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Search for lepton flavor violating decays of the Higgs boson

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Search for lepton flavor violating decays of the Higgs boson

A Dissertation

Submitted to the Graduate School

of the University of Notre Dame

in Partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

by

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, Director

Graduate Program in Physics

Notre Dame, Indiana

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Search for lepton flavor violating decays of the Higgs boson

Abstract

by

Fanbo Meng

this going to put with the abstract, a summary of the whole analysis

NEW DEDICATION NAME

To be written

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probably I will write some preface, but it depends

ACKNOWLEDGMENTS

this part is going to be filled with acknowledge

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probably I have to put something there

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LFV event selection

For both the 8TeV analysis $H \to e\tau_h$ channel and 13TeV analysis $H \to \mu\tau_h$, events are selected in several steps. The loose(base) selection on the different IDs, energy, geometry parameters of the analysis related objects and so on are applied. For both $H \to e\tau_h$ and $H \to \mu\tau_h$ analysis channel, a following cut-based analyses are applied. For $H \to \mu\tau_h$, a multivariate analysis with Boosted decision tree (BDT) is exploited to provide more sensitive results.

6.1 $H \to \mu\tau_h$

6.1.1 Loose selection

In $H \to \mu\tau_h$ events, tau leptons from signal events decay hadronically and most of the time, μ candidates pass all the way to the muon detector. SM higgs is much heavier than the LFV decay products μ and τ, so μ and τ are expected to have high P_T. Since the decay products are boosted, a cut on the $\Delta R > 0.3$ is applied, in which ΔR is defined as $\Delta R = \sqrt{(\Delta phi^2 + \Delta eta^2)}$. Higgs particle has no charge, so μ and τ candidates are required to have opposite charges. Further, the events with additional μ and τ that pass a loose selection, the events with jets that are identified by the combined secondary vertex(CSVv2) b-tagging algorithm

TABLE 6.1

Muon ID used in the analysis, for the LHC data 2016, running period BCDEF.

ICHEP mediumID description	Technical description
Loose muon ID	PFLoose Muon
Fraction of valid tracker hits	> 0.49
Good Global muonGood Global muon	Global muon
	Normalized global-track $\chi^2 < 3$
	Tracker-Standalone position match < 12
	kick finder < 20
	Segment compatibility > 0.303
2. Tight segment compatibility	Segment compatibility > 0.451

Hadronic taus are required to have $P_T > 30$GeV,$|\eta| < 2.3$, pass old tau decay mode finding(chapter 4.2) and an MVA based tight tau isolation ID(chapter 4.2) and tau discriminators against other objects. These discriminators are very loose MVA based rejection against electrons and the cut-based tight rejection against muons.

The events in the analysis are divided into four categories based on the number of jets in the events. In 2-jets categories, it is furthered divided into 2 categories, 2-jet gluon gluon fusion higgs production(ggH) category and 2-jet VBF category based on the value of 2 jets invariant mass(M_{jj}) . In the 0-jet category, the

TABLE 6.2

Muon ID used in the analysis, for the LHC data 2016, running period G and H, also the monte Carlo samples.

Standard mediumID description	Technical description
Loose muon ID	PFLoose Muon
Fraction of valid tracker hits	> 0.8
Good Global muonGood Global muon	Global muon
	Normalized global-track $\chi^2 < 3$
	Tracker-Standalone position match < 12
	kick finder < 20
	Segment compatibility > 0.303
2. Tight segment compatibility	Segment compatibility > 0.451

signal mainly comes from ggH. In 1-jet category, the dominant signal production mode is also ggH, but with a boosted jet associated with the production, some of the VBF higgs signal also shows up in this category. In the 2-jet ggH category, signal evens mainly comes from ggH and in 2-jet VBF, VBF production dominants the production mode. In the following is a more detailed listing of the selection condition in each categories.

0-jet: No events have jets pass the loose PF ID and with jet $P_T > 30$ GeV, $|\eta| < 4.7$.

1-jet: The events with one jet passes losse PF ID and jet $P_T > 30$ GeV, $|\eta| < 4.7$.

2-jets GG: The events have two jets pass loose PF ID and with jet $P_T > 30$ GeV and $|\eta| < 4.7$, also require an invariant mass of the two jets, $\mathrm{M}_{jj} < 550$.

2 jets VBF: The events have two jets pass loose PF ID and with jet $P_T > 30$ GeV and $|\eta| < 4.7$, also require $\mathrm{M}_{jj} > 550$.

The threshold on M_{jj} has been optimized to give the best expected limits.

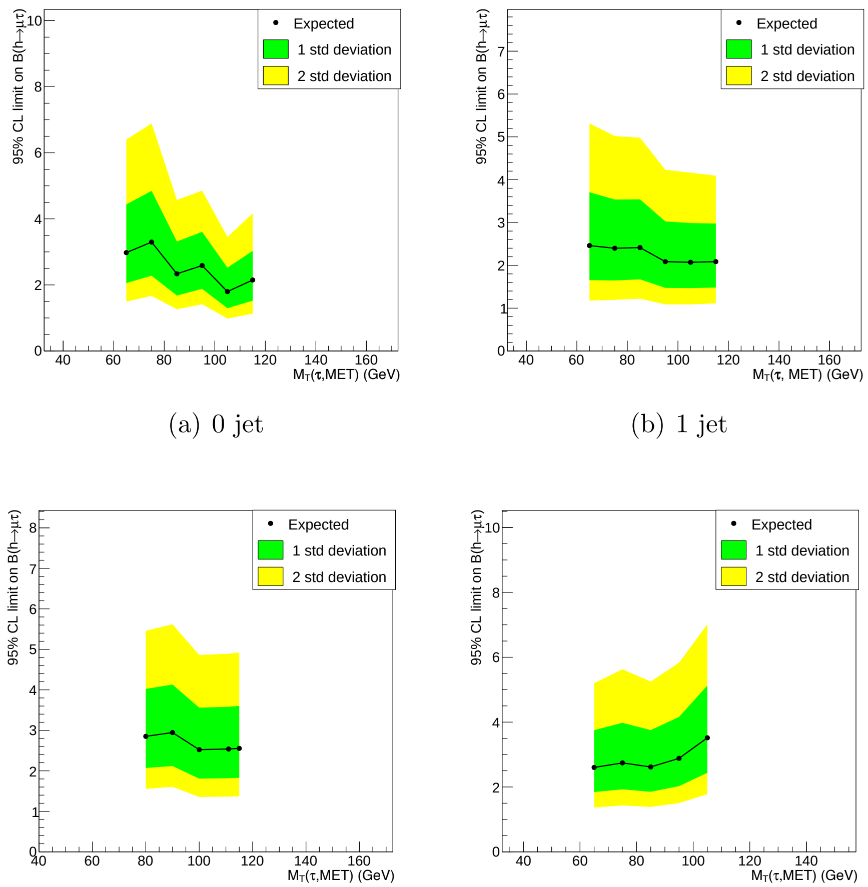
6.1.2 Cut-based analysis

With the loose selection, including the categorization, a further cut-based selection strategy is applied. The selected variables that can help distinguish signal from background used in this analysis are the following ones: P_T^{μ}, P_T^{τ}, $M_T(\tau_h)$. The lepton P_T variables are very powerful background discriminant variables, but it will also cause the problem that signal picks under the background. Leptons from signal process incline to have higher P_T values, by cutting tighter on the lepton P_T, more background events can be removed. However this will also reshape some of the backgrounds, making them peak closer under signal so as making the signal discovery processes affected more by the background statistics fluctuation. In the $H \rightarrow e\tau_h$ analysis, the effect of cutting hard on lepton P_T will be shown. So in $H \rightarrow \mu\tau_h$ search, lepton P_T variables are kept at loose values and tune on other variables to achieve better signal significance.

The tuning process is done only with Monte Carlo samples to not double use data. The final results are extract with data, so the double use of data may cause a bias on results. The fake background estimated with full data driven method, with be replaced with the semi data driven estimation in tuning. In $M_T(\tau_h)$ channel, the variables tuned are M_{jj} and $M_T(\tau_h)$.

The cut thresholds have been optimized to give the most stringent expected limits based on an Asimov dataset. Examples of limits obtained from different threshold are shown in Fig.6.1 for the $M_T(\tau, MET)$ for the different categories. Fig. 6.2 shows the optimization for the di-jet invariant mass for the two 2-jet categories.

6.2 Multivarite analysis



(a) 0 jet

(b) 1 jet

(c) 2 jets, gg-enriched

(d) 2 jets, VBF-enriched

Figure 6.1. Expected limits based on an Asimov dataset as a function of $M_T(\tau, MET)$ for the different categories.

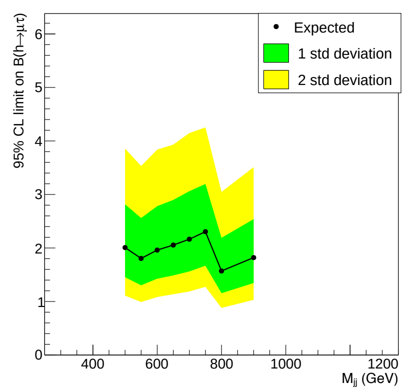


Figure 6.2. Expected limits based on an Asimov dataset as a function of M_{jj} for the 2 jet categories.

CHAPTER 7

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LFV Higgs decay searching results

CHAPTER 9

Conclusion

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