Z(ll)H, H->WW at 240 GeV

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Process: ee⟶ZH, H⟶WW

$$e^+ e^- \rightarrow Z H \rightarrow Z (\mu\mu) H (WW) \rightarrow Z (\mu\mu) W (q \bar{q}) W (q \bar{q})$$

Process	Sample	Cross Section (pb)	Events processed
SIGNAL			
ee →Z(μμ) H, H→WW	wzp6_ee_mumuH_HWW_ecm240	0.001456	400,000
BACKGROUND			
ee →WW	p8_ee_WW_ecm240	16.4385	74,728,784
ee →ZZ	p8_ee_ZZ_ecm240	1.35899	11,300,000
ee →Z(μμ) γ	wzp6_ee_mumu_ecm240	5.288	21,360,000
ee →Z(μμ) H, H→ZZ	wzp6_ee_mumuH_HZZ_ecm240	0.0001786	400,000
ee →Z(qq) H, H→ZZ	wzp6_ee_qqH_HZZ_ecm240	0.001409	1,200,000
ee →Z(bb) H, H→ZZ	wzp6_ee_bbH_HZZ_ecm240	0.0007915	1,000,000
ee →Z(cc) H, H→ZZ	wzp6_ee_ccH_HZZ_ecm240	0.0006164	1,200,000
ee →Z(ss) H, H→ZZ	wzp6_ee_ssH_HZZ_ecm240	0.0007912	600,000

Final state:

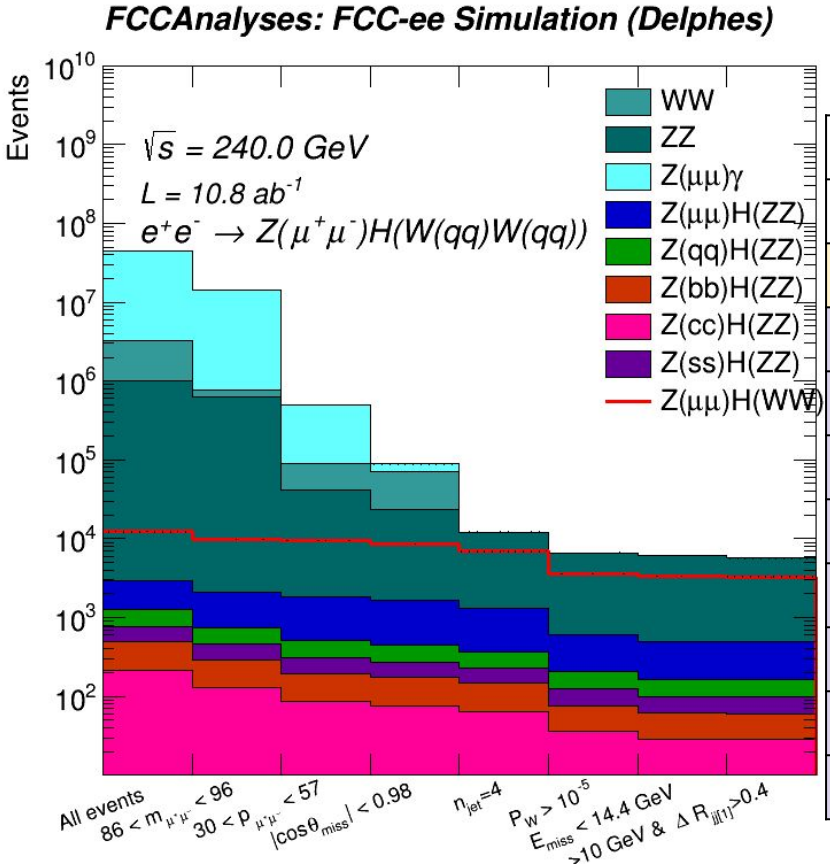
- 2 μ's
- 4 jets

Muon selection:

- p > 20 Gev
- At least one with ISO > 0.25
- Exactly 2, opposite-charged

Using 20% of p8_ee_WW_ecm240 and p8_ee_ZZ_ecm240 samples

Plots (Signal not stacked): Cut Flow



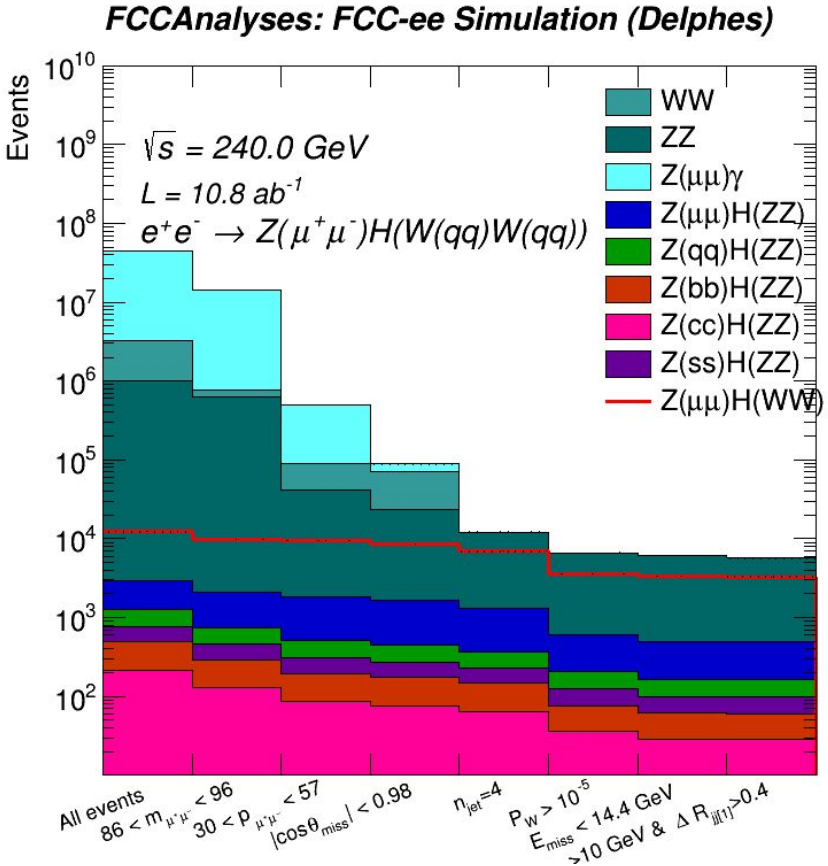
Selections:

- 86 GeV < m(μμ) < 96 GeV
- 30 GeV < p(μμ) < 57 GeV
- $\cos(\theta_{miss}) < 0.98$
- $n_{jet}=4$
- $P_W>10^{-5}$
- $E_{miss}<14.4$ GeV
- $m_{jj[1]}>10$ GeV && $\Delta R_{jj[1]}>0.4$

	Cut Flow (%)						
Sample	**m(μμ)**	**p(μμ)**	**$\cos(\theta_{miss})$**	**n_{jet}**	**P_W**	**E_{miss}**	**$m_{jj[1]}$, $\Delta R_{jj[1]}$**
ee →Z(μμ)H(WW)	80.67%	78.64%	70.93%	56.56%	29.17%	27.16%	26.95%
ee →WW	6.73%	2.13%	2.06%	0.00%	0.00%	0.00%	0.00%
ee →ZZ	62.63%	4.08%	2.22%	1.09%	0.61%	0.57%	0.52%
ee →Z(μμ)γ	33.13%	0.99%	0.04%	0.00%	0.00%	0.00%	0.00%
ee →Z(μμ)H(ZZ)	81.02%	78.97%	71.60%	55.91%	23.35%	19.95%	19.63%
ee →Z(qq)H(ZZ)	58.94%	39.92%	34.18%	28.47%	16.32%	13.27%	12.96%
ee →Z(bb)H(ZZ)	58.38%	39.35%	35.90%	29.97%	14.69%	11.65%	11.48%
ee →Z(cc)H(ZZ)	58.83%	39.45%	35.00%	29.16%	16.44%	13.26%	13.03%
ee →Z(ss)H(ZZ)	58.85%	39.90%	34.47%	28.67%	16.68%	13.53%	13.12%

Using 20% of p8_ee_WW_ecm240 and p8_ee_ZZ_ecm240 samples

Plots (Signal not stacked): m(μμ)



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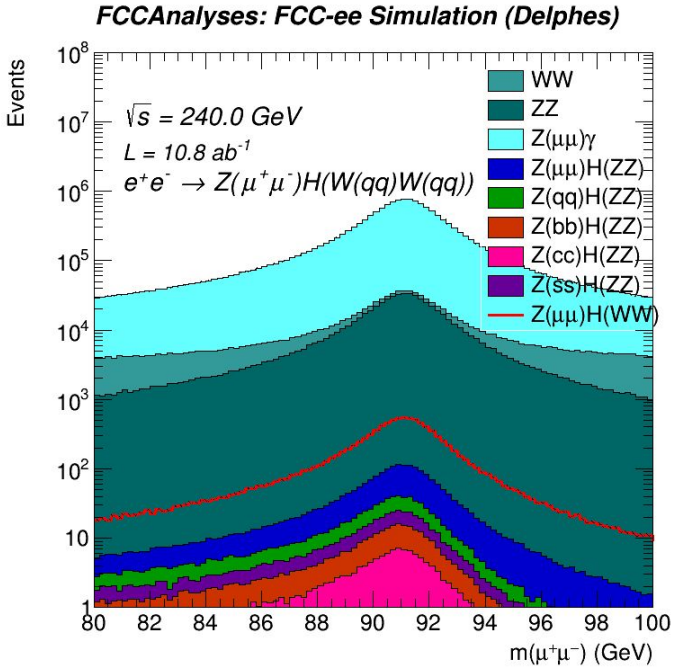
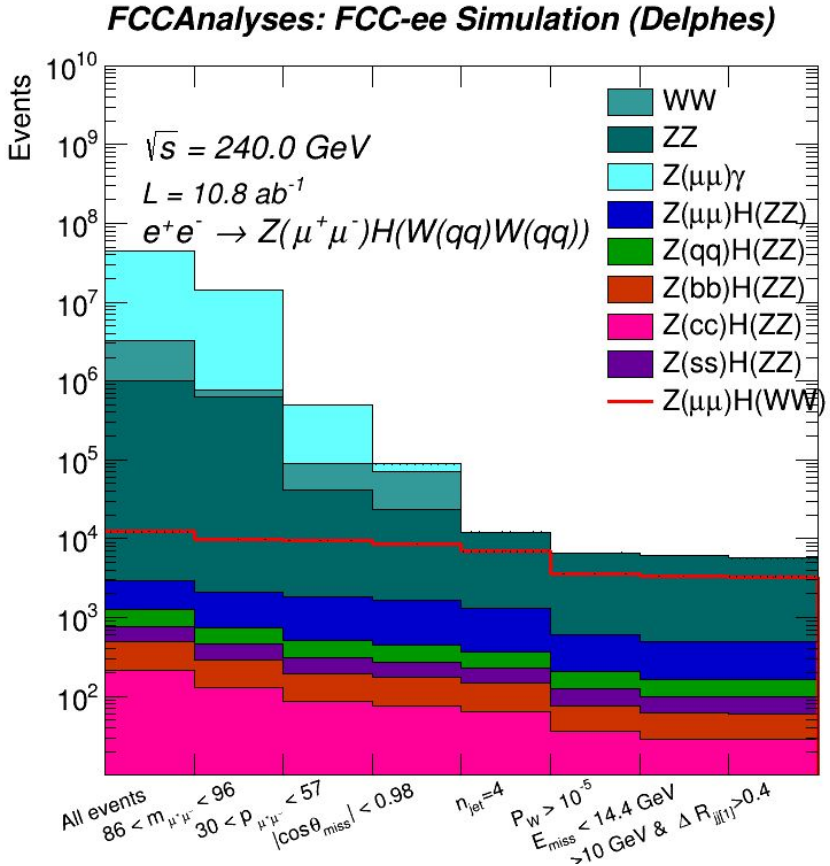


Using 20% of p8_ee_WW_ecm240 and p8_ee_ZZ_ecm240 samples

Plots (Signal not stacked): p(μμ)



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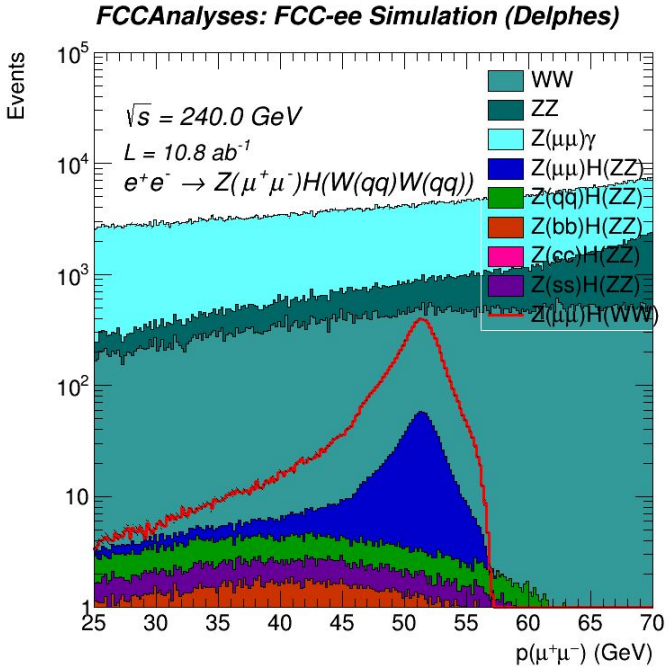

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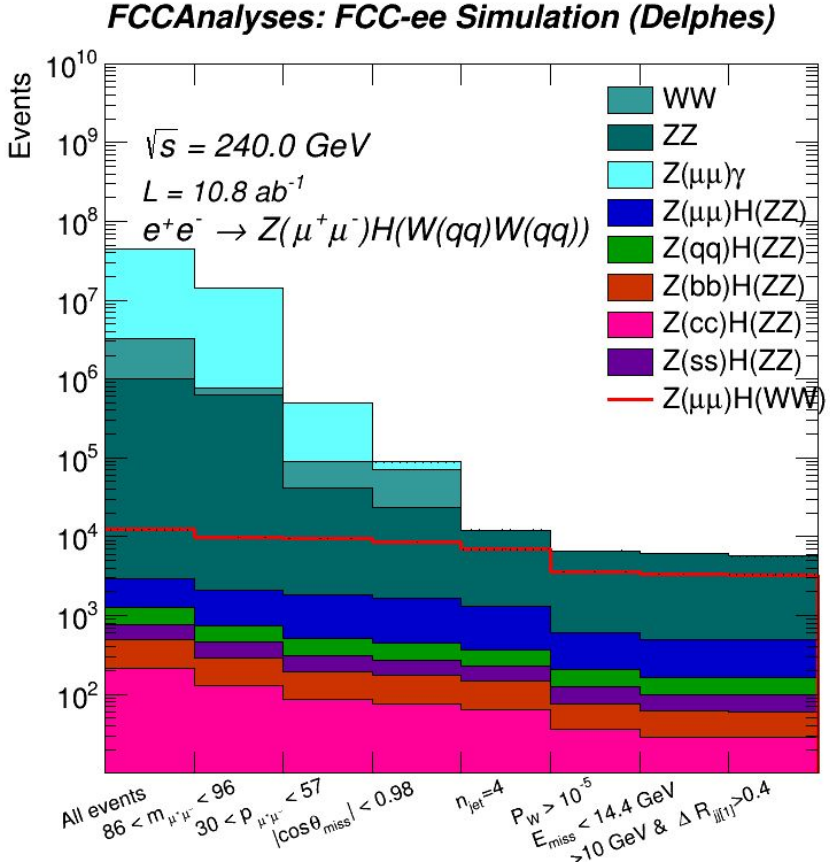
Plots (Signal not stacked): $\cos(\theta_{miss})$



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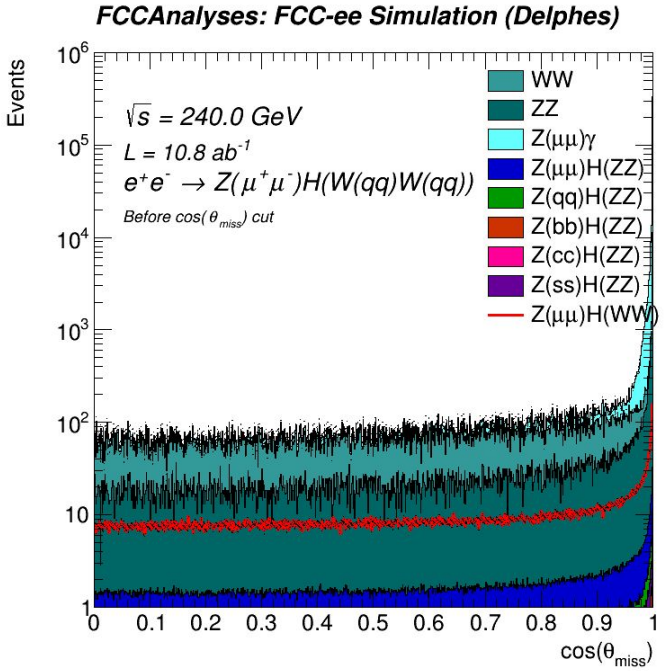
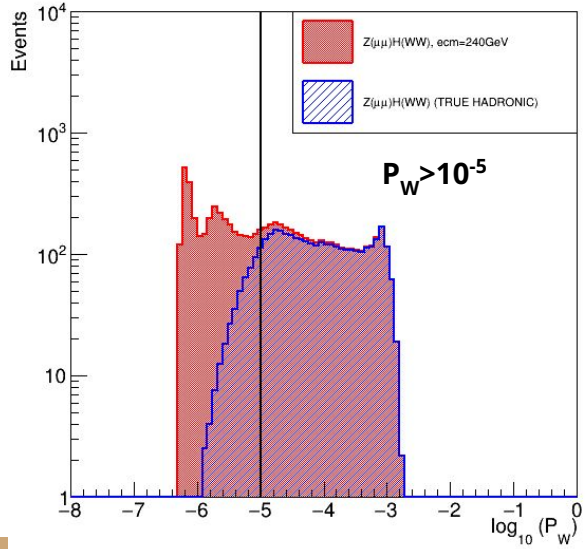


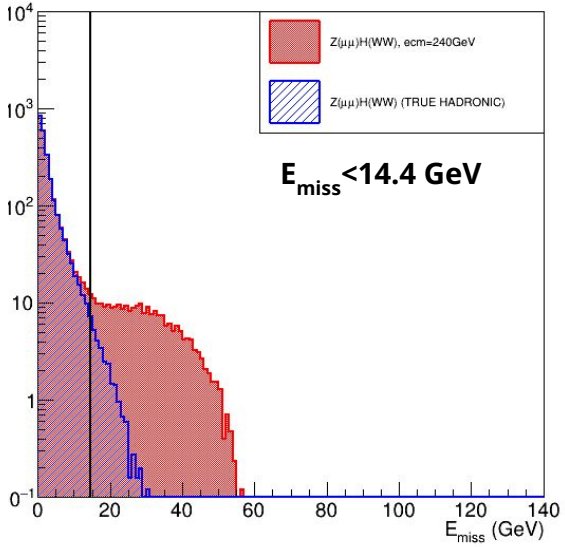
Jet Clustering and Choice of Di-Jet pairs

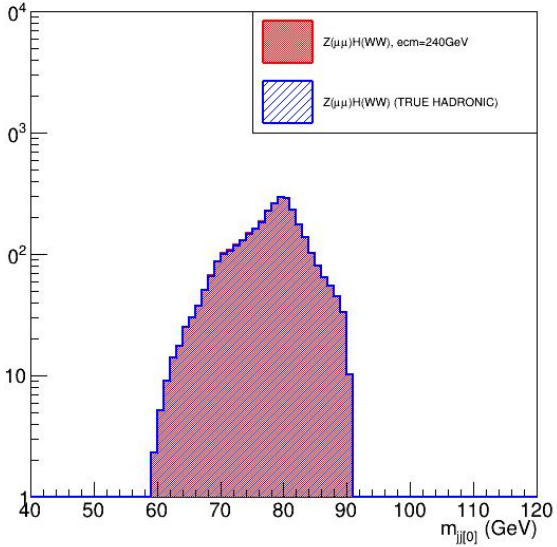
$H \longrightarrow WW^* \longrightarrow qqqq$

- Exclusive Jet Clustering n=4, after veto of muons with p > 5 GeV and electrons with p > 5 GeV.
- Jet pairs selected by maximizing $\mathbf{P_W}$, for at least one of the pairs (considered to come from the on-shell W).

$$P_{W,m_{jj}} = \frac{M_W^2\,\Gamma_W^2}{(m_{jj}{}^2 - M_W^2)^2 + M_W^2\,\Gamma_W^2}$$







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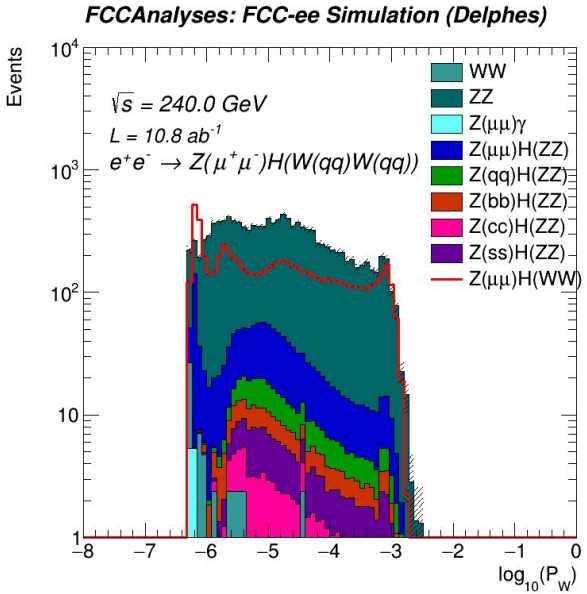

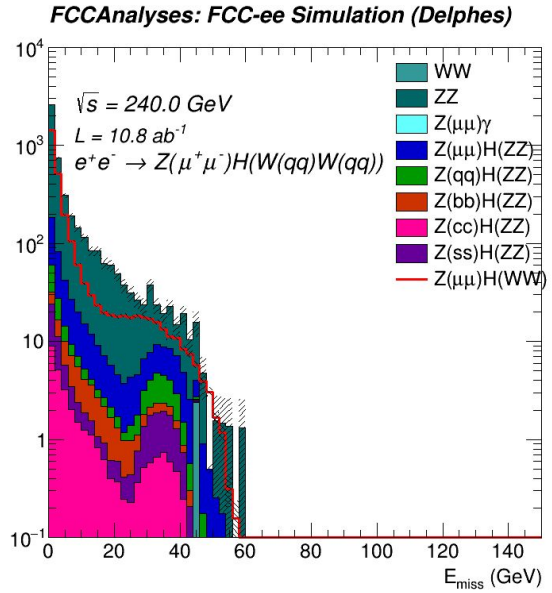

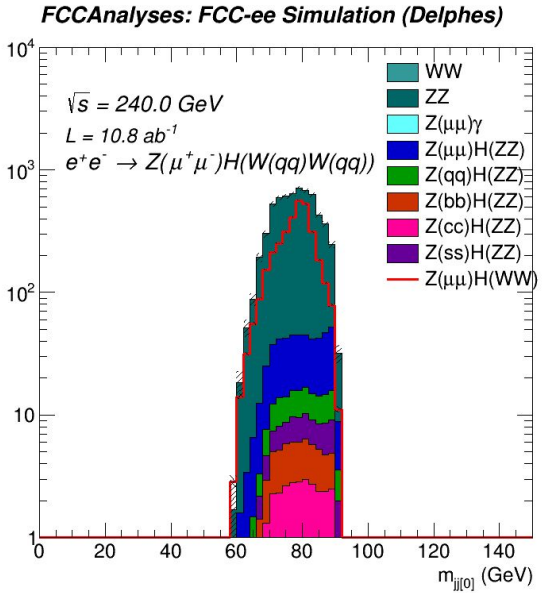

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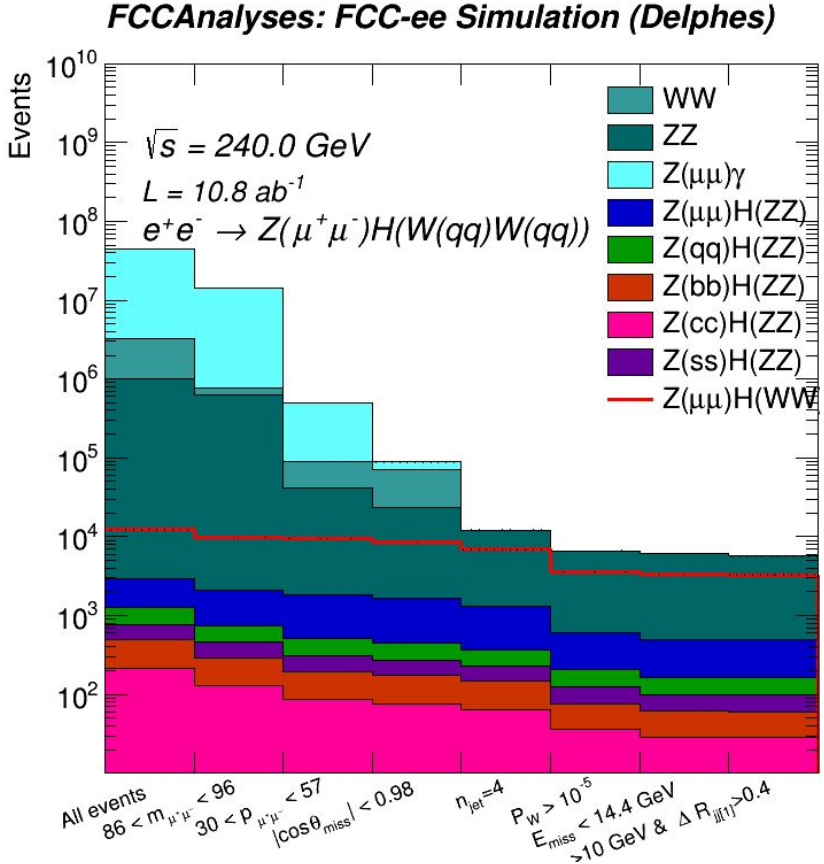
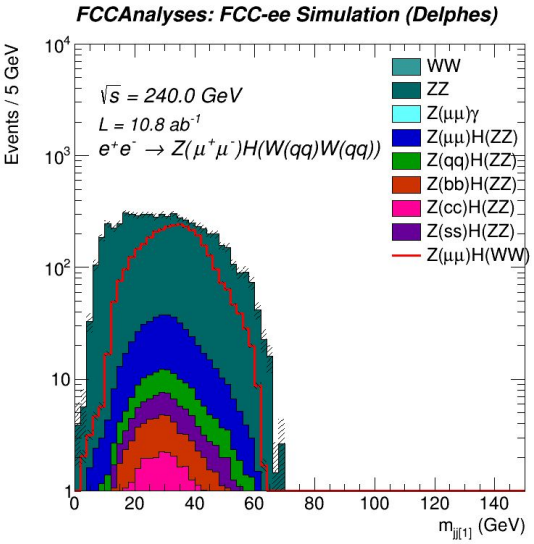
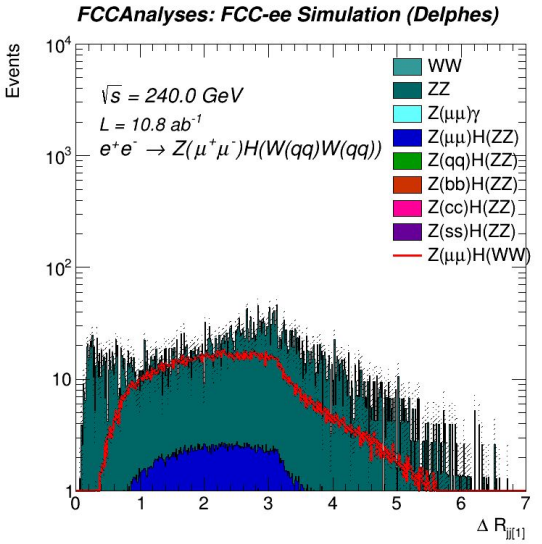
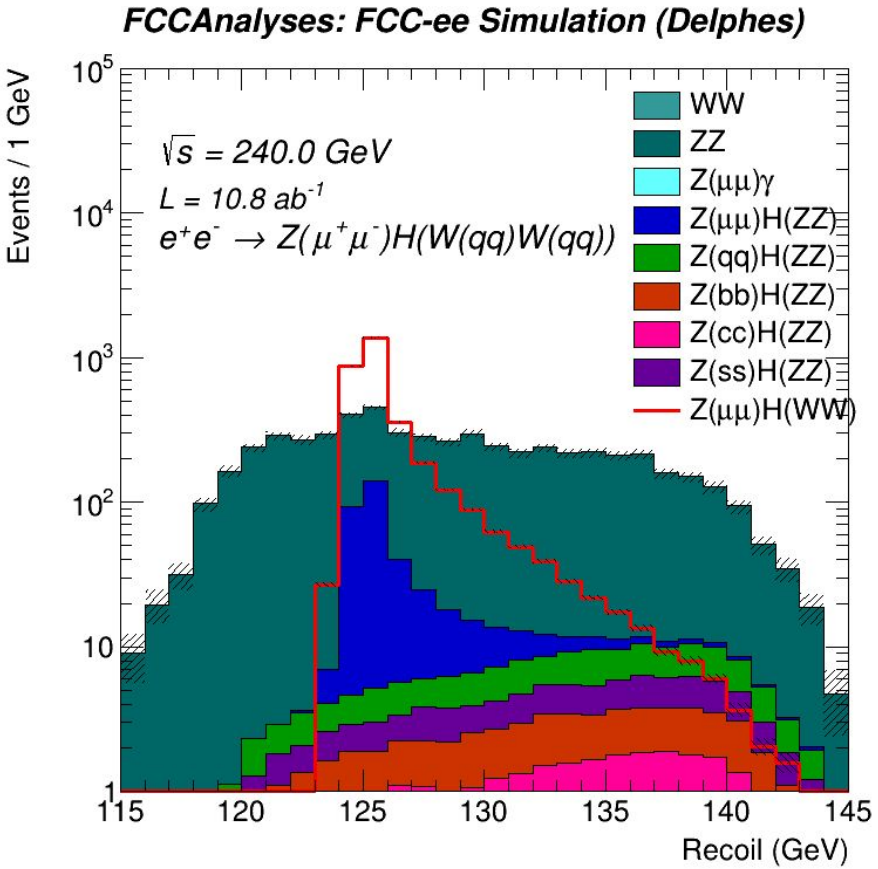






(Signal not stacked) m_{recoil} after selections and significance



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Uncertainty of 2.2%

Significance before selections:

$$\sigma = \frac{S}{\sqrt{B}} = 2.29, \quad \hat{\sigma} = \frac{S}{\sqrt{S+B}} = 2.29$$

Significance after all selections:

$$\sigma = \frac{S}{\sqrt{B}} = 43.81, \quad \hat{\sigma} = \frac{S}{\sqrt{S+B}} = 34.82$$

Findings

- Selections significantly reduce WW background, ZZ background.
- Recoil mass best candidate for fitting.
- There is more room for optimizing the selection.

TO DO

- Shape fit with combine to get the final numbers.
- Work on the note for this study to be considered for the Feasibility Study Report.
- Analize Z(ee) in addition to Z(μμ).
- Employ BDT training with more statistics.

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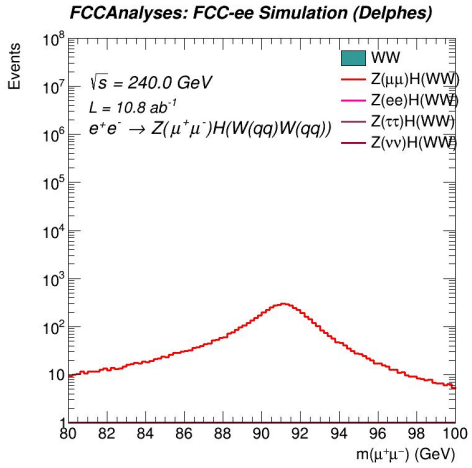
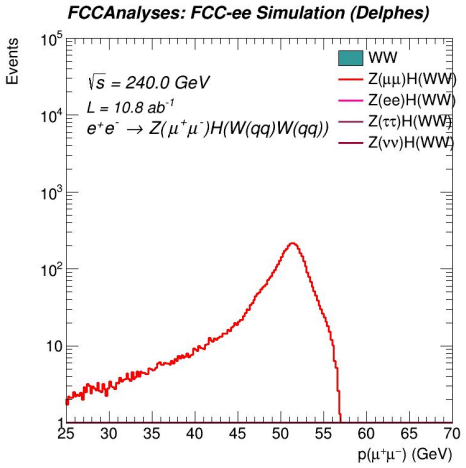
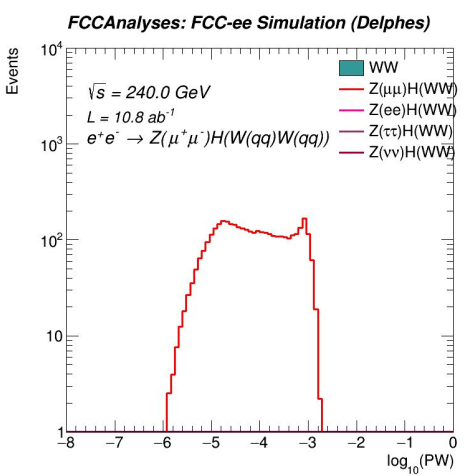
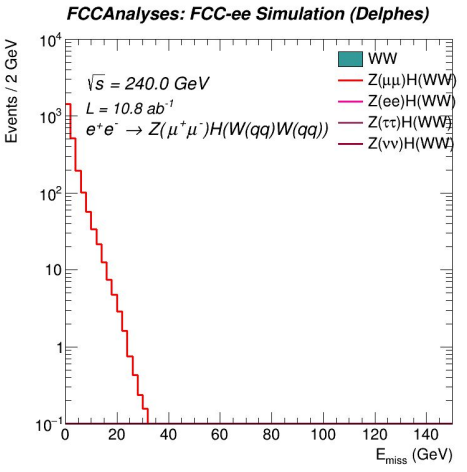
AUXILIARY SLIDES

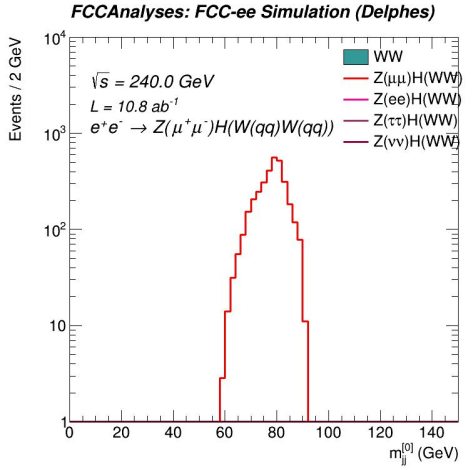
True Hadronic plots

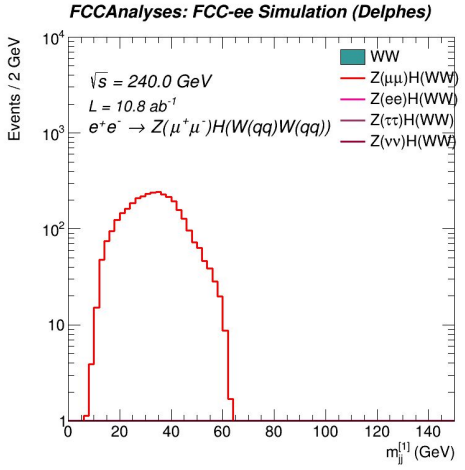


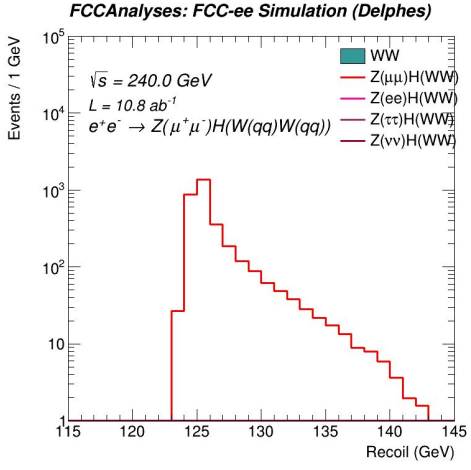






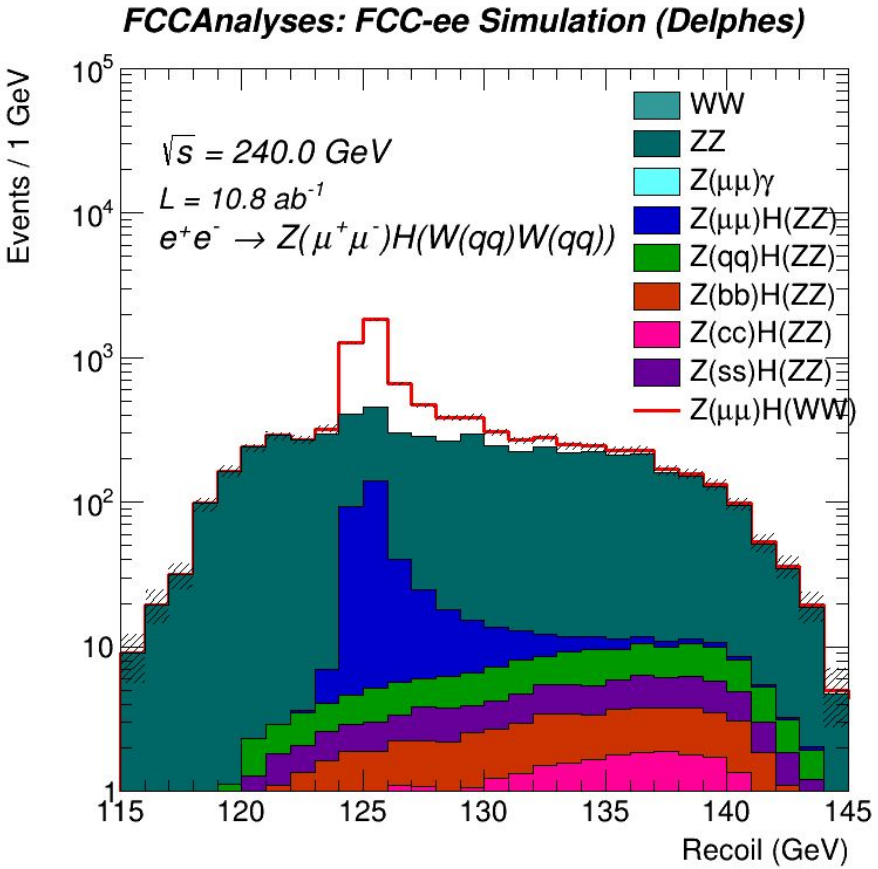






STACKED PLOTS

(STACKED) m_{recoil} after selections and significance



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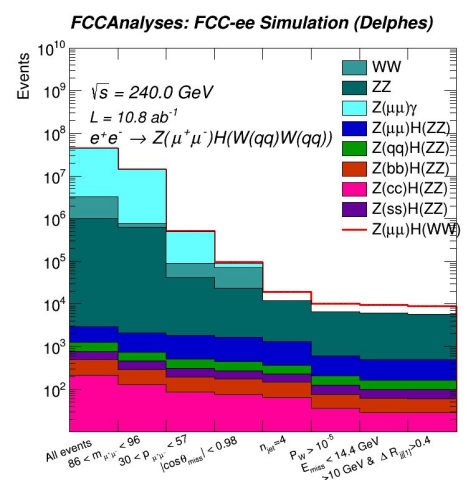
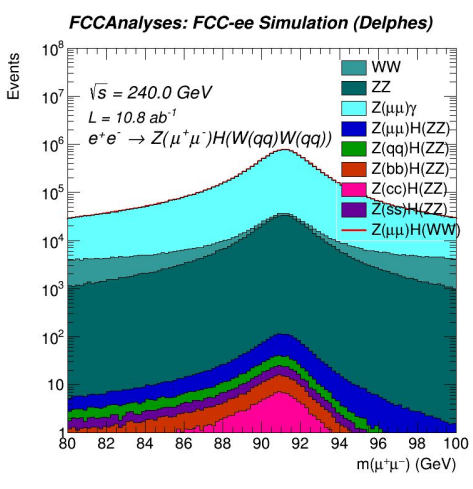

FCCAnalyses: FCC-ee Simulation (Delphes)
Events
√s = 240.0 GeV
L = 10.8 ab-1
e+e- → Z(μ+μ-)H(W(qq)W(qq))
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
All events
86 < mμ+μ- < 96
30 < pμ+μ- < 57
|cosθmiss| < 0.98
njet=4
Pw > 10-5
Emiss < 14.4 GeV
>10 GeV & ΔR(jj)>0.4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Events
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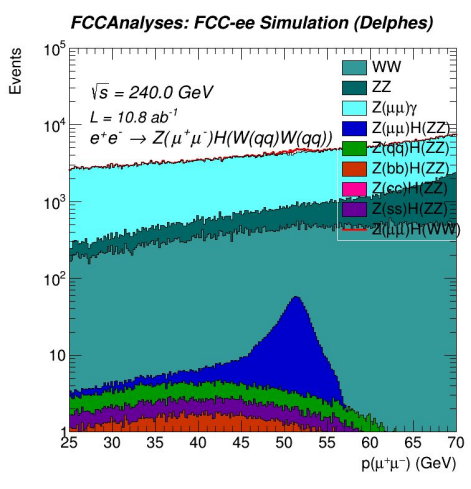
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
m(μ+μ-) (GeV)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Events
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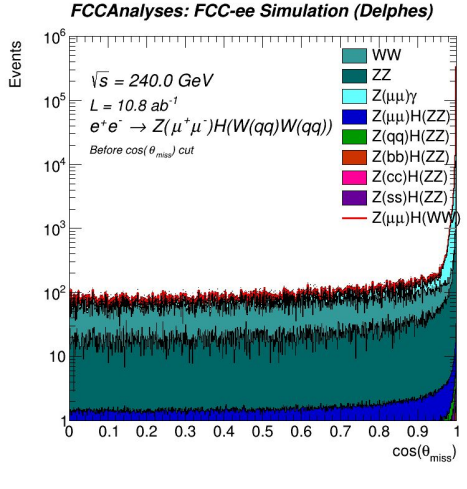
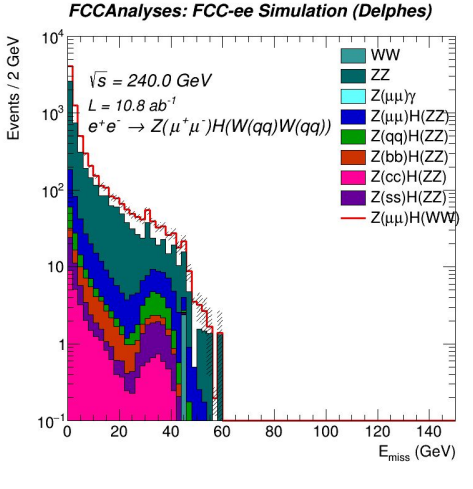
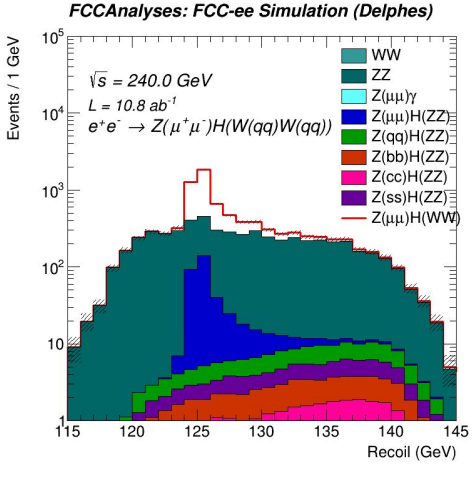
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
p(μ+μ-) (GeV)


FCCAnalyses: FCC-ee Simulation (Delphes)
Events
√s = 240.0 GeV
L = 10.8 ab-1
e+e- → Z(μ+μ-)H(W(qq)W(qq))
Before cos(θmiss) cut
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
cos(θmiss)


FCCAnalyses: FCC-ee Simulation (Delphes)
Events / 2 GeV
√s = 240.0 GeV
L = 10.8 ab-1
e+e- → Z(μ+μ-)H(W(qq)W(qq))
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
Emiss (GeV)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Events / 1 GeV
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e+e- → Z(μ+μ-)H(W(qq)W(qq))
WW
ZZ
Z(μμ)γ
Z(μμ)H(ZZ)
Z(qq)H(ZZ)
Z(bb)H(ZZ)
Z(cc)H(ZZ)
Z(ss)H(ZZ)
Z(μμ)H(WW)
Recoil (GeV)