

Constraining the Georgi-Machacek model with HiggsBounds/HiggsSignals

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Motivation

- Want to constrain the parameter space of a model using experimental data
- Given:
 - Code to calculate model decay rates and couplings
 - Code to implement experimental constraints

Outline

- Background
 - Georgi-Machacek (GM) model
 - GMCALC
 - HiggsBounds
 - HiggsSignals
- Methods and Results
 - H5plane benchmark
 - General scan, high mass
 - General scan, low mass
 - HiggsSignals scans
- Outlook

GM model

- Extends SM Higgs by adding a real and a complex scalar isospin triplet field
- Preserves the ρ parameter: $\rho \equiv \frac{M_W^2}{M_Z^2 \cos^2 \theta_w}$
- Results in two singlets (h and H), a triplet (H_3^0, H_3^\pm), and a fiveplet ($H_5^0, H_5^\pm, H_5^{\pm\pm}$)
- Seven free parameters once vev and m_h are fixed
- One possible parametrization: $m_H, m_3, m_5, \sin \theta_H, \sin \alpha, M_1, M_2$
- The H5plane benchmark is a 2D slice of the parameter space with $m_5 \in [200, 3000]$ GeV and $s_H \in [0, 1]$.

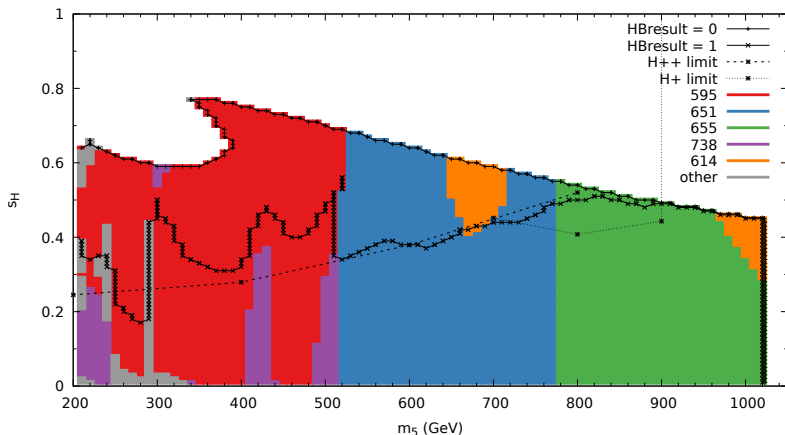
GMCALC and HiggsBounds/HiggsSignals

- GMCALC: Calculates couplings and decay rates in GM model, checks theoretical constraints
- HiggsBounds: Implements direct-search constraints on Higgs production and decays
 - Is the model excluded at the 95% confidence level?
 - What search channel is most sensitive to the model?
- HiggsSignals: Tests model predictions against observed Higgs signals (χ^2 test)

Methods

- Performed three separate scans, feeding GMCALC output to HiggsBounds and HiggsSignals:
 - Grid of points in H5plane benchmark (but $m_5 \in [200, 1050]$ GeV)
 - Randomly scanned points in entire parameter space with $m_5 \in [200, 1050]$ GeV
 - Randomly scanned points in entire parameter space with $m_5 \in [75, 200]$ GeV
- HiggsBounds constraints were applied to non-SM Higgses
- HiggsSignals was used to constrain SM Higgs
- Additional constraints on singly and doubly charged Higgses plotted on top of exclusion curves

H5plane - all non-SM Higgses

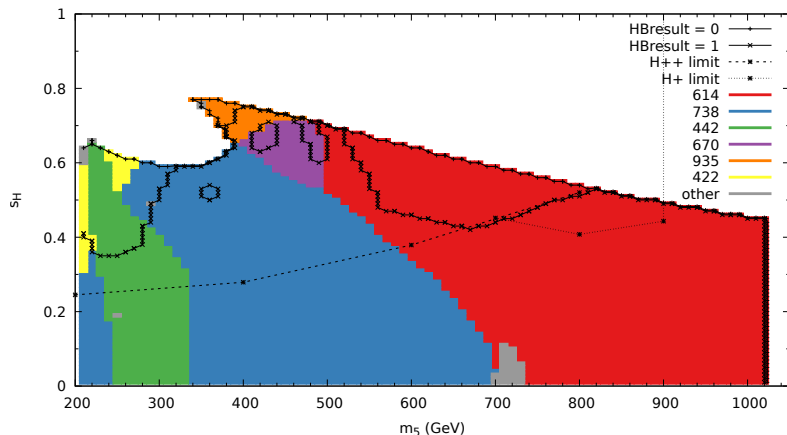


595: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$. 651: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$.

655: $gg \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$. 738: $p\bar{p} \rightarrow H \rightarrow ZZ$.

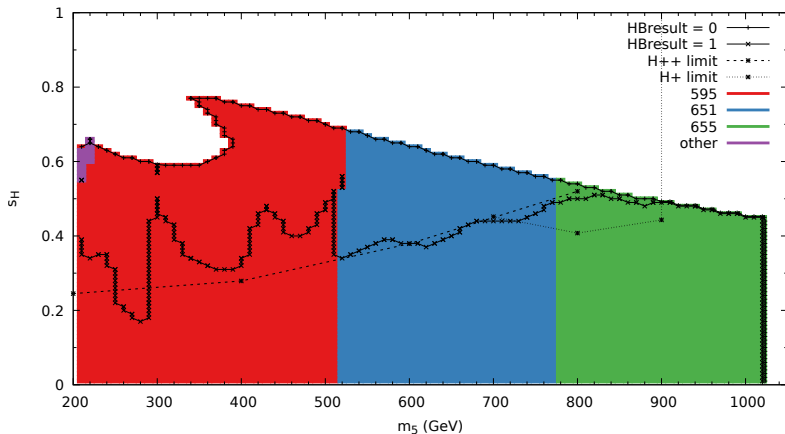
614: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}b\bar{b}$.

H5plane - H



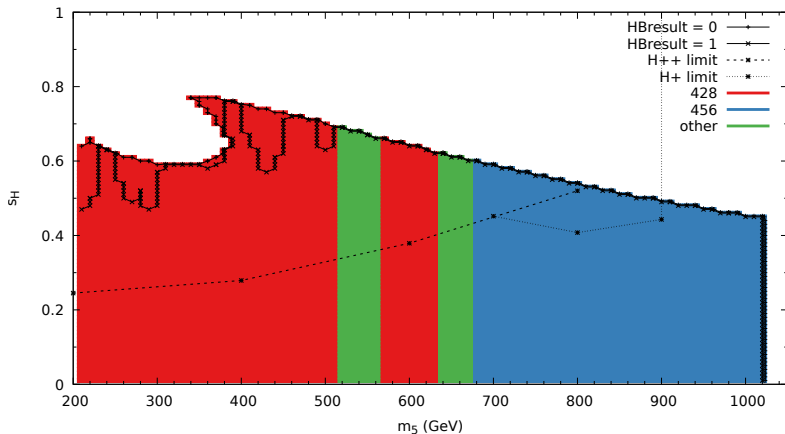
614: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}b\bar{b}$. 738: $p\bar{p} \rightarrow H \rightarrow ZZ$.
442: $p\bar{p} \rightarrow H \rightarrow VV$. 670: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}b\bar{b}$.
935: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow \gamma\gamma b\bar{b}$. 422: $gg \rightarrow H \rightarrow ZZ \rightarrow 4\ell$.

H5plane - H_3^0



595: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$. 651: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$.
 655: $gg \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$.

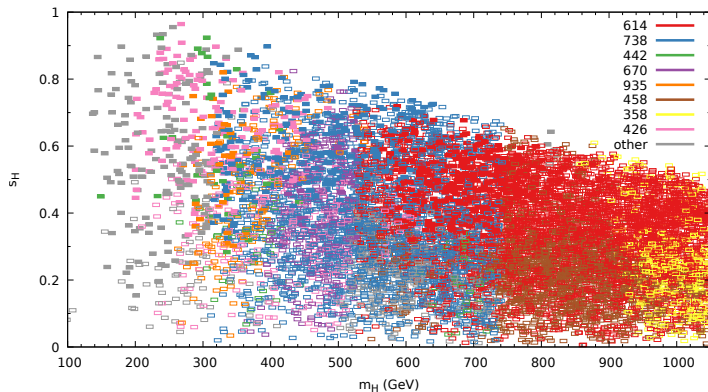
H5plane - H_5^0



$$428: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ \rightarrow 4\ell . \quad 456: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ \rightarrow \ell\ell q\bar{q} .$$

$$744: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ .$$

General scan ($m_5 \in [200, 1050]$ GeV) - H



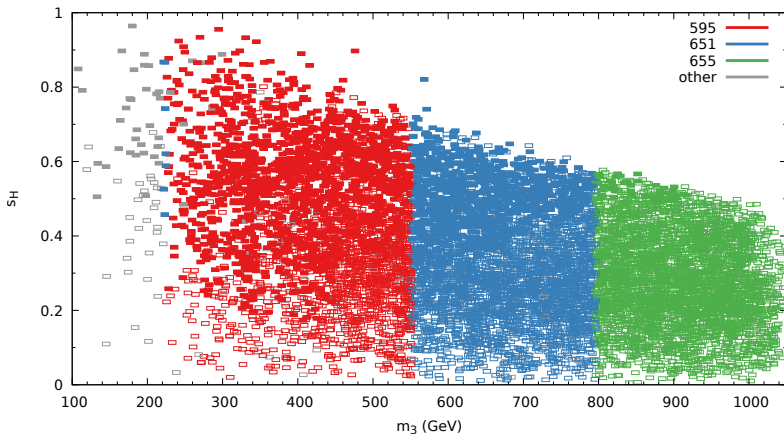
614: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}b\bar{b}$. 738: $p\bar{p} \rightarrow H \rightarrow ZZ$.

442: $p\bar{p} \rightarrow H \rightarrow VV$. 670: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}b\bar{b}$.

935: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow \gamma\gamma b\bar{b}$. 458: $p\bar{p} \xrightarrow{VBF} H \rightarrow ZZ \rightarrow llq\bar{q}$.

358: $p\bar{p} \rightarrow H \rightarrow WW \rightarrow lvq\bar{q}$. 426: $p\bar{p} \xrightarrow{VBF} H \rightarrow ZZ \rightarrow 4l$.

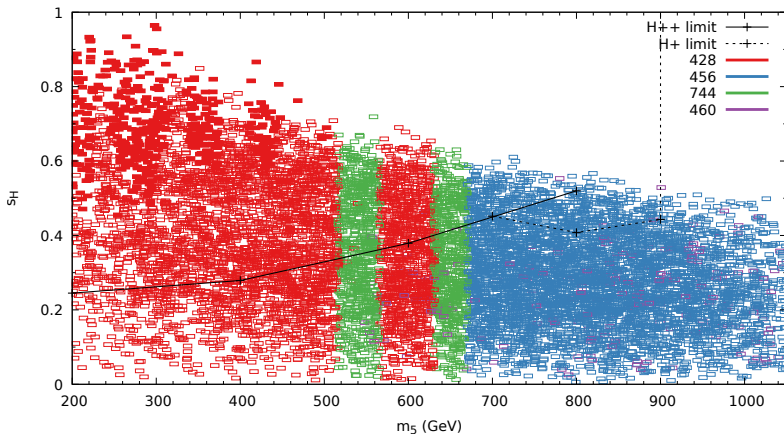
General scan ($m_5 \in [200, 1050]$ GeV) - H_3^0



595: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$. 651: $p\bar{p} \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$.

655: $gg \rightarrow H_3^0 \rightarrow Zh \rightarrow llb\bar{b}$.

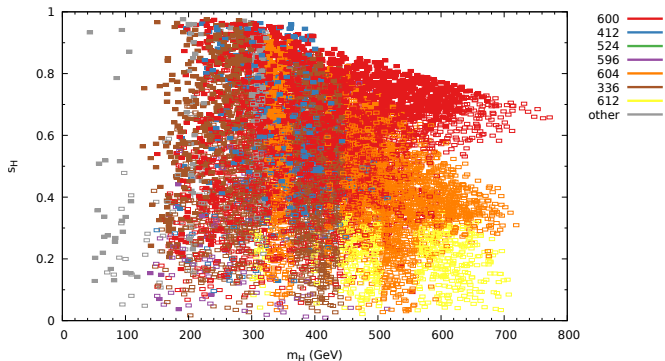
General scan ($m_5 \in [200, 1050]$ GeV) - H_5^0



$$428: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ \rightarrow 4\ell . \quad 456: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ \rightarrow \ell\ell q\bar{q} .$$

$$744: p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ .$$

General scan ($m_5 \in [75, 200]$ GeV) - H



600: $p\bar{p} \rightarrow H \rightarrow ZZ$. 412: $p\bar{p} \rightarrow H \rightarrow VV$.

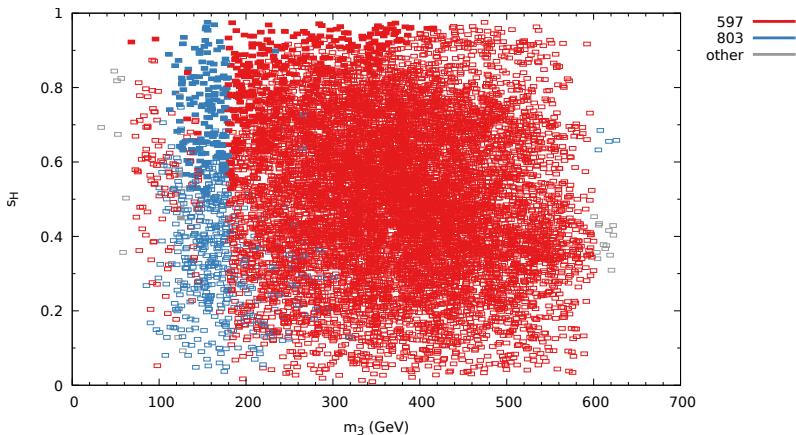
524: $p\bar{p} \rightarrow H \rightarrow hh \rightarrow b\bar{b}/\tau\tau/WW/\gamma\gamma$.

596: $p\bar{p} \rightarrow H/VBF/WH/ZH/t\bar{t}H \rightarrow \gamma\gamma$.

604: $p\bar{p} \xrightarrow{VBF} H \rightarrow ZZ$. 336: $p\bar{p} \xrightarrow{VBF} H \rightarrow WW$.

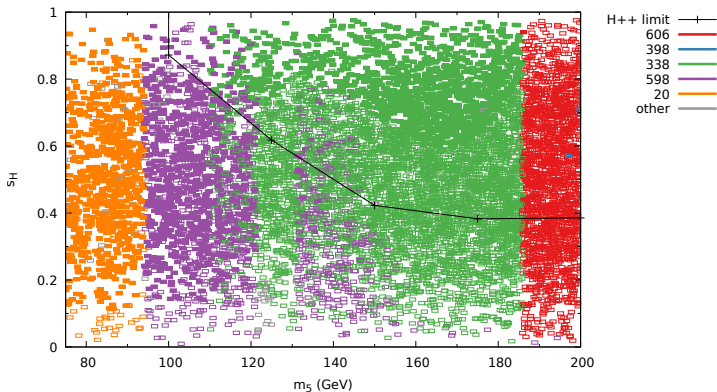
612: $p\bar{p} \xrightarrow{VBF} H \rightarrow WW$.

General scan ($m_5 \in [75, 200]$ GeV) - H_3^0



597: $p\bar{p} \rightarrow H_3^0/VBF/WH/ZH/t\bar{t}H_3^0 \rightarrow \gamma\gamma$. 803: $p\bar{p} \rightarrow H_3^0 \rightarrow \tau\tau$

General scan ($m_5 \in [75, 200]$ GeV) - H_5^0



606: $p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow ZZ$. 398: $p\bar{p} \rightarrow H_5^0/VBF/Vh \rightarrow ZZ \rightarrow 4\ell$.

338: $p\bar{p} \xrightarrow{VBF} H_5^0 \rightarrow WW$.

598: $p\bar{p} \rightarrow H_5^0/VBF/WH/ZH/t\bar{t}H_5^0 \rightarrow \gamma\gamma$.

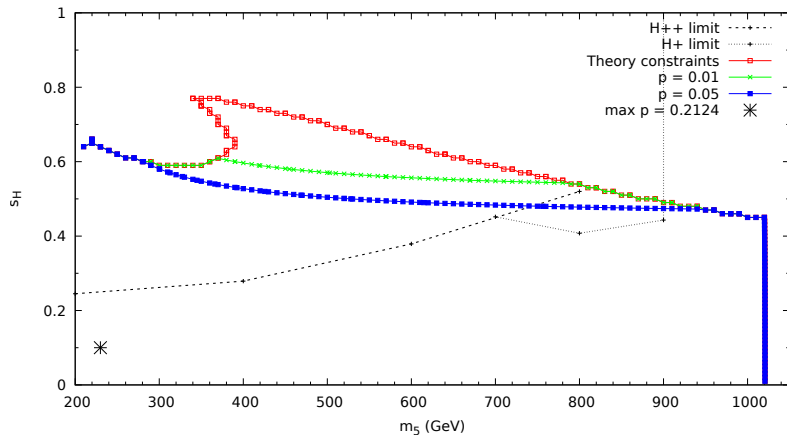
20: $e^+e^- \rightarrow H_5^0 Z \rightarrow \gamma\gamma Z$.

Outlook

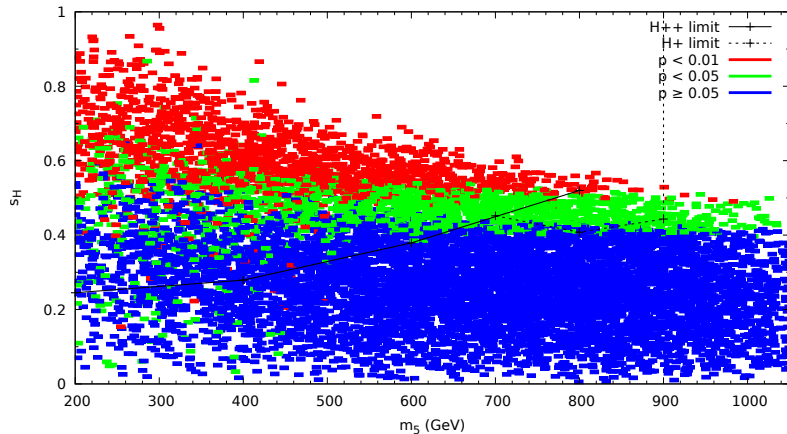
- Compare to global fit of GM model parameters implemented in 1807.10660
- New beta versions of HiggsBounds and HiggsSignals
- Interfacing with HiggsBounds/HiggsSignals in future GMCALC releases

- Fortran
- Compilers and libraries
- Higgs mechanism, EWSB, custodial $SU(2)$ symmetry
- Writing

HiggsSignals - H5plane



HiggsSignals - general scan ($m_5 \in [200, 1050]$ GeV)



HiggsSignals - general scan ($m_5 \in [75, 200]$ GeV)

