Analysis of Higgs to 4l at the Future Circular Collider FCC-ee

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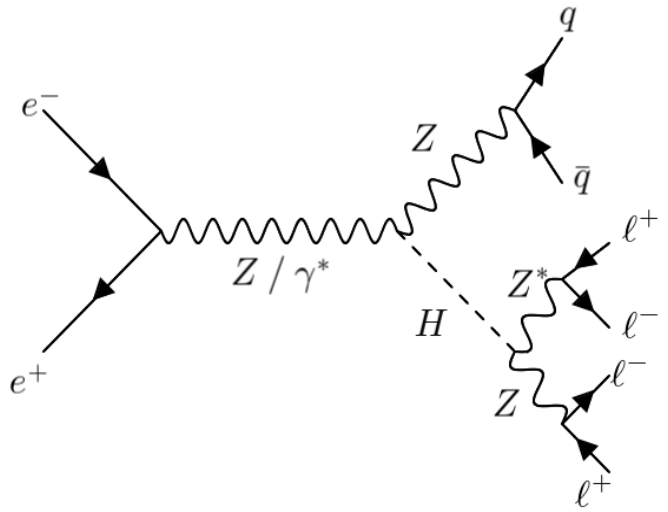
ZH at FCCee: Higgs to 4l

Updates from last meeting:

- Added the rest hadronic flavours for **Z(jj) H(4l)**
- Added the rest of the leptonic flavours (**4e** and **2e2μ**)
- Added the **Z(νν) H(4l)** channel.
- Improvements on cuts



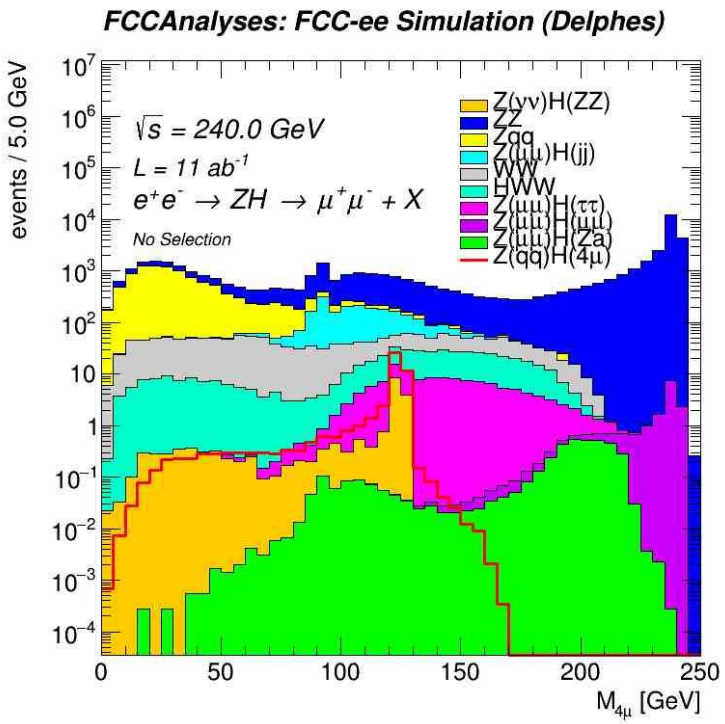
Lepton Selection criteria (Same for hadronic and invisible channels):

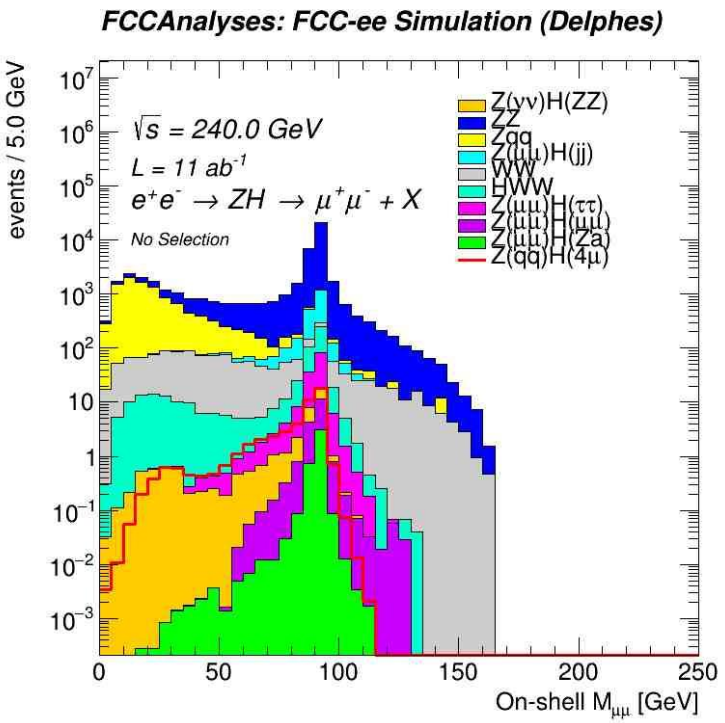
- First pair of leptons (From On-shell Z)
  - Oppositely charged leptons
  - The pair which minimises $|M_{ll} - M_Z|$

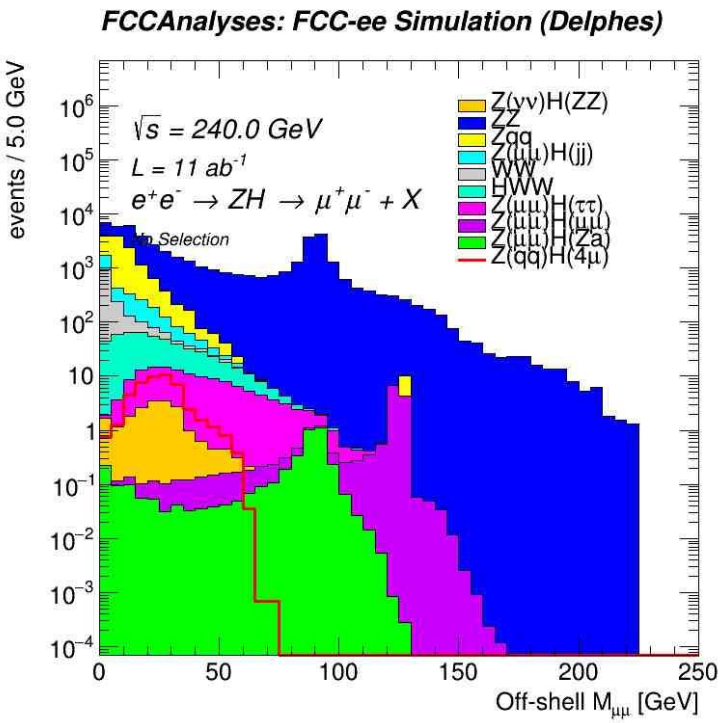
- Second Pair of leptons (From off-shell Z)
  - Oppositely charged leptons
  - Highest momentum oppositely charged pair of the remaining

- Additional cut for 2e2mu: On-shell Z mass > 60 GeV. This is to remove contribution from Off-Shell Z leptons.

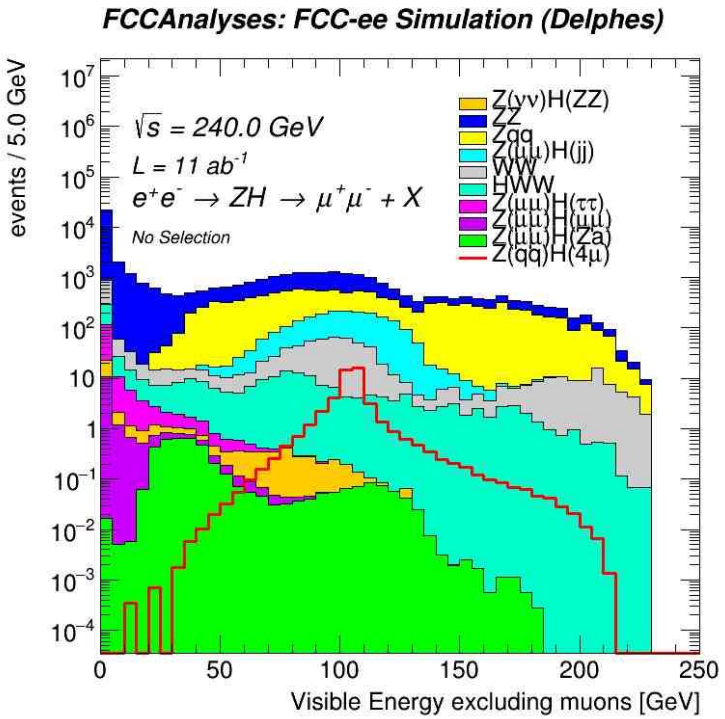
Before Selection: Z(jj) H(4μ)

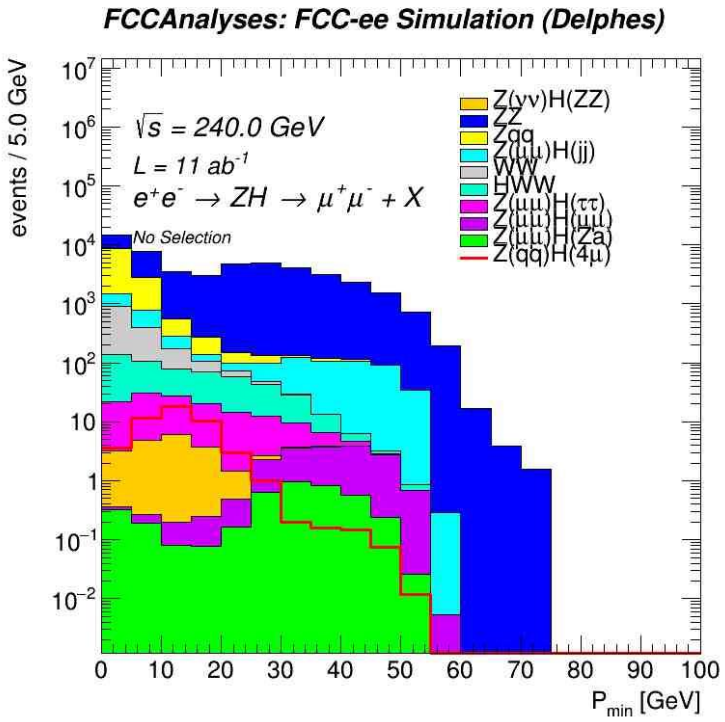


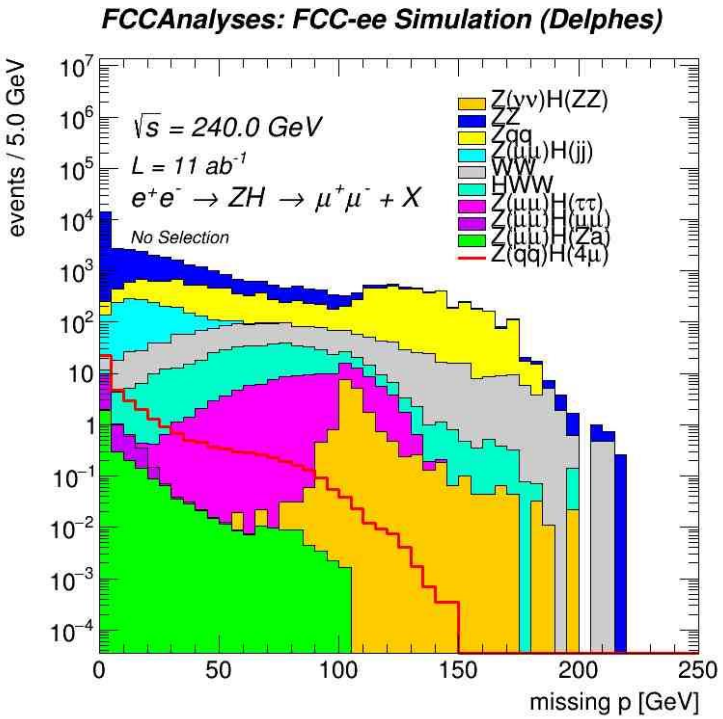




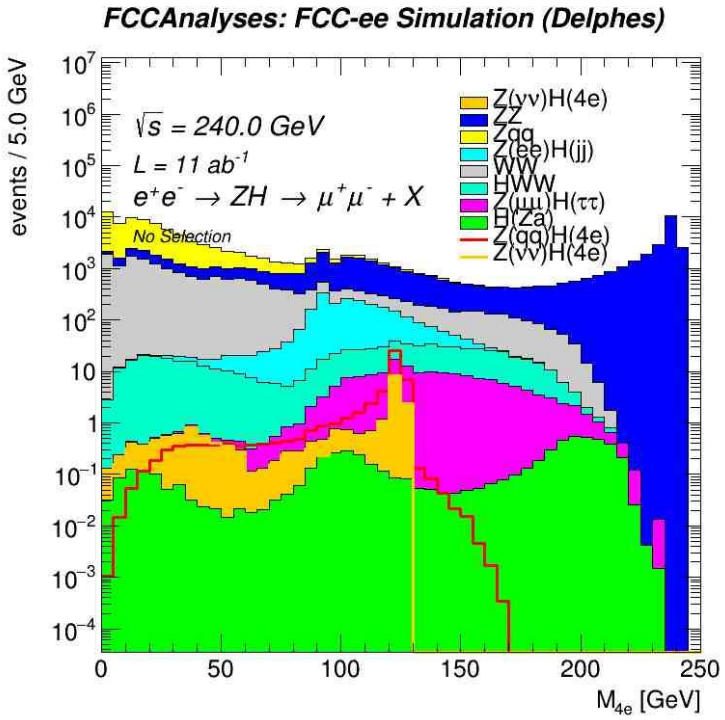
Before Selection: Z(jj) H(4μ)

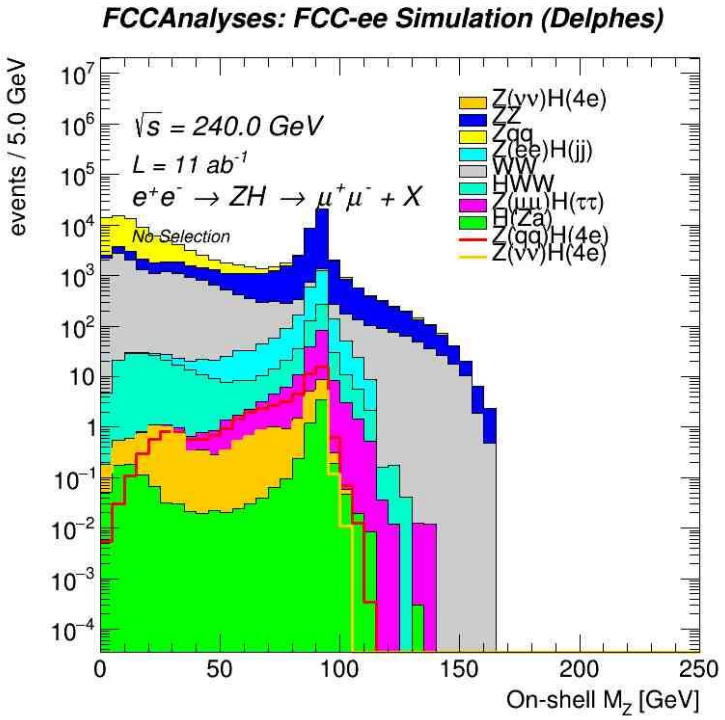


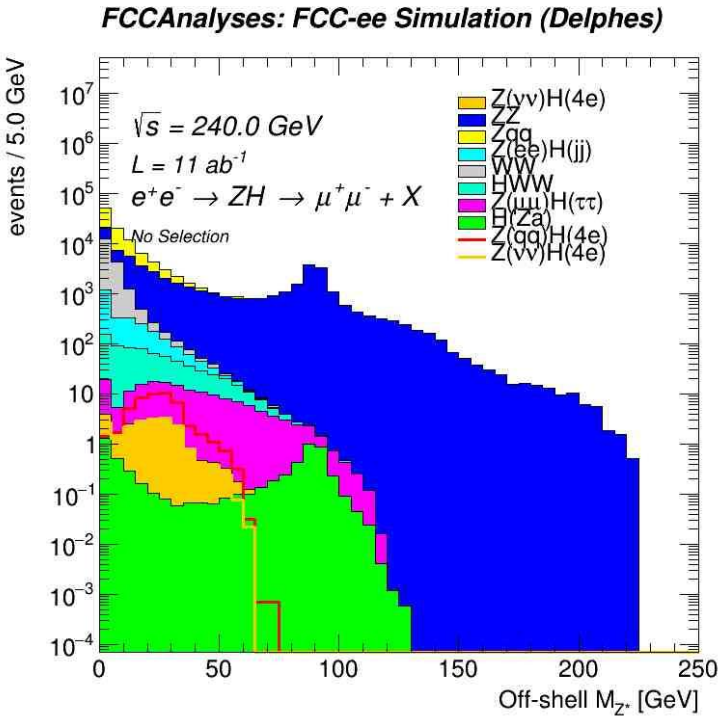




Before Selection: Z(jj) H(4e)







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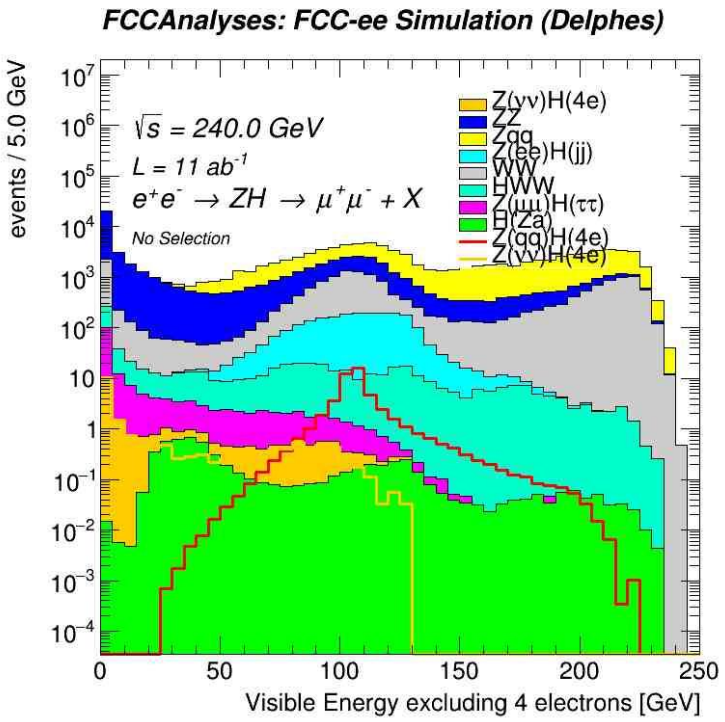
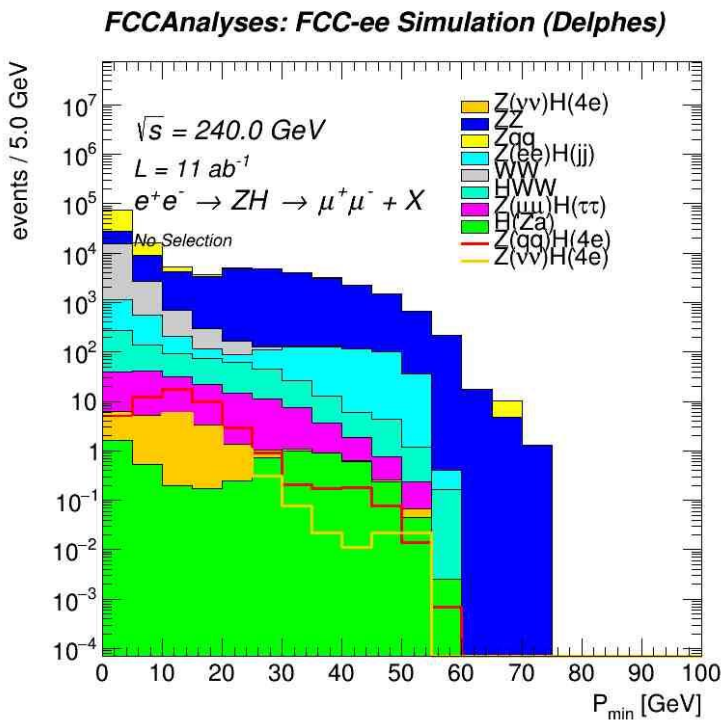
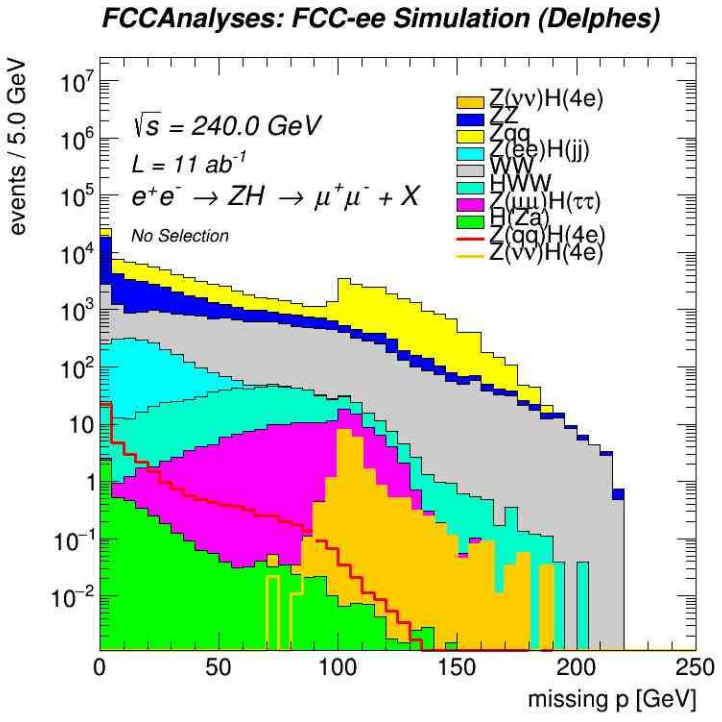
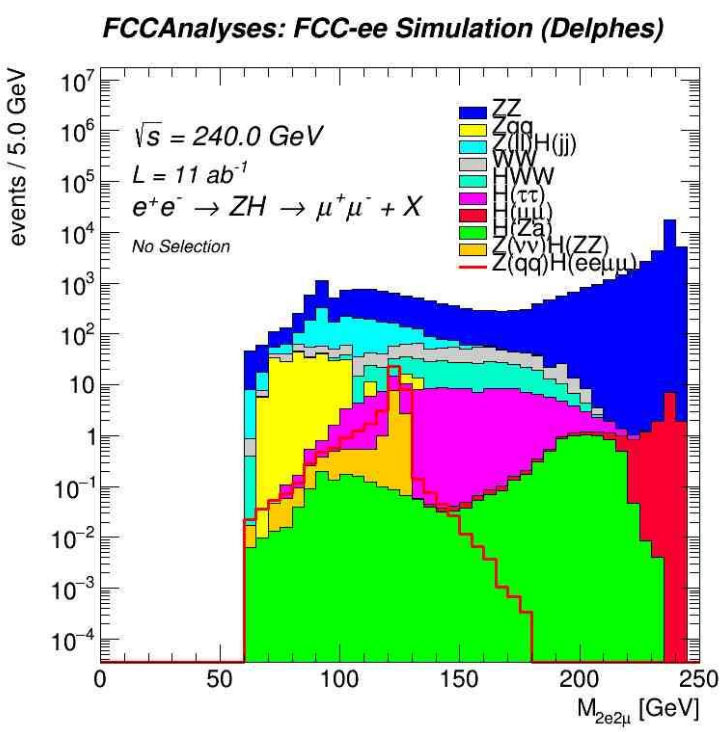
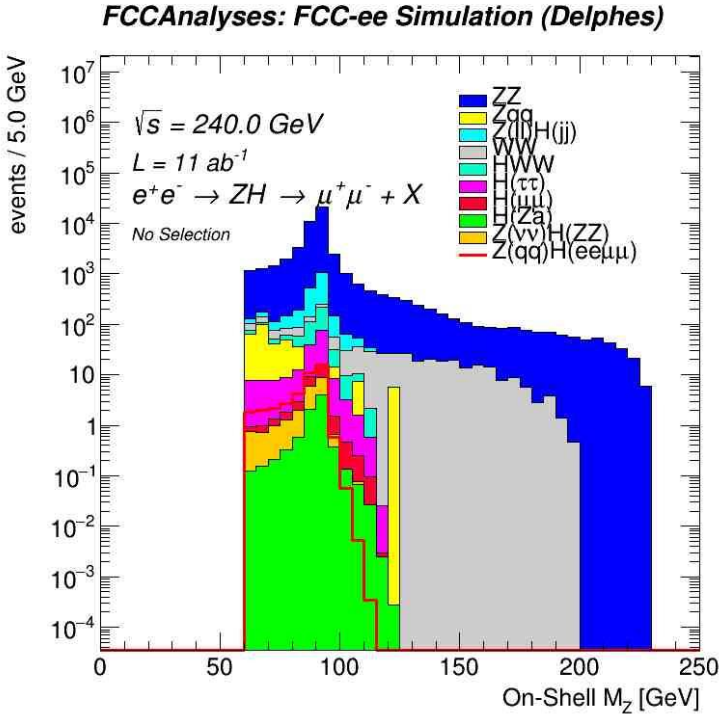


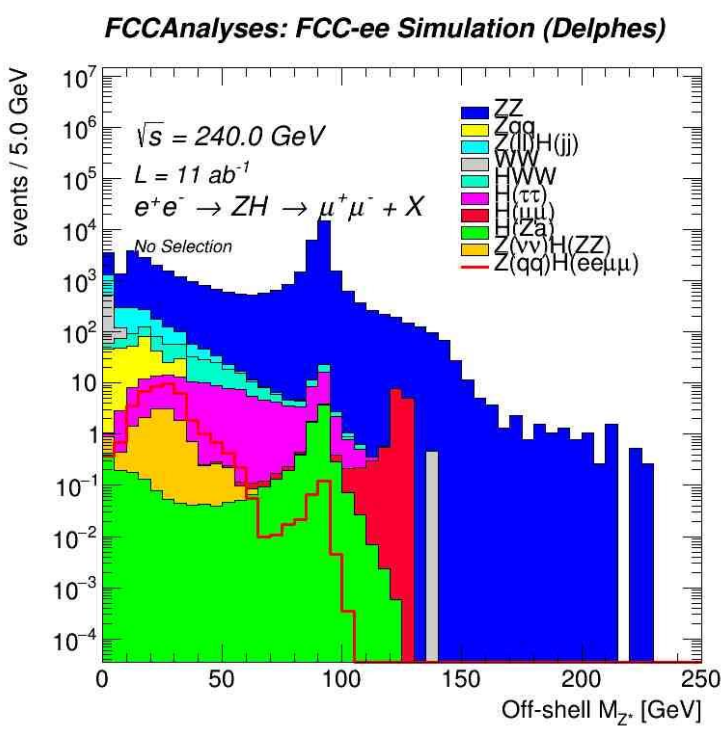




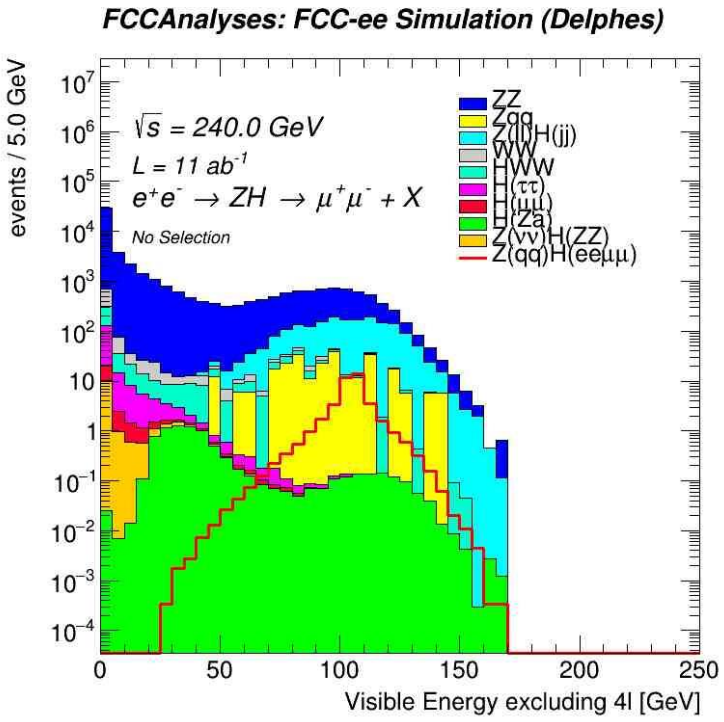
Before Selection: Z(jj) H(2e2μ)

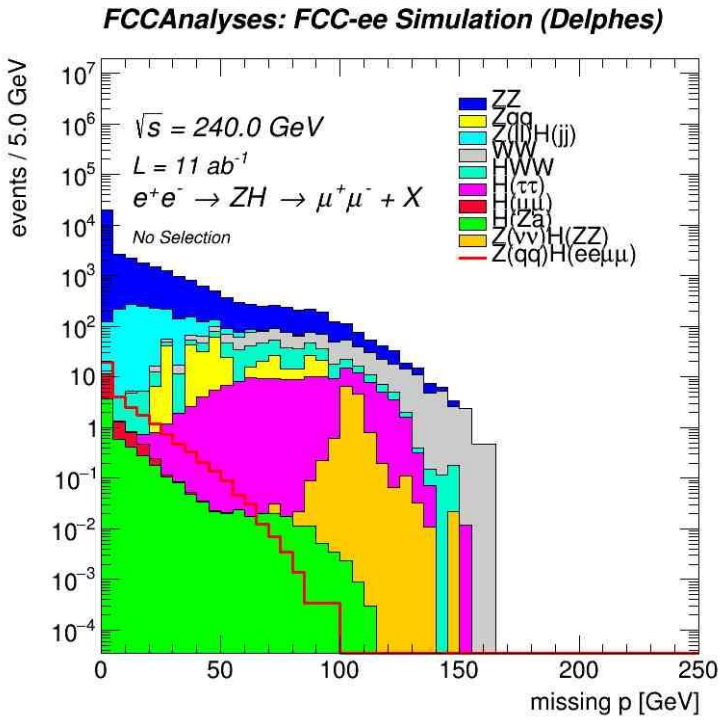


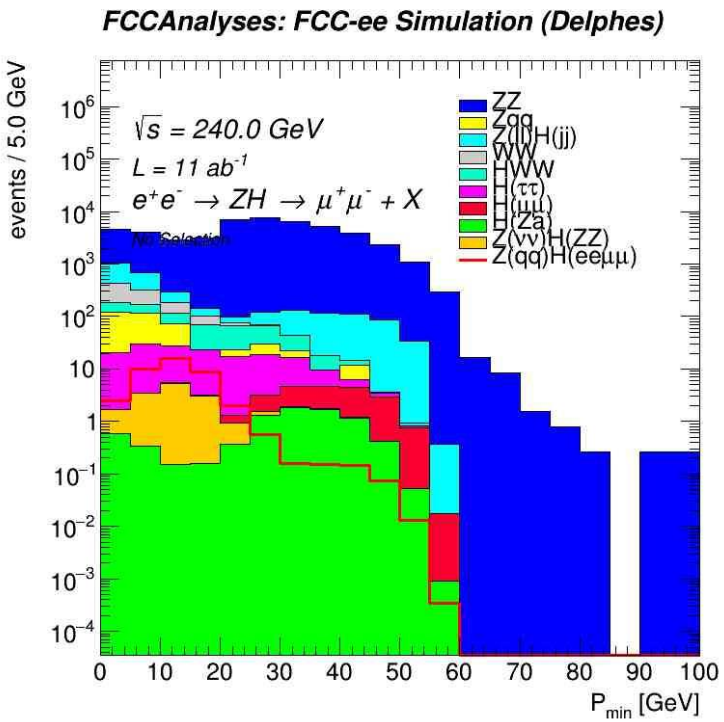




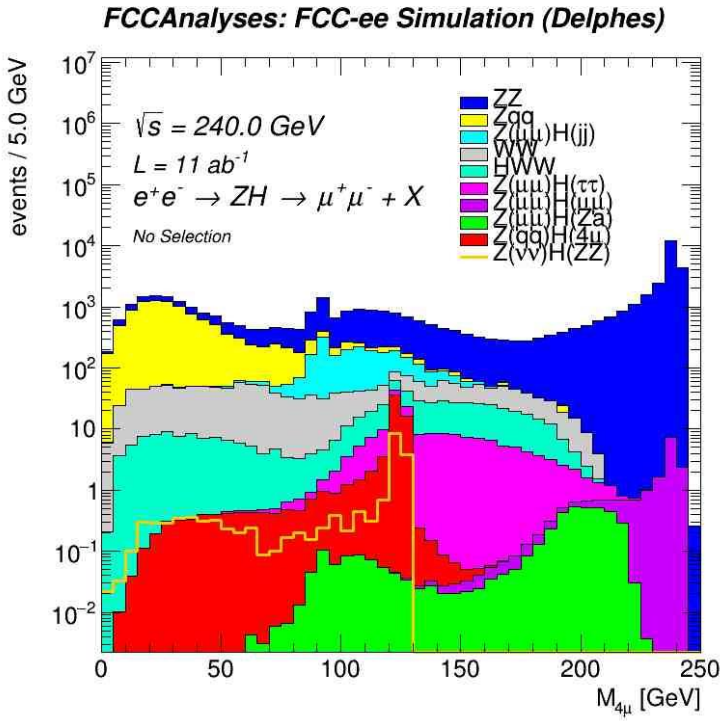
Before Selection: Z(jj) H(2e2μ)

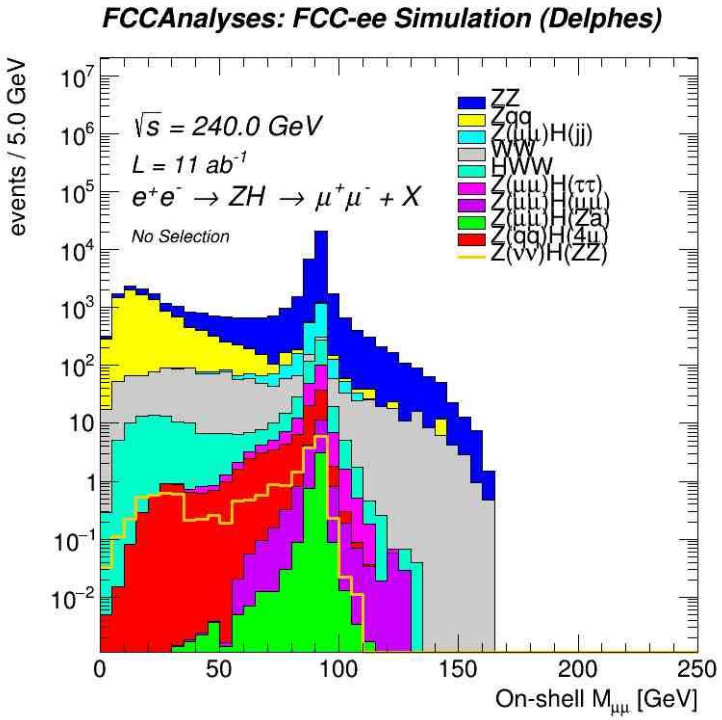


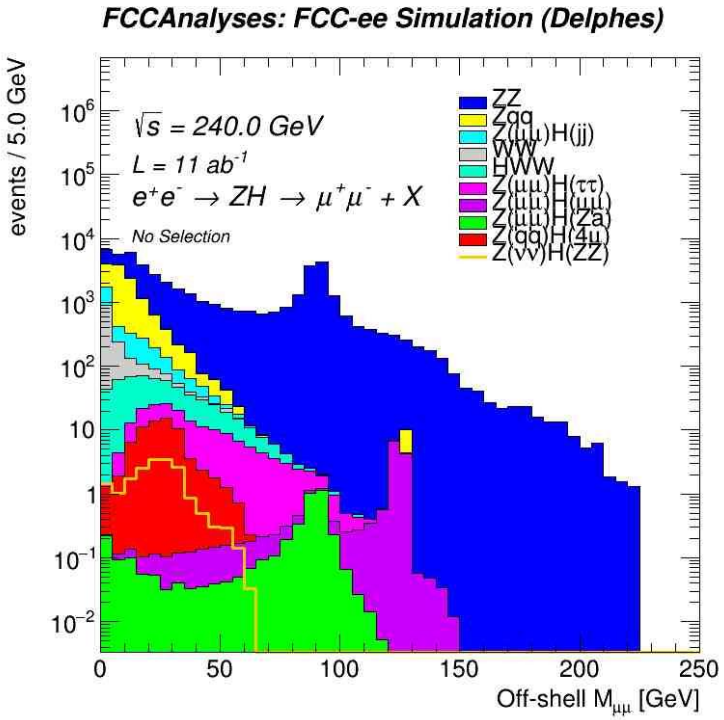




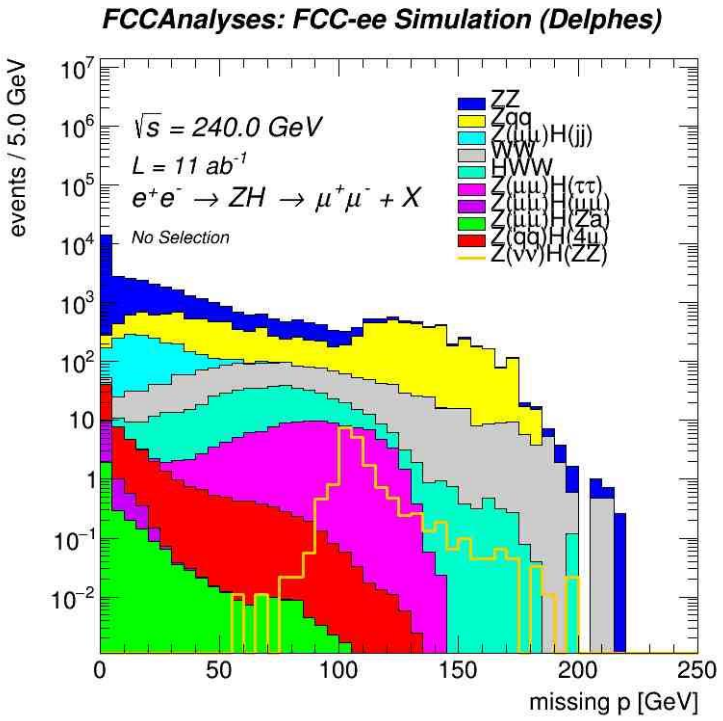
Before Selection: Z(νν) H(4μ)

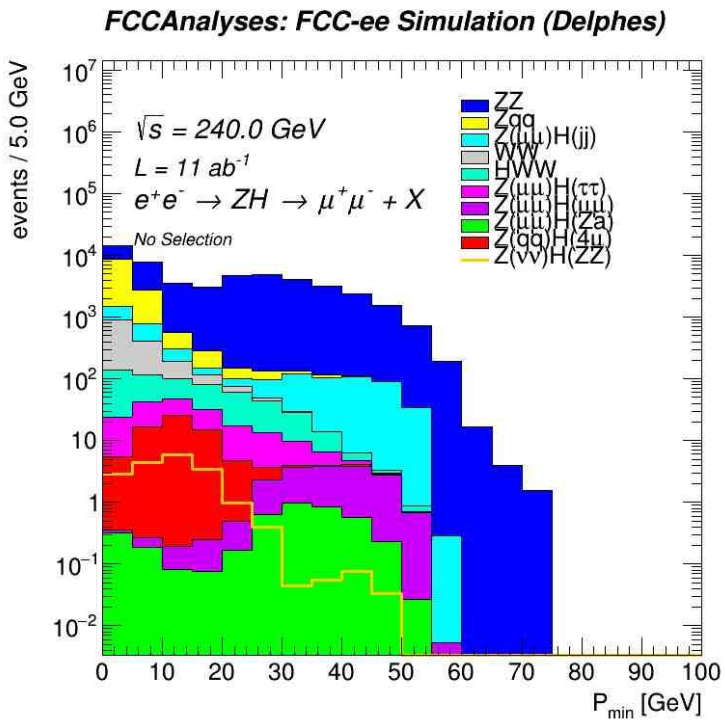




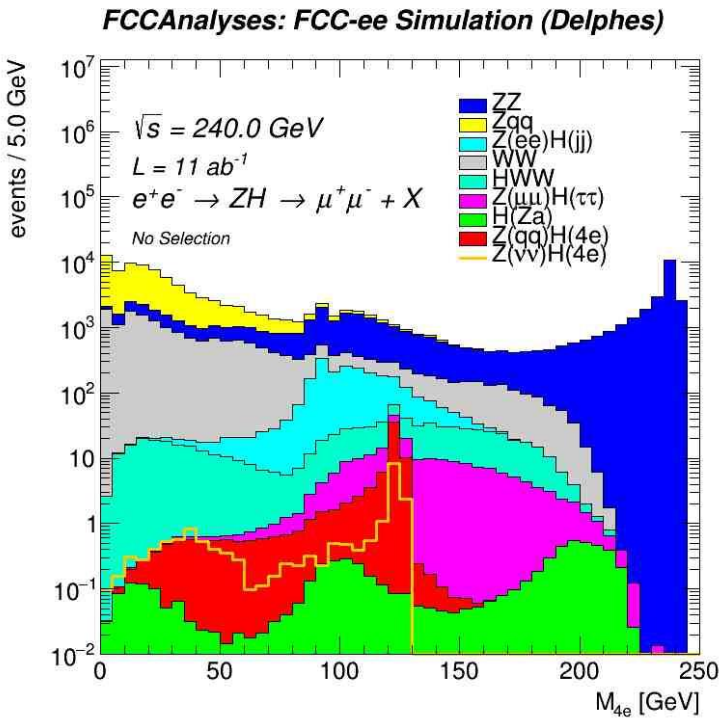


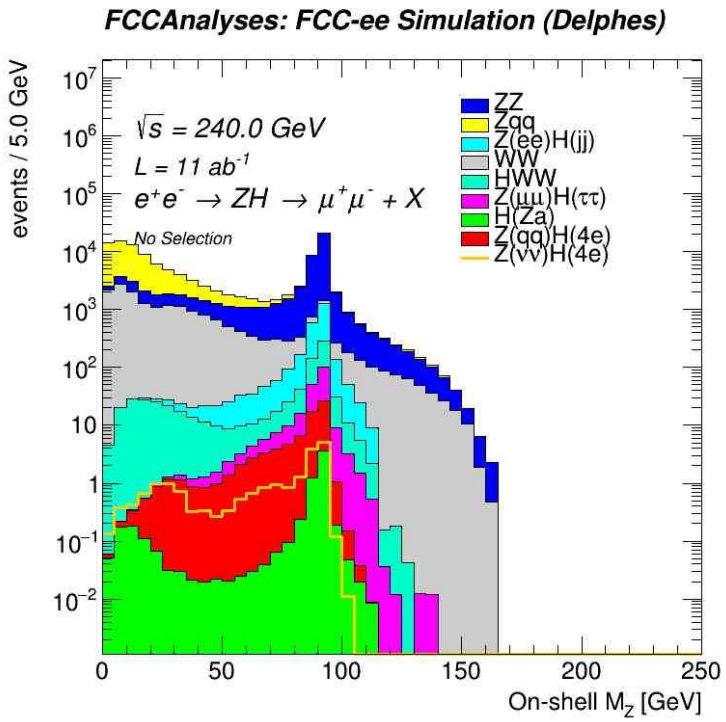
Before Selection: Z(vv) H(4μ)

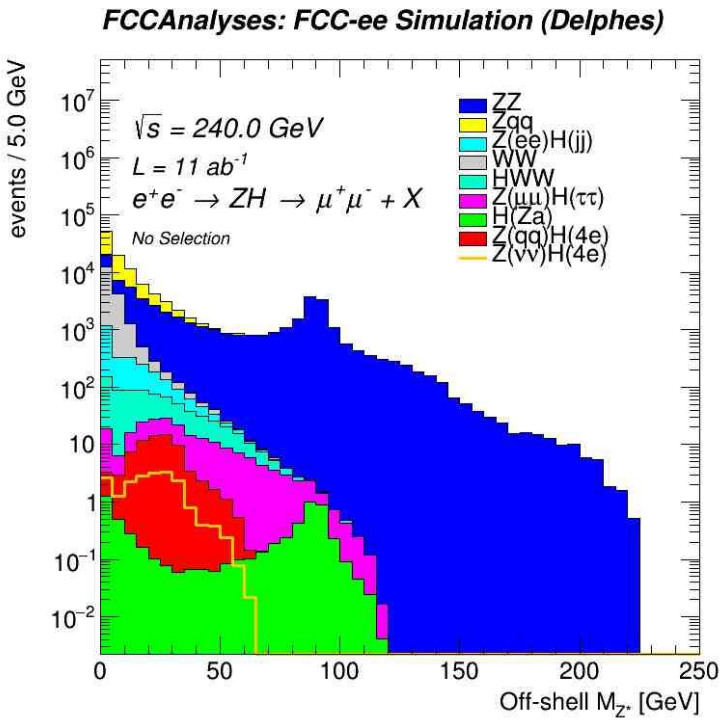




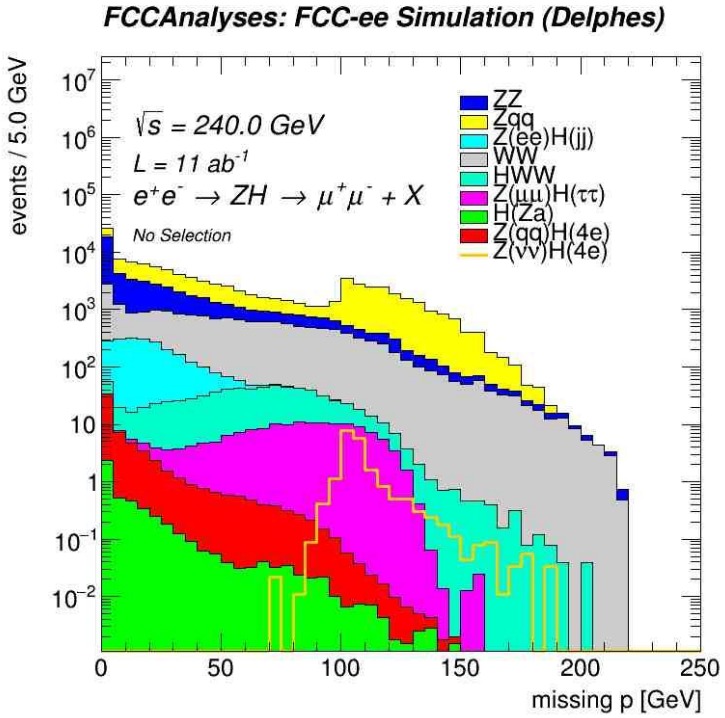
Before Selection: Z(vv) H(4e)

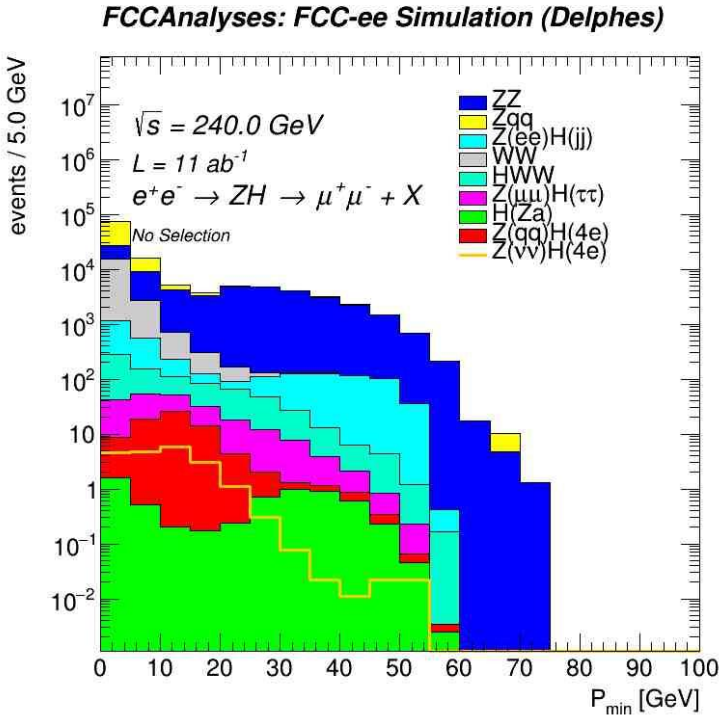




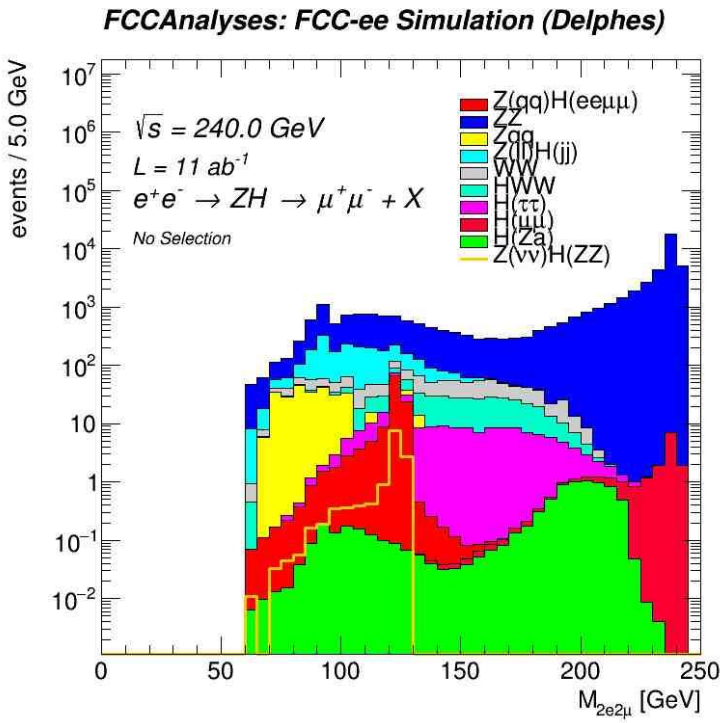


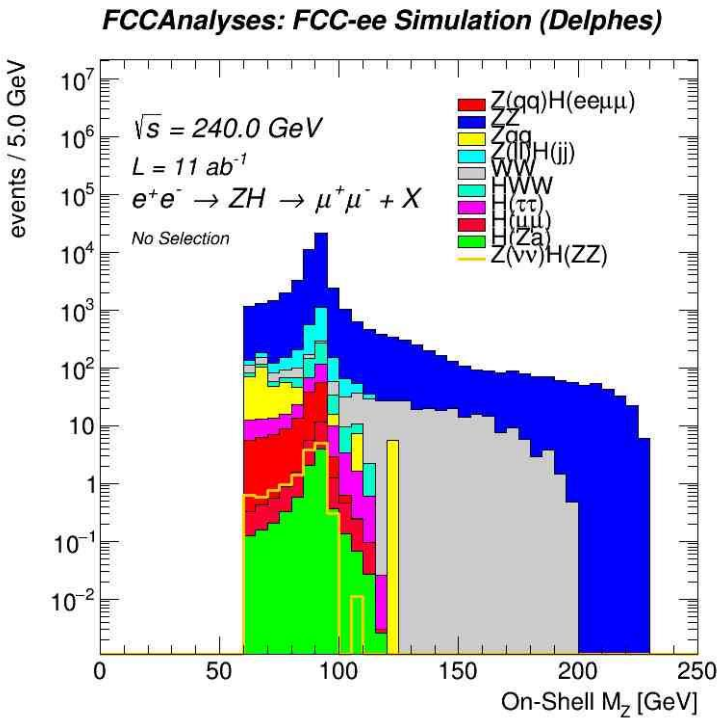
Before Selection: Z(vv) H(4e)

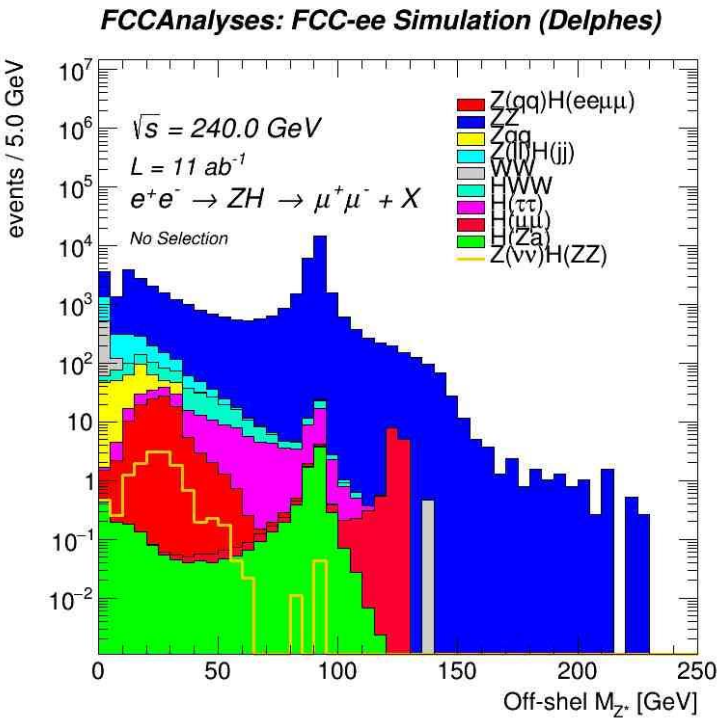




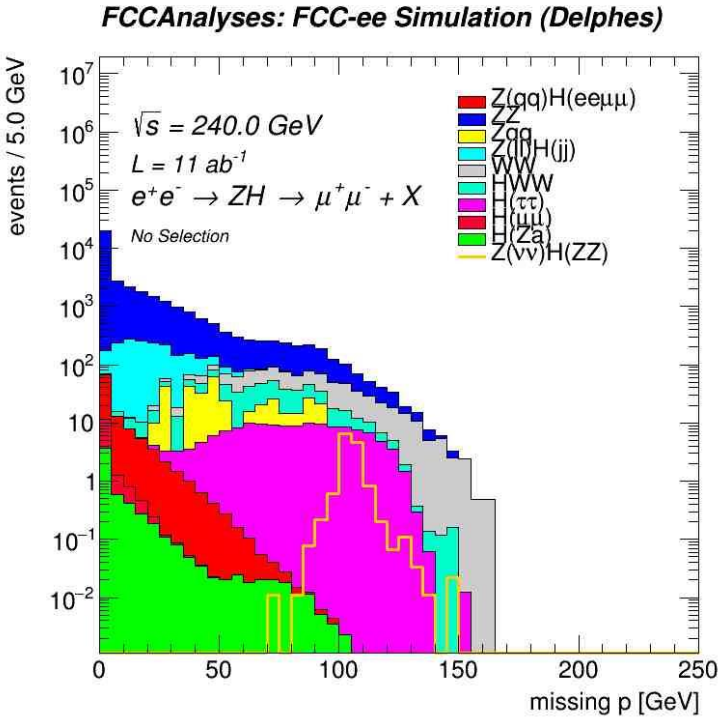
Before Selection: Z(νν) H(2e2μ)

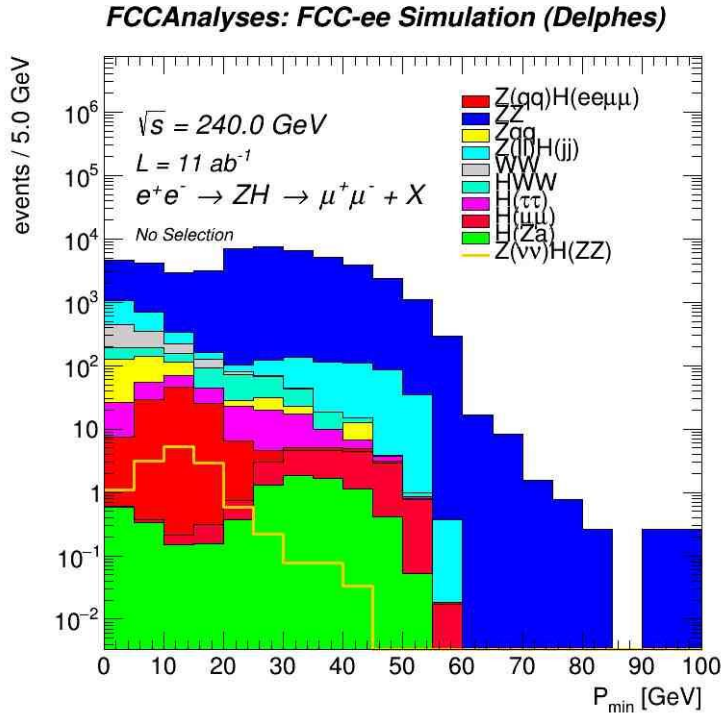






Before Selection: Z(νν) H(2e2μ)





Analysis cuts: Z(jj) H(4l)

- Momentum of the softest lepton of the reconstructed 4 lepton:

  P_{min} > 5 GeV.
- Missing momentum cut:

  P_{miss} < 40 GeV
- Visible energy of all the reconstructed particles

  excluding the 4 leptons

  E_{vis} > 30 GeV
- Invariant mass of dimuon pair from the Off-shell Z*

  10 <M_{Z^*} < 65 GeV
- Invariant mass of the 4 leptons:

  124 < M_{4l} < 125.5 GeV

Analysis cuts: Z(νν) H(4l)

- Momentum of the softest lepton of the reconstructed 4 lepton:

  P_{min} > 5 GeV
- Missing momentum cut:

  P_{miss} > 100 GeV
- Visible energy of all the reconstructed particles excluding the 4 leptons

  E_{vis} > 30 GeV
- Invariant mass of dimuon pair from the Off-shell Z*

  10 <M_{Z^*} < 65 GeV
- Invariant mass of the 4 leptons:

  124 < M_{4l} < 125.5 GeV

Final analysis : Z(jj)H(4μ)

Signal and background **yields** after each cut (cumulative).

Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**Z(μμ) H(jj)**	**WW**	**HWW**	**Z(μμ) H(ττ)**	**Z(μμ) H(μμ)**	**Z(μμ) H(Za)**	**Z(qq) H(4μ)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	37575	9602	1606	1208	391	114	14	4	47	50514	0.2090210
$P_{min} > 5$ GeV	31710	2499	1010	439	278	95	14	3	44	36048	0.23160461
$P_{miss} < 20$ GeV	25985	344	533	6	5	0	14	3	39	26890	0.23765912
$E_{vis} < 95$ GeV	1584	299	436	6	2	0	0	0	37	2327	0.76098831
$10 < M_{Z^*} < 65$ GeV	785	220	177	1	1	0	0	0	37	1184	1.0588730
$124 < M_{4\mu} < 125.5$ GeV	2	0	1	0	0	0	0	0	26	3	4.82807879

Final analysis : Z(jj)H(4e)

Signal and background **yields** after each cut (cumulative).

Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**Z(ee) H(jj)**	**WW**	**HWW**	**Z(μμ)H(ττ)**	**Z(ee)H(Za)**	**Z(qq) H(4e)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	45481	56532	1971	17055	563	147	6	49	121755	0.1403
$P_{min} > 5$ GeV	33280	8855	1112	2873	327	113	4	44	46564	0.203
$P_{miss} < 20$ GeV	27020	2855	618	377	16	1	4	39	30891	0.221
$E_{vis} < 95$ GeV	2804	2646	520	371	12	0	0	37	6353	0.4628
$10 < M_{Z^*} < 65$ GeV	1185	1244	197	111	5	0	0	37	2742	0.7018
$124 < M_{4\mu} < 125.5$ GeV	6	0	2	0	0	0	0	19	8	3.6565

Final analysis : Z(jj)H(2e2μ)

Signal and background **yields** after each cut (cumulative).

Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**Z(ll) H(jj)**	**WW**	**HWW**	**H(ττ)**	**H(Za)**	**Z(qq)H(2e2μ)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	45666	260	1590	519	318	138	14	40	48513	0.1815
$P_{min} > 5$ GeV	42050	158	981	266	256	119	14	37	43851	0.1766
$P_{miss} < 20$ GeV	37105	0	520	0	5	0	14	35	37651	0.1802
$E_{vis} < 95$ GeV	1042	0	427	0	1	0	0	33	1470	0.8512
$10 < M_{Z^*} < 65$ GeV	362	0	174	0	1	0	0	33	537	1.3822
$124 < M_{4\mu} < 125.5$ GeV	2	0	3	0	0	0	0	20	5	4.00

Final analysis: Z(νν)H(4μ)

Signal and background **yields** after each cut (cumulative).

Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**H(jj)**	**WW**	**HWW**	**Z(μμ) H(ττ)**	**Z(μμ) H(μμ)**	**Z(μμ) H(Za)**	**Z(νν) H(4μ)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	37575	9602	1606	1208	391	114	14	4	18	50514	0.0003
$P_{min} > 5$ GeV	31710	2499	1010	439	278	95	14	3	15	36048	0.07898
$P_{miss} > 100$ GeV	286	678	0	139	22	21	0	0	14	1146	0.41105
$10 < M_{Z^*} < 65$ GeV	215	418	0	14	15	21	0	0	13	683	0.49276
$124 < M_{4\mu} < 125.5$ GeV	3	0	0	0	0	1	0	0	9	4	2.49615

Final analysis: Z(νν)H(4e)

Signal and background **yields** after each cut (cumulative).

Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**Z(ee)H(jj)**	**WW**	**HWW**	**Z(μμ)H(ττ)**	**Z(ee)H(Za)**	**Z(νν)H(4e)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	45481	56532	1971	17055	563	147	6	19	121755	0.0544
$P_{min} > 5$ GeV	33280	8855	1112	2873	327	113	4	15	46564	0.0695
$P_{miss} > 100$ GeV	363	1917	0	616	24	24	0	13	2944	0.2390
$10 < M_{Z^*} < 65$ GeV	219	650	0	61	16	23	0	13	969	0.414
$124 < M_{4\mu} < 125.5$ GeV	1	0	0	0	0	1	0	6	2	2.1213

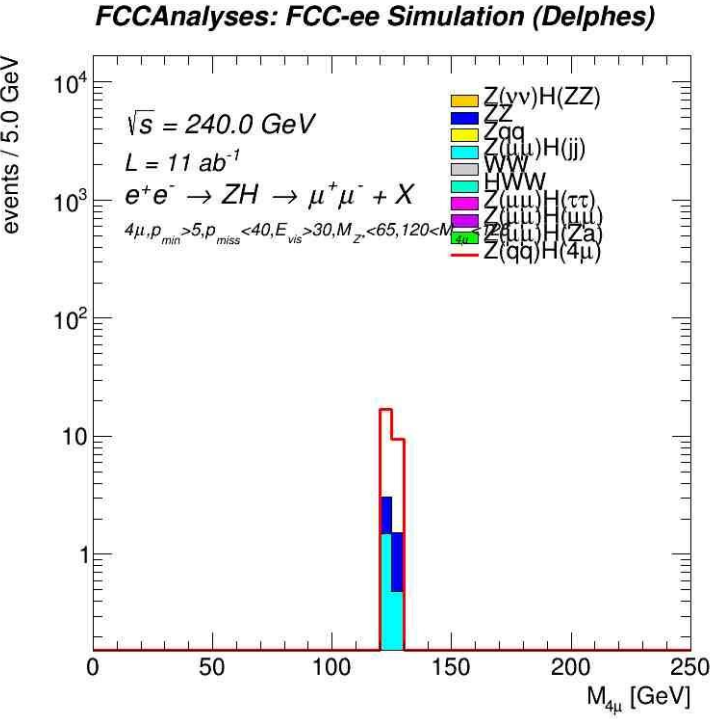
Final analysis: Z(νν)H(2e2μ)

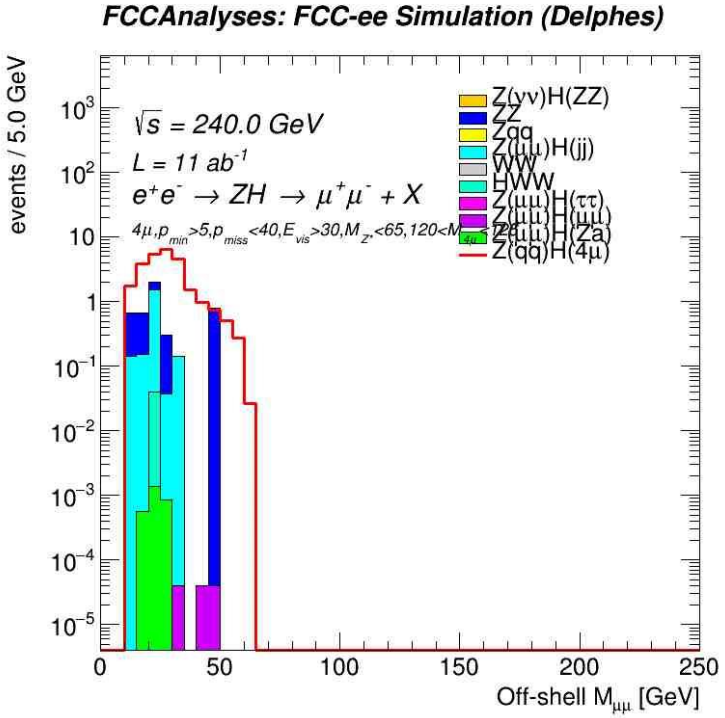
Signal and background **yields** after each cut (cumulative).

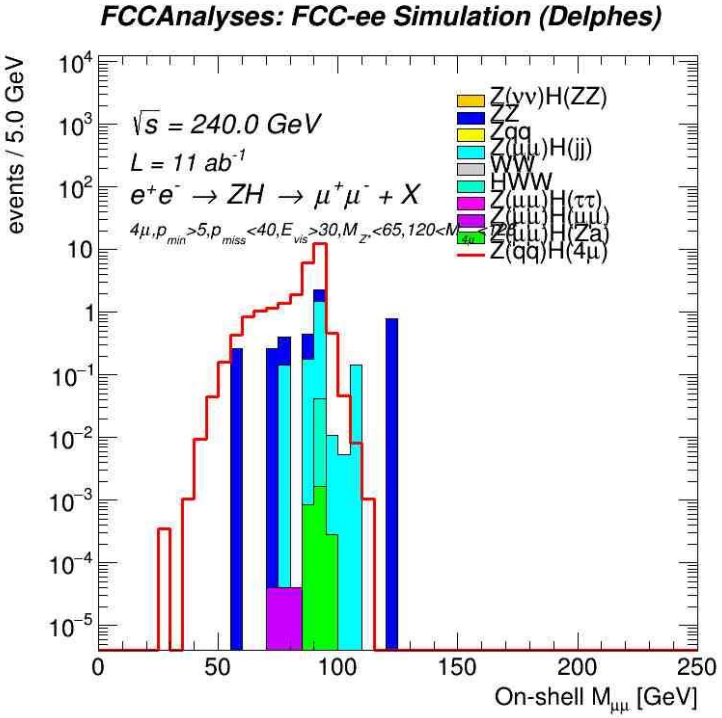
Also, the significance of the signal is calculated : **$s/\sqrt{(s+b)}$**

selection	**ZZ**	**Zqq**	**H(jj)**	**WW**	**HWW**	**H(ττ)**	**H(Za)**	**Z(νν) H(2e2μ)**	**Total Bckg**	**$s/\sqrt{(s+b)}$**
No cuts	45666	260	1590	519	318	138	14	13	48513	0.1815
$P_{min} > 5$ GeV	42050	158	981	266	256	119	14	12	43851	0.1766
$P_{miss} > 100$ GeV	77	0	0	64	13	21	0	11	175	0.8065
$10 < M_{Z^*} < 65$ GeV	67	0	0	0	9	21	0	11	97	1.0584
$124 < M_{4\mu} < 125.5$ GeV	2	0	0	0	0	1	0	7	3	2.2135

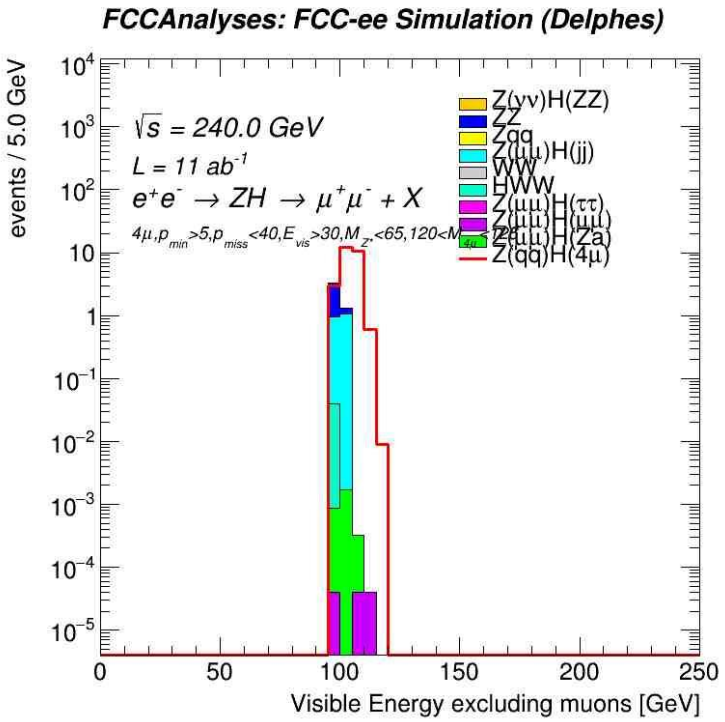
After Selection: Z(jj) H(4μ)

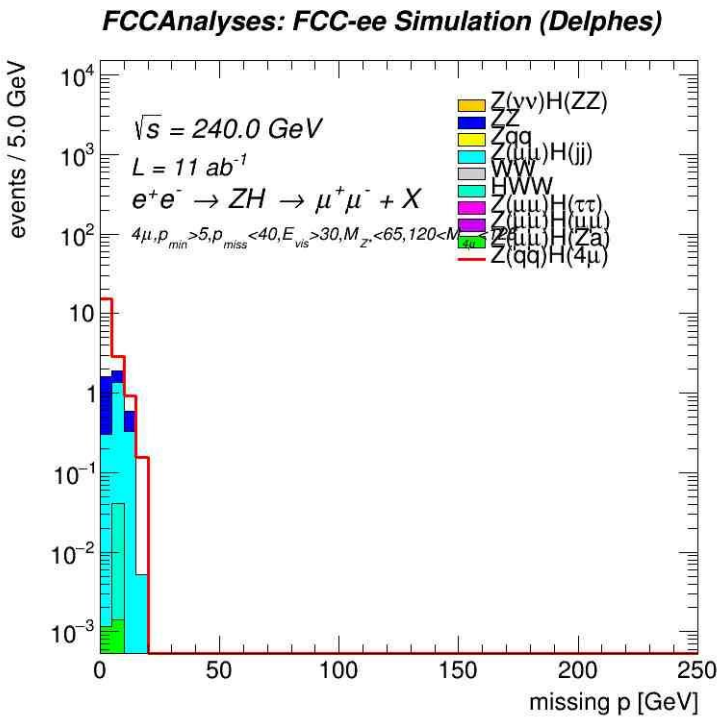


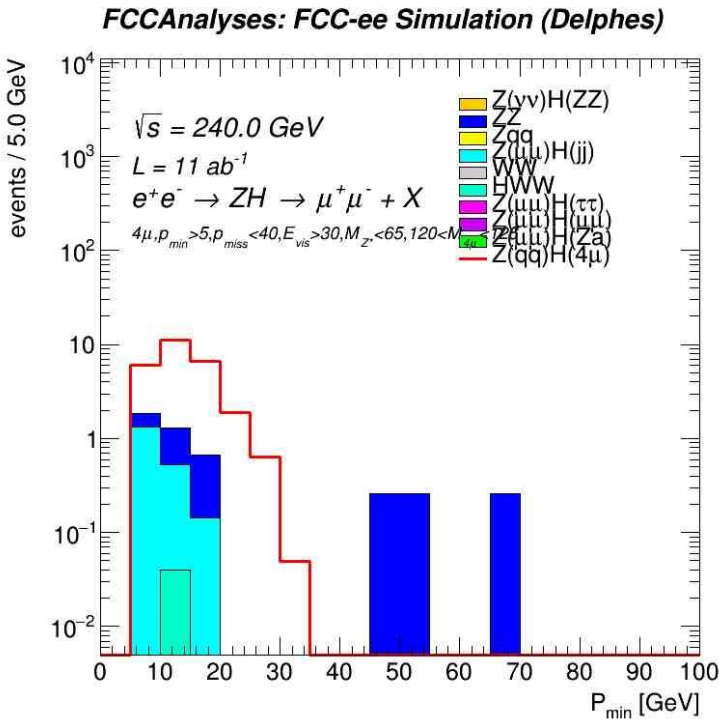




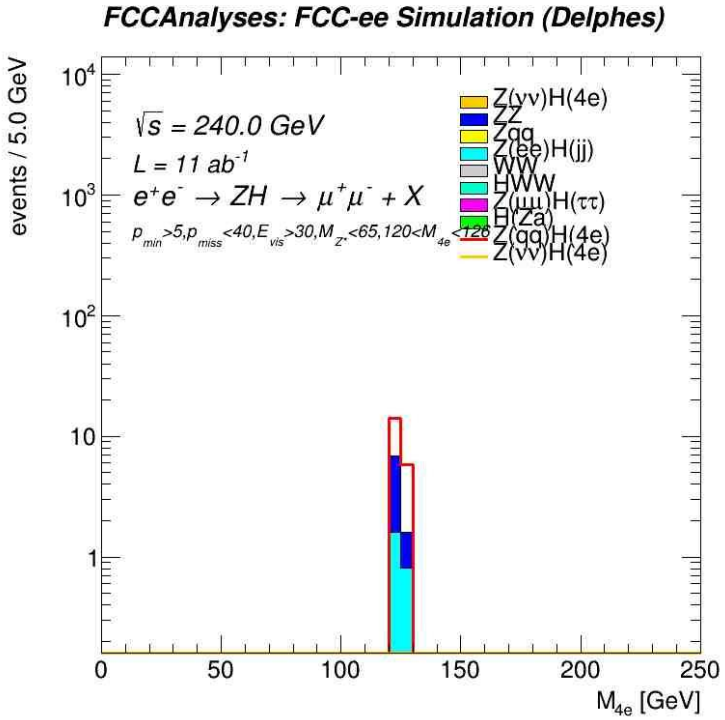
After Selection: Z(jj) H(4μ)

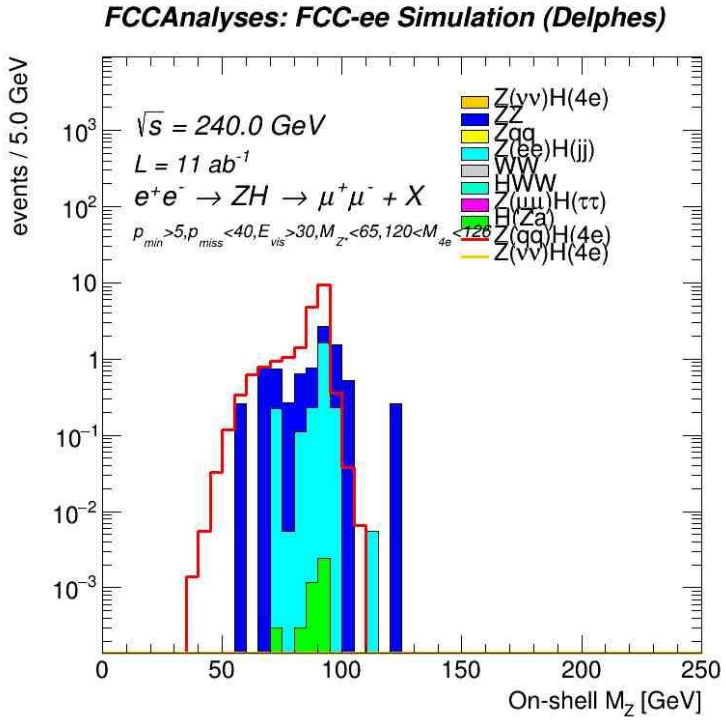


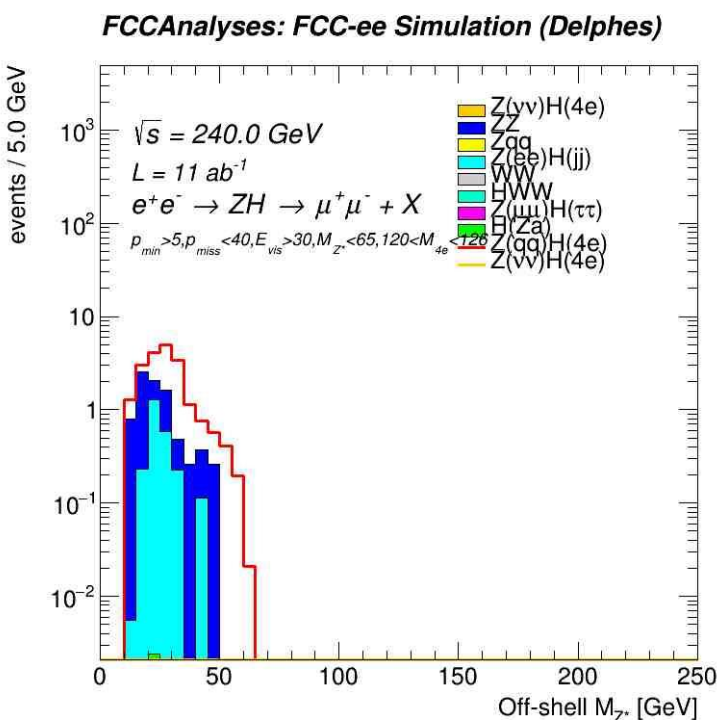




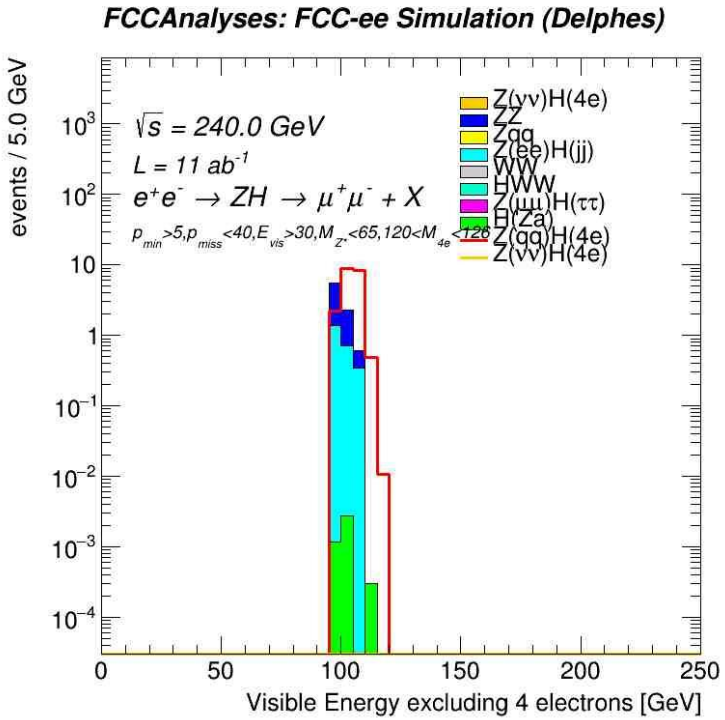
After Selection: Z(jj) H(4e)

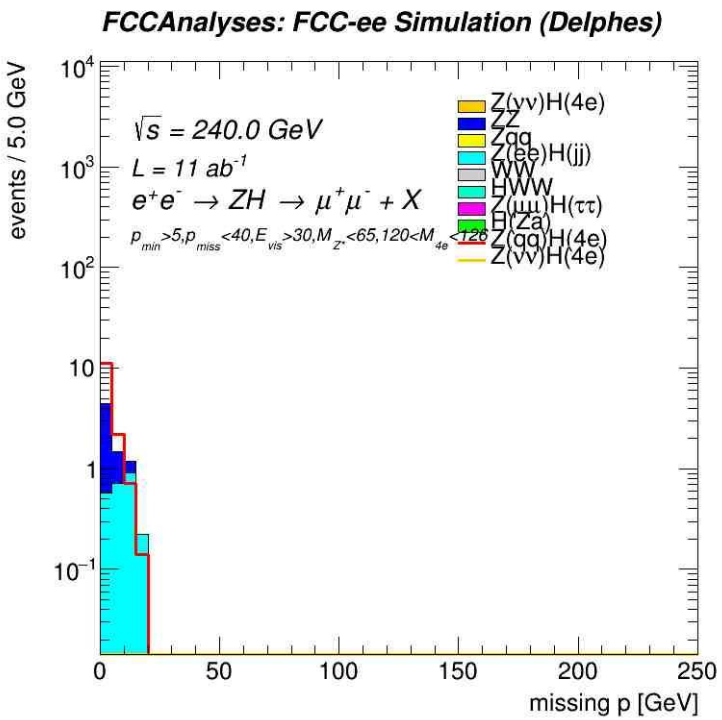


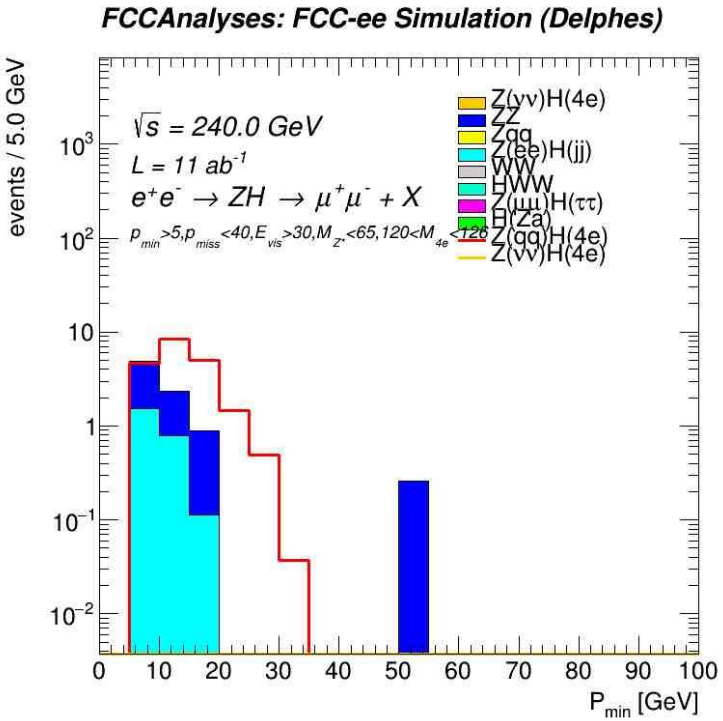




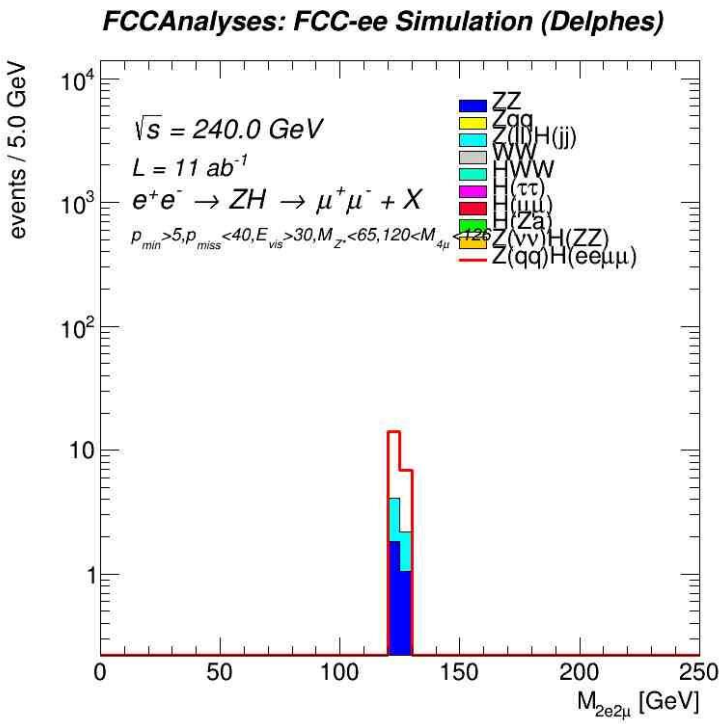
After Selection: Z(jj) H(4e)

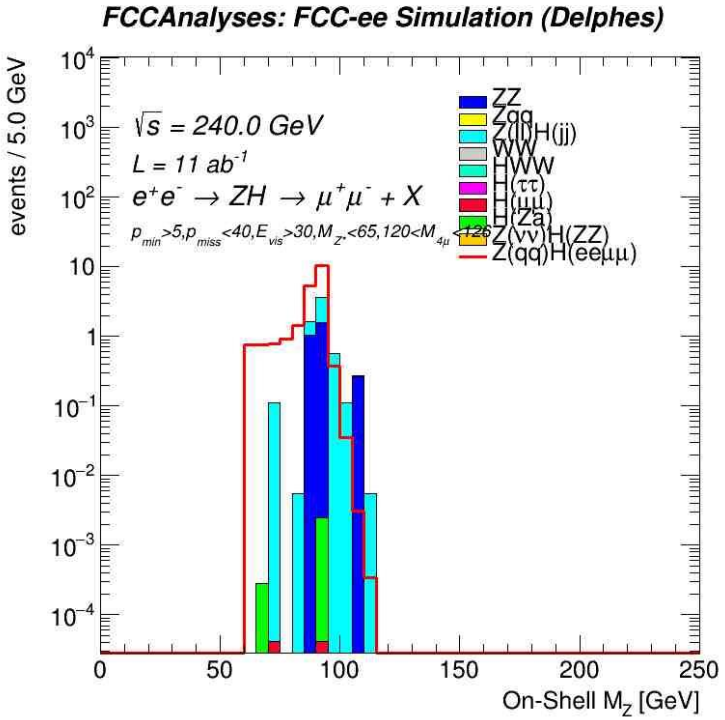


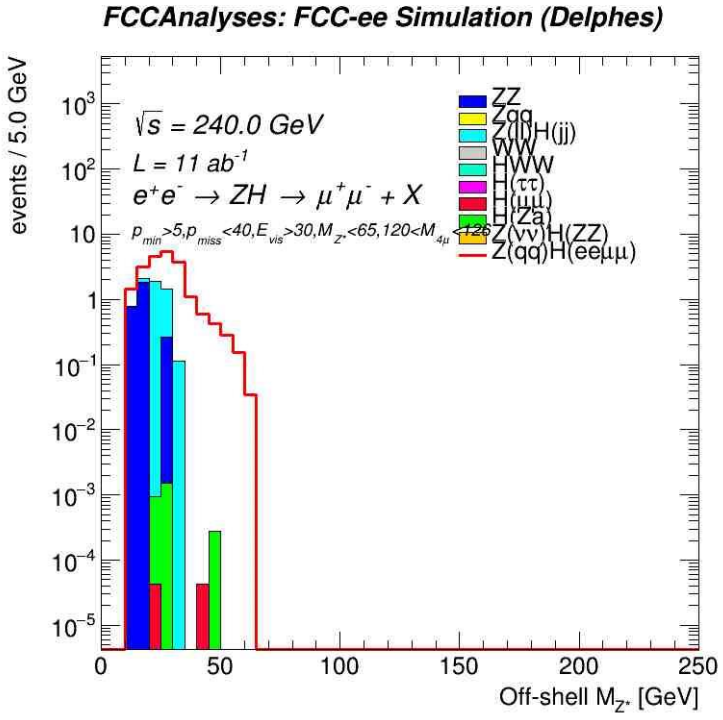




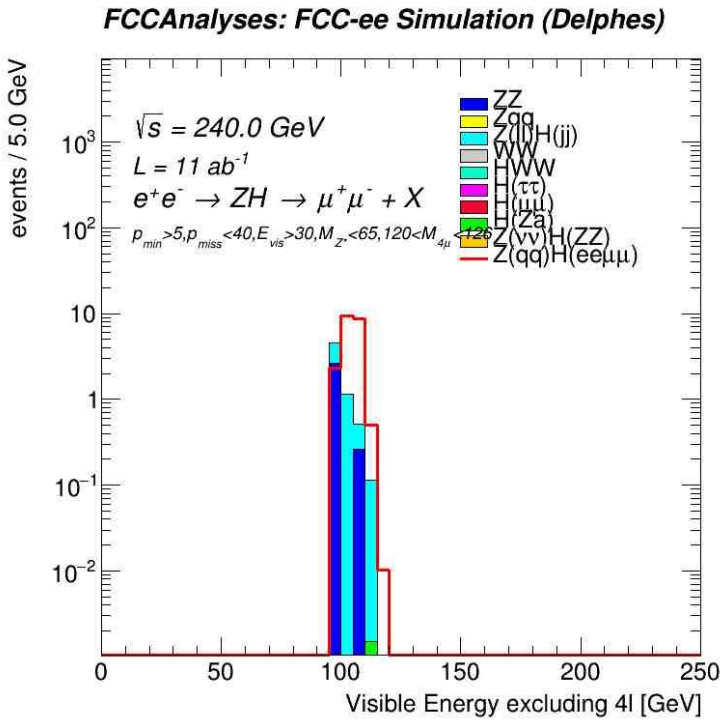
After Selection: Z(jj) H(2e2μ)

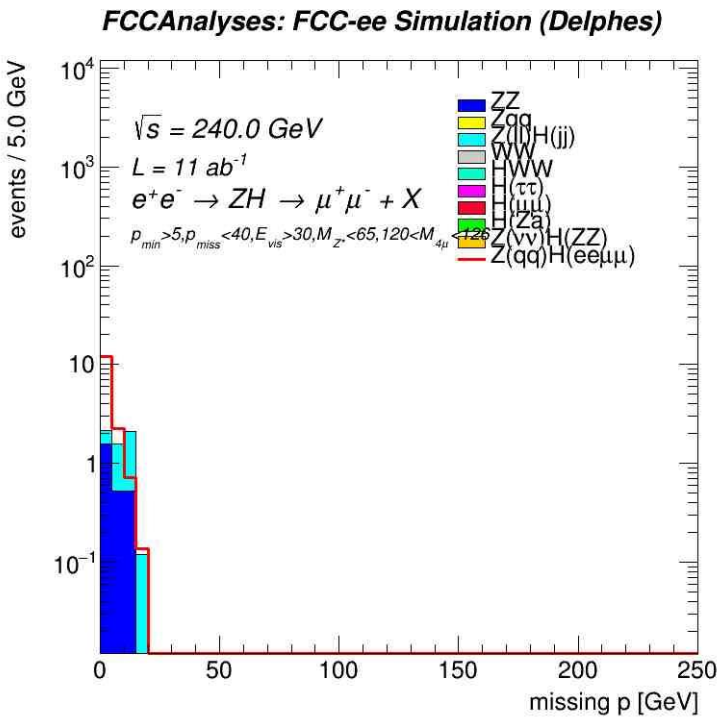


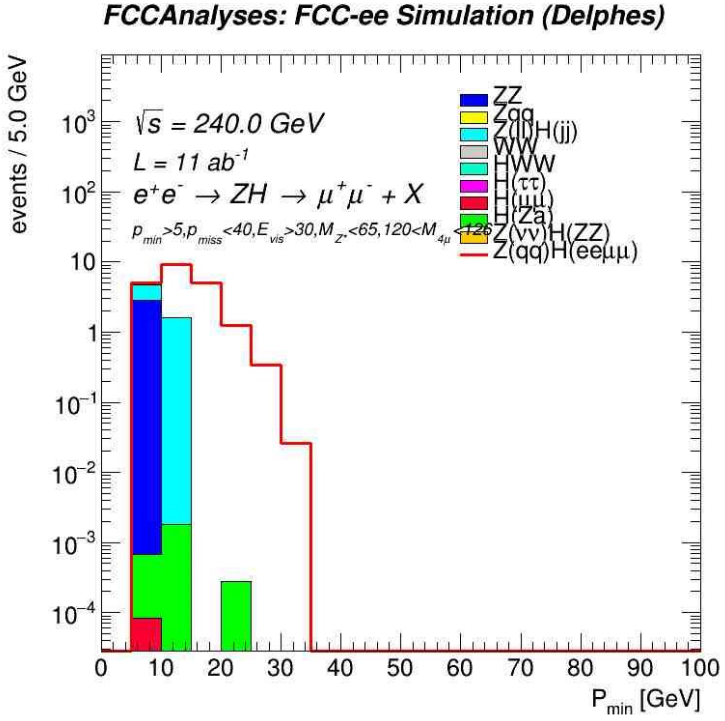




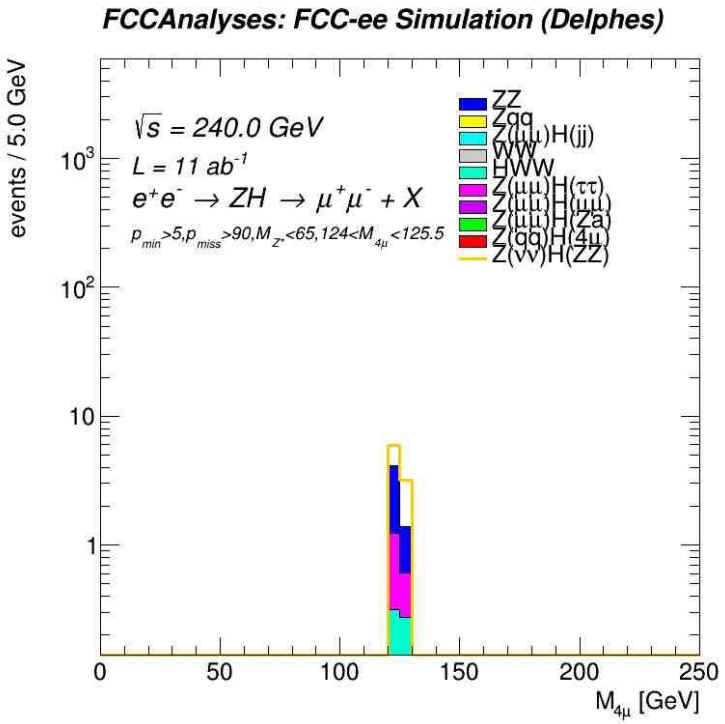
After Selection: Z(jj) H(2e2μ)

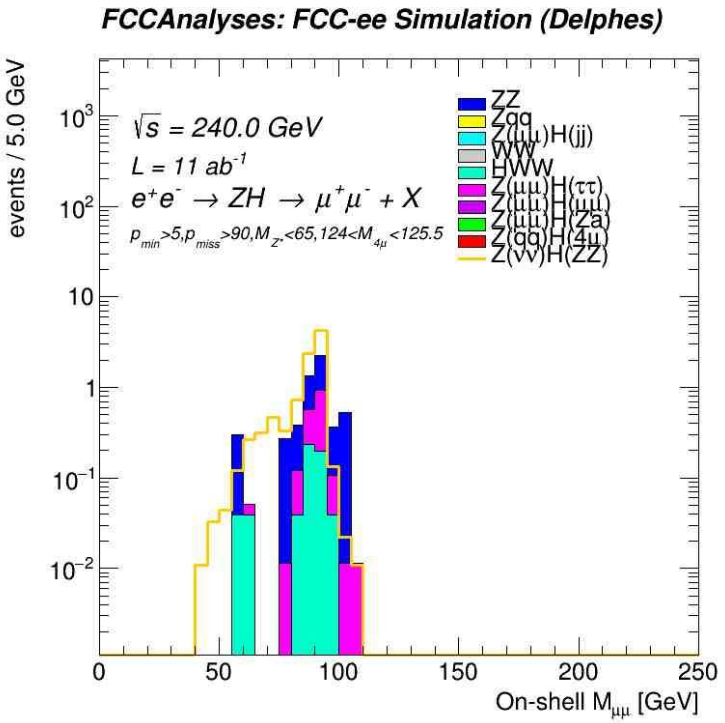


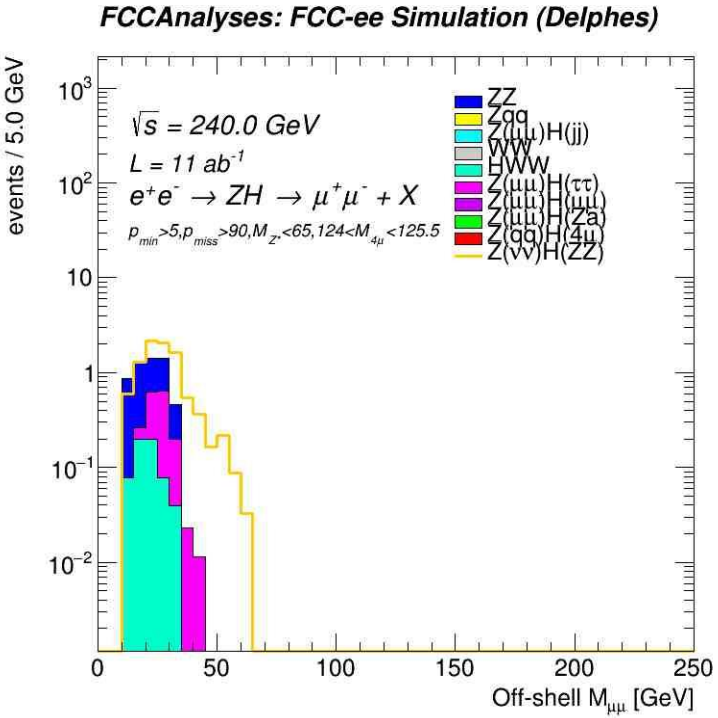




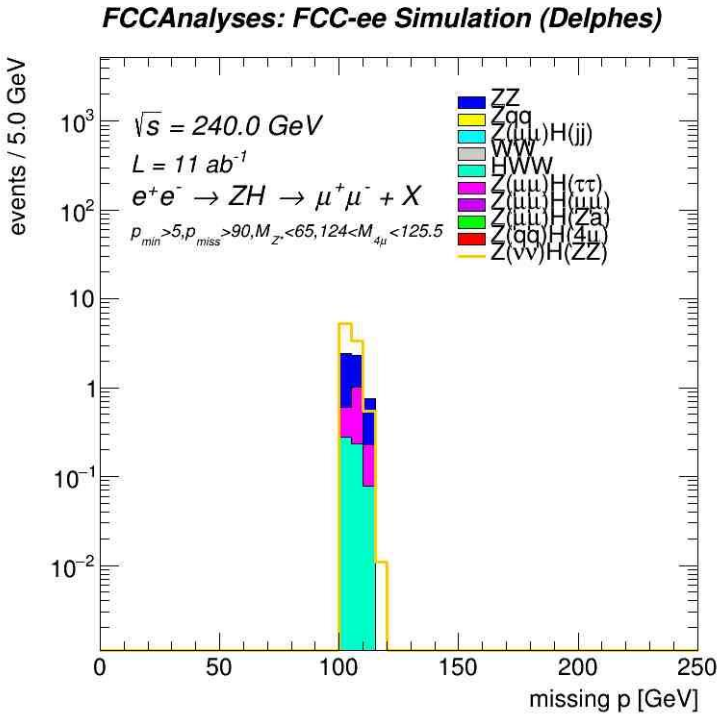
After Selection: Z(jj) H(4μ)

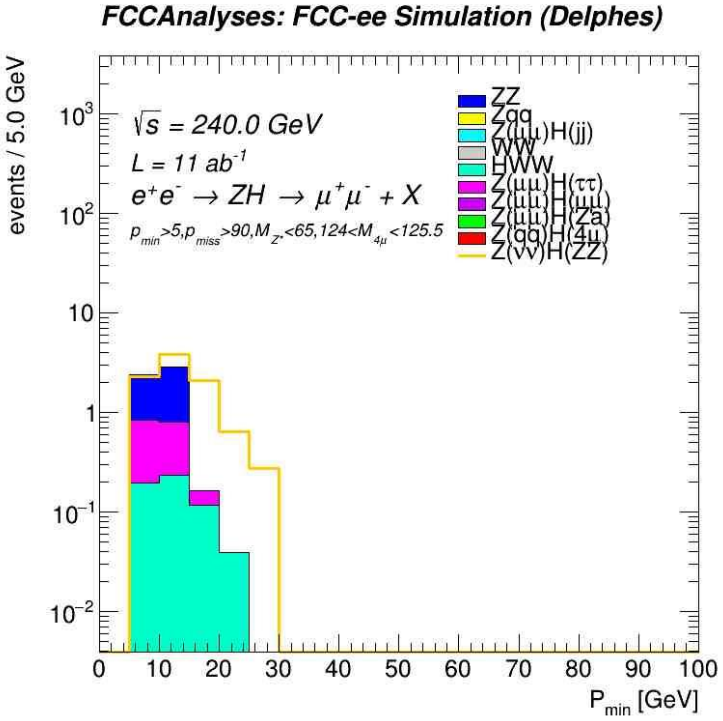




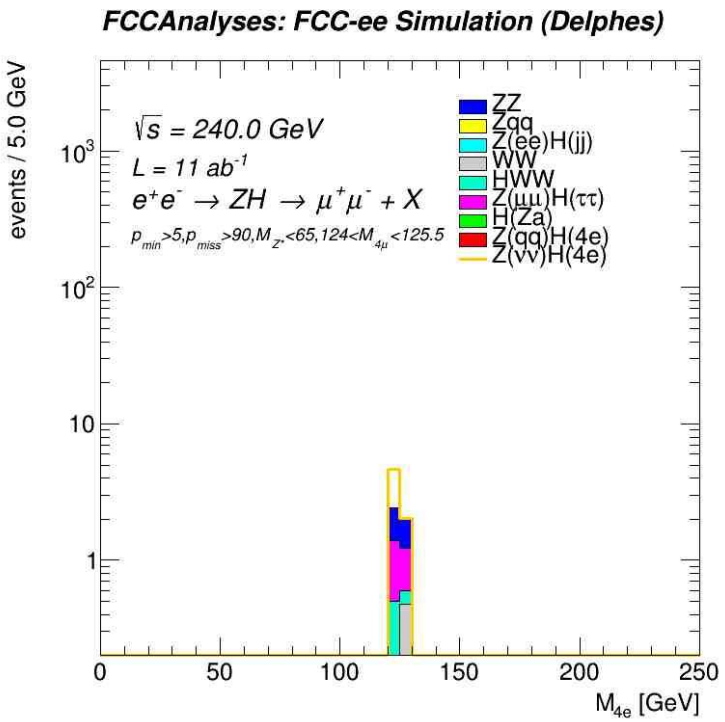


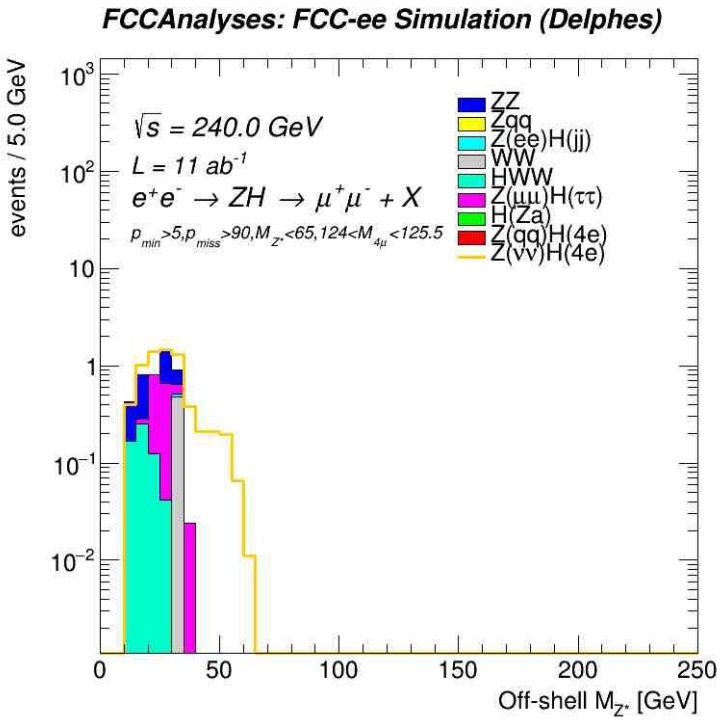
After Selection: Z(jj) H(4μ)

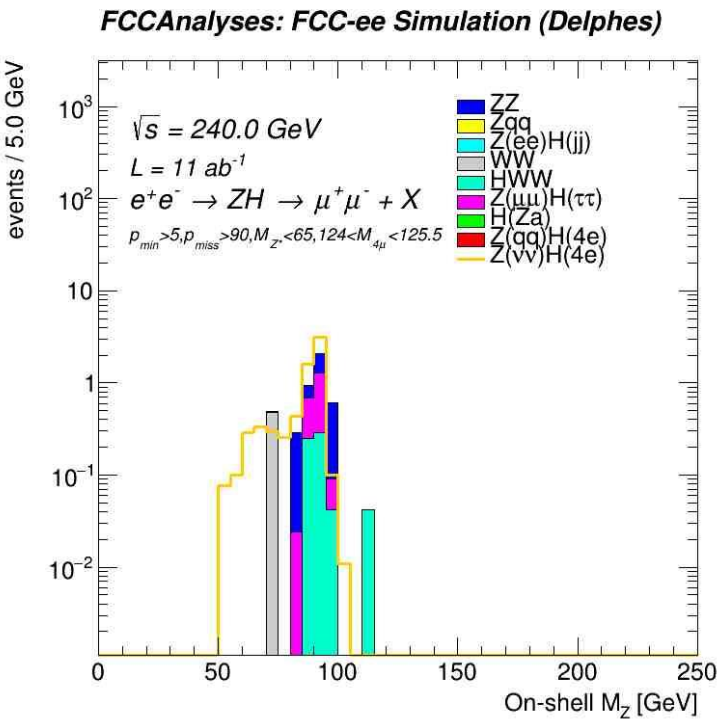




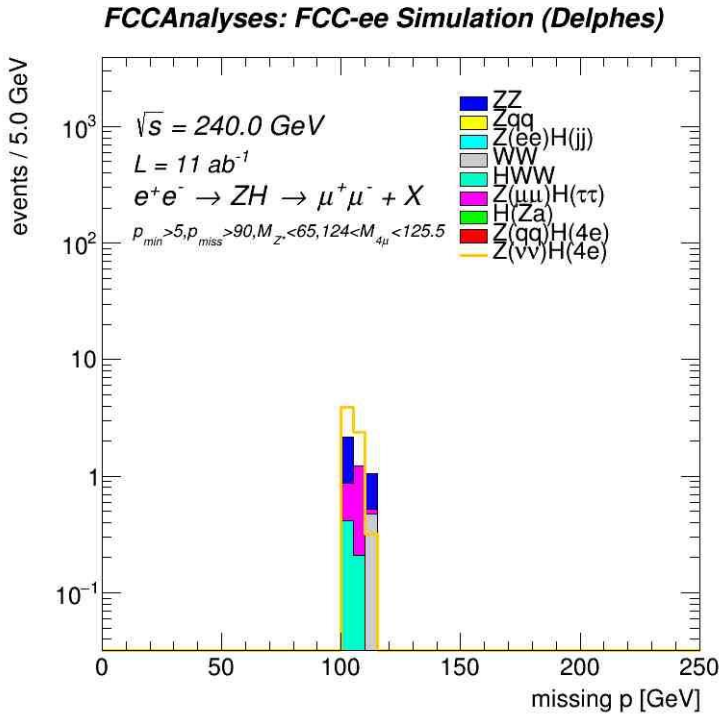
After Selection: Z(jj) H(4e)

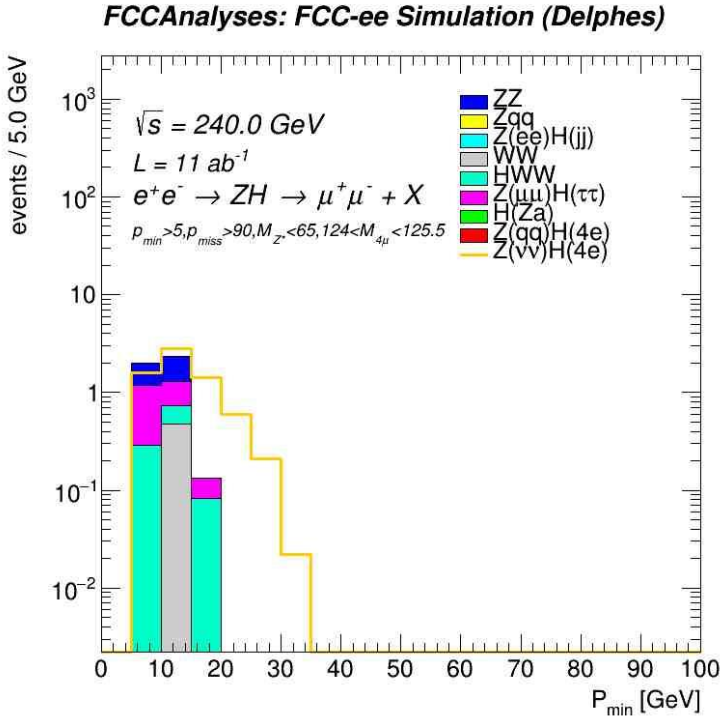




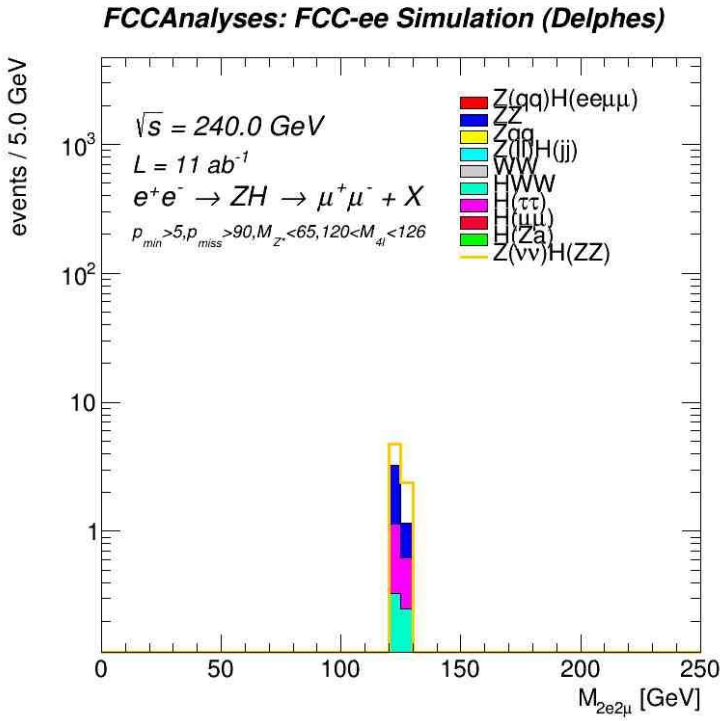


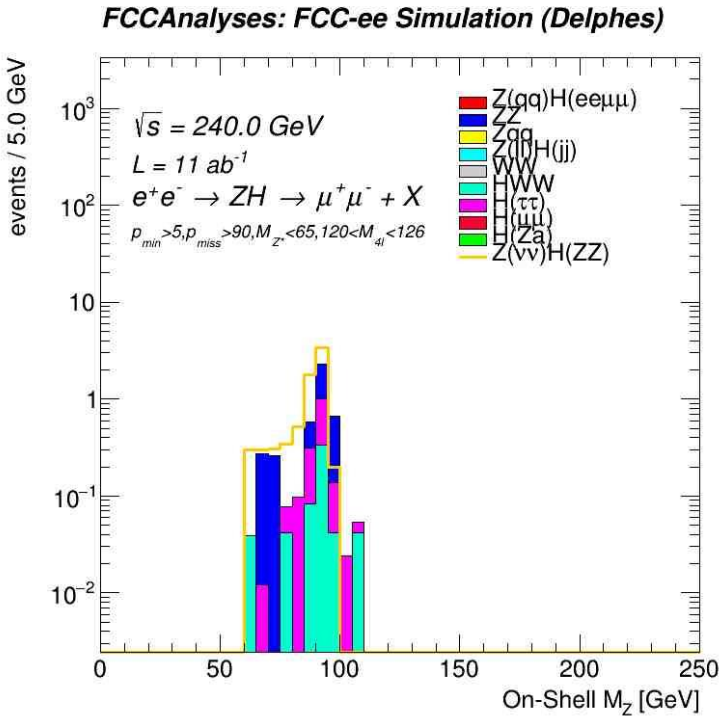
After Selection: Z(jj) H(4e)

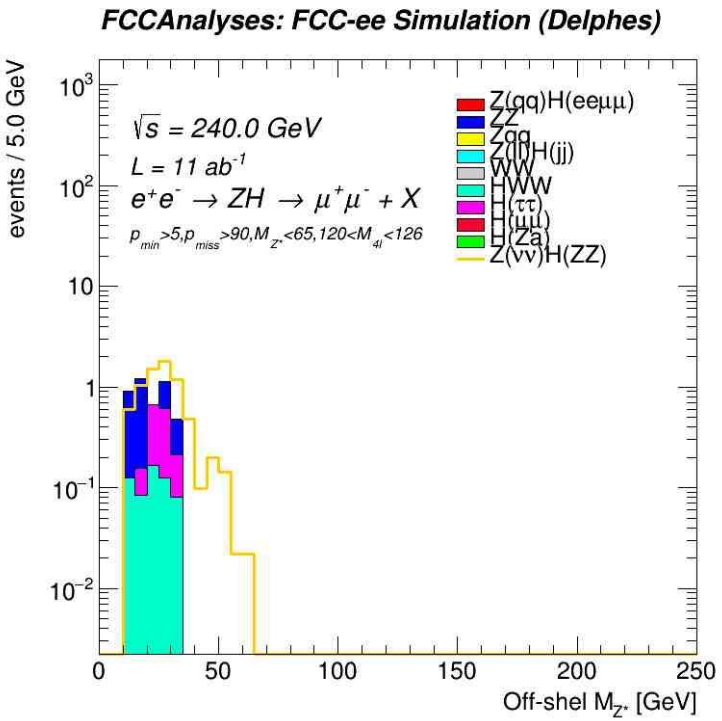




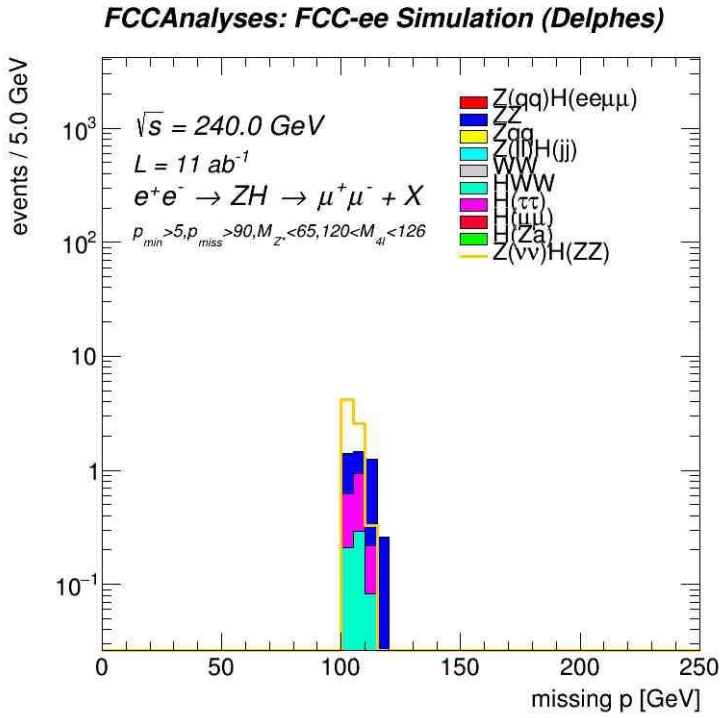
After Selection: Z(jj) H(2e2μ)

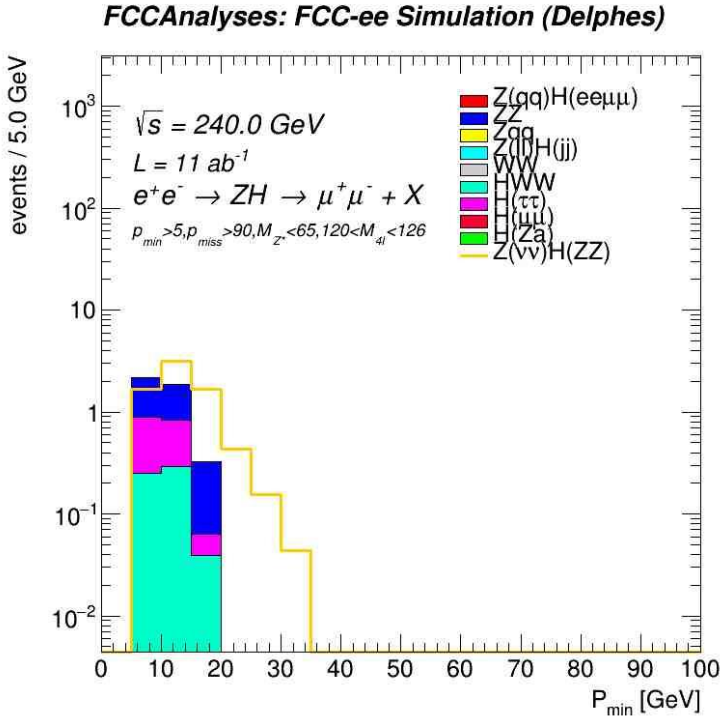






After Selection: Z(jj) H(2e2μ)





Conclusion

- Improvements were made to the cuts.
- Remaining jet flavours were added.
- Added leptonic 4l flavor combination 4e and 2e2μ
- Added a Z(vv) in addition to the Z(jj) channel.

Thank you