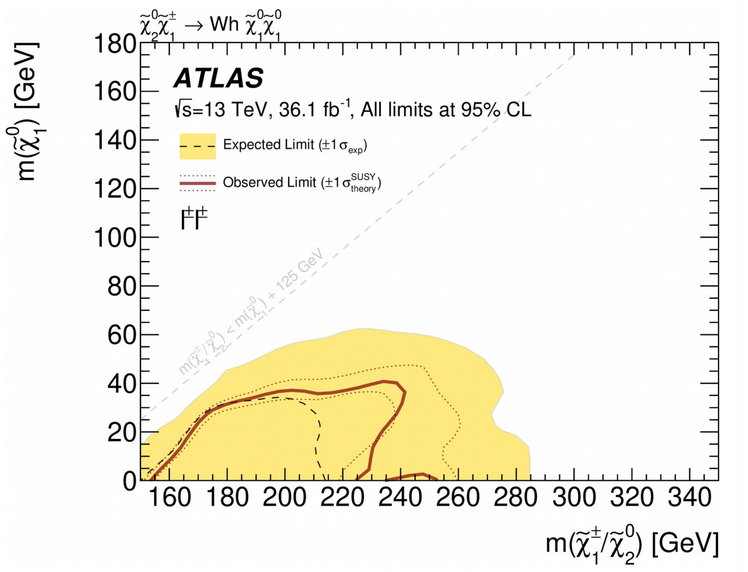
$\tilde{\chi}_1^\pm \tilde{\chi}_2^0 \rightarrow Wh \rightarrow 2\ell$ same-sign search



Production of $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ decaying to 2ℓ same-sign via *Wh*

2 isolated same-sign (SS) *e* or *μ* + E_T^{miss} + light (not b-tagged) jets

- Simplified model with same assumptions as 3ℓ case
- 2ℓ-SS search is **complementary** to 3ℓ search → facilitate **statistical combination** of multileptonic searches
- Analysis strategy similar to 3ℓ case (orthogonal SRs/CRs/VRs)
- Some of the expected backgrounds include **SM *WZ*** (**irreducible** with prompt leptons) and lepton charge mis-reconstruction, or **charge-flip** (**reducible**)
- Early Run 2 results show good agreement with the SM prediction [5]
  → Upper limits on $m(\tilde{\chi}_1^\pm/\tilde{\chi}_2^0)$ and $m(\tilde{\chi}_1^0)$ using the CL_s prescription
- Stay tuned for more exciting ATLAS SUSY results!



Limits at 95% CL for the *Wh* model in 2ℓ-SS channel [5]

[1] S. P. Martin, Adv. Ser. Direct. High Energy Phys.18,1(1998)
[2] https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections
[3] The ATLAS Collaboration, JINST 3 (2008) no. 08, S08003
[4] The ATLAS Collaboration, ATLAS-CONF-2020-015
[5] The ATLAS Collaboration, PhysRevD.100.012006