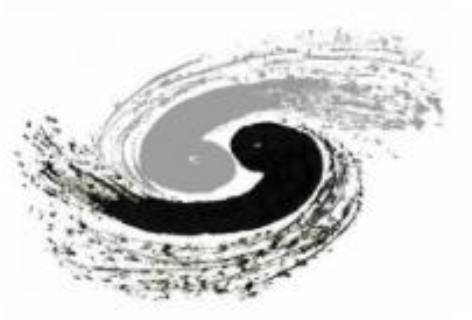


H->WW Analysis*

Liao Libo (HZNU & IHEP)

Contents

1 Introduction

Target:

1 Measurement of Br(H->WW*).
2 Measurement of width of Higgs.
3 Test the performance of CEPC detector.

Current:

Z Decay / W Decay	ll	νν	ττ	qq
lνlν				
lνqq				
qqqq				
τ+X				

Green: done
Purple: undone
Blue: SJTU
Red: depend on Tau finder

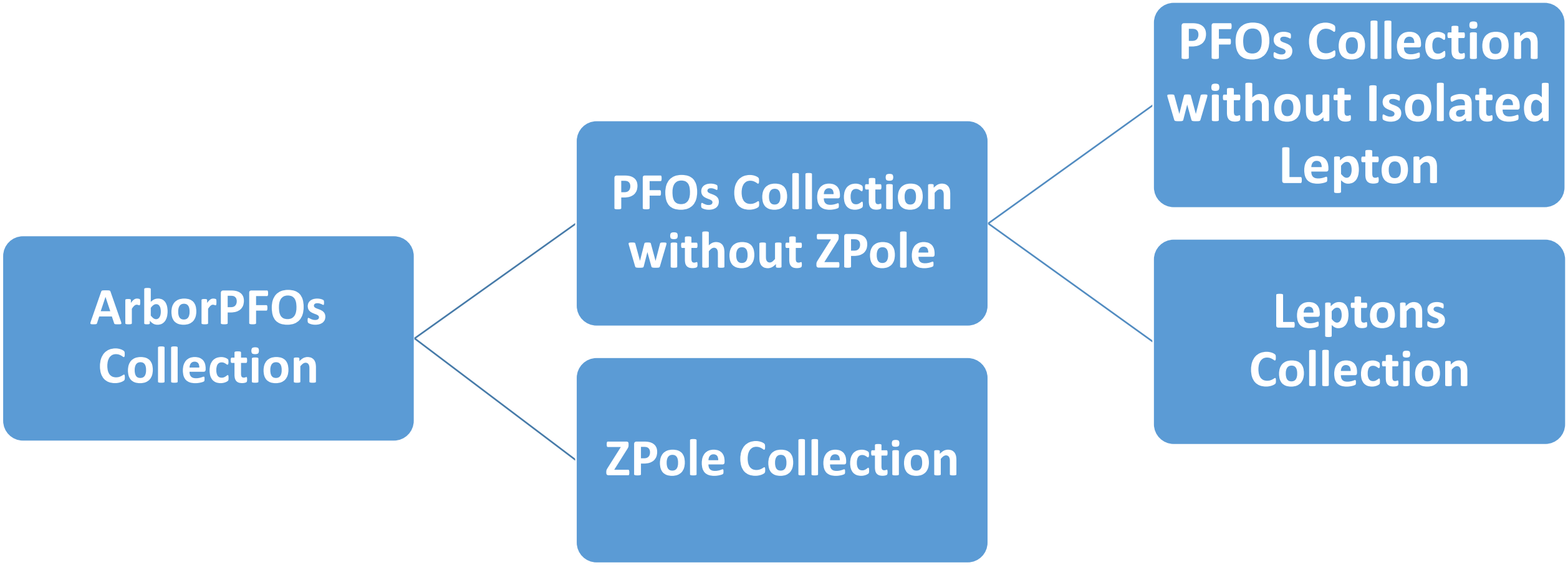
2 Monte Carlo Sample

Generator: Whizard 1.95 (with ISR, Luminosity: 5ab^{-1}, M_H=125 GeV)

Background: 2-fermion (lepton or quark pairs)
4-fermion (WW, ZZ, Single W and Single Z)
The all background are pre-selected

Simulation: Mokka (CEPC_V1)
Reconstruction: Arbor (V3.1_KD)

3 Analysis of subchannels



3.1 Analysis of μμH

$H \to WW^* \to \mu\nu\mu\nu$

Category	Signal	ZH	ZZ	Single Z
Total	348	34624	5499688	7788916
$N_{ZPole} = 2; N_{Isolep} = 2; l = \mu$	77	129	5309	0
80 GeV $< M_{Inv}^{\mu^+\mu^-} <$ 100 GeV	73	124	4143	0
120 GeV $< M_{Rec}^{\mu^+\mu^-} <$ 150 GeV	66	118	2548	0
$N_{Remain} < 3$	66	56	2442	0
10 GeV $< M_{Inv}^{\mu^+\mu^-} <$ 65 GeV	58	46	411	0
40 GeV $< E_{Missing} <$ 100 GeV	55	26	231	0
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 5$	54	7	226	0
Total $P_T > 20$ GeV	52	3	3	0

Table 2: Cut chain of $\mu\mu$ final state

$H \to WW^* \to evev$

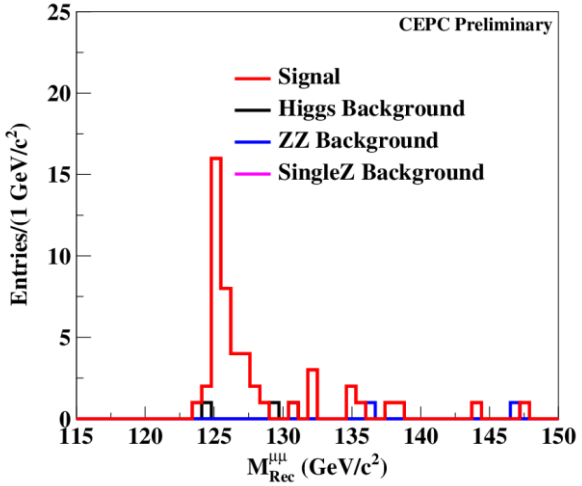
Category	Signal	ZH	ZZ	Single Z
Total	348	34624	5499688	7788916
$N_{ZPole} = 2; N_{Isolep} = 2; l = e$	61	114	4	1807
80 GeV $< M_{Inv}^{\mu^+\mu^-} <$ 100 GeV	53	105	2	1165
120 GeV $< M_{Rec}^{\mu^+\mu^-} <$ 150 GeV	52	101	1	726
$N_{Remain} < 3$	51	60	0	692
10 GeV $< M_{Inv}^{e^+e^-} <$ 65 GeV	49	47	0	49
35 GeV $< E_{Missing} <$ 100 GeV	49	27	0	31
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 6$	39	4	0	24
Total $P_T > 20$ GeV	36	4	0	0

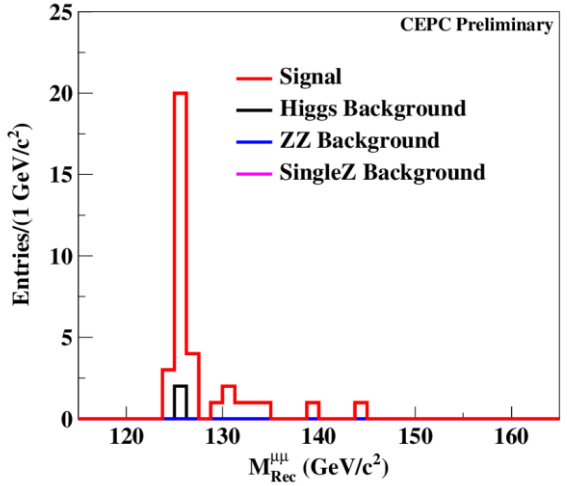
Table 3: Cut chain of ee final state

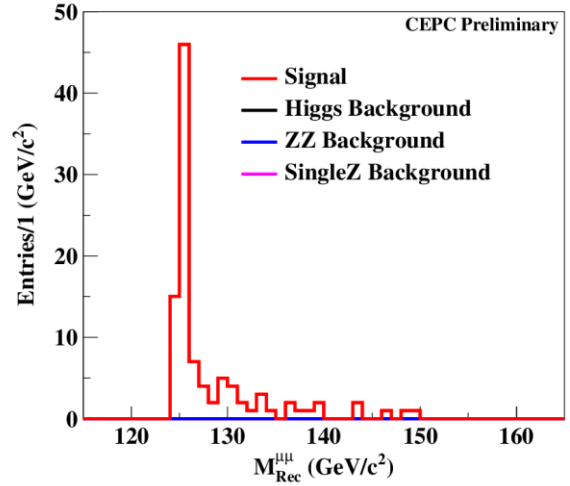
$H \to WW^* \to e\nu\mu\nu$

Category	Signal	ZH	ZZ	Single Z
Total	348	34624	5499688	7788916
$N_{ZPole} = 2; N_{Isolep} = 2; l_1 = e, l_2 = \mu$	147	136	32	1
80 GeV $< M_{Inv}^{\mu^+\mu^-} <$ 100 GeV	134	119	21	0
120 GeV $< M_{Rec}^{\mu^+\mu^-} <$ 150 GeV	130	117	15	0
$N_{Remain} < 3$	130	89	3	0
10 GeV $< M_{Inv}^{e\mu} <$ 65 GeV	123	79	3	0
35 GeV $< E_{Missing} <$ 110 GeV	123	68	2	0
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 4$	105	0	0	0

Table 1: Cut chain of $e\mu$ final state



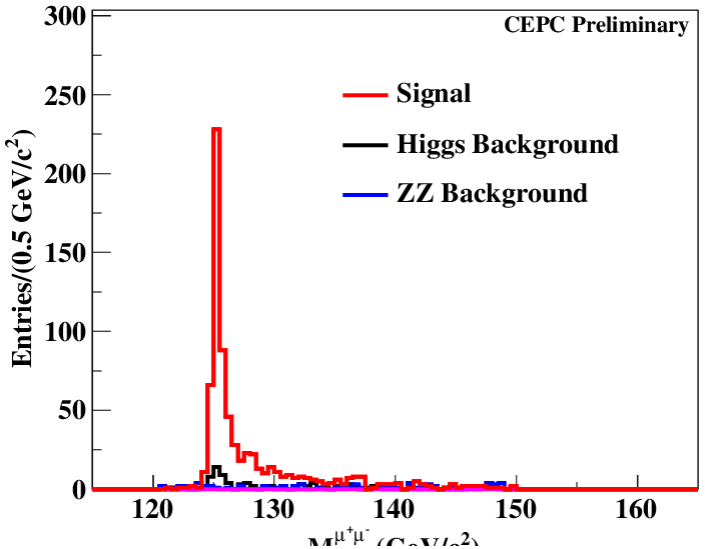




Category	Signal	ZH	ZZ	Single Z
Total	2215	32291	5499688	7788916
$N_{ZPole} = 2; N_{Isolep} = 1; N_{Jets} = 2; l = \mu$	988	1667	508	0
$80\ \mathrm{GeV}/c^2 < M_{Inv}^{\mu^+\mu^-} < 100\ \mathrm{GeV}/c^2$	879	1455	296	0
$120\ \mathrm{GeV}/c^2 < M_{Rec}^{\mu^+\mu^-} < 150\ \mathrm{GeV}/c^2$	853	1412	170	0
$M_{Missing}^2 < 2000\ \mathrm{GeV}^2/c^4$	837	1074	142	0
$E_\mu > 15$ GeV	741	292	93	0
$15\ \mathrm{GeV}/c^2 < M_{Rec}^{di-Jet} < 95\ \mathrm{GeV}/c^2$	724	129	78	0
$\lvert\delta E_{Jets}\rvert < 60$ GeV	717	86	73	0

Table 5: Cut chain of semi leptonic decay of $H \to WW^* \to \mu\nu qq$

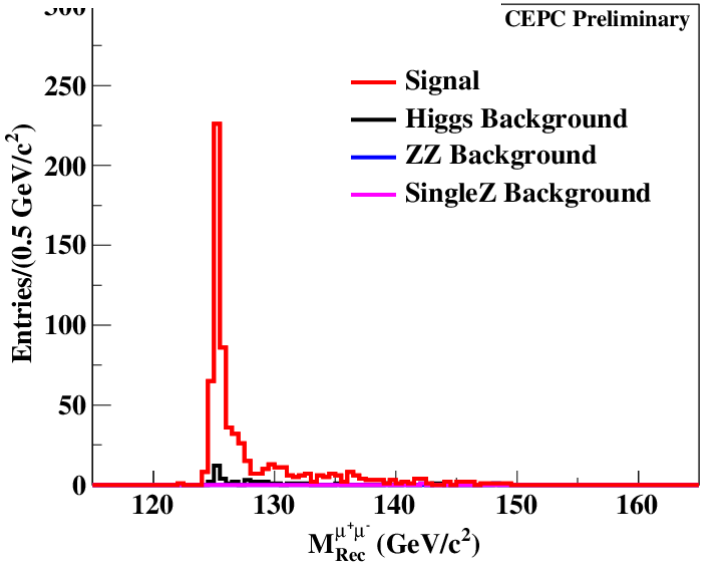
$H \to WW^* \to \mu\nu qq$



Category	Signal	ZH	ZZ	Single Z
Total	2215	32291	5499688	7788916
$N_{ZPole} = 2; N_{Isolep} = 1; N_{Jets} = 2; l = e$	864	881	83	824
$80\ \mathrm{GeV}/c^2 < M_{Inv}^{\mu^+\mu^-} < 100\ \mathrm{GeV}/c^2$	774	738	52	472
$120\ \mathrm{GeV}/c^2 < M_{Rec}^{\mu^+\mu^-} < 150\ \mathrm{GeV}/c^2$	755	717	31	314
$M_{Missing}^2 < 2000\ \mathrm{GeV}^2/c^4$	743	406	11	308
$10\ \mathrm{GeV} < E_e < 70$ GeV	699	227	6	210
$15\ \mathrm{GeV}/c^2 < M_{Rec}^{di-Jet} < 95\ \mathrm{GeV}/c^2$	676	90	3	99
$N_{Remain} > 6$	670	65	3	4
$\lvert\delta E_{Jets}\rvert < 60$ GeV	663	43	1	1

Table 4: Cut chain of semi leptonic decay of $H \to WW^* \to evqq$

$H \to WW^* \to evqq$



3.1 Analysis of μμH

Sub channel	Yield	Objects	Events after selection		Accu.
			Signal	Bkg	
$e\nu e\nu$	88	76(86%)	36(41%)	6	17.57%
$\mu\nu\mu\nu$	89	80(90%)	52(58%)	4	14.65%
$\mu\nu e\nu$	174	157(90%)	105(60%)	0	9.76%
$e\nu qq$	1105	1042(94.3%)	663(60.0%)	45	4.02%
$\mu\nu qq$	1110	1056(95.1%)	717(64.6%)	159	4.13%

3.2 Analysis of eeH

Efficiency of pre-selection

Condition for Full leptonic:

1)InvMass: 55-110; 2)RecMass: 90-150; 3)Lepton: =4

Bkg	Single W	Single Z	WW	ZZ
Total Event (before pre-selection)	$2.57*10^7$	$2.37*10^7$	$7.74*10^7$	$5.17*10^6$
Total Event (after pre-selection)	9	67758	1	98
efficiency	~0	0.29%	~0	0.0019%

Condition for Semi leptonic:

1)InvMass: 55-110; 2)RecMass: 90-150; 3)Lepton: =3; 4)Total No. > 5

Bkg	Single W	Single Z	WW	ZZ
Total Event (before pre-selection)	$2.57*10^7$	$2.37*10^7$	$7.74*10^7$	$5.17*10^6$
Total Event (after pre-selection)	405	66150	40	109
efficiency	0.0016%	0.28%	~0	0.0021%

3.1 Analysis of μμH

$H \to WW^* \to \mu\nu\mu\nu$

Category	Signal	ZH	Single Z
Total	82	37825	67758
$N_{ZPole} = 2; N_{Isolep} = 2; l_1 = \mu, l_2 = \mu$	63	175	4674
$80\ \mathrm{GeV} < M_{Inv}^{e^+e^-} < 100\ \mathrm{GeV}$	53	129	2340
$120\ \mathrm{GeV} < M_{Rec}^{e^+e^-} < 150\ \mathrm{GeV}$	51	121	748
$N_{Remain} < 5$	51	71	729
$0\ \mathrm{GeV} < M_{Mis}^2 < 6000\ \mathrm{GeV}$	50	41	471
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 5$	50	19	441
$10\ \mathrm{GeV} < M_{Inv}^{ee} < 60\ \mathrm{GeV}$	49	6	115
$P_T > 10\ \mathrm{GeV}$	48	6	45
$Cos\theta_{(eeofZ)} < 0.9$	44	2	26

Table 7: Cut chain of $\mu\mu$ final state

$H \to WW^* \to e\nu e\nu$

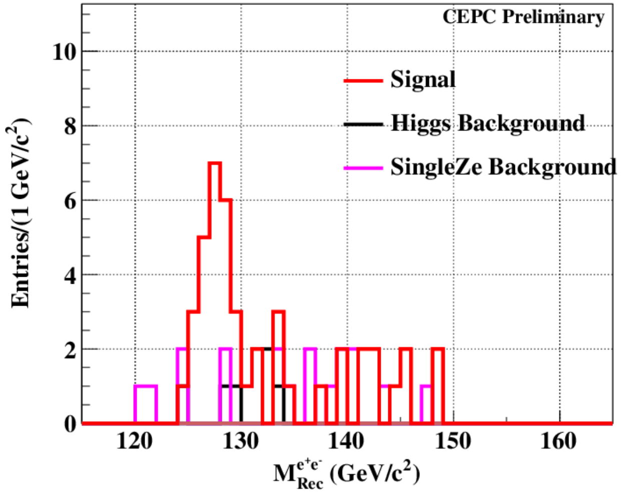
Category	Signal	ZH	Single Z
Total	91	37825	67758
$N_{ZPole} = 2; N_{Isolep} = 2; l_1 = e, l_2 = e$	60	149	18179
$80\ \mathrm{GeV} < M_{Inv}^{e^+e^-} < 100\ \mathrm{GeV}$	55	122	10795
$120\ \mathrm{GeV} < M_{Rec}^{e^+e^-} < 150\ \mathrm{GeV}$	48	115	5045
$N_{Remain} < 4$	46	71	4873
$100\ \mathrm{GeV} < M_{Mis}^2 < 6000\ \mathrm{GeV}$	42	37	1555
$Cos\theta_{ee} > -0.2$	38	26	776
$P_T > 20\ \mathrm{GeV}$	31	19	67
$Cos\theta_{(eeofZ)} < 0.7$	24	14	36
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 11$	22	1	21
$M_{Inv}^{ee} < 60\ \mathrm{GeV}$	22	1	14

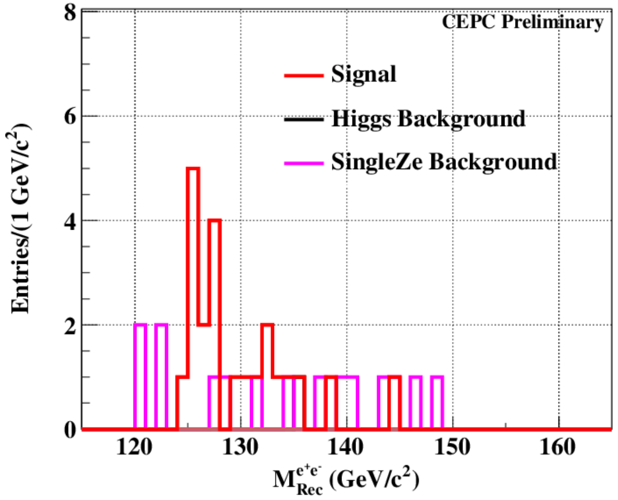
Table 6: Cut chain of ee final state

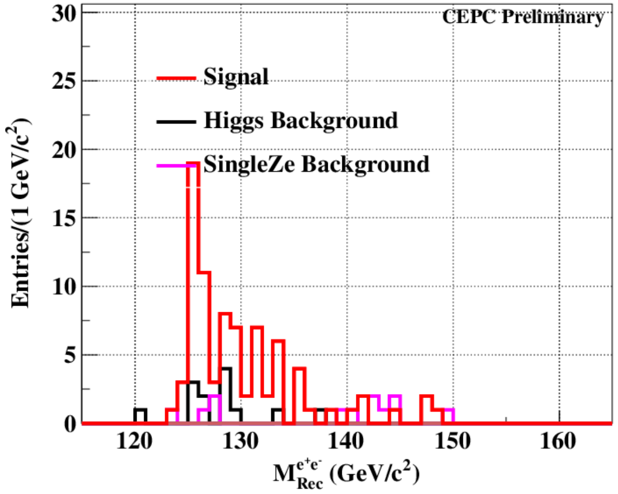
$H \to WW^* \to e\nu\mu\nu$

Category	Signal	ZH	Single Z
Total	178	37825	67758
$N_{ZPole} = 2; N_{Isolep} = 2; l_1 = e, l_2 = \mu$	124	197	1069
$80\ \mathrm{GeV} < M_{Inv}^{e^+e^-} < 100\ \mathrm{GeV}$	106	147	585
$120\ \mathrm{GeV} < M_{Rec}^{e^+e^-} < 150\ \mathrm{GeV}$	98	139	188
$N_{Remain} < 4$	97	106	172
$0\ \mathrm{GeV} < M_{Mis}^2 < 5500\ \mathrm{GeV}$	93	49	72
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 5$	81	8	8

Table 8: Cut chain of $e\mu$ final state







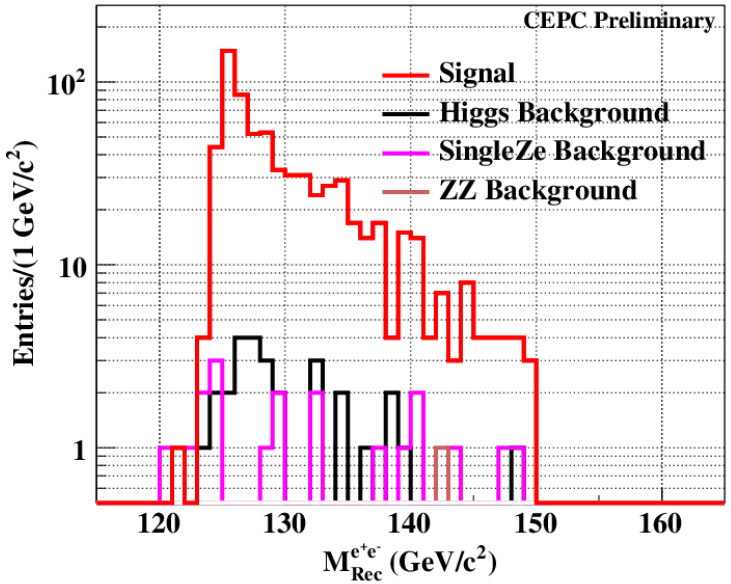
Category	Signal	ZH	ZZ	Single Z
Total	1182	35773	109	66150
$N_{ZPole} = 2; N_{Isolep} = 1; N_{Jets} = 2; l = e$	916	1450	11	7965
$80\ \mathrm{GeV}/c^2 < M^{e^+e^-}_{Inv} < 100\ \mathrm{GeV}/c^2$	728	947	4	4032
$120\ \mathrm{GeV}/c^2 < M^{e^+e^-}_{Rec} < 150\ \mathrm{GeV}/c^2$	687	879	2	1386
$7 < N_{Remain} < 30$	657	350	1	374
$10\ \mathrm{GeV}/c^2 < M^{di-Jet}_{Rec} < 85\ \mathrm{GeV}/c^2$	630	184	1	274
$Btag < 1$	628	132	1	142
$M^2_{Missing} < 4000\ \mathrm{GeV}^2/c^4$	626	101	1	137
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 40$	617	85	1	130
$\lvert\delta E_{Jets}\rvert < 60\ \mathrm{GeV}$	612	75	1	112

Table 9: Cut chain of semi leptonic decay of $H \to WW^* \to evqq$

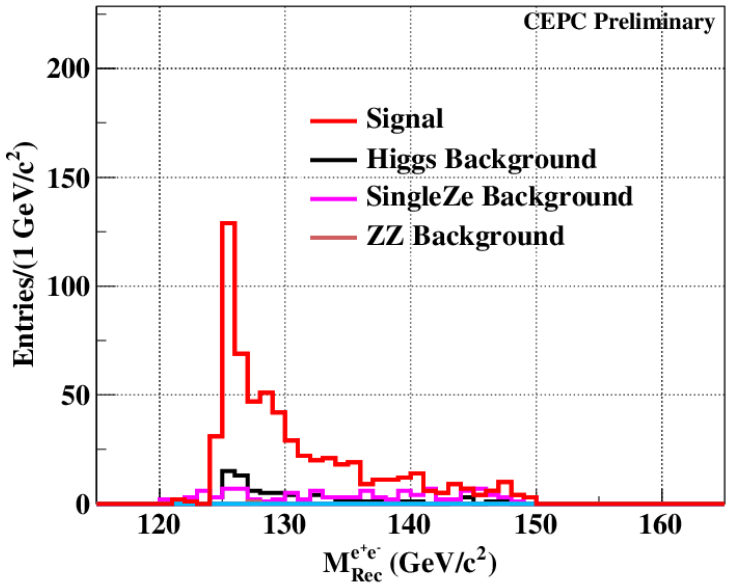
Category	Signal	ZH	ZZ	Single Z
Total	1221	35773	109	66150
$N_{ZPole} = 2; N_{Isolep} = 1; N_{Jets} = 2; l = \mu$	1048	1195	33	19965
$80\ \mathrm{GeV}/c^2 < M^{e^+e^-}_{Inv} < 100\ \mathrm{GeV}/c^2$	782	1447	10	4901
$120\ \mathrm{GeV}/c^2 < M^{e^+e^-}_{Rec} < 150\ \mathrm{GeV}/c^2$	751	1394	6	1331
$7 < N_{Remain} < 30$	722	705	1	328
$15\ \mathrm{GeV}/c^2 < M^{di-Jet}_{Rec} < 95\ \mathrm{GeV}/c^2$	693	274	1	200
$Btag < 1$	689	147	1	81
$M^2_{Missing} < 3000\ \mathrm{GeV}^2/c^4$	686	104	1	68
$\sqrt{(\frac{D0}{sigD0})^2 + (\frac{Z0}{sigZ0})^2} < 5$	684	28	1	20

Table 10: Cut chain of semi leptonic decay of $H \to WW^* \to \mu vqq$

$H \to WW^* \to \mu vqq$



$H \to WW^* \to evqq$



3.2 Analysis of eeH

Sub channel	Yield	Objects	Events after selection		Accu.
			Signal	Bkg	
$e\nu e\nu$	91	62(68.13%)	22(18.68%)	16	34.30%
$\mu\nu\mu\nu$	82	63(76.83%)	44(53.66%)	24	18.74%
$\mu\nu e\nu$	178	132(74.16%)	82(46.07%)	25	12.61%
$e\nu qq$	1182	1041(80.12%)	612(51.78%)	188	4.62%
$\mu\nu qq$	1221	1194(80.02%)	684(56.02%)	49	3.96%

3.3 Analysis of vvH

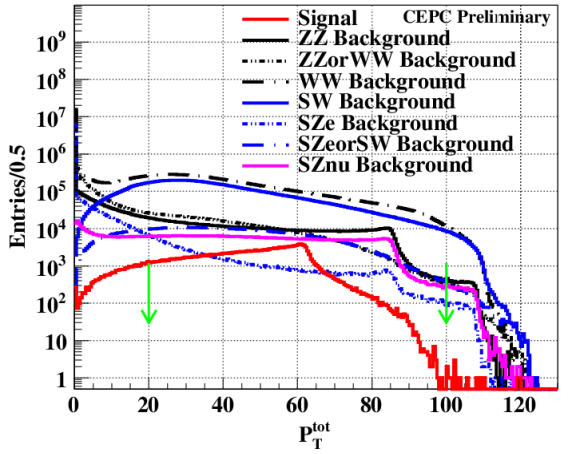
Pre-selection efficiency

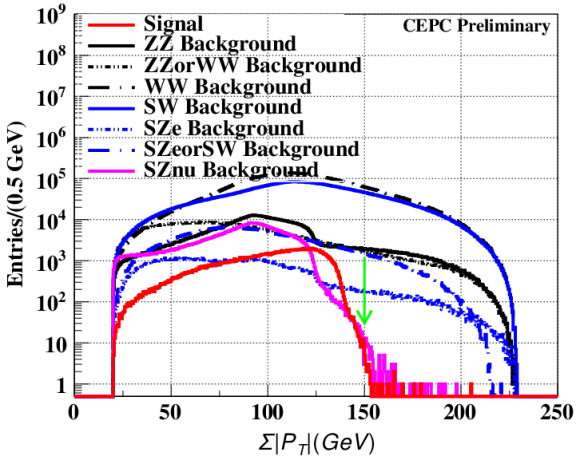
Cut1: $20 < P_T^{tot} < 100$

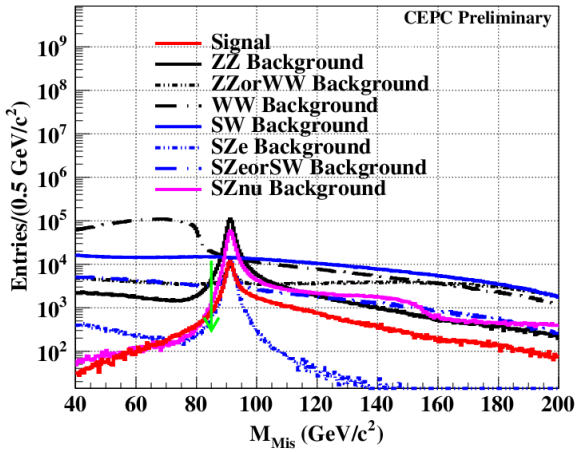
Cut2: $\sum|P_T| < 150$

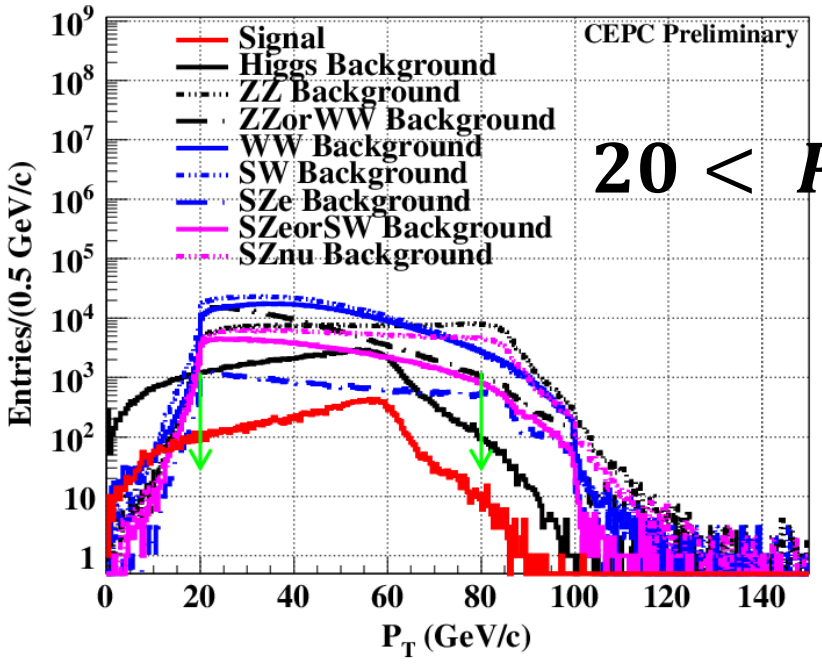
Cut3: $M_{Mis} > 85$

bkg	total	After generator cut	
ZZ	5711445	1081199	18.93%
ZZorWW	17977941	865073	4.81%
WW	44786678	1447307	3.23%
SW	17361538	1847572	10.64%
SZe	7267644	102329	1.41%
SZeorSW	1259165	363420	28.86%
SZnu	1063039	746257	70.20%
SUM	95427450	6453157	6.76%

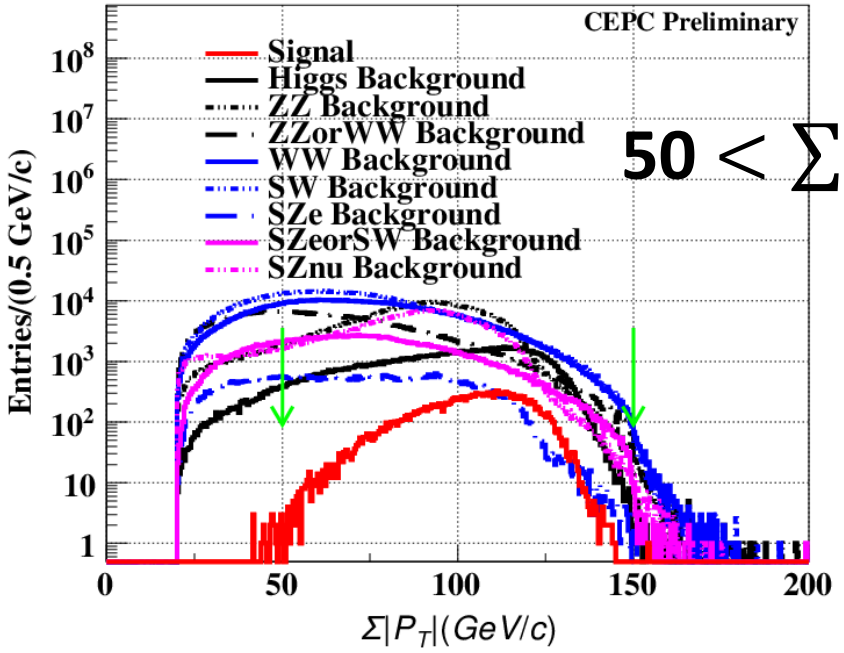




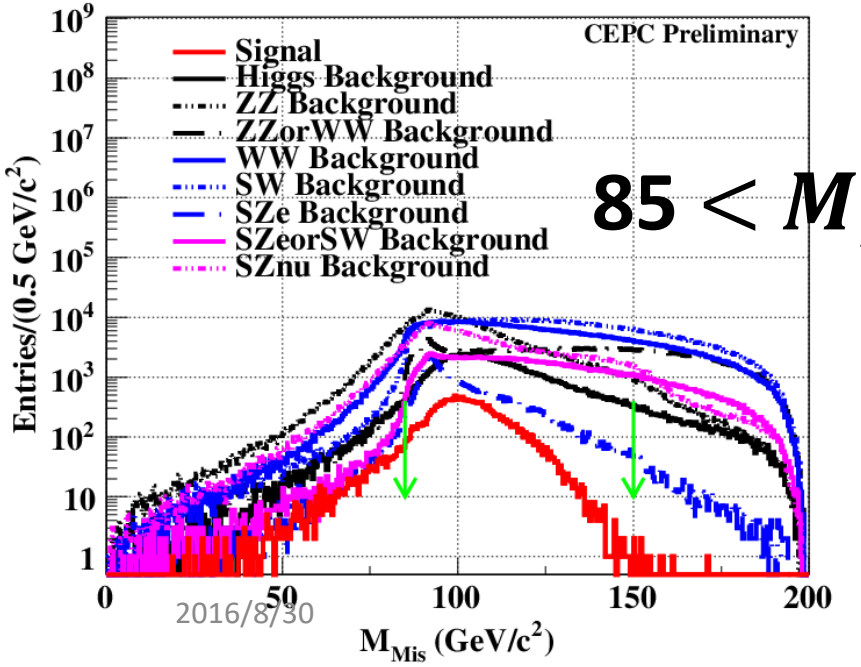




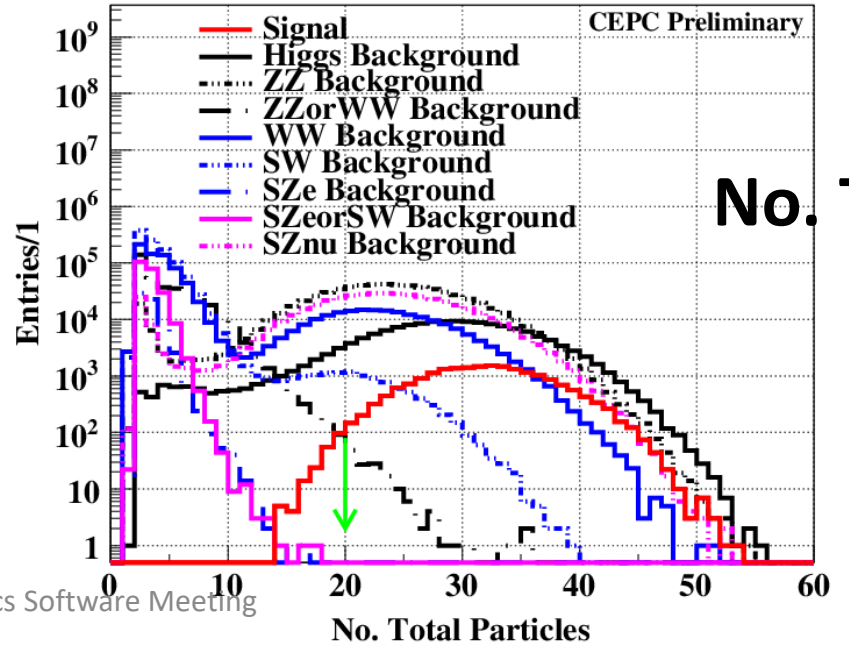
$20 < P_T^{tot} < 80$



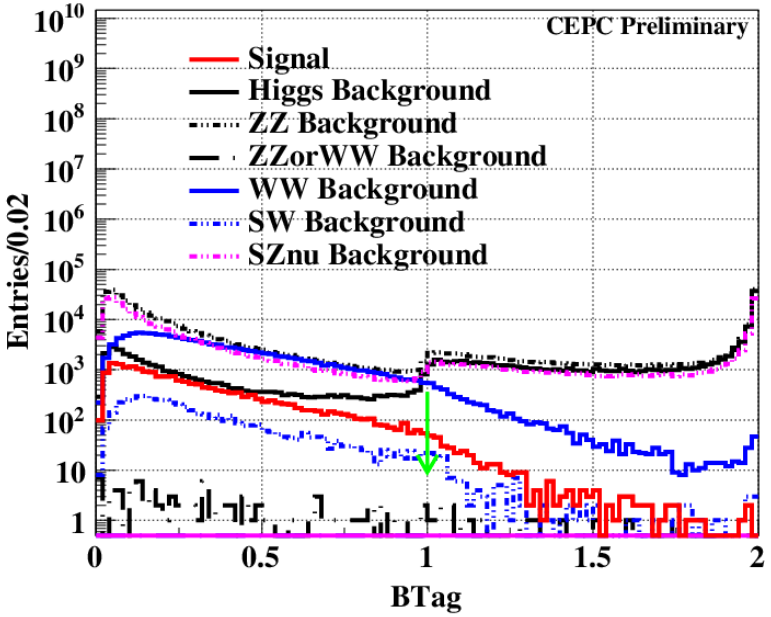
$50 < \sum|P_T| < 150$

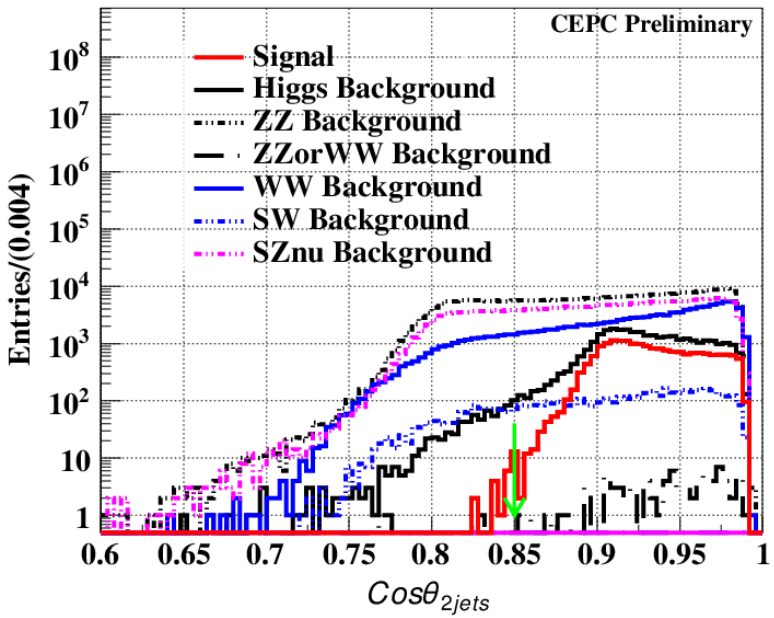


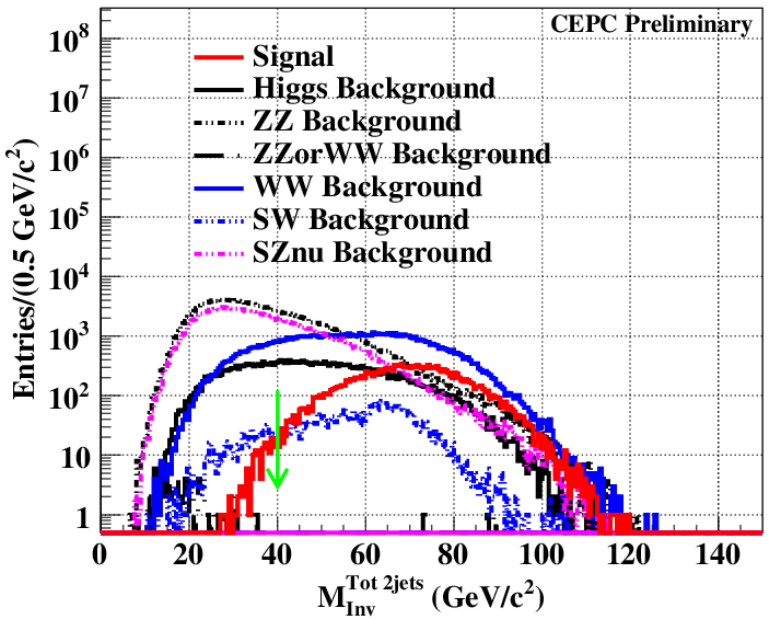
$85 < M_{Mis} < 150$



No. Tot Part >20



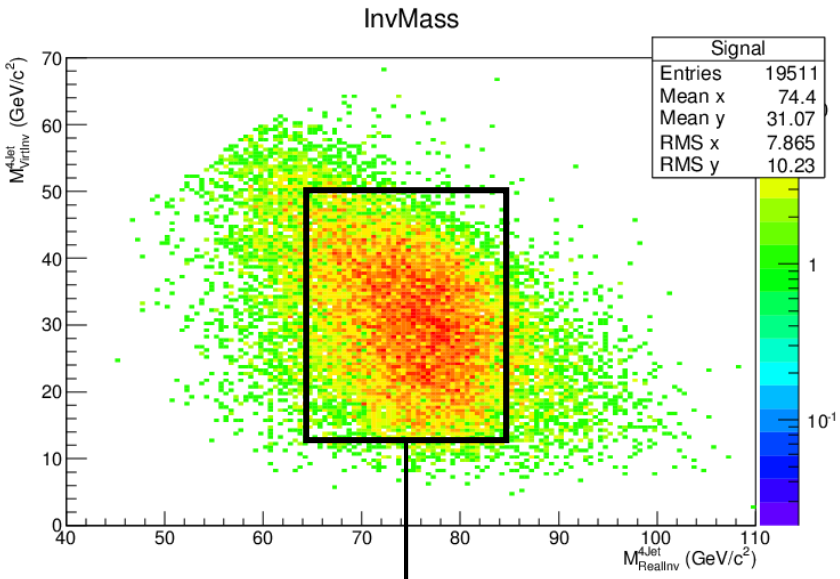




Btag < 1

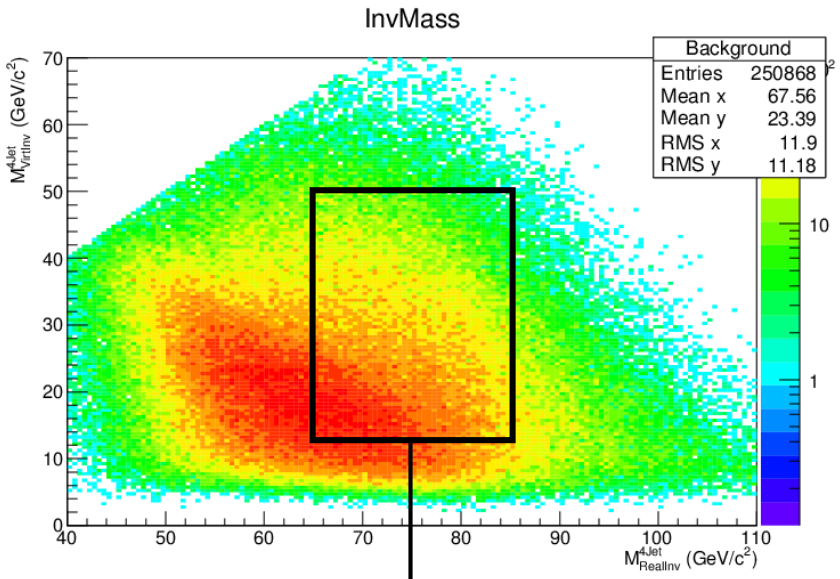
$$cos\ \theta_{2jets} > 0.85$$

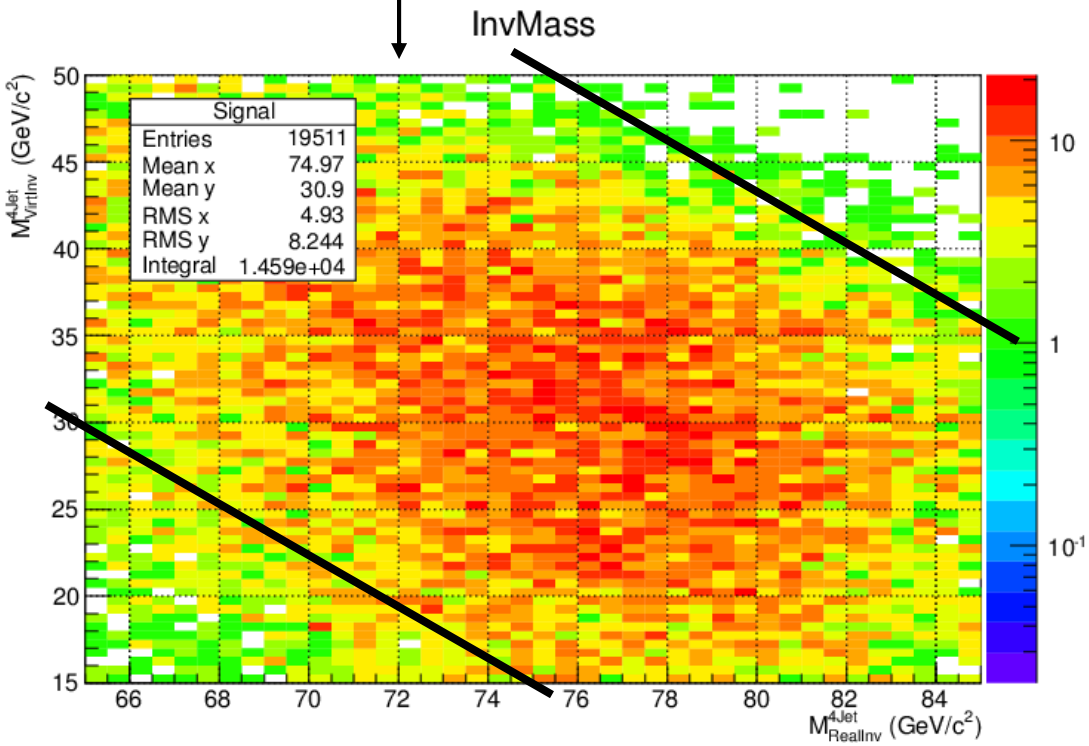
$$M_{Inv}^{tot\ 2jet} > 40$$

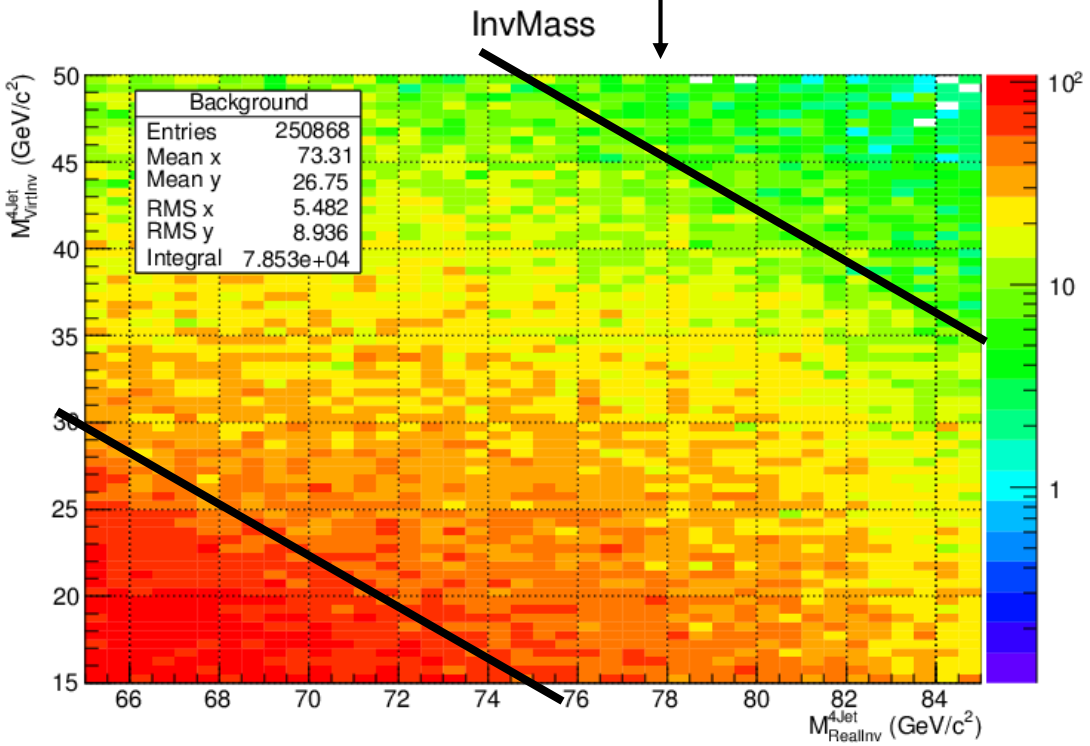


Cut:

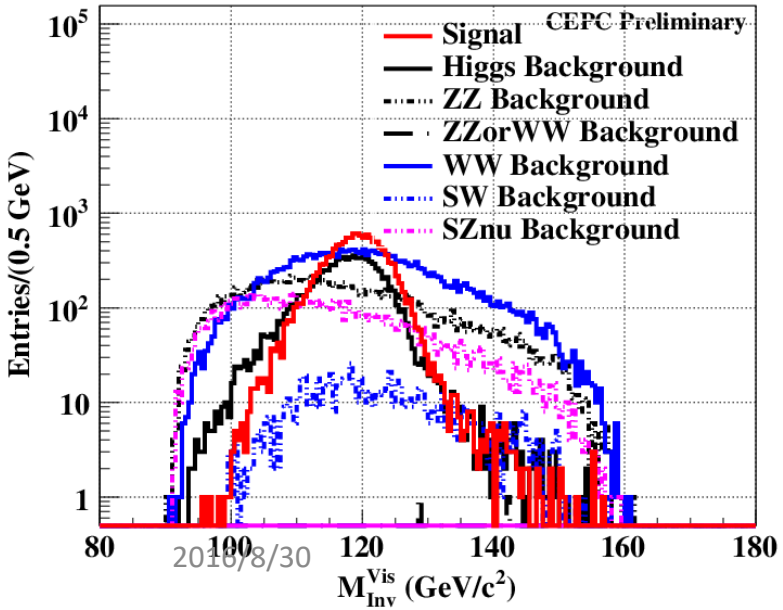
1) $65 < M_{Inv}^{Real\ 4jet} < 85$
2) $15 < M_{Inv}^{Virt\ 4jet} < 50$
3) $-M_{Inv}^{Virt\ 4jet} > 1.5 * M_{Inv}^{Real\ 4jet} + 127.5$
4) $-M_{Inv}^{Virt\ 4jet} < 1.5 * M_{Inv}^{Real\ 4jet} + 162.5$







Category	Signal	ZH	ZZ	$ZZorWW$	WW	Single W	Single $Z\nu$
Total	24030	218440	1013884	865307	1445826	1847106	733236
$20\ \text{GeV} < P_T^{Tot} < 80\ \text{GeV}$	21933	191195	879206	835961	1386878	1776319	654859
$50\ \text{GeV} < \Sigma\lvert P_T\rvert < 150\ \text{GeV}$	21912	180913	815996	544372	1099261	1343993	579238
$85\ \text{GeV} < M_{Missing} < 150\ \text{GeV}$	20410	159904	682296	372075	865453	1034089	486289
$N_{Particle}^{Tot} > 20$	20063	137649	441058	101	126072	5103	299649
$Btag < 1$	19699	34131	316551	85	121262	4965	219638
$Cos\theta_{2jets} > 0.85$	19680	33402	233443	81	102515	3937	165188
$\Sigma\lvert M_{Inv}^{2jet}\rvert > 40\ \text{GeV}$	19511	22438	82622	3	84815	3357	57633
Combined Variable	13549	9541	13398	2	24033	850	8033
Stat.	56.38%	4.37%	1.32%	0%	1.66%	0.05%	1.10%



hain of hadronic decay of $H \to WW^* \to qqqq$

Visible Invariant Mass after all cuts

4 Summery

Category	Signal	Relative Error
$Z \to \mu\mu; H \to WW^* \to e\nu\mu\nu$	105±11	10.5%
$Z \to \mu\mu; H \to WW^* \to e\nu e\nu$	36±7	19.4%
$Z \to \mu\mu; H \to WW^* \to \mu\nu\mu\nu$	52±8	15.4%
$Z \to \mu\mu; H \to WW^* \to \mu\nu qq$	717±30	4.2%
$Z \to \mu\mu; H \to WW^* \to e\nu qq$	663±27	4.1%
$Z \to ee; H \to WW^* \to e\nu\mu\nu$	82±11	13.4%
$Z \to ee; H \to WW^* \to e\nu e\nu$	22±7	31.8%
$Z \to ee; H \to WW^* \to \mu\nu\mu\nu$	44±9	20.5%
$Z \to ee; H \to WW^* \to \mu\nu qq$	684±28	4.1%
$Z \to ee; H \to WW^* \to e\nu qq$	612±29	4.7%
$Z \to \nu\nu; H \to WW^* \to qqqq$	13549±264	2.0%
Combination	±	1.4%

Table 12: Statistic error of Signal and Relative error

5 Plan

W Decay \ Z Decay	ll	νν	ττ	qq
lνlν				
lνqq				
qqqq				
τ+X				

1 Study the influence of different detectors for data analysis

2 Prepare note and paper

3 Analyze the qqlvlv and qqlvqq (alternative)

4 others