CEPC Higgs Combination towards CDR

ZhangKaili* WangJin LiuZhen

2017-10-23

A quick look on ZZ study

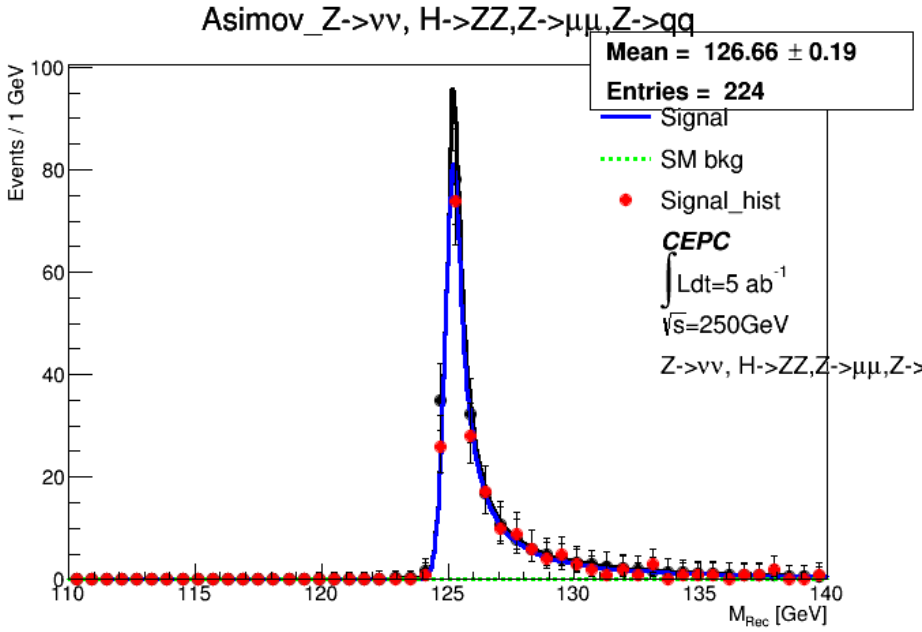
- Using old ntuples and cuts Yuqian gave me last year;
- Contain:
  - $Z \to \mu\mu, H \to ZZ^* \to \nu\nu jj$
  - $Z \to \nu\nu, H \to ZZ^* \to eejj$
  - $Z \to \nu\nu, H \to ZZ^* \to \mu\mu jj$
  - and
  - $Z \to ee, H \to ZZ^* \to ll(ee, \mu\mu)jj$

Variables used	
$M_{missingMass}$	
min_a1	inter angle of lepton-jet pair 1
min_a1	inter angle of lepton-jet pair 2
an_lj	inter angle of l-pair and j-pair.
nPFOs	Number of Particle Flow Object
P_total	Total Momentum
$\cos\theta$	$\cos\theta$ of total momentum

$Z \to \mu\mu, H \to ZZ^* \to \nu\nu jj$

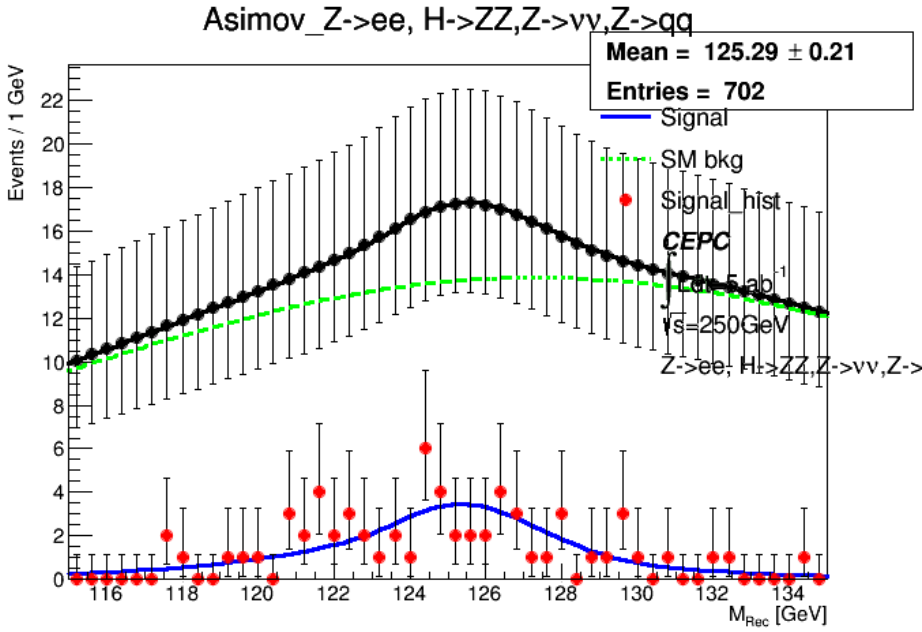
Cut used
$M_{missing} > M_{\text{jet}}$
$15 < nPFOs < 50$
$120 < E_{vis} < 155$
$10 < M_{jet} < 38$
$M_{jet} + 0.55M_{missing} > 50$
min_a1>0.22
$-0.8 < \cos\theta < 0.93$

Final:	Signal	ZH bkg	SM bkg
	211	24	5



$Z \to \nu\nu, H \to ZZ^* \to eejj$

Cut used
$M_{ee} > M_{\text{jet}}, M_{ee} > 50$
$80 < M_{ee} + M_{jet} < 140$
$58 < M_{missing} < 138$
min_a1>0.2
0.66<min_a2<2.26
$-0.81 < \cos\theta < 0.81$
an_lj<2.3
$178 < Reco_{jj} <227$
$114 < P_{total} < 135$

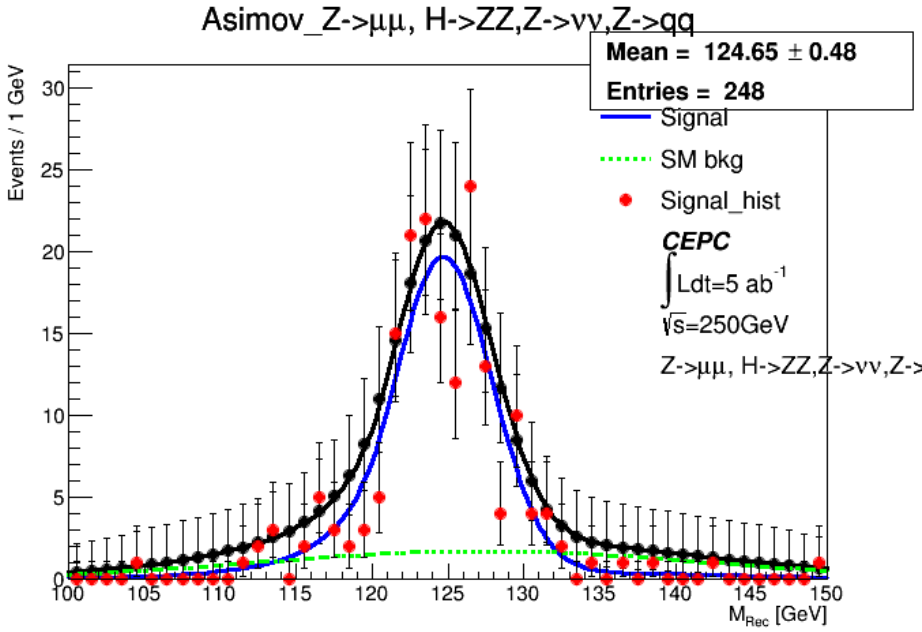


Final:	Signal	ZH bkg	SM bkg
	67	5	668

$Z \to \nu\nu, H \to ZZ^* \to mmjj$

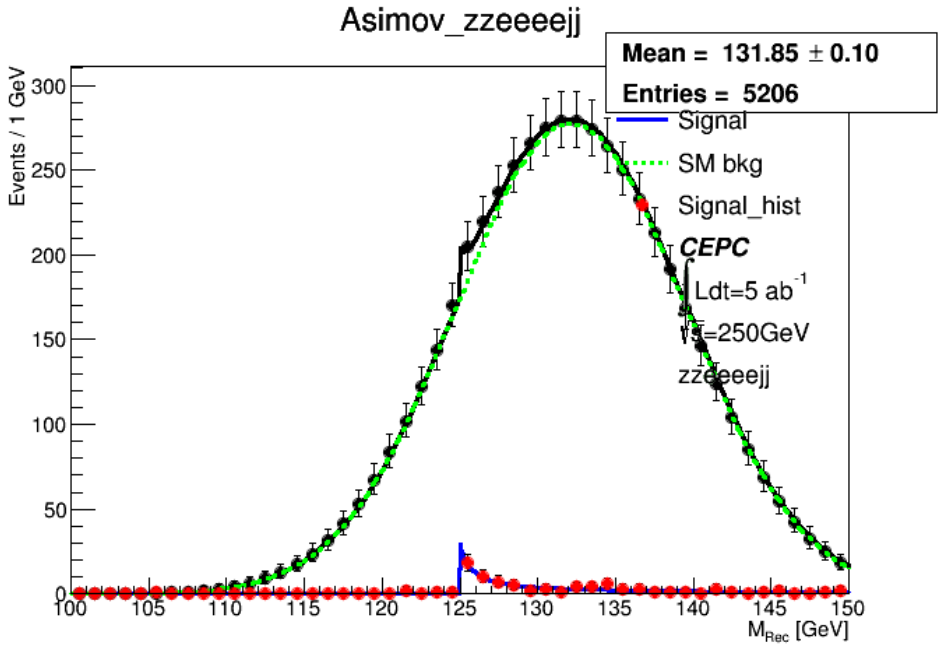
Cut used	
$58 < M_{missing} < 128$	
$M_{\mu\mu} > 15$	
$M_{\mu\mu} > M_{\text{jet}}$	$M_{\mu\mu} < M_{\text{jet}}$
$13 < M_{jet} < 49$	$53 < M_{jet} < 107$
an_lj<2.3	an_lj<1.75
	$Reco_{jj} > 116$
	$112 < P_{total} < 140$
	min_a1>0.24
	min_a1>min_a2-1.7

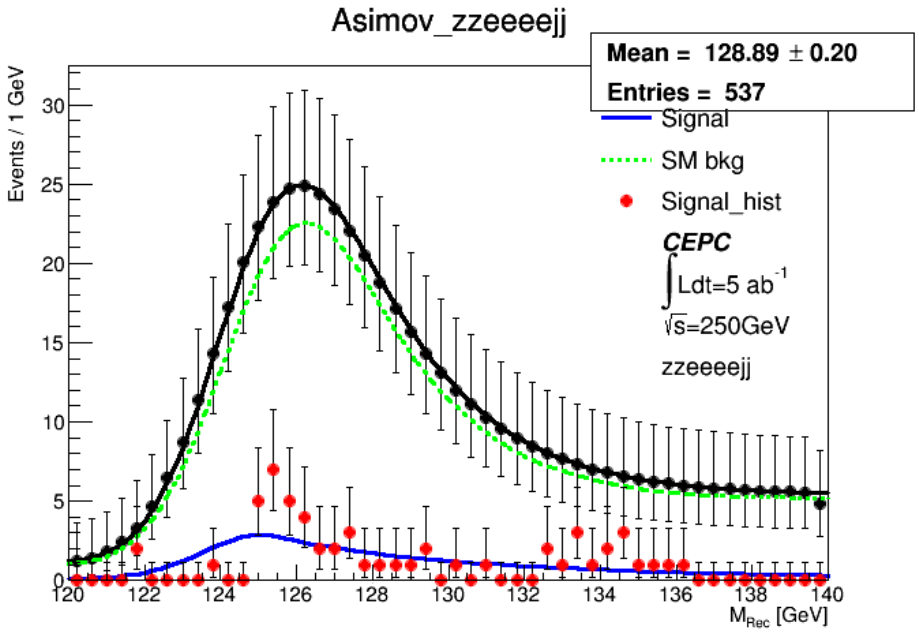
Final:	Signal	ZH bkg	SM bkg
	180	18	71



$Z \to ee, H \to ZZ^* \to eejj$

Before cuts





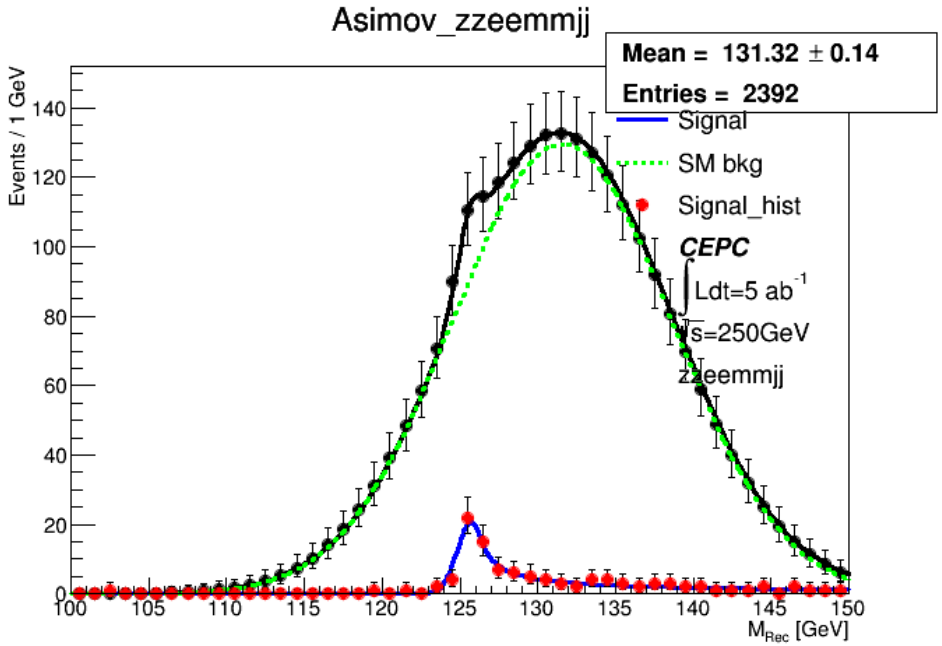
Cut tried(preliminarily)
15<nPFOs<70
m_missing<m_ll<100
Reco_jj<220

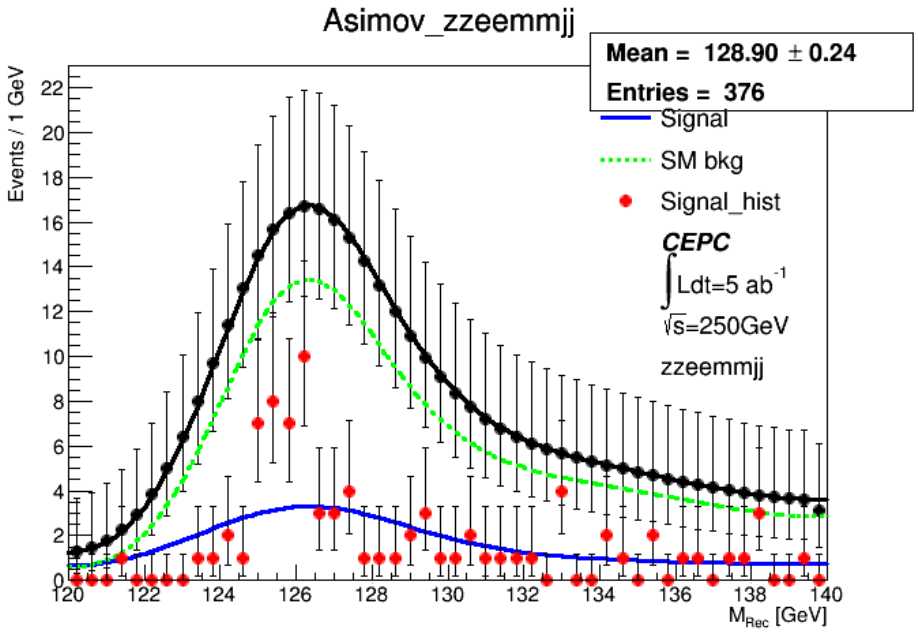
	Signal	Bkg
Initial	91	6240
Final	65	622

$Z \to ee, H \to ZZ^* \to \mu\mu jj$

All this give $ZZ\{^{+5.05\%}_{-5.09\%}$

Before cuts





Cut tried(preliminarily)
15<nPFOs<70
m_missing<m_ll<100
Reco_jj<220

	Signal	Bkg
Initial	120	2716
Final	102	372

Channels Table

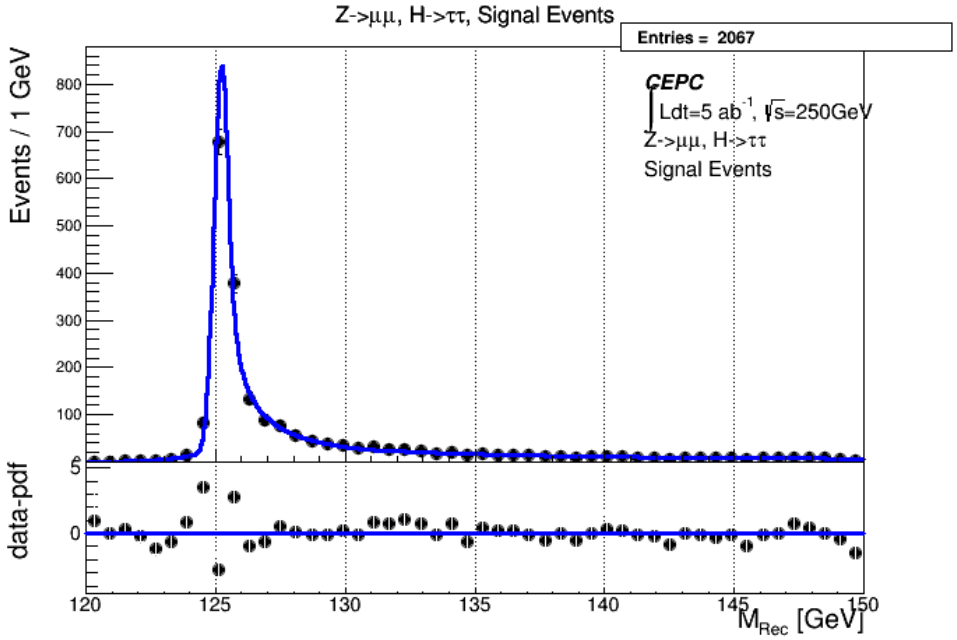
Signal		Observed Events	Who takes charge	Last update
Z	H			
H->Inclusive				
νν	Inclusive	164170	Libo	2017.8
μμ	Inclusive	29552		
ee	Inclusive	22200		
H->qq				
ee	bb	7655	Baiyu	2017.7
	cc	351		
	gg	1058		
μμ	bb	11108		2017.9
	cc	567		
	gg	1762		
qq	bb	176542		2017.7
	cc	8272		
	gg	25293		
νν	bb	70608		
	cc	3061		
	gg	9633		
H→γγ,Zγ				
ll	γγ	93	Feng	2015
νν		309		
qq		822	Yitian	2017.4
qq	Zγ	219	Weimin	2017.9
H->Invisible				
qq	νννν	202	MoXin	2017.7
ee		8		
μμ		18		

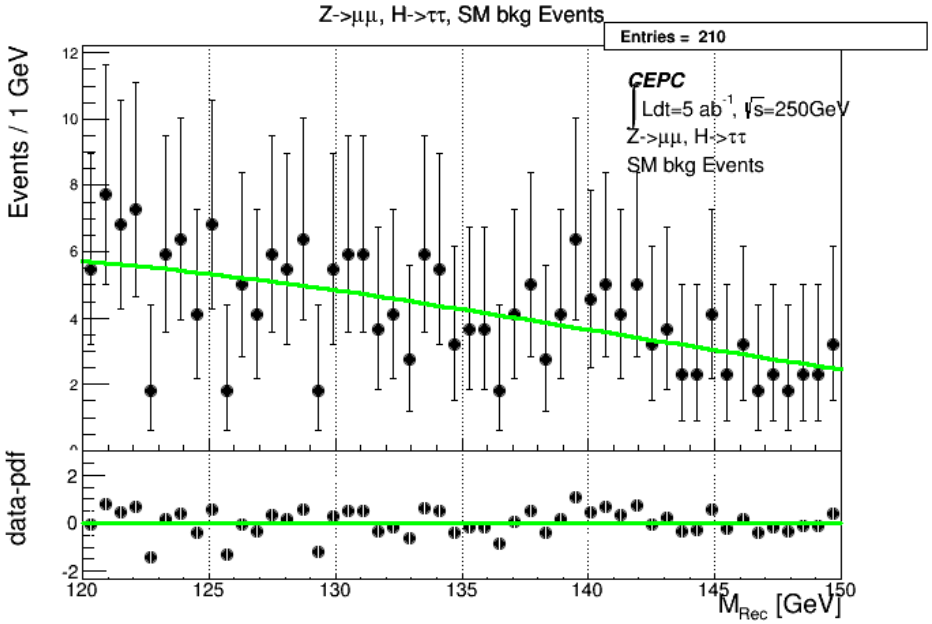
Signal		Observed Events	Who takes charge	Last update
Z	H			
νν H(WW fusion)				
νν	bb	10256	LiangHao	2017.9
H->WW				
μμ	μνμν	52	Libo	2017.4
	evev	36		
	evμν	105		
	evqq	663		
	μνqq	717		
ee	μνμν	44		
	evev	22		
	evμν	81		
	evqq	612		
	μνqq	684		
νν	qqqq	9022		
H->ZZ				
νν	μμjj	179	Yuqian	2016.9
νν	eejj	64		
μμ	νjj	200		
ee	eejj	55		
ee	mmjj	81		
H→ll				
μμ	ττ	2068	Dan	2017.9
qq		36023		
νν		12456		
qq	μμ	71	Zhenwei	2017.8
ee		1		
μμ		4		
νν		14		

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

Asimov & Observed data comparison

Jianming Commented,
since we use unbinned fit and use function to describe shape,
we must guarantee the shape is correct.
Most channels fit well.

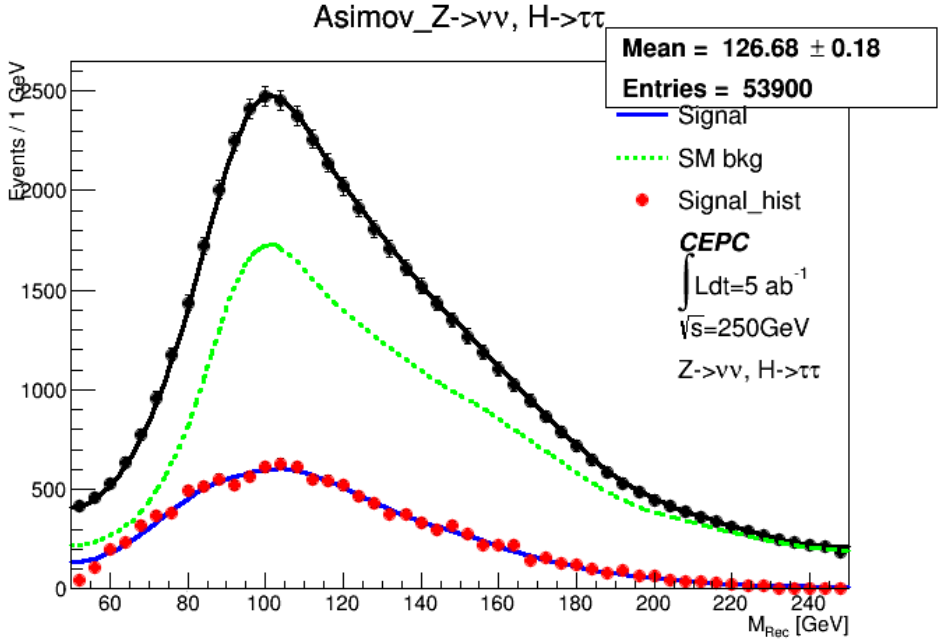


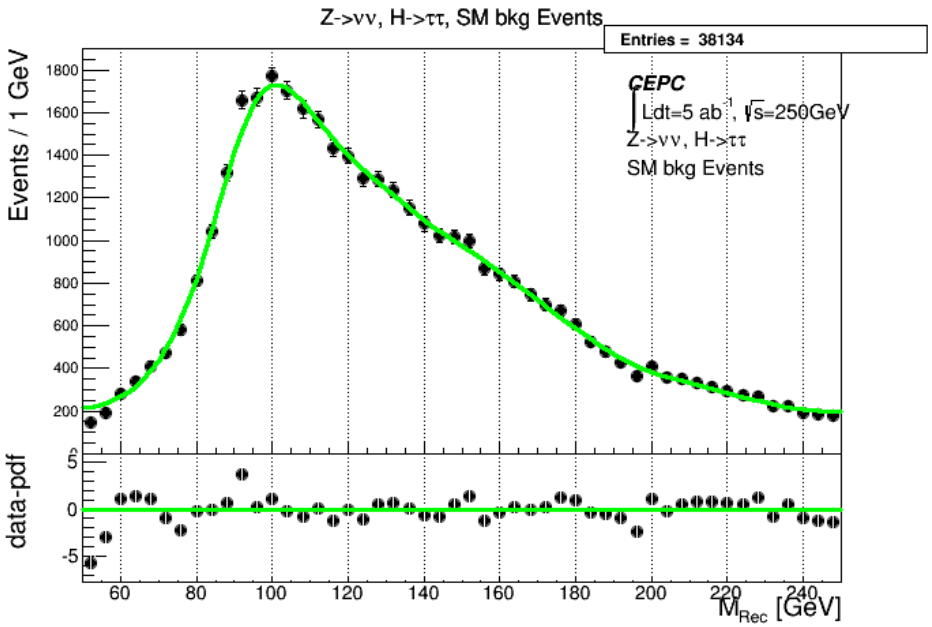


signal & ZH: Cystal Ball+Gaussian
bkg: 2nd Exponential.

Asimov & Observed data comparison

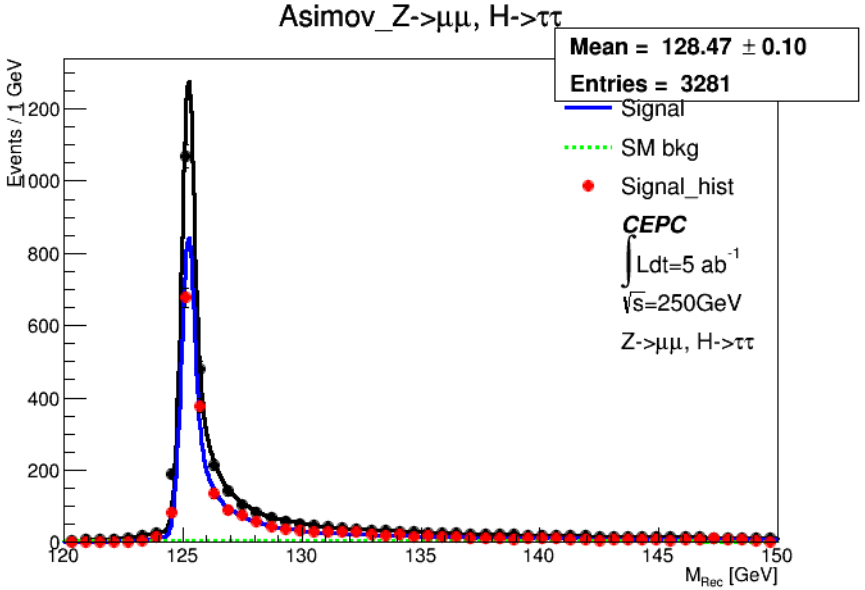
For some pdfs, we use RooKeysPdf (Multiple Gaussians) with scale factor 2 to fit the shape.

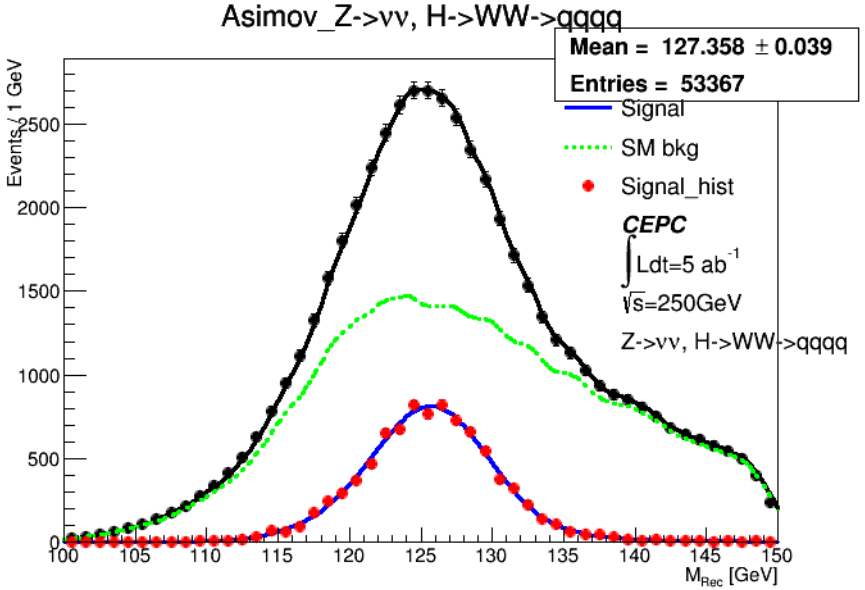


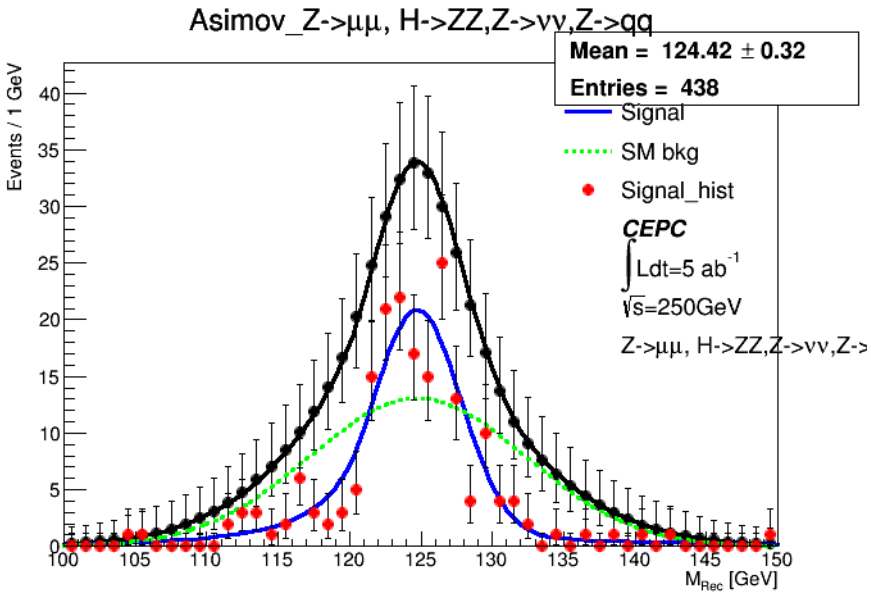


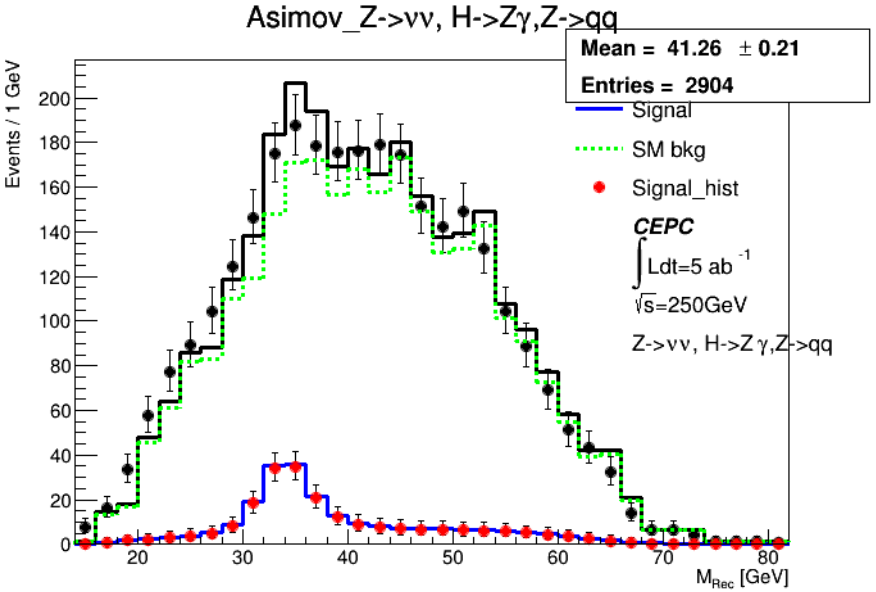
And, as the number of events are fixed, the difference of pdf shape seems

Asimov plots









All these plots are uploaded to the git server in Combination/plots folder.

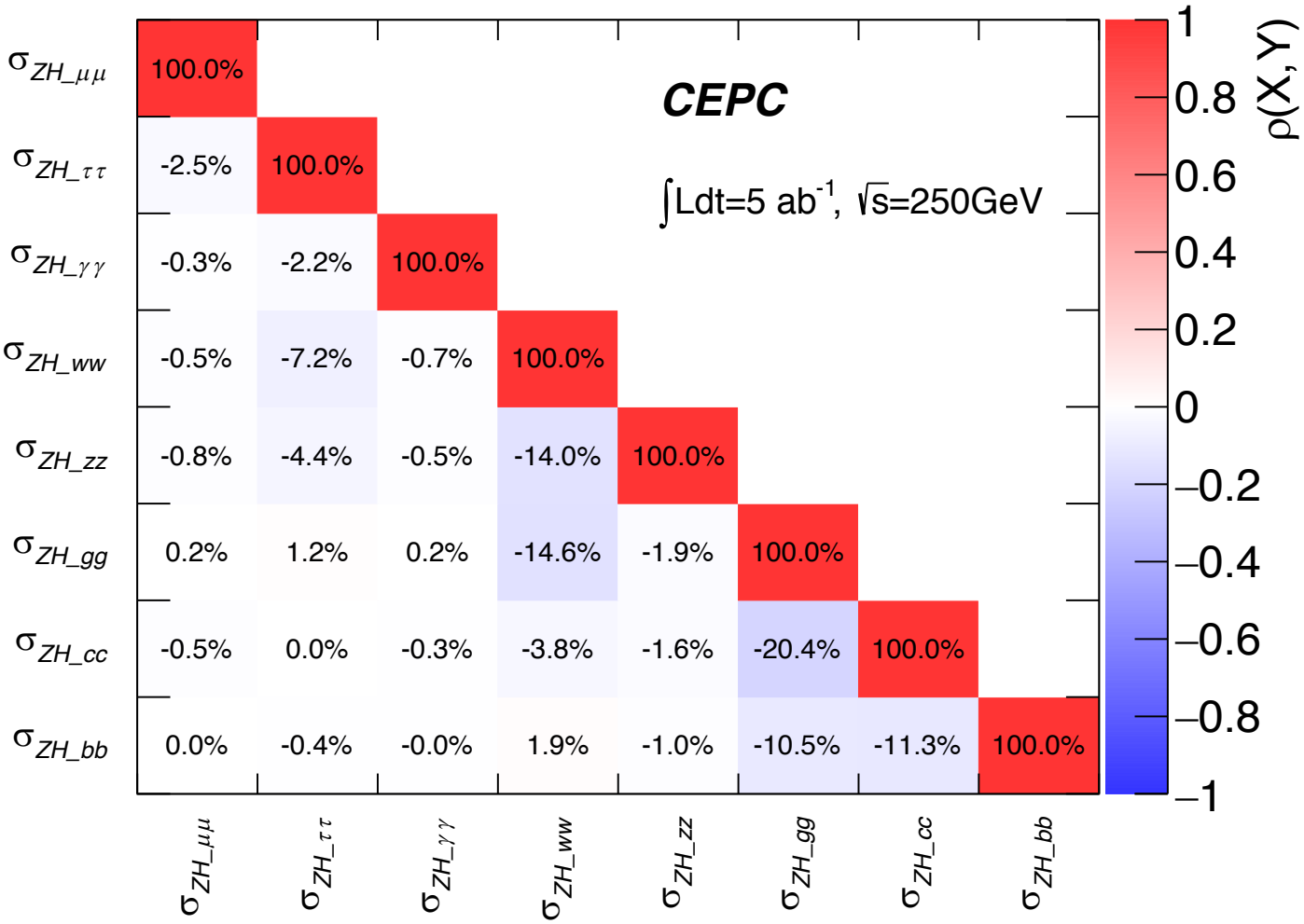
fit Result

	PreCDR	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%	$^{+3.50\%}_{-3.47\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{gg})$	1.6%	$^{+1.44\%}_{-1.44\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{WW})$	1.5%	$^{+1.21\%}_{-1.22\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mathrm{ZZ})$	4.3%	$^{+5.05\%}_{-5.09\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \tau\tau)$	1.2%	$^{+0.68\%}_{-0.68\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \gamma\gamma)$	9.0%	$^{+8.25\%}_{-8.17\%}$
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to \mu\mu)$	17%	$^{+15.9\%}_{-15.0\%}$
$\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \to \mathrm{bb})$	2.8%	$^{+3.12\%}_{-3.11\%}$
$\mathrm{Br}(\mathrm{H} \to \mathrm{inv.})$	0.28%	0.18%
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	\	$4\sigma(^{+21.0\%}_{-21.4\%})$

7 κ	Scan Result	Pre_CDR
κ_b	$^{+1.24\%}_{-1.24\%}$	1.2%
κ_c	$^{+2.19\%}_{-2.18\%}$	1.6%
κ_g	$^{+1.50\%}_{-1.48\%}$	1.5%
κ_γ	$^{+4.29\%}_{-4.38\%}$	4.7%
κ_μ=κ_τ	$^{+1.30\%}_{-1.30\%}$	1.3%
κ_Z	$^{+0.135\%}_{-0.135\%}$	0.16%
κ_W	$^{+1.25\%}_{-1.26\%}$	1.2%

In general, fit result is consistent with results of Pre_CDR and Individual studies.

Correlations in $\sigma * Br$



Combination with HL-LHC

From ATL-PHYS-PUB-2014-016

7 κ	CEPC	HL-LHC
κ_b	1.2%	10%
κ_c	2.2%	7.6%
κ_g	1.5%	5.3%
κ_γ	4.3%	4.1%
κ_μ=κ_τ	1.3%	7.1%
κ_Z	0.14%	3.8%
κ_W	1.3%	4.2%

Mainly improved in $\gamma\gamma$ channel.

	CEPC				CEPC+HL-LHC			
Luminosity (ab^{-1})	0.5	2	5	10	0.5	2	5	10
Γ_h								
κ_b	3.4	1.7	1.1	0.76	3.1	1.6	1.0	0.70
κ_c	6.7	3.3	2.1	1.5	6.2	3.1	2.0	1.4
κ_g	4.3	2.1	1.4	0.96	3.9	1.9	1.2	0.86
κ_W	3.7	1.8	1.2	0.82	3.4	1.7	1.1	0.77
κ_τ	3.6	1.8	1.1	0.80	3.3	1.7	1.0	0.74
κ_Z	0.50	0.25	0.16	0.11	0.48	0.24	0.15	0.10
κ_γ	14	6.7	4.3	3.0	4.2	2.1	1.3	0.94
κ_μ	25	12	7.8	5.5	24	12	7.7	5.5
BR_{inv}			0.18				0.18	

	CEPC				CEPC+HL-LHC			
Luminosity (ab^{-1})	0.5	2	5	10	0.5	2	5	10
κ_b	3.9	1.9	1.2	0.87	3.6	1.8	1.1	0.81
κ_c	6.9	3.5	2.2	1.5	6.5	3.2	2.1	1.5
κ_g	4.7	2.3	1.5	1.1	4.2	2.1	1.3	0.94
κ_W	4.0	2.0	1.3	0.89	3.7	1.9	1.2	0.83
κ_l	4.1	2.0	1.3	0.91	3.8	1.9	1.2	0.85
κ_Z	0.43	0.21	0.14	0.10	0.42	0.21	0.13	0.09
κ_γ	14	6.8	4.3	3.0	4.2	2.1	1.3	0.94

Known Issues, besides H->ZZ:

- Z->qq, H-> ττ
  - SM bkg incomplete
- Z->νν,ll H-> γγ
  - sample outdated
- H->bb/cc/gg
  - ZH bkg not separated.
- Higgs width