Impact of a Z-pole run on Higgs/EW fits

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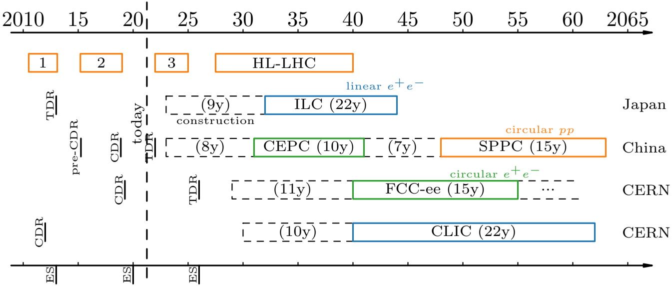
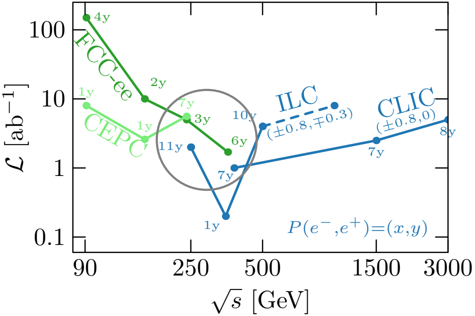
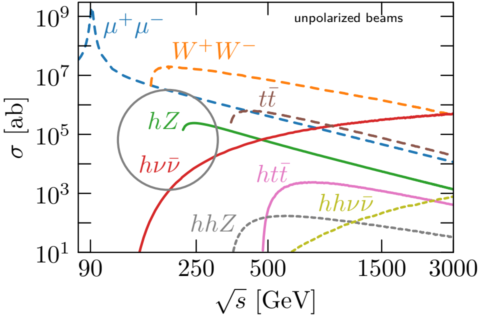
with Jorge de Blas, Christophe Grojean, Jiayin Gu, Ayan Paul

LCWS, 17 March 2021

Future lepton colliders







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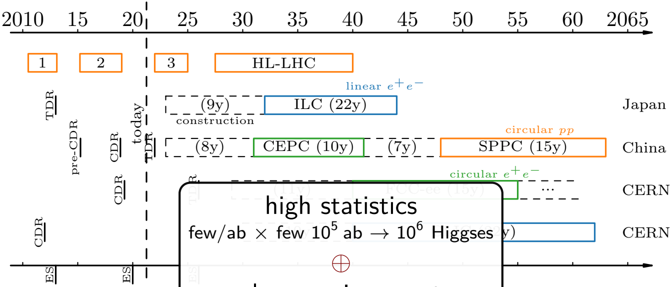


high statistics

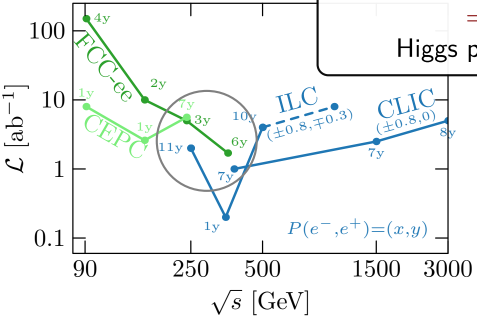
few/ab × few 10^5 ab → 10^6 Higgses

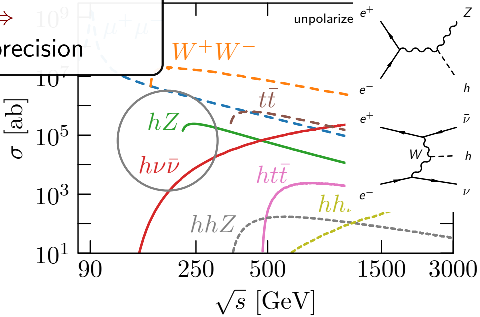
⊕

clean environment

⇒

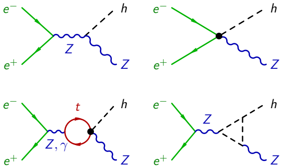
Higgs precision





Higgs/EW interplay

With sub-percent precision on Higgs couplings, current uncertainties on EW parameters should become relevant!



Uncertainties on top-quark param. would become very relevant too (assumed well constrained by HL-LHC and $e^+e^- \to t\,\bar{t}$).

[GD, Gu, Vryonidou, Zhang '18]
[Jung et al '20]

Questions

Impact of EW uncertainties
on Higgs coupling determinations?

Importance of Z-pole and WW-threshold runs?

Mitigation of their absence at linear colliders?

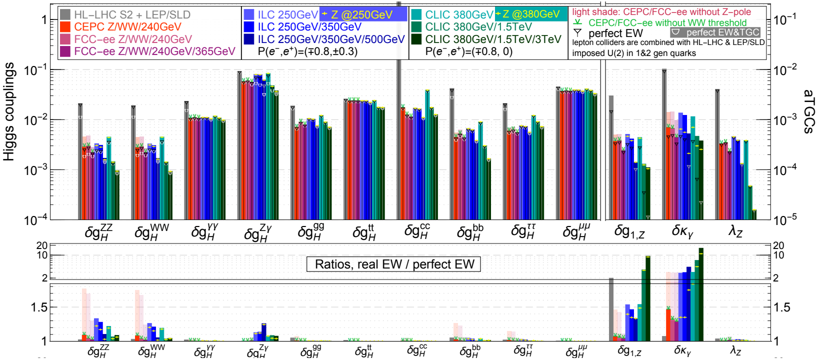
Impact of Higgs measurements
on EW parameters?

Framework: global effective field theory

A global Higgs+EW EFT analysis (13+15 param.)
of CEPC, FCC-ee, ILC and CLIC prospects
combined with existing measurements (incl. LEP/SLC)
and detailed HL-LHC projections.

leaving aside EW top-quark couplings, CP and flavour violation
imposing $U(2)_q \times U(2)_u \times U(2)_d$ among first two quark gen.

Higgs-TGC constaints



15 EW param. also marginalized over / assumed perfectly constrained

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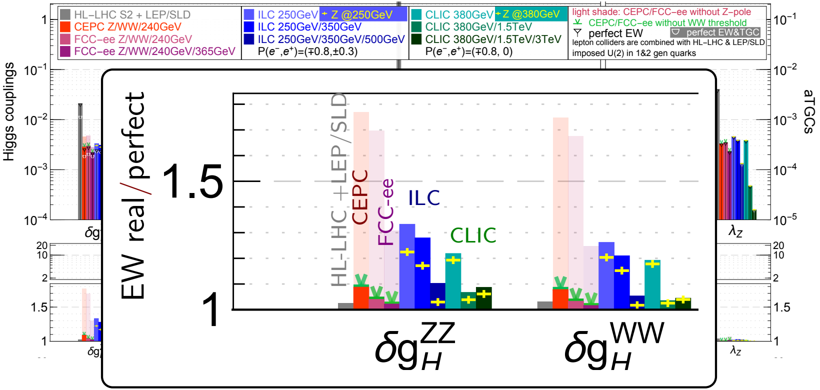

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$$\delta g_H^{ZZ} \equiv \sqrt{\frac{\mathrm{Br}(H\to ZZ^*\to\mathrm{all})}{\mathrm{Br}(H\to ZZ^*\to\mathrm{all})^{\mathrm{SM}}}} - 1$$

$$\delta g_H^{WW} \equiv \sqrt{\frac{\mathrm{Br}(H\to WW^*\to\mathrm{all})}{\mathrm{Br}(H\to WW^*\to\mathrm{all})^{\mathrm{SM}}}} - 1$$

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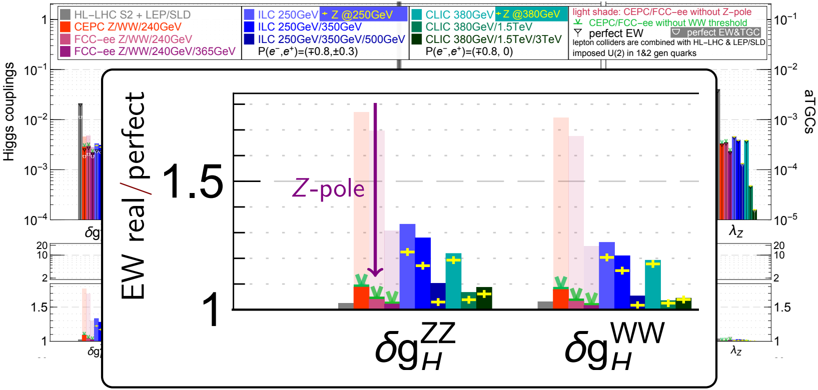

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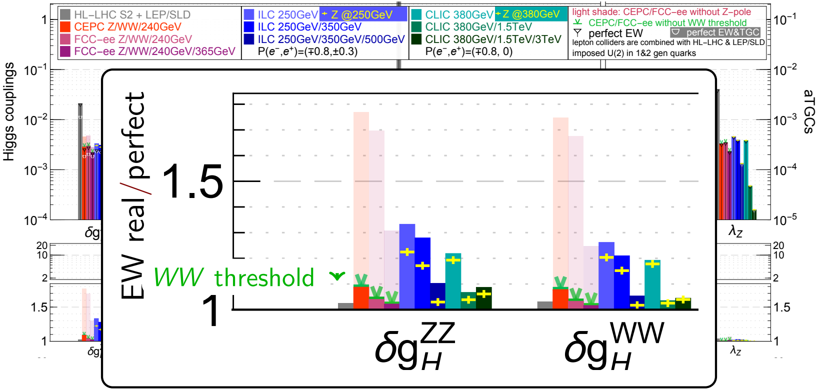

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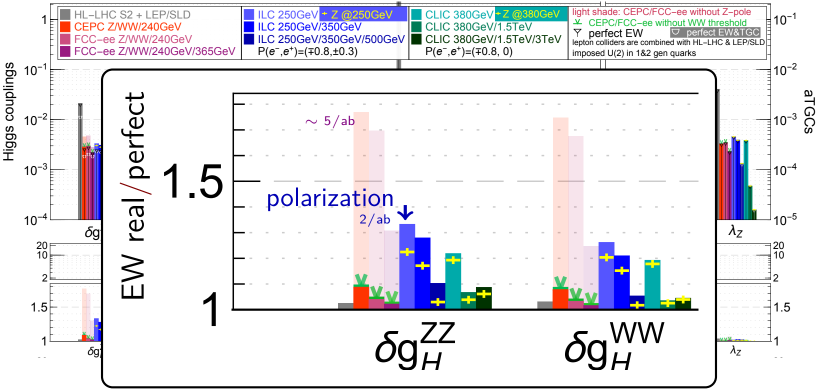

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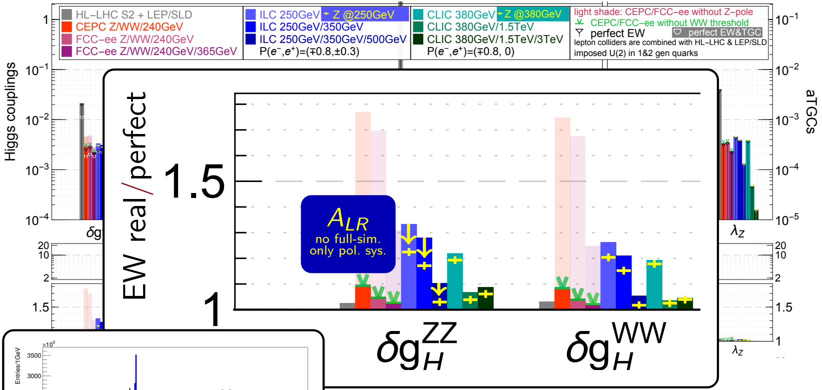

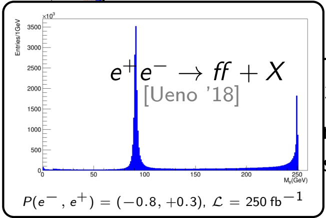

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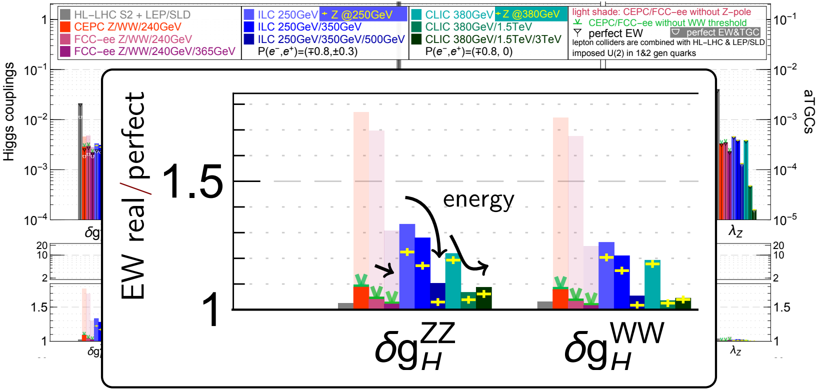

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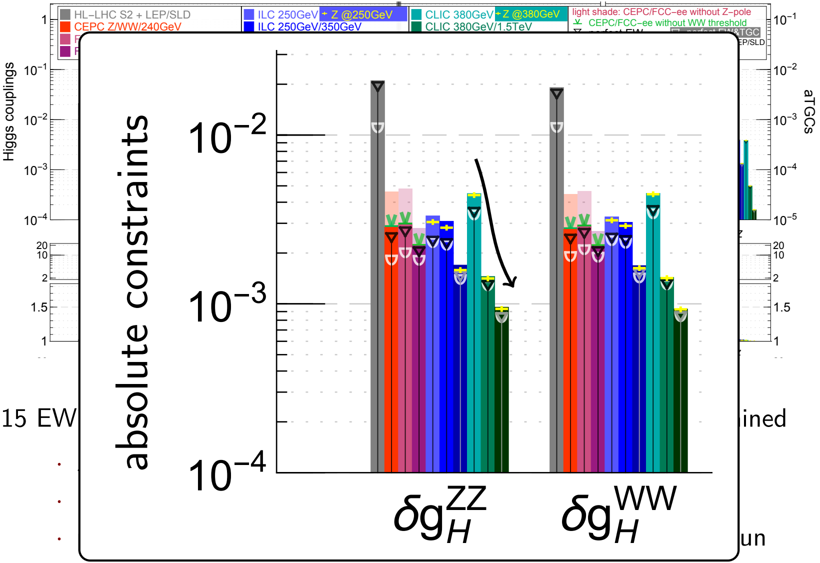

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Giga-Z at linear colliders

LEP: 17×10^6 Z's
SLC: 0.6×10^6 Z's
Tera-Z: 5×10^{12} Z's

radiative return at ILC250: 90×10^6 Z's [LCC Physics WG '19]

$\delta A_{LR}(= A_e) \sim 0.1\%$ stat.+sys. $\sim$SLC/10 (fast sim.) [Ueno '18]

Giga-Z with $100\,\text{fb}^{-1}$ and 30/80% polarization: 5×10^9 Z's

[ECFA WG '19]

Quantity	Current	HL-LHC	FCC-ee	CEPC	ILC Giga-Z	ILC 250 GeV	CLIC Giga-Z	CLIC 380 GeV
δm_{top} [MeV]	$\sim$500 [a)]	$\sim$400 [a)]	20 [b)]	–	–	17 [b)]	–	20-22 [b)]
δM_Z [MeV]	2.1	–	0.1	0.5	–	–	–	–
$\delta\Gamma_Z$ [MeV]	2.3	–	0.1	0.5	1	–	1	–
$\delta\Gamma_{Z\to\text{had}}$ [MeV]	2.0	–	–	–	0.7	–	0.7	–
$\delta\sigma^0_{\text{had}}$ [pb]	37	–	4	5	–	–	–	–
δM_W [MeV]	12	7	0.7	1.0 (2-3) [c)]	–	2.4 [d)]	–	2.5
$\delta\Gamma_W$ [MeV]	42	–	1.5	3	–	–	–	–
$\delta\text{BR}_{W\to e\nu}[10^{-4}]$	150	–	3	3	–	4.2	–	11
$\delta\text{BR}_{W\to\mu\nu}[10^{-4}]$	140	–	3	3	–	4.1	–	11
$\delta\text{BR}_{W\to\tau\nu}[10^{-4}]$	190	–	4	4	–	5.2	–	11
$\delta\text{BR}_{W\to\text{had}}[10^{-4}]$	40	–	1	1	–	–	–	–
δA_e $[10^{-4}]$	140	–	1.1 [e)]	3.2 [e)]	5.1	10	10	42
δA_μ $[10^{-4}]$	1060	–	–	–	5.4	54	13	270
δA_τ $[10^{-4}]$	300	–	3.1 [e)]	5.2 [e)]	5.4	57	17	370
δA_b $[10^{-4}]$	220	–	–	–	5.1	6.4	9.9	40
δA_c $[10^{-4}]$	400	–	–	–	5.8	21	10	30
δA^μ_{FB} $[10^{-4}]$	770	–	0.54	4.6	–	–	–	–
δA^b_{FB} $[10^{-4}]$	160	–	30 [f)]	10 [f)]	–	–	–	–
δA^c_{FB} $[10^{-4}]$	500	–	80 [f)]	30 [f)]	–	–	–	–
δR_e $[10^{-4}]$	24	–	3	2.4	5.4	11	4.2	27
δR_μ $[10^{-4}]$	16	–	0.5	1	2.8	11	2.2	27
δR_τ $[10^{-4}]$	22	–	1	1.5	4.5	12	4.3	60
δR_b $[10^{-4}]$	31	–	2	2	7	11	7	18
δR_c $[10^{-4}]$	170	–	10	10	30	50	23	56
δR_ν $[10^{-3}]$ [g)]	–	–	–	–	–	–	–	9.4
δR_{inv} $[10^{-3}]$ [g)]	–	–	0.27	0.5	–	–	–	–

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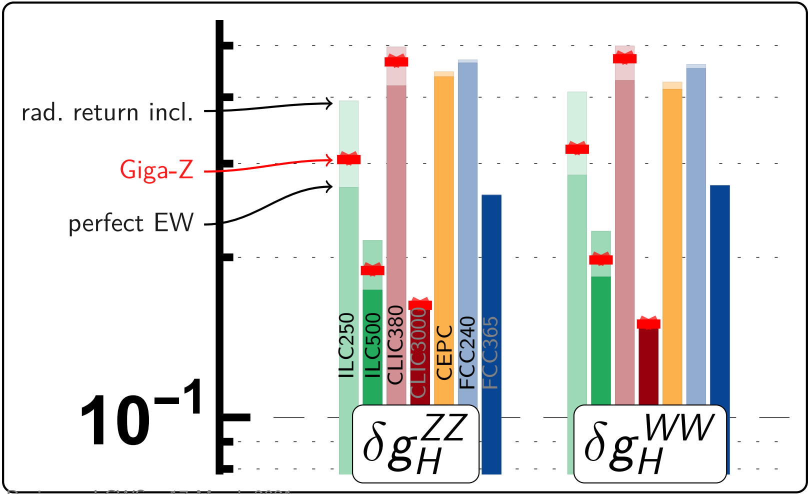
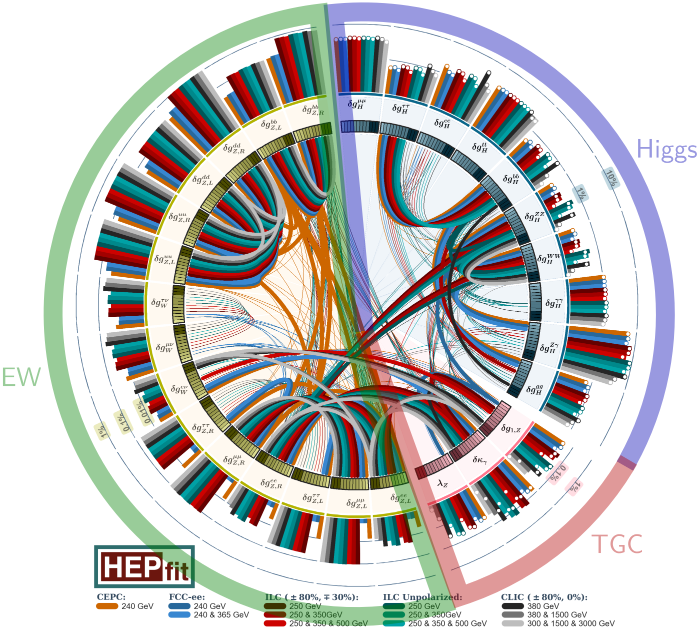


WG '19]

Higgs-TGC / EW correlations



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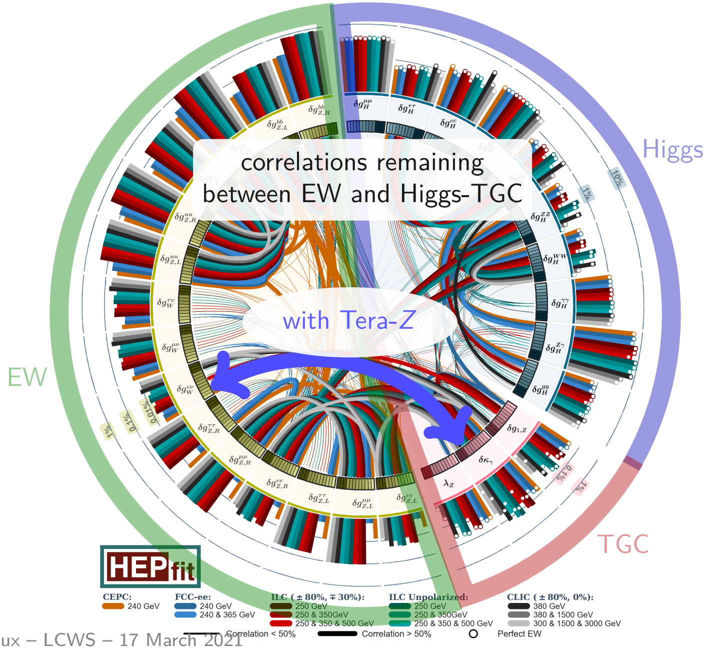

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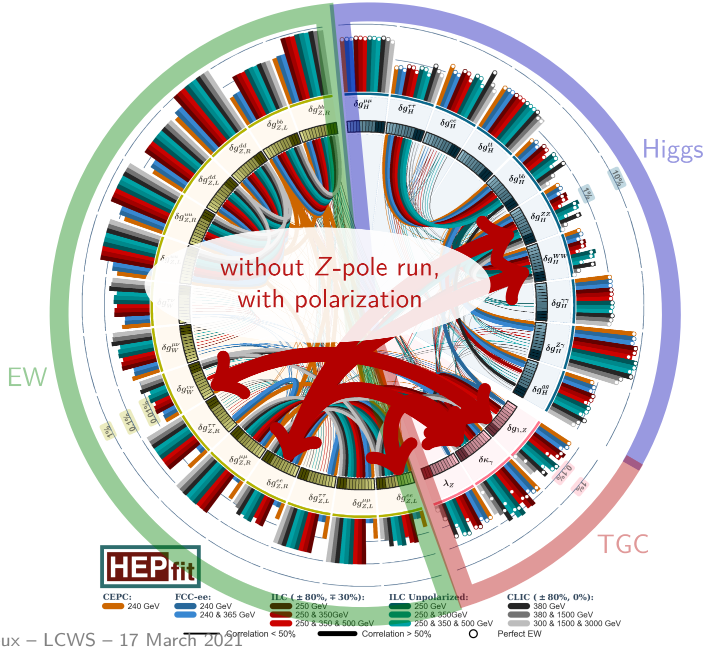

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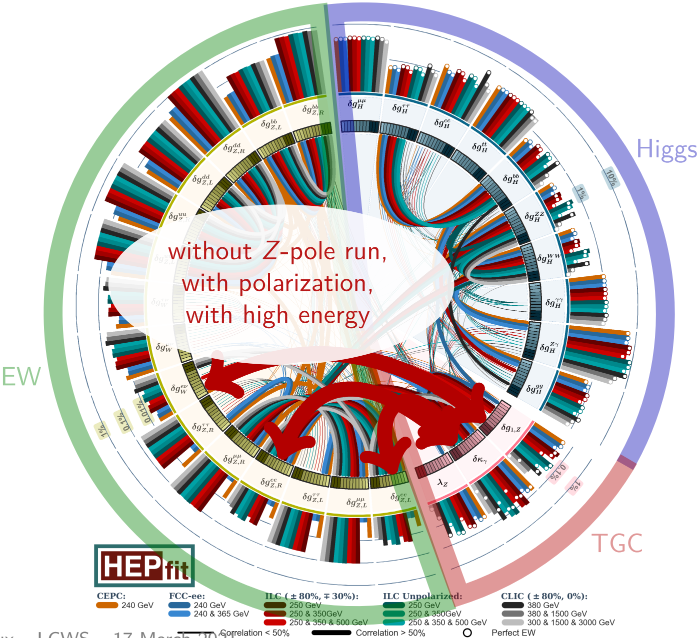
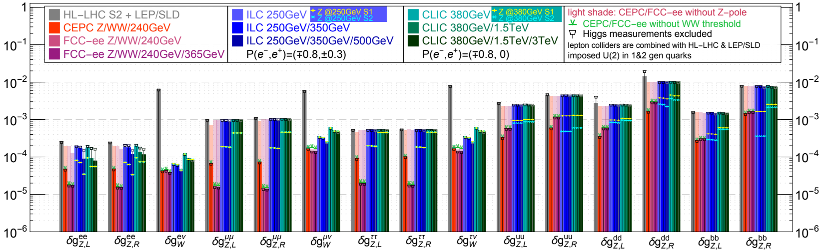


Global EW constraints

15 EW parameters (13 Higgs-TGC ones also marginalized over)



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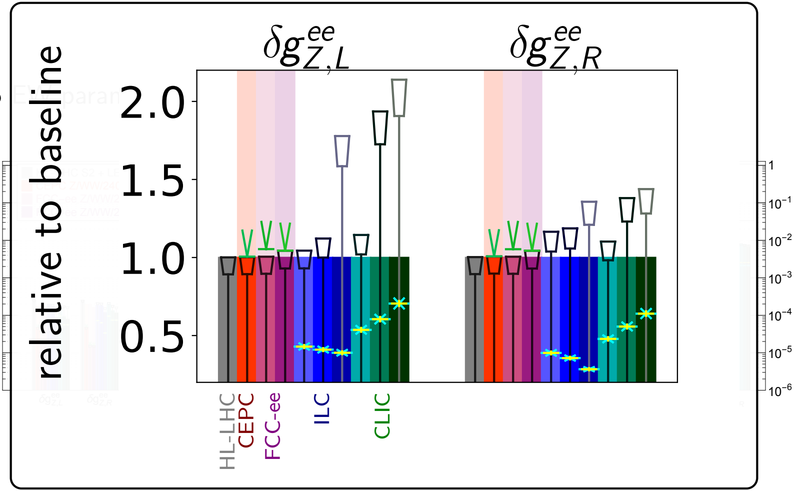

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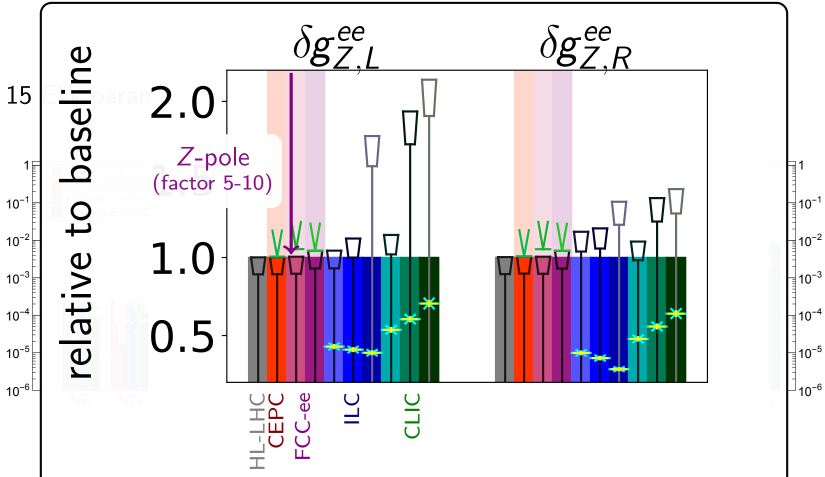

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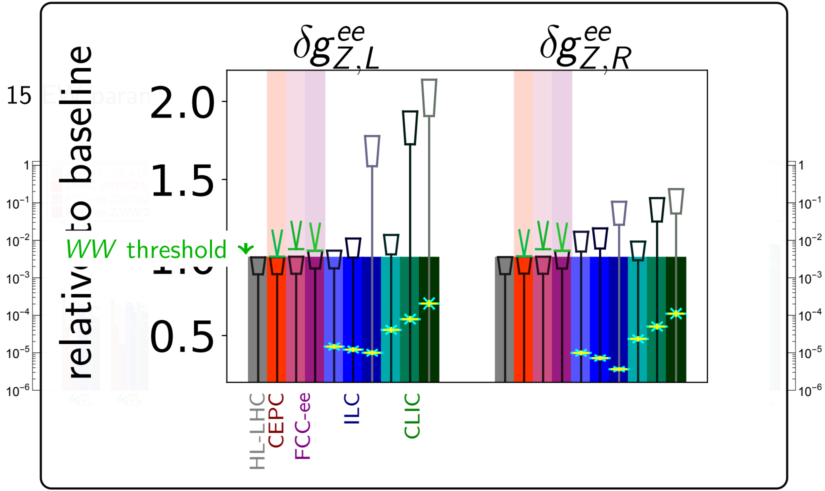

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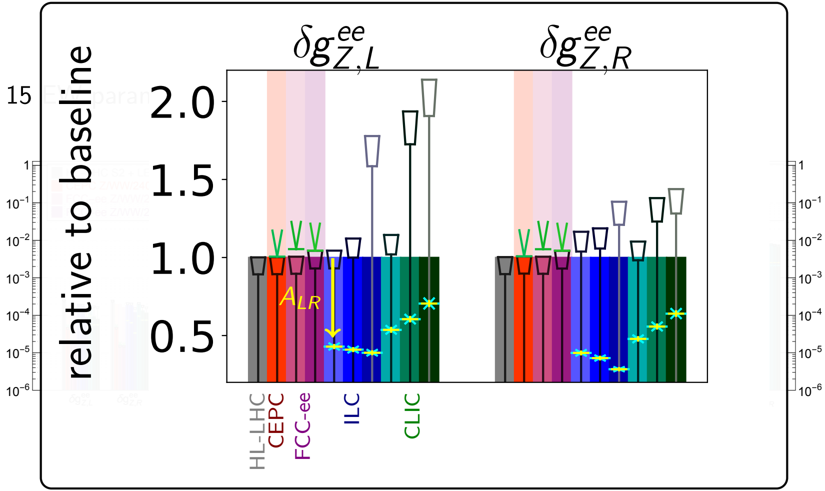

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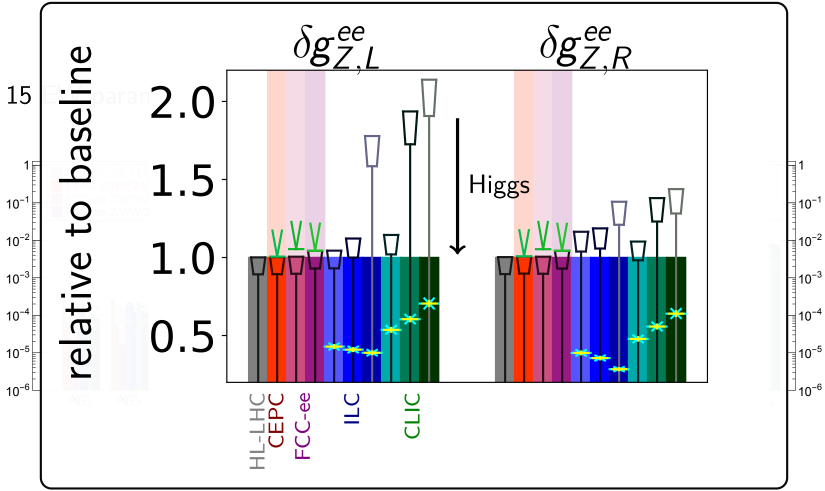

Higgs measurements could help constraining *Zee* at linear colliders,

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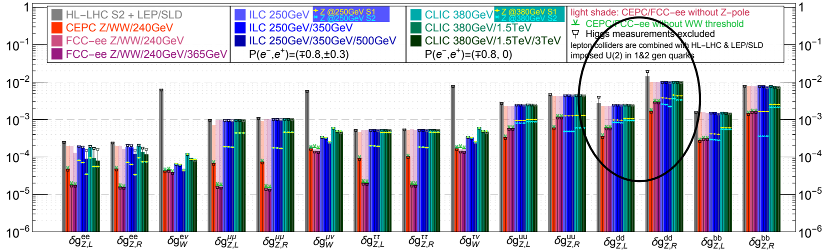

Higgs measurements could help constraining *Zee* at linear colliders, and *Zdd* couplings at the HL-LHC.*

* only diboson and m_W included as EW measurements

Impact of a Z-pole run on Higgs/EW fits

At circular colliders, a Z-pole run is crucial for controlling EW uncertainties in Higgs coupling determinations (a WW threshold run isn't).

At linear colliders, radiative return and high energies help mitigating the possible absence of Z-pole run.

Higgs measurements could otherwise help improving EW parameter determinations.