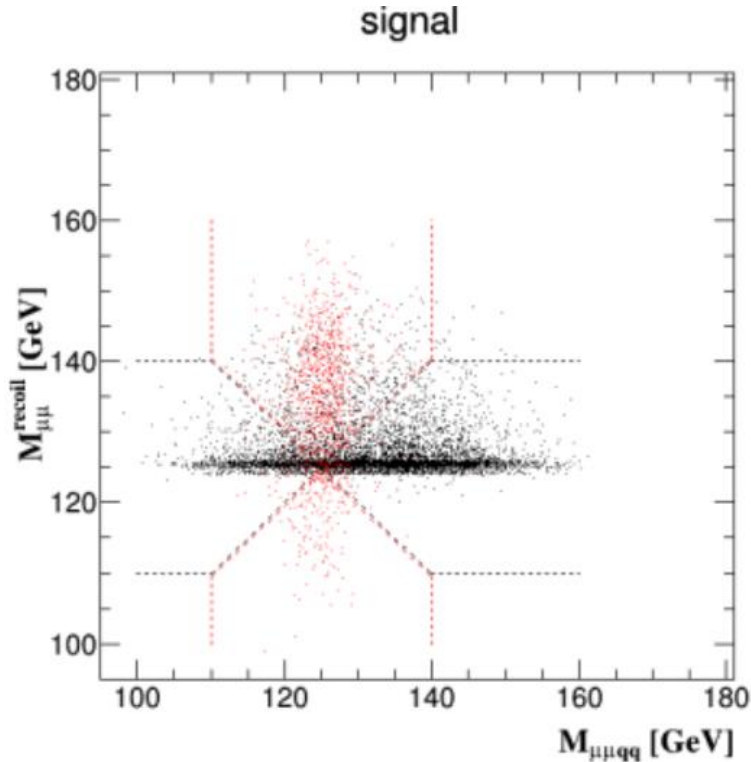# BDT Analysis Update

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Introduction

➢ **Use "2D" cut to suppress signal overlap**

signal

- Separate this phase space into two regions, so as to eliminate the overlap of analysis region.

- μμHννqq → "black region" or " μμHννqq' "

  ννHμμqq ▸ "red region" or " ννHμμqq' "

➢ **Add "2D cut" to the several pre-BDT cuts**

$\mu\mu H\nu\nu qq$

➢ Cut flow comparison

Without 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	1000	1140511	801811977	107203890	
$Pre-selection$	616	30494	480828	515424	
$Signal\ or\ not$	211	30282	480828	515424	
$M_{missing} > M_{dijet}$	107	1608	115062	28811	0.283
$N(pfo)$	104	908	33480	14161	0.4722
M_{dimuon}	92	296	24151	1629	0.5714
M^{rec}_{dimuon}	89	256	1642	406	1.8279
$cos\theta_{visible}$	85	240	388	127	2.9422
$BDT\ score$	45	6	0	2	6.1727

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	1000	1140511	801811977	107203890	
$Pre-selection$	616	30494	480828	515424	
$Signal\ or\ not$	211	30282	480828	515424	
$M_{missing} > M_{dijet}$	107	1608	115062	28811	0.283
$N(pfo)$	104	908	33480	14161	0.4722
M_{dimuon}	92	296	24151	1629	0.5714
M^{rec}_{dimuon}	89	256	1642	406	1.8279
$cos\theta_{visible}$	85	240	388	127	2.9422
$2D\ Mass\ Cut\ 1$	85	240	388	127	2.9423
$2D\ Mass\ Cut\ 2$	77	187	335	121	2.876
$BDT\ score$	57	14	0	6	6.484

$\mu\mu H\nu\nu qq$

➢ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_ww	0.08176	3
nnh_zz	0.06832	2
zz_sl0mu_down	1.08025726079	1
zz_sl0tau_up	1.10880522921	1

With 2D cuts

name	scale	final
e2e2h_ww	0.08176	6
nnh_zz	0.06832	7
zz_sl0mu_up	1.09032214858	3
zz_sl0tau_up	1.10880522921	2
zz_l0taumu	1.0404004004	1

➢Explanations

➢ **For different BDT models & different BDT score cut points, the number of signals/backgrounds differs a lot**

$\mu\mu Hqq\nu\nu$

➤ Cut flow comparison

Without 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	1000	1140511	801811977	107203890	
$Pre-selection$	616	30494	480828	515424	
$Signal\ or\ not$	211	30282	480828	515424	
$M_{missing} < M_{dijet}$	103	28674	365766	486613	0.1102
$N(pfo)$	100	21686	12184	332136	0.1657
M_{dimuon}	89	16833	9085	207927	0.186
M^{rec}_{dimuon}	87	16144	321	25675	0.4236
$cos\theta_{visible}$	82	14667	0	12539	0.4992
$BDT\ score$	54	806	0	605	1.4262

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	1000	1140511	801811977	107203890	
$Pre-selection$	616	30494	480828	515424	
$Signal\ or\ not$	211	30282	480828	515424	
$M_{missing} < M_{dijet}$	103	28674	365766	486613	0.1102
$N(pfo)$	100	21686	12184	332136	0.1657
M_{dimuon}	89	16833	9085	207927	0.186
M^{rec}_{dimuon}	87	16144	321	25675	0.4236
$cos\theta_{visible}$	82	14667	0	12539	0.4992
2D Mass Cut 1	75	14224	0	11535	0.4712
2D Mass Cut 2	75	14224	0	11533	0.4712
$BDT\ score$	61	988	0	607	1.5079

μμHqqνν

➤ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_bb	0.21896	448
e2e2h_cc	0.011032	5
e2e2h_e3e3	0.023968	1
e2e2h_gg	0.0326888819557	1
e2e2h_ww	0.08176	298
e2e2h_zz	0.010024	5
e3e3h_zz	0.009968099681	1
qqh_e3e3	0.4844	11
qqh_ww	1.6464	1
qqh_zz	0.20216	30
zz_sl0mu_up	1.09032214858	127
zz_sl0mu_down	1.08025726079	455
zz_sl0tau_down	1.10887174477	5
ww_sl0muq	1.10890944134	13
ww_sl0tauq	1.10899434445	3

With 2D cuts

name	scale	final
e2e2h_bb	0.21896	571
e2e2h_cc	0.011032	6
e2e2h_e3e3	0.023968	3
e2e2h_gg	0.0326888819557	1
e2e2h_ww	0.08176	371
e2e2h_zz	0.010024	6
e3e3h_zz	0.009968099681	1
qqh_e3e3	0.4844	5
qqh_zz	0.20216	18
zz_sl0mu_up	1.09032214858	143
zz_sl0mu_down	1.08025726079	442
zz_sl0tau_down	1.10887174477	4
ww_sl0muq	1.10890944134	14
ww_sl0tauq	1.10899434445	2

➤ Explanations

➤ **For different BDT models & different BDT score cut points, the number of signals/backgrounds differs a lot**

➤ **But if the number of signals didn't change a lot, 2D cut could reduce the number of other signal channels that passed selections efficiently**

$\nu\nu H\mu\mu qq$

➢ Cut flow comparison

Without 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	6844	1140511	801811977	107203890	
$Pre-selection$	238	30494	480828	515424	
$Signal\ or\ not$	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
$BDT\ score$	80	12	0	27	7.383

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	6844	1140511	801811977	107203890	
$Pre-selection$	238	30494	480828	515424	
$Signal\ or\ not$	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
$2D\ Mass\ Cut\ 1$	87	21	87	69	5.3562
$2D\ Mass\ Cut\ 2$	87	21	87	67	5.378
$BDT\ score$	81	11	0	17	7.7125

$\nu\nu H\mu\mu qq$

➢ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_ww	0.08176	3
e2e2h_zz	0.010024	4
e3e3h_ww	0.0812	2
zz_sl0tau_up	1.10880522921	4
zz_l0taumu	1.0404004004	3
ww_sl0muq	1.10890944134	9
ww_sl0tauq	1.10899434445	4
zzorww_l0mumu	1.10891486372	3
sze_l0mu	1.10916641266	1

Note: Consistent with cut-based results

With 2D cuts

name	scale	final
e2e2h_ww	0.08176	4
e2e2h_zz	0.010024	4
e3e3h_ww	0.0812	2
zz_sl0tau_down	1.10887174477	1
zz_l04tau	0.258421381722	1
zz_l0taumu	1.0404004004	2
ww_sl0muq	1.10890944134	7
ww_sl0tauq	1.10899434445	3
zzorww_l0mumu	1.10891486372	1
sze_l0mu	1.10916641266	1

$\nu\nu Hqq\mu\mu$

➤ Cut flow comparison

Without 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	6844	1140511	801811977	107203890	
$Pre-selection$	238	30494	480828	515424	
$Signal\ or\ not$	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
$BDT\ score$	47	76	0	16	3.9875

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	6844	1140511	801811977	107203890	
$Pre-selection$	238	30494	480828	515424	
$Signal\ or\ not$	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
$2D\ Mass\ Cut\ 1$	73	430	0	360	2.4839
$2D\ Mass\ Cut\ 2$	60	240	0	263	2.5564
$BDT\ score$	55	96	0	43	3.9717

$\nu\nu Hqq\mu\mu$

➤ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_bb	0.21896	4
e2e2h_ww	0.08176	4
e3e3h_ww	0.0812	3
qqh_e3e3	0.4844	21
qqh_ww	1.6464	29
qqh_zz	0.20216	11
zz_sl0mu_down	1.08025726079	2
zz_sl0tau_up	1.10880522921	1
zz_sl0tau_down	1.10887174477	7
ww_sl0muq	1.10890944134	4
ww_sl0tauq	1.10899434445	1

With 2D cuts

name	scale	final
e2e2h_bb	0.21896	6
e2e2h_ww	0.08176	6
e3e3h_ww	0.0812	8
qqh_e3e3	0.4844	24
qqh_ww	1.6464	37
qqh_zz	0.20216	10
zz_sl0mu_down	1.08025726079	3
zz_sl0tau_up	1.10880522921	5
zz_sl0tau_down	1.10887174477	18
ww_sl0muq	1.10890944134	11
ww_sl0tauq	1.10899434445	4

$qqH\nu\nu\mu\mu$

➤ Cut flow comparison

Without 2D cuts

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

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	20254	1140511	801811977	107203890	
$Pre-selection$	826	30494	480828	515424	
$Signal\ or\ not$	203	30291	480828	515424	
$M_{missing} > M_{dimuon}$	94	3179	18606	40769	0.3795
$N(pfo)$	84	2242	1212	12626	0.6659
M_{dijet}	75	1532	7	4965	0.9263
M_{dijet}^{rec}	70	1318	0	1381	1.3315
$cos\theta_{visible}$	67	1259	0	541	1.551
$2D\ Mass\ Cut\ 1$	66	1252	0	511	1.562
$2D\ Mass\ Cut\ 2$	53	1062	0	440	1.35
$BDT\ score$	28	95	0	29	2.2701

$qqH\nu\nu\mu\mu$

➢ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_bb	0.21896	6
e2e2h_ww	0.08176	2
e3e3h_bb	0.21784	6
e3e3h_ww	0.0812	6
nnh_zz	0.06832	24
qqh_e3e3	0.4844	151
qqh_ww	1.6464	107
zz_sl0mu_down	1.08025726079	1
zz_sl0tau_up	1.10880522921	36
zz_sl0tau_down	1.10887174477	76
sze_l0mu	1.10916641266	2

With 2D cuts

name	scale	final
e3e3h_bb	0.21784	1
e3e3h_ww	0.0812	2
nnh_zz	0.06832	4
qqh_e3e3	0.4844	59
qqh_ww	1.6464	26
zz_sl0mu_down	1.08025726079	1
zz_sl0tau_up	1.10880522921	15
zz_sl0tau_down	1.10887174477	13

$qqH\mu\mu\nu\nu$

➤ Cut flow comparison

Without 2D cuts

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

With 2D cuts

Cut	Signal	ZH Background	2f Background	4f Background	$\frac{S}{\sqrt{S+B}}$
$Expected$	20254	1140511	801811977	107203890	
$Pre-selection$	826	30494	480828	515424	
$Signal\ or\ not$	203	30291	480828	515424	
$M_{missing} < M_{dimuon}$	108	27112	462222	474655	0.1104
$N(pfo)$	103	19806	17185	313602	0.1741
M_{dijet}	97	4531	44	250527	0.1937
M_{dijet}^{rec}	88	3385	7	33021	0.4622
$cos\theta_{visible}$	82	3081	0	18293	0.56
$2D\ Mass\ Cut\ 1$	64	1190	0	17441	0.4681
$2D\ Mass\ Cut\ 2$	64	1177	0	17441	0.4683
$BDT\ score$	21	48	0	10	2.3632

$qqH\mu\mu\nu\nu$

➤ Remained backgrounds comparison

Without 2D cuts

name	scale	final
e2e2h_bb	0.21896	24
e2e2h_ww	0.08176	18
e2e2h_zz	0.010024	2
qqh_e3e3	0.4844	81
qqh_ww	1.6464	31
zz_sl0mu_up	1.09032214858	4
zz_sl0mu_down	1.08025726079	27
zz_sl0tau_up	1.10880522921	3
zz_sl0tau_down	1.10887174477	16

With 2D cuts

name	scale	final
e2e2h_bb	0.21896	10
e2e2h_ww	0.08176	6
qqh_e3e3	0.4844	25
qqh_ww	1.6464	4
zz_sl0mu_up	1.09032214858	1
zz_sl0mu_down	1.08025726079	8
zz_sl0tau_down	1.10887174477	1