Search for charged Higgs bosons decaying to $W^{\pm}W^{\pm}$ or $W^{\pm}Z$ in 139 fb^{-1} of $\sqrt{s}$ = 13 TeV pp collisions with the ATLAS detector

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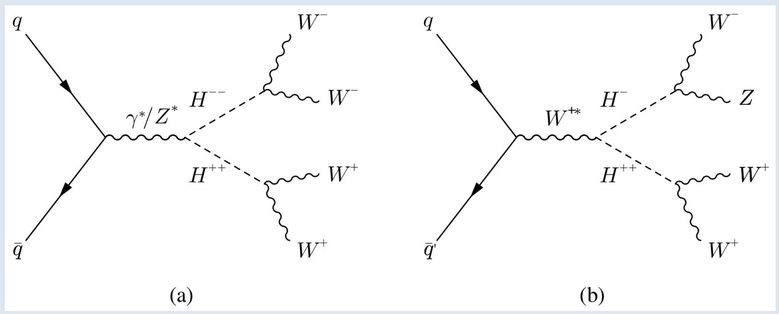
I. Abstract

This poster presents a search for charged Higgs bosons decaying into *WW* or *WZ* bosons, involving experimental signatures with two, three and four leptons with a variety of charge combinations, missing transverse momentum and jets. We are using a data sample of proton–proton collisions at a centre-of-mass energy of 13 TeV measured with the ATLAS detector between 2015 and 2018. The total integrated luminosity for this data is 139 fb^{-1}. The search is guided by a type-II seesaw model that extends the scalar sector of the Standard Model with a scalar triplet, leading to a phenomenology that includes doubly and singly charged Higgs bosons. Two scenarios are explored, corresponding to the pair production of doubly charged H bosons, or the associated production of a doubly charged H boson and a singly charged H boson. No significant deviations from the Standard Model predictions are observed. $H^{\pm\pm}$ bosons are excluded at 95% confidence level up to 350 GeV and 230 GeV for the pair and associated production modes, respectively.

I. Introduction & Motivation

- Neutrino oscillations have been observed by a multitude of experiments ⇨ **neutrinos are massive** ⇨ extension of the SM
- **Type-II seesaw model:** extends the Higgs sector in the SM with a hypercharge Y=2 scalar triplet Δ
- After the EWSB seven scalar bosons result: $H^{\pm}H^{\pm}$, $H^{\pm}$, A^0 (CP odd), H^0 (CP even) and h^0 (CP even and the SM Higgs boson)
- It provides non-zero neutrino masses proportional to the v_t
- **Production Mode**

1. Pair Production, figure (a): $pp \longrightarrow \gamma^*/Z^* \longrightarrow H^{\pm\pm}H^{\mp\mp}$
2. Associated Production, figure (b): $pp \longrightarrow W^{\pm *} \longrightarrow H^{\pm\pm}H^{\mp}$



- The mixing between the CP-even scalars is chosen to be 10^{-4} and $h^0 = 125$ GeV
- AFII signal samples: $m_{H^{\pm\pm}} = 200$ up to 600 GeV

$m_{H^{\pm\pm}}$ [GeV]	200	300	400	500	600
Cross-section [fb]	81.0	16.5	4.9	1.8	0.7
$m_{H^{\pm}}$ [GeV]	196	295	395	496	602
Cross-section [fb]	88.7	9.5	3.0	1.2	0.5

II. Event reconstruction

- **Data and MC samples:**
  - The analysis is based on a total integrated luminosity of 139 fb^{-1} of ATLAS data recorded between 2015 and 2018 at centre-of-mass energy of 13 TeV
- Only electrons and muons, no taus
- Requirements applied for: loose (L), loose and minimally isolated (L*) and tight (T) leptons:

	Electrons				Mouns			
	Candidate	L	L*	T	Candidate	L	L*	T
$\lvert z_0 \sin\theta\rvert$	< 0.5 mm				< 0.5 mm			
$\lvert d_0\rvert / \sigma(d_0)$	< 5				< 3			
Identification	Loose			Tight	Medium			
Isolation	No		Loose	Yes	No		FixedCut Loose	Yes
Non-prompt-lepton veto	No			Yes	No			Yes
Electron charge-flip veto	No	Yes			N/A			

- **Jets** with $p_T > 20$ GeV, $|\eta| < 2.5$, anti-k_T algorithm, $\Delta R = 0.4$
  - Pile-up jets with $p_T < 60$ GeV and $|\eta| < 2.4$ removed using the jet-vertex tagging discriminant
  - b-jets identified in $|\eta| < 2.5$ with the DL1r b-tagging algorithm (70% average efficiency)
- E_T^{miss} computed using METMakerTool
- **Overlap removal** applied: standard WP for electrons, p_T-dependent WP for muons
- **Trigger selection:**
  - The data have been collected by single lepton triggers
  - At least one lepton to be trigger matched and have a $p_T > 30$ GeV
  - Only tight leptons used for trigger matching

III. Event selection

- **Event preselection:**
  - Three final states (channels) classified according to the number of leptons: $2\ell^{SC}$, 3ℓ and 4ℓ
  - $2\ell^{SC}$ channel is divided in ee, $e\mu$ and $\mu\mu$ sub-channels
  - 3ℓ divided in two sub-channels: SFOC0 and SFOC1,2

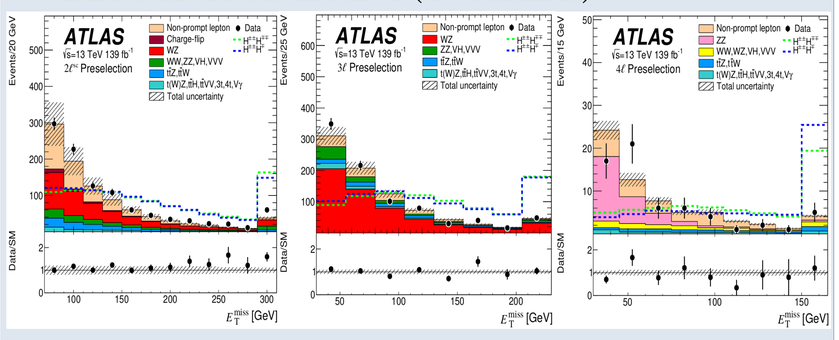
Selection criteria	$2\ell^{SC}$	3ℓ	4ℓ
At least one offline tight lepton with $p_T^{\ell} > 30$ GeV that triggered the event			
N_ℓ (type L)	= 2	= 3	= 4
N_ℓ (type L*)	-	-	= 4
N_ℓ (type T)	= 2	$\geq 2(\ell_{1,2})$	≥ 1
$\lvert\Sigma Q_\ell\rvert$	= 2	= 1	$\neq 4$
Lepton p_T	$p_T^{\ell 1,\ell 2}$>30, 20 GeV	$p_T^{\ell 1,\ell 2,\ell 3} > 10, 20, 20$ GeV	$p_T^{\ell 1,\ell 2,\ell 3,\ell 4} > 10$ GeV
E_T^{miss}	> 70 GeV	> 30 GeV	> 30 GeV
N_{jets}	≥ 3	≥ 2	-
$N_{b\text{-jets}}$	= 0		
Low SFOC $m_{\ell\ell}$ veto	-	$m_{\ell\ell}^{OC} > 15$ GeV	
Z boson decay veto	$\lvert m_{\ell\ell}^{SC} - m_Z\rvert > 10$ GeV	$\lvert m_{\ell\ell}^{OC} - m_Z\rvert > 10$ GeV	

- The selection is applied on top of the pre-selection defined above

Charged Higgs boson mass	$m_{H^{\pm\pm}}$ = 200 GeV	$m_{H^{\pm\pm}}$ = 300 GeV	$m_{H^{\pm\pm}}$ = 400 GeV	$m_{H^{\pm\pm}}$ = 500 GeV
Selection criteria	$2\ell^{SC}$ channel			
m_{jets} [GeV]	[100, 450]	[100, 500]	[300, 700]	[400, 1000]
S	< 0.3	< 0.6	< 0.6	< 0.9
$\Delta R_{\ell^\pm\ell^\pm}$	< 1.9	< 2.1	< 2.2	< 2.4
$\Delta\Phi_{\ell\ell,Et}^{miss}$	< 0.7	< 0.9	< 1.0	< 1.0
$m_{x\ell}$ [GeV]	[40, 150]	[90, 240]	[130, 340]	[130, 400]
E_t^{miss} [GeV]	> 100	> 130	> 170	> 200
Selection criteria	3ℓ channel			
$\Delta R\ell^\pm\ell^\pm$	[0.2, 1.7]	[0.0, 2.1]	[0.2, 2.5]	[0.3, 2.8]
$m_{x\ell}$ [GeV]	> 160	> 190	> 240	> 310
E_t^{miss} [GeV]	> 30	> 55	> 80	> 90
$\Delta R_{\ell jet}$	[0.1, 1.5]	[0.1, 2.0]	[0.1, 2.3]	[0.5, 2.3]
$p_T^{leading\ jet}$ [GeV]	> 40	> 70	> 100	> 95
Selection criteria	4ℓ channel			
$m_{x\ell}$ [GeV]	> 230	> 270	> 360	> 440
E_t^{miss} [GeV]	> 60	> 60	> 60	> 60
$p_T^{\ell 1}$ [GeV]	> 65	> 80	> 110	> 130
$\Delta R_{\ell^\pm\ell^\pm}^{min}$	[0.2, 1.2]	[0.2, 2.0]	[0.5, 2.4]	[0.6, 2.4]
$\Delta R_{\ell^\pm\ell^\pm}^{max}$	[0.3, 2.0]	[0.5, 2.6]	[0.4, 3.1]	[0.6, 3.1]

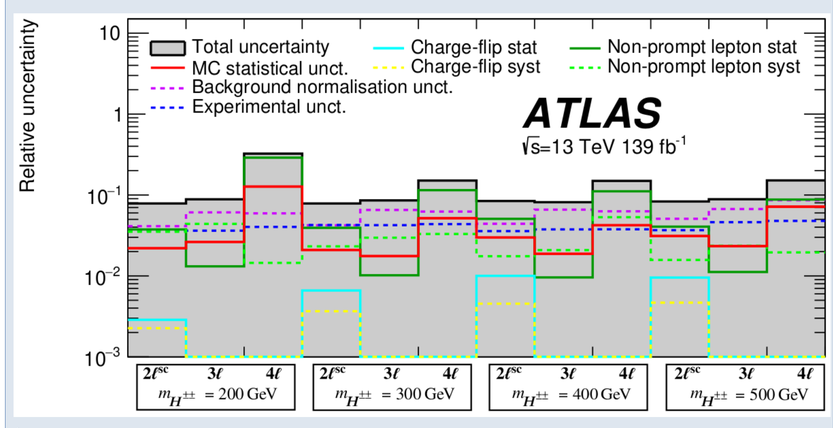
IV. Background model

- **Prompt background:** leptons from prompt leptonic decays of W and Z bosons
  - Estimated with MC simulations and normalized to the SM cross sections
  - WZ normalization corrected using data, with a dedicated control region (CR)
- **Fake/Non-prompt background:**
  - electron charge-flip: data-driven likelihood method ($2\ell^{SC}$)
  - fake/non-prompt leptons: data-driven fake factor method ($2\ell^{SC}$, 3ℓ channels) and semi-data-driven fake scale factor method (4ℓ channel)

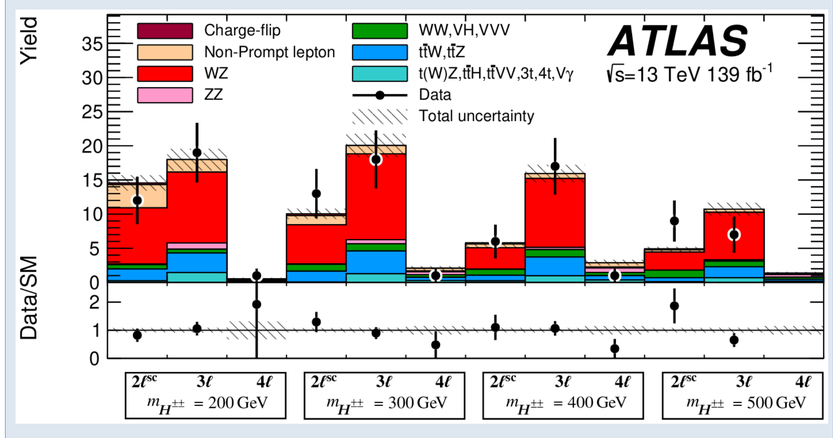


V. Results and conclusions

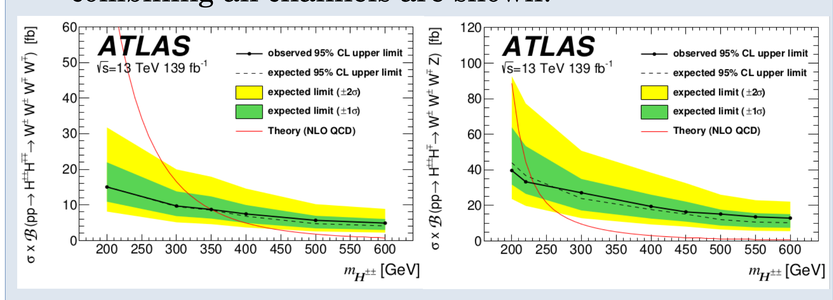
- The summary of all sources of uncertainties in all SRs:



- The uncertainties associated to the charge-flip background is small in all SRs
- The statistical uncertainties on the fake/NP leptons estimate or the theory uncertainty are dominant in the SRs



- No significant excess in any of the signal regions is observed
- The expected and observed limits obtained after combining all channels are shown:



- Combining all channels, the model is excluded at 95% C.L. for masses up to ~350 GeV for pair-production (left figure) and 220 GeV for associated-production (right figure) scenarios

VI. References

1 CERN-EP-2017-198, *Search for doubly charged Higgs boson production in multi-lepton final states with the ATLAS detector using proton-proton collisions at √s=13 TeV*

2 ATL-COM-PHYS-2016-1121, *Search for doubly and singly charged scalar Higgs bosons decaying into vector bosons in multi-lepton final states with the ATLAS detector using proton-proton collisions at √s=13 TeV*

3 W. Konetschny and W. Kummer, *Nonconservation of total lepton number with scalar bosons,* Phys. Lett. B 70 (1977) 433

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Reference: arXiv:2101.11961 [hep-ex]