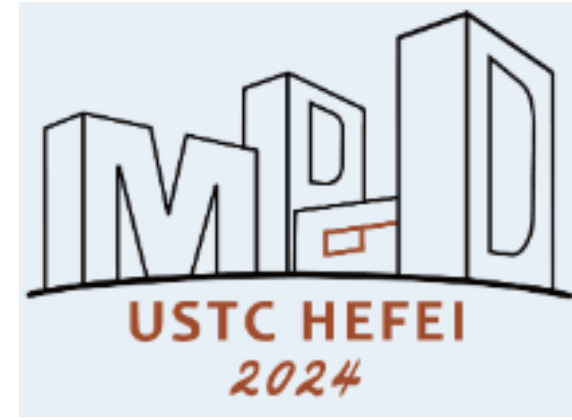




超级陶粲装置
Super Tau-Charm Facility



Future Colliders for High Energy Physics in China (CEPC & STCF)

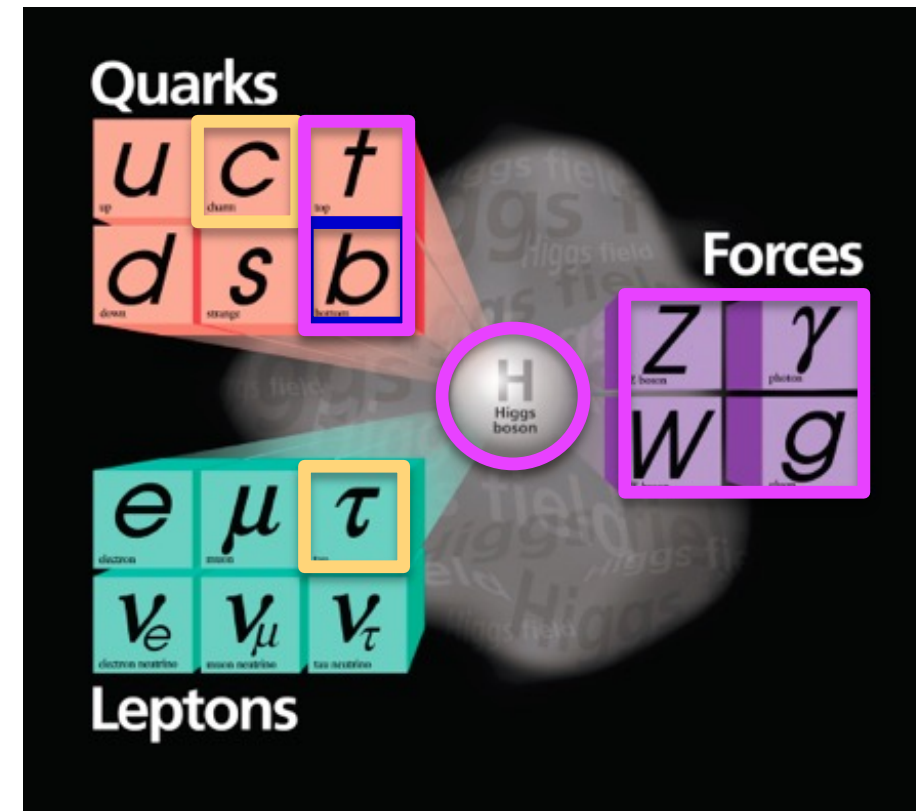
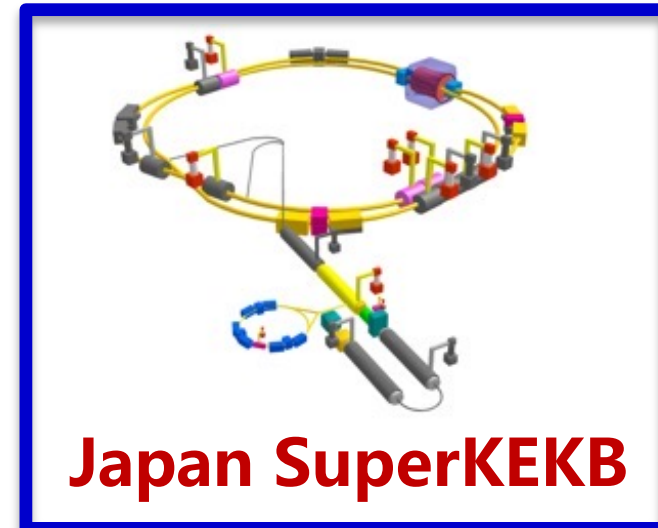
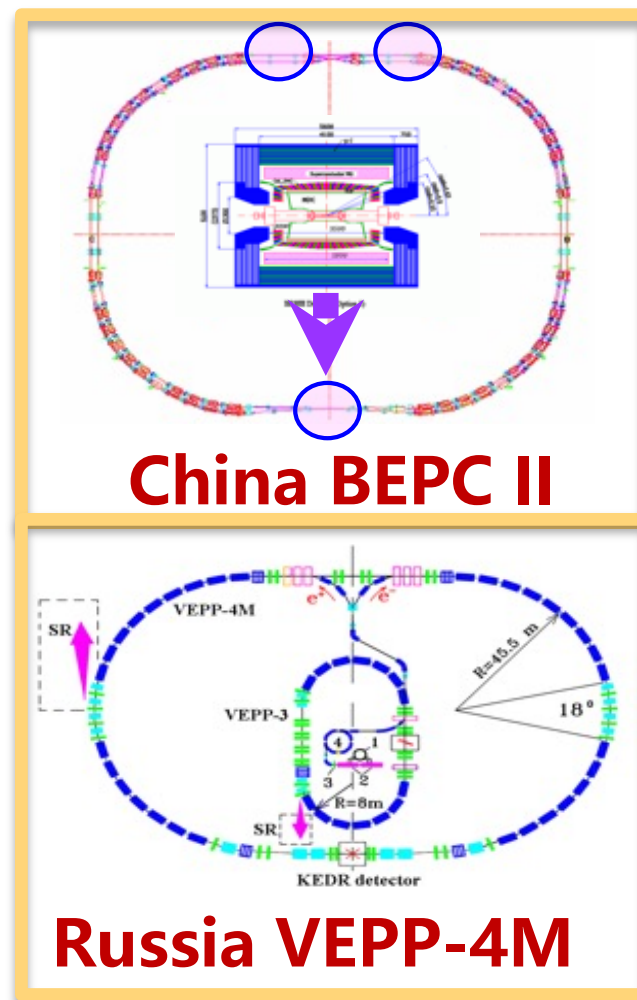
Jianbei Liu



中国科学技术大学
University of Science and Technology of China

The 8th International Conference on Micro-Pattern Gaseous Detectors
University of Science and Technology of China
Hefei, China
October 15, 2024

High Energy Physics with Colliders



High Precision Frontier

hadron structure, exotic states, nature of strong interaction, flavor physics & CPV ...

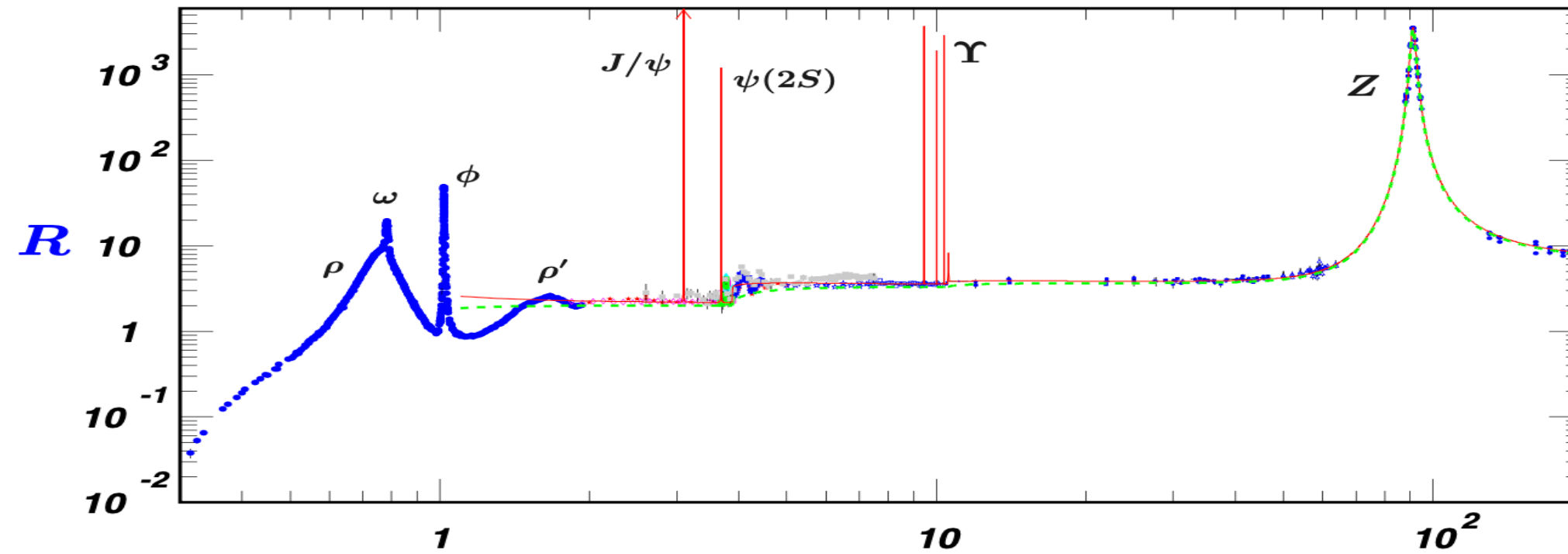
High Energy Frontier

origin of mass, nature of EWSB, new physics with Higgs, SUSY, Dark matter, universe evolution ...

In-depth exploration at both precision and energy frontiers is called for more than ever in the post Higgs era

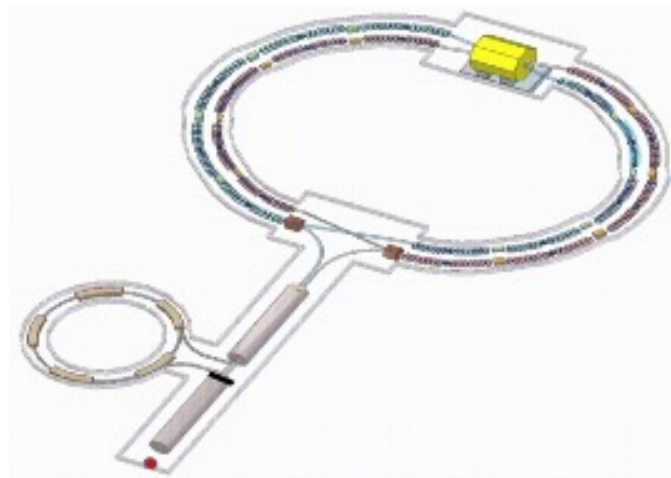
Future HEP Colliders Proposed in China

High Precision Frontier



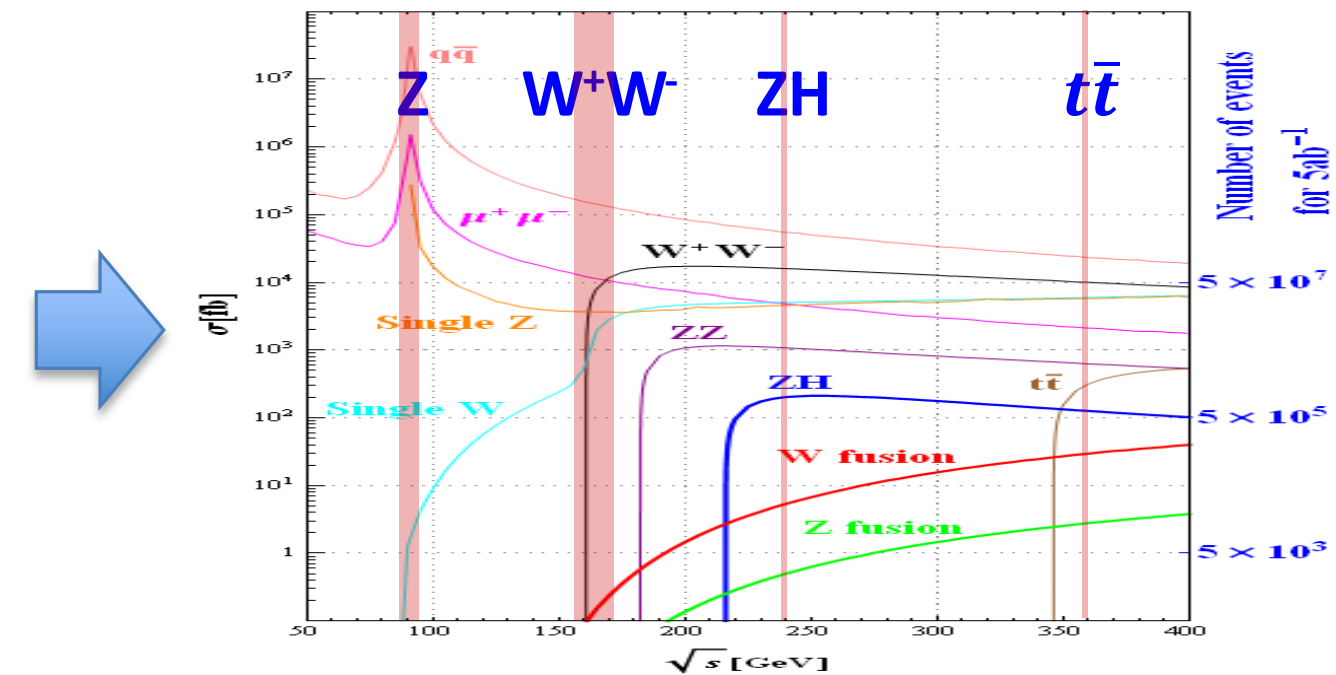
2-7 GeV

Super Tau-Charm Facility (STCF)



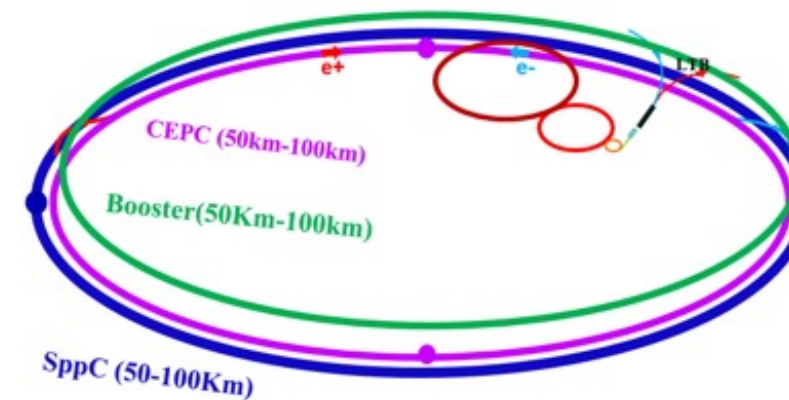
Ring ~1 km
 $E_{cm} = 2-7 \text{ GeV}$
 $L \geq 0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} @ 4 \text{ GeV}$

High Energy Frontier



90-360 GeV

Circular Electron Positron Collider (CEPC)



Ring ~100 km
 $E_{cm} = 90-360 \text{ GeV}$
 $L = 0.5 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} @ 240 \text{ GeV}$

Both are an e+e- machine

CEPC and STCF in International Context

High Precision Frontier

BEPCII

2-5 GeV, $10^{33} \text{ cm}^{-2}\text{s}^{-1}$



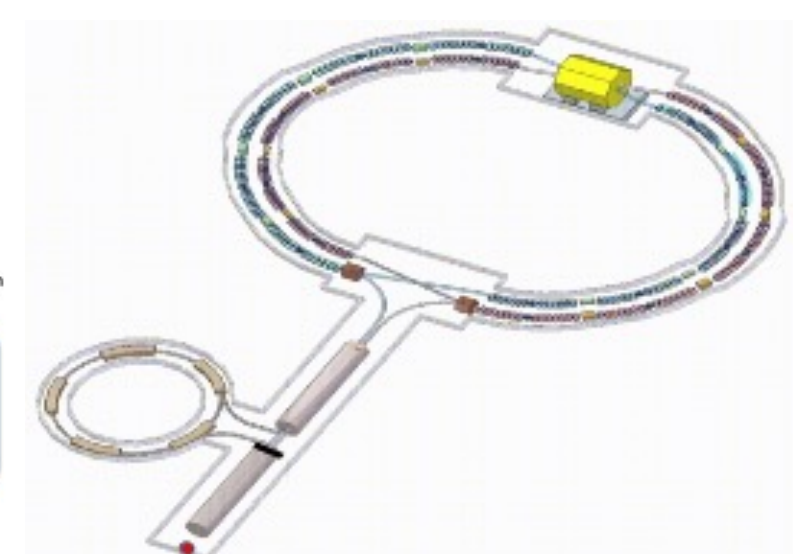
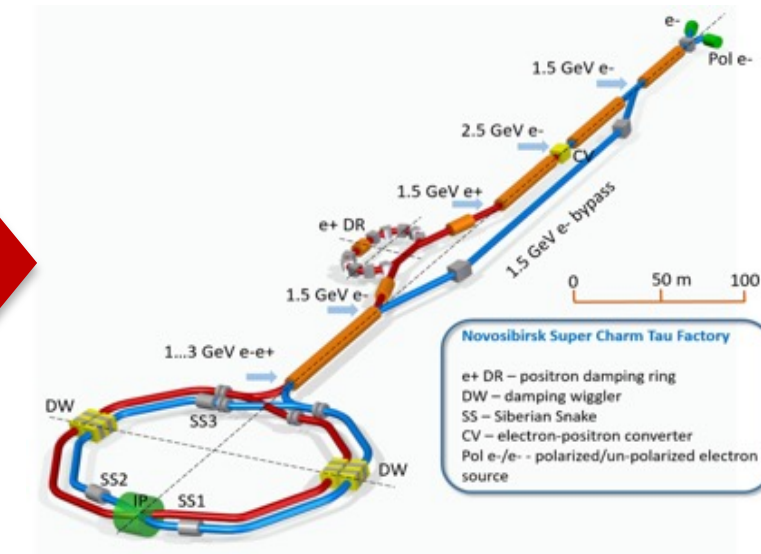
SKEKB

$\sim 10 \text{ GeV}$, $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (target)



SCTF, STCF

2-7 GeV, $\sim 10^{35} \text{ cm}^{-2}\text{s}^{-1}$



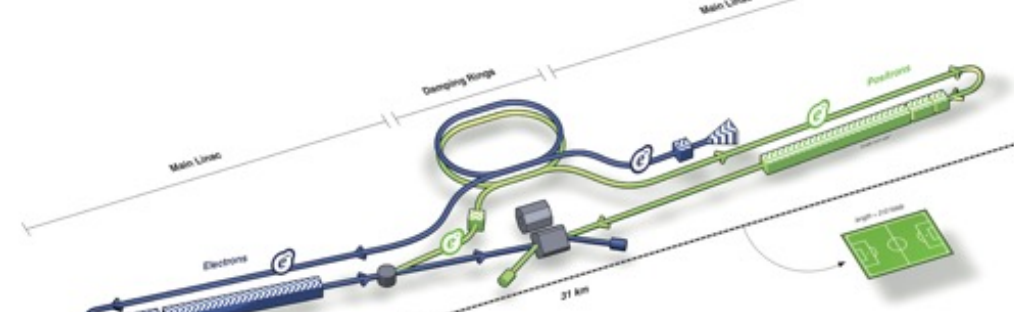
High Energy Frontier

LHC (HL-LHC)

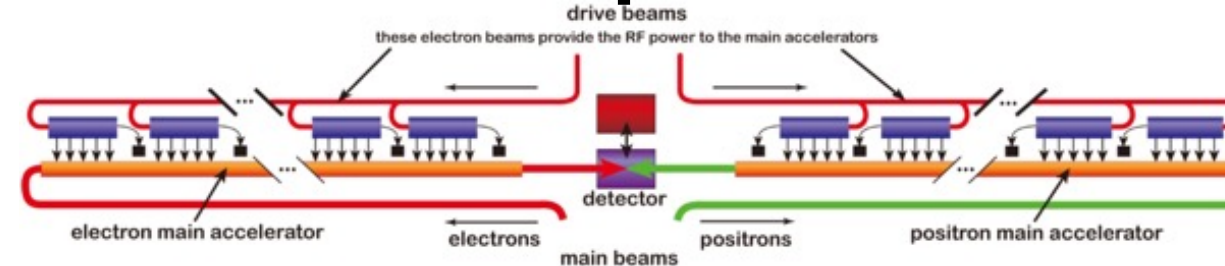
$\sim 14 \text{ TeV}$, $10^{34} \text{ cm}^{-2}\text{s}^{-1}$ ($\times 5-7$)



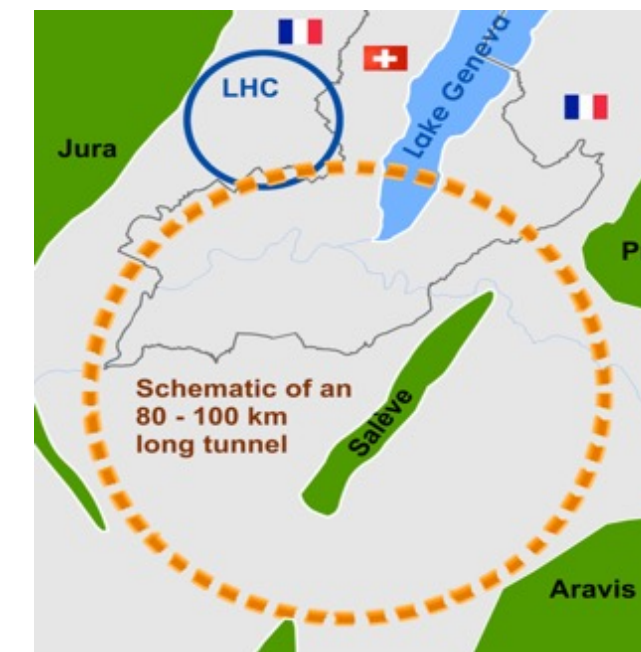
ILC: 0.25-1TeV



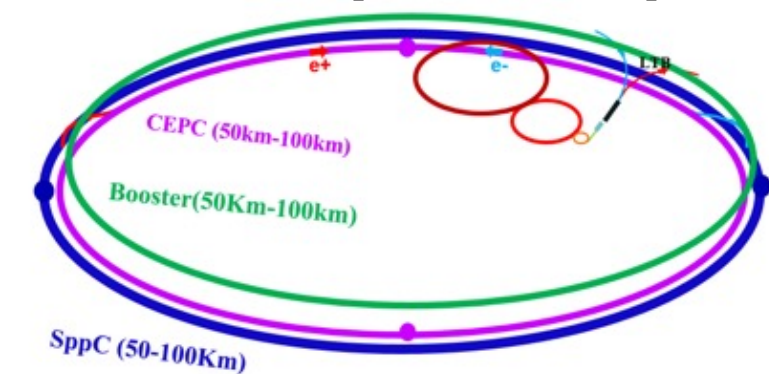
CLIC: up to 3TeV



FCC-ee, hh(100TeV)

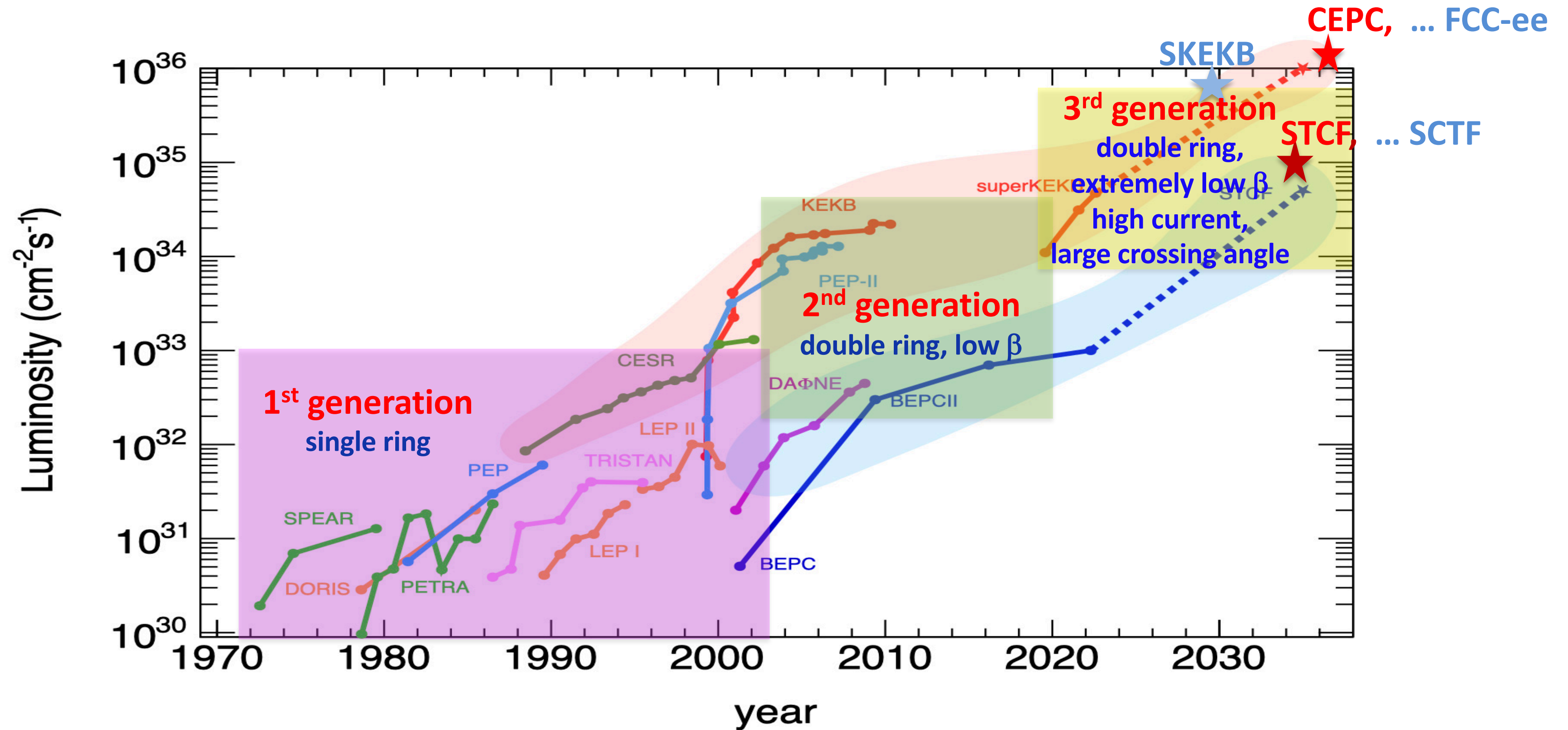


CEPC(90-360GeV)
SPPS(100TeV)



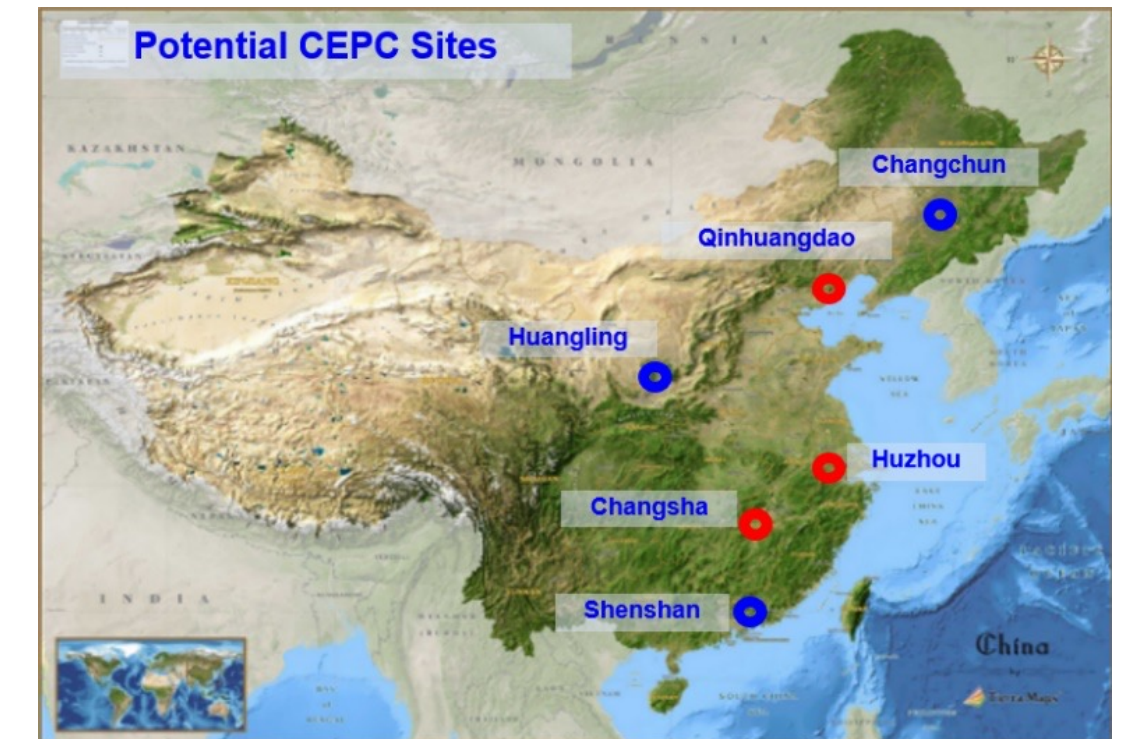
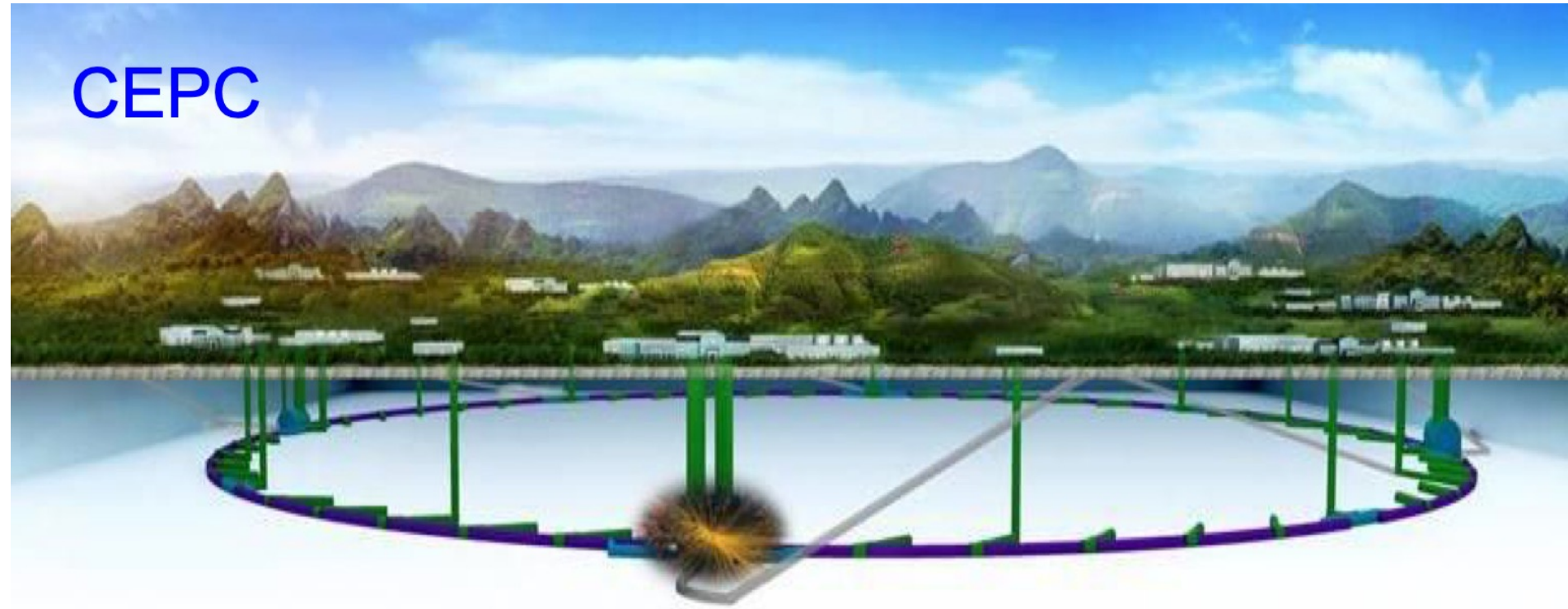
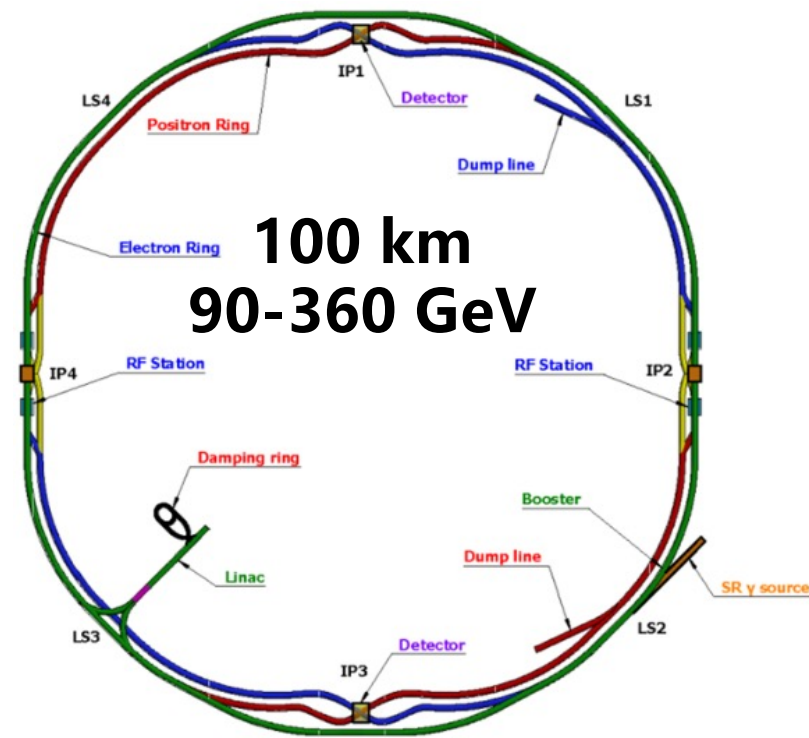
2020 European Strategy Update: An electron-positron Higgs factory is the highest-priority next collider

CEPC and STCF in Historical Context



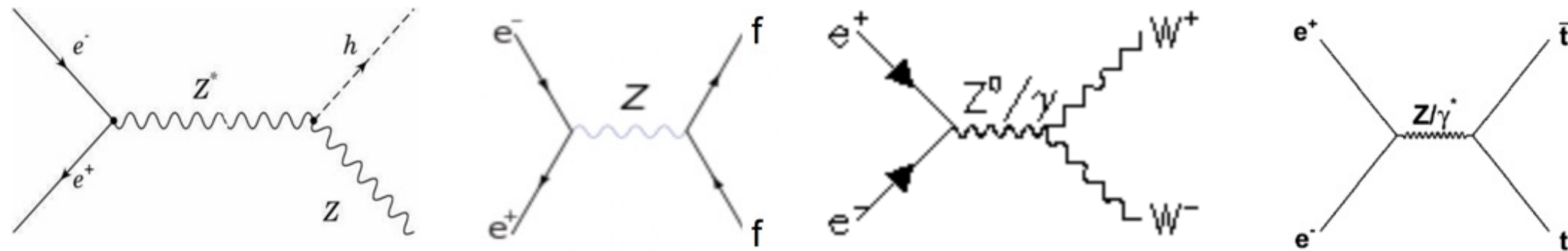
CEPC and STCF: both a 3th generation e+e- collider

CEPC

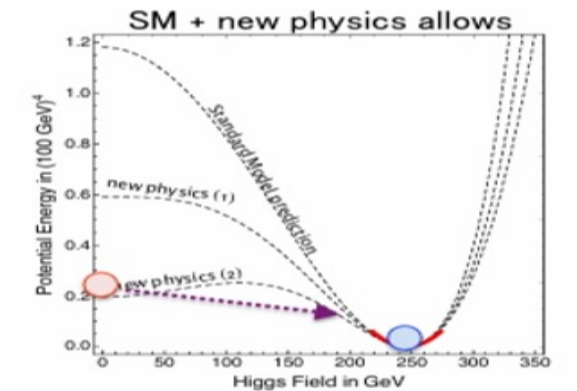


- ❑ Proposed in 2012 after the Higgs discovery.
- ❑ Aiming to start operation in 2030s, as a Higgs / Z / W factory.
- ❑ Abundant production of Higgs / W / Z bosons for precision measurements and new physics searches.
- ❑ Upgradable for a pp collider (SppC) of ~ 100 TeV in the future.

CEPC Physics Program



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



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

- The centerpiece: precise measurement of the Higgs boson properties
- Huge measurement potential for precision tests of SM: electroweak physics, flavor physics, QCD
- Searching for exotic or rare decays of H, Z, B and τ , and BSM physics (dark matter, EWPT, LLP ...)
- Top quark physics

An extremely versatile machine combining precision and discovery capabilities with a broad spectrum of physics opportunities → **Far beyond a Higgs factory**

CEPC Physics Studies

2018

IHEP-CEPC-DR-2018-02
IHEP-EP-2018-01
IHEP-TH-2018-01

CEPC
Conceptual Design Report
Volume II - Physics & Detector

The CEPC Study Group
October 2018

2019

Chinese Physics C Vol. 43, No. 4 (2019) 043002

Precision Higgs physics at the CEPC*

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Jun Gao(高俊)⁸ Yanyan Gao(高艳艳)³ Yuanming Gao(高原宁)³ Shaofeng Ge(葛峰)^{3,9}
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Higgs White Paper

2021

The Physics potential of the CEPC
Prepared for the US Snowmass Community Planning Exercise
(Snowmass 2021)
CEPC Physics Study Group

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SNOWMASS White Paper

2023

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Flavor Physics White Paper, More on EWK and NP in preparation

2024

PHYSICAL REVIEW LETTERS 132, 221802 (2024)

Jet-Origin Identification and Its Application at an Electron-Positron Higgs Factory

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To enhance the scientific discovery power of high-energy collider experiments, we propose and realize the concept of jet-origin identification that categorizes jets into five quark species (b, c, s, u, d), five antiquarks ($\bar{b}, \bar{c}, \bar{s}, \bar{u}, \bar{d}$), and the gluon. Using state-of-the-art algorithms and simulated $e^+e^- \rightarrow j\bar{j}$ events at 240-GeV center-of-mass energy at the electron-positron Higgs factory, the jet-origin identification simultaneously reaches jet flavor tagging efficiencies ranging from 57% to 92% for bottom, charm, and strange quarks and jet charge flip rates of 7%–24% for all quark species. We apply the jet-origin identification to Higgs tag and exotic decay measurements at the instant luminosity of the Circular Electron-Positron Collider and conclude that the upper limits on the branching ratios of $H \rightarrow s\bar{s}, u\bar{u}, d\bar{d}$ and $H \rightarrow b\bar{b}, c\bar{c}$ can be approximately 2×10^{-3} to 1×10^{-2} at 95% confidence level. The derived upper limit for $H \rightarrow d\bar{d}$ decay is determined to ≈ 3 times the prediction of the standard model.

DOI: 10.1103/PhysRevLett.132.221802

Introduction.—Quarks and gluons are standard model (SM) particles that carry color charges of the strong interaction. Because of the color confinement of quantum chromodynamics (QCD), colored particles cannot travel freely in spacetime and are confined to composite particles like hadrons. Once generated in high-energy collisions, quarks and gluons fragment into numerous particles that travel in directions approximately collinear to the initial colored particles. These collinear particles are called jets; see Fig. 1.

We define jet-origin identification as the procedure to determine from which colored particle a jet is generated and consider 11 different kinds: $b, \bar{b}, c, \bar{c}, s, \bar{s}, u, \bar{u}, d, \bar{d}, g$, and gluon. A successful jet-origin identification is critical for experimental particle physics at the energy frontier. At the Large Hadron Collider, successfully distinguishing quark jets from gluon ones could effectively reduce the typically large background from QCD processes [2–8]. Jet flavor tagging is essential for the Higgs property measurements at the LHC [6, 7, 9, 10]. The determination of jet charge [11, 12] was essential for weak mixing angle measurements at both LEP and LHC [13], is critical for time-dependent CP measurements [10, 15], and could have a significant impact on Higgs boson property measurements [16].

We realize the concept of jet-origin identification in physics events at an electron-positron Higgs factory using a GEANT4-based simulation [17] (referred to as full simulation for simplicity), since the electron-positron Higgs factory is identified as the highest-priority future collider project [18, 19]. We develop the necessary software tools, Atoch [20, 21] and ParticleNet [22], for the particle flow event reconstruction and the jet-origin identification. We

FIG. 1 Event display of an $e^+e^- \rightarrow t\bar{t}H \rightarrow b\bar{b}g$ ($\sqrt{s} = 240$ GeV) event simulated and reconstructed with the CEPC baseline detector [1]. Different particles are depicted with colored arrows and straight lines: red for e^+ , cyan for e^- , blue for t^+ , orange for photons, and magenta for neutral hadrons.

Development and Application of Advanced Analysis Tools

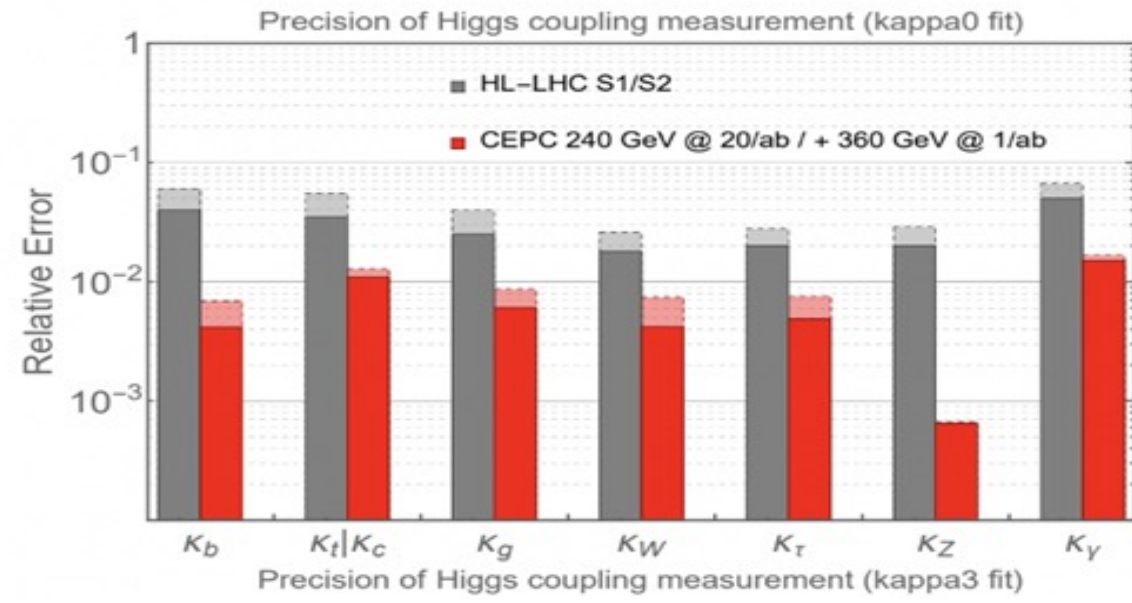


Participation in ECFA physics studies

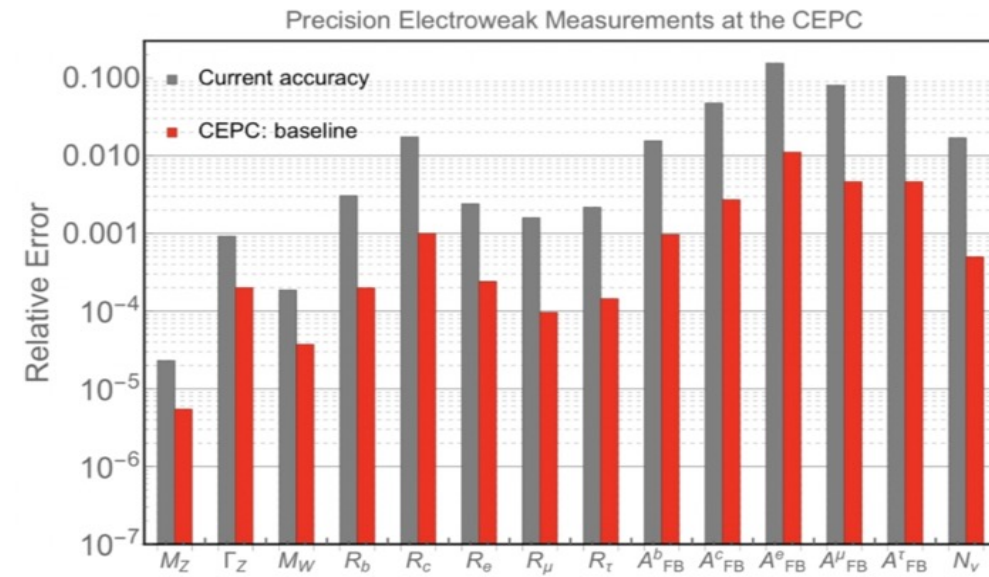
~100 Journal/arXiv papers

Precision and Discovery @ CEPC

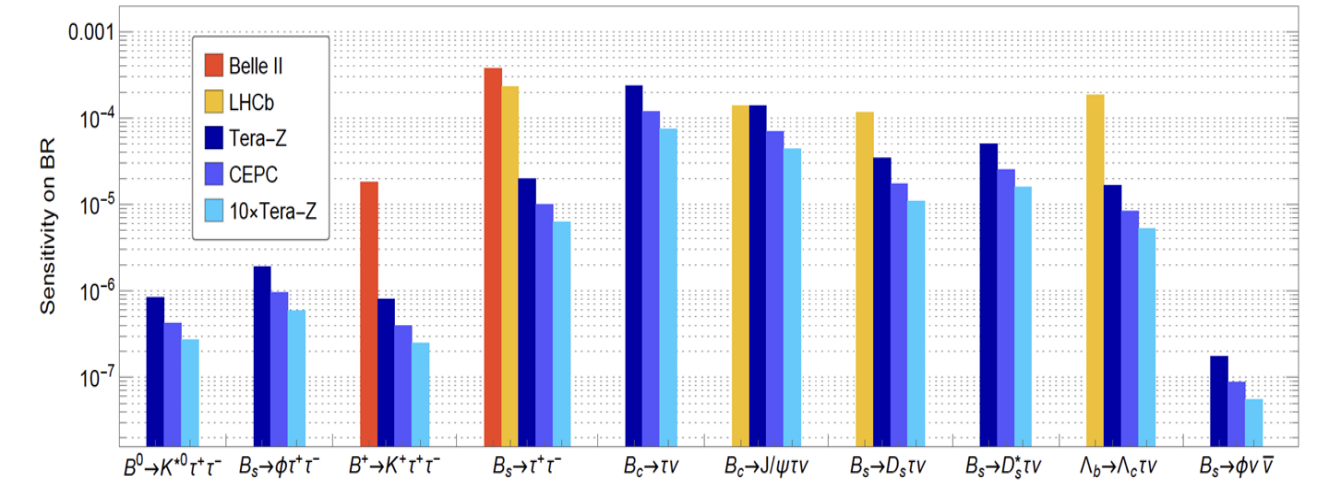
Higgs coupling measurements (model independent)



EWK measurements

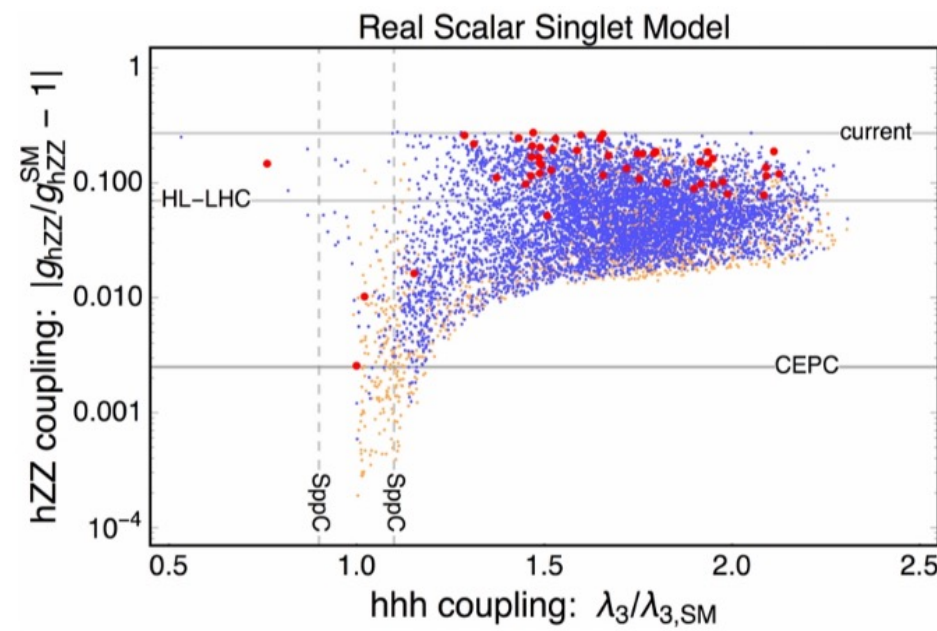
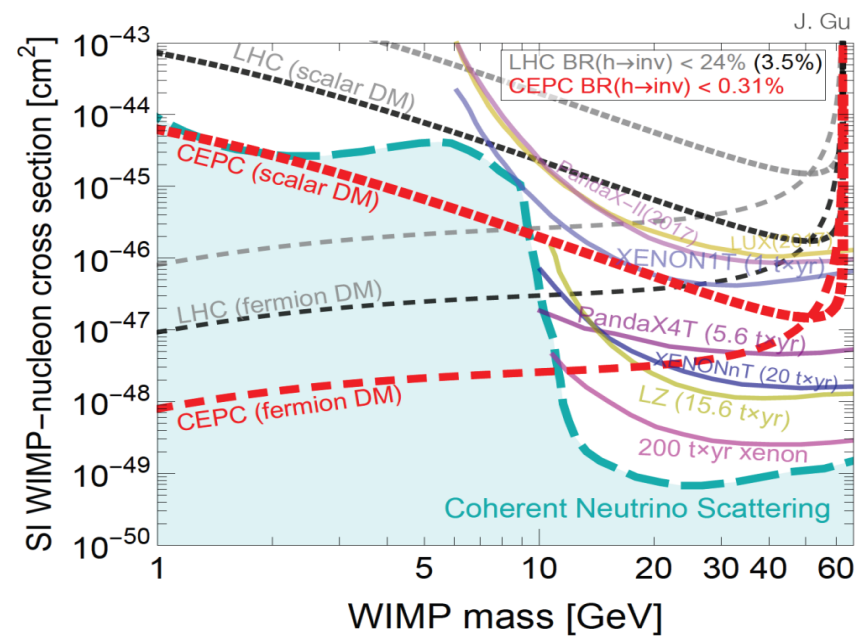


Rare decays

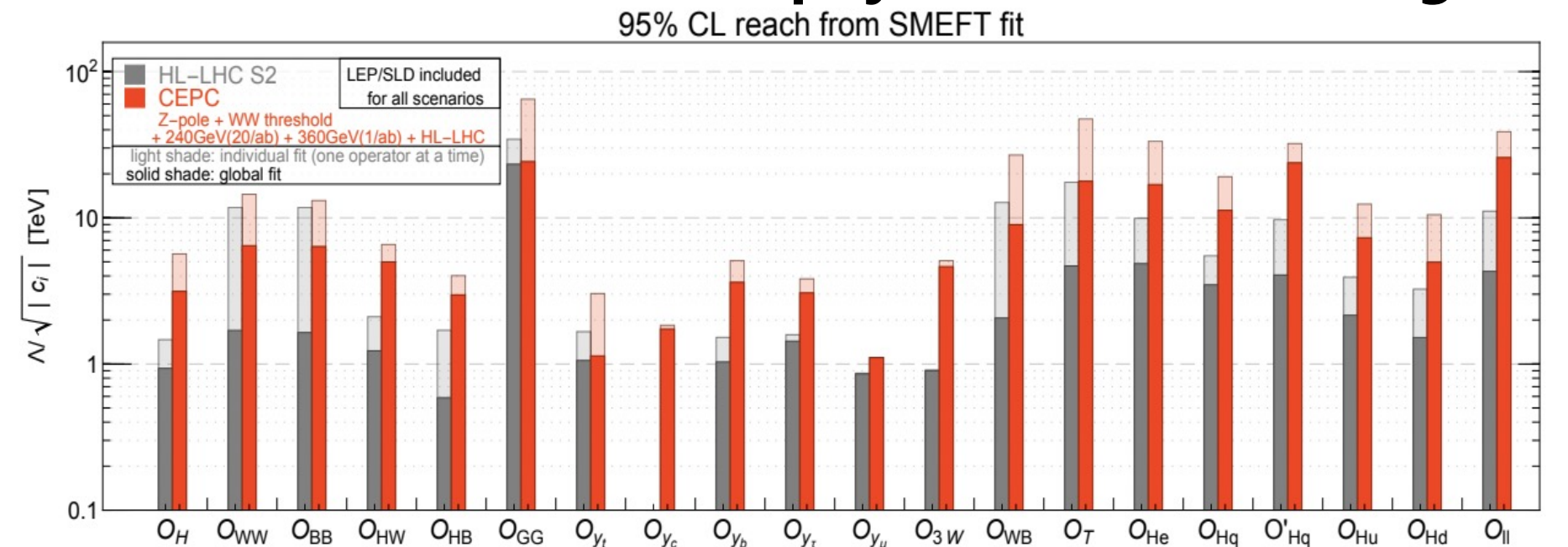


Mode	LEP bound (95% CL)	LHC bound (95% CL)	CEPC/FCC-ee
$BR(Z \to \mu e)$	1.7×10^{-6} [2]	7.5×10^{-7} [3]	$10^{-8} - 10^{-10}$
$BR(Z \to \tau e)$	9.8×10^{-6} [2]	5.0×10^{-6} [4, 5]	10^{-9}
$BR(Z \to \tau \mu)$	1.2×10^{-5} [6]	6.5×10^{-6} [4, 5]	10^{-9}

BSM: dark matter, EWPT etc.

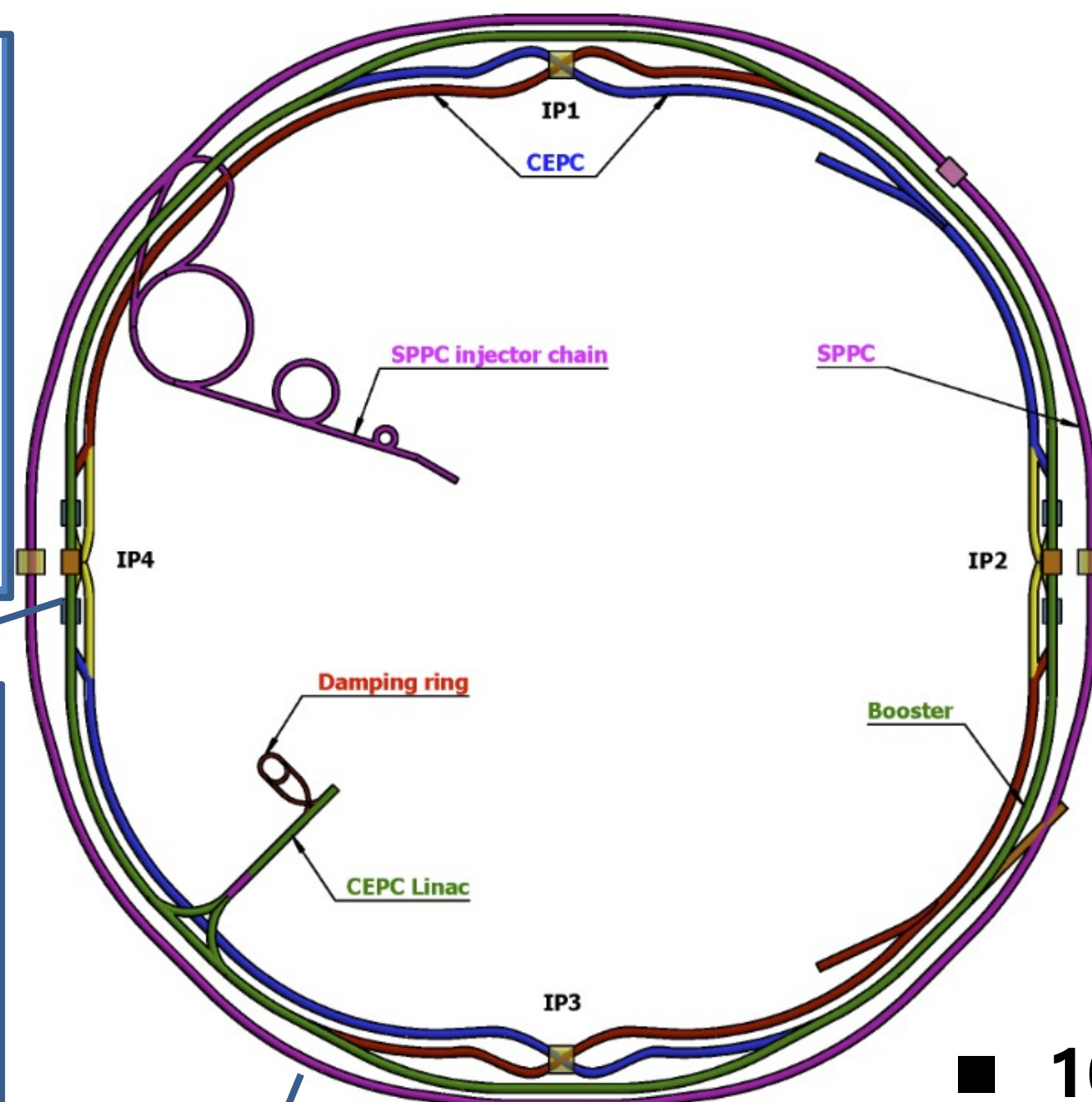
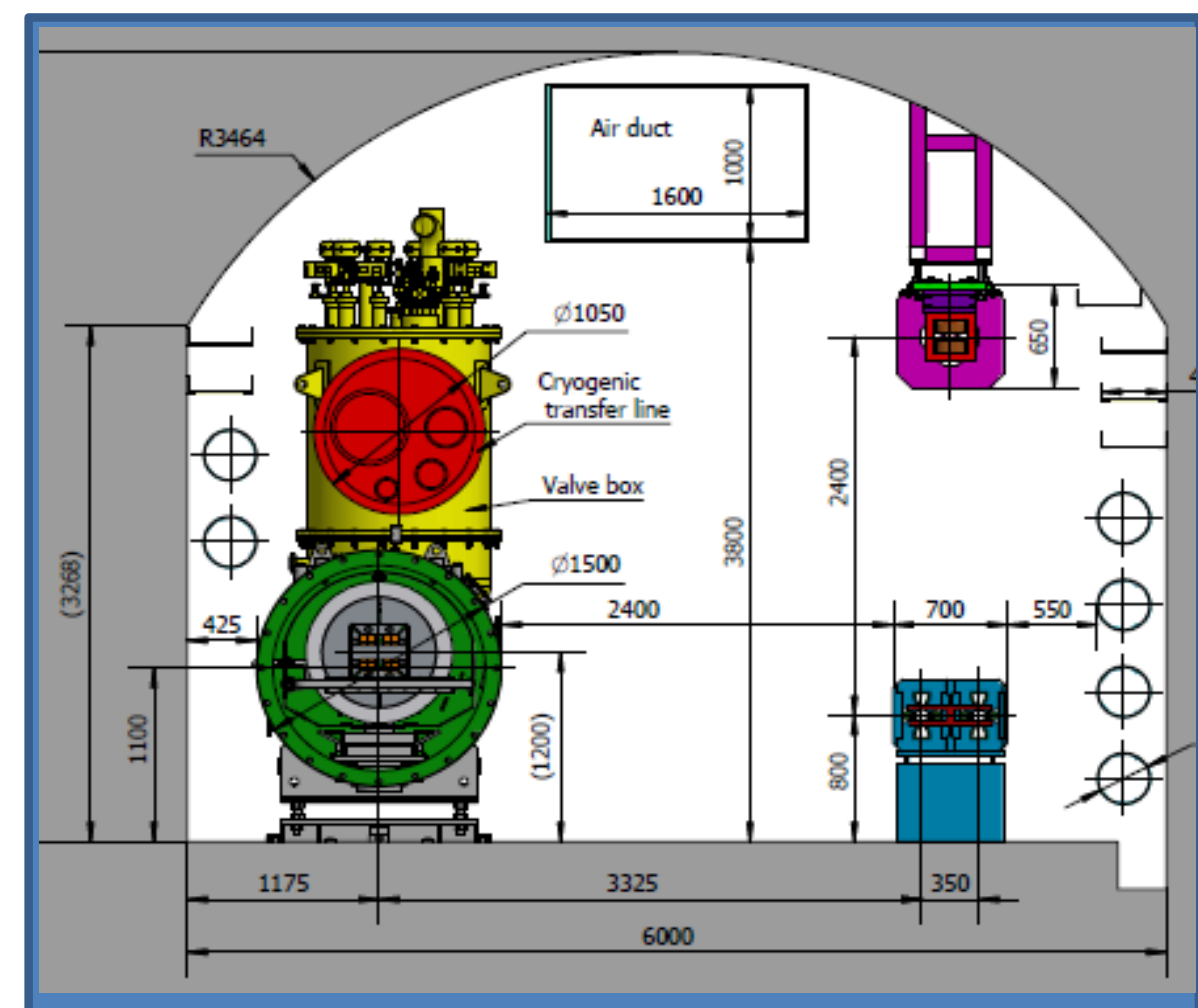
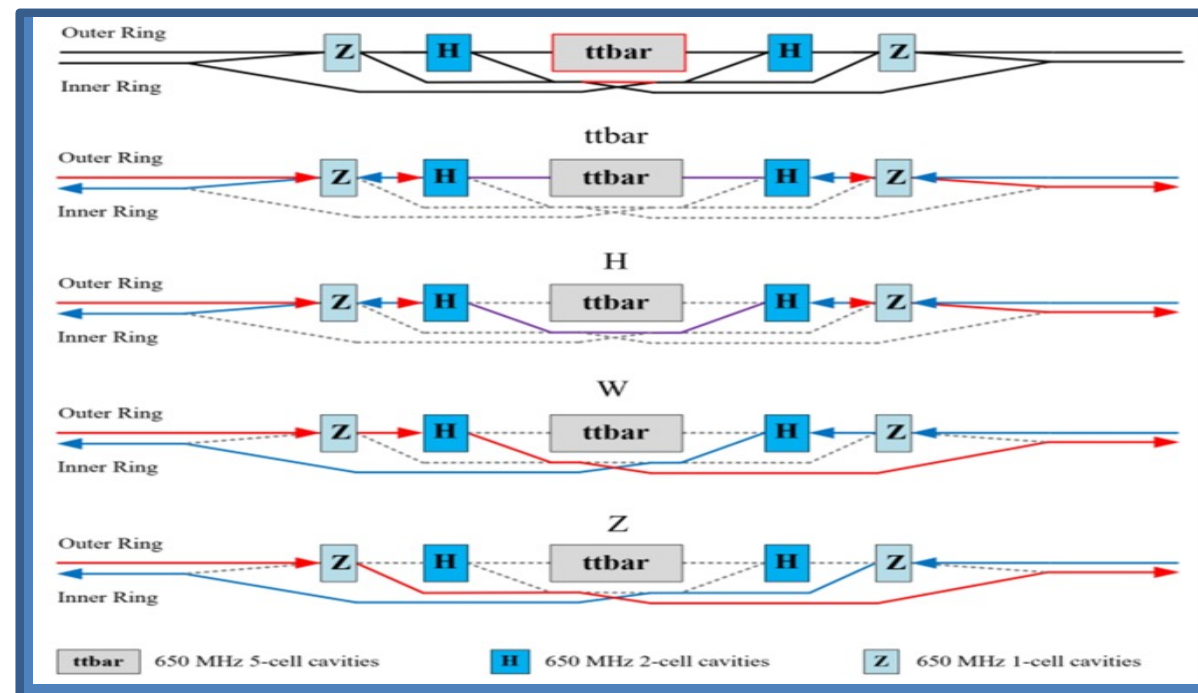


Potential to reveal new physics @10 TeV or higher



Unprecedented precisions or sensitivities: Orders of magnitude improvement or enhancement

CEPC Accelerator Design

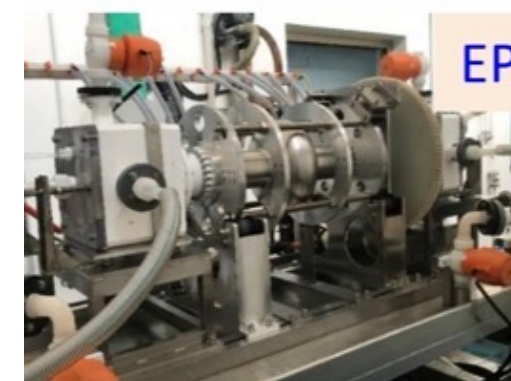
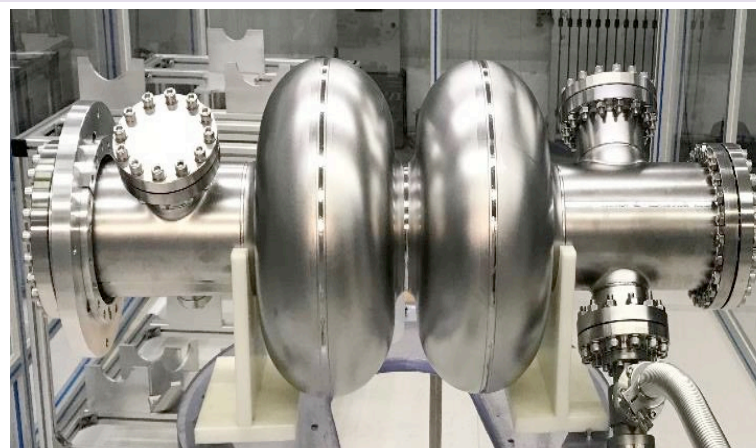
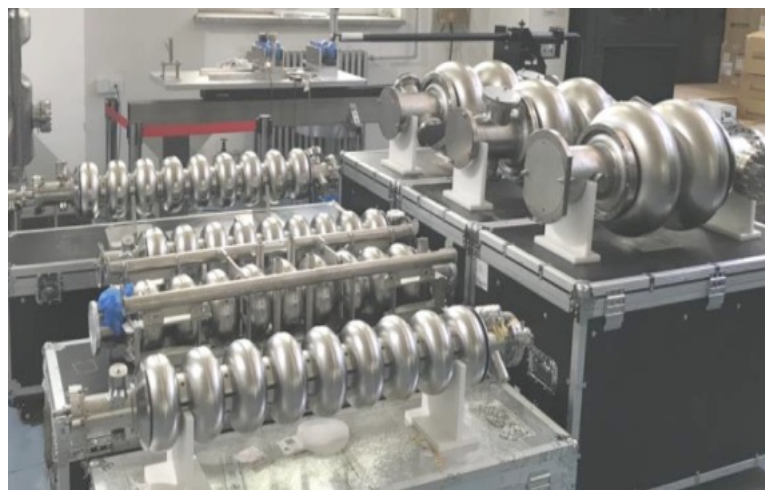


	Higgs	Z	W	$t\bar{t}$
Number of IPs	2			
Circumference (km)	100.0			
SR power per beam (MW)	30			
Energy (GeV)	120	45.5	80	180
Bunch number	268	11934	1297	35
Emittance ϵ_x/ϵ_y (nm/pm)	0.64/1.3	0.27/1.4	0.87/1.7	1.4/4.7
Beam size at IP σ_x/σ_y ($\mu\text{m}/\text{nm}$)	14/36	6/35	13/42	39/113
Bunch length (natural/total) (mm)	2.3/4.1	2.5/8.7	2.5/4.9	2.2/2.9
Beam-beam parameters ξ_x/ξ_y	0.015/0.11	0.004/0.127	0.012/0.113	0.071/0.1
RF frequency (MHz)	650			
Luminosity per IP ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	5.0	115	16	0.5

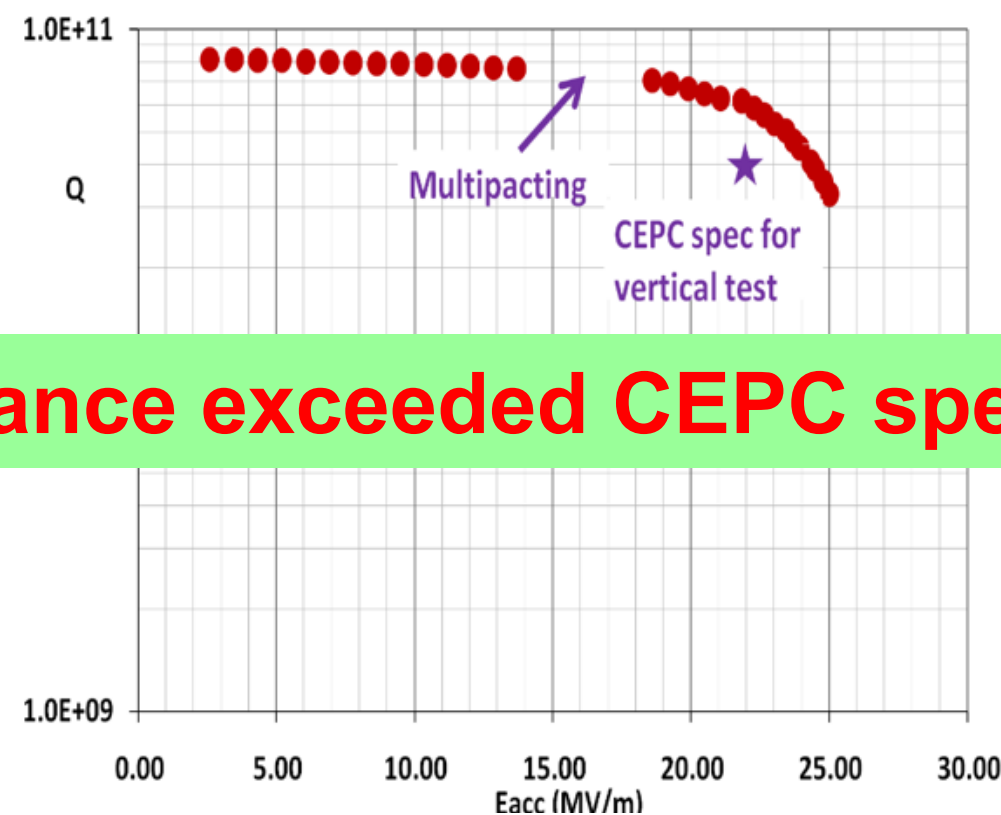
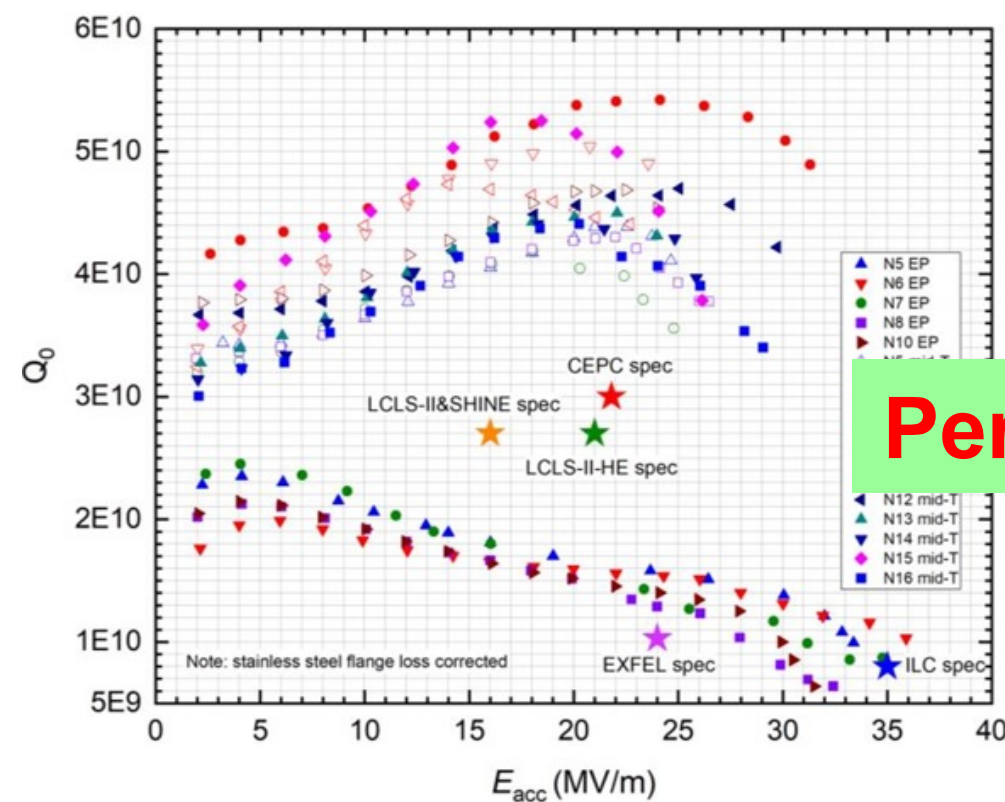
- 100 km double-ring (30 MW SR, upgradable to 50MW and ttbar)
- Switchable operation for H, Z, W and ttbar modes (bypass scheme)
- Common tunnel for CEPC and SppC

High Q SRF Cavities

- 1.3 GHz 9-cell SRF cavity (booster): $Q = 4.9E10 @ 31.0 \text{ MV/m}$
- 650 MHz 2-cell SRF cavity (collider): $Q = 6.0E10 @ 22.0 \text{ MV/m}$
- 650 MHz 1-cell SRF cavity (collider): $Q = 6.3E10 @ 31.0 \text{ MV/m}$

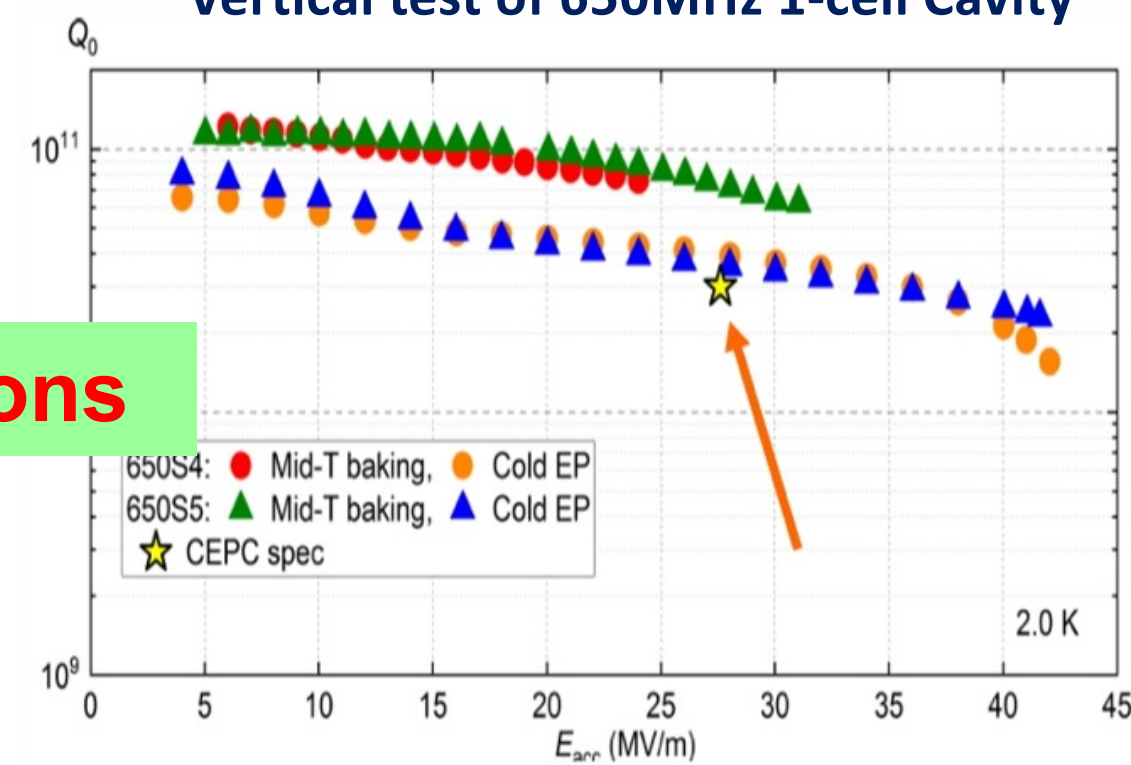


Vertical test of 650 MHz 2-cell cavity



Performance exceeded CEPC specifications

Vertical test of 650MHz 1-cell Cavity



Medium-temperature annealing adopted to reach $Q_0 = 4.9E10 @ 31.0 \text{ MV/m}$

N-infusion adopted to reach $Q_0 = 6.0E10 @ 22.0 \text{ MV/m}$

Cold-EP and Mid-T baking $Q_0 = 6.3E10 @ 31 \text{ MV/m}$

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}			

Performance exceeded CEPC specifications

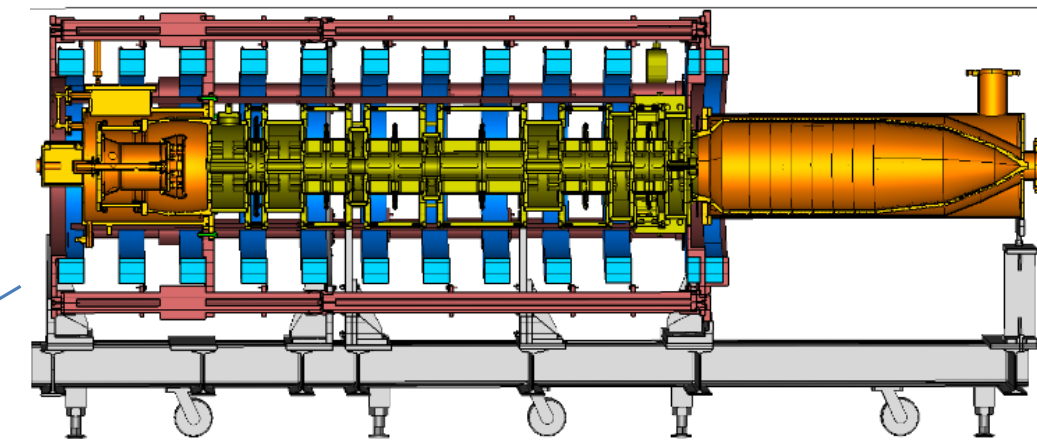


High Efficiency Klystrons

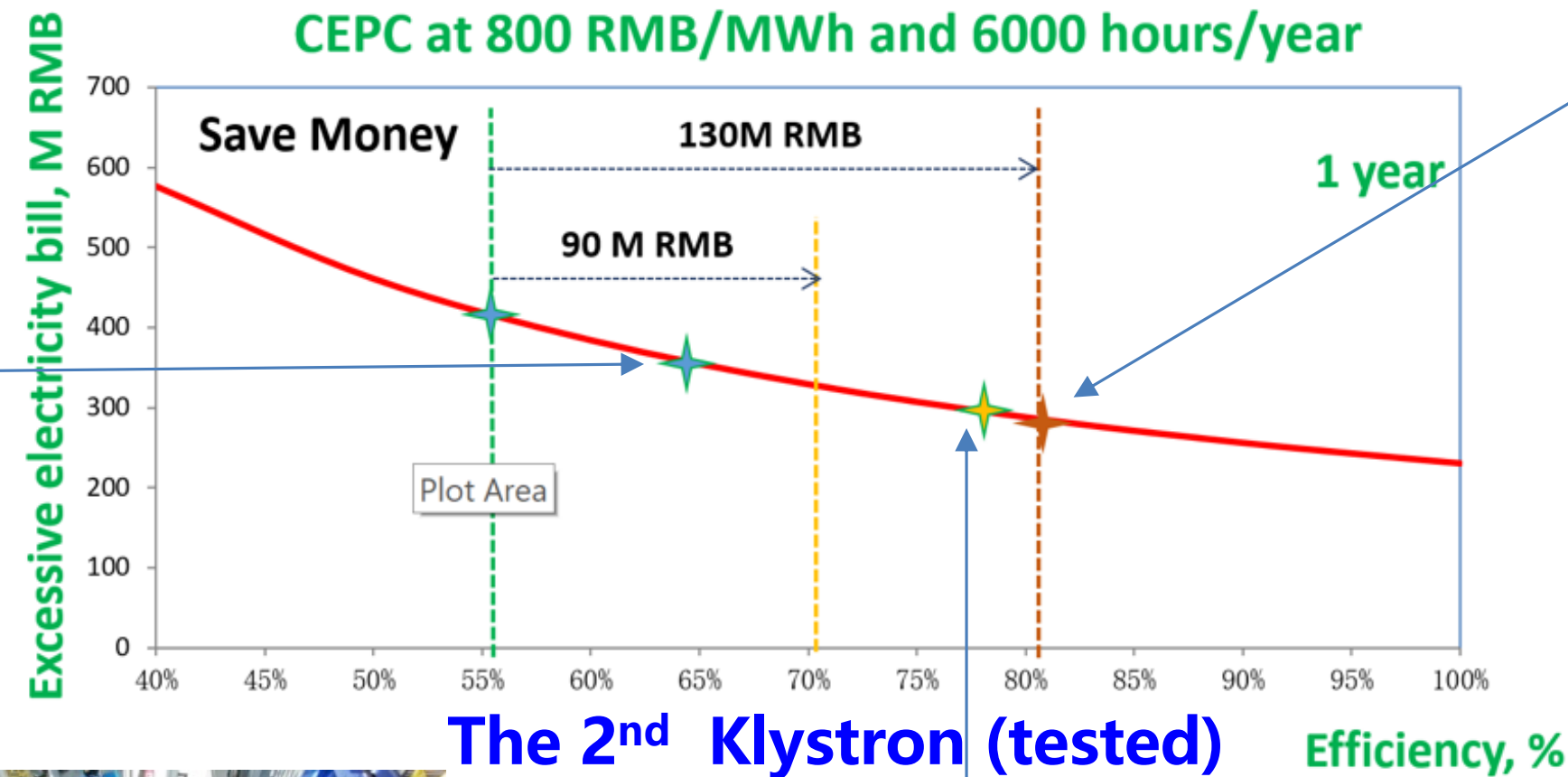
High-efficiency klystrons are key technology critical to saving power

- ❑ 1st Klystron prototype, efficiency tested ~ 62%
- ❑ 2nd Klystron prototype, efficiency tested ~ 77.2%
- ❑ 3rd Klystron prototype (MBK) under fabrication, target ~ 80%

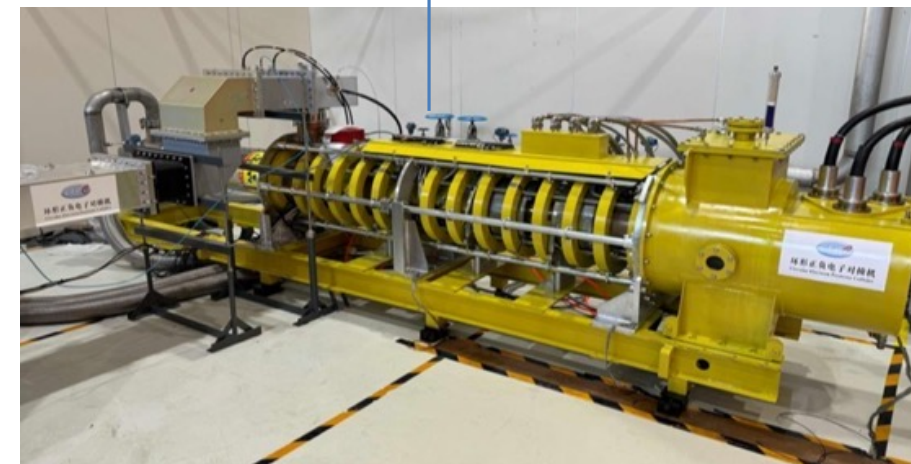
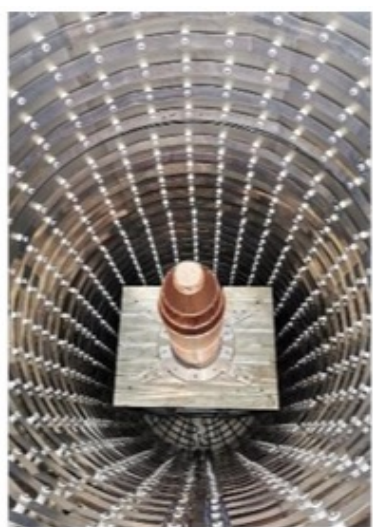
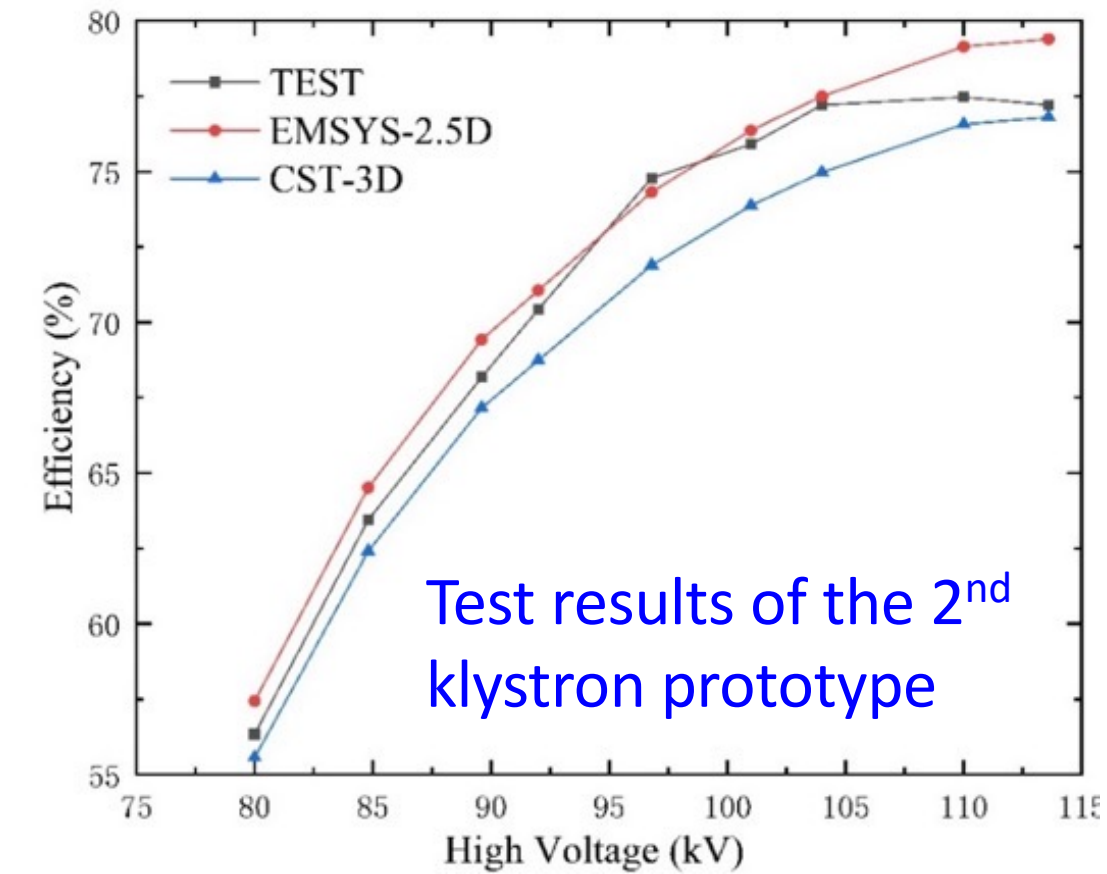
The 3rd multi-beam Klystron (MBK) under fabrication



The 1st Klystron (tested)

















The 2nd Klystron (tested)

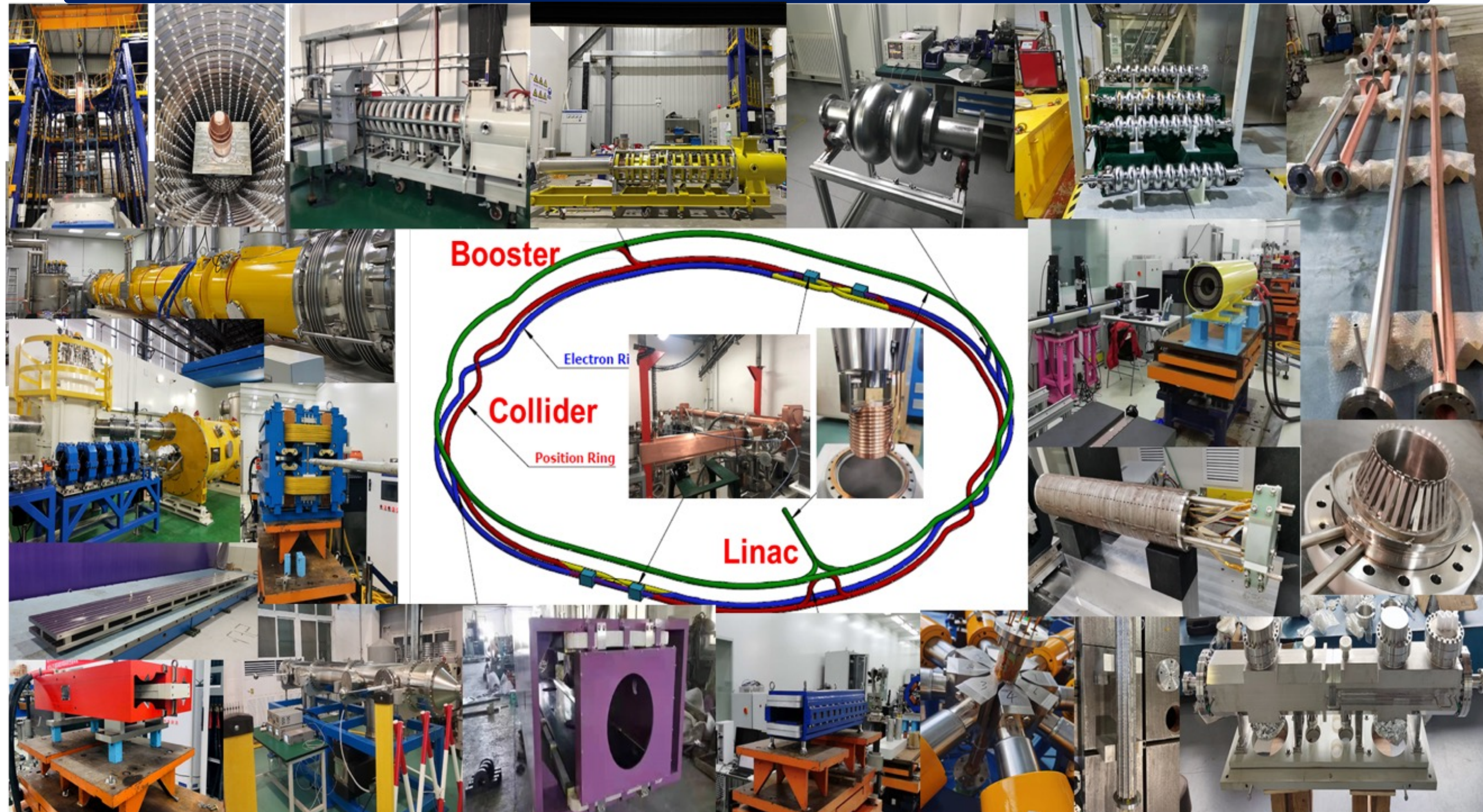


CEPC Accelerator R&D Overall Status

- CEPC accelerator key technologies R&D program has covered all key components listed in the CDR.
- 90% have met specifications. The remaining 10% to be completed by 2026.

 Specification Met
  Prototype Manufactured

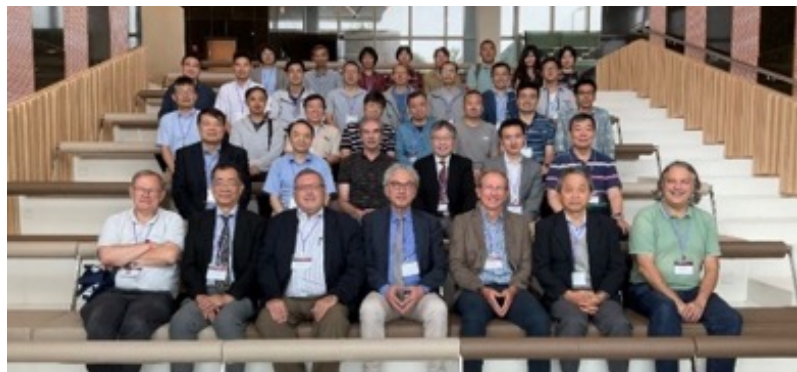
Accelerator	Ratio
 Magnets	27.3%
 Vacuum	18.3%
 RF power source	9.1%
 Mechanics	7.6%
 Magnet power supplies	7.0%
 SC RF	7.1%
 Cryogenics	6.5%
 Linac and sources	5.5%
 Instrumentation	5.3%
 Control	2.4%
 Survey and alignment	2.4%
 Radiation protection	1.0%
 SC magnets	0.4%
 Damping ring	0.2%



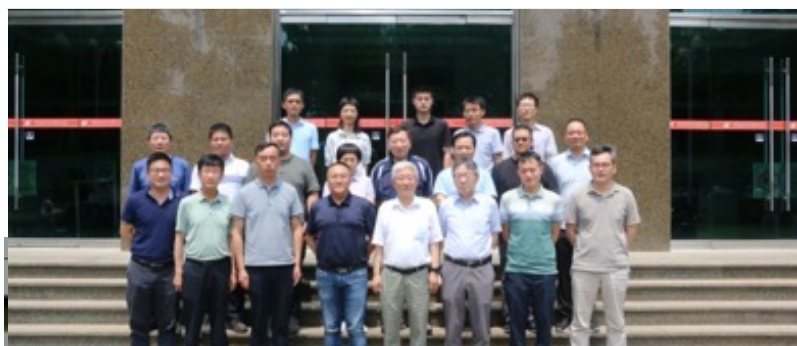
CEPC Accelerator TDR, and EDR Effort



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



CEPC Accelerator TDR released in December, 2023

IHEP-CEPC-DR-2023-01
IHEP-AC-2023-01

CEPC

Technical Design Report

Accelerator

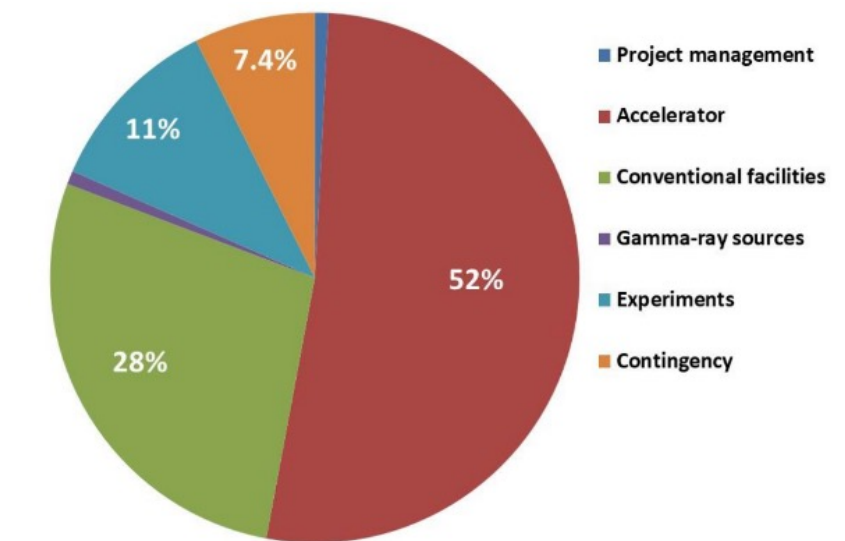
arXiv:2312.14363
1114 authors
278 institutes
(159 foreign institutes)
38 countries

The CEPC Study Group
December 2023

CEPC Project cost 36.4B RMB (~4.7B 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%

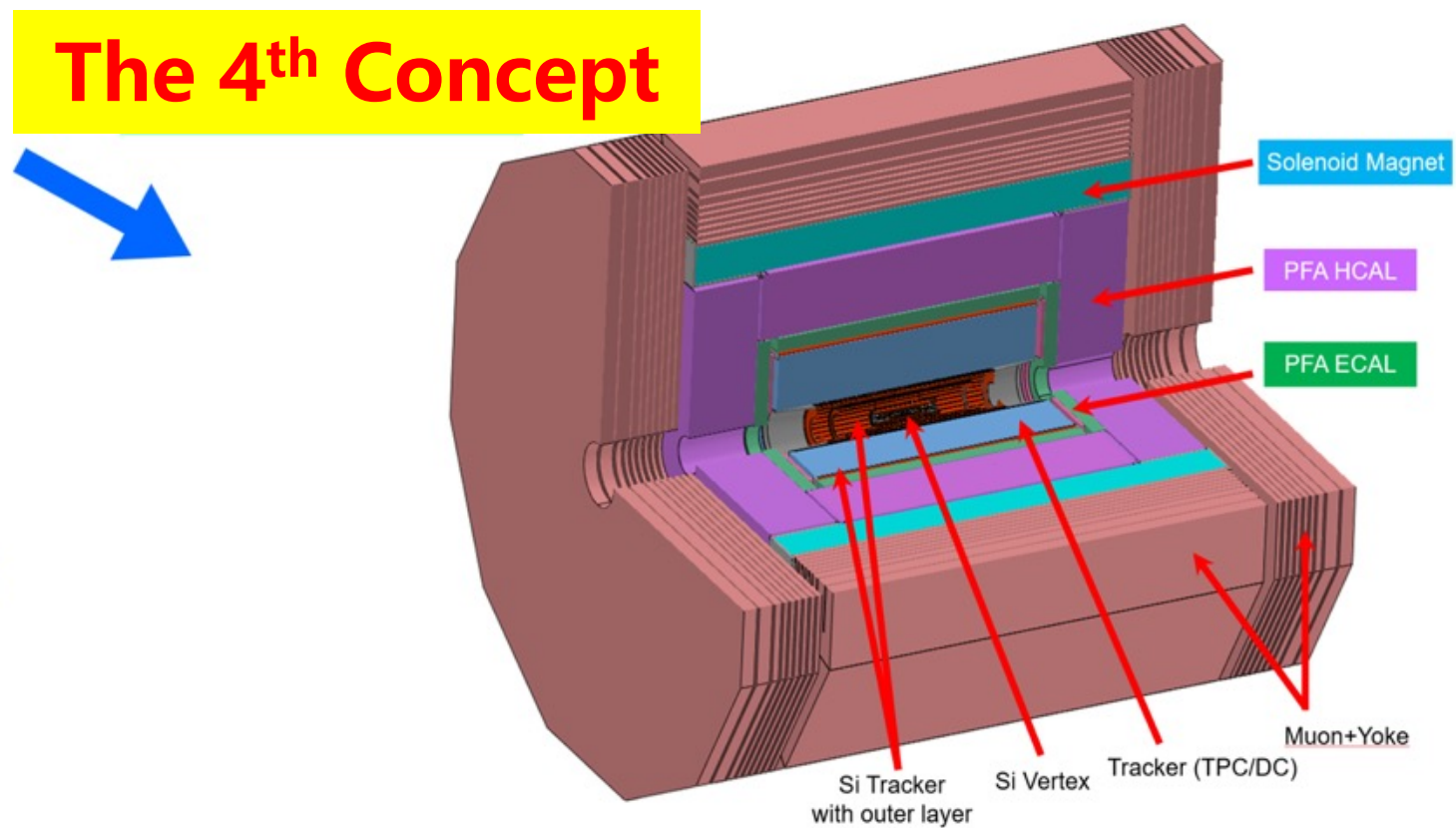
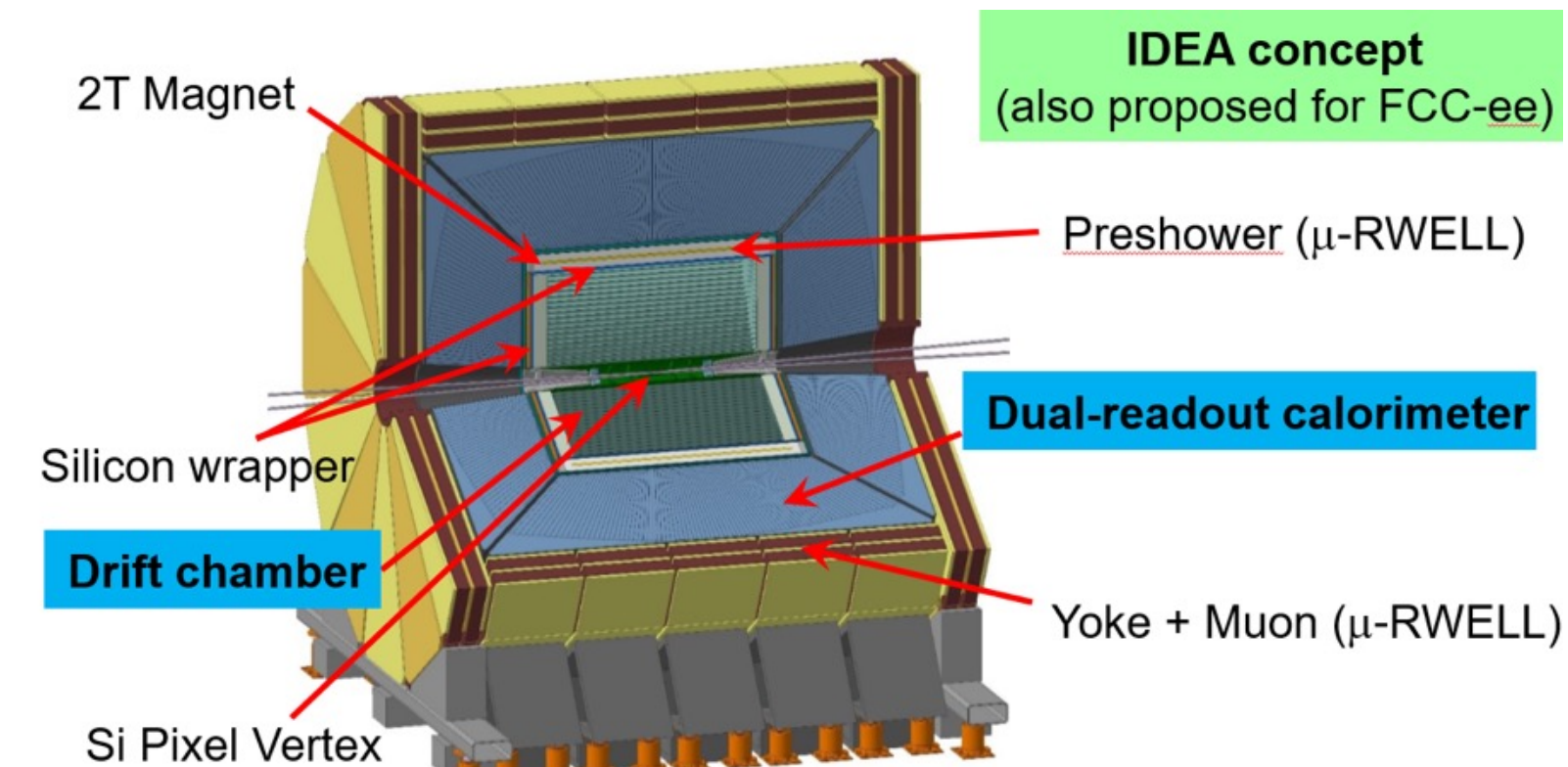
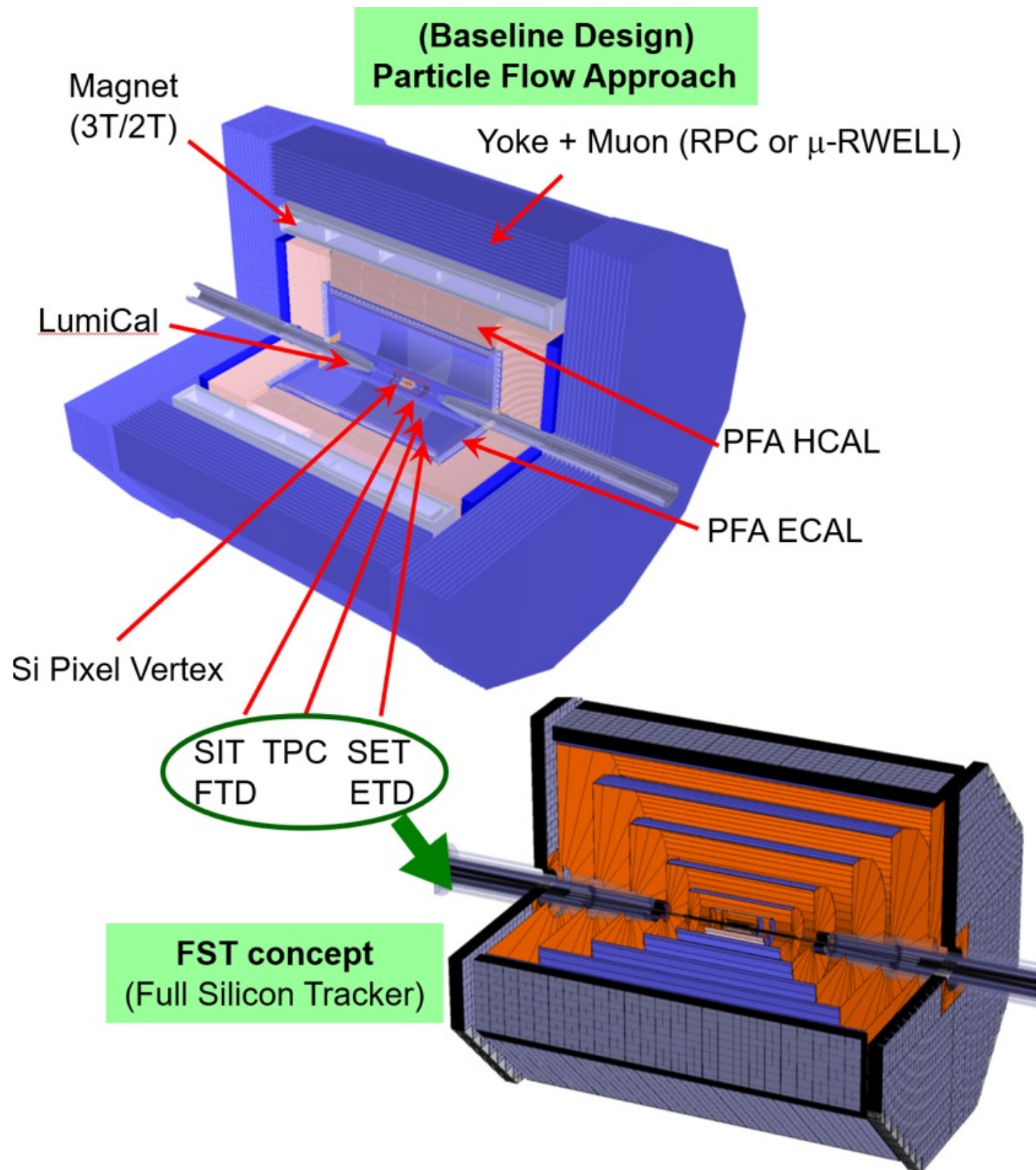


CEPC accelerator EDR effort has started in 2024, including 35 WGs focusing on designs and technologies in engineering aspects of the project construction.

CEPC Detector: CDR → New Concept

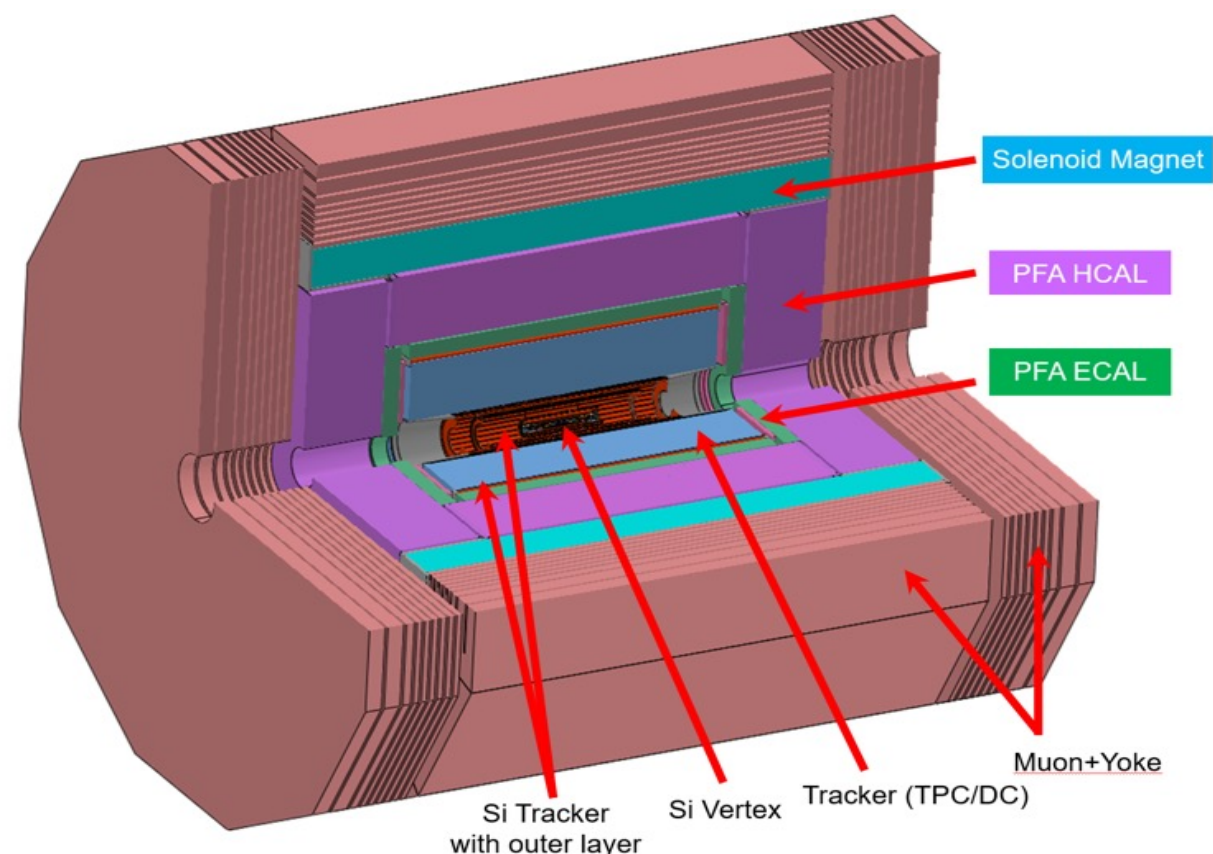
CDR detector requirements completely driven by Higgs physics

Physics process	Detector subsystem	Performance requirement
$ZH, Z \rightarrow e^+e^-, \mu^+\mu^-$ $H \rightarrow \mu^+\mu^-$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\text{GeV}) \sin^{3/2} \theta}$
$H \rightarrow b\bar{b}/c\bar{c}/g\bar{g}$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\text{GeV}) \times \sin^{3/2} \theta} (\mu\text{m})$
$H \rightarrow q\bar{q}, WW^*, ZZ^*$	ECAL HCAL	$\sigma_E^{\text{jet}}/E = 3 \sim 4\% \text{ at } 100 \text{ GeV}$
$H \rightarrow \gamma\gamma$	ECAL	$\frac{\Delta E}{E} = \frac{0.20}{\sqrt{E(\text{GeV})}} \oplus 0.01$



The 4th Concept Detector

CDR detector (focusing on Higgs) → The 4th concept (versatile)

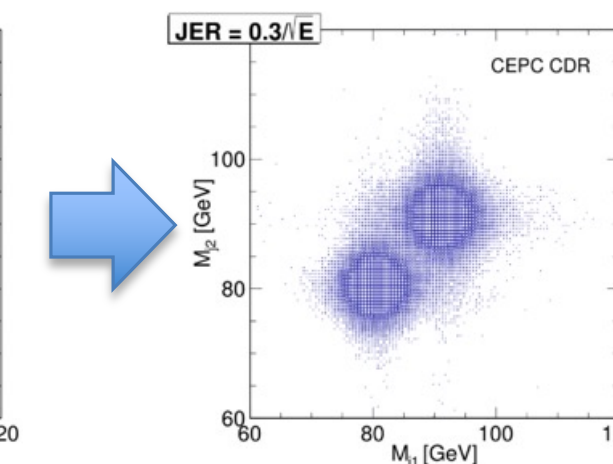
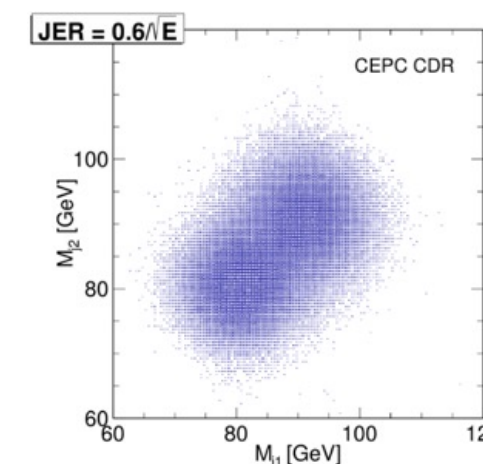
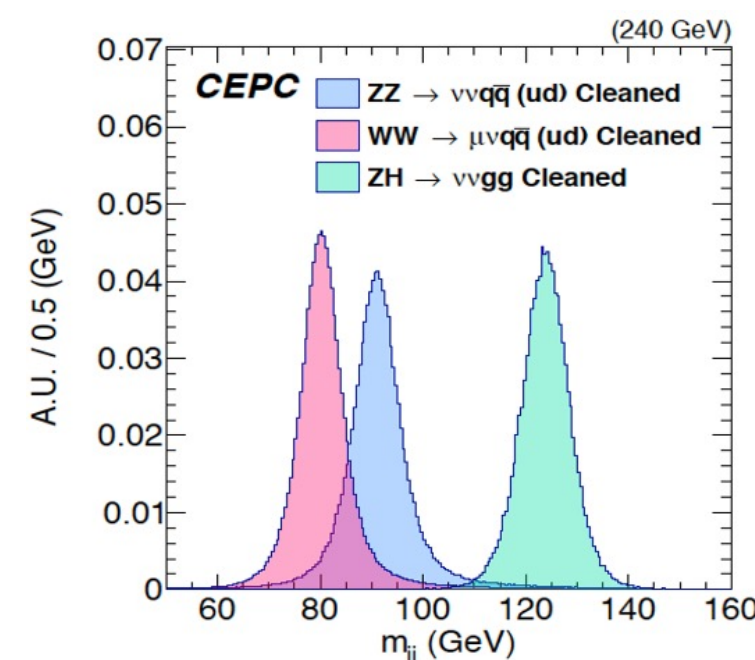


To fully meet the broad spectrum of physics demands from CEPC and fully explore the CEPC physics potential

- **Boson mass resolution 4% → 3%**
- **EM energy resolution 15% → 3%**
- **Hadron PID 3 σ up to 20 GeV/c**

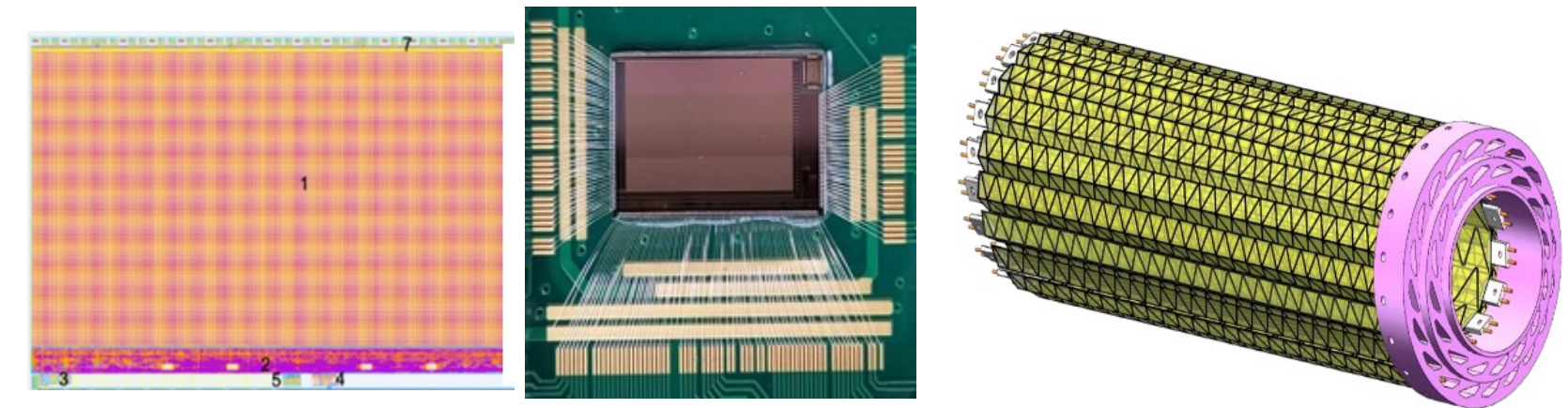
Detector	World-class level	4 th concept
PFA ECAL	~ 15-20% / \sqrt{E}	~ 3% / \sqrt{E}
PFA HCAL	~ 50-60% / \sqrt{E}	~ 40% / \sqrt{E}

- Silicon trackers (outer timing layer) combined with TPC/DC
Better tracking & PID
- Highly-granular crystal ECAL
PFA & high EM resolution
- Scintillating glass sampling HCAL
Better hadron energy resolution

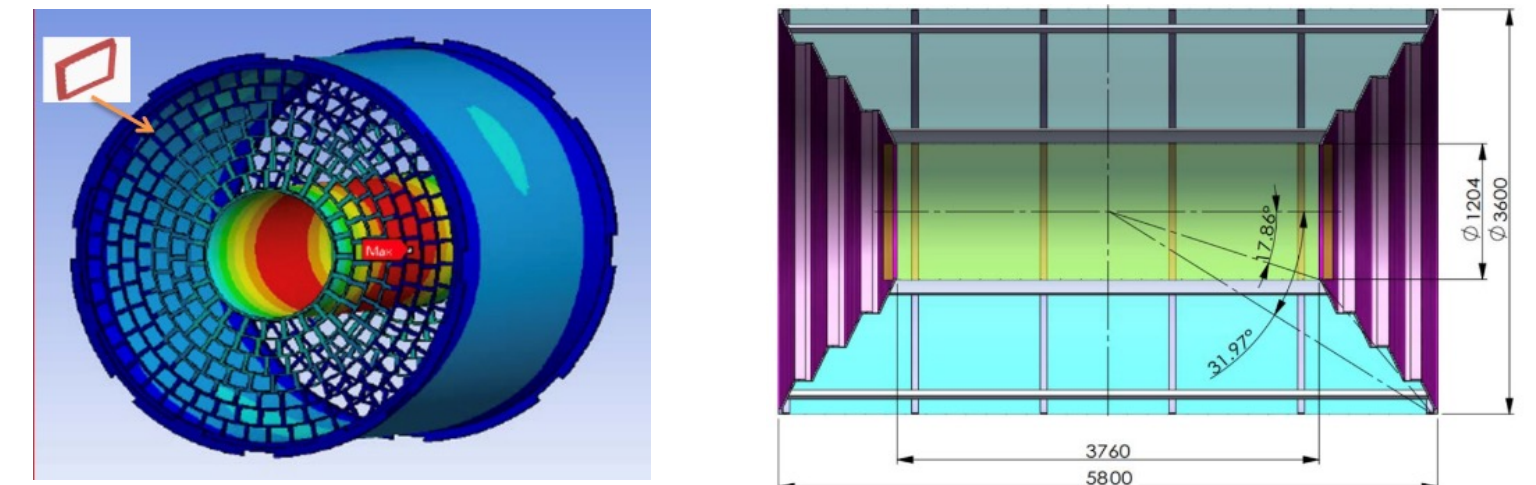


Technologies and Requirements

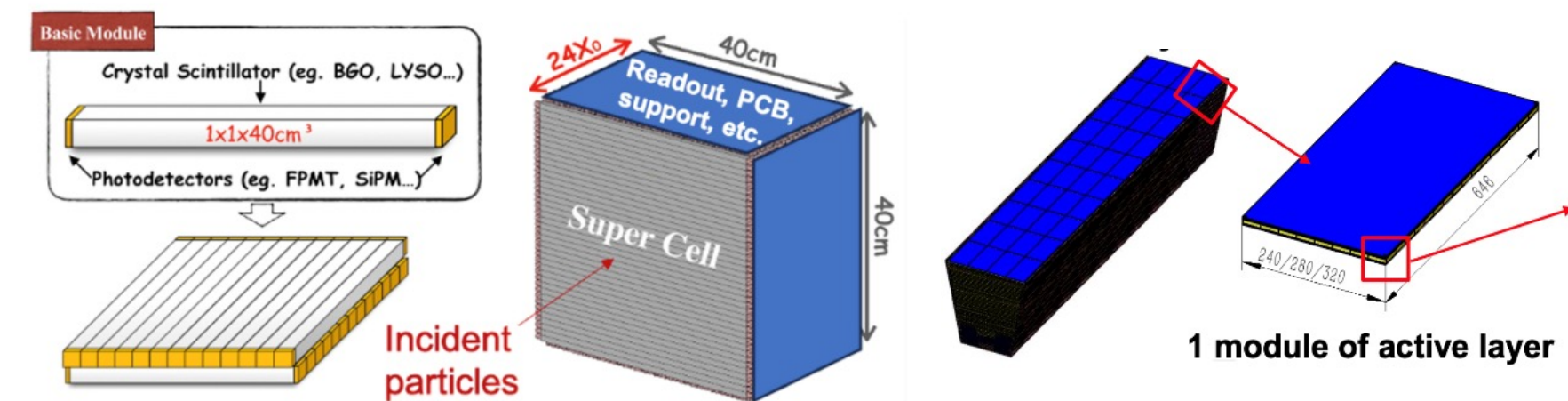
Detector	Technology	Performance Requirements
Silicon vertex detector	MAPS chip Low-mass structure	Position resolution $\sim 3 \mu\text{m}$ Material budget $< 0.15\% X_0/\text{layer}$
Silicon tracker	Large area silicon tracker	Momentum resolution $\sigma\left(\frac{1}{p_T}\right) \sim 2 \times 10^{-5} \oplus \frac{1 \times 10^{-3}}{p \sin^{3/2} \vartheta} (\text{GeV}^{-1})$
Gaseous tracker	High precision dE/dx (dN/dx) measurement	$\sim 2\%$
TOF detector	Silicon timing detector	Time resolution $\sim 30 \text{ ps}$
ECAL	4D crystal ECAL	EM energy resolution $\sim 3\%/\sqrt{E(\text{GeV})}$ Granularity $2\text{cm} \times 2\text{cm} \times 2\text{cm}$
Magnet	Low mass HTS magnet	B field $2\text{-}3 \text{ T}$ Thickness $< 150 \text{ mm}$ Material budget $< 1.5 X_0$
HCAL	Scintillator glass HCAL with high granularity	Hadron energy res $\sim 40\%/\sqrt{E(\text{GeV})}$ Jet energy resolution $\sim 30\%/\sqrt{E(\text{GeV})}$



MAPS and low-mass system



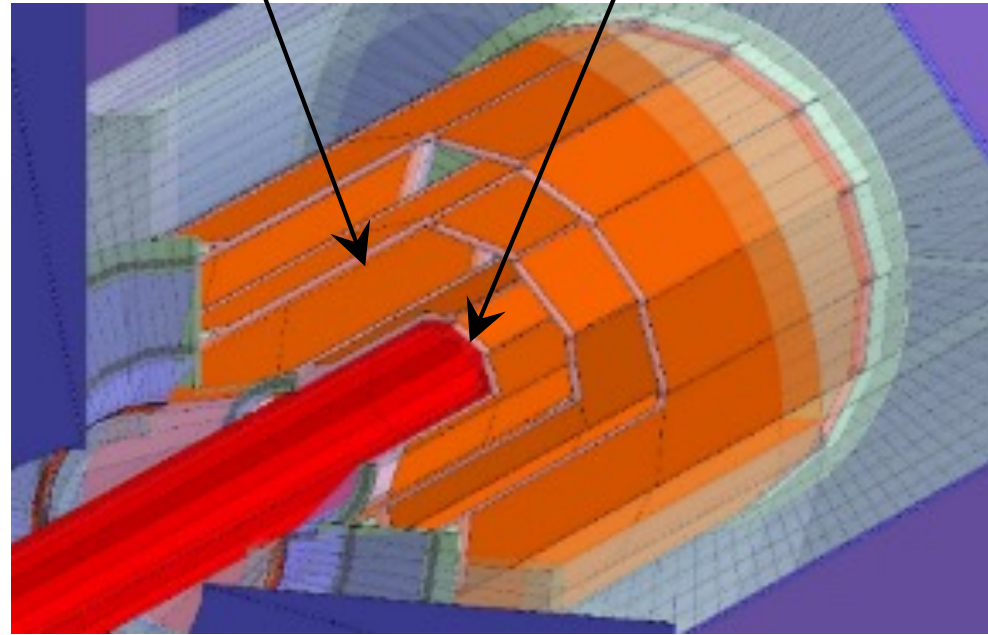
Large volume TPC or drift chamber



4D Crystal ECAL & Glass HCAL

MAPS and Detector Prototype

2 layers / ladder $R_{in} \sim 16$ mm



Goal: $\sigma(IP) \sim 5 \mu\text{m}$ for high P tracks

CDR design specifications

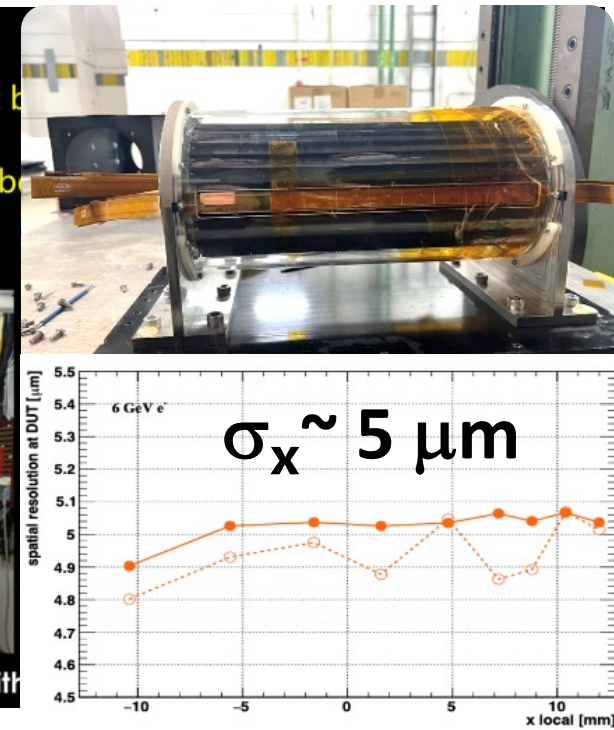
- Single point resolution $\sim 3 \mu\text{m}$
- Low material (0.15% X_0 / layer)
- Low power ($< 50 \text{ mW/cm}^2$)
- Radiation hard (1 Mrad/year)

Silicon pixel sensors developed in 5 series:
JadePix, CPV, TaichuPix, Arcadia, COFFEE

Vertex detector prototype with Taichu chips and its beam test

Test beam @ DESY

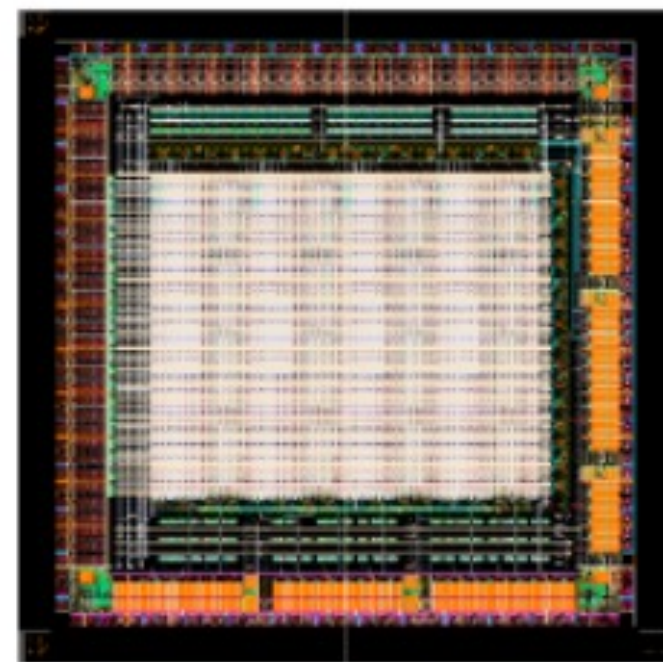
- 2nd testbeam: April 11-23 2023 DESY test beam
- Vertex detector prototype testbeam
- 1st testbeam: Dec 12-22 2022 DESY test beam
- TaichuPix Beam Telescope testbeam



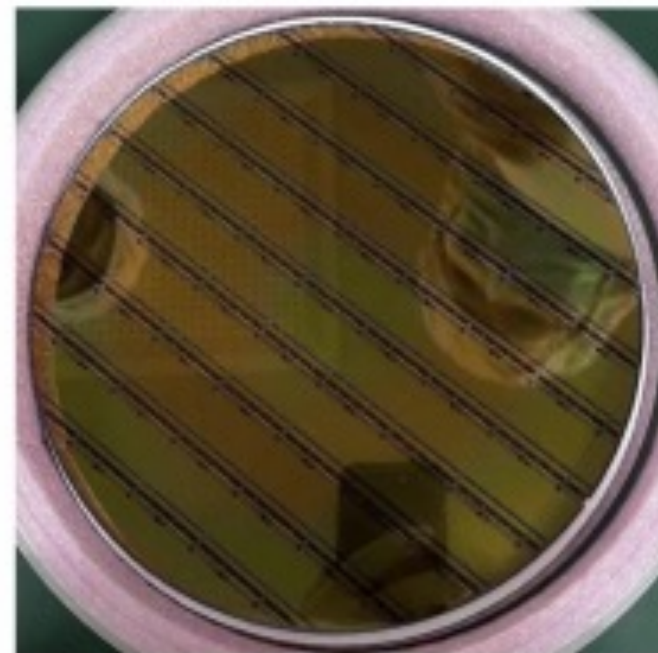
JadePix-3 pixel size $\sim 16 \times 23 \mu\text{m}^2$,
Tower-Jazz 180nm CiS process,
 $\sigma_x \sim 5 \mu\text{m}$, 53 mW/cm^2



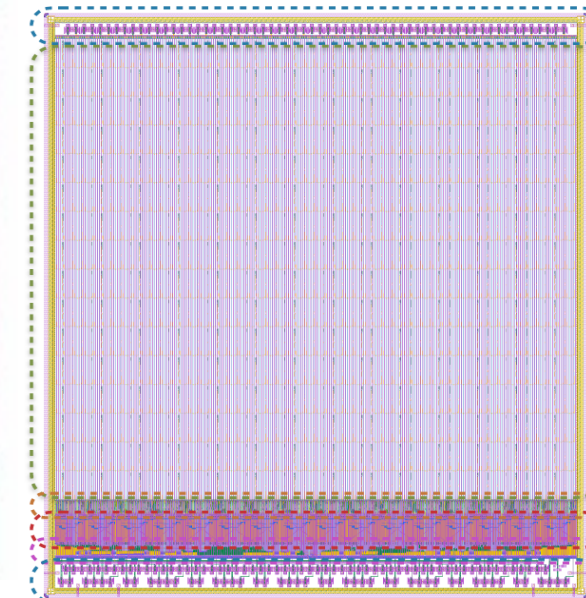
CPV4 (SOI-3D), 64×64 array
 $\sim 21 \times 17 \mu\text{m}^2$ pixel size



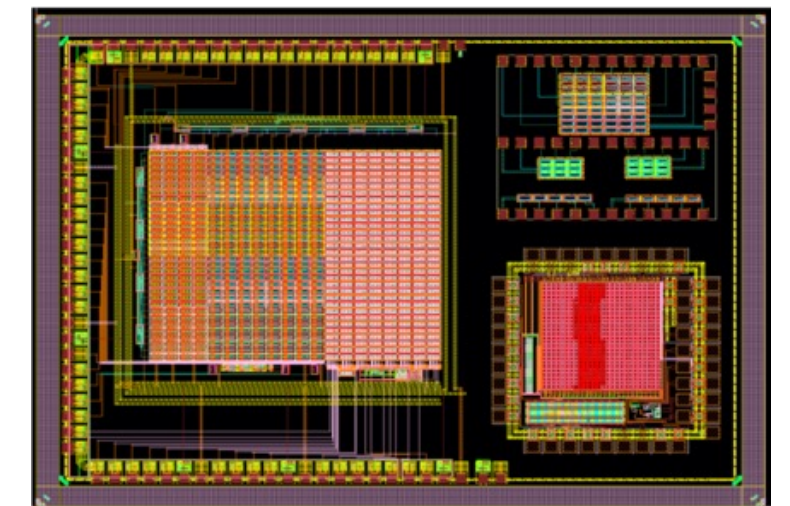
TaichuPix-3, FS $2.5 \times 1.5 \text{ cm}^2$
 $25 \times 25 \mu\text{m}^2$ pixel size



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



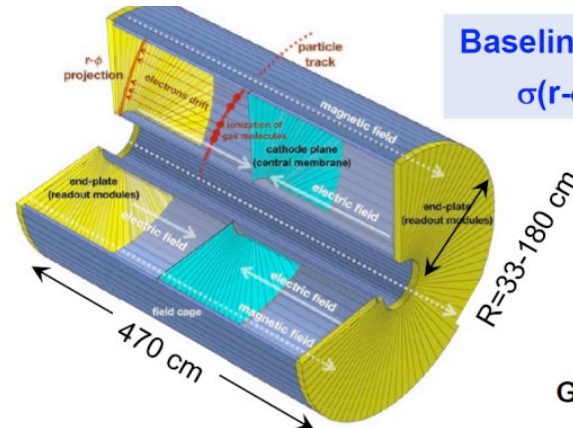
COFFEE for a CEPC
tracker using SMIC 55nm
HV-CMOS process



TPC, DC, PFA Calorimeters

TPC R&D

Baseline main tracker
 $\sigma(r-\phi) \sim 100 \mu\text{m}$



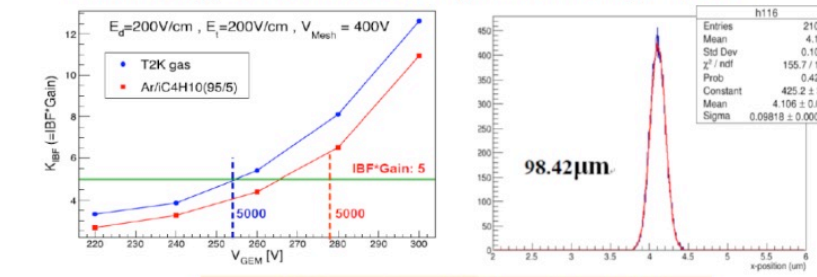
$R=33\text{-}180 \text{ cm}$
 470 cm

GEM-MM cathode TPC Prototype + UV laser beams

MOST 1 (IHEP+THU)
65 nm CMOS ASIC
Power < 2.5 mW/ch

Test of Prototype TPC

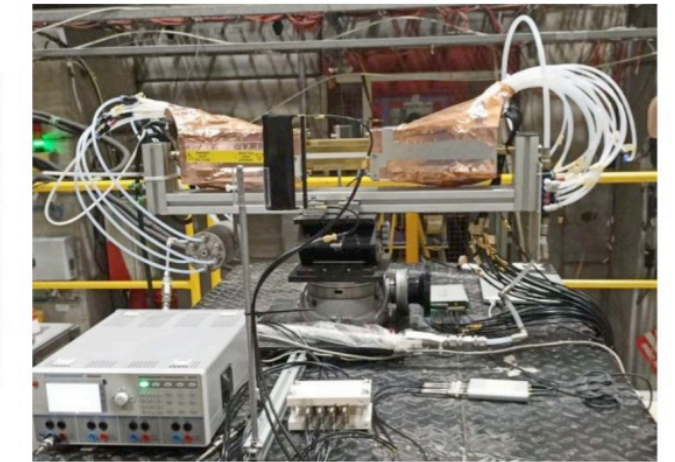
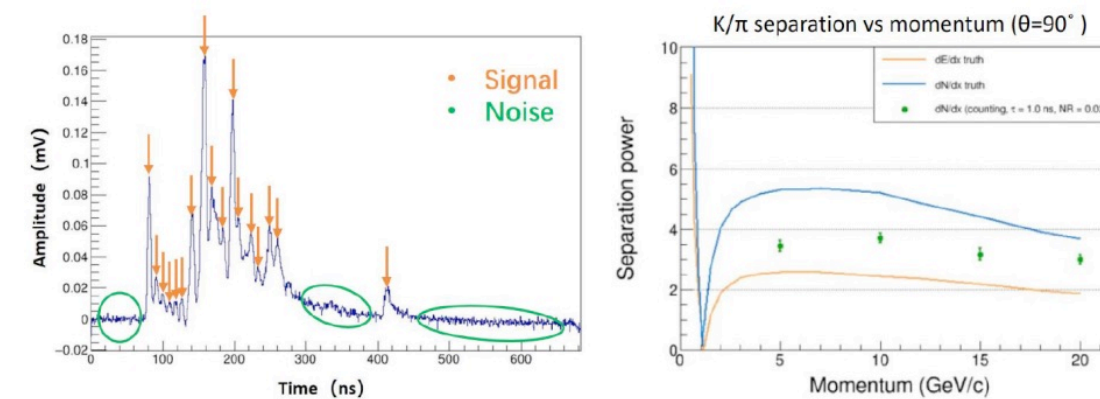
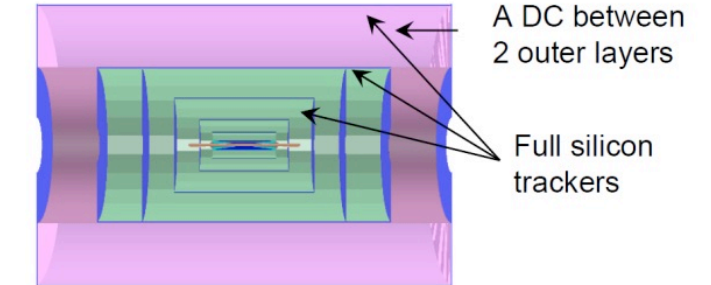
Challenge: Ion backflow (IBF) affects the resolution. It can be corrected by a laser calibration at low luminosity, but difficult at high luminosity Z-pole.



$\sigma_r < 100 \mu\text{m}$ for drift length of 27cm

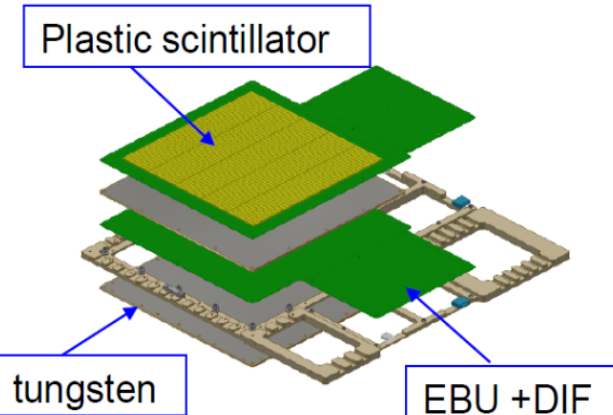
Drift Chamber R&D

- Goal: $3\sigma \pi/K$ separation up to $\sim 20 \text{ GeV/c}$.
- 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



Sci-W ECAL Prototype (32-layer, 6720 chs)



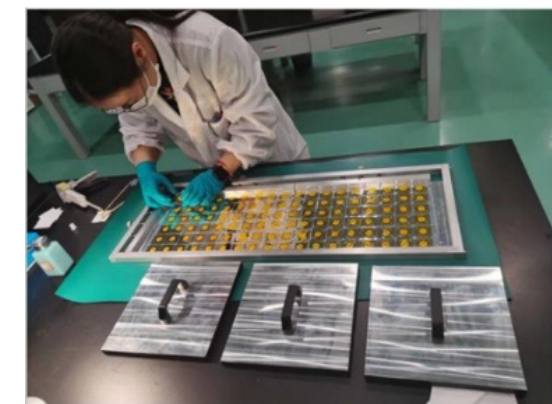
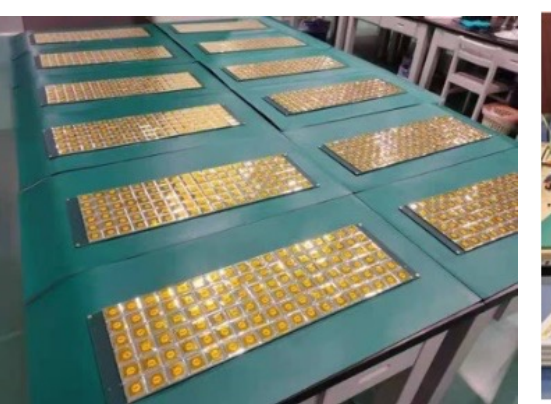

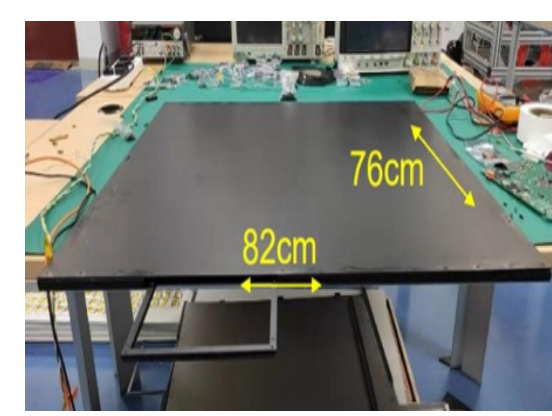


Plastic scintillator
 tungsten
 EBU + DIF



Sci-ECAL prototype

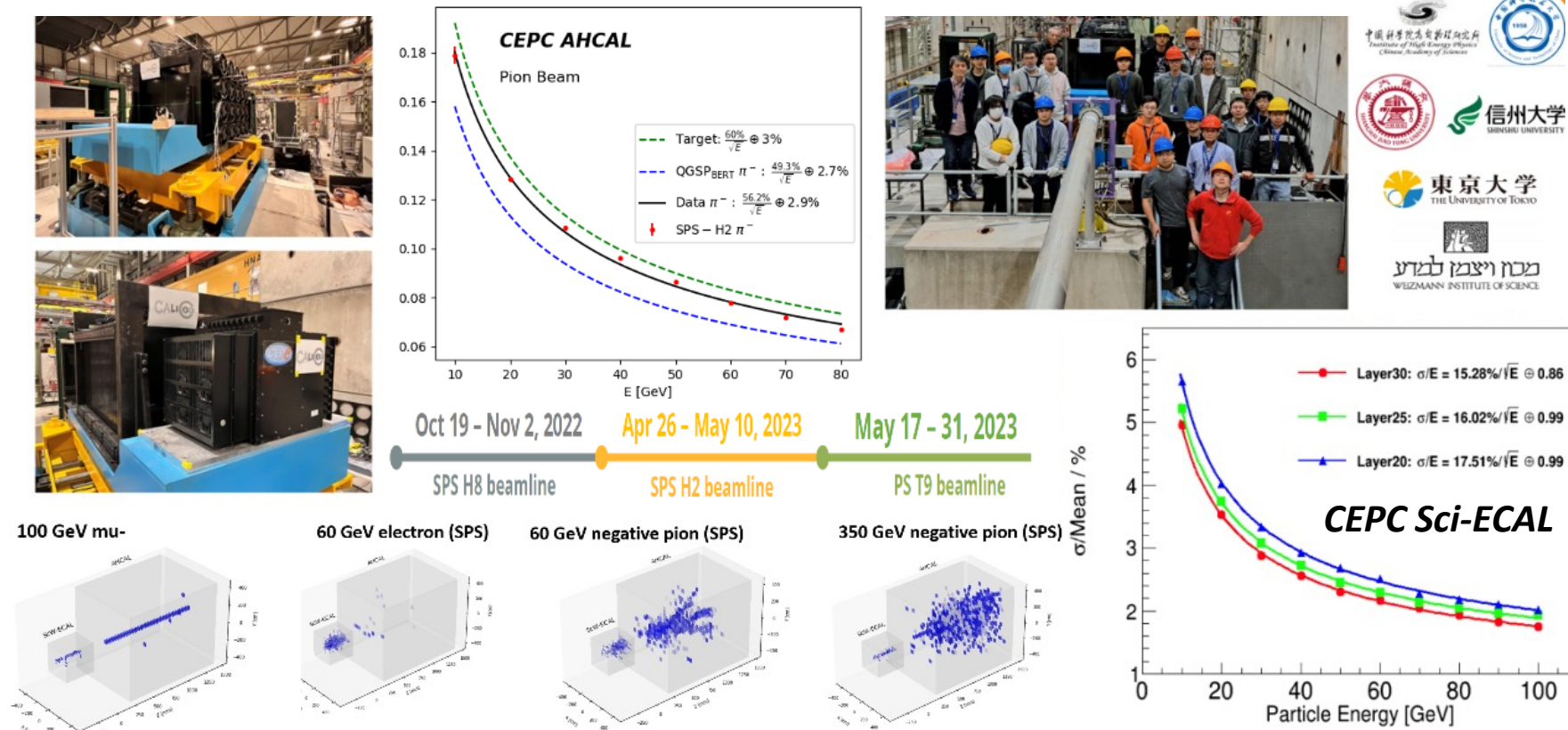



Sci-Fe AHCAL Prototype (40-layer, 12960 chs)

More on Calorimeters

Beam tests of Sci-W ECAL and Sci-Fe AHCAL Prototypes at CERN in 2022 & 2023



PFA DHCAL R&D

HCAL
 Steel
 Analog: Scintillator AHCAL
 Digital: RPC, MPGD SDHCAL

SDHCAL-GRPC (1.3 m³, IPNL)
 JINST 15, P10009 (2020)
 JINST 17, P07017 (2022)

RPWELL (50x50cm², WIS+IIT, Israel)

MOST 1: RPC and MPGD (RWELL) R&D, MIP Eff > 95%
 GRPC 1m x 1m (SJTU) JINST 16, P12022 (2021)
 RWELL 0.5m x 1m (USTC+IHEP)

R&D Plan: 5-D SDHCAL (X, Y, Z, E, Time) - MRPC + fast timing PETIROC ASIC (~40 ps)

Top steel plate
 Electronics
 Bottom steel plate

JTAG
 UART
 Ethernet
 ZCU102
 DIF Card
 FE Board

SJTU
 IPNL
 IJCLab
 OMEGA
 CIEMAT

FE Board
 128 pads with the cell size 5cm x 5cm

PFA crystal ECAL designs and simulation

Goal

- Boson Mass Resolution < 4%
- Better BMR than ScW-ECAL
- Much better sensitivity to γ/e , especially at low energy.

Bench Test

Full Simulation Studies + Optimizing PFA for crystals

Performance with photons
 Reconstructed Mass of Higgs
 H $\rightarrow \gamma\gamma$
 Crystal ECAL
 BMR = 1.2%
 BMR of SiW ECAL ~ 2.3%

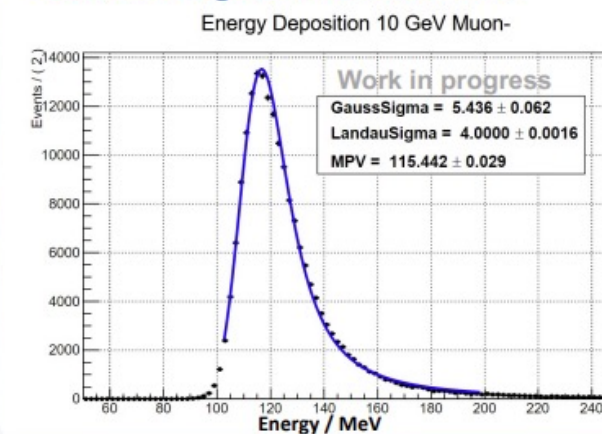
Performance with jets
 hInvMass
 H $\rightarrow gg$
 Crystal ECAL
 BMR: 3.6%

Crystal Fan Design: Fine segmentation in Z, ϕ , r

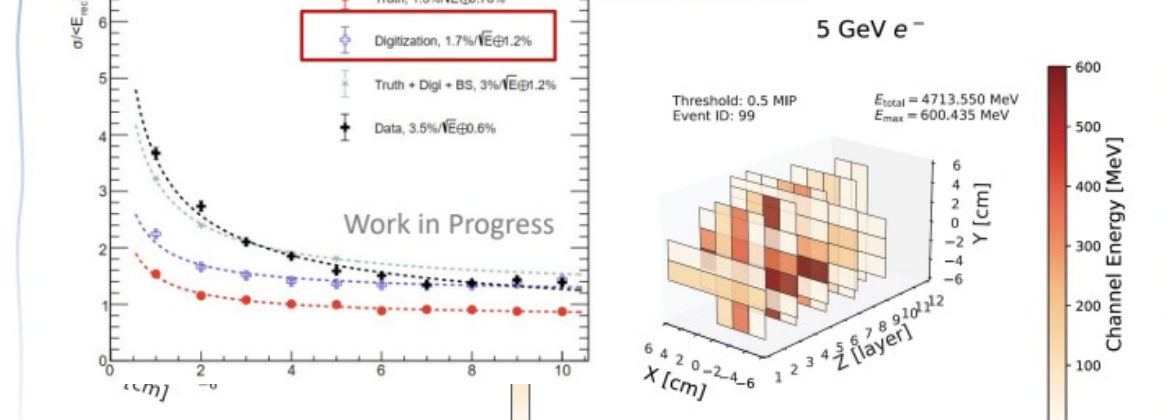
Long bars: 1 x 40 cm, super-cell: 40x40 cm²
 Timing at both ends for positioning along bar.
 Significant reduction of number of channels.

Crystal ECAL R&D

2023 CERN beam test at PS-T9
 - Successful system commissioning
 - Clear MIP signals for all channels

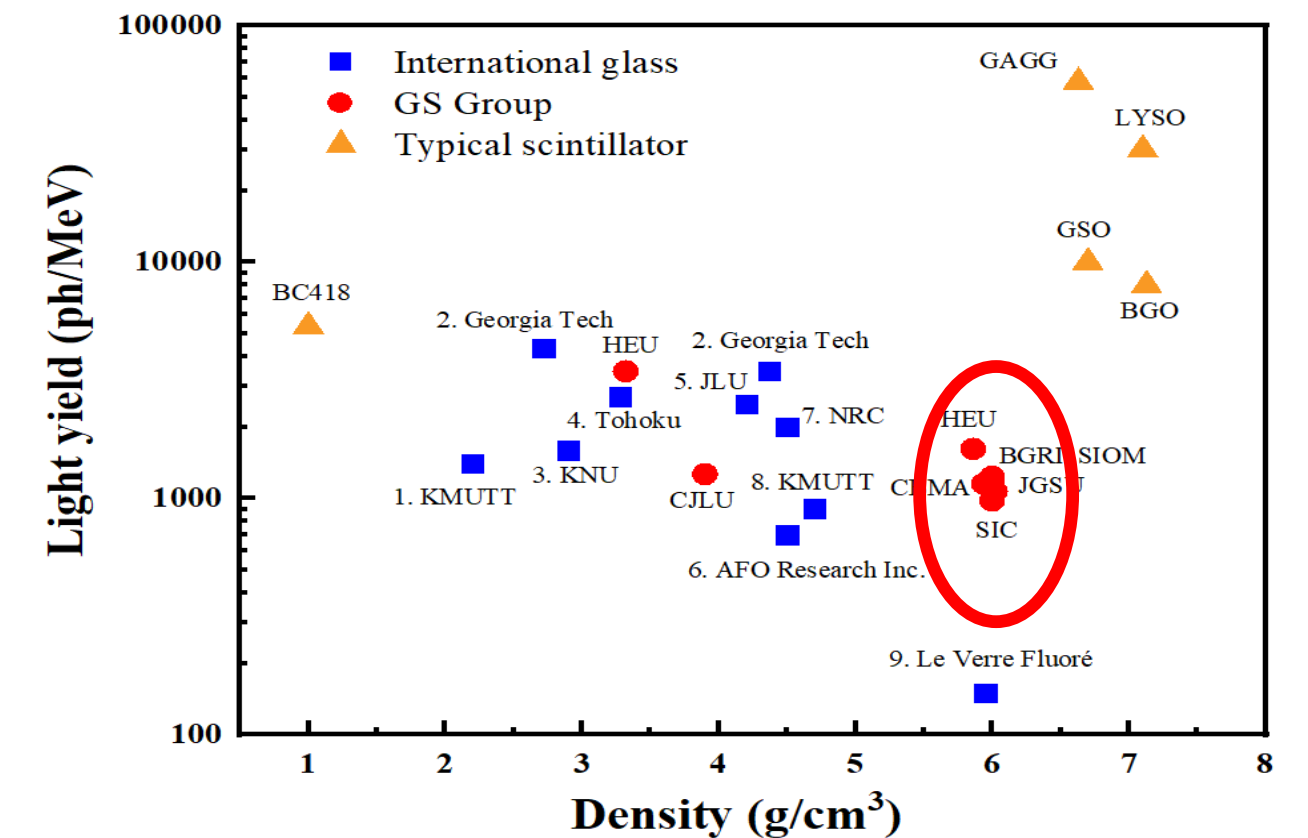
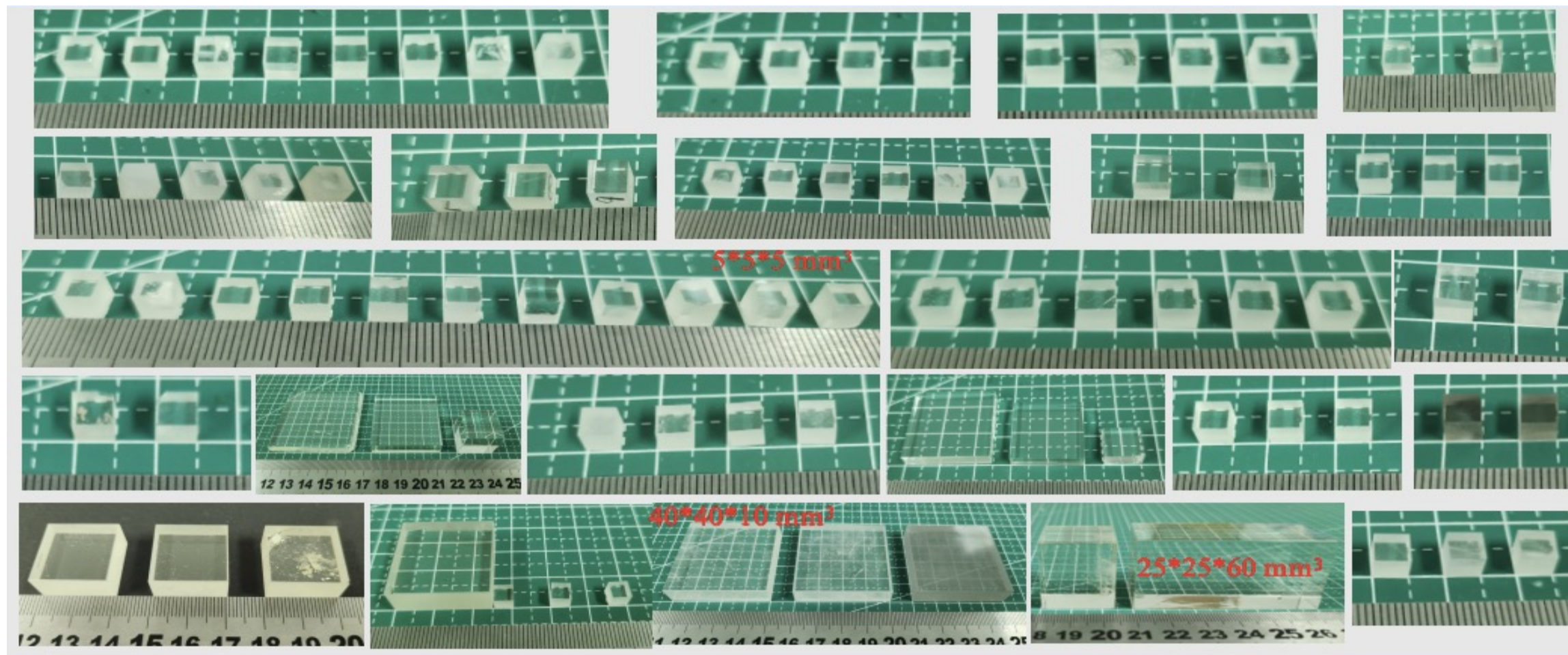
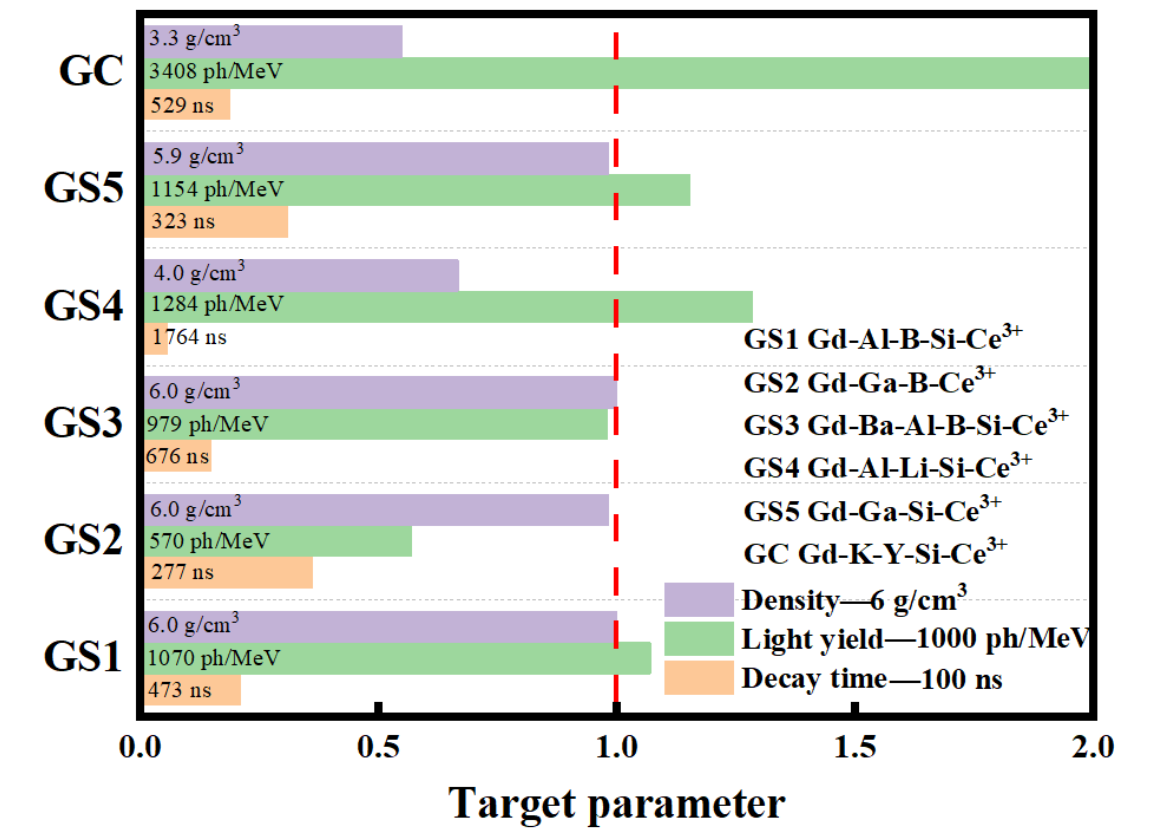


2024 CERN beam test at PS-T9 (June 24 - July 10)
 - Promising EM resolution with 1-10 GeV/c e^- beam
 - Lower profiles



Glass Scintillator R&D

- A collaboration with 11 institutes has been formed
- R&D targets: $\sim 6\text{g/cm}^3$, $\sim 1000\text{ph/MeV}$, $\sim 100\text{ns}$

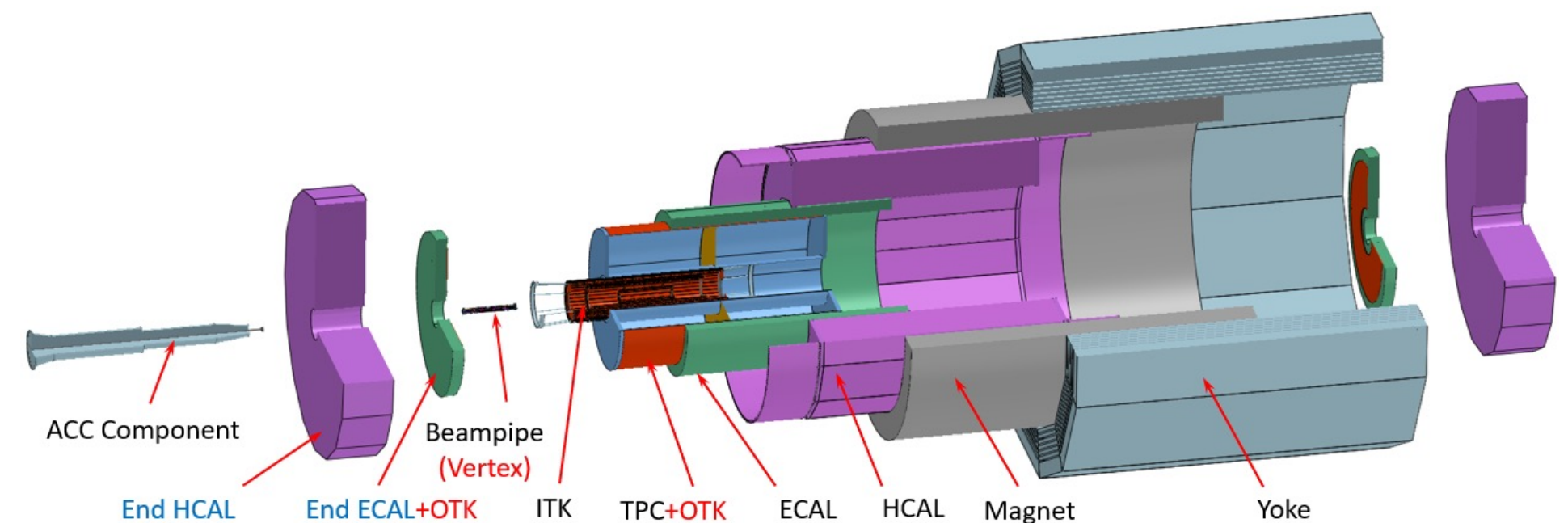


An important direction in future calorimeter development

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
	LGAD ToF	RPC	
	μ -Rwell		
Lumi	SiTrk+Crystal ECAL	HTS / LTS Magnet	MDI & Integration
	SiTrk+SiW ECAL		
	CEPC SW		
	TDAQ		

- A large number of detector technology options and R&D activities at different levels of maturity.
- Need to converge on a set of options to produce a CEPC reference detector TDR (Ref-TDR)
 - ❖ Ref-TDR effort started in Jan. 2024
 - ❖ Ref-TDR draft expected in Dec. 2024
 - ❖ Official release of Ref-TDR in Jun. 2025

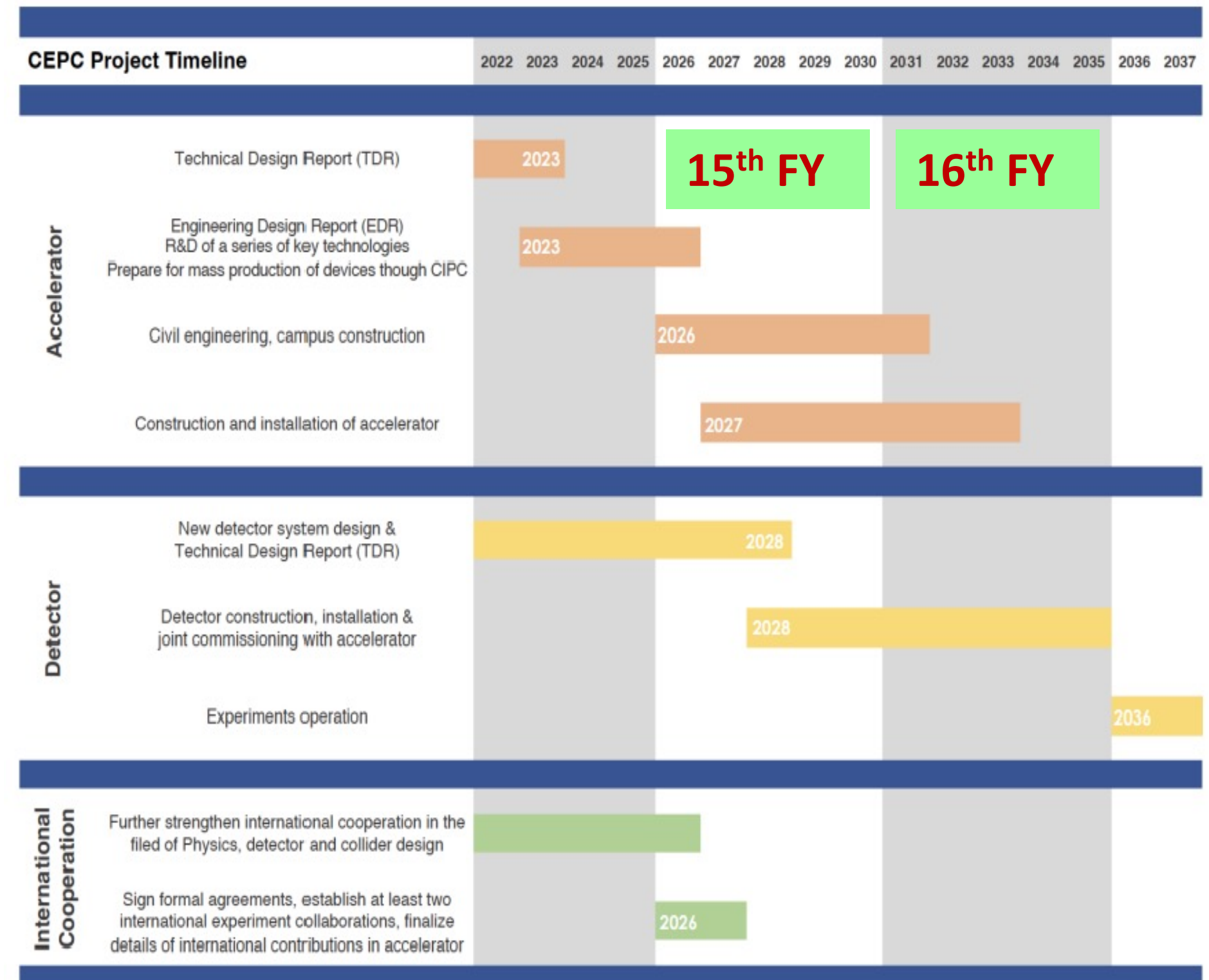


CEPC Project Planning and Schedule

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

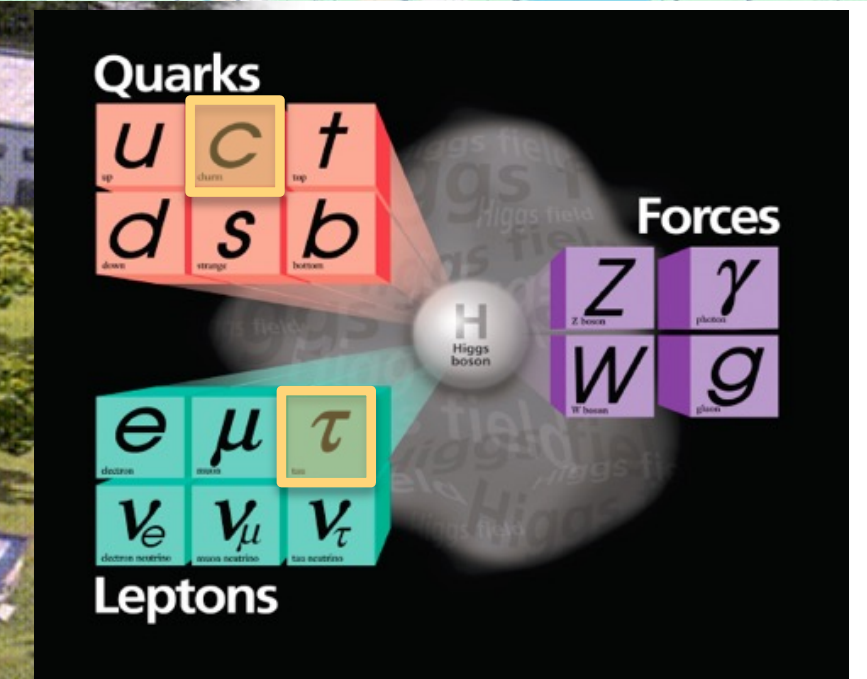
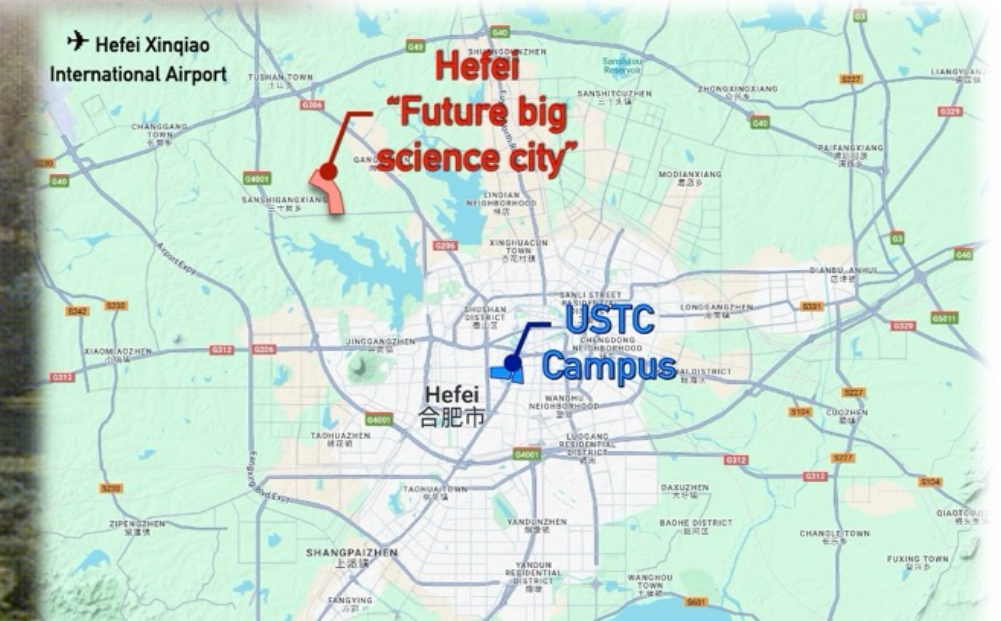
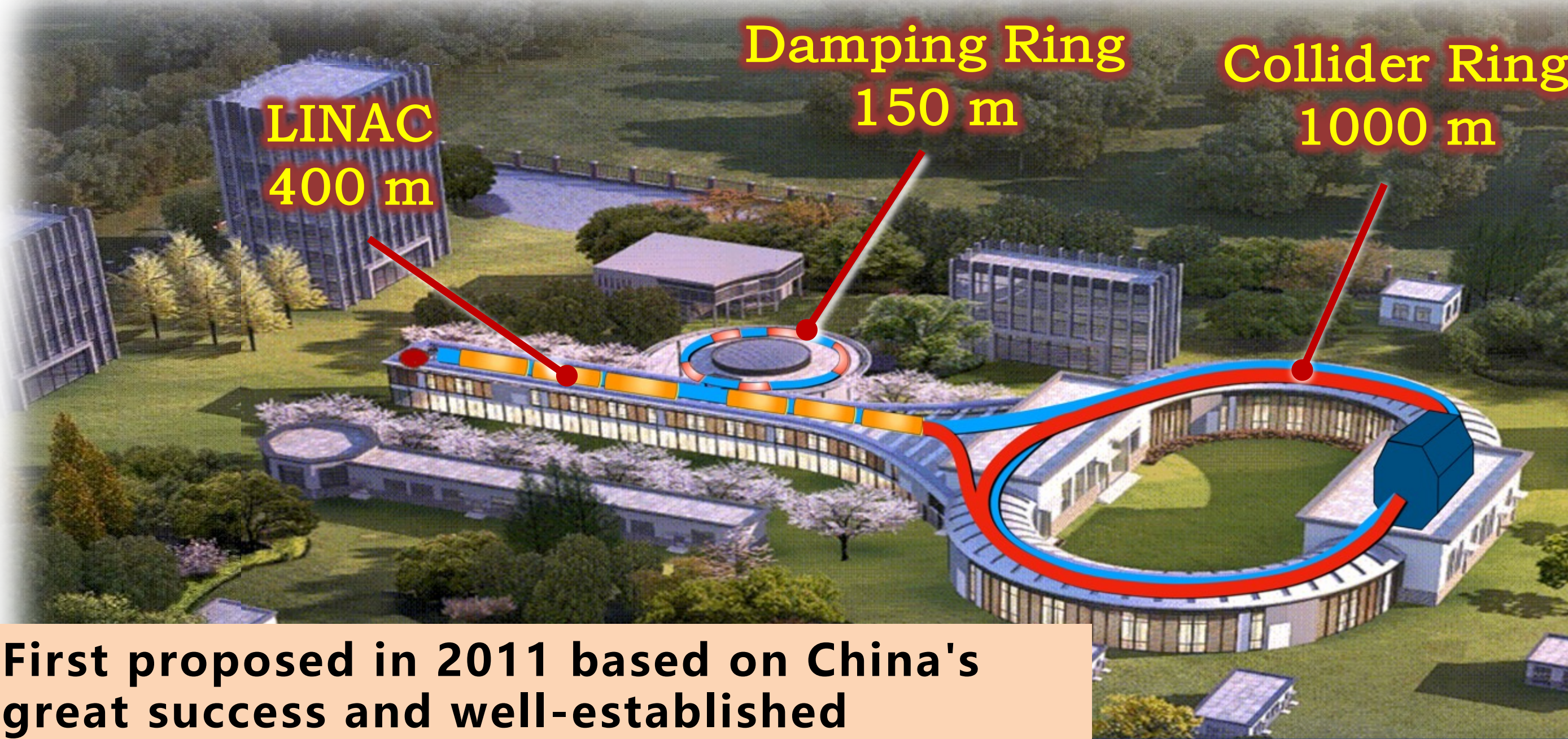
CEPC EDR Phase: 2024-2027

- **CEPC Accelerator EDR** started 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 national government for approval in **2025**
- **Upon approval**, establish at least two international experiment collaborations
- **CEPC construction starts** during the 15th five year plan (2026-2030, e.g. **2027**)
- **CEPC construction completes** around **2035**, at the end of the 16th five year plan



STCF

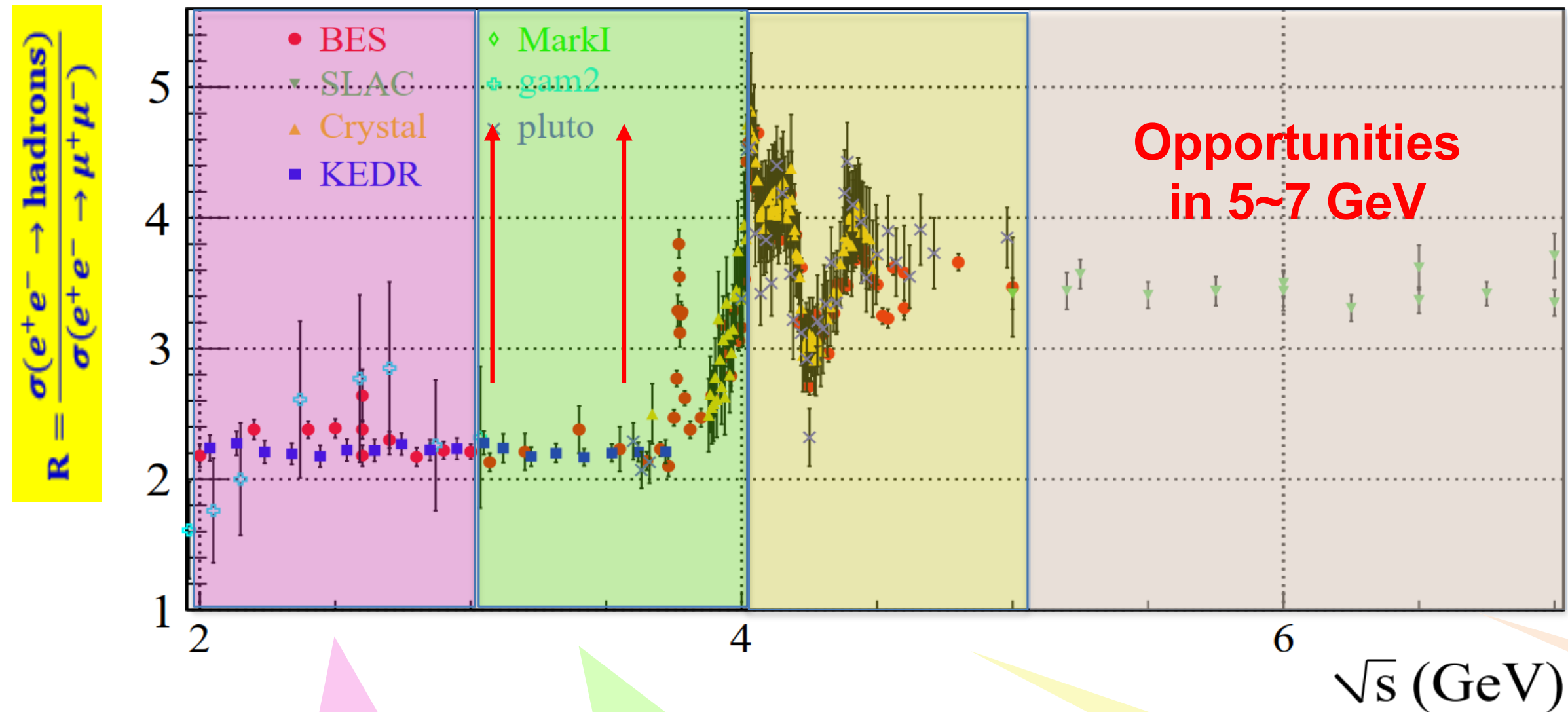
Candidate Site



- First proposed in 2011 based on China's great success and well-established international position in tau-charm physics (Beijing Electron-Positron Collider / BEPC)
- Energy: $2-7\text{GeV}$, peak $L > = 0.5 \times 10^{35} \text{cm}^{-2}\text{s}^{-1}$
- Potential for luminosity upgrade and beam polarization

STCF can produce an enormous amount of “clean” tau leptons and charm hadrons, allowing full exploration of the unique physics potential in the tau-charm energy region: QCD, exotic hadrons, flavor physics and CPV, new physics...

Unique Tau-Charm Energy Region



- Hadron form factors
- $Y(2170)$ resonance
- Multiquark states with s quark
- R value / g-2 related

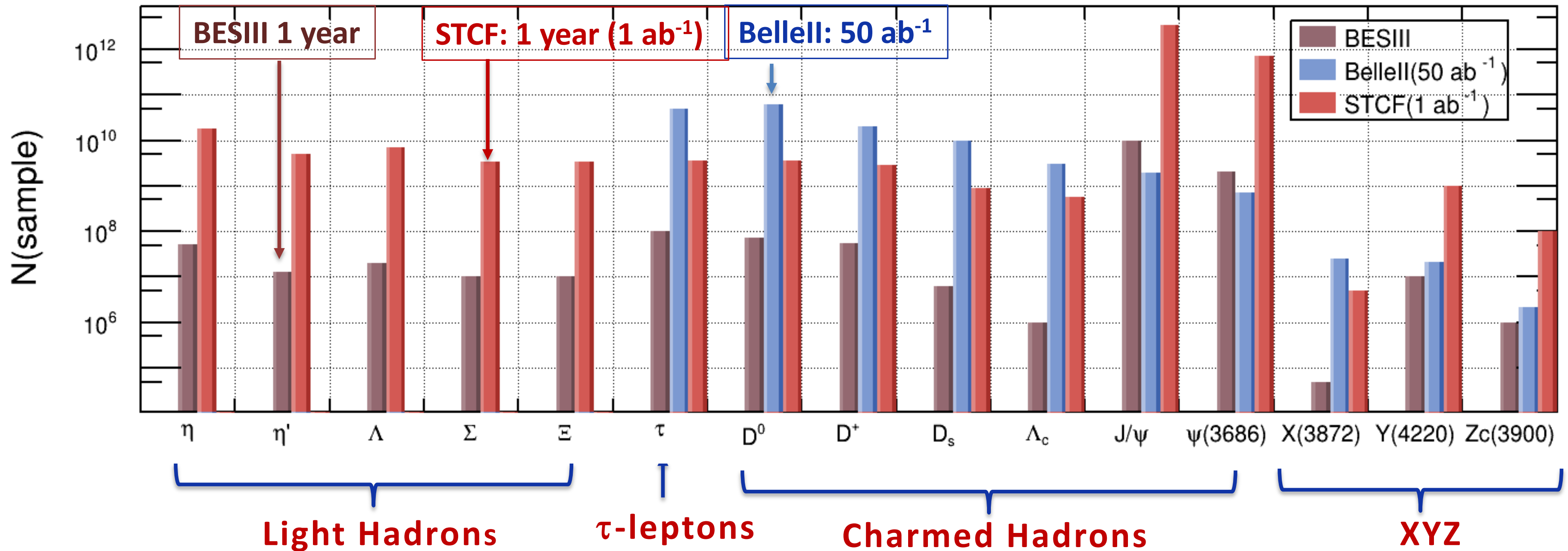
- Light hadron spectroscopy
- Gluonic and exotic states
- Processes of LFV and CPV
- Rare and forbidden decays
- Physics with τ lepton

- XYZ particles
- Physics with D mesons
- f_D and f_{D_s}
- $D^0 - \bar{D}^0$ mixing
- Charm baryons

- Complete XYZ family
- Hidden-charm pentaquarks
- Search for di-charmonium states
- More charmed baryons
- Hadron fragmentation

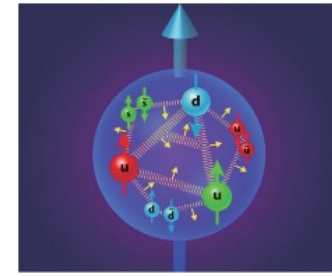
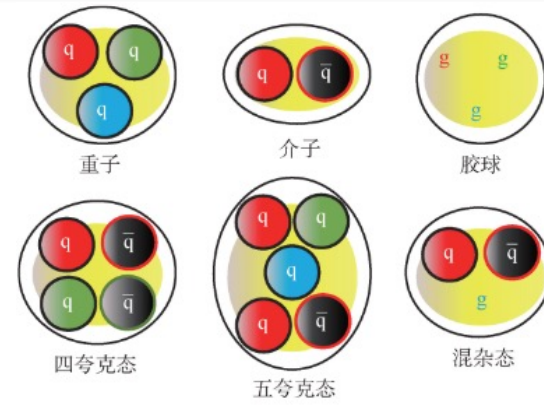
- **Transition** region between perturbative and non-perturbative QCD
- **Pair production** of hadrons and τ leptons **at threshold**
- **Abundant resonances**
- **Large production X-sec** for **charmonium(-like) states** and **exotic states**

STCF: A Super Factory of Various Particles

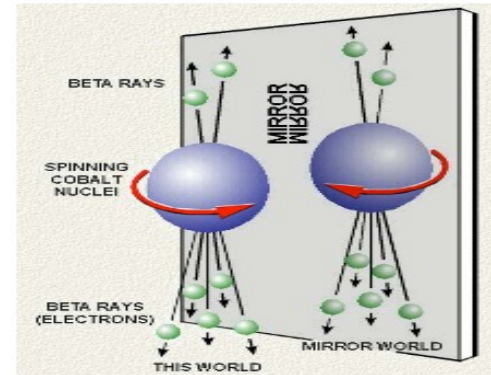
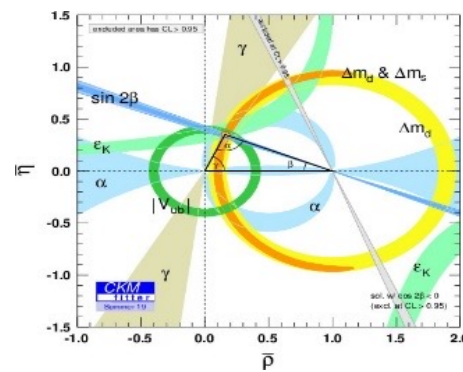


- **STCF is not only a super τ -charm factory, but also a super factory of XYZ, hyperons and light hadrons to unravel the **mystery of how quarks form matter** and the **symmetries of fundamental interactions****

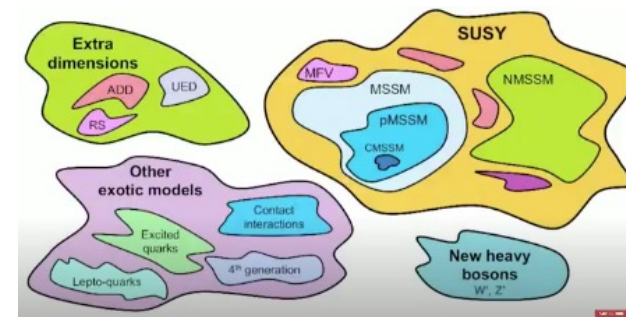
STCF Physics Program



QCD and hadronic physics



Flavor Physics and CP Violation



Forbidden/Rare decay and New Particle

Physics at STCF

XYZ Properties: $e^+e^- \rightarrow Y \rightarrow \gamma X, \eta X, \phi X$; $e^+e^- \rightarrow Y \rightarrow \pi Z c, K Z c s$

Hadron Spectroscopy: Excited $c\bar{c}$ and their transition, Charmed hadron spectroscopy, Light hadron spectroscopy

R value: $e^+e^- \rightarrow$ inclusive; τ mass: $e^+e^- \rightarrow \tau^+\tau^-$

Nucleon Form Factors: $e^+e^- \rightarrow B\bar{B}$ from threshold

Pentaquarks: $e^+e^- \rightarrow J/\psi p p \bar{p}$, $\Lambda_c D \bar{p}$, $\Sigma_c D \bar{p}$

Di-charmonium: $e^+e^- \rightarrow J/\psi \eta c, J/\psi h c$

Muon g-2: $e^+e^- \rightarrow \pi^+\pi^-, \pi^+\pi^-\pi^0, 4\pi, K^+K^-, \gamma\gamma \rightarrow \pi^0, \eta(\prime), \pi^+\pi^-$

Fragmentation functions: $e^+e^- \rightarrow (\pi, K, p, \Lambda, D) + X, e^+e^- \rightarrow (\pi\pi, KK, \pi K) + X$

CKM matrix (V_{cd}, V_{cs}): $D_{(s)}^+ \rightarrow l^+ \nu, D \rightarrow P l^+ \nu$

Charm hadron decay: $\Lambda_c^+, \Sigma_c, \Xi_c, \Omega_c$ decay

CPV in Hyperons: $J/\psi \rightarrow \Lambda \bar{\Lambda}, \Sigma \bar{\Sigma}, \Xi^- \Xi^+, \Xi^0 \Xi^0$

D0-D0bar mixing: $\psi(3770) \rightarrow (D_0 D_0^{\bar{0}})(CP=-), \psi(4140) \rightarrow \pi^0 (D_0 D_0^{\bar{0}})(CP=-)$ or $\gamma(D_0 D_0^{\bar{0}})(CP=+)$

CPV in τ : $\tau \rightarrow K_s \pi \nu$, EDM of τ , $\tau \rightarrow \pi/K \pi^0 \nu$ for polarized e^- beam

CPV in Charm: $D_0 \rightarrow K^+K^-/\pi^+\pi^-, \Lambda_c \rightarrow pK^-\pi^+\pi^0/\Lambda\pi^+\pi^-\pi^0/pK_s^+\pi^+\pi^-$

γ/ϕ^3 measurement: $D_0 \rightarrow K(s/L) \pi^+\pi^-, K(s/L) K^+K^-, K_3\pi, 4\pi$

γ polarization: $D_0 \rightarrow K_1 e^+ \nu_e$

LNV, BNV: $D(s)^+ \rightarrow l^+ l^+ X^-, J/\psi \rightarrow \Lambda_c e^-, B \rightarrow B^{\bar{0}} \dots$

Symmetry violation: $\eta(\prime) \rightarrow ll\pi^0, \eta(\prime) \rightarrow \eta ll \dots$

FLV decays: $\tau \rightarrow \gamma l, ll, l P_1 P_2, J/\psi \rightarrow ll', D_0 \rightarrow ll' (l' \neq l) \dots$

FCNC: $D \rightarrow \gamma V, D_0 \rightarrow l^+ l^-, e^+e^- \rightarrow D^* \dots, \Sigma^+ \rightarrow p l^+ l^- \dots$

Dark photon: $e^+e^- \rightarrow \gamma A' (\rightarrow l^+ l^-), J/\psi \rightarrow e^+e^- A' \dots$

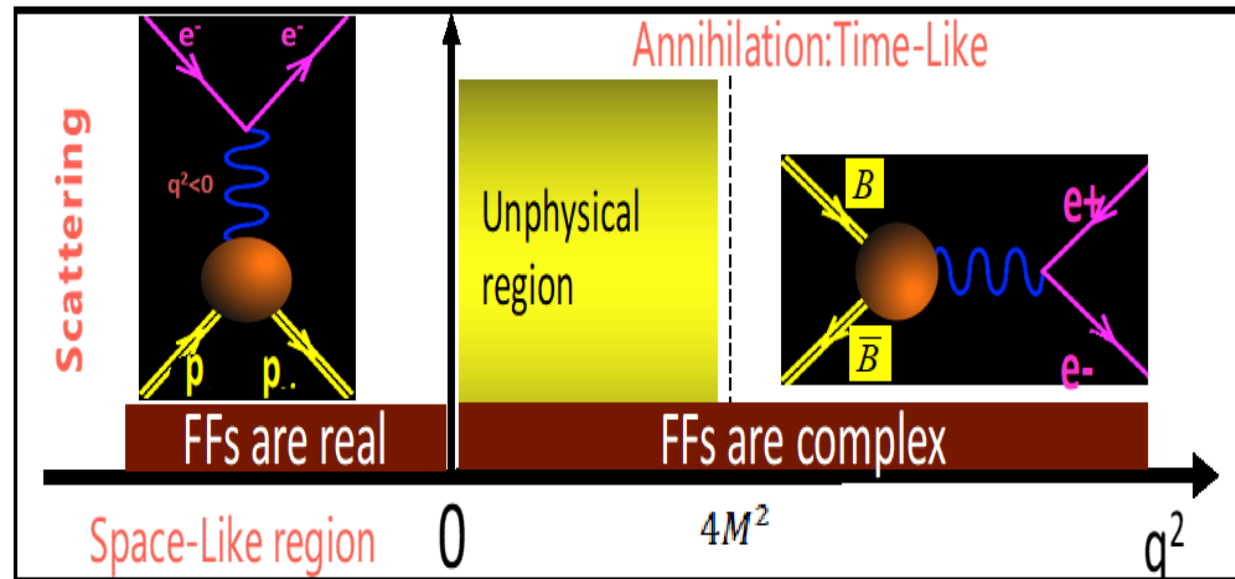
Millicharged: $e^+e^- \rightarrow X X^{\bar{}} Y \dots$

- **Leading role**
- Competing with Belle II/LHCb
- **Complementary to Belle II/LHCb/Eic/EicC**

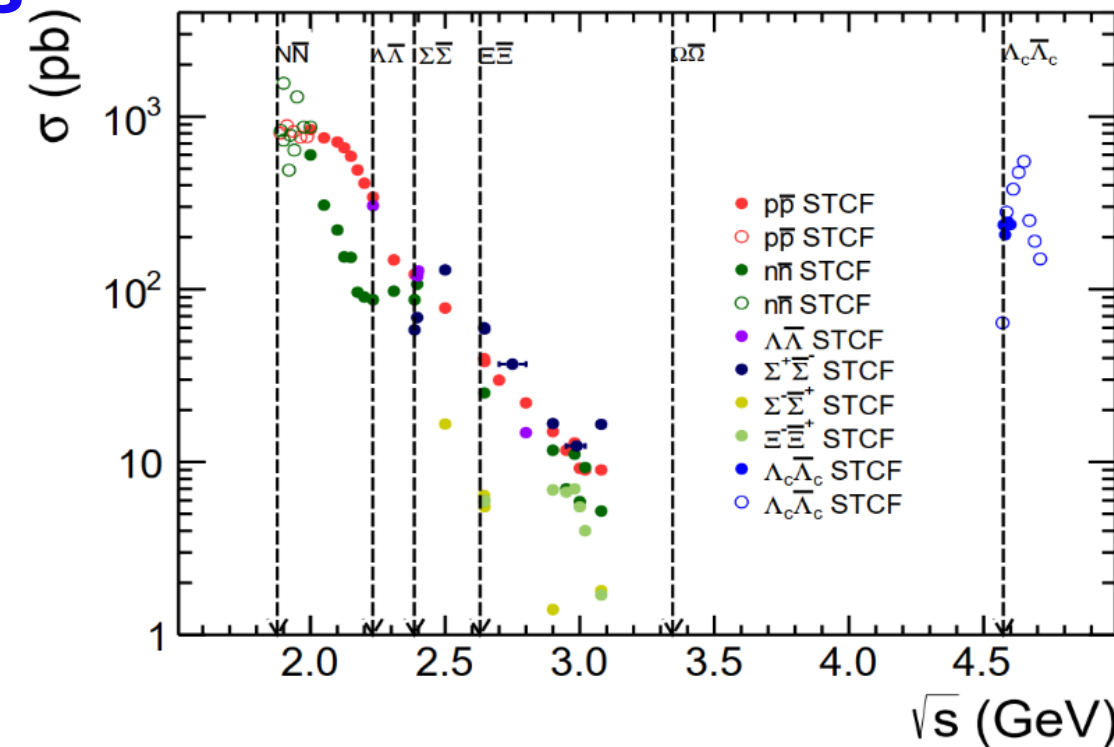
Hadron Production

Hadron production at STCF is a key avenue to study the strong interaction

Nucleons/Baryons EM form factors

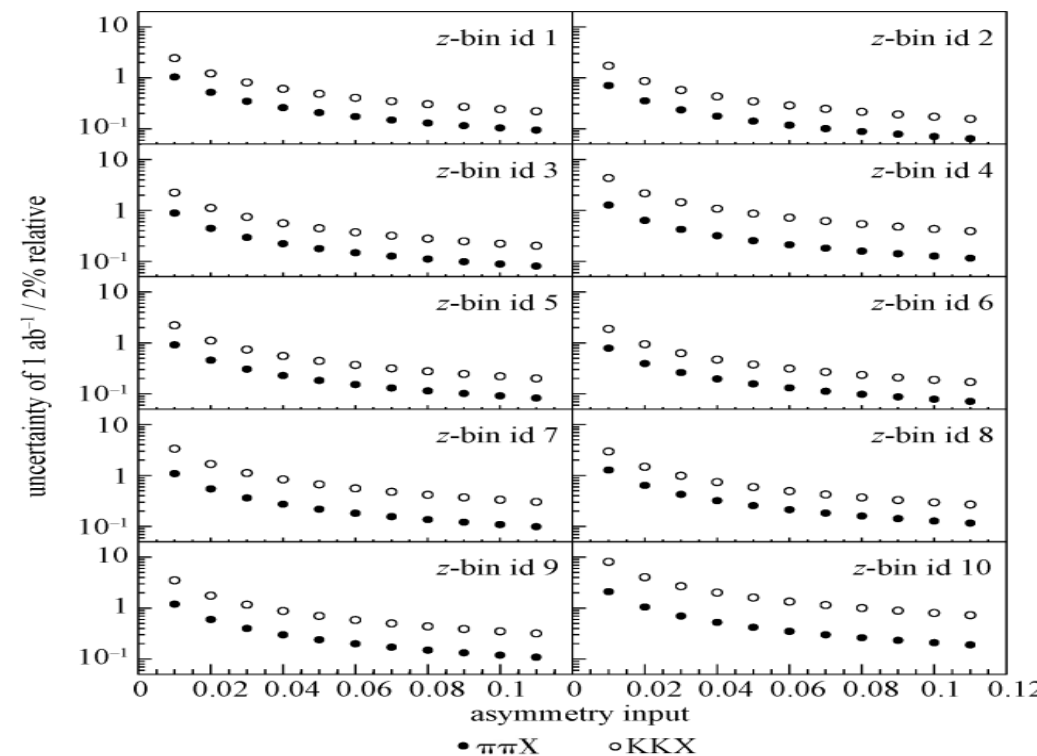
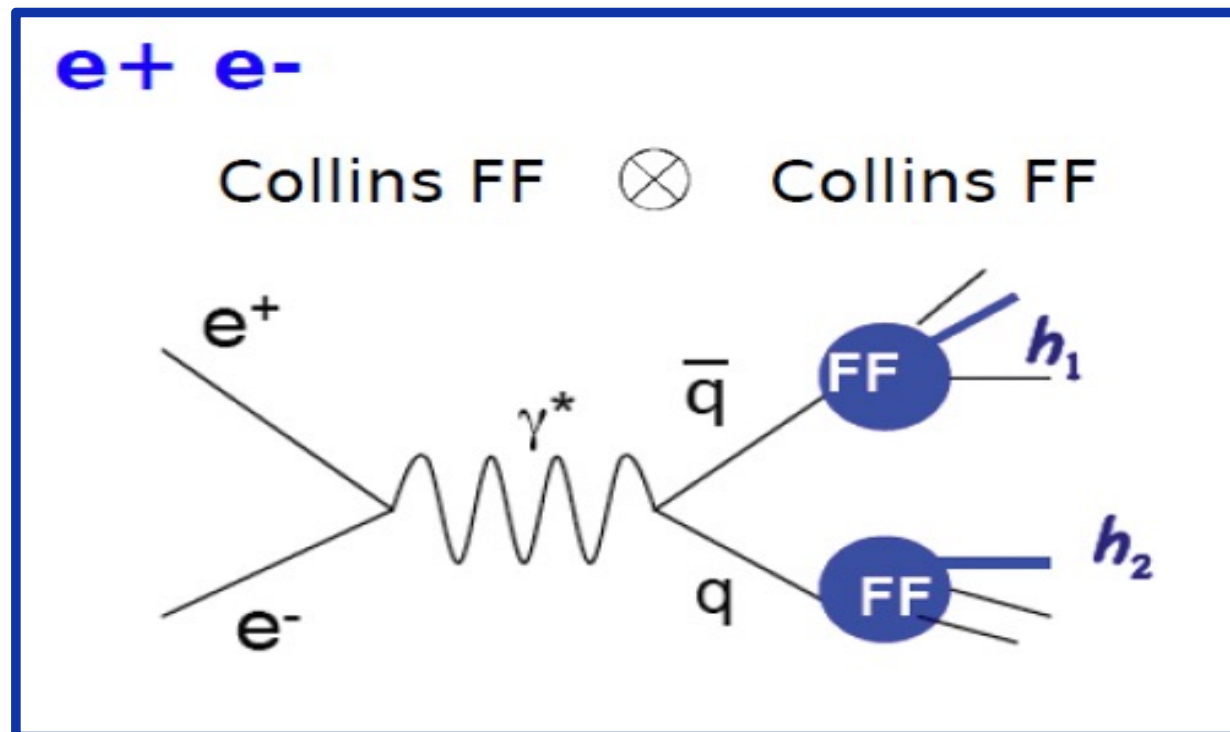


Eic/EicC \longleftrightarrow STCF



STCF will improve the measurement precision by 2 orders of magnitude, revealing the near-threshold cross section singularity and mystery of G_E and G_M

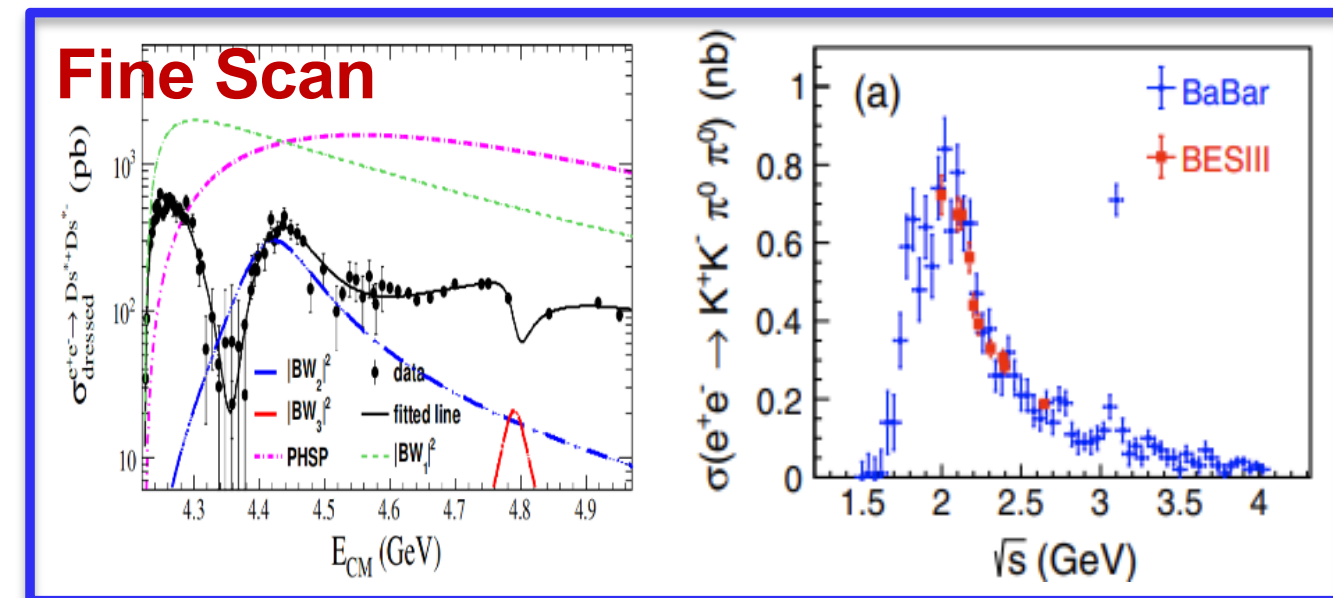
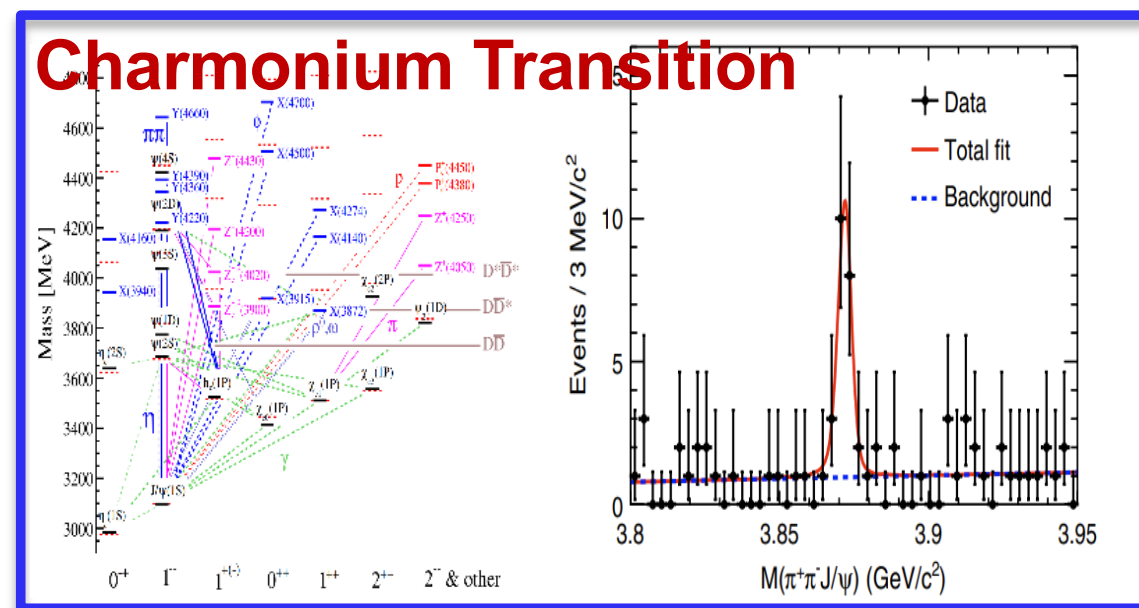
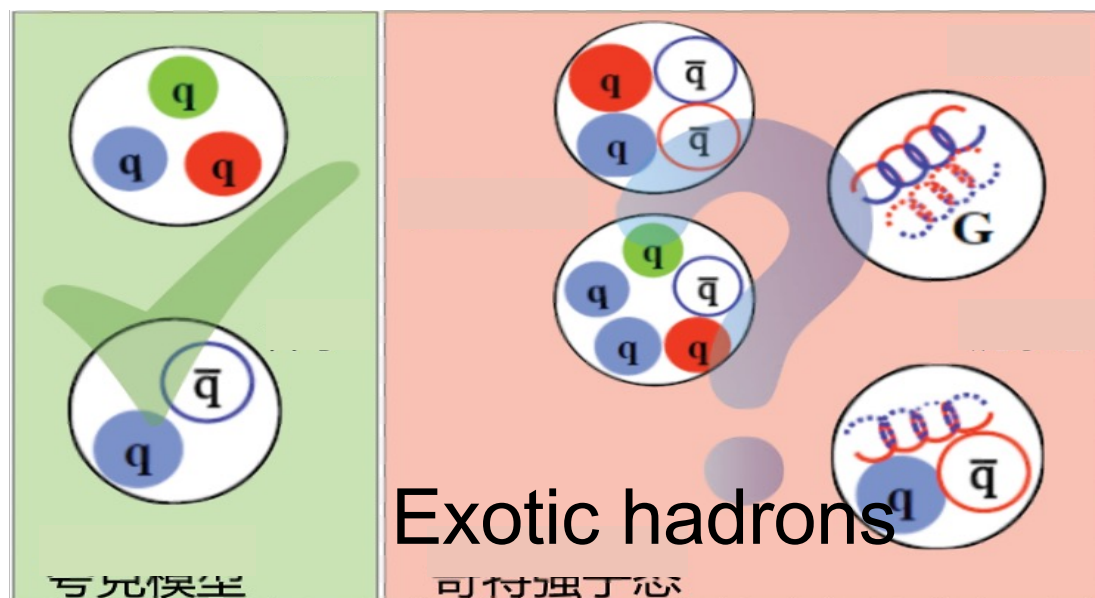
Fragmentation Functions



STCF will provide precise Collins FF input for TMD extraction at EIC/EicC

Hadron Spectroscopy and Exotic States

A **unique** territory for the QCD confinement



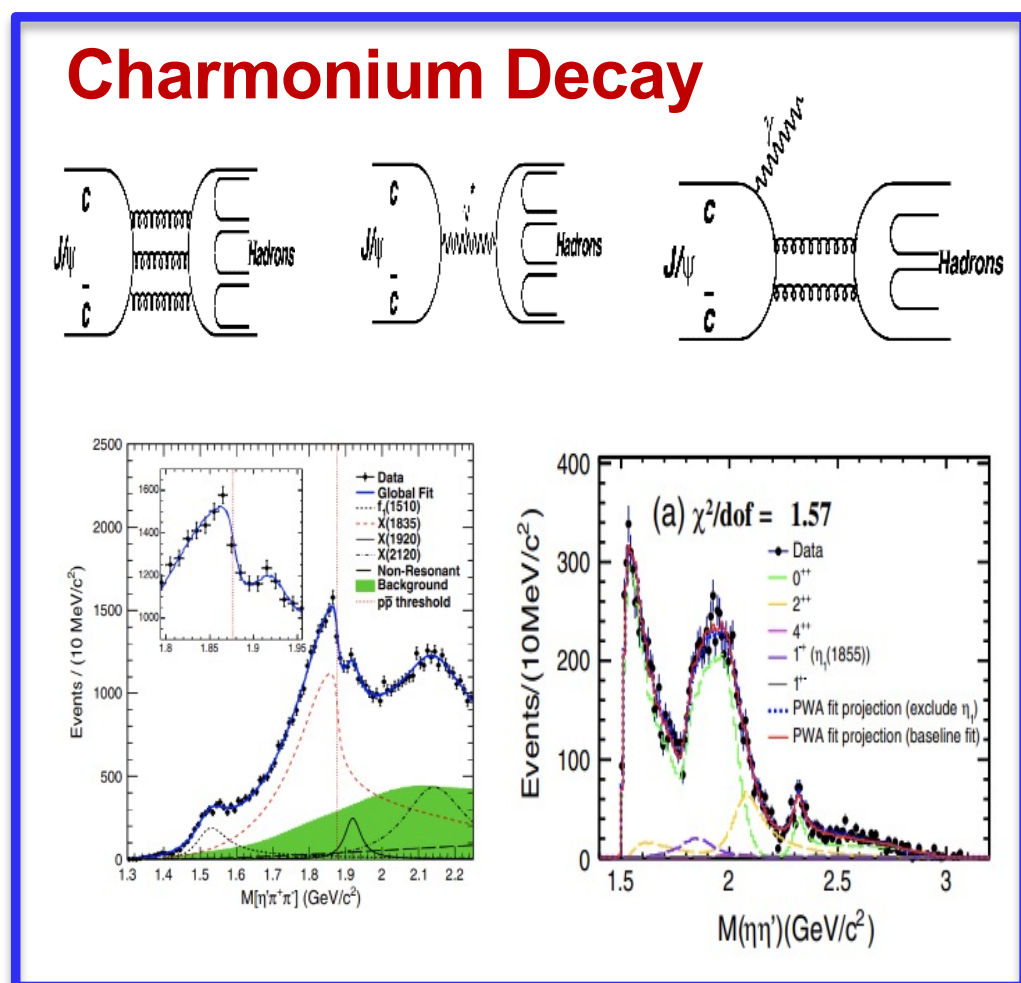
A Charmonium(-like) factory (per year):

- 3T J/ψ, 0.6T ψ(3686), 1B Y(4230), 100M Z_c(3900) and 5M X(3872)

Physics opportunities :

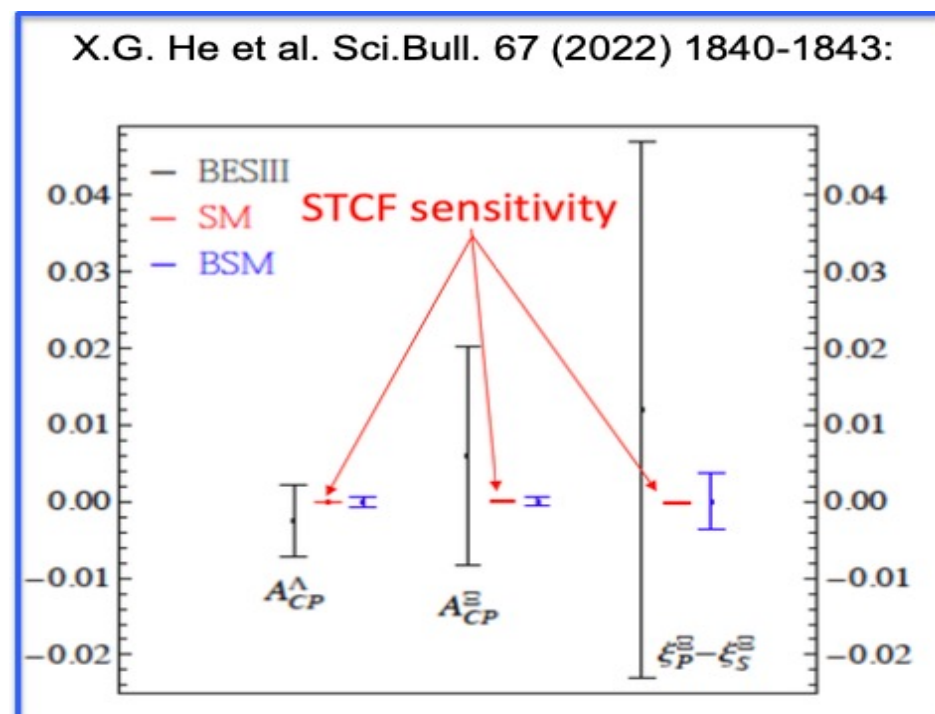
- Energy dependent structures of Z_{c(s)}
- More XYZ states → spectroscopy
- **Missing** charmonium states and their transitions
- Traces of **glueballs** and **hybrid** states

STCF has an **absolute advantage** in studying hadron spectroscopy and exotic states, and is expected to make **significant breakthroughs**



CPV

- CPV observed in K, B, D mesons, all consistent with CKM theory in SM
- Baryon asymmetry of the universe indicates the existence of non-SM CPV sources
- STCF is capable of searching for **CPV in hyperon and τ lepton**, as well as **CPT violation in Kaon** with high sensitivity
- **Unique advantages at STCF:** Quantum correlated, large statistics, clear environment



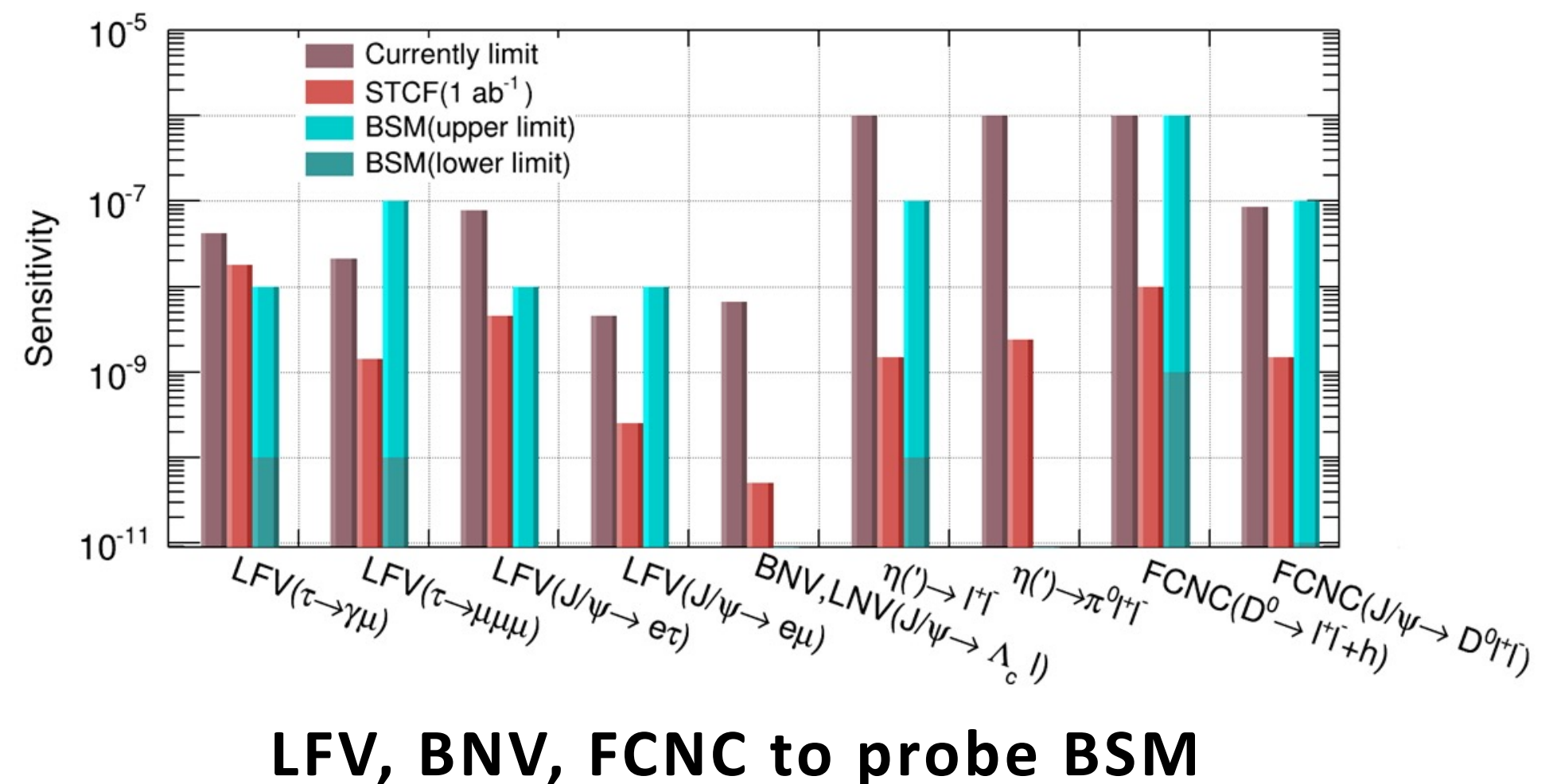
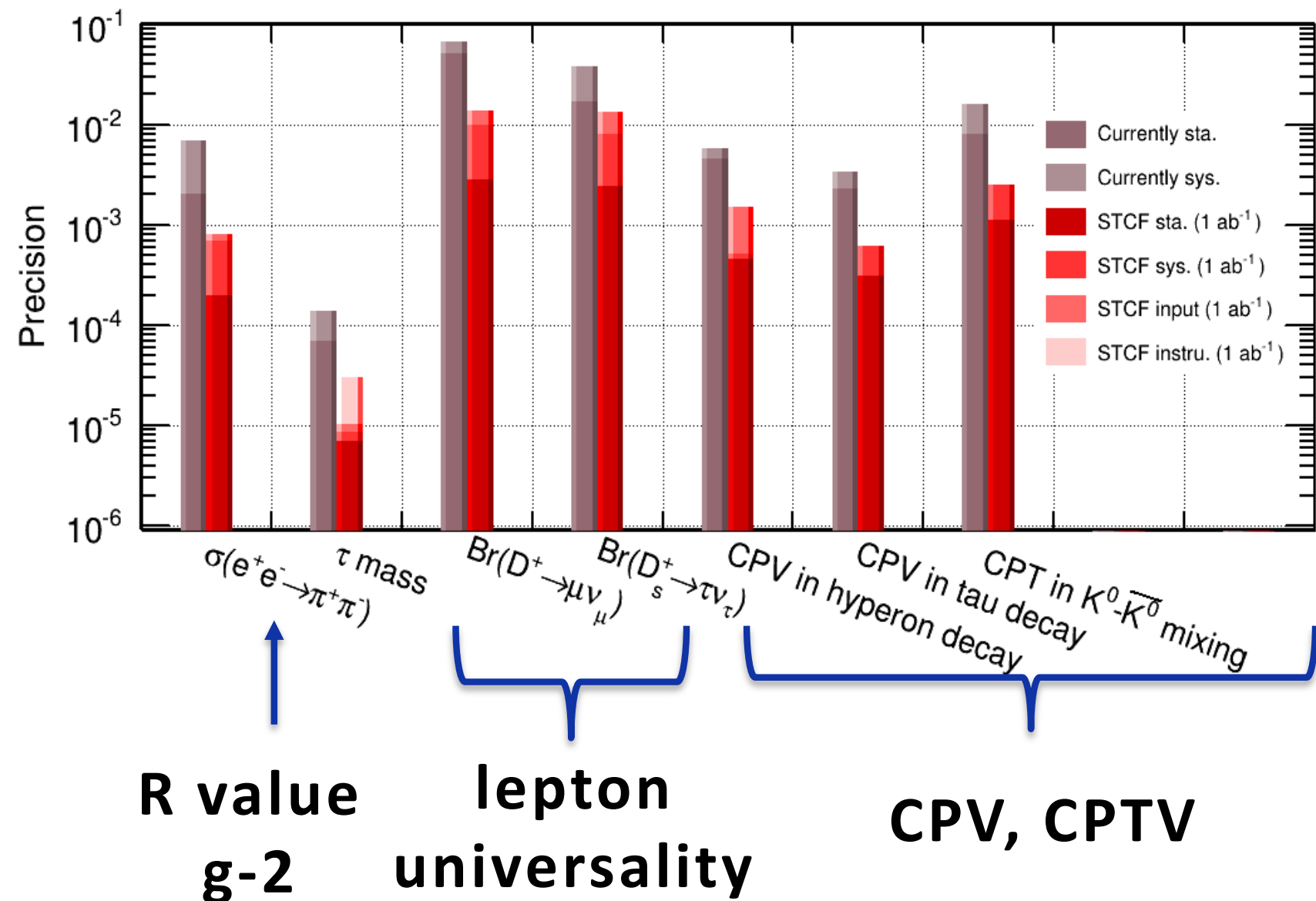
$$\sigma_{ACP} \approx \sqrt{\frac{3}{2}} \frac{1}{\alpha_1 \sqrt{N_{sig}} \sqrt{\langle P_B^2 \rangle}}$$

$$\xrightarrow{1 \times 10^9 \Lambda \bar{\Lambda}, \langle P_B^2 \rangle = 0.1} \sigma_{ACP} \sim 1.4 \times 10^{-4}$$

$$\xrightarrow{1 \times 10^9 \Lambda \bar{\Lambda}, \langle P_B^2 \rangle = 0.8} \sigma_{ACP} \sim 5 \times 10^{-5}$$

Precision Measurements and Rare Decays

- STCF is expected to improve the current precisions of many important measurements by ~ 1 order of magnitude and enhance sensitivities to various rare or forbidden decays by ~ 2 orders of magnitude
- Great potential to reveal new physics



STCF Conceptual Design Studies

Physics & Detector CDR

Accelerator Pre-CDR

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物理学前沿

FRONTIERS OF PHYSICS

REPORT
Volume 19 / Issue 1 / 14701 / 2024

STCF conceptual design report (Volume 1):
Physics & detector

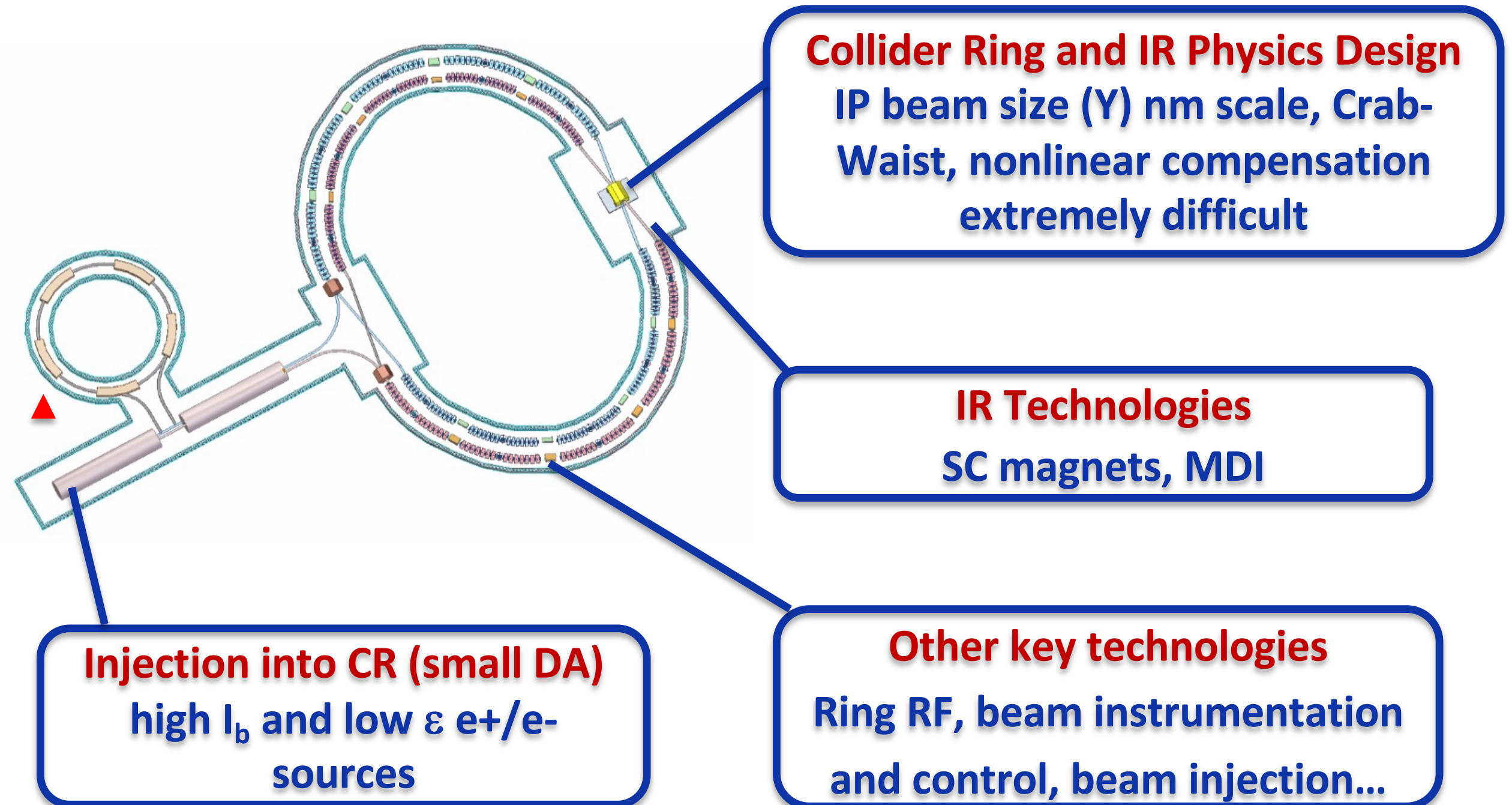
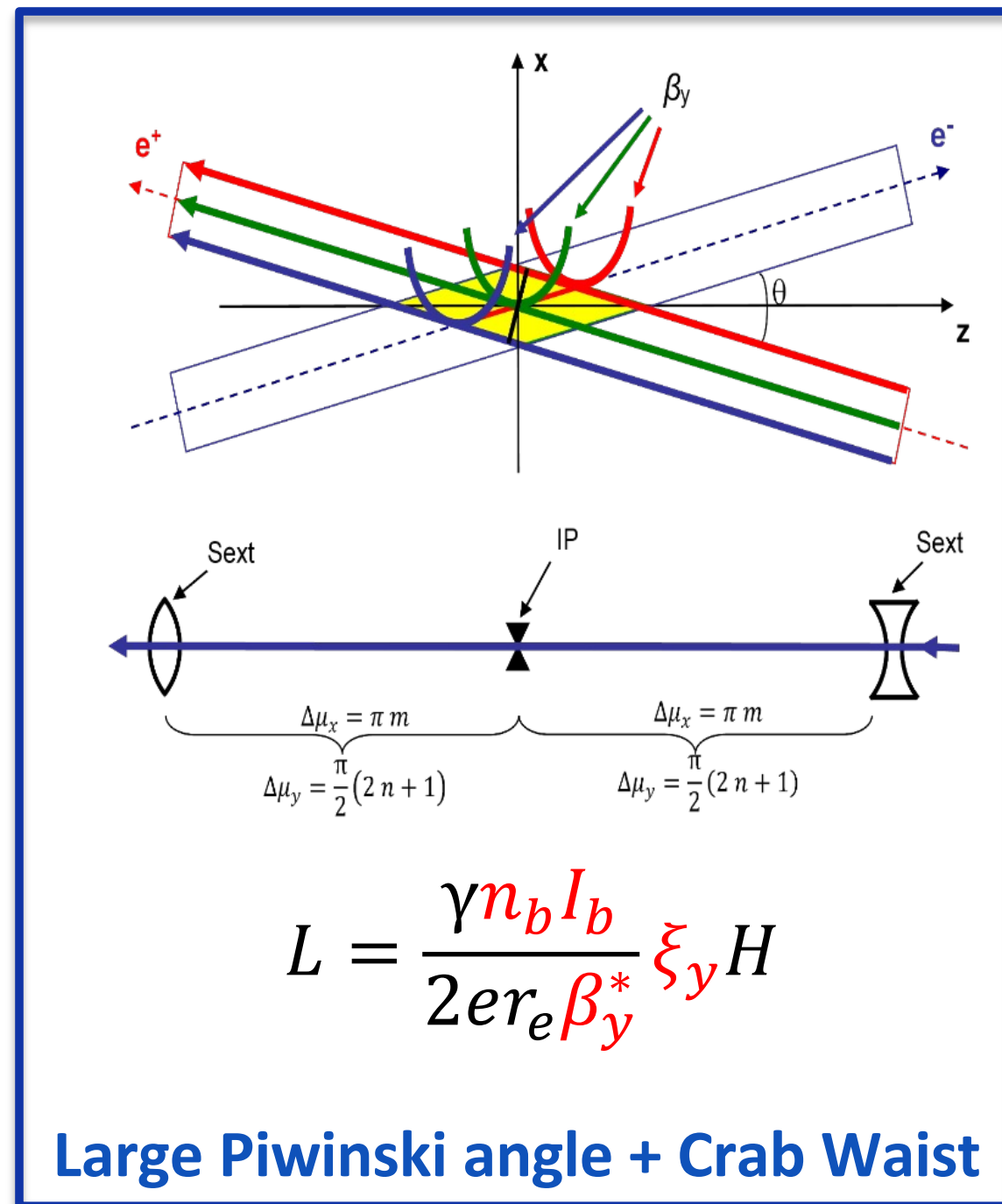
M. Achasov³, X. C. Ai⁸², R. Aliberti³⁸, Q. An^{63,72}, X. Z. Bai^{63,72}, Y. Bai⁶², O. Bakina³⁹, A. Barnyakov^{3,50}, V. Blinov^{3,50,51}, V. Bobrovnikov^{3,51}, D. Bodrov^{23,60}, A. Bogomyagkov³, A. Bondar³, I. Boyko³⁹, Z. H. Bu⁷³, F. M. Cai²⁰, H. Cai⁷⁷, J. J. Cao²⁰, Q. H. Cao⁵⁴, X. Cao³³, Z. Cao^{63,72}, Q. Chang²⁰, K. T. Chao⁵⁴, D. Y. Chen⁶², H. Chen⁸¹, H. X. Chen⁶², J. F. Chen⁵⁸, K. Chen⁶, L. L. Chen²⁰, P. Chen⁷⁸, S. L. Chen⁶, S. M. Chen⁶⁶, S. Chen⁶⁹, S. P. Chen⁶⁹, W. Chen⁶⁴, X. Chen⁷⁴, X. F. Chen⁵⁸, X. R. Chen³³, Y. Chen³², Y. Q. Chen³⁶, H. Y. Cheng³⁴, J. Cheng⁴⁸, S. Cheng²⁸, T. G. Cheng²

82 institutions, 453 authors
arXiv:2303.15790

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Challenges of STCF Accelerator

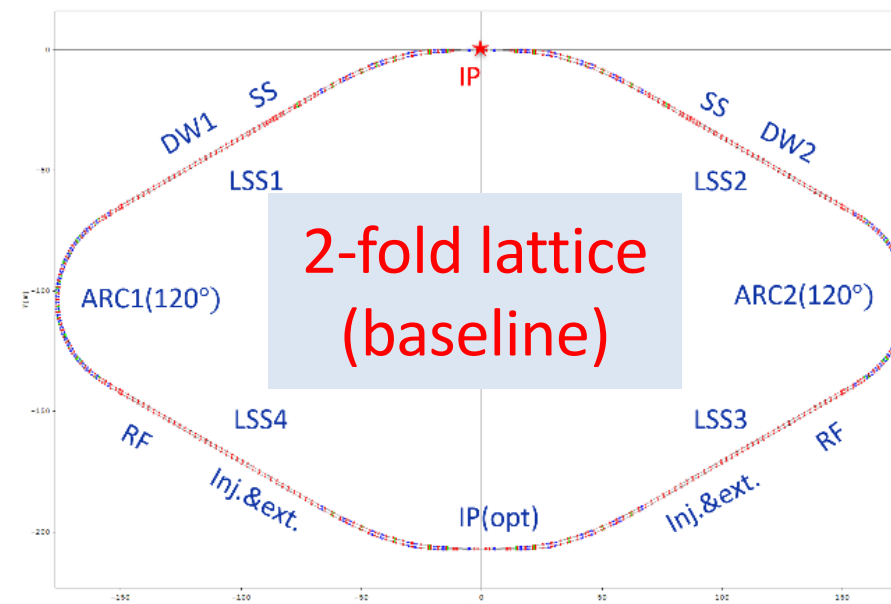
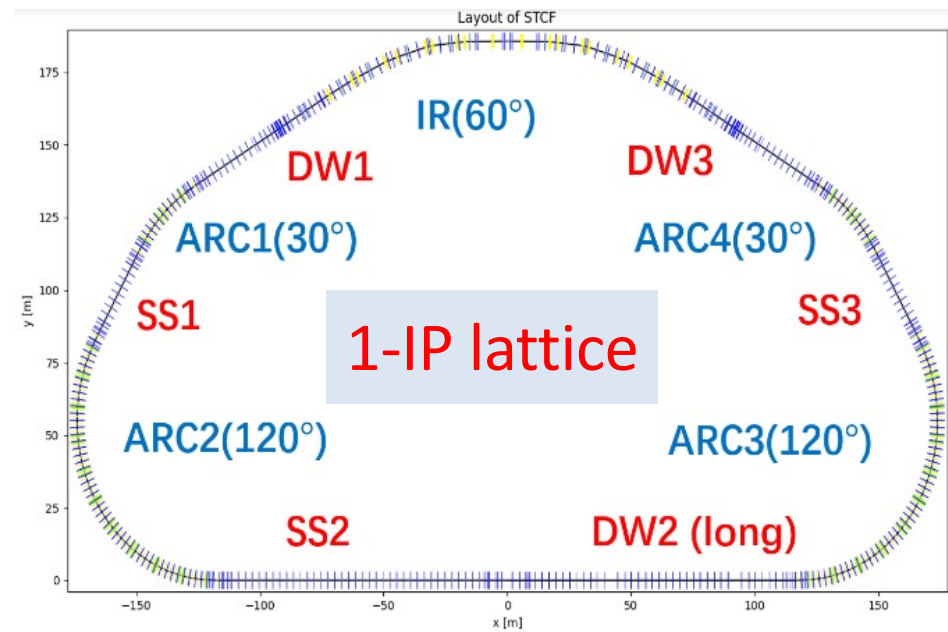
- Ultra-high luminosity in the tau charm energy region, high-quality beam, stable operation
- Characterized by extremely small bunch size, high beam current, strong nonlinearity and collective effects



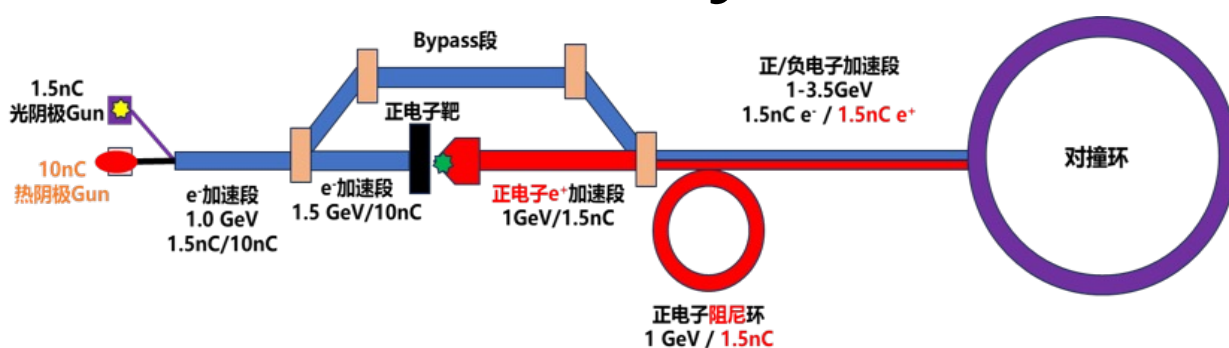
STCF Accelerator Conceptual Design

- Two Lattice designs, optimal beam energy: 2 GeV
- Injection energy: 1-3.5 GeV
- Two injection schemes: off-axis, swap-out (baseline)
 - ✓ Variable energy: 1-3.5 GeV
 - ✓ Damping ring (off-axis) or accumulator ring (swap-out) for positrons @1 GeV
 - ✓ Total length: ~400 m (+100 m beam transp.)

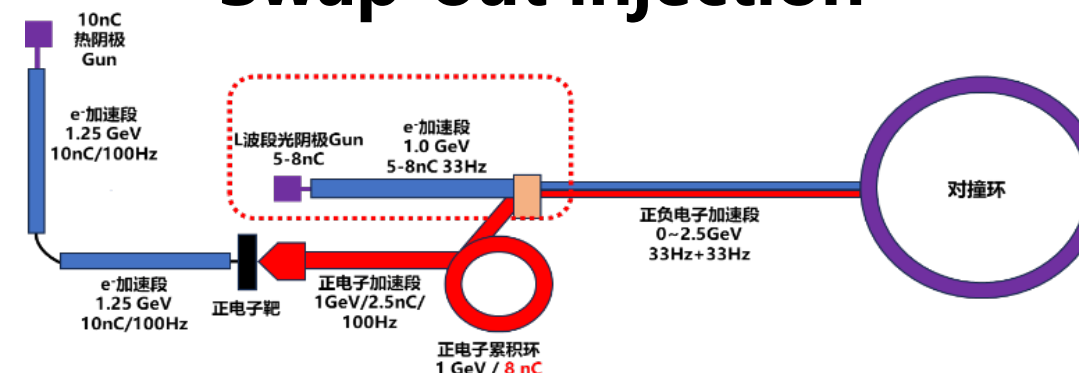
Parameters	Units	STCF
Optimal beam energy, E	GeV	2
Circumference, C	m	871.76
Crossing angle, 2θ	mrad	60
Revolution period, T	μs	2.908
Horizontal emittance, $\varepsilon_x/\varepsilon_y$	nm	6.857/0.034
Coupling, k		0.50%
Beta functions at IP, β_x/β_y	mm	40/0.6
Beam size at IP, σ_x/σ_y	μm	16.56/0.143
Betatron tune, ν_x/ν_y		32.55/29.57
Momentum compaction factor, α_p	10^{-4}	12.322
Energy spread, σ_e	10^{-4}	8.986
Beam current, I	A	2
Number of bunches, n_b		726
Particles per bunch, N_b	10^{10}	5.00
Single-bunch charge	nC	8.01
Energy loss per turn, U_0	keV	406.8
Damping time, $\tau_x/\tau_y/\tau_z$	ms	28.4/28.6/14.4
RF frequency, f_{RF}	MHz	499.333
Harmonic number, h		1452
RF voltage, V_{RF}	MV	1.8
Synchrotron tune, ν_z		0.0158
Bunch length, σ_z	mm	9.72
RF bucket height, δ_{RF}	%	1.47
Piwinski angle, ϕ_{pwi}	rad	17.61
Beam-beam parameter, ξ_x/ξ_y		0.0027/0.082
Hour-glass factor, F_h		0.87
Luminosity, L	$\text{cm}^{-2}\text{s}^{-1}$	1.0×10^{35}



Off-axis injection



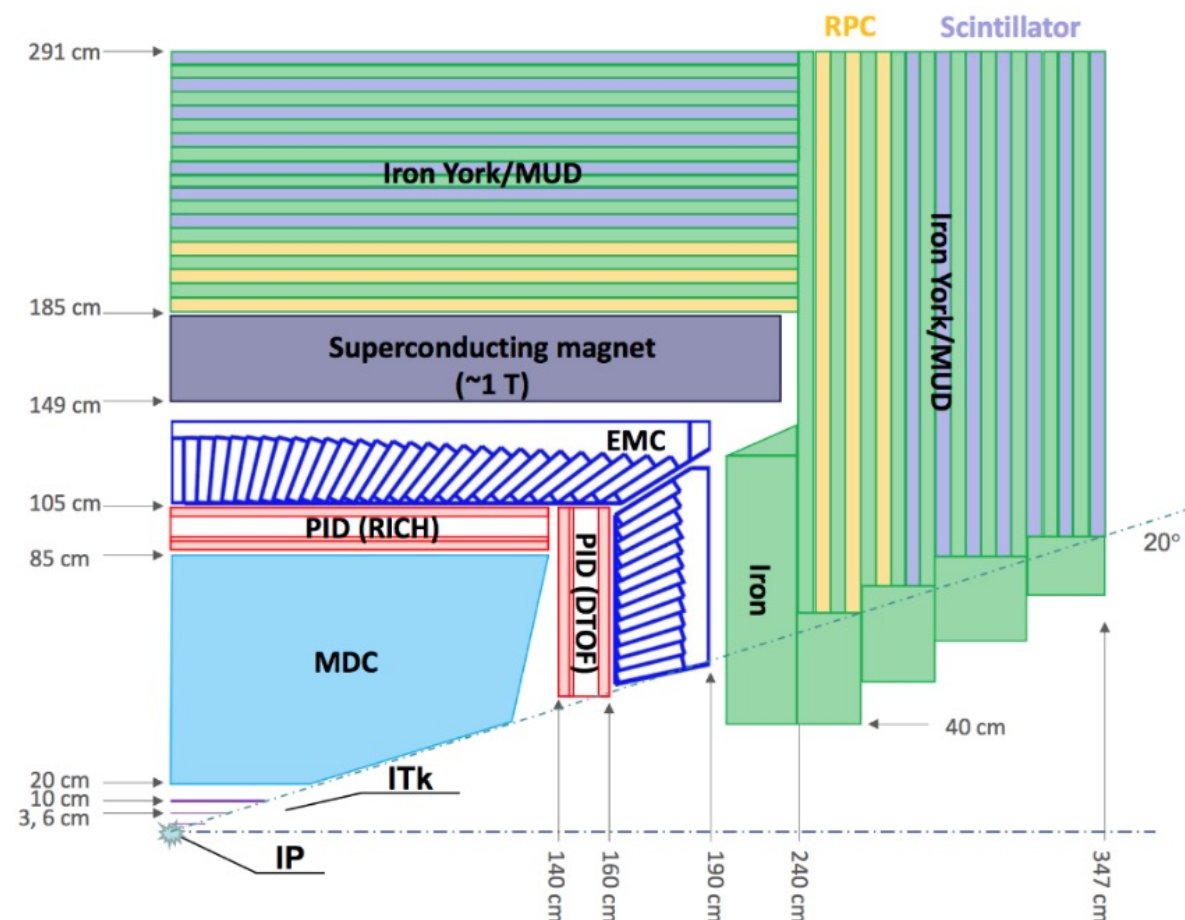
Swap-out injection



STCF Detector Conceptual Design

Detector Requirements from Physics

Process	Physics Interest	Optimized Subdetector	Requirements
$\tau \rightarrow K_s \pi \nu_\tau$, $J/\psi \rightarrow \Lambda \bar{\Lambda}$, $D_{(s)}$ tag	CPV in the τ sector, CPV in the hyperon sector, Charm physics	ITK+MDC	acceptance: 93% of 4π ; trk. effi.: > 99% at $p_T > 0.3$ GeV/c; > 90% at $p_T = 0.1$ GeV/c $\sigma_p/p = 0.5\%$, $\sigma_{\gamma\phi} = 130$ μm at 1 GeV/c
$e^+e^- \rightarrow KK + X$, $D_{(s)}$ decays	Fragmentation function, CKM matrix, LQCD etc.	PID	π/K and K/π misidentification rate < 2% PID efficiency of hadrons > 97% at $p < 2$ GeV/c
$\tau \rightarrow \mu\mu\mu$, $\tau \rightarrow \gamma\mu$, $D_s \rightarrow \mu\nu$	cLFV decay of τ , CKM matrix, LQCD etc.	PID+MUD	μ/π suppression power over 30 at $p < 2$ GeV/c, μ efficiency over 95% at $p = 1$ GeV/c
$\tau \rightarrow \gamma\mu$, $\psi(3686) \rightarrow \gamma\eta(2S)$	cLFV decay of τ , Charmonium transition	EMC	$\sigma_E/E \approx 2.5\%$ at $E = 1$ GeV $\sigma_{\text{pos}} \approx 5$ mm at $E = 1$ GeV
$e^+e^- \rightarrow n\bar{n}$, $D_0 \rightarrow K_L \pi^+ \pi^-$	Nucleon structure Unity of CKM triangle	EMC+MUD	$\sigma_T = \frac{300}{\sqrt{p^3(\text{GeV}^3)}} \text{ ps}$



Solid Angle Coverage : $94\% \cdot 4\pi$ ($\theta \sim 20^\circ$)

❖ Inner tracker (ITK, two options)

- ▶ MPGD: cylindrical MPGD
- ▶ Silicon: CMOS MAPS

❖ Central tracker (MDC)

- ▶ Main drift chamber

❖ PID

- ▶ Barrel: **RICH** with CsI-MPGD
- ▶ Endcaps: DIRC-like TOF (**DTOF**)

❖ EMC

- ▶ pure CsI + APD

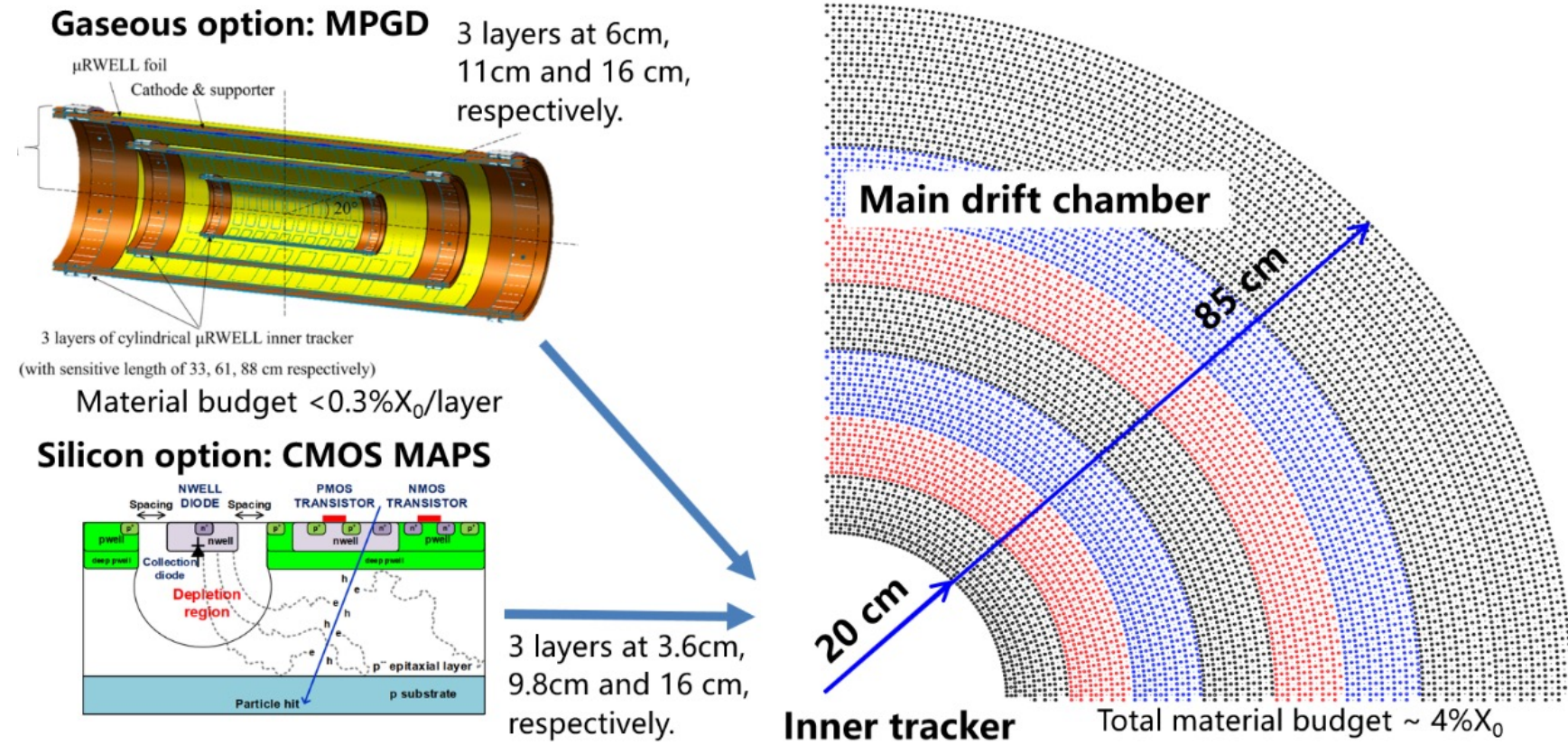
❖ Muon detector (MUD)

- ▶ RPC + scintillator strips

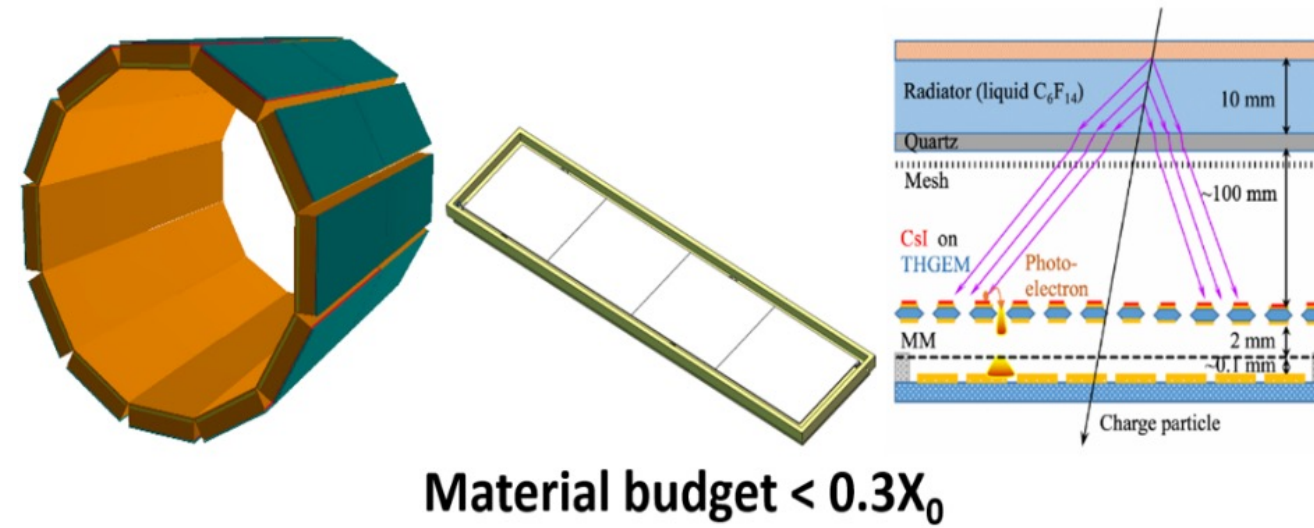
❖ Magnet

- ▶ Super-conducting solenoid, 1 T

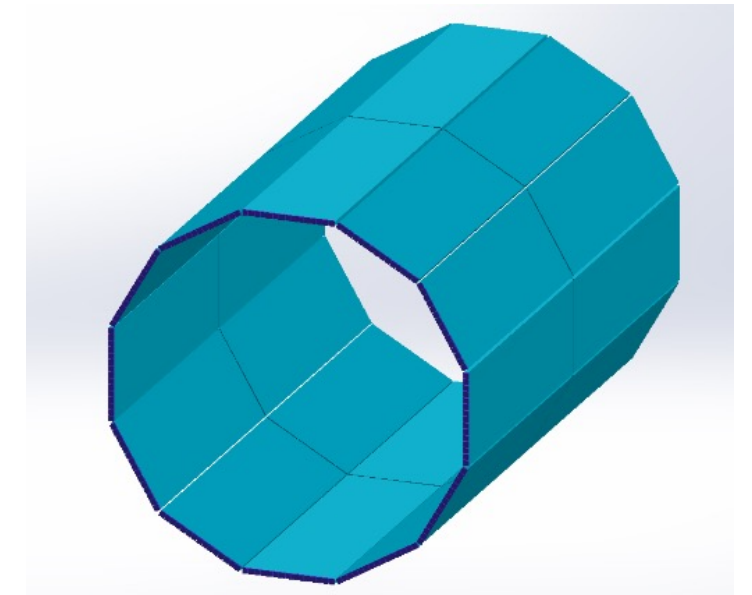
STCF Detector Conceptual Design



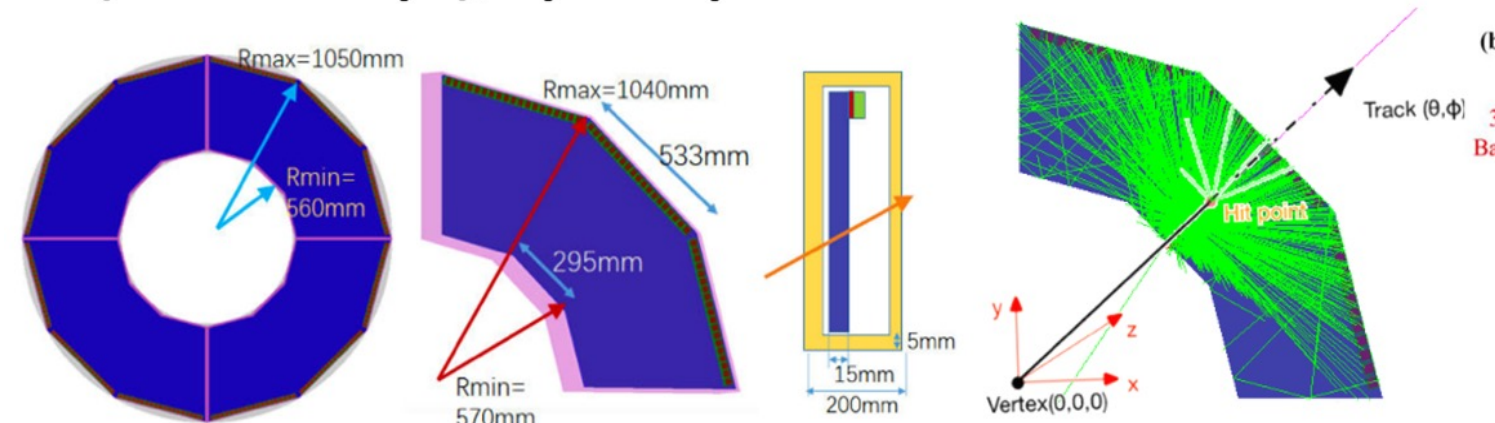
- Barrel PID: A RICH detector using MPGD (THGEM with CsI + MM) for photon detection



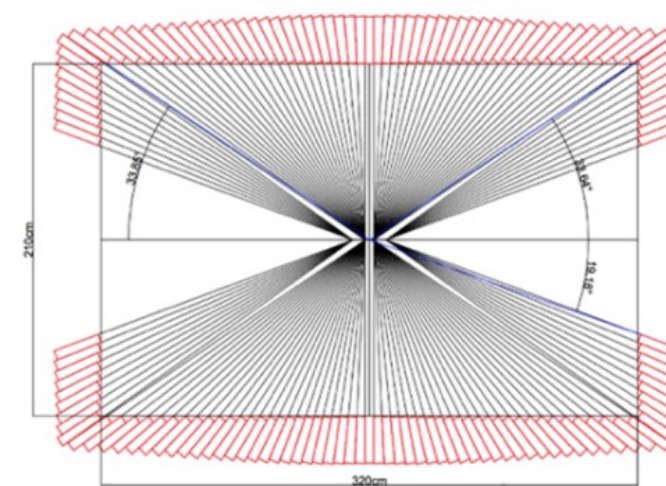
- Alternative: the same technology as the endcap PID (DToF)



- Endcap PID: A DIRC-like high-resolution TOF detector (DToF ~ 30 ps), quartz plate + MCP-maPMT

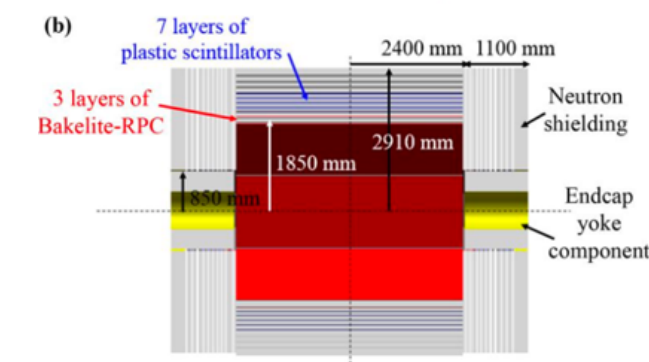


- EMC: A pure-CsI crystal calorimeter to tackle a high level of background ($\sim 1\text{MHz}/\text{ch}$)



- Crystal size 28cm (15X0) $5 \times 5\text{cm}^2$
- ~ 8670 crystals
- 4 large area APDs ($1 \times 1\text{cm}^2$) to enhance light yield

- MUD: A RPC-scintillator hybrid detector to optimize muon and neutral hadron ID



Parameter	Baseline design
R_{in} [cm]	185
R_{out} [cm]	291
R_z [cm]	85
L_{Barrel} [cm]	480
T_{Endcap} [cm]	107
Segmentation in ϕ	8
Number of detector layers	10
Iron yoke thickness [cm]	4/4/4.5/4.5/6/6/6/8/8 cm
Total: 51 cm, 3.04λ	
Solid angle	$79.2\% \times 4\pi$ in barrel
	$14.8\% \times 4\pi$ in endcap
	$94\% \times 4\pi$ in total
Total area [m^2]	Barrel ~ 717
	Endcap ~ 520
	Total ~ 1237

R&D Project Review and Kick-Off Meetings



Kick-off Meeting, Aug. 2023, USTC

More than 30 academicians of CAS, as well as government officials of Anhui province and Hefei city, along with representatives from various domestic research institutions, totaling 170 attendees.



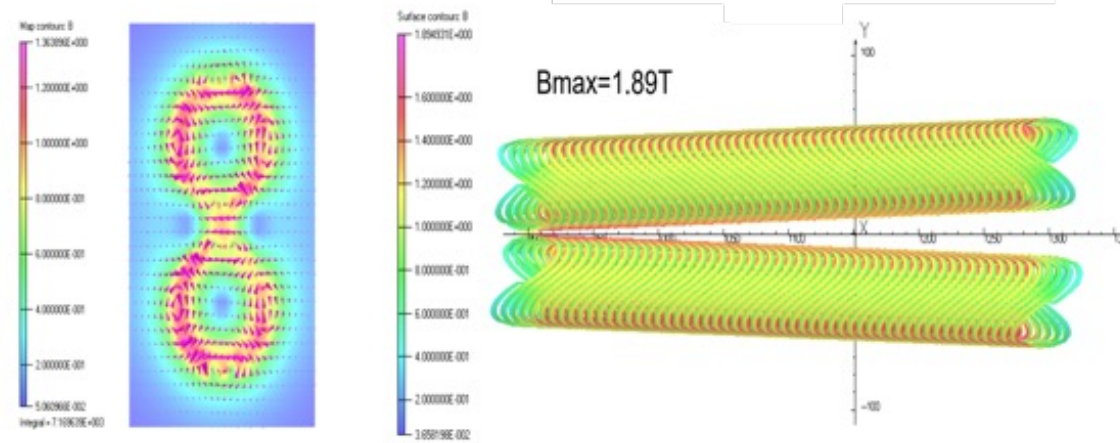
R&D Project Review, Dec. 2023, USTC

Organized by Development and Reform Commissions of Anhui province and Hefei city. The R&D project was approved for a total budget of **364 M RMB** and is jointly funded by Anhui, Hefei and USTC.

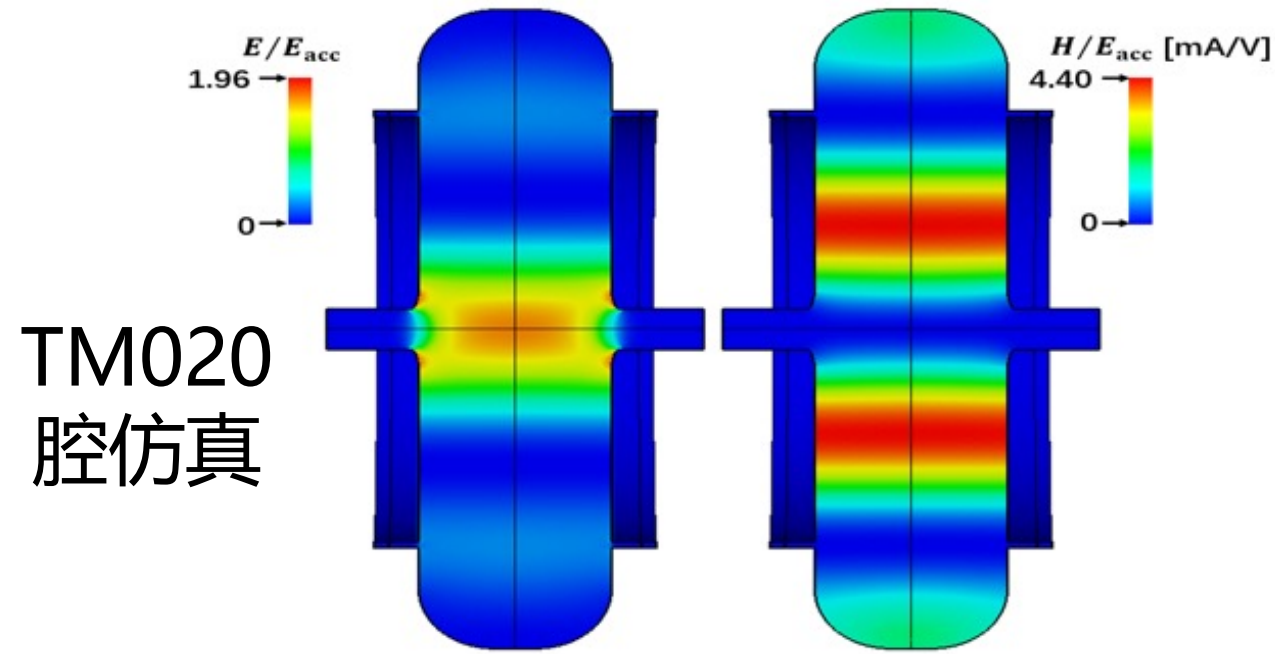
STCF Accelerator R&D

IR SC Magnets

Very constrained Space, 50T/m, CCT technology

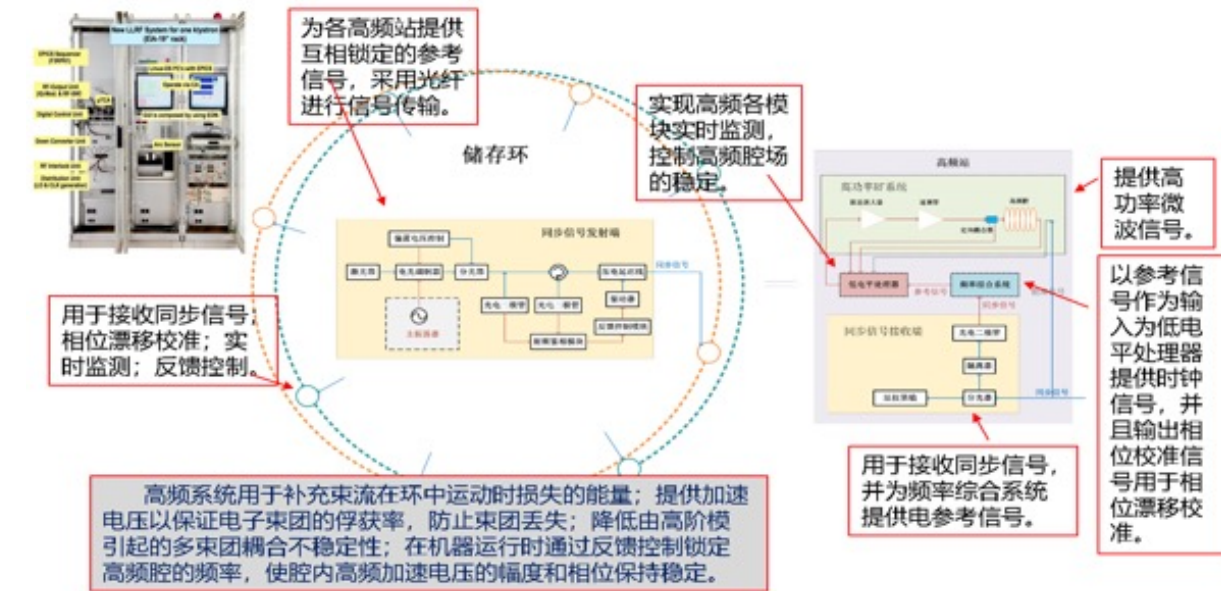


Room-temperature RF cavity



TM020
腔仿真

Low-level RF control system



Bunch by bunch 3D beam position measurement

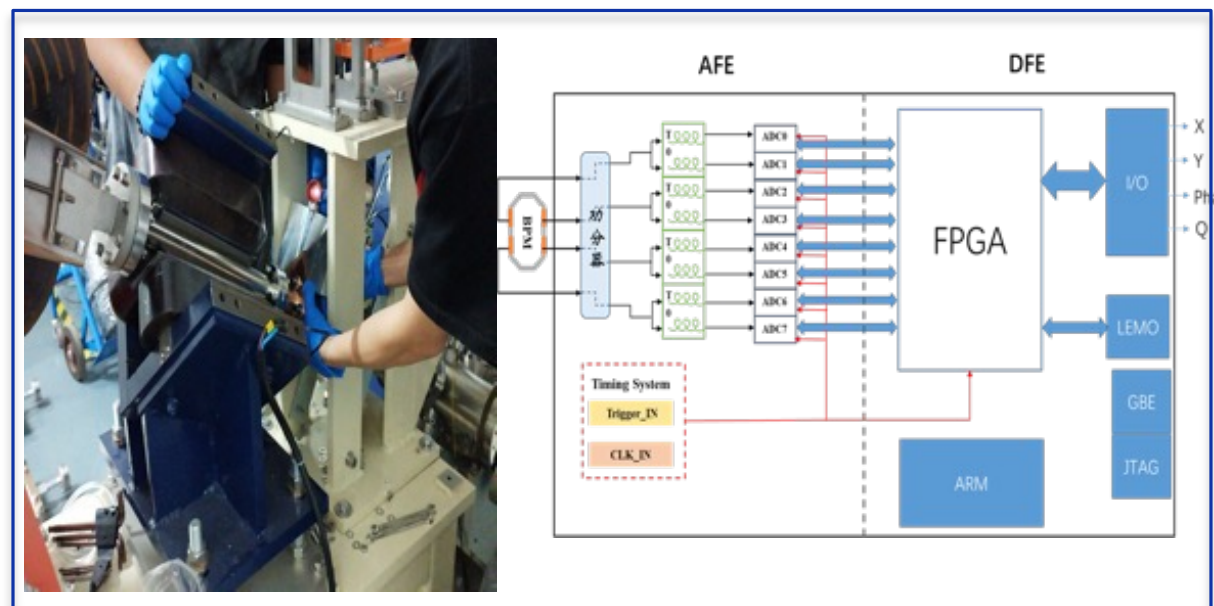
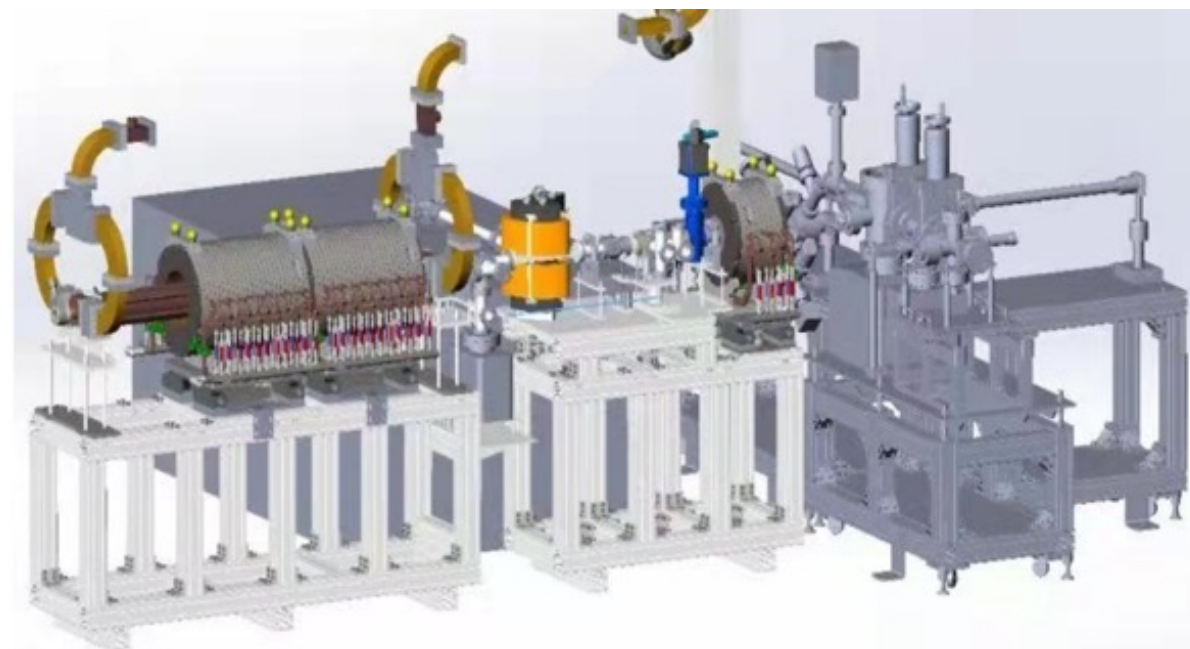
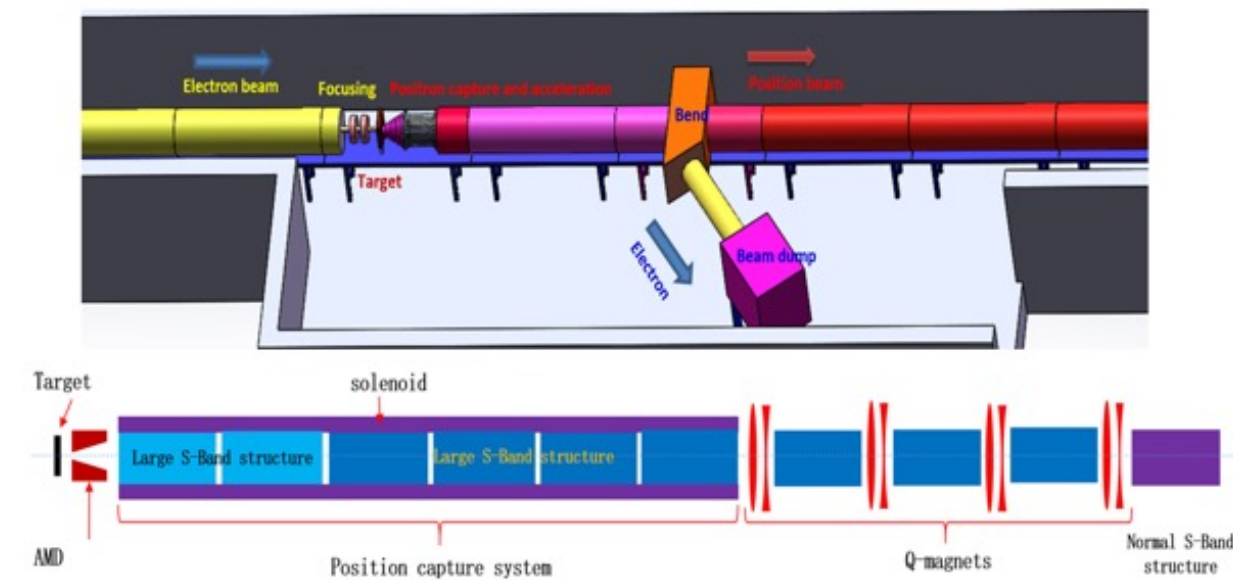


Photo-cathode electron gun

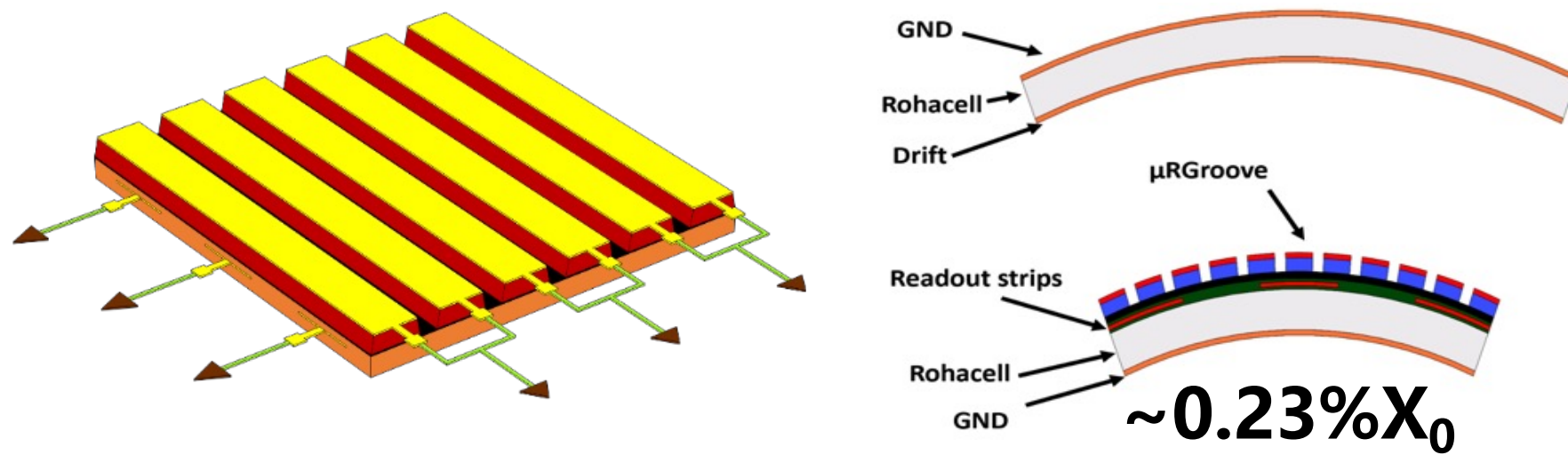


Positron source

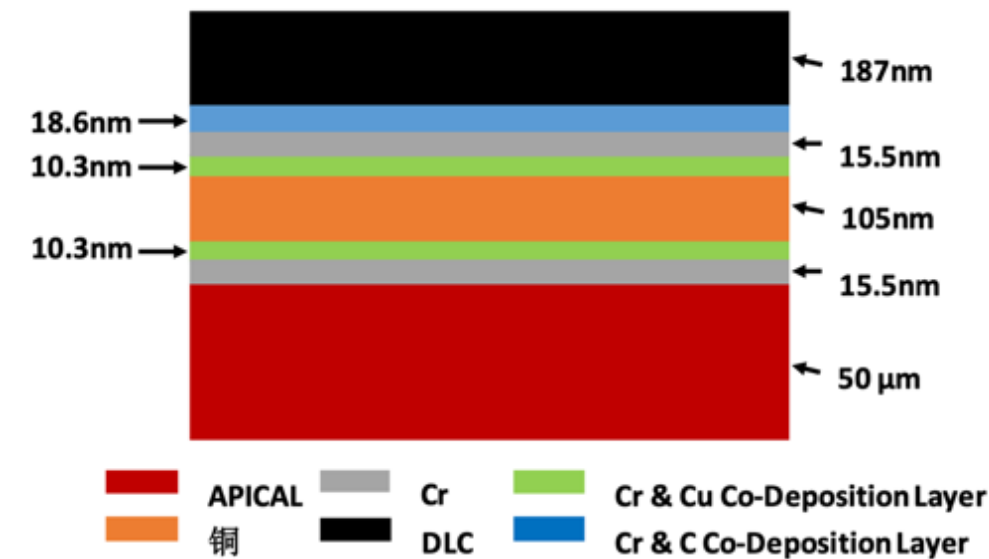


ITK-MPGD: μ RGroove

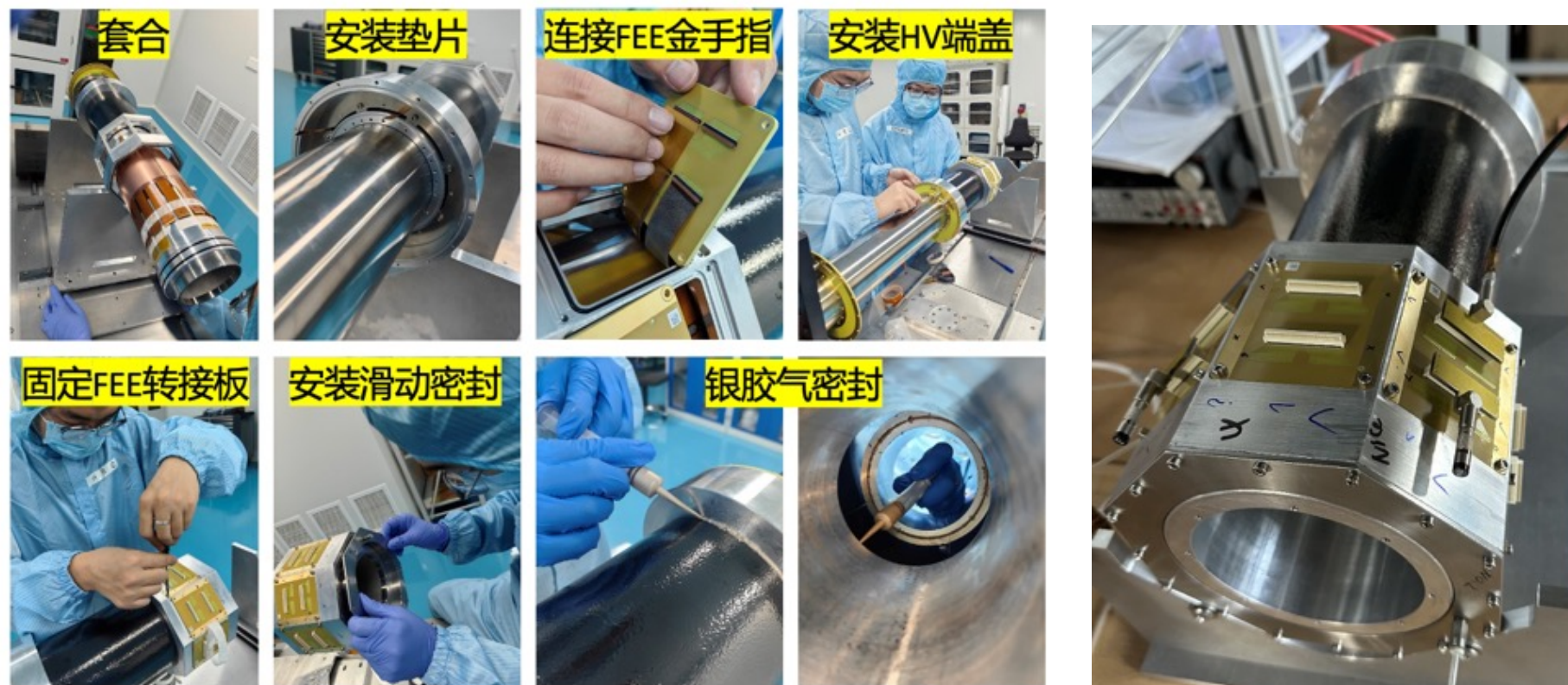
- μ RGroove : A single-stage MPGD involving no stretching or tensioning, 2D strip readout without charge sharing (large S/N), high rate with fast grounding, easy to make a cylinder, low mass, low production cost.



Development of low mass electrodes

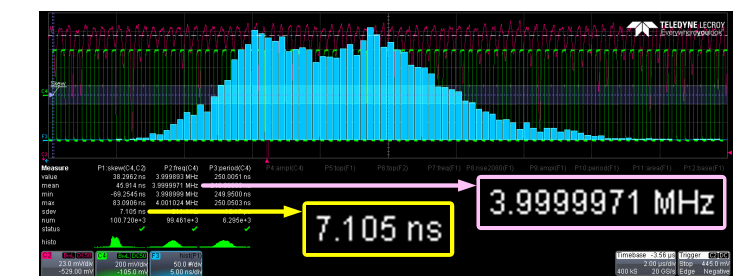
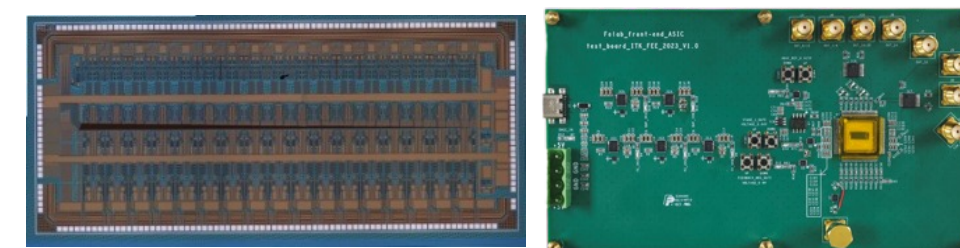
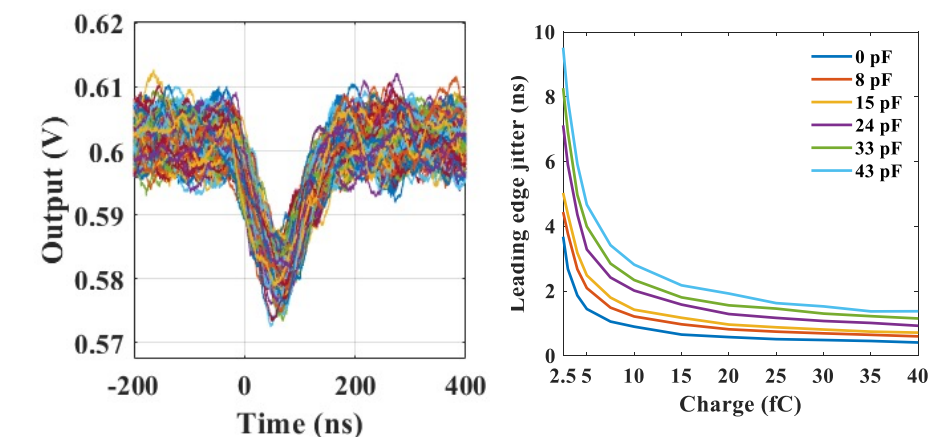


Fabricating cylindrical structure



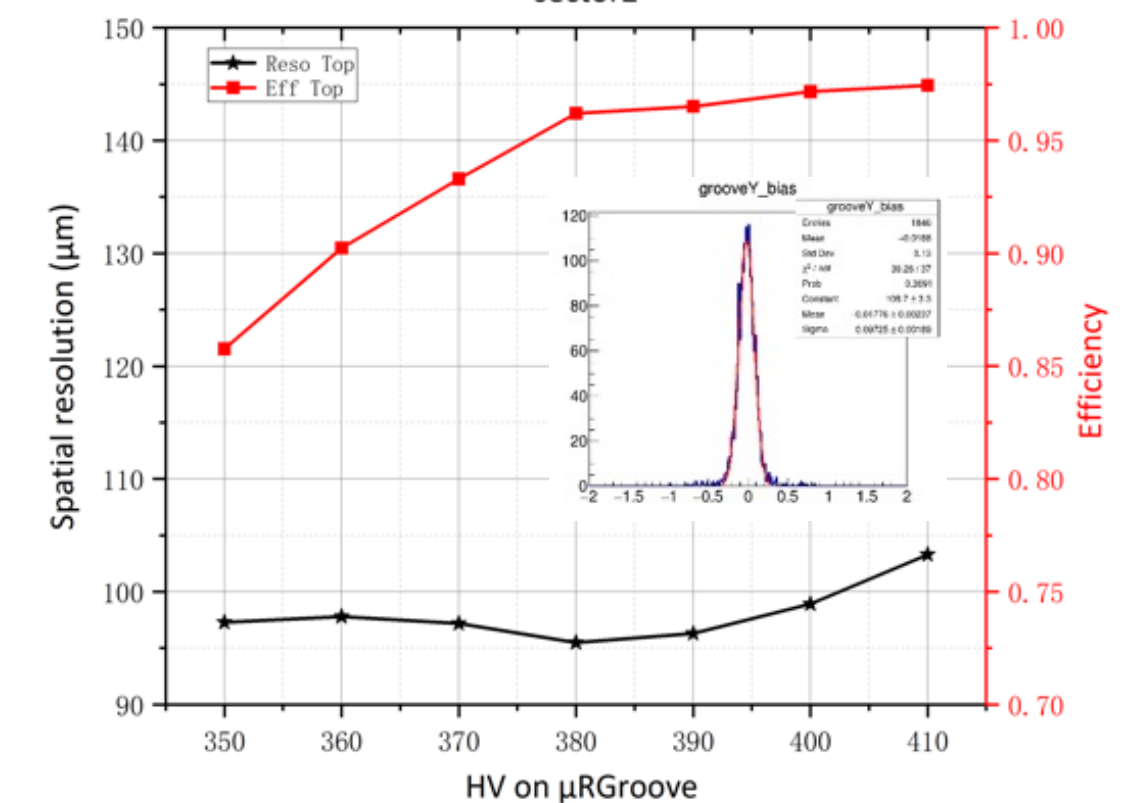
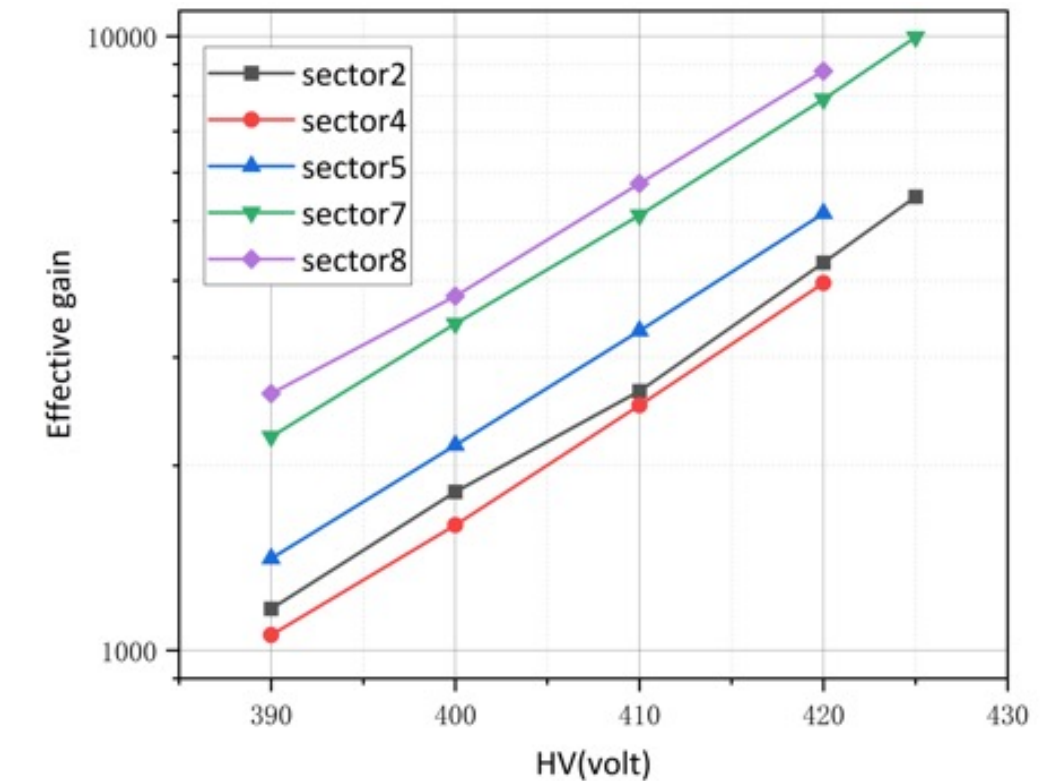
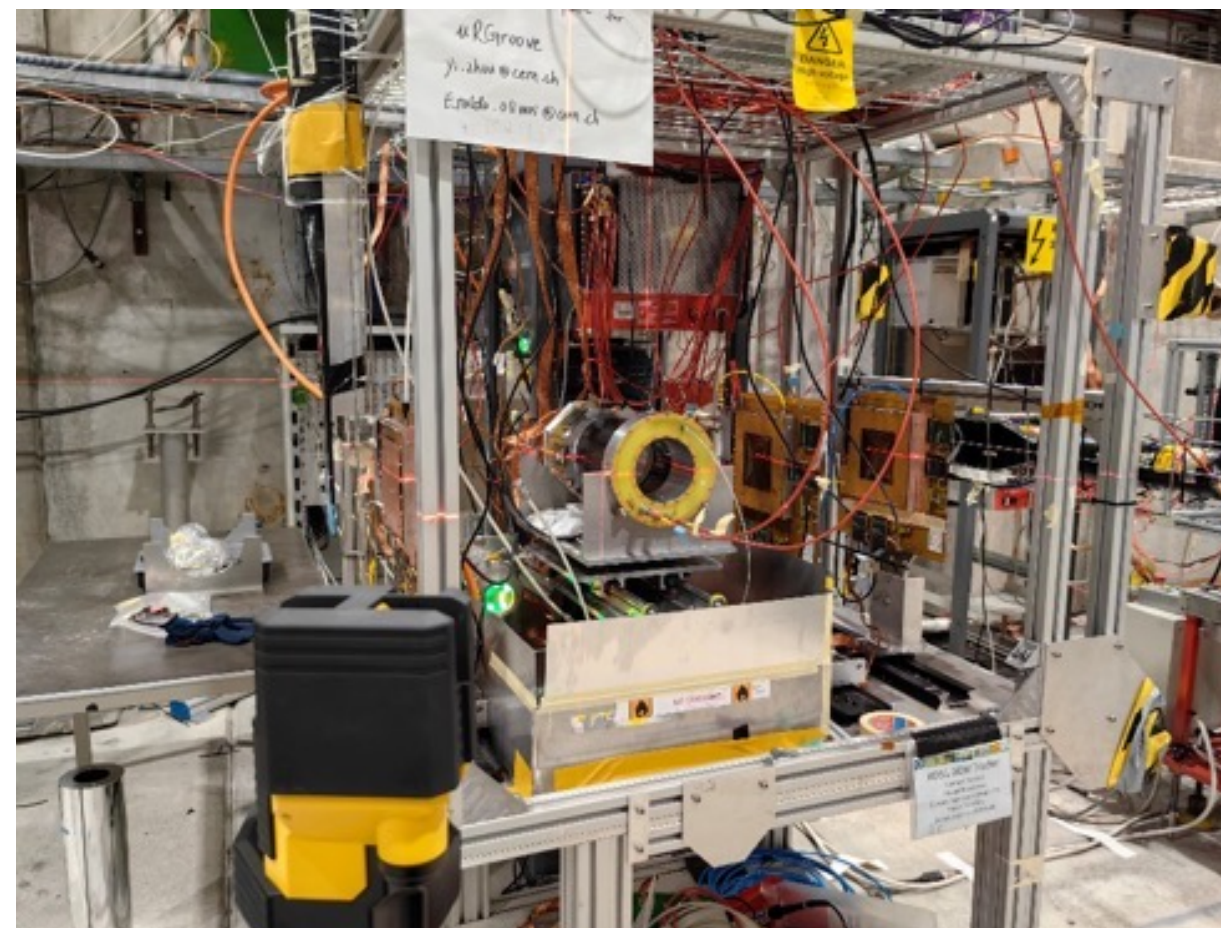
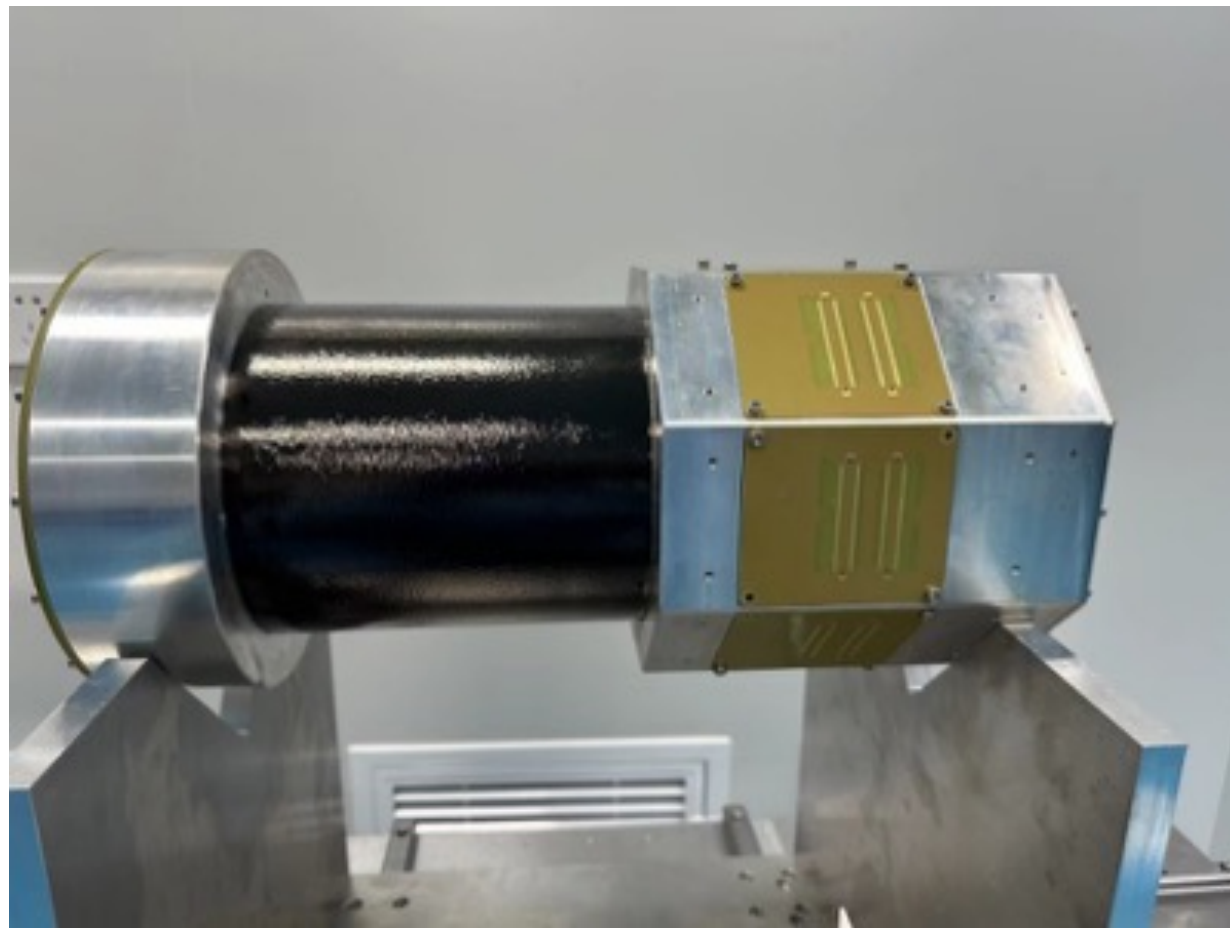
ASIC development

ASIC Specs	Demands
Charge Range	40 fC
Charge precision	~ 1 fC RMS
Time precision	< 10 ns RMS
Max. event rate	4 MHz



Cylindrical μ RGroove Prototype

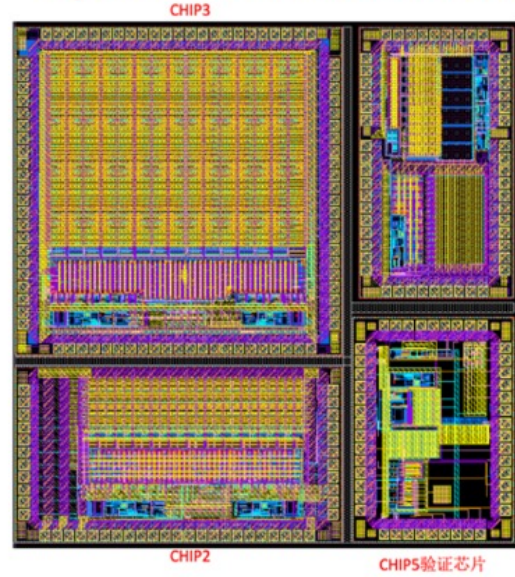
- Built a cylindrical μ RGroove prototype for the ITK inner most layer
- Tested the prototype with ^{55}Fe source in lab and SPS muon beam at CERN
- Effective gain ~ 5000 - 10000 for most sectors
- Spatial resolution < 100 μm and efficiency $> 95\%$
- The detector design and fabrication will be optimized in many aspects based on the prototyping experience



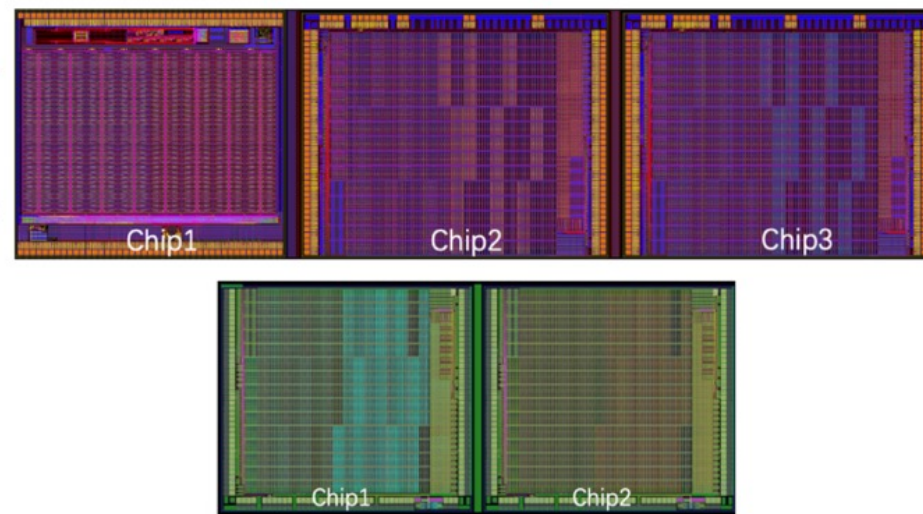
ITK-MAPS: Sensor Design

- Aiming for a low-power MAPS chip design (required for a low-mass system) with timing and charge measurement capability: position, time and charge (TOT)
- Low mass outweighs position resolution: exploring large pixel size to reduce power density

TowerJazz 180nm
Taped out in March 2024

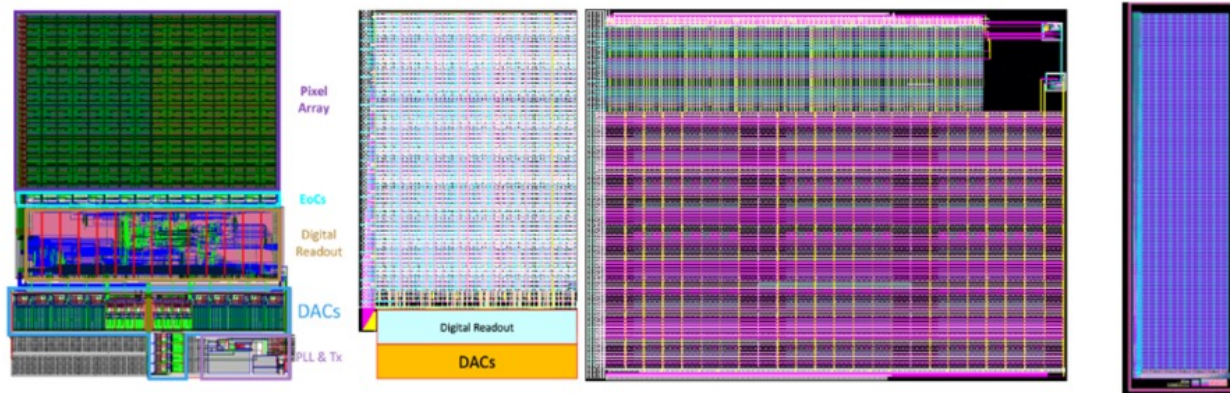


NexChip FCIS/BCIS 90nm
Taped out in May 2024



GSMC 130nm

Taped out in July 2024



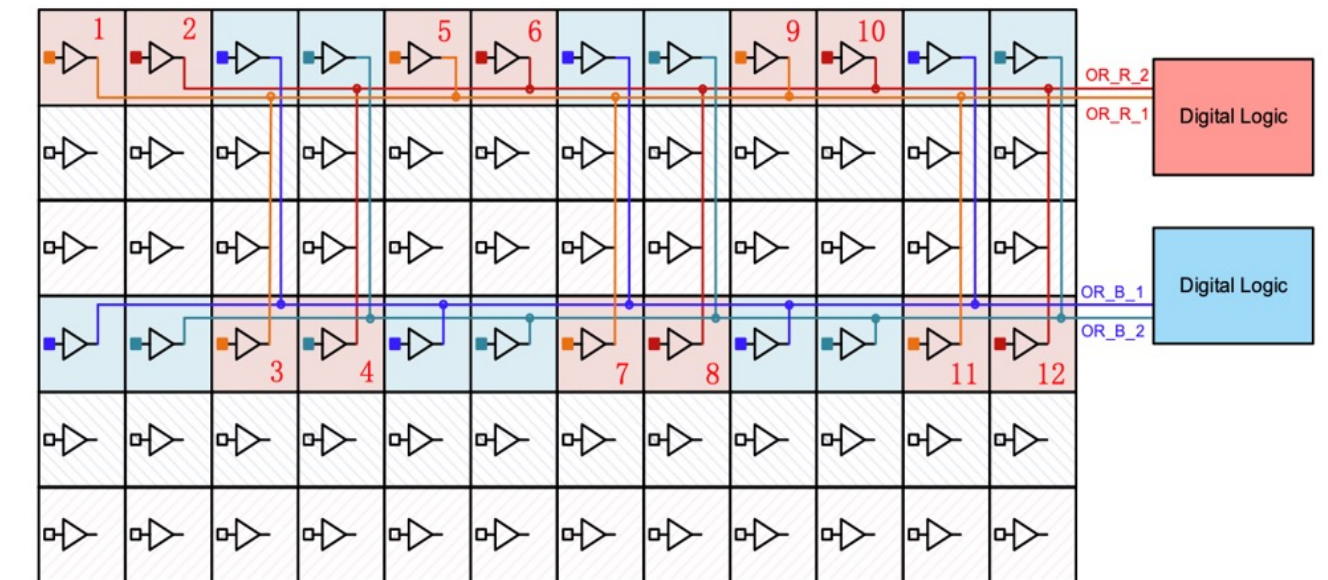
Simulated performance

	TJ-MAPS	GSMC-MAPS
Current	800 nA/pix	120*6 nA/pix
Supply Voltage	1.8 V	1.2 V
Threshold	309.0 e ⁻	153.8 e ⁻
ENC	11.4 e ⁻	5.1 e ⁻
Mismatch	5.7 e ⁻	5.8 e ⁻
t_r @400 e⁻	200 ns	81 ns

Items	Power consumption	Notes
Analog in pixel matrix	~26 mW/cm ²	Strip-based
	~15 mW/cm ²	Pixel-based
Timestamp clock distribution	12.2 mW/cm ²	
Dynamic power consumption of the pixel matrix	2.4 mW/cm ²	with a data rate of 8.7 MHz/cm ²
Periphery	23.5 mW	32MHz event rate
PLL, serializer, LVDS	39 mW	x 2 data/clock output
Analog configuration	20 mW	
Total	222.6 mW	Strip-based
	184.6 mW	Pixel-based

- Strip-based: 55.7 mW/cm²
- Pixel-based: 46.2 mW/cm²

Super Pixel Design

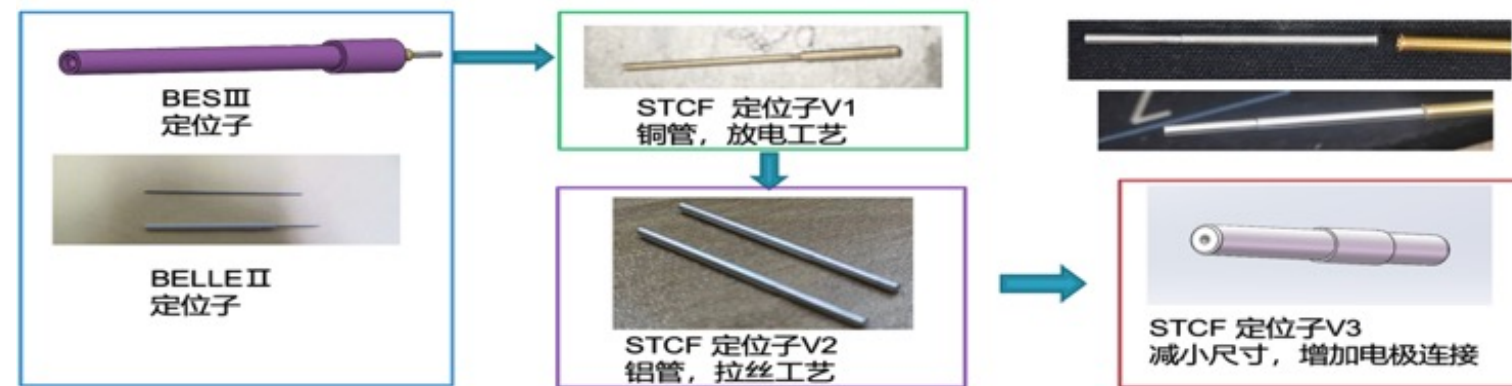
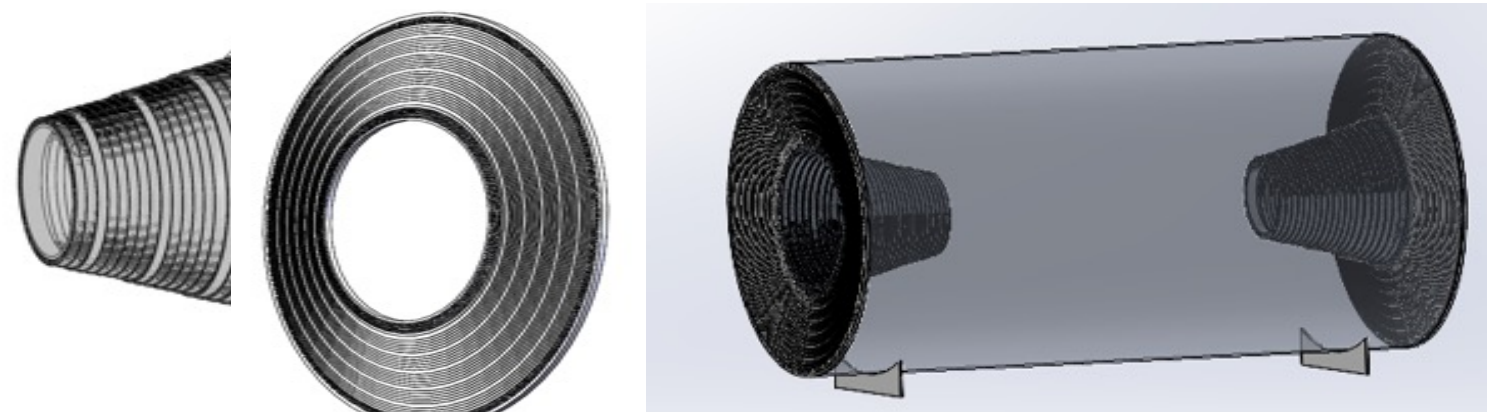


Providing both high position and high time resolutions for low power consumption

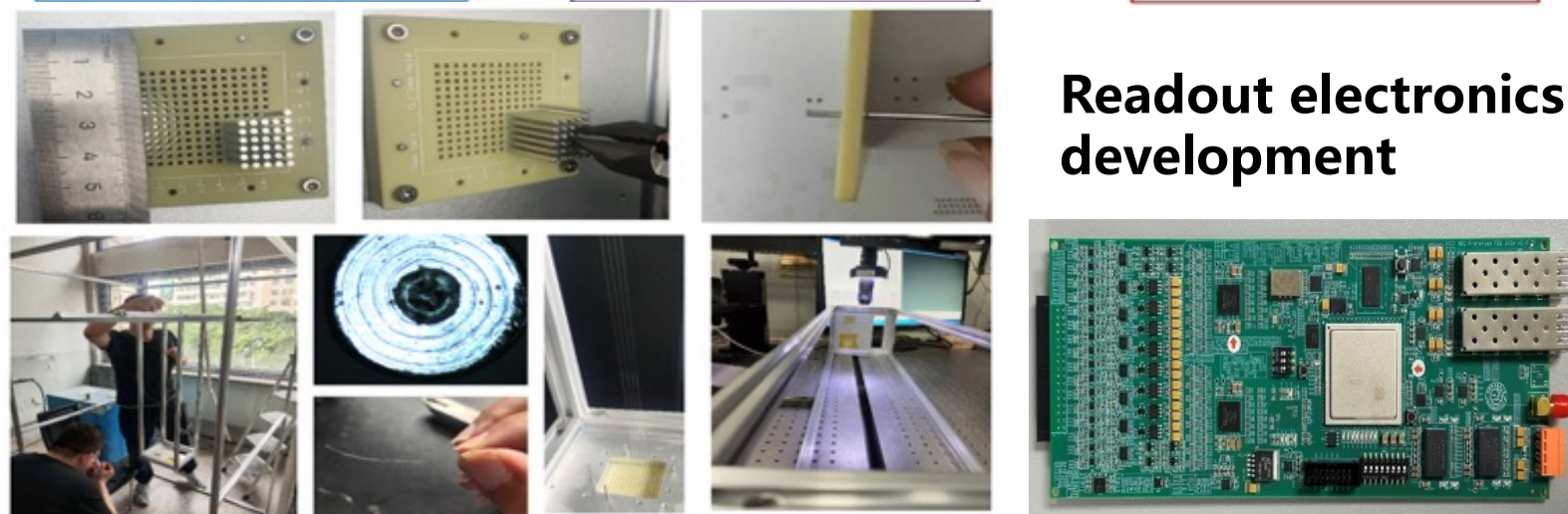
MDC, EMC

Main Drift Chamber

low mass(helium-based gas, aluminum wires),
super-small cell (5mm×5mm), high rate
(~100kHz/cell), spatial resolution <130μm

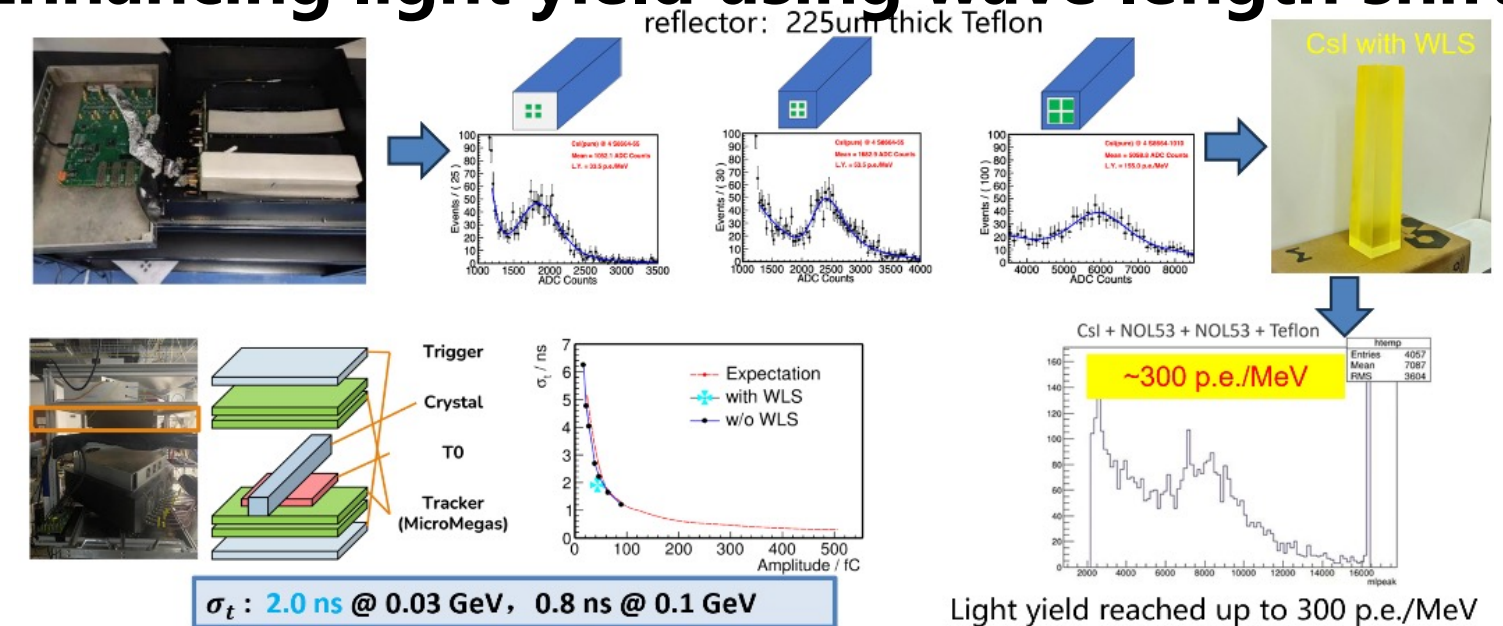


Readout electronics
development

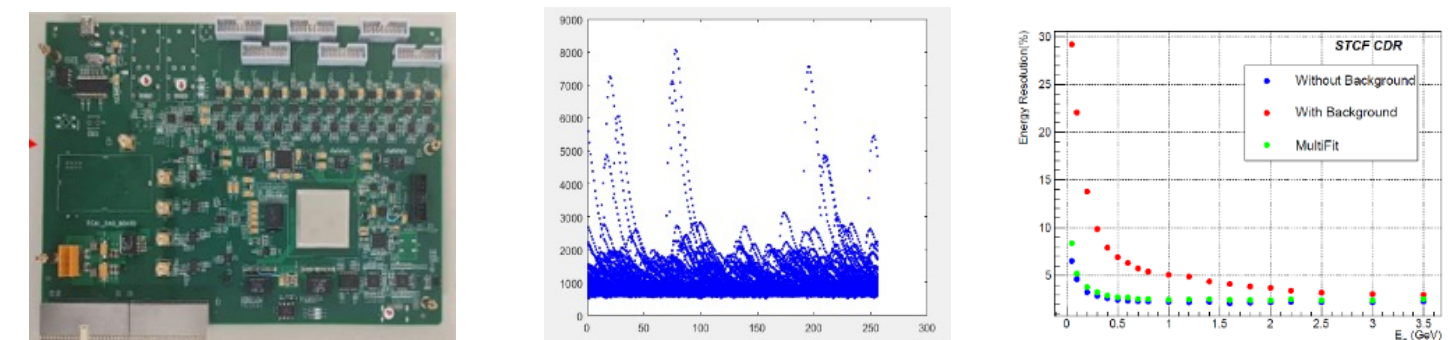


Electro-Magnetic Calorimeter

Enhancing light yield using wave length shifter



Pileup removal (~1 MHz/channel)
waveform digitization + waveform fitting

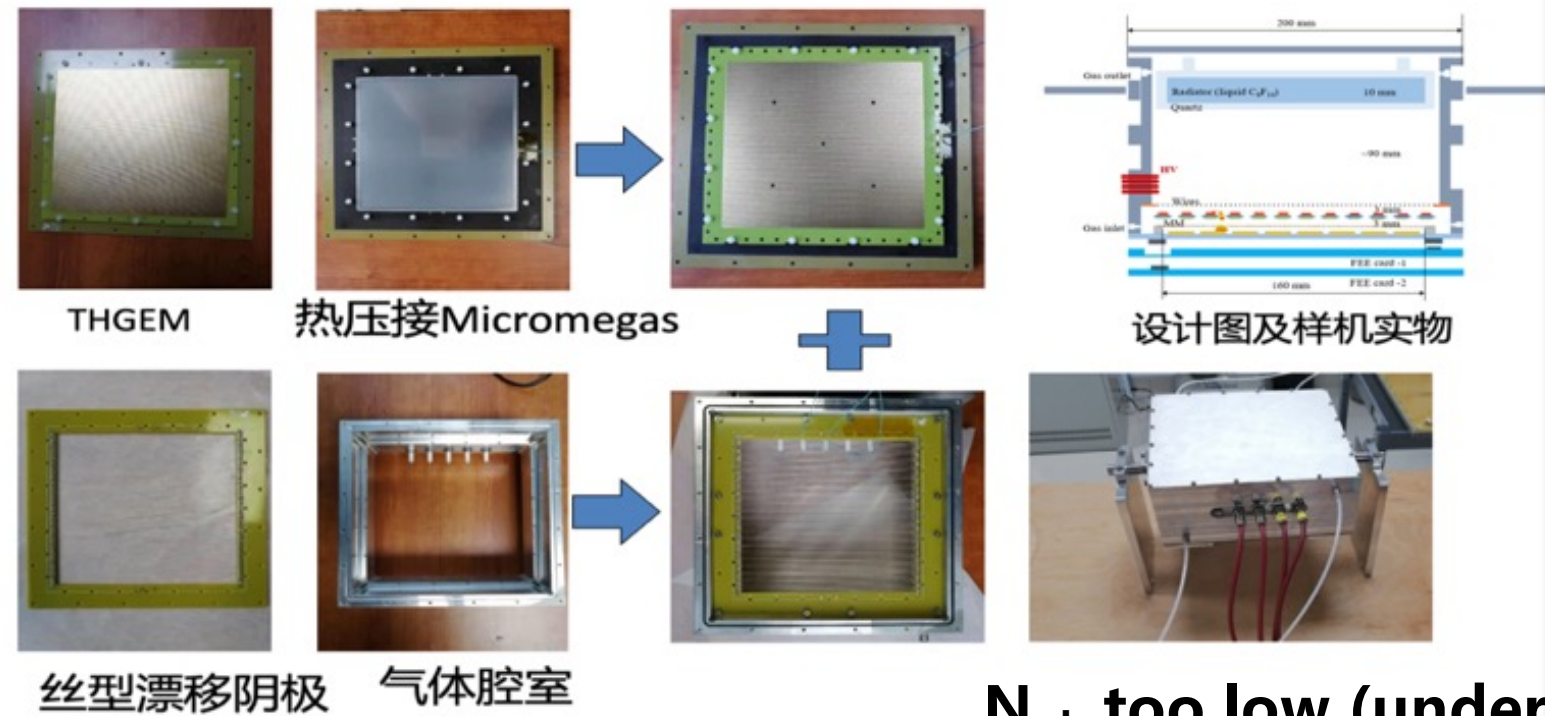


5×5 ECAL prototype



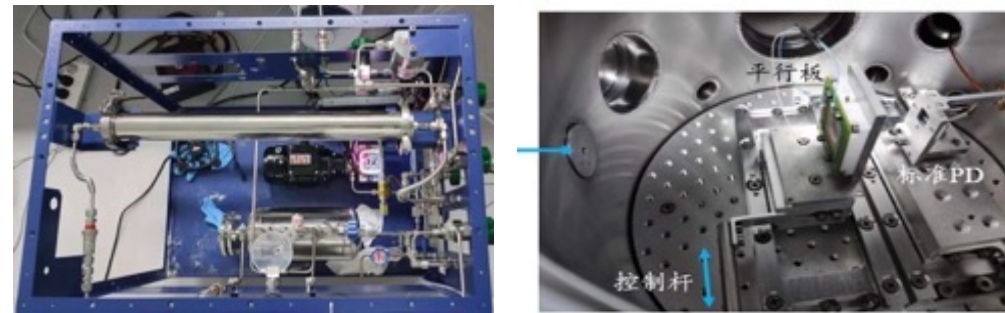
PID

Barrel PID: RICH

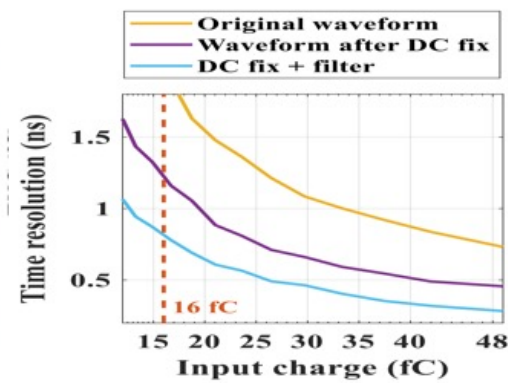
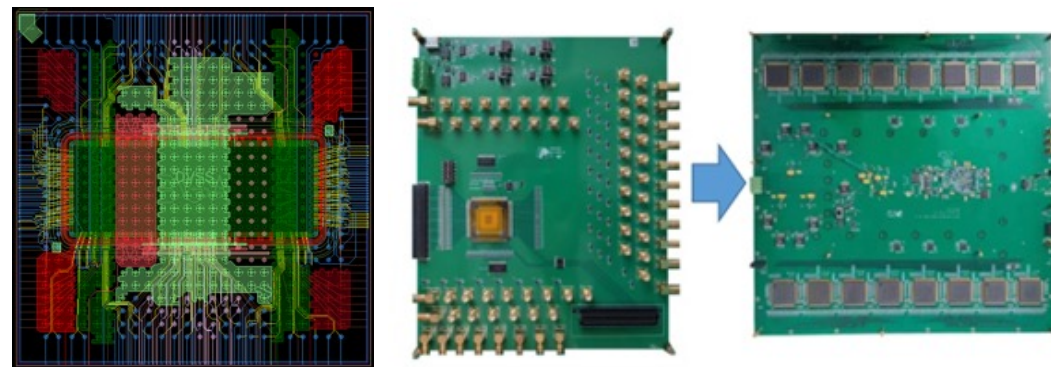


N_{ph} too low (under investigation)

Radiator Purification CsI Coating

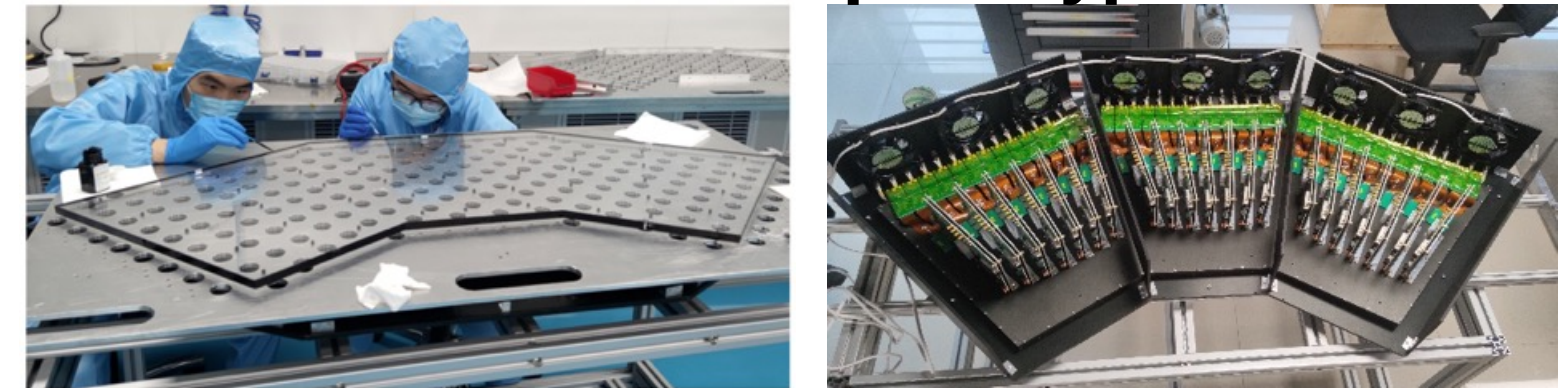


Readout ASIC Development

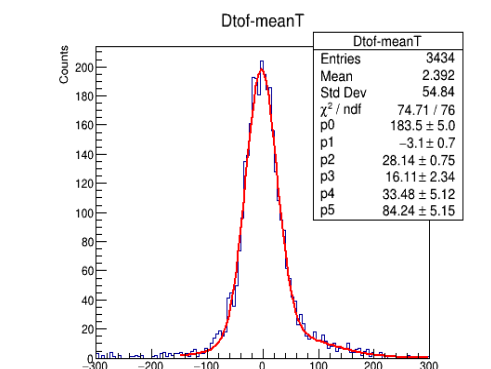
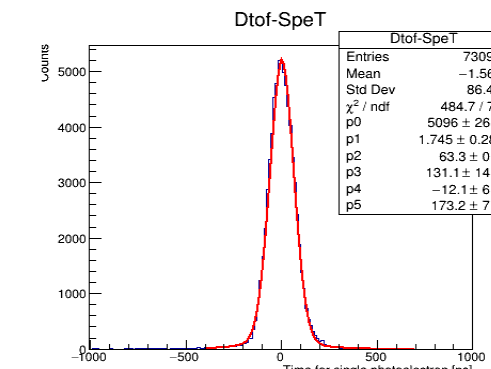
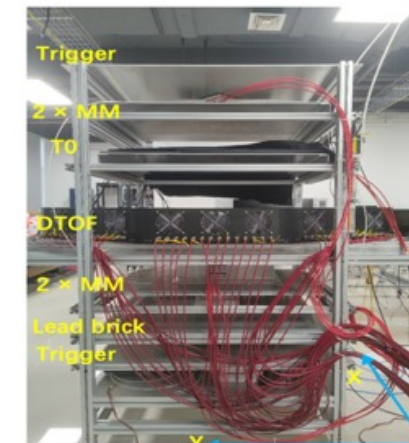


Endcap PID: DTOF

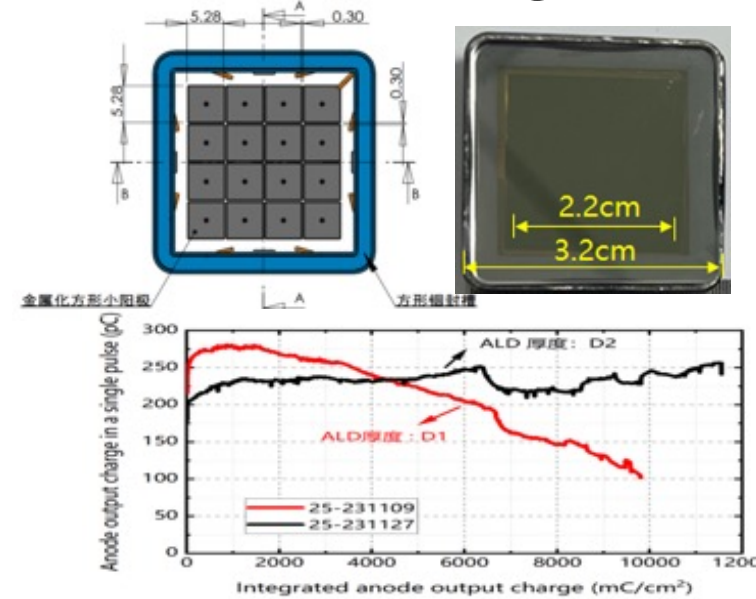
Full-sized prototype



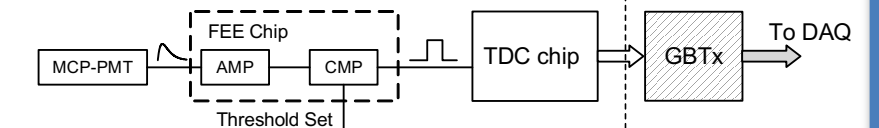
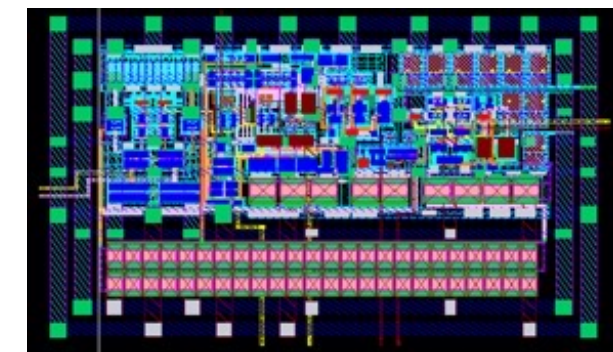
$\sigma_{spe} = 59 \text{ ps}$, $\sigma_{track} = 21 \text{ ps}$



Development of fast MCP-maPMT with long life time



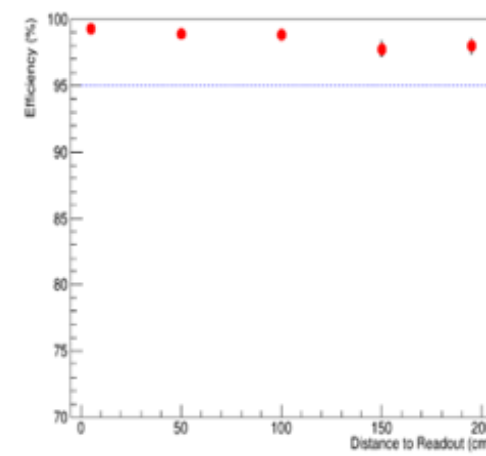
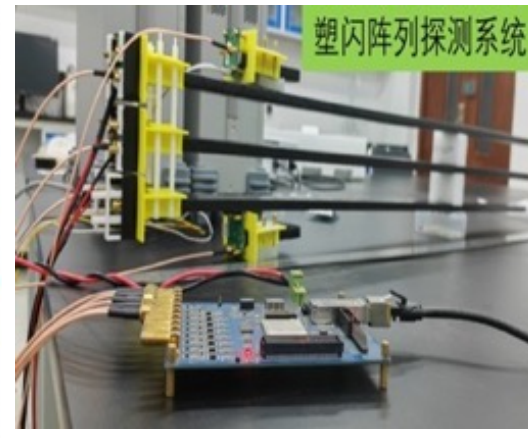
ASIC development



MUD, Trigger, DAQ, Clock, Data Link

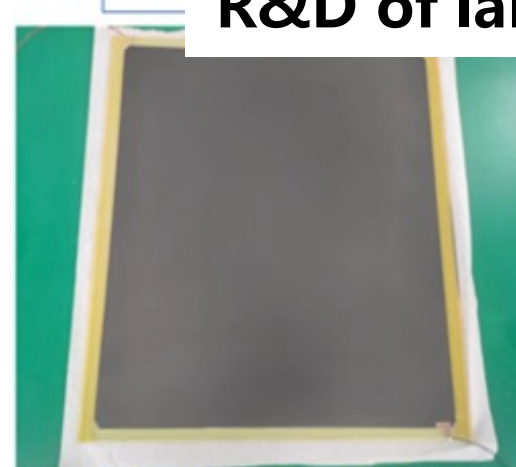
Muon Detector

R&D of scintillator strips



R&D of large area high-rate glass-RPC

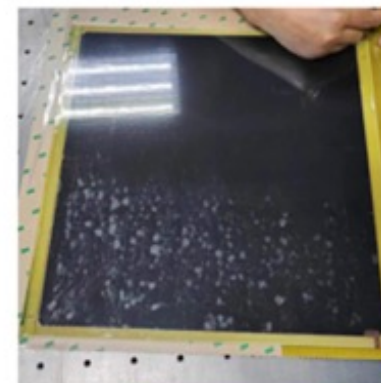
eck



HV electrode painting

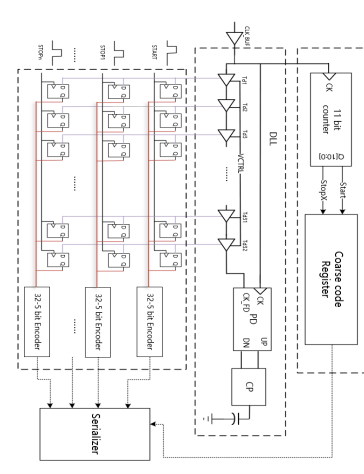
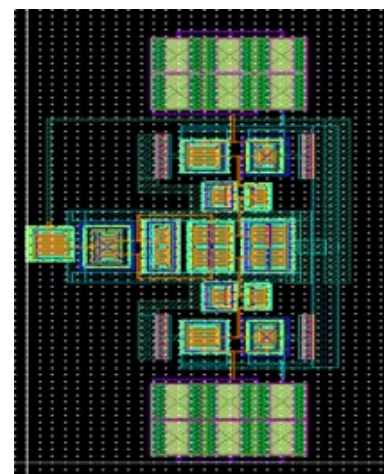
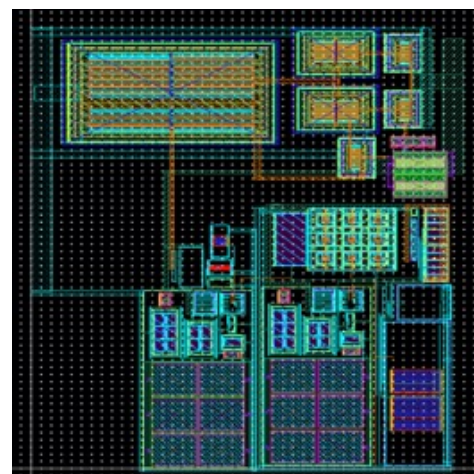


Applying insulation film



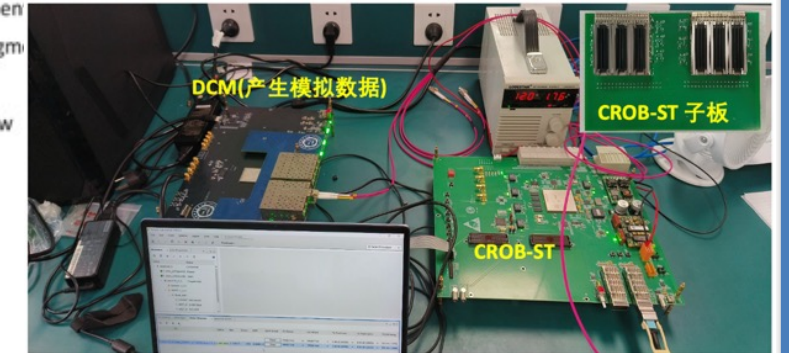
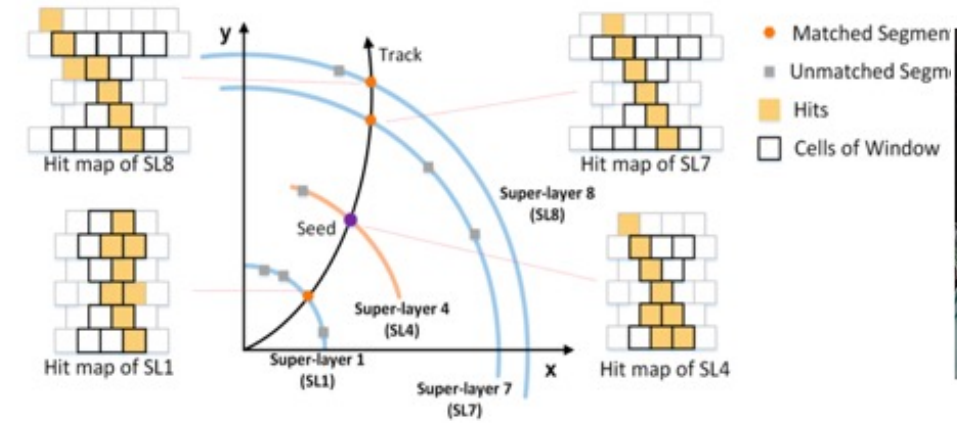
Finished gap

Readout ASIC

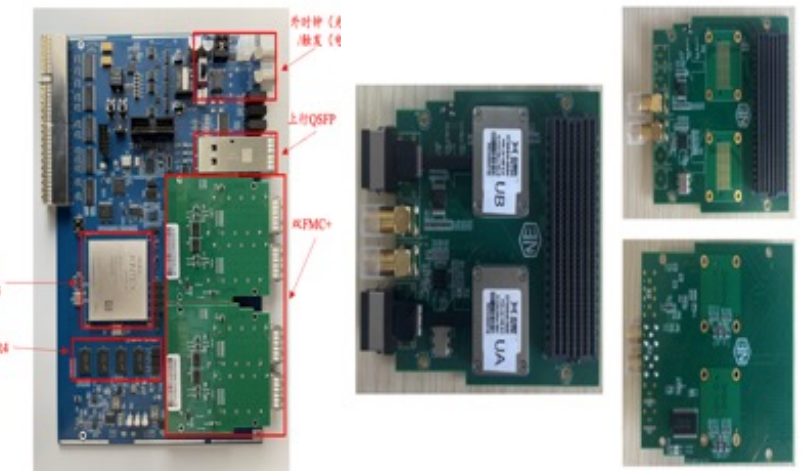
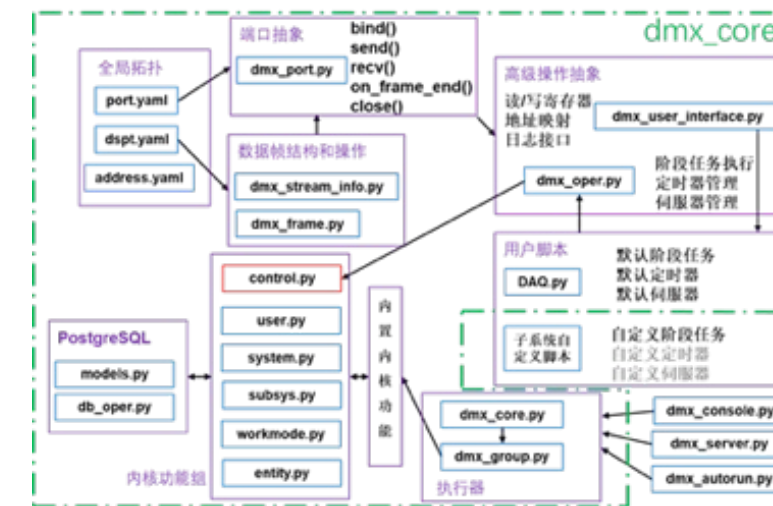


Trigger, DAQ, Clock, Data link

Trigger algorithms and electronics

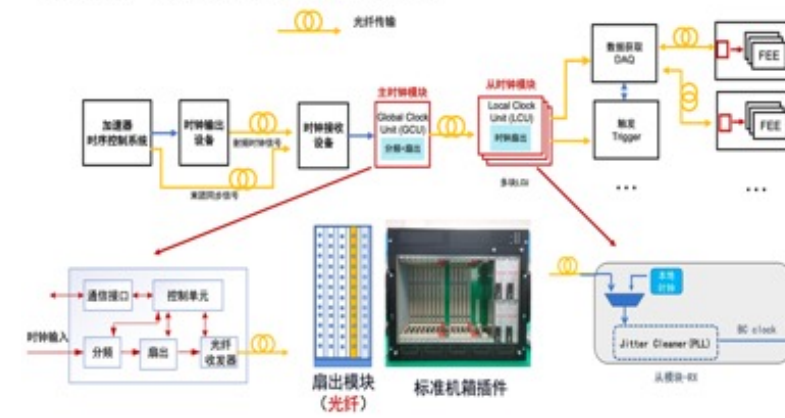


DAQ software design and electronics

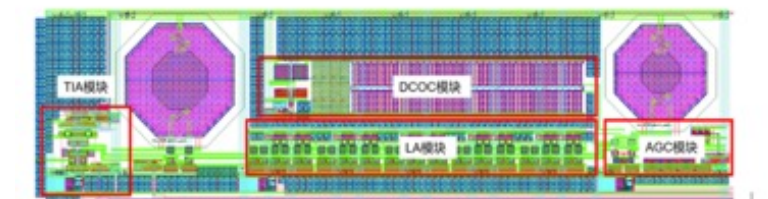


Clock distribution, GBT-like ASIC, Opto-driver ASIC

□ “主-从”时钟模块: 分频、扇出, 低抖动



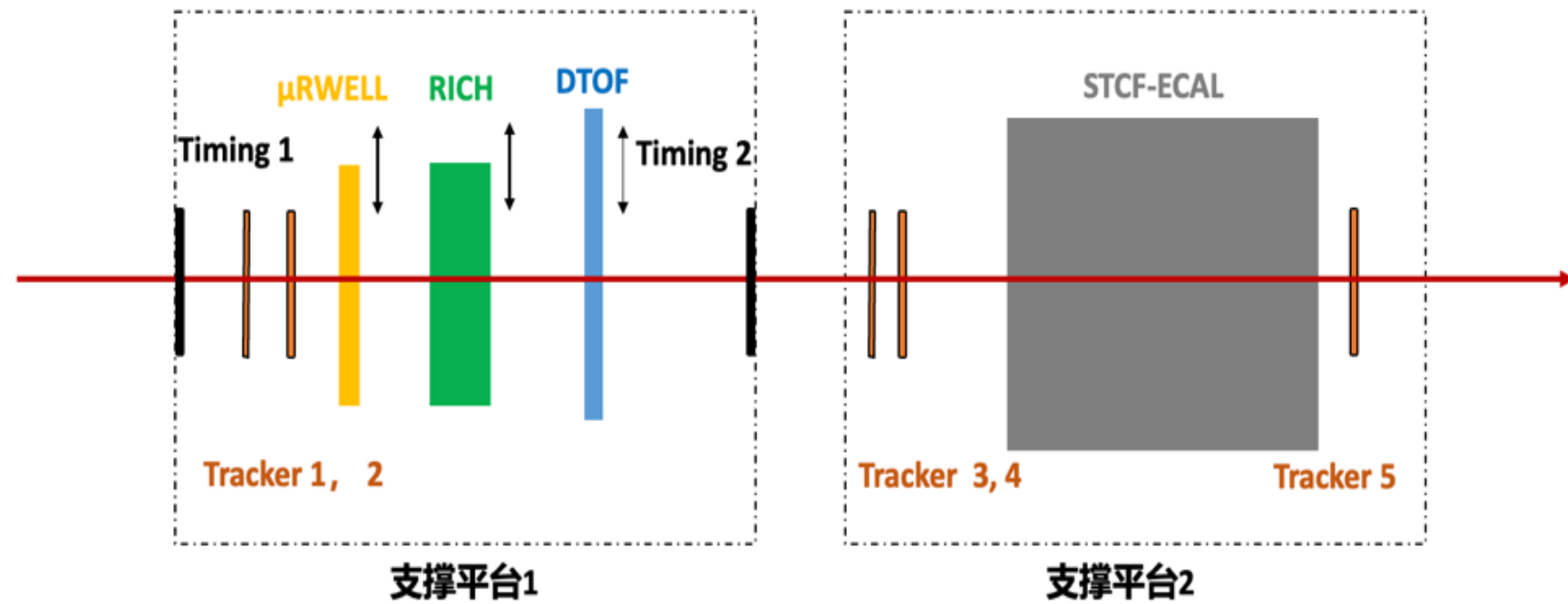
激光器驱动芯片单通道模拟核心版图基本完成



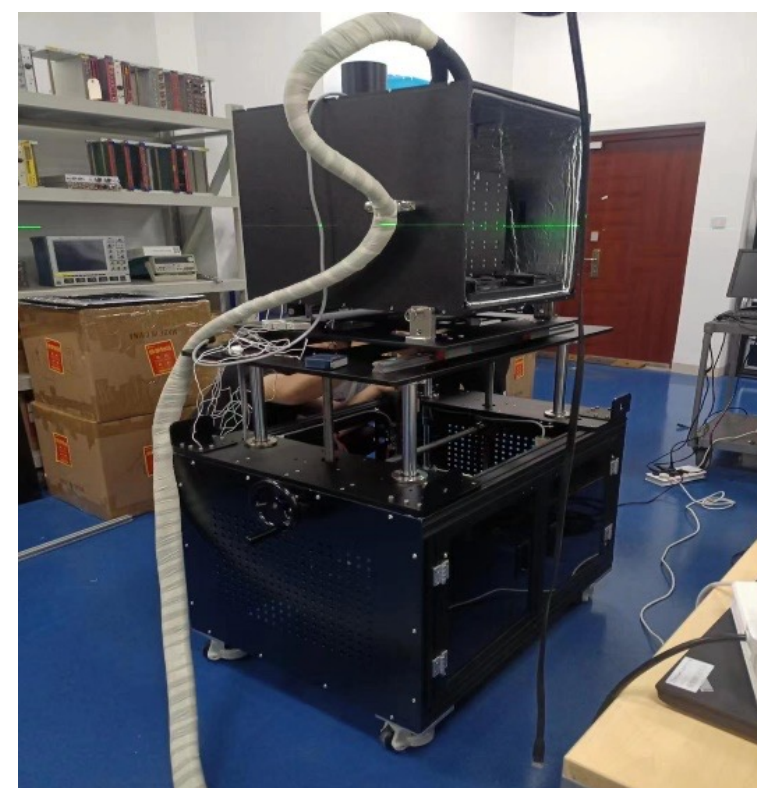
TIA跨导接收芯片单通道模拟核心版图基本完成

Combined Beam Test

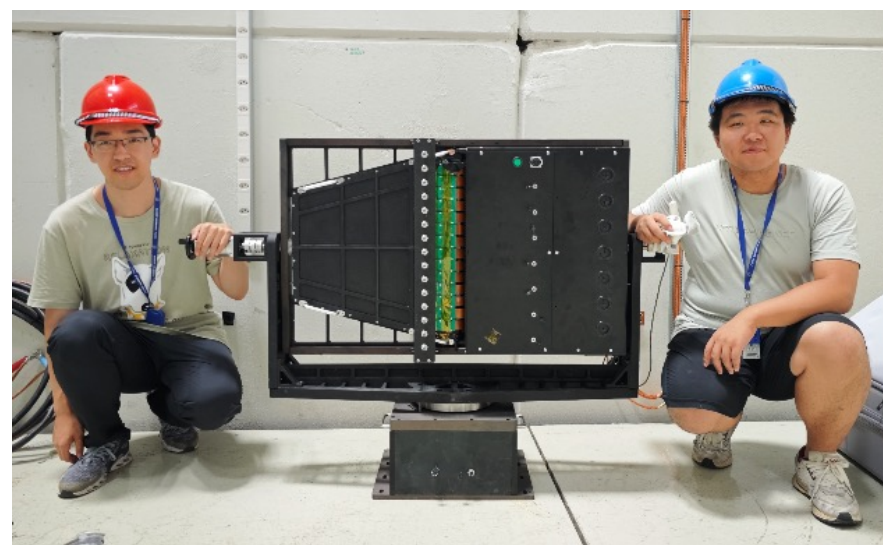
A test beam campaign for a combined system (DTOF, EMC, DAQ)



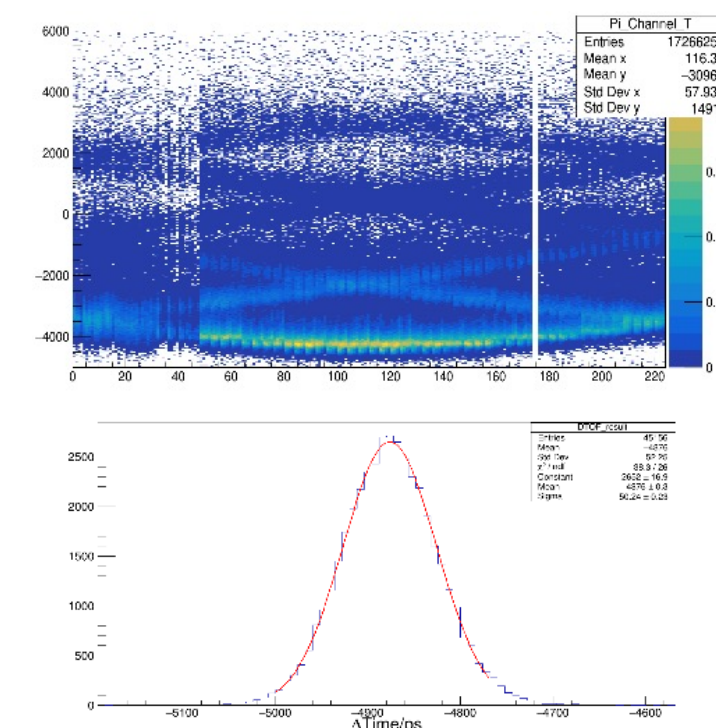
EMC Prototype



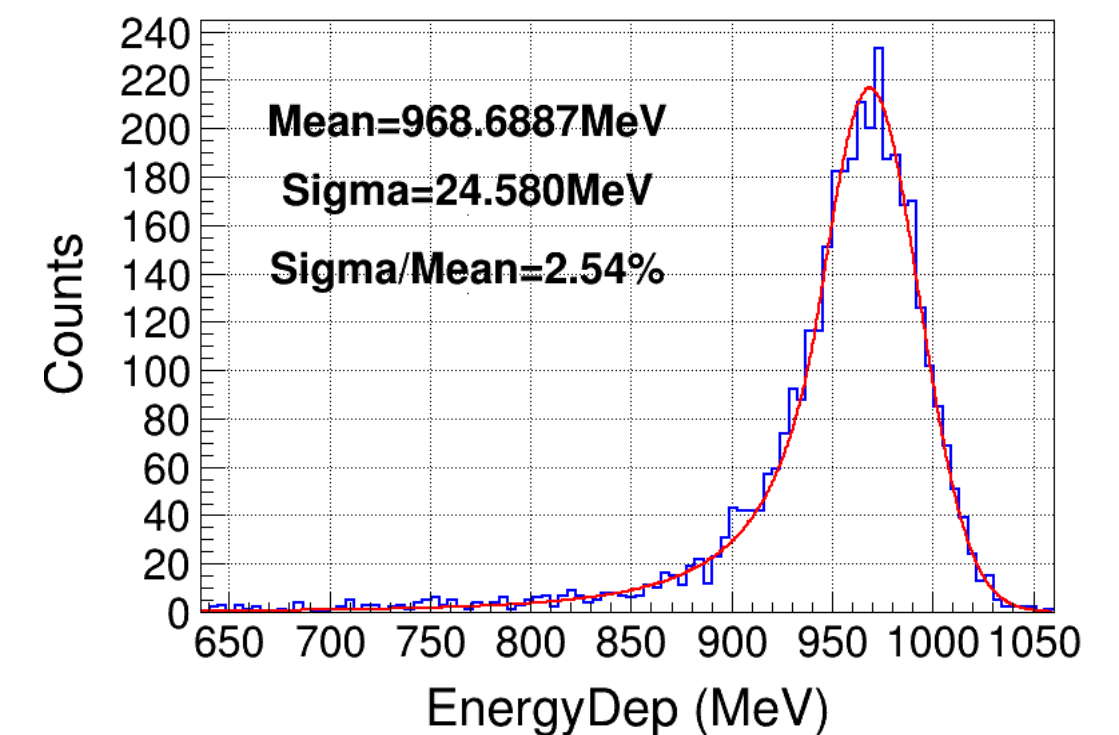
DTOF Prototype



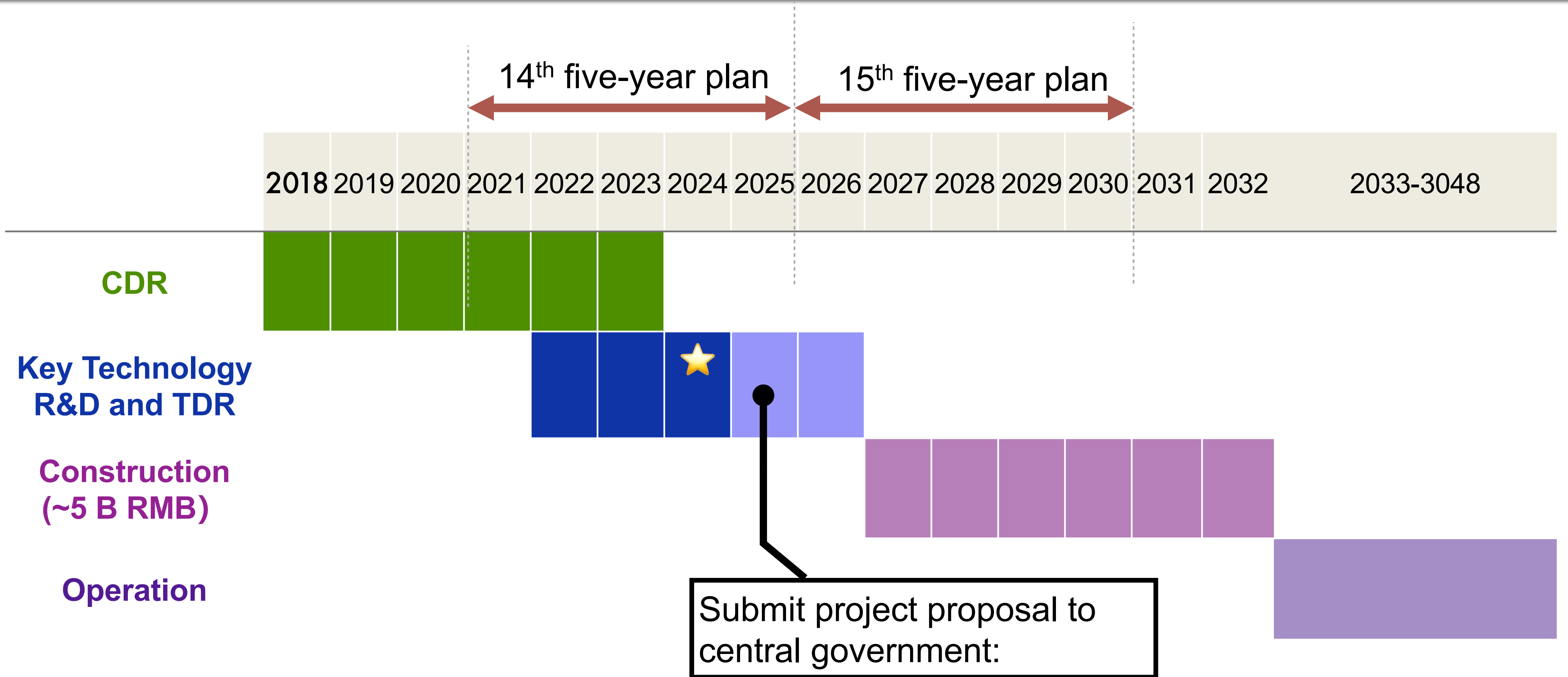
DTOF: $\sigma_t \sim 25$ ps



EMC: $\sigma_E/E \sim 2.5\%$



STCF Project Schedule



Final Remarks

- **SM has been "standard physics" for too long, and we know it's far from being the end of particle physics. We are desperate for new paradigms in our field and to break through the "standard", particularly in the post-Higgs era.**
- **Colliders have been and will continue to be one of the most powerful tools to explore particle physics and fundamental laws of nature. With no more definite guidance from theory, we need colliders at complementary frontiers for particle physics more than ever.**
- **CEPC and STCF are excellent examples of this complementarity, although they are at very much different scales in many ways.**
- **Tremendous progress has been made and many milestones have been achieved in both projects, demonstrating the passion, aspiration, strength and potential of Chinese HEP community. China should and could play a more important role in the course to HEP future.**
- **International collaboration is always essential or indispensable**
- **We should work together to ensure our future colliders be realized wherever the colliders will be in the world.**

The 2024 International Workshop on CEPC

Oct. 23-27, 2024, Hangzhou, China

International Workshop on The High Energy Circular Electron Positron Collider

October 23 - 27, 2024, Hangzhou, China

The purpose of this international workshop is to convene a global community of scientists to explore the physical potential of the Circular Electron Positron Collider (CEPC). The event aims to foster international collaboration in optimizing accelerators and detectors, as well as to intensify research and development (R&D) efforts in key technologies. Additionally, the workshop will delve into the exploration of industrial partnerships, focusing on the R&D of technologies and preparation for their industrialization.

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中山大学 SUN YAT-SEN UNIVERSITY **中国科学技术大学** University of Science and Technology of China

The 6th International Workshop on Future Tau Charm Facilities

FTCF, 2024, Guangzhou
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Dates: Nov. 17-21, 2024

Place: Sun Yat-sen University, Guangzhou

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