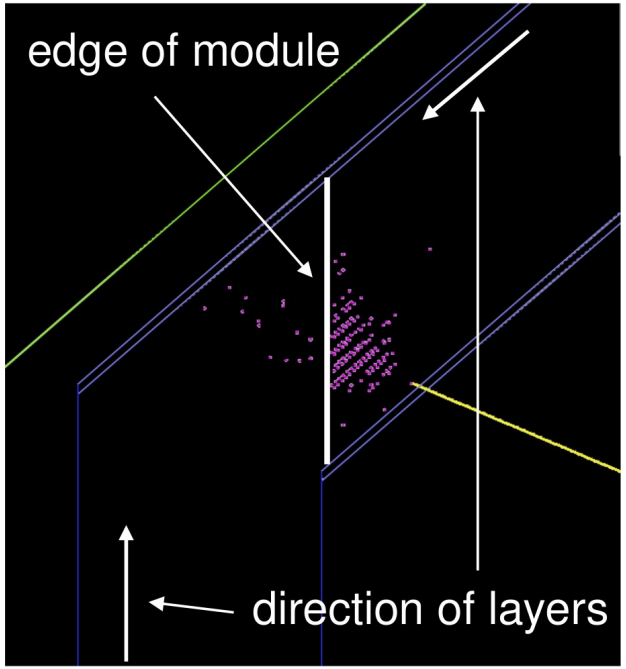
A(nother) First Look: Geant4 vs BIBAE photons from Pi0s comparison

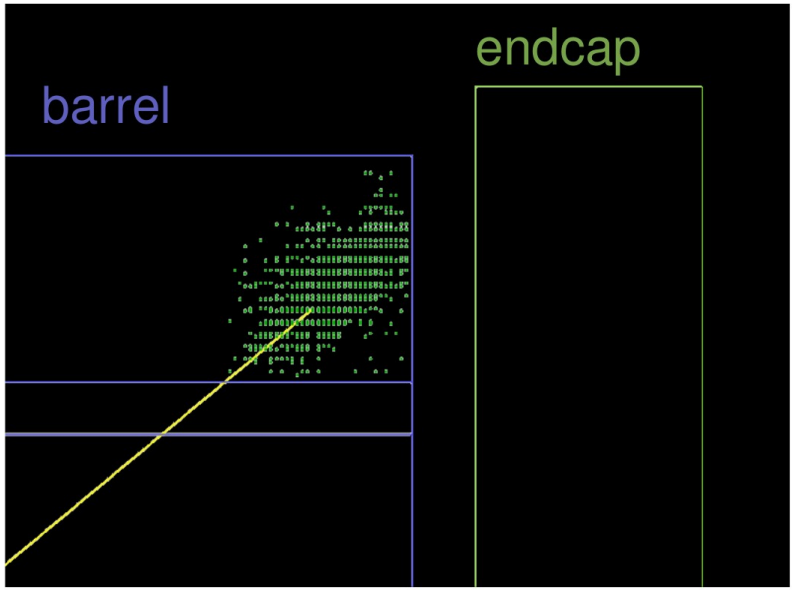
16.11.2023

Slides from Monday

Reminder on integration

- Fully conditioned BIBAE (2x angles and energy)
- Simulate down to 10 GeV photons, electrons and positrons
- Additionally exclude regions of detector where BIBAE can’t be applied
  - Corners of octagonal barrel
  - Transition between barrel and endcap
- Model now fully interfaced through DD4HEP and Geant4- can run full reconstruction
- Some results fresh off the press...





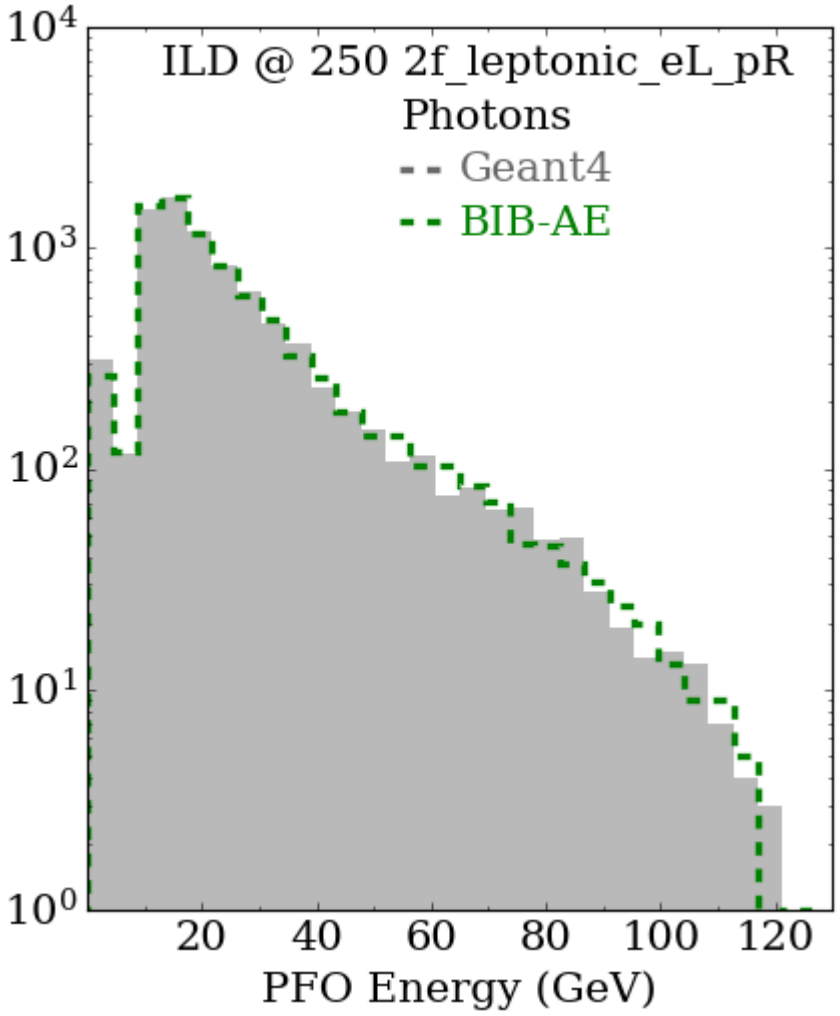
Pi0 photons: simulation to reconstruction

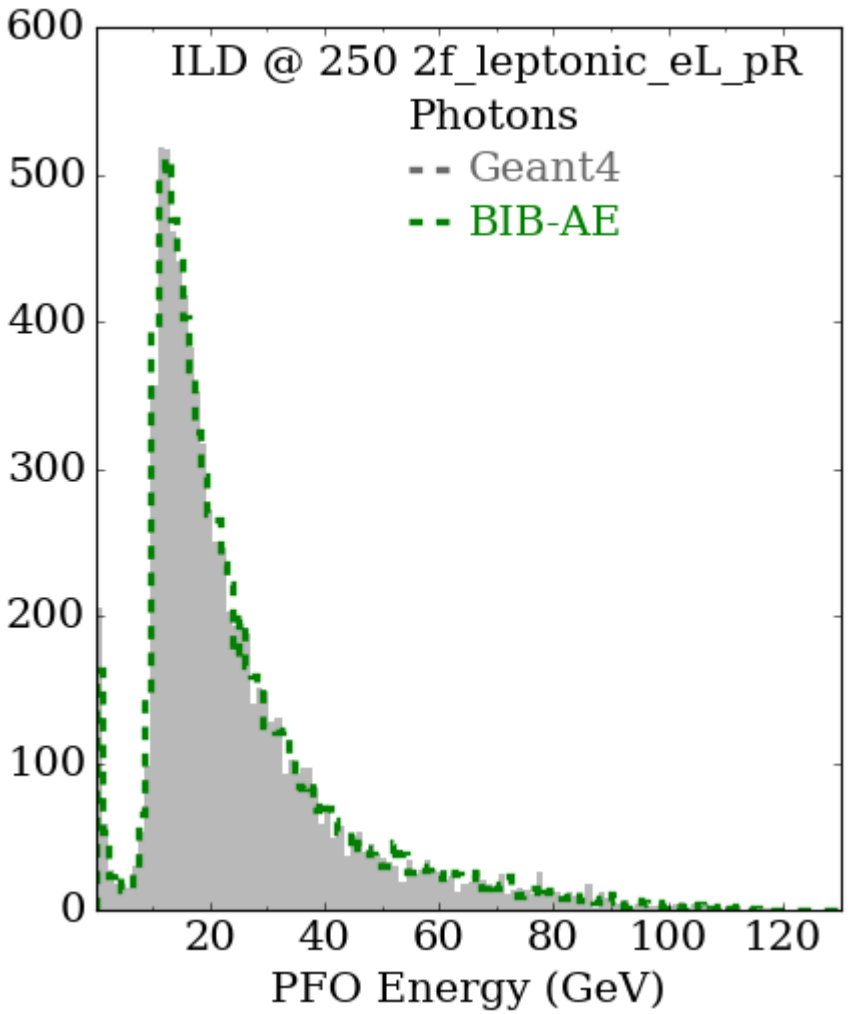
- Simulated 9,000 ee → ττ with the requirement that two photons produced by pi0 were above 10 GeV (trigger fast vs full sim)
- Same generator files used in both cases
- All photons and e+/- with energy > 10 GeV (+ passing geometrical constraints from trigger) were simulated with BIB-AE in BIB-AE sample
- Apply full standard reconstruction to all samples
- First, focused on photons from pi0s:
  - Reco-MCTruth link to get all pfos linked to mc photon
  - Require that parent of the photon is a pi0 and that the pi0 was produced by tau (through intermediate decay)
  - Also have restriction of mc photon energy > 10GeV, with geometry constraints on mc photon (see next slide)

Pi0 photons: simulation to reconstruction

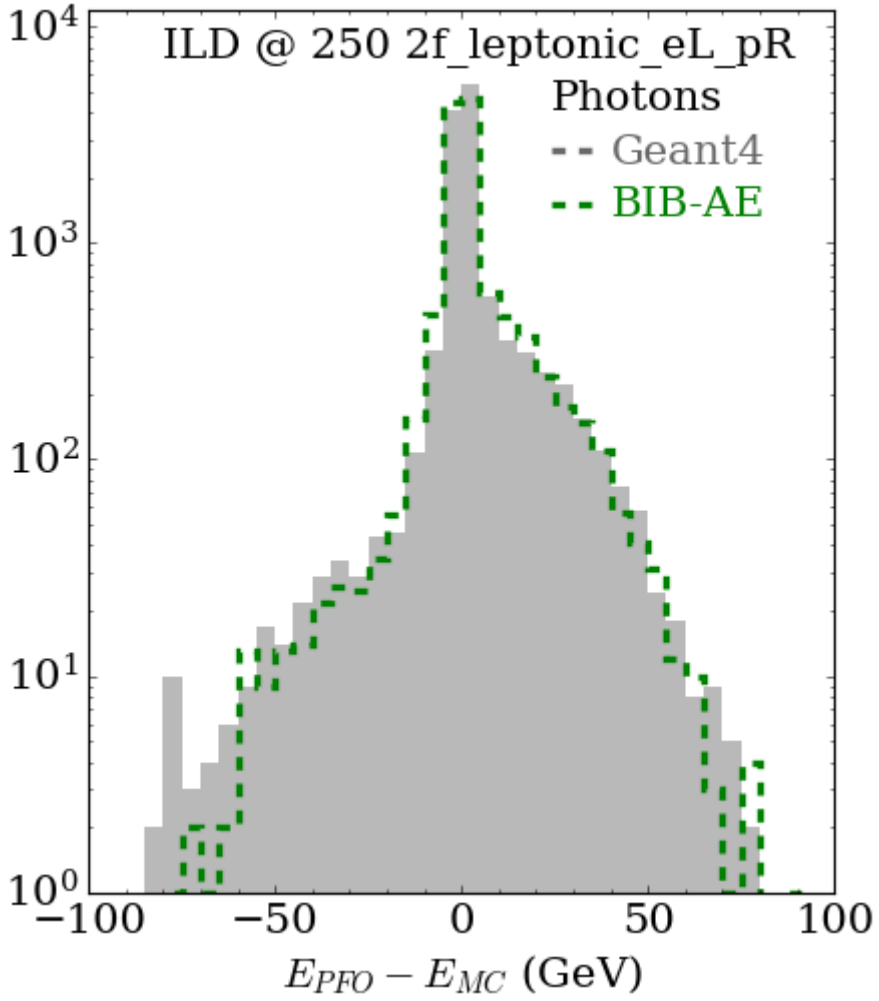
- Have a total of 12684 G4 PFOs linked to MC photon
  - 12425 are reconstructed as a photon (the rest as neutrons)
- Have a total of 12459 BIBAE PFOs linked to MC photon
  - 12286 are reconstructed as a photon (the rest as neutrons)
- Will now show plots for PFOs reconstructed as a photon that are linked to an MC photon

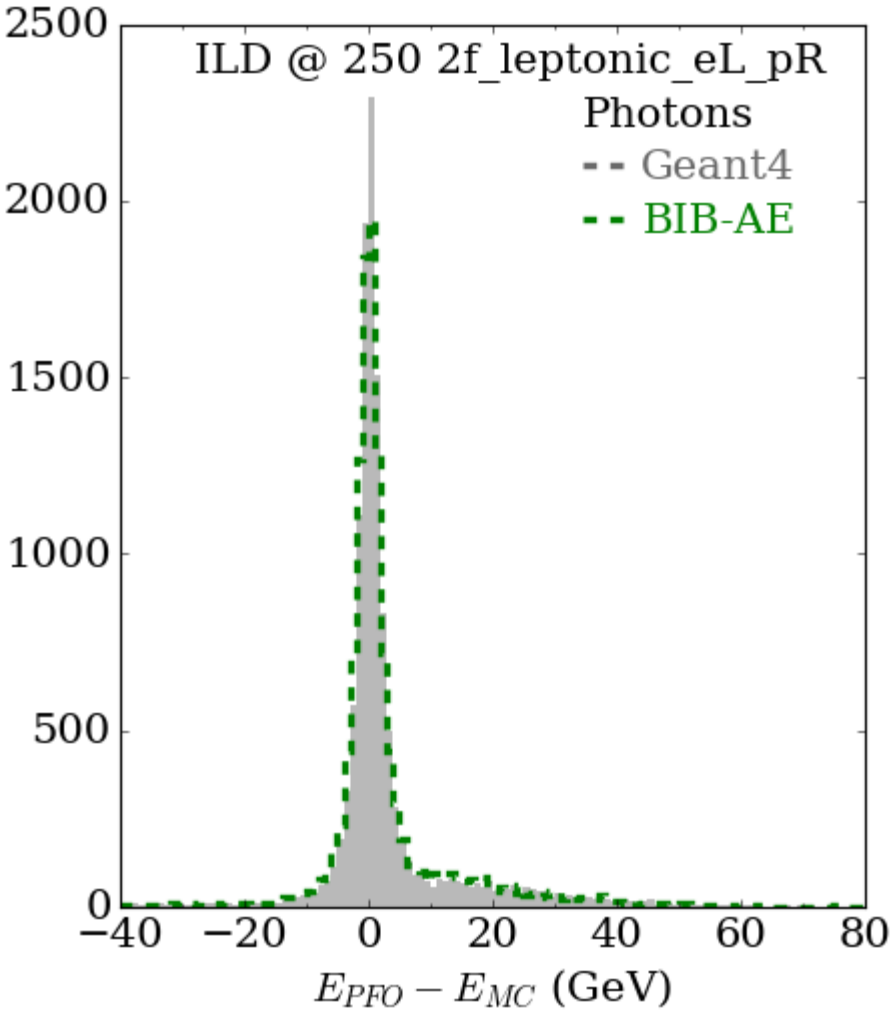
Pi0 photons: Energy vs num. PFOs



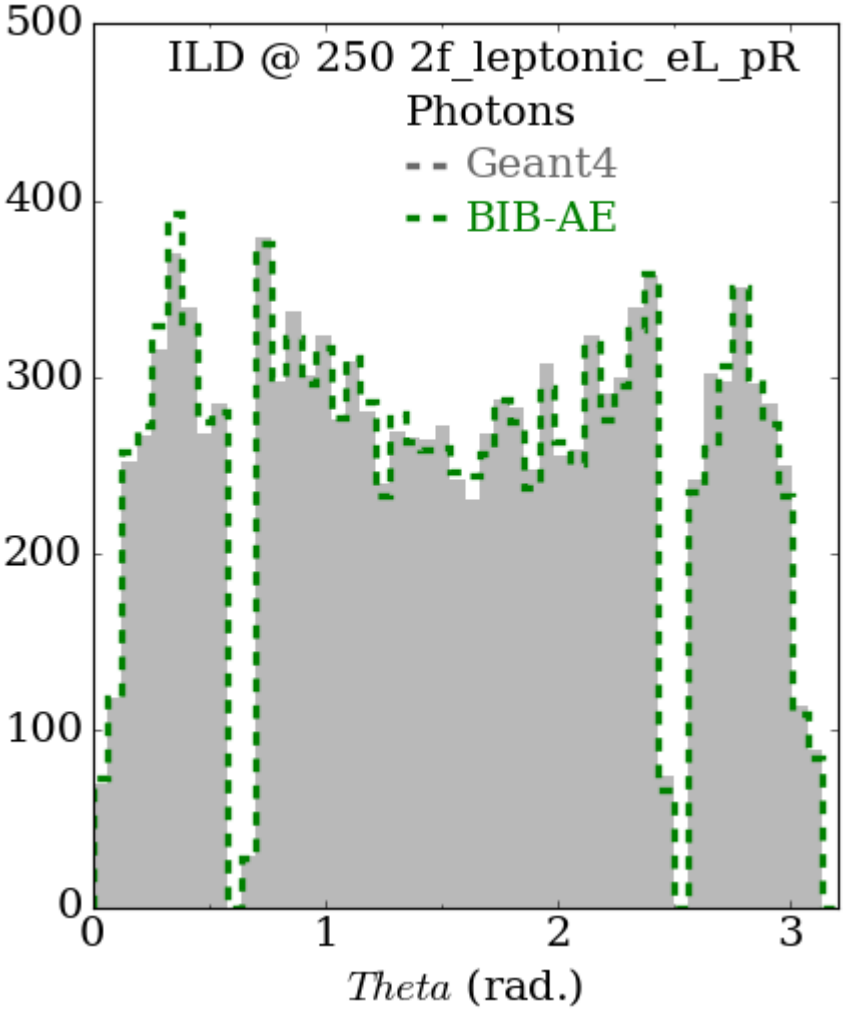


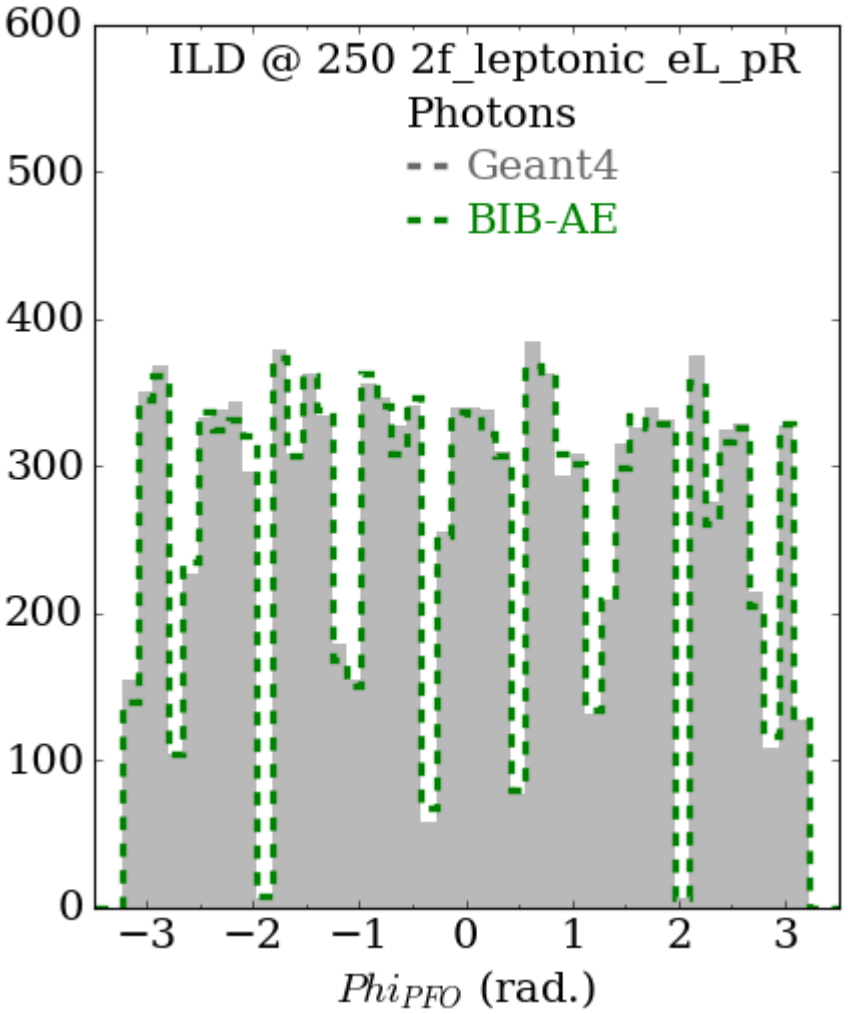
Pi0 photons: PFO Energy – MC energy vs num. PFOs



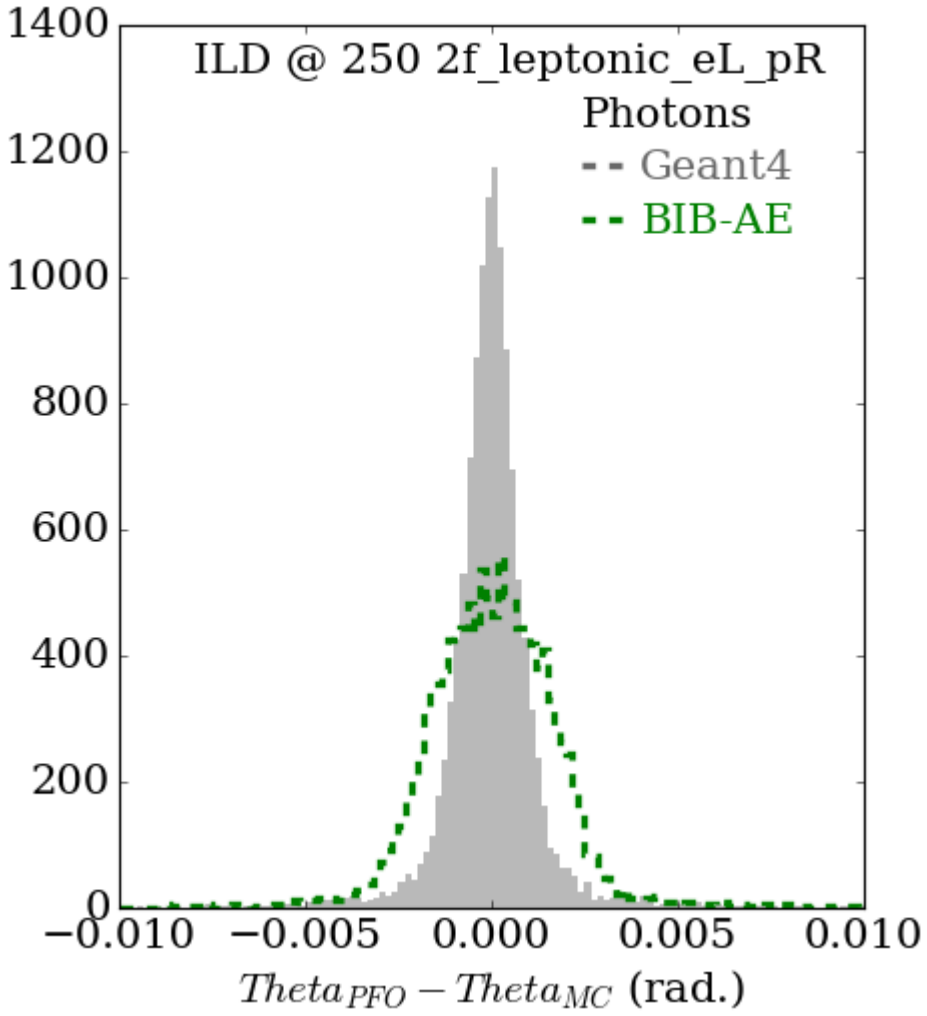


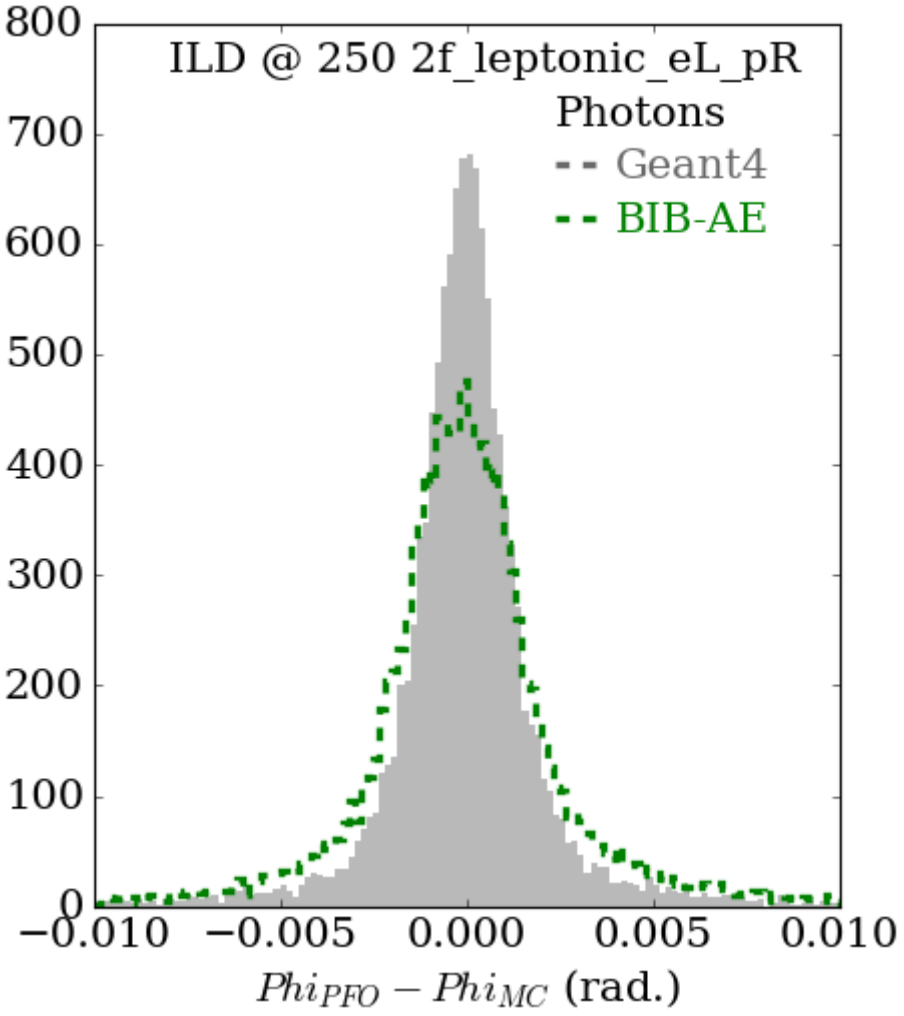
Pi0 photons: Theta and Phi vs num. PFOs





Pi0 photons: PFO Theta/Phi – MC Theta/Phi vs num. PFOs



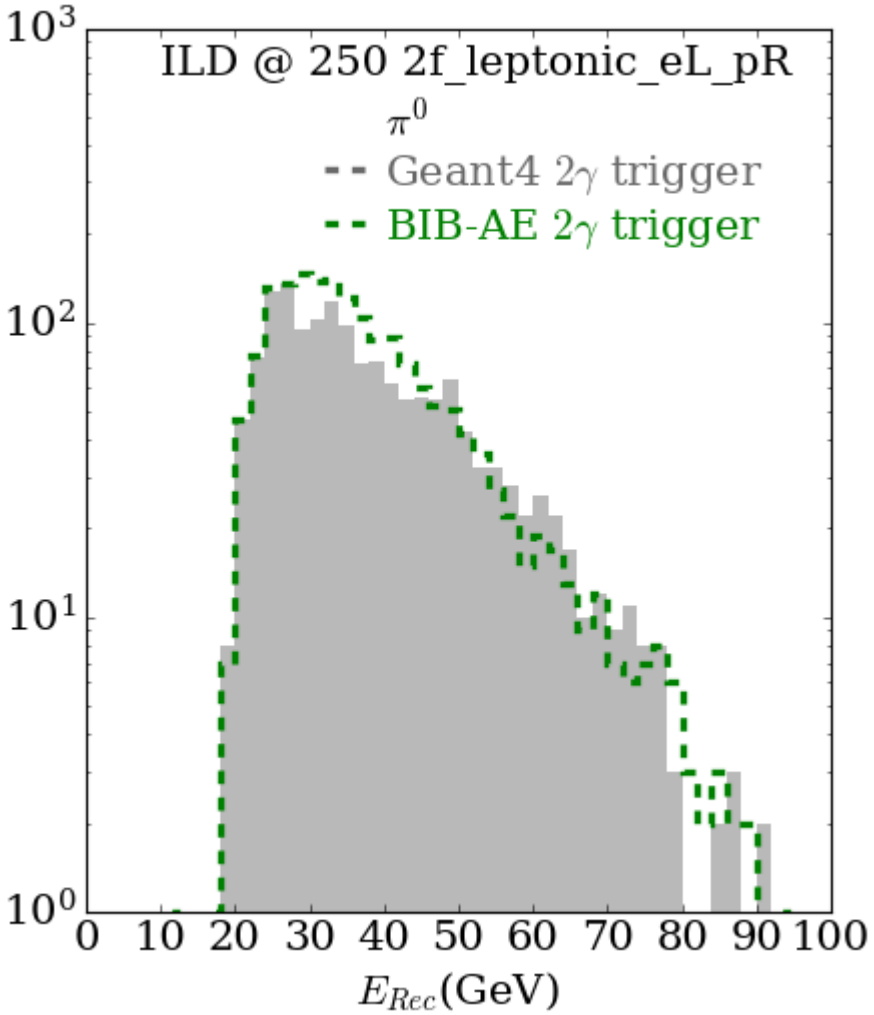


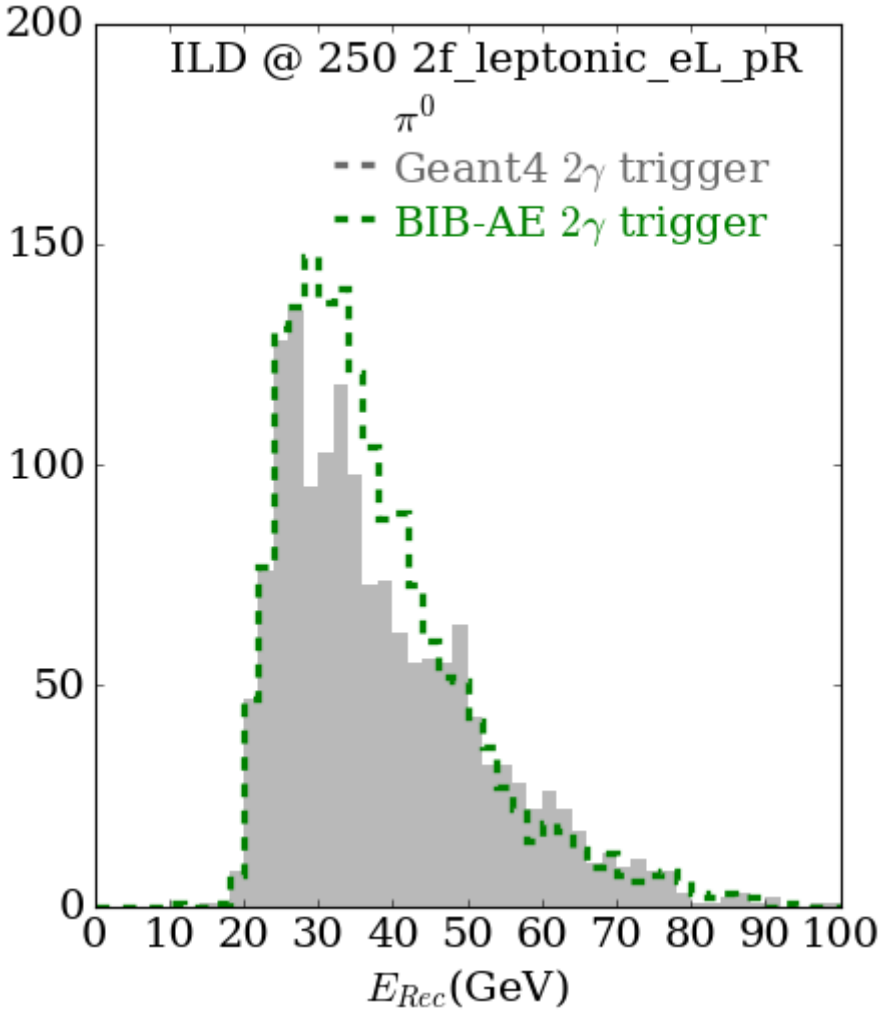
Now Pi0s...

- Loop over Pi0 candidates – check they are linked to pi0 from a tau and both MC photons have E >10 GeV
- Also apply geometry cuts

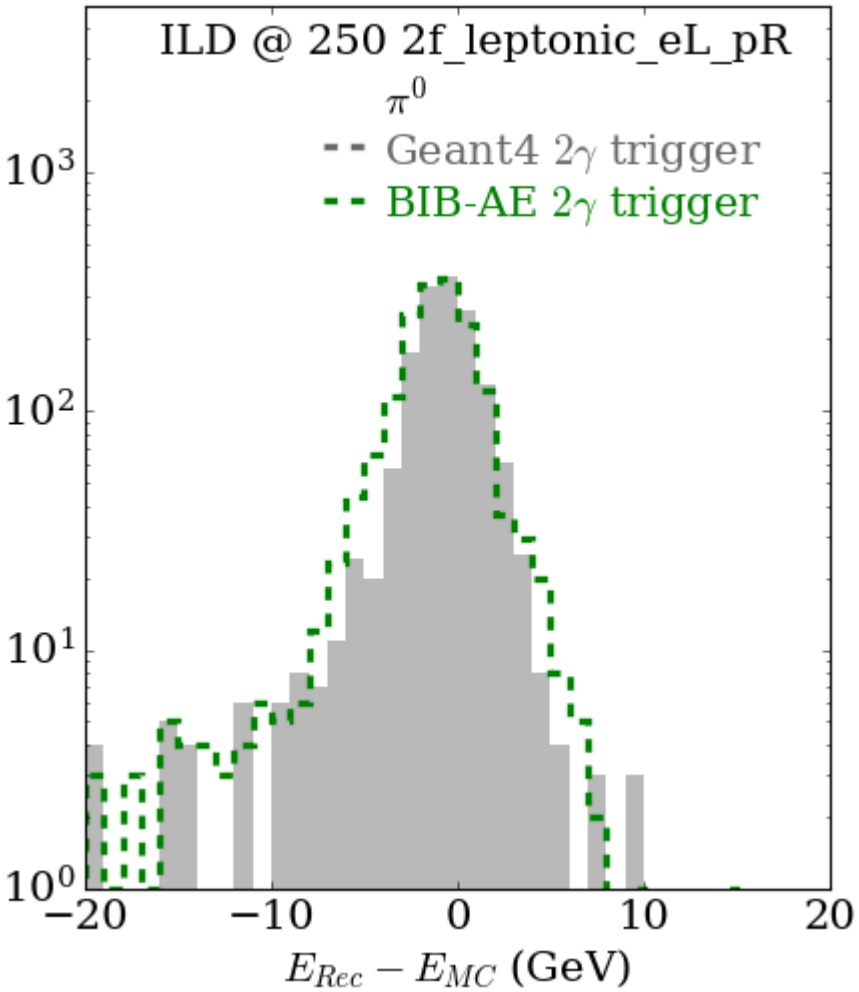
- Have a total of 2561 Geant4 pi0 candidates
- Have a total of 2742 BIBAE pi0 candidates

Pi0 Energy vs num. Pi0 Rec

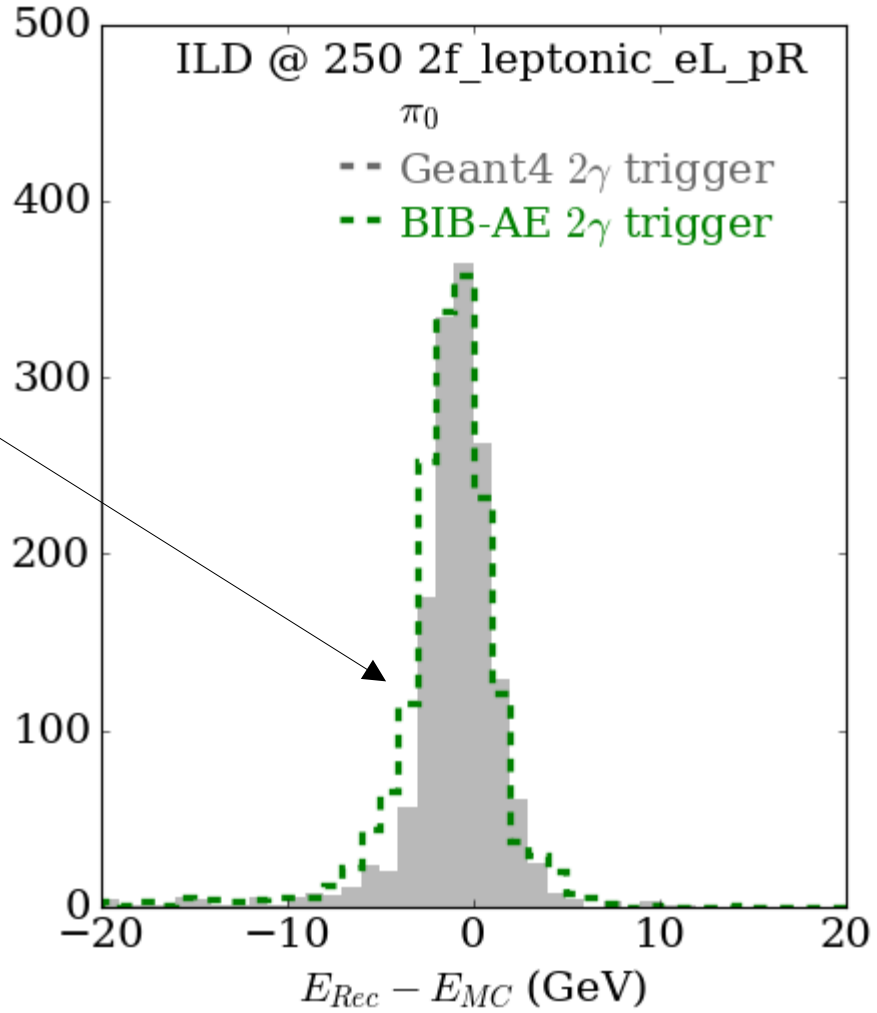




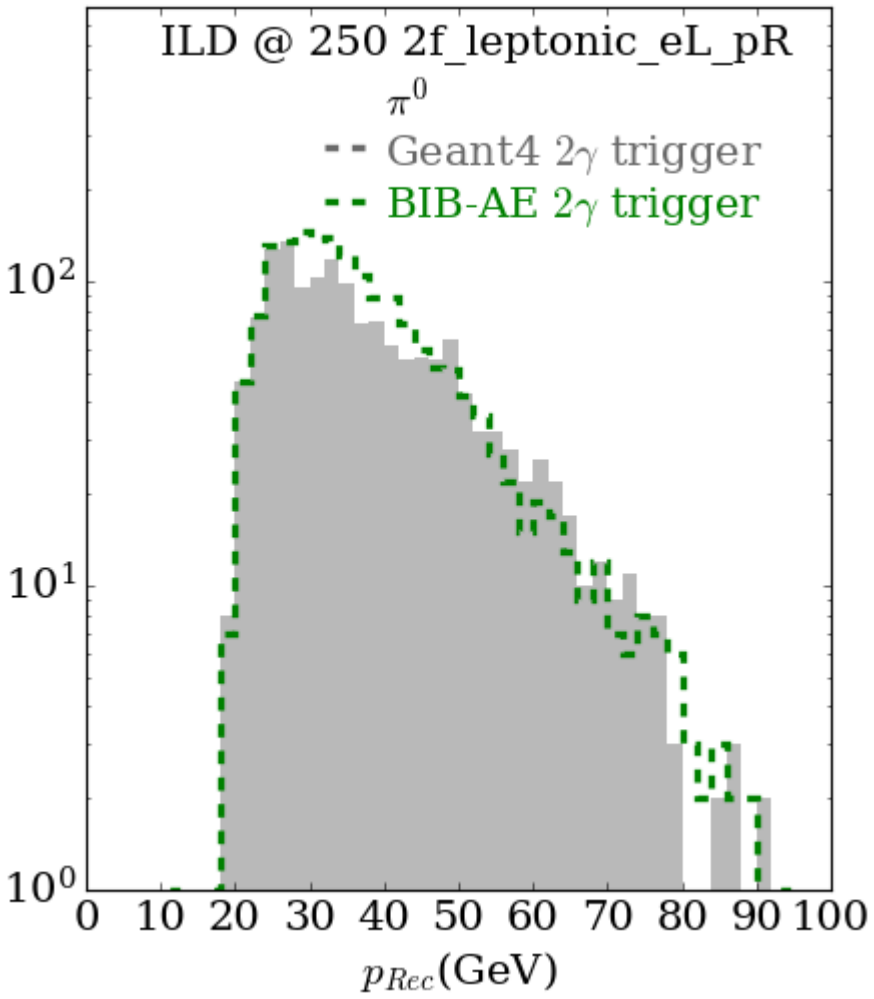
Pi0 Energy Rec – Energy MC vs num. Pi0 Rec

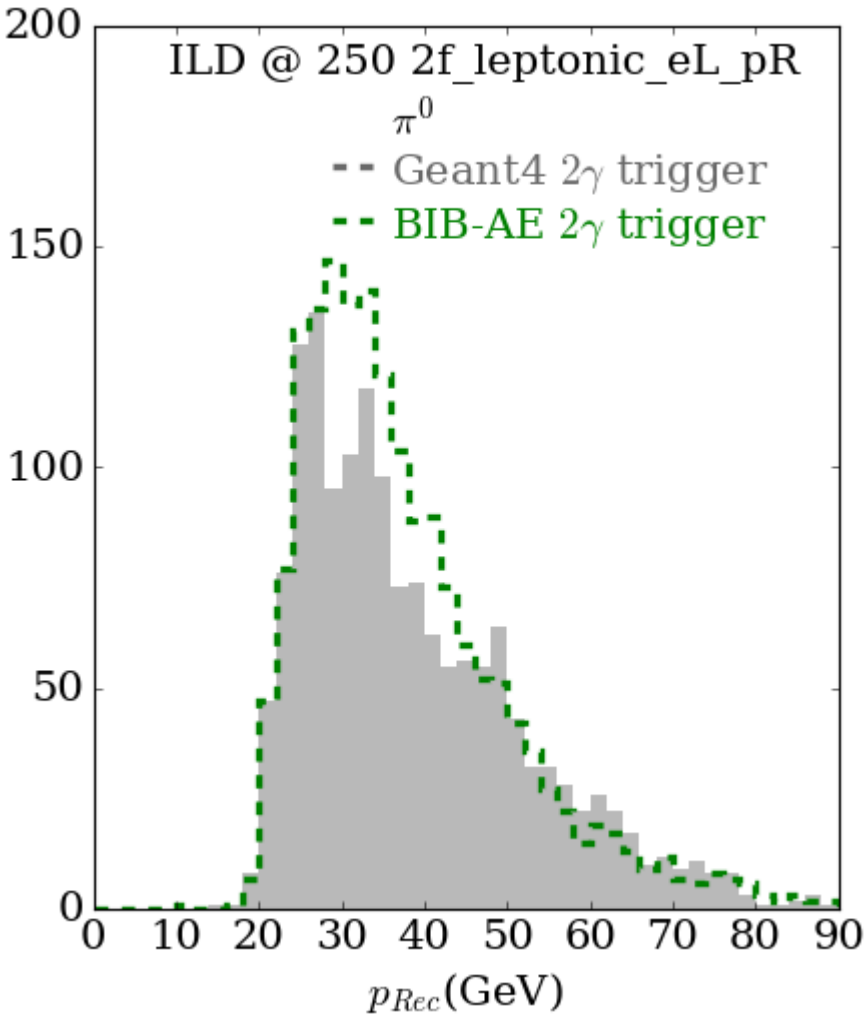


Bias to negative values larger for BIBAE

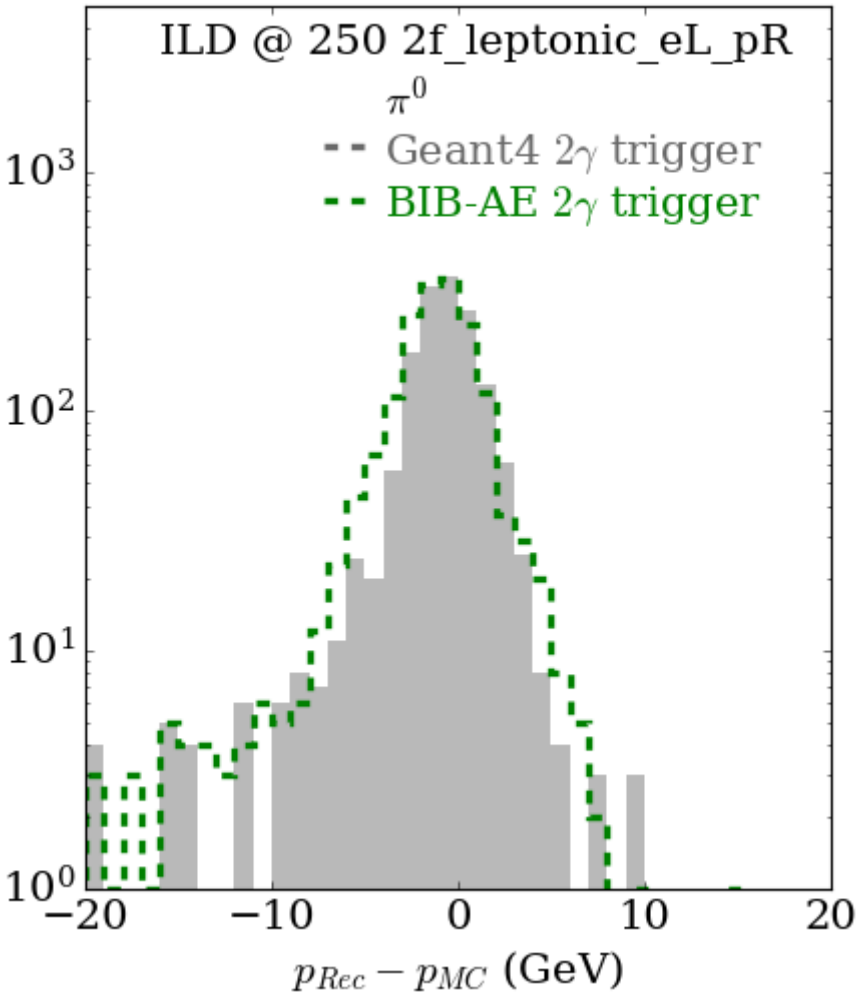


Pi0 Momentum vs num. Pi0 Rec





Pi0 Momentum Rec – Momentum MC vs num. Pi0 Rec



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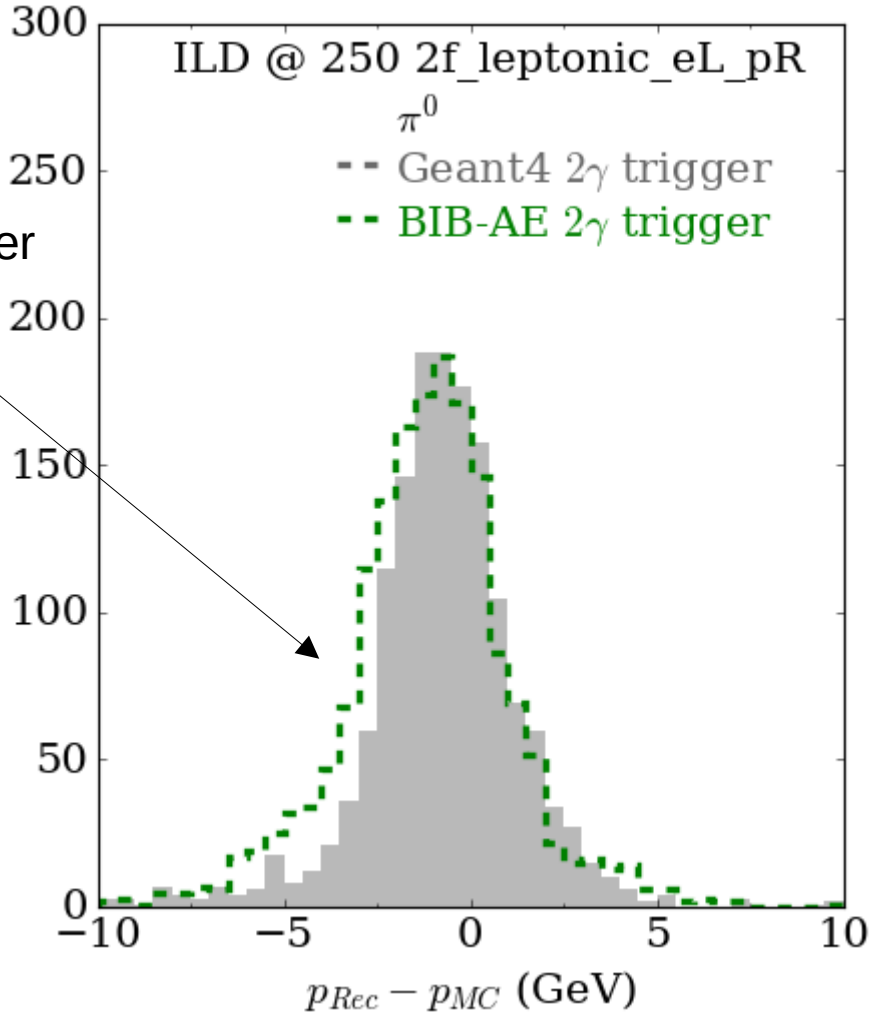
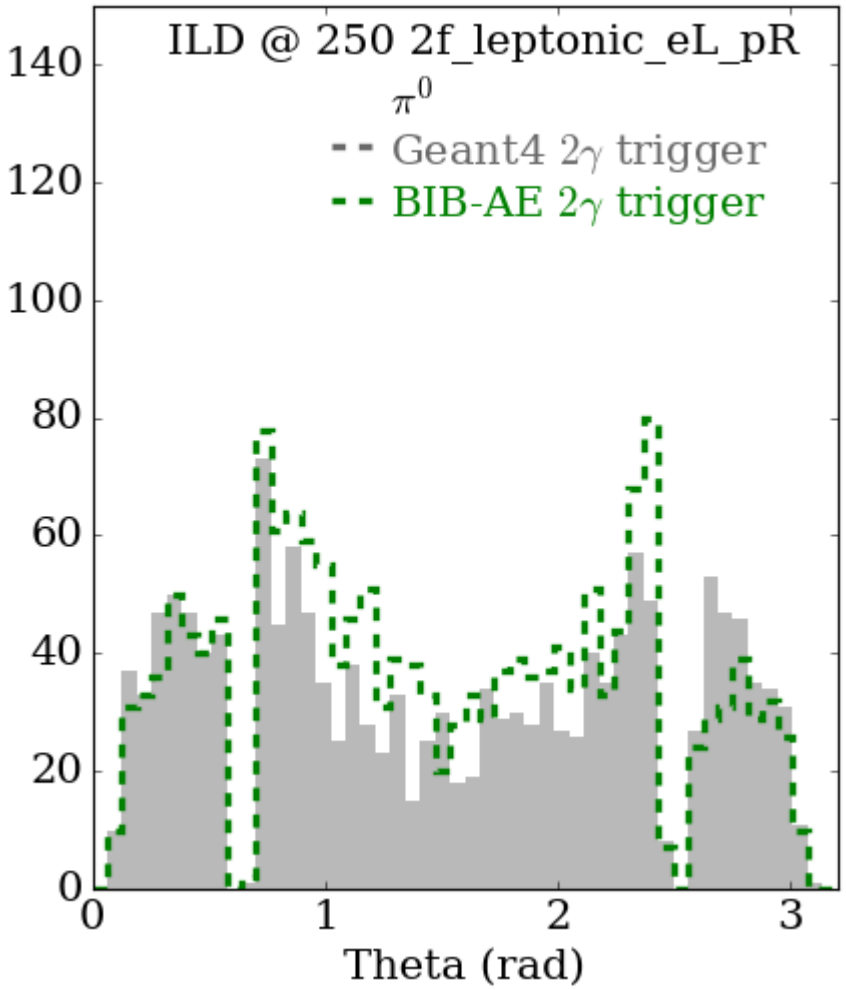
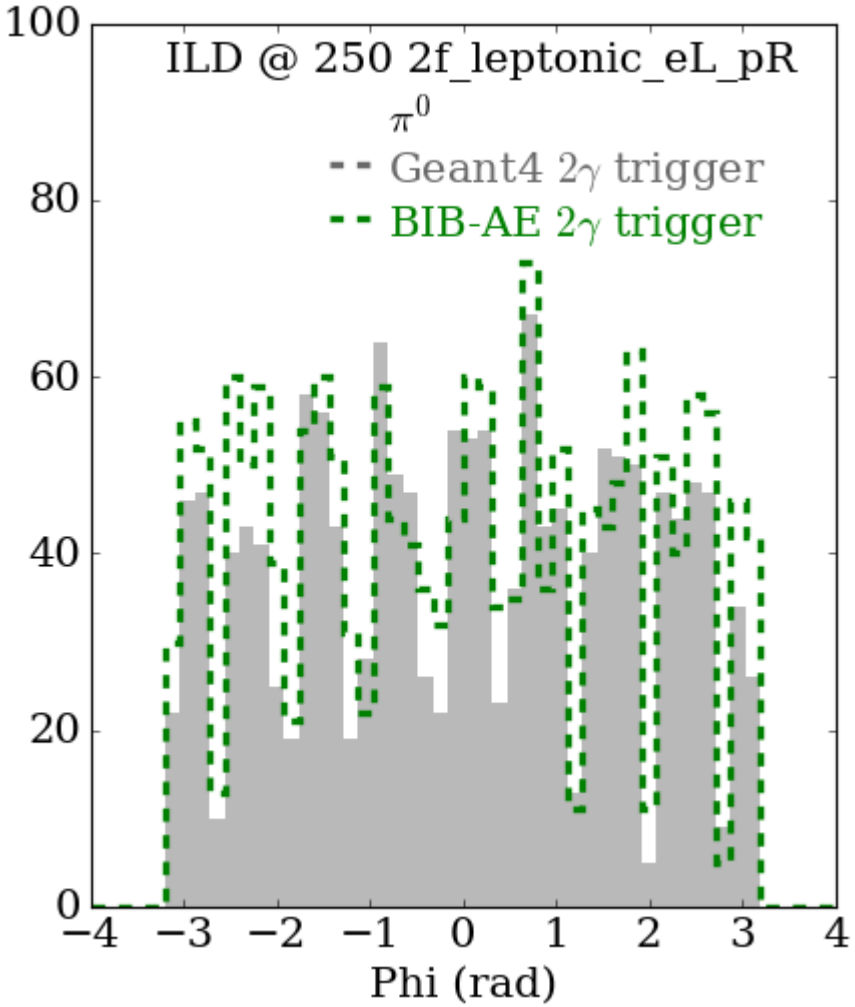


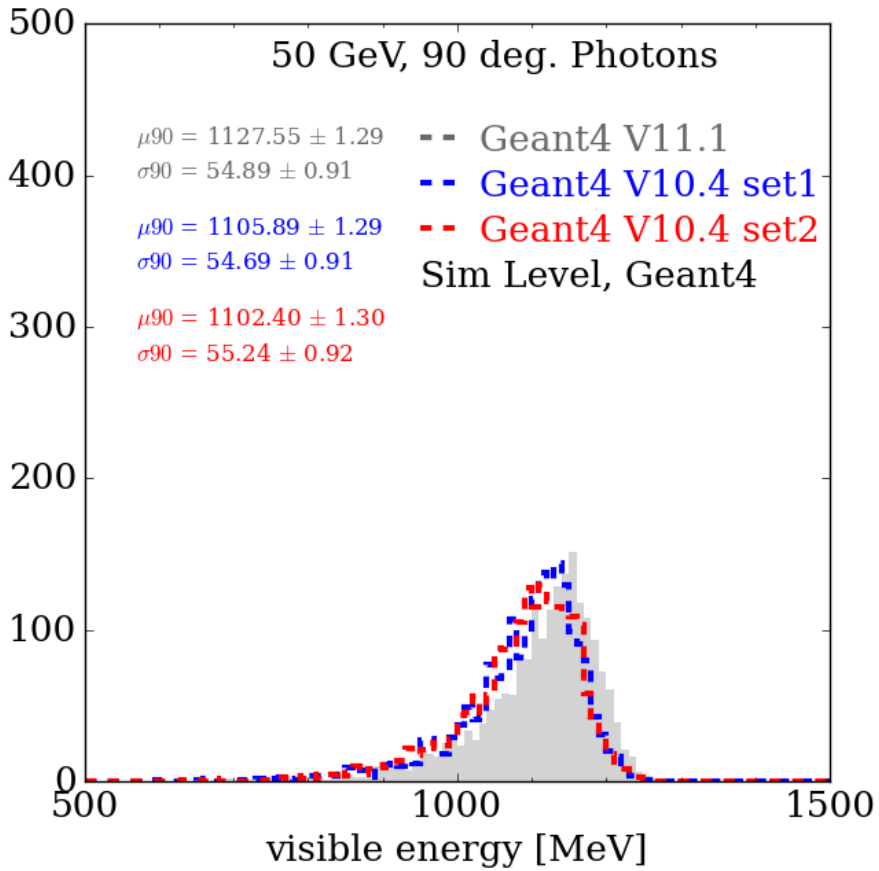
Pi0 Theta/Phi vs num. Pi0 Rec





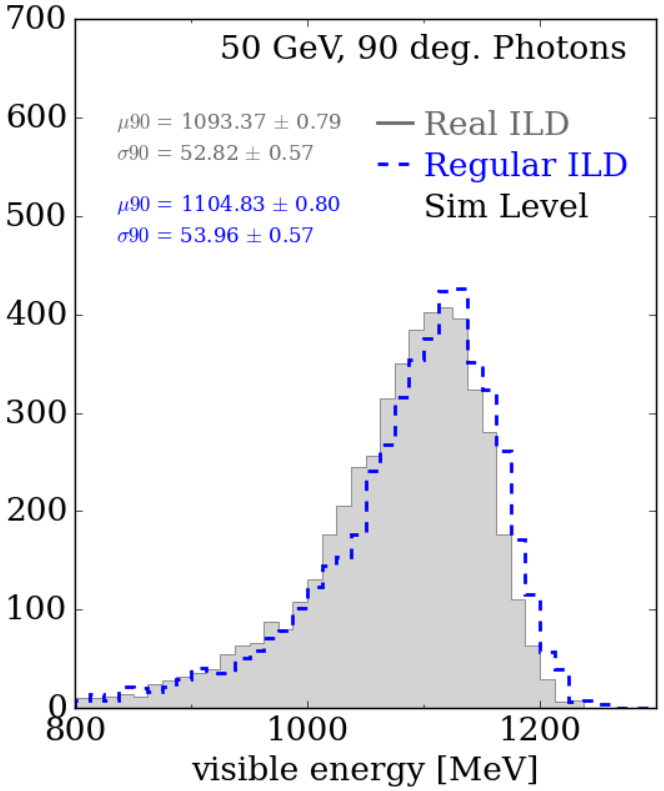
Uncertainties

- Need to add statistical errors ✓
- Additional uncertainty from necessary change in G4 version due to addition of Fast Sim hooks in G4 V11
  - Treat as uncertainty on MC



Potential Issue: Dead Material?

- BIBAE is a regular grid model: when handing back to G4 treat as a coarse grained point cloud, with separation = cell size
- This means that if hit lands in dead material entire hit is thrown away by G4- saw this previously (and expected):
  - Somewhat compensated by purely regular ECAL used for training



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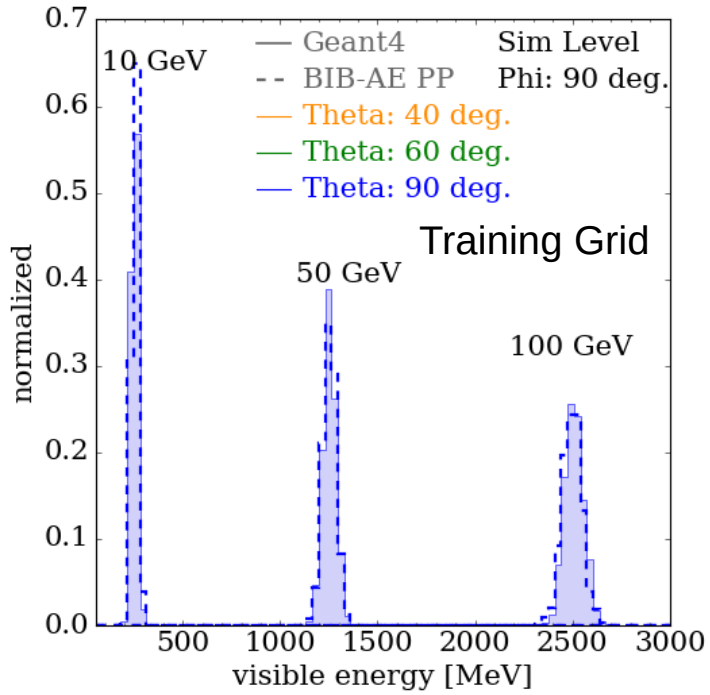
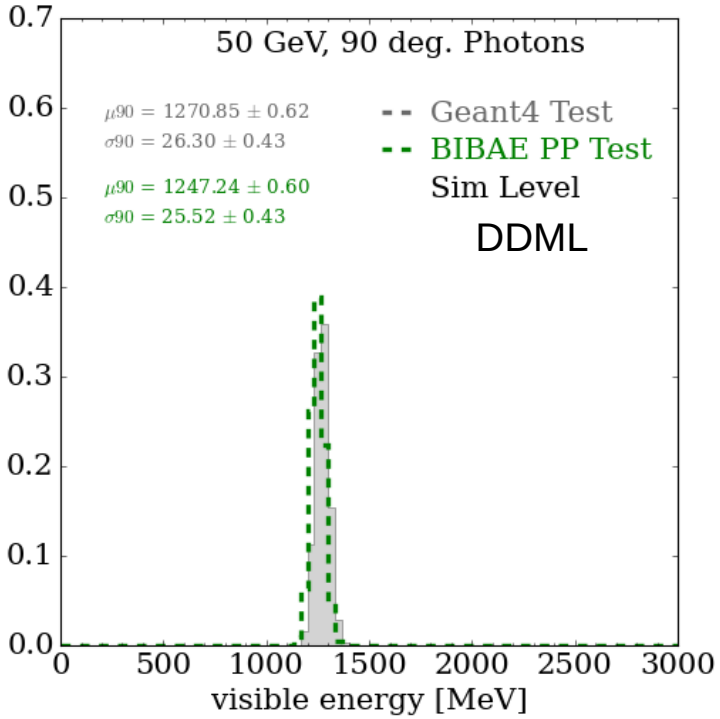
- BIBAE is a regular grid model: when handing back to G4 treat as a coarse grained point cloud, with separation = cell size
- This means that if hit lands in dead material entire hit is thrown away by G4- saw this previously (and expected):
- However: depending where in geometry you land, effects can range from this ...





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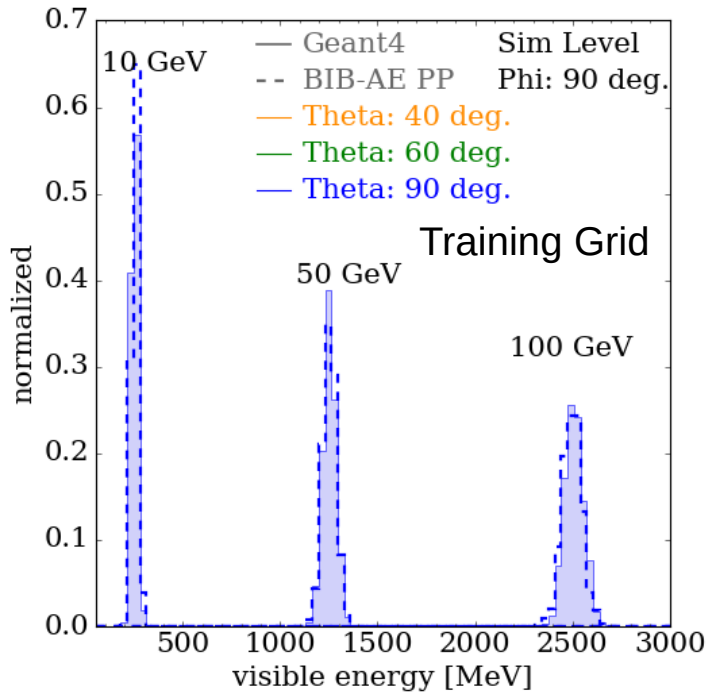
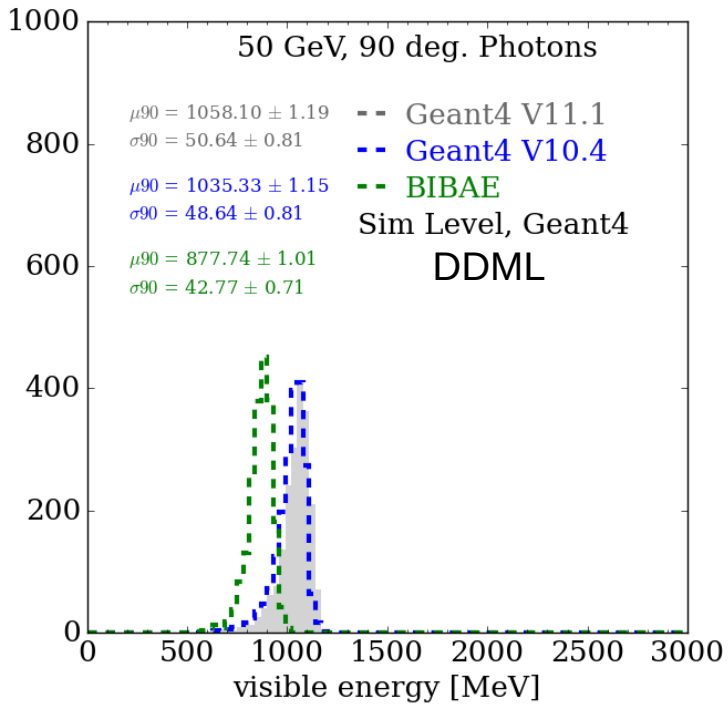
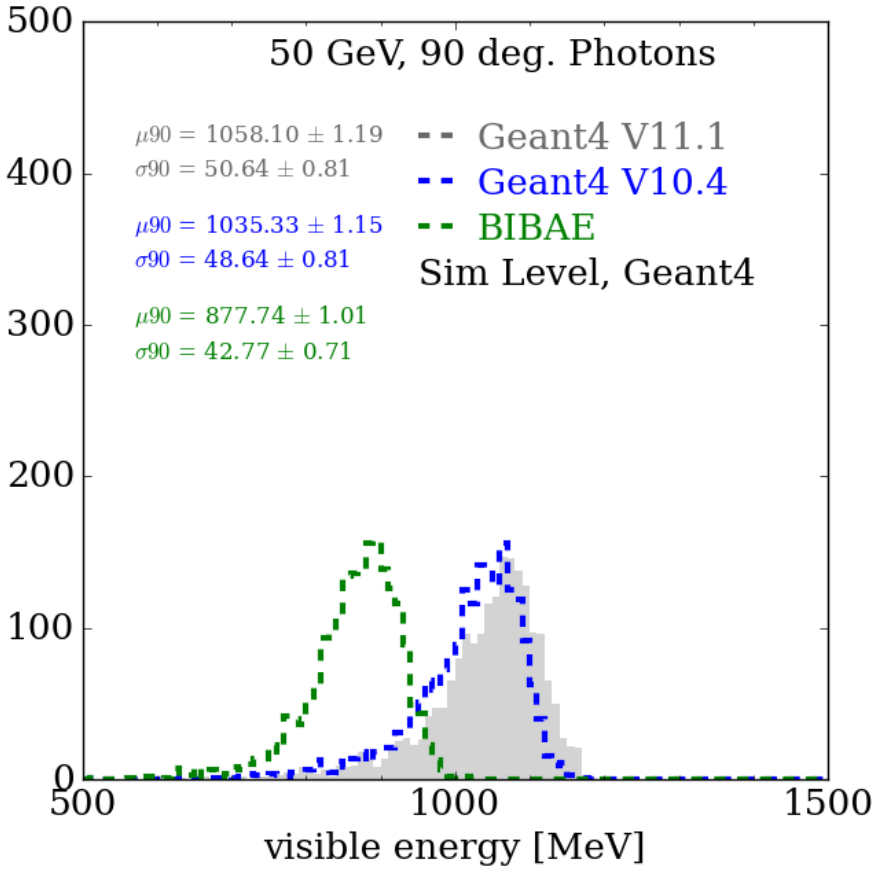
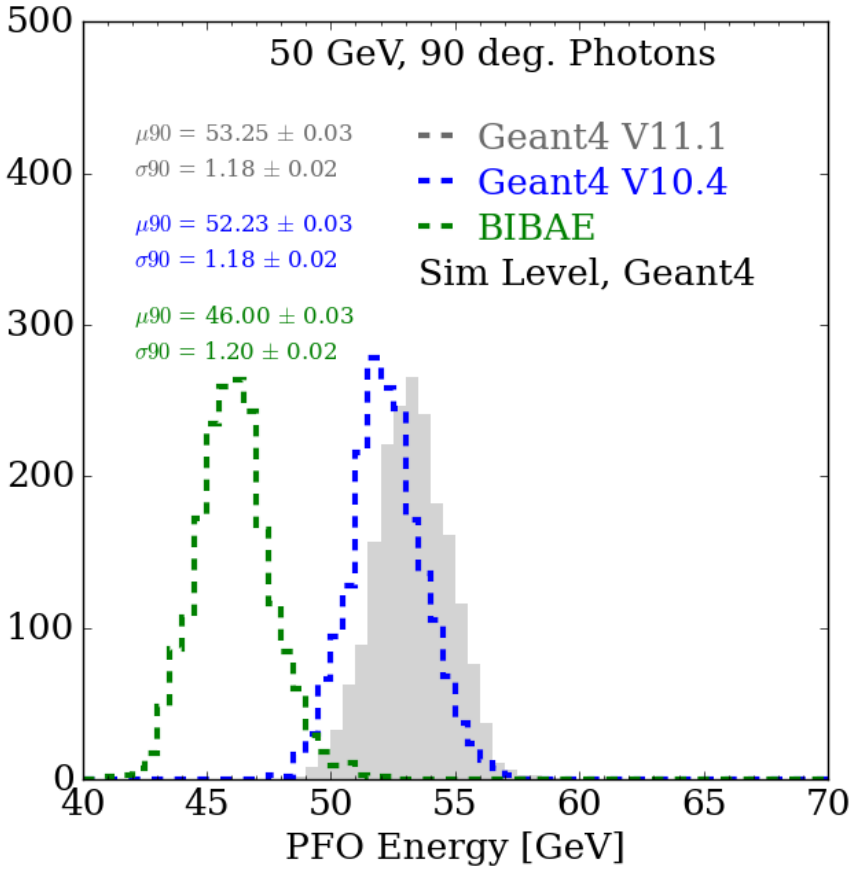
- To this ...





Potential Issue: Dead Material Post Rec

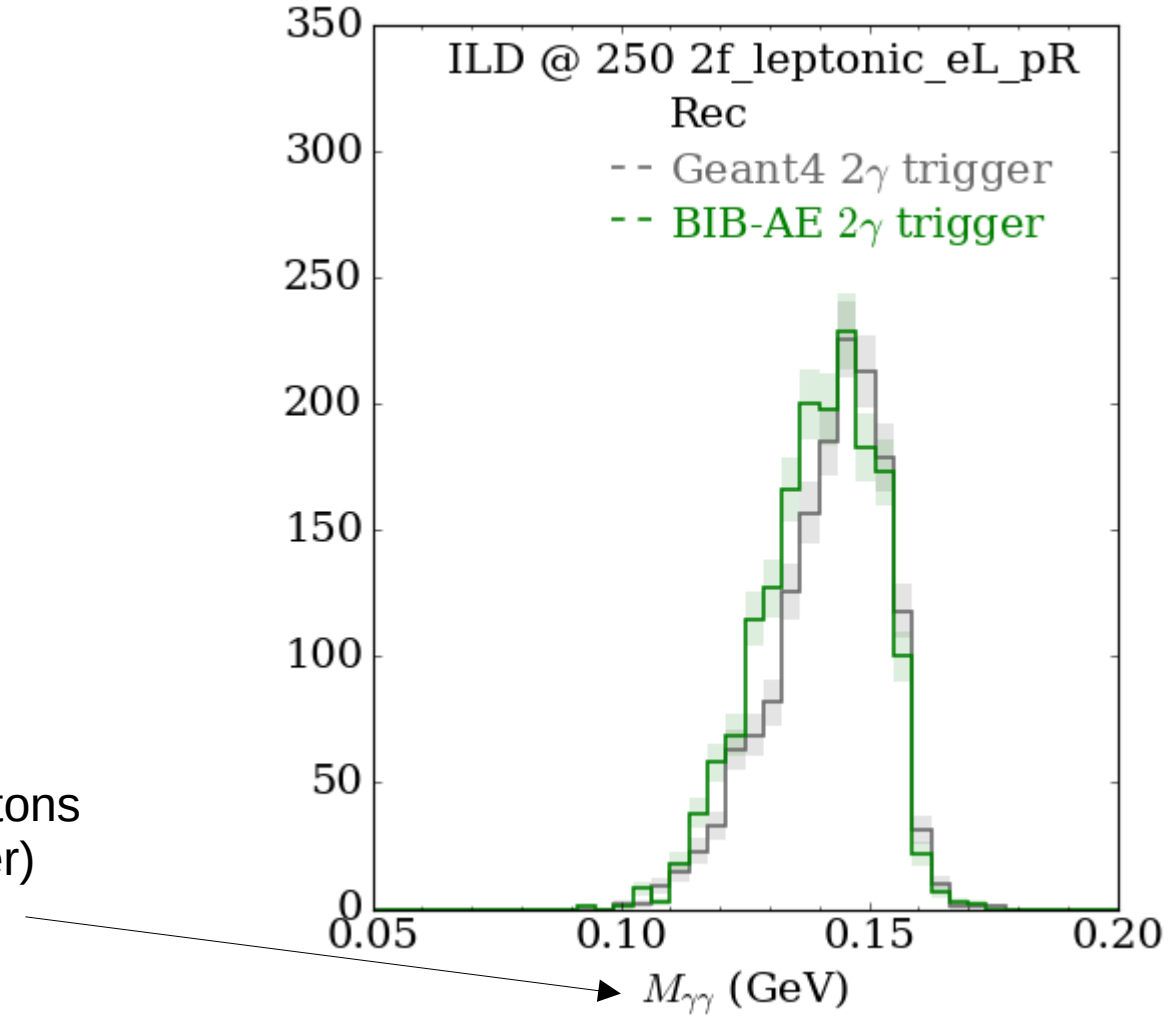




New Plots

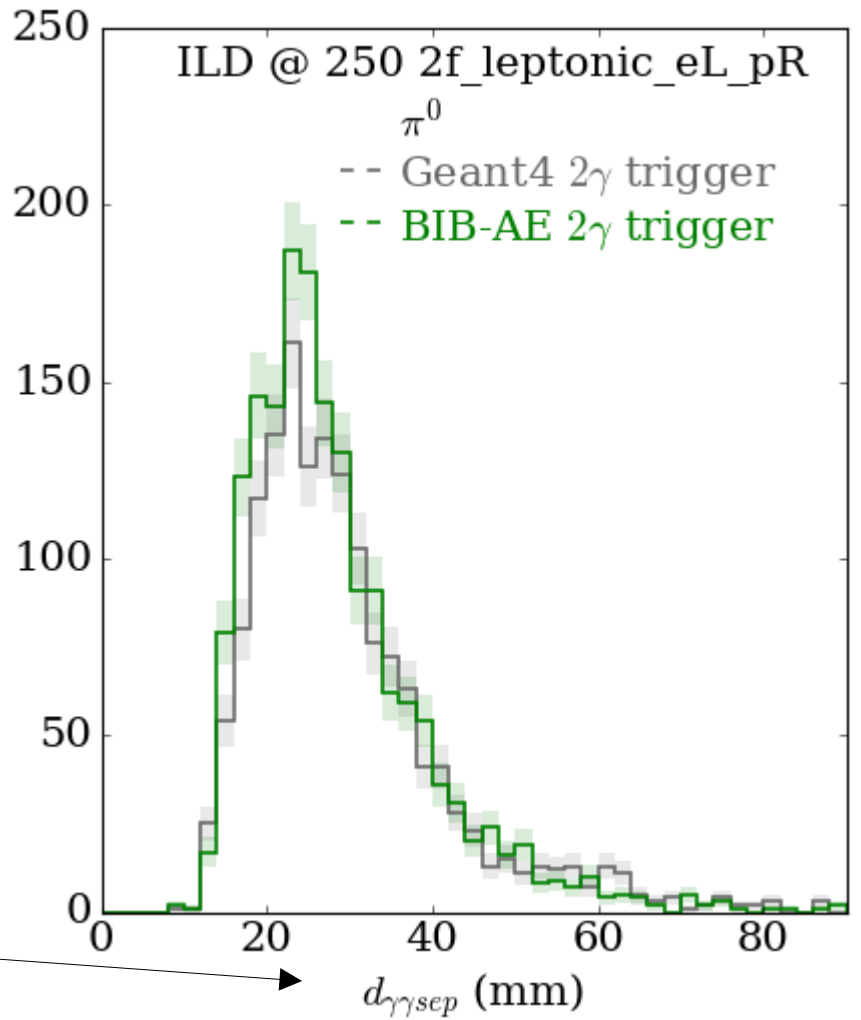
Two photon-system Invariant Mass vs num. Pi0 Rec

Use energy and momentum of reconstructed photons (require one cluster)

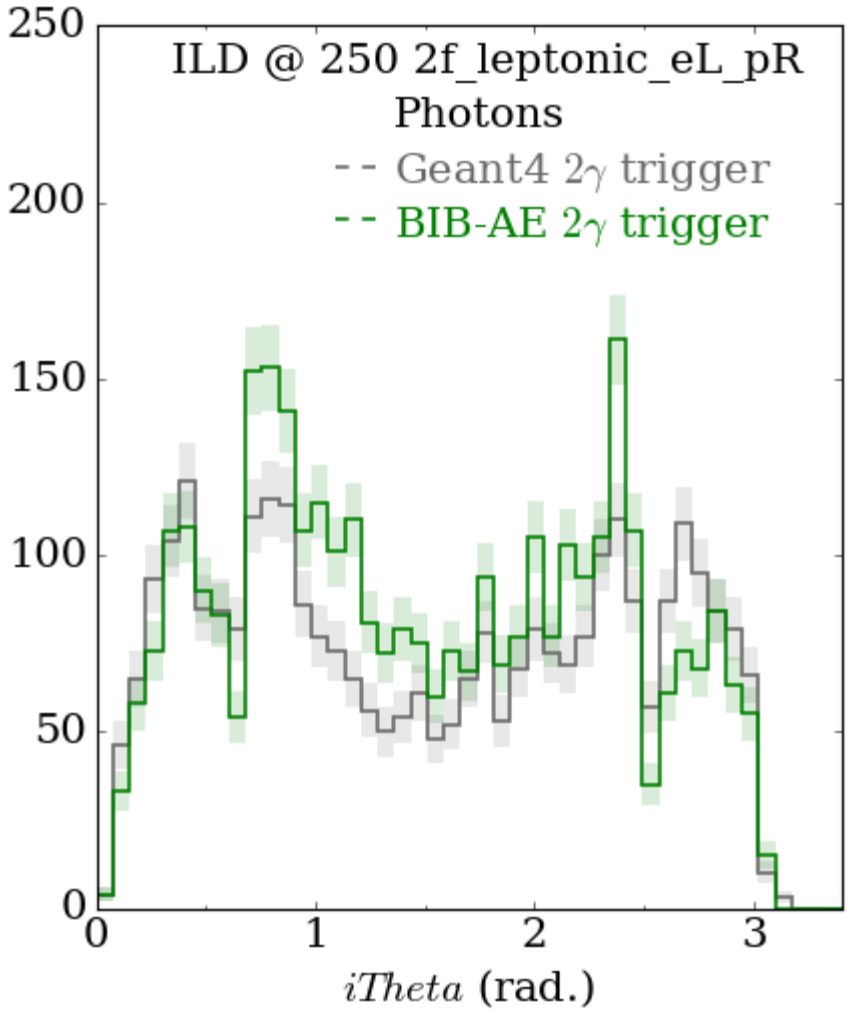


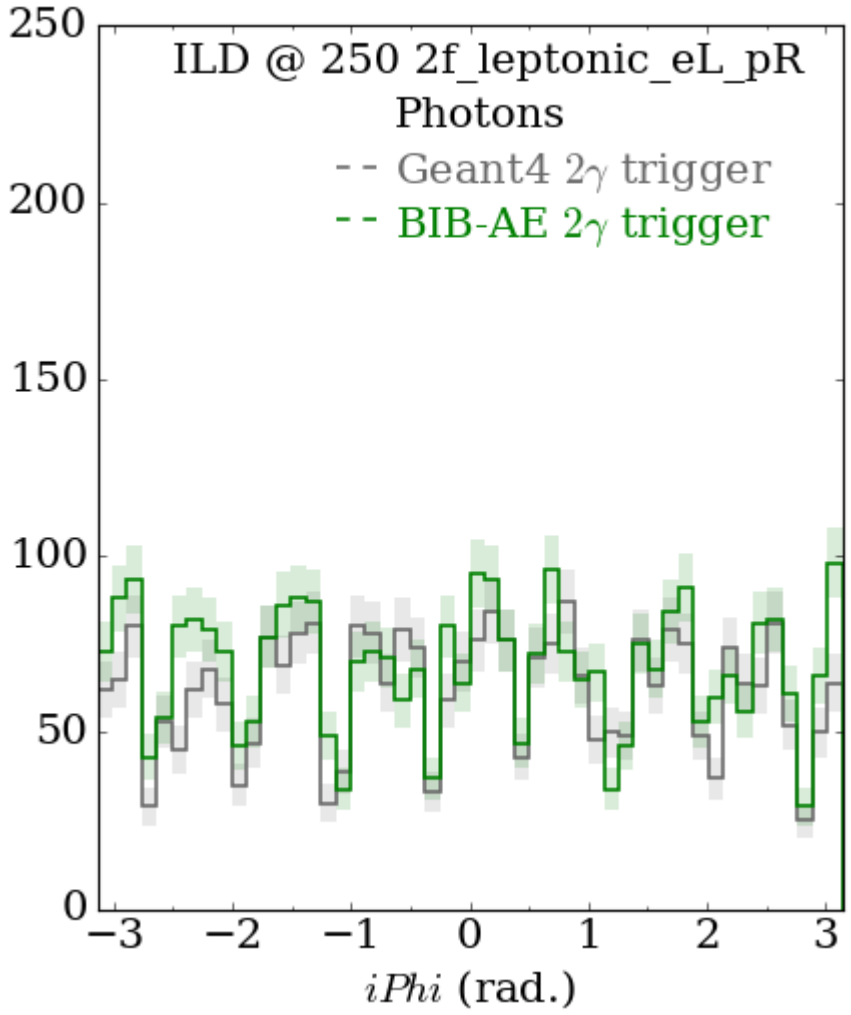
Pi0 di-photon separation vs num. Pi0 Rec

Separation of PFO cluster positions (require one cluster)



Cluster ITheta/IPhi vs num. Pi0 Rec





Next steps

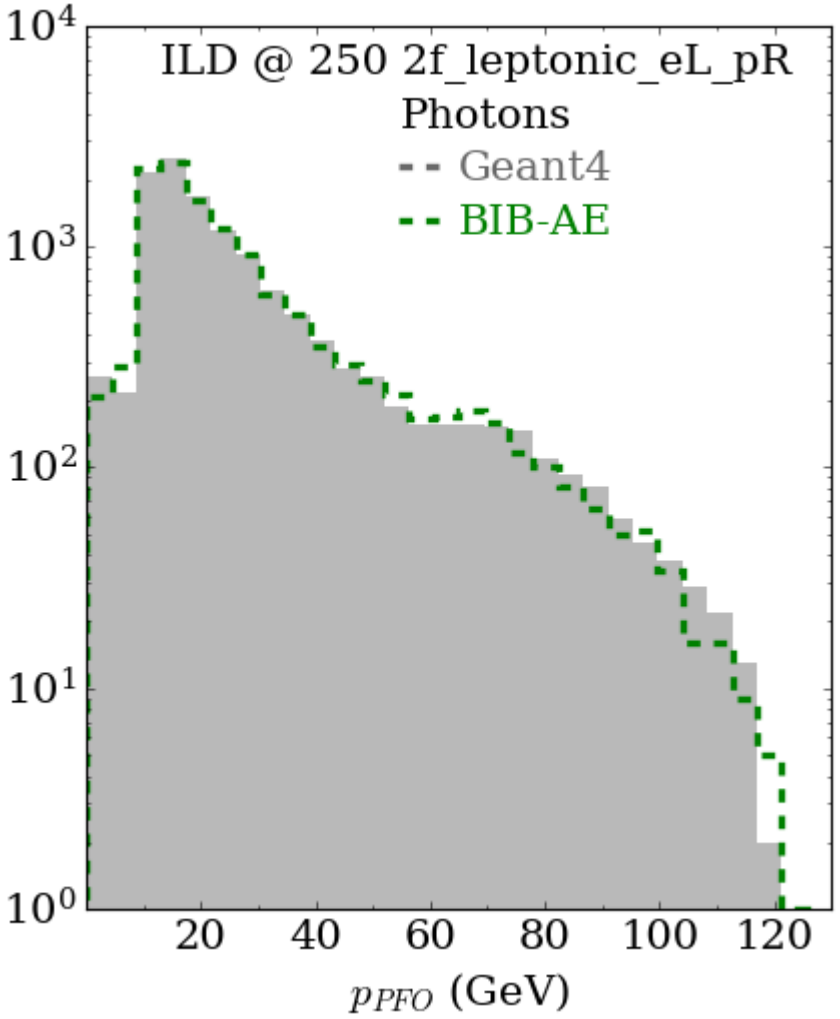
- Compare to previous version of Geant4 (simulate tau pairs)
- Definitely suspect insensitive volumes are playing a large role
  - Try hit-splitting approach? → Coherent story for thesis (burn some distributions for physics)
- Statistics? (compute+storage)
- Proper compute speed benchmark (+ for Bhabhas)

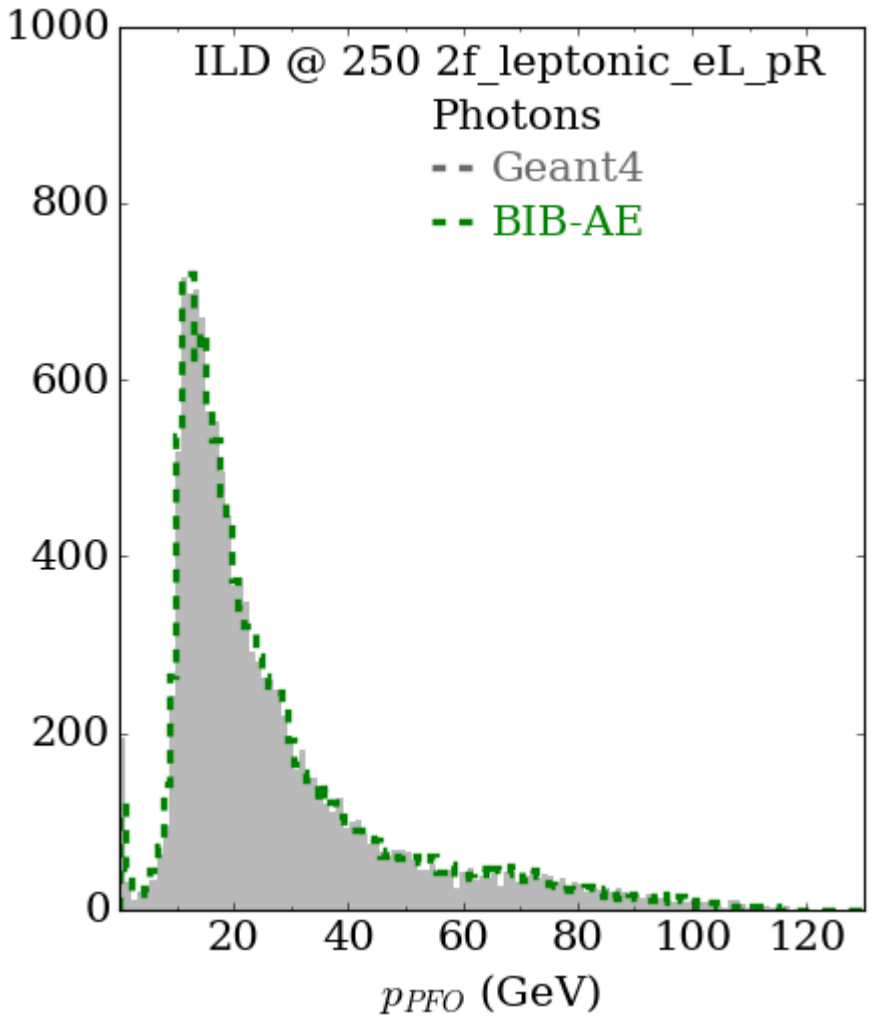
Could also try:

- Going up the MC chain (rather than down)- Would help find photons/pi0s that aren't recoed, but what would we learn?
- Dedicated di-photon samples- clean effect of overlapping showers (radial profile)
- Look at event displays to try to find cases of missed photons- might be difficult to figure out geometry effects
- I don't have time for everything --> be selective

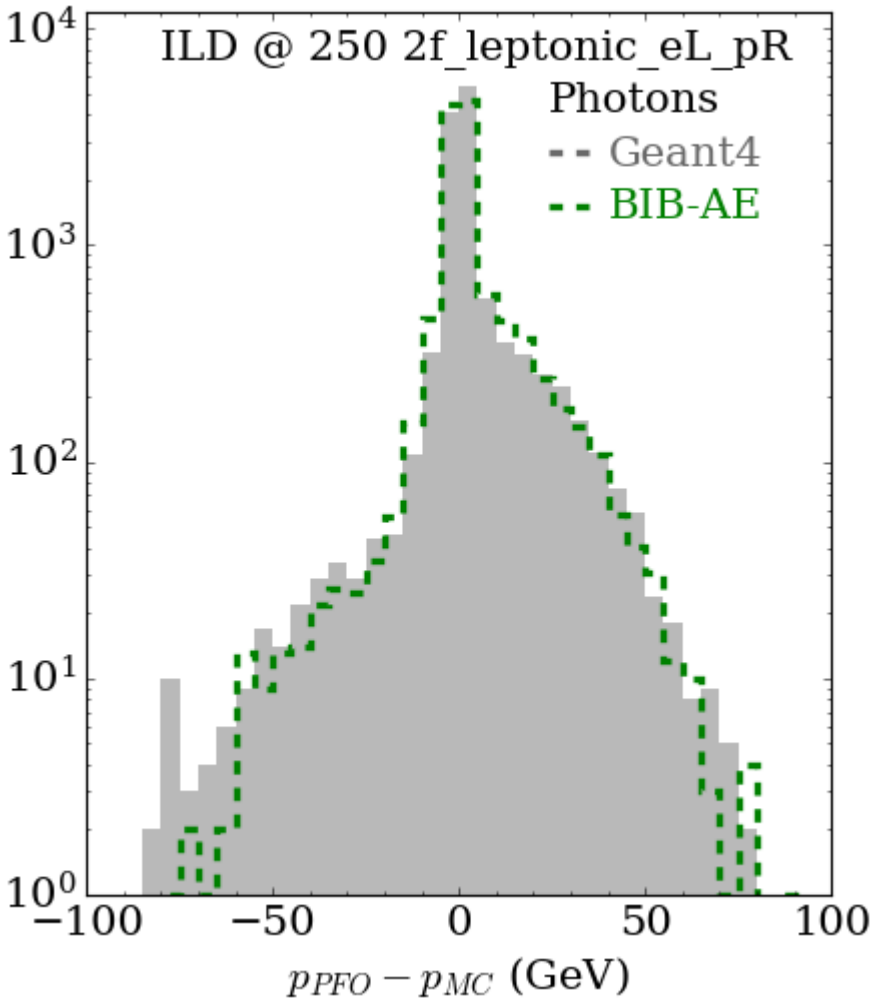
More Plots!

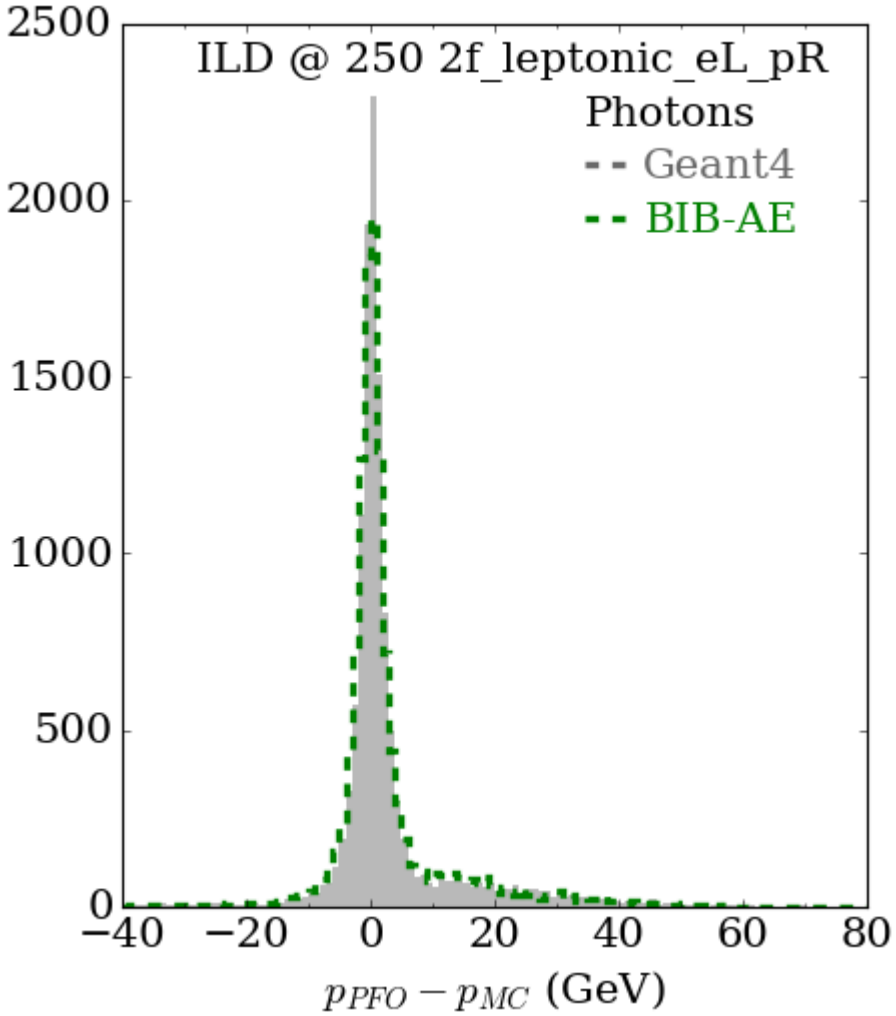
Pi0 photons: Momentum



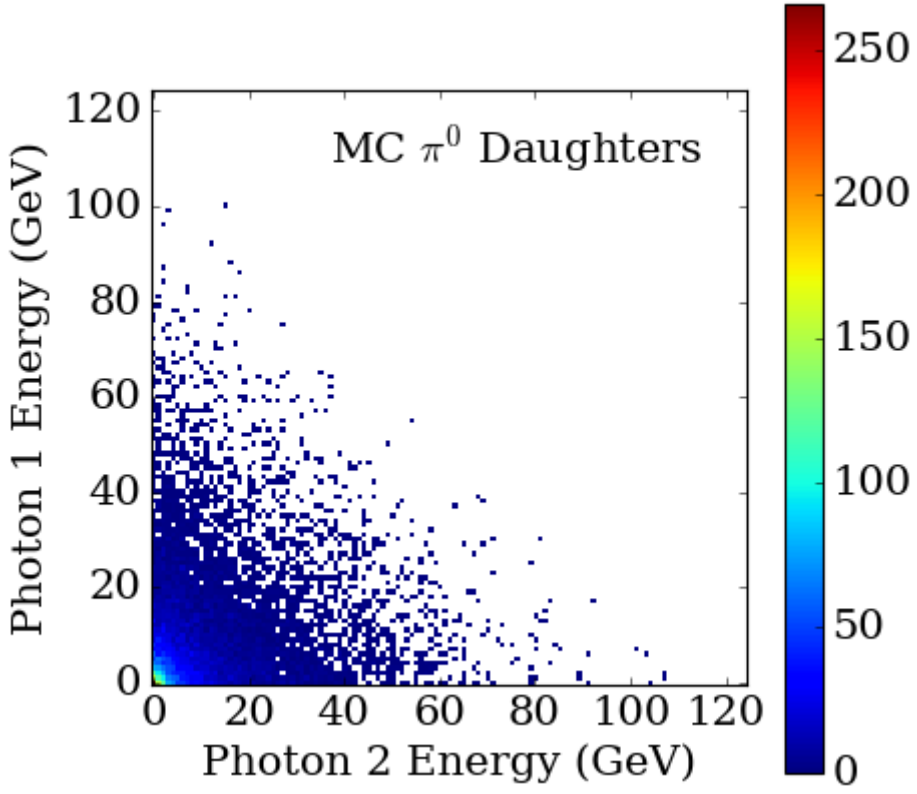


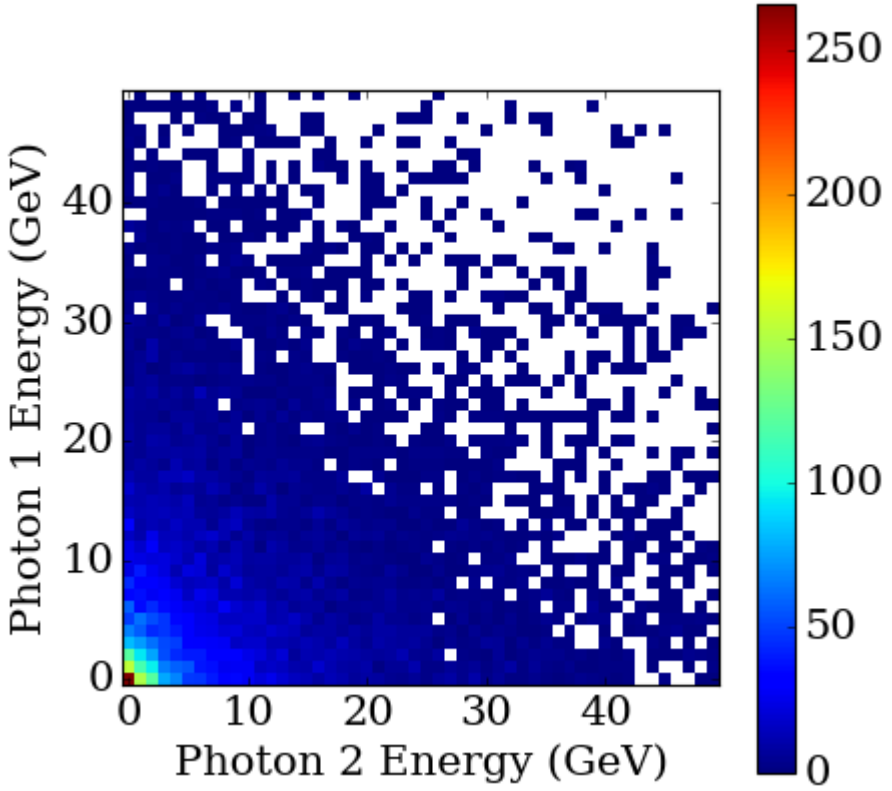
Pi0 photons: PFO Momentum – MC Momentum



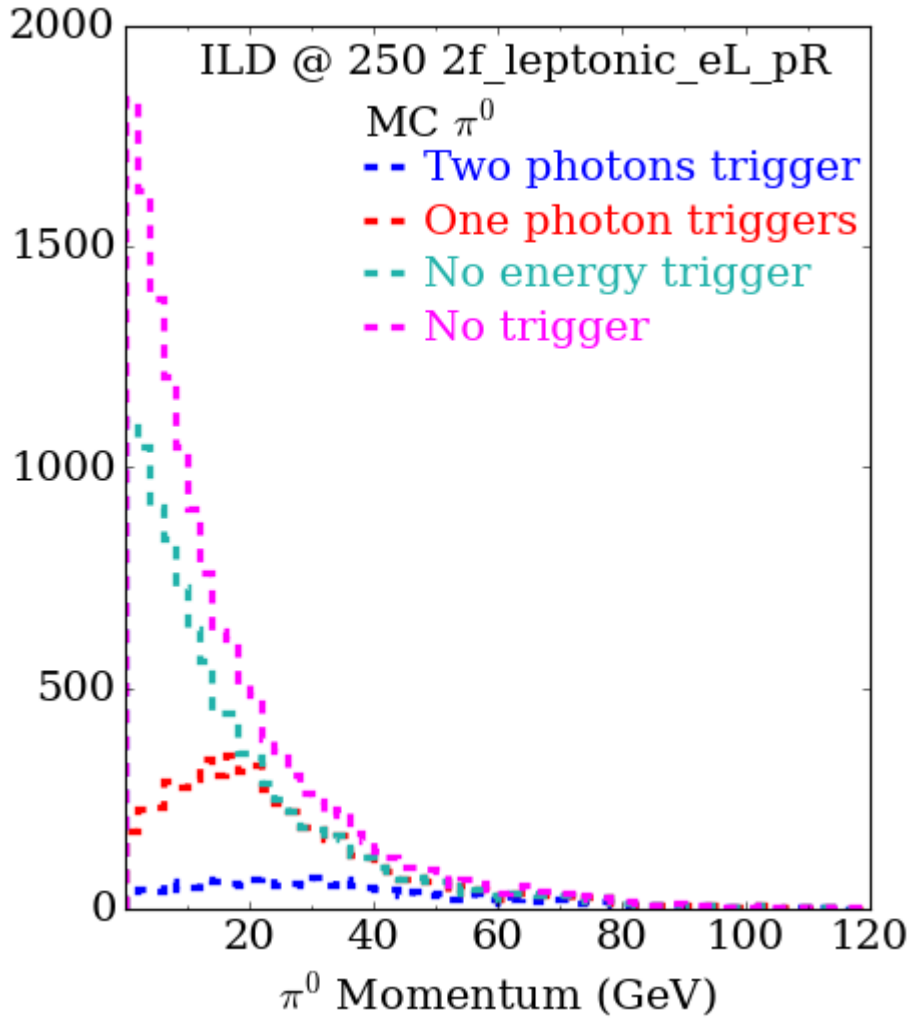


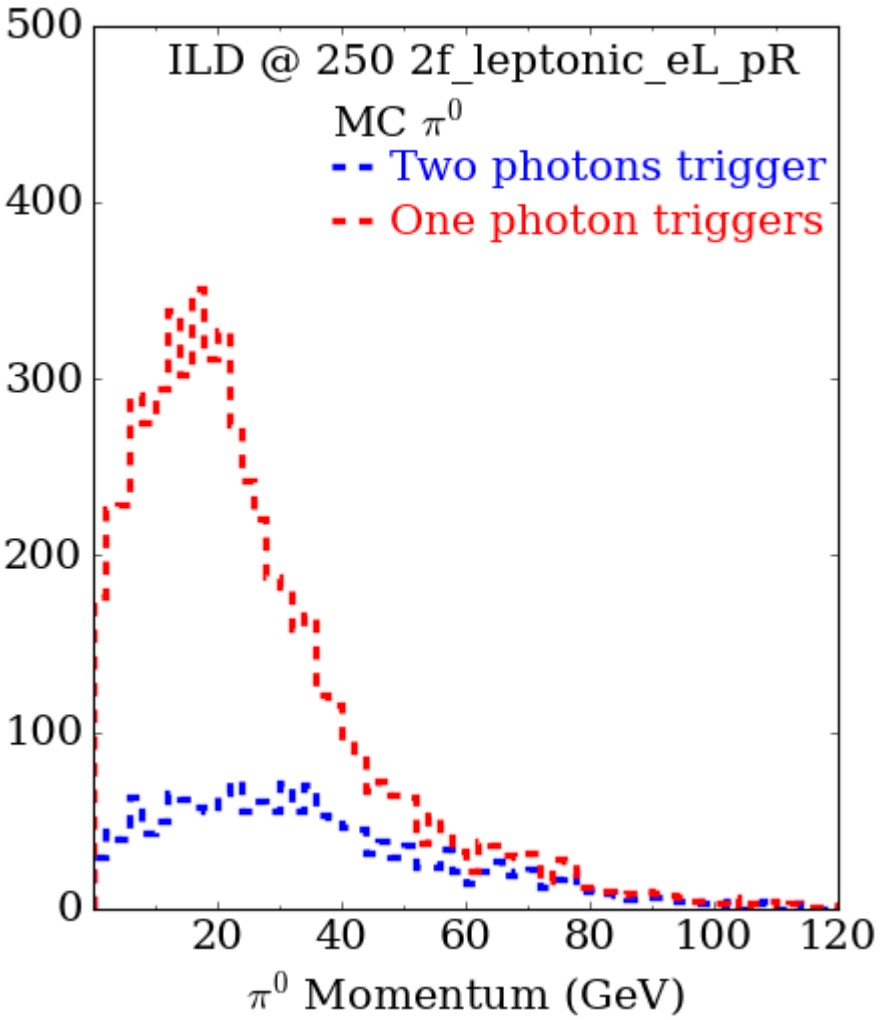
MC Pi0 – daughter correlations



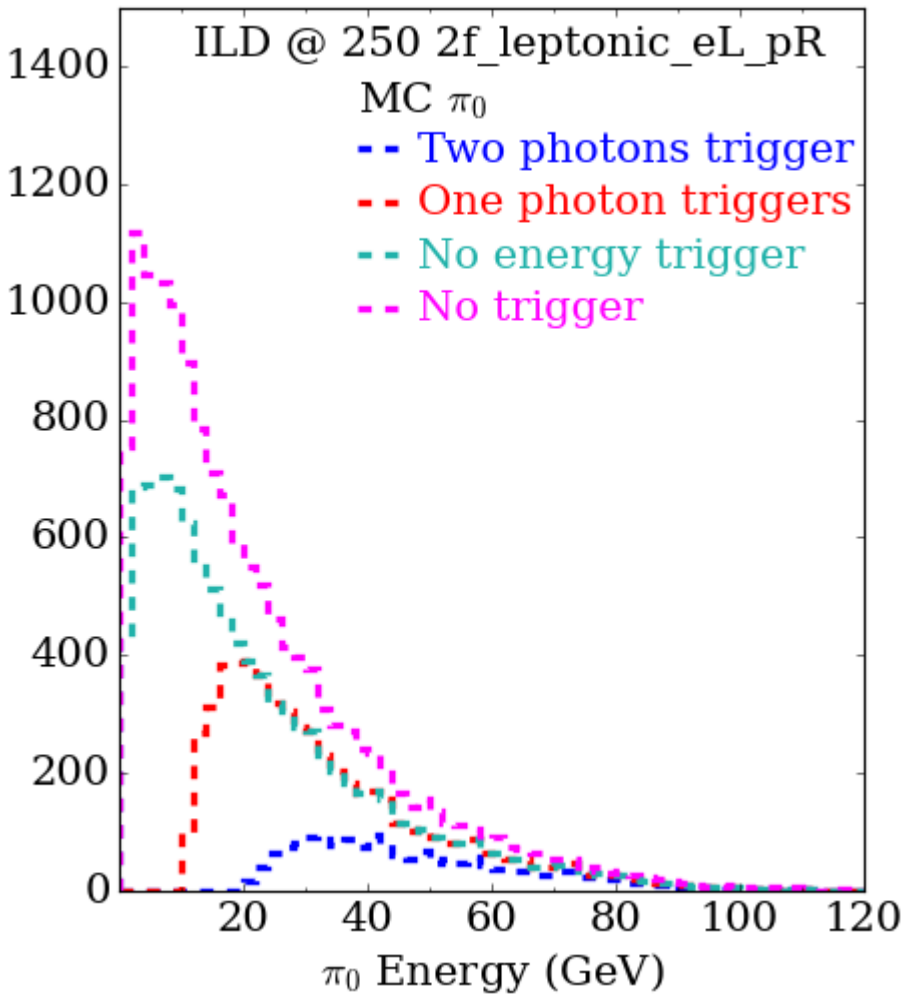


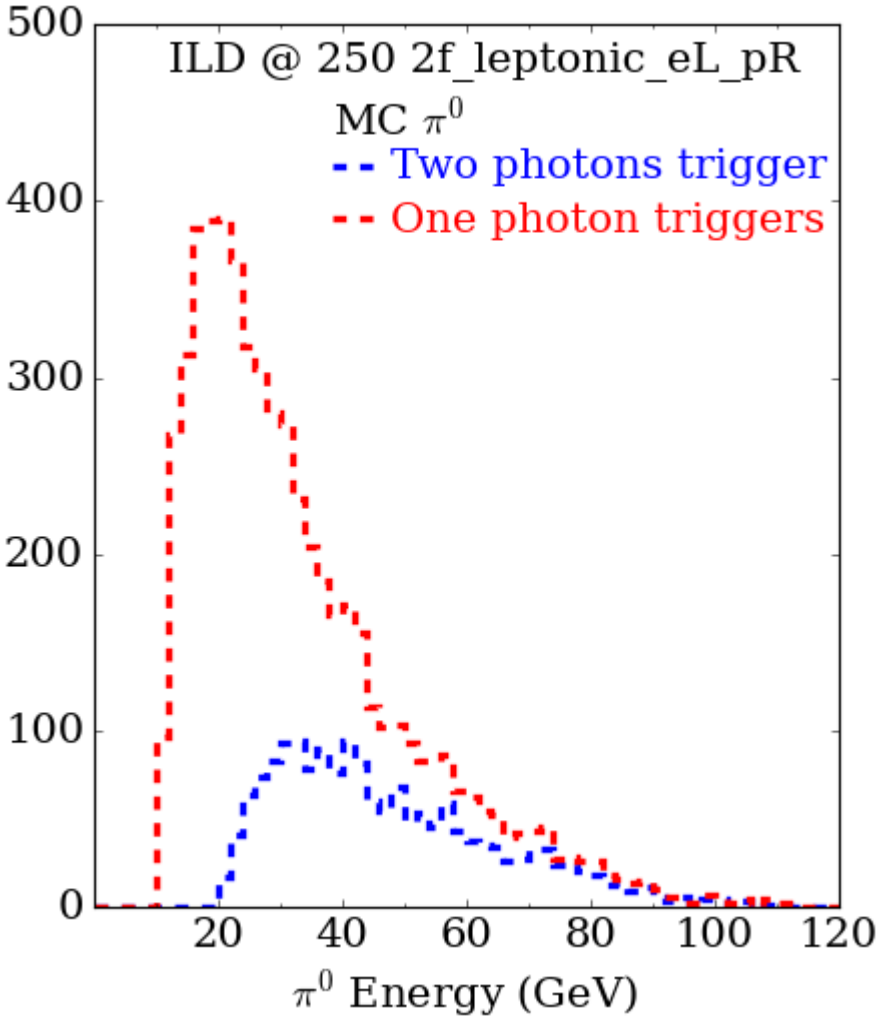
MC Pi0 – Momentum



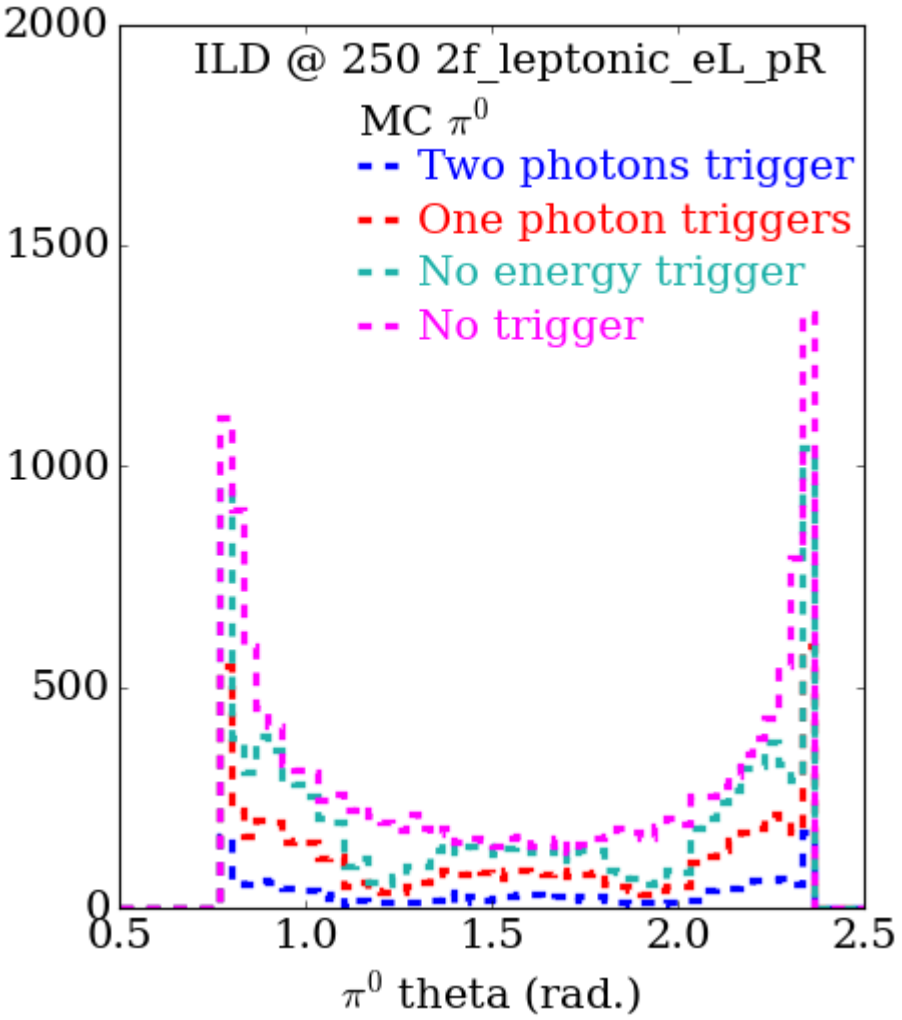


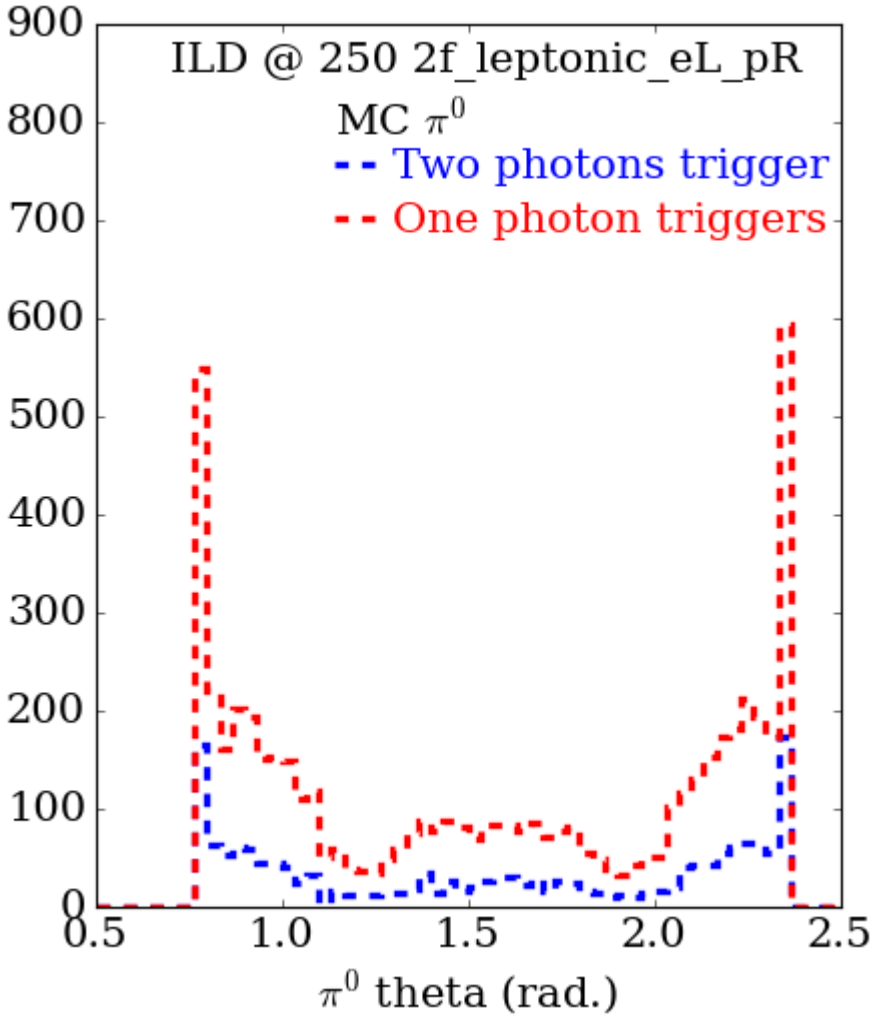
MC Pi0 – Energy



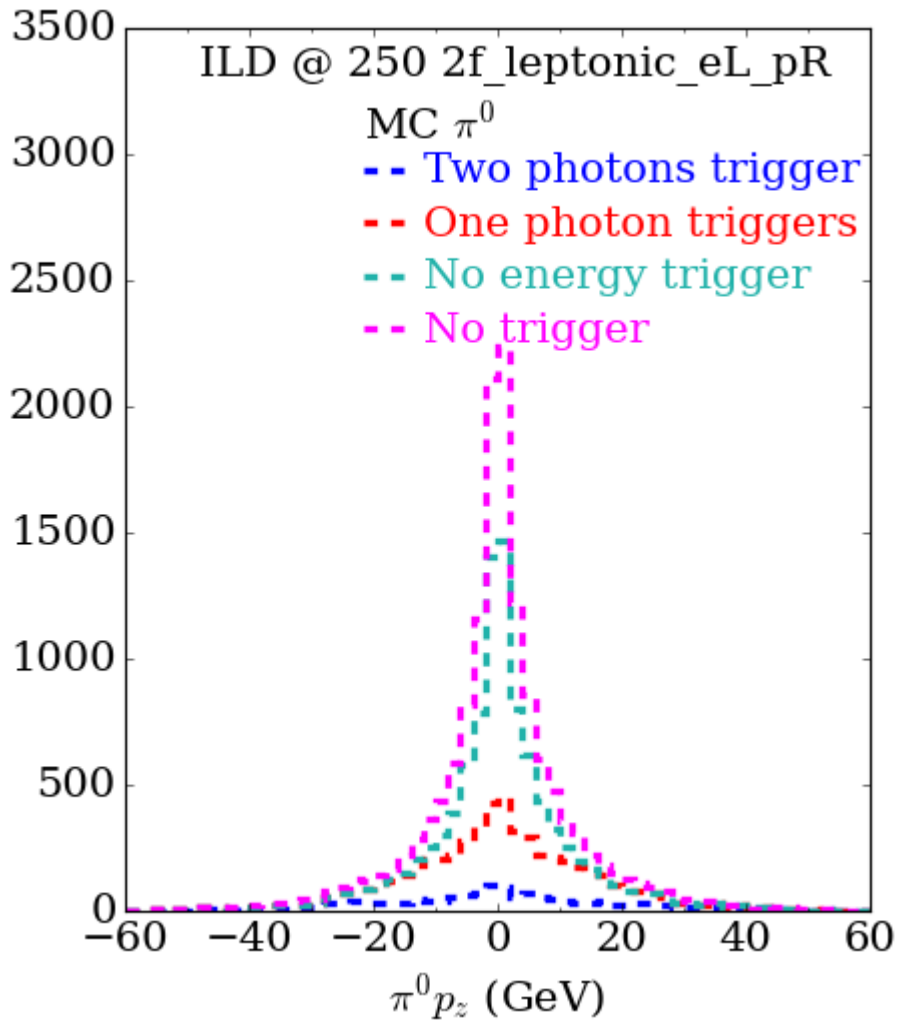


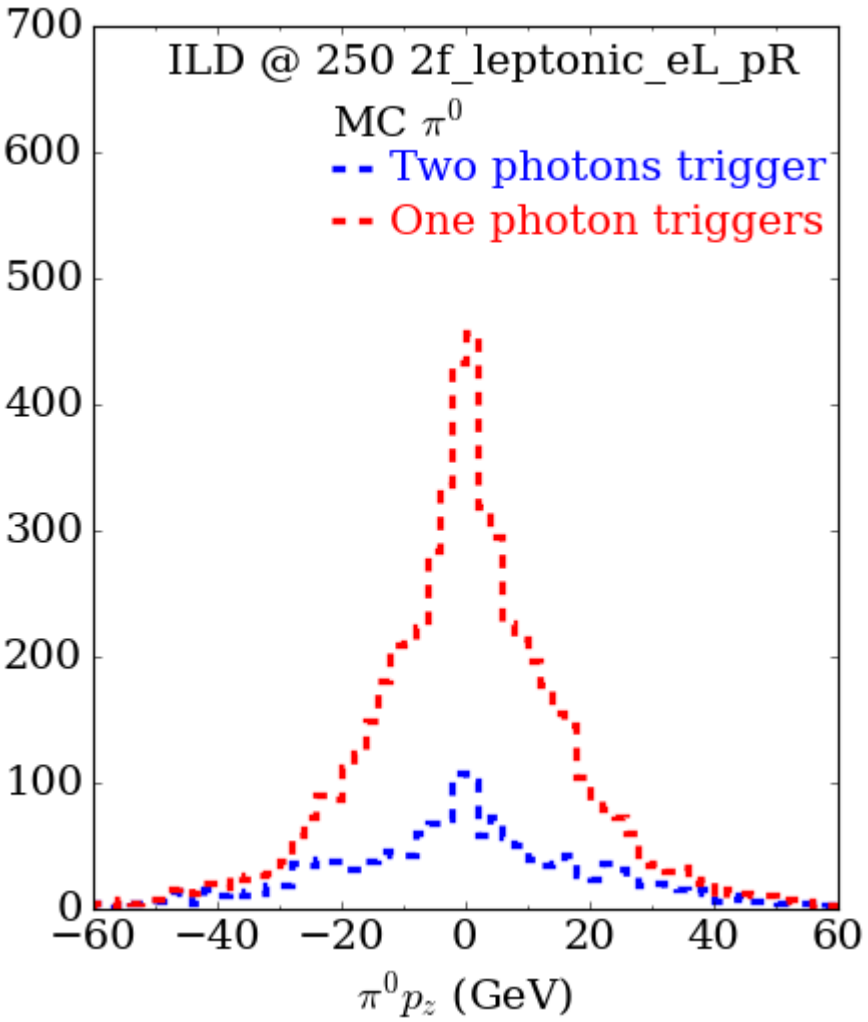
MC Pi0 – Theta


ILD @ 250 2f_leptonic_eL_pR
MC π^0
Two photons trigger
One photon triggers
No energy trigger
No trigger
2000
1500
1000
500
0
0.5
1.0
1.5
2.0
2.5
π^0 theta (rad.)

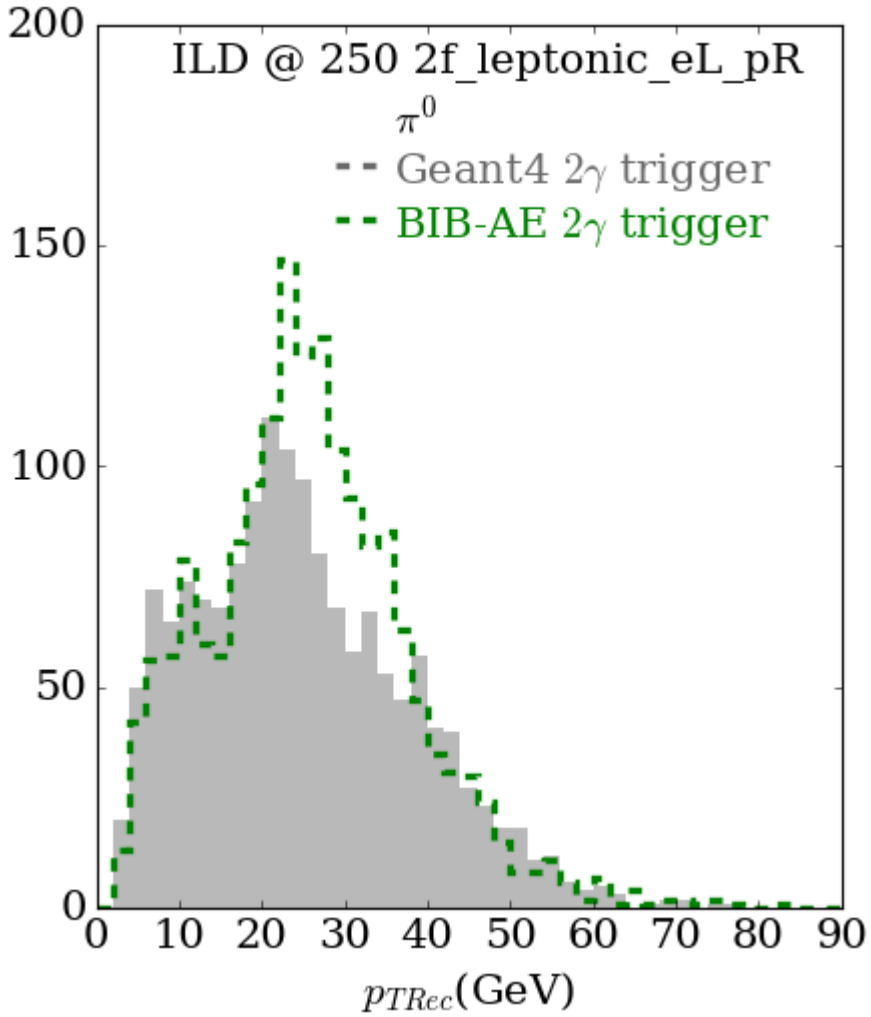

ILD @ 250 2f_leptonic_eL_pR
MC π^0
Two photons trigger
One photon triggers
900
800
700
600
500
400
300
200
100
0
0.5
1.0
1.5
2.0
2.5
π^0 theta (rad.)

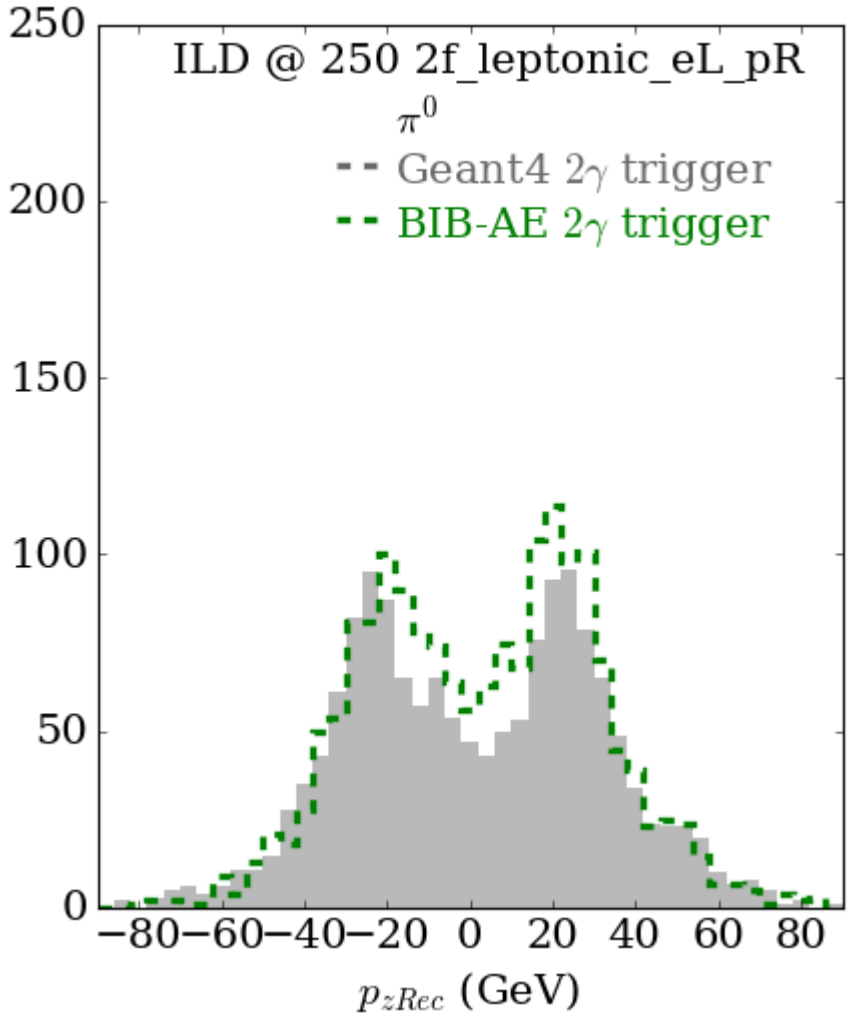
MC Pi0 – pz


ILD @ 250 2f_leptonic_eL_pR
MC π^0
Two photons trigger
One photon triggers
No energy trigger
No trigger
3500
3000
2500
2000
1500
1000
500
0
−60
−40
−20
0
20
40
60
$\pi^0 p_z$ (GeV)

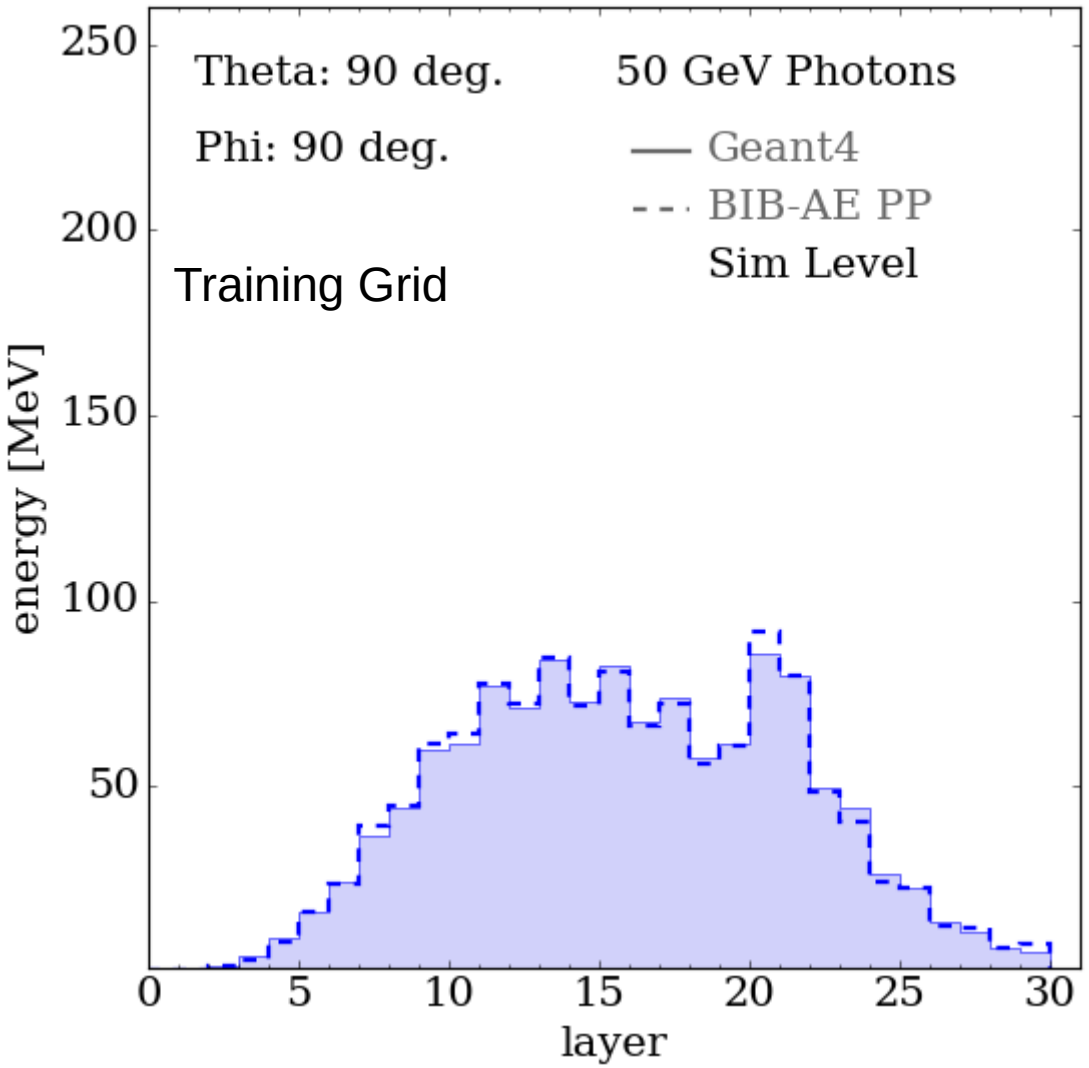

ILD @ 250 2f_leptonic_eL_pR
MC π^0
Two photons trigger
One photon triggers
700
600
500
400
300
200
100
0
−60
−40
−20
0
20
40
60
$\pi^0 p_z$ (GeV)

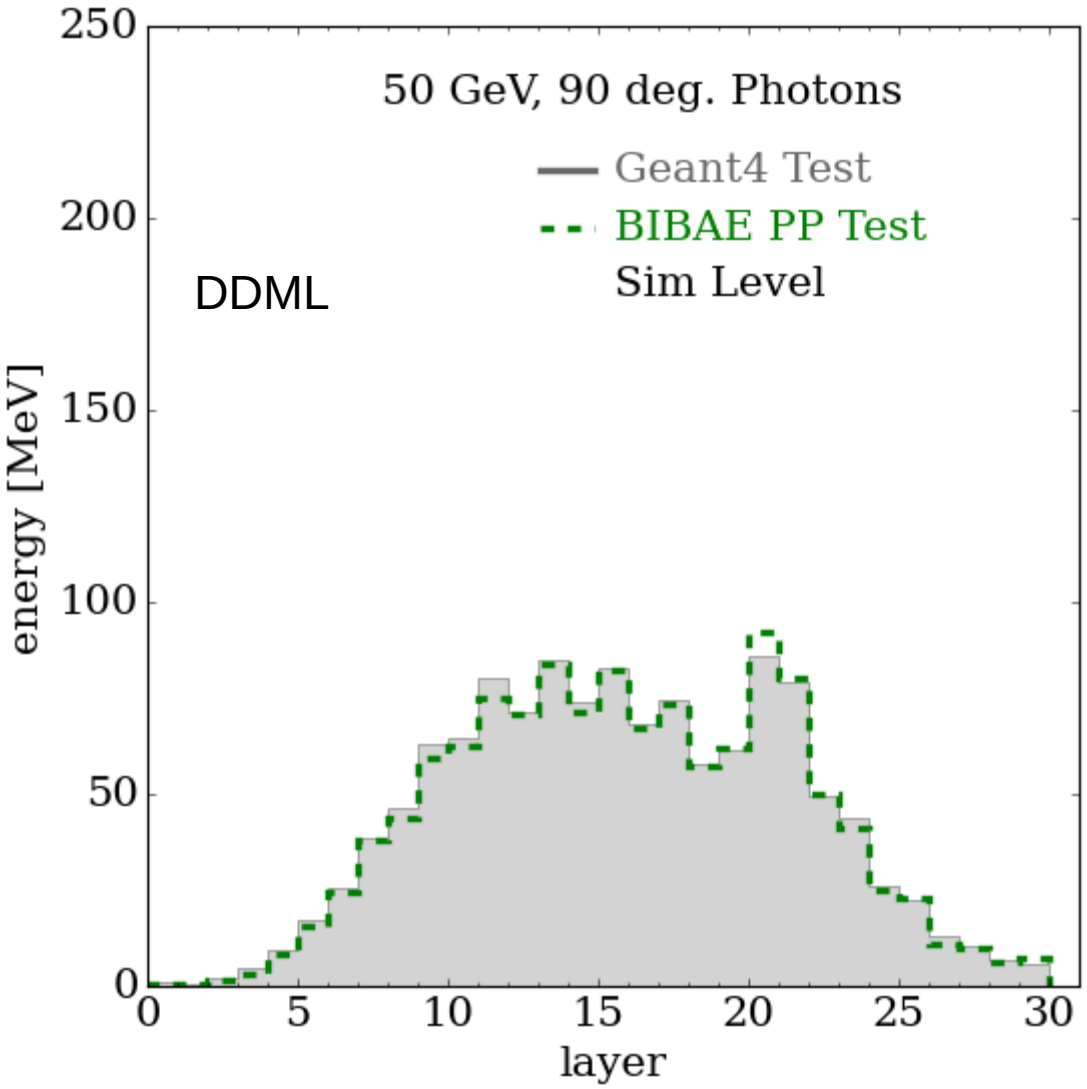
Pi0 Pt and Pz


ILD @ 250 2f_leptonic_eL_pR
π^0
Geant4 2γ trigger
BIB-AE 2γ trigger
200
150
100
50
0
0 10 20 30 40 50 60 70 80 90
p_{TRec}(GeV)

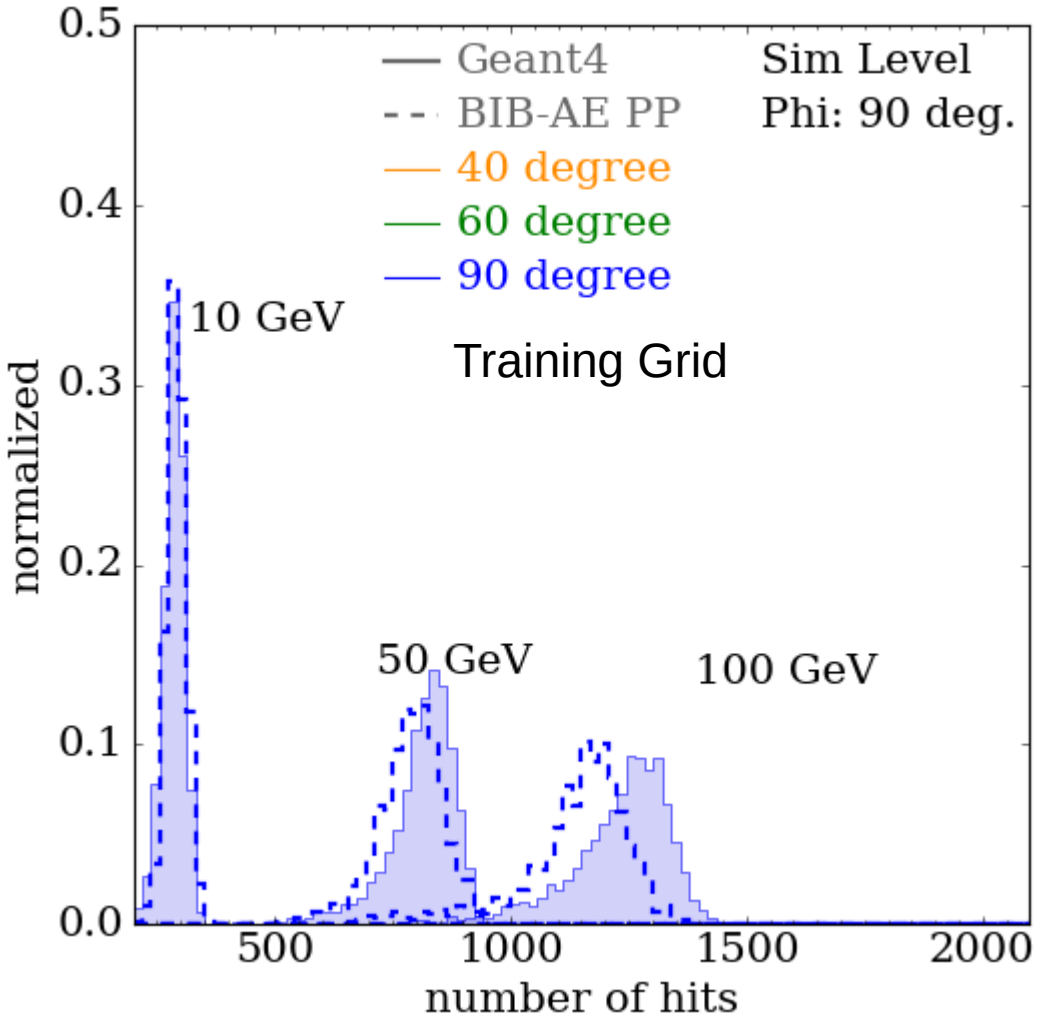

ILD @ 250 2f_leptonic_eL_pR
π^0
Geant4 2γ trigger
BIB-AE 2γ trigger
250
200
150
100
50
0
−80−60−40−20 0 20 40 60 80
p_{zRec} (GeV)

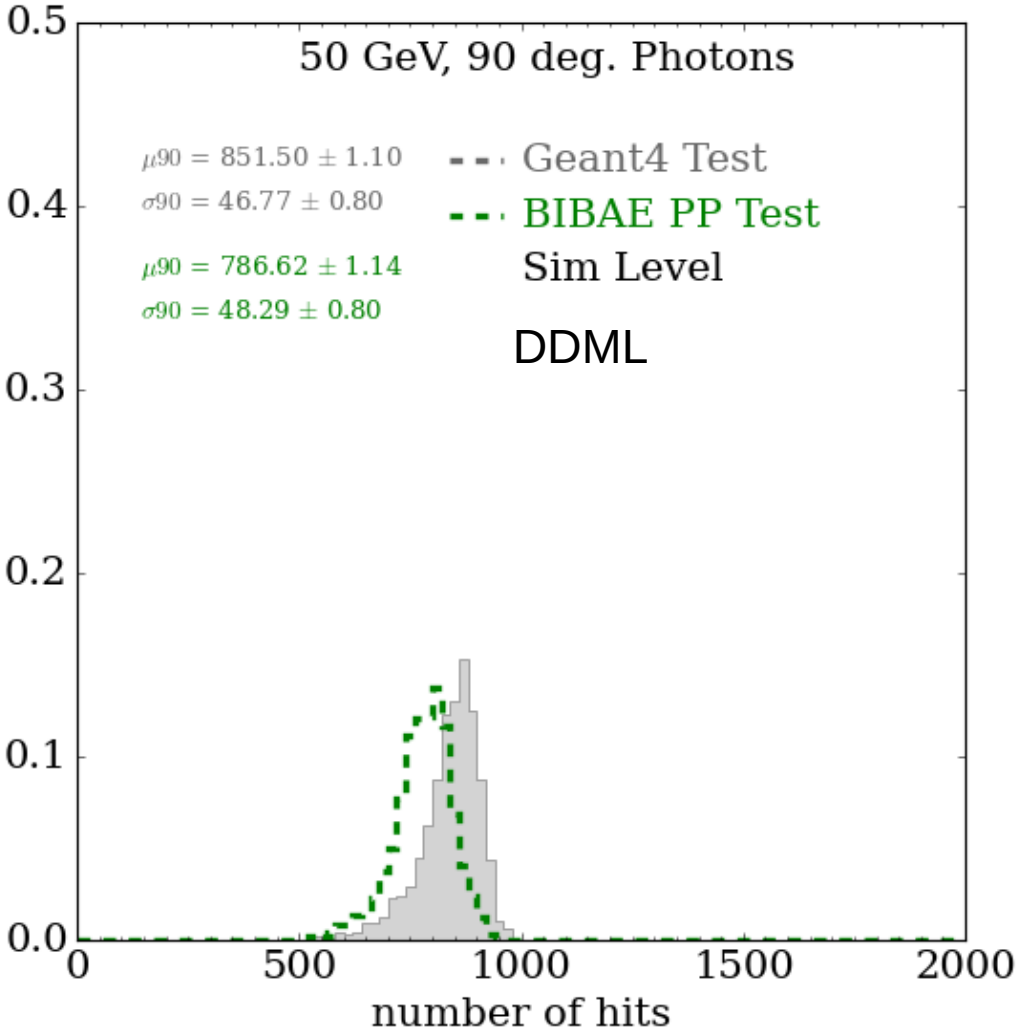
Longitudinal



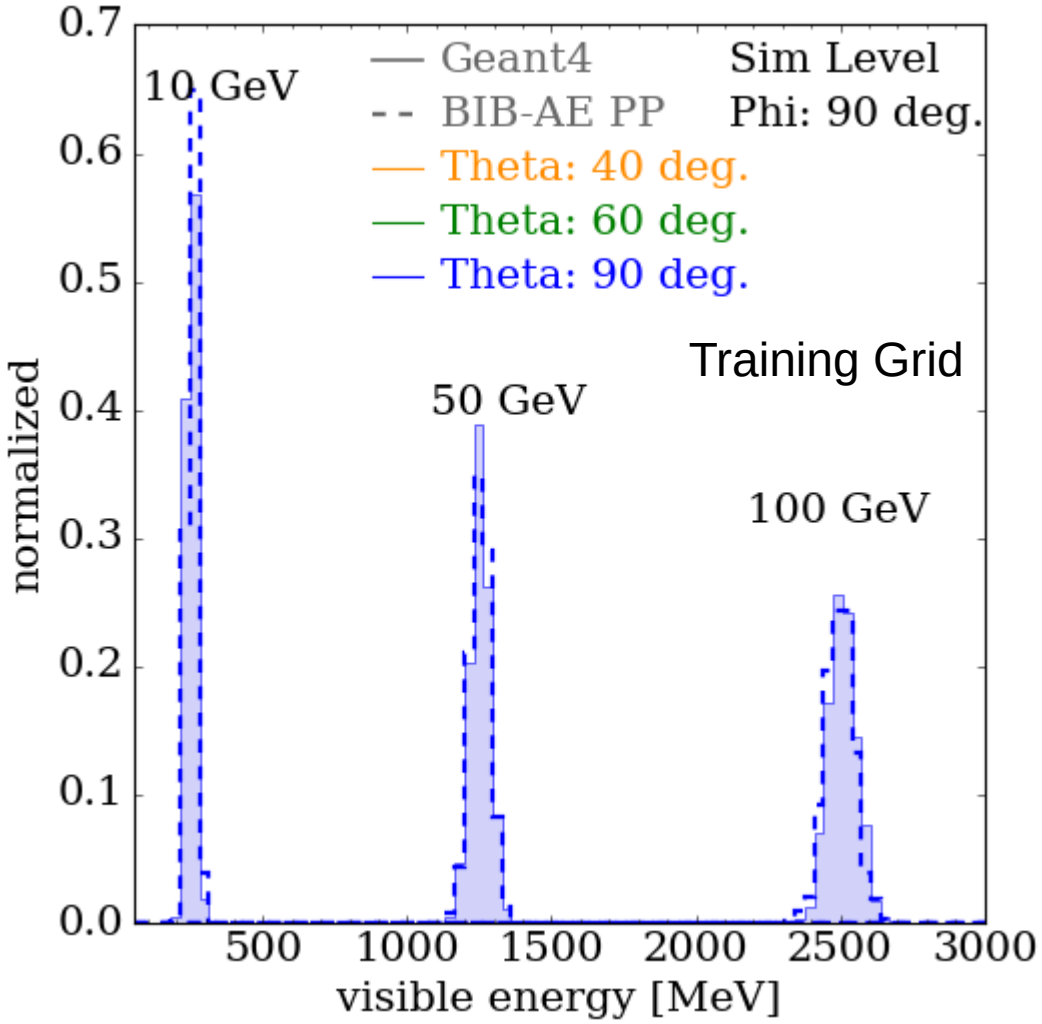


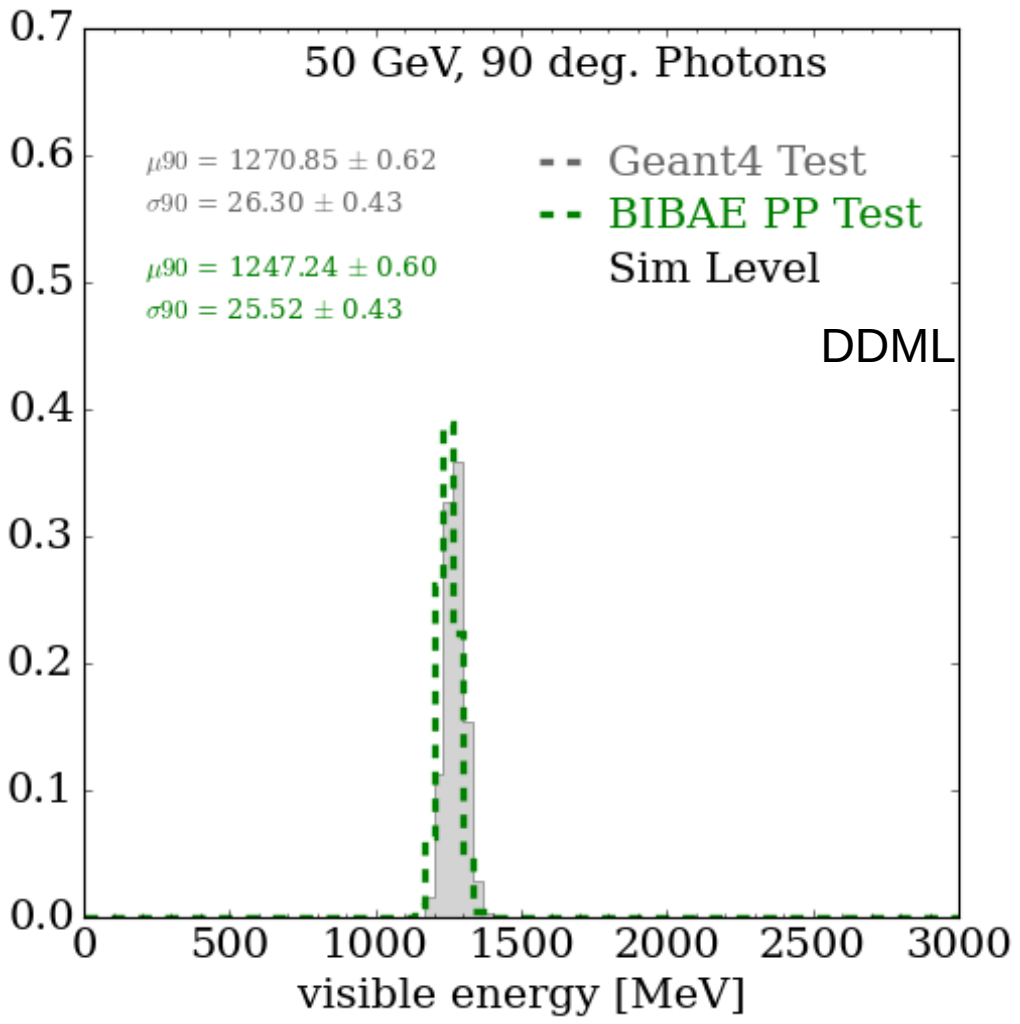
Nhits


Geant4
BIB-AE PP
40 degree
60 degree
90 degree
Sim Level
Phi: 90 deg.
10 GeV
50 GeV
100 GeV
Training Grid
normalized
number of hits
0.0
0.1
0.2
0.3
0.4
0.5
500
1000
1500
2000

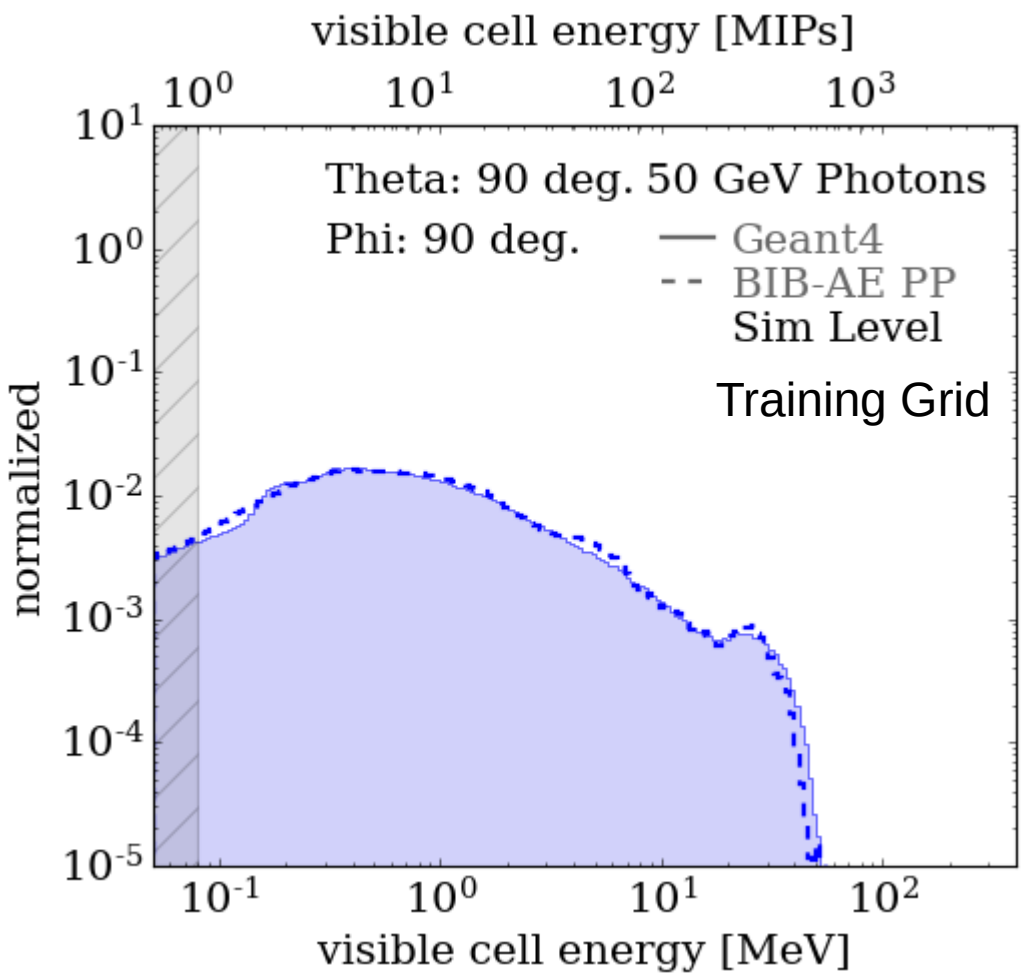

50 GeV, 90 deg. Photons
μ90 = 851.50 ± 1.10
σ90 = 46.77 ± 0.80
μ90 = 786.62 ± 1.14
σ90 = 48.29 ± 0.80
Geant4 Test
BIBAE PP Test
Sim Level
DDML
number of hits
0.0
0.1
0.2
0.3
0.4
0.5
0
500
1000
1500
2000

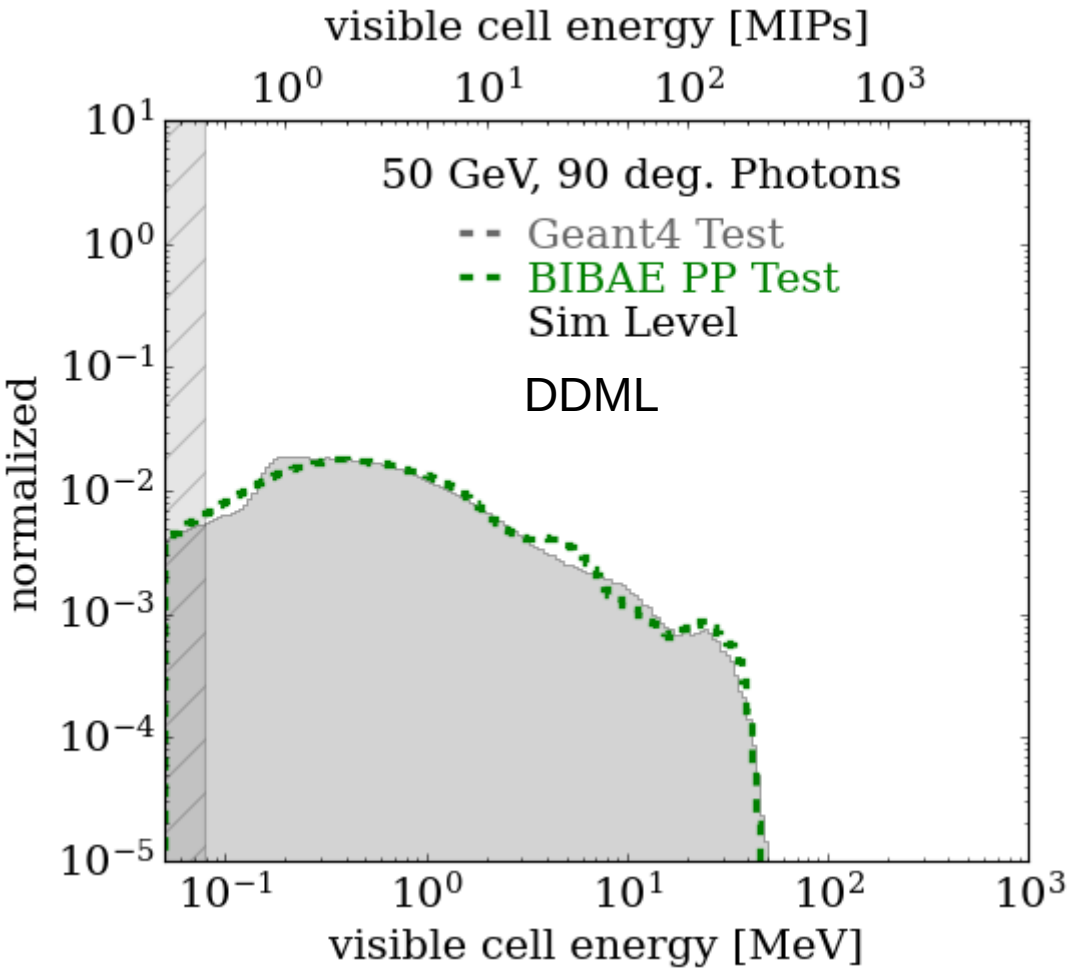
Visible energy





Cell Energy


visible cell energy [MIPs]
Theta: 90 deg. 50 GeV Photons
Phi: 90 deg.
Geant4
BIB-AE PP
Sim Level
Training Grid
normalized
visible cell energy [MeV]


visible cell energy [MIPs]
50 GeV, 90 deg. Photons
Geant4 Test
BIBAE PP Test
Sim Level
DDML
normalized
visible cell energy [MeV]

Radial Energy