Global fit for 4-fermion operators & operators at Z-pole

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In collaboration with Jorge de Blas, Christophe Grojean, Jiayin Gu, Michael Peskin, Junping Tian, Marcel Vos, Eleni Vryonidou

Short overview

Global fit with precision measurements from LEP, SLC, Tevatron ect has helped in constraining Higgs and top quark masses. HL-LHC and future colliders are at least precision machines, making them powerful tools for new physics discovery.

Four-fermion operators get more and more attention perhaps after the discovery of neutrino oscillations in particular. Various low-energy experiments are sensitive to those operators (COHERENT, CCFR, neutrino oscillation, etc.)

Today I will present our preliminary results on Z/W-pole and 4-fermion operators from a global fit.

Framework

For the pole observables

LHC Higgs Cross Section Working Group, 2017

$$\mathcal{L}_{\text{eff}}^{vff} \supset eA_\mu \sum_{f\in u,d,e} Q_f \left(\bar{f}\bar{\sigma}_\mu f + f^c \sigma_\mu \bar{f}^c \right)$$

$$+ \frac{g_L}{\sqrt{2}} \left(W_\mu^+ \bar{u}\bar{\sigma}_\mu \left(V + \delta g_L^{Wq} \right) d + W_\mu^+ \bar{u}\bar{\sigma}_\mu \delta g_R^{Wq} d_R + W_\mu^+ \bar{\nu}\bar{\sigma}_\mu \left(\mathbb{1} + \delta g_L^{W\ell} \right) e + \textbf{h.c.} \right)$$

$$+ \sqrt{g_L^2 + g_Y^2} Z_\mu \left[\sum_{f\in u,d,e,\nu} \bar{f}\bar{\sigma}_\mu \left(\mathbb{1} T_f^3 - \mathbb{1} s_\theta^2 Q_f + \delta g_L^{Zf} \right) f + \sum_{f^c\in u^c,d^c,e^c} f^c \sigma_\mu \left(-\mathbb{1} s_\theta^2 Q_f + \delta g_R^{Zf} \right) \bar{f}^c \right]$$

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$$\mathscr{L}_{\text{eff}}^{vff} \supset eA_\mu \sum_{f\in u,d,e} Q_f\left(\bar{f}\bar{\sigma}_\mu f + f^c\sigma_\mu \bar{f}^c\right)$$

$$+\frac{g_L}{\sqrt{2}}\left(W_\mu^+\bar{u}\bar{\sigma}_\mu\left(V+\delta g_L^{Wq}\right)d + W_\mu^+\bar{u}\bar{\sigma}_\mu\delta g_R^{Wq}d_R + W_\mu^+\bar{\nu}\bar{\sigma}_\mu\left(\mathbb{1}+\delta g_L^{W\ell}\right)e + \textbf{h.c.}\right)$$

$$+\sqrt{g_L^2+g_Y^2}Z_\mu\left[\sum_{f\in u,d,e,\nu}\bar{f}\bar{\sigma}_\mu\left(\mathbb{1}T_f^3-\mathbb{1}s_\theta^2Q_f+\delta g_L^{Zf}\right)f + \sum_{f^c\in u^c,d^c,e^c} f^c\sigma_\mu\left(-\mathbb{1}s_\theta^2Q_f+\delta g_R^{Zf}\right)\bar{f}^c\right]$$

$$m_W \to (1+\delta m)m_W$$

Framework

Notations $\mathscr{L} \supset \frac{1}{v^2} c_i^{IJKL} [\mathscr{O}_i]_{IJKL}$

One flavor $(I = 1 \ldots 3)$	Two flavors $(I < J = 1 \ldots 3)$
$[O_{\ell\ell}]_{IIII} = \frac{1}{2}\left(\bar{\ell}_I \bar{\sigma}_\mu \ell_I\right)\left(\bar{\ell}_I \bar{\sigma}_\mu \ell_I\right)$	$[O_{\ell\ell}]_{IIJJ} = \left(\bar{\ell}_I \bar{\sigma}_\mu \ell_I\right)\left(\bar{\ell}_J \bar{\sigma}_\mu \ell_J\right)$
$[O_{\ell e}]_{IIII} = \left(\bar{\ell}_I \bar{\sigma}_\mu \ell_I\right)\left(e_I^c \sigma_\mu \bar{e}_I^c\right)$	$[O_{\ell\ell}]_{IJJI} = \left(\bar{\ell}_I \bar{\sigma}_\mu \ell_J\right)\left(\bar{\ell}_J \bar{\sigma}_\mu \ell_I\right)$
	$[O_{\ell e}]_{IIJJ} = \left(\bar{\ell}_I \bar{\sigma}_\mu \ell_I\right)\left(e_J^c \sigma_\mu \bar{e}_J^c\right)$
$[O_{ee}]_{IIII} = \frac{1}{2}\left(e_I^c \sigma_\mu \bar{e}_I^c\right)\left(e_I^c \sigma_\mu \bar{e}_I^c\right)$	$[O_{\ell e}]_{JJII} = \left(\bar{\ell}_J \bar{\sigma}_\mu \ell_J\right)\left(e_I^c \sigma_\mu \bar{e}_I^c\right)$
	$[O_{\ell e}]_{IJJI} = \left(\bar{\ell}_I \bar{\sigma}_\mu \ell_J\right)\left(e_J^c \sigma_\mu \bar{e}_I^c\right)$
	$[O_{ee}]_{IIJJ} = \left(e_I^c \sigma_\mu \bar{e}_I^c\right)\left(e_J^c \sigma_\mu \bar{e}_J^c\right)$

LHC Higgs Cross Section Working Group, 2017

*Currently only flavor-conserving observables/operators are included in our fit.

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$$\delta m = \frac{1}{2}\delta g_{L,W\ell}^{11} + \frac{1}{2}\delta g_{L,W\ell}^{22} - \frac{1}{4} c_{\ell\ell}^{1221}$$

Observables: LEP-Z, W

#	Observables	Exp results [central, 1σ error]	Refs	SM prediction Gfitter	Definition
1	Γ_Z [GeV]	[2.4952, 0.0023]	LEP-Z	2.4950	$\sum_f \Gamma(Z \to f\bar{f})$
2	$\sigma_{\rm had}$ [nb]	[41.541, 0.037]	LEP-Z	41.484	$\frac{12\pi}{m_Z^2}\frac{\Gamma(Z\to ee)\Gamma(Z\to qq)}{\Gamma_Z^2}$
3	R_e	[20.804, 0.050]	LEP-Z	20.743	$\frac{\sum_q \Gamma(Z\to qq)}{\Gamma(Z\to ee)}$
4	R_μ	[20.785, 0.033]	LEP-Z	20.743	$\frac{\sum_q \Gamma(Z\to qq)}{\Gamma(Z\to \mu\mu)}$
5	R_τ	[20.764, 0.045]	LEP-Z	20.743	$\frac{\sum_q \Gamma(Z\to qq)}{\Gamma(Z\to \tau\tau)}$
6	$A_{\rm FB}^{0,e}$	[0.0145, 0.0025]	LEP-Z	0.0163	$\frac{3}{4}A_e^2$
7	$A_{\rm FB}^{0,\mu}$	[0.0169, 0.0013]	LEP-Z	0.0163	$\frac{3}{4}A_e A_\mu$
8	$A_{\rm FB}^{0,\tau}$	[0.0188, 0.0017]	LEP-Z	0.0163	$\frac{3}{4}A_e A_\tau$
9	R_b	[0.21629, 0.00066]	LEP-Z	0.21578	$\frac{\Gamma(Z\to bb)}{\sum_q \Gamma(Z\to qq)}$
10	R_c	[0.1721, 0.0030]	LEP-Z	0.17226	$\frac{\Gamma(Z\to cc)}{\sum_q \Gamma(Z\to qq)}$
11	$A_b^{\rm FB}$	[0.0992, 0.0016]	LEP-Z	0.1032	$\frac{3}{4}A_e A_b$
12	$A_c^{\rm FB}$	[0.0707, 0.0035]	LEP-Z	0.0738	$\frac{3}{4}A_e A_c$
13	A_e	[0.1516, 0.0021]	LEP-Z	0.1472	$\frac{\Gamma(Z\to e_L e_L)-\Gamma(Z\to e_R e_R)}{\Gamma(Z\to ee)}$
14	A_μ	[0.142, 0.015]	LEP-Z	0.1472	$\frac{\Gamma(Z\to \mu_L \mu_L)-\Gamma(Z\to \mu_R \mu_R)}{\Gamma(Z\to \mu\mu)}$
15	A_τ	[0.136, 0.015]	LEP-Z	0.1472	$\frac{\Gamma(Z\to \tau_L \tau_L)-\Gamma(Z\to \tau_R \tau_R)}{\Gamma(Z\to \tau\tau)}$
16	A_e	[0.1498, 0.0049]	LEP-Z	0.1472	$\frac{\Gamma(Z\to e_L e_L)-\Gamma(Z\to e_R e_R)}{\Gamma(Z\to \tau\tau)}$
17	A_τ	[0.1439, 0.0043]	LEP-Z	0.1472	$\frac{\Gamma(Z\to \tau_L \tau_L)-\Gamma(Z\to \tau_R \tau_R)}{\Gamma(Z\to \tau\tau)}$
18	A_b	[0.923, 0.020]	LEP-Z	0.935	$\frac{\Gamma(Z\to b_L b_L)-\Gamma(Z\to b_R b_R)}{\Gamma(Z\to bb)}$
19	A_c	[0.670, 0.027]	LEP-Z	0.668	$\frac{\Gamma(Z\to c_L c_L)-\Gamma(Z\to c_R c_R)}{\Gamma(Z\to cc)}$
20	A_s	[0.895, 0.091]	SLD	0.935	$\frac{\Gamma(Z\to s_L s_L)-\Gamma(Z\to s_R s_R)}{\Gamma(Z\to ss)}$
21	R_{uc}	[0.166, 0.009]	PDG2012	0.1724	$\frac{\Gamma(Z\to uu)+\Gamma(Z\to cc)}{2\sum_q \Gamma(Z\to qq)}$
22	g_A^u	[0.501, 0.110]	D0	0.501	Axial-vector Zuu
23	g_V^u	[0.201, 0.112]	D0	0.192	Vector Zuu
24	g_A^d	[-0.497, 0.165]	D0	-0.502	Axial-vector Zdd
25	g_A^d	[-0.351, 0.251]	D0	-0.347	Vector Zdd

W-pole observables

#	Observables	Exp results [central, error]	Refs	SM prediction	Definition
1	m_W [GeV]	[80.385, 0.015]	CDF & D0	80.364	$\frac{g_L v}{2}(1+\delta m)$
2	Γ_W [GeV]	[2.085, 0.042]	PDG2012	2.091	$\sum_f \Gamma(W\to ff')$
3	Br$(W\to e\,\nu)$	[0.1071, 0.0016]	LEP-W	0.1083	$\frac{\Gamma(W\to e\,\nu)}{\sum_f \Gamma(W\to ff')}$
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5	Br$(W\to \tau\,\nu)$	[0.1138, 0.0021]	LEP-W	0.1083	$\frac{\Gamma(W\to \tau\,\nu)}{\sum_f \Gamma(W\to ff')}$
6	R_{Wc}	[0.49, 0.04]	PDG2012	0.50	$\frac{\Gamma(W\to c\,s)}{\Gamma(W\to u\,d)+\Gamma(W\to c\,s)}$
7	R_σ	[0.998, 0.041]	CMS	1.000	$\frac{g_L^{Wq_3}}{g_{L,\rm SM}^{Wq_3}}$

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Flavor-violating ones

#	Observables	Current upper bound	Refs	SM prediction	Definition
1	Br($Z\to e\mu$)	7.5×10^{-7}	ATLAS	0	$\frac{\Gamma(Z\to e\mu)}{\sum_f \Gamma(Z\to ff')}$
2	Br($Z\to e\tau$)	9.8×10[illegible]	OPAL	0	$\frac{\Gamma(Z\to e\tau)}{\sum_f \Gamma(Z\to ff')}$
3	Br($Z\to \mu\tau$)	1.2×10^{-5}	DELPHI	0	$\frac{\Gamma(Z\to \mu\tau)}{\sum_f \Gamma(Z\to ff')}$
4	Br($t\to Zq$)	5.0×10^{-4}	CMS	0	$\frac{\Gamma(t\to Zu)+\Gamma(t\to Zc)}{\sum_f \Gamma(Z\to ff')}$

NOT included for now

Observables: More

Fermion-pair production

- $\sigma(e^+e^- \to \mu^+\mu^-), \quad \sigma_{\rm FB}(e^+e^- \to \mu^+\mu^-)$
- $\sigma(e^+e^- \to \tau^+\tau^-), \quad \sigma_{\rm FB}(e^+e^- \to \tau^+\tau^-)$
- $d\sigma(e^+e^- \to e^+e^-)/d\cos\theta$
- GF from τ decay (PDG)
- Michel parameters from polarized muon decay (PSI)

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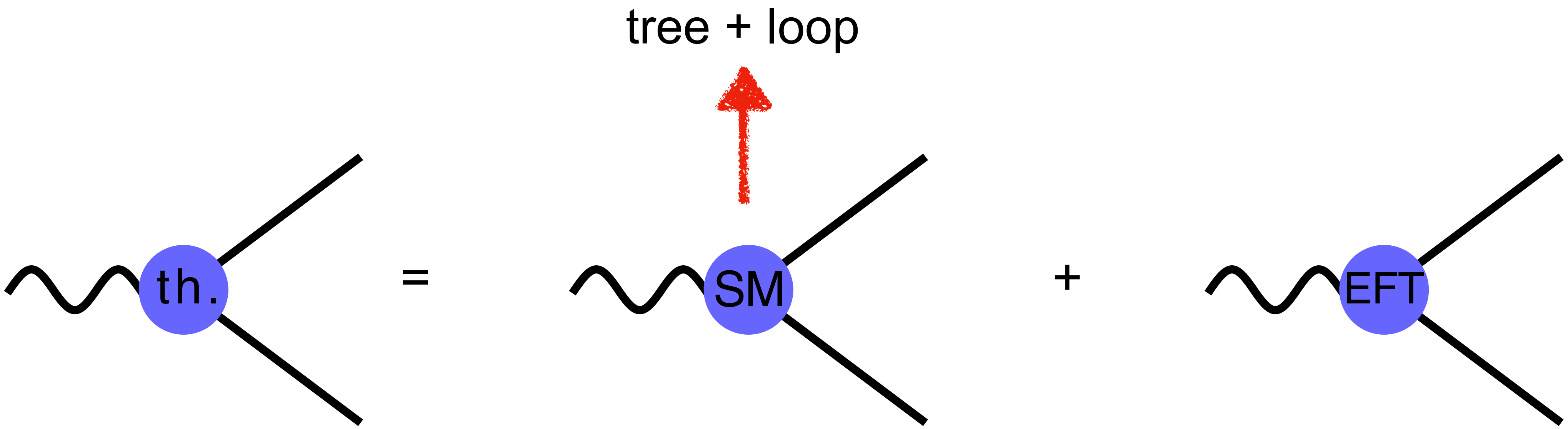
- GF from τ decay (PDG)

- Michel parameters from polarized muon decay (PSI)

  — Michel parameters from polarized tau decay with upgraded SuperKEKB (Banerjee and Roney's talk during last EF04 topical group meeting)

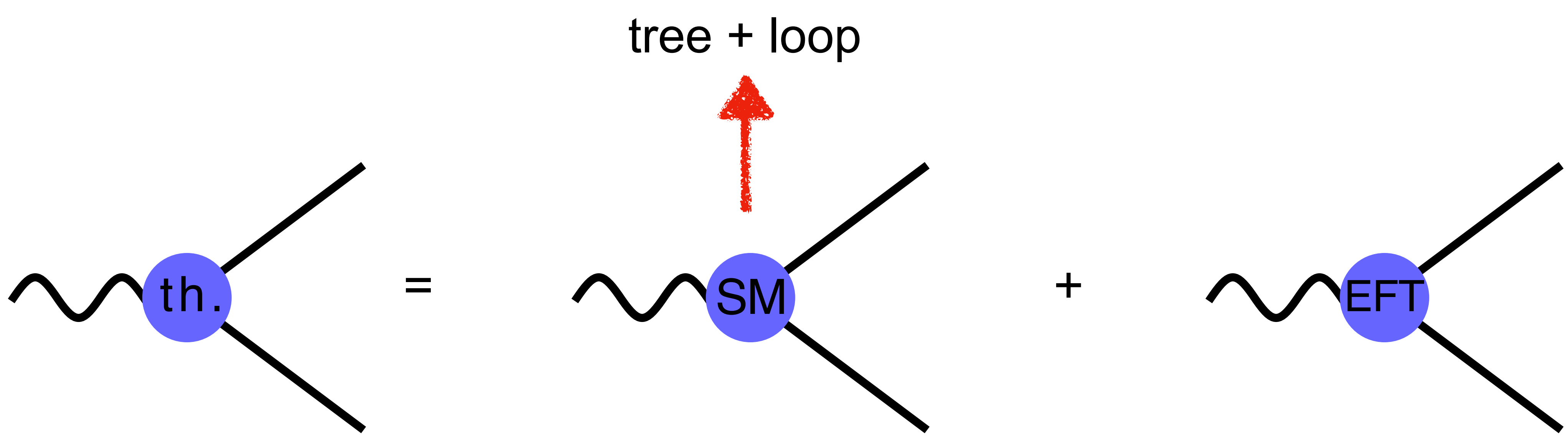
Strategy



$$\mathcal{M}^2_{\text{th.}} = \mathcal{M}^2_{\text{SM}} + 2\text{Re}\left(\mathcal{M}_{\text{SM}}\mathcal{M}^\dagger_{\text{EFT}}\right) + \mathcal{M}^2_{\text{EFT}}$$

$$\simeq \mathcal{M}^2_{\text{SM}} + 2\text{Re}\left(\mathcal{M}^{\text{tree}}_{\text{SM}}\mathcal{M}^\dagger_{\text{EFT}}\right) + \mathcal{O}\left(\alpha^2\delta g, \delta g^2\right)$$

Strategy



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$$\chi^2 = \sum_{ij}\left[O_{i,\text{exp}} - O_{i,\text{th}}\right]\sigma_{ij}^{-2}\left[O_{j,\text{exp}} - O_{j,\text{th}}\right]$$

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Optimistic: One operator at a time.
Conservative: Full correlation among observables are taken into account.

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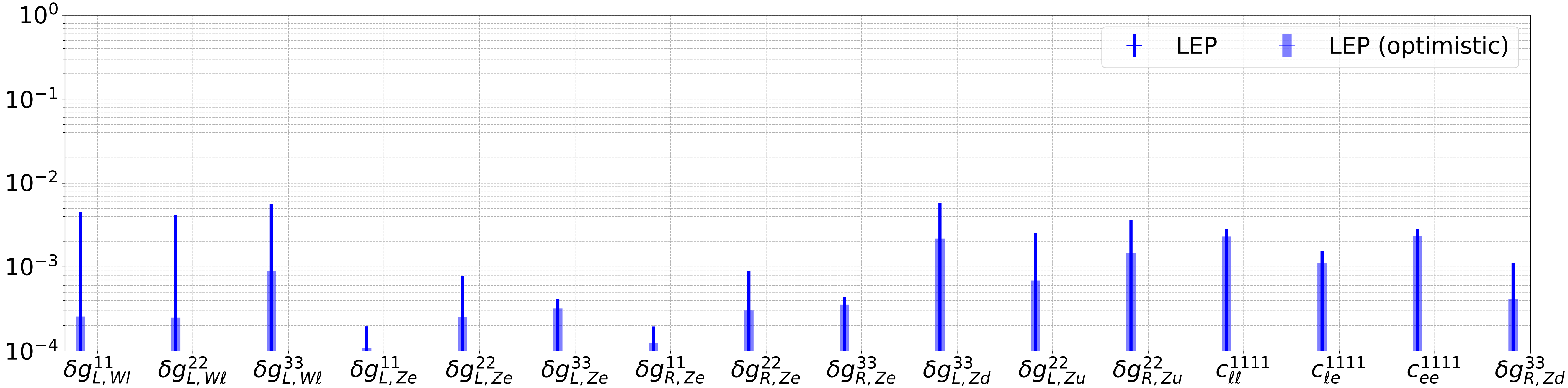
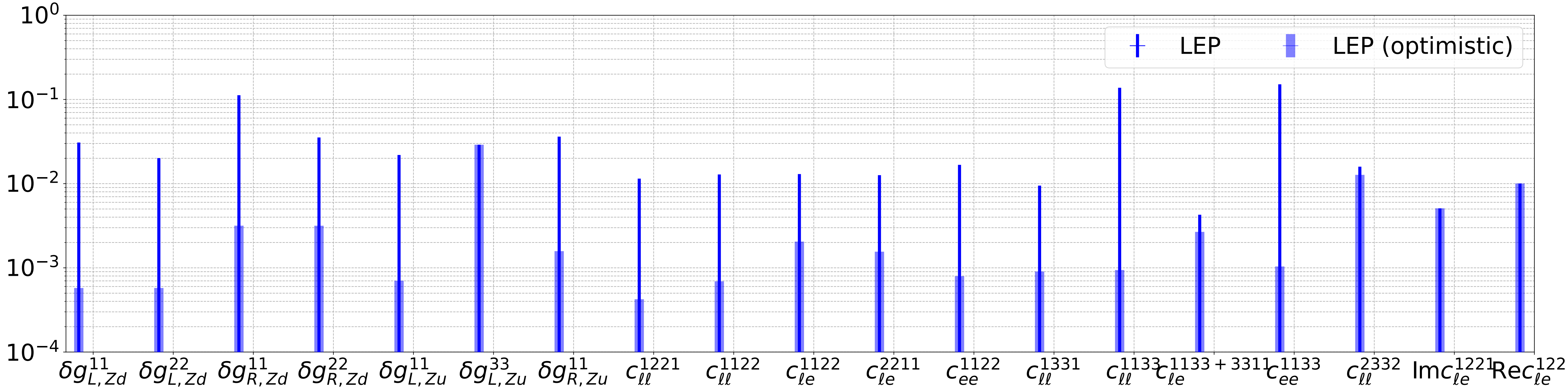


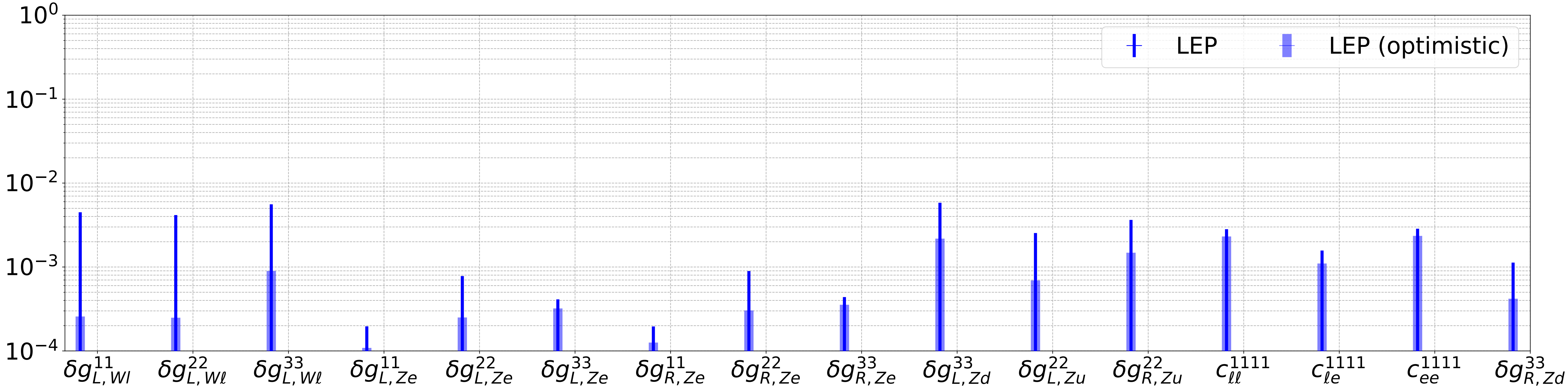


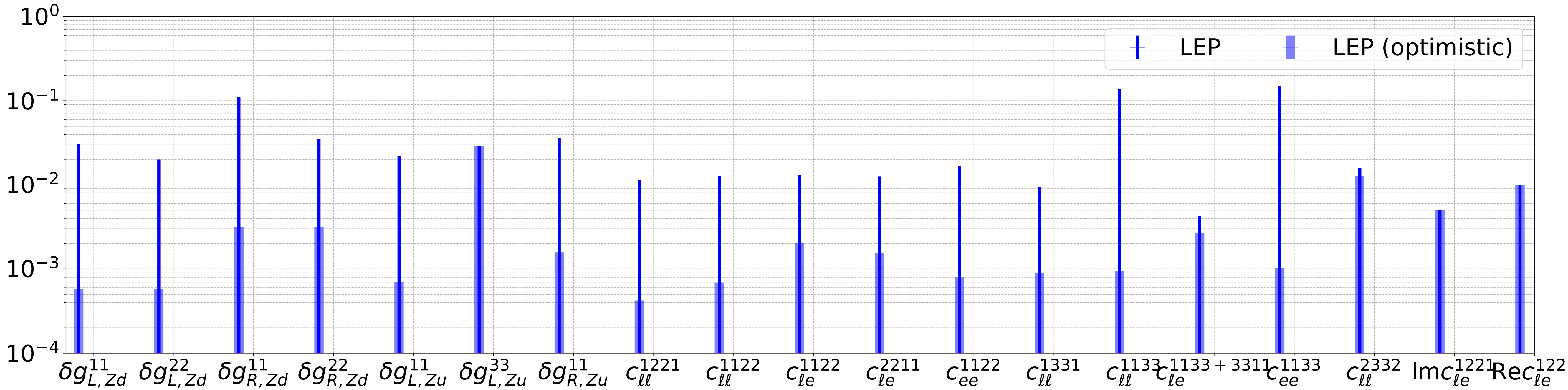
Strategy

Michel parameters from polarized tau decay

Optimistic: One operator at a time.

Conservative: Full correlation among observables are taken into account.





Observables: Future colliders

Future colliders as precision machines

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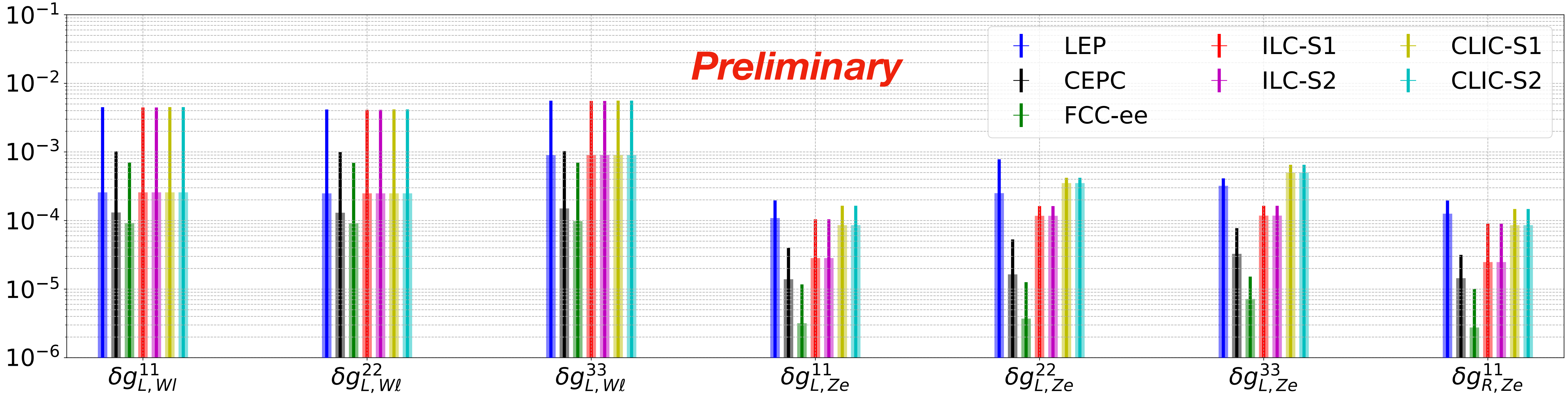
Future colliders as precision machines

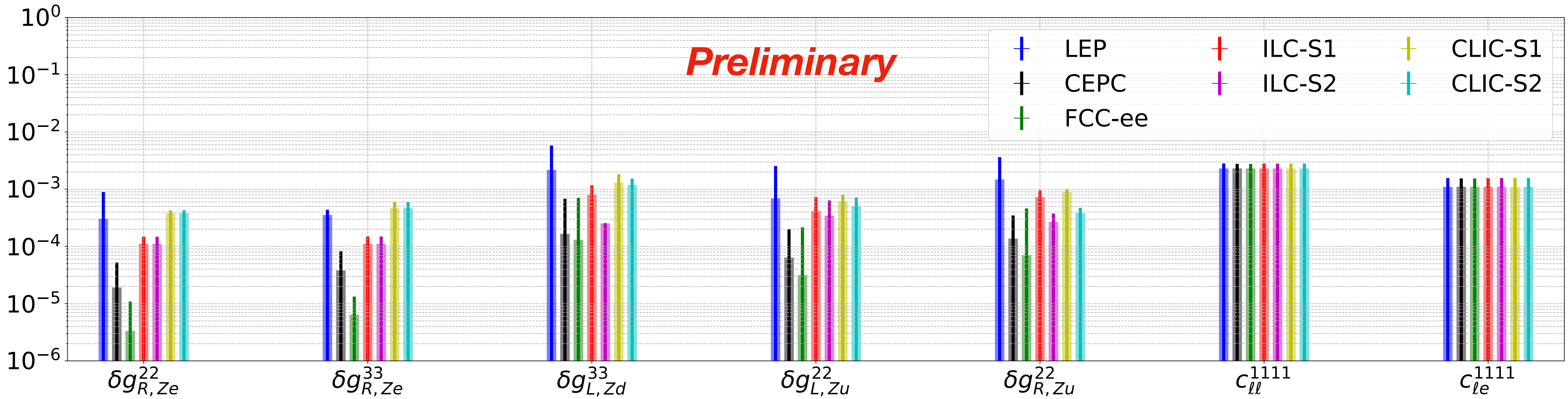
Current and future EWPO uncertainties											
(10^{-3})	L/S	CEPC	FCC-ee	ILC	CLIC	(10^{-3})	L/S	CEPC	FCC-ee	ILC	CLIC
M_Z (GeV)	2.1	0.5	0.1	—	—	A_e**	14.3	—	0.11	1.00	4.20
Γ_Z (GeV)	2.3	0.5	0.1	—	—	A_μ**	102.0	—	0.15	5.41	26.5
$\sigma_{\rm had}$ (nb)	37.0	5.0	5.0	—	—	A_τ**	102.0	—	0.3	5.71	37.4
R_e	2.41	0.6	0.3	1.14	2.70	R_b	3.06	0.2	0.3	1.06	1.76
R_μ	1.59	0.1	0.05	1.14	2.70	R_c	17.4	1.13	1.5	5.03	5.56
R_τ	2.17	0.2	0.1	1.15	5.99	$A_{\rm FB}^{0,b}$	15.5	1.0	—	—	—
$A_{\rm FB}^{0,e}$	154.0	5.0	—	—	—	$A_{\rm FB}^{0,c}$	47.5	3.08	—	—	—
$A_{\rm FB}^{0,\mu}$	80.1	3.0	—	—	—	A_b	21.4	—	3.0	0.64† 3.05	4.03† 4.88
$A_{\rm FB}^{0,\tau}$	104.8	5.0	—	—	—	A_c	40.4	—	8.0	2.12† 8.27	3.01† 8.49
A_e*	33.3	—	—	—	—	A_s	97.3	—	—	—	—
A_τ*	29.2	—	—	—	—	source:	[60, 101]	[69]	[67]		

de Blas, Durieux, Grojean, Gu, Paul, JHEP 2019

Results

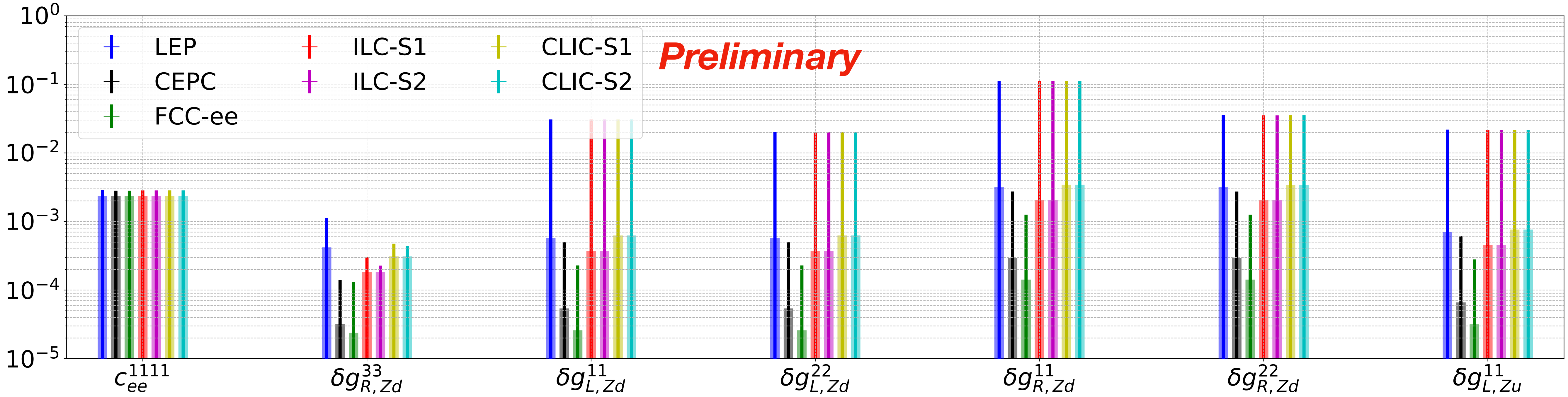


Preliminary
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$\delta g^{11}_{L,Wl}$
$\delta g^{22}_{L,W\ell}$
$\delta g^{33}_{L,W\ell}$
$\delta g^{11}_{L,Ze}$
$\delta g^{22}_{L,Ze}$
$\delta g^{33}_{L,Ze}$
$\delta g^{11}_{R,Ze}$

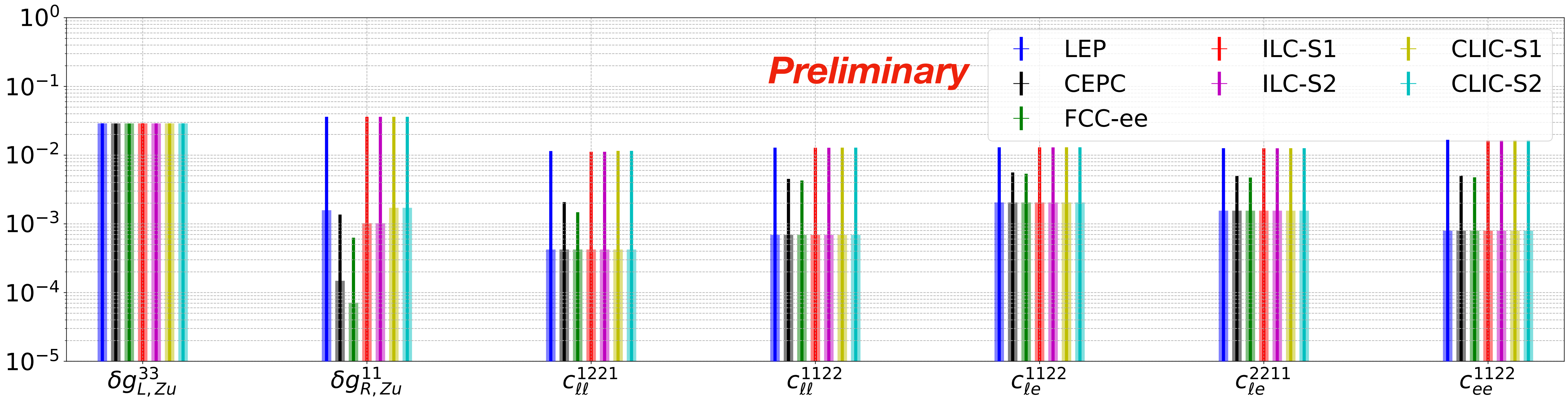


Preliminary
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$\delta g^{22}_{R,Ze}$
$\delta g^{33}_{R,Ze}$
$\delta g^{33}_{L,Zd}$
$\delta g^{22}_{L,Zu}$
$\delta g^{22}_{R,Zu}$
$c^{1111}_{\ell\ell}$
$c^{1111}_{\ell e}$

Results

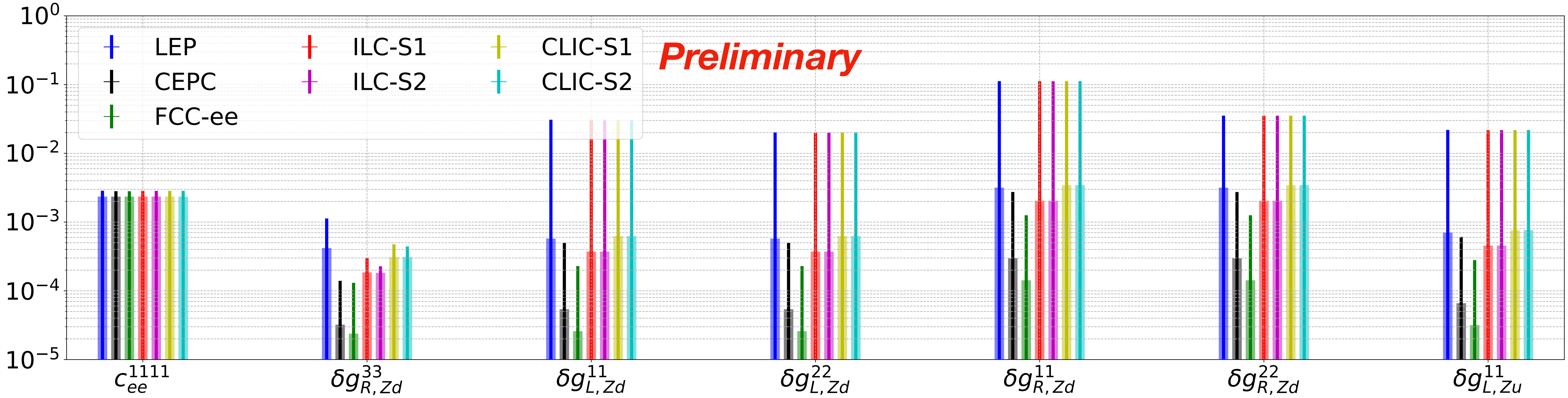


10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
Preliminary
c_{ee}^{1111}
$\delta g_{R,Zd}^{33}$
$\delta g_{L,Zd}^{11}$
$\delta g_{L,Zd}^{22}$
$\delta g_{R,Zd}^{11}$
$\delta g_{R,Zd}^{22}$
$\delta g_{L,Zu}^{11}$

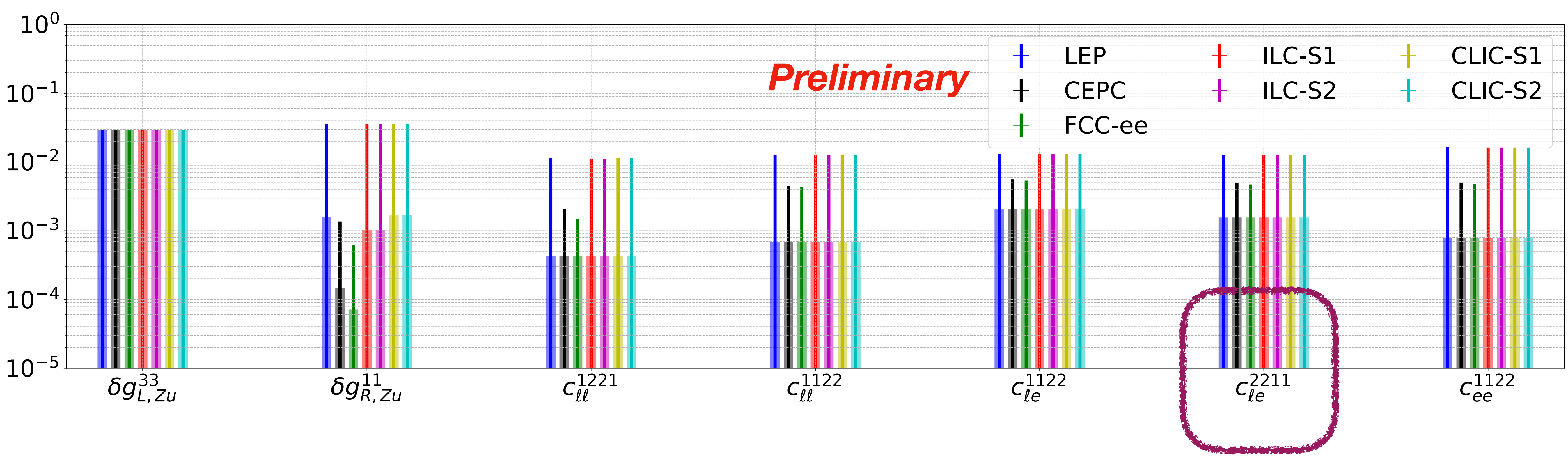


10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
Preliminary
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
$\delta g_{L,Zu}^{33}$
$\delta g_{R,Zu}^{11}$
$c_{\ell\ell}^{1221}$
$c_{\ell\ell}^{1122}$
$c_{\ell e}^{1122}$
$c_{\ell e}^{2211}$
c_{ee}^{1122}

Results



LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
Preliminary
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
c_{ee}^{1111}
$\delta g_{R,Zd}^{33}$
$\delta g_{L,Zd}^{11}$
$\delta g_{L,Zd}^{22}$
$\delta g_{R,Zd}^{11}$
$\delta g_{R,Zd}^{22}$
$\delta g_{L,Zu}^{11}$



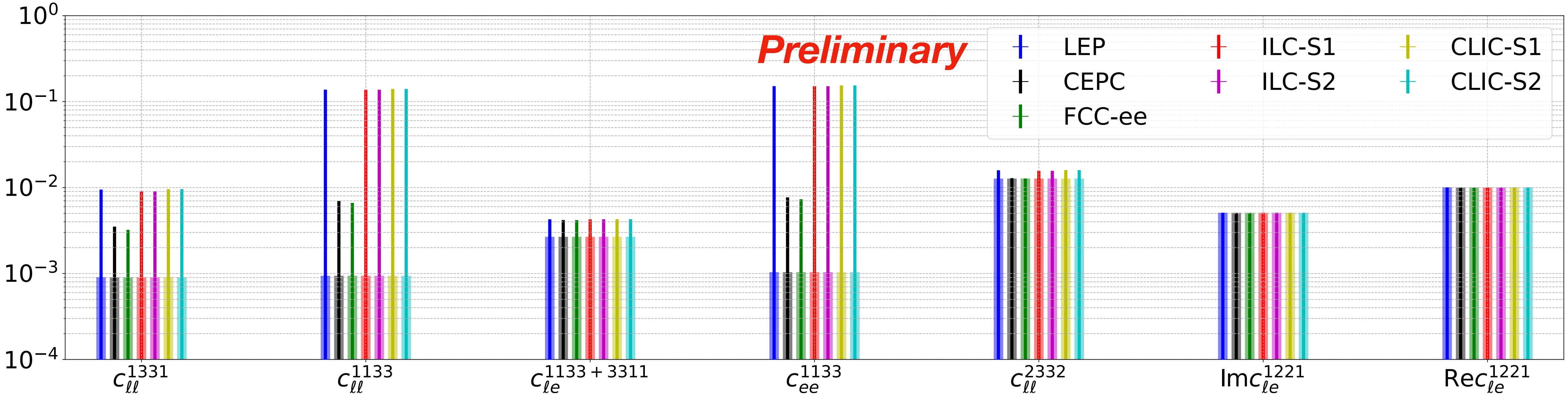
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
Preliminary
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$\delta g_{L,Zu}^{33}$
$\delta g_{R,Zu}^{11}$
$c_{\ell\ell}^{1221}$
$c_{\ell\ell}^{1122}$
$c_{\ell e}^{1122}$
$c_{\ell e}^{2211}$
c_{ee}^{1122}

Correlations

FCC-ee case

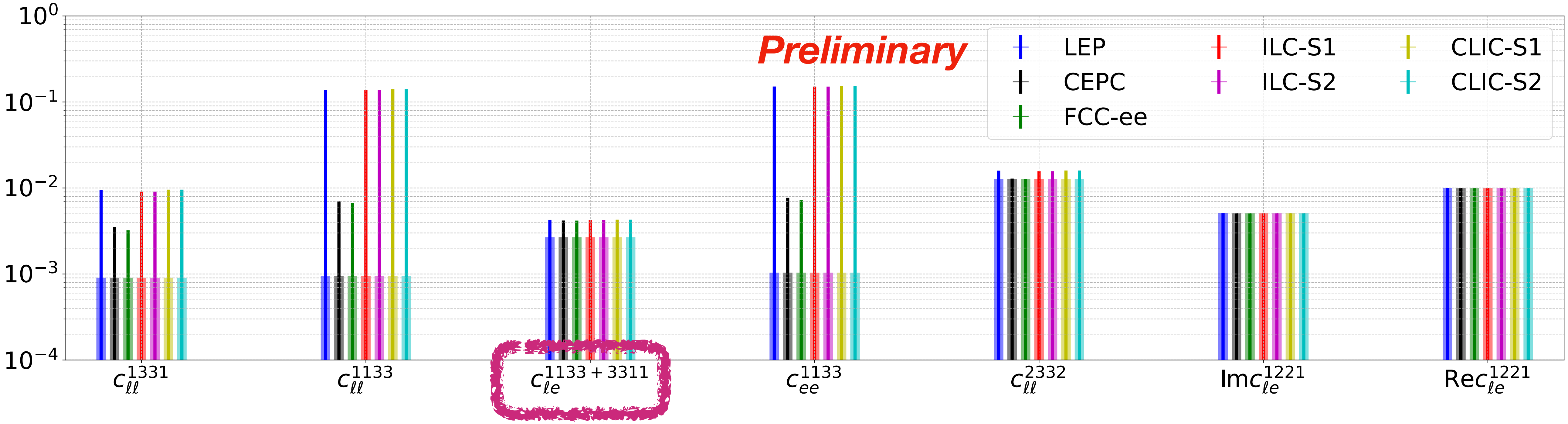
	cLL1221	cLL1122	cLe1122	cLe2211	cee1122	cLL1331	cLL1133	cLe1133PcLe3311	cee1133	cLL2332	ImcLe1221	RecLe1221
δgLWl11	0.477	-0.0309	0.145	-0.163	-0.13	0.182	-0.0438	0.00387	-0.0436	-0.107	-6.59e-07	-1.27e-10
δgLWl22	0.465	-0.116	-0.154	0.181	-0.0415	-0.346	0.0833	-0.00741	0.0828	0.0569	-9.27e-07	-1.42e-10
δgLWl33	-0.881	0.136	0.00333	-0.0111	0.162	0.189	-0.0455	0.00401	-0.0452	0.0604	1.47e-06	-2.09e-10
δgLZe11	-0.114	0.0207	0.00927	-0.012	0.0185	-0.0545	0.0134	-0.00159	0.0132	-0.0171	2.12e-07	9.51e-10
δgLZe22	0.145	-0.0246	-0.01	0.0122	-0.0238	0.0698	-0.0165	0.00113	-0.0165	0.0218	-2.75e-07	-1.56e-09
δgLZe33	0.117	-0.0199	-0.00757	0.00937	-0.0194	0.0564	-0.013	0.000392	-0.0132	0.0176	-2.23e-07	-1.41e-09
δgRZe11	0.113	-0.0205	-0.00925	0.012	-0.0184	0.0541	-0.0133	0.00158	-0.0131	0.0169	-2.1e-07	-9.42e-10
δgRZe22	-0.145	0.0245	0.00978	-0.0119	0.0237	-0.0694	0.0164	-0.00112	0.0165	-0.0217	2.73e-07	1.62e-09
δgRZe33	-0.116	0.0197	0.00743	-0.00921	0.0192	-0.0559	0.0129	-0.000358	0.0131	-0.0174	2.21e-07	1.49e-09
δgRZd33	-0.00812	0.00137	0.000513	-0.000633	0.00135	-0.00388	0.000918	-5.78e-05	0.00092	-0.00122	1.52e-08	7.89e-11
δgLZu22	-0.00772	0.0013	0.000499	-0.000615	0.00128	-0.00396	0.00094	-6.19e-05	0.000937	-0.00123	1.46e-08	7.91e-11
δgRZu22	0.00707	-0.00119	-0.000426	0.00053	-0.00118	0.00316	-0.000749	5.14e-05	-0.000747	0.000999	-1.32e-08	-6.52e-11
cLL1111	0.000195	-3.07e-05	-1.93e-05	2.43e-05	-3.67e-05	9.49e-05	-2.43e-05	-4.37e-07	-2.26e-05	2.96e-05	-9.81e-07	-1.65e-12
cLe1111	-0.000657	0.000115	5.65e-05	-7.24e-05	0.000112	-0.000318	7.94e-05	-5.43e-06	7.62e-05	-9.9e-05	9.13e-07	5.51e-12

Results



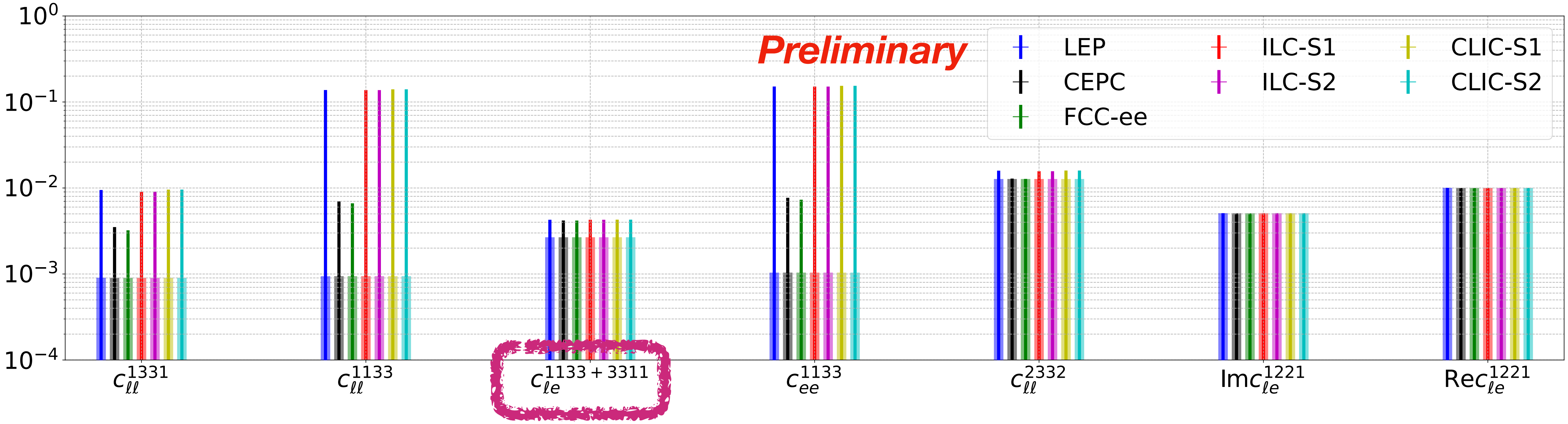
Preliminary
LEP
CEPC
FCC-ee
ILC-S1
ILC-S2
CLIC-S1
CLIC-S2
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$c_{\ell\ell}^{1331}$
$c_{\ell\ell}^{1133}$
$c_{\ell e}^{1133+3311}$
c_{ee}^{1133}
$c_{\ell\ell}^{2332}$
$\mathrm{Im}c_{\ell e}^{1221}$
$\mathrm{Re}c_{\ell e}^{1221}$

Results



Beam polarization @ILC, CLIC

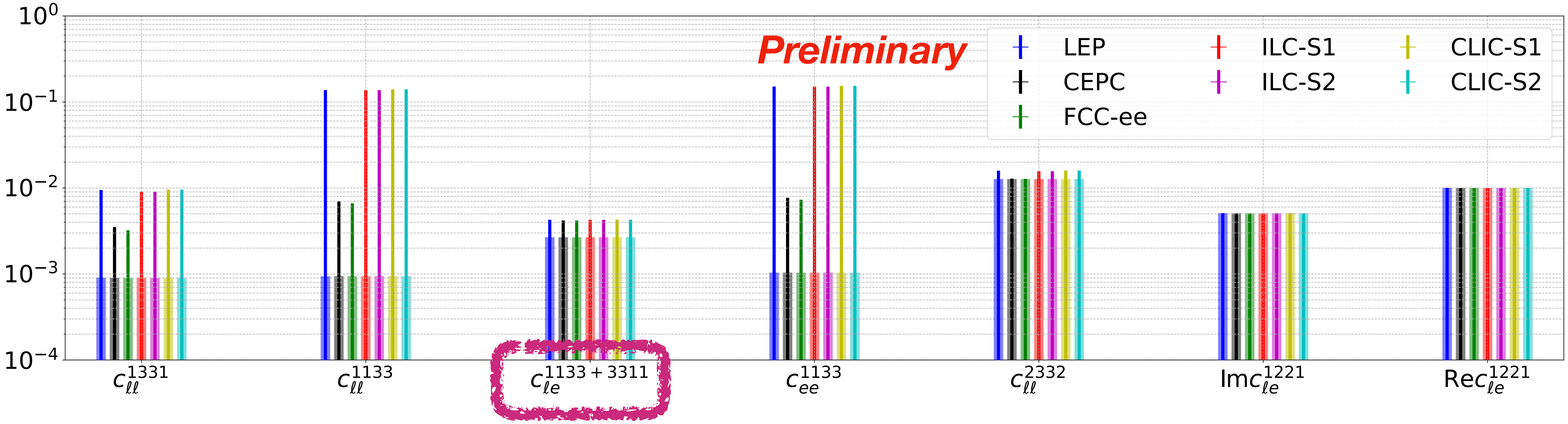
Results



Beam polarization @ILC, CLIC

Projections currently missing, it would be desirable to include them in the fit to lift the flat direction.

Results



Beam polarization @ILC, CLIC

Projections currently missing, it would be desirable to include them in the fit to lift the flat direction.

Currently no constraints on c_i^{2222} operators. Muon collider? ν_μ-μ scattering?

Summary and outlook

- Constraints on Z/W-pole and 4-fermion operators are obtained in the conservative & optimistic scenarios. Constraints from the former are in general weaker than the latter, suggesting measurements of observable correlations.

- Preliminary results are obtained for future colliders (CEPC, FCC-ee, ILC, CLIC). CEPC and FCC-ee dominate measurements of operators considered here.

- For operators considered here, one flat direction exists between (1,3) generation leptons. Beam polarizations at ICL and CLIC will help and it would be desirable to obtain the projections for future colliders.

Backup

Input

#	Input parameters	Exp central value	Refs
1	G_F [GeV^{-2}]	1.16637×10^{-5}	PDG2012
2	m_Z [GeV]	91.1875	LEP-Z
3	$\alpha_{\rm E.M.}(m_Z)$	7.755×10^{-3}	Burkhardt:2011ur

Will be updated for our final global fit result.

Correlations

LEP

	cLL1221	cLL1122	cLe1122	cLe2211	cee1122	cLL1331
cLL1221	1	-0.23	-0.178	0.182	-0.562	-0.396
cLL1122	-0.23	1	-0.739	0.76	-0.673	0.266
cLe1122	-0.178	-0.739	1	-0.972	0.773	0.227
cLe2211	0.182	0.76	-0.972	1	-0.781	-0.234
cee1122	-0.562	-0.673	0.773	-0.781	1	0.0726
cLL1331	-0.396	0.266	0.227	-0.234	0.0726	1

ILCS1

1	-0.225	-0.174	0.178	-0.554	-0.491
-0.225	1	-0.749	0.771	-0.684	0.296
-0.174	-0.749	1	-0.972	0.78	0.25
0.178	0.771	-0.972	1	-0.789	-0.257
-0.554	-0.684	0.78	-0.789	1	0.113
-0.491	0.296	0.25	-0.257	0.113	1

FCCee

1	-0.152	0.00551	0.00177	-0.187	-0.102
-0.152	1	-0.672	0.822	-0.912	0.0328
0.00551	-0.672	1	-0.83	0.743	0.0582
0.00177	0.822	-0.83	1	-0.79	-0.0679
-0.187	-0.912	0.743	-0.79	1	0.00206
-0.102	0.0328	0.0582	-0.0679	0.00206	1

CLICS1

1	-0.238	-0.184	0.189	-0.561	-0.374
-0.238	1	-0.737	0.758	-0.668	0.252
-0.184	-0.737	1	-0.972	0.779	0.215
0.189	0.758	-0.972	1	-0.788	-0.22
-0.561	-0.668	0.779	-0.788	1	0.0703
-0.374	0.252	0.215	-0.22	0.0703	1

CEPC

1	-0.204	-0.00231	0.0127	-0.247	-0.143
-0.204	1	-0.662	0.795	-0.871	0.0584
-0.00231	-0.662	1	-0.844	0.727	0.0994
0.0127	0.795	-0.844	1	-0.768	-0.114
-0.247	-0.871	0.727	-0.768	1	0.00621
-0.143	0.0584	0.0994	-0.114	0.00621	1

Setup validation