Higgs Invisible Searches at CEPC

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on behalf of

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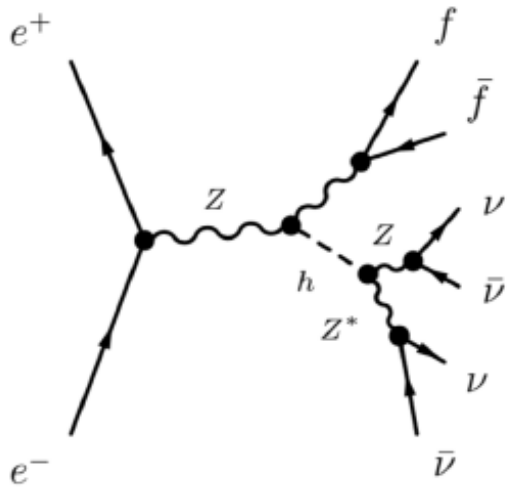
Outline

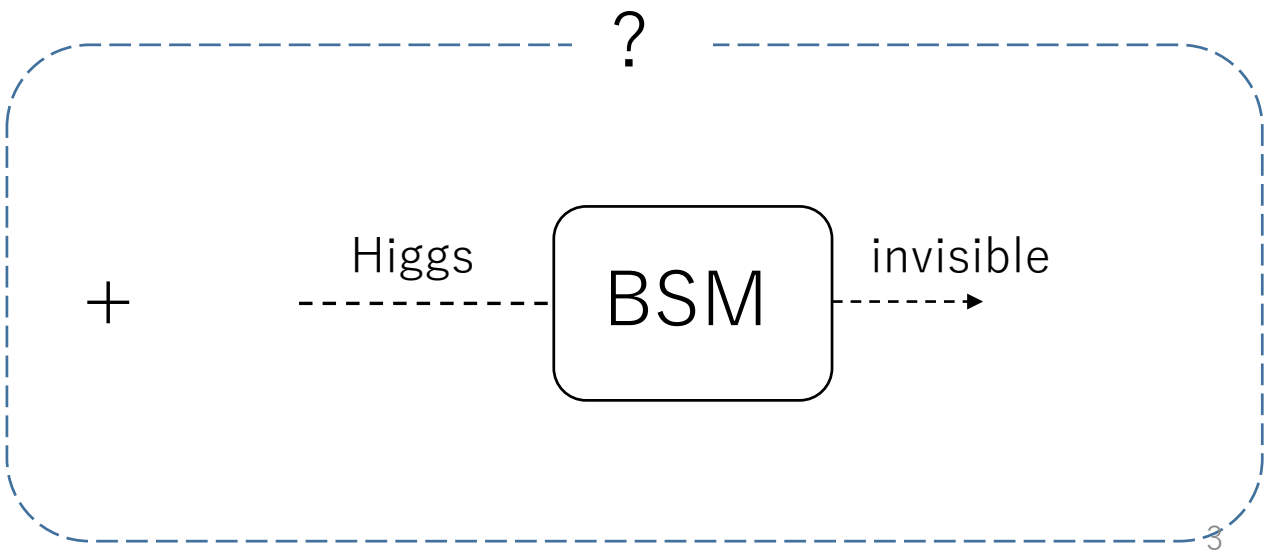
- Introduction
- Higgs->invisible search at CEPC
- Current status
- Summary

Introduction

・ In the SM, the Higgs boson decays invisibly only through the four neutrinos process , Higgs->ZZ->4ν, with a Br(Higgs->invi.) of about 0.1%.

・ Rate for invisible decays of the Higgs boson may be significantly enhanced in the context of several physics scenarios beyond the standard model (BSM).



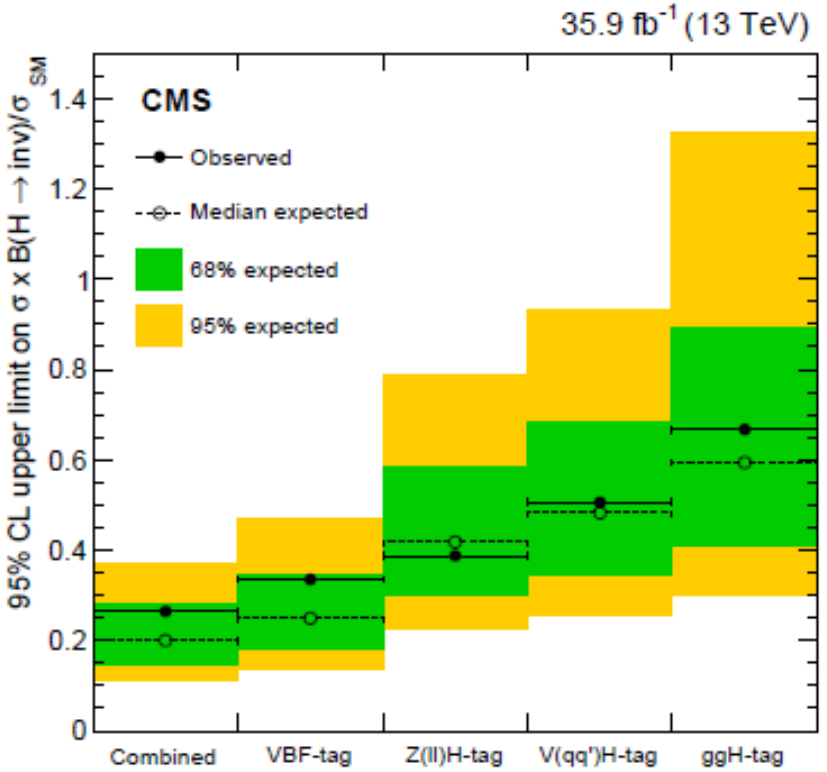


Constraints from LHC

-- Both CMS and ATLAS have conducted search of Higgs->invisible decay mode for both run I and run II.

-- CMS reports^1 obtained upper limit on the invisible Br as 24% at 95% C.L.

whereas ATLAS also reports^2 the upper limit on the invisible Br as 25% at 95% C.L.



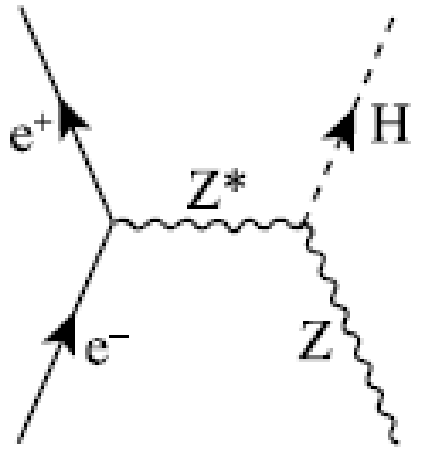
arXiv:1809.05937v1

Ref: [1] JHEP 02 (2017) 135, arXiv:1610.09218

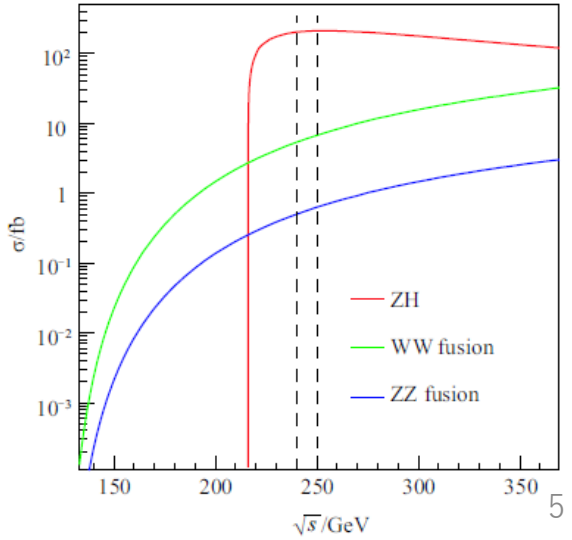
Ref: [2] JHEP 11 (2015) 206, arXiv:1509.00672

Higgs->invisible at CEPC

-- Higgs boson will be produced via mainly the ZH Higgsstrahlung at CEPC with center-of-mass energy of 240-250 GeV, which makes it possible to cleanly identify Higgs boson using the recoil of the associate Z boson.

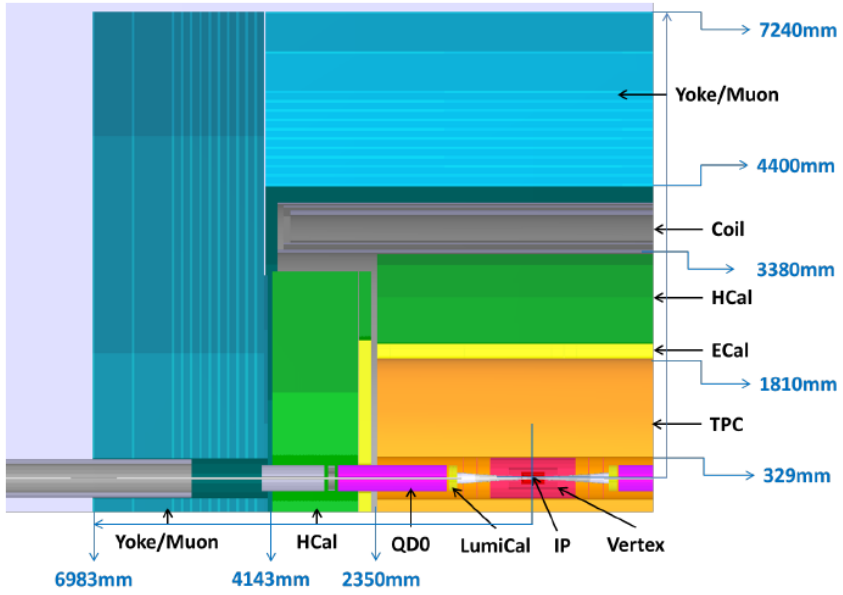


-- CEPC will produce ~1M Higgs boson (Higgs factory) within total integrated luminosity of 5 ab^{-1} . With the condition of relatively clean environment of lepton colliders, CEPC will probe the invisible decay mode of Higgs boson at smallest branching level ever.



Monte Carlo Simulation

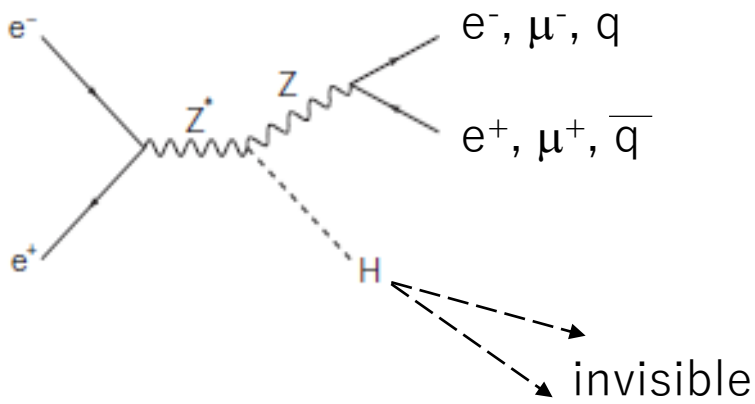
- CEPC_v1 (250GeV, 3.5T)
- Generator: Whizard 1.95
  (with ISR, L=5 ab^{-1}, M_{higgs}=125 GeV)
- Simulation :
  Geant4 and Mokka with ISR and bremsstrahlung effects
- Reconstruction:
  Marlin and ArborPFA



for the detail of CEPC detector concept
please refer arXiv:1810.09037

Signal

- Signal (3 channels separately)
  $Z(->e^+e^-)H(->invi.)$
  $Z(->\mu^+\mu^-)H(->invi.)$
  $Z(->qq)H(->invi.)$



Signal topology

Requirements (signal selection)

-- Two fermions from Z boson are required and
basically there should be nothing further except those.

-- Invariant Mass of two fermions

-- Recoil Mass of two fermions

-- Significant missing energy

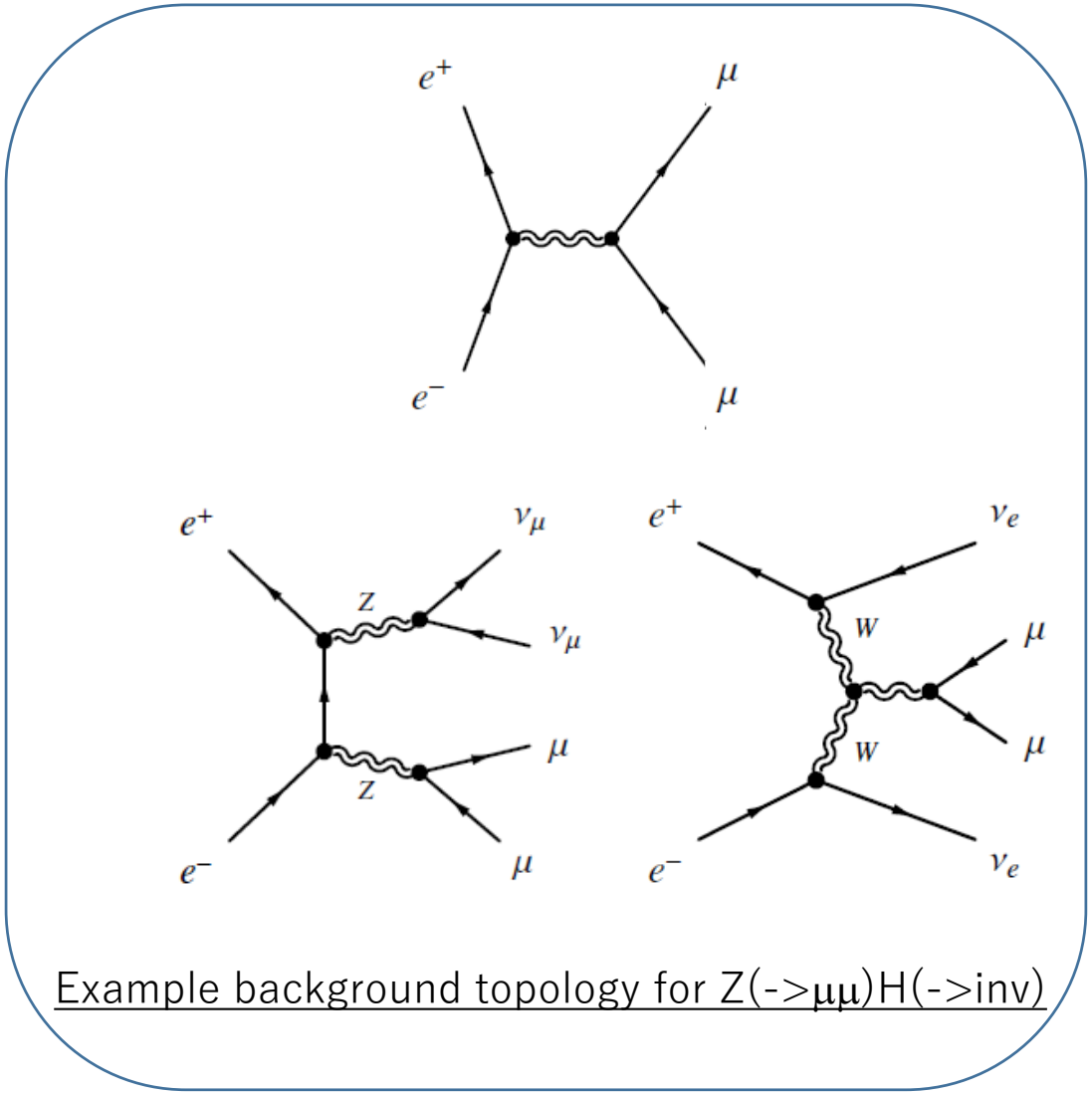
-- Pt of Z from two fermions

Backgrounds

- Background

  -- two/four fermion process
  -- other Higgs decays

The background events are well rejected during the signal selection. In addition, a BDT cut is applied to further suppress the components which have similar topology (some of examples are illustrated in right) to that of the signal .



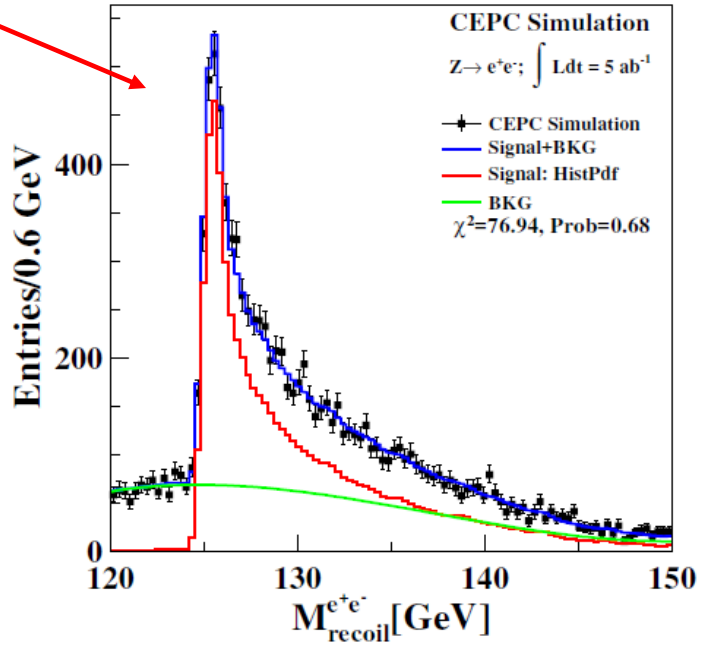
Example background topology for Z(->μμ)H(->inv)

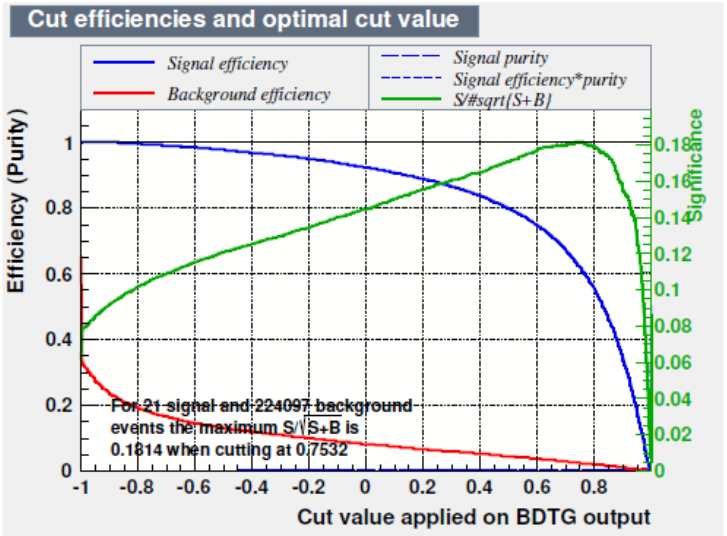
Signal and backgrounds : Z(->e^+e^-)

Table : Cut Efficiencies in the Z(->e^+e^-) channel

	Signal	VV	SV	$Z(2f)$	$Z(e^+e^-)H$
total generated	100000	68484064	26534108	423674068	100000
$2 \leq N_e \leq 3, N_{ch} \leq 3$	74.5%	0.05%	11.0%	17.3%	0.57%
$N_\gamma \leq 1$	68.2%	0.05%	10.2%	11.7%	0.13%
$10\text{GeV} < P_t^{e^+e^-} < 70\text{GeV}$	66.4%	0.04%	6.91%	6.61%	0.12%
$\lvert P_z^{e^+e^-} \rvert < 60\text{GeV}$	65.4%	0.04%	5.03%	2.97%	0.12%
$\lvert \cos\theta_{e^+e^-} \rvert < 0.8$	64.9%	0.03%	4.24%	2.89%	0.11%
90GeV¡Visible Energy¡120GeV	63.9%	0.00%	0.62%	0.04%	0.02%
$70\text{GeV} < M_{e^+e^-} < 100\text{GeV}$	56.4%	0.00%	0.42%	0.03%	0.01%
BDT cut	34.5%	0.00%	0.02%	0.00%	0.01%
fit window	34.2%	0.00%	0.01%	0.00%	0.01%

Br(Higgs->invi.) =50% is set to make structures visible. (and to study cut conditions etc.)





Signal and backgrounds : Z(->$q\bar{q}$)

Table : Cut Efficiencies in the Z(->$q\bar{q}$) channel

	Signal	VV	SV	$Z(2f)$	$Z(e^+e^-)H$
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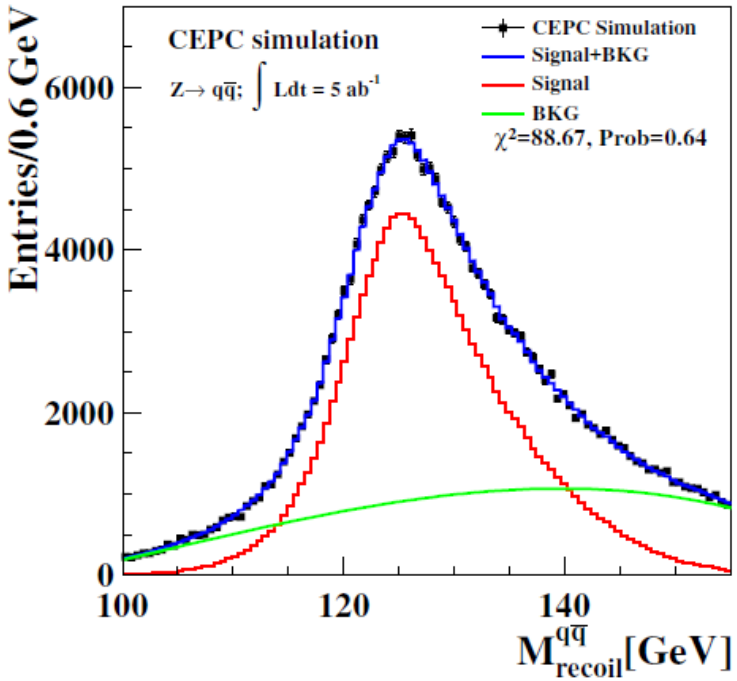
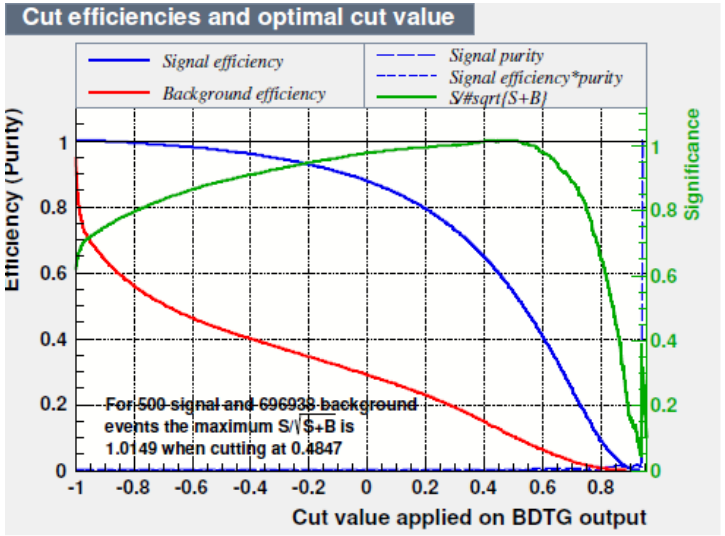
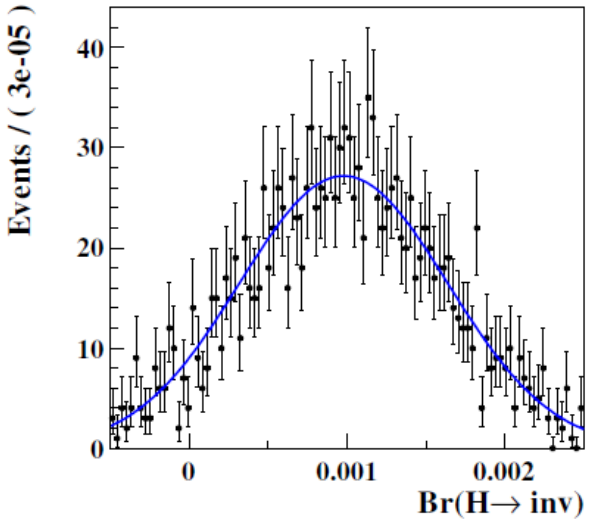
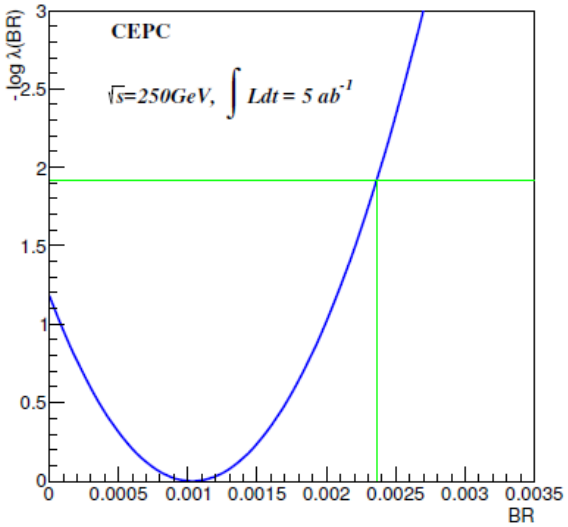




Combination of the results from all channels



Input-Output check



Likelihood profile for the combination, where the green lines show the 95% C.L.

ZH final state studied		Relative precision on $\sigma \times \mathrm{BR}$	Upper limit on $\mathrm{BR}(H \to \mathrm{inv})$
$Z \to e^+e^-$	$H \to \mathrm{inv}$	339%	0.82%
$Z \to \mu^+\mu^-$	$H \to \mathrm{inv}$	232%	0.60%
$Z \to q\bar{q}$	$H \to \mathrm{inv}$	217%	0.57%
Combination		143%	0.41%

Current Status

・Sensitivity of Br(Higgs->invisible) of ~0.41% is obtained based on CEPC_v1.

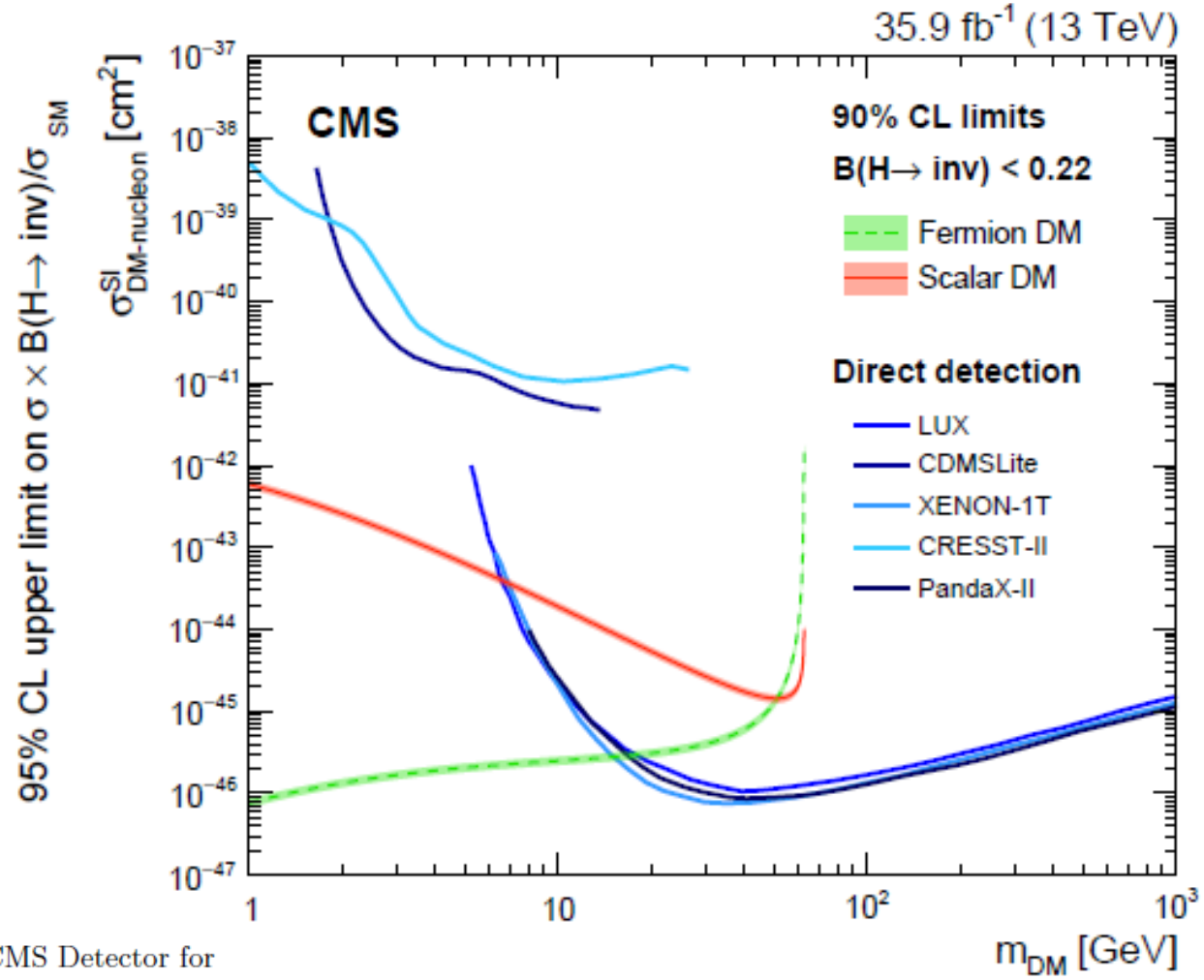
・Taking into account the BR_{SM}(Higgs->inv.) of 0.106% , it is equivalent to BR_{BSM}(Higgs->inv.) of 0.30%.

・Cross-check with CEPC_v4 (240GeV, 3.0T) is on-going

Interpretation to Higgs-portal DM scenario

-- U.L. on Br(Higgs->invi.) can be interpreted in the context of Higgs-portal DM interactions, where Higgs boson has a role of its meditator between SM and DM particles.

-- Sensitivity would reach as BR of 8~10% at 95% C.L. for 3000fb^{-1} at CMS/ATLAS, if systematic and theoretical errors are reduced.

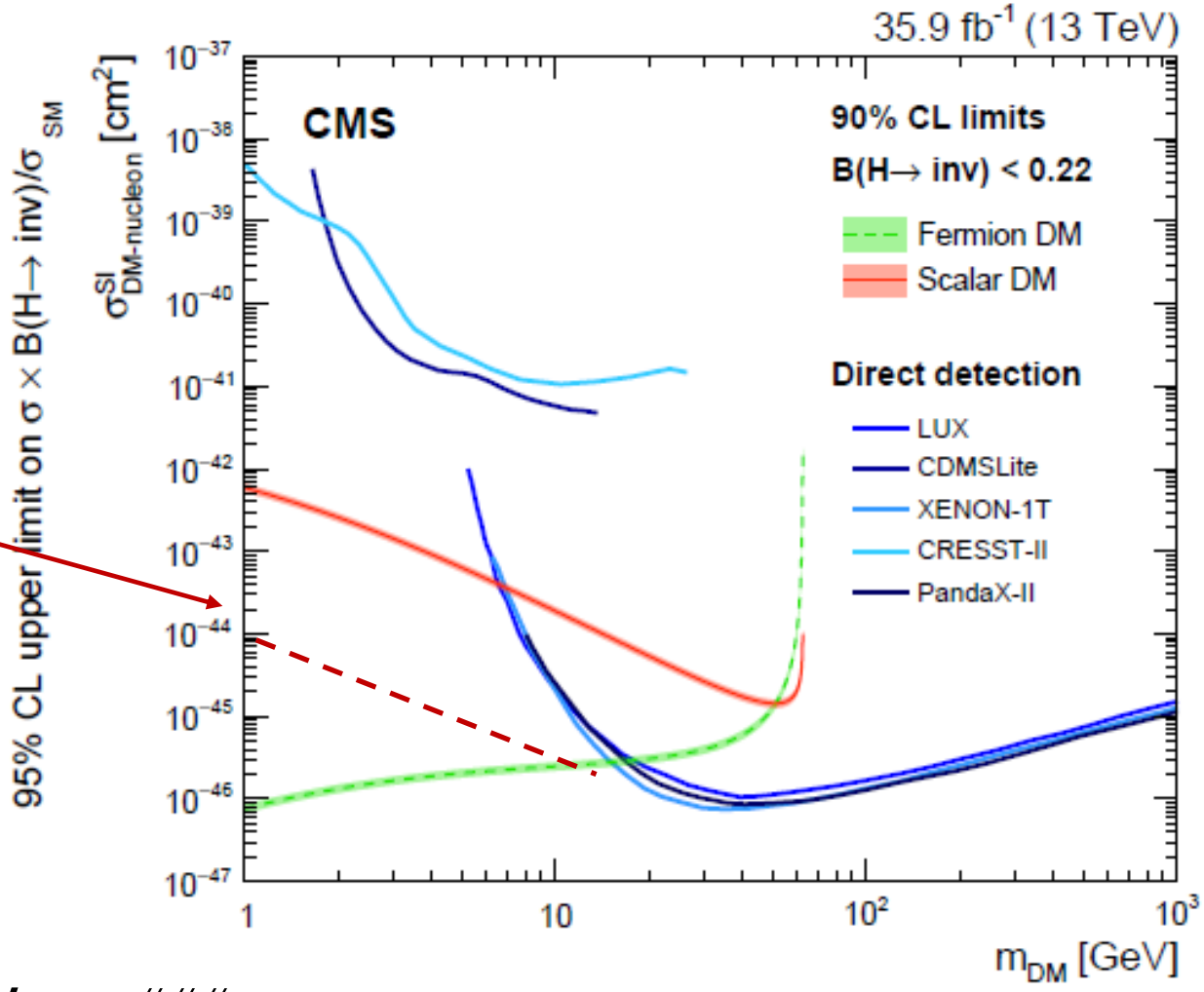


CMS Collaboration, "Updates on Projections of Physics Reach with the Upgraded CMS Detector for High Luminosity LHC,". https://cds.cern.ch/record/2221747.

arXiv:1809.05937v1

Comparison

CEPC has sensitivity around this level by assuming the Higgs portal DM interaction



"Neutrino Floor" at 1-10 GeV
O(10^{-43} - 10^{-44}) [cm^2]

Only order estimation is presented here

Summary

・ Search of the invisible decay of Higgs boson could she light on the BSM physics, and CEPC will provide us excellent environments for the search.

・Three channels have been evaluated with CEPC_v1 (250 GeV, 3.5T) Z(ee, μμ, qq)H(invi.). Combined 95% U.L. on the branching fraction to the invisible mode is ~0.41% which will play a decisive role for construction/limit BSM models.

Backup

Predictions of Invisible Higgs decay beyond SM

Although parameter spaces for simple BSM models are more and more constraint by various experiments, such as direct measurements, LHC , astrophysics, Higgs invisible search is still essential .

"Light neutralino dark matter in the NMSSM" Q. Mou, H. Wu, S. Zheng, arXiv: 1703.00343

"The invisible decay of Higgs boson in the context of a thermal and non-thermal relic in MSSM"
R. K. Barman, et.al., arXiv: 1703.03838

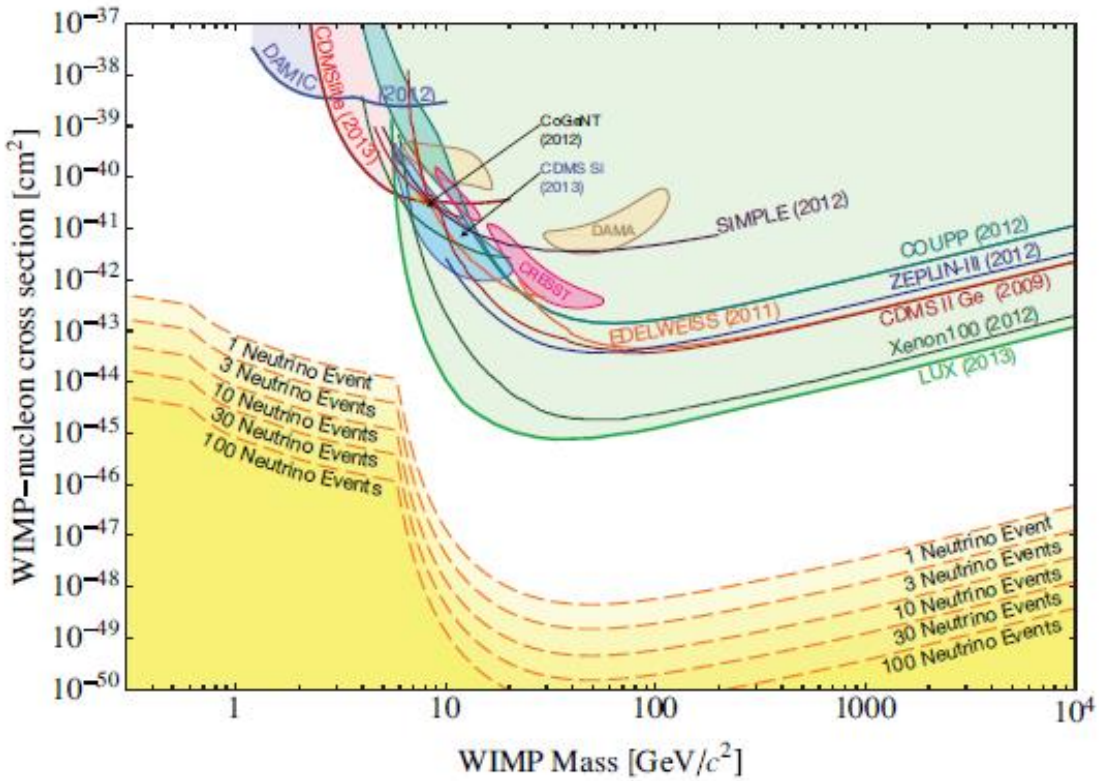
"A tale of two portals: Testing light, hidden new physics at future e^+e^- colliders"
J. Liu, X. Wang, F. Yu, arXiv: 1704.00730

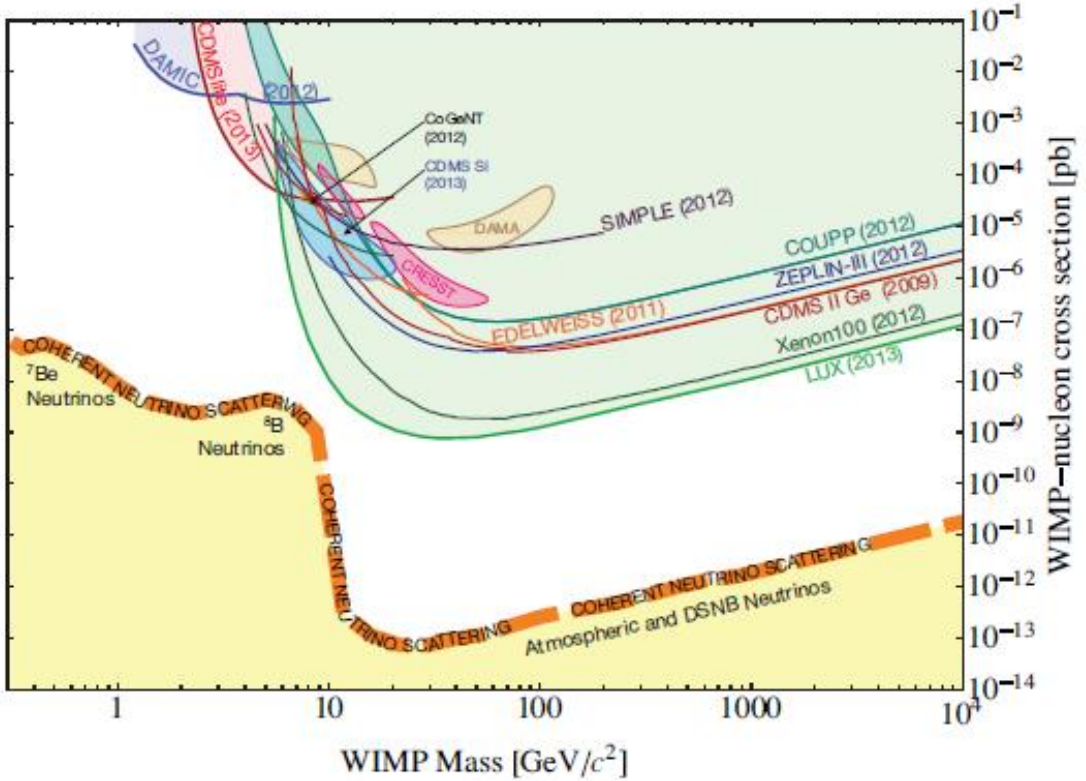
"Higgs portal dark matter in non-thermal cosmologies"
Edward Hardy, arXiv: 1804.06783

"Dark-photon searches via ZH production at e+e- colliders" (Higgs->γ+dark-photon)
S. Biswas, E. Gabrielli, M. Heikinheimo, B. Mele, arXiv: 1703.00402

Only some of "recent" papers are listed

Neutrino Floor





J Billard, L Strigari, E Figueroa-Feliciano, arXiv: 1307.05458