Exploring Charged Higgs Bosons in the Georgi-Machacek Model:
Latest Findings from the ATLAS Experiment at LHC

Introduction

➢ Search for $H^\pm \to W^\pm Z$ and $H^{\pm\pm} \to W^\pm W^\pm$ produced via the Vector Boson Fusion mechanism in fully leptonic final states, $\ell\nu\ell\ell$ and $\ell\nu\ell\nu$, respectively
➢ Full LHC Run 2 data with an integrated luminosity of 140 fb^{-1}
➢ Results interpreted in the Georgi-Machacek (GM) Model
➢ Set 95% confidence level (CL) upper limits on the model-dependent parameter in a wide mass range

SM Higgs Sector

$$\Phi = \begin{pmatrix} \phi^{0*} & \phi^+ \\ -\phi^{+*} & \phi^0 \end{pmatrix}$$

Extended Triplets

$$X = \begin{pmatrix} \chi^{0*} & \xi^+ & \chi^{++} \\ -\chi^{+*} & \xi^0 & \chi^+ \\ \chi^{++*} & -\xi^{+*} & \chi^0 \end{pmatrix}$$
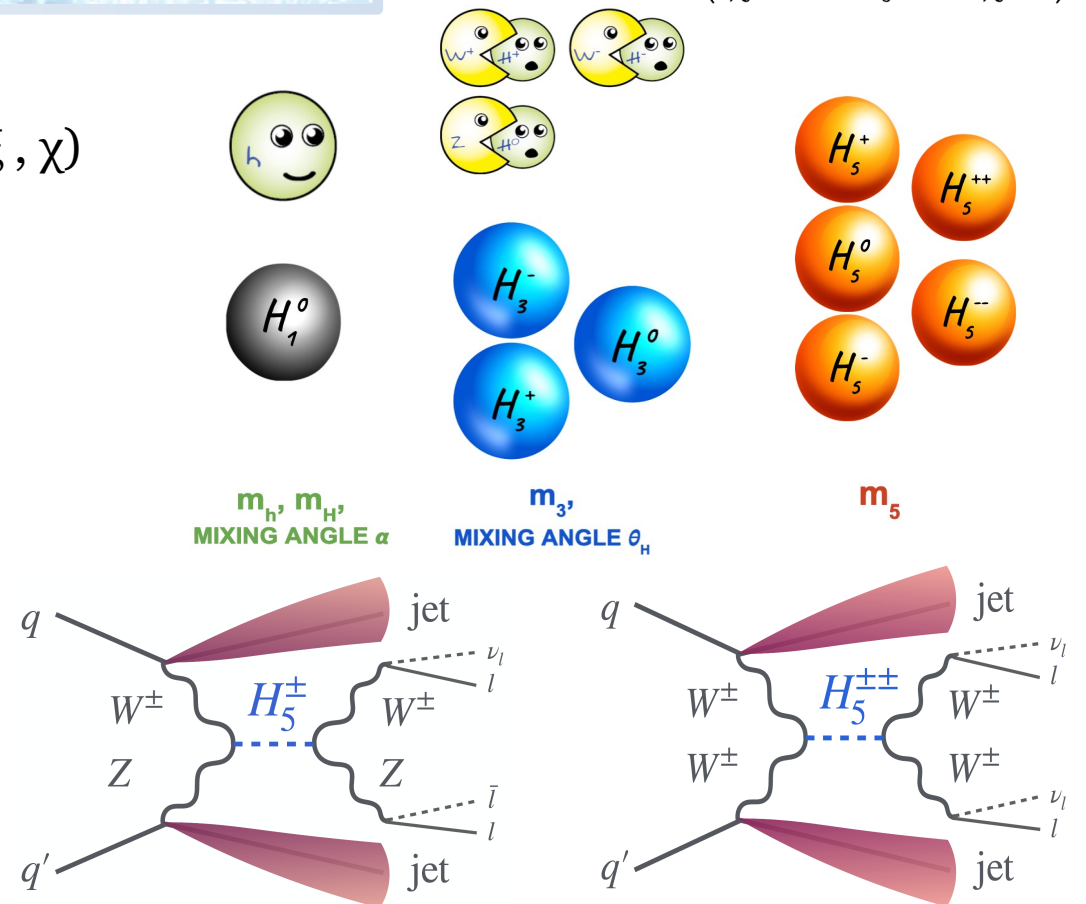
Georgi-Machacek Model[1]

Extension of SM Higgs sector with both real and complex triplets (ξ , χ)

➢ The EWSB is realized by three scalar fields
➢ Minimal triplet extension with custodial symmetry preserved
➢ Different multiplets under SU(2): quintuplet (H_5), triplet (H_3), two singlets (h, H)

H5Plane Benchmark is considered, assuming $m_3 > m_5$

➢ BR($H^\pm \to W^\pm Z$) = 1 and BR($H^{\pm\pm} \to W^\pm W^\pm$) = 1
➢ Vector Boson Fusion production
➢ Model dependent parameters:
  m_{H_5} (degenerate state mass), $\sin\theta_H$ (fraction of triplet contribution to VEV)
➢ Signal samples generated with MadGraph for the WZ and same-sign WW (ssWW)

$$\sin\theta_H = \frac{2\sqrt{2}\, v_\chi}{v} \qquad v_\phi^2 + 8v_\chi^2 \equiv v^2 \approx (246\ \text{GeV})^2$$
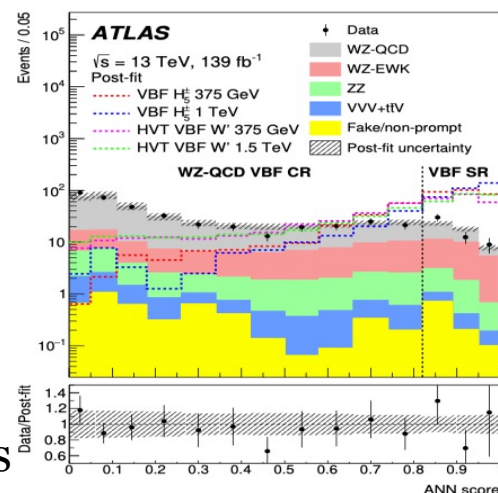
$m_h, m_H,$ MIXING ANGLE α $m_3,$ MIXING ANGLE θ_H m_5

Previous Studies at ATLAS[2,3]

Search for $H^\pm \to W^\pm Z$

➢ Artificial Neural Network (ANN) for VBF signal selections
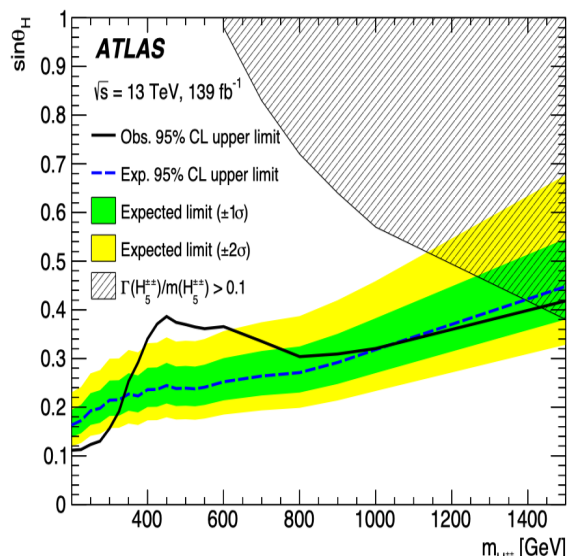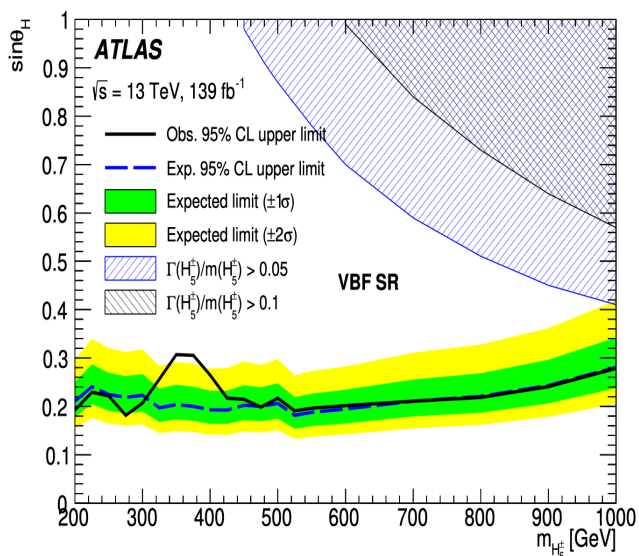➢ Dedicated WZ-QCD Control Region

Search for $H^{\pm\pm} \to W^\pm W^\pm$

➢ Signal extraction was performed via a 2D fit (m_{jj}, m_T)

Model dependent exclusion limits

➢ More sensitive by the ssWW in lower mass range
➢ Combining analyses aims to achieve better constraints

Combination Strategies

Orthogonality

➢ The WZ-QCD CR in ssWW analysis dropped due to overlap

Systematics Correlation

➢ Conservative approach always followed
➢ Combination still dominated by statistics

pQCD order harmonization

➢ Two signal samples generated at different pQCD
➢ Both samples scaled to NNLO by QCD K-factors
➢ Normalization factors uncertainties added

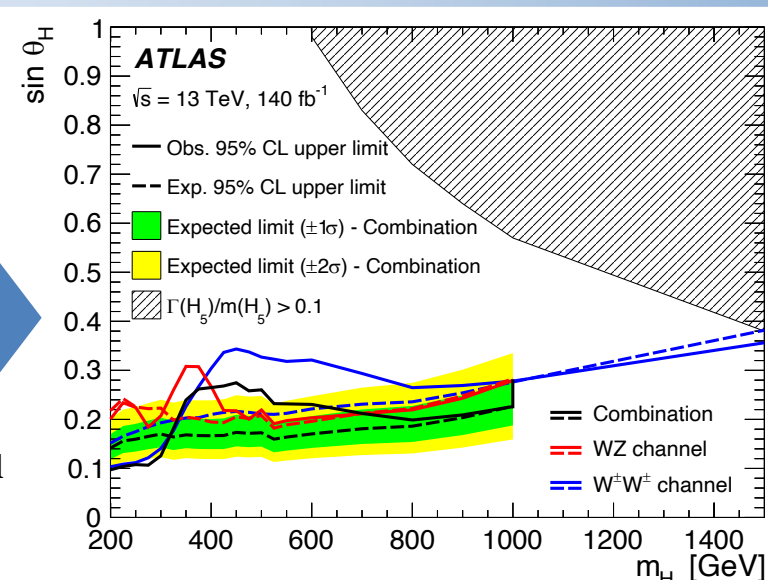| Combination signal extraction fit	
Region	Description
SR WZ	9 bins in m_{WZ}
SR same-sign WW	5 bins in m_{jj} and 8 bins in m_T
CR ZZ	17 bins in m_{WZ}
CR $W^\pm Z$ – QCD	9 bins in m_{WZ}
CR Low-m_{jj}	1 bin in m_{jj} and 8 bins in m_T
Parameter of interest	$\mu(H_5)$
Normalisation parameters	$\mu(W^\pm Z - \text{QCD})$, $\mu(ZZ)$ and $\mu(W^\pm W^\pm - \text{EW})$
Observables	m_{WZ}, m_{jj} and m_T

Combination Results[4]
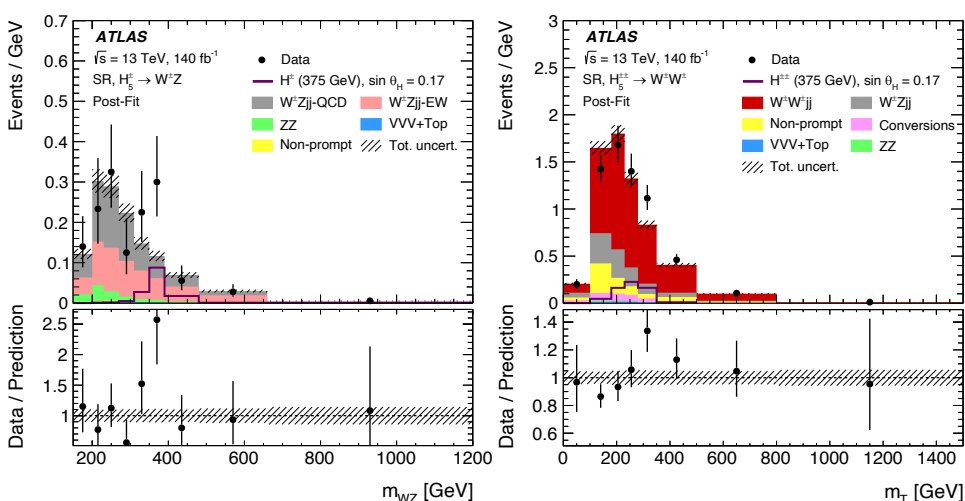
Post-fit m_{WZ} and m_T distributions under the Standard Model background-only hypothesis

GM Exclusion limits on $\sin\theta_H$

➢ Excluding $\sin\theta_H$ values greater than 0.10 - 0.36
➢ Improvements of 6% - 22% for all the mass points
➢ Largest local significance: **3.3 σ at 375 GeV**, global significance 2.5 σ

[1] arXiv:1610.07922
[2] Eur. Phys. J. C 83 (2023) 633
[3] JHEP04(2024)026
[4] arXiv:2407.10798

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