Jet energy calibration and study of Left-Right Asymmetry using $e^+e^- \rightarrow \gamma Z$ process at the ILC

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Abstract

We can calibrate the jet energy scale using $e^+e^- \rightarrow \gamma Z$ process with the uncertainty 5 to 20 MeV at the ILC.

If we can suppress the relative error on polarization to 0.1% and uncorrelated part of product of efficiency and luminosity to 0.016%, $A_{LR} = 0.22810 \pm 0.000178$ (stat) $\pm 0.000174$ (syst), 8.8 times better precision than that measured at the SLC.

1. International Linear Collider (ILC)

● Proposed high energy linear $e^-$ collider
● $E_{CM} = 250$ GeV, extendable to 1 TeV or higher
● Polarization: $e^-: \pm 80\% e^+: \pm 30\%$
● Well-defined initial state and small QCD background

2. Analysis Setup

Full Simulation: Geant4 based realistic detector simulation
● Realistic event reconstruction from detector signals
● With beamstrahlung and additional ISR photon effects

3. Motivation for the Jet Energy Calibration

ILD needs to precisely calibrate energy scales for various particles.

势力: To perform the jet energy calibration using the $e^+e^- \rightarrow \gamma Z, Z \rightarrow q\bar{q}$ process

Jet energy can be reconstructed using measured $\gamma$ and jet angles and jet masses.

4. Jet Energy Calibration

Angular Method: kinematically reconstruct the jet and photon energies Inputs $(p_1, p_2, \theta_1, \theta_2, \phi_1, \phi_2, \mu_1, \mu_2) \rightarrow$ Outputs $(P_{h}, P_{d}, P_{SR})$

Fit the $(E_{PFO}/E_{M,M})/E_{M,M}$ distribution for the $uds$ jets with 2-Gaussian + 1-Exponential as a function of $E$ and $\cos \theta$
Then derive the Calibration Factor $eta = E_{PFO}/E_{M,M}$

We can calibrate the jet energy scale with 5 to 20 MeV for 20 to 130 GeV jets.

5. Motivation for the $A_{LR}$ Measurement

SM effective field theory (SMEFT):

Express the deviation from the SM using dim-6 operators

$\Delta \mathcal{L} = \frac{C_2}{v^2} m_{\gamma}^2 \frac{1}{\sqrt{2}} \bar{L}_{\gamma} \gamma L + 4 \frac{C_2}{v^2} m_{t}^2 \frac{1}{\sqrt{2}} \bar{B}_{\gamma} \gamma B + \frac{1}{\sqrt{2}} \bar{B}_{\gamma} \gamma B$

Electroweak Precision Observables for Z boson are important.

Current best measurement (SLC): $A_{eLR} = 0.1514 \pm 0.0019$ (stat) $\pm 0.0011$ (syst)

$A_{LR} = A_e \frac{\sin 2\beta}{\sin \alpha}$

$A_{LR}$ Measurement

Background: All the events only with 2 jets in the final state → Following cuts were applied

Cut 1 $N_{PS} = 0$
Cut 2 $200 \text{GeV} < E_{CM} < 160 \text{GeV}$
Cut 3 $|\cos \phi_{\gamma}| > 0.95$
Cut 4 $N_{PS} > 4$
Cut 5 $E_{CM} > 6$
Cut 6 $50 \text{GeV} < E_{CM} < 160 \text{GeV}$
Cut 7 $\cos \theta > -0.99$ or $E_{CM} > 0.5$

Selection efficiency $\eta = 0.74166 \pm 0.00015$ (eLR)$\eta = 0.74235 \pm 0.00014$ (eRL)

Background/Signal: $0.0500$ (eLR)$0.0462$ (eRL)

If we can suppress the error $\Delta\eta = 0.001 (0.1\%)$ $\Delta\eta/\eta = 0.00016 (0.016\%)$

$A_{LR} = 0.22810 \pm 0.000178$ (stat) $\pm 0.000174$ (syst)

8.8 times better than the error at the SLC