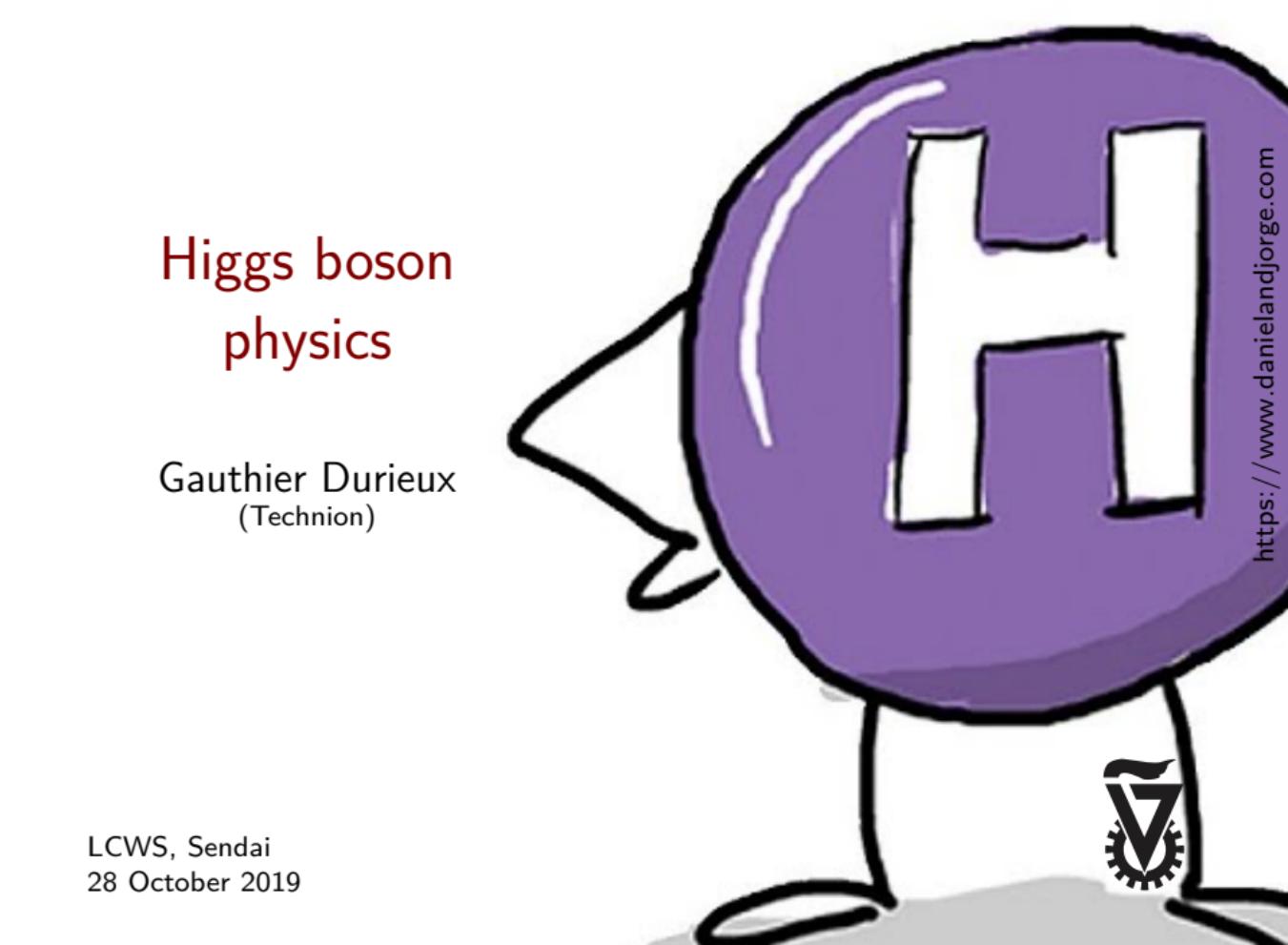


Higgs boson physics

Gauthier Durieux
(Technion)



Why studying the Higgs boson?

an honest
scientific goal



to characterise precisely the last SM^(?) particle discovered
and only fundamental^(?) scalar
presumably responsible for EWSB

the *quantum* (percent⁺) level as target

as precisely as, e.g., EW interactions
studied by previous-generation lepton colliders

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to probe new physics

- new light particles easily couple to a neutral scalar
- the Higgs is *UV* sensitive to heavy new physics

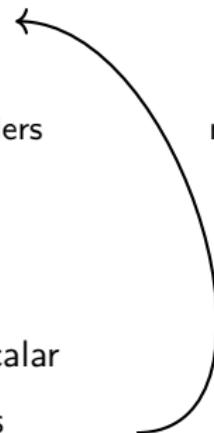
[see next talk]

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modifying
interaction
magnitudes and
structures

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[see next talk]

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The SM is a successful effective field theory!

(our E 's have been $\ll \Lambda$)

Effective field theories (EFTs)

What are they?

the most general quantum field theories

[conjecture by Weinberg '79]

with given – symmetries (gauge & Lorentz)
– field content

from a Lagrangian with *all* allowed interactions (aka operators)

Are they predictive? Yes!

- measurements of finite precision only require op.'s of finite dim.
at finite energies
- EFTs are renormalizable order by order in operator dim.

Effective field theories (EFTs)

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The SMEFT systematically parametrizes
deviations from the renormalizable SM
due to new physics at $\Lambda > E$!

Are they predictive? Yes!

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- EFTs are renormalizable order by order in operator dim.

The SM is a successful EFT!

The SM is a successful EFT...

- dim 4 operators fit all data collected
- dim 5,6,... effects are suppressed
 - neutrino masses only arise at dim. 5 and are <eV
 - proton decay only arises at dim. 6 and $\tau_p > 10^{34}$ years
 - tree-level FCNCs only arise at dim. 6
- no new state has been found at probed E 's

... with some notable failures

- *marginal $G\tilde{G}$ operator coefficient $\ll 1$* (aka strong CP problem)
dim=4

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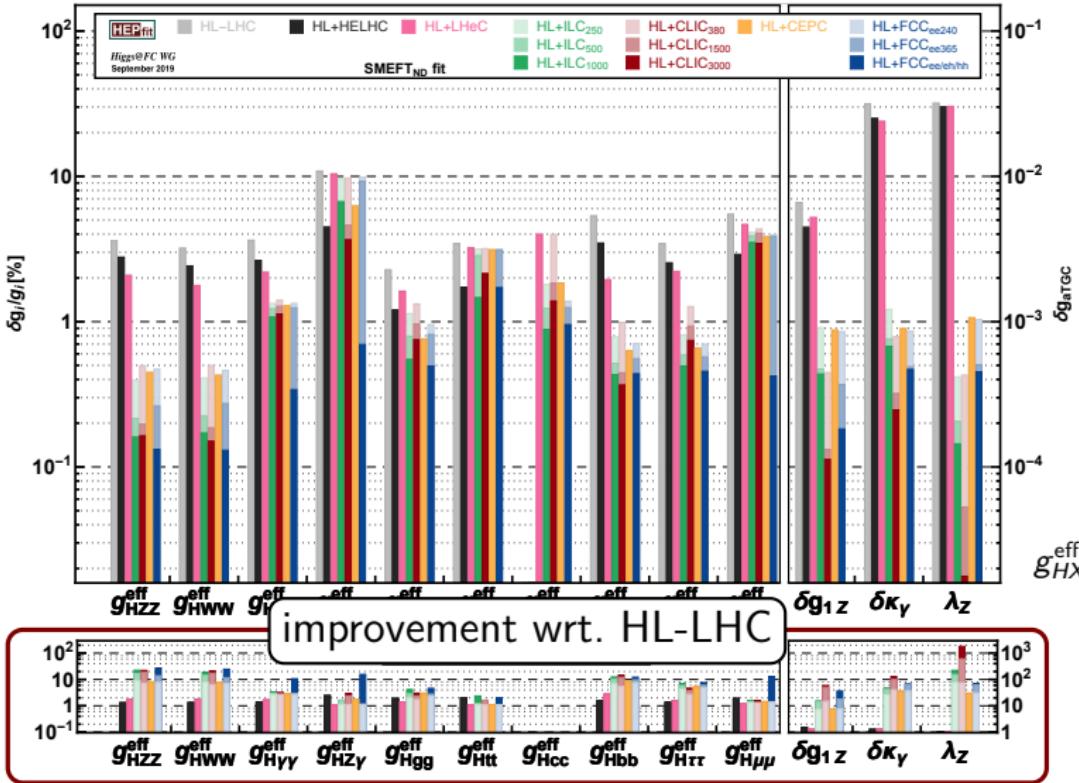
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The Higgs is *UV* sensitive to heavy new physics!

The Higgs is special!

Future lepton colliders would boost our knowledge!

[Higgs@FC '19]



[Ellis, You '15]

[Ellis et al '17]

[de Blas et al '16]

[GD et al '17]

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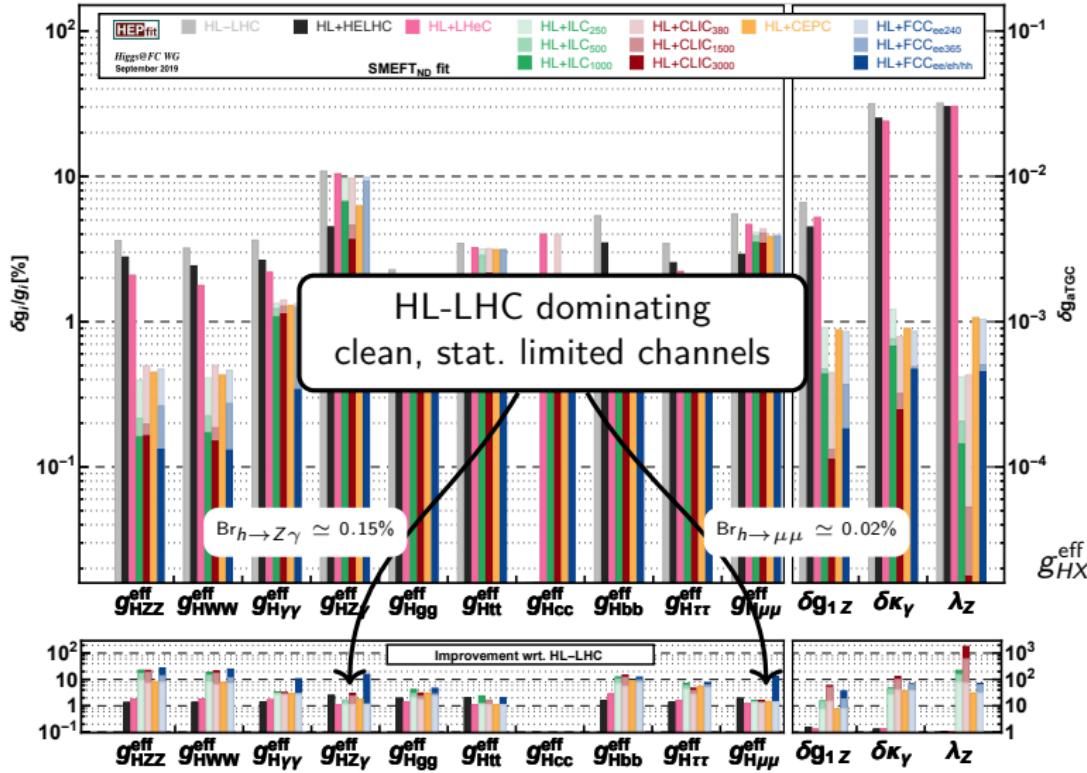
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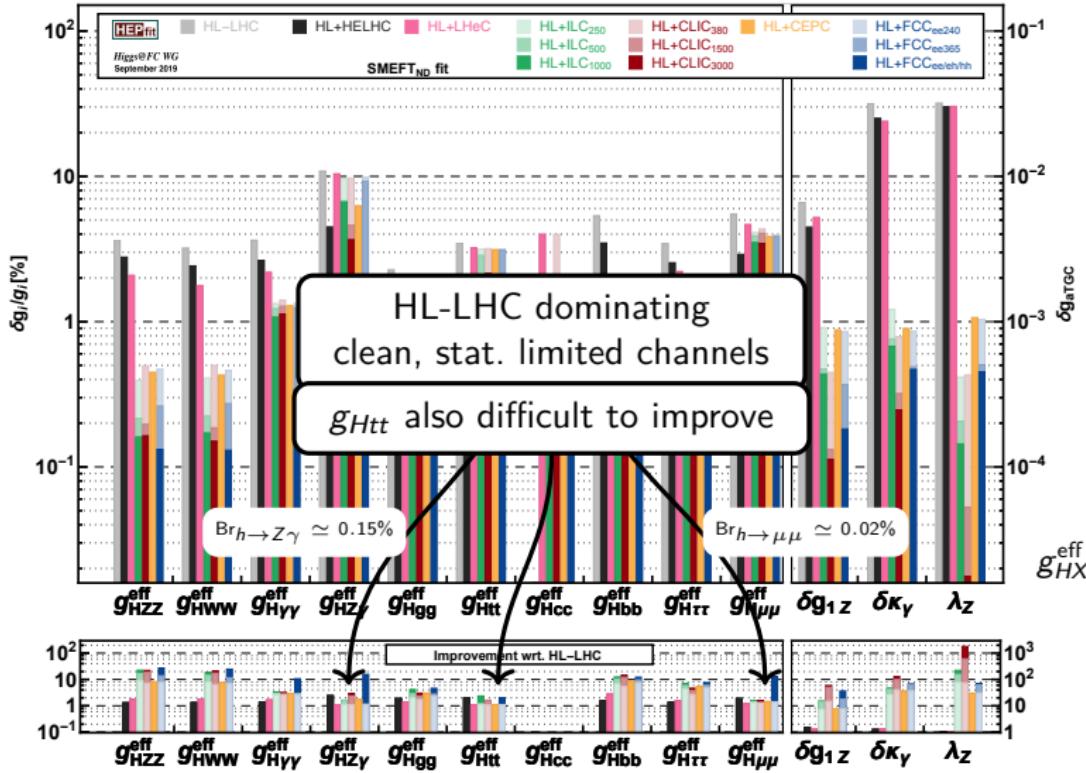
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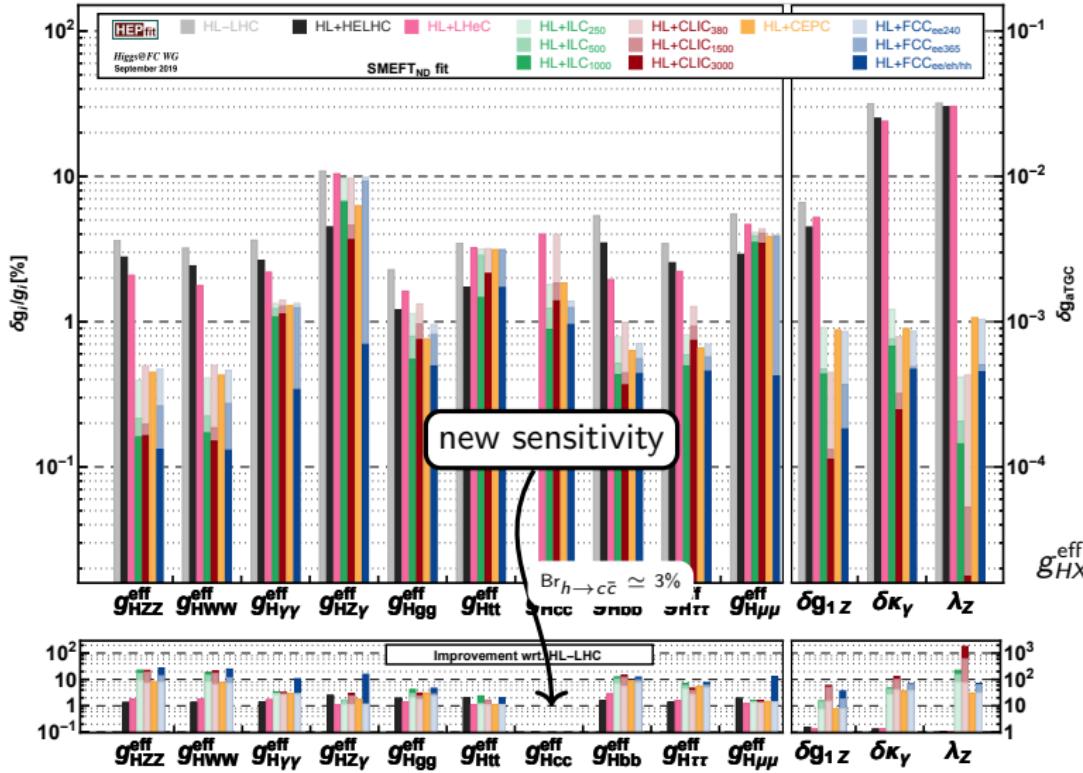
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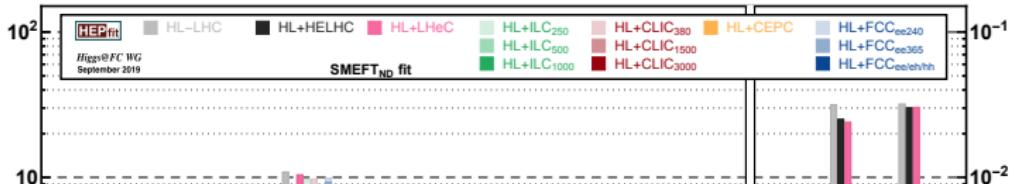
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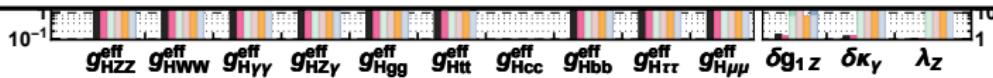
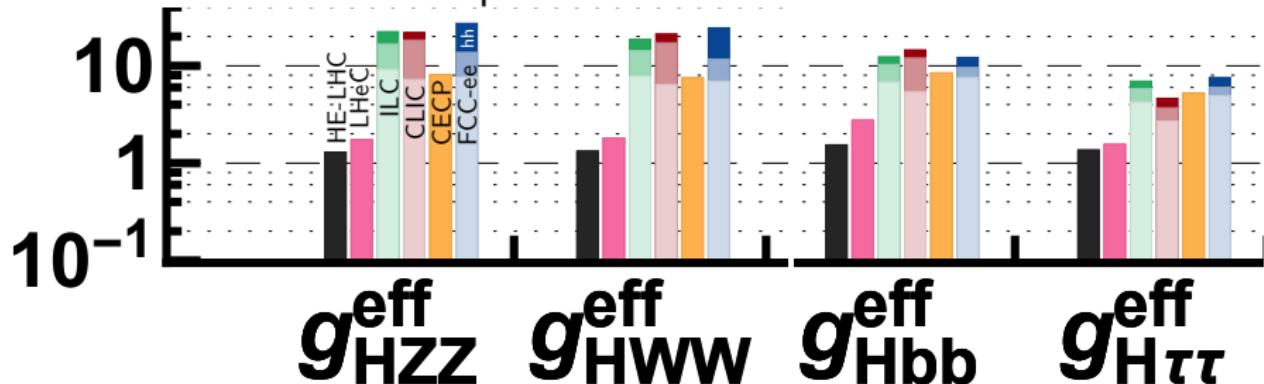
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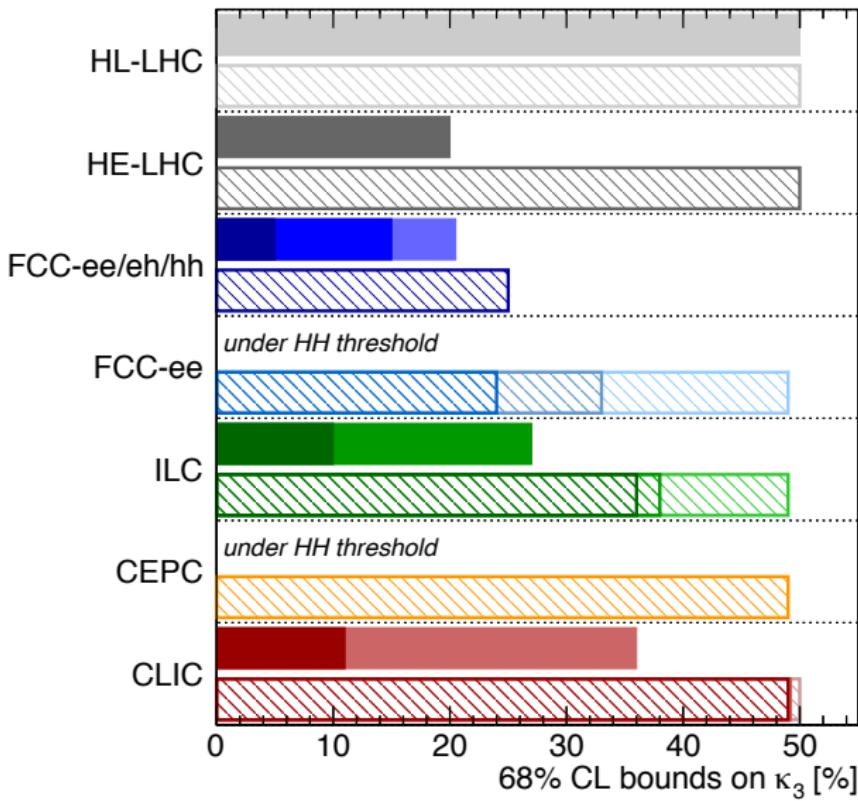
[CD et al '17]

improvement wrt. HL-LHC



Higgs trilinear self-coupling

[Higgs@FC '19]



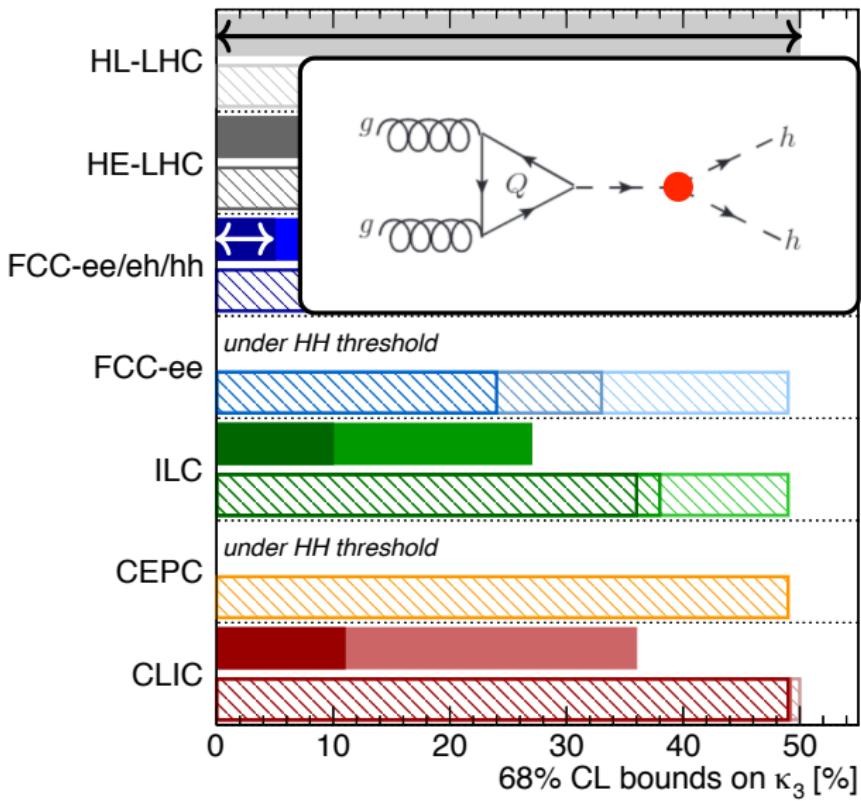
Higgs@FC WG September 2019

di-Higgs	single-Higgs
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FCC-eh ₃₅₀₀ -17+24%	FCC-eh ₃₅₀₀ n.a.
	FCC-ee ₃₆₅ 24% (14%)
	FCC-ee ₃₆₅ 33% (19%)
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ILC ₁₀₀₀ 10%	ILC ₁₀₀₀ 36% (25%)
ILC ₅₀₀ 27%	ILC ₅₀₀ 38% (27%)
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All future colliders combined with HL-LHC

Higgs trilinear self-coupling

[Higgs@FC '19]



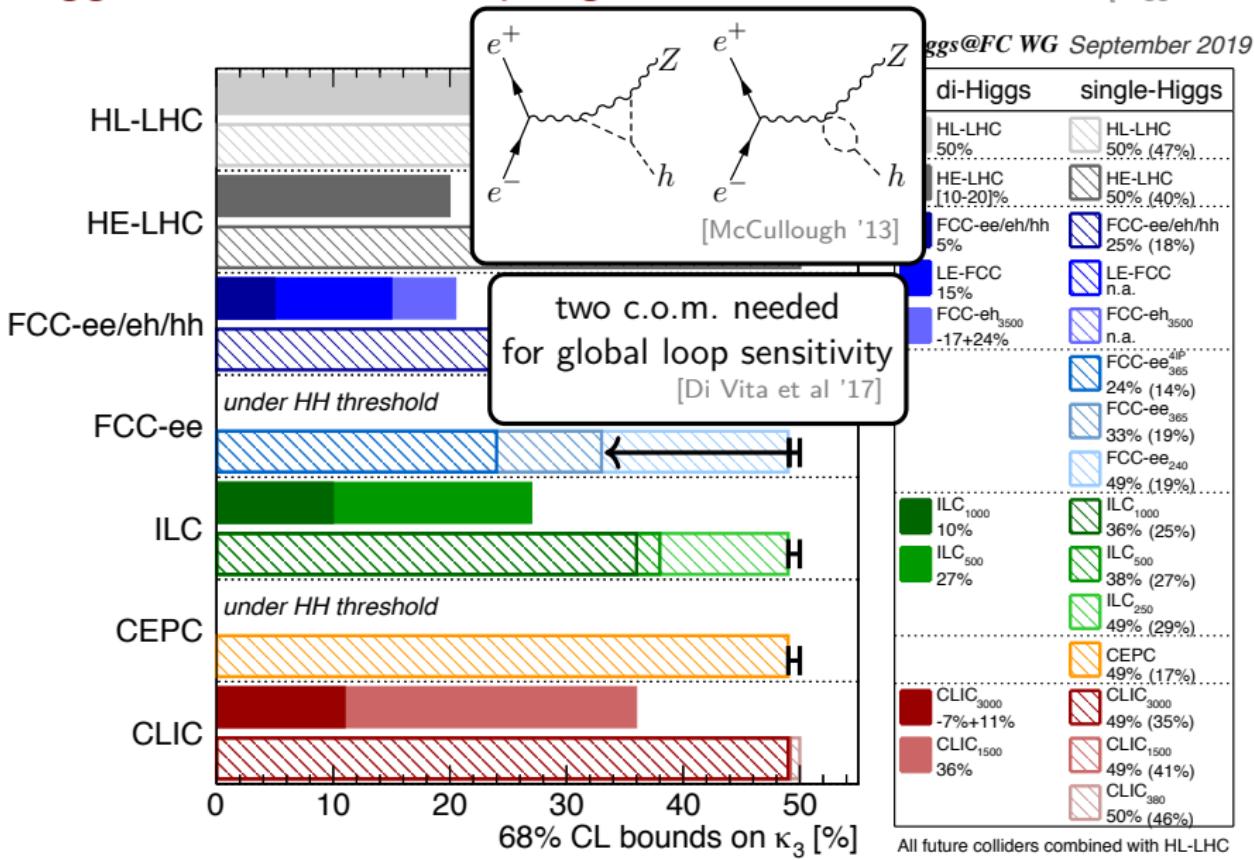
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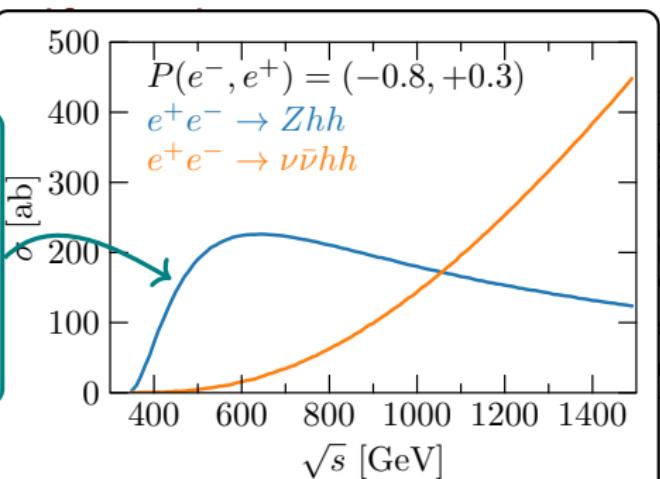
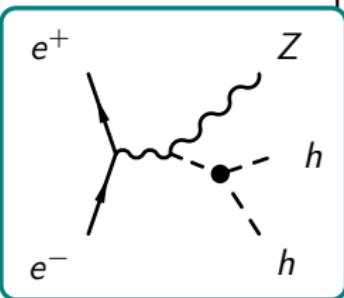
Higgs trilinear self-coupling

[Higgs@FC '19]



Higgs trilinear

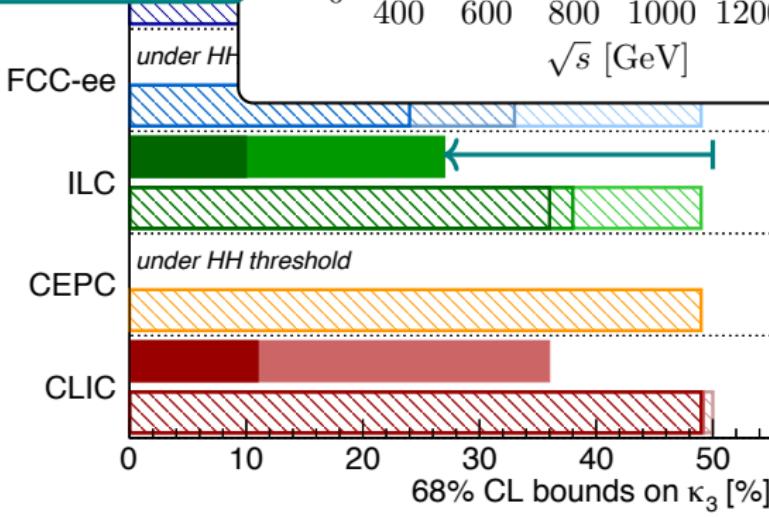
[Higgs@FC '19]



C WG September 2019

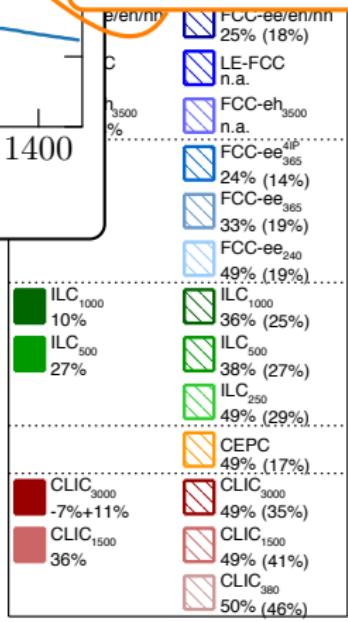
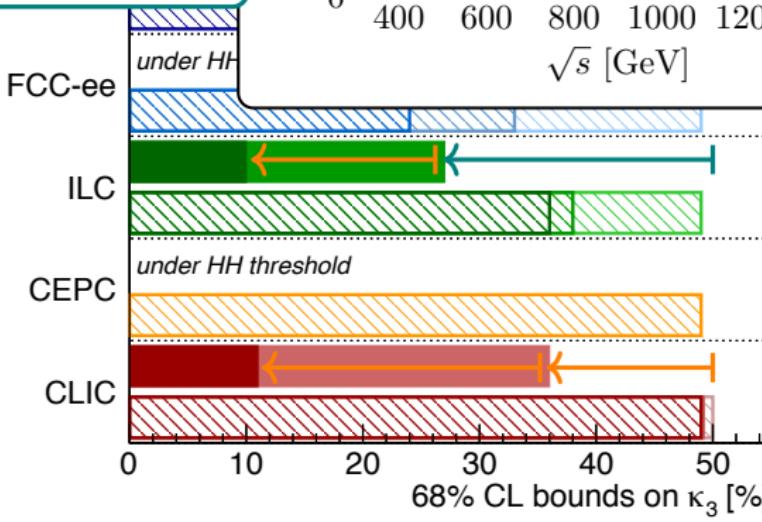
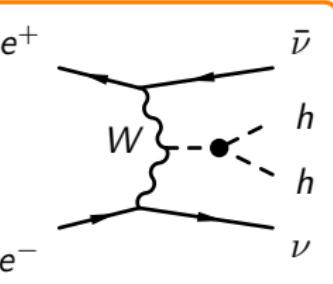
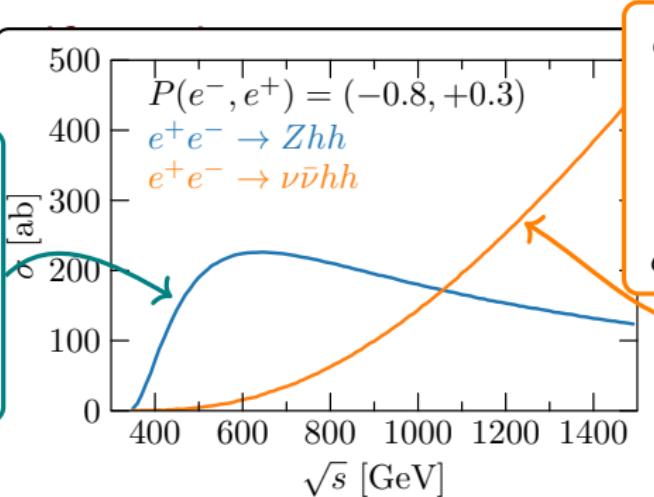
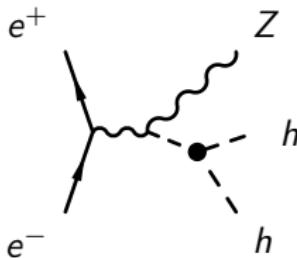
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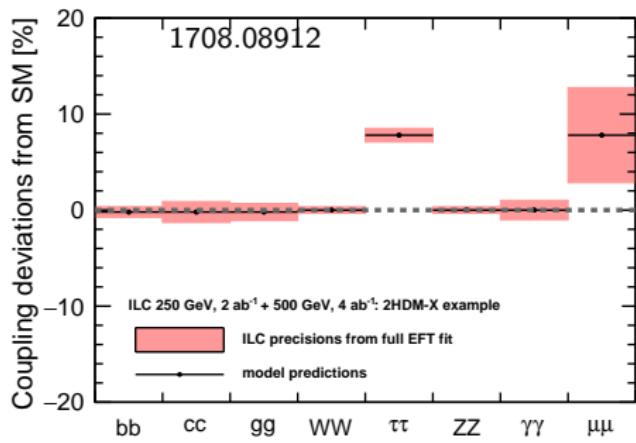
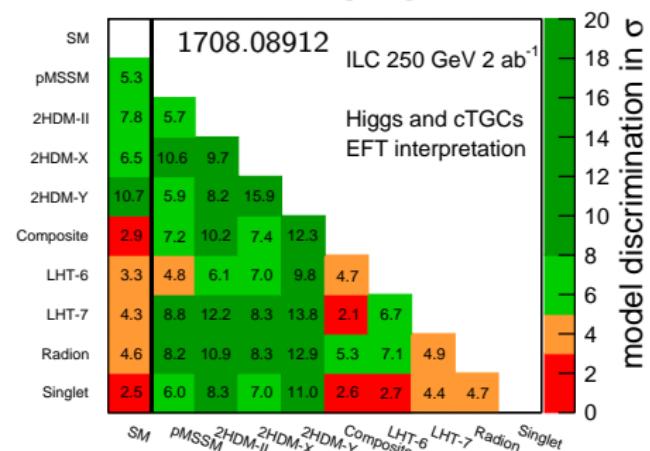
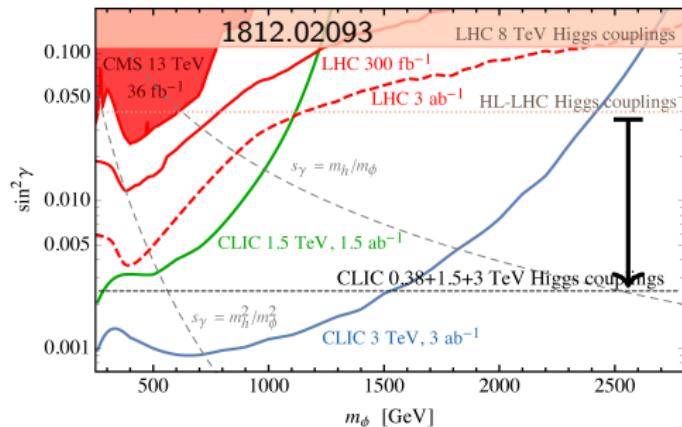
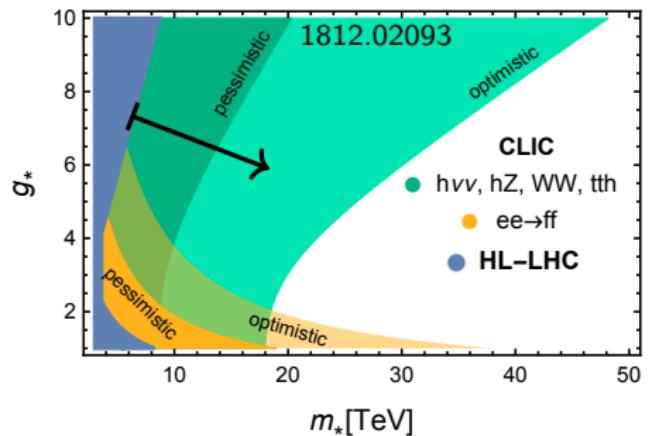


All future colliders combined with HL-LHC

Higgs trilinear



Covering uncharted BSM territory, with discovery potential



Higgs factories
would meet the challenge!

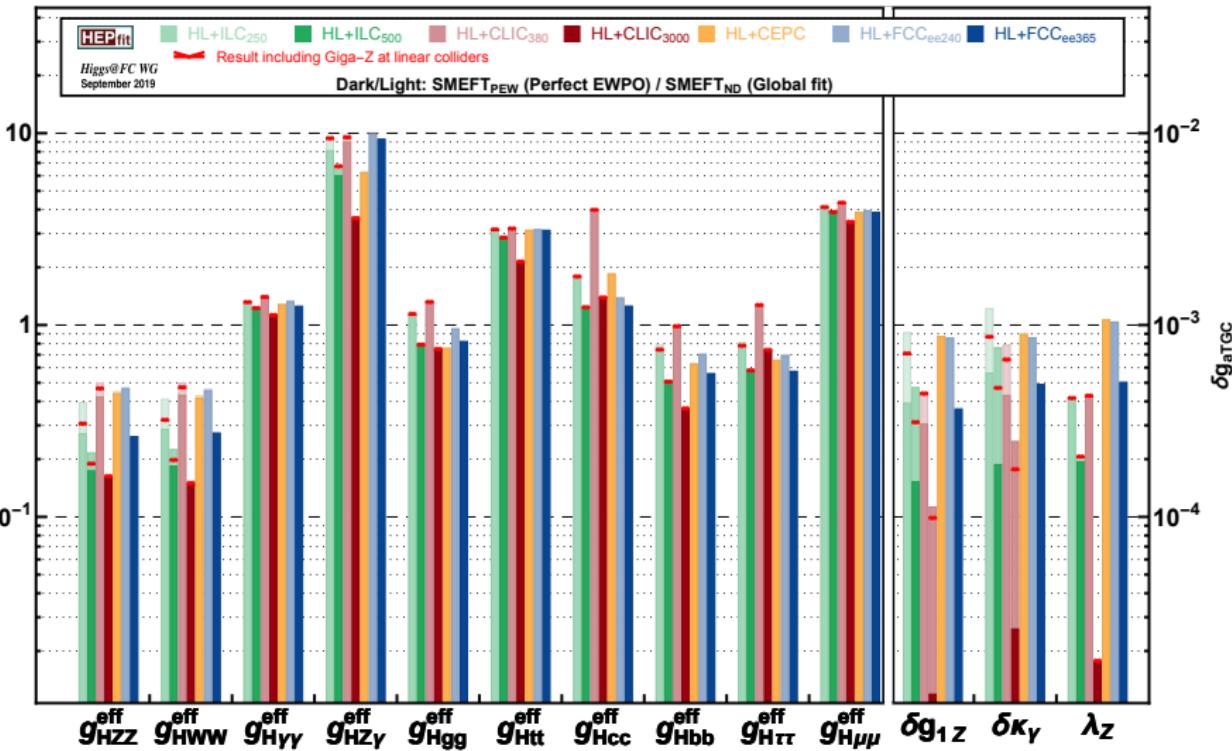
The Higgs is not alone!

Higgs production and decay modes
involve non-Higgs interactions
at tree and loop levels.

Their uncertainties matter
for precision Higgs physics!

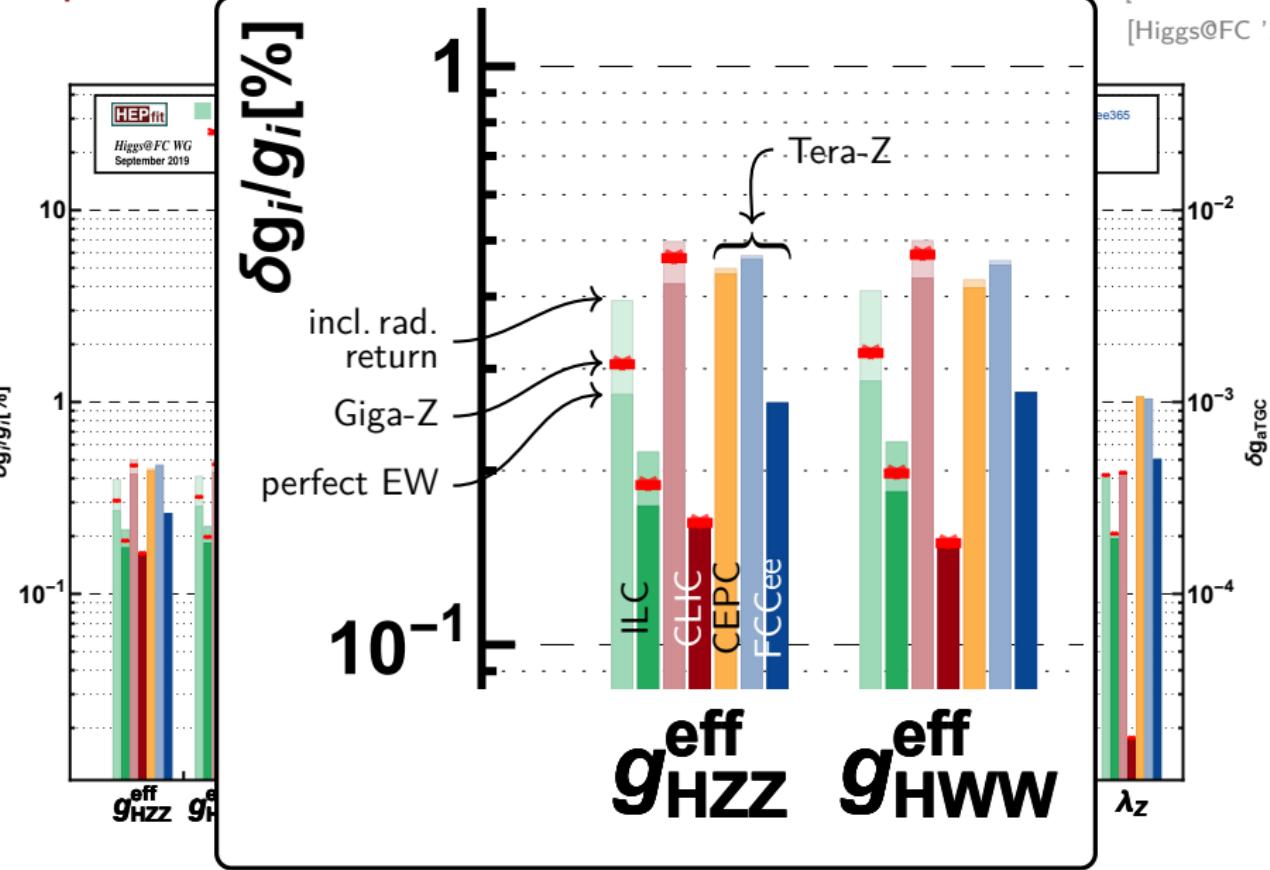
Impact of EW uncertainties

[de Blas et al '19]
 [talk tomorrow]
 [Higgs@FC '19]



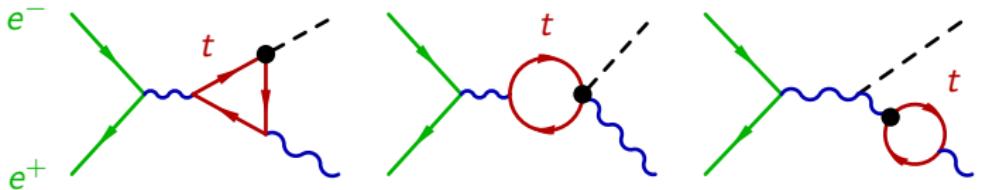
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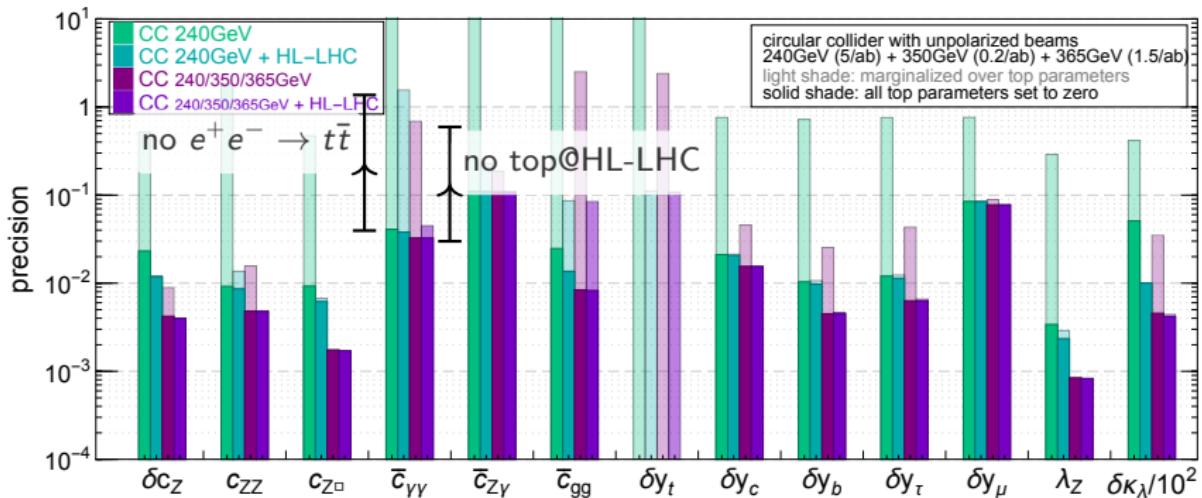


Top loop uncertainty contaminations

[GD, Gu, Vrionidou, Zhang '18]
[+ Sunghoon Jung's talk]



light shades: 12 Higgs op. floated, 6 top op. floated
dark shades: 12 Higgs op. floated, 6 top op. $\rightarrow 0$



top@HL-LHC and $e^+e^- \rightarrow t\bar{t}$ needed for precision Higgs@ee

Summary

The SM is a successful EFT
where the Higgs boson is UV sensitive.

dim>4 operators provide
a systematic parametrization of any heavy new physics.

Future lepton colliders could bring our knowledge of Higgs interactions down to the *quantum* (percent⁺) level.

Uncharted new-physics territory will be probed and opportunities of discovery offered.

Precise electroweak and top measurements are required to achieve the full potential of the Higgs program.