Tracing the bottom EW dipole operators at future lepton colliders

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based on arXiv: 2410.05398,

in collaboration with Jiayin Gu, Jiayu Guo

Motivation

- "What is next beyond SM?"
- New lepton colliders are expected to be on their way
  $\rightarrow$ A telescope to high scale physics (luminosity frontier)
- Especially for circular ones $\rightarrow$ Higgs/Z factories & EW precision test
- For new physics scale $\Lambda \gg E, v$, Standard Model Effective Field Theory (SMEFT) provides an effective and model independent tool

$$\mathcal{L}_{\mathrm{SMEFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{C_i^{(6)}}{\Lambda^2} O_i^{(6)} + \cdots$$

- This study will focus on EW sector about bottom dipole operators

Z-pole status

Some Z pole observables [PDG2023]

Quantity	Exp. Value	SM prediction
M_Z [GeV]	91.1876 ± 0.0021	91.1882 ± 0.0020
Γ_Z [GeV]	2.4955 ± 0.0023	2.4941 ± 0.0009
σ_{had} [nb]	41.481 ± 0.033	41.482 ± 0.008
R_e	20.804 ± 0.050	20.736 ± 0.010
R_b	0.21629 ± 0.00066	0.21582 ± 0.00002
R_c	0.1721 ± 0.0030	0.17221 ± 0.00003
$A_{FB}^{(0,e)}$	0.0145 ± 0.0025	0.01617 ± 0.00007
$A_{FB}^{(0,b)}$	0.0996 ± 0.0016	0.1029 ± 0.0002
$A_{FB}^{(0,c)}$	0.0707 ± 0.0035	0.0735 ± 0.0002
A_e	0.1498 ± 0.0049	0.1468 ± 0.0003
A_b	0.923 ± 0.020	0.9347
A_c	0.670 ± 0.027	0.6677 ± 0.0001

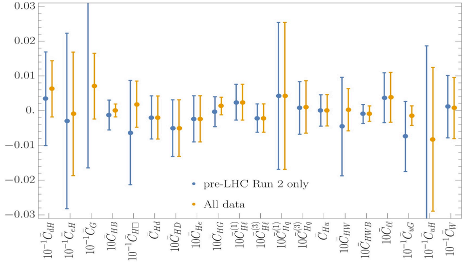
* For A_e, only LEP 1 results shown here

- Most observables are measured precisely and consistent with theoretical prediction.
- Except A_{FB} for b-quark, still exist $\sim 2\,\sigma$ deviation.
- At future lepton colliders, trillion Z bosons could be produced.

$\Rightarrow$ Opportunity to reveal potential BSM NP with much improved precision.

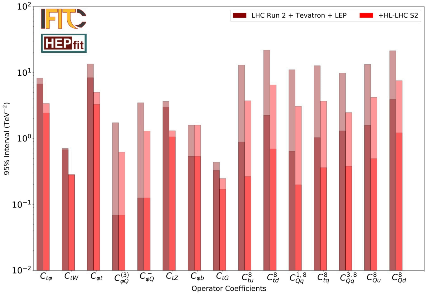
SMEFT & dipole operators

Many global fit analysises are performed



(95% CL, in Warsaw basis)

[J. Ellis et al., 1803.03252]



Dipole operators are usually not included!

[except... e.g. A. Lukas et al., 2311.00020, indirect analysis]

[J. Blas et al. 2206.08326 (Snowmass2021)]

SMEFT & dipole operators

SMEFT dim-6 dipole operators

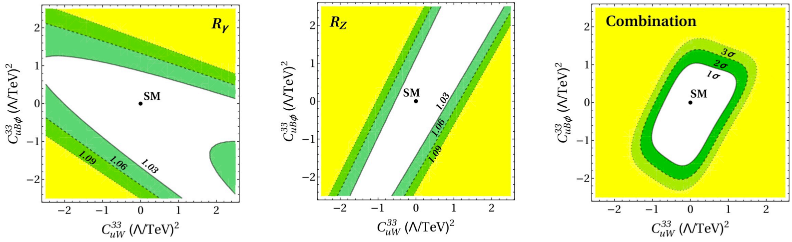
(Warsaw basis, 3rd generation quarks)

$$\mathcal{O}_{tW} = \left(\bar{q}_\mathrm{L}\sigma^{\mu\nu}\tau^I t_\mathrm{R}\right)\tilde{H}W^I_{\mu\nu}, \qquad \mathcal{O}_{bW} = (\bar{q}_L\sigma^{\mu\nu}b_R)\,\sigma^i H W^i_{\mu\nu},$$

$$\mathcal{O}_{tB} = (\bar{q}_\mathrm{L}\sigma^{\mu\nu}t_\mathrm{R})\,\tilde{H}B_{\mu\nu}, \qquad \mathcal{O}_{bB} = (\bar{q}_L\sigma^{\mu\nu}b_R)\,HB_{\mu\nu}.$$

where, $\sigma^{\mu\nu} = \frac{i}{2}[\gamma^\mu, \gamma^\nu]$, $W^i_{\mu\nu} = \partial_\mu W^i_\nu - \partial_\nu W^i_\mu - g_W \varepsilon^{ijk} W^j_\mu W^k_\nu$ (similar form of $B_{\mu\nu}$)

- Generally, the leading effect from interference of dipole and SM $\propto m_f v/\Lambda^2$
- Top is the exception, constraint of its dipole at LHC:



$C_{tw} = [-1.2, +1.4](\Lambda/\ \mathrm{TeV})^2$ and $C_{tB} = [-1.9, +1.2](\Lambda/\ \mathrm{TeV})^2$

(ttZ/γ measurement @ LHC Run2, 95% CL) [M. Schulze, Y. Soreq 1603.08911]

$Zb\bar{b}$ dipole can be traced

- Future lepton colliders (e.g. FCC-ee/CEPC):

  tremendous amount of Z events + higher precision of measurements

  $\Rightarrow$ possible to trace $Zb\bar{b}$ dipole

- Z pole observables

$$R_b = \frac{\Gamma(Z\to dd)}{\sum_q \Gamma(Z\to q\bar{q})}$$

$$A_\ell = \frac{\Gamma(Z\to \ell_L\bar{\ell}_L) - \Gamma(Z\to \ell_R\bar{\ell}_R)}{\Gamma(Z\to \ell\bar{\ell})}$$

$$A_b = \frac{\Gamma(Z\to b_L\bar{b}_L) - \Gamma(Z\to b_R\bar{b}_R)}{\Gamma(Z\to b\bar{b})}$$

$$A^b_{FB} = \frac{3}{4}A_\ell A_b$$

- Off pole scattering

$$A^b_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

- Projections of CEPC here (similar for FCC-ee)

Quantity	Projected Precision	Runs
ΔR_b	4.4×10^{-5}	Z pole
ΔA_e	1.5×10^{-5}	Z pole
ΔA_b	2.1×10^{-4}	Z pole
$\sigma(b\bar{b})$[fb]	275.64 ± 0.12	$\sqrt{s} = 240$ GeV
$A_{FB}(b\bar{b})$	0.592 ± 0.00034	$\sqrt{s} = 240$ GeV
$\sigma(b\bar{b})$[fb]	108.33 ± 0.33	$\sqrt{s} = 360$ GeV
$A_{FB}(b\bar{b})$	0.602 ± 0.0024	$\sqrt{s} = 360$ GeV

($[c_\theta^{min}, c_\theta^{max}]$=[-0.9,0.9], $\epsilon = 0.15$)

[J.D. Blas et al., 2206.08326 (Snowmass2021)]

$Zb\bar{b}$ dipole and the Lagrangian

- **SMEFTsim** package was used to extract dipole coupling and calculate observables

  [Brivio et al. 2012.11343]

- Effective Lagrangian with effective $\gamma/Zb\bar{b}$ couplings

$$\mathcal{L} \supset -eA_\mu \bar{b}\gamma^\mu b - \frac{g}{\cos\theta_W} Z_\mu \left(g_{Lb} \bar{b}_L \gamma^\mu b_L + g_{Rb} \bar{b}_R \gamma^\mu b_R \right)$$
$$+ \frac{\kappa_{bA}}{m_b} \left(\bar{b} \sigma^{\mu\nu} b \right) A_{\mu\nu} + \frac{\kappa_{bZ}}{m_b} \left(\bar{b} \sigma^{\mu\nu} b \right) Z_{\mu\nu} \,,$$

- Coefficients and relations $\{\delta g_{Lb},\, \delta g_{Rb},\, \kappa_{bA},\, \kappa_{bZ}\}$:

$$g_{Lb} = -\frac{1}{2} + \frac{1}{3}\sin^2\theta_W + \delta g_{Lb}, \quad g_{Rb} = \frac{1}{3}\sin^2\theta_W + \delta g_{Rb}\,,$$
$$\delta g_{Lb} = (c_{Hq}^{(1)} + c_{Hq}^{(3)}) \frac{v^2}{2\Lambda^2}\,, \quad \delta g_{Rb} = c_{Hb} \frac{v^2}{2\Lambda^2}\,,$$
$$\kappa_{bZ} = \frac{m_b v}{\sqrt{2}\Lambda^2} (\cos\theta_W\, c_{bW} + \sin\theta_W\, c_{bB})\,, \quad \kappa_{bA} = \frac{m_b v}{\sqrt{2}\Lambda^2} (\cos\theta_W\, c_{bB} - \sin\theta_W\, c_{bW})\,.$$

- For convenience, set $\Lambda = 1$ TeV and only keep real parts of dipole WCs
- 4 parameters included, and ratio of γ and Z diagrams varies from energy

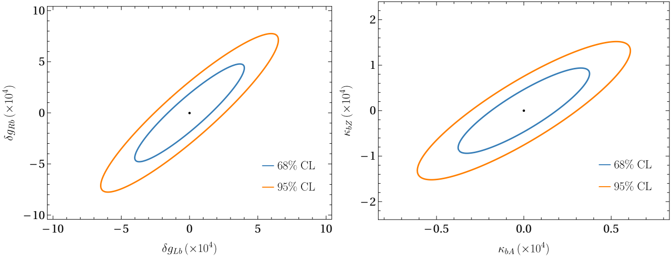
  $\Rightarrow$ need to include Z pole and off pole measurements.

- Central values of future measurements are assume to be SM-like.

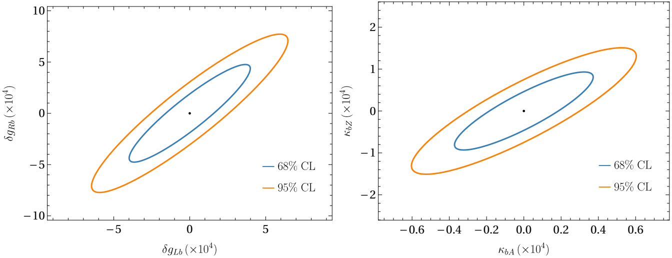
χ^2 constrain analysis

Preferred region (linear fit, only interference)

Z pole + 240 GeV



Z pole + 240 GeV + 360 GeV



*global fit analysis with $\{\delta g_{Lb}, \delta g_{Rb}, \kappa_{bA}, \kappa_{bZ}\}$ in this and following page

Squared items contribution

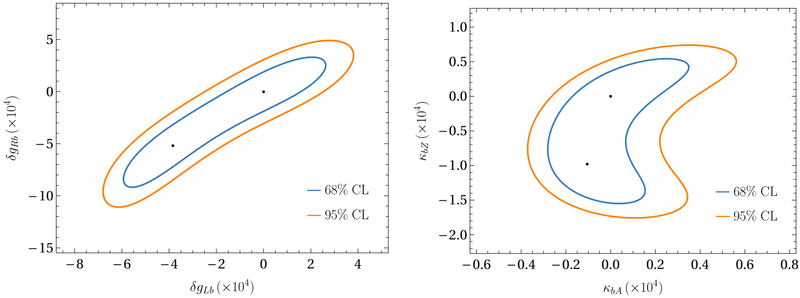
A generic observable has the form:

$$\sigma = \sigma_{\text{SM}} + \sum_{\alpha} \sigma_{\alpha} C_{a} + \sum_{\alpha,\beta} \sigma_{\alpha\beta} C_{\alpha} C_{\beta}$$

where σ_{SM}, σ_{α}, $\sigma_{\alpha\beta}$ denote the SM, interference and squared contributions respectively.

If not omit squared items (full fit)

***Z* pole + 240 GeV**

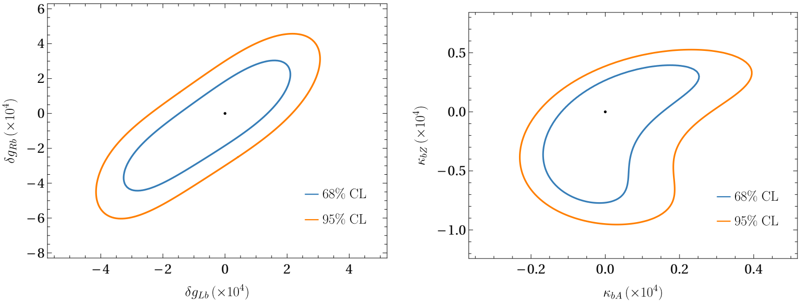


- 2nd non-SM best fit: $\{\delta g_{Lb}, \delta g_{Rb}, \kappa_{bA}, \kappa_{bZ}\} = \{-3.84, -5.19, -0.105, -0.980\} \times 10^{-4}$

Squared items contribution

Extra off pole measurement

Z pole + 240 + 360 GeV



- Squared terms of the dipole contributions play important role in the full fit.
- Including more off pole measurement:
  - ⇒ may be minor contribution in the linear fit,
  - ⇒ help to lift the 2nd non-SM best fit point.

χ^2 constrain analysis

1 σ bound and correlation matrix ρ (effective coupling)

Z pole + 240 GeV

	Linear fit	Correlation ρ				Full fit
	1σ bound ($\times 10^{-4}$)	δg_{Lb}	δg_{Rb}	κ_{bZ}	κ_{bA}	1σ bound ($\times 10^{-4}$)
δg_{Lb}	±2.66	1				[-5.34, 1.87]
δg_{Rb}	±3.17	0.919	1			[-7.94, 2.32]
κ_{bZ}	±0.621	0.975	0.914	1		[-1.41, 0.398]
κ_{bA}	±0.249	0.804	0.784	0.868	1	[-0.228, 0.228]

Z pole + 240 GeV + 360 GeV

	Linear fit	Correlation ρ				Full fit
	1σ bound ($\times 10^{-4}$)	δg_{Lb}	δg_{Rb}	κ_{bZ}	κ_{bA}	1σ bound ($\times 10^{-4}$)
δg_{Lb}	±2.64	1				[-2.58, 1.50]
δg_{Rb}	±3.15	0.918	1			[-3.30, 2.10]
κ_{bZ}	±0.616	0.975	0.913	1		[-0.624, 0.304]
κ_{bA}	±0.247	0.803	0.783	0.868	1	[-0.126, 0.168]

* $\chi^2 = \sum_{ij}\left(\hat{c}_i - \hat{c}_i^0\right)\sigma_{ij}^{-2}\left(\hat{c}_j - \hat{c}_j^0\right)$, where $\sigma_{ij}^{-2} = \left[\delta\hat{c}_i\rho_{ij}\delta\hat{c}_j\right]^{-1}$ [1411.0669]

χ^2 constrain analysis

1 σ bound and correlation matrix ρ (in Warsaw basis)

Z pole + 240 GeV

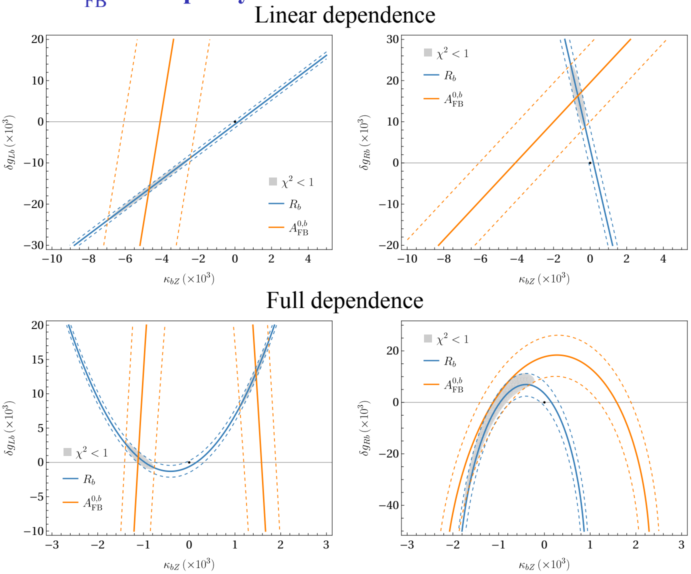
	Linear fit	Correlation ρ				Full fit
	1σ bound ($\times 10^{-2}$)	$(c_{Hq}^{(1)} + c_{Hq}^{(3)})$	c_{Hb}	c_{bB}	c_{bW}	1σ bound ($\times 10^{-2}$)
$(c_{Hq}^{(1)} + c_{Hq}^{(3)})$	± 0.877	1				[-1.76, 0.617]
c_{Hb}	± 1.05	0.919	1			[-2.62, 0.765]
c_{bB}	± 6.82	0.933	0.887	1		[-9.90, 5.10]
c_{bW}	± 6.17	0.978	0.908	0.938	1	[-17.0, 3.75]

Z pole + 240 GeV + 360 GeV

	Linear fit	Correlation ρ				Full fit
	1σ bound ($\times 10^{-2}$)	$(c_{Hq}^{(1)} + c_{Hq}^{(3)})$	c_{Hb}	c_{dB}	c_{dW}	1σ bound ($\times 10^{-2}$)
$(c_{Hq}^{(1)} + c_{Hq}^{(3)})$	± 0.871	1				[-0.851, 0.495]
c_{Hb}	± 1.04	0.918	1			[-1.09, 0.693]
c_{bB}	± 6.76	0.932	0.887	1		[-4.80, 3.75]
c_{bW}	± 6.13	0.978	0.907	0.939	1	[-7.20, 2.80]

* $\chi^2 = \sum_{ij} \left(\hat{c}_i - \hat{c}_i^0\right) \sigma_{ij}^{-2} \left(\hat{c}_j - \hat{c}_j^0\right)$, where $\sigma_{ij}^{-2} = \left[\delta\hat{c}_i \rho_{ij} \delta\hat{c}_j\right]^{-1}$ [1411.0669]

Recall the LEP $A_{\mathrm{FB}}^{0,b}$ discrepancy



*Constraints from LEP in $\{\kappa_{bZ}, \delta g_{Lb}\}$ and $\{\kappa_{bZ}, \delta g_{Rb}\}$ plane individually here.

*Existing problem: $|\kappa_{bZ}| \sim 0.001$ to generate such $A_{\mathrm{FB}}^{0,b}$. Assuming $c_{bW}, c_{bB} \sim 1/16\pi^2 \Rightarrow \Lambda \lesssim 10^2$ GeV...

Summary

- **SMEFT & dipole**
  - Dipoles are usually overlooked in the analysises (Except the heavy top).
  - dim-6 dipole operators might contribute to the A_{FB} inconsistency.
- **Future lepton collider offers opportunity to trace $Zb\bar{b}$ dipole**
  - Z pole measurements $\Rightarrow$ only flat constraint.
  - Off Z pole measurement $\Rightarrow$ interference of γ and Z diagram $\Rightarrow$ closed constraint.
  - Quadratic items also give contribution (full fit).
  - All runs are essential: extra off pole measurements lift the non-SM best-fit.
  - Our estimation (Z pole + 240 + 360 GeV):
    $k_{bZ} = [-0.624, 0.304] \times 10^{-4}$, $k_{bA} = [-0.126, 0.168] \times 10^{-4}$.
- **More efforts are needed and in progress**
  - Further combined analysis, distributions …
  - More off pole analysises at other future lepton colliders …
  - Appropriate models to contribute such $A_{\rm FB}^{0,b}$ discrepancy...

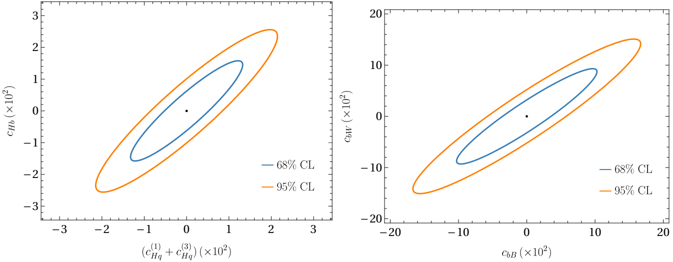
Thank you!

Backups

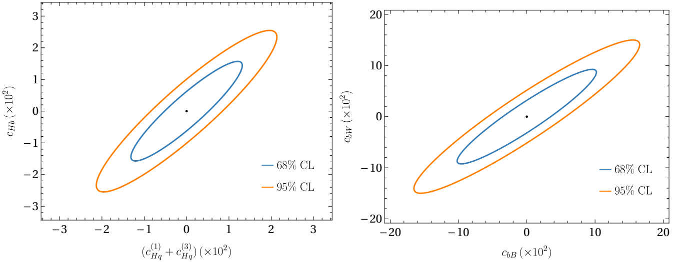
χ^2 constrain analysis - backup

Preferred region (linear fit, only interference, in Warsaw basis)

Z pole + 240 GeV



Z pole + 240 GeV + 360 GeV

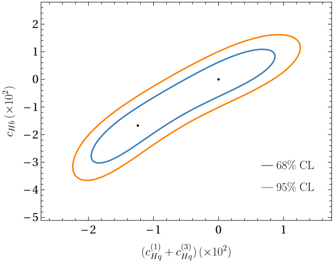


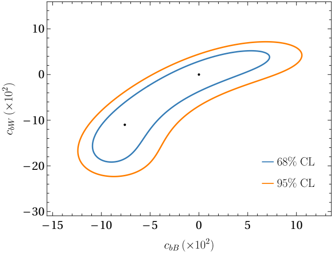
*global fit analysis with $\left\{ (c_{Hq}^{(1)} + c_{Hq}^{(3)}),\ c_{Hb},\ c_{bB},\ c_{bW} \right\}$ here and in the next

Quadratic items contribution - backup

Preferred region (Full fit, in Warsaw basis)

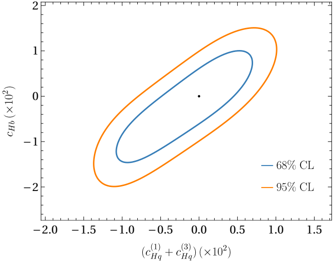
Z pole + 240 GeV

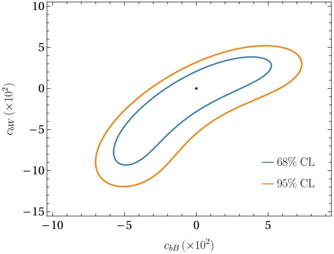




2nd non-SM best fit: $\left\{ (c_{Hq}^{(1)} + c_{Hq}^{(3)}),\, c_{Hb},\, c_{bB},\, c_{bW} \right\} = \{-1.24, -1.67, -7.60, -11.0\} \times 10^{-2}$

Z pole + 240 + 360 GeV





Backups

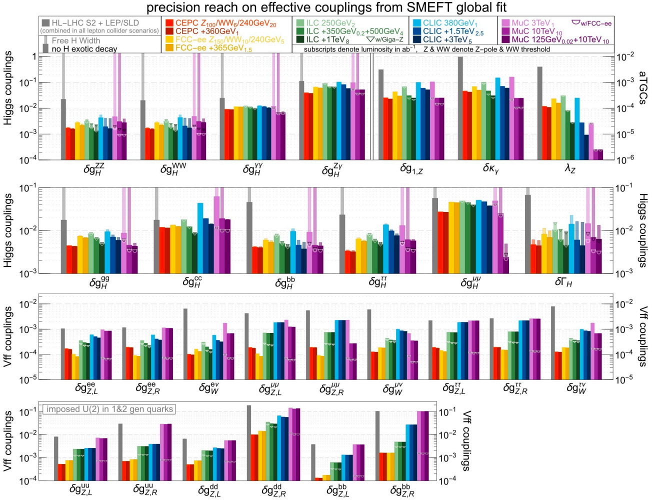
$\mathcal{L}_6^{(6)} - \psi^2 XH$	
Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r)\sigma^i H W^i_{\mu\nu}$
Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$
Q_{uG}	$(\bar{q}_p \sigma^{\mu\nu} T^a u_r)\widetilde{H}\, G^a_{\mu\nu}$
Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\sigma^i \widetilde{H}\, W^i_{\mu\nu}$
Q_{uB}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\widetilde{H}\, B_{\mu\nu}$
Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^a d_r) H\, G^a_{\mu\nu}$
Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r)\sigma^i H\, W^i_{\mu\nu}$
Q_{dB}	$(\bar{q}_p \sigma^{\mu\nu} d_r) H\, B_{\mu\nu}$

$\mathcal{L}_6^{(7)} - \psi^2 H^2 D$	
$Q_{Hl}^{(1)}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{l}_p \gamma^\mu l_r)$
$Q_{Hl}^{(3)}$	$(H^\dagger i \overleftrightarrow{D}^i_\mu H)(\bar{l}_p \sigma^i \gamma^\mu l_r)$
Q_{He}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{e}_p \gamma^\mu e_r)$
$Q_{Hq}^{(1)}$	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{q}_p \gamma^\mu q_r)$
$Q_{Hq}^{(3)}$	$(H^\dagger i \overleftrightarrow{D}^i_\mu H)(\bar{q}_p \sigma^i \gamma^\mu q_r)$
Q_{Hu}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{u}_p \gamma^\mu u_r)$
Q_{Hd}	$(H^\dagger i \overleftrightarrow{D}_\mu H)(\bar{d}_p \gamma^\mu d_r)$
Q_{Hud} + h.c.	$i(\widetilde{H}^\dagger D_\mu H)(\bar{u}_p \gamma^\mu d_r)$

[arXiv:2012.11343]

Dipole operators of dim-6 SMEFT in the Warsaw basis.

Global SMEFT fit



[arXiv:2206.08326]

EWPOs FCC-ee

Quantity	current	ILC250	ILC-GigaZ	FCC-ee	CEPC	CLIC380
$\Delta\alpha(m_Z)^{-1}$ ($\times 10^3$)	17.8*	17.8*		3.8 (1.2)	17.8*	
Δm_W (MeV)	12*	0.5 (2.4)		0.25 (0.3)	0.35 (0.3)	
Δm_Z (MeV)	2.1*	0.7 (0.2)	0.2	0.004 (0.1)	0.005 (0.1)	2.1*
Δm_H (MeV)	170*	14		2.5 (2)	5.9	78
$\Delta\Gamma_W$ (MeV)	42*	2		1.2 (0.3)	1.8 (0.9)	
$\Delta\Gamma_Z$ (MeV)	2.3*	1.5 (0.2)	0.12	0.004 (0.025)	0.005 (0.025)	2.3*
ΔA_e ($\times 10^5$)	190*	14 (4.5)	1.5 (8)	0.7 (2)	1.5	64
ΔA_μ ($\times 10^5$)	1500*	82 (4.5)	3 (8)	2.3 (2.2)	3.0 (1.8)	400
ΔA_τ ($\times 10^5$)	400*	86 (4.5)	3 (8)	0.5 (20)	1.2 (6.9)	570
ΔA_b ($\times 10^5$)	2000*	53 (35)	9 (50)	2.4 (21)	3 (21)	380
ΔA_c ($\times 10^5$)	2700*	140 (25)	20 (37)	20 (15)	6 (30)	200
$\Delta\sigma^0_{\rm had}$ (pb)	37*			0.035 (4)	0.05 (2)	37*
δR_e ($\times 10^3$)	2.4*	0.5 (1.0)	0.2 (0.5)	0.004 (0.3)	0.003 (0.2)	2.7
δR_μ ($\times 10^3$)	1.6*	0.5 (1.0)	0.2 (0.2)	0.003 (0.05)	0.003 (0.1)	2.7
δR_τ ($\times 10^3$)	2.2*	0.6 (1.0)	0.2 (0.4)	0.003 (0.1)	0.003 (0.1)	6
δR_b ($\times 10^3$)	3.0*	0.4 (1.0)	0.04 (0.7)	0.0014 ($<$ 0.3)	0.005 (0.2)	1.8
δR_c($\times 10^3$)	17*	0.6 (5.0)	0.2 (3.0)	0.015 (1.5)	0.02 (1)	5.6

Table 3: EWPOs at future e^+e^-: statistical error (experimental systematic error). Δ

FCC-ee $\sqrt{s}$ [GeV]	Final state	$\mathcal{L}$ [fb^{-1}]	σ [fb]	A_{FB}	$[c_\theta^{\rm min}, c_\theta^{\rm max}]$	ϵ
240	e^-e^+	5000	77330.4±3.87	0.96±0.00001388	[-0.9, 0.9]	0.98
	$\mu^-\mu^+$		1870.84±0.612	0.521±0.000279	[-0.95, 0.95]	0.98
	$\tau^-\tau^+$		1589.15±0.564	0.506±0.000306	[-0.9, 0.9]	0.9
	$c\bar{c}$		93.38±0.1367	0.62±0.00115	[-0.9, 0.9]	0.03
	$b\bar{b}$		275.64±0.235	0.592±0.000687	[-0.9, 0.9]	0.15
365	e^-e^+	1500	34221.5±4.72	0.957±0.0000399	[-0.9, 0.9]	0.98
	$\mu^-\mu^+$		787.74±0.725	0.488±0.000803	[-0.95, 0.95]	0.98
	$\tau^-\tau^+$		669.11±0.668	0.473±0.00088	[-0.9, 0.9]	0.9
	$c\bar{c}$		38.11±0.1594	0.595±0.00336	[-0.9, 0.9]	0.03
	$b\bar{b}$		105.12±0.2647	0.603±0.00201	[-0.9, 0.9]	0.15

[arXiv:2206.08326]

EWPOs CEPC

Quantity	current	ILC250	ILC-GigaZ	FCC-ee	CEPC	CLIC380
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$\Delta\Gamma_W$ (MeV)	42*	2		1.2 (0.3)	1.8 (0.9)	
$\Delta\Gamma_Z$ (MeV)	2.3*	1.5 (0.2)	0.12	0.004 (0.025)	0.005 (0.025)	2.3*
ΔA_e ($\times 10^5$)	190*	14 (4.5)	1.5 (8)	0.7 (2)	1.5	64
ΔA_μ ($\times 10^5$)	1500*	82 (4.5)	3 (8)	2.3 (2.2)	3.0 (1.8)	400
ΔA_τ ($\times 10^5$)	400*	86 (4.5)	3 (8)	0.5 (20)	1.2 (6.9)	570
ΔA_b ($\times 10^5$)	2000*	53 (35)	9 (50)	2.4 (21)	3 (21)	380
ΔA_c ($\times 10^5$)	2700*	140 (25)	20 (37)	20 (15)	6 (30)	200
$\Delta\sigma^0_{\rm had}$ (pb)	37*			0.035 (4)	0.05 (2)	37*
δR_e ($\times 10^3$)	2.4*	0.5 (1.0)	0.2 (0.5)	0.004 (0.3)	0.003 (0.2)	2.7
δR_μ ($\times 10^3$)	1.6*	0.5 (1.0)	0.2 (0.2)	0.003 (0.05)	0.003 (0.1)	2.7
δR_τ ($\times 10^3$)	2.2*	0.6 (1.0)	0.2 (0.4)	0.003 (0.1)	0.003 (0.1)	6
δR_b ($\times 10^3$)	3.0*	0.4 (1.0)	0.04 (0.7)	0.0014 (<0.3)	0.005 (0.2)	1.8
δR_c($\times 10^3$)	17*	0.6 (5.0)	0.2 (3.0)	0.015 (1.5)	0.02 (1)	5.6

Table 3: EWPOs at future e^+e^-: statistical error (experimental systematic error). Δ

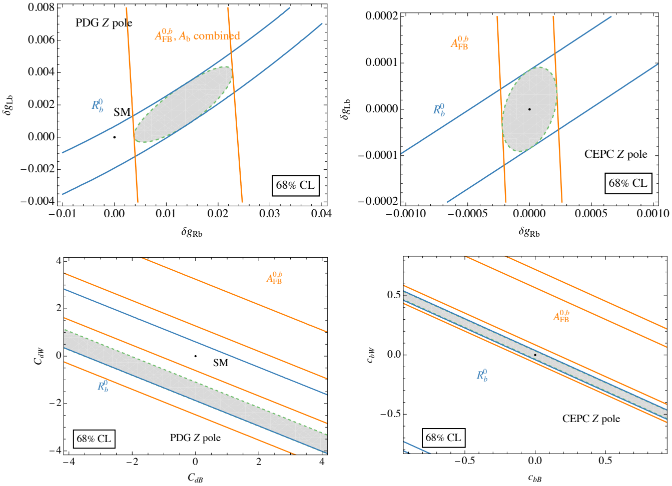
CEPC $\sqrt{s}$ [GeV]	Final state	$\mathcal{L}$ [fb^{-1}]	σ [fb]	A_{FB}	$[c_\theta^{\rm min}, c_\theta^{\rm max}]$	ϵ
240	e^-e^+	5000	77330.4±1.937	0.96±0.00000694	[-0.9, 0.9]	0.98
	$\mu^-\mu^+$		1870.84±0.306	0.521±0.0001395	[-0.95, 0.95]	0.98
	$\tau^-\tau^+$		1589.15±0.282	0.506±0.000153	[-0.9, 0.9]	0.9
	$c\bar{c}$		93.38±0.0683	0.62±0.000574	[-0.9, 0.9]	0.03
	$b\bar{b}$		275.64±0.1174	0.592±0.0003434	[-0.9, 0.9]	0.15
360	e^-e^+	1500	35147.9±5.85	0.957±0.0000482	[-0.9, 0.9]	0.98
	$\mu^-\mu^+$		810.18±0.9	0.4885±0.00097	[-0.95, 0.95]	0.98
	$\tau^-\tau^+$		688.17±0.83	0.474±0.001061	[-0.9, 0.9]	0.9
	$c\bar{c}$		39.22±0.198	0.596±0.004056	[-0.9, 0.9]	0.03
	$b\bar{b}$		108.33±0.329	0.602±0.002425	[-0.9, 0.9]	0.15

[arXiv:2206.08326]

χ^2 constrain comparison - backup

Present Z pole data (PDG) vs Z pole estimation in the future

*(analyze individually for $\delta g_{Lb} - \delta g_{Rb}$ and $C_{bB} - C_{bW}$ only in this page)



Flat constraint only ⇒ We need off Z pole run for combined analysis.