Introduction to CEPCSW and performance study

Gang LI

Outline

- CEPC
- CEPC software & detectors
- Generator samples
- Some useful information

Attendances of IHEP

Jianchun Wang
co-convener of detector group

Joao Costa
co-convener of detector group

Mingshui Chen
physics performance

Yong Liu
(crystal) ECal

Huirong Qi
(pixelated) TPC

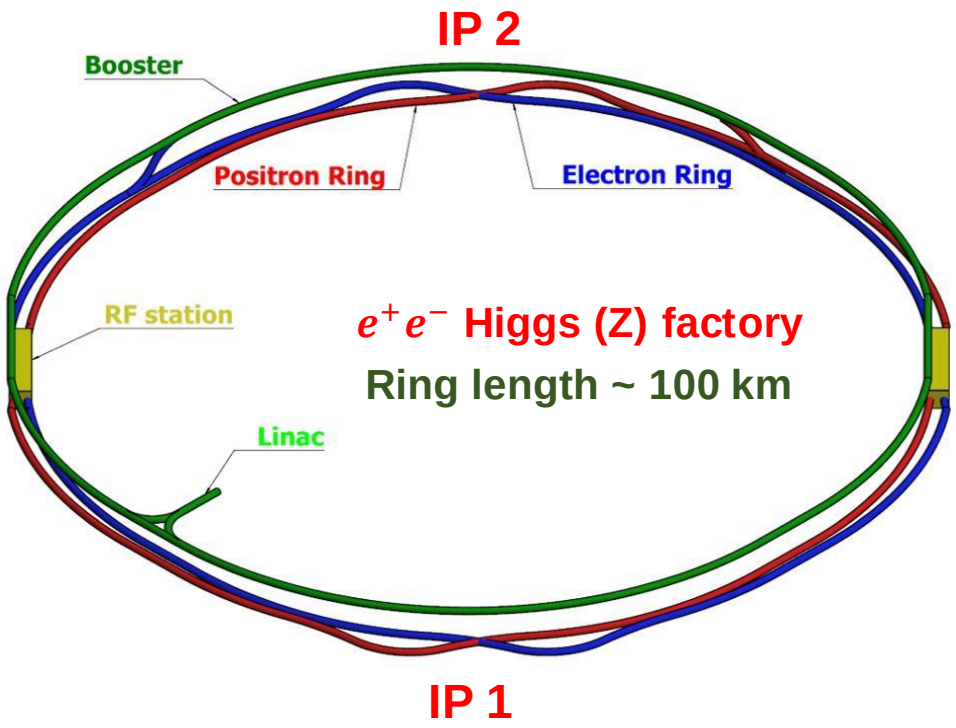
Manqi Ruan
White papers

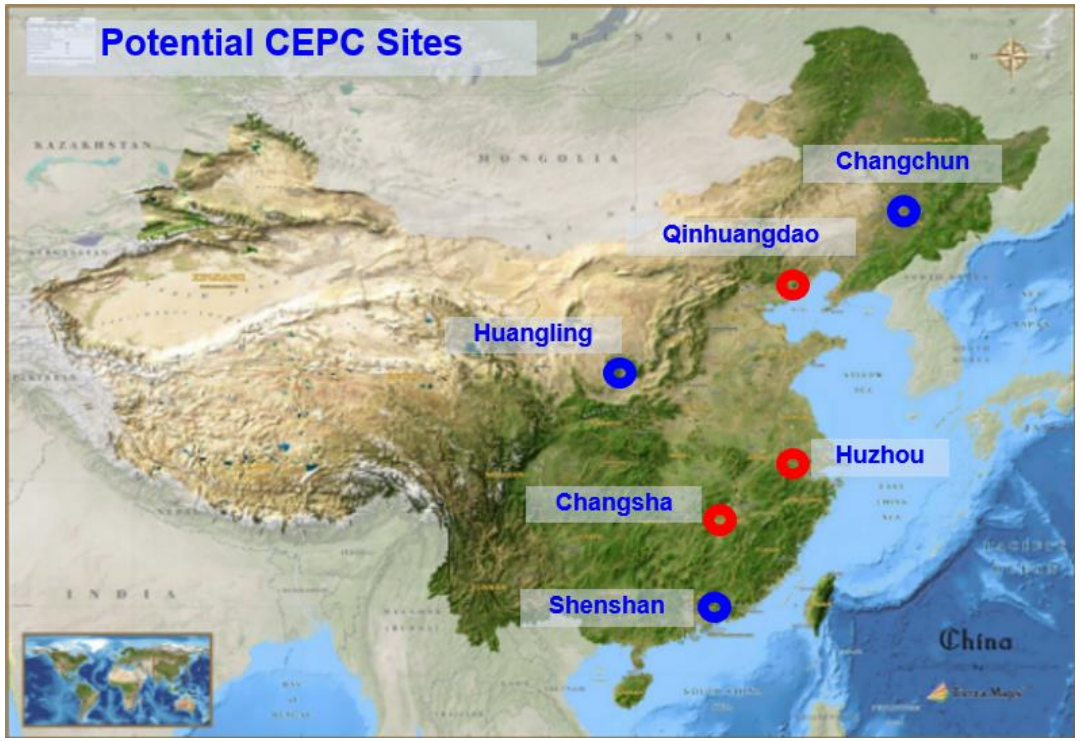
Gang Li
software, physics generators, tracker

General introduction

Circular Electron Positron Collider (CEPC)

- CEPC is an e^+e^- Higgs factory producing Higgs / W / Z bosons and top quarks, aims at discovering new physics beyond the Standard Model
- Proposed in 2012 right after the Higgs discovery
- Proposed to commence construction in ~2027 and start operation in 2030s.
- Upgrade: Super pp Collider (SppC) of $\sqrt{s}$ ~ 100 TeV in the future.





arXiv:1809.00285, arXiv:2203.09451

CEPC Physics Program

CEPC Operation mode		ZH	Z	W^+W^-	ttbar
$\sqrt{s}$ [GeV]		~ 240	~ 91.2	~ 160	~ 360
Run time [years]		7	2	1	-
CDR (30MW)	L / IP [$\times 10^{34}$ $cm^{-2}s^{-1}$]	3	32	10	-
	$\int L\,dt$ [ab^{-1}, 2 IPs]	5.6	16	2.6	-
	Event yields [2 IPs]	1×10^6	7×10^{11}	2×10^7	-
Run time [years]		10	2	1	5
Latest TDR (50MW)	L / IP [$\times 10^{34}$ $cm^{-2}s^{-1}$]	8.3	191.7	26.6	0.8
	$\int L\,dt$ [ab^{-1}, 2 IPs]	20	96	7	1
	Event yields [2 IPs]	4×10^6	4×10^{12}	5×10^7	5×10^5

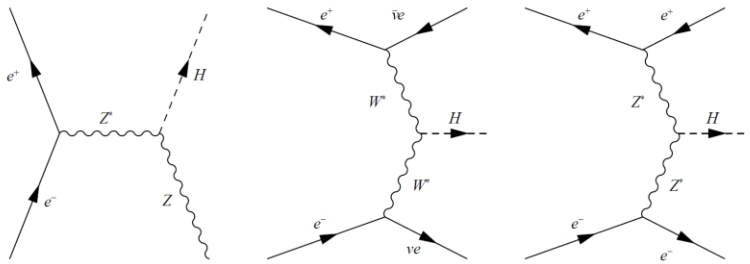
Systematically examine the SM and search for new physics beyond SM

Higgs&EW, QCD, Flavor, new hadron states, new phenomena, …

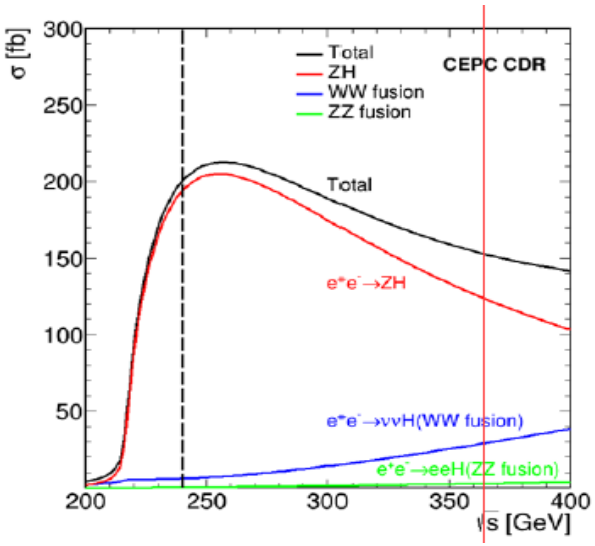
Not only number counting, but differentials, even probe new physics via some new technologies, such as AI.

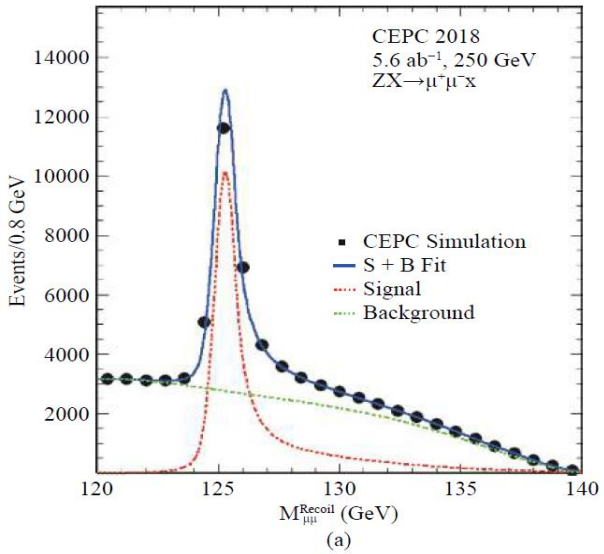
CEPC Physics(selected)

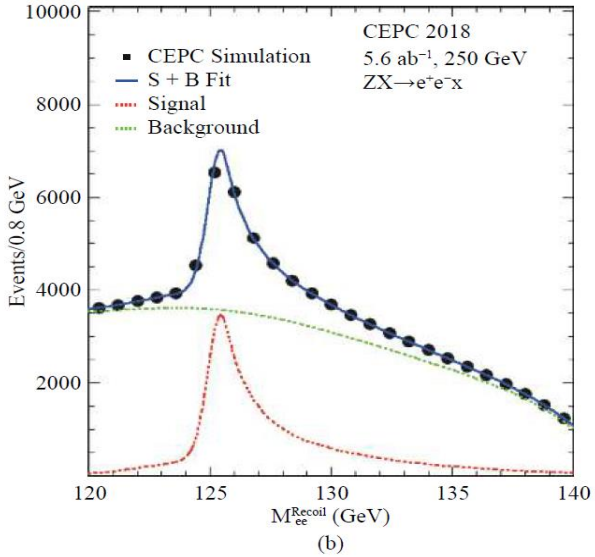
e^+e^- annihilations at the CEPC

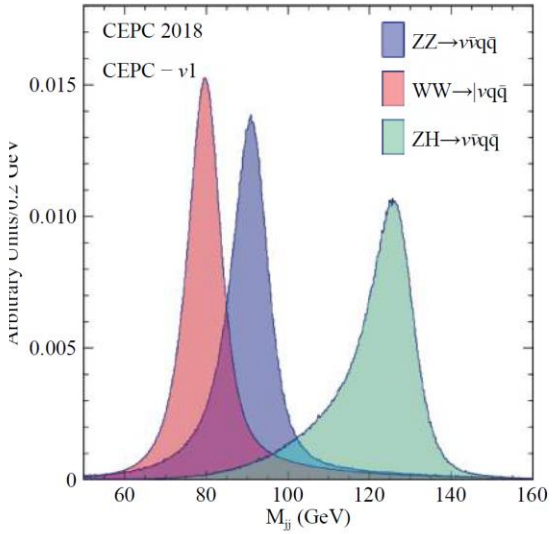


- CEPC can make detailed study of various physics processes
- Higgs bosons are detected via recoil mass of the reconstructed Z, allowing for model independent & full investigation of the Higgs and any new physics that Higgs may reveal
- Very challenging events with missing neutrinos and jets are well reconstructed and identified









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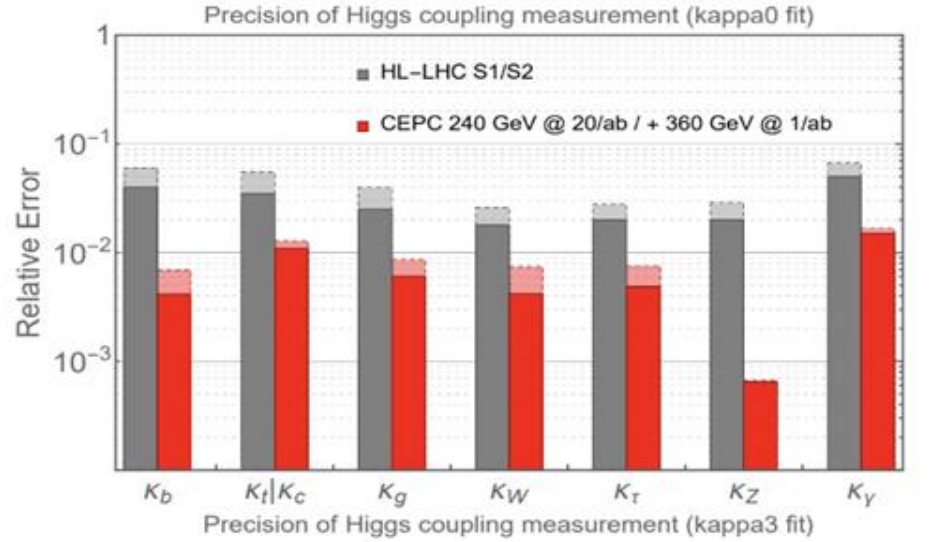
CEPC Physics(selected)

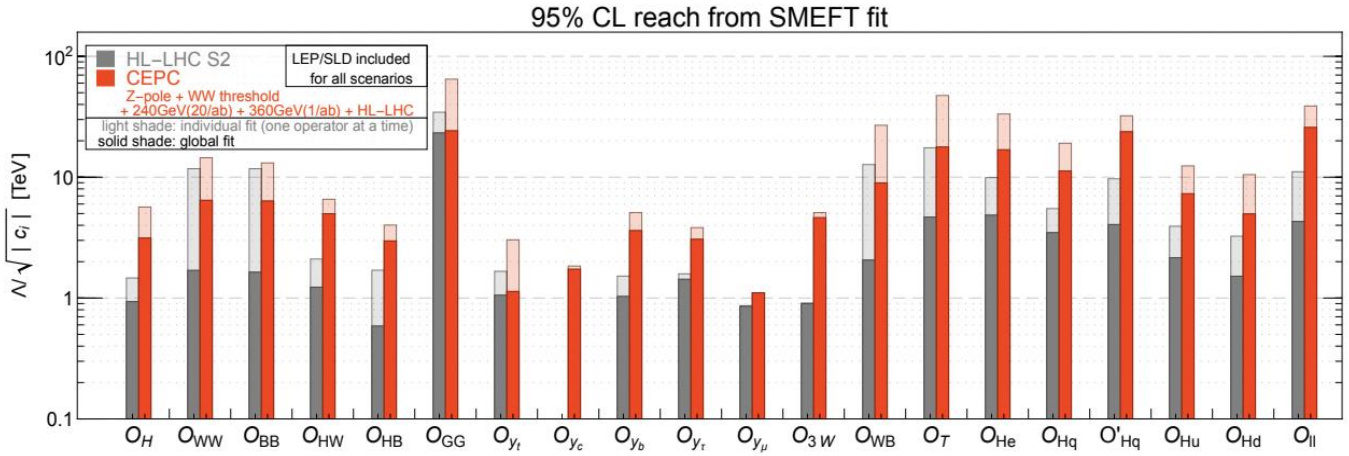
- Precision Higgs, EW, flavor physics & QCD measurements at unprecedented precision
- BSM physics (e.g. dark matter, EW phase transition, SUSY, LLP, …) up to ~ 10 TeV scale

	240 GeV, 20 ab^{-1}		360 GeV, 1 ab^{-1}		
	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%	
$H \to \tau\tau$	0.42%		2.10%	4.20%	7.50%
$H \to \gamma\gamma$	3.02%		11%	16%	
$H \to \mu\mu$	6.36%		41%	57%	
$H \to Z\gamma$	8.50%		35%		
$\mathrm{Br}_{upper}(H \to inv.)$	0.07%				
Γ_H	1.65%		1.10%		

arXiv:2205.08553



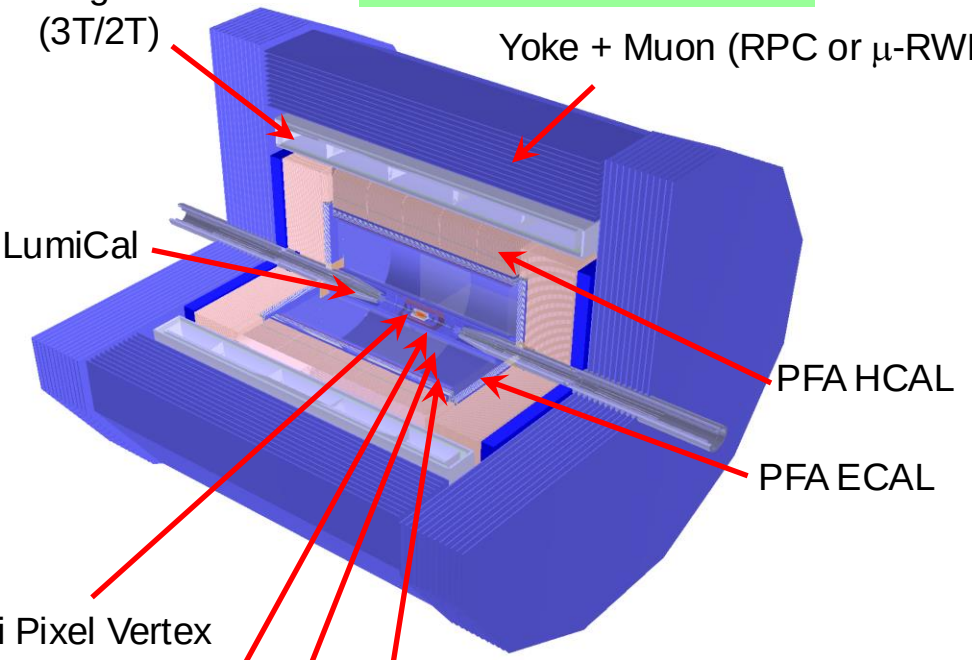
Energy scale probed



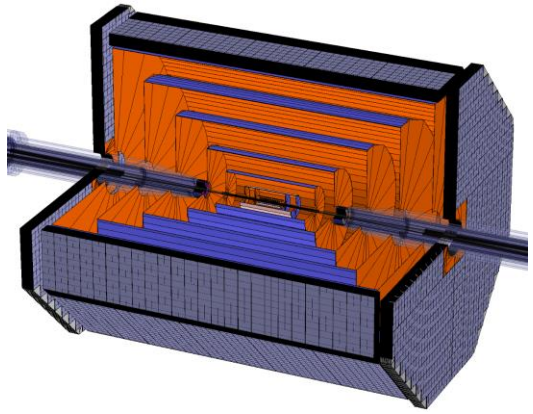
CEPC can reveal new physics at energy ~ 10 TeV or higher

CEPC Conceptual Detectors: development

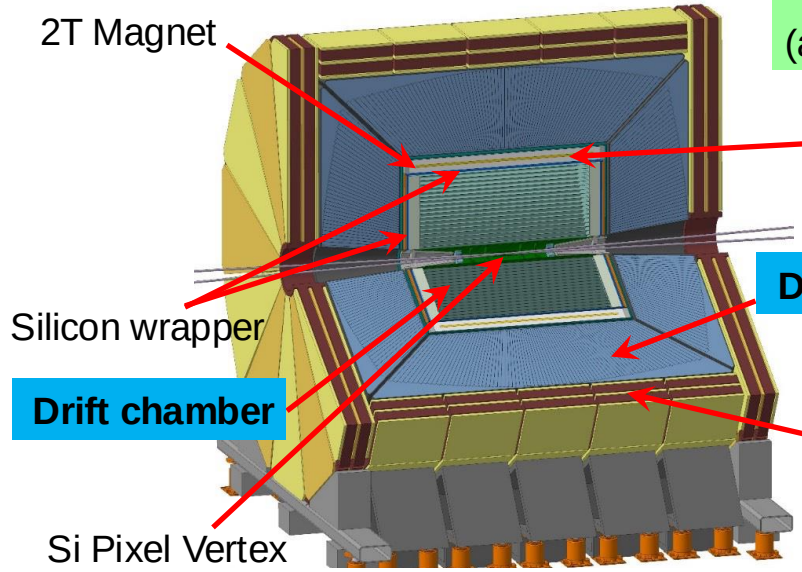
(Baseline Design)
Particle Flow Approach



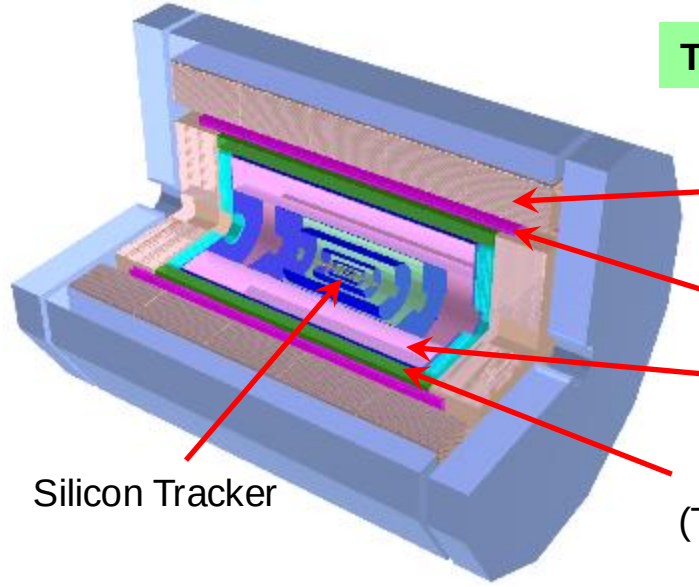
FST concept
(Full Silicon Tracker)



IDEA concept
(also proposed for FCC-ee)



The 4th Concept

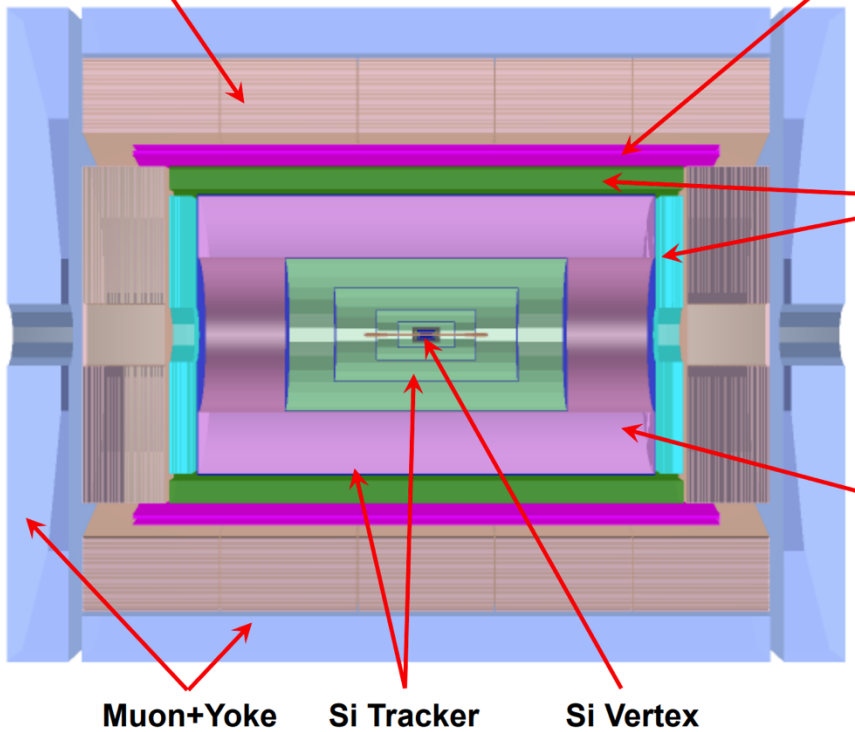


Novel Conceptual Detector Design

Scint Glass PFA HCAL

Advantage: Cost efficient, high density

Challenges: Light yield, transparency, massive production.



Solenoid Magnet (3T / 2T) Between HCAL & ECAL

Advantage: the HCAL absorbers act as part of the magnet return yoke.

Challenges: thin enough not to affect the jet resolution (e.g. BMR); stability.

Transverse Crystal bar ECAL

Advantage: better π^0/γ reconstruction.

Challenges: minimum number of readout channels; compatible with PFA calorimeter; maintain good jet resolution.

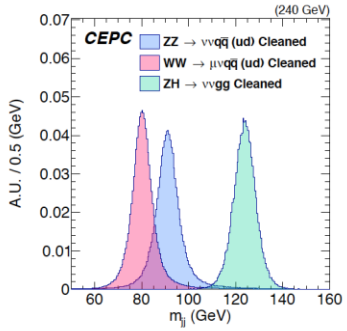
A Drift chamber that is optimized for PID

Advantage: Work at high luminosity Z runs

Challenges: sufficient PID power; thin enough not to affect the moment resolution.

Det	Technology
Pixel Vertex	JadePix
	TaichuPix
	Arcadia
	CPV(SOI)
	Stitching
Tracker & PID	TPC
	CEPCPix
	Drift chamber
	PID DC
	LGAD
	Silicon Strip

Det	Technology
Calorimeter	Crystal ECAL
	Si+W ECAL
	Scint+W ECAL
	Scint AHCAL
	ScintGlass AHCAL
	RPC SDHCAL
	MPGD SDHCAL
	DR Calorimeter
Muon	Scintillation Bar
	RPC
	μ-Rwell
Lumi	SiTrk+Crystal ECAL
	SiTrk+SiW ECAL



Novel detector design based on PFA calorimeter. Aim at improving BMR 4% → 3%

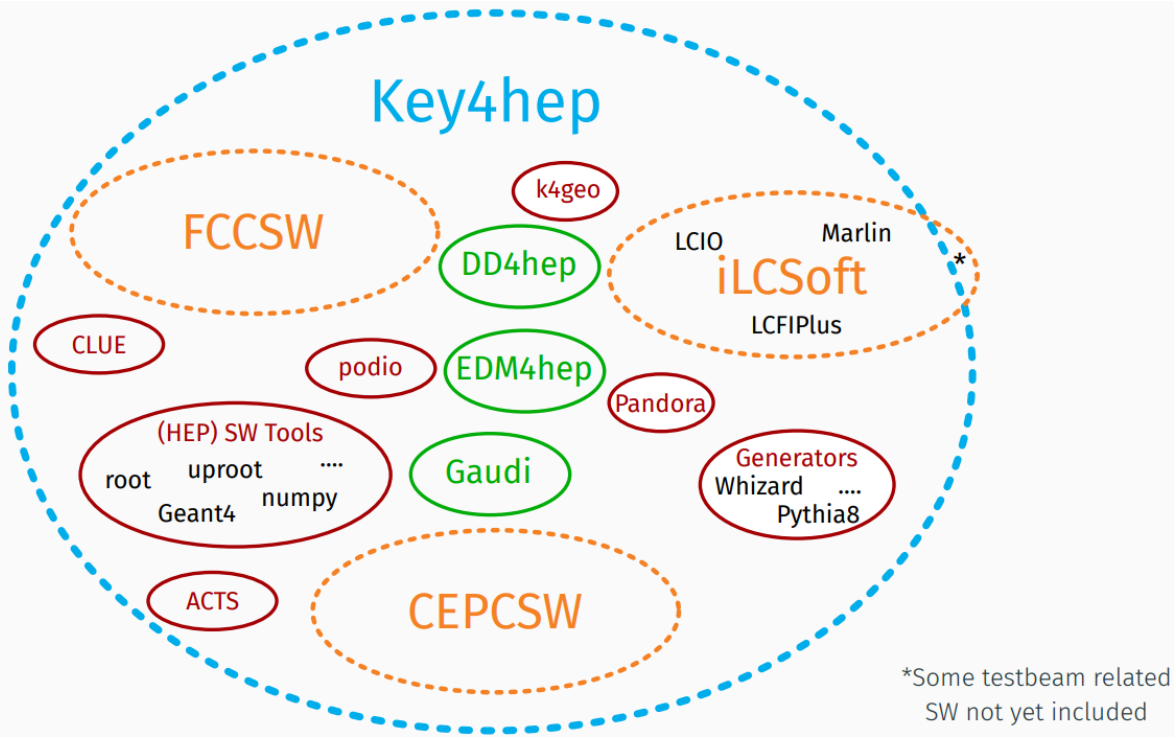
Detector	World-class level	CEPC design
PFA based (ECAL)	~ 15% / √E	< 3% / √E (Crystal ECAL)
PFA based (HCAL)	~ 50% / √E	~ 40% / √E (Scintillating glass HCAL)

CEPC offline software

CEPCSW

- The development of CEPC software started with the iLCSoft
  - Developed CEPC components for simulation and reconstruction
  - Generated M.C. data for detector design and physics potential studies
  - Particularly, CEPC CDR studies done with the iLCSoft
- The consensus among CEPC, CLIC, FCC, ILC and other future experiments was reached at the Bologna workshop in June, 2019.
  - Develop a Common Turnkey Software Stack (Key4hep) for future collider experiments
  - Maximize the sharing of software components among different experiments

T.Madlener | Key4hep & EDM4hep
CEPC workshop, Edinburgh

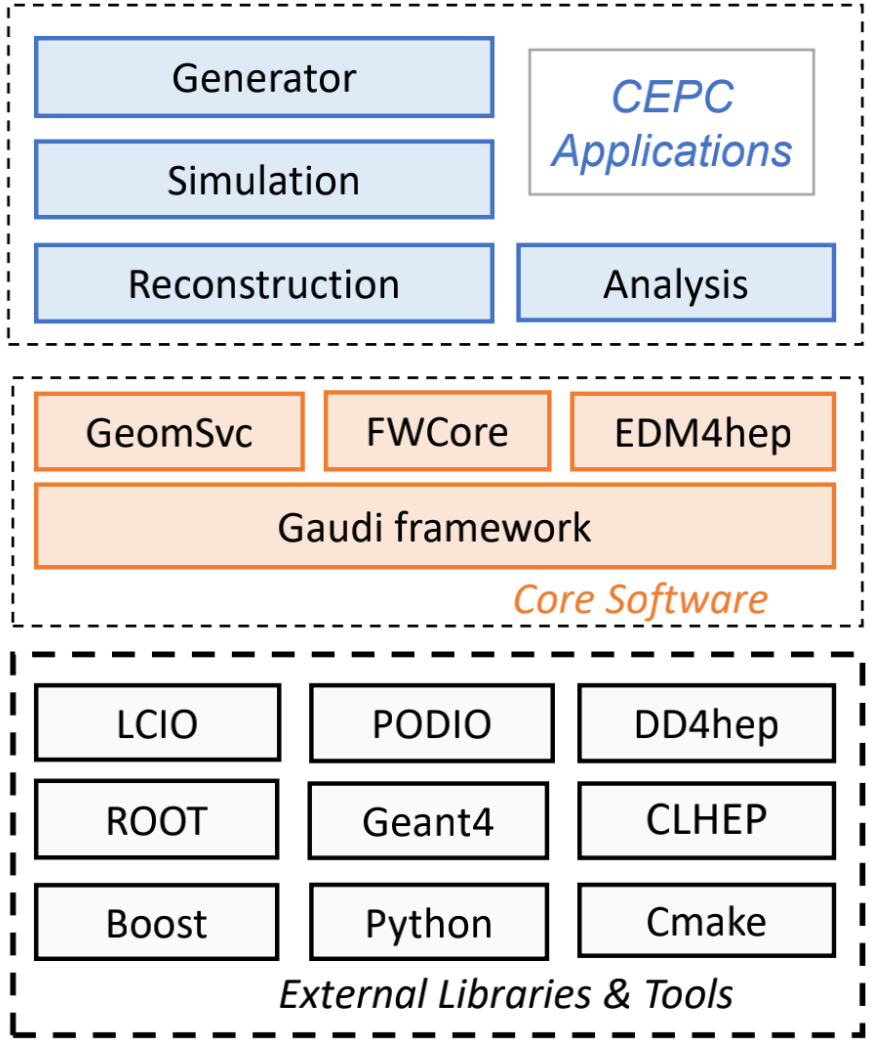


Key4hep project: https://github.com/key4hep
CEPCSW is the first application based on Key4hep.

CEPCSW: Architecture

- CEPCSW is organized as a multi-layer structure
  - Applications: simulation, reconstruction and analysis
  - Core software
  - External libraries

- The key components of core software include:
  - Gaudi: defines interfaces to all software components and controls their execution
  - EDM4hep: generic event data model
  - K4FWCore: manages the event data
  - DD4hep: geometry description
  - CEPC-specific framework software: generator, Geant4 simulation, beam background mixing, fast simulation, machine learning interface, etc.



https://code.ihep.ac.cn/cepc/CEPCSW

Generator samples

- Whizard+pythia6 is the main generator
- Pythia 8, madgraph5, Herwig, … also used

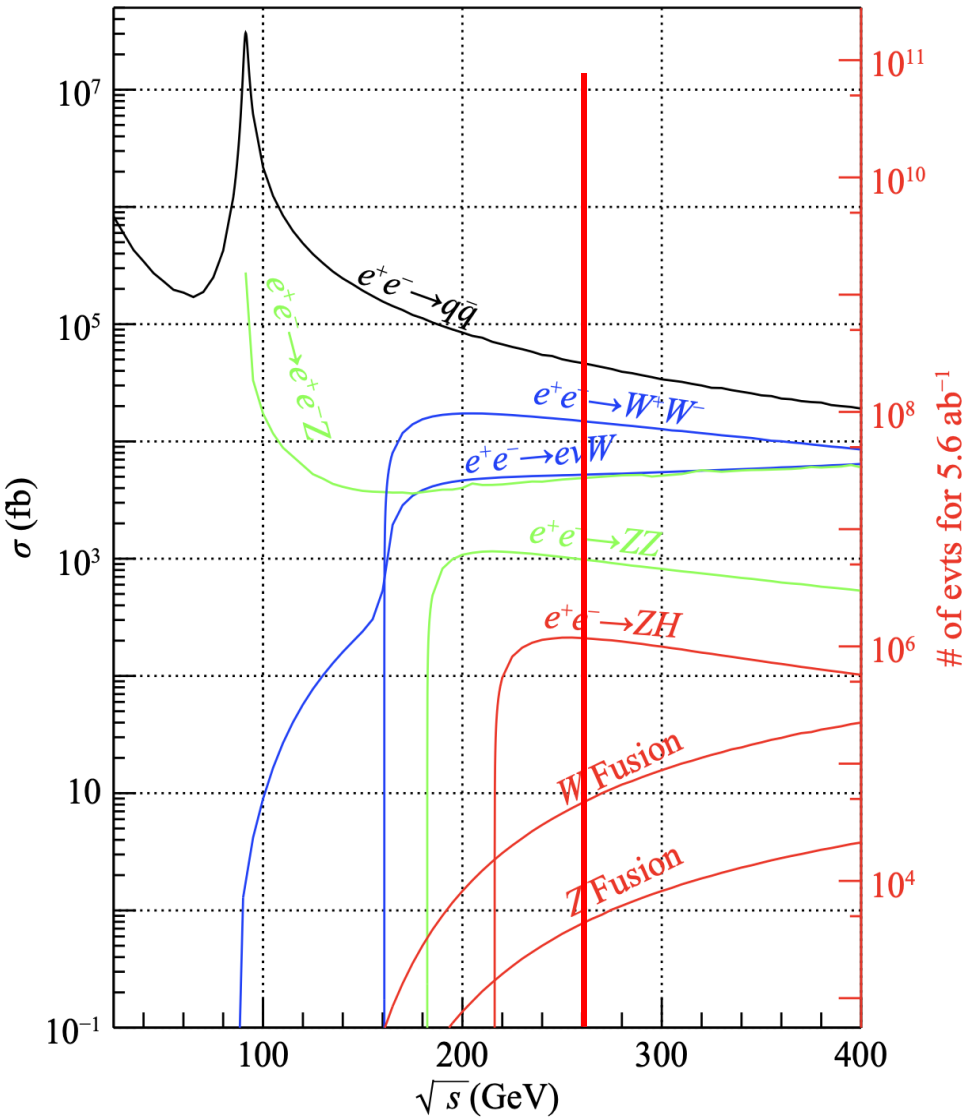
For more detail information, please follow the meetings in
https://indico.ihep.ac.cn/category/1043/
Dedicated tutorial on simulation production and analysis
https://indico.ihep.ac.cn/event/25350/
https://indico.ihep.ac.cn/event/24004/

For Higgs study

20/ab in 240GeV, 1/ab in 360GeV.
?? In 91 GeV and 160 GeV

Signals(fb)	240	360
ZH	196.9	126.6
WW fusion	6.2	29.61
ZZ fusion	0.5	2.80
Total	203.6	159.0
Total Events	4M	0.16M

Background(pb)		240	360
2fermion	ee(γ)	930	325
	$\mu\mu(\gamma)$	5.3	2.1
	qq(γ)	54.1	23.2
	$t\bar{t}$	\	0.317
4fermion	WW	16.7	10.0
	ZZ	1.1	0.63
	sZ	4.54	5.78
	sW	5.09	6.00



Z-pole and W threshold study

- Z pole
  - Hadron cross section ~ 30nb --- 4 Tera Z boson events
  - Generate samples on demanding
- W threshold scan for W mass measurement
  - Various energy points
  - Moderate statistics
  - Also on demanding

Some useful information

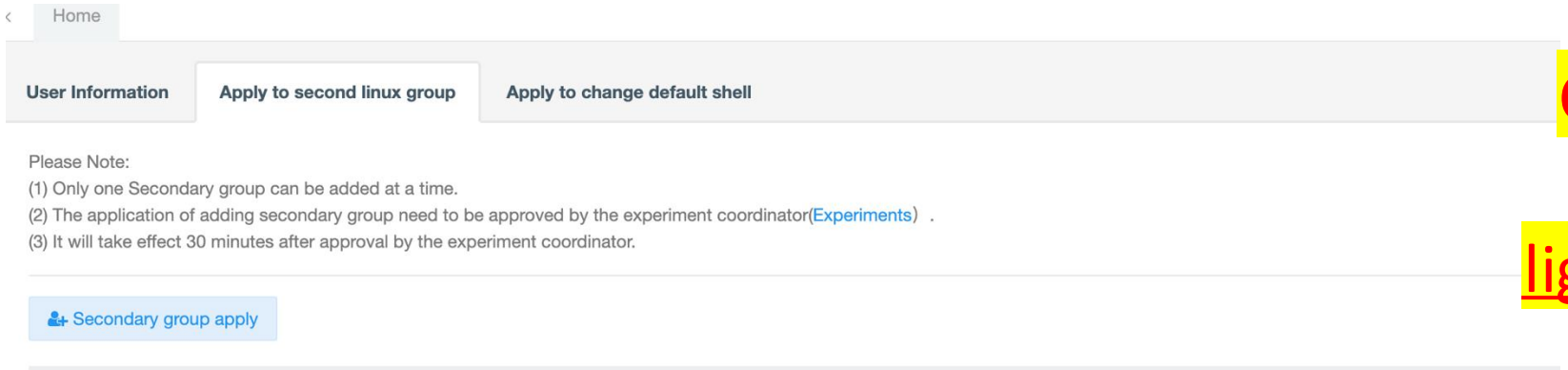
How to apply an computing account of IHEP

- If you do not have IHEP SSO
  - Step 1: Apply SSO account on login.ihep.ac.cn by click the “register” button
  - Step 2: Apply AFS computing account once you have an SSO account and login to login.ihep.ac.cn

Apply for IHEP Computing Cluster Account

Computing Service	Experiment	App. Date
AFS	BES	2023-03-06

- If you already have an AFS account but in higgs group
  - Login ccsinfo.ihep.ac.cn to request to join the second linux group : higgs



Contact person:
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ligang@ihep.ac.cn

Websites and github repos.

- CEPC website: http://cepc.ihep.ac.cn/
- Internal wiki: http://cepc.ihep.ac.cn/~cepc/cepc_twiki/index.php/Main_Page
- Internal docs: http://cepcdoc.ihep.ac.cn/cgi-bin/DocDB/DocumentDatabase
- CEPCSW gitlab repo: https://code.ihep.ac.cn/cepcsw/CEPCSW
  - Github repo: https://github.com/cepc/CEPCSW
  - Github key4hep repo:
    - https://github.com/key4hep/k4FWCore
    - https://github.com/key4hep/EDM4hep
- Previous CEPC software documentation: http://cepcsoft.ihep.ac.cn/

Summary

- General introduction to CEPC detector, software, and physics study
- Some useful information
- More you want to know about the CEPC?