PROCEEDINGS OF SCIENCE

Higgs physics at CLIC

Matthias Weber on behalf of the CLICdp collaboration[*]
CERN, Switzerland
E-mail: matthias.artur.weber@cern.ch

The Compact Linear Collider (CLIC) is a mature option for a future electron-positron collider operating at centre-of-mass energies of up to 3 TeV. CLIC will be built and operated in a staged approach with three centre-of-mass energy stages currently assumed to be 380 GeV, 1.5 TeV and 3 TeV. This contribution discusses the physics potential of CLIC in the area of Higgs physics based on benchmark analyses using full detector simulations. The initial stage of operation allows study of Higgs production in Higgsstrahlung and WW-fusion, resulting in precise measurements of the production cross sections and the total Higgs-boson decay width. Operation at high energy will provide high-statistics samples of Higgs bosons produced in WW-fusion enabling tight constraints on Higgs couplings. High-energy operation also gives access to the $t\bar{t}H$ process and Higgs self-coupling, through the measurement of double Higgs production. Global fits of the CLIC Higgs analyses are presented.

The 39th International Conference on High Energy Physics (ICHEP2018)
4-11 July, 2018
Seoul, Korea

PoS(ICHEP2018)682

---

[*] Speaker.

© Copyright owned by the author(s) under the terms of the Creative Commons
Attribution-NonCommercial-NoDerivatives 4.0 International License (CC BY-NC-ND 4.0).

1. Introduction

The Compact Linear Collider (CLIC) is a proposed future high-luminosity linear e^+e^- collider, which will be operated in a staged approach from a few hundred GeV up to 3 TeV [1, 2]. In the Higgs physics studies presented [4], the nominal centre-of-mass energies the three stages are assumed to be $\sqrt{s} = 350\,\mathrm{GeV}$, 1.4 TeV, and 3 TeV. The data from these studies have been scaled to the latest assumptions on the integrated luminosity [3] of 1 ab^{-1} for the first, 2.5 ab^{-1} for the second, and 5 ab^{-1} for the third energy stage. The CLIC baseline design includes a ±80% beam polarisation electrons, and no positron polarisation. A the first energy stage, half of the data are taken at -80% and half at +80% electron polarisation. At the second and third stage it is foreseen to divide the running time between -80% and +80% electron polarisation in the ratio 4:1. Unlike in hadron-hadron collisions no triggers are needed, and all Higgs events will be used. With event selection efficiencies ranging from about 20-60% hundreds of thousands up to millions of Higgs bosons are available for analysis. All results shown in the following are based on realistic full detector simulations including the impact of beam-beam effects.

PoS(ICHEP2018)682

2. Higgs measurements

At the first stage the dominant Higgs production mechanism is $e^+e^- \to ZH$. Sub-leading at the first stage, the WW fusion production process $e^+e^- \to H\nu_e\bar{\nu}_e$ becomes the dominant production mechanism at the second and third stage. Unlike at the first stage, at both higher energy stages the Higgs bosons will be produced at polar angles close to the beam line. Unique to lepton colliders is the recoil mass measurement, where the ZH event is identified from the Z recoil mass $m^2_{\mathrm{rec}} = (\sqrt{s} - E_Z)^2 - p^2_Z$, since the centre-of-mass energy is a known parameter. The recoil mass analysis is performed both in leptonic and hadronic Z events, where the fine-grained granular calorimeter allows for high precision measurements through particle flow reconstruction. Combining both channels provides a model-independent measurement of the coupling of the Higgs boson to the Z-boson g_{HZZ} with a precision of 0.6%. Possible Higgs decays to invisible final states can be tested via the recoil mass in $Z \to q\bar{q}$ decays, and the invisible decay width of the Higgs can be constrained to $\mathrm{BR}(\mathrm{H_{inv}}) < 0.69\%$ at 90% confidence level. Due to very precise flavour tagging at CLIC it is possible to simultaneously extract the branching ratios of $H \to b\bar{b}$, $c\bar{c}$ and $g\bar{g}$ using a maximum likelihood template fit based on the two-dimensional distributions of $b\bar{b}$ and $c\bar{c}$ likelihoods. At the second stage the associated production of Higgs and top-antitop pairs is accessible. The $t\bar{t}H$ cross-section measurement can be translated into a search for a CP-odd contribution to the $t\bar{t}H$ coupling [5]. Although the cross-section varies as a function of the mixing angle by up to a factor of 3.5 with respect to the Standard Model value, the sensitivity is almost independent of the mixing angle $\sin^2\phi$ around a relative accuracy of 7%.

At the high energy stages double Higgs production $e^+e^- \to HH\nu_e\bar{\nu}_e$ can be studied. Double Higgs production is sensitive to the quartic coupling g_{HHWW} as well as the trilinear Higgs self-coupling λ. The relative accuracy of λ can be enhanced by operating with beam polarisation $P(e^-) = -80\%$, as well as using differential distributions. The projected accuracy of the Higgs self-coupling is $\Delta\lambda/\lambda \approx 14\%$ from the total cross-section, and about 10% by including differential distributions. This allows to test models of physics beyond the Standard Model, which predict deviations of the triple Higgs boson coupling of a couple of % up to 25% [6].

3. Combined Fits

The precisions of all Higgs coupling measurements are summarised in Fig. 1, which illustrates the results of two types of fits based on a χ^2 minimisation using the MINUIT package [7], including relevant correlations. The first type is a model-independent fit with minimal theoretical assumptions on additional Higgs decays. The second type is a model-dependent fit following a LHC like strategy, which assumes no non-Standard-Model Higgs decays (e.g. into new invisible particles). In the model independent fit the results are limited by the relative uncertainty of the total cross section measurement of ZH. The Higgs width can be extracted with an accuracy of about 4.7% after the first stage, and 2.5% using the data of all three stages. For the model-dependent fits for most couplings an accuracy of sub-percent level can be achieved. A comparison with the projected results after the completion of high luminosity (HL) LHC from ATLAS [8] shows, that the LHC results can be largely improved for the couplings to WW, ZZ, gg, bb, cc and $\tau\tau$. The accuracies in those channels are already surpassed after the completion of the first CLIC stage.

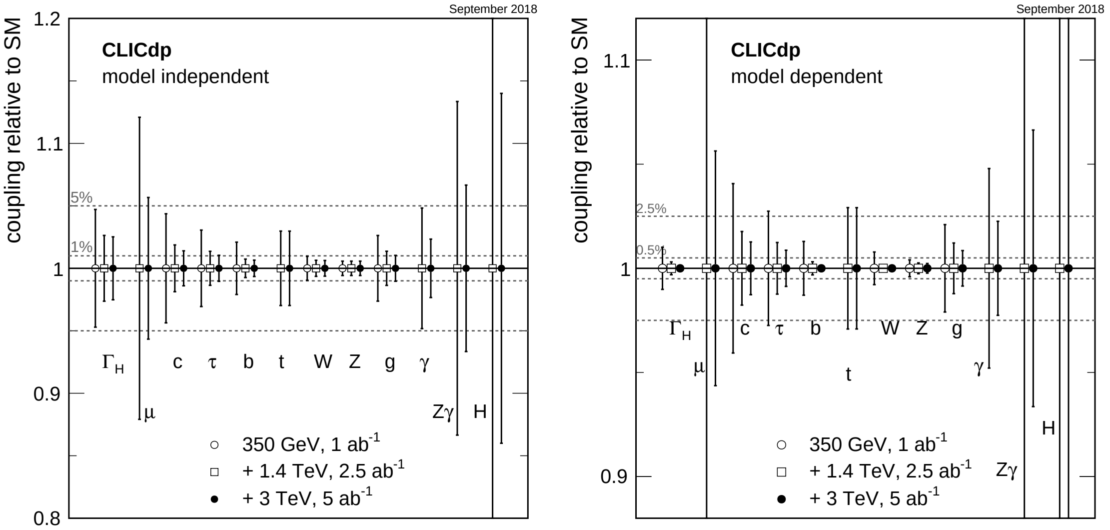

Figure 1: Illustration of the precision of the Higgs couplings of the three-stage CLIC programme determined in a model-independent (left) and a model-dependent fit (right) without systematic or theoretical uncertainties. The dotted lines show the relative precisions of 1% and 5% for the model-independent and 0.5% and 2.5% for the model-dependent fit.

4. Summary

CLIC is capable to enhance the understanding of the Higgs boson significantly beyond the precision of the HL-LHC. The Higgs cross section and the total Higgs width are determined in a model independent measurement. For many Higgs couplings an accuracy better than 1% can be reached. Double Higgs production measurement profits from running at the highest possible energies. The projected relative accuracy of the trilinear self-coupling extraction is around 10%.

PoS(ICHEP2018)682

PoS(ICHEP2018)682

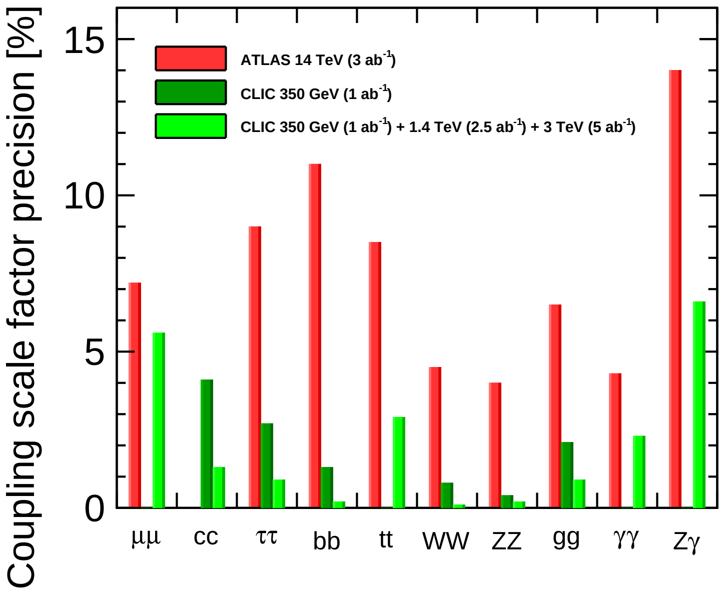

Figure 2: Comparison between the projected relative precision of the coupling scale factor of the three-stage CLIC programme and the projected ATLAS HL-LHC results [8].

References

[1] L. Linssen, A. Miyamoto, M. Stanitzki and H. Weerts (eds), *Physics and Detectors at CLIC: CLIC Conceptual Design Report*, CERN-2012-003 (2012).

[2] P. Lebrun, L. Linssen, A. Lucaci-Timoce, D. Schulte, F. Simon, S. Stapnes, N. Toge, H. Weerts and J. Wells (eds), *The CLIC Programme: Towards a Staged e+e- Linear Collider Exploring the Terascale : CLIC Conceptual Design Report*, CERN-2012-005 (2012).

[3] A. Robson, P. Roloff et al, *Updated CLIC luminosity staging baseline and Higgs coupling prospects*, CLICdp-Note-2018-002 (2018).

[4] The CLICdp collaboration, *Higgs Physics at the CLIC Electron-Positron Linear Collider*, EPJC **77** (2017) 120.

[5] The CLICdp collaboration, *Top-Quark Physics at the CLIC Electron-Positron Linear Collider*, arXiv:1807.02441

[6] R.S. Gupta, H. Rzehak and J. Wells, *How well do we need to measure the Higgs boson mass and self-coupling?*, Phys.Rev.D **88** (2013) 055024.

[7] F. James and M. Roos, *Minuit: A System for Function Minimization and Analysis of the Parameter Errors and Correlations*, Comput.Phys.Commun. **10** (1975) 343.

[8] The ATLAS collaboration, *ATLAS detector upgrade prospects*, ATL-PHYS-PROC-2016-224.