Global Analysis of Electroweak Data

Pheno22

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Based on work with: J. de Blas, M. Pierini, L. Reina, L. Silvestrini, and members of the HEPfit collaboration.

Global Fits: What and Why?

Phenomenological analyses:

⬇

Constraining model **parameters** and **predictions**

✚

Ideal for **precision physics**

✚

Proven to be **successful in the past**

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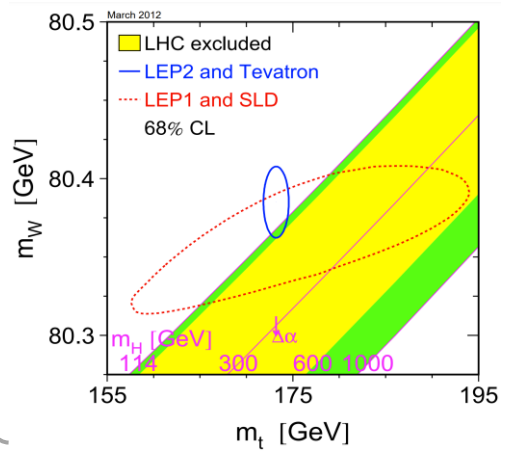
Essential to make the most out of the available precision data



Global fits fundamental in constraining the Higgs-mass

Global Fit: Electroweak Precision Fits

Most recent analyses:

- arXiv:2112.07274 [hep-ph] : *Global analysis of electroweak data in the Standard Model*
- arXiv:2204.04204 [hep-ph] : *Impact of the recent measurements of the top-quark and W-boson masses on electroweak precision fits*

Question: Are the new measurements reveling New Physics in the EW-sector?

M_W = 80.379 ± 0.012 GeV
m_t = 172.58 ± 0.45 GeV

Previous Average

'Before'

M_W(CDF) = 80.4335 ± 0.0094 GeV
m_t(CMS) = 171.77 ± 0.38 GeV

New Measurements

M_W = 80.4133 ± 0.0080 GeV
m_t = 171.79 ± 0.38 GeV

New Average

'After'

Global Fit: Electroweak Precision Fits

- HEPfit → open-source tool
- Statistical framework based on a Bayesian MCMC analysis
- Supports SM and BSM models

Experiment → Precise Measurements

LEP + SLD + Tevatron:

$$M_Z\,,\Gamma_Z\,,\sigma^0_{hd}\,,R_l\,,A^l_{FB}\,,P^{pol}_\tau\,,sin^2\theta_{eff}$$

$$A_l\,,R_b\,,R_c\,,A^b_{FB}\,,A^c_{FB}\,,A_b\,,A_c$$

$$BrW\,,\Gamma_W\,,A_s\,,R_{uc}\,,M_W\,,m_t$$

+ LHC:

$$m_H\,,m_t\,,sin^2\theta_{eff}\,,M_W$$

HEPfit

Theory → Precise Predictions

- Structure:

$$W:\,(M_W,\Gamma_{(W\bar{f}f')})\rightarrow(BrW)$$

$$Z:\,(g^f_V,g^f_A)\rightarrow(\Gamma_{(Z\bar{f}f)}\,,A_f\,,sin^2\theta)\rightarrow(\sigma^0_{had},R_f,A^f_{FB})$$

- Highest known SM corrections.
- Input-scheme: $\{\alpha,M_Z,G_F\}$ $\{M_W,M_Z,G_F\}$

Fit model parameters + **Obtain predictions for observables**

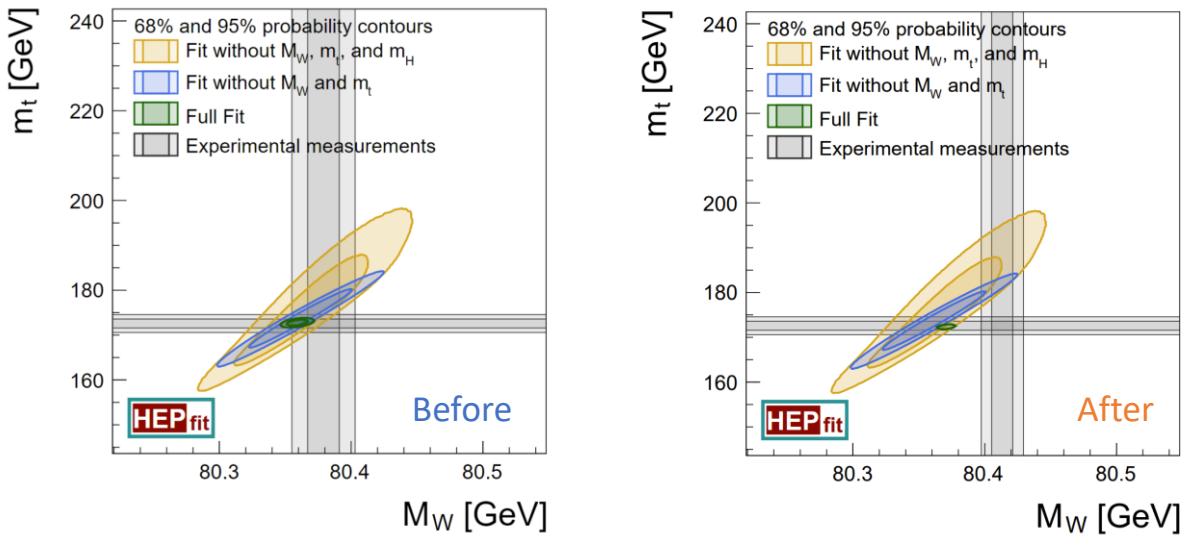
I – Standard Model

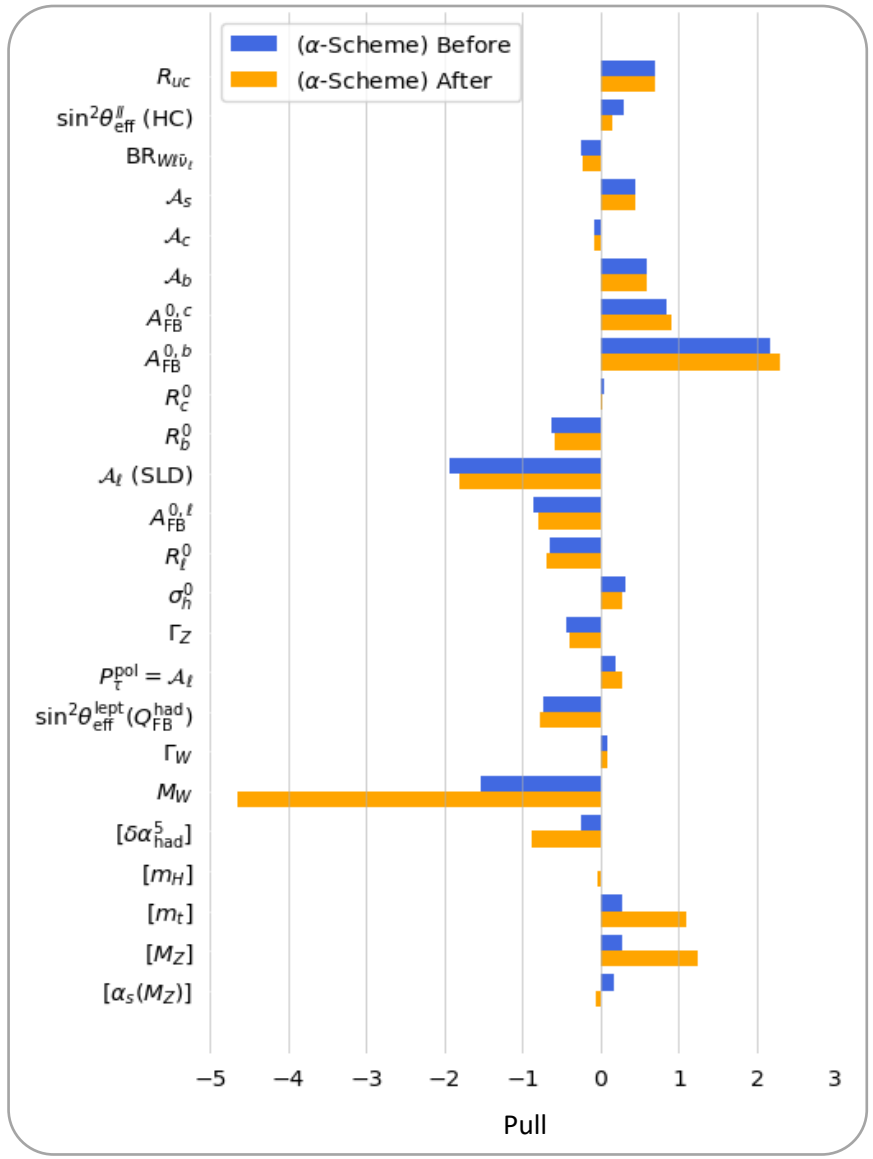
Global Fit: SM

$$M_W^2 = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}G_F s_W^2}$$

α-Scheme:

- Evident tension in the W-mass
- …but no significant difference for most of the EWPOs.





Global Fit: SM

$$\alpha(M_Z^2) = \frac{M_W^2 \sqrt{2} G_F s_W^2}{\pi}$$

α-Scheme*:*

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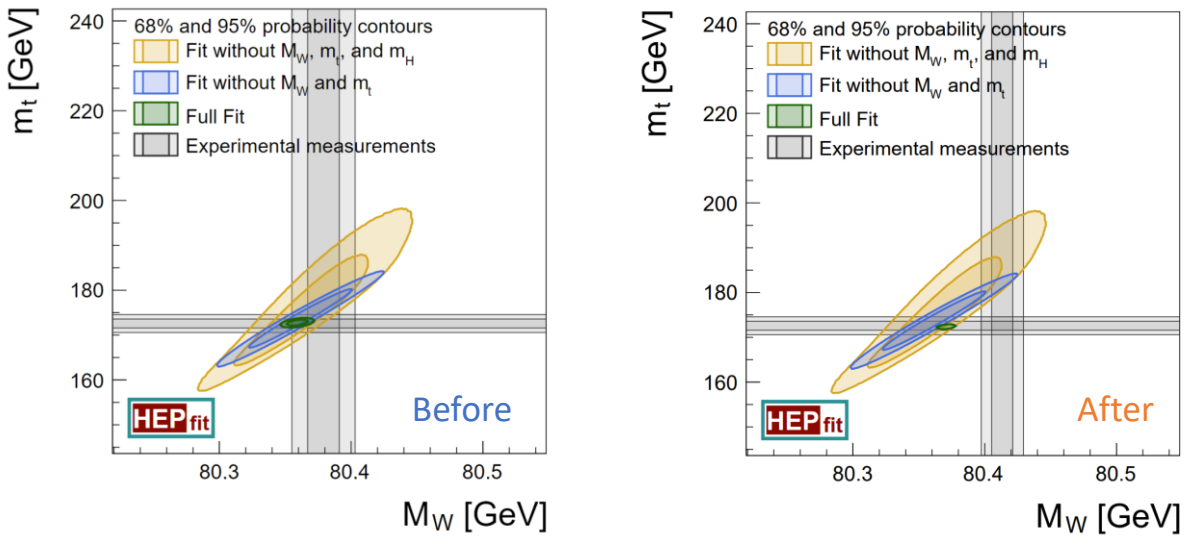
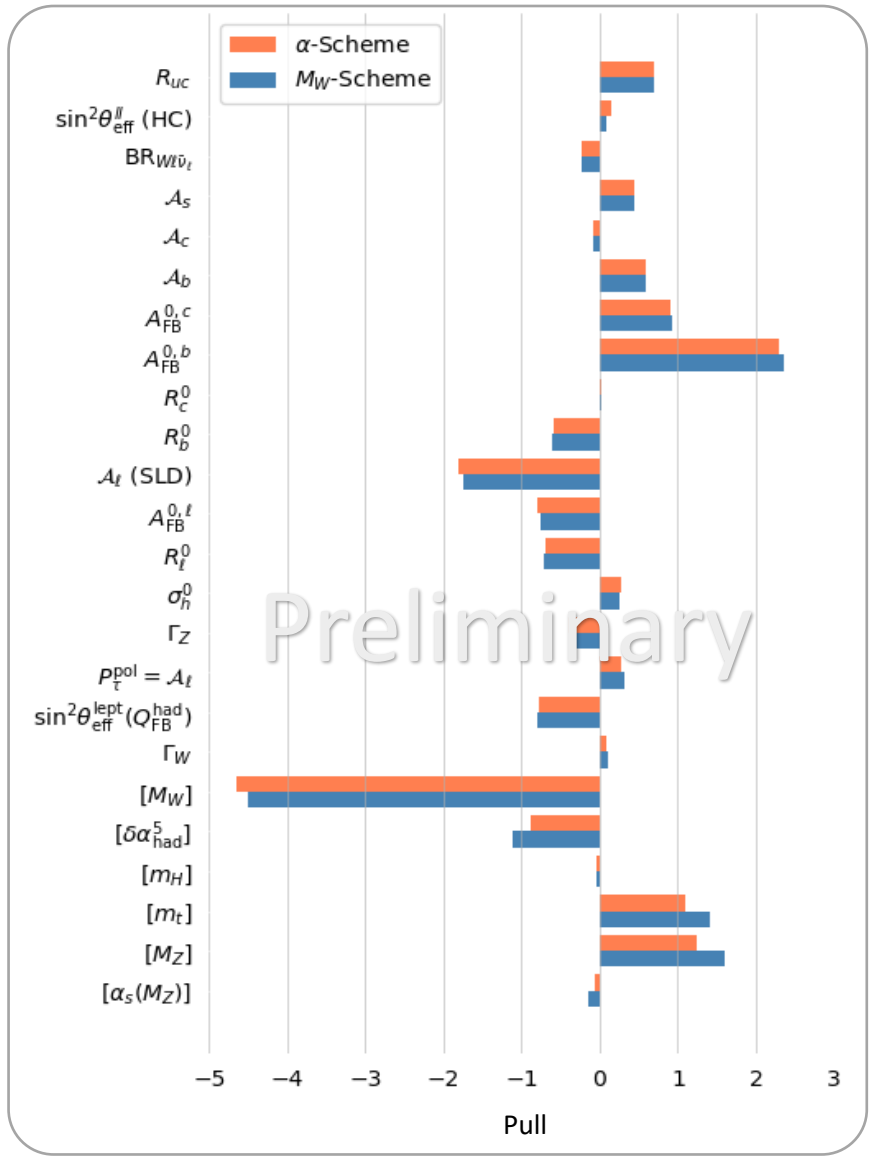


Mw-Scheme*:*

- Not significantly different from the α-scheme.



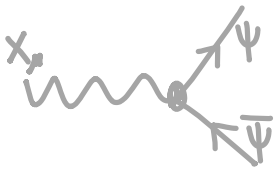
II – New Physics with Oblique Parameters

Global Fit: {S,T,U}

New Physics effects through the oblique corrections of the gauge fields ( )

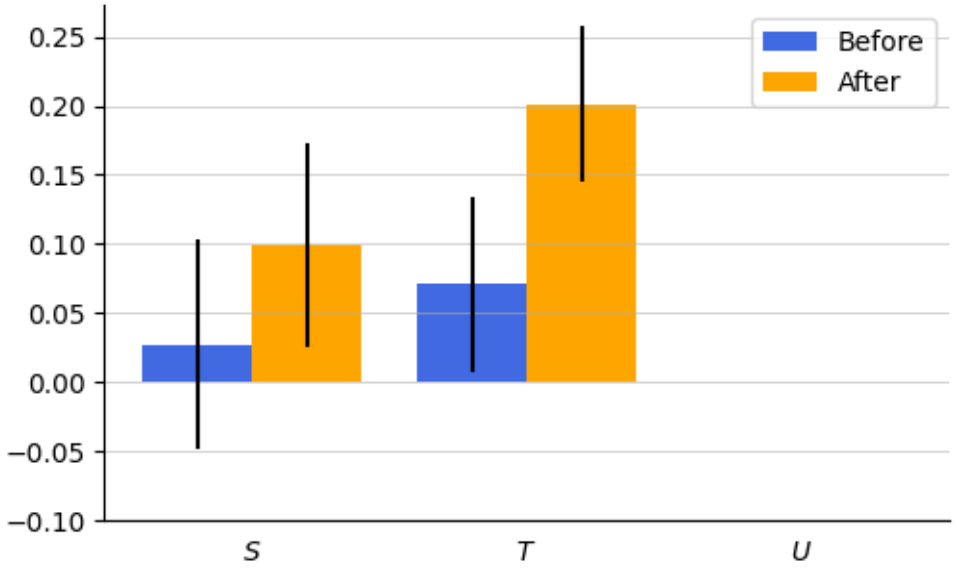
$$O = O_{SM} + \Delta O_{NP}(S,T,U)$$

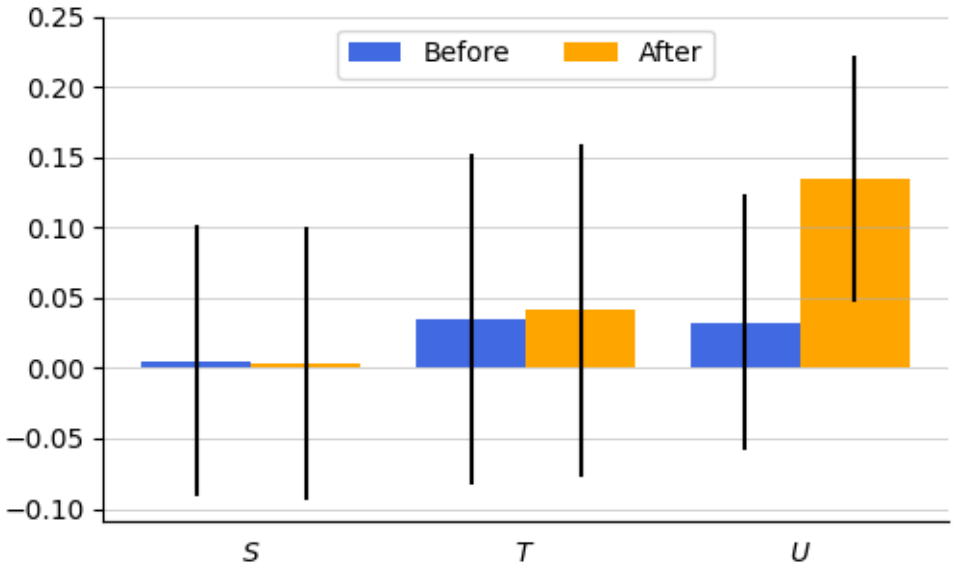
For EW observables:



$$\rightarrow (g^{SM} + \Delta g) \begin{cases} \Delta g^{(Z\bar{f}f)} \propto (S,T) \\ \Delta g^{(W\bar{f}f')} \propto (S,T,U) \end{cases}$$

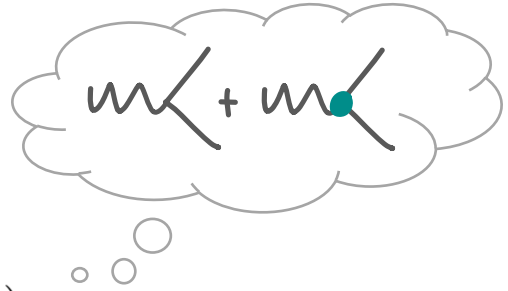
- U=0: significant increase in the bounds on T.
  - ↳ indirectly affected by W-mass.
- U≠0: significant increase in the bounds on U.
  - ↳ directly affected by W-mass.





III – New Physics with the SMEFT

Global Fit: SMEFT

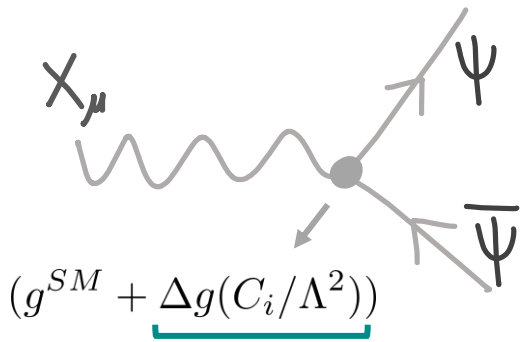


New Physics effects through higher-dimensional operators,

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM}^{(4)} + \sum_{d\geq 5} \frac{C_i^{(d)}}{\Lambda^{d-4}} Q_i^{(d)} \longrightarrow O = O_{SM} + \Delta O_{NP}(C_i^{(d)}/\Lambda^{d-4})$$

For EW observables:

dim=6 → Warsaw Basis → $\{C_{\varphi l}^{(1)}, C_{\varphi l}^{(3)}, C_{\varphi e}, C_{\varphi q}^{(1)}, C_{\varphi q}^{(3)}, C_{\varphi u}, C_{\varphi d}, C_{LL}, C_{\varphi WB}, C_{\varphi D}\}$



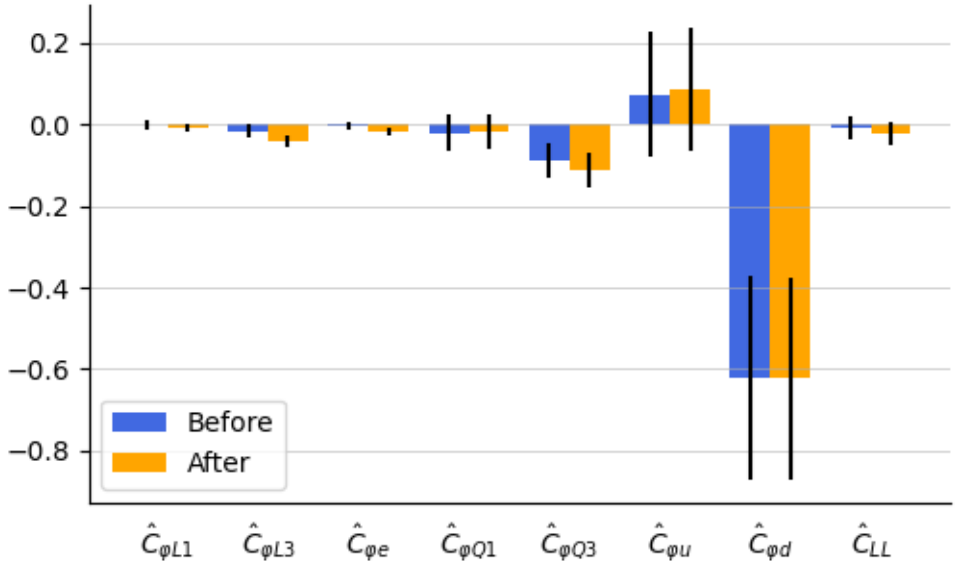
$\psi^2\varphi^2 D$: Vertex corrections

$(\bar{L}L)(\bar{L}L)$: G_F correction

$X^2\varphi^2$, $\varphi^4 D^2$: Bilinear Gauge-fields corrections

Global Fit: SMEFT

Fitting *all* operators *at the time:*



- EW observables can constrain 8 out of 10 Ci's.
  - $\{C_{\varphi WB}, C_{\varphi D}\}$ absorbed by the rest Ci's.
- Higgs and top observables can lift the degeneracy.
  - Analysis in progress!

Global Fit: SMEFT

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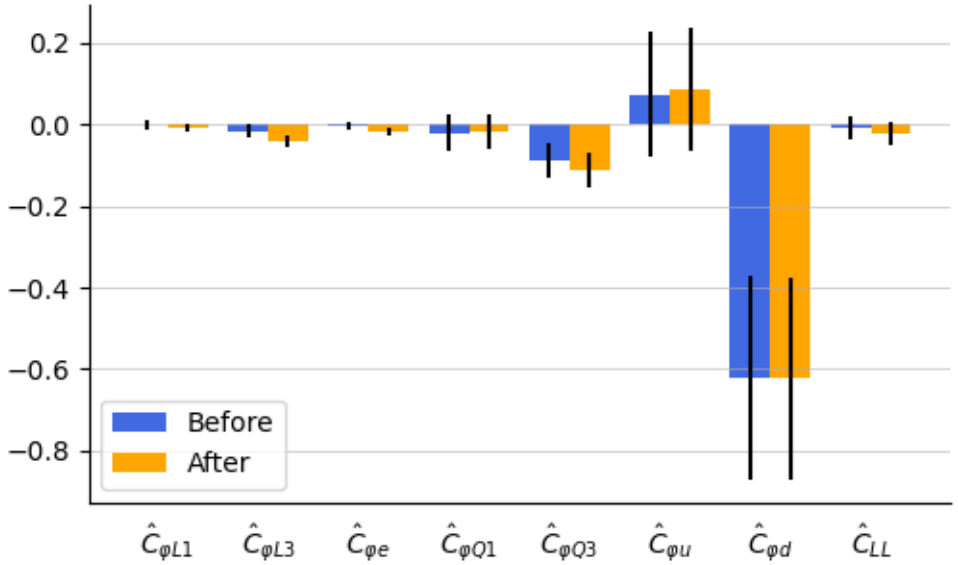

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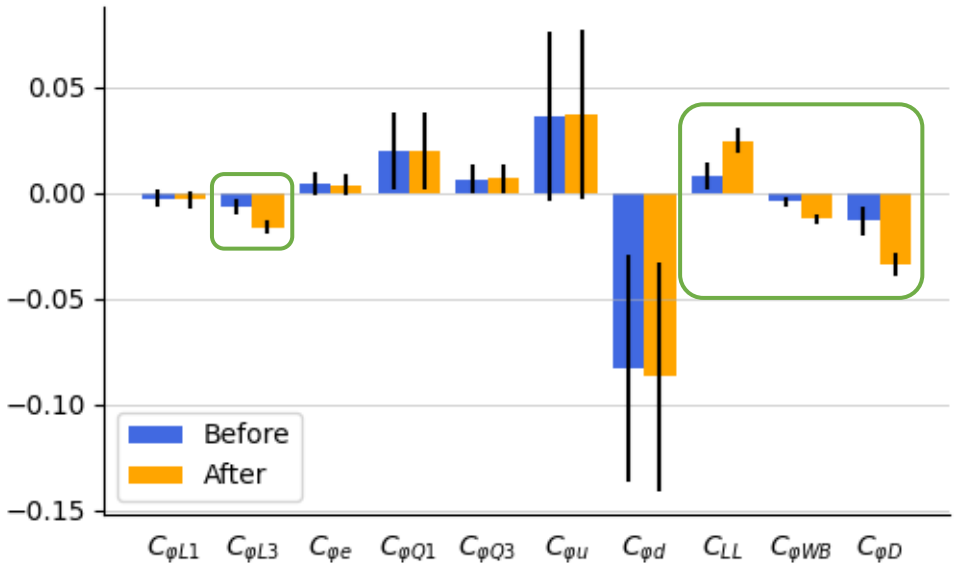
Fitting *one* operator *at the time:*



- Significant effects on $C_{\varphi WB}, C_{\varphi D}, C^{(3)}_{\varphi L}, C_{LL}$.

	$C_{\varphi D}$	$C_{\varphi WB}$	$C^{(3)}_{\varphi L}$	C_{LL}	$C^{(1)}_{\varphi L}$	$C_{\varphi e}$	$C^{(1)}_{\varphi Q}$	$C^{(3)}_{\varphi Q}$	$C_{\varphi u}$	$C_{\varphi d}$
M_W	✓	✓	✓	✓						
$\sin^2\theta_{eff,l}$	✓	✓	✓	✓	✓	✓				
Γ_W	✓	✓	✓	✓	✓		✓			✓
⋮										
Γ_Z	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Conclusions: effects of the recent (m_t, M_W) measurements

EWPOs:

- Mildly affected overall

Oblique Parameters (S,T,U):

- Visible effects in S, T (U=0) or U (U≠0)

Wilson Coefficients (SMEFT):

- All-operators-at-the-time → Mildly affected
- One-operator-at-the-time → Statistically significant difference in the coefficients that parametrize Mw ($C_{\varphi WB}, C_{\varphi D}, C^{(3)}_{\varphi L}, C_{LL}$)

Choice of input scheme:

- Compatible fit results between the α and M_W schemes.

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Outlook:

Extend current global fits of the SM and general NP models with EW + Higgs + top observables !