tth study @ $\sqrt{s}$ = 500 GeV

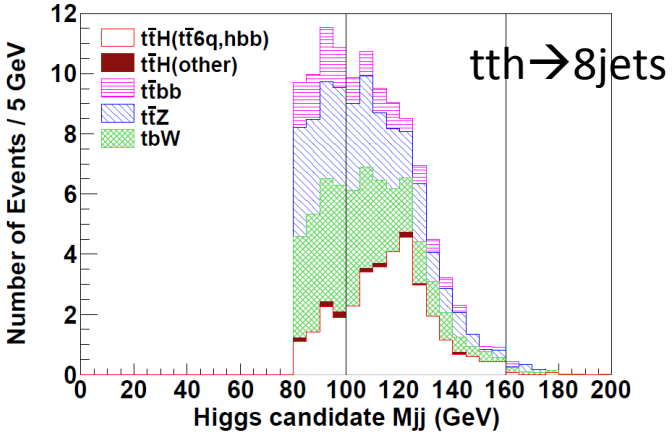
The 37th general meeting of the ILC physics working group

June 21 2014

Yuji Sudo (Kyushu University)

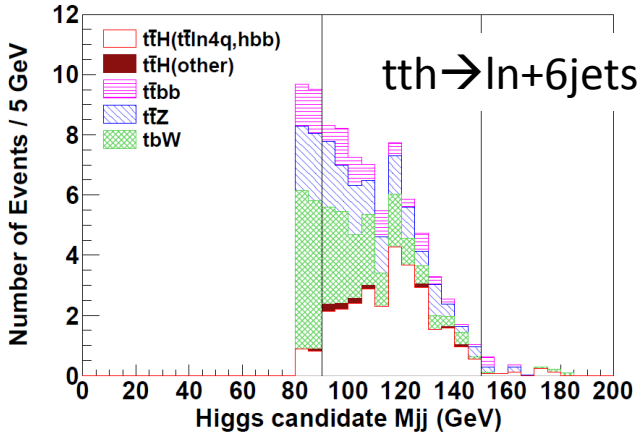
Remainder

- signal: tth→8 jets (h→bb)
  tth→ln+6jets (h→bb)
- background: ttZ, ttg(g→bb), tbW



Results at last meeting

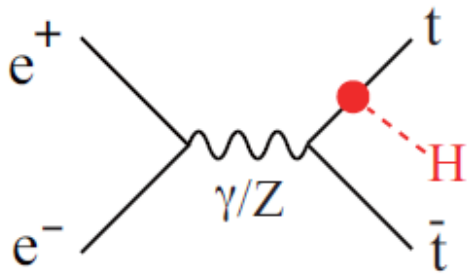
- Mh = 125 GeV
- $\sqrt{s}$ = 500 GeV, L = 1000 fb^{-1}
- tth→8jets $S/\sqrt{S+B}$ = 3.16
- tth→ln+6jets $S/\sqrt{S+B}$ = 3.45
- combine → significance = 4.67
  $|\Delta g_t/g_t|$ = 10.6%



update

- analysis @ L = 500/1600 fb^{-1}
- overlay low Pt beam background
- apply Kt clustering to remove low Pt background

Results at AWLC



- direct top Yukawa coupling measurement
- $\sqrt{s}$ = 500 GeV ILC, L = 500 fb^{-1} , Mh = 125 GeV
- interference term is negligible
- cut based event selection and counting analysis
- target signal: tth→4q+4b, lv+2q+4b
- backgrounds: ttZ, ttg, tbW
- tth→8jets $S/\sqrt{S+B}$ = 2.04
- tth→ln+6jets $S/\sqrt{S+B}$ = 2.42
- combined result

  significance = 3.16

  → $|\Delta g_t/g_t|$ = 15.7%
- In the cases of lumi-up(L=1600fb^{-1})

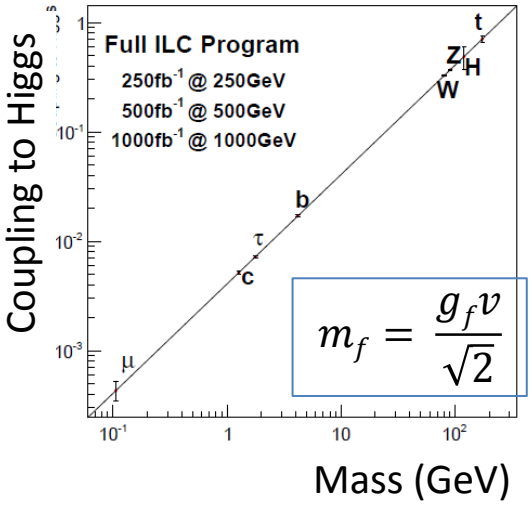
  or $\sqrt{s}$ = 520 GeV, significance reaches 5

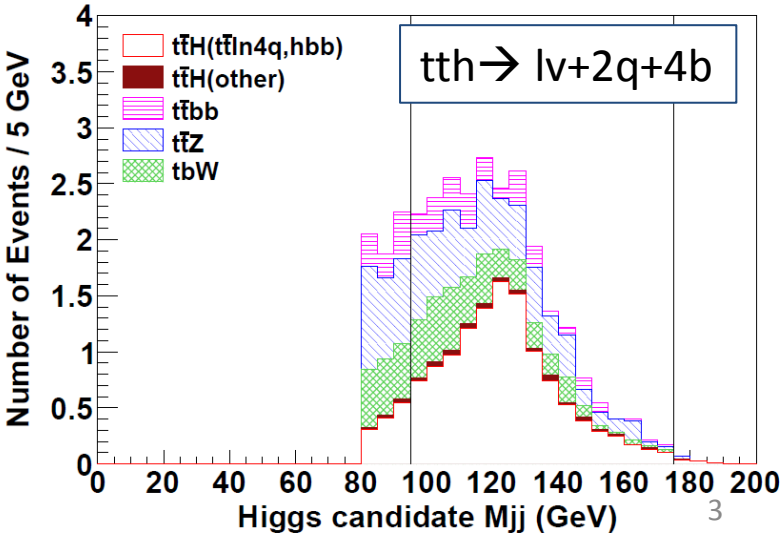
(* overlay low Pt background)

(* Kt clustering was not applied)

next steps

- estimate systematic uncertainties
- use MVA
- Improve Lepton ID method

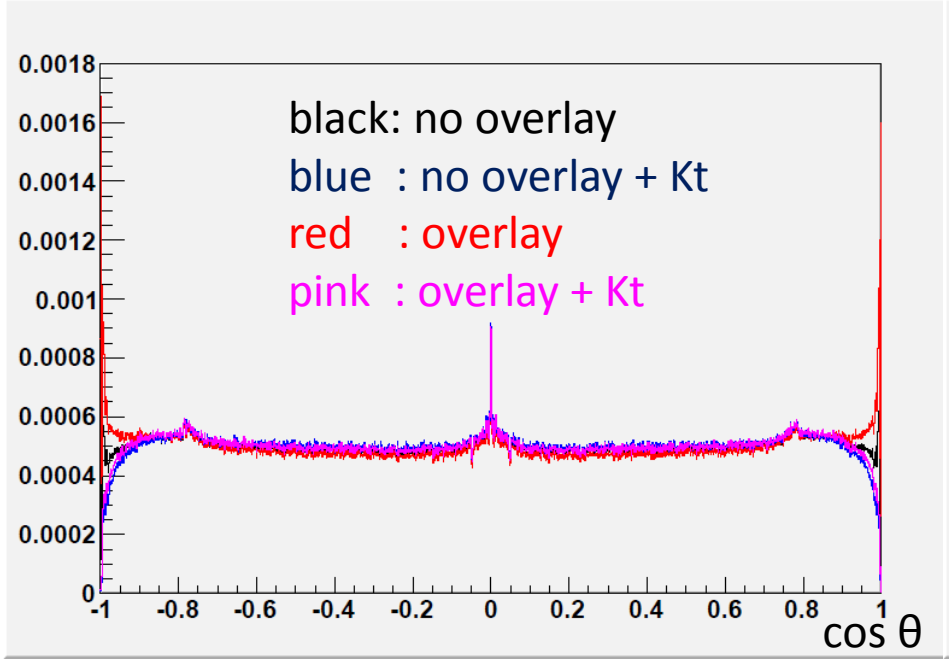


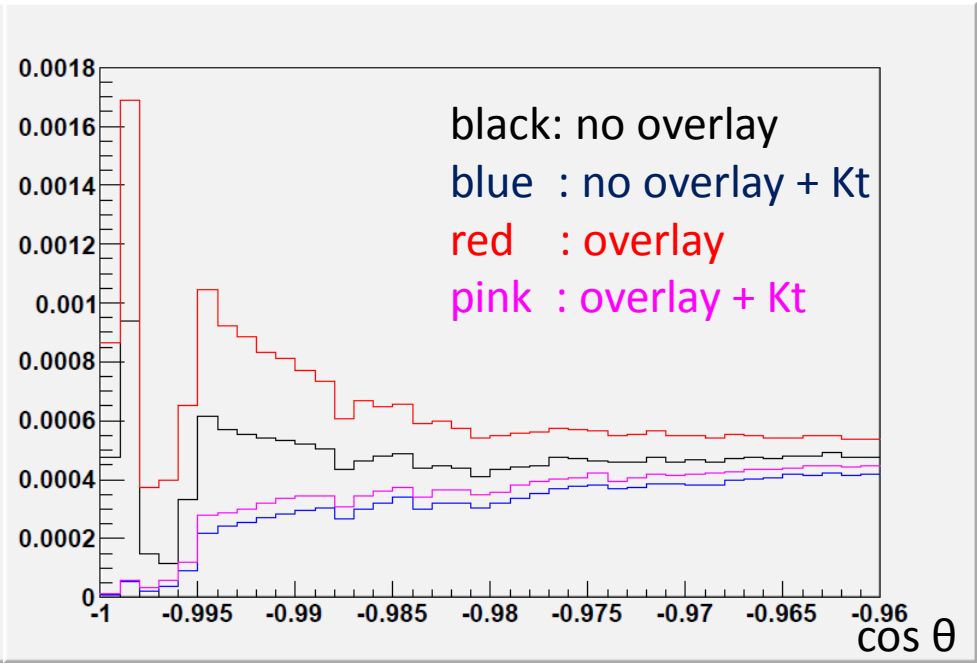


apply Kt clustering

- We apply Kt clustering to remove low Pt jets related to beam

cosθ distribution



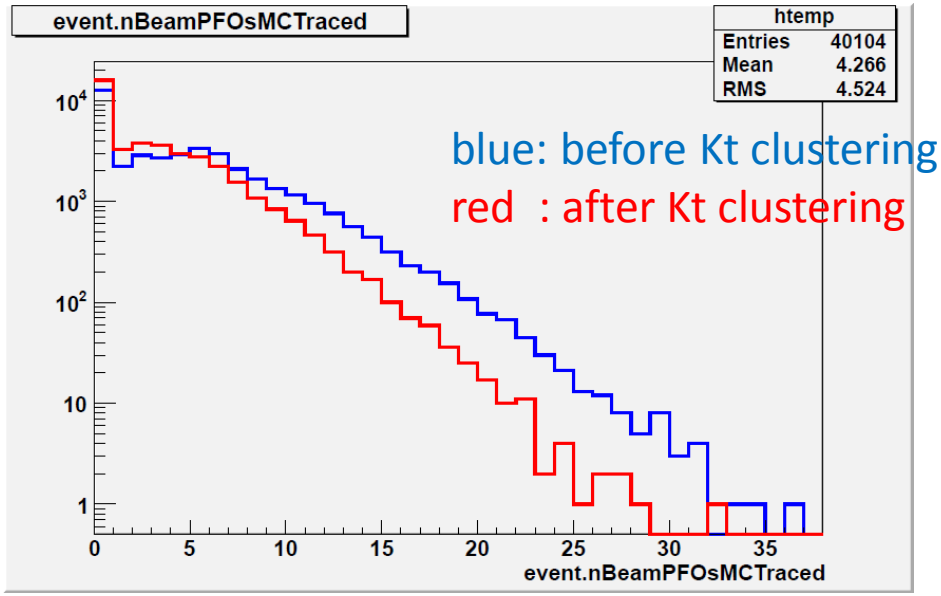


- Kt clustering works to remove PFOs with large cosθ

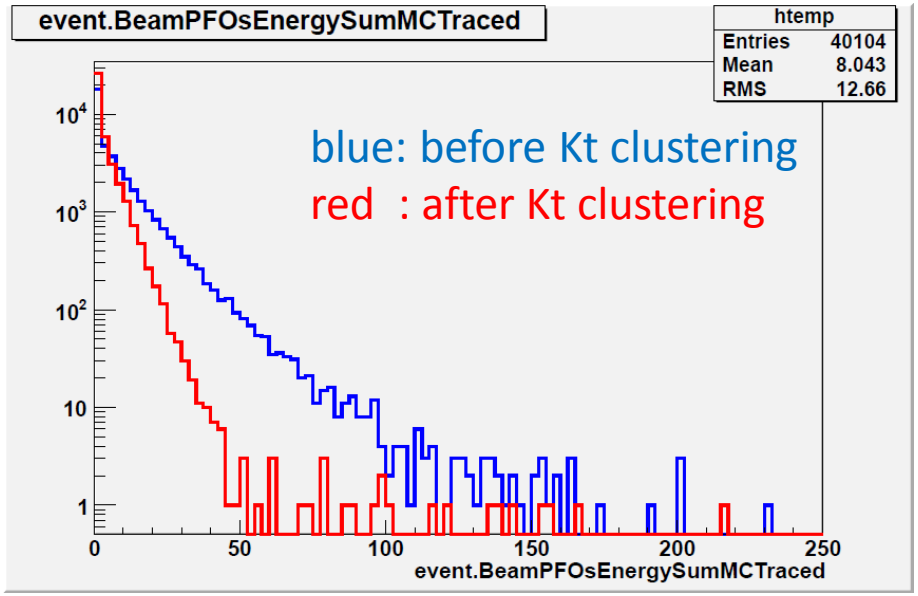
Beam background in reconstructed Jets

- trace PFOs and MC truth information from reconstructed jets

Number of PFOs originated with beam



Energy sum of PFOs originated with beam



- Kt clustering works well (not perfect) to remove beam background

signal acceptance (tth→8jet)

* Cut parameters are optimized for each analysis

with Kt clustering

Acceptance table (%)

requirement	Number of Events
noCut	100
noIsoLep	92.5
8jetReq	87.2
4bjetReq	49.56
absCosThetaLT0.99	48.8
chi2 cut	39.0
hcandMjj>80	34.9
jet01EnergySum	28.0
jet567EnergySum	28.0
Mtop>140	26.1

without Kt clustering (result at AWLC)

Acceptance table (%)

requirement	Number of Events
noCut	100
noIsoLep	92.4
8jetReq	82.5
4bjetReq	47.9
absCosThetaLT0.99	38.0
chi2 cut	26.9
hcandMjj>80	25.0
jet01EnergySum	23.5
jet567EnergySum	21.1
Mtop>140	20.7

- signal acceptance is increased ~4.4% .
  (before selection of Mh range)

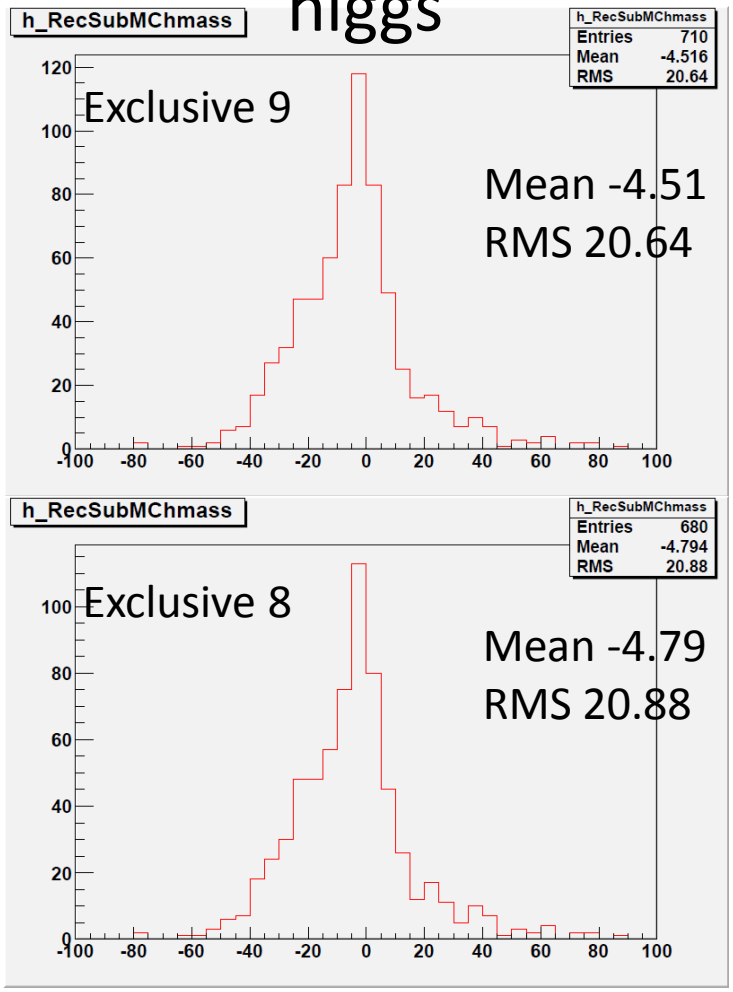
Backup

reconstructed mass – MC

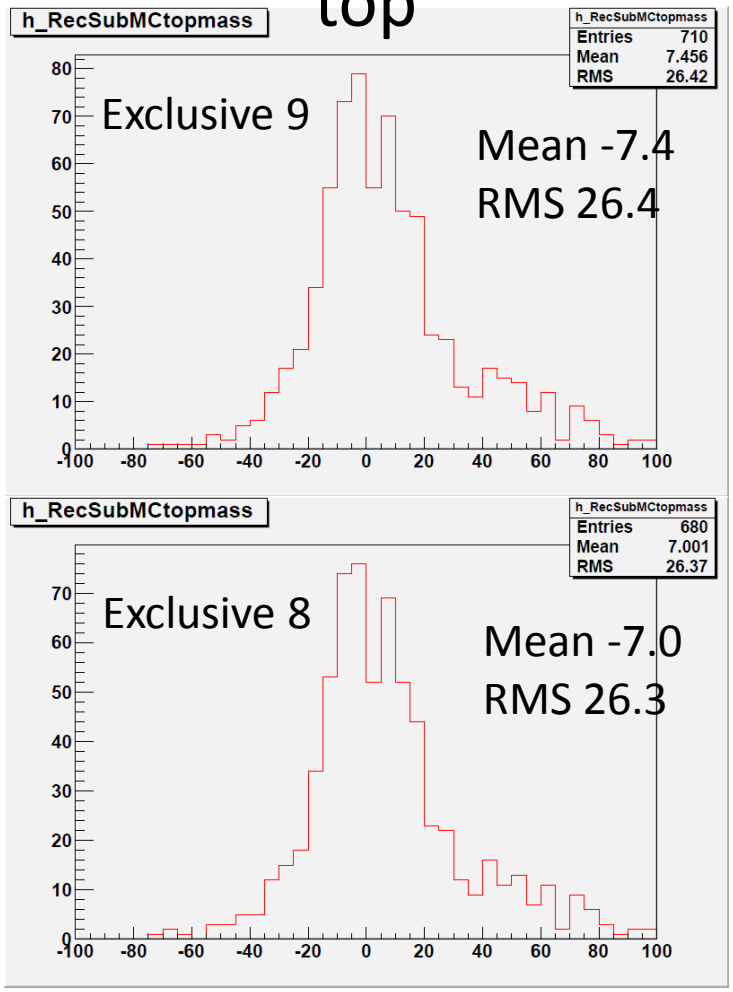
reconstructed mass : using jets matched to MC

MC: MC truth – ν

higgs



top



ex 9, N matched = 710 (/2500)

ex 8, N matched = 680 (/2500)

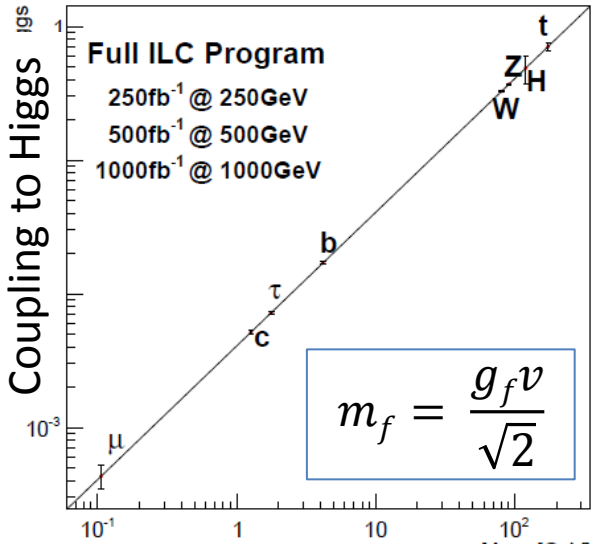
Introduction

- We can directory measure the top quark Yukawa coupling via tth channel with $\sqrt{s}$ = 500 GeV ILC.
- Previous tth analysis was performed assuming Mh = 120GeV.

(R. Yonamine et al., PHYSICAL REVIEW D 84, 014033(2011))

- Higgs boson mass is ~125 GeV.
- We are working on tth study assuming Mh=125 GeV.
- ILD full simulation
- Polarization : $(Pe^-,Pe^+)=(-0.8,+0.3)$

	Mh=120GeV→	Mh=125GeV
production cross section (fb)	0.641 →	0.485
Branching ratio of h→bb	0.68 →	0.577



Signal and Background

ttbar cross section is increased
around ttbar threshold
by ttbar bound-state effect

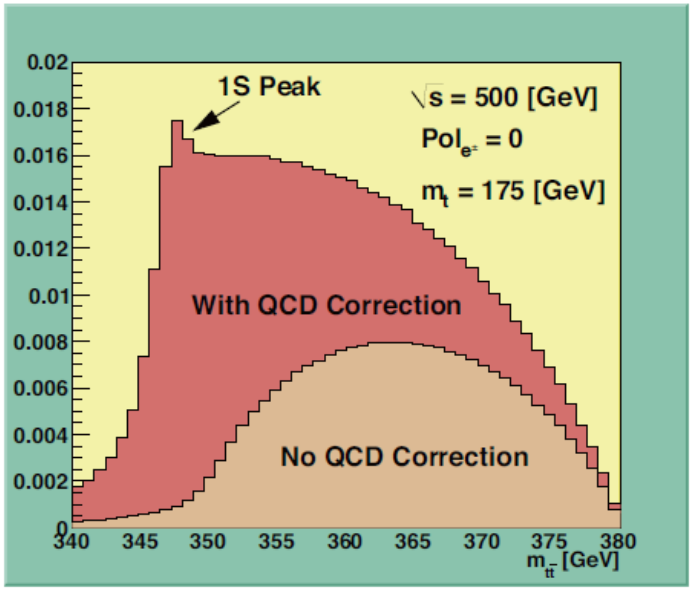
- tth cross section is enhanced
- ttZ cross section is also increased

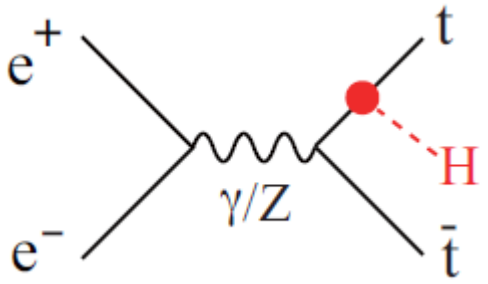
Signals

- tth→8jets (h→bb)
  tth→ln+6jets (h→bb)

Main Backgrounds

- ttZ, ttg(bb), tbW





expected # of events @ 500fb^{-1}

- $\sqrt{s}$ = 500 GeV, Mh = 125 GeV, (Pe^-,Pe^+)=(-0.8,+0.3)
- production cross section

Process	σ (fb)
$e^-e^+ \rightarrow$ tth	0.485
$e^-e^+ \rightarrow$ ttZ	1.974
$e^-e^+ \rightarrow$ ttg(bb)	1.058
$e^-e^+ \rightarrow$ tbW	979.8

- Branching ratio

Decay mode	Branching ratio
h→bb	0.577
tt→bqqbqq	0.457
tt→blvbqq	0.438
tt→blvblv	0.105

- expected # of signals and Backgrounds(@500fb^{-1})

tth(tt6j, hbb)	63.9	tth(ttln4j,hbb)	61.3
tth(ttall, hnobb)	102.6	ttZ	987
tth(ttlvlv2j, hbb)	14.6	ttg(bb)	529
		tbW	489902

tth→8jets(ln+6jets) analysis

- interference term is negligible
- counting analysis with cut based event selection

In this analysis, higgs decays into two b jets

- 4 b jets out of 8(6) jets
- No (one) isolated lepton

Event Selection

- signal topology

✓ Y cut (6, 8 jet event)
✓ No(one Isolated Lepton)
✓ B jet candidate ≥ 4

- detector acceptance

$|\text{Jet } \cos\theta| \leq 0.99$

- jet pairing

✓ $\chi 2 \leq 9.5$ (34.5)

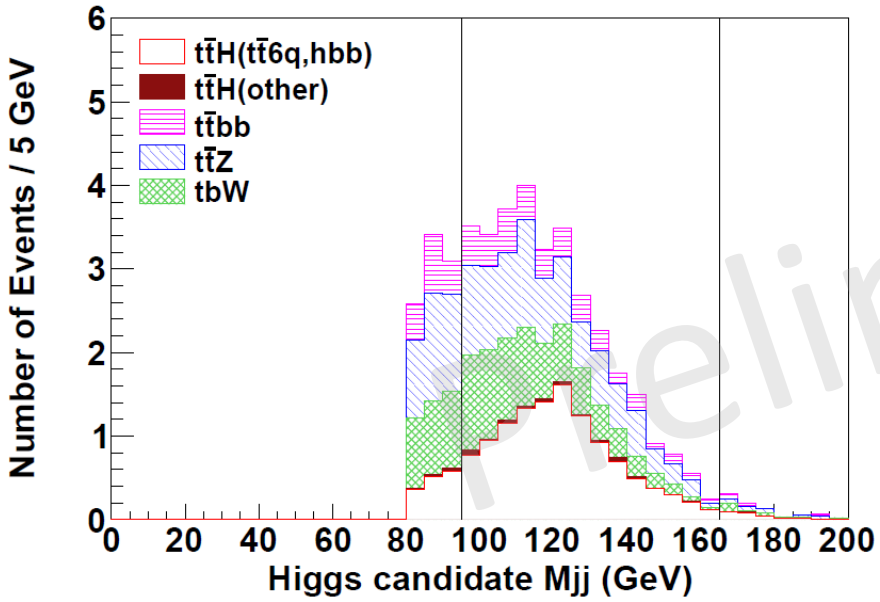
- kinematics

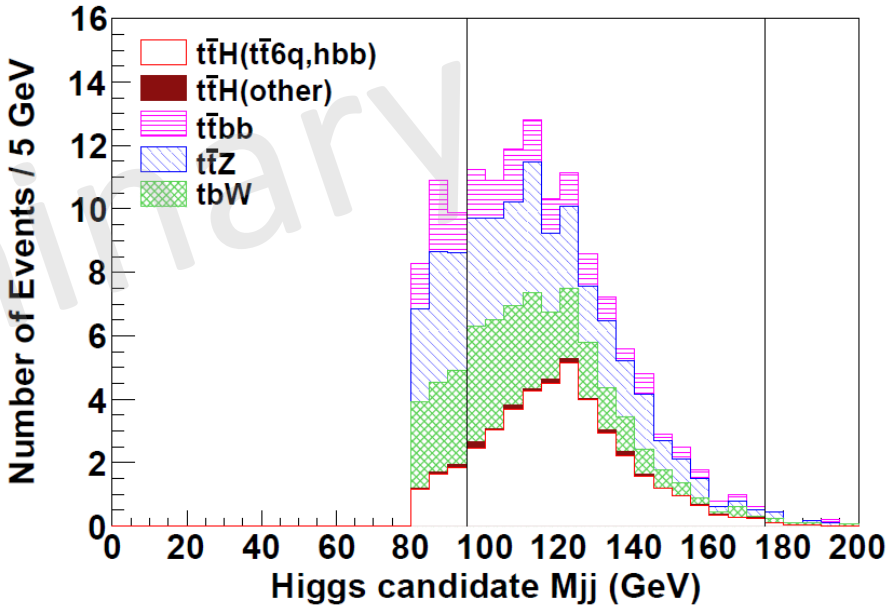
✓ Leading 2 Jet Energy Sum
✓ Lowest 3 Jet Energy Sum (for 8jets mode)
(Lowest 2 Jet Energy Sum (for 6jets mode))
✓ Missing momentum > 20 GeV (for 6jtes mode)

- reconstructed mass

✓ top candidate Mjjj $\geq$ 140 GeV
✓ higgs candidate Mjj $\geq$ 80 GeV
✓ 95GeV $\leq$ h candidate Mjj $\leq$ 165(175)GeV

Significance (tth→8jets)

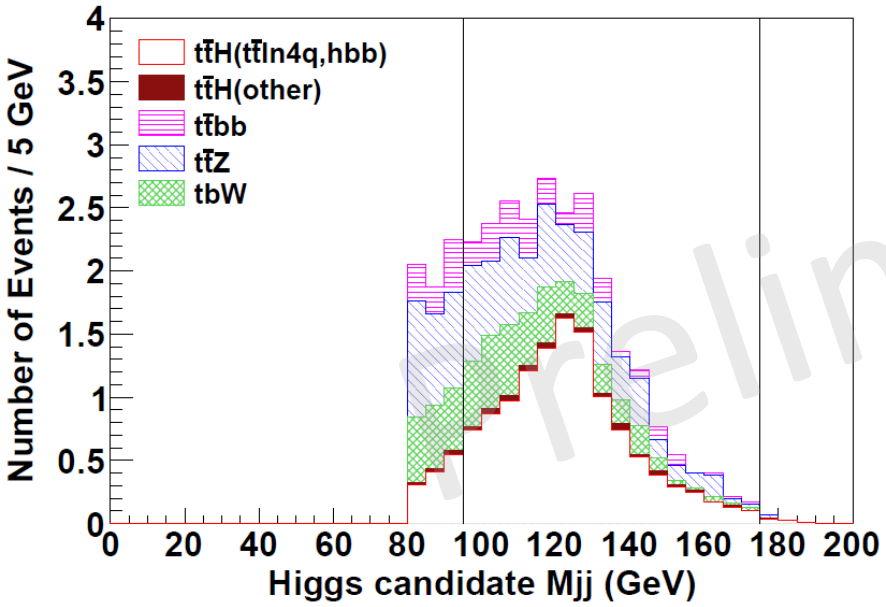


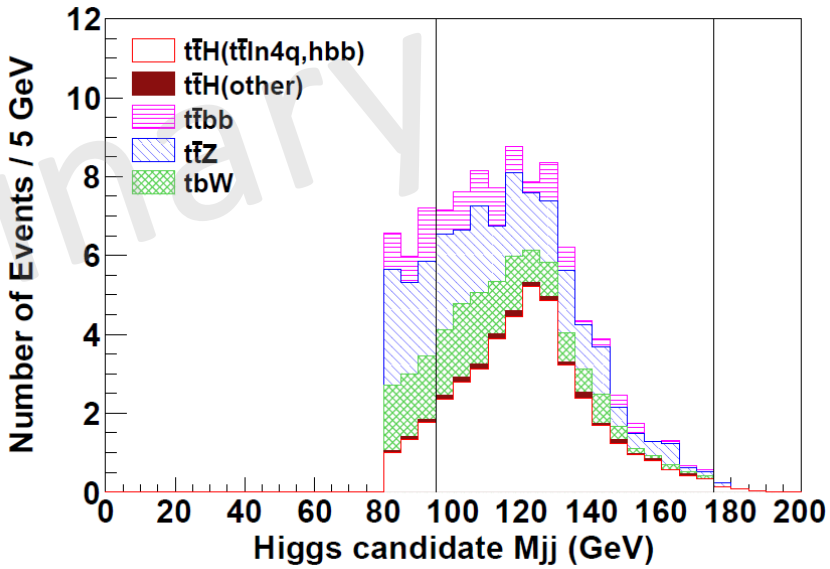


- baseline
- $\sqrt{s}$ = 500 GeV, 500 fb^{-1}
- Cut base + counting analysis
- Nsig/$\sqrt{\text{Nsig} + \text{Nbkgd}}$ = 2.04,
- $|\Delta g_t/g_t|$ ~ 24.5%

- lumi-up
- $\sqrt{s}$ = 500 GeV, 1600 fb^{-1}
- Cut base + counting analysis
- Nsig/$\sqrt{\text{Nsig} + \text{Nbkgd}}$ = 3.67,
- $|\Delta g_t/g_t|$ ~ 13.6%

Significance (tth→ln+6jets)





- baseline
- $\sqrt{s}$ = 500 GeV, 500 fb^{-1}
- Cut base + counting analysis
- Nsig/$\sqrt{\text{Nsig} + \text{Nbkgd}}$ = 2.42,
- $|\Delta g_t/g_t|$ ~ 20.7%

- lumi-up
- $\sqrt{s}$ = 500 GeV, 1600 fb^{-1}
- Cut base + counting analysis
- Nsig/$\sqrt{\text{Nsig} + \text{Nbkgd}}$ = 4.33,
- $|\Delta g_t/g_t|$ ~ 11.5%

Rough estimation of significance and $|\Delta g_t/g_t|$

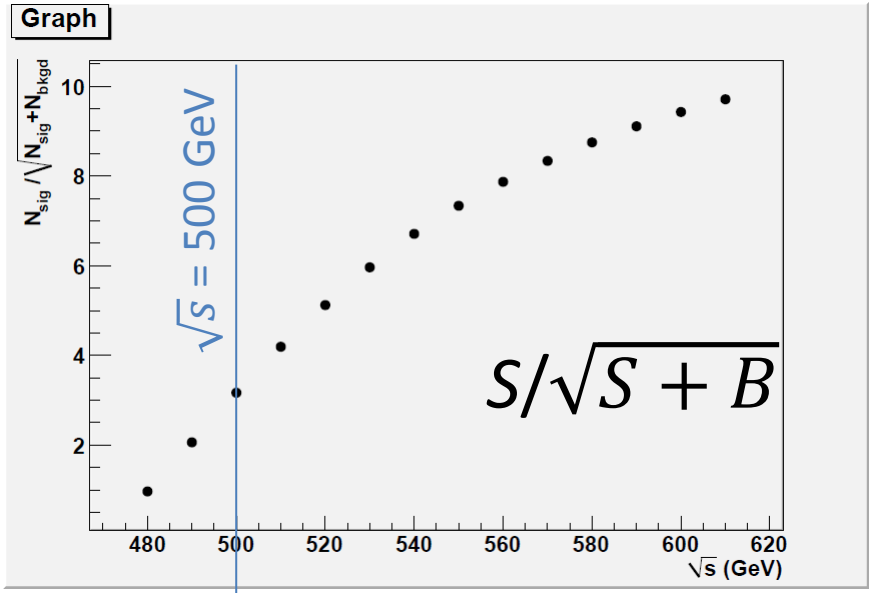
$\sqrt{s}$ = 480-610 GeV, 500 fb^{-1}

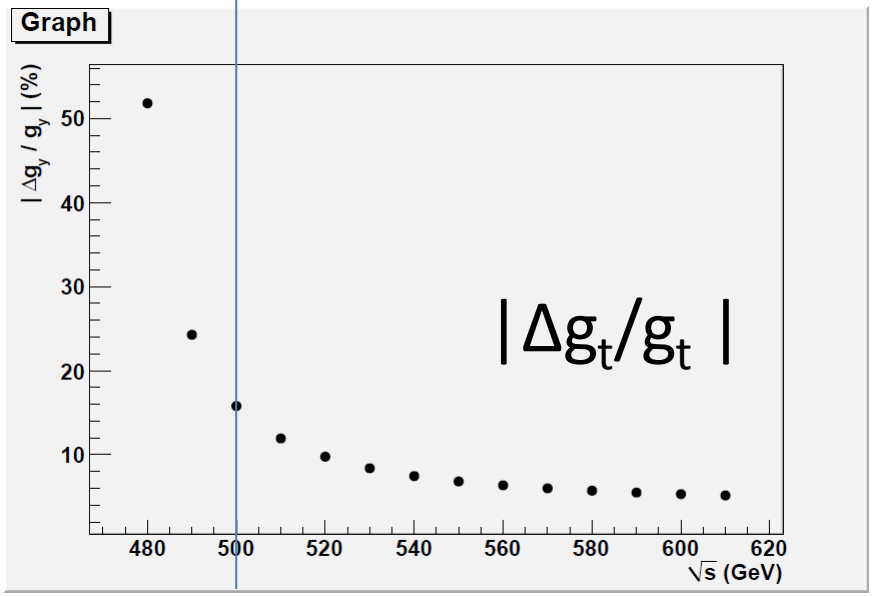
8 jets & ln6jtes combined result

$\sqrt{s}$	: $S/\sqrt{S+B}$	: $\|\Delta g_t/g_t\|$ %
490	: 2.06	: 24.2
500	: 3.16	: 15.7
510	: 4.19	: 11.9
520	: 5.12	: 9.76
530	: 5.96	: 8.38
540	: 6.70	: 7.45
550	: 7.33	: 6.81

cross section (fb)

$\sqrt{s}$	: tth(total)	: ttz	: ttbb	: tbw
490	: 0.272	: 1.569	: 1.009	: 991.1
500	: 0.485	: 1.974	: 1.058	: 979.8
510	: 0.725	: 2.373	: 1.105	: 967.0
520	: 0.981	: 2.753	: 1.151	: 953.5
530	: 1.244	: 3.118	: 1.199	: 939.4
540	: 1.504	: 3.469	: 1.243	: 924.5
550	: 1.743	: 3.806	: 1.285	: 909.5





event selection table, $\sqrt{s}$ = 500GeV, 500 fb^{-1}

8 jets

Selection	$t\bar{t}h(t\bar{t}6j\ hbb)$	$t\bar{t}h(t\bar{t}all\ hnobb)$	$t\bar{t}h(t\bar{t}ln4j\ hbb)$	$t\bar{t}h(t\bar{t}2l2n2j\ hbb)$	$t\bar{t}Z$	$t\bar{t}g^*(b\bar{b})$	tbW
No Cut	63.9	102.6	61.3	14.6	987.3	529.3	489902.1
No Isolated Lepton	59.1	48.0	8.3	0.34	517.8	308.2	291330.0
Y cut for 8 jets	52.7	42.8	4.3	0.05	354.0	174.5	51265.1
b jet candidate ≥ 4	30.6	1.1	2.5	0.03	43.1	78.7	941.5
$\mid$ Jet $\cos\theta \mid \leq 0.99$	24.3	0.8	1.5	0.01	32.6	56.6	390.8
$\chi^2 \leq 9.5$	17.2	0.4	0.4	0	20.5	21.5	99.7
h Candidate $M_{jj} \geq 80$ (GeV)	16.0	0.3	0.2	0	17.2	12.1	47.9
Leading 2 JetEnergySum < 208 GeV	15.0	0.3	0.2	0	15.9	8.0	29.7
Lowest 3 JetEnergySum > 104 GeV	13.5	0.3	0.1	0	13.1	5.8	14.3
$M_{\text{top}} \geq 140$ (GeV)	13.2	0.3	0.1	0	12.6	5.3	10.2
$95 \leq h$ Candidate $M_{jj} \leq 165$ (GeV)	11.5	0.2	0.1	0	9.0	3.7	7.4

ln+6jets

Selection	$t\bar{t}h(t\bar{t}ln4j\ hbb)$	$t\bar{t}h(t\bar{t}all\ hnobb)$	$t\bar{t}h(t\bar{t}6j\ hbb)$	$t\bar{t}h(t\bar{t}2l2n2j\ hbb)$	$t\bar{t}Z$	$t\bar{t}g^*(b\bar{b})$	tbW
No Cut	61.3	102.6	63.9	14.6	987.3	529.3	
One Isolated Lepton	50.2	38.6	4.7	3.0	344.4	188.6	
$Ycut$ (6 jets)	49.9	38.4	4.7	2.4	314.3	175.6	
b jet candidate ≥ 4	27.0	0.8	2.3	1.3	29.3	64.0	
$\mid$ Jet $\cos\theta \mid \leq 0.99$	23.2	0.7	2.1	0.8	24.0	50.2	
Missing P > 20	22.9	0.6	0.8	0.8	22.3	46.1	
$\chi^2 \leq 34.5$	21.8	0.5	0.6	0.5	21.0	40.1	
h Candidate $M_{jj} \geq 80$ (GeV)	18.9	0.4	0.5	0.3	16.3	17.2	
Leading 2 JetEnergySum < 195 GeV	15.8	0.3	0.1	0.3	11.8	8.1	
lowest 2 JetEnergySum > 66 GeV	14.5	0.3	0.1	0.1	9.8	4.0	
$M_{\text{top}} \geq 140$ (GeV)	13.3	0.3	0.07	0.1	8.3	3.1	
$95 \leq h$ Candidate $M_{jj} \leq 175$ (GeV)	11.9	0.3	0.06	0.05	5.9	2.2	3.9