ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

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

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Giuseppe Carratta
On behalf of the ATLAS Collaboration

Introduction

The discovery of **neutrino flavour oscillations implies non-null masses** for neutrinos.

Explanation for mass of neutrinos requires an **extension of the originally** formulated **Standard Model**.

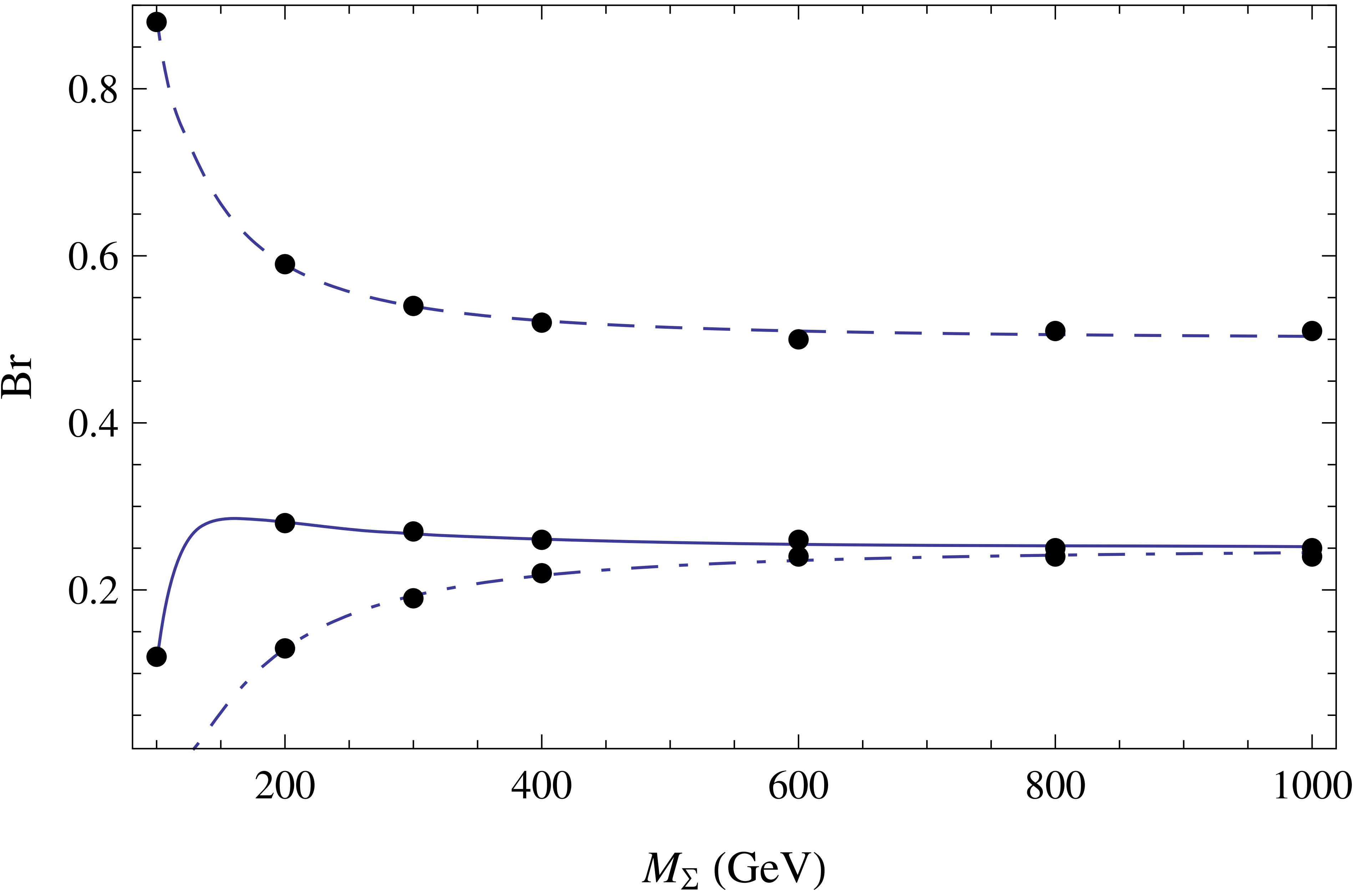

Fig.1 Branching ratios of the charged components. *Continuous lines* for decay into Z, *dashed* into W, *dotdashed* into H[2]. It is the same for the neutral component.

Type-III SeeSaw[1] 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.

Final states include:

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

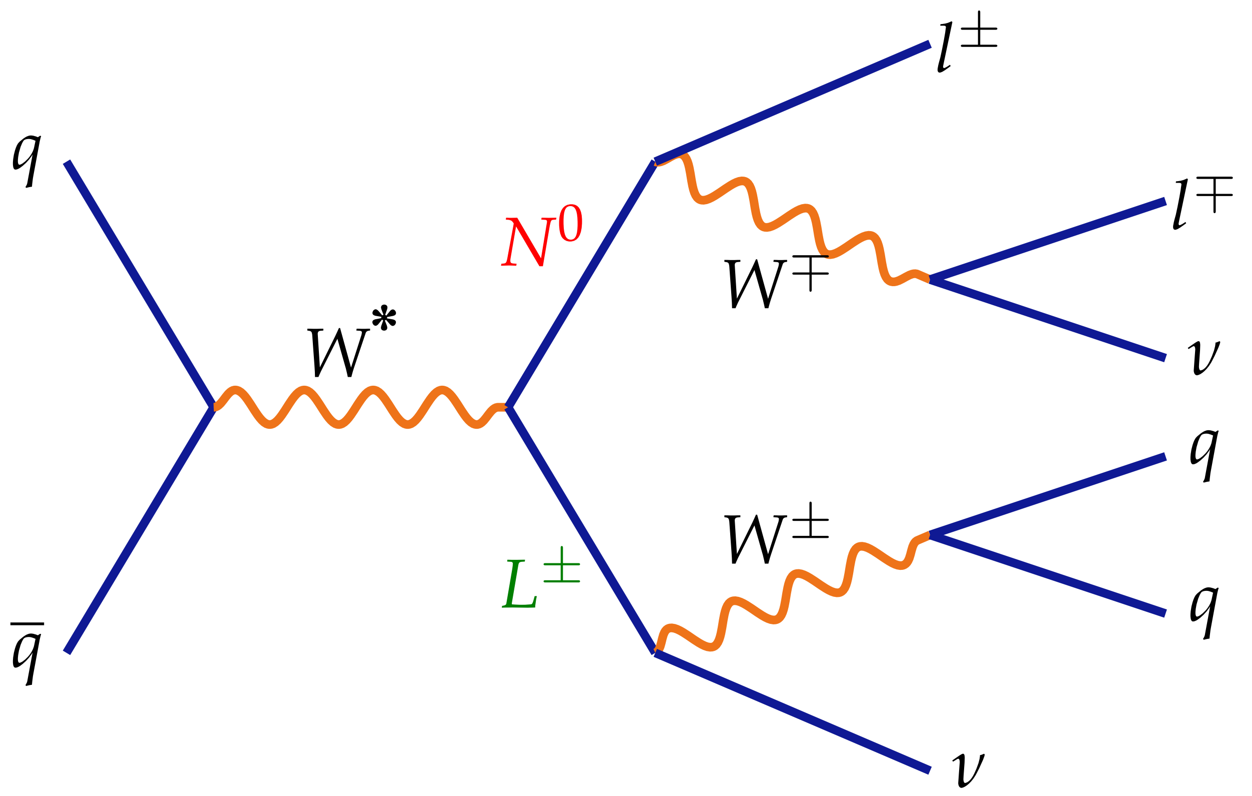

Fig.2 Final state with OS leptons

[1] R. Foot, H. Lew, X. G. He and G. C. Joshi, *Seesaw Neutrino Masses Induced by a Triplet of Leptons*, Z. Phys.C44(1989) 441

[2] C. Biggio and F. Bonnet, *Implementation of the Type III Seesaw Model in FeynRules/MadGraph and Prospects for Discovery with Early LHC Data*, Eur. Phys. J.C72(2012) 1899, **arXiv**:1107.3463 [hep-ph]

Analysis strategy

To perform this search, different **analysis regions[3]** are defined:

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

	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
Sig(E_T^{miss})	≥ 5	≥ 10	≥ 10	≥ 5	≥ 5	≥ 7.5
$\Delta\phi(E_T^{miss}, l)_{min}$	—	—	≥ 1	—	—	—
$p_T(jj)$ [GeV]	—	—	≥ 100	—	—	≥ 60
$p_T(\ell\ell)$ [GeV]	—	—	≥ 100	—	—	≥ 100
* $H_T + E_T^{miss}$ [GeV]	≥ 300	≥ 300	≥ 300	(300, 500)	≥ 500	≥ 300

Table 1 Summary of the analysis regions definition.

* H_T is the scalar sum of the transverse momenta of selected objects

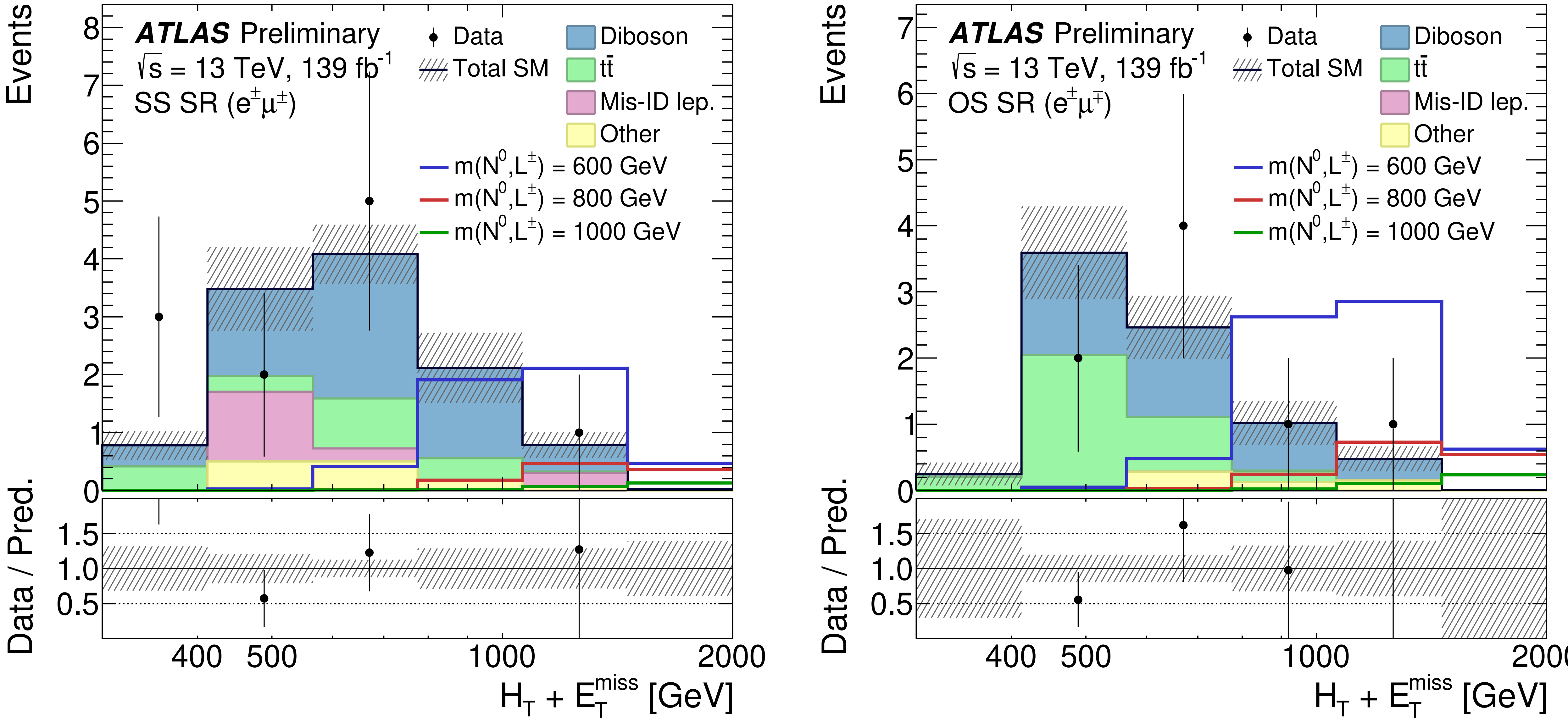

Fig.3 Distributions of $H_T + E_T^{miss}$ in SS (left) and OS (right) SRs for the electron-muon channel.

These analysis regions have different background contribution:

- **Prompt background leptons** are estimated using Monte Carlo samples and are originating from decays of Z, W, H bosons, or from prompt leptonic τ decays
- **Charge mis-identification** is corrected by a charge-flip scale factor derived from a data and MC comparison
- **Fake leptons** are originated from in-flight decays of mesons (non-prompt leptons), jets reconstructed as leptons and photon converting into electron-positron pair

[3] ATLAS Collaboration, Search for type-III seesaw heavy leptons in dilepton final states with a $\sqrt{s}$ = 13 Tev with the ATLAS Detector, EXOT-2018-33

Results

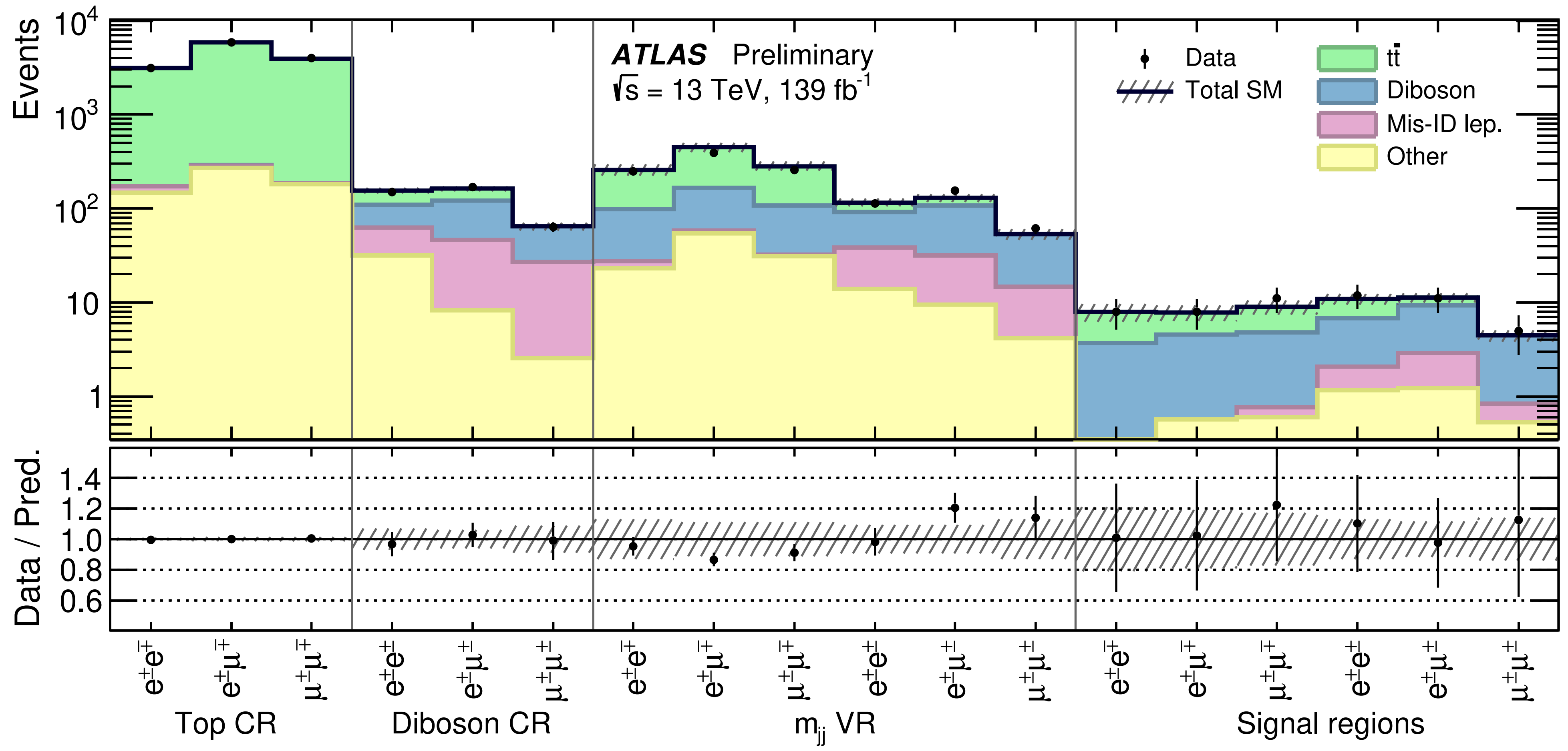

Fig.4 Number of observed and expected events in each analysis regions.

All the **six SRs** are combined in the fit.

(ee, eμ, μμ) x (OS,SS)

No excess with respect the SM is found. Then, **a lower limit** on the **heavy lepton mass** at 95% of Confidence Level is set:

Observed: 790 GeV

Expected: 820 GeV

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

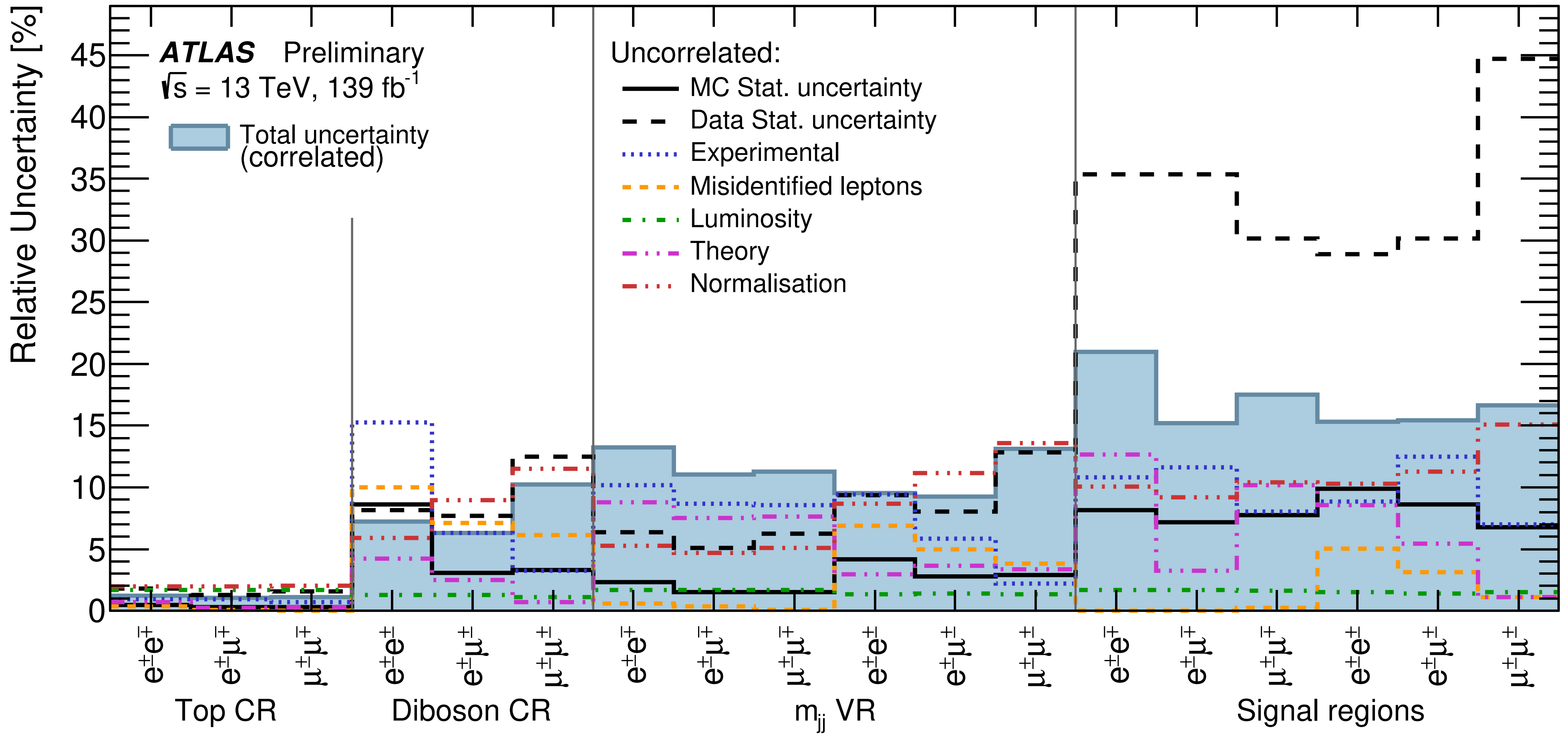

Fig.5 Relative uncertainties in the total background yield estimation after fit.

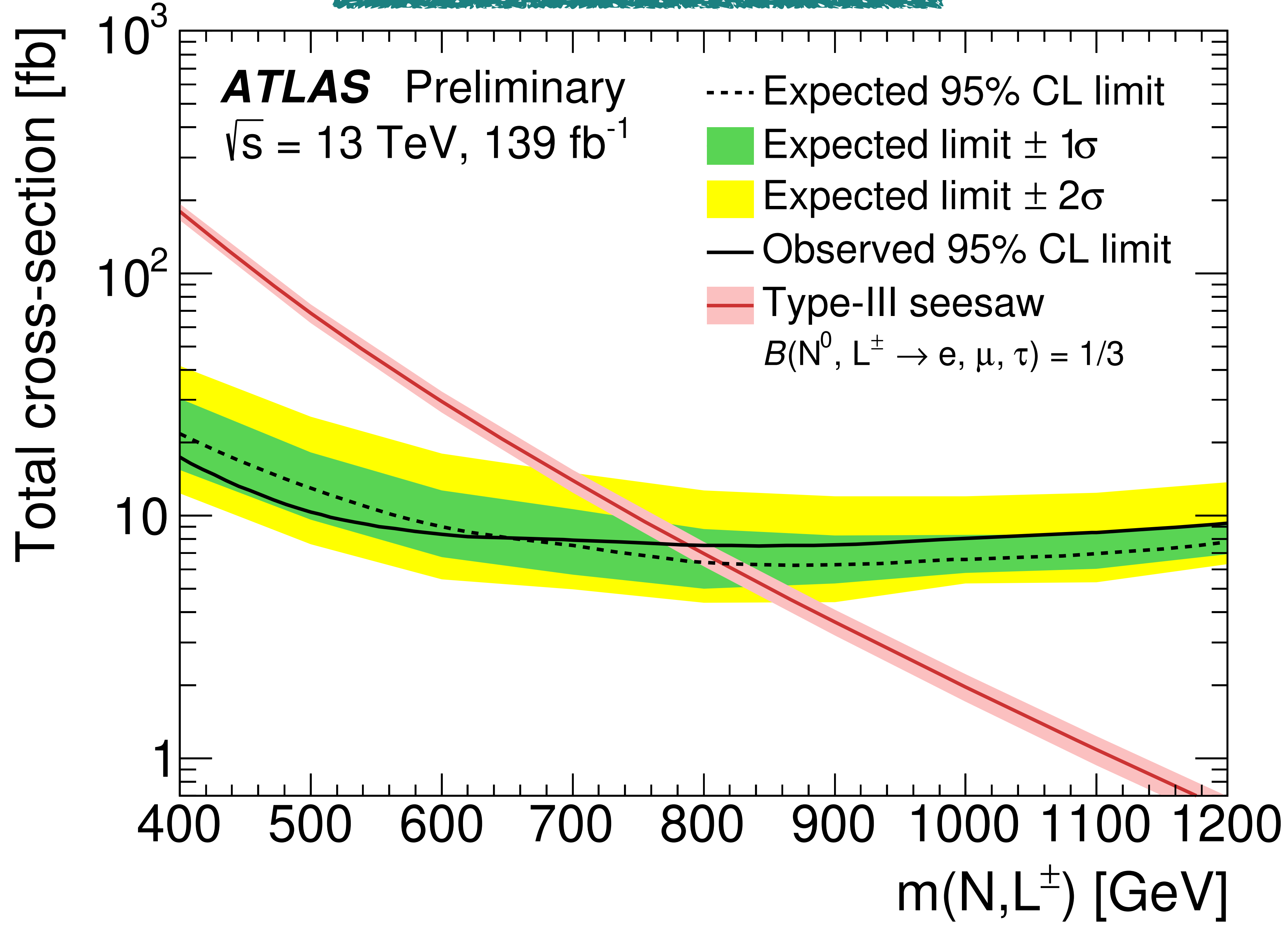

Fig.6 Heavy lepton mass exclusion limit.