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Physics motivation for Polarized beam collision

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CEPC working day meeting

Introduction

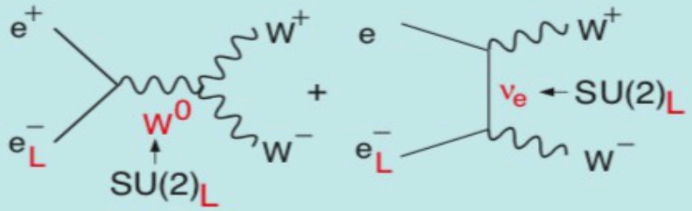
- What is Polarized beam collision ?
  - Usually mean longitudinal polarized beam for physics

Type	Polarized beam collision	Beam energy measurement
Polarized Type	Longitudinal polarized	Transverse polarized
Fraction of polarization	>30% (50%)	5~10% is enough

Type	Longitudinal polarized e-	Longitudinal polarized e+	Transverse polarized Beam
CEPC	To be discussed	To be discussed	Yes (Z,WW)
Fcc-ee	No	NO	Yes (Z,WW)
ILC	yes	yes	-

Polarized beam collision: motivation

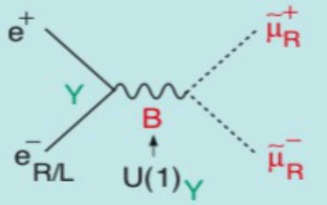
W^+W^- (Largest SM BG in SUSY searches)



In the symmetry limit, $\sigma_{WW} \to 0$ for e^-_R !

BG Suppression

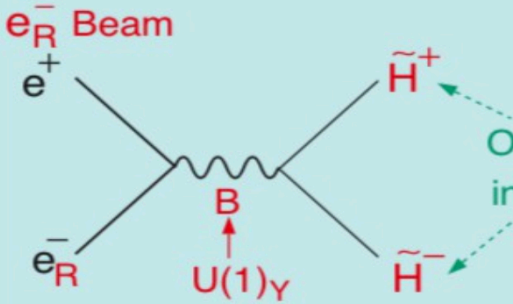
Slepton Pair



$\begin{cases} Y_L = -1/2 : e^-_L \\ Y_R = -1 : e^-_R \end{cases}$

In the symmetry limit, $\sigma_R = 4\,\sigma_L$!

Chargino Pair

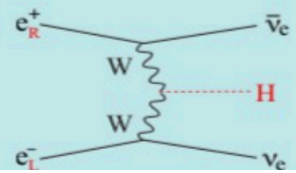


$\tilde{\chi}^\pm_1 = \bigcirc \cdot \tilde{W}^\pm + \bullet \cdot \tilde{H}^\pm$

$\bullet \equiv \langle \tilde{H}^\pm | \tilde{\chi}^\pm_1 \rangle$

Decomposition

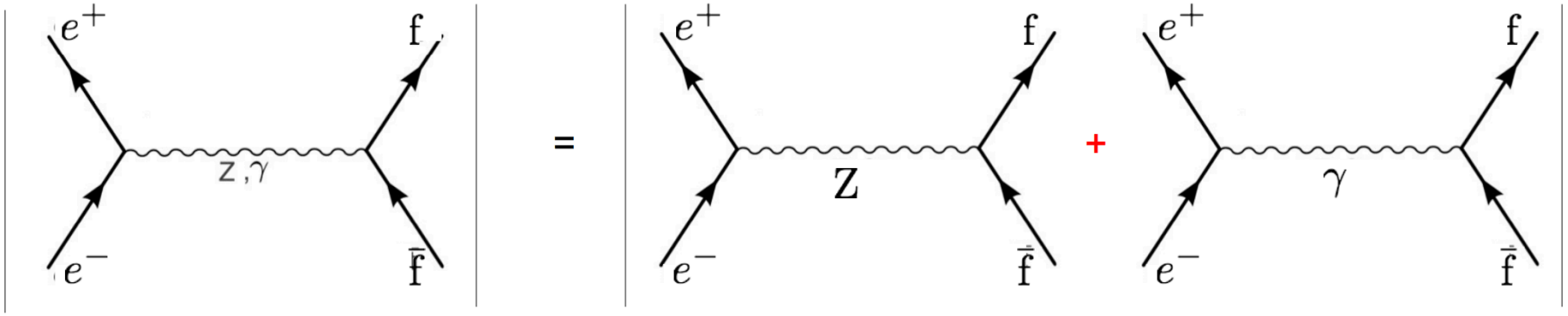
WW-fusion Higgs Prod.



	ILC
Pol (e^-)	-0.8
Pol (e^+)	+0.3
$(\sigma/\sigma_0)_{\nu\nu H}$	1.8x1.3=2.34

Signal Enhancement

Polarized beam collision: motivation



Interference between individual amplitudes of γ and Z exchange

$$\mathcal{M}_Z = -\frac{\sqrt{2}G_F M_Z^2}{s - M_Z^2}\left[\bar{f}\gamma^\rho\left(c_V^f - c_A^f\gamma^5\right)f\right] g_{\rho\sigma}\left[\bar{e}\gamma^\sigma\left(c_V^e - c_A^e\gamma^5\right)e\right]$$

$$\mathcal{M}_\gamma = -\frac{e^2}{s}(\bar{f}\gamma^\nu f)g_{\mu\nu}(\bar{e}\gamma^\nu e)$$

$$g_L^f = c_V^f + c_A^f$$

$$g_R^f = c_V^f - c_A^f$$

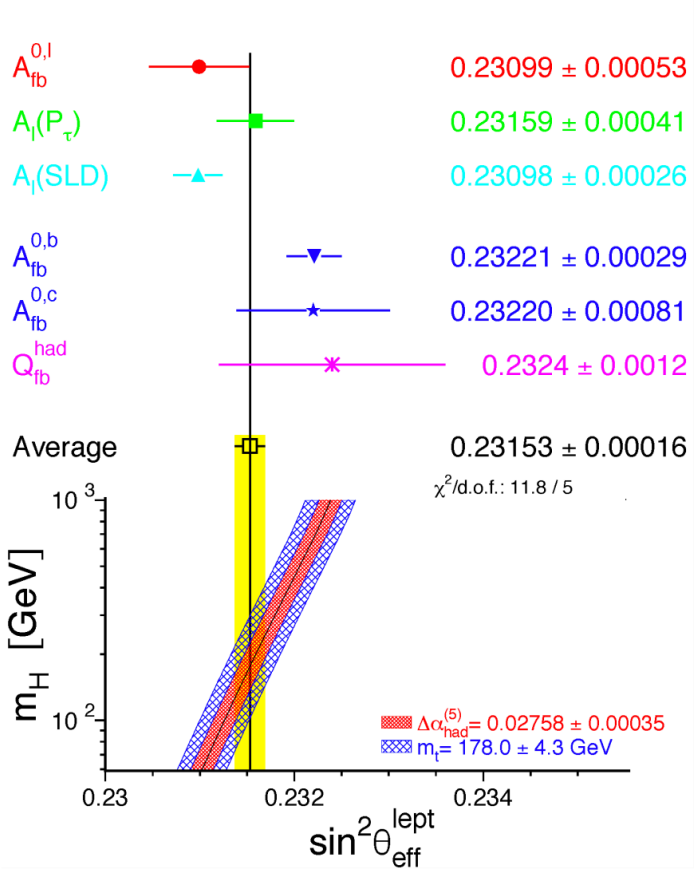
Differential cross section:

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s}\left[A_0(1+\cos^2\theta) + A_1\cos\theta\right]\begin{cases} \sim (1+\cos^2\theta) & \text{'Usual' Vector current, symmetric in } \cos\theta \\ \backsim \cos\theta & \text{Axial Vector current, asymmetric in } \cos\theta \end{cases}$$

Weak interaction introduces forward backward asymmetry

=> Asymmetry is intrinsic to electroweak processes!!!

Motivation: LEP vs SLD



- Most precise single Individual determination of $\sin^2\theta_{\mathrm{eff}}^{\ell}$ from SLC
  - Left-right asymmetry of leptons
- Most precise measurement of $\sin^2\theta_{\mathrm{eff}}^{\ell}$. from forward backward asymmetry A_{FB}^{b} in ee->bb at LEP

Two lessons:

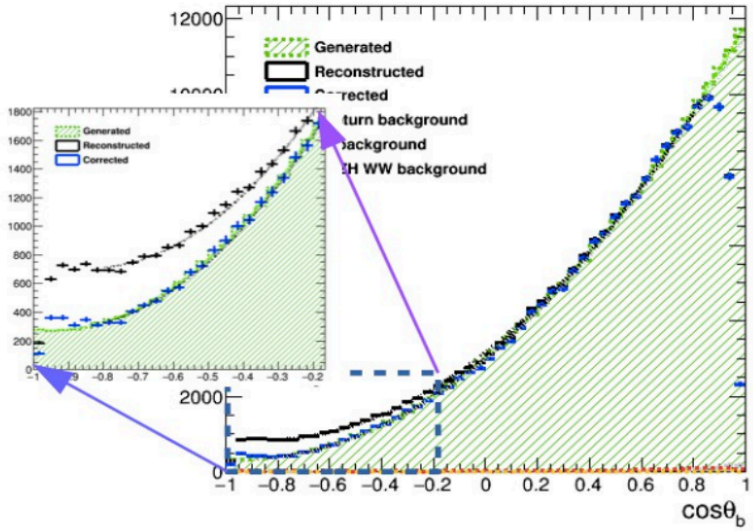
- Most precise determininations of $\sin^2\theta_{\mathrm{eff}}^{\ell}$. differ significantly
  - Cries for verification
  - Beam polarisation can match up for luminosity

Polarized beam collision analysis example

$\sqrt{s} = 250\,\mathrm{GeV}\ \ L = 250\,\mathrm{fb}^{-1}$

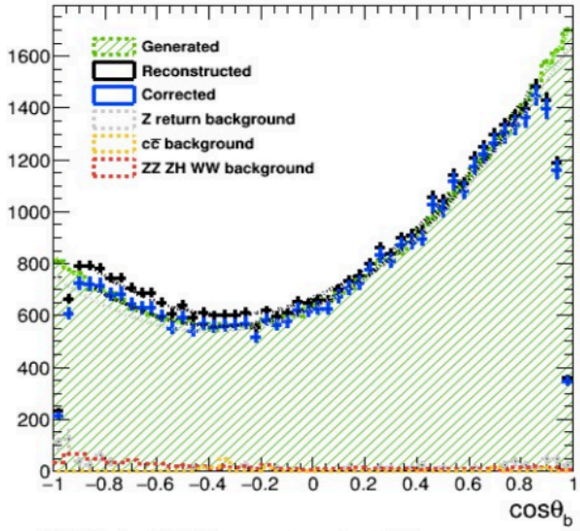
From ILC

$e^-_L e^+_R \to b\bar{b}$



$A^{rec}_{fb}/A^{gen}_{fb} = 100.7\% \pm 0.62\%$

$e^-_R e^+_L \to b\bar{b}$



$A^{rec}_{fb}/A^{gen}_{fb} = 104.9\% \pm 2.25\%$

Full simulation study (with ILD concept), Benchmark reaction for 250 GeV running

- Experimental challenge: Measurement of b-quark charge on event-by-event basis

Long lever arm in cos θ_b to extract from factors or couplings

$$\frac{d\sigma^I}{d\cos\theta} = S^I(1+\cos^2\theta) + A^I\cos\theta \qquad I = L, R$$

Form factors/couplings from S and A

CEPC EWK input to ECFA

	Γ_Z	$\sigma_{\rm had}$		A_e (τ pol)	A_τ (τ pol)
CEPC	0.5 MeV	0.005 nb		0.0003	0.0005
FCC-ee	0.1 MeV	0.005 nb		–	–
	R_e	R_μ	R_τ	R_b	R_c
CEPC	0.0003	0.0001	0.0002	0.0002	0.001
FCC-ee	0.0003	0.00005	0.0001	0.0003	0.0015
	$A_{\rm FB}^{0,e}$	$A_{\rm FB}^{0,\mu}$	$A_{\rm FB}^{0,\tau}$	$A_{\rm FB}^{0,b}$	$A_{\rm FB}^{0,c}$
CEPC	0.005	0.003	0.005	0.001	0.003
FCC-ee	–	–	–	–	–
(fitted)	A_e	A_μ	A_τ	A_b	A_c
CEPC	0.0003	0.003	0.0005	0.001	0.003
FCC-ee	0.0001	0.00015	0.0003	0.003	0.008

Table 1: A comparison of CEPC and FCC-ee Z-pole inputs. All uncertainties are relative **(normalized to 1)** except for Γ_Z and $\sigma_{\rm had}$. "τ pol" denotes that the measurement is from τ polarization in $Z \to \tau^+\tau^-$. The 5 fitted asymmetry observables ($A_{e,\mu,\tau,b,c}$) are derived from a simutanous fit of all the $A_{\rm FB}^{0,}$ observables as well as the A_e and A_τ from τ polarization.

Impact of Polarized beam collision

- A_e is obtained from Z->ττ
  - Fcc-ee expected precision : 0.0001
  - CEPC expected precision : 0.0003
  - CEPC expected precision (with polarized beam) : 0.0001
    - limited by statistics , a factor of 2~3 worse than Fcc
    - By using polarized beam collision, A_e precision can improve by 3
- A_μ
  - Fcc-ee expected precision : 0.00015
  - CEPC expected precision : 0.003
  - CEPC expected precision (with polarized beam) : 0.0003
  - By using polarized beam collision, A_e precision can improve by 10

Summary

- Polarized beam collision can enrich our physics program for new physics search.
  - Especially to some SUSY model
- Improve precision for weak mixing angle measurement
  - Expect to improve A_e by a factor of 3
  - Expect to improve A_μ by a factor of 10