PROCEEDINGS OF SCIENCE

First attempt to search for $\mathrm{H}^+ \rightarrow \mathrm{c\bar{b}}$ in top quark decays at CMS

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Results on the first search for a light charged Higgs boson H^+ decaying to $\mathrm{c\bar{b}}$ in top quark pair events using the CMS detector at the LHC are presented. The total dataset corresponds to 19.7 fb^{-1} of proton-proton collisions at $\sqrt{s}$ = 8 TeV. In $\mathrm{t\bar{t}}$ decays, if one top quark decays to $\mathrm{H}^+\mathrm{b}$ and the H^+ subsequently decays to $\mathrm{c\bar{b}}$, while other top quark decays leptonically ($\mathrm{\bar{t}} \rightarrow \mathrm{W}^-\mathrm{\bar{b}} \rightarrow l\bar{\nu}\mathrm{\bar{b}}$)), the final state then consists of four jets (three b quark jets), one lepton (electron or muon), and missing energy: $\mathrm{t\bar{t}} \rightarrow (\mathrm{H}^+\mathrm{b})(\mathrm{W}^-\mathrm{\bar{b}}) \rightarrow (\mathrm{c\bar{b}b})(l\bar{\nu}\mathrm{\bar{b}})$. The main observable used in the analysis is an invariant mass of two jets, one of which is identified as a b-quark jet. The dijet pair is selected from at least four jets in an event by a dedicated kinematic fitter. No signal for the presence of a charged Higgs boson is observed and upper limits are set at 95% confidence level on the branching ratio for $\mathrm{t} \rightarrow \mathrm{H}^+\mathrm{b}$ from 1.1–0.4% for the charged Higgs boson mass in the range 90–150 GeV in the assumption of branching ratio of $\mathrm{B}(\mathrm{H}^+ \rightarrow \mathrm{c\bar{b}}) = 100\%$.

38th International Conference on High Energy Physics
3-10 August 2016
Chicago, USA

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PoS(ICHEP2016)776

1. Introduction

The discovery of a particle compatible with the standard model (SM) Higgs boson completes the list of the standard model particles. However, still many questions remain unexplained in the scope of SM, such as dark matter, neutrino oscillations, and several others. In order to solve those questions, several hypotheses have been suggested and are being tested. Among the models which extends the SM, the so called two Higgs doublet model (2HDM) employing a minimum extension of the SM Higgs sector is widely used. The 2HDM results in five Higgs bosons, 2 neutral scalar, 1 neutral pseudoscalar, and 2 charged, from the electroweak symmetry breaking. Depending on the Higgs scalars coupling to fermions the 2HDM is broken down to four different types: type-I, type-II, type-X, and type-Y. This analysis assumes H^+ having lighter mass than a top quark mass, thus the top quark can decay into H^+ and b-quark ($t \rightarrow H^+ b$). The light H^+ has been searched in $\tau\nu$ and $c\bar{s}$ decays which dominates in most 2HDM phase space. Here we report the first search on $H^+ \rightarrow c\bar{b}$ [1] that is predicted as a main decay channel of H^+ in type-Y.

The H^+ boson is then searched in top quark pair ($t\bar{t}$) events in lepton+jets channel where one W decays leptonically and the other W decays into two jets. Dominant background process of this search is the SM top pair production. Single top quark, $t\bar{t}$+H/Z/W, W/Z boson with jets, diboson, are also considered as additional background. Those SM background processess are estimated using various MC programs and passed through the simulation of the CMS detector. Multijet background is instead obtained directly from data. Detailed description of the CMS detector is found in Ref. [2]. Final state objects used in this analysis are reconstructed with the standard CMS particle-flow (PF) algorithm [3].

2. $t\bar{t}$ event selection and reconstruction

Events are selected by requiring single lepton triggers. For electron (muon) channel, a single isolated electron (muon) with a $p_T > 27$ (24) GeV and $|\eta| < 2.5$ (2.1) is required. At least one good primary vertex is also required to exist. Additional selection cuts are applied to the triggered events as follows. The electron (muon) candidates are required to have a minimum $p_T > 30$ (26) GeV within $|\eta| < 2.4$ (2.1), and relative isolation is less than 0.1 (0.12) within a cone of $\Delta R < 0.3$ (0.4). Fiducial and identification cuts are imposed on each lepton candidate accordingly. Jets are considered having $p_T > 30$ GeV within the tracker coverage of $|\eta| < 2.4$, and additional quality cuts are used to remove fake jets reconstructed from detector noise. A series of corrections are imposed on the jet energy-momentum 4-vector in order to account for the effect of pileup, non-uniform detector response, and residual data-simulation differences. We use the combined secondary vertex tagger to identify jets originating from b-quarks. Missing transverse momentum vector ($\not{E}_T$) is defined as the projection on the plane perpendicular to the beams of the negative vector sum of the momenta of all reconstructed particles in an event.

In order to reconstruct $t\bar{t}$ events, it is required to have only one single lepton, $\not{E}_T > 20$ GeV, and at least four jets in which two of them are b-tagged. Events are further categorized by lepton candidate flavour (e/μ) and number of b-tagged jets, =2 or ≥ 3. To find the best-matched assignment of four jets a procedure based on a kinematic fit is used. The p_T of leading four jets, which are input jets to the fitter, are again corrected to have the corresponding quark energy based on the jet p_T, η, and assigned quark flavor. The fitter minimizes χ^2 by varying the p_T of input jets and lepton, and the $\not{E}_T$ while constraining the invariant masses of the leptonic W, and both the leptonic and hadronic top quarks to the simulation values, 80.4 GeV and 172.5 GeV, respectively. Then, the remaining dijet mass represent where two jets are from, either H^+ or W. The H^+ extraction is done by template fit on dijet mass distributions in 2 b-jets and ≥ 3 b-jets simultaneously.

In the 2 b-jets event two b-jets are assigned to each b-quark from $t\bar{t}$, however in 3 b-jets H^+ event, another ambiguity occurs because two b-jets are assigned to same hadronic top quark. One comes directly from top quark and the other is decayed from H^+. Based on the H^+ simulation study we force the b-jet with softer p_T assigned to the b-quark from top quark when mass of H^+ is greater than 120 GeV. Figure 1 shows the dijet mass template for 2 b-tag events, 3 b-tag events for $m(H^+) \leq 120$ GeV, and 3 b-tag events for $m(H^+) \geq 130$ GeV.

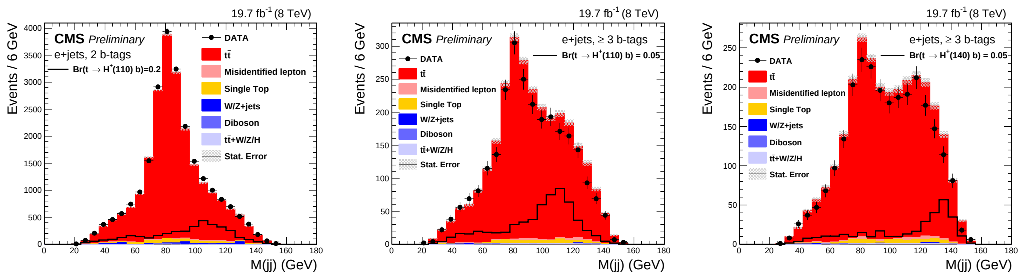

Figure 1: Dijet mass distribution MC background stack in the two b-tagged jets events in e+jets channel for 2 b-tags (left), 3 b-tags with $m(H^+)$ = 110 GeV, and 3 b-tags with $m(H^+)$ = 140 GeV.

Table 1: Summary of the systematic uncertainties in the search for a charged Higgs boson covering both the μ+jet and e+jet channels. For cases where the uncertainties in the μ+jet and e+jet channels differ, range is given. Rate uncertainties for the H^+ signal, $t\bar{t}$, non-$t\bar{t}$ are listed for the 2 b-tag and 3 b-tag selections, and the uncertainties marked with (s) are used for shape systematic uncertainties.

Source of uncertainty	signal (m_{H^+} = 120)		$t\bar{t}$		non- $t\bar{t}$		QCD multijet	
	2 b-tag	3 b-tag	2 b-tag	3 b-tag	2 b-tag	3 b-tag	2 b-tag	3 b-tag
$t\bar{t}$ cross section	6.5	20	6.5	20				
Top quark mass	5 (s)	5 (s)	5 (s)	5 (s)				
$t\bar{t}$ p_T reweighting	(s)	(s)	(s)	(s)				
NLO-vs-LO shape (Powheg-vs-MadGraph)	8.5–9.0 (s)	7.6–8.8 (s)	8.3–8.5 (s)	8.0 (s)				
PYTHIA–MADGRAPH $p_T(t\bar{t})$ difference	(s)	(s)						
ME-PS matching			0.6–0.8 (s)	0.8–1.4 (s)				
Renormalization and factorization scales	4.0–4.2 (s)	6.8–7.2 (s)	1.3–1.7 (s)	1.3–2.0 (s)				
Jet energy scale (JES)	4.6–5.3 (s)	5.0–5.9 (s)	3.4 (s)	3.3 (s)	7.5–9.6 (s)	0.9–2.8 (s)		
Flavour-dependent JES (b-quark)	0.3–0.4 (s)	0.2–0.6 (s)	0.1 (s)	9.0 (s)	0.1–0.7 (s)	0.5–0.9 (s)		
Flavour-dependent JES (udsc,g)	0.9–1.2 (s)	0.4–0.6 (s)	1.0 (s)	9.0 (s)	3.1–4.1 (s)	1.1–1.8 (s)		
Jet energy resolution	0.1–0.2 (s)	0.2–0.8 (s)	0.3 (s)	0.4 (s)	1.1 (s)	1.5 (s)		
B-tag scale factor for b/c quark jets	1.2–2.1	5.6–5.8	3.6	5.7	2.9–3.0	4.0–4.4		
Mis-tag scale factor for light quark jets	0.1–0.2	0.2–0.7	0.2	0.3–0.7	0.7–1.3	0.3–0.4		
Pileup reweighting	≈ 0.5							
Electron scale factor (e+jets)	2.0							
Muon scale factor (μ+jets)	2.0							
Luminosity	2.6							
Data driven prediction							Shift anti-Iso$_{rel}$ region (s)	

3. Systematic Uncertainties

Effect on the analysis templates from systematic sources appears in two aspects. The first one is related to the overall rate of signal and background contributions, while the second one affects the shape of the dijet mass distribution. In several cases the systematic source changes both rate and kinematic shape. Considered sources of uncertainties are summarized in Table 1.

4. Results

Search for H^+ in top quark decays is performed using 19.7 fb^{-1} CMS data collected from pp collisions at $\sqrt{s}$ = 8 TeV. This is the first time that a search for $H^+ \to c\bar{b}$ in top quark decays is performed. The dijet mass of selected lepton+jets $t\bar{t}$ events agrees with the W mass distribution of SM $t\bar{t}$. Thereby we set the upper limit with 95% C.L. on branching ratio of $t \to H^+ b$ to 1.1% to 0.4% depending on the H^+ mass as seen in figure 2.

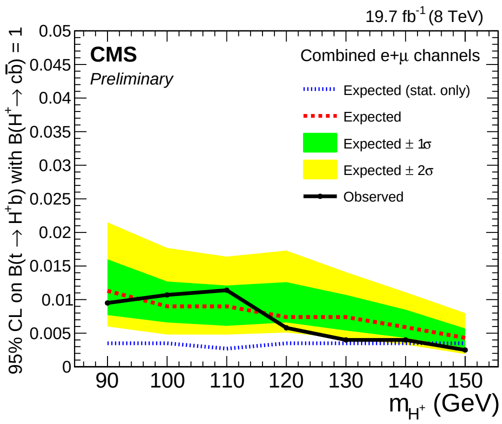

Figure 2: Observed upper limits on combined e+μ channel with expected limts including all systematic uncertainties. The limits with statistical uncertainty only are overlaid in blue dots to show the effect of systematic uncertainties.

This research was supported by the National Research Foundation of Korea (NRF-2015R1A4A1042542) and Promising-Pioneering Research Program through Seoul National University.

References

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