Rehearsal

CEPC Higgs Combination

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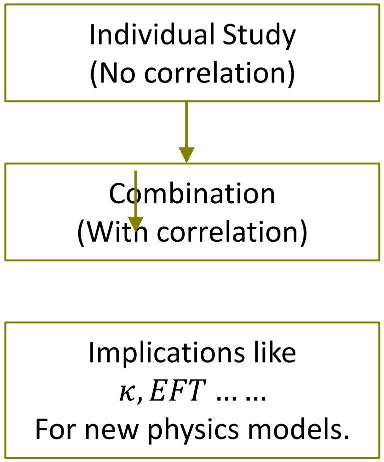
OUTLINE

- Why and How we do combination
- Results of $\sigma(ZH) * \mathrm{Br}$
- κ Framework
- $H \rightarrow \mu\mu$ study
- Summary

Why Combination?

- Uniformed, simultaneous statistical framework
  - Get likelihood scan result   Robust & Reliable;
  - Correctly consider the correlations between individual channels
    - bb/cc/gg;   ZH bkg treatment；   WW fusion; width……
  - Extensibility
    - systematic uncertainties, theoretic assumptions……
- Currently, with MC sample
  - Build Asimov* data from signal and bkg spectrum
  - To fit the estimated precisions of $\sigma * Br$, and κ.
    - Statistic calculation like Significance / Upper limit can also be applied;
  - Can do more with observed data in the future.
  - All the results based in Layout=CEPC_v1, ECM=250GeV, B=3.5T.



*:see more in arXiv:1007.1727

Fit techniques

- Input: Various. Binned/unbinned, 1d/2d spectrum used.
- Parameter of interest: $\sigma * Br$, Higgs coupling κ
  - $\mathrm{N}_{total} = \mu * S + B,$ $\mu = \sigma * Br = \frac{\kappa\kappa}{\Gamma}$ and share the same relative uncertainty;
- Nuisance parameter: Represents systematic uncertainties
  - more NPs can be introduced in the future.
  - currently results are all determined by statistical uncertainty.
- PDF: To describe the shape of the spectrum.
  - Mainly, signal: Double sided Crystal ball; bkg: 2rd-order poly exponential.
  - RooHistPdf/RooKeysPdf used for some channels;
- Algorithm: Likelihood Scan
  - Asymmetric result, from Minuit2; $\pm 1\sigma$ deviation from profile likelihood

Fit techniques

- For each channel
  - Input observables from MC sample.
  - Build combined S+B Pdf Tot=N_{bb}*Pdf+N_{cc}*Pdf_{cc}+……+N_{bkg}*Pdf_{bkg}
  - For event number N_{bb}:
    - When measure $\sigma * Br$, $N_{bb} = N_{bb\_SM} * \mu_{bb}$ N_{bb_SM} directly from event yield ($5ab^{-1}$)
    - When measure Br, $N_{bb} = N_{bb\_SM} * \frac{Br}{Br_{SM}} * \frac{\sigma(ZH)}{\sigma(ZH)_{SM}}$ $\Delta(\sigma(ZH)) = 0.50\%$
    - When measure κ, $N_{bb} = N_{bb\_SM} * \kappa_z^2(\kappa_w^2) * \kappa_b^2/\Gamma_H$
    - Channel share the same μs. $Z \to ee, \mu\mu, qq, \nu\nu$, share the same μ_{bb}
    - Events number N_{bb} is float and the Pdf shape fixed all the time.
- Use Combined pdf to make Asimov data
- Scan the likelihood and obtain the 1σ deviation

Channels Table

All channels scaled to 5ab^{-1}

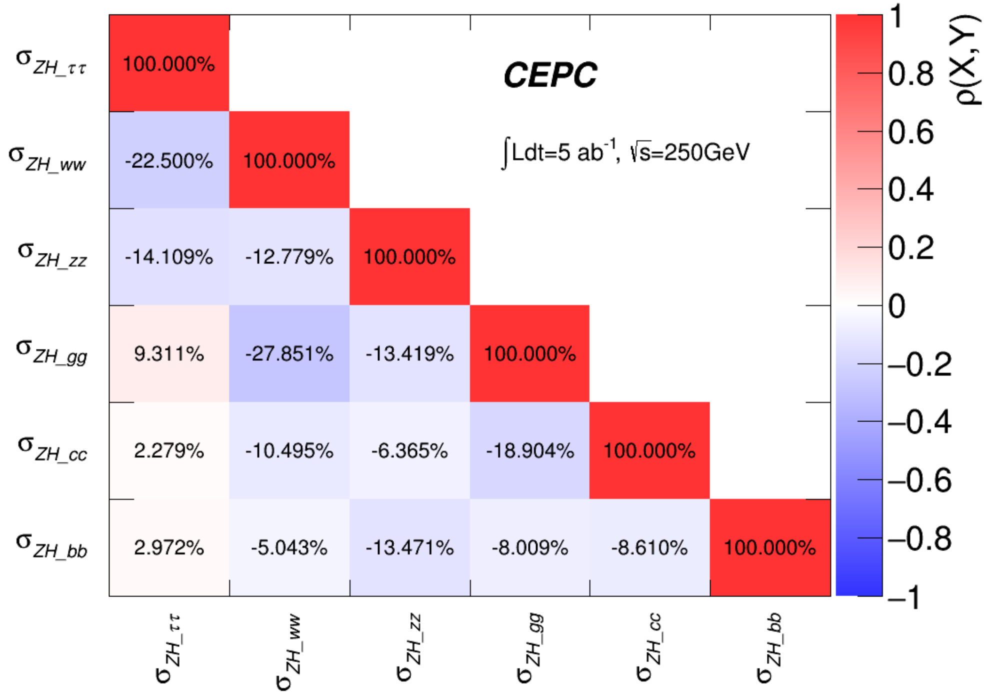
Signal Z	Signal H	Precision
H->qq		
ee	bb	1.6%
	cc	23.6%
	gg	13.3%
μμ	bb	1.1%
	cc	14.8%
	gg	8.0%
qq	bb	0.5%
	cc	11.9%
	gg	3.9%
vv	bb	0.4%
	cc	3.9%
	gg	1.5%
H→ττ		
ee	ττ	2.8%
μμ		2.8%
qq		1.0%
vv		3.1%

Signal Z	Signal H	Precision
H->WW		
ee	lvlv	9.2%
	evqq	4.6%
	μvqq	3.9%
μμ	lvlv	7.3%
	evqq	4.0%
	μvqq	4.0%
vv	qqqq	2.0%
	evqq	4.7%
	μvqq	4.2%
	lvlv	11.3%
qq	lvqq	2.2%(ILC)
ZH bkg contribution		3.0%
H→γγ, Zγ		
μμ+ττ	γγ	41.0%
vv		13.7%
qq		10.3%
vv	Zγ(qqγ)	21.2%

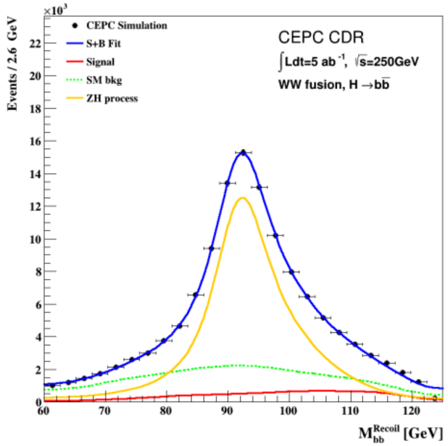
Signal Z	Signal H	Precision
H->ZZ		
vv	μμqq	8.2%
vv	eeqq	35.2%
μμ	vvqq	7.3%
ee	eeqq	35.1%
ee	μμqq	23.0%
ZH bkg contribution		19.4%
vvH(WW fusion)		
vv	bb	3.1%
H→μμ		
qq	μμ	15.9%
ee		
μμ		
vv		
H->Invisible		**Br, Upper**
qq	ZZ(vvvv)	0.8%
ee		0.6%
μμ		0.6%

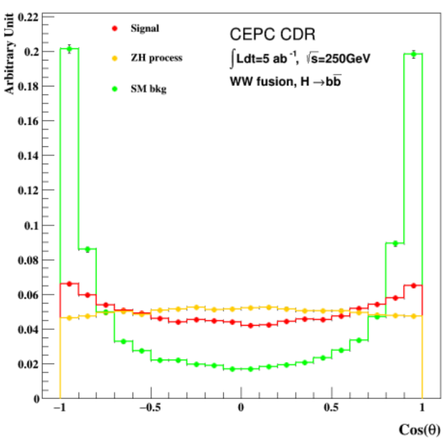
Treatment for ZH bkg

- In individual analysis, other ZH processes are tagged as bkg;
  - Signal in one channel can be bkg for another channel.
  - Should taken into account in combination.
    - $Z \to \mu\mu, H \to \tau\tau$, the main bkg is $H \to WW$.
      - These WW events should be considered in μ_{WW}.
      - Standalone WW channel 1.2% improved to 1.0% this way;
    - Combined fit for H->bb/cc/gg/ww/zz hadronic decay, Fully correlated.



Correlation: $vvH \rightarrow bb$





- 2d fit $\mathrm{M}_{\mathrm{jj}}^{\mathrm{reco}}$ & $\mathrm{Cos}\ \theta_{\mathrm{jj}}$
- Correlated with ZH process;
  - Fix ZH process, Initial error is 2.89%.
  - But must consider the uncertainty from ZH process.
- Use the likelihood from $Z \rightarrow ee/\mu\mu/qq, H \rightarrow bb$ to constrain
  - Already have the form of μ_{ZH}, no assumption made;
  - Esp., $vvH \rightarrow bb$ and $\mathrm{Z}H \rightarrow bb$ share the anti-correlation -46%.
- Simultaneous Fit 3.1% ; consistent with individual study 3.1%.

Correlation: Higgs width

- In Pre_CDR, width determined by

$$\Gamma_H = \frac{\Gamma_{H\to ZZ}}{Br(H\to ZZ)} \propto \frac{\sigma(ZH)}{Br(H\to ZZ)} \text{ and } \Gamma_H = \frac{\Gamma_{H\to bb}}{Br(H\to bb)} \propto \frac{\sigma(\nu\nu H\to \nu\nu bb)}{Br(H\to bb)Br(H\to WW)}$$

- If two independent: 2.83% (consistent with pre_CDR, which gives 2.8%)

- But width correlated with all channels
  - Like correlation like $\nu\nu H \to \nu\nu bb$ and $ZH \to \nu\nu bb$ -46% not included;

- Combined fit in 10κ framework:

$$\Delta(\Gamma_H) = 3.3\%$$

Fit result of $\sigma(ZH) * \mathrm{Br}$

($5ab^{-1}$)	Pre_CDR	Combined
$\sigma(ZH)$	0.51%	**0.50%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{bb})$	0.28%	**0.28%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{cc})$	2.2%	**3.5%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{gg})$	1.6%	**1.4%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{WW})$	1.5%	**1.0%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{ZZ})$	4.3%	**5.0%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \tau\tau)$	1.2%	**0.8%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \gamma\gamma)$	9.0%	**8.1%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow \mu\mu)$	17%	**16%**
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{bb})$	2.8%	**3.1%**
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \rightarrow \mathrm{inv.})$	0.28%	**0.42%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \rightarrow Z\gamma)$	\	**4σ(21%)**

bb: most precise, highly correlated with cc/gg due to flavor tagging algorithm (improving);

With MC sample, signal strength for each channel are all exactly to 1. (Guaranteed by Asimov Data)

κ Framework

κ defined as the ratio of the Higgs coupling to SM expects.

$$\kappa_f = \frac{g(hff)}{g(hff;\mathrm{SM})},\ \kappa_V = \frac{g(hVV)}{g(hVV;\mathrm{SM})}$$

- Model independent implication
  - Detector's benchmark; Constrain to new physics models;
- In CEPC
  - We have $\sigma(ZH) = 0.50\%$ constrain $\sigma(\kappa_z) < 0.25\%$.
  - For Production, ZH & WW fusion process, all contribute to $\kappa_Z^2; \kappa_W^2;$
  - For Partial decay, no top quark κ_t like: $\kappa_Z^2, \kappa_W^2, \kappa_b^2, \kappa_c^2, \kappa_g^2, \kappa_\tau^2, \kappa_\gamma^2, \kappa_\mu^2,$ ... ...
  - For Total width Γ_H. $\Gamma_H = \Gamma_{SM} + \Gamma_{BSM}$.
  - If we assume no exotic decay, Γ_{SM} can be resolved as: all κ correlated this way;

$$\Gamma_{SM} = 0.2137\kappa_W^2 + 0.02619\kappa_Z^2 + 0.5824\kappa_b^2 + 0.08187\kappa_g^2 + 0.002270\kappa_\gamma^2 + 0.06294\kappa_\tau^2 + 0.02891\kappa_c^2$$

  - $Z \to \mu\mu, H \to \tau\tau$ channel, the signal will be $\kappa_Z^2\kappa_\tau^2/\Gamma_H$; For $\nu\nu H \to bb$, it's $\kappa_W^2\kappa_b^2/\Gamma_H$

Fit result of κ

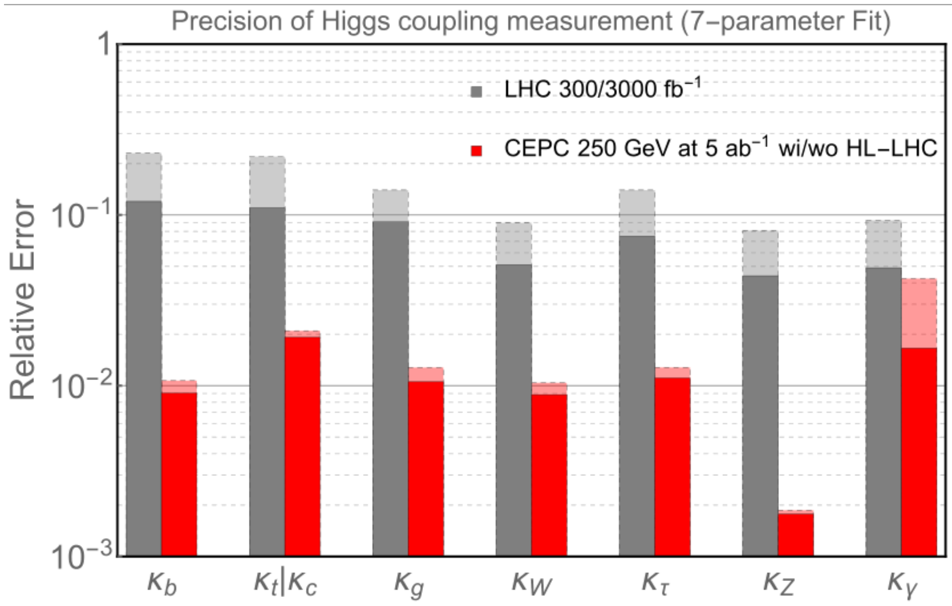
In different interpretation,
Higgs width can be independent or resolved by branch ratio.

	10κ	Pre_CDR	**7κ**	Pre_CDR
κ_b	**1.6%**	1.3%	**1.0%**	1.2%
κ_c	**2.3%**	1.7%	**2.1%**	1.6%
κ_g	**1.6%**	1.5%	**1.2%**	1.5%
κ_γ	**4.4%**	4.7%	**4.3%**	4.7%
κ_τ	**1.6%**	1.4%	**1.1%**	1.3%
κ_Z	**0.21%**	0.26%	**0.17%**	0.16%
κ_W	**1.4%**	1.2%	**1.0%**	1.2%
κ_μ	**8.1%**	8.6%		
Br_{inv}	**0.42%**	0.28%		
Γ_H	**3.3%**	2.8%		

From 10κ to 7κ, we assume
- No exotic decay Γ_{BSM}
- Drop Br_{inv}
- $\kappa_\mu=\kappa_\tau$

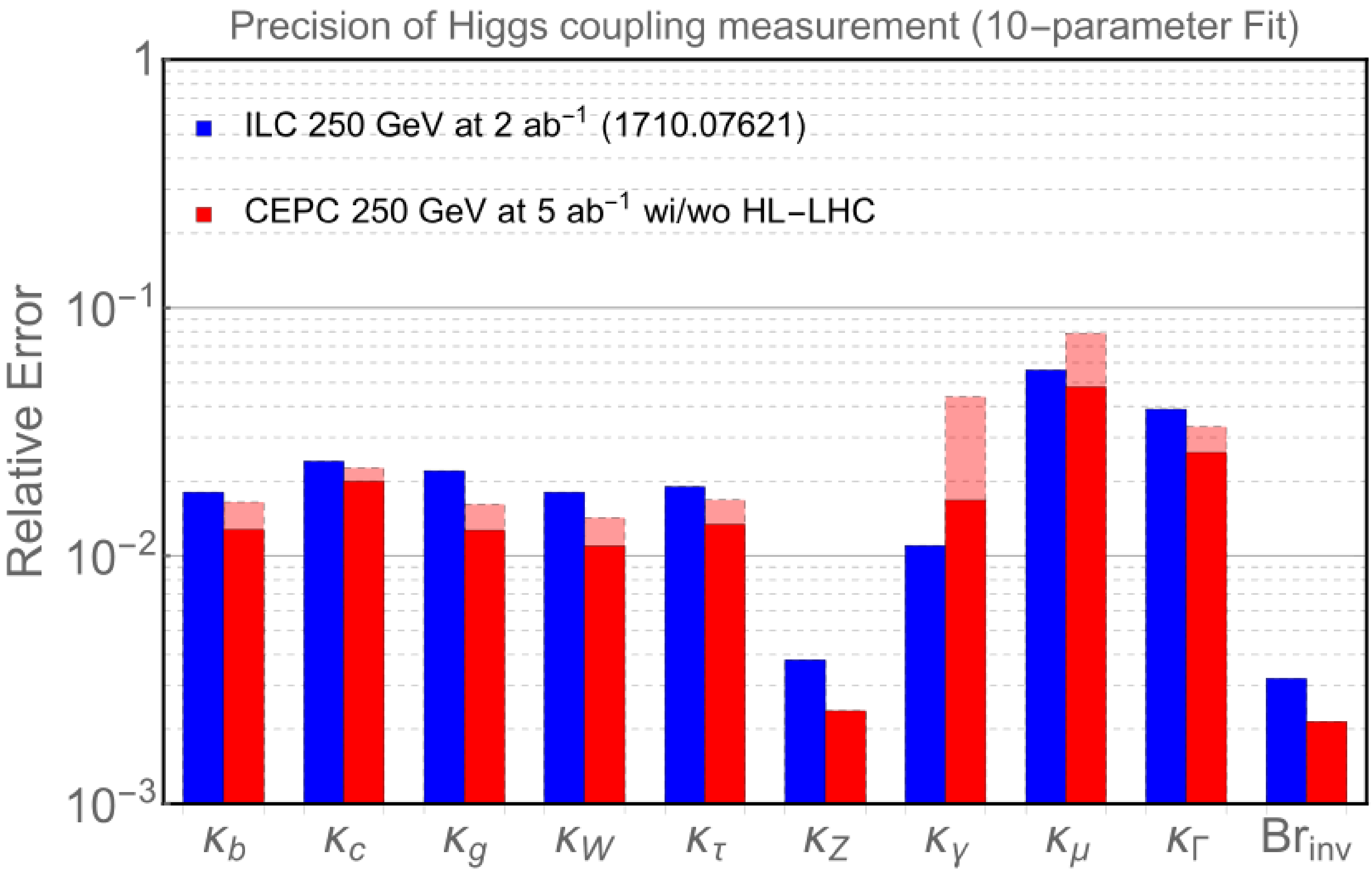
Integration to HL-LHC

	10-parameter fit		7-parameter fit	
	CEPC	+HL-LHC	CEPC	+HL-LHC
Γ_h	3.2	2.5	–	–
κ_b	1.6	1.2	1.0	0.9
κ_c	2.3	2.0	2.1	1.9
κ_g	1.6	1.2	1.2	1.0
κ_W	1.4	1.1	1.0	0.9
κ_τ	1.6	1.2	1.1	1.0
κ_Z	0.21	0.21	0.17	0.16
κ_γ	4.4	1.7	4.3	1.7
κ_μ	8.1	4.9	–	–
$\mathrm{BR_{inv}}$	0.31	0.31	–	–



*: here Br_{inv} for BSM.

Compared to ILC(1710.07621)



Correlation of κ

For each entry,
upper one is CEPC result
lower one is CEPC+HL-LHC result.

7−parameter fit Correlation

	κ_b	κ_c	κ_g	κ_W	κ_τ	κ_Z	κ_γ
κ_b	100.	−35. −32.	−52. −51.	−59. −56.	−44. −43.	66. 63.	−9.6 −3.7
κ_c	−35. −32.	100.	2.5 −3.4	17. 16.	2.9 2.8	−38. −36.	2.4 0.92
κ_g	−52. −51.	2.5 −3.4	100.	6.7 1.6	6.8 4.3	−39. −28.	2.2 0.55
κ_W	−59. −56.	17. 16.	6.7 1.6	100.	−22. −21.	−55. −56.	2.8 1.1
κ_τ	−44. −43.	2.9 2.8	6.8 4.3	−22. −21.	100.	1.8 1.3	−0.85 −0.32
κ_Z	66. 63.	−38. −36.	−39. −28.	−55. −56.	1.8 1.3	100.	−4.7 −7.5
κ_γ	−9.6 −3.7	2.4 0.92	2.2 0.55	2.8 1.1	−0.85 −0.32	−4.7 −7.5	100.

10−parameter fit Correlation

	κ_b	κ_c	κ_g	κ_W	κ_τ	κ_Z	κ_γ	κ_μ	Br_{inv}	κ_Γ
κ_b	100.	−4.4 −4.2	−7.6 −6.1	−19. −19.	4.2 4.2	78. 77.	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−92. −91.
κ_c	−4.4 −4.2	100.	−19. −18.	−9.3 −8.6	2.3 2.2	−6.1 −5.7	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	2.7 2.5
κ_g	−7.6 −6.1	−19. −18.	100.	−25. −19.	9.2 7.4	3.2 8.7	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−5.8 −13.
κ_W	−19. −19.	−9.3 −8.6	−25. −19.	100.	−22. −21.	−6.9 −7.8	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	5.7 5.5
κ_τ	4.2 4.2	2.3 2.2	9.2 7.4	−22. −21.	100.	25. 24.	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−31. −31.
κ_Z	78. 77.	−6.1 −5.7	3.2 8.7	−6.9 −7.8	25. 24.	100.	2.8 −4.7	1.5 −0.61	<0.1 <0.1	−83. −83.
κ_γ	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	2.8 −4.7	100.	<0.1 <0.1	<0.1 <0.1	−3.4 −1.3
κ_μ	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	1.5 −0.61	<0.1 <0.1	100.	<0.1 <0.1	−1.8 −1.1
Br_{inv}	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	100.	<0.1 <0.1
κ_Γ	−92. −91.	2.7 2.5	−5.8 −13.	5.7 5.5	−31. −31.	−83. −83.	−3.4 −1.3	−1.8 −1.1	<0.1 <0.1	100.

Summary

	Current
$\sigma(ZH)$	0.50%
$\sigma(ZH) * Br(H \to bb)$	0.28%
$\sigma(ZH) * Br(H \to cc)$	3.5%
$\sigma(ZH) * Br(H \to gg)$	1.4%
$\sigma(ZH) * Br(H \to WW)$	1.0%
$\sigma(ZH) * Br(H \to ZZ)$	5.0%
$\sigma(ZH) * Br(H \to \tau\tau)$	0.8%
$\sigma(ZH) * Br(H \to \gamma\gamma)$	8.1%
$\sigma(ZH) * Br(H \to \mu\mu)$	16%
$\sigma(\nu\nu H) * Br(H \to bb)$	3.1%
$Br_{upper}(H \to inv.)$	0.42%
$\sigma(ZH) * Br(H \to Z\gamma)$	4σ(21%)

	10κ	**7κ**
κ_b	1.6%	1.0%
κ_c	2.3%	2.1%
κ_g	1.6%	1.2%
κ_γ	4.4%	4.3%
κ_τ	1.6%	1.1%
κ_Z	0.21%	0.17%
κ_W	1.4%	1.0%
κ_μ	8.1%	
Br_{inv}	0.42%	
Γ_H	3.2%	

	10-parameter fit		7-parameter fit	
	CEPC	+HL-LHC	CEPC	+HL-LHC
Γ_h	3.2	2.5	–	–
κ_b	1.6	1.2	1.0	0.9
κ_c	2.3	2.0	2.1	1.9
κ_g	1.6	1.2	1.2	1.0
κ_W	1.4	1.1	1.0	0.9
κ_τ	1.6	1.2	1.1	1.0
κ_Z	0.21	0.21	0.17	0.16
κ_γ	4.4	1.7	4.3	1.7
κ_μ	8.1	4.9	–	–
BR_{inv}	0.31	0.31	–	–

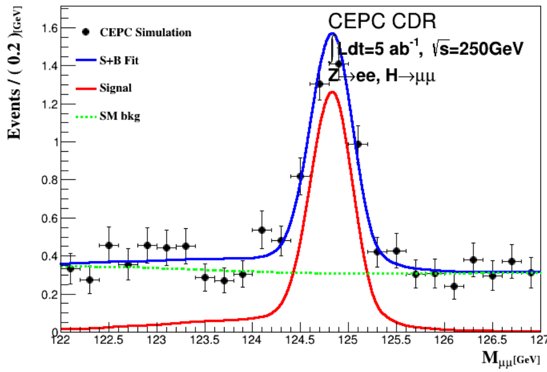
Δm_H	Γ_H	$\sigma(ZH)$	$\sigma(\nu\bar{\nu}H) \times BR(H \to b\bar{b})$
5.9 MeV	3.2%	0.50%	3.1%

Decay mode	$\sigma(ZH) \times$ BR	BR
$H \to b\bar{b}$	0.28%	0.42%
$H \to c\bar{c}$	3.5%	3.5%
$H \to gg$	1.4%	1.5%
$H \to \tau^+\tau^-$	0.8%	0.9%
$H \to WW^*$	1.0%	1.1%
$H \to ZZ^*$	5.0%	5.0%
$H \to \gamma\gamma$	8.1%	8.3%
$H \to \mu^+\mu^-$	16%	16%
$H \to$ inv	–	$<$ 0.42%

H→$\mu\mu$

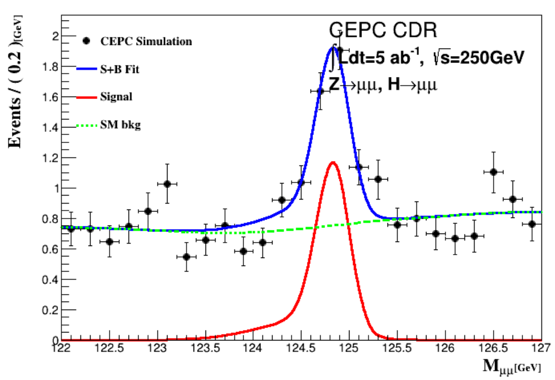
More information to be added.

- Z->ee



Cut 变量	signal	ZZ	WW(SW)	ZZorWW	SingleZ	2f
初始条件	4.7	18	0	9	22672	8.0
$120<M_{\mu^+\mu^-}<130$	4.3	0	0	0	747	0.0
$90.5<M_{recoil_\mu}<92.5$	2.5	0	0	0	34	0.0
$cos_{\mu^+\mu^-}<-0.603$	2.5	0	0	0	33	0.0
$P_{T_{\mu^+\mu^-}}<62.5$	2.5	0	0	0	31	0.0
$138.5<E_{\mu^+\mu^-}<139.7$	2.2	0	0	0	8	0.0
efficiency	46.8%					

- Z->mm consider combination $\delta = (\frac{pair1.M}{\Delta Z})^2 + (\frac{pair2.M}{\Delta H})^2$
  - Choose $\Delta Z = 1.5, \Delta H = 0.75$

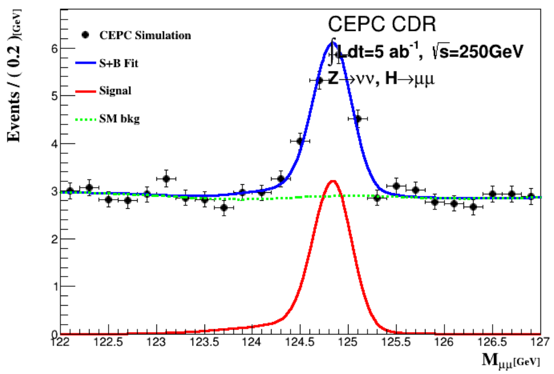


Category	signal	ZZ	WW(SW)	ZZorWW	SingleZ	2f
Preselection	6.6	17631.0	0	0	0	0.0
$120<E_{\mu^+\mu^-}<130$	6.0	1685.2	0	0	0	0.0
$90.6< M_{recoil_\mu} <93.4$	3.9	128.8	0	0	0	0.0
$90.2<M_{\mu^+\mu^-}$(Z)<92.8	3.2	58.1	0	0	0	0.0
$cos_{\mu^+\mu^-}$(H)<-0.603	3.2	50.0	0	0	0	0.0
$cos_{\mu^+\mu^-}$(Z)<-0.364	3.2	47.0	0	0	0	0.0
$138.0<E_{\mu^+\mu^-}$(H)<139.8	3.0	15.5	0	0	0	0.0
$P_{T_{\mu^+\mu^-}}$(H)<62.5	3.0	14.7	0	0	0	0.0
efficiency	45.5%					

bkg shape all after smoothing.

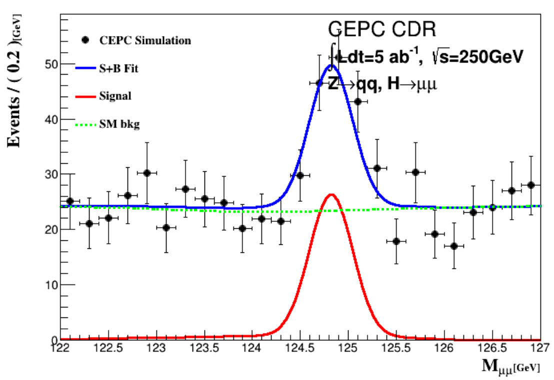
H→$\mu\mu$

- Z->vv
  - 38%



Cut 变量	signal	ZZ	WW(SW)	ZZorWW	SingleZ	2f
初始条件	41.7	34901	121952	489686	25619	1635887
120<$M_{\mu^+\mu^-}$<130	38.4	382	16677	56029	315	49490
MET>8.5	37.9	291	16264	53740	305	8600
90.8<M_{recoil_μ}<93.4	24.0	96	834	2034	79	184
$\cos\theta_{Z\mu^+}$ <0.999	24.0	96	833	2034	79	126
$\cos\theta_{Z\mu^-}$ <0.999	24.0	96	833	2034	79	57
$cos\theta_{\mu^+}$>0	12.0	33	28	108	25	10
$cos\theta_{\mu^-}$<0	9.1	22	11	86	17	9
efficiency	21.8%					

- Z->qq
  - 17%



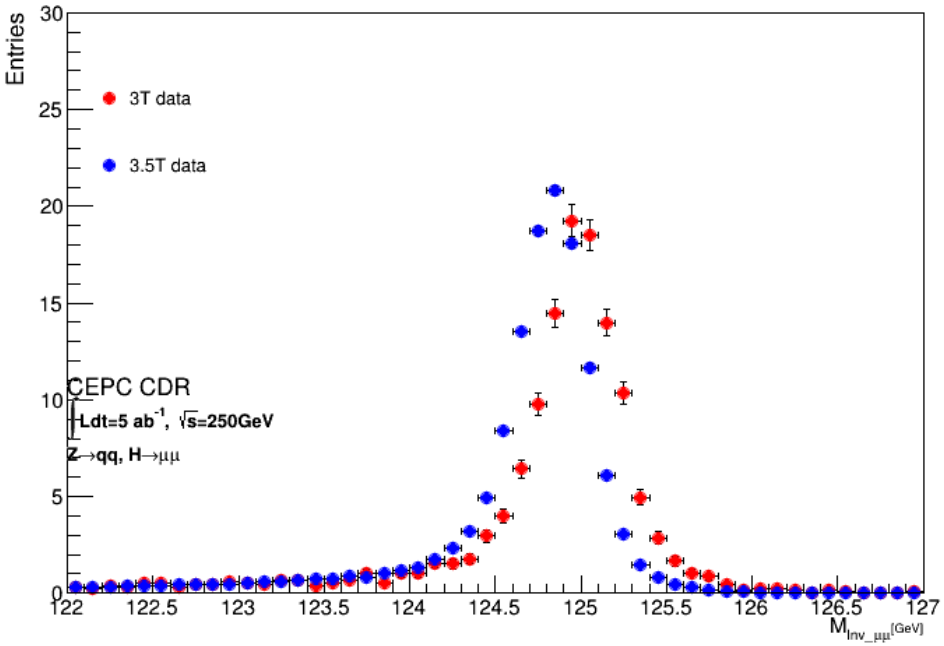
Cut 变量	signal	ZZ	WW	ZZorWW	SingleZ	2f
初始条件	156.3	390775	183751	463361	101164	63217
120< $M_{\mu^+\mu^-}$ <130	141.6	3786	181	227	244	100
M_{j1}>4.2 M_{j2}>2.8	133.0	3216	111	0	9	60
M_{jj}>76.0	127.5	2917	2	0	8	59
90.9<$M^{\mu^+\mu^-}_{recoil}$ <93.5	75.2	893	0	0	0	0
20<$P_{T_{\mu^+\mu^-}}$<64	74.5	777	0	0	0	0
-58<$P_{Z_{\mu^+\mu^-}}$<58	74.5	748	0	0	0	0
$\cos\theta_{\mu^+}$>-0.98 $\cos\theta_{\mu^-}$<0.98	74.2	747	0	0	0	0
efficiency	47.5%					

- Combined:15.9%

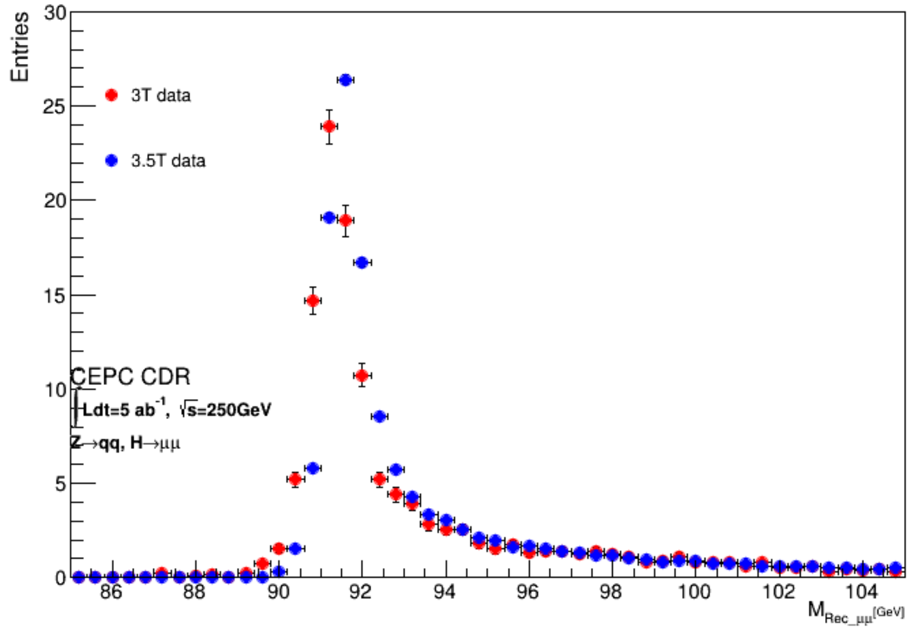
$Z \to qq,\ H \to \mu\mu$ 3T

Full Simulation, Signal Events scaled

H mass



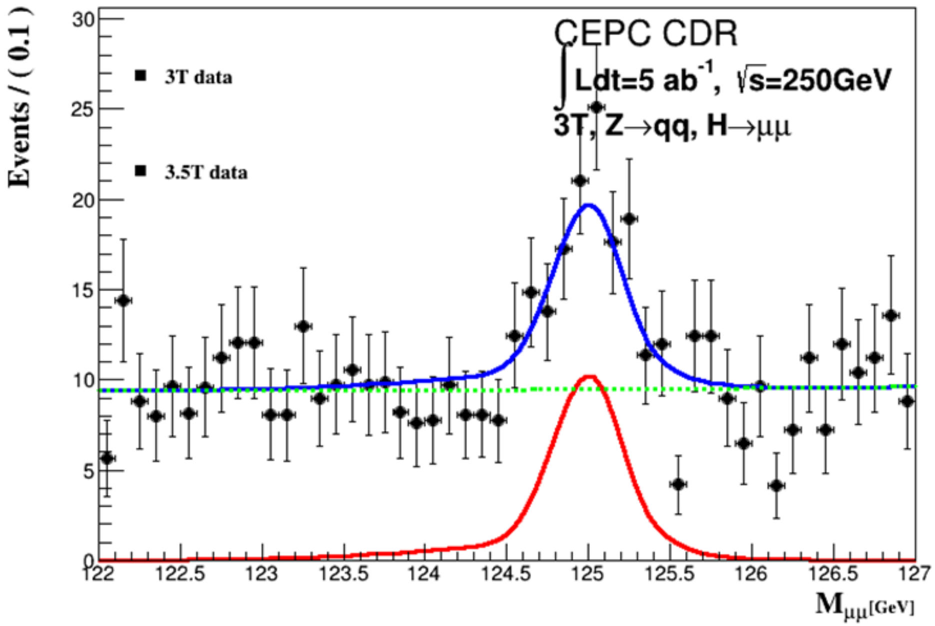
Z mass



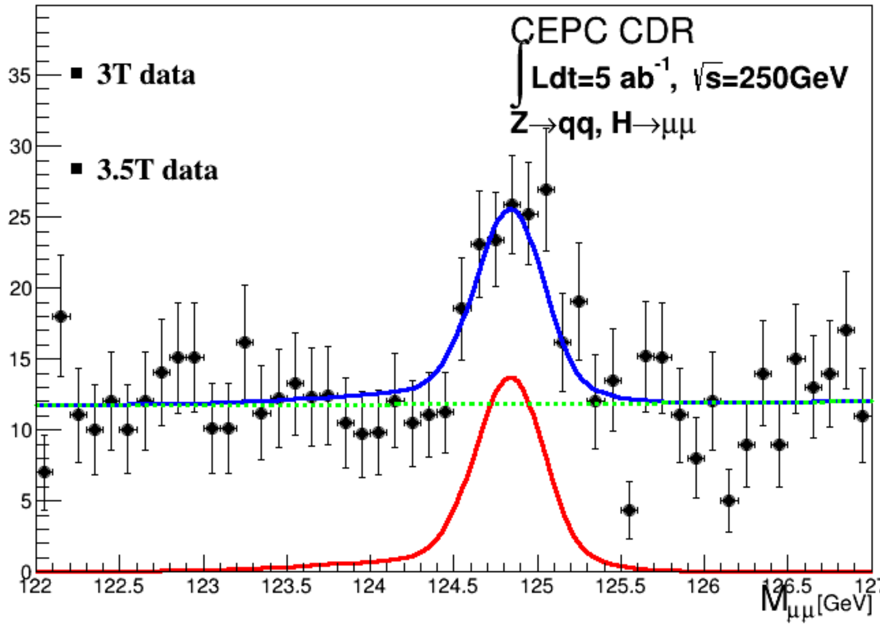
Shift in the central value (0.2GeV), width no big change.

$Z \to qq,\ H \to \mu\mu$ Comparison

3T: 20.3%



3.5T: 17.6%



Due to the signal events loss 19% at the beginning. Reason under study.

Events(scaled)	3.5T	3T
$120 < M_{\mu\mu} < 130$	134.1	112.5

backup

Individual analysis

Explanation for difference

($5ab^{-1}$)	Pre_CDR	Combined
$\sigma(ZH)$	0.51%	**0.50%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	0.28%	**0.28%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{cc})$	2.2%	**3.5%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	1.6%	**1.4%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{WW})$	1.5%	**1.0%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{ZZ})$	4.3%	**5.0%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \tau\tau)$	1.2%	**0.8%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	9.0%	**8.1%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mu\mu)$	17%	**16%**
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	2.8%	**3.1%**
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \to \mathrm{inv.})$	0.28%	**0.42%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	\	**4σ(21%)**

- bb,cc,gg: Due to flavor tagging algorithm, The template gives b/c likeness, updated algorithm has less cc candidate events left.
- WW: more subchannels studied and ZH bkg contribution.
- ZZ: The extrapolation in Pre_CDR from FCC-ee too optimistic.
- $\tau\tau$: τ finding algorithm updated.
- $\gamma\gamma$: different estimation from full/fast simulation.
- $\nu\nu H$: consider the correlation
- $H \to invisible$: Pre_CDR studied an exotic decay $H \to \chi_1\chi_1$ and assuming 200fb^{-1}. Now we study the upper limit of $H \to ZZ \to \nu\nu\nu\nu$.

bb/cc/gg

$$B_{likeness} = \frac{b_{j1}b_{j2}}{b_{j1}b_{j2} + (1 - b_{j1})(1 - b_{j2})}$$

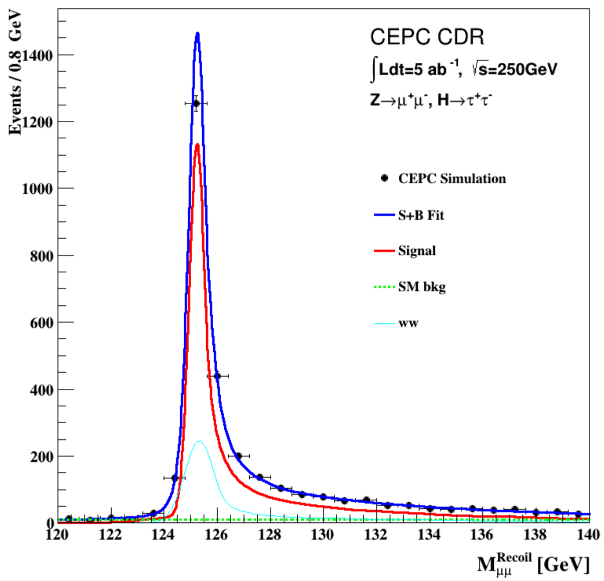
- Template fit: Flavor tagging algorithm
  - $Z \to ee\ \mu\mu\ qq\ vv, \mathrm{H} \to bb/cc/gg$ are studied.
  - 2D fit, with dijets' b/c likeness; mass info not used;
  - 7 parts, Tot=bb+cc+gg+ww+zz+tt+bkg_{sm}.
  - Build individual pdf by MC, then fit to determine fraction.
  - the shape of bkg is fixed.
    - Which means we have a wonderful understanding with bkg,
    - may be more suitable for CEPC.
  - ToyMC test to get precision
  - Now plan to use 3d fit in llH;
  - Systematic uncertainties ongoing;

Scan	μ_bb	μ_cc	μ_gg
eeH	1.3%	15.0%	8.2%
mmH	1.0%	11.3%	5.5%
qqH	0.5%	17%	7.2%
vvH	0.4%	3.9%	1.6%
Combined	0.28%	3.48%	1.44%

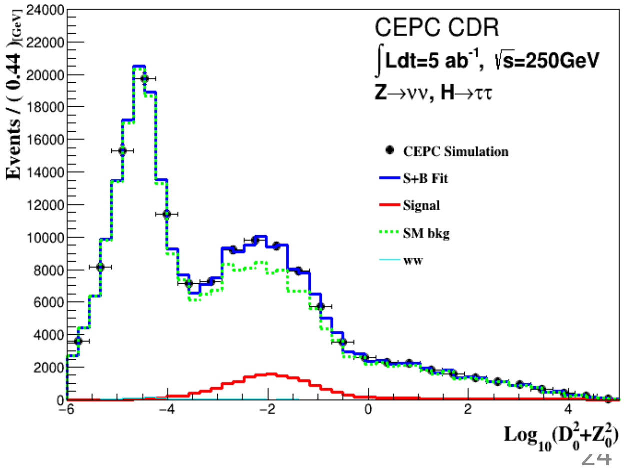
$\tau\tau$

	preCDR	Now
$\tau\tau$	1.2%	**0.81%**

- Pre_CDR concludes the precision 1.2% but no description.
- Develop LICH to identify lepton. Eff>99%
- Signal and ZH events(Main WW) share the same shape
  - use $\log_{10}(D_0^2 + Z_0^2)$ fit to separate signal
    - Impact parameter, Distance from beam spot



	BR (H→ $\tau\tau$)	δ ($\sigma\times$ BR)/($\sigma\times$ BR)
$\mu\mu$H	6.40	2.68%
eeH(extrapolated)	6.37	2.72%
$\nu\nu$H	6.26	4.38%
qqH	6.23	0.93%
combined	6.28	0.81%



WW

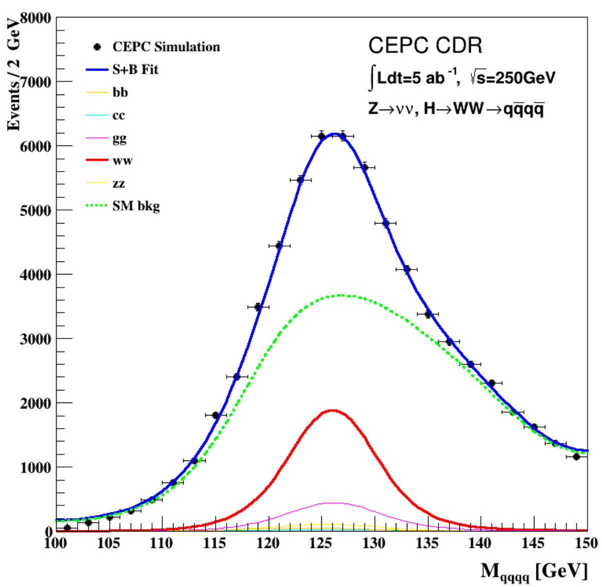
	preCDR	Now
WW	1.5%	1.0%

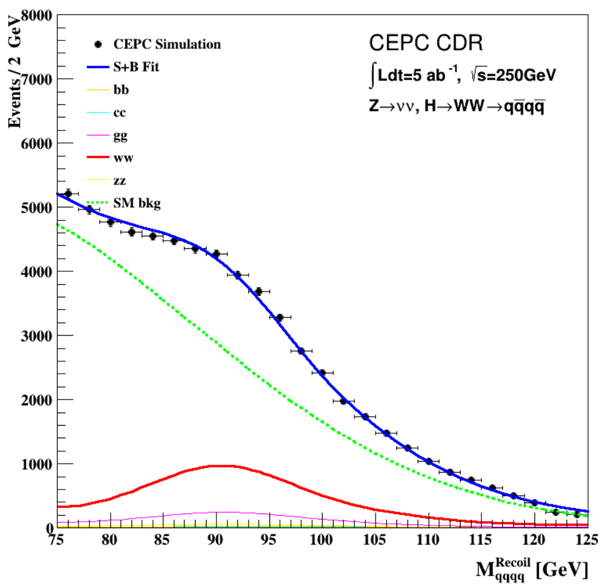
Signal		Precision
Z	H	
H->WW		
ee	lvlv	9.2%
	evqq	4.6%
	μvqq	3.9%
μμ	lvlv	7.3%
	evqq	4.0%
	μvqq	4.0%
vv	qqqq	2.0%
	evqq	4.7%
	μvqq	4.2%
	lvlv	11.3%
qq	lvqq	2.2%(ILC)
ZH bkg contribution		3.0%

- Currently have 17 channels of WW

Green: studied

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





ZZ

	preCDR	Now
ZZ	4.3%	5.0%

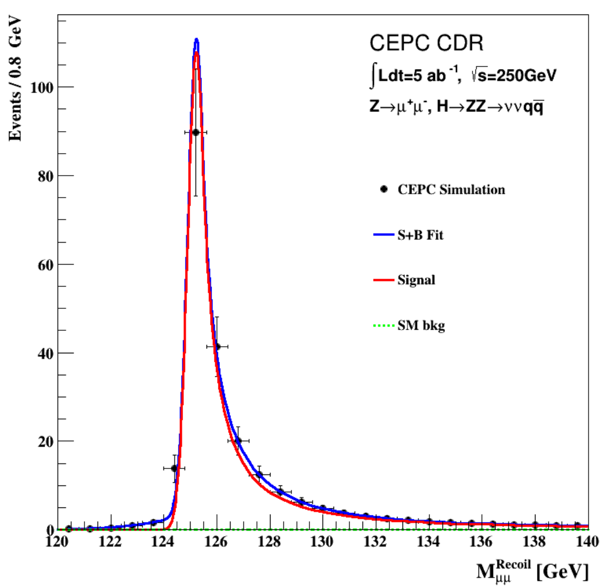
Channel	Precision	Comment
$\sigma(Z(\nu\bar{\nu})H + \nu\bar{\nu}H) \times \mathrm{BR}(H \to ZZ)$	6.9%	CEPC Fast Simulation
$\mathrm{BR}(H \to ZZ^{*})$	4.3%	Extrapolation from FCC-ee [36]

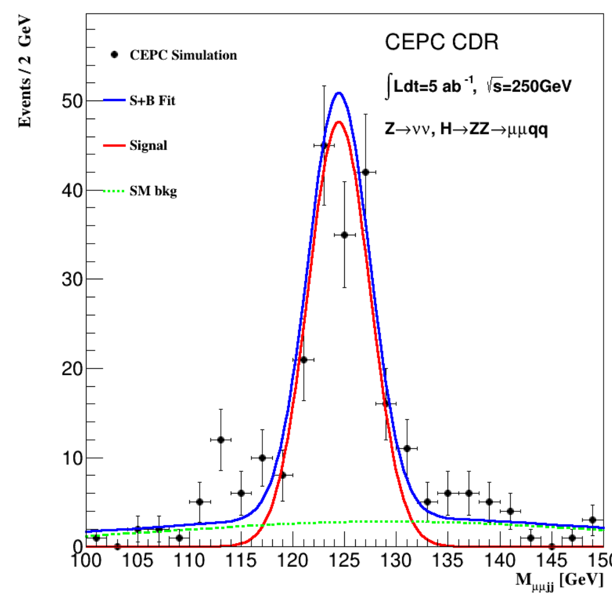
- Pre_CDR's result from extrapolating the FCC-ee.
- Now has 5 channels clear and easy to study

Signal		Precision
Z	H	
H->ZZ		
νν	μμqq	8.2%
νν	eeqq	35.2%
μμ	ννqq	7.3%
ee	eeqq	35.1%
ee	μμqq	23.0%
ZH bkg contribution		19.4%

Green: studied

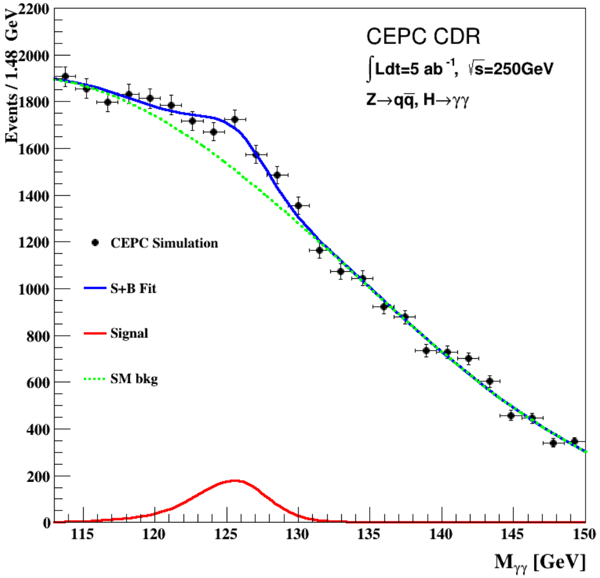
	Z	ee	μμ	νν	qq
ZZ	ee+qq				
	μμ+qq				
	νν+qq				
	ll+ll				
(Invi)	νν+νν				
	qq+qq				
	ll+νν				



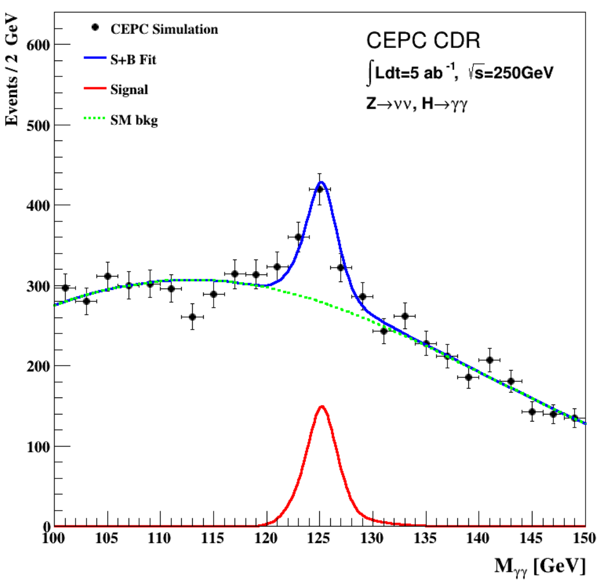


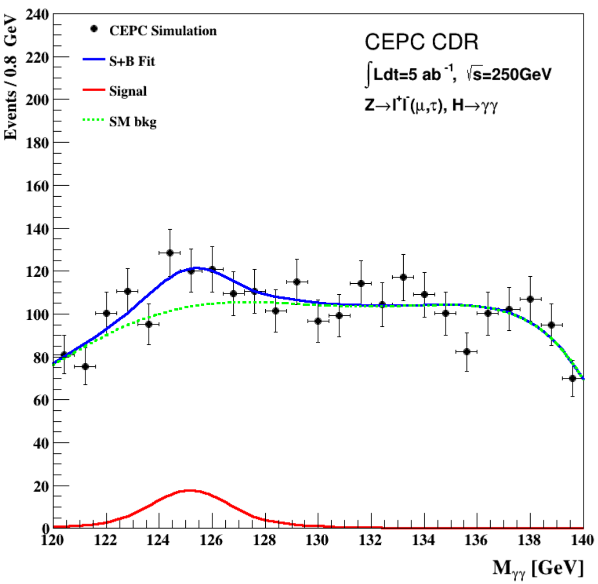
$\gamma\gamma$

	preCDR	Now
$\gamma\gamma$	9.0%	8.1%



Signal		Precision
Z	H	
H→γγ		
μμ+ττ	γγ	24.8%
νν		11.7%
qq		12.8%

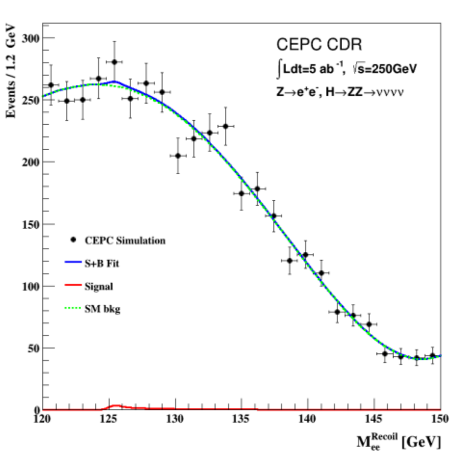


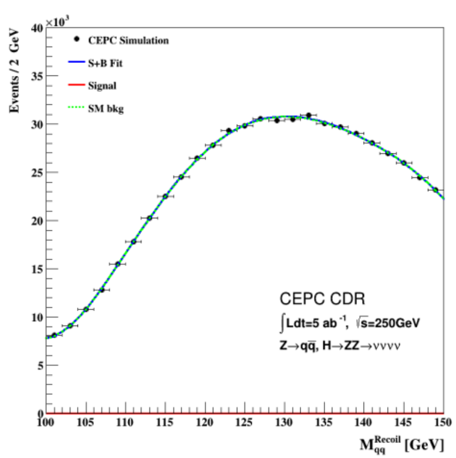


$H \rightarrow invisible$

	preCDR	Now
invisible	0.28%	0.42%

- Moxin studied H->ZZ->vvvv
    - Large irreducible bkg, use BDT and seek upper limit.
    - Huge fluctuation, use Asimov Data to get correct fit result.
    - precision 148%, upper limit for Br: 0.42%
    - Upper limit for BSM H->invisible: 0.31%





	Precision	significance	Br Upper limit
Z->ee	350%		0.84%
Z->mm	242%		0.62%
Z->qq	226%		0.59%
Combined	148%	0.68σ	0.42%

$\mu\mu, Z\gamma$ and others

	preCDR	Now
$\mu\mu$	17%	16%

- $\mu\mu$ process
  - Pre_CDR's 17% not reliable;
  - Zhen Wei separate Z->ee,mm, vv and qq
- $Z \rightarrow qq,\ H \rightarrow Z\gamma \rightarrow qq\gamma$ studied;
  - Pre_CDR not conclude;
  - Take $\mathrm{m}_{Z\gamma-\mathrm{Z}}$ as observable;
  - 4σ significance; Precision about 21%.
- $e\mu, ee$ process studied.
  - Since low stats and no clear ratio, not taken into fit model.