Measurement of *W* Boson Fusion, $H \rightarrow bb$ at CEPC with 360GeV

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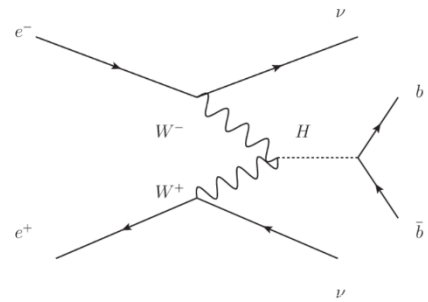
July 1 2019 CEPC WORKSHOP PKU

Contents

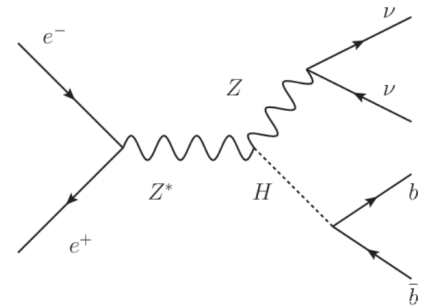
Introduction

Measurement

- ✓ W boson fusion one of main Higgs boson production process at CEPC with 360GeV



W fusion, $H \to bb$



$vvH(ZH), H \to bb$

Crucial for determining the width of Higgs boson

$$\Gamma = \Gamma_{\mathrm{SM}} \cdot \frac{\mu_{WW\,\mathrm{fusion},H\to b\bar{b}}}{\left(\frac{\mathrm{Br}(H\to b\bar{b})\mathrm{Br}(H\to W^-W^+)}{\mathrm{Br}_{\mathrm{SM}}(H\to b\bar{b})\mathrm{Br}_{\mathrm{SM}}(H\to W^-W^+)}\right)}$$

Cross-section

- ✓ Increase by factor of 5 @ 360GeV from 240GeV

$\sqrt{s}$ [GeV]	240GeV		360GeV	
$\int \mathrm{L}\,\mathrm{d}t$ [fb^{-1}]	5600		2000	
Process	$vvH(ZH)$	W boson fusion	$vvH(ZH)$	W boson fusion
X-section [fb]	40	6.2	26	30

Monte Caro Sample

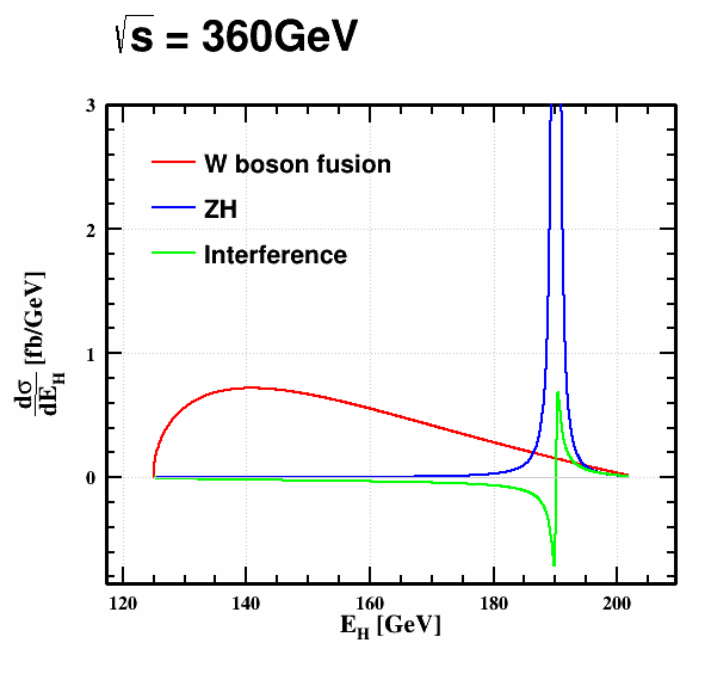
Generation

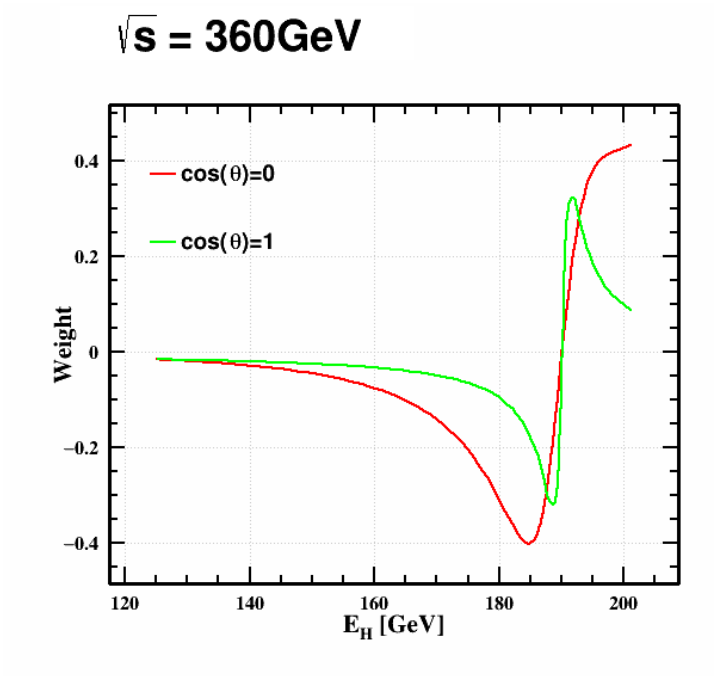
- ✓ *Whizard* 1.95 (tree level, w/ ISR photons)

Simulated with baseline detector of CEPC

Interference

- ✓ Re-weighting the sample of ZH and W boson fusion
- ✓ $\text{Weight}_{ZH} = \text{Weight}_{\text{W fusion}} \approx \frac{\mathrm{d}^2\sigma_{\text{Inter}}/\mathrm{d}E_H^*\mathrm{d}\theta_H^*(\sqrt{s^*})}{\mathrm{d}^2\sigma_{ZH+W\text{fusion}}/\mathrm{d}E_H^*\mathrm{d}\theta_H^*(\sqrt{s^*})}$ star → center of mass frame of $\nu\nu H$ system





Events Selection

Main backgrounds

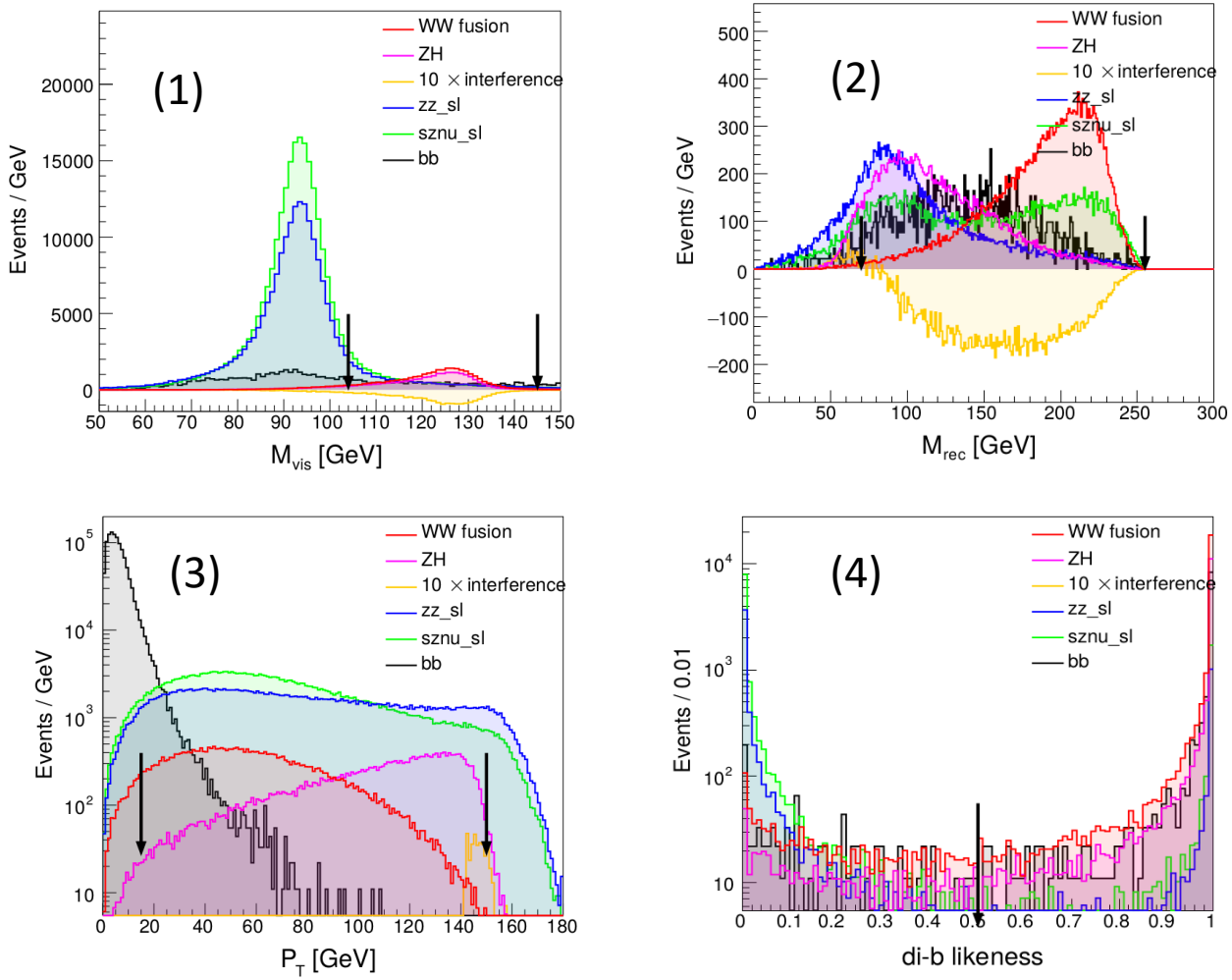
- ✓ $ZH \rightarrow \nu\nu qq$
- ✓ zz_sl: $\nu_{\mu/\tau}\nu_{\mu/\tau}qq$
- ✓ sznu_sl: $\nu_e\nu_e qq$
- ✓ bb

Major weapons

- ✓ Invariant Mass
- ✓ Missing Mass
- ✓ P_T
- ✓ Flavor tagging

di-b likeness

$$\frac{L_b(1)L_b(2)}{(1-L_b(1))(1-L_b(1)) + L_b(1)L_b(2)}$$



Events Selection

Cuts flow

- ✓ Some cuts are added for future completing the backgrounds(from the experience of analysis with 240GeV)

bb Pre-selection Eff. = 0.17

	$\nu\nu bb(W\text{fusion})$	$\nu\nu bb(ZH)$	Inter.	zz-sl	sz-nu	bb
No.	34.5k	29.5k	-2.1k	289.4k	356.8k	1530.0k
$N_{\text{PFOs}} \leq 17$	100.0%	100.0%	99.9%	97.9%	96.8%	99.5%
100 <E< 200	96.3%	85.9%	102.8%	85.3%	82.9%	73.4%
$15 < P_T < 150$	91.3%	84.6%	100.7%	77.1%	77.2%	4.0%
$N_{\text{lep}} \leq 1$	87.6%	81.6%	96.6%	73.5%	73.2%	3.8%
$104 < M < 145$	77.0%	70.2%	84.6%	7.4%	6.9%	1.2%
$M_{\text{rec}} < 255$	76.5%	65.0%	87.5%	5.5%	6.0%	1.1%
$y_{12} < 0.1$	74.2%	54.9%	82.3%	4.0%	5.0%	1.0%
$y_{23} < 0.07$	70.6%	54.1%	79.9%	3.9%	4.7%	0.9%
$y_{34} < 0.01$	69.0%	53.5%	78.4%	3.8%	4.5%	0.9%
$\cos(\theta_{\text{di-jet}}) < 0.2$	68.1%	47.0%	78.1%	2.2%	3.5%	0.7%
di-b likeness > 0.5	64.9%	45.0%	74.9%	0.5%	0.6%	0.7%
No.	22.4k	13.3k	-1.5k	1.3k	2.2k	10.6k

qq(zz_sl)	light	cc	bb
Eff.	0.4%	5%	93%

Fit Model

Fit on M_{rec} & Polar angle

The backgrounds

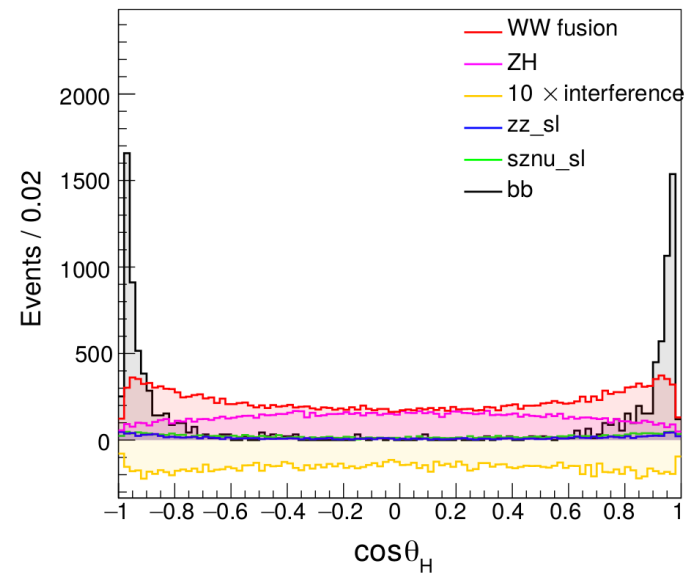
- ✓ Expected number of SM backgrounds assumed to be exactly known
- ✓ Use knowledge from $eeH/\mu\mu H/qqH, H \to bb$
  - Neglecting ZZ fusion
  - Neglecting uncertainty of EW measurement
  - $\to vvH(ZH), H \to bb$ is proportional to $eeH/\mu\mu H/qqH, H \to bb$
  - $(ee + \mu\mu + qq)H, H \to bb$ assumed to be measured to 0.76%, See Kaili's talk

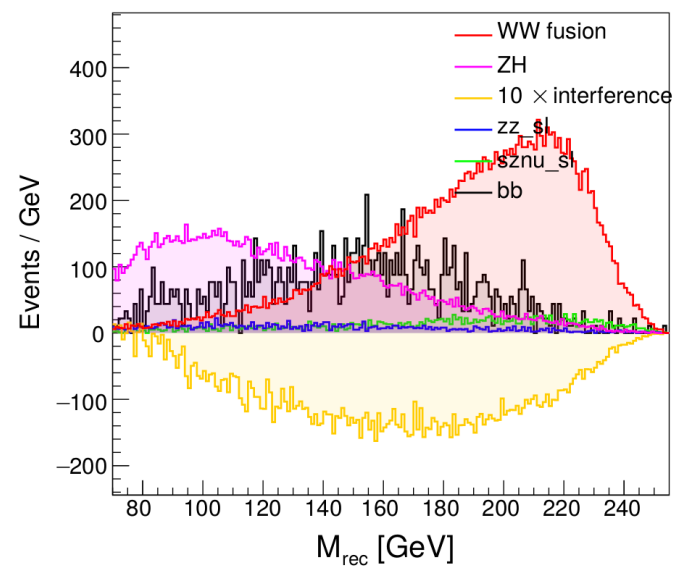
Interference

- ✓ Assumption: $\mu_{\mathrm{inter}} = \sqrt{\mu_{W\ \mathrm{fusion}} \times \mu_{ZH}}$
- ✓ $\mu_{ZH}/\mu_{W\ \mathrm{fusion}}$ = signal strength of ZH/W fusion, $H \to bb$

Likelihood fit

- ✓ $-2\log(L) = -2\log \mathrm{Prob}(\mathrm{data}; \mathrm{pdf}) + \left(\frac{\mu_{ZH}-1}{0.76\%}\right)^2$
- ✓ $\mathrm{pdf} = \mu_{W\ \mathrm{fusion}}\mathrm{pdf}_{W\ \mathrm{fusion}} + \mu_{\mathrm{inter}}\mathrm{pdf}_{\mathrm{inter}} + \mu_{ZH}\mathrm{pdf}_{ZH}$
- ✓ Simple version of κ framework





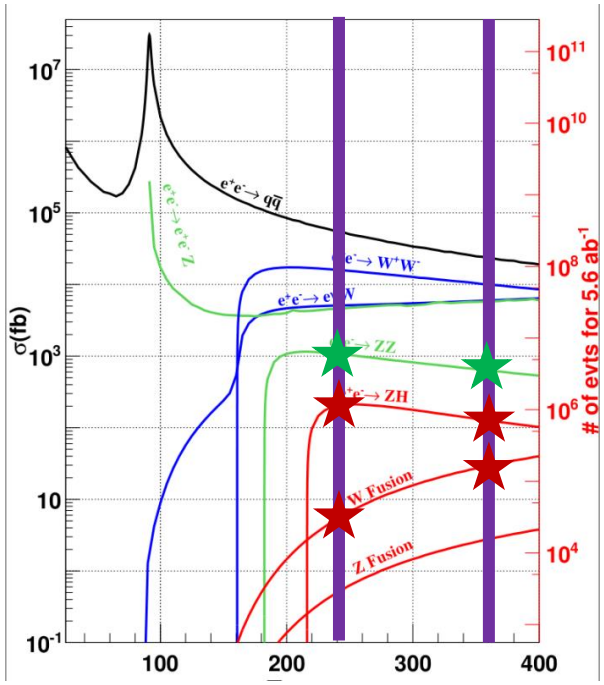
Result and Discussion

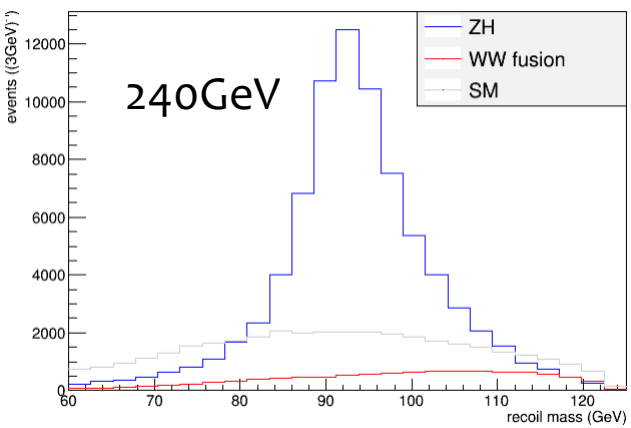
Accuracy of 0.85% for signal strength of W boson fusion leads to accuracy of 1% level for Higgs boson mass.

Comparable to Kaili's result 0.8

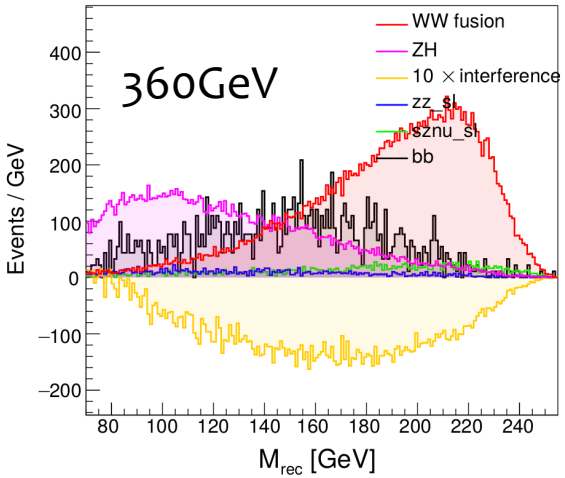
Compared to 240GeV

- ✓ The integral luminosity decreases. *However*
- ✓ The x-section & number of events of signal increase
- ✓ The x-section of backgrounds decrease
- ✓ Better signal-backgrounds separation
- ✓ Overall: better accuracy 3% → beter than 1%





Approach 2



Result and Discussion

Interference

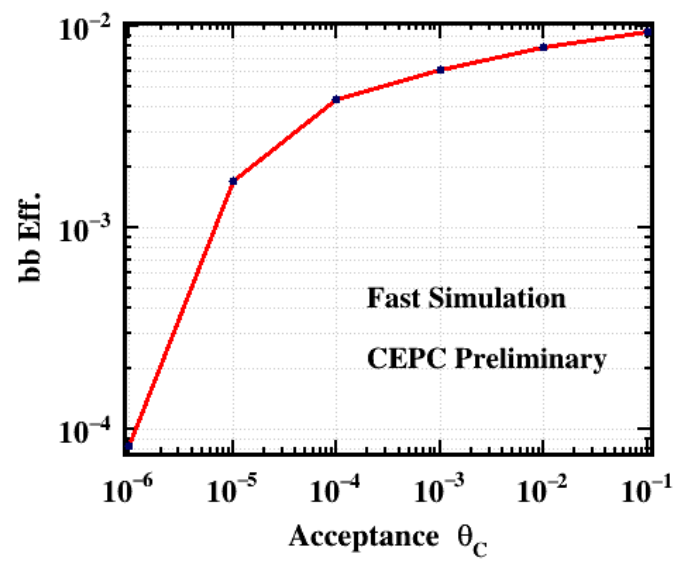
Fake data w/ inter. ?			
p.d.f w/ inter. ?			
Statistical Accuracy	1 ± 0.085	1 ± 0.085	0.949 ± 0.084

- ✓ No degradation on statistical error w/ interference
- ✓ Need to consider in real data analysis, to avoid big bias

The trick that replacing the measured energy with the energy calculated by momentum improves little. The reason is that the Higgs is more boosted.

Backgrounds of $b\bar{b}\gamma$

- ✓ Extremely large x-section (~5000pb)
- ✓ Missing energy and mass due to escape of ISR photons
  - Cuts on missing energy and mass are extremely useful, but can't veto all
- ✓ Dedicate detector for ISR?



Result and Discussion

$t\bar{t}$

- ✓ Smaller x-section than zz
- ✓ $tt \rightarrow bbWW \rightarrow bb + 2l2\nu/l\nu UD/2U2D$
- ✓ Tools: Missing energy always accompanied by isolated lepton & Clustering & Flavor Tagging
- ✓ ILC analysis showed it was absolutely negligible @ 500GeV
- ✓ Full simulation coming soon

Result is still preliminary & More simulation needs to be done

Thanks