Status on e^+e^- -> γZ process Benchmark

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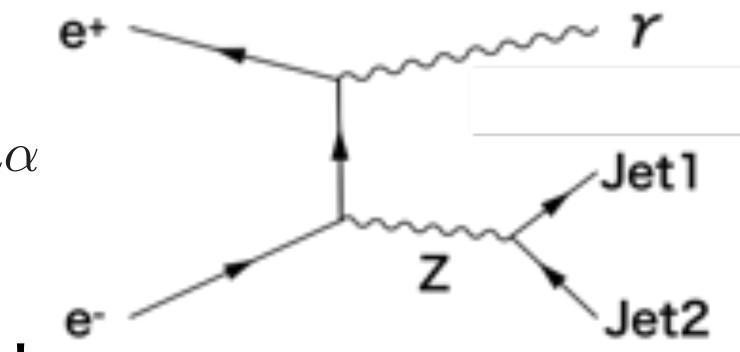
- ILD note: circulated
  -> I got 2 comments and implementing them now.

- Jet Energy Scale calibration
  2f_z_h sample implemented.
  -> I will discuss today

Reconstruction Method

Based on 4-momentum conservation

$$
\begin{cases}
\sqrt{P_{J1}^2 + m_{J1}^2} + \sqrt{P_{J2}^2 + m_{J2}^2} + |P_\gamma| + |P_{ISR}| = 500 \\
P_{J1} sin\theta_{J1} cos\phi_{J1} + P_{J2} sin\theta_{J2} cos\phi_{J2} + P_\gamma sin\theta_\gamma cos\phi_\gamma + |P_{ISR}| sin\alpha = 500 sin\alpha \\
P_{J1} sin\theta_{J1} sin\phi_{J1} + P_{J2} sin\theta_{J2} sin\phi_{J2} + P_\gamma sin\theta_\gamma sin\phi_\gamma = 0 \\
P_{J1} cos\theta_{J1} + P_{J2} cos\theta_{J2} + P_\gamma cos\theta_\gamma \pm |P_{ISR}| cos\alpha = 0
\end{cases}
$$



Beam Crossing Angle ≡2α : α = 7.0 mrad

Direction Angle
θ : polar angle
ϕ : azimuthal angle

- ISR photon = **additional** unseen photon
- Several reconstruction methods (Method 1, 2’, 2, and 3) are considered.

Method 1: Ignore ISR

Using (θ_{J1}, θ_{J2}, θ_γ, φ_{J1}, φ_{J2}, φ_γ, m_{J1}, m_{J2}) -> Determine (P_{J1}, P_{J2}, P_γ)

$$
\begin{cases}
\sqrt{P_{J1}^2 + m_{J1}^2} + \sqrt{P_{J2}^2 + m_{J2}^2} + |P_\gamma| = 500 \\
\begin{pmatrix} sin\theta_{J1} cos\phi_{J1} & sin\theta_{J2} cos\phi_{J2} & sin\theta_\gamma cos\phi_\gamma \\ sin\theta_{J1} sin\phi_{J1} & sin\theta_{J2} sin\phi_{J2} & sin\theta_\gamma sin\phi_\gamma \\ cos\theta_{J1} & cos\theta_{J2} & cos\theta_\gamma \end{pmatrix} \begin{pmatrix} P_{J1} \\ P_{J2} \\ P_\gamma \end{pmatrix} = \begin{pmatrix} 500 sin\alpha \\ 0 \\ 0 \end{pmatrix}
\end{cases}
$$

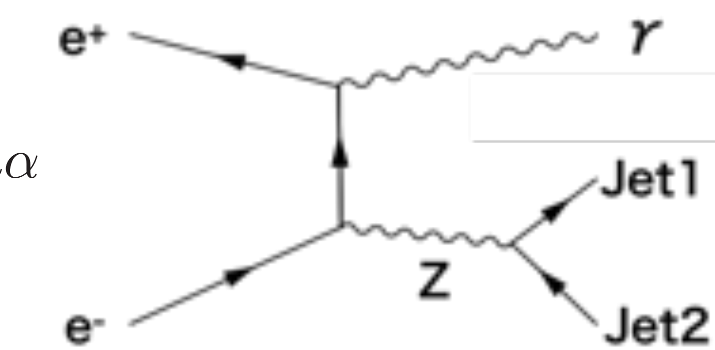
Matrix A —— Inverse

Reconstruction Method

Based on 4-momentum conservation

$$\begin{cases} \sqrt{P_{J1}^2+m_{J1}^2}+\sqrt{P_{J2}^2+m_{J2}^2}+|P_\gamma|+|P_{ISR}|=500 \\ P_{J1}sin\theta_{J1}cos\phi_{J1}+P_{J2}sin\theta_{J2}cos\phi_{J2}+P_\gamma sin\theta_\gamma cos\phi_\gamma+|P_{ISR}|sin\alpha=500sin\alpha \\ P_{J1}sin\theta_{J1}sin\phi_{J1}+P_{J2}sin\theta_{J2}sin\phi_{J2}+P_\gamma sin\theta_\gamma sin\phi_\gamma=0 \\ P_{J1}cos\theta_{J1}+P_{J2}cos\theta_{J2}+P_\gamma cos\theta_\gamma \pm |P_{ISR}|cos\alpha=0 \end{cases}$$

Beam Crossing Angle ≡2α : α = 7.0 mrad



Direction Angle
θ: polar angle
ϕ: azimuthal angle

In Method 2’ and 2, measured P_γ is used as input.

Measured P_γ is smeared as

$$\mathbf{P_{\gamma MC}} + P_{\gamma MC}\times 0.15\sqrt{P_{\gamma MC}}\times gRandom->Gaus(0.,1.)$$

corresponding to the photon energy resolution

$$\frac{\sigma_{E\gamma}}{E_\gamma}=\frac{0.15}{\sqrt{E_\gamma}}$$

Reconstruction Method

Method 2': Ignore ISR and use smeared P_γ

Using ($\theta_{J1},\theta_{J2},\theta_\gamma,\varphi_{J1},\varphi_{J2},\varphi_\gamma,m_{J1},m_{J2},P_\gamma$) -> Determine ($P_{J1},P_{J2}$)

$$\left\{ \begin{pmatrix} sin\theta_{J1}cos\phi_{J1} & sin\theta_{J2}cos\phi_{J2} \\ sin\theta_{J1}sin\phi_{J1} & sin\theta_{J2}sin\phi_{J2} \end{pmatrix} \begin{pmatrix} P_{J1} \\ P_{J2} \end{pmatrix} = \begin{pmatrix} 500sin\alpha - sin\theta_\gamma cos\phi_\gamma P_\gamma \\ -sin\theta_\gamma sin\phi_\gamma P_\gamma \end{pmatrix} \right.$$

Method 2: Consider ISR and use smeared P_γ

Using ($\theta_{J1},\theta_{J2},\theta_\gamma,\varphi_{J1},\varphi_{J2},\varphi_\gamma,m_{J1},m_{J2},P_\gamma$) -> Determine ($P_{J1},P_{J2},P_{ISR}$)

$$\left\{ \begin{array}{l} \sqrt{P_{J1}^2 + m_{J1}^2} + \sqrt{P_{J2}^2 + m_{J2}^2} + |P_\gamma| + |P_{ISR}| = 500 \quad ① \\ \begin{pmatrix} sin\theta_{J1}cos\phi_{J1} & sin\theta_{J2}cos\phi_{J2} & sin\alpha \\ sin\theta_{J1}sin\phi_{J1} & sin\theta_{J2}sin\phi_{J2} & 0 \\ cos\theta_{J1} & cos\theta_{J2} & \pm cos\alpha \end{pmatrix} \begin{pmatrix} P_{J1} \\ P_{J2} \\ |P_{ISR}| \end{pmatrix} = \begin{pmatrix} 500sin\alpha - sin\theta_\gamma cos\phi_\gamma P_\gamma \\ -sin\theta_\gamma sin\phi_\gamma P_\gamma \\ -cos\theta_\gamma P_\gamma \end{pmatrix} \end{array} \right.$$

Matrix A

Inverse

2 solutions for each sign of P_{ISR}

-> choose the best answer which satisfies ① better

Reconstruction Method

Method 3: Consider ISR and solve the full equation

Using ($\theta_{J1},\theta_{J2},\theta_\gamma,\varphi_{J1},\varphi_{J2},\varphi_\gamma,m_{J1},m_{J2}$) -> Determine ($P_{J1},P_{J2},P_\gamma,P_{ISR}$)

$$\begin{cases} \sqrt{P_{J1}^2 + m_{J1}^2} + \sqrt{P_{J2}^2 + m_{J2}^2} + |P_\gamma| + |P_{ISR}| = 500 \\ \begin{pmatrix} sin\theta_{J1}cos\phi_{J1} & sin\theta_{J2}cos\phi_{J2} & sin\theta_\gamma cos\phi_\gamma \\ sin\theta_{J1}sin\phi_{J1} & sin\theta_{J2}sin\phi_{J2} & sin\theta_\gamma sin\phi_\gamma \\ cos\theta_{J1} & cos\theta_{J2} & cos\theta_\gamma \end{pmatrix} \begin{pmatrix} P_{J1} \\ P_{J2} \\ P_\gamma \end{pmatrix} = \begin{pmatrix} (500 - |P_{ISR}|)sin\alpha \\ 0 \\ \pm|P_{ISR}|cos\alpha \end{pmatrix} \end{cases}$$

Matrix A

Inverse

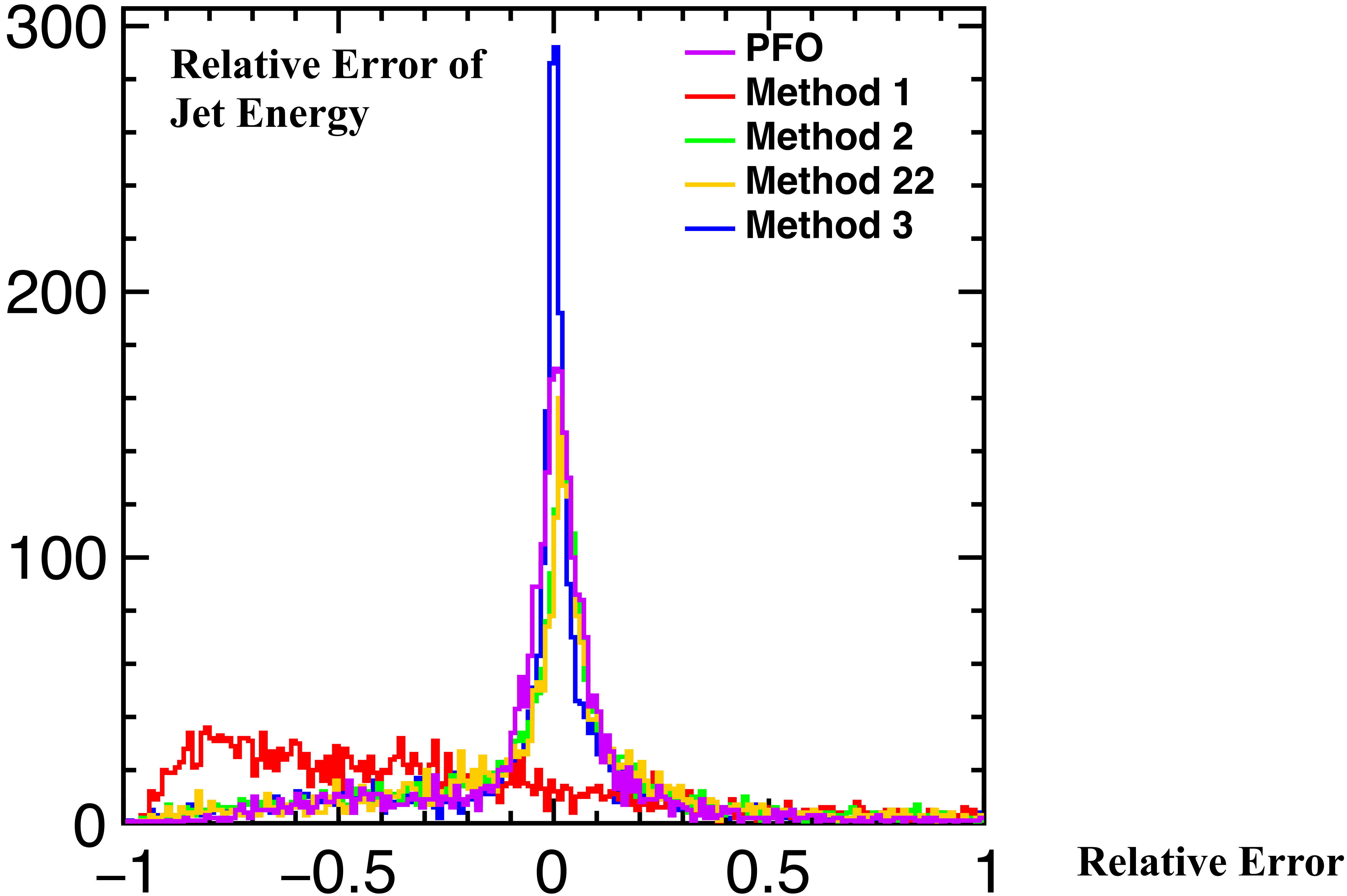
Inserting P_{J1},P_{J2},P_γ into the first equation

-> 8 Possible Solutions!

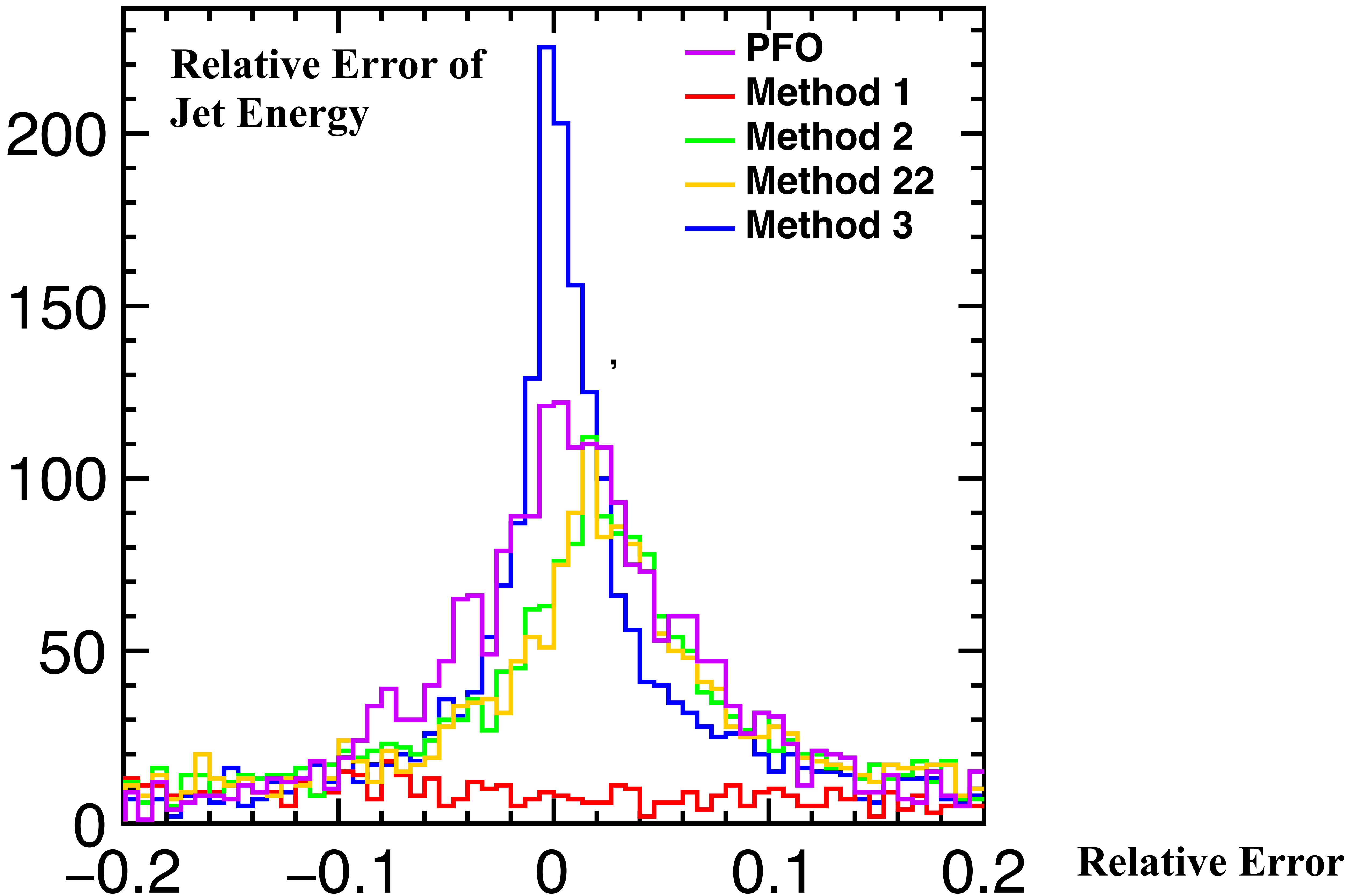
4: Quartic Equation of $|P_{ISR}|$ X 2: sign of ISR

- **Choose real and positive solutions**
- **Solved P_γ close to the measured (smeared) P_γ**

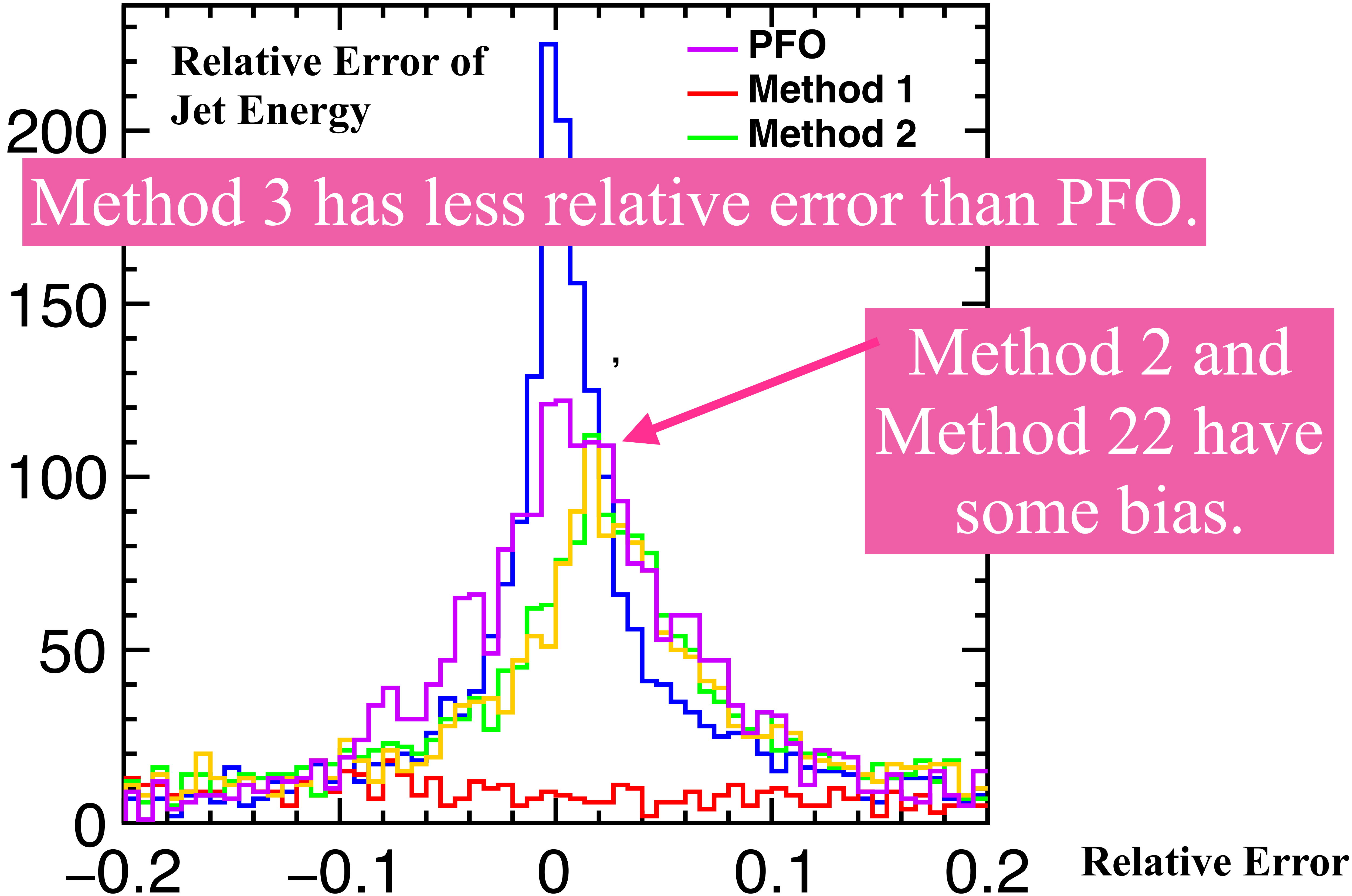
Method Comparison Result



Method Comparison Result



Method Comparison Result



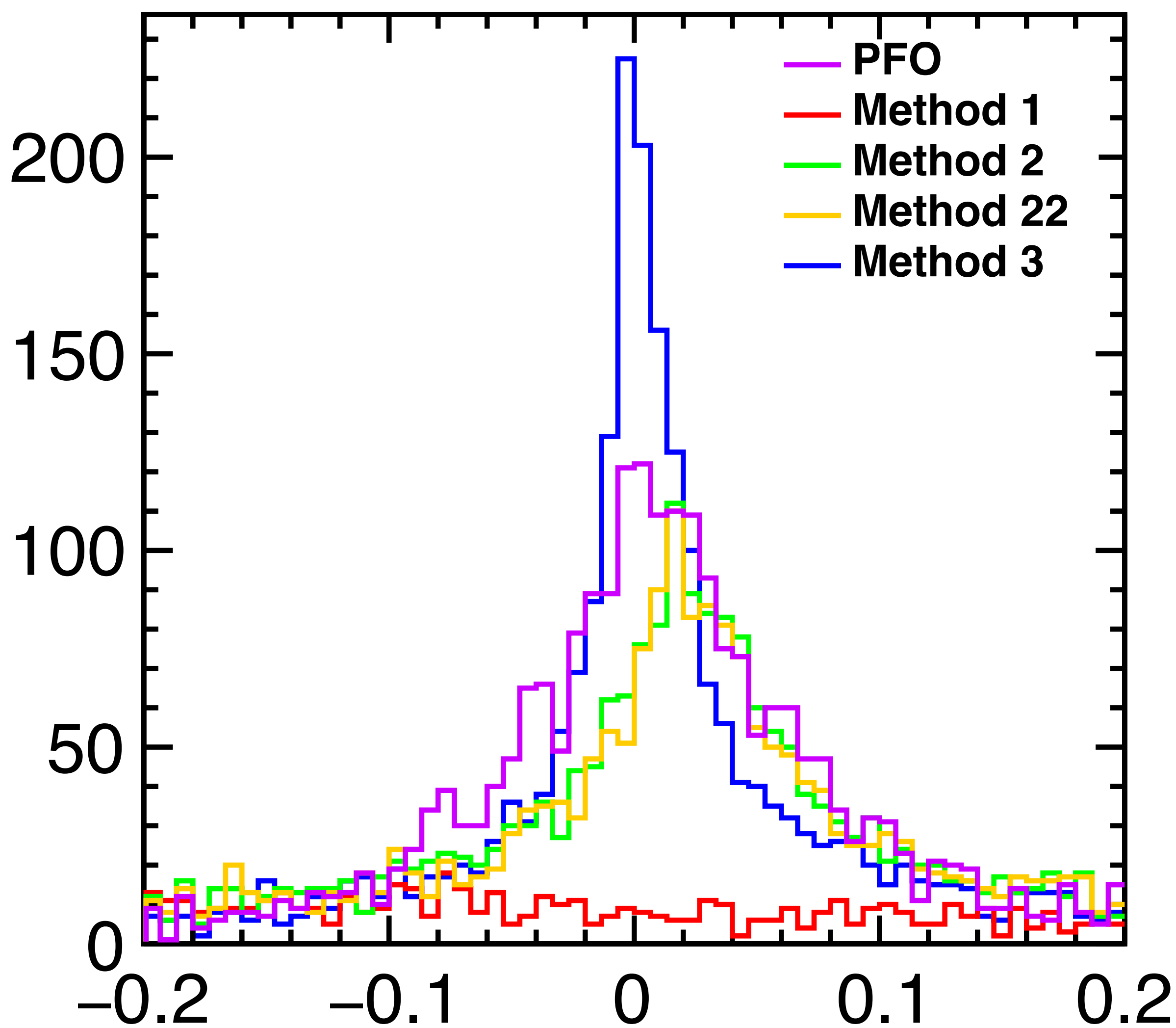
Method 3 has less relative error than PFO.

Method 2 and Method 22 have some bias.

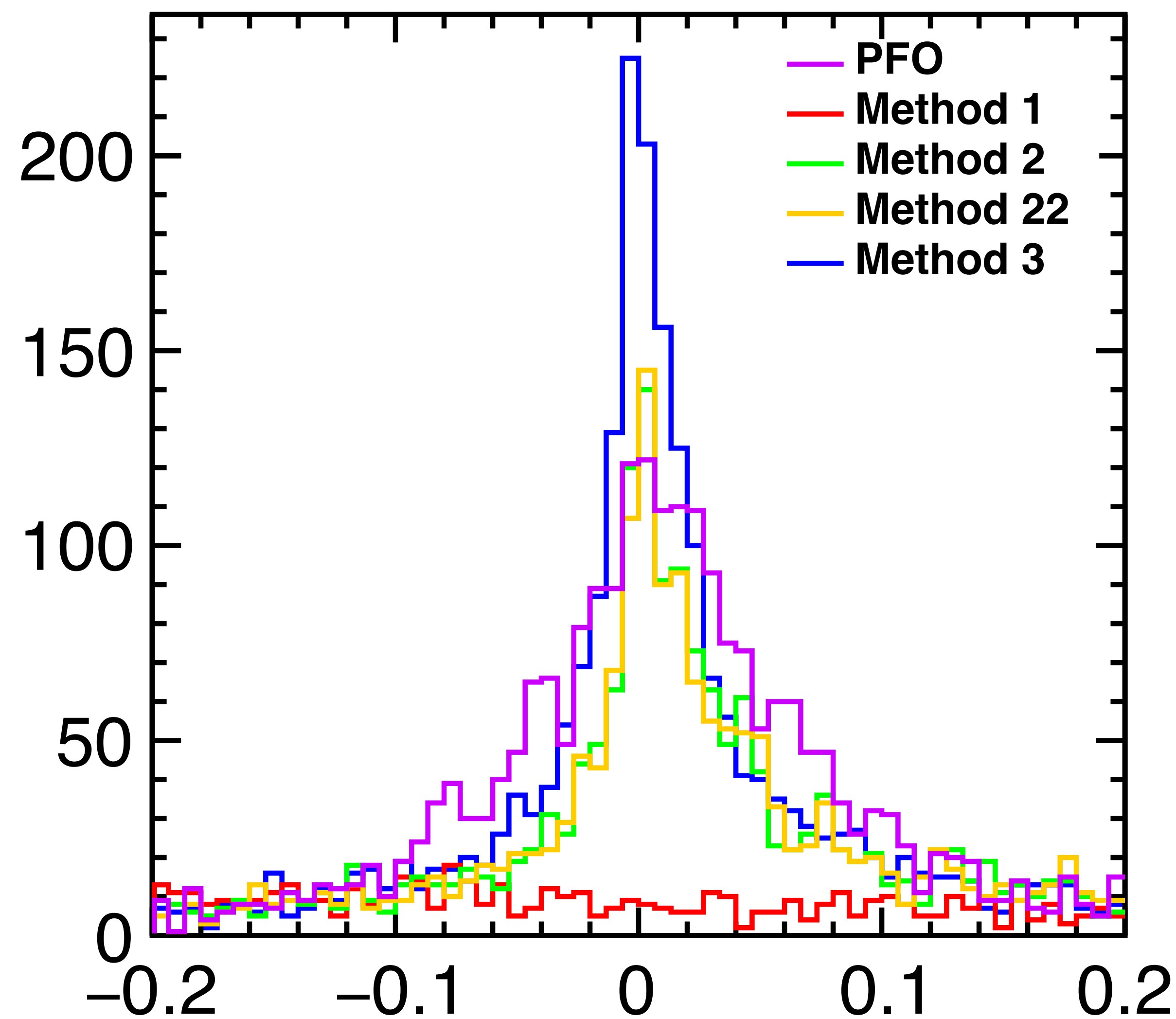
Method Comparison Result

If using MCtrue photon energy as input,

PFO photon E as input



MC photon E as input

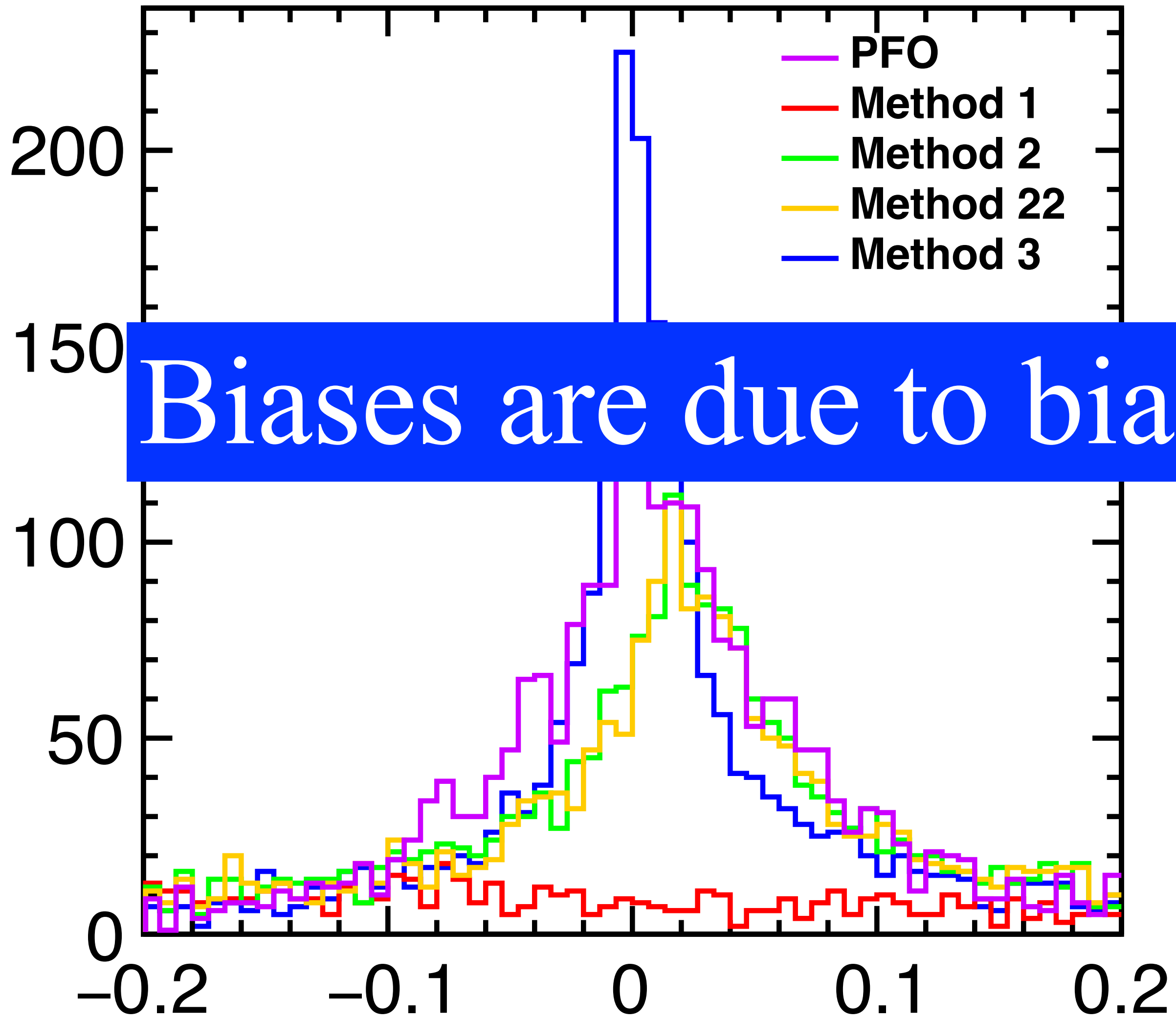


Biases in Method 2 and 22 disappeared.

Method Comparison Result

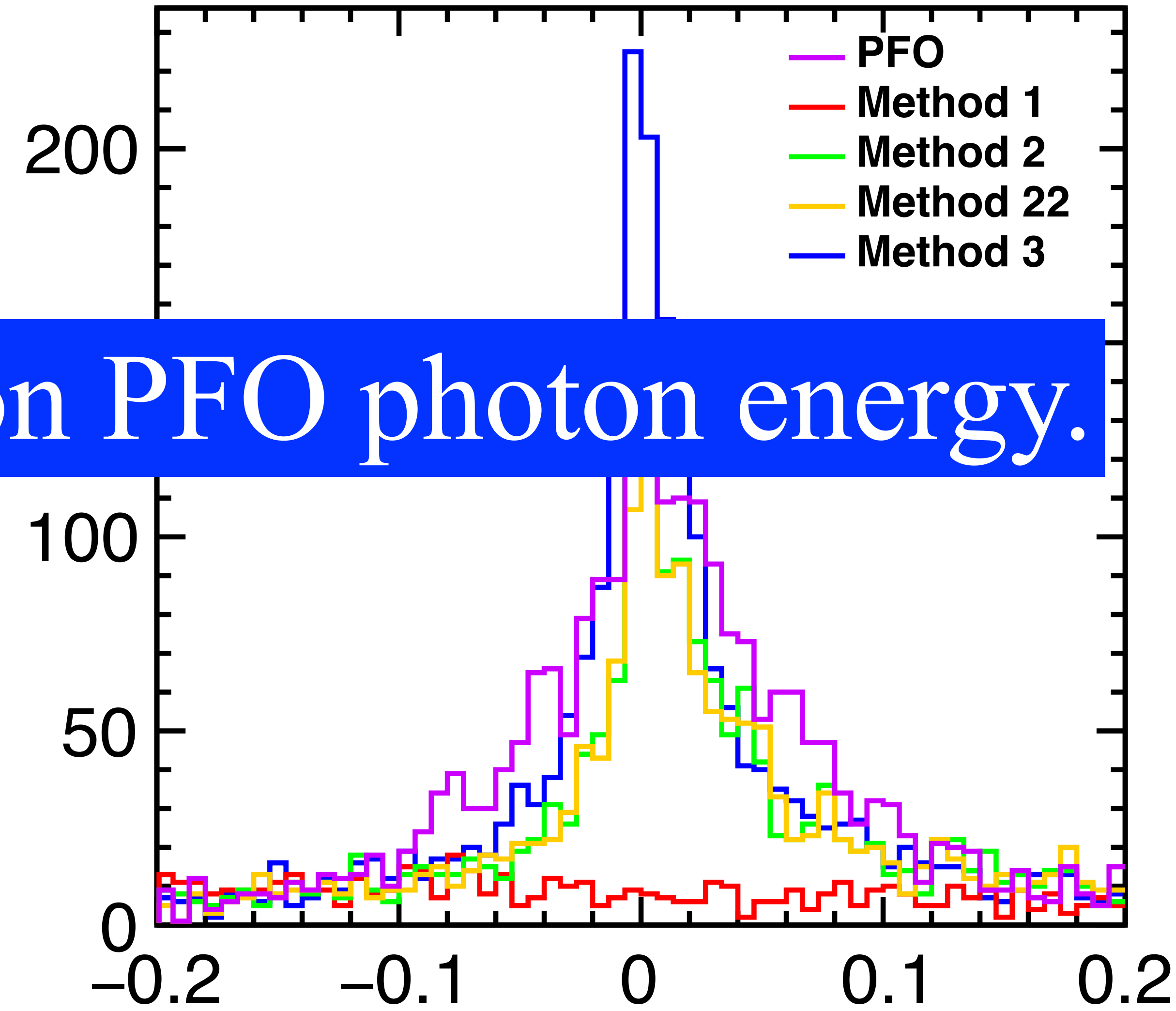
If using MCtrue photon energy as input,

PFO photon E as input



,

MC photon E as input



Biases are due to bias on PFO photon energy.

Biases in Method 2 and 22 disappeared.

Result

Method comparison using 2f_z_h sample is performed.

Method3 is better than the PFO.

Method2 and 22 have biases because of the bias on PFO photon energy.

Status on e^+e^- -> γZ process Benchmark

Future work

- Prepare a presentation at ICCEP Symposium
- For the jet energy reconstruction:
  Understand the which factor limits the jet energy resolution
  check the angle dependence