Combination of CEPC Higgs precision measurement

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Follow up study from:
http://indico.ihep.ac.cn/event/6618/session/22/contribution/141/material/slides/0.pdf

Channels Table

Observed=tagged signal after cutflow and in fit range.
All events are weighted and normalized to 5ab^{-1}.

Signal		Observed Events	Who takes charge	Precision
Z	H			
H->Inclusive				
νν	Inclusive	164170	Liao Libo	\
μμ	Inclusive	29552		
ee	Inclusive	22200		
H->qq				
ee	bb	7655	Bai Yu	1.3%
	cc	351		15%
	gg	1058		8.2%
μμ	bb	11108		1.0%
	cc	567		11%
	gg	1762		5.5%
qq	bb	176542		0.5%
	cc	8272		17%
	gg	25293		7.2%
νν	bb	70608		0.4%
	cc	3061		3.9%
	gg	9633		1.6%
H→γγ,Zγ				
ll	γγ	93	Wang Feng	27%
νν		309		12%
qq		822	Sun Yitian	13%
qq	Zγ	219	Yao Weimin	21%
H->Invisible				Br, Upper
qq	νννν	202	Mo Xin	0.3%
ee		8		1.1%
μμ		18		0.7%
νvH(WW fusion)				
νν	bb	10256	Liang Hao	3.1%

Signal		Observed Events	Who takes charge	Precision
Z	H			
H->WW				
μμ	μνμν	52	Liao Libo	2.6%
	evev	36		
	evμν	105		
	evqq	663		
	μνqq	717		
ee	μνμν	44		2.9%
	evev	22		
	evμν	81		
	evqq	612		
	μνqq	684		
νν	qqqq	9022		1.3%
H->ZZ				
νν	μμjj	179	Wei Yuqian	8.3%
νν	eejj	64		34%
μμ	νvjj	200		7.4%
ee	eejj	55		40%
ee	mmjj	81		23%
H→ττ				
ee	ττ	\	Yu Dan	3.0%
μμ		2135		2.8%
qq		23168		1.9%
νν		8809		3.7%
H→μμ				
qq	μμ	71	Cui Zhenwei	15%
ee		1		
μμ		4		
νν		14		

$\tau\tau$

	preCDR	Now
$\tau\tau$	1.2%	**1.34%**

- 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
  - Dan use $\log_{10}(D_0^2 + Z_0^2)$ fit to separate signal
    - Impact parameter, Distance from beam spot
  - Determine the ratio, then use ratio to produce signal sample.
  - eeH is extrapolated from mmH, assuming bkg 4 times worse;

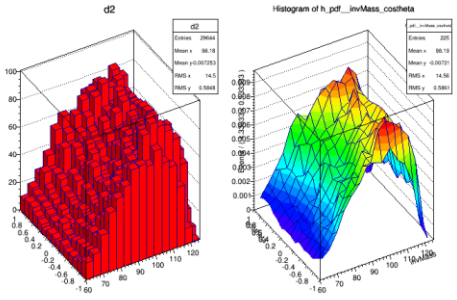
Still tuning

	BR (H→ $\tau\tau$)	δ ($\sigma\times$ BR)/($\sigma\times$ BR)	Mine
$\mu\mu$H	6.40 ± 0.18	2.68%	2.75%
eeH(extrapolated)	6.37 ± 0.18	4.34%	2.98%
$\nu\nu$H	6.19 ± 0.17	4.29%	3.69%
qqH	6.25 ± 0.04	1.71%	1.93%
combined	6.28 ± 0.07	1.30%	1.34%

Table showed here use number counting;
After discussing with Dan,
We think my result is more reliable.

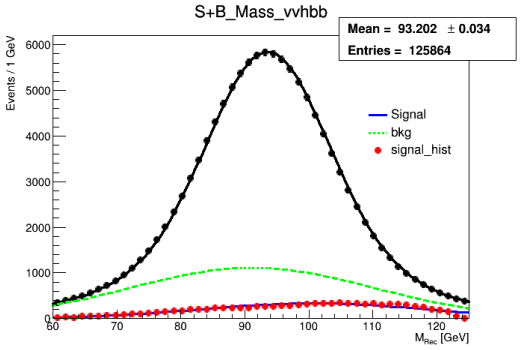
see more details in https://agenda.linearcollider.org/event/7645/contributions/40070/attachments/32408/49220/lcws2017_Dan.pdf

Correlation: $vvH \rightarrow bb$



2d fit
Mass &cos of 2 jets

- WW fusion channel contains many ZH bkg;
  - Initial error is 2.89%, (Pre_CDR 2.8%)
  - But must consider the uncertainty of ZH process(~0.4%)
- In individual analysis
  - $-\mathrm{Log}L = 0.5\left(\frac{\mu_{ZH}-1}{0.375\%}\right)^2 - P\left(data\middle|\mu_{\mathrm{ZH}}N_{ZH}Pdf_{ZH} + \mu_{\mathrm{wwf}}N_{wwf}Pdf_{wwf} + N_{SM}Pdf_{SM}\right)$



Mass Spectrum

- Here we can directly use the likelihood in Z->ee/mm/qq, H->bb channel
  - Already have the form of μ_{ZH} no assumption made;
- Combine Fit $\{^{+3.12\%}_{-3.11\%}$; consistent with individual result 3.1%.

Correlation: Higgs width

- Model independent determination

$$\Gamma_H = \frac{\Gamma_{H\to ZZ}}{Br(H\to ZZ)} \propto \frac{\sigma(ZH)}{Br(H\to ZZ)} \qquad 5.2\%$$

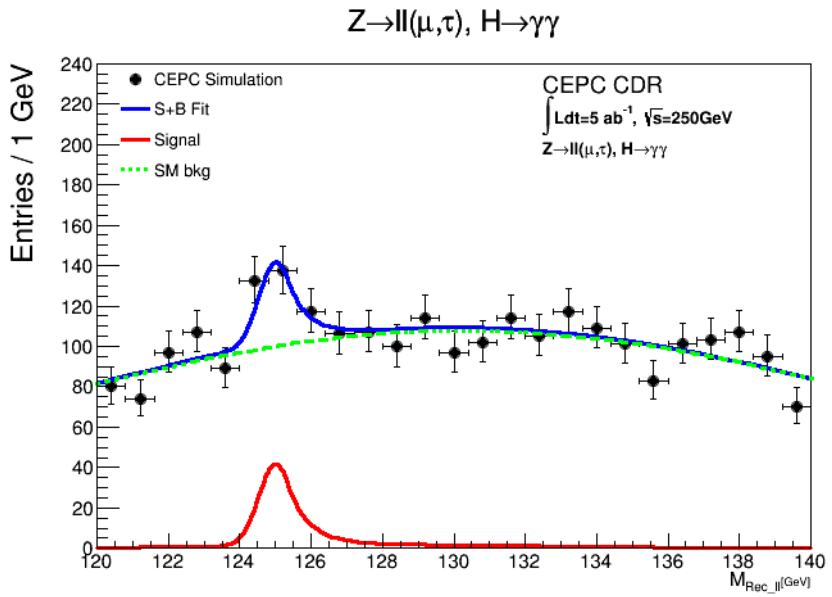
- and

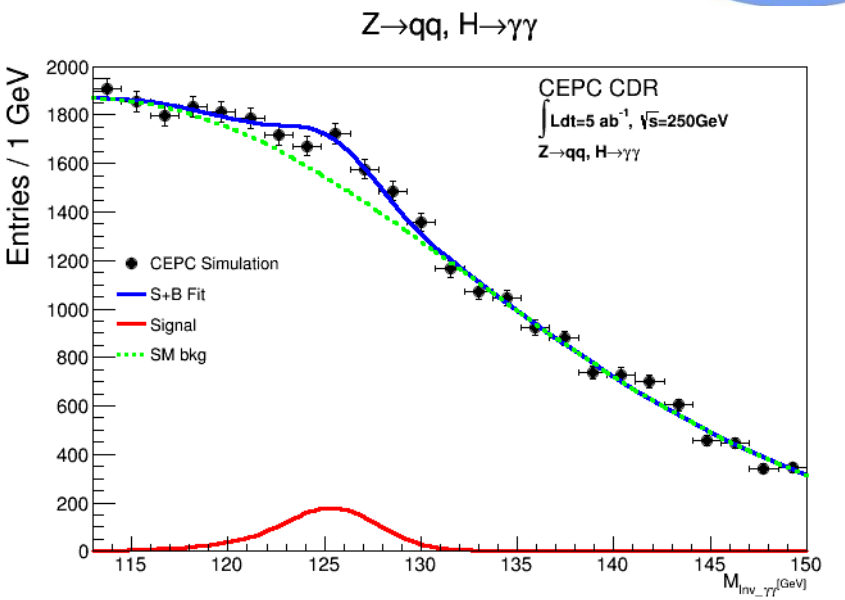
$$\Gamma_H = \frac{\Gamma_{H\to bb}}{Br(H\to bb)} \propto \frac{\sigma(\nu\nu H\to \nu\nu bb)}{Br(H\to bb)Br(H\to WW)} \qquad 3.3\%$$

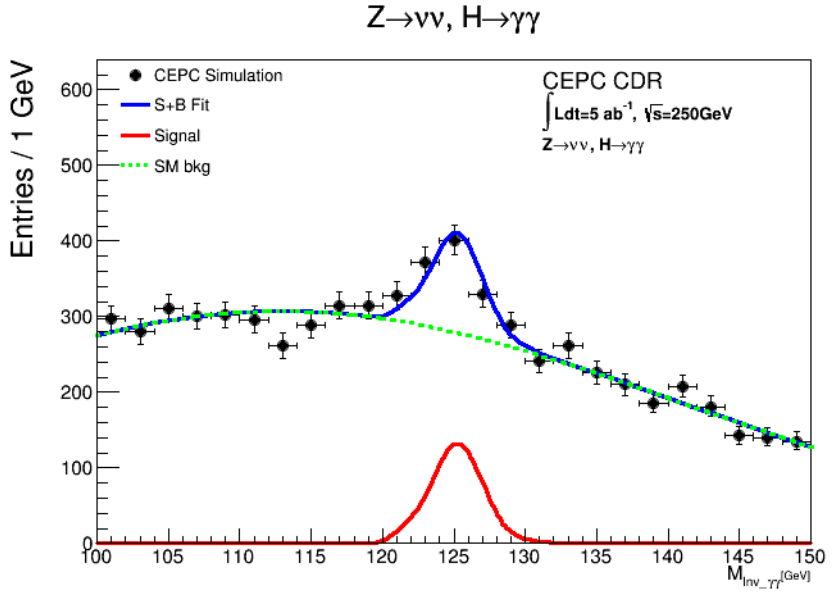
- If two independent: 2.83% (pre_CDR 2.8%)
- Consider correlation, then combine in 10κ framework:

$$\Delta(\Gamma_H) = 3.1\%$$

$\gamma\gamma$ plots







Change fit functions

- Now fit shapes better than before.

Change plot style

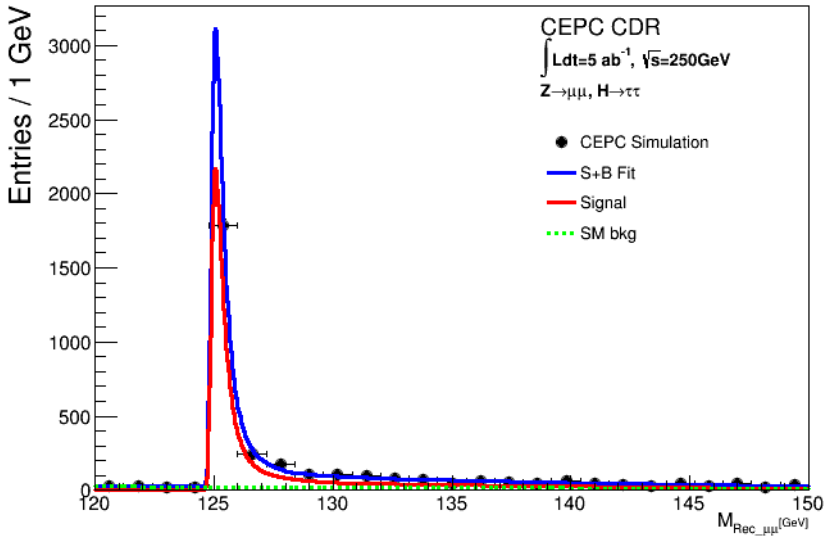
- Now black dot stands for MC total data.
- Legend & CEPC logo
- Less points, X-axis error bar

Please comment if any other demands

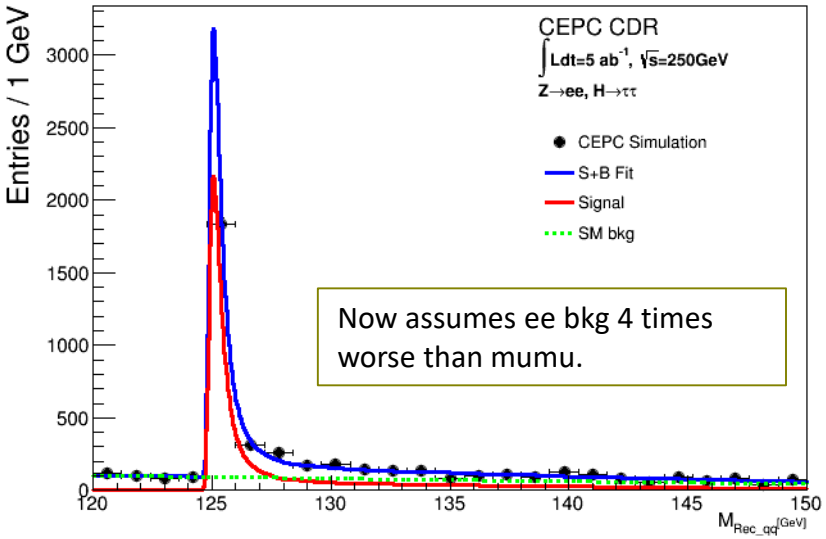
$\tau\tau$ plots

These plots just for demonstration, Dan didn't use this to fit the result.
(Using Impact parameter)

$Z \to \mu\mu, H \to \tau\tau$

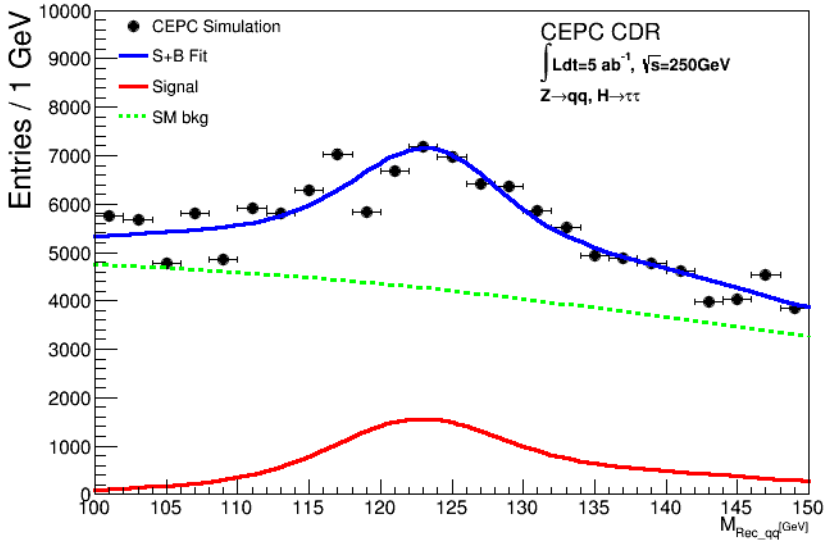


$Z \to ee, H \to \tau\tau$

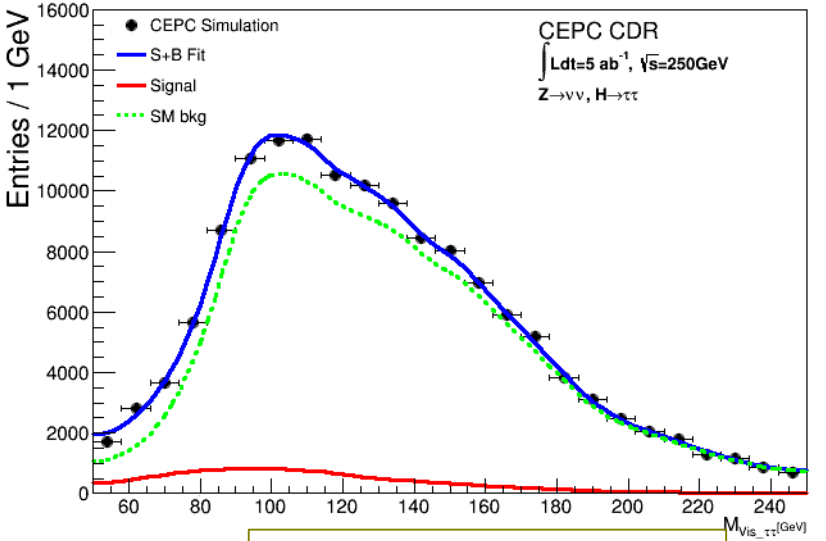


Now assumes ee bkg 4 times worse than mumu.

$Z \to qq, H \to \tau\tau$

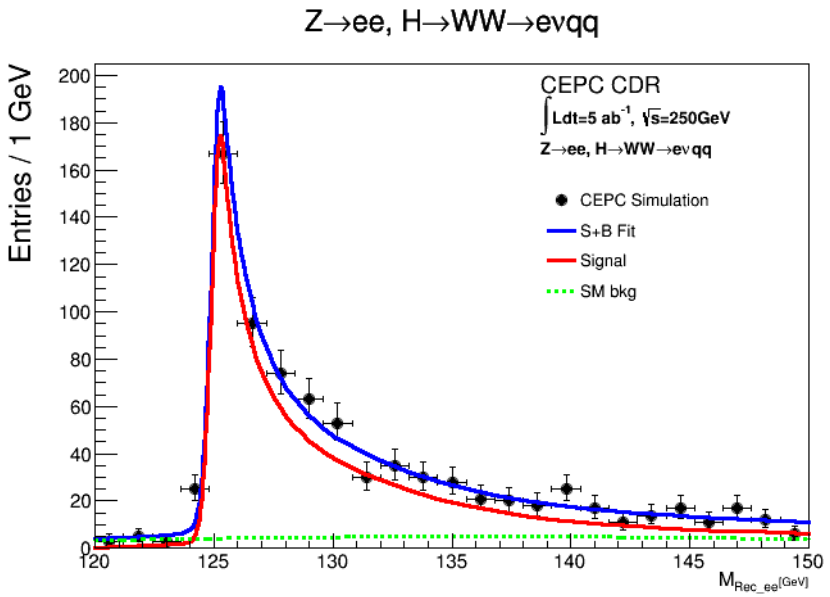


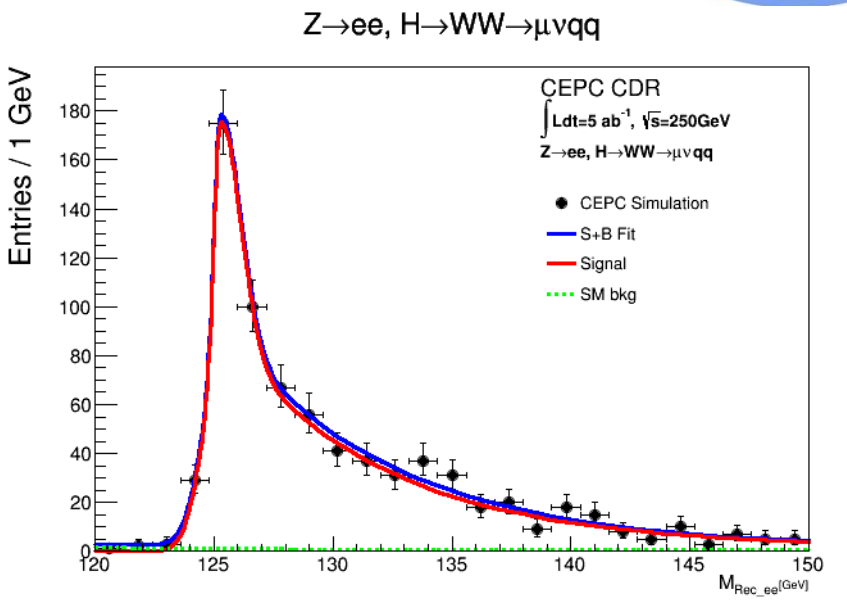
$Z \to \nu\nu, H \to \tau\tau$

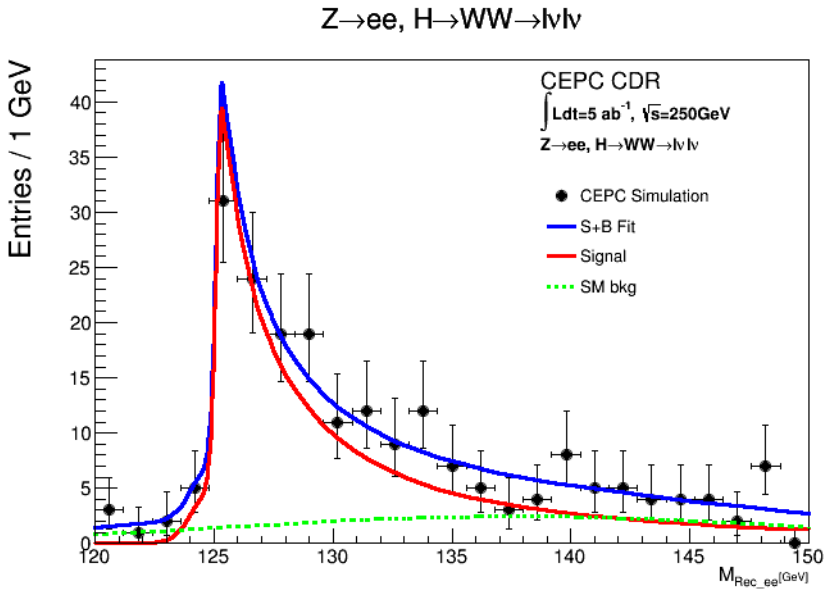


Visible Mass from 2 tau
Bkg shape from RooKeysPdf

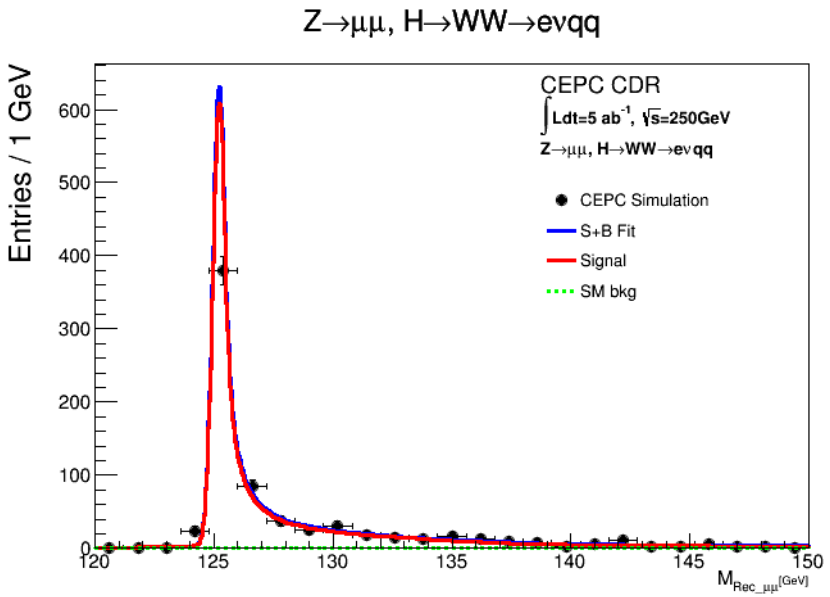
WW plots

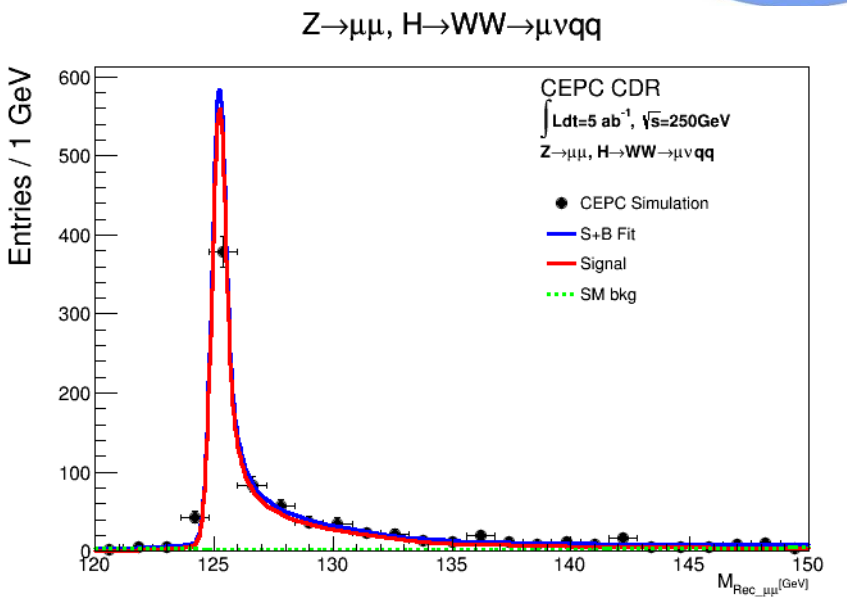

Z→ee, H→WW→evqq
CEPC CDR
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→WW→evqq
CEPC Simulation
S+B Fit
Signal
SM bkg
Entries / 1 GeV
M_Rec_ee[GeV]

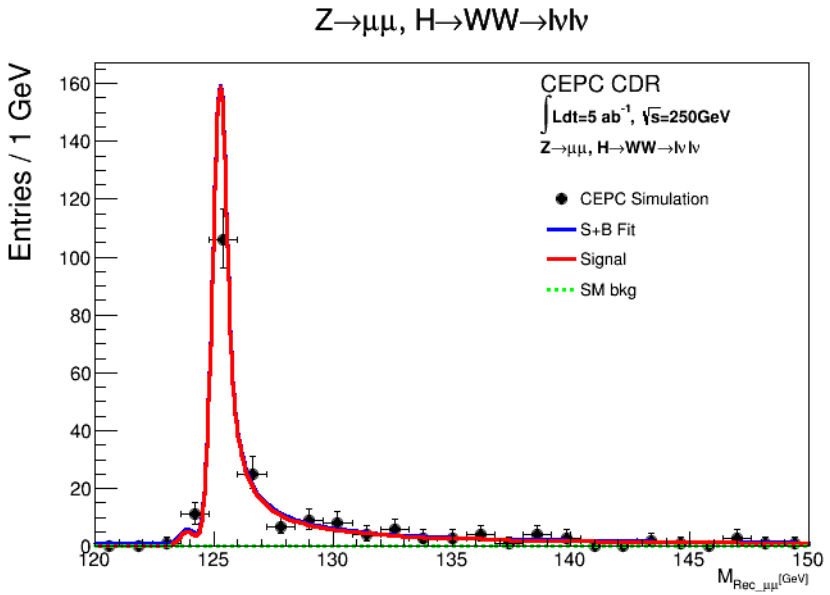

Z→ee, H→WW→μνqq
CEPC CDR
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→WW→μνqq
CEPC Simulation
S+B Fit
Signal
SM bkg
Entries / 1 GeV
M_Rec_ee[GeV]

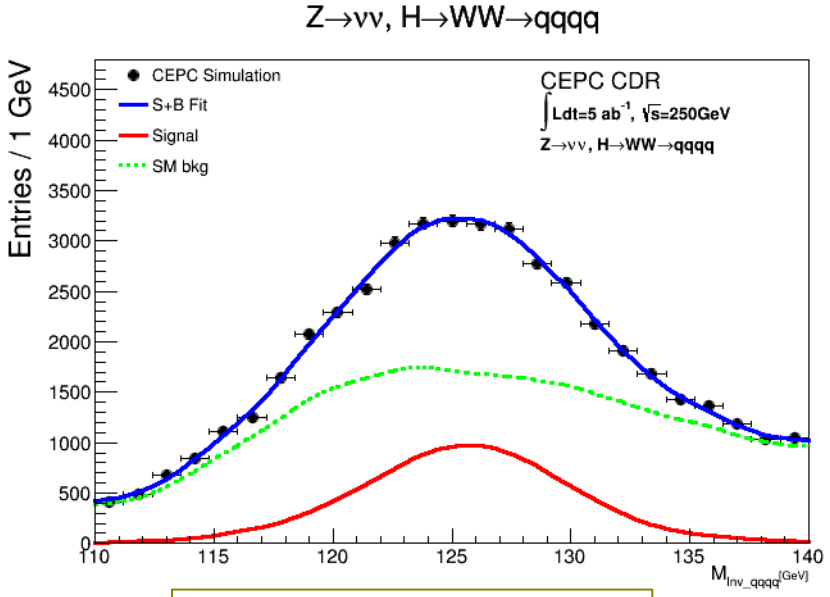

Z→ee, H→WW→lνlν
CEPC CDR
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→WW→lνlν
CEPC Simulation
S+B Fit
Signal
SM bkg
Entries / 1 GeV
M_Rec_ee[GeV]

WW plots





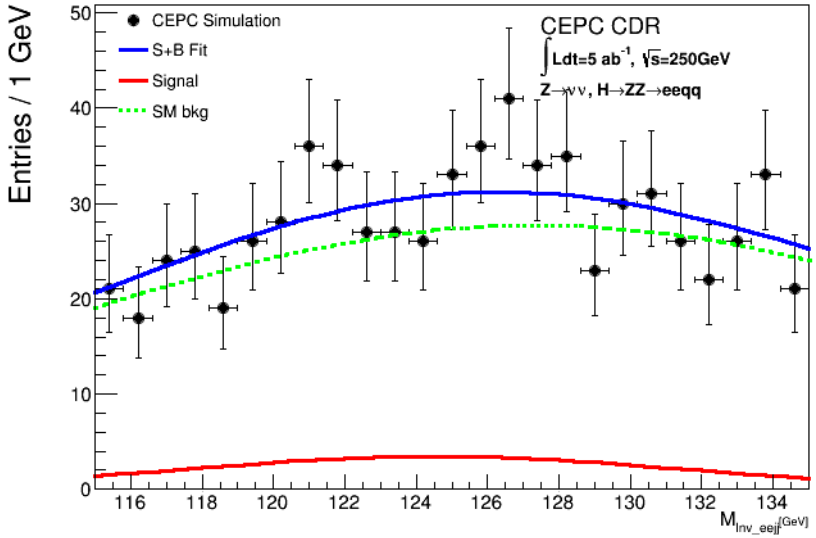




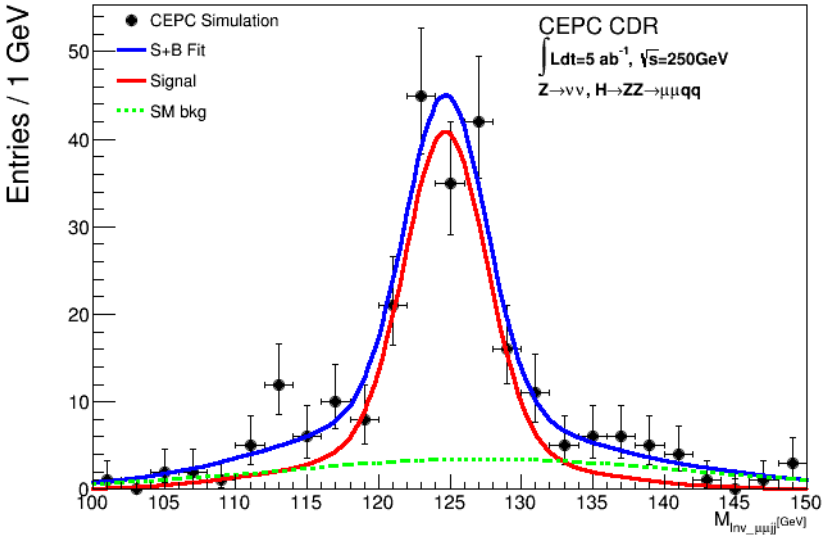
Bkg shape from RooKeysPdf

ZZ plots

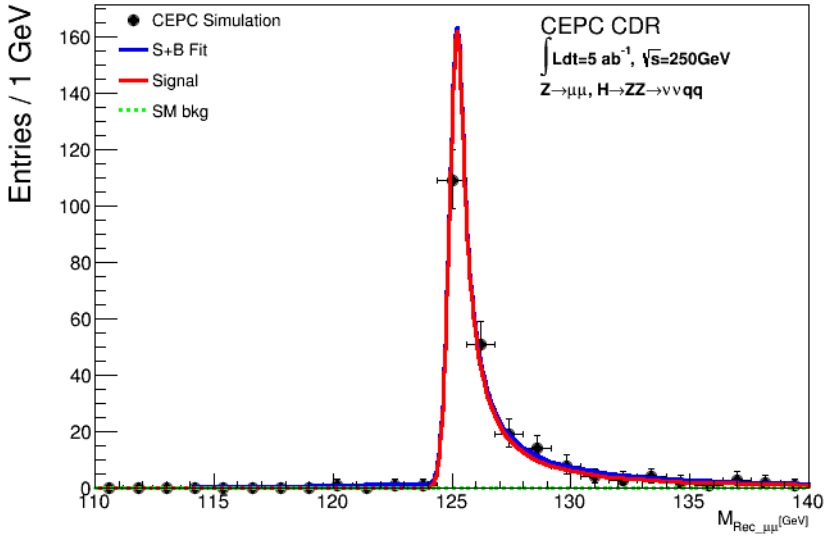
Z→νν, H→ZZ→eeqq



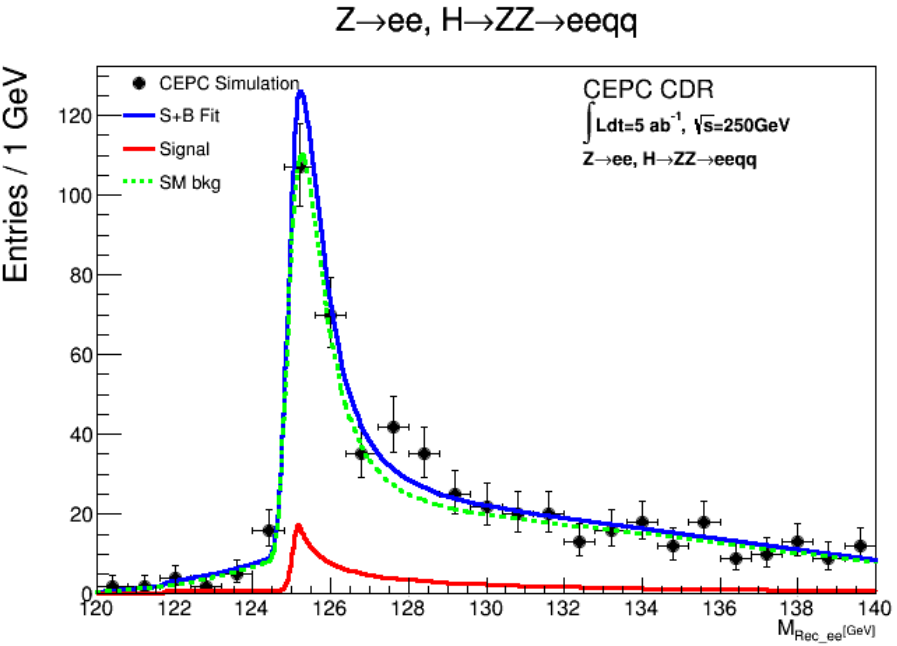
Z→νν, H→ZZ→μμqq

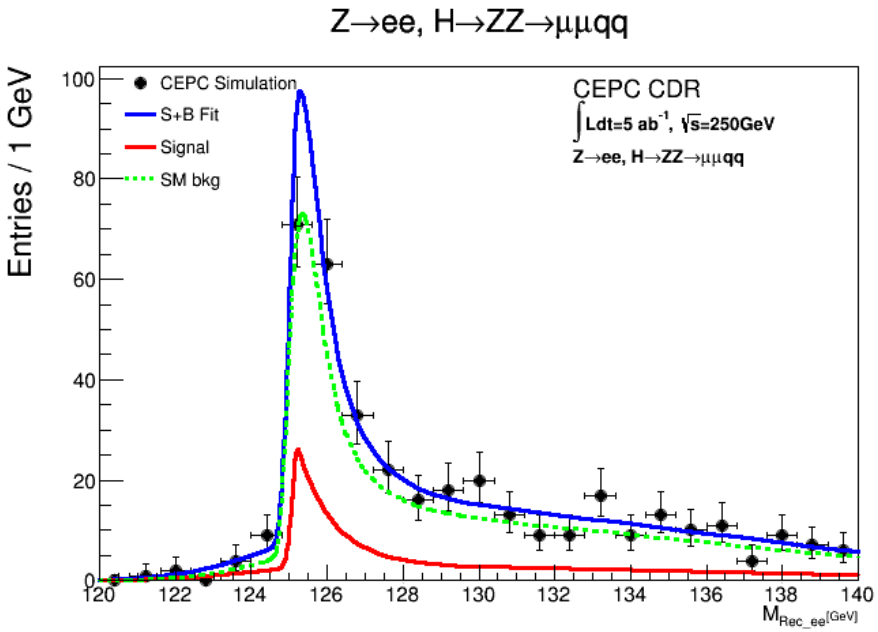


Z→μμ, H→ZZ→ννqq

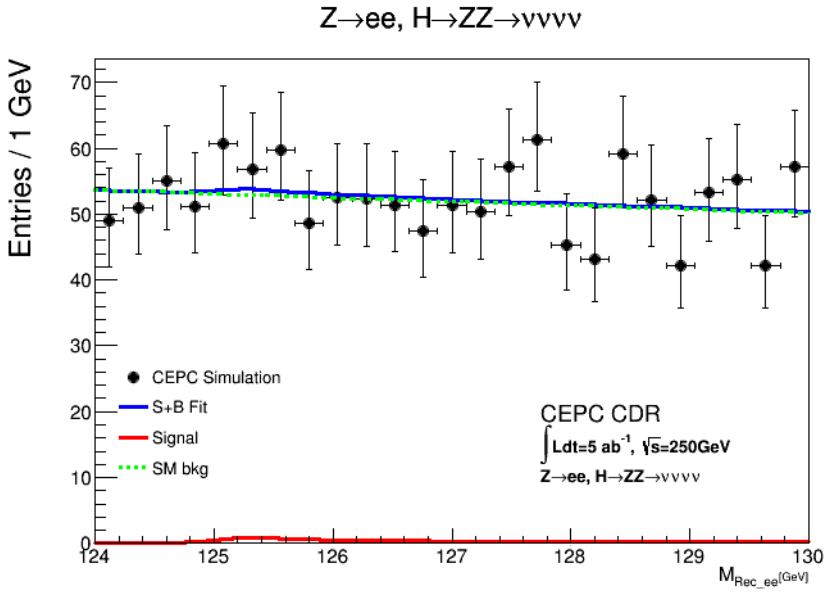


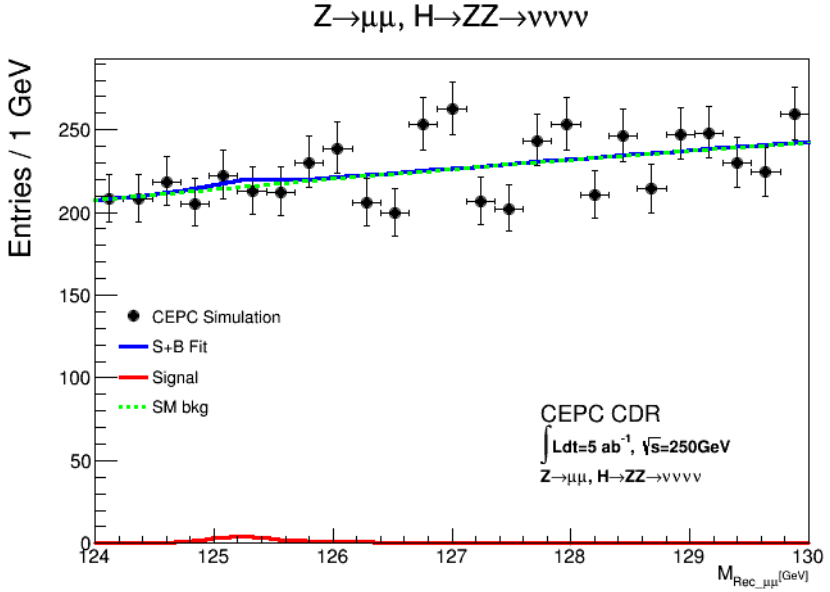
ZZ plot

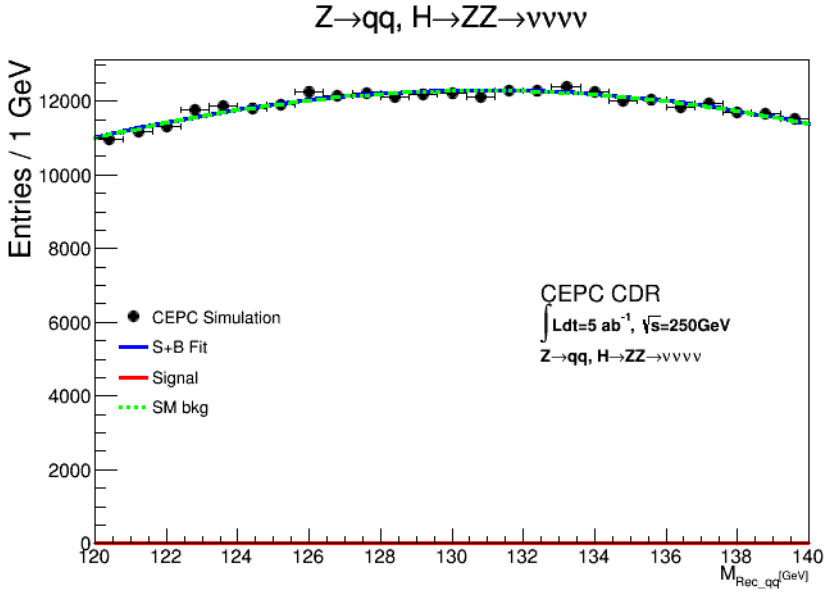

Z→ee, H→ZZ→eeqq
CEPC Simulation
S+B Fit
Signal
SM bkg
CEPC CDR
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→eeqq
Entries / 1 GeV
M Rec_ee [GeV]


Z→ee, H→ZZ→μμqq
CEPC Simulation
S+B Fit
Signal
SM bkg
CEPC CDR
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→μμqq
Entries / 1 GeV
M Rec_ee [GeV]

Invisible channel

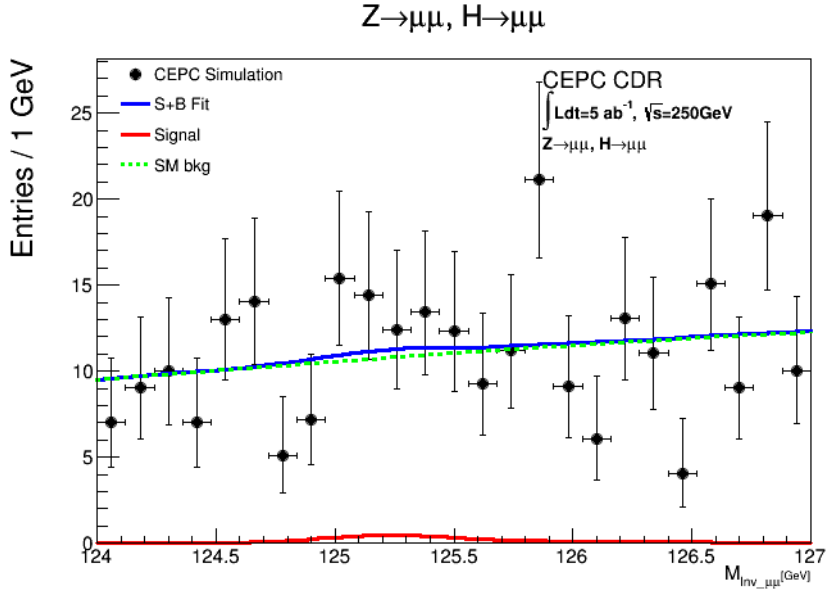


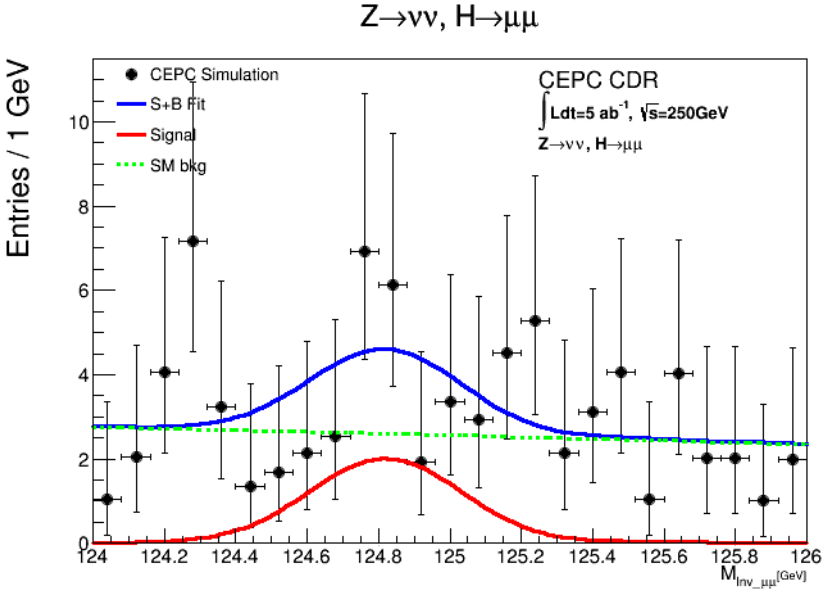


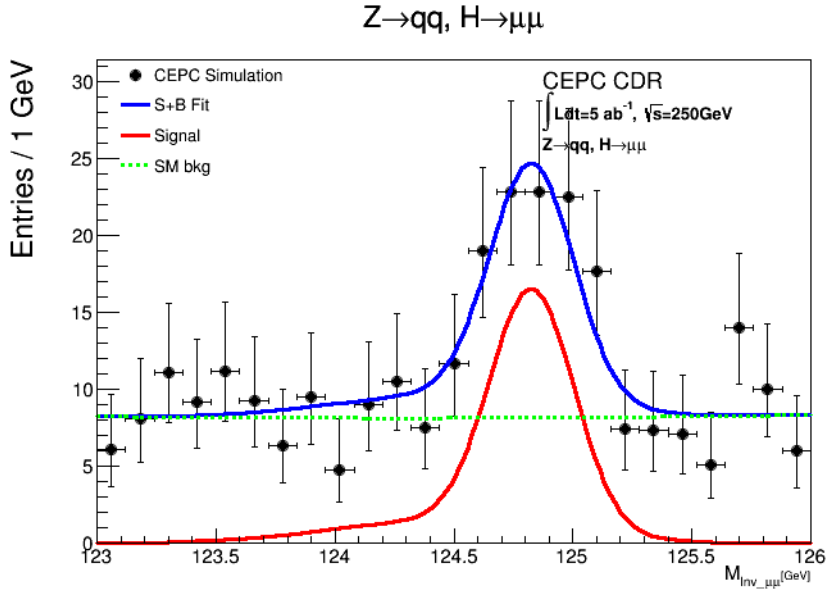


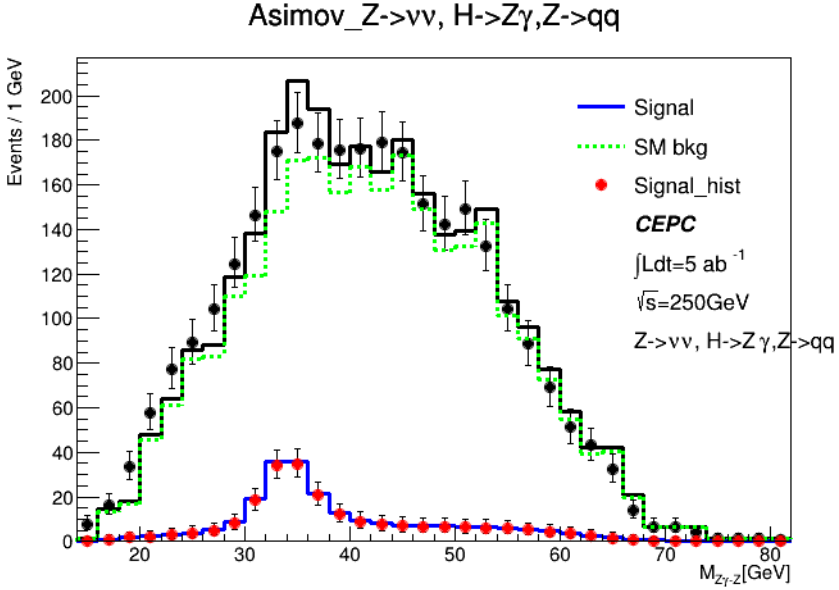
Precision of Br*CrossX:	158%
Upper limit of Br:	0.24%
Br:	$0.103\% \pm 0.075\%$

$\mu\mu$, $Z\gamma$ channel









$Z\gamma$ from Weimin, binned fit

Fit results

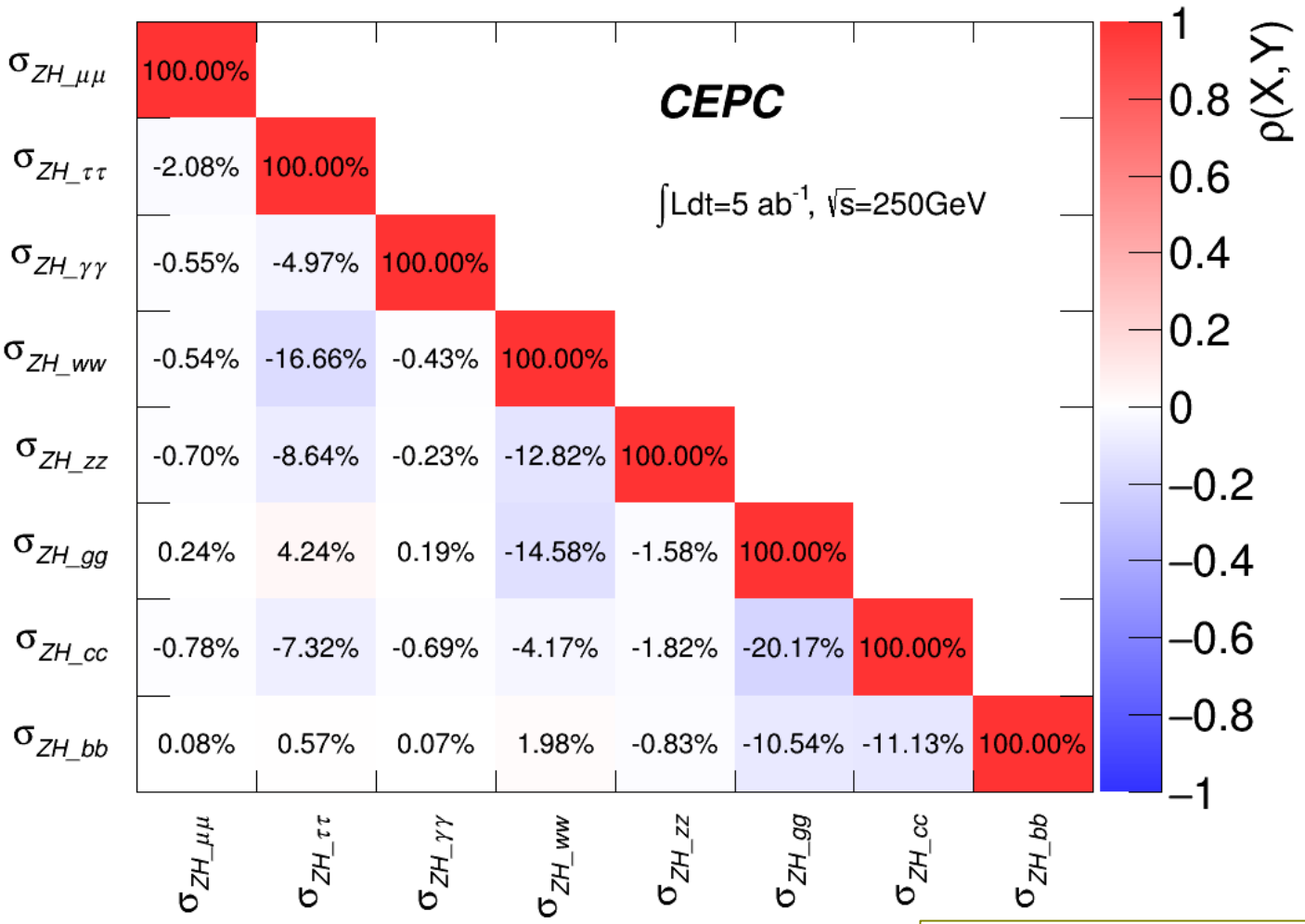
(5ab^{-1})	Pre_CDR	Current
$\sigma(ZH)$	0.51%	0.50%
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	0.28%	$^{+0.27\%}_{-0.27\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{cc})$	2.2%	$^{+3.46\%}_{-3.44\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	1.6%	$^{+1.44\%}_{-1.44\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{WW})$	1.5%	$^{+1.20\%}_{-1.20\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{ZZ})$	4.3%	$^{+5.25\%}_{-5.10\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \tau\tau)$	1.2%	$^{+1.34\%}_{-1.34\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	9.0%	$^{+8.20\%}_{-8.12\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mu\mu)$	17%	$^{+15.8\%}_{-14.9\%}$
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	2.8%	$^{+3.12\%}_{-3.11\%}$
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \to \mathrm{inv.})$	0.28%	0.24%
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	\	$4\sigma(^{+21.0\%}_{-21.4\%})$

	10κ	Pre_CDR	7κ	Pre_CDR
κ_b	1.5%	1.3%	1.2%	1.2%
κ_c	2.4%	1.7%	2.2%	1.6%
κ_g	1.6%	1.5%	1.5%	1.5%
κ_γ	4.4%	4.7%	4.3%	4.7%
κ_τ	1.6%	1.4%	1.4%	1.3%
κ_Z	0.25%	0.26%	0.13%	0.16%
κ_W	1.4%	1.2%	1.2%	1.2%
κ_μ	7.9%	8.6%		
Br_{inv}	0.24%	0.28%		
Γ_H	3.1%	2.8%		

From 10κ to 7κ, we assume
- No exotic decay Γ_{BSM}
- Drop Br_{inv}
- κ_μ=κ_τ

10Kappa from Zhen, 7Kappa from Mine;

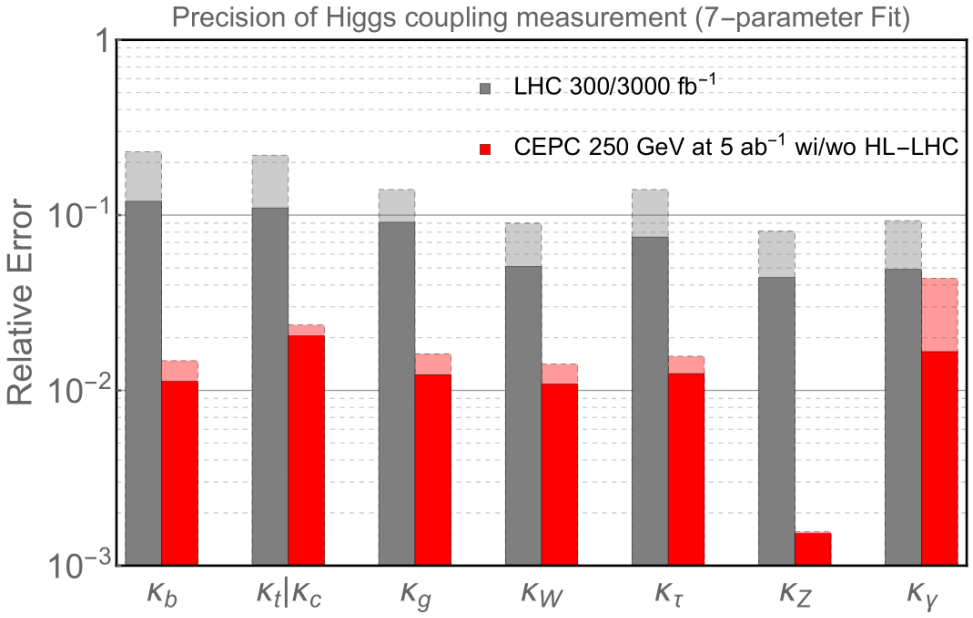
Correlations in channel

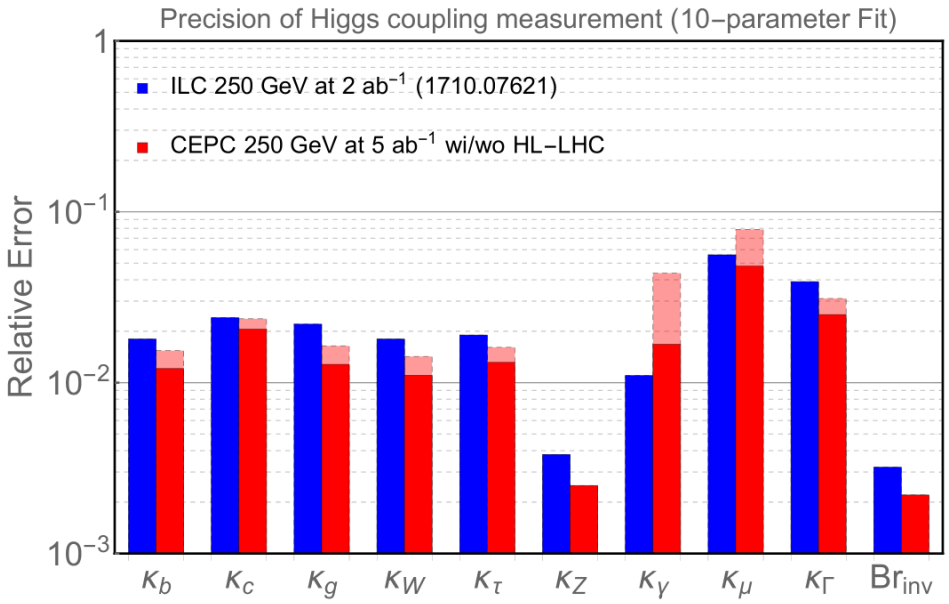


bb/cc/gg correlated because template fit;
Other are linked by ZH bkg events.

κ with HL-LHC, ILC

HL-LHC: ATL-PHYS-PUB-2014-016
ILC: 1710.07621





Correlation of κ, From Zhen

The implication, under discussing;

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

7–parameter fit Correlation

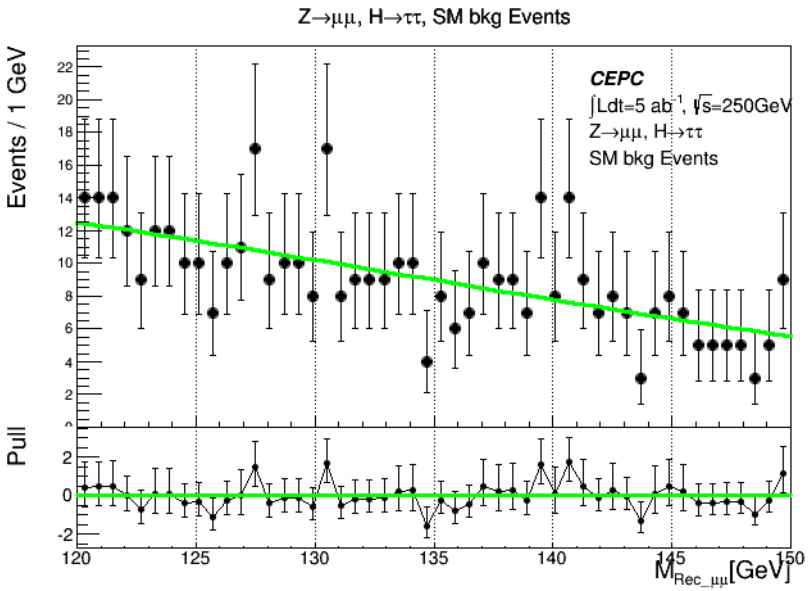
	κ_b	κ_c	κ_g	κ_W	κ_τ	κ_Z	κ_γ
κ_b	100.	−25. −23.	−51. −51.	−74. −70.	−47. −46.	62. 59.	−8.7 −3.4
κ_c	−25. −23.	100.	−7.1 −12.	11. 11.	2.4 2.4	−24. −23.	1.1 0.42
κ_g	−51. −51.	−7.1 −12.	100.	14. 7.0	1.6 −0.91	−28. −17.	1.1 0.15
κ_W	−74. −70.	11. 11.	14. 7.0	100.	3.5 3.8	−60. −61.	2.2 0.89
κ_τ	−47. −46.	2.4 2.4	1.6 −0.91	3.5 3.8	100.	−12. −12.	−1.1 −0.42
κ_Z	62. 59.	−24. −23.	−28. −17.	−60. −61.	−12. −12.	100.	−4.0 −7.5
κ_γ	−8.7 −3.4	1.1 0.42	1.1 0.15	2.2 0.89	−1.1 −0.42	−4.0 −7.5	100.

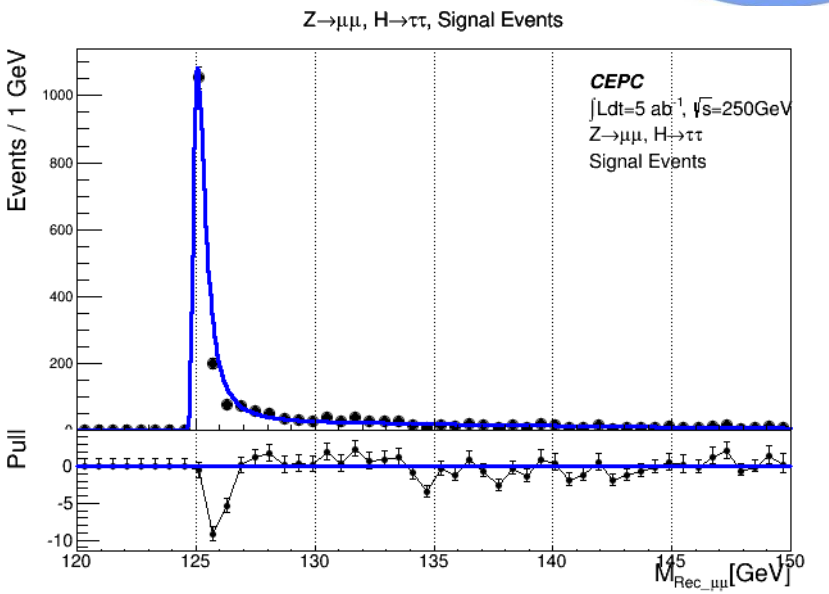
10–parameter fit Correlation

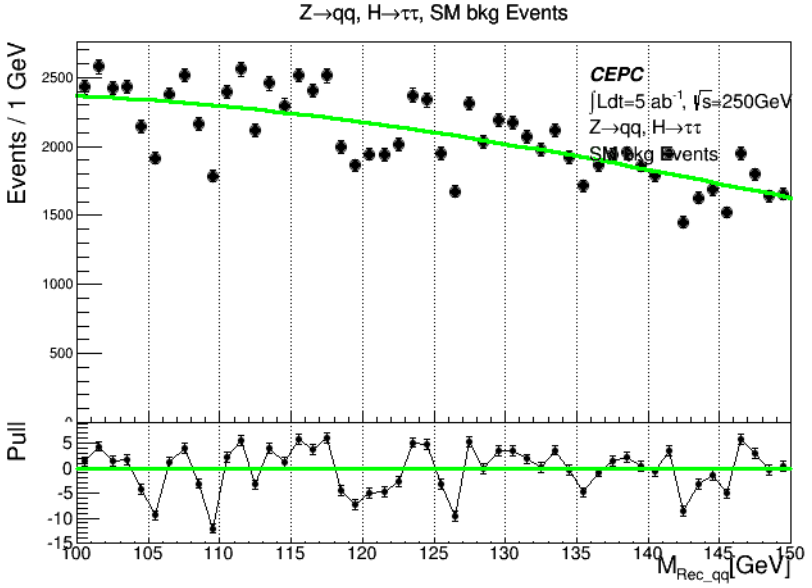
	κ_b	κ_c	κ_g	κ_W	κ_τ	κ_Z	κ_γ	κ_μ	Br_{inv}	κ_Γ
κ_b	100.	3.7 3.5	−0.24 −0.19	−13. −12.	<0.1 <0.1	84. 83.	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−94. −93.
κ_c	3.7 3.5	100.	−16. −16.	−9.1 −8.3	0.13 0.13	6.6 6.2	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−6.8 −6.4
κ_g	−0.24 −0.19	−16. −16.	100.	−7.2 −5.6	0.45 0.36	13. 16.	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−15. −19.
κ_W	−13. −12.	−9.1 −8.3	−7.2 −5.6	100.	−5.5 −5.3	1.3 −0.16	−0.85 −0.33	−0.34 −0.20	<0.1 <0.1	−4.9 −4.7
κ_τ	<0.1 <0.1	0.13 0.13	0.45 0.36	−5.5 −5.3	100.	16. 16.	−1.1 −0.45	−0.47 −0.29	<0.1 <0.1	−19. −19.
κ_Z	84. 83.	6.6 6.2	13. 16.	1.3 −0.16	16. 16.	100.	2.4 −4.8	1.3 −0.65	<0.1 <0.1	−89. −89.
κ_γ	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−0.85 −0.33	−1.1 −0.45	2.4 −4.8	100.	<0.1 <0.1	<0.1 <0.1	−2.8 −1.1
κ_μ	<0.1 <0.1	<0.1 <0.1	<0.1 <0.1	−0.34 −0.20	−0.47 −0.29	1.3 −0.65	<0.1 <0.1	100.	<0.1 <0.1	−1.5 −0.93
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	−94. −93.	−6.8 −6.4	−15. −19.	−4.9 −4.7	−19. −19.	−89. −89.	−2.8 −1.1	−1.5 −0.93	<0.1 <0.1	100.

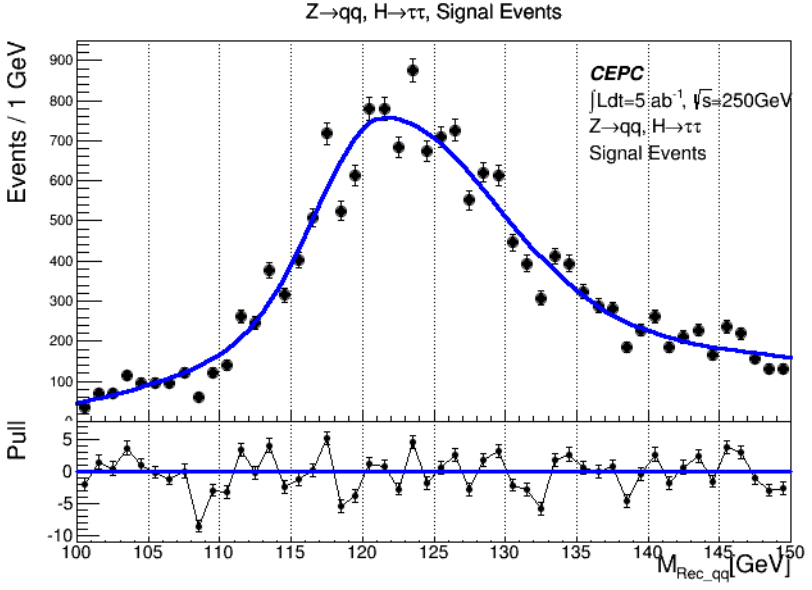
Backup

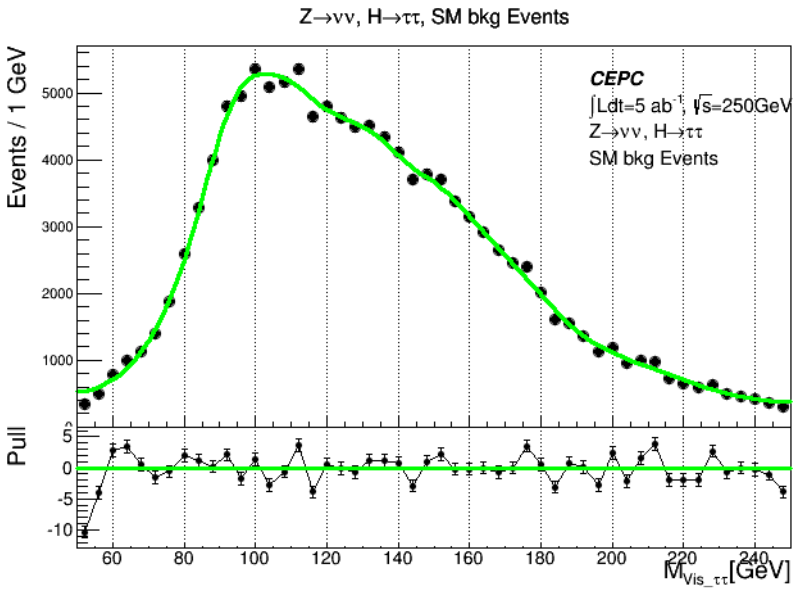
Signal & Bkg plot for demonstration

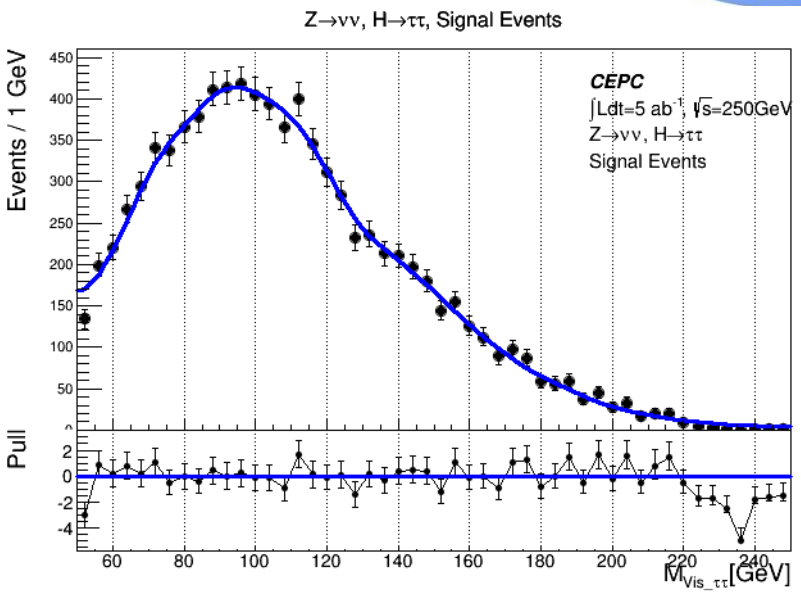

Z→μμ, H→ττ, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→ττ
SM bkg Events
Events / 1 GeV
Pull
M Rec_μμ [GeV]

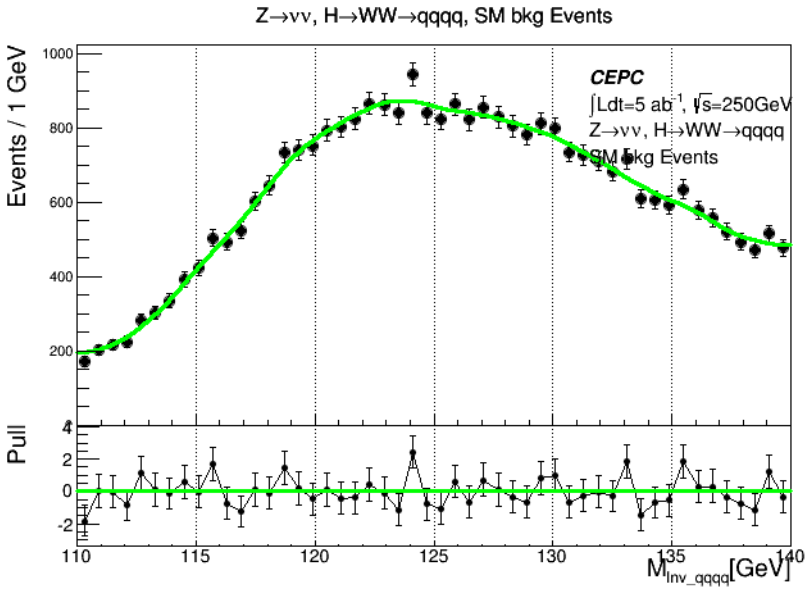

Z→μμ, H→ττ, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→ττ
Signal Events
Events / 1 GeV
Pull
M Rec_μμ [GeV]

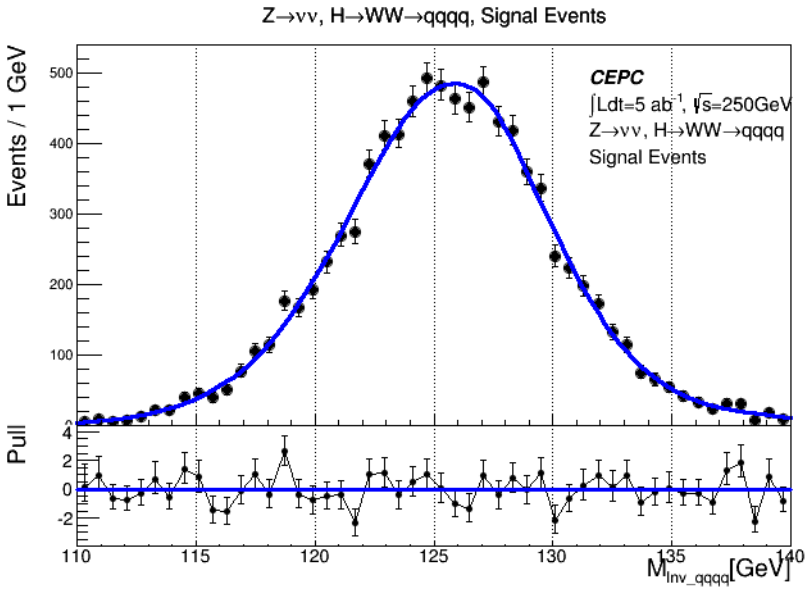

Z→qq, H→ττ, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→qq, H→ττ
SM bkg Events
Events / 1 GeV
Pull
M Rec_qq [GeV]


Z→qq, H→ττ, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→qq, H→ττ
Signal Events
Events / 1 GeV
Pull
M Rec_qq [GeV]

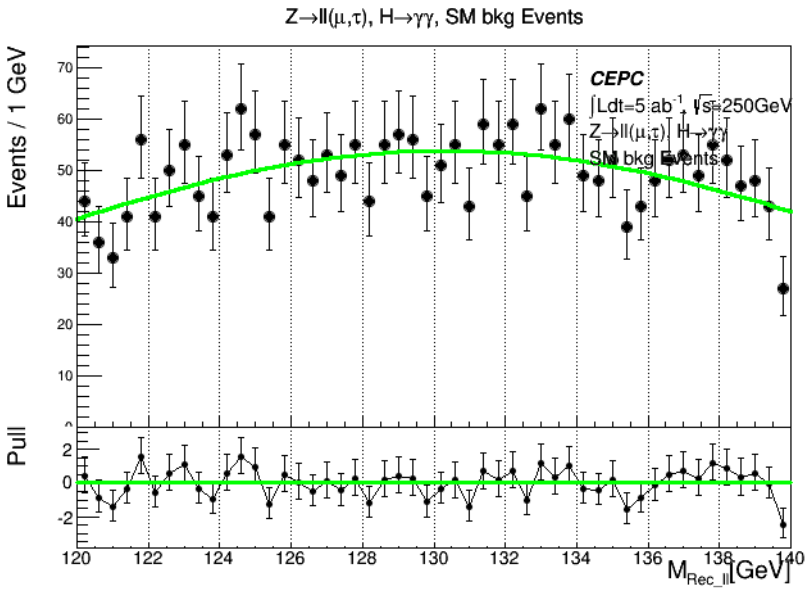


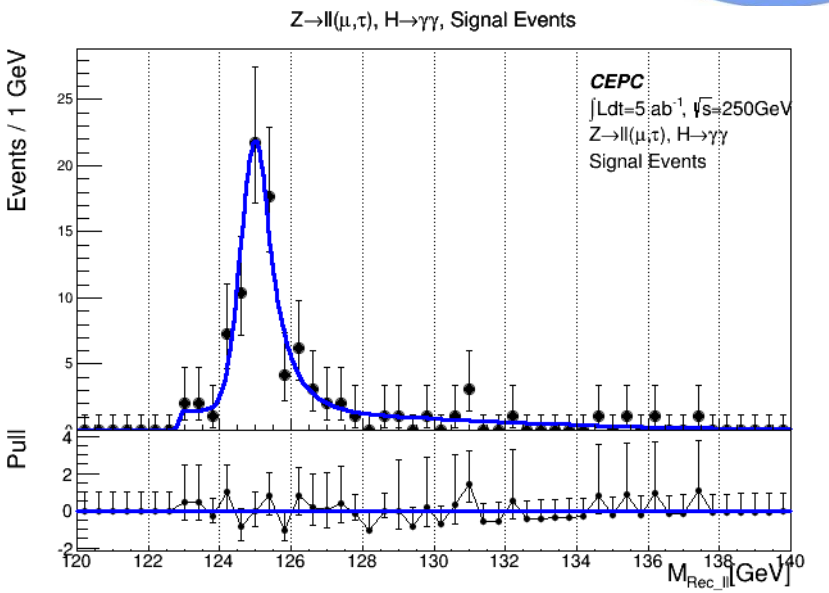


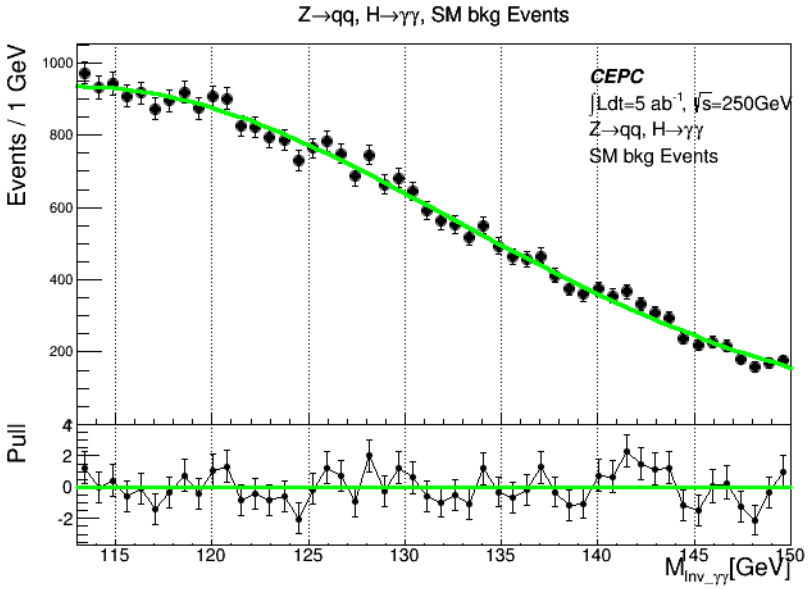


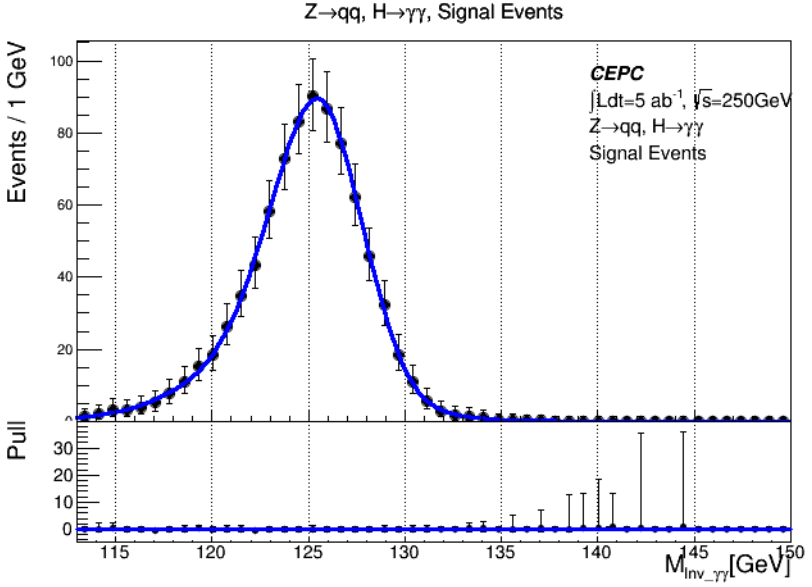


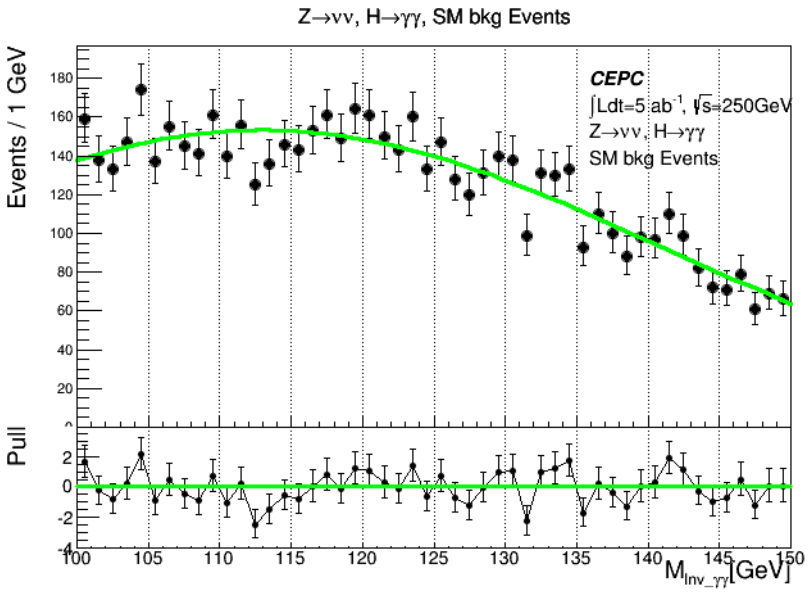
By RooKeysPdf

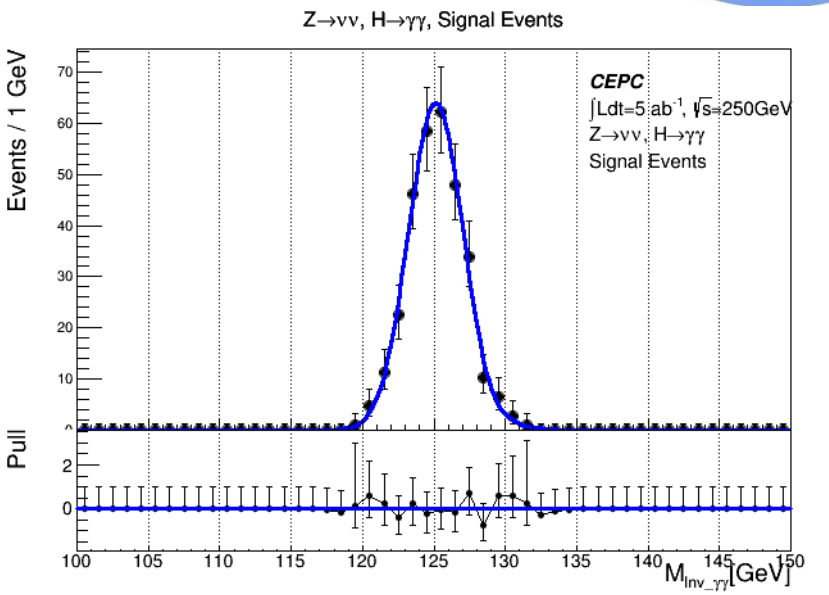

Z→ll(μ,τ), H→γγ, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ll(μ,τ), H→γγ
SM bkg Events
Events / 1 GeV
Pull
M_Rec_ll[GeV]

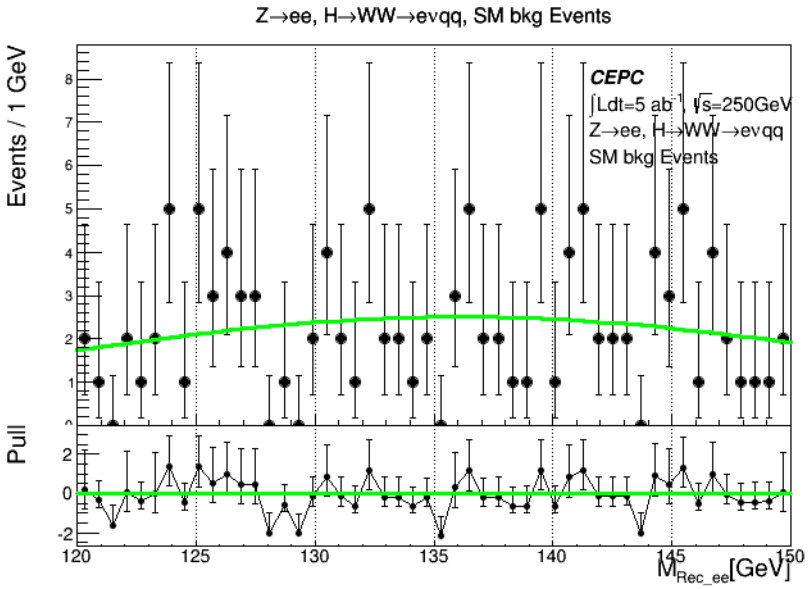

Z→ll(μ,τ), H→γγ, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ll(μ,τ), H→γγ
Signal Events
Events / 1 GeV
Pull
M_Rec_ll[GeV]

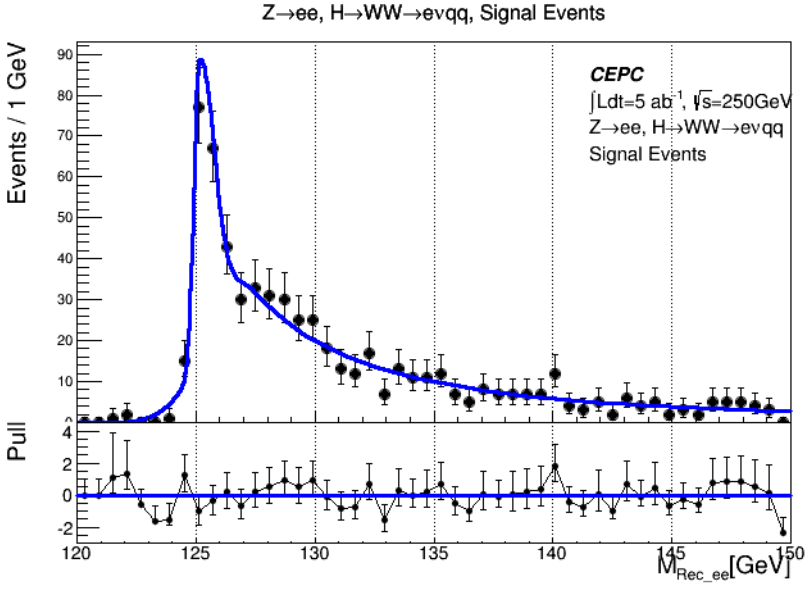

Z→qq, H→γγ, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→qq, H→γγ
SM bkg Events
Events / 1 GeV
Pull
M_Inv_γγ[GeV]

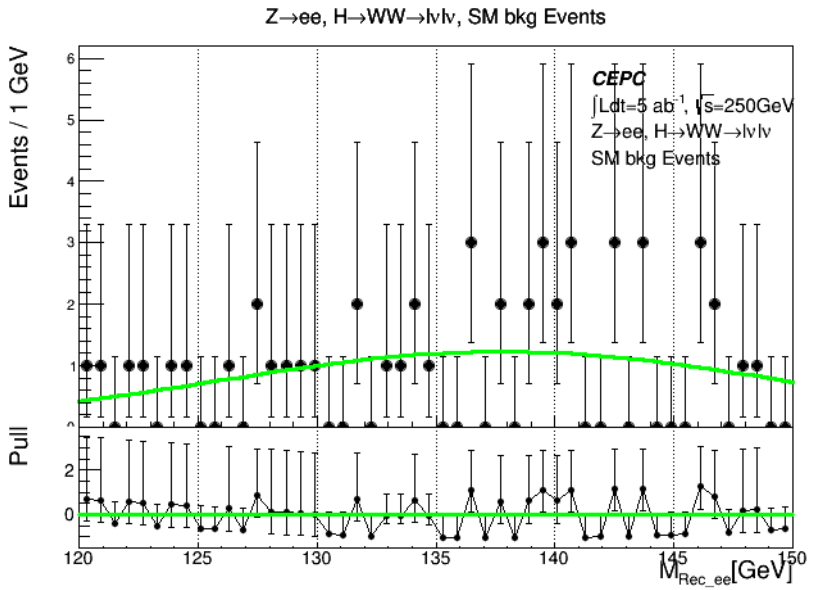

Z→qq, H→γγ, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→qq, H→γγ
Signal Events
Events / 1 GeV
Pull
M_Inv_γγ[GeV]

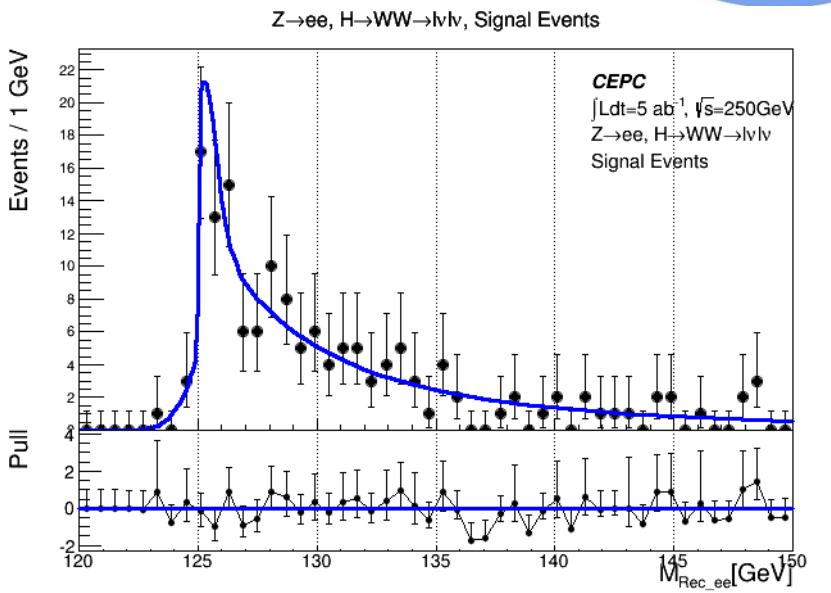

Z→νν, H→γγ, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→νν, H→γγ
SM bkg Events
Events / 1 GeV
Pull
M_Inv_γγ [GeV]

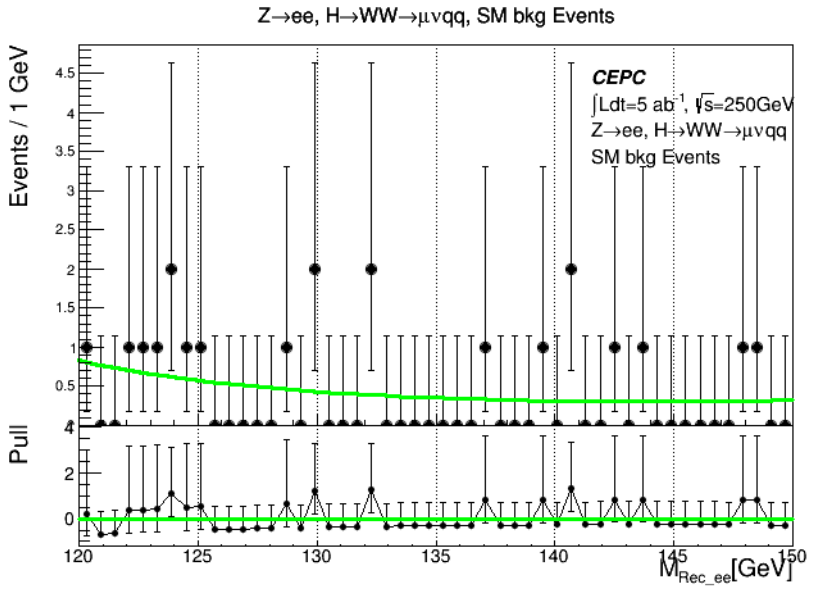

Z→νν, H→γγ, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→νν, H→γγ
Signal Events
Events / 1 GeV
Pull
M_Inv_γγ [GeV]

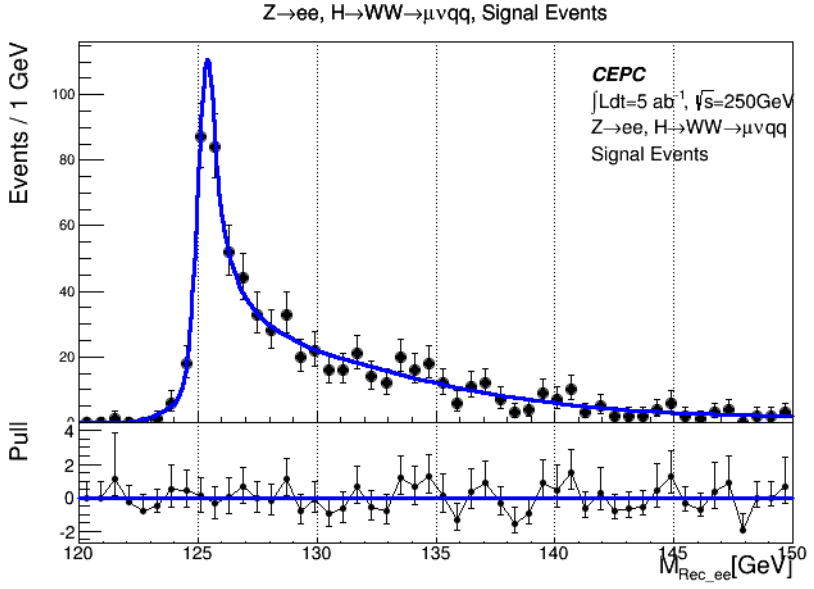

Z→ee, H→WW→evqq, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→WW→evqq
SM bkg Events
Events / 1 GeV
Pull
M_Rec_ee [GeV]


Z→ee, H→WW→evqq, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→WW→evqq
Signal Events
Events / 1 GeV
Pull
M_Rec_ee [GeV]

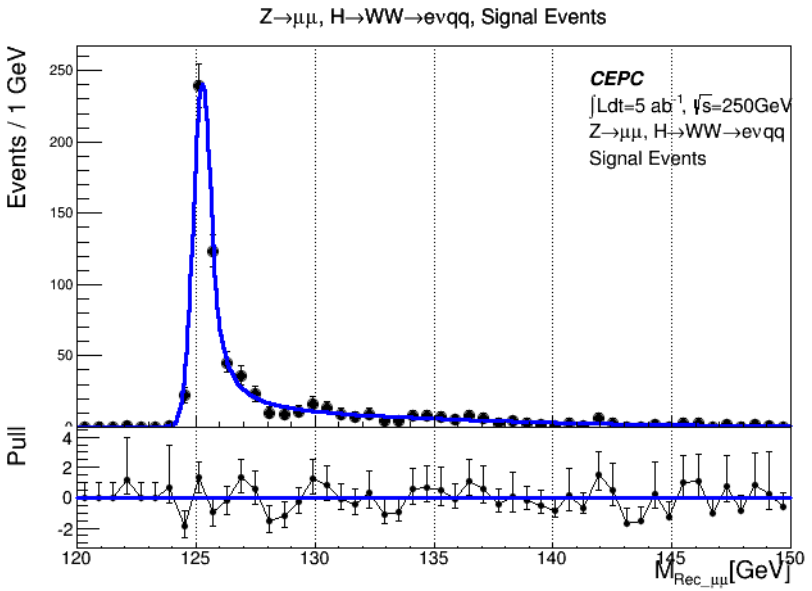


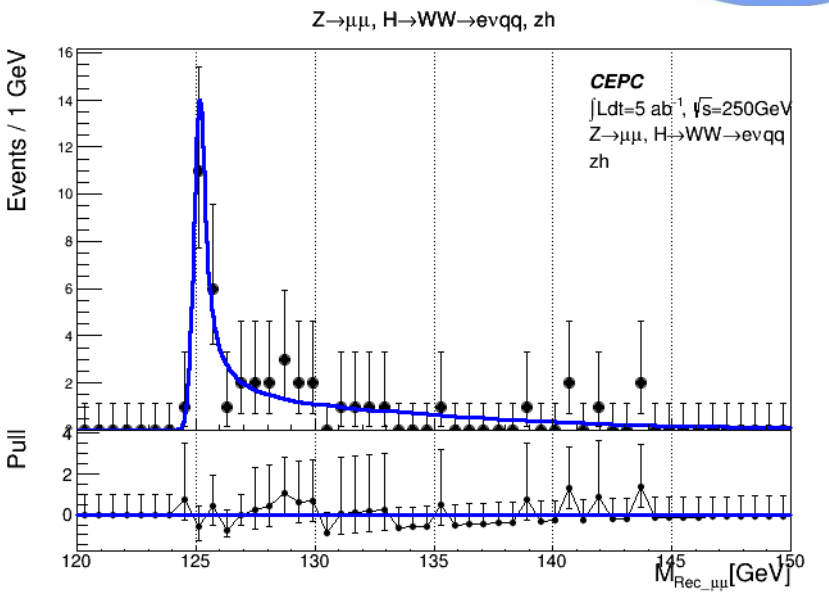


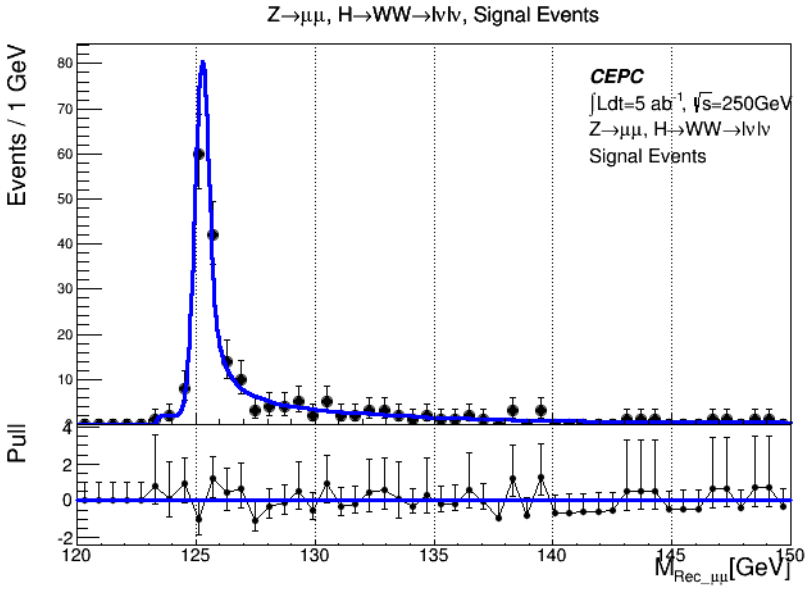


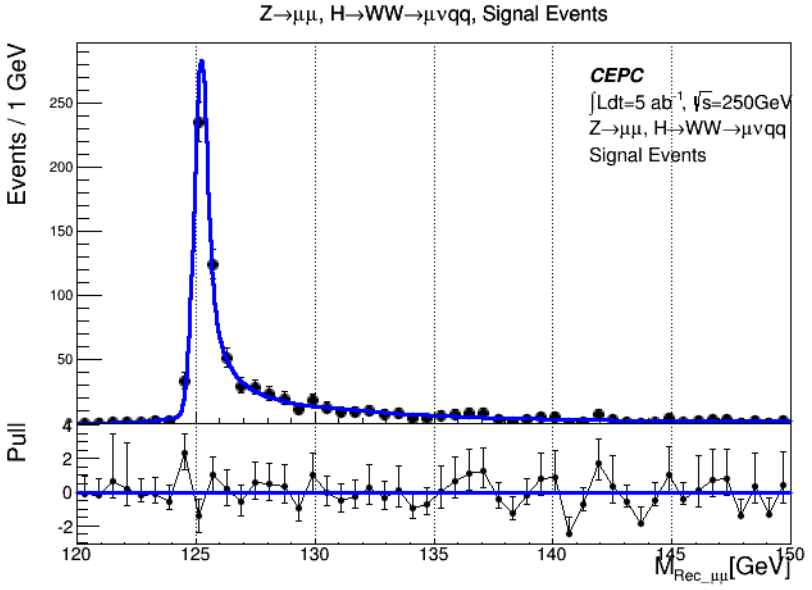


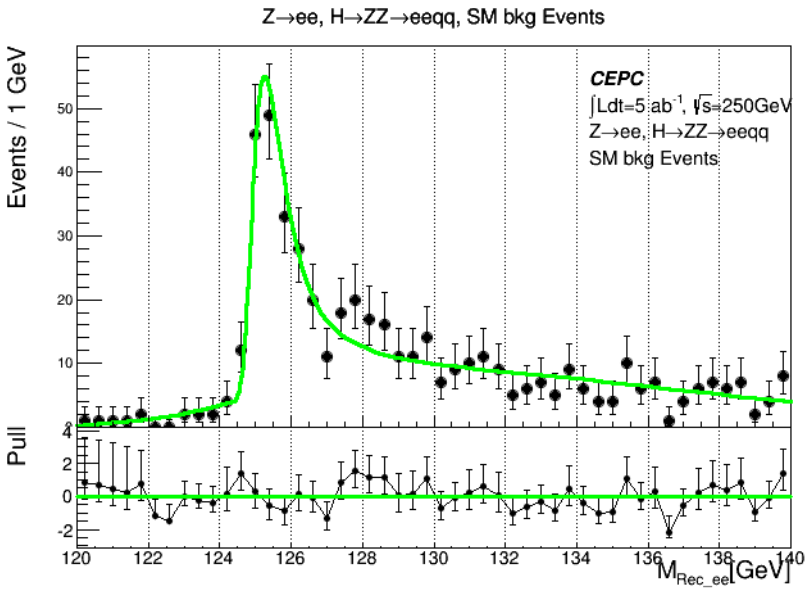
Difficult to fit such low stats events.

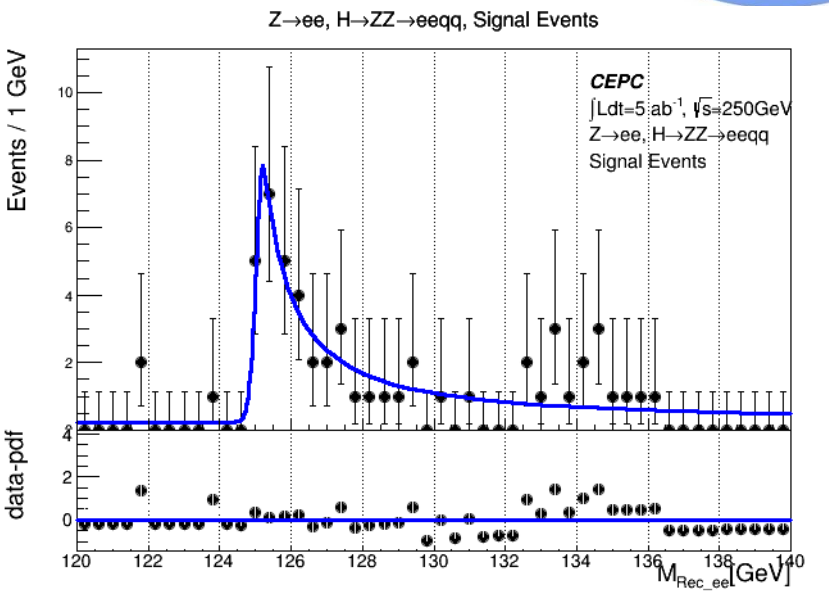

Z→μμ, H→WW→evqq, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→WW→evqq
Signal Events
Events / 1 GeV
Pull
M Rec_μμ [GeV]

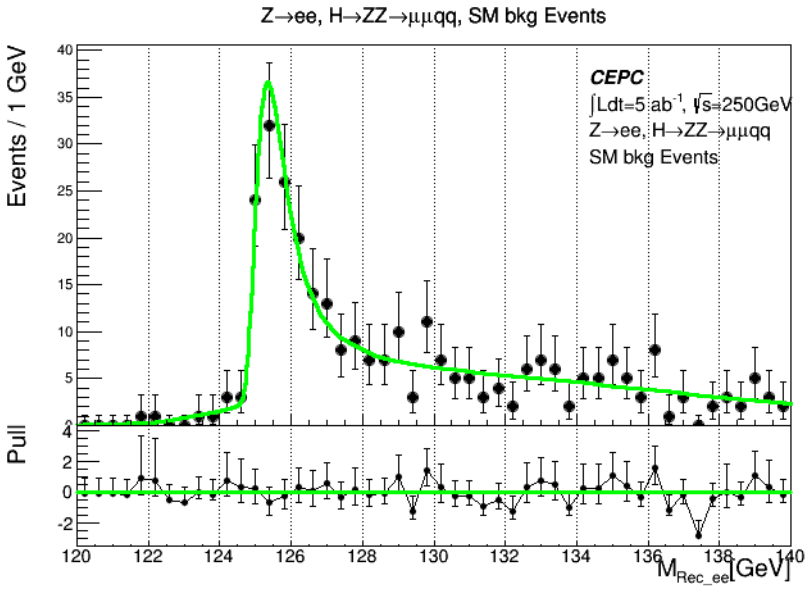

Z→μμ, H→WW→evqq, zh
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→WW→evqq
zh
Events / 1 GeV
Pull
M Rec_μμ [GeV]

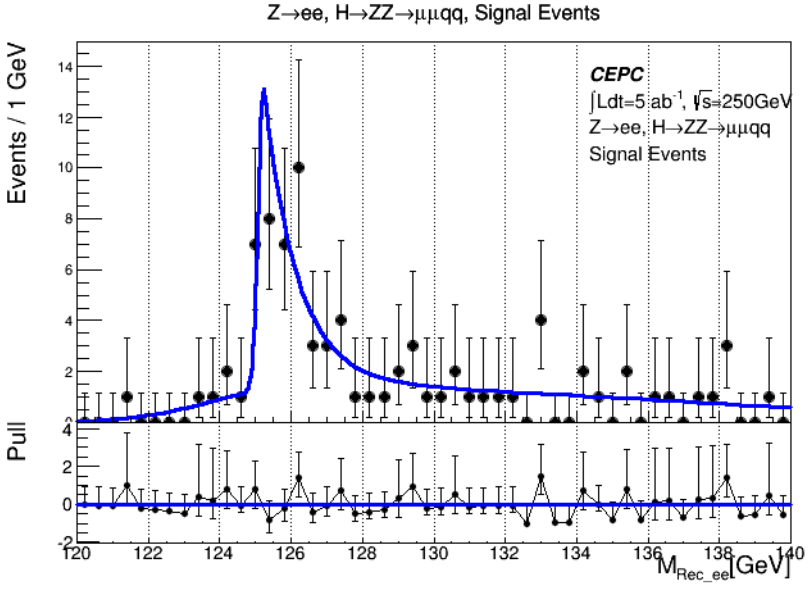

Z→μμ, H→WW→lνlν, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→WW→lνlν
Signal Events
Events / 1 GeV
Pull
M Rec_μμ [GeV]

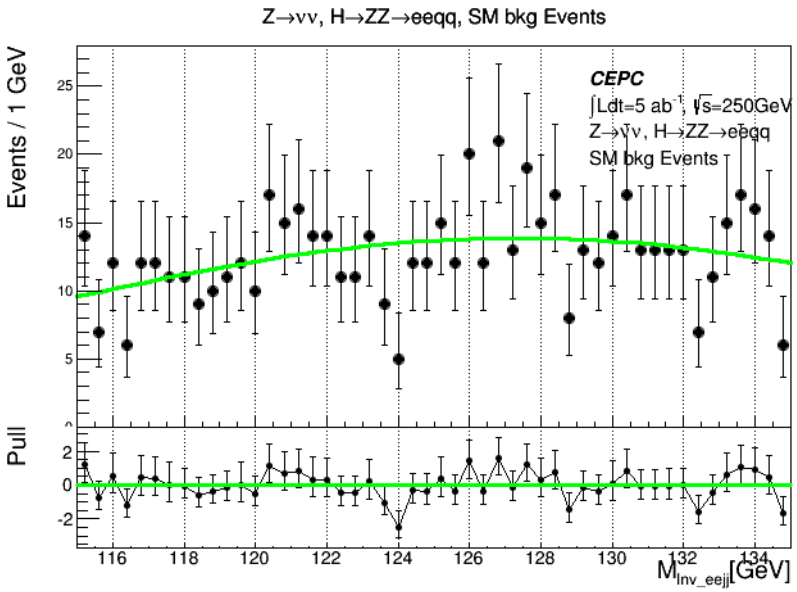

Z→μμ, H→WW→μνqq, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→μμ, H→WW→μνqq
Signal Events
Events / 1 GeV
Pull
M Rec_μμ [GeV]

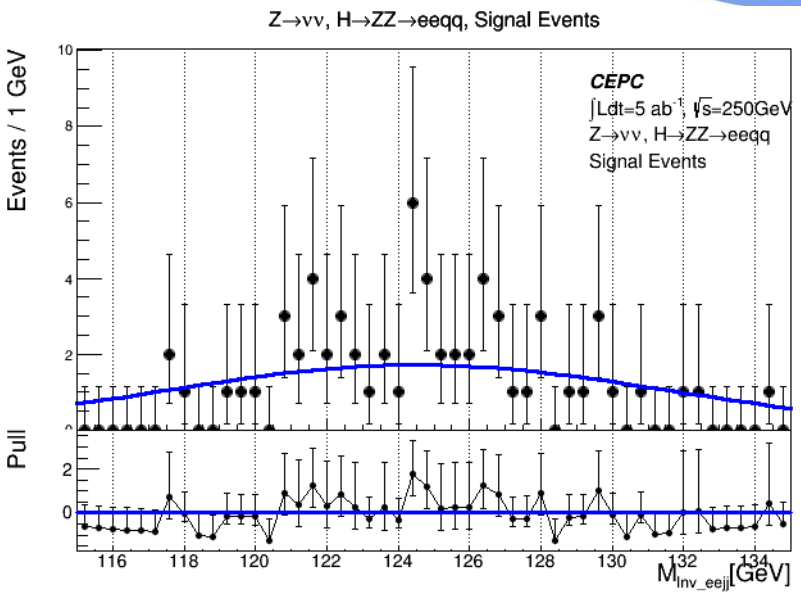

Z→ee, H→ZZ→eeqq, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→eeqq
SM bkg Events
Events / 1 GeV
Pull
MRec_ee[GeV]

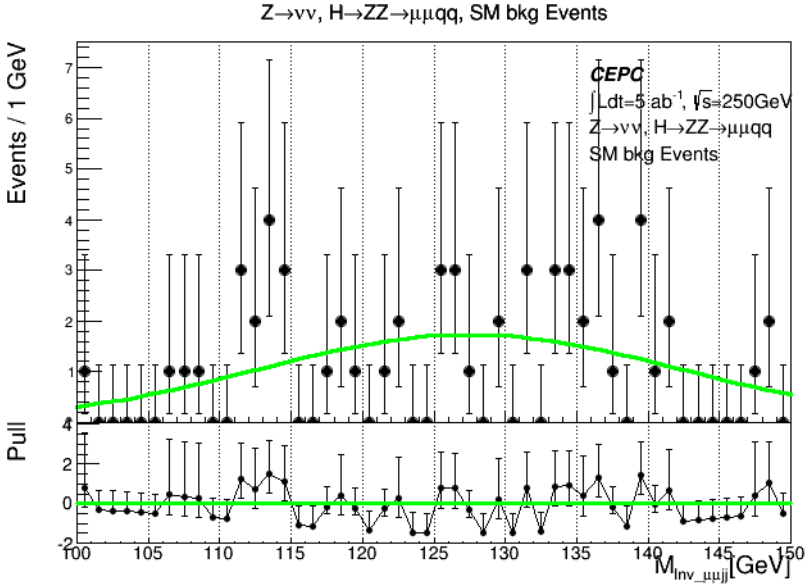

Z→ee, H→ZZ→eeqq, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→eeqq
Signal Events
Events / 1 GeV
data-pdf
MRec_ee[GeV]

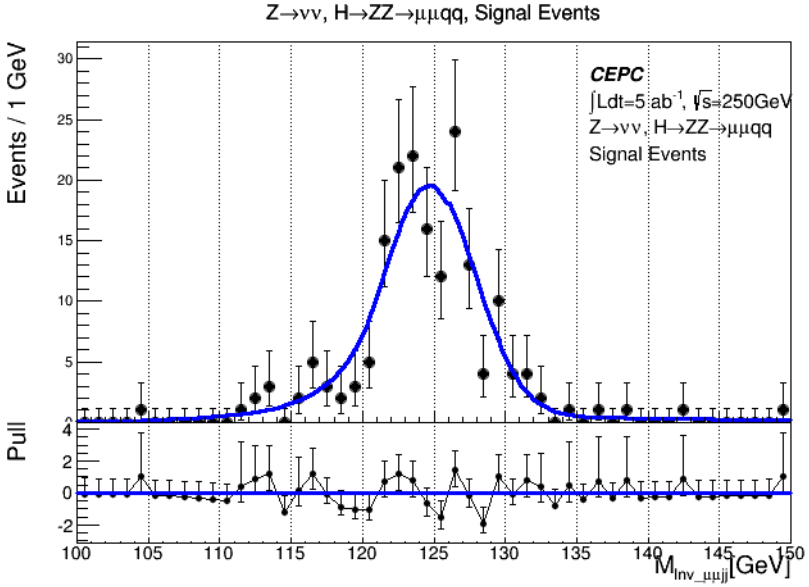

Z→ee, H→ZZ→μμqq, SM bkg Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→μμqq
SM bkg Events
Events / 1 GeV
Pull
MRec_ee[GeV]


Z→ee, H→ZZ→μμqq, Signal Events
CEPC
∫Ldt=5 ab-1, √s=250GeV
Z→ee, H→ZZ→μμqq
Signal Events
Events / 1 GeV
Pull
MRec_ee[GeV]


Z→νν, H→ZZ→eeqq, SM bkg Events
CEPC
∫Ldt=5 ab⁻¹, √s=250GeV
Z→νν, H→ZZ→eeqq
SM bkg Events
Events / 1 GeV
Pull
M_Inv_eejj[GeV]


Z→νν, H→ZZ→eeqq, Signal Events
CEPC
∫Ldt=5 ab⁻¹, √s=250GeV
Z→νν, H→ZZ→eeqq
Signal Events
Events / 1 GeV
Pull
M_Inv_eejj[GeV]


Z→νν, H→ZZ→μμqq, SM bkg Events
CEPC
∫Ldt=5 ab⁻¹, √s=250GeV
Z→νν, H→ZZ→μμqq
SM bkg Events
Events / 1 GeV
Pull
M_Inv_μμjj[GeV]


Z→νν, H→ZZ→μμqq, Signal Events
CEPC
∫Ldt=5 ab⁻¹, √s=250GeV
Z→νν, H→ZZ→μμqq
Signal Events
Events / 1 GeV
Pull
M_Inv_μμjj[GeV]