Measurement of the σ x BR(H→ZZ*) at 350 GeV and 3 TeV center-of-mass energies CLIC

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1. Introduction

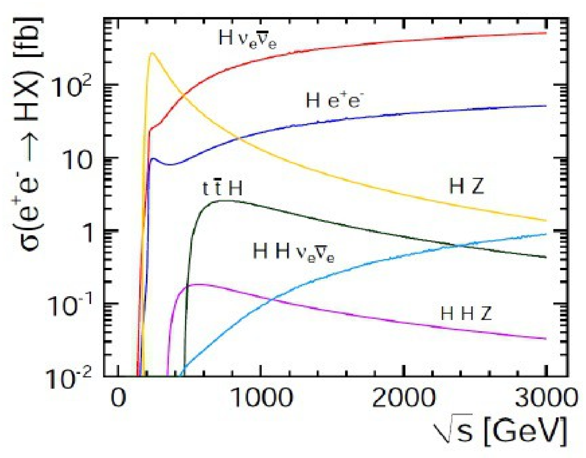
The Compact LInear Collider (CLIC) is a mature option for a future Higgs factory at CERN. If approved, the CLIC could be ready for construction in 2026, with the first collisions in 2035. CLIC is foreseen as a staged machine that will run at center-of-mass energies: 380 GeV, 1.5 TeV and 3 TeV.

At 350 (380) GeV Higgsstrahlung is the dominant Higgs production mechanism, while at higher energies WW-fusion takes over. Individual σ ×BR measurements at all energy stages serve as input to global fits, either model-independent or model-dependent, to extract the Higgs couplings with the utmost precision.

Stage 1: 350 / 380 GeV
- Precision SM Higgs (couplings,mass, width, invisible decays) + top physics

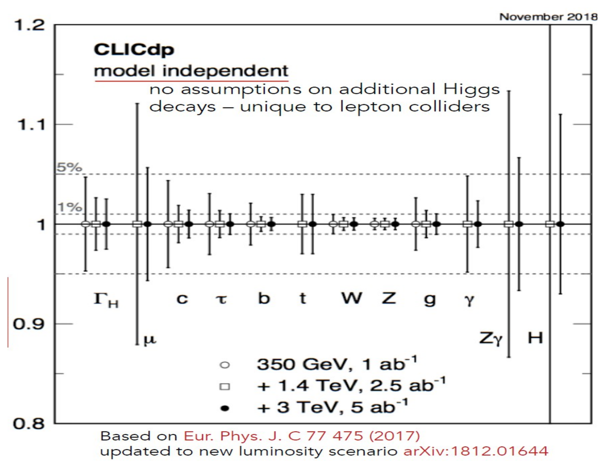
Stage 2: 1.5 TeV
- BSM physics
- top-Yukawa coupling
- rare Higgs processes and decays

Stage 3: 3 TeV
- Best BSM sensitivity
- rare Higgs processes and decays
- double Higgs production – Higgs self-coupling



H to ZZ couplings can be measured below 1% stat. uncertainty from a global fit (model indent/dependent).

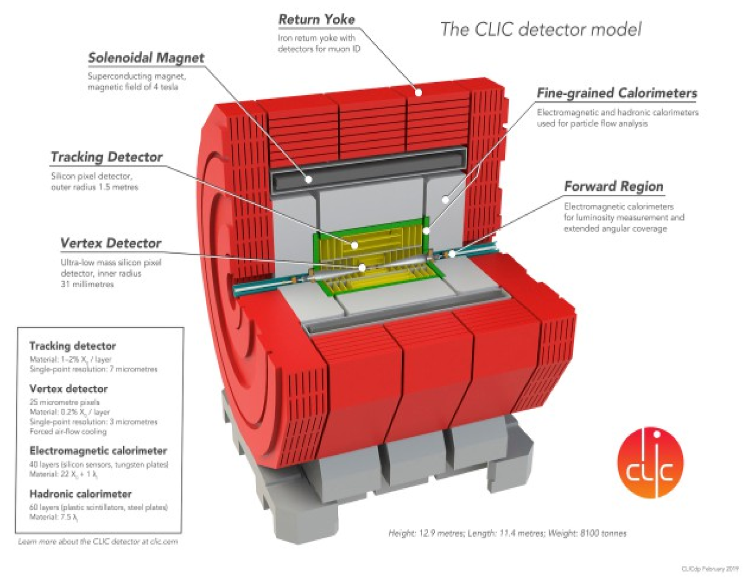
Already at the first stage better precision than at HL-LHC, in particular for c/b/W/Z couplings.



2. CLIC Detector

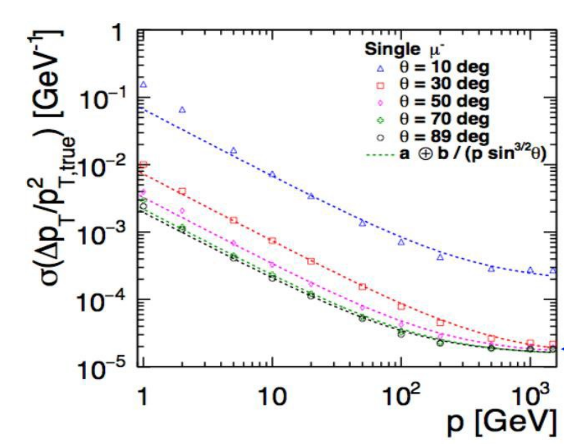
The CLIC_ILD detector, based on the International Large Detector (ILD) detector concept for International Linear Collider (ILC), has been modified for the experimental conditions at CLIC.

- B-field: 4T
- Vertex detector with double layers
- Si tracking system: 1,5m radius
- **Particle reconstruction and identification is done using Particle Flow Algorithm (PFA)**
- ECAL with 40 layers (22 X_0)
- HCAL with 60 layers (7.5 λ)
- Excellent performance of lepton reconstruction and identification due to the highly efficient vertex detector and Si tracking system

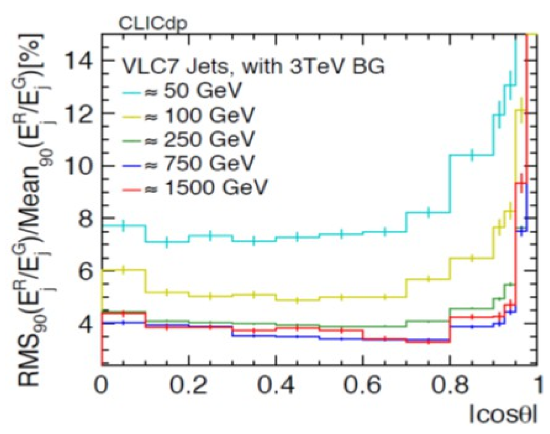


Both CLIC_ILD (detector model applied here) and CLICdet exhibits excellent particle ID and reconstruction proven through experimental testing and detailed simulations:

separation of H/W/Z jets, [illegible] 5% - 3.5%
lepton identification efficiency > 95%



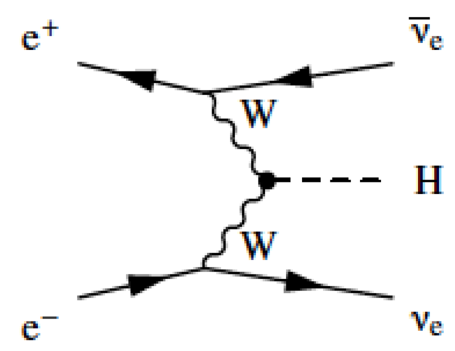
Transverse momentum resolution as a function of momentum for muons for different polar angles [1]



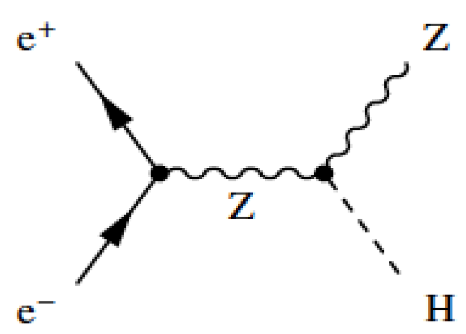
Jer energy resolution distributio for varoius jet energies as a function of cos θ [1]

3. Signal

- σ(Hνυ) at 3 TeV is 415 fb
- σ(Hυυ) x BR (H→ZZ*; ZZ→qqll) = 1.13 fb
- N_{signal} ~ 6000 evt/5ab^{-1}



- σ(HZ) at 350 GeV is 93 fb
- σ(HZ; Z→qq) x BR (H→ZZ*; ZZ*→qqll) = 0.24 fb
- N_{signal} ~ 240 evt/1ab^{-1}



Overview of the method

-Lepton Isolation with Bremsstrahlung recovery
First the 2 isolated electrons or muons are found

-Jet Reconstruction
Events are then grouped in 2 (4) jets by kT algorithm, with cone radius of R = 0.7 at 3 TeV and R = 1.1 at 350 GeV

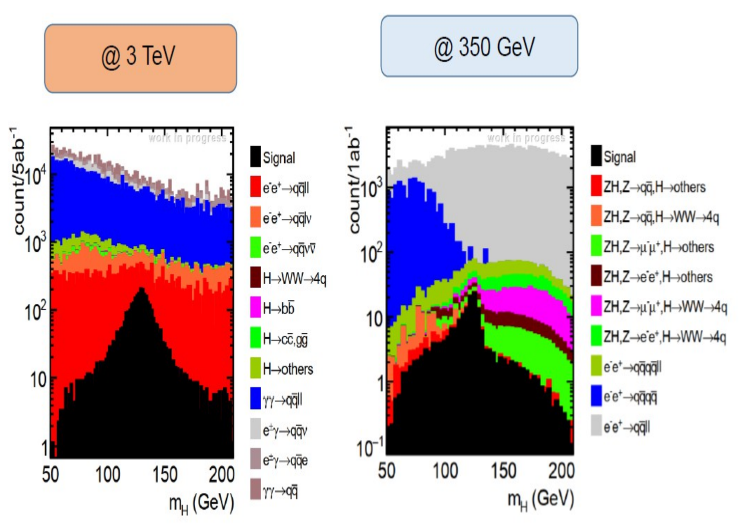
-Z reconstruction
Larger of two fermion invariant masses is considered as on-shell Z boson

-LCFIVertexing(heavy flavors)
Helps to reduce background processes H→bb and H→cc

-Preselection (reduce large cross-section backgrounds)
Exactly 2 isolated leptons per event

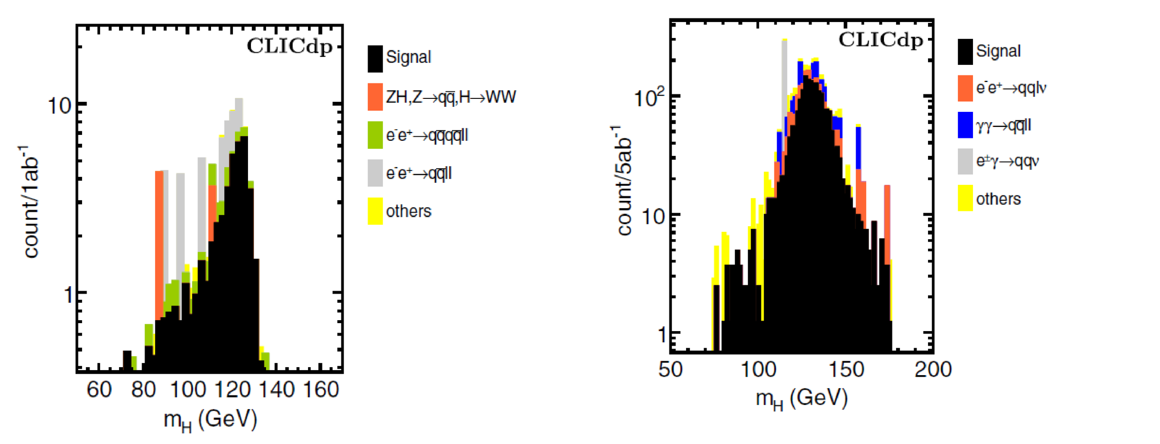
-MVA Selection
Maximizing statistical significance (S) of signal to background separation

Preselection



Signal preselection efficiency':
67% 77%

4. Results and discussion



Stacked histograms of the Higgs mass distributions after MVA, at 350 GeV and 3 TeV center-of-mass energies.

- Overall signal efficiency for 350 GeV analysis is 19% and for 3 TeV is 36 %. MVA is selecting signal events to maximize statistical significance. Since the signal is relatively rare in Nature, with less than 200 preselected events in 1ab^{-1}, the smallest loss of signal leads to a significant loss in signal efficiency and decrease significance value. Significance for 340 GeV and 3 TeV analysis is 5 and 33 respectively.

-Due to chiral nature of WW-fusion, signal statistics at 3 TeV can be effectively increased for a factor of ~ 1.5, without influence on Higgstrahlung at 350 GeV.

Statistical uncertainties

The uncertainty of the estimated number of signal and background events at 350 GeV and 3 TeV, leads to statistical uncertainty of δ [20% ± 2%] and δ [3% ± 0.1%] respectively. The uncertainties of our estimates are calculated from the Poisson variance of the number of selected signal and background events.

Conclusion

Each background process is simulated under the same assumptions of realistic experimental conditions as for the signal, including initial state radiation and final state radiation, realistic luminosity spectrum, presence of Beastrahlung photons and hadrons produced by Beamstrahlung overlaid in each event before the digitization phase. The statistical uncertainty at 3 TeV is consistent with the expectations from [2] on luminosity scaling of the precision of a 1.4 TeV result. The ultimate sub percent precision of the Higgs to Z bosons coupling will be obtained from a global fir of individual measurements as the ones discussed in [2], combined in a model-independent or model-dependent way. Results from this analysis can be found in [3]

References: [1] D. Arominski et al., A detector for CLIC: Main parameters and performance, arxiv:1812.07337v1 (2018).
[2] H. Abramowicz, A. Abusleme, K. Afanaciev et al., Higgs physics at the CLIC electron-positron linear collider, Eur.Phys. J. C 77, 475 (2017).
[3] N. Vukasinovic et al., Measurement of the H to ZZ branching fraction at a 350 GeV and 3 TeV CLIC, Phys Rev . D ***105, 092008 (2022)***

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