ICHEP 2020

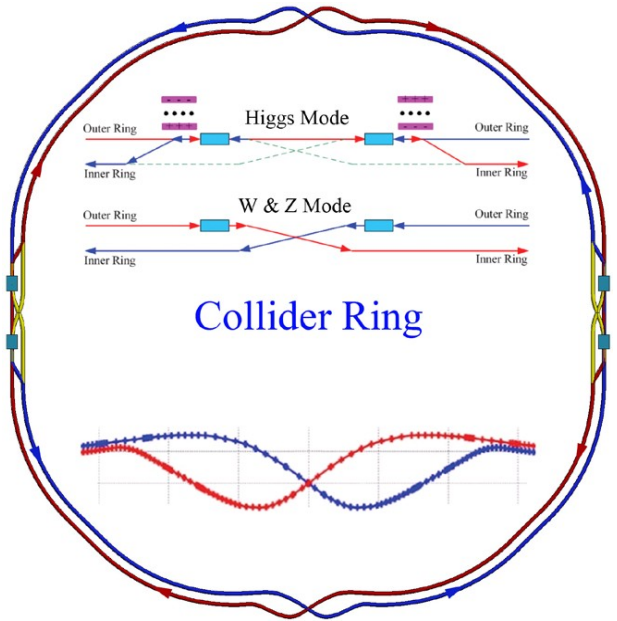
HIGGS TO WW DECAY IN ALL-JET FINAL STATE AT CEPC

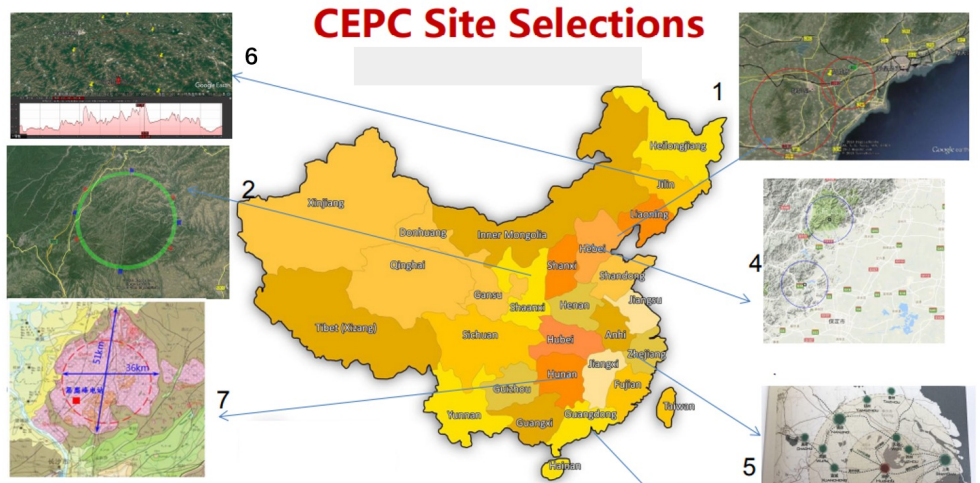
MILA PANDUROVIC

VINCA INSTITUTE OF NUCLEAR SCIENCES, UNIVERSITY OF BELGRADE

CEPC

- Proposed circular electron-positron collider in China
- Circumference 100 km
- Two two interaction points



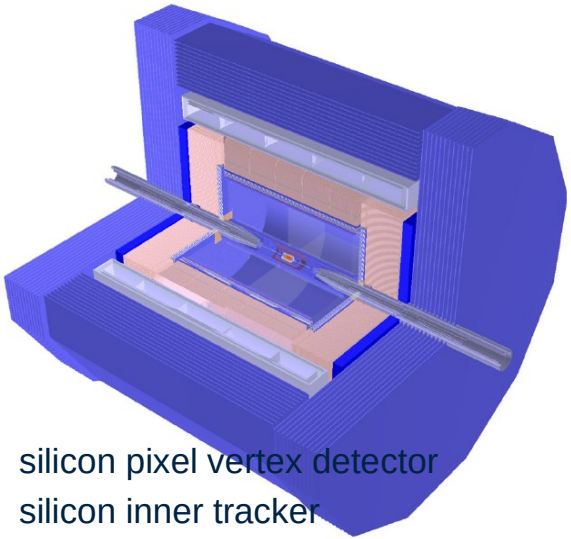


	Center of mass energy [GeV]	Integrated Luminosity [ab^{-1}]	Running time [years]	Yield
Higgs Factory	240	5.6	7	10^{8}
WW production	158–172	2.6	1	10^{7}
Z production	91.2	1	2	10^{11}

CEPC Conceptual Design Report, arXiv:1811.10545, arXiv:1809.00285

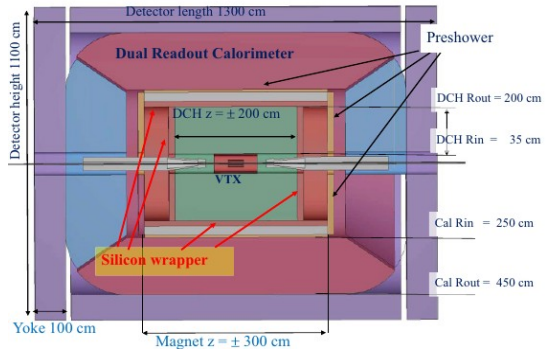
CEPC Detector Concept

- CEPC ILD – baseline model – Particle flow method



- silicon pixel vertex detector
- silicon inner tracker
- TPC
- silicon outer tracker
- ECAL (Tungsten-Silicon)
- HCAL (Iron-Resistive Plate Chamber - RPC)
- solenoid 3 T
- return yoke embedded with a muon detector

- CEPC_IDEA - Dual readout calorimetry method



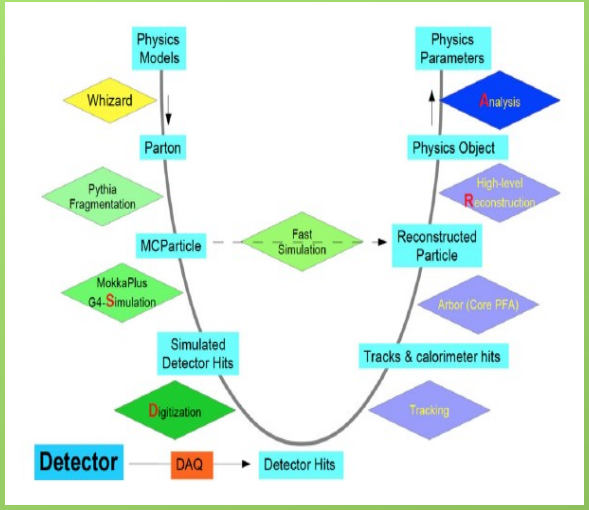
- silicon vertex
- drift chamber
- silicon wrapper
- solenoid 2 T
- preshower
- dual-readout calorimeter: lead-scintillating/Cerenkov fibers
- yoke+muon chamber

Event generation and reconstruction

SIMULATION

Whizard generator V1.95

Pythia 8.2



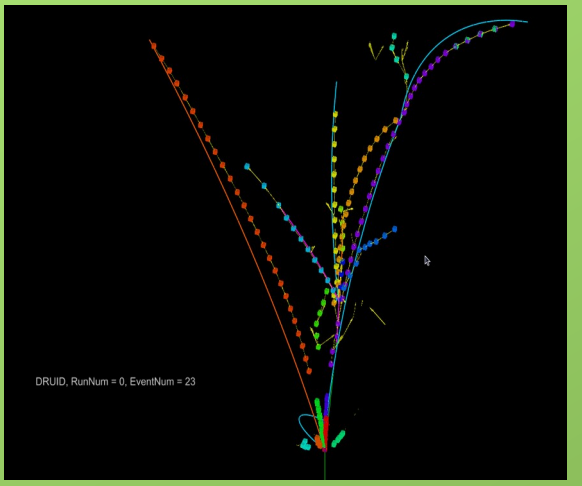
RECONSTRUCTION

- ARBOR reconstruction software
- developed for the CEPC_ILD
- Relays on the Particle Flow paradigm

Particle reconstruction	ε [%]
Charged Kaon efficiency	91-97
Pion efficiency	98
Muon E>2GeV	99.5
Electron E>2GeV	99.5
Photon E>1GeV	98
Jet energy resolution	3-4

Arbor reconstruction

- Reconstruction of the ‘tree’ like structures of the shower development
- TPC hits → trees, forest
- Tree decomposition into track segments → merge → TRACKS
- Track refitting → track parameters

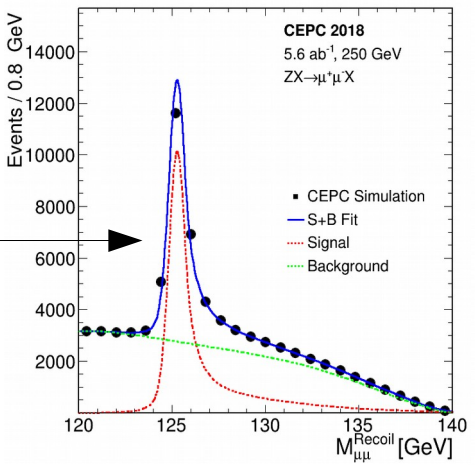


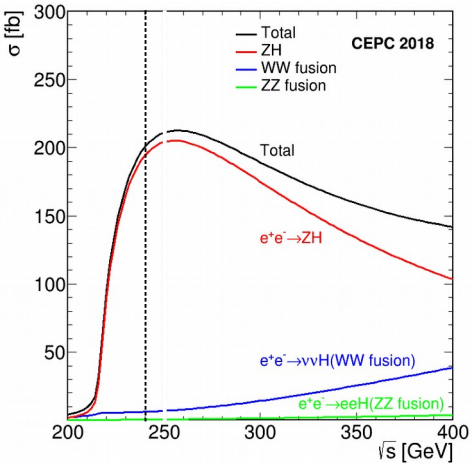
”Reconstruction of physics objects at the Circular Electron Positron Collider with Arbor”,ArXiv:1806.04879, M. Ruan et al.

Higgs Production at CEPC

- Higgsstrahlung is the dominant channel for Higgs production
- Unpolarized beams $e^+e^- \to HZ$ $\sigma_{HZ}(250\ GeV) = 204.7\ fb$

Absolute coupling g_{HZZ} determination

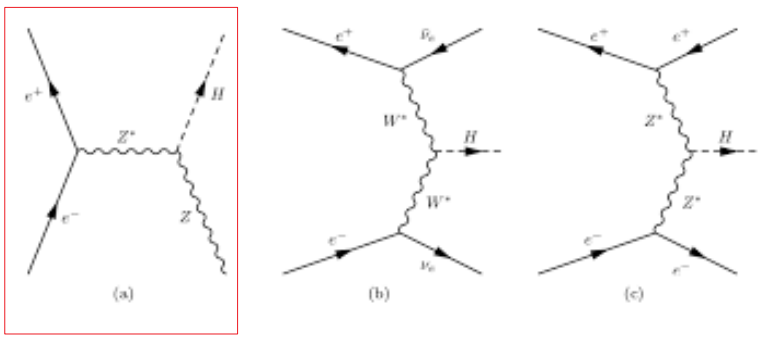




Higgs width

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

$$\Gamma_H = \frac{\Gamma(H \to b\bar{b})}{\mathrm{BR}(H \to b\bar{b})} \propto \frac{\sigma(e^+e^- \to \nu_e\bar{\nu}_e H)}{\mathrm{BR}(H \to WW^*)}$$



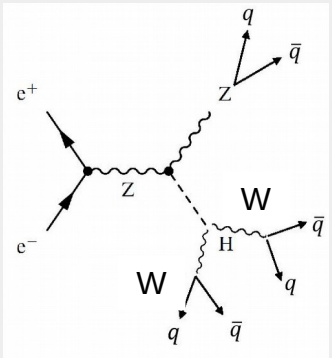
Signal and background

SIGNAL

Fully hadronic H→WW decay in Higgsstrahlung

$HZ,\ Z \to qq\ ,\ H \to WW^* \to qqqq$

$\sigma_{(HZ,\ Z \to qq\ ,\ H \to WW^* \to qqqq\ )}$ ~ 14,0 fb @ 250GeV



Signal signature: 6 central jets in the final state

Baseline detector concept CEPC V1

Arbor 3.1

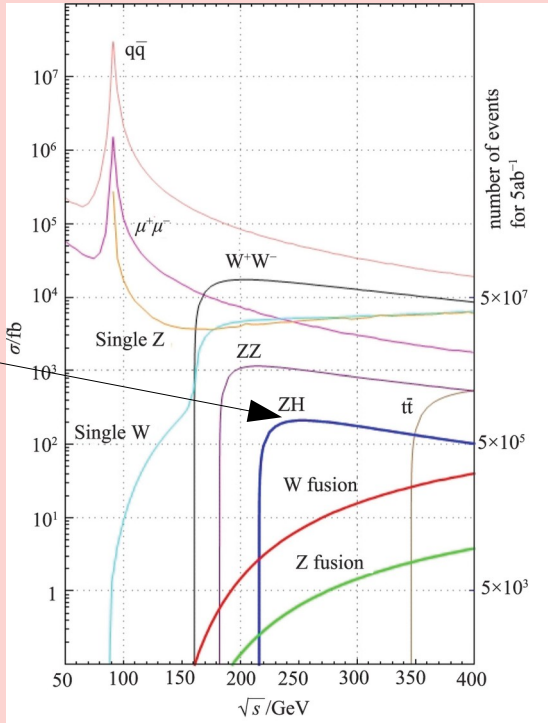
$$\frac{g^2_{HZZ} \cdot g^2_{HWW}}{\Gamma_H}$$

The statistical potential for the measurement of the cross-section x BF

Analysis method: - preselection

- multivariate analysis (BDT)

BACKGROUND

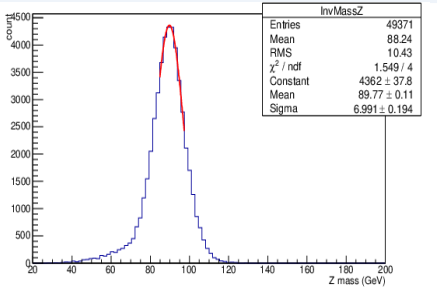


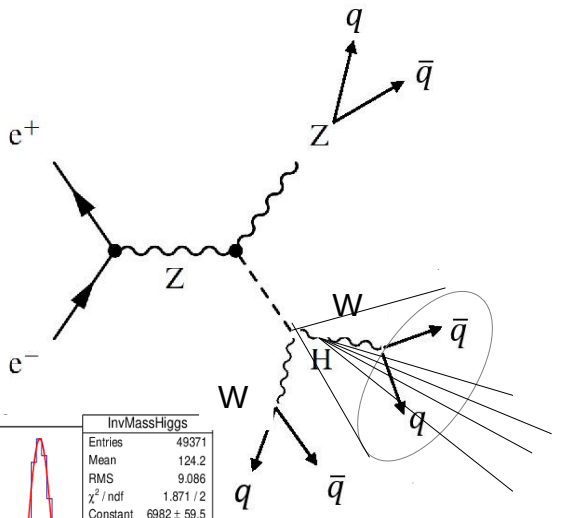
Event reconstruction

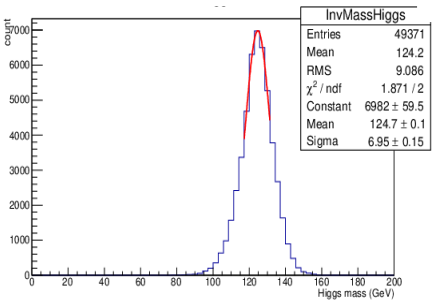
- Kt clustering algorithm
- Event is forced into six jets
- Jets are grouped into three pairs to form the Z, the real W and virtual W* boson
- From WW* pair - the Higgs boson reconstruction

- The combination which minimizes the χ^2 is chosen:

$$\chi^2 = \frac{(m_{ij} - m_W)^2}{\sigma^2_W} + \frac{(m_{kl} - m_Z)^2}{\sigma^2_Z} + \frac{(m_{ijmn} - m_H)^2}{\sigma^2_H}$$



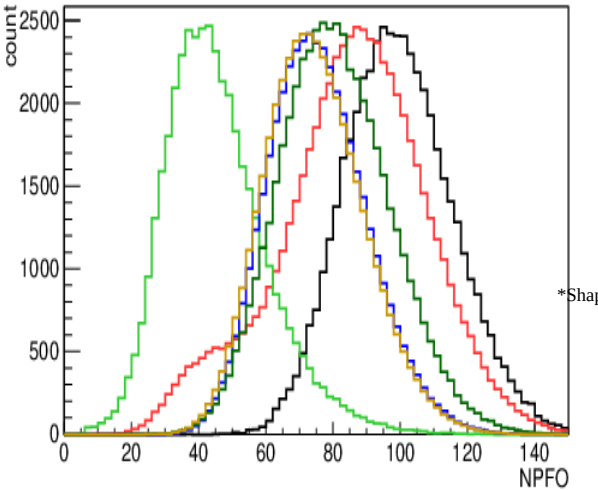




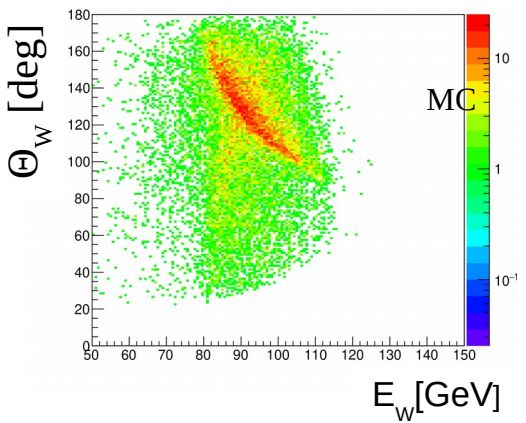
Preselection

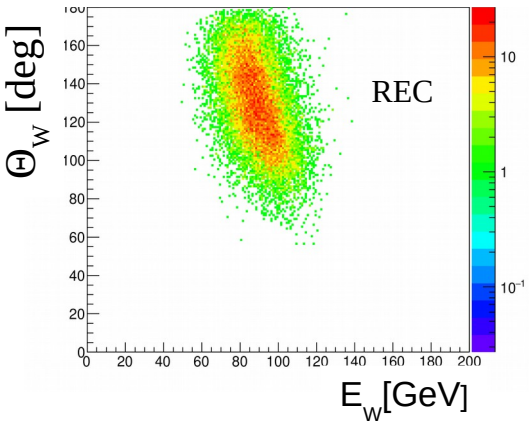
Preselection variables

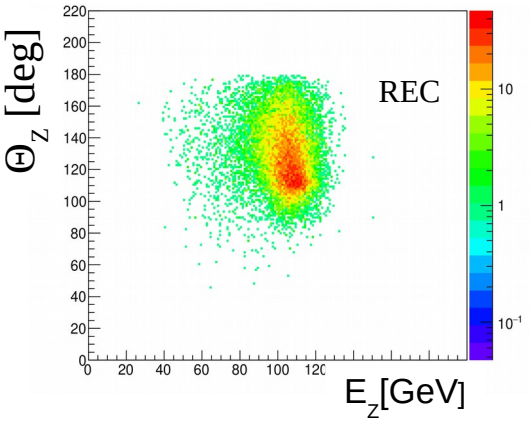
1) Number of final state particles
2) The combined use of the energy and jet angle distributions for W and Z boson

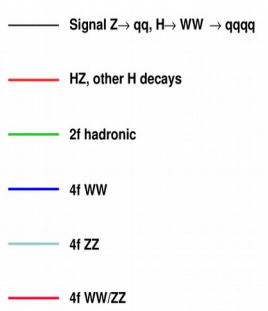


*Shape comparison









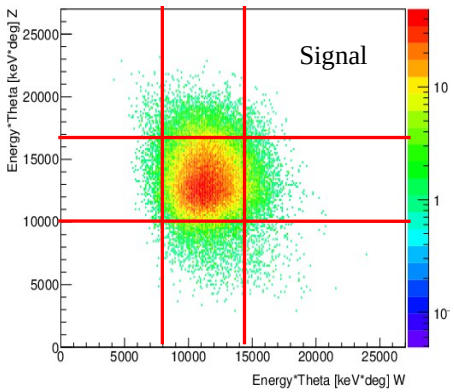
Preselection

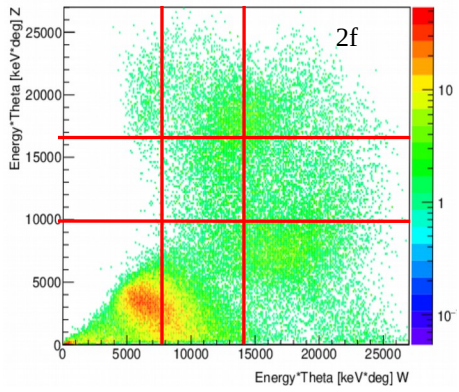
ENERGY-THETA VARIABLES

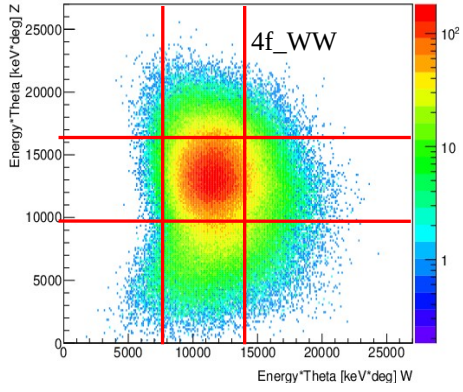
$Energy_W * \theta_W$ $Energy_Z * \theta_Z$

$\theta_W = (jet1_w, jet2_w)$ $\theta_Z = (jet1_Z, jet2_Z)$

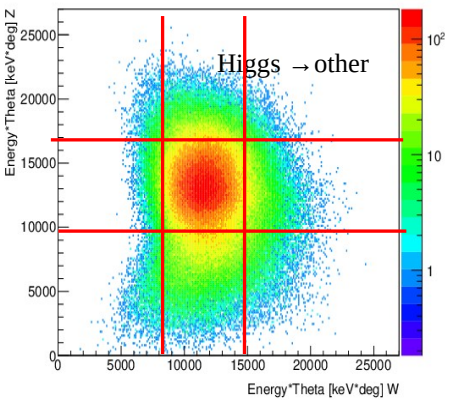
Variable	
Number of final state particles	$NPFO > 80$
$Energy_Z * \theta_Z$	$10000 < E * \theta_Z < 17000$
$Energy_W * \theta_W$	$8000 < E * \theta_W < 14000$







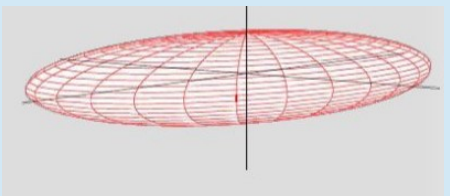
process	$\sigma[fb]$	ε_{pres}	$\sigma_{pres}[fb]$
signal ZH $Z \to q\bar{q}, H \to WW \to q\bar{q}q\bar{q}$	15	70%	11
$e^+e^- \to q\bar{q}$	49561	0.8%	397
$e^+e^- \to WW \to q\bar{q}q\bar{q}$	3733	17%	635
$e^+e^- \to ZZ \to q\bar{q}q\bar{q}$	501	25%	125
$e^+e^- \to WW/ZZ \to q\bar{q}q\bar{q}$	3139	17%	554
other Higgs decays	190	43%	82

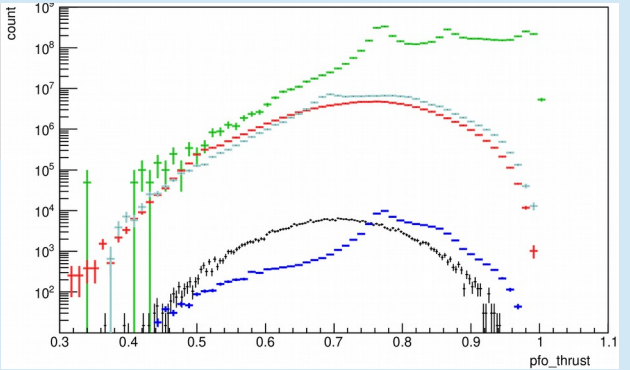


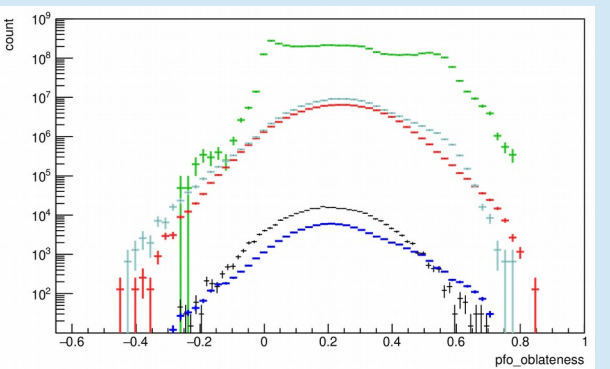
Event SELECTION

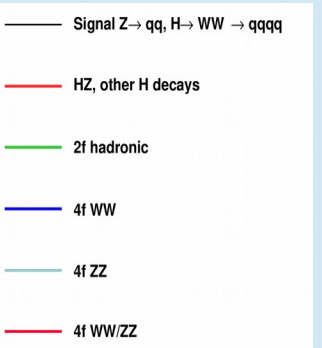
EVENT SHAPE VARIABLES

$$T = \max_{|n|=1} \frac{\sum_i |n \cdot p_i|}{\sum_i |p_i|}$$



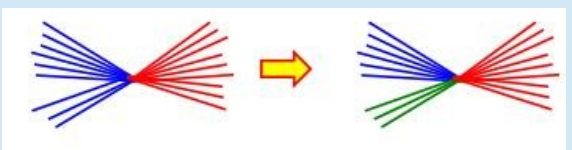




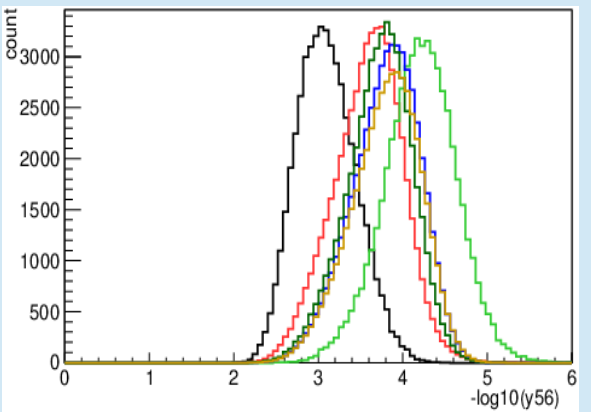


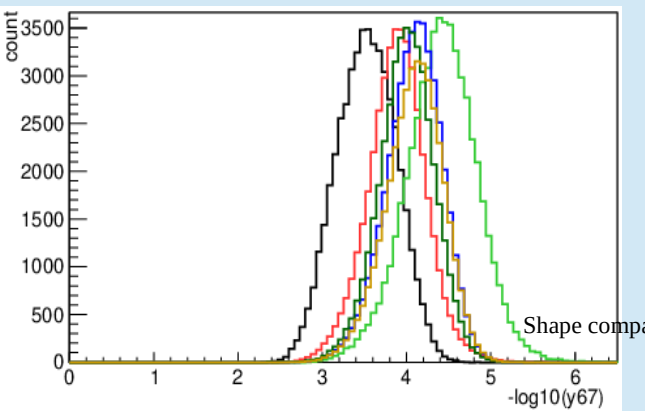
JET TRANSITIONS

Kt value at which number of jets 'transits' from i to i+1



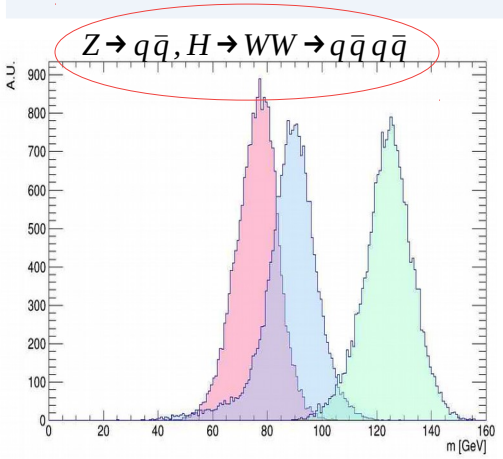
2 *jets* → 3 *jets*



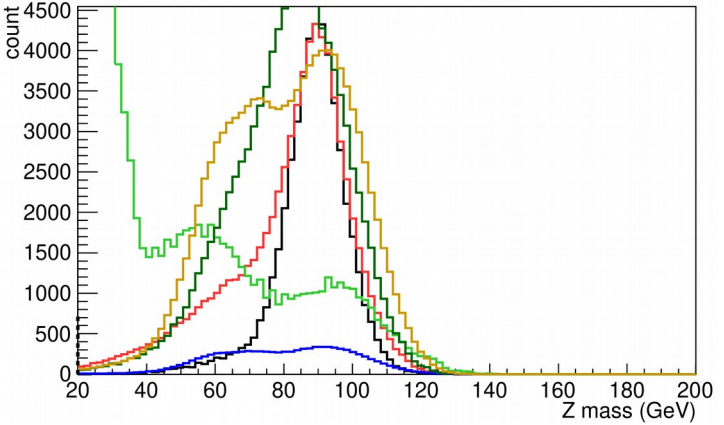


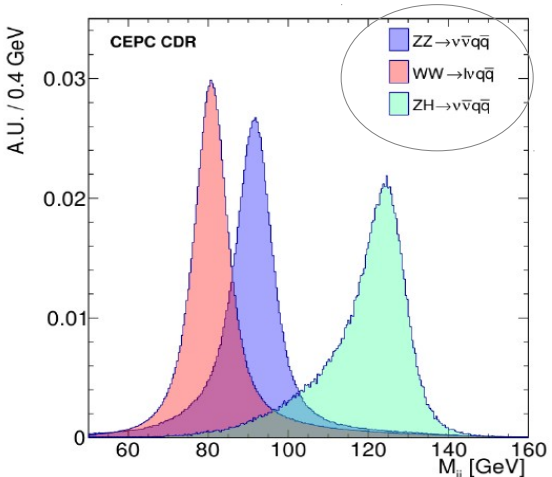
Shape comparison

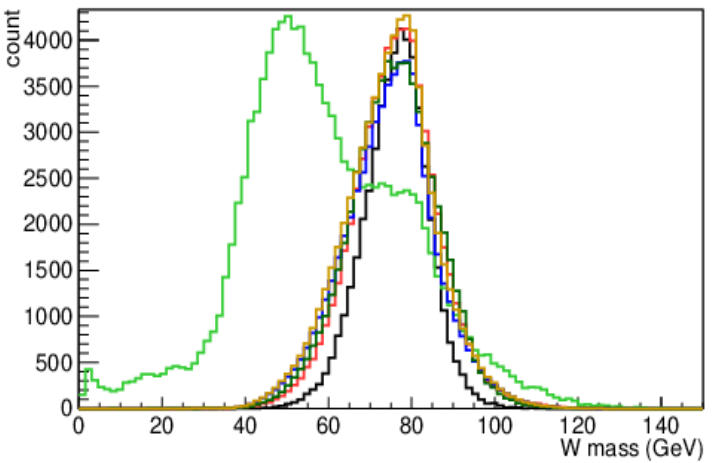
Event selection

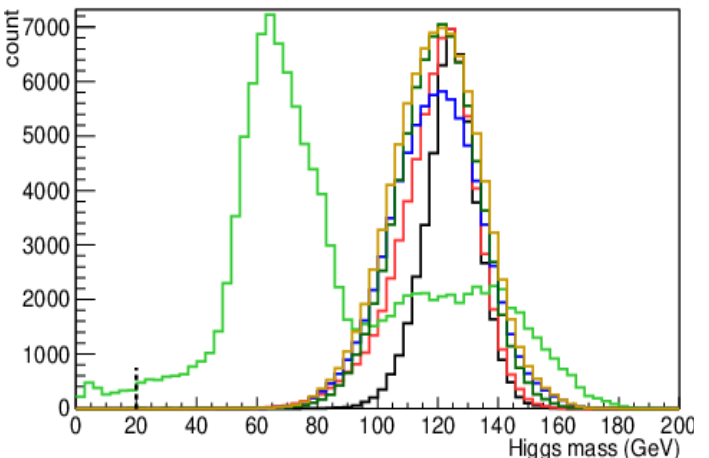


RECONSTRUCTED W,Z,H BOSON MASSES







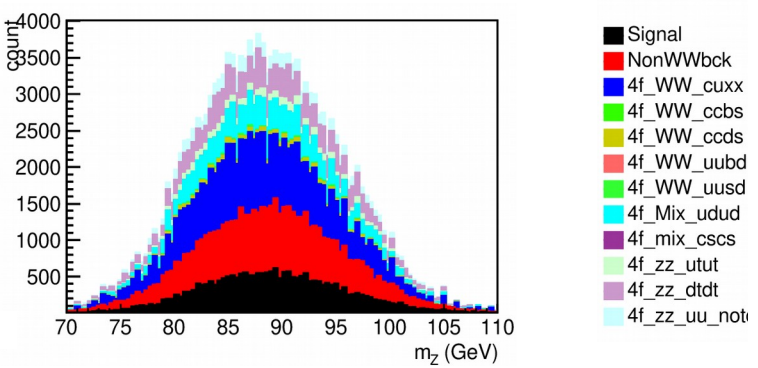


Results

MULTIVARIATE method

- **I step Preselection**
  - Number of final state particles
  - EnergyTheta W, Z
- **II step MVA BDT**
  - Event shape variables
  - Jet transitions
  - Invariant masses: m_{Higgs} $\mathbf{m_Z}$ m_W
  - Number of final state particles
  - Jet Pt, Pt Higgs
  - Flavour tagging

process	$\sigma[fb]$	$\varepsilon_{preselecion+MVA}$
signal ZH $Z\to q\bar{q}, H\to WW\to q\bar{q}q\bar{q}$	15	29%
$e^+e^-\to q\bar{q}$	49561	0.002%
$e^+e^-\to WW\to q\bar{q}q\bar{q}$	3733	0.25%
$e^+e^-\to ZZ\to q\bar{q}q\bar{q}$	501	1.7%
$e^+e^-\to WW/ZZ\to q\bar{q}q\bar{q}$	3139	0.27%
other Higgs decays	190	6.1%



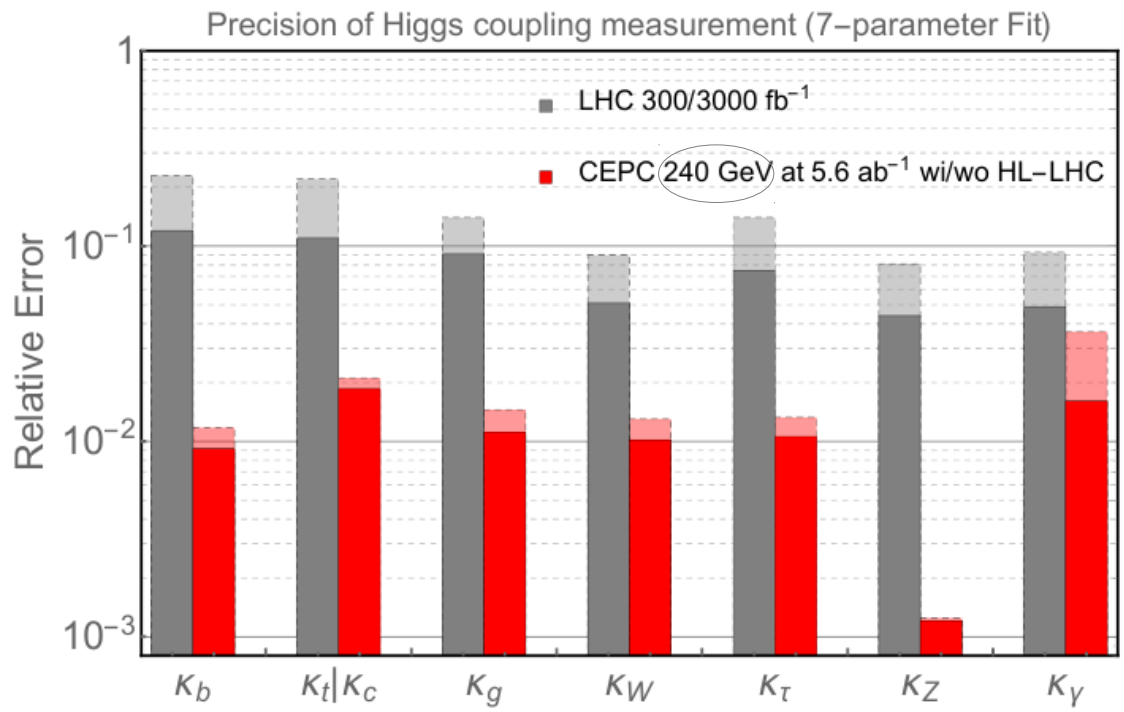
	Multivariate method
$\frac{\Delta\sigma}{\sigma}=\frac{\sqrt{S+B}}{S}$	1.7 %
ε_{signal}	29 %

Global Higgs Fit Results

	Multivariate method
$\frac{\Delta\sigma}{\sigma}=\frac{\sqrt{S+B}}{S}$	1.7 %
ε_{signal}	29 %

250 GeV

	ZH	Precision
$Z\to e^+e^-$	$WW\to l\nu l'\nu, l\nu q\bar{q}$	2.6 %
$Z\to \mu^+\mu^-$	$WW\to l\nu l'\nu, l\nu q\bar{q}$	2.4%
$Z\to \nu\nu$	$WW\to l\nu q\bar{q}, q\bar{q}q\bar{q}$	1.5%
$Z\to q\bar{q}$	$WW\to q\bar{q}q\bar{q}$	1.7%
	combination	0.9 %



Precision Higgs physics at the CEPC, Chinese Physics C, Volume 43, Number 4

Conclusion

- CEPC is the proposed electron positron collider to be build in China
- Circular collider, 100 km circumference
- Center of mass energy: 91.2 – 240 GeV
- Three operation modes: Higgs factory, Z pole, W pair production
- Corresponding integrated luminosities of 5.6 , 2.6 , 1 ab^{-1}
- All-jet final state of $H \rightarrow WW^* \rightarrow qqqq$, $Z \rightarrow qq$ in Higgsstrahlung is studied
- It has been shown that $\sigma(HZ) \times BR(H \rightarrow WW^*)$ at 250 GeV, can be measured with a statistical accuracy of 1.7% using all-jet final state
- The precision obtained by overall Higgs fit for $H \rightarrow WW^*$ at CEPC is 0.9% at 250 GeV (1 % at 240 GeV)

THANK YOU FOR YOUR ATTENTION