2016 Summer Student Report CMS experiment

Summer Student | Supervisor

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Study of new variables for the search of the Higgs boson coupled to top quarks in the four b jets final state

Motivation to study

After the discovery of Higgs boson,the final particle in Stand Model was discovered.Now we want to know the property of the Higgs boson. ATLAS and CMS experiments have exactly measured the mass of Higgs boson which is 125.7 $\pm$ 0.3 (stat.) $\pm$ 0.3 (syst.)Gev/c2.Up to now,the property of Higgs boson is compatible with the Stand Model.

We are interested in the coupling between Higgs and Top quark.Because the Top quark have the largest mass in SM.We now have a indirection way to measure the coupling but it is on the strength of no influence beyond Stand Model.We want to get the coupling in direction way.If there are some deviations,we can find the new physics.

But there are still some challenge in experiment.Because the cross-section of top-Higgs is very small.It’s only 0.5pb in 13TeV,but the main background of tt+jet is 830pb.

The ttHbb production and decay

Now we know the Higgs was produced by ttH,the Higgs can decay into ZZ,WW, $\tau\tau$ and $b\bar{b}$ .The top quark decay into one b quark and one W boson.The Feynman diagram is in Figure 1.We main research the channel which the final state is four b jets

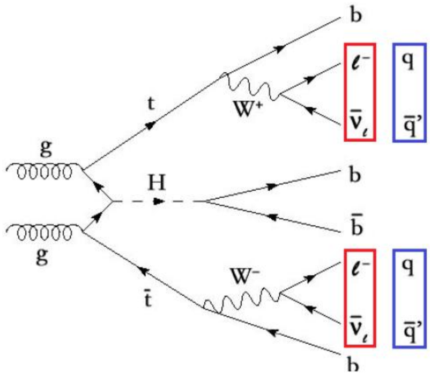
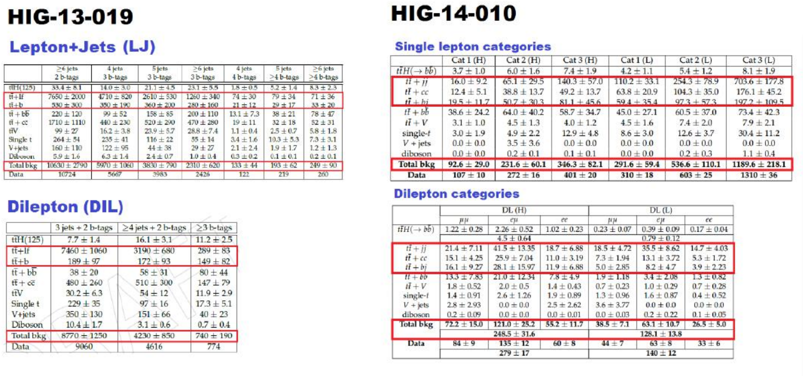


Figure1.the ttHbb production and decay

How to discriminate the background from signal

There are many backgrounds in Figure 2,such as tt+cc,tt+bb,tt+2b,tt+b,tt+lf.But the tt+light flavor jets is the main background,so it's important to distinguish the tt+light flavor jets.



HIG-13-019

Lepton+Jets (LJ)

	≥6 jets 2 b-tags	4 jets 3 b-tags	5 jets 3 b-tags	≥6 jets 3 b-tags	4 jets 4 b-tags	5 jets ≥4 b-tags	≥6 jets ≥4 b-tags
$t\bar{t}H(125)$	33.4 ± 8.1	14.0 ± 3.0	21.1 ± 4.5	23.1 ± 5.5	1.8 ± 0.5	5.2 ± 1.4	8.3 ± 2.3
$t\bar{t}$+lf	7650 ± 2000	4710 ± 820	2610 ± 530	1260 ± 340	74 ± 30	79 ± 34	71 ± 36
$t\bar{t}$+b	530 ± 300	350 ± 190	360 ± 200	280 ± 160	21 ± 12	29 ± 17	33 ± 20
$t\bar{t}+b\bar{b}$	220 ± 120	99 ± 52	158 ± 85	200 ± 110	13.1 ± 7.3	38 ± 21	78 ± 47
$t\bar{t}+c\bar{c}$	1710 ± 1110	440 ± 230	520 ± 290	470 ± 280	19 ± 11	32 ± 18	52 ± 31
$t\bar{t}V$	99 ± 27	16.2 ± 3.8	23.9 ± 5.7	28.8 ± 7.4	1.1 ± 0.4	2.5 ± 0.7	5.8 ± 1.8
Single t	264 ± 54	235 ± 41	116 ± 22	55 ± 14	3.4 ± 1.6	10.3 ± 5.3	7.3 ± 3.1
V+jets	160 ± 110	122 ± 95	44 ± 38	29 ± 27	2.1 ± 2.4	1.9 ± 1.7	1.2 ± 1.3
Diboson	5.9 ± 1.6	6.3 ± 1.4	2.4 ± 0.7	1.0 ± 0.4	0.3 ± 0.2	0.1 ± 0.1	0.2 ± 0.1
Total bkg	10630 ± 2790	5970 ± 1060	3830 ± 790	2310 ± 620	133 ± 44	193 ± 62	249 ± 90
Data	10724	5667	3983	2426	122	219	260

Dilepton (DIL)

	3 jets + 2 b-tags	≥4 jets + 2 b-tags	≥3 b-tags
$t\bar{t}H(125)$	7.7 ± 1.4	16.1 ± 3.1	11.2 ± 2.5
$t\bar{t}$+lf	7460 ± 1060	3190 ± 680	289 ± 83
$t\bar{t}$+b	189 ± 97	172 ± 93	149 ± 82
$t\bar{t}+b\bar{b}$	38 ± 20	58 ± 31	80 ± 44
$t\bar{t}+c\bar{c}$	480 ± 260	510 ± 300	147 ± 79
$t\bar{t}V$	30.2 ± 6.3	54 ± 12	11.9 ± 2.9
Single t	229 ± 35	97 ± 16	17.3 ± 5.1
V+jets	350 ± 130	151 ± 66	40 ± 23
Diboson	10.4 ± 1.7	3.1 ± 0.6	0.7 ± 0.4
Total bkg	8770 ± 1250	4230 ± 850	740 ± 190
Data	9060	4616	774

HIG-14-010

Single lepton categories

	Cat 1 (H)	Cat 2 (H)	Cat 3 (H)	Cat 1 (L)	Cat 2 (L)	Cat 3 (L)
$t\bar{t}H(\to b\bar{b})$	3.7 ± 1.0	6.0 ± 1.6	7.4 ± 1.9	4.2 ± 1.1	5.4 ± 1.2	8.1 ± 1.9
$t\bar{t}+jj$	16.0 ± 9.2	65.1 ± 29.5	140.3 ± 57.0	110.2 ± 33.1	254.3 ± 78.9	703.6 ± 177.8
$t\bar{t}+cc$	12.4 ± 5.1	38.8 ± 13.7	49.2 ± 13.7	63.8 ± 20.9	104.3 ± 35.0	176.1 ± 45.2
$t\bar{t}+bj$	19.5 ± 11.7	50.7 ± 30.3	81.1 ± 45.6	59.4 ± 35.4	97.3 ± 57.3	197.2 ± 109.5
$t\bar{t}+b\bar{b}$	38.6 ± 24.2	64.0 ± 40.2	58.7 ± 34.7	45.0 ± 27.1	60.5 ± 37.0	73.4 ± 42.3
$t\bar{t}+V$	3.1 ± 1.0	4.5 ± 1.3	4.0 ± 1.2	4.5 ± 1.6	7.4 ± 2.0	7.9 ± 2.1
single-t	3.0 ± 1.9	4.9 ± 2.2	12.9 ± 4.8	8.6 ± 3.0	12.6 ± 3.7	30.4 ± 11.2
V + jets	0.0 ± 0.0	3.5 ± 3.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
diboson	0.0 ± 0.0	0.2 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.2 ± 0.3	1.1 ± 0.4
Total bkg	**92.6 ± 29.0**	**231.6 ± 60.1**	**346.3 ± 82.1**	**291.6 ± 59.4**	**536.6 ± 110.1**	**1189.6 ± 218.1**
Data	**107 ± 10**	**272 ± 16**	**401 ± 20**	**310 ± 18**	**603 ± 25**	**1310 ± 36**

Dilepton categories

	DL (H)			DL (L)		
	$\mu\mu$	$e\mu$	ee	$\mu\mu$	$e\mu$	ee
$t\bar{t}H(\to b\bar{b})$	1.22 ± 0.28	2.26 ± 0.52	1.02 ± 0.23	0.23 ± 0.07	0.39 ± 0.09	0.17 ± 0.04
	4.5 ± 0.64			0.79 ± 0.12		
$t\bar{t}+jj$	21.4 ± 7.11	41.5 ± 13.35	18.7 ± 6.88	18.5 ± 4.72	35.5 ± 8.62	14.7 ± 4.03
$t\bar{t}+cc$	15.1 ± 4.25	25.9 ± 7.04	11.0 ± 3.19	7.3 ± 1.94	13.1 ± 3.72	5.3 ± 1.72
$t\bar{t}+bj$	16.1 ± 9.27	28.1 ± 15.97	11.9 ± 6.88	5.0 ± 2.85	8.2 ± 4.7	3.9 ± 2.23
$t\bar{t}+b\bar{b}$	13.3 ± 7.83	21.0 ± 12.34	7.8 ± 4.9	1.9 ± 1.18	3.4 ± 2.08	1.3 ± 0.82
$t\bar{t}+V$	1.8 ± 0.52	2.0 ± 0.5	1.4 ± 0.43	0.7 ± 0.23	1.0 ± 0.29	0.7 ± 0.28
single-t	1.4 ± 0.91	2.6 ± 1.26	1.9 ± 0.89	1.3 ± 0.96	1.6 ± 0.87	0.4 ± 0.52
V + jets	2.8 ± 2.93	0.0 ± 0.0	2.5 ± 2.62	3.6 ± 3.77	0.0 ± 0.0	0.0 ± 0.0
diboson	0.2 ± 0.09	0.0 ± 0.0	0.0 ± 0.01	0.0 ± 0.03	0.2 ± 0.22	0.1 ± 0.05
Total bkg	**72.2 ± 15.0**	**121.0 ± 25.2**	**55.2 ± 11.7**	**38.5 ± 7.1**	**63.1 ± 10.7**	**26.5 ± 5.0**
	248.5 ± 31.6			**128.1 ± 13.8**		
Data	**84 ± 9**	**135 ± 12**	**60 ± 8**	**44 ± 7**	**63 ± 8**	**33 ± 6**
	279 ± 17			**140 ± 12**		

Figure 2.the background

In order to searching for this decay,we must reduce the main background.We must know how to discriminate the b jet events from light-flavor jets first. In Figure 3 the b quark has a non-negligible lifetime so the b jets are from Secondary vertex.But the light-flavor jets are come from the Primary vertex .

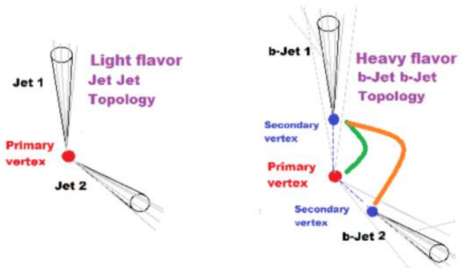


Figure 3.events with 2 light-avor jets and events with 2 b jets

In the Figure 4 We show the signal event and background event respectively. The background have more flavor jets and less b jets than signal.So we can define discriminating variables depend on this.

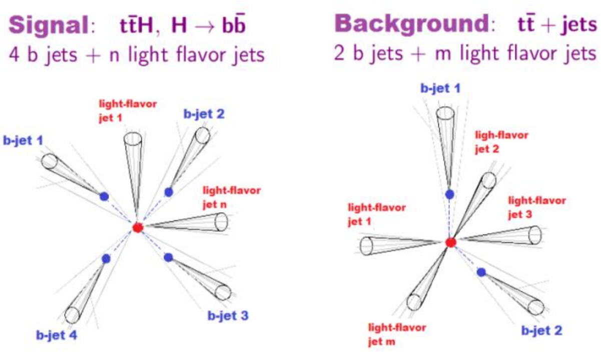


Figure 4.The signal event and background event

In Figure 5 take projection of the track,the Impact Parameter(IP) indicate the minimum distance of the track to the primary vertex(PV).If the track belong to PV,the IP is lower .If the track don't belong to PV,the IP is higher.

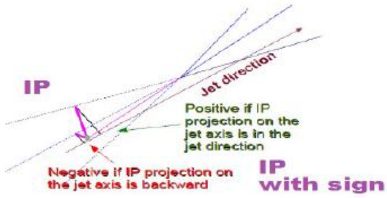


Figure 5.Picture illustrating the IP and the signed IP.

Comparison between Monte Carlo expectation and data

We can rely on the principle explained in the last chapter to define new variable to discriminate the signal from background.

Define the variable of Average value of the IP in xy plane $\sum_{i=1}^{n} IP_i/n$ (n is the number of tracks in the events) .So The variable is lower for background and higher for signal.

Define the average of track pairs not coming from the same vertex in one event.If the variable is higher,the event is signal. If the variable is lower,the event is background.

Define the ratio of energy coming from PV and SV. The ratio is high for the signal and is lower for the background.

In the Figure 6 shows the variables for MC simulated processes and data.As we expert the variable are lower for background and higher for signal.

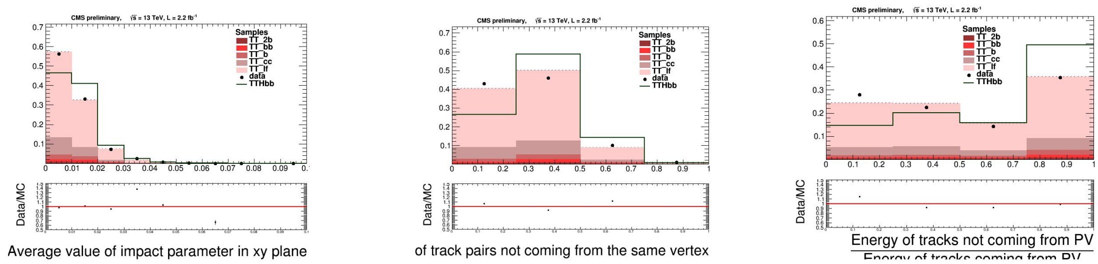


Figure 6.Left:Variable of value of the IP.Center:Variable of average of track pairs not coming from the same vertex.Right:The ratio of energy coming from PV and SV.

Conclusion and symmetry

ttHbb process represents a golden mechanism to study the coupling of the Higgs boson to top quarks.The current analysis uses already the three new variable to distinguish ttHbb events from tt+jets background events.comparison between MC simulation and data show a better discrimination using these variable.This encourages the use of these variables in the analysis.