PROCEEDINGS OF SCIENCE

Search for Type-III SeeSaw heavy leptons in dileptonic final states using 139 fb^{-1} of pp collision at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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The discovery of neutrino oscillations implies they have non-null masses much smaller than charged leptons. This is difficult to accommodate in a natural way through a pure Standard Model Yukawa coupling to the Higgs field. Type-III SeeSaw is a proposed beyond the SM mechanism, introducing at least two new triplets of fermionic fields with zero hypercharge in the adjoint representation of $SU(2)_L$, resulting in two heavy Dirac charged leptons and an heavy Majorana neutral lepton. The search for these heavy leptons is performed in dileptonic final states using the data collected by the ATLAS detector at $\sqrt{s}$ = 13 TeV with an integrated luminosity of 139 fb^{-1} corresponding to the full Run-2 dataset recorded between 2015-2018. The analysis includes all possible production and boson decay channels of these heavy leptons, which are assumed to be degenerate in mass. The search is optimized for final state with two leptons, two jets and two neutrinos. The power of the considered semi-leptonic channels lies in the low expected background from Standard Model processes. The result of this search is a cross section exclusion limit placing a lower bound to the heavy leptons mass.

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The smallness of neutrino masses, with respect to the charged leptons, is difficult to accommodate in a natural way through a pure Standard Model (SM) Yukawa coupling to the Higgs field [1]. A possible extension of the SM is the Type-III SeeSaw mechanism [2], introducing two heavy Dirac charged leptons and a heavy Majorana neutral lepton, that couple to electroweak gauge bosons and generate neutrino masses through Yukawa couplings to the Higgs boson and neutrinos.

The ATLAS search presented in this document uses a minimal Type-III SeeSaw model, which allows to consider only the lightest fermionic triplet of unknown (heavy) masses, two oppositely-charged leptons and one neutral, called respectively L^+, L^-, N^0. Here L^+ is the antiparticle of L^- and N^0 is a Majorana particle. Heavy leptons are assumed to be degenerate in mass.

The data used in this analysis corresponds to pp collision at $\sqrt{s}$ = 13 TeV recorded by the ATLAS detector [3], between 2015-2018, at the LHC with an integrated luminosity of 139 fb^{-1}.

The analysis focuses on the process with the largest effective cross-section, where both $L^{\pm}$ and N^0 decay to the final states containing a W boson: $pp \rightarrow N^0 + L^{\pm} \rightarrow W^{\pm} + \ell^{\mp} + W^{\pm} + \nu$. The search is performed considering final states with two light leptons (two electrons, two muons, or one electron and one muon, including the ones coming from leptonic tau decays), two neutrinos and two jets.

In order to perform a statistical interpretation of the data, several *analysis regions* with a different categorization of events must be defined. These regions are used to fit two kinds of hypotheses: one matching the only SM background expectation, the other consistent with the background plus signal hypothesis. Signal is expected to produce an excess over the SM expectation in a region of the phase space defined as *signal region* (SR). A *control region* (CR) is used to constrain a specific background, while a *validation region* (VR) can estimate the goodness of the background-only fit before applying the normalization factor to the signal region.

A first event selection is obtained by requiring exactly two leptons with a $p_T \geq 40$ GeV using dilepton triggers and two jets with a $p_T \geq 20$ GeV. In Table 1, additional criteria to define the analysis regions are reported.

	OS ($\ell^+\ell^- = e^+e^-, e^{\pm}\mu^{\mp}, \mu^+\mu^-$)			**SS** ($\ell^{\pm}\ell^{\pm} = e^{\pm}e^{\pm}, e^{\pm}\mu^{\pm}, \mu^{\pm}\mu^{\pm}$)		
	Top CR	m_{jj} VR	SR	Diboson CR	m_{jj} VR	SR
N(jet)	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2
N(b-jet)	≥ 2	0	0	0	0	0
m_{jj} [GeV]	$(60, 100)$	$(35, 60) \cup (100, 125)$	$(60, 100)$	$(0, 60) \cup (100, 300)$	$(0, 60) \cup (100, 300)$	$(60, 100)$
$m_{\ell\ell}$ [GeV]	≥ 110	≥ 110	≥ 110	≥ 100	≥ 100	≥ 100
$\mathcal{S}(E_{\mathrm{T}}^{\mathrm{miss}})$	≥ 5	≥ 10	≥ 10	≥ 5	≥ 5	≥ 7.5
$\Delta\phi(E_{\mathrm{T}}^{\mathrm{miss}}, \ell)_{\mathrm{min}}$	—	—	≥ 1	—	—	—
$p_{\mathrm{T}}(jj)$ [GeV]	—	—	≥ 100	—	—	≥ 60
$p_{\mathrm{T}}(\ell\ell)$ [GeV]	—	—	≥ 100	—	—	≥ 100
$H_{\mathrm{T}} + E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	≥ 300	≥ 300	≥ 300	$(300, 500)$	≥ 500	≥ 300

Table 1: Summary of the analysis regions definition.

The backgrounds contribution in each analysis region comes from *prompt background leptons*, estimated using Monte Carlo samples, *charge misidentificaton* and *fake leptons* estimated using a data-driven technique [4].

In Figure 1 the number of observed and expected events for each CR, VR and SR divided per lepton flavour and charge is reported.

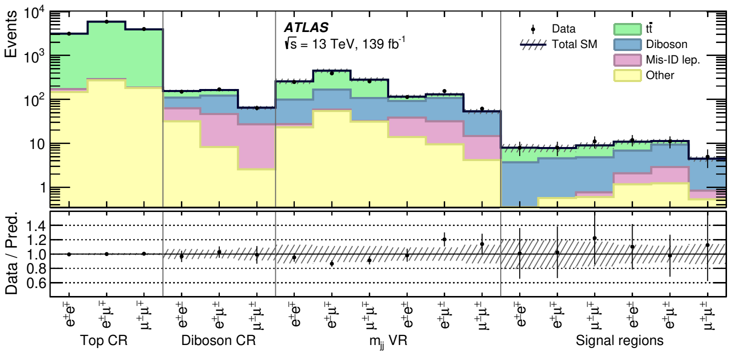

Figure 1: Number of observed and expected events in each analysis regions [4].

Performing a statistical analysis considering heavy lepton masses between 300-1200 GeV, excess of signal events was searched for by comparing data with the background plus signal hypothesis. Since no excess was found, exclusion limits for each point of mass are set at the 95% CL. The expected 95% CL exclusion plot is shown in Figure 2. The observed lower mass limit of the Type-III Seesaw heavy leptons is 790 GeV to be compared with an expected lower mass limit of 820^{+40}_{-60} GeV.

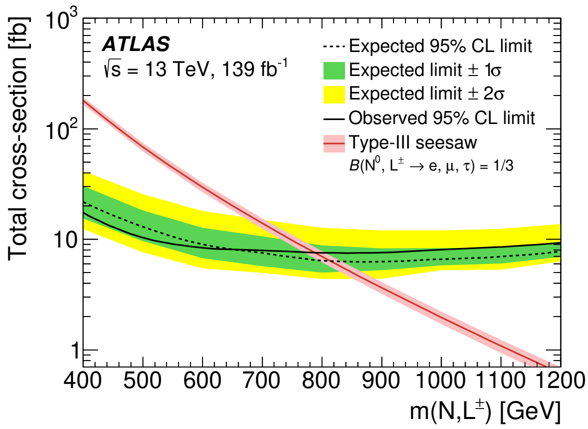

Figure 2: Expected 95% CL (dashed line) upper limit on cross-section of the Type-III Seesaw process with the corresponding one (green) and two (yellow) standard deviation bands. Observed limit is shown with a continuous black line. The theoretical cross-sections for heavy lepton production are presented in red line [4].

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References

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