e^+e^- -> gamma Z Physics analysis

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Introduction (1)

Primary Target of ILC 250: to precisely measure *the coupling constants between Higgs boson and various other particles*

SMEFT

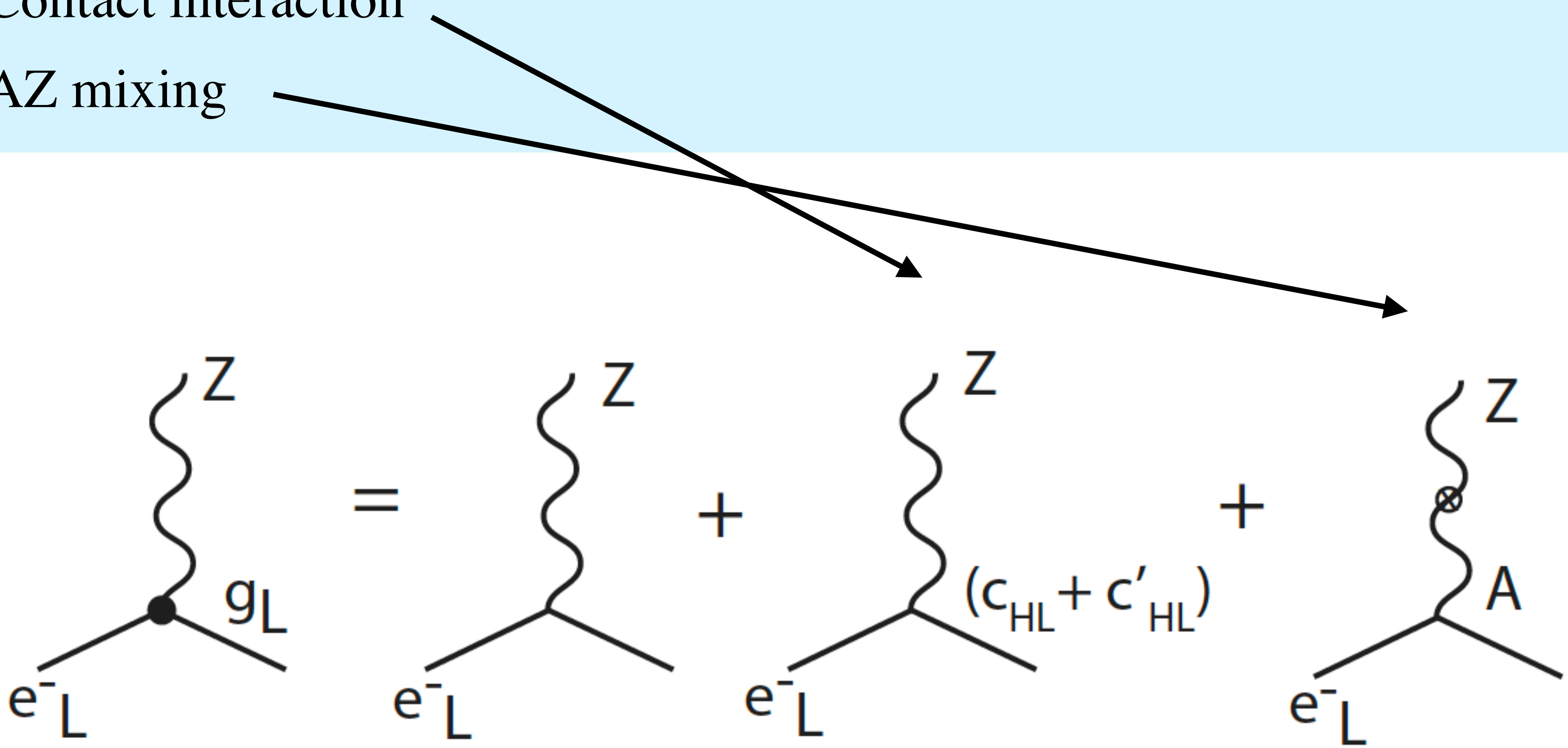
- Model-independent BSM analysis
- $SU(2) \times U(1)$ gauge invariant
- Need to measure various processes **including the process without Higgs**

Asymmetry in left- and right-handed **eeZ coupling** is very powerful to improve the constraints on SMEFT operators

Introduction (2)

eeZ coupling contains BSM effect

- Contact interaction
- AZ mixing



Introduction (3)

Contribution to the deviation in the eeZ couplings is **different in each polarization**

$$g_L = \frac{g}{c_w}\left[(-\frac{1}{2} + s_w^2)(1 + \frac{1}{2}\delta Z_Z) - \frac{1}{2}(c_{HL} + c'_{HL}) - s_w c_w \delta Z_{AZ}\right]$$

$$g_R = \frac{g}{c_w}\left[(+s_w^2)(1 + \frac{1}{2}\delta Z_Z) - \frac{1}{2}c_{HE} - s_w c_w \delta Z_{AZ}\right]$$

$$\delta Z_{AZ} = s_w c_w \Big((8c_{WW}) - (1 - \frac{s_w^2}{c_w^2})(8c_{WB}) - \frac{s_w^2}{c_w^2}(8c_{BB})\Big)$$

Introduction (4)

Left-right asymmetry in the cross section

A_{LR}

$A_{LR} = A_e$

$$\mathcal{A}_f = \frac{g_{Lf}^2 - g_{Rf}^2}{g_{Lf}^2 + g_{Rf}^2} = \frac{2 g_{Vf} g_{Af}}{g_{Vf}^2 + g_{Af}^2} = 2\frac{g_{Vf}/g_{Af}}{1 + (g_{Vf}/g_{Af})^2}$$

$g_A = g_L + g_R$

$g_V = g_L + g_R$

Depend only on the ratio of the couplings

By measuring A_{LR}, we can constraint SMEFT operators c_{HL}, c'_{HL}, c_{HE}, c_{WW}, c_{WB} and c_{BB}.

Introduction (5)

Current best measurement

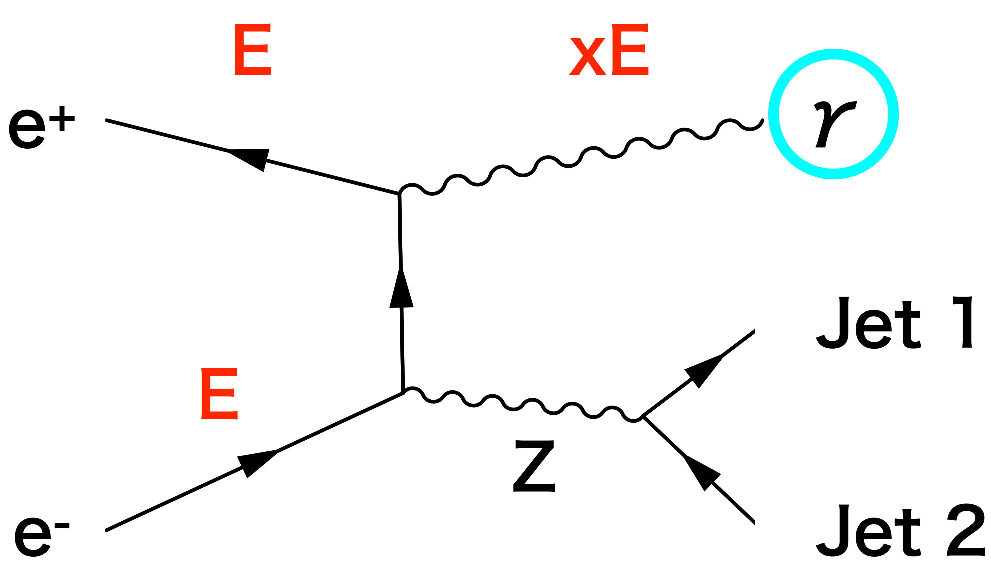
A_{LR}= 0.1514±0.0019 (statistic error) ±0.0011(systematic error)

LEP: **17 million** Z decays (ALEPH + DELPHI + L3+ OPAL, LEP-I, 1989-1995)
SLC: **600 thousand** Z decays (SLD, 1992-1998, polarization of e^-)

ILC250: **90 million** radiative return events

Final goal is to access how much we can improve these systematic errors.

Analysis method



If we ignore the jet mass,

Initial(s): (E,0,0,-E) → ← (E,0,0,E)

Jet system(s'): (E,0,0,-E) → ← ((1-x)E,0,0,(1-x)E)

s' ~ (1-x)s

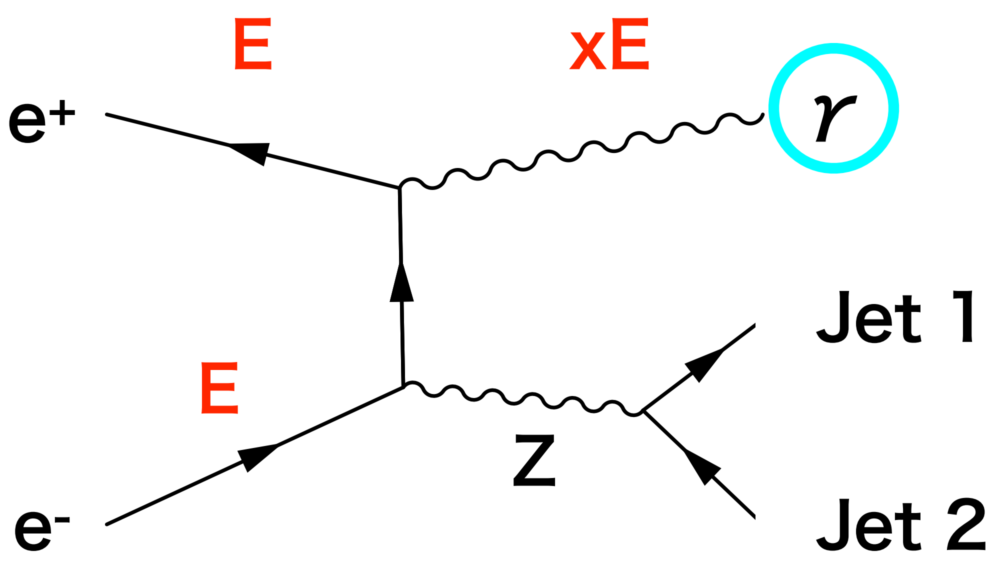
β = x/(2-x) i.e. x=2β/(1+β)

$m_Z^2 = s' = s(1-\beta)/(1+\beta)$

$$\beta = \frac{|\sin(\theta_1+\theta_2)|}{\sin\theta_1 + \sin\theta_2}$$

θ_i: Polar angle of jet i

Analysis method



If we ignore the jet mass,

Initi

Reconstruct m_Z from the polar angle of jets

Jet system(s'): (E,0,0,-E) → ← ((1-x)E,0,0,(1-x)E)

$s' \sim (1-x)s$

$\beta = x/(2-x)$ i.e. $x=2\beta/(1+\beta)$

$m_Z^2 = s' = s(1-\beta)/(1+\beta)$

$$\beta = \frac{|\sin(\theta_1+\theta_2)|}{\sin\theta_1+\sin\theta_2}$$

θ_i: Polar angle of jet i

Simulation setup

- **Geant4-based full detector simulation** is performed for the $e^+e^- \rightarrow \gamma Z$, $Z \rightarrow$ 2 Jets process using a **realistic ILD detector model**, at **E_{CM}= 250 GeV** with $\int Ldt$=900fb^{-1} each for 2 beam polarizations: (P_{e^-}, P_{e^+}) = (-0.8, +0.3) and (+0.8, -0.3).

Simulation setup is not well settled yet.

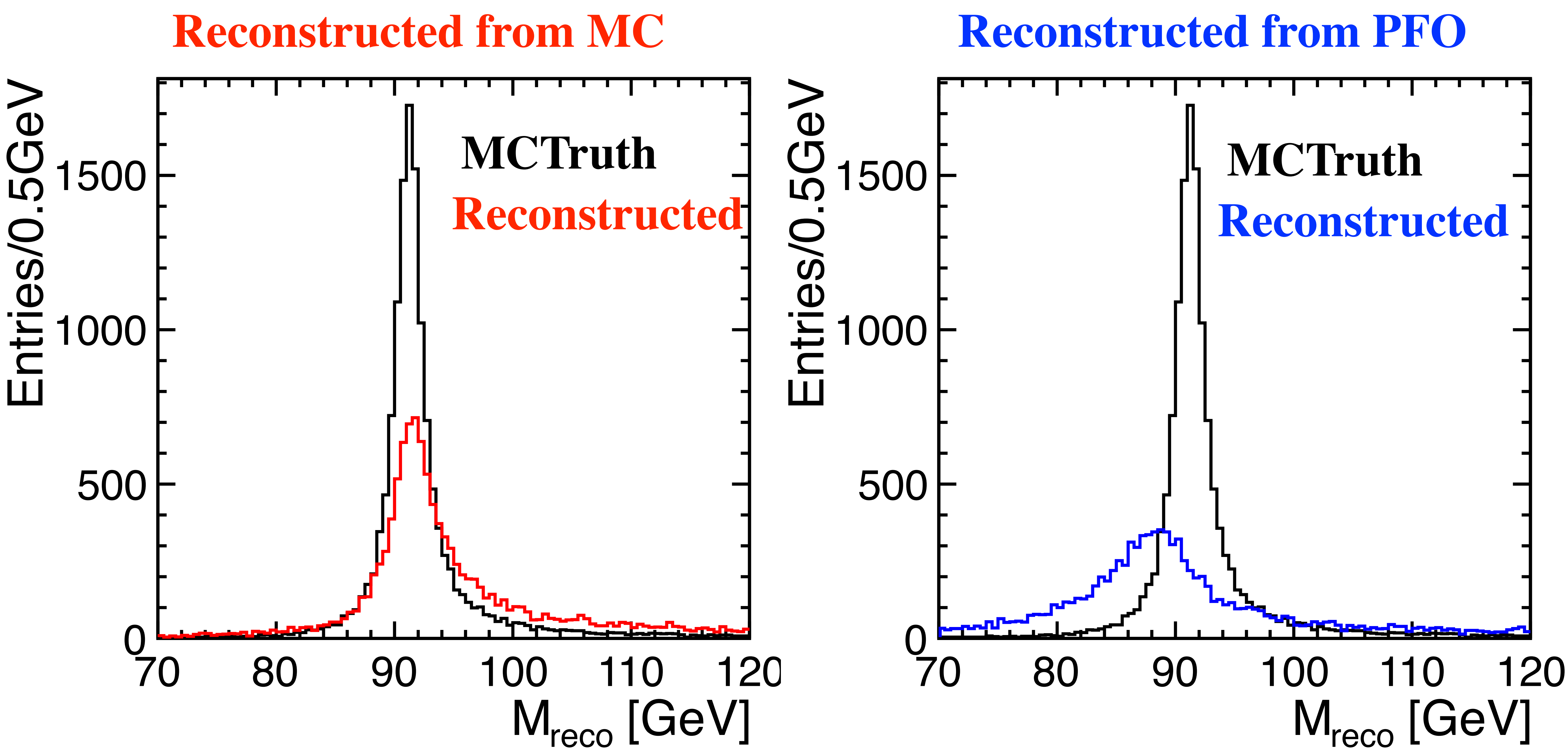
Trying to analyze

- DBD 250 GeV samples
- New samples

Looking at background (e.g. 4f_singleW_semileptonic)

Temporary result

DBD 250 GeV signal samples (ee->Zγ, Z->2jets)



Peak in the PFO reconstructed MZ is much below 91.2 GeV.
Need to improve the method.

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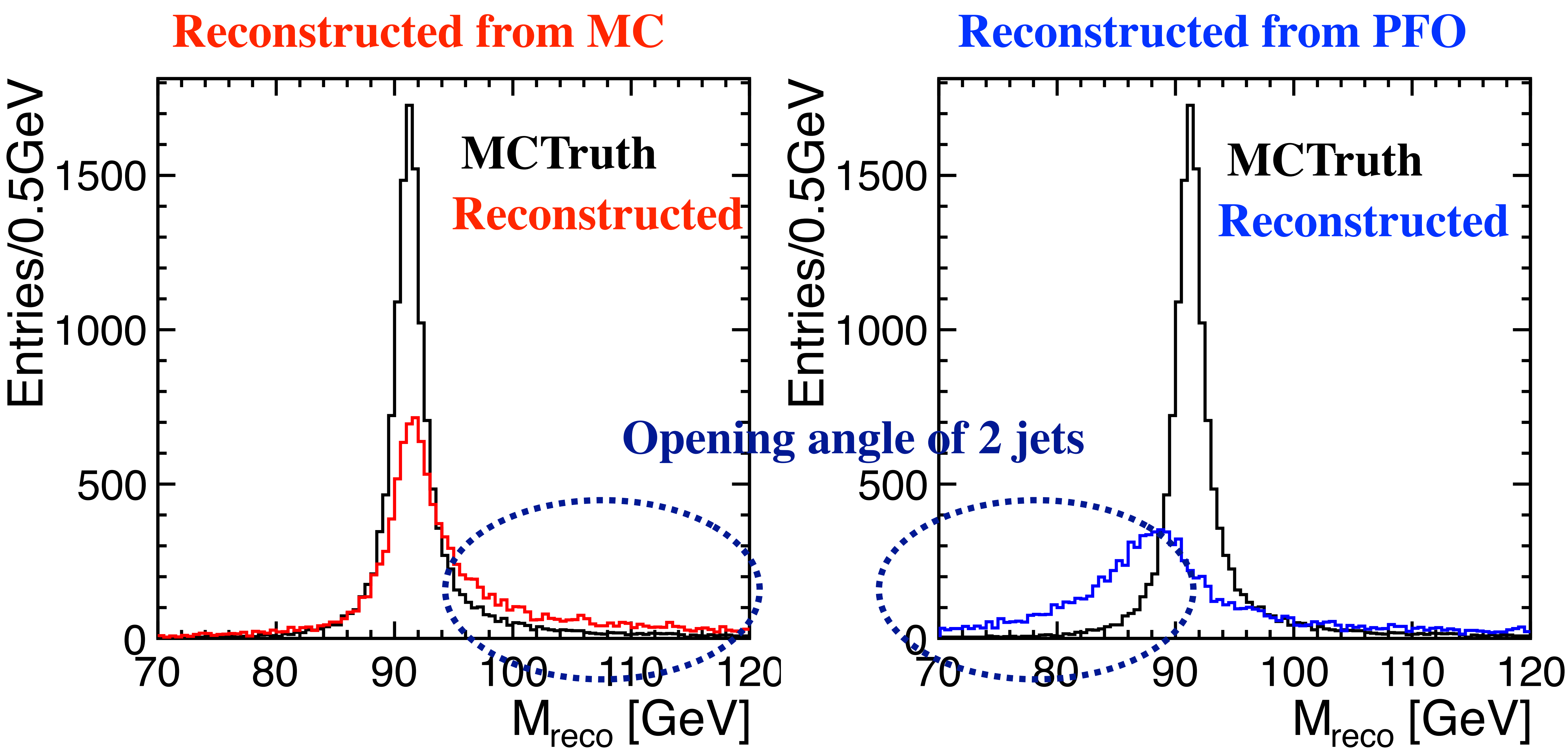

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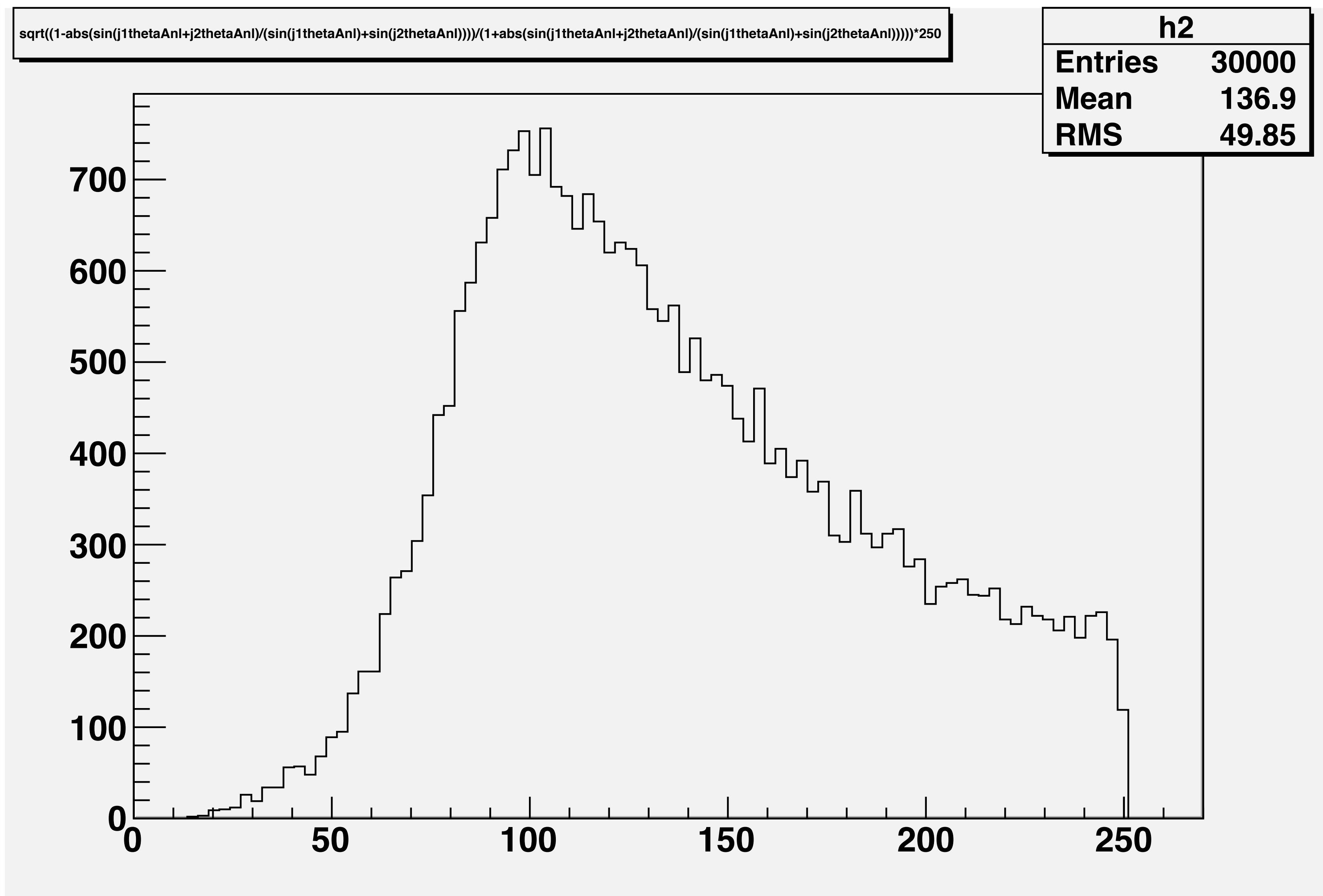
Temporary result

Background samples (ee->Weν, W->2jets)

Reconstructed from PFO



Normalize and consider how to cut the background events.

Conclusion/ Future work

- Full simulation study for the A_{LR} measurement using $e^+e^- \to \gamma Z$ process is started.

- M_Z can be reconstructed using the polar angle of 2 jets in the MC level inputs.

- Shift to the simulation using the new sample.

- Look at the background events. Normalize the distribution and consider how to cut out those events.