Sensitivity to invisible scalar decays at CLIC

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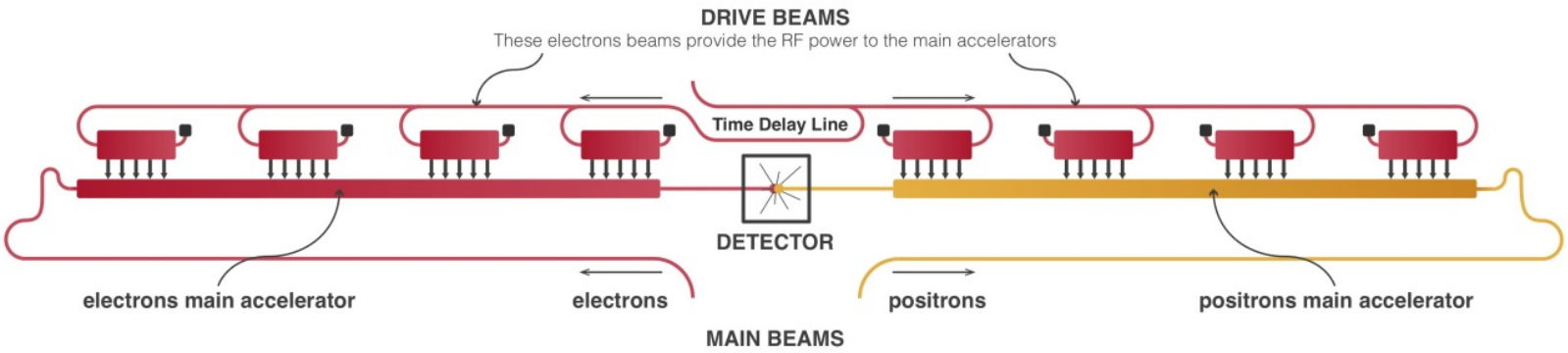
Compact LInear Collider (CLIC)



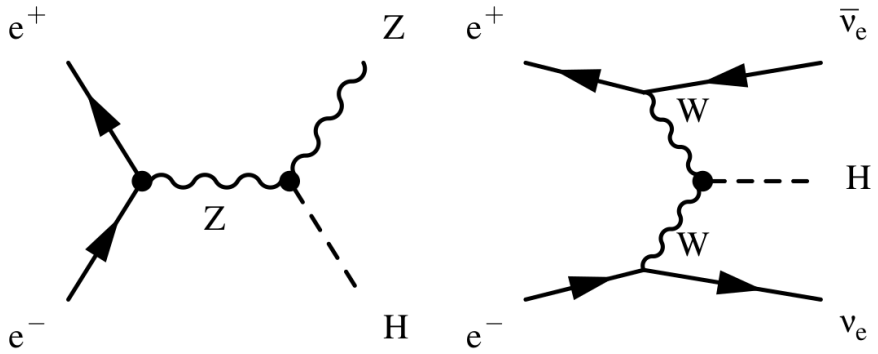
- two-beam accelerating scheme
- length of 11-50 km
- 3 energy stages: 380 GeV, 1.5 TeV, 3 TeV
- electron beam polarisation of 80%

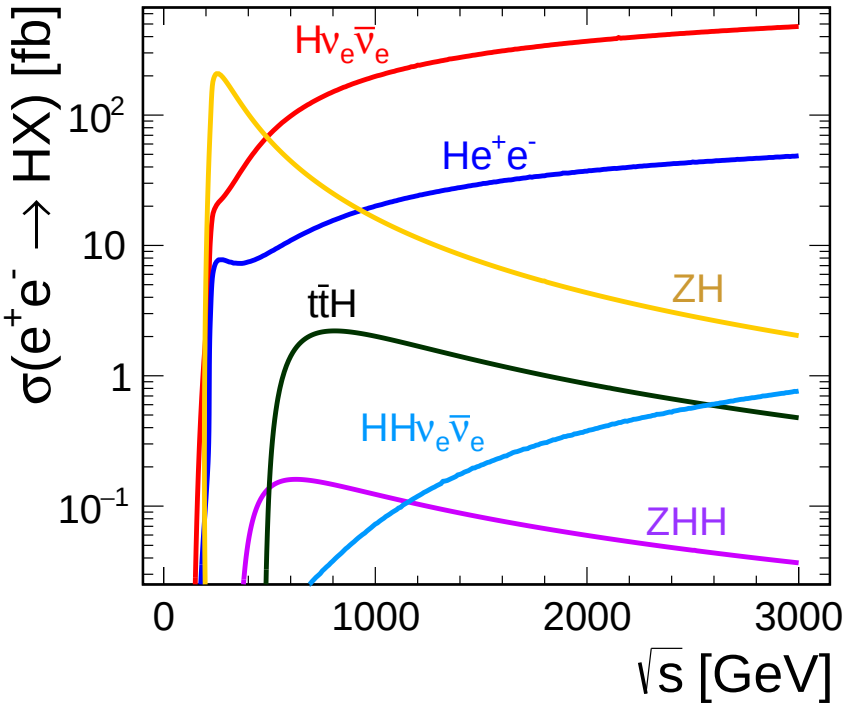
Higgs production

Two main Higgs production channels at CLIC:

- ZH production dominant at 380 GeV
- $H\nu\nu$ channel dominant at higher energy stages

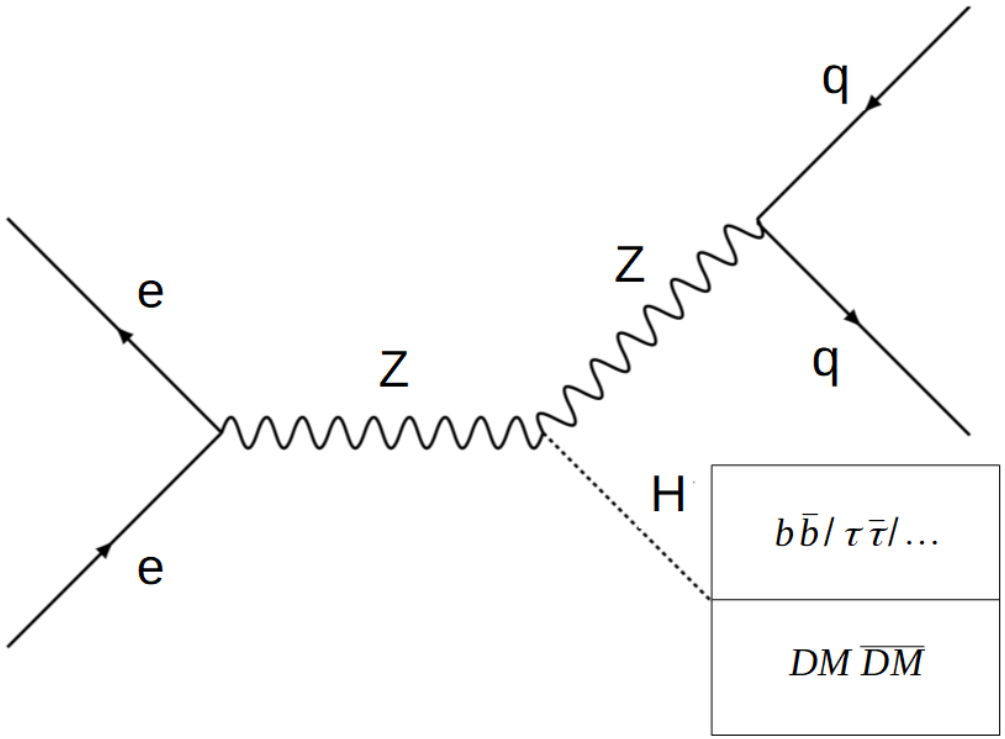
ZH channel allows for event selection independent on the Higgs decay channel $\longrightarrow$ sensitive also to invisible decays





Signal

SM(-like) Higgs boson decay to invisible states (Dark Matter?)



Signature of invisible Higgs decay:

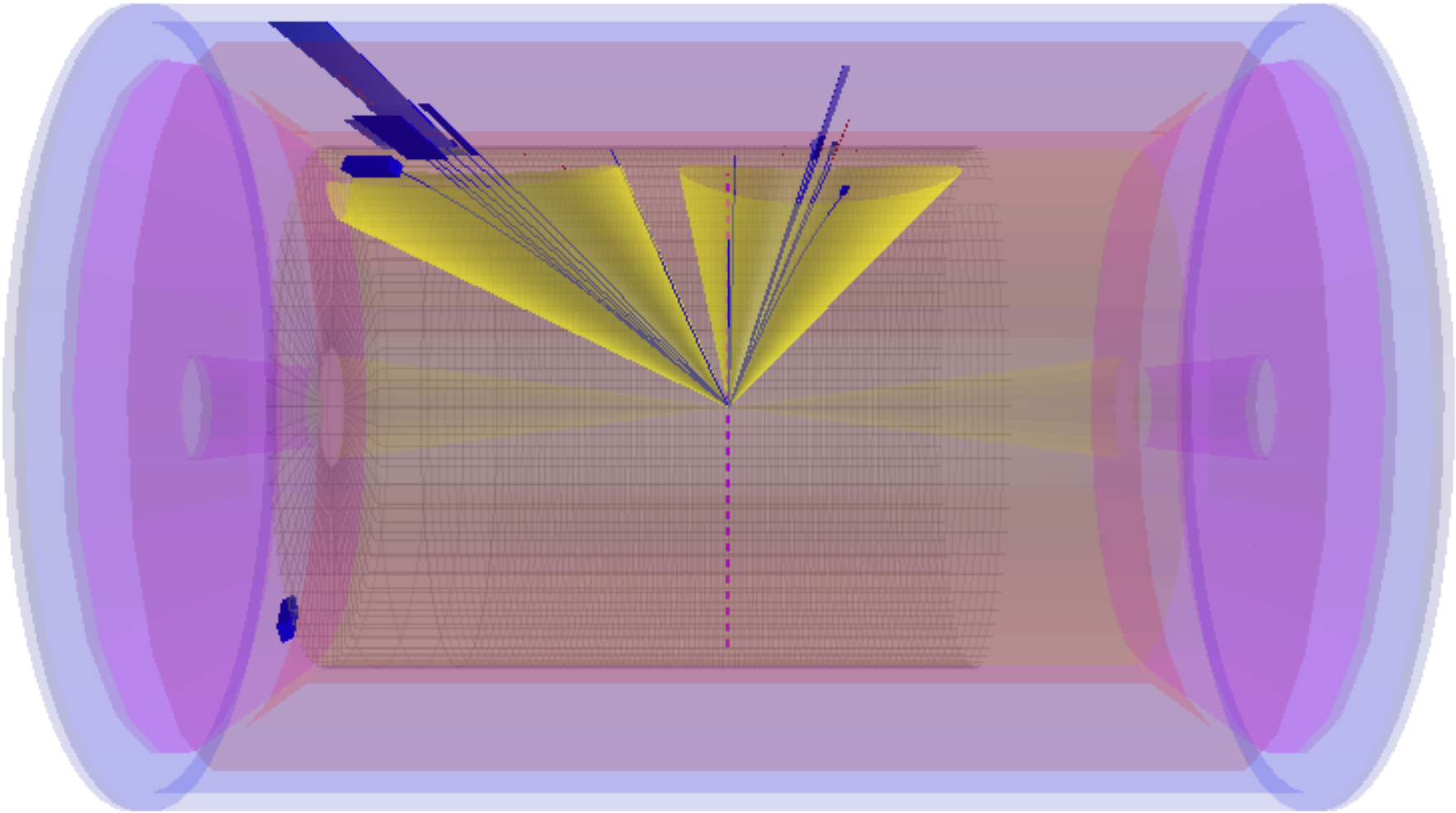
- two jets consistent with hadronic Z decay (higher statistics)
- missing energy-momentum consistent with production of invisible massive state of 125 GeV

Simulation framework

- event samples generated with WHIZARD 2.7.0
  - signal: $H + qq$ production with Higgs defined as stable
  - SM Higgs boson production:
    $H + qq$, $H + ll$, $H + \nu\nu$ (with 100% SM decays)
  - non-Higgs background: qq, ll, $qqqq$, $qqll$, $qql\nu$, $qq\nu\nu$, $qql\nu\nu\nu$
  - beamstrahlung and EPA photon interactions (WHIZARD 2.8.5):
    qq, $qq\nu$, $qqqq$, $qqll$, $qql\nu$, $qq\nu\nu$
- CLIC energy spectra for **380** GeV
- CLIC integrated luminosity of **1000** fb^{-1} (unpolarised)
- detector simulation and event reconstruction with DELPHES, using modified *CLICdet_Stage1* cards (to make Higgs invisible in the detector)
- required topology: two jets reconstructed with VLC algorithm ($R = 1.5$, $\beta = \gamma = 1$)

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

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



Preselection

Preselection cuts were used to select events with proper signature and kinematics consistent with invisible Higgs boson decay:

- No isolated electrons, muons or photons reconstructed with energy above 2 GeV, 3 GeV and 5 GeV respectively
- Energy "lost" in the jet clustering below 10 GeV
- At least 2 charged particles in each jet
- Two jet topology: $y_{23} < 0.01$ and $y_{34} < 0.001$
- Jet invariant mass: $80 < M_{jj} < 100\,\text{GeV}$ (Z mass)
- Dijet emision angle: $|\cos\Theta_{jj}| < 0.8$ (Z direction)

Preselection efficiency

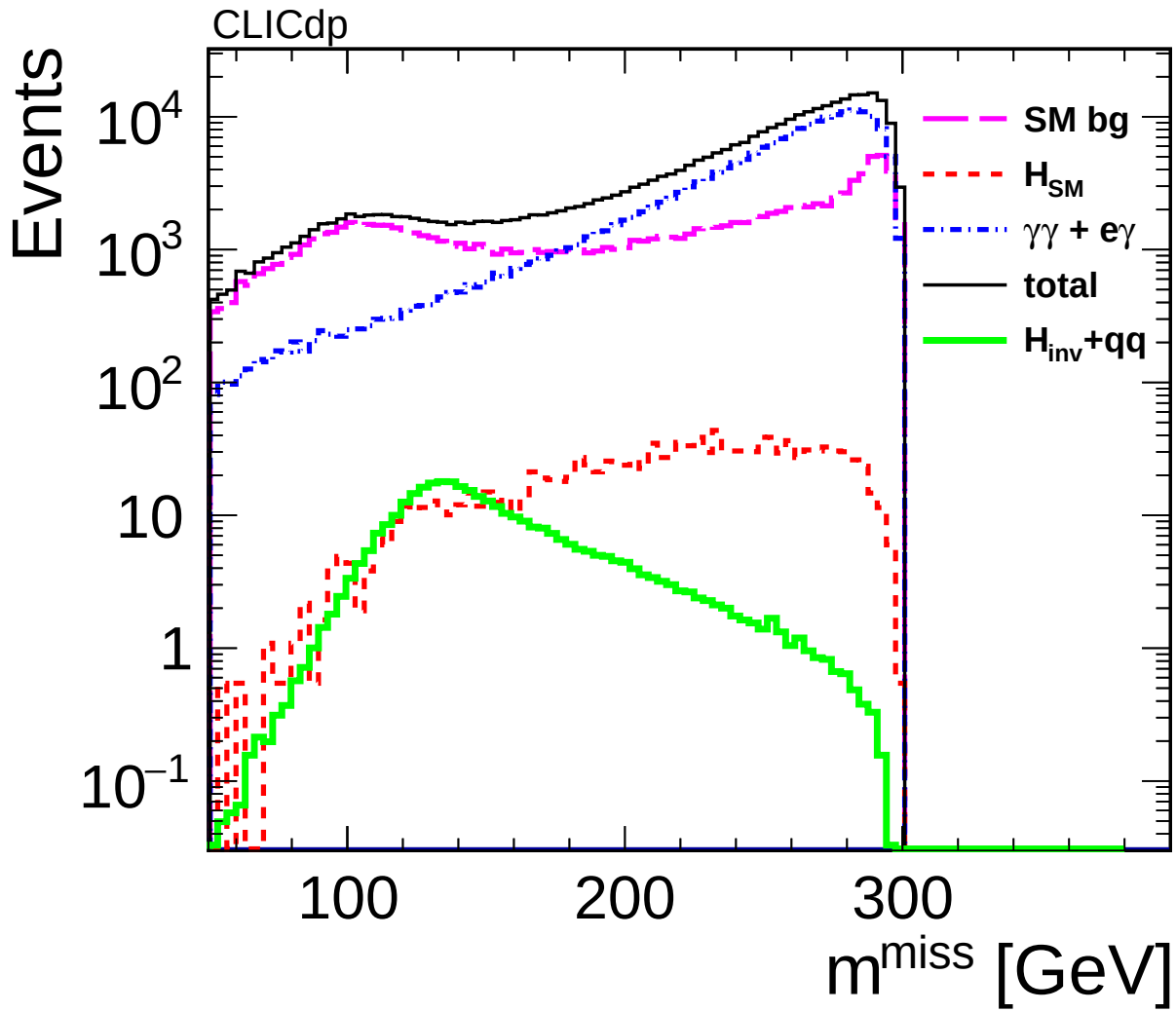
Event class	*Efficiency*	*Events after cuts*
Non-Higgs background	**0.21%**	**115,398**
leading channels:		
$qq\nu\nu$	20.47%	64,965
$qql\nu$	0.60%	33,065
qq	0.08%	16,684
Photon interactions	**5.11%**	**201,492**
leading channels:		
$\gamma^{EPA}e^+ \to qq\nu$	6.20%	56,489
$\gamma^{EPA}e^- \to qq\nu$	6.32%	56,054
$\gamma^{BS}e^+ \to qq\nu$	6.68%	42,823
$\gamma^{BS}e^+ \to qq\nu$	6.73%	42,707
SM Higgs decays	**0.86%**	**1313**
$H + qq$ **invisible decays**	**43.56%**	**35,920***

* – assuming BR($H \to inv$) = 100%

Preselection

Recoil mass distribution after preselection cuts

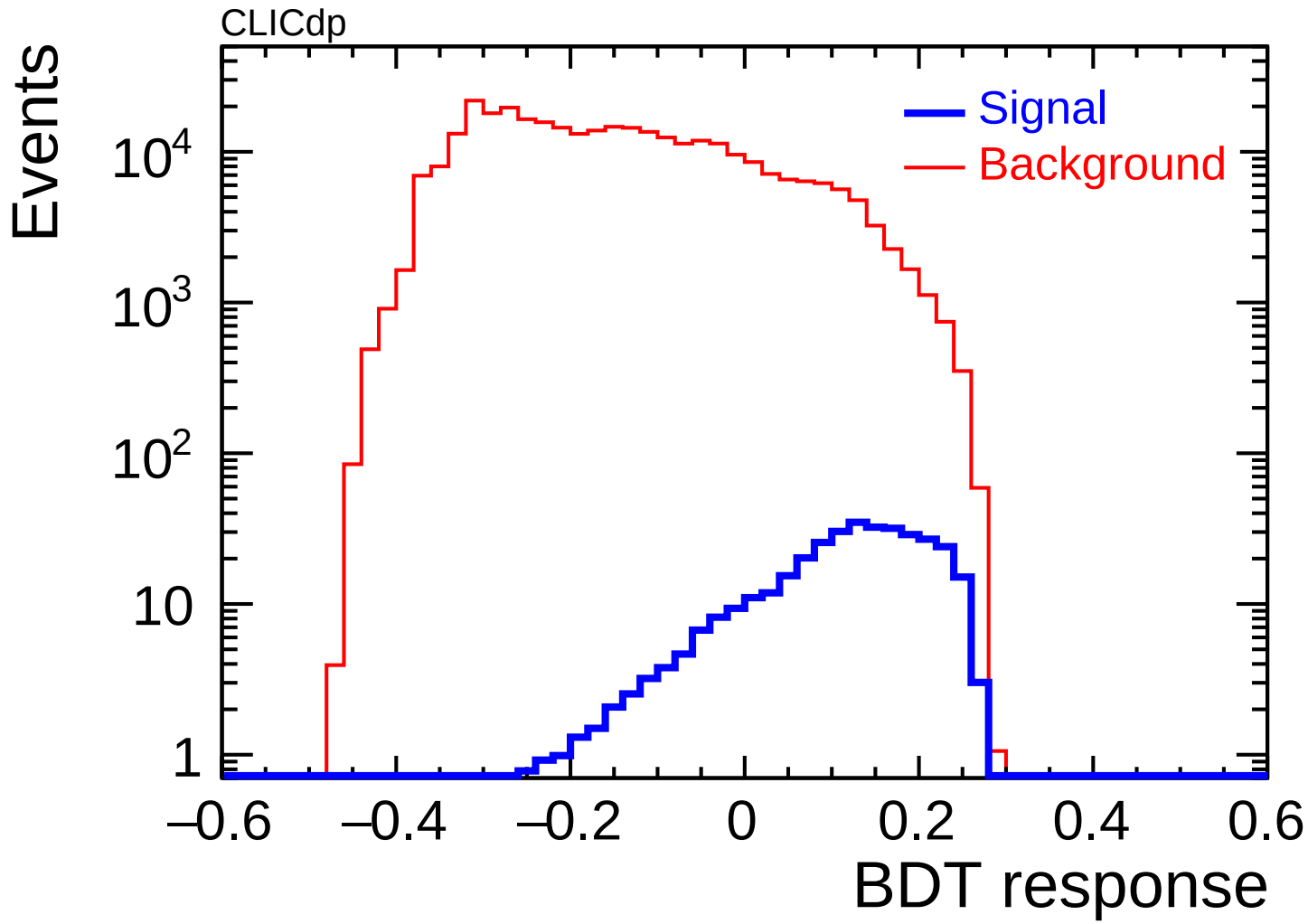
for 1000 fb^{-1} collected at 380 GeV, assuming BR(H→inv) = 1% for signal



Selection

Final event selection based on the multivariate analysis (5 variables).

for 1000 fb^{-1} collected at 380 GeV, assuming BR(H→inv) = 1% for signal



Results

95% C.L. limit expected for 1000 fb^{-1} collected at 380 GeV:

$$BR(H \rightarrow inv) \quad < \quad 1.0\%$$

Assuming **no excess** above predicted SM background is observed

Limits on new scalar production – CLIC380

Same approach can be used to search for production of H' state in the process $e^+e^- \rightarrow ZH' \rightarrow qq + inv$

(H' generated in WHIZARD as SM-Higgs particle with a different mass)

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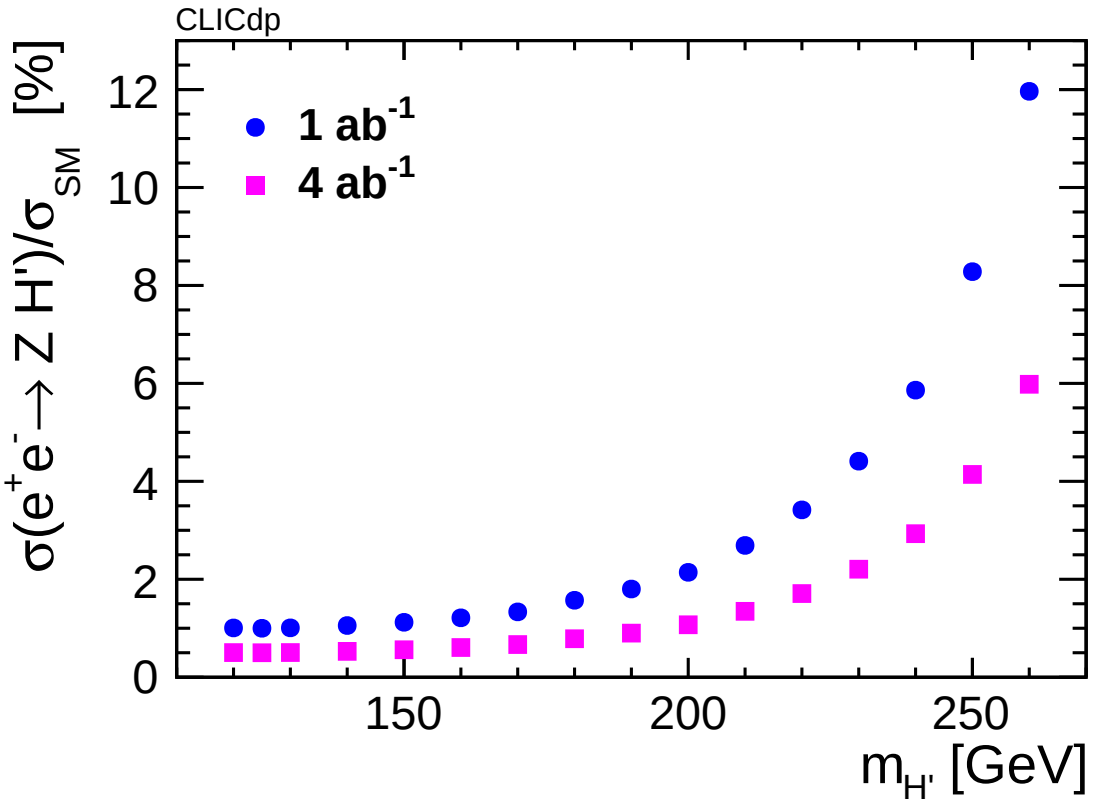
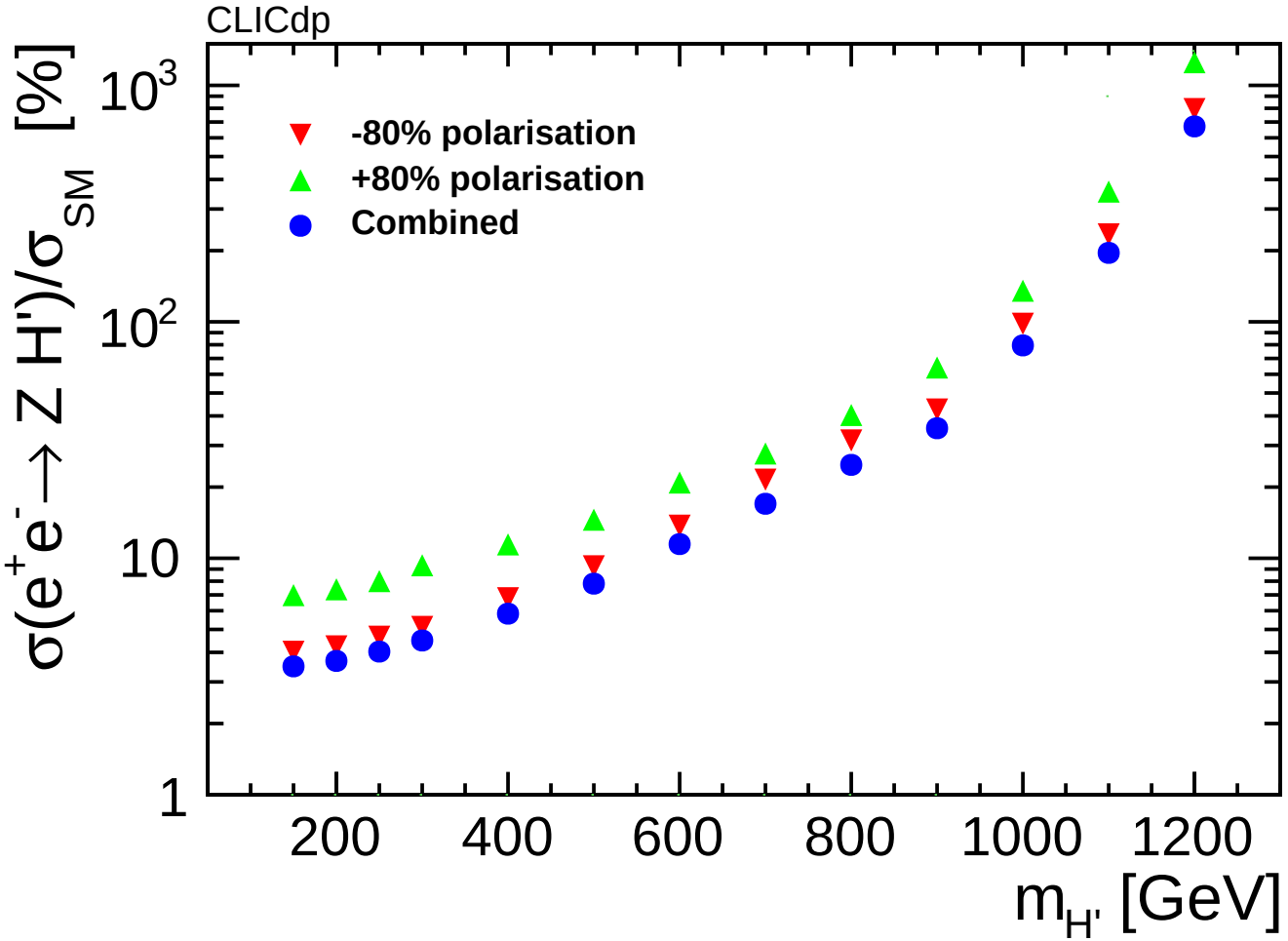
(H' generated in WHIZARD as SM-Higgs particle with a different mass)

Expected limits on the H' production cross section, relative to SM, for CLIC at 380 GeV, assuming BR($H' \to inv$) $\approx$ 100%:

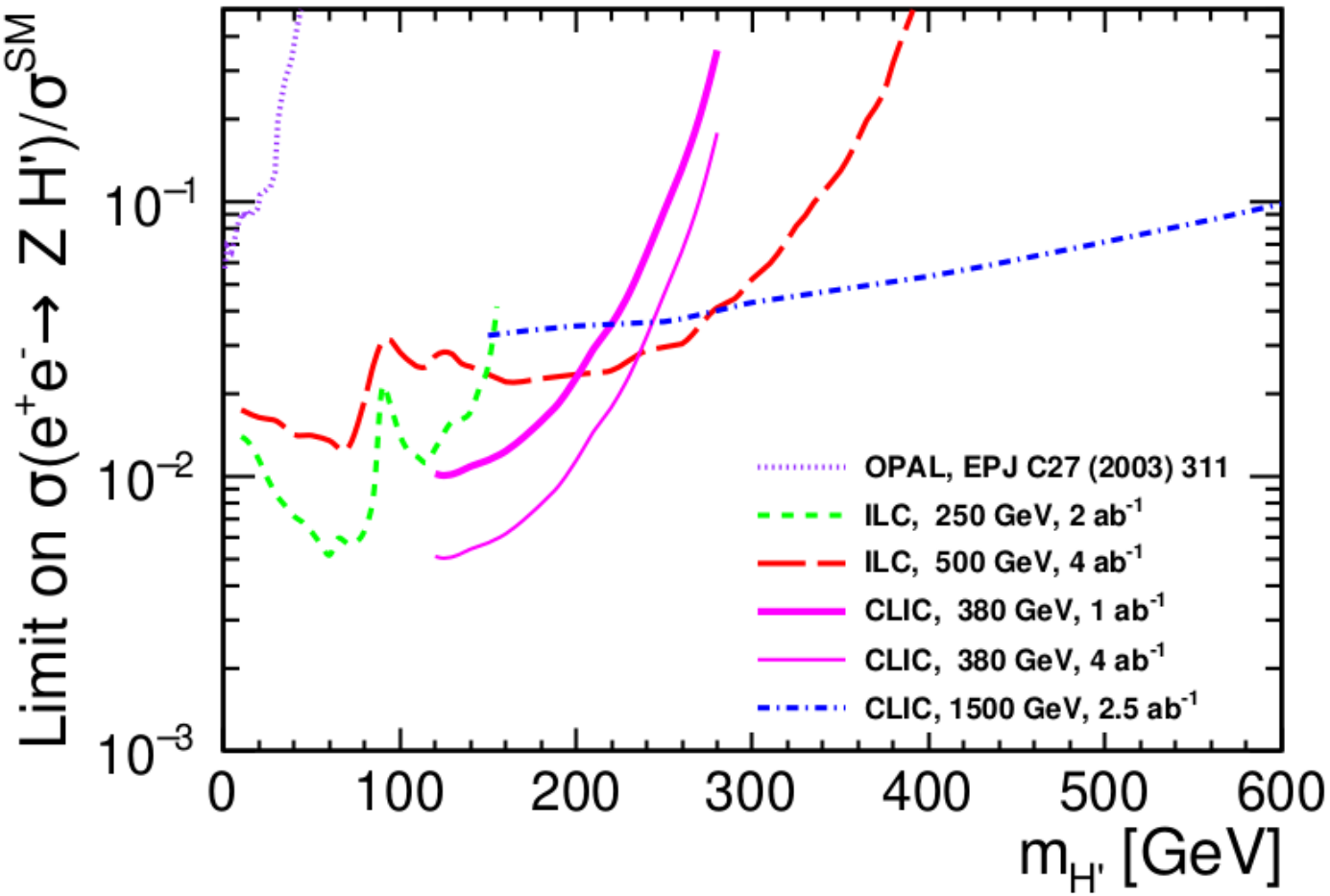


Limits on new scalar production – CLIC1500

Similar analysis can be performed for CLIC at 1.5 TeV (2500 fb^{-1}):



Limits on new scalar production



Other results obtained in a decay-mode independent approach for leptonic Z decays

Conclusions

1. We searched for invisible Higgs boson decays using WHIZARD event generation and fast simulation with DELPHES, including γ-induced background.
2. CLIC running at 380 GeV (lum. 1 ab^{-1}) can constrain the invisible decays of the SM Higgs boson to 1%.
3. The study can be extended to search for extra scalars at CLIC operating at 380 GeV and 1.5 TeV.

References

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BACKUP: preselection cuts