Forward-Backward Asymmetry in Process $e+e- > \mu+\mu-$

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Introduction

- Weak Mixing Angle (θ_W) is the angle by which spontaneous symmetry breaking rotates the original W_0 and B_0 vector boson plane, producing as a result the Z_0 boson, and the photon.

$$\begin{pmatrix} \gamma \\ Z^0 \end{pmatrix} \begin{pmatrix} \cos\theta_w & \sin\theta_w \\ -\sin\theta_w & \cos\theta_w \end{pmatrix} \begin{pmatrix} B^0 \\ W^0 \end{pmatrix}$$

- It also gives the relationship between the masses of the W and Z bosons: $\cos\theta_W = \frac{m_W}{m_Z}$

Previous Measurements and CEPC Expectation

The resonance parameters measured at LEP are:

- $M_Z = (91.1885 \pm 0.0031)GeV/c^2$
- $\gamma_Z = (2.4951 \pm 0.0043)GeV$
- $\sigma^0_{had} = (41.559 \pm 0.058)nb$
- combining the three lepton flavours, $R_l = 20.725 \pm 0.039$
- $\sin\theta^{lept}_{eff} = 0.23153 \pm 0.00016$

Expectation on CEPC:

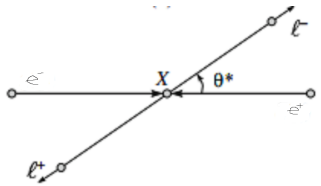
- stat error:0.02%.
- systematic error:0.01%

Motivation

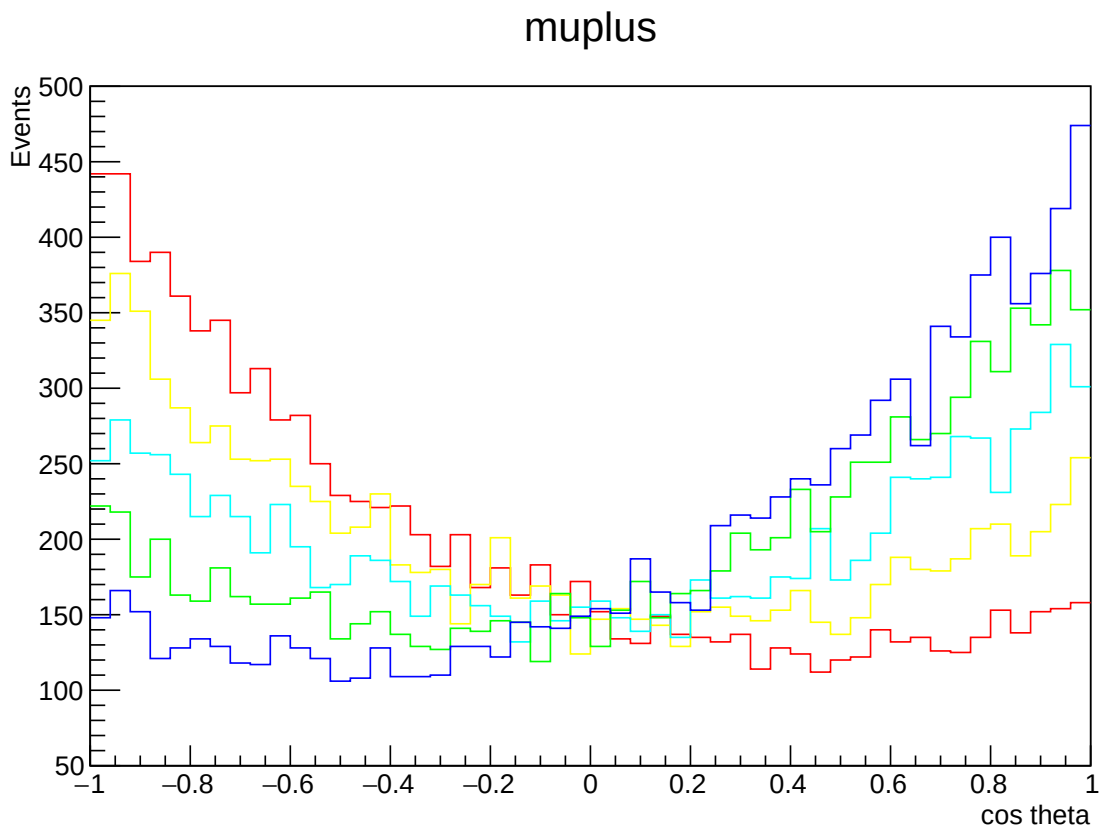
- Cross section for reaction $e + e- > l + l-$ is expected to be:

$$\frac{d\sigma}{d\cos\theta} \propto (1 + \cos^2\theta + \frac{8}{3} A_{FB} \cos\theta)$$

  where θ is defined as angle between incoming electron and outgoing $\mu-$ (Shown in the bottom picture.)
- It shows asymmetry between forward and backward on first order $\frac{8}{3} A_{FB} \cos\theta$.
- I choose five energies, which are exactly z mass, z mass -4GeV, z mass -2GeV, z mass +2GeV and z mass +4GeV.
- At each energy point,I generated 10000 Monte Carlo Events, using seed from Madgraph website.It's a small number, for I'm concentrate on modify the code and it could be much faster with few events. I can try more events if necessary.



Distribution of $\cos\theta$ in $e+e- > \mu+\mu-$



Yellow:z pole -4 Red:z pole -2 Cyan:z pole Green:z pole +2 Purple:z pole +4

A_{FB} Calculation

$$\frac{d\sigma}{d\cos\theta} \propto (1+\cos^2\theta+\frac{8}{3}A_{FB}\cos\theta)$$

define $\sigma_+ =$

$$\int_0^{\frac{\pi}{2}} (1+\cos^2\theta+\frac{8}{3}A_{FB}\cos\theta)\, d\cos\theta.$$

define $\sigma_- =$

$$\int_0^{\frac{\pi}{2}} (1+\cos^2\theta+\frac{8}{3}A_{FB}\cos\theta)\, d\cos\theta.$$

then $A_{FB} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$

A_{FB} Calculation

$E_{cms}(Gev)$	A_{fb}
86Gev	-0.3250 ± 0.0002
88Gev	-0.1474 ± 0.0002
90Gev	0.0364 ± 0.0002
92Gev	0.211 ± 0.0002
94Gev	0.355 ± 0.0002

Note: The error above just contains statistics uncertainty.

Summary

- In Forward-Backward Asymmetry process $e + e- > l + l-$, the formula of scattering distribution is:

$$\frac{d\sigma}{d\cos\theta} \propto (1 + \cos^2\theta + \frac{8}{3} A_{FB} \cos\theta)$$

  where $\cos\theta$ is defined as angle between incoming electron and outgoing negative lepton.
- Draw plots of polar angle distribution of $\mu\mu$. $\mu\mu$events show a significant forward-backward asymmetry.
- Calculate A_{FB}.