Search for new Higgs bosons via same-sign top-quark production in association with an extra jet

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Theoretical background

After the discovery of the 125 GeV Higgs boson, a natural question emerge: are there additional scalar bosons? In the two-Higgs-doublet model (2HDM), Z_2 symmetry is usually imposed to forbid flavor changing neutral current (FCNC). It has been shown that it can be suppressed by the mass-mixing hierarchy and alignment limit instead[1]. In such a 2HDM without Z_2 symmetry, called generalized 2HDM (g2HDM), subTeV exotic Higgs bosons and O(1) extra Yukawa couplings are not yet ruled out by the LHC and it may also help to explain baryongenesis[2] and the possible muon g-2 anomaly[3].

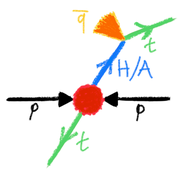
The way forward

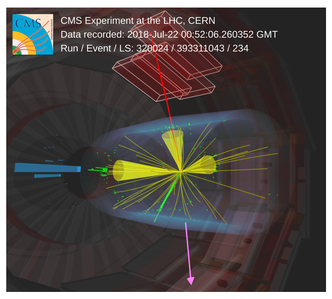
- No hints of new physics beyond Standard Model.
- No other discoveries @ LHC
- We believe energy scales best suited for LHC haven't been exhausted, and look for new Higgs bosons at ~500 GeV mass scale.

Search for $pp \to tH/A \to tt\bar{c}/tt\bar{u}$ with full CMS Run2 Data [7]

Assume one of extra Yukawa couplings, ρ_{tu} or ρ_{tc}, to be non-zero, leading to $tt\bar{u}$ or $tt\bar{c}$ processes.

$$pp \to tH/A \to tt\bar{c}/tt\bar{u}$$
$$\to (\ell^+ b\nu)(\ell^+ b\nu)(\bar{c}/\bar{u})$$



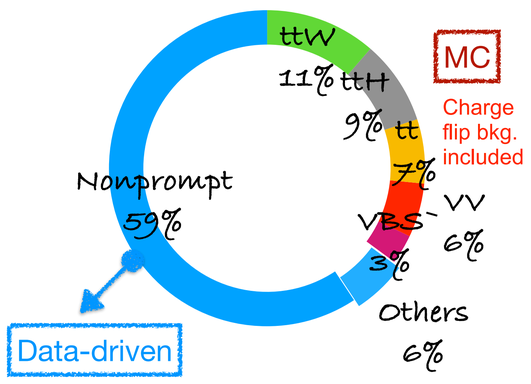


Signature: Two leptons of same sign charge, energetic charm/up+bottom quarks, MET. BDT discriminants are used to further suppress backgrounds. Signature [4,5] only recently started to be explored at the LHC [6,7].

Analysis Strategy

- Search for an extra scalar (H) or pseudo scalar (A) in g2HDM through same-sign top quark in association with an extra jet.
  - Search covers H/A mass values from 200 GeV to 1 TeV for scenarios when only one extra H or A boson exists (**non-interference**) and for when they coexist and interfere with a mass difference of 50 GeV (**interference**).
  - b jets, c jets, and light jets are distinguished via jet flavor probability ratios, CvsL and CvsB.
  - A boosted decision tree (BDT) discriminant used to separate signal and background.

Background contribution

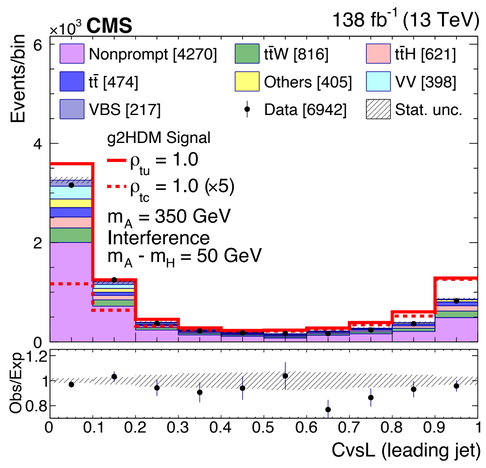


Multivariate discriminant

Input variables of the BDT

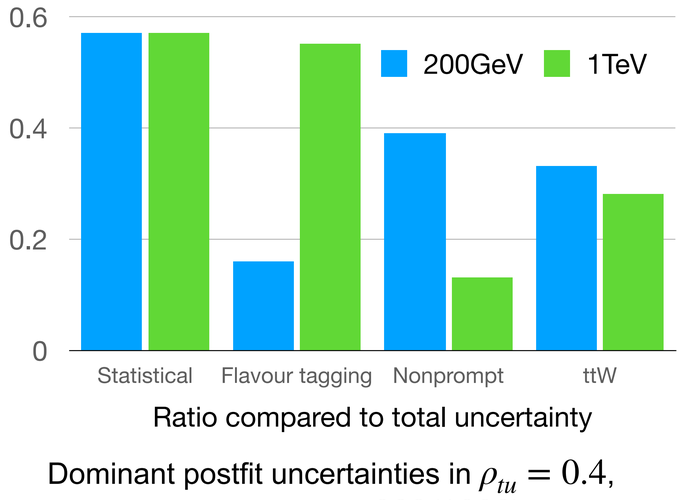
$$p_T(\ell_i) : i = 1,2; H_T, p_T^{miss}$$
$$CvsL(j_i), CvsB(j_i) : i = 1,2,3$$
$$m_{\ell\ell}, m_{\ell\ell}(j_i) : i = 1,2,3$$
$$\Delta R(j_n, j_m), m(j_n, j_m) : 1 \le n < m \le 3$$
$$\Delta R(j_n, \ell_m), m(j_n, \ell_m) : n = 1,2,3; m = 1,2$$

Flavor tagging technique



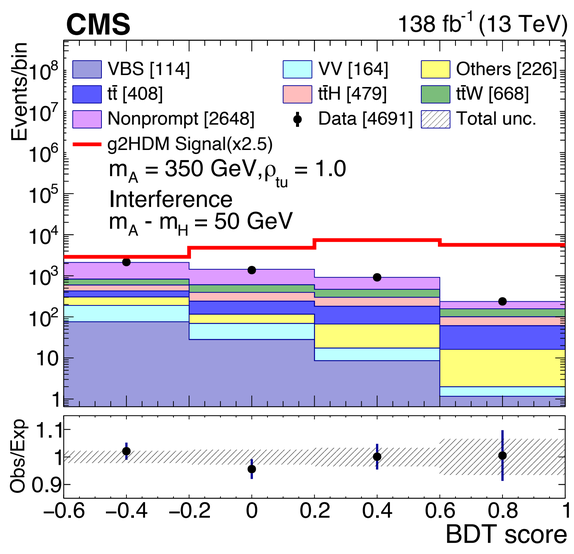
Flavor tagging variable CvsL from machine learning DeepJet algorithm.

Dominant uncertainties

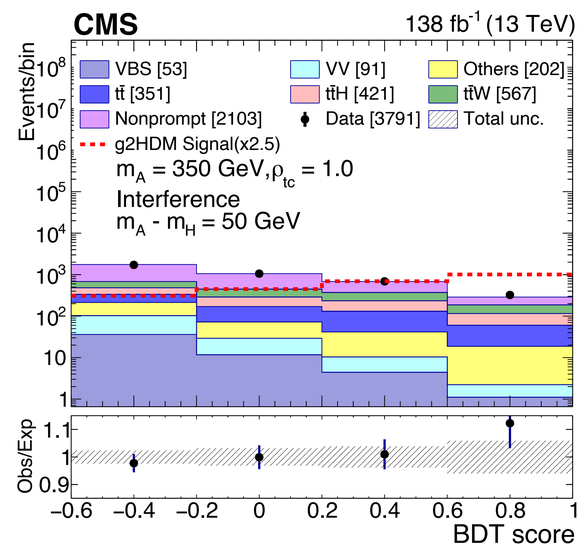


Dominant postfit uncertainties in $\rho_{tu} = 0.4$, noninterference $m_{H/A} = 200(1000)$ GeV cases. The uncertainies are obtained by freezing all other nuisances and perform MLE fit.

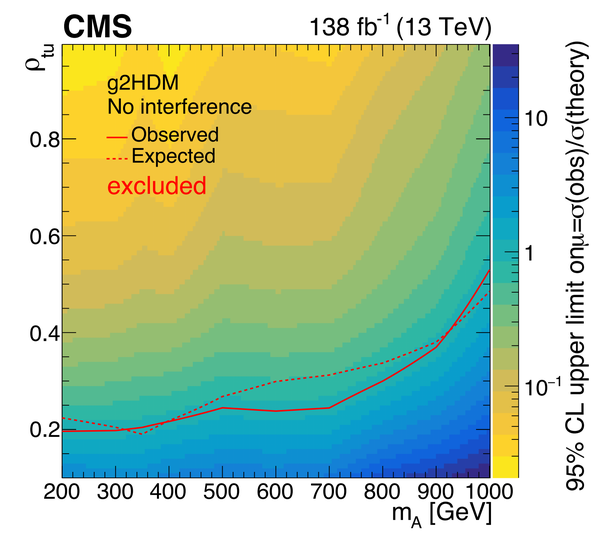
Results

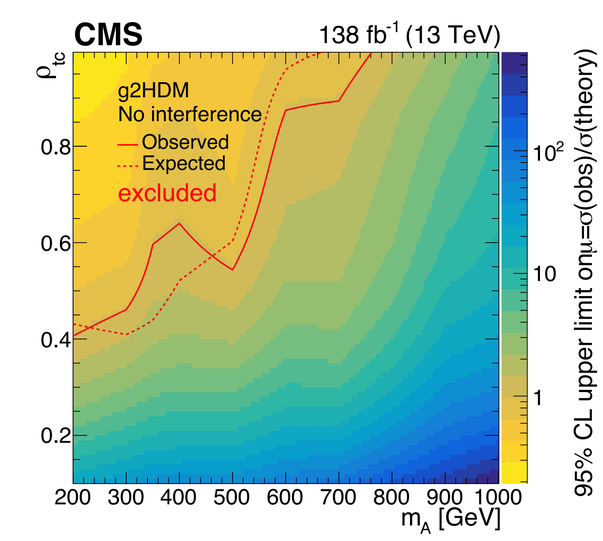


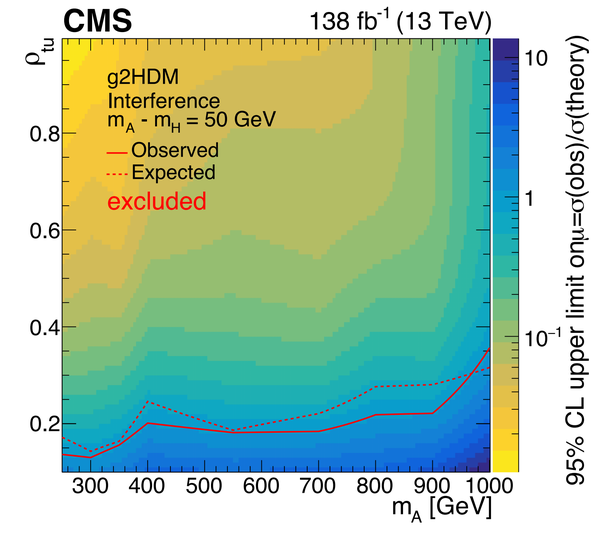
Post-fit BDT variable for all channels combined for m_A=350 GeV with ρ_{tu}=1.0 (interference).

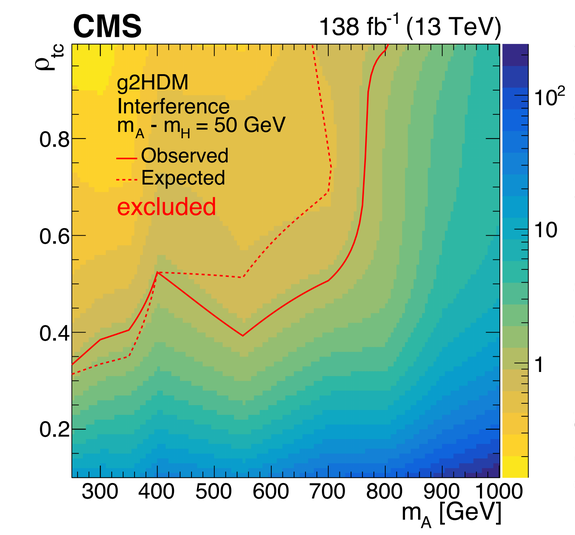


Post-fit BDT variable for all channels combined for m_A=350 GeV with ρ_{tc}=1.0 (interference).









Observed 95% CL upper limit on the signal strength as a function of m_A and extra Yukawa coupling ρ_{tu} (left) and ρ_{tc}(right) with A-H non-interference (up) and A-H interference assuming m_A-m_H=50 GeV(down) scenarios. Expected and observed exclusion of phase space are also provided.

- No significant excess above SM prediction observed for subTeV new Higgs bosons with O(1) extra Yukawa couplings

Other processes in search for new Higgs bosons

- Looking for new Higgs bosons in different final states with different experimental signatures, and increase our chance to find hints of new Higgs bosons i.e. $pp \to bH^+ \to bt\bar{b}$, $pp \to tH/A \to tt\bar{t}$.

Acknowledgments

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References

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