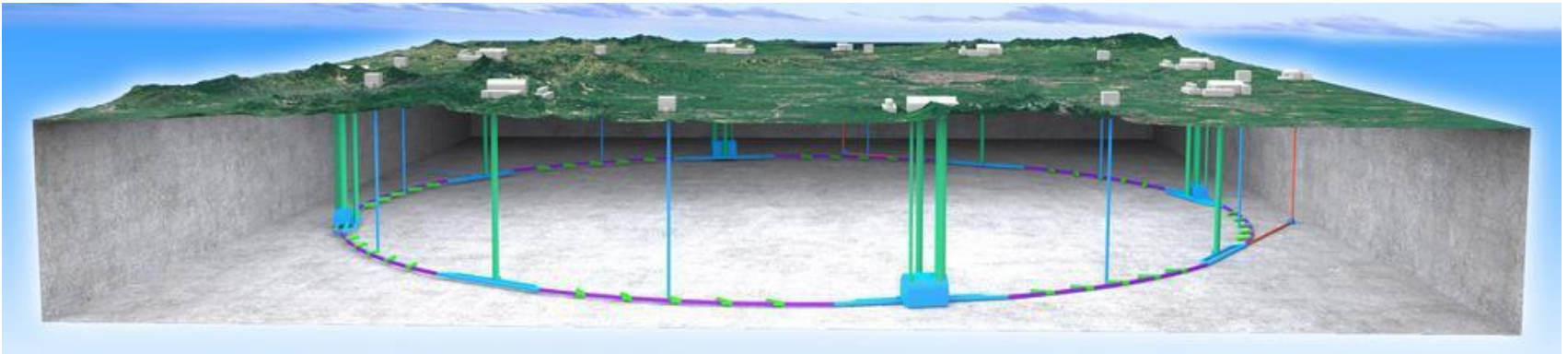




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## Physics at CEPC collider



The 22nd Lomonosov Conference

Moscow State University, Moscow, Russia, August 21 - 27, 2025

**Details about CEPC project were presented in Thursday plenary talk:  
J. Gao (IHEP, CAS) “CEPC project status”.**

In my talk physics potential of CEPC project for Higgs boson parameter measurements and respective searches for Beyond the Standard Model (BSM) effects will be discussed.

Due to limited time I cannot cover other topics, which are relevant for studies at CEPC (deferred until next year ☺). Only a few summary slides will be shown.

**There are theoretical arguments (not strong, but very reasonable), that BSM physics have to emerge below  $\sim 50\text{-}100$  TeV (Higgs mass?, astrophysics ?).**

LHC ruled out Beyond the Standard Model physics up to  $\sim 1.5\text{-}2.0$  TeV.

HL-LHC will increase the region of sensitivity to about 3 TeV.

CEPC can indirectly investigate region (depends on process) up to  $\sim 5\text{-}50$  TeV.

SPPC can discover directly (or close) BSM up to  $\sim 40\text{-}50$  TeV.

# CEPC Physics white papers

## Precision Higgs physics at the CEPC

Fendun An (安方敦)<sup>4,23</sup> Yu Bai (白碧)<sup>8</sup> Chuanlin Chen (陈春琳)<sup>23</sup> Xin Chen (陈鑫)<sup>1</sup> Zhengxin Chen (陈正欣)<sup>1</sup>  
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Zhaolin Liang (梁志均)<sup>28</sup> Libo Luo (廖志斌)<sup>29</sup> Tong Liu (刘彤)<sup>30</sup> Jintao Liu (刘建太)<sup>31</sup> Tao Lin (林涛)<sup>32</sup>  
Zhen Liu (刘震)<sup>33</sup> Xinchao Luo (罗辛丑)<sup>34,35</sup> Liming Ma (马连良)<sup>36</sup> Bruce Mellado<sup>37</sup> Xin Mo (莫欣)<sup>38</sup>

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The Physics potential of the CEPC

Prepared for the US Snowmass Community Planning Exercise

(Snowmass 2021)

CEPC Physics Study Group

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PREPARED FOR SUBMISSION TO JHEP

## Flavor Physics at CEPC: a General Perspective

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New Physics Search at the CEPC: a General

## Perspective

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**Higgs:** 2019 Chinese Phys. C 43 043002, see also [1810.09037](#)

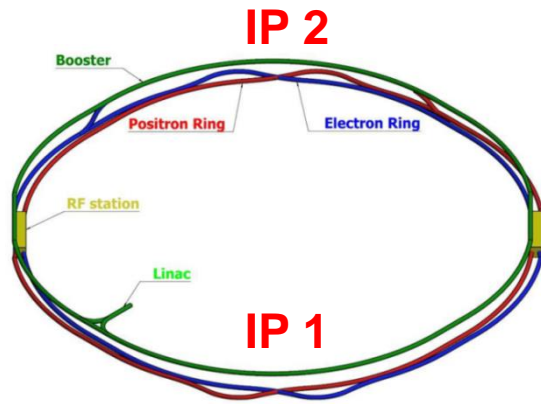
Snowmass Whitepaper: covers Higgs, EW, Flavor, NP, etc, available at [2205.08553v1](#)

**Flavor:** Accepted by CPC (July 4th), available at [2412.19743v2](#)

**New Physics:** Submitted to CPC (July 17th), available at [2505.24810v1](#)

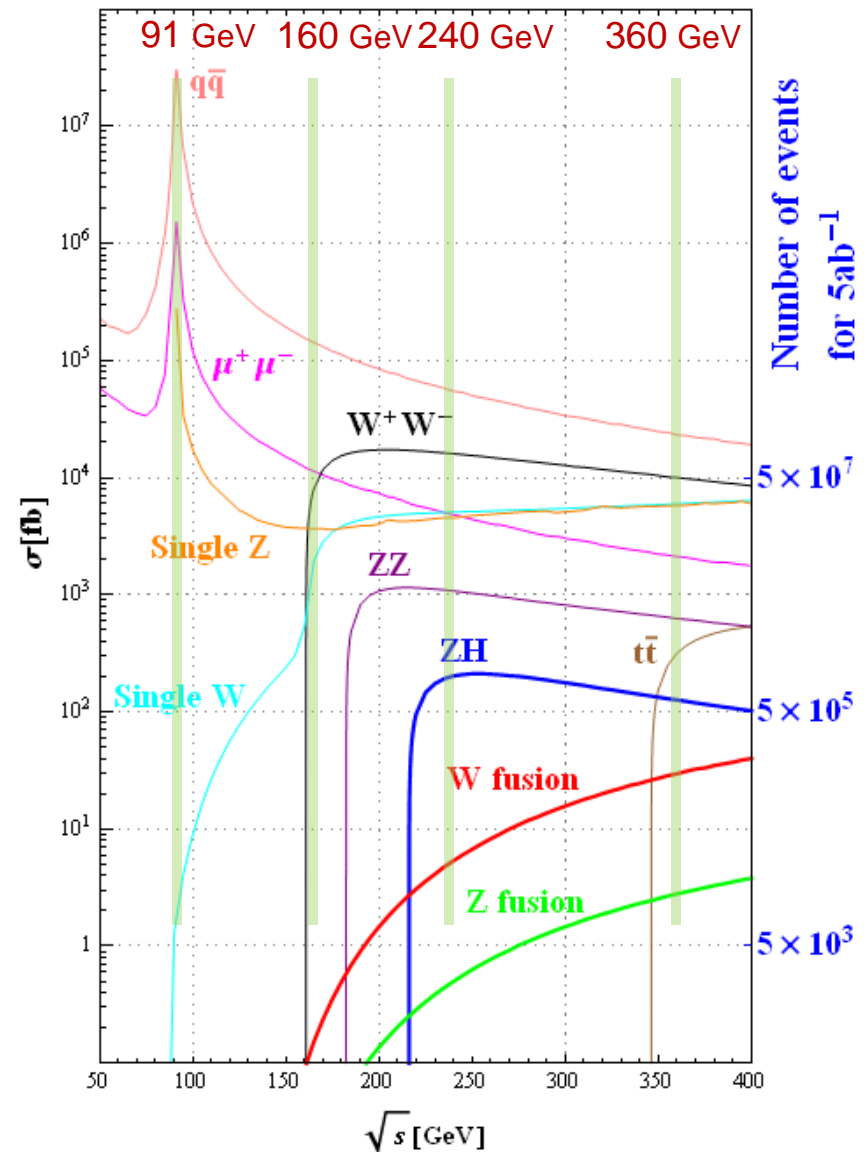
**EW** white paper: in progress. Plan to submit to ArXiv ~ Nov.

# Circular $e^+e^-$ collider CEPC (Higgs factory, China)



100 km ring, booster and collider in one tunnel. 2 interaction points, 2 detectors.  
Expected start of data taking is in 2035.

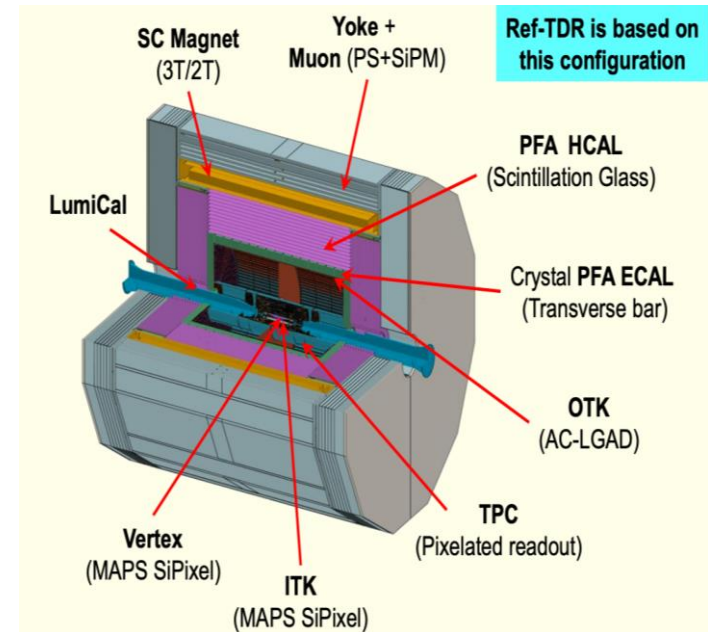
Operation mode		ZH	Z	$W^+W^-$	$t\bar{t}$
$\sqrt{s}$ [GeV]		~240	~91	~160	~360
Run Time [years]		10	2	1	5
30 MW	$L / IP [ \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} ]$	5.0	115	16	0.5
	$\int L dt [\text{ab}^{-1}, 2 \text{ IPs}]$	13	60	4.2	0.65
	Event yields [2 IPs]	$2.6 \times 10^6$	$2.5 \times 10^{12}$	$1.3 \times 10^8$	$4 \times 10^5$
50 MW	$L / IP [ \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} ]$	8.3	192	26.7	0.8
	$\int L dt [\text{ab}^{-1}, 2 \text{ IPs}]$	21.6	100	6.9	1
	Event yields [2 IPs]	$4.3 \times 10^6$	$4.1 \times 10^{12}$	$2.1 \times 10^8$	$6 \times 10^5$



# Baseline detector

Design of the CEPC detector evolves with the R&D progressing and better understanding of the physic reach.

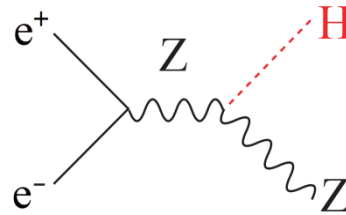
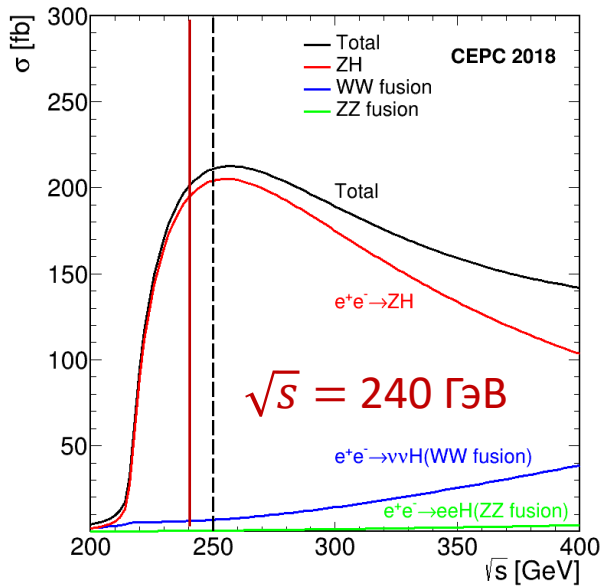
Record resolutions for all subdetectors.



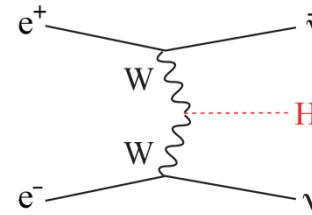
Sub-system	Key technology	Key Specifications
Vertex	6-layer CMOS SPD	$\sigma_{r\phi} \sim 3 \mu\text{m}$ , $X/X_0 < 0.15\%$ per layer
Tracking	CMOS SPD ITK, AC-LGAD SSD OTK, TPC + Vertex detector	$\sigma\left(\frac{1}{P_T}\right) \sim 2 \times 10^{-5} \oplus \frac{1 \times 10^{-3}}{P \times \sin^{3/2} \theta} (\text{GeV}^{-1})$
Particle ID	dN/dx measurements by TPC Time of flight by AC-LGAD SSD	Relative uncertainty $\sim 3\%$ $\sigma(t) \sim 30 \text{ ps}$
EM calorimeter	High granularity crystal bar PFA calorimeter	EM resolution $\sim 3\%/\sqrt{E(\text{GeV})}$ Granularity $\sim 1 \times 1 \times 2 \text{ cm}^3$
Hadron calorimeter	Scintillation glass PFA hadron calorimeter	Support PFA jet reconstruction Single hadron $\sigma_E^{\text{had}} \sim 40\%/\sqrt{E(\text{GeV})}$ Jet $\sigma_E^{\text{jet}} \sim 30\%/\sqrt{E(\text{GeV})}$



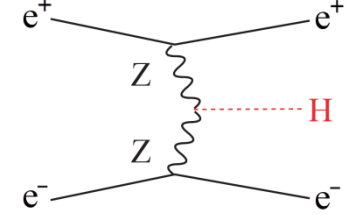
# Higgs boson production processes at 240 GeV



Higgs strahlung

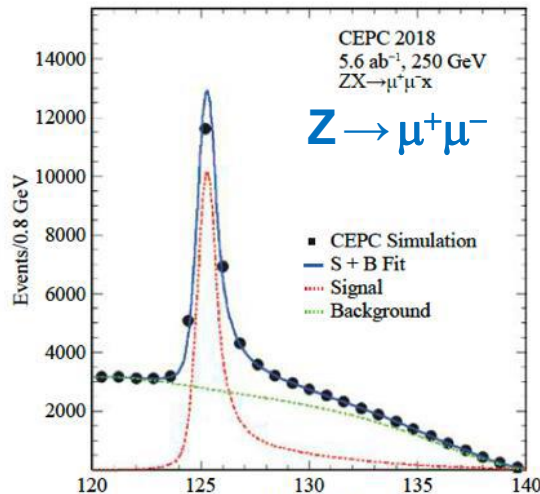


W boson fusion



Z boson fusion

Main backgrounds:  $e^+e^- \rightarrow ZZ$ ,  $e^+e^- \rightarrow WW$ ,  $e^+e^- \rightarrow q\bar{q}$  and some others (see slide 3).



Recoil mass to  $Z(\mu^+\mu^-)$

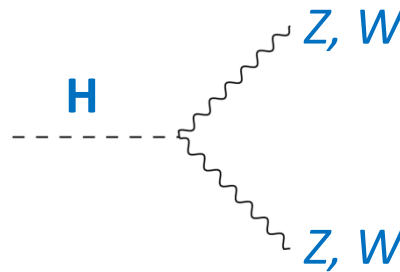
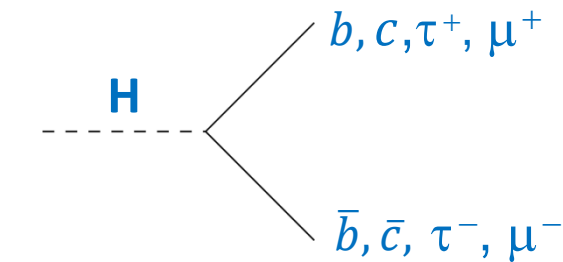
Process  $e^+e^- \rightarrow Z(\mu^+\mu^-)H$  provides absolute normalization for branching fraction measurements. Number of Higgs bosons in data sample can be obtained from fit of recoil mass distribution to  $\mu^+\mu^-$  combination, without any requirements on Higgs boson. Using this normalization Higgs boson decay branching fractions can be measured in model independent way.



# Higgs boson decays

Branching fractions of Higgs boson decays (%),  $M(h) = 125.08$  GeV (theory predictions).

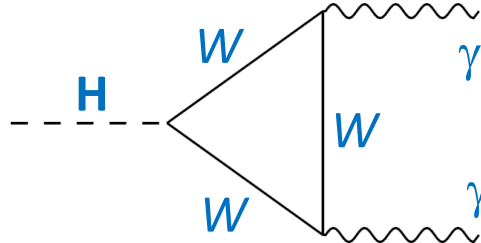
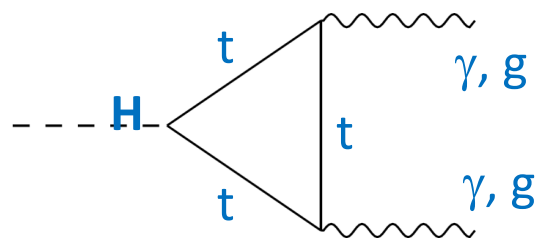
$b\bar{b}$	$c\bar{c}$	$\tau^+\tau^-$	$\mu^+\mu^-$	$WW^*$	$ZZ^*$	$gg$	$\gamma\gamma$	$Z\gamma$
58.1	2.88	6.26	0.0217	21.5	2.64	8.18	0.227	0.154
$\pm 1.3\%$	$^{+5.5}_{-2.0}\%$	$\pm 1.6\%$	$\pm 1.7\%$	$\pm 1.5\%$	$\pm 1.5\%$	$\pm 5.2\%$	$\pm 2.1\%$	$\pm 5.8\%$



SM:  $\kappa$ -framework

$$\kappa_i = g_i / g_i^{\text{SM}}$$

SM global fit

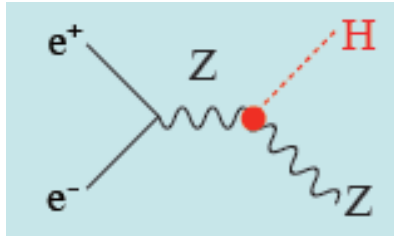


$$\begin{aligned}\kappa_g^2 &= 1.06 \kappa_t^2 - 0.07 \kappa_t \kappa_b + 0.01 \kappa_b^2 \\ \kappa_\gamma^2 &= 1.59 \kappa_W^2 - 0.66 \kappa_W \kappa_t + 0.07 \kappa_t^2 \\ \kappa_{Z\gamma}^2 &= 71.12 \kappa_W^2 - 0.15 \kappa_W \kappa_t + 0.03 \kappa_t^2\end{aligned}$$

Additional diagrams are possible in **EFT**, where  $\kappa$  is not enough to get branching fractions. Within EFT approach set of measured parameters can be constrained in EFT global fit. Keep in mind difference between measured branching fractions and ones from EFT fit.

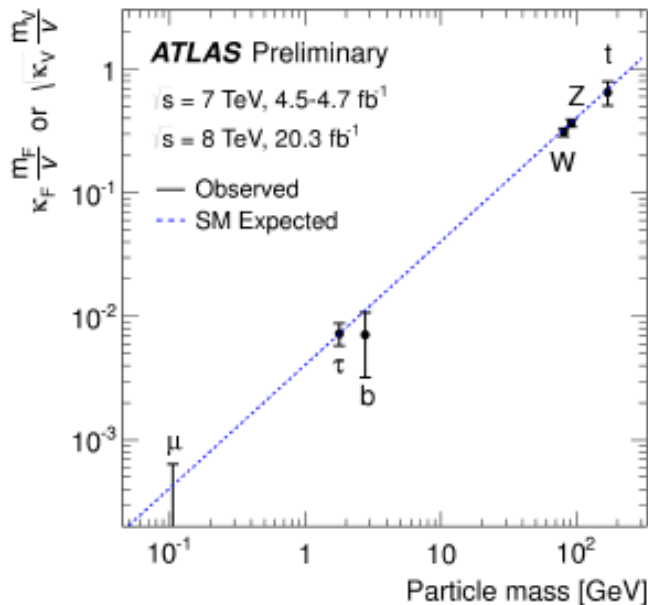


# Measurement of Higgs boson parameters at CEPC



At CM energy 240 GeV the main process of Higgs boson production is  $e^+ e^- \rightarrow ZH$  with cross section of  $\sim 200$  fb.

# of Higgs bosons:  $5600 \text{ fb}^{-1} \times 200 \text{ fb} \sim 1.12 \times 10^6 H$



Main task at CEPC: model-independent measurement of Higgs boson branching fractions (and, respectively, couplings) with accuracy of  $\sim 1\%$  or better.

Within SM couplings are proportional to fermion masses and squared boson masses with a high accuracy.

$$\mathcal{L} = -g_{H\bar{f}f} H \bar{f}f + \delta_V g_{HVV} H V_\mu V^\mu + 1/6 \times g_{HHH} H^3$$

$$g_{H\bar{f}f} = m_f/v, \quad g_{HVV} = 2m_V^2/v, \quad g_{HHH} = 3m_H^2/v.$$

Test of linearity:

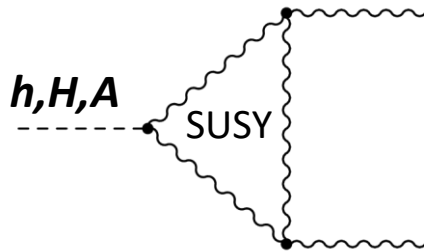
high sensitivity to New Physics (NP fingerprint)

Other Higgs boson parameters measurements: mass, width  $\Gamma_H$ , search for  $CP$ -odd admixture, search for invisible decay and rare decays.



# Higgs couplings shifts from linearity in different BSM models

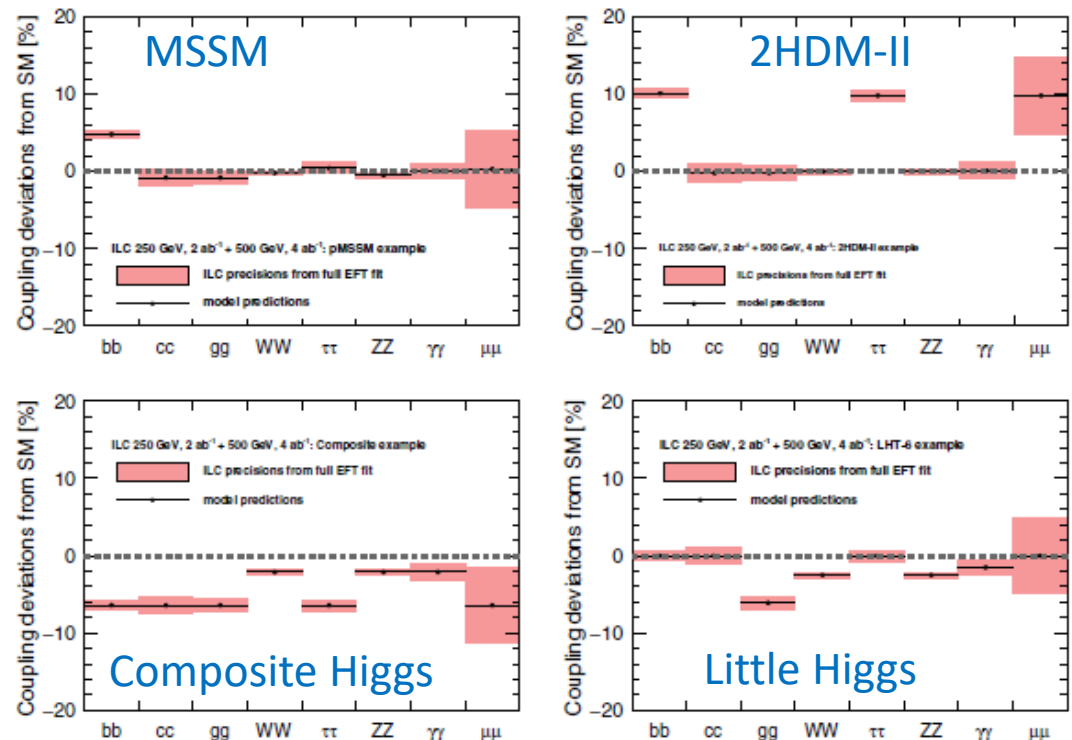
Different BSM models result in different shifts from linearity (model fingerprint).



Some shifts from linearity are  $\sim 5\%$ .  
→ we need to reach  $\sim 1\%$  accuracy in branching fraction measurements.

Shifts depend on BSM model and model parameters.  
Shifts become smaller with increasing BSM masses.

Barklow *et al.* PRD 97 053003 (2018)



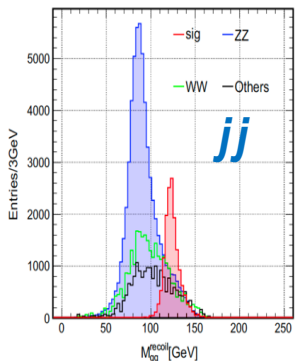
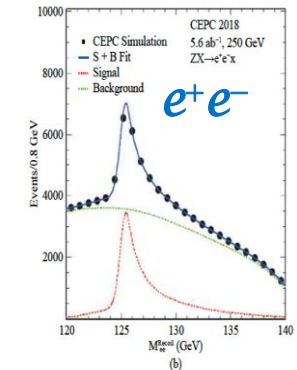
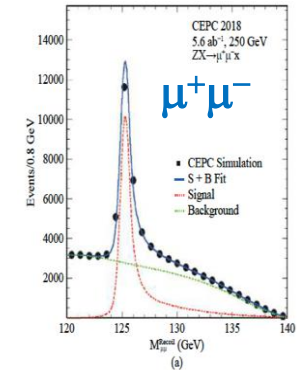
The study of the deviations from these predictions is guided by the idea that each Higgs coupling has **its own personality** and is guided by different types of new physics. This is something of a caricature, but, still, a useful one.

M. Peskin @ HPNP2015



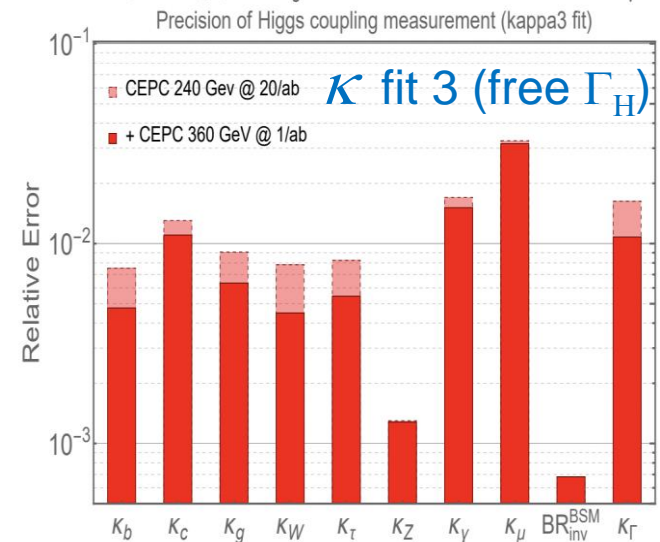
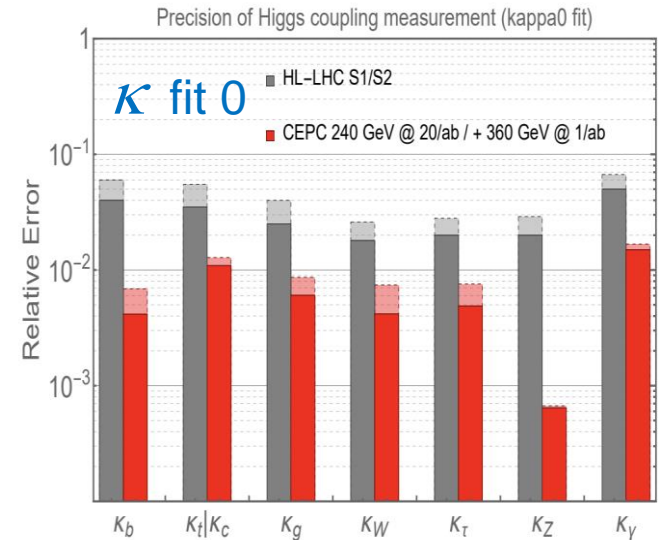
# Discovery power: Higgs precision

## Recoil mass to



## Expected CEPC measurements

	240 GeV, 20 ab <sup>-1</sup>		360 GeV, 1 ab <sup>-1</sup>		
	ZH	vvH	ZH	vvH	eeH
inclusive	0.26%		1.40%	\	\
H→bb	0.14%	1.59%	0.90%	1.10%	4.30%
H→cc	2.02%		8.80%	16%	20%
H→gg	0.81%		3.40%	4.50%	12%
H→WW	0.53%		2.80%	4.40%	6.50%
H→ZZ	4.17%		20%	21%	
H→ττ	0.42%		2.10%	4.20%	7.50%
H→γγ	3.02%		11%	16%	
H→μμ	6.36%		41%	57%	
H→Zγ	8.50%		35%		
Br <sub>upper</sub> (H→inv.)	0.07%				
Γ <sub>H</sub>	1.65%		1.10%		



# Higgs boson mass measurement

PDG (LHC) :  $M = 125.20 \pm 0.11 \text{ GeV}$

HL-LHC (2030) :  $M = 125.20 \pm 0.07 \text{ GeV}$

Recoil mass method:  $e^+ e^- \rightarrow Z (\mu^+ \mu^-) H$

Accuracy (CEPC,  $5.6 \text{ ab}^{-1}$ ):

$Z (\mu^+ \mu^-) : \sigma \sim 6.5 \text{ MeV}$

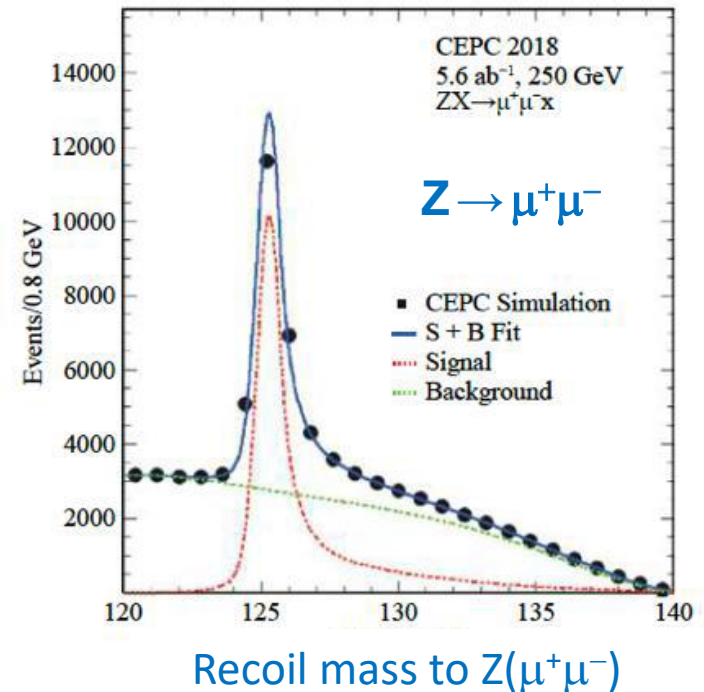
$Z(e^+ e^-) : \sigma \sim 14 \text{ MeV}$

Systematics (few MeV):

1. Precise charged particle momenta calibration
2. Precise beam energy measurement ( $\sim 1\text{-}2 \text{ MeV}$ )
3. Detailed knowledge of ISR (Initial State Radiation)
4. Detailed knowledge beam radiation (beamstrahlung)

Expected accuracy of Higgs mass measurement at CEPC  $\sim 6 \text{ MeV}$  !

Important value for different theoretical calculations.



# Higgs boson width measurement

PDG (LHC) :  $\Gamma = 3.2^{+2.4}_{-1.7} \text{ MeV}$

HL-LHC (2030) :  $\Gamma = 4.1 \pm 0.8 \text{ MeV}$

$$(i) \quad \sigma(HZ) \times \mathcal{B}r(Z \rightarrow \mu^+ \mu^-) = C_1 \cdot g_Z^2$$

$$(ii) \quad \sigma(HZ) \times \mathcal{B}r(Z \rightarrow \mu^+ \mu^-) \times \mathcal{B}r(H \rightarrow WW^*) = C_2 \cdot g_Z^2 g_W^2 / \Gamma_H$$

$$(iii) \quad \sigma(HZ) \times \mathcal{B}r(Z \rightarrow \mu^+ \mu^-) \times \mathcal{B}r(H \rightarrow b\bar{b}) = C_3 \cdot g_Z^2 g_b^2 / \Gamma_H$$

$$(iv) \quad \sigma(H\nu\bar{\nu}) \times \mathcal{B}r(H \rightarrow b\bar{b}) = C_4 \cdot g_W^2 g_b^2 / \Gamma_H$$

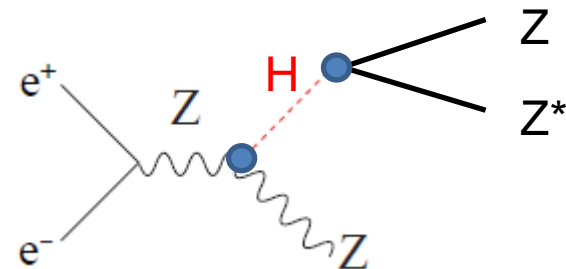
Using these 4 measurements width of Higgs boson can be calculated.

Basic version CEPC, energy 240 GeV, accuracy ~ 3 % or ~ 0.1 MeV

$$\sigma(e^+ e^- \rightarrow HZ) \times \mathcal{B}r(H \rightarrow ZZ^*) = C \cdot g_Z^4 / \Gamma_H$$

One of tree Z bosons decays in leptons others  
In jets or neutrinos (to suppress backgrounds).

ILD:  $2 \text{ ab}^{-1}$ , accuracy ~5%, => ~3% for CEPC



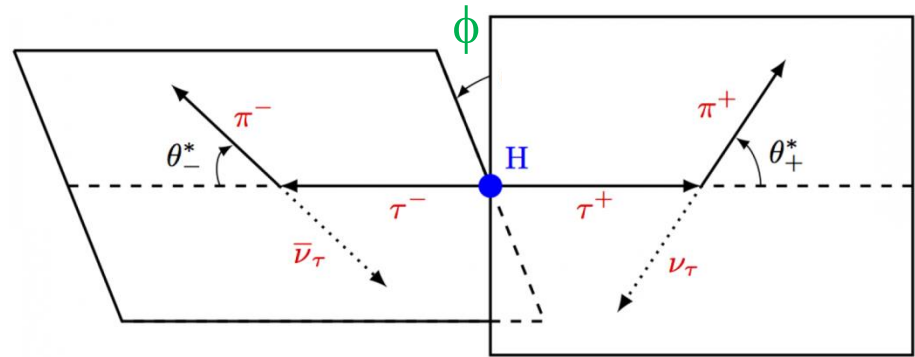
Finally, combined accuracy of 2 measurements

at CEPC: ~2% or < 0.1 MeV => important test of BSM models

# Search for $CP$ -odd admixture at 125 GeV Higgs using $H \rightarrow \tau^+\tau^-$

Higgs boson with mass 125 GeV cannot have spin 1, because decay  $H \rightarrow \gamma\gamma$  is observed (Landau-Yang theorem). In some BSM models (2HDM, SUSY) additional Higgs bosons can appear ( $h, H, A$ ) and mixing of  $0^-$  и  $0^+$  states is possible. Upper limit on  $0^-$  component in 125 GeV Higgs boson has to be set.

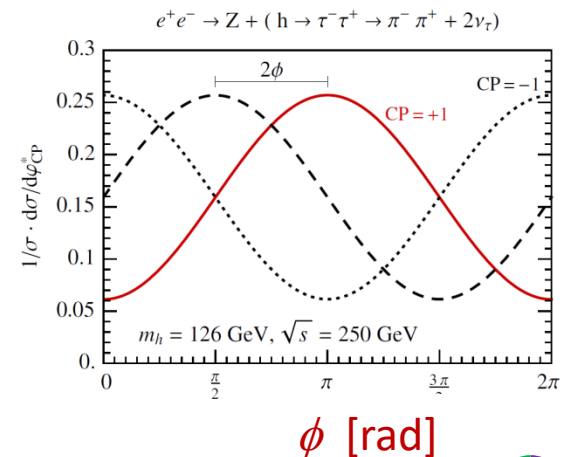
Best method is measurement of angular distributions in decay  $H \rightarrow \tau^+\tau^-$ ,  $\tau \rightarrow \pi/\rho \nu$ .



$$\mathcal{L} = -\frac{m_\tau}{v} H \bar{\tau} (\cos \psi_{CP} + i \sin \psi_{CP} \gamma^5) \tau$$

Distribution for angle  $\phi$  is very sensitive to  $CP$ -admixture

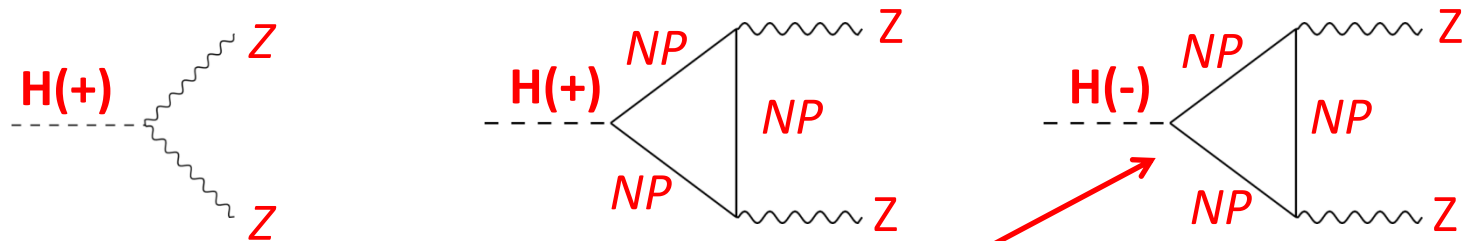
At ILD upper limit for mixing angle  $\psi_{cp}$  was calculated:  $\sim 4.3^\circ$  at 250 GeV and  $2 \text{ ab}^{-1}$  (arXiv:1804.01241).



# Search for $CP$ -odd component in $HZZ$ vertex

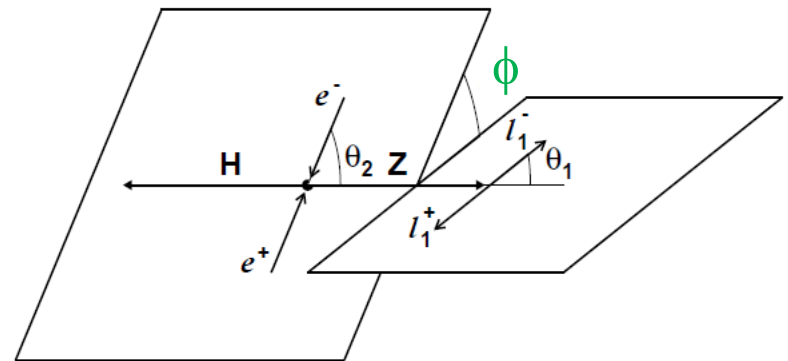
$CP$ -odd component can be searched for in process  $e^+ e^- \rightarrow Z (\mu^+ \mu^-) H$

Higgs  $CP$ -odd component can connect to  $ZZ$  only by loop diagram. Potentially such loop diagrams can be enhanced in some BSM models (EFT approach).



$$\mathcal{L}_{\text{eff}} \supset c_{ZZ}^{(1)} H Z_\mu Z^\mu + c_{ZZ}^{(2)} H Z_{\mu\nu} Z^{\mu\nu} + c_{Z\tilde{Z}} H Z_{\mu\nu} \tilde{Z}^{\mu\nu} + c_{AZ} H Z_{\mu\nu} A^{\mu\nu} + c_{A\tilde{Z}} H Z_{\mu\nu} \tilde{A}^{\mu\nu}$$

Search for  $CP$ -odd component can be done using angular distributions in process  $e^+ e^- \rightarrow Z (\mu^+ \mu^-) H$ . Most sensitive parameter is angle  $\phi$  between  $Z$  boson production and decay planes.



CEPC, arXiv: 2203.11707

CEPC ( $1\sigma$ ,  $5.6 \text{ ab}^{-1}$ ):  $\tilde{c}_{ZZ} : [-0.06 ; +0.06]$

LHC ( $1\sigma$ ,  $3.0 \text{ ab}^{-1}$ ):  $\tilde{c}_{ZZ} : [-0.33 ; +0.33]$



# Invisible and exotic Higgs boson decays searches

$$e^+ e^- \rightarrow Z (\mu^+ \mu^-) H (\text{invisible})$$

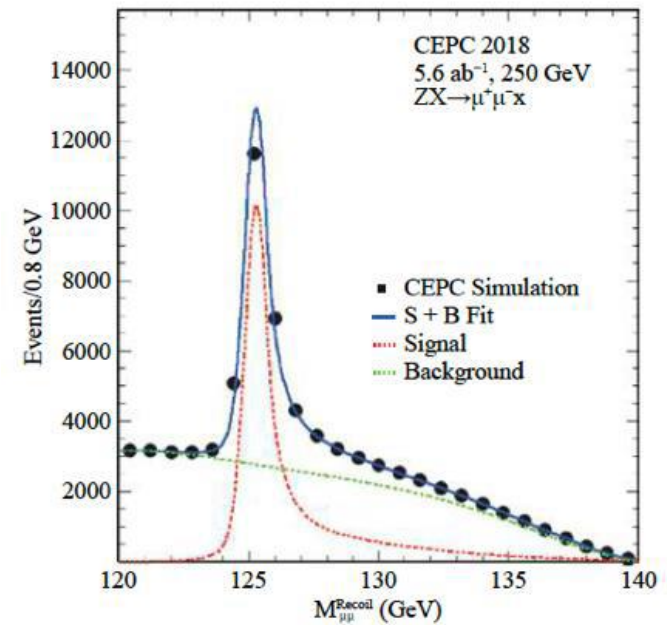
Potentially it is possible to use  $Z (jj)$ .

BSM physics can enhance invisible BF.

Branching fraction for invisible decay in SM is very small ( $\sim 0.3\%$ ). Mostly  $H \rightarrow ZZ^* \rightarrow 4\nu$ .

This  $BF$  upper limit was estimated at CEPC for  $5.6 \text{ ab}^{-1}$  :  $< 0.1\%$ .

Upper limits (2022): ATLAS  $< 11\%$ ,  
CMS  $< 19\%$ , HL-LHC  $< 3.8\%$

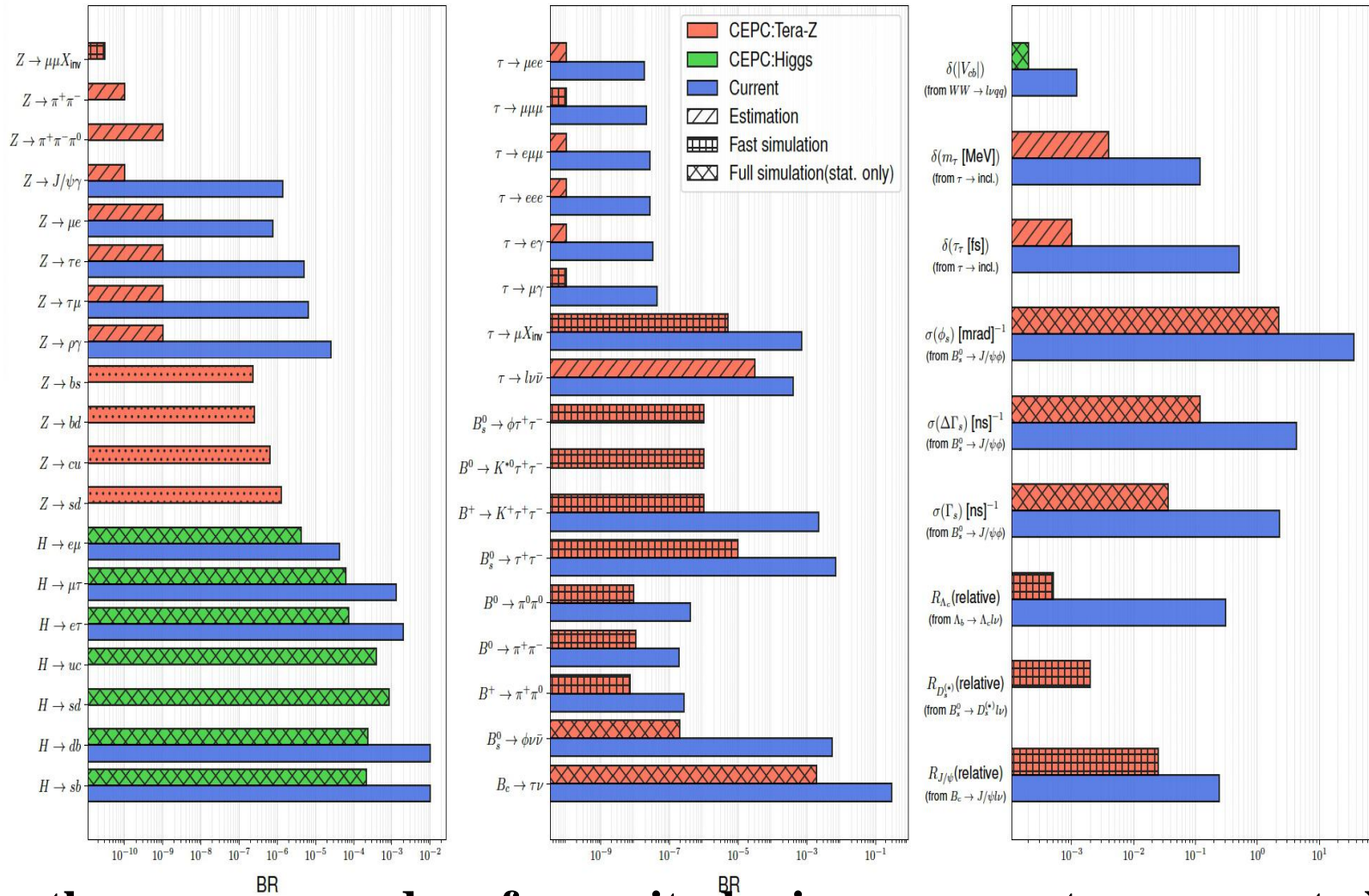


Within the Standard model branching fractions for rare decays shown below are very small ( $< 10^{-8}$ ), and cannot be observed at CEPC.

$$h \rightarrow \tau^+ \mu^-, \quad h \rightarrow b \bar{s}, \quad h \rightarrow c \bar{d}.$$

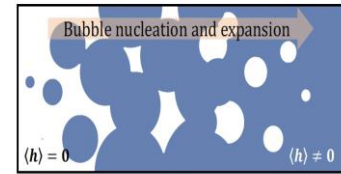
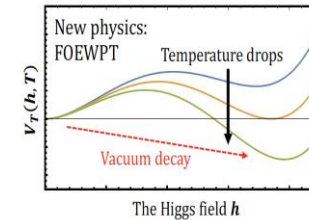
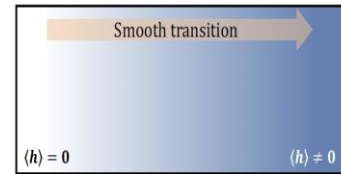
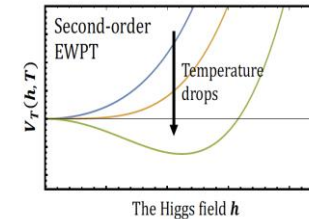
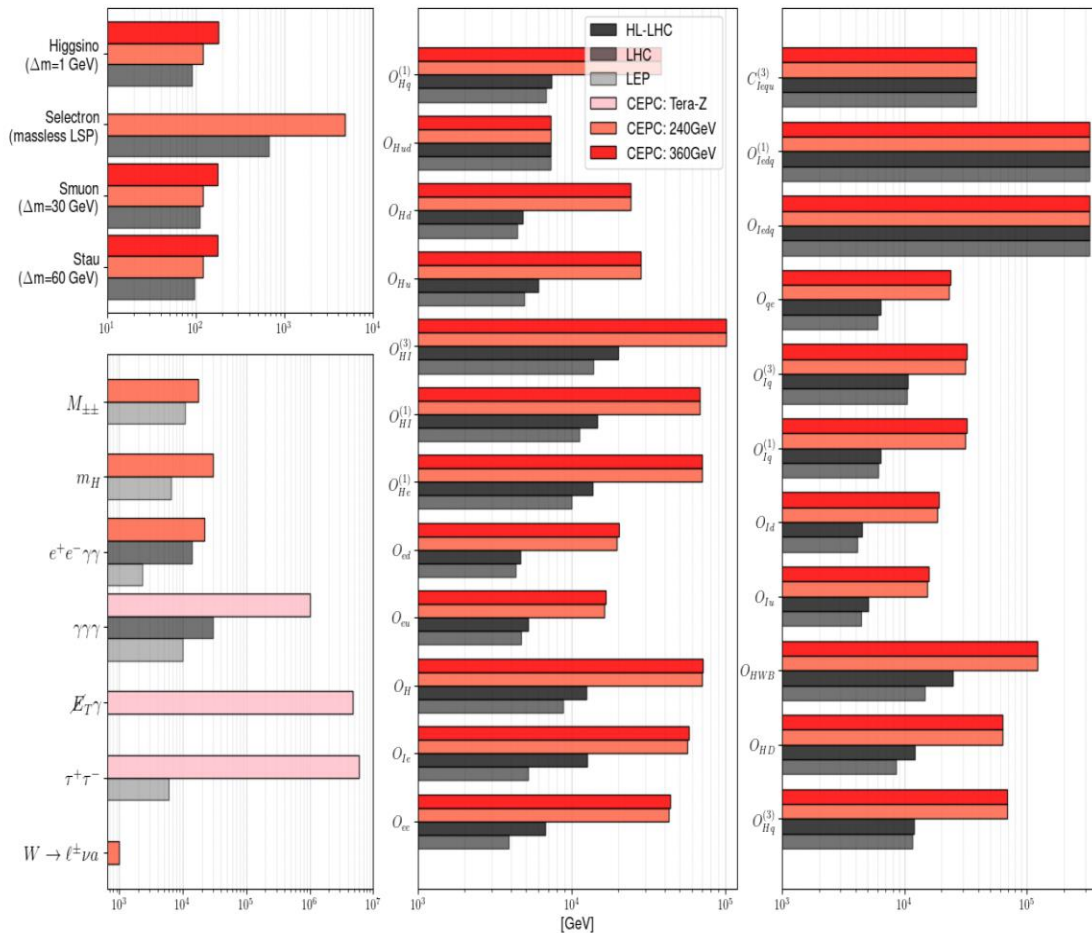
However these branching fractions can be enhanced in some BSM models. Therefore these processes have to be searched for at CEPC.

# Discovery power: flavor

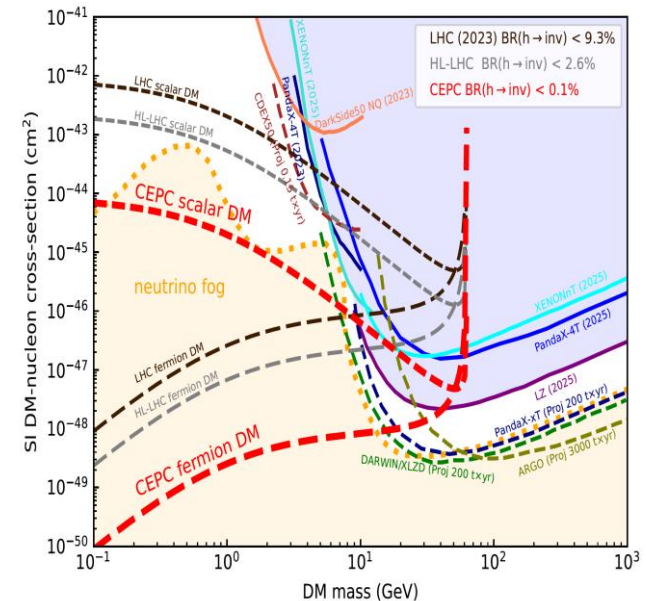


See the non-seen, order of magnitudes improvements, + access to NP of 10 TeV or higher...

# Discovery power: direct NP search

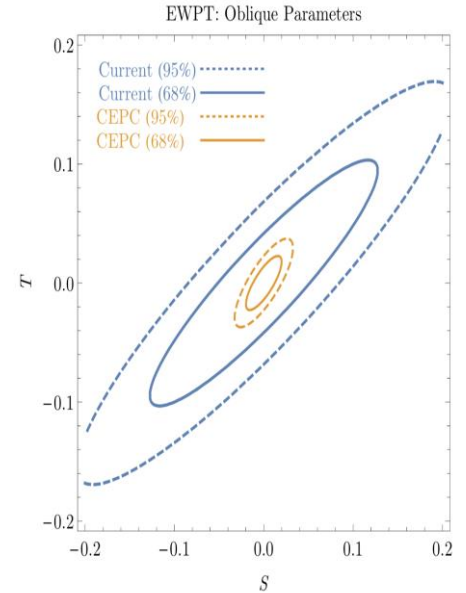
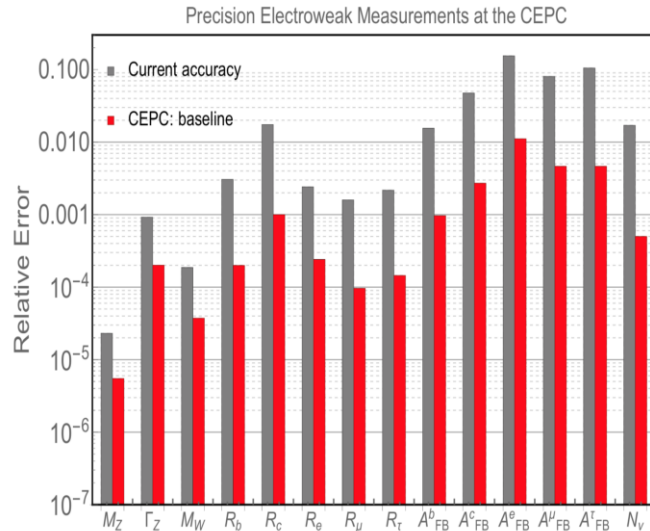
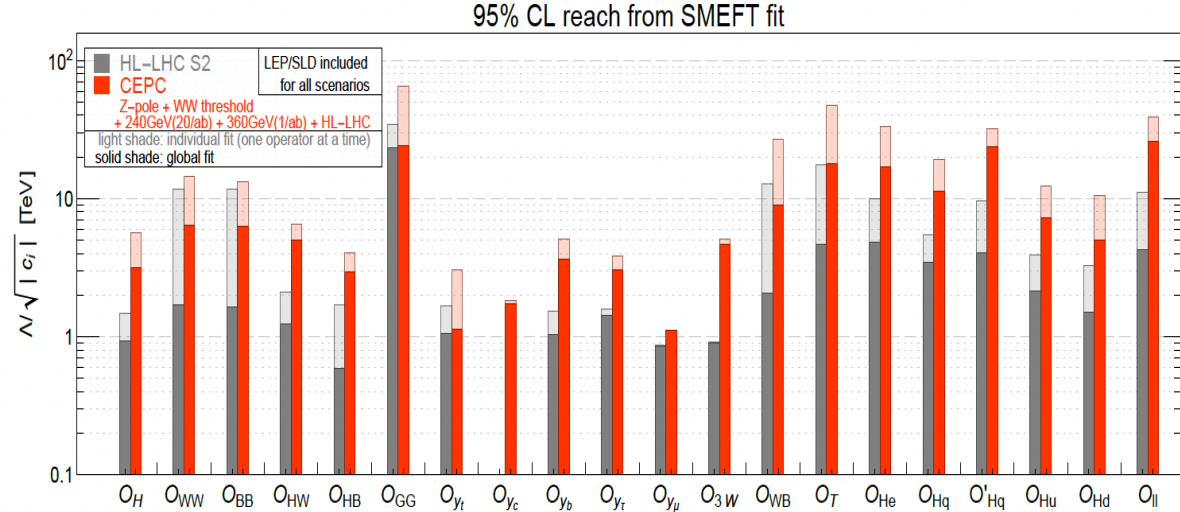


**Order of magnitudes improvements, Dark matter**  
**Matter origin: decisive test of 1<sup>st</sup> order EW**  
**phase transition in early universe, synergy with**  
**CPV studies...**



# Discovery power: Higgs + EW

Observable	current precision	CEPC precision (Stat. Unc.)	CEPC runs	main systematic
$\Delta m_Z$	2.1 MeV [37–41]	0.1 MeV (0.005 MeV)	Z threshold	$E_{beam}$
$\Delta \Gamma_Z$	2.3 MeV [37–41]	0.025 MeV (0.005 MeV)	Z threshold	$E_{beam}$
$\Delta m_W$	9 MeV [42–46]	0.5 MeV (0.35 MeV)	WW threshold	$E_{beam}$
$\Delta \Gamma_W$	49 MeV [46–49]	2.0 MeV (1.8 MeV)	WW threshold	$E_{beam}$
$\Delta m_t$	0.76 GeV [50]	$\mathcal{O}(10)$ MeV <sup>a</sup>	$t\bar{t}$ threshold	
$\Delta A_e$	$4.9 \times 10^{-3}$ [37, 51–55]	$1.5 \times 10^{-5}$ ( $1.5 \times 10^{-5}$ )	Z pole ( $Z \rightarrow \tau\tau$ )	Stat. Unc.
$\Delta A_\mu$	0.015 [37, 53]	$3.5 \times 10^{-5}$ ( $3.0 \times 10^{-5}$ )	Z pole ( $Z \rightarrow \mu\mu$ )	point-to-point Unc.
$\Delta A_\tau$	$4.3 \times 10^{-3}$ [37, 51–55]	$7.0 \times 10^{-5}$ ( $1.2 \times 10^{-5}$ )	Z pole ( $Z \rightarrow \tau\tau$ )	tau decay model
$\Delta A_b$	0.02 [37, 56]	$20 \times 10^{-5}$ ( $3 \times 10^{-5}$ )	Z pole	QCD effects
$\Delta A_c$	0.027 [37, 56]	$30 \times 10^{-5}$ ( $6 \times 10^{-5}$ )	Z pole	QCD effects
$\Delta\sigma_{had}$	37 pb [37–41]	2 pb (0.05 pb)	Z pole	luminosity
$\delta R_b^0$	0.003 [37, 57–61]	0.0002 ( $5 \times 10^{-6}$ )	Z pole	gluon splitting
$\delta R_c^0$	0.017 [37, 57, 62–65]	0.001 ( $2 \times 10^{-5}$ )	Z pole	gluon splitting
$\delta R_e^0$	0.0012 [37–41]	$2 \times 10^{-4}$ ( $3 \times 10^{-6}$ )	Z pole	$E_{beam}$ and t channel
$\delta R_\mu^0$	0.002 [37–41]	$1 \times 10^{-4}$ ( $3 \times 10^{-6}$ )	Z pole	$E_{beam}$
$\delta R_\tau^0$	0.017 [37–41]	$1 \times 10^{-4}$ ( $3 \times 10^{-6}$ )	Z pole	$E_{beam}$
$\delta N_\nu$	0.0025 [37, 66]	$2 \times 10^{-4}$ ( $3 \times 10^{-5}$ )	ZH run ( $\nu\nu\gamma$ )	Calo energy scale

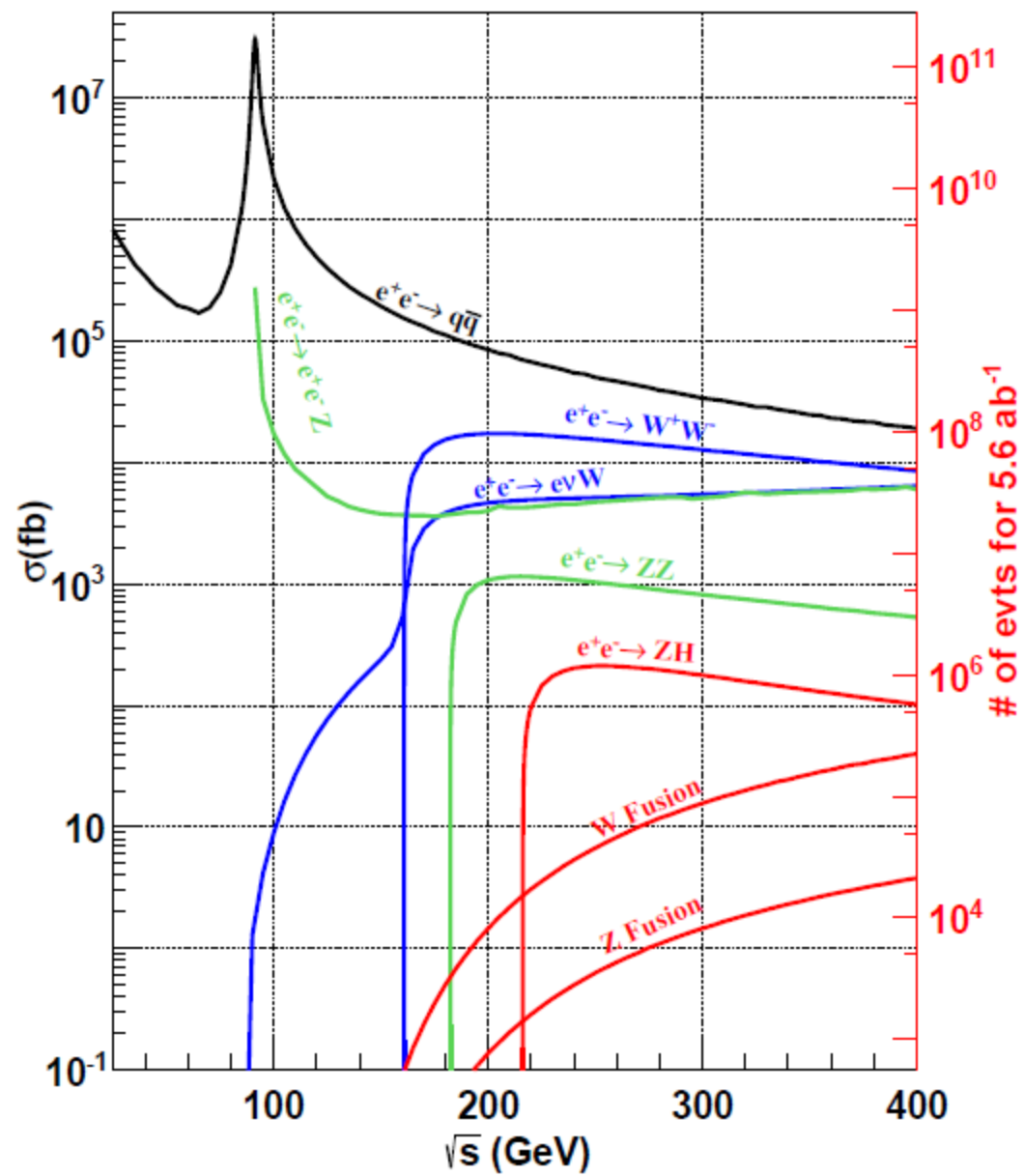


# Conclusion

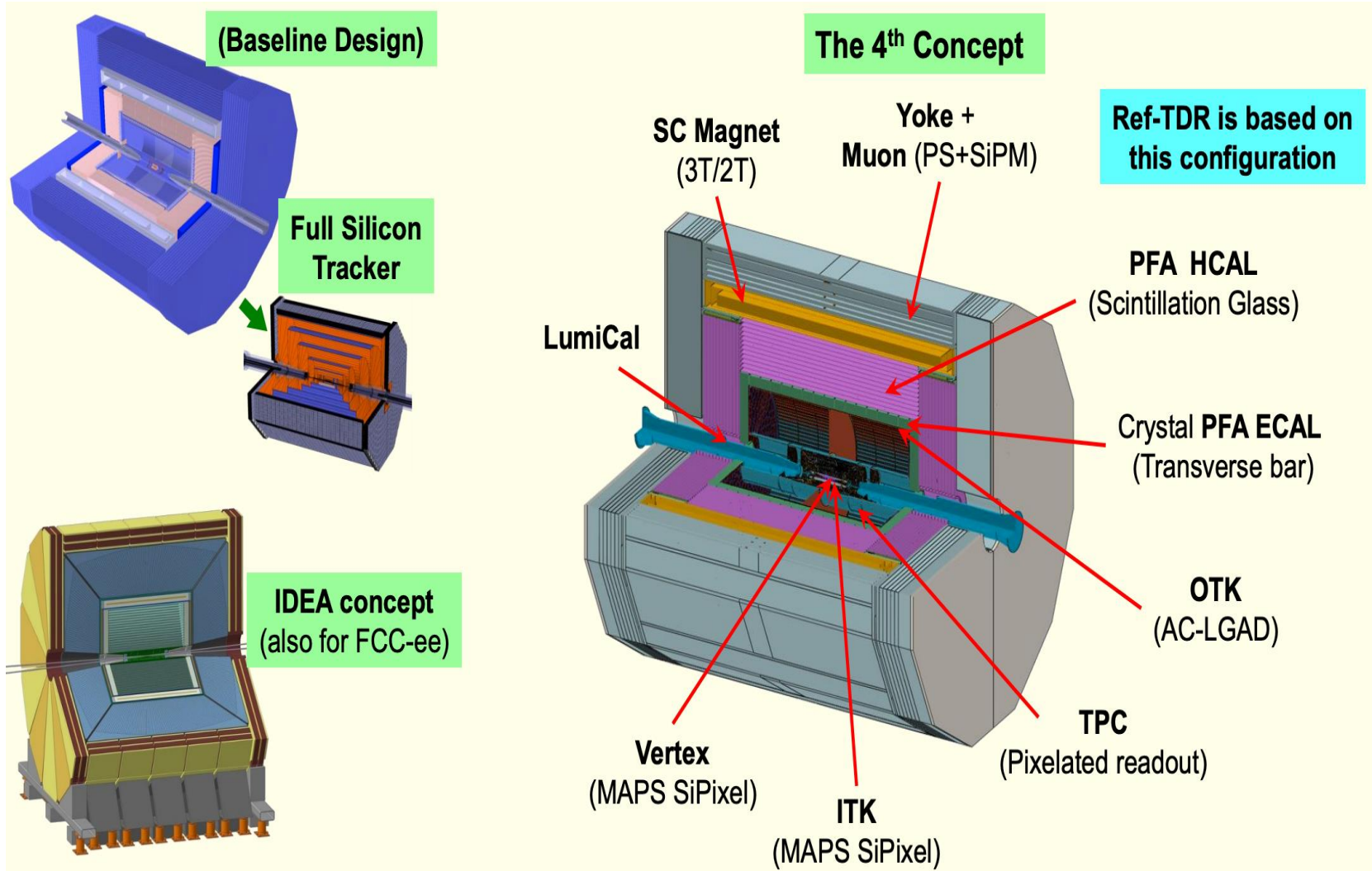
**Project CEPC has great physics potential for detailed studies of Higgs boson and respective searches for effects Beyond the Standard Model.**

## Background slides





# Two CEPC detectors



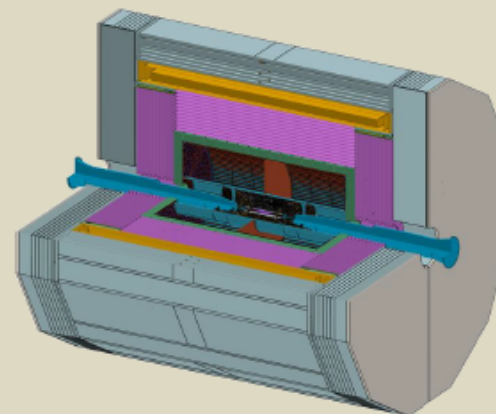
Baseline detector concept and detector IDEA.



System	Technologies	
	Baseline	Backup / Comparison
Beam pipe	$\Phi 20$ mm	
LumiCal	SiTrk + Crystal	
Vertex	CMOS + Stitching	CMOS Si Pixel
Tracker	CMOS Si Pixel ITK	SSD + RO Chip, CMOS SSD
	Pixelated TPC	PID Drift Chamber
	AC-LGAD OTK	SSD / SPD OTK
		LGAD ToF
ECAL	4D Crystal Bar	Stereo Crystal Bar, GS+SiPM, PS+SiPM+W, SiDet+W
HCAL	GS+SiPM+Fe	PS+SiPM+Fe, RPC+Fe
Magnet	LTS	HTS
Muon	PS bar+SiPM	RPC
TDAQ	Conventional	Software Trigger
BE electr.	Common	Independent

- The CEPC study group started to compare different technologies in January, 2024
- By the end of June, 2024 the baseline technologies were chosen.
- Multiple factors were considered in the process: performance, cost, R&D efforts, technology maturity, ...

Radius

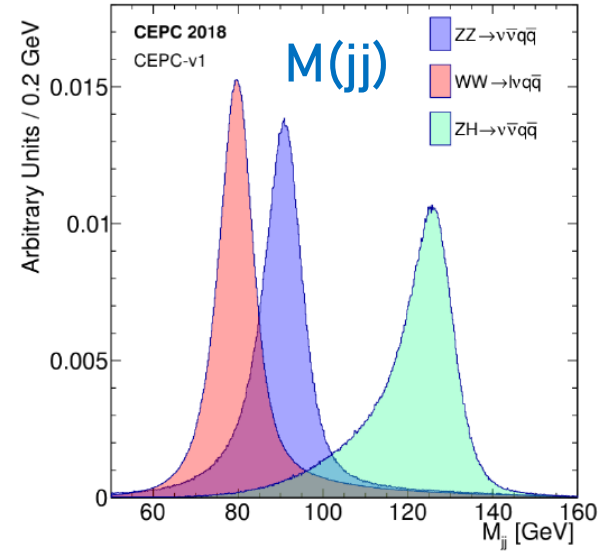
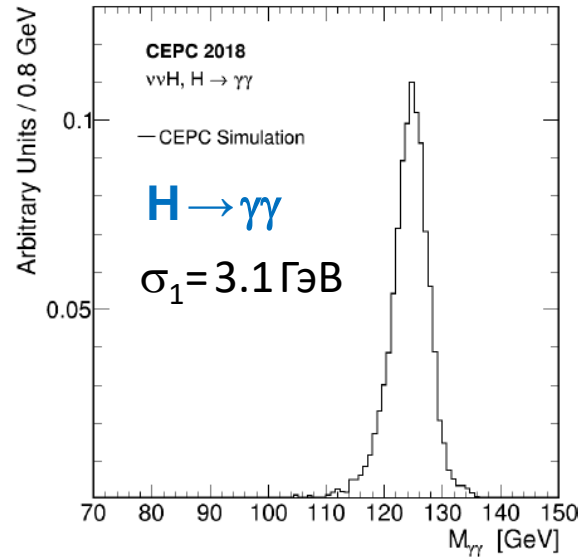
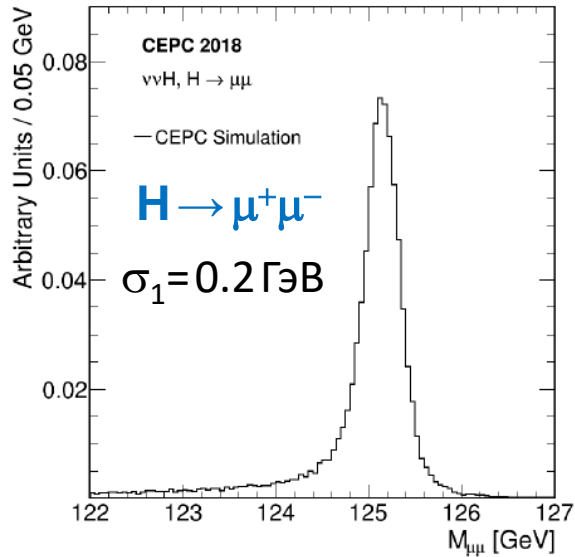


- We will continue pursuing better technologies for the two final detectors at CEPC

10/26/2024

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# Signal resolutions



Perfect resolutions for charged particles, photons, jets

Perfect identification of  $b$ - and  $c$ - jets.

Jets reconstruction procedures can be further improved:  
 ML methods, better counting of secondary vertices ...

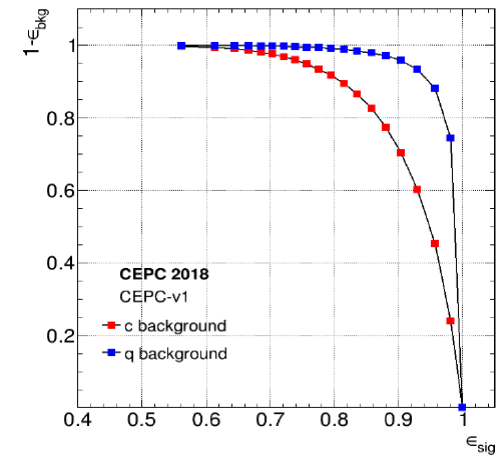
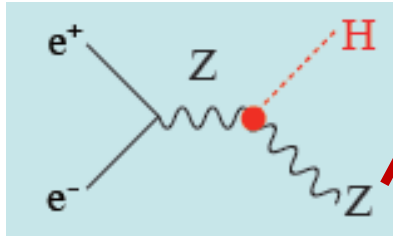
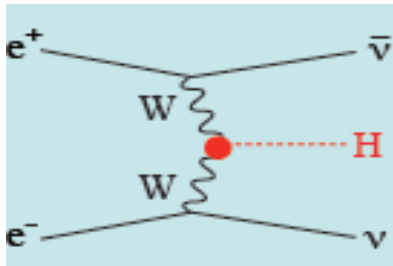


Fig. 6. Efficiency for tagging  $b$ -jets vs rejection for light-jet background (blue) and  $c$ -jet background (red), determined from an inclusive  $Z \rightarrow q\bar{q}$  sample from the  $Z$  factory operation.

# Higgs boson width measurement



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



$$\begin{aligned} H &\rightarrow \text{all} \\ H &\rightarrow b\bar{b} \\ H &\rightarrow WW^* \end{aligned}$$

Measurements at  $\sqrt{s} \sim 250\text{-}500$  GeV

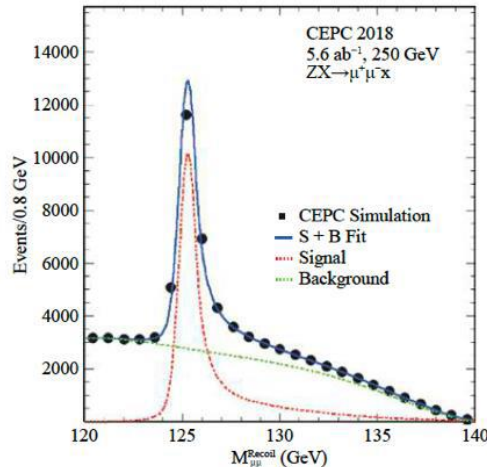
$$Y_1 = \sigma_{ZH} = F_1 \cdot g_Z^2$$

$$Y_2 = \sigma_{ZH} \times \text{Br}(H \rightarrow b\bar{b}) = F_2 \cdot \frac{g_Z^2 g_b^2}{\Gamma_H}$$

$$Y_3 = \sigma_{\nu\bar{\nu}H} \times \text{Br}(H \rightarrow b\bar{b}) = F_3 \cdot \frac{g_W^2 g_b^2}{\Gamma_H}$$

$$Y_4 = \sigma_{\nu\bar{\nu}H} \times \text{Br}(H \rightarrow WW^*) = F_4 \cdot \frac{g_W^4}{\Gamma_H}$$

$$Y_5 = \sigma_{ZH} \times \text{Br}(H \rightarrow WW^*) = F_5 \cdot \frac{g_Z^2 g_W^2}{\Gamma_H}$$



Constants  $F_1, F_2, F_3, F_4, F_5$  can be calculated with a high accuracy and small theoretical uncertainties

1. Obtain  $g_Z$  from first measurement of x-section
2. Obtain ratio  $g_Z/g_W$  from the second and third measurements
3. Using obtained  $g_Z$  and  $g_W$ , we can get  $\Gamma_H$  from four of fifth measurements

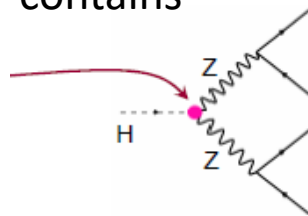
# Higgs boson CPV studies at LHC ( $h \rightarrow ZZ^*$ )

Coupling  $hZZ$  is tree-level for  $CP$ -even Higgs and loop-induced for  $CP$ -odd (suppressed).  
Therefore decay  $h \rightarrow Z (\lambda_1 \lambda_2) Z' (\lambda_3 \lambda_4)$  is not sensitive to Higgs  
 $CP$ -odd admixture. Only pure 100%  $CP$ -odd Higgs can be ruled out.

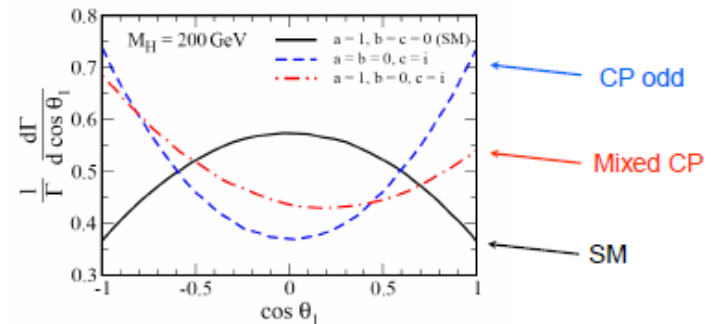
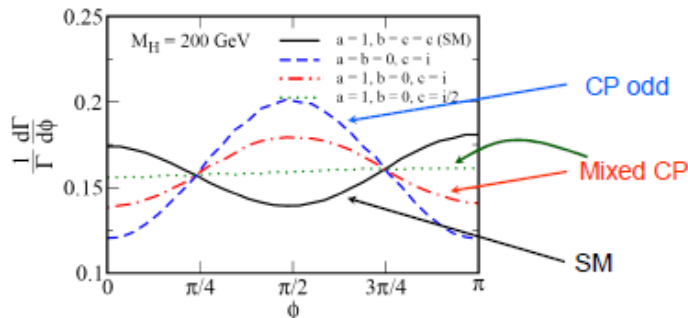
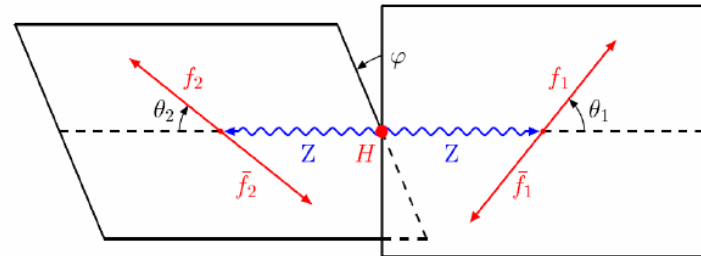
$$h \rightarrow Z (\ell_1 \ell_2) Z' (\ell_3 \ell_4)$$

Information about  $CP$  contains  
in this vertex

hep-ex/1308.4930



Polarization angles are used in analysis



hep-ex/1307.1432 ATLAS:  $0^-$  is rejected at 97.8% CL

hep-ex/1212.6639 CMS:  $0^-$  is rejected at 97.6% CLs

ATLAS and CMS rejected  $0^-$  for  $h(125)$ , but didn't get upper limit on  $CP$ -odd admixture



# CPV in Higgs decay $H \rightarrow \tau^+ \tau^-$

CPV appears in many extensions of Higgs Sector.

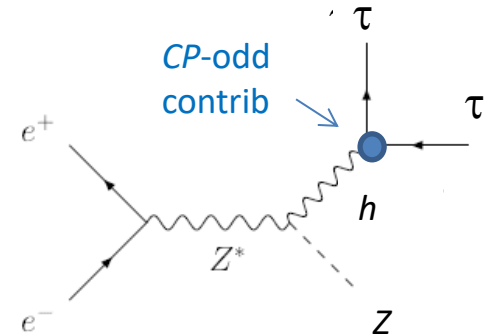
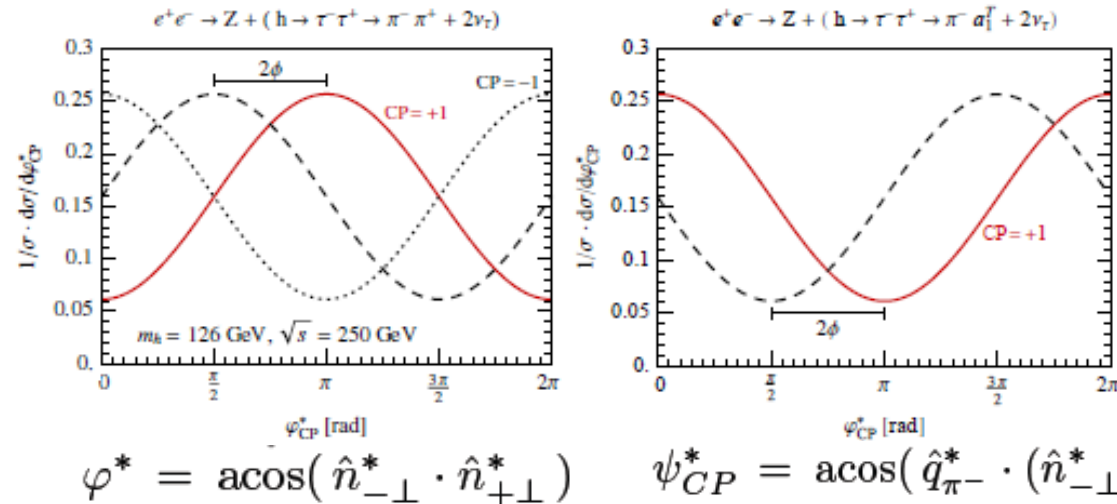
**2HDM** : two doublets of scalar fields with identical quantum numbers.

Three neutral fields :  $h, H, A$  ; two first are  $CP$ -even, last one is  $CP$ -odd.

These states are mixed to physical mass states in Higgs basis.

If  $h(125)$  has small  $CP$ -odd admixture:

$$e^+ e^- \rightarrow Z h, \quad h \rightarrow \tau^+ \tau^-, \quad \tau \rightarrow \pi, \rho, a_1$$



Uncertainties of about  $(5-10)^\circ$  in mixing phase at ILC with a few hundreds  $\text{fb}^{-1}$ .

Here decay products ( $\pi, \rho, a_1$ ) and their impact parameters have to be measured.

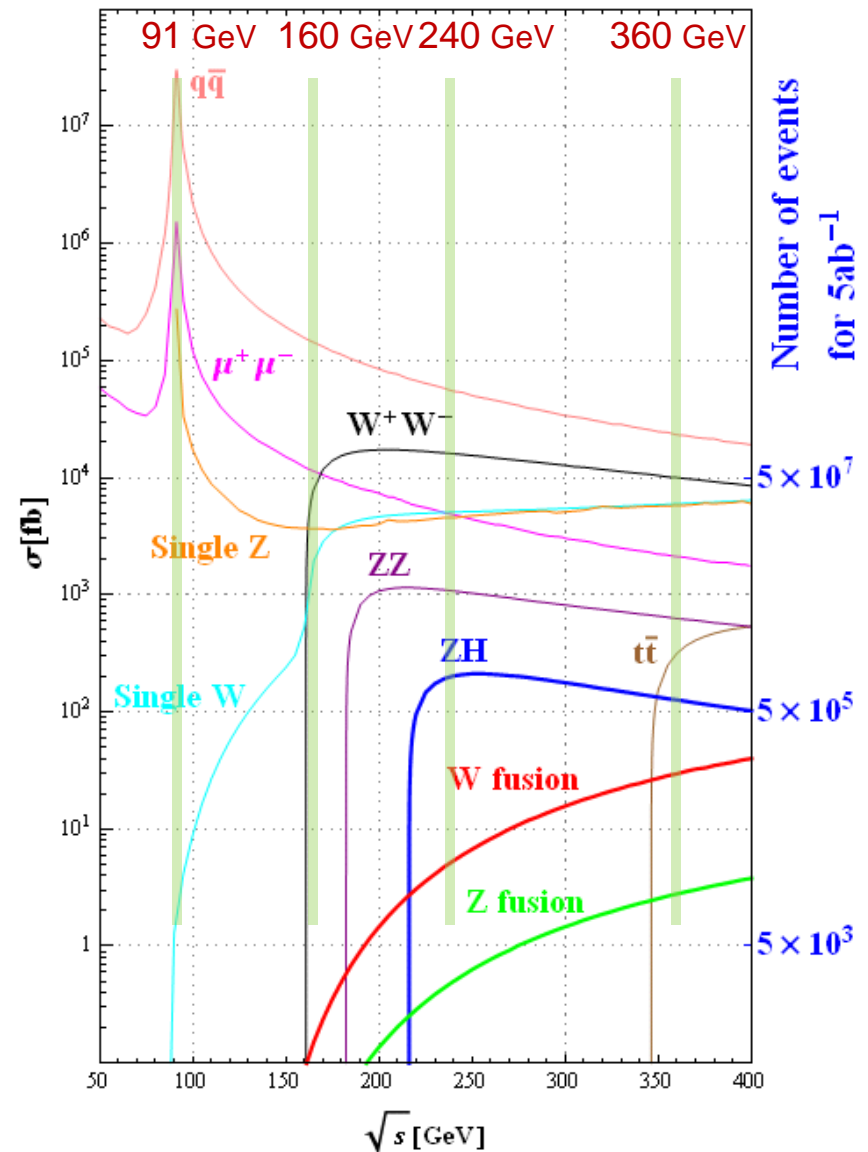
# Physics at CEPC collider

**91 GeV** – Z factory.  
Measurement of EW parameters,  
 $e^+e^- \rightarrow b\bar{b}, c\bar{c}, \tau^+\tau^-$

**160 GeV** - WW threshold.  
W mass measurement,  
W decays measurements

**240 GeV** – HZ, Higgs factory.  
Precise measurement of Higgs  
boson parameters. Higgs boson,  
as window in New Physics

**360 GeV** - tt threshold.  
t-quark mass measurement,  
t-quark decays measurements.



# Precision of parameter measurements for H, Z, W, t at CEPC

Table 2.1: Precision of the main parameters of interests and observables at the CEPC, from Ref. [1] and the references therein, where the results of Higgs are estimated with a data sample of 20 ab<sup>-1</sup>. The HL-LHC projections of 3000 fb<sup>-1</sup> data are used for comparison. [2]

Higgs <b>×2 (5.6 ab<sup>-1</sup>)</b>			W, Z and top		
Observable	HL-LHC projections	CEPC precision	Observable	Current precision	CEPC precision
$M_H$	20 MeV	3 MeV	$M_W$	9 MeV	0.5 MeV
$\Gamma_H$	20%	1.7%	$\Gamma_W$	49 MeV	2 MeV
$\sigma(ZH)$	4.2%	0.26%	$M_{\text{top}}$	760 MeV	$\mathcal{O}(10)$ MeV
$B(H \rightarrow bb)$	4.4%	0.14%	$M_Z$	2.1 MeV	0.1 MeV
$B(H \rightarrow cc)$	-	2.0%	$\Gamma_Z$	2.3 MeV	0.025 MeV
$B(H \rightarrow gg)$	-	0.81%	$R_b$	$3 \times 10^{-3}$	$2 \times 10^{-4}$
$B(H \rightarrow WW^*)$	2.8%	0.53%	$R_c$	$1.7 \times 10^{-2}$	$1 \times 10^{-3}$
$B(H \rightarrow ZZ^*)$	2.9%	4.2%	$R_\mu$	$2 \times 10^{-3}$	$1 \times 10^{-4}$
$B(H \rightarrow \tau^+\tau^-)$	2.9%	0.42%	$R_\tau$	$1.7 \times 10^{-2}$	$1 \times 10^{-4}$
$B(H \rightarrow \gamma\gamma)$	2.6%	3.0%	$A_\mu$	$1.5 \times 10^{-2}$	$3.5 \times 10^{-5}$
$B(H \rightarrow \mu^+\mu^-)$	8.2%	6.4%	$A_\tau$	$4.3 \times 10^{-3}$	$7 \times 10^{-5}$
$B(H \rightarrow Z\gamma)$	20%	8.5%	$A_b$	$2 \times 10^{-2}$	$2 \times 10^{-4}$
$B_{\text{upper}}(H \rightarrow \text{inv.})$	2.5%	0.07%	$N_\nu$	$2.5 \times 10^{-3}$	$2 \times 10^{-4}$

Accuracy can be improved for some parameters. Measurements can be combined in EFT global fit to get better accuracy.