Rare Higgs Decay at the FCCee:

$H \rightarrow aa \rightarrow 4K$

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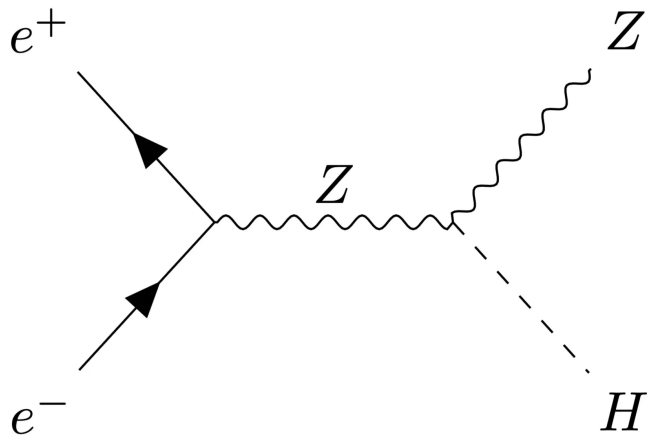
Reminder

Processes

One signal (*500,000 events*)

- ee → Z → ZH
  - Z → ee
  - H → aa
    - aa → $K^-K^+K^-K^+$

“p8_ee_eeH_Hpsps_ecm240”



Reminder

Processes

Three backgrounds

- ee $\rightarrow$ WW ($\sim 3.7 * 10^8$ *events*)

"p8_ee_WW_ecm240"

- ee $\rightarrow$ ZZ ($\sim 5.6 * 10^7$ *events*)

"p8_ee_ZZ_ecm240"

- ee $\rightarrow$ Z $\rightarrow$ qq ($\sim 1 * 10^8$ *events*)

u, d, c, s, b

"p8_ee_Zqq_ecm240"

Reminder

Sample generation

- Signal events are generated with Delphes+Pythia8
- Definition of new pseudo-scalar from Pythia card
  - spin type: 0
  - Nominal mass: 1.5 GeV
  - Γ_{BW}: $1.9732 * 10^{-12}$ GeV (very prompt)
  - One decay channel → 2 charged kaons → 100%

```
! Definition of new pseudoscalar
9000006:all = ps psbar 0 0 0 1.5 1.9732e-12 1.0 75.0 0
9000006:oneChannel = 2 1.000 101 321 -321
9000006:mayDecay = on
9000006:isResonance = on
9000006:onMode = off
9000006:onIfAny = 321
```

Analysis

Reconstruction of the Higgs

- Filtered out events that did not have exactly 4 kaons
- Individual masses of the 4 kaons were then summed up

Reconstruction of the Z

- Filtered out events that did not have exactly 2 electrons
- Individual masses of the 2 electrons were then summed up

Analysis

Reconstruction of the Higgs

- Filtered out events that did not have exactly 4 kaons
- Individual masses of the 4 kaons were then summed up

Selections

- $0.2 < K+_{mass} < 0.7$ GeV
- $K+_{energy} > 2$ GeV
- $H_{mass} > 120$ GeV

Reconstruction of the Z

- Filtered out events that did not have exactly 2 electrons
- Individual masses of the 2 electrons were then summed up

Note: it seems like Delphes cannot differentiate between kaons and pions so reco. kaon mass is the pion mass

Analysis

Signal

- All events in tree: 459, 561
- After “KaonCut”: 459, 545

Selections

- $0.2 < K+_{mass} < 0.7$ GeV
- $K+_{energy} > 2$ GeV

Analysis

Signal

- All events in tree: 459, 561
- After “KaonCut”: 459, 545

ee → WW

- All events in tree: 12, 426
- After “KaonCut”: 5

ee → ZZ

- All events in tree: 51, 844
- After “KaonCut”: 16

ee → Z → qq

- All events in tree: 2, 503
- After “KaonCut”: 3

Selections

- $0.2 < K+_{mass} < 0.7$ GeV
- $K+_{energy} > 2$ GeV

Analysis

Signal

- All events in tree: 459, 561
- After “KinematicCut”: 459, 545

Selections

- $0.2 < K+_{mass} < 0.7$ GeV
- $K+_{energy} > 2$ GeV
- $H_{mass} > 120$ GeV

Analysis

Signal

- All events in tree: 459, 561
- After “KinematicCut”: 459, 545

ee → WW

- All events in tree: 12, 426
- After “KinematicCut”: 0

ee → ZZ

- All events in tree: 51, 844
- After “KinematicCut”: 0

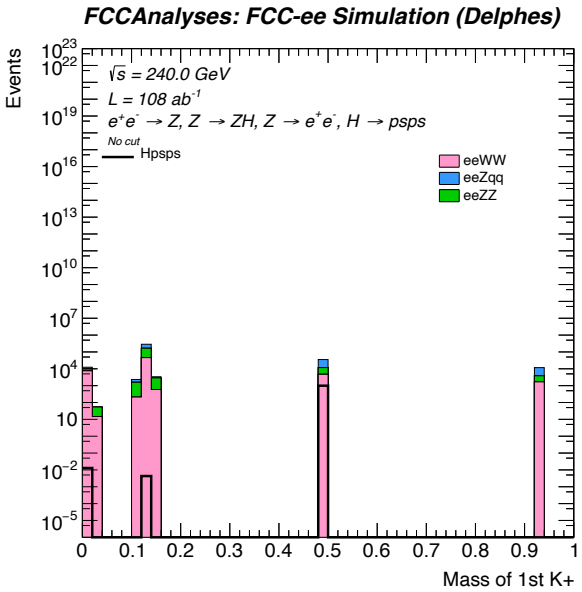
ee → Z → qq

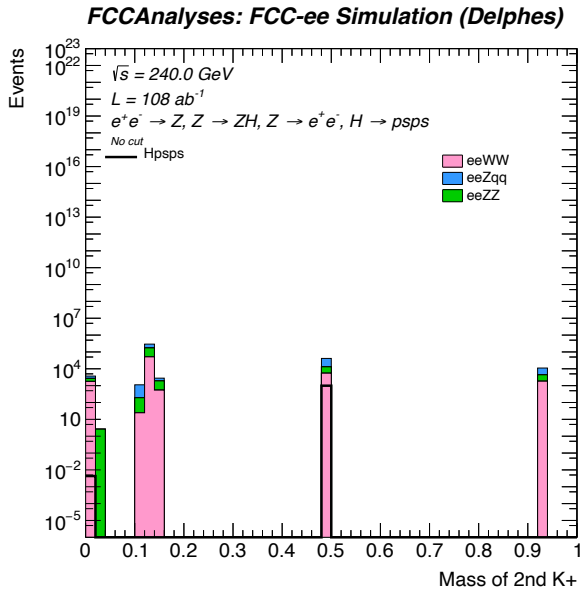
- All events in tree: 2, 503
- After “KinematicCut”: 0

Selections

- $0.2 < K+_{mass} < 0.7$ GeV
- $K+_{energy} > 2$ GeV
- $H_{mass} > 120$ GeV

Plots


FCCAnalyses: FCC-ee Simulation (Delphes)
√s = 240.0 GeV
L = 108 ab-1
e+e- → Z, Z → ZH, Z → e+e-, H → psps
No cut
Hpsps
eeWW
eeZqq
eeZZ
Events
Mass of 1st K+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No cut
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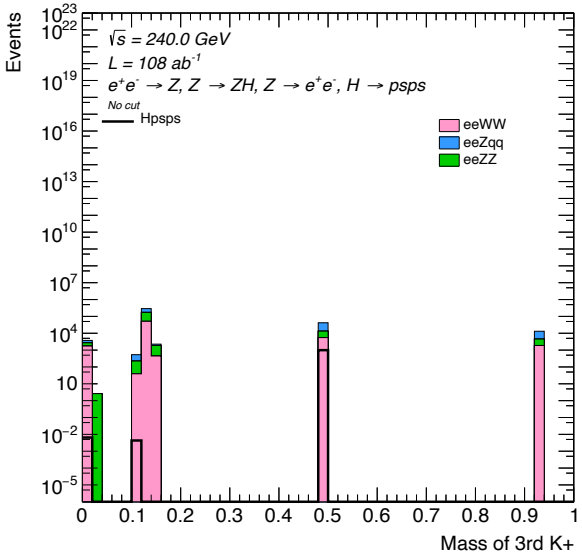
Events
Mass of 2nd K+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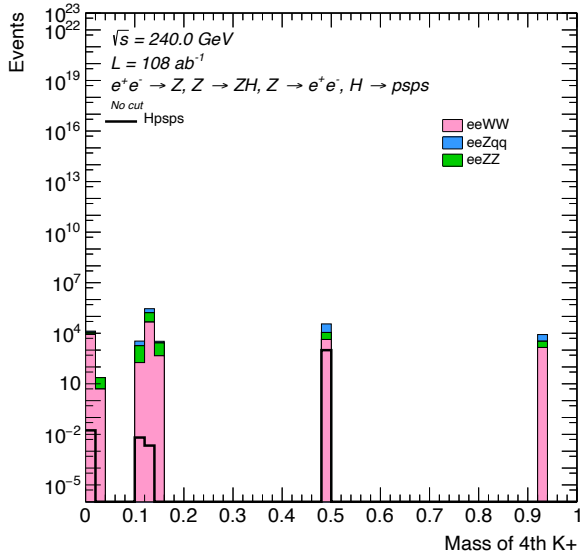
eeZZ
Events
Mass of 3rd K+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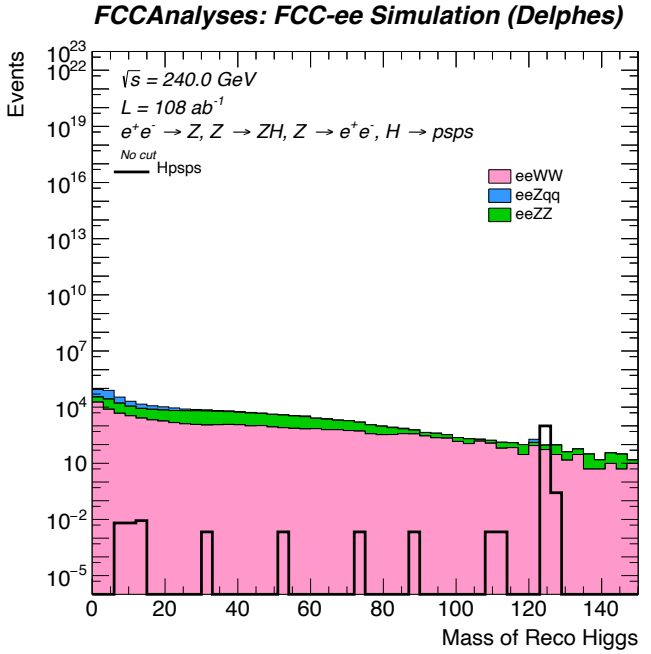
Events
Mass of 4th K+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No cut
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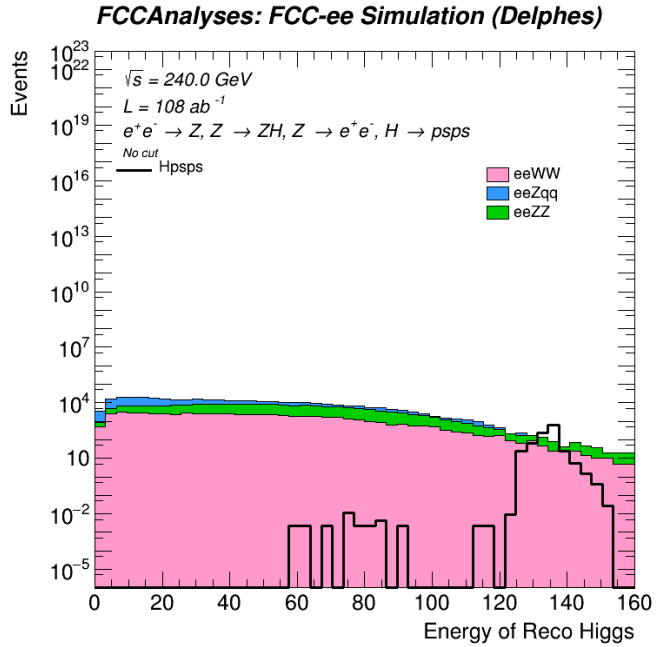
eeZqq
eeZZ
Events
Mass of Reco Higgs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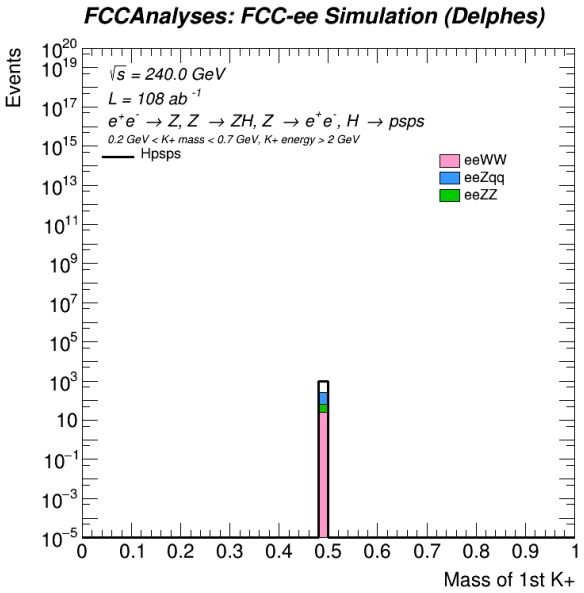
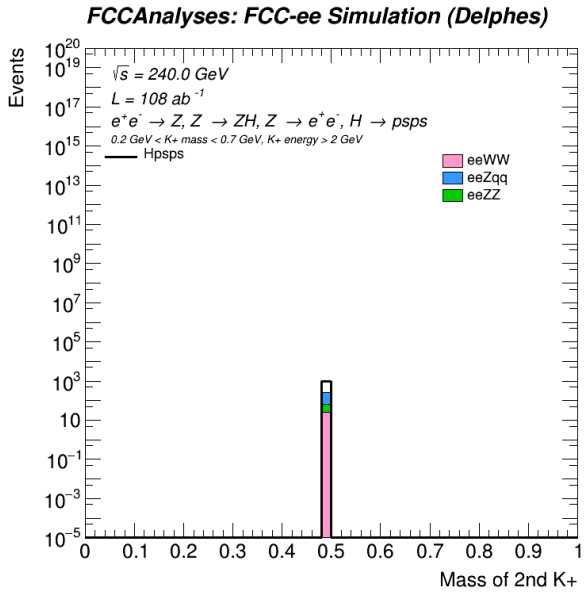
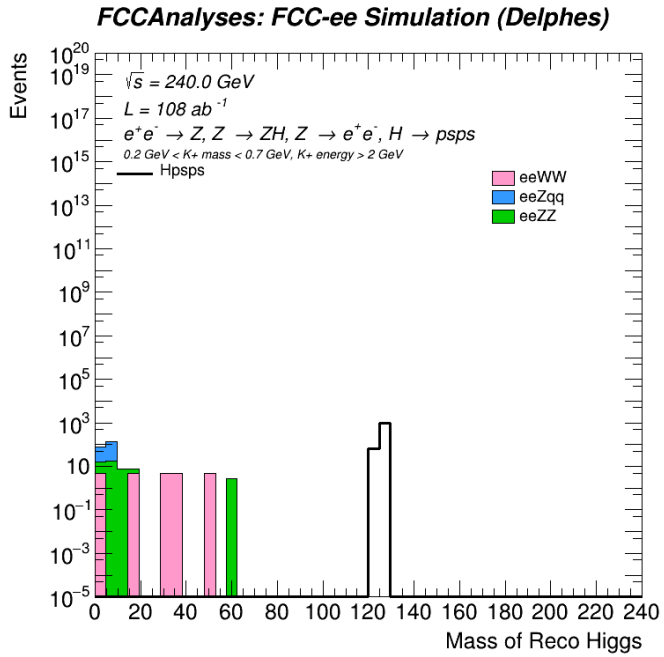
Events
Energy of Reco Higgs

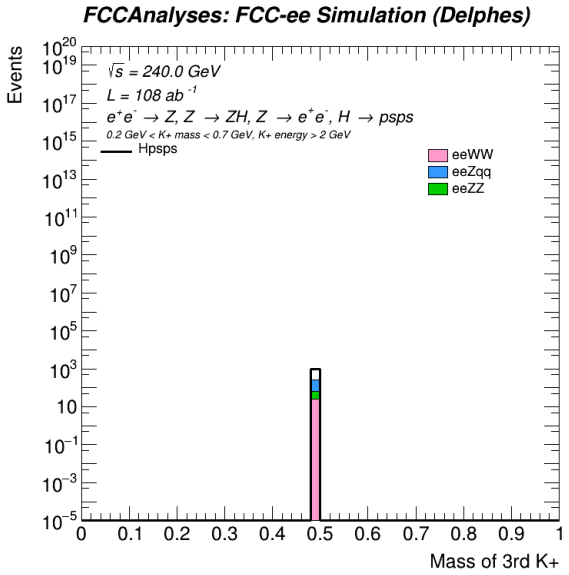
No cut

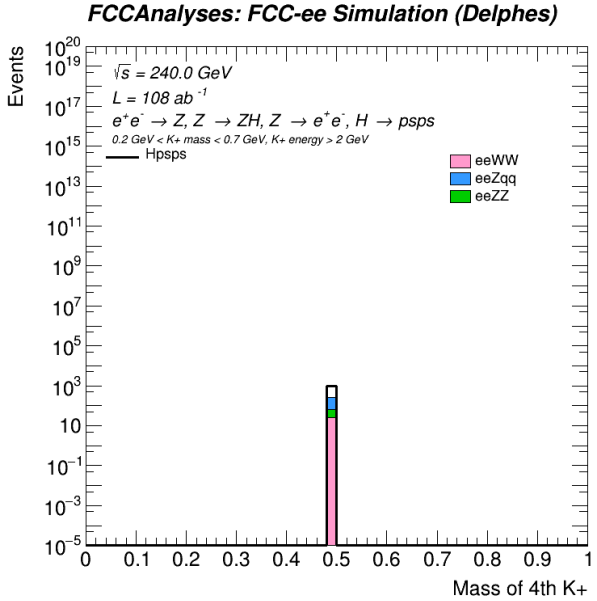
Plots

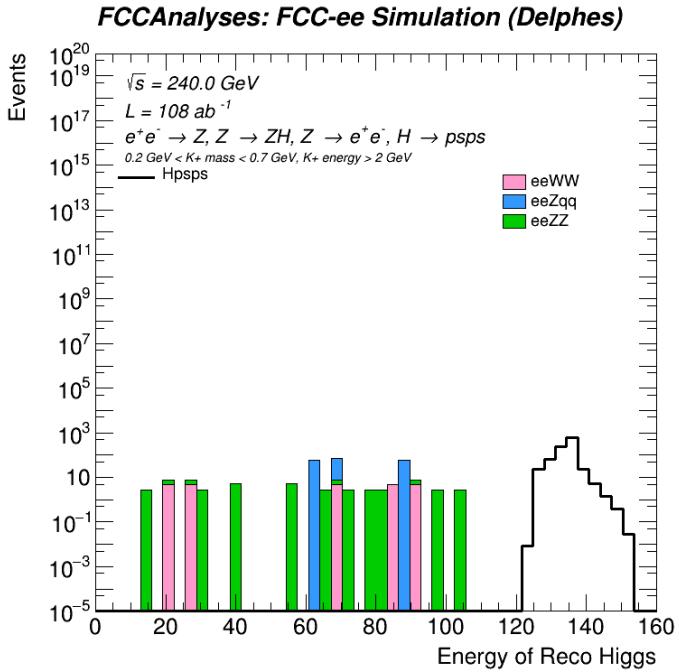






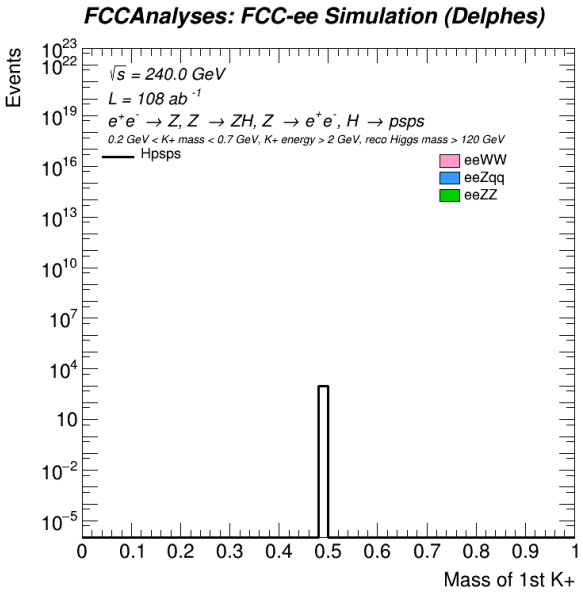


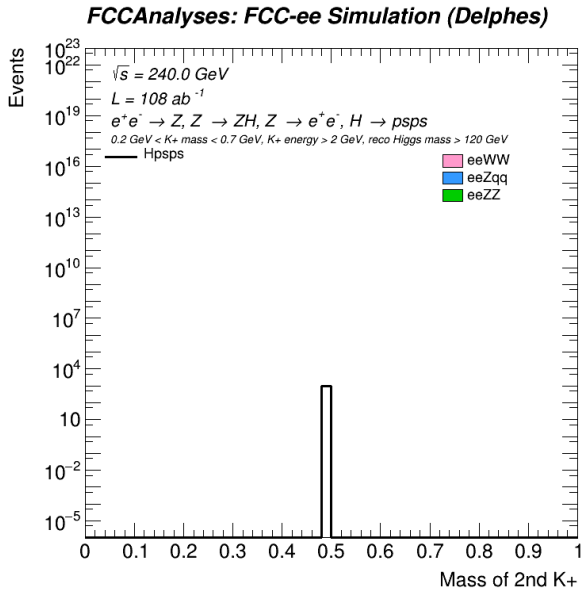


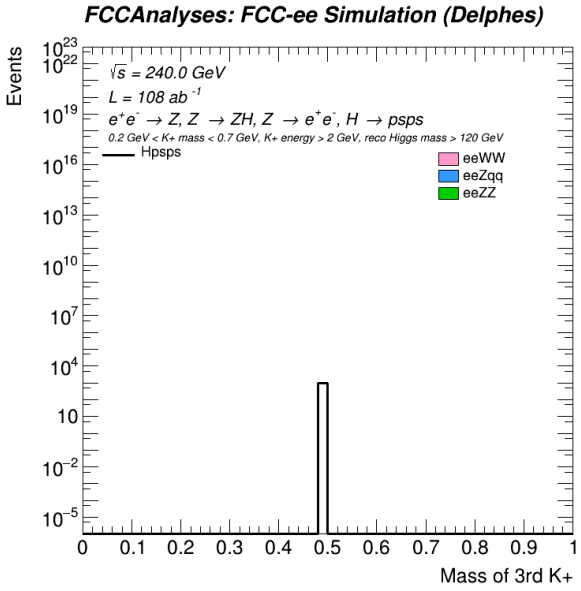


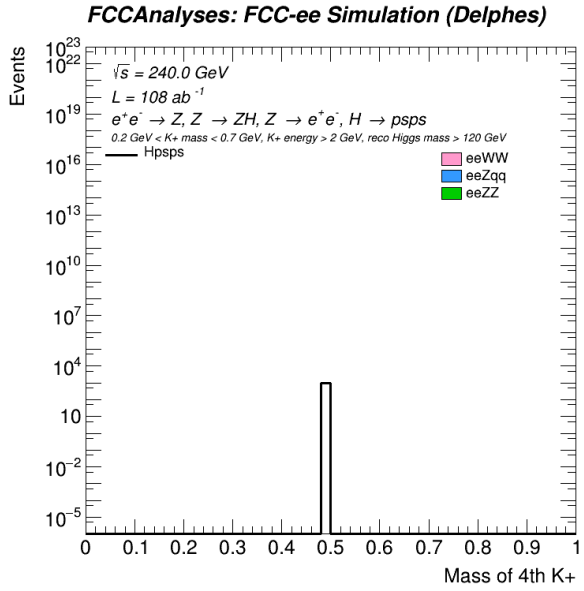
Kaon cut

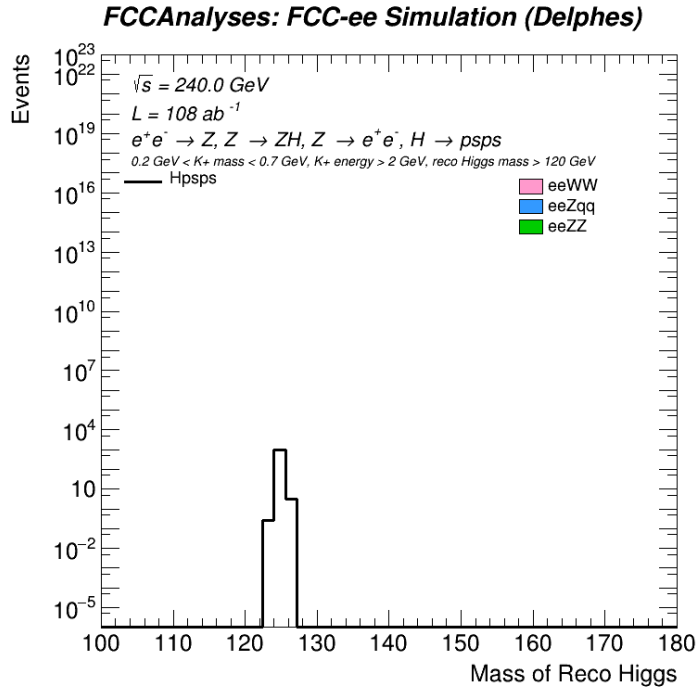
Plots

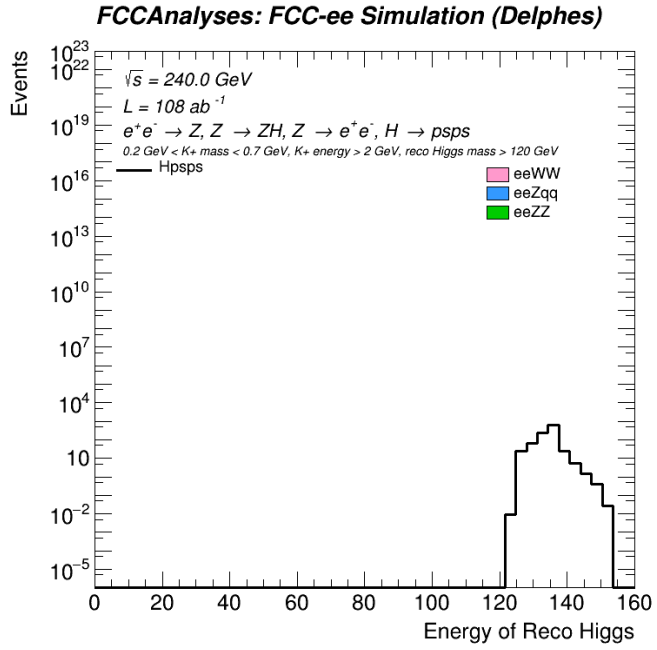






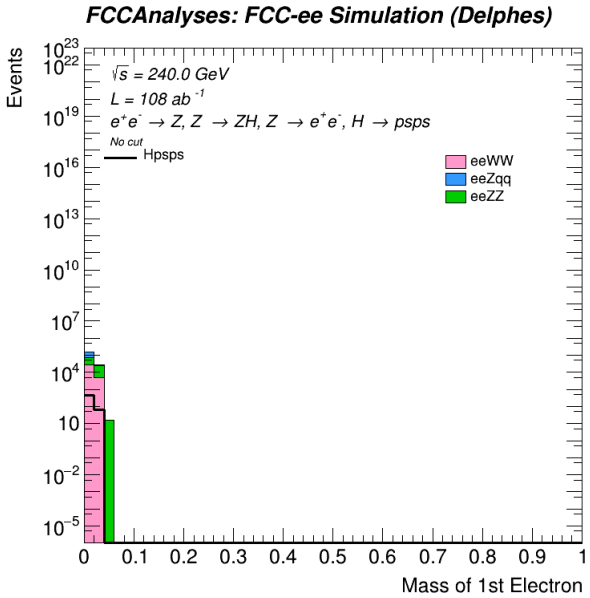






Kinematic cut

Plots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No cut
Hpsps
eeWW
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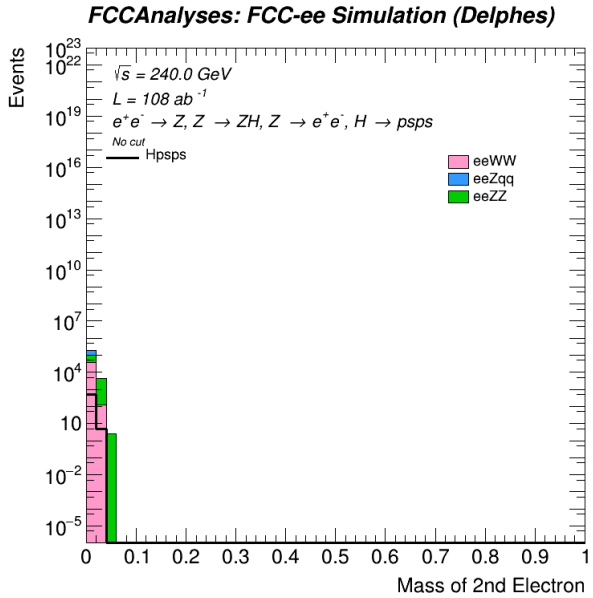
Mass of 1st Electron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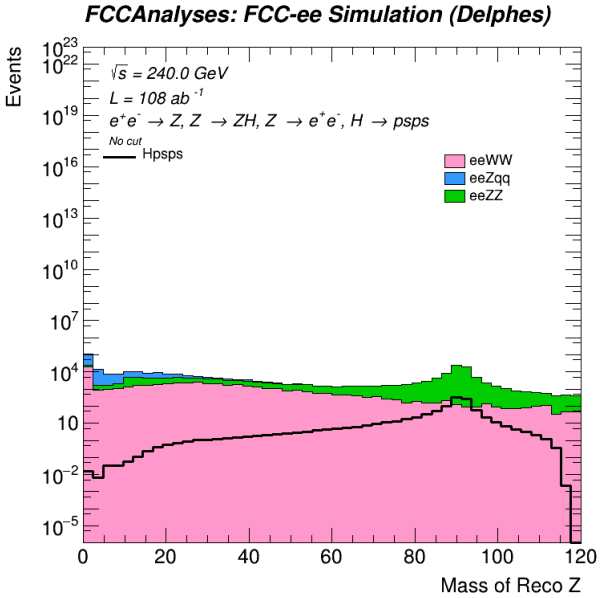
Mass of 2nd Electron

No cut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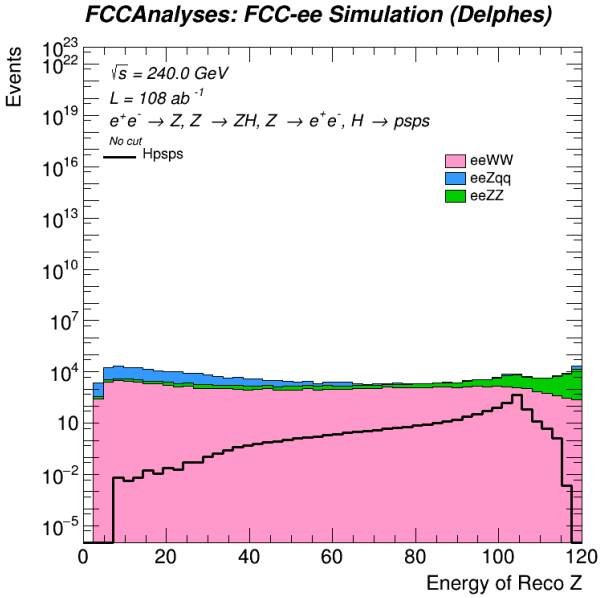
eeZZ
Mass of Reco Z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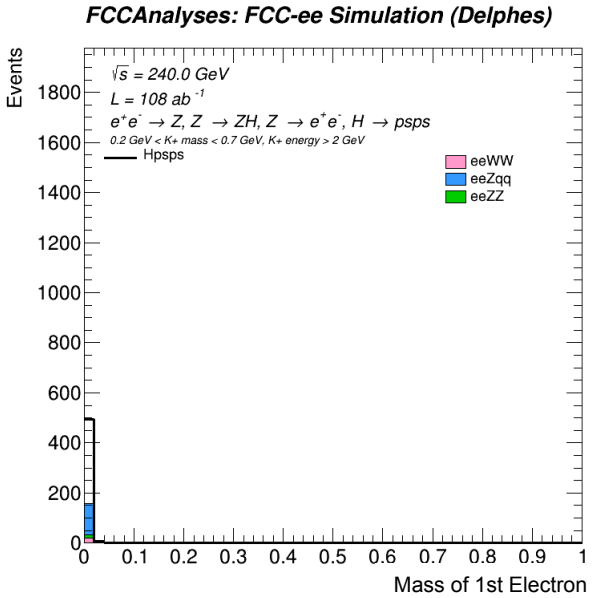
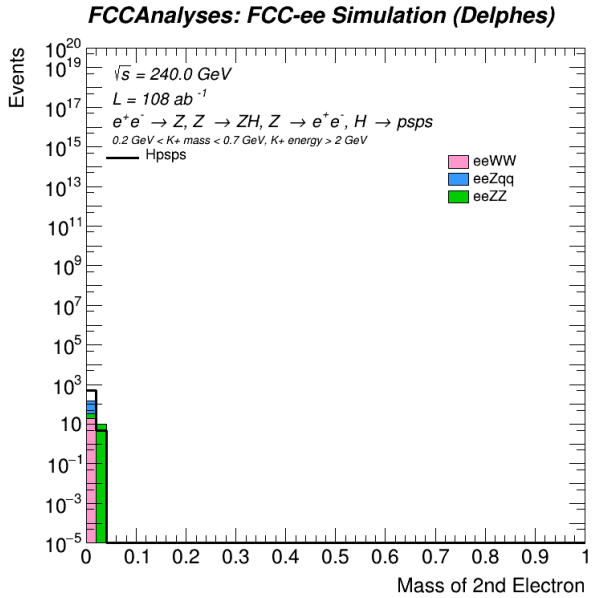
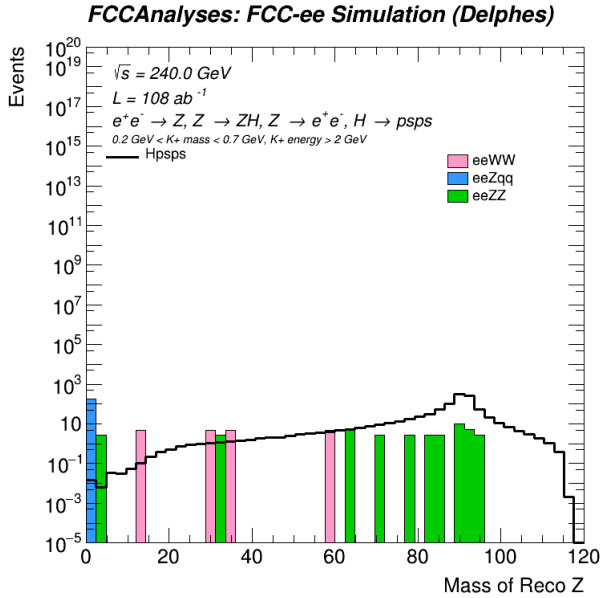
Energy of Reco Z

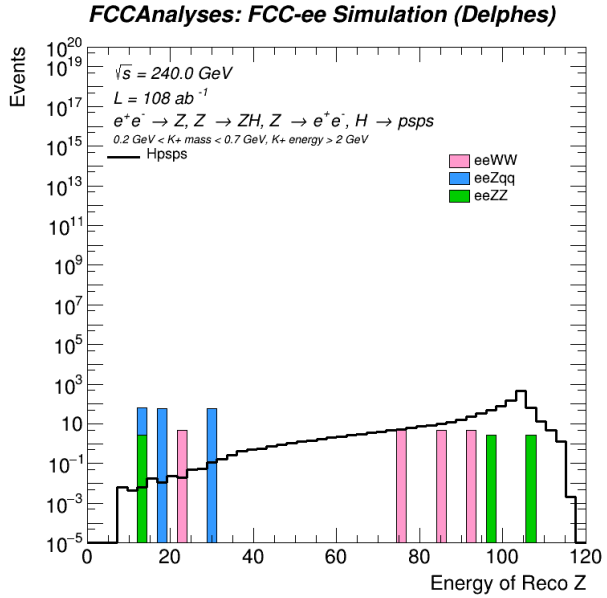
Plots



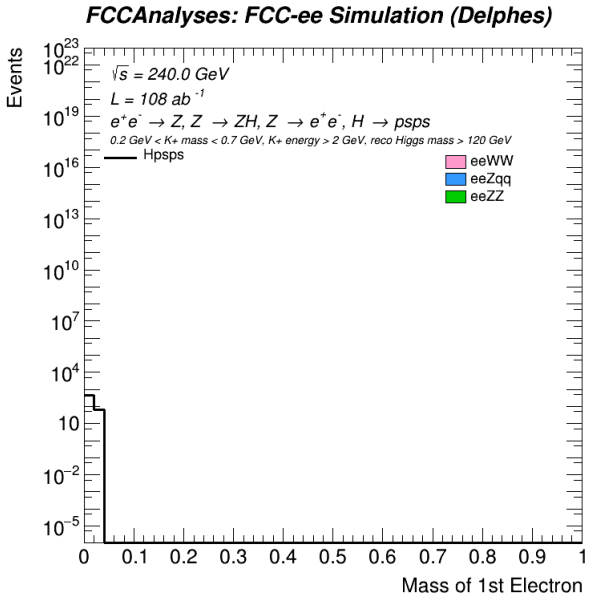


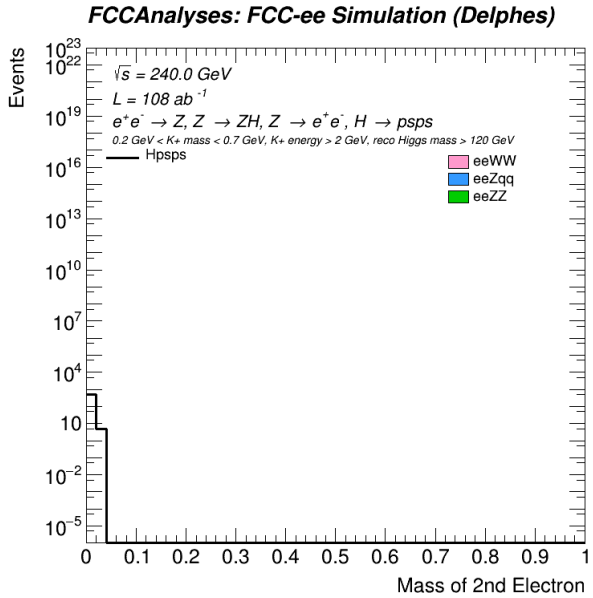
Kaon cut



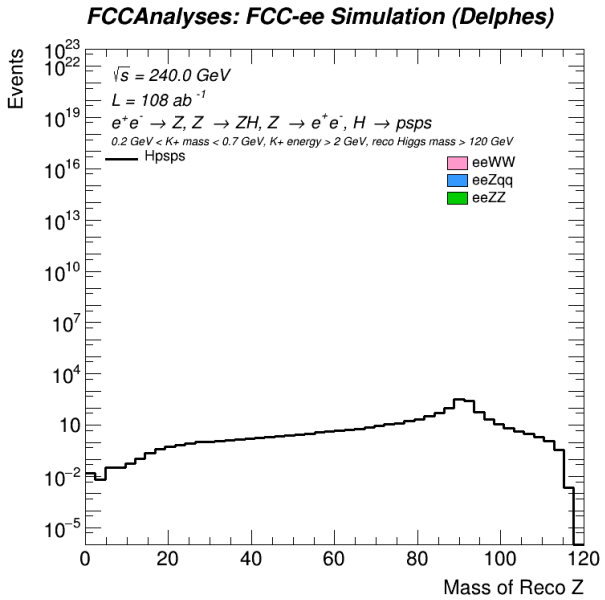


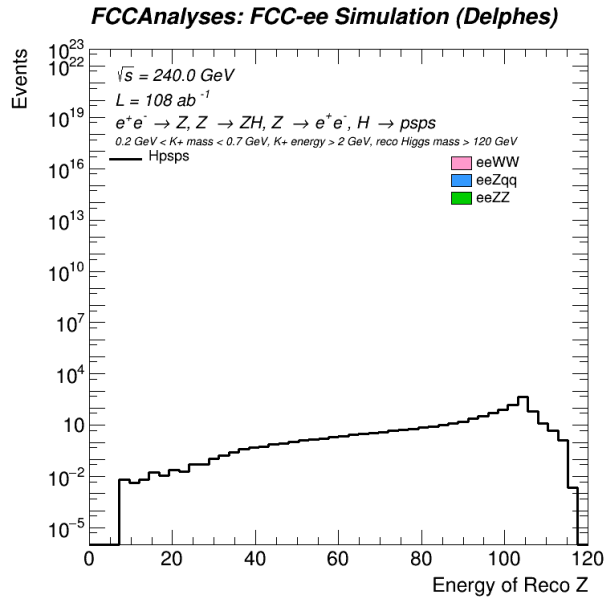
Plots





Kinematic cut





Next steps

- Apply vertex reconstruction on the kaons and determine displacement from IP
  - Useful for a new sample with LLP ALPs
- Include more signal & background processes
  - Generate more events for signal
- Including missing energy plots
- ALP reconstruction
  - Combinations of the 4 kaons