

Benchmark Analysis for $e^+e^- \rightarrow \text{gamma } Z \text{ process}$

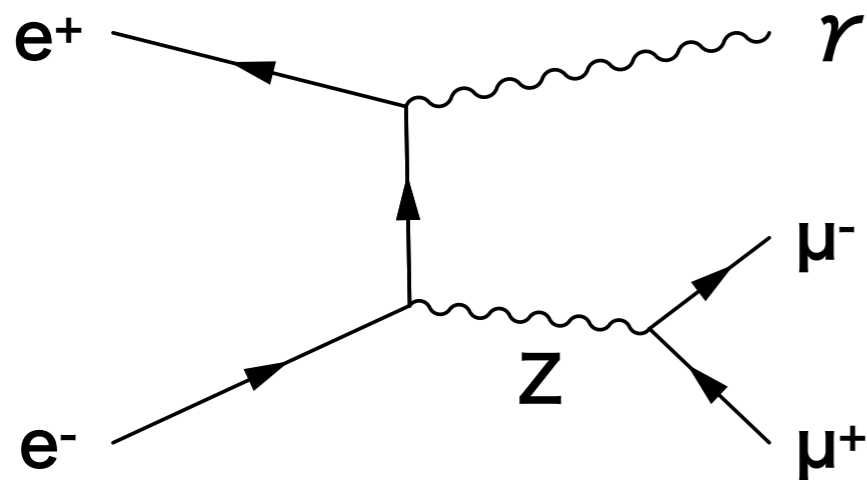
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Status report on $e^+e^- \rightarrow \text{gamma Z}$ analysis

- I'm working on photon energy calibration using **direction angles of μ^- , μ^+ and γ** .
- I checked
 - (1) the correspondence between reconstructed energy and MCtrue energy
 - (2) photon 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 $(E_{\mu^-}, E_{\mu^+}, E_{\gamma}, E_{\text{ISR}})$

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

• Case 1

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

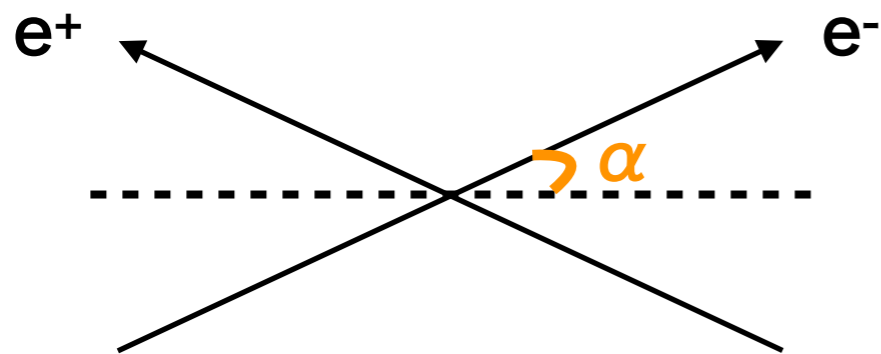
• Case2: Consider **Beamstrahlung**

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

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

$$\left\{ \begin{array}{l} E_{\mu} + E_{\mu^+} + E_{\gamma} + |P_{ISR}| = 500 \\ E_{\mu} \sin\theta_{\mu} \cos\phi_{\mu} + E_{\mu^+} \sin\theta_{\mu^+} \cos\phi_{\mu^+} + E_{\gamma} \sin\theta_{\gamma} \cos\phi_{\gamma} + |P_{ISR}| \sin\alpha = 500 \sin\alpha \\ E_{\mu} \sin\theta_{\mu} \sin\phi_{\mu} + E_{\mu^+} \sin\theta_{\mu^+} \sin\phi_{\mu^+} + E_{\gamma} \sin\theta_{\gamma} \sin\phi_{\gamma} = 0 \\ E_{\mu} \cos\theta_{\mu} + E_{\mu^+} \cos\theta_{\mu^+} + E_{\gamma} \cos\theta_{\gamma} \pm |P_{ISR}| \cos\alpha = 0 \end{array} \right.$$

Crossing Angle ($\equiv 2\alpha$)



Case 1:

Using $(\theta_{\mu^-}, \theta_{\mu^+}, \theta_r, \phi_{\mu^-}, \phi_{\mu^+}, \phi_r)$

-> Determine $(E_{\mu^-}, E_{\mu^+}, E_r)$

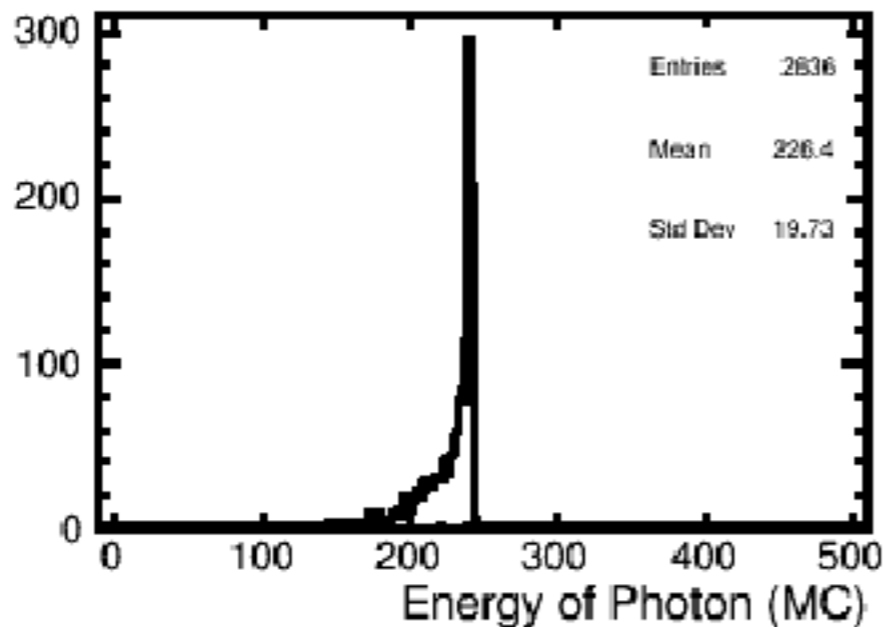
Samples:

$|\cos(\mu)| < 0.75$

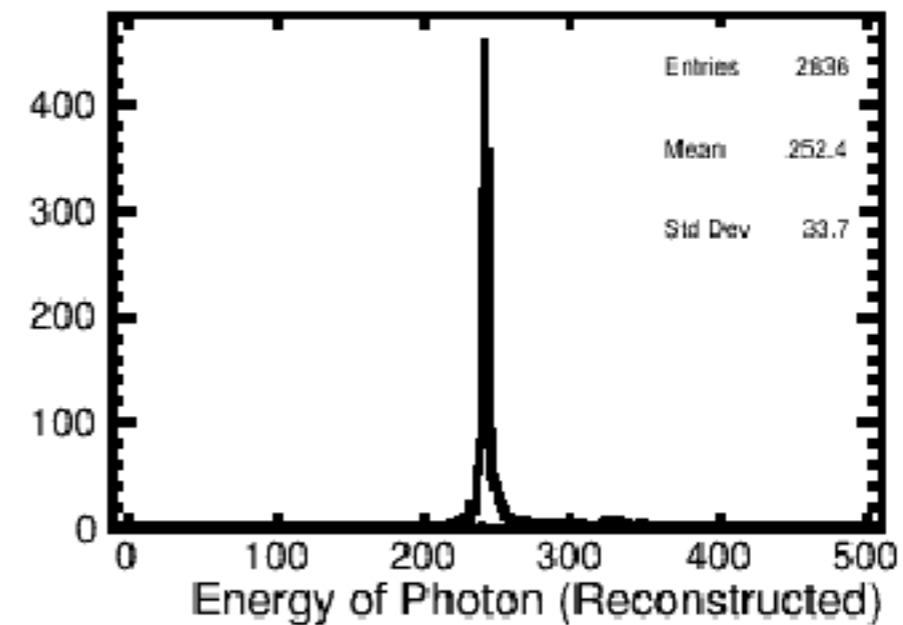
$|M(\mu^+\mu^-) - 91.2| < 10 \text{ GeV}$

Large ILD model

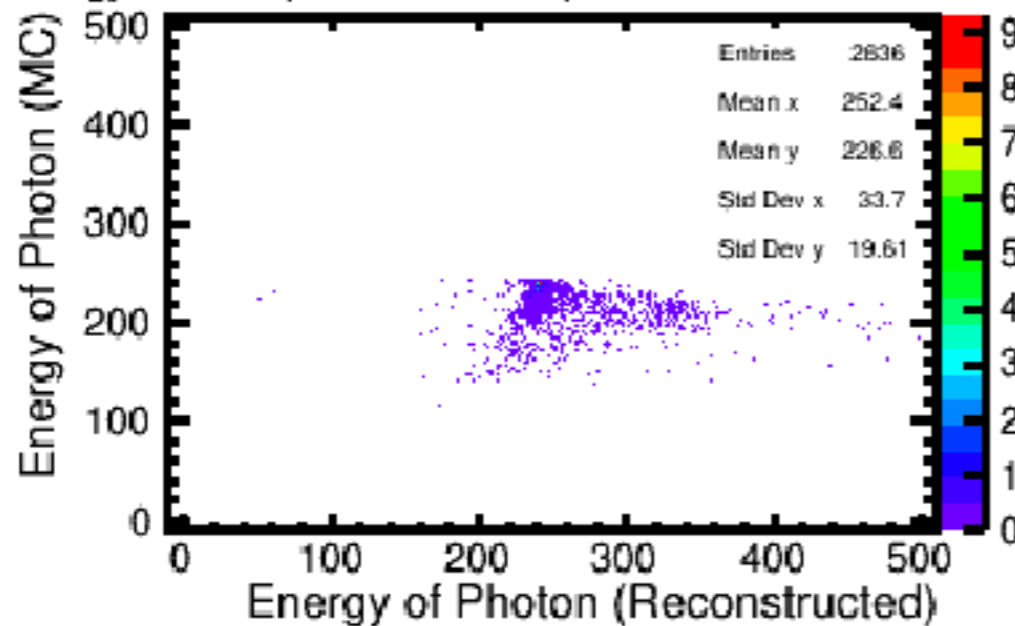
Energy of Photon (MC)



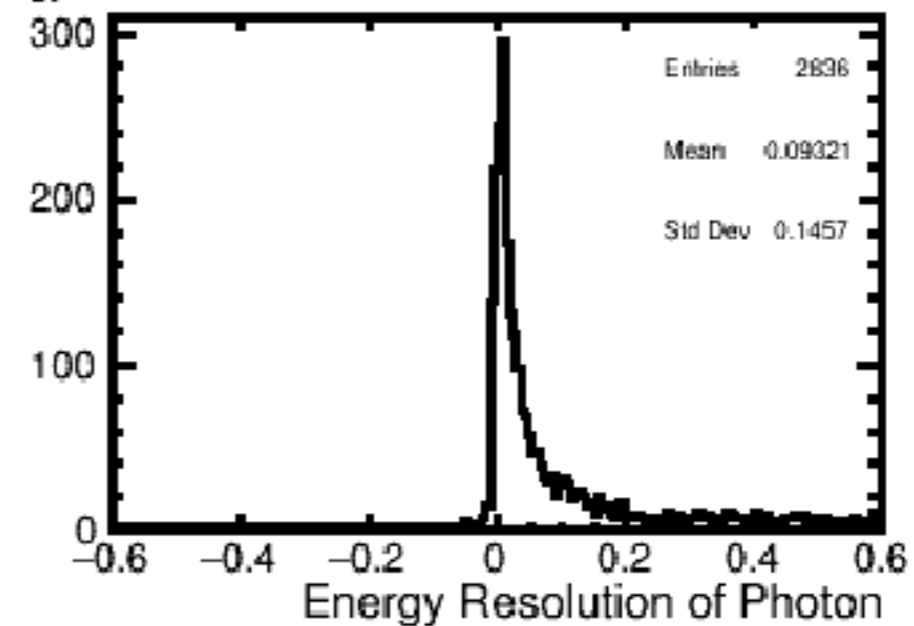
Energy of Photon (Reconstructed)



Energy of Photon (MC:Reconstructed)



Energy Resolution of Photon



Case 3: Add the effect of **Crossing Angle**

Using $(\theta_{\mu^-}, \theta_{\mu^+}, \theta_r, \phi_{\mu^-}, \phi_{\mu^+}, \phi_r)$

-> Determine $(E_{\mu^-}, E_{\mu^+}, E_r, E_{ISR})$

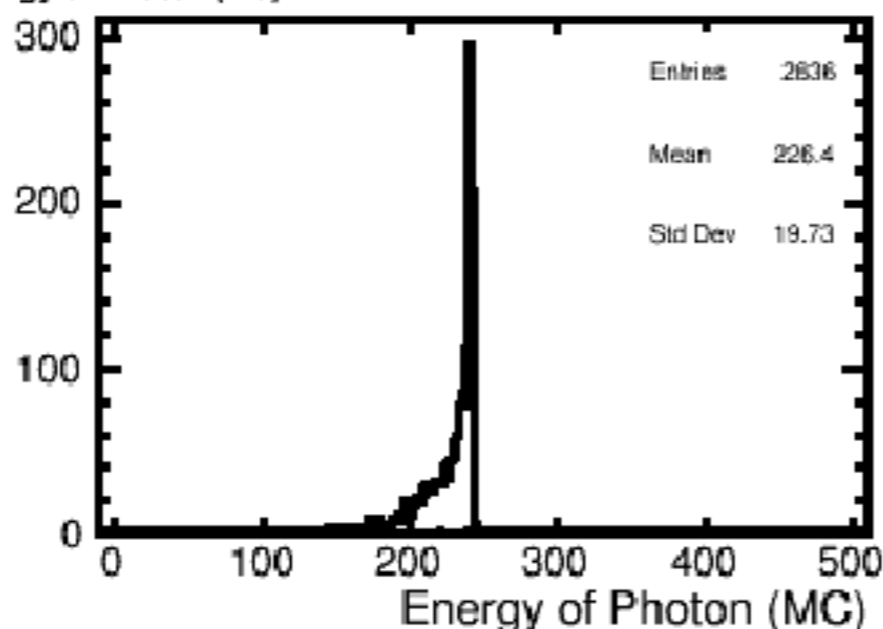
Samples:

$|\cos(\mu)| < 0.75$

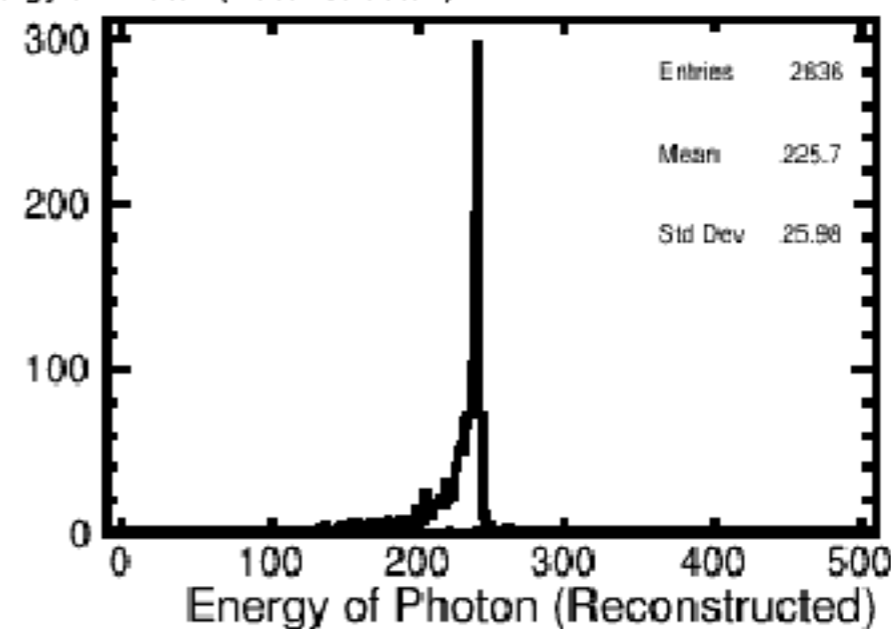
$|M(\mu^+\mu^-) - 91.2| < 10 \text{ GeV}$

Large ILD model

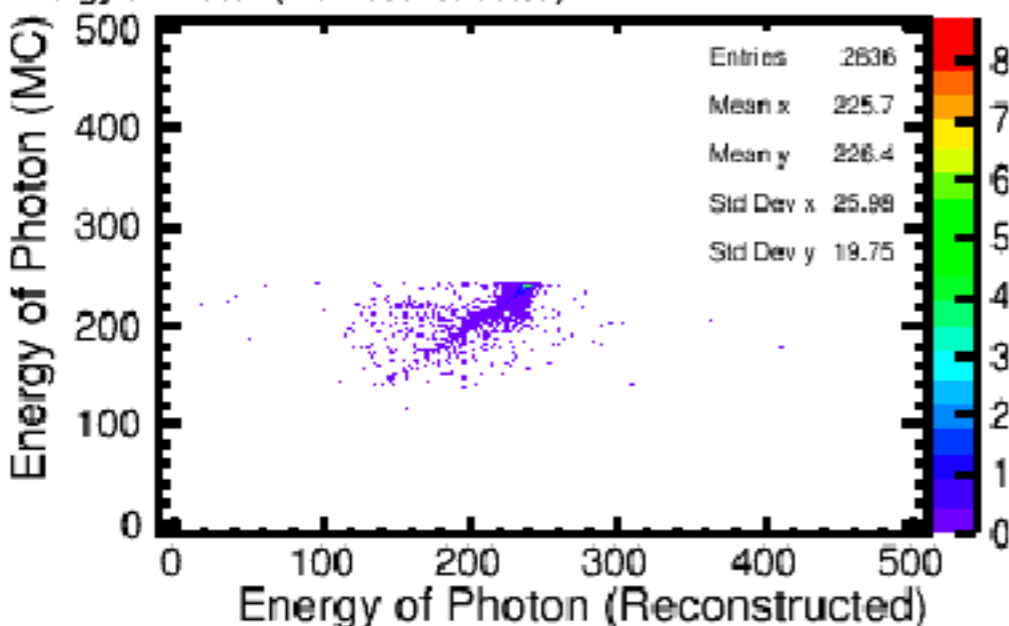
Energy of Photon (MC)



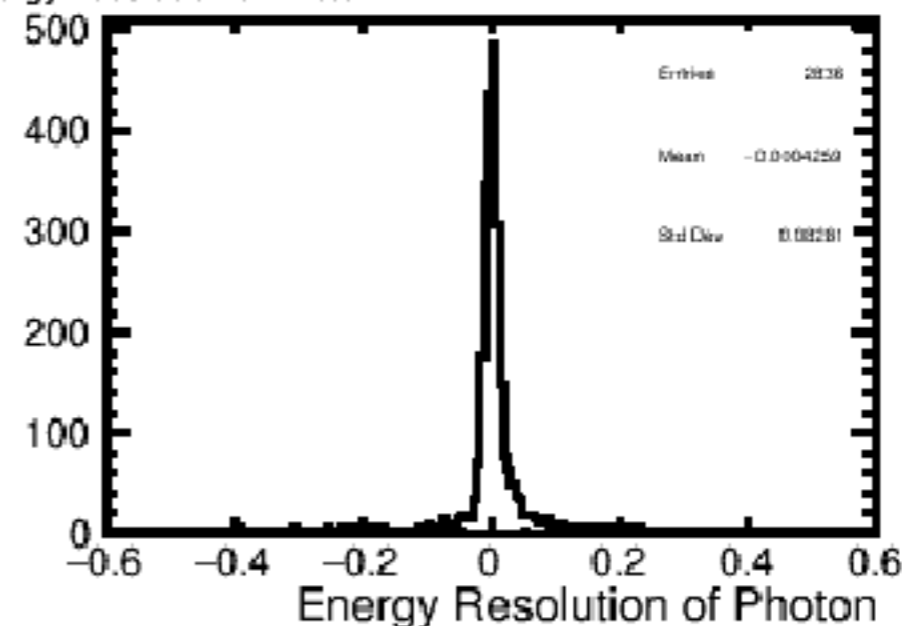
Energy of Photon (Reconstructed)



Energy of Photon (MC:Reconstructed)



Energy Resolution of Photon



Next Step

- Case 2 still have some bugs. I should fix the code.
- I will try below

Case 4: With ISR and the effect of Crossing Angle
Using $(\theta_{\mu-}, \theta_{\mu+}, \theta_{\gamma}, \phi_{\mu-}, \phi_{\mu+}, \phi_{\gamma}, E_{\mu-}, E_{\mu+})$
-> Determine (E_{γ}, E_{ISR})

and compare the energy resolution.