Probing heavy new physics systematically at FCC

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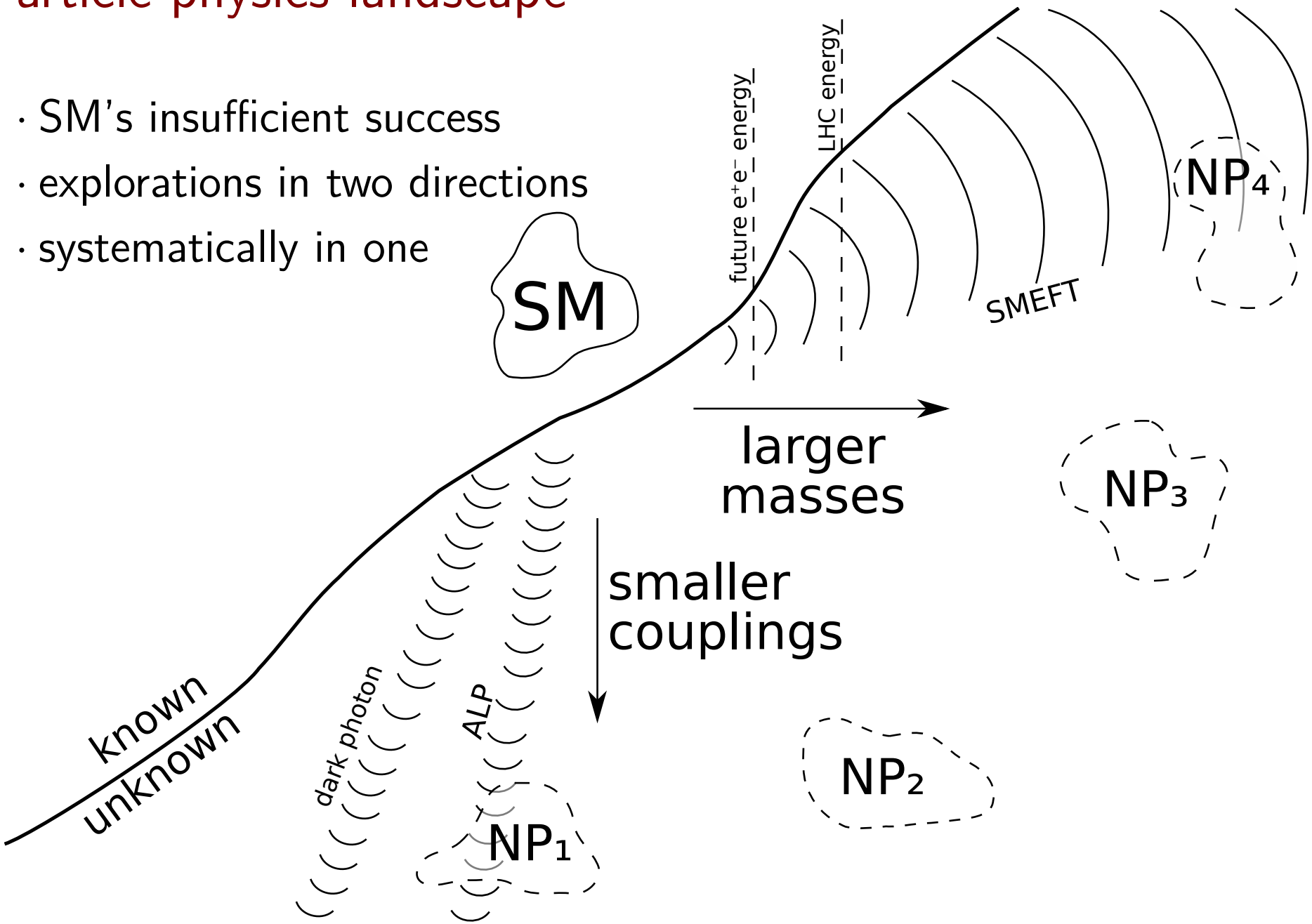
(CERN)

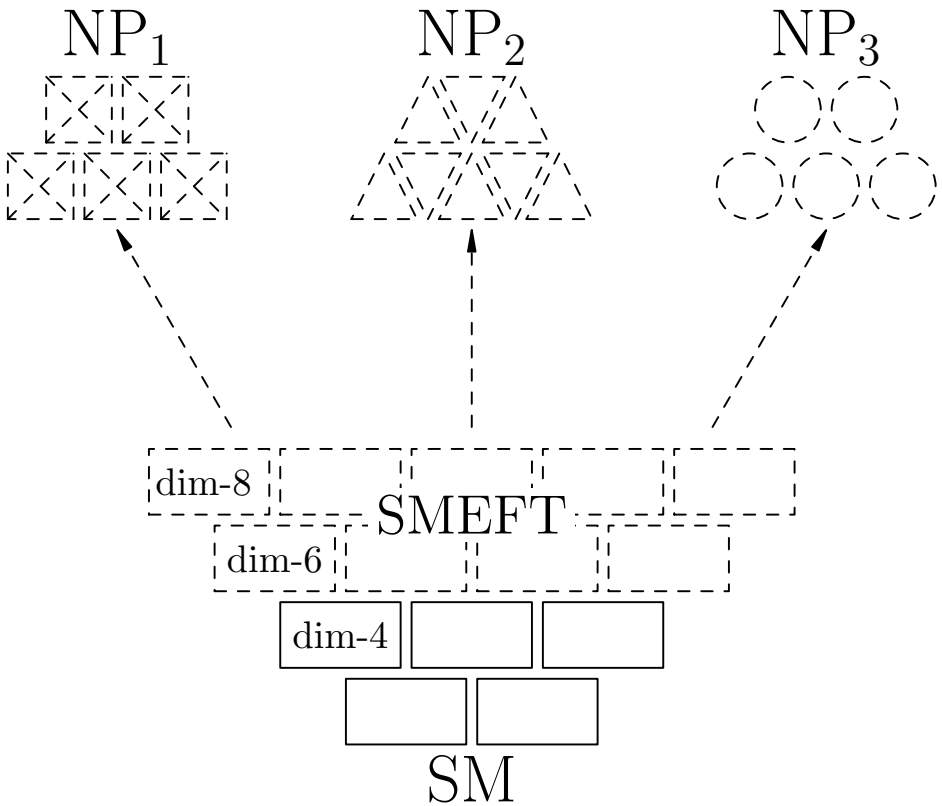
FCC-week
30 June 2021

Particle physics landscape

- SM's insufficient success
- explorations in two directions
- systematically in one



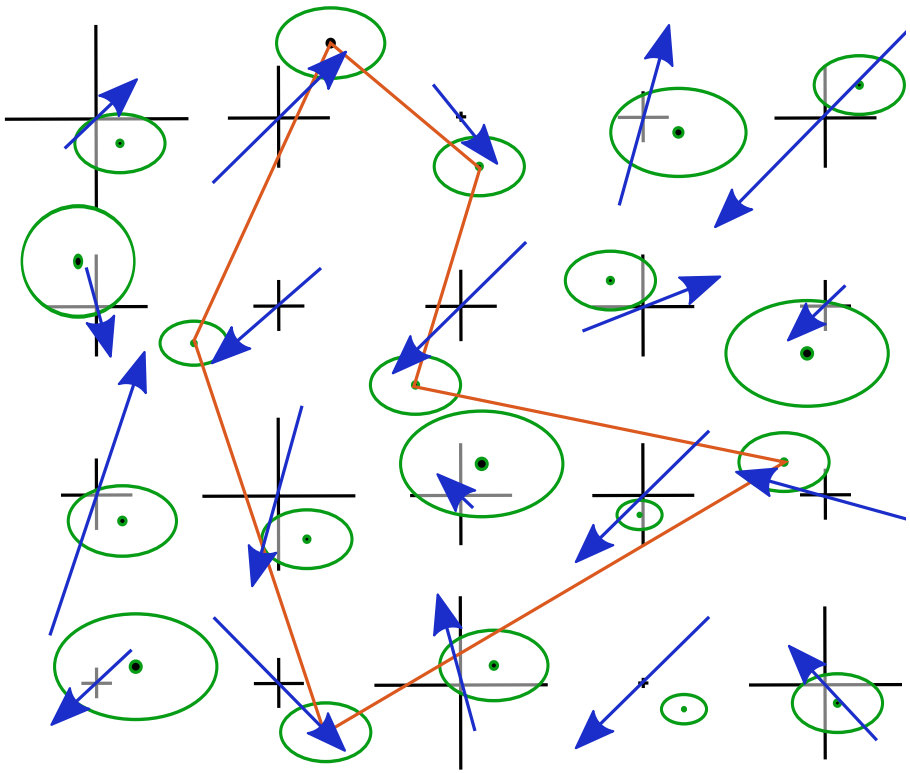
Taking the SM to higher dimensions



- using established bricks (fields and symmetries)
- extension organised in layers (by dimension)
- including all deformations (theory space coverage)

$\rightarrow$ a global approach

Identifying patterns of new physics

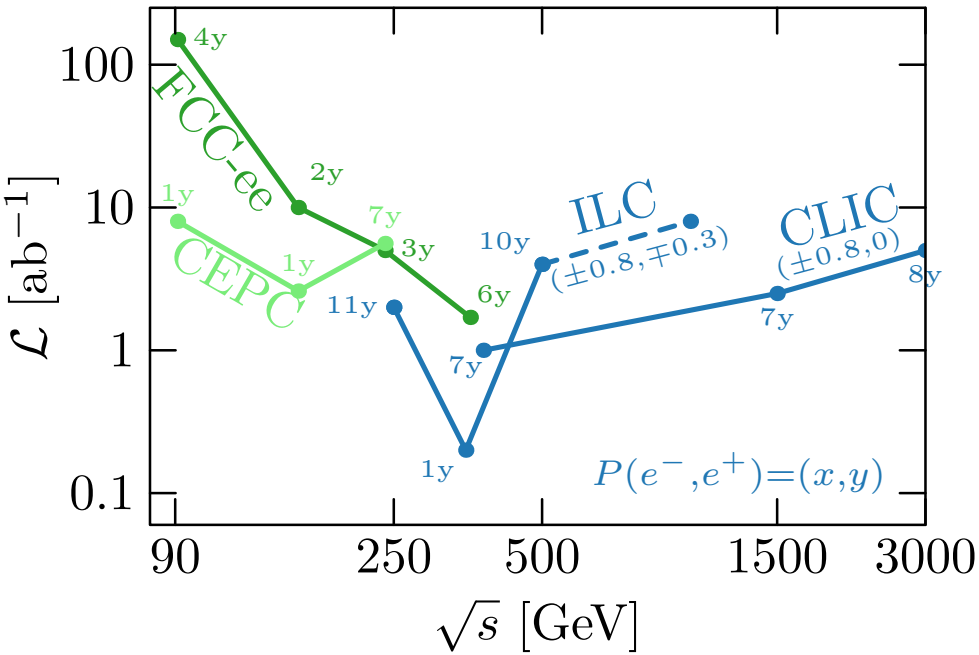


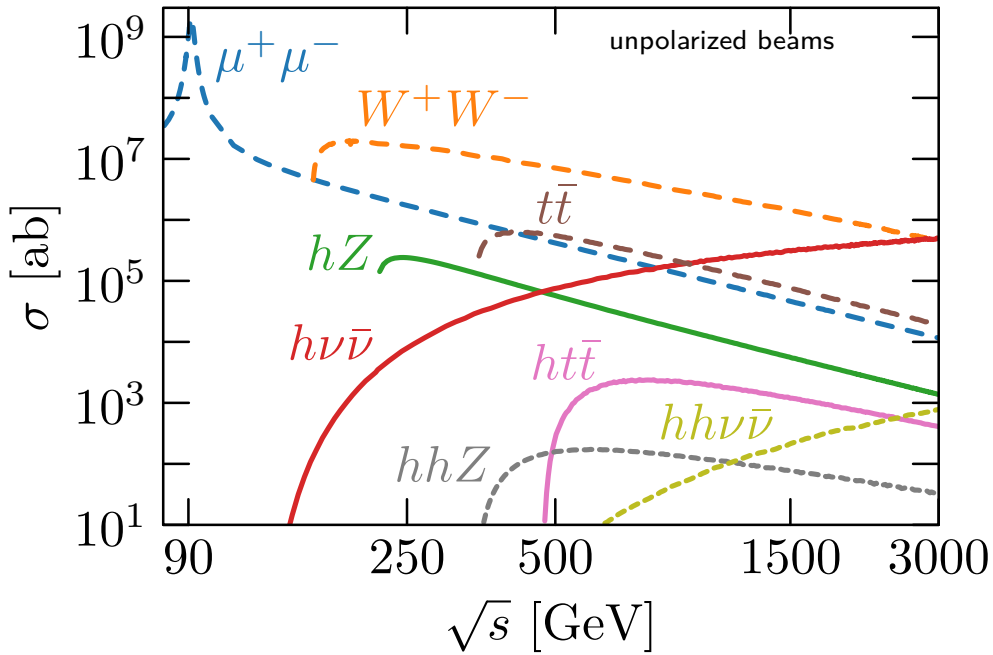
design sensitive observables

- precise SM predictions
- precise SMEFT predictions
- precise measurements

→ leverage correlations

Precision at e^+e^-





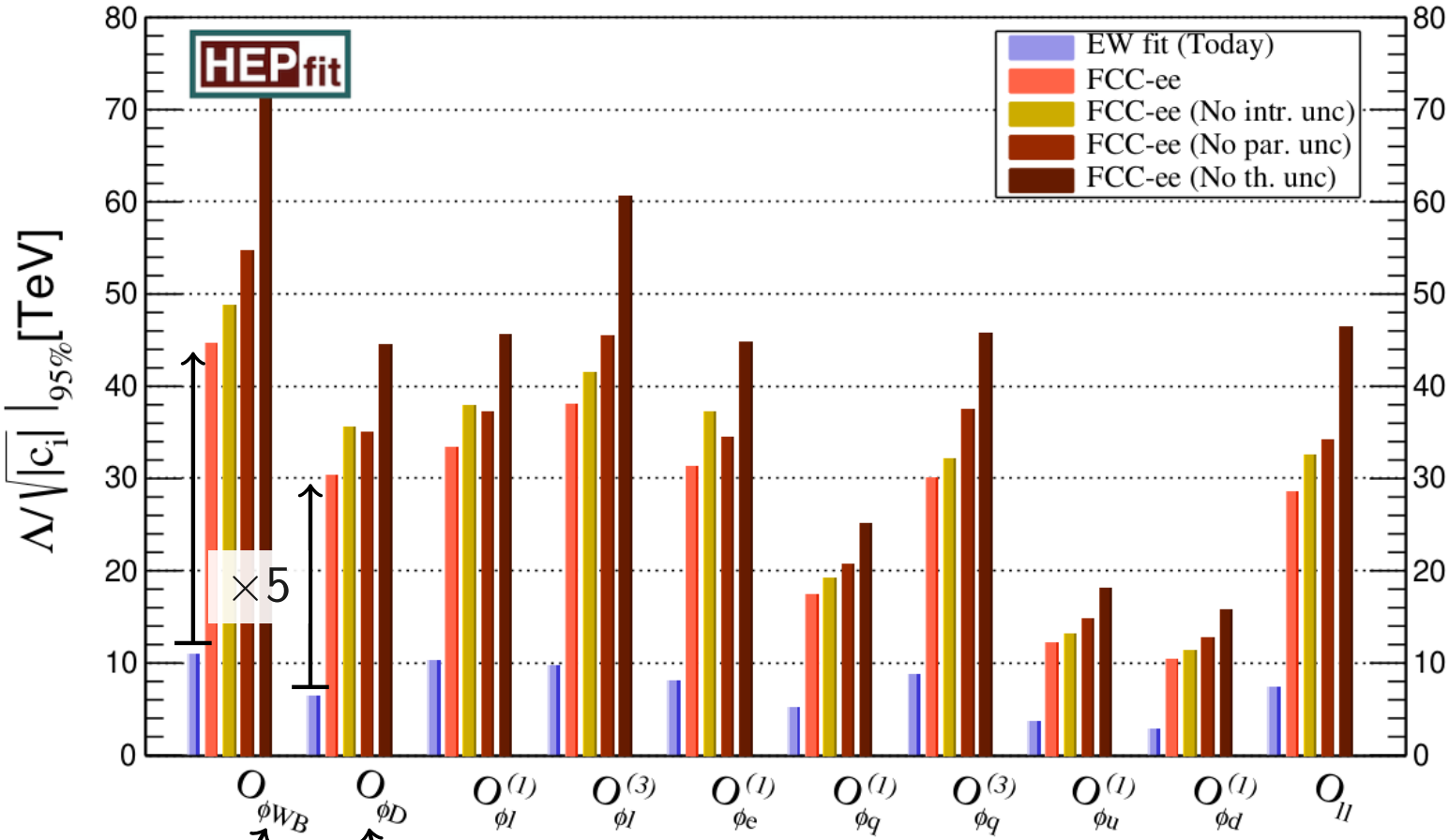
clean environment

large statistics

$10^{12}\,Z$, $10^8\,W$, $10^6\,H$, $10^6\,t$

Electroweak sector

The enduring 'model-killing' legacy of LEP, brought to a new level.
(m_Z, Γ_Z, $A_{\rm FB}$, R_x, $\alpha(m_Z)$, m_W, m_t, etc.)



S parameter

T parameter

custodial ~~symmetry~~

[FCC-ee CDR]

Higgs sector

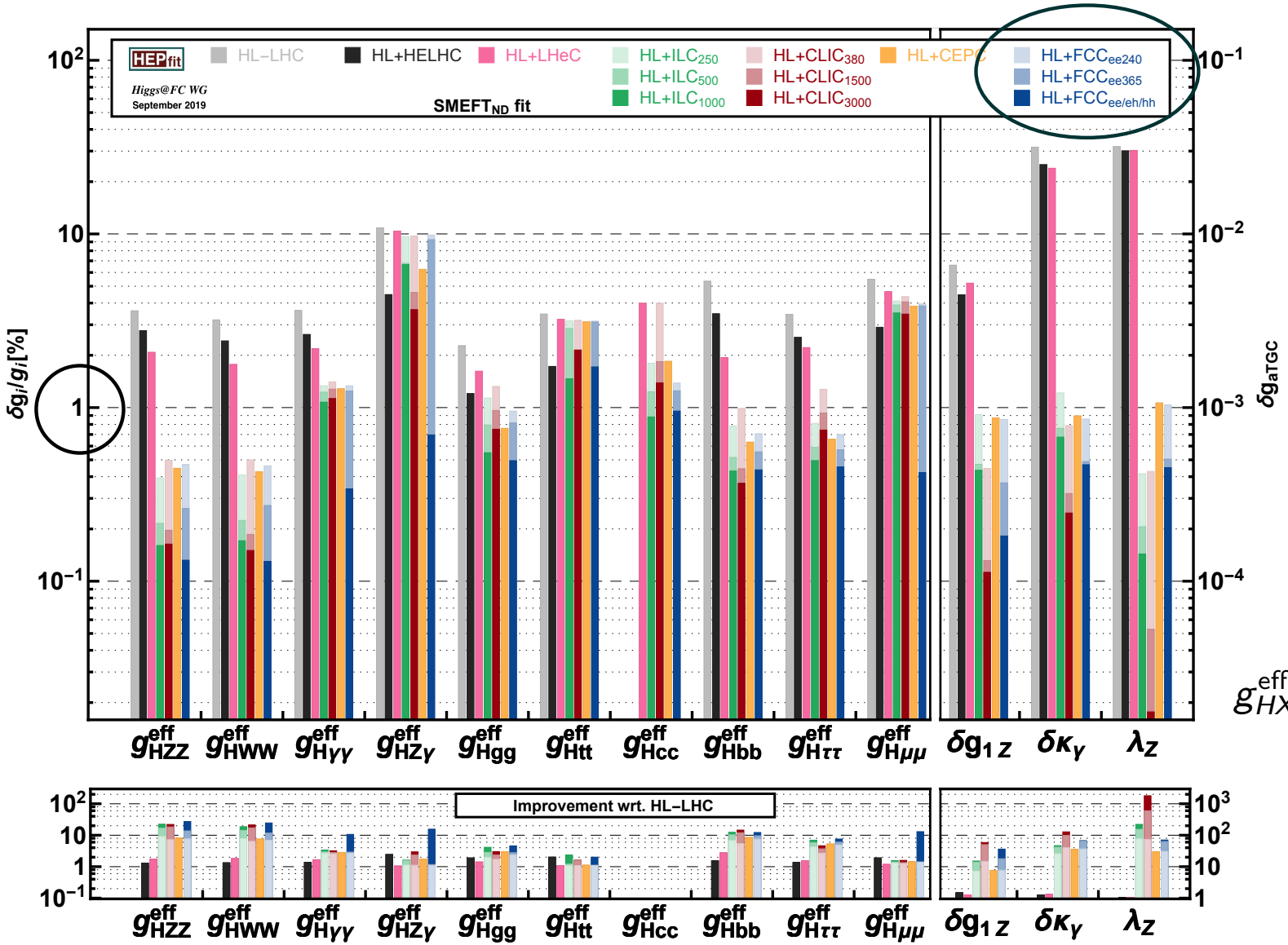
Reach the sub-percent.

Go quantum!

Just as LEP for the EW sector.

Higgs sector

[Higgs@FC '19]



[Ellis,You '15]

[Ellis et al '17]

[de Blas et al '16]

[GD et al '17]

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$$g^{\text{eff}}_{HXX} \equiv \sqrt{\frac{\Gamma_{H\to XX}}{\Gamma^{\text{SM}}_{H\to XX}}}$$

Higgs sector

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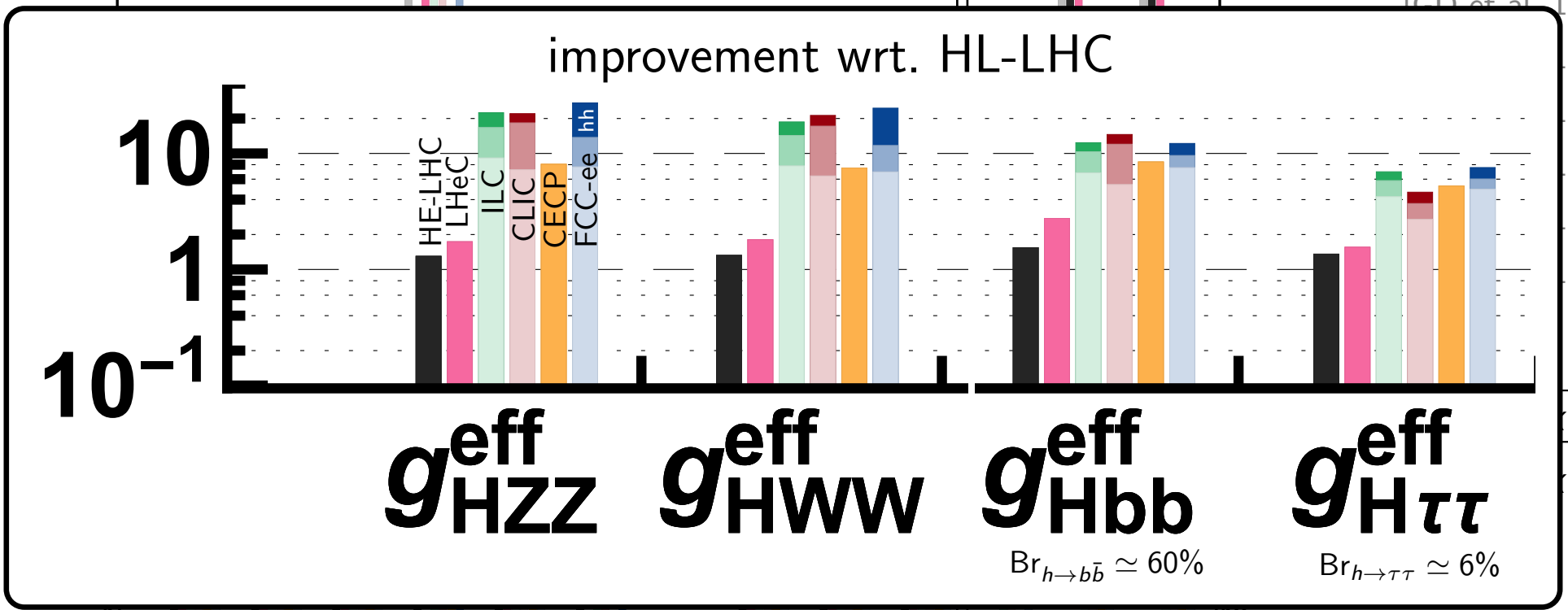

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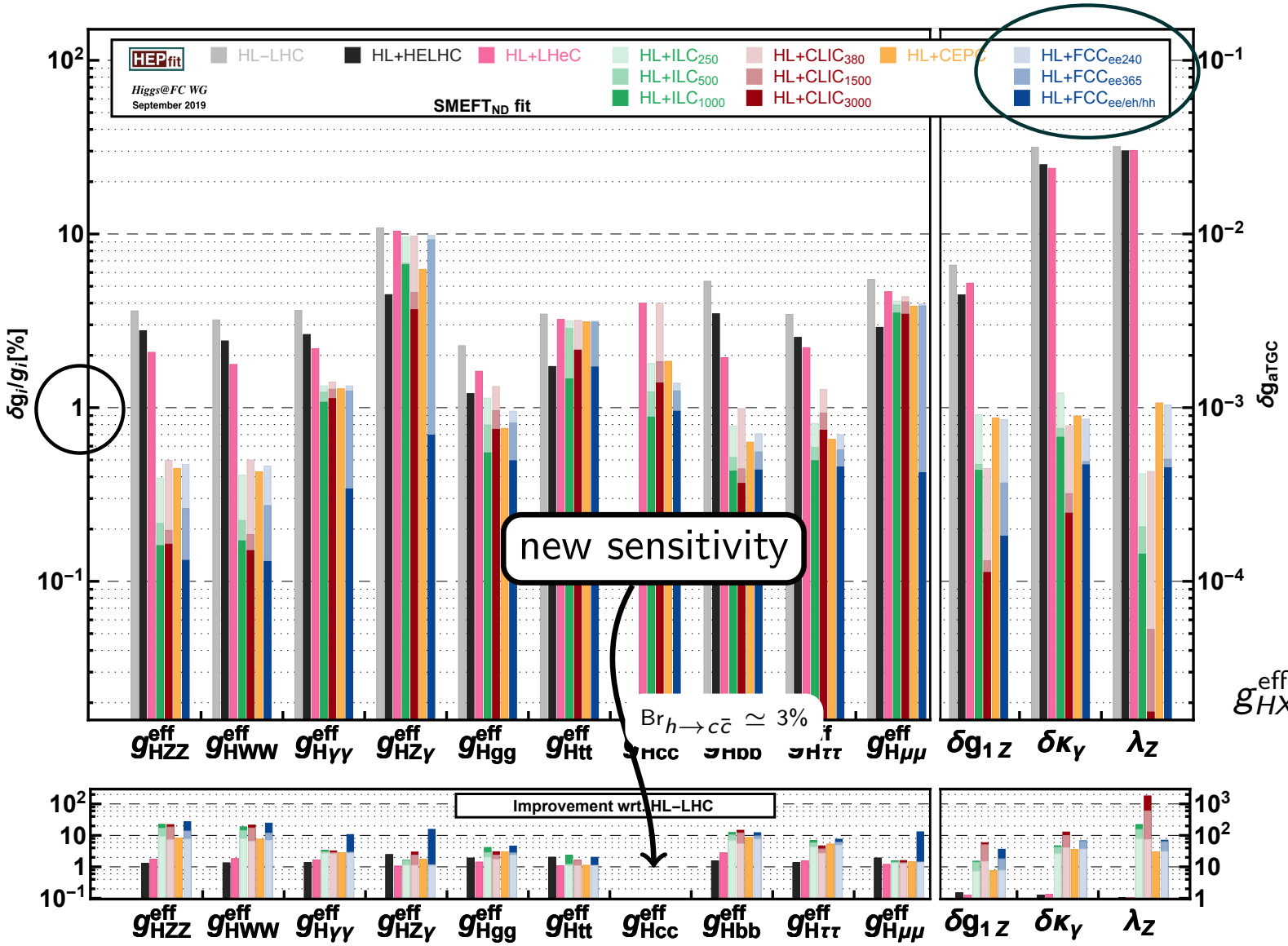

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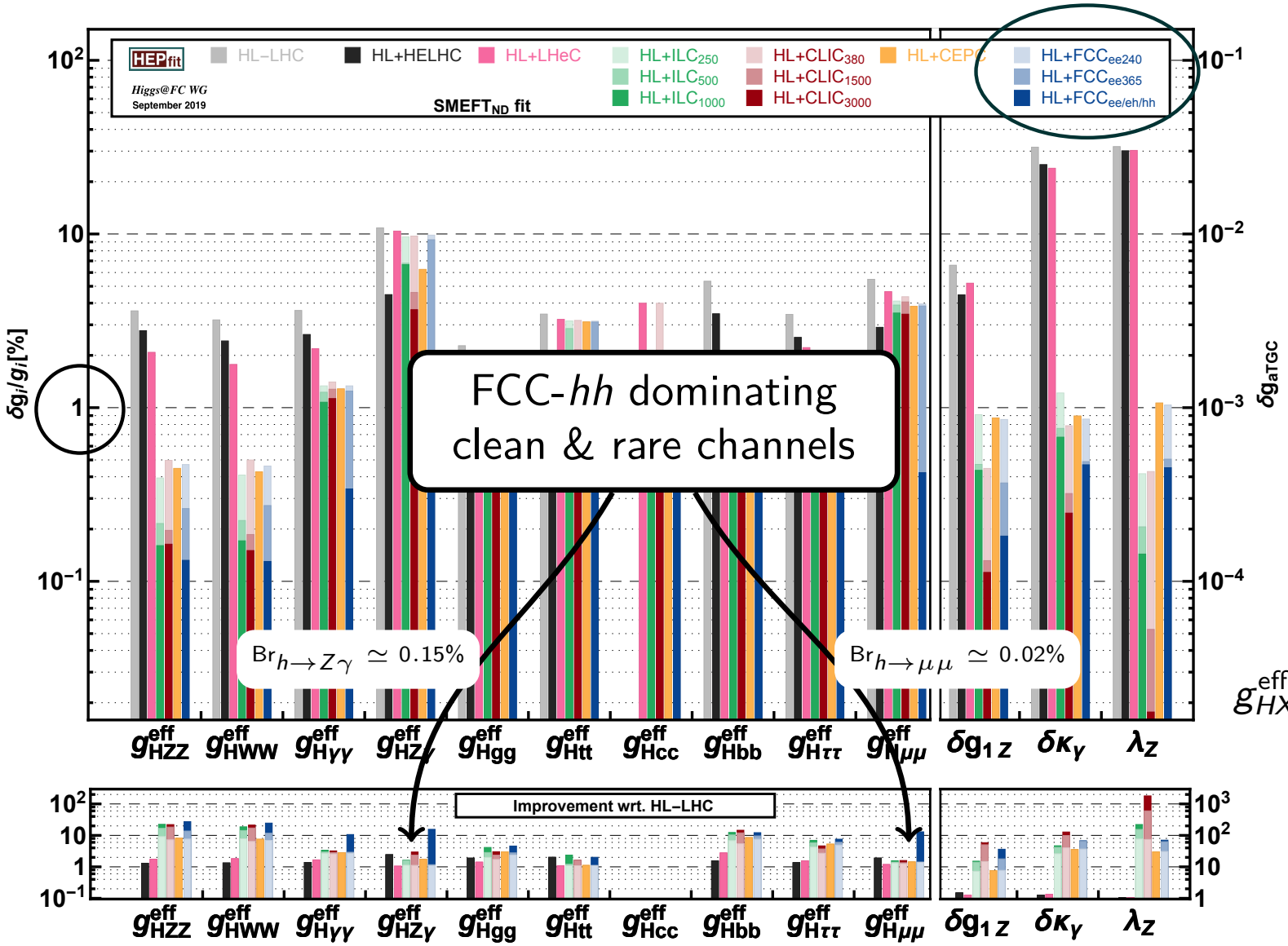

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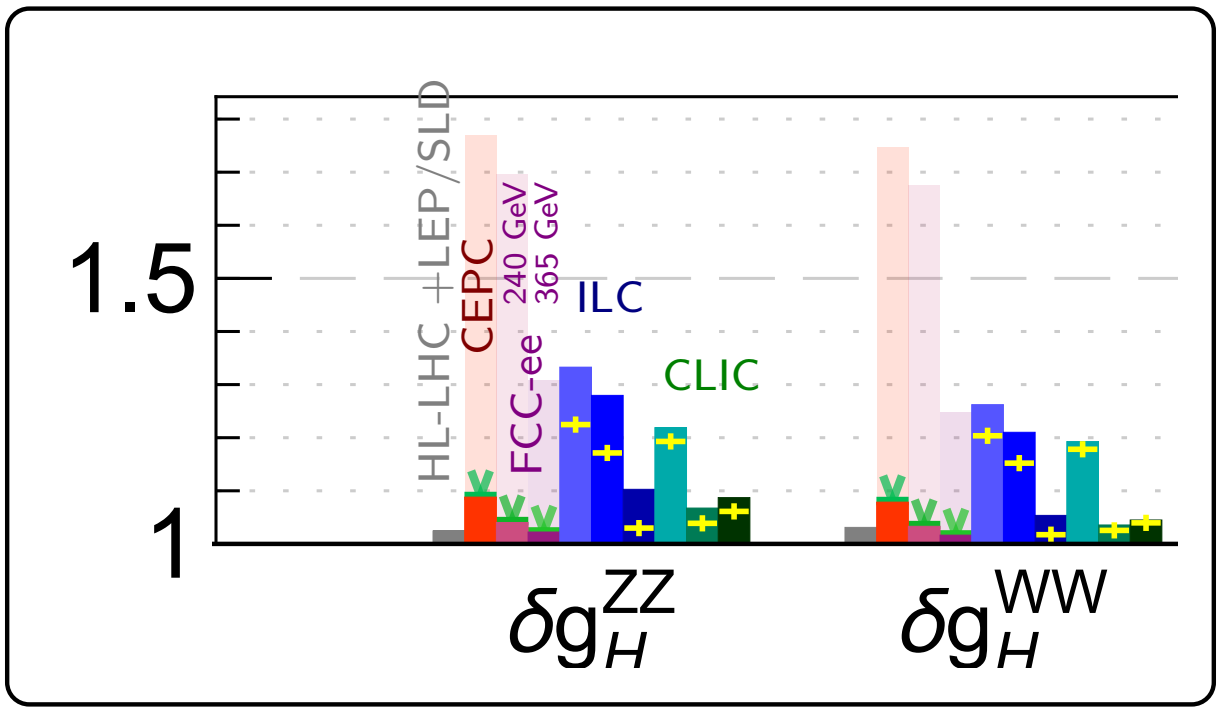
EW-Higgs interplay

[de Blas, GD, Grojean, Gu, Paul '19]

Contaminations from EW coupling uncertainties must be controlled!



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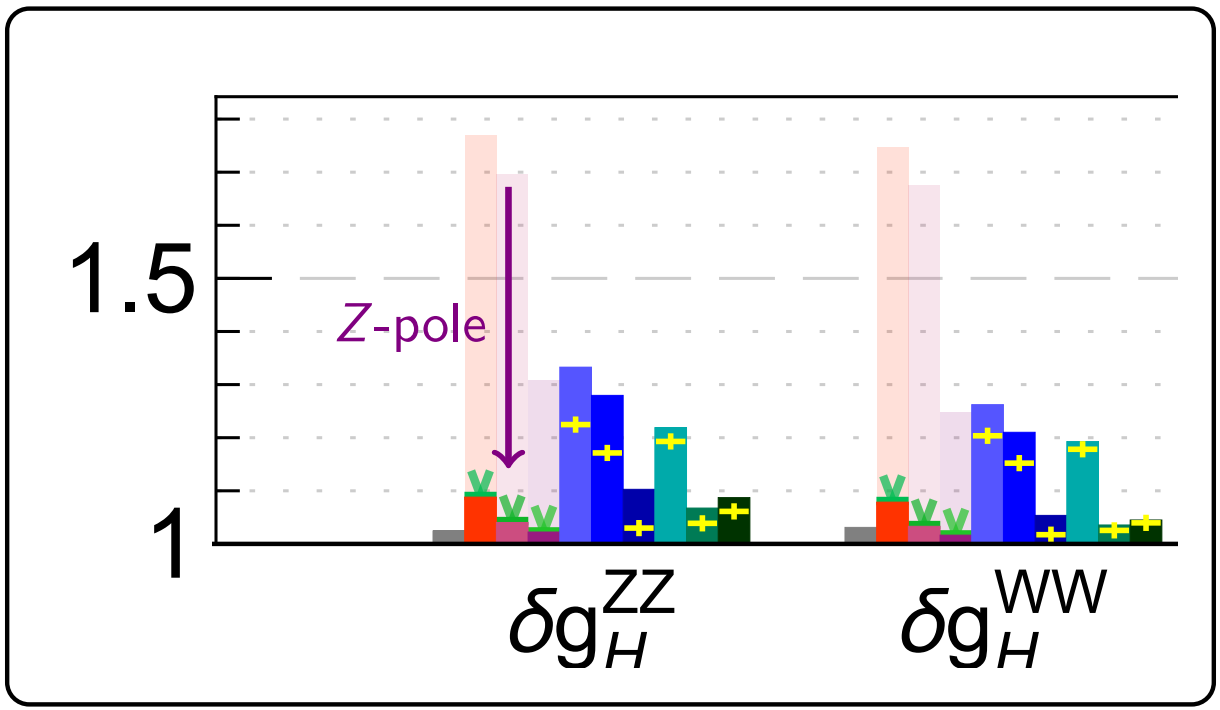

- Z-pole is crucial

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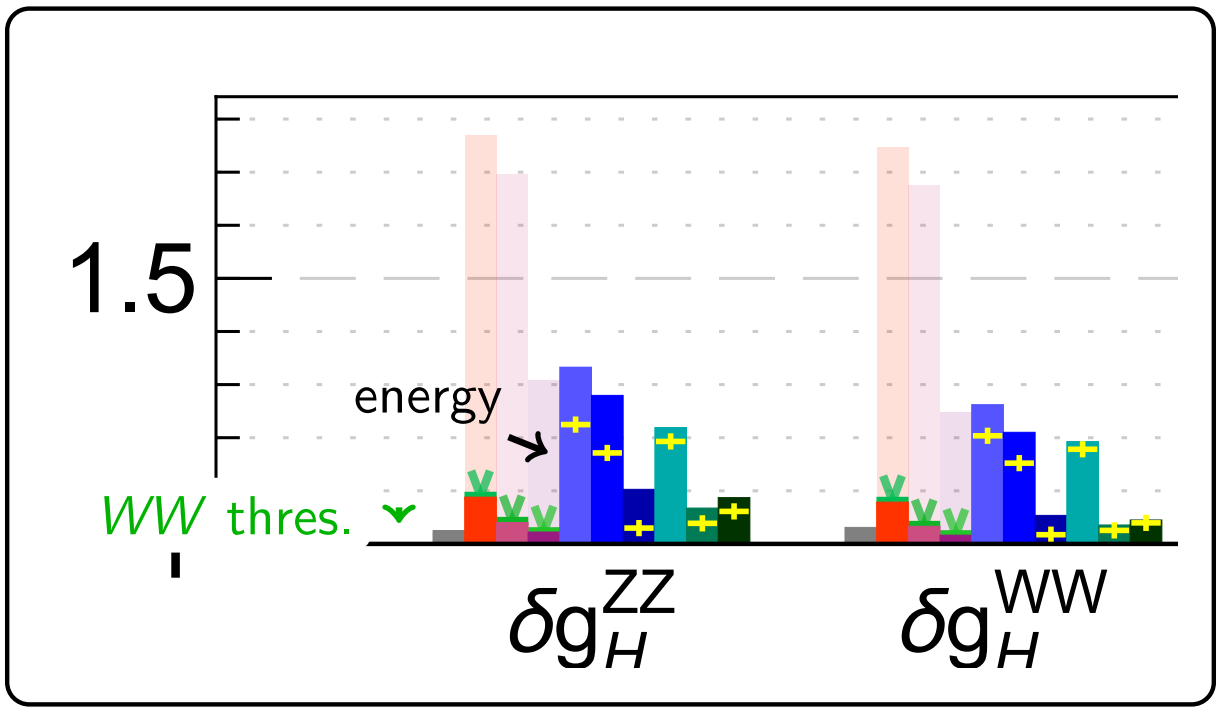

- Z-pole is crucial
- WW threshold doesn't
- energy doesn't hurt

Higgs self coupling: go quantum!

- NLO sensitivity (finite and gauge-invariant NLO EW subset)
- dominated by $e^+e^- \to hZ$ at threshold

[McCullough '13]
[Gorbahn, Haisch '16]
[Degrassi et al. '16]
[Bizon et al. '16]
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[Kribs et al. '17]
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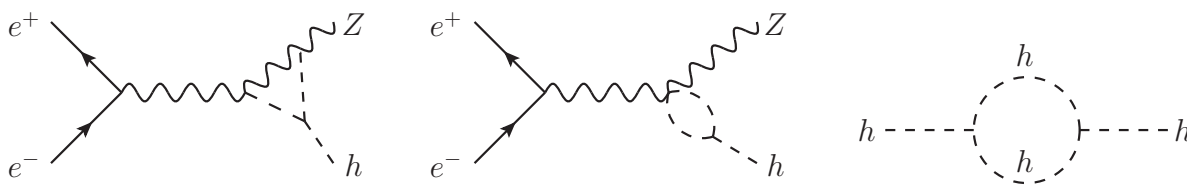
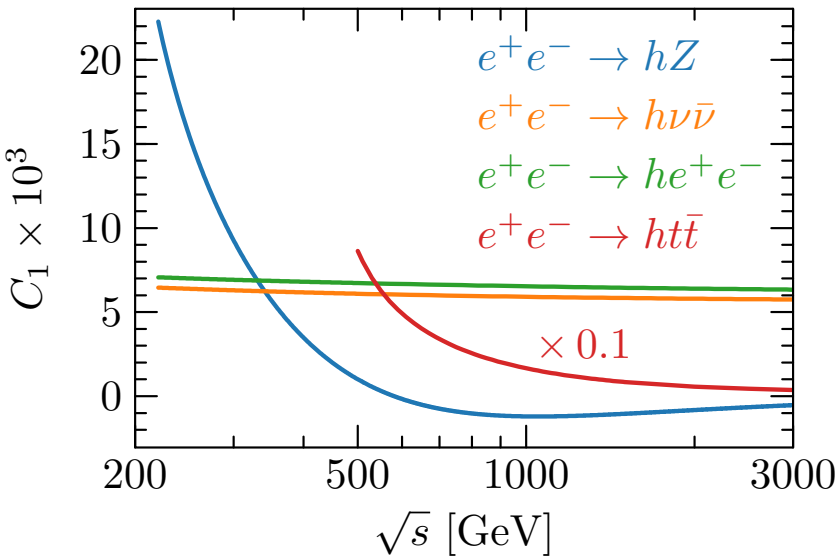


$$\Sigma_{\rm NLO}/\Sigma^{\rm SM}_{\rm NLO} \simeq 1 + (C_1 - 0.0031)\,\delta\kappa_\lambda + \ldots$$

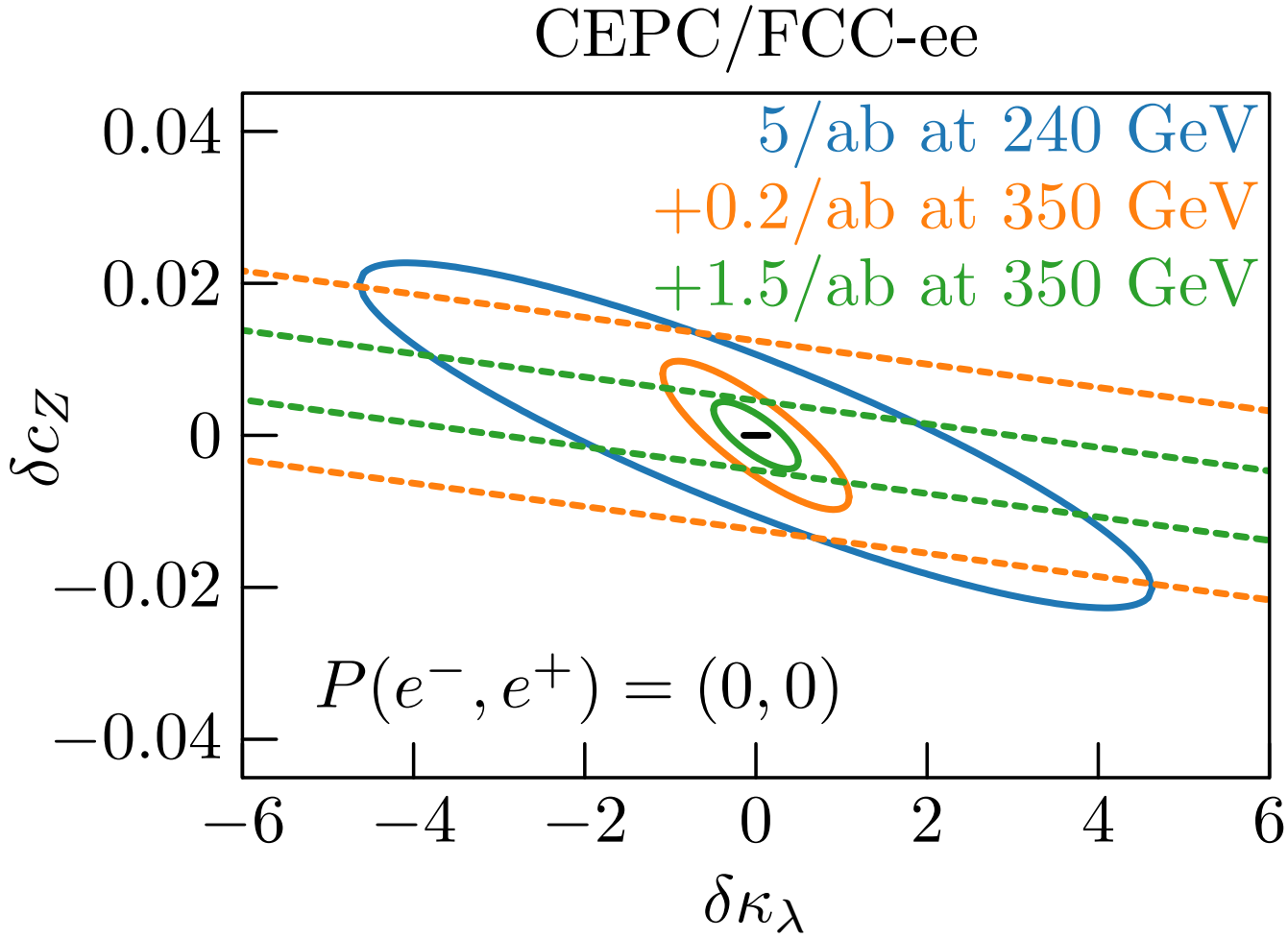


$\to$ few permil hZ measurement naively implies a few 10% constraint

Higgs self-coupling

[Di Vita et al. '17]

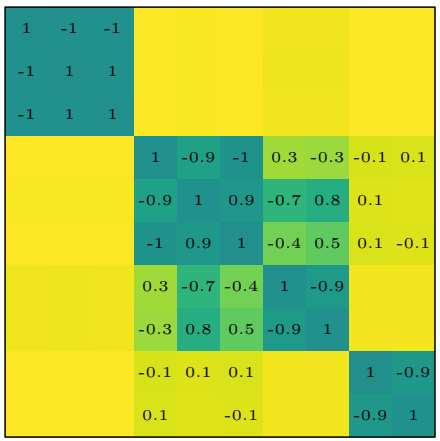
- individual $\Delta\chi^2$=1 limit (14%) much tighter than global ones (460, 110, 50%)
- 350 GeV run necessary to lift approximate degeneracies, without LHC

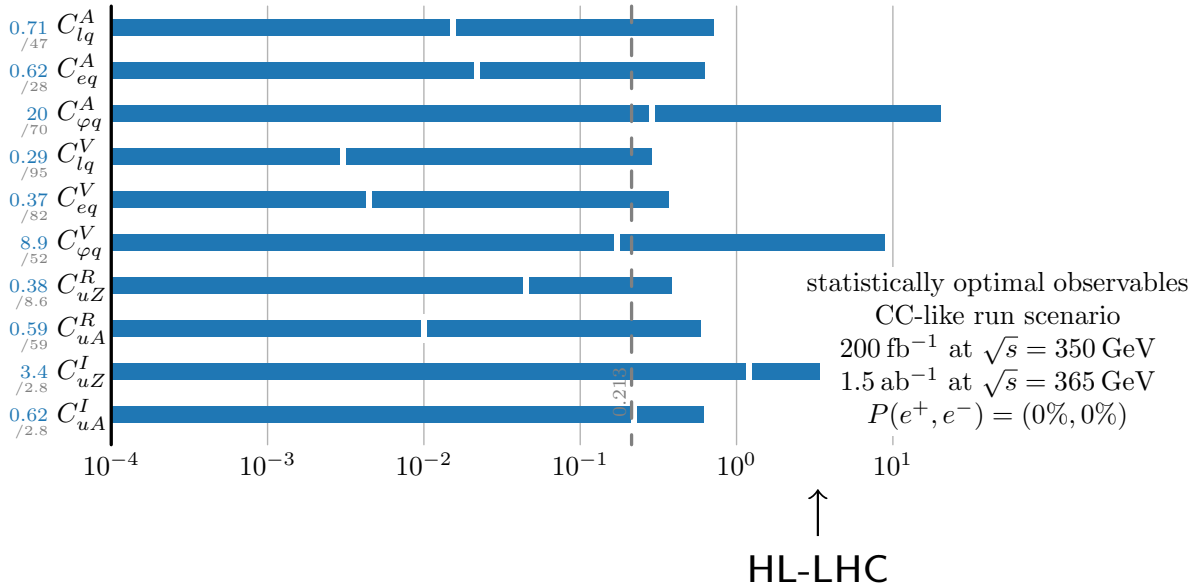


Top-quark sector

[GD, Perelló, Vos, Zhang '18]
[see also Janot '15]

vertex and dipole $t\bar{t}Z, t\bar{t}\gamma$ & contact $t\bar{t}e\bar{e}$ interactions
accessible in $e^+e^- \to t\,\bar{t}$





- in TeV^{-2}, $\Delta\chi^2 = 1$
- white marks: individual constraints
- /xx: global/individual ratios

difficulties at FCC-ee:

- small energy lever arm
  to separate $t\bar{t}V$ and $t\bar{t}e\bar{e}$
- unknown interplay
  with m_t, Γ_t extractions

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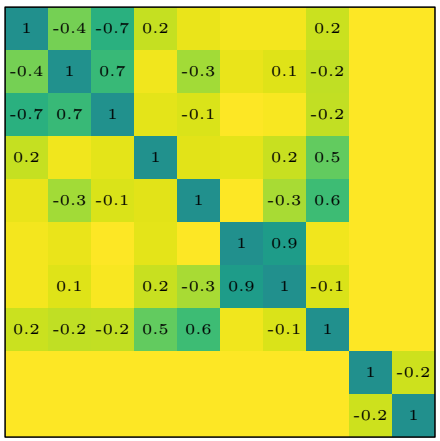

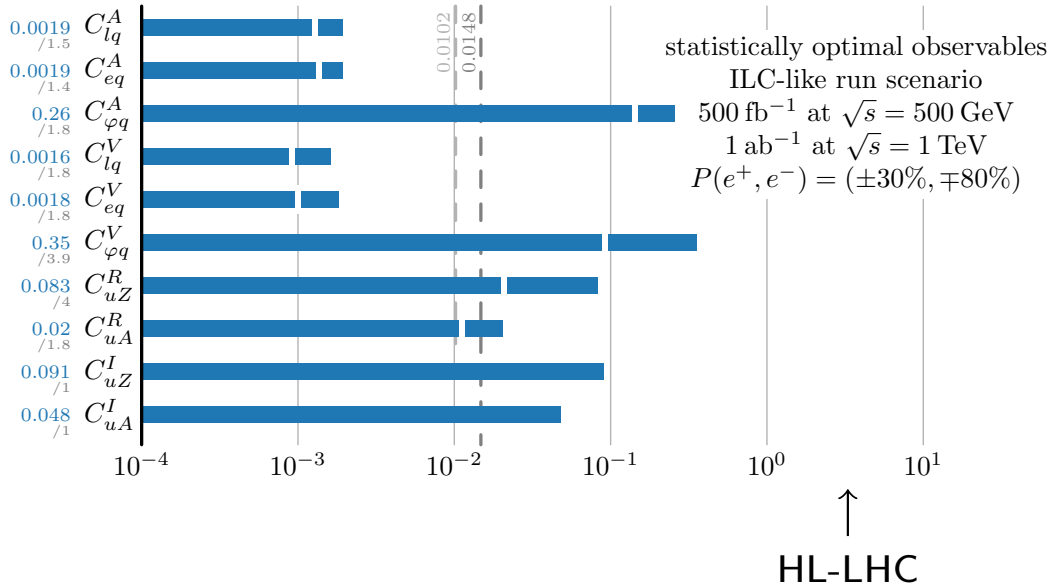

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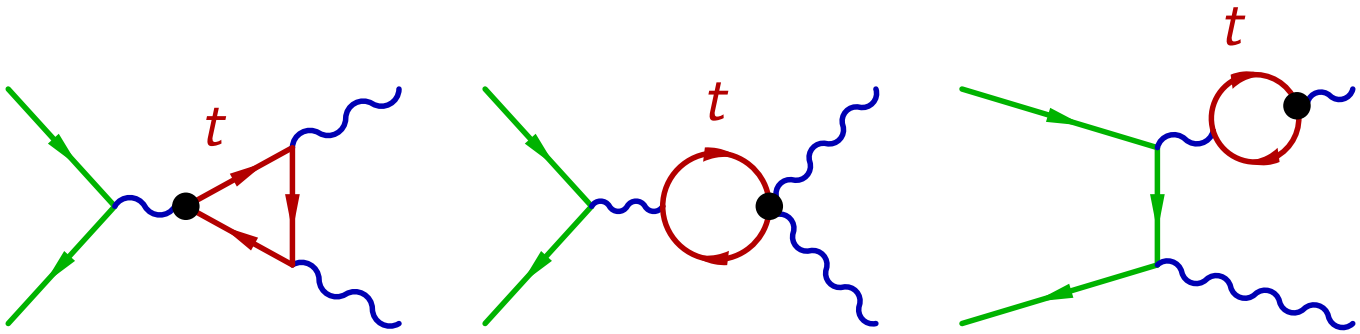
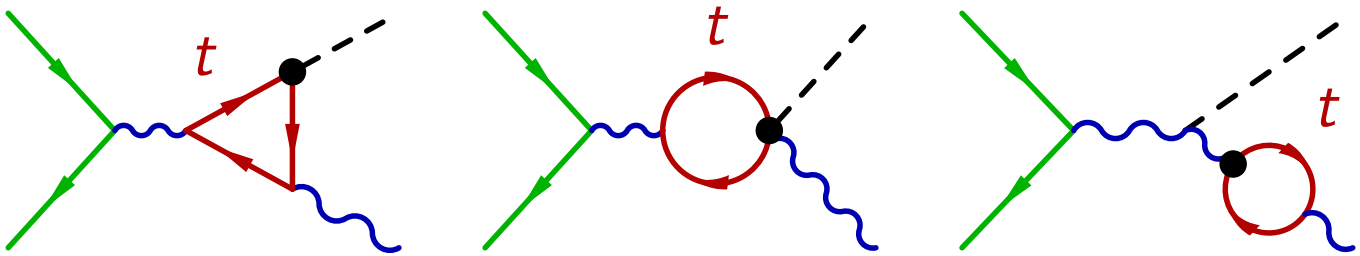
Top-quark interactions: go quantum!

- At the Z pole, in m_W and Γ_W [Zhang, Greiner, Willenbrock '12]
- In diboson production [GD, Gu, Vrionidou, Zhang '18]

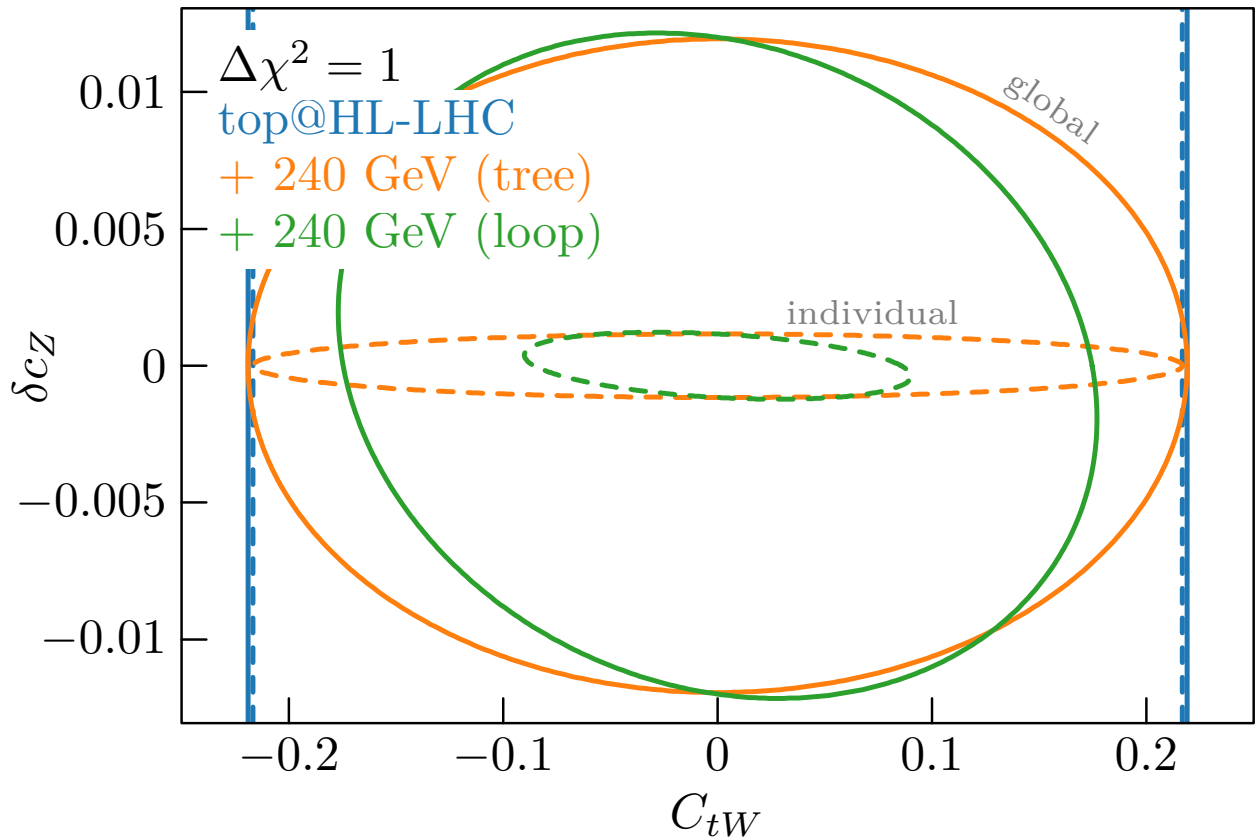


- In Higgs [Vrionidou, Zhang, '18] [see also Boselli et al '18]



Top-Higgs interplay

[GD, Gu, Vrionidou, Zhang '18]

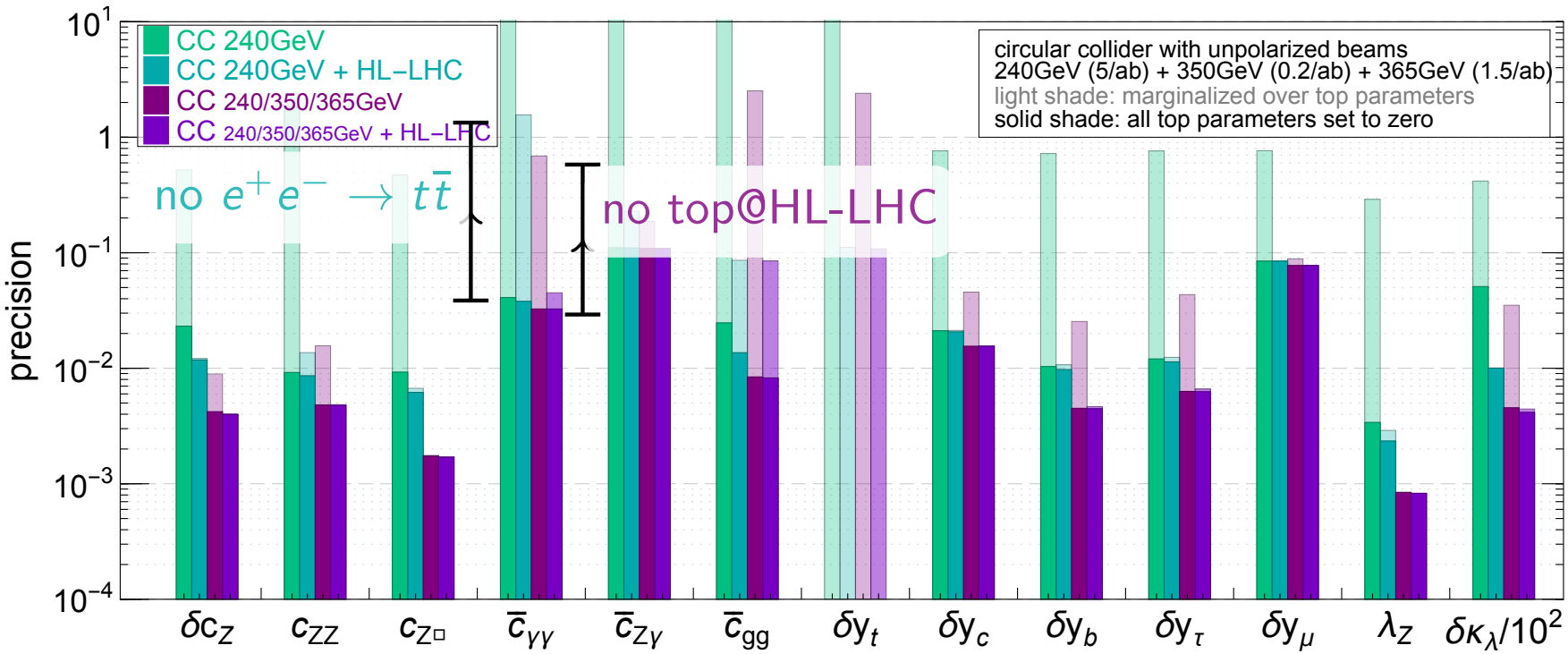


- extra parameter space covered thanks to loop sensitivity
- room for improvement between glo. and ind. constraints (with more differential information?)

Top-Higgs interplay

[GD, Gu, Vrionidou, Zhang '18]
[see also Jung, Lee, Perelló, Tian, Vos '20]

light shades: Higgs & top floated
dark shades: top $\to$ 0



Top uncertainties contaminate Higgs extractions!

Probing heavy new physics systematically at FCC

SMEFT leverages precision measurements
to cover theory space systematically
and identify patterns of new physics.

FCC-ee would bring LEP EW legacy below a new bar,
probe Higgs interactions to the quantum level,
giving access the top and *hhh* coupling loops,
exhibiting the interplay between Higgs-EW-top sectors.