$e^+e^- \to ZH \to \nu\bar{\nu}WW^* \to \nu\bar{\nu}\bar{l}\nu l\bar{\nu}(l = e, \nu)$

Xianke He Jun Yan
Adviser: Prof.Jun Guo Prof.Gang LI

SJTU

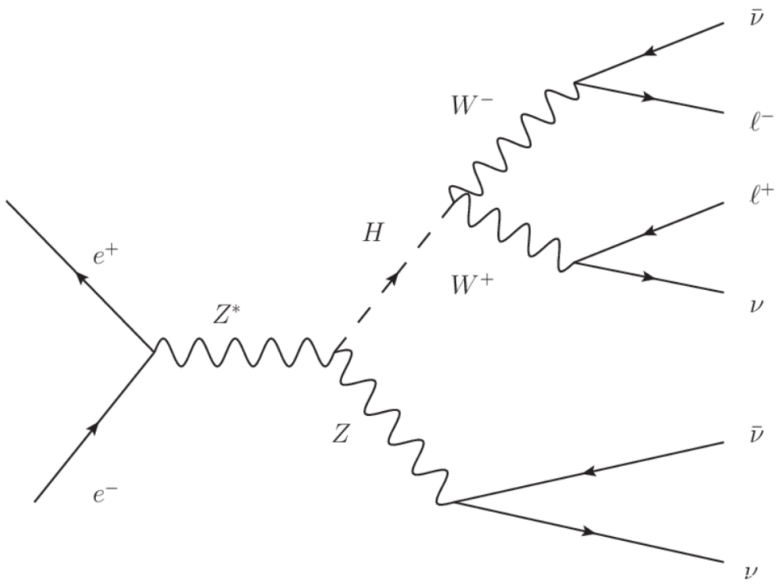
2018.6.28

Outline

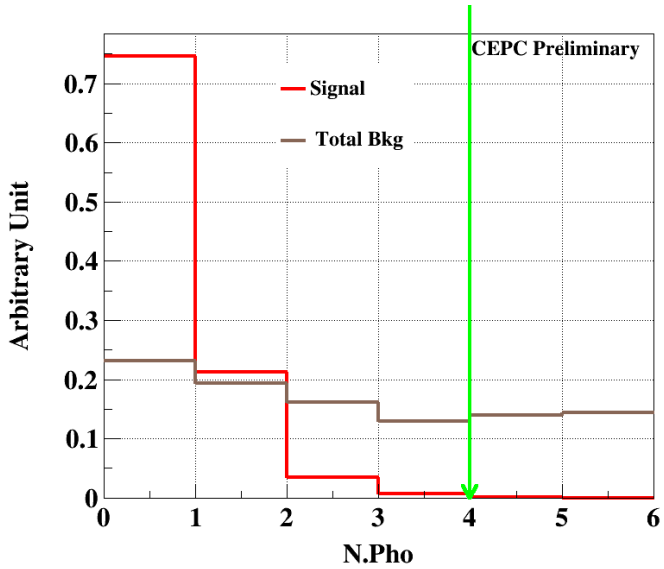
- Precut
- BDT result
- Fit result
- Branch ratio
- Summary

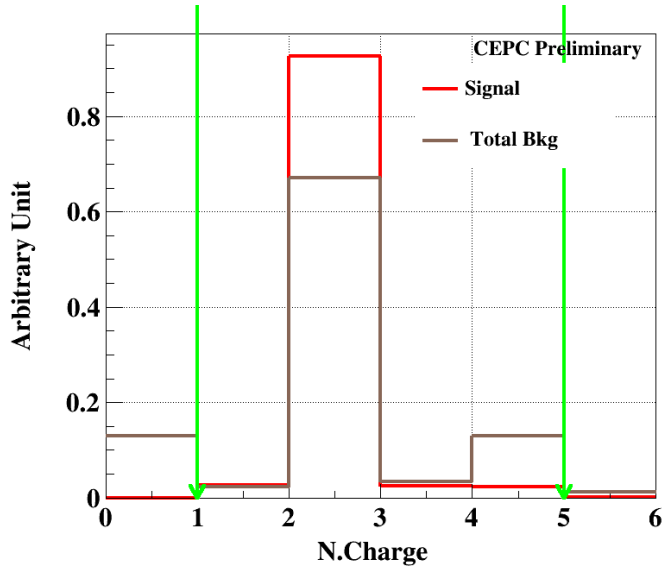
Physics Motivation

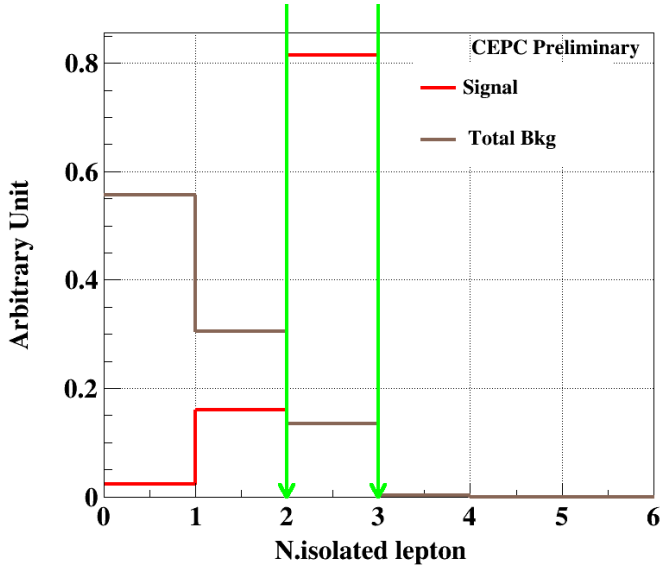
- Measure the branch ratio of $H \to WW$ through $WW \to \bar{l}\nu l\bar{\nu}(l = e, \mu)$ on CEPC



Precut on $WW \to \bar{e}\nu e\bar{\nu}$

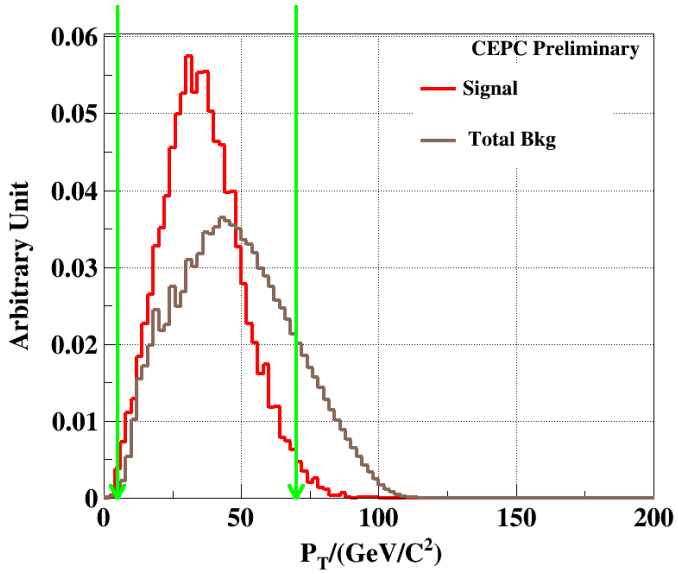


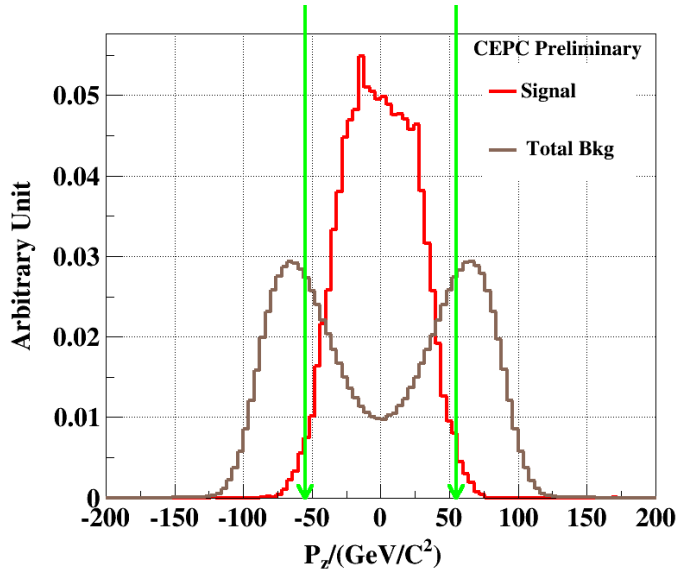


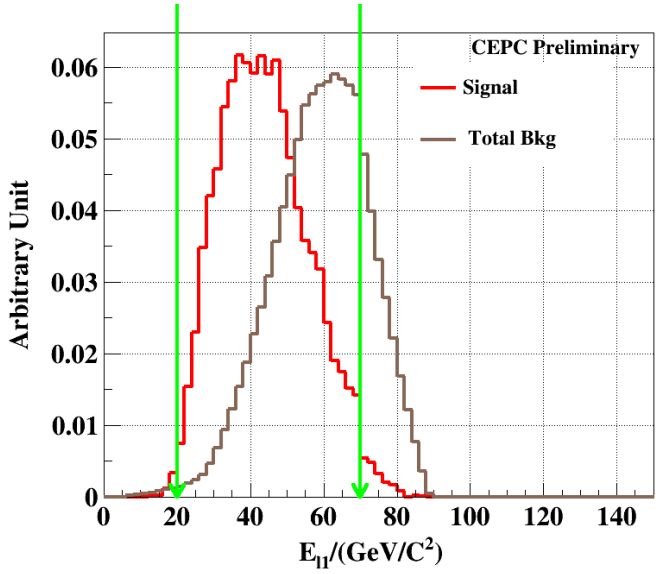


- Number of Photon: $N.Pho < 4$
- Number of Charge: $1 \leq N.Charge < 5$
- Number of Isolated Lepton: $N.IsolatedLepton = 2$

Precut on $WW \to \bar{e}\nu e\bar{\nu}$

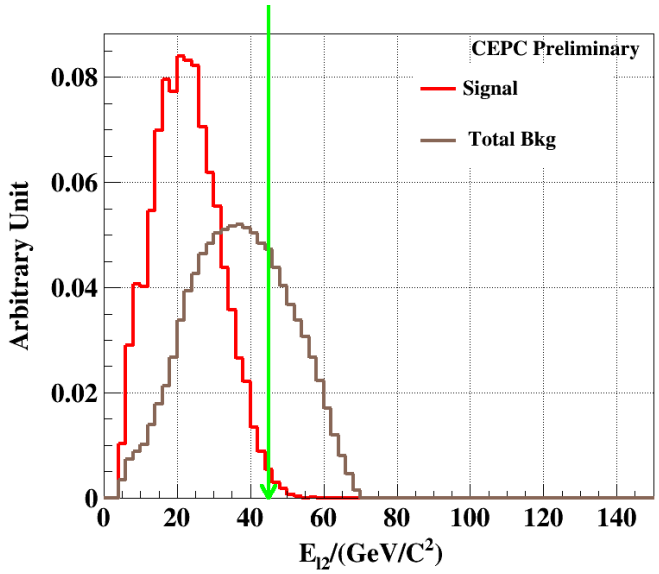


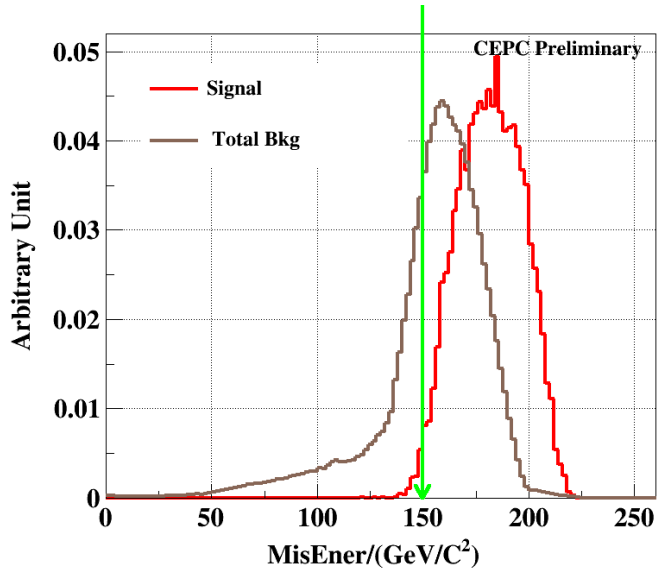


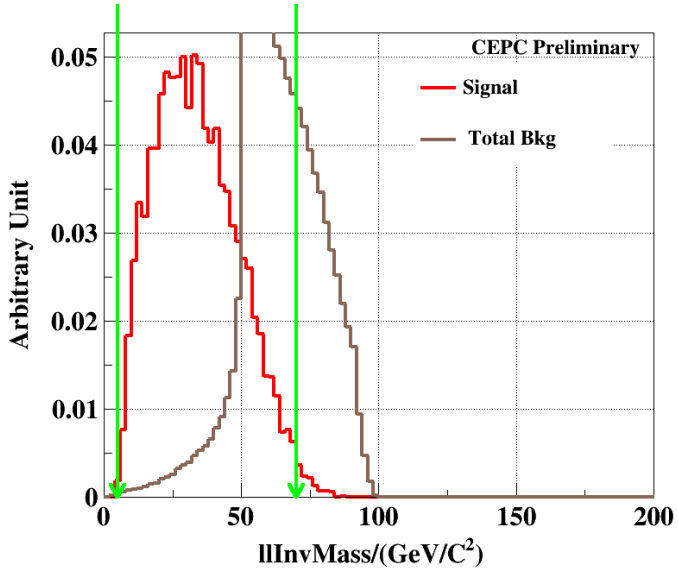


- the Leading Leptons' Transverse Momentum: $5 < P_T < 70$
- the Leading Leptons' Longitudinal Momentum: $-55 < P_Z < 55$
- the Leading Leptons' Energy: $20 < E_{l1} < 70$

Precut on $WW \to \bar{e}\nu e\bar{\nu}$

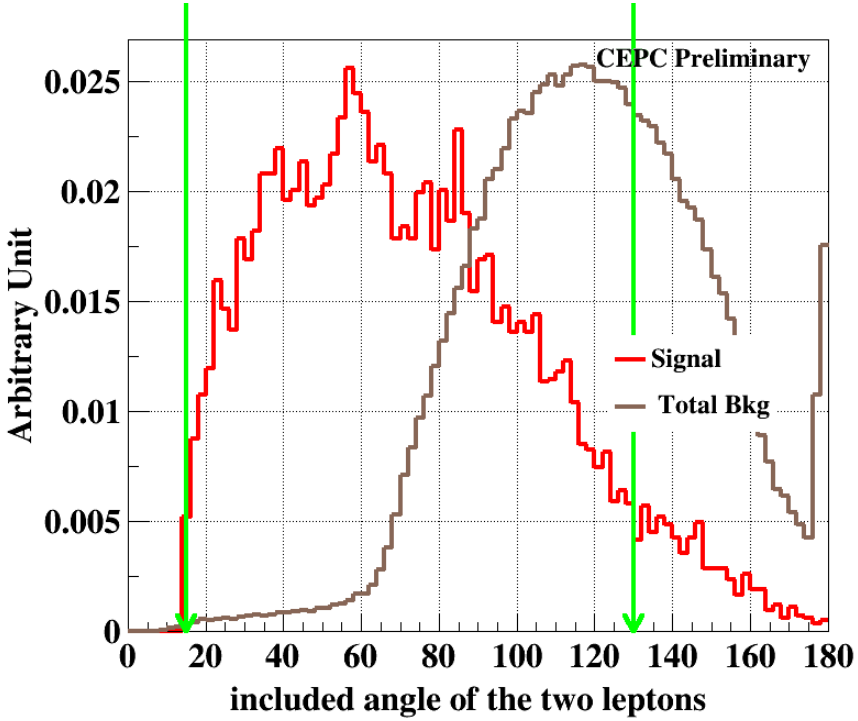


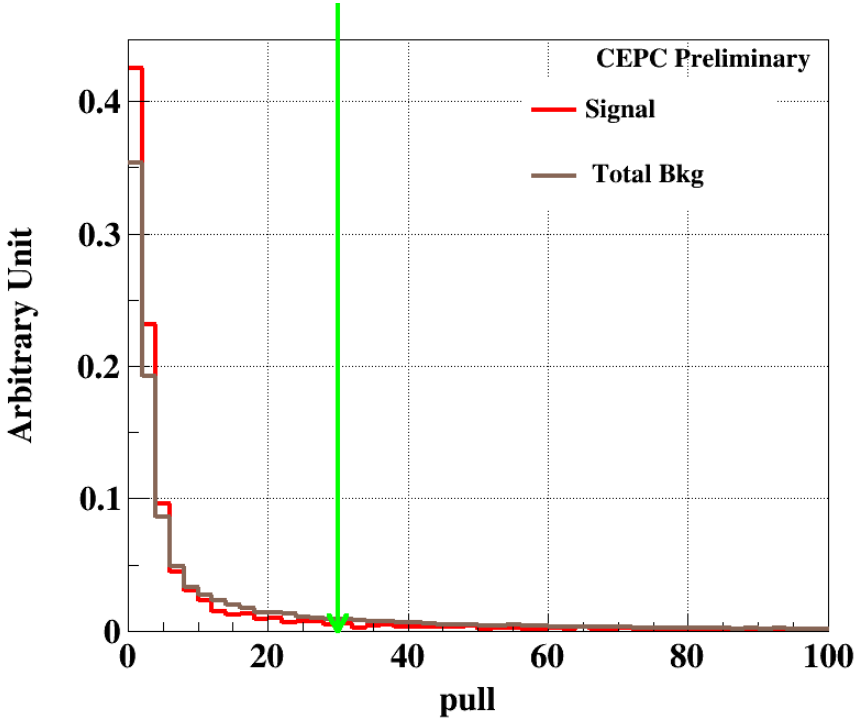




- the second Leading Leptons' Energy: $E_{l2} < 45$
- Miss Energy: $150 < MisEner$
- the two leptons' Invariant Mass: $5 < llInvMass < 70$

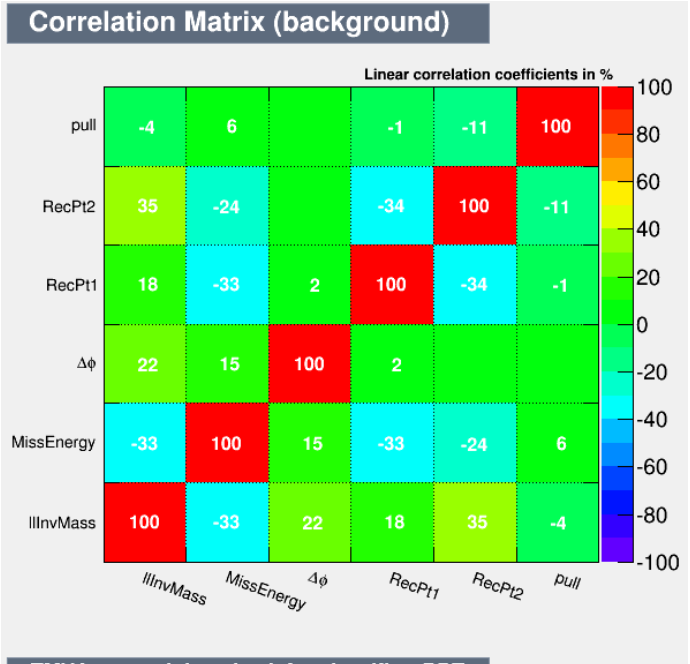
Precut on $WW \to \bar{e}\nu e\bar{\nu}$

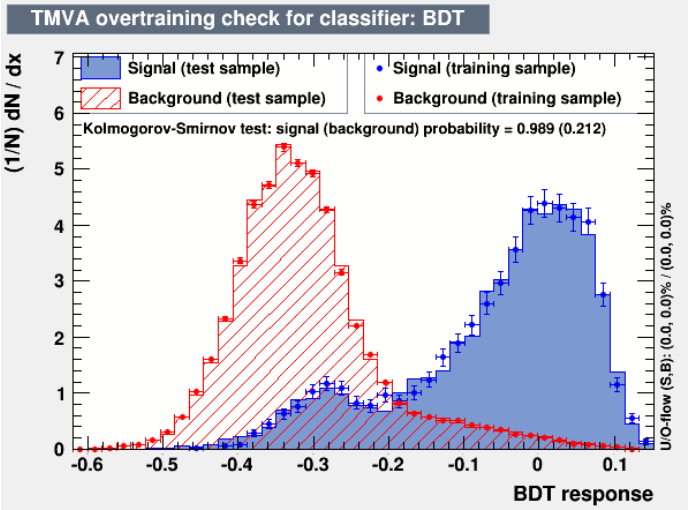


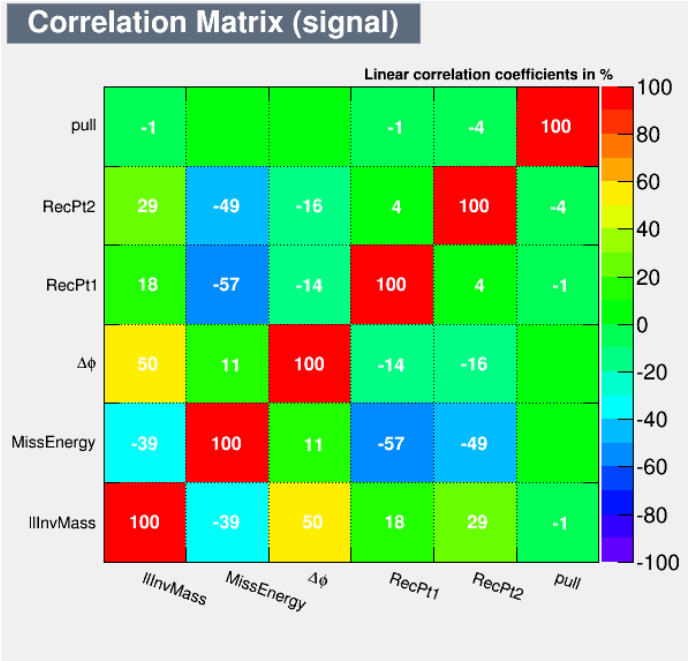


- included angle of the two leptons: $15 < llAngle < 130$
- pull: $\sqrt{(\frac{trkD0_0^2}{sigD0_0^2} + \frac{trkZ0_0^2}{sigZ0_0^2}) \cdot (\frac{trkD0_1^2}{sigD0_1^2} + \frac{trkZ0_1^2}{sigZ0_1^2})} < 30$

BDT result of $WW \to \bar{e}\nu e\bar{\nu}$







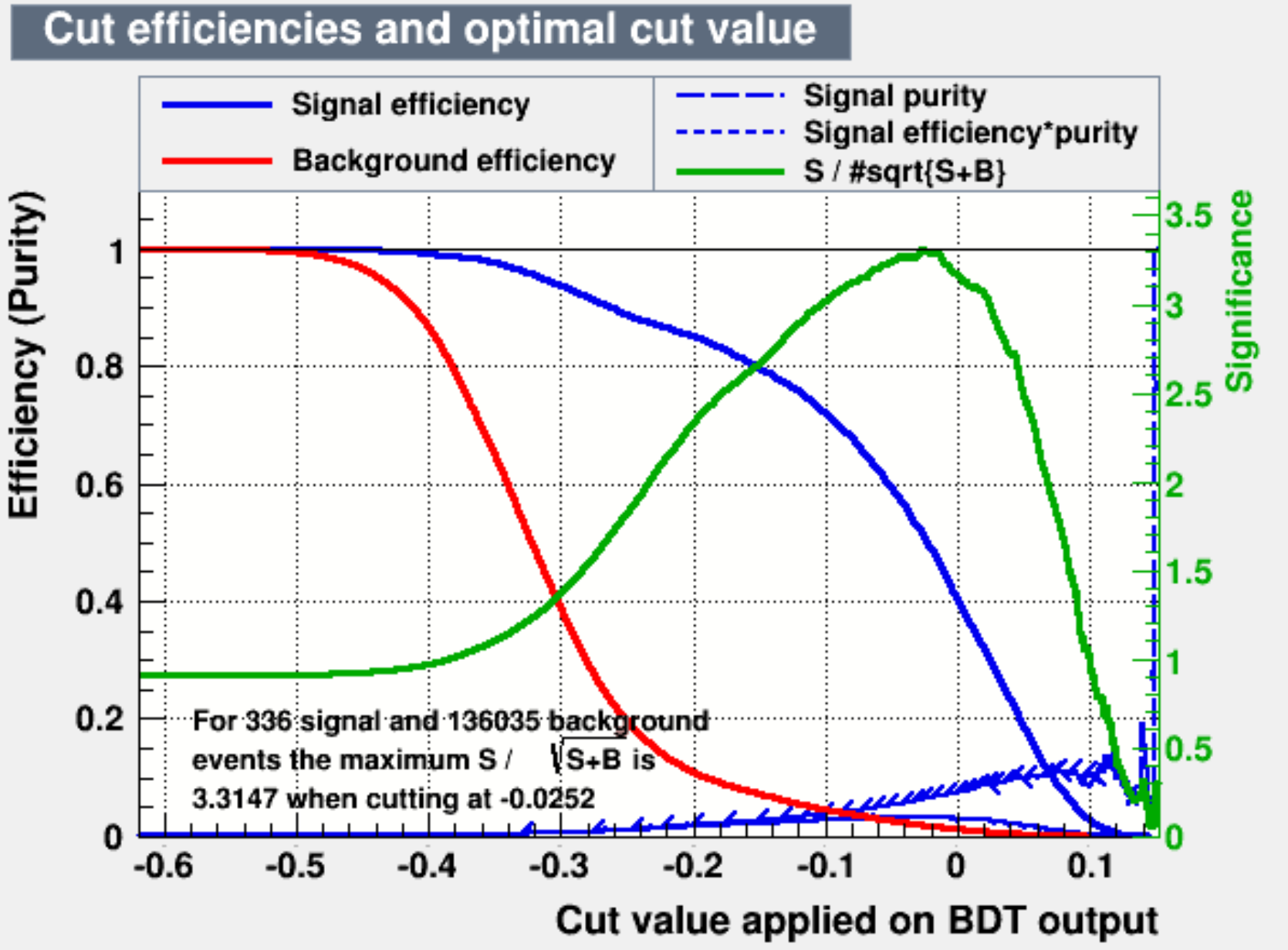
- RecPt1: the Leading Leptons' Transverse Momentum
- RecPt2: the second Leading Leptons' Transverse Momentum
- $\triangle\phi$: azimuth angle between the two leptons

BDT Cut Chain of $WW \to \bar{e}\nu e\bar{\nu}$

BDT	$Signal$	$ZHbkg$	SZ	SW	$ZorW$
-0.4	330.546	248.256	1330	51850	22431
-0.35	321.874	246.041	1117	34539	15801
-0.30	307.898	242.997	906	18032	9211
-0.25	290.969	239.076	715	7371	4957
-0.20	278.607	233.633	592	3520	3241
-0.15	263.016	221.963	500	2001	2328
-0.10	236.632	200.791	415	933	1514
-0.05	194.379	152.542	312	328	885
0	133.215	80.2149	198	90	459
0.05	64.301	25.9695	74	14	166

BDT	ZZ	WW	$ZZorWW$	$2f$
-0.4	415.488	13201	12972	432
-0.35	371.498	9016	9535	324
-0.30	312.842	5605	5549	233
-0.25	265.475	3703	2988	168
-0.20	229.231	2734	2093	117
-0.15	197.729	1989	1625	79
-0.10	164.476	1370	1176	59
-0.05	121.627	762	732	29
0	79.1129	295	394	7
0.05	29.5636	64	180	7

BDT result of $WW \to \bar{e}\nu e\bar{\nu}$

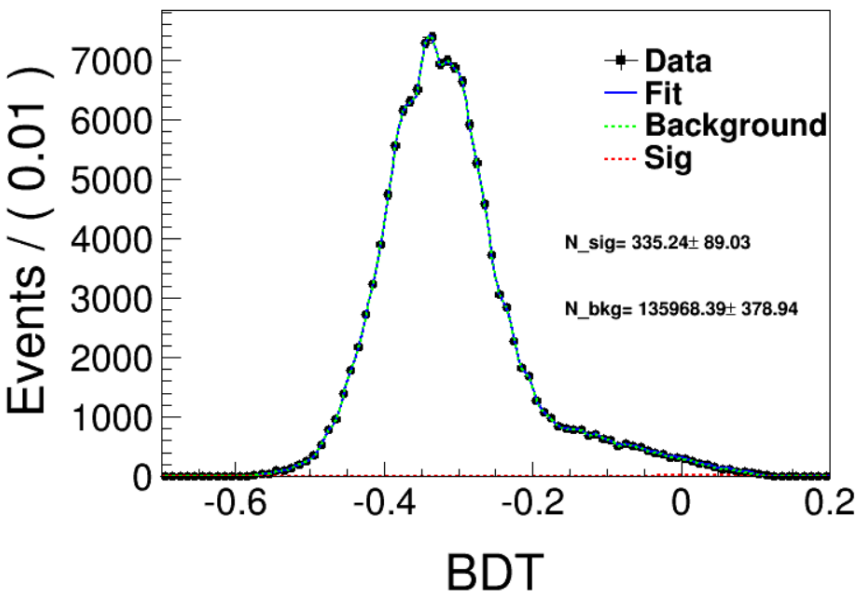


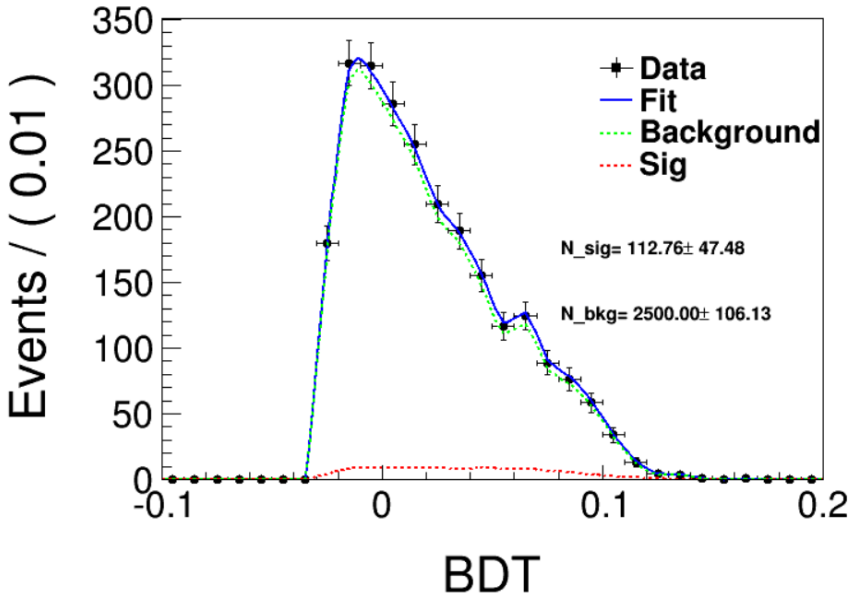
Cut Chain of $WW \to \bar{e}\nu e\bar{\nu}$

$e^+e^- \to$	$Signal$	$ZHbkg$	SZ	SW	$ZorW$
Total	11582	948400	871051	3.3278×10^6	520935
$N_\gamma < 4, 1 \leq < N_{ch} < 5$	99.8%	5.69%	20.4%	66.6%	99.6%
$N_{iso\_lep} == 2$	81.4%	1.24%	13.3%	36.6%	81.0%
$5GeV < P_T < 70GeV$	79.9%	1.22%	10.8%	30.5%	68.7%
$\|P_Z\| < 55GeV$	77.8%	1.20%	4.60%	14.8%	35.7%
$20GeV < E_{l1} < 70GeV$	76.0%	1.01%	3.43%	11.5%	28.1%
$E_{l2} < 45GeV$	75.3%	1.01%	1.68%	7.92%	17.4%
$150GeV < E_{Miss} < 215GeV$	74.4%	1.01%	0.59%	5.80%	11.9%
$5GeV < llInvMass < 70GeV$	73.5%	1.00%	0.32%	3.72%	7.54%
$15^o < Angle < 130^o$	68.5%	0.92%	0.24%	2.53%	6.14%
$Pull < 30$	62.9%	0.61%	0.19%	2.08%	5.61%
$-0.0252 < BDT$	32.2%	0.02%	0.00%	0.00%	0.1%
$number(weight \quad considered)$	172	120	256	174	701

$e^+e^- \to$	ZZ	WW	$ZZorWW$	$2f$
Total	1.12546×10^6	7.47571×10^6	838472	7.91415×10^6
$N_\gamma < 4, 1 \leq < N_{ch} < 5$	6.29%	16.4%	80.7%	12.5%
$N_{iso\_lep} == 2$	2.96%	5.37%	33.9%	4.42%
$5GeV < P_T < 70GeV$	2.24%	4.34%	28.3%	3.99%
$\|P_Z\| < 55GeV$	1.34%	1.88%	14.8%	1.18%
$20GeV < E_{l1} < 70GeV$	0.98%	1.48%	11.7%	1.00%
$E_{l2} < 45GeV$	0.64%	1.22%	8.33%	0.79%
$150GeV < E_{Miss} < 215GeV$	0.26%	0.97%	6.52%	0.30%
$5GeV < llInvMass < 70GeV$	0.23%	0.65%	4.26%	0.18%
$15^o < Angle < 130^o$	0.15%	0.37%	2.39%	0.03%
$Pull < 30$	0.05%	0.25%	1.92%	0.01%
$-0.0252 < BDT$	0.00%	0.00 %	0.00%	0.00%
$number(weight \quad considered)$	101	481	573	22

BDT fit





- left: before bdt cut; right: after bdt cut

the measurement of $Br_{H\to WW}$ (1/2)

- after BDT cut

channel ($WW \to l\nu l\nu$)	N.sig	N.bkg	$\Delta N.sig/N.sig = \sqrt{s+b}/s$
$e\nu e\nu$	172	2428	29.6%

- considering

$$Br_{H\to WW} = \frac{N.sig/(\omega \cdot \varepsilon_{sig})}{L \cdot \sigma_{ZH} \cdot Br^2_{W\to e\nu}}$$

ω is weight,ε_{sig} is cut flow efficiency,set $\Delta\omega = 0$,$\Delta\varepsilon_{sig} = 0$. $\frac{\Delta\sigma}{\sigma} = 0.5\%$ and ignore the ΔL ,so

$$\frac{\Delta Br}{Br} = \sqrt{(\frac{\Delta N.sig}{N.sig})^2 + (\frac{\Delta\sigma}{\sigma})^2 + (\frac{\Delta B_{H\to e\nu}}{B_{H\to e\nu}})^4} \approx 29.6\%$$

the measurement of $Br_{H\to WW}$(2/2)

- from last page,before we adopt BDT cut,the cut efficiency is 62.9%
- but we don't adopt this value , we randomly select one half data from 11582 events, then get a new efficiency: ε_{sig}

channel ($WW \to e\nu e\nu$)	N.sig
before cut	11582
after cut	1902
ε_{sig}	32.3%

- so the reconstructed N.sig from $H \to WW \to e\nu e\nu$: $\frac{11582*32.2\%}{32.3\%} \approx 11546$
- the measured $Br_{H\to WW} = \frac{11546\cdot 21.5\%}{11582} \approx 21.4\%$
- so $Br_{H\to WW} \approx 21.4\% \pm 29.6\%$

Summary and To do

- Br of $H \to WW$ is $21.4\% \pm 29.6\%$ through $WW \to e\nu e\nu$
- the fit result seems not better than number counting
- the combined measurements of the 3 channels is not finished

Thanks !

backup

Explanation of my signal weight

- professor Gang Li helped me generated 997637($\approx 10^6$) $\nu\nu H(\rightarrow WW)$ MC samples
- for my three signal channel $WW \rightarrow e\nu e\nu$,$WW \rightarrow e\nu\mu\nu$,$WW \rightarrow \mu\nu\mu\nu$,i could roughly get $997637 \times (10.71\%^2 + 2 \times 10.71\% \times 10.63\% + 10.63\%^2) \approx 45432$ events.
- considering $L \cdot \sigma_{ZH} \cdot Br_{Z\rightarrow\nu\nu} \cdot Br_{H\rightarrow WW^*} \cdot (Br^2_{W\rightarrow e\nu} + Br^2_{W\rightarrow\mu\nu} + 2 \cdot Br_{W\rightarrow e\nu} \cdot Br_{W\rightarrow\mu\nu}) = 5050 \cdot 212.13 \cdot 20\% \cdot 21.5\% \cdot (10.71\%^2 + 2 \cdot 10.71\% \cdot 10.63\% + 10.63\%^2) \approx 2097$
- the weight value:$2097/45432 \approx 0.046$
- actually,i get 46018 events,not reach but close to 45432.

the measurement of $Br_{H\to WW}$ through number counting (2/2)

- after BDT cut

channel ($WW \to l\nu l\nu$)	N.sig	N.bkg	$\Delta s/s = \sqrt{s+b}/s$
$e\nu e\nu$	172	2428	29.6%
$e\nu\mu\nu$	419	3489	14.9%
$\mu\nu\mu\nu$	223	2801	24.6%

- combined $\Delta s/s = \frac{1}{\sqrt{(1/29.6\%)^2+(1/14.9\%)^2+(1/24.6\%)^2}} = 11.7\%$
- considering
- considering

$$Br_{H\to WW} = \frac{N}{L \cdot \sigma_{ZH} \cdot (Br^2_{W\to e\nu} + Br^2_{W\to\mu\nu} + 2 \cdot Br_{W\to e\nu} \cdot Br_{W\to e\nu})}$$

$\frac{\Delta\sigma}{\sigma} = 0.5\%$ and ignore the ΔL ,so ?

Previous result

- after BDT cut

channel ($WW \to l\nu l\nu$)	N.sig	N.bkg	$\Delta s/s = \sqrt{s+b}/s$
$e\nu e\nu$	179	3053	31.7265%
$e\nu\mu\nu$	419	3489	14.8996%
$\mu\nu\mu\nu$	223	2801	24.6314%

- combined
  $\Delta s/s = \frac{1}{\sqrt{(1/31.7265\%)^2+(1/31.7265\%)^2+(1/31.7265\%)^2}} = 11.8293\%$
- considering

$$Br = \frac{N}{L \cdot \sigma}$$

$\frac{\Delta\sigma}{\sigma} = 0.5\%$ and ignore the ΔL ,so

$$\frac{\Delta Br}{Br} = \sqrt{(\frac{\Delta s}{s})^2 + (\frac{\Delta\sigma}{\sigma})^2} = \sqrt{0.5\%^2 + 11.8293\%^2} \approx 11.84\%$$