Search for Supersymmetry in multileptonic final states

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Why looking into multi-lepton events?

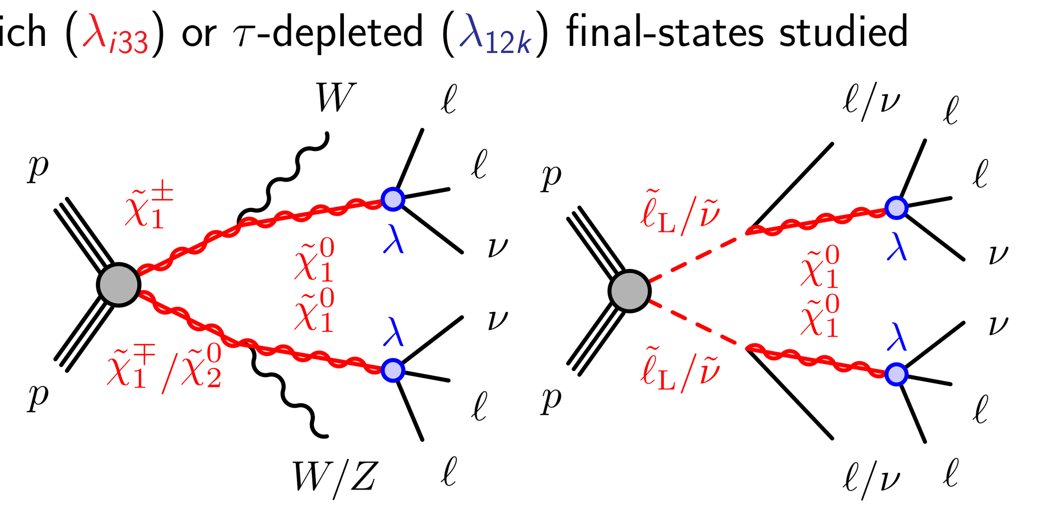
The four-lepton final state, rare in the Standard Model, is an attractive channel for the search of supersymmetry. Charged decay-leptons may arise from the cascade decays of SUSY particles to the lightest supersymmetric particle (LSP), or from R-parity violating (RPV) decays of the LSP itself to Standard Model particles. A search for Supersymmetry in events with at least four charged leptons has been performed in 36 fb^{-1}of data at $\sqrt{s}=13$ TeV recorded by the ATLAS experiment. Final states with zero to two τ leptons have been considered for this analysis. The results are interpreted in terms of RPV and GGM simplified models.

R-Parity violating (RPV) simplified models

Focus on all possible electroweak production modes ($\tilde{\chi}\tilde{\chi}$, $\tilde{\ell}\tilde{\ell}$, $\tilde{\ell}\tilde{\nu}$, $\tilde{\nu}\tilde{\nu}$)

LSP decays to leptons due to $W_{\mathrm{LLE}} = \lambda_{ijk} L_i L_j E_k$

τ-rich (λ_{i33}) or τ-depleted (λ_{12k}) final-states studied

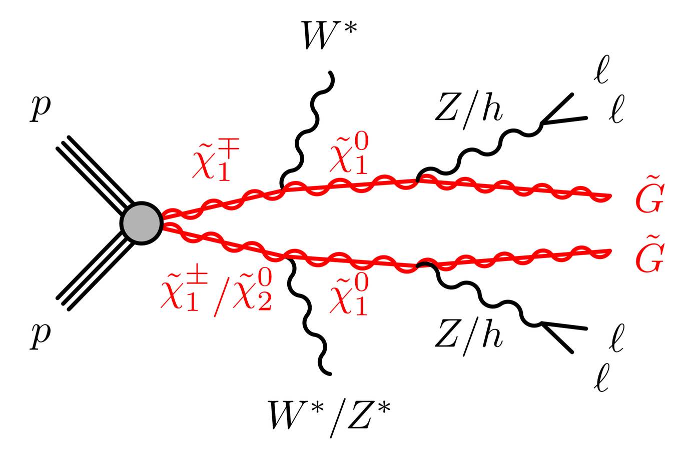


General Gauge Mediation (GGM)

Higgsino like $\tilde{\chi}_1^0\tilde{\chi}_1^{\pm}$ triplet produced in pp collisions

Each $\tilde{\chi}_1^0$ decays to Z/h stable $\tilde{G}$-LSP

Z/h-boson cascade further to two same-flavour (SFOS) e/μ-pairs



Estimating the SM background

Standard Model background events are classified into irreducible and reducible. For irreducible events all four selected leptons originate directly from the primary process:

ZZ, $t\bar{t}$+Z, ZZW/ZZZ/ZWW, Higgs, 3&4 top

This part of the background is estimated from simulated events where all selected leptons satisfy good quality criteria.

In the case of reducible events one or two leptons must come from secondary meson decays or must be classified wrongly by the detector:

$t\bar{t}$,Z+jets, WZ, WWW

The reducible background is estimated by deploying the *fake-factor matrix* method. The rate of simulated reducible events containing leptons failing the good quality criteria (loose) is compared to the event rate with good leptons only via the fake-factor

$$F = \frac{N_{\mathrm{good}}}{N_{\mathrm{loose}}}$$

Data events where one (CR1) or two (CR2) of the leptons fail the quality selection criteria are then weighted by the fake-factor to obtain the full background estimate:

$$N_{\mathrm{SM}} = N_{\mathrm{SR}}^{\mathrm{irreducible}} + F\times\left(N_{\mathrm{CR1}}^{\mathrm{data}} - N_{\mathrm{CR1}}^{\mathrm{irreducible}}\right) - F\times F\times\left(N_{\mathrm{CR2}}^{\mathrm{data}} - N_{\mathrm{CR2}}^{\mathrm{irreducible}}\right)$$

Object & event selection

Electrons	Muons	Taus
$p_{\mathrm{T}} > 7$ GeV, $\lvert\eta\rvert < 2.47$	$p_{\mathrm{T}} > 5$ GeV, $\lvert\eta\rvert < 2.7$	$p_{\mathrm{T}} > 20$ GeV, $\lvert\eta\rvert < 2.47$

impact parameter & modified isolation requirements

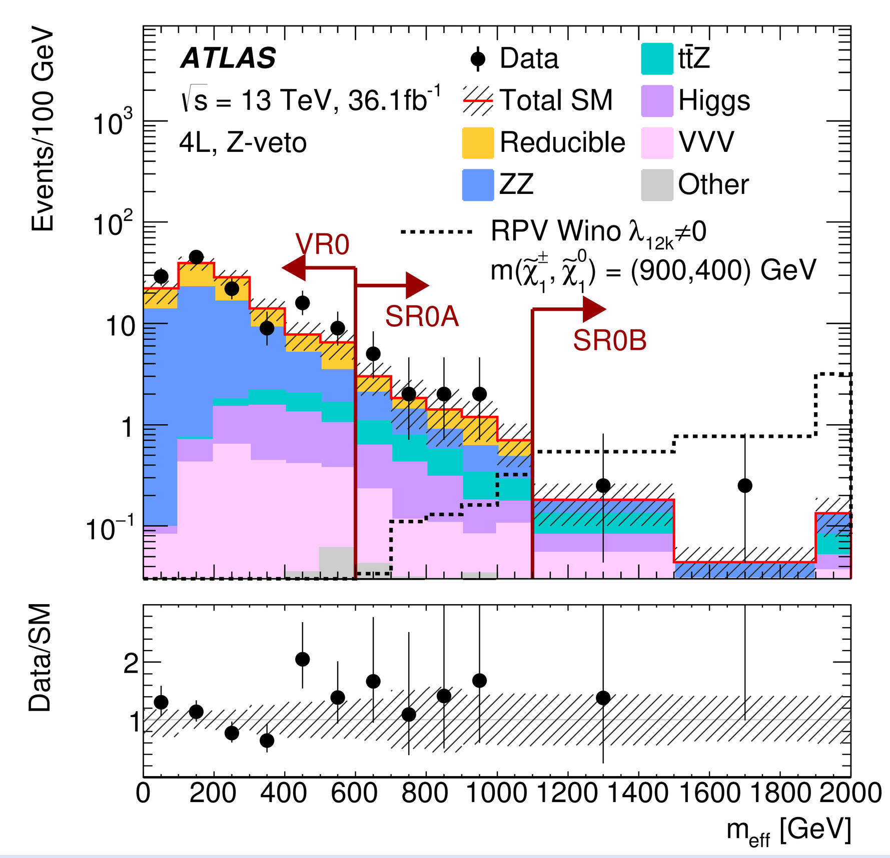
Signal Regions (SR0A/B,SR1,SR2) targeting for RPV models are defined using the effective mass

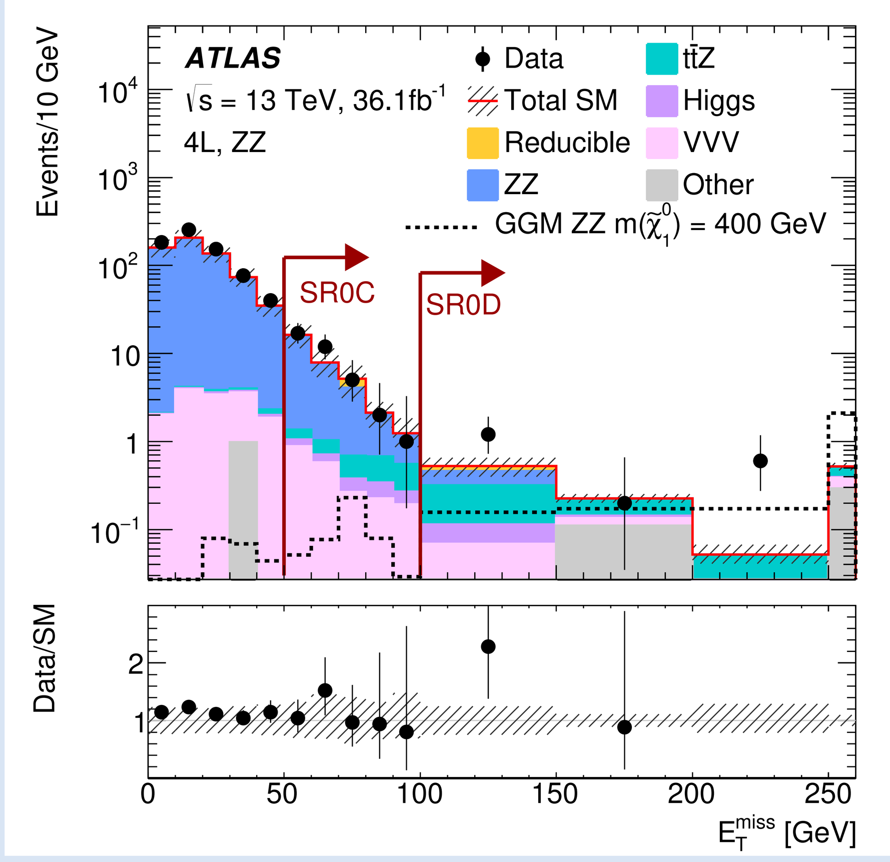
$$m_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + \sum_{\mathrm{Leptons}} p_{\mathrm{T}} + \sum_{\substack{\mathrm{Jets}\\ p_{\mathrm{T}}>40\ \mathrm{GeV}}} p_{\mathrm{T}}$$

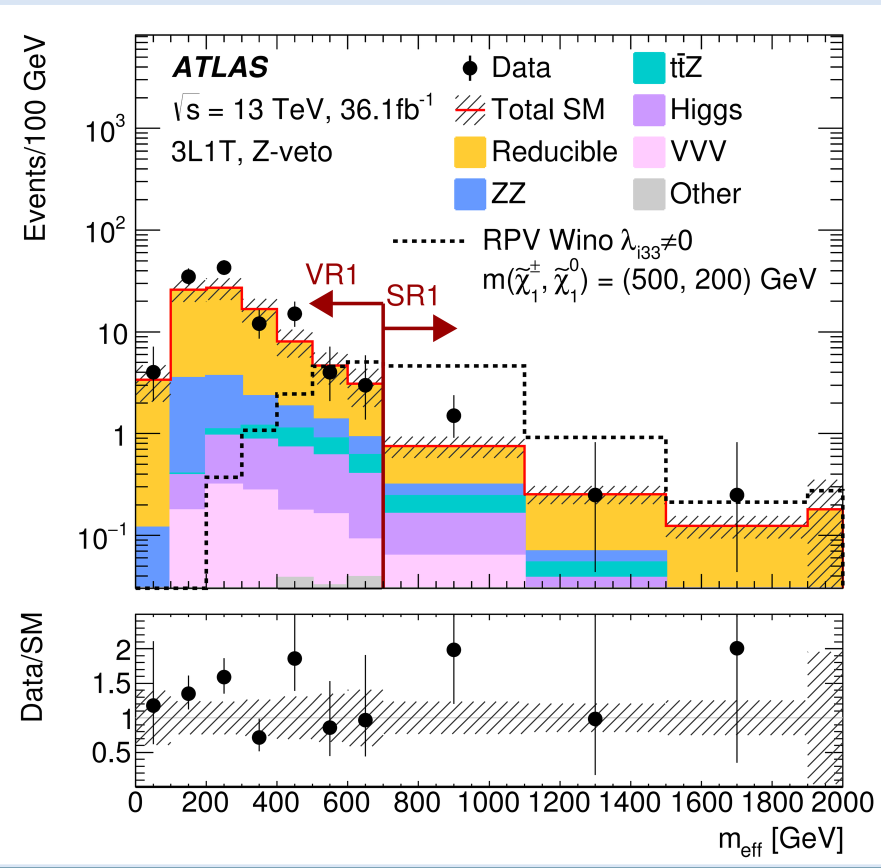
and vetoing any Z candidate.

The regions SR0C/D are optimized for signature of the GGM model, which involves the presence of two Z bosons and a large amount of $E_{\mathrm{T}}^{\mathrm{miss}}$.

Region	$N(\tau)$	Z boson	Discriminating variable	[GeV]
SR0A	$=0$	veto	m_{eff}	600
SR0B	$=0$	veto	m_{eff}	1100
SR0C	$=0$	$2\times Z$	$E_{\mathrm{T}}^{\mathrm{miss}}$	50
SR0D	$=0$	$2\times Z$	$E_{\mathrm{T}}^{\mathrm{miss}}$	100
SR1	≥ 1	veto	m_{eff}	700
SR2	≥ 2	veto	m_{eff}	650







Observations

Sample	SR0A	SR0B	SR0C	SR0D	SR1	SR2
Observed	13	2	47	10	8	2
SM Total	10.2±2.1	1.31±0.24	37±9	4.1±0.7	4.9±1.6	2.3±0.8
$\langle\epsilon\sigma\rangle_{obs}^{95}$ fb	0.32	0.14	0.87	0.36	0.28	0.13
S_{obs}^{95}	12	4.9	31	13	10	4.6
S_{exp}^{95}	$9.3^{+3.6}_{-2.3}$	$3.9^{+1.6}_{-0.8}$	23^{+8}_{-5}	$6.1^{+2.1}_{-1.3}$	$6.5^{+3.5}_{-1.3}$	$4.7^{+2.0}_{-1.3}$
CL_b	0.76	0.74	0.83	0.99	0.86	0.47
$p_{s=0}$	0.23	0.25	0.15	0.011	0.13	0.61
Z	0.75	0.69	1.0	2.3	1.2	0

The background-enriched validation regions show a good data-simulation agreement. No significant excess has been observed in any signal region except for SR0D where a small excess of 2.3σ is observed. The results have been used to derive the exclusion limit contours at 95% C.L. for each model.

Results & limits