Update on e+e- -> Z gamma benchmark analysis

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Status report on e^+e^- -> gamma Z analysis

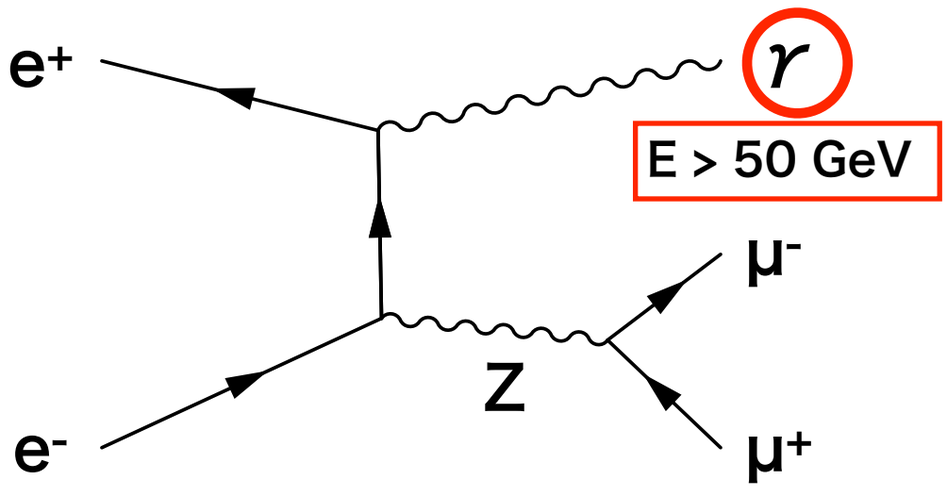
- I'm working on **photon energy calibration.** I checked

- Resolved energy of photon when using measured muons' energy in addition to measured angle data

- Distribution of Photon Energy and Photon Angle in PFO

- ISR Energy distribution

Determine the energy of photon and muons based on measured direction angle



Direction Angle
θ: azimuthal angle
ϕ: polar angle

- **4-momentum conservation is considered.**
- **The mass of muon is neglected.**

Case 1:
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}$)
-> Determine ($E_{\mu^-}, E_{\mu^+}, E_{\gamma}$)

Case 2: Consider **Beamstrahlung**
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}$)
-> Determine ($E_{\mu^-}, E_{\mu^+}, E_{\gamma}, E_{ISR}$)

Case 3: Consider **Beamstrahlung**
and **Crossing Angle**
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}$)
-> Determine ($E_{\mu^-}, E_{\mu^+}, E_{\gamma}, E_{ISR}$)

Case 4: Case 3 using muons' energies
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}, E_{\mu^-}, E_{\mu^+}$)
-> Determine (E_{γ}, E_{ISR})

- **Case 1**

$$\begin{cases} E_\mu + E_{\mu^+} + E_\gamma = 500 \\ E_\mu sin\theta_\mu cos\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} cos\phi_{\mu^+} + E_\gamma sin\theta_\gamma cos\phi_\gamma = 0 \\ E_\mu sin\theta_\mu sin\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} sin\phi_{\mu^+} + E_\gamma sin\theta_\gamma sin\phi_\gamma = 0 \\ E_\mu cos\theta_\mu + E_{\mu^+} cos\theta_{\mu^+} + E_\gamma cos\theta_\gamma = 0 \end{cases}$$

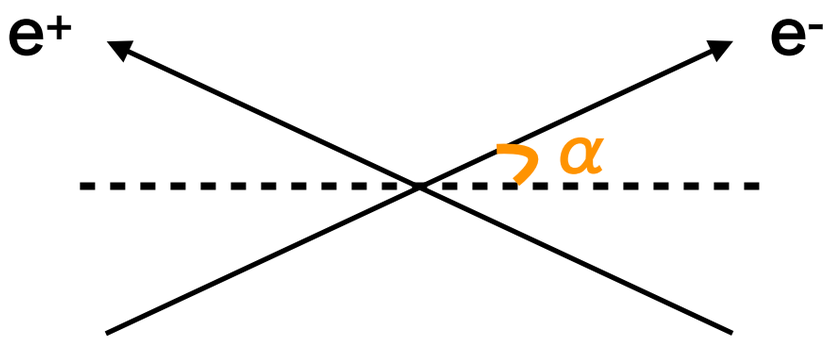
- **Case2: Consider Beamstrahlung**

$$\begin{cases} E_\mu + E_{\mu^+} + E_\gamma + |P_{ISR}| = 500 \\ E_\mu sin\theta_\mu cos\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} cos\phi_{\mu^+} + E_\gamma sin\theta_\gamma cos\phi_\gamma = 0 \\ E_\mu sin\theta_\mu sin\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} sin\phi_{\mu^+} + E_\gamma sin\theta_\gamma sin\phi_\gamma = 0 \\ E_\mu cos\theta_\mu + E_{\mu^+} cos\theta_{\mu^+} + E_\gamma cos\theta_\gamma + P_{ISR} = 0 \end{cases}$$

- **Case 3: Consider Beamstrahlung + Crossing Angle**

$$\begin{cases} E_\mu + E_{\mu^+} + E_\gamma + |P_{ISR}| = 500 \\ E_\mu sin\theta_\mu cos\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} cos\phi_{\mu^+} + E_\gamma sin\theta_\gamma cos\phi_\gamma + |P_{ISR}| sin\alpha = 500 sin\alpha \\ E_\mu sin\theta_\mu sin\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} sin\phi_{\mu^+} + E_\gamma sin\theta_\gamma sin\phi_\gamma = 0 \\ E_\mu cos\theta_\mu + E_{\mu^+} cos\theta_{\mu^+} + E_\gamma cos\theta_\gamma \pm |P_{ISR}| cos\alpha = 0 \end{cases}$$

Crossing Angle ($\equiv 2\alpha$)



α = 7.0 mrad

- **Case 4: Using measured muon energies**

$$\begin{cases} E_\mu + E_{\mu^+} + E_\gamma + |P_{ISR}| = 500 \\ E_\mu sin\theta_\mu cos\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} cos\phi_{\mu^+} + E_\gamma sin\theta_\gamma cos\phi_\gamma + |P_{ISR}| sin\alpha = 500 sin\alpha \\ E_\mu sin\theta_\mu sin\phi_\mu + E_{\mu^+} sin\theta_{\mu^+} sin\phi_{\mu^+} + E_\gamma sin\theta_\gamma sin\phi_\gamma = 0 \\ E_\mu cos\theta_\mu + E_{\mu^+} cos\theta_{\mu^+} + E_\gamma cos\theta_\gamma \pm |P_{ISR}| cos\alpha = 0 \end{cases}$$

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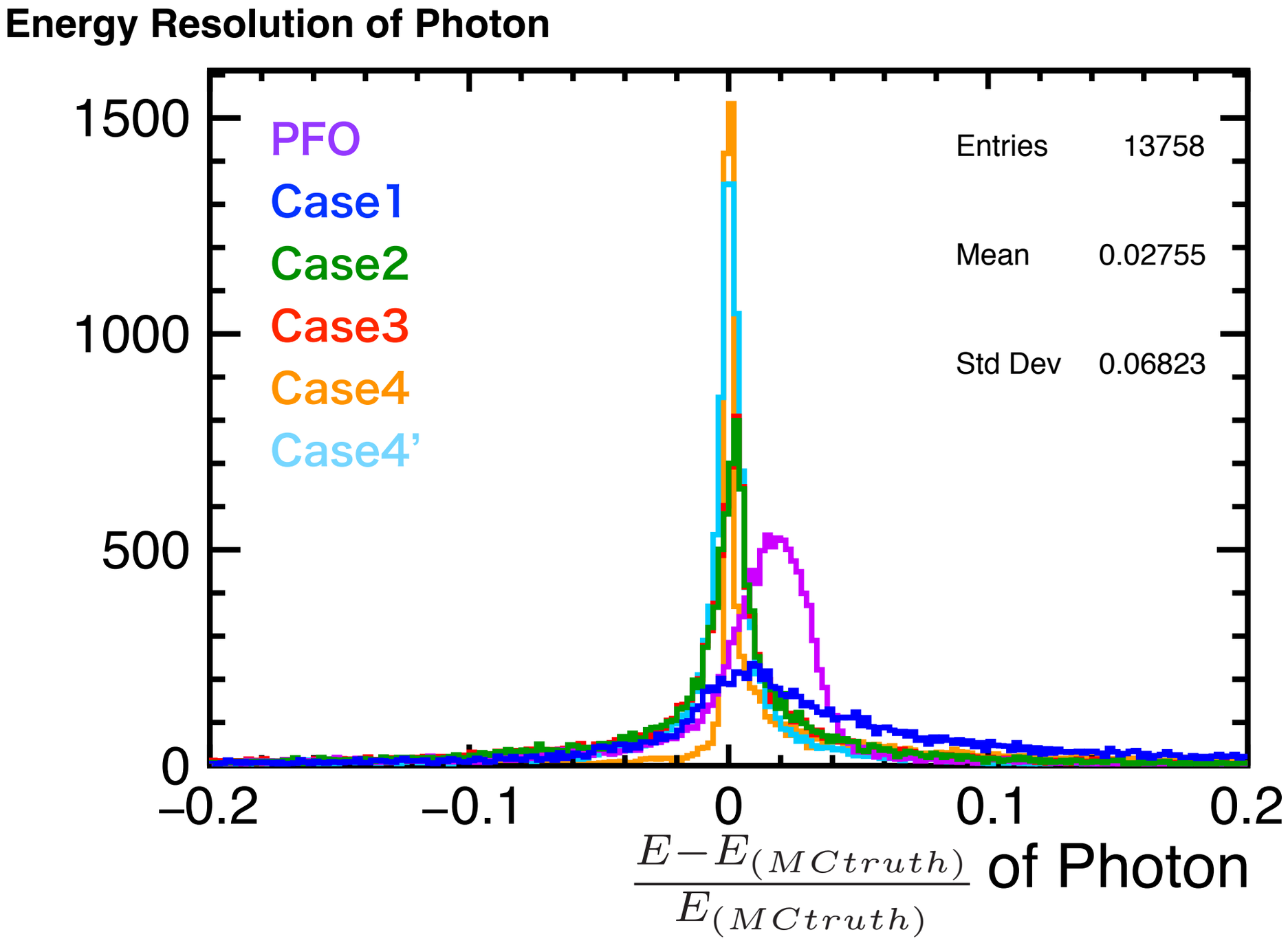
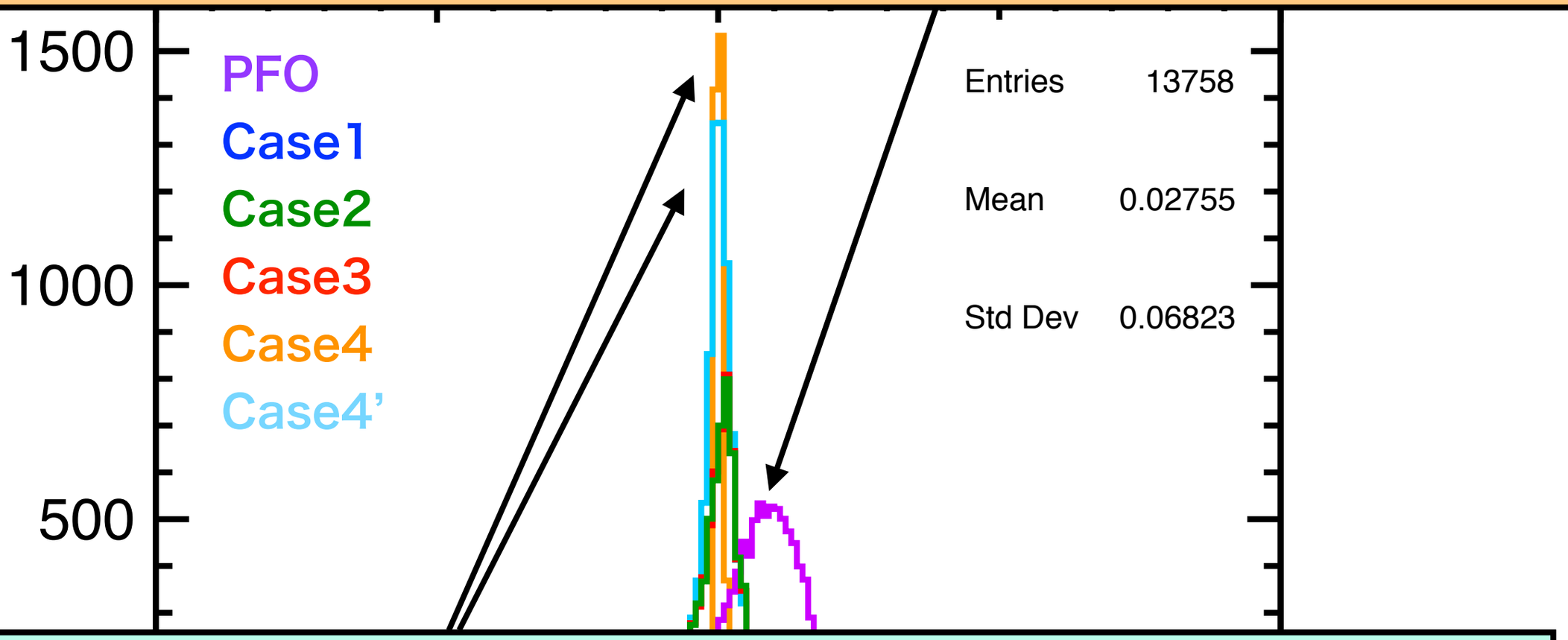
This is of no use when $\sin\phi_\gamma = 0$??

Resolved Energy of Photon



Resolved Energy of Photon

- The peak of PFO is shifted to the positive region.
  I will discuss this later.



- Case 4' is the best for now due to
  it's peak height and shape (symmetry).
  In the end, all 4 equations are to be considered.

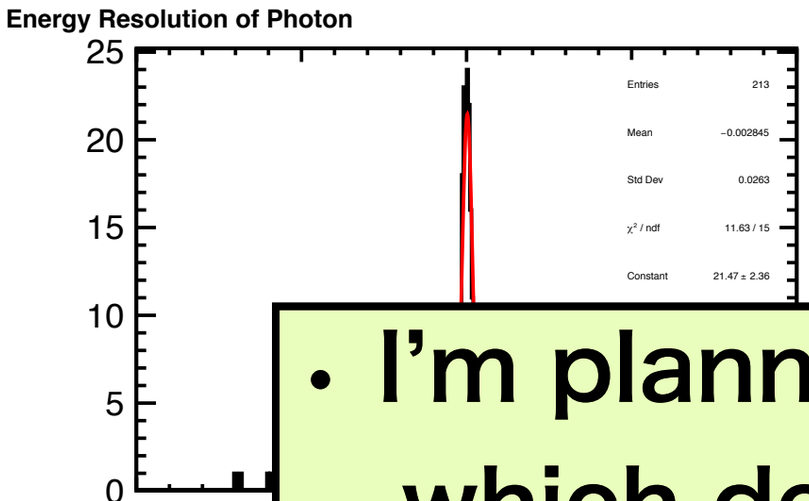
Case 4': Case 3 using muons' energies

Using (θ_{μ^-}, θ_{μ^+}, θ_{γ}, ϕ_{μ^-}, ϕ_{μ^+}, ϕ_{γ}, E_{μ^-}, E_{μ^+})

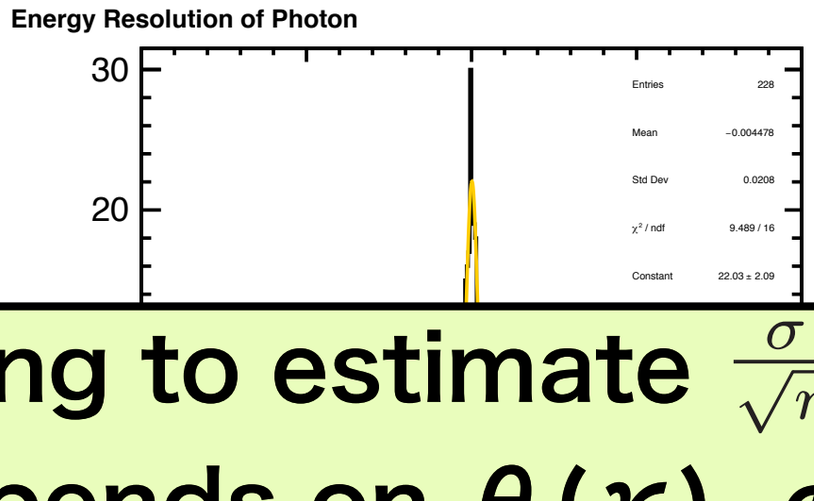
-> Determine (E_{γ}, E_{ISR})

Samples:
$|M(\mu^+\mu^-)-91.2| < 10$ GeV
$0.4 < |\sin\phi(\gamma)| < 0.8$
Large ILD model

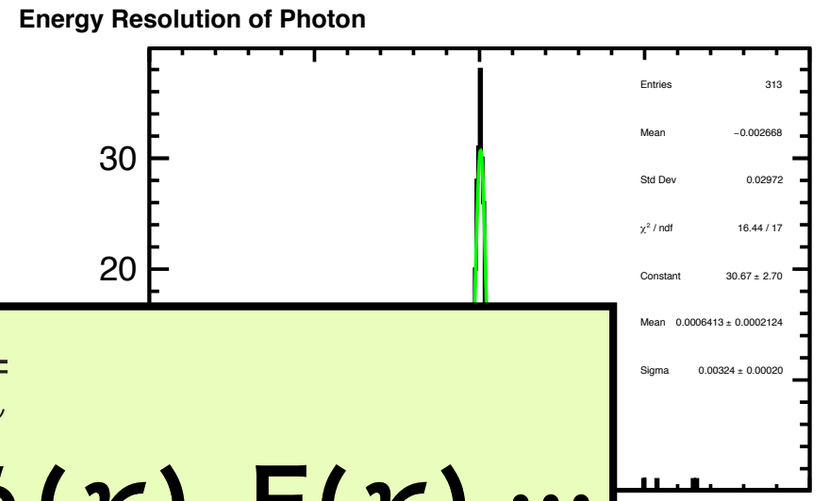
$|\cos\theta(\gamma)| < 0.2$



$0.2 < |\cos\theta(\gamma)| < 0.4$

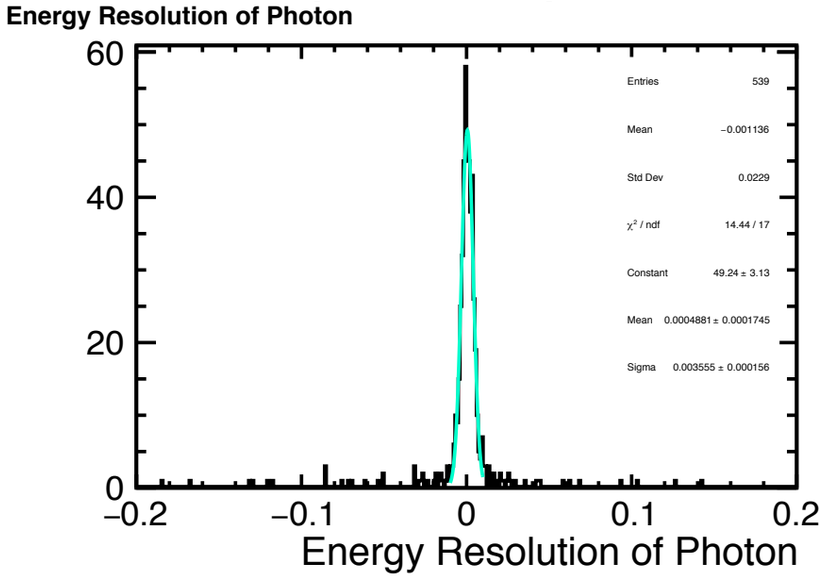


$0.4 < |\cos\theta(\gamma)| < 0.6$

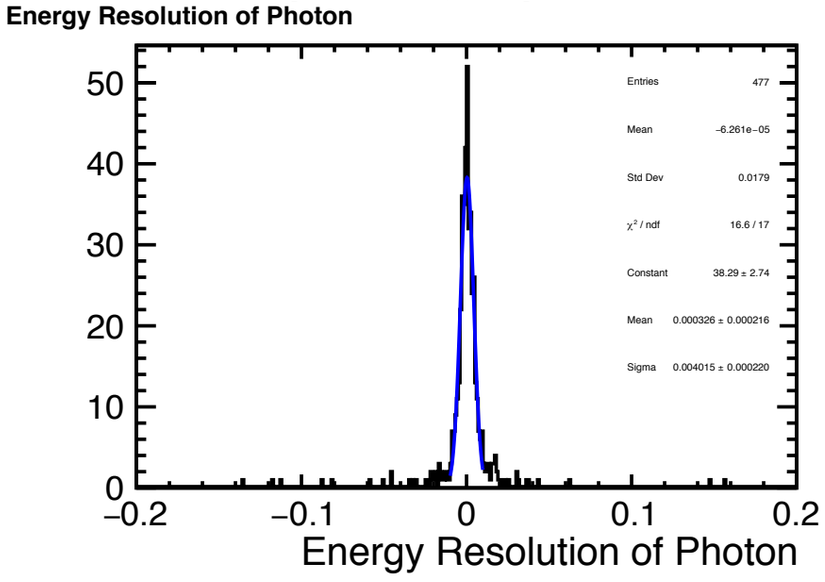


- I'm planning to estimate $\frac{\sigma}{\sqrt{n}}$,which depends on $\theta(\gamma)$, $\phi(\gamma)$, $E(\gamma)$ ···

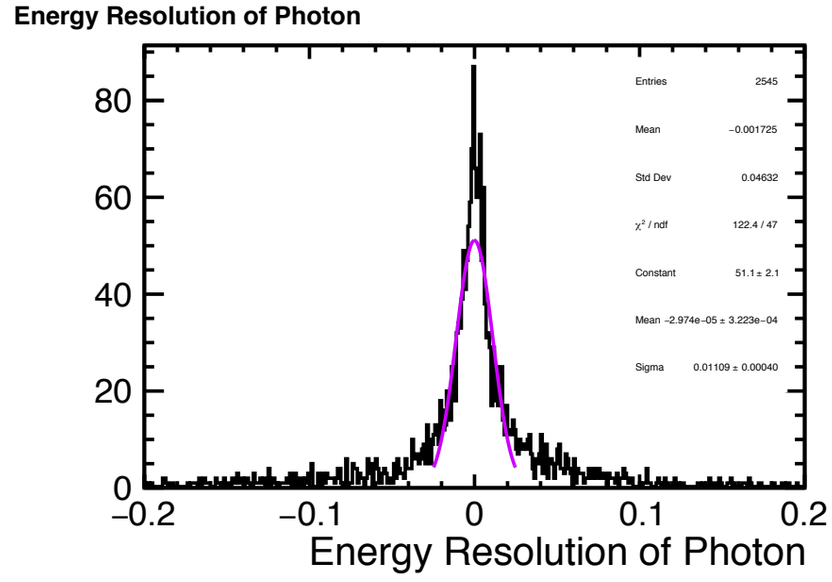
$0.6 < |\cos\theta(\gamma)| < 0.8$



$0.8 < |\cos\theta(\gamma)| < 0.9$



$0.9 < |\cos\theta(\gamma)|$



Resolved Energy of Photon

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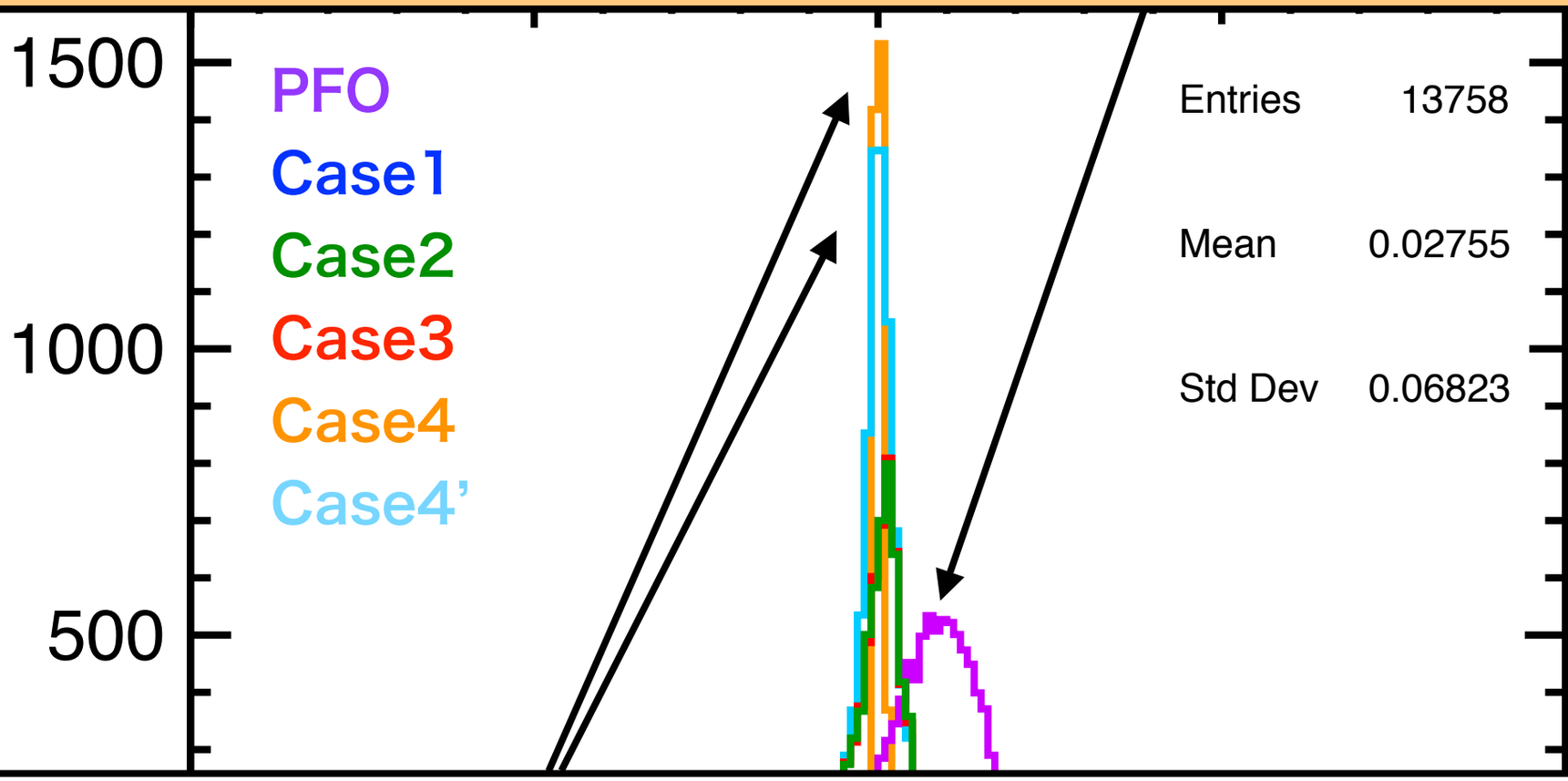

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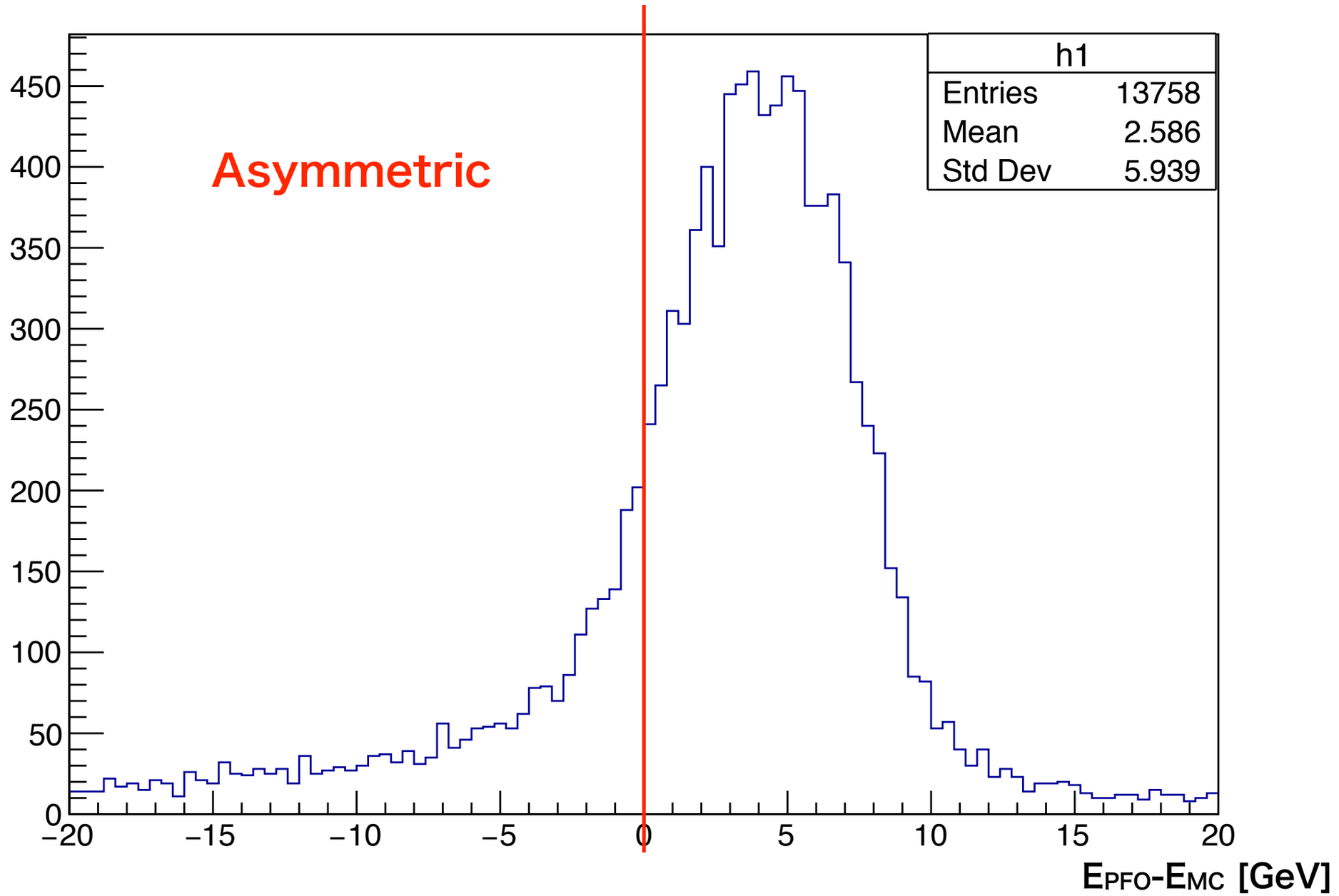
  it's peak height and shape (symmetry).
  In the end, all 4 equations are to be considered.

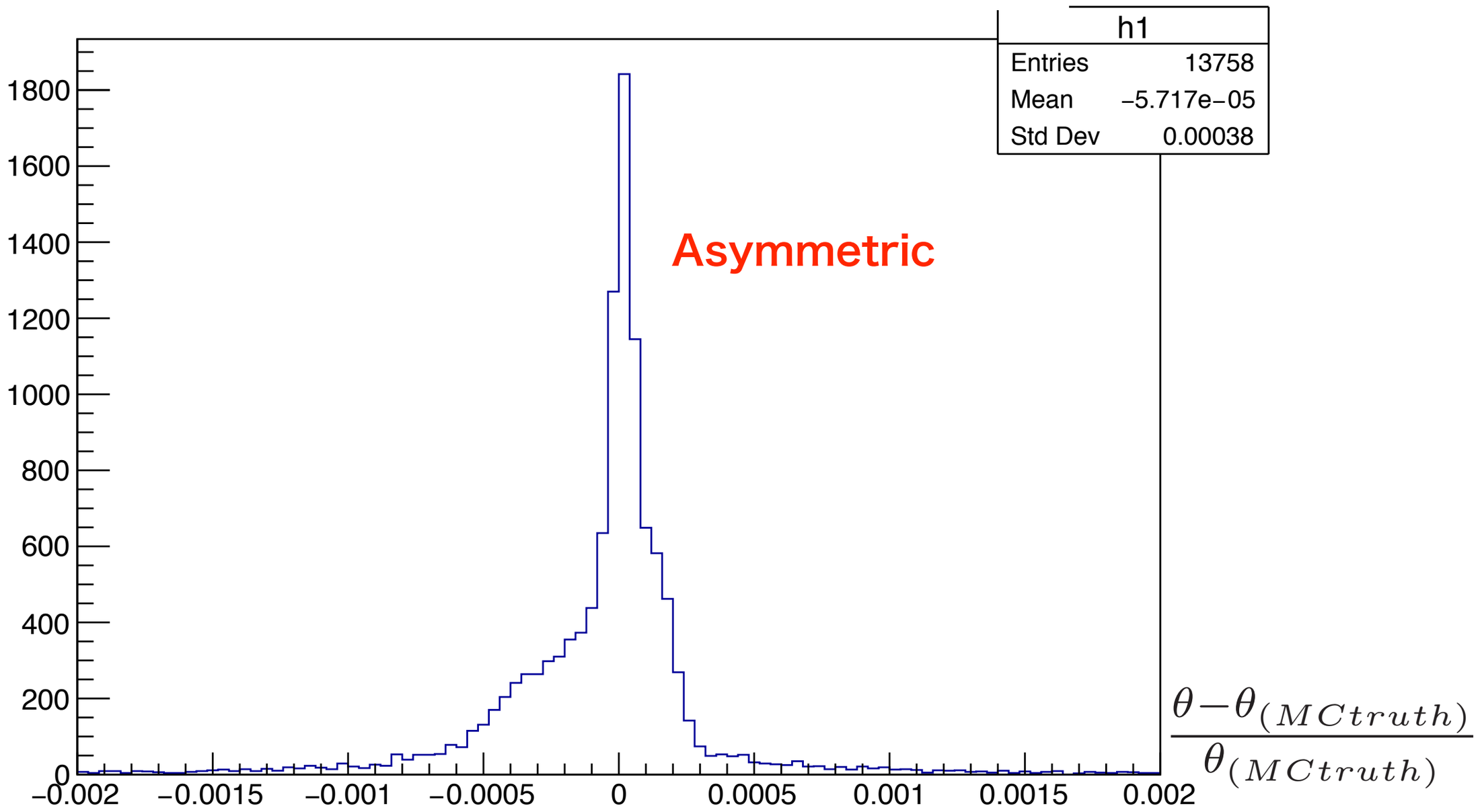
Distribution of PFO Photon Energy

Samples:
$|M(\mu^+\mu^-)-91.2| < 10$ GeV
Large ILD model



Distribution of PFO Photon Angle (theta)

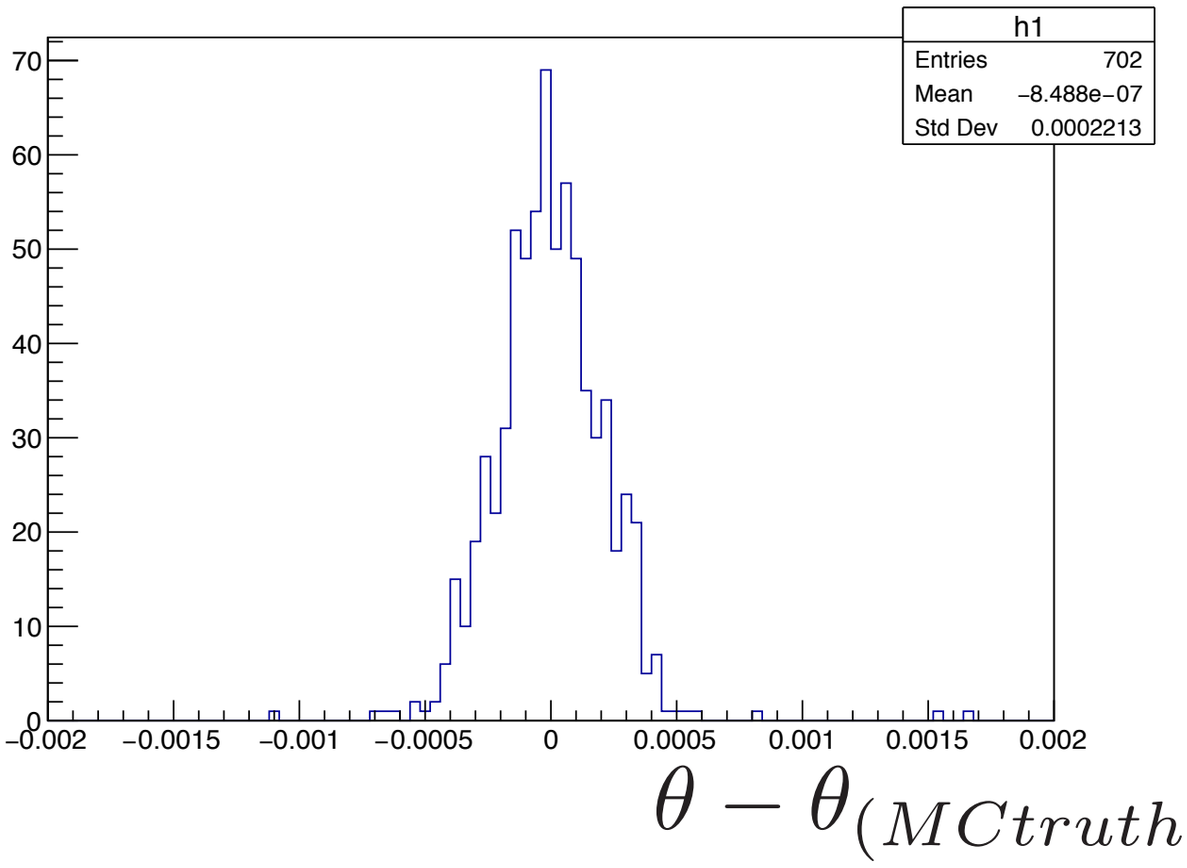
Samples:
$|M(\mu^+\mu^-)-91.2| < 10$ GeV
Large ILD model



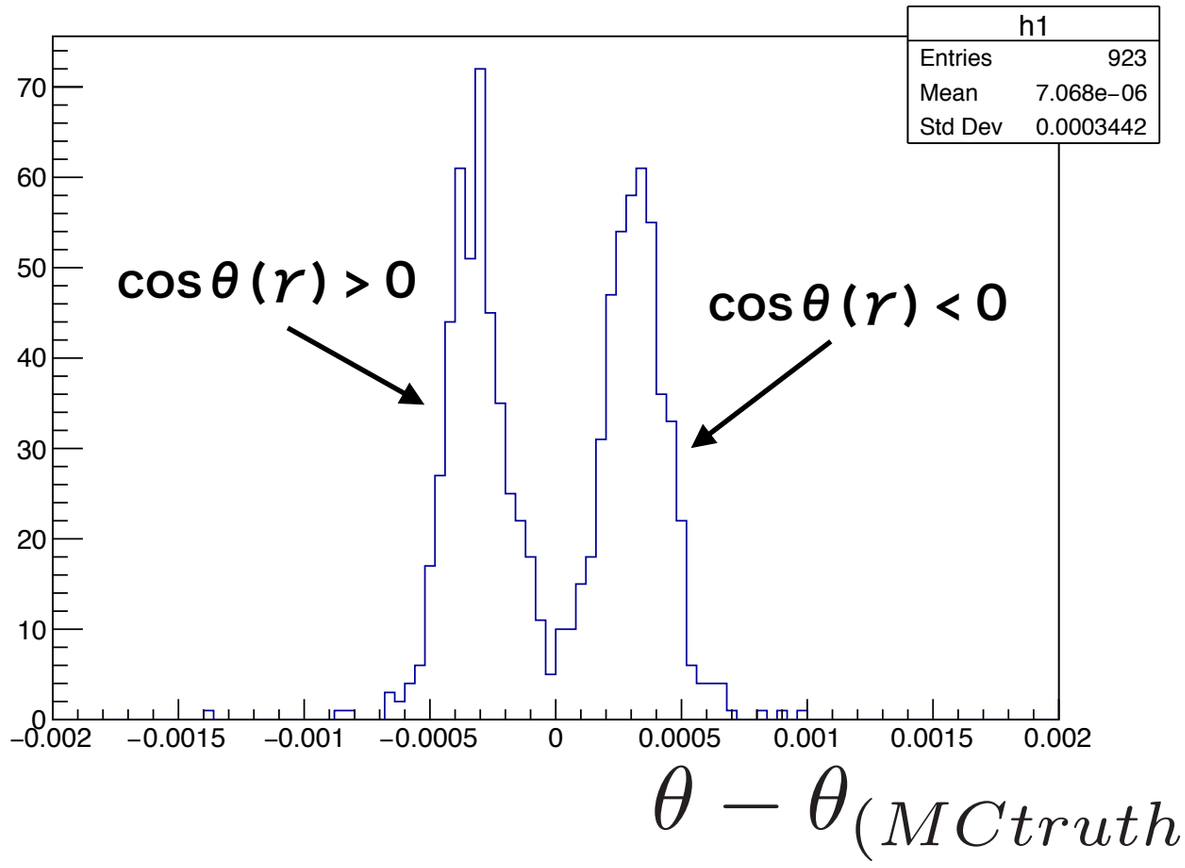
Distribution of PFO Photon Angle (theta)

Samples:
$|M(\mu^+\mu^-)-91.2| < 10$ GeV
Large ILD model

$|\cos\theta(\gamma)| < 0.2$



$0.4 < |\cos\theta(\gamma)| < 0.6$

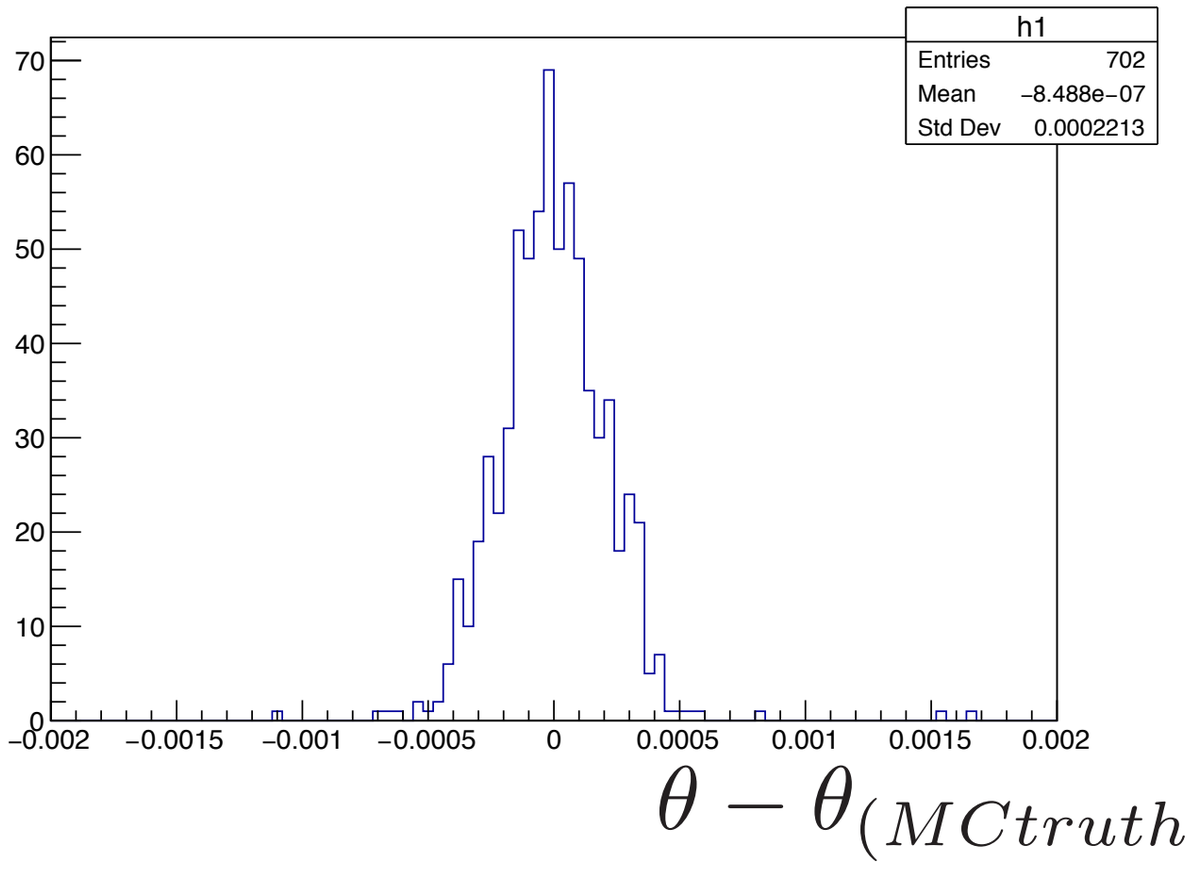


When theta is larger, bias gets more prominent.
In the PFO, the center of shower seems to be shifted to B-field direction due to the B field.

Distribution of PFO Photon Angle (theta)

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
Large ILD model

$|\cos\theta(\gamma)| < 0.2$



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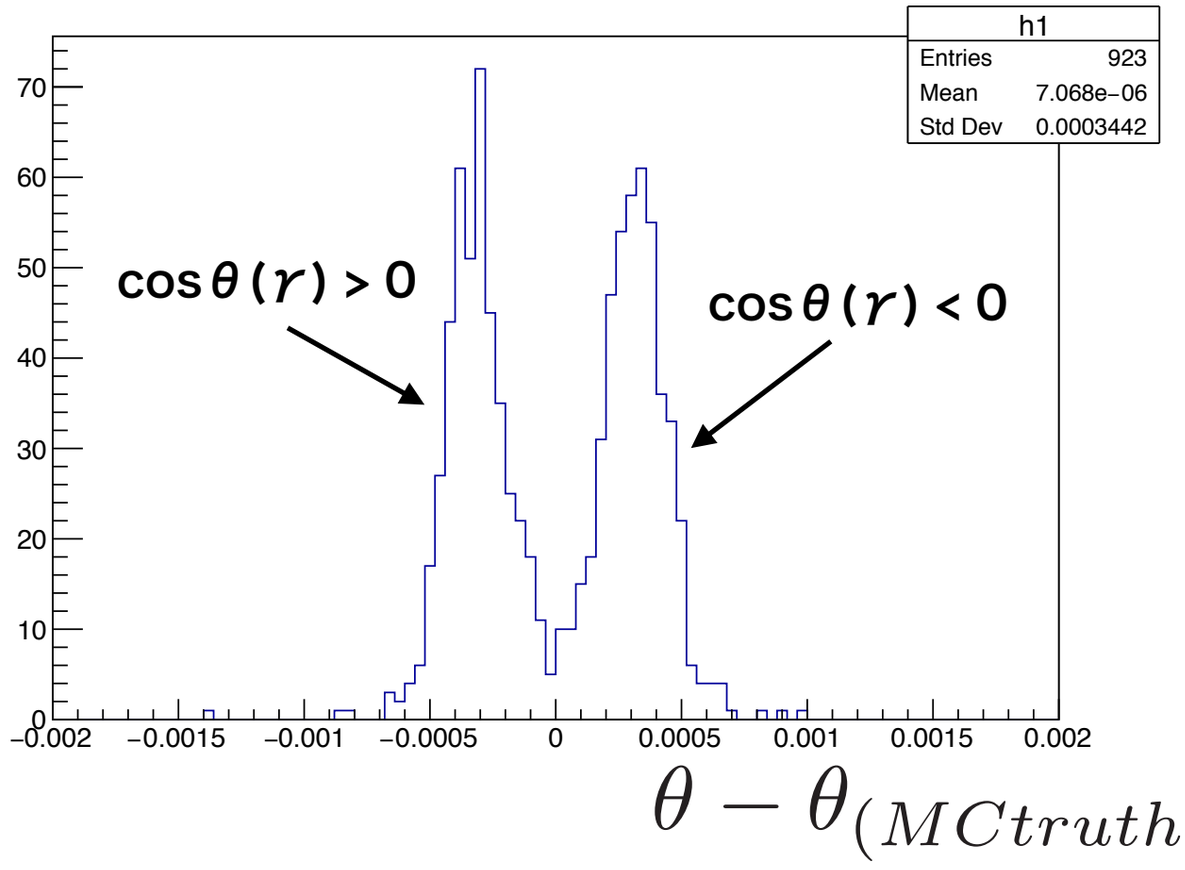

I am also checking distribution of Phi of PFO photon now.