Higgs physics at a future collider

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One problem to rule them all

After Gavin Salam: The Higgs sector is key to all of the central questions in particle physics — and we must study it to exhaustion!

$$\mathscr{L} = \ldots + (D^\mu \Phi)^\dagger D_\mu \Phi - y_{ij} \bar{\psi}_i \Phi^\dagger \psi_j \text{ (+h.c.)} + \mu^2 \Phi^\dagger \Phi - \lambda (\Phi^\dagger \Phi)^2$$

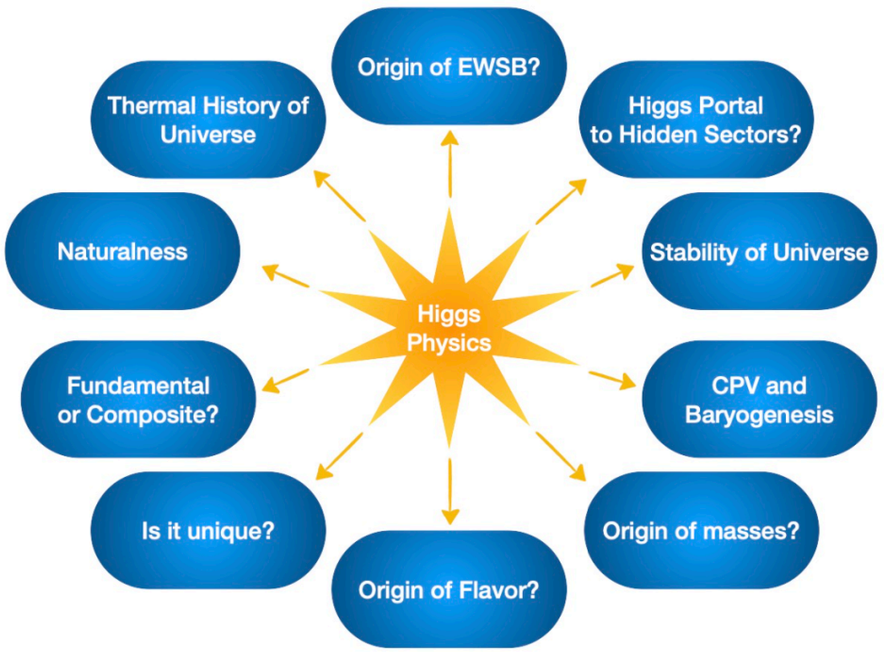
Gauge interactions:
studied for decades
but now with an
elementary scalar

Yukawa interactions:
studied since Higgs
boson discovery

Basis of "flavour physics"

Higgs potential:
not yet probing this

Theory connection to
naturalness & stability
of the Universe



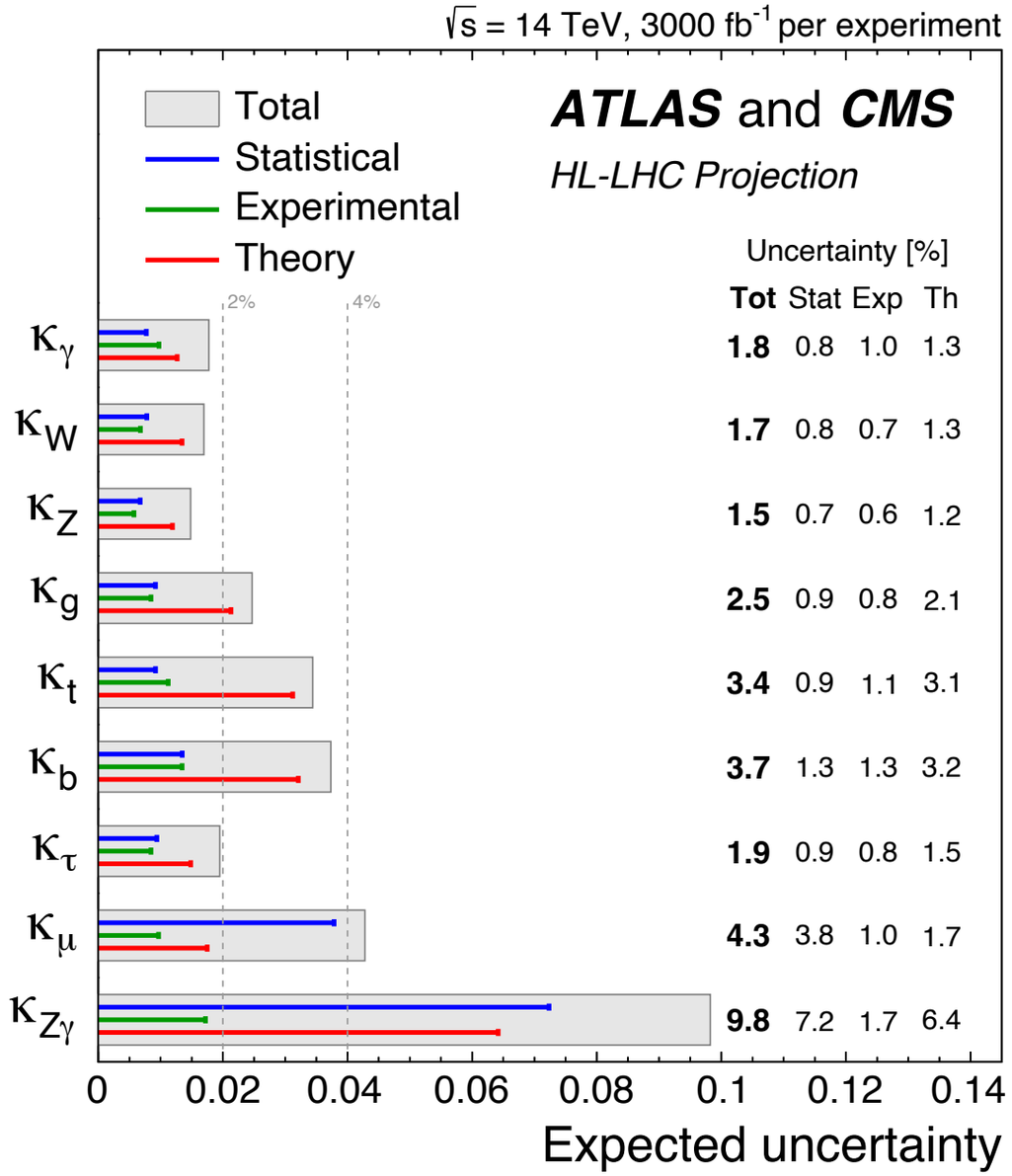
HL-LHC Single-Higgs projections

Precision on many coupling constants will already be exciting!

- theoretical uncertainties assumed to be reduced by a factor of 2
- statistical uncertainties follow $1/\sqrt{L}$ scaling
- same for data-driven systematic uncertainties
- improvements to methods assumed to offset harsher HL-LHC environment

Notably missing: 1st and 2nd generation Yukawa couplings

- with exception of κ_μ
- present limit: $|\kappa_c/\kappa_b| < 2.7$

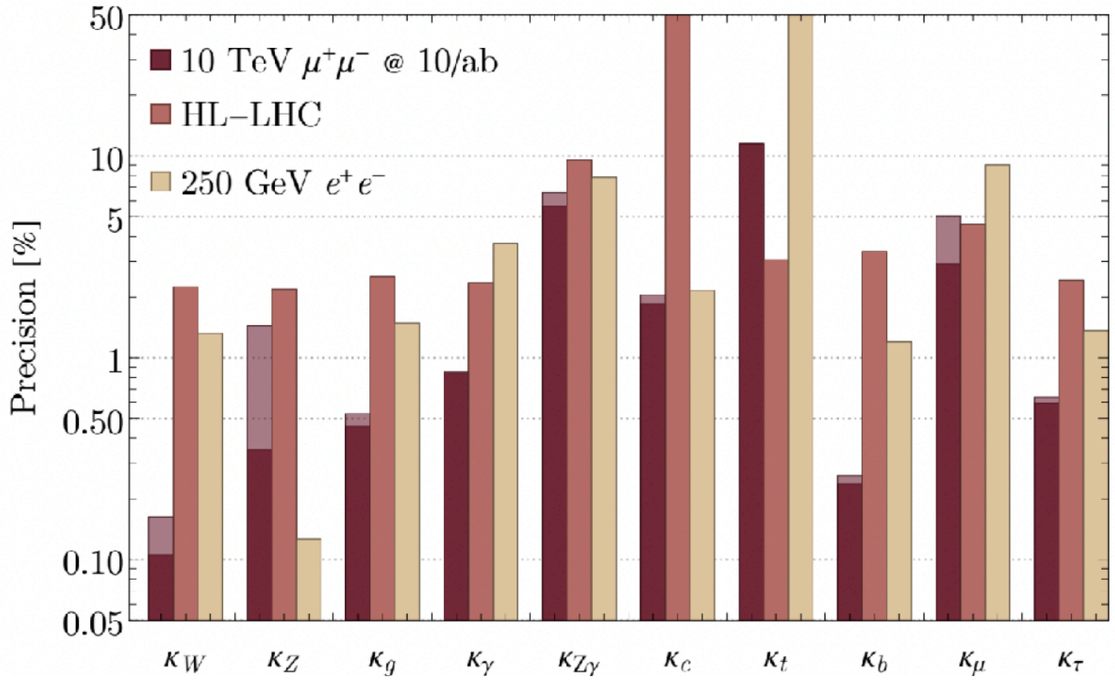


Source: 2019 ATLAS+CMS Yellow Report

Single-Higgs physics at future colliders

Many different collider options will allow us to make progress beyond what the HL-LHC can offer

- even if the details depend on who makes the comparison, and the assumptions made



The similarity in prospective sensitivities suggests that other arguments (construction time & costs) may be more important considerations

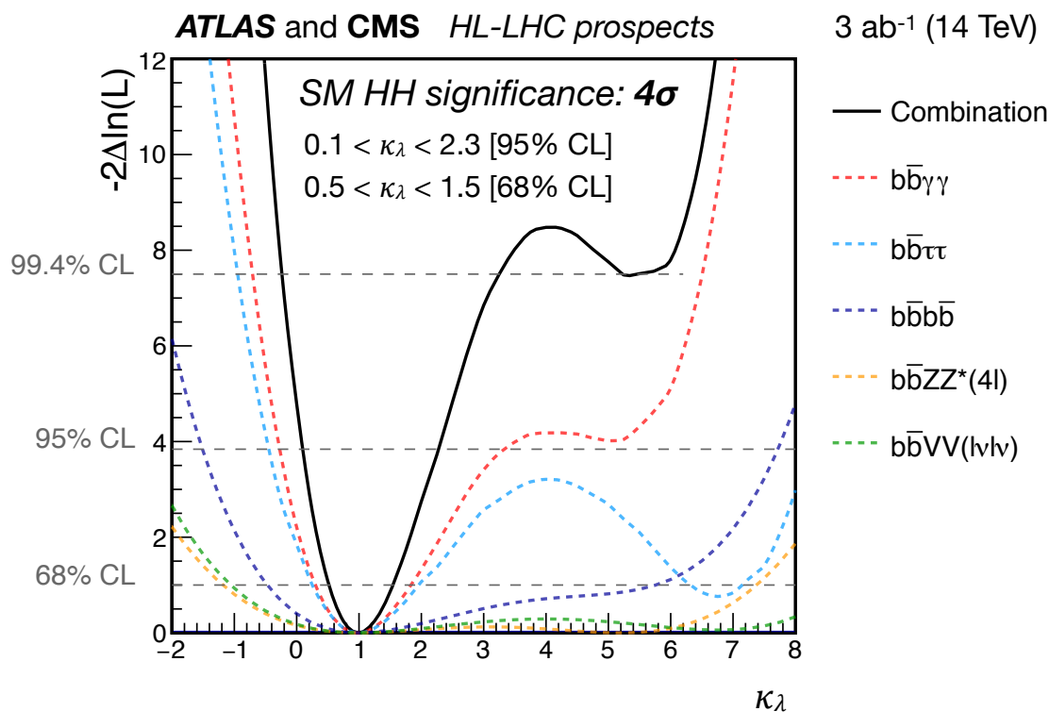
HL-LHC Higgs pair production projections

Higgs pair production: best way to probe self-coupling λ

- some sensitivity from precise measurement of single-Higgs production (but through loop effects, which may be susceptible to other new physics)

HL-LHC will exclude $\kappa_\lambda = 0$ scenario by more than 95% CL, but will not constrain it to better than ~ 0.5

- barring significant performance improvements



Source: 2019 ATLAS+CMS Yellow Report

Higgs pair production at future colliders

Significant improvements possible at possible lepton colliders:

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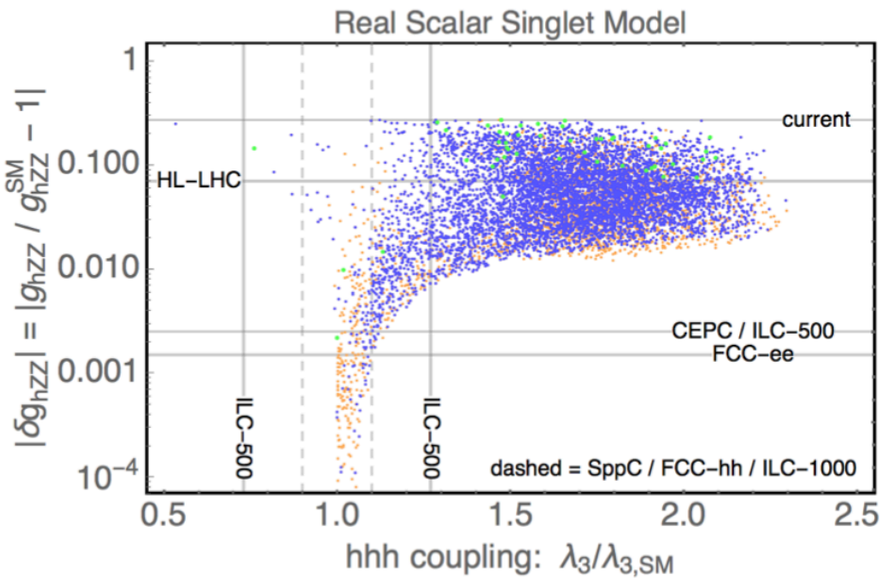
- ZHH production (CCC): ~ 10 %
- VBF (high-E muon collider): ~ 2—15 %
  - strongly dependent on $\sqrt{s}$
- ZH production (FCC-ee, CCC): ~ 40%
  - this depends on access through loop effects



There is no unique precision threshold that probes all new physics scenarios (and BSM physics modifying κ_λ typically comes with other modifications)

- but interesting benchmark models hint at requiring a precision of ~ 5—10%

Now that we have made the study of the Higgs self-couplings a driving motivation for the HL-LHC, it will be imperative that we follow this up with precision measurements at a next collider

- and it is much better to do so via tree-level processes than to have to depend on loop effects