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

Ting-Hsiang Hsu on behalf of CMS Collaboration
Department of Physics, National Taiwan University, Taipei 10617, Taiwan

Theoretical background

After the discovery of the 125 GeV Higgs boson, a natural question emerges: are there additional scalar bosons? In the two-Higgs-doublet model (2HDM), Z₂ 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 Z₂ 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 baryogenesis[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 → tH/A → t¯c/t¯t with full CMS Run2 Data [7]

Assume one of extra Yukawa couplings, ρu or ρc, to be non-zero, leading to t¯t or t¯tt processes.

pp → tH/A → t¯c/t¯t → (e+bu)(e+bu) (¯c/¯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

谎谎谎谎

Input variables of the BDT

p_T(ℓ): i = 1,2; H/ρ
\

CvsL(i), CvsB(i): i = 1,2,3

\Delta R(j_1,j_2),m(j_1,j_2): 1 ≤ n < m ≤ 3

\Delta R(j_1,c_{v_B}), m(j_1,c_{v_B}): n = 1,2,3; m = 1,2

Flavor tagging technique

Flavor tagging variable CvsL from machine learning DeepJet algorithm.

Dominant uncertainties

200 GeV 1 TeV

0.6

0.4

0.2

0

0.6

0.4

0.2

0

Statistical Flavor tagging Nonprompt TH

Ratio compared to total uncertainty

Dominant postfit uncertainties in p_T = 0.4, noninterference m_H = 200 (1000) GeV cases. The uncertainties are obtained by freezing all other nuisances and perform MLE fit.

Results

Post-fit BDT variable for all channels

Observed 95% CL upper limit on the signal strength as a function of m_H and extra Yukawa coupling p_u(left) and p_c(right) with H→H non-interference (up) and A→H interference assuming m_H-m_A=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 → bH⁺ → bzb, pp → tH/A → ttt.

Acknowledgments

Supported by NSTC 111-2639-M-002-004-ASP and 110-2112-M-002-017.

References