Excerpts by KF from

tth study
with increased MC stat.

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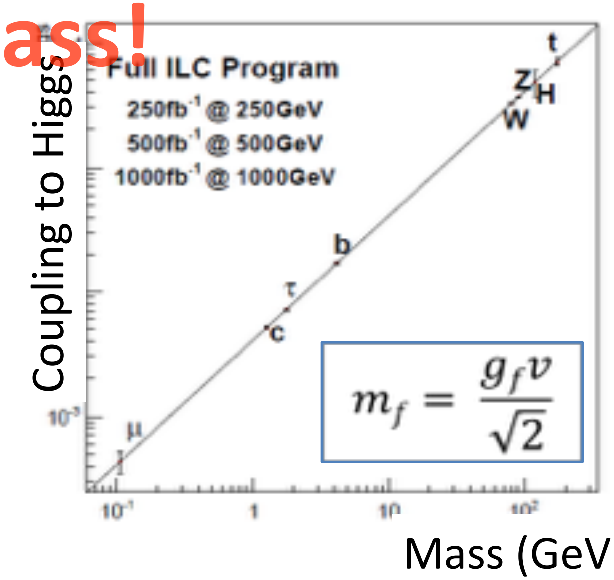
tth, ttz, ttbb: 100k~200k events

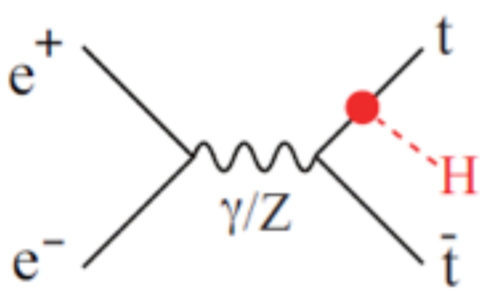
tbW(DBD samples): 10k~100k events

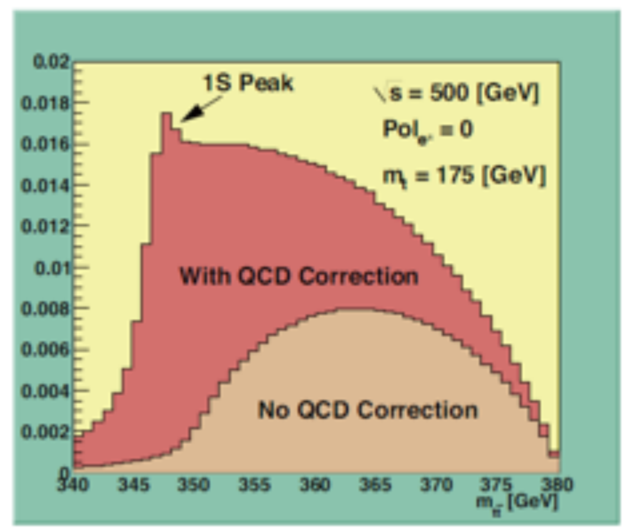
Introduction

- We are working on tth study assuming
  - Mh=125 GeV. **Update Higgs mass!**
  - Polarization : $(Pe^-, Pe^+) = (-0.8, +0.3)$
  - Integrated luminosity 500 fb^{-1}
  - ILD full simulation
- ttbar cross section is increased around ttbar threshold by ttbar bound-state effect
- tth cross section is enhanced
- ttZ cross section is also increased

We can directly measure the top-Yukawa coupling via tth channel at $\sqrt{s}$ = 500 GeV.







Expected # of events @ $500fb^{-1}$

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

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

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

New: Inclusion of lvlv4b mode!

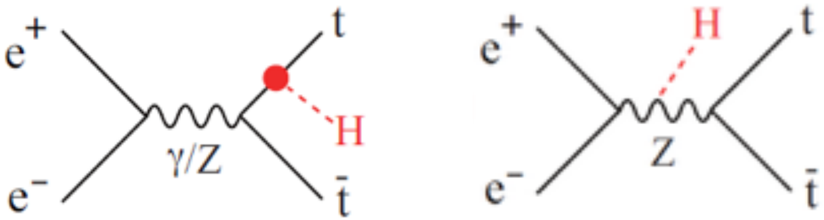
- expected # of signals and Backgrounds(@$500fb^{-1}$)

tth(tt6j, hbb)	**63.9**	**tth(ttln4j,hbb)**	**61.3**
tth(ttall, hnobb)	***102.6***	***ttZ***	***987***
tth(ttlvlv2b, hbb)	***14.6***	***ttg(bb)***	***529***
		tbW	***489902***

tth analysis

- interference term is negligible
- counting analysis with cut based event selection
- Use Kt clustering only for removing low Pt background
- lepton ID (cut base)

 - muon selection
 - electron selection
 - tau (leptonic decay)
 - tau (hadronic decay)



New : BDT lepton ID

- forced 8 jets clustering & 0 isolated lepton → 8jets channel
- forced 6 jets clustering & 1 isolated lepton → lv6jets channel
- forced 4 jets clustering & 2 isolated leptons → 2l2v 4jets channel

In this analysis, higgs decays into two b jets

- require at least 4 b jets (b tagging: LCFIPlus)

Event Selection

- signal topology

✓ Y cut (Jet clustering : Durham algorithm)
✓ isolated lepton selection
✓ b jet candidate ≥ 4

- detector acceptance

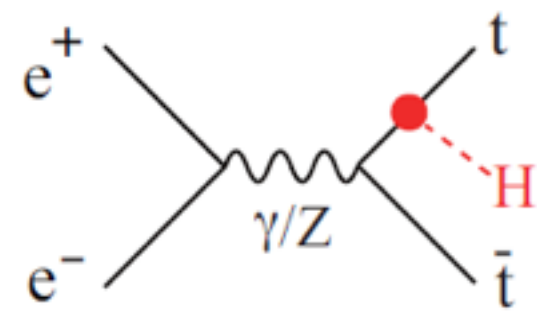
|Jet cosθ| ≤ 0.99

- jet pairing

angle between 2 b jets of h candidate
M_W, M_{top}

- kinematics cut

✓ Leading 2 Jet Energy Sum
8jets mode, lowest 3 Jet Energy Sum
6jets mode, lowest 2 Jet Energy Sum
4jets mode, lowest jet Energy
✓ Missing momentum > 20 GeV (for 4, 6jtes mode)



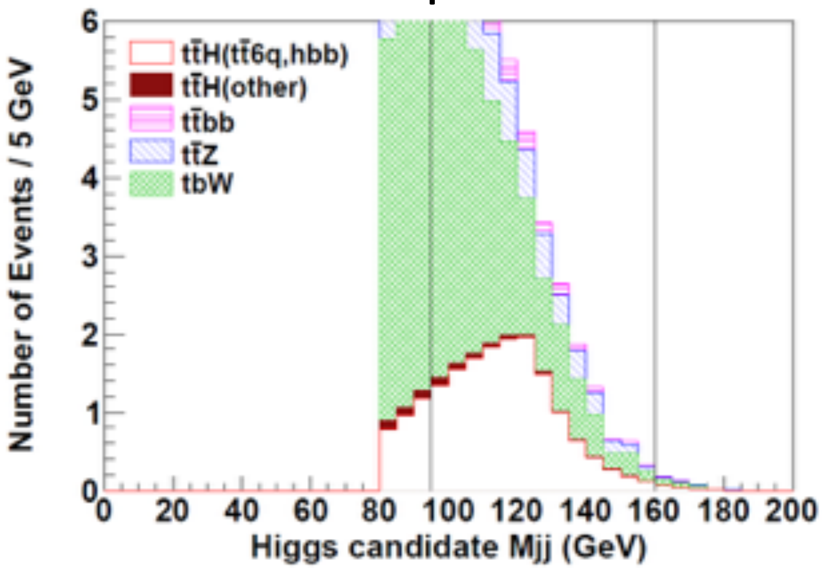
- reconstructed mass

✓ top candidate Mjjj ≥ 140 GeV
✓ higgs candidate Mjj ≥ 80 GeV
✓ h candidate Mjj cut to maximize sensitivity

* tbW shape is used 2 b tagged category's shape.

tth→8jets

cut base lepton ID



number of events
passed all selection

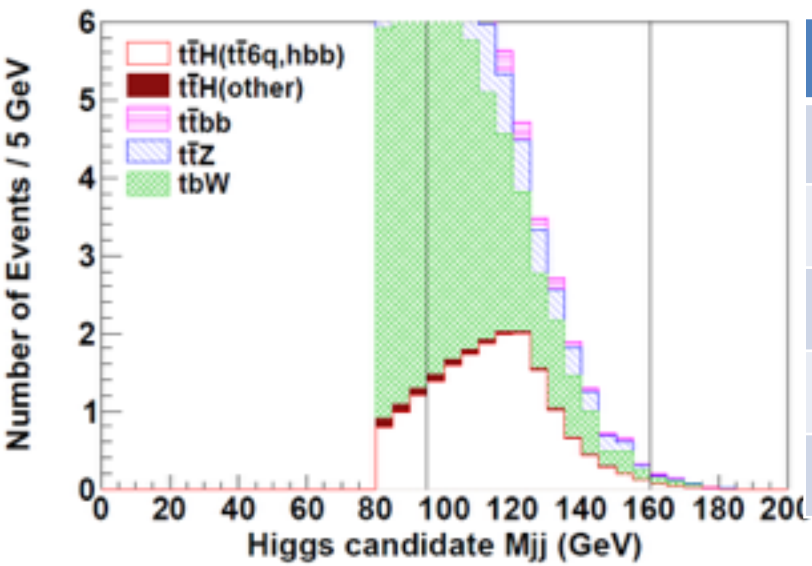
Process	# of evt
tth→4q+4b	*14.4*
tth (other)	*0.46*
ttZ	*7.29*
ttbb	*2.59*
tbW	*25.0*

tth→8jtes

- Nsig = 14.4
- Nbkgd = 35.4
- $S/\sqrt{S+B}$ = 2.04

previous result
(low MC stat)
$S/\sqrt{S+B}$ = 2.38

lepton ID with BDT



Process	# of evt
tth→4q+4b	*14.7*
tth (other)	*0.44*
ttZ	*7.35*
ttbb	*2.71*
tbW	*25.7*

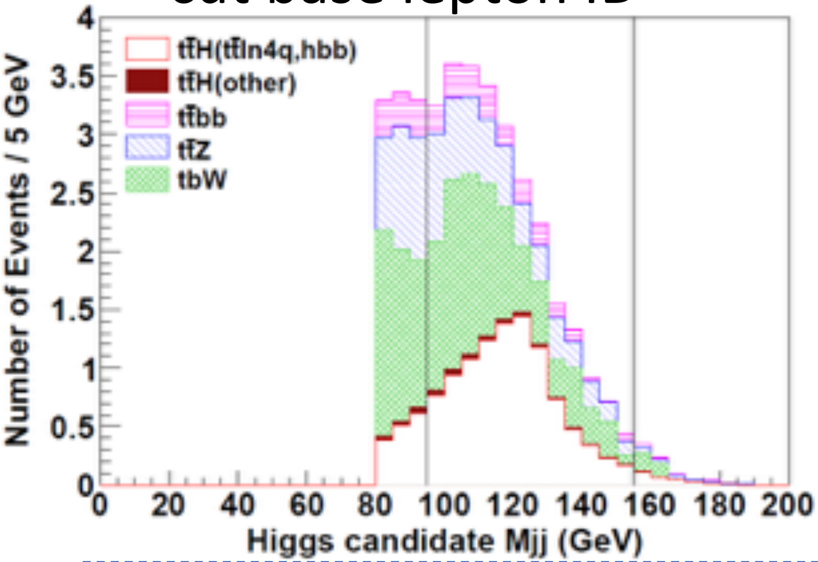
tth→8jtes

- Nsig = 14.7
- Nbkgd = 36.2
- $S/\sqrt{S+B}$ = 2.06

tth→ln+6jets

number of events passed all selection

cut base lepton ID



Process	# of evt
tth→ ln	*9.99*
tth (other)	*0.25*
ttZ	*5.12*
ttbb	*1.99*
tbW	*9.30*

tth→lv+6jtes

- Nsig = 9.99
- Nbkgd = 16.6
- $S/\sqrt{S+B}$ = 1.93

previous result (low MC stat) $S/\sqrt{S+B}$ = 2.11

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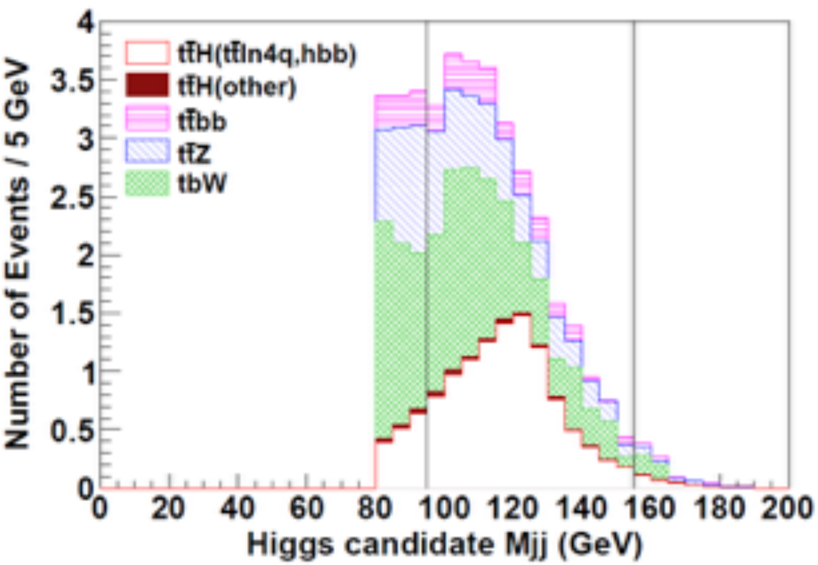
lepton ID with BDT



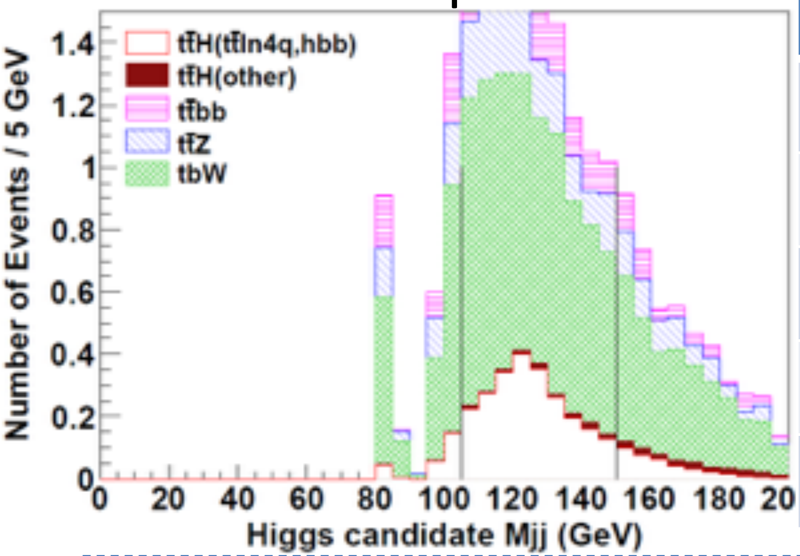
Process	# of evt
tth→ ln	*10.2*
tth (other)	*0.25*
ttZ	*5.17*
ttbb	*2.02*
tbW	*9.80*

tth→lv+6jtes

- Nsig = 10.2
- Nbkgd = 17.2
- $S/\sqrt{S+B}$ = 1.95

tth→2l2n+4b jets

cut base lepton ID



number of events passed all selection

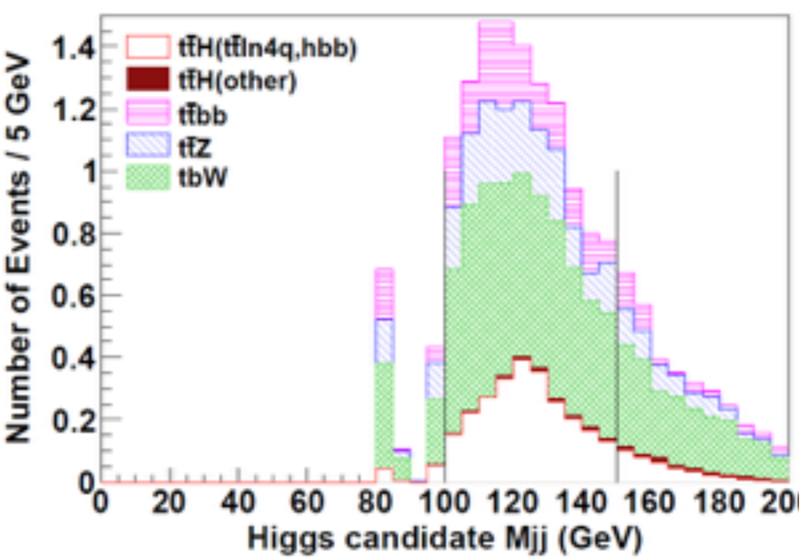
Process	# of evt
tth→ 2l2n	*2.34*
tth (other)	*0.12*
ttZ	*1.78*
ttbb	*1.61*
tbW	*7.32*

tth→2l2v+4b jtes

- Nsig = 2.34
- Nbkgd = 10.8
- $S/\sqrt{S+B} = 0.64$

previous result (low MC stat)
$S/\sqrt{S+B}$ = 0.77

lepton ID with BDT



Process	# of evt
tth→ 2l2n	*2.48*
tth (other)	*0.08*
ttZ	*1.98*
ttbb	*1.72*
tbW	*5.49*

tth→2l2v+4b jtes

- Nsig = 2.48
- Nbkgd = 9.28
- $S/\sqrt{S+B} = 0.72$

Summary2 & Conclusions

Signal Acceptance	Cut-based lepton ID	BDT lepton ID
tth→8jets	***22.5 %***	***23.0 %***
tth→ln+6jets	***16.3 %***	***16.6 %***
tth→2l2n+4b	***16.0 %***	***17.0 %***

$\sqrt{s}$ = 500 GeV, 500 fb^{-1}, P(e-,e+)=(-0.8,+0.3)

$S/\sqrt{S+B}$

tth→8jets : 2.06

tth→lv+6jets : 1.95

tth→2l2v+4b : 0.72

- tbW event acceptance is very low
  * Only 0 - 40 events are passed tth event selection
- tbW event estimation with large stat. is important.

At least 1,000 times of tbW MC stat. is need for cut-based analysis more than 1,000 times of tbW MC stat. is need for MVA analysis (current status: MC stat. is 10k~100k for each tbW category)

Backup

Rough estimation of significance and $|\Delta g_{tth}/g_{tth}|$ @$\sqrt{s}$ = 500-550 GeV, 500 fb^{-1}
Combined result of 8jets and 6jets mode
(* syst. error is not included)

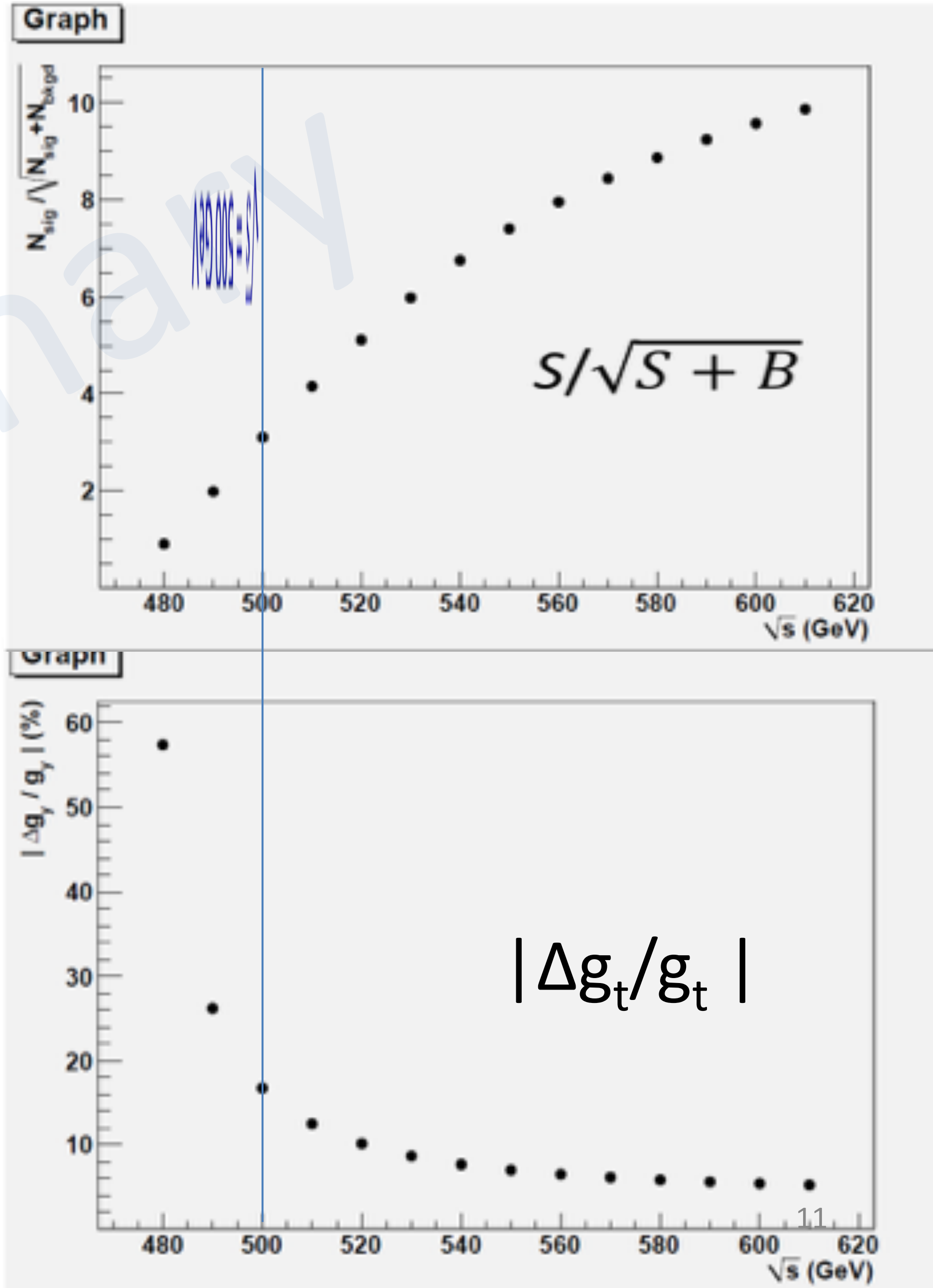
Preliminary

$\sqrt{s}$	: $S/\sqrt{S+B}$	: $|\Delta g_{tth}/g_{tth}|$ %
500	: 3.105	: 16.74
520	: 5.113	: 10.16
550	: 7.403	: 7.023

cross section (fb)

$\sqrt{s}$	: tth(total)	: ttz	: ttbb	: tbw
500	: 0.485	: 1.974	: 1.058	: 979.8
520	: 0.981	: 2.753	: 1.151	: 953.5
550	: 1.743	: 3.806	: 1.285	: 909.5

- ILC 1600fb^{-1} at $\sqrt{s}$ = 500 GeV
  $|\Delta g_{tth}/g_{tth}|$ ~ 9.48% (1% syst. included)
  9.36% (stat. only)



Event Selection

- Jet clustering : Durham algorithm $$Y_{ij} = \frac{2\min\{E_i^2, E_j^2\}(1-\cos\theta)}{E_{cm}^2}$$
  - forced 8 jet clustering for tth→8jets channel
  - ✓ "Y_{87} > 0.00055" + "Y_{87}<=0.00055 && Y_{76}>0.0012"
  - forced 6 jet clustering for tth→lν+6jets channel
  - ✓ "Y_{65} > 0.00165" + "Y_{65}<=0.00165 && Y_{54}>0.005"
- Isolated Lepton

Definition

- reject events with very forward jets
- ✓ |Jet cosθ| ≤ 0.99
- events with large missing momentum
- ✓ MP > 20 GeV

(old definition)

✓ require no(one) Isolated lepton to 8jet(lν+6jet) channel

✓ b candidate jets ≥ 4 (b likeness >=0.85 ,0.8, 0.6, 0.2)

- reject events with very forward jets
- ✓ |Jet cosθ| ≤ 0.99
- events with large missing momentum
- ✓ MP > 20 GeV

Jet pairing, χ2 Cut

- $\sqrt{s}$ = 500GeV is near by threshold of the tth production
  - P_{higgs} should be small
  - Dijet angle becomes large

→ Angle information between higgs candidate jets is effective to choose correct jet pair.

$$\chi^2 = \left(\frac{\Delta angle(j_1, j_2) - \Delta angle(higgs\ jj)}{\sigma_{\Delta angle(higgs\ jj)}}\right)^2 + \left(\frac{m_{j_3 j_4 j_5} - M_{top}}{\sigma_{M_{top}}}\right)^2 + \left(\frac{m_{j_4 j_5} - M_W}{\sigma_{M_W}}\right)^2 + \left(\frac{m_{j_6 j_7 j_8} - M_{top}}{\sigma_{M_{top}}}\right)^2 + \left(\frac{m_{j_7 j_8} - M_W}{\sigma_{M_W}}\right)^2$$

require b likeness ≥ 0.2 to j_1, j_2, j_3, j_6

- try all combination and choose a pair with minimum χ^2 value

reject large χ^2 events

✓ $\chi^2 \leq 11.2$

- Reference values are made from reconstructed jets which are matched with MC information
  - Mtop = 171.5GeV
  - sigma Mtop = 16.8 GeV
  - MW = 80. 5GeV
  - sigma MW = 9.9 GeV
  - angle(jj) = 2.448
  - sigma angle(jj) = 0.277

higgs and top pairing, χ2 Cut

$$\chi^2 = \left(\frac{\Delta angle(j_1, j_2) - \Delta angle(higgs\ jj)}{\sigma_{\Delta angle(higgs\ jj)}}\right)^2 + \left(\frac{m_{j_3 j_4 j_5} - M_{top}}{\sigma_{M_{top}}}\right)^2 + \left(\frac{m_{j_4 j_5} - M_W}{\sigma_{M_W}}\right)^2 + \left(\frac{m_{j_6 l \nu} - M_{top}}{\sigma_{M_{top}}}\right)^2$$

Angle information between higgs candidate jets is effective to choose correct jet pair.

A W mass is reconstructed with Isolated lepton and Missing P

- try all combination and choose a pair with minimum χ^2 value

reject large χ^2 events

✓ $\chi^2 \leq 16.5$

require b likeness ≥ 0.2 to j_1, j_2, j_3, j_6

- Reference values are made from reconstructed jets which are matched with MC information

- Mtop = 171.5GeV
- sigma Mtop = 16.8 GeV
- MW = 80. 5GeV
- sigma MW = 9.9 GeV
- angle(jj) = 2.448
- sigma angle(jj) = 0.277

tth study
Lepton ID with BDT

2015/02/27
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Motivation

- cut based lepton ID is useful to find isolated lepton with small systematic uncertainty

but

it is important to increase signal acceptance for tth study.

- MVA lepton identification will be improve lepton ID efficiency and miss ID fraction.

  → signal acceptance will be improved.

-- issues related to MVA lepton ID method are

 - specified lepton ID method to tth study

 - more complicate lepton ID method than cut-based lepton selection

training and test sample

signal : e, mu, tau(e), tau(mu), tau(1-prong), tau(3-prong)
training and test samples: tth→2l2nbbbb

background: mu, tau(e), tau(mu), tau(1-prong), tau(3-prong), b jet, lf jet
training and test samples: ttZ for light flavor jet
: tth→2l2nbbbb for the other background

- PFOs which can be traced to MC information are used to make samples.

BDTs:

Backgrounds

Signals

	e	mu	tau(e)	tau(mu)	tau	tau	bjet	lf jet
e	**-**	***x***	***x***	***x***	***x***	***x***	***x***	***x***
mu		-	x	x	x	x	x	x
tau(e)			**-**	***x***	***x***	***x***	***x***	***x***
tau(mu)				-	x	x	x	x
tau(1-prong)					**-**	***x***	***x***	***x***
tau(3-prong)						-	x	x

Input variables

Input variables are chosen from the following parameters

- hadOvEM: E_{hcal}/E_{ecal}
- calEovE: $(E_{hcal}+E_{ecal})/Epfo$
- coneE2woSeed: E_{cone2} without seed E_{PFO}
- isoCutOld: $6(E_{PFO}-15)^2 – (coneE2woSeed)^2$
- pfoR0 : $sqrt(trkD0^2+trkZ0^2)$
- coneE1OvConeE2: E_{cone1}/E_{cone2}
- coneMass1: reconstructed mass with PFOs in cone1
- coneMass3: reconstructed mass with PFOs in cone3
- clusterShape0: χ2 of fit
- clusterShape1: maximum deposited energy (GeV)
- clusterShape2: shower Max (mm)
- clusterShape3: transverse absorption length(mm)
- clusterShape5: shower Max/ Expected shower Max
- clusterShape16: xl20 (mm)
- yokuE: deposited energy in the yoku
- pfoe: PFO energy
- pt: Pt of PFO
- cone1E
- maxTrkEInCone13: Maximum energy of a PFO with track between cone1 and cone2
- nNeutralCone1: Number of PFOs with no track in cone1

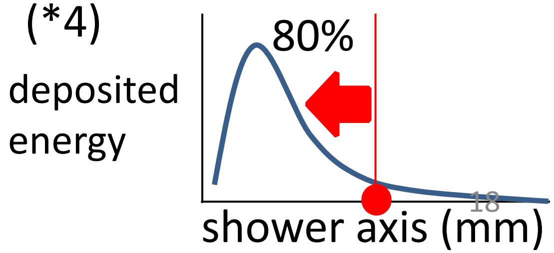
(*1) cone1: cosθ>0.99
cone2: cosθ>0.98
cone3: cosθ>0.93

(*2)cluster shape variables
- choose the highest energy cluster
- electron shower shaped is used to fit

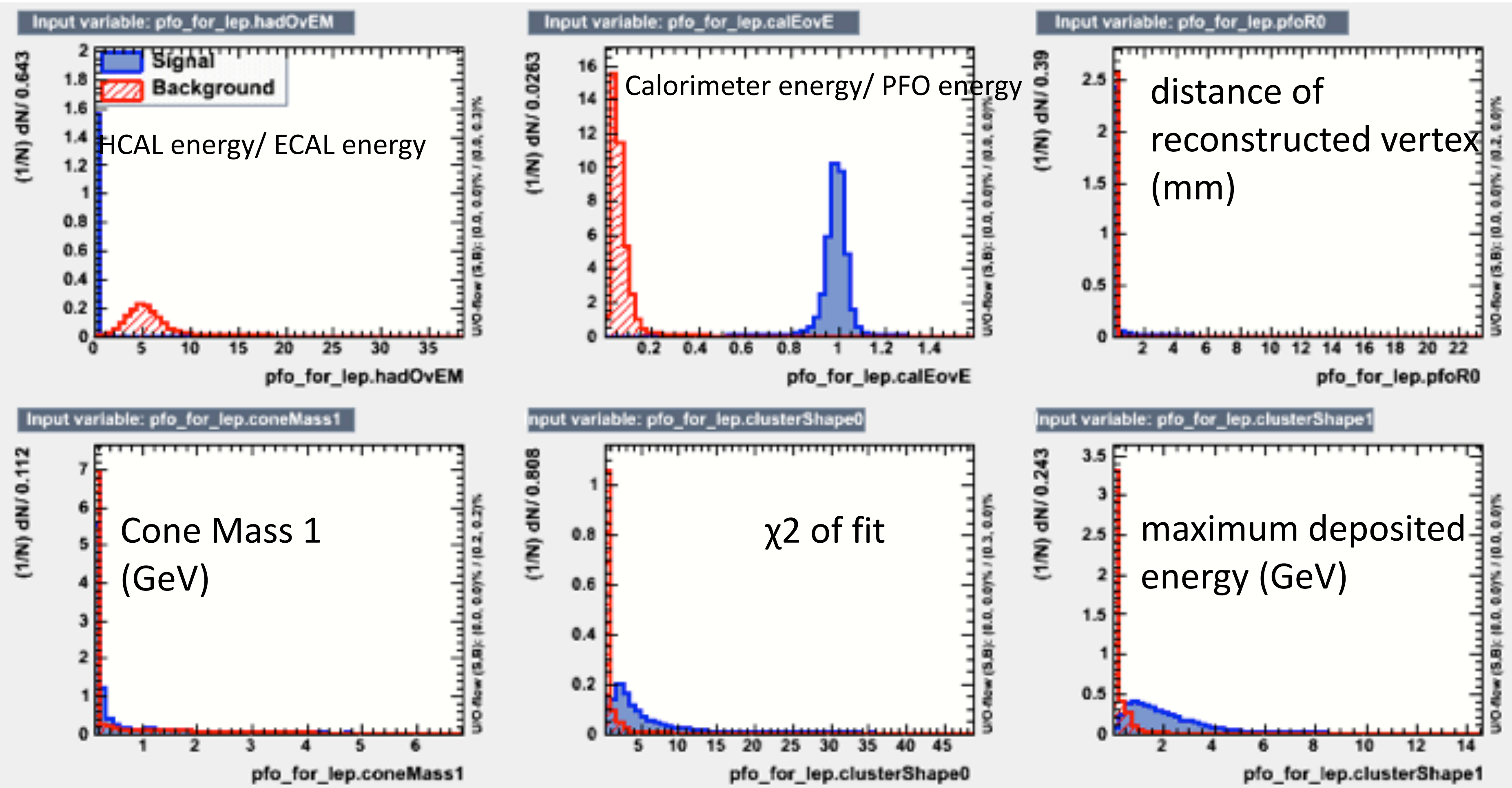
(*3) transverse absorption length : distance btw shower center and location where cluster energy goes down to 1/e

(*4) xl20:length to the positon where the deposited energy reaches 80 % of total energy on shower axis

(*4)



input variables e-mu 1
signal:e, background:mu

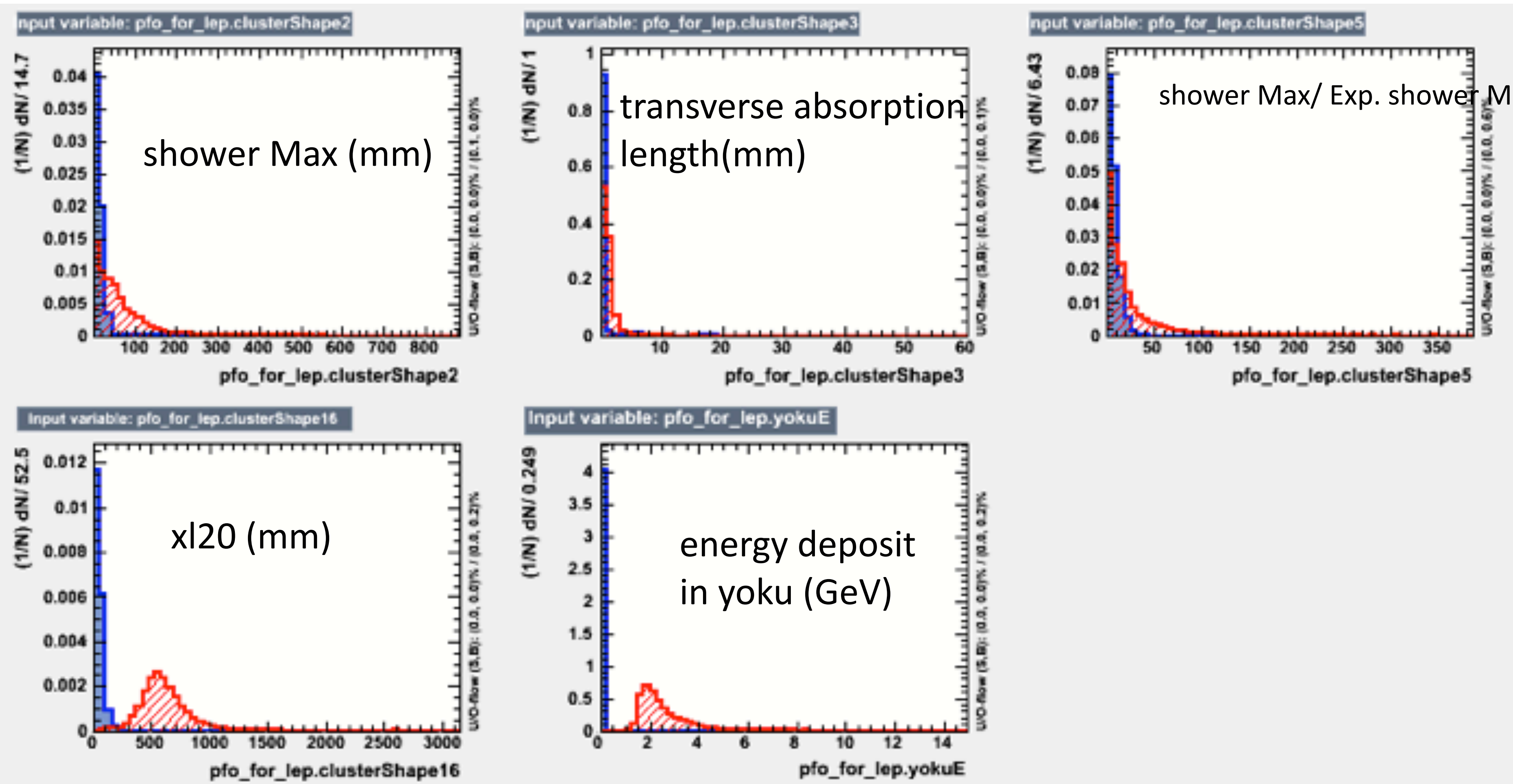


cone1: cosθ>0.99
cone2: cosθ>0.98
cone3: cosθ>0.93

- cluster shape variables

- choose the highest energy cluster
- electron shower shape is used to fit

input variables e-mu 2
signal : e, background : mu



cone1: cosθ>0.99
cone2: cosθ>0.98
cone3: cosθ>0.93

- cluster shape variables

choose the highest energy cluster

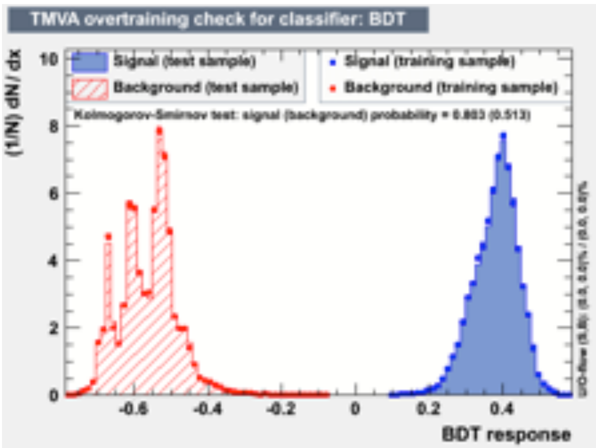
transverse absorption length : distance btw shower center and location where cluster energy goes down to 1/e

BDT Output, signal: electron

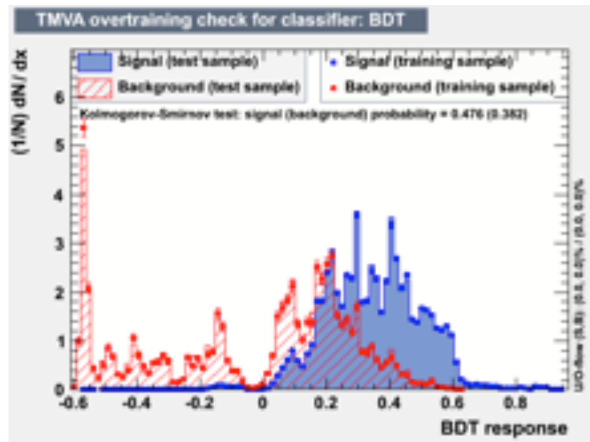
pre-cut : PFO energy > 2 GeV, PFO with track

additional pre-cut for electron or muon: PFO energy > 5 GeV

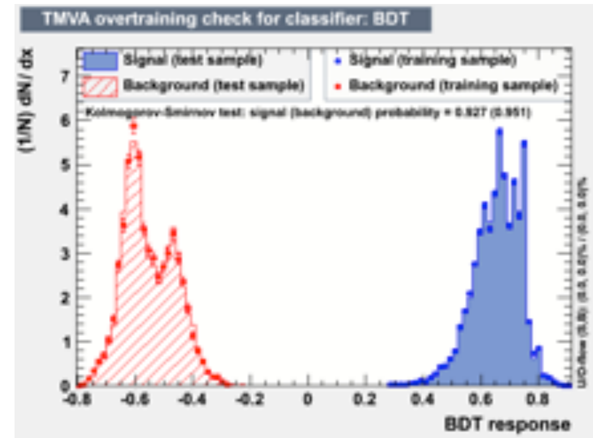
background: muon



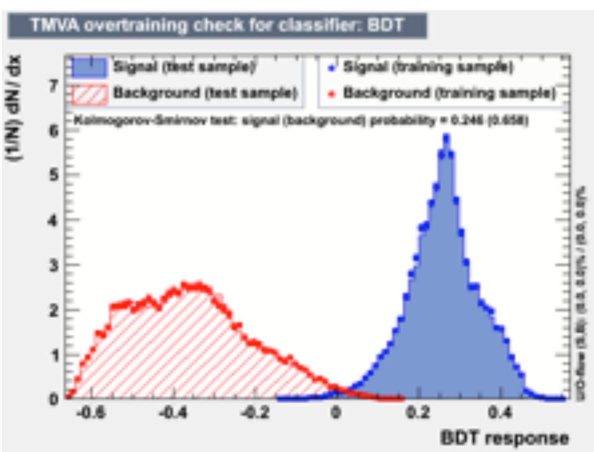
background: tau(e)



background: tau (μ)

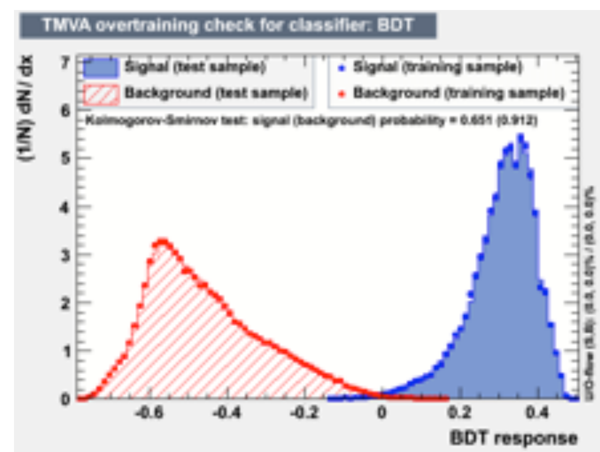


background: tau(h)



background: b jet

background: lf jet



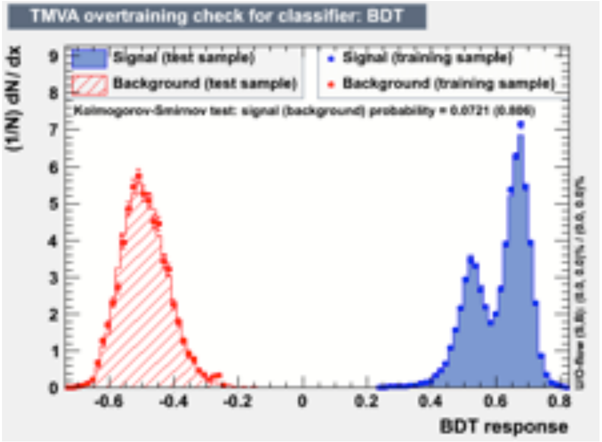
BDT Output, signal: muon

pre-cut : PFO energy > 2 GeV, PFO with track

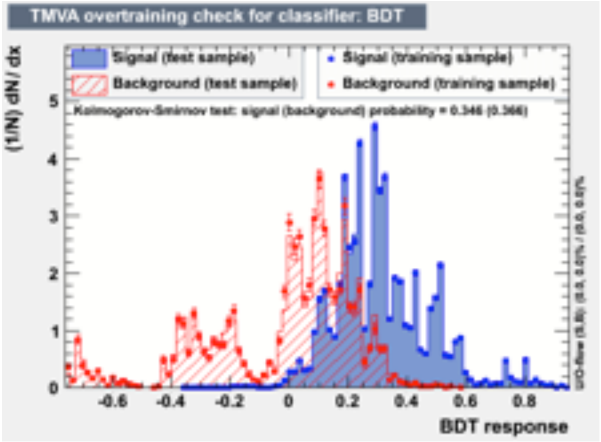
additional pre-cut for electron or muon: PFO energy > 10 GeV

background: muon

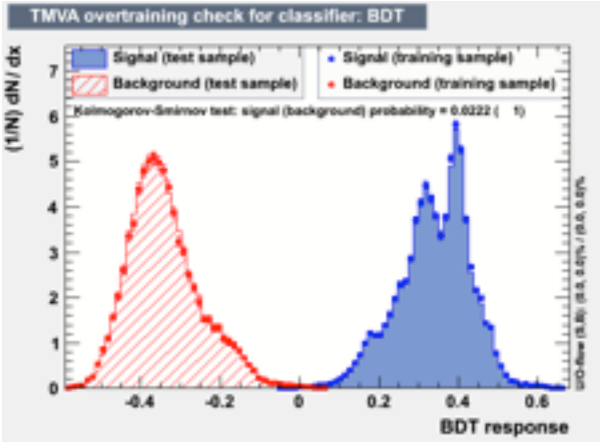
background: tau(e)



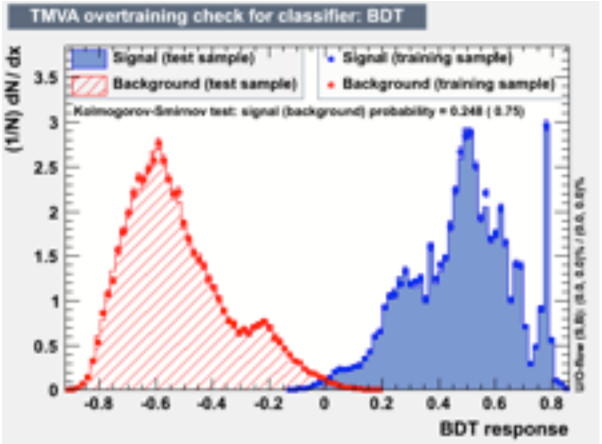
background: tau (μ)



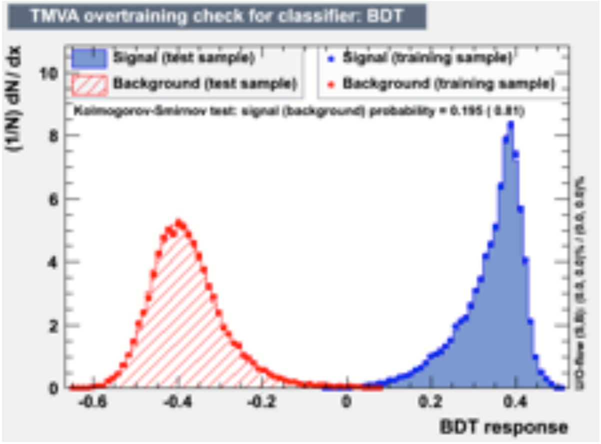
background: tau(h)



background: b jet



background: lf jet



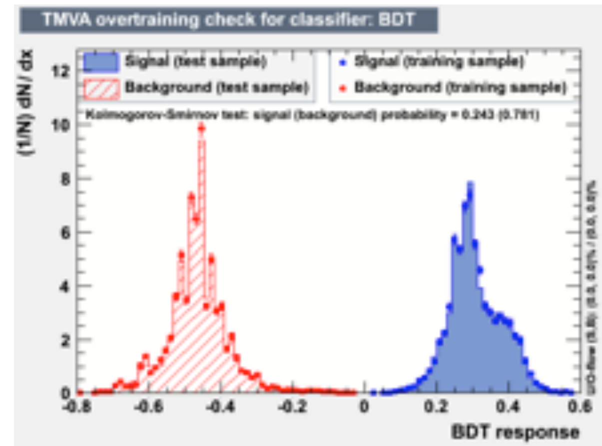
BDT Output, signal: tau(e)

pre-cut : PFO energy > 2 GeV, PFO with track

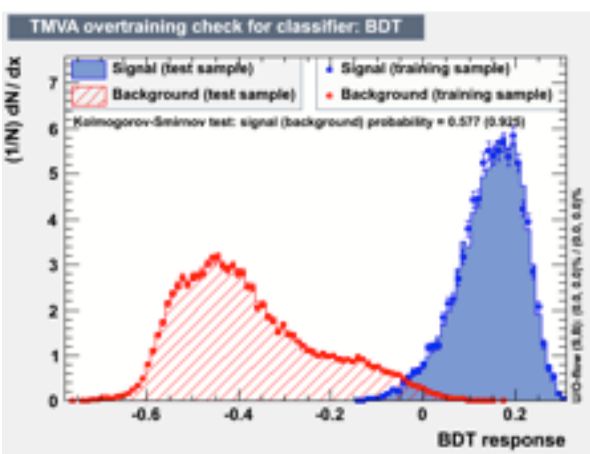
background: muon

background: tau(e)

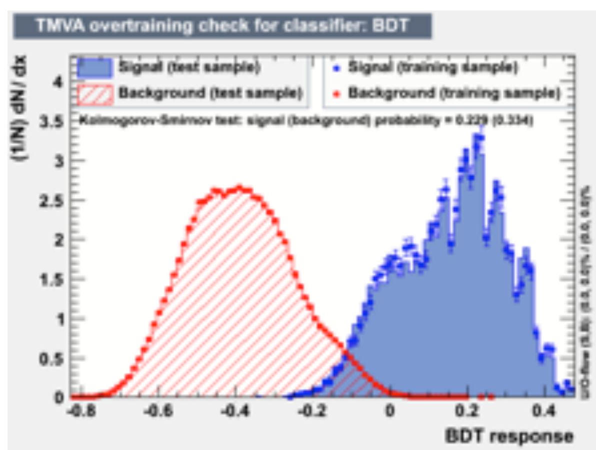
background: tau (μ)



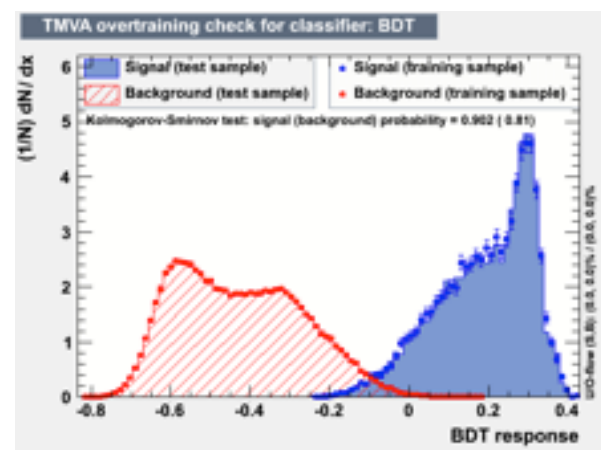
background: tau(h)



background: b jet



background: lf jet



BDT Output, signal: tau(m)

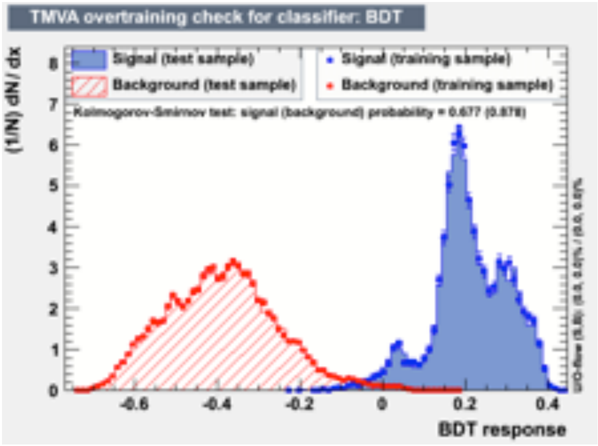
pre-cut : PFO energy > 2 GeV, PFO with track

background: muon

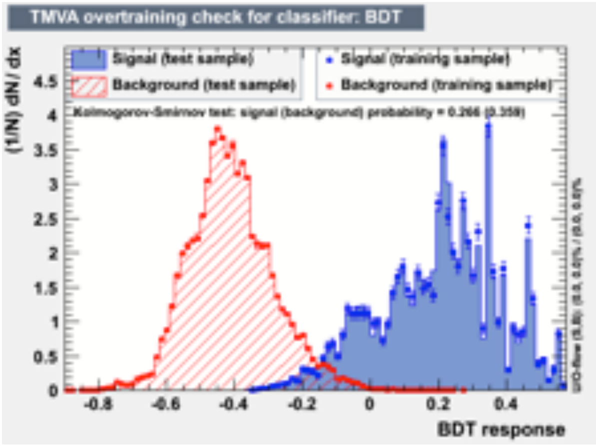
background: tau(e)

background: tau (μ)

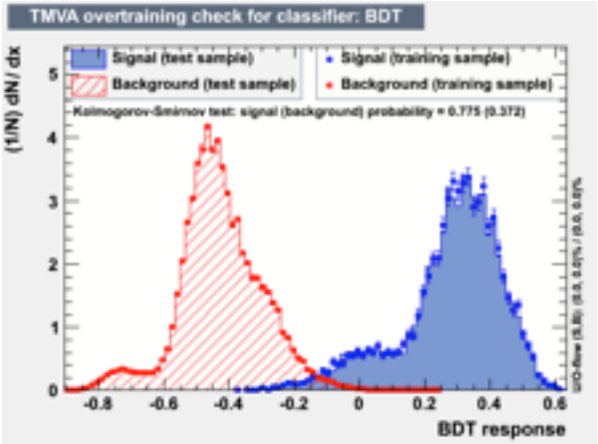
background: tau(h)



background: b jet



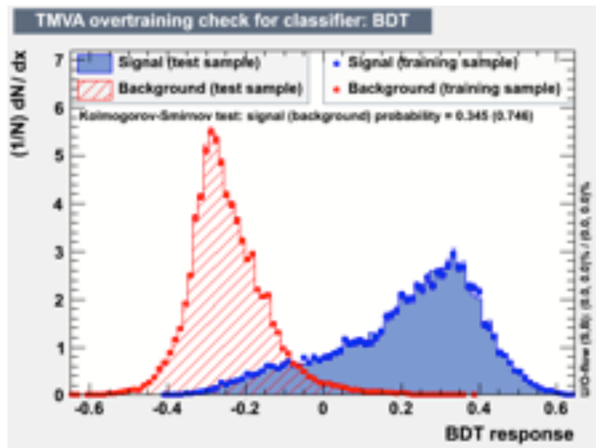
background: lf jet



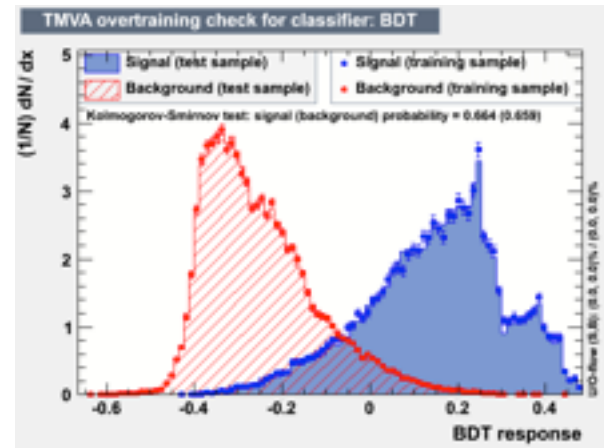
BDT Output, signal:
tau 1-prong (top), tau 3-prong (bottom)

pre-cut : PFO energy > 2 GeV, PFO with track

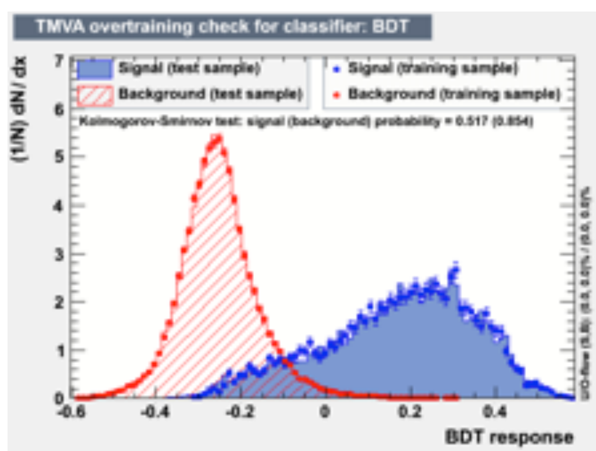
background: b jet



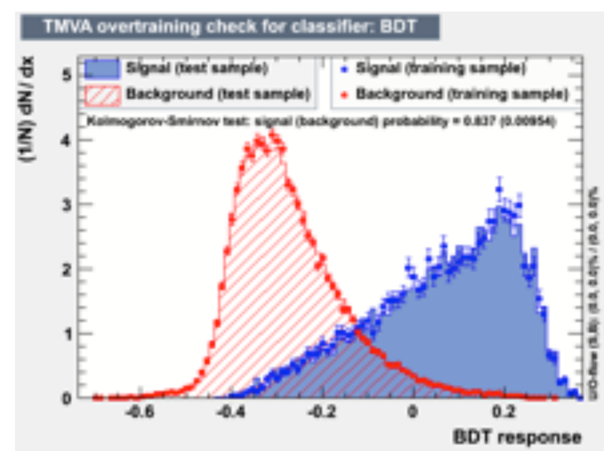
background: lf jet



background: b jet



background: lf jet



tth 2l2n

- Lepton ID efficiency with TMVA BDT (cut base) lepton selection

particles

* in this table,
0 means less than 0.01%

Selection

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
elec	92 (85.08)	0 (0)	43.42 (28.82)	0 (0)	0.42 (0.31)	0 (0.06)	0 (0)	N/A
muon	0 (0)	95.11 (92.14)	0 (0)	40.36 (18.19)	0.03 (0.01)	0 (0)	0 (0)	N/A
taue	0.94 (2.24)	0 (0)	29.32 (18.76)	0 (0)	0.33 (0.42)	0 (0)	0.04 (0.02)	N/A
taum	0 (0)	1.34 (2.66)	0 (0)	34.22 (35.07)	0.11 (0.09)	0 (0)	0.04 (0.03)	N/A
tauh1	0.28 (3.56)	0.06 (0.53)	0.71 (15.4)	0.04 (12.46)	55.64 (46.21)	0 (0)	0.04 (0.06)	N/A
tauh3	0 (0)	0 (0.01)	0.04 (0.08)	0 (0.04)	0 (0)	49.29 (38.74)	0.01 (0.04)	N/A
nonlep	6.76 (9.09)	3.47 (4.65)	26.49 (36.91)	25.37 (34.22)	43.44 (52.92)	50.7 (61.18)	99.84 (99.83)	N/A

tth 2l2n

- Lepton ID efficiency with TMVA BDT (cut base) lepton selection

particles

* in this table,
0 means less than 0.01%

Selection

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
elec	92 (85.08)	0 (0)	43.42 (28.82)	0 (0)	0.42 (0.31)	0 (0.06)	0 (0)	N/A
muon	0 (0)	95.11 (92.14)	0 (0)	40.36 (18.19)	0.03 (0.01)	0 (0)	0 (0)	N/A
taue	0.94 (2.24)	0 (0)	29.32 (18.76)	0 (0)	0.33 (0.42)	0 (0)	0.04 (0.02)	N/A
taum	0 (0)	1.34 (2.66)	0 (0)	34.22 (35.07)	0.11 (0.09)	0 (0)	0.04 (0.03)	N/A
tauh1	0.28 (3.56)	0.06 (0.53)	0.71 (15.4)	0.04 (12.46)	55.64 (46.21)	0 (0)	0.04 (0.06)	N/A
tauh3	0 (0)	0 (0.01)	0.04 (0.08)	0 (0.04)	0 (0)	49.29 (38.74)	0.01 (0.04)	N/A
nonlep	6.76 (9.09)	3.47 (4.65)	26.49 (36.91)	25.37 (34.22)	43.44 (52.92)	50.7 (61.18)	99.84 (99.83)	N/A

tth 2l2n

- Lepton ID efficiency with TMVA BDT (cut base) lepton selection

* in this table,
0 means less than 0.01%

particles

Selection

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
elec	92 (85.08)	0 (0)	43.42 (28.82)	0 (0)	0.42 (0.31)	0 (0.06)	0 (0)	N/A
muon	0 (0)	95.11 (92.14)	0 (0)	40.36 (18.19)	0.03 (0.01)	0 (0)	0 (0)	N/A
taue	0.94 (2.24)	0 (0)	29.32 (18.76)	0 (0)	0.33 (0.42)	0 (0)	0.04 (0.02)	N/A
taum	0 (0)	1.34 (2.66)	0 (0)	34.22 (35.07)	0.11 (0.09)	0 (0)	0.04 (0.03)	N/A
tauh1	0.28 (3.56)	0.06 (0.53)	0.71 (15.4)	0.04 (12.46)	55.64 (46.21)	0 (0)	0.04 (0.06)	N/A
tauh3	0 (0)	0 (0.01)	0.04 (0.08)	0 (0.04)	0 (0)	49.29 (38.74)	0.01 (0.04)	N/A
nonlep	6.76 (9.09)	3.47 (4.65)	26.49 (36.91)	25.37 (34.22)	43.44 (52.92)	50.7 (61.18)	99.84 (99.83)	N/A

ttZ

- Lepton ID efficiency with TMVA BDT (cut base) lepton selection

particles

* in this table,
0 means less than 0.01%

Selection

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
elec	90.92 (84.62)	0.01 (0.01)	44.3 (28.27)	0 (0)	0.15 (0.11)	0 (0.11)	0.01 (0.02)	0.01 (0.02)
muon	0 (0)	94.93 (92.23)	0 (0)	39.98 (18.28)	0 (0)	0.11 (0)	0.01 (0)	0 (0.01)
taue	1.16 (1.96)	0 (0.01)	28.08 (20.01)	0 (0)	0.34 (0.23)	0 (0)	0.02 (0.02)	0 (0)
taum	0 (0)	1.59 (2.93)	0 (0)	33.42 (36.28)	0.15 (0.07)	0 (0)	0.02 (0.03)	0 (0)
tauh1	0.31 (3.14)	0.05 (0.49)	0.56 (15.08)	0 (10.98)	54.97 (45.37)	0 (0)	0.01 (0.02)	0.38 (0.4)
tauh3	0.09 (0.05)	0 (0)	0 (0.08)	0 (0)	0 (0)	48.14 (37.99)	0 (0.02)	0.18 (0.2)
nonlep	7.5 (10.2)	3.39 (4.29)	27.03 (36.62)	26.59 (34.44)	44.36 (54.19)	51.73 (61.88)	99.89 (99.86)	99.4 (99.34)

Summary1

- Prepare BDT Lepton ID method
- Lepton ID efficiency is improved
  - ID efficiency is slightly increased
  - miss ID rate is slightly decreased
- I hope sensitivity of tth(h→bb) channel will be improved

some issues

- cluster shape values has sometimes “Nan” value.

  → PFOs with “Nan” input value are rejected to MVA samples

- some BDT outputs have peaked distribution

  Is it acceptable or not?

- many input variables are used