

CEPC HZZ Analysis Update

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2020.4.22

Status

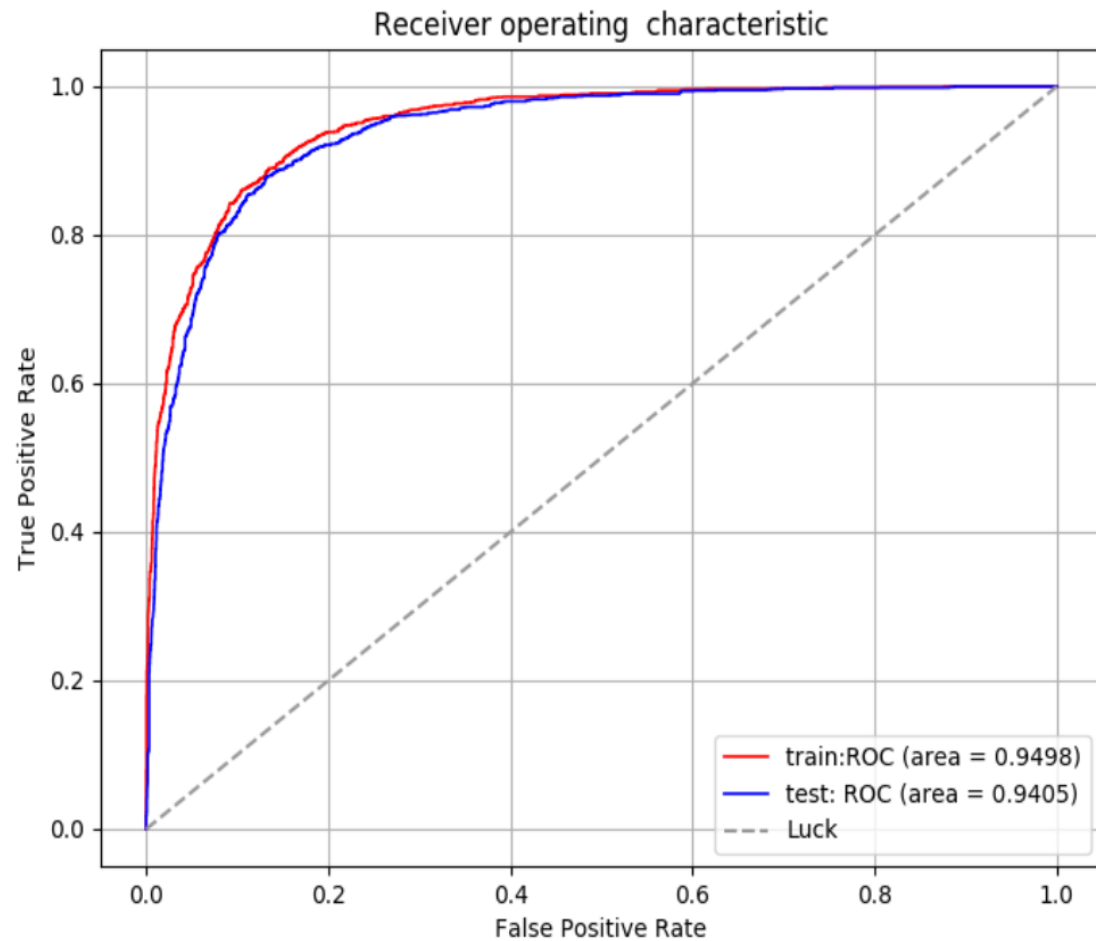
- **CEPC memo v1.0 completed**
- **Merely cut-based code updated**
- **The other 4 channels' BDT study finished**

BDT on vvHZZ ($\mu\mu jj$)

➤ Pre-BDT cuts

Cut
$M_{di-muon} > M_{di-jet}$
$20 < N(pfo) < 60$
$75 < M_{missing} < 110$
$110 < M_{visible} < 140$
$ \cos \theta_{visible} < 0.95$

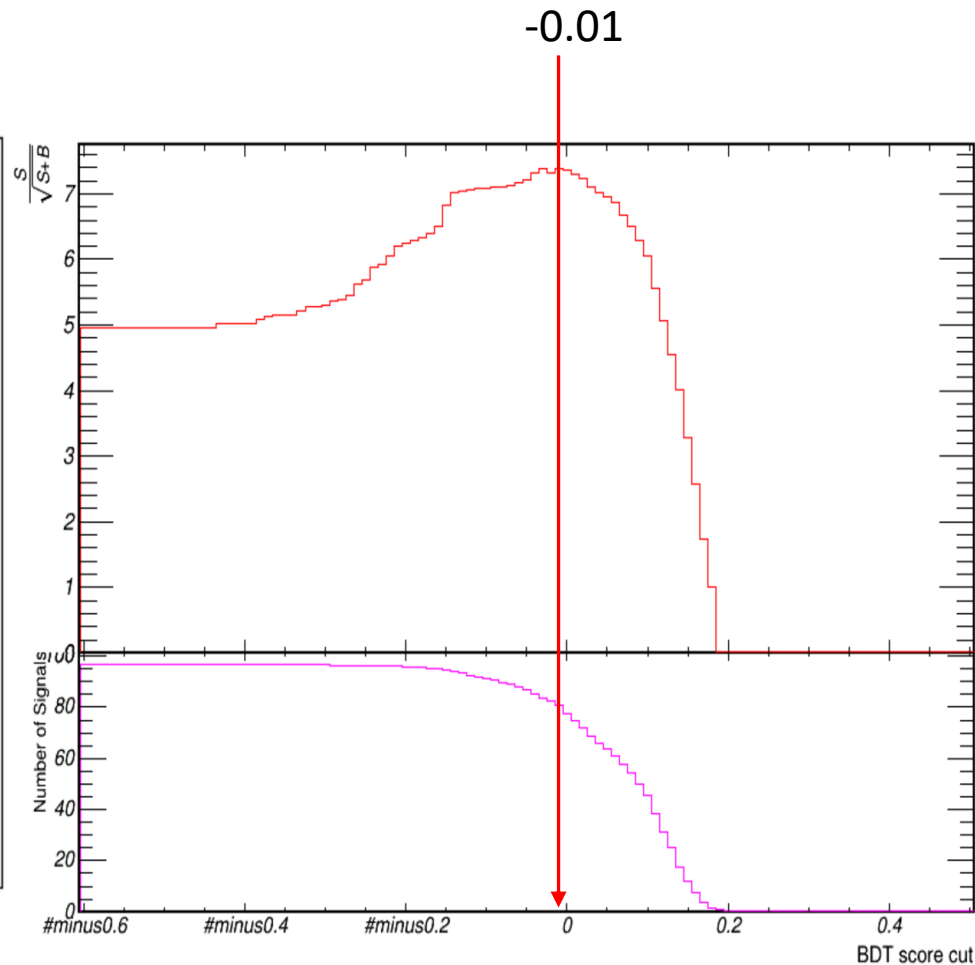
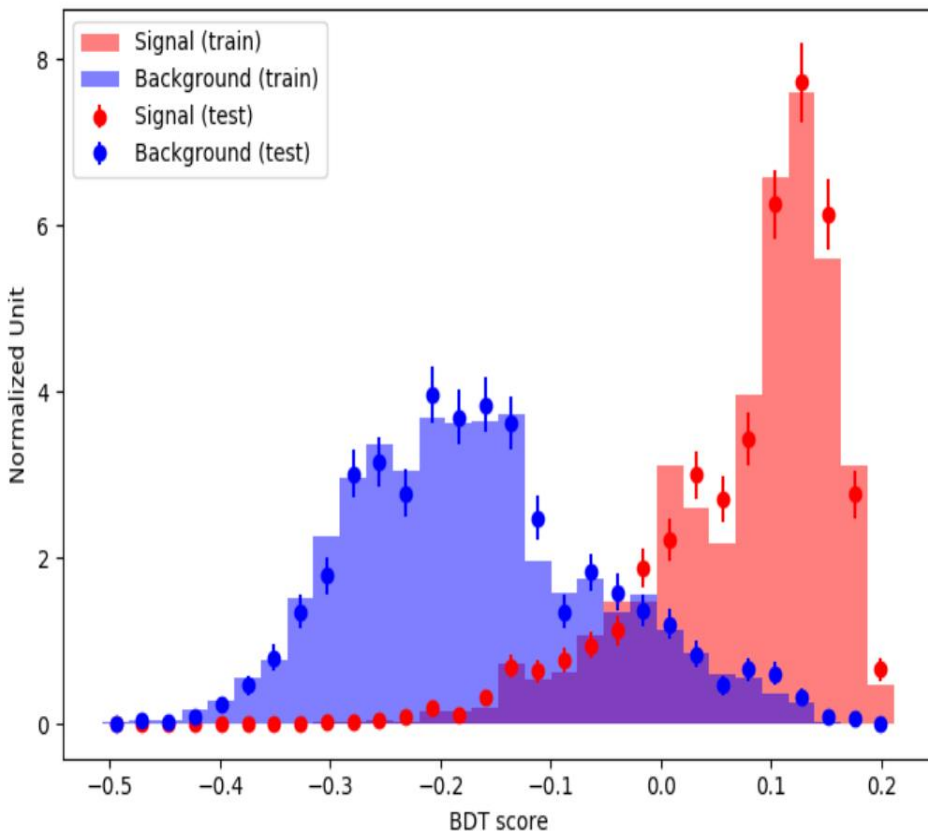
➤ ROC Curve



BDT on vvHZZ ($\mu\mu jj$)

➤ Output BDT score

➤ $\frac{S}{\sqrt{S+B}}$ vs BDT score cut



BDT on vvHZZ ($\mu\mu jj$)

➤ Cut Flow

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	6844	1140511	801811977	107203890	
<i>Pre – selection</i>	238	30494	480828	515424	
<i>Signal or not</i>	226	30268	480828	515424	
$M_{dimuon} > M_{dijet}$	125	2832	421952	156993	0.1642
$N(pfo)$	117	1259	60398	68100	0.325
$M_{missing}$	102	147	2152	791	1.8168
$M_{visible}$	101	82	696	325	2.9267
$cos\theta_{visible}$	96	77	124	79	4.9672
<i>BDT score</i>	80	12	0	27	7.383

BDT this time

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	6844	1140511	801811977	107203890	
<i>Pre – selection</i>	238	30494	480828	515424	
<i>Signal or not</i>	226	30268	480828	515424	
$M_{dimuon} > M_{dijet}$	125	2832	421952	156993	0.1642
$N(pfo)$	117	1259	60398	68100	0.325
$M_{missing}$	102	147	2152	791	1.8168
M_{dimuon}	95	136	1762	258	2.007
M_{dijet}	94	131	258	204	3.5888
$*cos\theta$	94	131	258	204	3.5888
$cos\theta_{visible}$	89	125	37	57	5.0842
$Angle_{\mu j}$	83	72	0	16	6.3751
$*M_{dimuon}^{rec}$	83	72	0	16	6.3751
$*M_{dijet}^{rec}$	83	72	0	16	6.3751
$M_{visible}$	83	56	0	11	6.7871
$*P_{visible}$	83	56	0	11	6.7871
$*P_{T_{visible}}$	83	56	0	11	6.7871
$*E_{leading\ jet}$	83	56	0	11	6.7871
$*P_{T_{leading\ jet}}$	83	56	0	11	6.7871
$*E_{sub-leading\ jet}$	83	56	0	11	6.7871
$*P_{T_{sub-leading\ jet}}$	83	56	0	11	6.7871
<i>not $\mu^+\mu^- HZZ$</i>	72	17	0	9	7.2837
<i>not $qqHZZ$</i>	72	17	0	9	7.2837

Merely cut-based

BDT on $\nu\nu\text{HZZ}$ ($\text{jj}\mu\mu$)

➤ Pre-BDT cuts

Cut

$$M_{di-\mu\mu} < M_{di-jet}$$

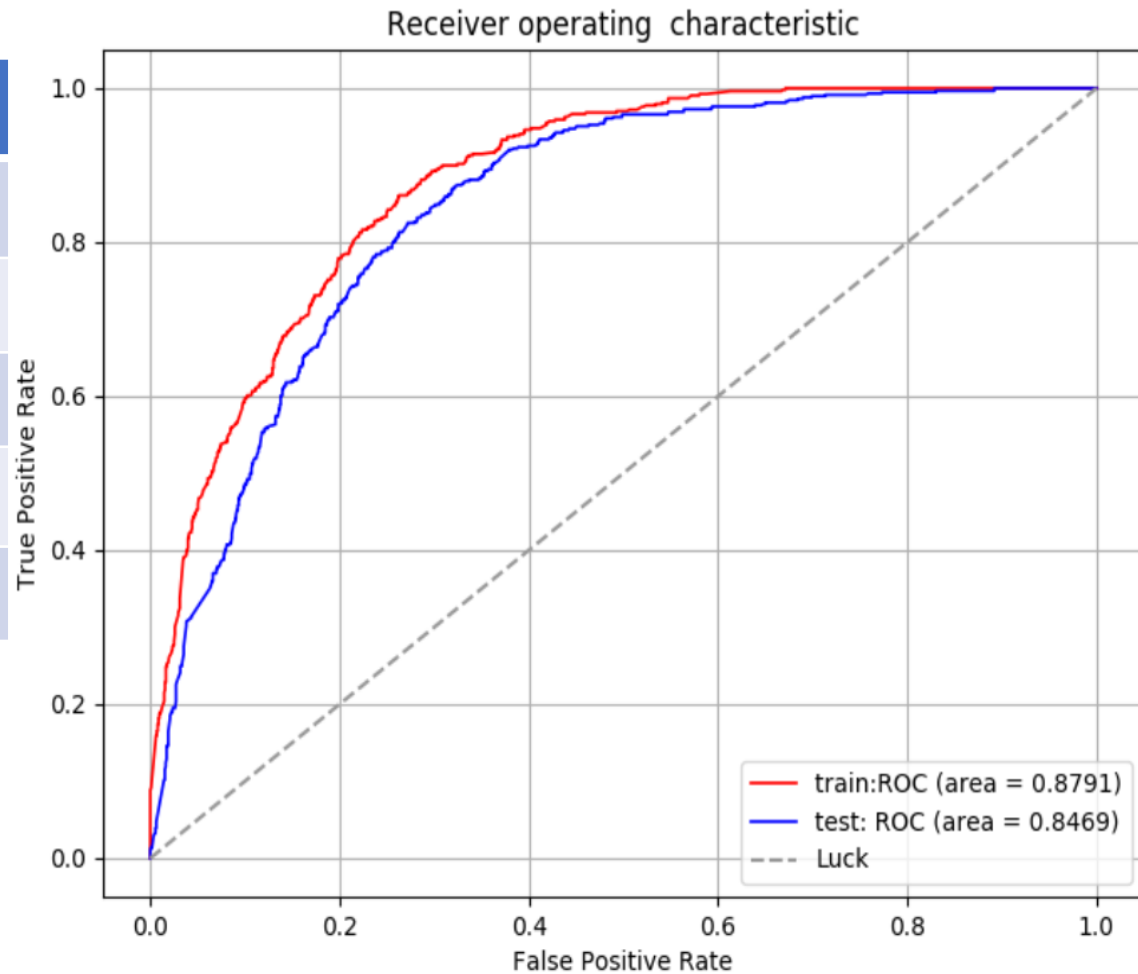
$$30 < N(pfo) < 100$$

$$75 < M_{missing} < 110$$

$$110 < M_{visible} < 140$$

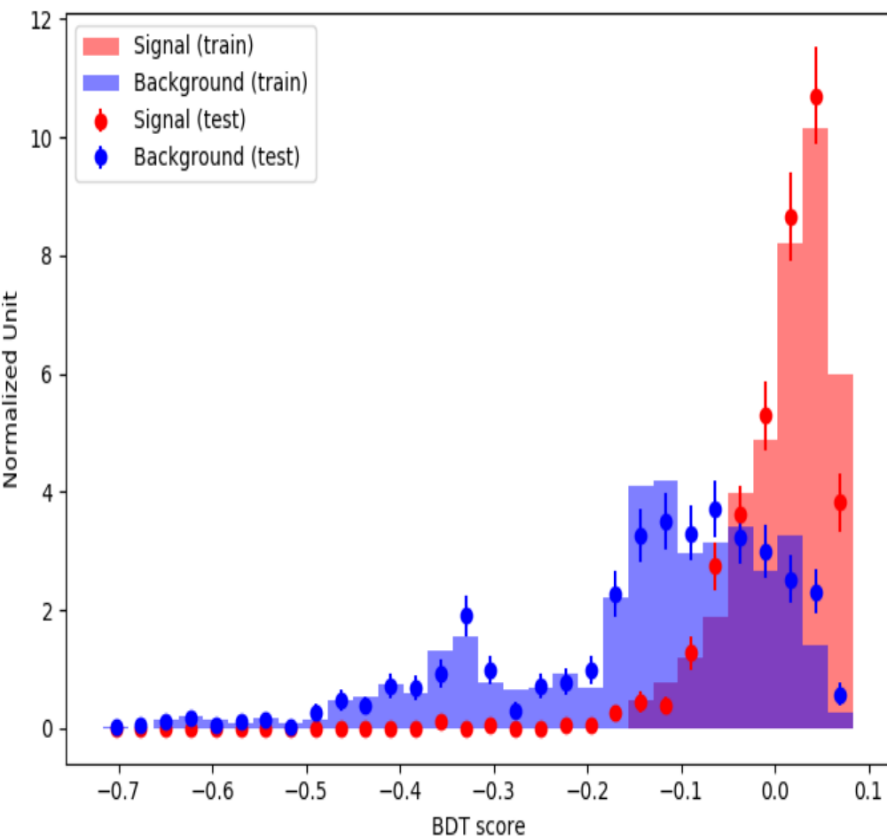
$$|\cos\theta_{visible}| < 0.95$$

➤ ROC Curve

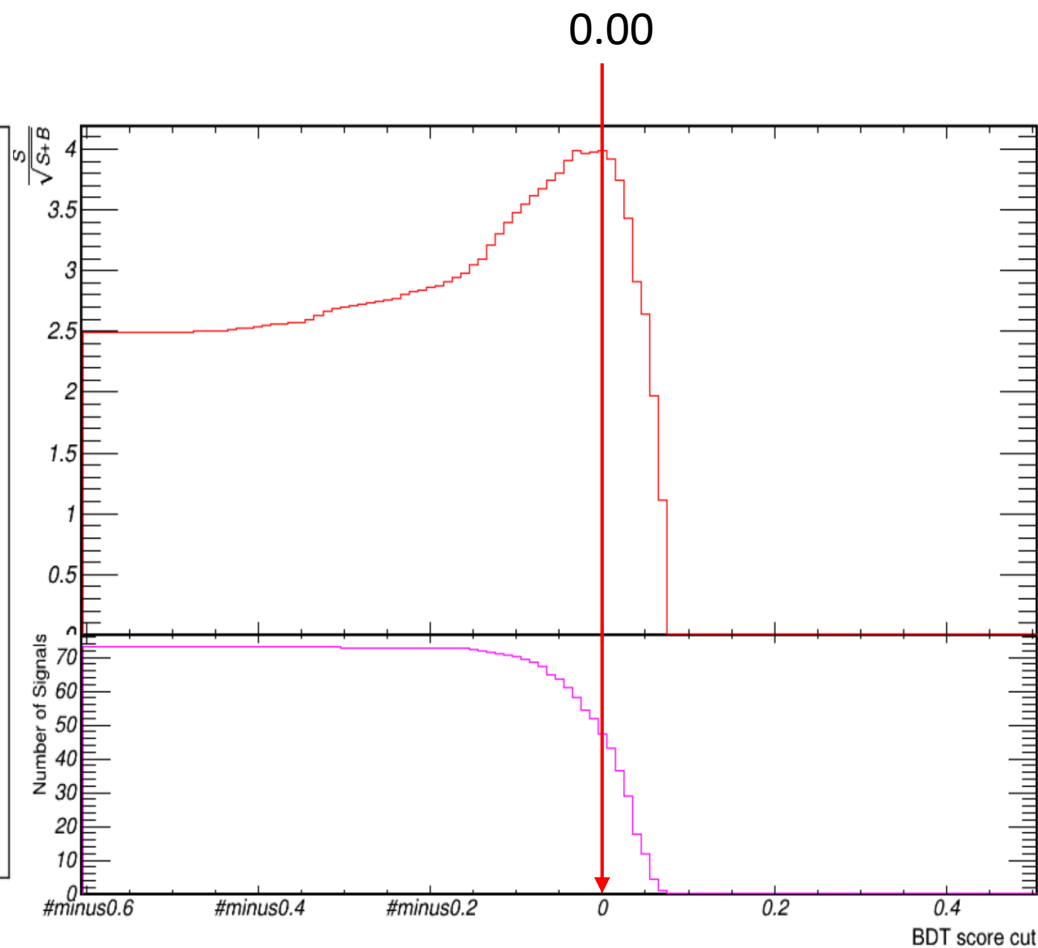


BDT on vvHZZ (jjμμ)

➤ Output BDT score



➤ $\frac{S}{\sqrt{S+B}}$ vs BDT score cut



BDT on vvHZZ (jjμμ)

➤ Cut Flow

BDT this time

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	6844	1140511	801811977	107203890	
<i>Pre – selection</i>	238	30494	480828	515424	
<i>Signal or not</i>	226	30268	480828	515424	
$M_{dimuon} < M_{dijet}$	101	27436	58876	358431	0.1521
$N(pfo)$	97	20843	364	231698	0.1939
$M_{missing}$	79	769	37	2083	1.4508
$M_{visible}$	76	445	0	910	2.0327
$cos\theta_{visible}$	73	430	0	360	2.4836
<i>BDT score</i>	47	76	0	16	3.9875

Merely cut-base

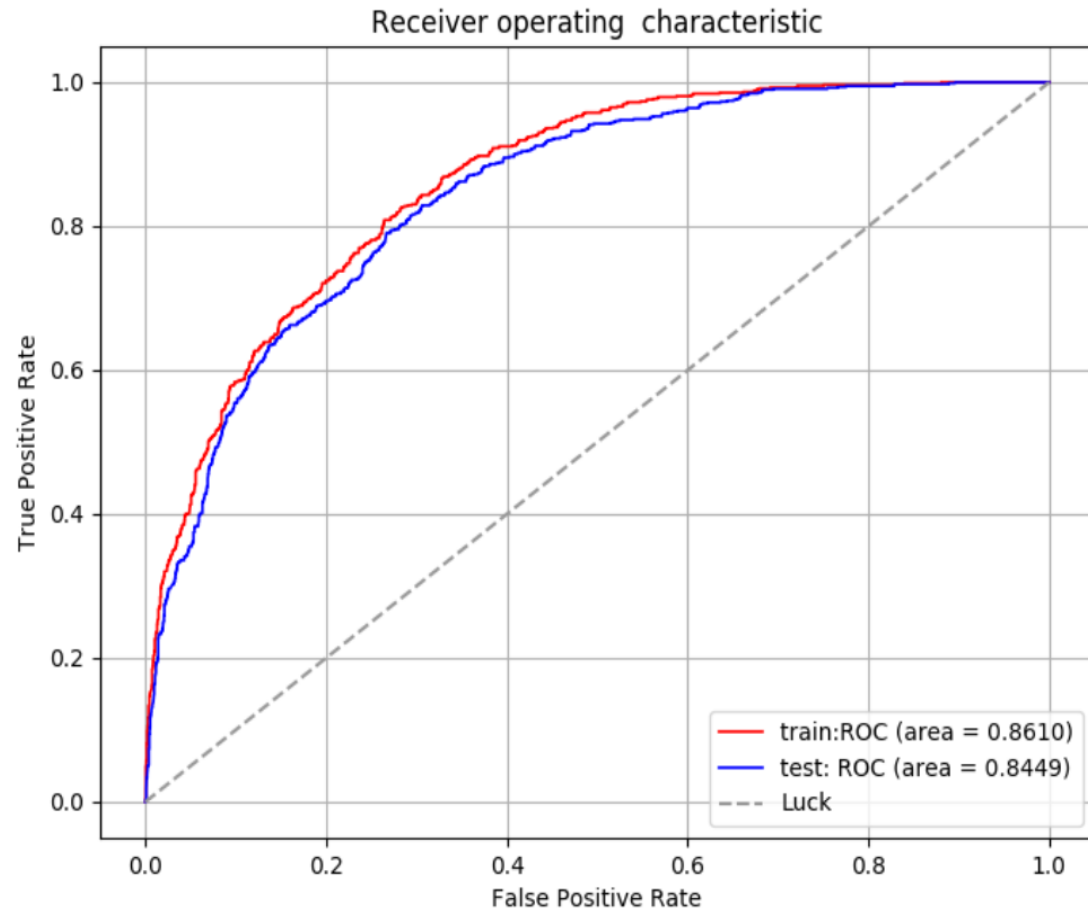
Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	6844	1140511	801811977	107203890	
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<i>Signal or not</i>	226	30268	480828	515424	
$M_{dimuon} < M_{dijet}$	101	27436	58876	358431	0.1521
$N(pfo)$	97	20843	364	231698	0.1939
$M_{missing}$	79	769	37	2083	1.4508
M_{dimuon}	78	707	7	1732	1.5596
M_{dijet}	68	576	0	830	1.7719
$*cos\theta$	68	576	0	830	1.7719
$cos\theta_{visible}$	64	552	0	452	1.9743
$Angle_{\mu j}$	59	239	0	70	3.1041
M_{dimuon}^{rec}	58	214	0	65	3.184
$*M_{dijet}^{rec}$	58	214	0	65	3.184
$M_{visible}$	57	175	0	54	3.4122
$*P_{visible}$	57	175	0	54	3.4122
$*P_{T_{visible}}$	57	175	0	54	3.4122
$*E_{leading\ jet}$	57	175	0	54	3.4122
$*P_{T_{leading\ jet}}$	57	175	0	54	3.4122
$*E_{sub-leading\ jet}$	57	175	0	54	3.4122
$*P_{T_{sub-leading\ jet}}$	57	175	0	54	3.4122
<i>not $\mu^+\mu^-HZZ$</i>	57	175	0	54	3.4122
<i>not $qqHZZ$</i>	50	130	0	43	3.3773

BDT on qqHZZ ($\nu\nu\mu\mu$)

➤ Pre-BDT cuts

Cut
$M_{missing} > M_{di-muon}$
$40 < N(pfo) < 95$
$75 < M_{di-jet} < 105$
$110 < M_{di-jet}^{rec} < 140$
$ \cos \theta_{visible} < 0.95$

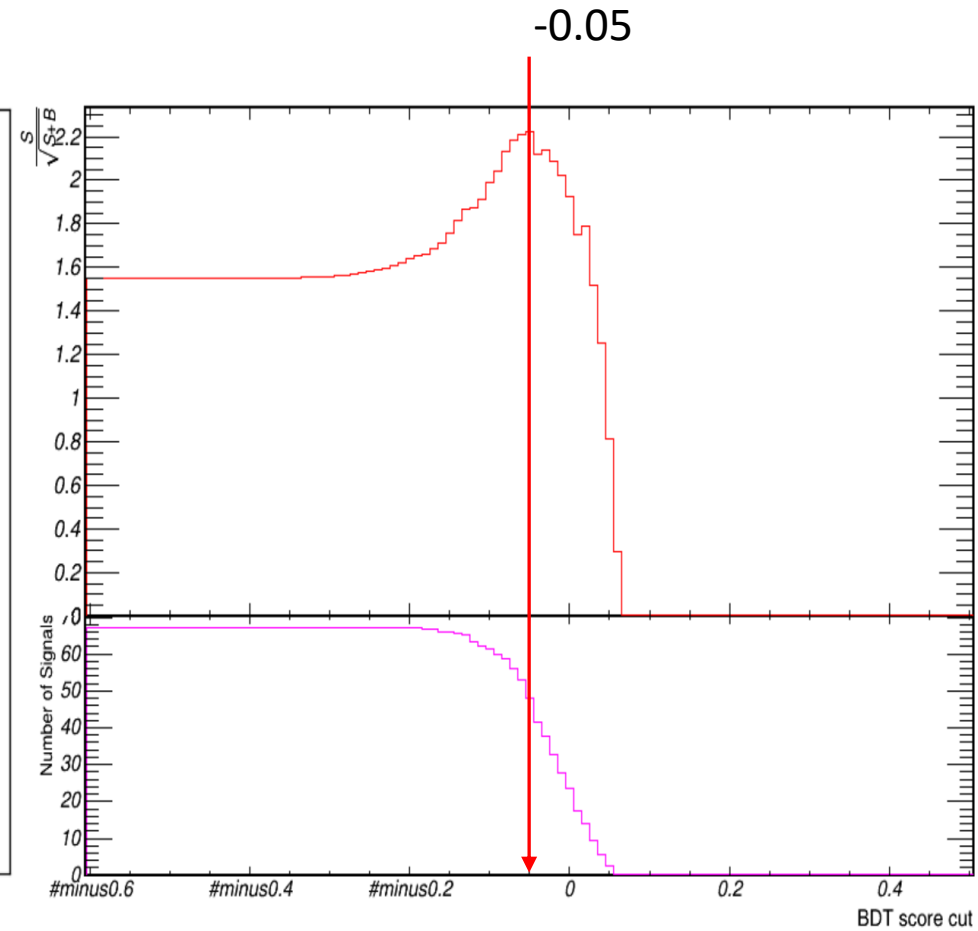
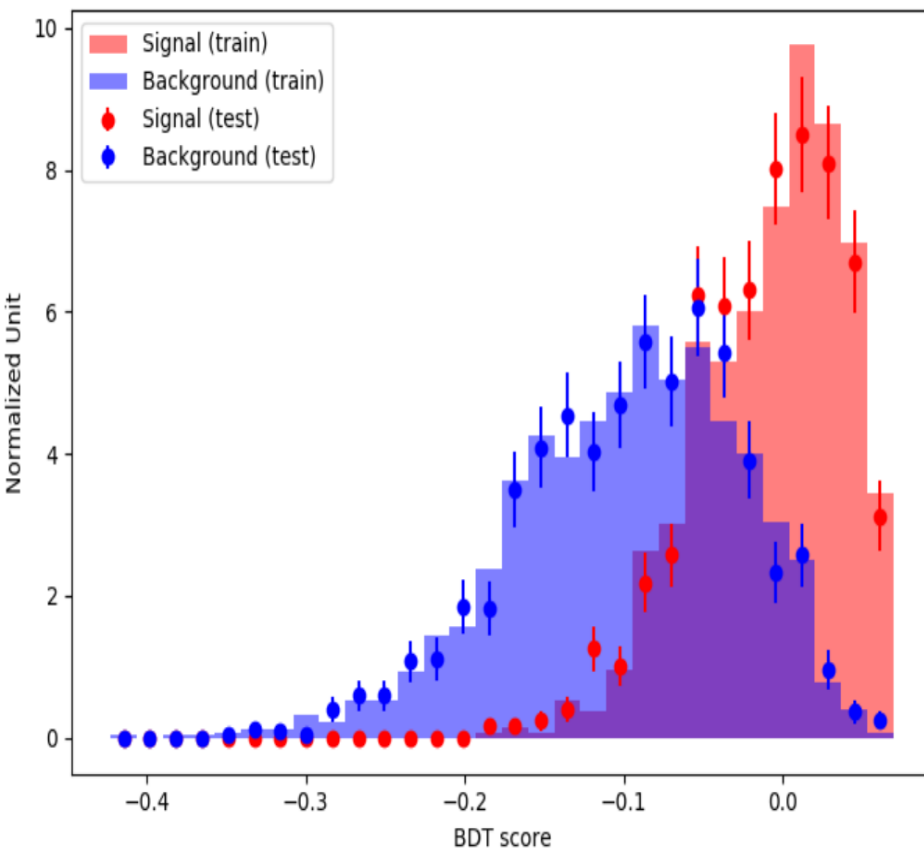
➤ ROC Curve



BDT on qqHZZ ($\nu\nu\mu\mu$)

➤ Output BDT score

➤ $\frac{S}{\sqrt{S+B}}$ vs BDT score cut



BDT on qqHZZ ($\nu\nu\mu\mu$)

➤ Cut Flow

BDT this time

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	20254	1140511	801811977	107203890	
<i>Pre – selection</i>	826	30494	480828	515424	
<i>Signal or not</i>	203	30291	480828	515424	
$M_{\text{missing}} > M_{\text{dimuon}}$	94	3179	18606	40769	0.3795
$N(\text{pfo})$	84	2242	1212	12626	0.6659
M_{dijet}	75	1532	7	4965	0.9263
$M_{\text{dijet}}^{\text{rec}}$	70	1318	0	1381	1.3315
$\cos\theta_{\text{visible}}$	67	1259	0	541	1.551
<i>BDT score</i>	48	305	0	116	2.2226

Merely cut-based

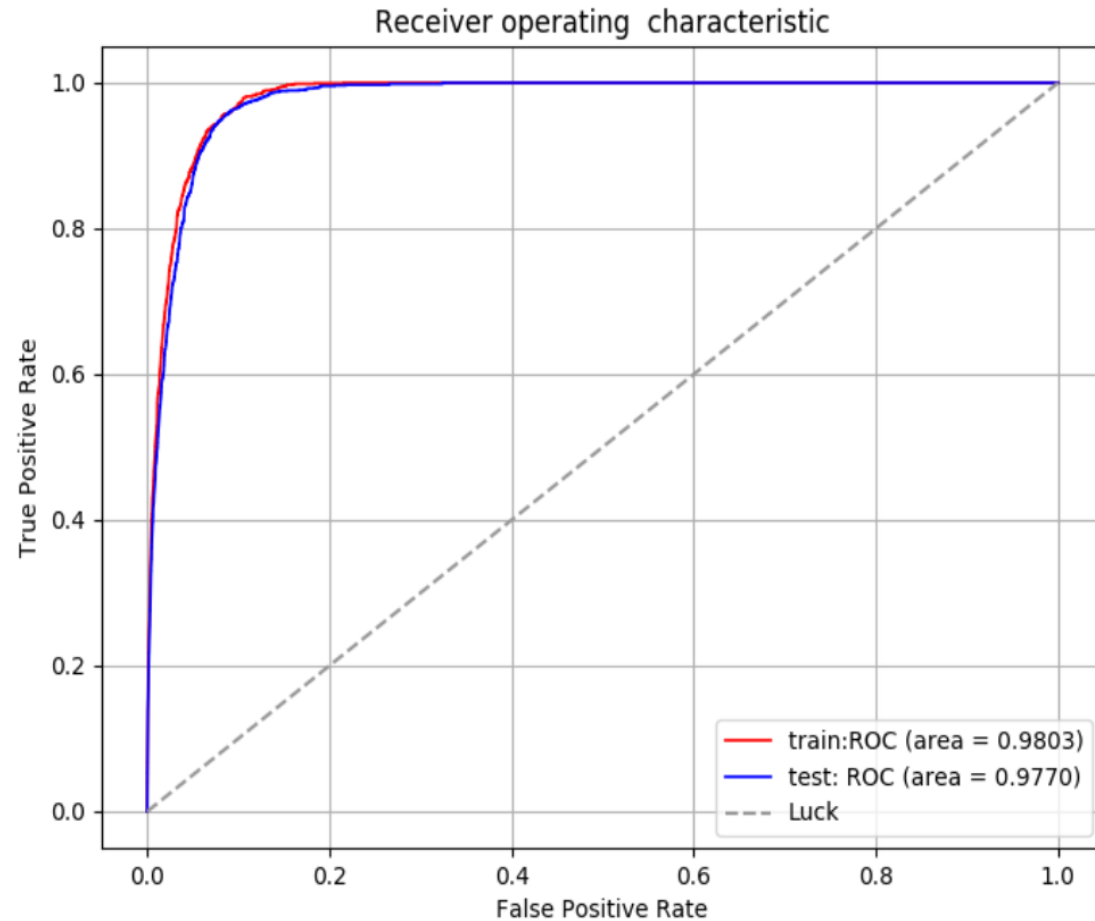
Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	20254	1140511	801811977	107203890	
<i>Pre – selection</i>	826	30494	480828	515424	
<i>Signal or not</i>	203	30291	480828	515424	
$M_{\text{missing}} > M_{\text{dimuon}}$	94	3179	18606	40769	0.3795
$N(\text{pfo})$	84	2242	1212	12626	0.6659
M_{dijet}	75	1532	7	4965	0.9263
M_{dimuon}	68	1231	0	2803	1.0623
M_{missing}	57	575	0	572	1.6625
$*\cos\theta$	57	575	0	572	1.6625
$\cos\theta_{\text{visible}}$	55	551	0	403	1.7334
$*\text{Angle}_{\mu j}$	55	551	0	403	1.7334
$M_{\text{dimuon}}^{\text{rec}}$	53	493	0	348	1.7877
$M_{\text{dijet}}^{\text{rec}}$	51	418	0	237	1.9265
M_{visible}	48	374	0	209	1.9087
$*P_{\text{visible}}$	48	374	0	209	1.9087
$*P_{T_{\text{visible}}}$	48	374	0	209	1.9087
$*E_{\text{leading jet}}$	48	374	0	209	1.9087
$*P_{T_{\text{leading jet}}}$	48	374	0	209	1.9087
$*E_{\text{sub-leading jet}}$	48	374	0	209	1.9087
$*P_{T_{\text{sub-leading jet}}}$	48	374	0	209	1.9087
<i>not $\mu^+\mu^-HZZ$</i>	48	374	0	209	1.9087
<i>not $\nu\nu HZZ$</i>	41	326	0	190	1.764

BDT on qqHZZ ($\mu\mu\nu\nu$)

➤ Pre-BDT cuts

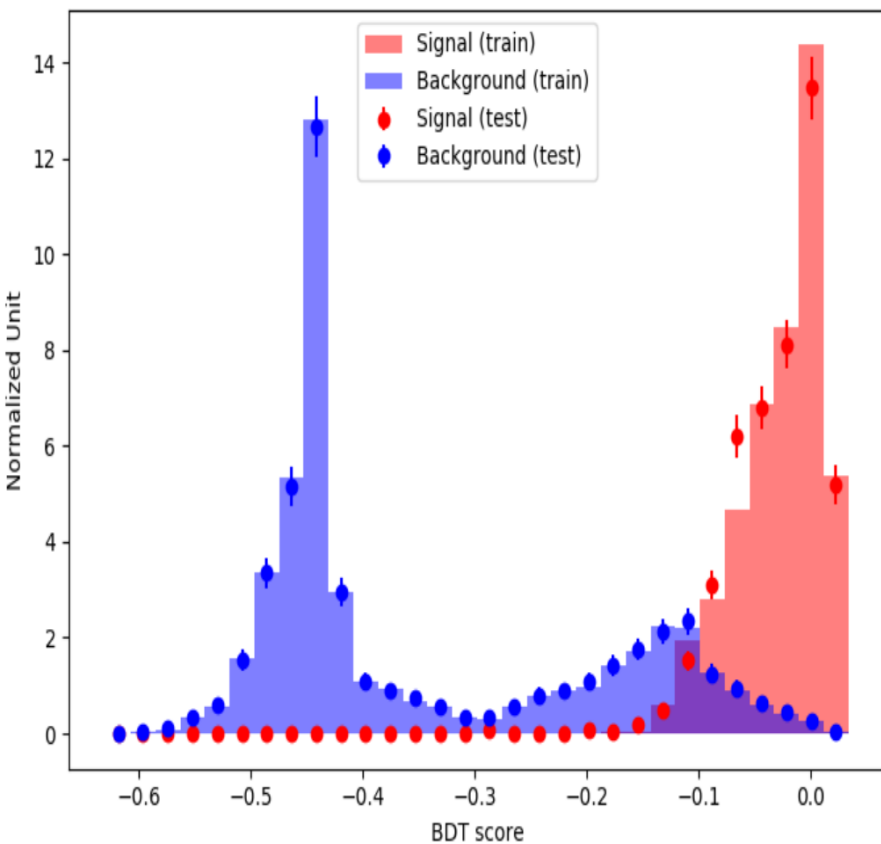
Cut
$M_{missing} < M_{di-muon}$
$35 < N(pfo) < 100$
$75 < M_{di-jet} < 110$
$110 < M_{di-jet}^{rec} < 140$
$ \cos \theta_{visible} < 0.95$

➤ ROC Curve

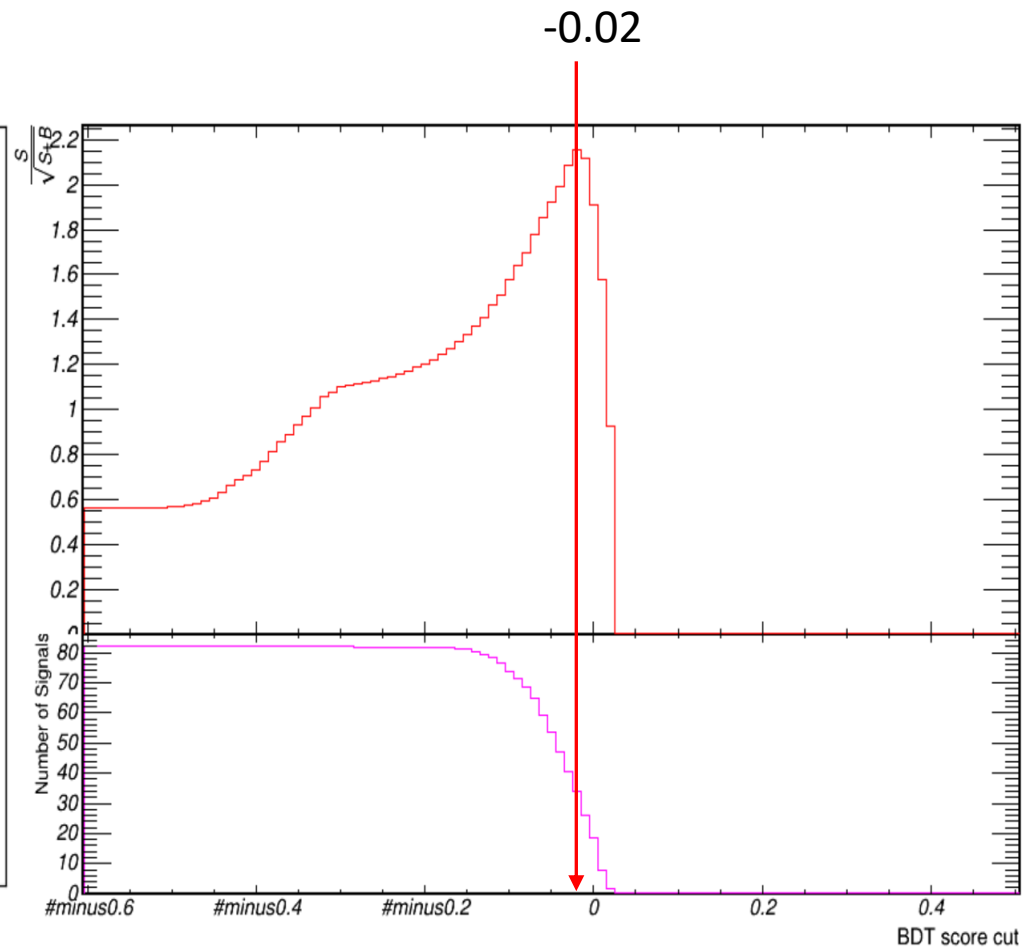


BDT on qqHZZ ($\mu\mu\nu\nu$)

➤ Output BDT score



➤ $\frac{S}{\sqrt{S+B}}$ vs BDT score cut



BDT on qqHZZ ($\mu\mu\nu\nu$)

➤ Cut Flow

BDT this time

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	20254	1140511	801811977	107203890	
<i>Pre – selection</i>	826	30494	480828	515424	
<i>Signal or not</i>	203	30291	480828	515424	
$M_{\text{missing}} < M_{\text{dimuon}}$	108	27112	462222	474655	0.1104
$N(\text{pfo})$	103	19806	17185	313602	0.1741
M_{dijet}	97	4531	44	250527	0.1937
$M_{\text{dijet}}^{\text{rec}}$	88	3385	7	33021	0.4622
$\cos\theta_{\text{visible}}$	82	3081	0	18293	0.56
<i>BDT score</i>	33	161	0	51	2.1536

Merely cut-base

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
<i>Expected</i>	20254	1140511	801811977	107203890	
<i>Pre – selection</i>	826	30494	480828	515424	
<i>Signal or not</i>	203	30291	480828	515424	
$M_{\text{missing}} < M_{\text{dimuon}}$	108	27112	462222	474655	0.1104
$N(\text{pfo})$	103	19806	17185	313602	0.1741
M_{dijet}	97	4531	44	250527	0.1937
M_{dimuon}	83	3468	14	174150	0.1989
M_{missing}	64	1961	7	11132	0.5648
$\cos\theta$	64	1961	7	11132	0.5648
$\cos\theta_{\text{visible}}$	60	1796	0	6827	0.652
$\text{Angle}_{\mu j}$	53	1197	0	1264	1.0622
$M_{\text{dimuon}}^{\text{rec}}$	51	1194	0	661	1.1737
$M_{\text{dijet}}^{\text{rec}}$	48	950	0	534	1.2364
M_{visible}	45	749	0	464	1.2781
$*P_{\text{visible}}$	45	749	0	464	1.2781
$*P_{T_{\text{visible}}}$	45	749	0	464	1.2781
$*E_{\text{leading jet}}$	45	749	0	464	1.2781
$*P_{T_{\text{leading jet}}}$	45	749	0	464	1.2781
$*E_{\text{sub-leading jet}}$	45	749	0	464	1.2781
$*P_{T_{\text{sub-leading jet}}}$	45	749	0	464	1.2781
<i>not $\mu^+\mu^-HZZ$</i>	39	275	0	345	1.5366
<i>not $\nu\nu HZZ$</i>	39	275	0	345	1.5366

Next to do

- **Fitting for BDT results**