FCAL Efficiency Studies Using $\omega \rightarrow \pi^+\pi^-\pi^0$ Decays

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Event Selection

- Matches combo requirements for
$$\omega \rightarrow \pi^+\pi^-\pi^0, \pi^0 \rightarrow (\gamma)\gamma$$
- P4 & vertex fit (kinfit CL > 0.001)
- All beam E accepted
- Reconstructed photon > 500 MeV

All quantities shown are accidental subtracted

(more details in backups)

Extracting Efficiencies Using $\omega \rightarrow 3\pi$ w/ Missing Photon

- Define efficiency as:

$$\frac{\pi^0\ invariant\ mass\ \text{yield}}{missing\ mass\ yield\ (around\ \omega\ mass\ region)}$$

(where I use "unused neutral shower" closest in orientation to form π^0 candidates)

- Use yields from fitted quantities
- Fit in 20 bins of ~equal statistics varying over:
  - Missing photon energy (all accepted)
- Compare:
  - "Golden runs" Spring '16 data
  - Bggen sim_1.2.1 ("golden" run numbers)
  - 1 M signal MC events (genr8 w/ 9 GeV beam photons)

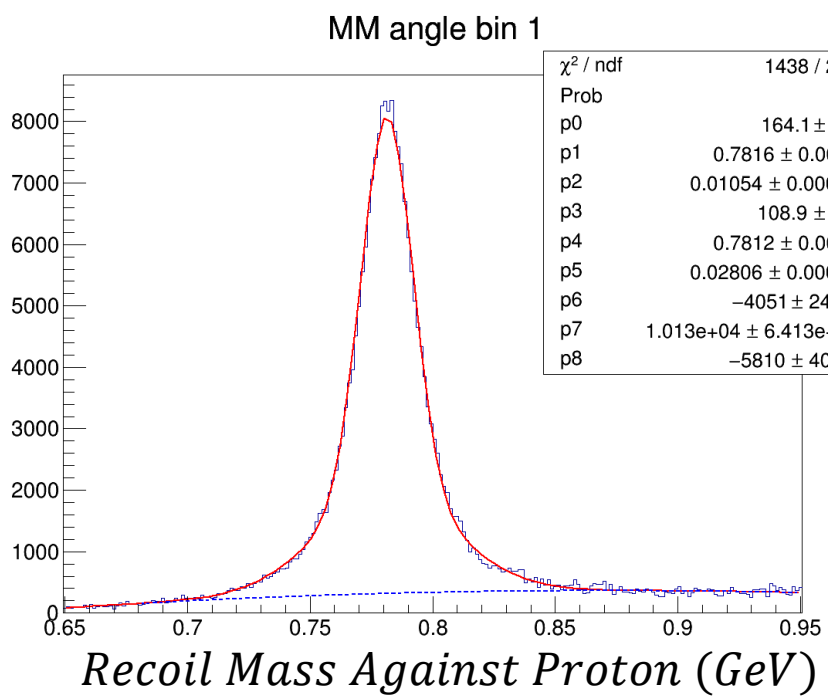
GlueX Code: "Unused Neutral Showers"

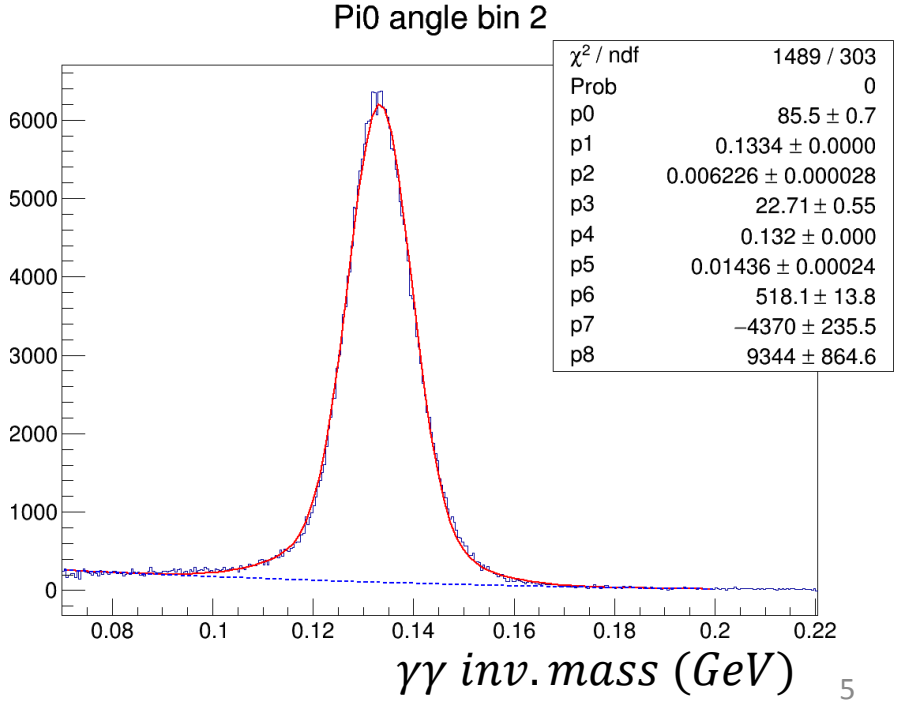
- Use "unused neutral showers" for determining an invariant π^0 mass
  - dAnalysisUtilities->Get_UnusedNeutralShowers(…)
  - Contains unused calorimeter showers that aren't too close to any projected tracks
- Today: only consider the neutral shower closest in spacial orientation to missing 4-momenta
  - Will revisit using all showers

Signal Extraction (some examples)

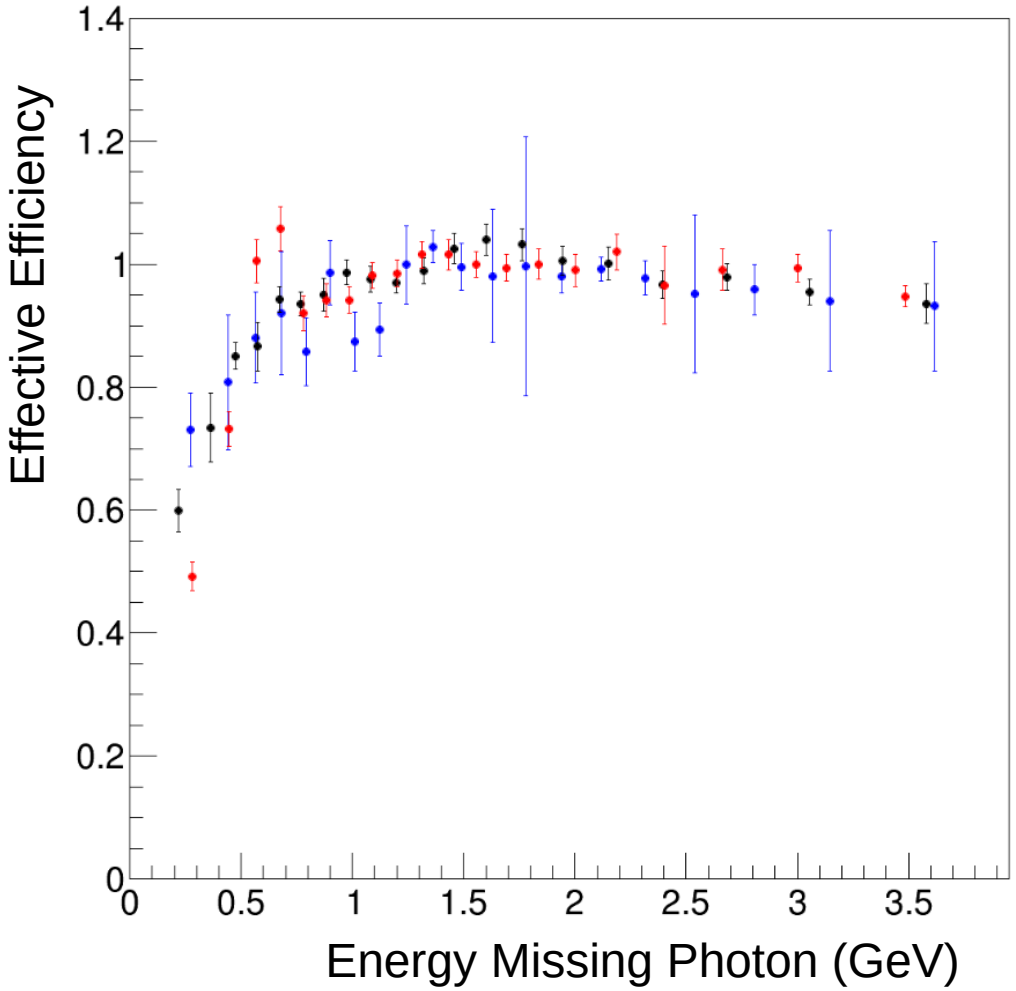
- Double Gaussian signal parameterization
- 2nd order polynomial background

(detailed algorithm in backup slides)





Efficiency As Function of Energy

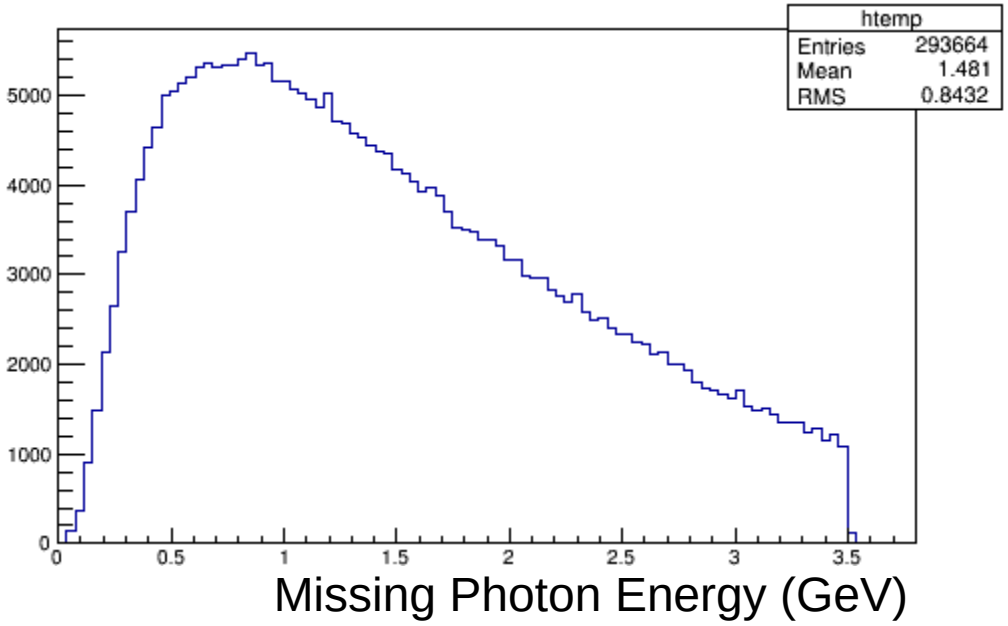


Black: data (golden runs) Red: bggen Blue: signal MC

Probing Lower Energy Photons

- Won't get much below ~300 MeV with this channel, even with looser cuts

- Plotted: signal MC with looser kinfit CL cut and no requirement on reconstructed photon energy

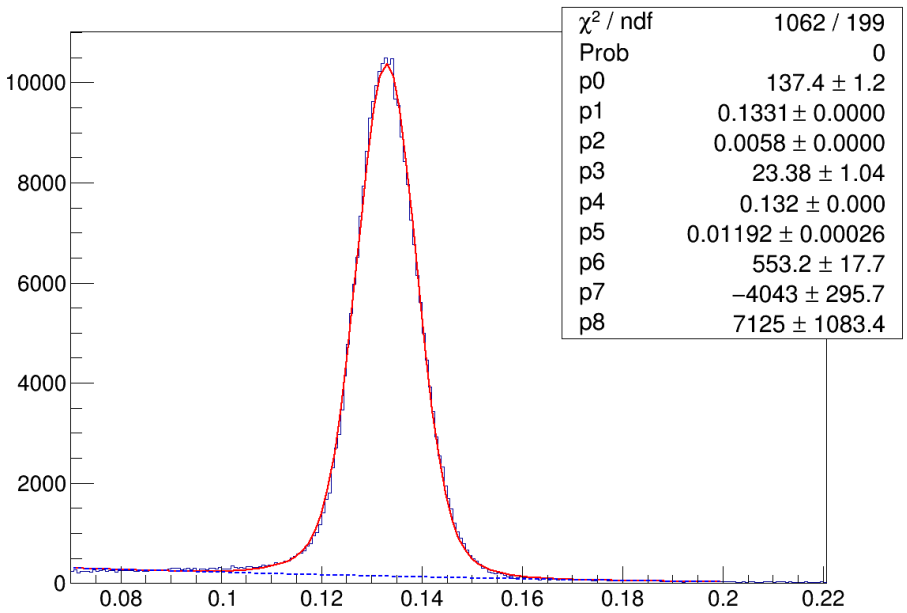


Looking Ahead

- Definition of efficiency may change, spirit of analysis will largely remain the same
- Geometric efficiency in FCAL: ironing out systematics
- *Trigger simulation/studies crucial*

Backup: All unused showers: π^0 candidates (Signal MC)

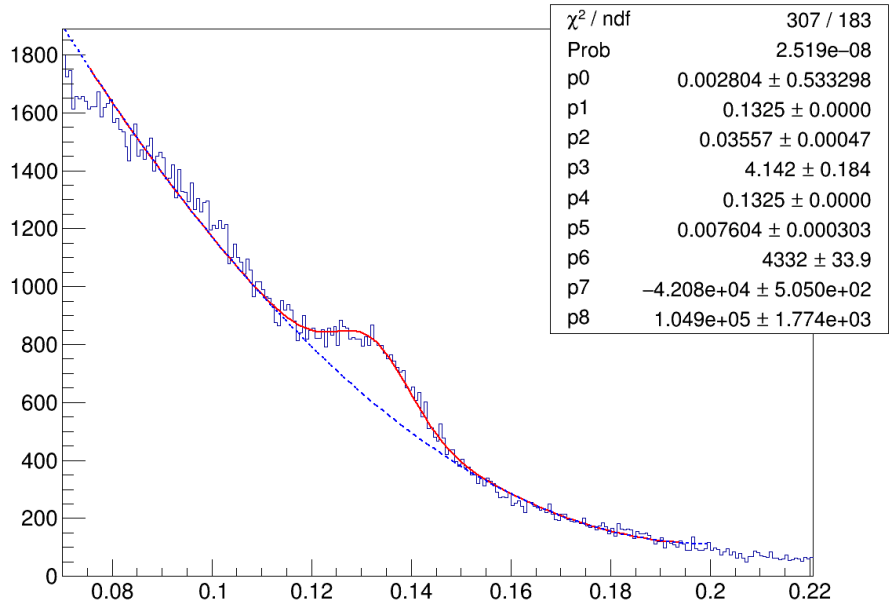
Closest shower in orientation



Diphoton Mass (GeV)

Yeild: 257226±2486

All other "unused neutrals"



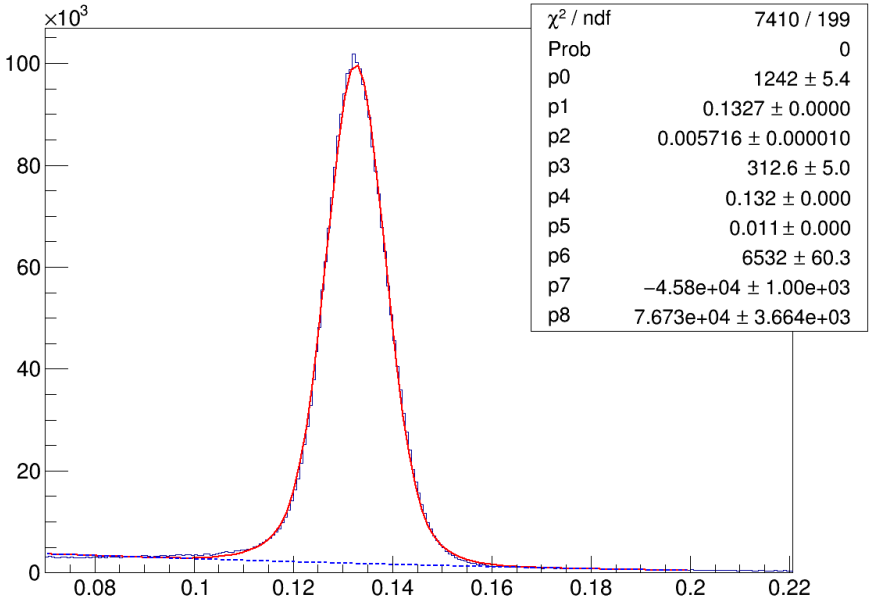
Diphoton Mass (GeV)

Yeild: 6631±902

~2.5% effect

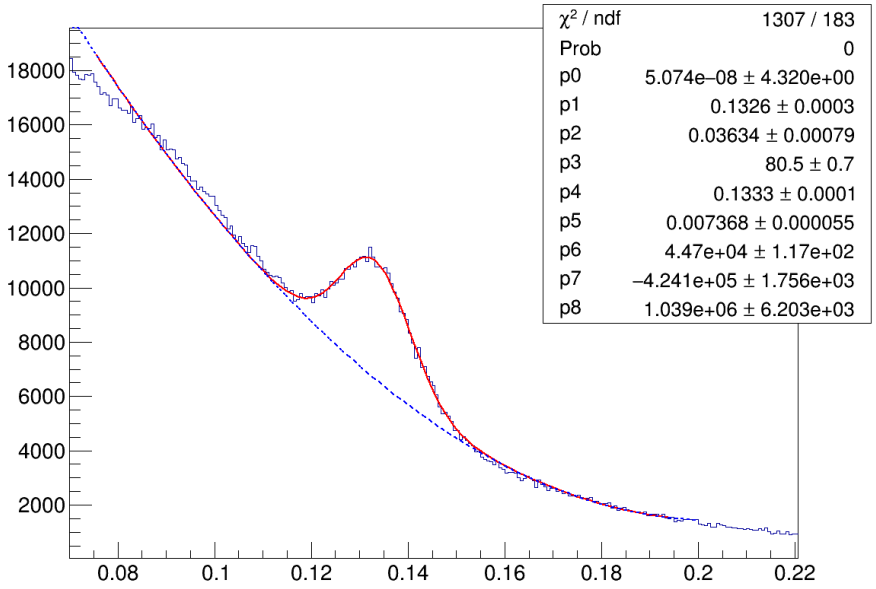
Backup: All unused showers: π^0 candidates (bggen sim_1.2.1)

Closest shower in orientation



Diphoton Mass (GeV)
Yeild: 2487139±11778

All other "unused neutrals"

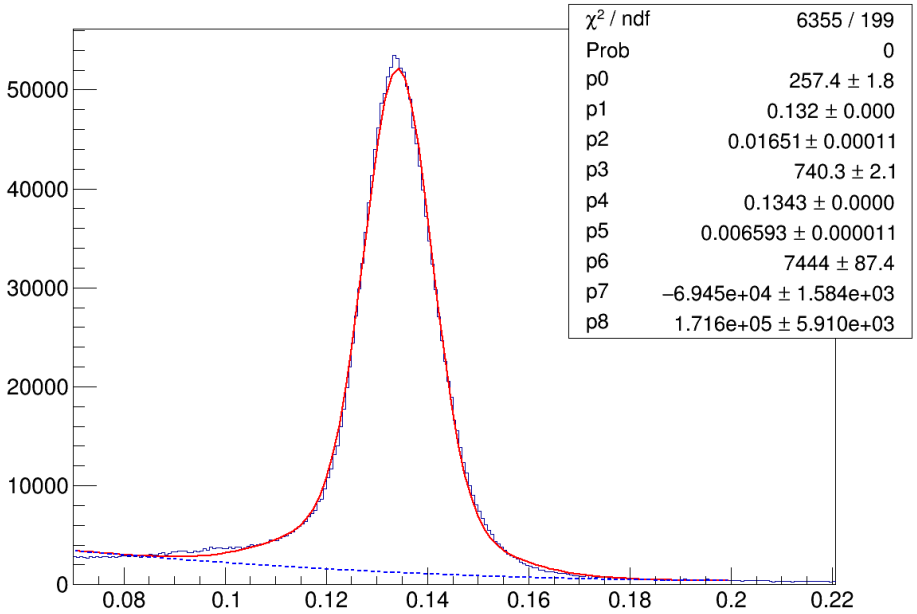


Diphoton Mass (GeV)
Yeild: 128800±6991

~5% effect

Backup: All unused showers: π^0 candidates (data)

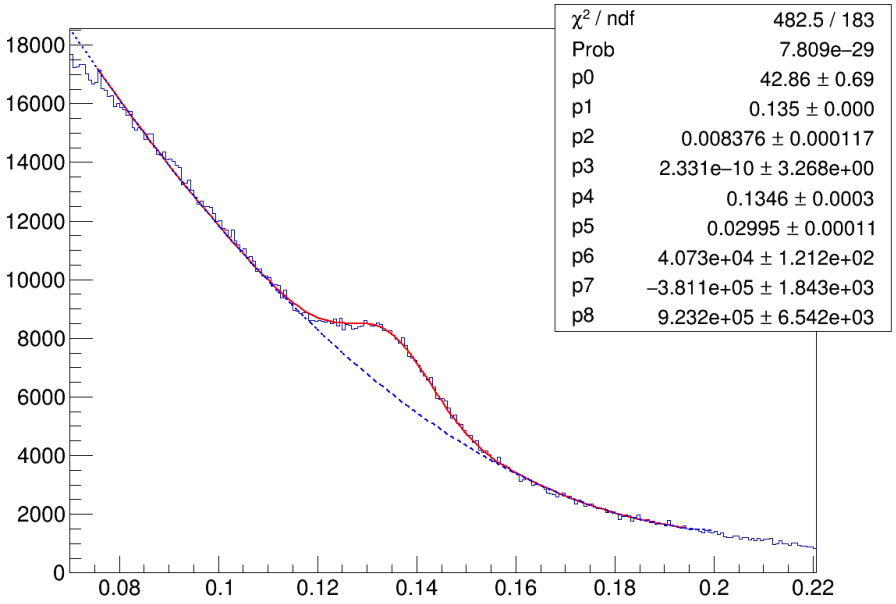
Closest shower in orientation



Diphoton Mass (GeV)

Yeild: 257226±2486

All other "unused neutrals"



Diphoton Mass (GeV)

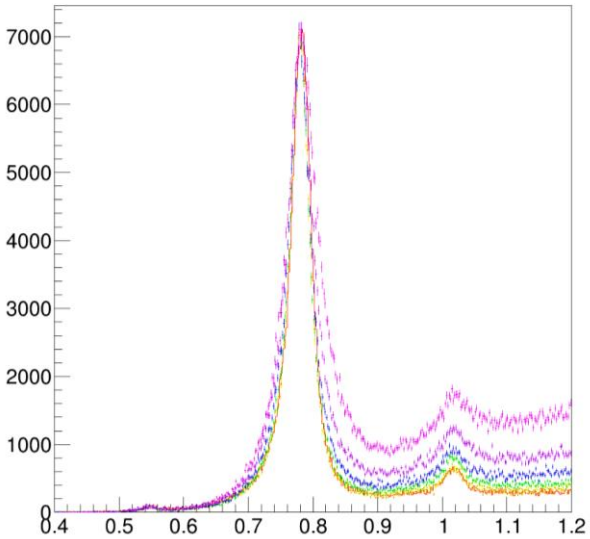
Yeild: 6631±902

~4% effect

Backup: ω Missing Mass: MC (over angle θ)

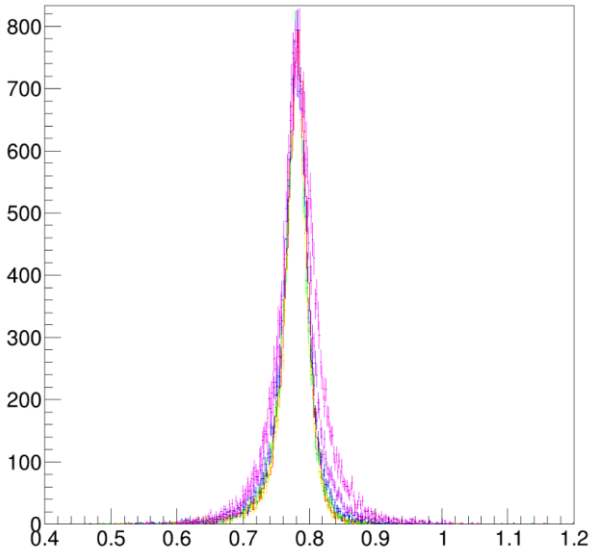
- Peak widens as angle increases

Bggen 1.2.1



Missing Mass (GeV)

Signal MC

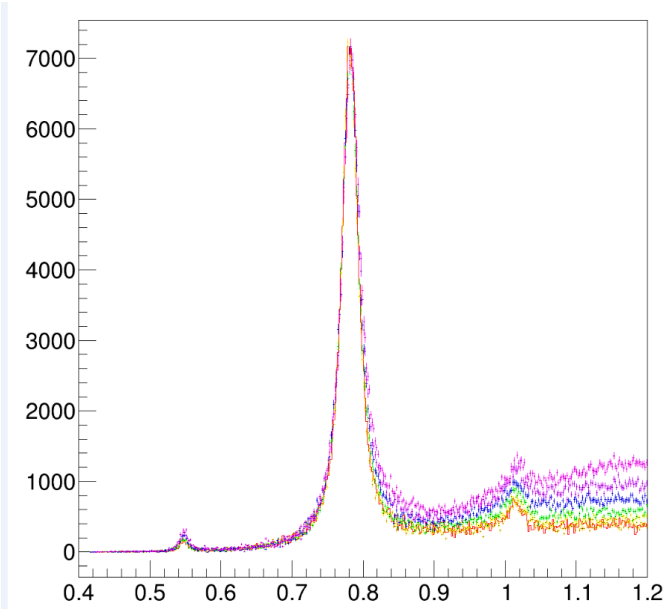


Missing Mass (GeV)

Increasing angle from red -> violet (normalized to peak)

Backup: ω Missing Mass: Data (over angle θ)

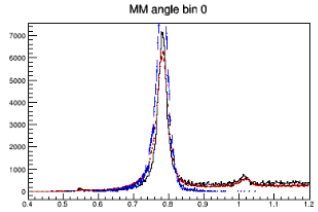
- ω missing mass resolution doesn't vary as strongly in data

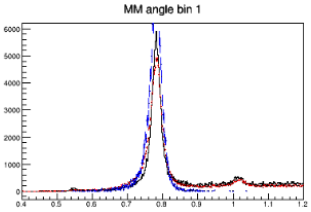


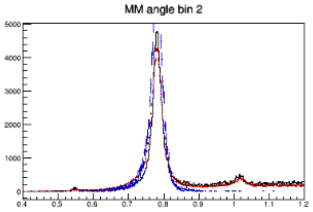
Increasing angle from red -> violet
(normalized to peak)

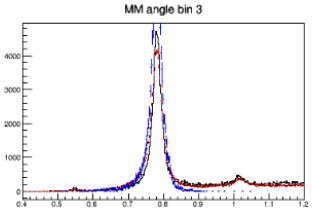
Backup: Missing Mass ω Yields

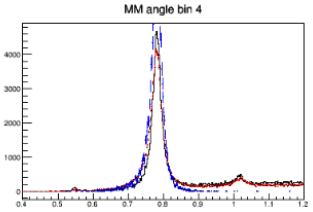
- 20 bins of equal statistics ranging from $\theta = 0 - 12°$
- First 10 bins shown

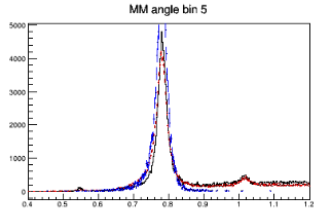


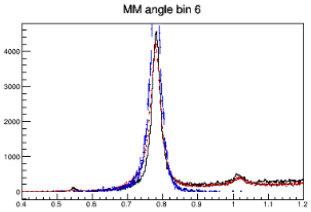


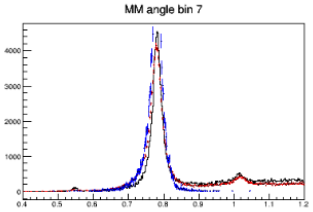


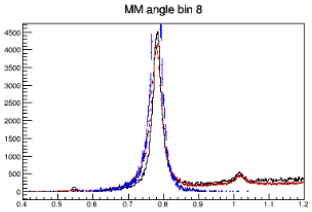


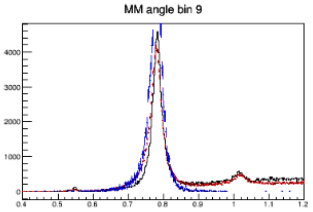








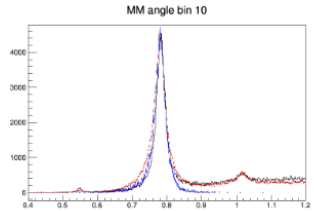


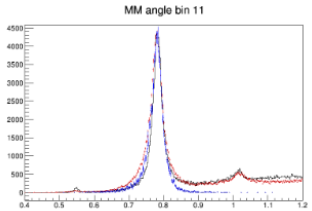


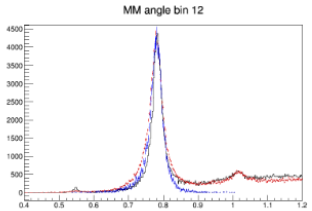
Black: data (golden runs) Red: bggen (scaled to peak) Blue: signal MC (scaled to peak)

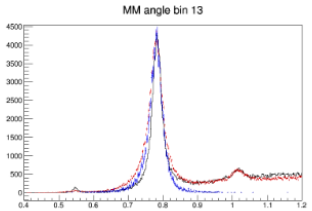
Backup: Missing Mass ω Yields Over Polar Angle

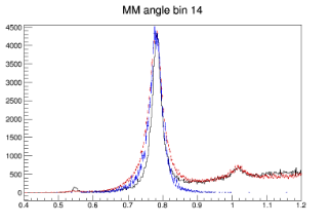
- 20 bins of equal statistics ranging from $\theta = 0 - 12°$
- Last 10 bins shown

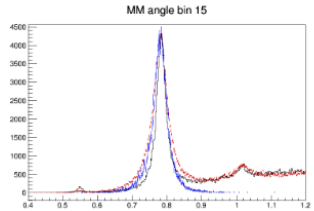


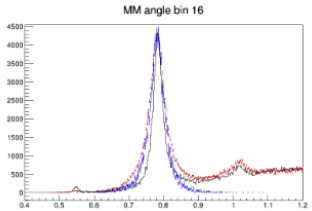


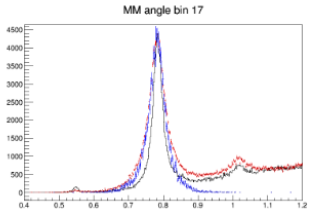


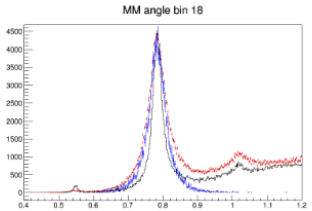


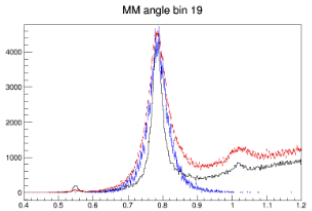










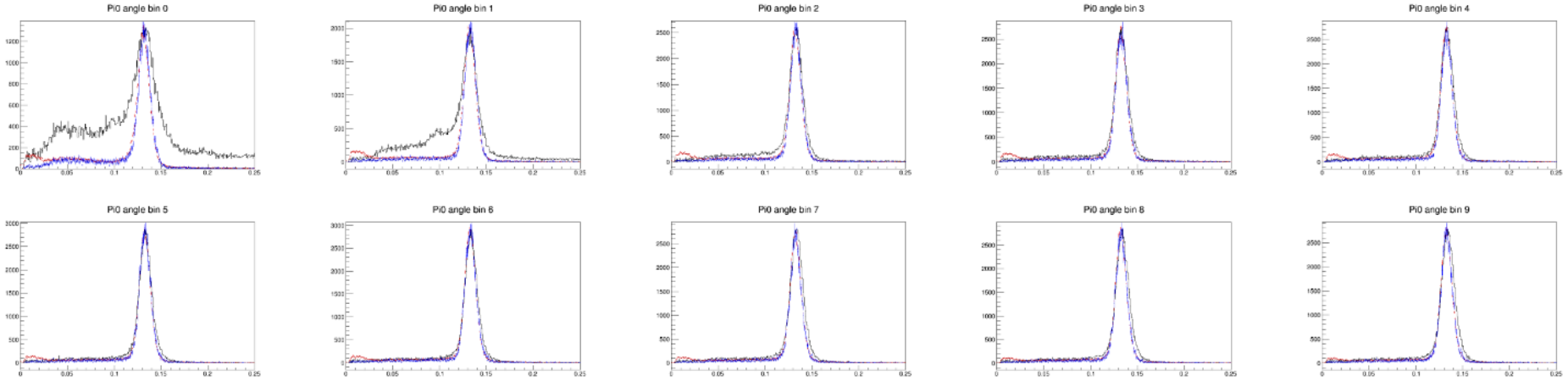


As angle increases, bggen and signal MC widen compared to data

Black: data (golden runs) Red: bggen (scaled to peak) Blue: signal MC (scaled to peak)

Backup: Invariant Mass π^0 Yields

- 20 bins of equal statistics ranging from $\theta = 0 - 12°$
- First 10 bins shown

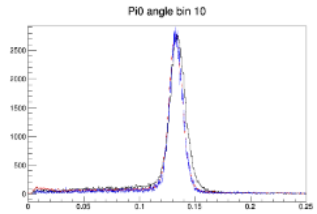


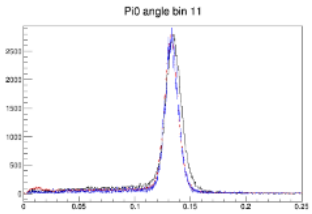
EM Background shows up at low angle in data, is not included in MC samples

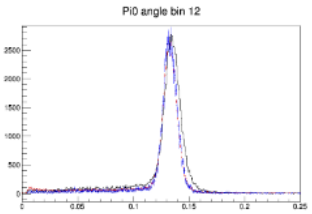
Black: data (golden runs) Red: bggen (scaled to peak) Blue: signal MC (scaled to peak)

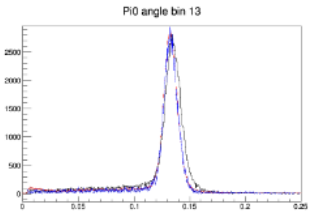
Backup: Invariant Mass π^0 Yields

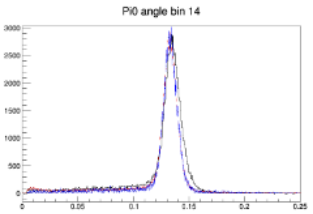
- 20 bins of equal statistics ranging from $\theta = 0 - 12°$
- Last 10 bins shown

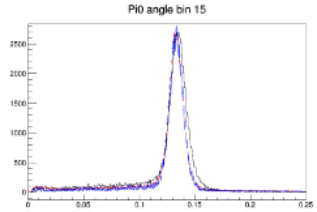


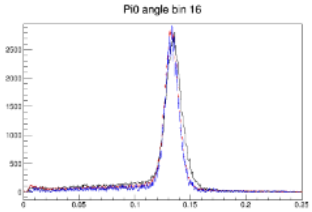


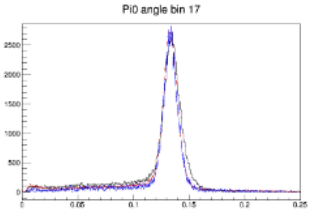


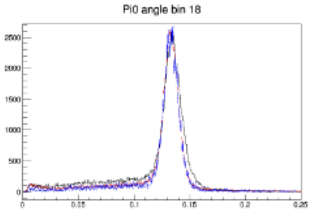


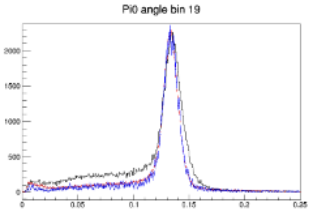












Black: data (golden runs) Red: bggen (scaled to peak) Blue: signal MC (scaled to peak)

Backup: Event Selection (Detailed)

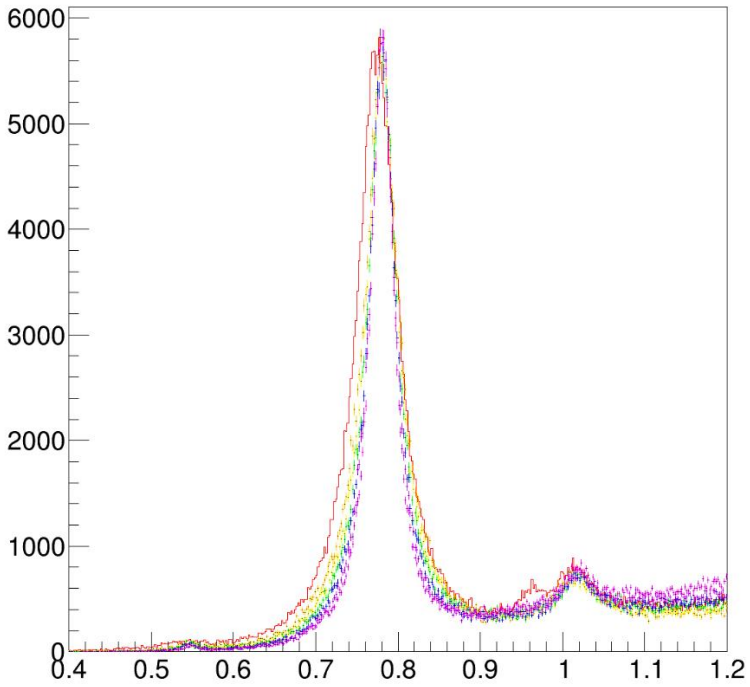
- No extra tracks
- Reconstructed photon > 500 MeV
- -0.1 < Missing Measured Mass^2 < 0.1 GeV^2
- All tracks:
  - 48 cm < Z-vertex < 78 cm
  - DOCA < 1 cm
- PID timing:
  - Δt < 1 ns TOF
  - Δt < 3 ns BCAL
  - Δt < 2.5 ns FCAL
- Kinematic Fitting:
  - Vertex fit
  - Constraint requiring missing (photon) mass = 0
  - 0.001 fiducial CL cut
- 12 max unused showers in event (for coding simplicity, cuts maybe 1 in 100,000 events)

Backup: Fitting Procedure (detailed)

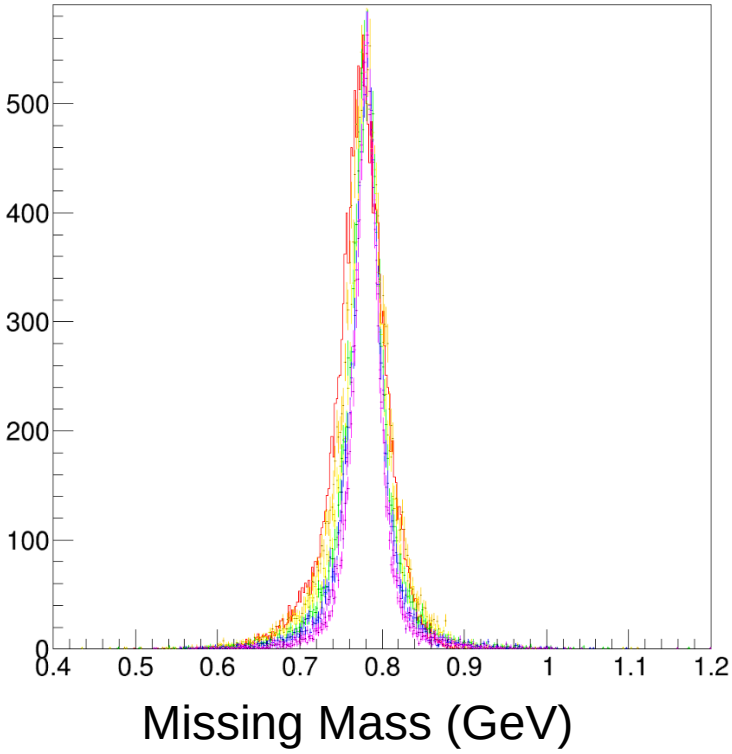
- Mostly leaving as a reference for others
- (tried using RooFit, fits were failing miserably)
- Fit function: double Gaussian with 2^{nd} order poly bkg
  - Require mass position to be near true mass
  - Require reasonable width
  - Gaussian amplitude must be positive
  - If 2^{nd} order bkg integral is negative under peak, try again
- Fitting functions that didn't do well:
  - Single Gaussian
  - Voigt: Gaussian + BW (w/ BW mass fixed)
  - Crystal ball function (left-sided and double-sided symmetric)
  - GausExp (Gaussian less than 1σ from mean, exponential past 1σ)

Backup:
ω Missing Mass: MC (over energy)

Bggen 1.2.1

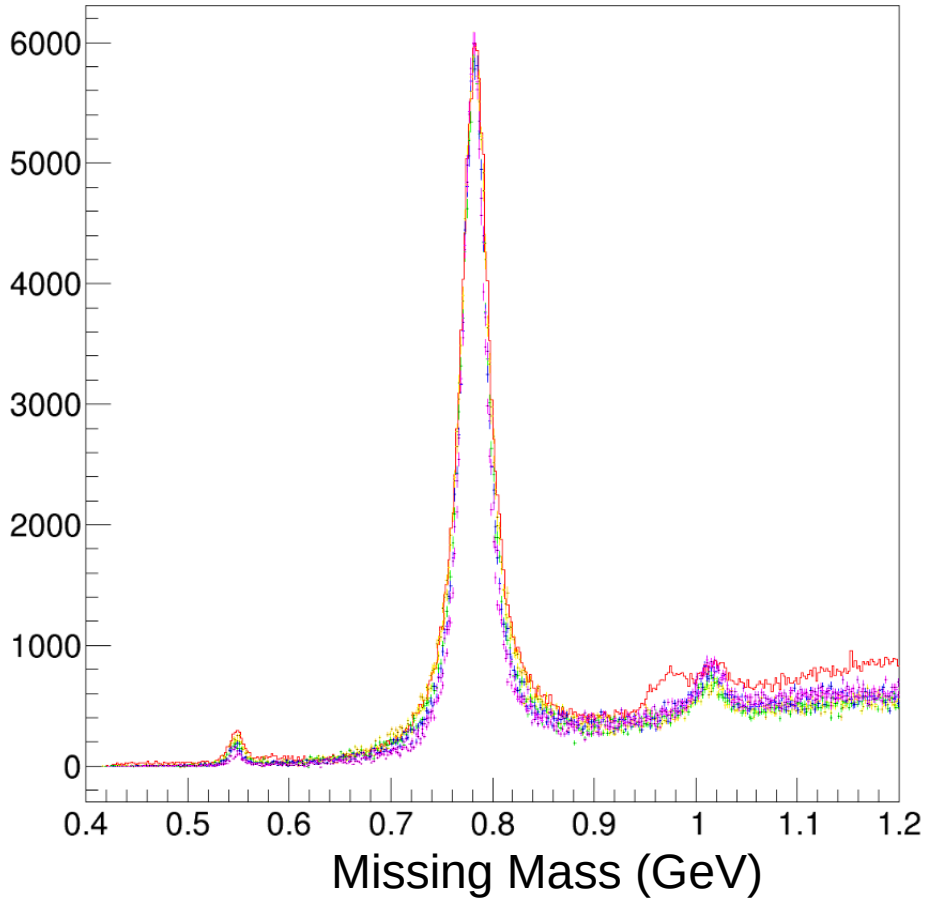


Signal MC



Increasing energy from red -> violet (normalized to peak)

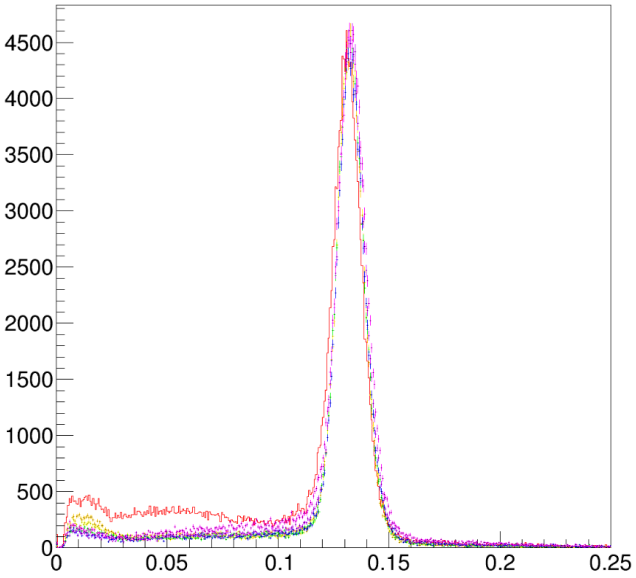
Backup:
ω Missing Mass: Data (over energy)



Increasing energy from red -> violet
(normalized to peak)

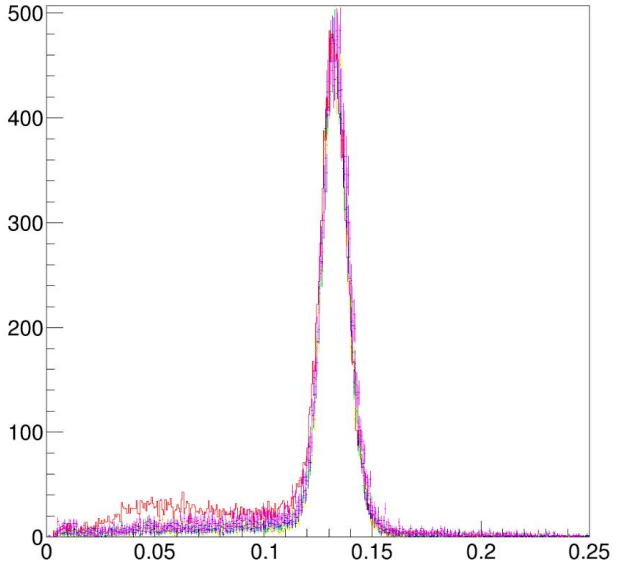
Backup: π^0 Invariant Mass: MC (over angle θ)

Bggen 1.2.1



$\gamma\gamma\ inv.\ mass$ (GeV)

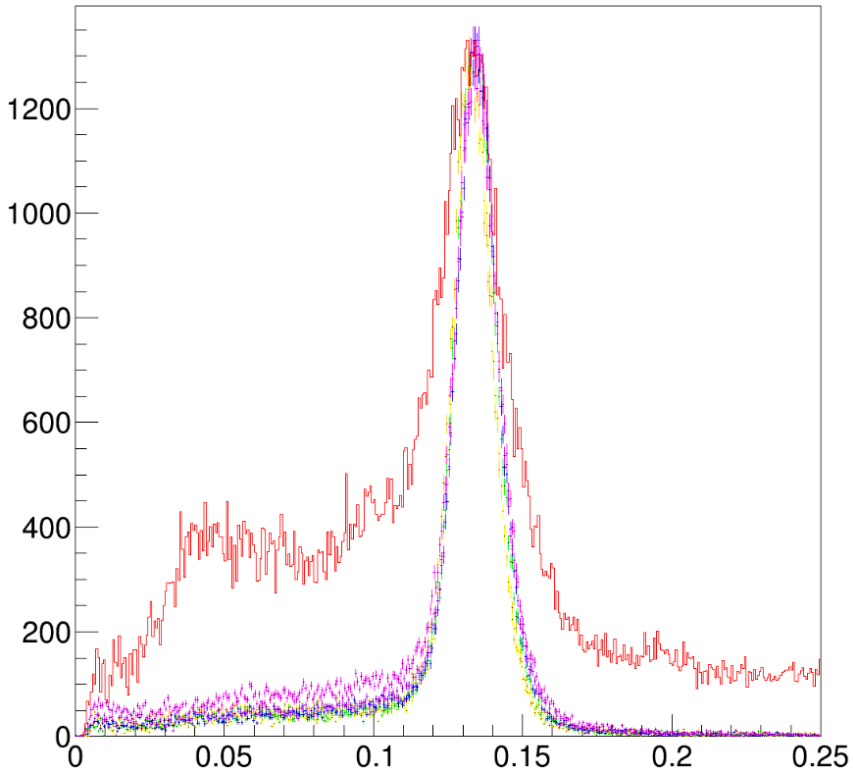
Signal MC



$\gamma\gamma\ inv.\ mass$ (GeV)

Increasing angle from red -> violet (normalized to peak)
(reminder: no EM background)

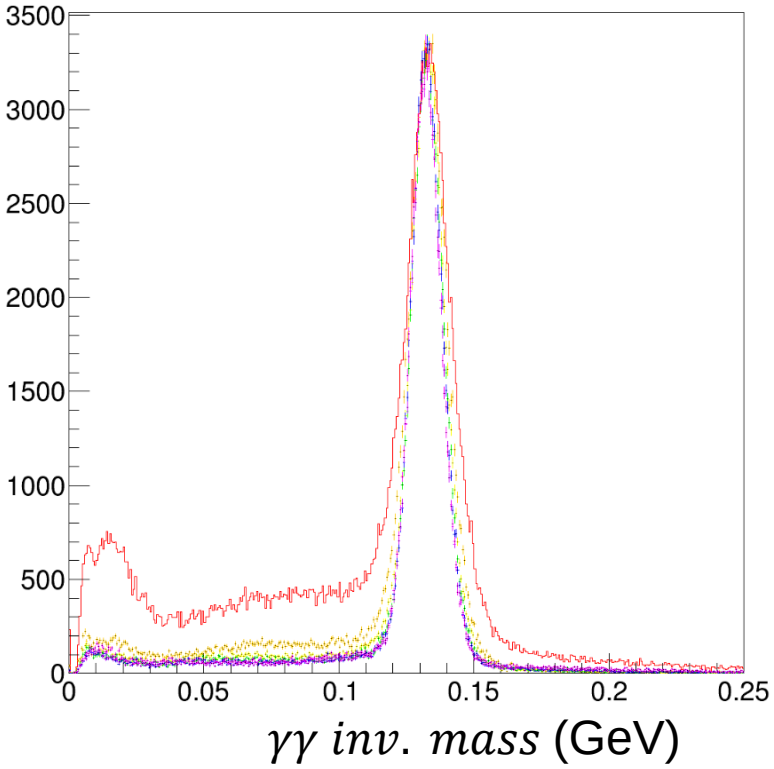
Backup:
π^0 Invariant Mass: Data (over angle θ)



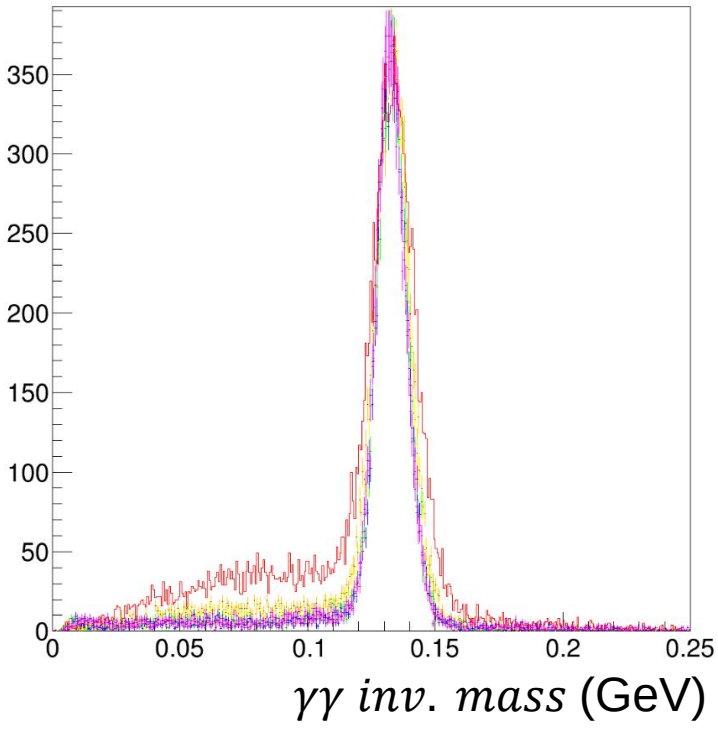
Increasing angle from red -> violet
(normalized to peak)

Backup: π^0 Invariant Mass : MC (over energy)

Bggen 1.2.1

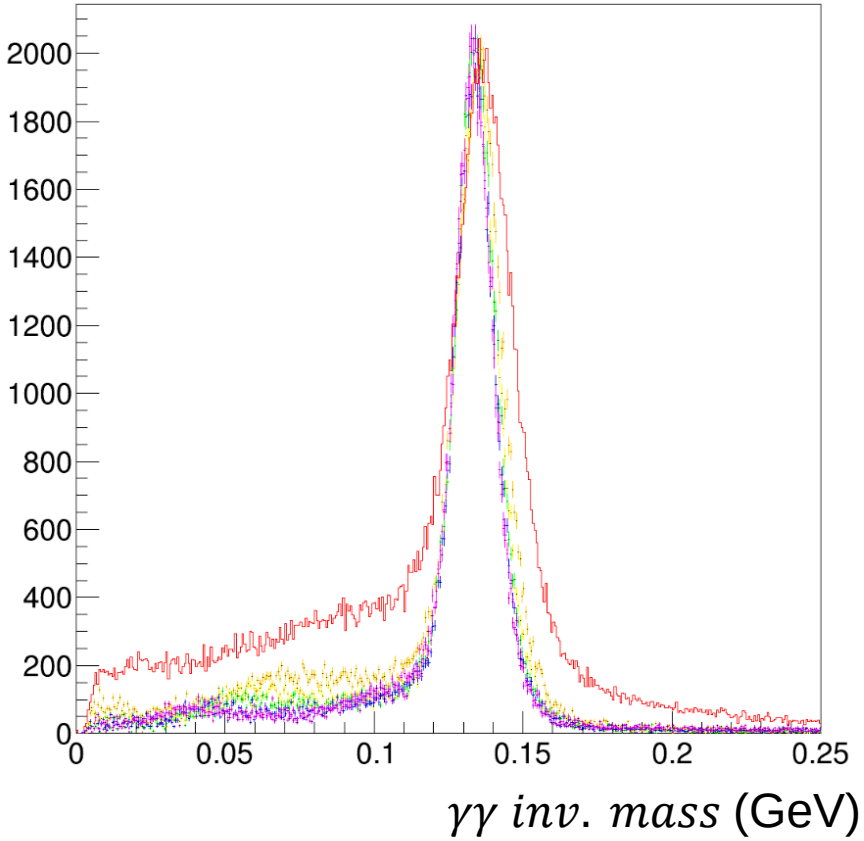


Signal MC



Increasing energy from red -> violet (normalized to peak)

Backup:
π^0 Invariant Mass : Data (over energy)



Increasing energy from red -> violet
(normalized to peak)