

CEPC HZZ Project

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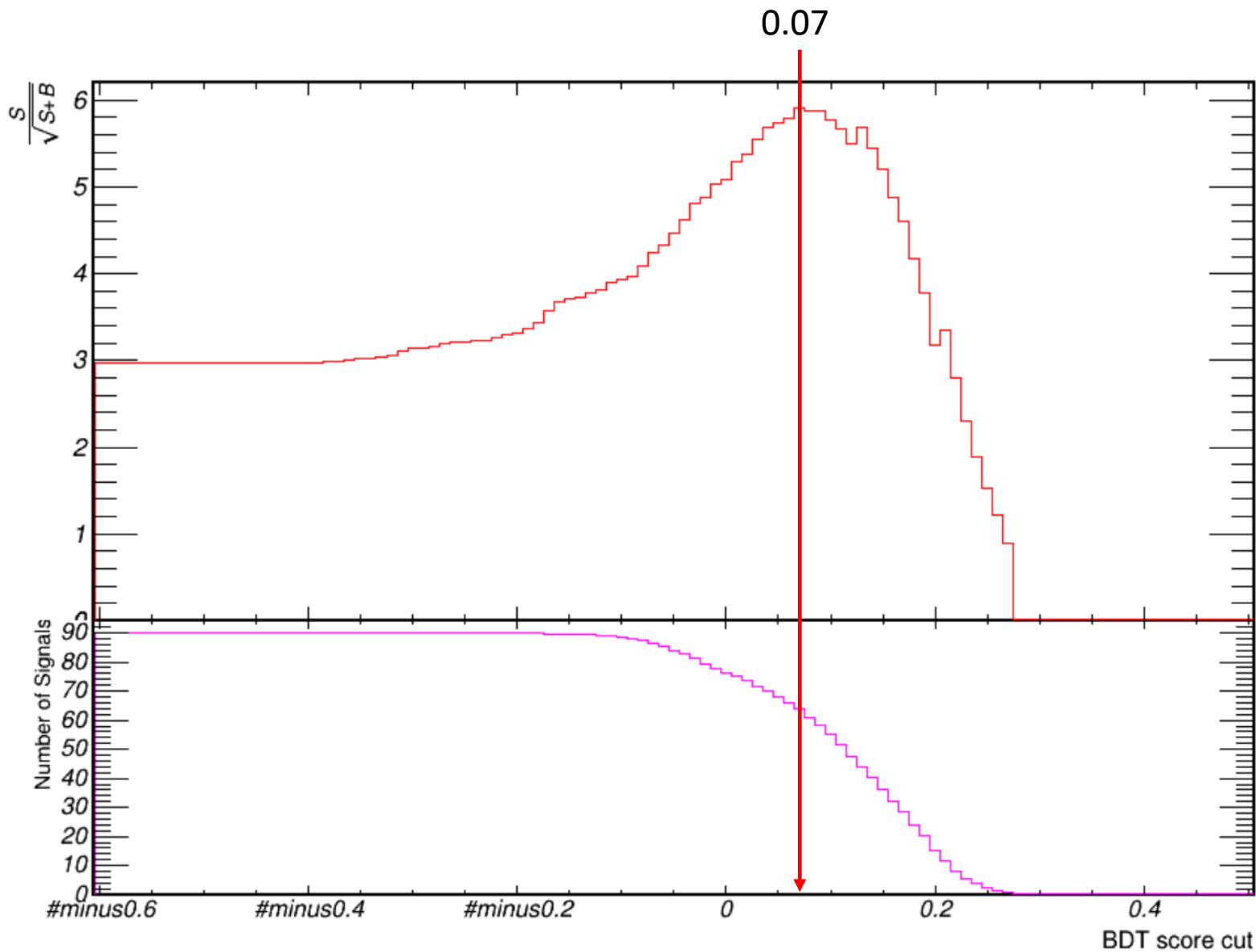
Project Overview

	mm(vvjj)	mm(jjvv)	vvHZZ	qq(vvmm)	qq(mmvv)
Cut-based	Done	Done	Done	Done	Done
Merge into framework	Done	Done	Done	Done	Done
BDT Study	Done	Done	Done	Done	Done
Put BDT code in package	Done	Done	Done	Done	Done
Optimize cuts again	Done	Done	Done	Done	Done
Higgs width fitting in the framework	Done	Done	Done	Done	Done
Combined fitting	Done				

	Status
Table & Plot style	Done
Draft	On-going
ee channel	On-going
EFT	On-going

BDT on $\mu\mu HZZ$ ($\nu\nu jj$)

$\Rightarrow \frac{S}{\sqrt{S+B}}$



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

➤ Cut Flow

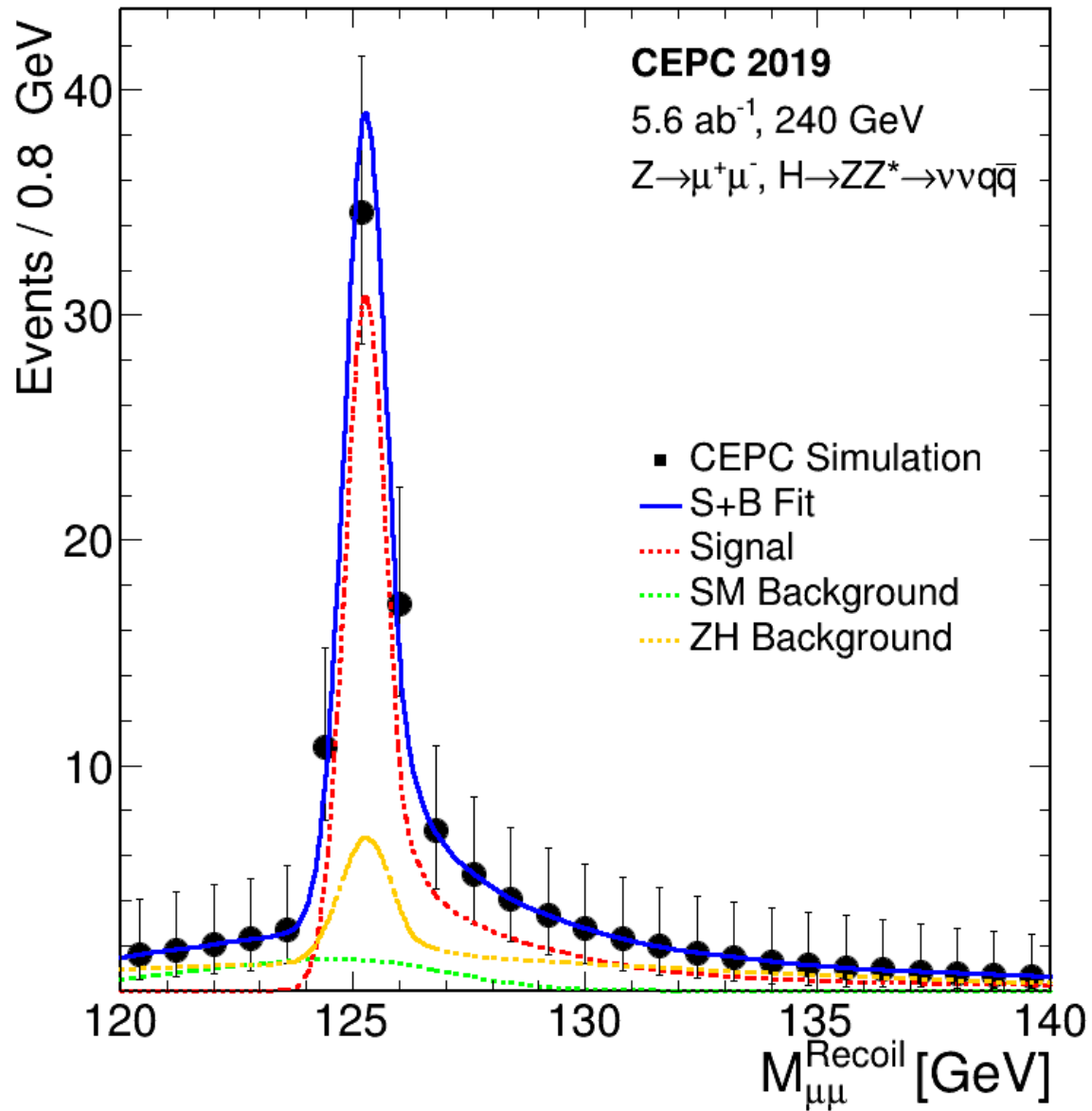
Cut	Signal	ZH background	2f background	4f background
<i>Expected</i>	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30494	480828	515424
<i>Signal or not</i>	211	30282	480828	515424
$M_{\text{missing}} > M_{\text{dijet}}$	107	1608	115062	28811
M_{dimuon}	95	725	73741	6833
$M_{\text{dimuon}}^{\text{rec}}$	95	706	7886	1359
$N(\text{pfo})$	94	336	3268	574
Pt_{visible}	89	312	342	168
<i>BDT score</i>	66	36	14	11

Table 1: $\mu^+\mu^-$ HZZ ($\nu\nu\text{jj}$) Cutflow (BDT)

BDT on $\mu\mu HZZ$ ($\nu\nu jj$)

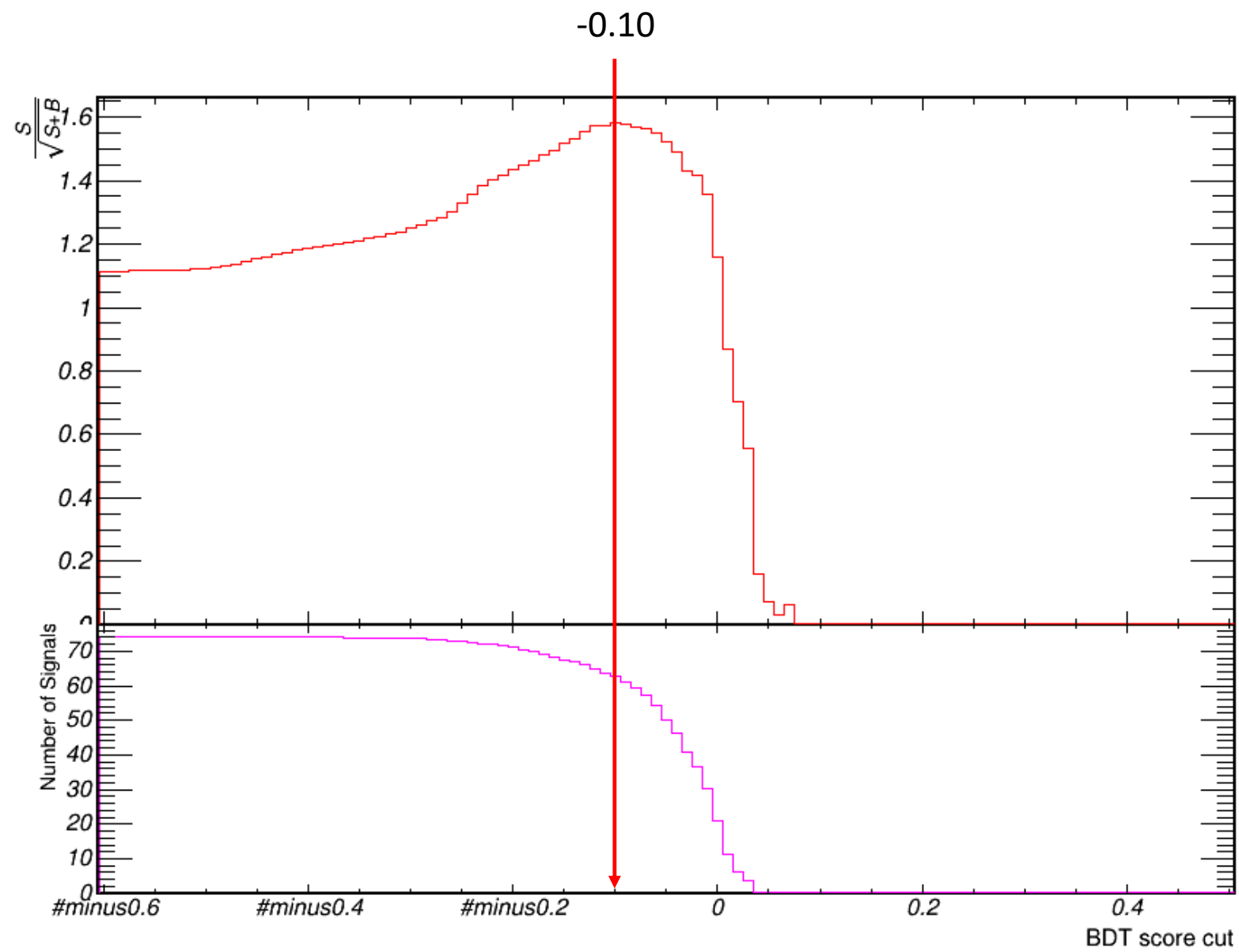
➤ Fitting Result

$$\frac{\Delta (\sigma (ZH) * BR(H \rightarrow ZZ *))}{\sigma (ZH) * BR(H \rightarrow ZZ *)} = 15.10\%$$



BDT on $\mu\mu HZZ$ (jj $\nu\nu$)

$\Rightarrow \frac{S}{\sqrt{S+B}}$



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

➤ Cut Flow

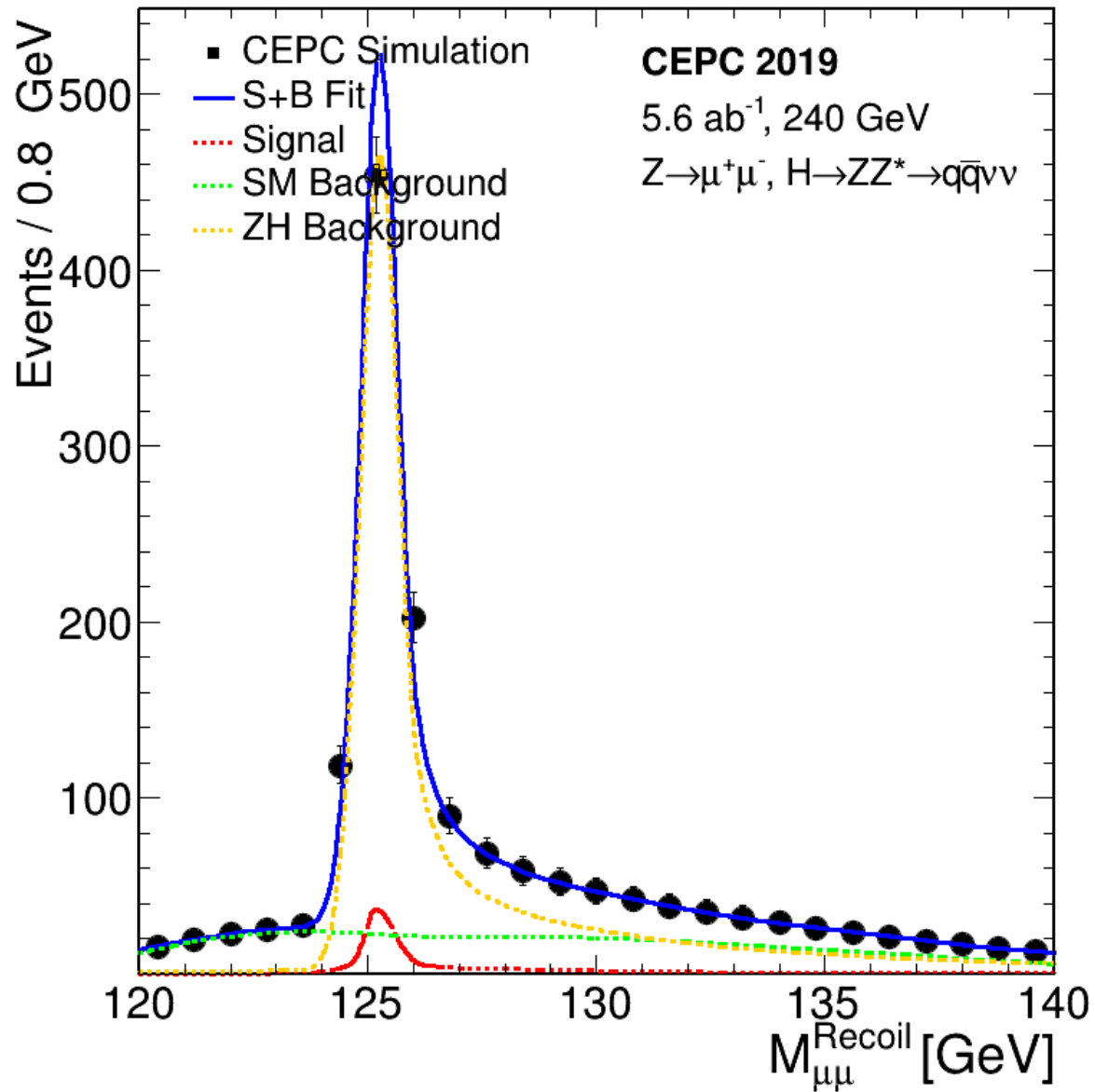
Cut	Signal	ZH background	2f background	4f background
<i>Expected</i>	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30494	480828	515424
<i>Signal or not</i>	211	30282	480828	515424
$M_{\text{missing}} < M_{\text{dijet}}$	103	28674	365766	486613
M_{dimuon}	92	22473	215445	239023
$M_{\text{dimuon}}^{\text{rec}}$	92	22379	17363	20611
$N(\text{pfo})$	89	16760	321	16304
Pt_{visible}	74	4341	59	1273
<i>BDT score</i>	63	1073	7	494

Table 2: $\mu^+\mu^-$ HZZ (jj $\nu\nu$) Cutflow (BDT)

BDT on $\mu\mu HZZ$ ($\nu\nu jj$)

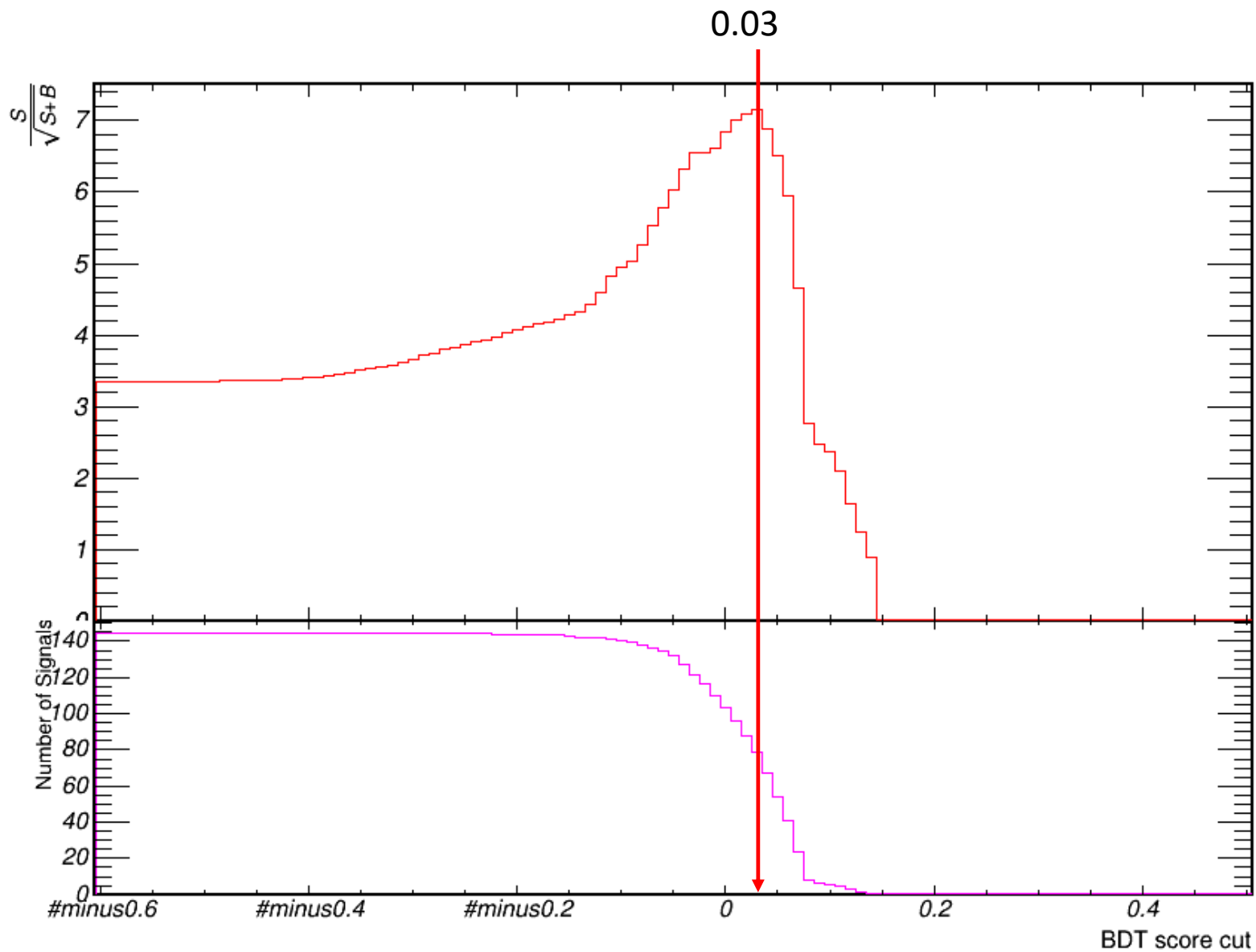
➤ Fitting Result

$$\frac{\Delta(\sigma(ZH) * BR(H \rightarrow ZZ^*))}{\sigma(ZH) * BR(H \rightarrow ZZ^*)} = 56.76\%$$



BDT on vvHZZ

➤ $\frac{S}{\sqrt{S+B}}$



BDT on $\nu\nu\text{HZZ}$

➤ Cut Flow

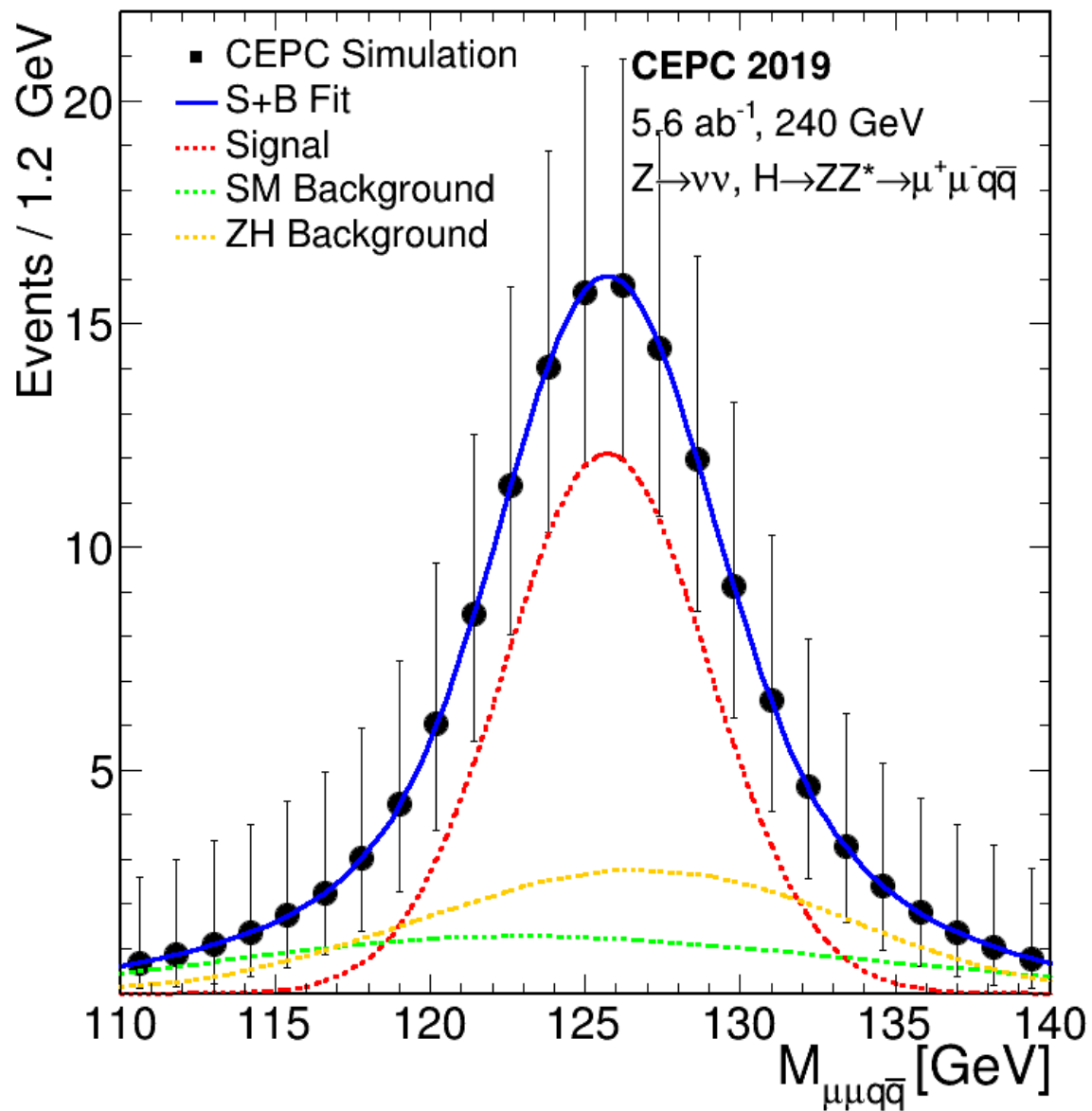
Cut	Signal	ZH background	2f background	4f background
<i>Expected</i>	6844	1140511	801811977	107203890
<i>Pre – selection</i>	238	30494	480828	515424
<i>Signal or not</i>	226	30268	480828	515424
<i>$N(pfo)$</i>	226	29861	152634	444218
<i>$M_{visible}$</i>	201	710	15429	10306
<i>$\cos \theta$</i>	144	510	367	831
<i>BDT score</i>	87	42	0	23

Table 3: $\nu\nu$ HZZ Cutflow (BDT)

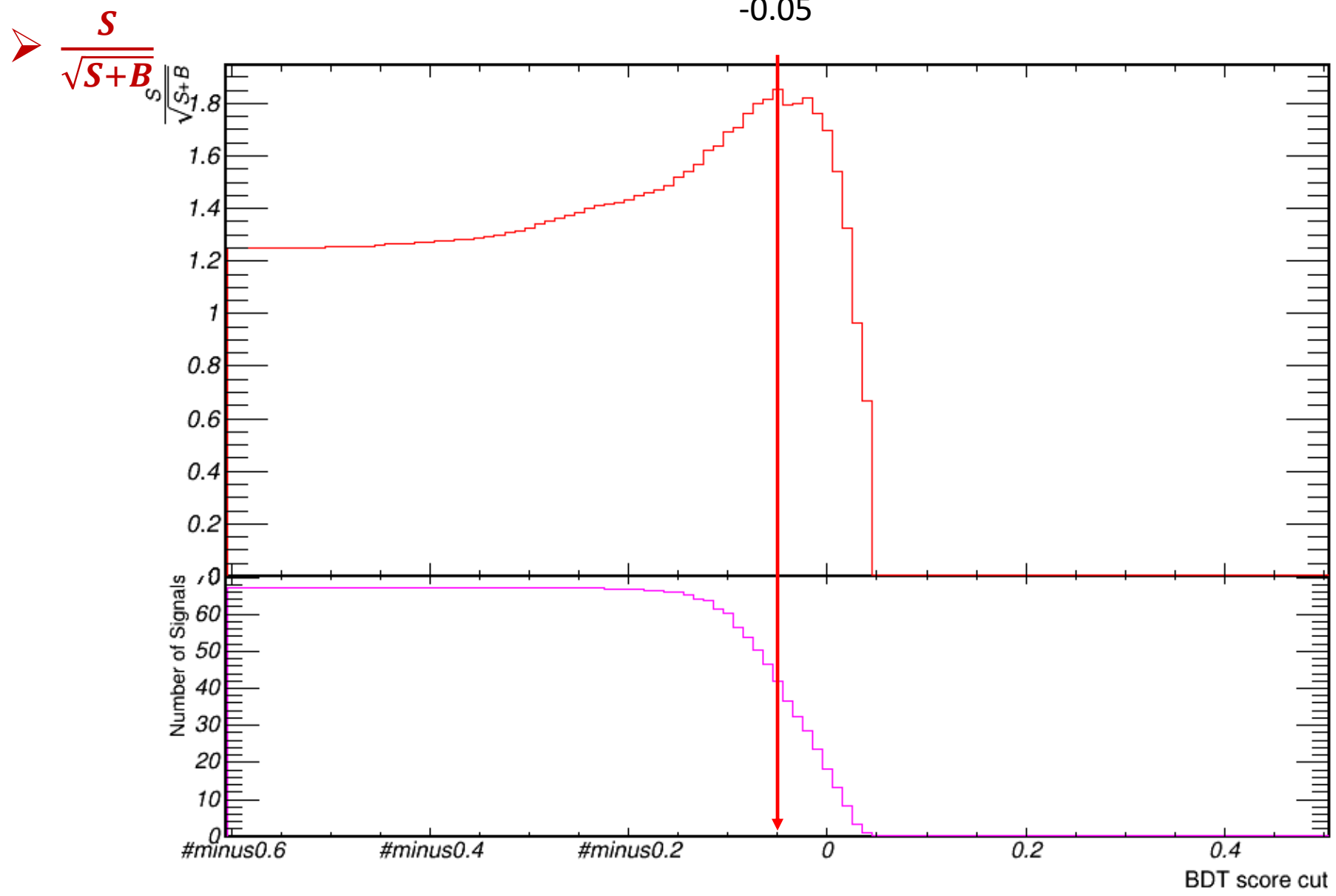
BDT on $\nu\nu\text{HZZ}$

➤ Fitting Result

$$\frac{\Delta(\sigma(ZH) * BR(H \rightarrow ZZ^*))}{\sigma(ZH) * BR(H \rightarrow ZZ^*)} = 13.45\%$$



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



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

➤ Cut Flow

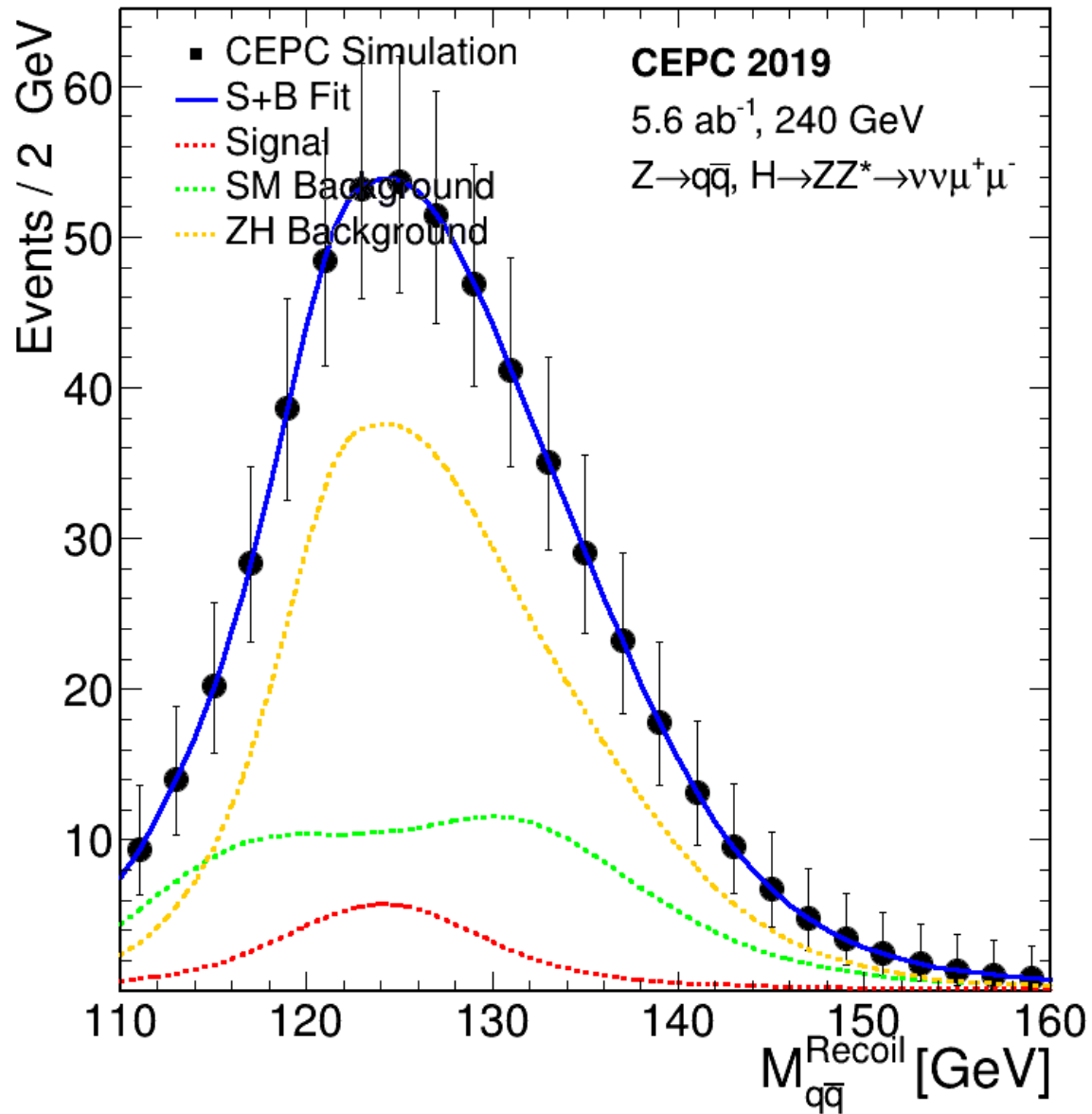
Cut	Signal	ZH background	2f background	4f background
<i>Expected</i>	20254	1140511	801811977	107203890
<i>Pre – selection</i>	826	30494	480828	515424
<i>Signal or not</i>	203	30291	480828	515424
$M_{missing} > M_{dimuon}$	94	3179	18606	40769
$N(pfo)$	91	2502	2050	15114
M_{dijet}	85	1793	14	6178
$\cos \theta$	67	1439	0	2175
$M_{visible}$	67	1345	0	1476
<i>BDT score</i>	46	377	0	233

Table 4: qq HZZ ($\nu\nu \mu^+ \mu^-$) Cutflow (BDT)

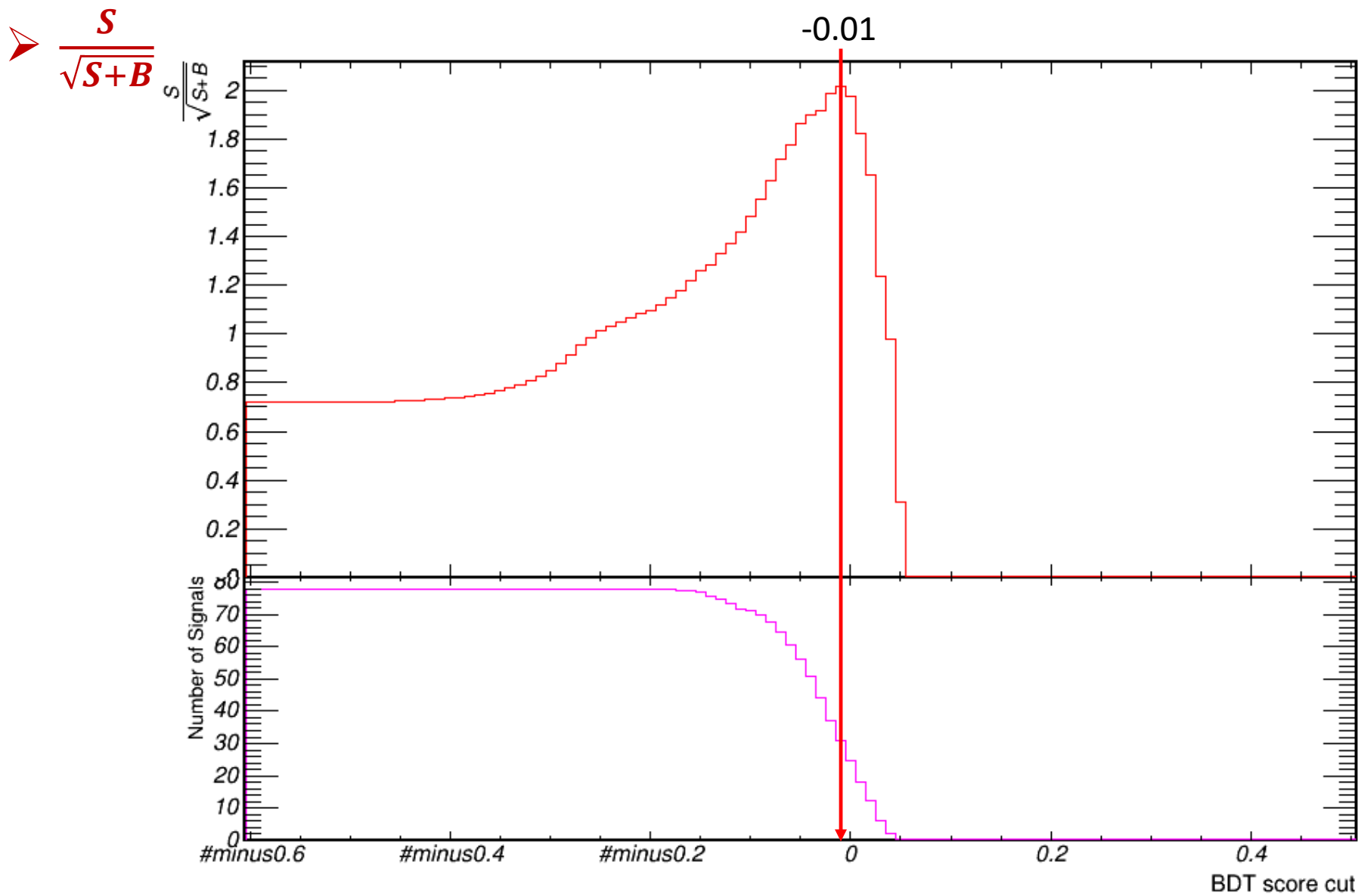
BDT on qqHZZ ($\nu\nu\mu\mu$)

➤ Fitting Result

$$\frac{\Delta(\sigma(ZH) * BR(H \rightarrow ZZ^*))}{\sigma(ZH) * BR(H \rightarrow ZZ^*)} = 50.89\%$$



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



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

➤ Cut Flow

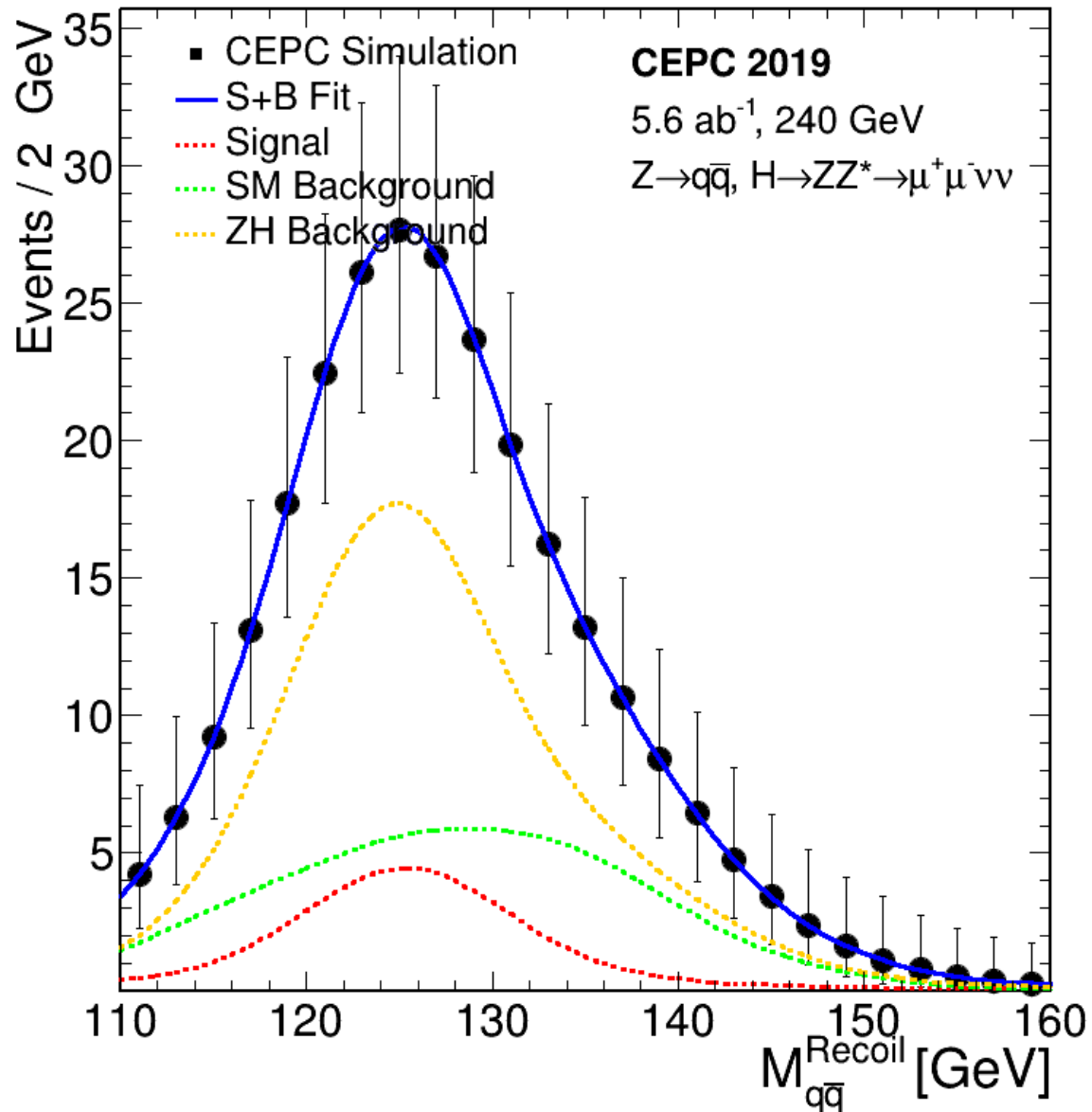
Cut	Signal	ZH background	2f background	4f background
<i>Expected</i>	20254	1140511	801811977	107203890
<i>Pre – selection</i>	826	30494	480828	515424
<i>Signal or not</i>	203	30291	480828	515424
$M_{missing} < M_{dimuon}$	108	27112	462222	474655
$N(pfo)$	106	21480	27891	332167
M_{dijet}	103	4833	141	265479
$\cos \theta$	80	3576	7	156099
$M_{visible}$	77	2913	0	8750
<i>BDT score</i>	37	167	0	148

Table 5: qq HZZ ($\mu^+\mu^- \nu\nu$) Cutflow (BDT)

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

➤ Fitting Result

$$\frac{\Delta(\sigma(ZH) * BR(H \rightarrow ZZ^*))}{\sigma(ZH) * BR(H \rightarrow ZZ^*)} = 45.60\%$$



Cut optimization on $\mu\mu HZZ$ ($\nu\nu jj$)

➤ Cut Flow

Previous

Cut	Signal	ZH background	2f background	4f background
Expected	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30524	481301	515955
<i>Signal or not</i>	211	30307	481301	515955
$M_{missing} > M_{dijet}$	107	1605	115175	28838
M_{dimuon}	95	726	73813	6836
M_{dimuon}^{rec}	95	707	7894	1360
$N(pfo)$	94	336	3271	574
$Pt_{visible}$	89	312	342	168
$Angle_{min}$	85	298	283	139
$M_{missing}$ and M_{dijet}	62	80	254	46
<i>Single Jet</i>	54	67	0	9

Optimized

cut	signal	zh background	2f background	4f background
<i>Expected</i>	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30494	480828	515448
<i>Signal or not</i>	211	30282	480828	515448
$M_{missing} > M_{dijet}$	107	1608	115062	28809
$M_{\mu^+\mu^-}$	95	725	73741	6830
M_{dimuon}^{rec}	93	671	4911	1032
$N(pfo)$	89	253	1396	324
$Pt_{visible}$	85	235	261	77
$Angle_{min}$	81	225	216	64
$M_{missing}, M_{dijet}$	63	65	0	6
$Pt_{jet1,2}, E_{jet1,2}$	56	56	0	3
<i>not $qqHZZ$</i>	56	56	0	3
<i>not $\nu\nu HZZ$</i>	47	22	0	3

Cut optimization on $\mu\mu HZZ$ (jjvv)

➤ Cut Flow

Previous

Cut	Signal	ZH background	2f background	4f background
Expected	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30524	481301	515955
<i>Signal or not</i>	211	30307	481301	515955
$M_{missing} > M_{dijet}$	103	28701	366125	487117
M_{dimuon}	92	22495	215657	239256
M_{dimuon}^{rec}	92	22401	17380	20630
$N(pfo)$	89	16776	321	16319
$Pt_{visible}$	74	4345	59	1273
$Angle_{min}$	71	4186	59	1216
$M_{missing}$ and M_{dijet}	47	866	0	276
<i>Single Jet</i>	42	716	0	260

Optimized

cut	signal	zh background	2f background	4f background
<i>Expected</i>	1000	1140511	801811977	107203890
<i>Pre – selection</i>	616	30494	480828	515448
<i>Signal or not</i>	211	30282	480828	515448
$M_{dijet} < M_{missing}$	103	28674	365766	486638
$M_{\mu^+\mu^-}$	92	22473	215445	239022
M_{dimuon}^{rec}	90	21802	13226	17787
$N(pfo)$	87	16327	186	14406
$Pt_{visible}$	66	3423	0	744
$Angle_{min}$	64	3294	0	711
$M_{missing}, M_{dijet}$	43	703	0	200
$Pt_{jet1,2}, E_{jet1,2}$	38	589	0	189
<i>not qqHZZ</i>	35	510	0	175
<i>not $\nu\nu HZZ$</i>	35	510	0	175

Cut optimization on $\nu\nu HZZ$

➤ Cut Flow

Previous

Cut	Signal	ZH background	2f background	4f background
Raw events	6844	1140511	801811977	107203890
<i>Pre – selection</i>	238	30494	480828	515425
<i>Signal or not</i>	226	30268	480828	515425
$N(pfo)$	198	10580	61902	268709
$115\text{GeV} < M_{visible} < 135\text{GeV}$	175	450	9694	6533
$ \cos\theta < 0.9$	126	328	132	414
$130\text{GeV} < M_{dimuon}^{rec} < 220\text{GeV}$	123	285	125	366
$43\text{GeV} < P_{visible} < 60\text{GeV}$	109	157	6	105
$10\text{GeV} < M_{dijet} < 100\text{GeV}$	106	150	6	100
$E_{leading\ jet}$	99	122	0	54
$E_{subleading\ jet}$	97	116	0	46
$Angle_{\mu j}$	92	103	0	34
$13\text{GeV} < M_{dimuon} < 100\text{GeV}$	92	100	0	33
$\cos\theta_{visible}$	92	100	0	33
$80\text{GeV} < M_{visible}^{rec} < 107\text{GeV}$	87	89	0	30
$not\ 120\text{GeV} < M_{dimuon}^{rec} < 130\text{GeV}$	75	65	0	30
$not\ 120\text{GeV} < M_{dijet}^{rec} < 130\text{GeV}$	71	46	0	26

Optimized

cut	signal	zh background	2f background	4f background
<i>Expected</i>	6844	1140511	801811977	107203890
<i>Pre – selection</i>	238	30494	480828	515424
<i>Signal or not</i>	226	30268	480828	515424
$N(pfo)$	198	10580	61902	268708
$M_{visible}$	175	450	9694	6533
$\cos\theta$	126	328	132	414
M_{dimuon}	123	211	118	239
$P_{visible}$	109	87	0	55
M_{dijet}	106	77	0	33
$E_{leading\ jet}$	99	61	0	18
$E_{subleading\ jet}$	97	60	0	15
$Angle_{\mu j}$	92	57	0	11
$M_{\mu^+\mu^-}$	92	49	0	11
$\cos\theta_{visible}$	92	49	0	11
$M_{visible}^{rec}$	87	46	0	9
$not\ \mu^+\mu^- HZZ$	79	31	0	9
$not\ qqHZZ$	77	21	0	8

Cut optimization on qqHZZ ($\nu\nu\mu\mu$)

➤ Cut Flow

cut	signal	zh background	2f background	4f background
Raw events	20254	1140511	801811977	107203890
<i>Pre – selection</i>	826	30494	480828	515425
<i>Signal or not</i>	203	30271	480828	515425
$M_{\text{missing}} > M_{\text{dimuon}}$	94	3167	18606	40769
$N(pfo)$	91	2502	2050	15114
M_{visible}	90	2220	557	6573
$\cos\theta$	72	1797	59	2156
$M_{\text{dimuon}}^{\text{rec}}$	70	1506	14	1942
P_{visible}	69	1459	14	1843
M_{dijet}	67	1207	0	1526
E_{leading}	67	1191	0	1203
$E_{\text{subleading}}$	67	1186	0	1119
$\text{Angle}_{\mu j}$	67	1165	0	1003
M_{dimuon}	67	1105	0	970
$\cos\theta_{\text{visible}}$	64	1048	0	850
$M_{\text{visible}}^{\text{rec}}$	64	973	0	817
$P_{t\text{visible}}$	63	962	0	775
<i>not $\mu^+\mu^-HZZ$</i>	63	962	0	775
<i>not $\nu\nu HZZ$</i>	56	884	0	744

Previous

Optimized

cut	signal	zh background	2f background	4f background
<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
$N(pfo)$	91	2502	2050	15114
M_{visible}	76	1326	118	3582
$\cos\theta$	60	1061	0	1131
$M_{\text{dimuon}}^{\text{rec}}$	45	379	0	659
P_{visible}	43	348	0	583
M_{dijet}	41	289	0	502
$E_{\text{leading jet}}$	40	277	0	322
$E_{\text{subleading jet}}$	39	270	0	268
$\text{Angle}_{\mu j}$	39	264	0	240
M_{dimuon}	39	246	0	229
$\cos\theta_{\text{visible}}$	37	233	0	202
$M_{\text{visible}}^{\text{rec}}$	37	210	0	119
$P_{t\text{visible}}$	37	210	0	119
<i>not $\mu^+\mu^-HZZ$</i>	37	210	0	119
<i>not ν</i>	30	166	0	110

Cut optimization on qqHZZ ($\mu\mu\nu\nu$)

➤ Cut Flow

cut	signal	zh background	2f background	4f background
Expected	20254	1140511	801811977	107203890
<i>Pre – selection</i>	826	30494	480828	515425
<i>Signal or not</i>	203	30271	480828	515425
$M_{\dimuon} > M_{\text{missing}}$	108	27103	462222	474656
$N(pfo)$	106	21479	27891	332167
M_{visible}	102	5496	2277	46449
$\cos\theta$	82	4051	0	13096
$M_{\dimuon}^{\text{rec}}$	77	3492	0	2617
P_{visible}	77	3461	0	2507
M_{dijet}	75	2795	0	1841
$E_{\text{leading jet}}$	74	2584	0	1466
$E_{\text{subleading jet}}$	73	2544	0	1397
$\text{Angle}_{\mu j}$	68	2157	0	963
$M_{\dimuon}$	66	1832	0	772
$\cos\theta_{\text{visible}}$	64	1734	0	570
$M_{\text{visible}}^{\text{rec}}$	50	844	0	395
P_{visible}	49	822	0	369
<i>not $\mu^+\mu^-HZZ$</i>	44	335	0	324
<i>not $\nu\nu HZZ$</i>	44	335	0	324

Previous

Optimized

cut	signal	zh background	2f background	4f background
<i>Expected</i>	20254	1140511	801811977	107203890
<i>Pre – selection</i>	826	30494	480828	515424
<i>Signal or not</i>	203	30291	480828	515424
$M_{\dimuon} > M_{\text{missing}}$	108	27112	462222	474655
$N(pfo)$	104	21274	17185	318984
M_{visible}	86	3138	261	25231
$\cos\theta$	69	2345	0	6503
$M_{\dimuon}^{\text{rec}}$	50	626	0	708
P_{visible}	48	542	0	572
M_{dijet}	45	325	0	404
$E_{\text{leading jet}}$	44	302	0	277
$E_{\text{subleading jet}}$	44	300	0	238
$\text{Angle}_{\mu j}$	43	272	0	217
$M_{\dimuon}$	39	177	0	101
$\cos\theta_{\text{visible}}$	38	165	0	57
$M_{\text{visible}}^{\text{rec}}$	33	149	0	51
P_{visible}	33	147	0	45
<i>not $\mu^+\mu^-HZZ$</i>	33	147	0	45
<i>not $\nu\nu HZZ$</i>	33	147	0	45

BDT on $\mu\mu HZZ$ ($\nu\nu jj$)

➤ Fitting Result

Channel	BDT (%)	Cut (previous) (%)	Cut (new) (%)
$\mu\mu H\nu\nu jj$	15.10	17.82	16.89
$\mu\mu H jj\nu\nu$	56.76	71.09	71.62
$\nu\nu HZZ$	13.45	15.41	13.22
$qq H\nu\nu\mu\mu$	50.89	65.23	54.19
$qq H\mu\mu\nu\nu$	45.60	54.17	42.74
Combined	9.49	11.09	9.85

Summary

- **BDT study for all channels completed**
- **BDT merged into the frame work (local)**
- **All channels' cuts optimized**

Next to do

- **Update framework on github (framework optimization, new cuts, fitting code, etc.)**
- **Merge request for BDT part**
- **Work on the draft**