Global EFT constraints at future lepton colliders

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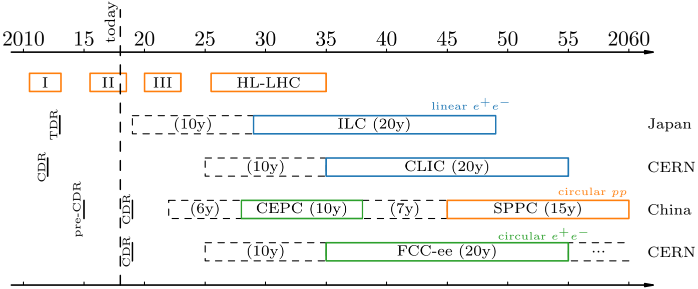
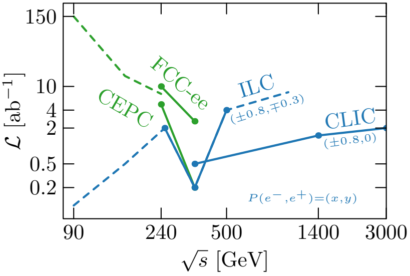
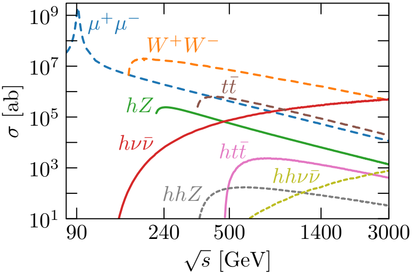
Future lepton colliders







SM effective field theory

Parametrizes systematically
the theory space in direct vicinity of the SM
through a proper QFT.

- employ the Higgs basis of dim-6 operators
- focus on Higgs-related processes:

$$e^+e^- \to \quad hZ,\ W^+W^- \quad \text{(incl. angular distributions)}$$
$$h\nu\bar{\nu},\ ht\bar{t}$$
$$h \to ZZ^*,\ WW^*,\ \gamma\gamma,\ \gamma Z,\ gg,\ b\bar{b},\ c\bar{c},\ \tau^+\tau^-,\ \mu^+\mu^-$$

- only relax flavour universality to distinguish Yukawa's
- assume CPV, EW parameters, dipole operators are well constrained

$\longrightarrow$ 13 parameters: $\Gamma_{xy}/\Gamma_{xy}^{\text{SM}} \sim 1 + 2\bar{c}_{xy} + \ldots$

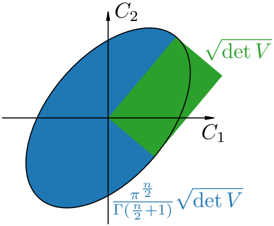
$$\delta c_Z\,,\quad c_{ZZ}\,,\quad c_{Z\Box}\,,$$
$$\bar{c}_{\gamma\gamma}\,,\quad \bar{c}_{Z\gamma}\,,\quad \bar{c}_{gg}\,,$$
$$\delta y_t\,,\quad \delta y_c\,,\quad \delta y_b\,,\quad \delta y_\tau\,,\quad \delta y_\mu\,,$$
$$\lambda_Z\,, \delta\kappa_\lambda$$

Global determinant parameter

In a n-dimensional Gaussian fit,
with covariance matrix V,

$$\text{GDP} \equiv \sqrt[2n]{\det V}$$

provides a geometric average
of the constraints strengths.

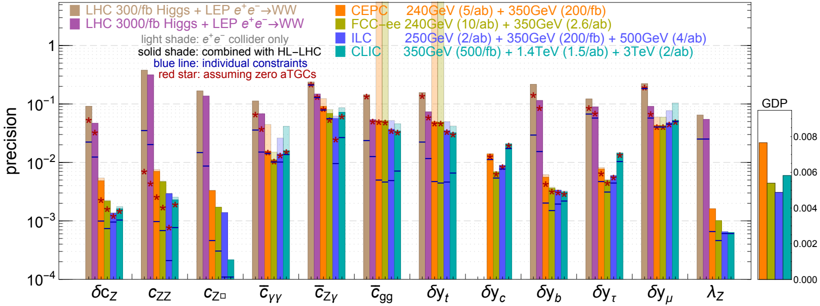


Interestingly, GDP ratios are operator-basis independent!

- as the volume scales linearly with coefficient normalization
- as the volume is invariant under rotations

$\Longrightarrow$ convenient to assess constraints strengthening.

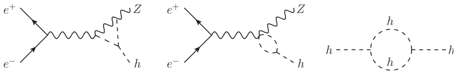
Global constraints (without Higgs self-coupling)



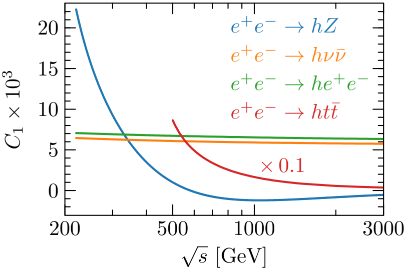
- importance of complementary measurements
  (different c.o.m. energies, polarizations, distributions)
- importance of diboson measurement precision
  (not studied much by exp. collaborations)
- order of magnitude improvement wrt LHC on δc_Z, δc_{ZZ}, $\delta c_{Z\Box}$, δy_b, δy_τ, λ_Z
- LHC helps for $\bar{c}_{\gamma\gamma}$, δy_μ, and δy_t (below 500 GeV!)

Higgs self-coupling: low energies

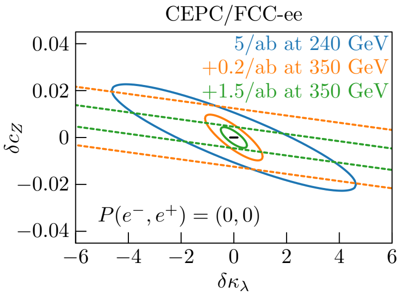
- NLO sensitivity (finite and gauge-invariant NLO EW subset)
- dominated by $e^+e^- \to hZ$ at threshold [McCullough '13]

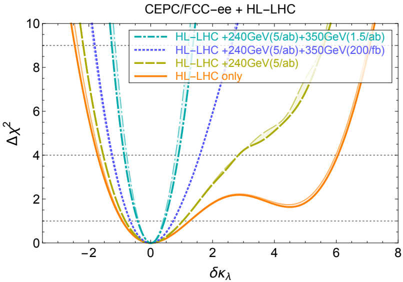


$$\Sigma_{\rm NLO}/\Sigma_{\rm NLO}^{\rm SM} \simeq 1 + (C_1 - 0.0031)\,\delta\kappa_\lambda + \ldots$$



- individual 1σ limit (14%) much tighter than global ones (460, 110, 50%)

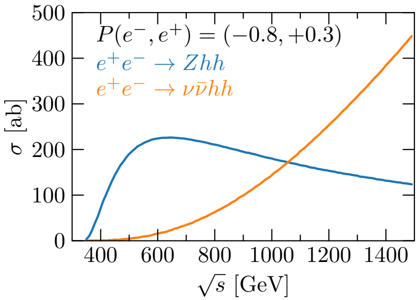


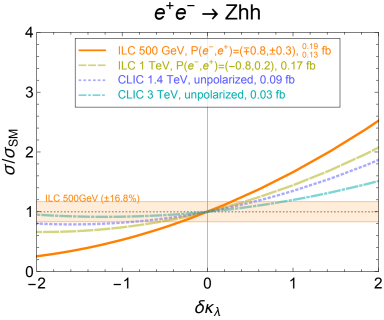


- second LHC minimum already resolved by a 240 GeV run
- constraints dominated by lepton colliders for 1.5 ab^{-1} at 350 GeV ($\sim$ 40%)

Higgs self-coupling: high energies

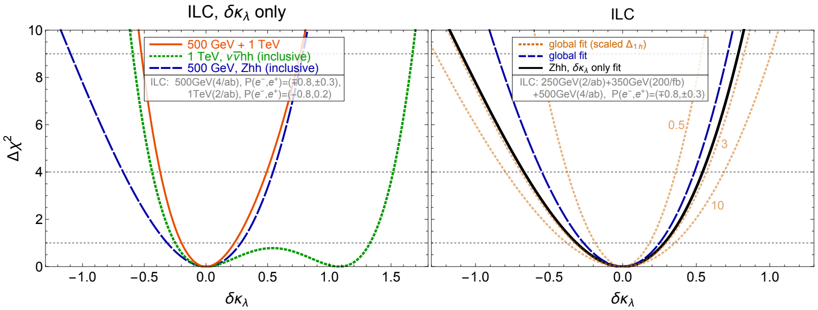
- two production modes: double Higgsstrahlung and WW-fusion
- sensitivity to $\delta\kappa_\lambda$ decreases with $\sqrt{s}$





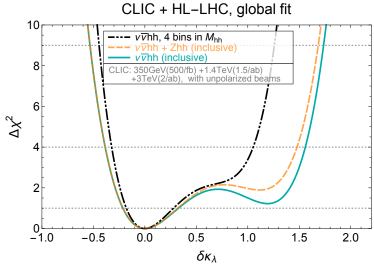
ILC

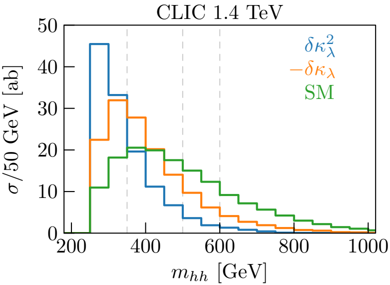
- perfect complementarity between 500 GeV and 1 TeV runs
- both individual and global 1σ limits $\sim 20\%$
- though, single Higgs measurements could have an impact



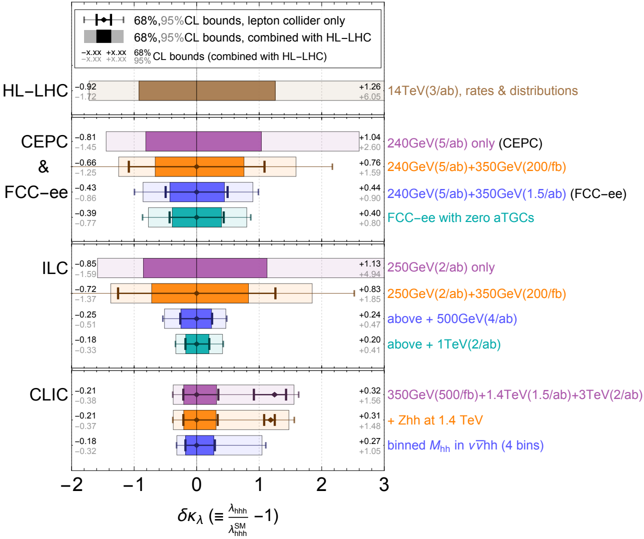
CLIC

- missing low-energy $e^+e^- \to Zhh$ to constrain positive $\delta\kappa_\lambda$
- exploiting m_{hh} invariant mass, instead [Contino et al '13]
- both individual and global 1σ limits $\sim -20, +30\%$





Higgs self-coupling: summary



- robust indirect constraints at low energy require a global analysis

  $\rightarrow \sigma_{\delta\kappa_\lambda} \sim 75\%$ with $0.2\,\text{ab}^{-1}$ at 350 GeV, $\sim 40\%$ with $1.5\,\text{ab}^{-1}$
- single-Higgs measurements could affect direct high-energy determinations

  $\rightarrow \sigma_{\delta\kappa_\lambda} \sim 20\%$ with 500 GeV run

Open questions

Could indirect constraints on the top Yukawa
compete with LHC ones? [Shen,Zhu'15]

Would one need a new Z pole run
to continue factorizing out EW paramters? [Barklow et al.'17]

What is the best lepton collider?

The one actually built!

M.Peskin