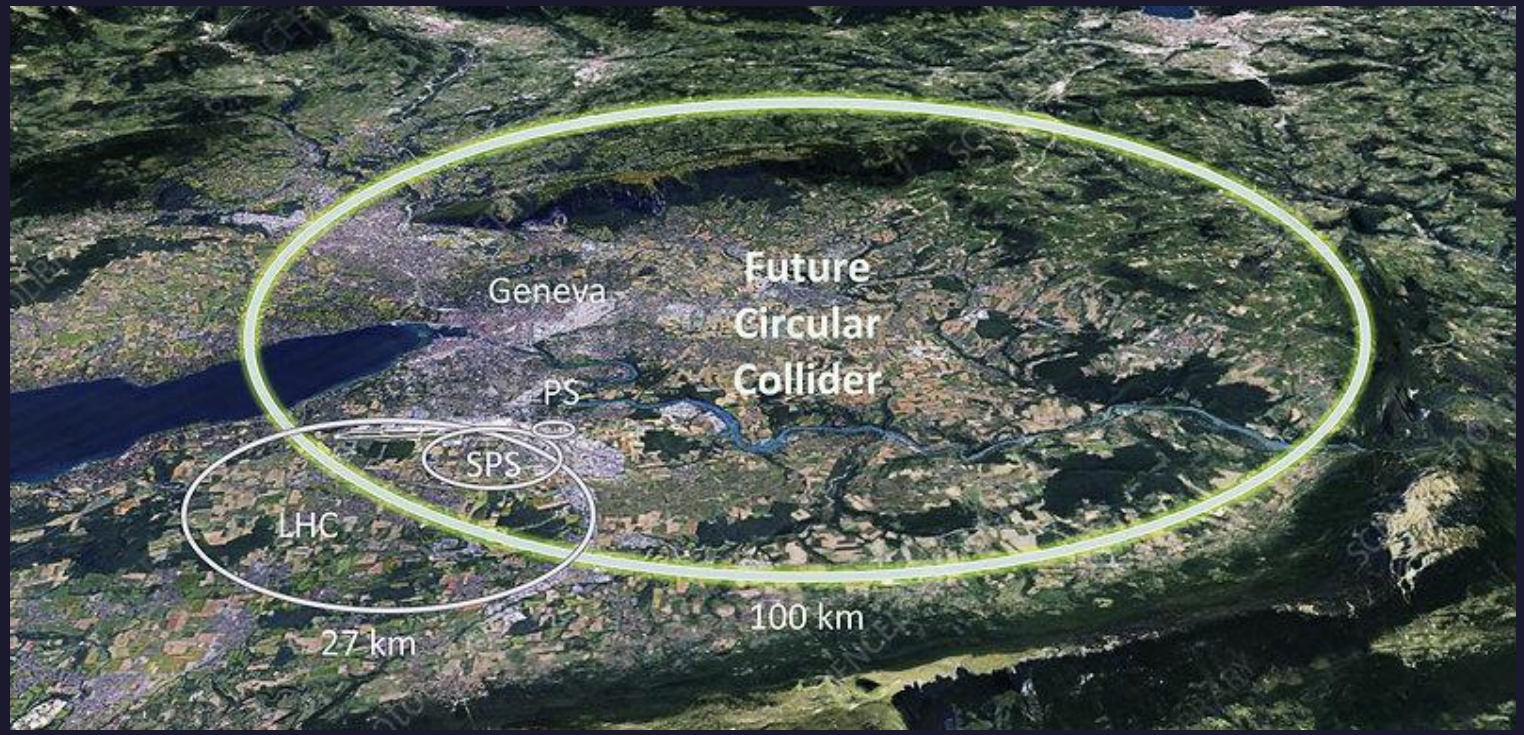
Long-lived axion-like particles at the FCC-ee

Weekly meeting with Juliette



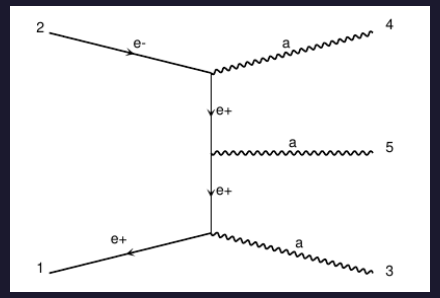
Elnura Bakhishova

HELMHOLTZ

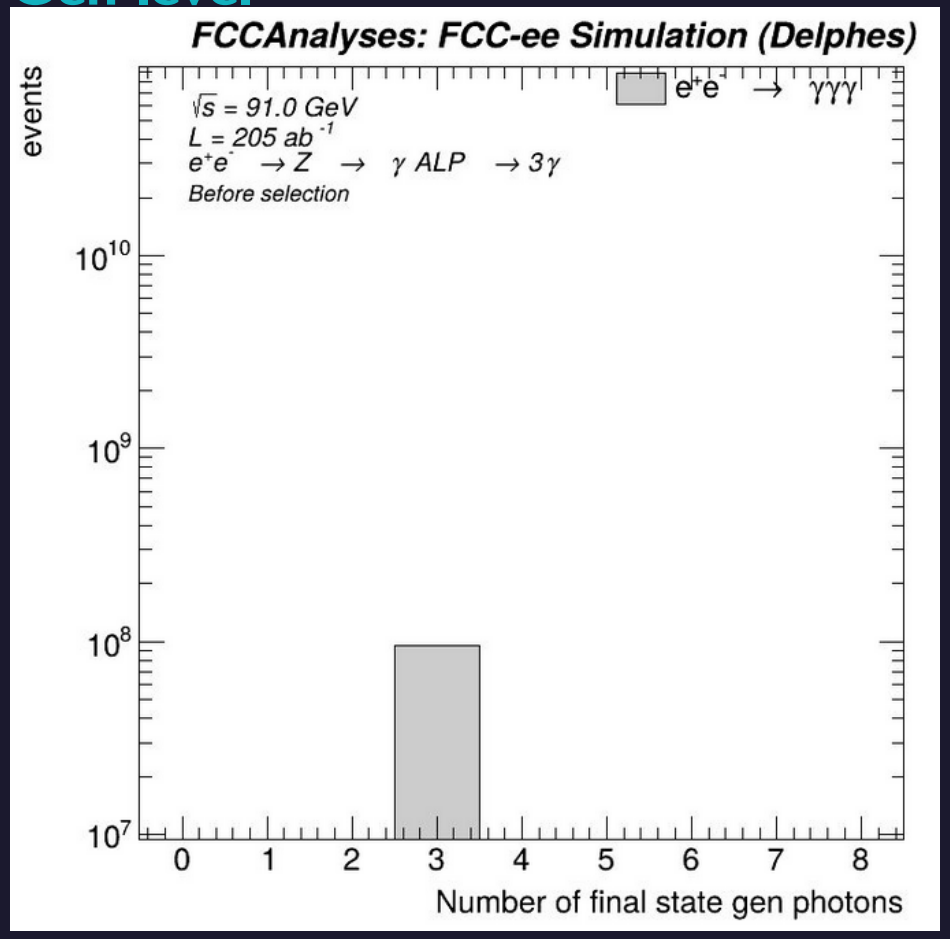
23.01.25

DESY.

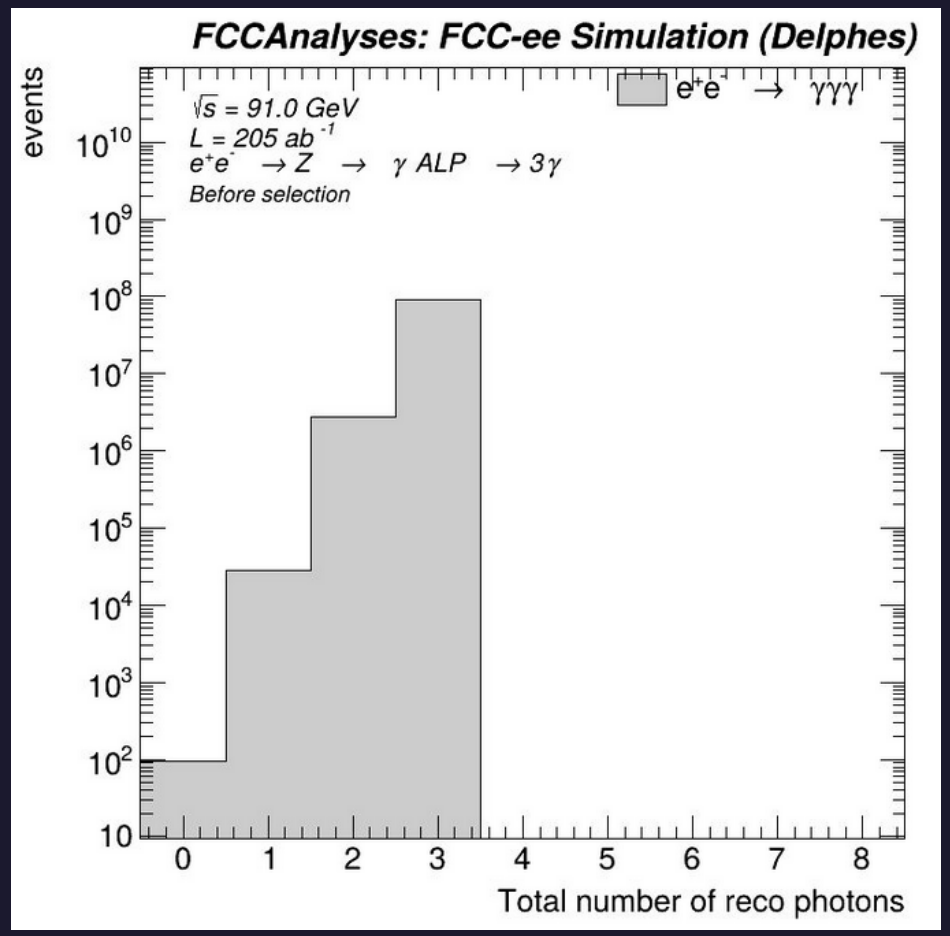
Background Photons --> aaa



Gen level



Reco level



-> No photon radiation from PYTHIA for the incoming electrons and exchange particle

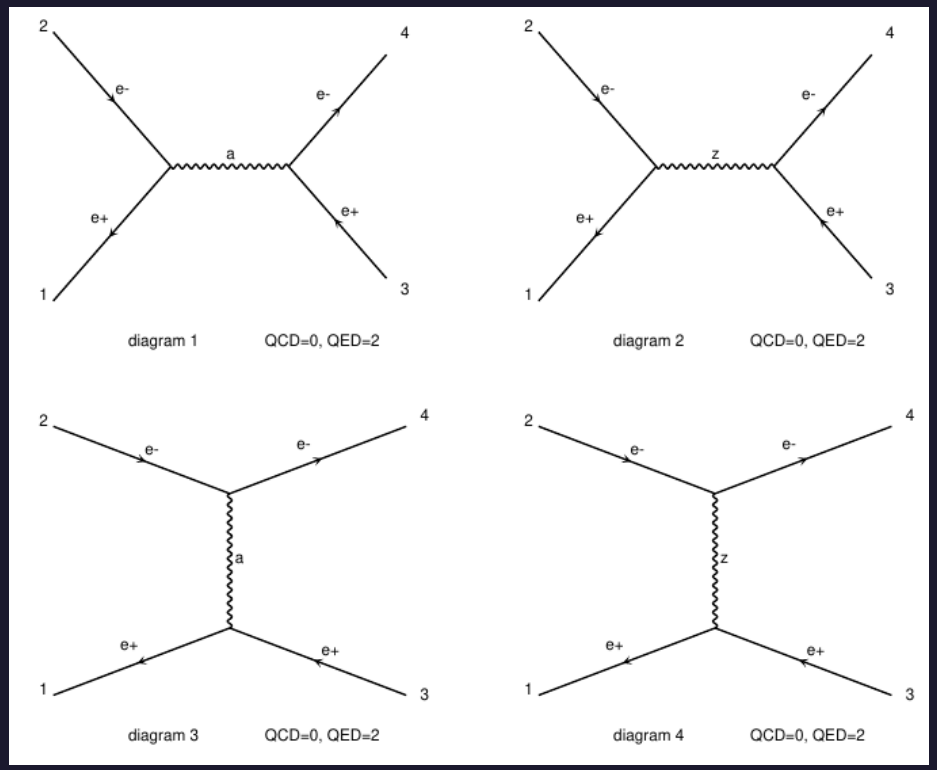
HELMHOLTZ

DESY.

Backgrounds with ee

Created background samples (1Mio events each):

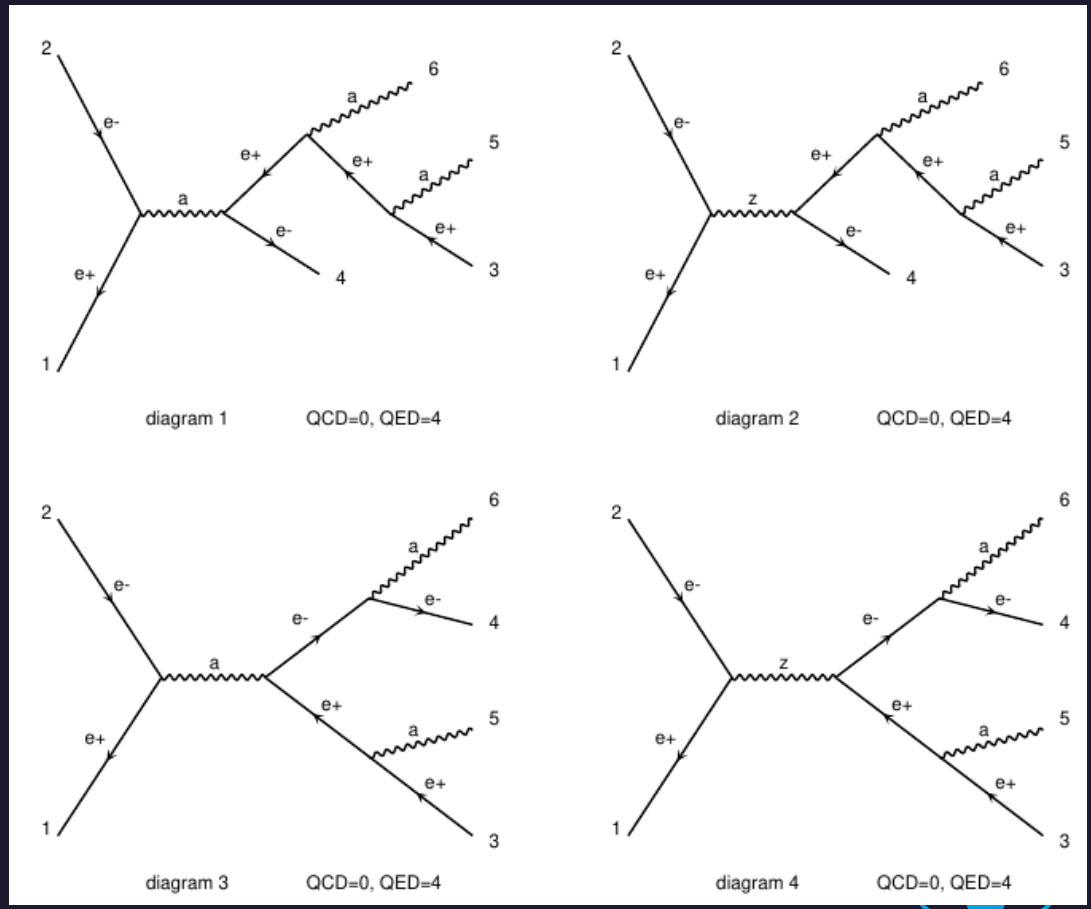
ee->ee: → 1 000 000 events
4500 +- 0.2189 pb



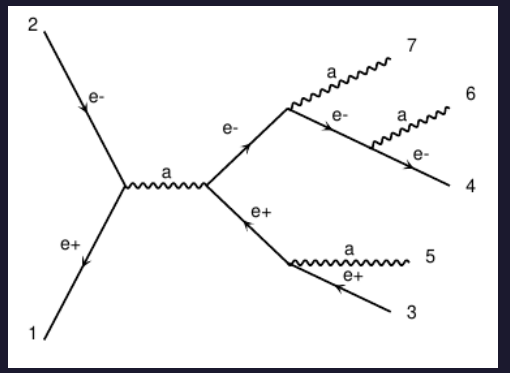
ee->eea: → 1 000 000 events
29.76 +- 0.01041 pb

ee->eeaa: → 1 000 000 events
0.09864 +- 4.426e-05 pb

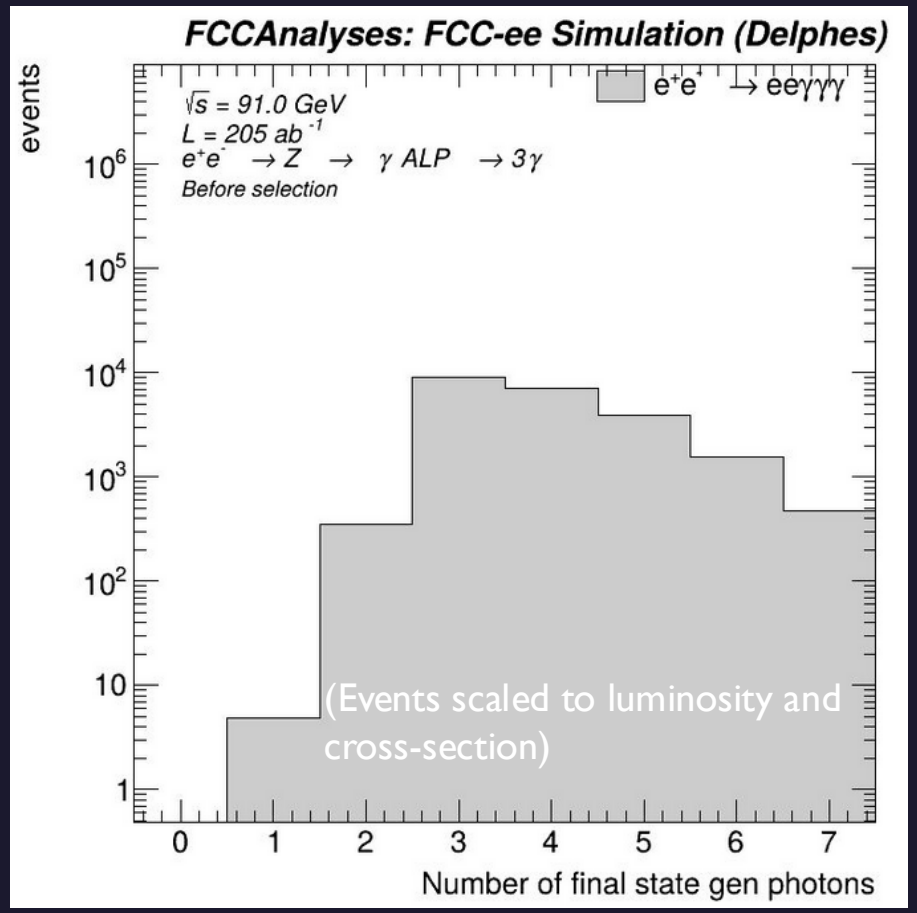
ee->eeaaa: → 1 000 000 events
0.000111 +- 4.238e-08 pb



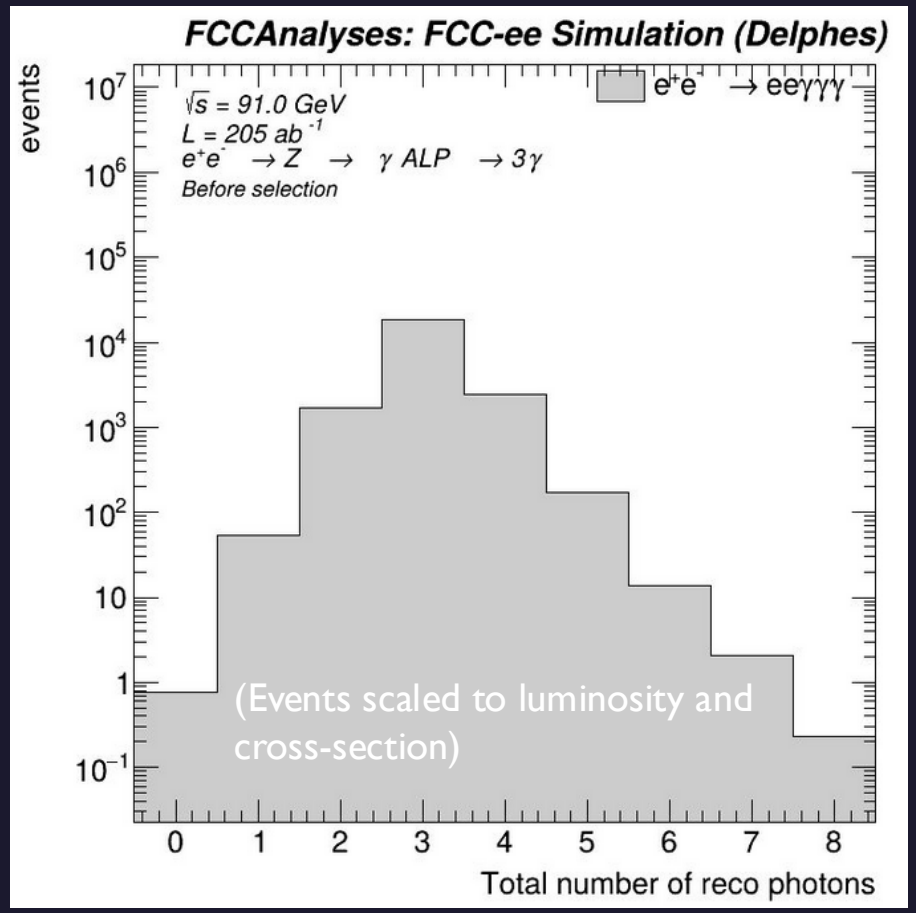
Background n_photons --> eeaaa



Gen level



Reco level



Why less than 3 photons on gen level?

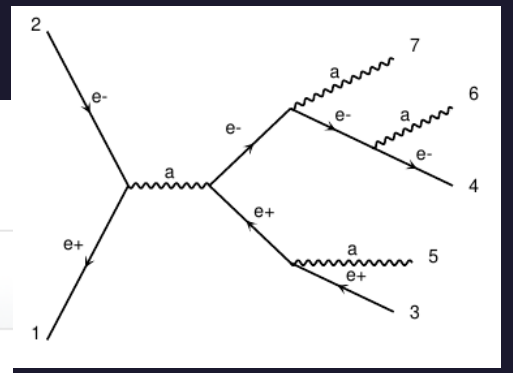
-> Radiation from PYTHIA

```
.Define("GenPhoton_PID", "MCParticle::sel_pdgID(22, false)(Particle)")
.Define("FSGenPhoton", "MCParticle::sel_genStatus(1)(GenPhoton_PID)") #gen status==1 means final state particle (FS)
```

HELMHOLTZ

DESY.

Background n_photons -> eeaaa



Status Codes for Top MC Generators

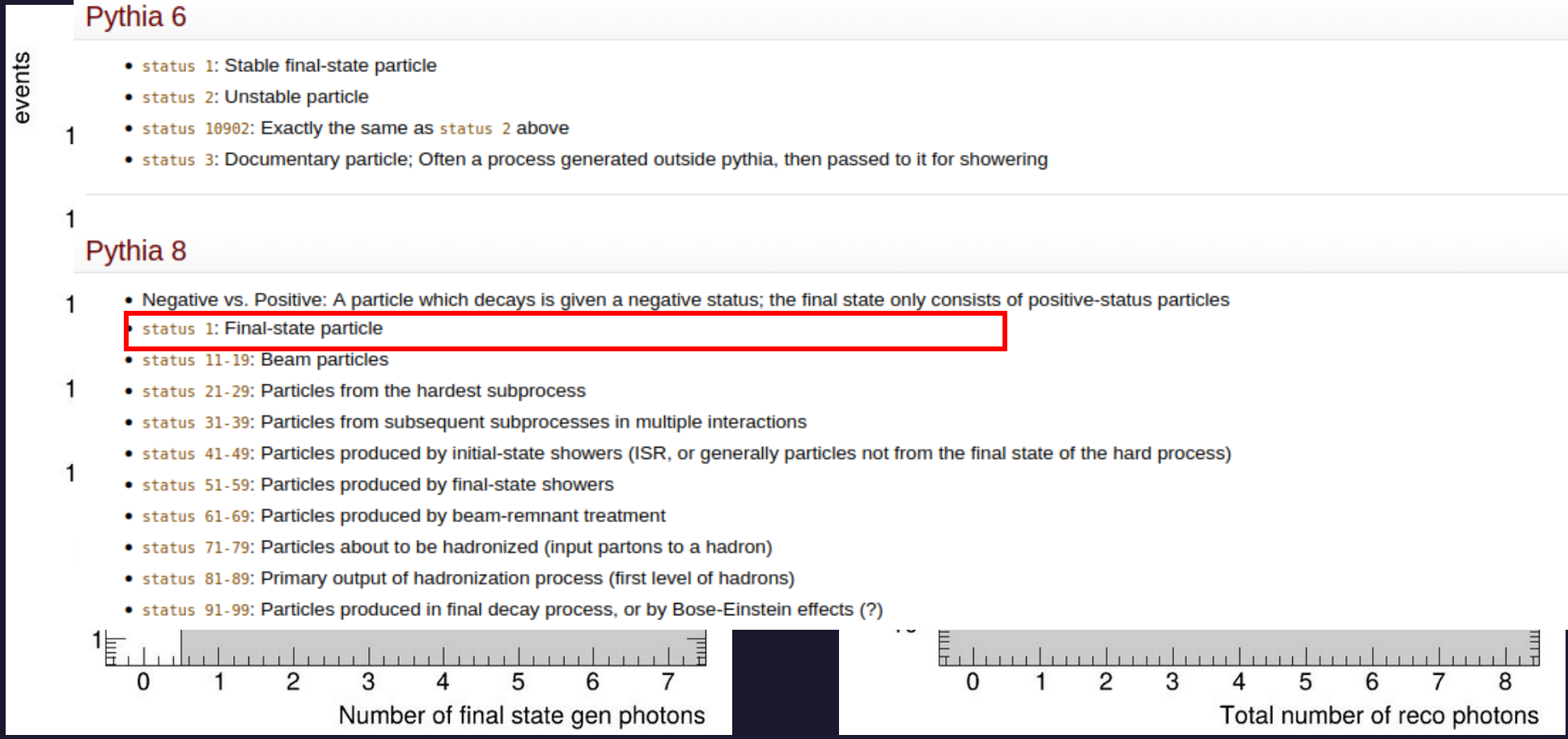
Status code information for the various generators used in top analyses is hard to find; the following explain how status codes are assigned for Pythia and Herwig generators

Pythia 6

- `status 1`: Stable final-state particle
- `status 2`: Unstable particle
- `status 10902`: Exactly the same as `status 2` above
- `status 3`: Documentary particle; Often a process generated outside pythia, then passed to it for showering

Pythia 8

- Negative vs. Positive: A particle which decays is given a negative status; the final state only consists of positive-status particles
- `status 1`: Final-state particle
- `status 11-19`: Beam particles
- `status 21-29`: Particles from the hardest subprocess
- `status 31-39`: Particles from subsequent subprocesses in multiple interactions
- `status 41-49`: Particles produced by initial-state showers (ISR, or generally particles not from the final state of the hard process)
- `status 51-59`: Particles produced by final-state showers
- `status 61-69`: Particles produced by beam-remnant treatment
- `status 71-79`: Particles about to be hadronized (input partons to a hadron)
- `status 81-89`: Primary output of hadronization process (first level of hadrons)
- `status 91-99`: Particles produced in final decay process, or by Bose-Einstein effects (?)



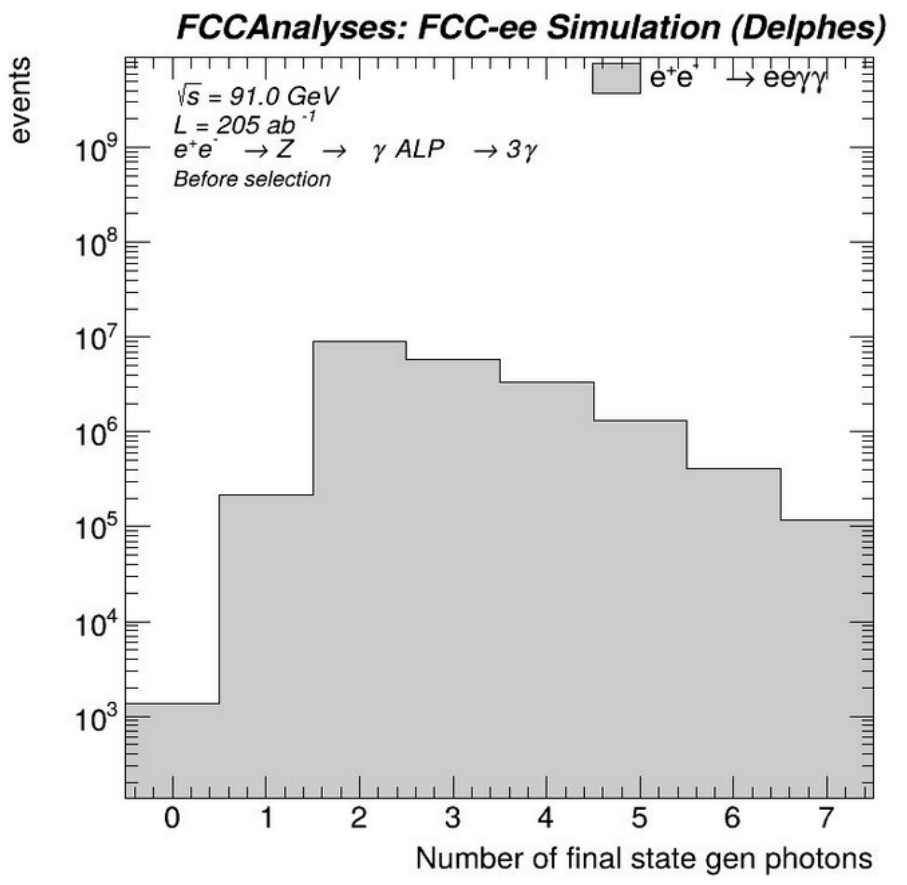
Why less than 3 photons on gen level?

-> Radiation from PYTHIA

```
.Define("GenPhoton_PID", "MCParticle::sel_pdgID(22, false)(Particle)")
.Define("FSGenPhoton", "MCParticle::sel_genStatus(1)(GenPhoton_PID)") #gen status==1 means final state particle (FS)
```

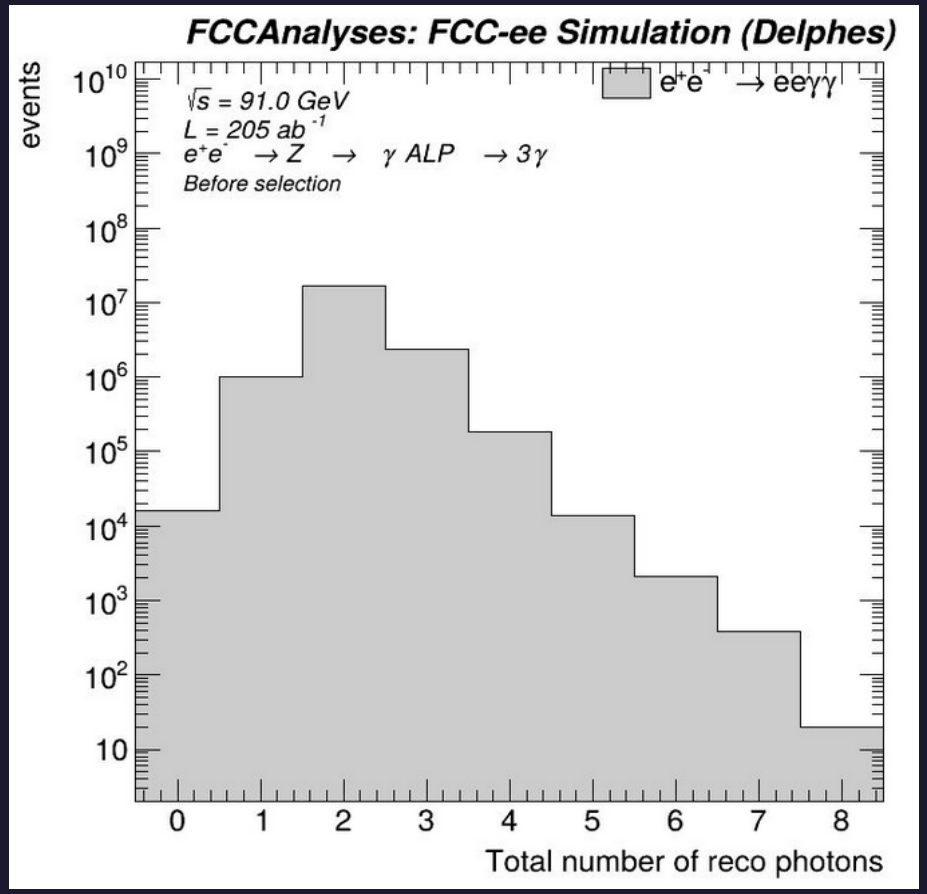
Background n_photons --> eeaa

Gen level



-> Radiation from PYTHIA

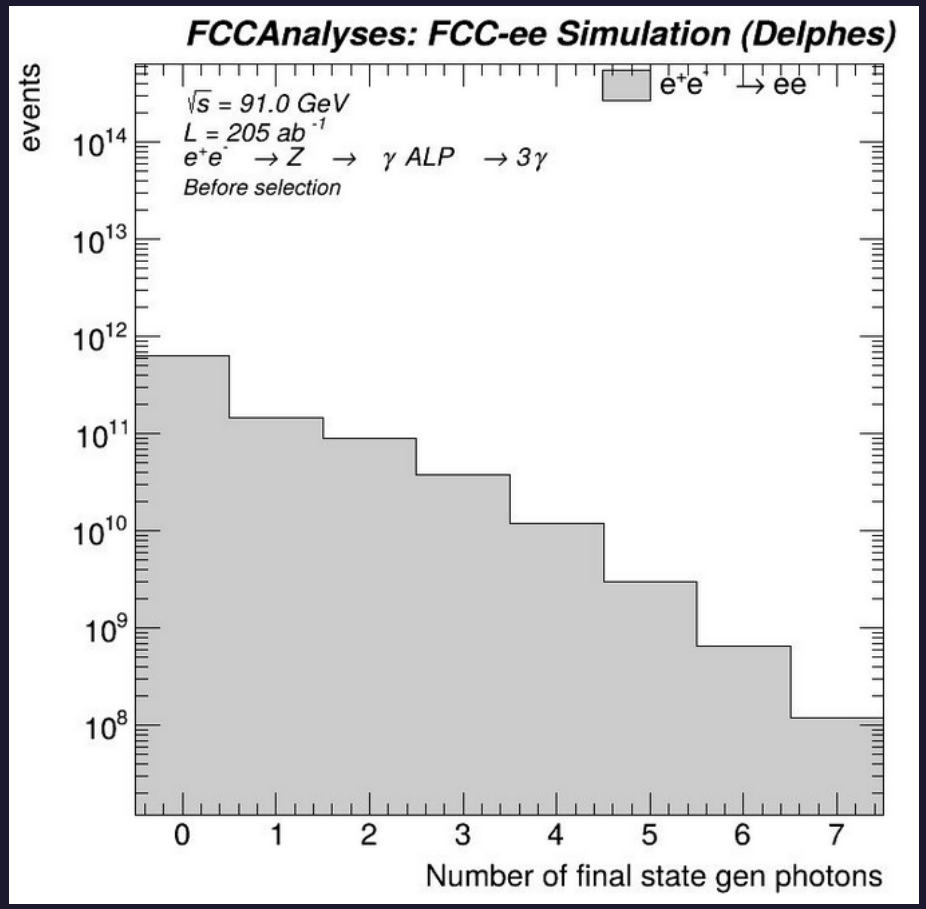
Reco level



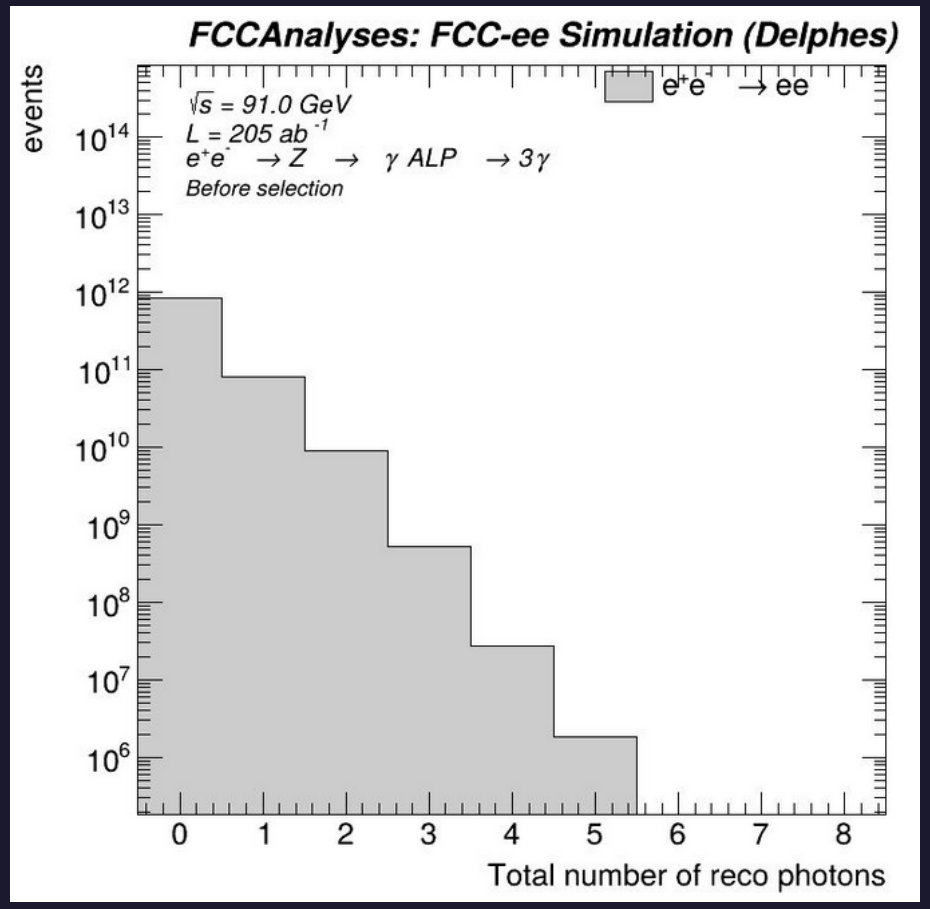
Why less than 2 photons on gen level?

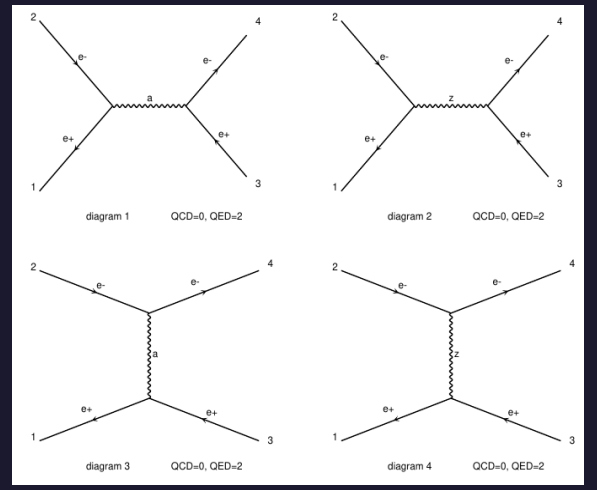
Background n_photons --> ee

Gen level



Reco level





-> Radiation from PYTHIA

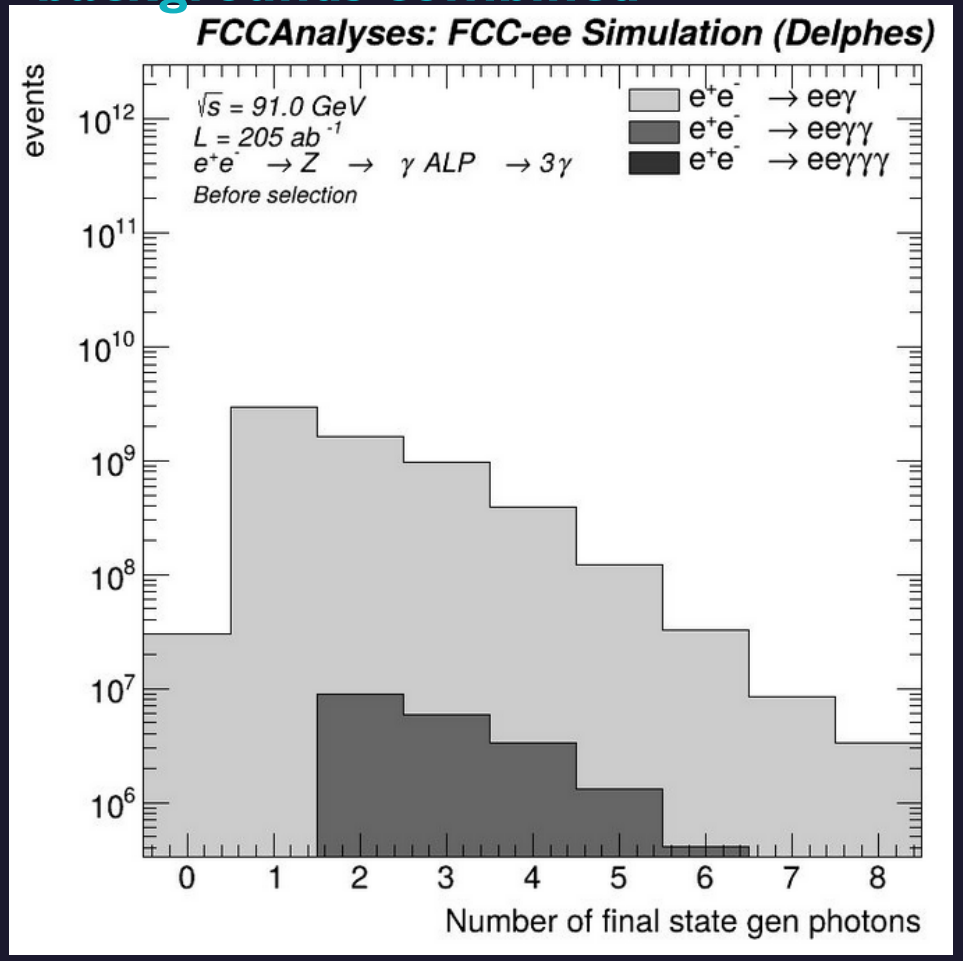
HELMHOLTZ

DESY.

Stacking eea,eeaa,eeaaa backgrounds

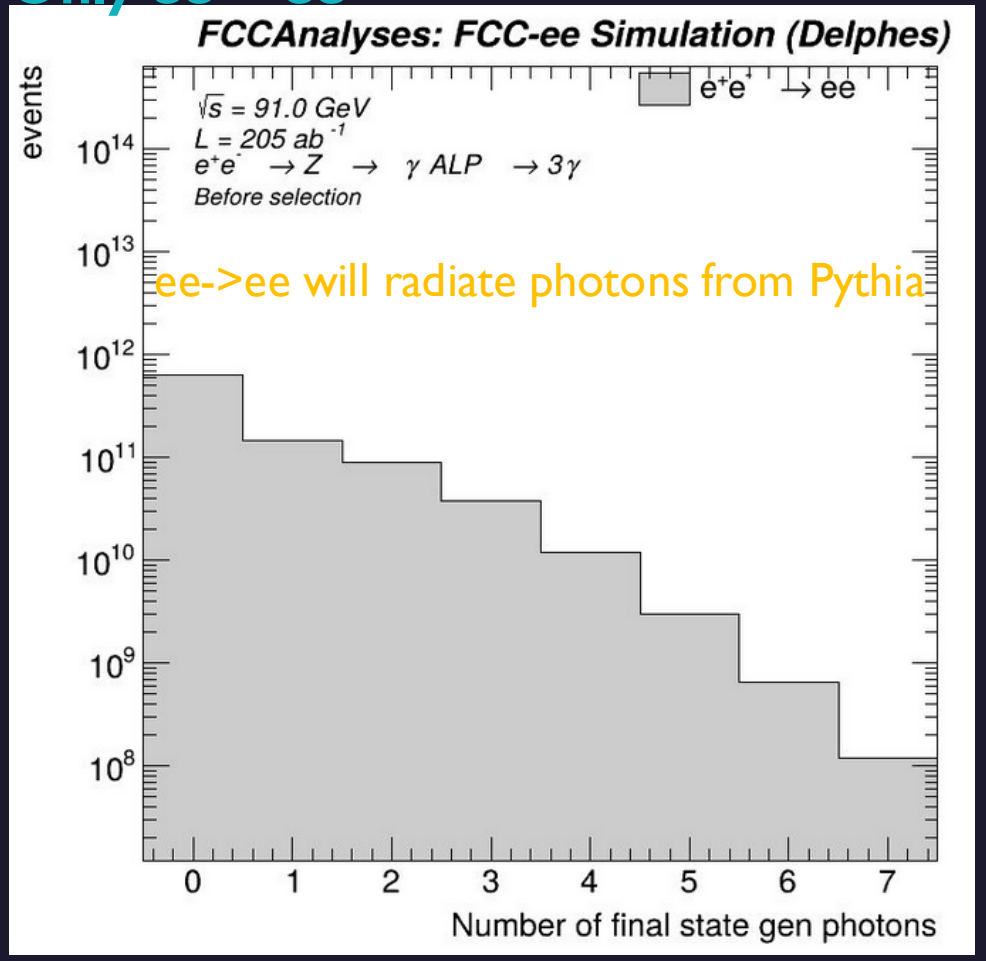
Are these backgrounds already included in ee-->ee? Comparison:

backgrounds combined



(Events scaled to luminosity and cross-section)

Only ee-->ee



(Events scaled to luminosity and cross-section)

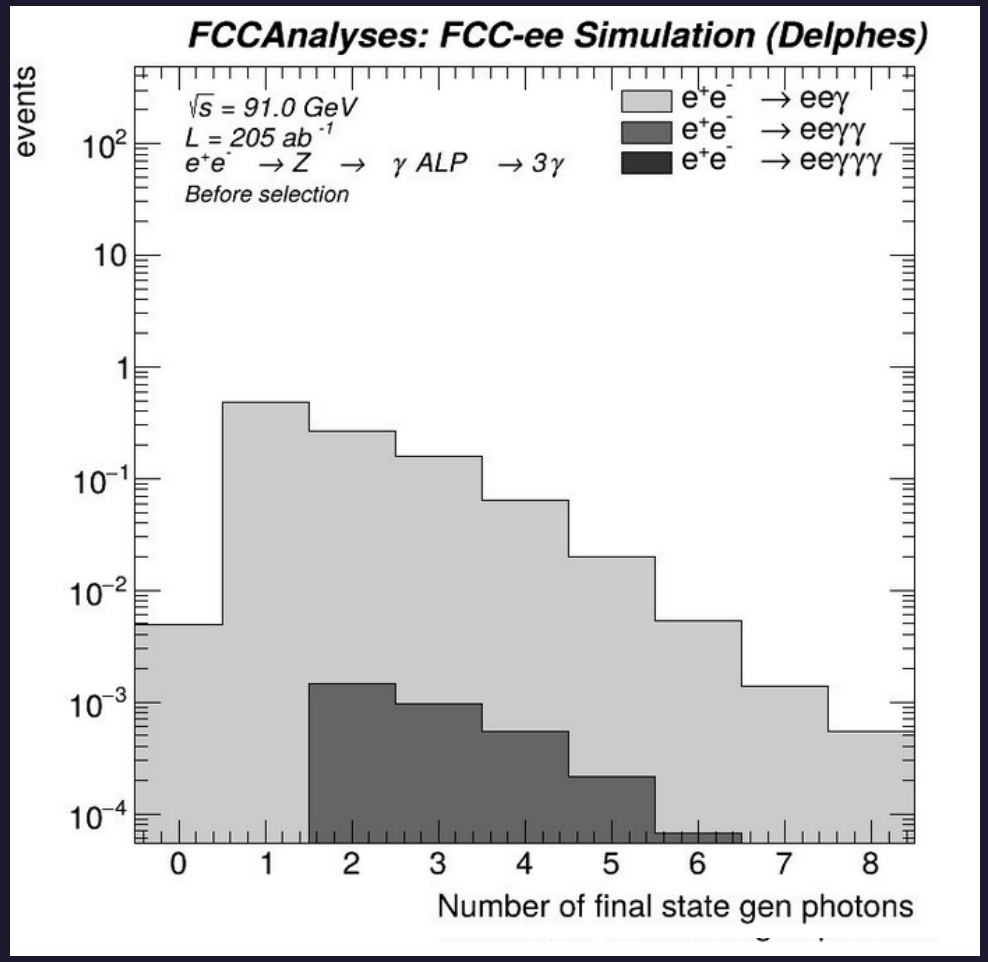
- Stacking does not add up to number of events for ee->ee background,
- Up to 2 orders of magnitude difference

HELMHOLTZ

DESY.

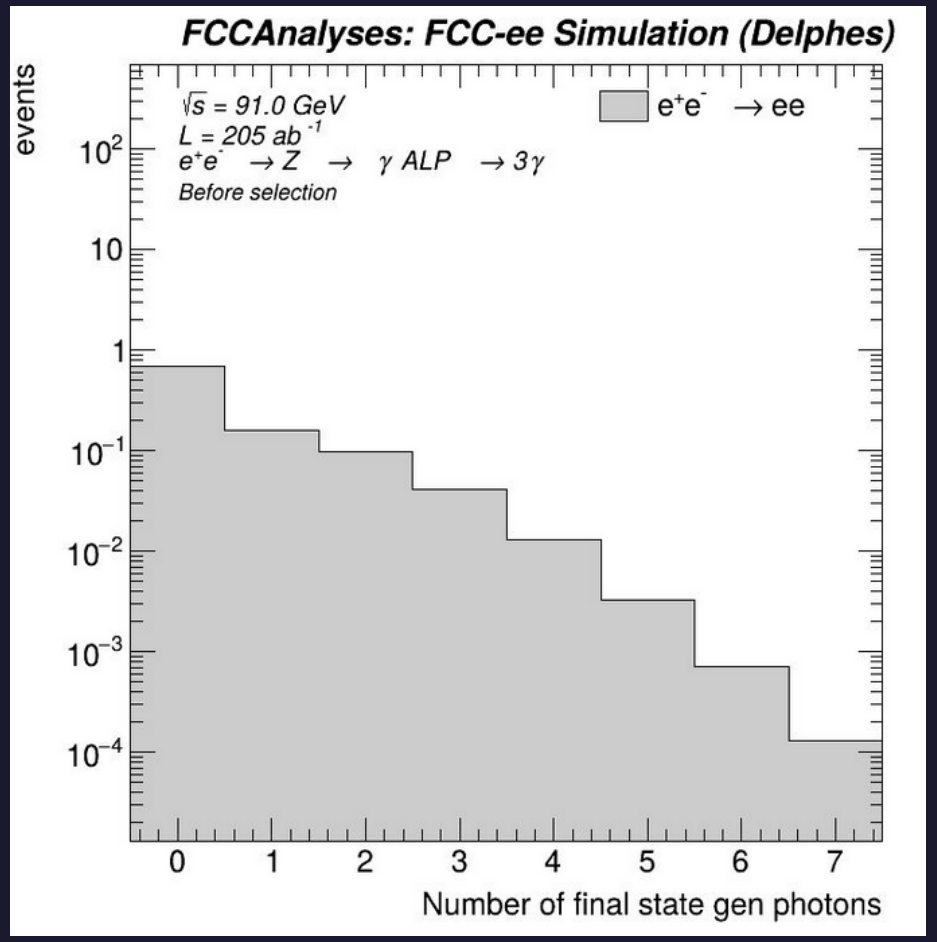
Stacking eea,eeaa,eeaaa backgrounds

Are these backgrounds already included in ee-->ee? Comparison:



(Events scaled to unit area)

ee->ee will radiate photons from Pythia



(Events scaled to unit area)

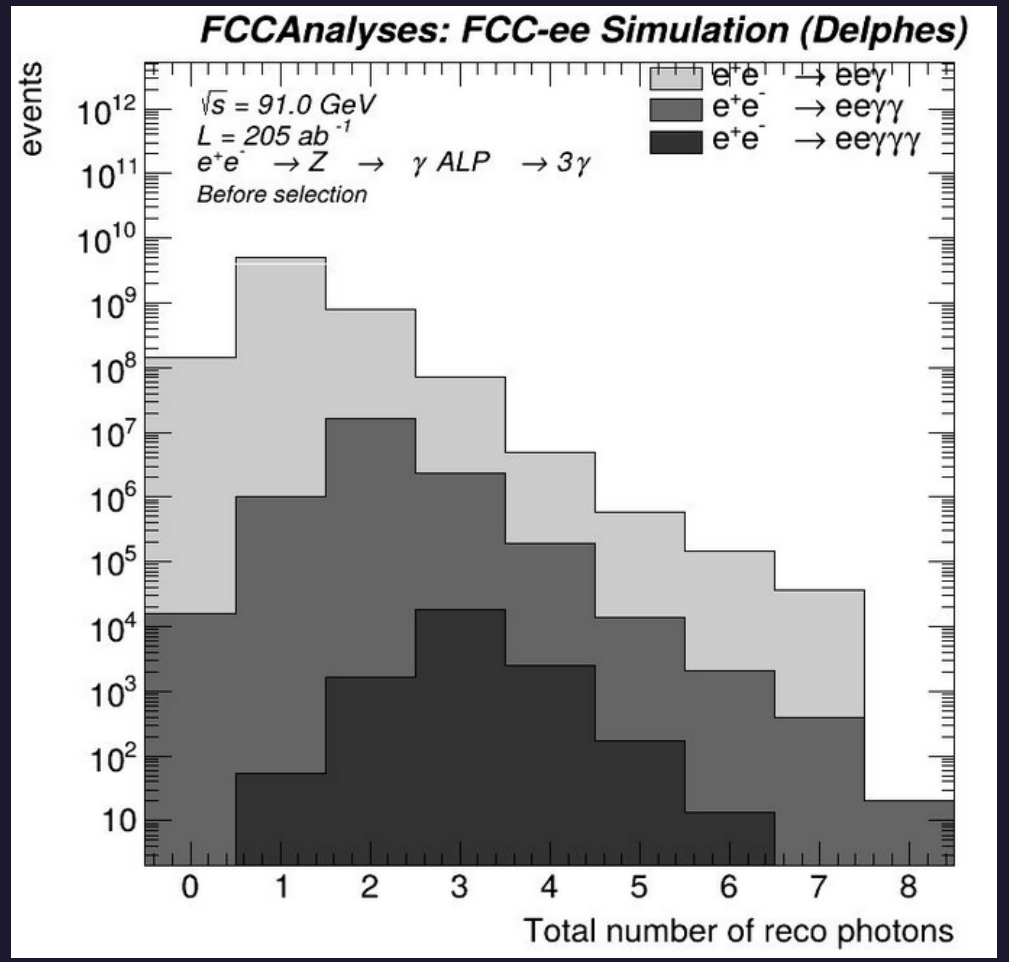
Normalized to 1 now:
e.g. n_photon=2
20% vs 10%

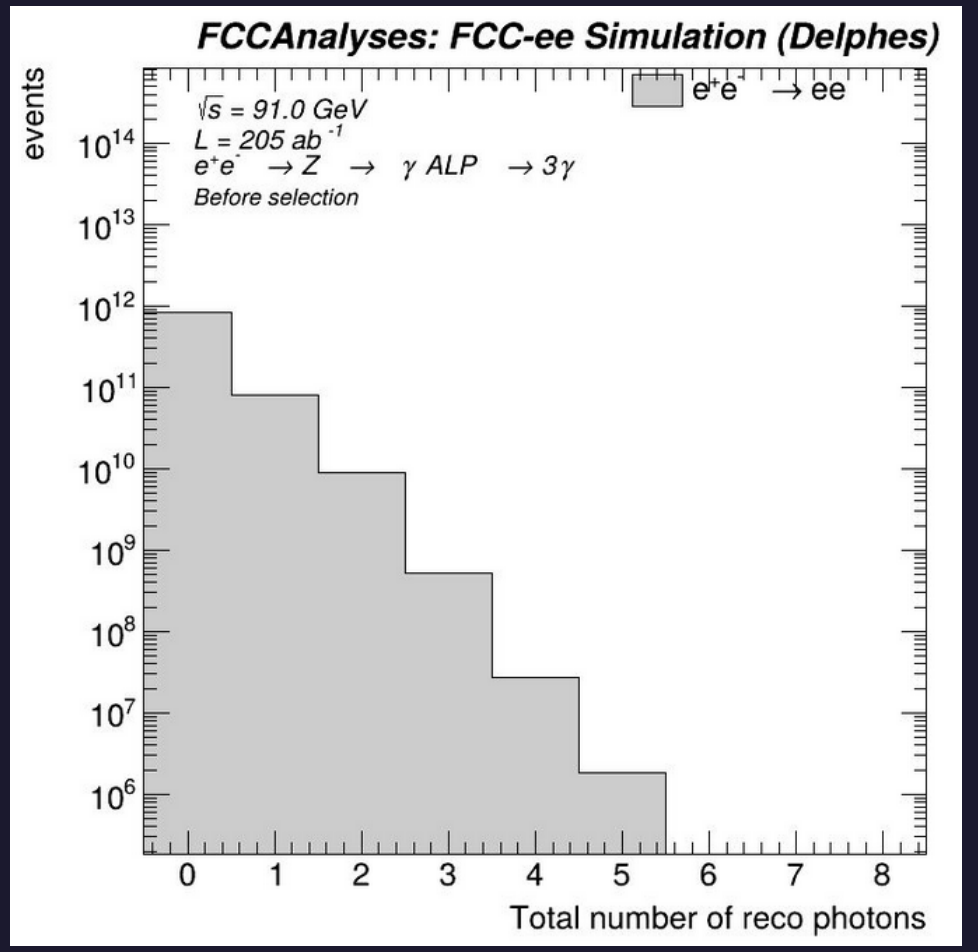
HELMHOLTZ

DESY.

Stacking eea,eeaa,eeaaa backgrounds

Are these backgrounds already included in ee-->ee? Comparison:





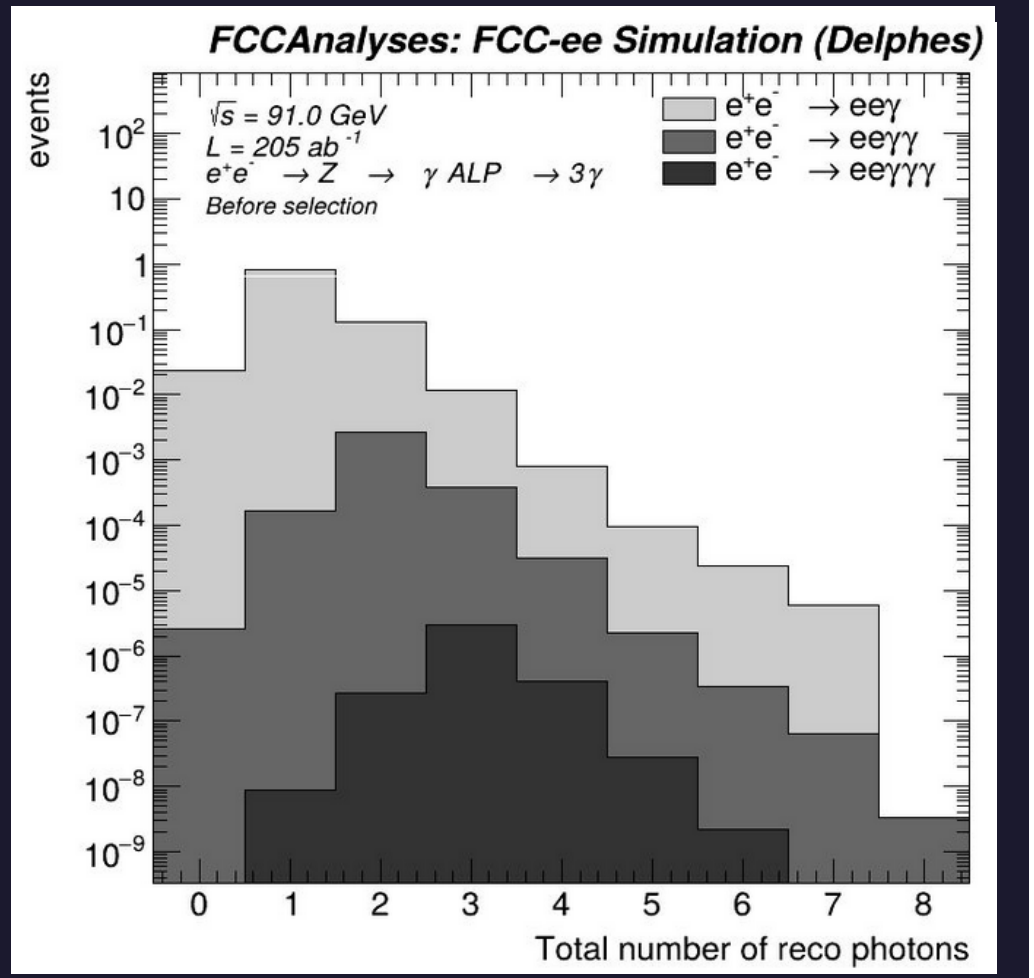
Reco photons, normalized to lumi and cross-section

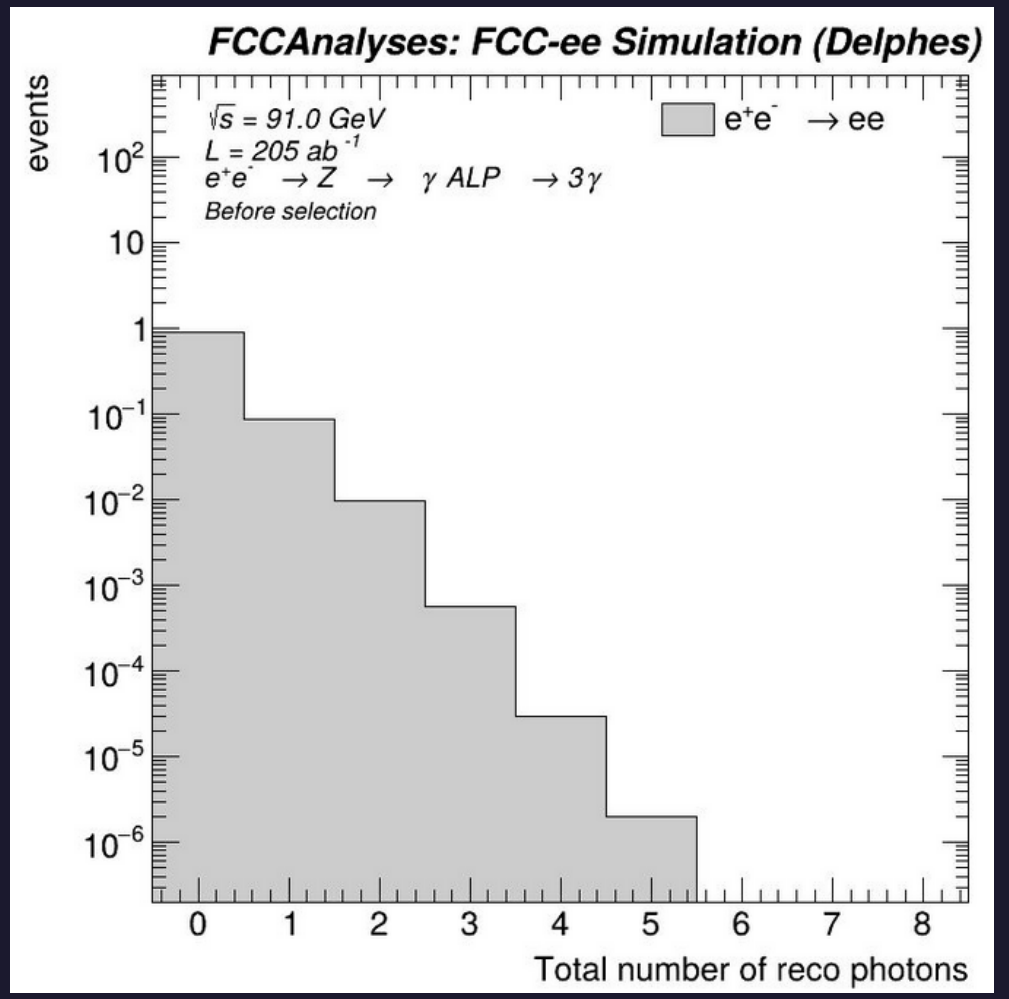
HELMHOLTZ

DESY.

Stacking eea,eeaa,eeaaa backgrounds

Are these backgrounds already included in ee-->ee? Comparison:





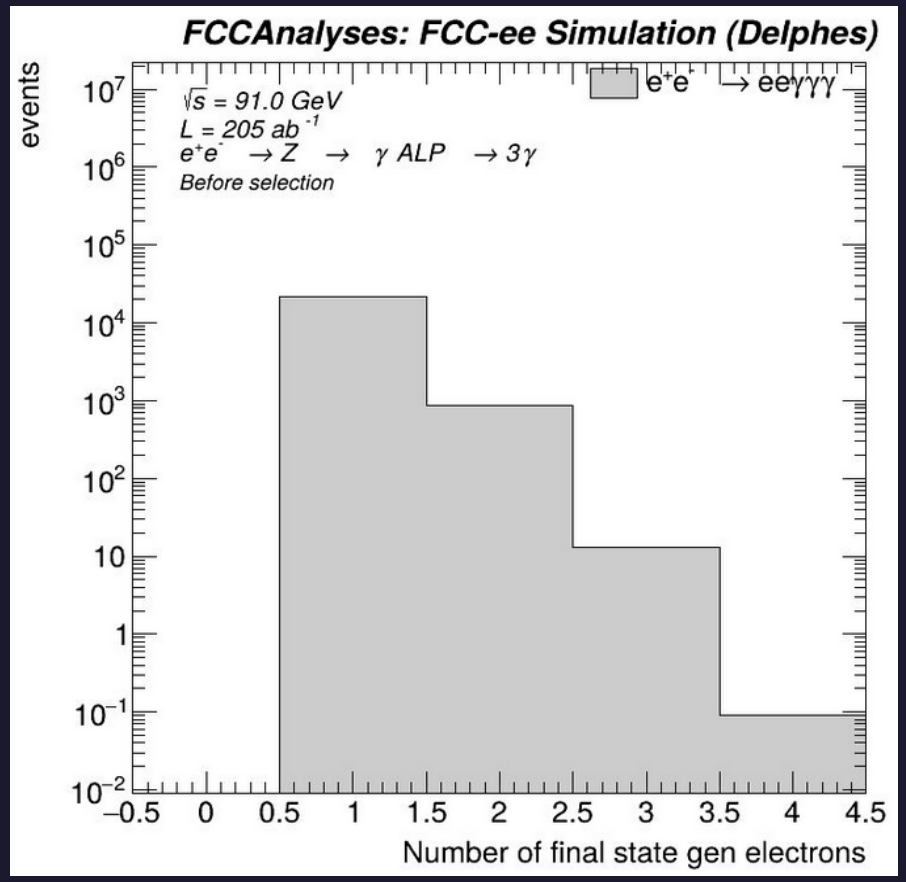
Normalized to 1

HELMHOLTZ

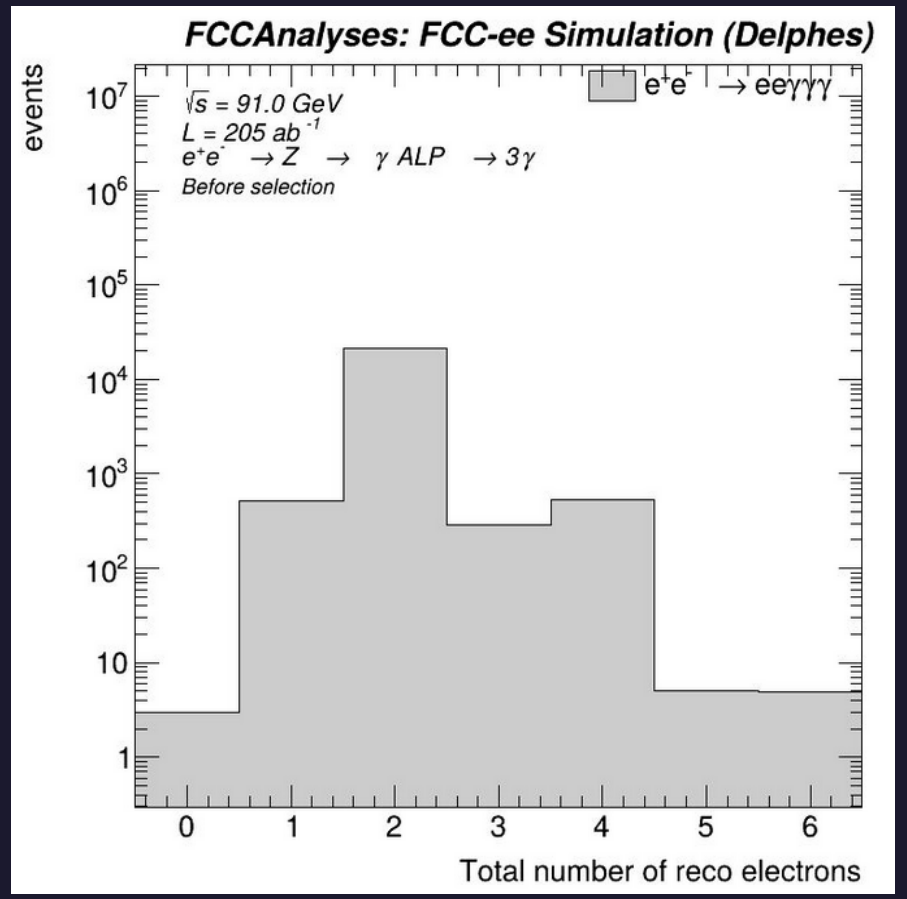
DESY.

Background electrons --> eeaaa

Gen level



Reco level



Why max for 1 electron at gen level?

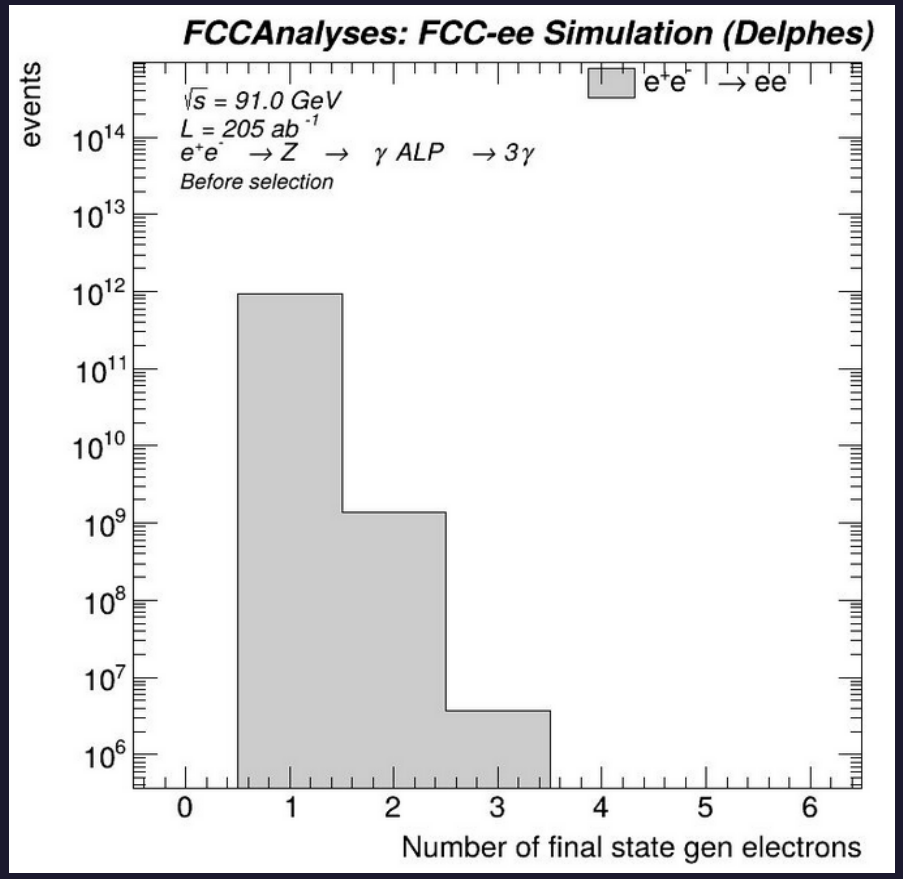
```
.Define("FSGenElectron", "MCParticle::sel_genStatus(1)(GenElectron_PID)") #gen status==1 means final state particle (FS)
```

HELMHOLTZ

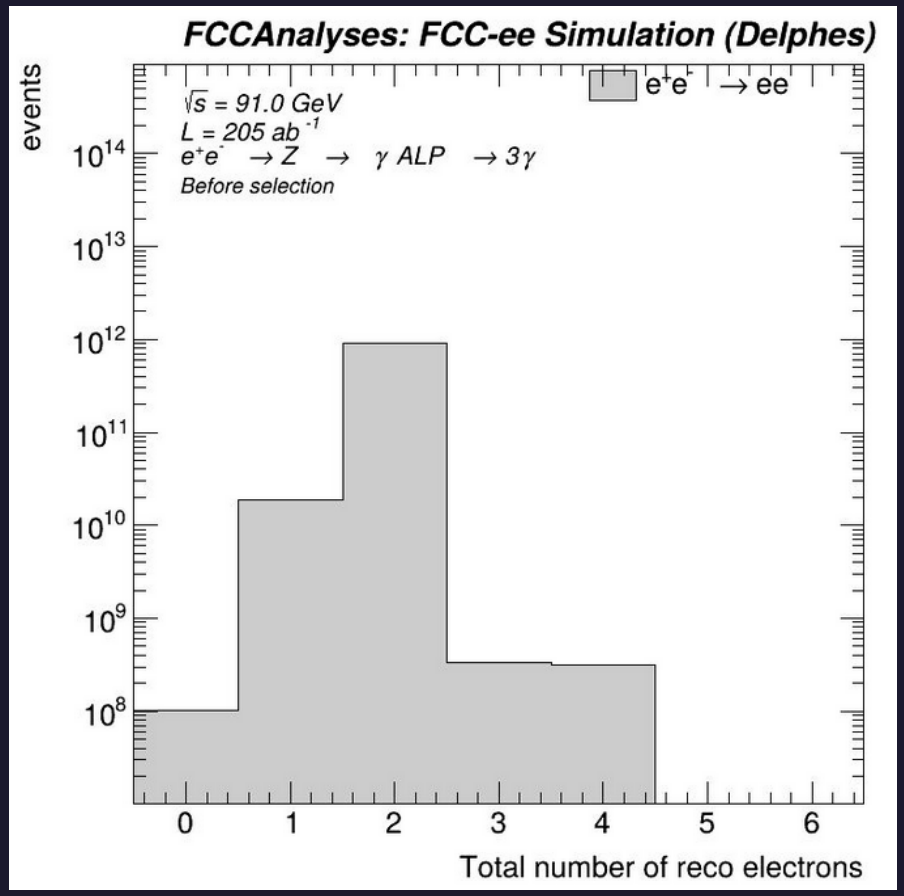
DESY.

Background electrons --> ee

Gen level



Reco level



Why max for 1 electron at gen level?

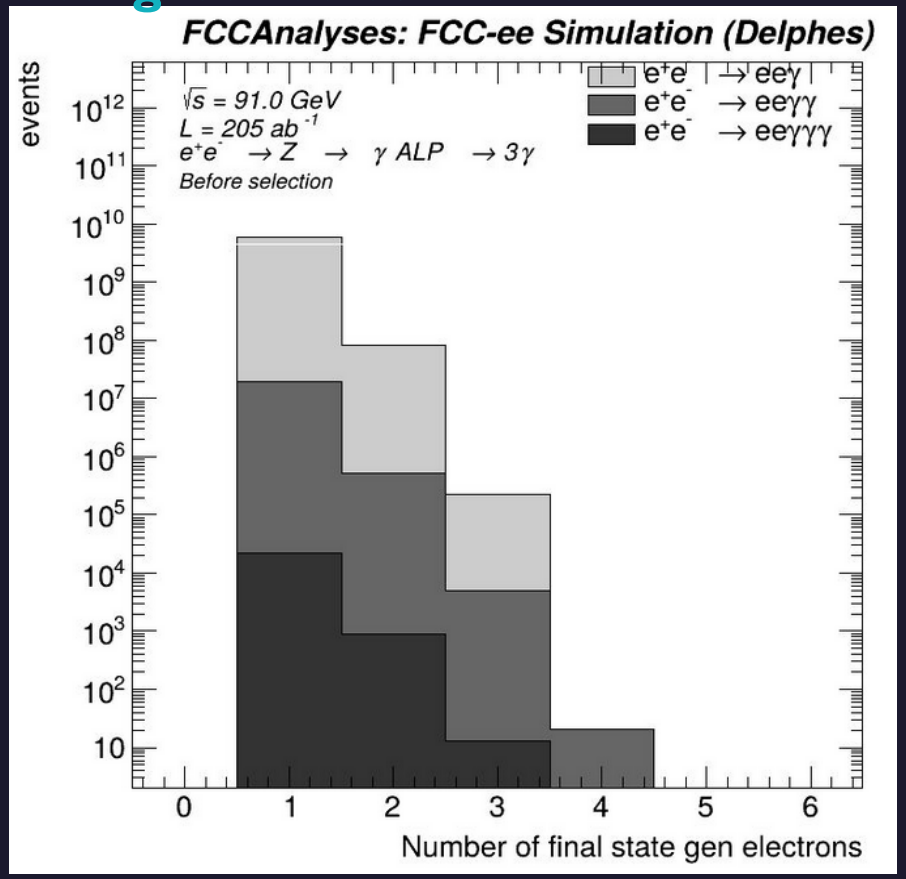
HELMHOLTZ

DESY.

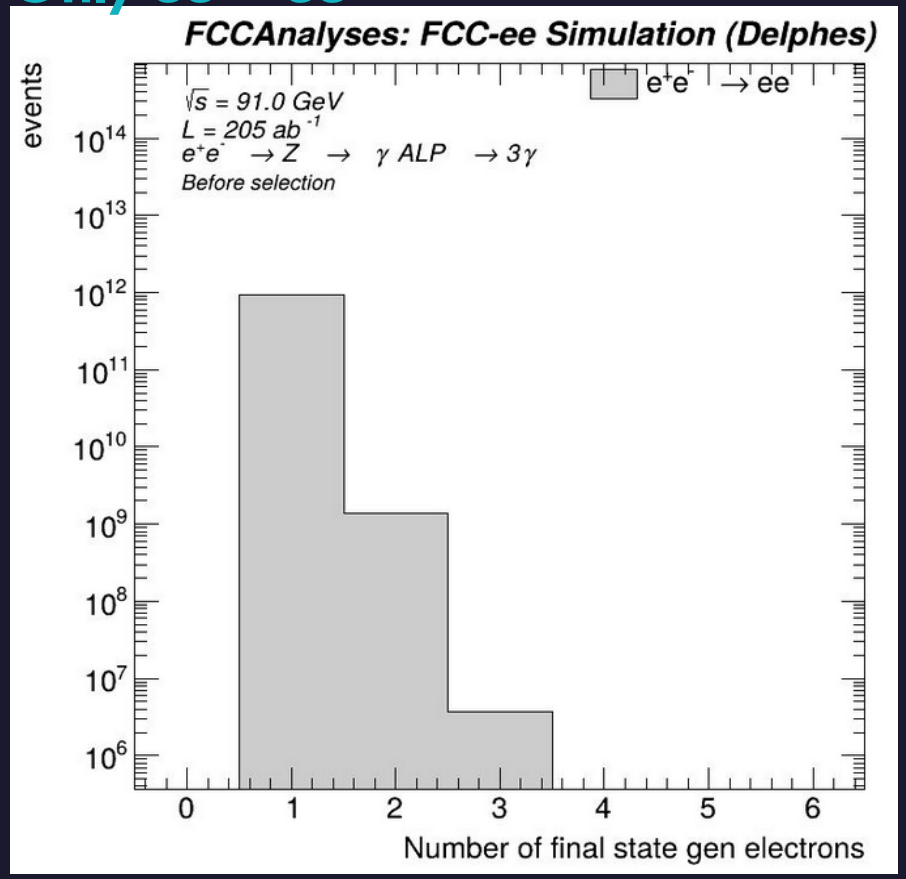
Stacking eea,eeaa,eeaaa backgrounds

Are these backgrounds already included in ee-->ee? Comparison:

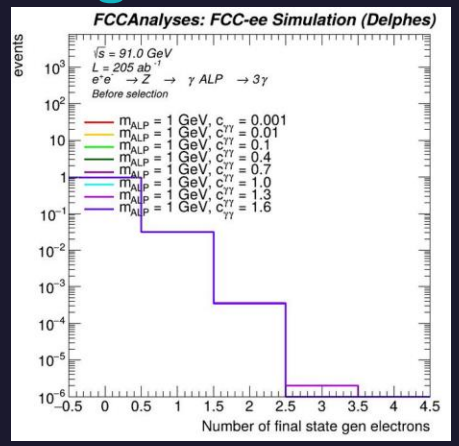
backgrounds combined



Only ee-->ee



signal event

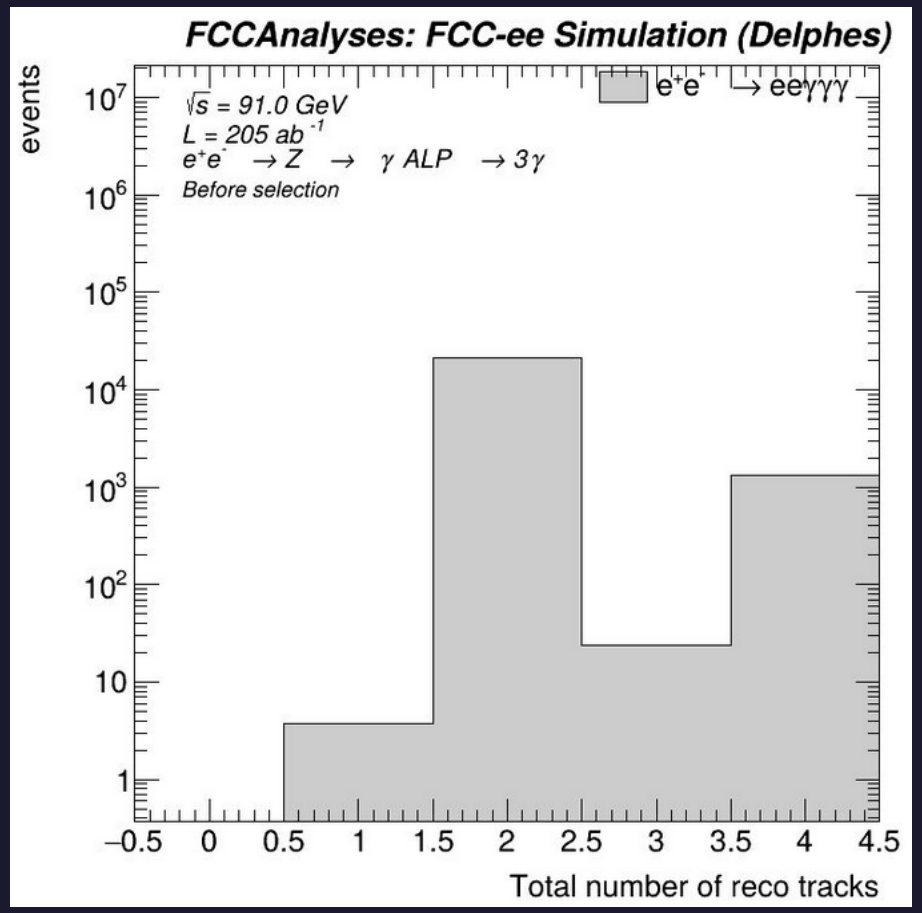


Why max for 1 electron at gen level?

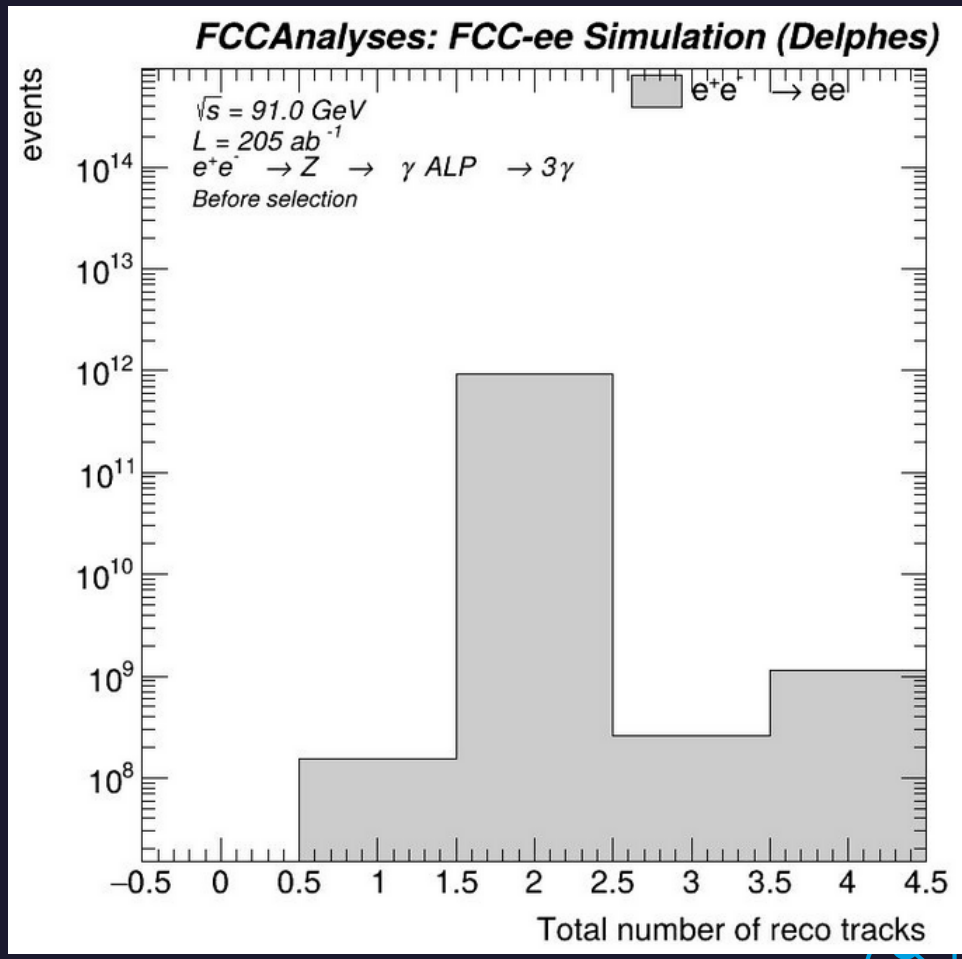
DESY.

Background --> eeaaa | Background --> ee

Reco level



Reco level



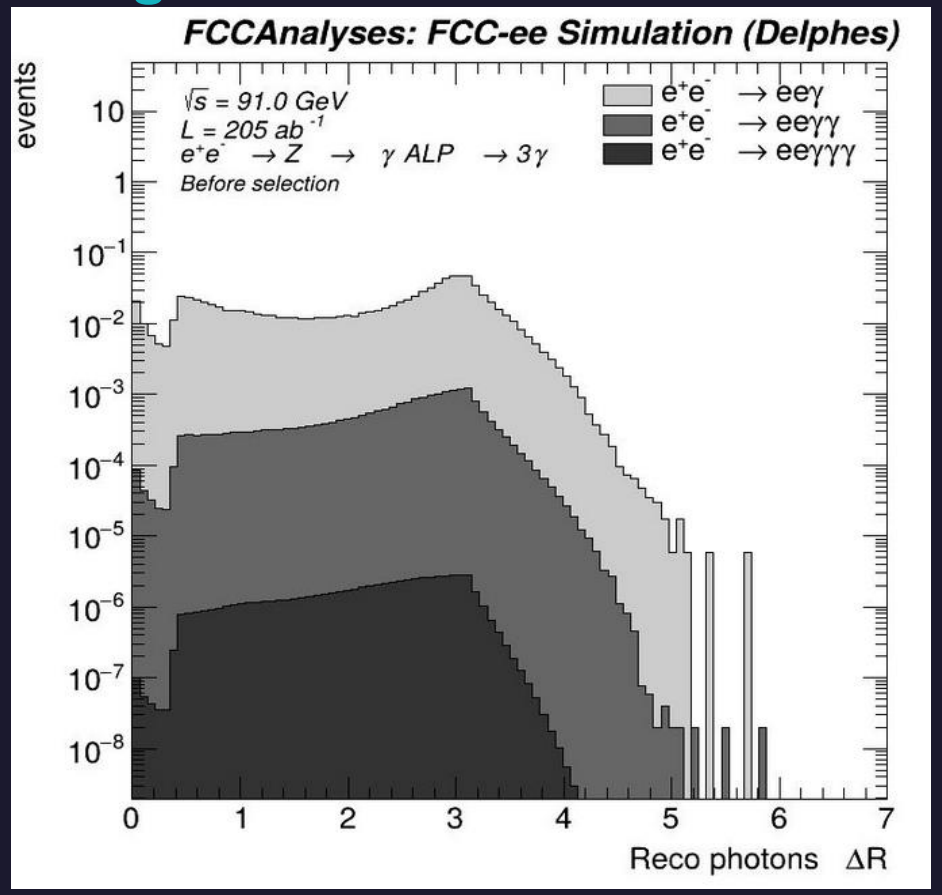
How to understand track plots?

HELMHOLTZ

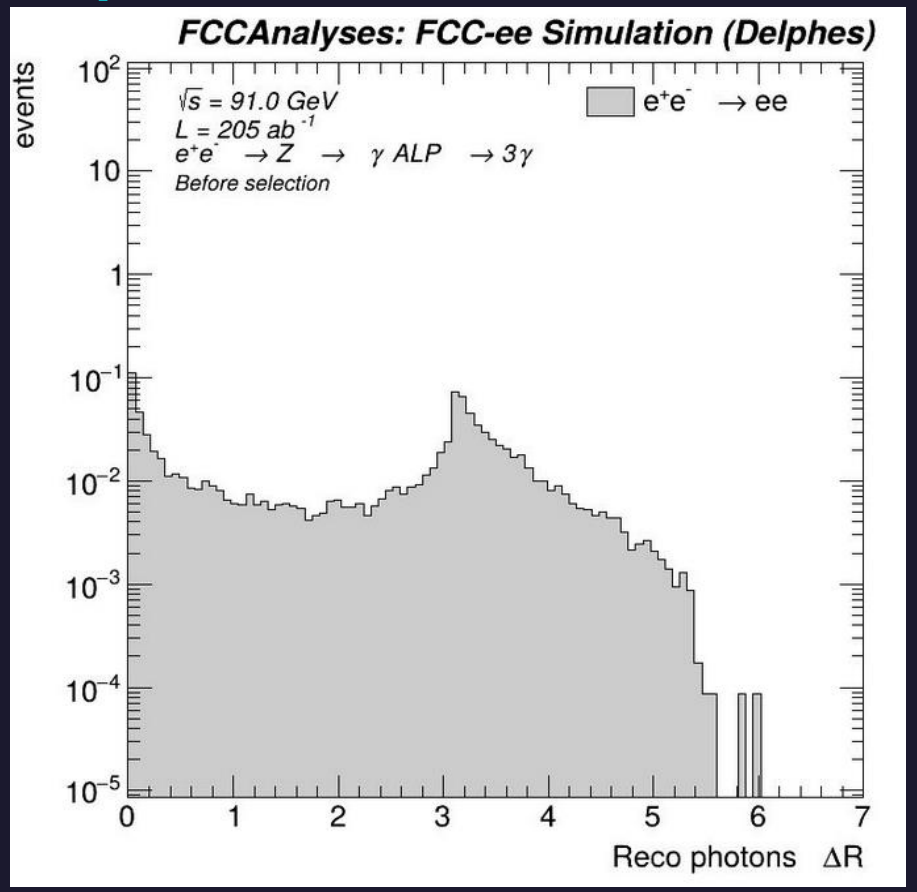
DESY.

Stacking eea,eeaa,eeaaa backgrounds

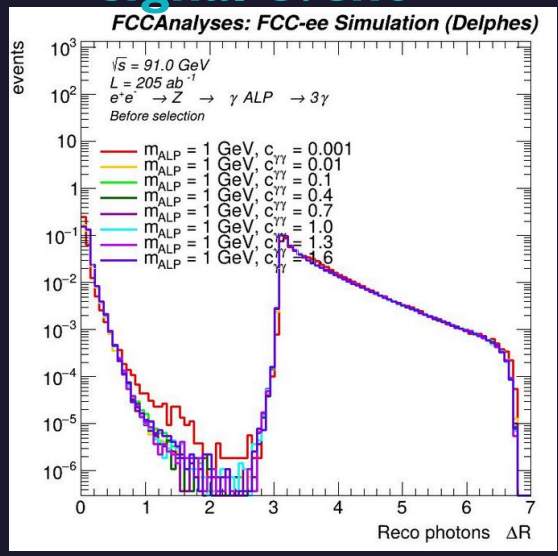
backgrounds combined



Only ee-->ee



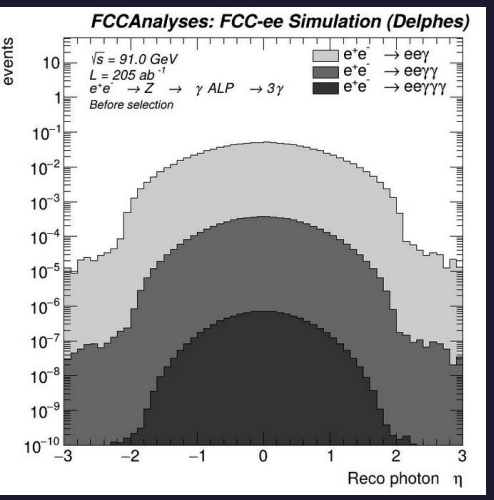
signal event

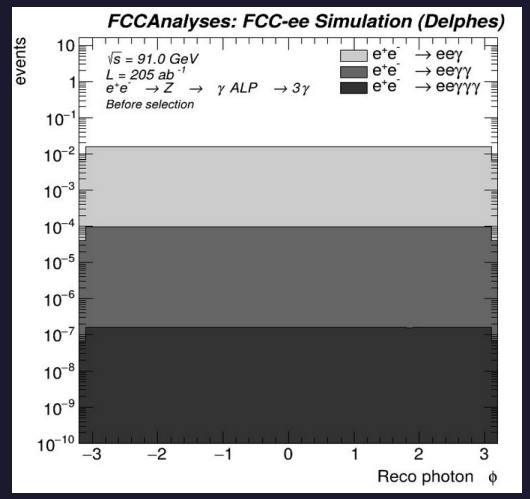


Possible difference for the properties of photons in MG vs Pythia?

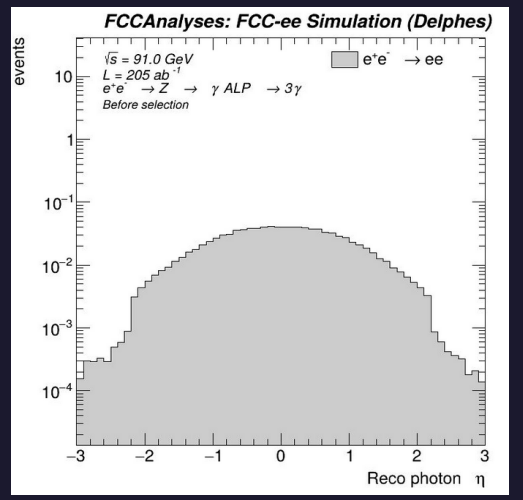
Stacking eea,eeaa,eeaaa backgrounds

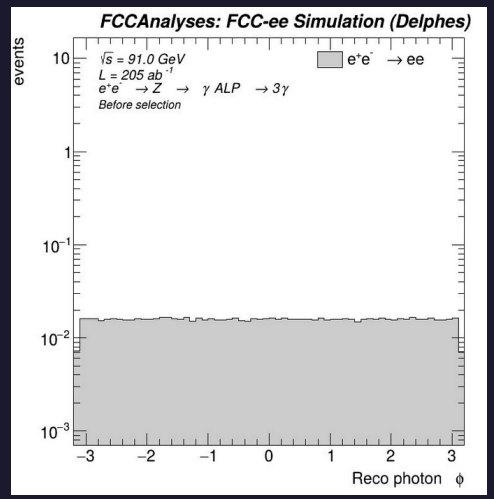
Possible difference for the properties of photons the in MG vs Pythia?

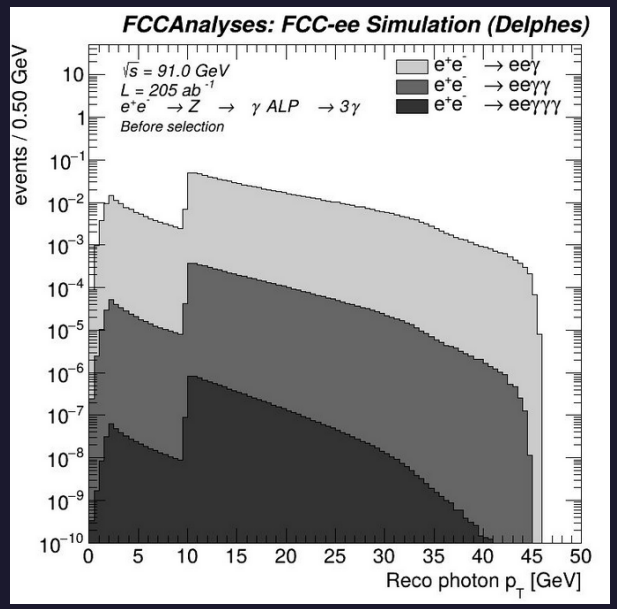




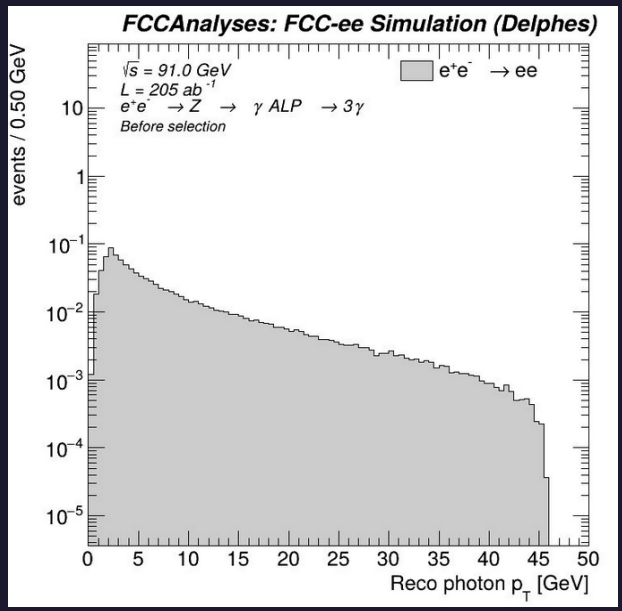
No difference of the hist shapes between both plots for phi, eta, theta







Momentum different,
Reason for dip?
Phsical reason for the dip?



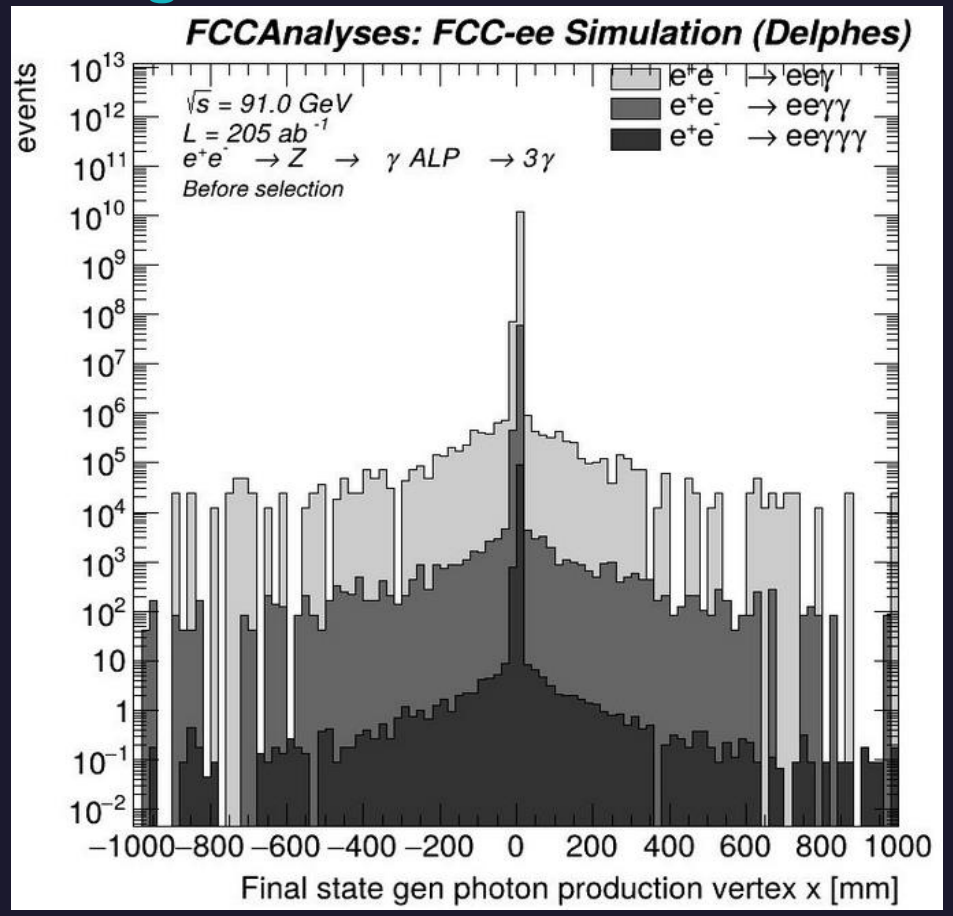
HELMHOLTZ

DESY.

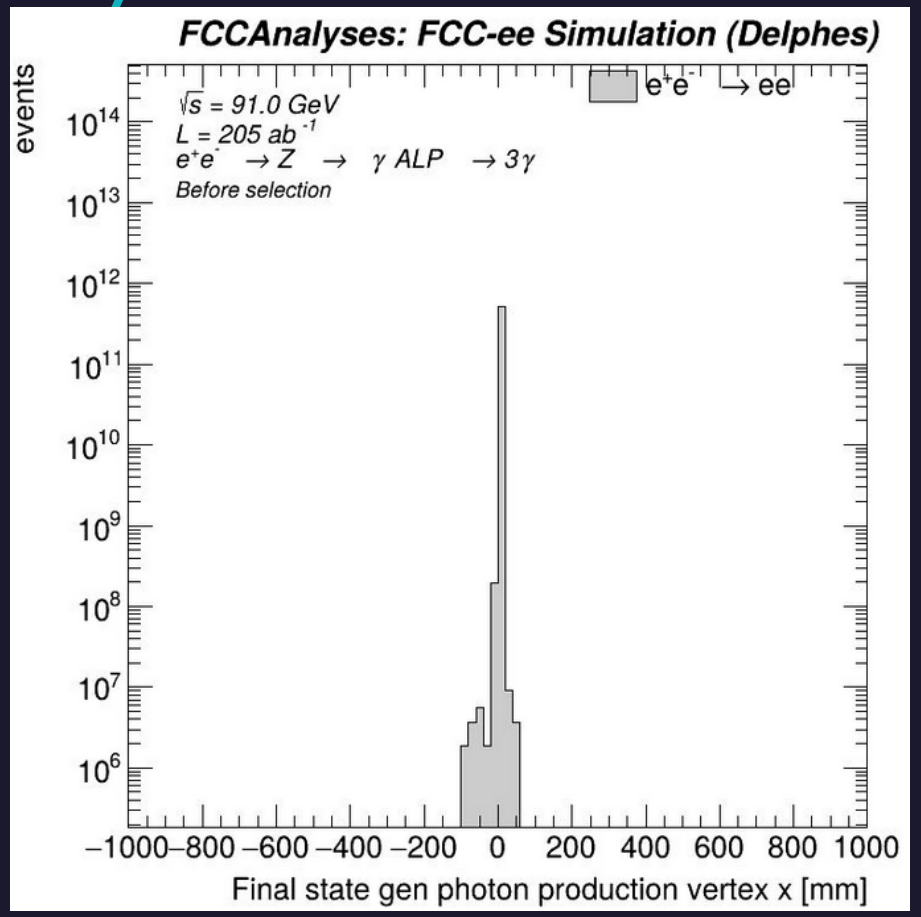
Stacking eea,eeaa,eeaaa backgrounds

Are these backgrounds already included in ee-->ee? Comparison:

backgrounds combined



Only ee-->ee



HELMHOLTZ

DESY.

Sample creation problem

Edit Selection View Go Run Terminal Help

MCParticle.cc | ReconstructedParticle.cc | runPythiaDelphesCondor.sh | mg.sh | ALP_pythia.cmnd | particles.py | analysis_stage1_new.py | condor_job.ALP_Z_aa_2p0GeV_cYY1p0.373111.0.error | analysis_final.py | condor_job.ALP_Z_aa_3p0GeV_cYY1p0.366784.0.error | analysis_plots.py | condor_job.ALP_Z_aa_5p0GeV_cYY1p0.41066.0.error | condor_job.ALP_

```
----> INFO: Loading analyzers from libFCCAnalyses...
----> INFO: Loading analysis script:
          /afs/cern.ch/user/e/ebakhish/FCCAnalyses/examples/FCCee/bsm/LLPs/ALPs/analysis_stage1_new.py
----> INFO: Multithreading enabled. Running over 4 threads
----> INFO: Running over files provided in command line argument...
----> INFO: Creating dataframe object from files:
            - root://eosuser.cern.ch//eos/user/e/ebakhish/MG/Pythia_Output//ALP_Z_aa_2p0GeV_cYY1p0/ALP_Z_aa_2p0GeV_cYY1p0_0.root

----> INFO: Number of local events: 1,000,000
----> INFO: Output file path:
          /eos/user/e/ebakhish/stage1_output/masses_different/ALP_Z_aa_2p0GeV_cYY1p0/chunk_0.root
Error in <TStreamerInfo::Build>: The class "FCCAnalyses::VertexingUtils::FCCAnalysesVertex" is interpreted and for its data member "updated_track_parameters" we do not have a dictionary for the collection "ROOT::VecOps::RVec<TVectorT<double> >". Because of this, we will not be able to read or write this data member.
RDataFrame::Run: event loop was interrupted
RDataFrame::Run: event loop was interrupted
RDataFrame::Run: event loop was interrupted
Traceback (most recent call last):
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/bin/fccanalysis", line 105, in <module>
    main()
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/bin/fccanalysis", line 101, in main
    run(parser)
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/install/python/run_analysis.py", line 1026, in run
    run_stages(args, rdf_module, anapath)
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/install/python/run_analysis.py", line 620, in run_stages
    run_local(rdf_module, args.files_list, args)
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/install/python/run_analysis.py", line 527, in run_local
    inn, outn = run_rdf(rdf_module, file_list, outfile_path, args)
                ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
  File "/afs/cern.ch/user/e/ebakhish/FCCAnalyses/install/python/run_analysis.py", line 346, in run_rdf
    dframe3.Snapshot("events", out_file, branch_list)
TypeError: Template method resolution failed:
  ROOT::RDF::RResultPtr<ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void> > ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void>::Snapshot(string_view treename, string_view filename, const ROOT::RDF::ColumnNames_t& columnList, const ROOT::RDF::RSnapshotOptions& options = RSnapshotOptions()) =>
    out_of_range: RVecN::at: size is 0 but out-of-bounds index 0 was requested.
  ROOT::RDF::RResultPtr<ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void> > ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void>::Snapshot(string_view treename, string_view filename, const ROOT::RDF::ColumnNames_t& columnList, const ROOT::RDF::RSnapshotOptions& options = RSnapshotOptions()) =>
    out_of_range: RVecN::at: size is 0 but out-of-bounds index 0 was requested.
  Failed to instantiate "Snapshot(std::string,std::string,std::vector<string>*)"
  ROOT::RDF::RResultPtr<ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void> > ROOT::RDF::RInterface<ROOT::Detail::RDF::RLoopManager,void>::Snapshot(string_view treename, string_view filename, const ROOT::RDF::ColumnNames_t& columnList, const ROOT::RDF::RSnapshotOptions& options = RSnapshotOptions()) =>
    out_of_range: RVecN::at: size is 0 but out-of-bounds index 0 was requested.
```

HELMHOLTZ

DESY.