Sensitivity to new physics scenarios in invisible Higgs boson decays at CLIC

K. Mękała, A.F. Żarnecki

Faculty of Physics, University of Warsaw
Work carried out in the framework of the CLICdp collaboration

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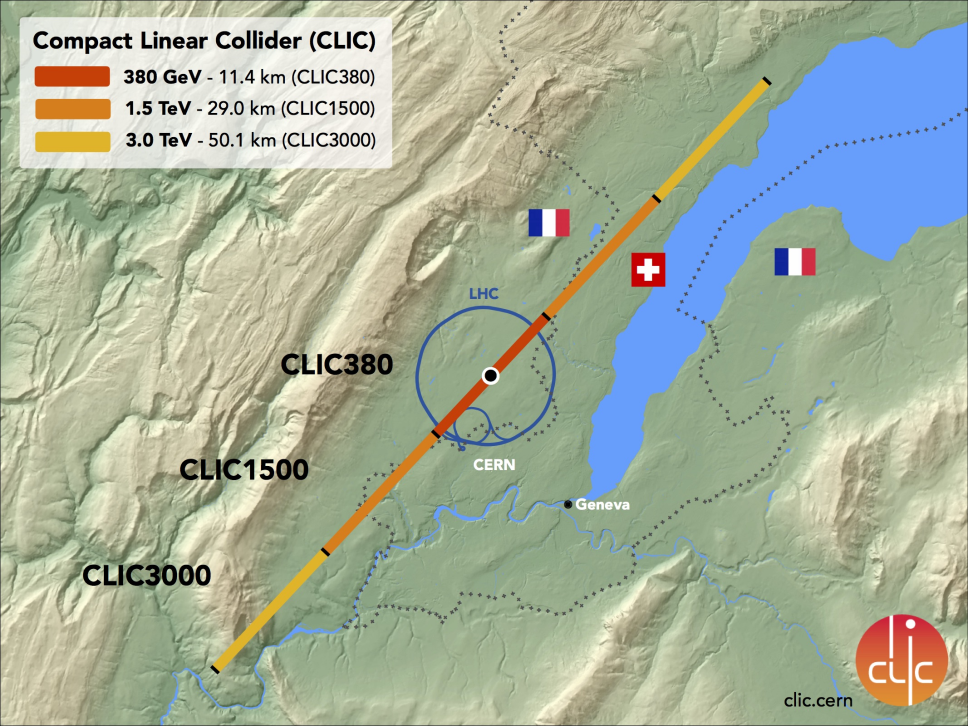
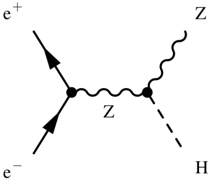
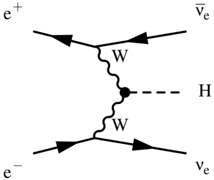
Scalars 2019

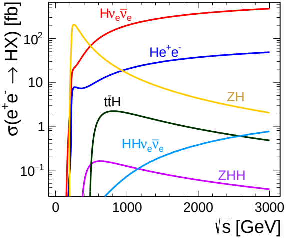

Compact Linear Collider (CLIC)
380 GeV - 11.4 km (CLIC380)
1.5 TeV - 29.0 km (CLIC1500)
3.0 TeV - 50.1 km (CLIC3000)
LHC
CLIC380
CLIC1500
CLIC3000
CERN
Geneva
clic
clic.cern

Compact Linear Collider (CLIC)

380 GeV $\longrightarrow$ focus on studying Higgs boson properties

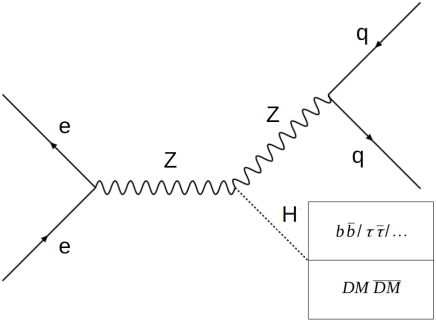






CLIC can estimate Higgs couplings to most of SM particles with an accuracy of around 1% or better.

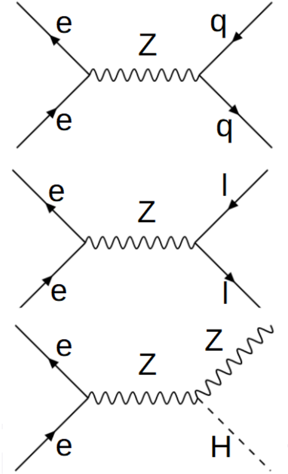
Signal

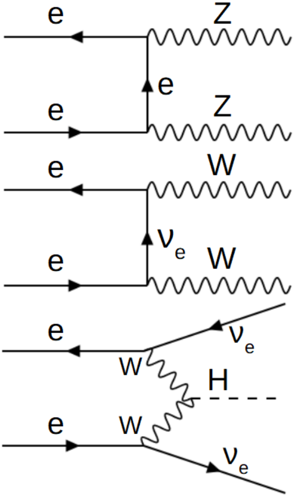


Signature of invisible Higgs decay:

- two jets consistent with hadronic Z decay
- missing energy-momentum consistent with production of invisible massive state (125 GeV)

Background processes considered



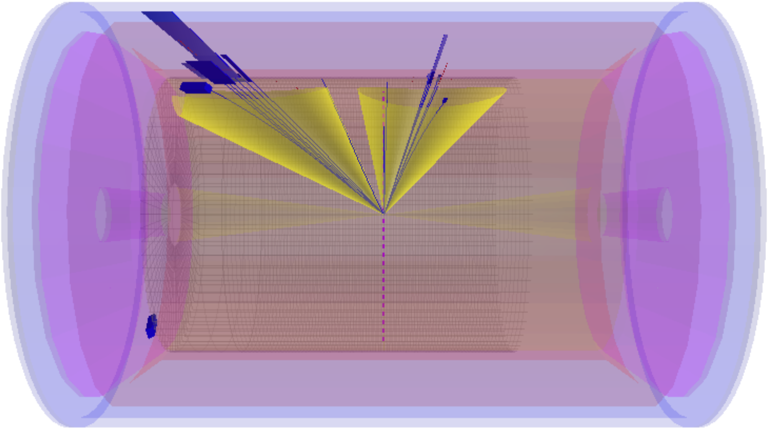


Technical information

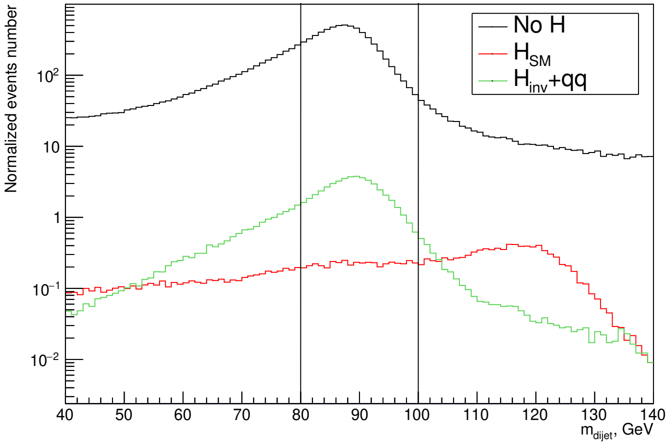
- event samples generated with WHIZARD 2.7.0 (using the VFDM model arXiv:1710.01853)
- CLIC energy spectra for **380** GeV
- CLIC integrated luminosity of **1000** fb^{-1}
- detector simulation and event reconstruction with DELPHES, using (modified) *CLICdet_Stage1* cards

Signature of $e^+e^- \to HZ \to jj + \mathit{inv}$

Two-jet events without electrons, muons, or isolated photons...



Preselection cuts: di-jet mass



Preselection – efficiency

Event class	Efficiency
Background	0.37%
SM Higgs decays	1.70%
Invisible Higgs decays	47.00%

Selection – variables

Final event selection based on the multivariate analysis.
Variables used as input for Boosted Decision Tree (BDT):

1. α_{jj} – angle between two jets in LAB frame
2. m_{jj} – dijet invariant mass
3. m^{miss} – missing mass
4. E_{jj} – dijet energy
5. p_t^{miss} – missing transverse momentum

Results

Limits expected for 1000 fb^{-1} collected at 380 GeV CLIC:

Results

Limits expected for 1000 fb^{-1} collected at 380 GeV CLIC:
Assuming **no excess** above predicted SM background is observed

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$\Downarrow$ CL **95%** $\Downarrow$

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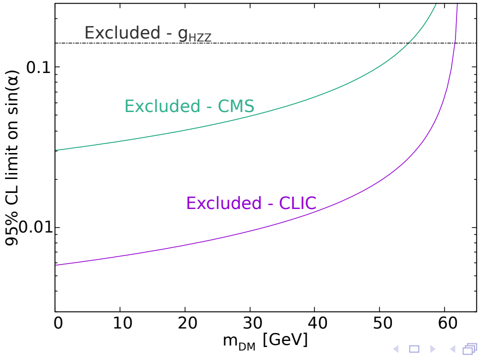
CLICdp preliminary: invisible Higgs boson decays are rarer than **0.86%** of all Higgs boson decays

Previously: 0.94%
(350 GeV, 500 fb^{-1}, The European Physical Journal C, 76(2):72)

The VFDM model

Within the *Vector-fermion dark matter* model, invisible Higgs boson decays into DM candidates are due to the exchange of the 125 GeV Higgs and the second scalar state; their couplings are parameterized by the mixing angle α.



New scalars

New "dark sector" scalars are expected in Higgs-portal models. If they are light, they can be produced in e^+e^- collisions in the same way as the SM-like Higgs boson:
$e^+e^- \rightarrow \mathrm{Z}\ \mathrm{h}_2 \rightarrow \mathrm{qq} + inv$

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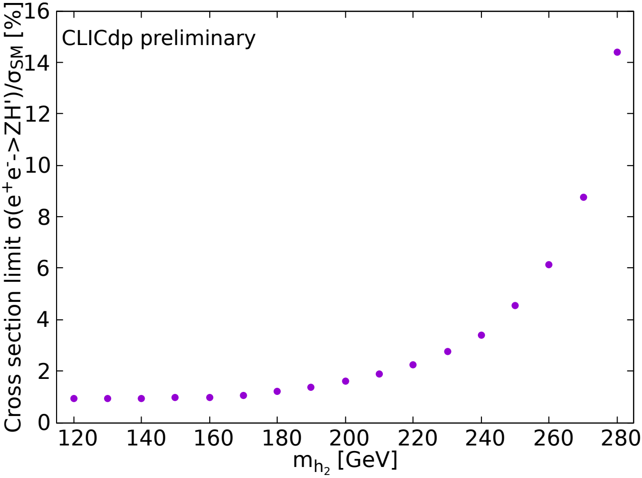
Assuming:

- domination of invisible decays
  ($BR(h_2 \rightarrow inv) \approx 100\%$)
- production due to mixing with SM Higgs particle

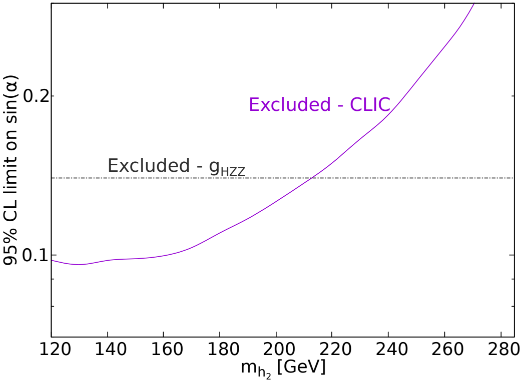
we can extend our method to search for production of h_2.

Limits on cross sections for new scalars



The VFDM model

Expected limits on the production cross section can be translated within the VFDM model into limits on the mixing angle α.



Conclusions

1. Search for invisible Higgs boson decays based on the WHIZARD event generation and fast simulation with DELPHES.
2. CLIC running at 380 GeV can constrain the invisible decays of the SM Higgs boson to below 1%.
3. Results consistent with the previous study based on full simulation.
4. The study can be extended to search for extra scalars.
5. Cross section limits can be translated to the limits on new physics model parameters.
6. Sensitivity to invisible scalar decays at high energy CLIC (1.5 TeV) still to be studied.

References

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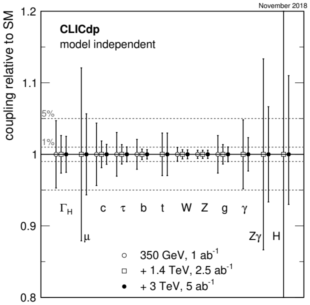
BACKUP

Parameter	Relative precision		
	350 GeV 1 ab^{-1}	+ 1.4 TeV + 2.5 ab^{-1}	+ 3 TeV + 5 ab^{-1}
g_{HZZ}	0.6 %	0.6 %	0.6 %
g_{HWW}	1.0 %	0.6 %	0.6 %
g_{Hbb}	2.1 %	0.7 %	0.7 %
g_{Hcc}	4.4 %	1.9 %	1.4 %
$g_{H\tau\tau}$	3.1 %	1.4 %	1.0 %
$g_{H\mu\mu}$	−	12.1 %	5.7 %
g_{Htt}	−	3.0 %	3.0 %
$g^{\dagger}_{Hgg}$	2.6 %	1.4 %	1.0 %
$g^{\dagger}_{H\gamma\gamma}$	−	4.8 %	2.3 %
$g^{\dagger}_{HZ\gamma}$	−	13.3 %	6.7 %
Γ_H	4.7 %	2.6 %	2.5 %



Final state	**Efficiency**	**$\mathbf{N}_{pre}$**
Background		
$qq\nu\nu$	23,00%	72135
$ql\nu$	0,68%	37588
qq	0,087%	19234
$qqll$	0,043%	593
$qqqq$	0,0010%	51
In total:	0,37%	129601
SM Higgs decays		
$H_{SM} + \nu\nu$	4,60%	2515
$H_{SM} + ll$	0,017%	3
$H_{SM} + qq$	0,0057%	47
In total:	1,70%	2565
Invisible Higgs boson decays		
$H_{inv} + qq$	47,00%	38557