Status report

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Introduction

- When we used the new LHeC delphes_card (eflowphotons→photons), the LHeC is capable of probing $\mathrm{Br}(h \to \not{E}_T) = 7.25\%$ at 2σ level (only statistical error considered).
- When we used the new LHeC delphes_card (eflowphotons→photons) in the updated Delphes (version; 3.3.2), the electron efficiency wasn't improved very well.

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Cut optimization (Cut-based analysis)

We calculated the branching ratio, using 5^8 ways and selected the best combination of all.

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
0.8	50	2.0	1.0	-1.4	0.4	0.04	0.4
0.9	60	2.5	1.1	-1.3	0.5	0.05	0.45
1.0	70	3.0	1.2	-1.2	0.6	0.06	0.5
1.1	80	3.5	1.3	-1.1	0.7	0.07	0.55
1.2	90	4.0	1.4	-1.0	0.8	0.08	0.6

The candidates of the cut value

Red values : I had used these cut values in my study before ($\sim 7.25\%$ $at\ 2\sigma\ level$).

Cut optimization (Cut-based analysis)

The candidates of the cut value

Red values : the best combination of all ($\sim 6.50\%\ at\ 2\sigma\ level$).

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
0.8	50	2.0	1.0	−1.4	0.4	0.04	0.4
0.9	60	2.5	1.1	−1.3	0.5	0.05	0.45
1.0	70	3.0	1.2	−1.2	0.6	0.06	0.5
1.1	80	3.5	1.3	−1.1	0.7	0.07	0.55
1.2	90	4.0	1.4	−1.0	0.8	0.08	0.6

After the optimization, the cut value (cut1, 4, 5, 6) became a maximum value of the candidates.

⇒ The branching ratio may be smaller if the number of candidates increases.

Cut optimization (Cut-based analysis)

We calculated the branching ratio, using 5^8 ways and selected the best combination of all.

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.0	50	1.5	1.2	−1.2	0.6	0.06	0.45
1.1	60	2.0	1.3	−1.1	0.7	0.07	0.5
1.2	70	2.5	1.4	−1.0	0.8	0.08	0.55
1.3	80	3.0	1.5	−0.9	0.9	0.09	0.6
1.4	90	3.5	1.6	−0.8	1.0	0.1	0.65

The candidates of the cut value

Red values : the previous best combination of all.

Cut optimization (Cut-based analysis)

The candidates of the cut value

Red values : the best combination of all ($\sim 6.17\%\ at\ 2\sigma\ level$).

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.0	50	1.5	1.2	−1.2	0.6	0.06	0.45
1.1	60	2.0	1.3	−1.1	0.7	0.07	0.5
1.2	70	2.5	1.4	−1.0	0.8	0.08	0.55
1.3	80	3.0	1.5	−0.9	0.9	0.09	0.6
1.4	90	3.5	1.6	−0.8	1.0	0.1	0.65

After the optimization, the cut value (cut1, 4, 5) became a maximum value of the candidates.

⇨ The branching ratio may be smaller if the number of candidates increases.

Cut optimization (Cut-based analysis)

We calculated the branching ratio, using 5^8 ways and selected the best combination of all.

Cut1	**Cut2**	**Cut3**	**Cut4**	**Cut5**		**Cut6**	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.2	50	2.0	1.4	−1.1	0.8	0.07	0.45
1.3	60	2.5	1.5	−1.0	0.9	0.08	0.5
1.4	70	3.0	1.6	−0.9	1.0	0.09	0.55
1.5	80	3.5	1.7	−0.8	1.1	0.1	0.6
1.6	90	4.0	1.8	−0.7	1.2	0.11	0.65

The candidates of the cut value

Red values : the previous best combination of all.

Cut optimization (Cut-based analysis)

The candidates of the cut value

Red values : the best combination of all ($\sim 6.03\%\ at\ 2\sigma\ level$).

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.2	50	2.0	1.4	−1.1	0.8	0.07	0.45
1.3	60	2.5	1.5	−1.0	0.9	0.08	0.5
1.4	70	3.0	1.6	−0.9	1.0	0.09	0.55
1.5	80	3.5	1.7	−0.8	1.1	0.1	0.6
1.6	90	4.0	1.8	−0.7	1.2	0.11	0.65

After the optimization, the cut value (cut4, 5) became a maximum (or minimum) value of the candidates.

The branching ratio may be smaller if the number of candidates increases.

Cut optimization (Cut-based analysis)

We calculated the branching ratio, using 5^8 ways and selected the best combination of all.

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.3	40	2.0	1.6	−1.3	1.0	0.07	0.5
1.4	50	2.5	1.7	−1.2	1.1	0.08	0.55
1.5	60	3.0	1.8	−1.1	1.2	0.09	0.6
1.6	70	3.5	1.9	−1.0	1.3	0.1	0.65
1.7	80	4.0	2.0	−0.9	1.4	0.11	0.7

The candidates of the cut value

Red values : the previous best combination of all.

Cut optimization (Cut-based analysis)

We calculated the branching ratio, using 5^8 ways and selected the best combination of all.

Cut1	Cut2	Cut3	Cut4	Cut5		Cut6	
$\lvert\phi_j - \phi_{\not{E}_T}\rvert >$	$\not{E}_T >$	$\eta_j - \eta_e >$	$\lvert\phi_j - \phi_e\rvert <$	$< \eta_e <$		$< y_e <$	
1.3	40	2.0	1.6	−1.3	1.0	0.07	0.5
1.4	50	2.5	1.7	−1.2	1.1	0.08	0.55
1.5	60	3.0	1.8	−1.1	1.2	0.09	0.6
1.6	70	3.5	1.9	−1.0	1.3	0.1	0.65
1.7	80	4.0	2.0	−0.9	1.4	0.11	0.7

The candidates of the cut value

Red values : the best combination of all.

Result for 1ab^{-1}

new LHeC delphes_card (eflowphotons→photons) (version; 3.1.2)

Event	cut0	cut1	cut2	cut3	cut4	cut5	cut6	cut7
Signal (Br=100%)	12079	7743	5261	3108	2454	2252	1961	1916
$Wj\nu$	332243	212432	113323	4632	3301	2810	872	845
Zje	30635	17799	8131	1396	975	745	480	469
$W^{+}je$	312747	163603	65123	23611	11816	9399	7527	1410
$W^{-}je$	320639	142326	29292	8894	4879	3849	3180	550
…								
Total background	1224569	666413	273873	39074	21346	17155	12130	3305

The number of events of the signal and the main backgrounds after application of each cut, assuming an integrated luminosity of 1ab^{-1}

Statistical significance:

$$Z = \frac{N_s}{\sqrt{N_b}} = \frac{1916 \times \mathrm{Br}(h \to \not{E}_T)}{\sqrt{3305}}$$

In the case of 2σ ⇒ $\mathrm{Br}(h \to \not{E}_T) \sim 6.00\%$

※$\mathrm{Br}(h \to \not{E}_T) \sim 7.25\%$ (before optimization)

The number of the jets cut

We added the cut using the number of the jets in the cut7 ($N_j = 1$).

Event	**cut0**	**cut1**	**cut2**	**cut3**	**cut4**	**cut5**	**cut6**	**cut7**
Signal (Br=100%)	12079	7743	5261	3108	2454	2252	1961	1542
$Wj\nu$	332243	212432	113323	4632	3301	2810	872	660
Zje	30635	17799	8131	1396	975	745	480	350
W^+je	312747	163603	65123	23611	11816	9399	7527	764
W^-je	320639	142326	29292	8894	4879	3849	3180	323
…								
Total background	1224569	666413	273873	39074	21346	17155	12130	2111

The number of events of the signal and the main backgrounds after application of each cut, assuming an integrated luminosity of $1ab^{-1}$

Statistical significance:

In the case of 2σ

$$Z = \frac{N_s}{\sqrt{N_b}} = \frac{1542 \times \mathrm{Br}(h \to \not{E}_T)}{\sqrt{2111}} \Rightarrow \mathrm{Br}(h \to \not{E}_T) \sim 5.96\%$$

MVA

We analyzed the signal and the backgrounds by MVA (BDT).

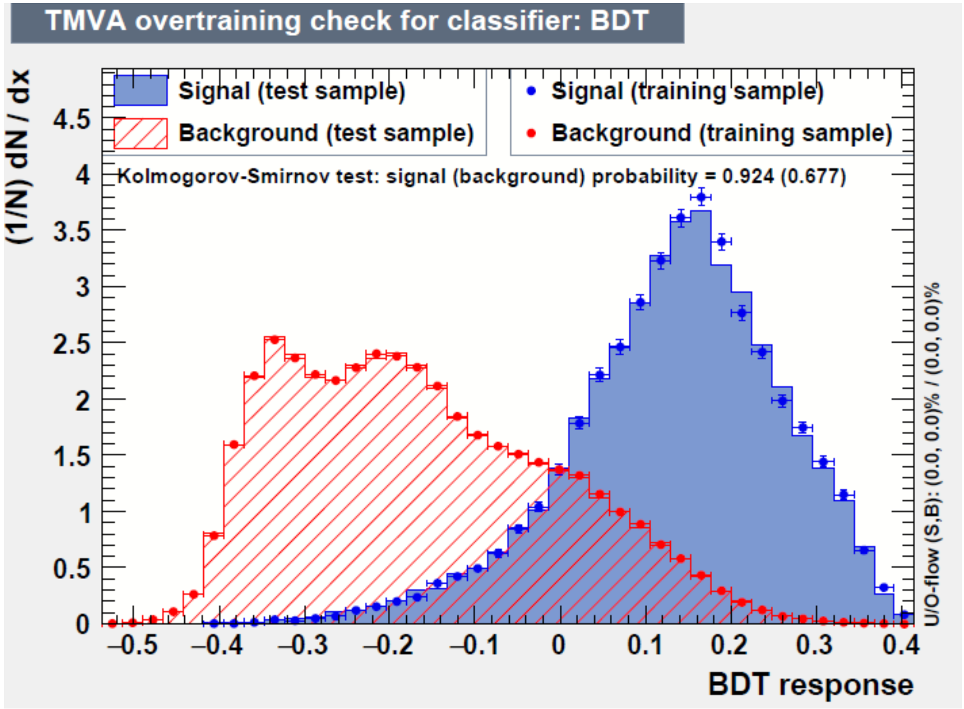
MC sample:

Signal and backgrounds after cut0 and cut7.

Input variables:

$\left|\phi_j - \phi_{\not{E}_T}\right|, missing\ E_T, \eta_j - \eta_e,$
$\left|\phi_j - \phi_e\right|, \eta_e, y_e$

(which is used in cut1～cut6)

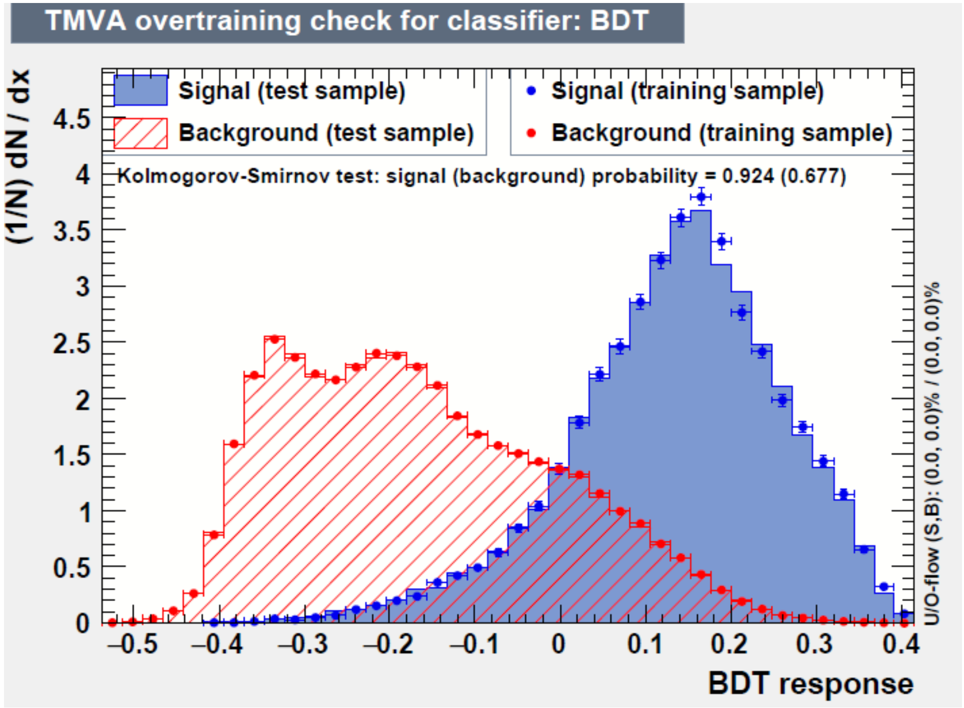


This isn’t overtraining.

Cut optimization (MVA)

We calculated the branching ratio, using 8 ways and selected the best combination of all.

Score >	N_s	N_B	**Br[%]**
0	10166	121942	6.87
0.05	9114	78079	6.13
0.1	7614	44624	5.55
0.15	5628	21358	5.19
0.2	3545	8142	5.09
0.25	1983	2722	5.26
0.3	920	819	6.22
0.35	238	118	9.13



$$Z = \frac{N_s}{\sqrt{N_b}} = \frac{3545 \times \mathrm{Br}(h \to \not{E}_T)}{\sqrt{8142}}$$

In the case of 2σ

$$\mathrm{Br}(h \to \not{E}_T) \sim 5.09\%$$

※$\mathrm{Br}(h \to \not{E}_T) \sim 5.96\%$ (cut-based)

Summary

- After the cut optimization (cut- based analysis), $\mathrm{Br}(h \to \not{E}_T) = 6.00\%$ at 2σ level (only statistical error considered).
- When we added the number of the jets cut ($N_j = 1$), $\mathrm{Br}(h \to \not{E}_T) = 5.96\%$ at 2σ level (only statistical error considered).
- When we analyzed by MVA, $\mathrm{Br}(h \to \not{E}_T) = 5.09\%$ at 2σ level (only statistical error considered).

Back up

Cut0:basic cut

After the Delphes simulation

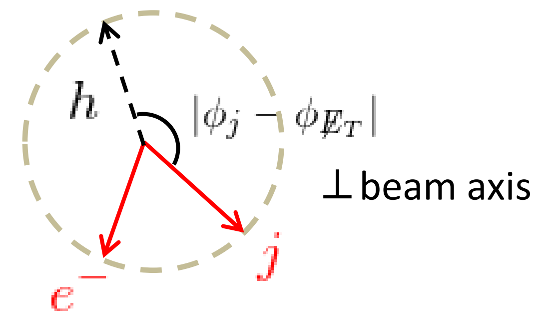
Basic cut：

- $N_j \geq 1, N_e \geq 1$ for the jet and the electron
- $p_T > 20\mathrm{GeV}$ 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

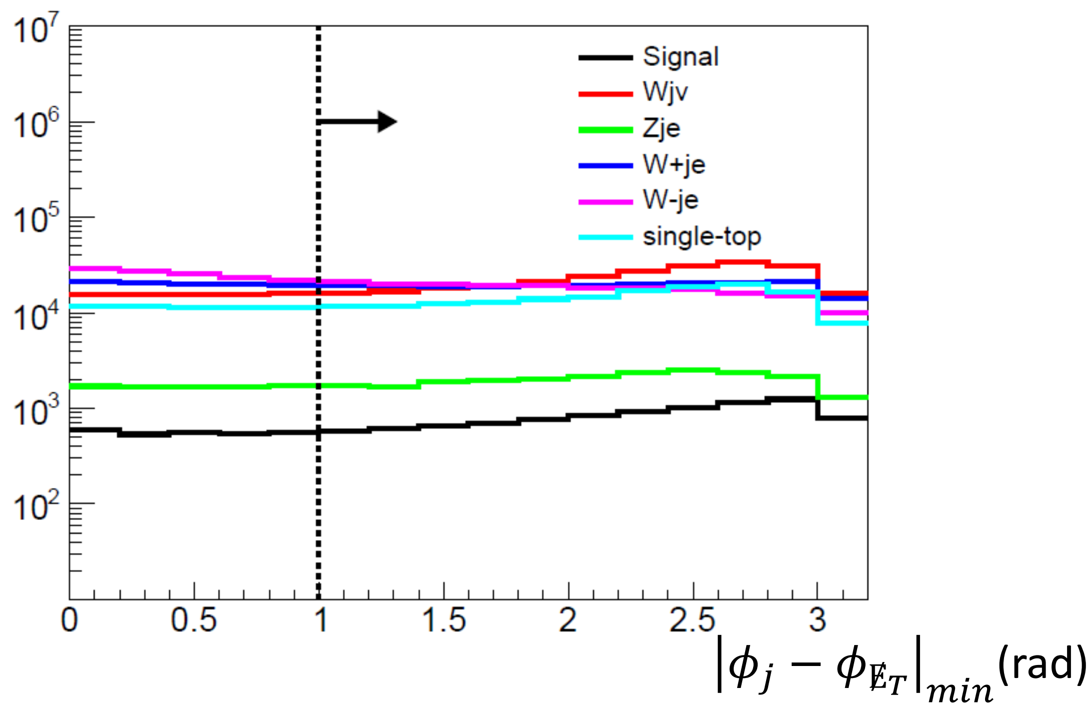
Leading jet (electron):
the one with the highest transverse momentum of the reconstructed jets (electrons)

Cut1: $|\phi_j - \phi_{\not{E}_T}| > 1\text{rad}$

In the $e + multijet(inside)$ production, the missing E_T comes from the jet energy mismeasurement. Therefore $|\phi_j - \phi_{\not{E}_T}|$ in the $e + multijet(inside)$ production tends to be smaller than that in the signal

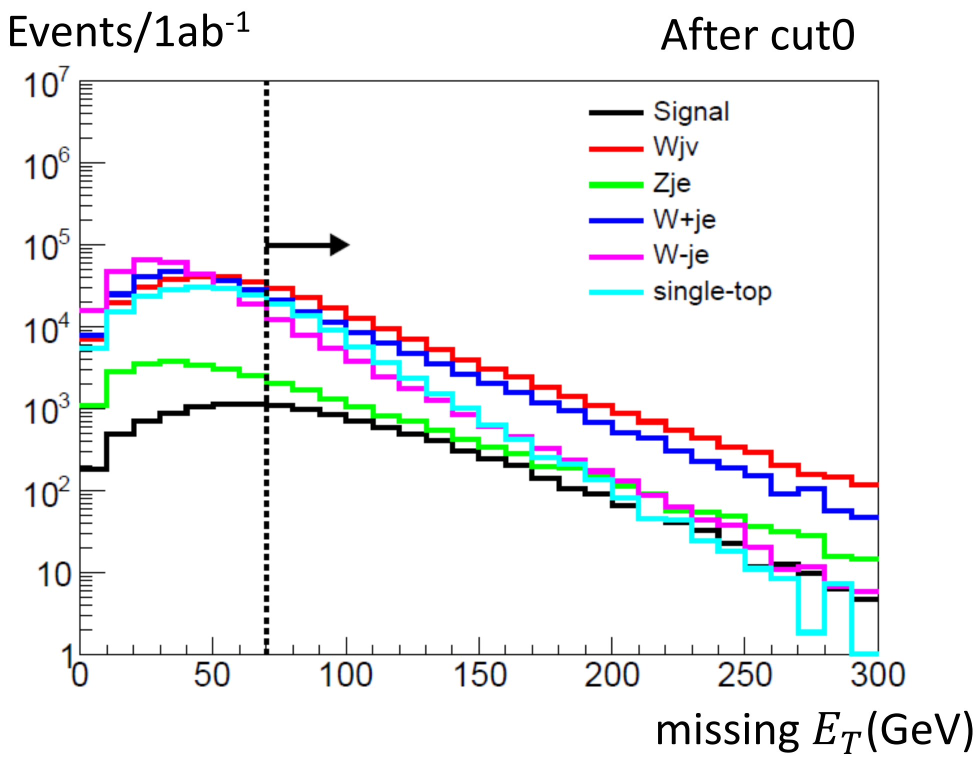


Events/1ab^{-1} After cut0



Cut2: $\not{E}_T > 70$ GeV

In the $e + multijet(inside)$ production, the missing E_T comes from the jet energy mismeasurement. Therefore the missing E_T in the $e + multijet(inside)$ production tends to be smaller than that in the signal.



Cut3: $\eta_j - \eta_e > 3.0$

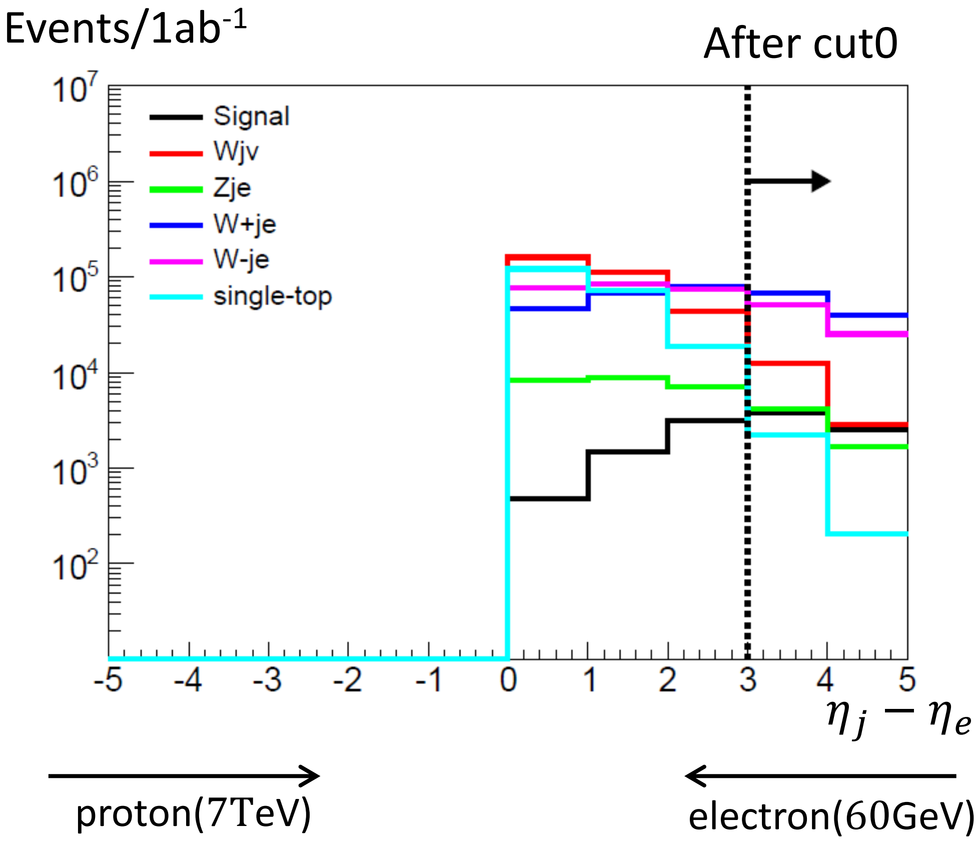
$\eta_j - \eta_e$ tends to be larger in the signal than the backgrounds because

- $E_p(7TeV) \gg E_e(60GeV)$

  $\Rightarrow$ η_j tends to be larger

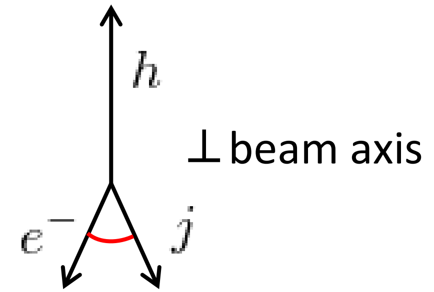
- The signal is t-channel

  $\Rightarrow$ η_e tends to be smaller

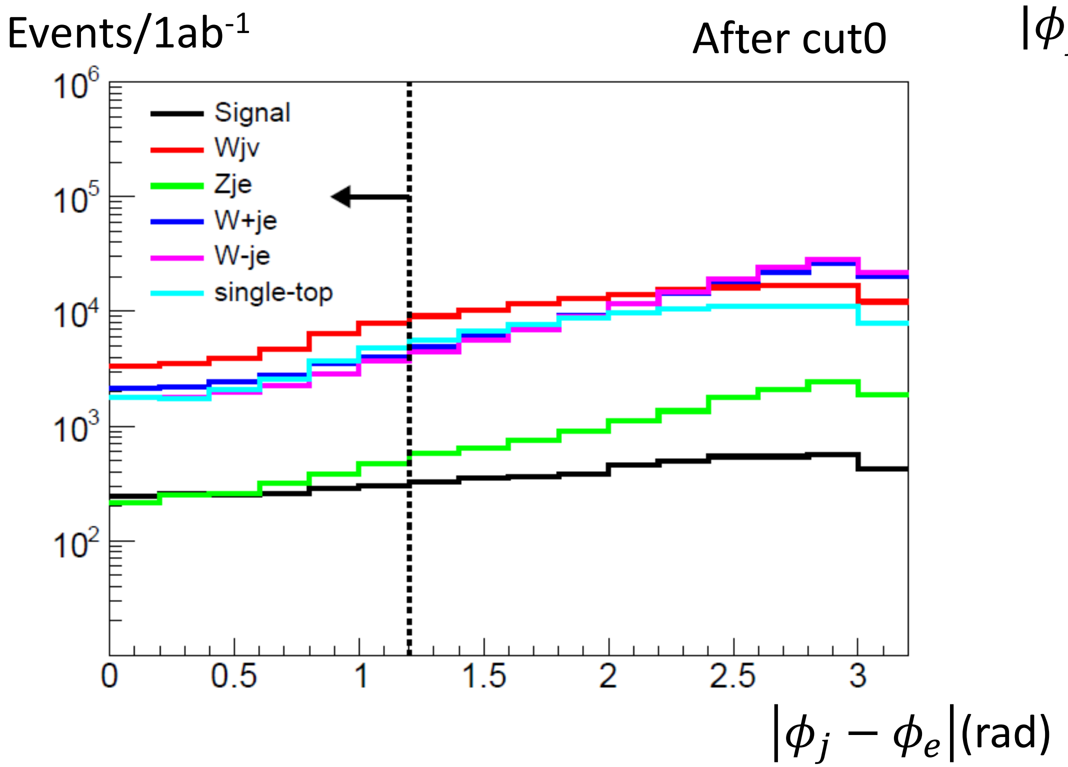


Cut4: $|\phi_j - \phi_e| < 1.2$

The missing energy directs toward the motion direction of the Higgs boson. Therefore, due to the momentum conservation, $|\phi_j - \phi_e|$ tends to be smaller In the signal than the backgrounds.



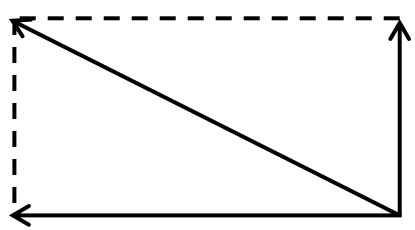
$|\phi_j - \phi_e|$ is small



Cut5: $-1.2 < \eta_e < 0.6$

The signal is t-channel. Therefore η_e tends to be smaller in the signal than the backgrounds

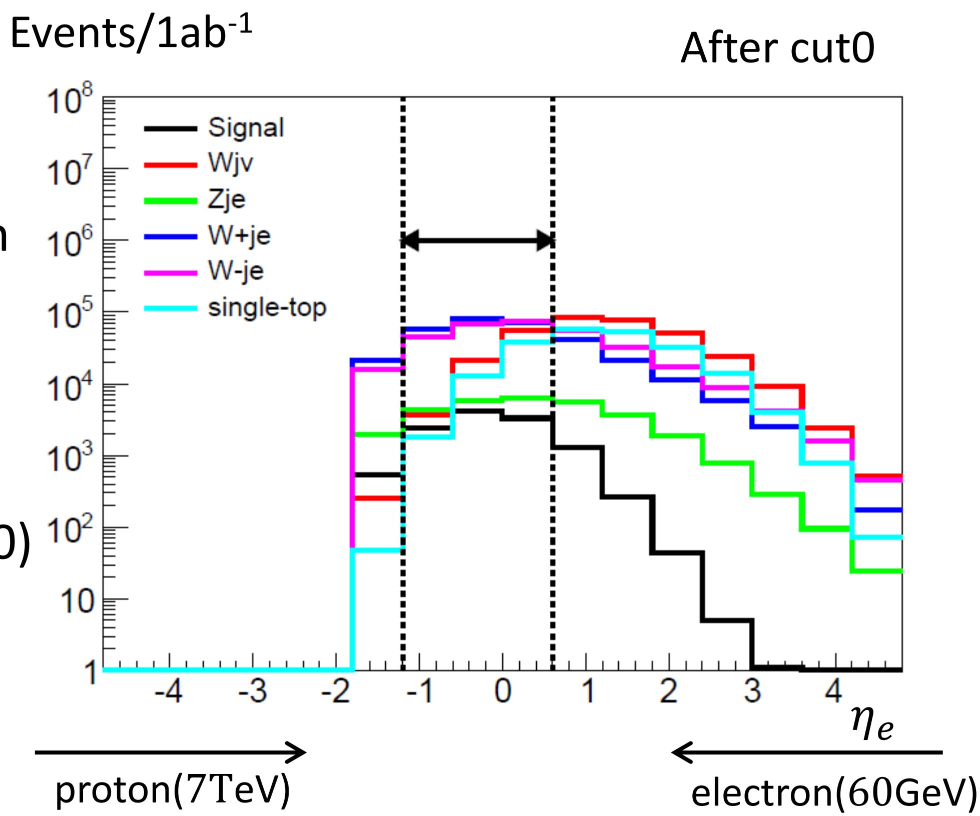
$\eta_e \sim -1.8$



> 20GeV (from cut0)

< 60GeV (initial electron p_Z)

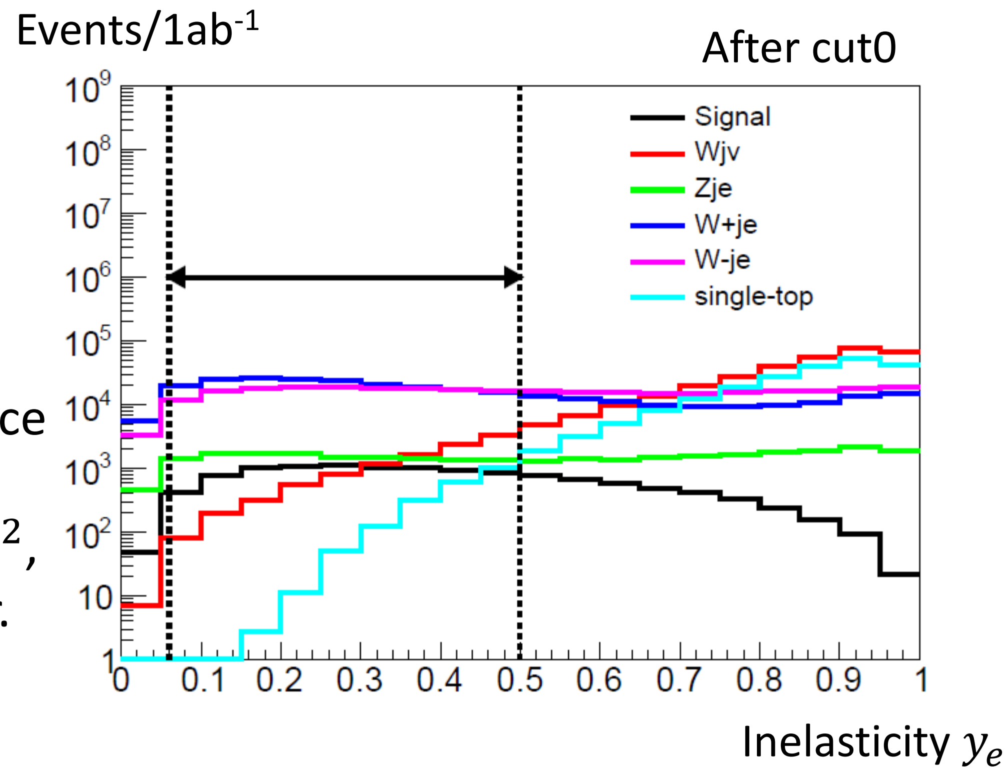
η_e must be > -1.8



Cut6: $0.06 < y_e < 0.5$

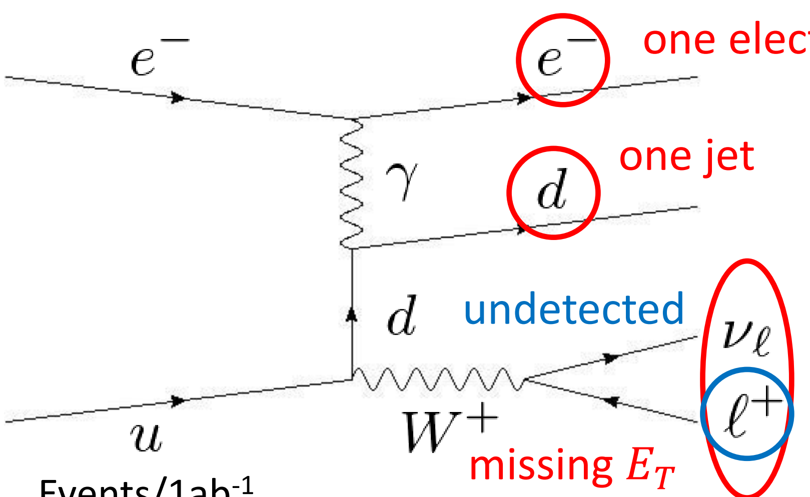
$$Q^2 = sxy_e$$

A high-x parton is required to produce a heavy particle like a Higgs boson. Therefore, when assuming a fixed Q^2, the inelasticity y tends to be smaller.

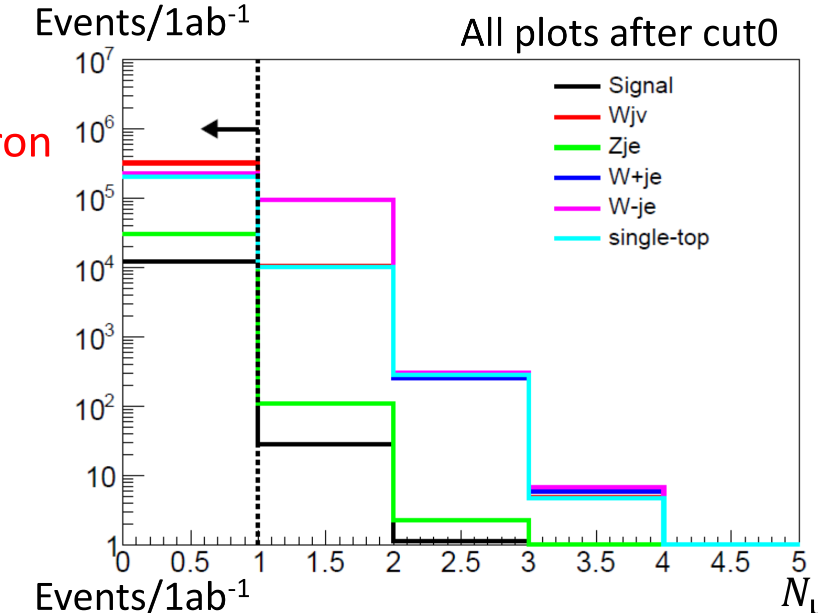


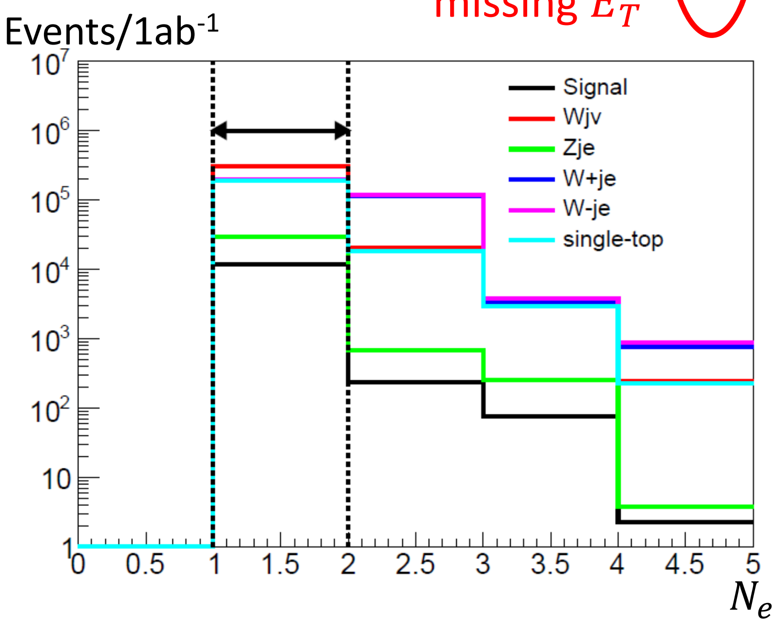
Cut7: $N_e = 1, N_\mu = N_\tau = 0$

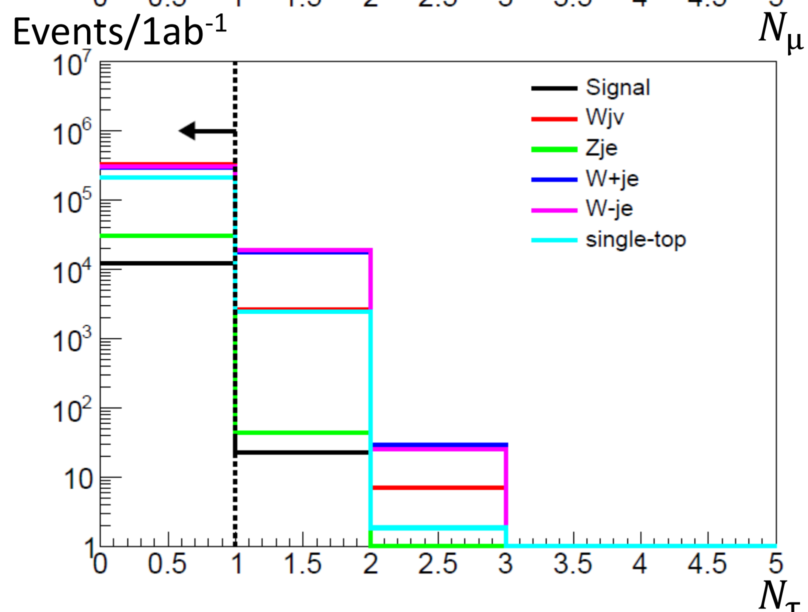
Wje background



All plots after cut0







The number of jets distribution