

**$e^+e^- \rightarrow HA \rightarrow bbbb$  at 1 TeV ILC**

**Abhinav Dubey**  
**Tohoku University**

- Aim is cross-section and mass measurement for the process  $e^+e^- \rightarrow HA \rightarrow b\bar{b}b\bar{b}$  at  $\sqrt{s} = 1$  TeV.
- Integrated luminosity of  $1000 \text{ fb}^{-1}$  is assumed.
- Generated sample of  $HA \rightarrow b\bar{b}b\bar{b}$  signal using Whizard, Pythia used for decay, with following specifications:

same mass for both particles, 400 GeV

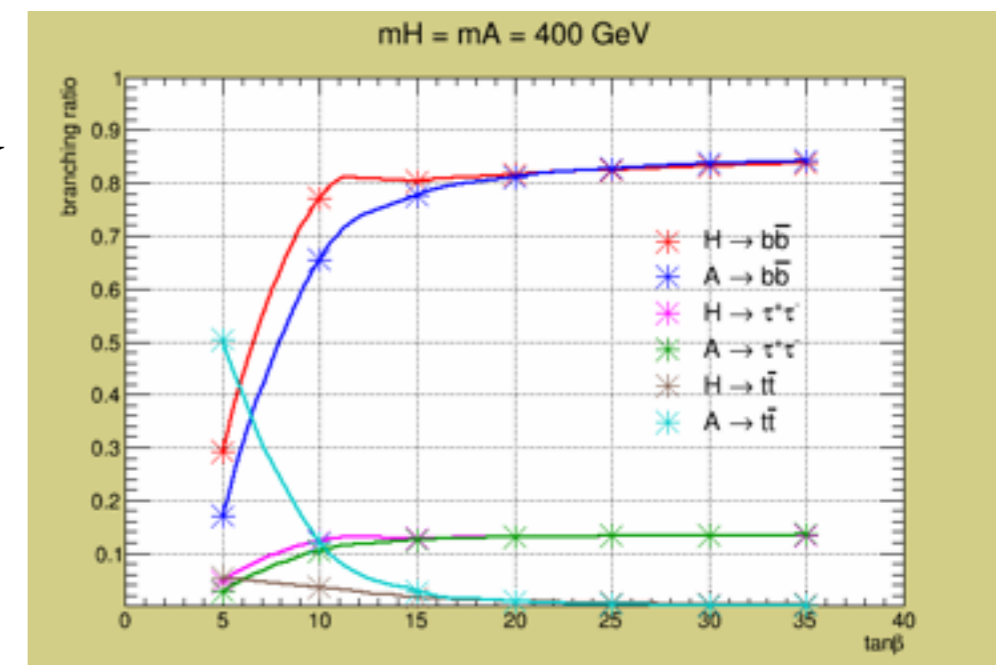
$\tan\beta = 10$

x-section:  $\sqrt{s} = 1$  TeV 2.38 fb

prominent decay into  $b\bar{b}(\text{bar})$

Branching fraction for  $H \rightarrow b\bar{b}$  77%

$A \rightarrow b\bar{b}$  65%



- $HA$  production is usually independent of  $\tan\beta$  but branching fraction depends on the  $\tan\beta$ .

## 4 jet events are selected using mass reconstruction.

- Reconstruction using ChiSquare minimization

- same mass is assumed for both particles

$$\chi^2 = \sum \frac{(M_{ij} - M_{kl})^2}{\sigma_H^2}$$

- three set of jet pairs possible

- set of jet pairs with minimum ChiSquare are selected

- Sigma from truth matching reconstruction fit is used.

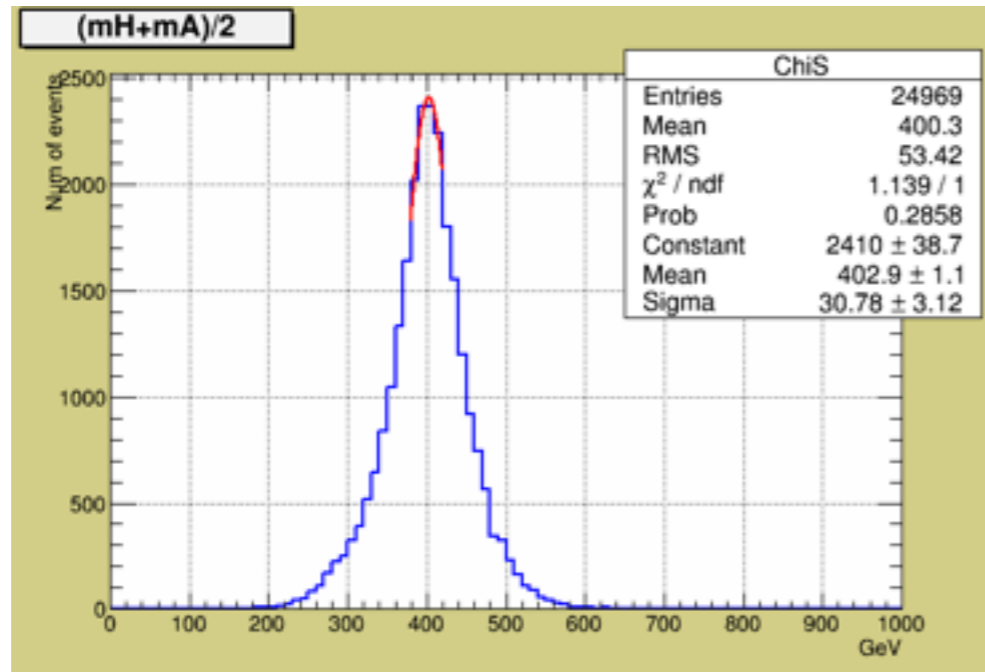
- Reconstruction using truth-matching

- associate the reconstructed jets to generated b-quarks from

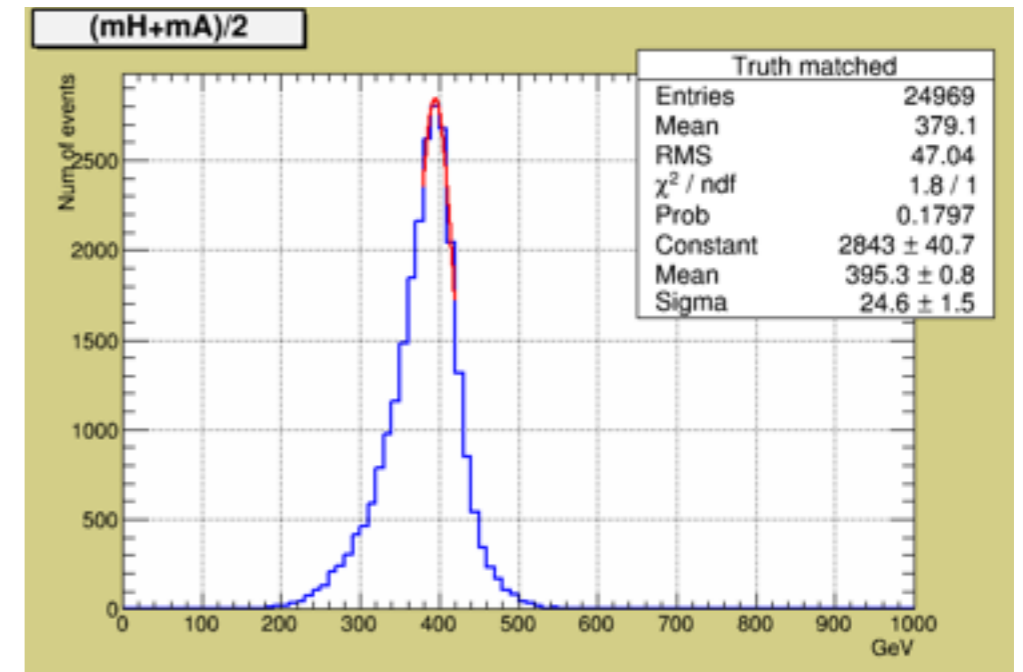
- H/A decays using minimum  $\Delta R$  between the jet and parton.

- in case of duplication, next minimum  $\Delta R$  is selected.

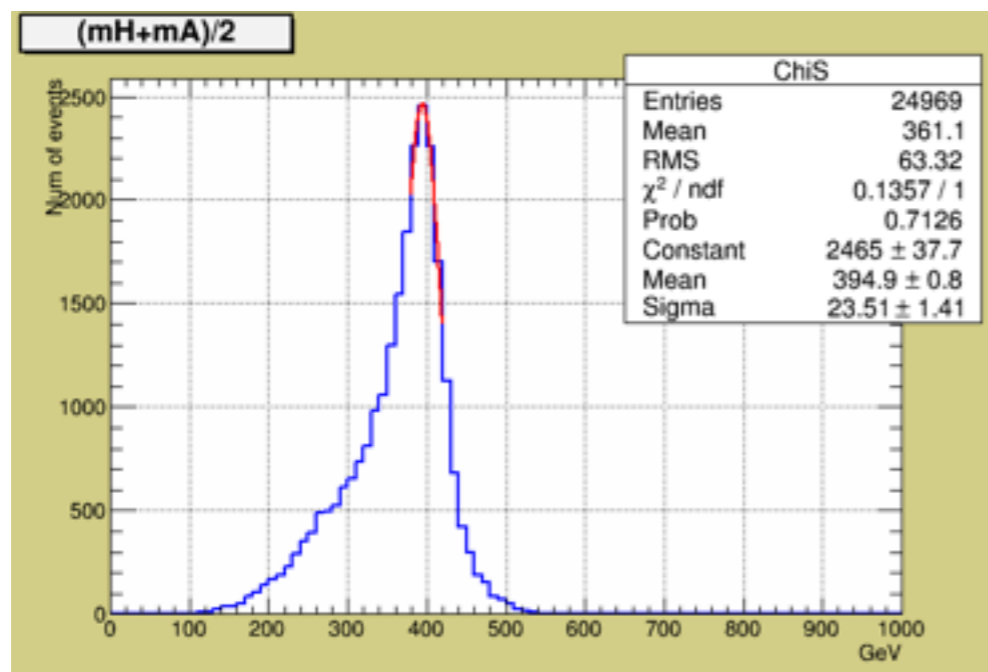
## Truth match jets : Durham



## kT algorithm with R=1.5



## ChiSquare selected jets : kT



kT algorithm removes some of beam backgrounds resulting in Better resolution.

Chi square selected kT jets used for analysis.

Main backgrounds giving same final states are bosons related:

Z hadronic

ZZ hadronic

WW hadronic

ZZWWMix hadronic

top pair related

ttbb : all decay states

tth : consists of decay states

tth-2l2nbb-hbb, tth-2l2nbb-hnonbb

tth-ln4q-hbb, tth-ln4q-hnonbb

tth-6q-hbb, tth-ln4q-hnonbb

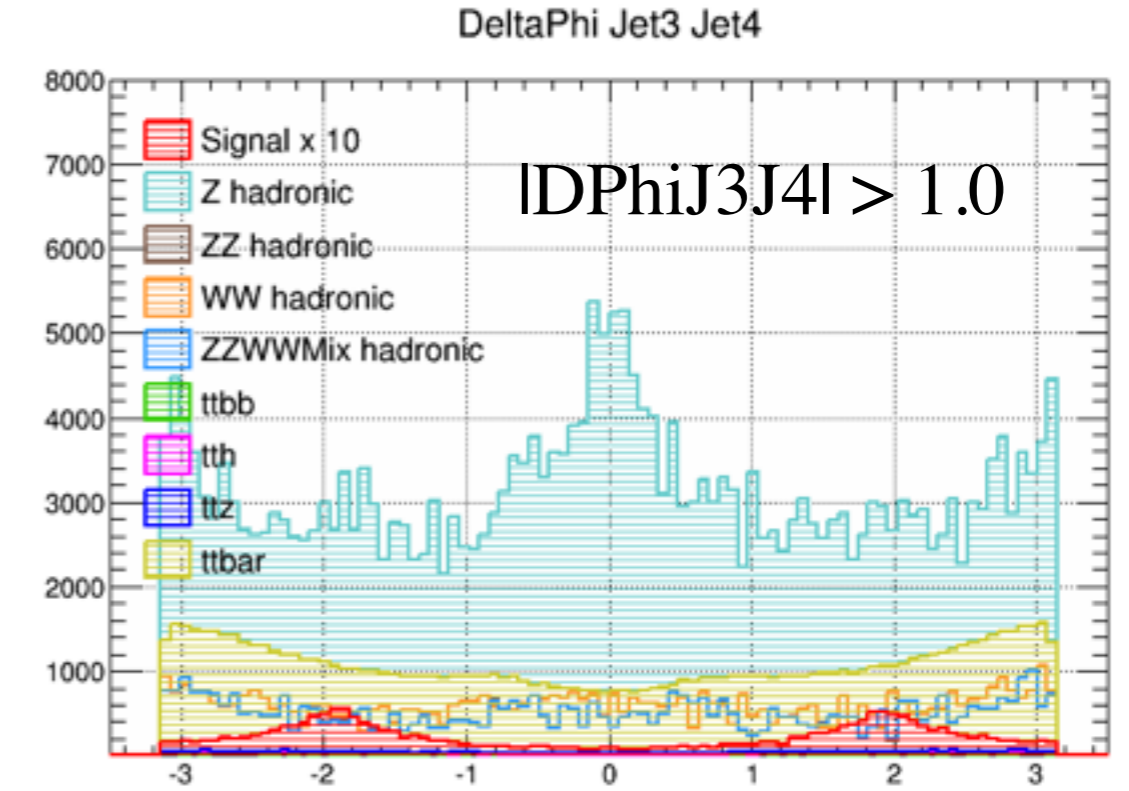
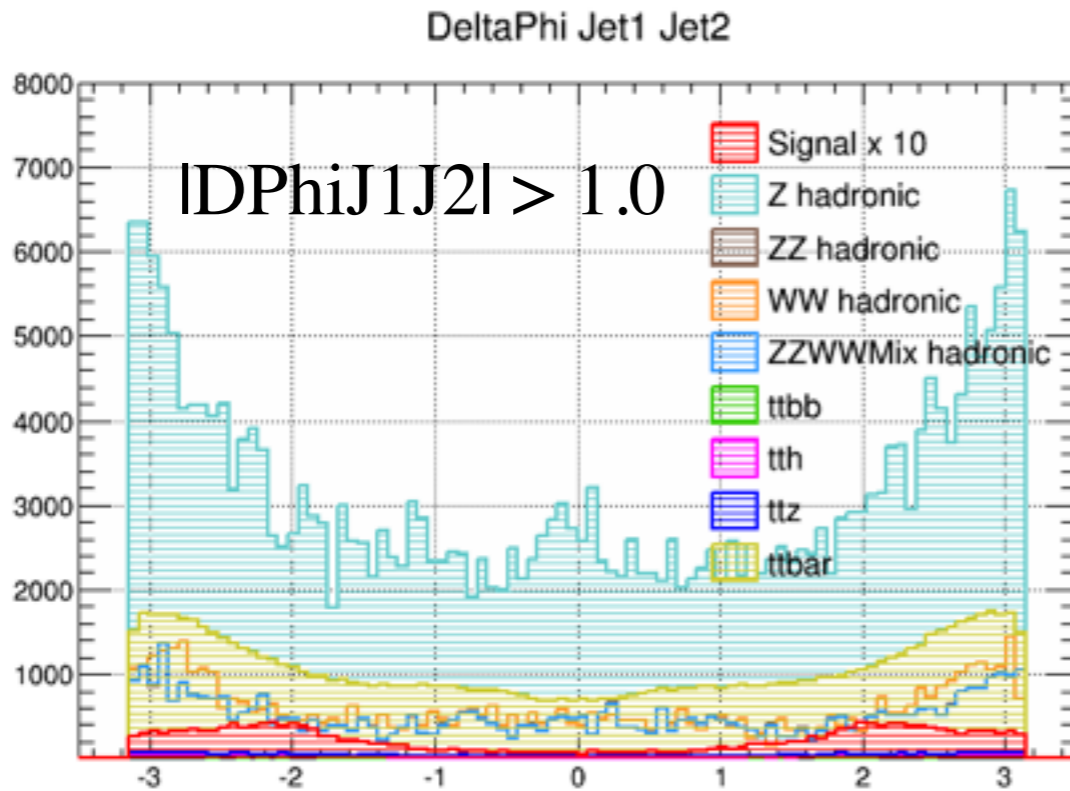
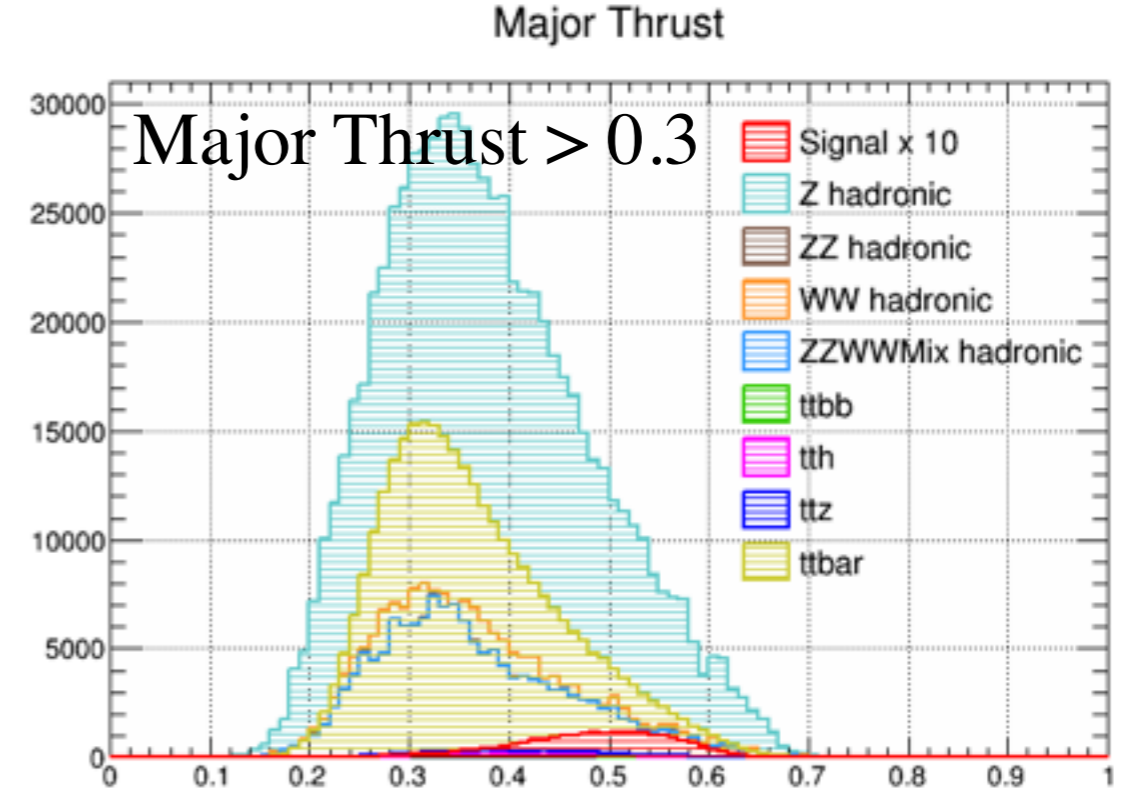
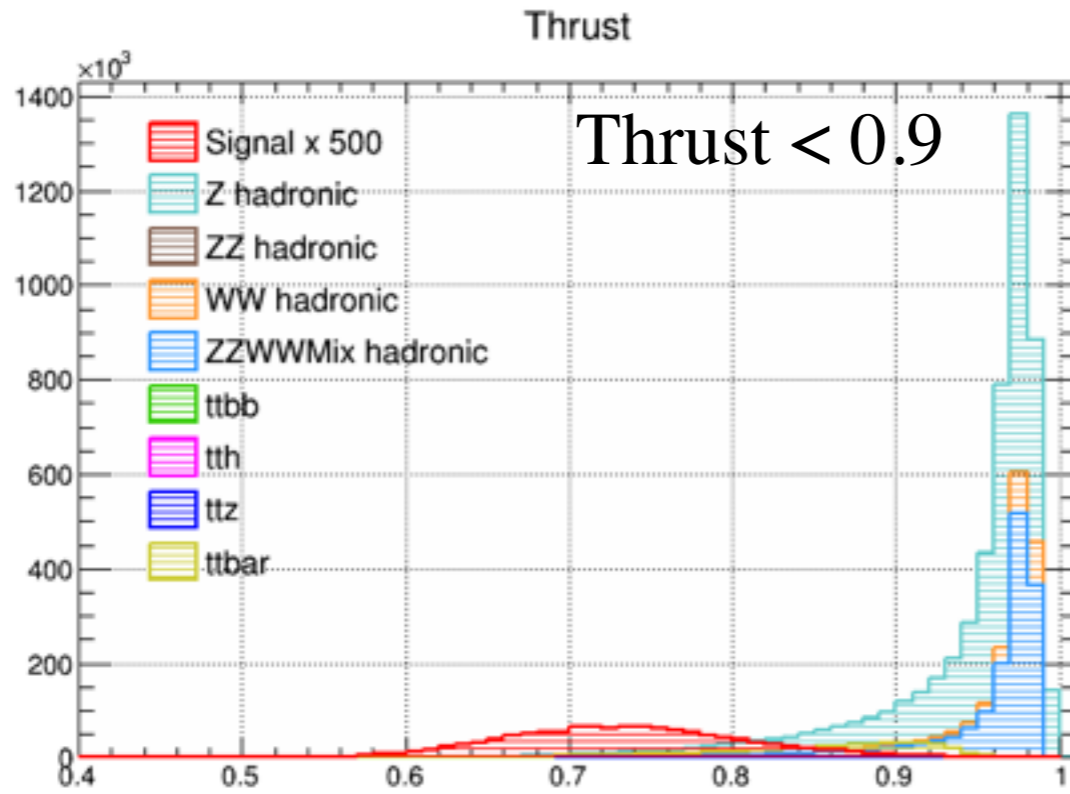
ttz : all decay states.

ttbar : ttbar decaying to 6 fermions.

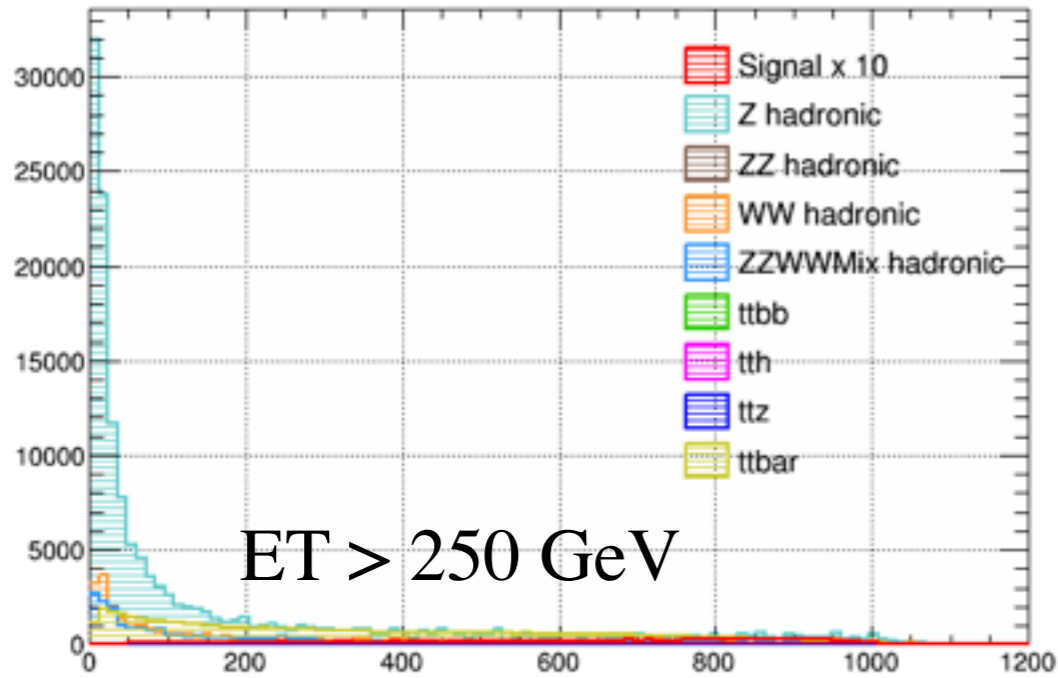
Cross-sections at (-0.8, +0.2) polarity

Cross-sections (fb)	eL.pR	eR.pL
Signal	2.27833	0.108
Z had	5062.662	208.134
ZZ had	162.806	4.61696
WW had	1811.6784	0.3517804
ZZWWMix had	1509.4836	1.1612
ttbb	3.184	0.106
tth	3.184	0.106
ttz	3.81691	0.174685
ttbar	436.489	1.17792

All samples generated using Whizard and Pythia.



EVis Transverse

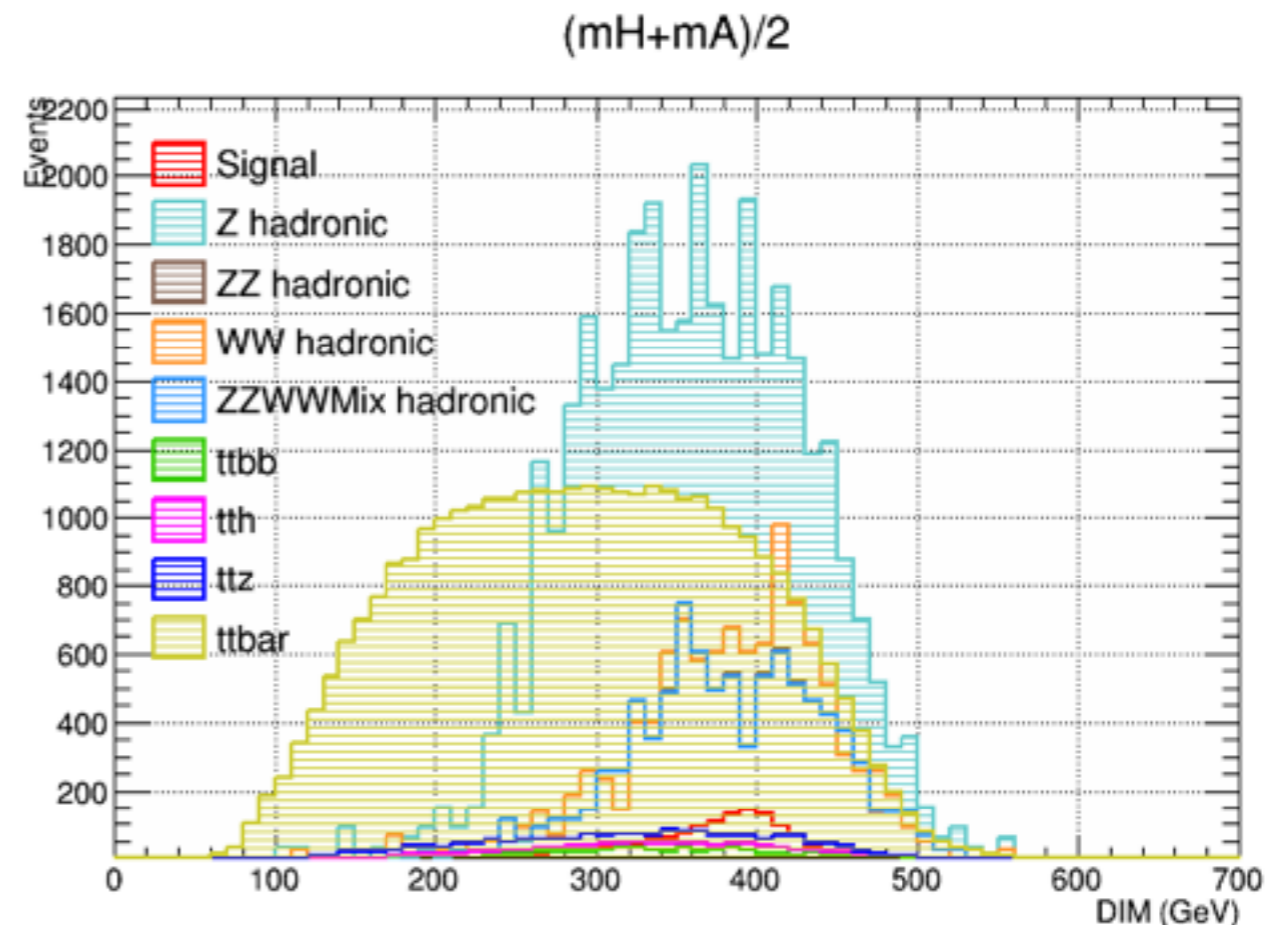


## Preliminary Cuts:

- Cut 1 : Principal Thrust < 0.9
- Cut 2 : Major Thrust > 0.3
- Cut 3 : DPhi jet pairs > 1.0
- Cut 4 : Transverse EVis > 250

After applying cuts still lots of background left.

So we will use TMVA analysis for further separation of signal from backgrounds.



Sample	Signal	Z hadronic	ZZ hadronic	WW hadronic	ZZWW hadronic	ttbb	tth	ttz	ttbar	S/ $\sqrt{S+B}$
Cuts										
Total	2386.33	5270800	167423	1812030	1510650	3290.41	3290.38	7745.81	437667	
Cut1	2350.28	745221	29138.9	171006	145472	3104.42	3273.35	7601.03	308032	
Eff %	98.49	14.14	17.40	9.44	9.63	94.35	99.48	98.13	70.38	1.98
Cut 2	1993.37	283567	10291.5	54032	46166.2	1260.97	1885.97	3902.8	96106.5	
Eff %	83.53	5.38	6.15	2.98	3.06	38.32	57.32	50.39	21.96	2.82
Cut 3	1528.52	145172	5739.32	29381.9	25159.9	802.79	1267.29	2526.36	57637.7	
Eff %	78.69	2.75	3.43	1.62	1.66	24.40	38.52	32.62	13.17	2.95
Cut 4	1308.1	34183.2	2116.57	10692.3	9051.87	592.79	928.84	1802.94	33083.1	
Eff %	54.82	0.65	1.26	0.59	0.60	18.02	28.23	23.28	7.56	4.27

After applying these cuts :

Signal events : 1308

Background events : 92452

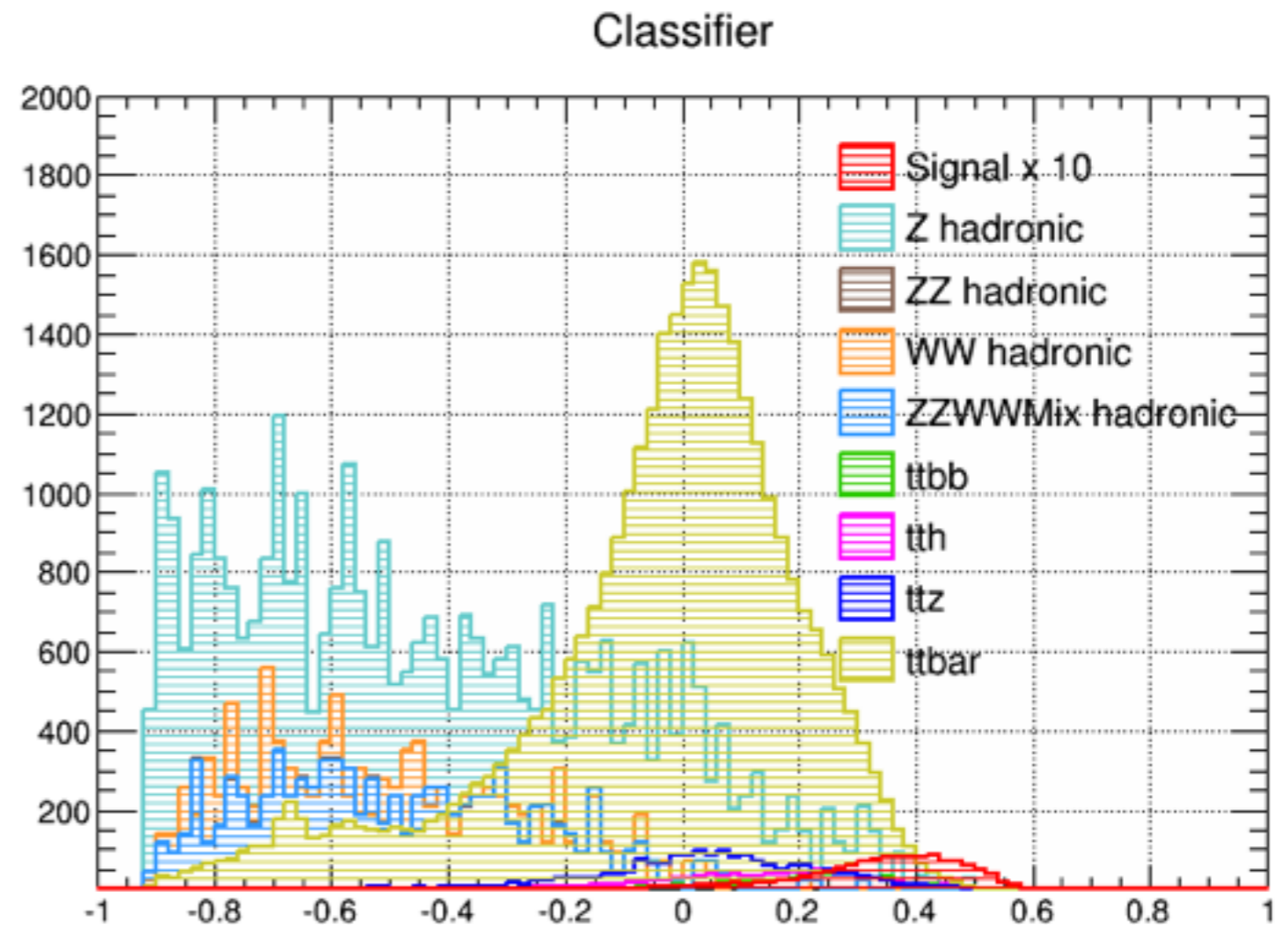
$S/\sqrt{S+B} = 4.27$



Variables used for BDT training:

- BTag value for jets
- Y45, Y56, Y67, Y78  
(distance for rejecting next jet cluster)

After applying all the cuts half of rest of events were used for training and other half for testing.

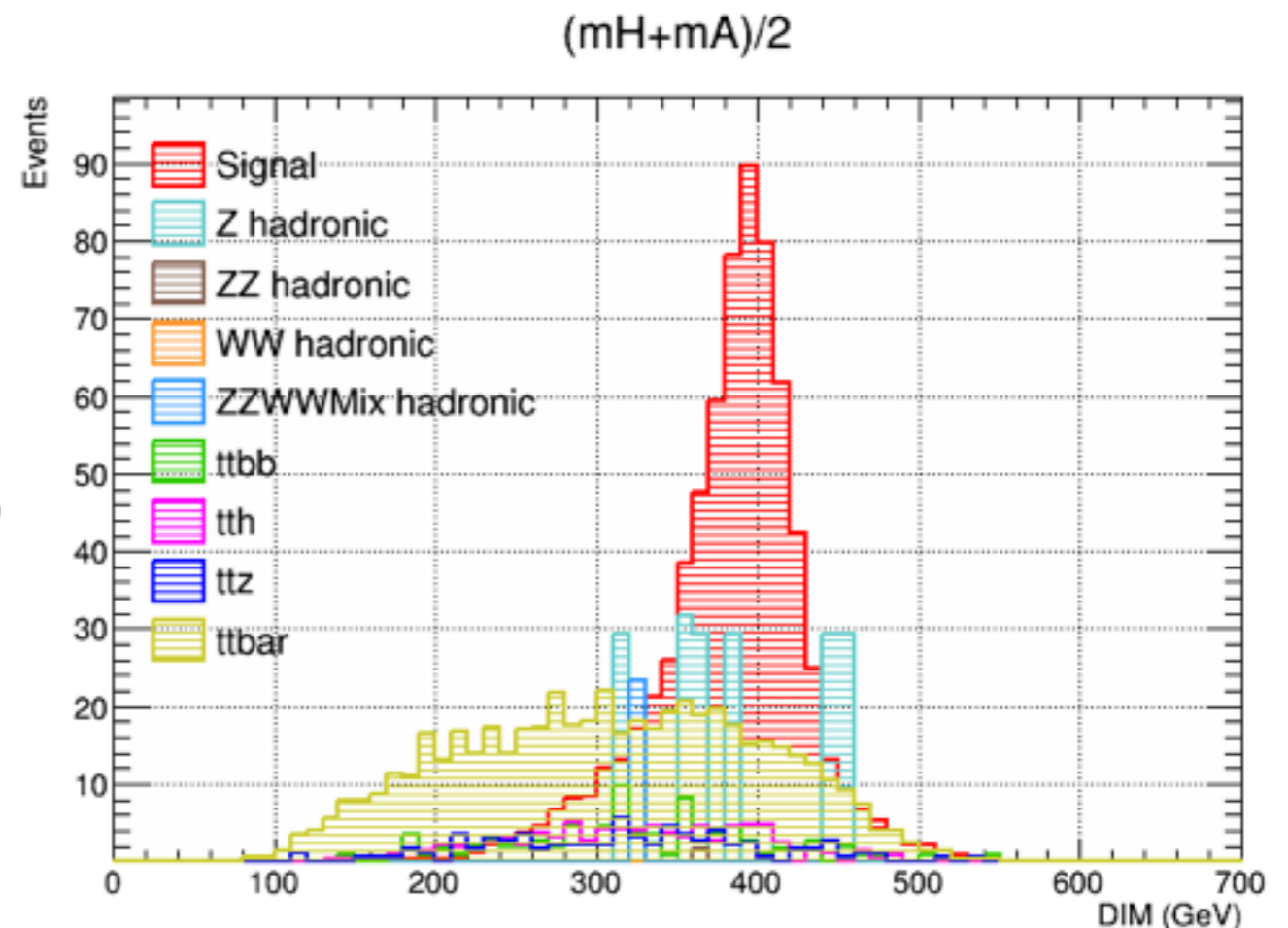


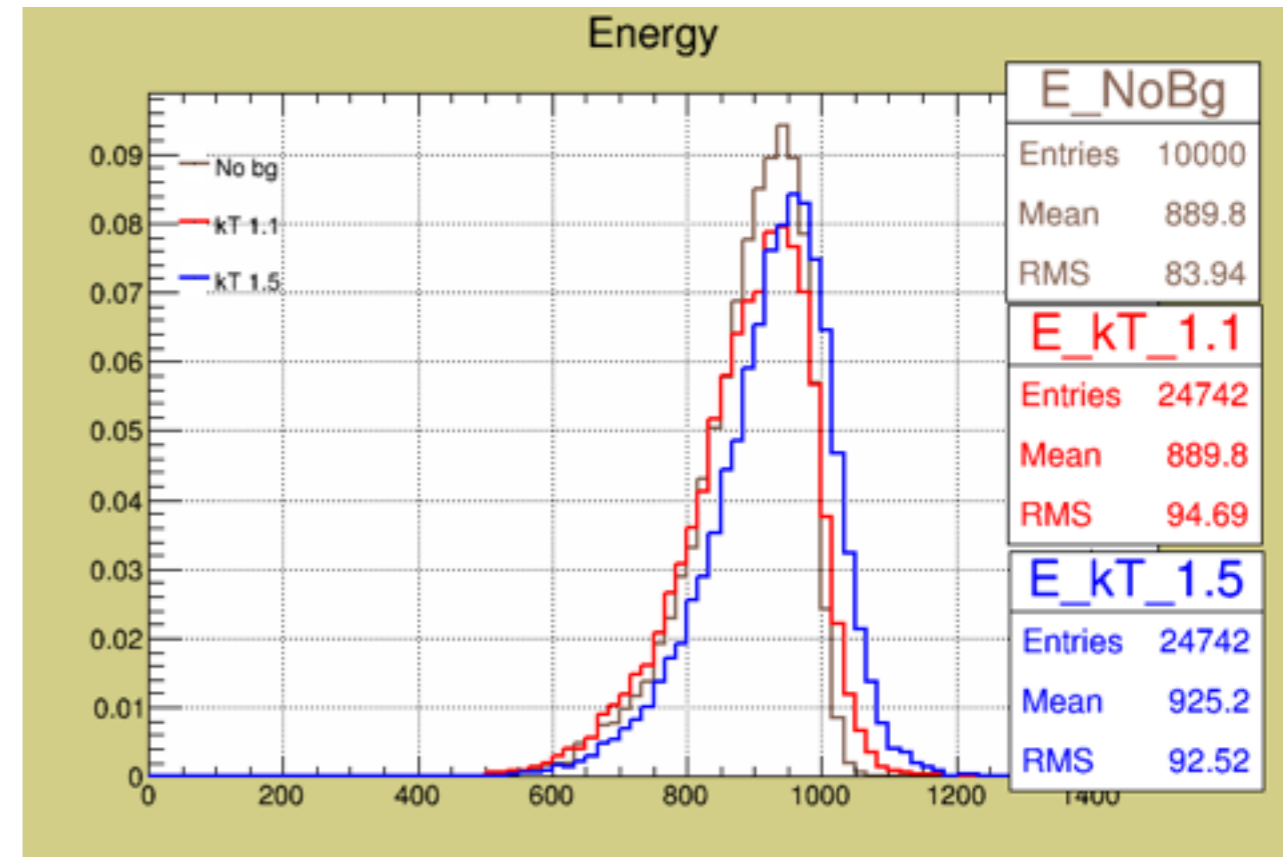
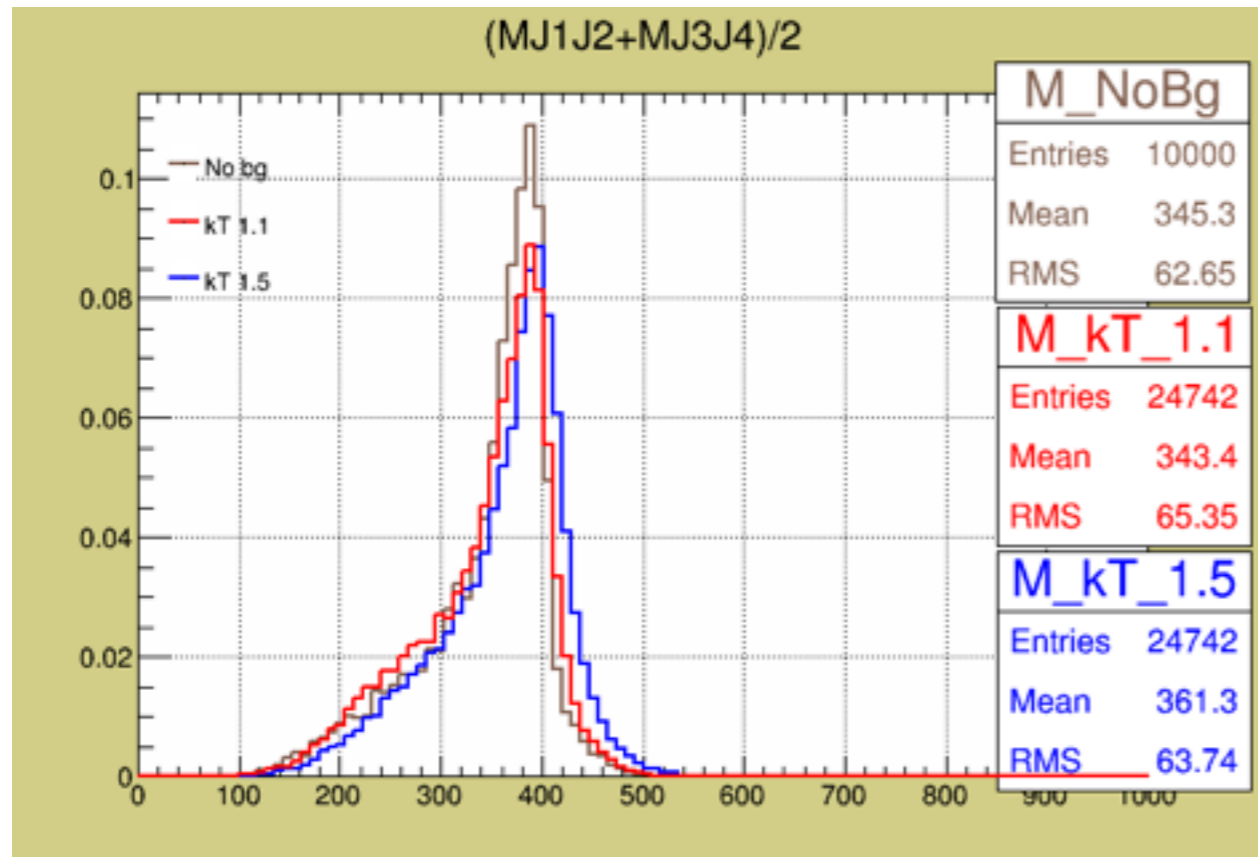
Classifier output is shown where we can see background events are peaking in -ve side and signal events are peaking in +ve side.

Sample	Signal	Z hadronic	ZZ hadronic	WW hadronic	ZZWW hadronic	ttbb	tth	ttz	ttbar	S/ $\sqrt{S+B}$
Cuts										
Total	2386.33	5270800	167423	1812030	1510650	3290.41	3290.38	7745.81	437667	
All Cuts	2350.28	745221	29138.9	171006	145472	3104.42	3273.35	7601.03	308032	
Eff %	54.82	0.65	1.26	0.59	0.60	18.02	28.23	23.28	7.56	4.30
BDT	697.21	183.19	48.28	0	23.28	87.17	87.24	71.63	529.56	
Eff %	29.16	0.003	0.03	0	0.001	2.64	2.65	0.92	0.12	21.68

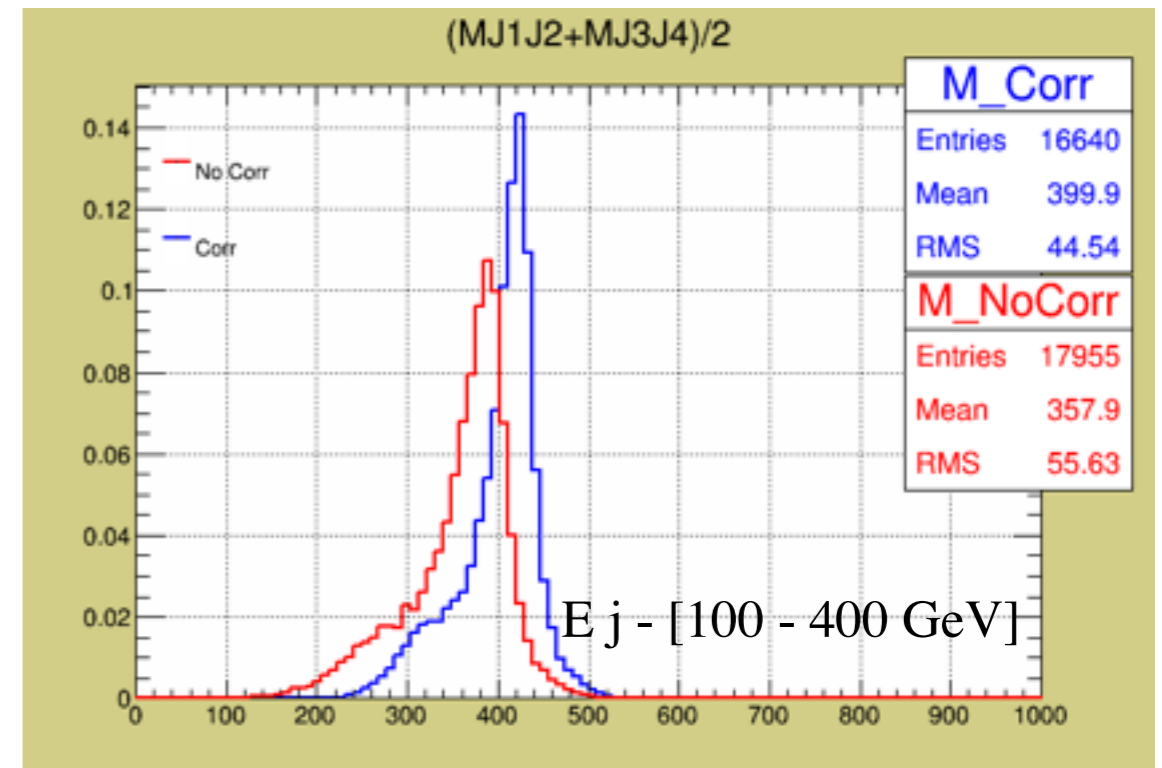
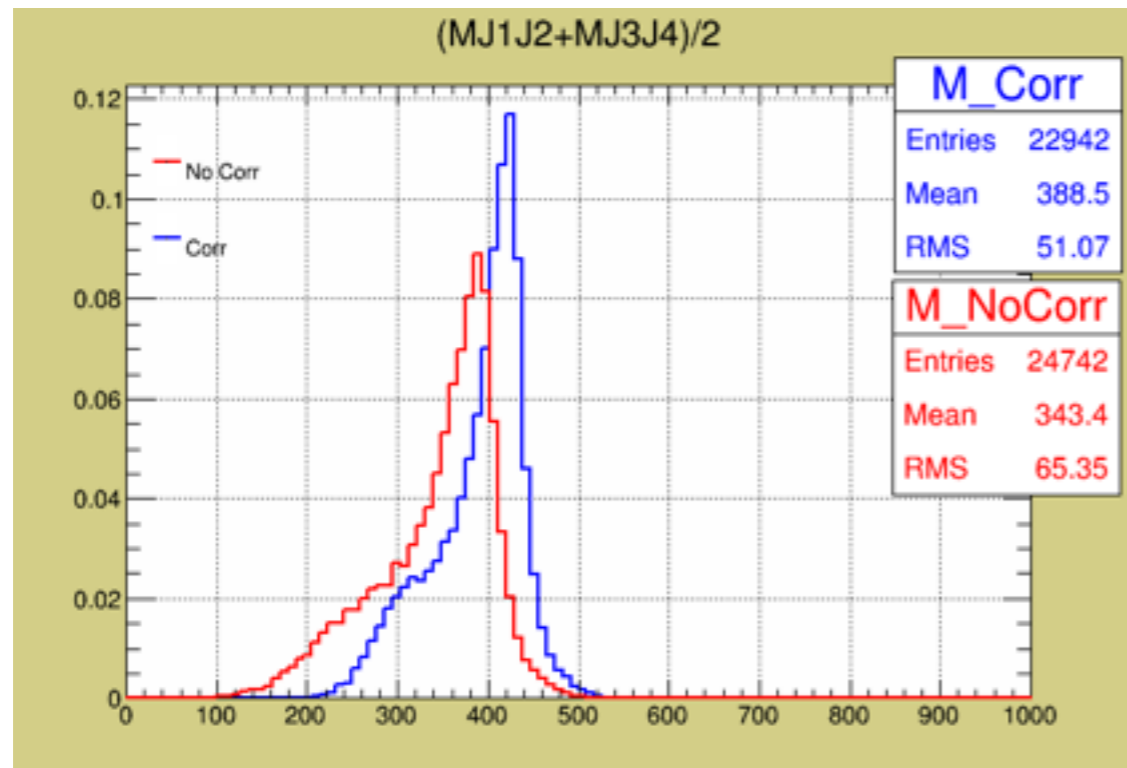
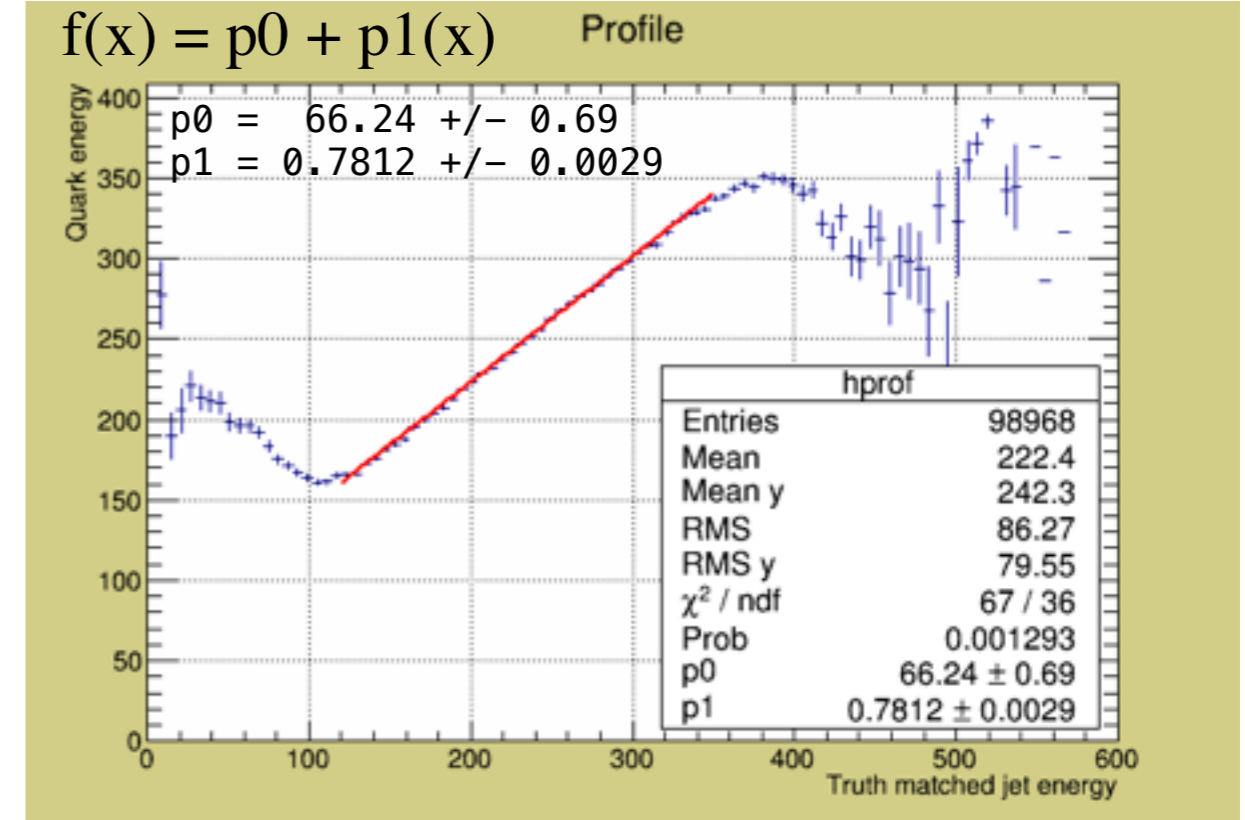
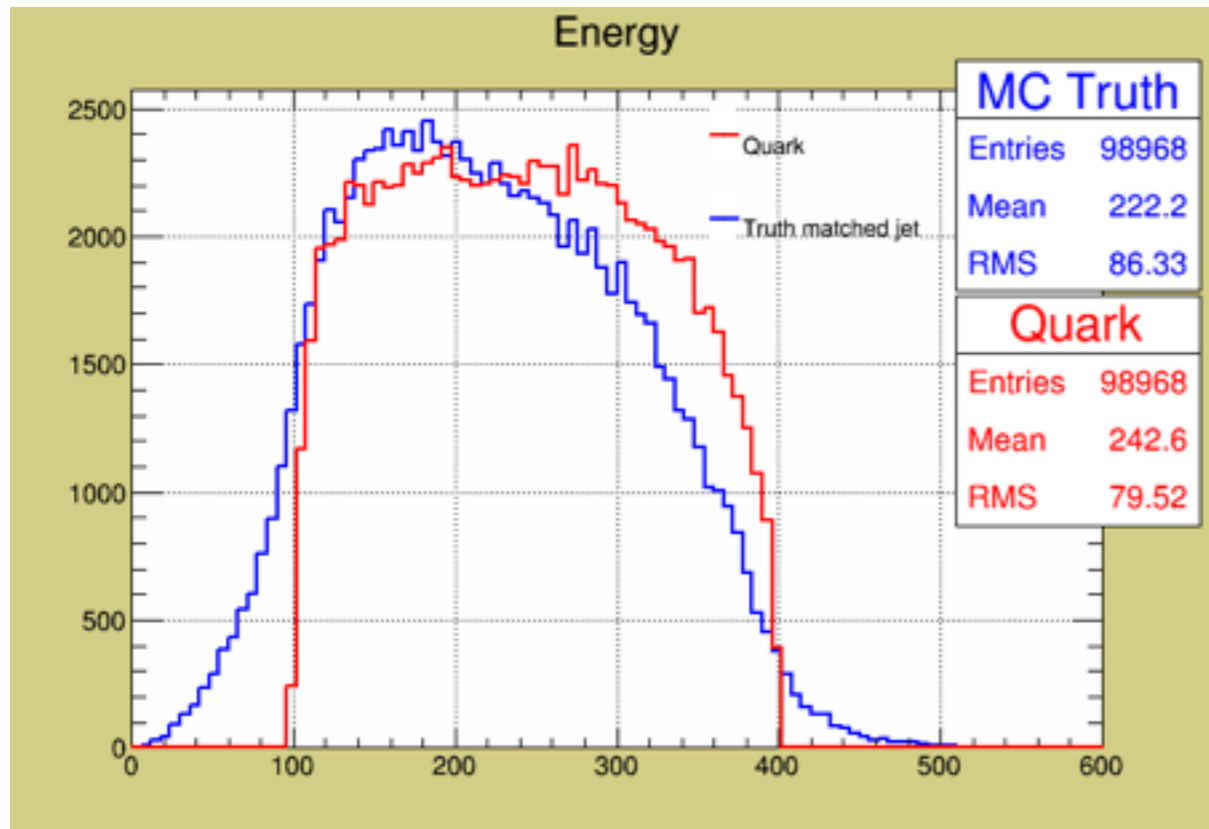
Applying a cut of 0.35 on BDT :  
 Signal events : 697  
 Background events : 1030  
 $S/\sqrt{S+B} = 16.77$

Clear separation of Signal.



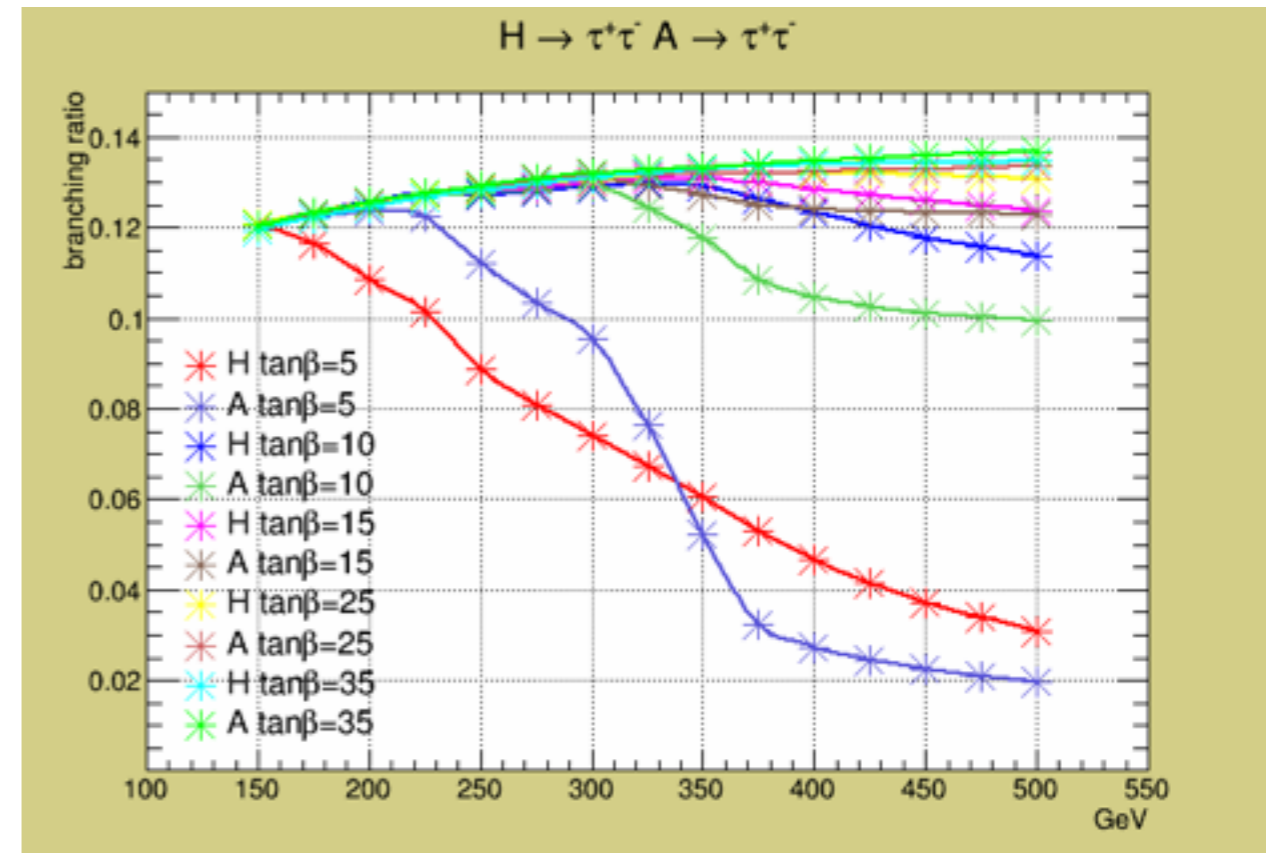
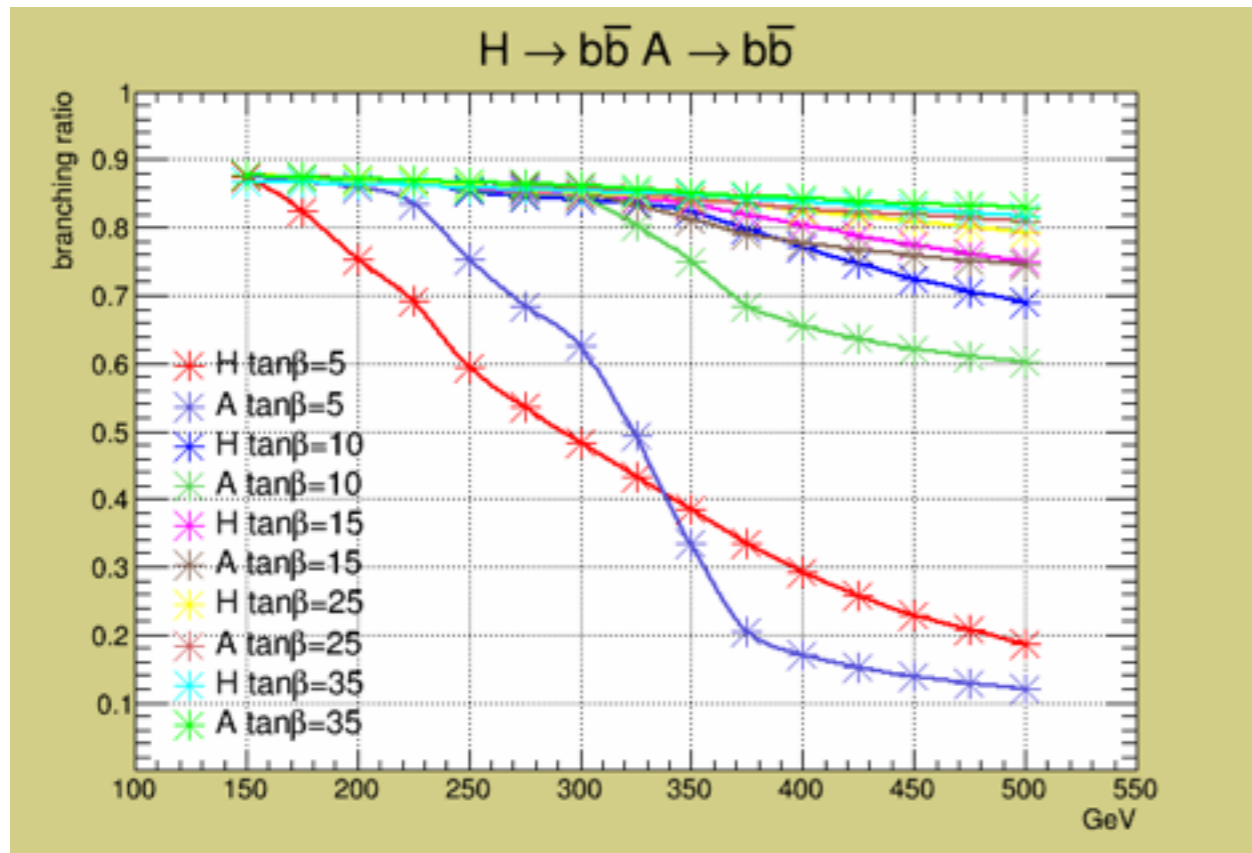


R=1.1 gives better matching, so will use this value.



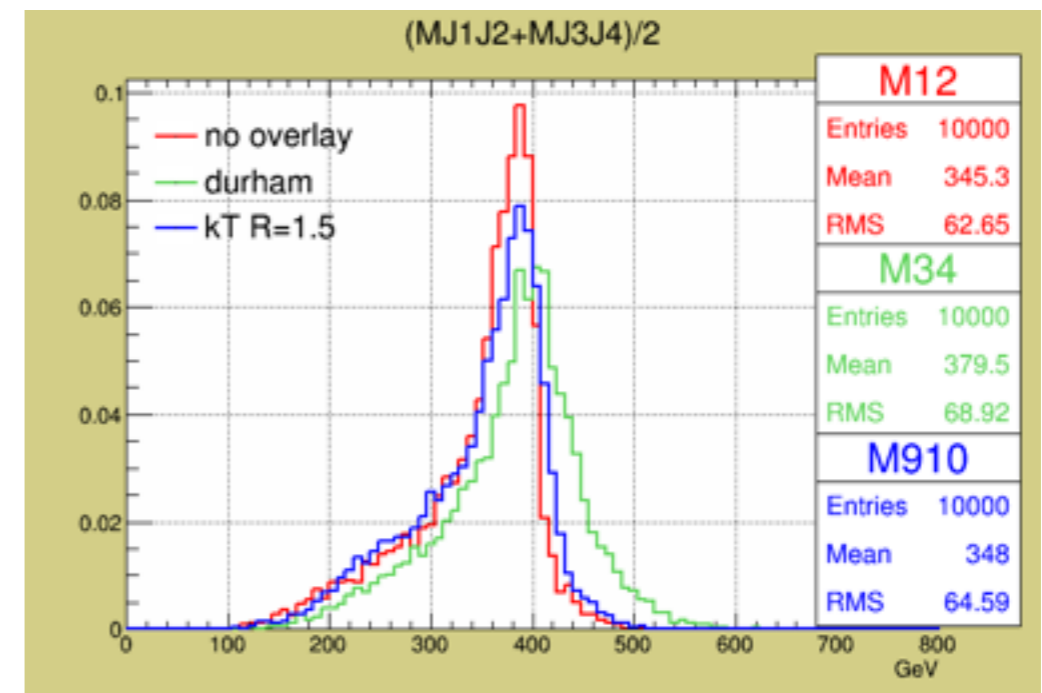
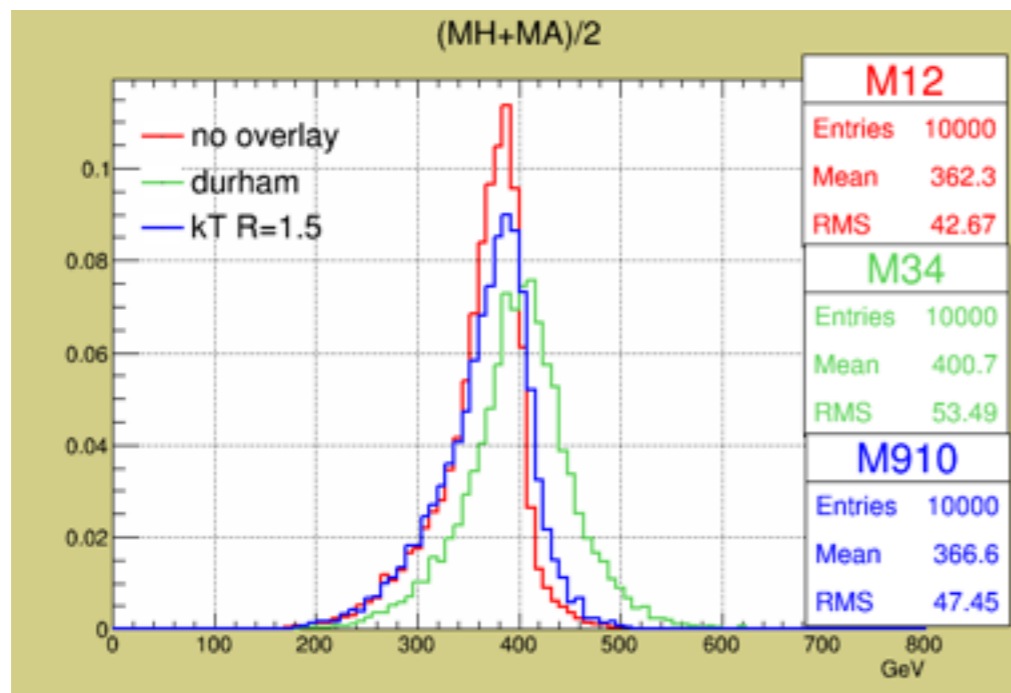
- Have to completely understand beam background, so that proper b-jet energy corrections can be applied.
- Trying to find some way to tag leptons inside jets, no success yet.
- Will complete mass and cross-section measurements at  $\tan\beta$  and also evaluate systematics.
- Next plan is to set a limit independent of mass and  $\tan\beta$ .

# BACKUP

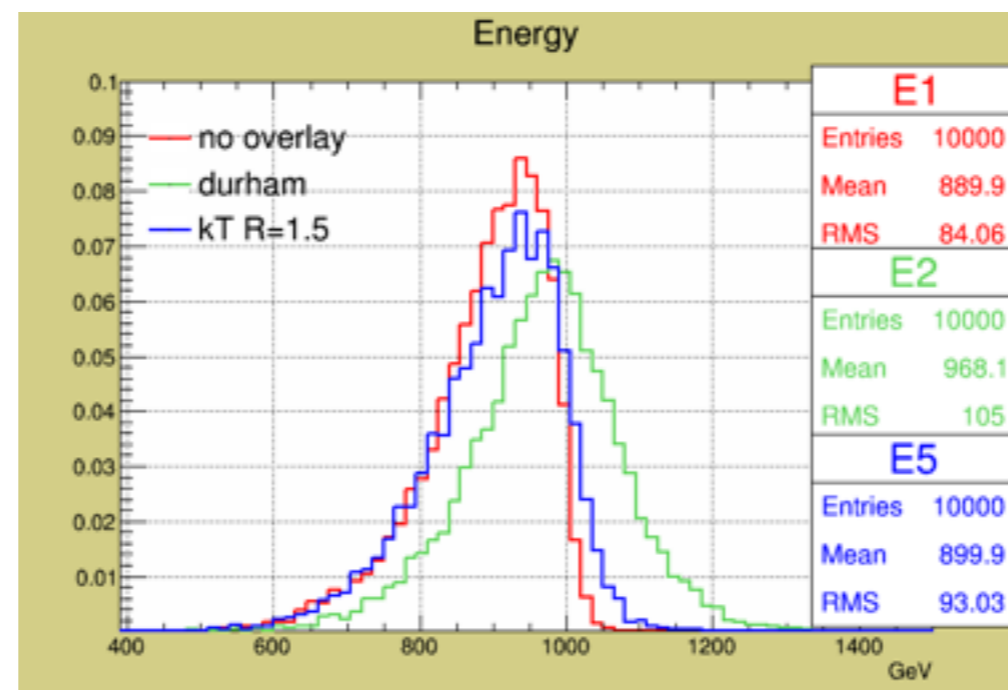


Mass : Truth matched jets

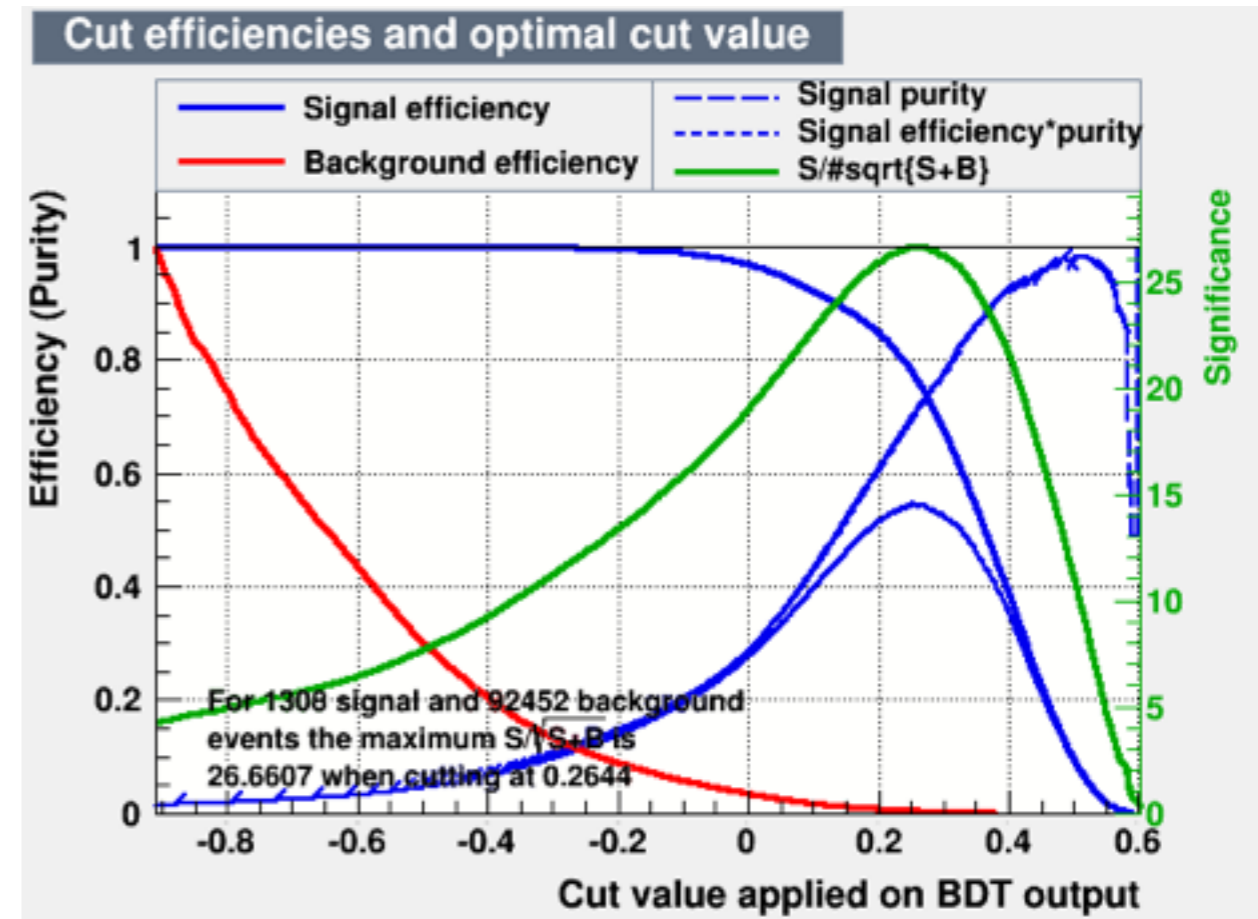
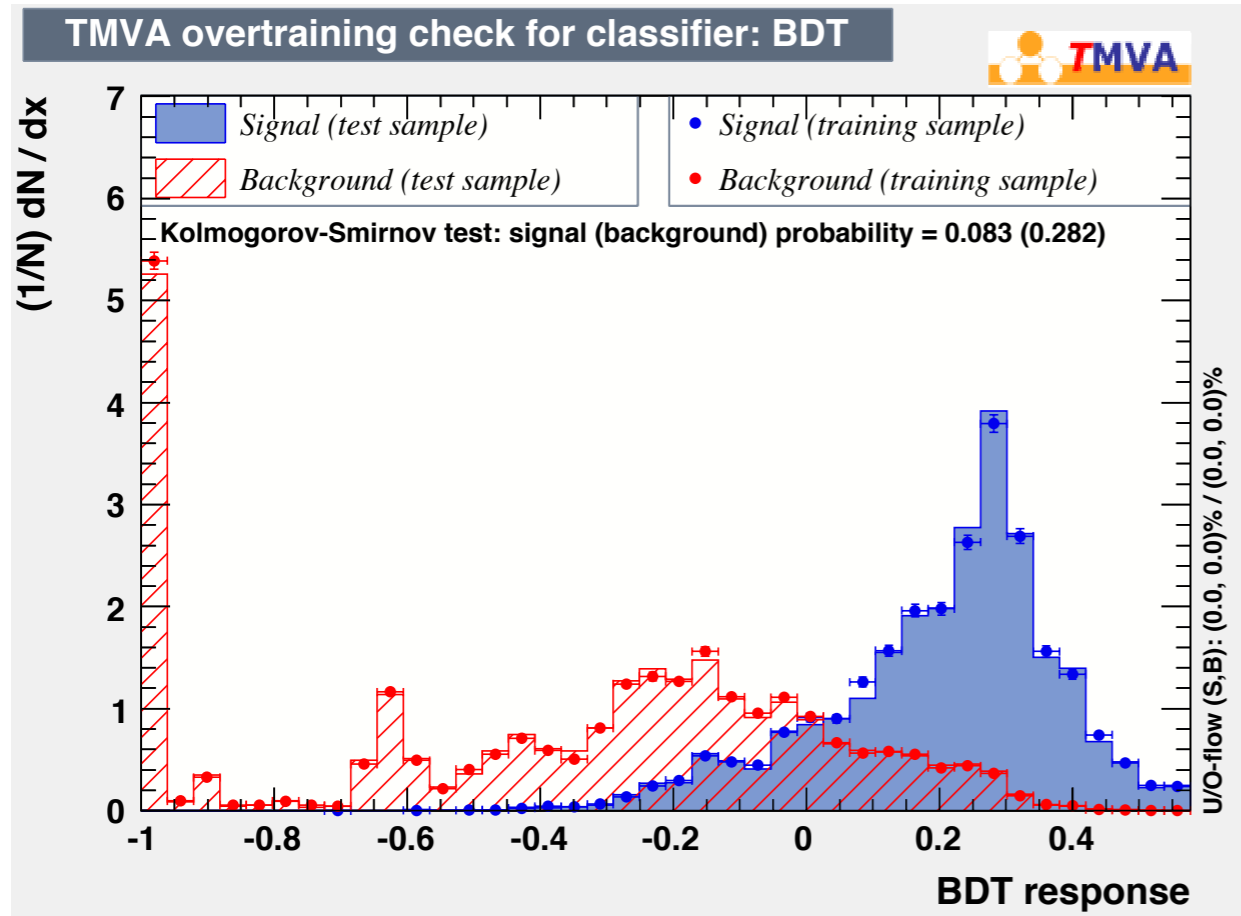
Mass : Chi square jets



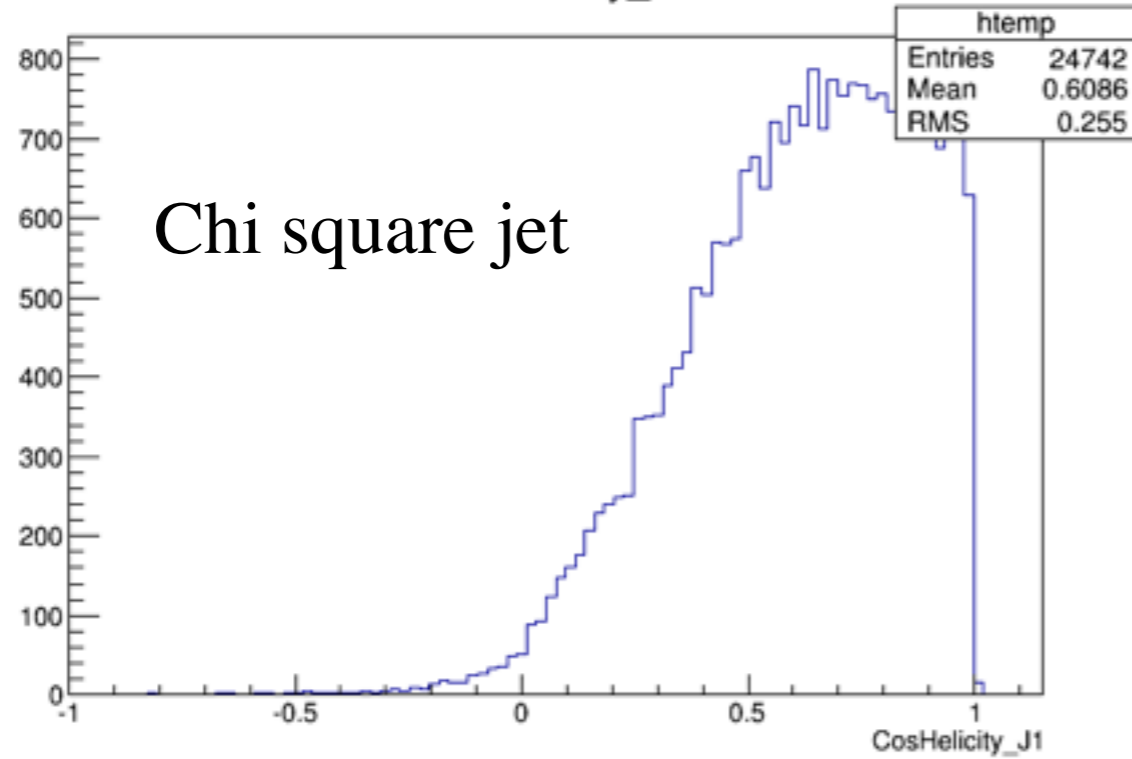
Total visible energy



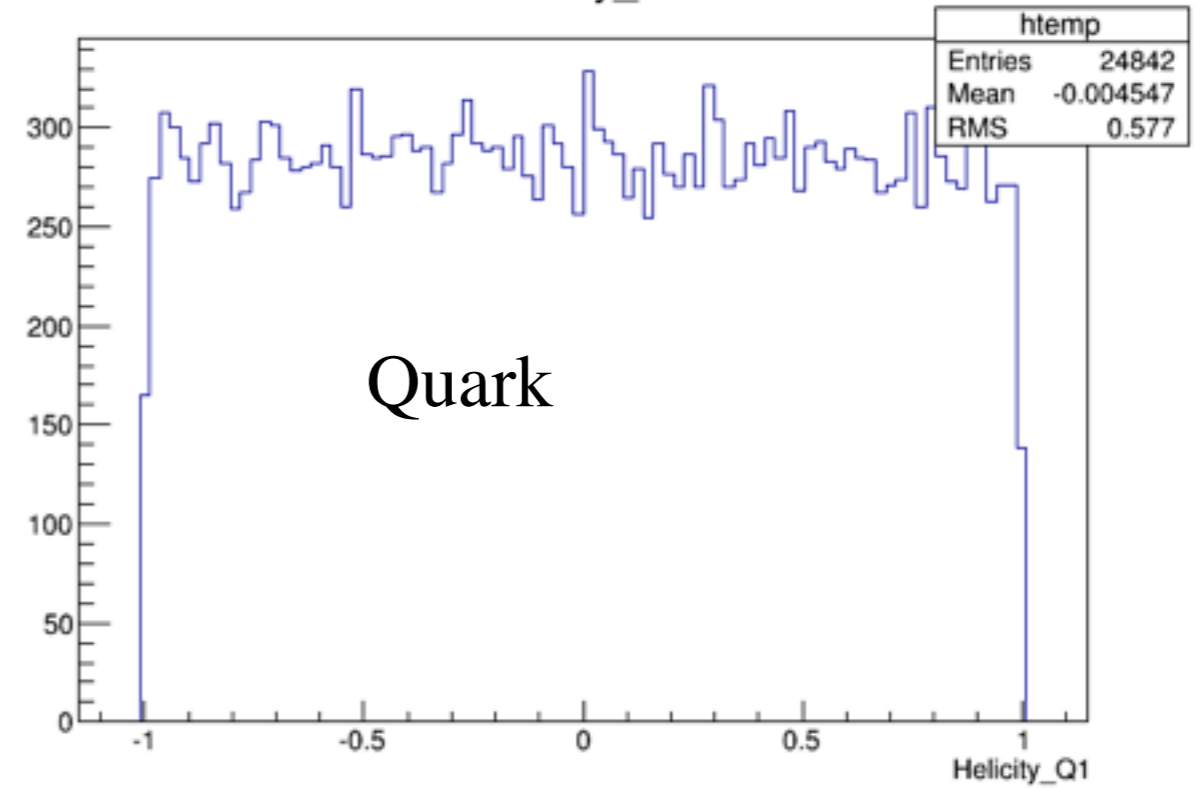




CosHelicity\_J1



Helicity\_Q1



Helicity\_J1

