# tth study Lepton ID with BDT

2015/02/27 Yuji Sudo

# training and test sample

signal : e, mu, tau(e), tau(mu), tau(1-prong), tau(3-prong) training and test samples: tth $\rightarrow$ 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 $\rightarrow$ 2l2nbbbb for the other background

2

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

BDTs:

Signals

Backgrounds	5
-------------	---

	е	mu	tau(e)	tau(mu)	tau 1-prong	tau 3-prong	bjet	lf jet
е	-	х	Х	x	x	х	х	х
mu		-	Х	x	х	х	х	х
tau(e)			-	x	x	х	х	х
tau(mu)				-	х	х	х	х
tau(1-prong)					-	х	X	x
tau(3-prong)						-	х	х

# Input variables are chosen from the following parameters

- hadOvEM: E<sub>hcal</sub>/E<sub>ecal</sub>
- calEovE: (E<sub>hcal</sub>+E<sub>ecal</sub>)/Epfo
- coneE2woSeed: E<sub>cone2</sub> without seed E<sub>PFO</sub>
- isoCutOld: 6(E<sub>PFO</sub>-15)<sup>2</sup> (coneE2woSeed)<sup>2</sup>
- pfoR0 : sqrt(trkD0<sup>2</sup>+trkZ0<sup>2</sup>)
- coneE1OvConeE2: E<sub>cone1</sub>/E<sub>cone2</sub>
- 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
- eNeutralCone1: Energy sum 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) deposited energy



# BDT Output, signal: electron

pre-cut : PFO energy > 2 GeV, PFO with track additional pre-cut for electron or muon: PFO energy > 5 GeV

õ

(1/N) dN/

3.5

2.5

1.5

0.5

-0.6

-0.4

-0.2

Ó

0.2

0.4

0.6

BDT response

### background: muon

# TWVA overtraining check for classifier: BDT

### background: tau(h)



### background: tau(e)



background: b jet

-Kolmogorov-Smirnov test: signal (background) probability = 0.205 ( 0.92)

Signal (training sample)

Background (training sample)

TMVA overtraining check for classifier: BDT

Background (test sample)

Signal (test sample)

### background: tau (µ)



### background: If jet

TMVA overtraining check for classifier: BDT



# 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: If jet



# BDT Output, signal: tau(e)

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

background: muon

background: tau(e)

### background: tau (µ)



### background: If jet



### background: b jet



TMVA overtraining check for classifier: BDT



# 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: If jet



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

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

background: b jet

#### TMVA overtraining check for classifier: BDT õ Signal (test sample) Signal (training sample) /ND (N/L) Background (test sample) Background (training sample) -Kolmogorov-Smirnov test: signal (background) probability = 0.345 (0.746 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 **BDT** response

# background: If jet



### background: If jet







# tth 2l2n

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

particles

\* in this table,0 means less than 0.01%

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
elec	<mark>92</mark> (85.08)	0 (0)	43.42 (28.82)	0 (0)	0.42 (0.31)	0 (0.06)	0 (0)	N/A
muon	0 (0)	<mark>95.11</mark> (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)	<mark>29.32</mark> (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)	<mark>34.22</mark> (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)	<mark>55.64</mark> (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)	<mark>49.29</mark> (38.74)	0.01 (0.04)	N/A
nonlep	<mark>6.76</mark> (9.09)	<mark>3.47</mark> (4.65)	<mark>26.49</mark> (36.91)	25.37 (34.22)	<mark>43.44</mark> (52.92)	<mark>50.7</mark> (61.18)	<mark>99.84</mark> (99.83)	N/A

Selection

### ttZ

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

particles

\* in this table,0 means less than 0.01%

(%)	elec	muon	taue	taum	tauh1	tauh3	bjet	ljet
	90.92	0.01	44.3	0	0.15	0	0.01	0.01
elec	(84.62)	(0.01)	(28.27)	(0)	(0.11)	(0.11)	(0.02)	(0.02)
muon	0	94.93	0	39.98	0	0.11	0.01	0
muon	(0)	(92.23)	(0)	(18.28)	(0)	(0)	(0)	(0.01)
taua	1.16	0	28.08	0	0.34	0	0.02	0
laue	(1.96)	(0.01)	(20.01)	(0)	(0.23)	(0)	(0.02)	(0)
taum	0	1.59	0	33.42	0.15	0	0.02	0
laum	(0)	(2.93)	(0)	(36.28)	(0.07)	(0)	(0.03)	(0)
tauh1	0.31	0.05	0.56	0	54.97	0	0.01	0.38
launi	(3.14)	(0.49)	(15.08)	(10.98)	(45.37)	(0)	(0.02)	(0.4)
tauh2	0.09	0	0	0	0	48.14	0	0.18
launs	(0.05)	(0)	(0.08)	(0)	(0)	(37.99)	(0.02)	(0.2)
nonlon	7.5	3.39	27.03	26.59	44.36	51.73	99.89	99.4
nomep	(10.2)	(4.29)	(36.62)	(34.44)	(54.19)	(61.88)	(99.86)	(99,34)

Selection

## BDT input variables table 1

	e-m	e-taue	e-taum	e-tauh	e-bjet	e-lfjet	m-taue	m-taum	m-tauh	m-bjet	m-lfjet
hadOvEM	$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$				
calEovE	$\checkmark$	$\checkmark$	$\checkmark$			$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$
coneE2woSeed		$\checkmark$				$\checkmark$		$\checkmark$			
isoCutOld		$\checkmark$	1	1		$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$
pfoR0	$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$		$\checkmark$		$\checkmark$	
coneE1OvConeE2					$\checkmark$	$\checkmark$	$\checkmark$				
coneMass1	$\checkmark$			$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$				$\checkmark$
coneMass3		$\checkmark$									
clusterShape0	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$				$\checkmark$
clusterShape1	$\checkmark$		$\checkmark$	$\checkmark$	✓	$\checkmark$	$\checkmark$				$\checkmark$
clusterShape2	$\checkmark$		$\checkmark$		✓	$\checkmark$	$\checkmark$				$\checkmark$
clusterShape3	$\checkmark$	$\checkmark$	$\checkmark$			$\checkmark$		$\checkmark$		$\checkmark$	$\checkmark$
clusterShape5	$\checkmark$						$\checkmark$				$\checkmark$
clusterShape16	$\checkmark$		$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$		$\checkmark$		
yokuE	$\checkmark$		$\checkmark$					$\checkmark$	$\checkmark$		$\checkmark$
pfoe			$\checkmark$								
pt							$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$
cone1E		$\checkmark$			$\checkmark$	$\checkmark$					$\checkmark$
nTrkInCone1		$\checkmark$			$\checkmark$	$\checkmark$					
maxTrkEInCone13		$\checkmark$		$\checkmark$		$\checkmark$					$\checkmark$
nNeutralCone1				$\checkmark$		$\checkmark$			$\checkmark$		$\checkmark$
eNeutralCone1		$\checkmark$		$\checkmark$		1			$\checkmark$	$\checkmark$	11

	taue-	taue-	taue-	taue-	taum-	taum-	taum-	tauh1-	tauh1-	tauh3-	tauh3-
	taum	tauh	bjet	lfjet	tauh	bjet	lfjet	bjet	lfjet	bjet	lfjet
hadOvEM	$\checkmark$										
calEovE		$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$				$\checkmark$	
coneE2woSeed		$\checkmark$					$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	
isoCutOld	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$		$\checkmark$		$\checkmark$	
pfoR0		$\checkmark$	$\checkmark$	$\checkmark$			$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
coneE1OvConeE2	$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$			$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
coneMass1		$\checkmark$						$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
coneMass3		$\checkmark$	$\checkmark$	$\checkmark$		1	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
clusterShape0	$\checkmark$	$\checkmark$	$\checkmark$								
clusterShape1		$\checkmark$	$\checkmark$	$\checkmark$			$\checkmark$			$\checkmark$	
clusterShape2			$\checkmark$			1				$\checkmark$	
clusterShape3	$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$
clusterShape5	$\checkmark$	$\checkmark$			$\checkmark$						
clusterShape16	$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$							
yokuE					$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$		$\checkmark$	
pfoe		$\checkmark$	$\checkmark$	$\checkmark$	$\checkmark$		$\checkmark$		$\checkmark$	$\checkmark$	$\checkmark$
pt									$\checkmark$	$\checkmark$	
cone1E		$\checkmark$		$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$		$\checkmark$	$\checkmark$
nTrkInCone1		$\checkmark$	$\checkmark$	$\checkmark$							
maxTrkEInCone13		$\checkmark$	$\checkmark$	$\checkmark$				$\checkmark$		$\checkmark$	
nNeutralCone1								$\checkmark$			
eNeutralCone1								$\checkmark$		$\checkmark$	12

# Input variables and Linear correlation matrix

• input variables are chosen to maximize area of ROC curve

# **Correlation plots**

### electron

### muon



### Correlation Matrix (signal)



# BDT input variables e-mu 1



# BDT input variables e-mu 2



# Correlation

### electron

### tau(e)

**Correlation Matrix (background)** 



#### Linear correlation coefficients in % 100 or\_lep.pfoR0 4 100 -1 80 usterShape3 2 100 60 rkEInCone13 3 100 40 -8 lep.calEovE 2 100 20 usterShape0 10 6 3 100 2 leutralCone1 70 -47 100 -8 0 p.isoCutOld -87 -51 100 -47 -20 100 -51 nTrkInCone1 2 -40 1 coneMass3 100 -60 neE2woSeed 100 -87 70 -80 lep.cone1E 100 1 -100

# BDT input variables e-taue 1



# BDT input variables e-taue 2



# Correlation

### electron

### tau(m)



### **Correlation Matrix (signal)**

100	in %	ients	coeffic	ation o	correla	inear	L						
100		100		11	1	1	46	8	2	35		5	_for_lep.pfoe
80			100					1	2		-5	1	or_lep.yokuE
60	-	11		100	22	8	7	7		6		2	sterShape16
40	_	1		22	100	5	21	-4		-1	-6	8	usterShape3
20	_	1		8	5	100	4			1	3	1	usterShape2
0	_	46		7	21	4	100	-16		17	5	-3	usterShape1
-20		8	1	7	-4		-16	100	6	-2		13	usterShape0
40		2	2					6	100	-18		5	o.coneMass3
-40		35		6	-1	1	17	-2	-18	100	6	-4	p.isoCutOld
-60			-5		-6	3	5			6	100	-14	lep.calEovE
-80		5	4	2	8		_3	13	5	A	-14	100	en hadOvEM
-10		Dfe	Df.	Df.	Dfe	Dfe	Df.	Dfe	Df.	Dfe	Dfe	Dfe	op.maaovem

# BDT input variables e-taum 1



# BDT input variables e-taum 2



# Correlation

### electron

Correlation Matrix (signal)

EInCone13		-3	-2	7	-1	-1	-1	65	4		-10	1	100		'
_lep.pfoR0	-2	-3	-3	22	-1	-1		5	1	1	-1	100	1		8
.isoCutOld	4	11	7	-55	-66	2	-52	-29	-35		100	-1	-10	_	6
sterShape0	-23	5	-17		4	2	1		1	100		1		_	Δ
utralCone1	-5	-3	-5	43		-2	66	21	100	1	-35	1	4		-
coneMass3	-2	2	-1	38	20	1	11	100	21		-29	5	65		2
utralCone1	-2		-3	31	56		100	11	66	1	-52		-1	_	0
sterShape1	2	37	7	-1	20	100		1	-2	2	2	-1	-1		_
lep.cone1E	4	51	15	49	100	20	56	20		4	-66	-1	-1		
coneMass1	-4	-2	-5	100	49	-1	31	38			-55	22	7		~
p.hadOvEM	56	38	100	-5	15	7	-3	-1	-5	-17	7	-3	-2	_	-1
or_lep.pfoe	15	100	38	-2	51	37		2	-3	5	11	-3	-3		-1
terShape16	100	15	56	-4	4	2	-2	-2	-5	-23	4	-2			
	Pfo	pfe	pte	pfo	pfe	pfo	pfo	pfo	pfo	pfo	pfo	Pf	pfo	£.,	-

tau(h)

								.inea	r cor	elatio	on co	effici	ents	in %	10
kEInCone13	-1	-5	2	15	-3	-3		68	8	2	-13		100		
or_lep.pfoR0	-2	-8		10	-1	-4	12	1	2		-13	100			80
p.isoCutOld	6	35	-4	-43	-7	17	-70	-18	-31	-2	100	-13	-13	_	60
usterShape0	7	8	13	7	10	-16	2	6	2	100	-2		2		1
eutralCone1	-10	3		41	25		39	22	100	2	-31	2	8		
.coneMass3		2	5	40	9		6	100	22	6	-18	1	68		2
eutralCone1	-8	-24	4	22	22	-13	100	6	39	2	-70	12		_	0
usterShape1	7	46	-3	-2		100	-13			-16	17	-4	-3		-:
_lep.cone1E	7	86	7	20	100	39	22	9	25	10	-7	-1	-3		
.coneMass1	-2	-1	5	100	20	-2	22			7	-43	10	15		-4
ep.hadOvEM	2	5	100	5	7	-3	4	5		13	-4		2	_	-
for_lep.pfoe	11	100	5	-1	86	46	-24	2	3	8	35	-8	-5	_	-8
	400	44	2	-2	7	7	-8		-10	7	6	-2	-1		

# BDT input variables e-tauh 1



# BDT input variables e-tauh 2



# BDT input variables e-tauh 3



# Correlation

### electron

### b jet



100

80

60

40

20

0

-20

-40

-60

-80

# BDT input variables e-bjet 1



# BDT input variables e-bjet 2



# Correlation

### electron

### lf jet

### Correlation Matrix (signal)

											Lin	ear	cor	rela	tio	1 CC	effi	cie	nts	in %	100
p.isoCutOld	35	-4	-43	-7	17	-37	-31	-18	6	-90	1	-1	6	35	-70	-13	-2	-13	10(	)	100
or_lep.pfoR0	-8		10	-1	-4	1	2	1	-2	13				-2	12			100	-13		80
usterShape0	8	13	7	10	-16	5	2	6	7	5		-4		-3	2	2	100		-2		00
rkEInCone13	-5	2	15	-3	-3	14	8	68	-1	15	-1			-33		100	2		-13		60
leutralCone1	-24	4	22	22	-13	8	39	6	-8	83	-2	1	-13	-2	100		2	12	-70		00
E1OvConeE2	12	-2	-31	7	6	-31	-17	-42	2	-41				100	-2	-33	-3	-2	35		40
_lep.calEovE		-14	-3	-5	5		-13			-10	3	-6	100		-13				6		
usterShape3	1	8		2	21		-4		22		5	100	-6		1		-4		-1	-	20
usterShape2	1	1			4		-4		8	-1	100	5	3		-2	-1			1		
neE2woSeed	-23	6	50	24	-13	40	45	26	-7	100	-1		-10	-41	83	15	5	13	-90		0
sterShape16	11	2	-2	7	7	-1	-10		100	-7	8	22		2	-8	-1	7	-2	6		
o.coneMass3	2	5	40	9		35	22	100		26				-42	6	68	6	1	-18	-	-20
leutralCone1	3		41	25		28	100	22	-10	45	-4	-4	-13	-17	39	8	2	2	-31		
nTrkInCone1	-5	5	80	11	-3	100	28	35	-1	40				-31	8	14	5	1	-37	-	-40
usterShape1	46	-3	-2	39	100	-3			7	-13	4	21	5	6	-13	-3	-16	-4	17		
_lep.cone1E	86	7	20	100	39	11	25	9	7	24		2	-5	7	22	-3	10	-1	-7	-	-60
o.coneMass1	-1	5	100	20	-2	80	41	40	-2	50			-3	-31	22	15	7	10	-43		~~
ep.hadOvEM	5	100	5	7	-3	5		5	2	6	1	8	-14	-2	4	2	13		-4		-80
for_lep.pfoe	100	5	-1	86	46	-5	3	2	11	-23	1	1		12	-24	-5	8	-8	35		400
	ÞI	تم م	Pt	5.Pt	5.PI	r_P	E_PI		-Pt	Pt		5.Pl	-Dt	-PI	-Dt		-PI	PI	-P	£	-100
		1	or 1		es/		ŏr'	er l		j, l		5 / J			j l		5	s l	6		r lep in
				, f	106	ad	8Ú	Ma	He was	terk	βÊ	<i>RP</i>	腃	ier.	Hs	ers	獻	斜	Eq	<i>B</i>	REES
									-01		'aj	5élé	10)	酚	·'aj	e fi	69	ģŹ	,e3	- 10	SREEFO

### Correlation Matrix (background)

Linear correlation coefficients in %														100							
p.isoCutOld	3	4	-58	-74		-45	-40	-27	3	-88			-2	-4	-52	-3		2	100		100
or_lep.pfoR0	-2	-5	17	-5	-1	-4	-2	5	-2	-3			-1	-2	-2	2		100	2		80
usterShape0		-7			3				-9				3				100				00
rkEInCone13	-10	-4	-8	-17	-3	-5	-7	54	-2	2				-41	-12	100		2	-3		60
leutralCone1	5	-1	46	65	2	11	65	12	-1	62			1	28	100	-12		-2	-52		
E1OvConeE2	24	9	27	44	8	19	19	-21	4	5			2	100	28	-41		-2	-4	_	40
_lep.calEovE	9	24	2	6	13	2	-1	1	11	3		-1	100	2	1		3	-1	-2		
usterShape3		-1			-1				-1			100	-1							_	20
usterShape2			-1		-2				1	,	100										
neE2woSeed	-1	-4	70	85		57	51	32	-3	100			3	5	62	2		-3	-88	_	0
sterShape16	12	46	-1	2	3	-1	-2	-2	100	-3	1	-1	11	4	-1	-2	-9	-2	3		
o.coneMass3		-2	33	19		26	19	100	-2	32			1	-21	12	54		5	-27	-	-20
leutralCone1	1	-2	50	50	-1	26	100	19	-2	51			-1	19	65	-7		-2	-40		
nTrkInCone1	-3	-2	66	54	-1	100	26	26	-1	57			2	19	11	-5		-4	-45	-	-40
usterShape1	36	9	2	13	100	-1	-1		3		-2	-1	13	8	2	-3	3	-1			
_lep.cone1E	36	10	71	100	13	54	50	19	2	85			6	44	65	-17		-5	-74		-60
o.coneMass1	9	-1	100	71	2	66	50	33	-1	70	-1		2	27	46	-8		17	-58		~~
ep.hadOvEM	39	100	-1	10	9	-2	-2	-2	46	-4		-1	24	9	-1	-4	-7	-5	4		-80
for_lep.pfoe	100	39	9	36	36	-3	1		12	-1			9	24	5	-10		-2	3		400
	Þi	5.P1	Pl	5.01	- Pl	-DI	5.01	5.Pt	-PI		- Pf	_ <i>₽t</i>	Pt		~PI	5.Pl	-Pt				-100
		1	Sr-1		6.4	sr'				<i>[</i> ]		5	ic l		i, l			5	5-10	r le	, leo i
					'oé	ad	SUL	Ma	摧	ler.	ne.	僻	腾	ēfs	Hs	ES.	影	縱	ĽΨ.	<u>Rat</u>	REGES
									- 37		ap	éf	20	ne j	- al	re h	036	est ex	63	109	REEF

# BDT input variables e-lfjet 1



# BDT input variables e-lfjet 2



# BDT input variables e-lfjet 3



# BDT input variables elfjet- 4



# Correlation

### tau(e)

#### Correlation Matrix (background) Linear correlation coefficients in % fo\_for\_lep.pt -5 100 -11 8 78 80 for\_lep.pfoe 9 100 78 Q 5 64 sterShape16 100 9 60 usterShape5 14 -42 100 -10 1 40 usterShape2 1 100 -14 20 9 64 usterShape1 100 -42 7 usterShape0 6 100 -21 0 100 o.coneMass3 -49 1 -20 -56 o.coneMass1 -1 100 3 1 1 4 -40 -30 -49 E1OvConeE2 100 -3 6 -60 p.isoCutOld 100 -56 -28 1 18 -11 lep.calEovE 100 2 -80 ep.hadOvEM 100 1 -1 -100 Pfo pfo.

### muon



### **Correlation Matrix (signal)**

# BDT input variables mu-taue 1


### BDT input variables mu-taue 2



## BDT input variables mu-taue 3



#### muon

#### tau(m)







100

80

#### BDT input variables mu-taum 1



#### muon

#### tau(h)

Correlation Matrix (background)

100

100



#### Linear correlation coefficients in % 100 leutralCone1 -5 -5 100 80 sterShape16 100 3 -2 60 leutralCone1 -53 100 40 for\_lep.pfoe 100 20 fo\_for\_lep.pt -56 100 0 -20 o.coneMass3 100 -40 p.isoCutOld 100 -56 -53 1

Pfo\_for\_lep.yokuE

-60

-80

## BDT input variables mu-tauh 1



## BDT input variables mu-tauh 2



#### muon

#### b jet







## BDT input variables mu-bjet 1



# BDT input variables mu-bjet 2



#### muon

terShape0	3		-2		7	3				2	3		-1	4	100		
terShape1	13	1			32	11		-4	-1	8	-28	-1	-9	100	4		8
terShape2	-4	2	5	-2	2	-2	-2		-1	-12	30	1	100	-9	-1		G
terShape3	-1			1							6	100	1	-1			0
terShape5	-10		1					1			100	6	30	-28	3	_	4
_for_lep.pt	12	-60	1	19	25	83	53	30	-7	100			-12	8	2		2
EInCone13	-1	-2	-1	60	-6	-10	-1	-3	100	-7			-1	-1			21
utralCone1	-3	-35	-1	19	-8	44	46	100	-3	30	1			-4		_	0
oneMass1		-50	-1	36	-1	62	100	46	-1	53			-2				
ep.cone1E	7	-71	3	21	30	100	62	44	-10	83			-2	11	3		-4
r_lep.pfoe	12	8	14	-1	100	30	-1	-8	-6	25			2	32	7	_	-4
oneMass3		-24		100	-1	21	36	19	60	19		1	-2				
lep.yokuE	-27	2	100		14	3	-1	-1	-1	1	1		5		-2		-0
isoCutOld	-1	100	2	-24	8	-71	-50	-35	-2	-60			2	1		-	-8
p.calEovE	100	-1	-27		12	7		-3	-1	12	-10	-1	-4	13	3		
	Pf																-1 [_/g

lf jet

Correlation Matrix (background)

#### Correlation Matrix (signal)

Linear correlation coefficients in % 100															100		
usterShape0	9		4		1	1		2		3	-11		-11	38	100		100
usterShape1	6	1	14		8	8	1	2		7	-19	-2	-21	100	38	_	80
usterShape2	-6	1	3		4	4					82	2	100	-21	-11		60
usterShape3			7								1	100	2	-2			00
usterShape5	-7		-3		4	4				-1	100	1	82	-19	-11	_	40
fo_for_lep.pt	-38	9	10	5	78	80	16	5	-1	100	-1			7	3		20
rkEInCone13	5	-23	-1	67	-6	-3	16	13	100	-1							20
leutralCone1	11	-46	-2	33	-1	13	57	100	13	5				2	2	_	0
o.coneMass1	2	-53		41	3	20	100	57	16	16				1			20
_lep.cone1E	-48	12	8	8	97	100	20	13	-3	80	4		4	8	1		-20
for_lep.pfoe	-52	30	8	2	100	97	3	-1	-6	78	4		4	8	1	_	-40
o.coneMass3	1	-24	-1	100	2	8	41	33	67	5							60
or_lep.yokuE	-2	2	100	-1	8	8		-2	-1	10	-3	7	3	14	4		-00
p.isoCutOld	-18	100	2	-24	30	12	-53	-46	-23	9			1	1		-	-80
_lep.calEovE	100	-18	-2	1	-52	-48	2	11	5	-38	-7		-6	6	9		100
	Pf															2.101	-100
		-•,	_ <sup>lep</sup>	cal	7180 750 0VE	Y P	lep con	pfo Ma	con			Thep Thay utra	Die Die Like	cius	-cius tere	cius ters	, lep.clu Cluster
							q	48	\$3		-42	st	one	ijc.	ne13	ape	lape 3 p

## BDT input variables mu-lfjet 1



### BDT input variables mu-lfjet 2



# BDT input variables mu-lfjet 3



#### **Correlation Matrix (signal)** Linear correlation coefficients in % 100 sterShape16 100 80 60 usterShape5 100 40 usterShape3 100 20 usterShape0 100 0 -20 100 E10vConeE2 -40 p.isoCutOld 100 -60 -80 100 ep.hadOvEM -100 Pfo\_for\_lep.clusterShape0 pto\_tor\_lep.clusterShape3 pfo\_for\_lep.hadOvEM pfo\_for\_lep.coneE10vConeE2 Pfo\_for\_lep.clusterShapes pfo\_for\_lep.isoCutOld pfo\_for\_lep.cluste

tau(e)



#### tau(m)

#### BDT input variables taue-taum 1



# BDT input variables taue-taum 2



#### tau(h)

#### tau(e)

#### Correlation Matrix (signal)

Linear correlation coefficients in %															100				
usterShape3	11	2	-3	-2			-2	-7		-3	-2	1	6			-6	100		100
_lep.cone1E	5	6	-14	3	33	19	65	89	18	9	13		-3	-2		100	-6		80
rkEInCone13		1	-18		15	66	-2	-3	15	-34		23			100				
usterShape5	-7	3	-2	6	1		-32	-3			11	2		100		-2		_	60
or_lep.pfoR0	-1		-5	3	8	2	-5	-6	1	-6		6	100			-3	6		40
neE2woSeed	-1	2	-87	-1	64	41	-4	-3	52	-46	4	100	6	2	23	35	1		40
usterShape0	11	8		3	7	6	-12	13	4		100	4		11		13	-2		20
E10vConeE2	2	-1	35		-21	-43	11	15	-25	100		-46	-6		-34	9	-3		
nTrkInCone1		3	-49	2	80	39	-2	-2	100	-25	4	52	1		15	18		_	0
for_lep.pfoe	7	6	20	4	6	8	74	100	-2	15	13	-3	-6	-3	-3	89	-7		
usterShape1	6	1	15	8	3	5	100	74	-2	11	-12	-4	-5	-32	-2	65	-2		-20
o.coneMass3	1	3	-28	1	44	100	5	8	39	-43	6	41	2		66	19			-40
o.coneMass1	1	3	-57		100	44	3	6	80	-21	7	64	8	1	15	33			-40
_lep.calEovE	1	4	-1	100		1	8	4	2		3	-1	3	6		3	-2		-60
p.isoCutOld			100	-1	-57	-28	15	20	-49	35		-87	-5	-2	-18	-14	-3		
ep.hadOvEM	2	100		4	3	3	1	6	3	-1	8	2		3	1	6	2		-80
sterShape16	100	2		1	1	1	6	7	Ì	2	11	-1	-1	-7		5	11		100
	Pf	o P/	0 <i>P/</i>	0 <i>P/</i>	o P/	0 <i>Rf</i>	o P/	o P/	o P/	o Rf	o Af	h Af	o Af	o Af	o Pf	, Pf	o Afo		-100
		~/0	16	0/ 10 P:C															lep isonsi
					-916	rsh	靜	668	Ew	ass	i se i ss	3 <sup>Sh</sup>	ipe1	Con	t del	č%		vos.	Shrkel
								•									~c.5	Ű.	ed .

#### Correlation Matrix (background)

Linear correlation coefficients in														n %	100				
usterShape3	-1	-1												1			100		100
_lep.cone1E	9	19	-64	10	52	19	22	53	32	30	1	76	-6		-4	100		_	80
rkEInCone13	-2	-3	-11	-1	5	64	-2	-6	7	-28		9	4		100	-4			
usterShape5	-2	-3		-2		1	-8	2						100			1	-	60
or_lep.pfoR0	-5	-4	-1	-4	16	5	-3	-7		-10			100		4	-6			40
neE2woSeed	-5	-7	-90		62	32	-1	-7	48	-4		100			9	76			40
usterShape0	-12	-8		5			1	2		-1	100					1			20
E10vConeE2	9	10	7	4	6	-25	8	23	-1	100	-1	-4	-10		-28	30			
nTrkInCone1	-5	-7	-43	1	59	29	-4	-11	100	-1		48			7	32		_	0
for_lep.pfoe	22	42	10	16	1	1	39	100	-11	23	2	-7	-7	2	-6	53			
usterShape1	5	9	2	12			100	39	-4	8	1	-1	-3	-8	-2	22			-20
.coneMass3	-2	-1	-30		37	100		1	29	-25		32	5	1	64	19			-40
o.coneMass1	-3	-3	-56		100	37		1	59	6		62	16		5	52			-40
lep.calEovE	16	26		100			12	16	1	4	5		-4	-2	-1	10			-60
p.isoCutOld	5	7	100		-56	-30	2	10	-43	7		-90	-1		-11	-64			
ep.hadOvEM	57	100	7	26	-3	-1	9	42	-7	10	-8	-7	-4	-3	-3	19	-1		-80
sterShape16	100	57	5	16	-3	-2	5	22	-5	9	-12	-5	-5	-2	-2	9	-1		400
	Pf	6 A/	6 <i>R</i> /	o Af	o Af	0 <i>R</i> /	o Pf	o Pf	o Pf	, Af	o Af	o Af	o Af	0 <i>R</i> /	o Pf	o Pf	o Afe		-100
		~_/0	16			6			1000										lep cl
					ste	rsh	影	68	EW	ass	i ste i ss	\$ha	' Kiñ I/De 1	Con	760 67	<i>Estis</i>	ES.	ster Vo.s	Shape
							/	0								-11	ees	-06	ed .

## BDT input variables taue-tauh 1



### BDT input variables taue-tauh 2



### BDT input variables taue-tauh 3



#### b jet

#### **Correlation Matrix (background)**



#### tau(e)

**Correlation Matrix (signal)** 

Linear correlation coefficients in %														
usterShape2			1	2	5			10	7			100		100
or_lep.pfoR0	-5		3	2	-6	1		-1	-5		100			80
rkEInCone13	-18	1		66	-3	15			-2	100				60
usterShape1	15	1	8	5	74	-2	-12	6	100	-2	-5	7	_	40
sterShape16		2	1	1	7		11	100	6		-1	10		20
usterShape0		8	3	6	13	4	100	11	-12					•
nTrkInCone1	-49	3	2	39	-2	100	4		-2	15	1			U
_for_lep.pfoe	20	6	4	8	100	-2	13	7	74	-3	-6	5		-20
o.coneMass3	-28	3	1	100	8	39	6	1	5	66	2	2		-40
_lep.calEovE	-1	4	100	1	4	2	3	1	8		3	1		-60
ep.hadOvEM		100	4	3	6	3	8	2	1	1				-80
p.isoCutOld	100		-1	-28	20	-49			15	-18	-5			100
	Pfo		pfo for	Pfo for	pfo for	, Pfc for	p for	pfo for	, Dfo	, Pfo		, Pfo	for	-100
			ep.isc	ep.ña Cuto		ep.co	neMa	99.11 00.11 883	ep čiu rkinC	ep.či Isters	ep.cl Isters han	iep.ma usters han	P.p. XTrk	for of the second
								2		-1	hel	<i>j 2e1</i>	6 26	,7 ℃0,

### BDT input variables taue-bjet 1



### BDT input variables taue-bjet 2



#### lf jet

#### **Correlation Matrix (background)**



#### tau(e)

**Correlation Matrix (signal)** 

Linear correlation coefficients in %															100
usterShape3	-3	2	-2	-7		11		6	-3	-2	-6		100		100
rkEInCone13	-18	1		-3	66		15		-34	-2		100			80
_lep.cone1E	-14	6	3	89	19	5	18	-3	9	65	100		-6	_	60
usterShape1	15	1	8	74	5	6	-2	-5	11	100	65	-2	-2		40
E1OvConeE2	35	-1		15	-43	2	-25	-6	100	11	9	-34	-3		40
or_lep.pfoR0	-5		3	-6	2	-1	1	100	-6	-5	-3		6		20
nTrkInCone1	-49	3	2	-2	39		100	1	-25	-2	18	15			0
sterShape16		2	1	7	1	100		-1	2	6	5		11		-20
o.coneMass3	-28	3	1	8	100	1	39	2	-43	5	19	66			
_for_lep.pfoe	20	6	4	100	8	7	-2	-6	15	74	89	-3	-7		-40
_lep.calEovE	-1	4	100	4	1	1	2	3		8	3		-2	_	-60
ep.hadOvEM		100	4	6	3	2	3		-1	1	6	1	2		-80
p.isoCutOld	100		-1	20	-28		-49	-5	35	15	-14	-18	-3		400
	Pfc			pfo	pfc	pto	pfo		pfo	pto	pfo		pfo	for	-100
			lep.is	ep.h oCut	lep'c adov Ola	lep p ale p EM	lep.c.	lep.c	lep.n uster	lep p Trkin	lep c for o	lep.c. oneE	lep.co	lep. ne1	lep.clu nax Trki
					-10		-			-nap	e16	1	~vca	Dne	191

### BDT input variables taue-Ifjet 1



## BDT input variables taue-lfjet 2



# BDT input variables taue-lfjet 3



#### tau(h)



#### tau(m)



#### Correlation Matrix (signal)

## BDT input variables taum-tauh 1



## BDT input variables taum-tauh 2



tau(m)



#### Correlation Matrix (background) Linear correlation coefficients in % 100 usterShape2 100 80 60 lep.calEovE 100 40 20 o.coneMass3 100 0 r\_lep.yokuE 100 -20 -40 ep.hadOvEM 100 -60 -80 p.isoCutOld 100 -100 Pfo\_for\_lep.coneMass3 pfo\_for\_lep.calEovE pfo\_for\_lep.isoCutOld Pfo\_for\_lep.hadOvEM pfo\_for\_lep.yokuE Pfo\_for\_lep.cluste

b jet

#### BDT input variables taum-bjet 1



# **Correlation plots**

#### tau(m)



#### Correlation Matrix (background)



lf jet

#### BDT input variables taum-lfjet 1



## BDT input variables taum-lfjet 2


### tau(1-prong)

62

-42

-4 -4

5

-4

-4

-11 100

100

13 22

33 -18

100

13

100

usterShape3

neE2woSeed

p.isoCutOld

>r\_lep.yokuE

ep.hadOvEM

rkEInCone13

leutralCone1

o.coneMass1

leutralCone1

or\_lep.pfoR0

E10vConeE2

o.coneMass3

lep.cone1E

-55

8

### **Correlation Matrix (signal)** Linear correlation coefficients in % 100 Linear correlation coefficients in % 100 usterShape3 100 -1 100 80 80 95 -90 100 neE2woSeed 33 -56 -89 100 -5 -40 -83 100 -90 60 p.isoCutOld 49 -23 43 -43 -55 -24 -3 100 -89 60 6 100 r\_lep.yokuE 100 40 40 -3 100 1 100 ep.hadOvEM 21 9 20 20 -3 100 6 rkEInCone13 56 -30 1 100 1 -24 0 -55 65 60 100 -83 95 leutralCone1 79 100 0 90 74 71 100 o.coneMass1 79 100 79 9 -43 -20 -20 -42 100 71 leutralCone1 71 24 100 -43 -4 74 9 -40 -40 -4 or\_lep.pfoR0 2 100 -60 E1OvConeE2 -60 22 -23 100 36 -56 coneMass3 100 2 -23 -80 -80 -55 lep.cone1E 100 90 21 -49 75 79 -3 -100 -100 p.maxtrauovew eutralCone1 utraiCone1 eutralCone1 traiCone1

### **Correlation Matrix (background)**

b jet

### BDT input variables tauh1-bjet 1



### BDT input variables tauh1-bjet 2



# BDT input variables tauh1-bjet 3



### tau(1-prong)



### lf jet



### BDT input variables tauh1-lfjet 1



### BDT input variables tauh1-2



### tau(3-prong)

### **Correlation Matrix (background)** Linear correlation coefficients in % 100 usterShape3 100 61 neE2woSeed 18 70 3 -94 2 100 80 -8 -34 1 1 13 -2 lep.calEovE 1 -1 100 2 60 -3 43 10 -14 64 15 -55 100 88 fo\_for\_lep.pt 61 usterShape2 100 1 40 12 -53 -17 -63 2 -12 -58 -55 -2 -94 100 p.isoCutOld 20 17 -1 35 -2 -3 15 13 3 5 100 usterShape1 9 12 76 -1 13 -12 100 5 -58 64 leutralCone1 4 1 61 34 67 1 0 50 - 17 -10 -3 100 -12 -3 -12 rkEInCone13 -14 1 11 34 - 13 7 -4 11 -2 30 100 -3 10 - 34 - 1 or\_lep.yokuE -2 2 -20 43 -8 7 for\_lep.pfoe -4 48 -1 100 30 -10 13 35 28 36 -40 or\_lep.pfoR0 -1 15 3 -1 100 -1 -1 -1 -3 lep.cone1E 11 -17 76 17 -63 88 -1 70 81 100 -1 48 1 -60 coneMass3 8 100 3 -4 -4 1 18 67 12 -53 -80 71 -1 59 o.coneMass1 37 100 8 81 15 36 7 -13 1 E10vConeE2 100 37 9 12 -2 -16 -100 Pfo Pro for Helenciu Helenciu Heleveon

oneE2

b jet

### Correlation Matrix (signal)

Linear correlation coefficients in %														100				
usterShape3				-1						-1	1				-1	100		100
neE2woSeed	-8	32	18	80	4			6	49	2	-95	-1	67		100	-1		80
_lep.calEovE	4	-1		8	-1	13	-13	-1	-4	11		-1	11	100				
fo_for_lep.pt	21	21	3	84	-4	42	5	-4	27	16	-61	-5	100	11	67			60
usterShape2							1		-1	-2	1	100	-5	-1	-1			40
p.isoCutOld	13	-32	-19	-72	-5	5		-8	-49		100	1	-61		-95	1		70
usterShape1	5	1	-1	20	-2	34	2	-3	-4	100		-2	16	11	2	-1	-	20
leutralCone1	-1	39	18	37	4	-6	-2	3	100	-4	-49	-1	27	-4	49			
rkEInCone13	-34	6	68	-7	4	-4	-1	100	3	-3	-8		-4	-1	6			U
or_lep.yokuE	1			6		12	100	-1	-2	2		1	5	-13			_	-20
for_lep.pfoe	14	9	2	50	-4	100	12	-4	-6	34	5		42	13				
or_lep.pfoR0	-10	32	8		100	-4		4	4	-2	-5		-4	-1	4		_	-40
_lep.cone1E	24	29	5	100		50	6	-7	37	20	-72		84	8	80	-1		-60
.coneMass3	-40	29	100	5	8	2		68	18	-1	-19		3		18			-00
o.coneMass1	-6	100	29	29	32	9		6	39	1	-32		21	-1	32		-	-80
E10vConeE2	100	-6	-40	24	-10	14	1	-34	-1	5	13		21	4	-8			400
	Pf	. Rfi	. Rf	h Rf	h Rt	. Rf	. Rf	h Af	h Rt	. Rf	. Rf	. Rf	. Rf	. Rf	. Rf	. Rf		-100
		10	~ <i>l</i> @															lepci,
				0,	'eE'j	8%	len Ss f	iss3	erro00	e o	UE <sup>a</sup>	×Trk	Elit	Ver	SHE	Sigr	Shap	es es
							e''e	52						one	13	~/		~<

hape2

### BDT input variables tauh3-bjet 1



### BDT input variables tauh3-bjet 2



### BDT input variables tauh3-bjet 3



### tau(3-prong)

### Correlation Matrix (background) Linear correlation coefficients in % Linear correlation coefficients in % 100 100 100 usterShape3 100 80 80 60 60 100 or\_lep.pfoR0 100 40 40 100 for lep.pfoe 100 20 20 100 0 lep.cone1E 100 0 -20 -20 100 o.coneMass1 100 70 -40 -40 E10vConeE2 100 -60 -60 -80 -80 .coneMass3 100 -100 -100 pfo\_for\_lep.coneE10vConeE2 pfo\_for\_lep.coneE10vConeE2 pfo\_for\_lep.coneMass3 Pfo\_for\_lep.coneMass1 pfo\_for\_lep.coneMass3 Pfo\_for\_lep.coneMass1 pto\_for\_lep.cone1E pfo\_for\_lep.pfoe Pfo\_for\_lep.pfoR0 pfo\_for\_lep.cluste pto\_for\_lep.cone1E pfo\_for\_lep.pfoe pfo\_for\_lep.pfoR0 pfo\_for\_lep.cluste

lf jet

### **Correlation Matrix (signal)**

100

100

usterShape3

or\_lep.pfoR0

for lep.pfoe

lep.cone1E

o.coneMass1

E10vConeE2

o.coneMass3

### BDT input variables tauh3-lfjet 1



# BDT input variables tauh3-lfjet 2

