CEPC Higgs Combination

Updates since November

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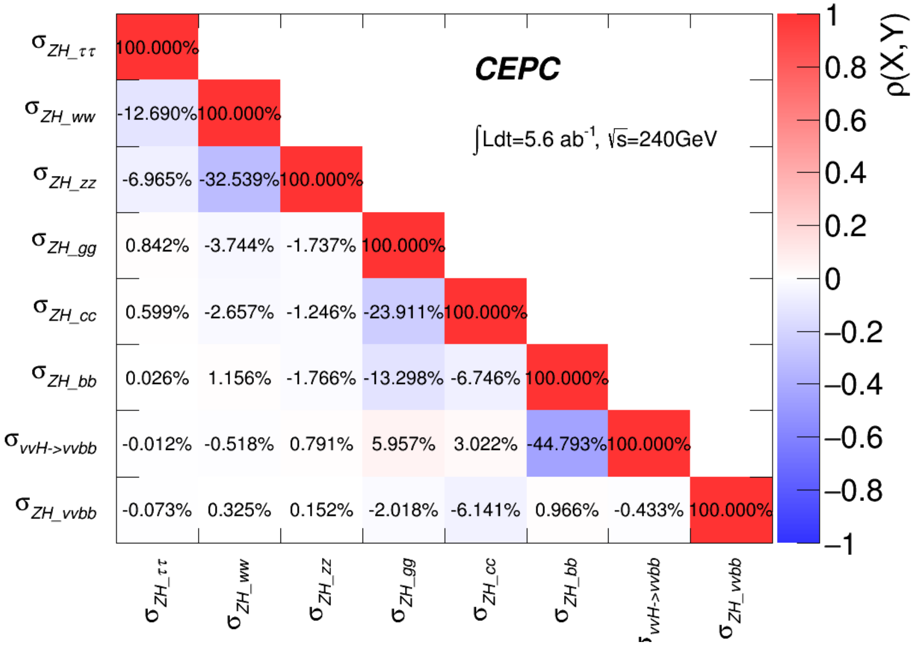
CDR's results

	Estimated Precision			
Property	CEPC-v1		CEPC-v4	
m_H	5.9 MeV		5.9 MeV	
Γ_H	2.7%		2.8%	
$\sigma(ZH)$	0.5%		0.5%	
$\sigma(\nu\bar{\nu}H)$	3.0%		3.2%	
Decay mode	$\sigma \times$ BR	BR	$\sigma \times$ BR	BR
$H \to b\bar{b}$	0.26%	0.56%	0.27%	0.56%
$H \to c\bar{c}$	3.1%	3.1%	3.3%	3.3%
$H \to gg$	1.2%	1.3%	1.3%	1.4%
$H \to WW^*$	0.9%	1.1%	1.0%	1.1%
$H \to ZZ^*$	4.9%	5.0%	5.1%	5.1%
$H \to \gamma\gamma$	6.2%	6.2%	6.8%	6.9%
$H \to Z\gamma$	13%	13%	16%	16%
$H \to \tau^+\tau^-$	0.8%	0.9%	0.8%	1.0%
$H \to \mu^+\mu^-$	16%	16%	17%	17%
$\mathrm{BR}_{\mathrm{inv}}^{\mathrm{BSM}}$	–	$< 0.28\%$	–	$< 0.30\%$



Channels Table(2018.11)

All scaled to 240 GeV， 5.6ab^{-1}

Signal Z	Signal H	Precision
H->qq		
ee	bb	1.32%
	cc	13.5%
	gg	7.22%
μμ	bb	0.99%
	cc	9.54%
	gg	5.01%
qq	bb	0.46%
	cc	11.1%
	gg	3.64%
νν	bb	0.39%
	cc	3.83%
	gg	1.47%
H->Invisible		
qq	ZZ(νννν)	232%
ee		370%
μμ		245%

Signal Z	Signal H	Precision
H->WW		
ee	lνlν	9.52%
	eνqq	4.56%
	μνqq	3.93%
μμ	lνlν	7.29%
	eνqq	3.90%
	μνqq	3.90%
νν	qqqq	1.90%
	eνqq	4.65%
	μνqq	4.14%
	lνlν	11.5%
qq	qqqq	1.75%
H->ZZ		
νν	μμqq	8.26%
νν	eeqq	40%
μμ	ννqq	7.32%
ZH bkg contribution		19.4%

Signal Z	Signal H	Precision
H→γγ, Zγ		
μμ	γγ	23.7%
νν		10.5%
qq		9.84%
νν	Zγ(qqγ)	15.7%
ννH(WW fusion)		
νν	bb	3.00%
H→μμ		
qq	μμ	17.1%
ee		
μμ		
νν		
H→ττ		
ee	ττ	2.75%
μμ		2.61%
qq		0.95%
νν		2.66%

Possible improvement in analysis

- Advised by Jianming
  - For Higgs Width: Dominant.
    - H → ZZ. Esp. for Z→qq.
    - other vvH than bb;
  - Others, H→$Z\gamma$; Z→$\tau\tau$, H→$anything$
- Advised by Zhen
  - H→$inclusive$; Correlation.
- Full hadronic b/c/g/W/Z.
- Long term goal.

	Z	ee	μμ	vv	qq
WW	ev+ev				
	μv+μv				
	ev+μv				
	ev+qq				
	μv+qq				
	qq+qq				

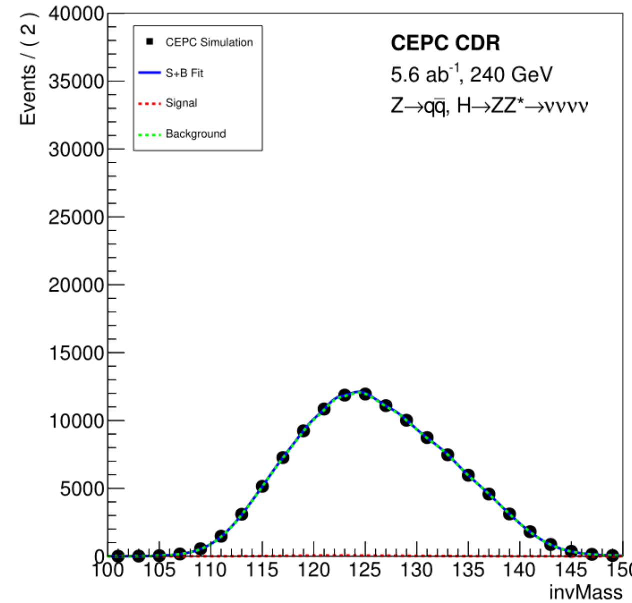
	Z	ee	μμ	vv	qq
ZZ	ee+qq				
	μμ+qq				
	vv+qq				
	ll+ll				
(Invi)	vv+vv				
	qq+qq				
	ll+vv				

New analysis since Novemeber

- H→$invisible$ By Tan Yuhang
  - 153% → 71%.
- Z→qq, H→$\mu\mu$ By Ran Kunlin
  - 19% → ~10%
- H→ZZ By Kong Lingteng, Alex
  - Result even worse since bkg are underestimated in previous study.
- τ finding By Yu Dan
  - Could use tau relevant variables in all analysis
  - Not applied for most channels yet.

H→*invisible*

- Major improved in qq.
  - Add tau information
  - Bkg total is ~6x smaller than Moxin's study.



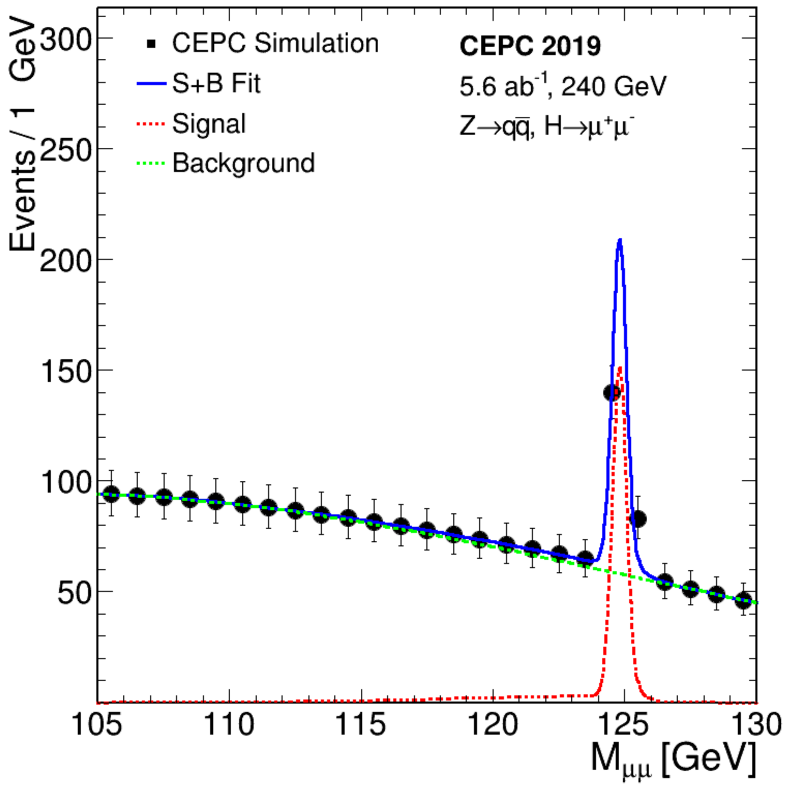
Process	qqH_inv	2f	single_w	single_z	szorsw	zz	ww	zzorww	ZH	total_bkg	$\frac{\sqrt{S+B}}{S}$
Total generate	383068	801811976	19517400	9072952	1397088	6389429	50826213	20440840	1140496	910596394	7.879 %
$100GeV < M^{visible}_{recolil} < 150GeV$	369001	44494225	1388874	822725	229216	507558	1752824	658202	98165	49951789	1.922 %
$30GeV < P^{visible}_{t} < 60GeV$	281557	4593818	741546	188509	106037	204895	902902	316297	56883	7110887	0.966 %
$20GeV < P_{visible} < 58GeV$	259869	717680	373630	81835	50917	69855	516699	161088	51050	2022754	0.581 %
$85GeV < M_{visible} < 102GeV$	216155	234894	115978	53848	17545	36325	171538	53279	11125	694532	0.441 %
$\Delta\phi_{visible} < 175°$	210034	151338	112375	51521	17222	34799	167144	51859	10688	596946	0.428 %
90GeV<Visible Energy<117GeV	210011	151304	112321	51514	17216	34788	167047	51837	10683	596710	0.428 %
$N_{neutral} > 15, N_{lepton} = 0$	200035	2133	6758	45257	22	31116	53848	4480	7477	151091	0.296 %
$M_{Tau} < 105GeV, Impact_{Tau} < 0.00007$	190319	795	2568	42254	4	28681	33499	902	6641	115344	0.290 %
Effectiveness	49.683%	0.000%	0.013%	0.466%	0.000%	0.449%	0.066%	0.004%	0.582%	0.013%	

ZH final state studied	Relative precision on $\sigma(ZH)/BR$	Upper limit on $BR(H \to inv)$
$Z \to e^+e^-$, H→ inv	341%	0.83%
$Z \to \mu^+\mu^-$, H→inv	191%	0.51%
$Z \to q\bar{q}$, H→inv	78%	0.27%
Combination	71%	0.26%

	Previous	Now
Z->ee	370%	341%
Z->mm	245%	191%
Z->qq	232%	78%
Combined	153%	71%

Z→qq, H→$\mu\mu$

- Use latest sample to avoid the zero Z width
  - 12.68%

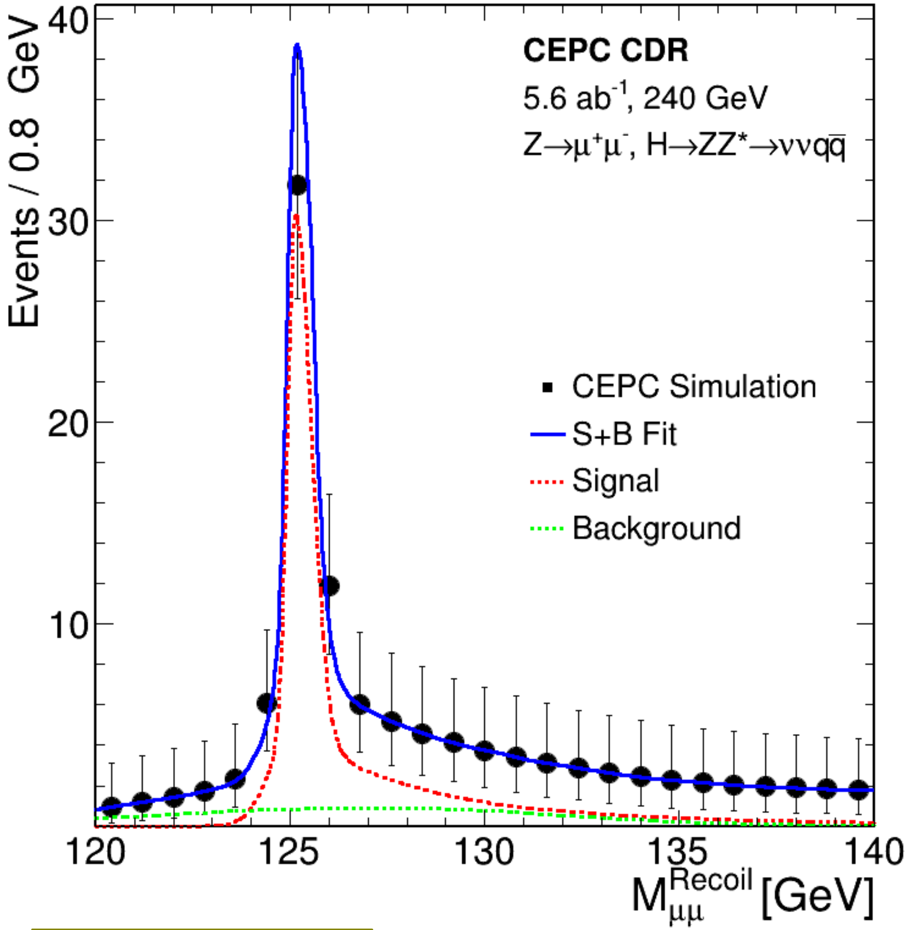


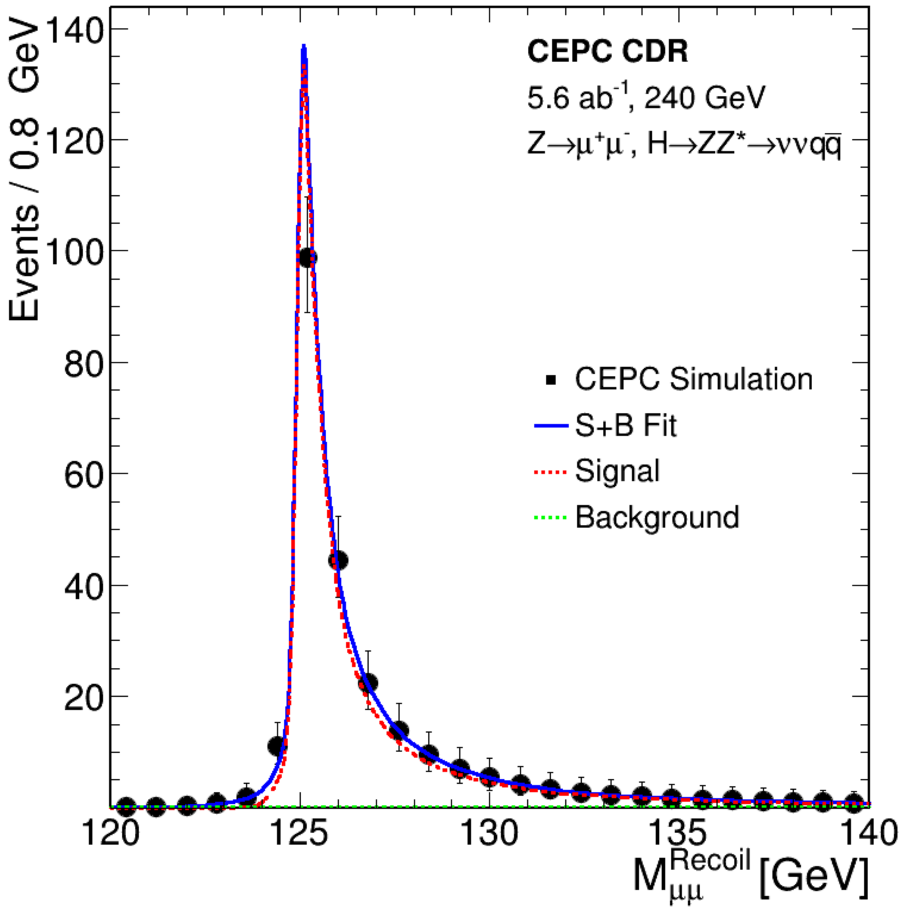
	qqh_e2e2		
[%]	Stat	Eff	Rel
Initial	148.85	100	100
N_mum > 0, N_mup > 0	148	99.43	99.43
105 < M_mumu < 130 GeV	123.75	83.14	83.62
25 < N_particle < 115	123.02	82.64	99.41
55 < M_qq < 125 GeV	122.02	81.97	99.19
P_ppmumu < 32 GeV, 195 < E_ppmumu < 265 GeV	121.32	81.51	99.43
35 < E_mum < 100 GeV, 35 < E_mup < 100 GeV	120.89	81.22	99.65
16 < p_mumu < 72 GeV	120.31	80.82	99.51
N_em < 6, N_ep < 6, N_e < 10	119.33	80.17	99.19
E_em < 10 GeV, E_ep < 10 GeV, E_ee < 19 GeV	116	77.93	97.21
124 < m_mumu < 125 GeV	73.27	49.22	63.17

$Z \to \mu\mu, H \to ZZ \to \nu\nu qq$

Current: This plot only show qq on shell.
(qq off shell side has much higher bkg.)

Old result:
qq on shell/ off shell not separated.
nearly free SM/ZH bkg
Actually impossible.





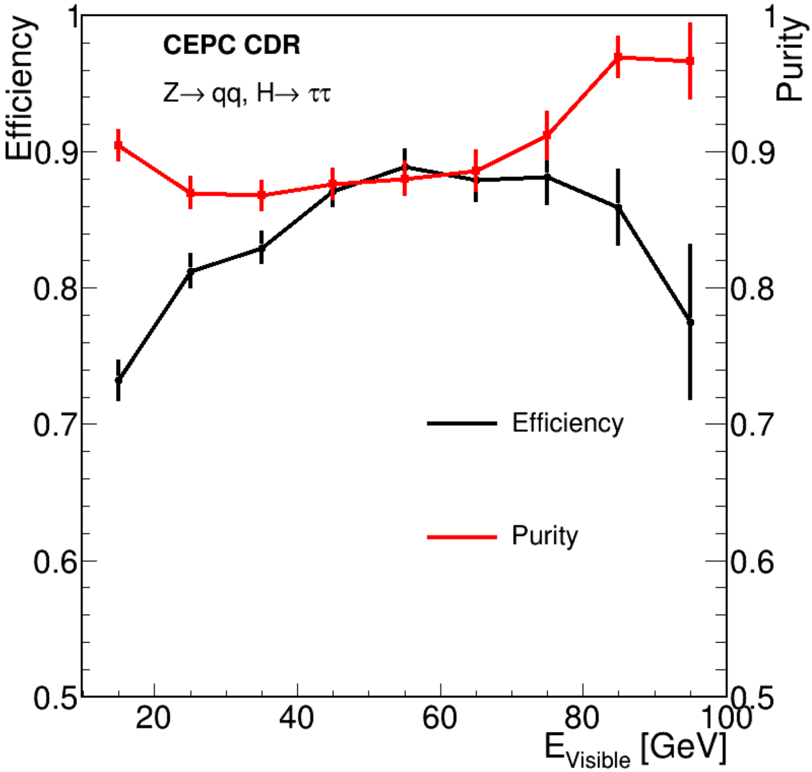
7.32%->12.2%

Need more manpower and effort on H->ZZ.

$Z \to \tau\tau$ extrapolation

Preliminary plan

- Currently all $Z \to \tau\tau$ events are not considered
  - Now tau finding has enough efficiency/purity
- Estimate from $Z \to \mu\mu$:
  - Signal
    - Cx $6.75/6.77 = 99.7\%$. Ignored.
    - For simplified case (Non-jets), 90%;
    - Jet case, 65%. (80%*80%).
  - SM bkg: 2x.
  - If using $M_{\mu\mu}^{recoil}$
    - width 5x larger;



$Z \to \tau\tau$ extrapolation

Ideal $\tau\tau$: same as μμ

Signal		Precision
Z	H	
ττ	bb	0.99%
	cc	9.54%
	gg	5.01%
	WW	2.47%
	γγ	24%
	μμ	100%
	ττ	2.70%
	invisible	191%
	ZZ(vvqq)	12.2%

Current $\tau\tau$: worse;

Signal		Precision
Z	H	
ττ	bb	1.37%
	cc	18.9%
	gg	10.0%
	WW	3.14%
	γγ	32%
	μμ	130%
	ττ	3.58%
	invisible	
	ZZ(vvqq)	16.3%

bb, WW and ττ would gain a bit in extrapolation.
Not so significant. Need more validation.

($5.6ab^{-1}$)	CEPC+$\tau\tau$
$\sigma(ZH)$	**0.50%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	**0.27%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{cc})$	**3.20%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	**1.26%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{WW})$	**0.85%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{ZZ})$	**5.1%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \tau\tau)$	**0.80%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	**6.8%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mu\mu)$	**10%**
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	**3.0%**
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \to \mathrm{inv.})$	**0.26%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	**16%**
Width	**2.8%**

Results

($5.6ab^{-1}$)	CEPC 2018.11	2019.4
$\sigma(ZH)$	**0.50%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	**0.27%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{cc})$	**3.3%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	**1.3%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{WW})$	**1.0%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{ZZ})$	**5.1%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \tau\tau)$	**0.8%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	**6.8%**	
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mu\mu)$	**17%**	10%
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	**3.0%**	
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \to \mathrm{inv.})$	**0.41%**	0.26%
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	**16%**	
Width	**2.8%**	

Fcc-ee CDR:
CERN-ACC-2018-0057

$\sqrt{s}$ (GeV)	240		365	
Luminosity (ab^{-1})	5		1.5	
$\delta(\sigma\mathrm{BR})/\sigma\mathrm{BR}$ (%)	HZ	$\nu\bar{\nu}$ H	HZ	$\nu\bar{\nu}$ H
$\mathrm{H} \to$ any	±0.5		±0.9	
$\mathrm{H} \to \mathrm{b\bar{b}}$	±0.3	±3.1	±0.5	±0.9
$\mathrm{H} \to \mathrm{c\bar{c}}$	±2.2		±6.5	±10
$\mathrm{H} \to \mathrm{gg}$	±1.9		±3.5	±4.5
$\mathrm{H} \to \mathrm{W^+W^-}$	±1.2		±2.6	±3.0
$\mathrm{H} \to \mathrm{ZZ}$	±4.4		±12	±10
$\mathrm{H} \to \tau\tau$	±0.9		±1.8	±8
$\mathrm{H} \to \gamma\gamma$	±9.0		±18	±22
$\mathrm{H} \to \mu^+\mu^-$	±19		±40	
$\mathrm{H} \to$ invisible	< 0.3		< 0.6	

kappa

Collider	HL-LHC	ILC_{250}	$CLIC_{380}$	$LEP3_{240}$	$CEPC_{250}$	$FCC\text{-}ee_{240+365}$		
Lumi (ab^{-1})	3	2	1	3	5	5_{240}	$+1.5_{365}$	+ HL-LHC
Years	25	15	8	6	7	3	+4	
$\delta\Gamma_H/\Gamma_H$ (%)	SM	3.6	4.7	3.6	2.8	2.7	**1.3**	1.1
$\delta g_{HZZ}/g_{HZZ}$ (%)	1.5	0.3	0.60	0.32	0.25	0.2	**0.17**	0.16
$\delta g_{HWW}/g_{HWW}$ (%)	1.7	1.7	1.0	1.7	1.4	1.3	**0.43**	0.40
$\delta g_{Hbb}/g_{Hbb}$ (%)	3.7	1.7	2.1	1.8	1.3	1.3	**0.61**	0.56
$\delta g_{Hcc}/g_{Hcc}$ (%)	SM	2.3	4.4	2.3	2.2	1.7	**1.21**	1.18
$\delta g_{Hgg}/g_{Hgg}$ (%)	2.5	2.2	2.6	2.1	1.5	1.6	**1.01**	0.90
$\delta g_{H\tau\tau}/g_{H\tau\tau}$ (%)	1.9	1.9	3.1	1.9	1.5	1.4	**0.74**	0.67
$\delta g_{H\mu\mu}/g_{H\mu\mu}$ (%)	4.3	14.1	n.a.	12	8.7	10.1	**9.0**	3.8
$\delta g_{H\gamma\gamma}/g_{H\gamma\gamma}$ (%)	1.8	6.4	n.a.	6.1	3.7	4.8	**3.9**	1.3
$\delta g_{Htt}/g_{Htt}$ (%)	3.4	–	–	–	–	–	–	3.1
BR_{EXO} (%)	SM	< 1.7	< 2.1	< 1.6	< 1.2	< 1.2	$< \mathbf{1.0}$	$< \mathbf{1.0}$