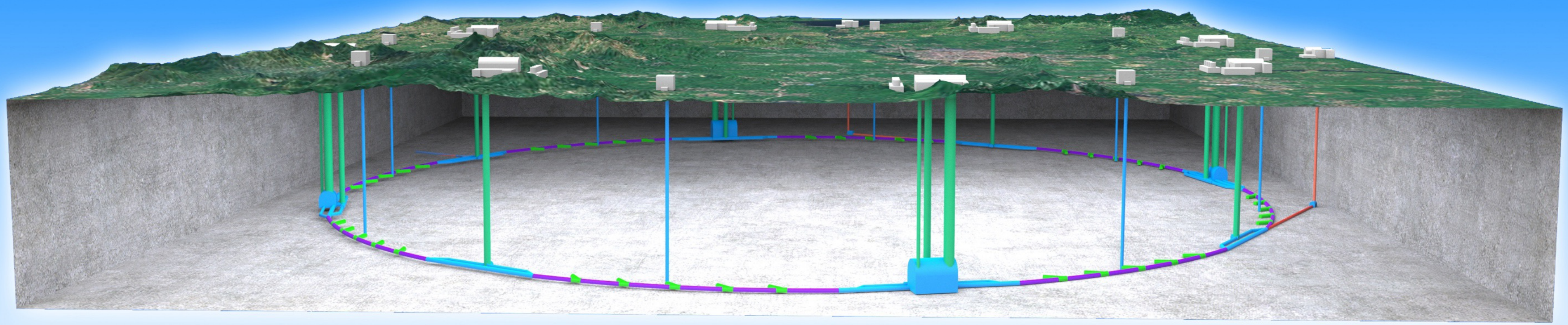
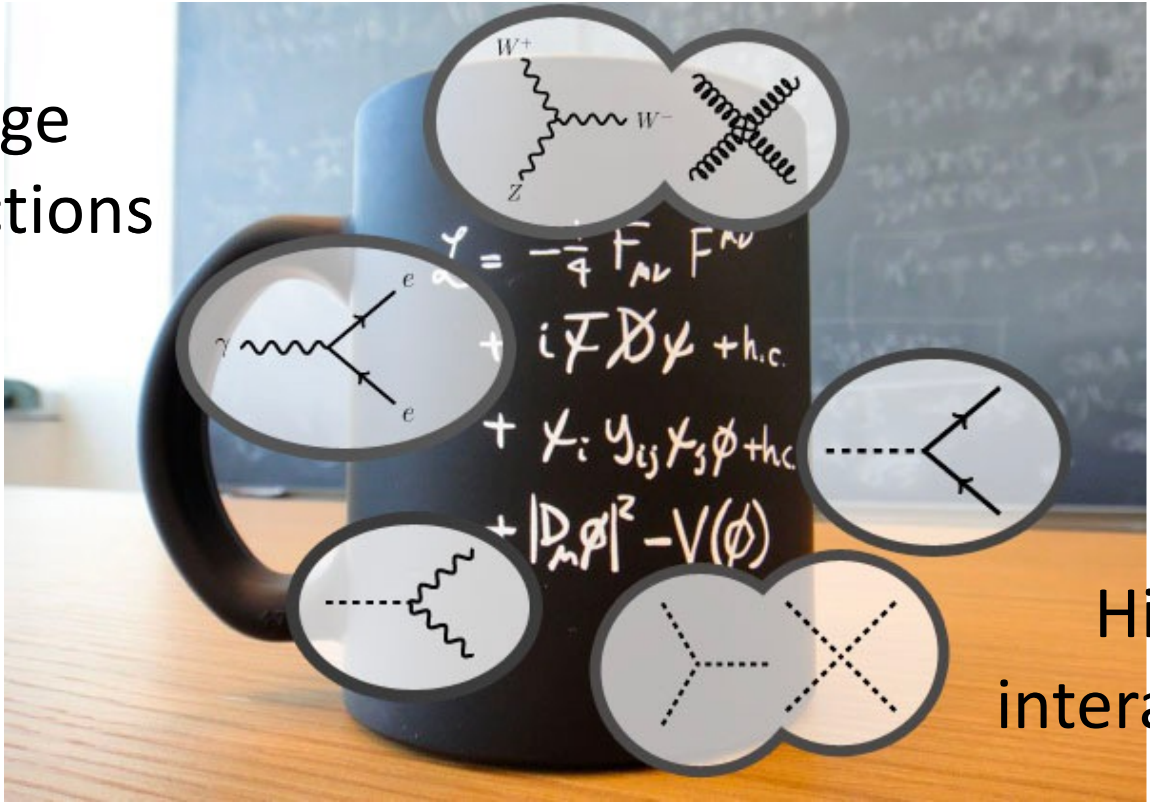
Science, Status, and AI enhanced reco. at the CEPC



Manqi RUAN(IHEP, Beijing)

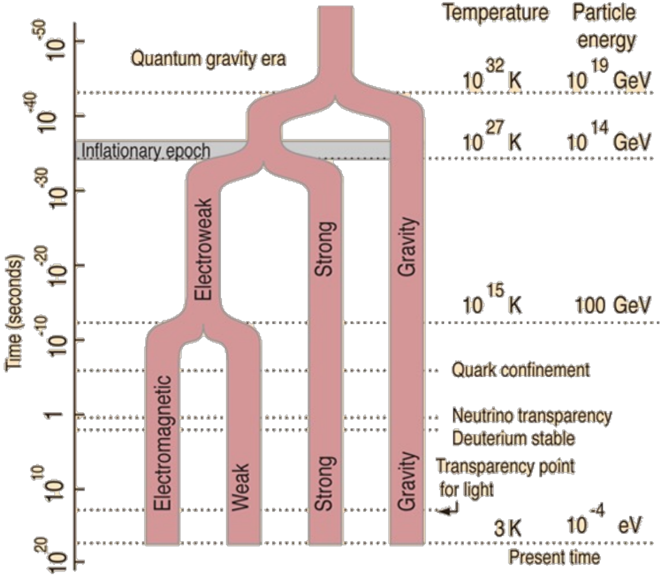
The Higgs field, heart of the SM

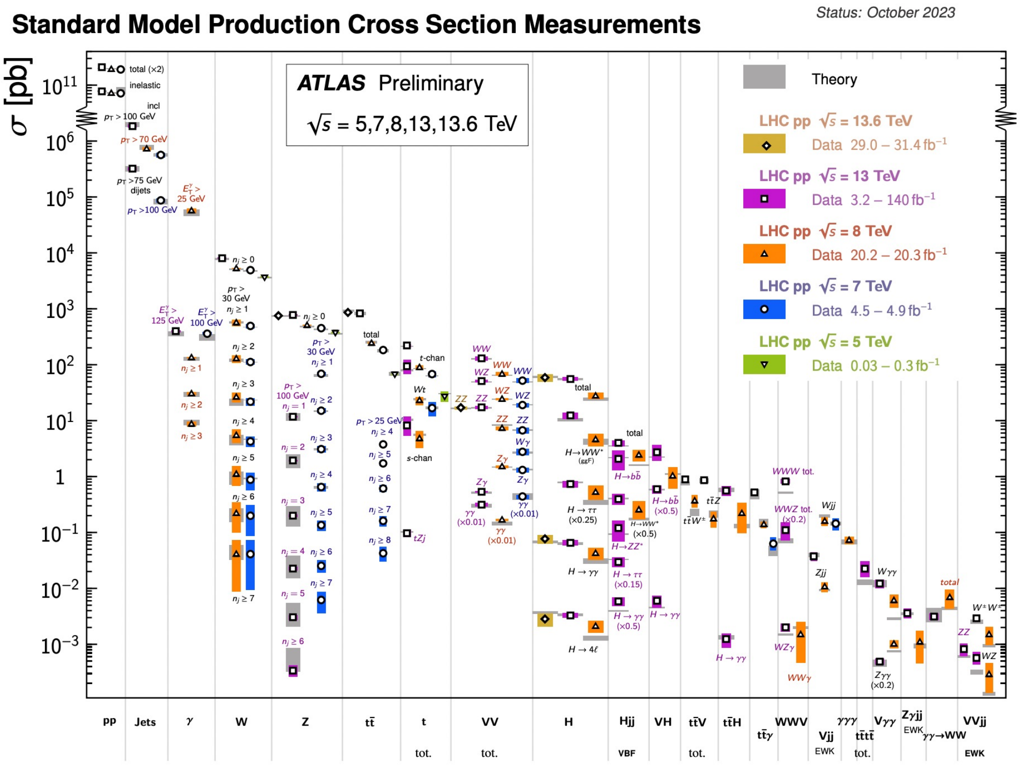
Gauge interactions



Higgs interactions

The SM: predicts and interprets almost all the experimental data at accelerator experiments





Seminar@LLR

The challenges to the SM

- Inflation
- Mass hierarchy
- Neutrino Mass
- Matter-Anti matter asymmetry
- Stability of the Universe: depends on the Particle Mass
- Dark Matter: nature & origin of mass…
- Dark Energy, Inflation: nature…

The challenges to the SM

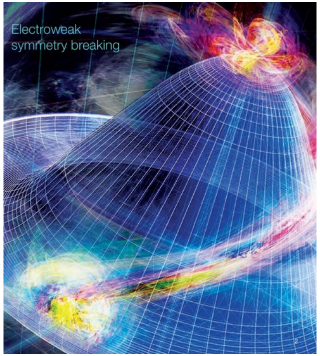
- Inflation
- Mass hierarchy
- Neutrino Mass
- Matter-Anti matter asymmetry
- Stability of the Universe: depends on the Particle Mass
- Dark Matter: nature & origin of mass…
- Dark Energy, Inflation: nature…

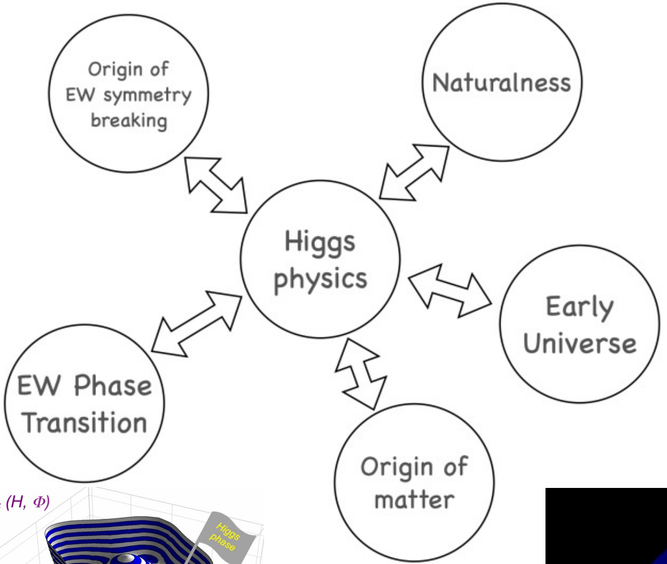
Higgs boson: a portal to new physics

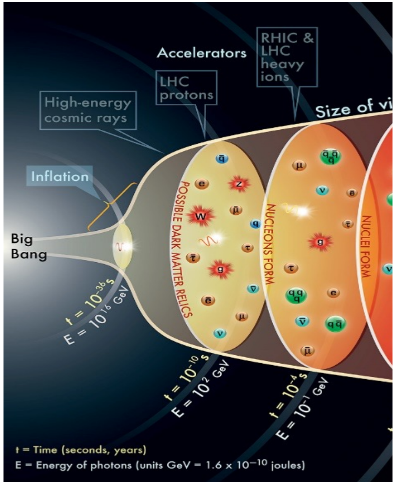
➔ EW symmetry breaking

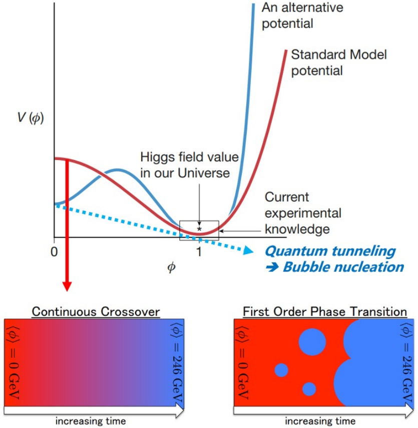
➔ Naturalness

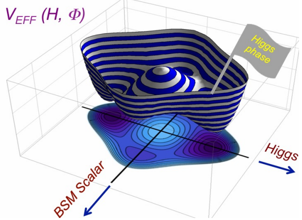
➔ Early Universe

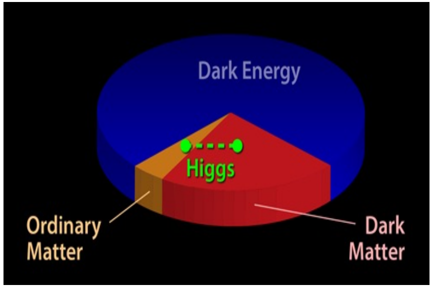










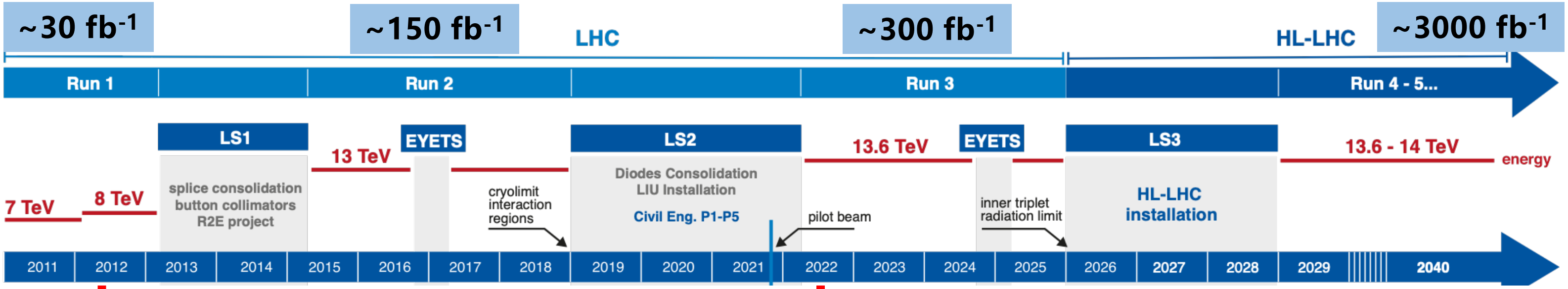


➔ EW Phase Transition

➔ Origin of matter

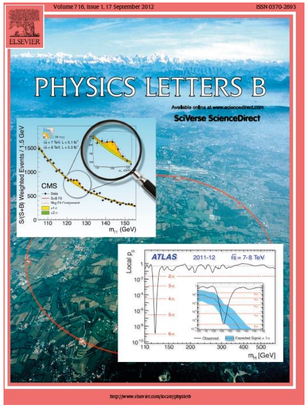
➔ Higgs portal to DM

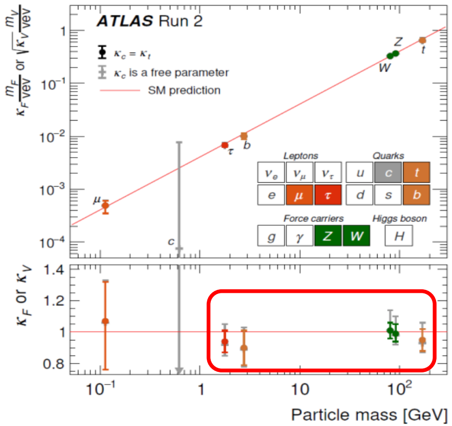
Higgs discovery to precision measurements



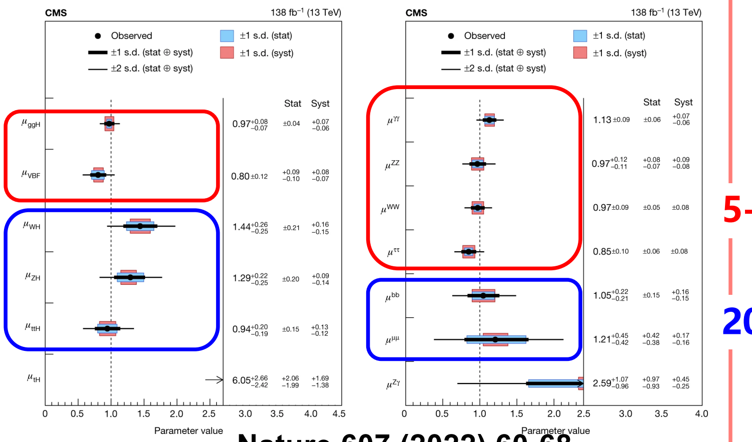
New milestone after 10 years of the Higgs discovery

Higgs Discovery





Nature 607 (2022) 52-59



Nature 607 (2022) 60-68

5-10%

20-40%

Global Consensus on Higgs Factories

The scientific importance and strategical value of e^+e^- Higgs factories is clearly identified.

China

2013, 2016: *China Xiangshan Science Conference concluded that* ***CEPC is the best approach*** *and a major historical opportunity for the national development of accelerator-based high-energy physics program.*

JAHEP Japan

2017: *Japan Association of High Energy Physicists (JAHEP) proposes to construct* ***A 250 GeV center of mass ILC promptly as a Higgs factory.***

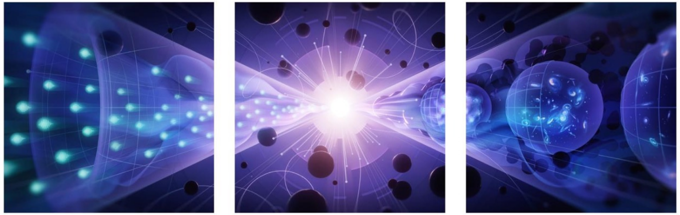
Europe

2020: *European Strategy for Particle Physics,* ***An electron-positron Higgs factory is the highest priority next collider.*** *For the longer term, the European particle physics community has the ambition to operate a proton-proton collider at the highest achievable energy.*

ICFA

2022, *ICFA "reconfirmed the international consensus on the importance of* ***a Higgs factory as the highest priority for realizing the scientific goals of particle physics****", and expressed support for the above-mentioned Higgs factory proposals*

P5 report, USA, 2023



Decipher the Quantum Realm | Explore New Paradigms in Physics | Illuminate the Hidden Universe

Elucidate the Mysteries of Neutrinos | Search for Direct Evidence of New Particles | Determine the Nature of Dark Matter

Reveal the Secrets of the Higgs Boson | Pursue Quantum Imprints of New Phenomena | Understand What Drives Cosmic Evolution

Exploring the Quantum Universe

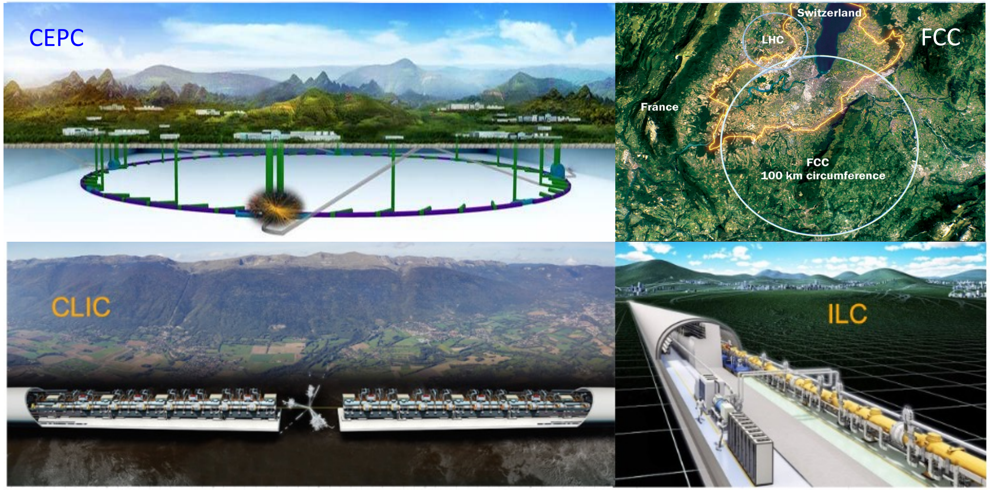
Recommendation 6

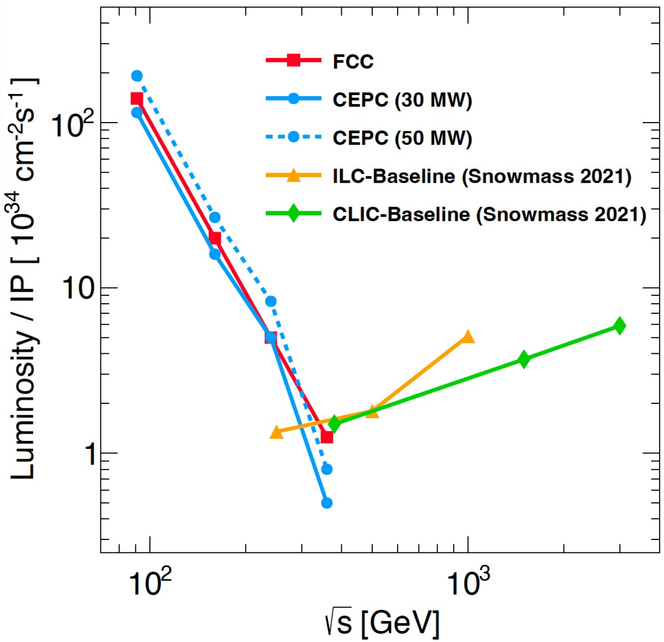
Convene a targeted panel with broad membership across particle physics later this decade that makes decisions on the US accelerator-based program at the time when major decisions concerning an off-shore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed. A plan for the Fermilab accelerator complex consistent with the long-term vision in this report should also be reviewed.

The panel would consider the following:

1. The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.
2. Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.
3. A plan for the evolution of the Fermilab accelerator complex consistent with the longterm vision in this report, which may commence construction in the event of a more favorable budget situation.

Comparison of Higgs factories: Circular vs Linear





CEPC has strong advantages among mature e^+e^- Higgs factories (design report delivered)

Versus FCC-ee

- Earlier data: collisions expected in 2030s (vs. ~ 2040s)
- Large tunnel cross section (ee & pp coexistence)
- Lower construction cost

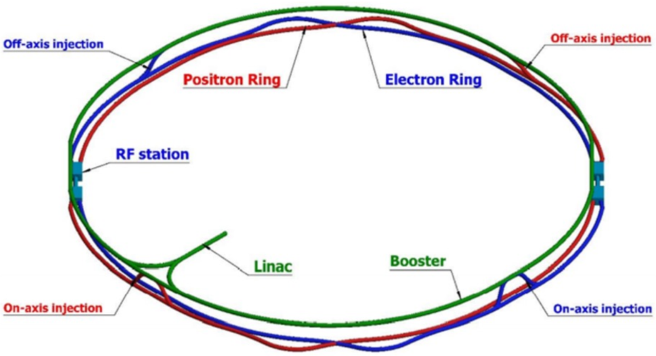
Versus Linear Colliders

- Higher luminosity / precision for Higgs & Z
- Potential upgrade for pp collider

A brief introduction to CEPC

- CEPC: an e^+e^- Higgs factory producing H and W/ Z bosons and top quarks
  aims at discovering new physics beyond the Standard Model
  - CEPC + SppC complex proposed in 2012 right after the Higgs discovery
  - Conceptual Design Report delivered in Nov. 2018, 1st for circular ee Higgs factory
  - R&D reaching maturity, accelerator TDR published at 2023, high-impact innovations

- Proposed to commence the construction in ~2026
  to deliver Higgs data in 2030s



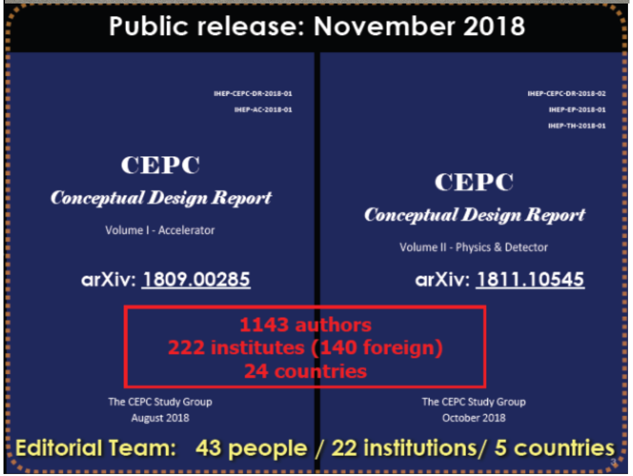
CEPC circumference ~ 100km

CEPC Major Milestones

CEPC-SPPC Kickoff (2013.9)

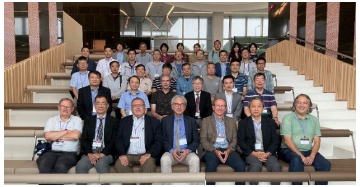
First CEPC IAC Meeting (2015.9)

CEPC CDR Released (2018.11)

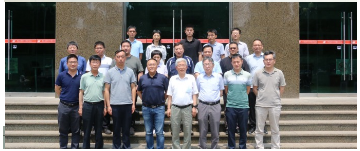


CEPC Major Milestones

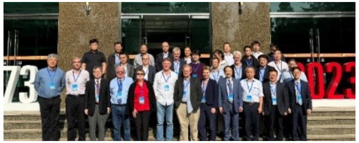
CEPC Accelerator TDR Review
June 12-16, 2023, Hong Kong



CEPC Accelerator TDR Cost Review
Sept. 11-15, 2023, Hong Kong



Domestic Civil Engineering
Cost Review, June 26, 2023, IHEP



9th CEPC IAC 2023 Meeting
Oct. 30-31, 2023, IHEP

CEPC Accelerator TDR released in December, 2023

IHEP-CEPC-DR-2023-01

IHEP-AC-2023-01

CEPC

Technical Design Report

Accelerator

arXiv:2312.14363
1114 authors
278 institutes
(159 foreign institutes)
38 countries
1090 pages

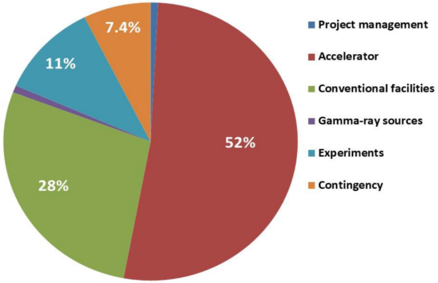
The CEPC Study Group
December 2023

Seminar@LLR

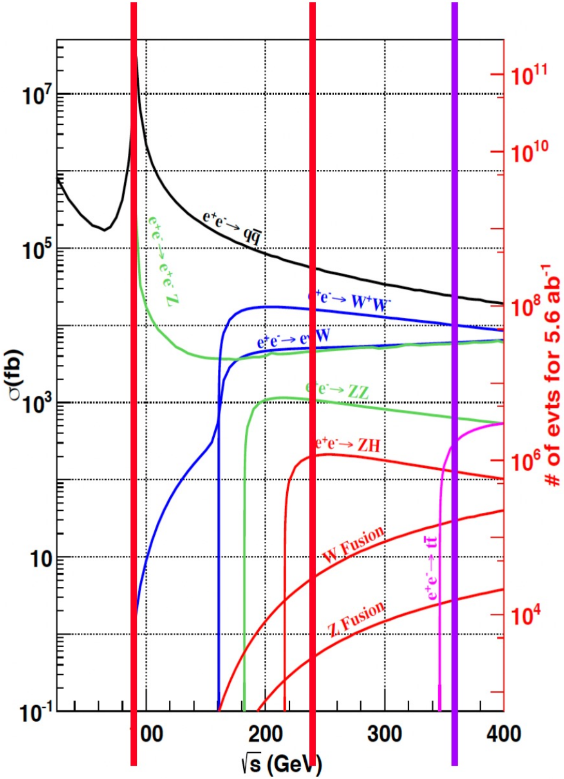
Distribution of CEPC Project TDR cost of 36.4B RMB (~4.6B Euro)

Table 12.1.2: CEPC project cost breakdown, (Unit: 100,000,000 yuan)

Total	**364**	**100%**
Project management	3	0.8%
Accelerator	190	52%
Conventional facilities	101	28%
Gamma-ray beam lines	3	0.8%
Experiments	40	11%
Contingency (8%)	27	7.4%



CEPC Physics Program



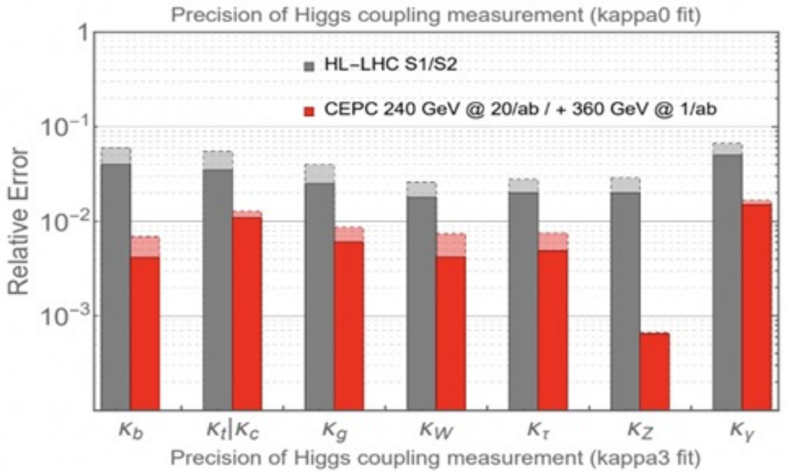
- **Measurements of Higgs, EW, flavor physics & QCD at unprecedented precision**
- **BSM physics (e.g. dark matter, EWPT, LLP, …) up to ~ 10 TeV scale**

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 [$\times10^{34}$ cm^{-2}s^{-1}]	**5.0**	**115**	**16**	**0.5**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	13	60	4.2	0.6
	Event yields [2 IPs]	2.6×10^6	2.5×10^{12}	1.3×10^8	4×10^5
50 MW	L / IP [$\times10^{34}$ cm^{-2}s^{-1}]	**8.3**	**192**	**26.7**	**0.8**
	$\int L\,dt$ [ab^{-1}, 2 IPs]	22	100	6.9	1
	Event yields [2 IPs]	4.3×10^6	4.1×10^{12}	2.1×10^8	6×10^5

CEPC：Higgs Properties

➢ **CEPC has significantly better precision on Higgs properties than that of HL-LHC**

	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%		
$Br_{upper}(H \to inv.)$	0.07%				
Γ_H	1.65%		1.10%		



《Precision Higgs Physics at CEPC》
Chinese Physics C, 43（2019）043002

CEPC：Electroweak Measurements

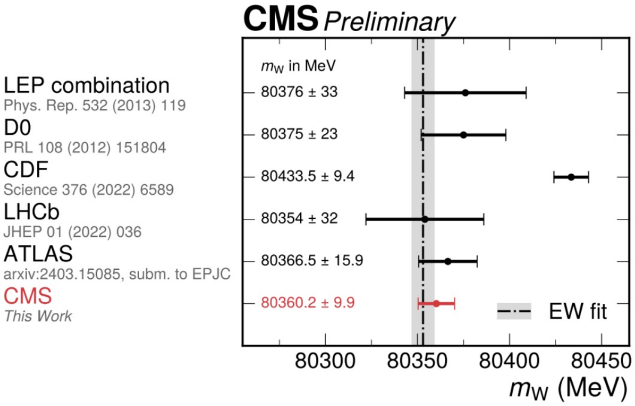
➢ **CEPC has better EW precisions than current value by 1-2 order of magnitude**

W, Z and Top		
Observable	Current Precision	CEPC Precision
M_W	9 MeV	0.5 MeV
Γ_W	49 MeV	2 MeV
M_{top}	760 MeV	O(10) MeV
M_Z	2.1 MeV	0.1 MeV
Γ_Z	2.3 MeV	0.025 MeV
R_b	3×10^{-3}	2×10^{-4}
R_c	1.7×10^{-2}	1×10^{-3}
R_μ	2×10^{-3}	1×10^{-4}
R_τ	1.7×10^{-2}	1×10^{-4}
A_μ	1.5×10^{-2}	3.5×10^{-5}
A_τ	4.3×10^{-3}	7.0×10^{-5}
A_b	2×10^{-2}	2×10^{-4}
N_ν	2.5×10^{-3}	2×10^{-4}

CDF (2022) : 80433.5 ± 9.4 MeV

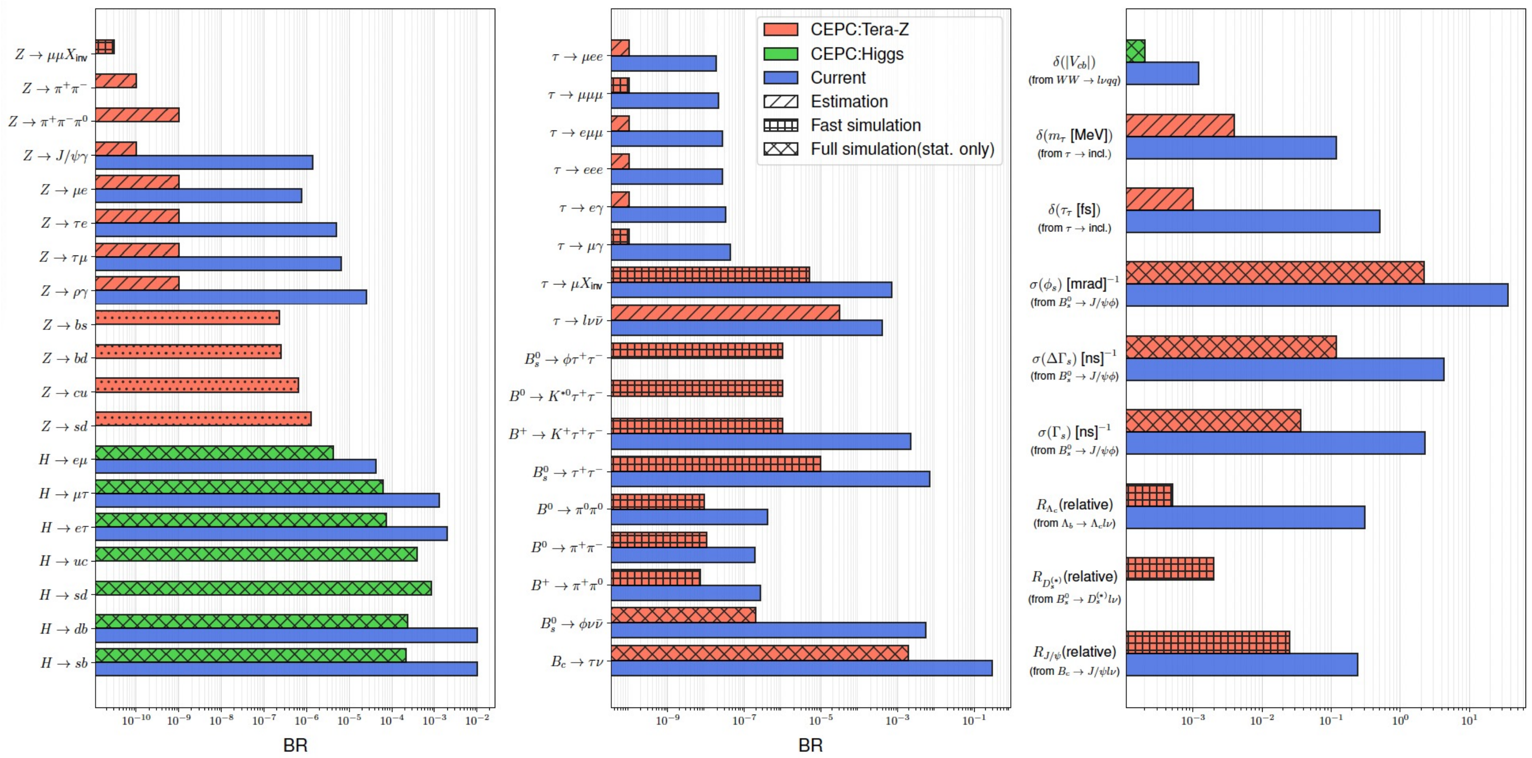
CMS(2024) : 80360.2 ± 9.9 MeV

SM Prediction : 80354 ± 7 MeV



➢ **CEPC: expected W mass resolution < 1MeV**

CEPC: Flavor Physics

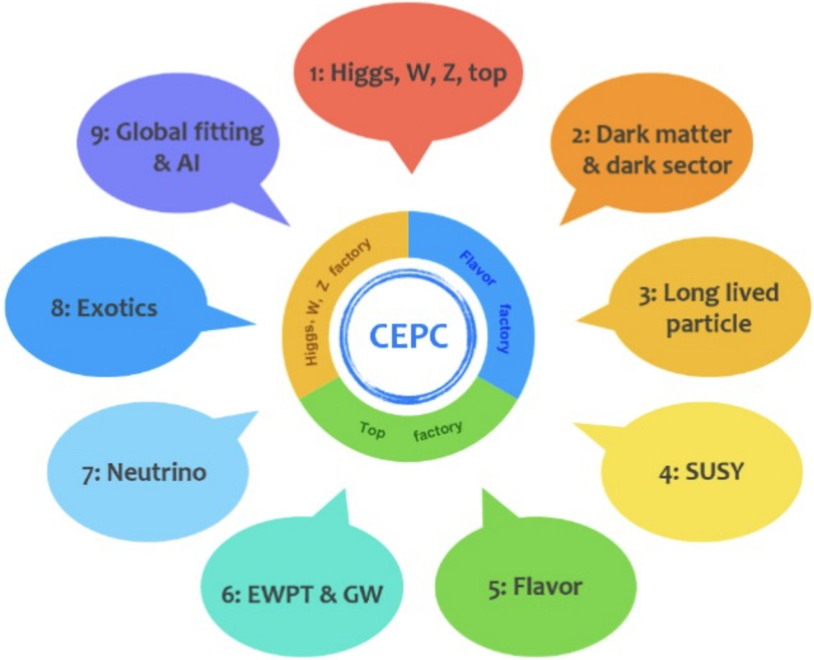


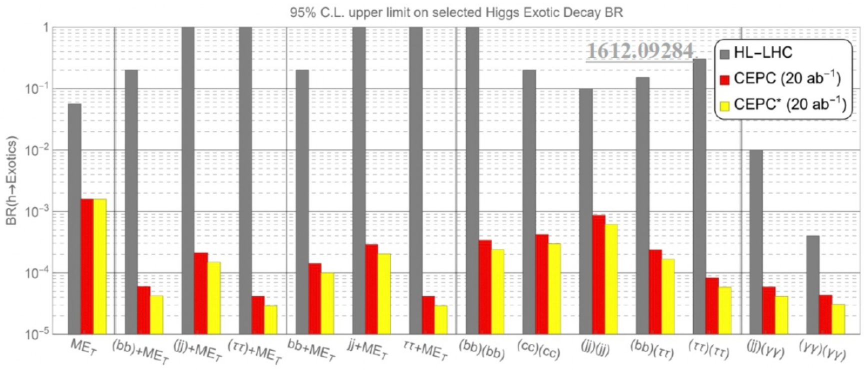
See the non-seen: i.e, Bc→tauv, Bs→Phivv

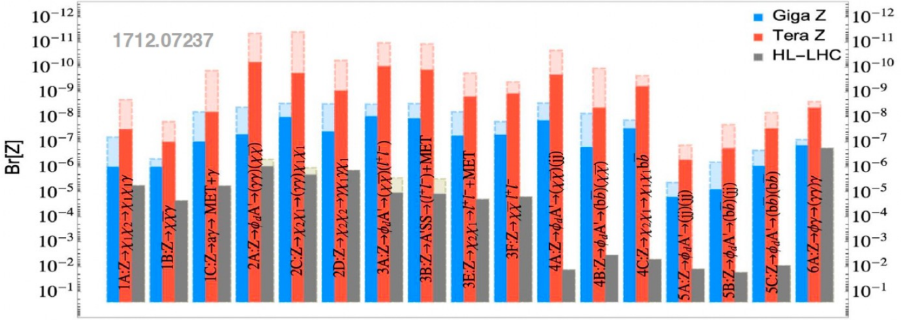
Orders of magnitudes improvements (1 – 2.5 orders...).

Access New Physics with energy scale of 10 TeV, or even above

CEPC：BSM Physics

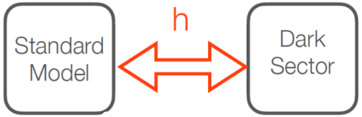




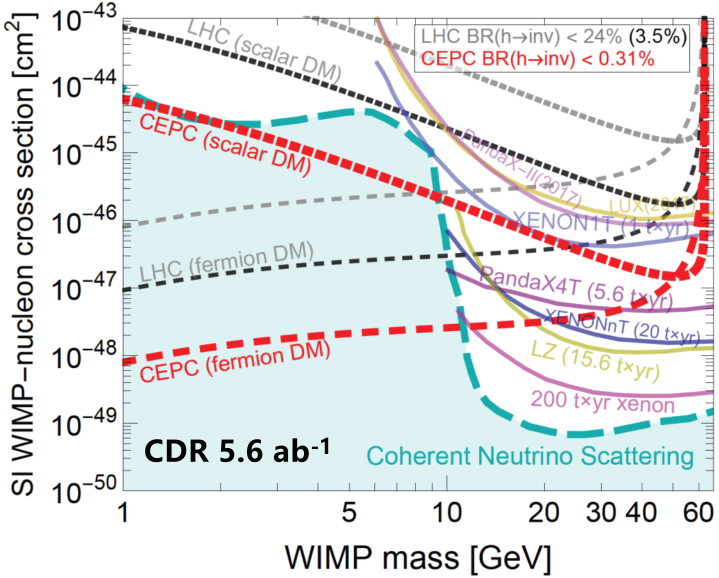


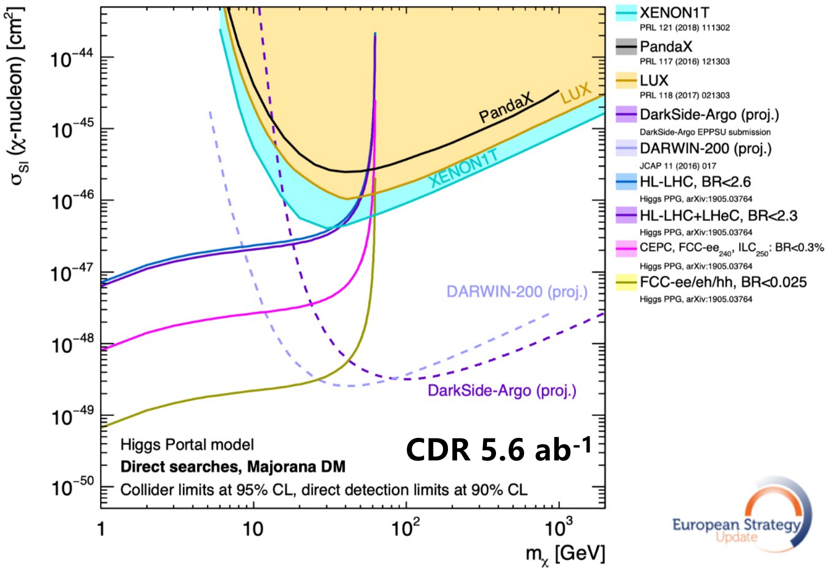
Higgs: Dark Matter Portal

Higgs-portal DM



$$h \rightarrow X_{\mathrm{dm}} X_{\mathrm{dm}}$$



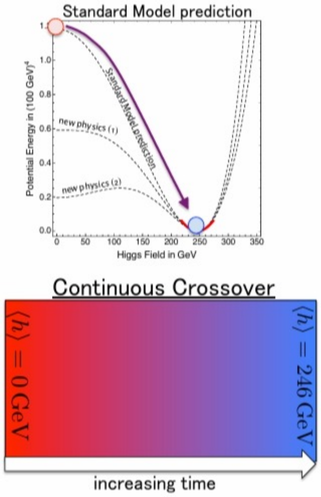


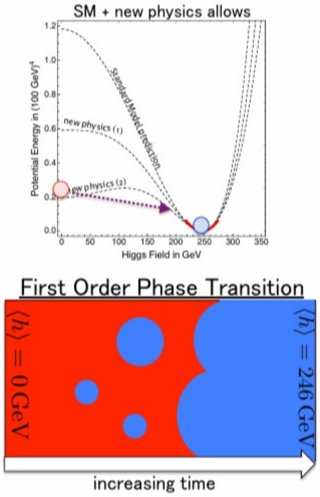
➔ **CEPC has significantly better detection sensitivity for DM than HL-LHC**

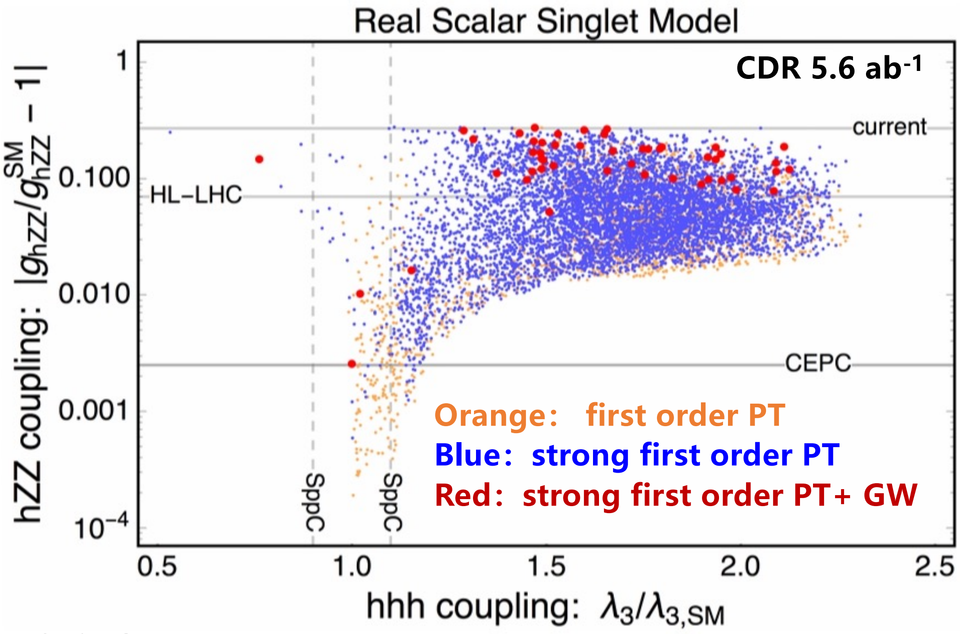
➔ **Complementary to direct DM search experiments for mass below 10 GeV**

Higgs： EW Phase Transition

➔ **CEPC can study EWPT via hZZ coupling measurement which may help to understand the matter-antimatter asymmetry, its detection sensitivity is about one order of magnitude better than that of the HL-LHC.**





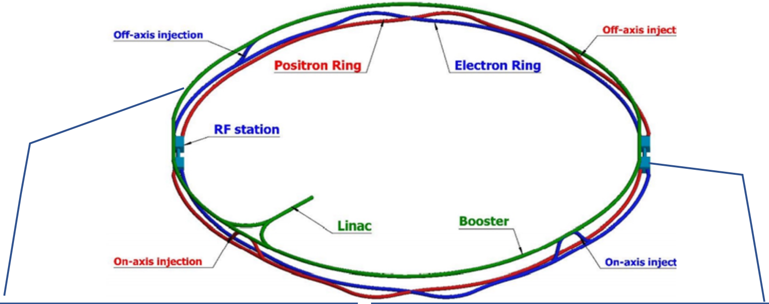


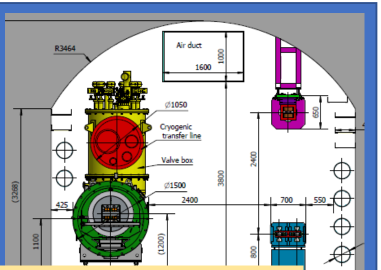
SM expects Higgs potential has smooth crossover

New Physics
Quantum tunneling
First order phase transition

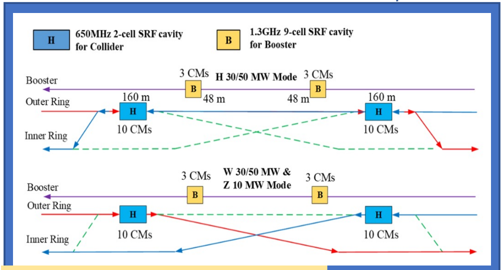
Design of experimental facility and technical requirements

- **Circular collider**: **Higher luminosity** than a linear collider
- **100km circumference**: Optimum **total cost**, good also for **SppC**
- **Shared tunnel**: Accommodate **CEPC** booster &collider and **SppC**
- **Switchable operation**: Higgs, W/Z, top



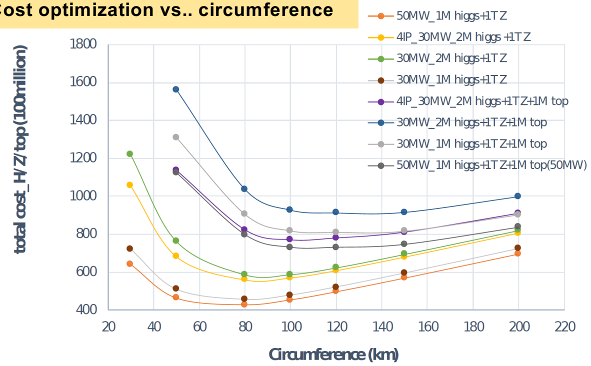


Common tunnel for booster/collider & SppC



Switchable Operation for Higgs W and Z

Cost optimization vs.. circumference



D. Wang *et al* 2022 *JINST* **17** P10018

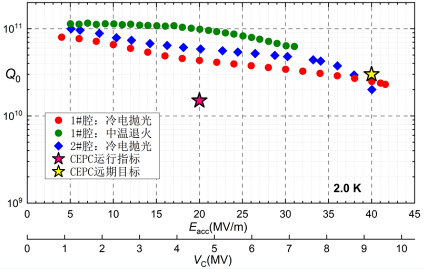
Main Parameters: High luminosity as a Higgs Factory

	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	**50**			
Energy [GeV]	**120**	**80**	**45.5**	**180**
Bunch number	415	2161	19918	59
Emittance (εx/εy) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (σx/σy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Beam-beam parameters (ξx/ξy)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF frequency [MHz]	650			
Luminosity per IP[10^{34}/cm^2/s]	**8.3**	**27**	**192**	**0.83**

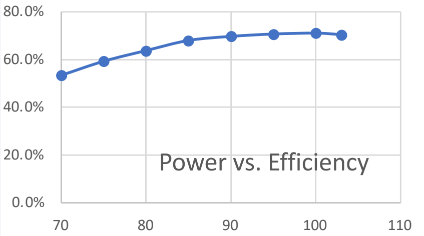
Status and maturities of the CEPC technologies

State-of-the-art: Key Components

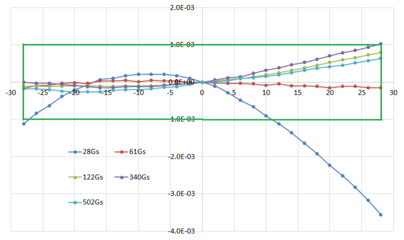
650MHz SRF cavity



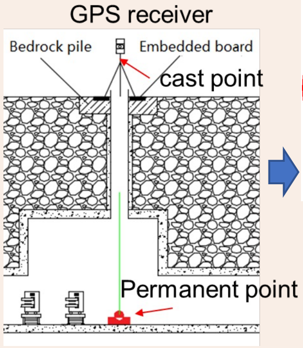
High efficiency klystron

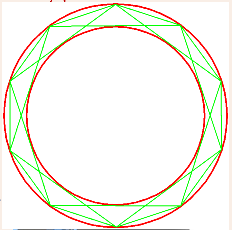


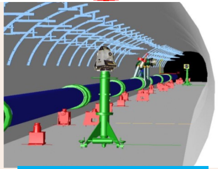
Weak field dipole

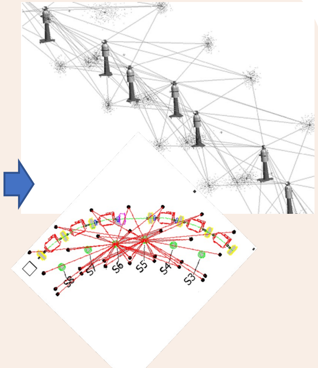


100km Acc. Alignment & Installation R&D

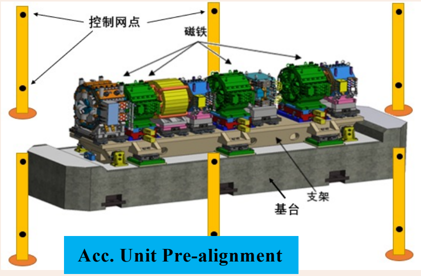




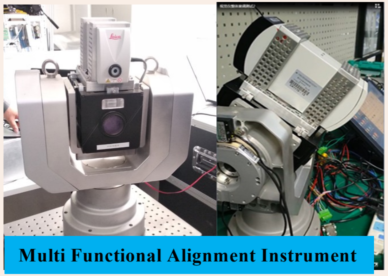




Control Point **Backbone Network** **Tunnel Control Network**



Acc. Unit Pre-alignment

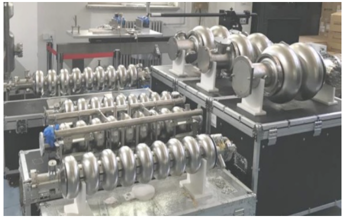


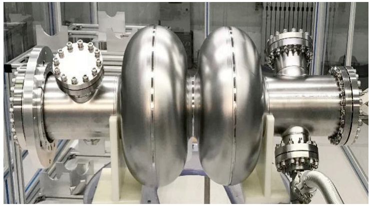
Multi Functional Alignment Instrument

Efficient alignment scheme + instrumentation R&D to guarantee the installation within 4 years

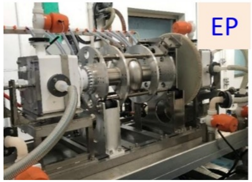
CEPC R&D: High Q SRF Cavities

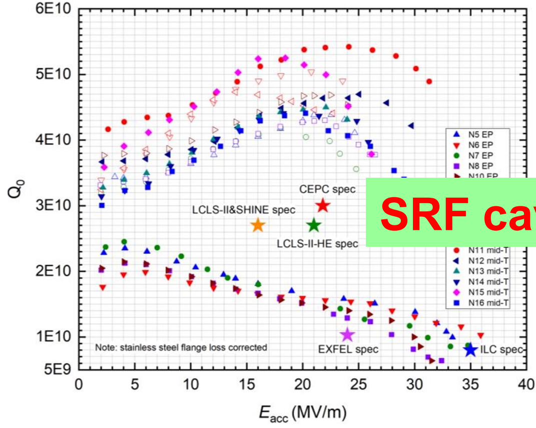
- 1.3 GHz 9-cell SRF cavity for booster: Q_0 = 3.4E10 @ 26.5 MV/m
- 650 MHz 2-cell SRF cavity for collider ring: Q_0 = 6.0E10 @ 22.0 MV/m
- 650 MHz 1-cell SRF cavity for collider ring: Q_0 = 6.0E10 @ 31.0 MV/m



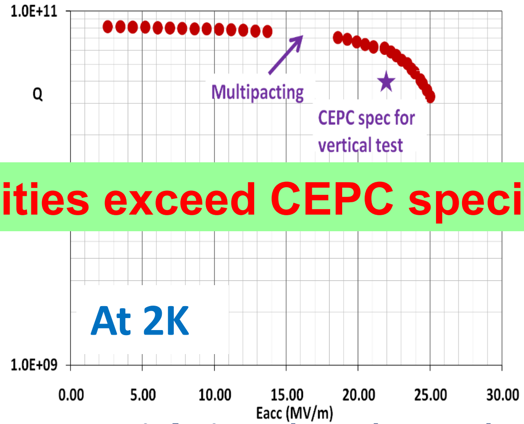


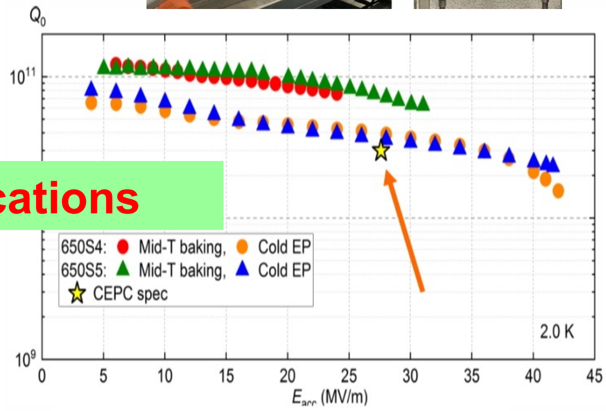
Vertical test of 650 MHz 2-cell cavity





SRF cavities exceed CEPC specifications





Medium-temperature (Mid-T) annealing adopted to reach Q_0 = 3.4E10 @ 26.5 MV/m

N-infusion adopted to reach Q_0 = 6.0E10 @ 22.0 MV/m

Cold-EP and Mid-T baking Q_0 = 6.0E10 @ 31 MV/m

CEPC R&D: 8 × 9-cell High Q Cryomodule

CEPC Booster 1.3 GHz SRF R&D and industrialization in synergy with CW FEL projects

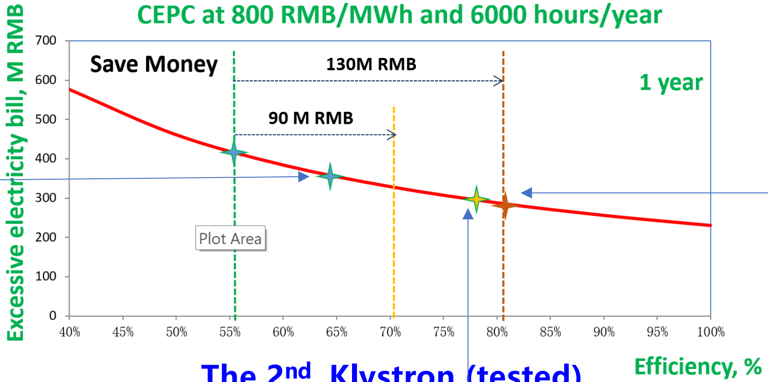
Parameters	Horizontal test results	CEPC Booster Higgs Spec	LCLS-II, SHINE Spec	LCLS-II-HE Spec
Average usable CW E_{acc} (MV/m)	23.1	3.0×10^{10} @ 21.8 MV/m	2.7×10^{10} @ 16 MV/m	2.7×10^{10} @ 20.8 MV/m
Average Q_0 @ 21.8 MV/m	3.4×10^{10}			

SRF cavities exceed CEPC specifications

CEPC R&D: High Efficiency Klystrons

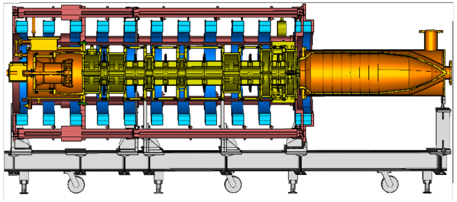
- The 1st Klystron prototype, achieved efficiency ~ 62%
- The 2nd Klystron prototype was tested in Feb. 2024, achieved efficiency ~ 77.2%
- The 3rd Klystron prototype (MBK) with manufacture underway, design efficiency is ~ 80.5%
- High efficiency Klystron helps to reduce electricity consumption

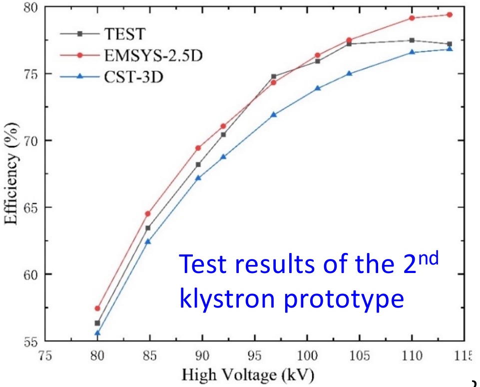
The 1st Klystron (tested)

The 2nd Klystron (tested)

The 3rd multi-beam Klystron (MBK) under fabrication

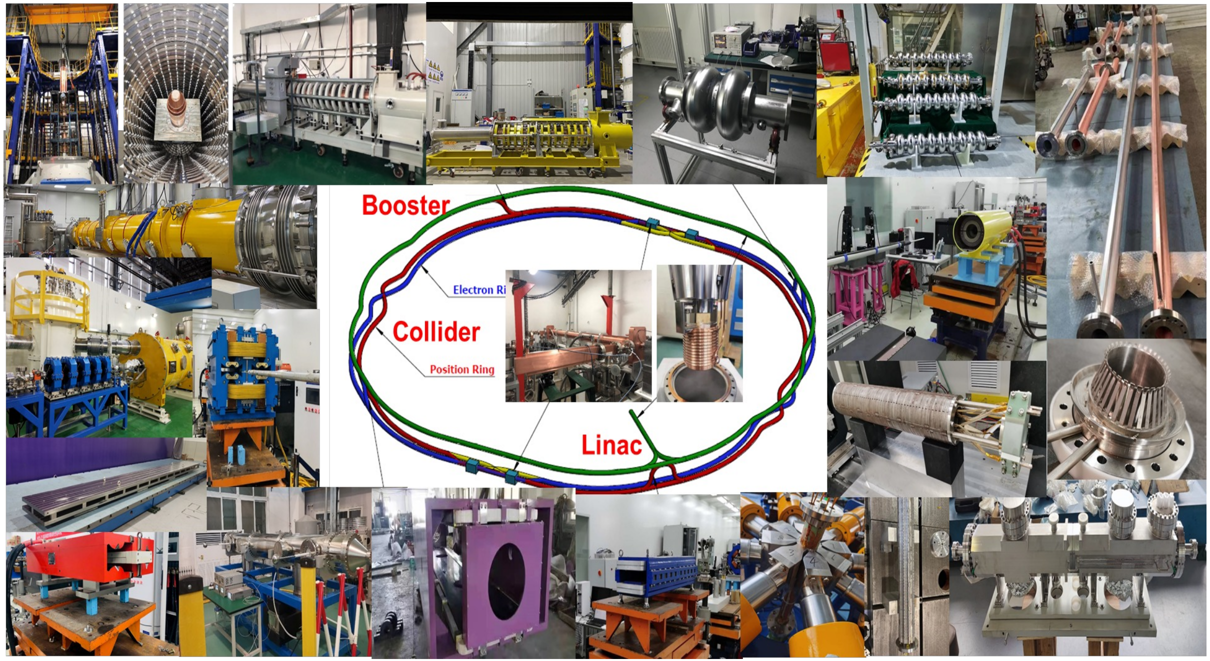




Test results of the 2nd klystron prototype

CEPC R&D: Accelerator Key Technologies

- Key technologies R&D span over all components listed in CDR.
- About 10% remaining (eg. RF power source, control, alignment, SC magnets, machine integration) to be completed by 2026.



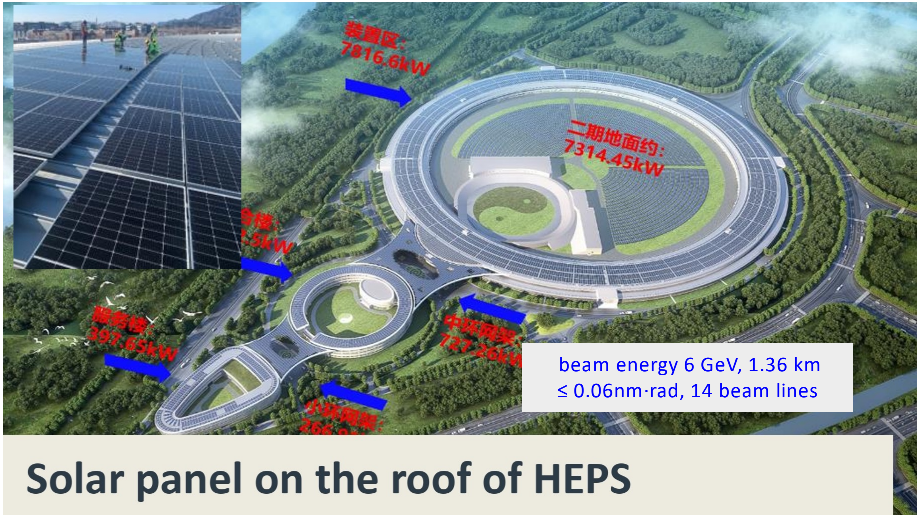
✓ Specification Met

☑ Prototype Manufactured

Accelerator	Fraction
✓ Magnets	27.3%
✓ Vacuum	18.3%
☑ RF power source	9.1%
✓ Mechanics	7.6%
✓ Magnet power supplies	7.0%
✓ SC RF	7.1%
✓ Cryogenics	6.5%
✓ Linac and sources	5.5%
✓ Instrumentation	5.3%
☑ Control	2.4%
☑ Survey and alignment	2.4%
✓ Radiation protection	1.0%
☑ SC magnets	0.4%
✓ Damping ring	0.2%

High Energy Photon Source (HEPS)

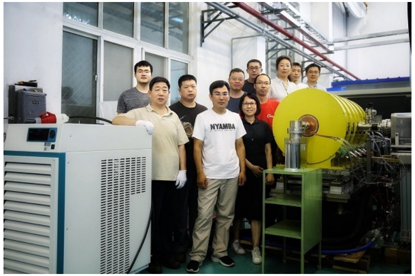
To be completed in 2025, great training and preparation for CEPC ➔ towards a green accelerator



Solar panel on the roof of HEPS

Experience at HEPS

- Solar panel:10 MW ➔ 10% saving
- Permanent magnet: 5.6 GWh saving/year
- Hot water (13 MW @ 42 ^{0}C) for heating

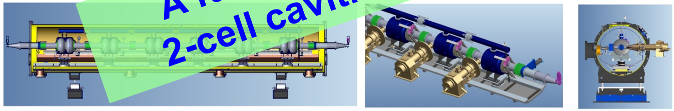


CEPC Accelerator EDR

CEPC Accelerator EDR tasks start with 35 WGs aiming for key issues.

CEPC Accelerator Main EDR Development: SRF

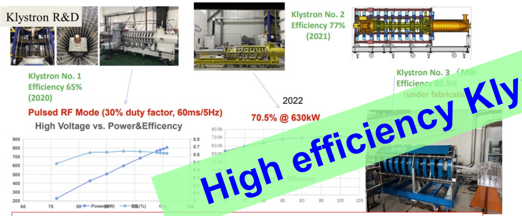
CEPC collider ring ... completed in TDR phase



A full size 6x650MHz 2-cell cavities module

The collider Higgs mode for 30 MW SR power per beam will use 32 units of 11 m-long collider cryomodules will contain six 650 MHz 2-cell cavities, and therefore, a full size 650 MHz cryomodule will be developed in EDR

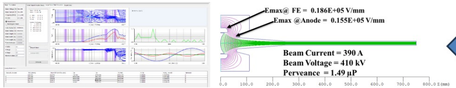
CEPC Accelerator Main EDR Development: Klystrons



CEPC collider ring 650MHz klystron development in TDR phase

Parameters	Value
Frequency	5720 MHz
Output Power	80MW
[illegible]	2.5us
Repetition rate	100Hz
Gain	54 dB
Efficiency	47%
3dB bandwith	±5MHz
Beam voltage	420 kV
Beam current	403 A
Focusing field	0.28 T

C band 5720MHz 80MW Klystron

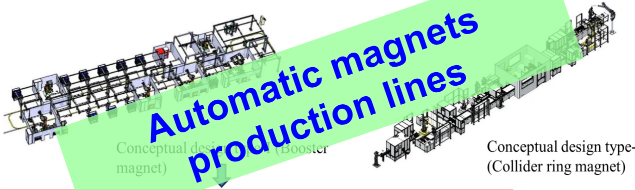


C band 5720MHz 80MW Klystron design progress

High efficiency Klystron

CEPC Magnets' Automatic Production Lines in EDR

To reduce the fabrication cost of the magnets of CEPC, automatic magnet production lines will be demonstrated in EDR and used during construction



Conceptual design type-I (Booster magnet)

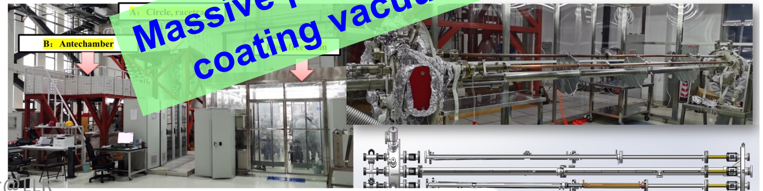
Conceptual design type-II (Collider ring magnet)

Automatic magnets production lines

Jan.-Sept. 2024：Complete the CEPC booster magnet automatic fabrication facility design.
Oct. 2024-Jun. 2025：Complete the small scale demonstration facility for booster iron core fabrication.

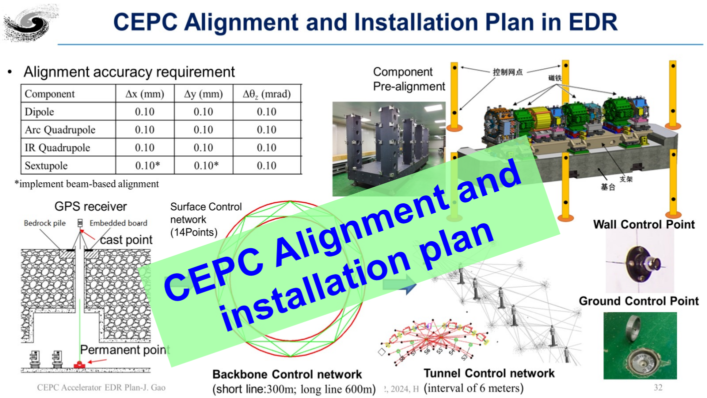
Massive Production Line of NEG Coating Vacuum Chambers in EDR

- The coating device A: Vacuum chambers are connected in parallel to 6 groups, each group of vacuum chambers length should be lower than 3.5m, outer diameter is about 0.47m;
- The coating device B: Antechamber are connected in parallel to 4 groups, each group of vacuum chambers length should be lower than 1.5m, due to its discharge difficulty.
- Two setups of NEG coating have been built for vacuum pipes ... IHEP Lab. And ... vacuum pipes have been coated, which shows that NEG film has go... and thickness ...
- **In EDR phase a dedicated CEPC NEG coating vacuum chamber production line is planned**

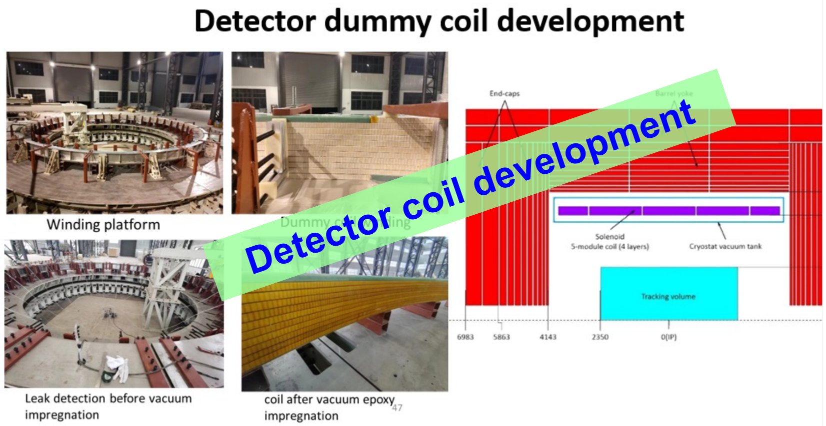


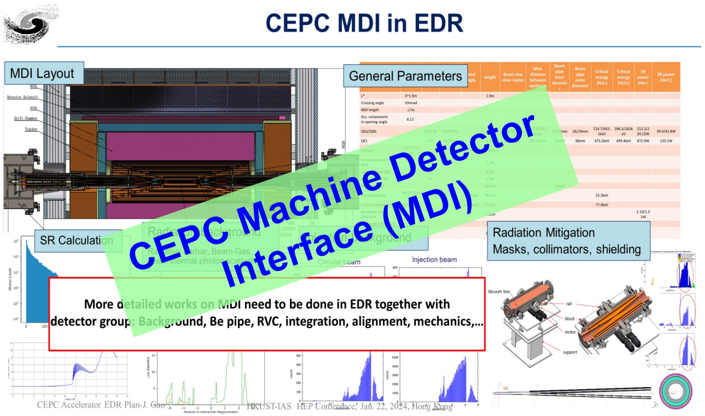
Massive production line of NEG coating vacuum chambers

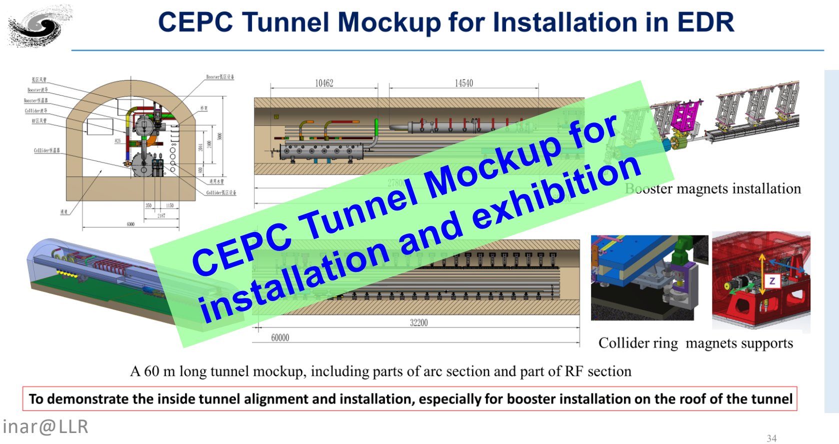
CEPC Accelerator EDR



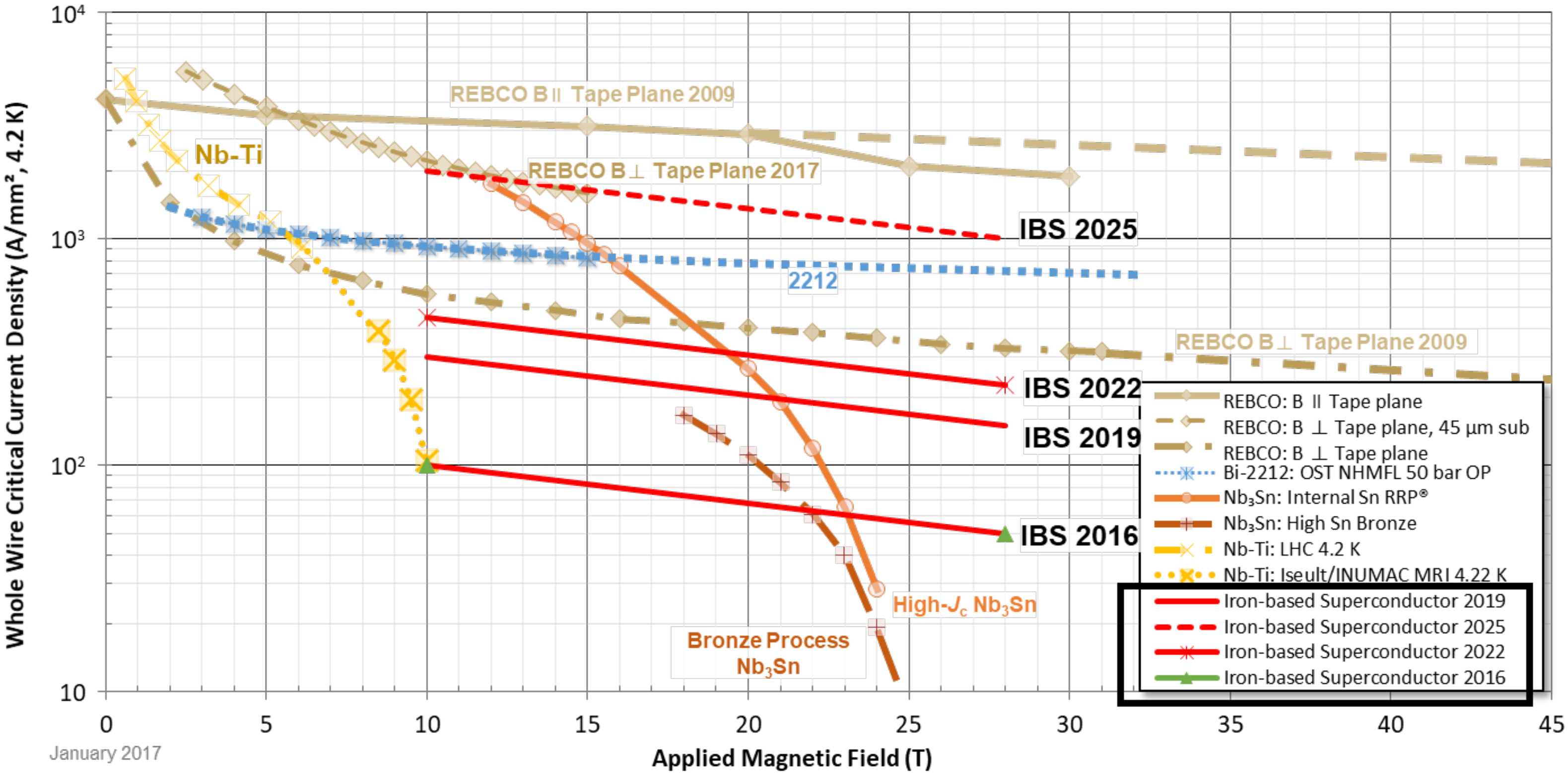
Component	Δx (mm)	Δy (mm)	$\Delta\theta_z$ (mrad)
Dipole	0.10	0.10	0.10
Arc Quadrupole	0.10	0.10	0.10
IR Quadrupole	0.10	0.10	0.10
Sextupole	0.10*	0.10*	0.10







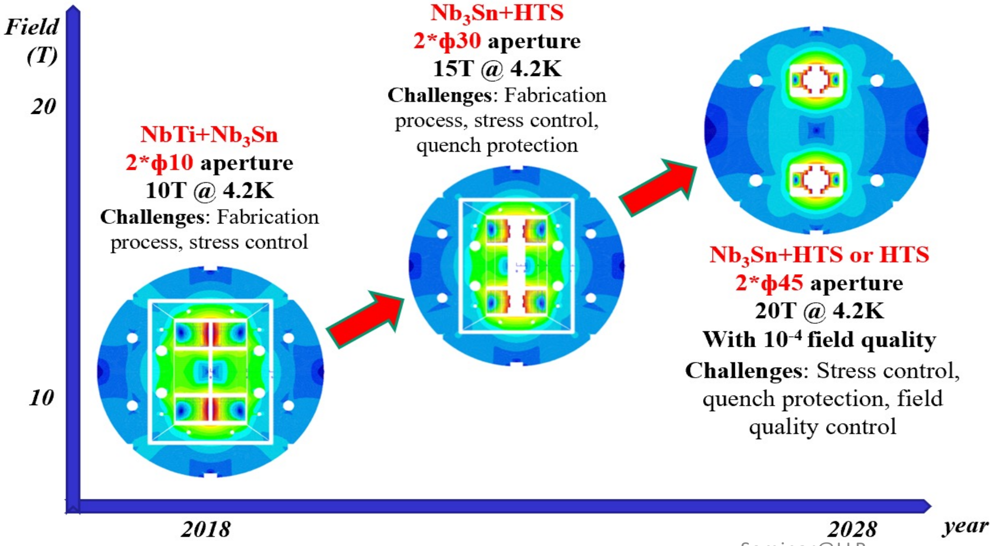
Iron Based High T Super Conducting Magnet

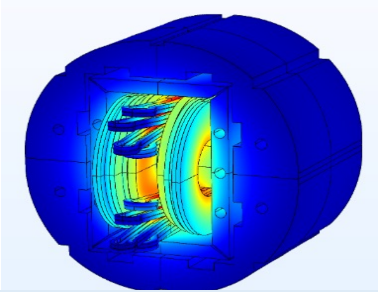


SPPC R&D: HTS SC Magnet

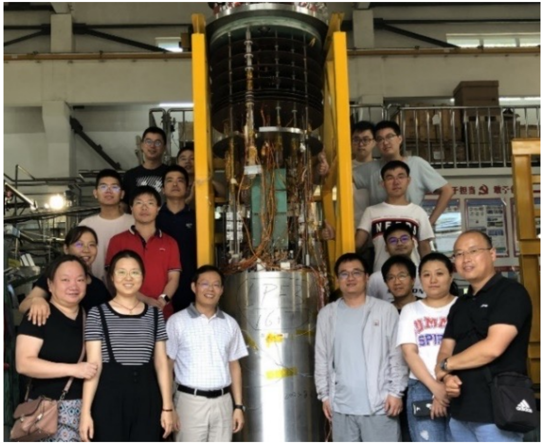
- 2023: SC dipole magnet, field reached 14T @ 4.2K
- 2024: aiming for 16T @ 4.2K (the world record)

10.2T (2018) → 12.5T (2021) → 14T (2023) → 16T (2024)





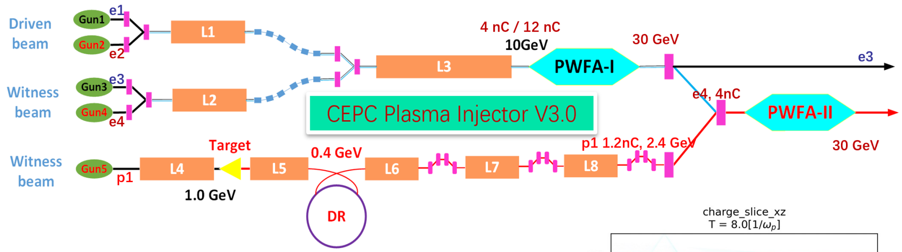
16T dipole (LTS+HTS)



Completion of SC magnet (2023.8)

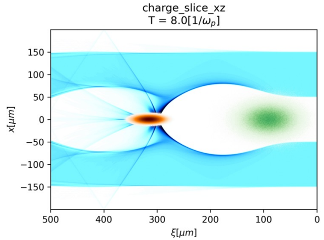
CEPC Accelerator: Plasma Injector

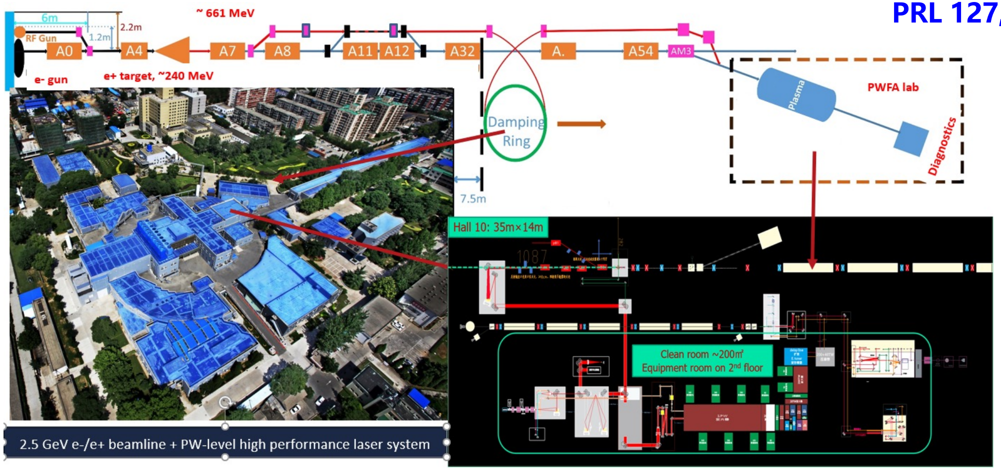
CEPC Plasma Injector Scheme
From 10 GeV → 30 GeV → TR ≥2



Simulation results show that it works on paper with reasonable error tolerances for both electron & positron beams injected to booster

PRL 127, 174801 (2021)





Phase I（Year0-Year2）

1. Re-design and install transport beamline and FF system, optimize the e- / e+ beam quality
2. Clean room and high power laser system (20... installation200TW
3. Beam instrumentation s...
4. RF Gun platfor...
5. Comm...

Phase II（

1. Up... 20/40 TW)
2. Test... install it on the BEPC...

Phase III（Yea...

1. Add a positron dumping ring the bunch compression beamline to improve the e+ quality
2. PBA-based FEL studies

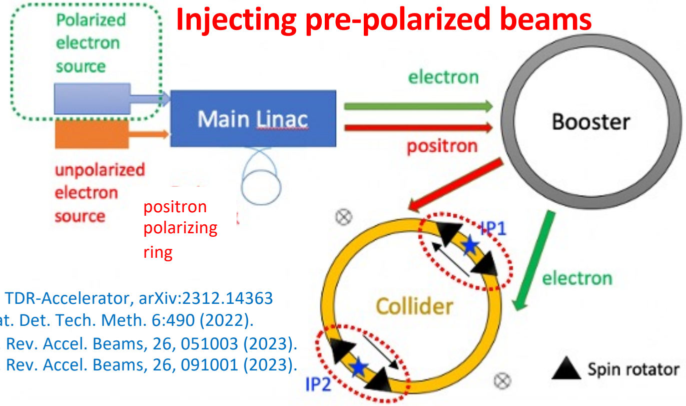
- **Positron and electron acceleration**
- **Cascading acceleration**
- **Future linear collider technologies**
- **High energy beam for detector R&D (possible application)**

PWFA/LWFA TF based on BEPC-II Linac and HPL has founded by CAS, 120M RMB in Sept. 2023

Beam polarization prospects and R&D efforts

Prospects of beam polarization at CEPC

- Beam energy calibration @ Z & W w/ resonant depolarization (~ 1e-6)
- 50%-70% longitudinal polarization for e- beam is a resonable goal @ Z & W
- Polarized e+ source: flux requirement ~ 1/60 of ILC, revisit of the Compton Ring scheme under way
- Attaining useful polarization level is challenging but possible @ Higgs.



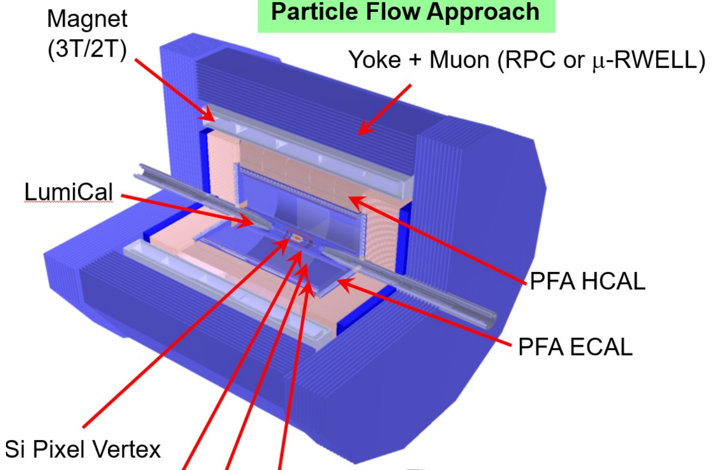
CEPC TDR-Accelerator, arXiv:2312.14363
Radiat. Det. Tech. Meth. 6:490 (2022).
Phys. Rev. Accel. Beams, 26, 051003 (2023).
Phys. Rev. Accel. Beams, 26, 091001 (2023).

Key technology R&D items

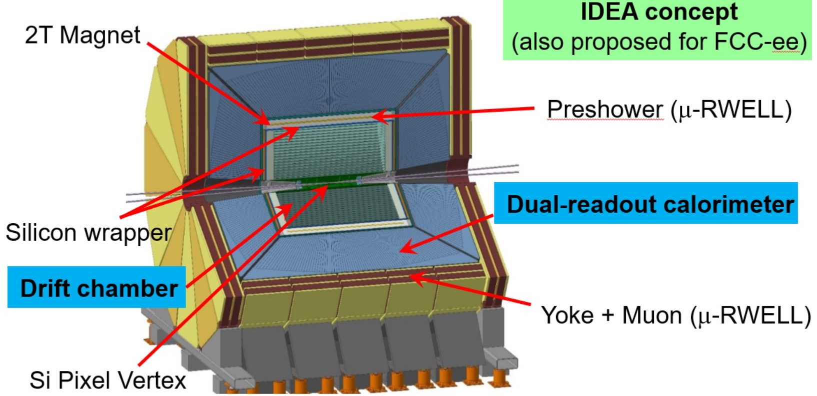
Aspects	Figure of merit	R&D goal	Milestone
Polarized electron source	polarization > 85%	a 400kV **polarized** DC gun @ PAPS, polarization > 85%	2027
Compton polarimeter	3D measurements~ 0.1%	**vertical** measurement @ BEPCII **longitudinal** measurement @ LPA-Ring TF, ~1%	2025 2028
Resonant depolarization	~1e-6 for Z & W	demonstration @ BEPCII	2026
Spin rotator for longitudinal polarization	Solenid integral field ~ 1000 T.m per IP @ Z	HTS solenoid, B ~ 12 T, BL > 10 T.m , **attain longitudinal polarization** @ LPA-Ring TF	2027 2028

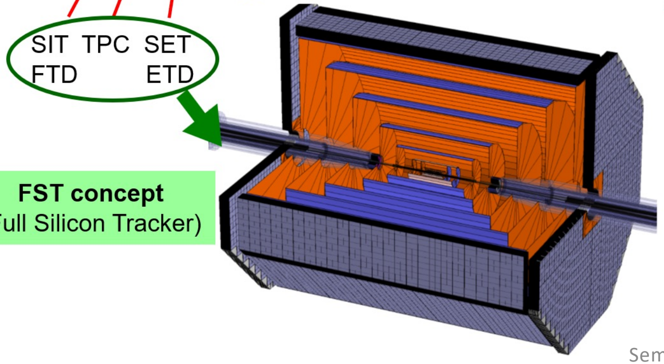
CEPC Detector Concepts ➔ New Design

(Baseline Design)
Particle Flow Approach



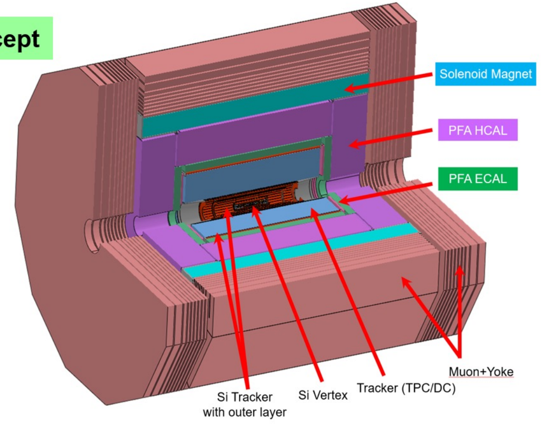
IDEA concept
(also proposed for FCC-ee)





FST concept
(Full Silicon Tracker)

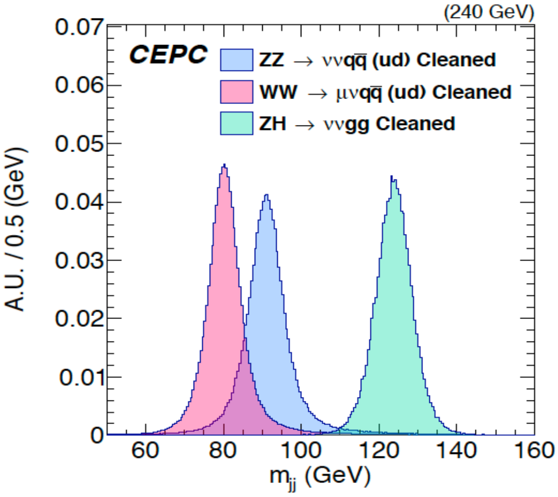
The 4th Concept

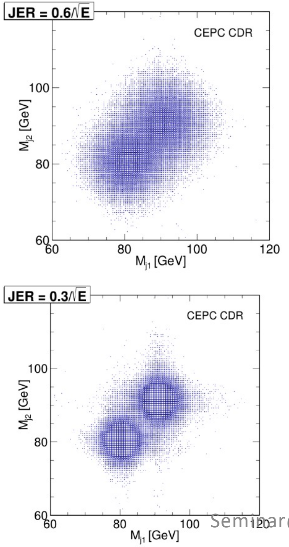


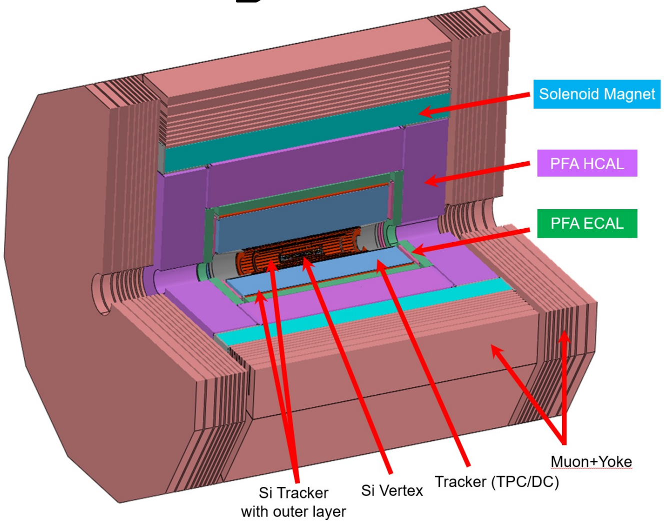
CEPC New Detector Design

Goal: with PFA calorimeters to improve boson mass resolution (BMR) from 4% ➔ 3%。

Calorimeter	World-class	New design
PFA ECAL	～ 15-20% / √E	～ 3% / √E
PFA HCAL	～ 50-60% / √E	～ 40% / √E



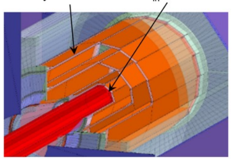




- **Silicon tracker with TPC / DC:**
  to improve track reconstruction & PID
- **PFA ECAL with crystal:**
  to improve π^0, γ energy resolution
- **PFA HCAL with scintillating glass:**
  to improve hadron energy resolution

CEPC Detector R&D: Silicon, TPC, DC Prototypes

2 layers / ladder R_{in}~16 mm



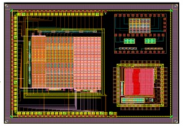
Goal: σ(IP) ~ 5 μm for high P track

CDR design specifications

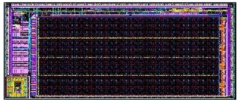
- **Single point resolution ~ 3μm**
- **Low material (0.15% X_0 / layer)**
- **Low power (< 50 mW/cm²)**
- **Radiation hard (1 Mrad/year)**

Silicon pixel sensor develops in 5 series: JadePix, TaichuPix, CPV, Arcadia, COFFEE

Develop **COFFEE** for a CEPC tracker using SMIC 55nm HV-CMOS process

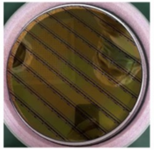


JadePix-3 Pixel size ~16×23 μm²

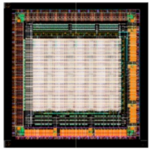


Tower-Jazz 180nm CiS process
Resolution 5 microns, 53mW/cm²

TaichuPix-3, FS 2.5x1.5 cm²
25×25 μm² pixel size

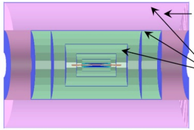


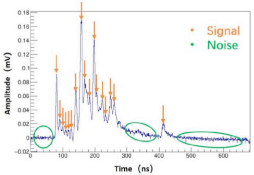
CPV4 (SOI-3D), 64×64 array
~21×17 μm² pixel size

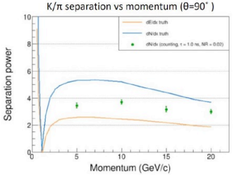


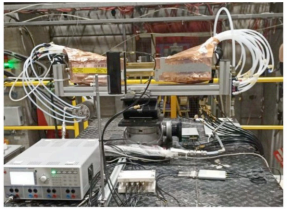
Arcadia by Italian groups for IDEA vertex detector
LFoundry 110 nm CMOS

- **Goal: 3σ π/K separation up to ~20 GeV/c.**
- Cluster counting method, or **dN/dx**, measures the number of primary ionization
- **Can be optimized specifically for PID**: larger cell size, no stereo layers, different gas mixture.
- Garfield++ for simulation, realistic electronics, peak finding algorithm development.









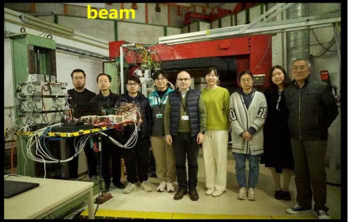
IHEP and Italian INFN groups have close collaboration and regular meetings.
IHEP joined the TB (led by INFN group) in 2021 and 2022

Test beam @ DESY

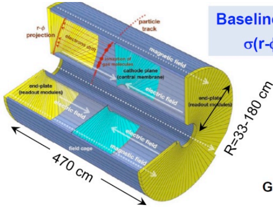
- 2nd testbeam: April 11-23 2023 DESY test beam in Germany (4-6 GeV electron)
  - Vertex detector prototype testbeam
- 1st testbeam: Dec 12-22 2022 DESY test beam in Germany (4-6 GeV electron)
  - TaichuPix Beam Telescope testbeam

2022 DESY test beam

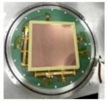
2023 DESY test beam



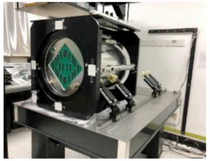
Excellent collaboration with DESY testbeam team



Baseline main tracker
σ(r-ϕ) ~100 μm

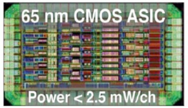


GEM-MM cathode



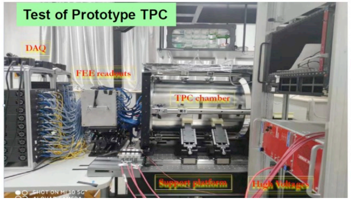
TPC Prototype + UV laser beams

MOST 1 (IHEP+THU)

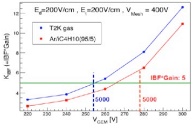


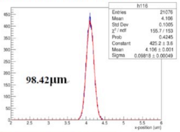
Low power FEE ASIC

Test of Prototype TPC



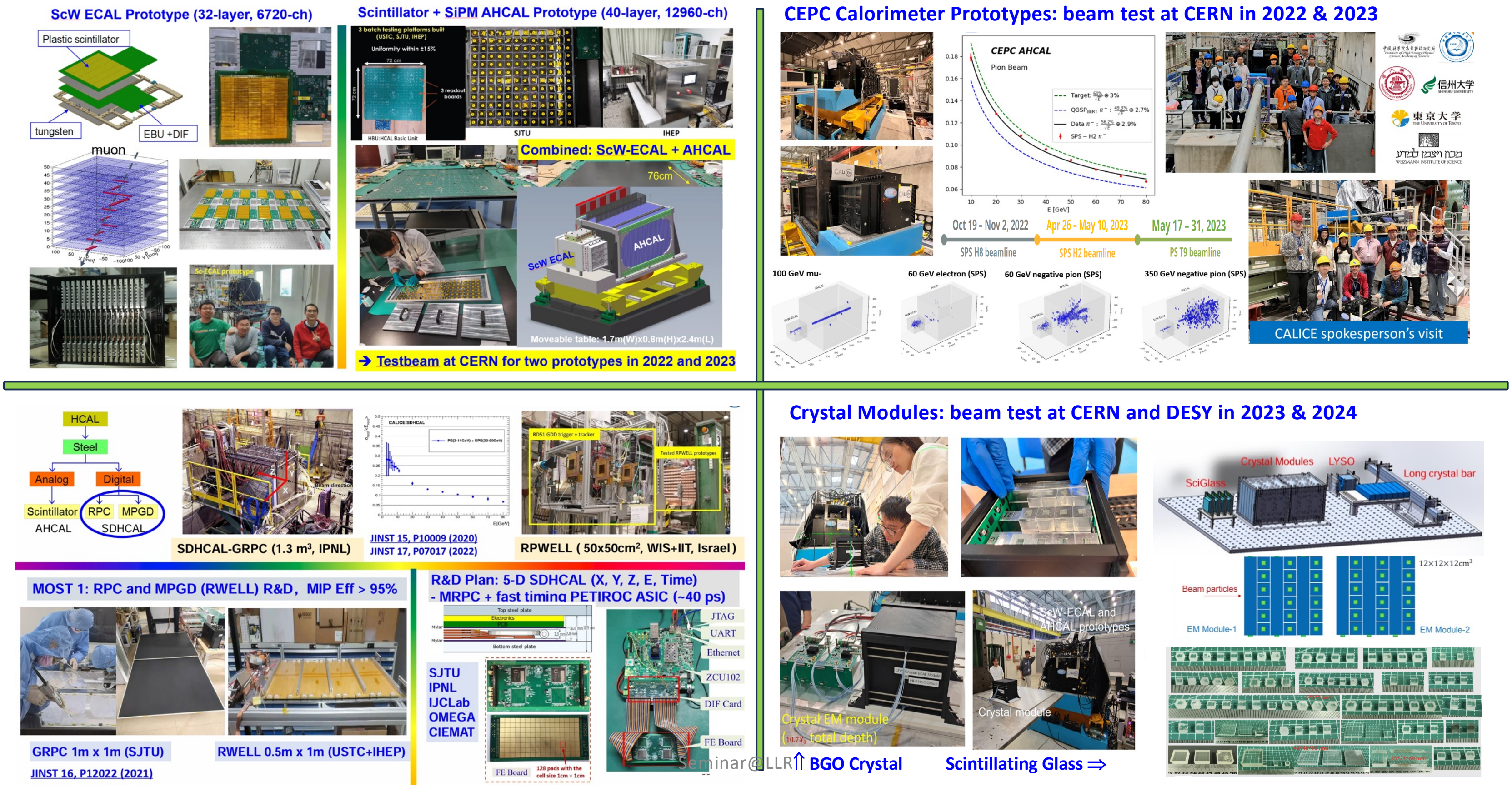
Challenge: Ion backflow (IBF) affects the resolution. It can be corrected by a laser calibration at low luminosity, but difficult at high luminosity Z-pole.





σ_x < 100 μm for drift length of 27cm

CEPC Detector R&D: Calorimeter Prototypes



CEPC Reference Detector TDR

Det	Technology	Det	Technology
Pixel Vertex	JadePix	Calorimeter	Crystal ECAL
	TaichuPix		Stereo Crystal ECAL
	CPV(SOI)		Scint+W ECAL
	Stitching		Si+W ECAL
	Arcadia		Scint+Fe AHCAL
Tracker & PID	CEPCPix		ScintGlass AHCAL
	Silicon Strip		RPC SDHCAL
	TPC		MPGD SDHCAL
	Drift chamber		DR Calorimeter
	PID drift chamber	Muon	Scintillation Bar
	LGAD ToF		RPC
Lumi	SiTrk+Crystal ECAL		μ-Rwell
	SiTrk+SiW ECAL		HTS / LTS Magnet
	CEPC SW		MDI & Integration
	TDAQ		

- **Large number of detector technology options and R&D projects on-going, they are not at similar level of maturity.**
- **Need to converge technology options towards a CEPC reference detector TDR**
  - Start preparation in Jan. 2024
  - A draft version of TDR in Dec. 2024
  - **Official release of ref-TDR in Jun. 2025**
- **Intl. detector collaborative efforts**
  - DRD collaboration (DRD1-8), more than 130 colleagues from 11 Chinese institutes joined so far.
  - HL-LHC detector R&D efforts help to prepare teams for CEPC detectors.

Industrial Partners and Suppliers Worldwide

	System
1	Magnet
2	Power supplier
3	Vacuum
4	Mechanics
5	RF Power
6	SRF / RF
7	Cryogenics
8	Instrumentation
9	Control
10	Survey and alignment
11	Radiation protection
12	e^-e^+Sources

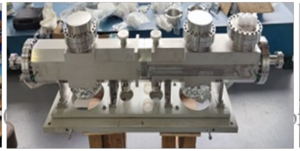
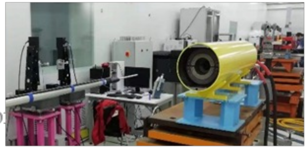
CEPC Industrial Promotion Consortium (CIPC, established in Nov. 2017)

Potential international collaborating suppliers and partners worldwide







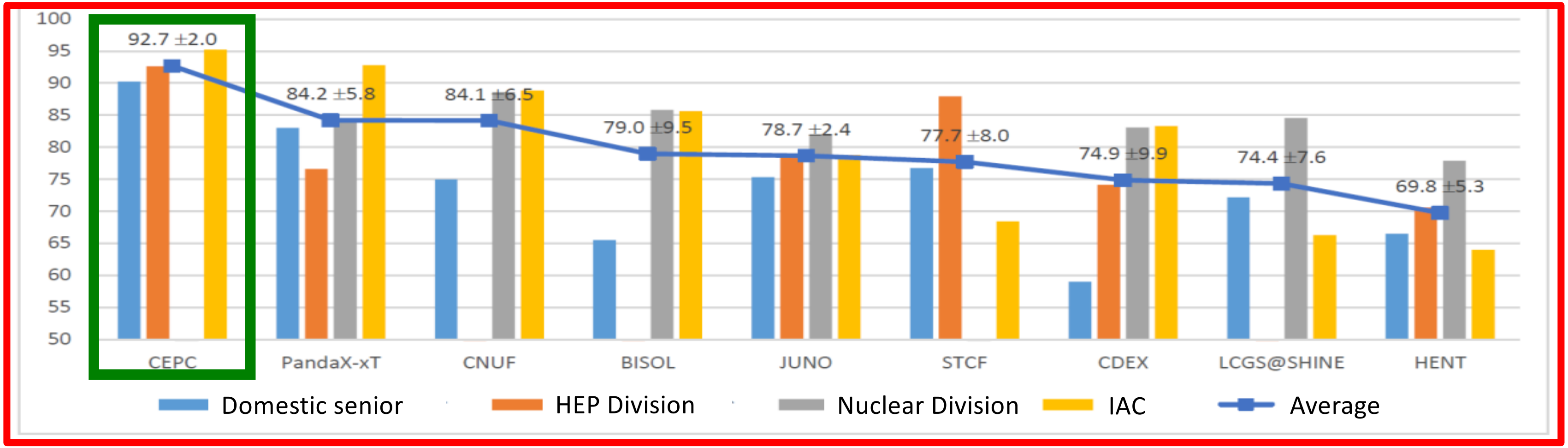

CEPC International Collaboration

CEPC attracts significant International participation

- Both CDR and TDR have significant intl. contributions
- 20+ MoUs signed with Intl. institutions and universities
- Intl. collaborative efforts: DRD & HL-LHC detector R&D
- CEPC International Workshop since 2014
- Annual working month at HKUST-IAS since 2015
- EU-US versions of CEPC Workshop since 2018

CEPC Planning and Development

- CAS is planning for the 15th 5-year plan for large science projects, and a steering committee has been established, chaired by the president of CAS.
- High energy physics and nuclear physics is one of eight groups (fields).
- CEPC is ranked No. 1 , by every committee (2 domestic and 1 international).
- A final report was submitted to CAS for consideration, this process is within CAS, and the following national selection process will be decisive.



CEPC Planning and Schedule

2012.9	2015.3	2018.11	2023.12	2025.6	2027	15th five year plan (2026-2030)
proposed	Pre-CDR	CDR	Acc. TDR	Det. TDR	EDR	Start of construction

CEPC EDR Phase: 2024-2027

- **CEPC Accelerator EDR** starts with 35 WGs in 2024, to be completed in **2027**
- **CEPC Reference Detector TDR** will be released by June, **2025**
- **CEPC proposal** will be submitted to the Chinese government for approval in **2025**
- **Upon approval**, establish at least two international collaborations on experiments
- **CEPC construction starts** during the 15th five-year plan (2026-2030, e.g. **2027**)
- **CEPC construction complete** around **2035**, at the end of the 16th five-year plan

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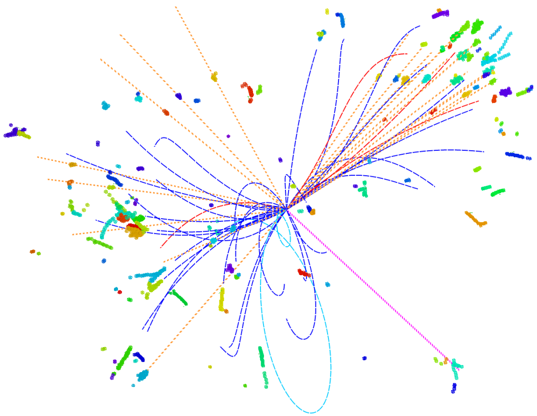
NEWS | 17 June 2024 | Correction 18 June 2024

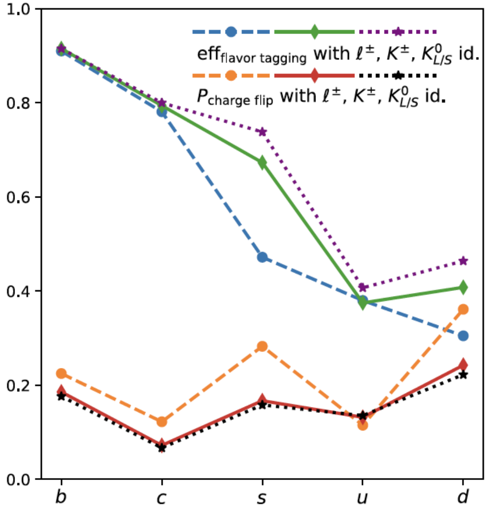
China could start building world's biggest particle collider in 2027

The US$5 billion facility would be cheaper, bigger and faster to build than a similar one proposed by European scientists.

AI usage: Jet origin id



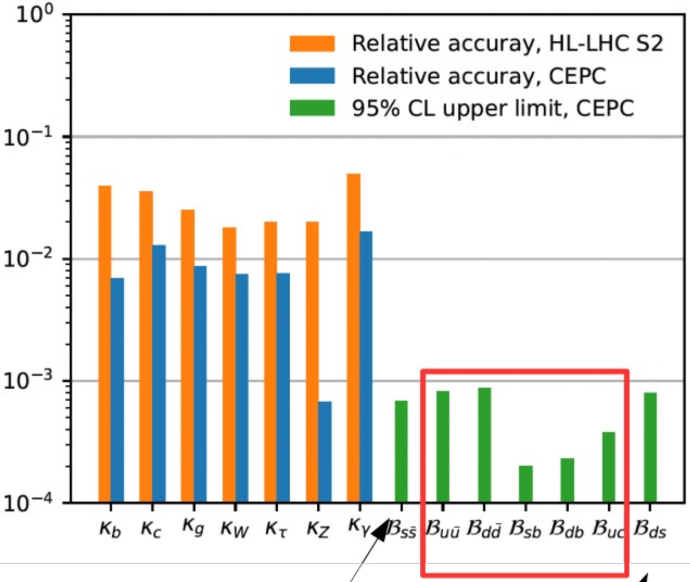
True \ Predicted	b	$\bar{b}$	c	$\bar{c}$	s	$\bar{s}$	u	$\bar{u}$	d	$\bar{d}$	G
b	0.745	0.163	0.033	0.025	0.004	0.003	0.002	0.003	0.002	0.002	0.017
$\bar{b}$	0.170	0.737	0.026	0.033	0.003	0.004	0.003	0.002	0.002	0.003	0.018
c	0.015	0.014	0.743	0.055	0.036	0.031	0.025	0.009	0.009	0.018	0.043
$\bar{c}$	0.016	0.015	0.056	0.739	0.032	0.037	0.009	0.026	0.017	0.010	0.043
s	0.003	0.002	0.020	0.018	0.543	0.102	0.030	0.080	0.063	0.045	0.092
$\bar{s}$	0.003	0.003	0.018	0.020	0.102	0.542	0.084	0.028	0.045	0.062	0.094
u	0.002	0.003	0.020	0.011	0.044	0.131	0.367	0.055	0.080	0.174	0.111
$\bar{u}$	0.003	0.003	0.011	0.019	0.132	0.043	0.062	0.356	0.178	0.081	0.111
d	0.003	0.003	0.012	0.019	0.112	0.092	0.082	0.207	0.277	0.079	0.112
$\bar{d}$	0.003	0.003	0.020	0.012	0.092	0.112	0.219	0.076	0.079	0.272	0.113
G	0.015	0.014	0.024	0.024	0.052	0.052	0.043	0.041	0.034	0.034	0.667



- Distinguish jets originated from 11 different kinds of colored particles: 5 quarks, 5 anti-quarks, and gluon.
- Strong impact on the physics reach:
  - Higgs rare & exotic hadronic decay up limits improved by 3 times – 2 orders of magnitudes, i.e., H->ss be limited to 3 times the SM prediction.
  - EW & Flavor Physics measurements.

https://arxiv.org/abs/2310.03440

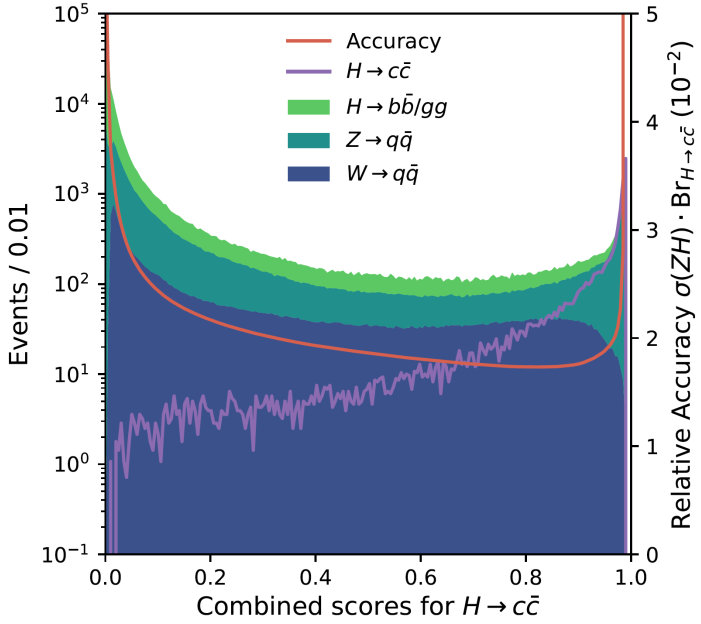
Impact on Physics: Higgs & W



Improved by ~3 times

Improved by 1-2 orders of magnitudes

Presumably... firstly quantified



https://arxiv.org/abs/2310.03440

Impact on Physics: EW & Flavor

Updated result on $\sin^2\theta^l_{eff}$ measurement

Table 2. Sensitivity S of different final state particles.

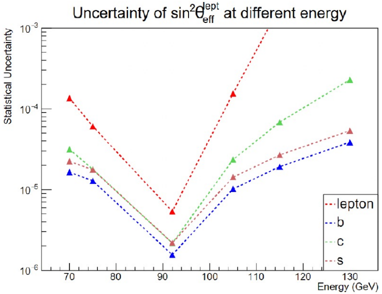
$\sqrt{s}$/GeV	S of $A^{e/\mu}_{FB}$	S of A^{d}_{FB}	S of A^{u}_{FB}	S of A^{s}_{FB}	S of A^{c}_{FB}	S of A^{b}_{FB}
70	0.224	4.396	1.435	4.403	1.445	4.352
75	0.530	5.264	2.598	5.269	2.616	5.237
92	1.644	5.553	4.200	5.553	4.201	5.549
105	0.269	4.597	1.993	4.598	1.994	4.586
115	0.035	3.956	1.091	3.958	1.087	3.942
130	0.027	3.279	0.531	3.280	0.520	3.261

Table 3. Cross section of process $e^+e^- \to f\bar{f}$ calculated using the ZFITTER package. Values of the fundamental parameters are set as $m_Z = 91.1875$ GeV, $m_t = 173.2$ GeV, $m_H = 125$ GeV, $\alpha_s = 0.118$ and $m_W = 80.38$ GeV.

$\sqrt{s}$/GeV	σ_μ/mb	σ_d/mb	σ_u/mb	σ_s/mb	σ_c/mb	σ_b/mb
70	0.039	0.032	0.066	0.031	0.058	0.028
75	0.039	0.047	0.073	0.046	0.065	0.043
92	1.196	5.366	4.228	5.366	4.222	5.268
105	0.075	0.271	0.231	0.271	0.227	0.265
115	0.042	0.135	0.122	0.135	0.118	0.132
130	0.026	0.071	0.068	0.071	0.066	0.069

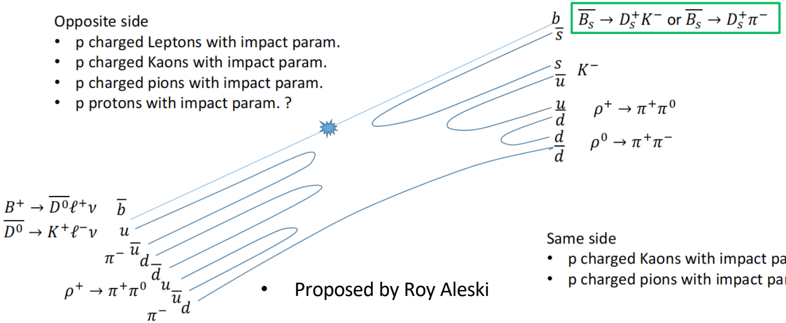
Verify the RG behavior... using
~1 month of data taking

Expected statistical uncertainties on $\sin^2\theta^l_{eff}$ measurement.
(Using one-month data collection, ~ *4e12/24 Z events* at Z pole)



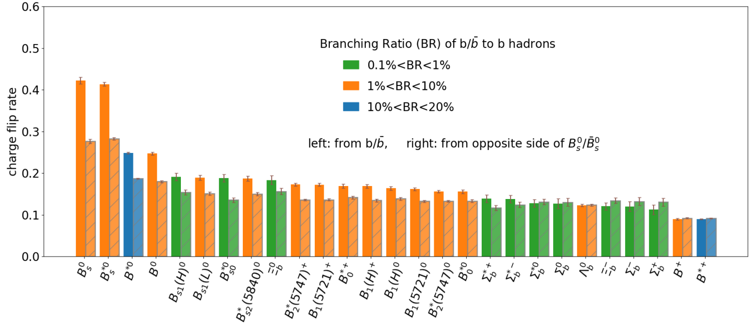
$\sqrt{s}$	b	c	s
70	1.6×10^{-5}	3.2×10^{-5}	2.2×10^{-5}
75	1.3×10^{-5}	1.8×10^{-5}	1.8×10^{-5}
92	1.6×10^{-6}	2.2×10^{-6}	2.2×10^{-6}
105	1.0×10^{-5}	2.4×10^{-5}	1.4×10^{-5}
115	1.9×10^{-5}	6.8×10^{-5}	2.7×10^{-5}
130	3.9×10^{-5}	2.3×10^{-4}	5.4×10^{-5}

Opposite side
- p charged Leptons with impact param.
- p charged Kaons with impact param.
- p charged pions with impact param.
- p protons with impact param. ?

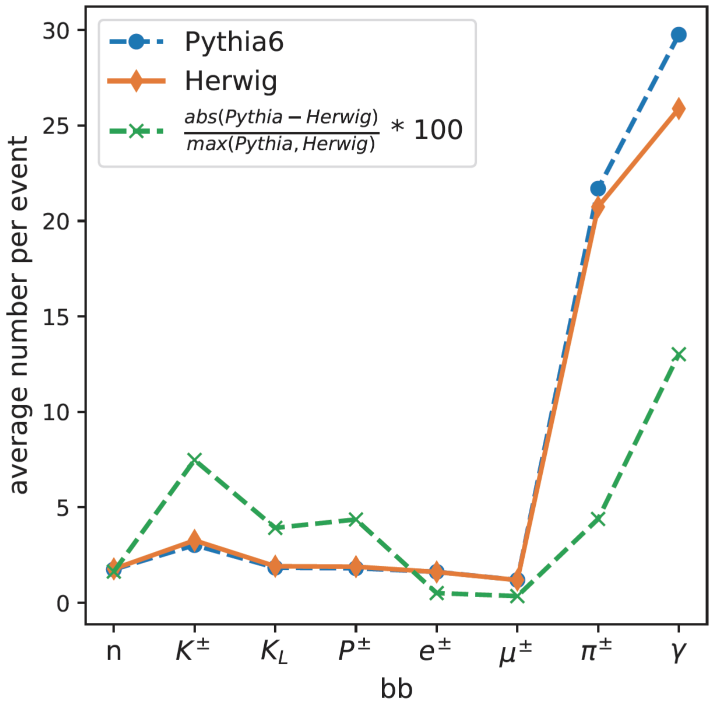


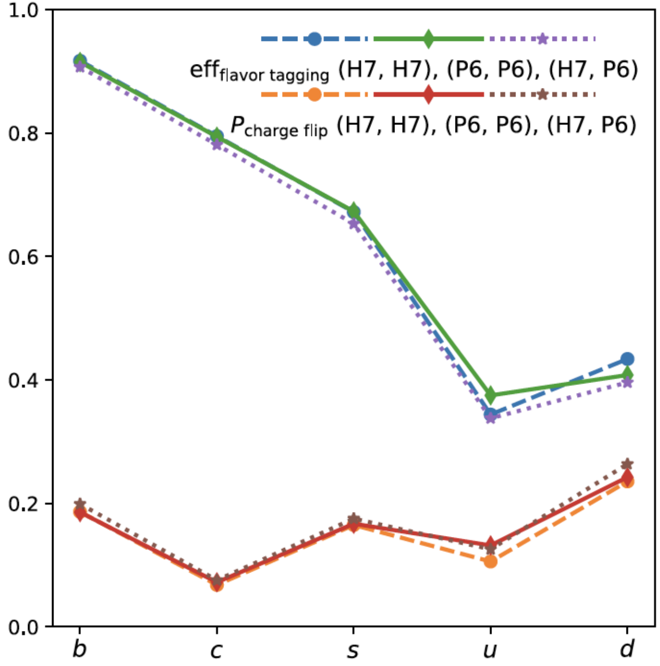
Same side
- p charged Kaons with impact param.
- p charged pions with impact param.

- Proposed by Roy Aleski

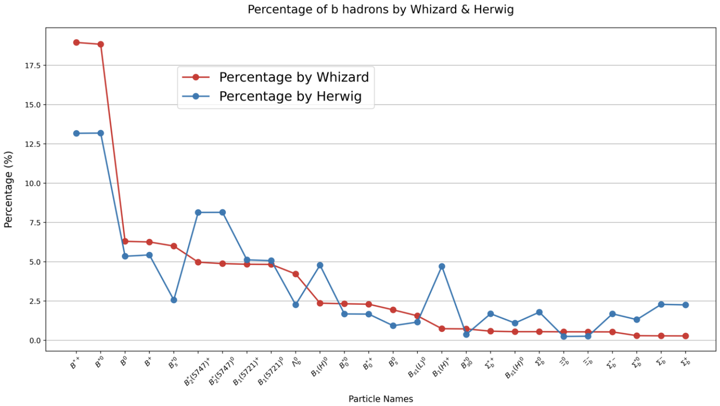


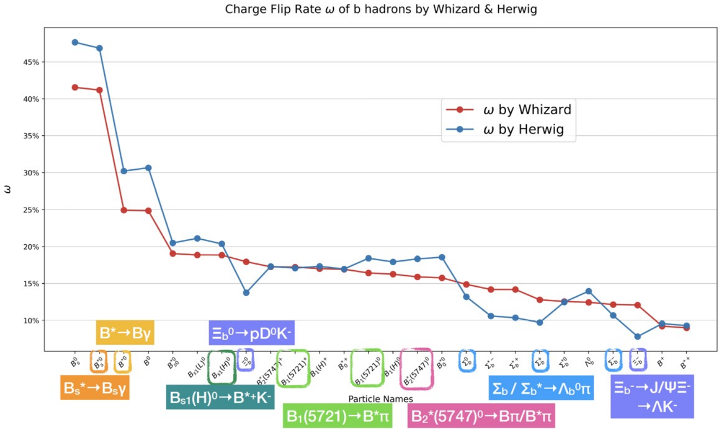
Validation: … Versus different Hadronization Models

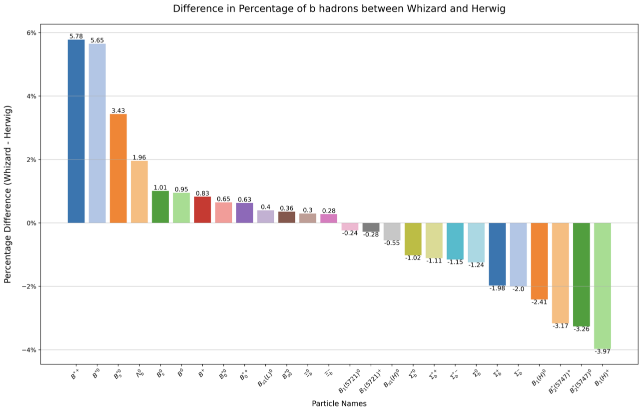


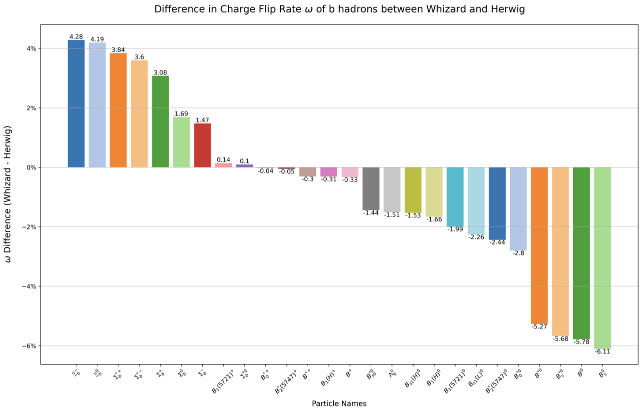


Hadronization: demon in details…

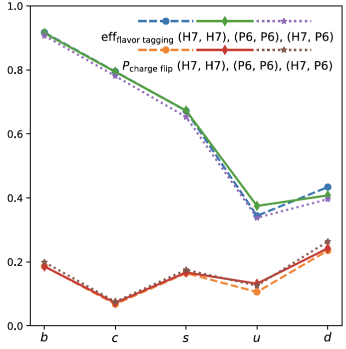


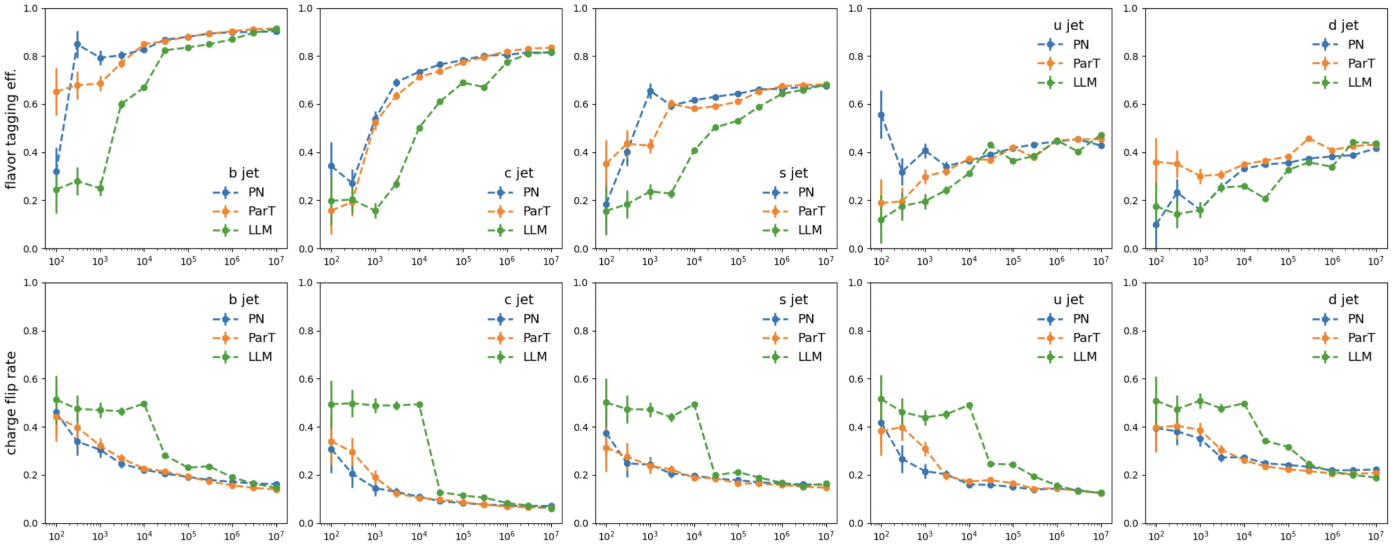






Scaling behaviors: at different models





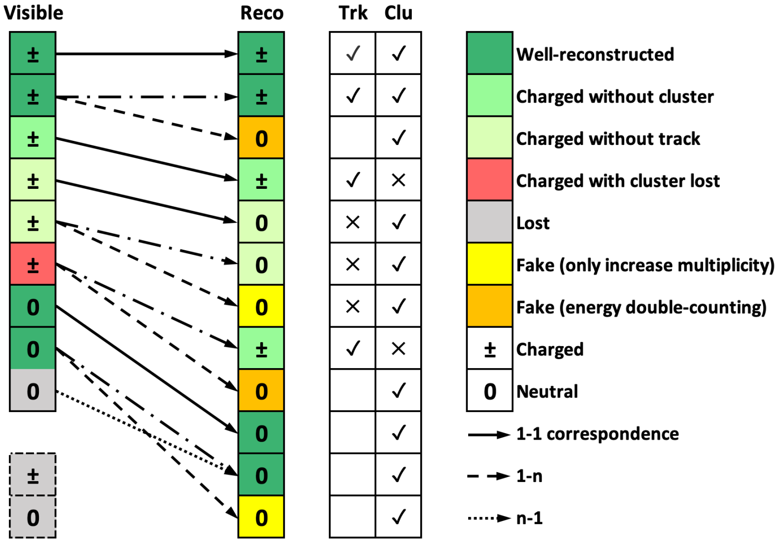
Comparable result with different scaling behavior

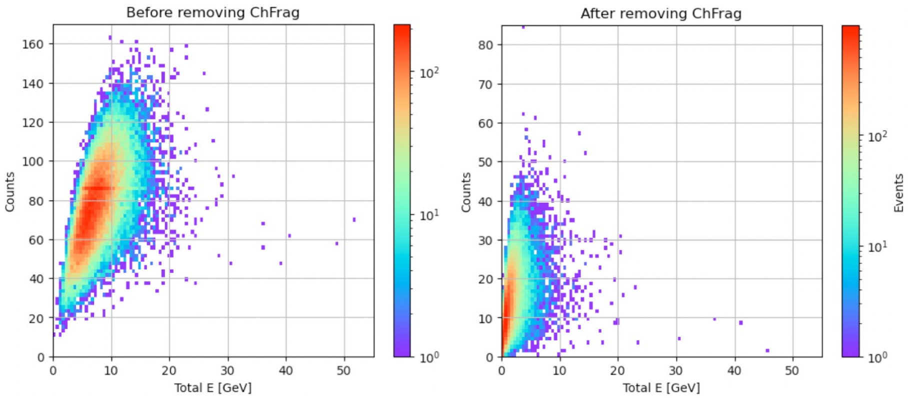
Para. Numbers: PN 360k, ParT 2.4M, BINBBT(Large Language Base Model) 150 M

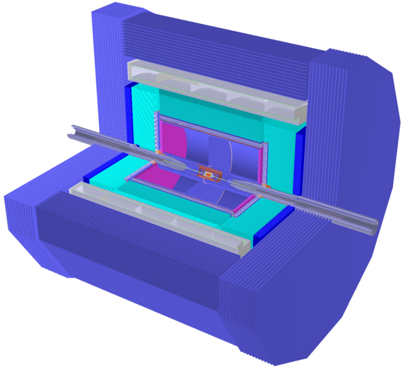
More details at: *https://arxiv.org/pdf/2412.00129*

超对称
Super Symmetry Technologies

AI usage: 1-1 corresponding reconstruction

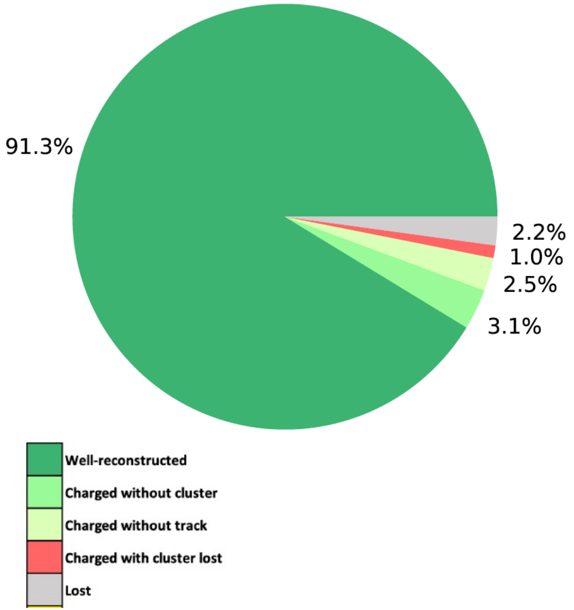


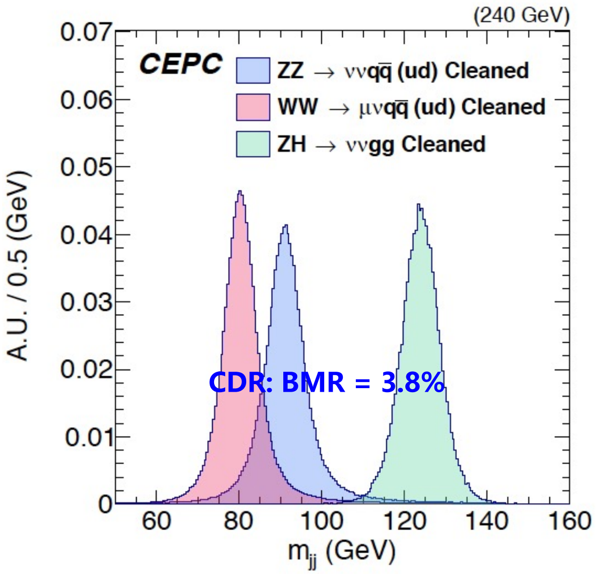


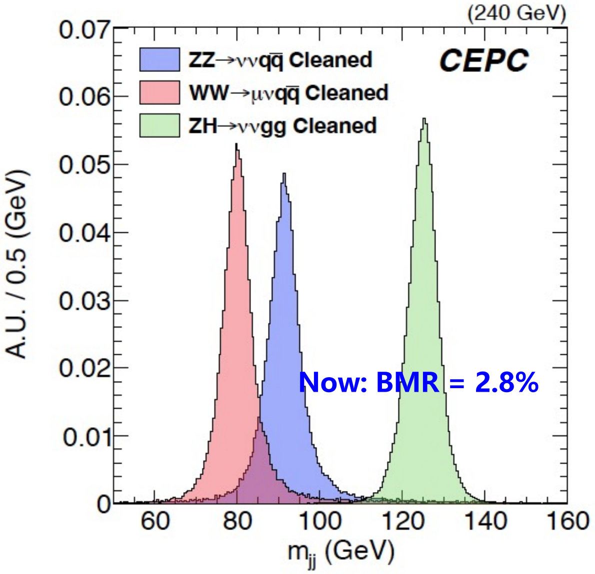


- Leading confusions, i.e., PFA oriented double counting, be reduced by 1 order of magnitudes; at the cost of marginally increased miss-vetoed low-E particles.

AI usage: 1-1 corresponding reconstruction

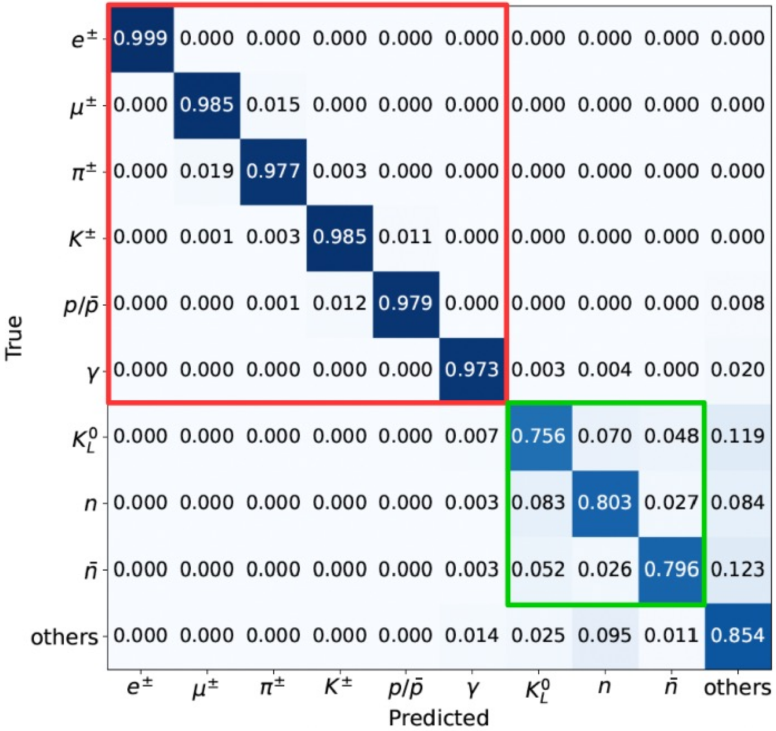


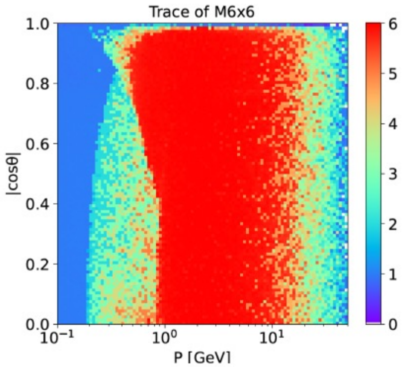


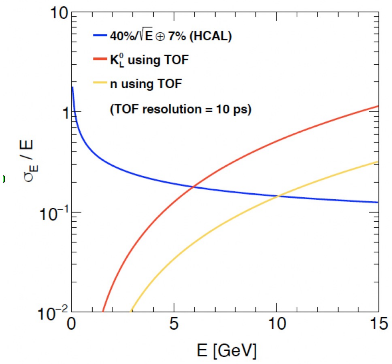


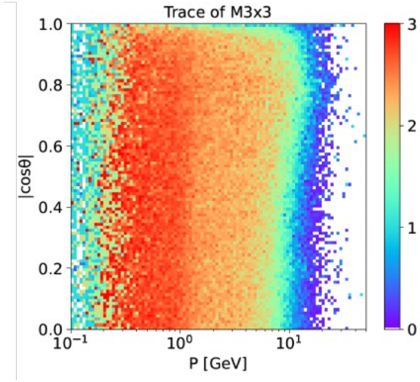
- Holistic event reconstruction: Via innovative detector design + PFA algorithm + AI technology: ~ 95% of visible energies are mapped to reconstructed particles that reserve 1-1 correspondence mapping
- BMR improved by ~ 30%

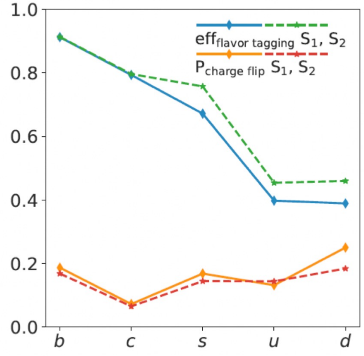
AI usage: 1-1 corresponding reconstruction











Prospective: BMR could potentially be improved to 2.2 - 2.4%, if the origin of every reconstructed particle could be identified…

Color Singlet identification

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PUBLISHED: *November 16, 2022*

The Higgs→ $b\bar{b}, c\bar{c}, gg$ measurement at CEPC

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University of Chinese Academy of Sciences,
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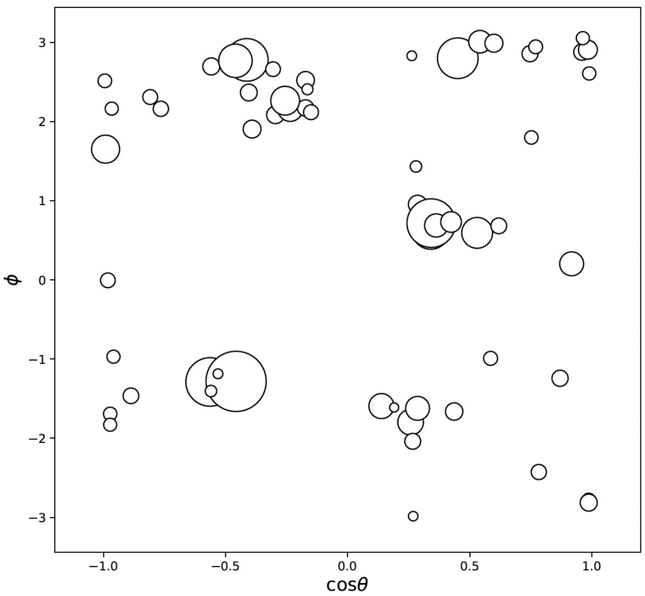
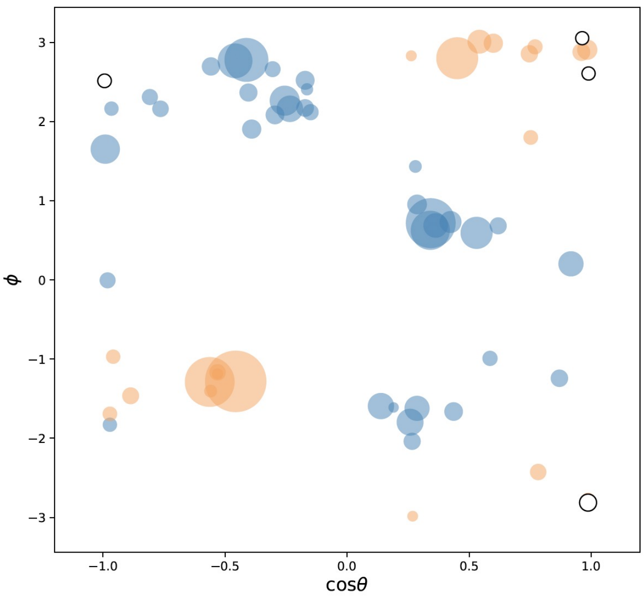
Z decay mode	$H \to b\bar{b}$	$H \to c\bar{c}$	$H \to gg$
$Z \to e^+e^-$	1.57%	14.43%	10.31%
$Z \to \mu^+\mu^-$	1.06%	10.16%	5.23%
$Z \to q\bar{q}$	0.35%	7.74%	3.96%
$Z \to \nu\bar{\nu}$	0.49%	5.75%	1.82%
combination	0.27%	4.03%	1.56%

Table 3. The signal strength accuracies for different channels.

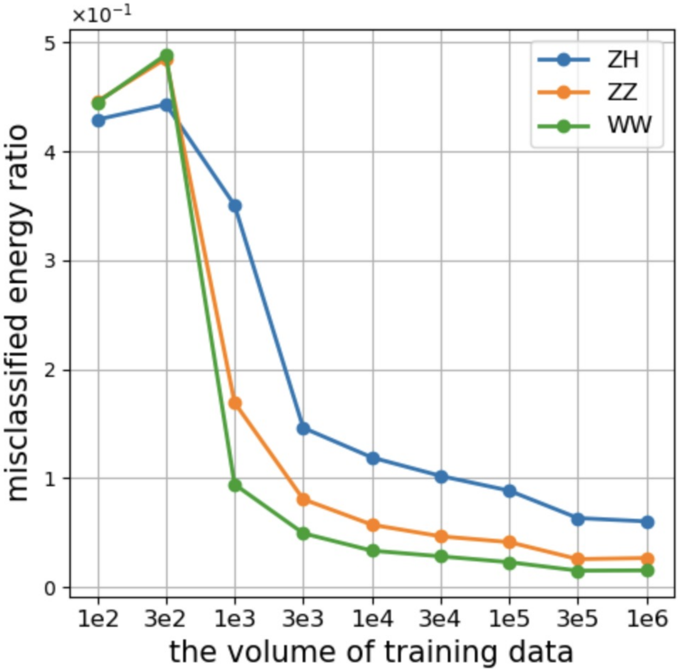
- Definition: to identify the color singlet origin of every final state particle, especially in the full hadronic events (i.e., in the full hadronic ZH event, identify whether a final state particle is coming from Z or H decay, or ISR photon, etc)
- Bottleneck of measurement with full hadronic events at energy higher than Z pole… i.e., H→cc & gg measurements at qqH channel is much worse than vvH channels, despite qqH has 3.5 times more statistic

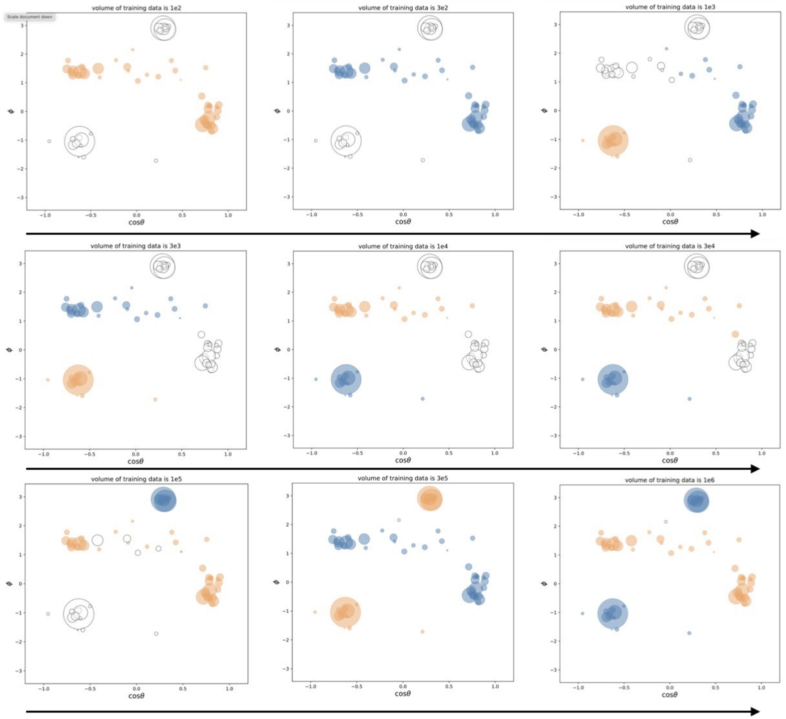
AI tool for CSI: using Particle Transformer





AI tool for CSI: Scaling behavior

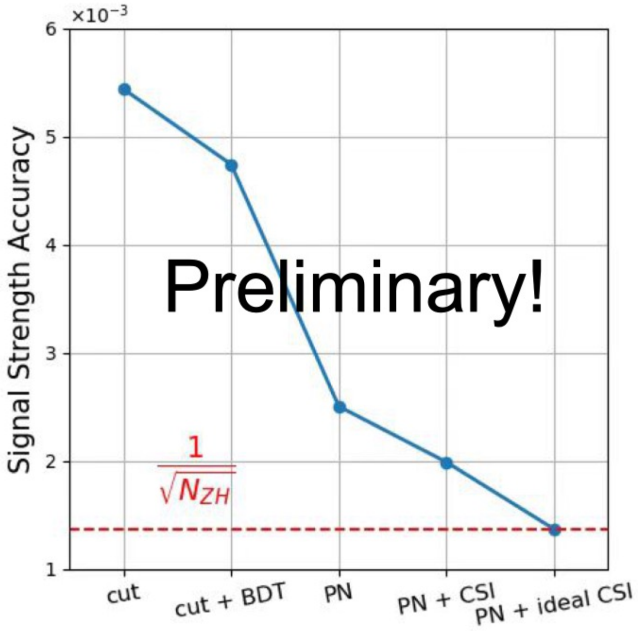




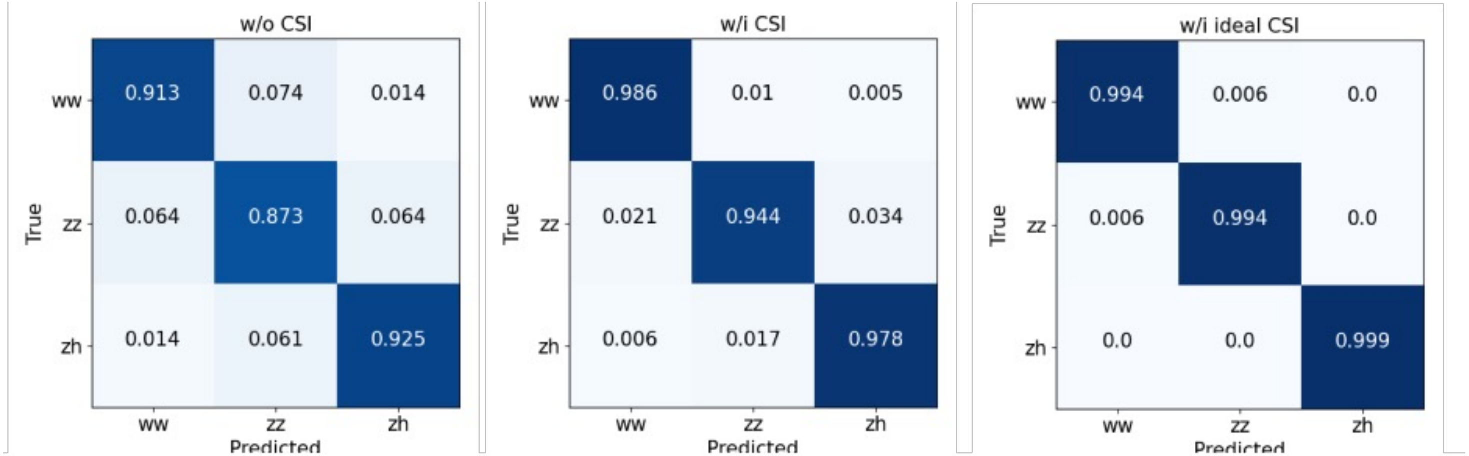
Toy analysis: identify ZH signal from ZZ + WW backgrounds (Full hadronic)

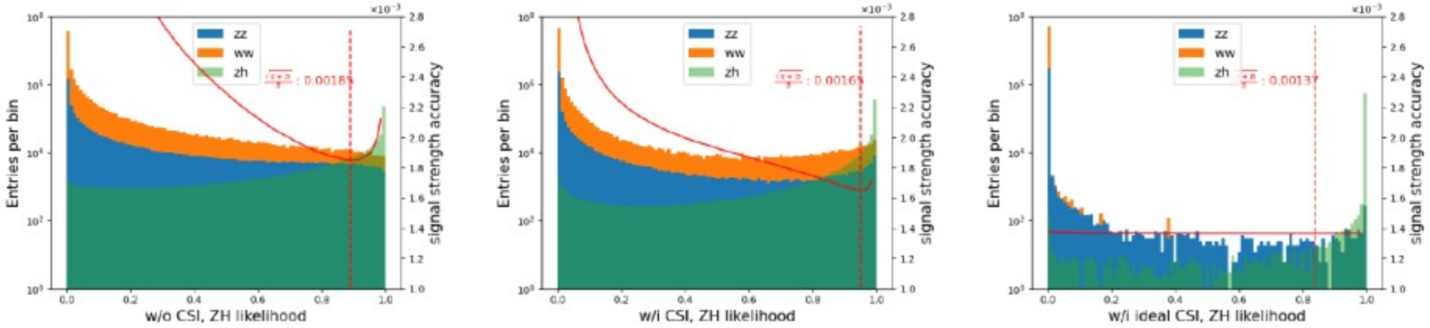
- Comparison between 5 methods
  - Cut based
  - BDT
  - Classification using all the reconstructable info (1-1 correspondence/PN)
  - 1-1 correspondence with reconstructed CSI
  - 1-1 correspondence with truth level CSI

- 5.6 iab: 540k ZH + 3.1M ZZ + 47 M WW full hadronic events



Migration matrix of 1-1 cases





Perspective & Discussion

- AI tools significantly enhance the discovery power, alter the experiments design. Trilogy of the event reconstruction for future Higgs factories
  - Jet Origin ID: 'see' quark & gluon as lepton & photon
  - 1-1 correspondence, at least at Higgs factory: Should & Could
    - New paradigm for analyses: Forget about artificial variable definition – feed all the reconstructable
    - Provide much more detailed info for system monitoring & systematic control
  - Color Singlet Id: decently addressed, enhance the accuracies of measurements with full hadronic final state by ~ 2 times.
- Bottleneck Shifts & Lots to be explored
  - Confusion -> Detector acceptance
  - Variables constructions & validation -> reliability of MC tool

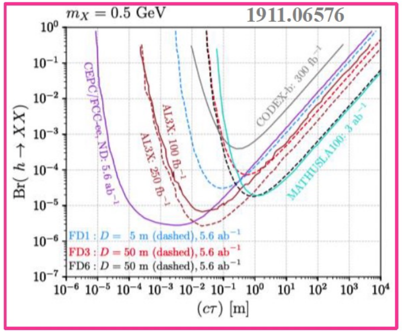
Summary

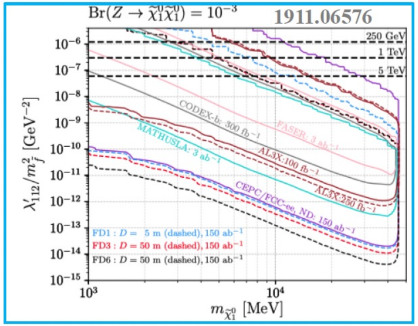
- CEPC addresses many most pressing and critical science problems in particle physics.
- Accelerator design and technology R&D are reaching maturity, TDR completed, enters EDR phase, ready for construction in 3-5 years.
- Reference detector TDR under preparation, to be completed by the mid-2025 for the proposal of China's 15^{th} 5-year plan.
- Any contributions from international colleagues, especially for accelerator EDR and reference detector TDR, are warmly welcome.
- CEPC schedule will follow the 15^{th} 5-year plan, call for international collaborations and proposals once CEPC is approved.
- CEPC will offer the worldwide HEP community an early Higgs factory.
- AI tools: significantly boost our discovery power!

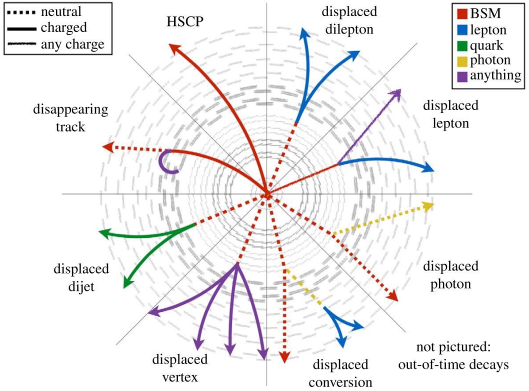
Back up

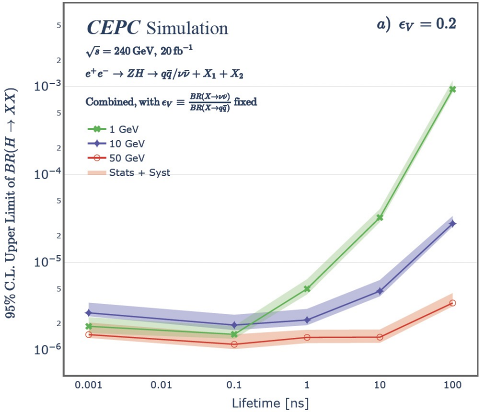
LLP Search at CEPC

LLP Type	Signal Signature	$\sqrt{s}$ [GeV]	$\mathcal{L}$ [ab^{-1}]	Detector	Sensitivities on parameters [Assumptions]	Figs.	Refs.
New scalar particles (X)	$Z(\to \text{incl.})\, h(\to XX)$, $X \to q\bar{q}/\nu\bar{\nu}$	240	20	ND	$\text{Br}(h \to XX) \sim 10^{-6}$ [$m \in (1, 50)$ GeV, $\tau \in (10^{-3}, 10^{-1})$ ns]	37	[80]
	$Z(\to \text{incl.})\, h(\to XX)$, $X \to \text{incl.}$	240	5.6	ND	$\text{Br}(h \to XX) \sim 3 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 5 \times 10^{-3}$ m]	49	[86]
				FD3	$\text{Br}(h \to XX) \sim 7 \times 10^{-5}$ [$m = 0.5$ GeV, $c\tau \sim 1$ m]	49	[86]
				LAYCAST	$\text{Br}(h \to XX) \sim 5 \times 10^{-6}$ [$m = 0.5$ GeV, $c\tau \sim 10^{-1}$ m]	49	[241]
RPV-SUSY neutralinos ($\tilde{\chi}_1^0$)	$Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^0 \to \text{incl.}$	91.2	150	ND	$\lambda'_{112}/m_{\tilde{f}}^2 \in (2 \times 10^{-14}, 10^{-8})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	43	[86]
				FD3	$\lambda'_{112}/m_{\tilde{f}}^2 \in (10^{-14}, 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[86]
				LAYCAST	$\lambda'_{112}/m_{\tilde{f}}^2 \in (7 \times 10^{-15}, 10^{-9})$ GeV^{-2} [$m \sim 40$ GeV, $\text{Br}(Z \to \tilde{\chi}_1^0\tilde{\chi}_1^0) = 10^{-3}$]	50	[241]
ALPs (a)	$Z^{(*)} \to \mu^-\mu^+ a$	91	150	ND	$f_a/C^A_{\mu\mu} \lesssim 950$ GeV	44	[85]
	$\gamma\, a$, $a \to \gamma\gamma$	91.2	150	ND	$C_{\gamma\gamma}/\Lambda \sim 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 2$ GeV]	51	[241]
				FD3	$C_{\gamma\gamma}/\Lambda \sim 6 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.3$ GeV]	51	[242]
				LAYCAST	$C_{\gamma\gamma}/\Lambda \sim 2 \times 10^{-3}$ TeV^{-1} [$C_{\gamma Z} = 0$, $m \sim 0.7$ GeV]	51	[241]
Hidden valley particles (π_V^0)	$Z\, h(\to \pi_V^0\pi_V^0)$, $\pi_V^0 \to b\bar{b}$	350	1.0	ND	$\sigma(h) \times \text{BR}(h \to \pi_v^0\pi_v^0) \sim 10^{-4}$ pb [$m \in (25, 50)$ GeV, $\tau \sim 10^2$ ps]	41	[243]
Dark photons (γ_D)	$Z(\to q\bar{q})\, h(\to \gamma_D\gamma_D)$, $\gamma_D \to \ell^-\ell^+/q\bar{q}$	250	2.0	ND	$\text{Br}(h \to \gamma_D\gamma_D) \sim 10^{-5}$, [$m \in (5, 10)$ GeV, $\tau \sim 10^2$ ps, $\epsilon \in (10^{-6}, 10^{-7})$]	42	[83]





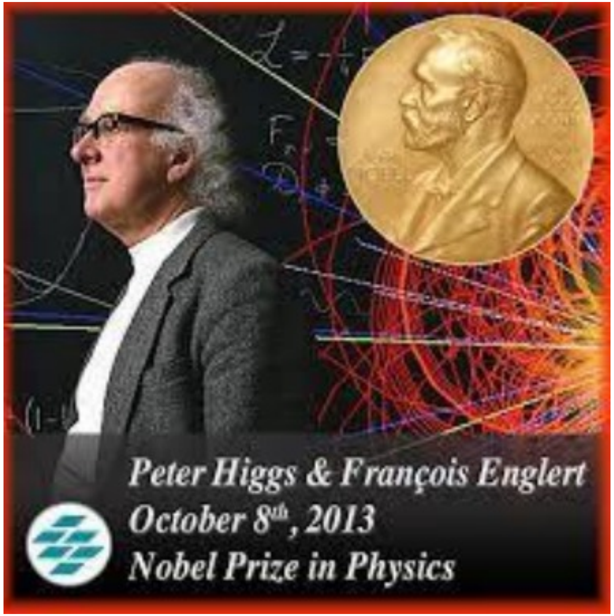


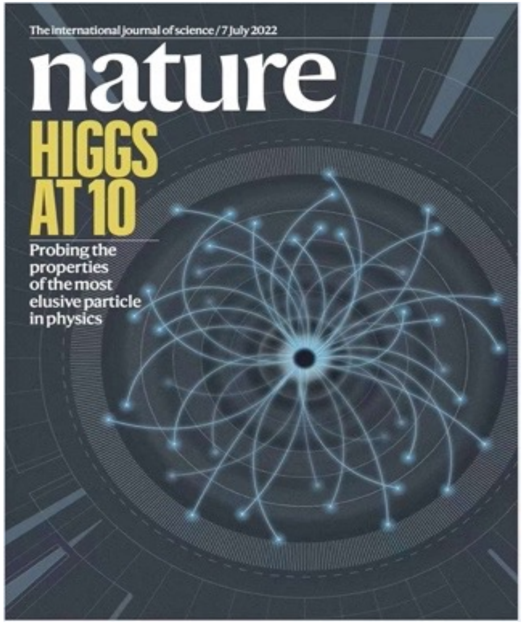


➔ CEPC has significant advantage for LLP search with small Life…

➔ Far detector could significantly enhance the LLP search performance, while dedicated R&D & optimization is needed

Higgs discovery to precision measurements





Discovery of Higgs boson

Phys. Lett. B 716 (2012) 1-29
Phys. Lett. B 716 (2012) 30-61
Science 338 (2012) 1569-1575
Science 338 (2012) 1576-1582

2012：Higgs mechanism explains the mass origin of SM particles

2013：Nobel Prize in Physics

Higgs Property Measurement

Nature 607, 52-59 (2022)
Nature 607, 60-68 (2022)

Core team, the host institution and the existing support

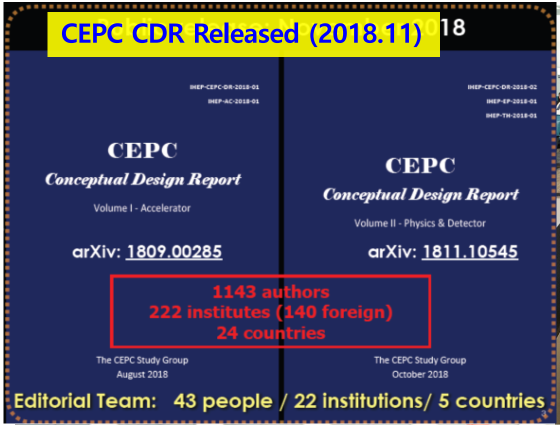
International collaboration

CEPC attracts significant International participation

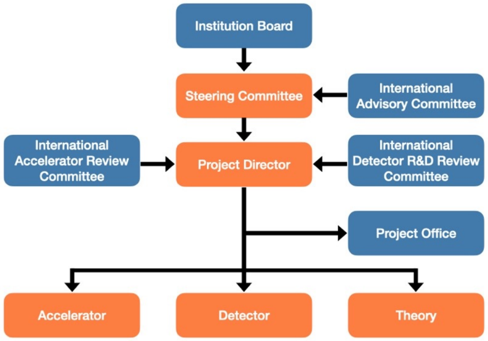
- Conceptual design report: 1143 authors from 221 institutes (including 140 International Institutes)
- More than 20 MoUs signed and executed

- Intensive collaboration on Physics studies
- Oversea scientists made substantial contributions to the R&D, especially the detector system

- CEPC International Workshop since 2014
- EU-US versions of CEPC WS: Next one at Marseille
- Annual working month at HKIAS (since 2015)



Core team, the host institution and the existing support



- Institution Board: 32 institutes, top universities/institutes in China
- Management team: comprehensive management experience at construction projects of BEPCII/CSNS/HEPS, and international projects of BESIII/Daya Bay/JUNO/…
- Accelerator team: fully over all disciplines with rich experiences at BEPCII, HEPS…
- Physics and Detector team: fully over all disciplines with rich experiences at BESIII, Daya Bay, JUNO, ATLAS, CMS, …

Table 7.2: Team of Leading and core scientists of the CEPC

Name	Brief introduction	Role in the CEPC team
Yifang Wang	Academician of the CAS, director of IHEP	The leader of CEPC, chair of the SC
Xinchou Lou	Professor of IHEP	Project manager, member of the SC
Yuanning Gao	Academician of the CAS, head of physics school of PKU	Chair of the IB, member of the SC
Jie Gao	Professor of IHEP	Convener of accelerator group, vice chair of the IB, member of the SC
Haijun Yang	Professor of SJTU	Deputy project manager, member of the SC
Jianbei Liu	Professor of USTC	Convener of detector group, member of the SC
Hongjian He	Professor of USTC	Convener of theory group, member of the SC
Shan Jin	Professor of NJU	Member of the SC
Nu Xu	Professor of IMP	Member of the SC
Meng Wang	Professor of SDU	Member of the SC
Qinghong Cao	Professor of PKU	Member of the SC
Wei Lu	Professor of THU	Member of the SC
Joao Guimaraes da Costa	Professor of IHEP	Convener of detector group
Jianchun Wang	Professor of IHEP	Convener of detector group
Yuhui Li	Professor of IHEP	Convener of accelerator group
Chenghui Yu	Professor of IHEP	Convener of accelerator group
Jingyu Tang	Professor of IHEP	Convener of accelerator group
Xiaogang He	Professor of SJTU	Convener of theory group
Jianping Ma	Professor of ITP	Convener of theory group

Management team, world-class leading scientists

Table 7.3: Team of the CEPC accelerator system

Number	Sub-system	Convener	Team (senior staff)
1	Accelerator physics	Chenghui Yu, Yuan Zhang	18
2	Magnets	Wen Kang, Fusan Chen	12
3	Cryogenic system	Rui Ge, Ruixiong Han	11
4	SC RF system	Jiyuan Zhai, Peng Sha	12
5	Beam Instrumentation	Yanfeng Sui, Junhui Yue	7
6	SC magnets	Qingjin Xu	10
7	Power supply	Bin Chen, Fengli Long	9
8	Injection & extraction	Jinhui Chen	7
9	Mechanical system	Jianli Wang, Lan Dong	4
10	Vacuum system	Haiyi Dong, Yongsheng Ma	5
11	Control system	Ge lei, Gang Li	6
12	Linac injector	Jingyi Li, Jingru Zhang	13
13	Radiation protection	Zhongjian Ma	3
Sum			117

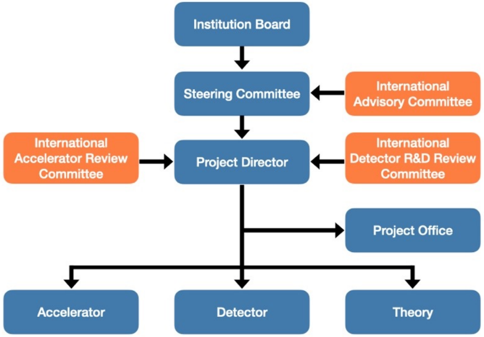
Table 7.4: Team of the CEPC detector system

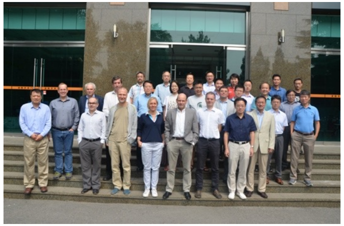
Number	Sub-system	Conveners	Institutions	Team (senior staff)
1	Pixel Vertex Detector	Zhijun Liang, Qun Ouyang, Xiangming Sun , Wei Wei	CCNU, IFAE, IHEP, NJU, NWPU, SDU, Strasbourg, ...	~ 40
2	Silicon Tracker	Harald Fox, Meng Wang, Hongbo Zhu	IHEP, INFN, KIT, Lancaster, Oxford, Queen Mary, RAL, SDU, Tsinghua, Bristol, Edinburgh, Livepool, USTC, Warwick, Sheffield, ZJU, ...	~ 60
3	Gaseous detector	Franco Bedeschi, Zhi Deng, Mingyi Dong, Huirong Qi	CEA-Saclay, DESY, LCTPC Collab., IHEP, INFN, NIKHEF, THU, ...	~ 30
4	Magnet	Feipeng Ning	IHEP	~ 10
5	Calorimetry	Roberto Ferrari, Jianbei Liu, Haijun Yang, Yong Liu	CALICE Collab., IHEP, INFN, SJTU, USTC...	~ 40
6	Muon	Paolo Giacomelli, Liang Li, Xiaolong Wang	FDU, IHEP, INFN, SJTU ...	~ 20
7	Physics	Manqi Ruan, Yaquan Fang, Liantao Wang, Mingshui Chen	IHEP, FDU, SJTU, ...	~ 80
8	Software	Shengseng Sun, Weidong Li, Xingtao Huang	IHEP, SDU, FDU, ...	~ 20
Sum				~ 300

117 accelerator + ~300 detector staffs currently, + ~ 400 from BEPC/BESIII/JUNO/HEPS…once CEPC approved

Core team, the host institution and the existing support

International Committees





Name	Affiliation	Country
Tatsuya Nakada	EPFL	Japan
Steinar Stapnes	CERN	Norway
Rohini Godbole	CHEP, Bangalore	India
Michelangelo Mangano	CERN	Switzerland
Michael Davier	LAL	France
Lucie Linssen	CERN	Holland
Luciano Maiani	U. Rome	San Marino
Joe Lykken	Fermilab	U.S.
Ian Shipsey	Oxford/DESY	U.K.
Hitoshi Murayama	IPMU/UC Berkeley	Japan
Geoffrey Taylor	U. Melbourne	Australia
Eugene Levichev	BINP	Russia
David Gross	UC Santa Barbara	U.S.
Brian Foster	Oxford	U.K
Marcel Demarteau	ORNL	USA
Barry Barish	Caltech	USA
Maria Enrica Biagini	INFN Frascati	Italy
Yuan-Hann Chang	IPAS	Taiwan, China
Akira Yamamoto	KEK	Japan
Hongwei Zhao	Institute of Modern Physics, CAS	China
Andrew Cohen	University of Science and Techbnology	Hong Kong, China
Karl Jakobs	University of Freiburg/CERN	Germany
Beate Heinemann	DESY	Germany

International Accelerator Review Committee

- Phillip Bambade, LAL
- Marica Enrica Biagini (Chair), INFN
- Brian Foster, DESY/University of Hamburg & Oxford University
- In-Soo Ko, POSTECH
- Eugene Levichev, BINP
- Katsunobu Oide, CERN & KEK
- Anatolii Sidorin, JINR
- Steinar Stapnes, CERN
- Makoto Tobiyama, KEK
- Zhentang Zhao, SINAP
- Norihito Ohuchi, KEK
- Carlo Pagani, INFN-Milano

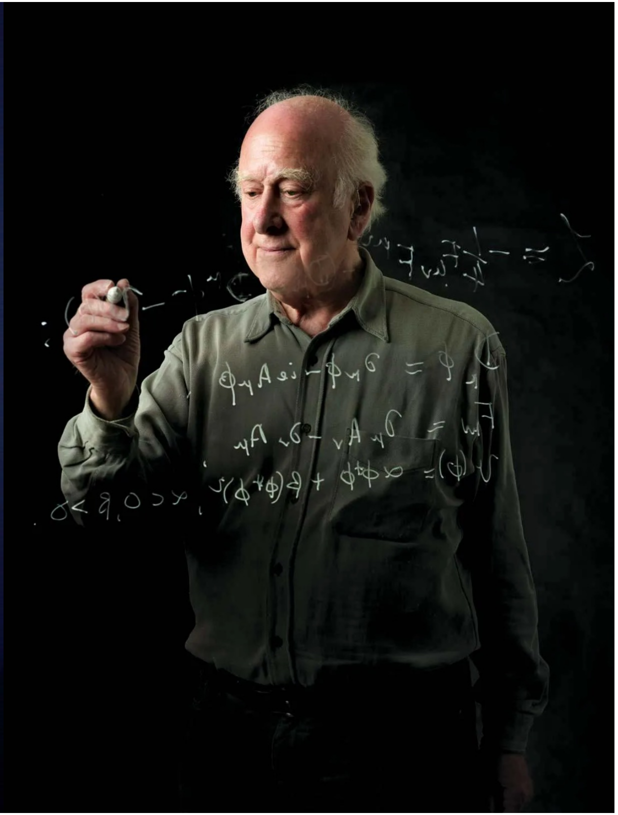
International Detector R&D Review Committee

- Jim Brau, USA, Oregon
- Valter Bonvicini, Italy, Trieste
- Ariella Cattai, CERN, CERN
- Cristinel Diaconu, France, Marseille
- Brian Foster, UK, Oxford
- Liang Han, China, USTC
- Dave Newbold, UK, RAL (chair)
- Andreas Schopper, CERN, CERN
- Abe Seiden, USA, UCSC
- Laurent Serin, France, LAL
- Steinar Stapnes, CERN, CERN
- Roberto Tenchini, Italy, INFN
- Ivan Villa Alvarez, Spain, Santader
- Hitoshi Yamamoto, Japan, Tohoku

IAC: global renowned scientists and top laboratory or project leaders who have ample experience in project management, planning, and execution of strategies, **operating since 2015**

IARC & IDRC: leading experts of this field, provide guide to the project director

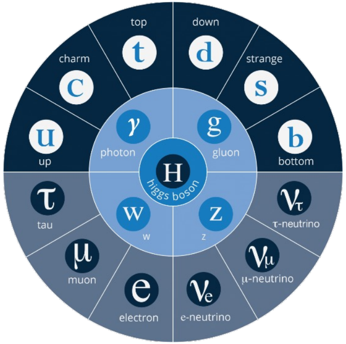
…Peter Higgs…

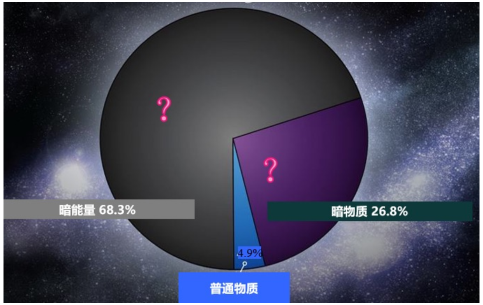


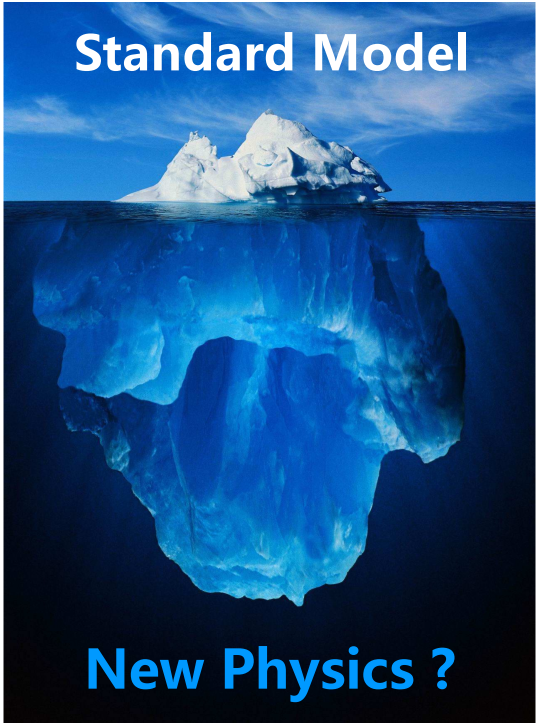
Particle Physics after the Higgs Discovery

SM is a complete and self-consistent theory after the Higgs discovery.

But it doesn't accommodate dark matter and dark energy ➔ New physics ?







Dark matter and dark energy ~ 95%

Upgrade capability and added values

SR power per beam upgrade to **50 MW**: High Luminosity (8E34 @ 240 GeV)

The **center-of-mass energy** can increase to **360 GeV**: top quark data

Add a **super proton-proton collider** (SppC) with c.m.s >**100 TeV**

Expandability: High energy & high flux synchrotron light source provides gamma-ray energy up to 300 MeV, critical for multi-disciplinary science

Boost the developments of multiple technologies:
Fast electronics, mechanics, vacuum, beam diagnostics, RF acceleration, cryogenic system, novel magnets, high-accuracy power supplies, control systems, big data, automation and intelligence, etc

- Upgradable scenarios: compatibilities included in design and construction
- Upgrades in several highly valuable ways, bring up discovery power, lifetime spans > 5 decades
- **Significant spillover effects on multidisciplinary sciences and applications**