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

Introduction

The discovery of **neutrino flavour oscillations implies non-null masses** for neutrinos. The smallness of neutrino masses is difficult to accommodate in a natural way through a pure Standard Model (SM) Yukawa coupling to the Higgs field. **Type-III SeeSaw** mechanism **extends the SM**, **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.

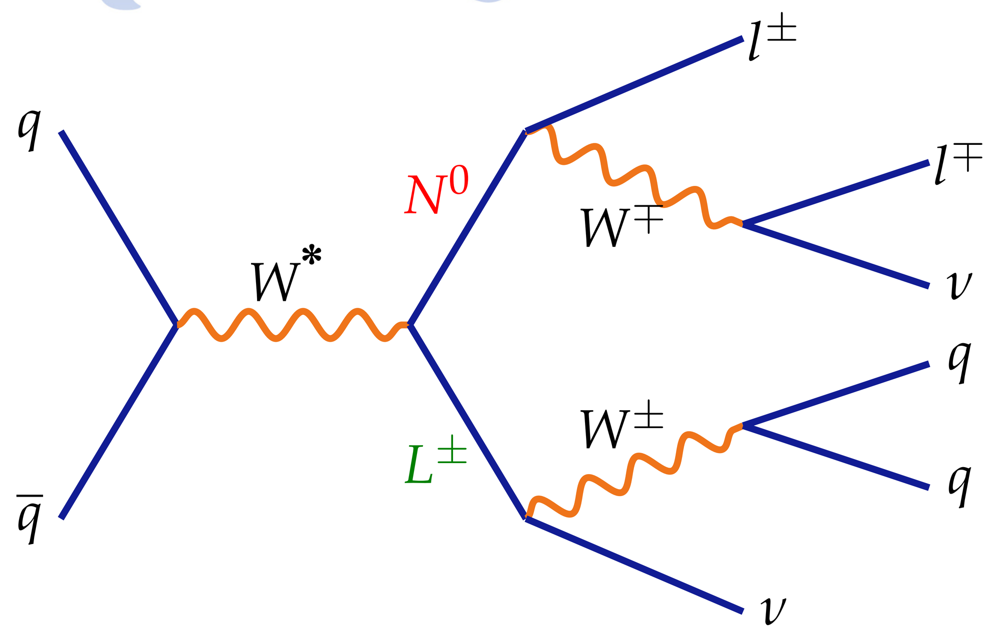

Fig.1 Final state with OS leptons

Here we focus on the dominant production mechanism:

$$pp \to W^* \to N^0 L^\pm \to \ell^\pm W^\mp \nu W^\pm$$

The **decay branching ratios** in the **SM leptons** are considered **equal**.

Only **light leptons are considered** in the final states in this analysis.

Final states include:

- **2 leptons** with opposite- (OS) or same-sign (SS)
- **2 neutrinos** providing large E_T^{miss} missing transverse energy
- **2 jets**

Event Categorization

The analysis regions[1] contain events with a **pair of leptons**, either ee, eμ or μμ, and **at least two high-p_T jets**. Both leptons should have p_T of at least 40 GeV.

- **$H_T + E_T^{miss}$ > 300 GeV (∈ [300,500) GeV in SS CR)**
  H_T is the scalar sum of the transverse momenta
- **$S(E_T^{miss})$ ≥ 10 (≥ 5 in CRs)**
  $S(E_T^{miss})$ is the E_T^{miss} significance defined as

$$\mathcal{S}^2 = \frac{\left|E_T^{miss}\right|^2}{\sigma_L^2\left(1-\rho_{LT}^2\right)}$$

- **m_{jj} ∈ [60,100) GeV (∉ [60,100] in SS CR)**
  m_{jj} is the invariant mass of the two leading jets.

Background Modelling

- Monte Carlo (MC) simulations are used to model dominant background:
  - ▶ **$t\bar{t}$ production** leptonic decay of two W bosons
  - ▶ **Diboson production**
- **Charge mis-identification** is corrected by a charge-flip scale factor derived from a data and Monte Carlo comparison
- **Fake leptons** are originated from in-flight decays of mesons (non-prompt leptons), jets reconstructed as leptons and photon converting in electron-positron pair. A **data-driven fake-factor method** is used.

References

[1] ATLAS Collaboration, *Search for type-III seesaw heavy leptons in dilepton final states in pp collisions at √s = 13 TeV with the ATLAS detector,*
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2018-33/

Results

Control Regions (CR): estimate $t\bar{t}$ and diboson contributions
Validation Regions (VR): validate background estimation
Signal Regions (SR): enriched in signal events.

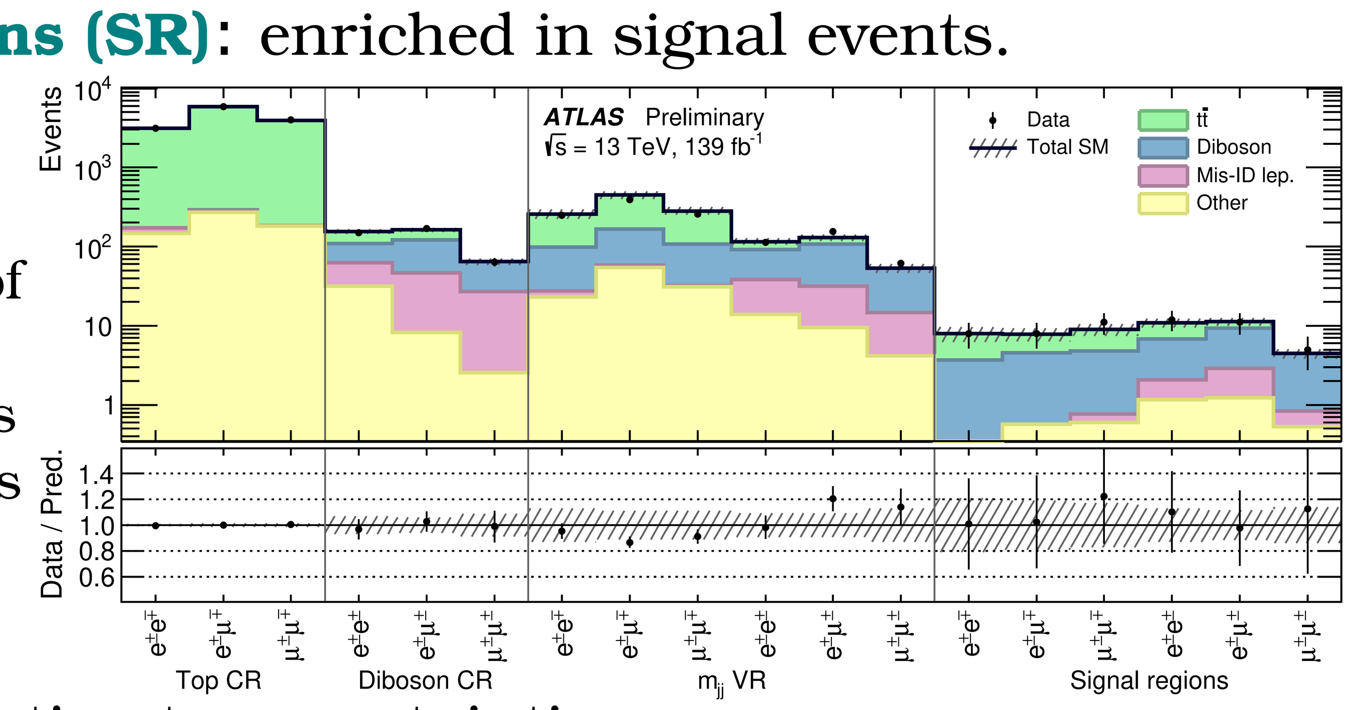

Fig.2 Number of observed and expected events in each analysis regions.

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
Fakes: data-driven background modelling
Normalisation fit: fitted $t\bar{t}$ and diboson contribution.

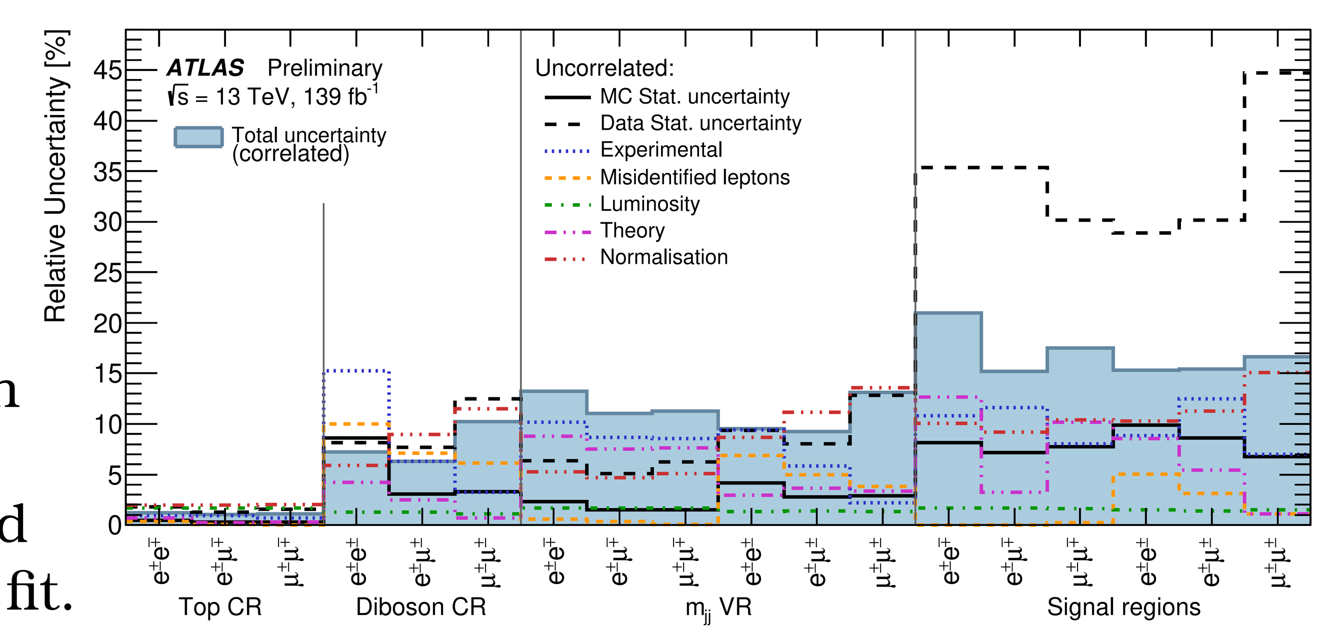

Fig.3 **Relative uncertainties** in the total background yield estimation after fit.

Exclusion Limit

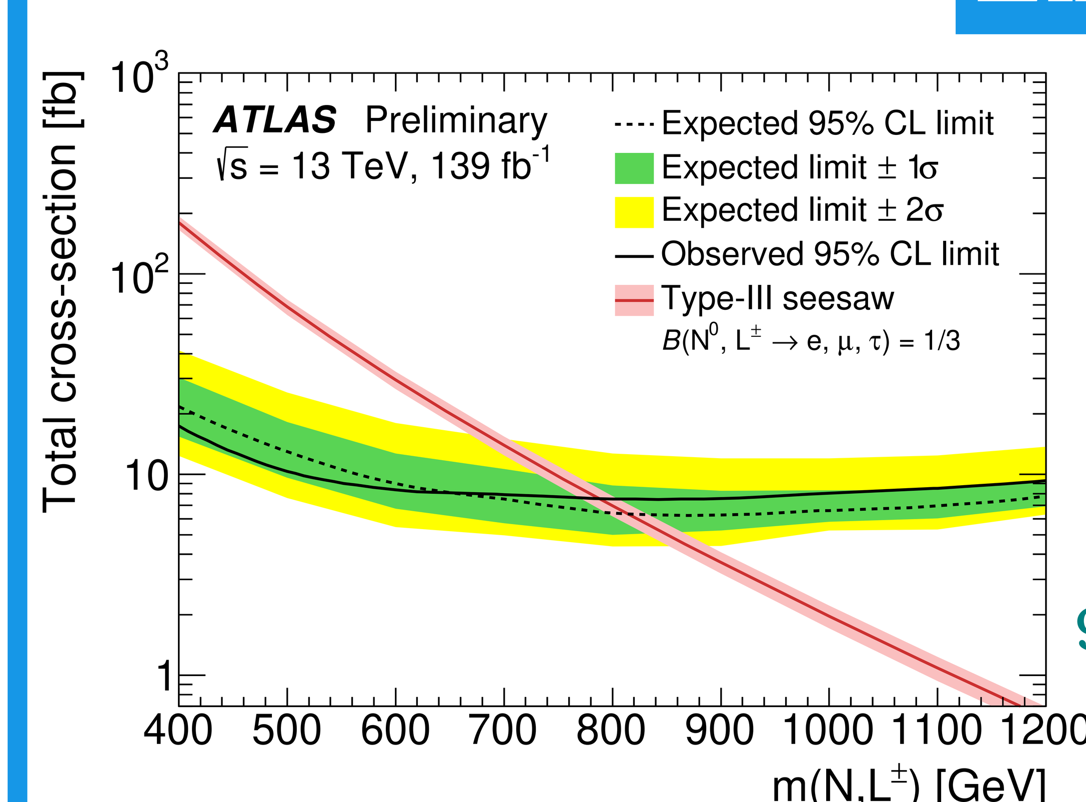

Fig.4 Heavy lepton mass exclusion limit.

6 SRs combined:
(ee, eμ, μμ) x (OS,SS)

The **observed limit** on the Type-III SeeSaw heavy leptons mass at 95% Confidence level is **790 GeV (820 GeV expected).**

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