FCAL Efficiency With "Tagged" $\omega \rightarrow \pi^+\pi^+\pi^-$

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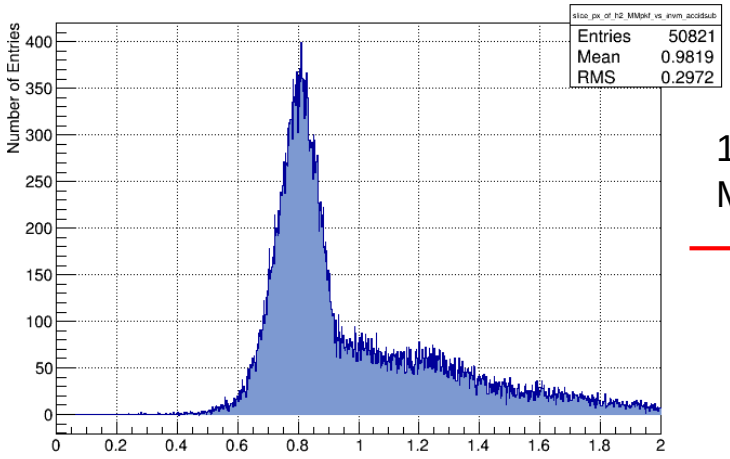
Intro

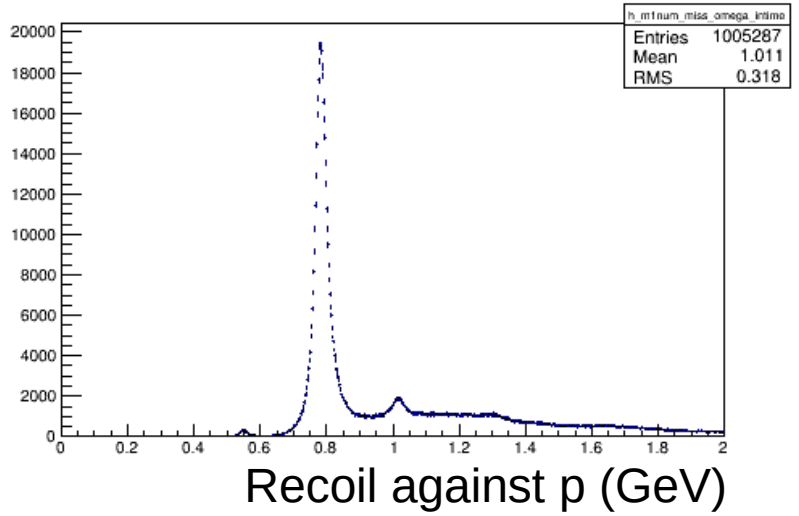
- Want to verify MC and data efficiencies match in FCAL:
  - As function of photon θ (integrated over all energies)
  - As function of photon E (integrated over all θ, ϕ in FCAL)
- Options:
  - Charged tracks to FCAL? (resolution, PID tricky, etc.)
  - Use exclusive channel with "tagged" final state photon
- $\omega \rightarrow \pi^+\pi^-\pi^0$:
  - Large cross section
  - Having proton, π^+, and π^- helps with exclusivity, vertexing
  - Result: fairly clean, well resolved even with a missing π^0 photon

2017 Data

- Starts off too messy to be workable, but can be cleaned up easily enough
- Some background and η and ϕ also in topology
- Topology: $\pi^+\pi^-\gamma(\gamma)p$



1 C kinematic fit
Missing π^0 mass cut



Running Over MC/Data (reference)

- Use ReactionFilter plugin!!
  - (there is a bug with missing photons topologies if you try to use your own separate plugin)
- Options to ReactionFilter I use:
  - No extra tracks
  - 1 C fit to constrain missing photon mass == 0
  - Don't constrain π^0 mass (default is to constrain)
  - Don't constrain vertex
  - Two out-of-time beam bunches before and after
- Word of caution:
  - 1 C fit to constrain missing photon works great
  - π^0 mass constraint, vertex tricky to work with… (smears tails)

Additional Event Selection (reference)

- Fairly tight π^0 missing mass cut (post-kinfit)
  - (0.11 < recoil against $\pi^+\pi^-$p < 0.16 GeV)
- All tracks must have hits in TOF/BCAL/FCAL for PID timing
- Loose χ^2 cuts on:
  - Tracking
  - Track timing
  - Track dE/dx
- For now: 8.2 < beam E < 8.8 GeV

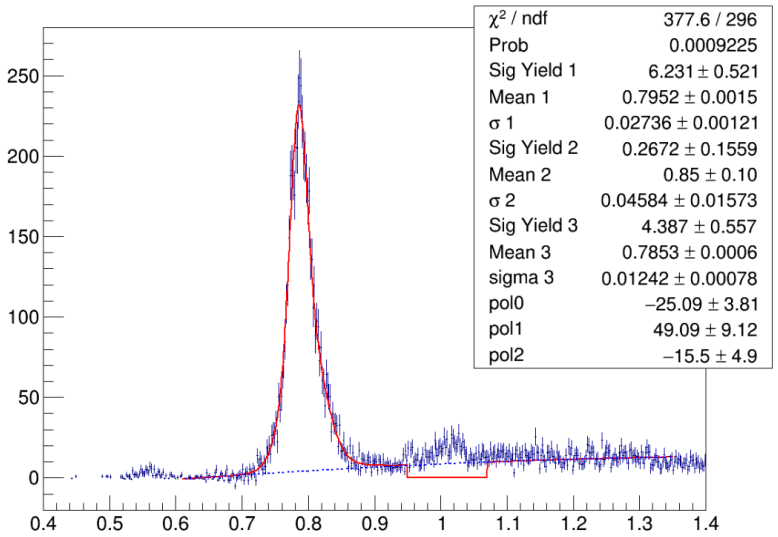
Basic idea

- Data driven method
- Single photon efficiency is given by
  - $\epsilon = \frac{\omega \to 3\pi \; yield, both \; \pi^0 \; photons \; found}{\omega \to 3\pi \; yield, one \; or \; both \; \pi^0 \; photons \; found}$
- Binned in $\theta_{(\gamma)}$ or $E_{(\gamma)}$ as statistics allow
- Want to decouple from detector resolution as best we can (reduce/eliminate cut dependence)
  - This is the tricky part!
- I use two parameterizations as way to cross check results

Method 1: Fit to MM Spectrum

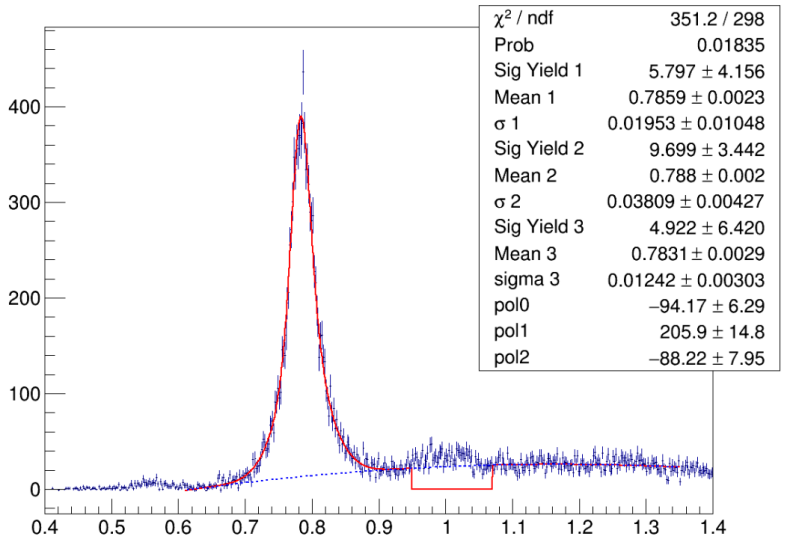
Numerator

- Exactly two neutral candidates
  - Candidates pass loose π^0 mass cut
- Loose $\Delta\phi$ cut
  - $\pi^+\pi^-\gamma\gamma$ should be opposite proton



Denominator

- 1-2 neutral candidates



ω yields: 3 gaussian signal, floating parameters
2nd order polynomial background

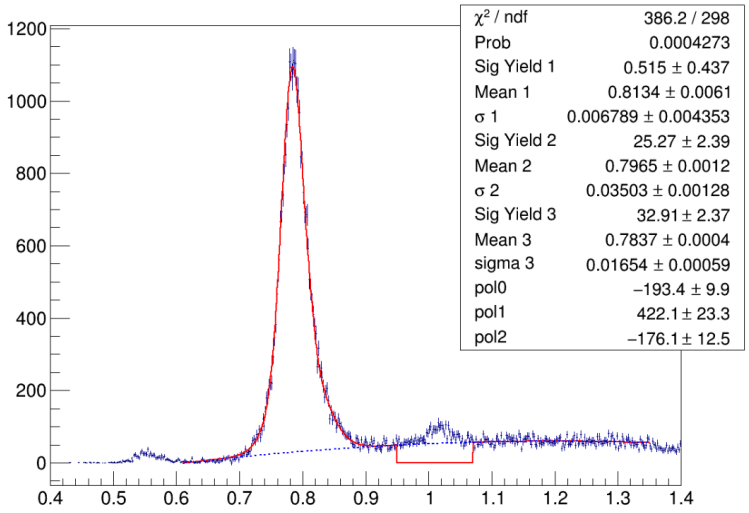
Method 2: Fit to Invariant Mass and "Inefficiency"

$$\epsilon = \frac{inv\ mass\ yield}{inv\ mass\ yield + inefficient}$$

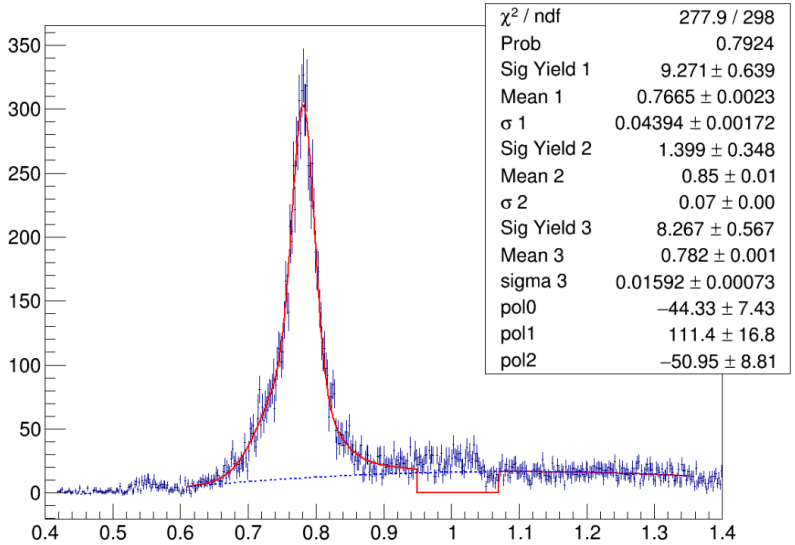
"Inefficient"

- Only one photon found, no candidate for second

Numerator



$\pi^+\pi^-\gamma\gamma$ inv mass (GeV)



Recoil against p (GeV)

ω yields: 3 gaussian signal, floating parameters
2nd order polynomial background

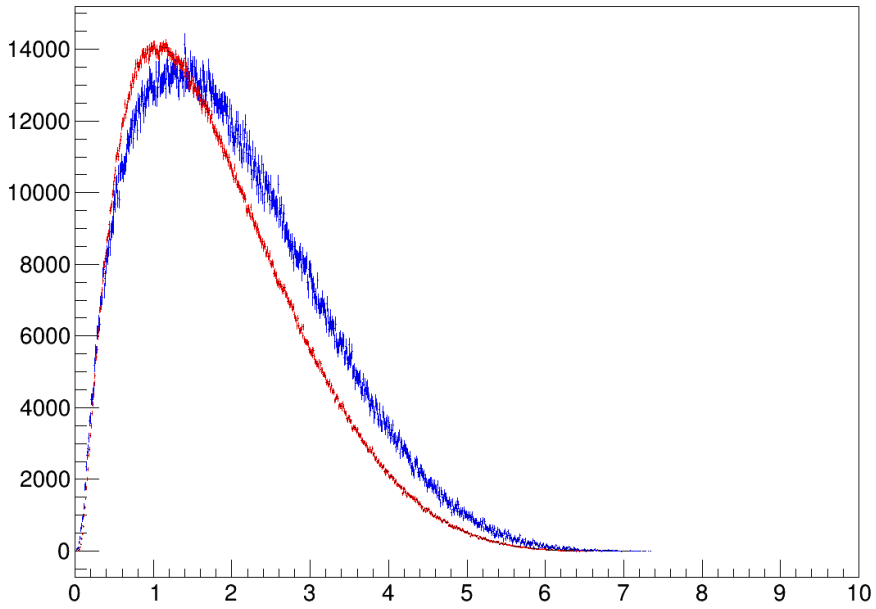
Initial Comparisons

- 2017 data:
  - Runs 30274-30600
  - 8.2-8.8 GeV beam E
- MC sample:
  - Genr8 signal MC: not a ton of physics input
  - 8.5 GeV fixed beam E
- MC sample does a reasonable matching photon kinematics
  - Further refinement of MC sample may be needed

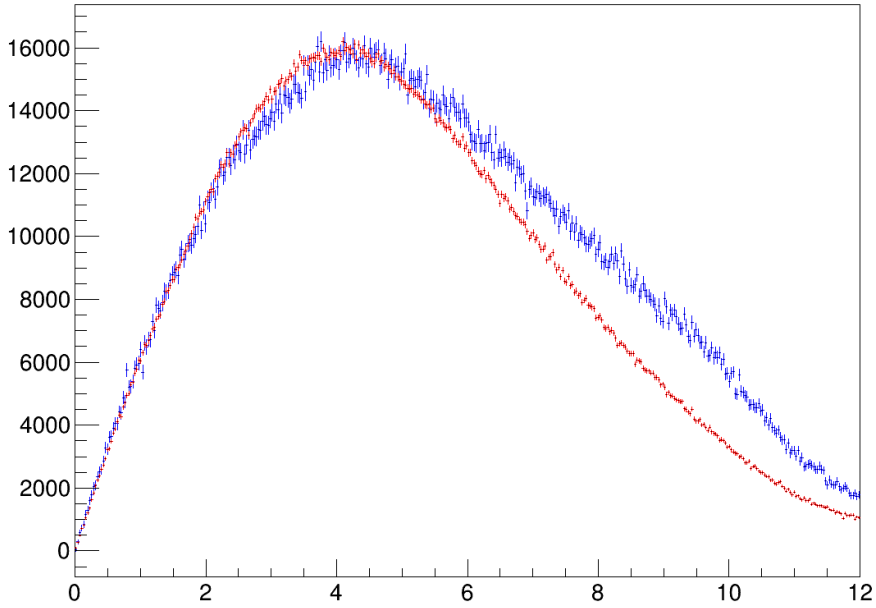
Missing Photon Kinematics

- In mass range of ω

Blue: data
Red: signal MC

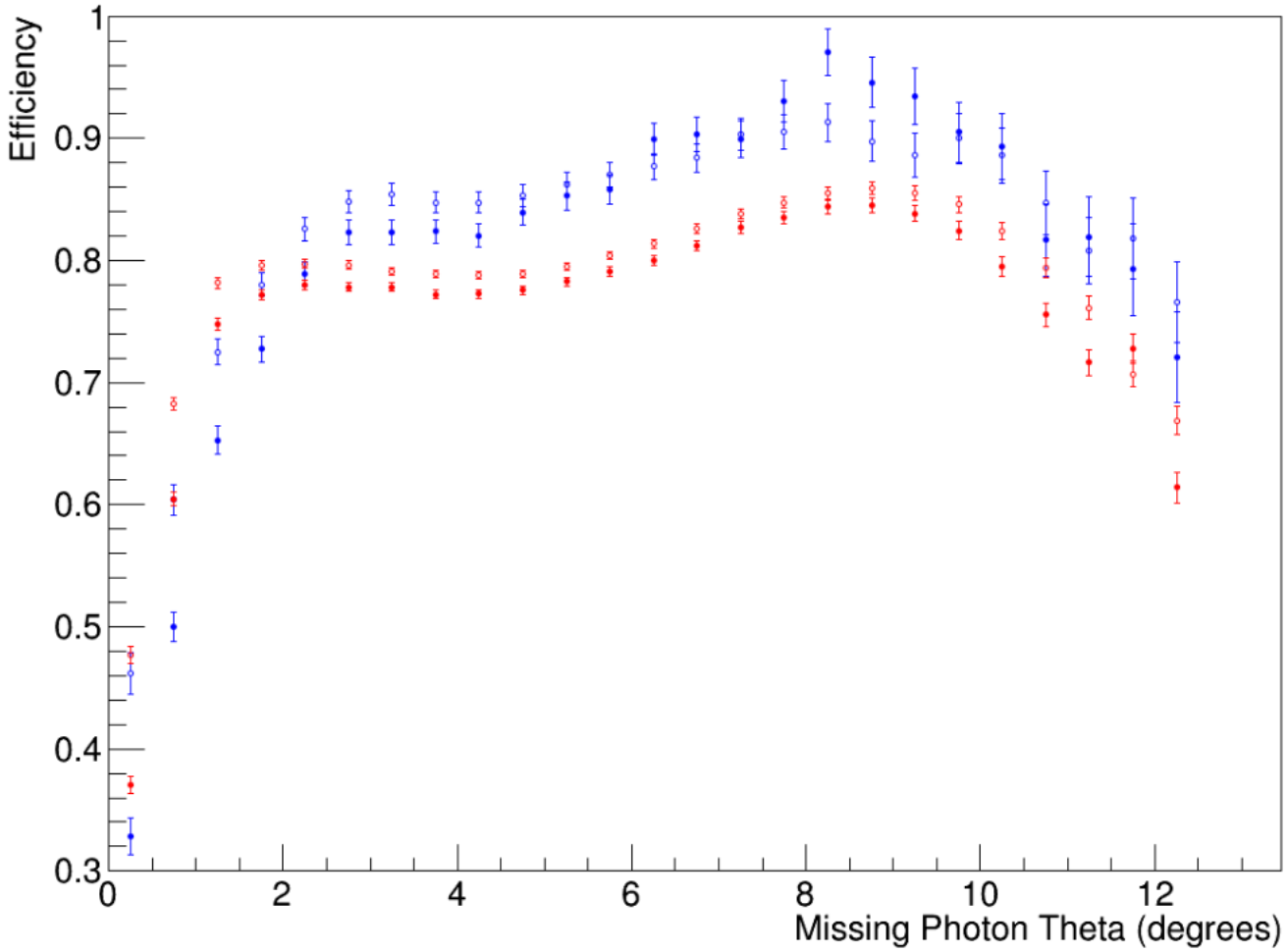


Missing Photon E (GeV)



Missing θ (degrees)

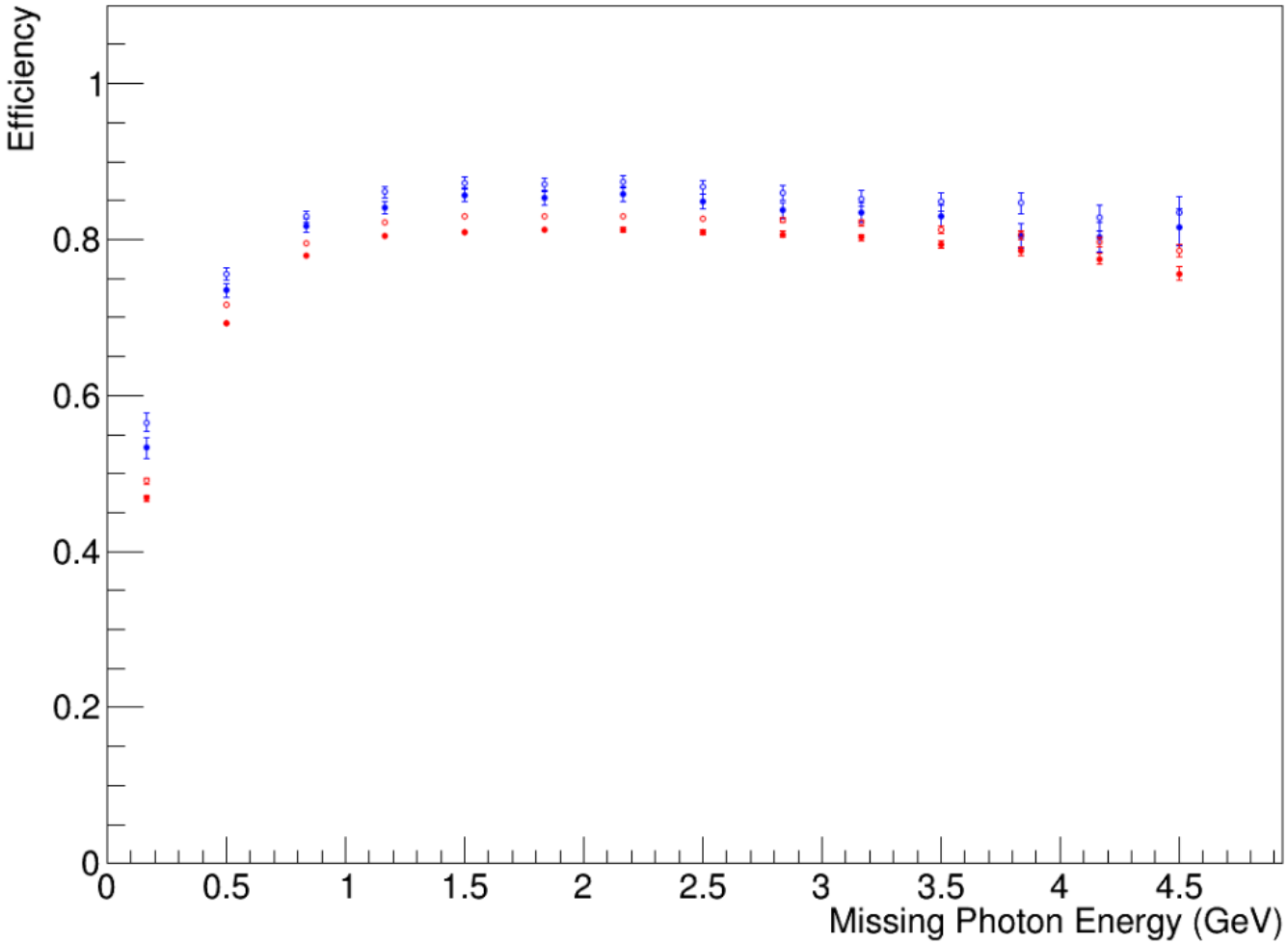
Initial Efficiencies: Energy Dependence



Blue: data
Red: signal MC

Filled circles: method 1
Open circles: method 2

Initial Efficiencies: Energy Dependence



Blue: data
Red: signal MC

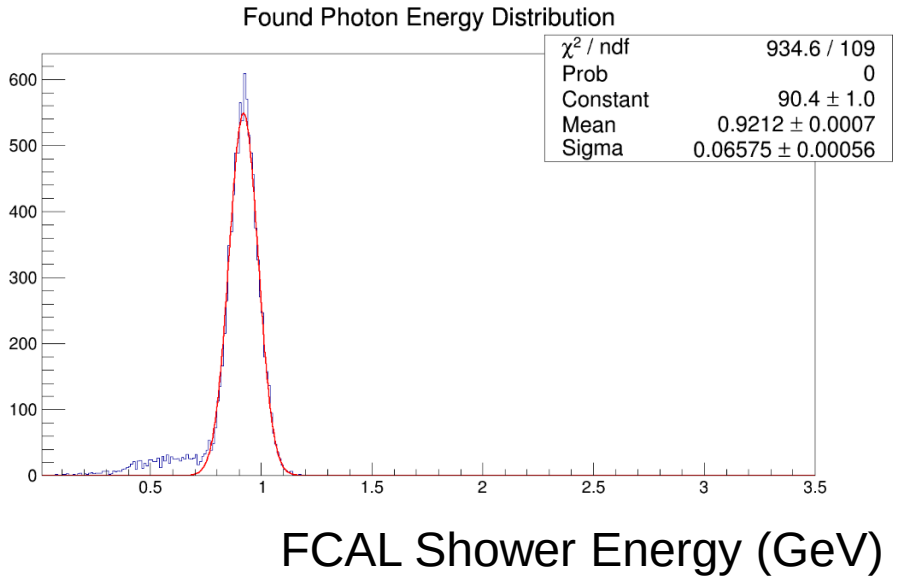
Filled circles: method 1
Open circles: method 2

Conclusions So Far

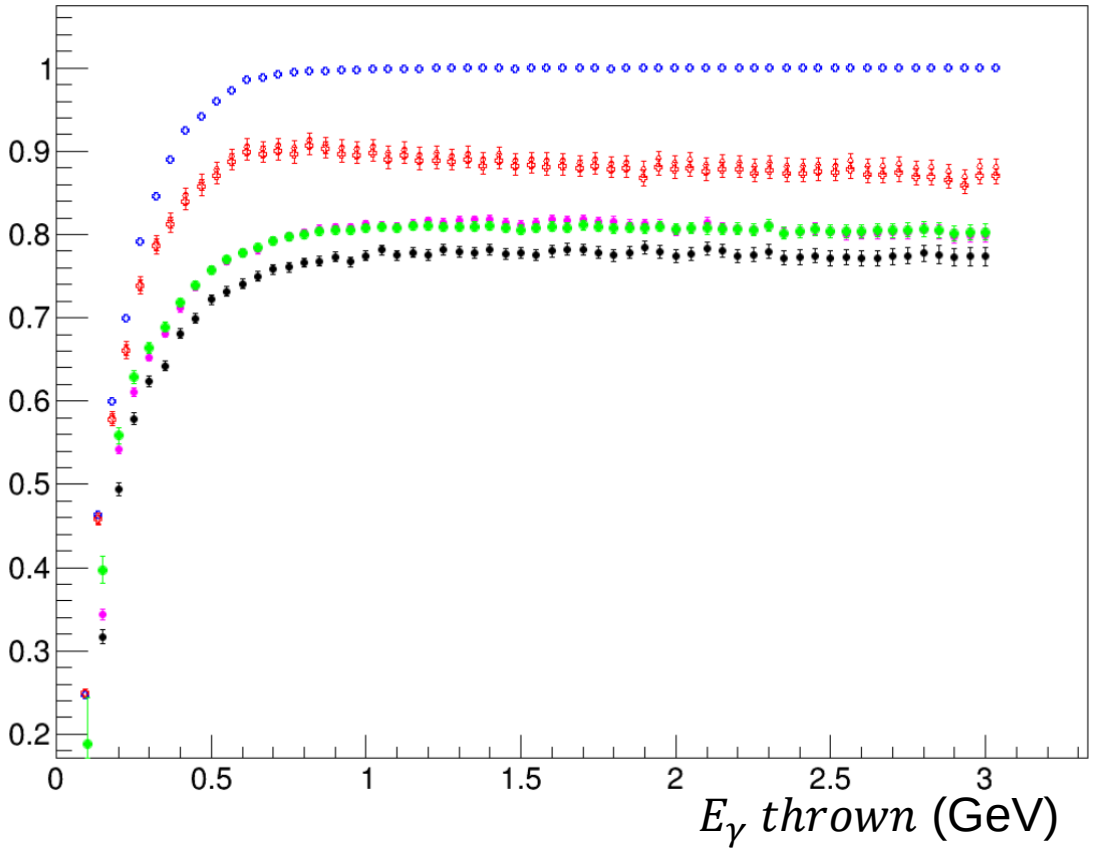
- No strong conclusions yet
  - Difference in efficiency as function of θ could just be due to slightly different kinematics
  - Difference in energy could just be reflection of θ differences
  - Need to generate more physical ω sample or reweight MC
- Efficiency appears much lower than we might expect from physical response alone... why?

Photon Gun MC

- Simplest thing we can do: photon gun
  - Photons of fixed $\theta(= 6°)$, any ϕ
  - Steps of energy
- Fit to gaussian core of distribution for fixed E step
- Efficiency = gaussian core yield / # generated
- Lower energy junk: mostly conversions in TOF or elsewhere



Photon Gun vs ω Signal MC

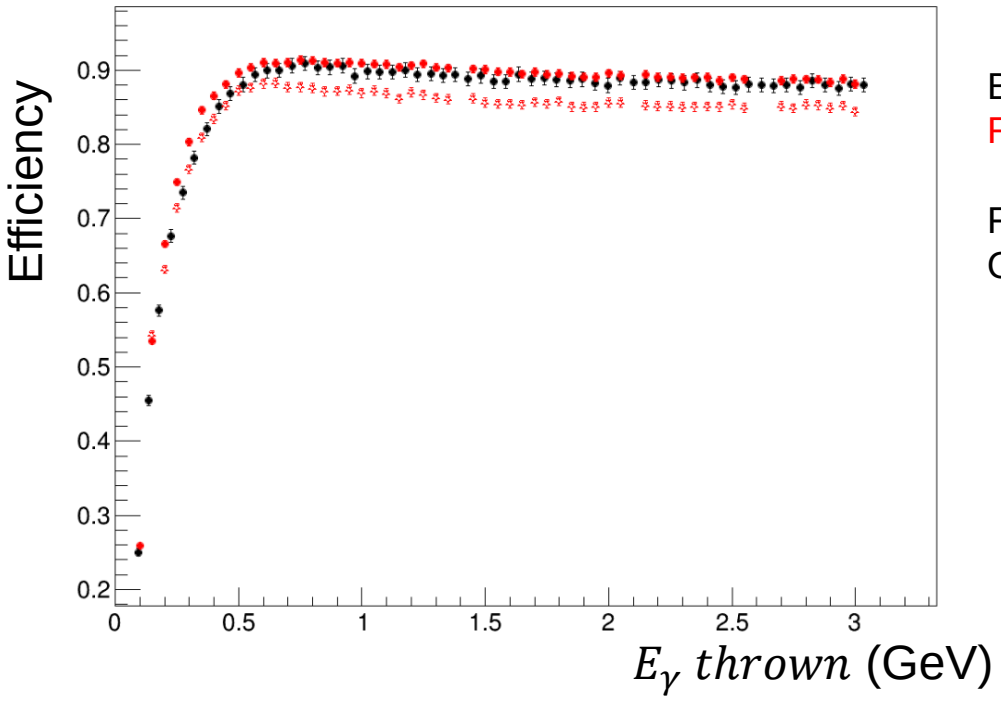


- ◇ Photon gun, any quality shower
- ◇ Photon gun, gaussian core
- • ω sample: any quality, one shower, gaussian core
- • ω sample: 2gaussian core, one shower (method 2)
- • ω sample: accepted π^0, one shower (method 1)

Pseudo-gun Generators

- Embed photon gun (fixed $\theta = 6°$, any ϕ, steps of E) within mock physics event
  - Beam photon 8.5 GeV
  - Protons according to ω genr8 kinematics
  - $\pi^+\pi^-$ according to ω genr8 kinematics

Photon Gun Sample Comparisons

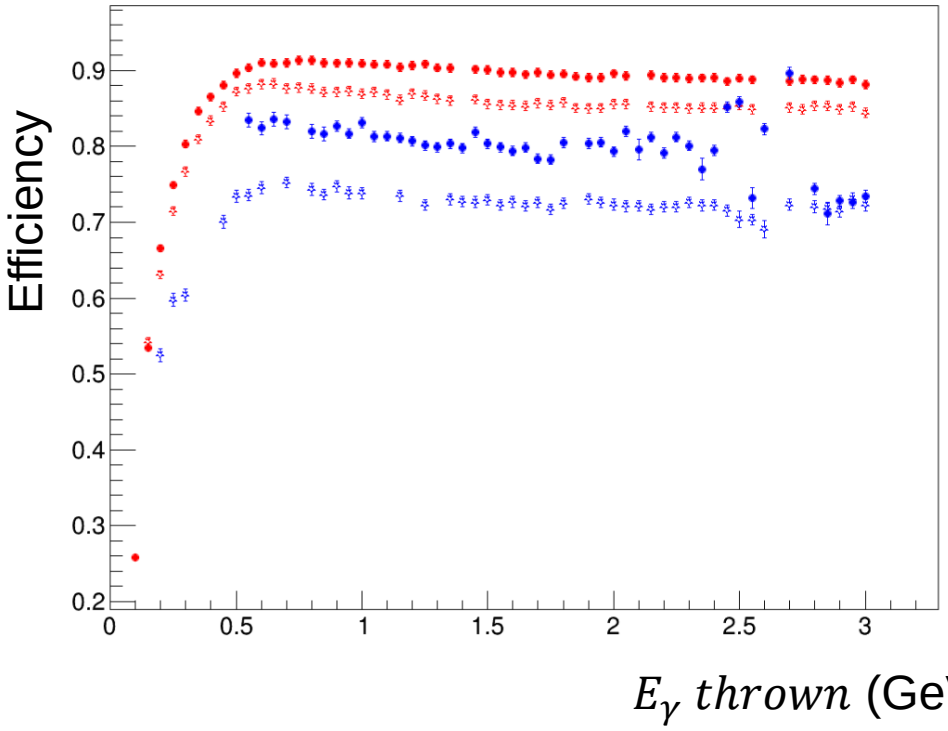


Black: photon gun
Red: photon gun + proton

Filled points: DFCALShower objects
Open points: ReactionFilter (neutral hypothesis

- Same exact thrown photons both cases
- Passing through standard GlueX analysis software (ReactionFilter) reduces efficiency (timing cuts? Need to verify)

Photon Gun Sample Comparisons



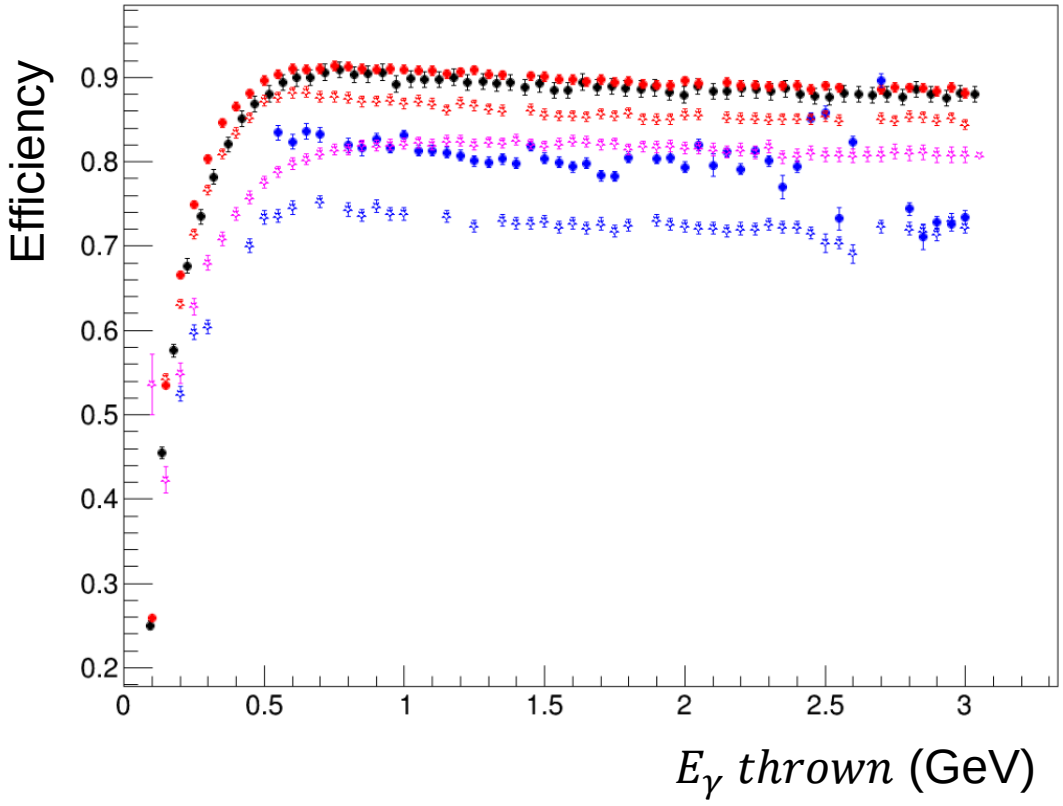
Red: photon gun + proton
Blue: photon gun + $\pi^+\pi^-$proton

Filled points: DFCALShower objects
Open points: ReactionFilter (neutral hypothesis

- Same exact thrown photons both cases
- Efficiency is reduced again by adding $\pi^\pm$ backgrounds, much moreso with standard GlueX analysis software (ReactionFilter)
  (track vetoing? Need to verify)

(fits are harder/less stable with blue points ($\pi^\pm$ backgrounds in FCAL))

Photon Gun Samples vs. ω MC



Black: photon gun
Red: photon gun + proton
Blue: photon gun + $\pi^+\pi^-$proton
Magenta: ω MC

Filled points: DFCALShower objects
Open points: ReactionFilter (neutral hypothesis)

Lessons From Photon Gun Studies (so far)

- Above a certain energy, everything showers in FCAL
  - Upstream conversions reduce number of good quality showers to about 90% at max
- Embedding a proton and beam photon gives the same result as simple photon gun…
  - For low-level DFCALShower objects
  - But not compared to higher level analysis ReactionFilter
- Embedding additional $\pi^+\pi^-$ further reduces efficiency

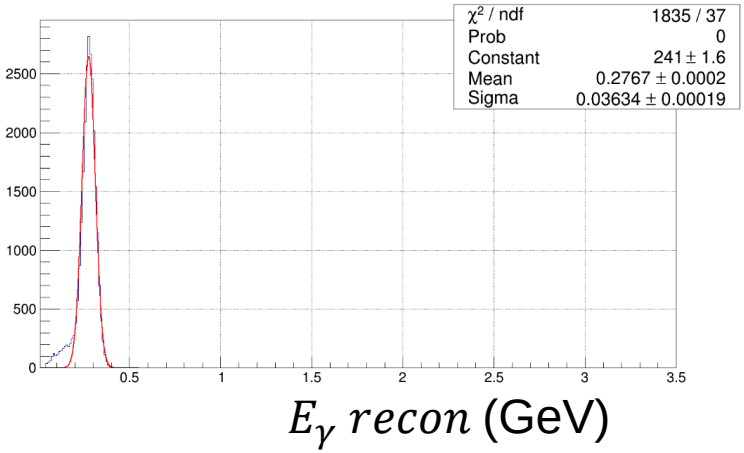
Potentially Useful Takeaways

- Making sure MC sample really mocks up data is very important
- FCAL can have large multiplicities and “correct” photon from geometry matching or invariant mass can often be ambiguous
  - My solution: exclude all events with ≥ 3 FCAL neutral showers
- Total reconstructed efficiency may have similar or greater loss due to software-level cuts under the hood
  - Topology-dependent (inclusive with tracks or no?)
  - Suspected culprits still need to be verified

Example Fits: Photon Gun + proton

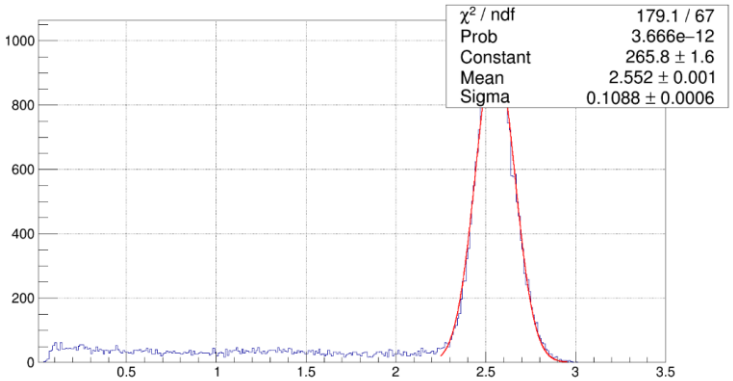
- Gaussian fit

$\gamma_{thrown} = 0.3\ GeV$



$E_\gamma\ recon$ (GeV)

$\gamma_{thrown} = 2.7\ GeV$

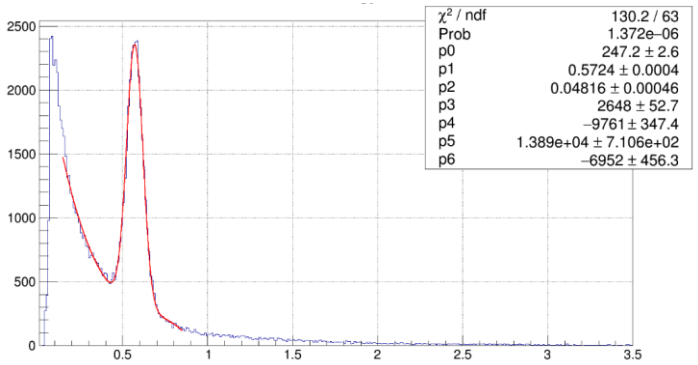


$E_\gamma\ recon$(GeV)

Example Fits: Photon Gun + $\pi^+\pi^-$ proton

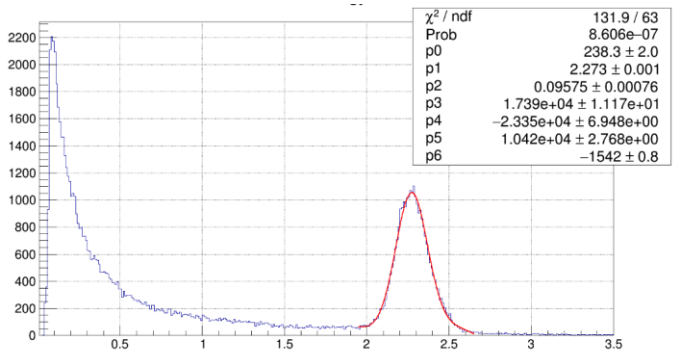
- Gaussian + 3rd order polynomial
- DFCALShowers

$\gamma_{thrown} = 0.6\ GeV$



$E_\gamma\ recon$ (GeV)

$\gamma_{thrown} = 2.3\ GeV$



$E_\gamma\ recon$(GeV)