Search for type-III seesaw heavy leptons in leptonic final states in *pp* collision at $\sqrt{s}$ = 13 TeV with the ATLAS detector

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1. The type-III seesaw model

The seesaw mechanism provides an elegant extension of the Standard Model explaining the smallness of the neutrino masses.This search uses *pp* collision data at a centre-of-mass energy of 13 TeV, corresponding to 139 fb^{-1} of integrated luminosity recorded by the ATLAS detector during Run 2 of the Large Hadron Collider. For the first time, a result considering a combination of the most important type-III seesaw heavy leptons decay modes in final states with two [1], three (3l) and four (4l) light-leptons [2] is presented.

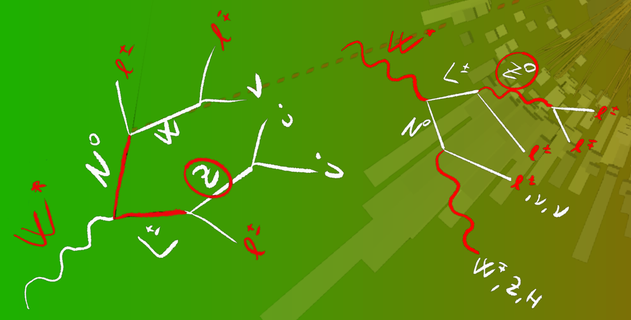

Figure 1. Feynman diagrams for the three- (left) and four-lepton (right) final states.

2. Event categorization

The analysis regions [2] are defined accounting all the possible topologies for the heavy leptons decays.
For the 3l channel three kinds of regions are considered:

- **ZL Regions**, characterized by a leptonically decaying Z boson
- **ZLVeto Regions**, defined vetoing events containing opposite-sign same flavour lepton pairs
- **JNLow Regions**, targeting decays where the electroweak bosons decay leptonically, therefore events with a small jet multiplicity are selected.

For the 4l channels, events are classified depending on the sum of the charges of the four leptons in the final state:

- **Zero Charge (Q0)**, with two lepton pairs with same-sign
- **Double Charge (Q2)** , where only one lepton has different charge with respect to the other

3. Background Modeling

Monte Carlo simulations are used to model signal samples and the dominant irreducible backgrounds:

- **Type-III seesaw** heavy leptons are analyzed in a range of mass between 400 GeV and 1200 GeV, with the cross-section calculated at next-to-leading order
- **RareTop** (RT) includes processes with 3 top quarks or more or tops with electroweak bosons in final state
- **Diboson** (DB) production involves events with 2 electroweak bosons (WW, ZZ, WZ)
- **Other** minor backgrounds such as $t\bar{t}$, single-top and Drell-Yan events are less than 2% and grouped in the **other category**.

Reducible backgrounds are due to experimental effects:

- **Charge-misidentification**, corrected by a charge- flip scale factor derived from a data and Monte Carlo comparison
- **Fakes**, non-prompt (**FNP**) leptons originated from in-flight decays of mesons or jets reconstructed as leptons and photon converting in electron-positron pair. A **data-driven fake-factor estimation** was used to account for their contribution.

Only results for the 3l and 4l final states are presented here [2].

Control Regions (CR): estimate RT and DB contributions
Validation Regions (VR): validate background estimation
Signal Regions (SR): enriched in signal events.

Main contribution to uncertainties:
Experimental: object calibration and efficiencies
Luminosity: 2% for ATLAS measurements in Run 2
Theory: QCD scales, PDF choice, parton shower parameters, α_S uncertainties
FNP: data-driven background modelling
Normalisation: fitted RT and DB contributions.

4. Results

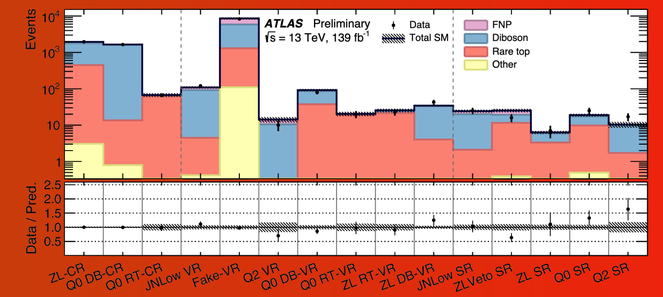

Figure 2. Number of observed and expected events in each analysis region.

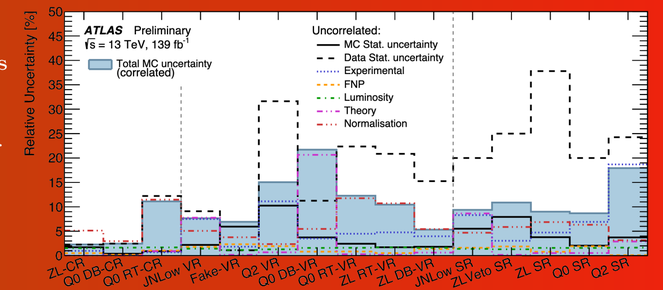

Figure 3. Relative uncertainties in the total background yield estimation after fit.

5. Exclusion Limits

- Combination of 6 SRs (ee, eμ, μμ) x (OS,SS) for **DiLepton channel [1]**
- Combination of 5 SRs (ZL, ZLveto, JNLow, Q0, Q2) for **3l +4l Channels [2]**
- Combination of 11 SRs for **all the channels together** [2]

The **observed limits** on the type-III seesaw heavy leptons mass at 95% Confidence level are:

- **790 GeV** (820 GeV expected) for the DiLepton channel
- **890 GeV** (910 GeV expected) for the 3l + 4l channels
- **910 GeV** (960 GeV expected) for the combination of all the final states

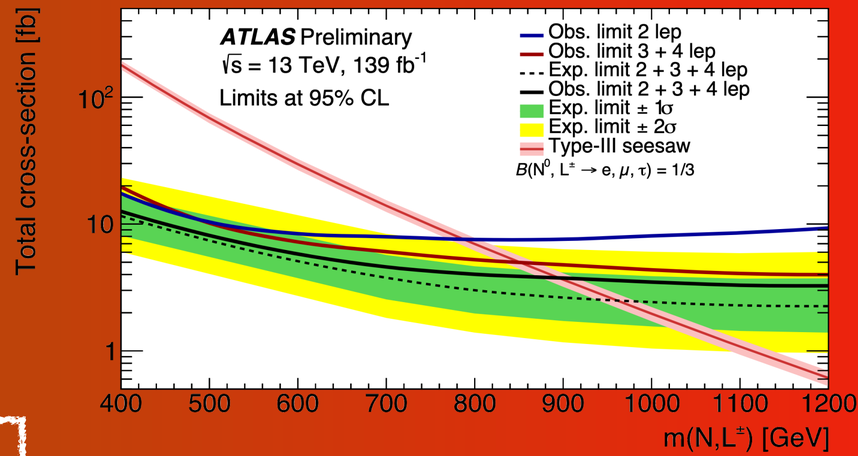

Figure 4. Expected and observed exclusion limits in the two [1], three- and four-lepton, and all the channels [2] for the type-III seesaw process.

References:
[1] ATLAS Collaboration, Search for type-III seesaw heavy leptons in dilepton final states in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector. DOI:10.1140/epjc/s10052-021-08929-9
[2] ATLAS Collaboration, Search for type-III seesaw heavy leptons in leptonic final states in pp collisions at $\sqrt{s}$= 13 TeV with the ATLAS detector ATLAS-CONF-2021-023