Higgs Recoil Mass Analysis at CEPC

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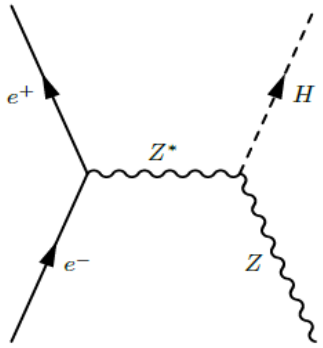
outline

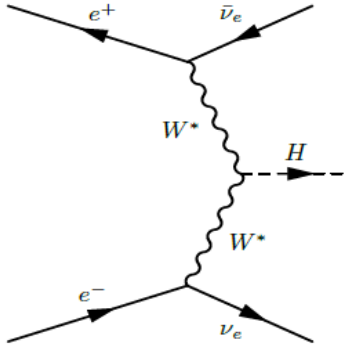
- Introduction
- Samples
- Analysis with Z boson leptonic decay
  - ✓ Model independent measurement of ZH cross section and Higgs mass
  - ✓ Model dependent measurement of Higgs mass
- Summary

Introduction

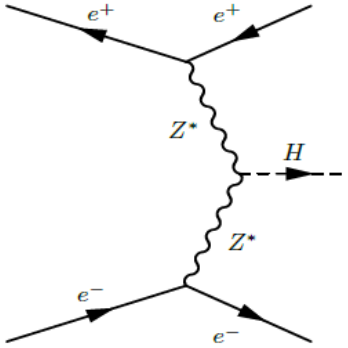
- The Higgs bosons are produced via Higgsstrahlung(ZH), WW fusion and ZZ fusion at CEPC



ZH



WW fusion

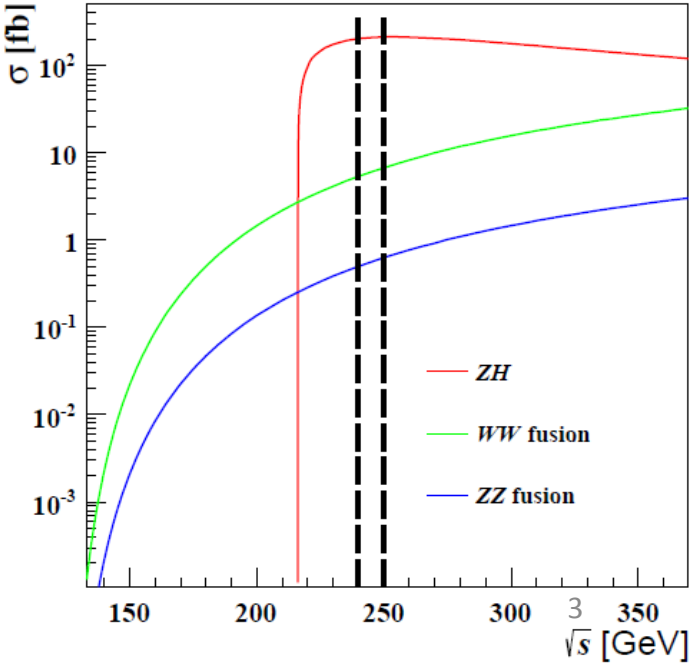


ZZ fusion

- ZH is the dominant Higgs production process.

- The ZH cross section is proportional to the square of g(HZZ)

- g(HZZ) is an essential input for the Higgs width measurement



Introduction

- The beam can be well controlled and precisely measured.
- The recoiling mass method can be used to reveal the Higgs signal

$$m_{\mathrm{rec}}^2 = (\sqrt{s} - E_{\ell\ell})^2 - \mathbf{p}_{\ell\ell}^2 = s - 2\sqrt{s}E_{\ell\ell} + E_{\ell\ell}^2 - \mathbf{p}_{\ell\ell}^2$$
$$= s - 2\sqrt{s}(E_{\ell 1} + E_{\ell 2}) + m_{\ell\ell}^2,$$

- The Higgs mass can be determined, and it is the only free parameter in the standard model Higgs potential
- No Higgs decay information→model independent mesurement→ inclusive ZH cross section and Higgs mass
- Higgs decay information →reduced background and model dependent mesurement →improved Higgs mass measurement

Samples

Central of mass energy: 250 GeV

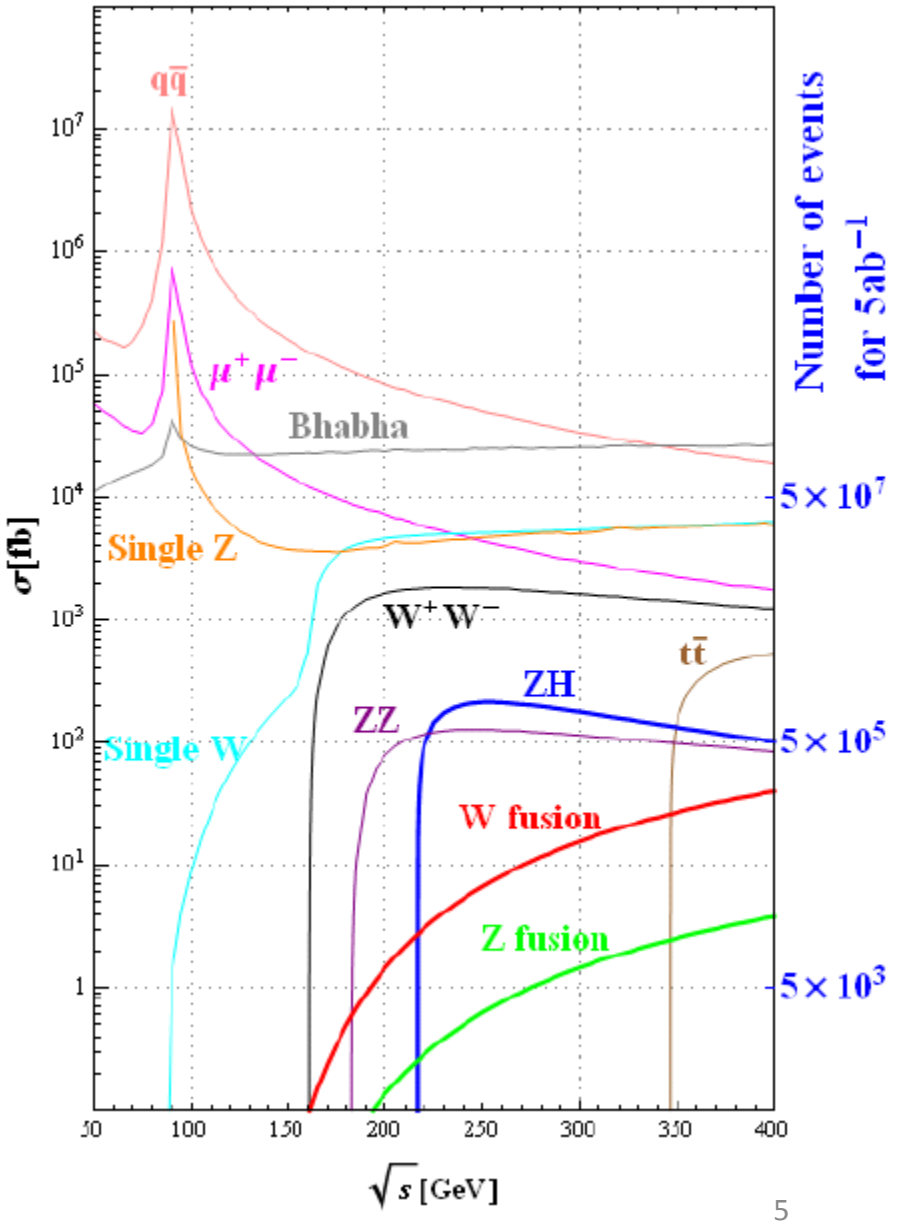
Beam energy spread: 0.16%

No polarized

Signal: full simulated with Arbor v3_1
Higgs mass: 125 GeV

SM background: fast simulated, with momentum resolution and detection efficiency parameterized for different particle types

Luminosity: 5 ab^{-1}



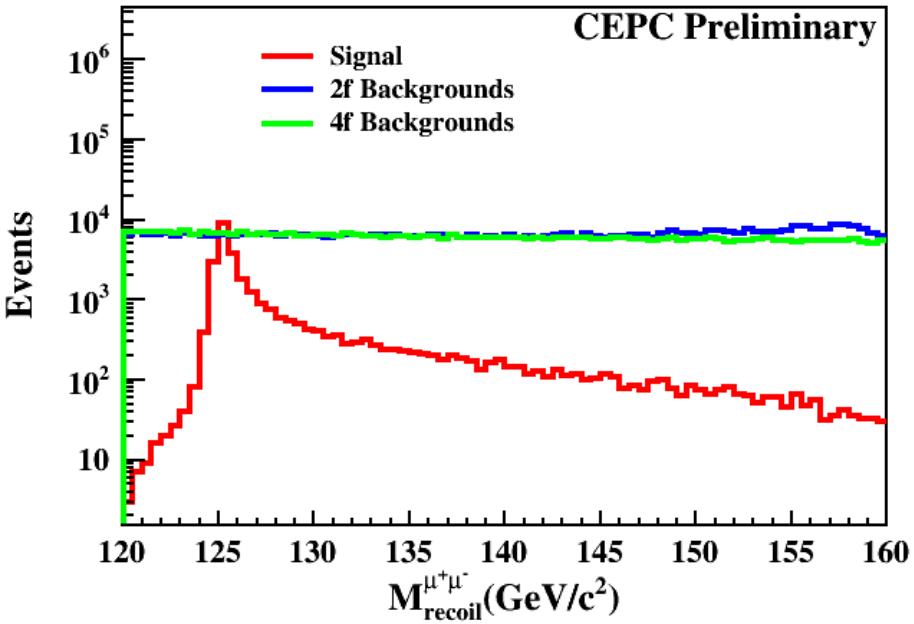
Analysis of $Z \rightarrow \mu^+\mu^-$

MI measurement via $Z \rightarrow \mu^+\mu^-$

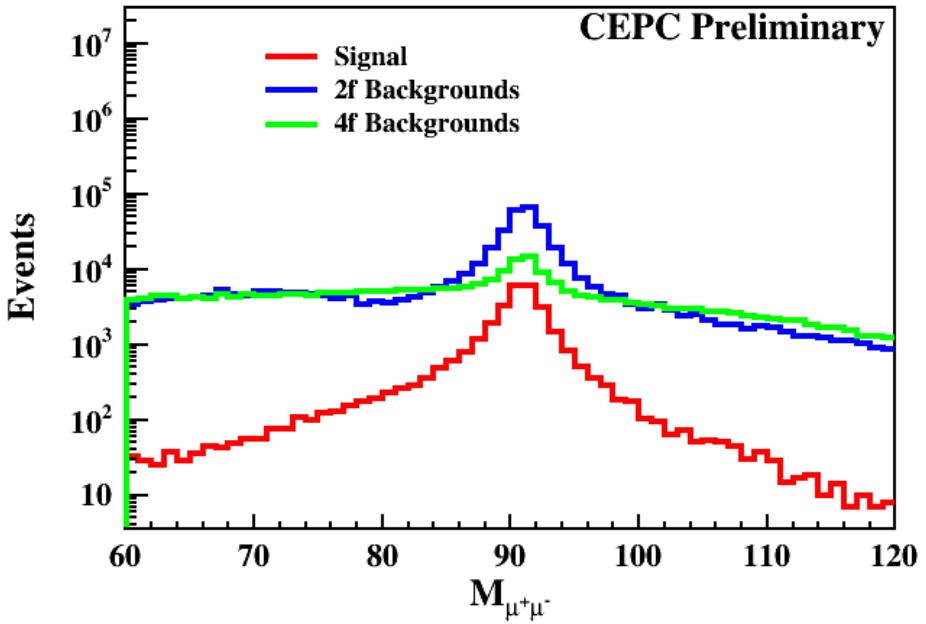
(1) At least one pair of $\mu^+\mu^-$ is reconstructed.

(2) Recoiling mass of $\mu^+\mu^-$: 120 GeV < $M_{\mu+\mu-}^{reco}$ < 150 GeV

(3) Invariant mass of $\mu^+\mu^-$: 80 GeV < $M_{\mu+\mu-}$ < 100 GeV



Based on (1)

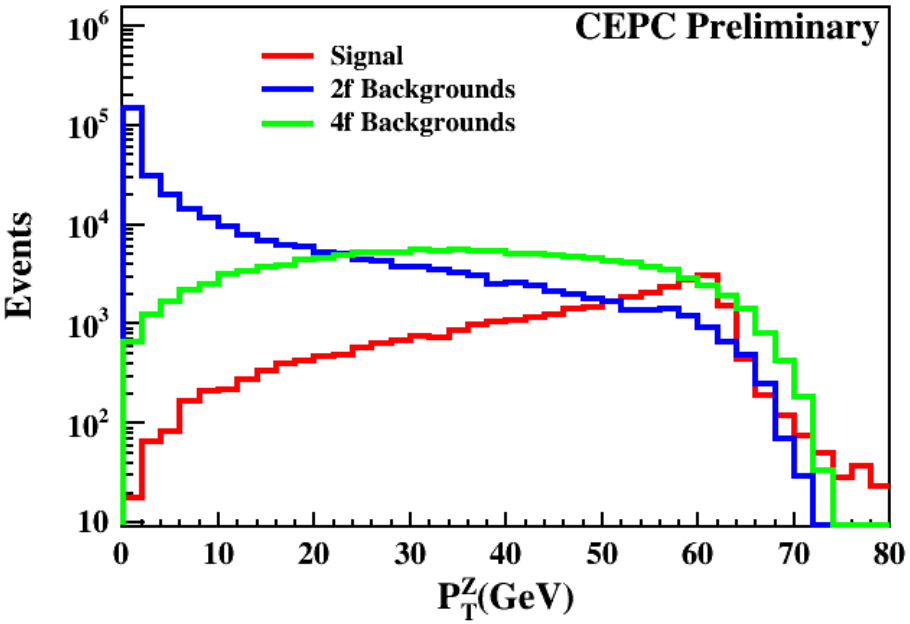


Based on (1)(2)

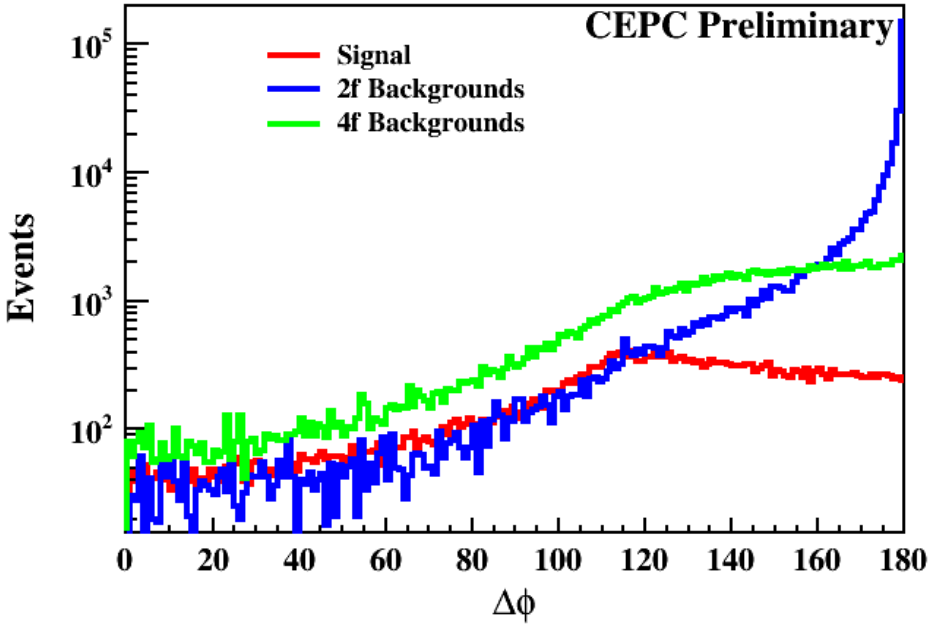
MI measurement via $Z \to \mu^+\mu^-$

(4) Transverse momentum of Z boson candidate: $P_T^Z > 20$ GeV

(5) The azimuthal angle difference between μ^+ and μ^-: $\Delta\phi < 175^\circ$



Based on (1)(2)(3)



Based on (1)(2)(3)(4)

MI measurement via $Z \rightarrow \mu^+\mu^-$

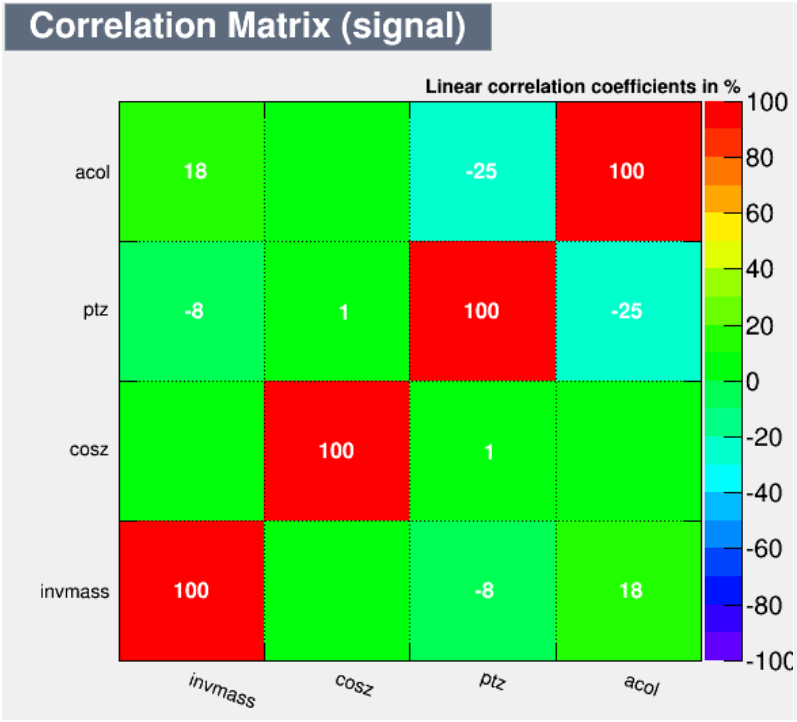
MVA:

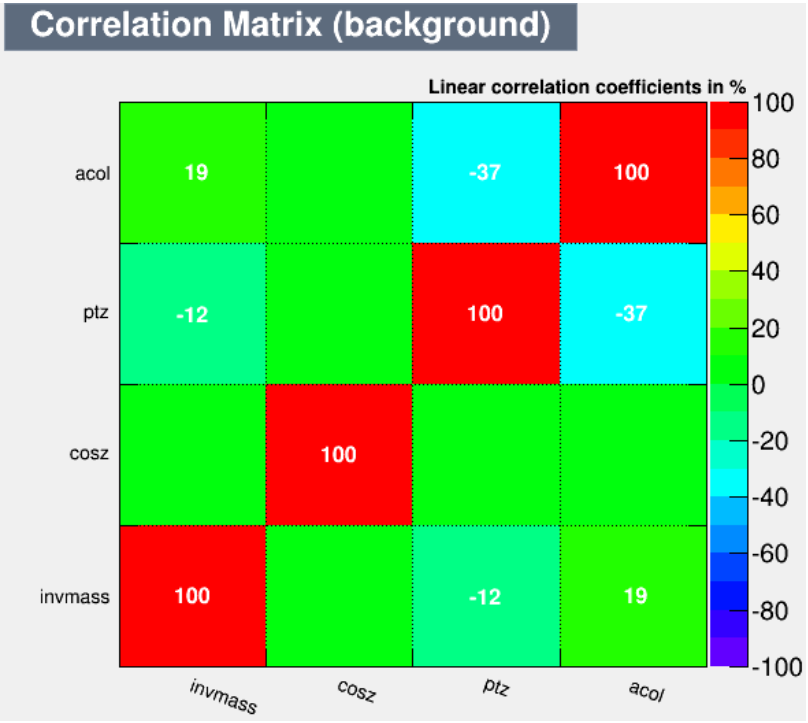
Inputs: $M_{\mu+\mu-}$

P_T^Z

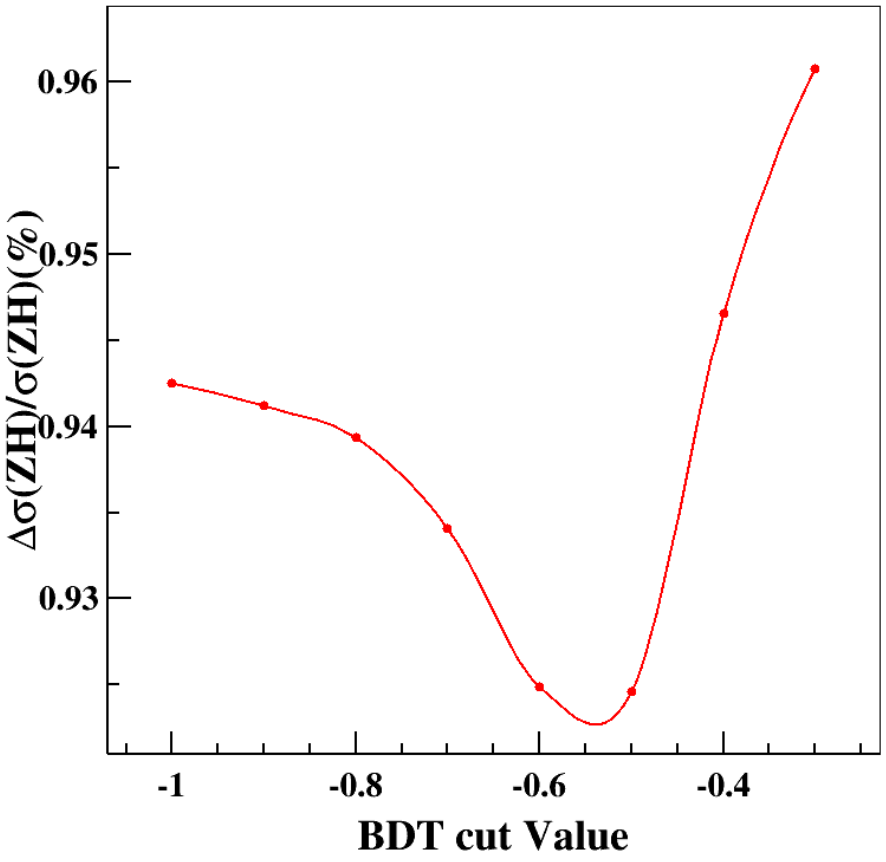
$\cos\theta_Z$ (θ_Z is the polar angle of Z boson candidate)

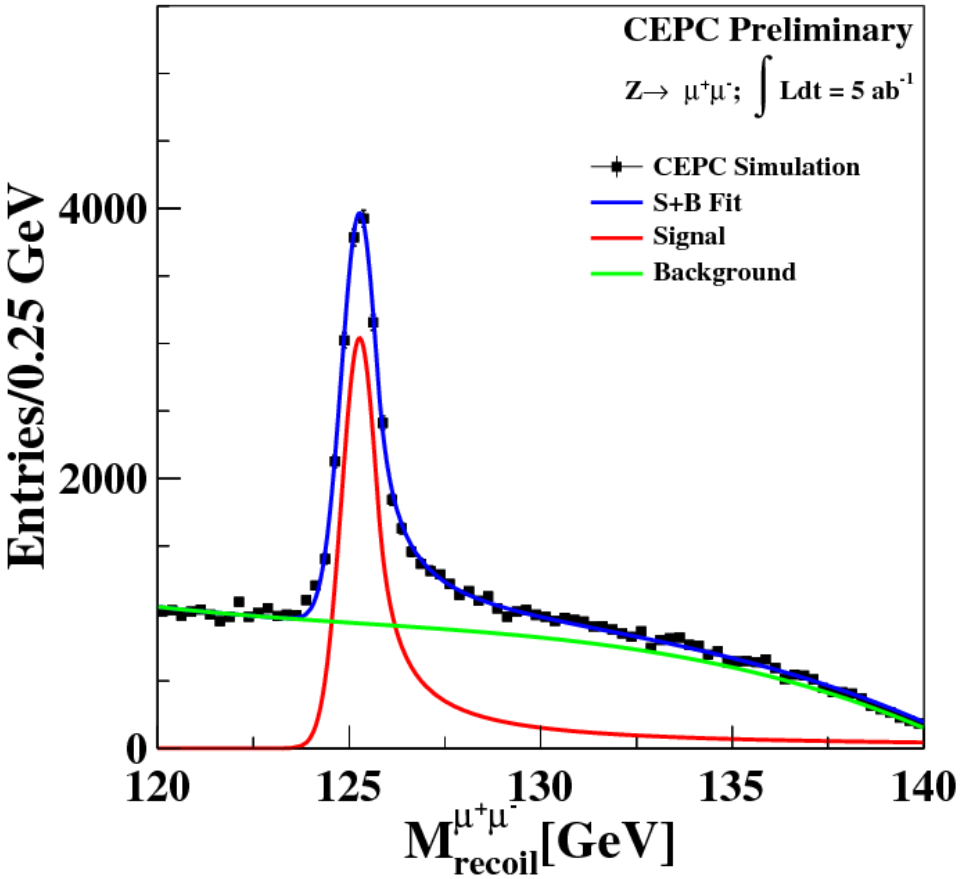
acollinearity(the angle between μ^+ and μ^-)





MI measurement via $Z \rightarrow \mu^+\mu^-$





Signal: Crystal Ball Background: shape extracted from MC sample
BDT optimized according to the ZH cross section precision
Cross section precision: 0.92%
Higgs mass precision: 6.52 MeV

Cut flow

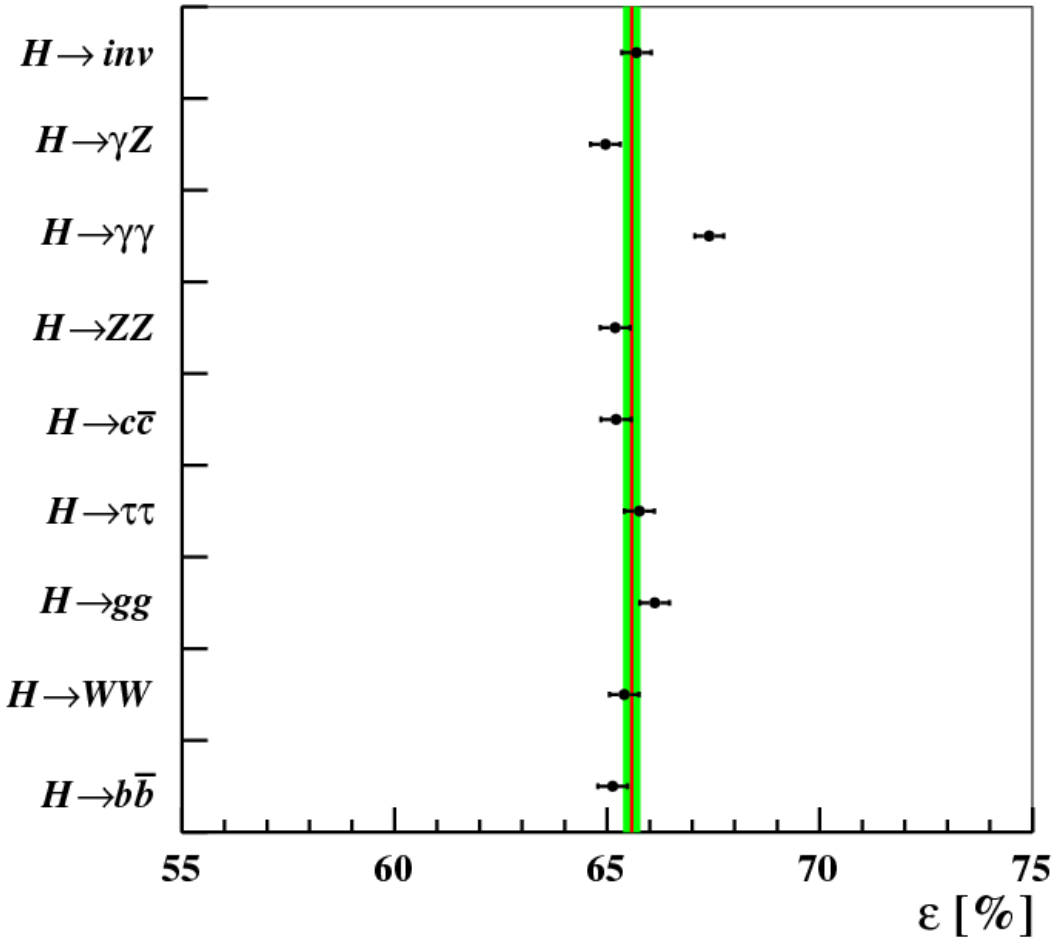
	ZH	ZZ	WW	ZZorWW	Single Z	Z(2f)
Total	35247	5347053	44180832	17801222	7809747	418595861
$N_{\mu+}>=1$, $N_{\mu-}>=1$	95.73%	11.95%	0.65%	3.92%	9.75%	1.64%
$120GeV/c^2<M_{rec}<150GeV/c^2$	93.19%	1.71%	0.23%	0.70%	1.93%	0.17%
$80GeV/c^2<M_{\mu+\mu-}<100GeV/c^2$	85.47%	0.68%	0.06%	0.22%	0.22%	0.10%
$P_{TZ}>20GeV/c$	80.22%	0.57%	0.06%	0.17%	0.16%	0.02%
$\|\varphi\mu+-\varphi\mu-\|<175$	77.76%	0.51%	0.05%	0.17%	0.15%	0.01%
BDT cut	65.48%	0.26%	0.01%	0.05%	0.06%	0.01%
$120GeV/c^2<M_{rec}<140GeV/c^2$	65.33%	0.26%	0.01%	0.05%	0.06%	0.01%

The main remaining backgrounds are Z(2f)

Model independence

The efficiencies of Higgs main decay modes are checked

No biase to any specific channel

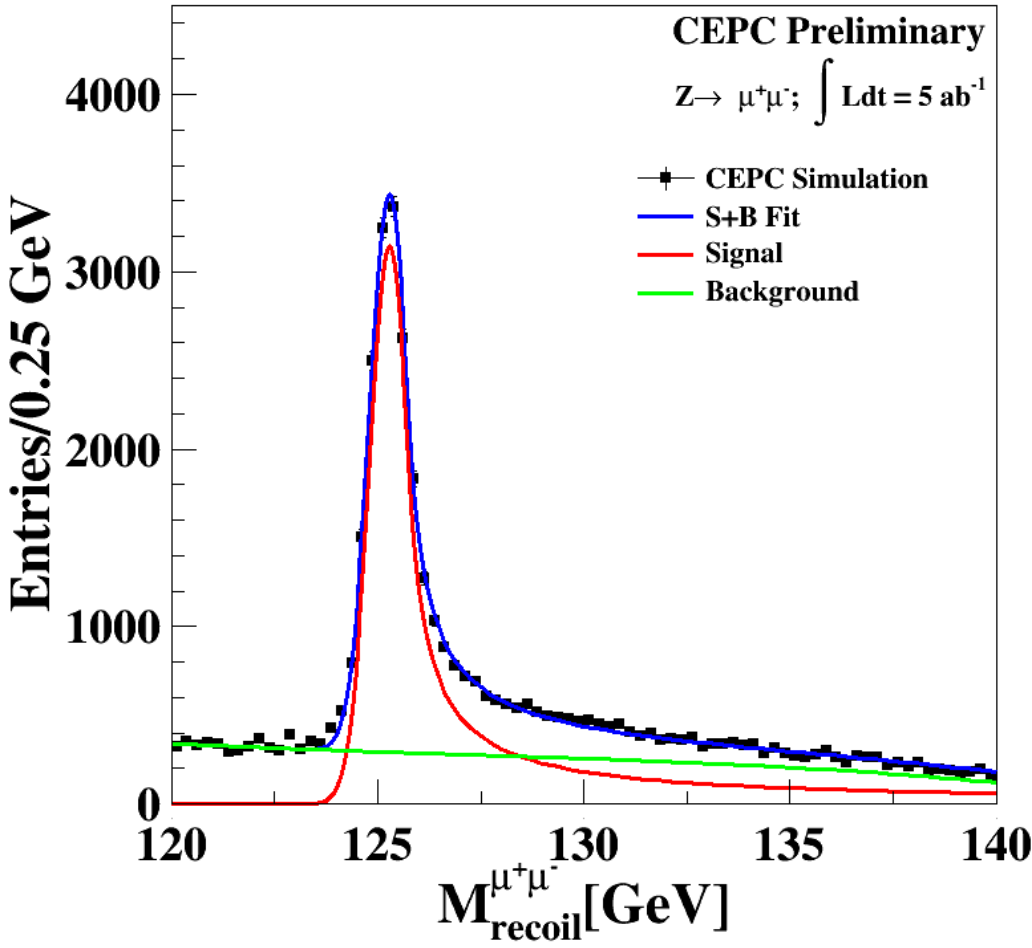


MD measurement via $Z \rightarrow \mu^+\mu^-$

Based on the MI selection criteria

$N_{ch} > 2$ (to suppress 2 fermion background)

The total reconstructed energy is also taken as an input for MVA



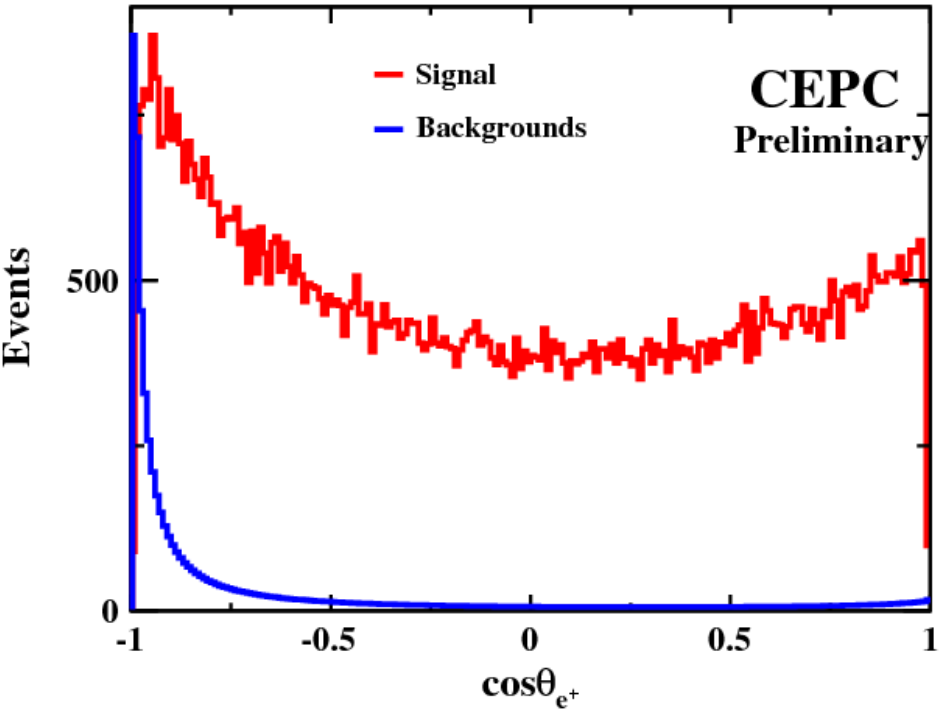
Signal: Crystal Ball Background: shape extracted from MC sample
BDT optimized according to the Higgs mass precision
Higgs mass precision: 5.38 MeV

Analysis of $Z \rightarrow e^+e^-$

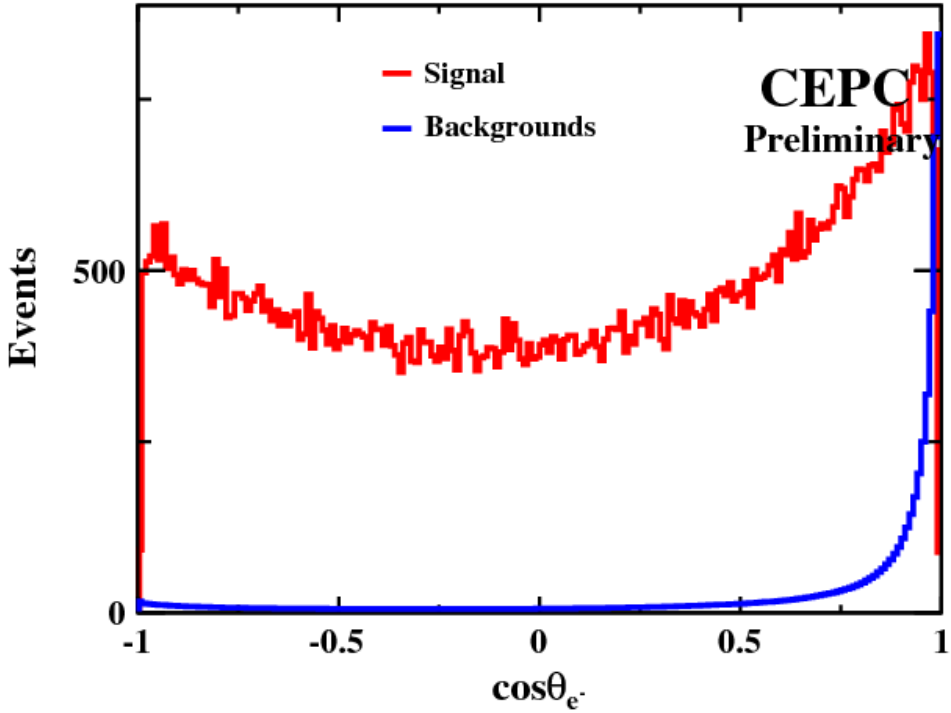
MI measurement via $Z \rightarrow e^+e^-$

(1) At least one pair of e^+e^- is reconstructed.

(2) Large background from Bhabha. Polar angle of electron and positron: $\cos\theta_{e+} > -0.9$ $\cos\theta_{e-} < 0.9$



Based on (1)



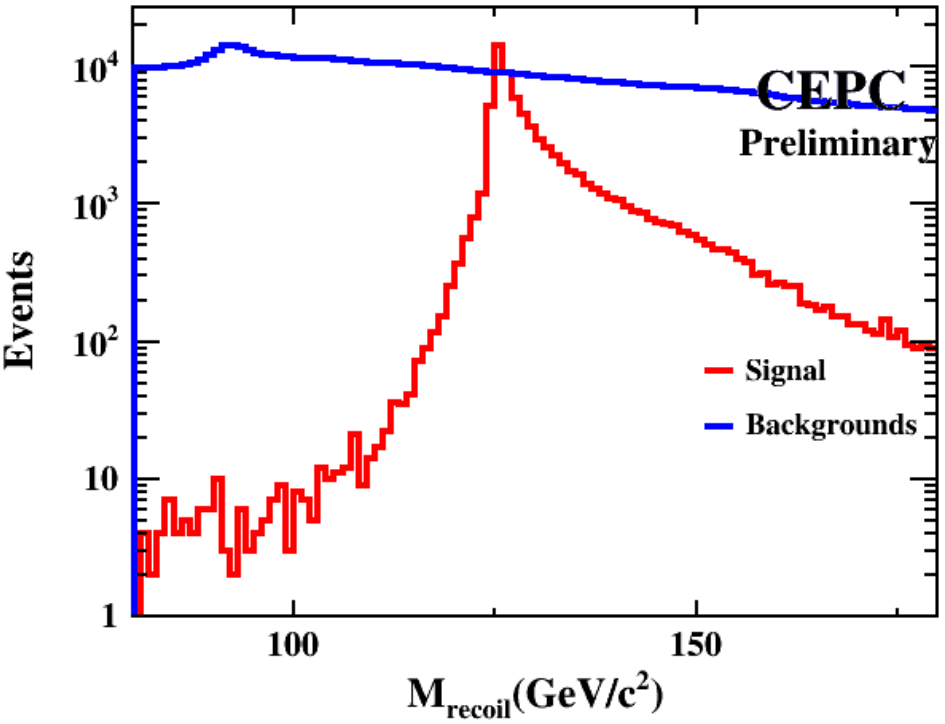
Based on (1)

MI measurement via $Z \rightarrow e^+e^-$

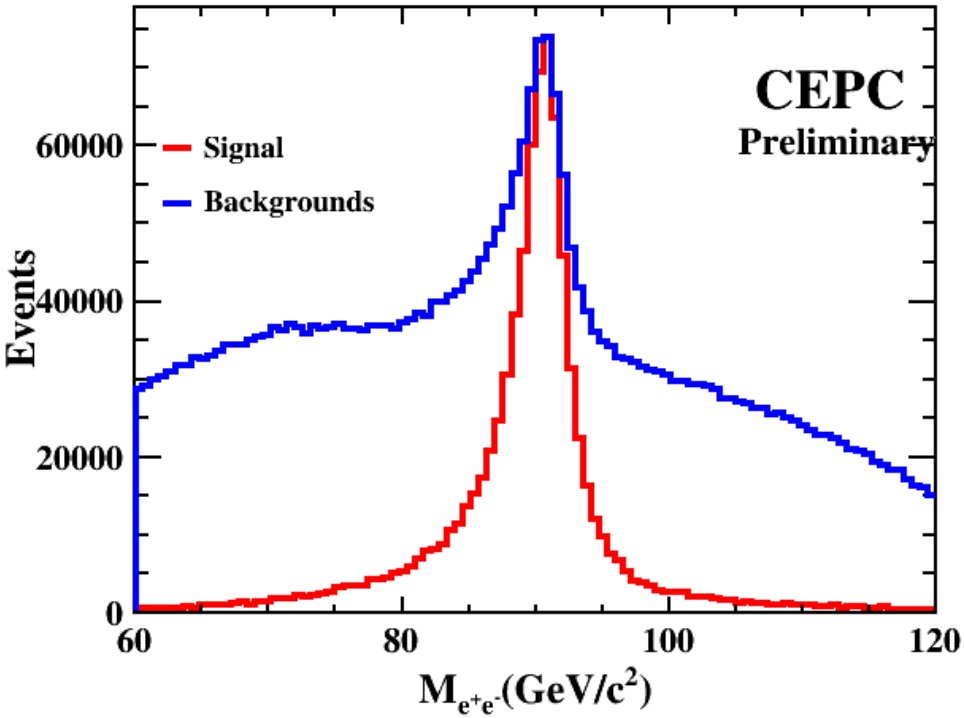
(3) Recoiling mass of e^+e^-: $120\ \text{GeV} < M_{e+e-}^{\text{reco}} < 160\ \text{GeV}$

(4) Invariant mass of e^+e^-: $80\ \text{GeV} < M_{e+e-} < 100\ \text{GeV}$

Bremstrahlung recovery: the momentum of photon close to the electron or positron in Z candidate is added



Based on (1)(2)

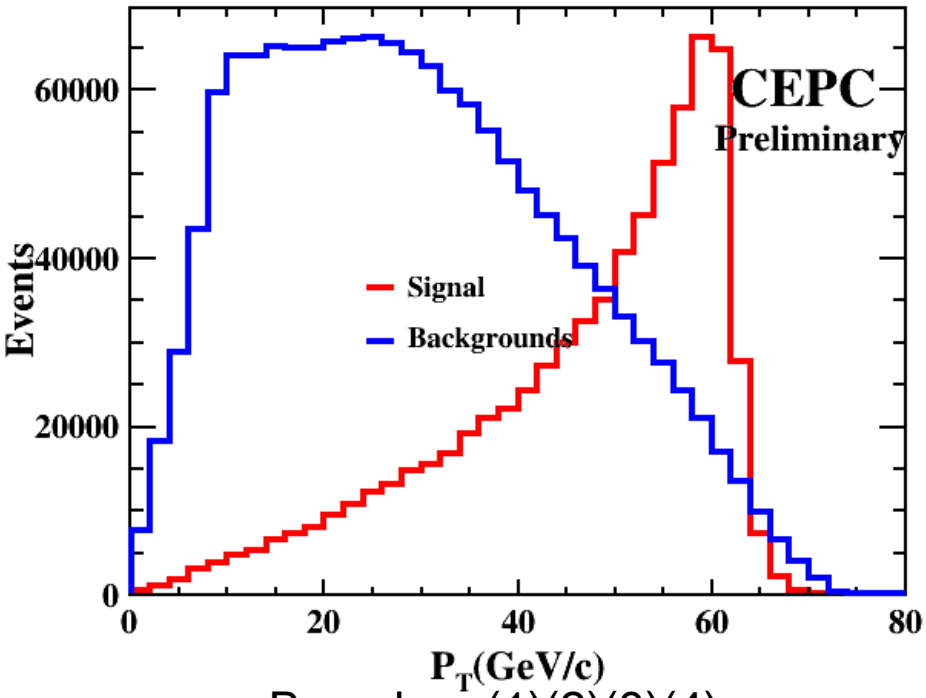


Based on (1)(2)(3)

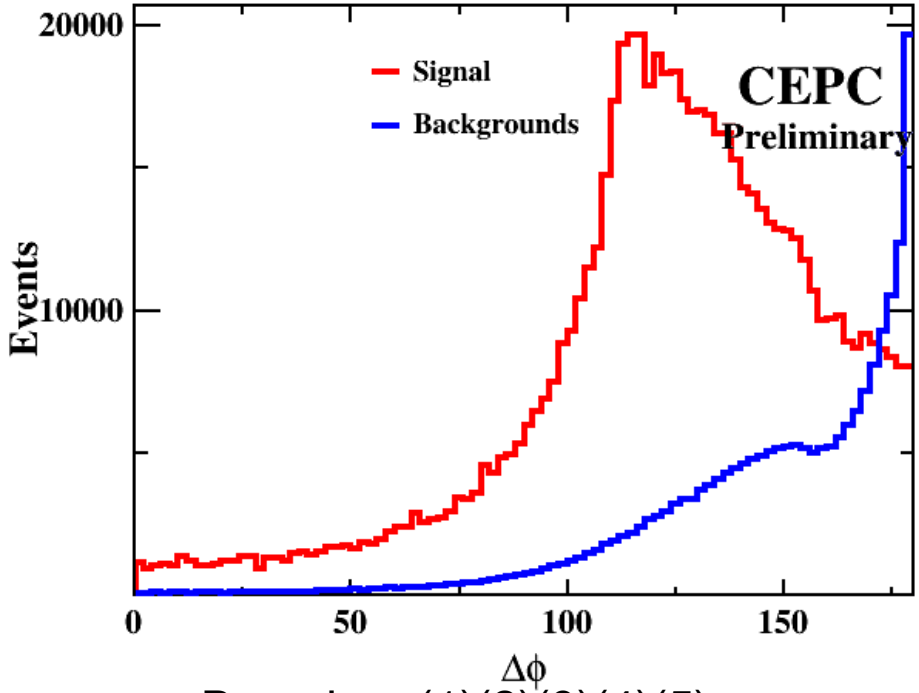
MI measurement via $Z \rightarrow e^+e^-$

(5) Transverse momentum of Z boson candidate: $P_T^Z > 20$ GeV

(6) The azimuthal angle difference between e^+ and e^-: $\Delta\phi < 175^\circ$



Based on (1)(2)(3)(4)



Based on (1)(2)(3)(4)(5)

MI measurement via $Z \rightarrow e^+e^-$

MVA:

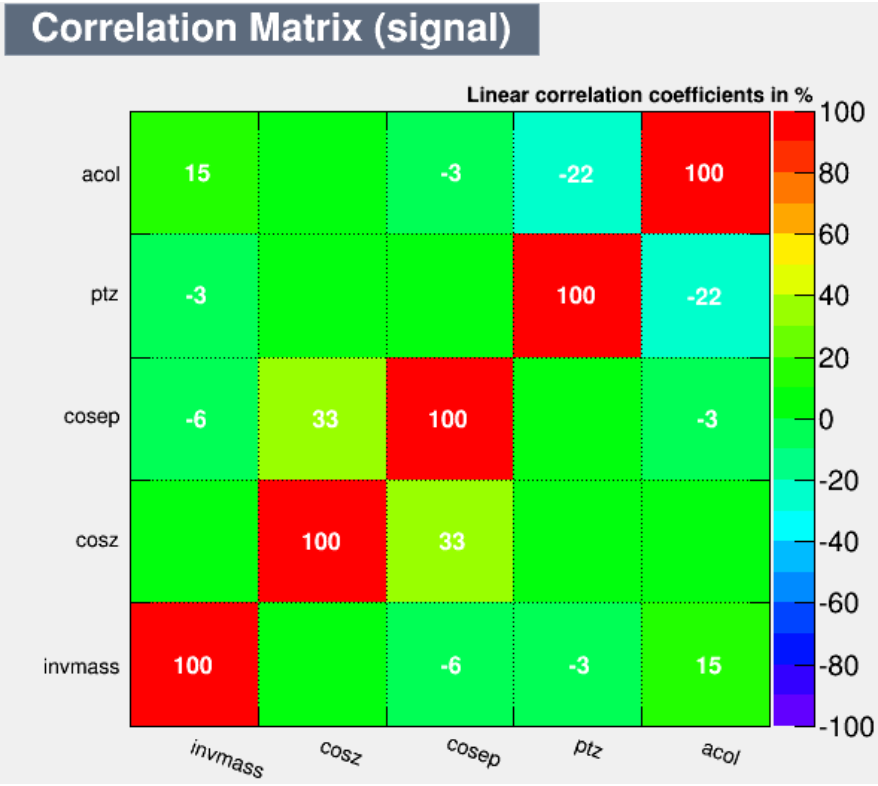
Inputs: M_{e+e-}

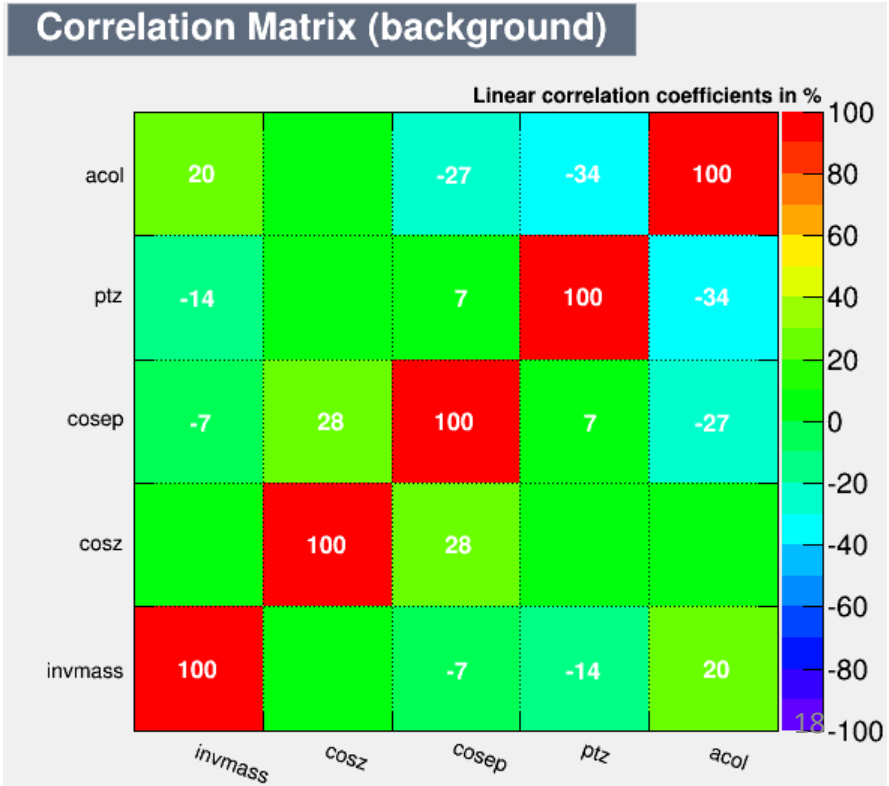
P_T^Z

cos θ_Z(θ_Z is the polar angle of Z boson candidate)

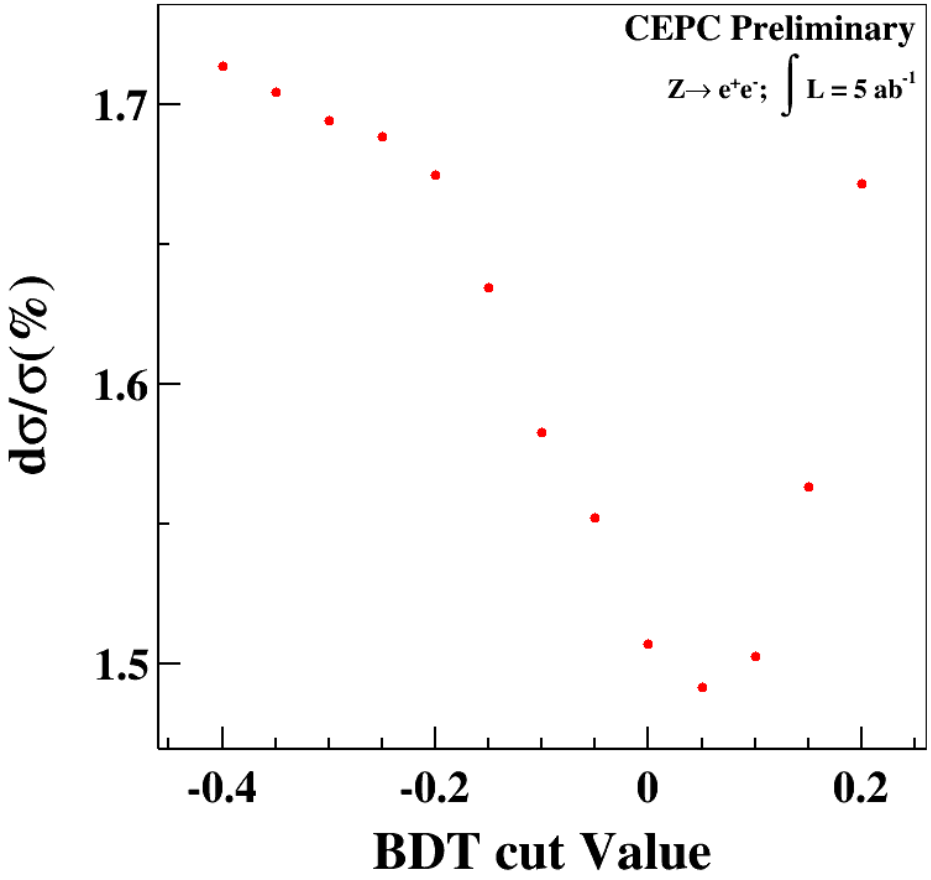
cos θ_{e+}(θ_{e+} is the polar angle of positron)

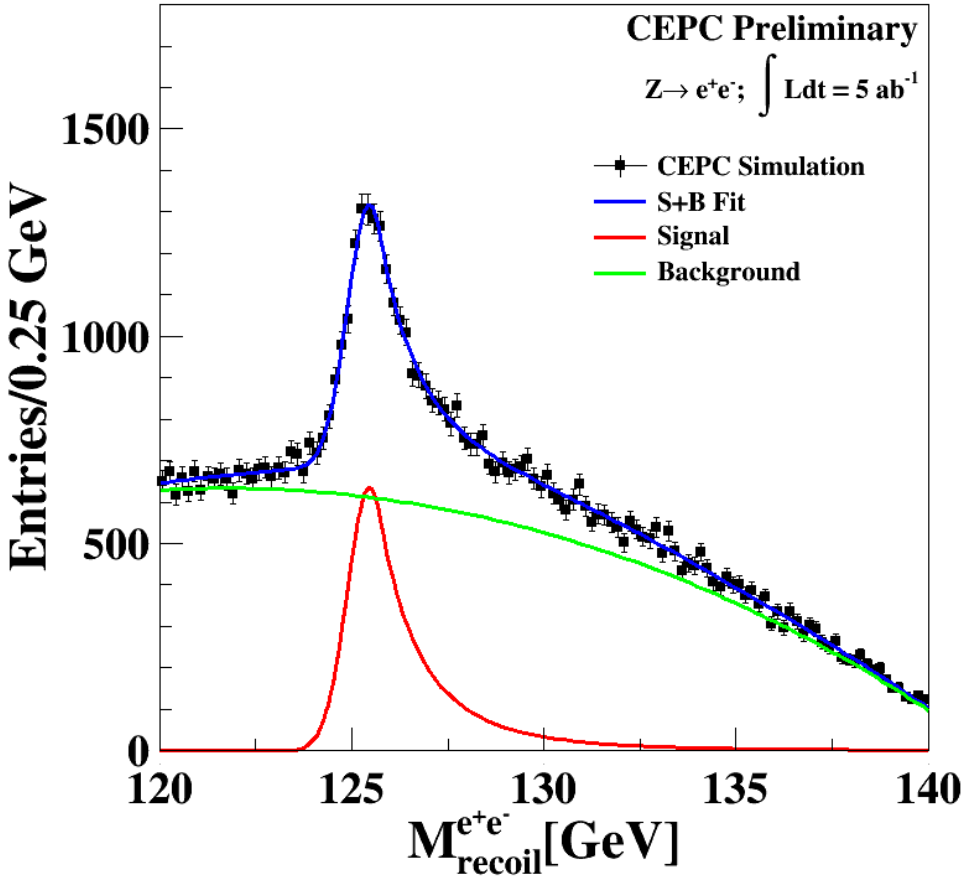
acollinearity(the angle between e^+ and e^-)





MI measurement via $Z \rightarrow e^+e^-$





Signal: Crystal Ball Background: shape extracted from MC sample

BDT optimized according to the ZH cross section precision

Cross section precision: 1.49%

Higgs mass precision: 19.17 MeV

Cut flow

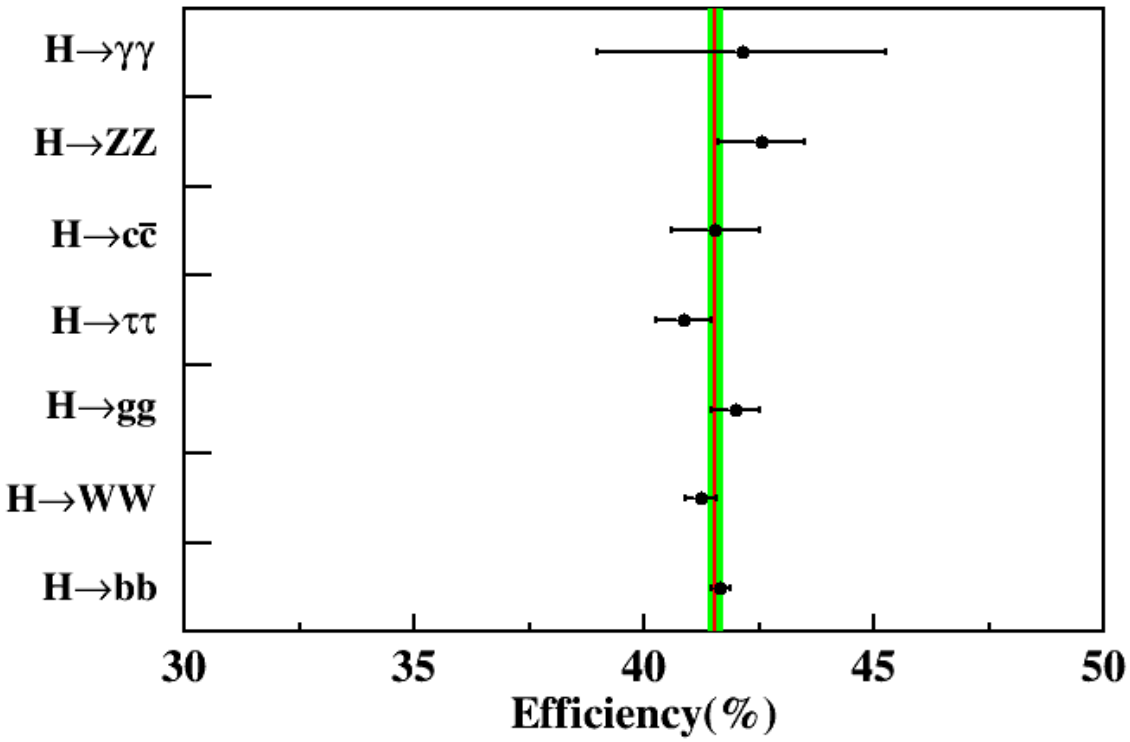
	ZH	ZZ	WW	ZZorWW	Z	W	ZorW	Z(2f)
total	35247	5436373	44181064	17799208	7808854	17020374	1246802	418598154
$N_{e+}>=1$, $N_{e-}>=1$ $\cos\theta_{e+}>-0.9$,$\cos\theta_{e-}<0.9$	28010	13615	16266	20105	574212	222811	626516	6594087
$120GeV/c^2<M_{rec}<160GeV/c^2$	26437	903	1428	3667	122997	82943	156757	1204575
$80GeV/c^2<M_{e+e-}<100GeV/c^2$	22958	118	220	1497	45438	25050	53851	414026
$P_{TZ}>20GeV/c$	21574	85	166	1056	36414	22252	43108	263375
$\|\varphi e+-\varphi e-\|<175$	20908	64	157	986	33909	20613	41468	206862
BDT cut	14614	4	9	68	10961	3512	10085	37160

Signal efficiency: 41.46%
The main remaining backgrounds are Z(2f)

Model independence

The efficiencies of Higgs main decay modes are checked

No biase to any specific channel

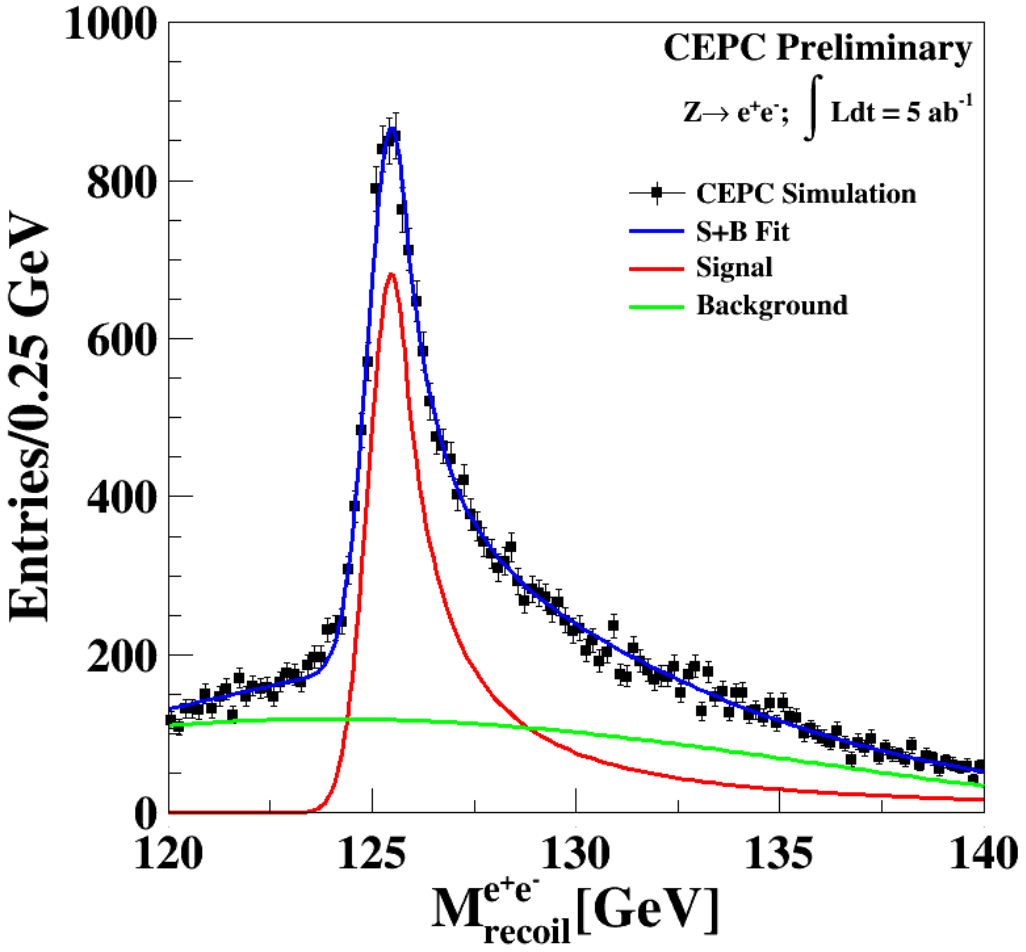


MD measurement via $Z \rightarrow e^+e^-$

Based on the MI selection criteria

$N_{ch} > 2$

The total reconstructed energy is also taken as an input for MVA



Signal: Crystal Ball Background: shape extracted from MC sample
BDT optimized according to the Higgs mass precision
Higgs mass precision: 13.09 MeV

Summary

Based on a full simulated sample of $5ab^{-1}$, the ZH process with Z boson decaying to leptons has been investigated at CEPC

The recoil mass method is applied.

In a model independent measurement, the relative precisions of ZH cross section are determined to be 0.92%($\mu^+\mu^-$) and 1.49%(e^+e^-). The Higgs mass precisions are 6.52 MeV($\mu^+\mu^-$) and 19.17 MeV(e^+e^-).

In a model dependent measurement, the Higgs mass precisions can be improved to 5.38 MeV($\mu^+\mu^-$) and 13.09 MeV(e^+e^-).

Thanks!