Status on e^+e^- -> γZ process
Jet Energy Calibration

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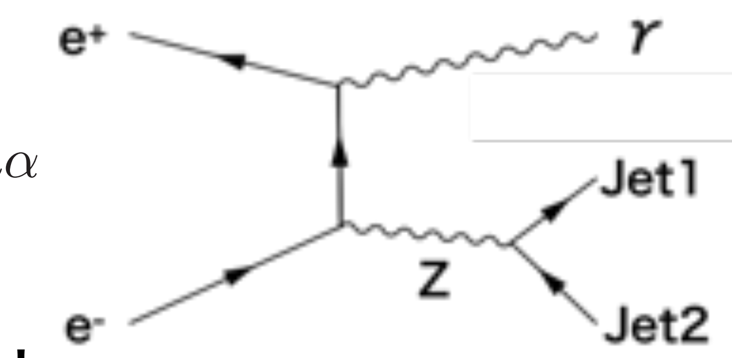
Reconstruction Method

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

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

Method 1: Ignore ISR

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

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

Matrix A — Inverse

Reconstruction Method

Method 2': Use measured P_γ as input and Ignore ISR
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: Use measured P_γ as input and Ignore ISR
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 $(P_{J1},P_{J2},P_\gamma,P_{ISR})$

$$\begin{cases} \sqrt{P_{J1}^2+m_{J1}^2}+\sqrt{P_{J2}^2+m_{J2}^2}+|P_\gamma|+|P_{ISR}|=500 \quad ① \\ \begin{pmatrix} sin\theta_{J1}cos\phi_{J1} & sin\theta_{J2}cos\phi_{J2} & sin\theta_\gamma cos\phi_\gamma \\ sin\theta_{J1}sin\phi_{J1} & sin\theta_{J2}sin\phi_{J2} & sin\theta_\gamma sin\phi_\gamma \\ cos\theta_{J1} & cos\theta_{J2} & cos\theta_\gamma \end{pmatrix} \begin{pmatrix} P_{J1} \\ P_{J2} \\ P_\gamma \end{pmatrix} = \begin{pmatrix} (500-|P_{ISR}|)sin\alpha \\ 0 \\ \pm|P_{ISR}|cos\alpha \end{pmatrix} \end{cases}$$

Matrix A

Inverse

The first equation ① becomes a quartic equation of $|P_{ISR}|$.

-> 8 Possible Solutions!
(2 direction options of ISR × 4 solutions for each quartic equation)

Choose the solution with (i) real and positive value
(ii) solved P_γ closest to the measured P_γ

2f_z_h sample simulation

eLpR samples
Large ILD model

Full simulation (ILCSOFT version v02-00-02)

- Event generation by Whizard 1.95
  with beamstrahlung and additional ISR photon effects
- Realistic event reconstruction from detector signals
- Process: $e^+e^- \to \gamma Z$, $Z \to$ 2Jets
- E_{CM}= 500 GeV
- Polarization: e^+: Right e^-: Left

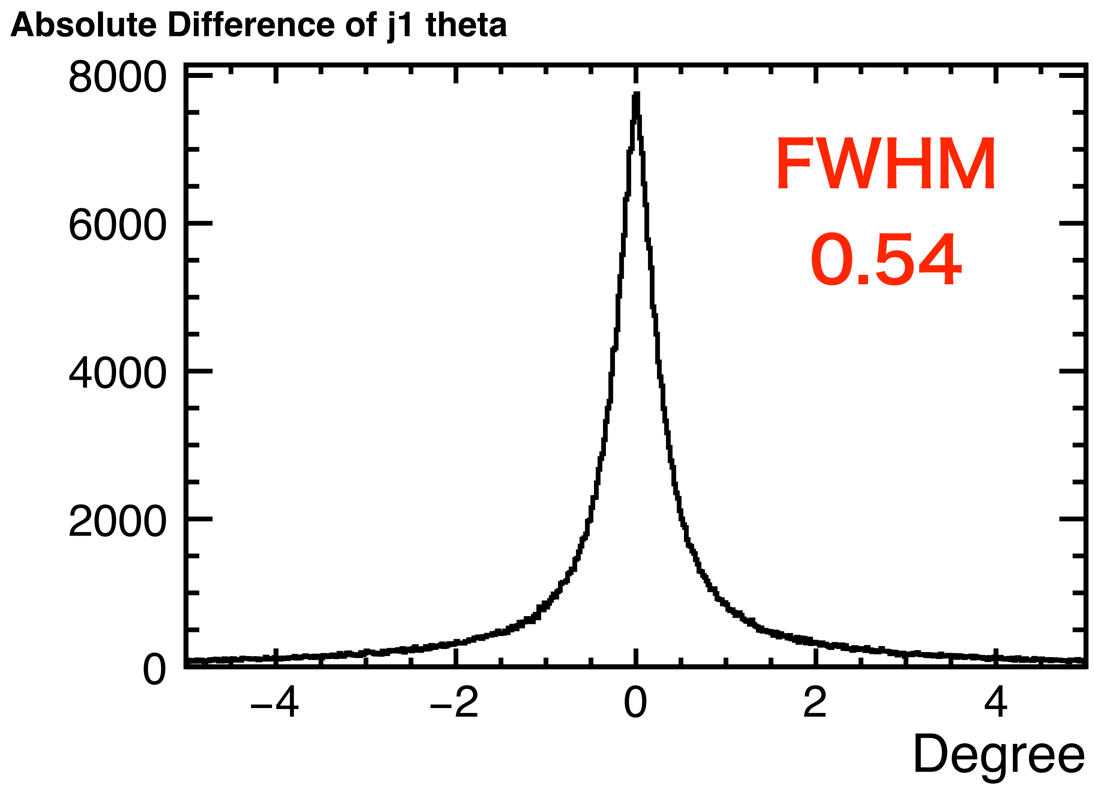
1. Comparison of physical quantities of jets between MCTruth and PFO

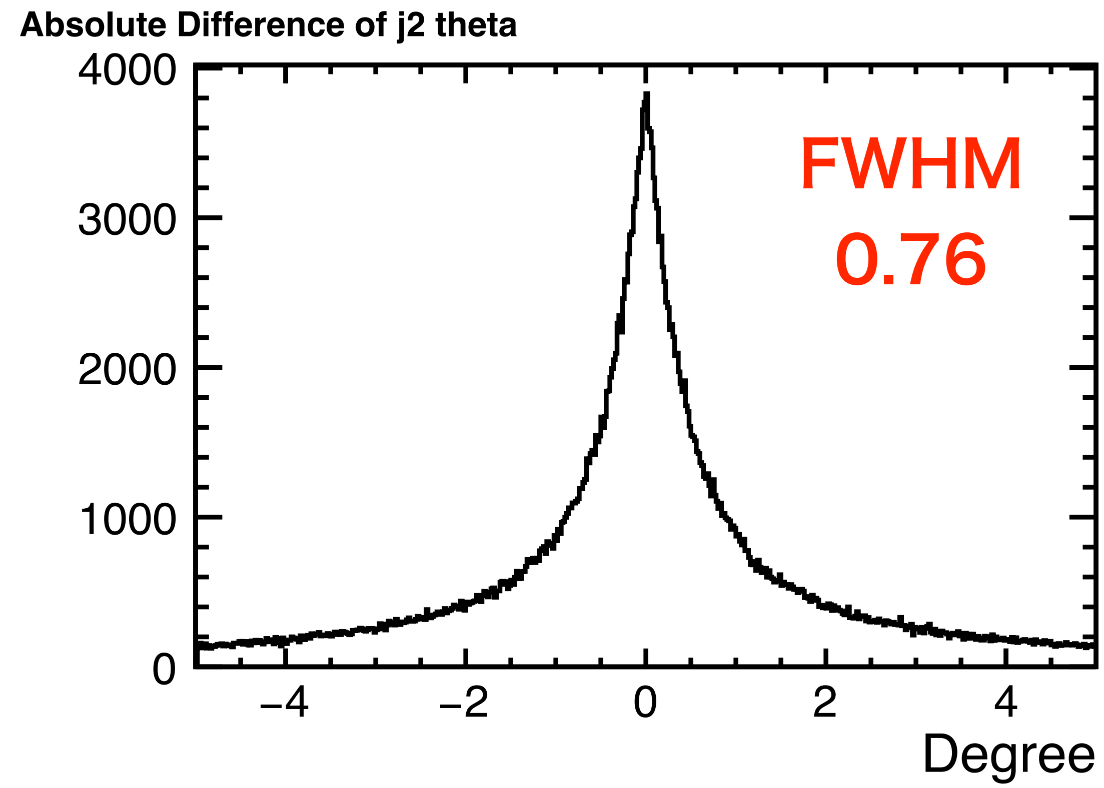
1.1. absolute theta difference of each jet and the absolute phi difference of each jet

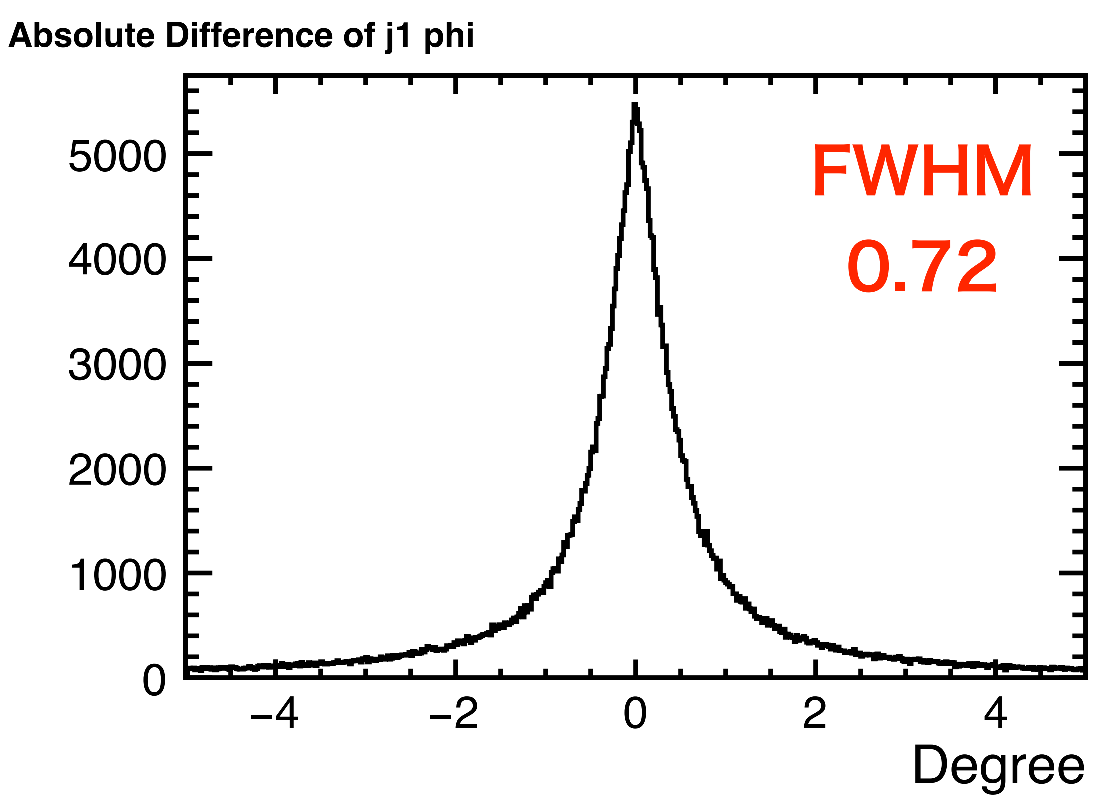
1.2. absolute mass difference of each jet

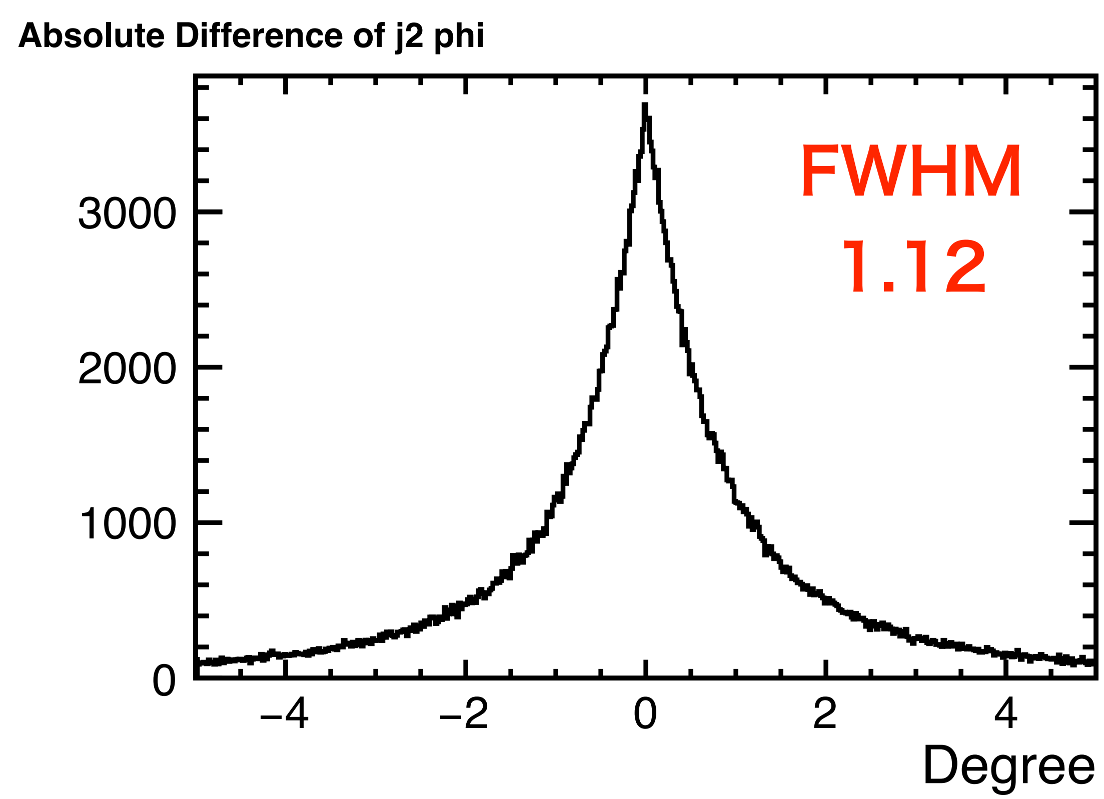
1.3. difference of the jet energy sum between PFO and MCTruth

1.1 Theta & Phi Comparison

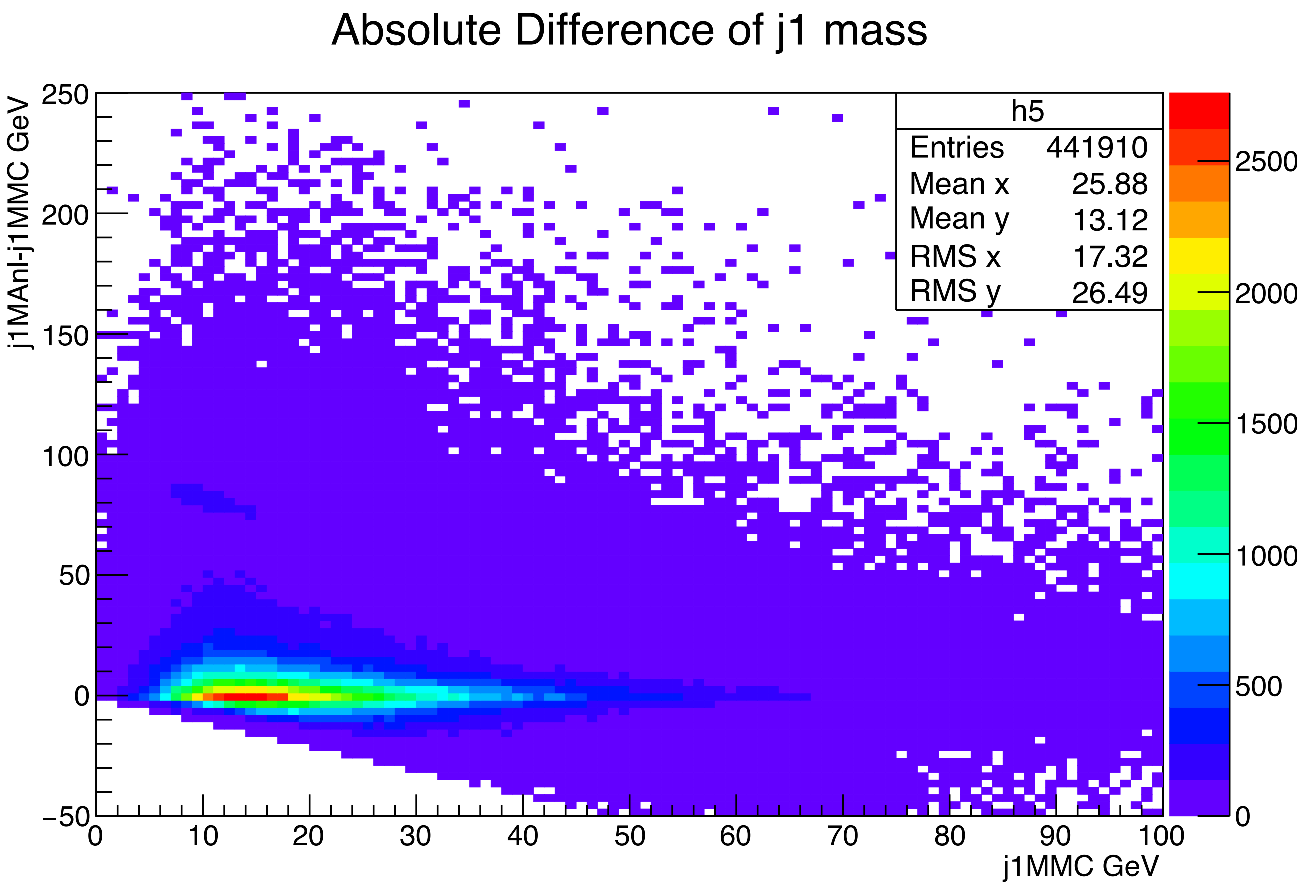


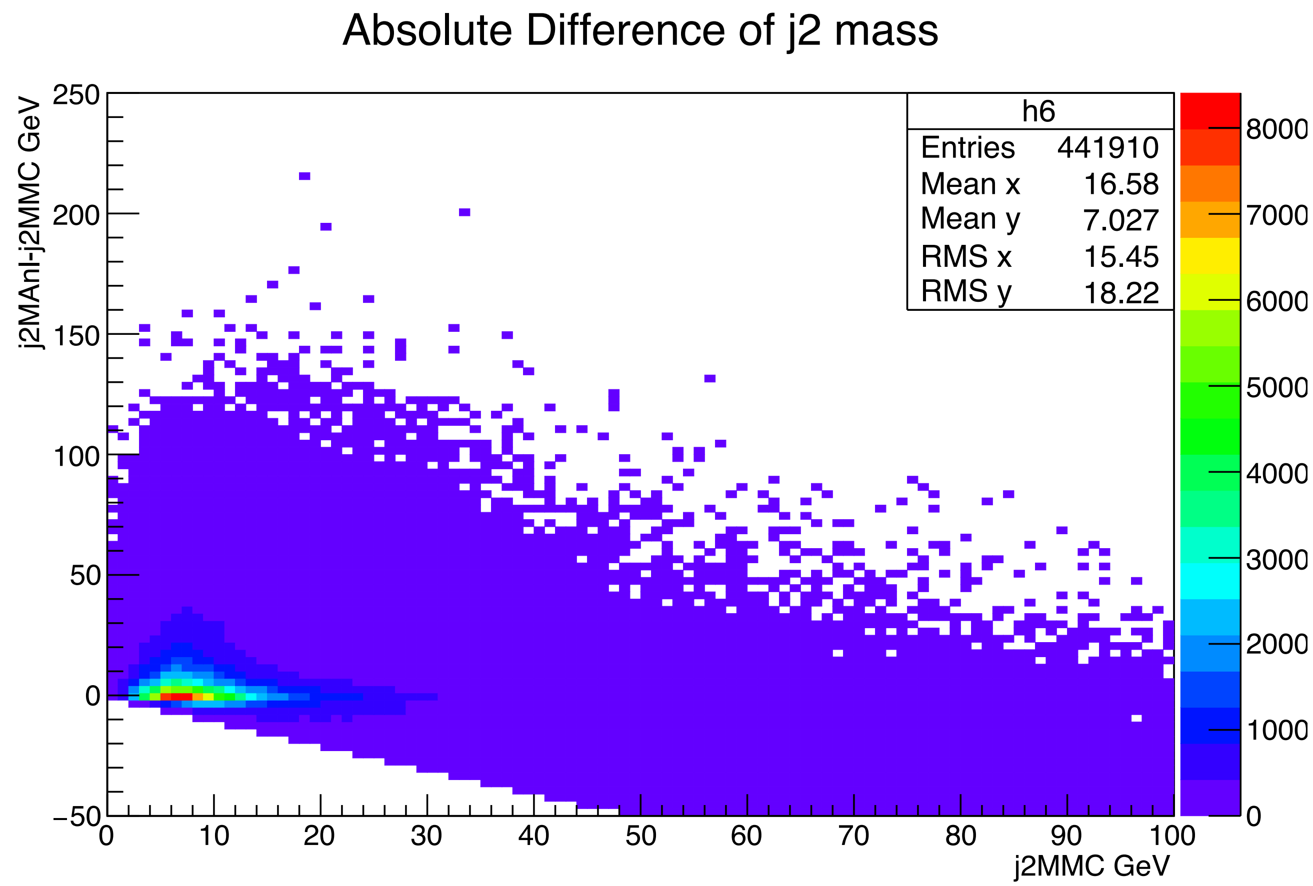






1.2. Jet mass deviation dependence on jet mass

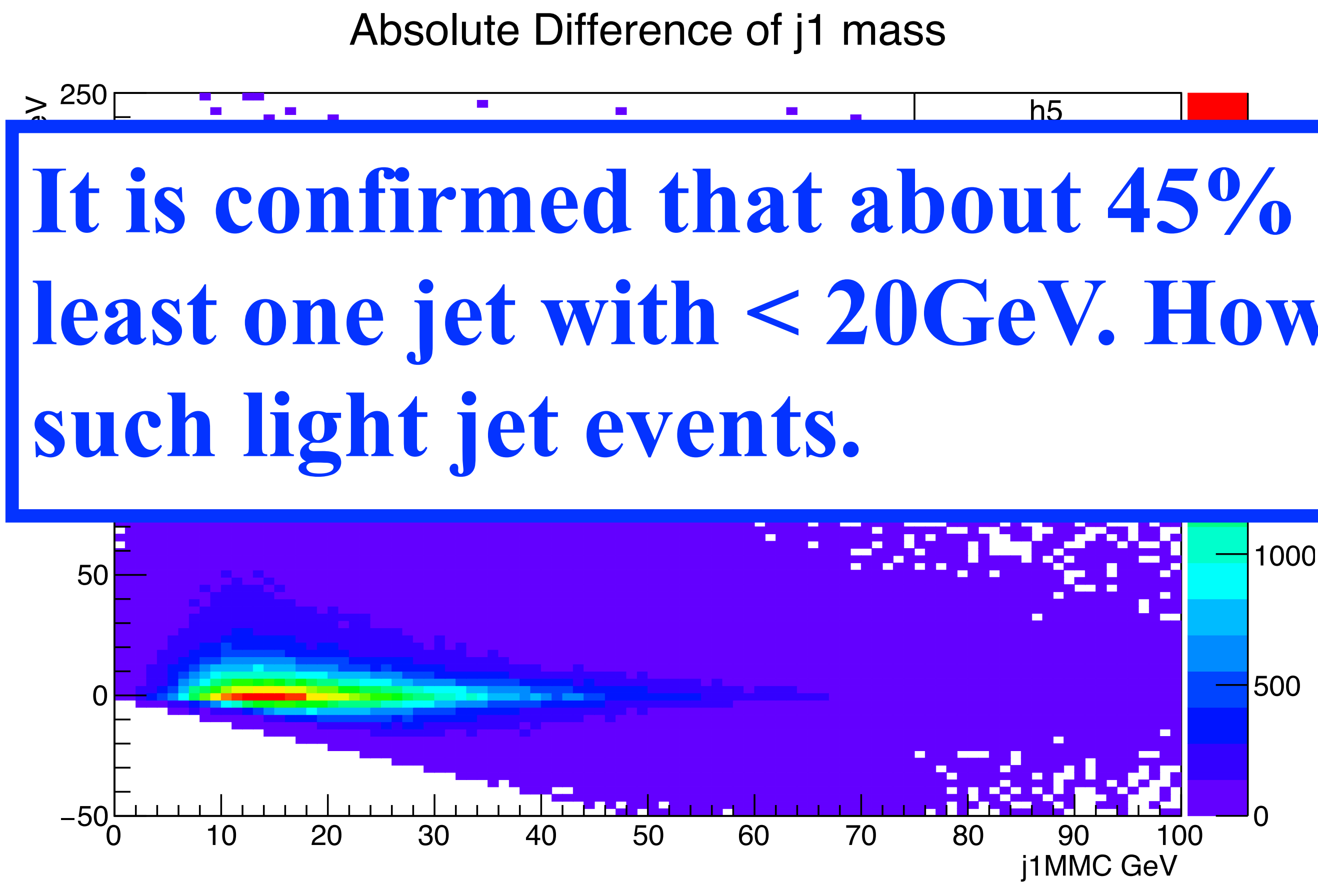


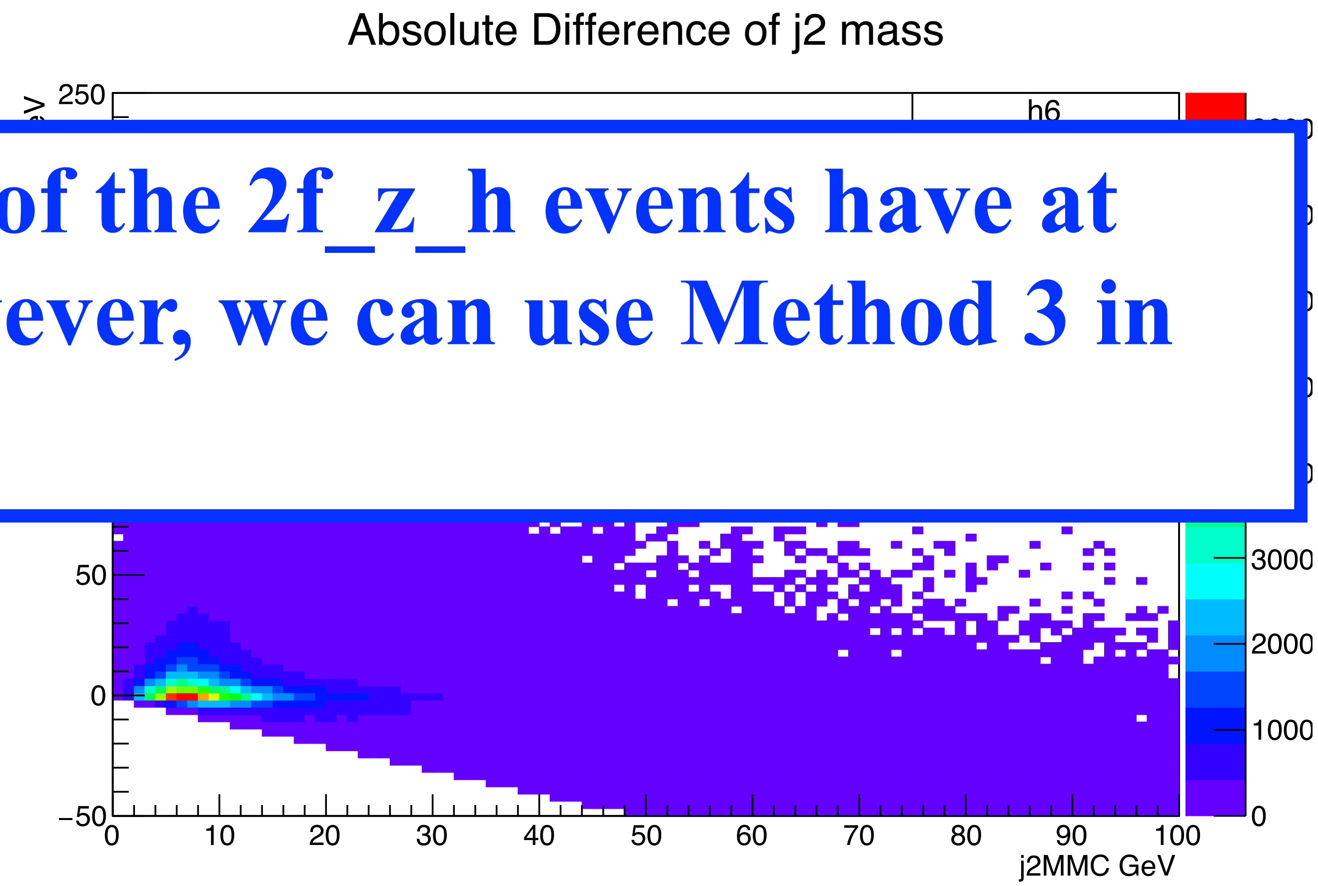


- **Mass resolution is found to be very bad (sometimes ~O(1)).**

When the jet is lighter, the resolution is worse.

1.2. Jet mass deviation dependence on jet mass



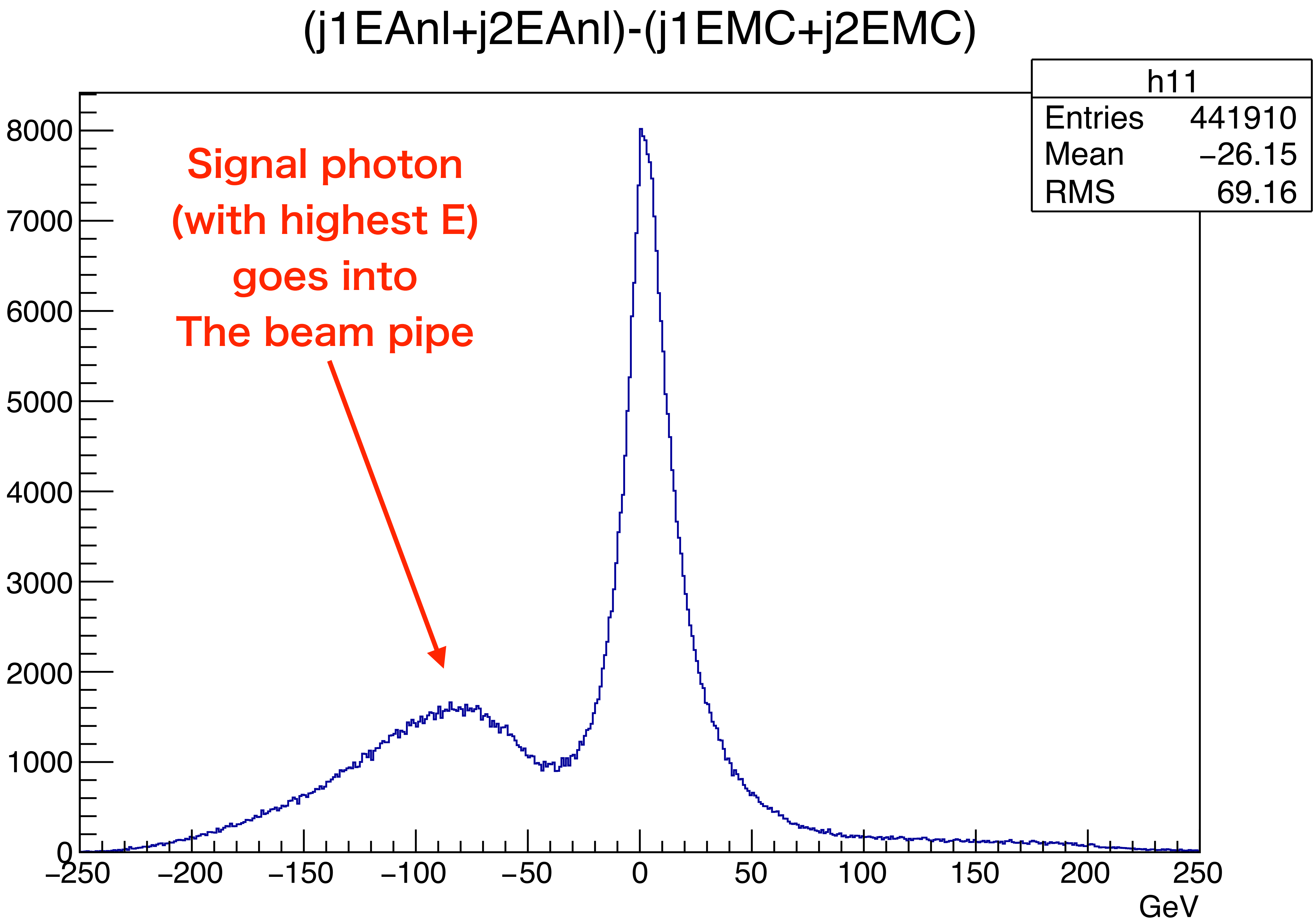


It is confirmed that about 45% of the 2f_z_h events have at least one jet with < 20GeV. However, we can use Method 3 in such light jet events.

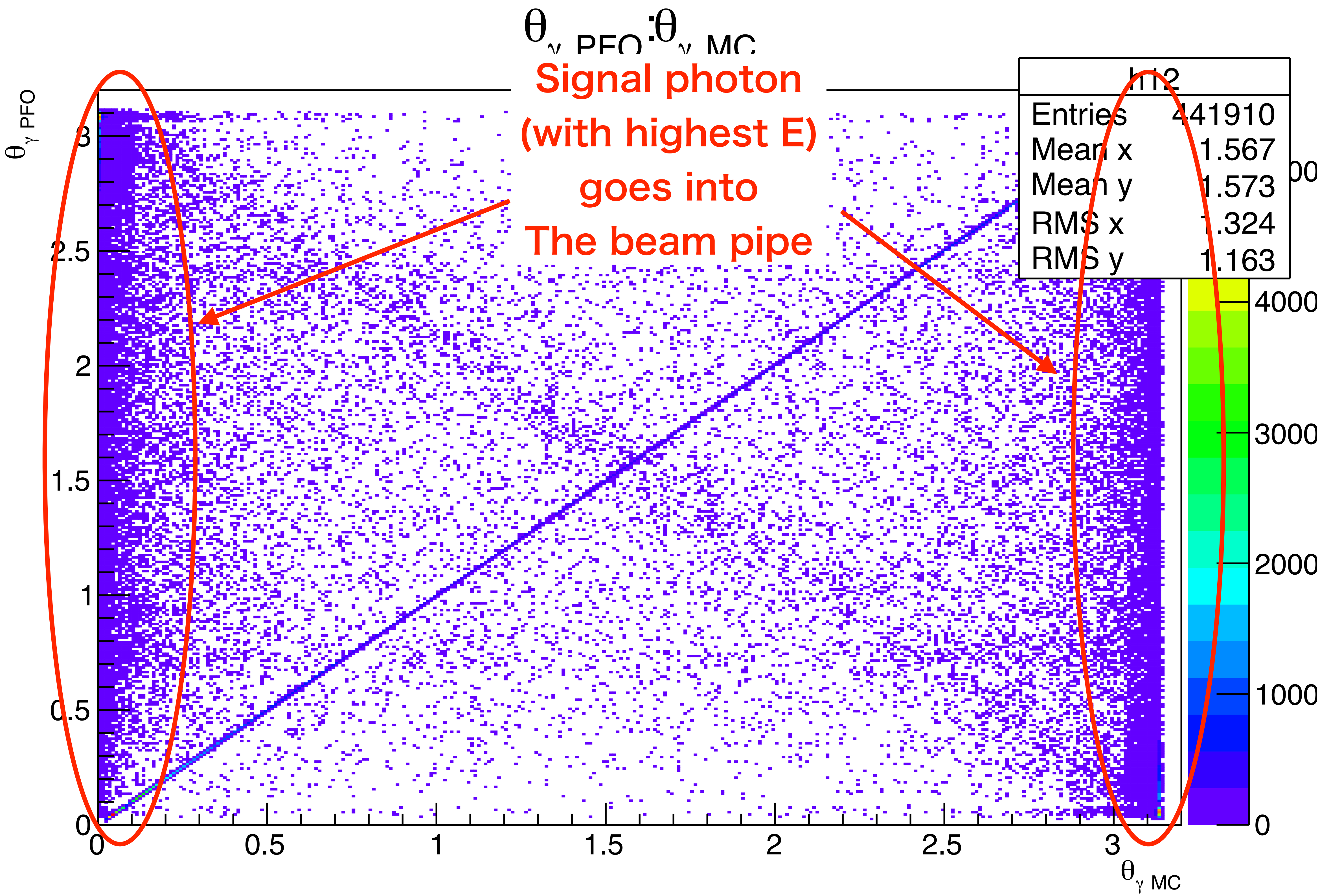
- **Mass resolution is found to be very bad (sometimes ~O(1)).**

  When the jet is lighter, the resolution is worse.

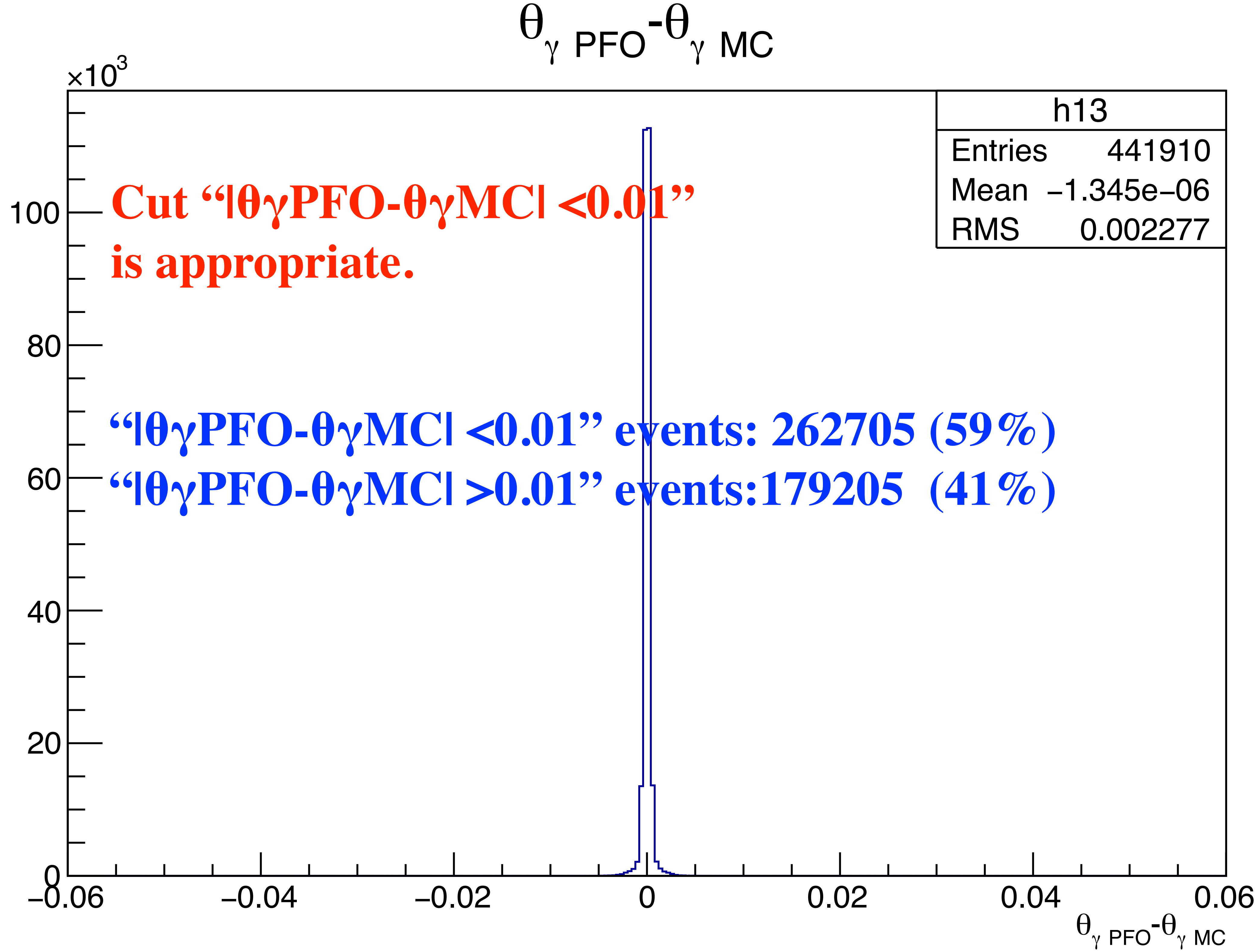
1.3. difference of the jet energy sum between PFO and MCTruth



1.3. difference of the jet energy sum between PFO and MCTruth



1.3. difference of the jet energy sum between PFO and MCTruth

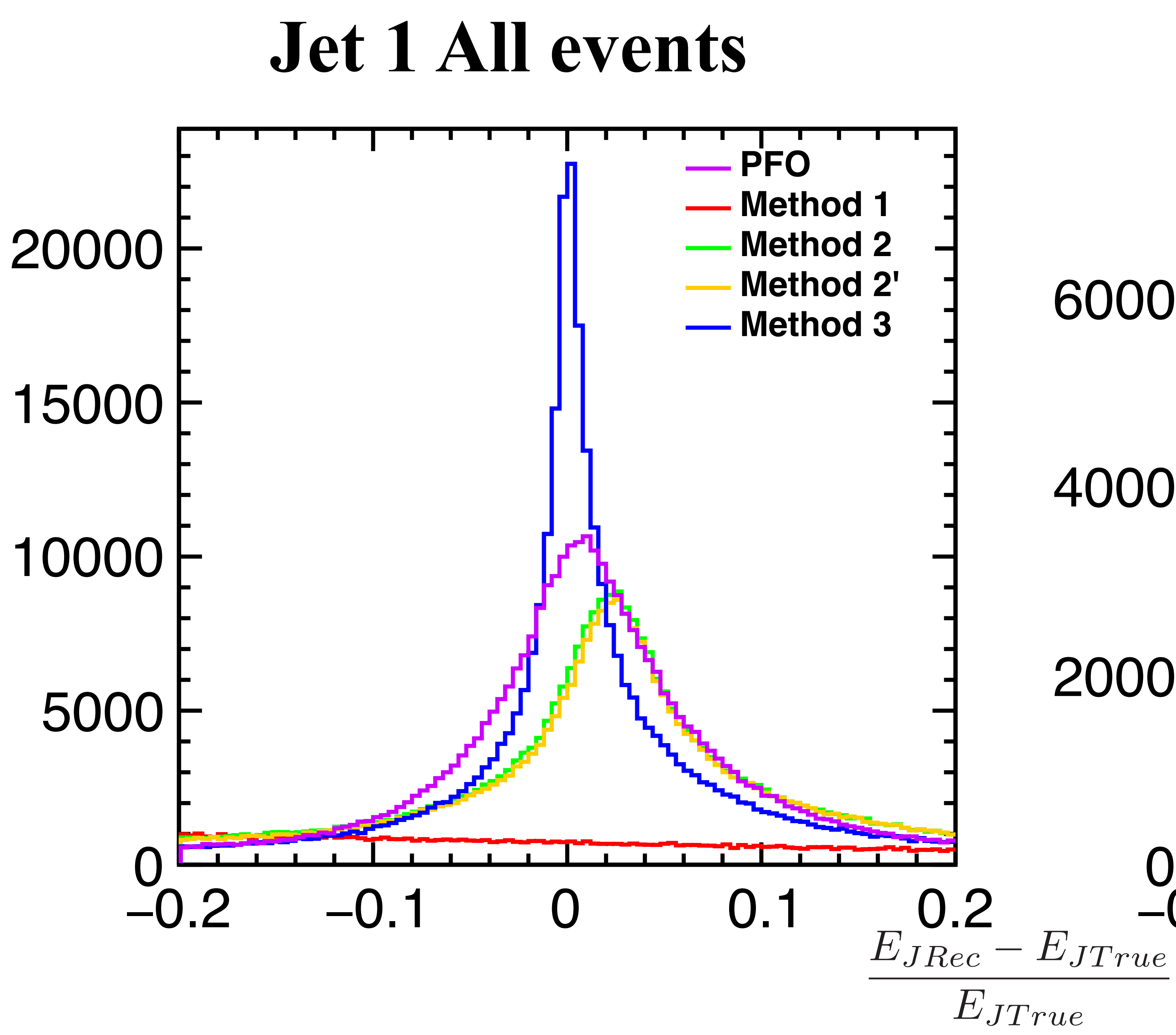


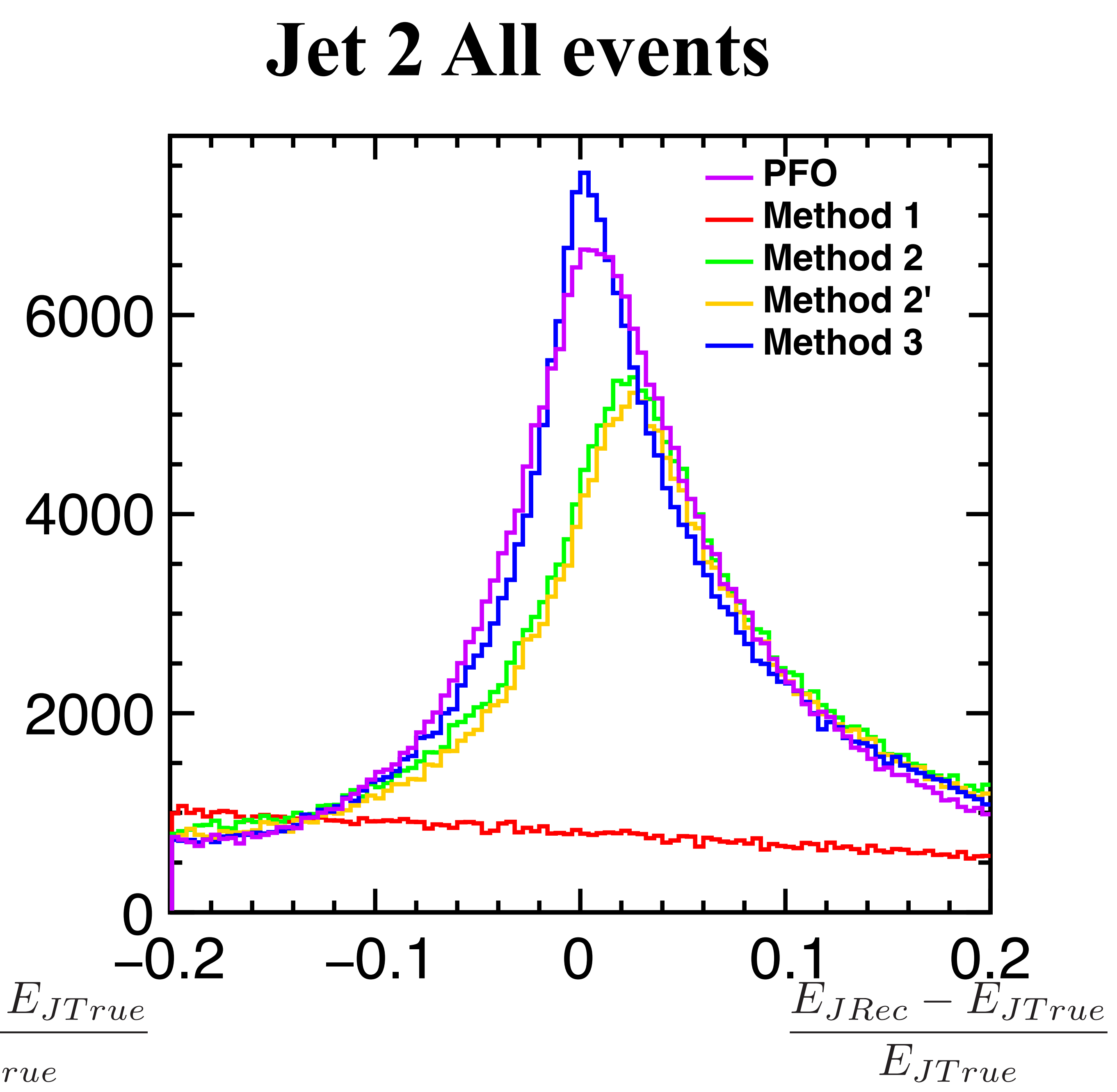
2. Full Simulation Result

2.1. Method comparison result

2.2. Angle dependence

2.1. Method Comparison

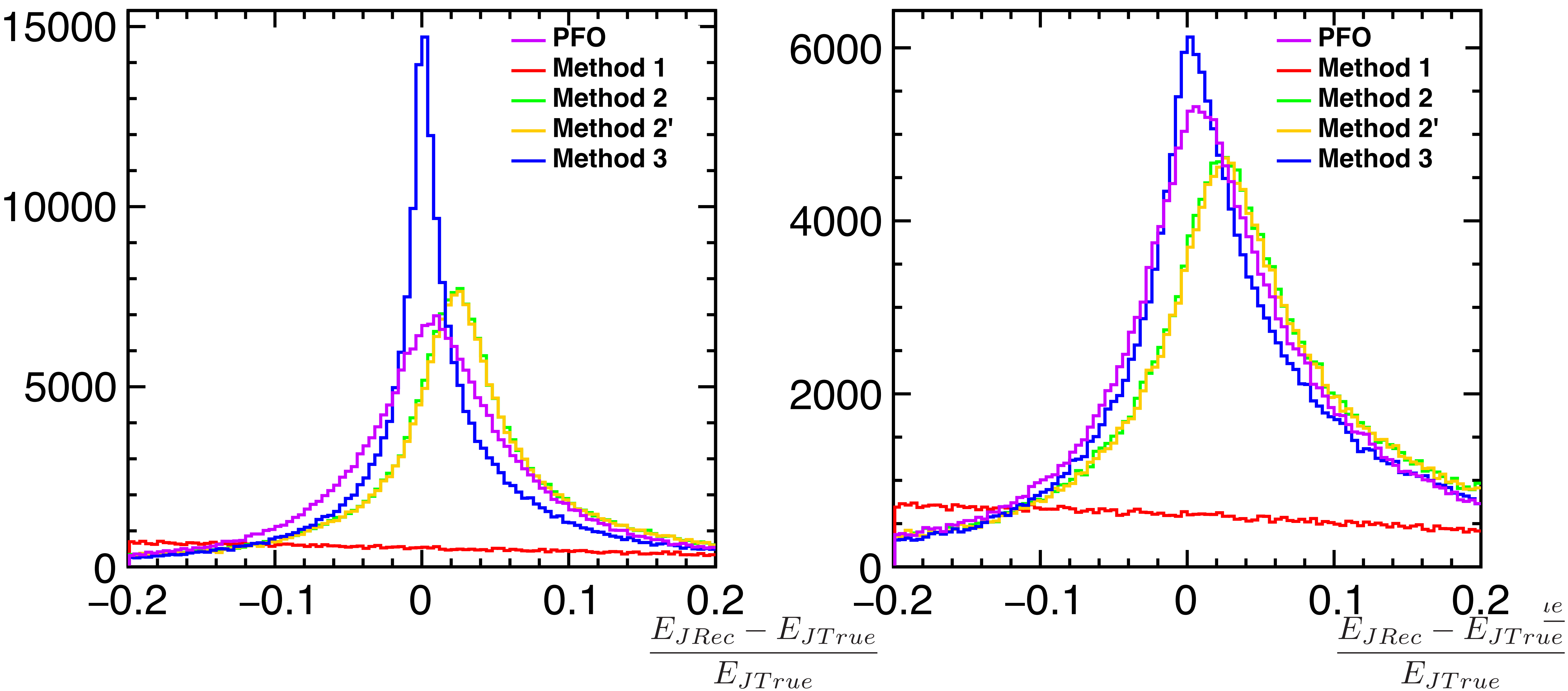




2.1. Method Comparison

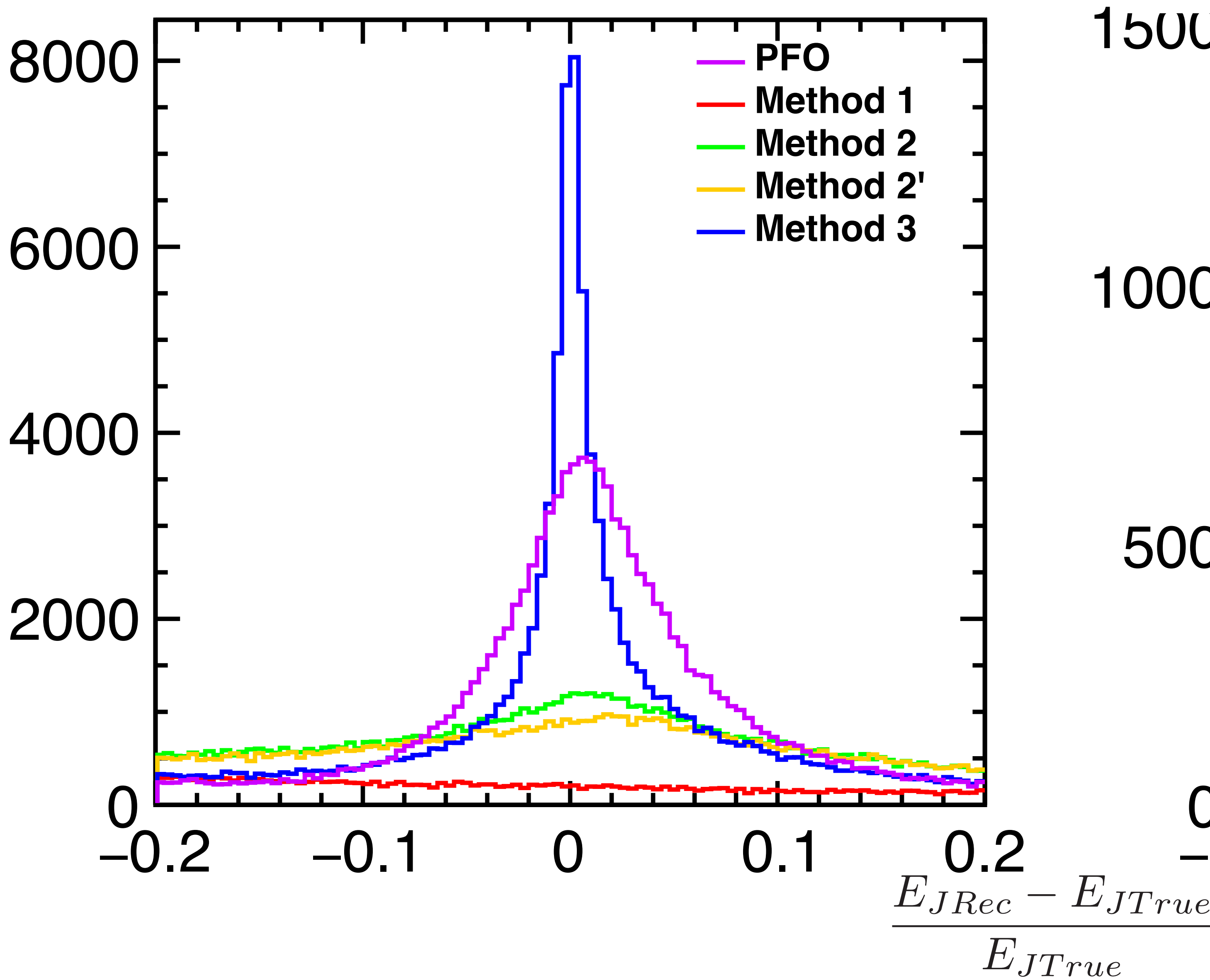
Jet 1
$|\theta\gamma_{PFO}-\theta\gamma_{MC}|<0.01$ events

Jet 2
$|\theta\gamma_{PFO}-\theta\gamma_{MC}|<0.01$ events

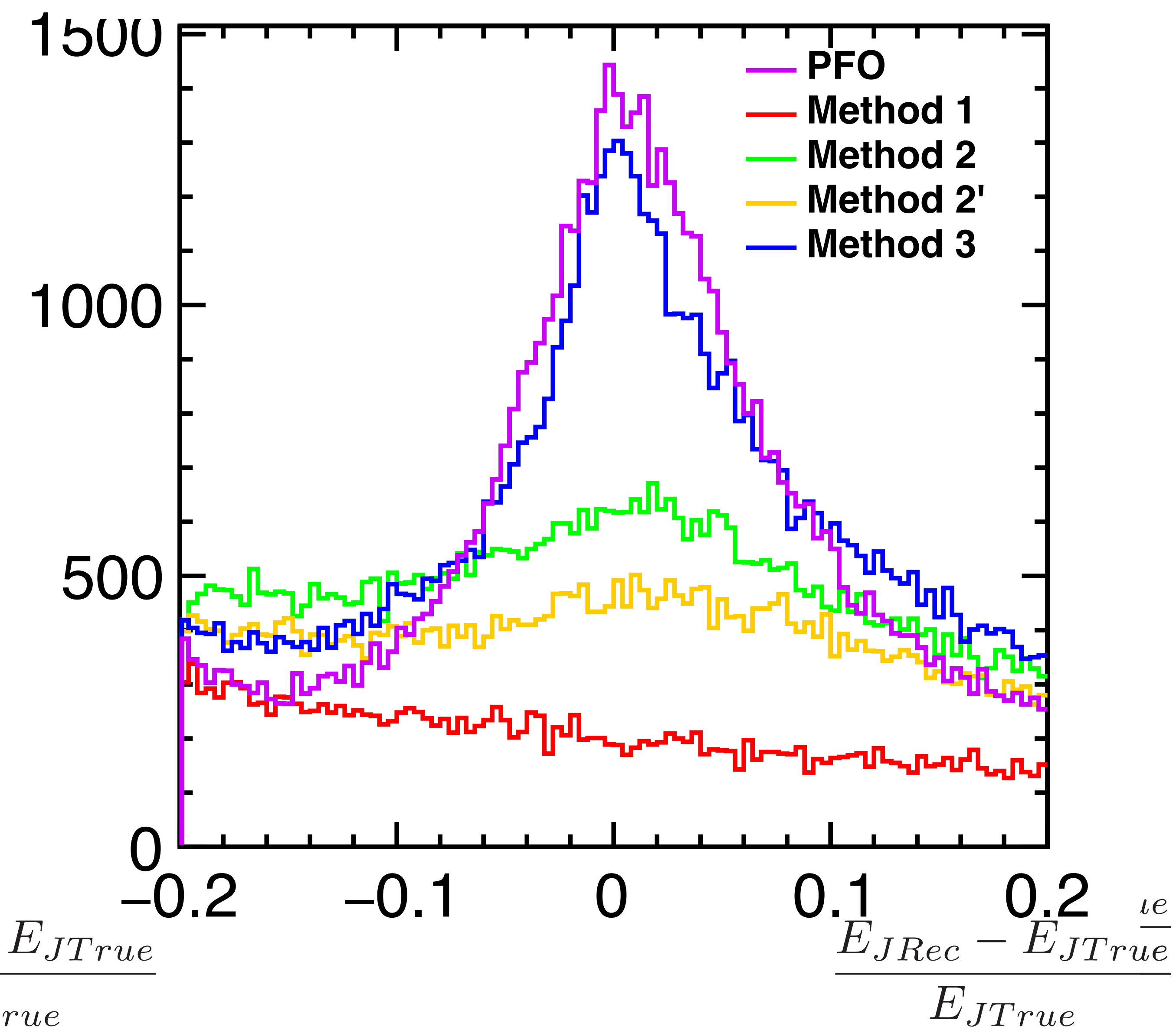


2.1. Method Comparison

Jet 1
$|\theta\gamma_{PFO}-\theta\gamma_{MC}|>0.01$ events



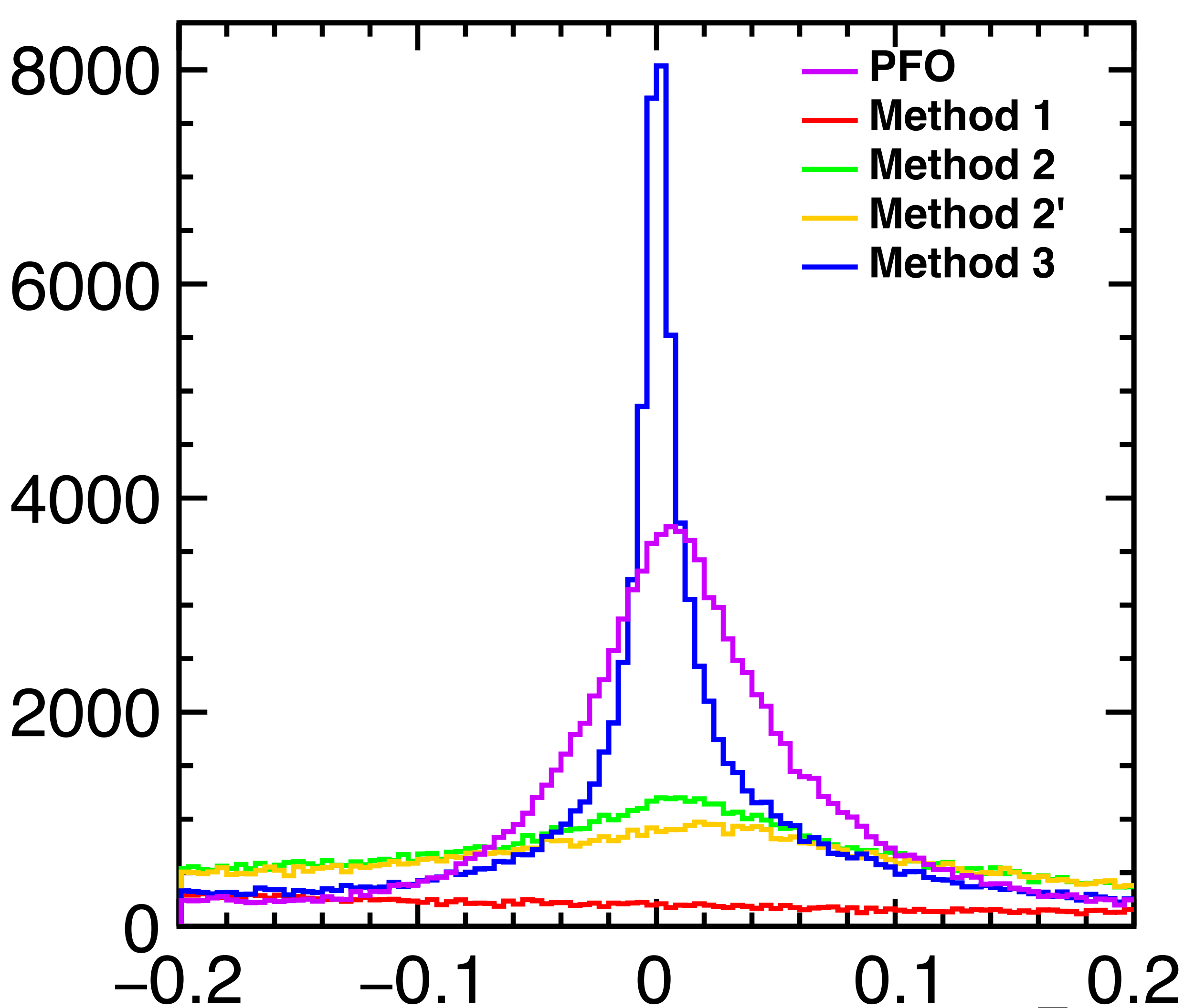
Jet 2
$|\theta\gamma_{PFO}-\theta\gamma_{MC}|>0.01$ events



2.1. Method Comparison

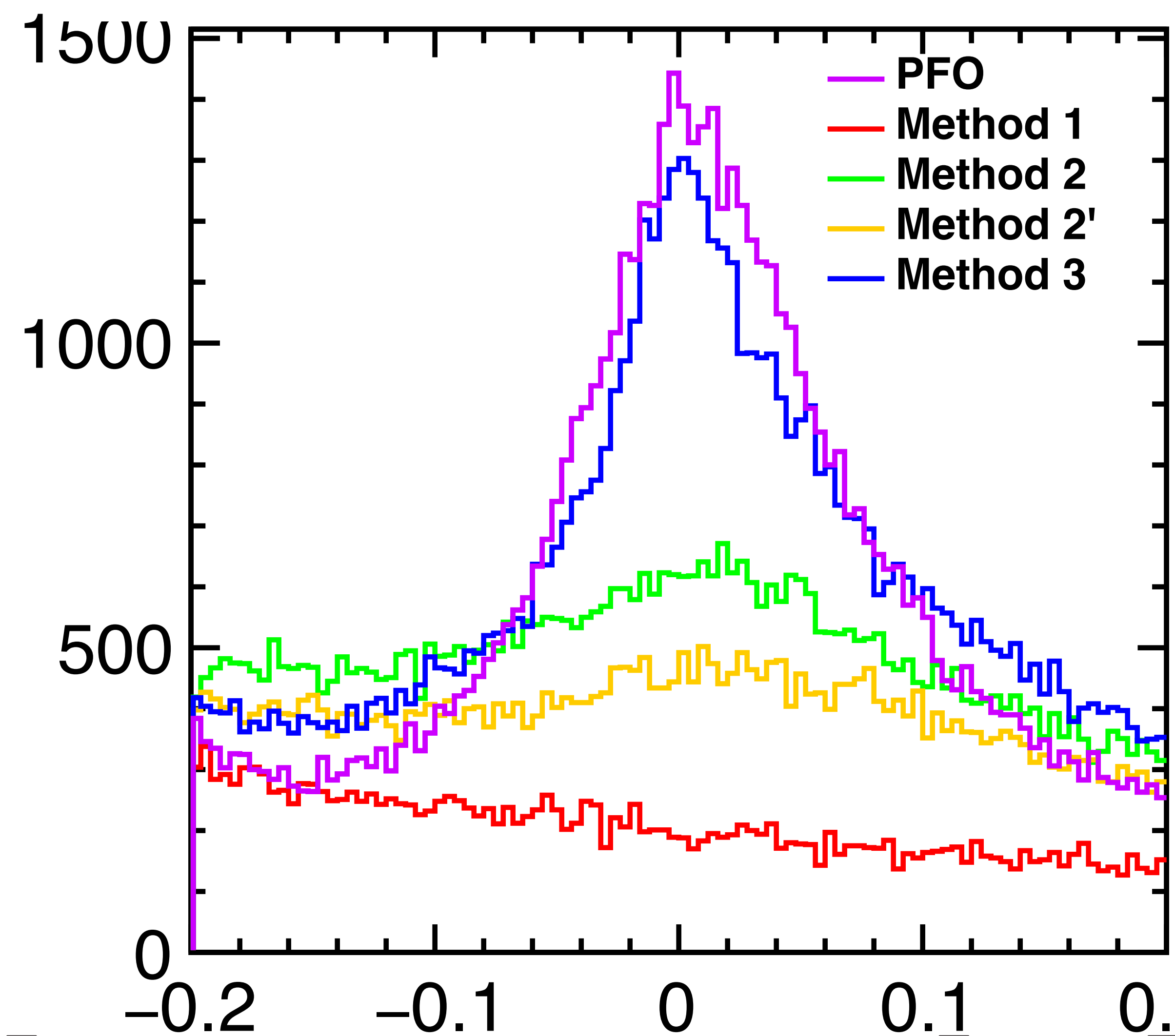
Jet 1

$|\theta\gamma_{PFO}-\theta\gamma_{MC}|>0.01$ events



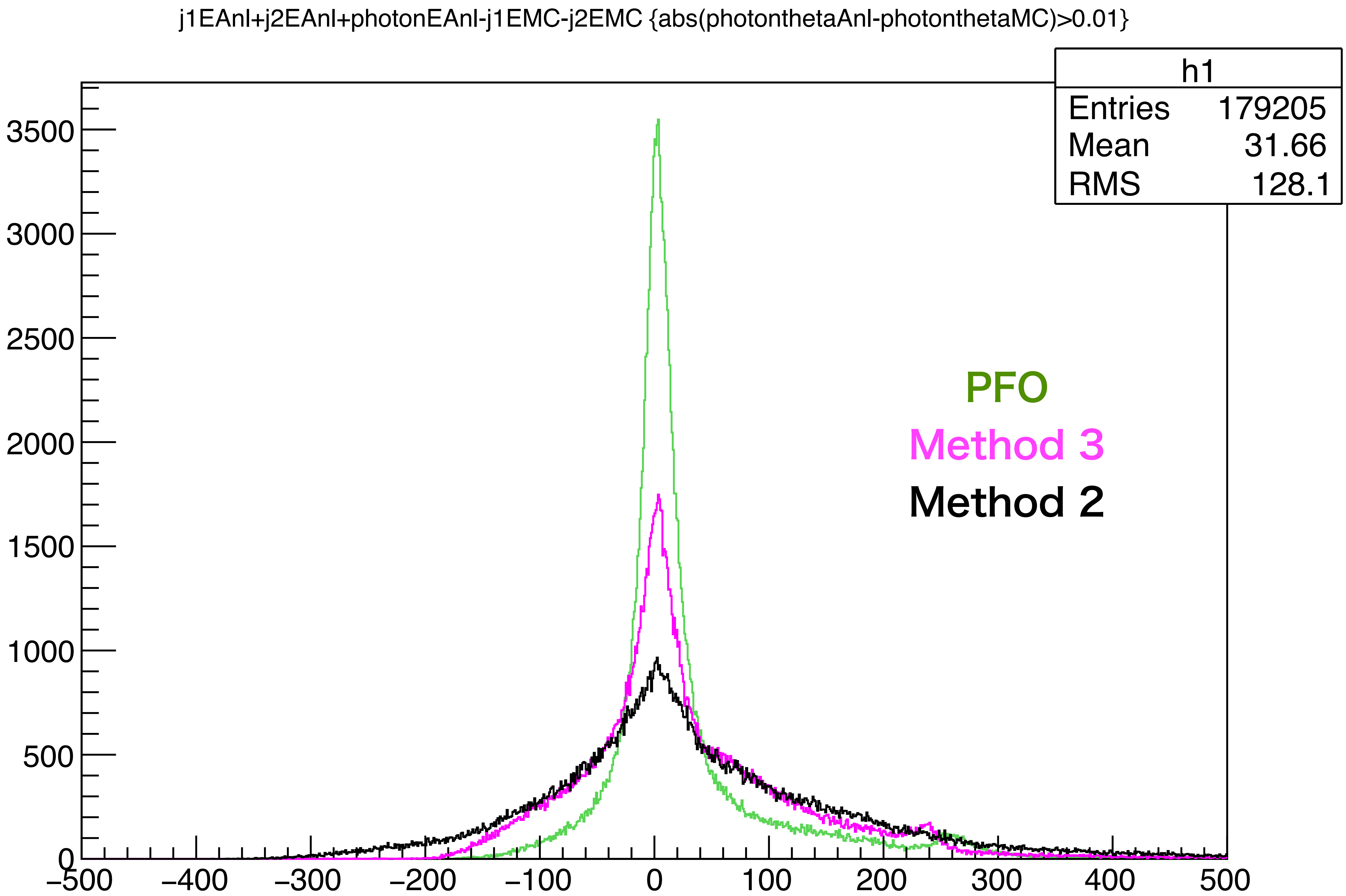
Jet 2

$|\theta\gamma_{PFO}-\theta\gamma_{MC}|>0.01$ events



Method 3 works well for jet 1 even in wrong photon choice cases
While Method 2 and 2' become useless.

2.1. Method Comparison

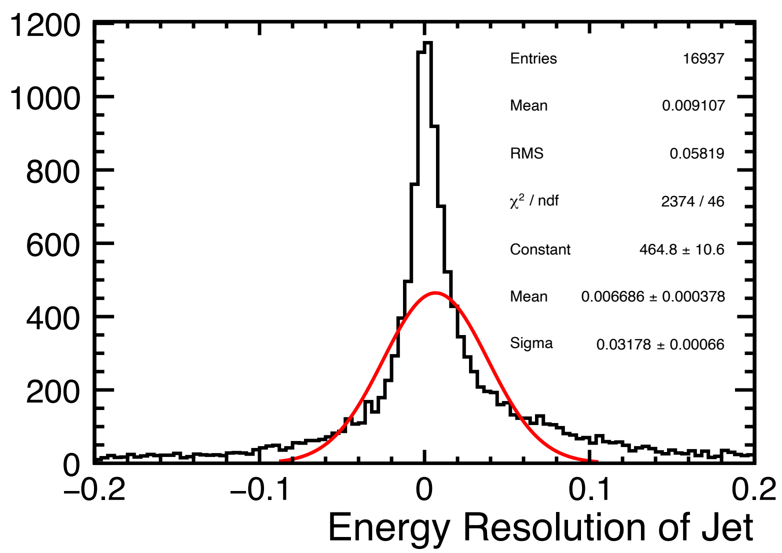


2.2. Method 3 angle dependence

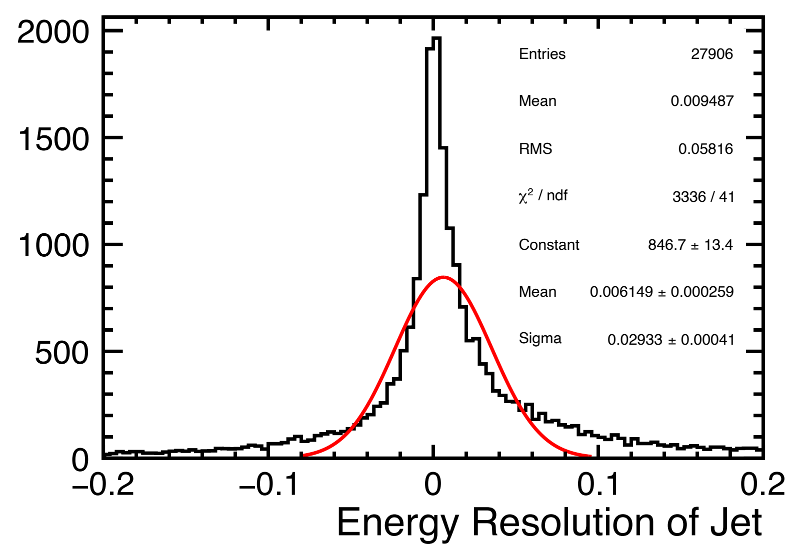
We saw some theta dependence previously.

Fitted $\frac{E_{JRec} - E_{JTrue}}{E_{JTrue}}$ **with Gaussian**

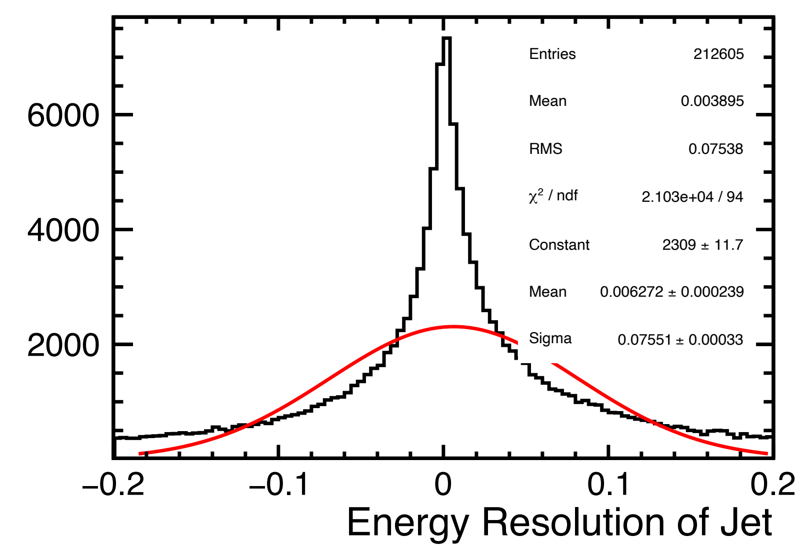
0.2<|cosθJet|<0.3



0.6<|cosθJet|<0.7



0.9<|cosθJet|<1.0



In order to see angle dependence, the number of events are still low.
(4 cut options: j1theta, j1phi, j2theta, j2phi)
-> First, events with both j1theta and j2theta are <0.8 are checked.

2.2. Angle dependence

Wrong photon case

Jet 1 **Jet 2**