Higgs recoil analysis and Higgs width measurement

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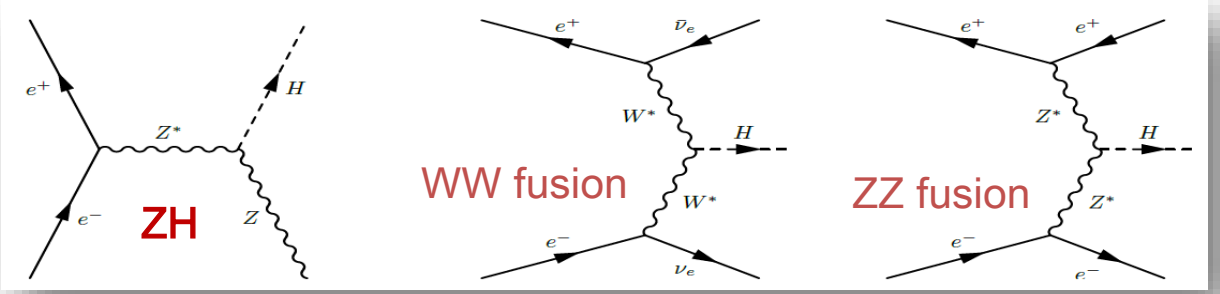
Outline

- Introduction
  - Recoil mass method and Higgs width determination
- Monte Carlo Simulation
- Recoil mass analysis at CEPC
  - ZH cross section and Higgs mass measurement
- Higgs width measurement at CEPC
- Summary
- Experience on paper publication

Recoil mass

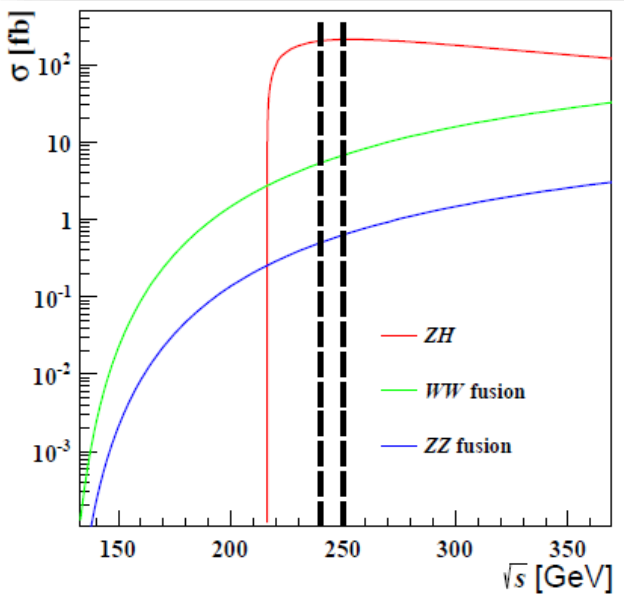
- CEPC will work at 240-250 GeV
- Higgs boson production: **ZH**(dominant), WW fusion, ZZ fusion



- Well known initial states at an e^+e^- collider
- In ZH, the leptonic decay of Z boson can be well reconstructed
- Recoil mass:

$$m^2_{\text{recoil}} = (\sqrt{s} - E_{f\bar{f}})^2 - p^2_{f\bar{f}} = s - 2E_{f\bar{f}}\sqrt{s} + m^2_{f\bar{f}}$$

- Higgs mass and ZH cross section can be determined in a model-independent way



Higgs width determination

- The Higgs width is a sensitive probe for BSM. Γ_H~4 MeV in SM, it is impossible to make a direct measurement due to limited detector resolution

- An indirect measurement at e^+e^- collider:

➢ Strategy I: with σ(ZH) and BR(H→ZZ)
limited statistics(BR(H →ZZ)~2.3% in SM)

$$\Gamma_H = \frac{\Gamma(H \to ZZ^*)}{\mathrm{BR}(H \to ZZ^*)} \propto \frac{\sigma(ZH)}{\mathrm{BR}(H \to ZZ^*)}$$

➢ Strategy II: with a series of measurements including σ(ZH) , σ(vvH, H→bb) , σ(ZH, H→bb), σ(ZH, H→WW)

$$\Gamma_H = \frac{\Gamma(H \to bb)}{BR(H \to bb)}$$

$$\sigma(\nu\bar{\nu}H \to \nu\bar{\nu}bb) \propto \Gamma(H \to WW^*) \cdot \mathrm{BR}(H \to bb) = \Gamma(H \to bb) \cdot \mathrm{BR}(H \to WW^*)$$

$$\Gamma_H \propto \frac{\Gamma(H \to bb)}{\mathrm{BR}(H \to bb)} \propto \frac{\sigma(\nu\bar{\nu}H \to \nu\bar{\nu}bb)}{\mathrm{BR}(H \to bb) \cdot \mathrm{BR}(H \to WW^*)}$$

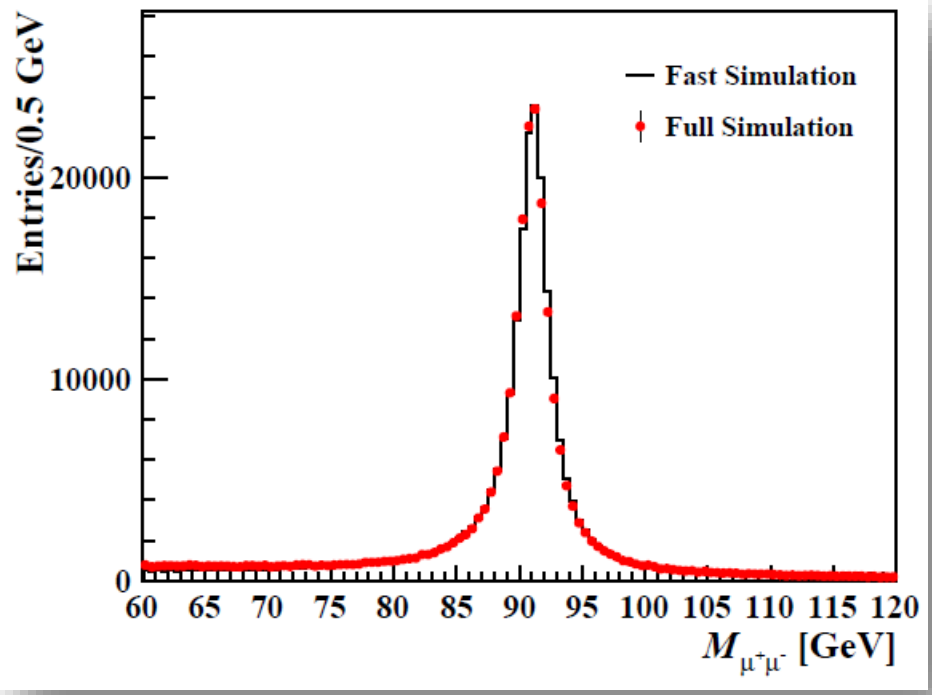
Monte Carlo Simulation

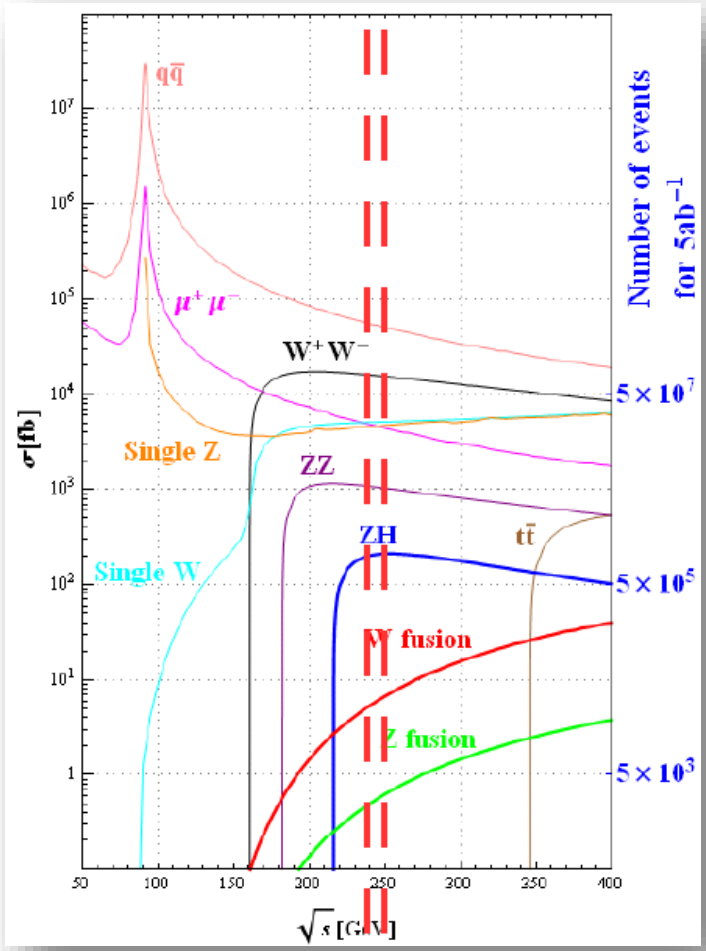
Generator: Whizard 1.95 (with ISR, Luminosity: $5ab^{-1}$, M_H=125 GeV)

Background: 2-fermion (lepton or quark pairs)
4-fermion (WW, ZZ, Single W and Single Z)
Chin. Phys. C 40 (2016) 033001

Simulation: Mokka

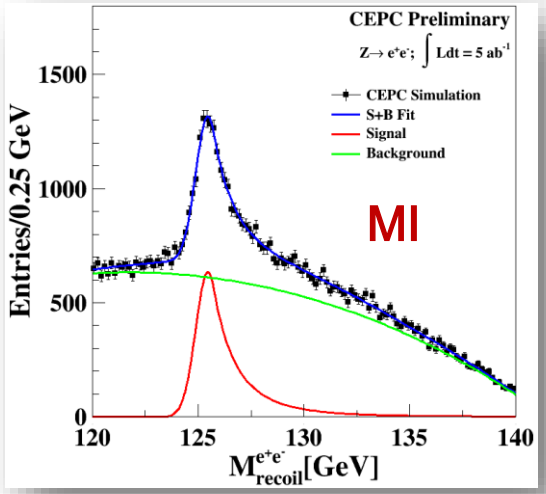
Reconstruction: Arbor

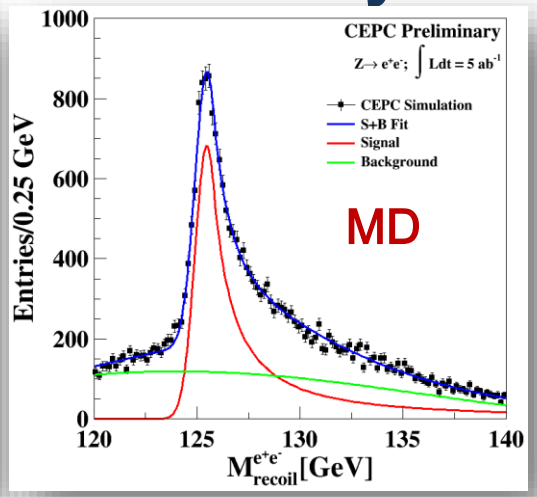




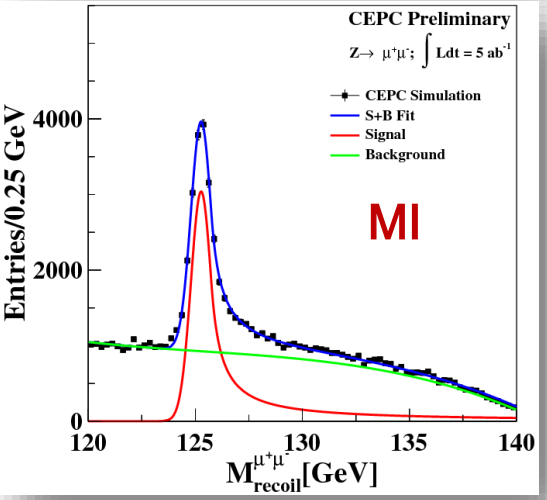
A validation with ZZ background sample

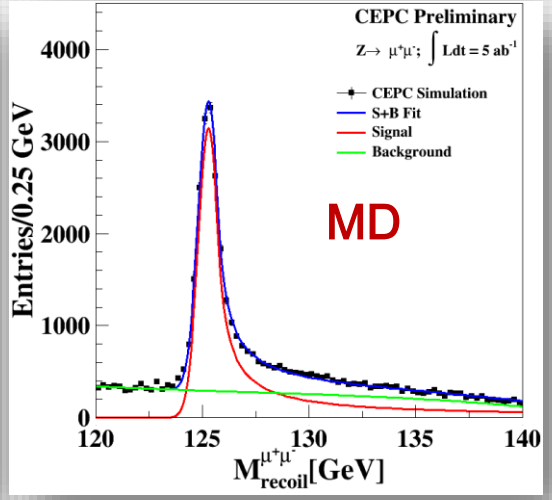
Recoil mass analysis: $Z \to e^+e^-$ or $\mu^+\mu^-$





Model-Independent: only information from Z boson decays ➡ an inclusive measurement





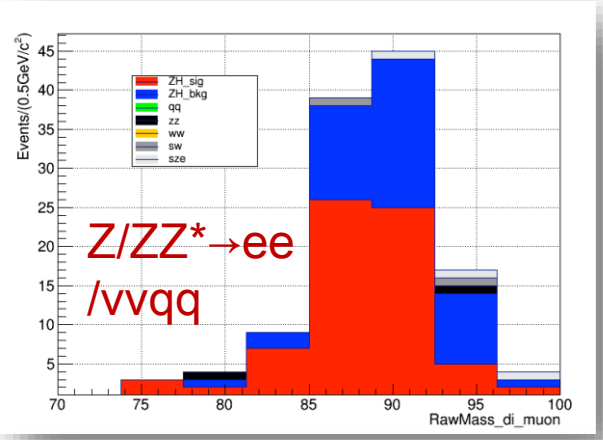
Model-Dependent: SM assumption ➡ reduced background and improved m_H precision

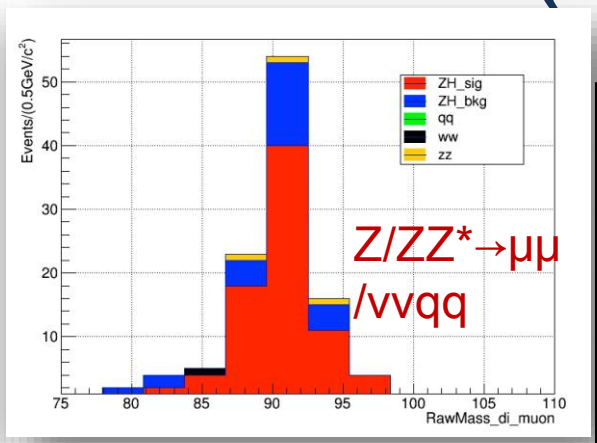
with a 0.16% beam energy spread

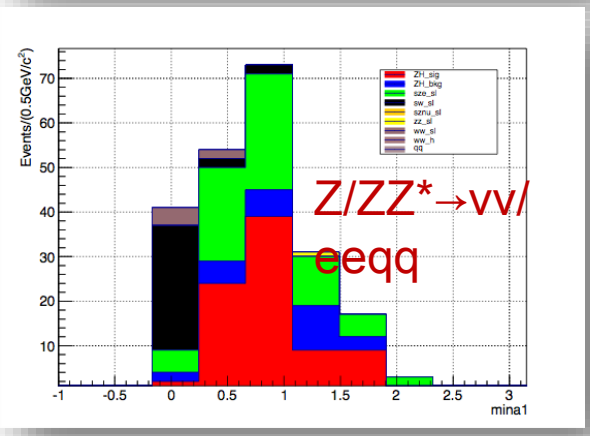
Channel	$\Delta\sigma(ZH)/\sigma(ZH)$	Δm_H (MI)	Δm_H (MD)
e^+e^-	1.49%	19.2 MeV	13.1 MeV
$\mu^+\mu^-$	0.92%	6.5 MeV	5.4 MeV

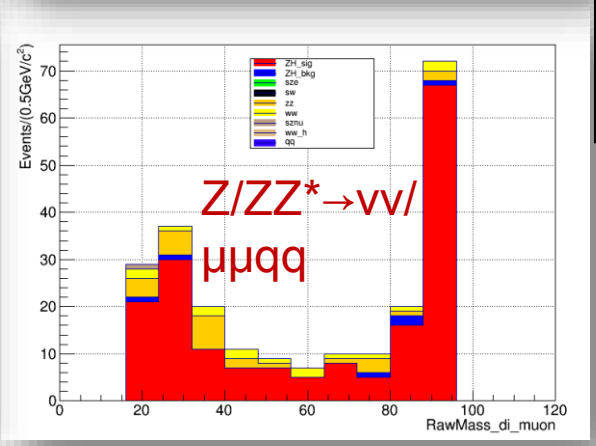
Measurement of ZH(H→ZZ*)

see Yuqian's talk









	Z→ll	taus	vv	qq
ZZ*→4q	888	444	3.10k	9.24k
vv+qq	508	254	1.77k	5.29k
ll+qq	170	85	596	1.78k
4v	73	36	254	756
ll+vv	49	24	170	508
4l	8	4	28	86
X+tau	120	60	418	1.25k

Limited accuracy ~ > 50%

H→invisible ~ 40%

Full simulated

Await for tau finder

Extrapolated from TLEP

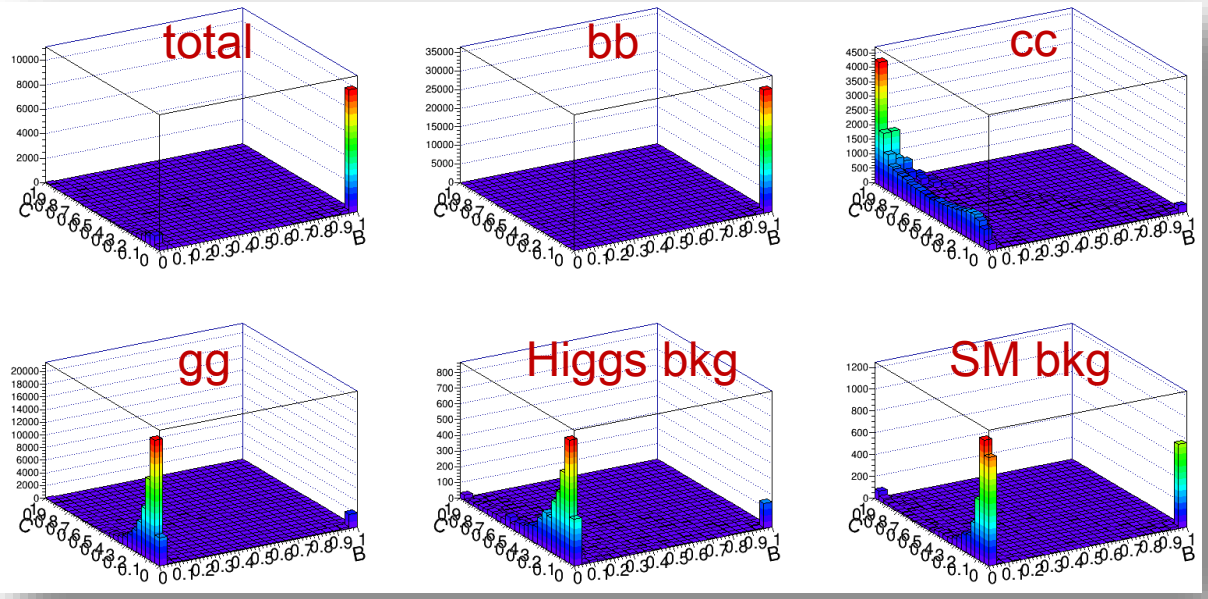
Await for Jet Clustering

Not Covered yet

Final state	Δσ(ZH, H→ZZ*)/σ(ZH, H→ZZ*)
ee + qq + vv	12.7%
μμ + qq + vv	7.0%
μμ + μμ + qq	19.9%
ee + μμ + qq	15.5%
Combined	5.4% (*TLEP: 4.3%*)

Measurement of ZH(H→bb)

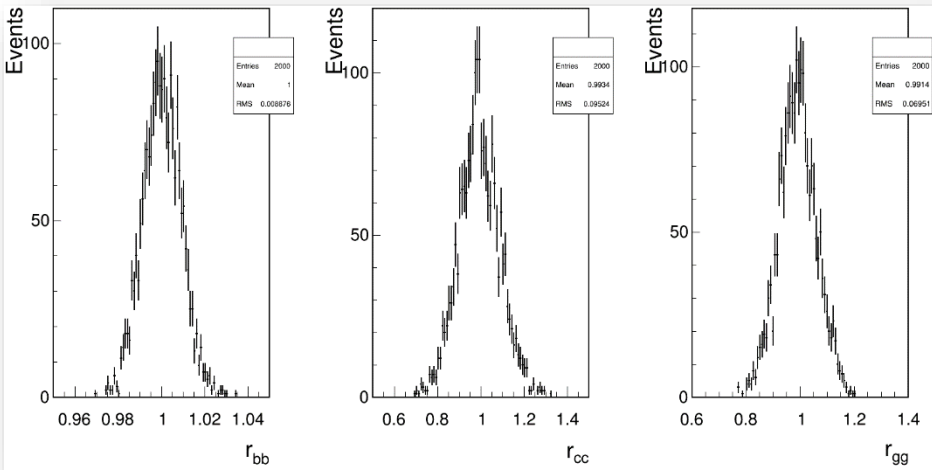
see Yu's talk



- Based on an analysis of Higgs decaying to 2 jets
- Precision extracted from a template fit on flavor tagging information

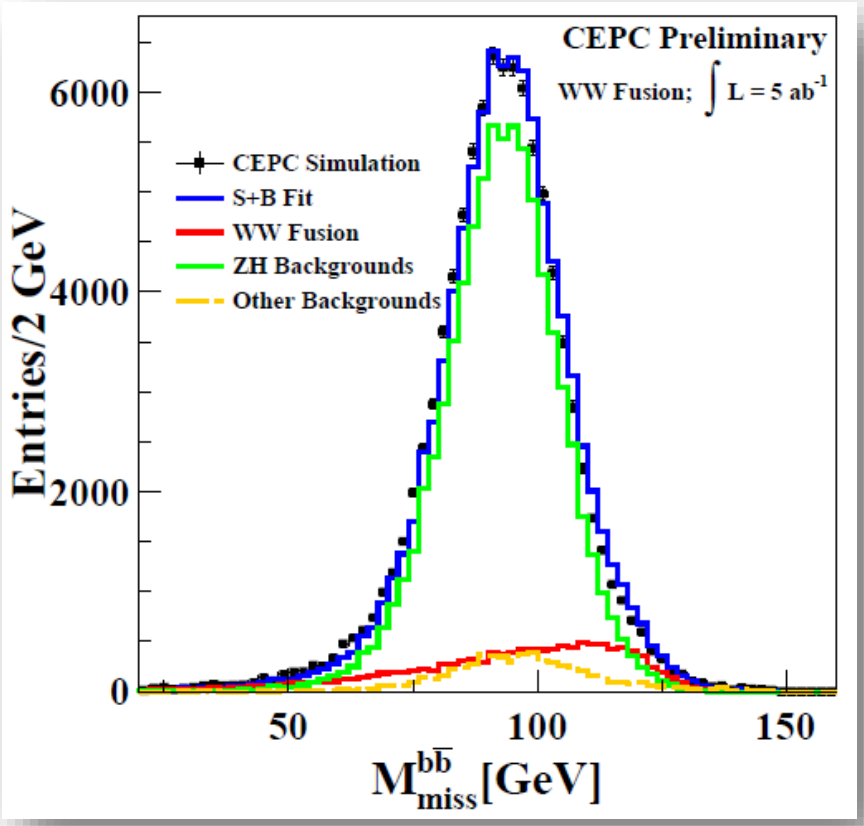
Z→	Δσ(ZH, H→bb)/σ(ZH, H→bb)
e^+e^-	1.3%
$\mu^+\mu^-$	0.9%
vv	0.3%
qq	0.4%
Combined	0.2%

$Z\to\mu^+\mu^-$



Measurement of vvH(H→bb)

- σ(vvH)/σ(ZH) ~ 10^{-2}
- Recoil mass of 2 jets: limited discriminating power
- main background: ZH(Z→vv,H→bb) (interference ignored)

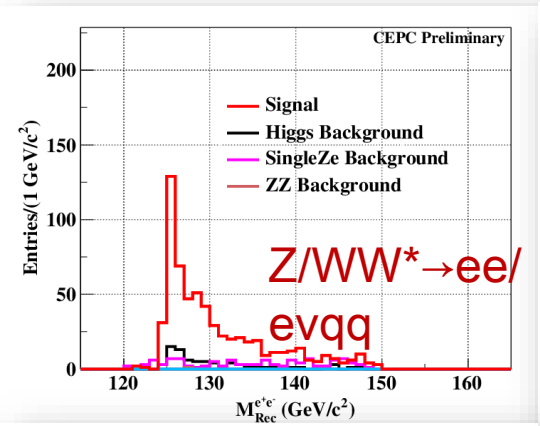


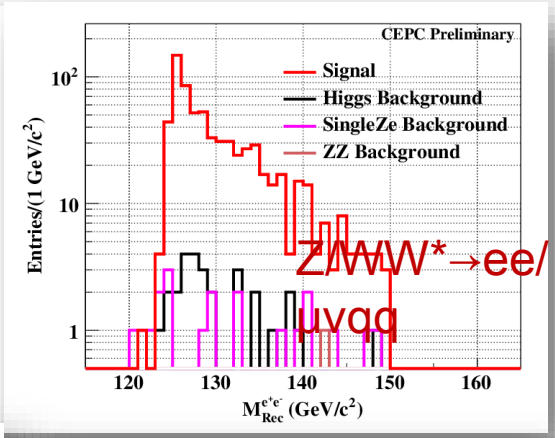
Δσ(vvH, H→bb)/σ(vvH, H→bb): 2.8%

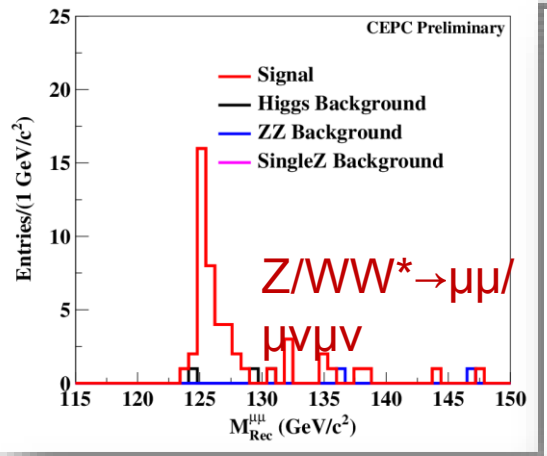
Fast simulated, consistent with preliminary full simulation

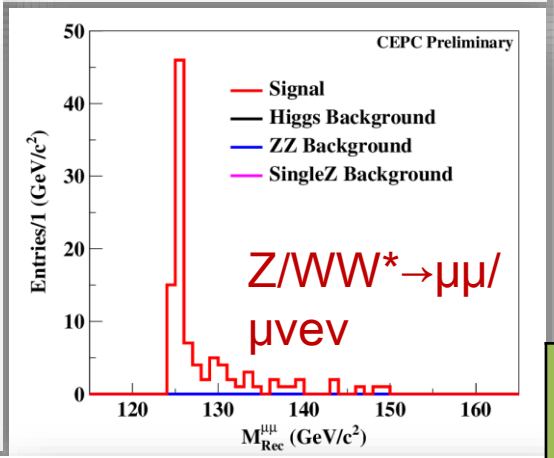
Measurement of ZH(H→WW*)

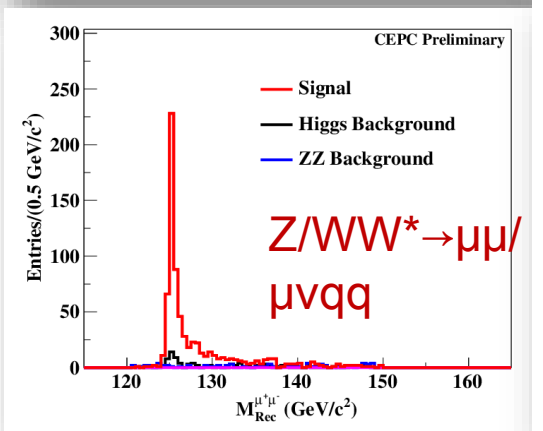
see Libo's talk

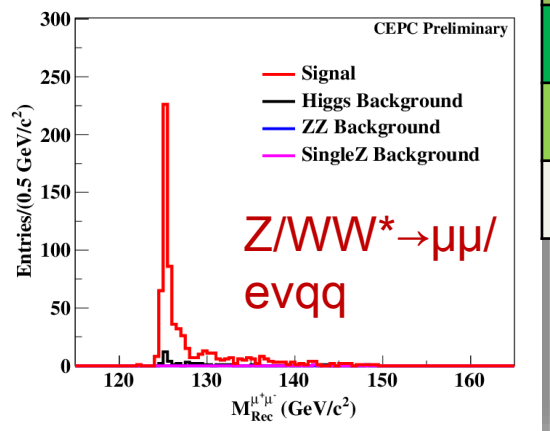












	Z→ll	taus	vv	qq
WW*→4q	6.91k	3.45k	19.74k	69.1k
lv+qq	4.53k	2.27k	12.94k	45.3k
lv+lv	745	377	2.13k	7.45k
X+tau	3.2k	1.60k	9.14k	32.0k

Await for tau finder

Extrapolated from ILC

Preliminary

Await for SM background

Full simulated

Not covered yet

Final state	Δσ(ZH, H→WW*)/σ(ZH, H→WW*)
	1.6%
	1.6%
Combined	1.1%

Higgs width determination

Strategy I:

$$\Gamma_H = \frac{\Gamma(H \to ZZ^*)}{\mathrm{BR}(H \to ZZ^*)} \propto \frac{\sigma(ZH)}{\mathrm{BR}(H \to ZZ^*)}$$

Strategy II:

$$\Gamma_H \propto \frac{\Gamma(H \to bb)}{\mathrm{BR}(H \to bb)} \propto \frac{\sigma(\nu\bar{\nu}H \to \nu\bar{\nu}bb)}{\mathrm{BR}(H \to bb) \cdot \mathrm{BR}(H \to WW^*)}$$

σ(ZH)	0.50%	
Decay mode	Cross section precision	Branching ratio precision
ZH, H→bb	0.21%	0.54%
ZH, H→WW	1.6% (*ILC: 1.1%*)	1.7% (*ILC: 1.2%*)
ZH, H→ZZ	5.4% (*TLEP: 4.3%*)	5.4% (*TLEP: 4.3%*)
vvH, H→bb	2.8%	-

- Higgs total width:
  - ✓ Strategy I: 5.4% (*TLEP: 4.4%*)
  - ✓ Strategy II: 3.3% (*ILC: 3.1%*)

Combined: 2.8% (with extrapolation: 2.6%)

Summary

- ✓ Based on 5 ab^{-1} full simulated (part of backgrounds are fast simulated) MC samples at the CEPC, the results of benchmark analysis are presented

- ✓ Using the recoil mass method, the ZH cross section is determined in a model-independent way, with a precision of 0.50%. Meanwhile, the precision of Higgs mass is 5.0 MeV

- ✓ Based on the measurements of $\sigma(ZH)$, $\sigma(ZH, H\rightarrow bb)$, $\sigma(\nu\nu H, H\rightarrow bb)$, $\sigma(ZH, H\rightarrow WW)$, $\sigma(ZH, H\rightarrow ZZ)$, the relative precision of Higgs width is determined to be 2.8%

Experience on paper publication

Cross Section and Higgs Mass Measurement with Higgsstrahlung at the CEPC
submitted to CPC

Author	Journal Decision
2016-01-21 submitted	2016-02-13 Major Revision
2016-03-29 submitted revision	2016-05-05 Major Revision
2016-06-21 submitted revision	2016-07-11 Minor Revision
2016-08-09 submitted revision	2016-09-13 Major Revision
2016-10-25 submitted revision	2016-11-14 Accept

Key point:

Mature result

Well organized (discussion on the systematic control)

Clear description

Thanks for your attention!