Status Report

2018/1/8 LHeC meeting

Tokyo Institute of Technology

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Table of Contents

- We analyzed Higgs Invisible with Satoshi-san at Double-LHC, using Cut based and BDT based analysis.

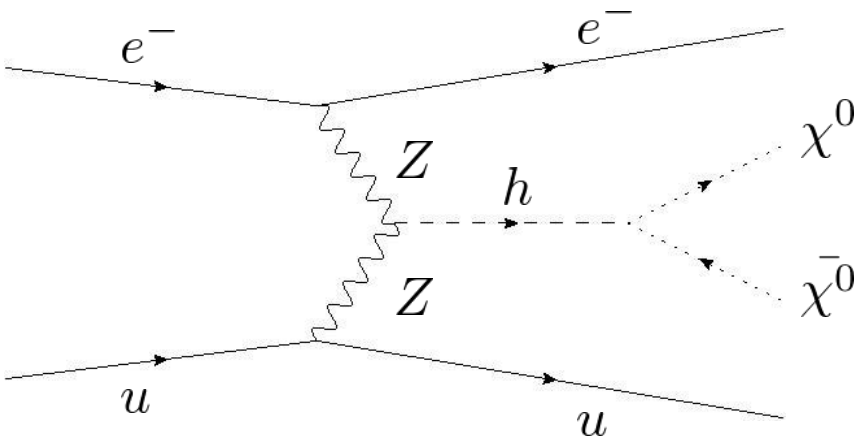
- Then we scaled result of LHeC and FCC, and compared them.

Setup

- Double-LHC($E_p = 14\ \mathrm{TeV}\ E_e = 60\ \mathrm{GeV}$)
- electron : -80% polarized
- MadGraph_v2.3.2, Pythia_v2.4.5, Delphes_v3.4.1
- delphes card : delphes_card_LHeC_PK_V2_eFilter.tcl
- Luminosity : $1\ \mathrm{ab}^{-1}$

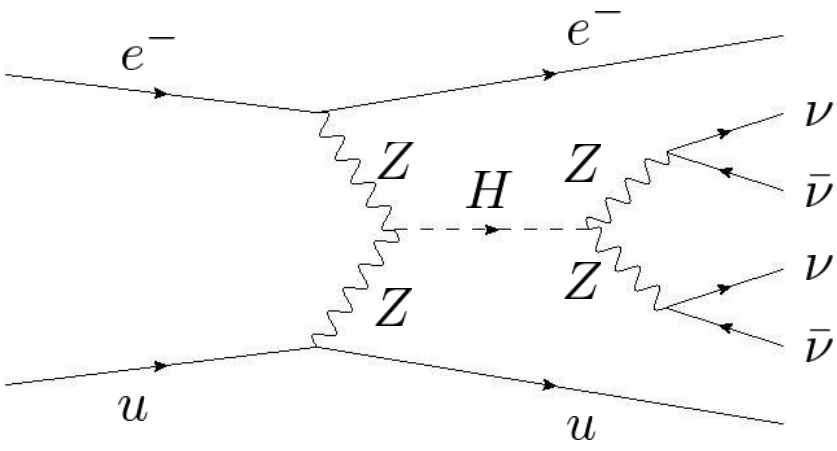
Signal

Higgs invisible decay



$NC: h \rightarrow \not{E}_T$

Standard model process



$NC: H \rightarrow ZZ \rightarrow 4\nu$

- We focus on NC: $h \rightarrow \not{E}_T$
- We emulate Higgs invisible decay by SM process NC: $H \rightarrow ZZ \rightarrow 4\nu$ assumed a branching ratio of 100%

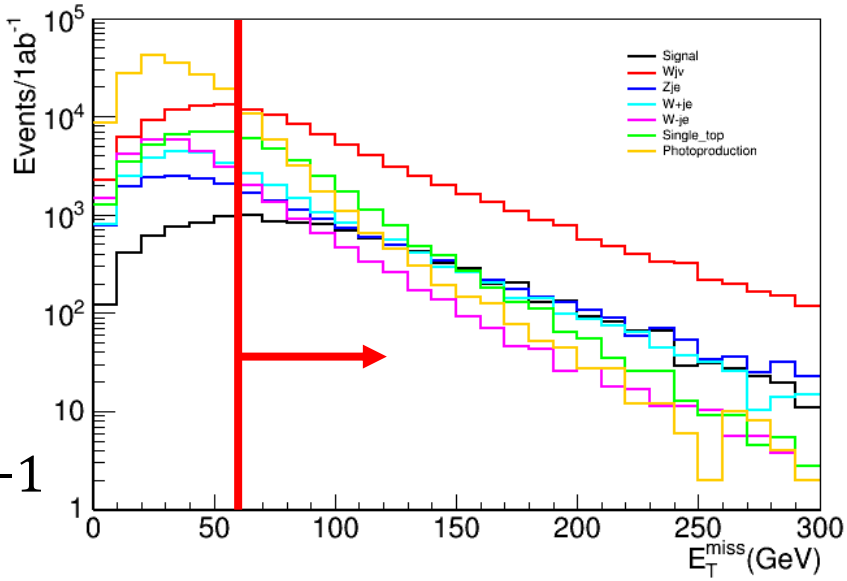
Cut based analysis

Preselection

- ✓ $N_j \geq 1, N_e \geq 1$ for the jet and the electron
- ✓ $p_{\mathrm{T}} > 20$ GeV for the leading jet and the leading electron
- ✓ $|\eta| < 5.0$ for the leading jet and the leading electron
- ✓ $\Delta R > 0.4$ for the leading jet and the leading electron

Cut 1: $\left|\phi_j - \phi_{\not{E}_T}\right| > 1.4$ rad
Cut 2: $\not{E}_T > 60$ GeV
Cut 3: $\eta_j - \eta_e > 3$
Cut 4: $\left|\phi_j - \phi_e\right| < 2.1$ rad
Cut 5: $-1.2 < \eta_e < 1.2$
Cut 6: $0.1 < y_e < 0.5$
Cut 7: $N_e = N_j = 1,\ N_\mu = N_\tau = 0, Q_e = -1$

$\not{E}_T > 60$ GeV



Result in cut based analysis

Events	After the cuts
Signal	2846
Wjv	482
Zje	496
Wje	1314
Single_top	4
Photoproduction …	23 …
All Background	2322

Branching ratio calculated by $\frac{S}{\sqrt{S+B}}$

$$Z = \frac{2846 \times \mathrm{Br}(h \to \not{E}_T)}{\sqrt{2846 \times \mathrm{Br}(h \to \not{E}_T) + 2322}}$$

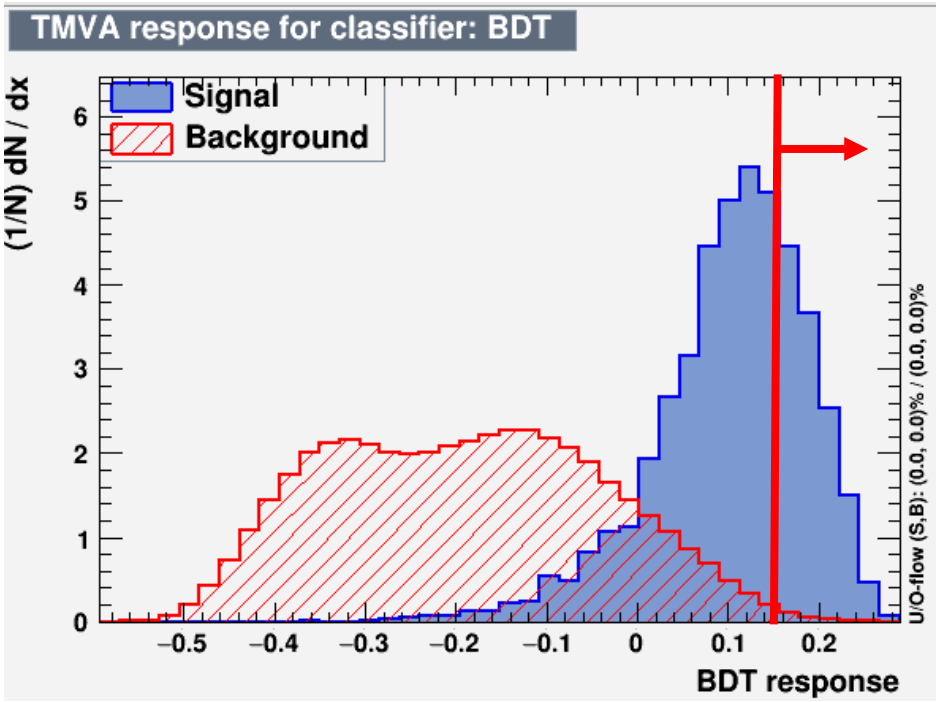
$$\Rightarrow \quad \mathrm{Br}(h \to \not{E}_T) \sim 3.46\%$$

In the case of 2σ

BDT based analysis

Preselection:

$N_j \geq 1, N_e \geq 1, p_{\mathrm{T}} > 20$ GeV, $|\eta| < 5.0$,
$\Delta R > 0.4, N_e = N_j = 1, N_\mu = N_\tau = 0$,
$Q_e = -1$



Input variables:

$p_{T,j}, \eta_j, \phi_j, M_j, p_{T,e}, |\phi_j - \phi_{\not{E}_T}|,$
$missing\ E_T, \eta_j - \eta_e, |\phi_j - \phi_e|, Q_e^2, y_e, M_{e,j}$

$\mathrm{Br}(h \to \not{E}_T)$ becomes minimum when BDT > 0.15

Result in BDT based analysis

Events	After the cuts
Signal	3727
Wjv	998
Zje	557
Wje	2309
Single_top	5
Photoproduction …	30 …
All Background	3902

Branching ratio calculated by $\frac{S}{\sqrt{S+B}}$

$$Z = \frac{3727 \times \mathrm{Br}(h \to \not{E}_T)}{\sqrt{3727 \times \mathrm{Br}(h \to \not{E}_T) + 3902}}$$

$\Rightarrow$ $\mathrm{Br}(h \to \not{E}_T) \sim 3.41\%$ (Cut base: 3.46%)

In the case of 2σ

Scaling

We scaled each events from cross section of LHeC, Double_LHC, FCC and compared the result.

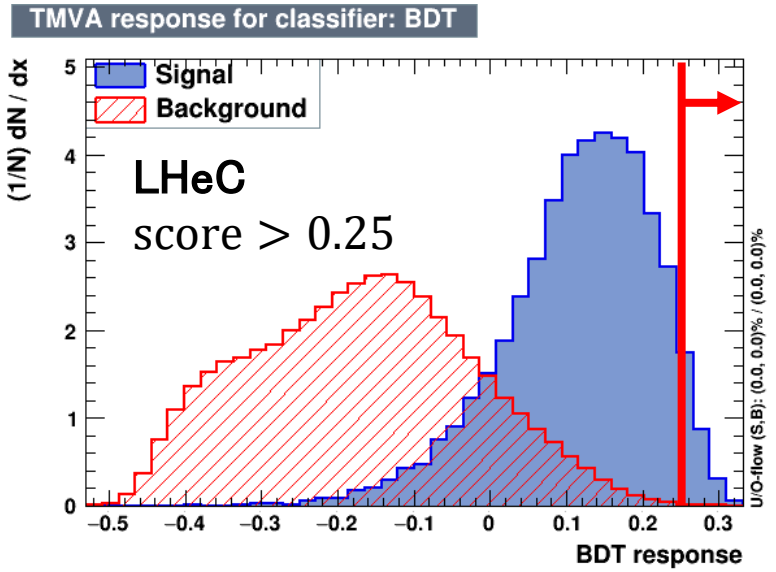
- LHeC→Double_LHC, FCC
- Double_LHC→LHeC, FCC
- FCC→LHeC, Double_LHC

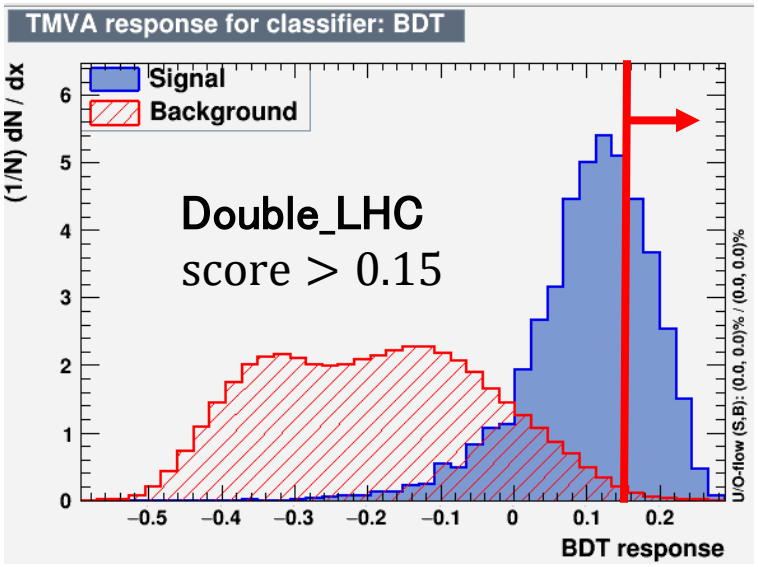
All these values are result of optimized BDT.

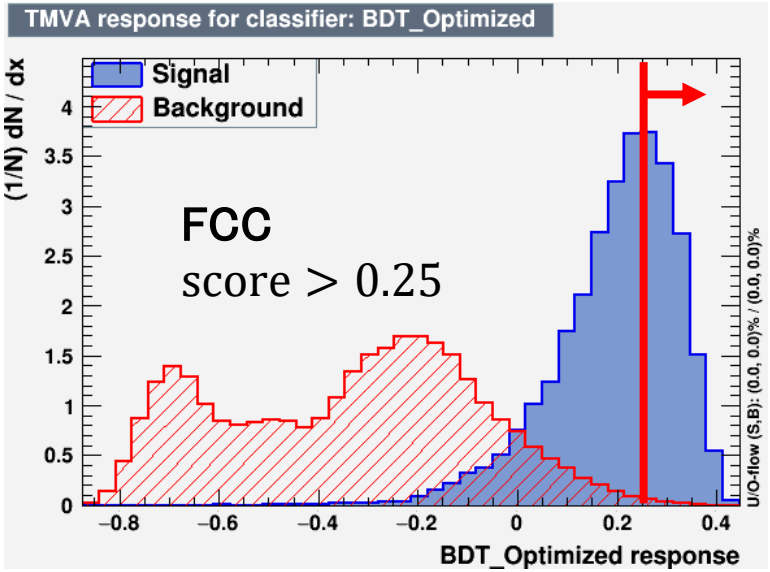
From \ To	LHeC	Double_LHC	FCC
LHeC	5.48%	3.59%	2.1%
Double_LHC	5.2%	3.41%	1.97%
FCC	4.46%	2.89%	1.68%

When we used the up scaling factor(LHeC→Double_LHC), $\mathrm{Br}(h \to \not{E}_T)$ is 3.59% at 2σ level.
$\mathrm{Br}(h \to \not{E}_T)$ is smaller with the increase of the cms energy.
(LHeC→Double_LHC→FCC)

BDT output distribution







Delphes card
LHeC, Double_LHC
“delphes_card_LHeC_PK_V2_eFilter.tcl”
FCC
“delphes_card_FCCeh_PK_finalHFL.tcl”

Summary

- When we analyzed higgs invisible at Double_LHC, $\mathrm{Br}(h \to \not{E}_T)$ is 3.46%(Cut based) and 3.41%(BDT) at 2 σ level, only statistical error considered.

- When we used the up/down scaling factor, $\mathrm{Br}(h \to \not{E}_T)$ becomes smaller with the increase of the cms energy(LHeC→Double_LHC→FCC).

Back up

Cross section

	LHeC	Double_LHC	FCC
Cross section $(H \to 2Z \to 4\nu)$	22.2[fb]	45.7[fb]	124[fb]

Main background($Wj\nu, Zje$)

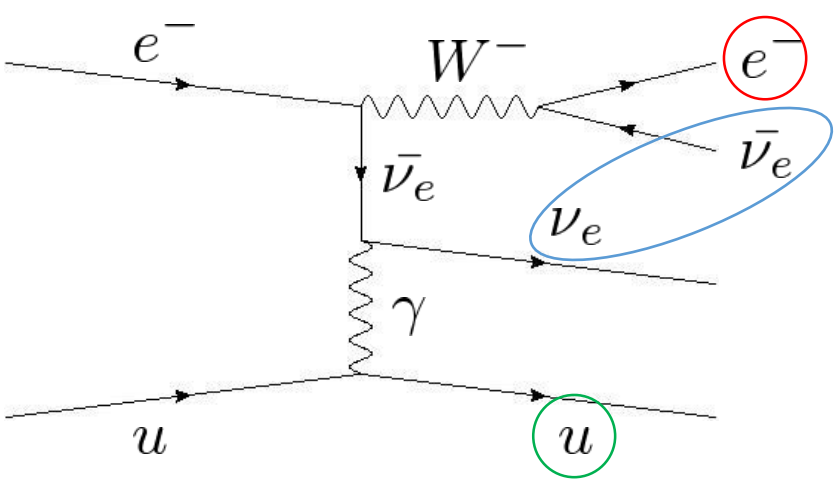
Signal feature

$N_e = 1, N_{jet} = 1, missing\ E_T$

$Wj\nu$

$$p + e^- \rightarrow W^- + j + \nu_e$$

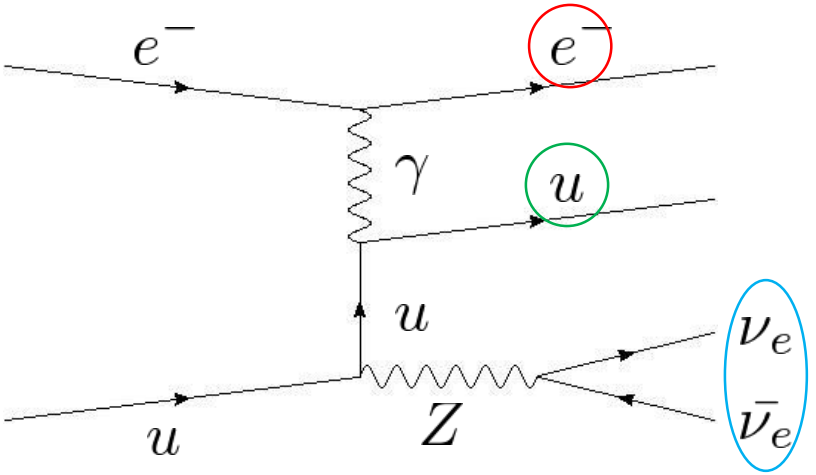
$$W^- \rightarrow e^- + \nu_e$$



Zje

$$p + e^- \rightarrow Z + j + e^-$$

$$Z \rightarrow \nu + \bar{\nu}$$



Main background(Wje)

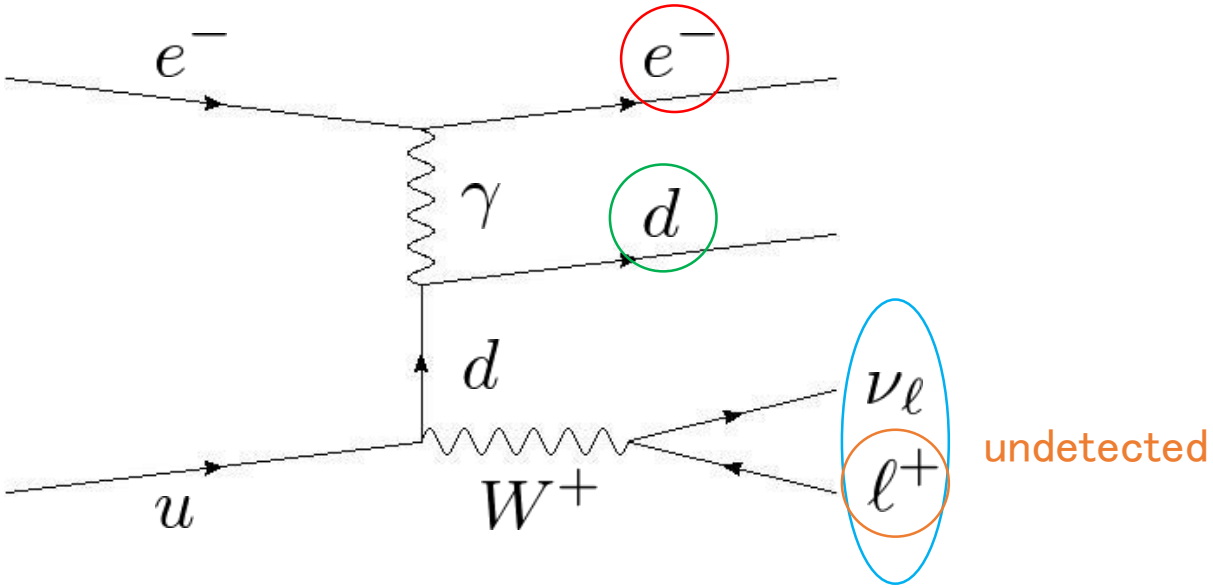
Signal feature

$N_e = 1, N_{jet} = 1, missing\ E_T$

Wje

$p + e^- \rightarrow W + j + e^-$ $\quad W \rightarrow \ell + \nu_\ell$

undetected



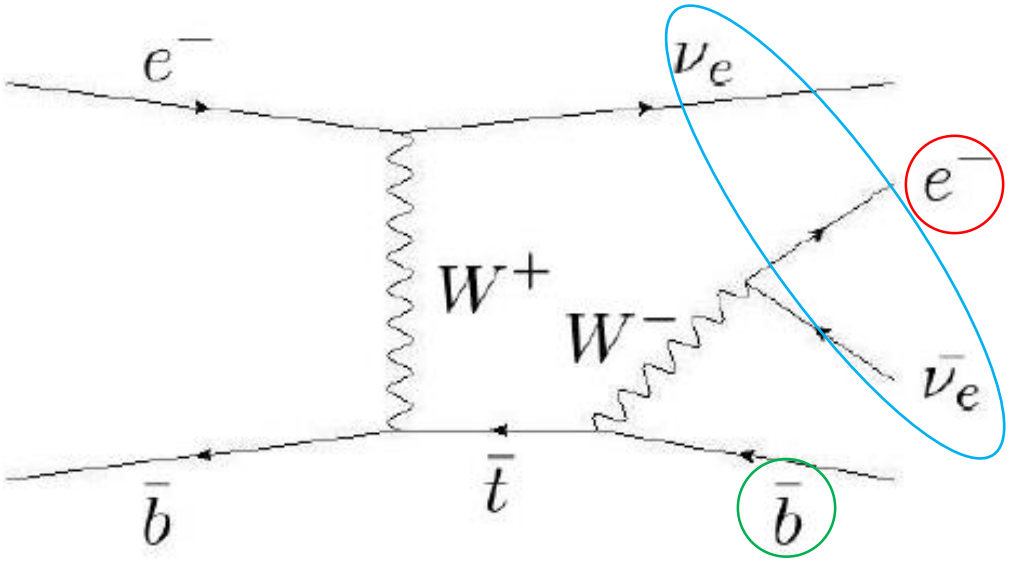
Main background(single_top)

Signal feature

$$N_e = 1, N_{jet} = 1, missing\ E_T$$

single_top

$$p + e^- \rightarrow \bar{t} + \nu_e \quad \bar{t} \rightarrow \bar{b} + W^- \rightarrow \bar{b} + \bar{\nu_e} + e^-$$



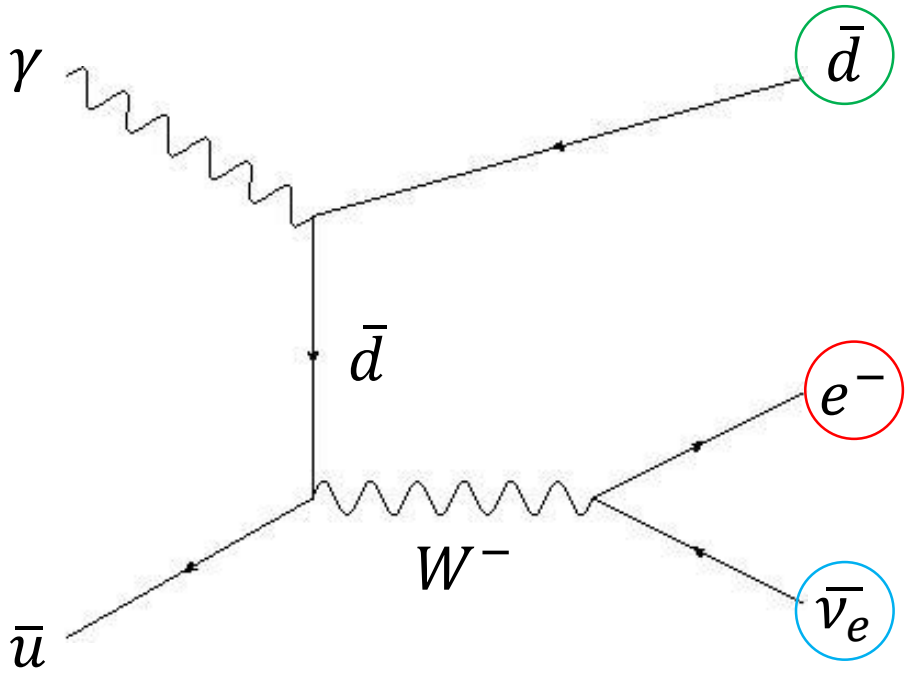
Main background(photoproduction)

Signal feature

$N_e = 1, N_{jet} = 1, missing\ E_T$

photoproduction

$p + \gamma \rightarrow W^- + j \quad W^- \rightarrow e^- + \bar{\nu_e}$



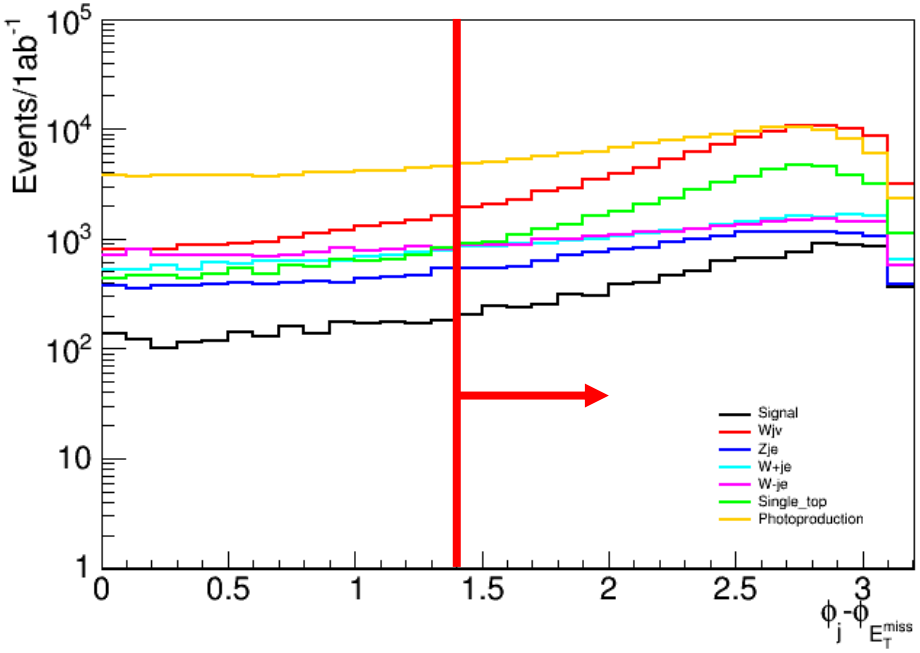
Generator cut

When generating the events

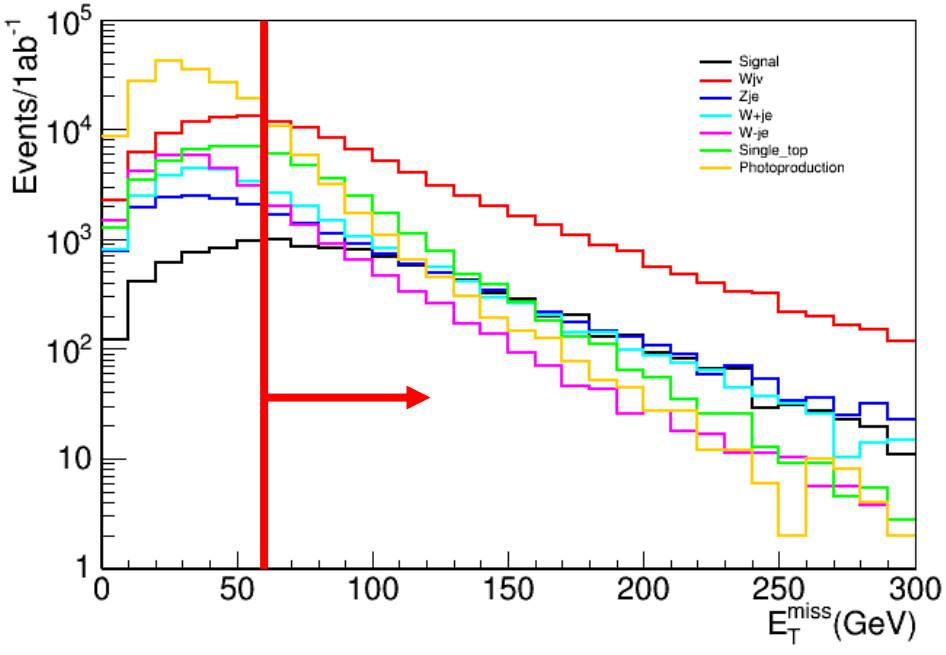
Generator cut:

- $p_T > 10$GeV for at least one parton and one charged lepton
- $|\eta| < 6.0$ for at least one parton and one charged lepton
- $\Delta R > 0.2$ for distance between all partons and charged leptons

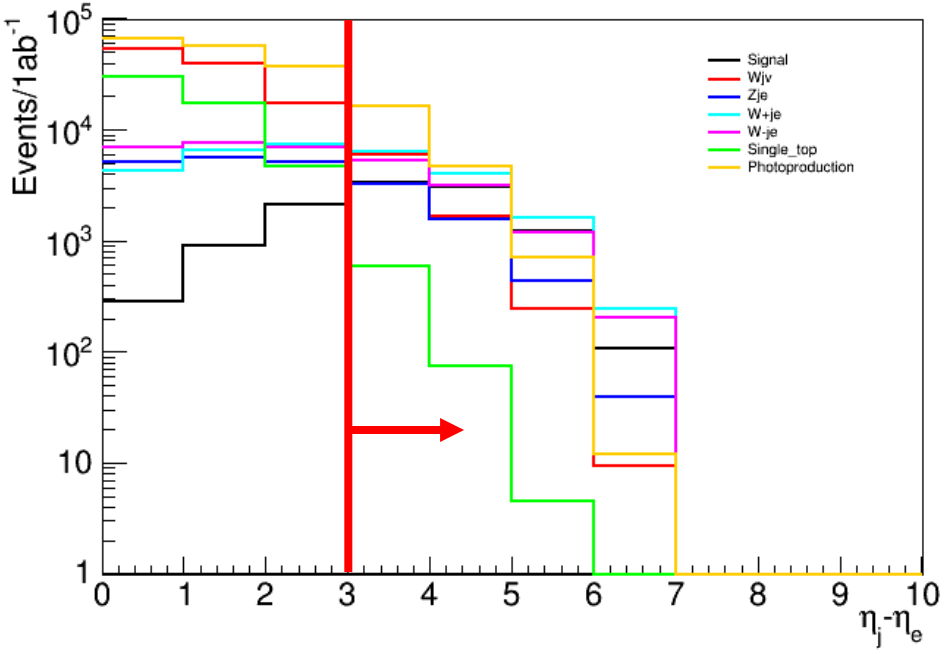
$\left|\phi_j - \phi_{\not{E}_T}\right| > 1.4$ rad



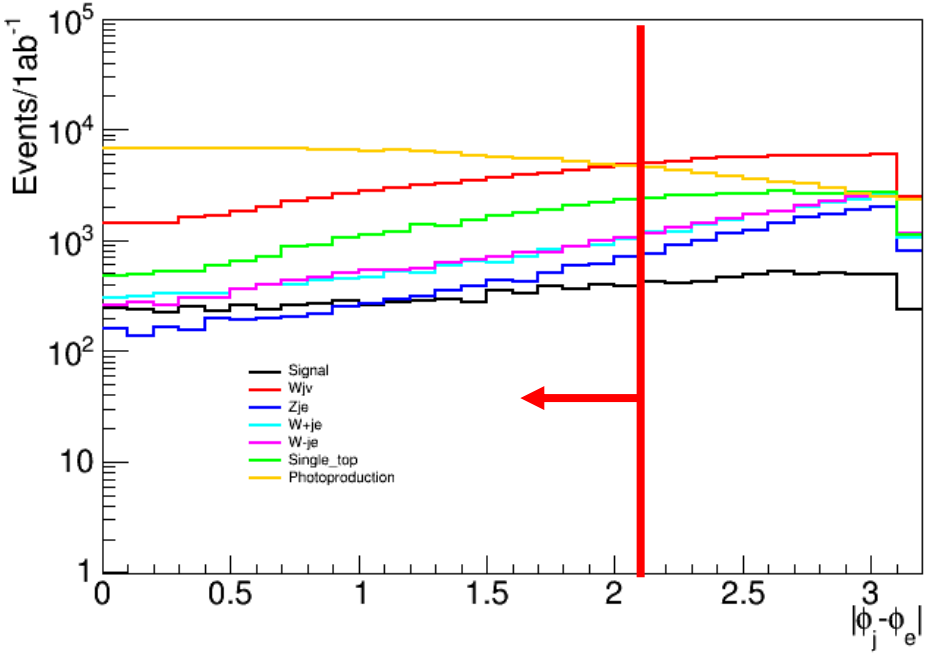
$\not{E}_T > 60$ GeV



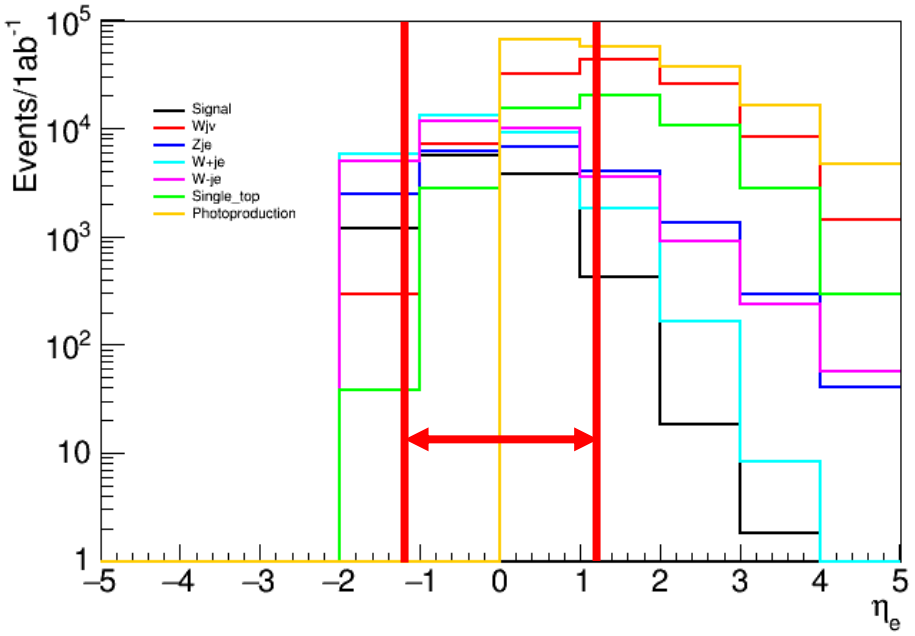
$\eta_j - \eta_e > 3$



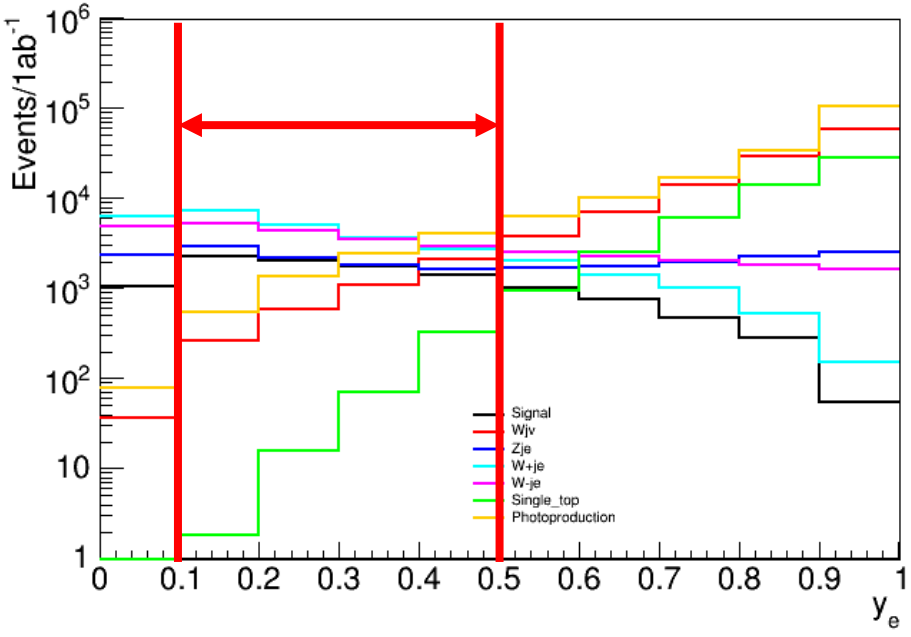
$|\phi_j - \phi_e| < 2.1$



$-1.2 < \eta_e < 1.2$



$0.1 < y_e < 0.5$



LHeC→Double_LHC, FCC

Double_LHC	Original	Scaled
N_S	3727	3848
N_B	3902	4642
Branching Ratio	3.41%	3.59%

FCC	Original	Scaled
N_S	7820	10445
N_B	4183	11817
Branching Ratio	1.68%	2.10%

Double_LHC and FCC perform better than LHeC

Double_LHC→LHeC, FCC

LHeC	Original	Scaled
N_S	2568	1815
N_B	6028	2132
Branching Ratio	6.13%	5.20%

FCC	Original	Scaled
N_S	7820	10138
N_B	4183	9815
Branching Ratio	1.68%	1.97%

Double_LHC performs better than LHeC but worse than FCC

FCC→LHeC, Double_LHC

LHeC	Original	Scaled
N_S	2568	1399
N_B	6028	909
Branching Ratio	6.13%	4.46%

Double_LHC	Original	Scaled
N_S	3727	2885
N_B	3902	1654
Branching Ratio	3.41%	2.89%

FCC performs better than LHeC and Double_LHC