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

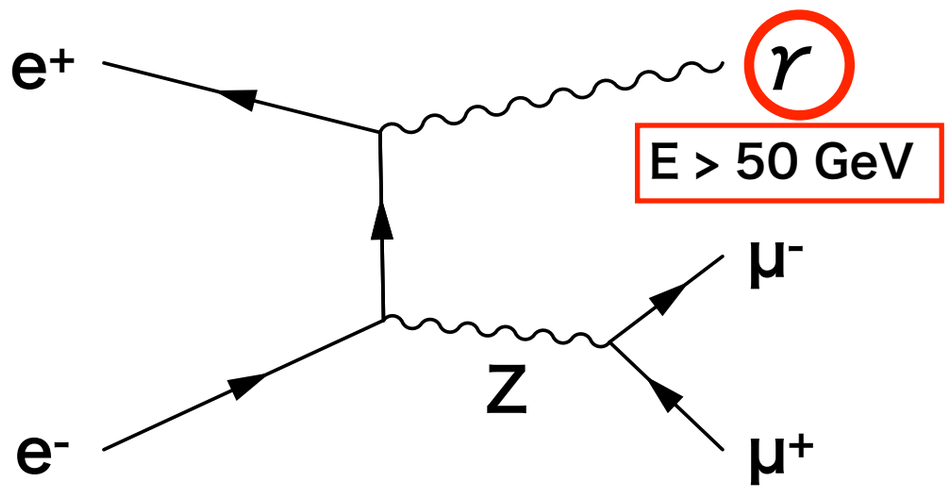
SOKENDAI
Takahiro Mizuno

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

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

- Today I will discuss
  (1) Comparison of the Resolved Energy of Photon for each Reconstruction Method
  (2) Distribution of Photon Energy and Photon Angle in PFO
  (3) Estimation of Energy Resolution

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.**

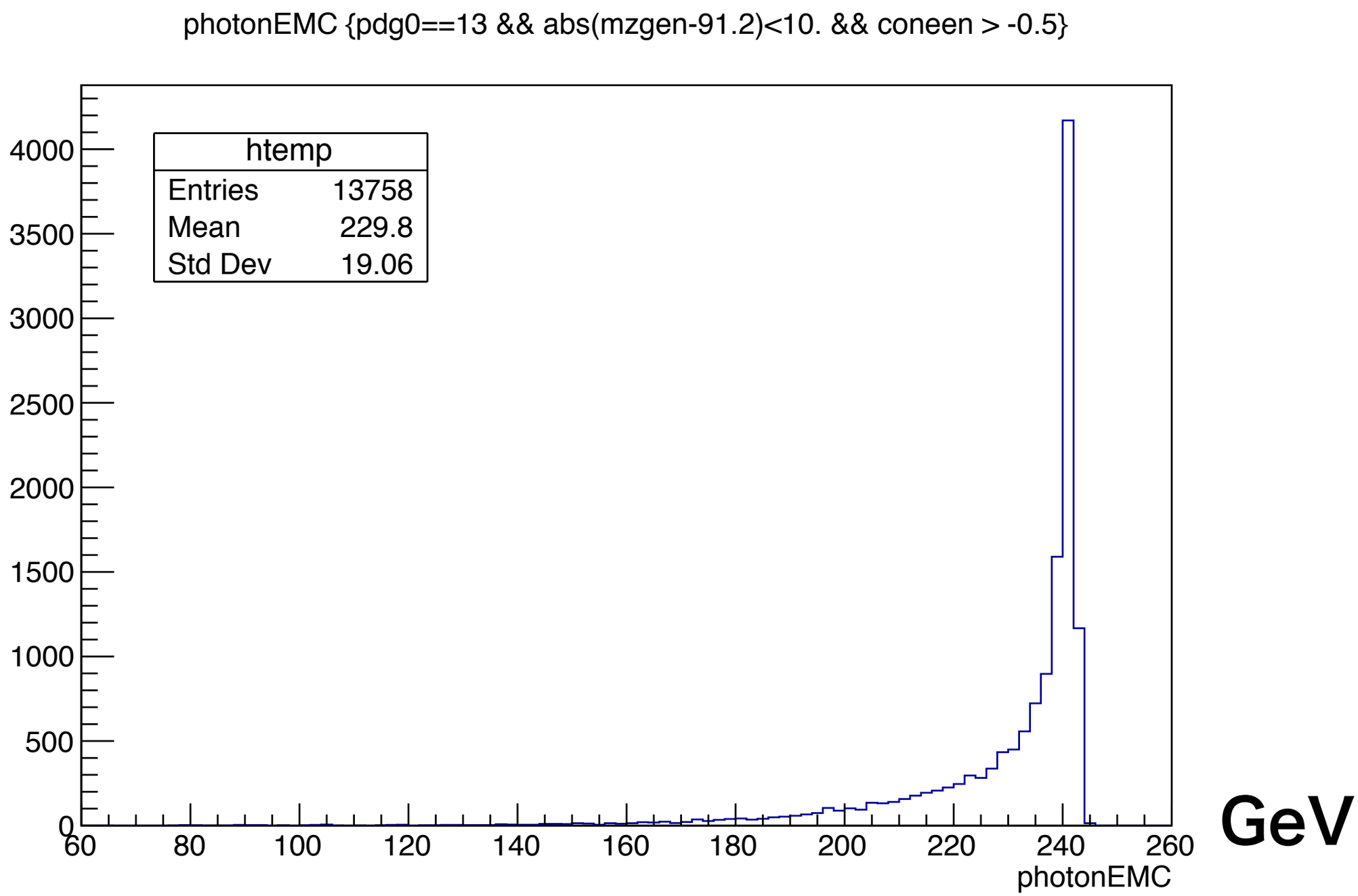
Case 1:
Using ($\theta_{\mu-}, \theta_{\mu+}, \theta_{\gamma}, \phi_{\mu-}, \phi_{\mu+}, \phi_{\gamma}$)
-> Determine ($E_{\mu-}, E_{\mu+}, E_{\gamma}$)

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})

MCTruth Energy of Photon in my Signal Channel



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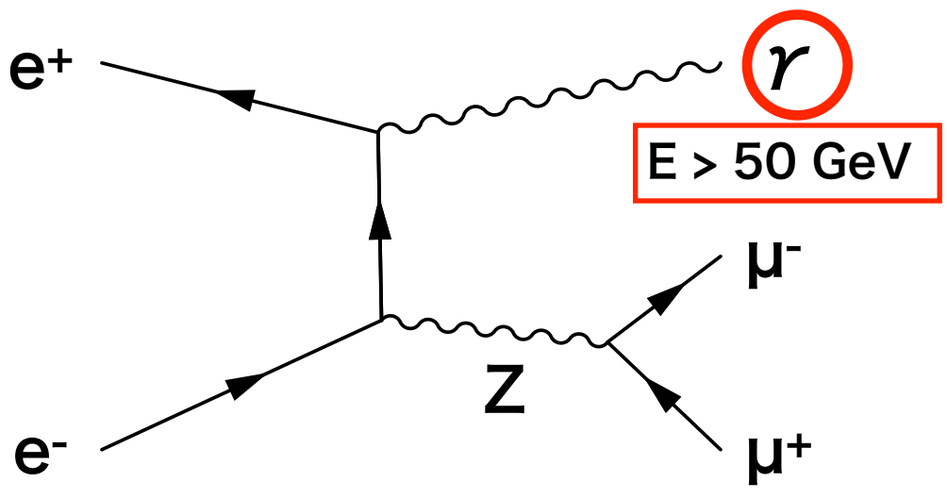

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Case 2: Consider **Beamstrahlung**
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}$)
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Case 3: Consider **Beamstrahlung** and **Crossing Angle**
Using ($\theta_{\mu^-}, \theta_{\mu^+}, \theta_{\gamma}, \phi_{\mu^-}, \phi_{\mu^+}, \phi_{\gamma}$)
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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**

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

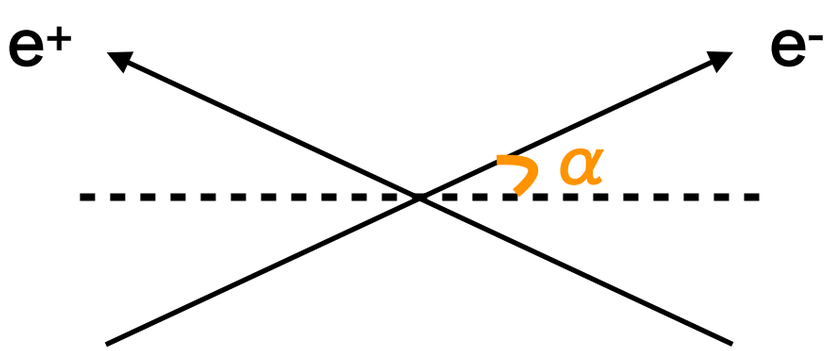
- **Case2: Consider Beamstrahlung**

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

• 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 (≡2α)



α = 7.0 mrad

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

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

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

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

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

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

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

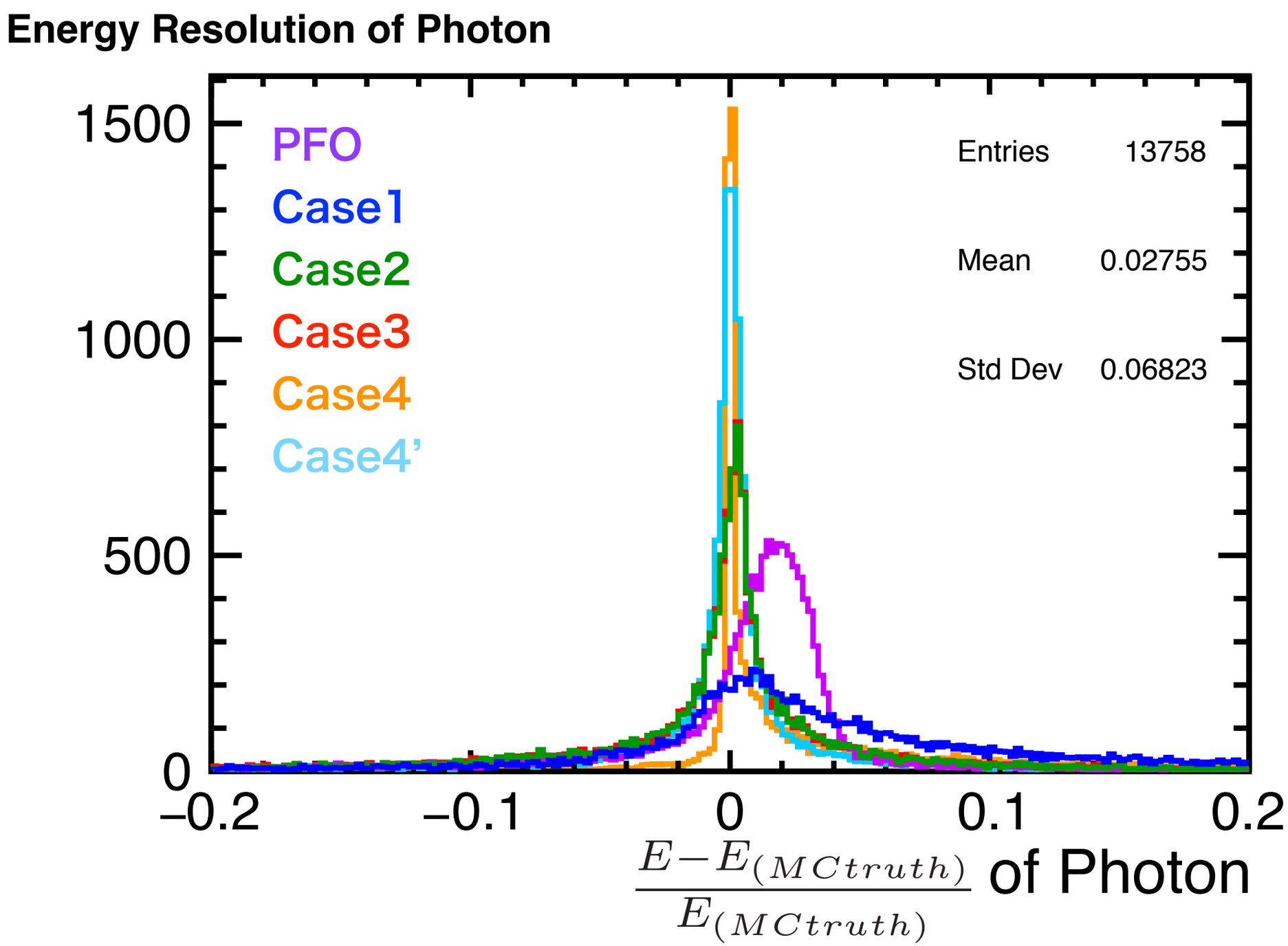
- Today I will discuss

(1) Comparison of the Resolved Energy of Photon for each Reconstruction Method

(2) Distribution of Photon Energy and Photon Angle in PFO

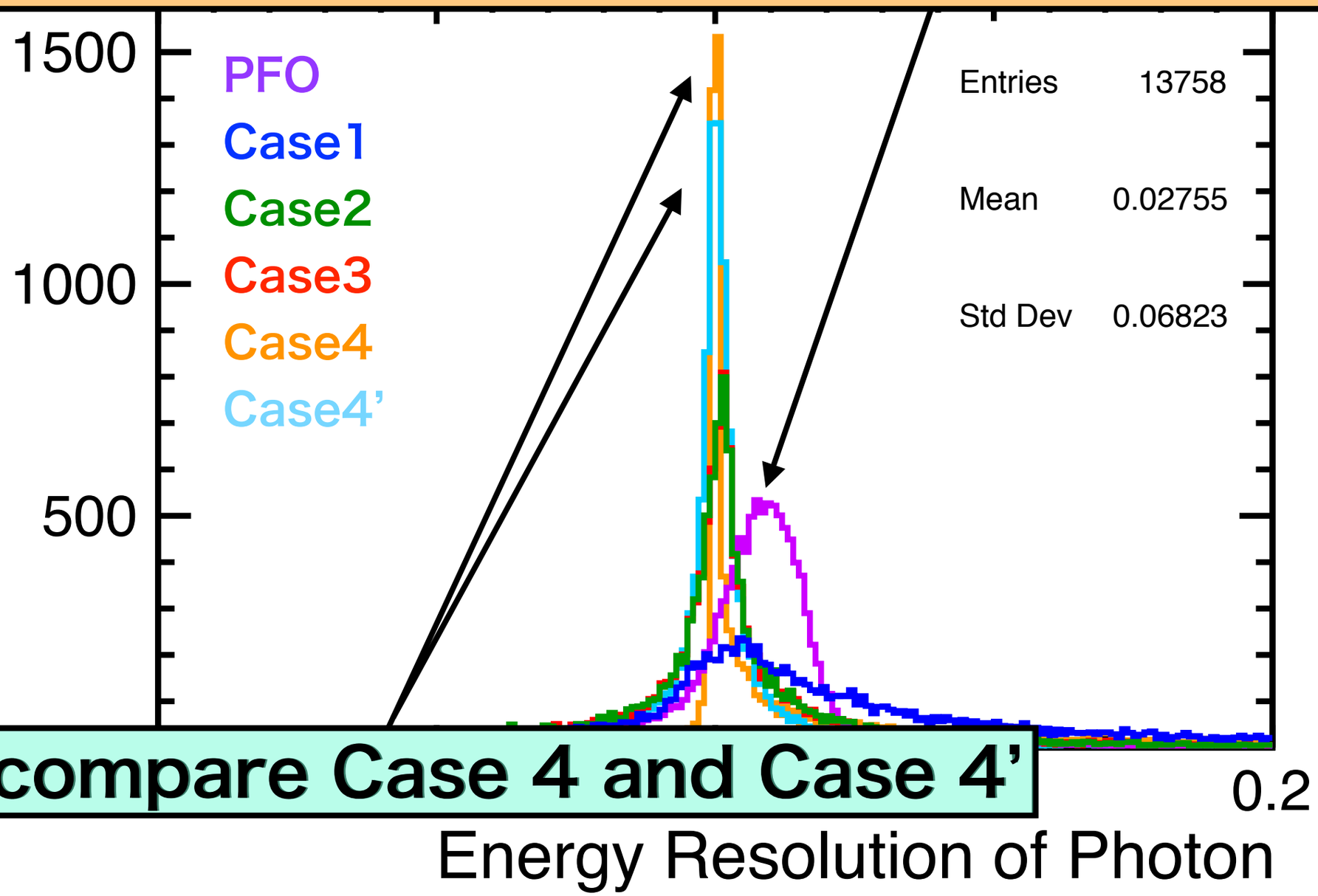
(3) Estimation of Energy Resolution

Resolved Energy of Photon



Resolved Energy of Photon

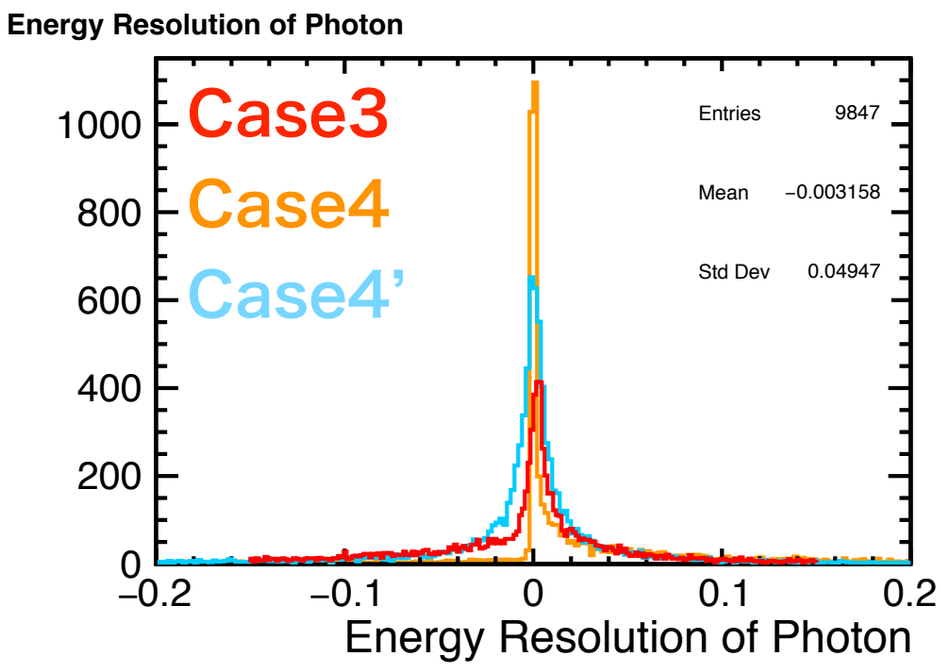
- The peak of PFO is shifted to the positive region. I will discuss this later.



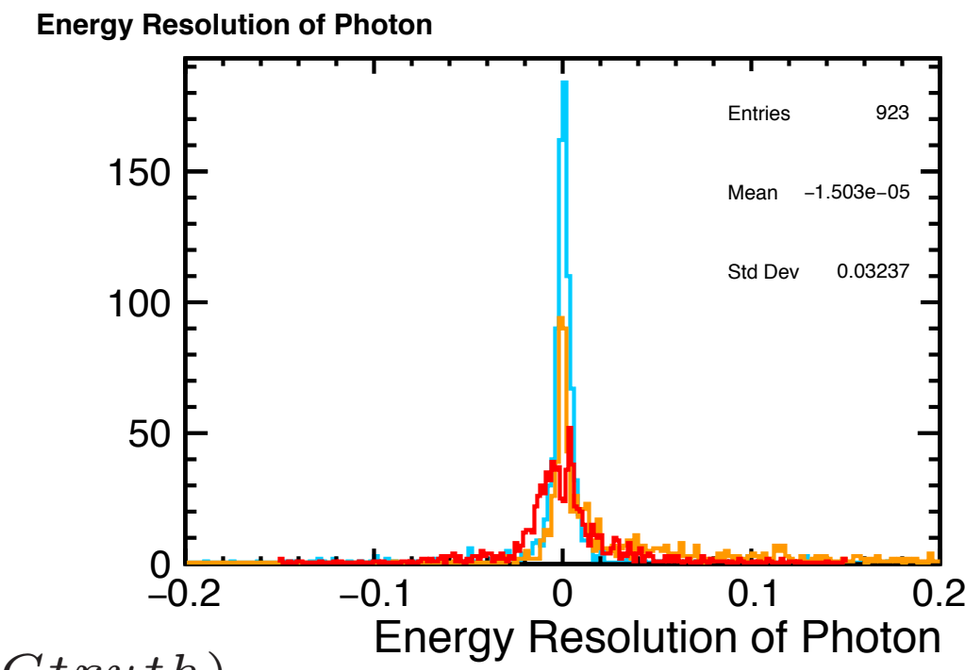
- I will compare Case 4 and Case 4'

Resolved Energy of Photon

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

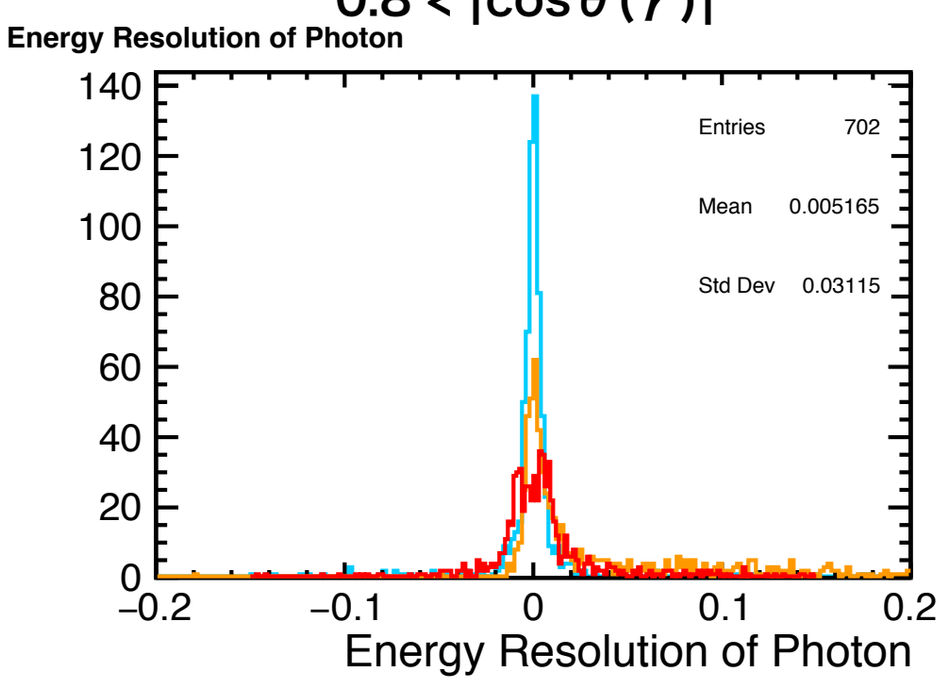


$0.4 < |\cos\theta(\gamma)| < 0.6$



$$\frac{E - E_{(MCtruth)}}{E_{(MCtruth)}}$$

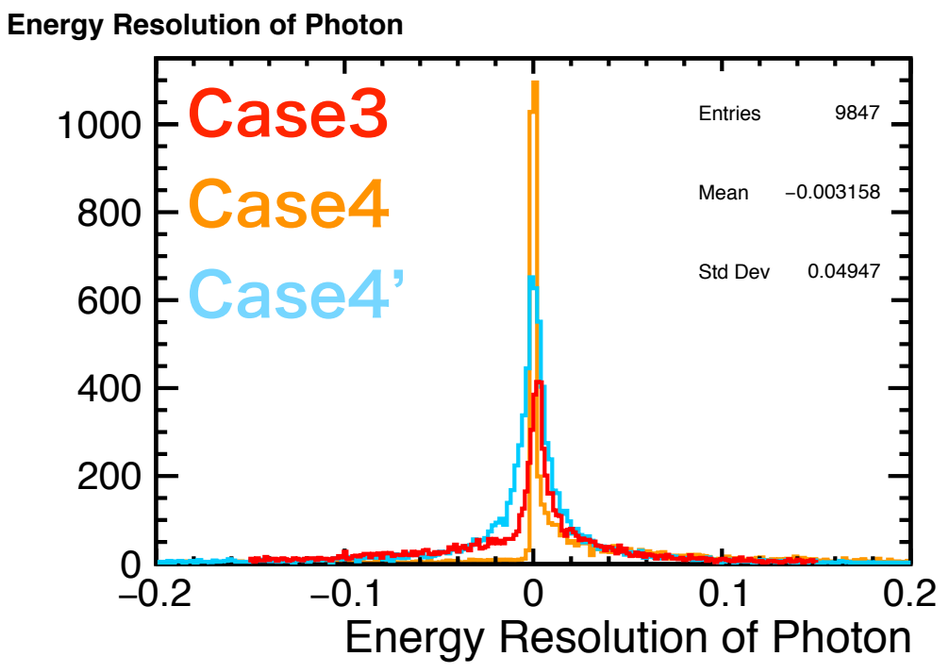
$0.8 < |\cos\theta(\gamma)|$



- Case 4' is better when $|\cos\theta(\gamma)|$ is > 0.4.
- The peak of Case 4 is asymmetric.

Resolved Energy of Photon

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



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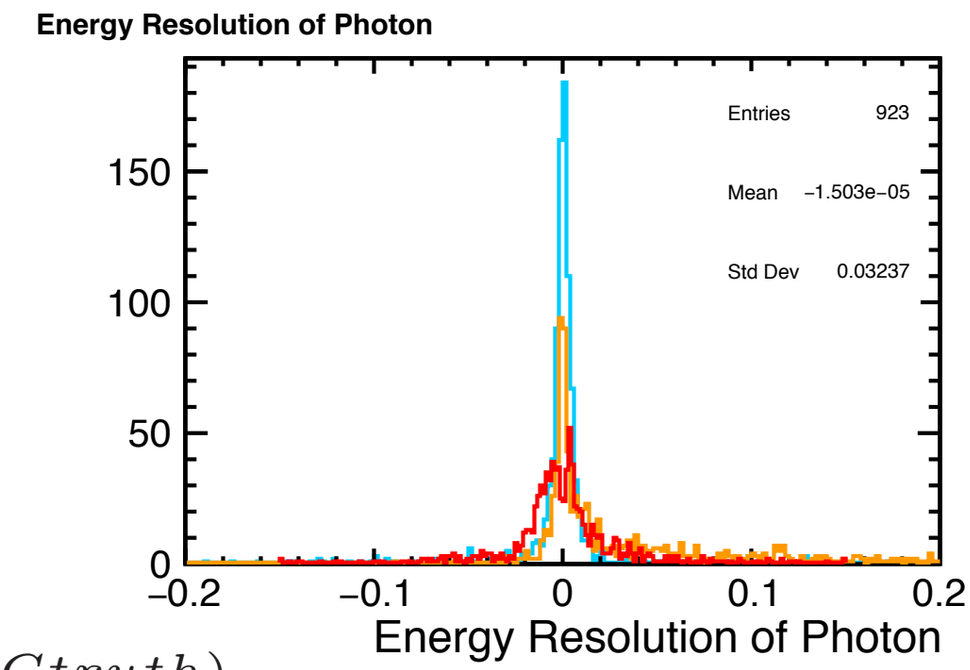
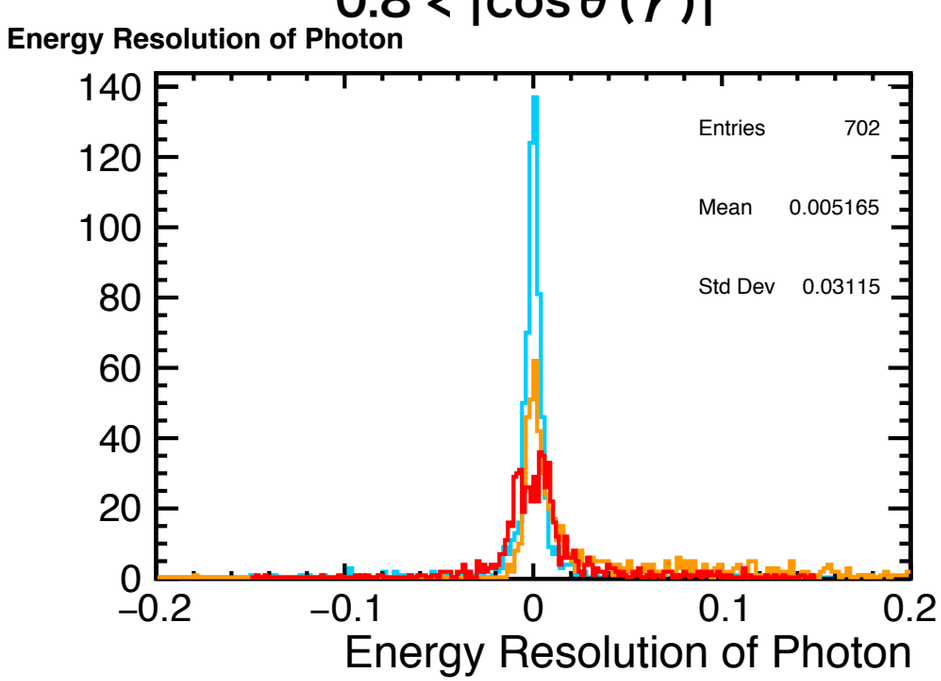


$$\frac{E - E_{(MCtruth)}}{E_{(MCtruth)}}$$

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



- Finally all 4 equations need to be considered.

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  (2) Distribution of Photon Energy and Photon Angle in PFO

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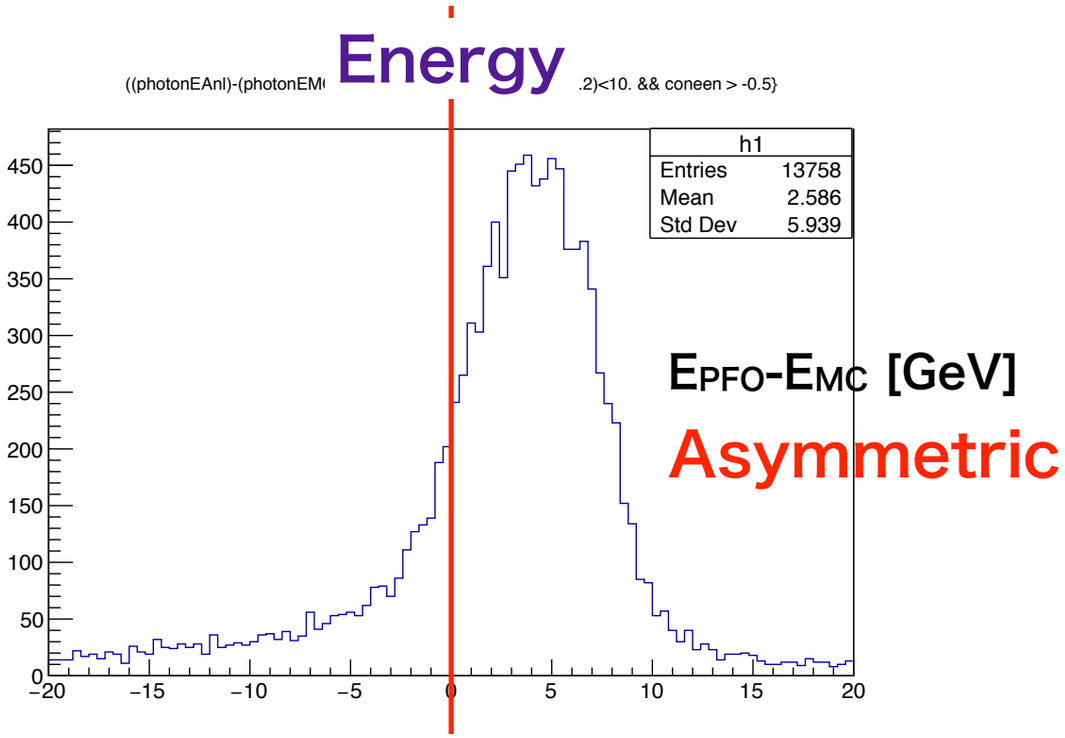
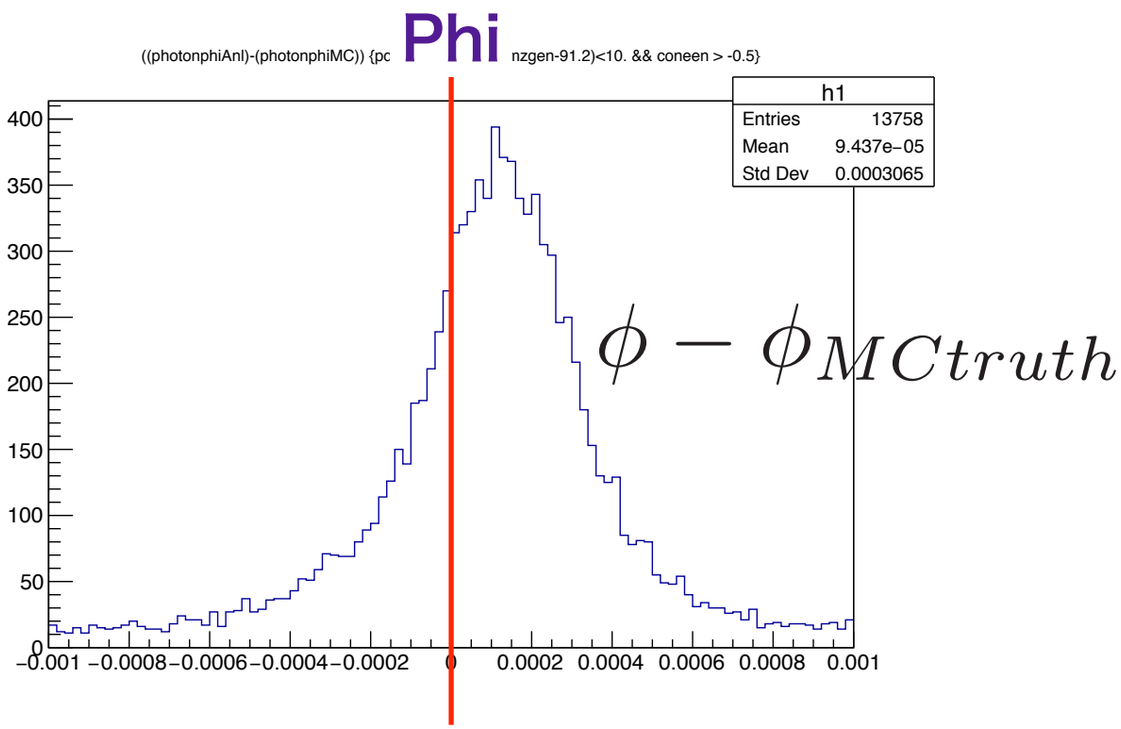
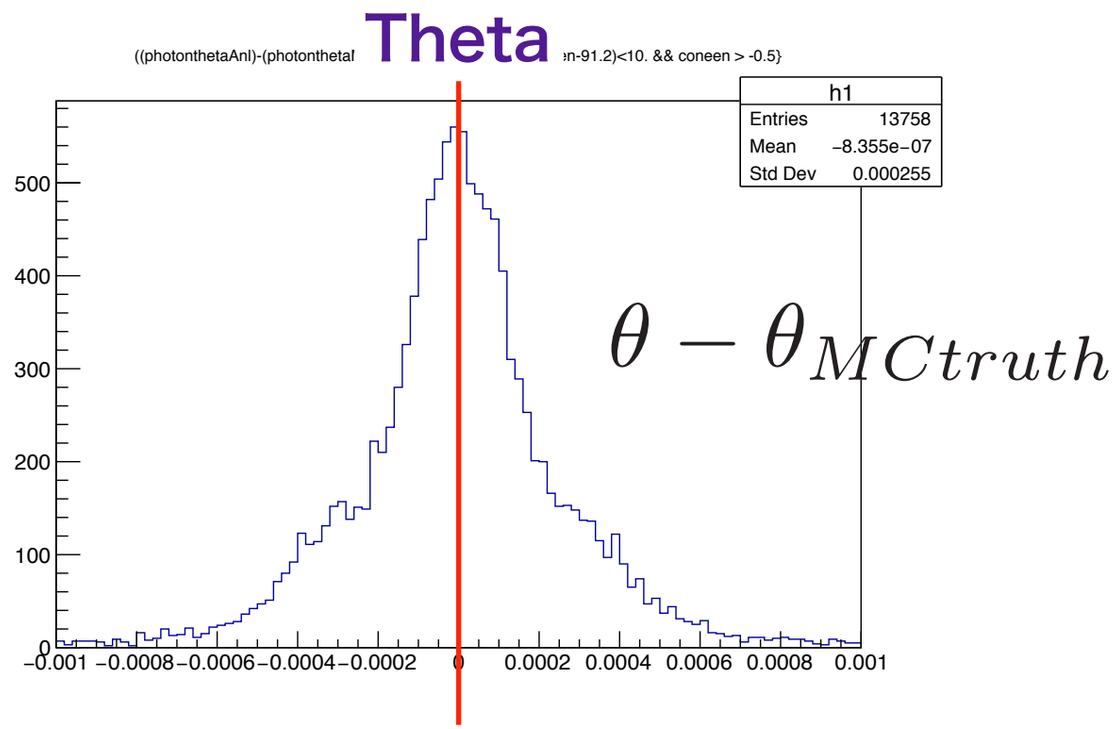
Distribution of PFO Photon Energy and Angle

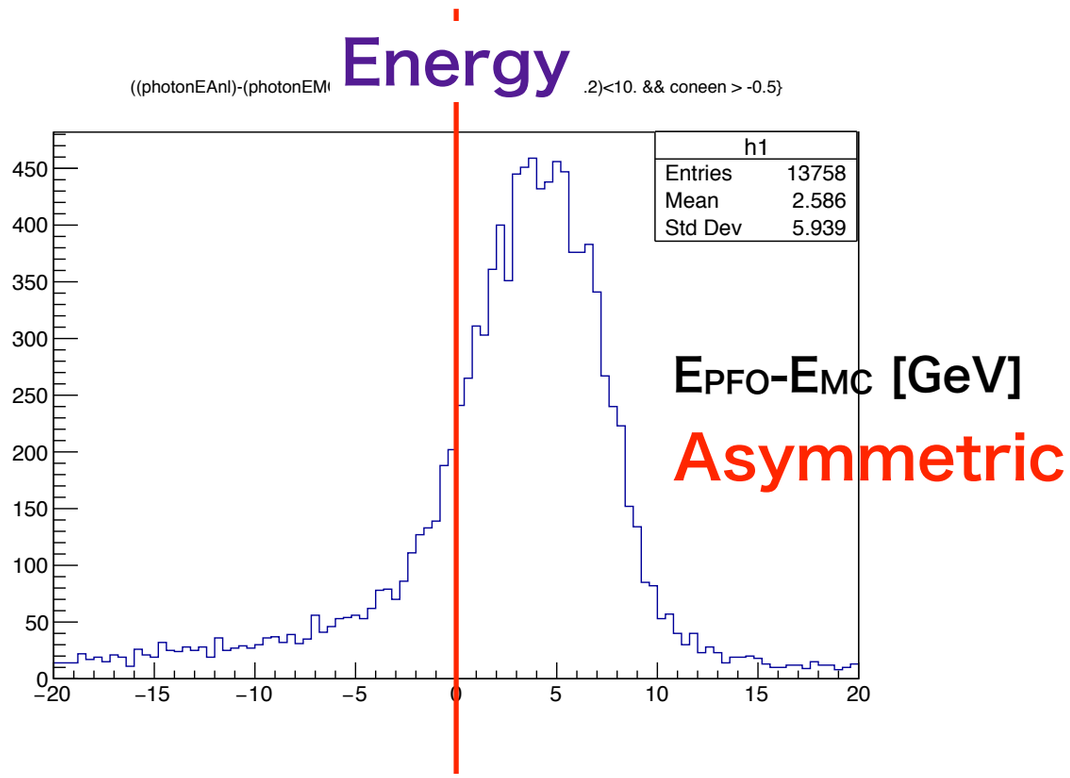
Samples:
$|M(\mu^+\mu^-)-91.2| < 10$ GeV
Large ILD model







Distribution of PFO Photon Energy

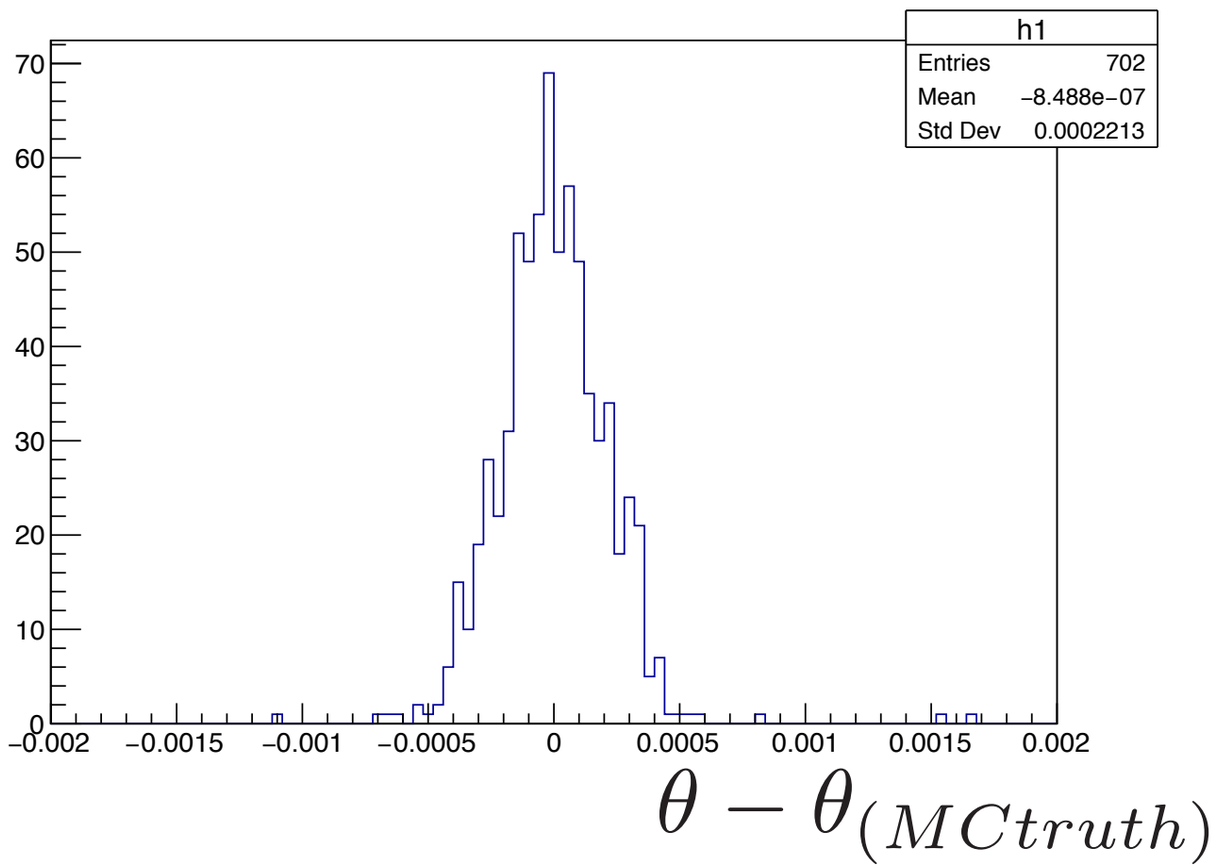


- It is said that same effect is seen by other analyzers who deal with high-energy photons.
- Most likely it seems to come from a miscalibration of the electromagnetic scale for the HCal in PandoraPFA.

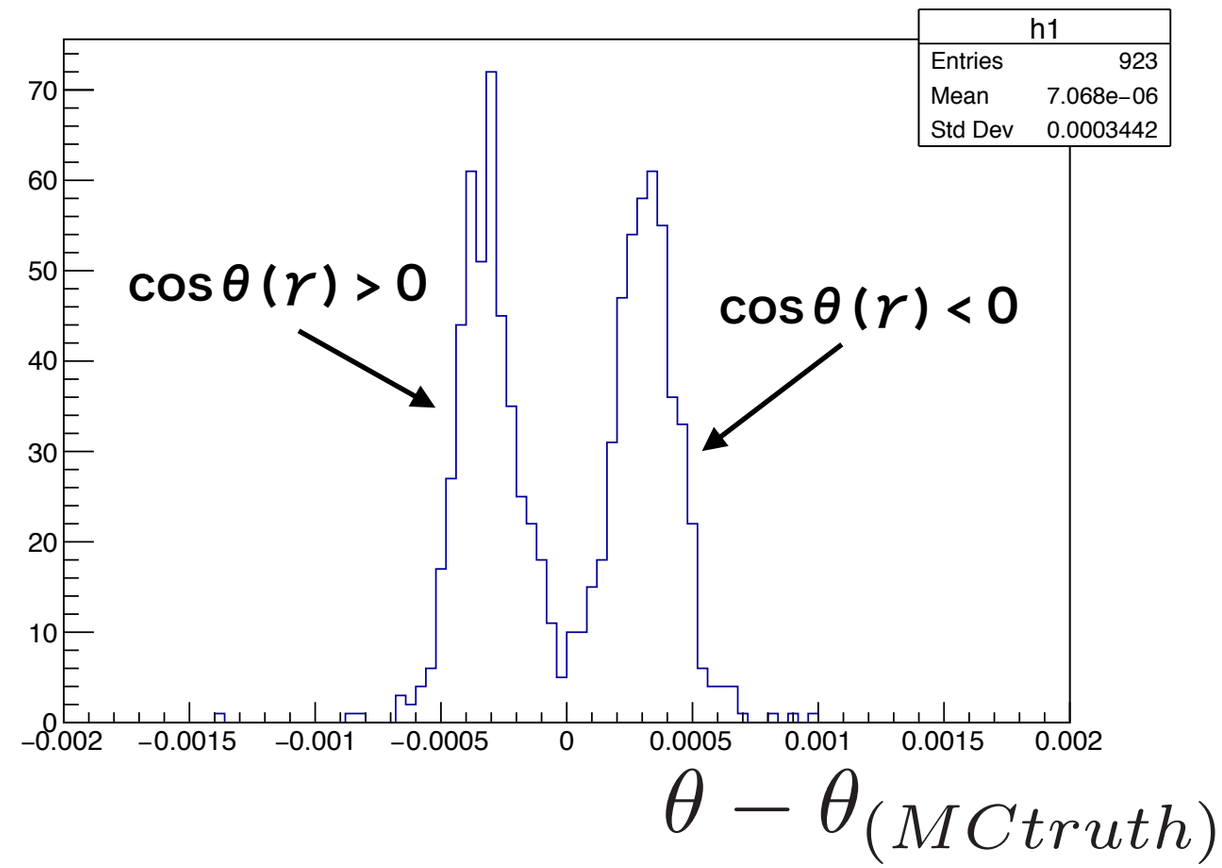
Distribution of PFO Photon Theta

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

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



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



When $|\cos\theta|$ is larger (except very forward region), bias gets more prominent. In the PFO, the center of shower seems to be shifted to B-field direction due to the B field.

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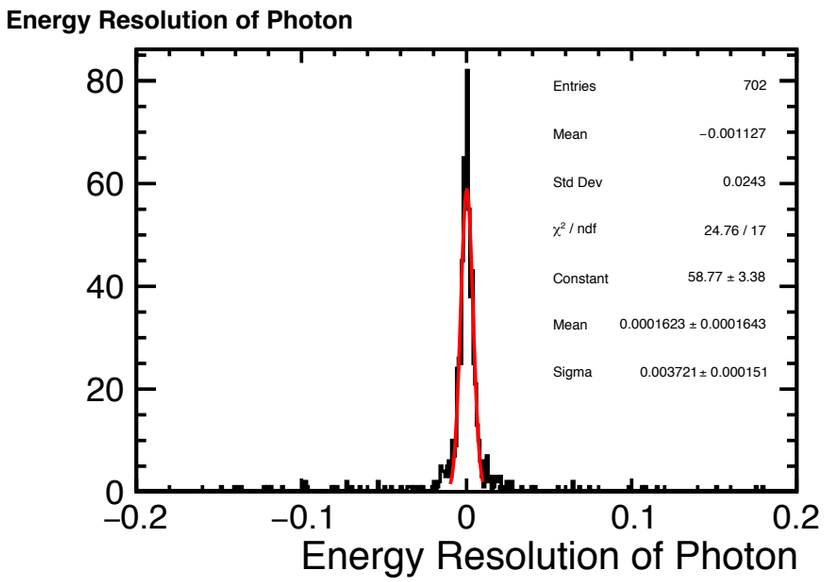
Case 4': dependence on θ_{γ}

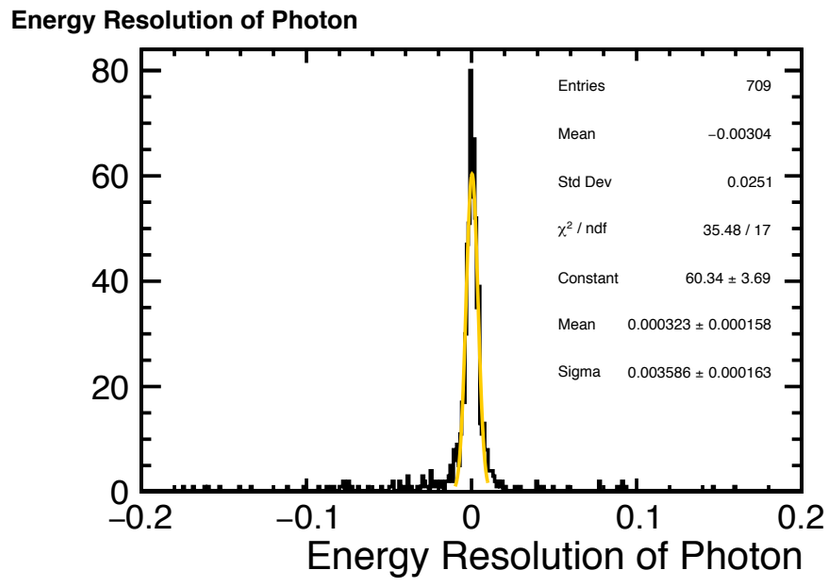
$$\frac{E - E_{(MCtruth)}}{E_{(MCtruth)}}$$

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
No $\phi(\gamma)$ Cut
Large ILD model

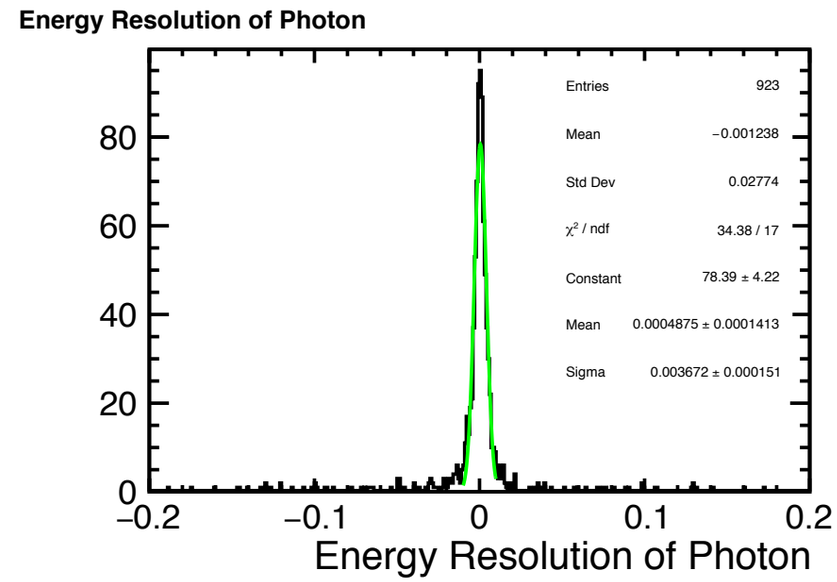
$|\cos\theta(\gamma)| < 0.2$



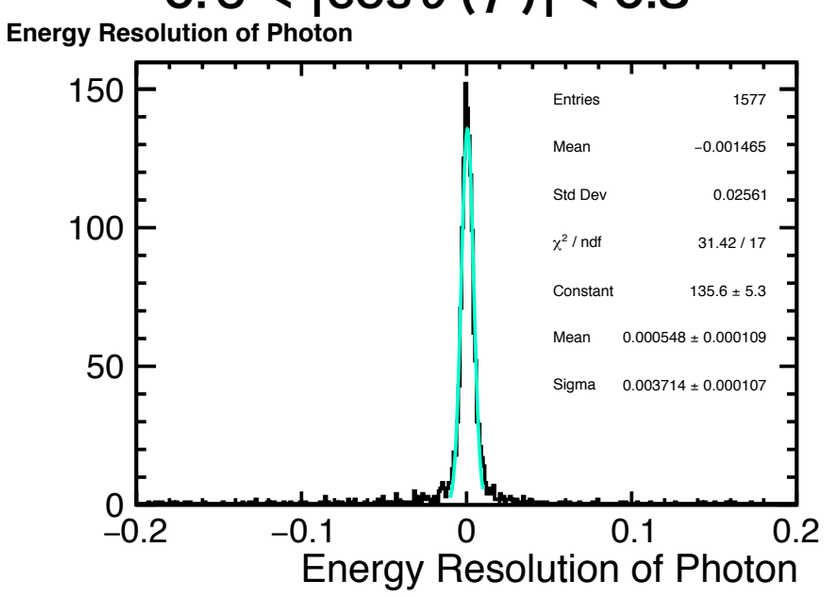
$0.2 < |\cos\theta(\gamma)| < 0.4$



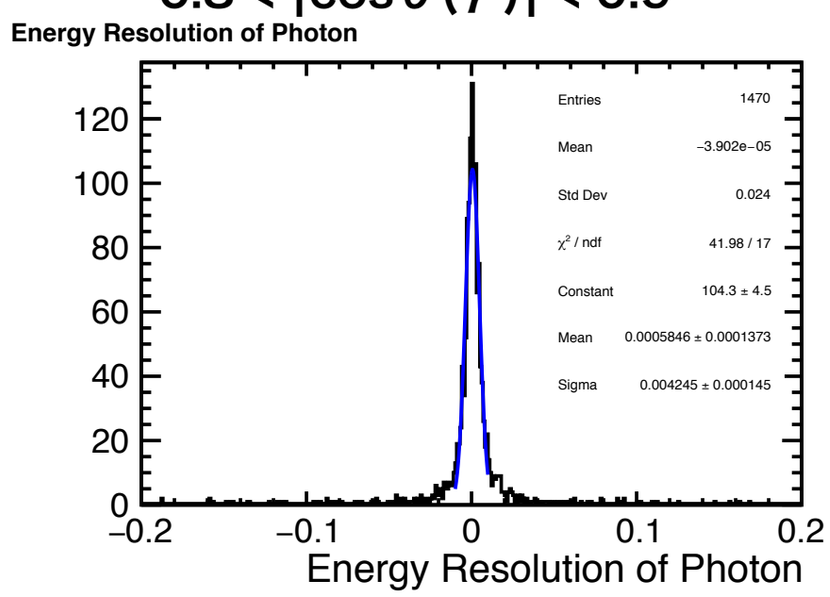
$0.4 < |\cos\theta(\gamma)| < 0.6$



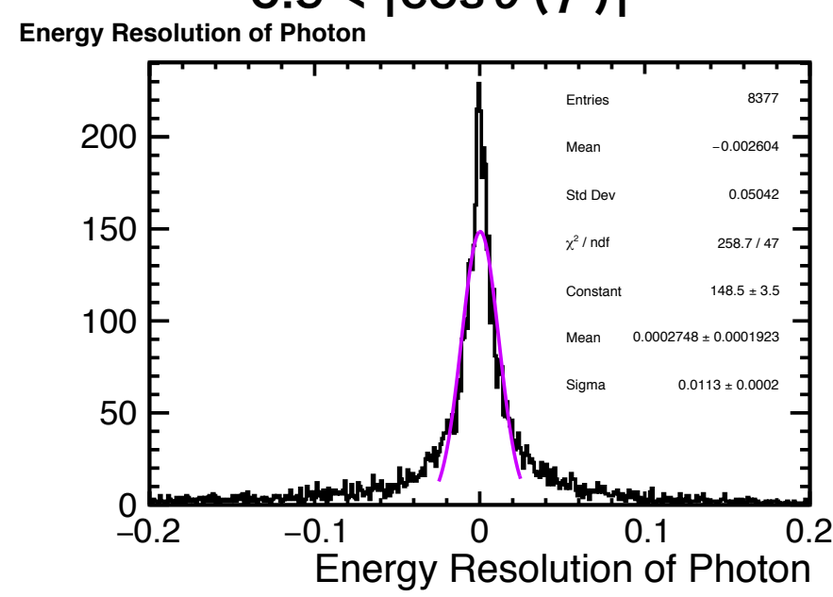
$0.6 < |\cos\theta(\gamma)| < 0.8$



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



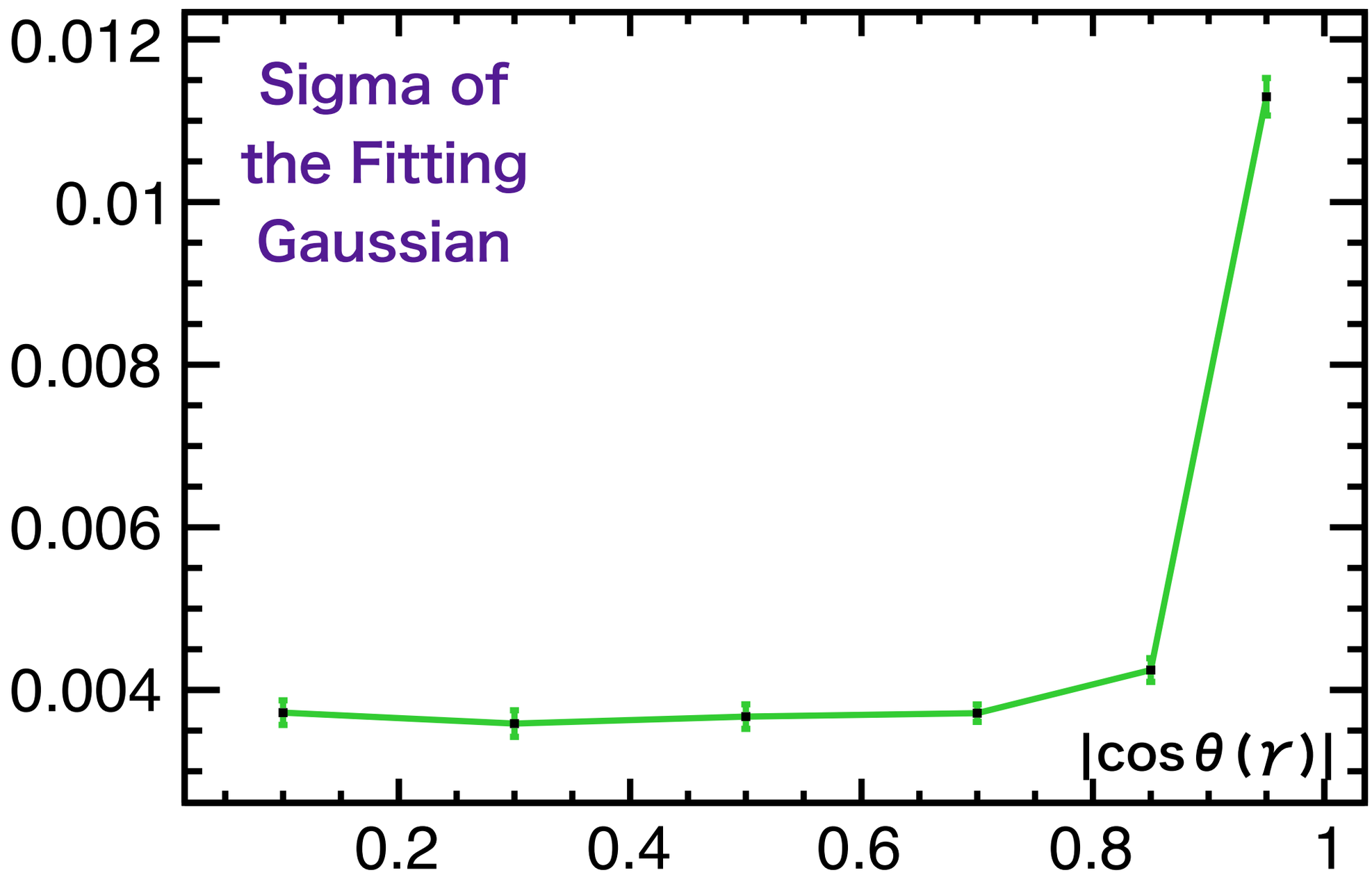
$0.9 < |\cos\theta(\gamma)|$



Case 4': dependence on θ_{γ}

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
No $\phi(\gamma)$ Cut
Large ILD model

Graph



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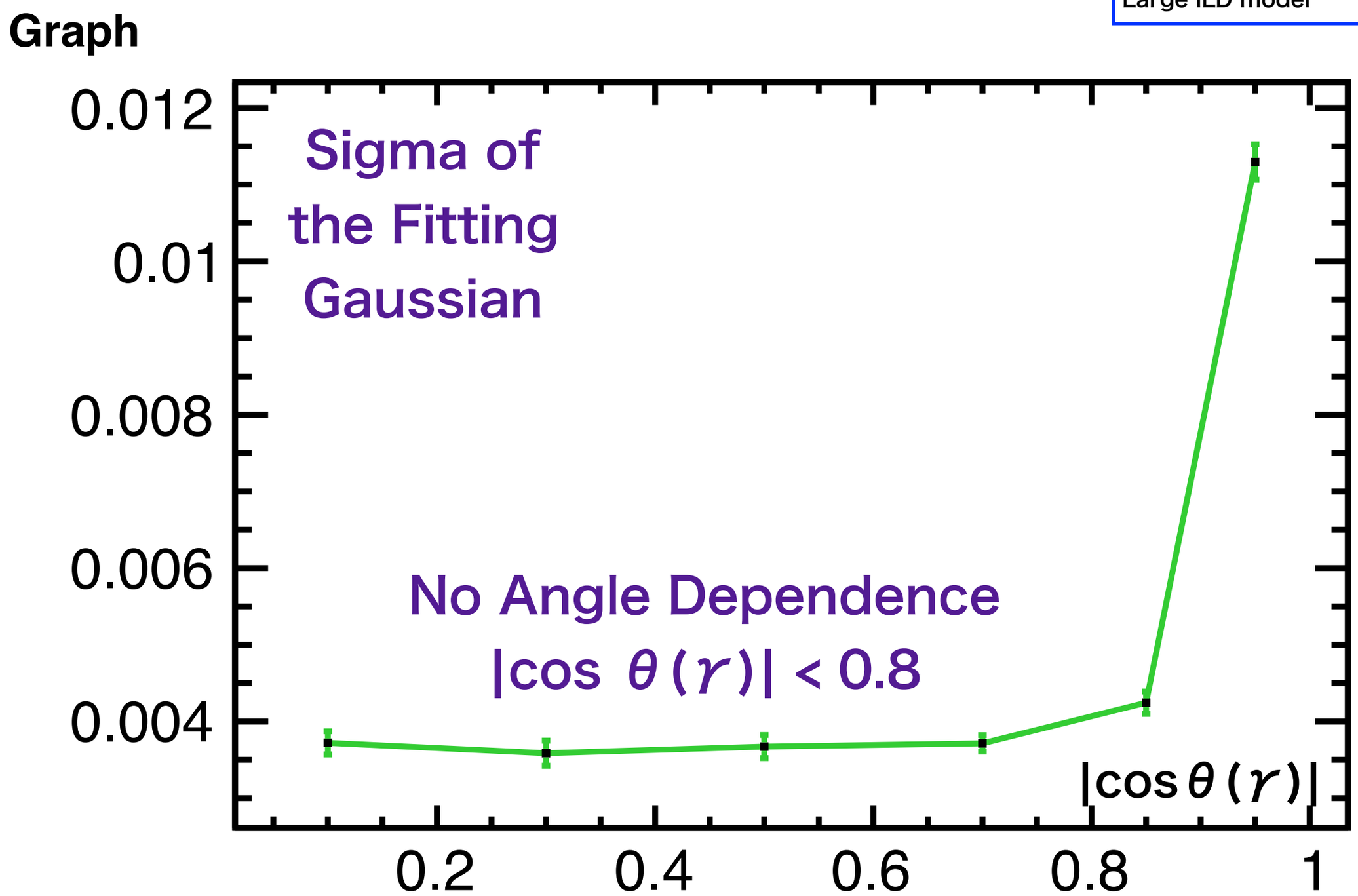
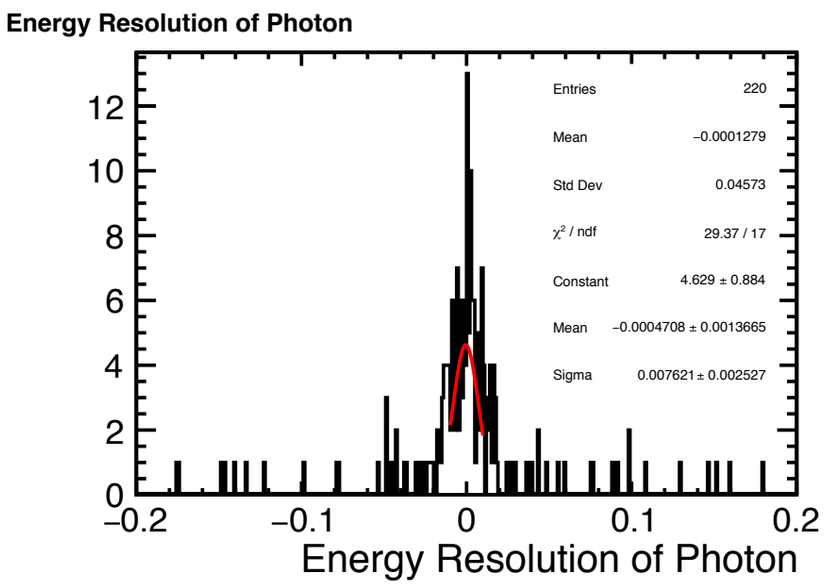


Case 4': dependence on ϕ_γ

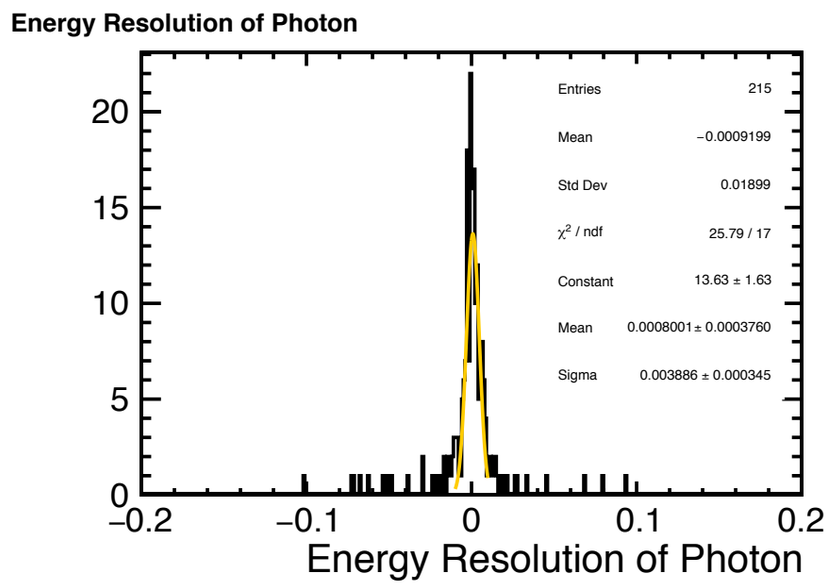
$$\frac{E - E_{(MCtruth)}}{E_{(MCtruth)}}$$

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
$|\cos\theta(\gamma)| < 0.75$
Large ILD model

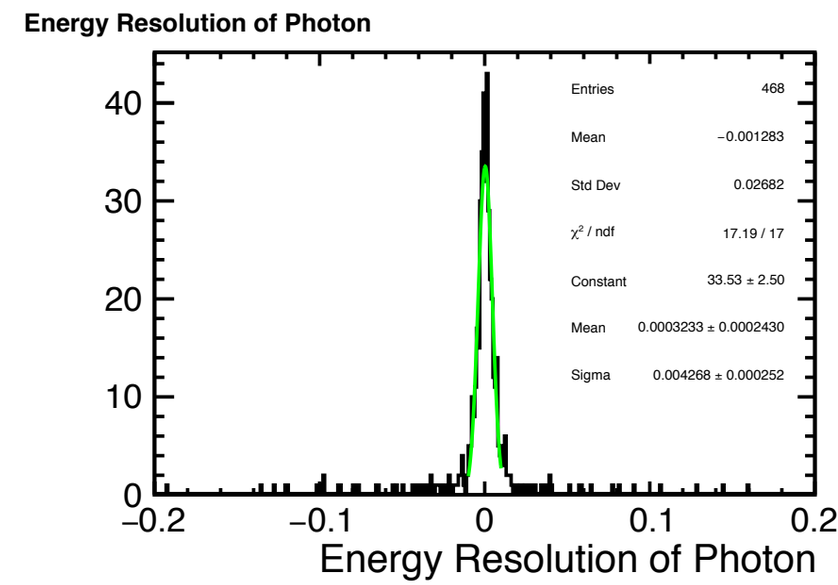
$|\sin\phi(\gamma)| < 0.1$



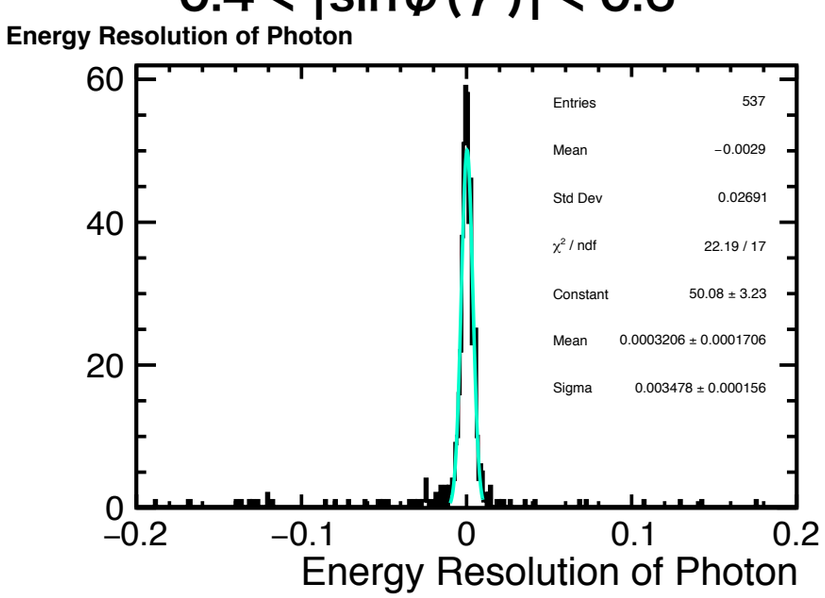
$0.1 < |\sin\phi(\gamma)| < 0.2$



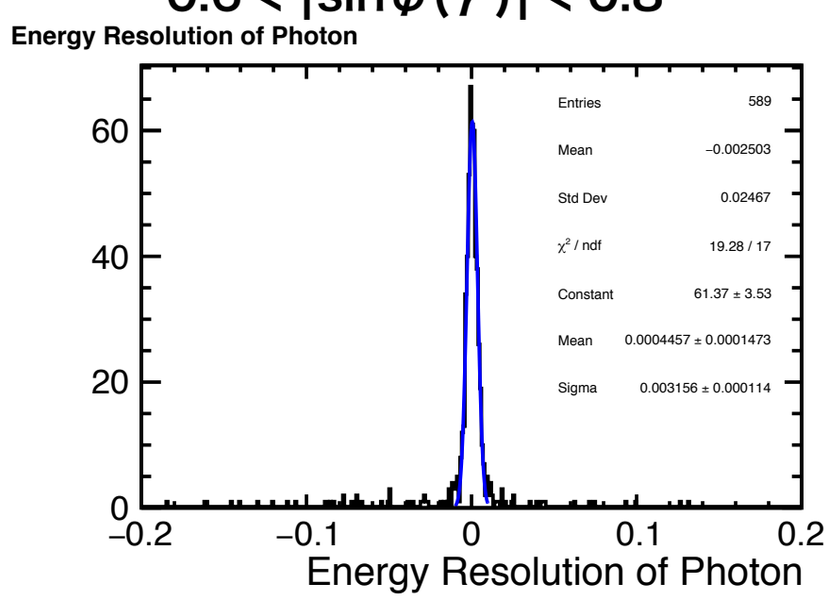
$0.2 < |\sin\phi(\gamma)| < 0.4$



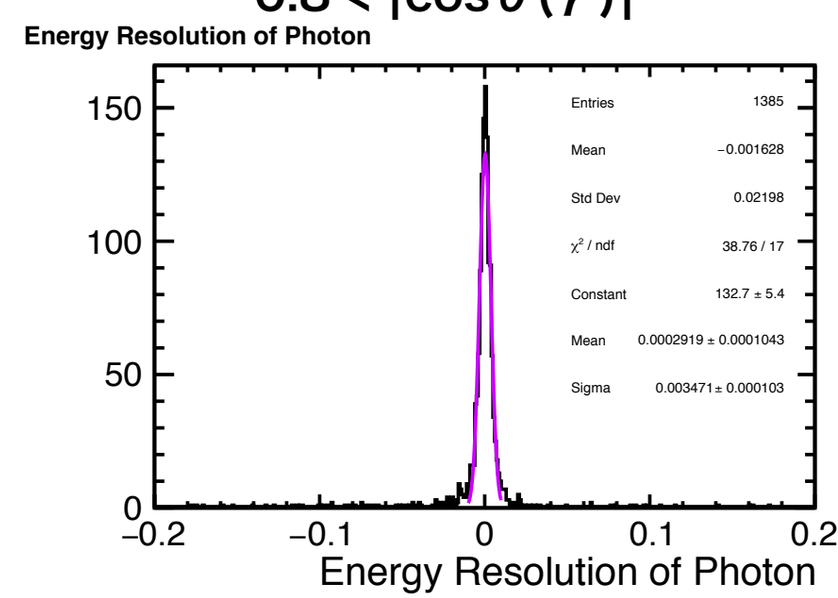
$0.4 < |\sin\phi(\gamma)| < 0.6$



$0.6 < |\sin\phi(\gamma)| < 0.8$



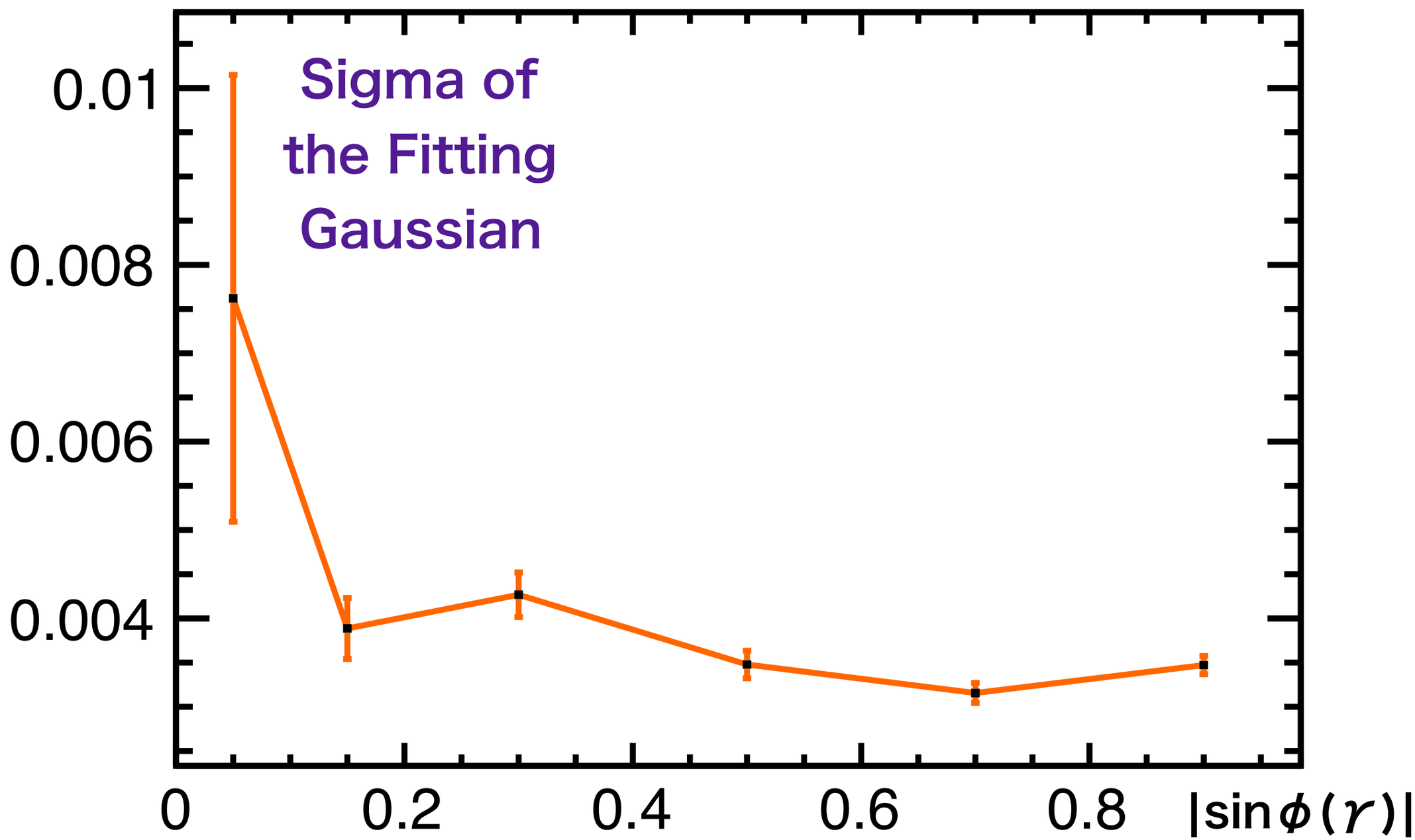
$0.8 < |\cos\theta(\gamma)|$



Case 4': dependence on ϕ_{γ}

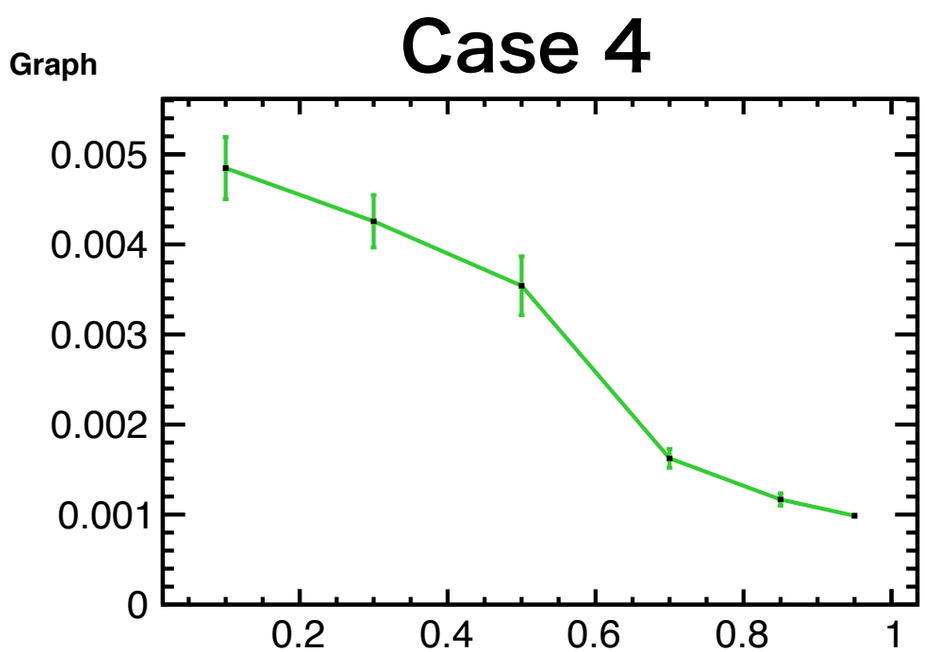
Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
$|\cos\theta(\gamma)| < 0.75$
Large ILD model

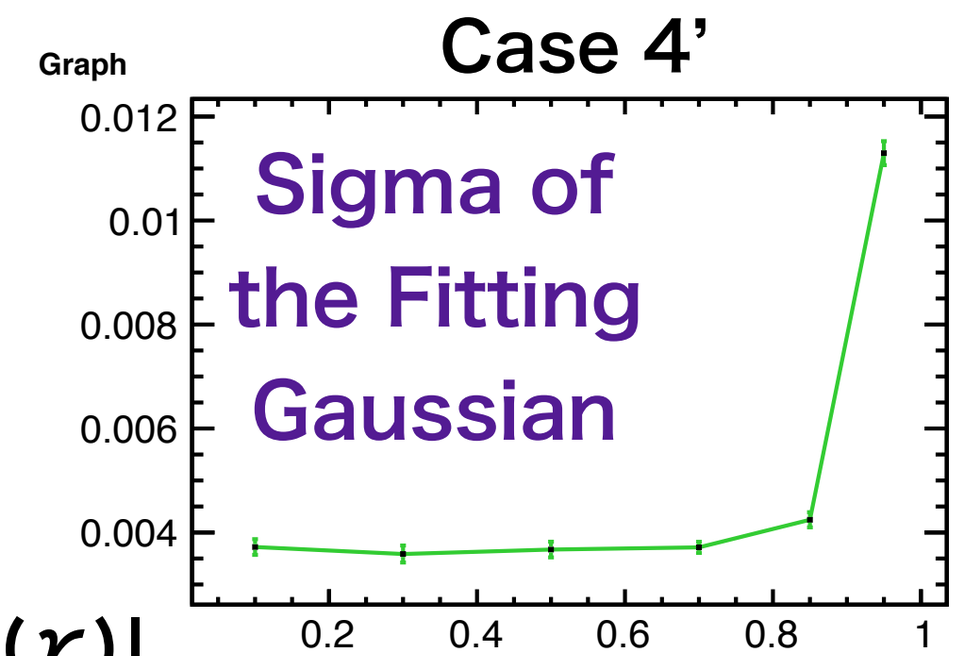
Graph



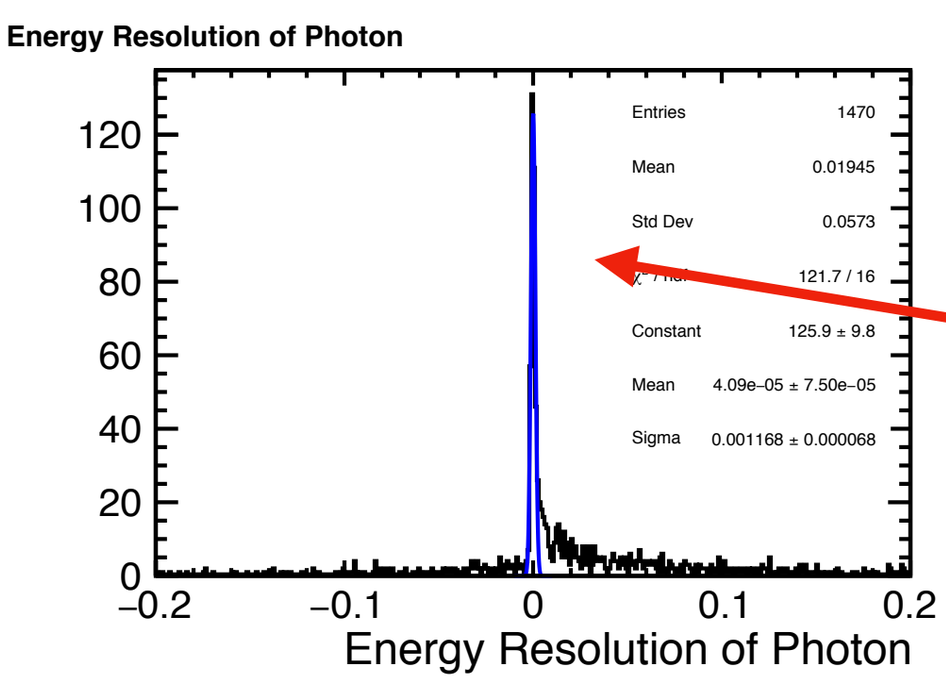
Case 4: dependence on θ_{γ}

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
No $\phi(\gamma)$ Cut
Large ILD model





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



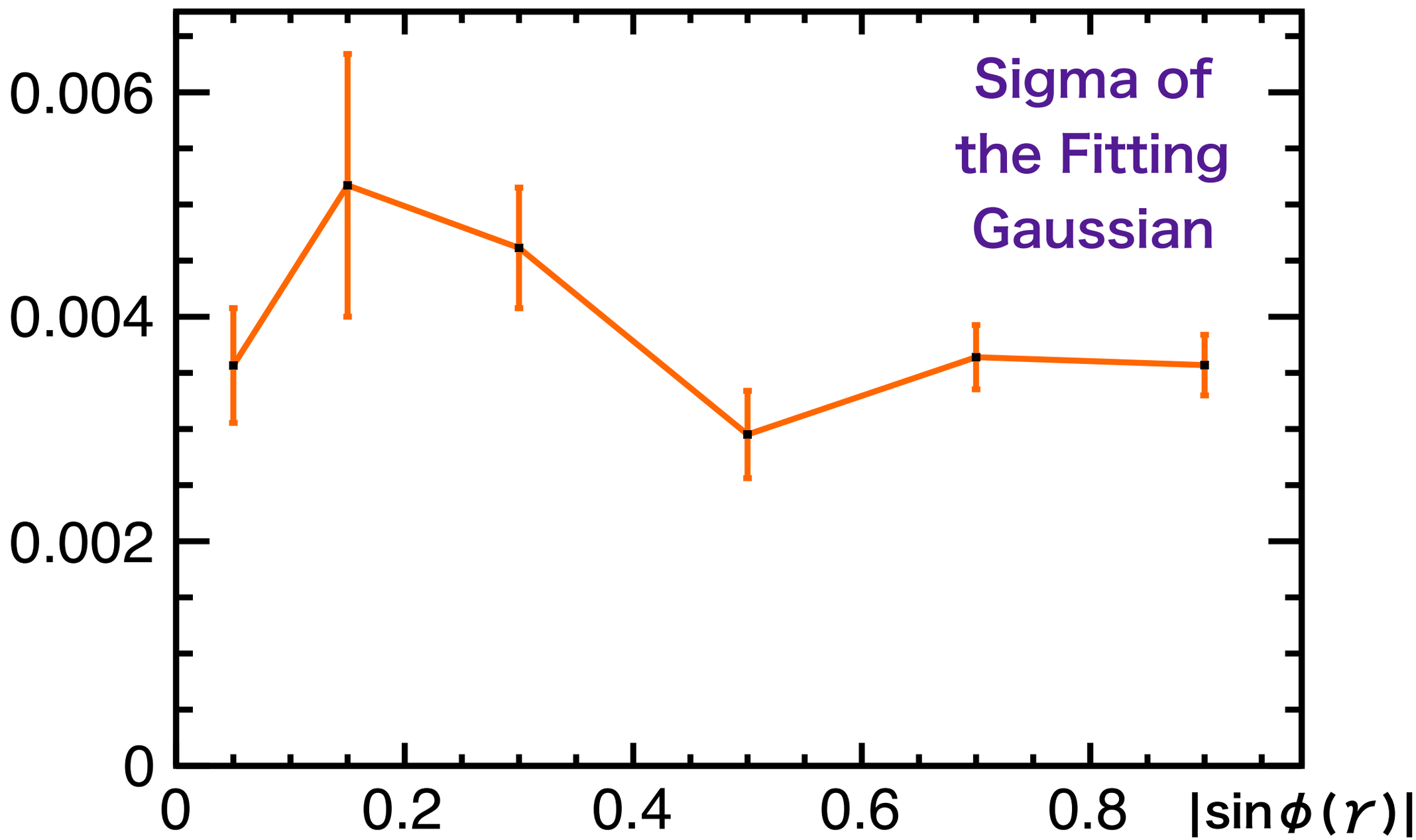
$$\frac{E - E_{(MCtruth)}}{E_{(MCtruth)}}$$

The value when this thin peak is fitted.

Case 4: dependence on ϕ_γ

Samples:
|M(μ⁺μ⁻)-91.2| < 10 GeV
$|\cos\theta(\gamma)| < 0.8$
Large ILD model

Graph



Next Step

- In photon energy reconstruction, I will consider all 4 equations.
- I'm planning to estimate $\frac{\sigma}{\sqrt{n}}$,which depends on $\theta(r)$, $\phi(r)$, E(r) $\cdots$