CEPC Higgs Results @ $t\bar{t}$ threshold

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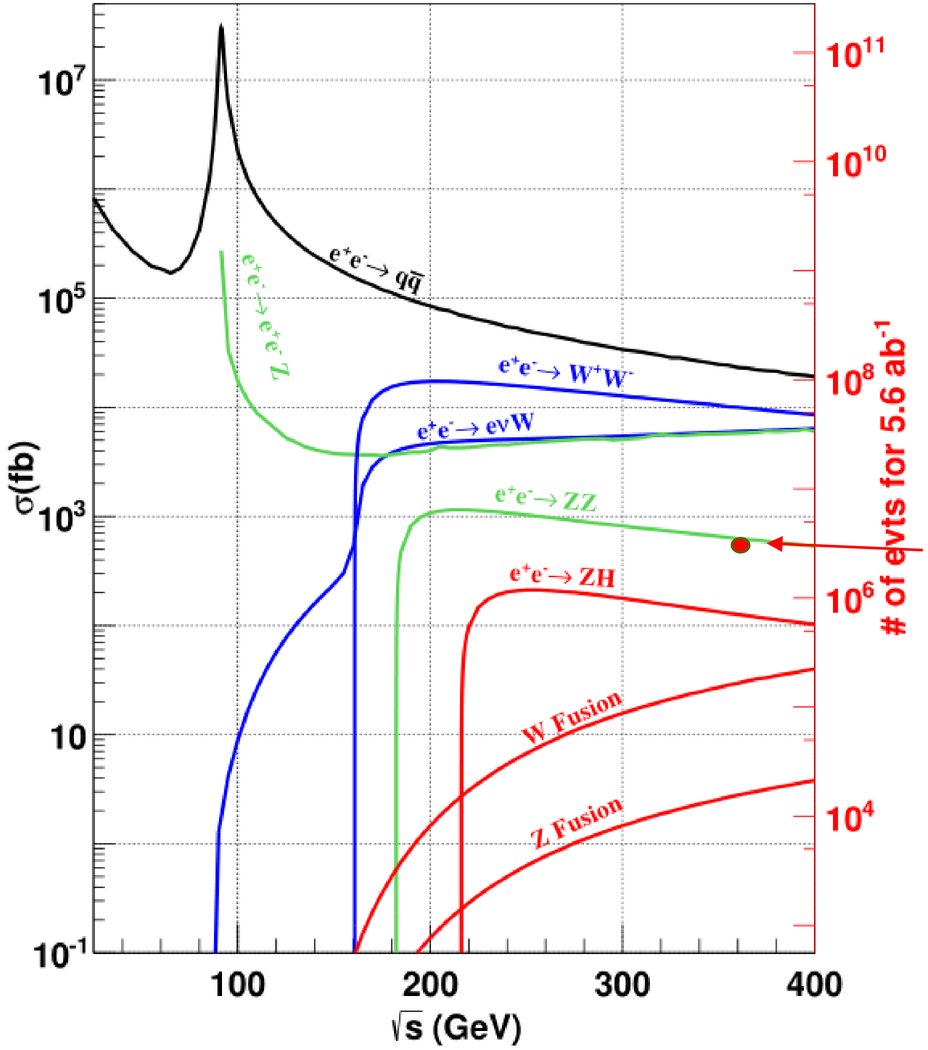
CEPC Physics



$t\bar{t}$: here

Current results for 240GeV:

	240GeV, 5.6ab^{-1}
	ZH
any	**0.50%**
$\mathrm{H} \to \mathrm{bb}$	**0.27%**
$\mathrm{H} \to \mathrm{cc}$	**3.3%**
$\mathrm{H} \to \mathrm{gg}$	**1.3%**
$\mathrm{H} \to \mathrm{WW}$	**1.0%**
$\mathrm{H} \to \mathrm{ZZ}$	**5.1%**
$\mathrm{H} \to \tau\tau$	**0.8%**
$\mathrm{H} \to \gamma\gamma$	**5.4%**
$\mathrm{H} \to \mu\mu$	**12%**
$\mathrm{Br}_{\mathrm{upper}}(\mathrm{H} \to \mathrm{inv.})$	**0.2%**
$\sigma(ZH) * \mathrm{Br}(\mathrm{H} \to Z\gamma)$	**16%**
Width	**3.0%**

$t\bar{t}$ run for Higgs

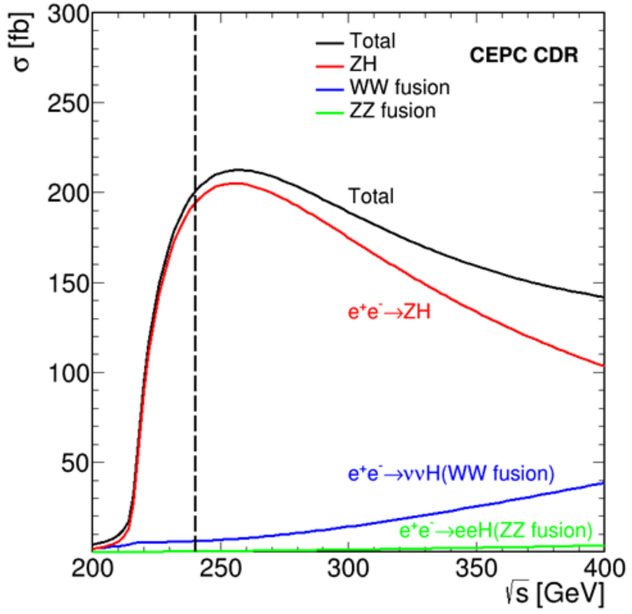
- Larger vvH cross section -> Better width precision.
  - New mass point constrain -> Better coupling.
- Not sensitive to specific mass point
  - 350/360/365, major physic processes do not have significant change. (For $t\bar{t}$, see #12.)
- Temporary benchmark: 2 iab @ 360GeV
  - Requested mainly by Top Physics
  - Fcc-ee use 0.2iab Scan + 1.5iab 365GeV
  - 2 iab take >5 years to take (Fcc speed). Scaling is easy.

Major Processes

Cross section calculated by Whizard;

fb	240	350	360	365	365/240
ZH	196.9	133.3	126.6	123.0	-38%
WW fusion	6.2	26.7	29.61	31.1	+401%
ZZ fusion	0.5	2.55	2.80	2.91	+482%
Total	203.6		159.0	157.0	
Total Events	1.14M		0.32M	0.31M	

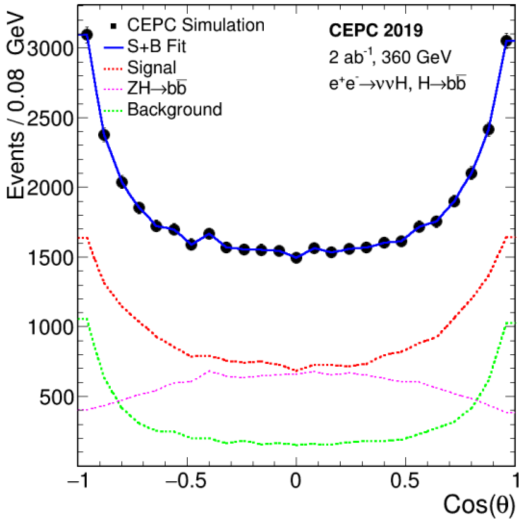
pb	240	350	360	365	365/240
$ee(\gamma)$	930	336	325	319	-65%
$\mu\mu(\gamma)$	5.3	2.2	2.1	2.1	-60%
$qq(\gamma)$	54.1	24.7	23.2	22.8	-57%
WW	16.7	10.4	10.0	9.81	-40%
ZZ	1.1	0.66	0.63	0.62	-43%
$t\bar{t}$	\	0.49	0.60	0.65	+
$WW^*\bar{b}b$		$>t\bar{t}$	$>t\bar{t}$	$>t\bar{t}$	+
sZ	4.54	5.72	5.78	5.83	+27%
sW	5.09	5.89	6.00	6.04	+18%

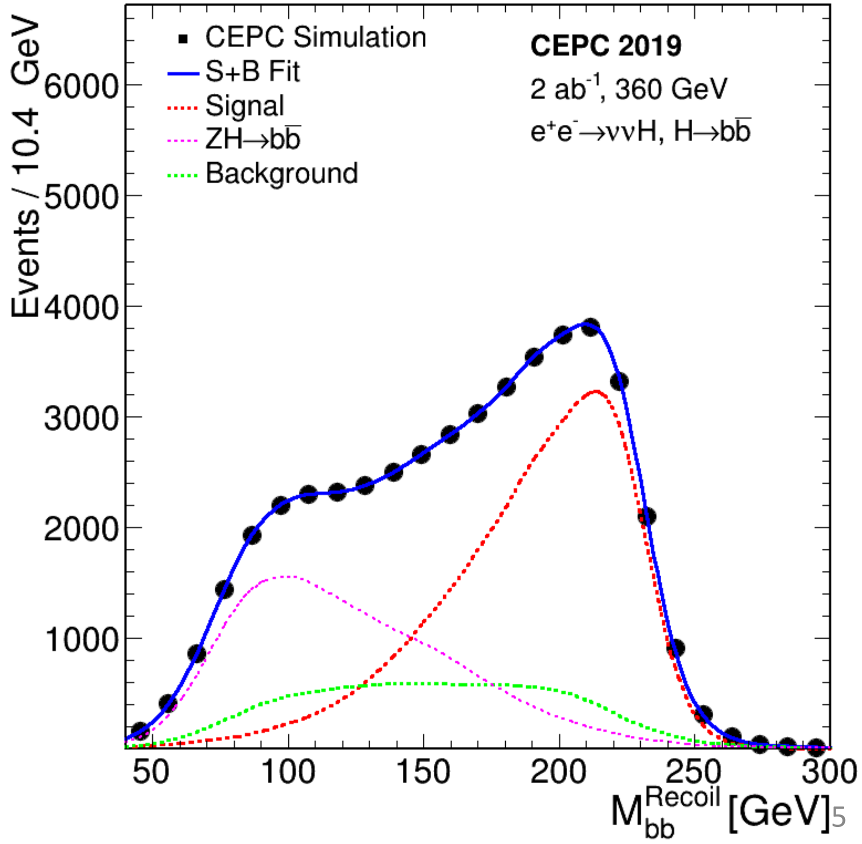


In total ~1.45M Higgs would be collected in CEPC 240+365GeV.
Correlation between ZH and vvH considered.
We have more higgs events in 360GeV than 365GeV.
So we scale the processes according to the yields, to extrapolate to 360GeV from the existing 240GeV.

vvH->bb, full simulation

- 2d Recoil qq + Cos θ_{qq} Fit
- Clear separation between ZH and vvH.
- Constrain from other ZH->bb$(ee, \mu\mu, qq)$ considered
  - $\sigma(\mathrm{vv}H) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{bb})$:0.76%
  - $\sigma(\mathrm{Z}H) * \mathrm{Br}(\mathrm{H} \rightarrow \mathrm{bb})$: 0.63%
  - share the anti-correlation -15.8%.





Higgs width

- Now CEPC Higgs width is fitted in the 10- κ framework.

- Adding one mass point would significantly improve the constrain.

  - Much more vvH event and better separation. Significantly improve the constrain.

  - Standalone 240GeV gives 3.0%, while 360GeV alone gives 2.8%.

  - Combined fit

$$\Delta(\Gamma_H) \approx 1.4\%$$

*: Fcc-ee assumes that exotic Br can not smaller than 0. This assumption lower the negative side, Like (-1.2%, 1.4%). Then Fcc use median 1.3%,

We didn’t take this assumption.

Higgs measurement results

	240GeV, $5.6ab^{-1}$	360GeV, $2ab^{-1}$	
	ZH	ZH	ννH
any	**0.50%**	**1%**	****
$H \to bb$	**0.27%**	**0.63%**	**0.76%**
$H \to cc$	**3.3%**	**6.2%**	**11%**
$H \to gg$	**1.3%**	**2.4%**	**3.2%**
$H \to WW$	**1.0%**	**2.0%**	**3.1%**
$H \to ZZ$	**5.1%**	**12%**	**13%**
$H \to \tau\tau$	**0.8%**	**1.5%**	**3%**
$H \to \gamma\gamma$	**5.4%**	**8%**	**11%**
$H \to \mu\mu$	**12%**	**29%**	**40%**
$Br_{upper}(H \to inv.)$	**0.2%**	****	****
$\sigma(ZH) * Br(H \to Z\gamma)$	**16%**	**25%**	****
Width	**3.0%**	**1.4%**	

Generally, since the extrapolation is not so accurate, results are comparable. For Higgs coupling, also similar performance could be expected as Fcc-ee. Higgs Performance would not have huge deviation for 360 and 365GeV.

Fcc:

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

See previous talk @CEPC day about some extrapolation details. Actually current number could be conservative.

Also note that, only statistics considered.

Higgs Coupling

For vvH: contribute to k_w^2.
HL-LHC input from 1902.00134.
Mainly improved κ_γ.

	CDR Results		Our benchmark		Compared to Fcc-ee		Fcc-ee
240 5.6iab +	+ \ + HL-LHC		+ 360 2iab+ HL-LHC		+ 360 1.5iab + HL-LHC		240 5iab+365 1.5iab
κ_b	1.49%	0.88%	0.59%	0.54%	0.63%	0.57%	0.67%
κ_c	2.17%	1.69%	1.51%	1.40%	1.57%	1.44%	1.3%
κ_g	1.56%	0.94%	0.78%	0.66%	0.82%	0.68%	1.0%
κ_W	1.39%	0.84%	0.41%	0.39%	0.45%	0.43%	0.43%
κ_τ	1.49%	0.89%	0.68%	0.61%	0.72%	0.64%	0.73%
κ_Z	0.25%	0.24%	0.22%	0.22%	0.23%	0.22%	0.17%
κ_γ	3.06%	1.35%	2.14%	1.24%	2.26%	1.27%	3.9%
κ_μ	6.18%	6.07%	5.38%	5.38%	5.53%	5.52%	8.9%
Γ_{total}	2.99%	1.88%	1.41%	1.31%	1.49%	1.36%	1.3%

One mass point,
Width have floor effect.

$\kappa_b, \kappa_W, \kappa_Z$ could be expected to have excellent precision in ttbar threshold run.

Different statistics

240 5.6iab + 360GeV Xiab	0	0.2	0.5	1	1.5	2	5
κ_b	1.49%	1.01%	0.82%	0.69%	0.63%	0.59%	0.47%
κ_c	2.17%	1.88%	1.75%	1.64%	1.57%	1.51%	1.27%
κ_g	1.56%	1.15%	0.99%	0.88%	0.82%	0.78%	0.63%
κ_W	1.39%	0.88%	0.66%	0.52%	0.45%	0.41%	0.30%
κ_τ	1.49%	1.06%	0.88%	0.77%	0.72%	0.68%	0.55%
κ_Z	0.25%	0.25%	0.24%	0.24%	0.23%	0.22%	0.20%
κ_γ	3.06%	2.78%	2.61%	2.41%	2.26%	2.14%	1.68%
κ_μ	6.18%	6.01%	5.88%	5.69%	5.53%	5.38%	4.69%
Γ_{total}	2.99%	2.14%	1.81%	1.60%	1.49%	1.41%	1.17%

If 2iab take long time to take, maybe shorter period is also acceptable for Higgs physics.
Even only threshold scan (200fb) would help Higgs coupling.
The key is we have one other constrain for ZH system.

$t\bar{t}$ samples at CEPC

- From Gang: Now Whizard2 could generate the sample correctly.
  - Ready to request $t\bar{t}$ samples.
  - First need to discuss about the strategy.

Currently Higgs extrapolation didn't consider too much about $t\bar{t}$ process, which assumes our performance is good enough to separate $t\bar{t}$ events.

- $t\bar{t} \to WW^*\bar{b}b$:
  - A brief estimation from Manqi:
    - *qqqq+bb:* *Eff*Purity≈50%*
    - *lvqq+bb:* *Eff*Purity≈75%* *One optimal-observable study in this channel described in* arXiv:1503.01325
    - *lvlv+bb:* *Eff*Purity≈90%*
  - In total we would have ~1.3Million $t\bar{t}$ events.
    - ~62% of them would be easy to tag. -> 800k.
  - Strict requirement for our jet performance.
    - $ee \to WW^*\bar{b}b$ has similar behavior and larger cross section.
    - 2/4/6 Jet separation, b-tagging and BMR?
  - Others: Kinematic Fitting? Boosted Top quark?

$$\chi^2 = \frac{(m^2_{\ell\nu b} - m_t)^2}{\sigma^2_{m_t,\text{lep}}} + \frac{(m^2_{jj} - m_W)^2}{\sigma^2_{m_W,\text{had}}} + \frac{(m^2_{jjj} - m_t)^2}{\sigma^2_{m_t,\text{had}}}.$$

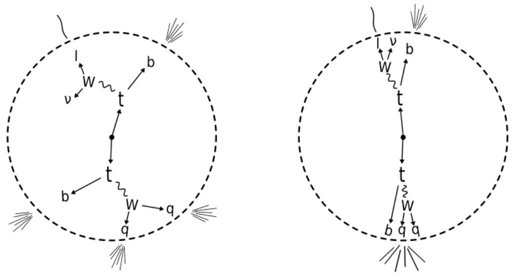


Figure 4: Illustration of resolved (left) and boosted (right) event topologies in single-lepton $t\bar{t}$ decays. Picture courtesy of Shawn Williamson.

Summary

- Expected Higgs measurement precision and coupling results shown.
  - $t\bar{t}$ threshold run have large vvH cross section.
  - Much better width measurement, much better coupling
- Comparison to Fcc-ee shown -> Comparable.
  - Different lumi results also shown; Even small statistics would help.
- Higgs physics need one $t\bar{t}$ run
  - But not sensitive with the mass point.
  - Significant improvement could be made.