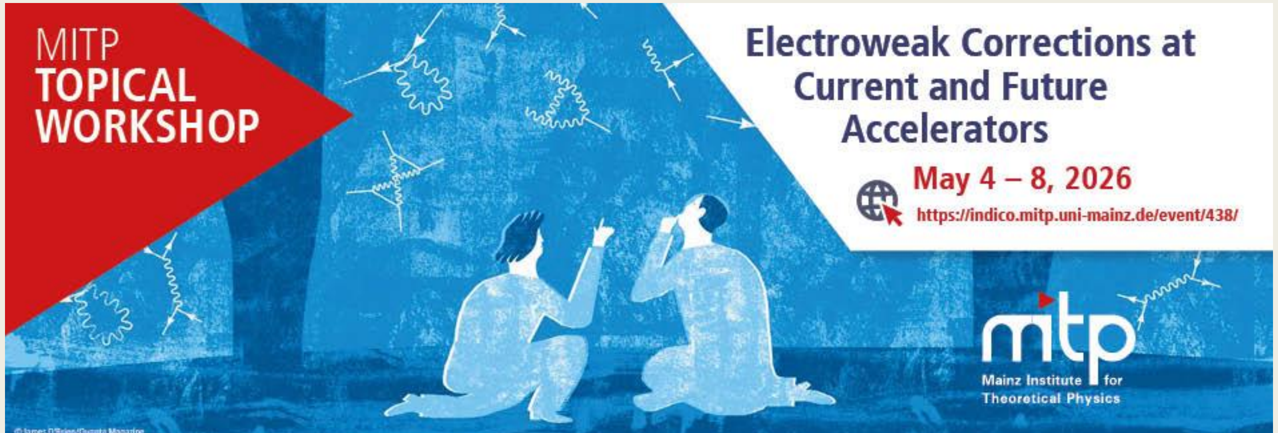
PRECISION BEYOND THE SM

Electroweak Corrections at Current and Future Accelerators

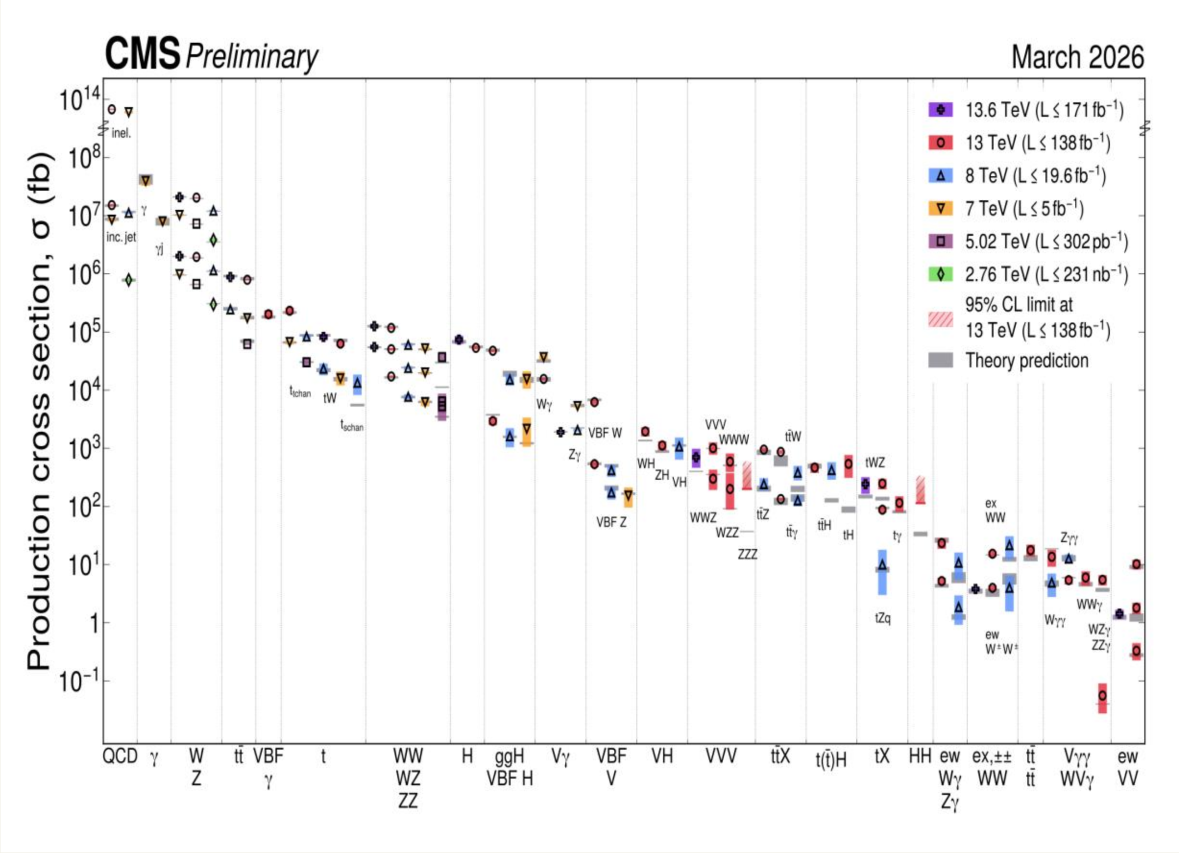
S. Dawson, BNL, May 2026

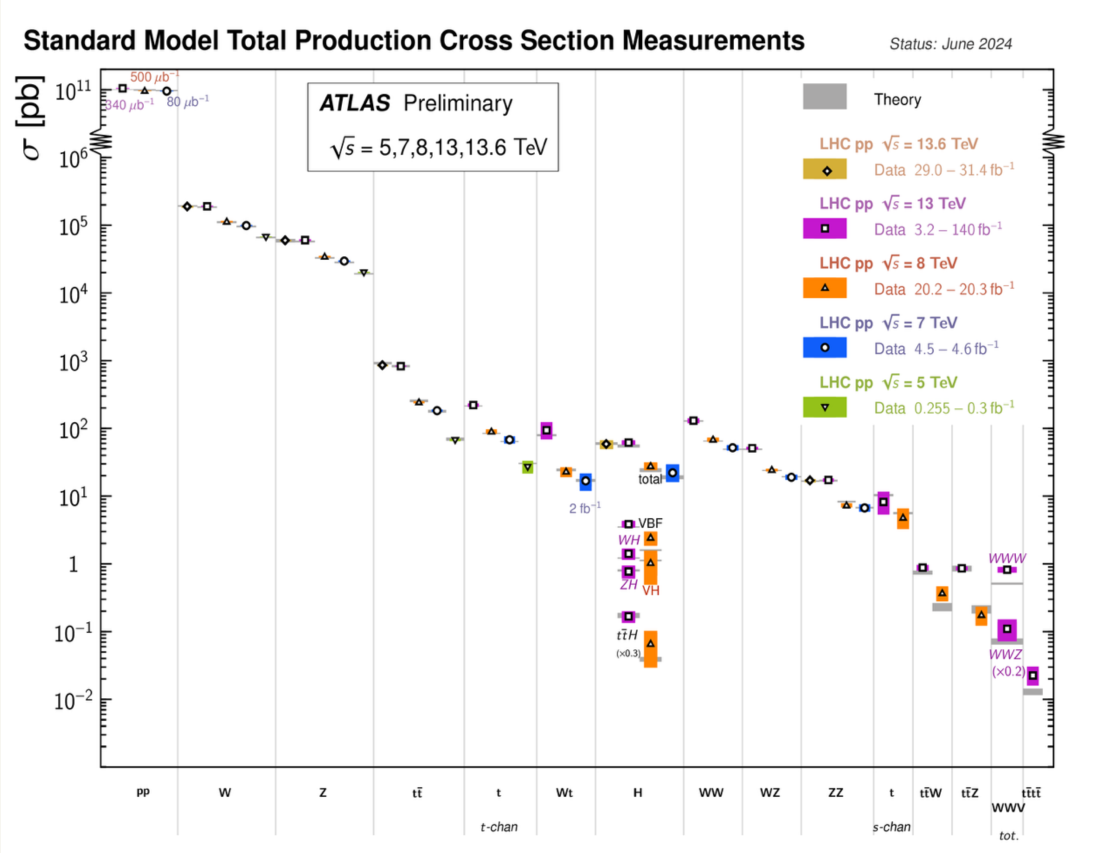


Work with Bellafronte, del Pio, Forslund, and Giardino

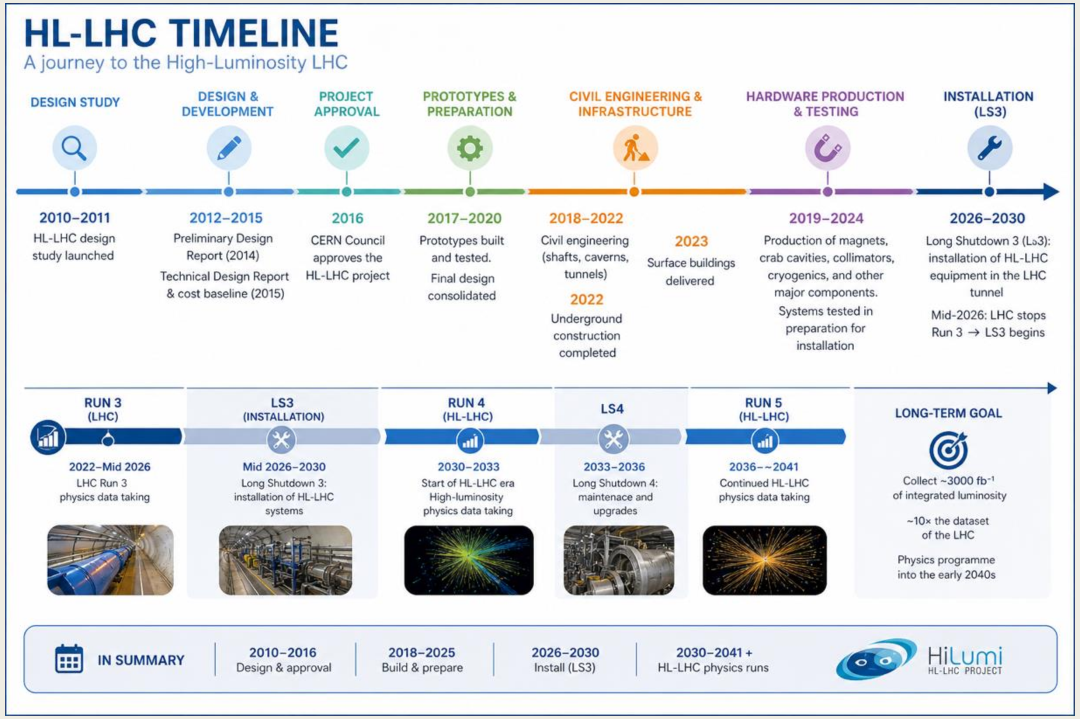
Precision beyond the SM

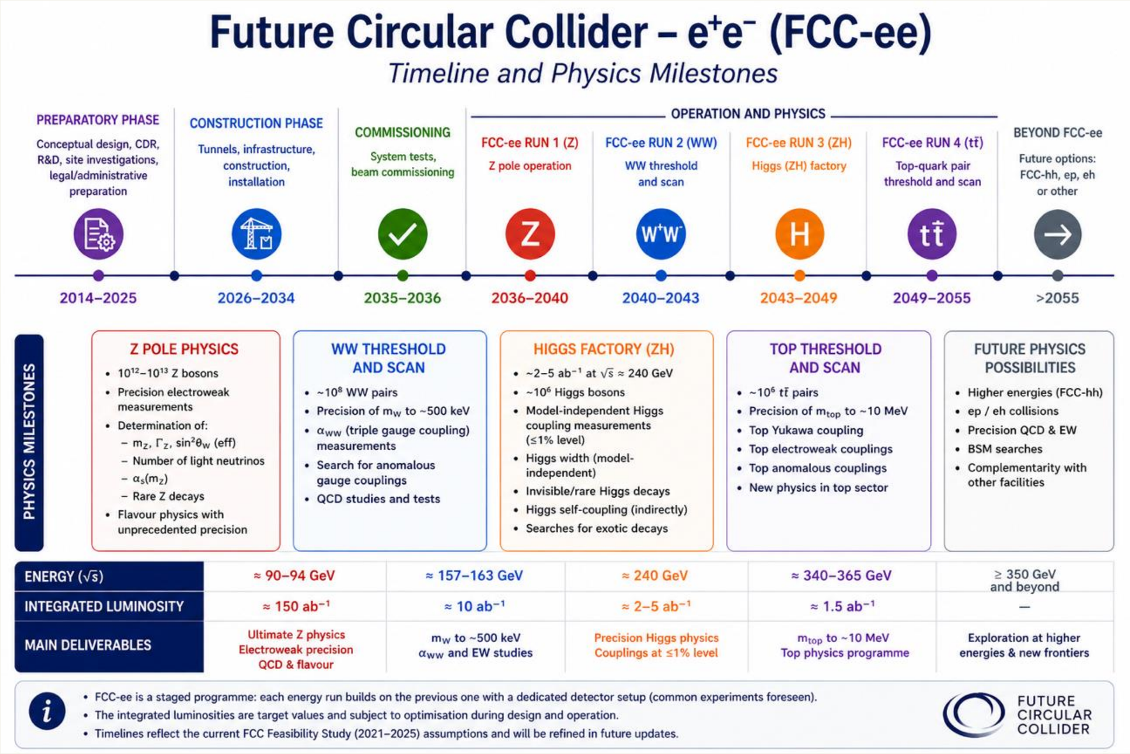
LHC data agrees well with SM…Across many orders of magnitude and many processes, so why talk about BSM?





The future





See Grojean talk

If we see a deviation from the SM, what can we learn?

- Verifying agreement with SM is first priority, but ***EFTs can help understand the UV physics causing the deviation***
- Focus on SMEFT: SU(3) x SU(2) x U(1) expansion around the SM with ***no new particles***

$$L_{SMEFT} = L_{SM} + \frac{L_5}{\Lambda} + \frac{L_6}{\Lambda^2} + \frac{L_7}{\Lambda^3} + \frac{L_8}{\Lambda^4}$$

$$L_d = \Sigma_i C_i^{(d)} O_i^{(d)}$$

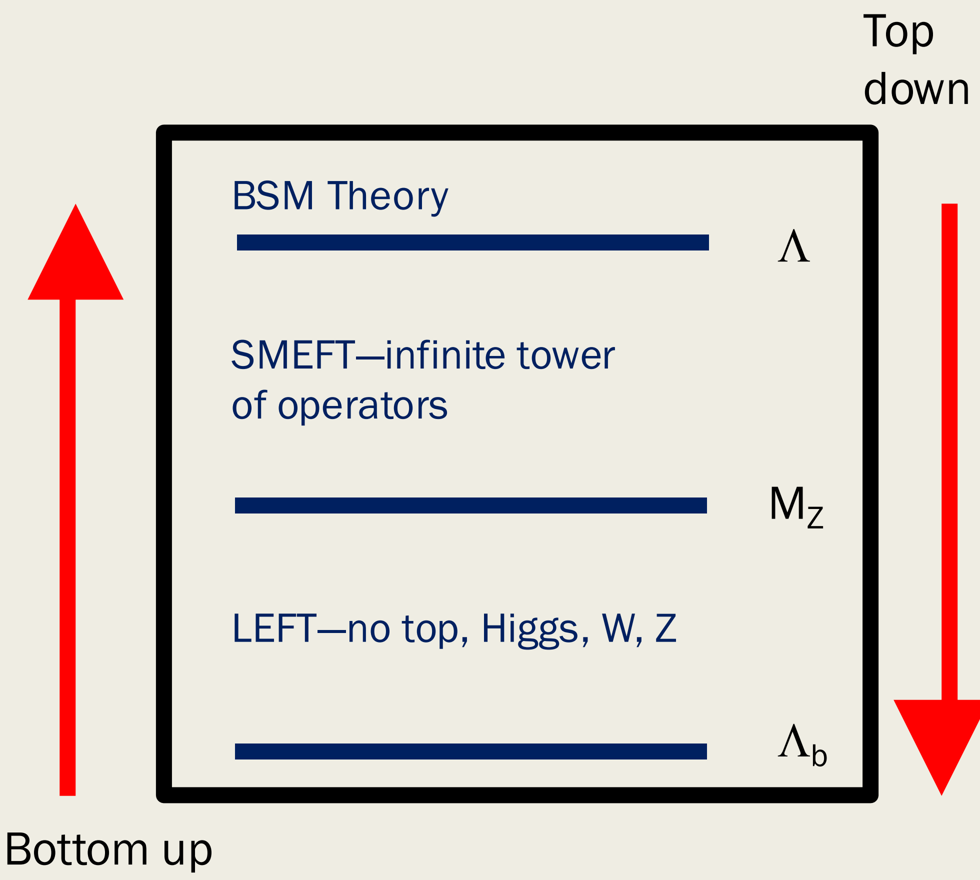
Concentrate on dimension-6 operators

  - Λ is scale much above weak scale, at Λ there is presumably some UV model
  - *A priori, many SMEFT coefficients, but in any given UV model there will typically be a small number of non-zero coefficients*

SMEFT assumes new physics is heavy and decoupling

If we see a deviation from the SM, what can we learn?

- Consider the SM as an EFT valid at the weak scale
  - *SMEFT is a gauge invariant field theory, so we can compute higher order corrections order by order in the SMEFT expansion*
  - *Use Warsaw basis (2499 baryon number conserving operators, with most associated with flavor structure)*
  - *Assume UV physics decouples*
  - *Compute to dimension-6 in SMEFT @ NLO*
  - *2 expansions: Loop expansion and $1/\Lambda$ expansion*



Going beyond Tree Level in the SMEFT

$$\mathcal{A} \sim A^0_{SM} + \frac{A^1_{SM}}{16\pi^2} + \Sigma_i \frac{C^6_i}{\Lambda^2}\left[A^0_{EFT,i} + \frac{B^1_{EFT,i}}{16\pi^2} + \frac{D^1_{EFT,i}}{16\pi^2}\log(\frac{\Lambda^2}{\mu^2})\right] + \Sigma_i \frac{C^8_i}{\Lambda^4} F^0_{EFT,i} + ...$$

- NLO QCD is automated, but *NLO EW corrections done on a case- by -case basis*
- At NLO, new operators contribute beyond those that contribute at tree level
  - *In general, effect of more operators is to weaken limits*
- Logarithms come for free from RGE. Do they dominate?

$$C_i(\mu) = C_i(\Lambda) + \frac{\gamma_{ij}}{16\pi^2} C_j(\Lambda) \log\left(\frac{\mu}{\Lambda}\right)$$

Not diagonal

We'd really like this to be the case!

Z pole observables

- At FCC-ee Z pole observables provide precise tests of validity of SM
- They can also probe existence of SMEFT coefficients that vanish at LO
- Consider observables

$$M_W, \Gamma_W, \Gamma_Z, \sigma_h, A_{l,FB}, A_{b,FB}, A_{c,FB}, A_b, A_c, A_l, R_l, R_b, R_c$$

- Tree level expressions depend on (in Warsaw basis) [neglecting flavor for now]

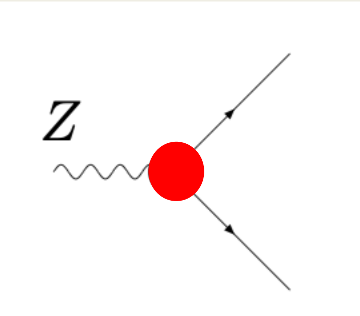
$$C_{ll}, C_{\phi WB}, C_{\phi u}, C_{\phi q}^{(3)}, C_{\phi q}^{(1)}, C_{\phi l}^{(3)}, C_{\phi l}^{(1)}, C_{\phi e}, C_{\phi D}, C_{\phi d}$$

- Tree level SMEFT expressions depend on 8 combinations of operators

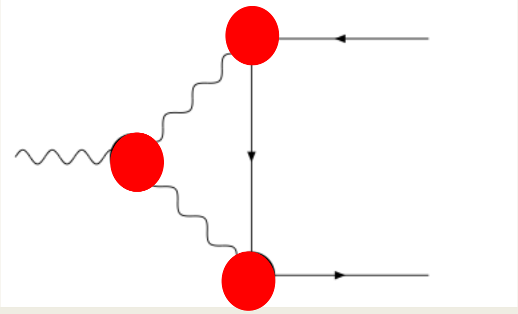
⇒ 2 blind directions (resolved by other measurements)

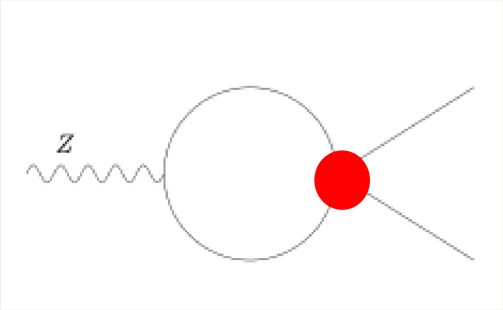
Details

- Standard techniques for NLO calculations: SM parameters renormalized on-shell, SMEFT coefficients renormalized in $\overline{MS}$
- Counting: Retain only interference (linear) of SM with single insertion of SMEFT coefficients in prediction observables
- Use “best” theory for SM contributions
- NLO results are $\mathcal{O}\left(\frac{CM_Z^2}{\Lambda^2 16\pi^2}\right)$

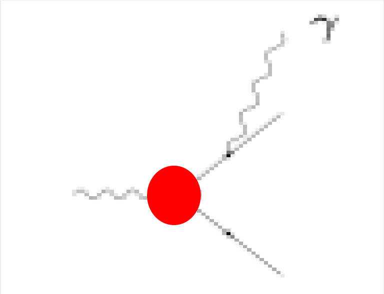


Non-SM couplings





New interactions



Real photon emission

Scheme dependence as uncertainty gauge

- NLO QCD/EW Results for $W \to f\bar{f}'$, $Z \to f\bar{f}$
- Input parameter schemes: $\{G_F, M_W, M_Z\}$, $\{\alpha(0), G_F, M_Z\}$, $\{\alpha(M_Z\}, M_Z, G_F\}$, $\{\alpha(M_Z), M_W, M_Z\}$
- Numerical (POPfx format) and analytic results available

Typical operators that contribute at LO

$Z \to \tau\tau$	SM	C_{HD}	C_{HWB}	$C_{Hl}^{(3)}[33]$
$\{\alpha(M_Z), M_W, M_Z\}$	-4%	-10.6%	-5.4%	-.5%
$\{G_F, M_W, M_Z\}$	< .1%	71.1%	-27.2%	-.4%
$\{\alpha(M_Z\}, M_Z, G_F\}$	1.0%	7.8%	17.4%	4.2%

* Relative to LO

POPfx is JSON format for SMEFT results: LHCEFT WG, 2511.17348

Biekotter,Pecjak,Scott,Smith, 2305.03763
Bellafronte, Dawson, Giardino, 2304.00029

Flavor assumptions

Operators that contribute to EWPO at NLO

Operator	$U(3)^5$	MFV	$U(2)^5$	3^{rd} gen specific	3^{rd} gen phobic	3^{rd} gen phobic + $U(2)^5$	Flavorless
Class A	7	12	16	9	14	7	9
Class B	11	17	27	5	23	11	6
Class C	11	21	44	11	44	11	11
Total	29	50	87	25	81	29	26

2-fermion → Class A

4-fermion with identical reps → Class B

Remaining 4-fermion → Class C

- Compare Z pole global fit results with $U(3)^5$, $U(2)^5$, MFV, only 3^{rd} generation operators, no flavor structure

Much work to be done understanding flavor in SMEFT global fits

* In all generality, 168 operators contribute to EWPO with no flavor assumptions

What good is all this?

- At scale Λ, match SMEFT to model parameters of UV complete theory, C(Λ)
- Only a few operators generated in a given model: eg. Heavy charge 2/3 quark gives:

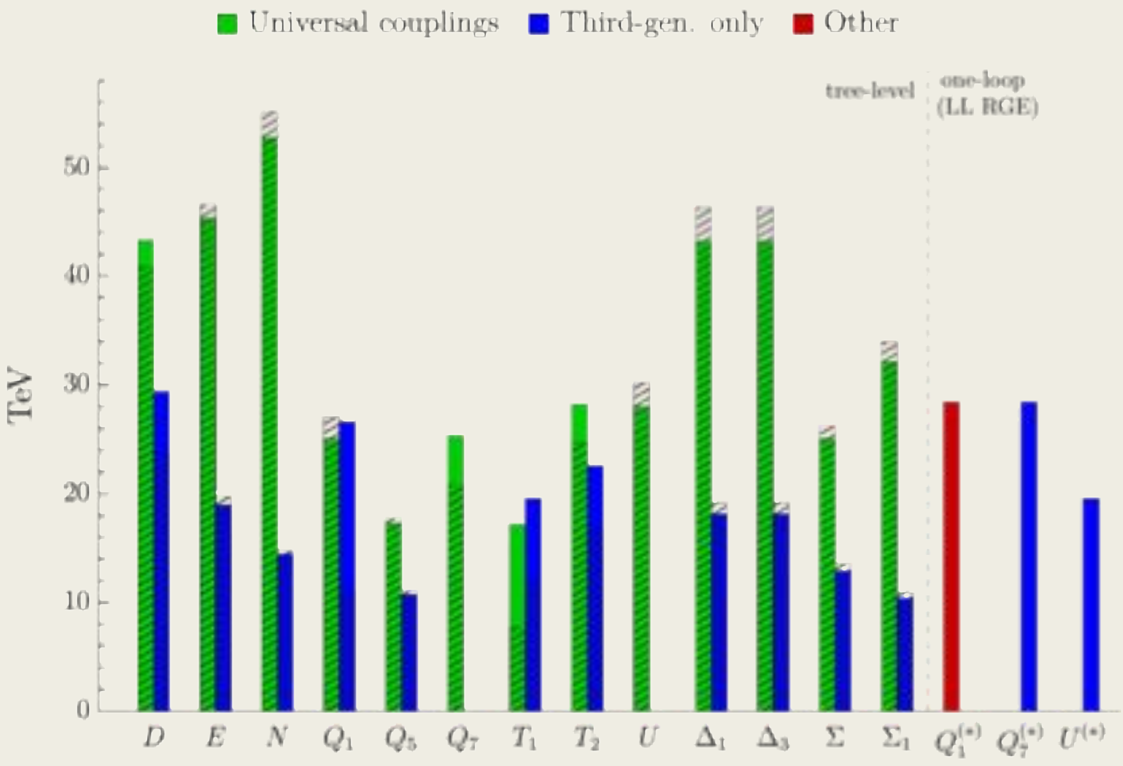
$$\begin{aligned}\mathcal{O}_{tH} &= (H^\dagger H)\left(\bar{q}_3\,\tilde{H}\,t\right) + \text{h.c.}\\ \mathcal{O}_{Hq}^{(1)[33]} &= \left(H^\dagger i\overleftrightarrow{D}_\mu H\right)\left(\bar{q}_3\gamma^\mu q_3\right)\\ \mathcal{O}_{Hq}^{(3)[33]} &= \left(H^\dagger i\overleftrightarrow{D}^I_\mu H\right)\left(\bar{q}_3\gamma^\mu\tau^I q_3\right).\end{aligned}$$

- RGE scale operator coefficients to C(M_Z): generates O_{HD}~ ΔT
- Match to predictions at M_Z
- Look for patterns

* Automated tools exist to do matching to 1-loop

Flavor matters

Tera-Z sensitivity to heavy fermions



2408.03992

Hatched bars have no RGE running

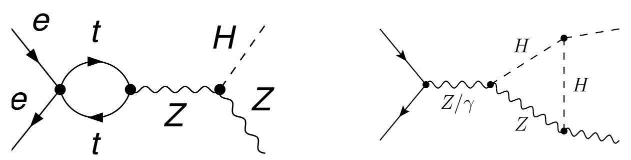
RGE operator mixing leads to new flavor structures

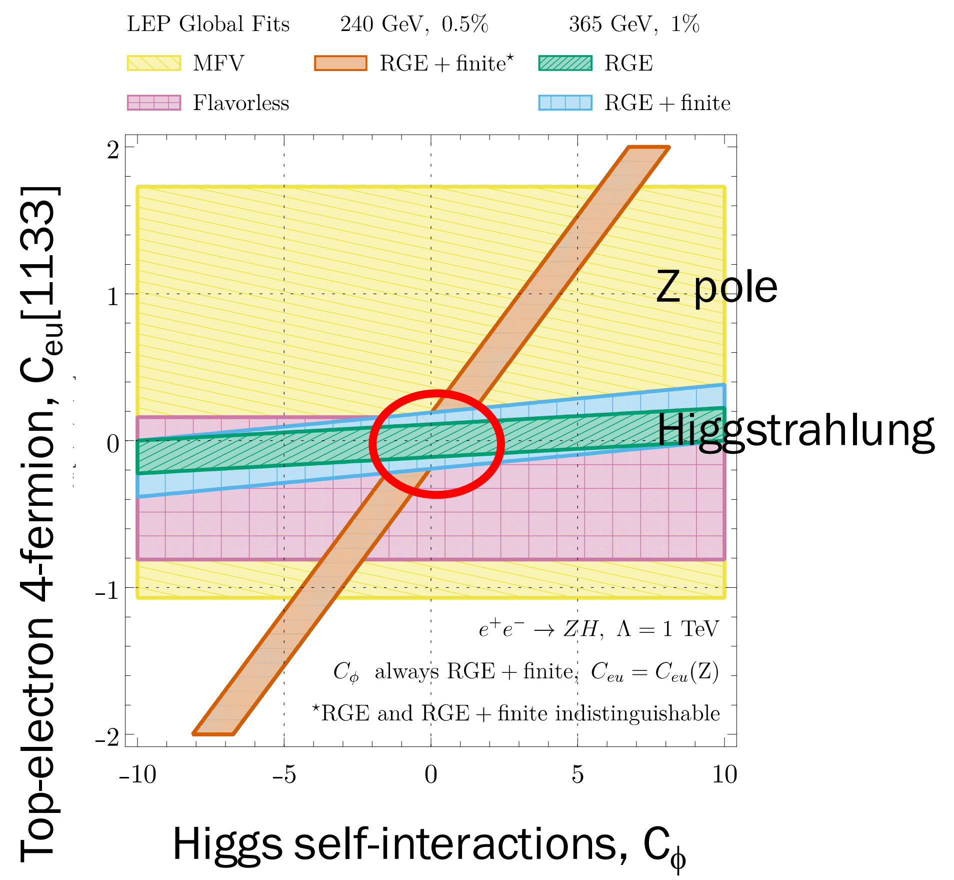
- Assume all (non-SM) couplings=1, and all dimensionful parameters=M
- This "dictionary" type of analysis is perhaps oversimplified

ALL BSM IS NOT RULED OUT…

$e^+e^- \rightarrow ZH$ is window to many new interactions

- Complete NLO QCD/EW calculation (~77 dimension-6 operators)
- Numerical results available
- Fixed order: Do we need resummation of $\log(s/m_e^2)$ terms?





- Effects of different operators is correlated
- Power of measurement at 2 different energies

Note: Z pole limits depend on flavor assumptions

In this example, logs dominate over finite terms

Asteriadis, Dawson, Giardino, Szafron 2406.03557

SMEFT EW loop corrections for Higgs decays

Higgs decays with full NLO EW/QCD results for dim-6 SMEFT

$H \to f\bar{f}$	2007.15238 , 1904.06358 ,2007.15238
$H \to \gamma\gamma,\ \gamma Z,\ gg$	1807.11504, 1805.00302 ,1507.03568, 2107.07470
$H \to Zf\bar{f}$	2411.08952
$H \to Wf\bar{f}'$	2508.14966
$H \to Zgg$	2508.14966, 2306.09963

Tree level in SMEFT, one-loop in SM

All H⟶4f operators in NWA

Crossing gives 3-body Z decays at NLO SMEFT

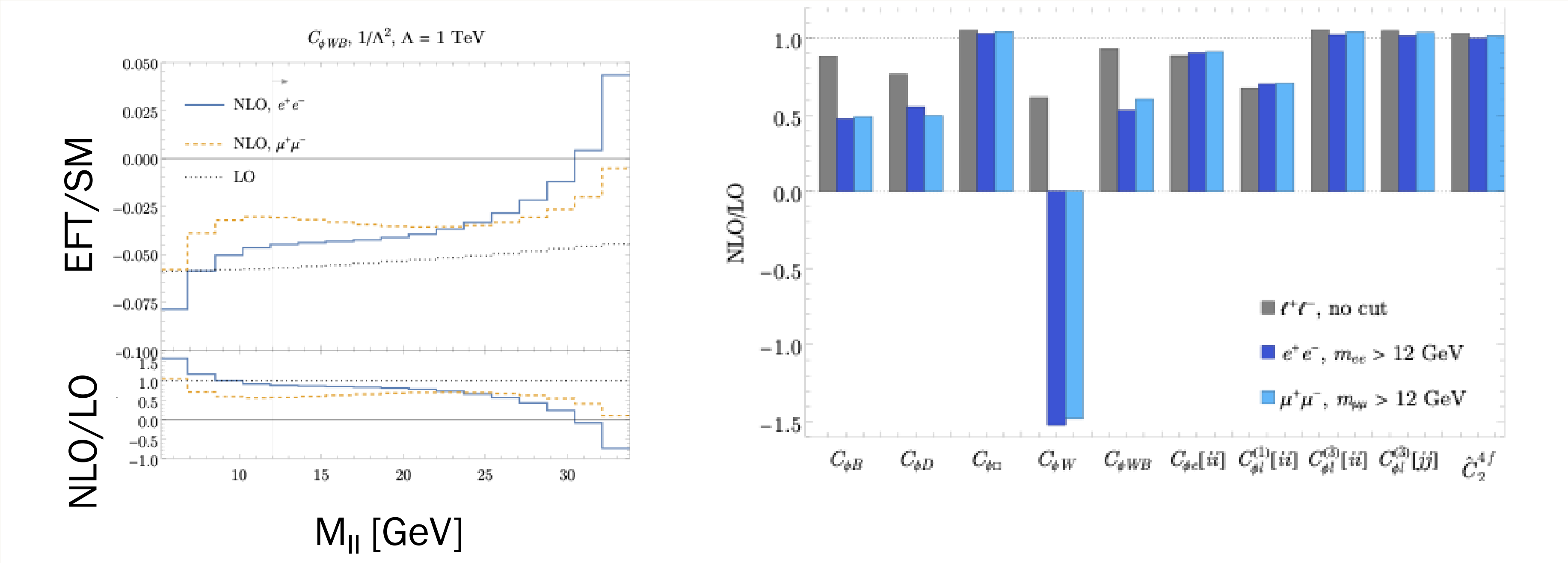
Bellafronte, Dawson, del Pio, Forslund, Giardino, 2601.09599 , 2508.14966

NEWiSH

- Fixed order Monte Carlo code for Higgs decays
- All relevant Higgs partial widths at NLO QCD/EW in dimension-6 SMEFT
- Exact $H \to 4f$ at LO, NWA at NLO
  - *At LO use complex mass scheme to include widths*
- Publicly available at https://gitlab.com/mforslund/newish/

H⟶ l^+l^- Z @ NLO in SMEFT

Significant corrections at NLO

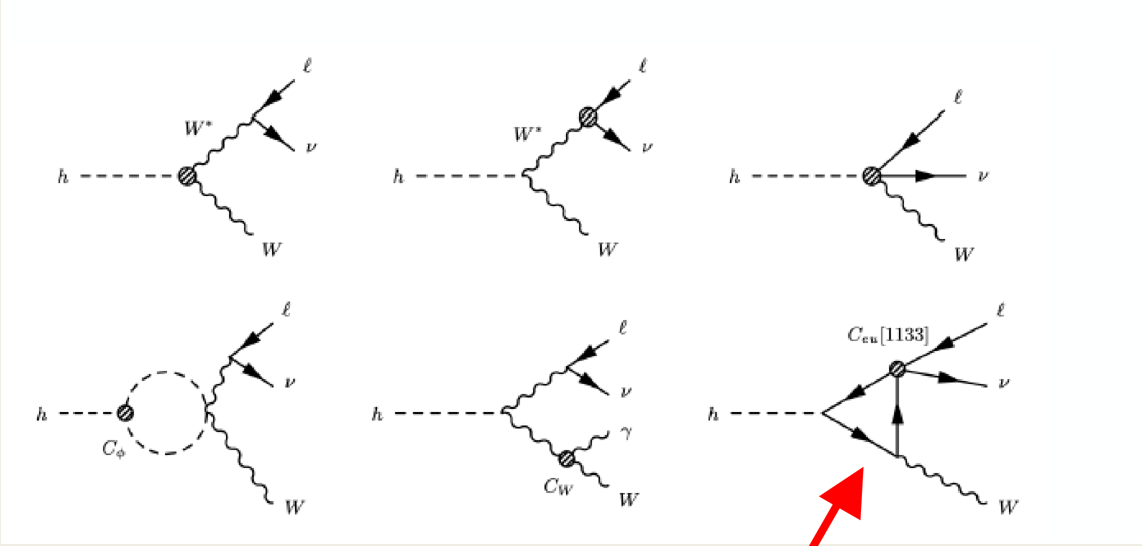


NLO SMEFT matters numerically

Dawson, Forslund, Giardino 2411.08952

H⟶4f

- Massless fermions (except top in loop)
- Partial widths always truncated to $O(1/\Lambda^2)$
- LO H⟶4f : use complex mass scheme to include widths
- H⟶4f at NLO: use NWA



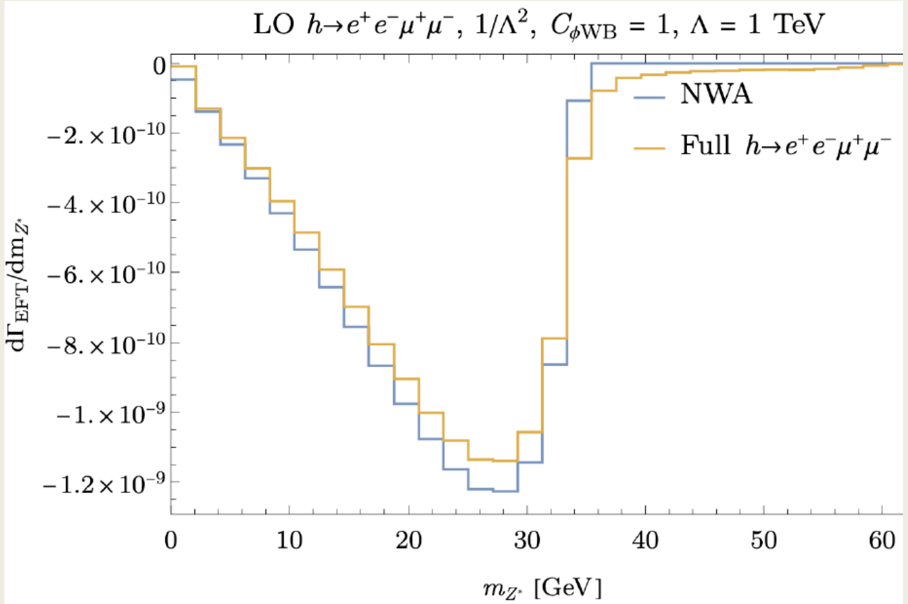
Narrow width approximation

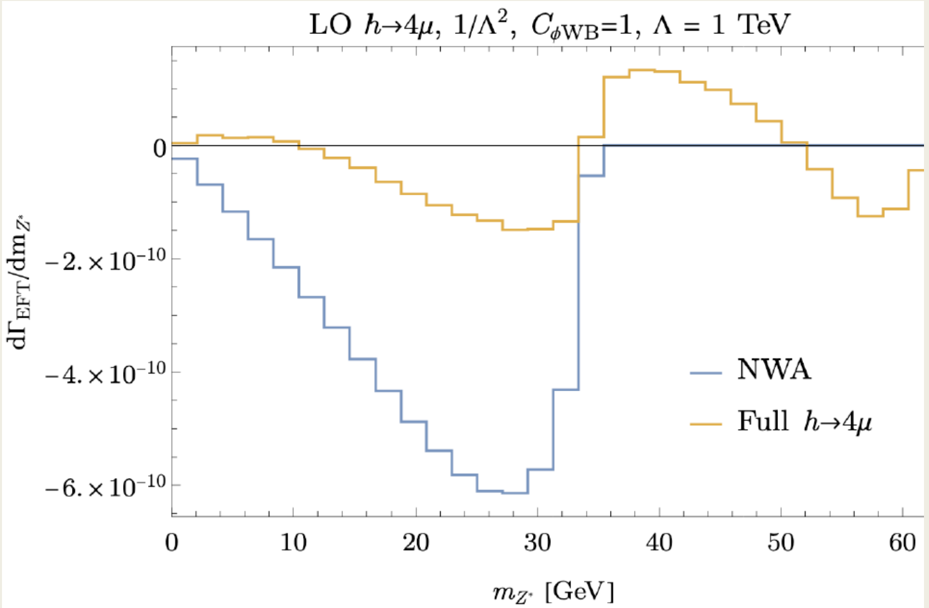
$$\Gamma\Big(H \to (f_1\bar{f}_2)(f_3\bar{f}_4)\Big) = \Gamma\Big(H \to V f_1\bar{f}_2\Big)\frac{\Gamma(V \to f_3\bar{f}_4)}{\Gamma(V \to \text{all})}$$

Cannot be approximated by NWA

Is the NWA Accurate?

Misses cross terms



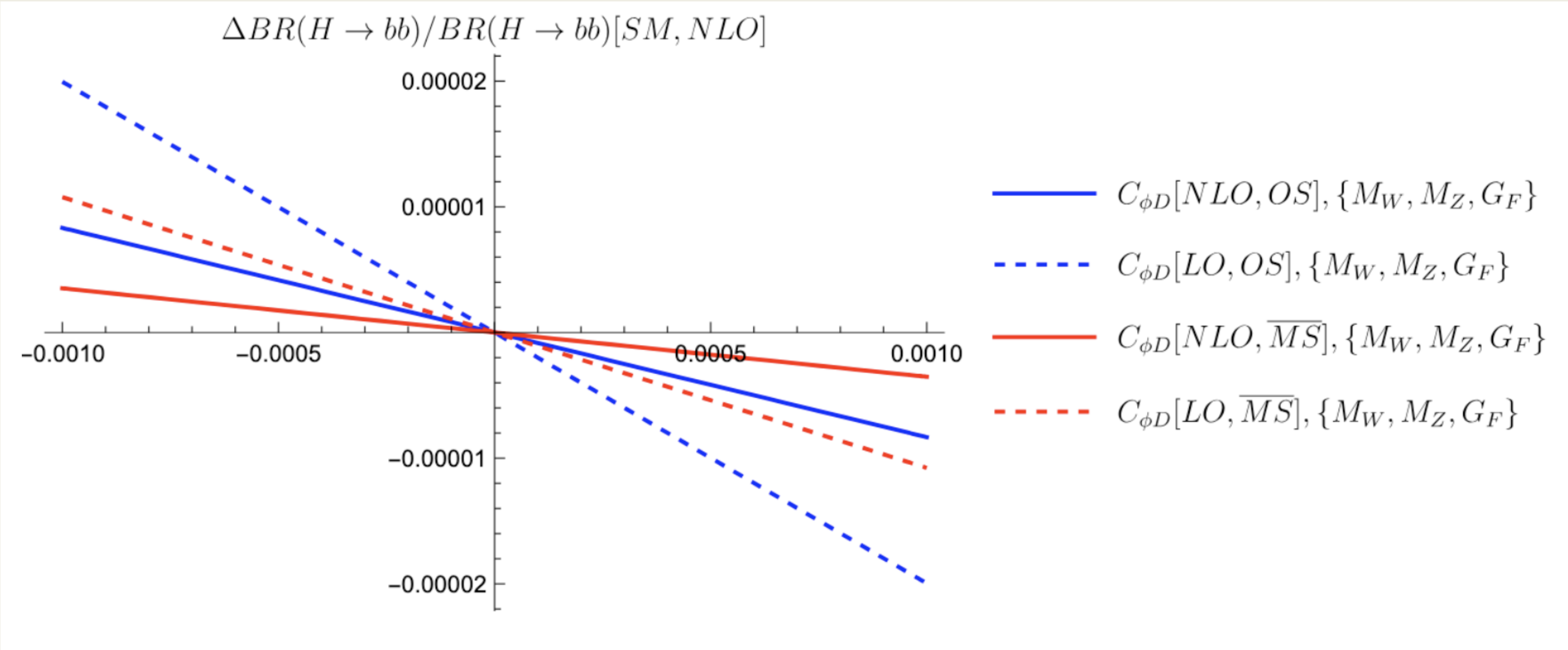


- Eventually want full H⟶4f calculation @ NLO
- For many operators, NWA gives 10% accuracy at LO

Dawson, Forslund, Giardino 2411.08952
Brivio, Corbett, Trott 1906.06949

Higgs decays to fermion pairs

- Scheme dependence: $\overline{MS}$ vs on-shell m_b small for SMEFT terms
- Both implemented in NEWiSH
- Coefficients evolved to $\mu=m_b$ using DsixTools for $\overline{MS}$



Affects all BRs through total width

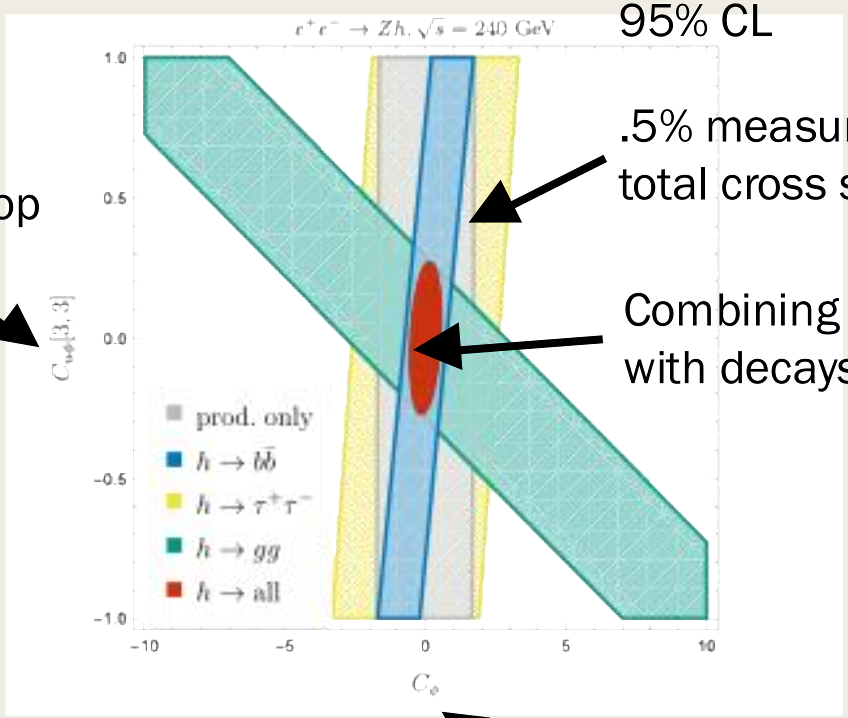
End-to-end NLO SMEFT d-6 EW/QCD fit

- $e^+e^- \to ZH,\ H \to XX$
- Use NWA and include full NLO corrections to $e^+e^- \to ZH,\ Z \to ff,\ H \to XX$
- Significantly more information when decays are included

95% CL

Modifies top Yukawa

These are coefficients that don't contribute at LO



.5% measurement of total cross section

Combining total rate with decays

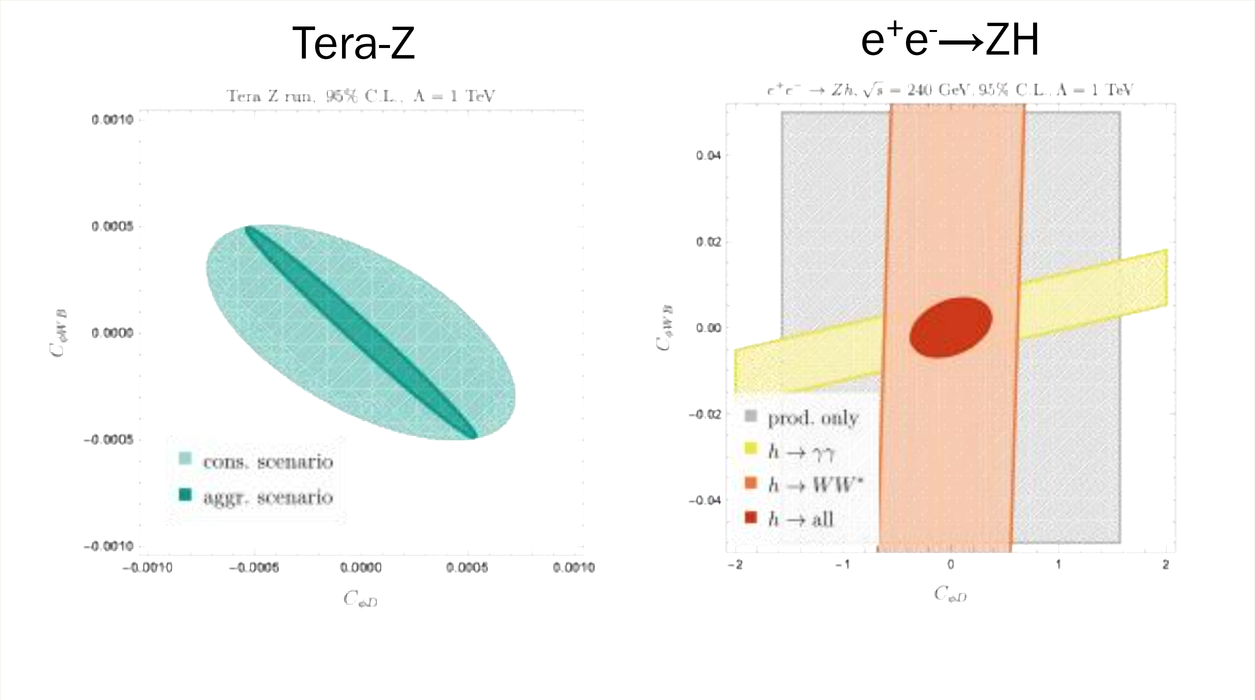
Higgs tri-linear

Decays break degeneracies

2508.14966

Projections sensitive to assumptions about theory

- Results include NLO QCD/EW SMEFT
- Assumptions from European Strategy Report (summarized in Tables 1-3 of 2601.09599)
- *Note scales on plots*
- For this set of coefficients, tera-Z nails it



Bellafronte, Dawson, del Pio, Forslund, Giardino 2601.09599

End-to-end NLO EW fit

- Translate to κ formalism (DANGER)

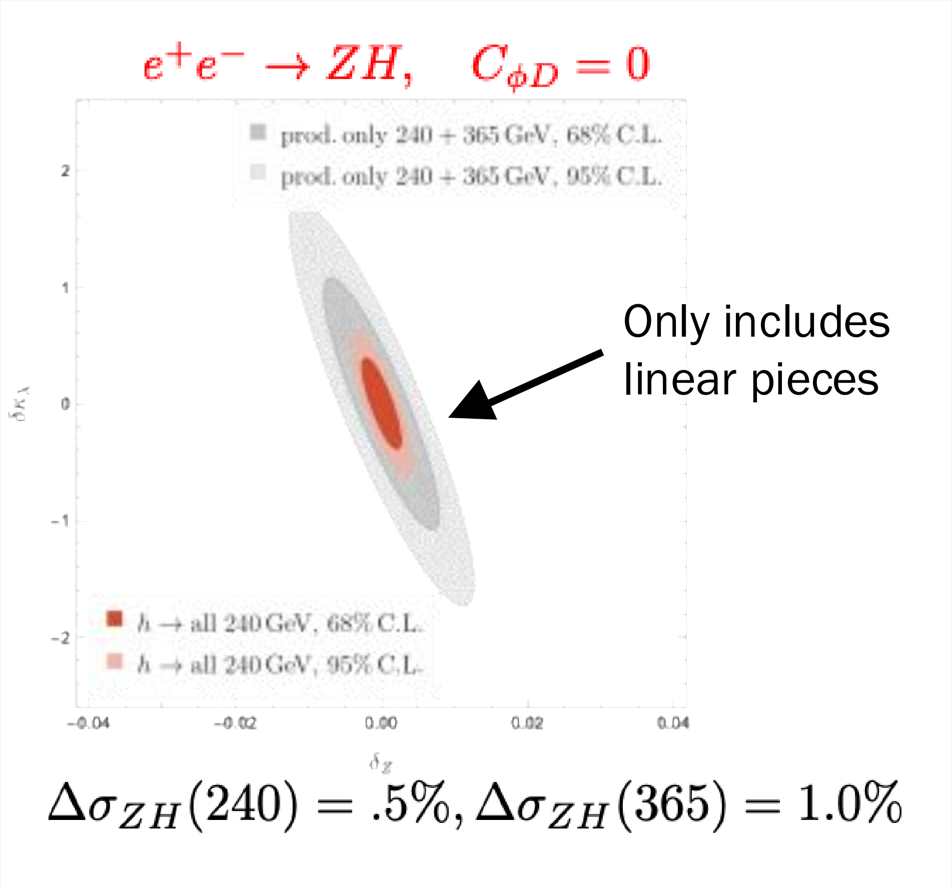
$$\delta_Z = \frac{1}{4}\frac{v^2}{\Lambda^2}\left(C_{\phi D} + 4C_{\phi\Box}\right)$$

$$\kappa_\lambda = 1 + \frac{v^2}{\Lambda^2}\left(3\left[\frac{C_{\phi D}}{4} - C_{\phi\Box}\right] - 2\frac{v^2}{m_H^2}C_\phi\right)$$

- Decays provide new information

Caution: 2-parameter SMEFT fit

How big can κ_λ be? Partial wave unitarity of hh→hh, $C_H < 8\pi\,(1\ \text{TeV}/\Lambda)^2$, perturbativity of series: $v^2 C_H/\Lambda^2 < 1$ [$\kappa_\lambda < 195$, 8]



2508.14966

Example

- 4-fermion operators generically occur in models with heavy Z's
- Contributions with top in loops often enhanced
- Operators that contribute to (ee)(tt) vertices:

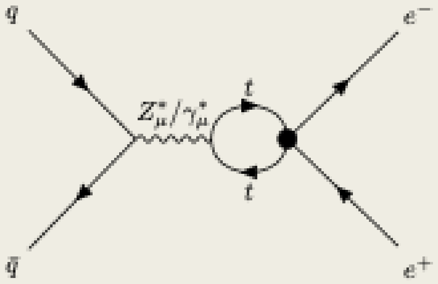
$$[\mathcal{O}_{eu}]_{prst} = (\bar{e}_p\gamma^\mu e_r)(\bar{u}_s\gamma_\mu u_t)$$

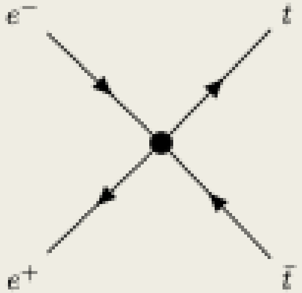
$$[\mathcal{O}_{qe}]_{prst} = (\bar{q}_p\gamma^\mu q_r)(\bar{e}_s\gamma_\mu e_t)$$

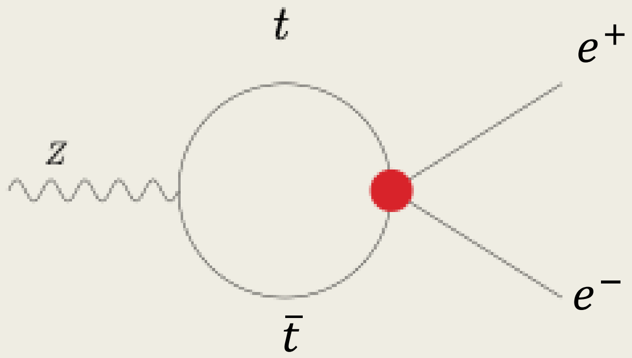
$$[\mathcal{O}^{(1)}_{\ell q}]_{prst} = (\bar{\ell}_p\gamma^\mu \ell_r)(\bar{q}_s\gamma_\mu q_t)$$

$$[\mathcal{O}^{(3)}_{\ell q}]_{prst} = (\bar{\ell}_p\gamma^\mu \sigma^I \ell_r)(\bar{q}_s\gamma_\mu \sigma^I q_t)$$

$$[\mathcal{O}_{\ell u}]_{prst} = (\bar{\ell}_p\gamma^\mu \ell_r)(\bar{u}_s\gamma_\mu u_t)$$



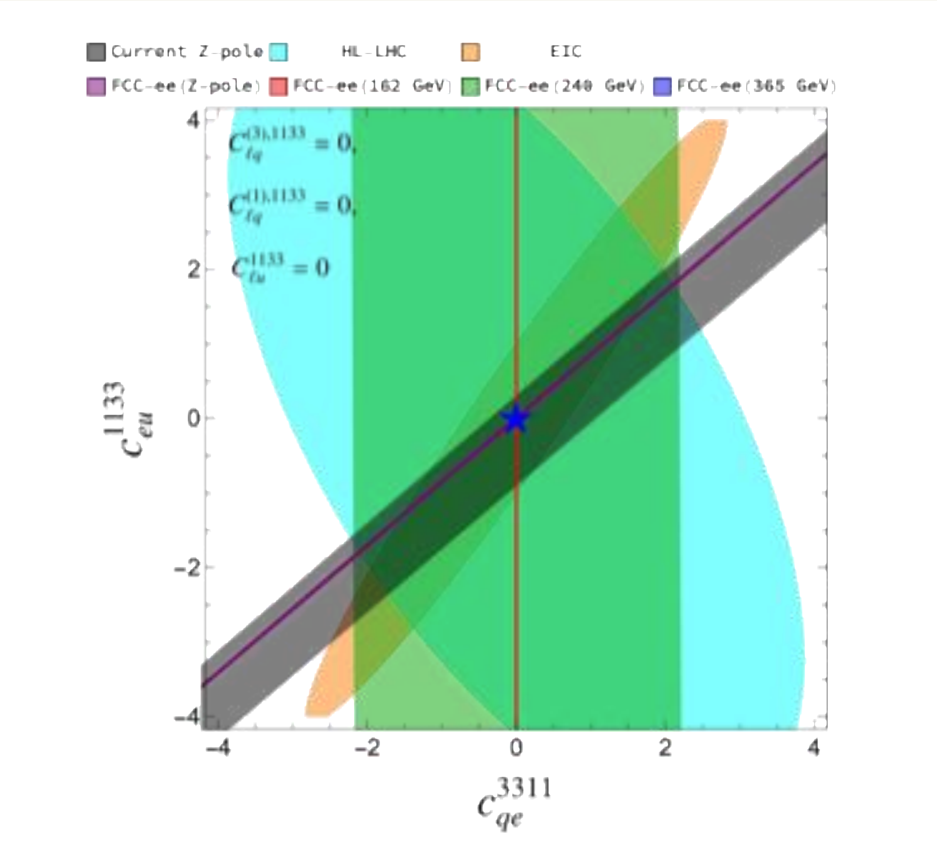




Coefficients for your favorite Z' model:
Dawson, Forslund, Schnubel,
https://arxiv.org/pdf/2404.01375

Constraints from many sources

- HL-LHC Drell-Yan (loops)
- EIC (loops)
- Tera-Z (Loops)
- $e^+e^- \rightarrow ZH$ (loops)
- $e^+e^- \rightarrow bb$ (tree level)
- $e^+e^- \rightarrow tt$ (tree level)
- Plot is full NLO EW fit—logs dominate over constant terms

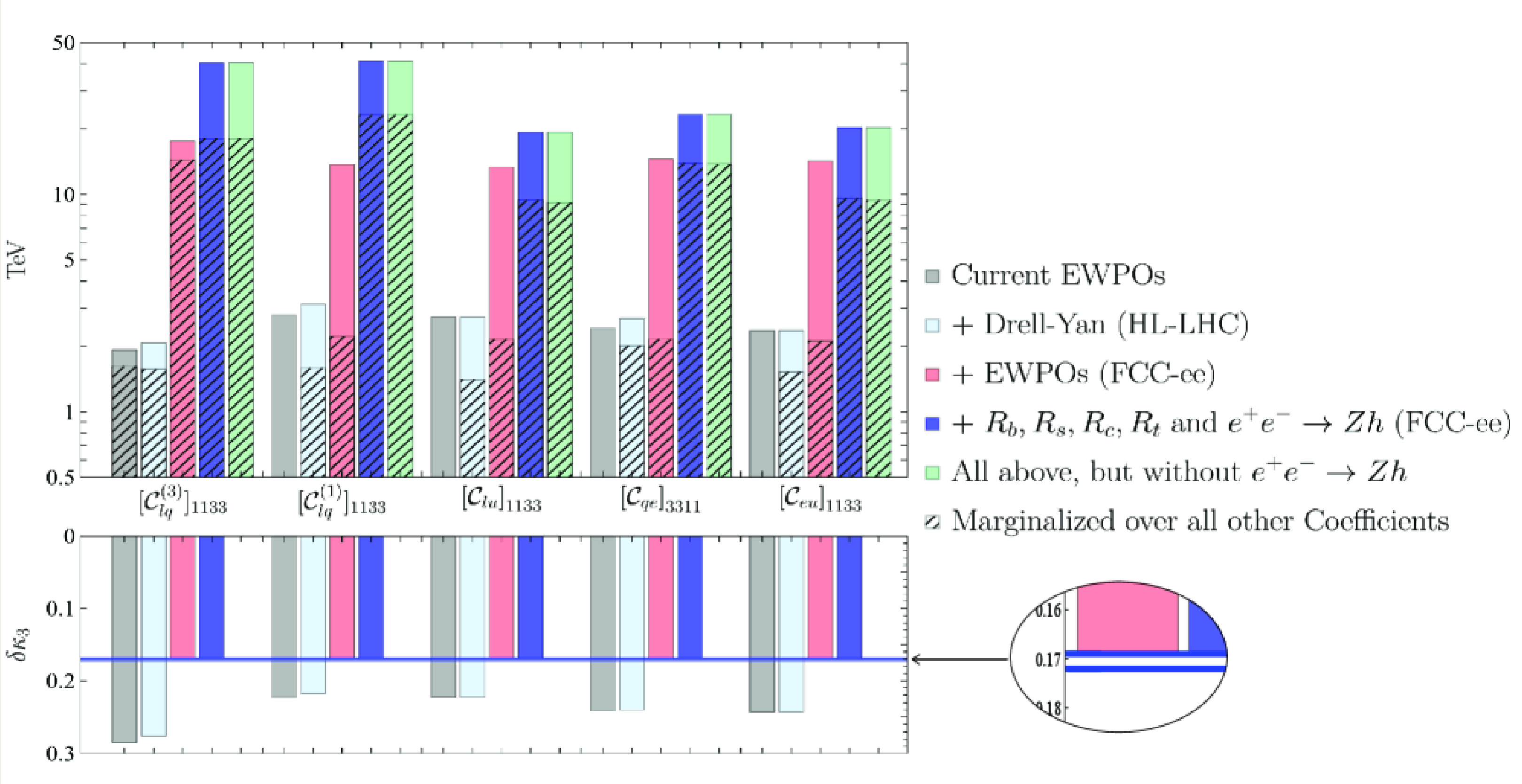


eett operators constrained by tera-Z and $e^+e^- \rightarrow bb$ alone

Importance of global fits!

Bellafronte, Dawson, Giardino, Liu [2507.02039](https://arxiv.org/abs/2507.02039)

Higgs tri-linear relatively insensitive to eett operators



$$\delta\kappa_3^{\text{marg}} = 0.17 \quad (1\sigma)$$

Remember it's really C_H

$$O_H = | H^\dagger H |^3$$

Will this conclusion hold with more operators?

Allwicher, Grojean, Tabatt 2512.06916

Missing pieces for full NLO QCD/EW LHC dim-6 SMEFT Study

- Z, W, Higgs decays at NLO EW/QCD dim-6 SMEFT known
- At LHC, need $gg \to H$ @2-loop SMEFT to capture dim-6 NLO SMEFT effects and SM
- At LHC, $qq \to VH$ can be obtained by crossing from $H \to qqV$
- NLO EW SMEFT for VBF is problematic (needs new techniques)

Goal: Global fit marginalized over operators where all observable predicted to NLO QCD/EW SMEFT

The future

- Top down: 2-loops
  - *Have tools for consistent NLO fits to models*
  - *Match models to 1-loop at Λ*
  - *NLO RGE (using 2-loop SMEFT RGEs) to M_Z*
  - *Fit to NLO predictions*
- Discussion: Bottom up
  - *How to use NLO EW results in fits?*
  - *How to include $1/\Lambda^4$, dimension-8?*

Serious comparison of precision fit results with direct search experiments lacking

Higgs couplings presented as precision measurements in SMEFT?
PROs: Can be theoretically rigorous, allows for global fits
CONS: Not very intuitive or visual, assumes no new light physics

BACKUP

Warsaw Basis

Table 2: Dimension-6 operators other than the four-fermion ones (from ref. [11]). For brevity, fermion chiral indices L, R are suppressed.

X^3		φ^6 and $\varphi^4 D^2$		$\psi^2\varphi^3$	
Q_G	$f^{ABC} G^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	Q_φ	$(\varphi^\dagger\varphi)^3$	$Q_{e\varphi}$	$(\varphi^\dagger\varphi)(\bar{l}'_p e'_r \varphi)$
$Q_{\widetilde{G}}$	$f^{ABC} \widetilde{G}^{A\nu}_{\mu} G^{B\rho}_{\nu} G^{C\mu}_{\rho}$	$Q_{\varphi\Box}$	$(\varphi^\dagger\varphi)\Box(\varphi^\dagger\varphi)$	$Q_{u\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}'_p u'_r \widetilde{\varphi})$
Q_W	$\varepsilon^{IJK} W^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$	$Q_{\varphi D}$	$(\varphi^\dagger D^\mu\varphi)^* (\varphi^\dagger D_\mu\varphi)$	$Q_{d\varphi}$	$(\varphi^\dagger\varphi)(\bar{q}'_p d'_r \varphi)$
$Q_{\widetilde{W}}$	$\varepsilon^{IJK} \widetilde{W}^{I\nu}_{\mu} W^{J\rho}_{\nu} W^{K\mu}_{\rho}$				
$X^2\varphi^2$		$\psi^2 X\varphi$		$\psi^2\varphi^2 D$	
$Q_{\varphi G}$	$\varphi^\dagger\varphi\, G^A_{\mu\nu} G^{A\mu\nu}$	Q_{eW}	$(\bar{l}'_p \sigma^{\mu\nu} e'_r)\tau^I\varphi W^I_{\mu\nu}$	$Q^{(1)}_{\varphi l}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{l}'_p\gamma^\mu l'_r)$
$Q_{\varphi\widetilde{G}}$	$\varphi^\dagger\varphi\, \widetilde{G}^A_{\mu\nu} G^{A\mu\nu}$	Q_{eB}	$(\bar{l}'_p \sigma^{\mu\nu} e'_r)\varphi B_{\mu\nu}$	$Q^{(3)}_{\varphi l}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu\varphi)(\bar{l}'_p\tau^I\gamma^\mu l'_r)$
$Q_{\varphi W}$	$\varphi^\dagger\varphi\, W^I_{\mu\nu} W^{I\mu\nu}$	Q_{uG}	$(\bar{q}'_p \sigma^{\mu\nu} T^A u'_r)\widetilde{\varphi}\, G^A_{\mu\nu}$	$Q_{\varphi e}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{e}'_p\gamma^\mu e'_r)$
$Q_{\varphi\widetilde{W}}$	$\varphi^\dagger\varphi\, \widetilde{W}^I_{\mu\nu} W^{I\mu\nu}$	Q_{uW}	$(\bar{q}'_p \sigma^{\mu\nu} u'_r)\tau^I\widetilde{\varphi}\, W^I_{\mu\nu}$	$Q^{(1)}_{\varphi q}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{q}'_p\gamma^\mu q'_r)$
$Q_{\varphi B}$	$\varphi^\dagger\varphi\, B_{\mu\nu} B^{\mu\nu}$	Q_{uB}	$(\bar{q}'_p \sigma^{\mu\nu} u'_r)\widetilde{\varphi}\, B_{\mu\nu}$	$Q^{(3)}_{\varphi q}$	$(\varphi^\dagger i\overleftrightarrow{D}^I_\mu\varphi)(\bar{q}'_p\tau^I\gamma^\mu q'_r)$
$Q_{\varphi\widetilde{B}}$	$\varphi^\dagger\varphi\, \widetilde{B}_{\mu\nu} B^{\mu\nu}$	Q_{dG}	$(\bar{q}'_p \sigma^{\mu\nu} T^A d'_r)\varphi\, G^A_{\mu\nu}$	$Q_{\varphi u}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{u}'_p\gamma^\mu u'_r)$
$Q_{\varphi WB}$	$\varphi^\dagger\tau^I\varphi\, W^I_{\mu\nu} B^{\mu\nu}$	Q_{dW}	$(\bar{q}'_p \sigma^{\mu\nu} d'_r)\tau^I\varphi\, W^I_{\mu\nu}$	$Q_{\varphi d}$	$(\varphi^\dagger i\overleftrightarrow{D}_\mu\varphi)(\bar{d}'_p\gamma^\mu d'_r)$
$Q_{\varphi\widetilde{W}B}$	$\varphi^\dagger\tau^I\varphi\, \widetilde{W}^I_{\mu\nu} B^{\mu\nu}$	Q_{dB}	$(\bar{q}'_p \sigma^{\mu\nu} d'_r)\varphi\, B_{\mu\nu}$	$Q_{\varphi ud}$	$i(\widetilde{\varphi}^\dagger D_\mu\varphi)(\bar{u}'_p\gamma^\mu d'_r)$

Tera-Z Accuracy

Table 3: Projected uncertainties on EWPO at FCC-ee from Tera-Z with 205 ab^{-1} and Γ_W measured at the W^+W^- threshold with 19.2 ab^{-1}, from Ref. [120] unless otherwise stated. Theory uncertainties are divided into those associated with the definition of pseudo-observables at the Z peak ("PO") and those coming from calculations ("Theory"). Both conservative ("C") and aggressive ("A") scenarios are considered. The dash means the uncertainty is assumed to be negligible. Numbers labeled by [*] are found by linear propagation of errors from Ref. [120].

FCC-ee Uncertainties	Stat	Syst	PO(C)	PO(A)	Theory(C)	Theory(A)
$\Delta\Gamma_Z$ (KeV)	4	12	35	–	80	16
δR_e	3.4×10^{-6} [143]	2.3×10^{-6} [143]	4×10^{-4}	–	1.2×10^{-3}	2×10^{-4}
δR_μ	2.4×10^{-6}	2.3×10^{-6}	4×10^{-4}	–	1.2×10^{-3}	2×10^{-4}
δR_τ	2.7×10^{-6} [143]	2.3×10^{-6} [143]	4×10^{-4}	–	1.2×10^{-3}	2×10^{-4}
δR_b	1.2×10^{-6}	1.6×10^{-6}	4.4×10^{-5}	9×10^{-6}	2×10^{-5}	3.5×10^{-6}
δR_c	1.4×10^{-6} [143]	2.2×10^{-6} [143]	1.7×10^{-4}	3.4×10^{-5}	1×10^{-5}	2×10^{-6}
$\Delta\sigma_h$ (pb)	0.03 [143]	0.8 [143]	1.7	–	1.6	0.3
ΔA_e	14×10^{-6} [143]	11×10^{-6} [143]	19.5×10^{-5} [*]	–	5.3×10^{-5} [*]	4.5×10^{-6} [*]
ΔA_μ	32×10^{-6} [143]		19.5×10^{-5} [*]	–	5.3×10^{-5} [*]	4.5×10^{-6} [*]
ΔA_τ	34×10^{-6} [143]		19.5×10^{-5} [*]	–	5.3×10^{-5} [*]	4.5×10^{-6} [*]
ΔA_c	60×10^{-6} [143]		91×10^{-5} [*]	–	2.3×10^{-5} [*]	2×10^{-6} [*]
ΔA_b	98×10^{-6} [143]		126×10^{-5} [*]	–	4.3×10^{-6} [*]	3.7×10^{-7} [*]
$\Delta A_{e,FB}$	3.3×10^{-6} [143]	2.4×10^{-6} [143]	4.3×10^{-5}	–	1.2×10^{-5} [*]	1×10^{-6} [*]
$\Delta A_{\mu,FB}$	2.3×10^{-6} [143]	2.4×10^{-6} [143]	4.3×10^{-5}	–	1.2×10^{-5} [*]	1×10^{-6} [*]
$\Delta A_{\tau,FB}$	2.8×10^{-6} [143]	2.4×10^{-6} [143]	4.3×10^{-5}	–	1.2×10^{-5} [*]	1×10^{-6} [*]
$\Delta A_{b,FB}$	4×10^{-6} [143]	4×10^{-6} [143]	3.2×10^{-5}	2.8×10^{-6}	3.8×10^{-5} [*]	3.2×10^{-6} [*]
$\Delta A_{c,FB}$	5×10^{-6} [143]	5×10^{-6} [143]	2.3×10^{-5}	2.1×10^{-6}	2.9×10^{-5} [*]	2.5×10^{-6} [*]
$\Delta\Gamma_W$ (KeV)	270	200			1000	100
$\Delta\alpha(M_Z)^{-1}$	8×10^{-4}	3.8×10^{-3}			5×10^{-5}	2×10^{-5}

Notes. The dash indicates a negligible uncertainty as compared to other error sources. Entries where the information separation between "PO" and "Theory" uncertainties does not apply have been left blank.

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