HEPfit: The Bayesian MCMC for HEP

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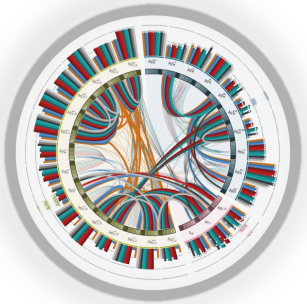
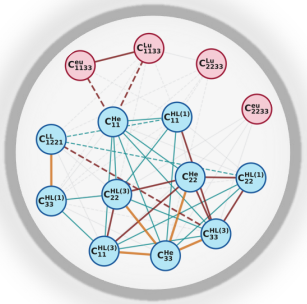
The **HEPfit** Framework: The power to combine knowledge



Some recent results in EW and Higgs Physics



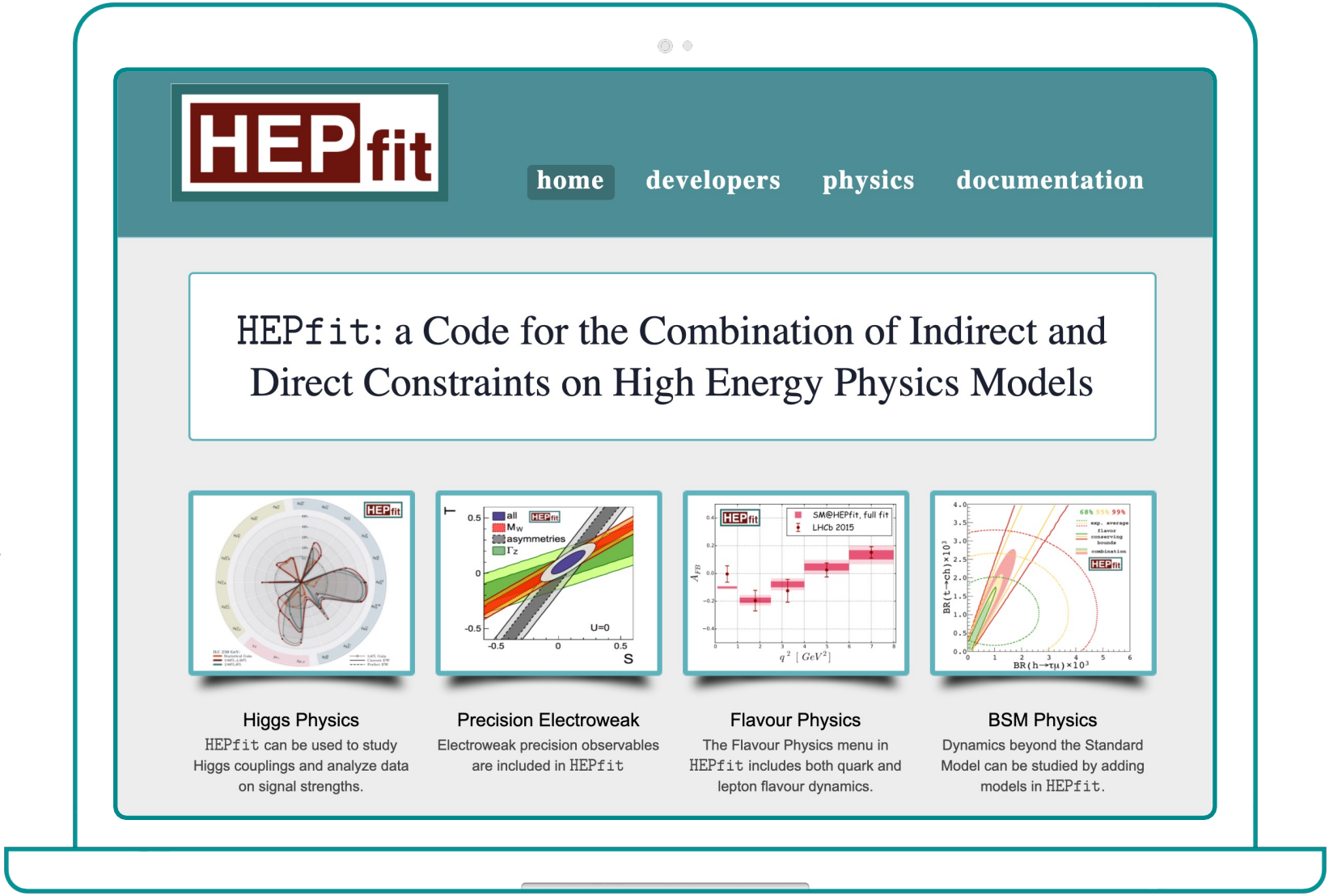
Some recent results in EW and Flavour Physics

The **HEPfit** Framework:
The power to combine knowledge

J. de Blas et. al., HEPfit, a code for the combination of indirect and direct constraints on high energy physics models, *Eur. Phys. J. C 80 (2020) 5, 456, arXiv:1910.14012*

HEPfit

http://hepfit.roma1.infn.it



J. de Blas et. al., HEPfit, a code for the combination of indirect and direct constraints on high energy physics models, *Eur. Phys. J. C* 80 (2020) 5, 456, arXiv: 1910.14012

the program

- ✓ an analysis tool for direct and indirect observables
- ✓ comes with Bayesian Analysis Tool based on Markov Chain Monte Carlo
- ✓ SM and BSM arranged modularly for extraction of model-based computations
- ✓ possibilities of adding user-generated models of new dynamics
- ✓ possibilities of adding user-defined observables
- ✓ possibilities of performing any choice of statistical analysis using the library
- ✓ a handy tool for getting very quick estimates and doing full-fledged statistical analyses
- ✓ deployable both on clusters and multicore CPUs for large statistical analyses.
- ✓ equally friendly for all level of users and developers (doxygened in detail)

the philosophy

everyone gets a candy they like:

- we offer a variety of interfaces that can cater to beginners, advanced users and developers
- a variety of NP models and observables will be included, and the developers can add more

statistical precision requires large samples:

- a lot of focus has been put on speed with extensive caching built in
- built-in MPI parallelization for deployment on large clusters

open source and open for customization:

- source is in the release phase under GPL with extensive documentation
- working developer version always available through git

observables menu

- **Unitarity triangle observables** (tested against UTFit)

  UT angles, $\Delta F = 2$ amplitudes, CKM elements

- **rare decays** (under development)

  $B \to X_s\gamma,\ B \to K^*\gamma$ (in progress)

  $B \to X_s\ell^+\ell^-,\ B \to K\ell^+\ell^-$ (in progress)

  $B \to K^*\ell^+\ell^-$

  $B_{s,d} \to \mu^+\mu^-$

  $K \to \pi\nu\bar{\nu}$ (in progress)

  $K \to \mu^+\mu^-$ (in progress)

  $\tau \to \mu\gamma,\ \tau \to 3\ell$ (+other LFV processes, in progress)

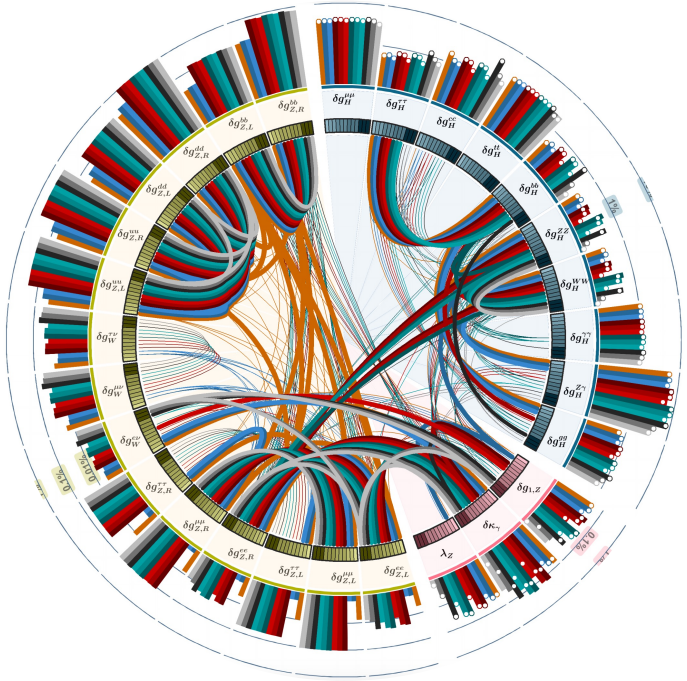
- **non-leptonic decays** (under development)

  $B \to PP,\ PV$ (in progress)

  ϵ'/ϵ (in progress)

Processes	Standard Model	THDM	MSSM	H_{eff}
$\Delta B = 2$	✓	✓	○	○
$\Delta S = 2$	✓		○	○
$B \to \tau\nu$	✓	✓	○	○
$B \to D^{(*)}\tau\nu$	○	✓		○
$B_{s/d} \to \mu\mu$	✓	○	○	○
rare K decays	○			○
$B \to X_s\gamma$	✓	✓	○	○
$B \to V\gamma$	✓			○
$B \to P/V\ell^+\ell^-$	✓			○
$B \to X_s\ell^+\ell^-$	○			○
$B \to PP/PV$	○			○
$l_i \to l_j\gamma$			✓	
$l_i \to 3l_j$			✓	
$(g-2)_\mu$			✓	

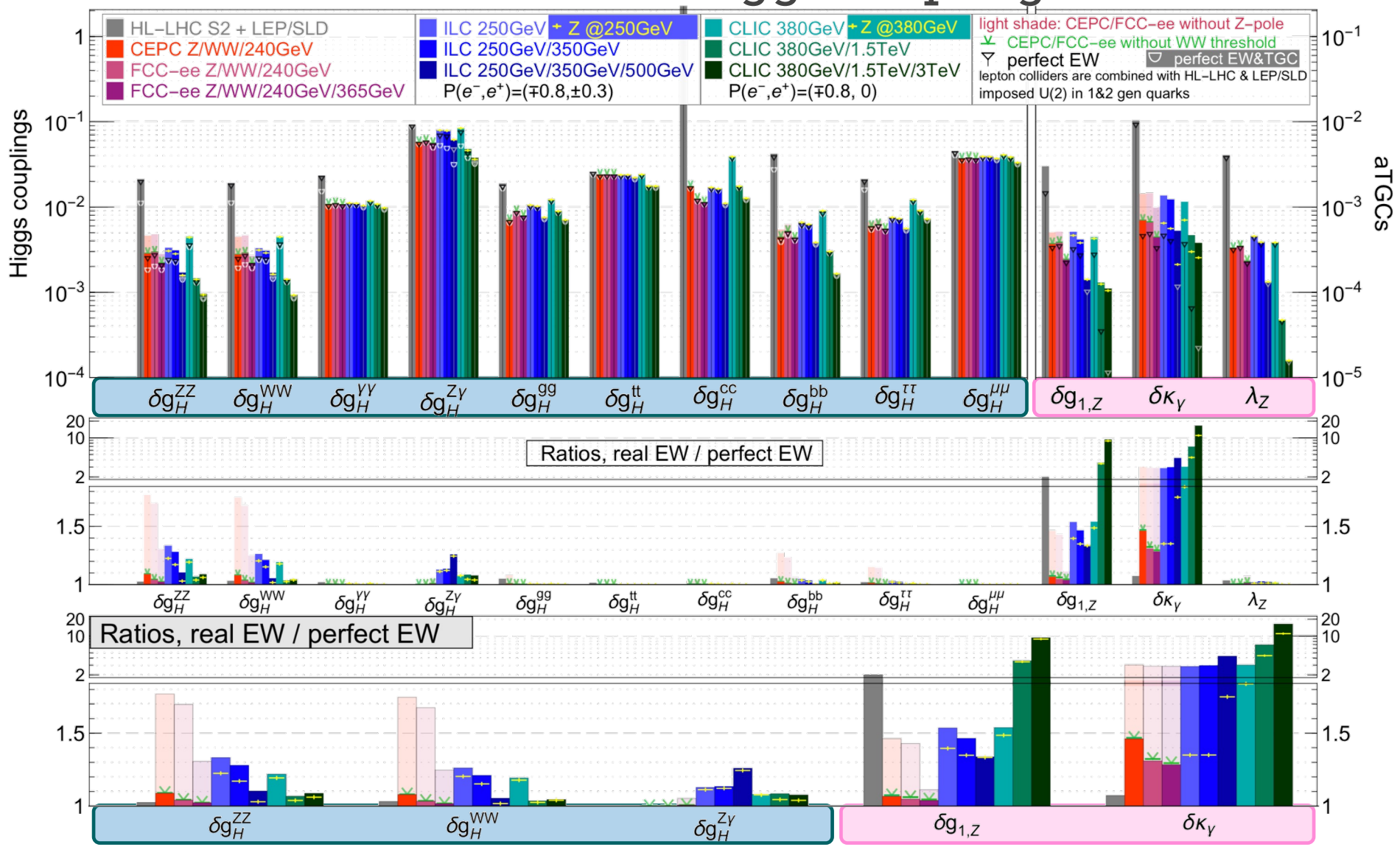
○ work in progress
✓ (almost) completed



Some recent results in EW and Higgs Physics

J. de Blas, G. Durieux, C. Grojean, J. Gu and A. Paul, On the future of Higgs, electroweak and diboson measurements at lepton colliders, *JHEP 12 (2019) 117, arXiV:1907.04311*

Constraints on Higgs couplings



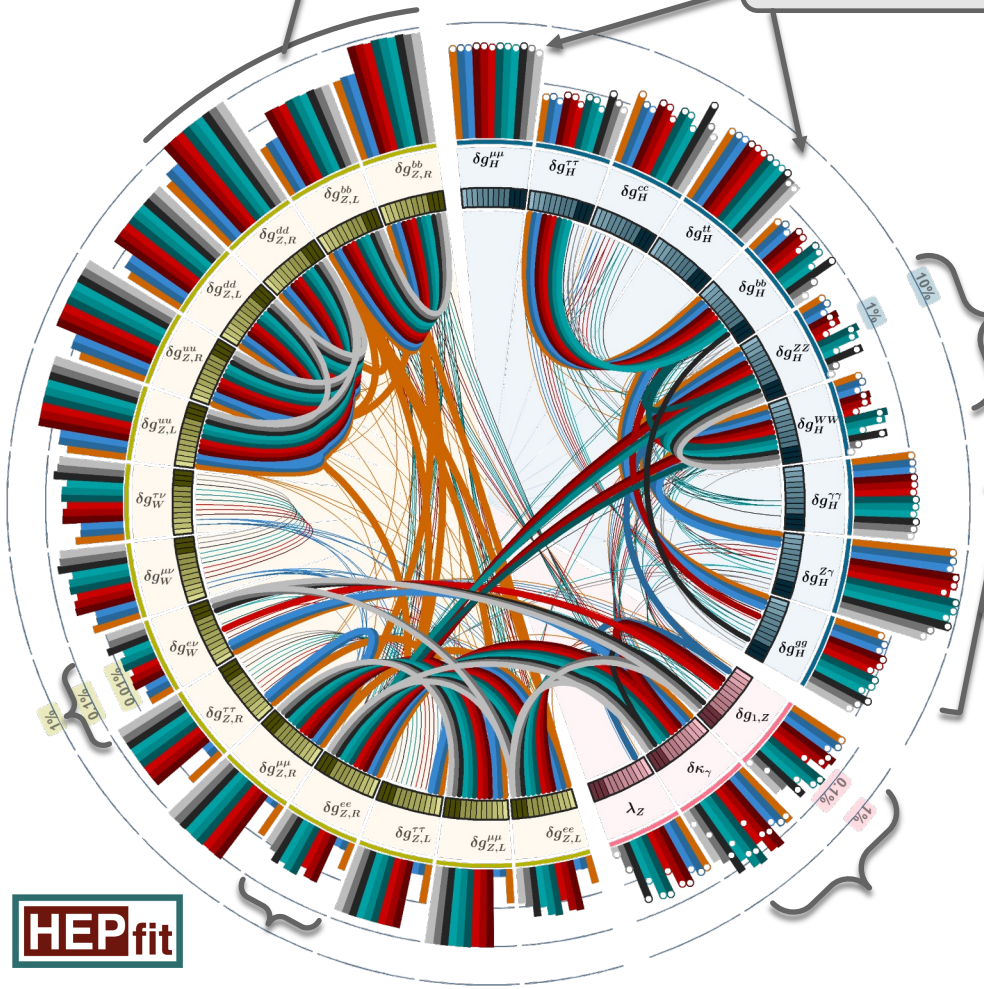
Correlations between the different sectors

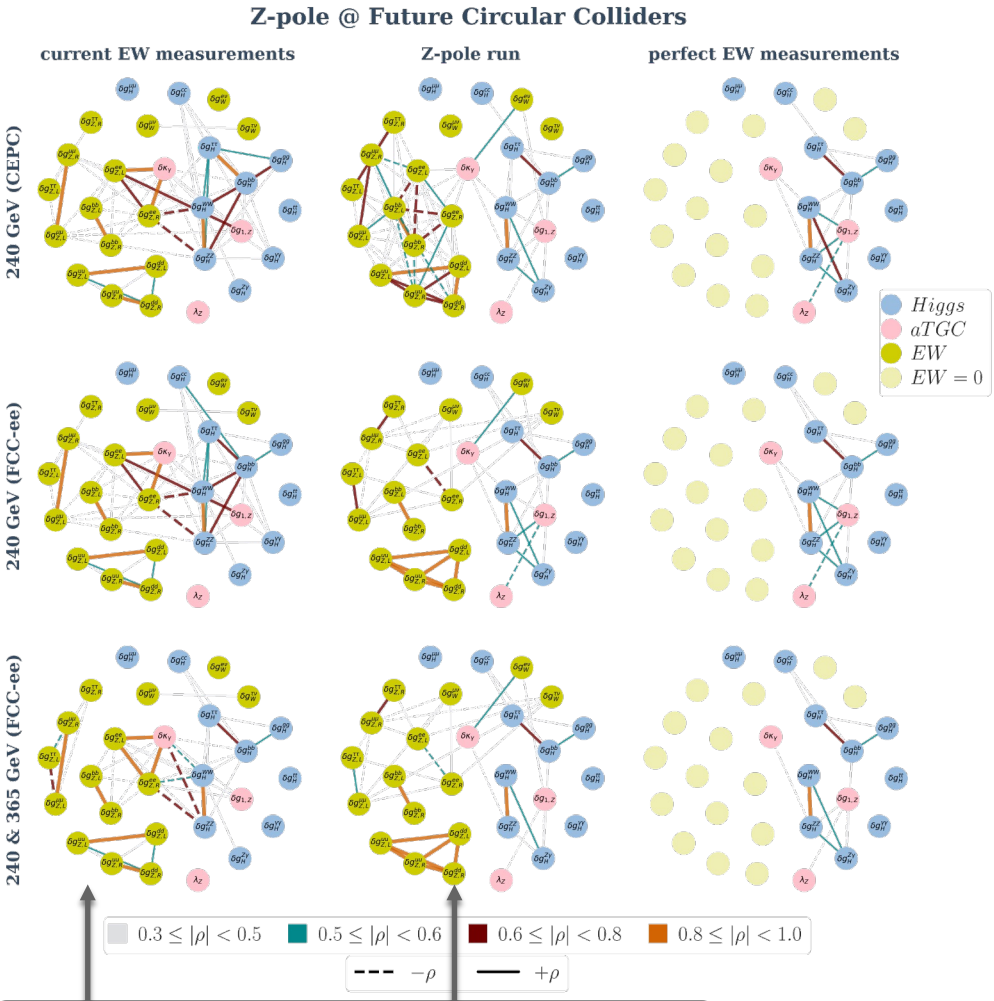
correlations differ between CEPC and FCC-ee because of different inputs

dominated by HL-LHC measurements

correlations between the Higgs and EW couplings

significant constraints from HL-LHC





Higgs and EW sectors get decorrelated after inclusion of Z-pole measurements

CEPC: 240 GeV
FCC-ee: 240 GeV, 240 & 365 GeV
ILC (±80%, ∓30%): 250 GeV, 250 & 350GeV, 250 & 350 & 500 GeV
ILC Unpolarized: 250 GeV, 250 & 350GeV, 250 & 350 & 500 GeV
CLIC (±80%, 0%): 380 GeV, 380 & 1500 GeV, 300 & 1500 & 3000 GeV
Correlation < 50%
Correlation > 50%
Perfect EW

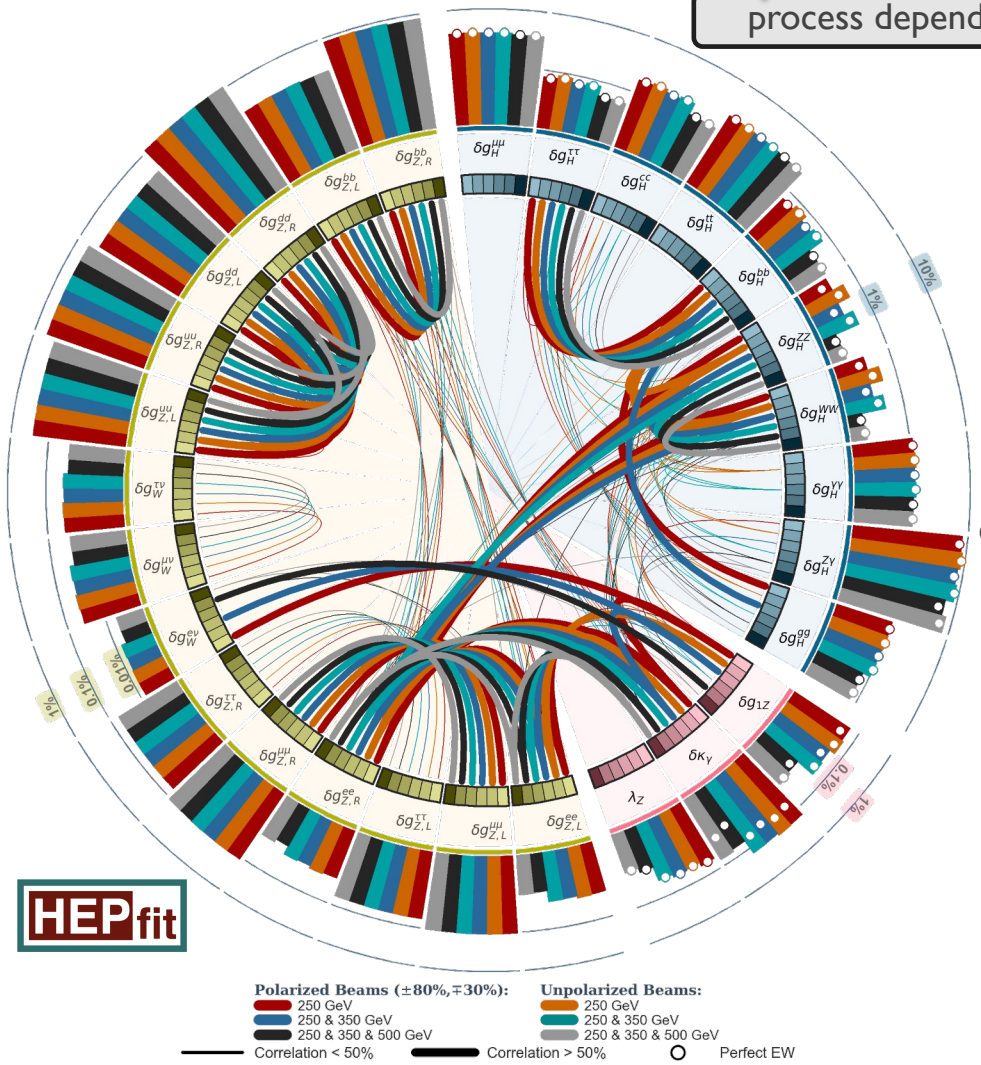
Effects of polarization

$$\sigma_{P_{e^+}P_{e^-}} = \sigma_0(1 - P_{e^+}P_{e^-})\left[1 - A_{LR}\frac{P_{e^-} - P_{e^+}}{1 - P_{e^+}P_{e^-}}\right]$$

process dependent

$$A_{LR}^{Zh} = 0.151$$
$$A_{LR}^{\nu\bar{\nu}h} = 1$$
$$A_{LR}^{WW} = 0.98$$

$$\left(\frac{\delta g\ (\text{unpolarized})}{\delta g\ (\text{polarized})} - 1\right)(\%)$$



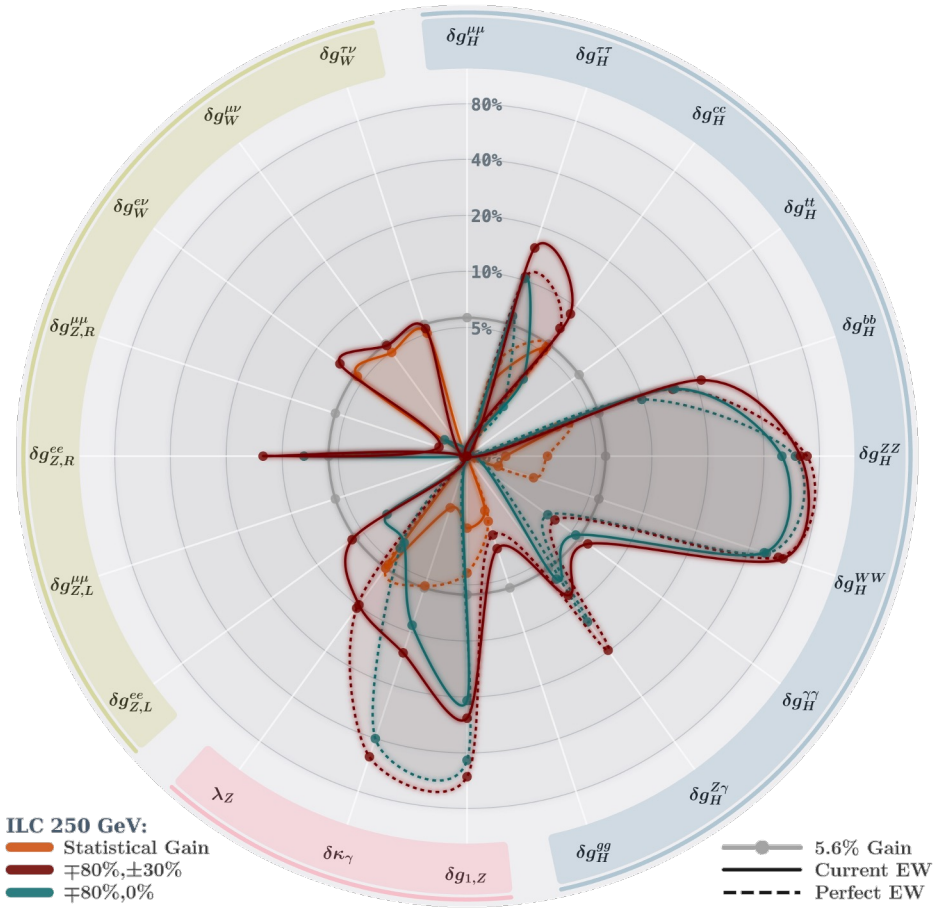
statistical scaling factor ≃1.24 when summed over both polarization with equal luminosities as in the ILC 250 GeV run

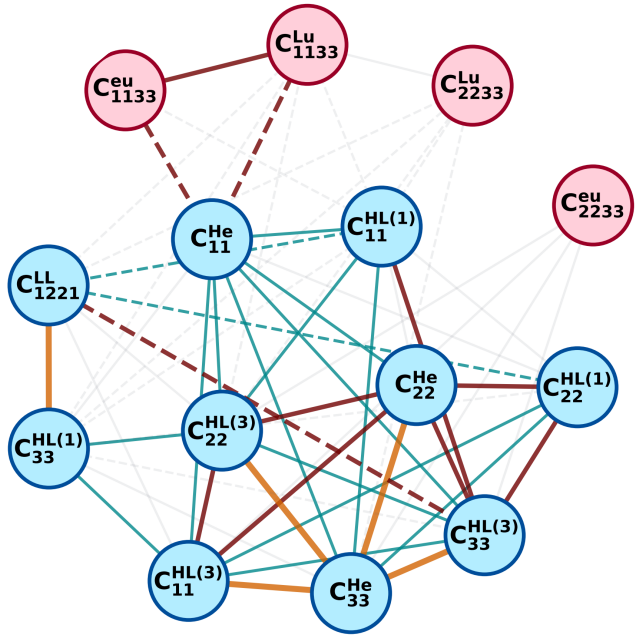
effective Higgs couplings get decorrelated from EW at higher energies.

aTGCs retain correlation with EW at higher energies

polarization does not fully compensate for the absence of EW measurements

polarization is important mostly for 250 GeV





Some recent results in EW and Flavour Physics

L. Alasfar, A. Azatov, A. Paul and M. Valli, B anomalies under the lens of electroweak precision, *accepted for publication in JHEP, arXiv:2007.04400*

Flavour

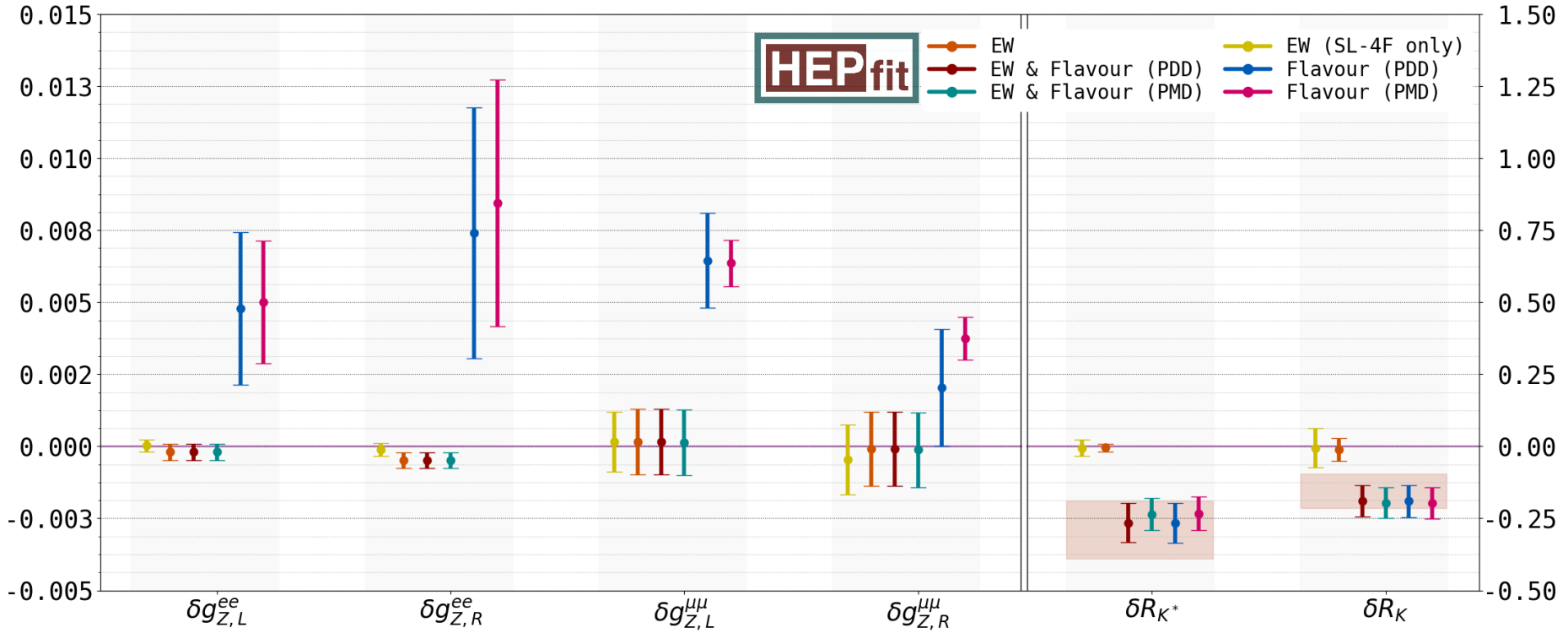
$$C^{\rm NP}_{9,\ell} = \frac{\pi v^2}{\alpha_e \Lambda^2}\left(\frac{y_t}{4\pi}\right)^2 \log\left(\frac{\Lambda}{\mu_{\rm EW}}\right)\left(C^{HL^{(3)}}_{\ell\ell} - C^{HL^{(1)}}_{\ell\ell} - C^{He}_{\ell\ell} + C^{Lu}_{\ell\ell 33} + C^{eu}_{\ell\ell 33}\right)$$

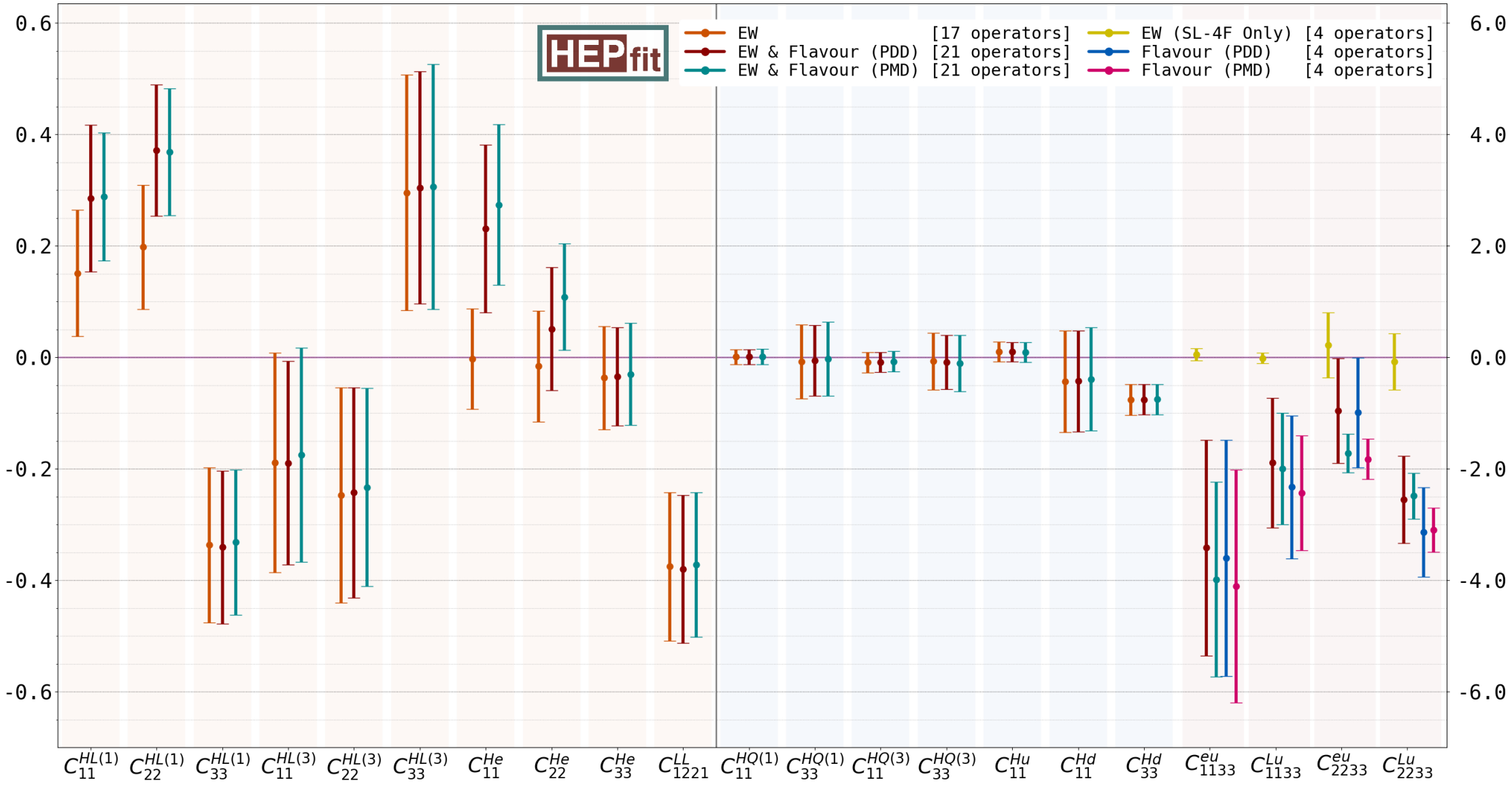
$$C^{\rm NP}_{10,\ell} = \frac{\pi v^2}{\alpha_e \Lambda^2}\left(\frac{y_t}{4\pi}\right)^2 \log\left(\frac{\Lambda}{\mu_{\rm EW}}\right)\left(C^{HL^{(1)}}_{\ell\ell} - C^{HL^{(3)}}_{\ell\ell} - C^{He}_{\ell\ell} - C^{Lu}_{\ell\ell 33} + C^{eu}_{\ell\ell 33}\right)$$

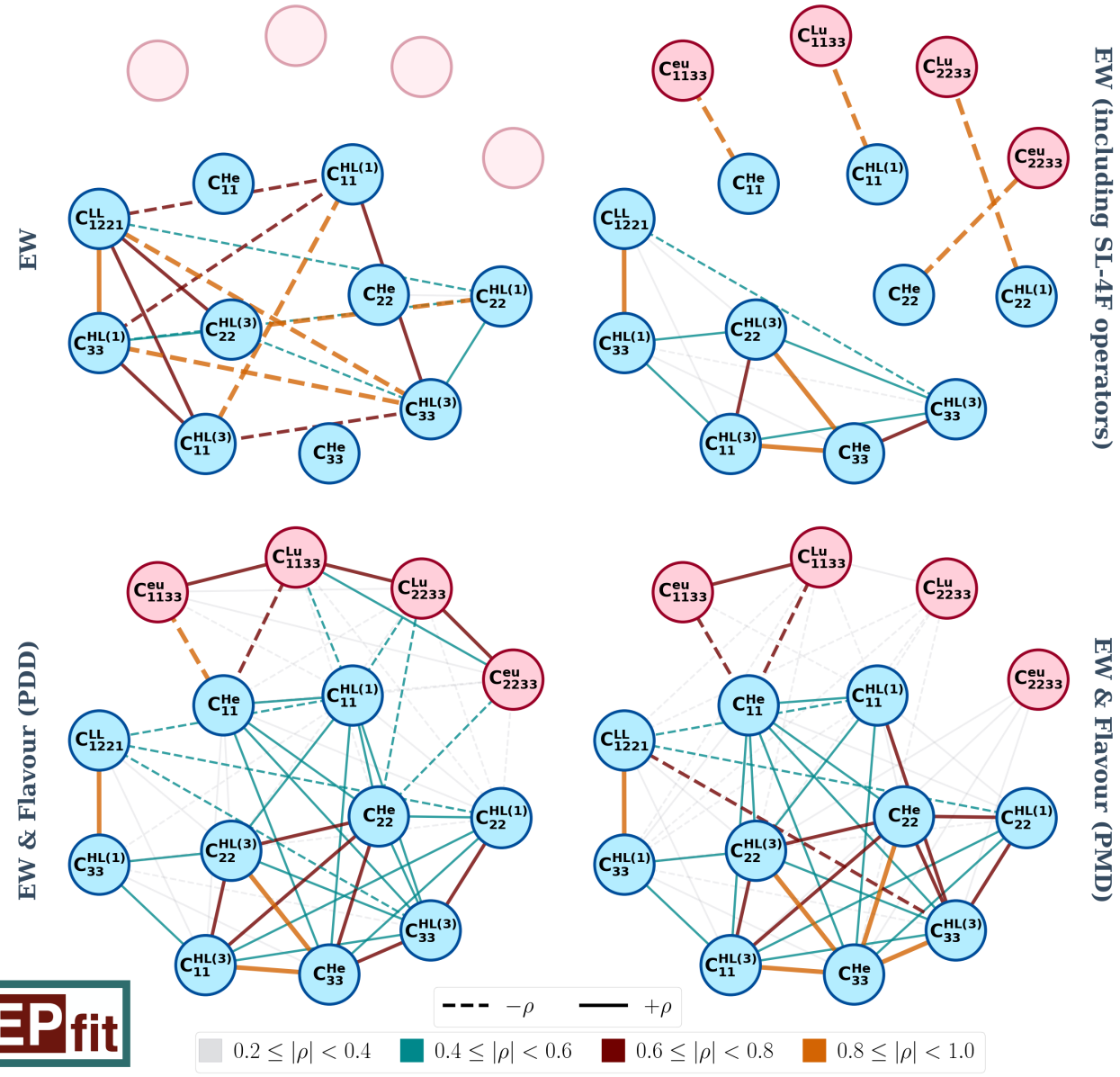
Electroweak

$$\Delta g^{\ell\ell}_{Z,L}\Big|_{\rm LUV} = -\frac{1}{2}\left(C^{HL^{(1)}}_{\ell\ell} + C^{HL^{(3)}}_{\ell\ell}\right)\frac{v^2}{\Lambda^2} - 3\left(\frac{y_t\, v}{4\pi\Lambda}\right)^2 \log\left(\frac{\Lambda}{\mu_{\rm EW}}\right) C^{Lu}_{\ell\ell 33}\,,$$

$$\Delta g^{\ell\ell}_{Z,R}\Big|_{\rm LUV} = -\frac{1}{2} C^{He}_{\ell\ell}\frac{v^2}{\Lambda^2} - 3\left(\frac{y_t\, v}{4\pi\Lambda}\right)^2 \log\left(\frac{\Lambda}{\mu_{\rm EW}}\right) C^{eu}_{\ell\ell 33}\,,$$




HEPfit
EW [17 operators]
EW & Flavour (PDD) [21 operators]
EW & Flavour (PMD) [21 operators]
EW (SL-4F Only) [4 operators]
Flavour (PDD) [4 operators]
Flavour (PMD) [4 operators]
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
$C_{11}^{HL(1)}$ $C_{22}^{HL(1)}$ $C_{33}^{HL(1)}$ $C_{11}^{HL(3)}$ $C_{22}^{HL(3)}$ $C_{33}^{HL(3)}$ C_{11}^{He} C_{22}^{He} C_{33}^{He} C_{1221}^{LL} $C_{11}^{HQ(1)}$ $C_{33}^{HQ(1)}$ $C_{11}^{HQ(3)}$ $C_{33}^{HQ(3)}$ C_{11}^{Hu} C_{11}^{Hd} C_{33}^{Hd} C_{1133}^{eu} C_{1133}^{Lu} C_{2233}^{eu} C_{2233}^{Lu}



the Key is in the Correlations

Diversity@DESY-Theory

- **Diversity@DESY-Theory** was started in June 2020 by Postdocs and PhD students as consolidation of efforts for BLM throughout the international academic community.
- **Philosophy:** Diversity includes is naturally multivariate in the academic world (gender, religion, school of thoughts, nationality, etc.) and they should be accommodated for.
- A monthly remote meeting is held where different issues related to diversity are discussed which includes published articles and opinions.
- The Diversity Office of the DESY Universe Cluster has been included with Eileen Schwanold providing expert advice on topics and actions.
- A core group of postdocs and students will be formed that can be approached by other members of DESY in case they want an unbiased discussion about any issues on diversity they might be facing.
- Topics related to diversity will be raised in workshops and conferences as a way of making people more aware of the core issues.
- Possible external outreach to other academic institutions to consolidate efforts of increasing inclusion in academia.
- The core group is managed by Davide Pagani, Ayan Paul and Jorinde van de Vis.

Promote Diversity and Inclusion in Academia!!

Thank You!

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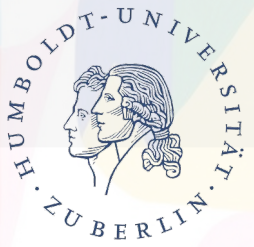
www.desy.de/~apaul
http://hepfit.roma1.infn.it



To my Mother and Father, who showed me what I could do,

and to Ikaros, who showed me what I could not.

"To know what no one else does, what a pleasure it can be!"

– adopted from the words of

Eugene Wigner.