SM Compton processes

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Introduction

I am only starting to untangle the wires.
Goals:

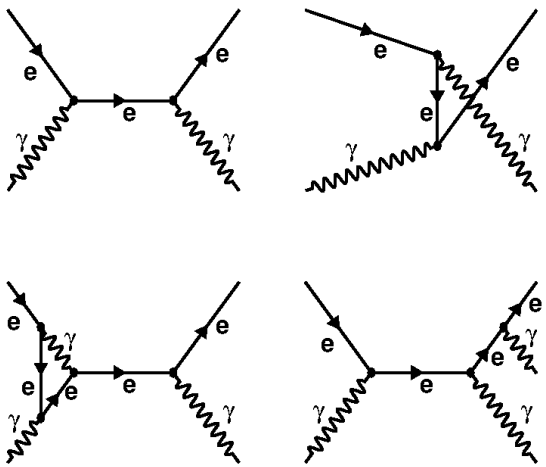
- Optimize Hall-D detectors, trigger, and software to measure single electron, pair (e^+e^-), and triplet (e^+2e^-) events to search for DM (see my talks of last year)
  - Basic requirements: GlueX with solenoid turn on
  - CCAL and solid target would be major pluses
  - + new detectors to be determined (tracker, plastic scintillator/paddle, and/or Cherenkov detectors covering polar angle between 0.?^{o} and 1.?^{o})
- SM Compton processes expected to be the main backgrounds for invisible searches (e.g. LLP) and can also be used as a control channel
- SM pair and triplet processes expected to be the main backgounds for visible searches (e.g. $A' \rightarrow e^+e^-$ in the target) and can also be used as control channels (not discussed in this talk)

SM Compton processes

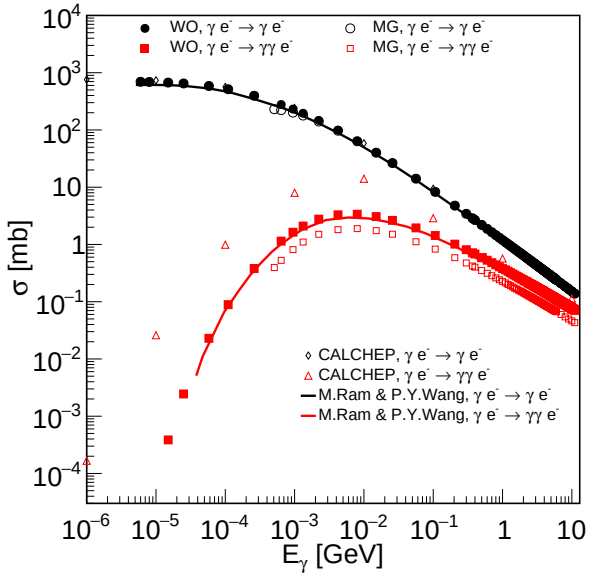
QED processes known theoretically since decades but almost no experimental measurements above 1 GeV in incident photon-beam

- Single Compton process, $\gamma e^- \rightarrow \gamma e^-$, O. Klein and Y. Nishina, *Z. Phys.*, **52**, 853 (1929)
- Double Compton process, $\gamma e^- \rightarrow \gamma\gamma e^-$, M. Ram and P.Y. Wang, *Phys. Rev. Lett.*, **26**, 476 (1971)
- N0 and NLO corrections, K.J. Mork, *Phys. Rev.*, **A4**, 917 (1971)

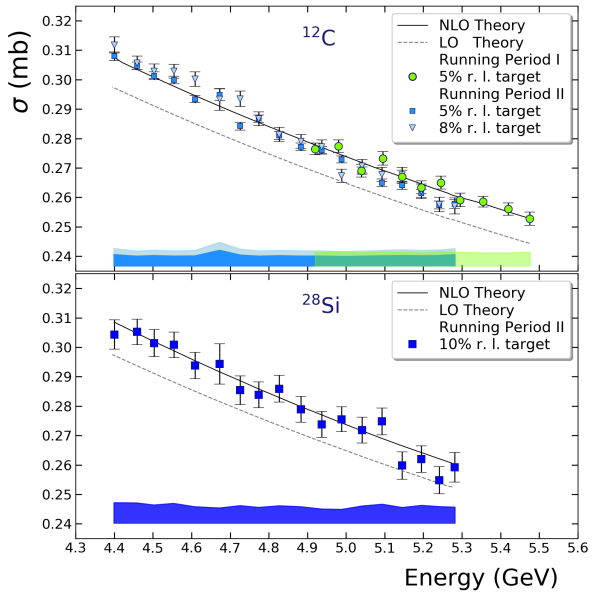
- Feynman diagrams



- Calculation for fixed order and tree-level process



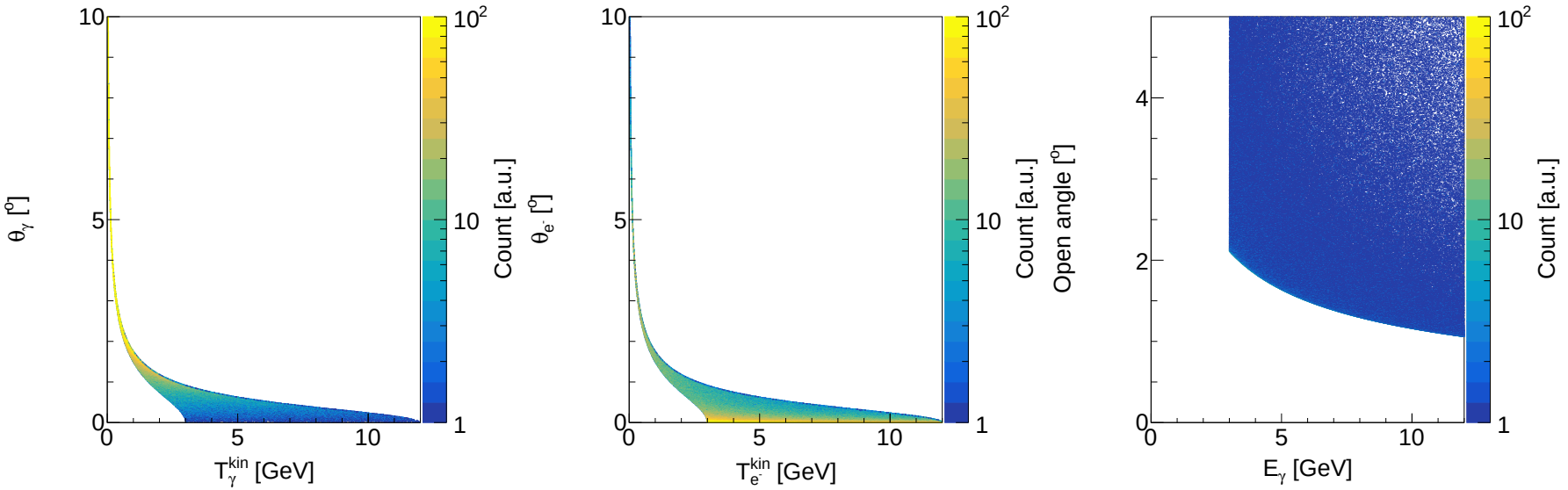
- PrimEX cross-section measurements (normalized to Z), Phys. Lett B797, 134884 (2019)



GlueX/PrimEX-D can repeat and extend the experimental measurements from 3 GeV to 12 GeV

SM Compton kinematics

- Most of the energy is transfered to the electron
- Final state particles polar angles is below 10^o
- Open angle between recoiling atomic electron and photon is decreasing with increasing incident photon-beam energies



- Large electron fraction goes to CCAL
- Large photon fraction goes to FCAL

MC simulation studies

Simulate 1M events with Geant3 and Geant 4 for two runs, 30496 (GlueX) and 61323 (PrimEX-D phase I):

- Default conditions with master data base:
  - GlueX with B-field and no CCAL
  - PrimEX-D phase I without B-field and CCAL
- Default conditions with local data base:
  - GlueX with B-field and no CCAL
  - PrimEX-D phase I without B-field and with CCAL
- GlueX with B-field and CCAL (with local data base)
- GlueX without B-field and with CCAL (with local data base)
- PrimEX-D phase I with B-field and CCAL (with local data base)

=> 28 different simulations produced by MCwrapper on ifarm

Reconstruction and analysis with (master) halld_recon (ReactionFilter with all standard build in cuts) and DSelector

- CCAL included in the neutral shower factory
- Covariance error matrix determination not yet finished, use at the moment future FCAL insert values/functions

Selection criteria

Two cases:

- $\gamma e^- \rightarrow \gamma\gamma$ (no KinFit)
- $\gamma e^- \rightarrow \gamma e^-$ (with and without KinFit)

Final state "γ" corresponds to neutral shower without any corresponding "charged track"
Final state "electron" corresponds to events with at least 6 hits in the FDC and possible match in FCAL
=> Electron producing 5 FDC hits or less and FCAL match are considered as "γ"s
(=> Matching between TOF and FCAL not yet implemented)
Basic selection criteria:

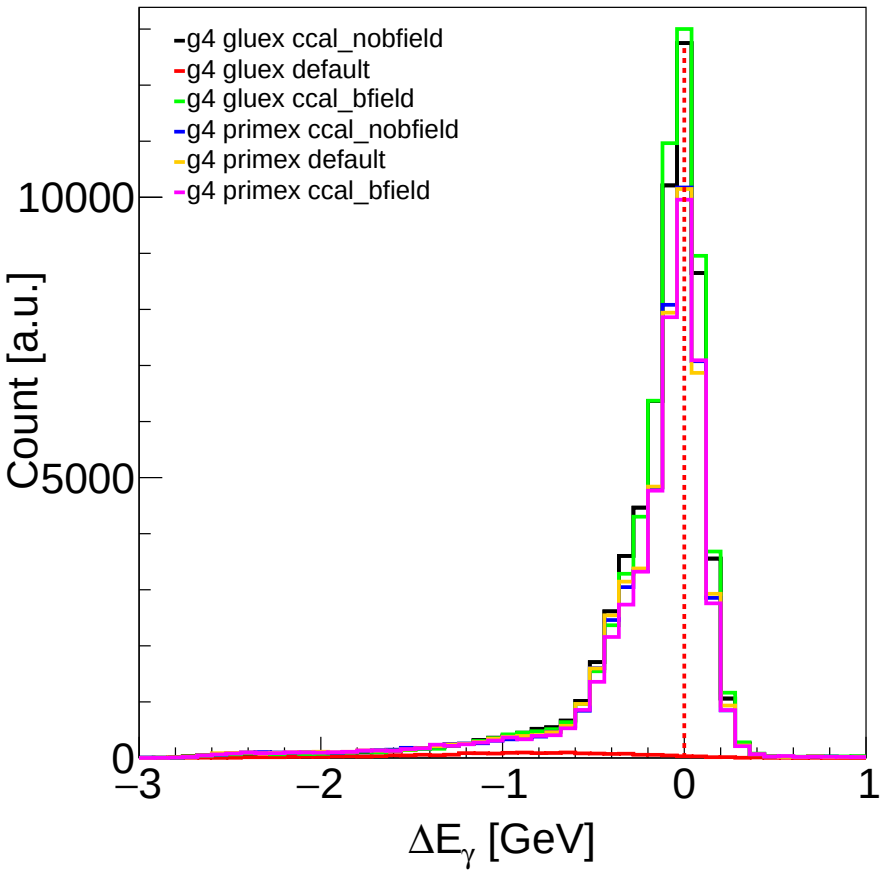
- Un-used track = 0
- Un-used shower = 0
- Coplanarity cuts, $|\phi_\gamma - \phi_{e-}| = 180^o$
- Polar angle cuts, $\theta_\gamma \leq 3^o$ and $\theta_{e-} \leq 3^o$

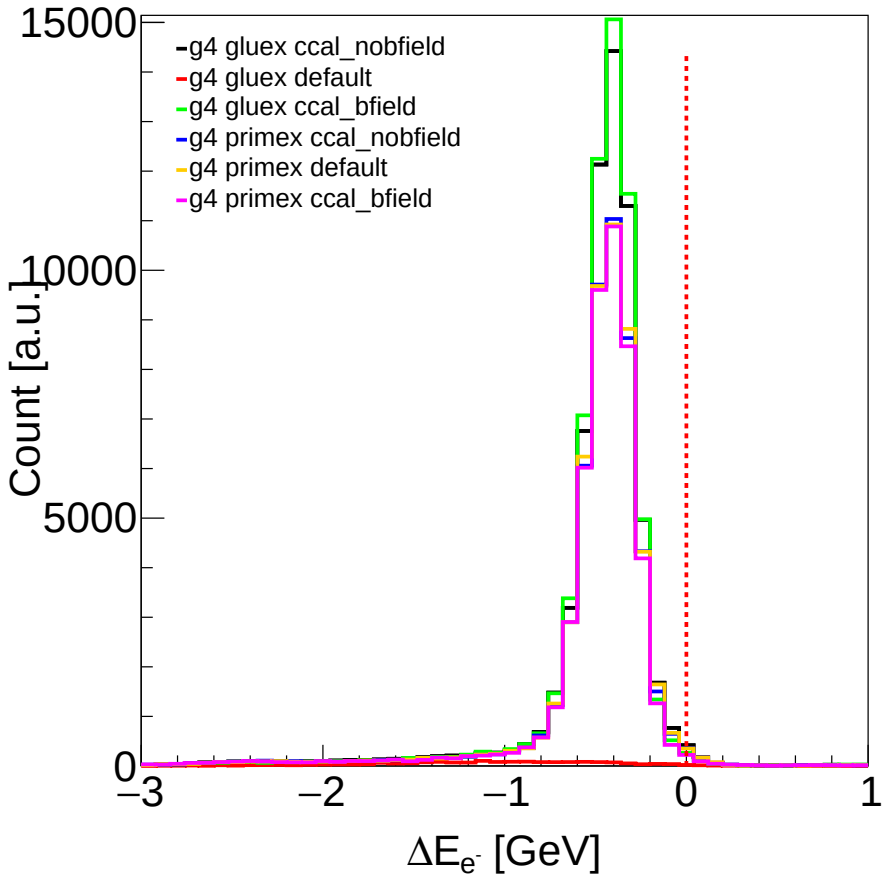
Other quantities that can be used in the selection and/or as observable:

- Final states particles missing mass squared, M^2
- Energy conservation (measured), $E_{total}^{meas.} - E_\gamma - m_{e-}$
- Energy conservation (partially calculated), $E_{total}^{Compton} - E_\gamma - m_{e-}$
  - $E_{total}^{Compton} = E_1^{Compton} + E_2^{Compton}$ with
  - $E_i^{Compton} = \frac{E_\gamma}{1+\frac{E_\gamma}{m_{e-}}(1-cos\theta_i)}$

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

Truth matching to ID which of the "γ" is in fact an electron

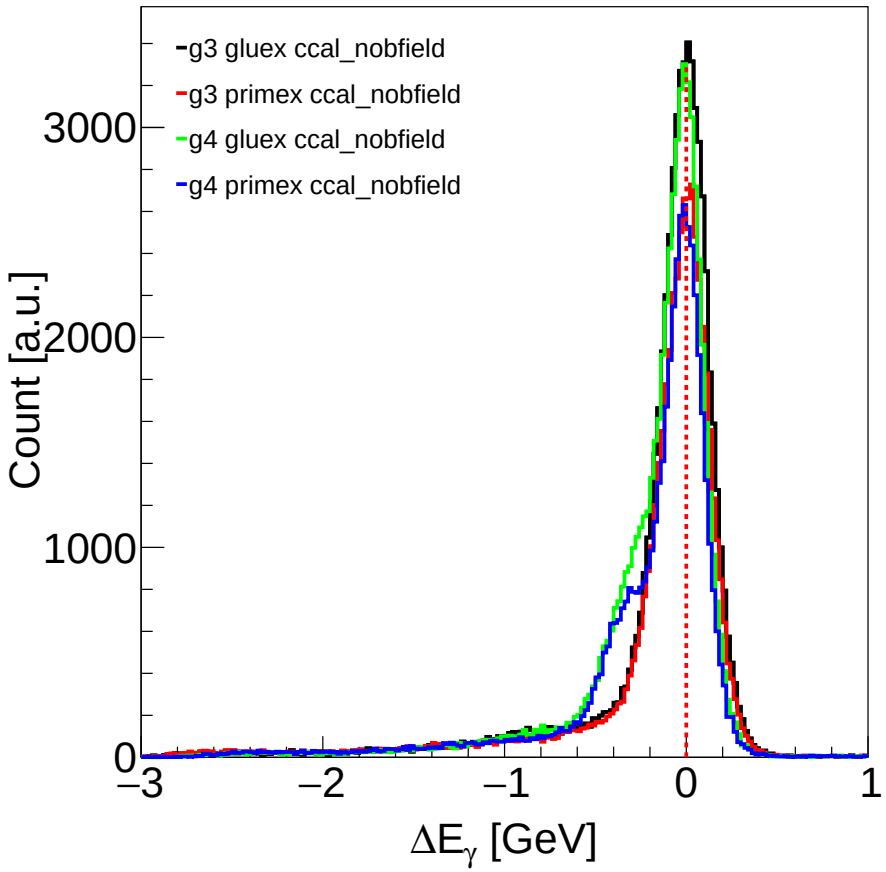


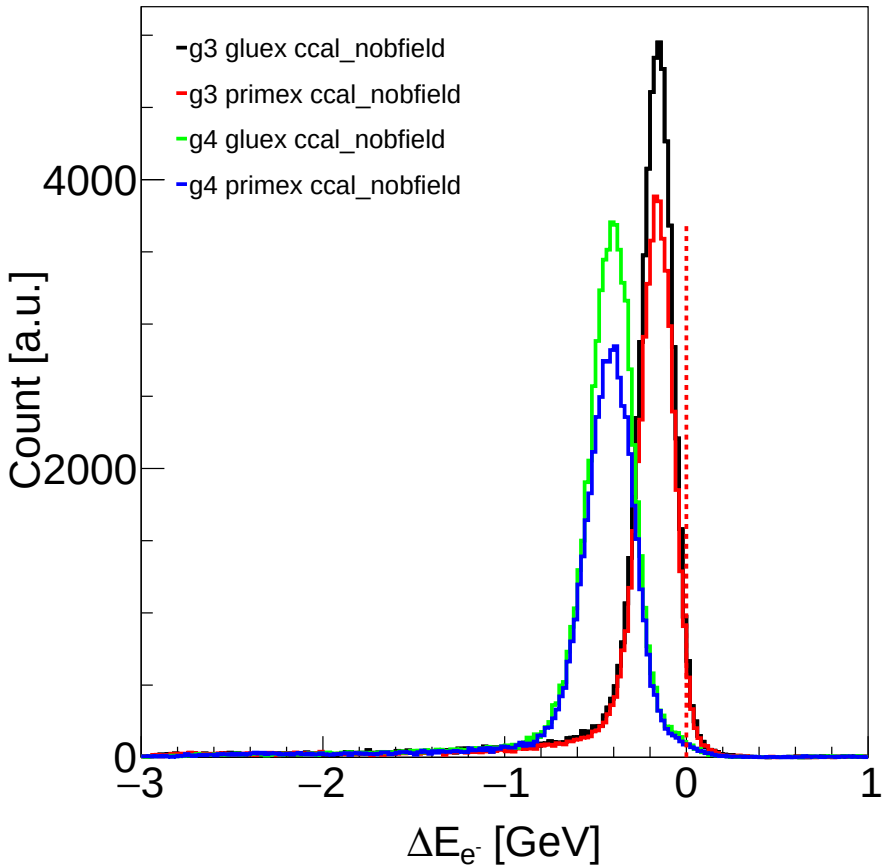


- Less events reconstructed for PrimEX-D run (mask effect and/or different mc calibration tables?)
- CCAL increases dramatically the detection efficiency (from ∼0.1% to ∼5% in average)
- As expected electron is off

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

And Geant3 and Geant4

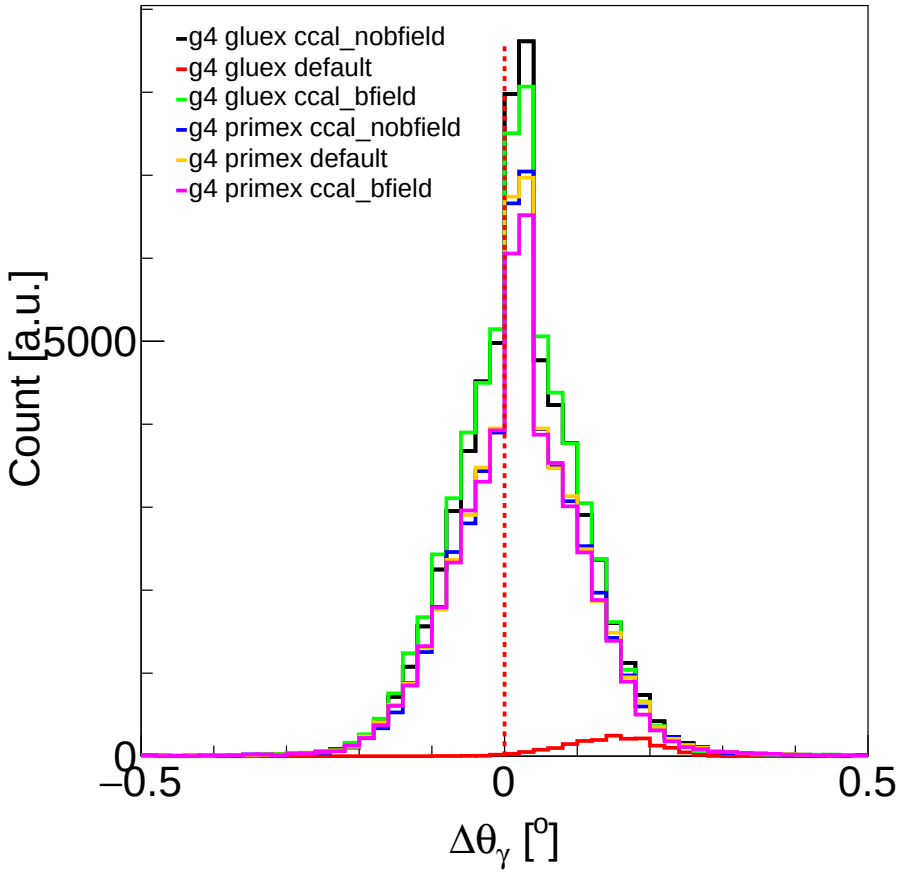


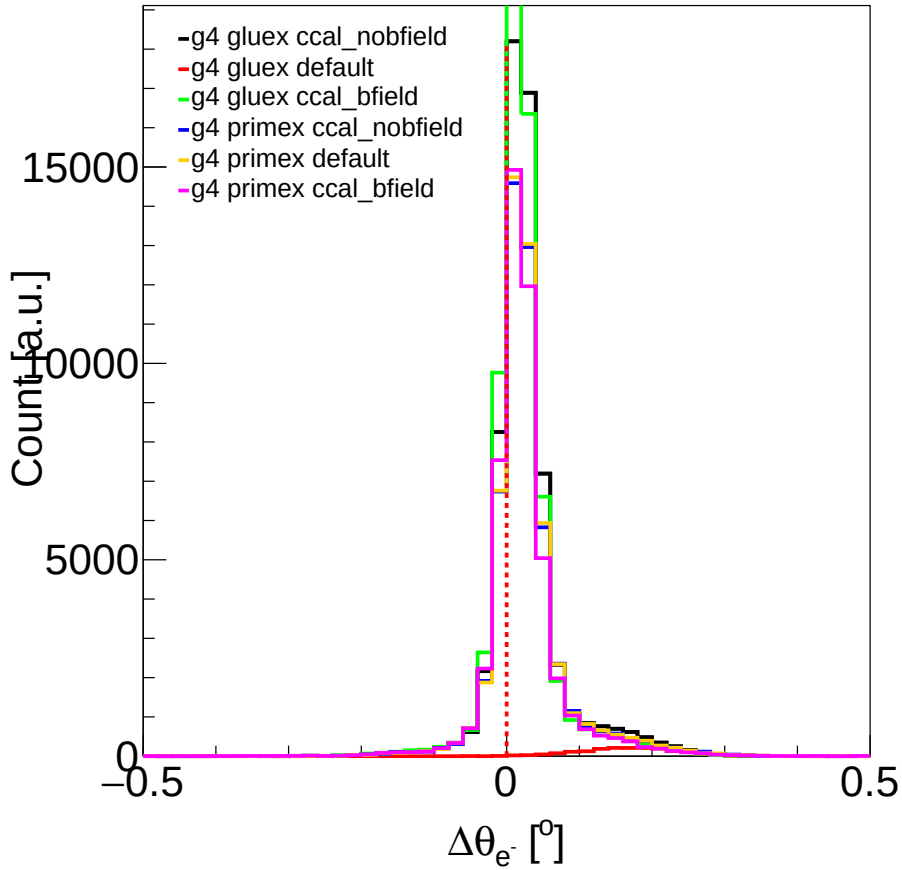


- Energy deposited by photons is slightly different
- Energy deposited and/or loss by electrons is dramatically different

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

- Photon resolution worse than electron resolution
- Polar angle for both electron and photon slightly off compared to thrown

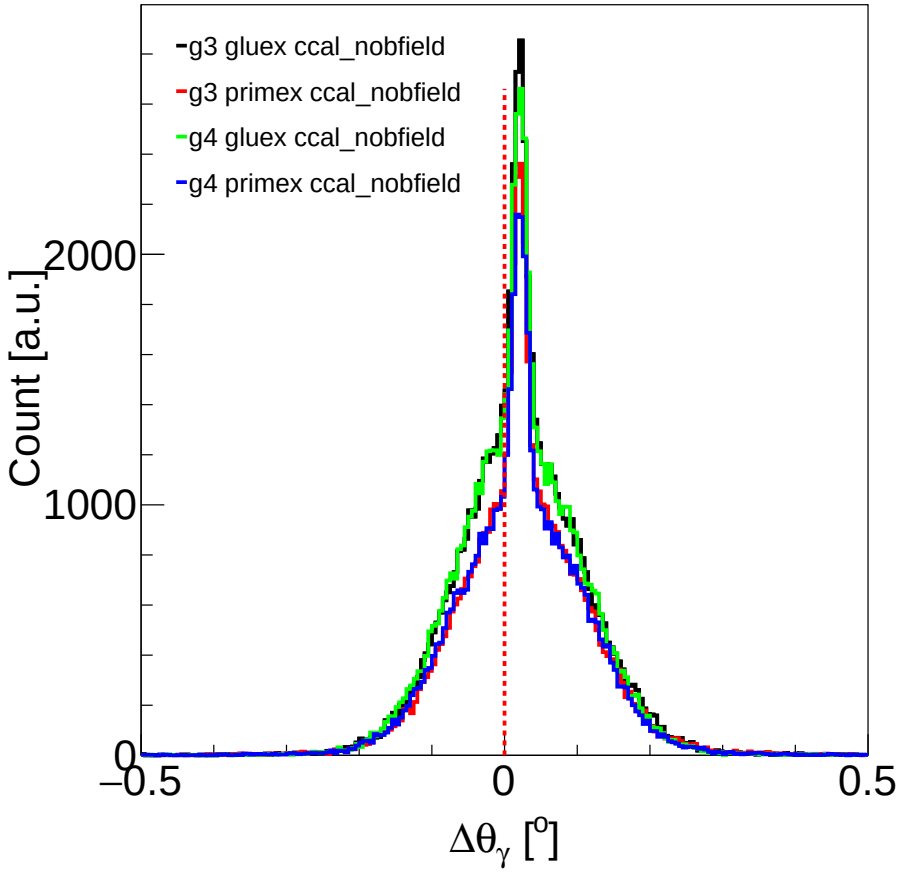


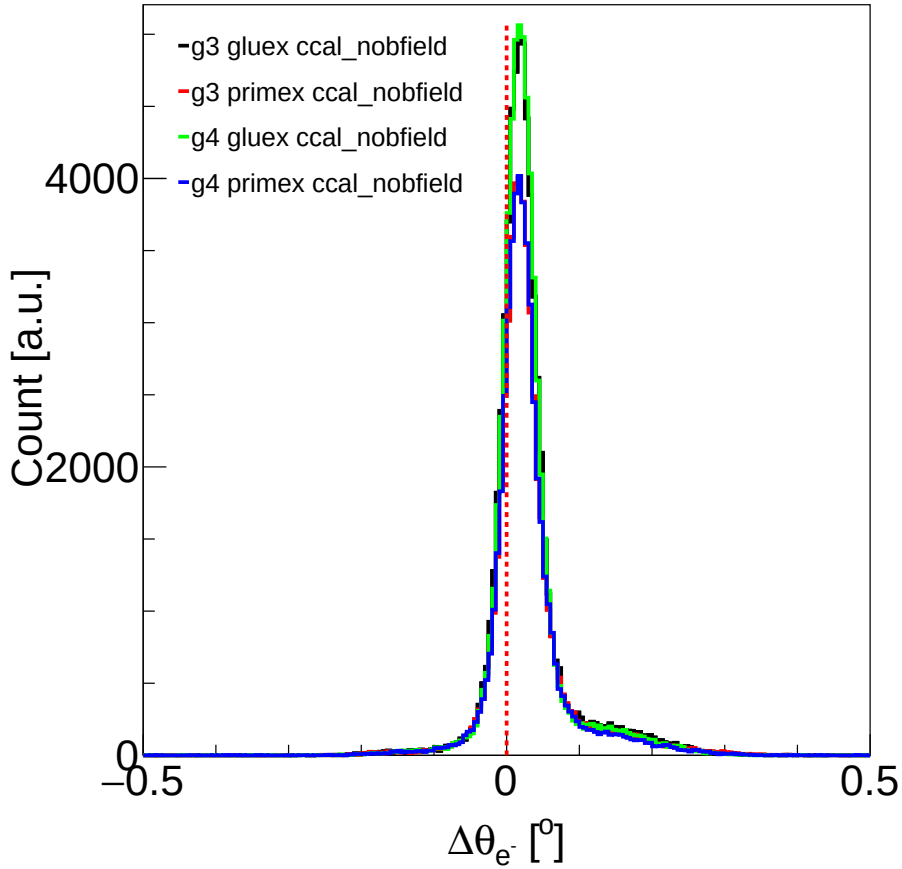


Polar angle not affected by the magnetic field (as expected)

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

And Geant3 and Geant4

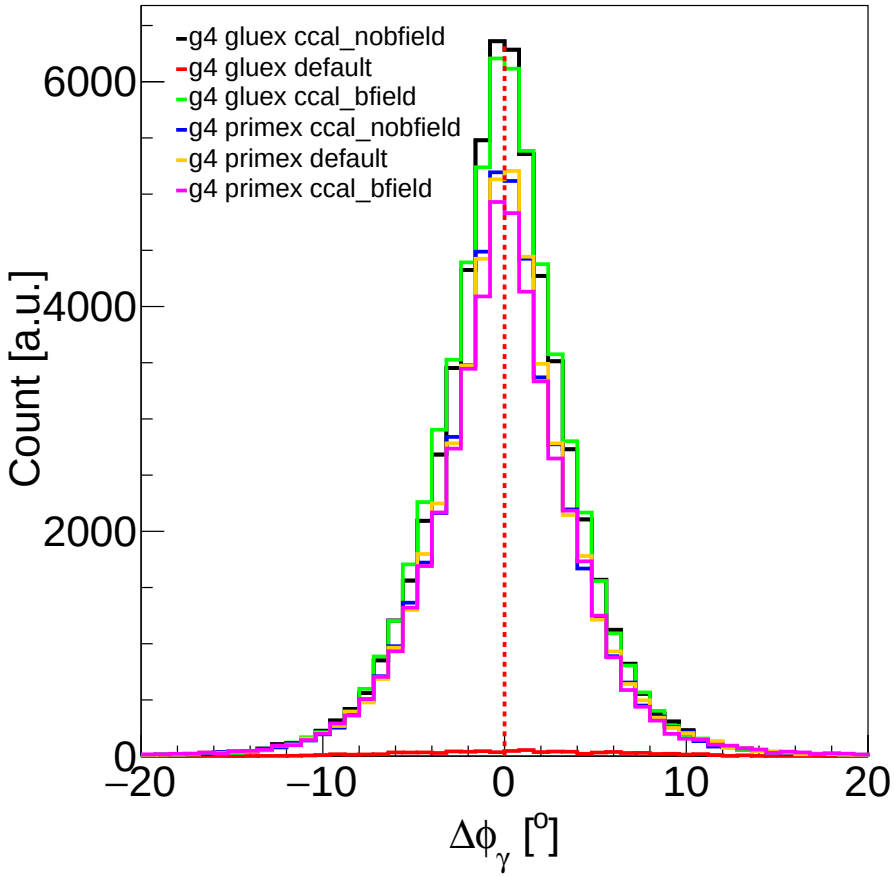


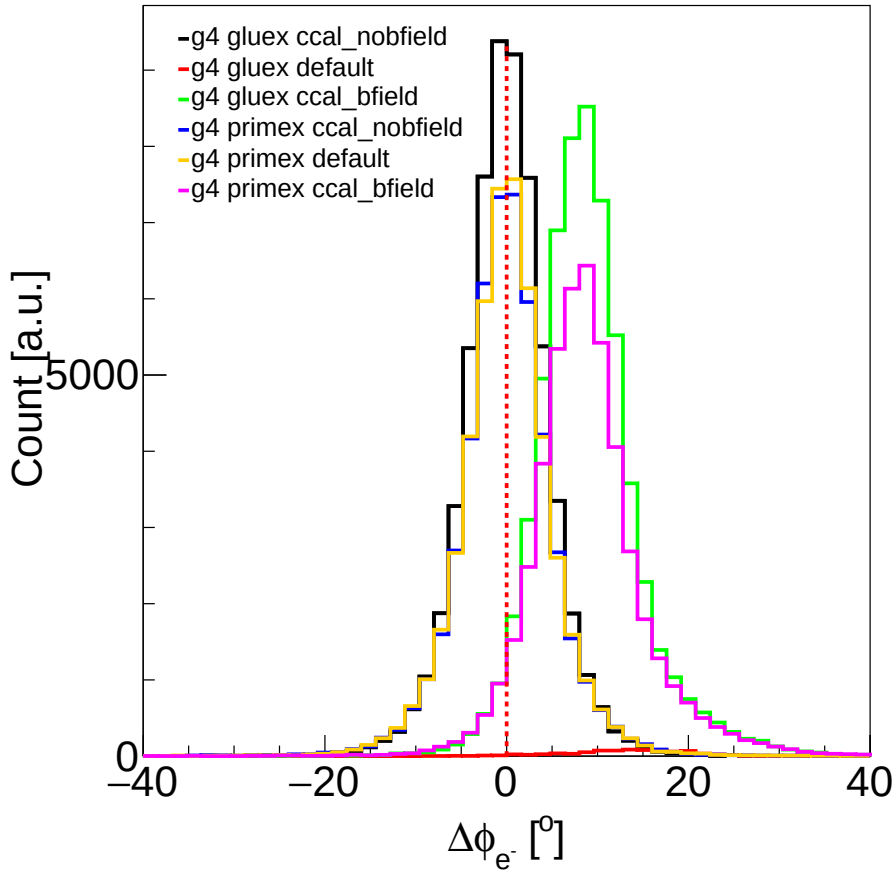


No comments

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

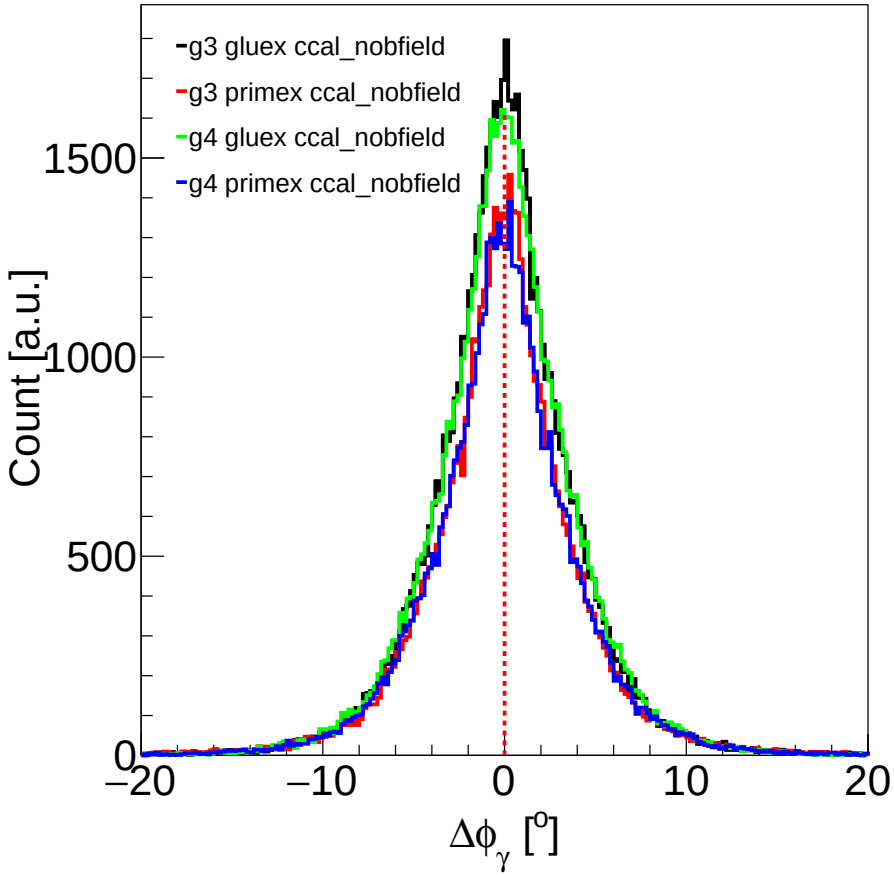
- Photon and electron resolutions fairly similar
- B-field introduces a bias as expected

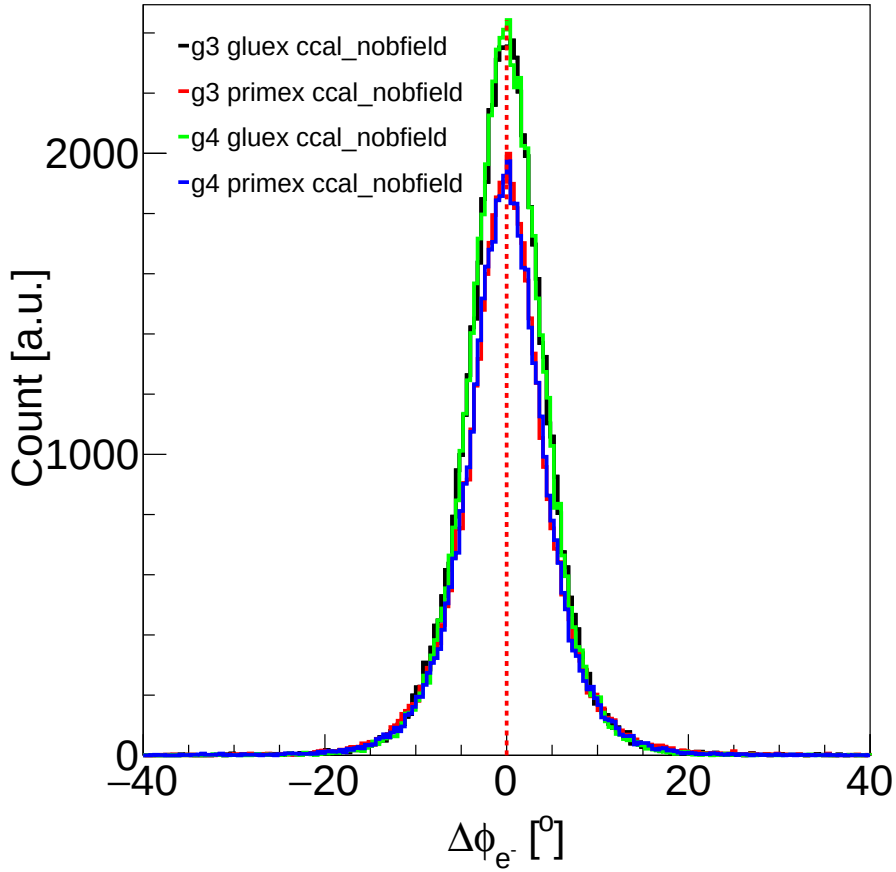




$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

And Geant3 and Geant4

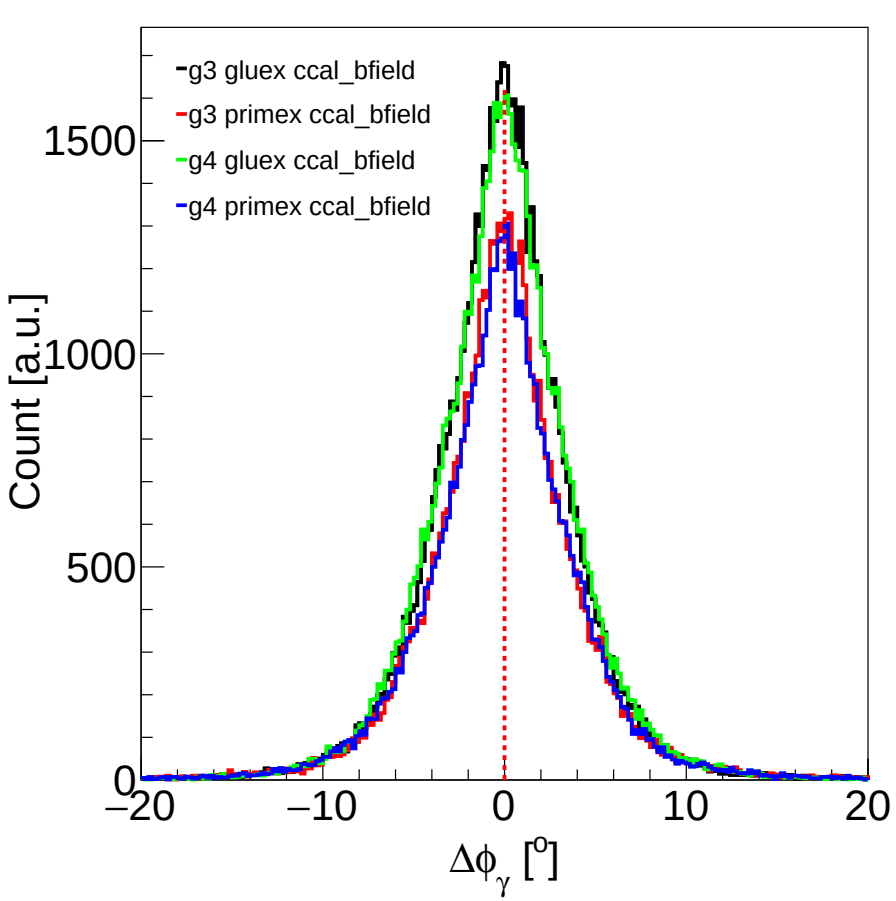


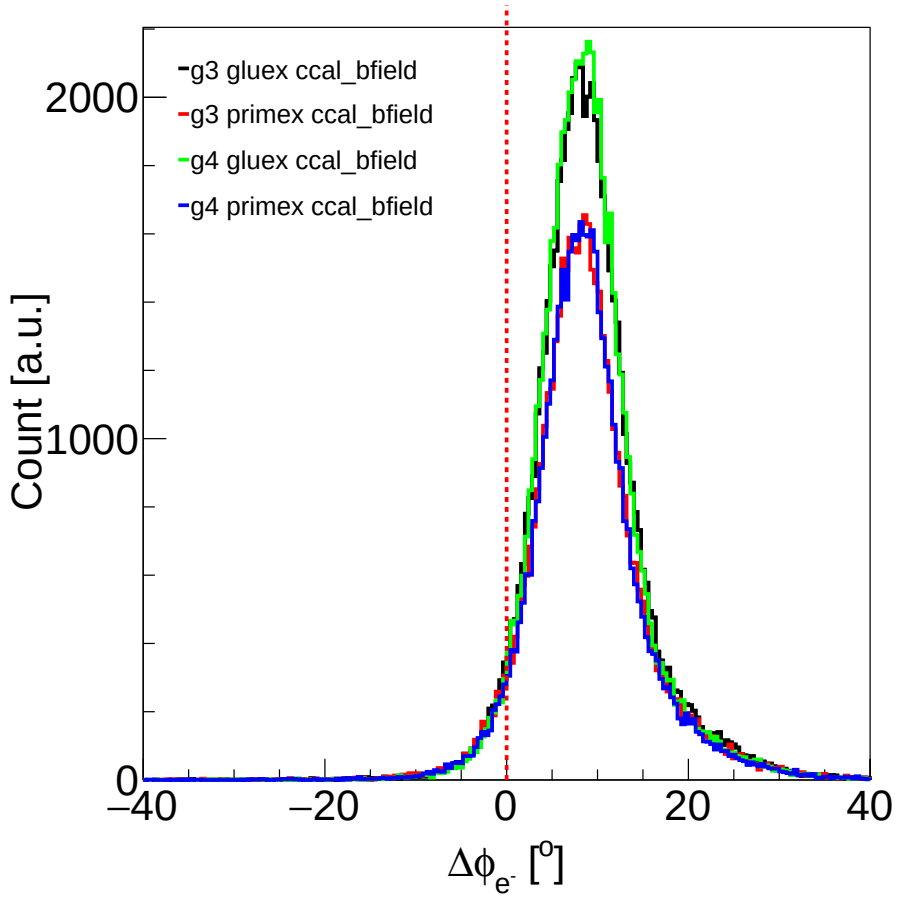


No comments

$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

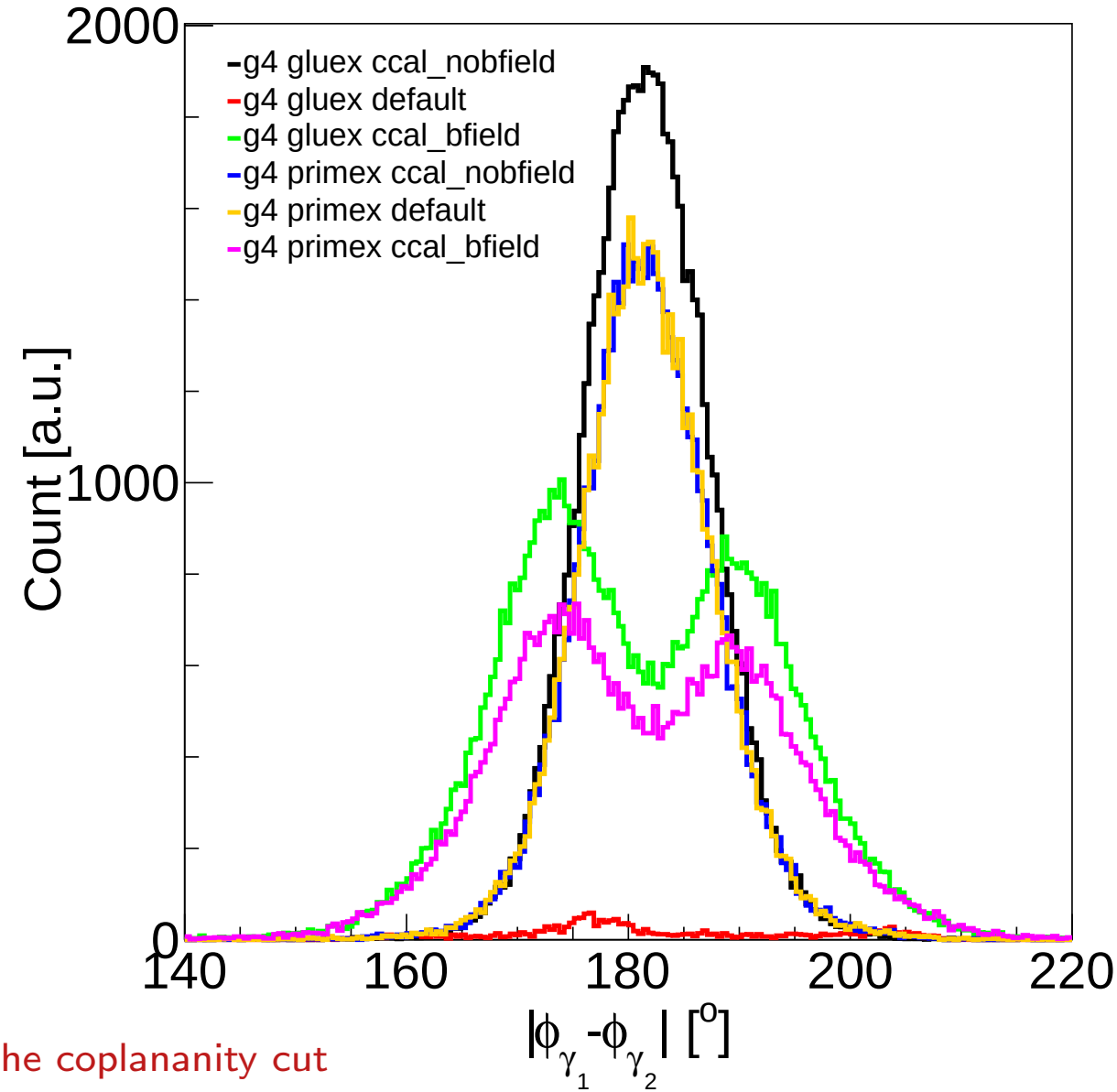
And Geant3 and Geant4





No comments

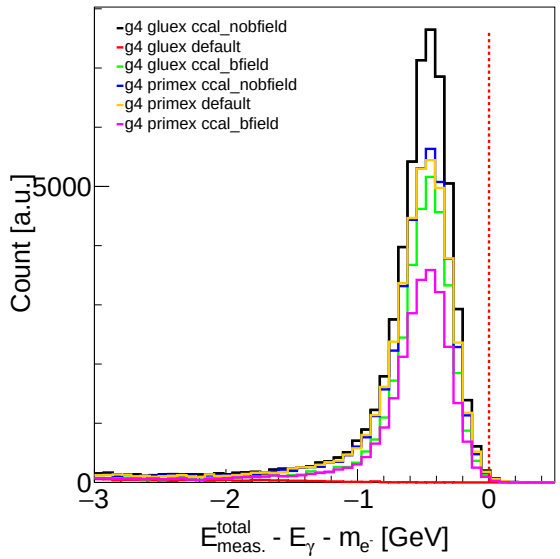
$\gamma e^- \rightarrow \gamma\gamma$, coplanarity cut

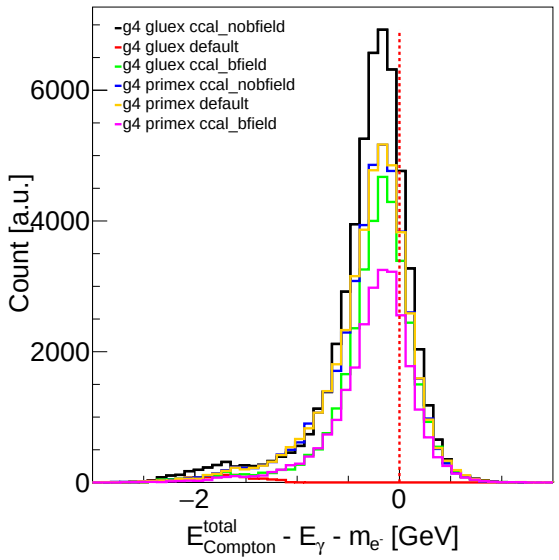


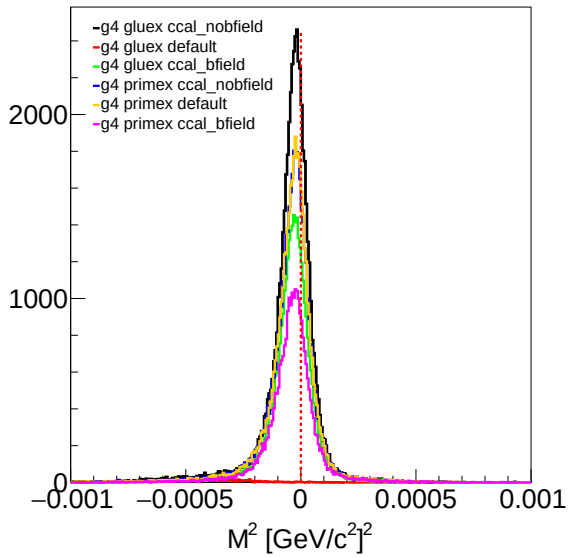
B-field affects the coplananity cut

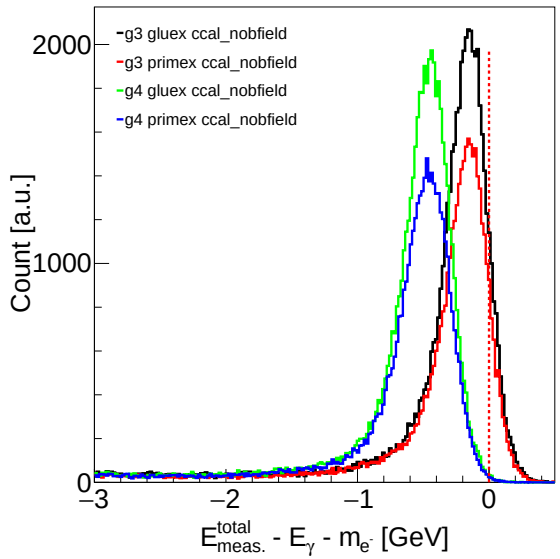
$\gamma e^- \rightarrow \gamma\gamma$, other variables

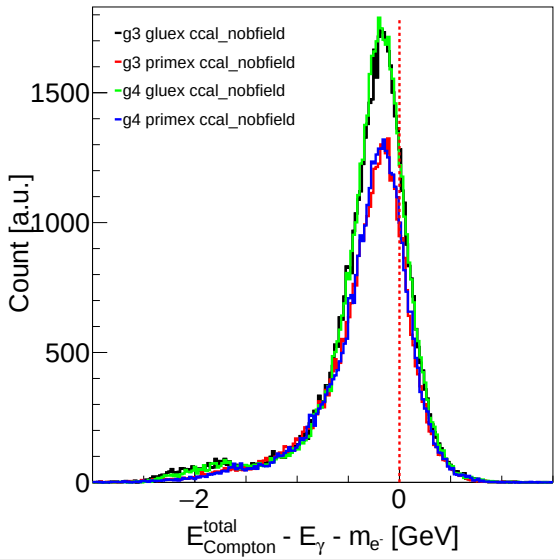
- Measured energy conservation
- Partially calculated energy conservation
- Final state missing M^2

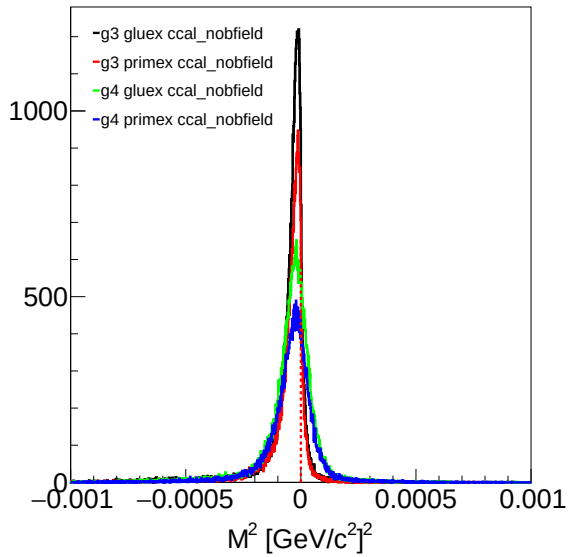






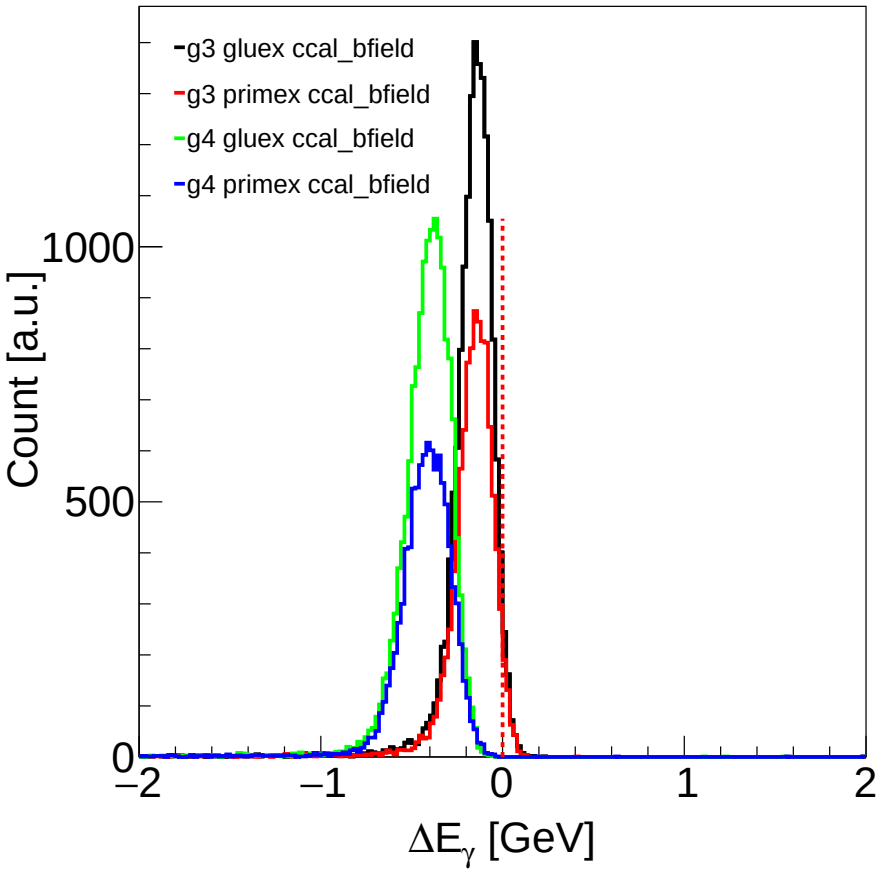


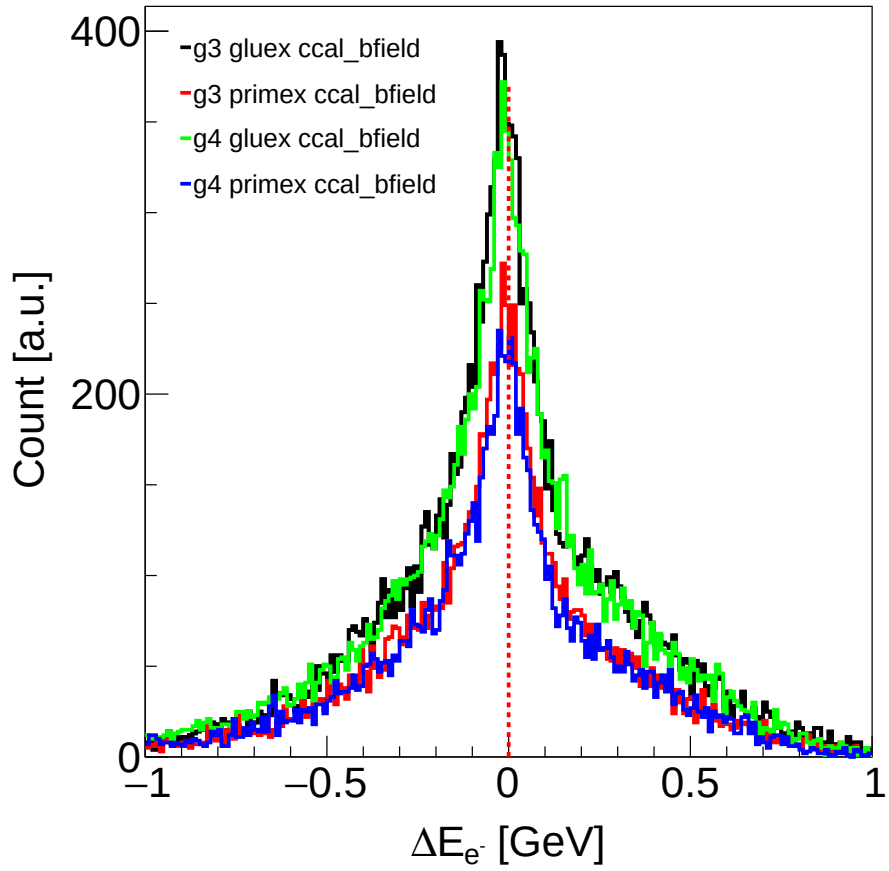




$\gamma e^- \rightarrow \gamma e^-$, comparison between thrown and measured

Truth matching



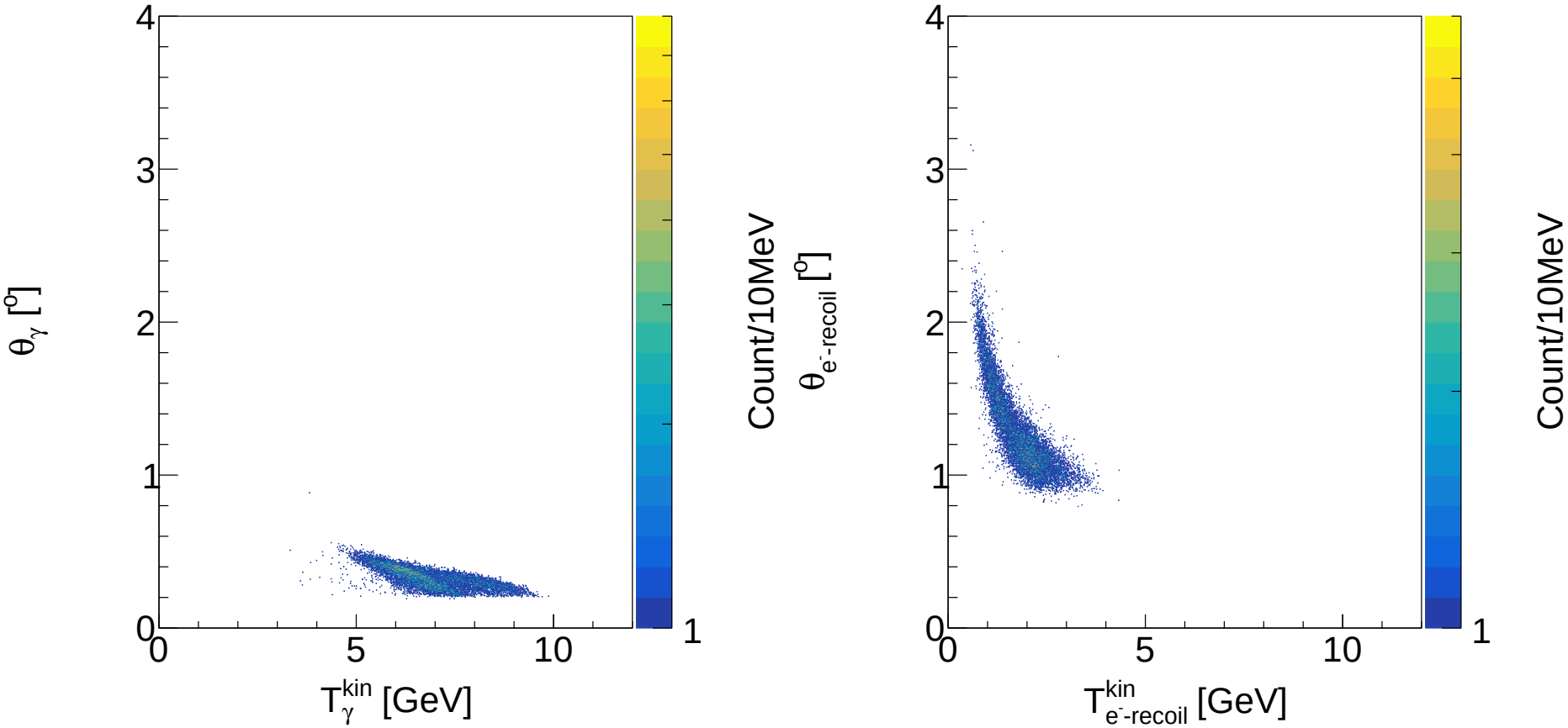


- Photon in CCAL and electron in FCAL
- CCAL not properly implemented in neutral factory, simulation and/or energy dependence calibration needs tuning?

Difference in slide 9 due to CCAL probably (to be checked)

$\gamma e^- \rightarrow \gamma e^-$, reconstruction kinematics

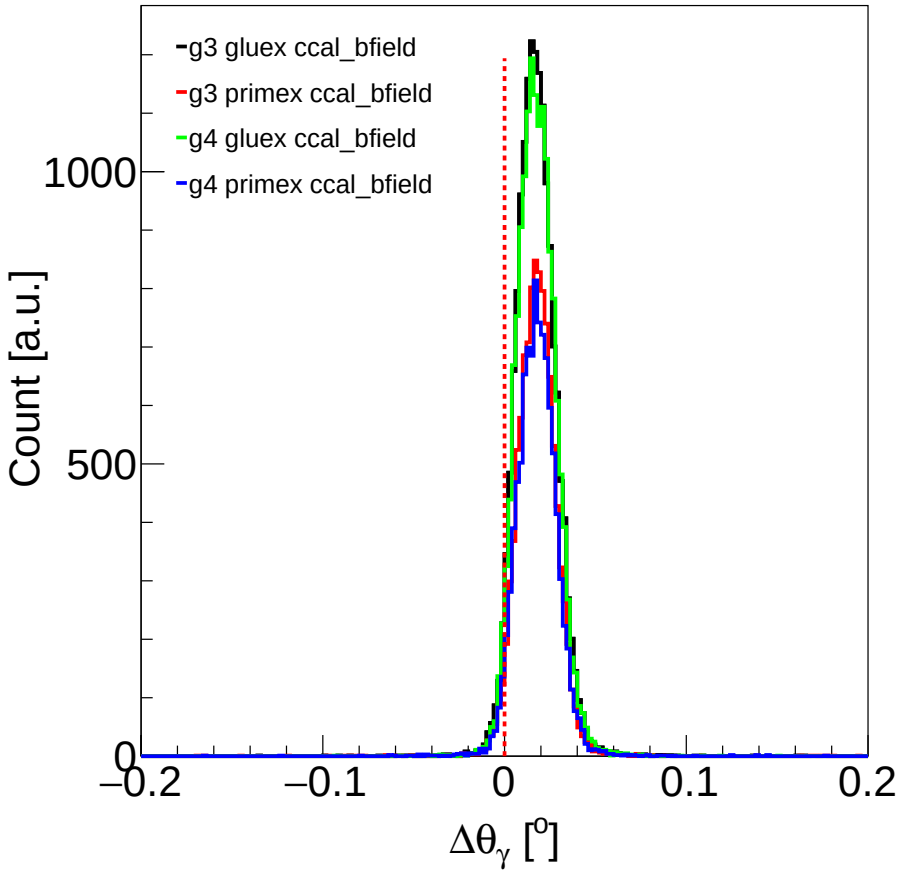
- Photon in CCAL
- Electron in FCAL

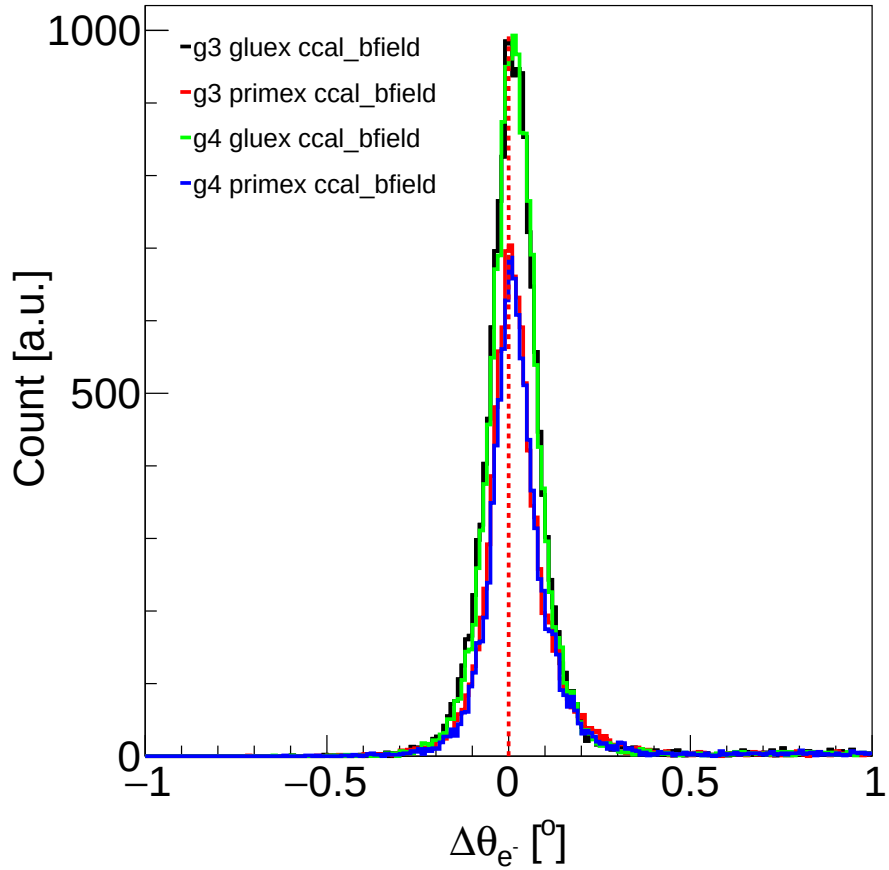


- FCAL starts to cover polar angle above 0.8^o
- CCAL covers polar angle between 0.2^o and 0.6^o

$\gamma e^- \rightarrow \gamma e^-$, comparison between thrown and measured

- Similar photon and electron resolutions
- Polar angle for both electron and photon slightly off compared to thrown

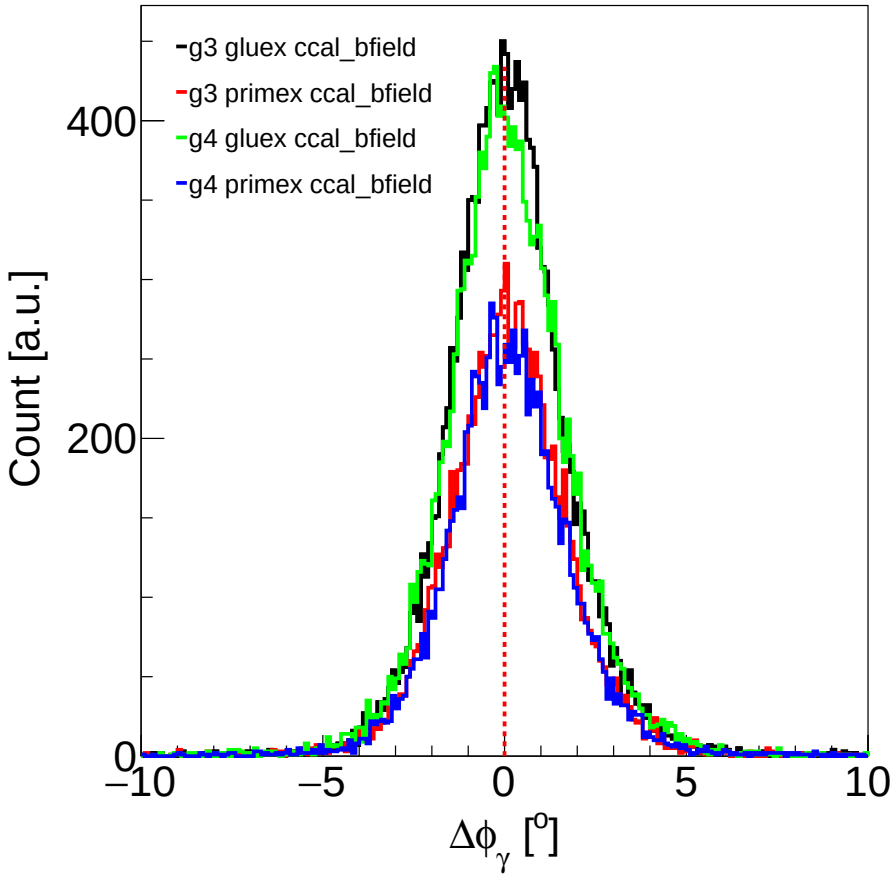


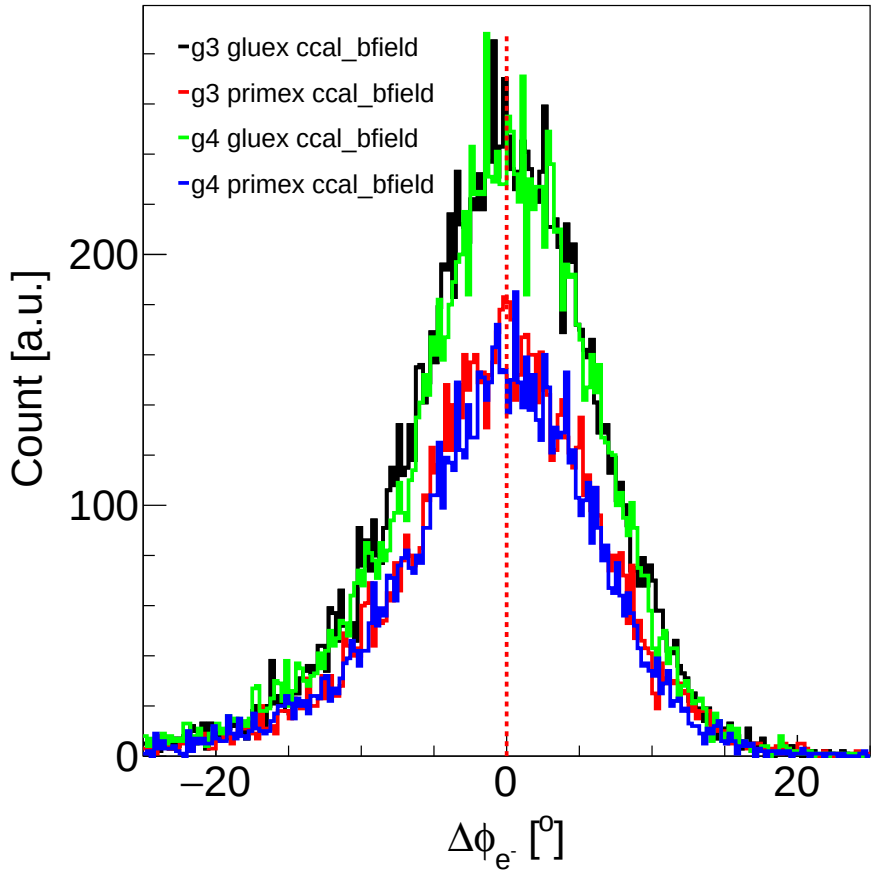


Polar angle not affected by the magnetic field (as expected)

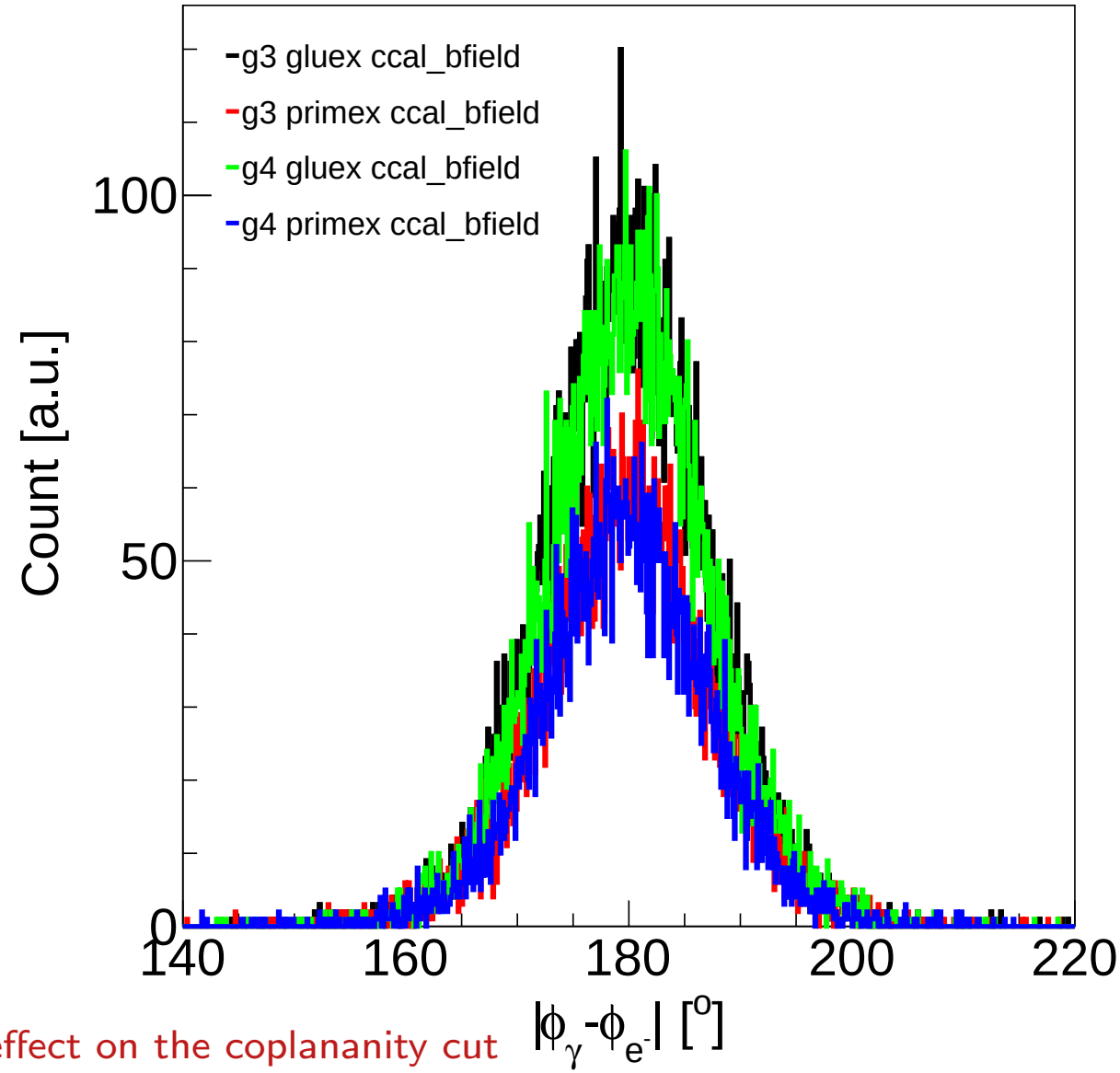
$\gamma e^- \rightarrow \gamma e^-$, comparison between thrown and measured

- Photons have better resolutions than electron
- B-field bias corrected by the Kalman track fitter





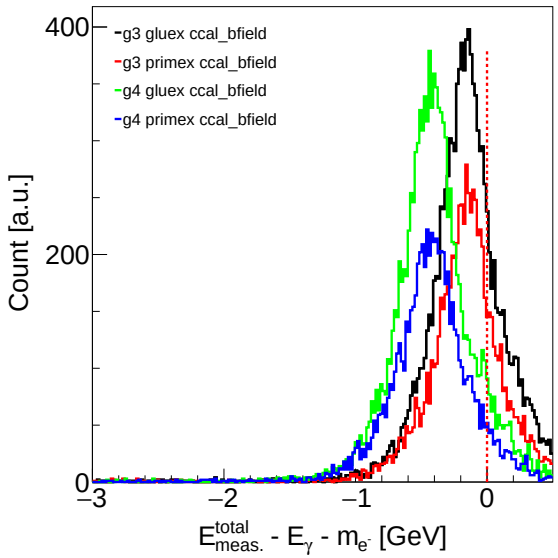
$\gamma e^- \rightarrow \gamma e^-$, coplanarity cut

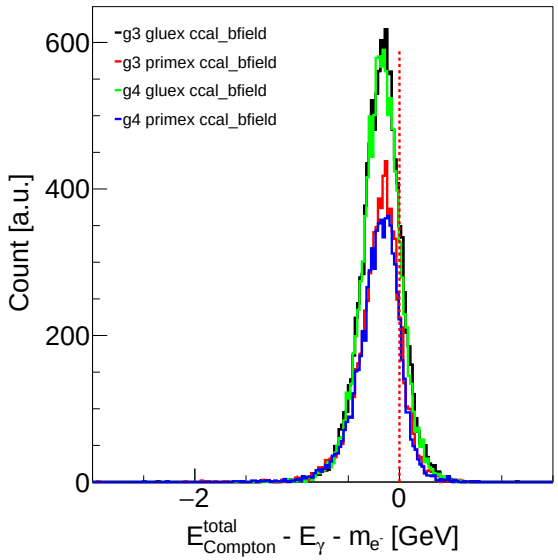


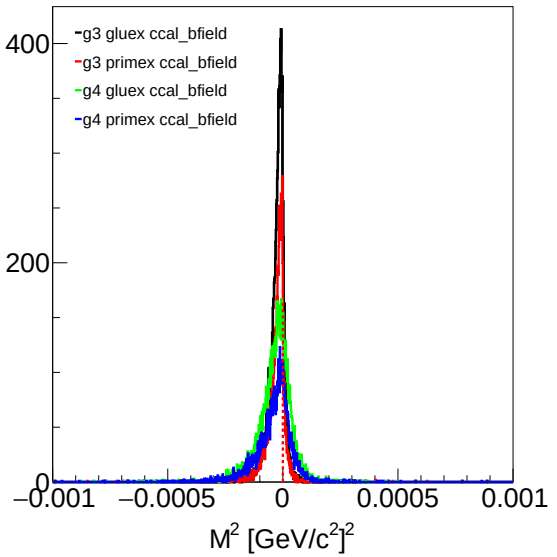
B-field has no effect on the coplananity cut

$\gamma e^- \rightarrow \gamma e^-$, other variables

- Measured energy conservation
- Partially calculated energy conservation
- Final state missing M^2





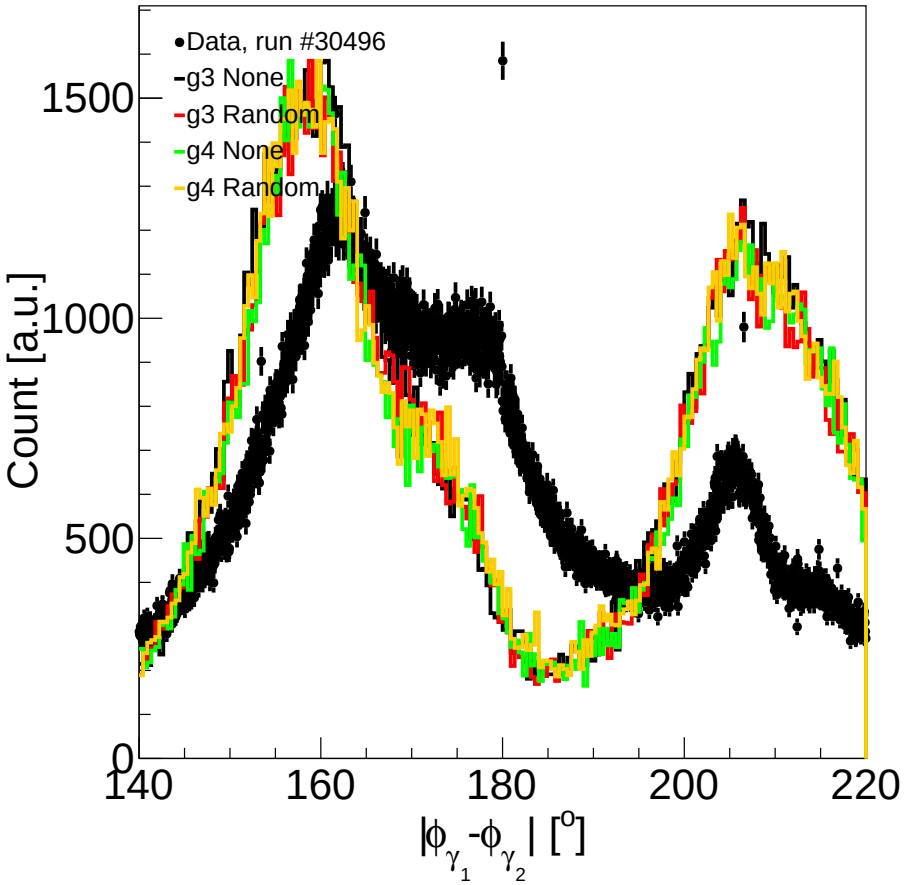


- Difference between Geant3 and Geant4 due to a bug?
  (I changed my local hdgeant4 to load from the DB the CCAL parameters as for Geant3)
- As the partially calculated energy conservation used the polar angle everything is fine

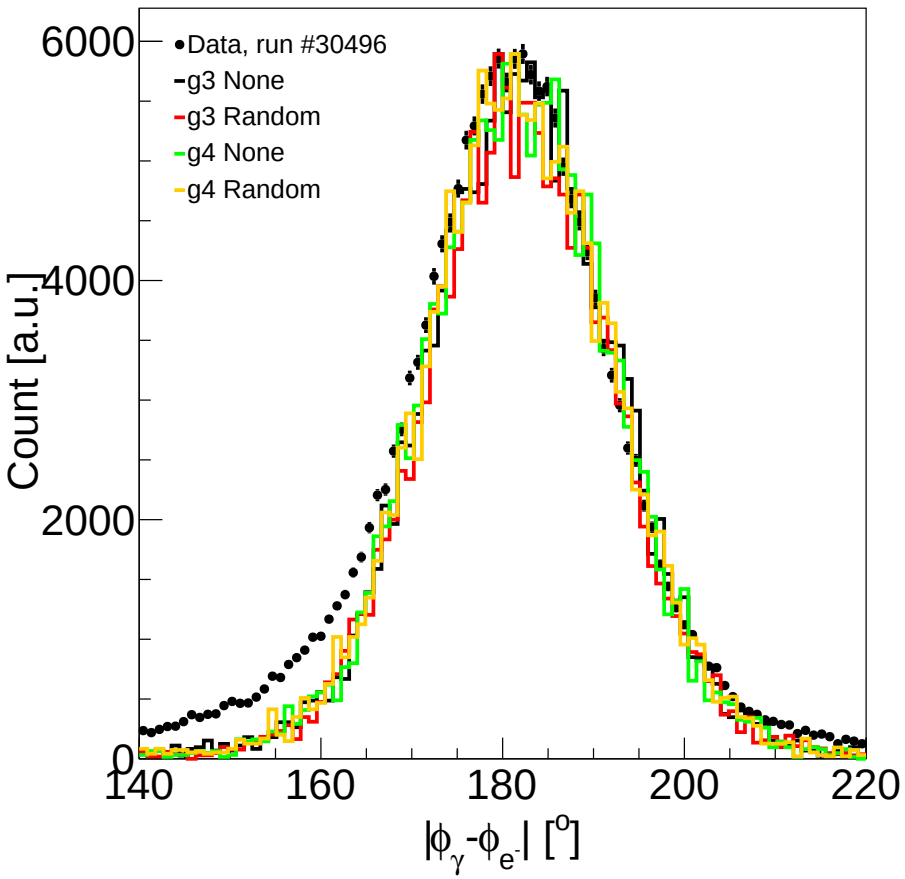
First look at the data

And comparison to the simulation (normal GlueX w/ master DB)

- $\gamma e^- \rightarrow \gamma\gamma$

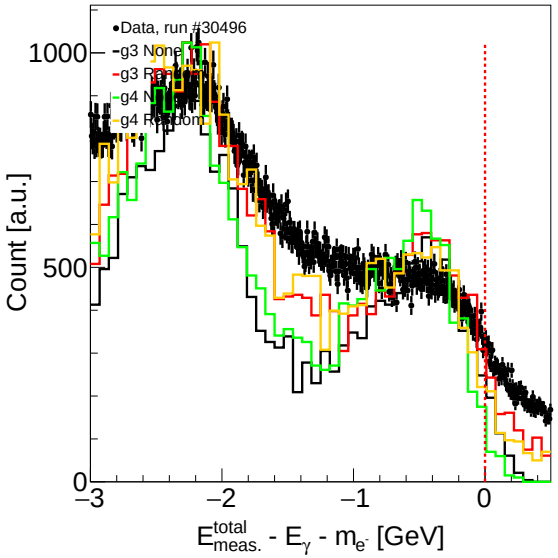


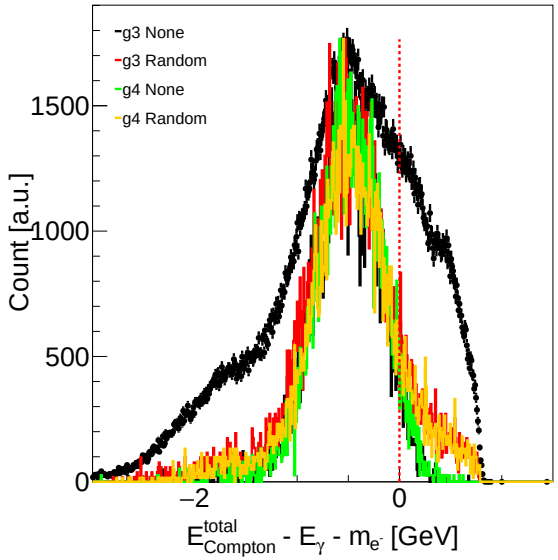
- $\gamma e^- \rightarrow \gamma e^-$

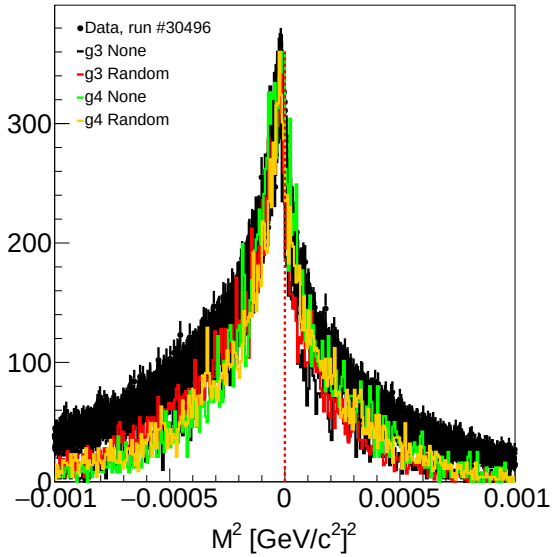


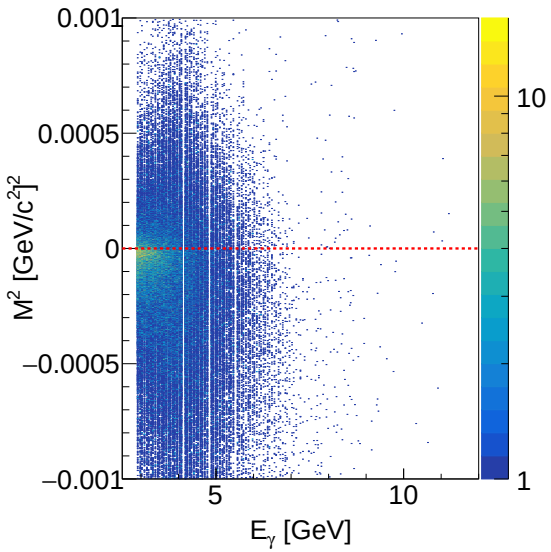
- Compton processes on top of background is possibly visible
- Bias introduced by B-field is visible as well as its correction by the Kalman fitter

First look at the data, $\gamma e^- \rightarrow \gamma\gamma$



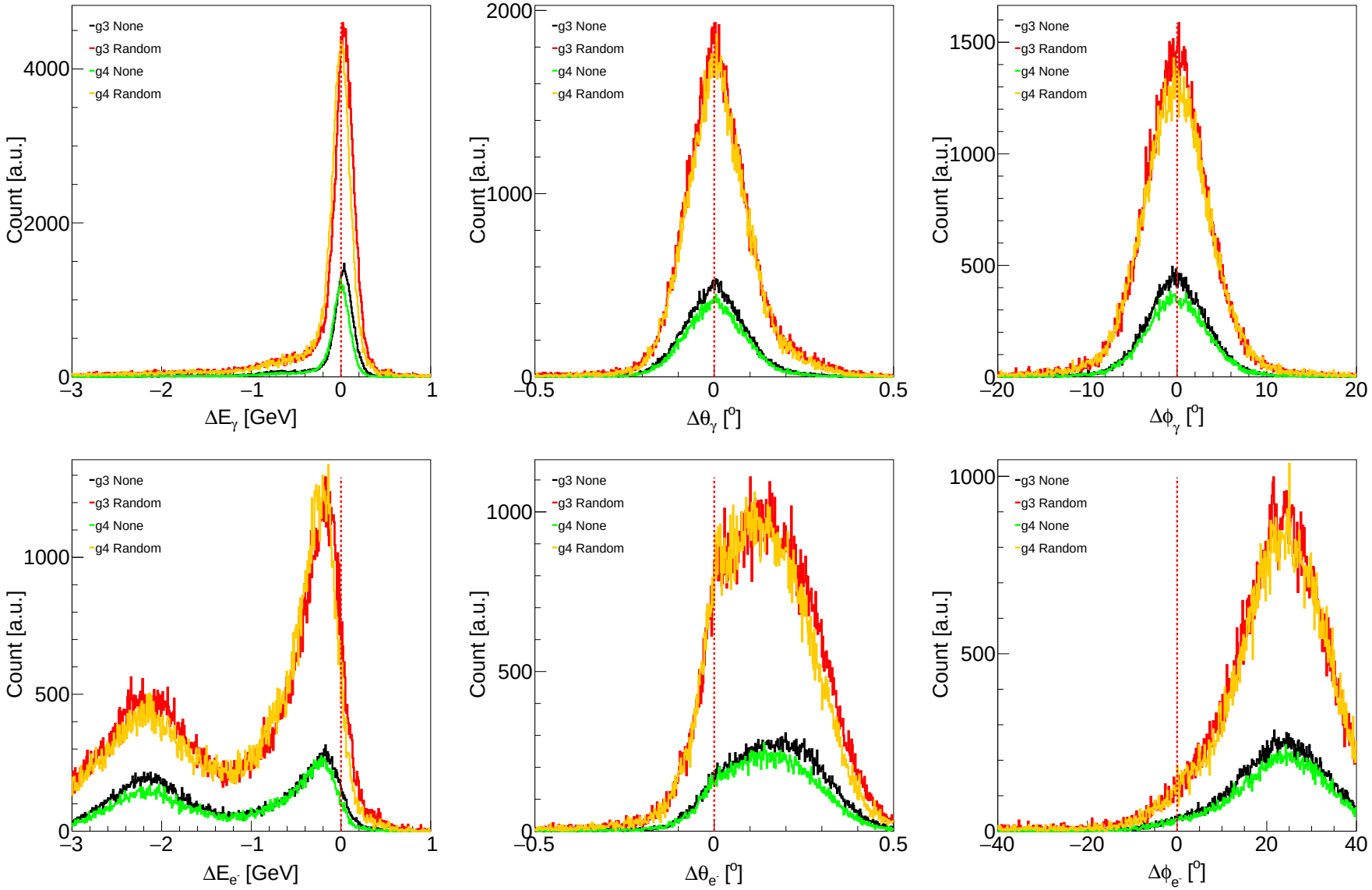




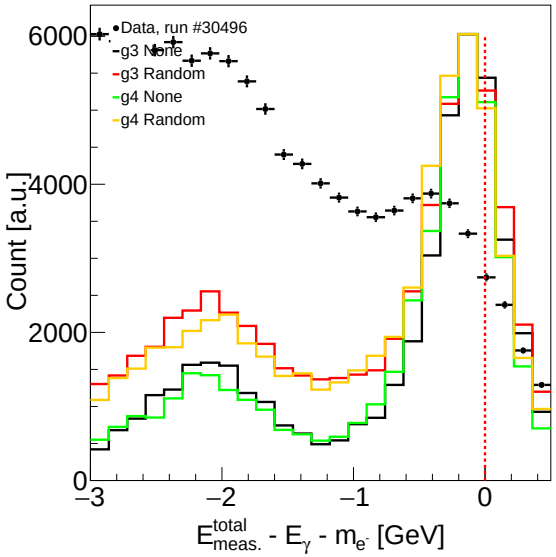


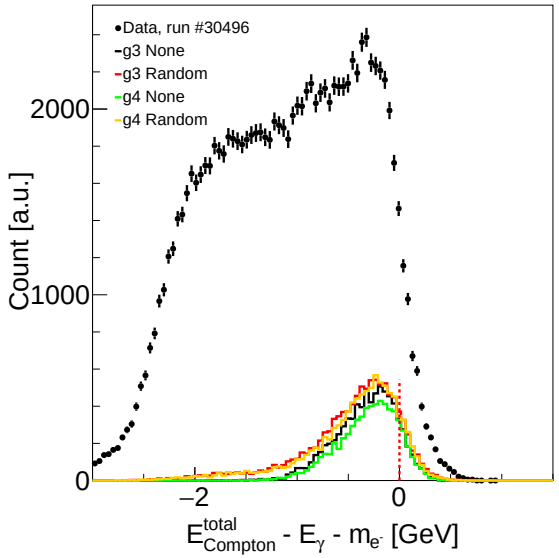
Compton processes measurements appear possible but are concentrated below 6GeV

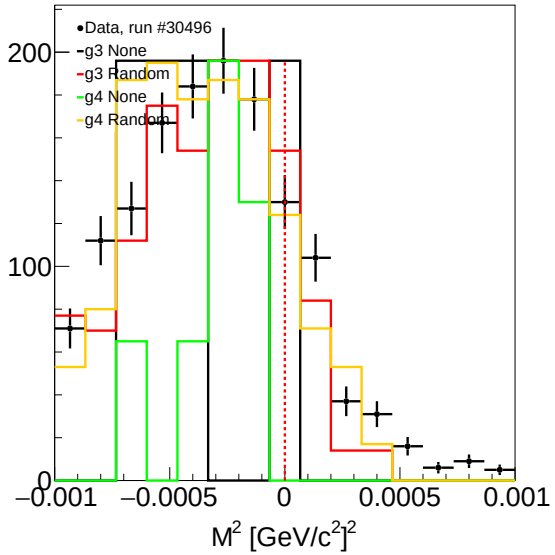
$\gamma e^- \rightarrow \gamma\gamma$, comparison between thrown and measured

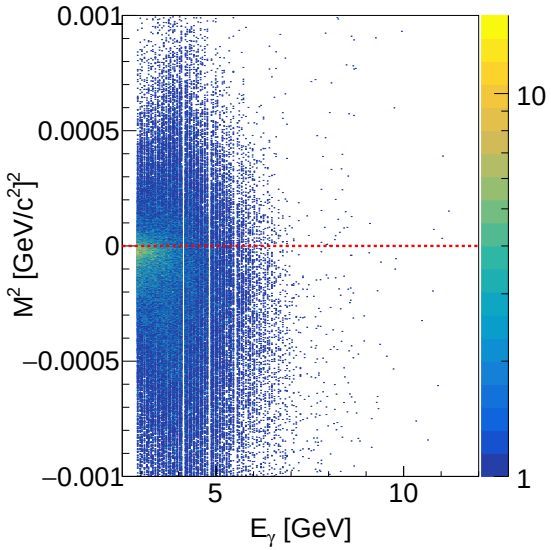


First look at the data, $\gamma e^- \rightarrow \gamma e^-$



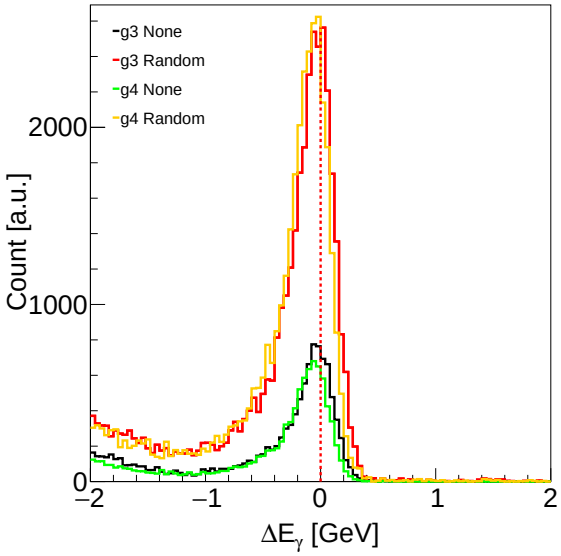


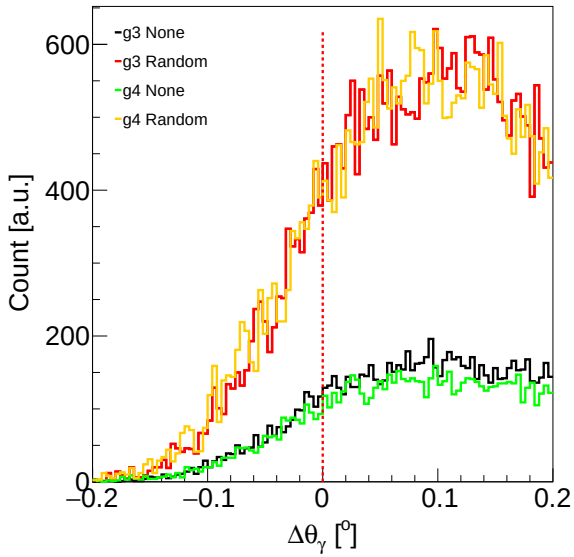


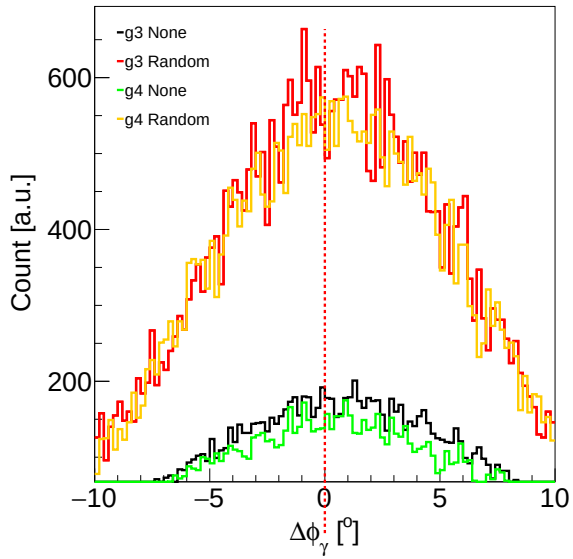


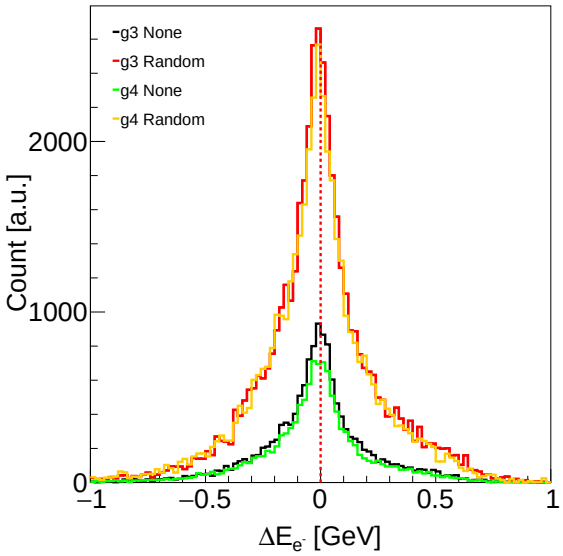
Compton processes measurements appear possible but are concentrated below 6GeV

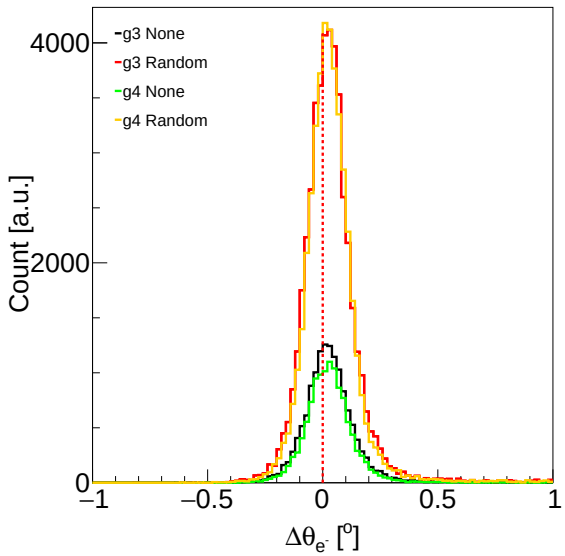
$\gamma e^- \rightarrow \gamma e^-$, comparison between thrown and measured

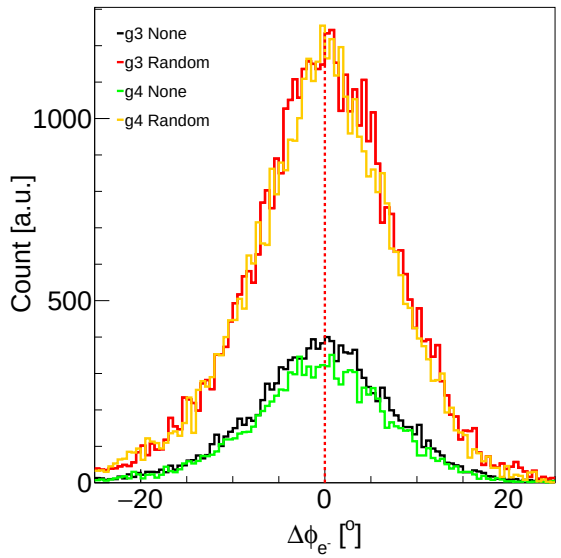












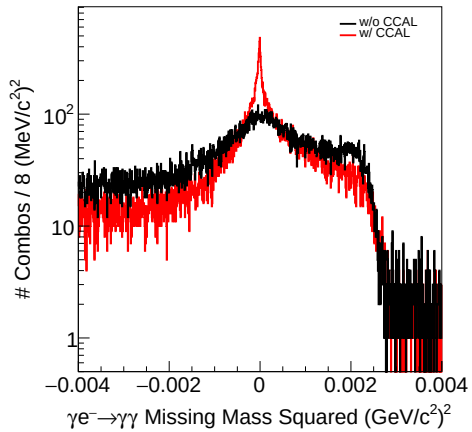
Conclusion

SM Compton processes appear to be measurable in GlueX

- Some software improvements are needed
  - Tune γ and electron PID by using FDC hits, TOF, and/or FCAL
  - Possible bug in my hdgeant4

Introduction of CCAL will dramatically improve detection efficiency and signal over background ratio

B-field introduces a bias that can be corrected by the Kalman fitter when the electron is detected



To-do-list:

- Convert PrimEX-D phase I analysis into GlueX type analysis
- Extract differential and total cross-section, and possibly beam asymmetry which was never measured so far
- Take data with CCAL during this run and possibly constinuously