# Search for a charged higgs boson ($H^{\pm}$) in the $Wh(h \to b\bar{b})$ boosted channel using multivariate methods with the ATLAS experiment

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In order to address the shortcomings of the Standard Model, many theories describing physics beyond the Standard Model being studied. One such extension is the Two-Higgs-Doublet Model (2HDM) [1], which predicts the existence of five physical Higgs bosons, including a pair of charged Higgs bosons $H^{\pm}$. Observing these would therefore provide clear evidence for physics beyond the Standard Model.

This work presents a search for a heavy charged Higgs boson produced in association with a top quark and a bottom quark in $pp \to tbH^{\pm}$. The $H^{\pm} \to W^{\pm}h$ decay is studied, with $h \to b\bar{b}$ and both the hadronic $W^{\pm} \to qq'$ and leptonic $W^{\pm} \to \ell\nu$ decays considered. The analysis uses the full ATLAS Run-2 dataset at $\sqrt{s} = 13$ TeV, corresponding to 140.1 fb$^{-1}$, and investigates charged-Higgs boson masses between 1.2 and 3.0 TeV.

The search focuses on the boosted regime, with events separated into hadronic $qqbb$ and leptonic $\ell\nu bb$ channels. The dominant backgrounds are top-quark pair production and $W/Z$+jets processes. Following the strategy of a previous study published by the ATLAS Collaboration [2], a baseline analysis using deep neural networks (DNNs) was performed for signal–background separation and to define signal and control regions. This work focuses on the study of mass-parameterized neural networks (PNNs). An initial PNN showed only limited improvement, which motivated the development of an optimized PNN-2 with improved input-variable selection and network configuration. PNN-2 improves separation between signals and backgrounds and can interpolate between intermediate charged-Higgs mass hypotheses that were not used during training.

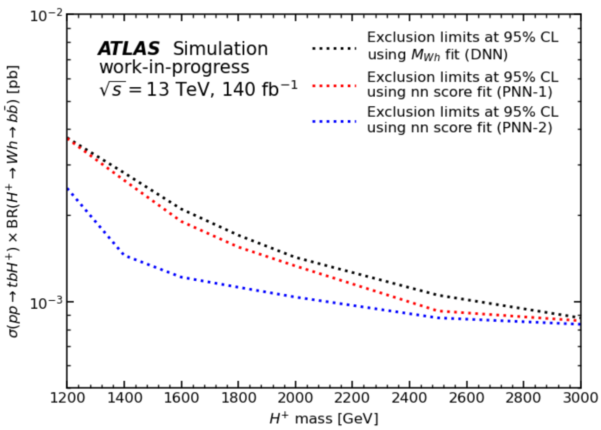


Figure 1: Expected 95% CL upper limits for the baseline DNN, PNN-1, and optimized PNN-2 analyses.

The final sensitivity is evaluated using a binned-likelihood analysis. First, a background-only fit is used to constrain the backgrounds. Then, a blinded signal-plus-background fit is used to determine the expected 95% confidence-level upper limits on $\sigma(pp \to tbH^{\pm}) \times \mathcal{B}(H^{\pm} \to W^{\pm}h \to W^{\pm}b\bar{b})$. The baseline analysis uses the reconstructed charged-Higgs mass, $m_{W^{\pm}h}$ as the fit discriminant, whereas the PNN analyses use the neural-network score. The fit distributions are binned to preserve sensitivity while maintaining sufficient event statistics.

As shown in Figure 1, the optimized PNN-2 analyses provides the strongest expected sensitivity, due to its mass parameterization, optimized input variables and network configuration, and the use of the PNN score as the final fit discriminant. Figure 2 shows the expected 95% CL upper limits from the optimized PNN-2 analysis including the available experimental systematic uncertainties.

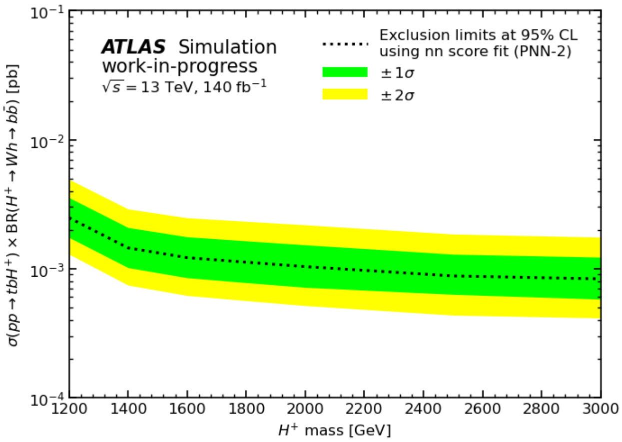


Figure 2: Expected 95% CL upper limits from the optimized PNN-2 analysis including the available experimental systematic uncertainties.

## References


[1] G.C. Branco, P.M. Ferreira, L. Lavoura, M.N. Rebelo, Marc Sher, and João P. Silva. Theory and phenomenology of two-higgs-doublet models. *Physics Reports*, 516(1–2):1–102, July 2012.

[2] ATLAS Collaboration. Search for a heavy charged higgs boson decaying into a w boson and a higgs boson in final states with leptons and b-jets in $\sqrt{s} = 13$ tev pp collisions with the atlas detector. *Journal of High Energy Physics*, 2025(2), February 2025.