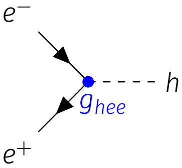
THE BSM IMPLICATIONS OF A MODIFIED ELECTRON YUKAWA COUPLING

...and what we learn from a Higgs pole run at FCC–ee

Ben Smith
(based on arXiv:2511.02642 w/ L. Allwicher, M. Mccullough, S. Renner, D. Rocha)

12th November 2025, **FCC-UK**

THE ELECTRON YUKAWA COUPLING



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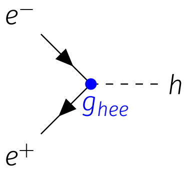

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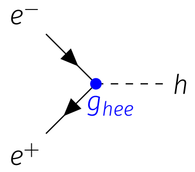

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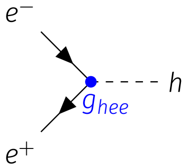

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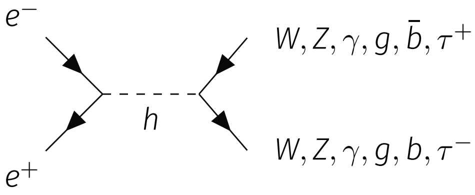
- Parametrise deviations in terms of $\kappa_e = \frac{g_{hee}}{g_{hee}^{SM}}$
- Constraints:
  - $\kappa_e^{\text{LHC}} < 240$ (Tumasyan et al. 2023)
  - $\kappa_e^{\text{HL-LHC}} < 120$ (Cepeda et al. 2019)

FCC-ee PROSPECTS

- Projected $|\kappa_e| < 1.6$ @ 95% C.L from a dedicated run at the Higgs pole ($\sqrt{s} = m_h$) (d'Enterria, Poldaru, and Wojcik 2022) .



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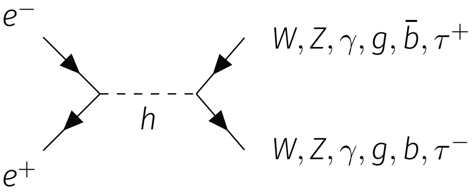

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    - Need monochromatised beams.
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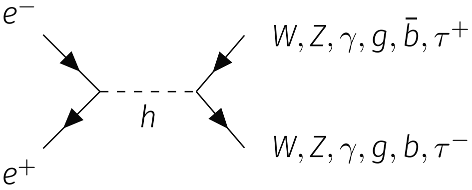

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⟹ What do we learn (EFT/Models)?
Other observables?

EFT PERSPECTIVE

LEPTON YUKAWAS IN THE SMEFT

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- Higgs-lepton coupling matrices are modified.

$$[g_{h\ell\ell}]_{ij} = \frac{1}{v}[M_\ell]_{ij} - \frac{v^2}{\sqrt{2}}[\mathcal{C}_{eH}^*]_{ji} \Rightarrow g_{H\ell\ell} \not\propto M_\ell!$$

- We assume first only $[\mathcal{C}_{eH}]_{11} \neq 0$: **“electrophilic”**
- We consider real-valued $\mathcal{C}_{eH}$ to avoid strong constraints from electric dipole moments. (Panico, Pomarol, and Riembau 2019)

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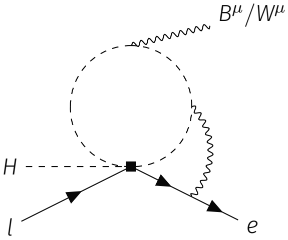
- Leading connection $\mathcal{O}_{eH} \to \mathcal{O}_{eW}/\mathcal{O}_{eB}$ is at the two-loop level.



(Panico, Pomarol, and Riembau 2019)

Δa_e vs κ_e

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2	[-1200,-39]	[-1200,2700]	< 88
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Working the SMEFT alone, Δa_e is insufficient to constrain κ_e to $\mathcal{O}(1)$.

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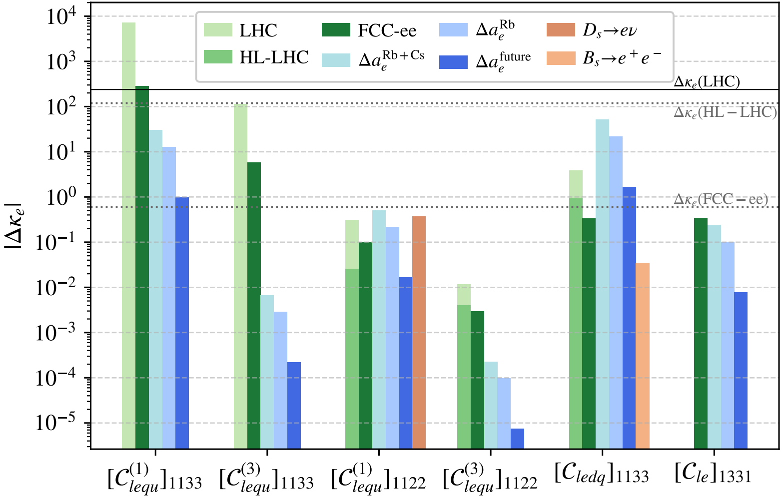
- Within the SMEFT we can study this scenario by looking for operators which generate $\mathcal{O}_{eH}$ via RGE mixing.
- Small number of operators can generate $\mathcal{O}_{eH}$, however, they have complementary collider and flavour constraints.

RADIATIVELY GENERATING $\mathcal{O}_{eH}$

$\Delta\kappa_e = \kappa_e - 1, \Lambda = 2$ TeV



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Other experiments offer better or competitive constraints for all but the electrophilic flavour assumption.

UV MODEL PERSPECTIVE

MATCHING PROCEDURE

- Study single field SM extensions which match to $\mathcal{O}_{eH}$ at tree level using results of (Blas, Criado, Perez-Victoria, and J. Santiago 2018) .
- Also consider single field extensions which match at one loop, we compute one-loop matching using *SOLD* (Guedes, Olgoso, and José Santiago 2023) , (Guedes and Olgoso 2024) .

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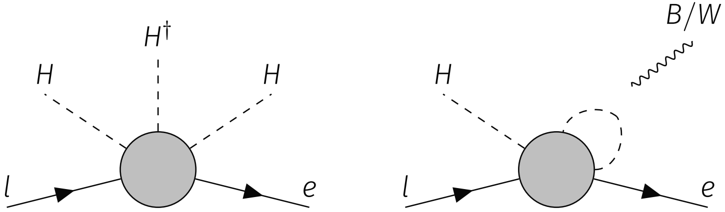
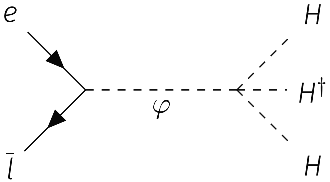


Grey blob = diagram of arbitrary loop order involving heavy state exchange.

THE φ (2HDM) EXCEPTION

- If extension is a scalar doublet $\varphi \sim (1, 2, \frac{1}{2})$, can generate $\mathcal{O}_{eH}$ at tree level.



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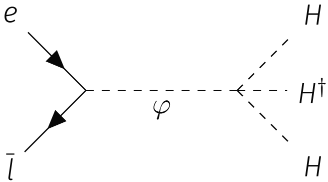

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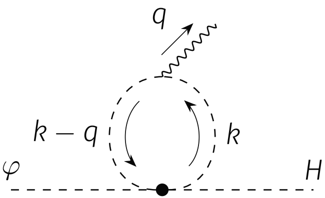
- However, we do *not* generate $\mathcal{O}_{eB}/\mathcal{O}_{eW}$ at one loop.



$$\propto \; q^\mu \epsilon^*_\mu(q) = 0.$$

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State	Spin	SM charges	$\mathcal{C}_{eH}$	$\mathcal{C}_{eB}/\mathcal{C}_{eW}$
$\mathcal{S}$	0	$(1,1,0)$	tree	1 loop
φ (with Higgs coupling)	0	$(1,2,\frac{1}{2})$	tree	2 loop
Ξ	0	$(1,3,0)$	tree	1 loop
Ξ_1	0	$(1,3,1)$	tree	1 loop
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Σ	$\frac{1}{2}$	$(1,3,0)$	tree	1 loop
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φ (with top coupling)	0	$(1,2,\frac{1}{2})$	1 loop	2 loop
ω_1	0	$(3,1,-\frac{1}{3})$	1 loop	1 loop
Π_7	0	$(3,2,\frac{7}{6})$	1 loop	1 loop
$\mathcal{U}_2$	1	$(3,1,\frac{2}{3})$	1 loop	1 loop
$\mathcal{Q}_5$	1	$(3,2,-\frac{5}{6})$	1 loop	1 loop

Blue = non-renormalisable interaction required to match to $\mathcal{C}_{eH}, \mathcal{C}_{eB}, \mathcal{C}_{eW} \Rightarrow$ See (Erdelyi, Gröber, and Selimovic 2025) .

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SCHEMATIC BOUNDS

$$\mathcal{C}_{e\gamma} = (\cos(\theta_W)\mathcal{C}_{eB} - \sin(\theta_W)\mathcal{C}_{eW}) = \frac{e}{16\pi^2}\left(\frac{g^2}{16\pi^2}\right)^{N_{\text{loops}}-1} \mathcal{C}_{eH}$$

N_{loops}	κ_e (Δa_e^{Rb})	κ_e $(\Delta a_e^{\text{Rb+Cs}})$	$\lvert\kappa_e\rvert$ $(\Delta a_e^{\text{future}})$
0	[0.80, 0.996]	[0.80, 1.4]	< 1.01
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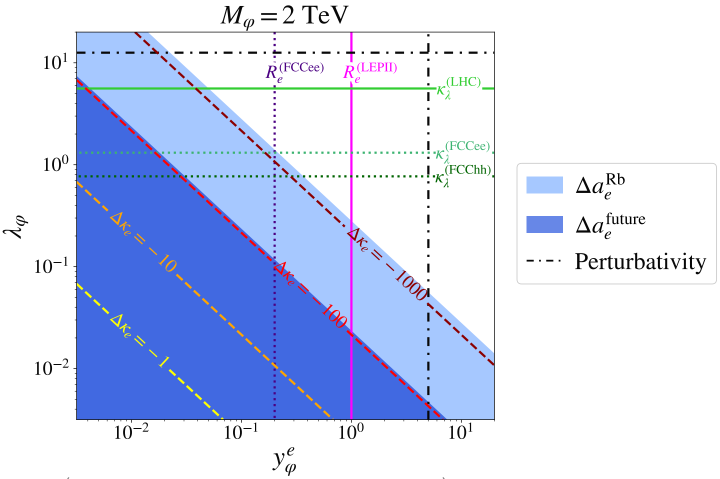
$\Longrightarrow$ Two loop suppression between κ_e and Δa_e required for large enhancements.



- R_e from (Greljo, Tiblom, and Valenti 2024)
- κ_λ(FCC-ee) from (Hoeve, Mantani, Rojo, Rossia, and Vryonidou 2025)

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- In most UV completions, the link $\kappa_e \to \Delta a_e$ is stronger than two loop and gives competitive constraints to FCC-ee.

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- Within the SMEFT, indirect constraints on κ_e from its two-loop connection to Δa_e are about two orders of magnitude weaker.
- Other collider constraints can be avoided if $\mathcal{C}_{eH}$ is generated at leading order and with an electrophilic flavour structure.
- In most UV completions, the link $\kappa_e \to \Delta a_e$ is stronger than two loop and gives competitive constraints to FCC-ee.
- Nevertheless, in certain electrophilic models, a direct measurement of κ_e remains the only probe of the relevant parameter space.

VISUAL SUMMARY

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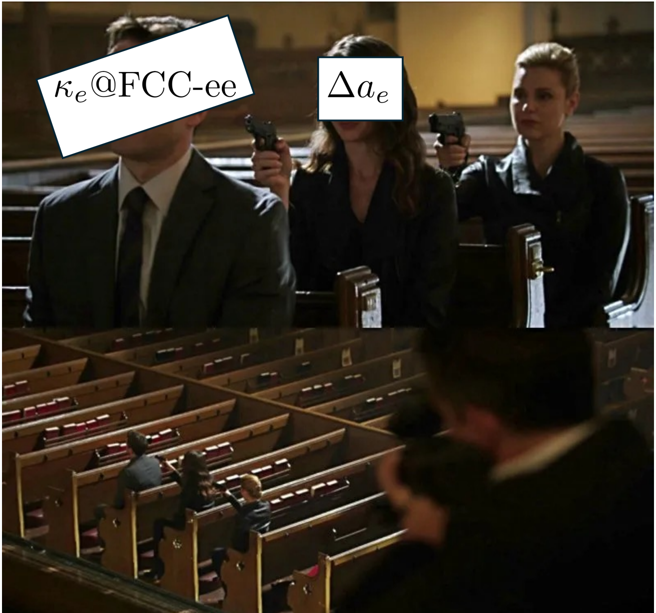
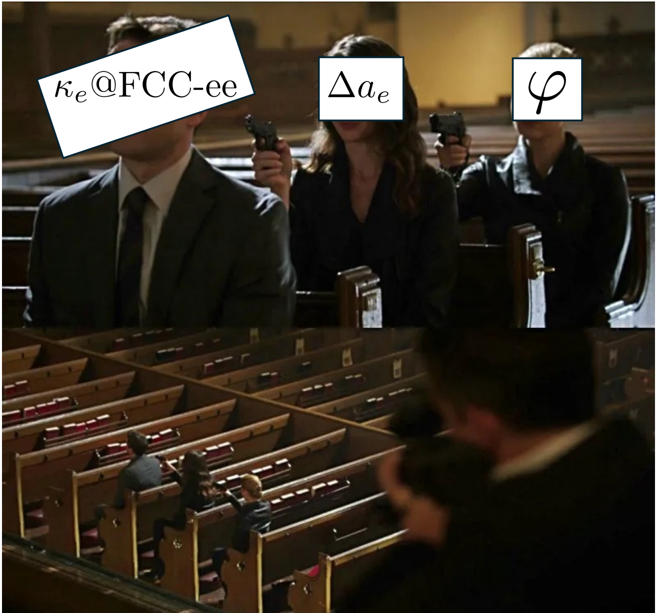
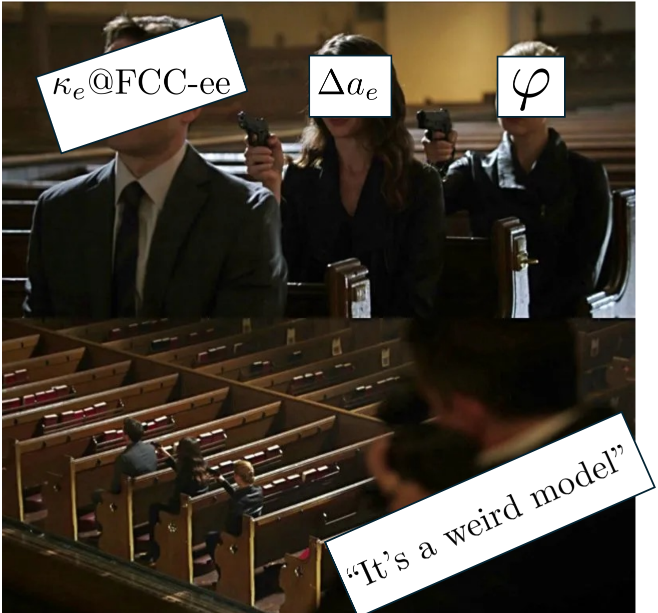

κ_e@FCC-ee
Δa_e


κ_e@FCC-ee
Δa_e
φ


κ_e@FCC-ee
Δa_e
φ
"It's a weird model"

Thank you!

BACKUP SLIDES

FINE-TUNING

$$\kappa_e = \frac{g_{hee}}{\frac{m_e}{v}} = \frac{\frac{1}{2}(y_e - \frac{3v^2}{\sqrt{2}}\mathcal{C}_{eH})}{\frac{1}{\sqrt{2}}(y_e - \frac{v^2}{2}\mathcal{C}_{eH})} = 1 - \frac{\frac{v^2\mathcal{C}_{eH}}{y_e}}{1 - \frac{v^2\mathcal{C}_{eH}}{2y_e}} = 1 - \frac{\zeta}{1-\zeta/2}$$

Large κ_e requires tuning ζ $(= \frac{v^2\mathcal{C}_{eH}}{2y_e})$ close to 1.

$$\Delta = \left|\frac{\partial \ln \kappa}{\partial \ln \zeta}\right| = \left|\frac{(1-\kappa)(3-\kappa)}{2\kappa}\right| \quad ,$$

which behaves as

$$\lim_{\kappa \gg 1} \Delta = \frac{\kappa}{2} \quad .$$

$\Rightarrow \kappa_e = 10$ requires $\sim 20\%$ tuning.

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