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Updates on EFT fit

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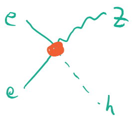
based on current work by J. de Blas, G. Durieux, C. Grojean, JG, A. Paul

Updates

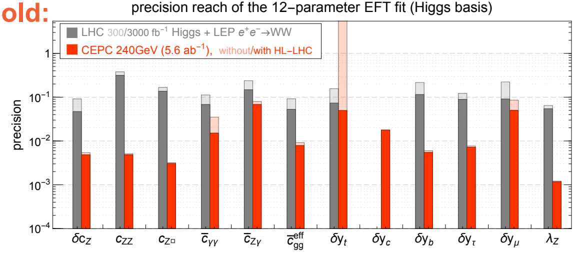
- **HL-LHC**
  - The new Higgs inputs in the LHC WG reports are implemented.
  - Diboson (TGC) measurements at HL-LHC are also implemented. [arXiv:1810.05149] Grojean, Montull, Riembau
- **CEPC**
  - New TGC analysis using optimal observables.
  - Implemented *Z*-pole measurements, *W* mass/width/BR measurements.
- **EFT framework**



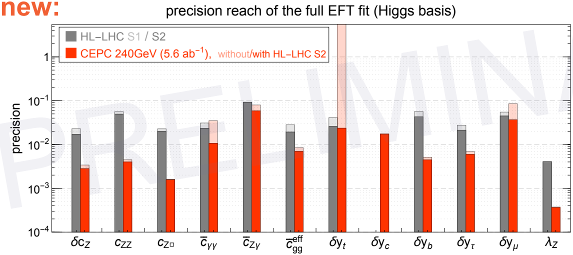
  - Previously we assume perfect EW measurements (*Z*-pole, *W* mass/width/BR).
  - Now we have implemented realistic EW measurements (and included the relevant operators).
  - Can the CEPC *Z*-pole measurements constrain the relevant operators well enough so they do not have an impact on the Higgs processes? (**Yes!**)

old *vs.* new (Higgs basis)

old:



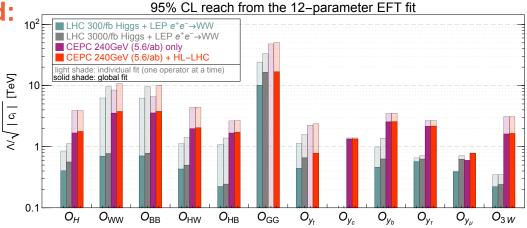
new:



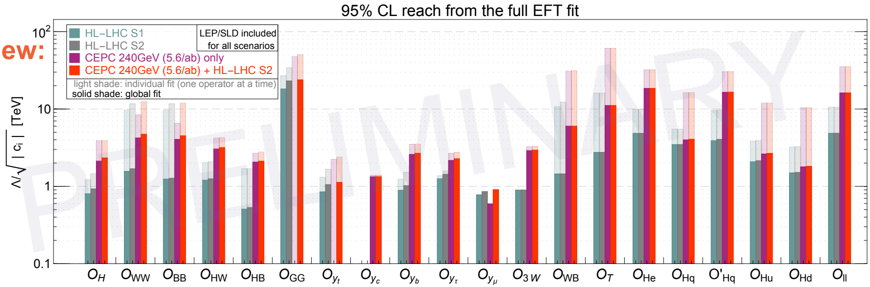
- Full fit: only the Higgs parameters are shown.
- HL-LHC: ATLAS and CMS are combined. (The correlation between ATLAS/CMS are not provided by the WG.)

old *vs.* new (D6 operators)

old:



new:



- R_c, $A^c_{\rm FB}$ still missing
- Flavor universality imposed on gauge couplings for now (can be removed later).

D6 operators

$\mathcal{O}_H = \frac{1}{2}(\partial_\mu \lvert H^2 \rvert)^2$	$\mathcal{O}_{GG} = g_s^2 \lvert H\rvert^2 G^A_{\mu\nu} G^{A,\mu\nu}$
$\mathcal{O}_{WW} = g^2 \lvert H\rvert^2 W^a_{\mu\nu} W^{a,\mu\nu}$	$\mathcal{O}_{y_u} = y_u \lvert H\rvert^2 \bar{Q}_L \tilde{H} u_R + \text{h.c.}$ $\quad (u \to t, c)$
$\mathcal{O}_{BB} = g'^2 \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}_{y_d} = y_d \lvert H\rvert^2 \bar{Q}_L H d_R + \text{h.c.}$ $\quad (d \to b)$
$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$	$\mathcal{O}_{y_e} = y_e \lvert H\rvert^2 \bar{L}_L H e_R + \text{h.c.}$ $\quad (e \to \tau, \mu)$
$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$	$\mathcal{O}_{3W} = \frac{1}{3!} g \epsilon_{abc} W^{a\,\nu}_\mu W^b_{\nu\rho} W^{c\,\rho\mu}$
$\mathcal{O}_{WB} = gg' H^\dagger \sigma^a H W^a_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}^{ij}_{H\ell} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{\ell}_i \gamma^\mu \ell_j$
$\mathcal{O}_T = \frac{1}{2}(H^\dagger \overleftrightarrow{D}_\mu H)^2$	$\mathcal{O}'^{ij}_{H\ell} = iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H \bar{\ell}_i \sigma^a \gamma^\mu \ell_j$
$\mathcal{O}_{\ell\ell} = (\bar{\ell}\gamma^\mu \ell)(\bar{\ell}\gamma_\mu \ell)$	$\mathcal{O}^{ij}_{He} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{e}_i \gamma^\mu e_j$
$\mathcal{O}^{ij}_{Hq} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{q}_i \gamma^\mu q_j$	$\mathcal{O}^{ij}_{Hu} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{u}_i \gamma^\mu u_j$
$\mathcal{O}'^{ij}_{Hq} = iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H \bar{q}_i \sigma^a \gamma^\mu q_j$	$\mathcal{O}^{ij}_{Hd} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{d}_i \gamma^\mu d_j$

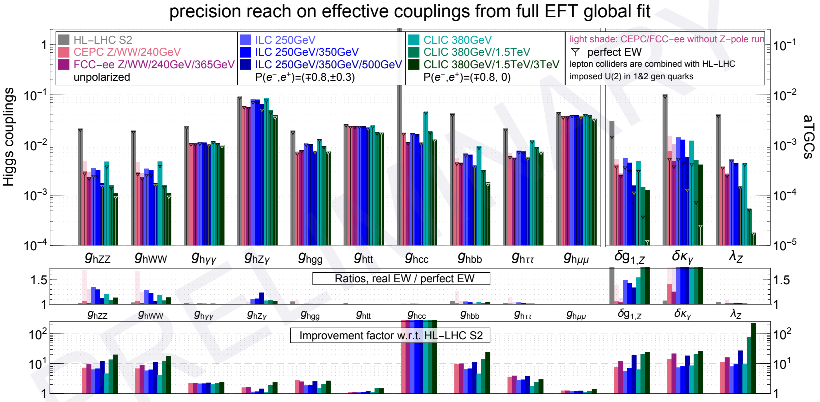
- “Modified SILH’ basis” ($O_W,\ O_B \to O_{WW},\ O_{WB}$)
- $\mathcal{O}^{11}_{Hl}$ and $\mathcal{O}'^{11}_{Hl}$ are eliminated via e.o.m. in this basis.
- Flavor Universality assumption (for gauge couplings): $c^{11} = c^{22} = c^{33}$, $c^{ij} = 0$ for $i \neq j$.

Basis choice

- In the CDR:
  - Higgs basis $\Leftrightarrow$ Higgs coupling precision
  - D6 operator basis (modified SILH') $\Leftrightarrow$ new physics scales
- Effective couplings ("Peskin basis", [arXiv:1708.08912], [arXiv:1708.09079], Peskin *et. al.*)
  - $g(hZZ)$, $g(hWW)$ defined at the scale of the relavent Higgs decay ($h \to ZZ$, $h \to WW$).
  - Used in ILC and FCC-ee official documents.
  - **It looks like κ but it is not κ!**
- Replace Higgs basis with "Peskin basis"? In any case, we can decide later...

Updated results for all colliders

current work, J. de Blas, G. Durieux, C. Grojean, JG, A. Paul



- FCC 240GeV($5\,\mathrm{ab}^{-1}$) + 350GeV($0.2\,\mathrm{ab}^{-1}$) + 365GeV($1.5\,\mathrm{ab}^{-1}$)
  ILC 250GeV($2\,\mathrm{ab}^{-1}$) + 350GeV($0.2\,\mathrm{ab}^{-1}$) + 500GeV($4\,\mathrm{ab}^{-1}$)
  CLIC 380GeV($1\,\mathrm{ab}^{-1}$) + 1.5TeV($2.5\,\mathrm{ab}^{-1}$) + 3TeV($5\,\mathrm{ab}^{-1}$)

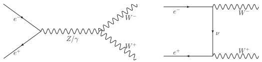
Conclusion

- HL-LHC numbers are better, but the overall picture is not changed.
- For the Higgs coupling measurements, the CEPC Z-pole run is “good enough” to constrain the EW operators that enters the Higgs processes.
- Some important advantages of CEPC are not reflected in the EFT framework. (Higgs total width measurement, Higgs exotic decays...)

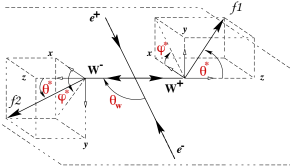
backup slides

A refined TGC analysis using Optimal Observables

- TGCs are sensitive to the differential distributions!
  - Current method: fit to binned distributions of all angles.
  - Correlations among angles are ignored.

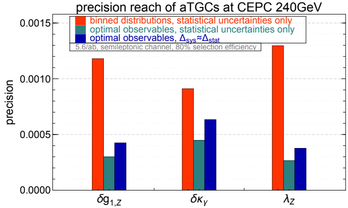


- What are optimal observables?
  (See *e.g.* Z.Phys. C62 (1994) 397-412 Diehl & Nachtmann)
  - For a given sample, there is an upper limit on the precision reach of the parameters.
  - In the limit of large statistics (everything is Gaussian) and small parameters (leading order dominates), this "upper limit" can be derived analytically!

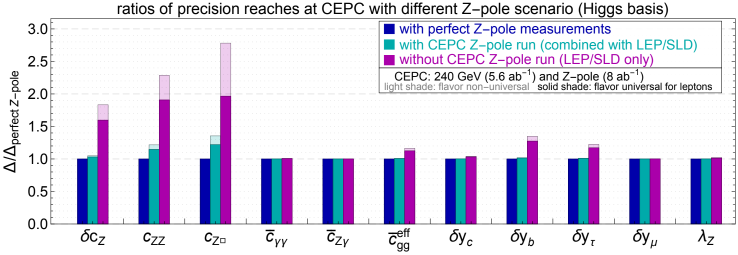


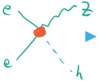
- $\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}|_{\rm SM} + \sum_i S(\Omega)_i\, g_i$. The optimal observables are simply the $S(\Omega)_i$.

- Very idealized! How well can we actually do?
  - Assume $\Delta_{\rm sys} \approx \Delta_{\rm stat}$?



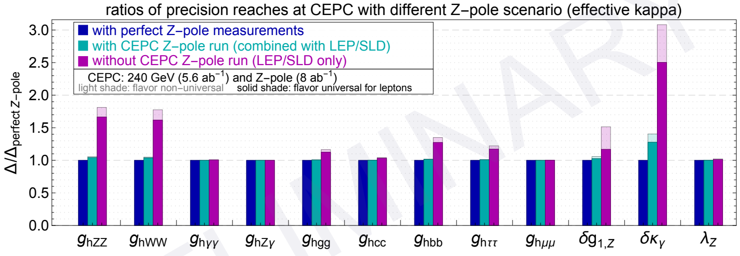
Results on Higgs couplings (Comparison with the perfect Z-pole case)





- The *hZee* contact interactions grow with energy, so they have a larger impact on the $e^+e^- \to hZ$ production.
- The *Zee* couplings also enter $e^+e^- \to WW$ and affect the reaches on aTGCs.
- The *hZZ* and *hWW* couplings are constrained less well.
- $\Delta g(hWW) \uparrow \quad \Rightarrow \quad \Delta\Gamma_{h\to WW} \uparrow \quad \Rightarrow \quad \Delta g(hbb) \uparrow$

In terms of effective couplings ("Peskin" basis)



- $\Gamma_{h\to WW}$ has a sizable contribution to the Higgs total width, which has an impact on the extraction of other couplings (in particular g_{hbb}).
- Also note the impacts on aTGCs.

How about the *WW* threshold run?

- The *WW* threshold hold run has a small impact in our EFT fit.
- m_W can also be measured relatively well at 240 GeV (2-3 MeV).
- Γ_W can be constrained indirectly by *WW* measurements at 240 GeV, assuming *W* has no exotic decays.
- The threshold run is not so sensitive to the aTGCs. ($e^+e^- \to WW$ is dominated by the *t*-channel diagram near the threshold.)