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CLIC Higgs coupling prospects with a longer first energy stage

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Abstract

One of the most attractive features of a linear collider is the ability to extend its energy reach in stages, and to adapt the running plan flexibly in terms of maximum centre-of-mass energy and time spent at each stage. The baseline luminosity staging scenario for CLIC is well-established, and has been used to obtain sensitivity projections for Standard Model measurements and Beyond Standard Model scenarios. Here, as an exercise to illustrate what could be obtained from an alternative running scenario, Higgs coupling sensitivities are presented for the case where more data is collected at the initial stage $\sqrt{s} = 380\,\text{GeV}$, before proceeding to the higher energy stages of $\sqrt{s} = 1.5$ and $3\,\text{TeV}$. This could be achieved through running for longer, or operating the collider at an increased repetition rate of 100 Hz at the initial stage, or a combination of both.

1 Introduction

The Compact Linear Collider, CLIC, offers high-energy e^+e^- collisions up to centre-of-mass energies of 3 TeV [1]. A rich programme of Higgs and top-quark physics is uniquely provided by the initial energy stage around $\sqrt{s} = 380\,\text{GeV}$; this is supplemented at the higher-energy stages by increased precision in Higgs and top-quark physics, and further reach to Beyond Standard Model (BSM) effects [2–4].

One of the most attractive features of a linear collider is the ability to extend the energy reach in stages. Correspondingly, this provides a high degree of flexibility in adapting the programme in terms both of maximum centre-of-mass energy and running times at each stage; this could be in response to physics results that suggest reoptimisation; to technical developments in CLIC or other accelerator technologies that suggest updating the global accelerator strategy; or to other considerations such as the availability of funding, which could change the schedule.

In the context of the European Strategy for Particle Physics, while the CLIC proposal presents a sequence of energy upgrades from $\sqrt{s} = 380\,\text{GeV}$ (CLIC_{380}) to 1.5 TeV (CLIC_{1500}) and 3 TeV (CLIC_{3000}), this flexibility means that it would also be possible to take a different route after the initial stage, for example:

$$\begin{aligned}
&\text{CLIC}_{380} + \text{CLIC}_{1500} + \text{CLIC}_{3000} \\
&\text{CLIC}_{380} + \text{CLIC}_{1500} + \text{FCC}_{hh} \\
&\text{CLIC}_{380} + \text{FCC}_{hh} \\
&\text{CLIC}_{380} + \text{muon collider} \\
&\text{CLIC}_{380} + \text{wakefield acceleration} \\
&\text{CLIC}_{380} + \text{dielectric-based acceleration.}
\end{aligned}$$

Starting with CLIC_{380} gives the option of reviewing the physics and technology landscape every few years, and choosing the best next step at that time, so the initial choice becomes:

$$\text{CLIC}_{380} + \text{best next step.}$$

To explore the options afforded by a flexible running scenario, as an exercise we examine here the extra sensitivity to Higgs couplings that would be obtained by collecting more integrated luminosity at $\sqrt{s} = 380\,\text{GeV}$. This could arise through changed accelerator parameters – for example running at the initial stage with a repetition rate of 100 Hz, which is double the baseline repetition rate – or through running for a longer time, or a combination of both.

2 Staging

CLIC's luminosity baseline was presented in [5, 6], where corresponding Higgs coupling sensitivities were given. The luminosity baseline assumes $1\,\text{ab}^{-1}$ of integrated luminosity collected at the initial stage, $\sqrt{s} = 380\,\text{GeV}$, followed by $2.5\,\text{ab}^{-1}$ at $\sqrt{s} = 1.5\,\text{TeV}$ and $5\,\text{ab}^{-1}$ at $\sqrt{s} = 3\,\text{TeV}$. The projected timescale includes a three-year ramp-up to reach the nominal instantaneous luminosity for the first energy stage, and two-year ramp-ups at the second and third stages.

For a comprehensive mapping of the Higgs (125 GeV) sector in e^+e^- collisions, some data must be taken close to the threshold for Higgs production, where the Higgs-strahlung process dominates. This allows a precise measurement of the total Higgs production cross-section through the so-called 'recoil' method, which is needed in order to extract Higgs couplings in a model-independent way from measured cross-sections times branching ratios.

The CLIC physics priority is to move to higher centre-of-mass energies quickly, to take advantage of the unique capability of CLIC to provide multi-TeV e^+e^- collisions. The higher-energy stages open production channels not accessible at the initial energy stage and provide enhanced sensitivity to BSM scenarios. The CLIC baseline luminosity scenario therefore moves to $\sqrt{s} = 1.5\,\text{TeV}$ after 8 years of running at the initial energy stage.

However, it is useful to see how sensitivities would be affected by taking more data at the initial stage, for example to adapt to the available funding profile.

Owing to the initial ramp-up in instantaneous luminosity, integrated luminosity is accumulated more quickly later in the run, after the nominal instantaneous luminosity has been reached. Therefore, by increasing the initial stage from 8 years to 13 years, the integrated luminosity is doubled. Furthermore, as discussed in [7], it would be possible to operate CLIC at 380 GeV at double the repetition rate – 100 Hz instead of 50 Hz – with only modest increase in cost (around the 5% level) and power (from around 170 MW to around 220 MW).

Taking both of these enhancements into account, as an exercise we consider sensitivities resulting from $4\,\text{ab}^{-1}$ collected at the initial stage, rather than the baseline $1\,\text{ab}^{-1}$. As in the baseline scenario, equal amounts of –80% and +80% polarisation running are foreseen throughout the initial energy stage.

The two examples of (a) the CLIC baseline of $1\,\text{ab}^{-1}$ collected at 380 GeV plus $2.5\,\text{ab}^{-1}$ collected at 1.5 TeV (presented in [5] and [6]), and (b) $4\,\text{ab}^{-1}$ collected at 380 GeV (presented here), provide realistic scenarios that can usefully be compared with other proposed e^+e^- collider options that are limited in centre-of-mass energy.

3 Higgs couplings

The total Higgs production cross section measurement $\sigma(\text{ZH})$, using only the system that recoils against the produced Higgs boson and without examining the Higgs decay products, is a unique feature of lepton colliders. It dominates the model-independent determination of the ZH coupling, g_{HZZ}, and is only possible at the initial energy stage. In turn this propagates into the extraction of all the other Higgs couplings. Accumulating more data at $\sqrt{s} = 380\,\text{GeV}$ therefore contributes to improved precision on the other Higgs couplings.

3.1 Summary of Higgs observables

Extensive studies of the CLIC sensitivities to Higgs couplings have been reported previously in [2], where details of the analyses and the extraction of Higgs observables through combined fitting can be found[1]. Sensitivities obtained assuming the current CLIC luminosity baseline can be found in [5].

Here, the precisions of the individual Higgs sector measurements are given for an increased luminosity of $4\,\text{ab}^{-1}$ at the initial energy stage, while the luminosities of the 1.4 (1.5) and 3 TeV stages are unchanged at 2.5 and $5.0\,\text{ab}^{-1}$, respectively. This serves to illustrate what could be obtained from the different stages of an alternative running scenario.

Precisions on the Higgs observables are given in Table 1 for the first energy stage, and in Table 2 for the two higher-energy stages. These individual results assume unpolarised beams.

Measurement of the cross section for double-Higgs production at 1.4 and 3 TeV gives sensitivity to the Higgs self-coupling λ. This is unchanged from that reported in [5, 8], with an ultimate precision on λ of $[-7\%, +11\%]$.

The recoil mass analysis from $e^+e^- \rightarrow \text{ZH}$ events can be used to search for BSM decay modes of the Higgs boson into 'invisible' final states. Scaling the result from [2] to $4\,\text{ab}^{-1}$ at $\sqrt{s} = 350\,\text{GeV}$ gives an upper limit on the invisible Higgs branching ratio of $BR(\text{H} \rightarrow \text{invis.}) < 0.34\%$ at 90% C.L. in the modified frequentist approach.

[1] Note that earlier studies assumed an energy staging of $\sqrt{s} = 350\,\text{GeV}$, 1.4 TeV, and 3 TeV; those energy stages are used for the results presented here, but with results scaled to the updated integrated luminosities.

Channel	Measurement	Observable	Statistical precision 350 GeV $4\,\mathrm{ab}^{-1}$	Reference [2]
ZH	Recoil mass distribution	m_{H}	39 MeV	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \text{invisible})$	Γ_{inv}	0.2 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{Z} \to \mathrm{l^+l^-})$	g^2_{HZZ}	1.3 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{Z} \to \mathrm{q\bar{q}})$	g^2_{HZZ}	0.6 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	0.30 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \mathrm{c\bar{c}})$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{Hcc}} / \Gamma_{\mathrm{H}}$	5 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \mathrm{gg})$		2.2 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \tau^+\tau^-)$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{H\tau\tau}} / \Gamma_{\mathrm{H}}$	2.2 %	[2]
ZH	$\sigma(\mathrm{ZH}) \times BR(\mathrm{H} \to \mathrm{WW}^*)$	$g^2_{\mathrm{HZZ}} g^2_{\mathrm{HWW}} / \Gamma_{\mathrm{H}}$	1.8 %	[2]
$\mathrm{H\nu_e\bar{\nu}_e}$	$\sigma(\mathrm{H\nu_e\bar{\nu}_e}) \times BR(\mathrm{H} \to \mathrm{b\bar{b}})$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{Hbb}} / \Gamma_{\mathrm{H}}$	0.7 %	[2]
$\mathrm{H\nu_e\bar{\nu}_e}$	$\sigma(\mathrm{H\nu_e\bar{\nu}_e}) \times BR(\mathrm{H} \to \mathrm{c\bar{c}})$	$g^2_{\mathrm{HWW}} g^2_{\mathrm{Hcc}} / \Gamma_{\mathrm{H}}$	9 %	[2]
$\mathrm{H\nu_e\bar{\nu}_e}$	$\sigma(\mathrm{H\nu_e\bar{\nu}_e}) \times BR(\mathrm{H} \to \mathrm{gg})$		3.5 %	[2]

Table 1: Summary of the precisions obtainable for the Higgs observables in the first stage of CLIC for an increased integrated luminosity of $4\,\mathrm{ab}^{-1}$ at $\sqrt{s} = 350\,\mathrm{GeV}$, assuming unpolarised beams, to illustrate the scenario where more data is taken at the inital energy stage than in the CLIC baseline. For the branching ratios, the measurement precision refers to the expected statistical uncertainty on the product of the relevant cross section and branching ratio; this is equivalent to the expected statistical uncertainty of the product of couplings divided by Γ_{H} as indicated in the third column.

3.2 Combined fits

Precisions on the Higgs couplings and width extracted from a model-independent global fit, described in [2], are given in Table 3. The fit assumes the baseline scenario for beam polarisation, but an increased integrated luminosity at the initial stage for illustration. The increase in cross-section from having a predominantly negatively-polarised electron beam is taken into account by multiplying the event rates for all WW-fusion measurements by a factor of 1.48, corresponding to a factor of 1.8 for 80 % of the statistics and 0.2 for the remaining 20 %. This approach is conservative because it assumes that all backgrounds, including those from s-channel processes, which do not receive the same polarisation enhancement, scale by the same amount.

Each energy stage contributes significantly to the Higgs programme: the initial stage provides g_{HZZ} and couplings to most fermions and bosons, while the higher-energy stages improve them and add the top-quark, muon, and photon couplings. The precision on g_{HZZ} is determined by the statistics at the initial stage.

Precisions extracted from a model-dependent global fit, also described in [2], are given in Table 4. This fit also assumes the baseline scenario for beam polarisation, but an increased integrated luminosity at the initial stage for illustration.

A global EFT fit has been carried out in [11] for the purposes of comparing future collider projects, and is extensively described there. The corresponding projections for the illustrative increased integrated luminosity at the initial CLIC stage, combined with the projected HL-LHC sensitivities, are given in Table 5 and Figure 3 for the model $\mathrm{SMEFT_{ND}}$, which does not assume flavour universality. The HL-LHC projections are also given separately for comparison.

Channel	Measurement	Observable	Statistical precision 1.4 TeV $2.5\,\mathrm{ab}^{-1}$	3 TeV $5.0\,\mathrm{ab}^{-1}$	Reference
$\mathrm{H}\nu_e\bar{\nu}_e$	$\mathrm{H}\to\mathrm{b\bar{b}}$ mass distribution	m_H	36 MeV	28 MeV	[2]
ZH	$\sigma(\mathrm{ZH})\times BR(\mathrm{H}\to\mathrm{b\bar{b}})$	$g^2_\mathrm{HZZ}g^2_\mathrm{Hbb}/\Gamma_\mathrm{H}$	$2.6\,\%^{\dagger}$	$4.3\,\%^{\dagger\ddagger}$	[9]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{b\bar{b}})$	$g^2_\mathrm{HWW}g^2_\mathrm{Hbb}/\Gamma_\mathrm{H}$	0.3 %	0.2 %	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{c\bar{c}})$	$g^2_\mathrm{HWW}g^2_\mathrm{Hcc}/\Gamma_\mathrm{H}$	4.7 %	4.4 %	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{gg})$		3.9 %	2.7 %	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\tau^+\tau^-)$	$g^2_\mathrm{HWW}g^2_\mathrm{H\tau\tau}/\Gamma_\mathrm{H}$	3.3 %	2.8 %	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mu^+\mu^-)$	$g^2_\mathrm{HWW}g^2_\mathrm{H\mu\mu}/\Gamma_\mathrm{H}$	29 %	16 %	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\gamma\gamma)$		12 %	$6\,\%^{*}$	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{Z}\gamma)$		33 %	$19\,\%^{*}$	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{WW}^*)$	$g^4_\mathrm{HWW}/\Gamma_\mathrm{H}$	0.8 %	$0.4\,\%^{*}$	[2]
$\mathrm{H}\nu_e\bar{\nu}_e$	$\sigma(\mathrm{H}\nu_e\bar{\nu}_e)\times BR(\mathrm{H}\to\mathrm{ZZ}^*)$	$g^2_\mathrm{HWW}g^2_\mathrm{HZZ}/\Gamma_\mathrm{H}$	4.3 %	$2.5\,\%^{*}$	[2]
$\mathrm{He}^+\mathrm{e}^-$	$\sigma(\mathrm{He}^+\mathrm{e}^-)\times BR(\mathrm{H}\to\mathrm{b\bar{b}})$	$g^2_\mathrm{HZZ}g^2_\mathrm{Hbb}/\Gamma_\mathrm{H}$	1.4 %	$1.5\,\%^{*}$	[2]
$\mathrm{t\bar{t}H}$	$\sigma(\mathrm{t\bar{t}H})\times BR(\mathrm{H}\to\mathrm{b\bar{b}})$	$g^2_\mathrm{Htt}g^2_\mathrm{Hbb}/\Gamma_\mathrm{H}$	5.7 %	–	[3]

Table 2: Summary of the precisions obtainable for the Higgs observables in the higher-energy CLIC stages for integrated luminosities of $2.5\,\mathrm{ab}^{-1}$ at $\sqrt{s}=1.4\,\mathrm{TeV}$, and $5.0\,\mathrm{ab}^{-1}$ at $\sqrt{s}=3\,\mathrm{TeV}$. In both cases unpolarised beams have been assumed. These are the same sensitivities given in [5]. For g_Htt, the 3 TeV case has not yet been studied. Numbers marked with $*$ are extrapolated from $\sqrt{s}=1.4\,\mathrm{TeV}$ to $\sqrt{s}=3\,\mathrm{TeV}$ while † indicates projections based on fast simulations. For the branching ratios, the measurement precision refers to the expected statistical uncertainty on the product of the relevant cross section and branching ratio; this is equivalent to the expected statistical uncertainty of the product of couplings divided by Γ_H, as indicated in the third column. ‡ The value for $\sigma(\mathrm{ZH})\times BR(\text{all hadronic})$ at 3 TeV has recently been confirmed as 4% in a full-simulation study [10].

4 Conclusions

Under different scenarios, CLIC could take more data at the initial energy stage than assumed in the CLIC luminosity staging baseline.

Here, the effect on the Higgs coupling sensitivities of taking $4\,\mathrm{ab}^{-1}$ instead of $1\,\mathrm{ab}^{-1}$ at the initial stage has been presented, as an exercise to illustrate what could be obtained from an alternative running scenario. This could be achieved by running for 13 years instead of 8 years, with an accelerator repetition rate of 100 Hz instead of 50 Hz.

Acknowledgements

This work is done in the context of the CLICdp Collaboration, and rescales results from many detailed analyses that are presented in [2].

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Parameter	Relative precision		
	350 GeV $4\,\text{ab}^{-1}$	+ 1.4 TeV + $2.5\,\text{ab}^{-1}$	+ 3 TeV + $5\,\text{ab}^{-1}$
g_{HZZ}	0.3 %	0.3 %	0.3 %
g_{HWW}	0.5 %	0.3 %	0.3 %
g_{Hbb}	1.0 %	0.5 %	0.4 %
g_{Hcc}	2.2 %	1.4 %	1.1 %
$g_{\text{H}\tau\tau}$	1.5 %	1.0 %	0.8 %
$g_{\text{H}\mu\mu}$	–	12.1 %	5.6 %
g_{Htt}	–	2.9 %	2.9 %
$g^{\dagger}_{\text{Hgg}}$	1.3 %	0.9 %	0.7 %
$g^{\dagger}_{\text{H}\gamma\gamma}$	–	4.8 %	2.3 %
$g^{\dagger}_{\text{HZ}\gamma}$	–	13.3 %	6.6 %
Γ_{H}	2.4 %	1.5 %	1.3 %

Table 3

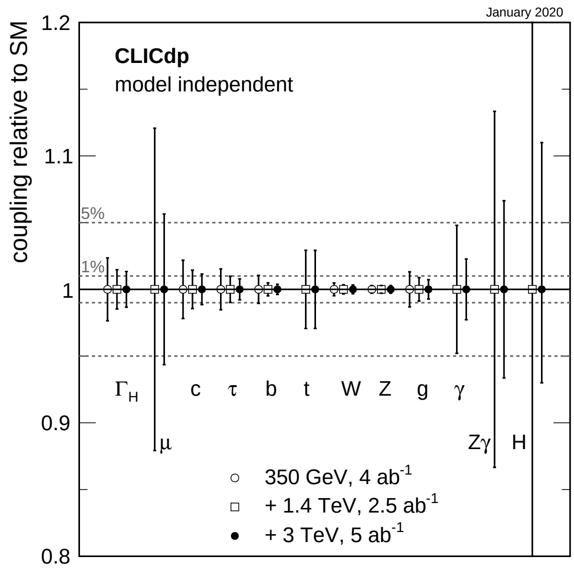

Figure 1

Results of the model-independent fit assuming $4\,\text{ab}^{-1}$ at $\sqrt{s} = 350\,\text{GeV}$, for an illustrative scenario where more data is taken at the inital energy stage than in the CLIC baseline. For g_{Htt}, the 3 TeV case has not yet been studied. The three effective couplings $g^{\dagger}_{\text{Hgg}}$, $g^{\dagger}_{\text{H}\gamma\gamma}$ and $g^{\dagger}_{\text{HZ}\gamma}$ are also included in the fit. Operation with $-80\,\%$ ($+80\,\%$) electron beam polarisation is assumed for 80 % (20 %) of the collected luminosity above 1 TeV, corresponding to the baseline scenario.

Parameter	Relative precision		
	350 GeV $4\,\text{ab}^{-1}$	+ 1.4 TeV $+\,2.5\,\text{ab}^{-1}$	+ 3 TeV $+\,5\,\text{ab}^{-1}$
κ_{HZZ}	0.2 %	0.1 %	0.1 %
κ_{HWW}	0.4 %	0.1 %	0.1 %
κ_{Hbb}	0.6 %	0.3 %	0.2 %
κ_{Hcc}	2.0 %	1.4 %	1.1 %
$\kappa_{H\tau\tau}$	1.4 %	0.9 %	0.7 %
$\kappa_{H\mu\mu}$	–	12.1 %	5.6 %
κ_{Htt}	–	2.9 %	2.9 %
κ_{Hgg}	1.0 %	0.8 %	0.6 %
$\kappa_{H\gamma\gamma}$	–	4.8 %	2.3 %
$\kappa_{HZ\gamma}$	–	13.3 %	6.6 %

Table 4

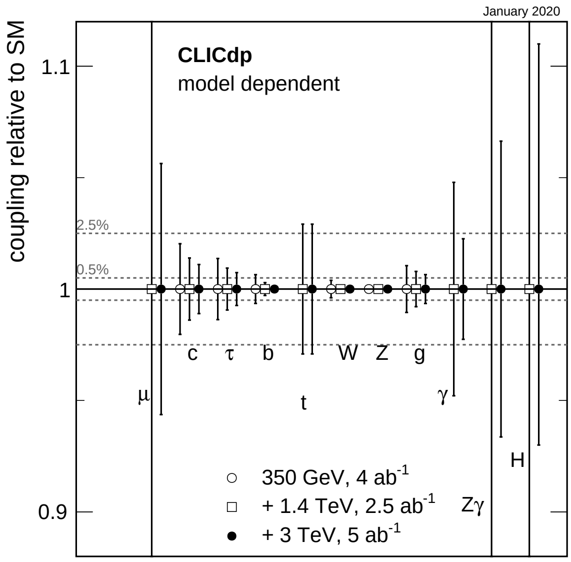

Figure 2

Results of the model-dependent fit without theoretical uncertainties, assuming $4\,\text{ab}^{-1}$ at $\sqrt{s} = 350\,\text{GeV}$, for an illustrative scenario where more data is taken at the inital energy stage than in the CLIC baseline. For κ_{Htt}, the 3 TeV case has not yet been studied. The uncertainty of the total width is calculated from the fit results. Operation with −80 % (+80 %) electron beam polarisation is assumed for 80 % (20 %) of the collected luminosity above 1 TeV, corresponding to the baseline scenario.

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	Benchmark	HL-LHC	HL-LHC + CLIC 380 GeV 4 ab^{-1}	1.5 TeV 2.5 ab^{-1}	3 TeV 5 ab^{-1}
$g^{\text{eff}}_{\text{HZZ}}$ [%]	SMEFT_{ND}	3.6	0.3	0.2	0.16
$g^{\text{eff}}_{\text{HWW}}$ [%]	SMEFT_{ND}	3.2	0.3	0.17	0.14
$g^{\text{eff}}_{\text{H}\gamma\gamma}$ [%]	SMEFT_{ND}	3.6	1.3	1.3	1.1
$g^{\text{eff}}_{\text{HZ}\gamma}$ [%]	SMEFT_{ND}	11.	9.3	3.2	2.5
$g^{\text{eff}}_{\text{Hgg}}$ [%]	SMEFT_{ND}	2.3	0.9	0.7	0.60
$g^{\text{eff}}_{\text{Htt}}$ [%]	SMEFT_{ND}	3.5	3.1	2.1	2.1
$g^{\text{eff}}_{\text{Hcc}}$ [%]	SMEFT_{ND}	–	2.1	1.5	1.2
$g^{\text{eff}}_{\text{Hbb}}$ [%]	SMEFT_{ND}	5.3	0.64	0.42	0.36
$g^{\text{eff}}_{\text{H}\tau\tau}$ [%]	SMEFT_{ND}	3.4	1.0	0.78	0.65
$g^{\text{eff}}_{\text{H}\mu\mu}$ [%]	SMEFT_{ND}	5.5	4.3	4.1	3.5
$\delta g_{1\text{Z}}$ [$\times 10^2$]	SMEFT_{ND}	0.66	0.027	0.009	0.007
$\delta\kappa_\gamma$ [$\times 10^2$]	SMEFT_{ND}	3.2	0.044	0.023	0.017
λ_{Z} [$\times 10^2$]	SMEFT_{ND}	3.2	0.022	0.0051	0.0018

Table 5: Sensitivity at 68% probability to deviations in the different effective Higgs couplings and anomalous triple gauge couplings from a Global SMEFT fit, using the benchmark SMEFT_{ND} described in [11]. (The information about the other degrees of freedom included in the SMEFT_{ND} fit in [11], i.e. $g^f_{L,R}$, is omitted in this table.) These numbers can be compared to those of Table 7 in [11]. For CLIC, results from the Z boson radiative return events are included. Results are for an illustrative scenario where more data is taken at the inital stage, than in the CLIC baseline.

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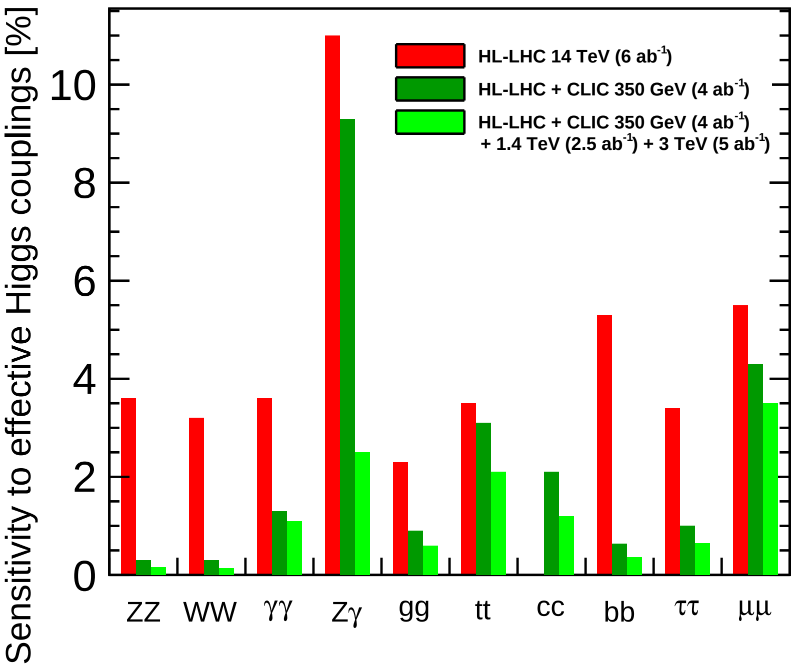

Figure 3: Comparison of the $\mathrm{SMEFT_{ND}}$ projections for HL-LHC and HL-LHC + CLIC.