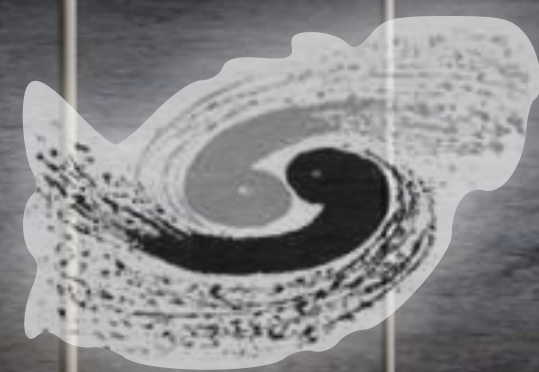


Latest progress and physics goals of CEPC

João Guimarães da Costa
(on behalf of the CEPC Project)



中国科学院高能物理研究所

*Institute of High Energy Physics
Chinese Academy of Sciences*

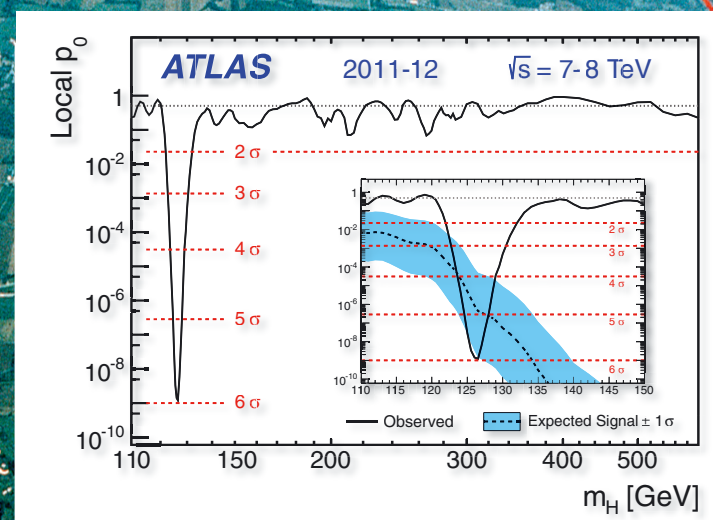
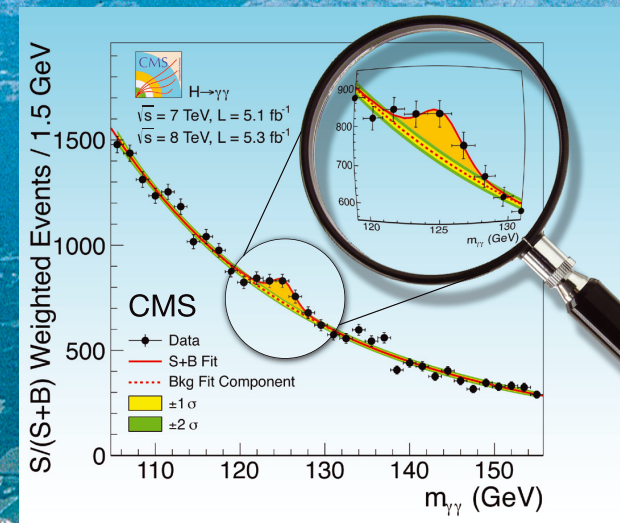
The Higgs Boson Discovery at LHC

Predicted in 1964, discovered in **2012**! 48 year hunting!

An effort by tens of thousands **scientists and engineers** from all over the world

ATLAS & CMS Observation

First observations of a new particle
in the search for the Standard
Model Higgs boson at the LHC



www.elsevier.com/locate/physletb

2013 Nobel Prize



Huge impact to humanity

Technology
Cultural

International Collaboration

The next step
for HEP was clear!

A Higgs factory



François Englert and Peter Higgs

Introduction: Project Overview

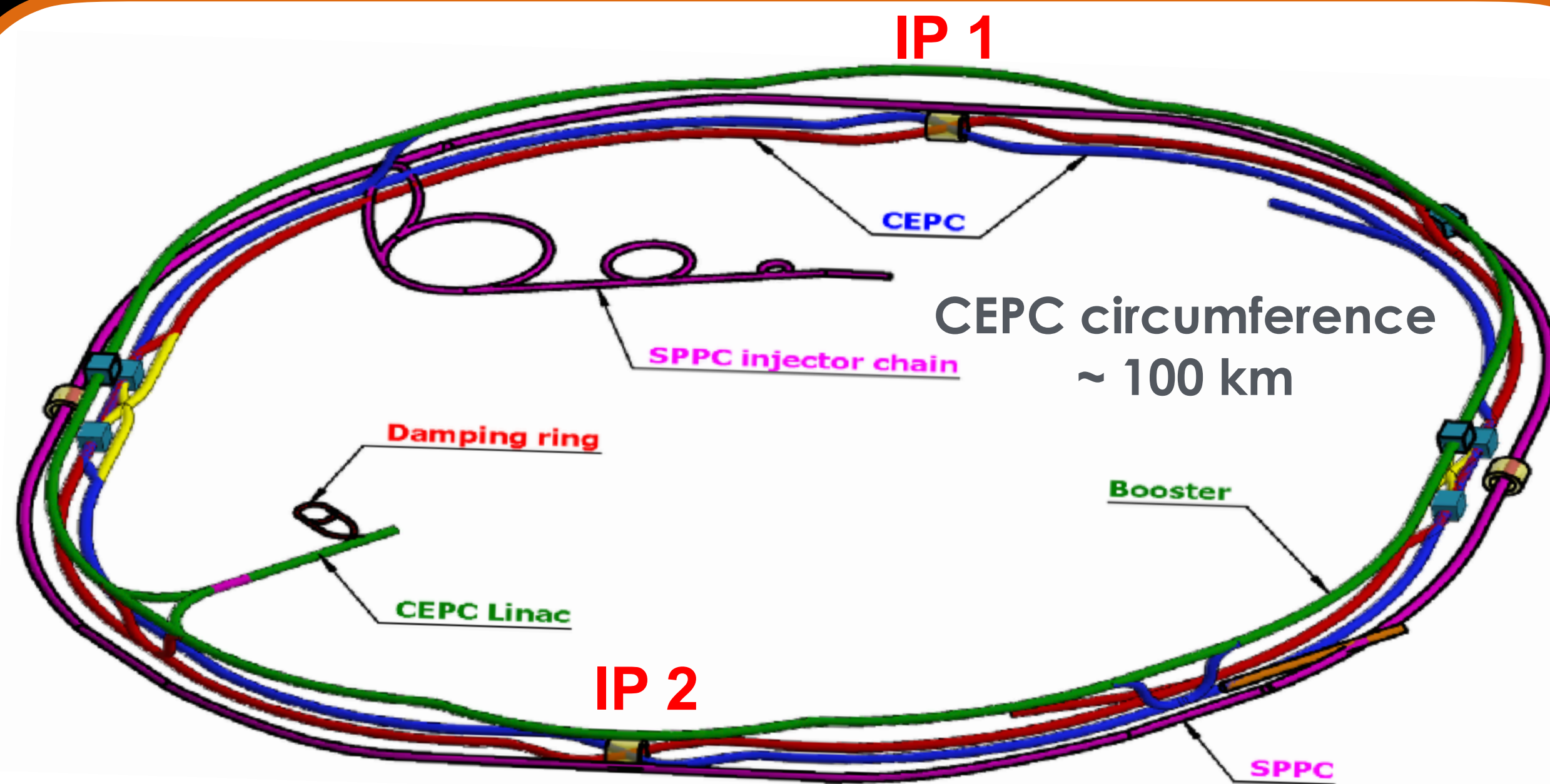


CEPC is an e^+e^- Higgs factory

possibly to be followed by a Super proton-proton Collider (SPPC)

Proposed in September 2012 right after the Higgs discovery

Tunnel can be reused for pp, heavy-ions, or ep collisions up to ~ 100 TeV



Mode	$\sqrt{s}$ (GeV)	Events
WH	240	>1 million
WW	160	
Z	90	Tera-Z

Upgrade path

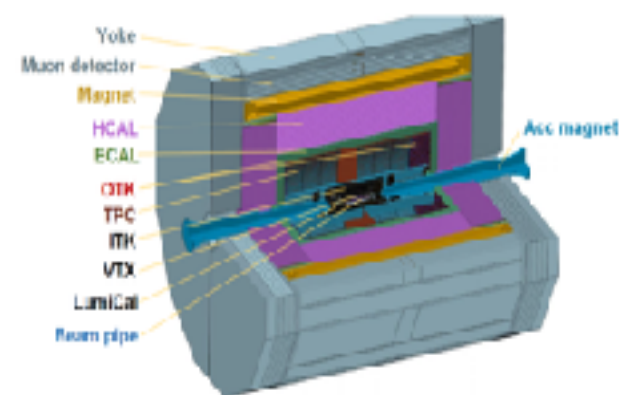
1. Higher power: 30 MW $\rightarrow$ 50 MW
2. Higher energy $\rightarrow$ top quark pair production
3. Super pp Collider (SppC) at ~ 125 TeV

CEPC Higgs Factory and SppC Layout in TDR/EDR

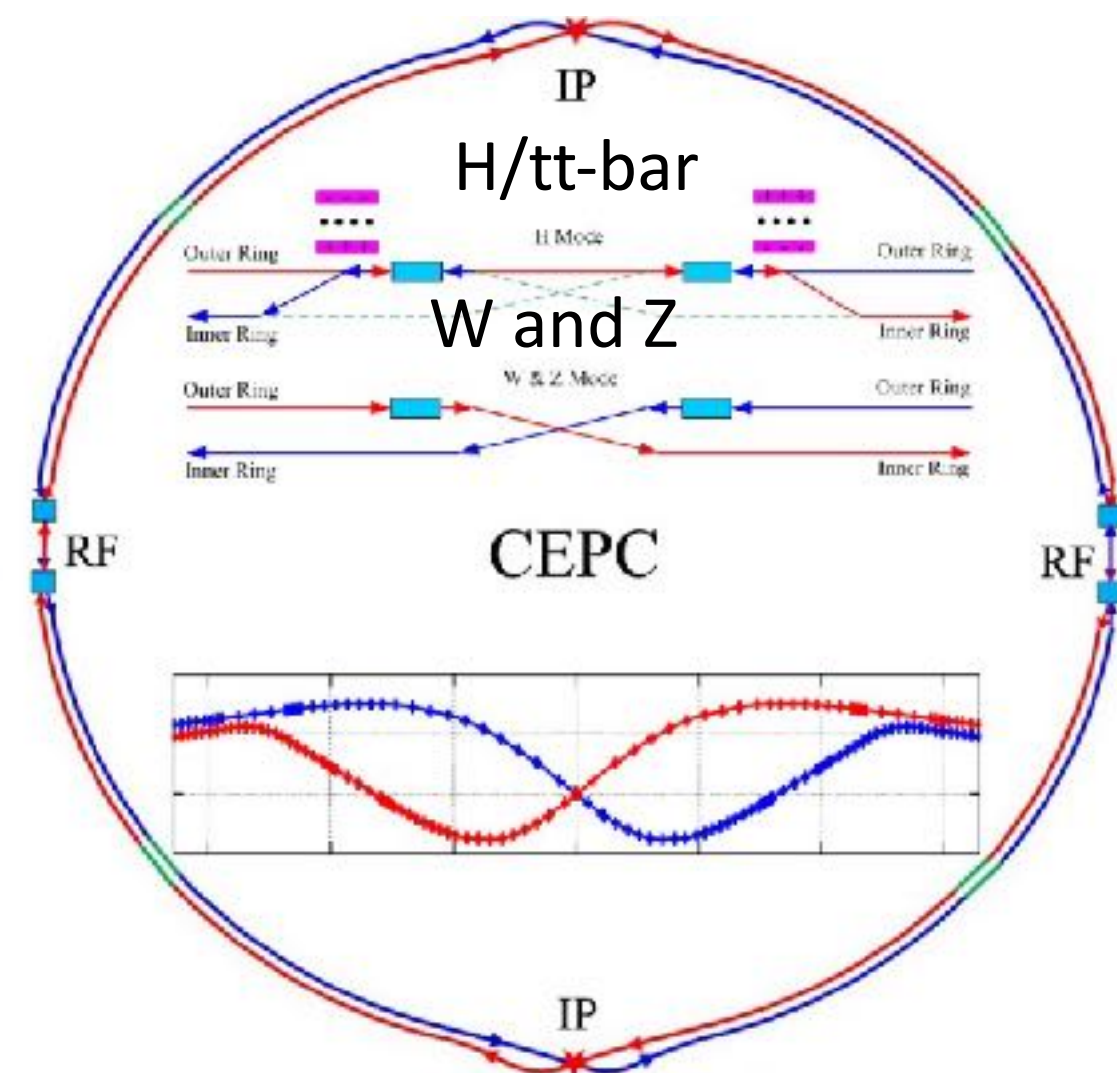


CEPC Higgs Factory: **H**, W, Z, upgradable to ttbar, followed by the SppC (a Hadron collider) ~125 TeV
30 MW SR power per beam (upgradable to 50 MW), high energy gamma ray 100 KeV~100MeV

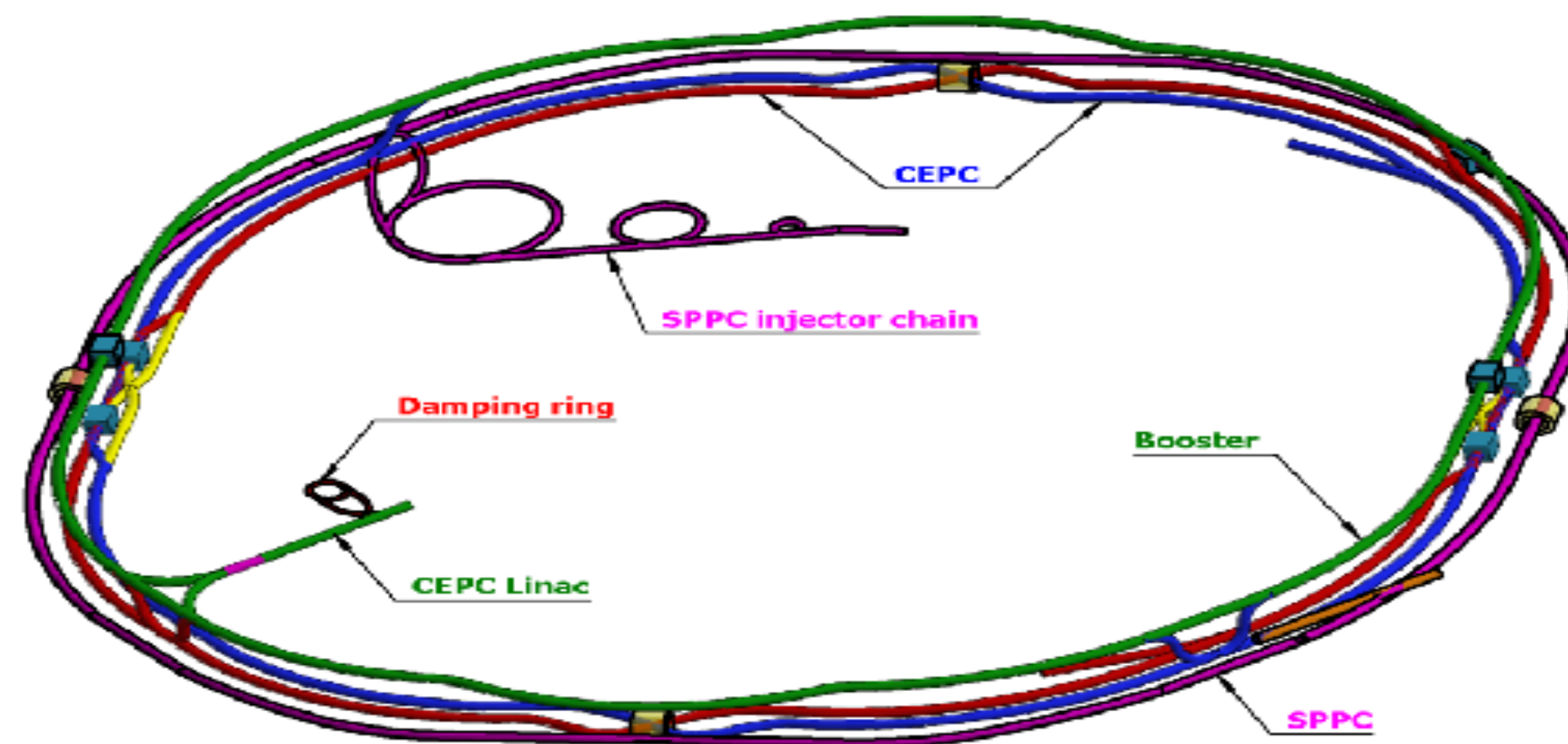
CEPC has
two detectors



CEPC TDR cost
36.4B RMB

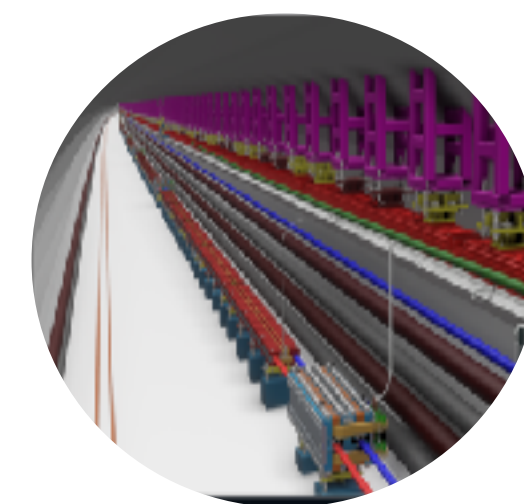
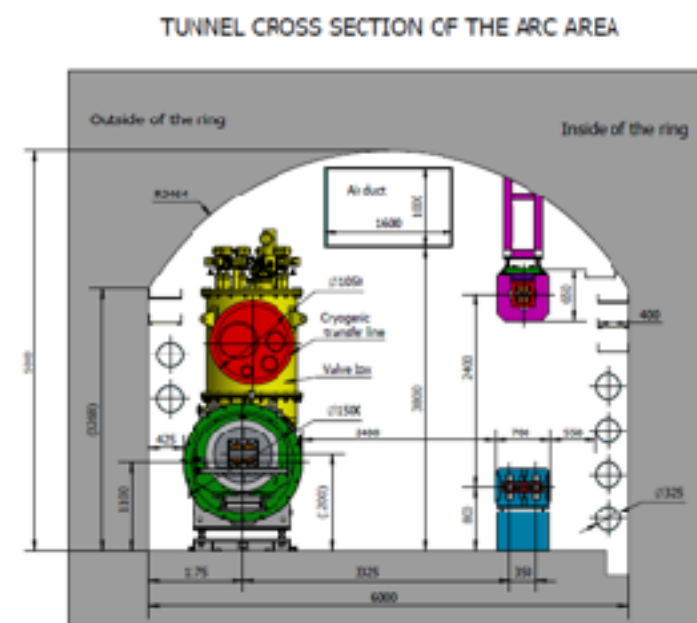
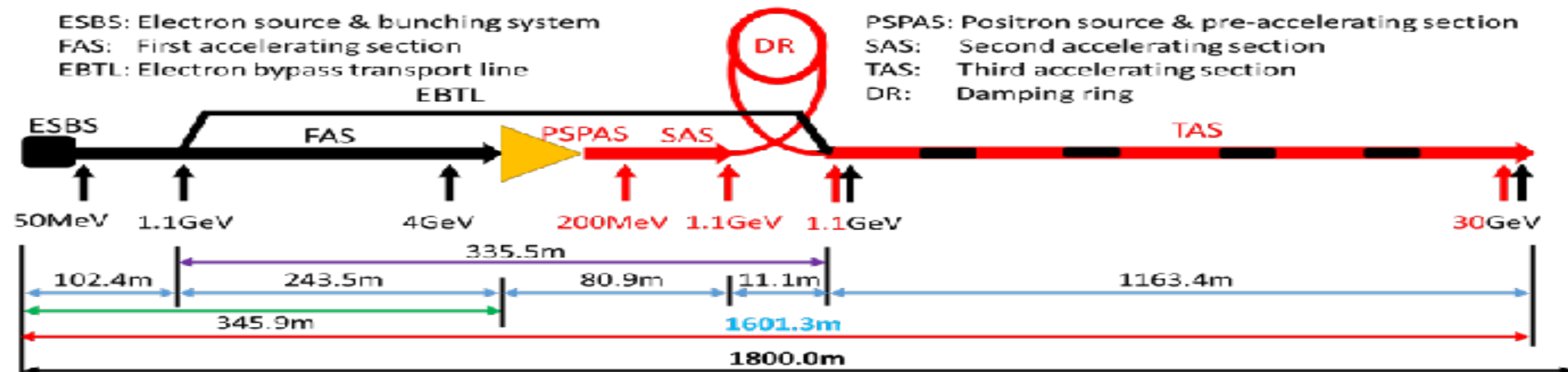


CEPC collider ring (100km)

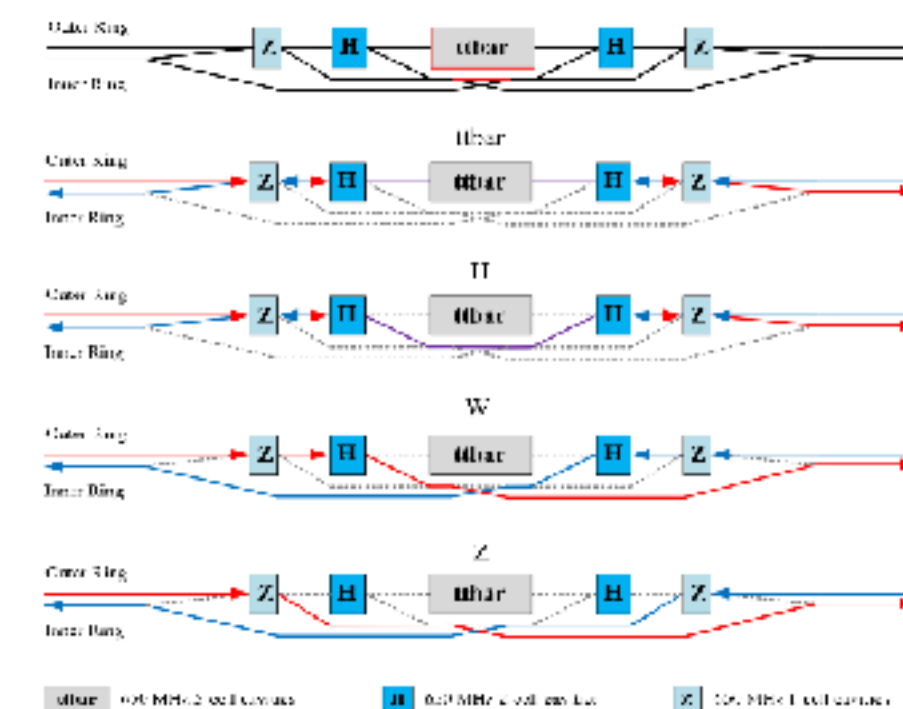


CEPC booster ring (100km)

CEPC TDR S+C-band 30GeV linac injector



CEPC/SppC in the same tunnel



Z, W, Higgs and ttbar energies

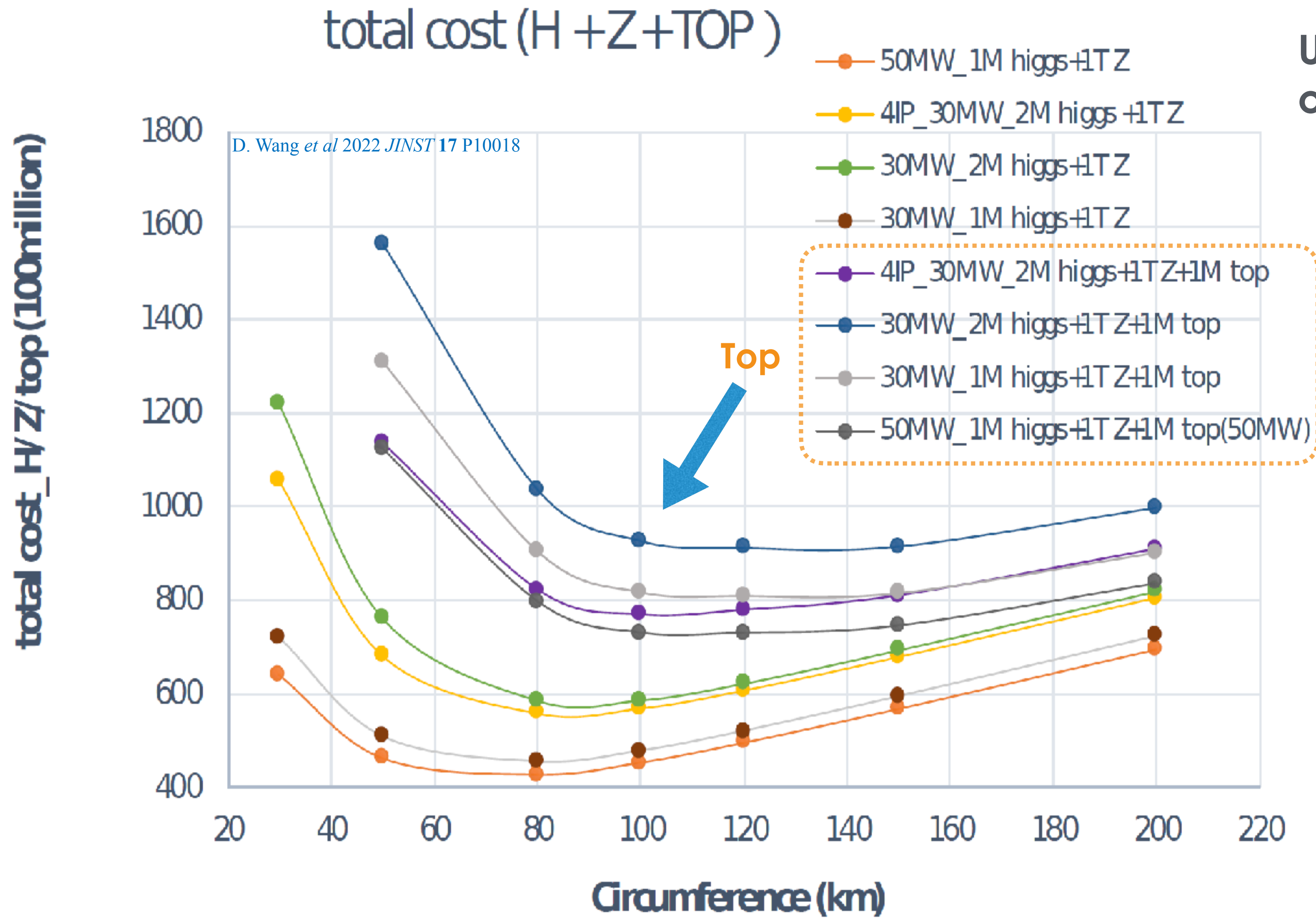
CEPC **Ultimate** Accelerator EDR Design Parameters

Main Parameters: High luminosity - (upgraded version - 50 MW)

	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 (ϵ_x/ϵ_y) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (σ_x/σ_y) [$\mu\text{m}/\text{nm}$]	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 (ξ_x/ξ_y)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF frequency [MHz]	650			
Luminosity per IP [$10^{34}/\text{cm}^2/\text{s}$]	8.3	27	192	0.83

Increase relative to CDR: **x 2.8** **x 2.7** **x 6**

CEPC Circumference and Cost Optimization

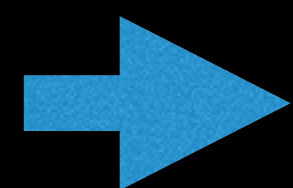


Upgrade to top quark pair operation requires 100 km ring

CEPC Ultimate Running Plan

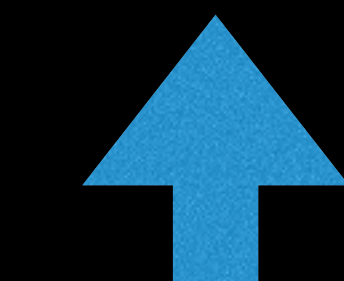
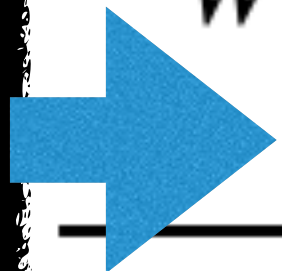


CEPC Upgraded Scenario



Ultimate Goal: When resources from international sources are identified

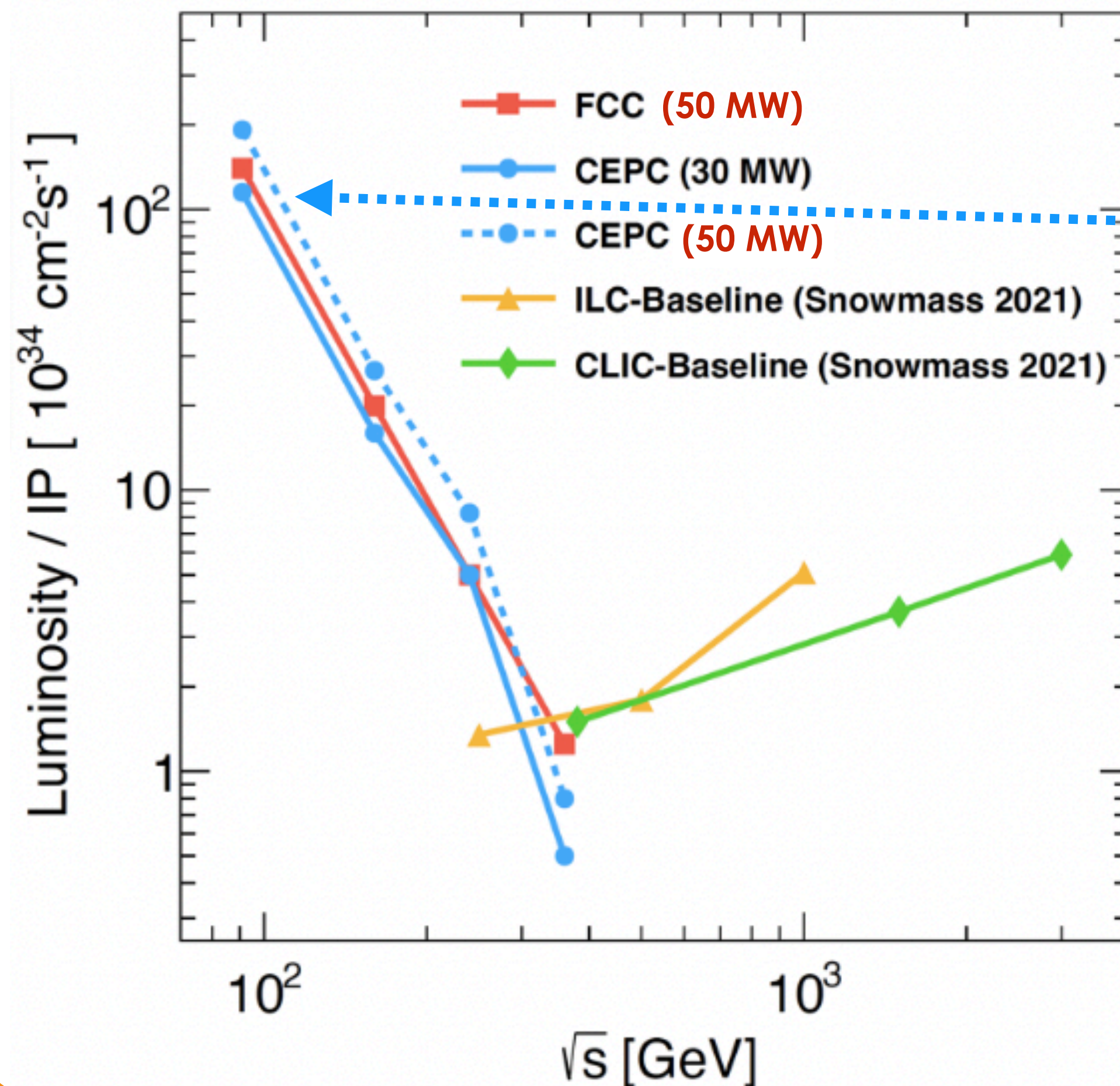
Operation mode	$\sqrt{s}$ (GeV)	SR power (MW)	$\mathcal{L}$ ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	$\int \mathcal{L}/\text{year}$ (ab^{-1} , 2 IPs)	Years	Total $\int \mathcal{L}$ (ab^{-1} , 2 IPs)	Event yields
H	240	50	8.3	2.2	10	21.6	4.3×10^6
Z	91	50	192(*)	50	2	100	4.1×10^{12}
W^+W^-	155-170	50	26.7	6.9	1	6.9	5.5×10^7
$t\bar{t}$	360	50	0.8	0.2	5	1.0	0.6×10^6



Synchrotron radiation power at 50 MW

CEPC physics potential is similar to FCC-ee

Luminosity per Interaction Point



Similar luminosity per IP in same conditions

CEPC baseline: 30 MW (extended 50 MW)

FCC: 50 MW

50 MW option: higher luminosity at CEPC given larger radius

CEPC baseline: 2 interaction points

FCC: 2 or 4 interaction points

Note: luminosity increases with $\sqrt{N_{\text{IP}}}$, not linearly

CEPC numbers from Snowmass White Paper

arXiv: 2203.09451v1, Tables 1 (30 MW) and Table 2 (50 MW)
(Similar as CEPC TDR)

FCC numbers from Frank Zimmerman

FCC Week, June 10; Barcelona, Oct 7

<https://indico.cern.ch/event/1440785/contributions/6063263/attachments/2942055/5169598/FCC-accelerator-RD-short.pdf>

<https://indico.cern.ch/event/1298458/contributions/5975662/attachments/2874361/5035180/accelerator-FCCW-2024-final.pdf>

The Physics Goals — Shopping List

Precision tests of Standard Model
(Higgs, W and Z)



Potential to find new physics

Higgs boson and electroweak symmetry breaking

Directly exploring new physics

- Exotic Higgs boson decays
- Exotics Z boson decays
- Dark matter and hidden sectors
- Extended Higgs sector

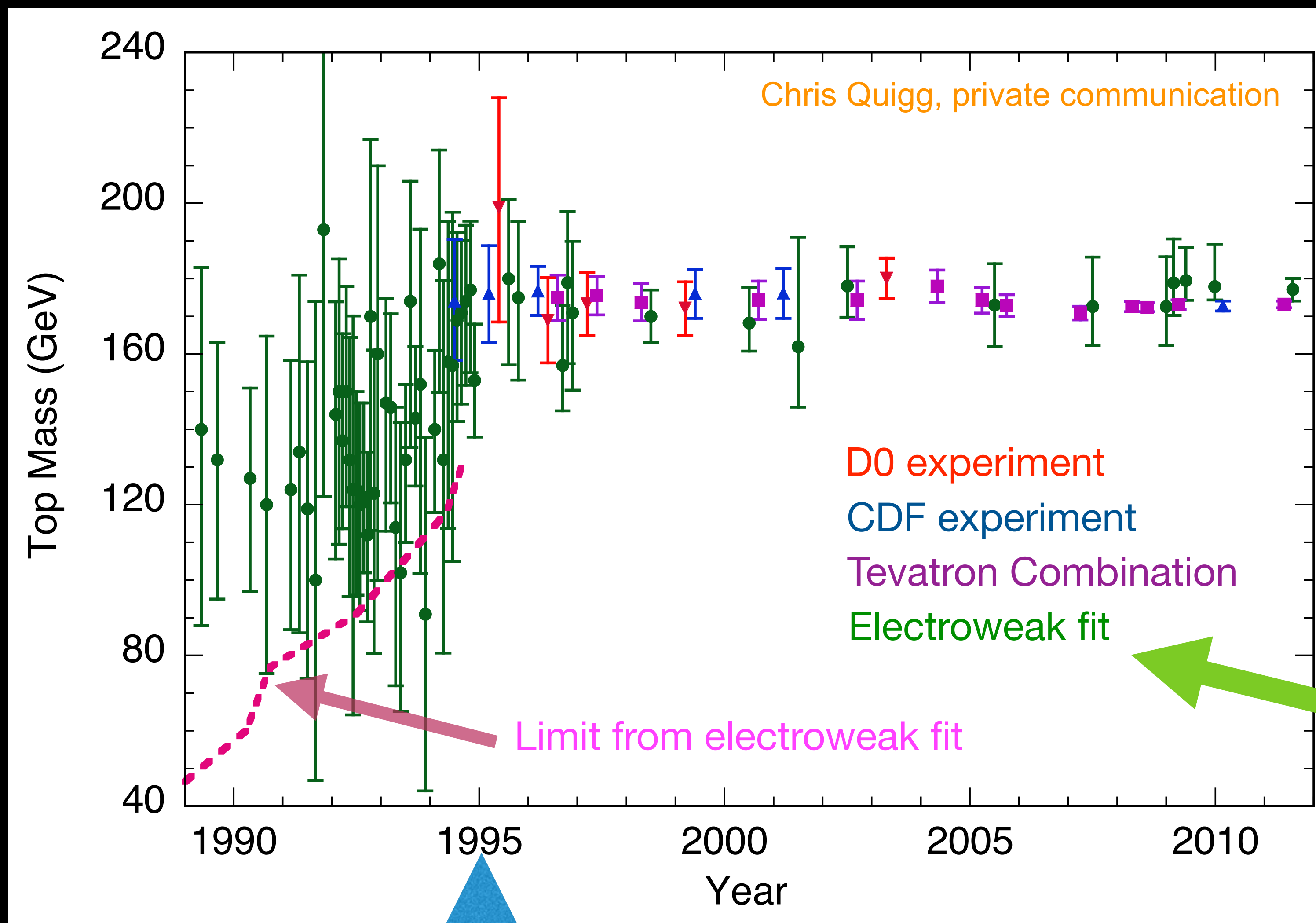
QCD precision measurements

- Precision α_s determination
- Jet rates at CEPC
- QCD dynamics, soft QCD effects
- QCD event shapes and light-quark Yukawa couplings

Flavor physics at the Z pole

- Tau lepton and charm-quark physics
- Rare B decays
- Flavor violating Z decays

Top Mass Prediction from Precision Electroweak data



History...

$M_{\text{top}} = 175 \rightarrow 173 \text{ GeV}$

Current world average:
 $m_{\text{top}} = 173.1 \pm 0.6 \text{ GeV}$
(0.35%)

From precision electroweak
physics measurements and
global fits to data

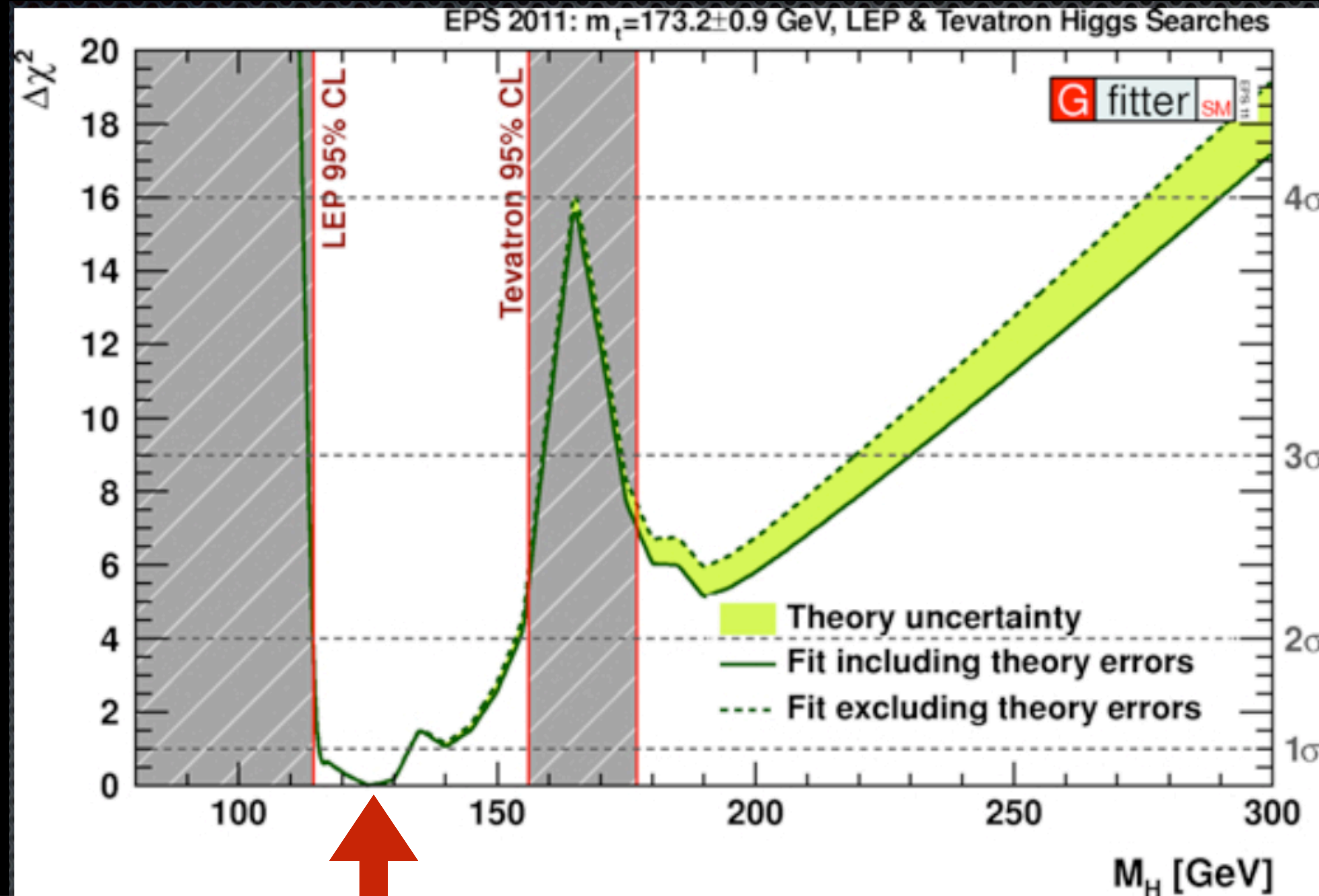
Top discovery at Tevatron

Higgs Mass Prediction from Precision Electroweak data

History...

Presented at
PANIC2011

from: July 28, 2011



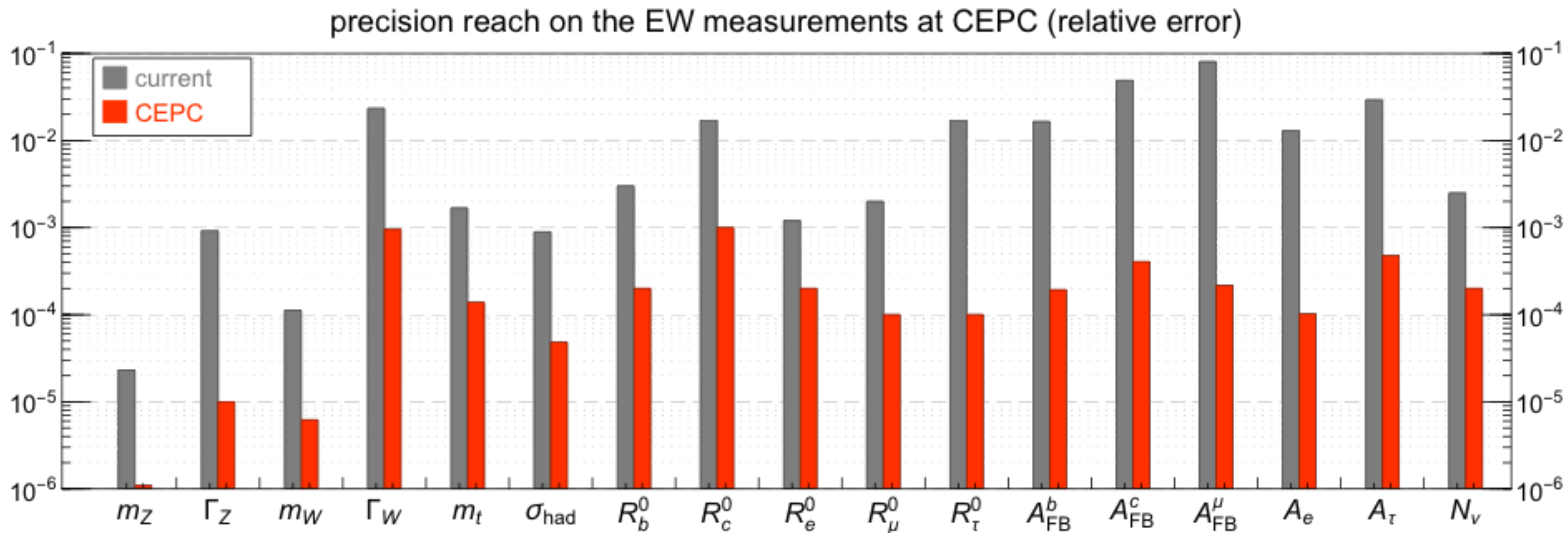
Complete Fit

m_H (minimum) = 125.2 GeV, Range $m_H = [116, 133]$, $m_H < 153.9$ GeV @ 95%

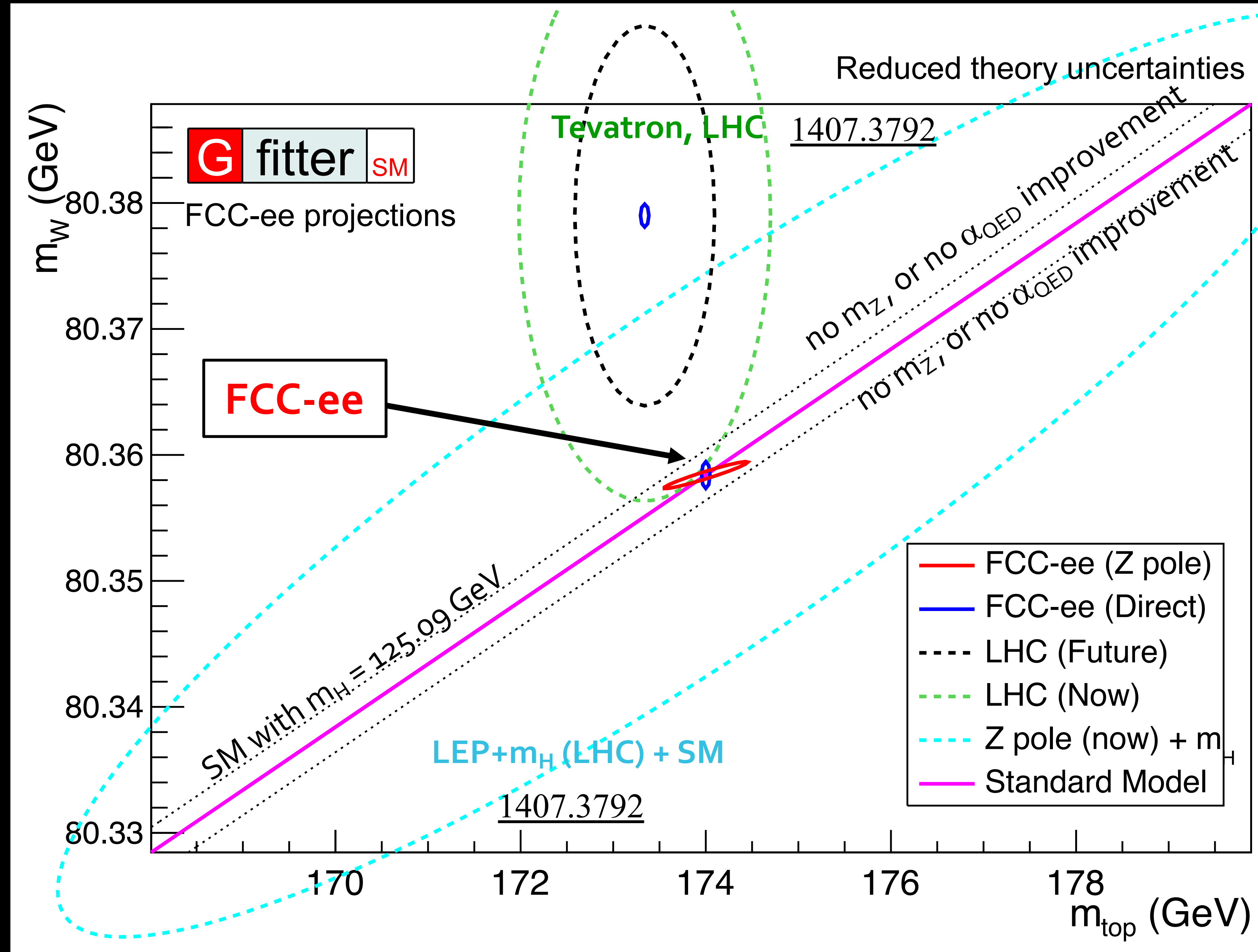
Thanks to Matthias Schott from the GFitter group

Electroweak precision measurements at CEPC

- Unprecedented precision from the Z, WW and Higgs data runs



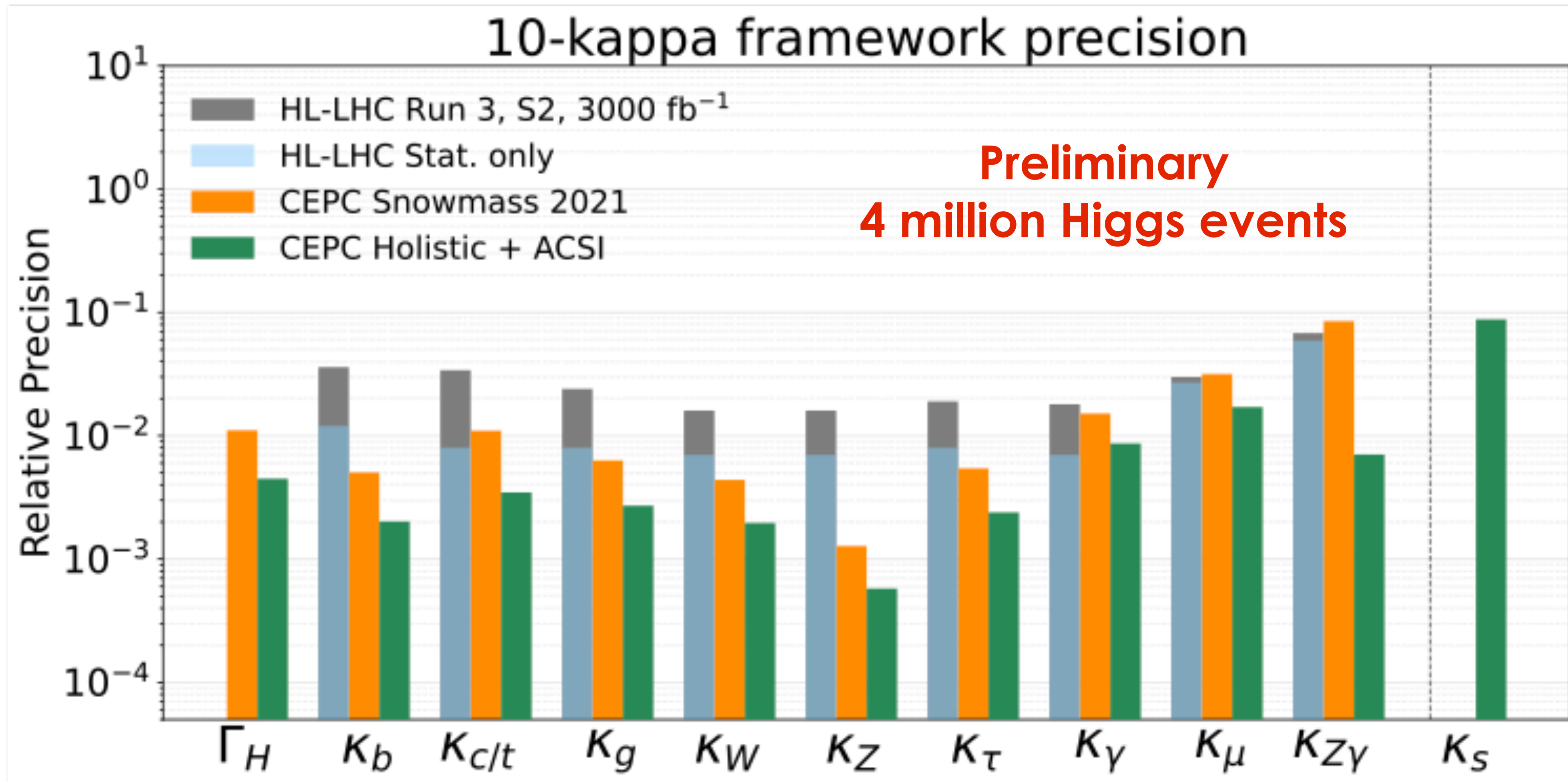
Combination of electroweak measurements



Precision of theory predictions needs to improve to take advantage of this experimental precision for full sensitivity to new physics

Higgs boson coupling measurement at CEPC

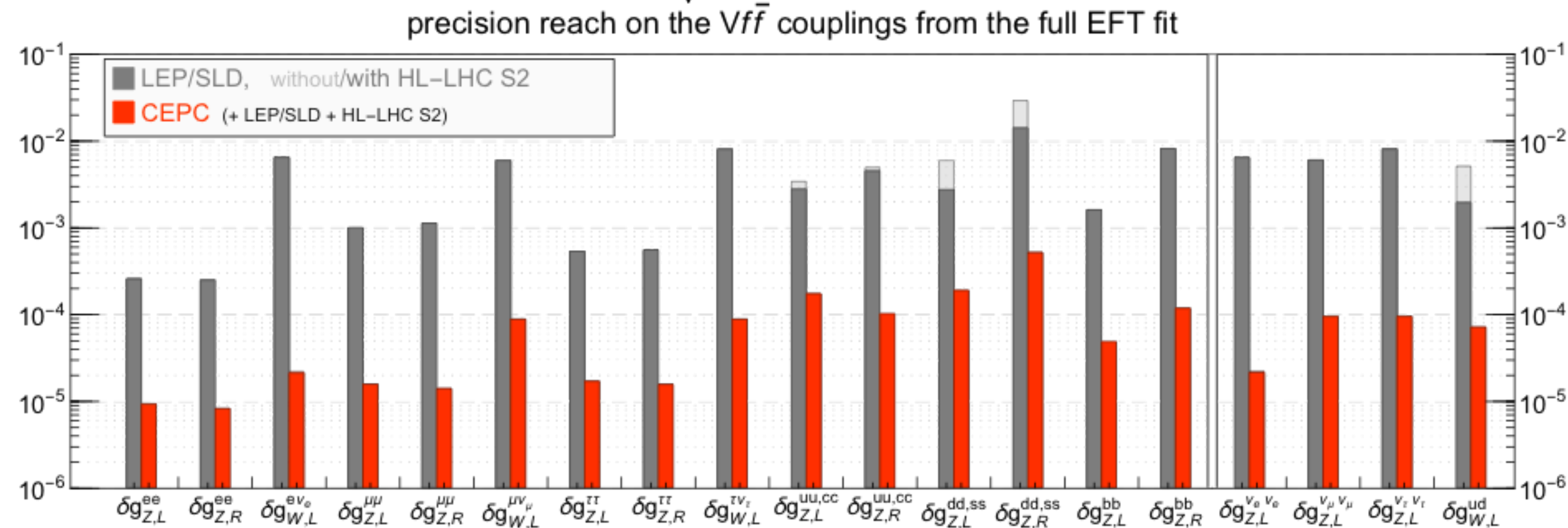
- Up to two orders of magnitude improvement relative to LHC (but not for all)



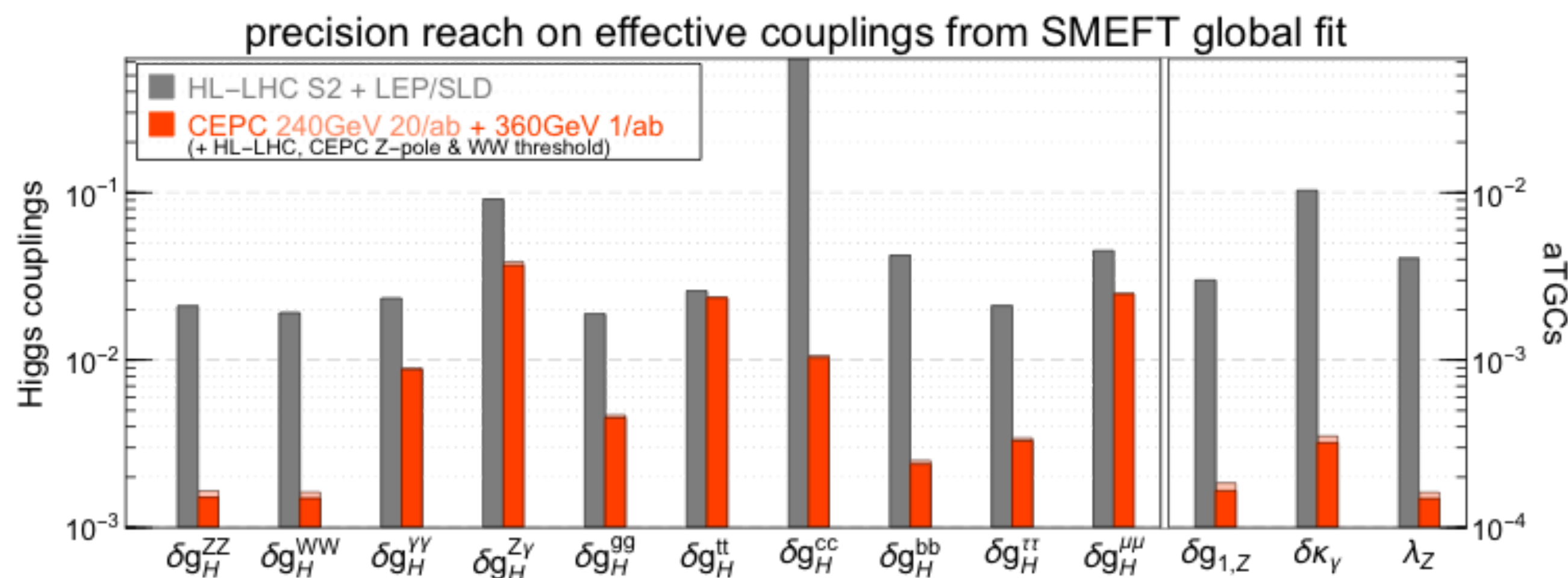
- Vector boson and Higgs couplings

$$\mathcal{L}_{\text{eff}}^{Vf\bar{f}} \supset \frac{g}{c_W} Z_\mu \left[\sum_{f=u,d,e,v} \bar{f}_L \gamma^\mu (T_f^3 - s_W^2 Q_f + \delta g_L^{Zf}) f_L + \sum_{f=u,d,e} \bar{f}_R \gamma^\mu (-s_W^2 Q_f + \delta g_R^{Zf}) f_R \right] \\ + \frac{g}{\sqrt{2}} \left[W_\mu^+ \bar{u}_L \gamma^\mu (V_{\text{CKM}} + \delta g_L^{Wq}) d_L + W_\mu^- \bar{d}_L \gamma^\mu (V_{\text{CKM}}^\dagger + \delta g_L^{Wq}) u_L + \text{h.c.} \right] ,$$

Vector bosons
effective
couplings

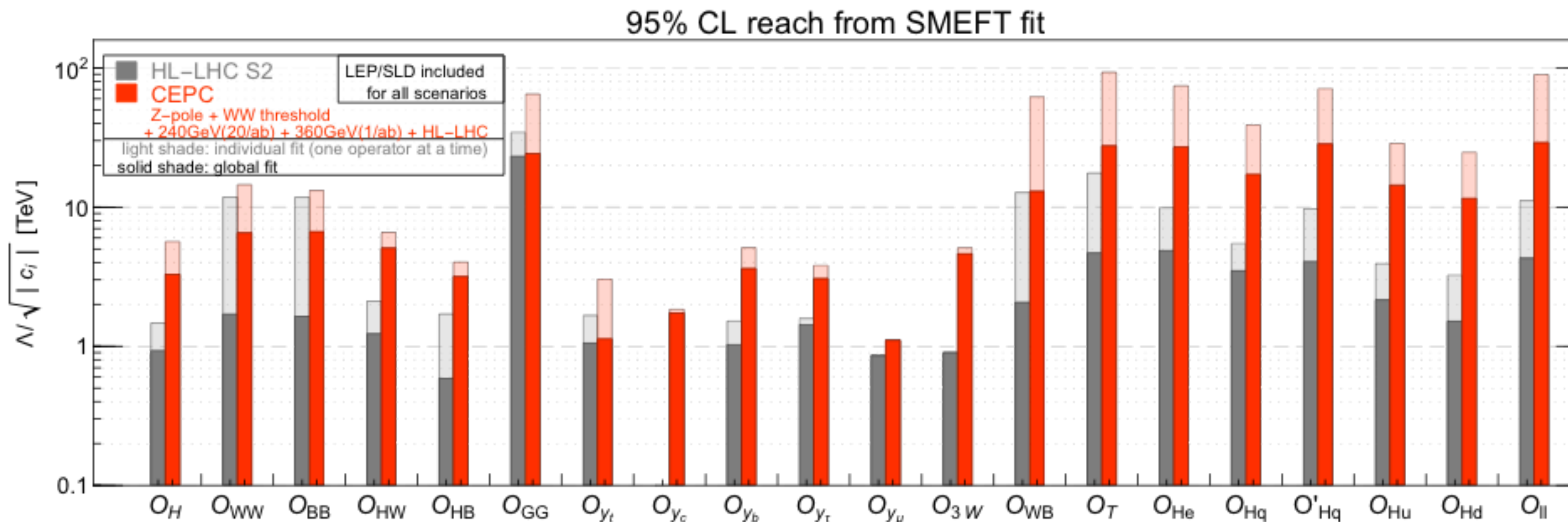


Higgs effective
couplings

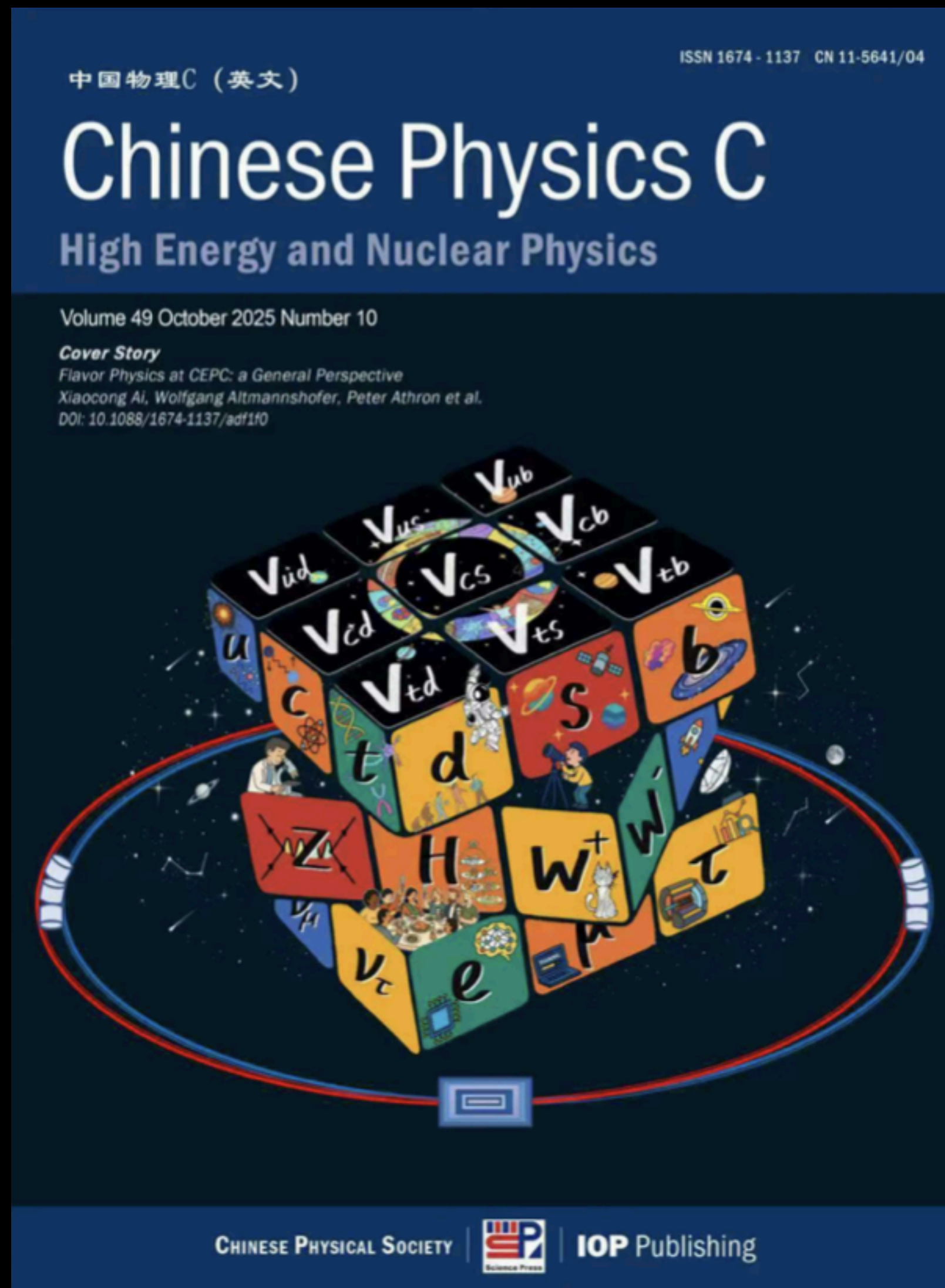


- **Physics reach up to 100 TeV**
- Set of dimension 6 operators contributing to Higgs and EW process

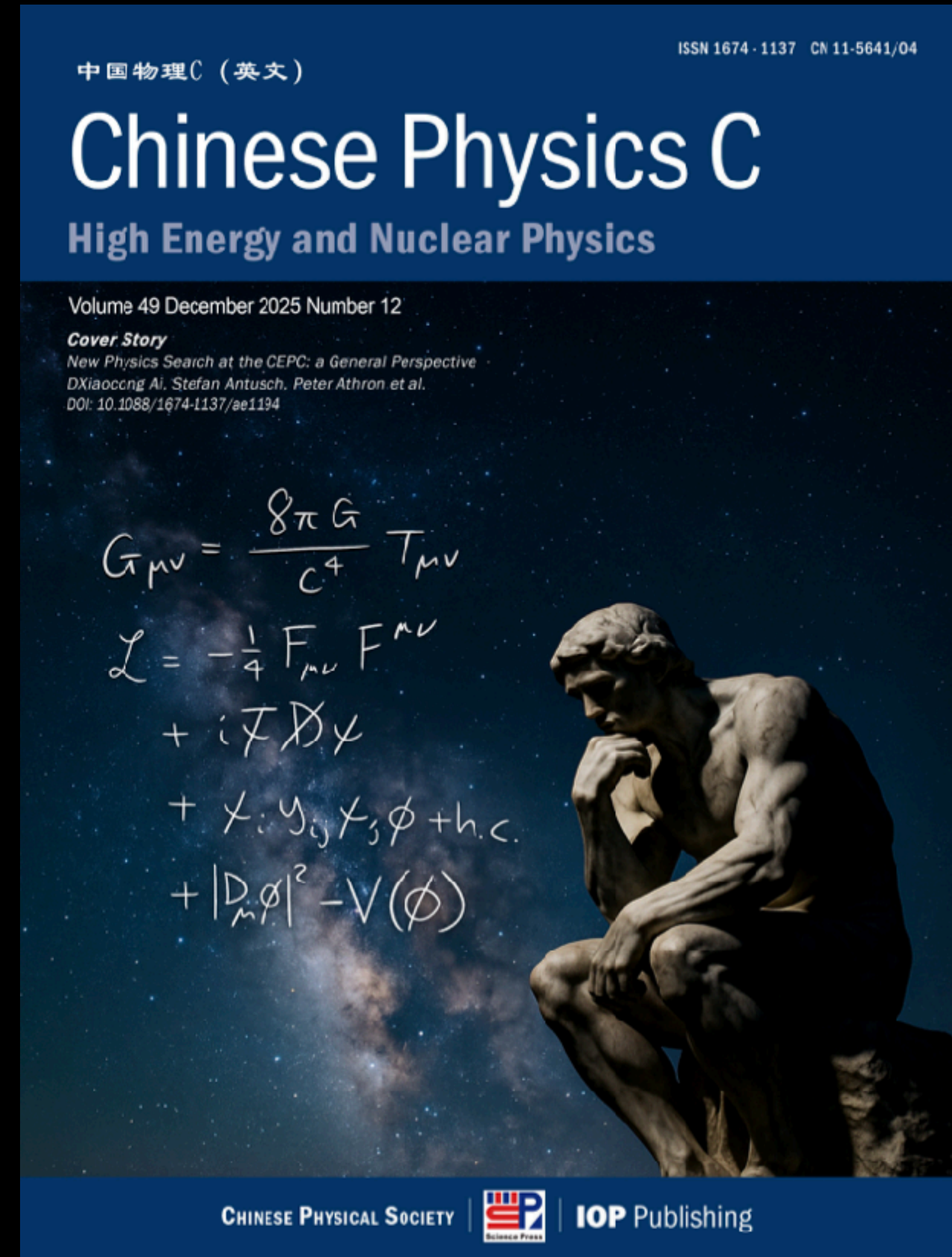
$\mathcal{O}_H = \frac{1}{2}(\partial_\mu H ^2)^2$	$\mathcal{O}_{GG} = g_s^2 H ^2 G_{\mu\nu}^A G^{A,\mu\nu}$
$\mathcal{O}_{WW} = g^2 H ^2 W_{\mu\nu}^a W^{a,\mu\nu}$	$\mathcal{O}_{y_u} = y_u H ^2 \bar{q}_L H u_R + \text{h.c.} \quad (u \rightarrow t, c)$
$\mathcal{O}_{BB} = g'^2 H ^2 B_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}_{y_d} = y_d H ^2 \bar{q}_L H d_R + \text{h.c.} \quad (d \rightarrow b)$
$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W_{\mu\nu}^a$	$\mathcal{O}_{y_e} = y_e H ^2 \bar{l}_L H e_R + \text{h.c.} \quad (e \rightarrow \tau, \mu)$
$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$	$\mathcal{O}_{3W} = \frac{1}{3!} g \epsilon_{abc} W_\mu^a W_\nu^b W^{\rho\mu c}$
$\mathcal{O}_{WB} = gg' H^\dagger \sigma^a H W_{\mu\nu}^a B^{\mu\nu}$	$\mathcal{O}_{\ell\ell} = (\bar{\ell}_L \gamma^\mu \ell_L)(\bar{\ell}_L \gamma_\mu \ell_L)$
$\mathcal{O}_T = \frac{1}{2} (H^\dagger \overleftrightarrow{D}_\mu H)^2$	$\mathcal{O}_{He} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{e}_R \gamma^\mu e_R$
$\mathcal{O}_{Hq} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{q}_L \gamma^\mu q_L$	$\mathcal{O}_{Hu} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{u}_R \gamma^\mu u_R$
$\mathcal{O}'_{Hq} = iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H \bar{q}_L \sigma^a \gamma^\mu q_L$	$\mathcal{O}_{Hd} = iH^\dagger \overleftrightarrow{D}_\mu H \bar{d}_R \gamma^\mu d_R$



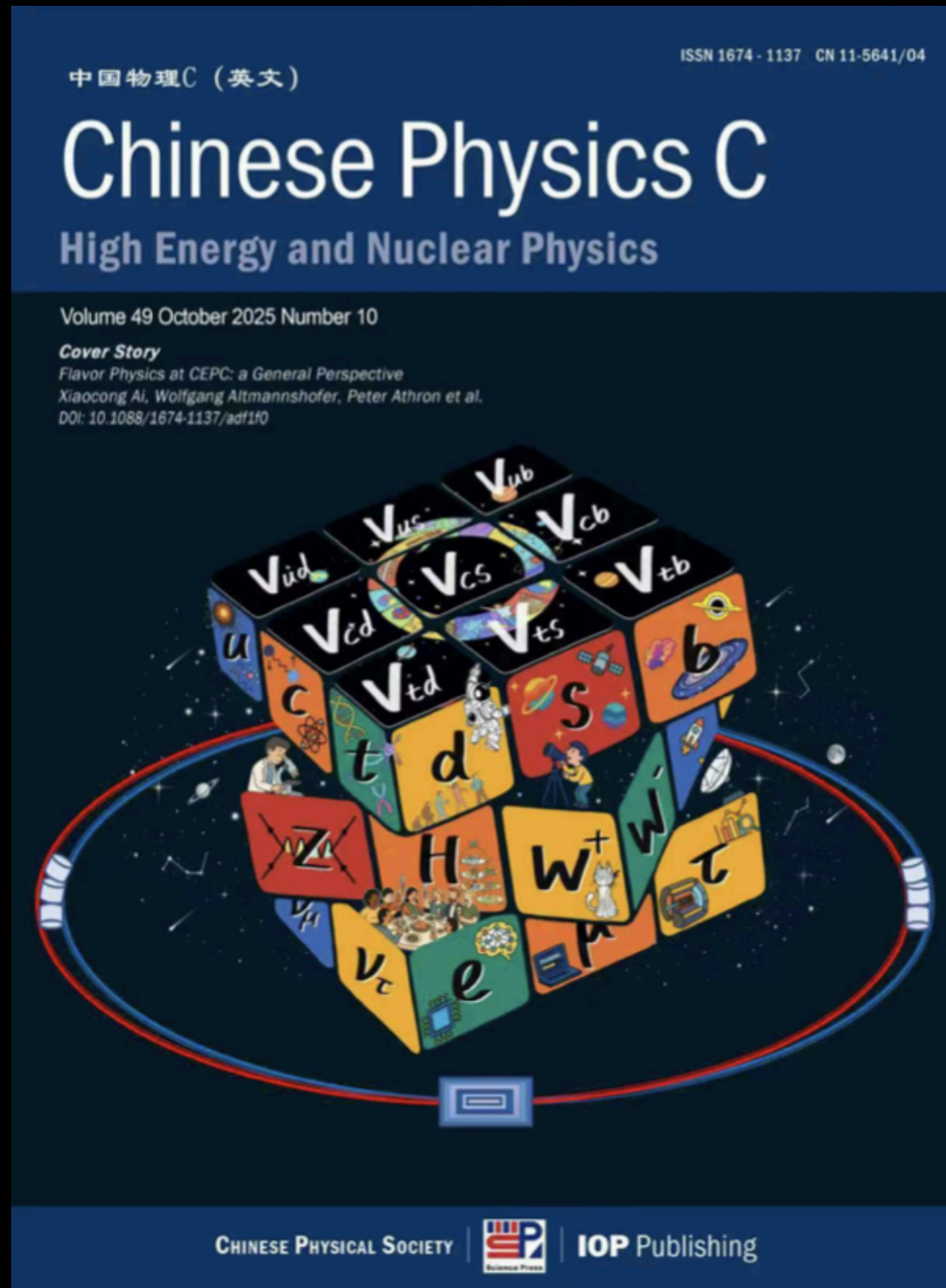
Flavor



New physics



Flavor



- **Luminosity**

- $L=100 \text{ ab}^{-1}$, $O(10^{12})$ Z decays/year/IP $\Rightarrow O(10^{11})$ bb , cc , and $\tau\tau$ pairs

Z decay modes:

$c\bar{c}$ (12.03 $\pm$ 0.21) %

$b\bar{b}$ (15.12 $\pm$ 0.05) %

- **Energy**

- besides producing states inaccessible at Belle II, STCF or other e^+e^- colliders
 $M_Z \gg 2m_b, 2m_\tau, 2m_c \Rightarrow$ surplus energy, boosted decay products
(better tracking and tagging, lower vertex uncertainty etc.)

- **Cleanliness**

- Like any other leptonic machine, full knowledge of the initial state
(e.g. Z mass constraint on invariant masses more powerful)
 $\Rightarrow$ it enables searches involving neutral/invisible particles

Expected charm / yields at STFC and CEPC



		STCF	CEPC
Collision Energy		2-7 GeV	91.2 GeV
Peak Luminosity		$0.5 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$	$1.92 \times 10^{36} \text{ cm}^{-2} \text{ s}^{-1}$
Integrated Luminosity		1 ab ⁻¹ per year	50 ab ⁻¹ per year (2 IPs)
Expected particle yields per year ^[1,2]	$D^0/\overline{D}^0$	8×10^9 (energy 3.77 GeV)	4.2×10^{11}
	D^+/D^-	6×10^9 (energy 3.77 GeV)	2.5×10^{11}
	D_s^+/D_s^-	2×10^9 (energy 4.09-4.18 GeV)	9×10^{10}
	Λ_c^+/Λ_c^-	1.2×10^9 (energy 4.63 GeV)	3.1×10^{10}
	τ^+/τ^-	3.6×10^9	6×10^{10}

[1] [STCF CDR](#) [2] [CEPC TDR](#)

Unique opportunities for flavour physics (1)

With 10^{11} b -hadrons and charm particles, CEPC will map the "heavy-flavour zoo":

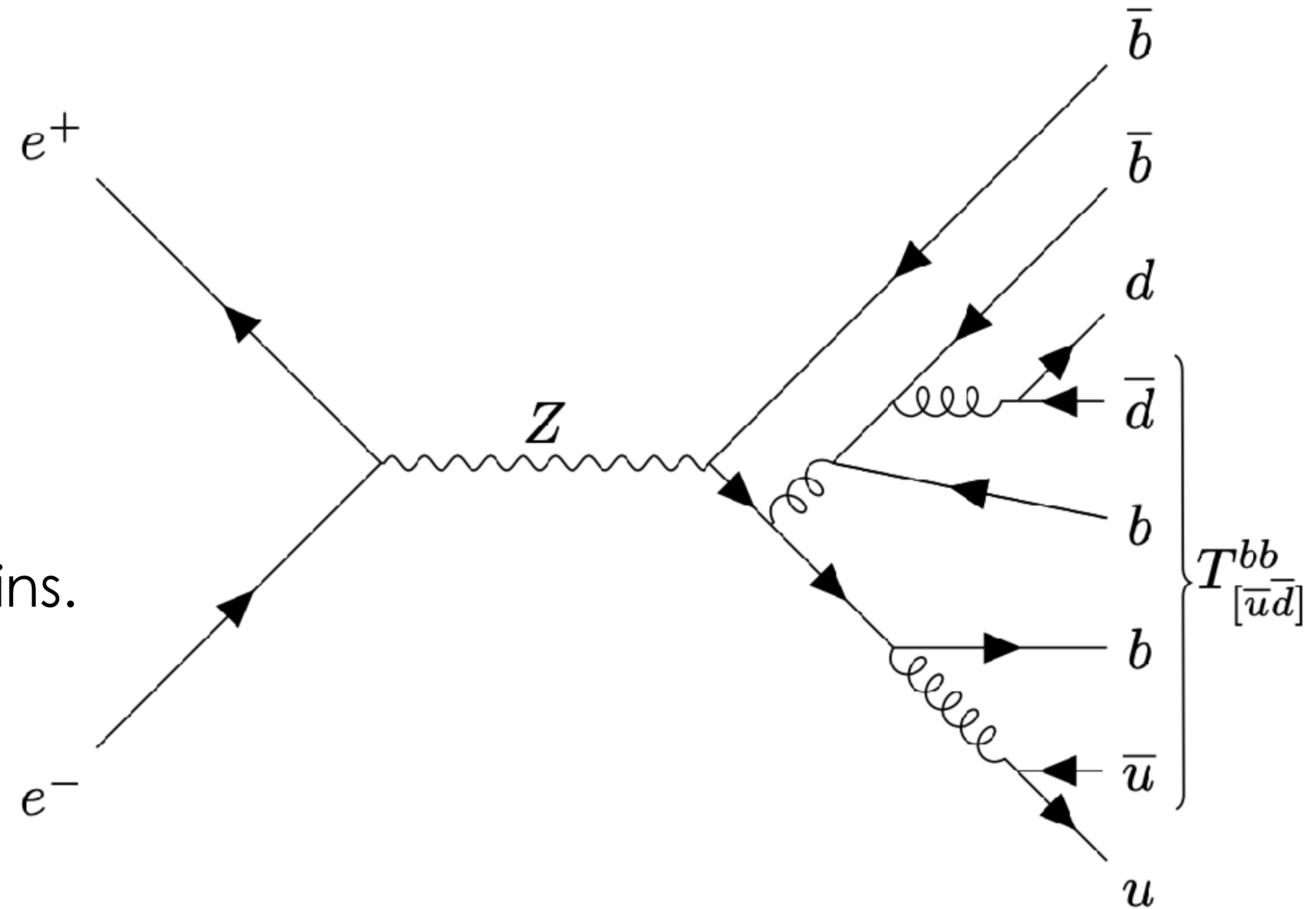
- Discover states predicted by QCD but rarely observed:

- tetraquarks (T_{cc}, T_{bb})
- pentaquarks (P_c)
- doubly heavy baryons (Ξ_{cc}, Ξ_{bb})

- Study production mechanisms of charmonium-like states

- (e.g., $X(3872)$) via $Z \rightarrow qq$ or B-decay chains.

- $Z \rightarrow bbbb, bbcc, cccc$ processes may give rise to highly exotic species.



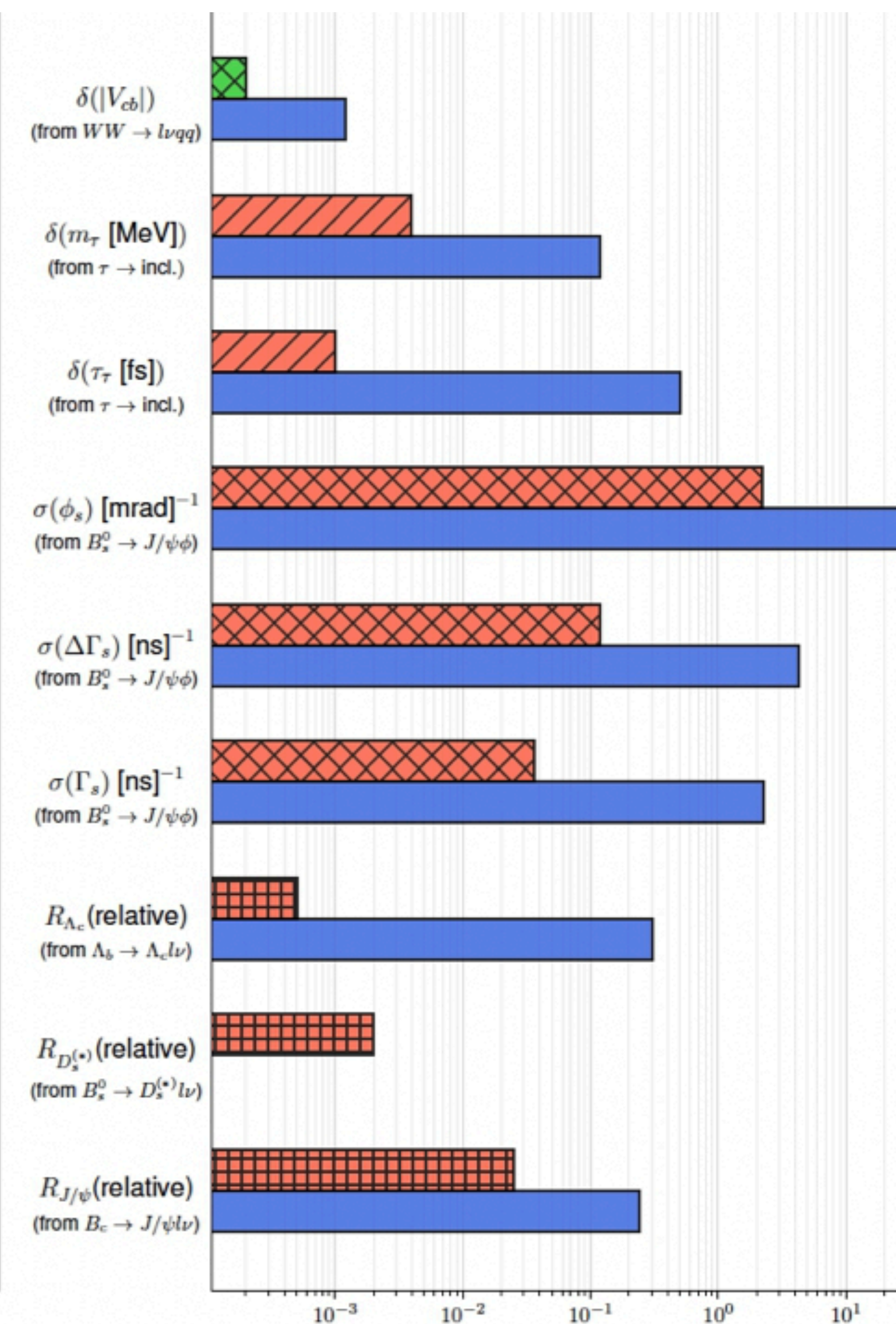
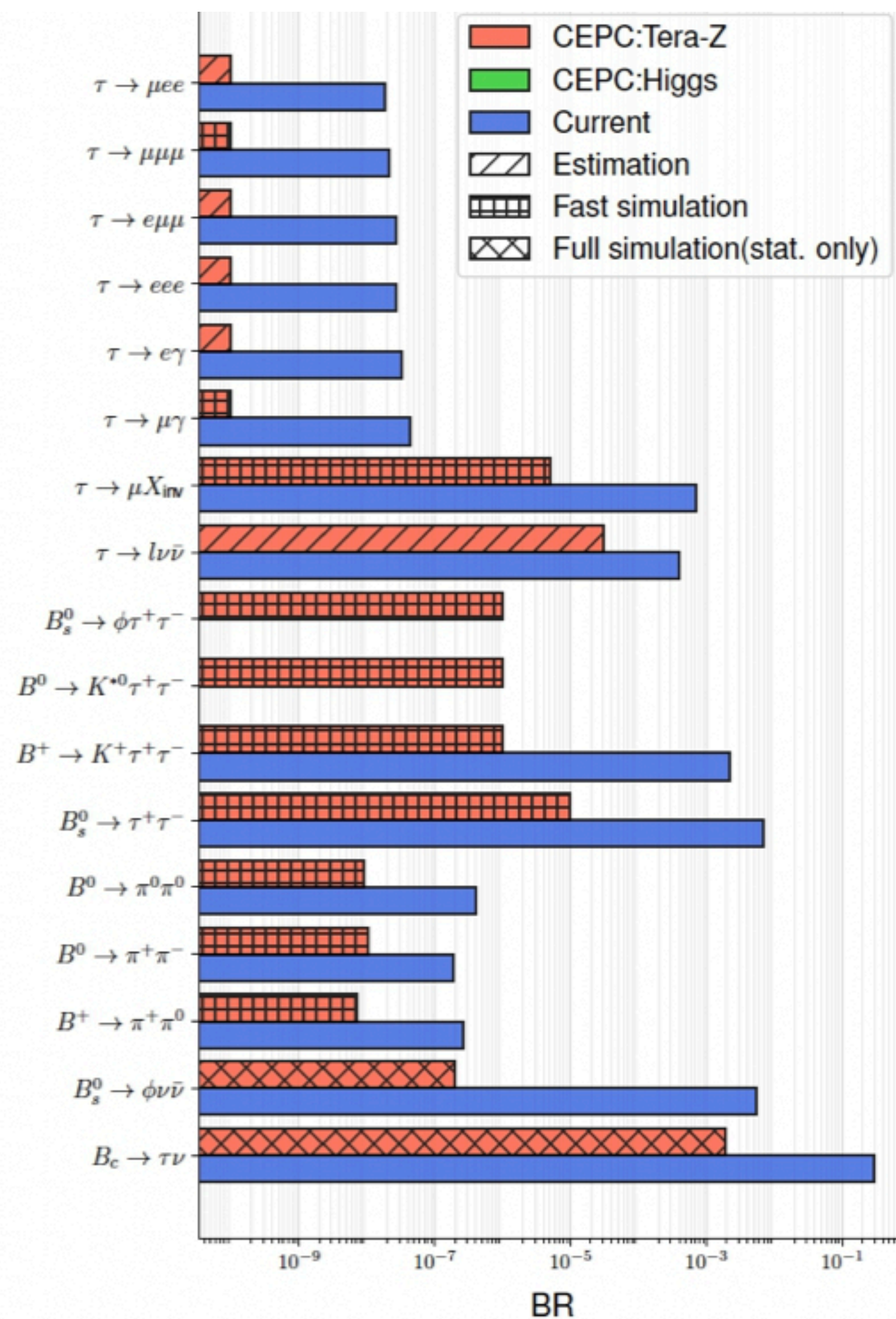
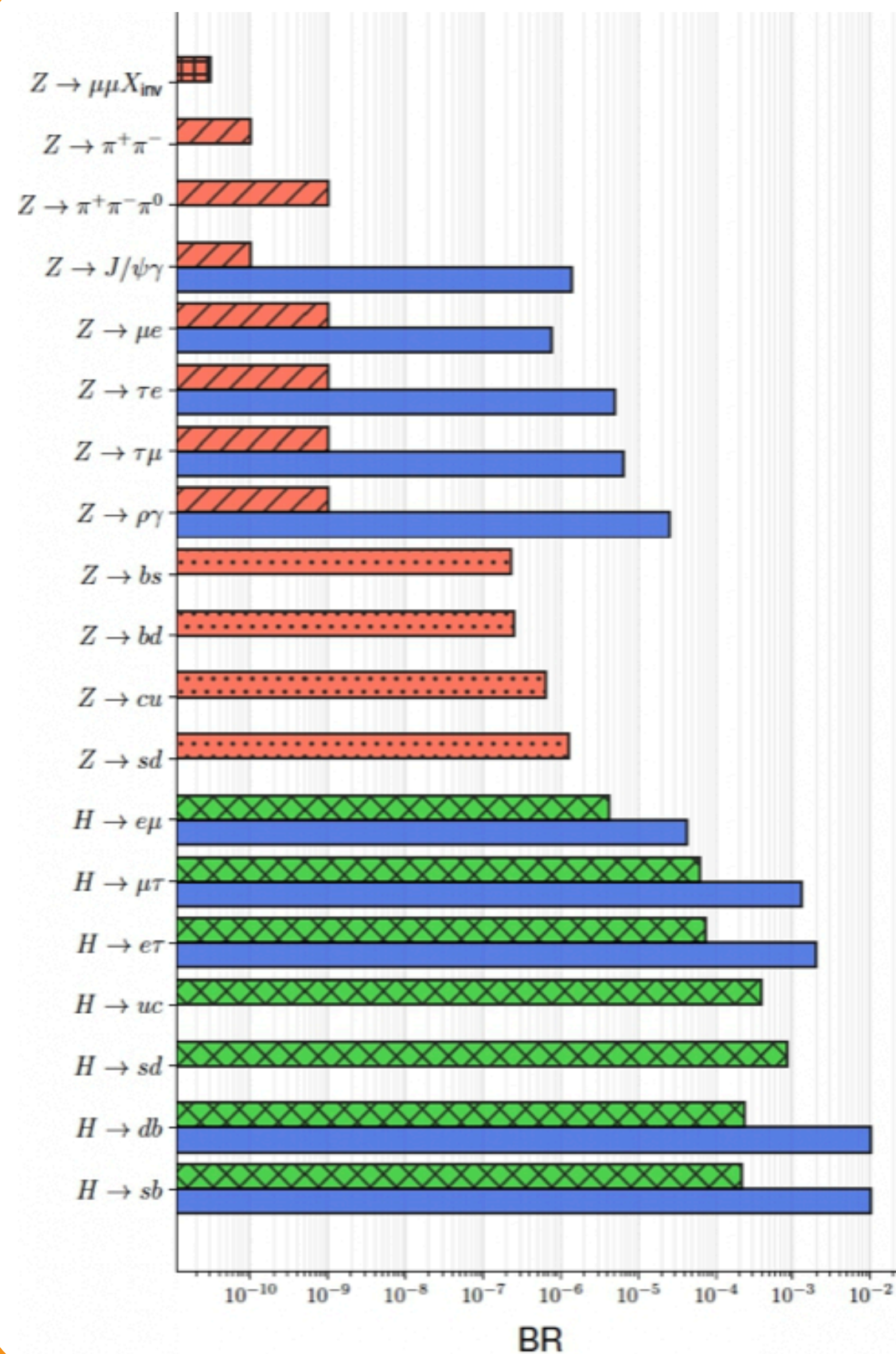
Rare & Forbidden decays processes are keys to new physics

- **Lepton flavour universality test at Z-pole**
 - Hunt for SM forbidden decays like $Z \rightarrow e\mu/e\tau/\mu\tau$. These searches are inaccessible at hadron colliders due to backgrounds, also inaccessible at lower energy
- **Flavour-changing neutral currents (FCNC):**
 - Search for $b \rightarrow s$ transitions suppressed in the Standard Model, e.g., $B_s \rightarrow \phi \nu \nu$ (aiming for 2% precision), $B \rightarrow K \tau \tau$, and $B_s \rightarrow \tau \tau$. Sensitivity to branching ratios as low as 10^{-7}
- **Baryon/lepton number violation:**
 - Probe decays like $B^+ \rightarrow \pi^- \ell^+ \ell^+$ or $\Lambda_b \rightarrow \pi^- \ell^+$ that challenge fundamental symmetries

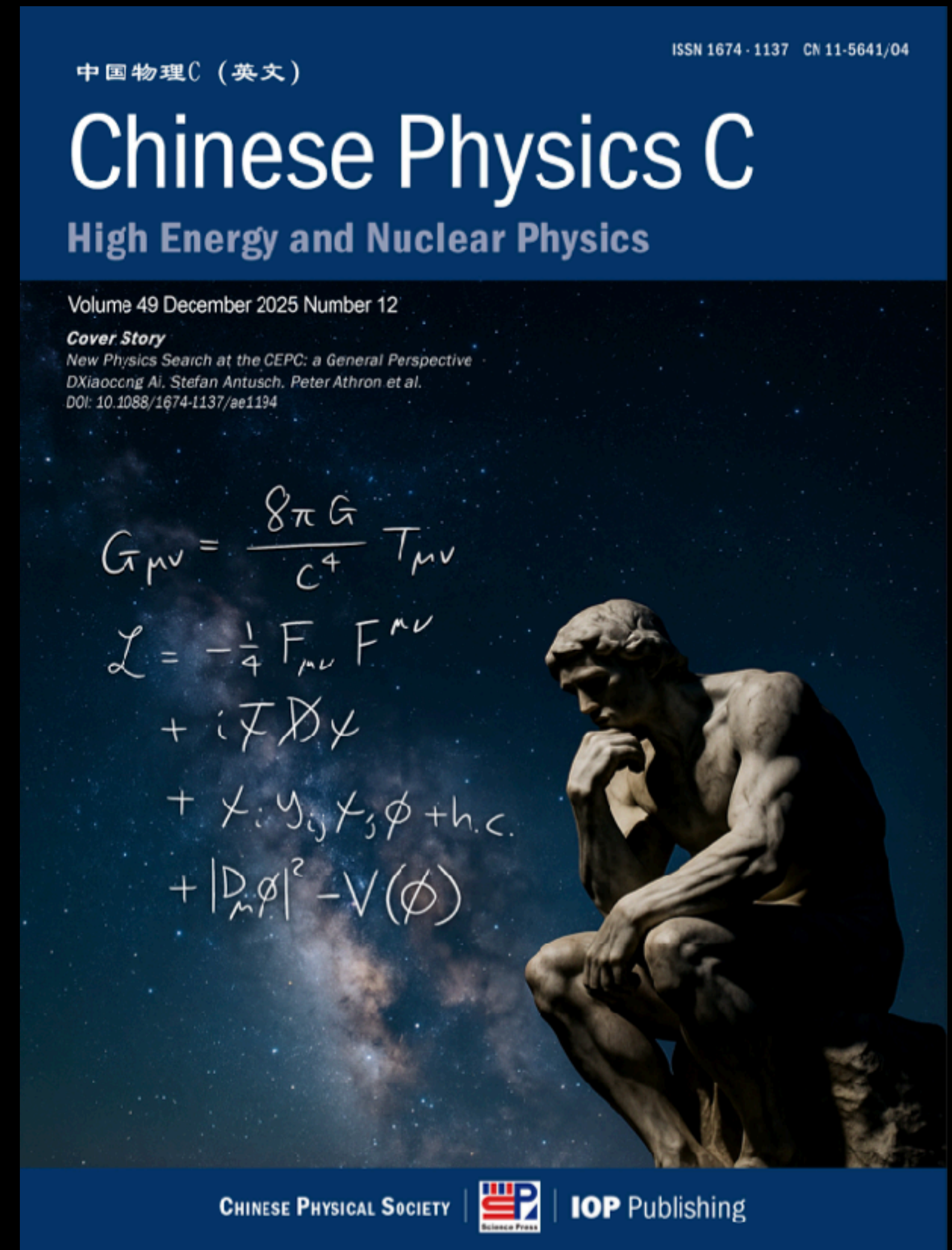
Higher-energy CEPC runs extend flavour studies

- **Higgs flavour violation:**
 - Search for $H \rightarrow b\bar{s}$, $H \rightarrow c\bar{u}$, or $H \rightarrow \tau\mu$ decays at the Higgs factory (240 GeV). Jet-origin identification via ML could constrain branching ratios to 10^{-3}
- **Top quark FCNC:**
 - At the $t\bar{t}$ threshold (360 GeV), probe anomalous $t \rightarrow cZ$ or $t \rightarrow cH$ decays, sensitive to new physics in top-Higgs couplings
- **CKM elements from WW threshold:**
 - Resolve long-standing tensions in CKM matrix elements (e.g., $|V_{cb}|$, $|V_{ub}|$) by combining data from B/D meson decays and on-shell W boson decays at the WW threshold. Target precision for $|V_{cb}|$ reaches 0.1–0.4%

Some flavour physics expectations



New physics

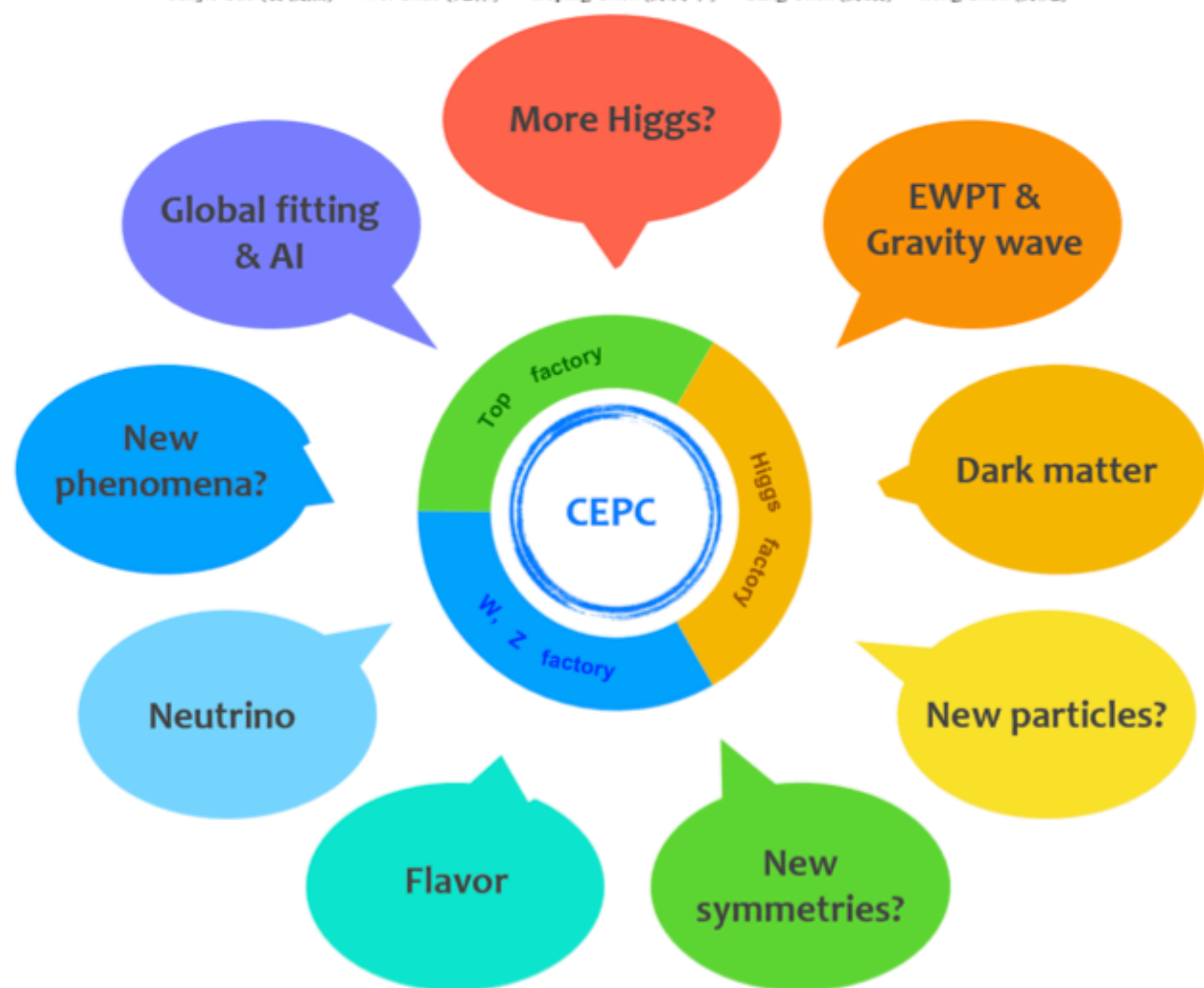


New physics searches landscape

Chinese Physics C Vol. 49, No. 12 (2025)

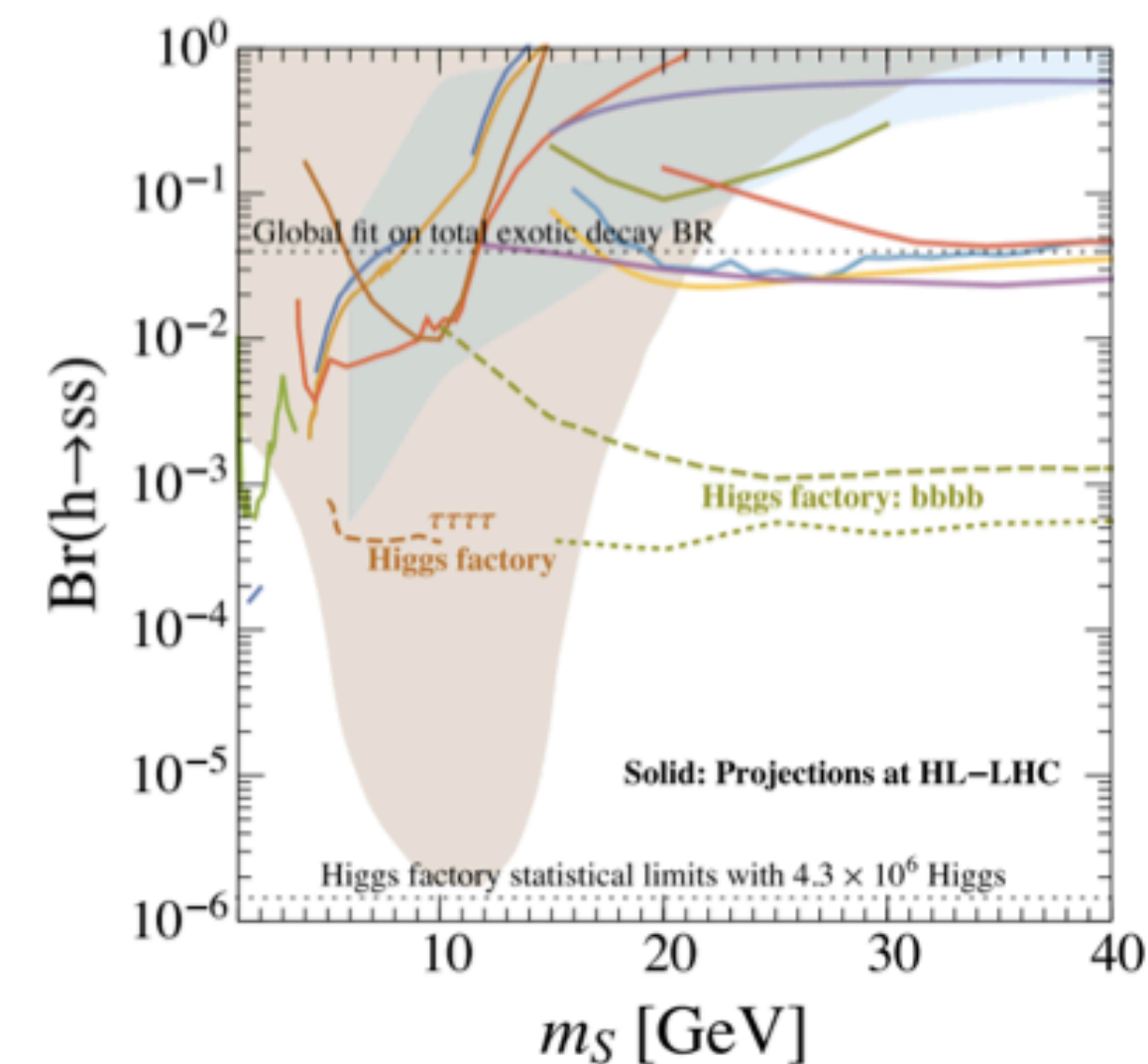
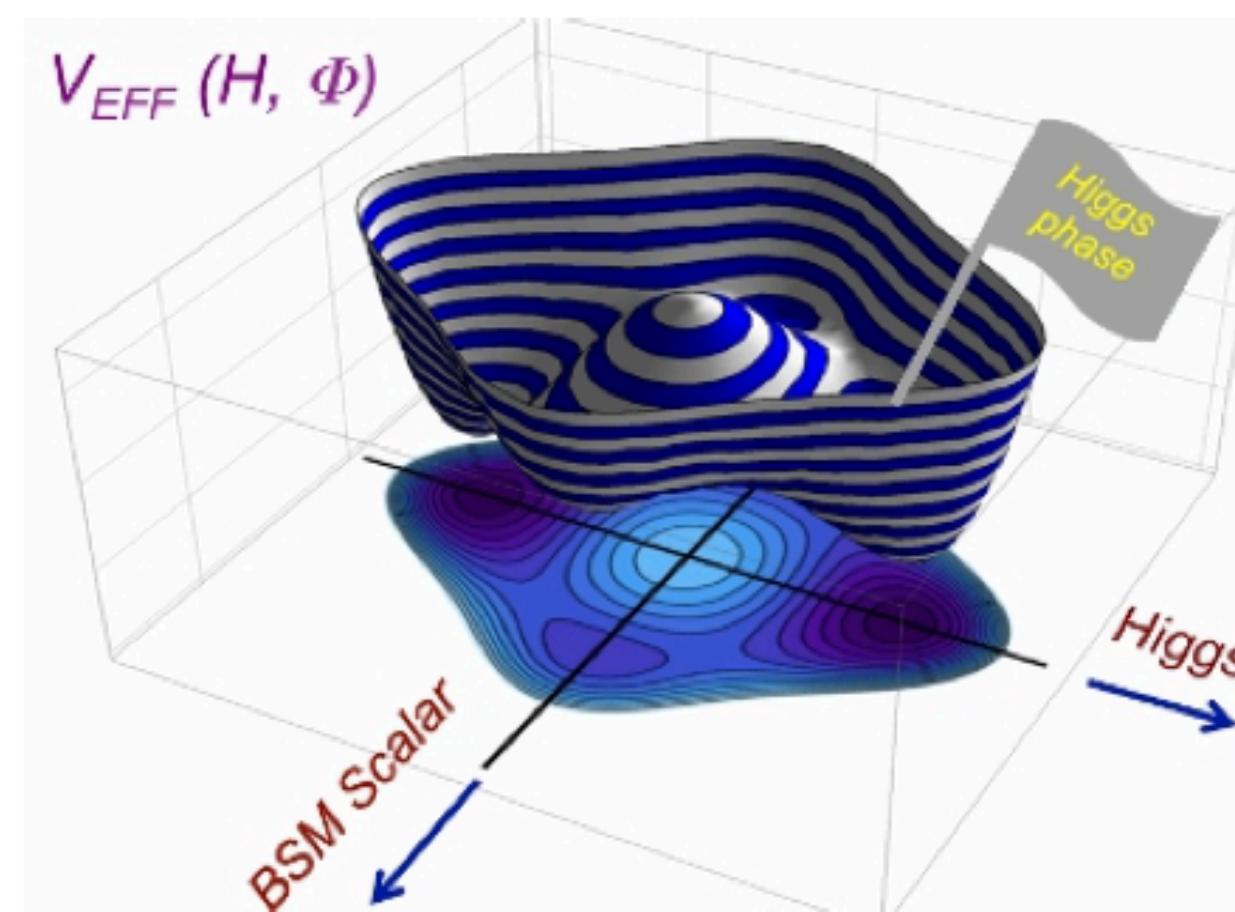
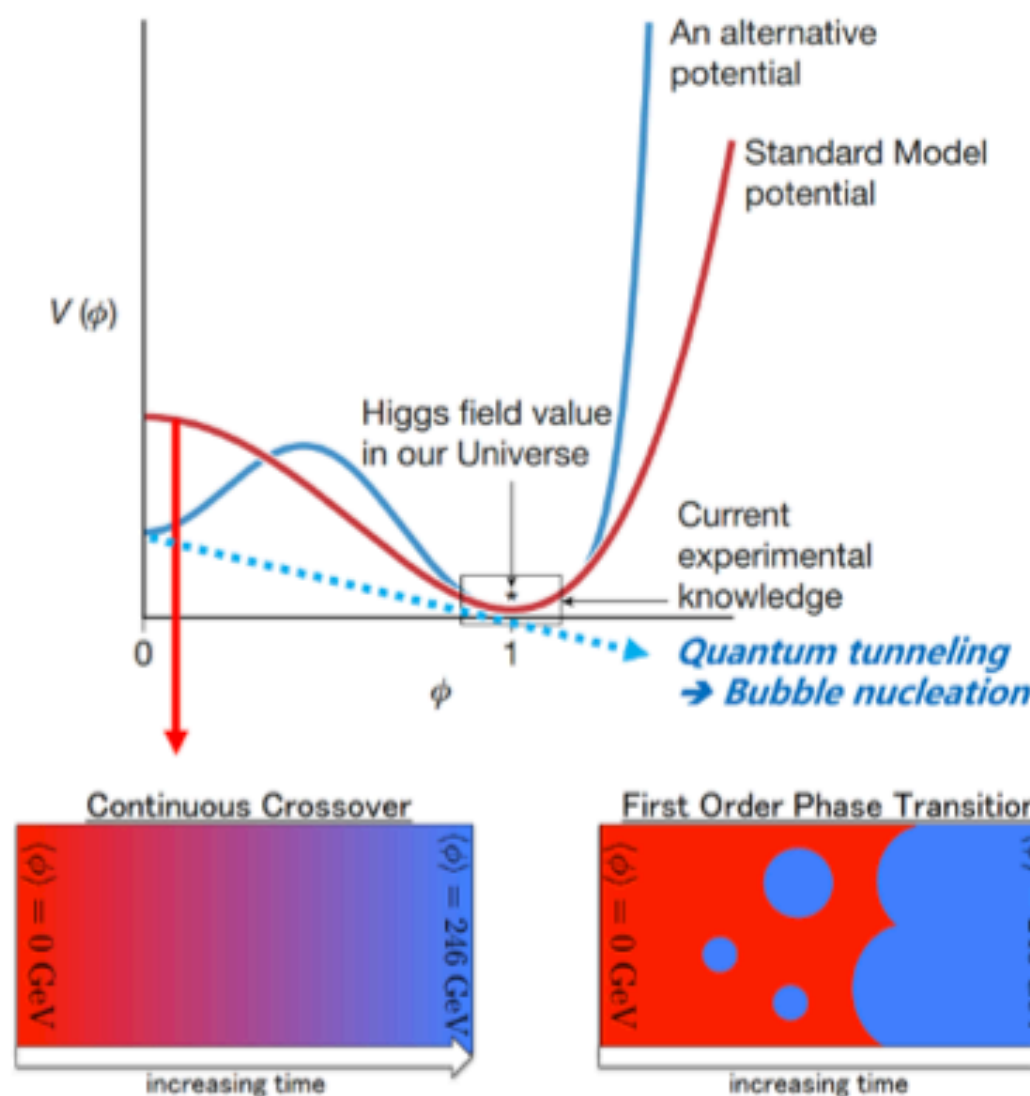
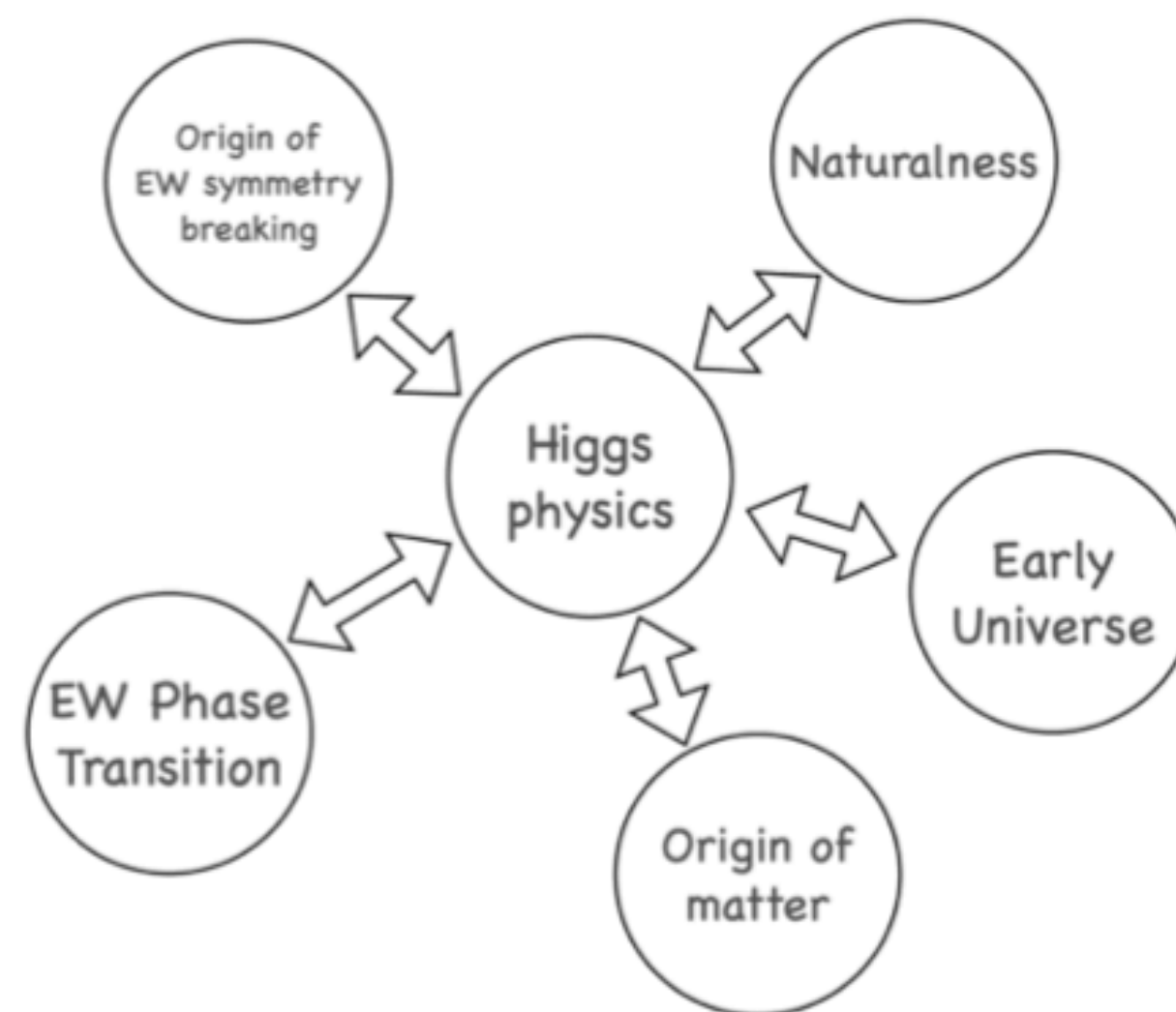
New physics search at the CEPC: a general perspective*

Xiaocong Ai (艾小聪)¹ Stefan Antusch² Peter Athron³ Yunxiang Bai (白云翔)^{4,5} Shou-Shan Bao (鲍守山)^{6,7}
Daniele Barducci^{8,9} Xiao-Jun Bi (毕效军)^{4,10} Tianji Cai (蔡恬吉)^{11,12} Lorenzo Calibbi¹³ Junsong Cang (仓俊松)¹⁴
Junjie Cao (曹俊杰)¹ Wei Chao (晁伟)¹⁵ Boping Chen (陈博平)⁴ Gang Chen (陈刚)⁴ Long Chen (陈龙)¹⁶



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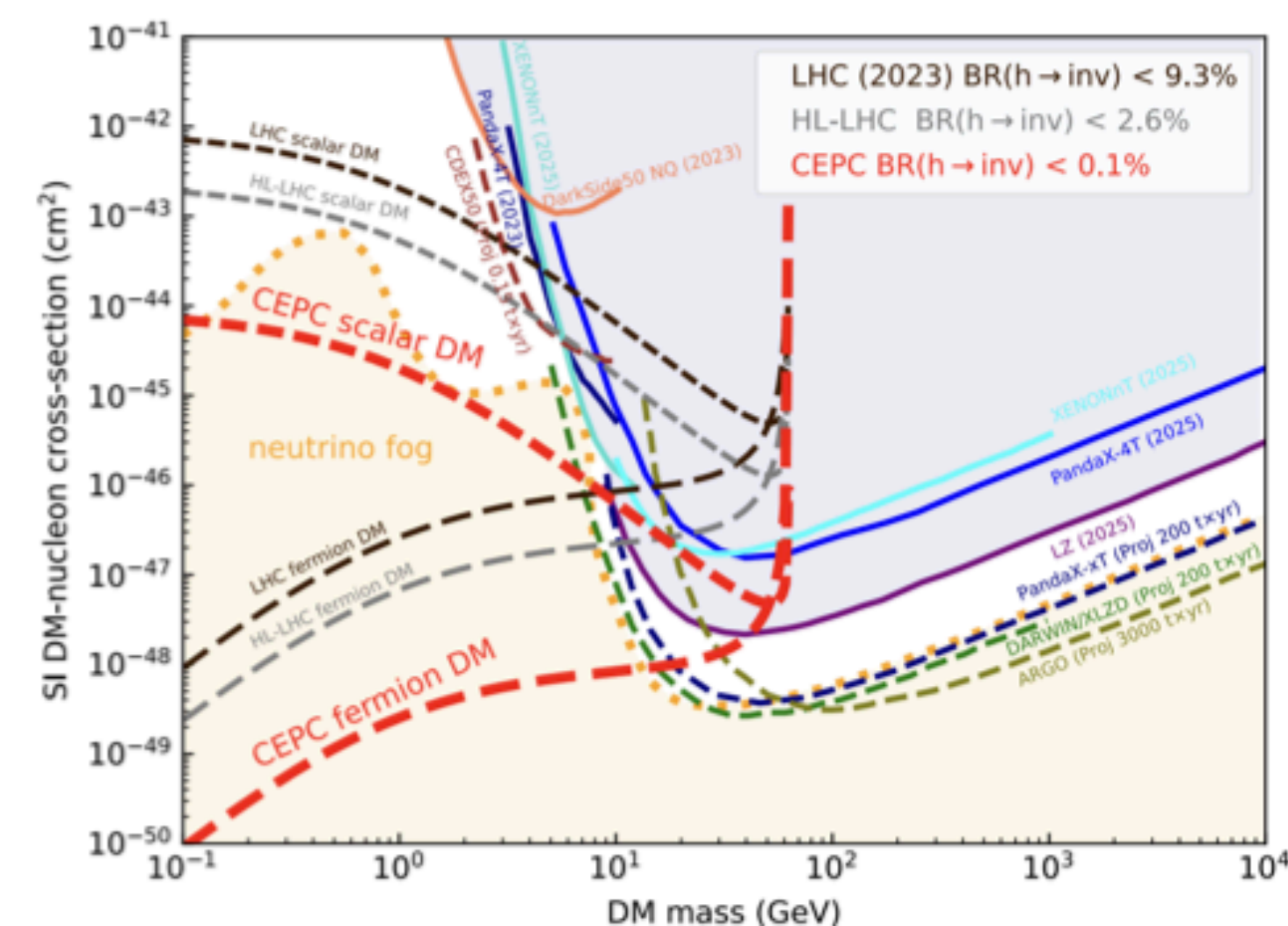
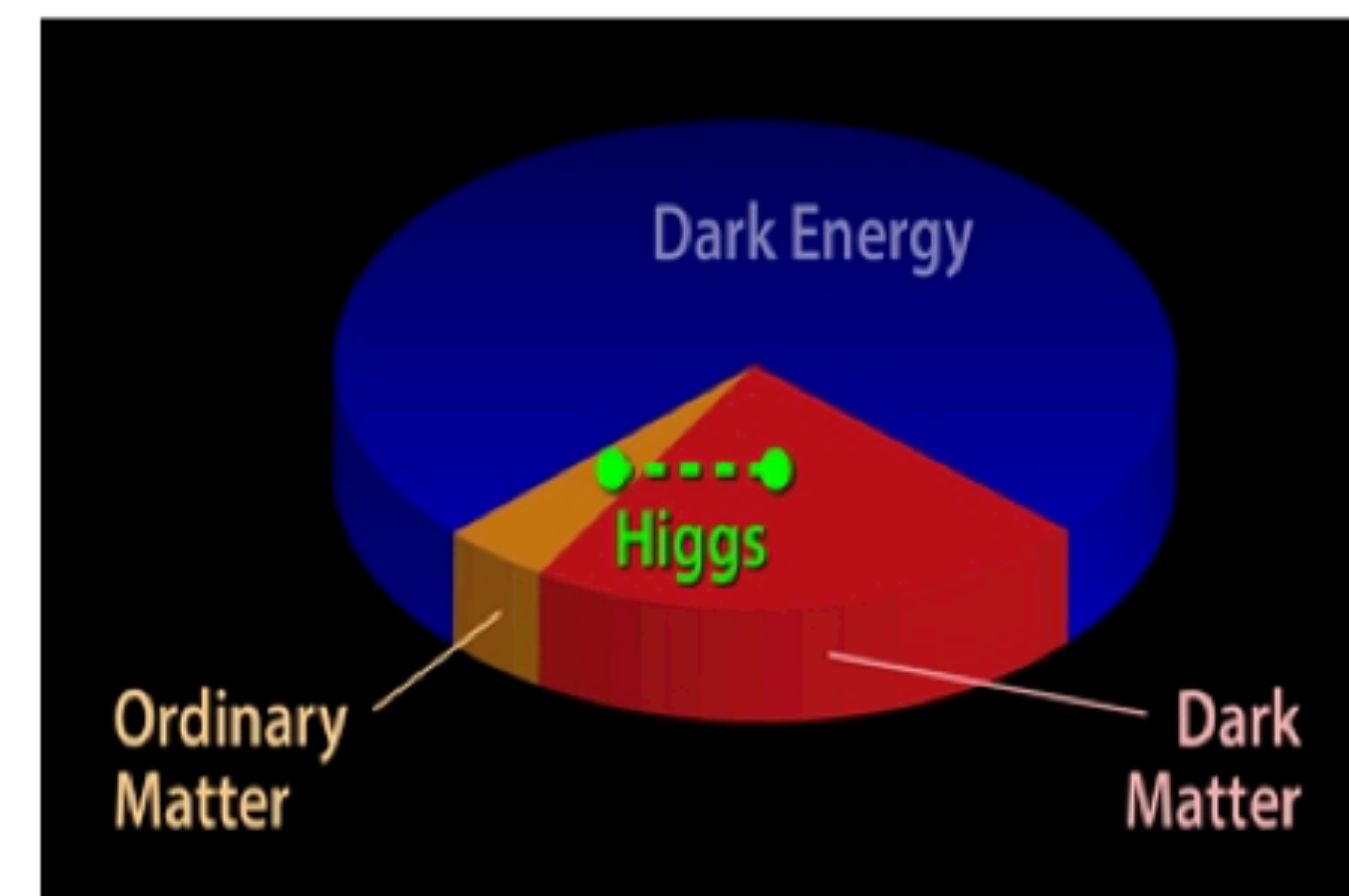
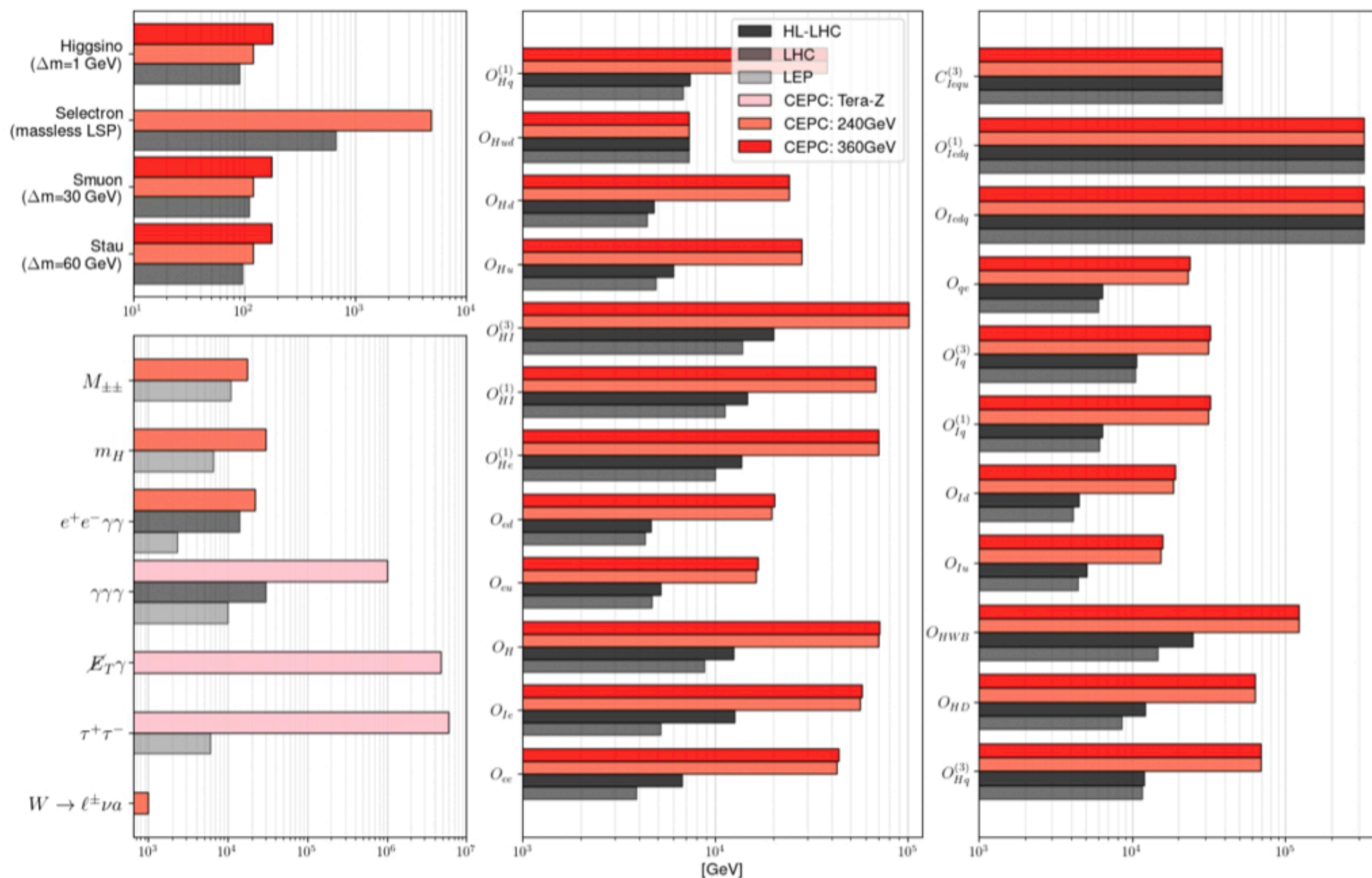
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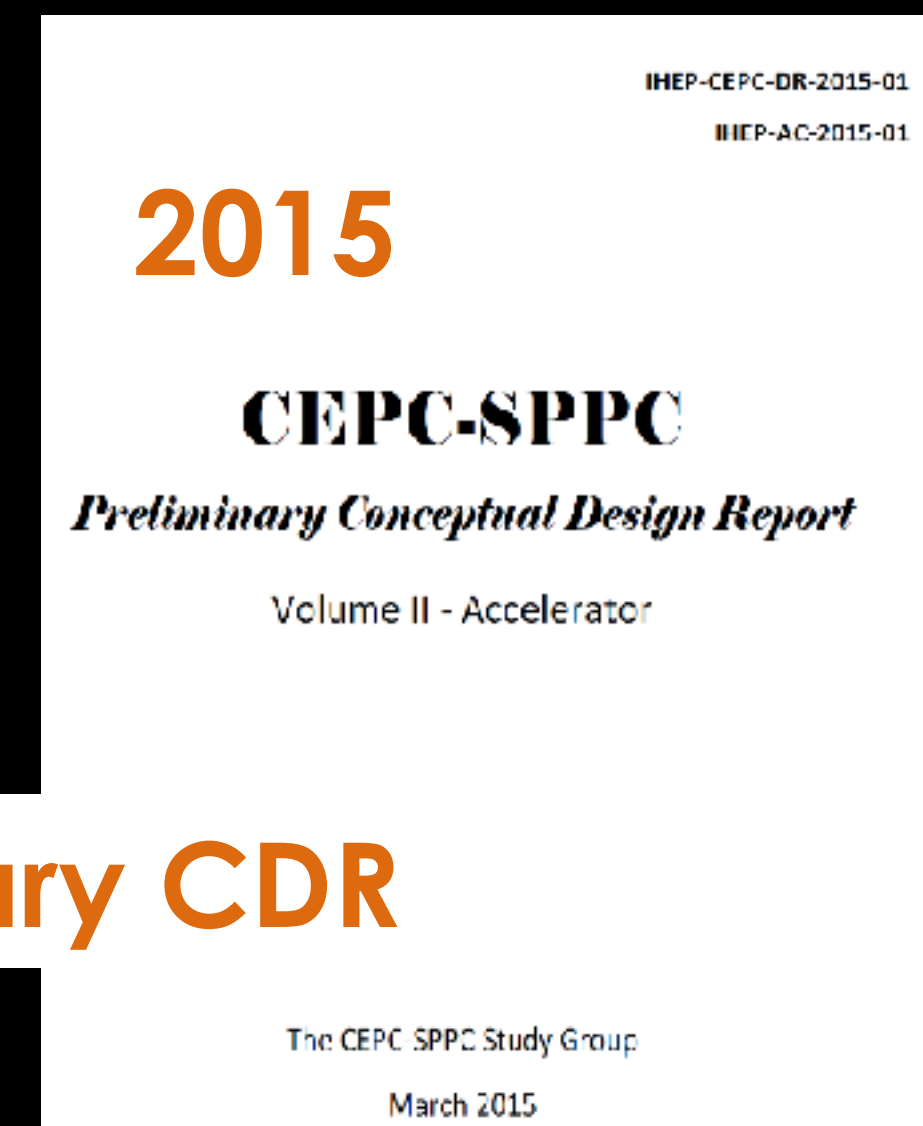
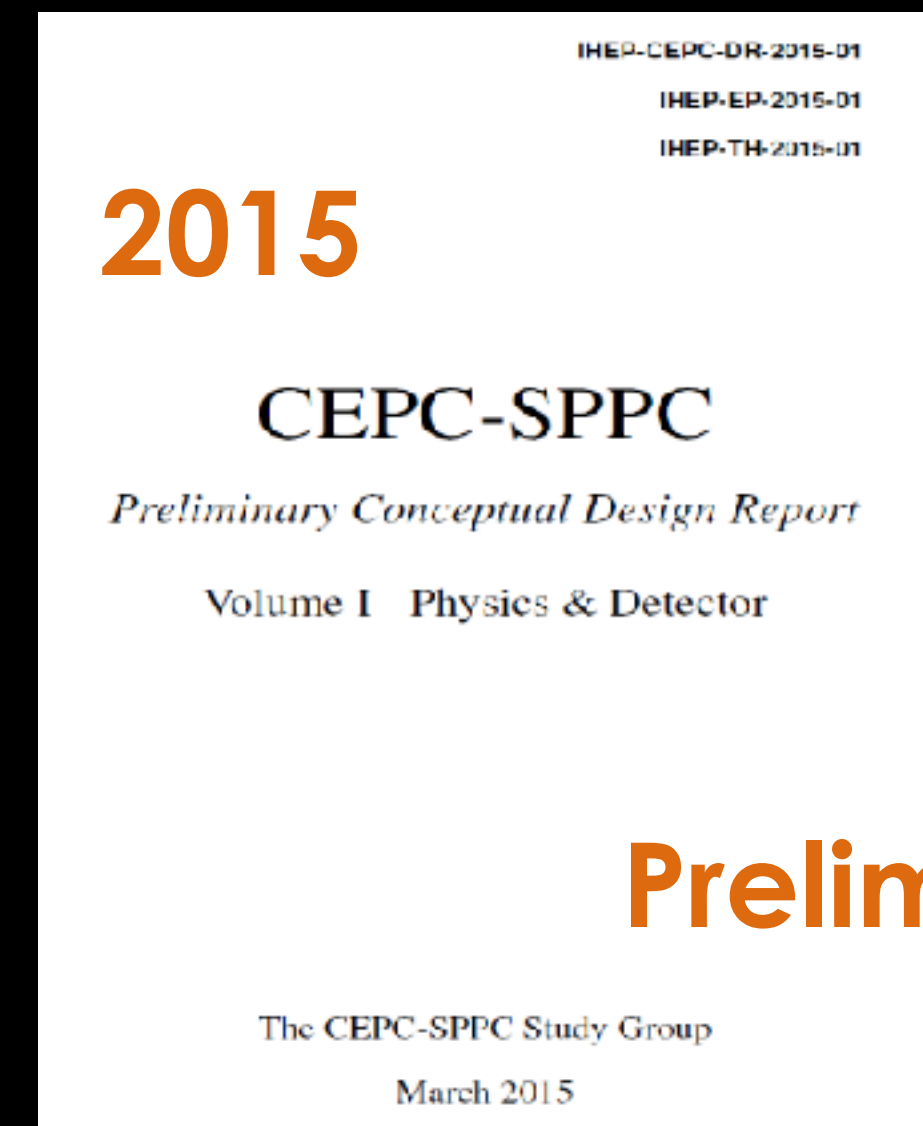
Sensitive to first order EW phase transition in early universe

New physics sensitive at CEPC

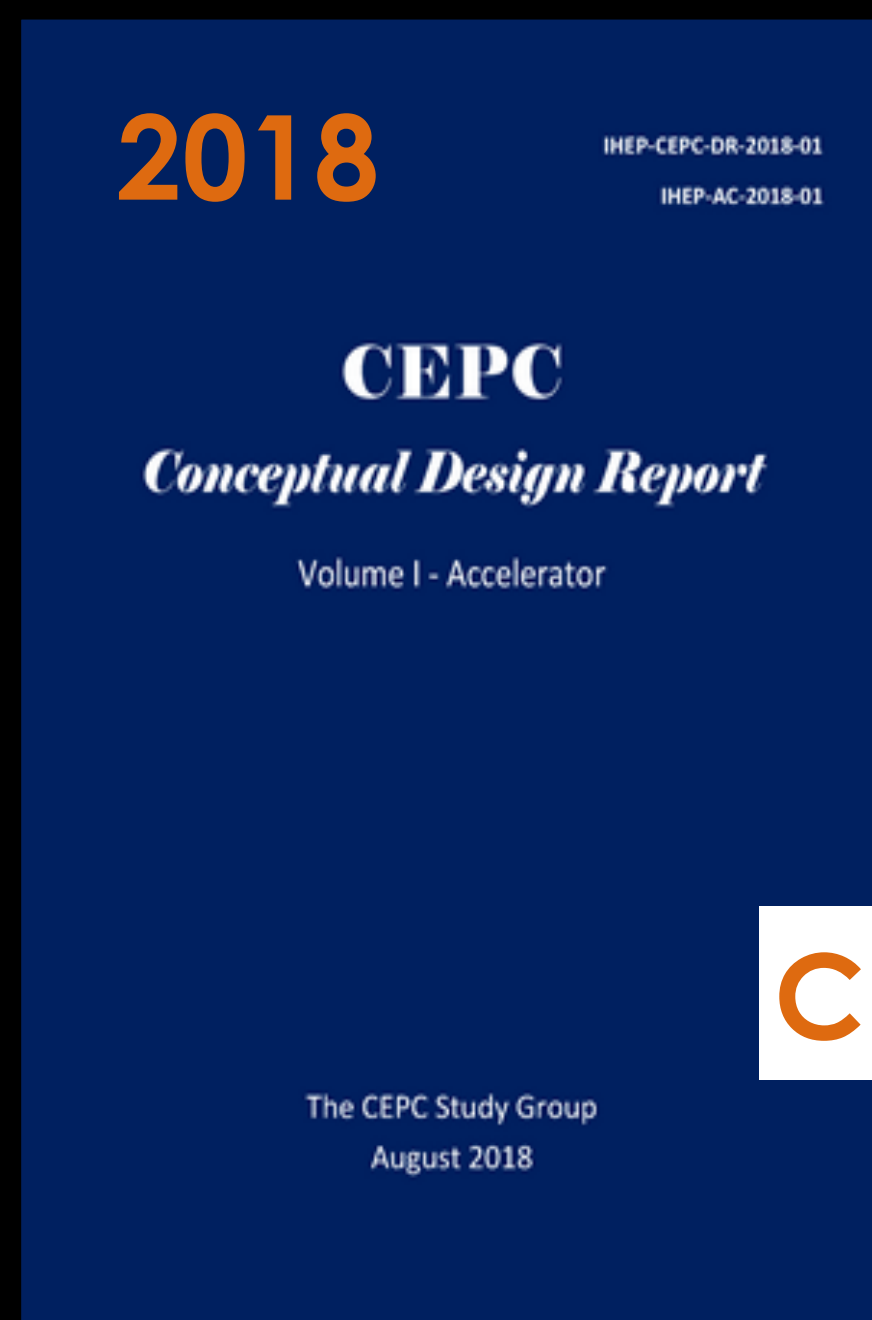
Dark matter: Higgs and Z-portal provide orders of magnitude higher sensitivity
Sensitive to physics up to 100 TeV



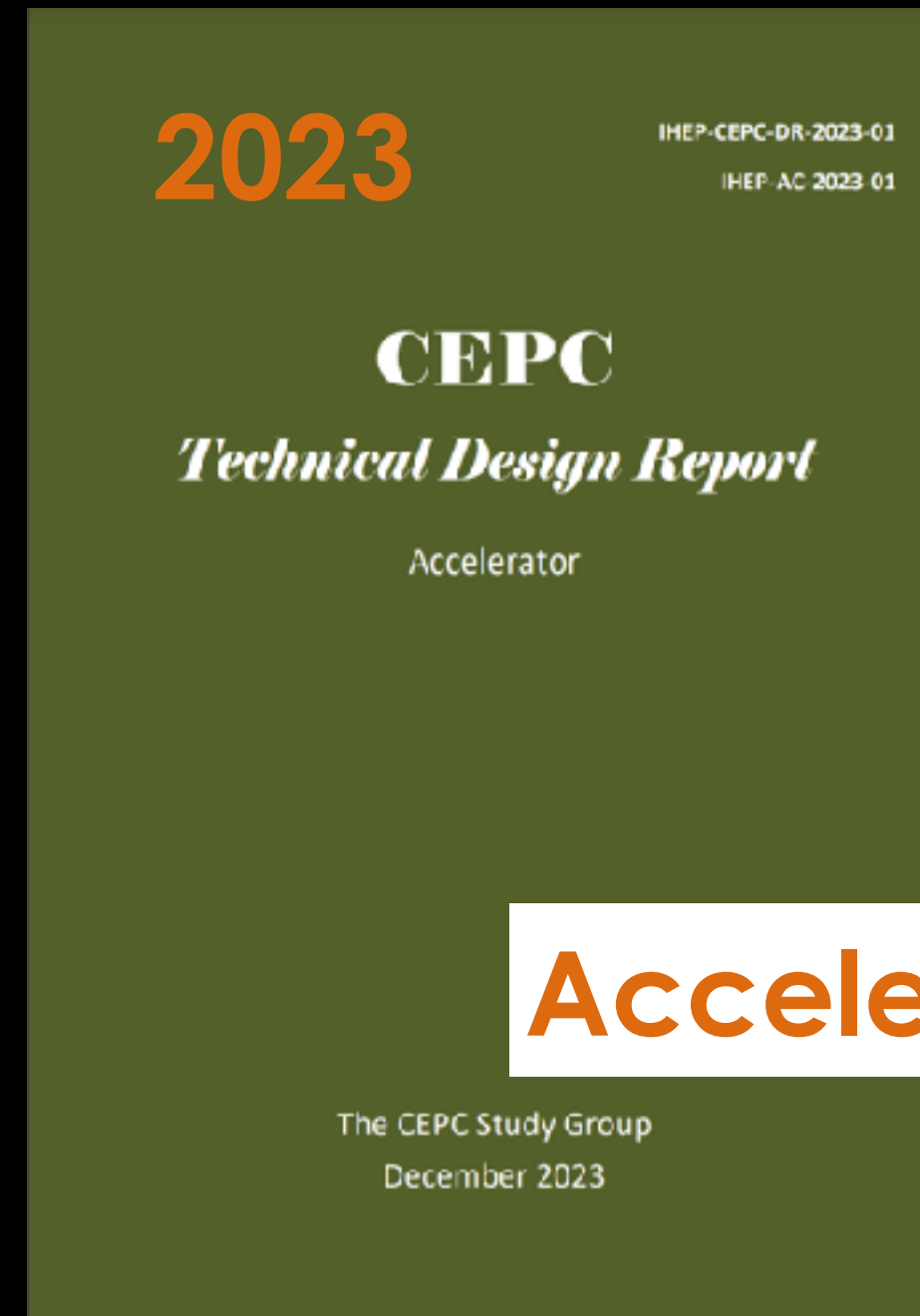
Introduction: Steps Towards Implementation



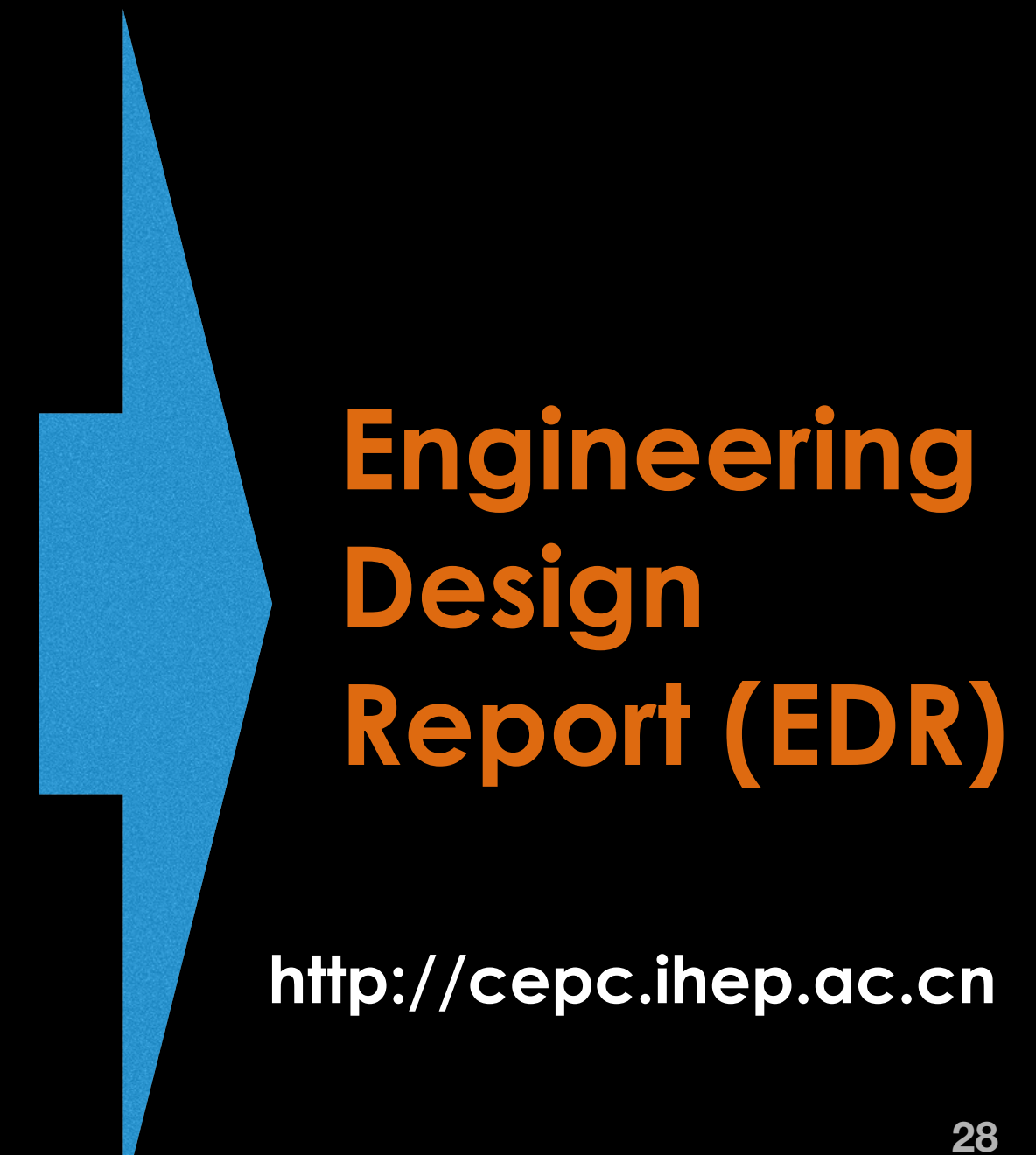
Preliminary CDR



CDR



Accelerator TDR



Engineering Design Report (EDR)

<http://cepc.ihep.ac.cn>

Accelerator International Review Committee (IARC)

CEPC International Accelerator Review Committee Meeting September 18-20, 2024 at IHEP → towards the EDR



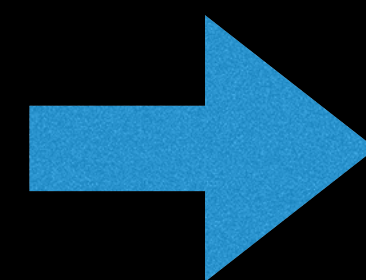
IARC members visited IHEP 4th Generation, 6 GeV HEPS light source in Huairou campus of IHEP on Sep 20, 2024

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First CEPC IARC EDR Review Report

CEPC IARC EDR Review Committee

11 October 2024



Being Implement

CEPC EDR Goal, Scope, Plan and Progresses

This document is prepared only for the CEPC IARC for the meeting to be held in Sept. 18-20, 2024, at IHEP in Beijing, and some of the details in this document may not be made for public due to their discretionary nature.

CEPC Accelerator EDR Phase Working Plan
2024 – 2027
 (July 23, 2024 updated)

CEPC EDR general goals:

CEPC accelerator activities have been carried out according to EDR plan and IARC/IAC recommendations and the accelerator EDR progresses have been reviewed by IARC on Sept. 16-19, 2025 at IHEP

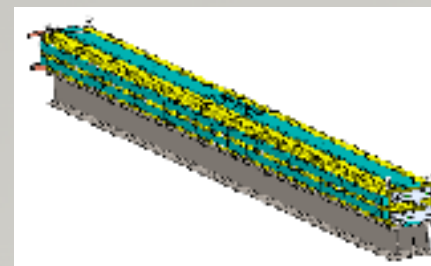
CEPC IAC Meeting, 2025/11/20

Highlights from the accelerator

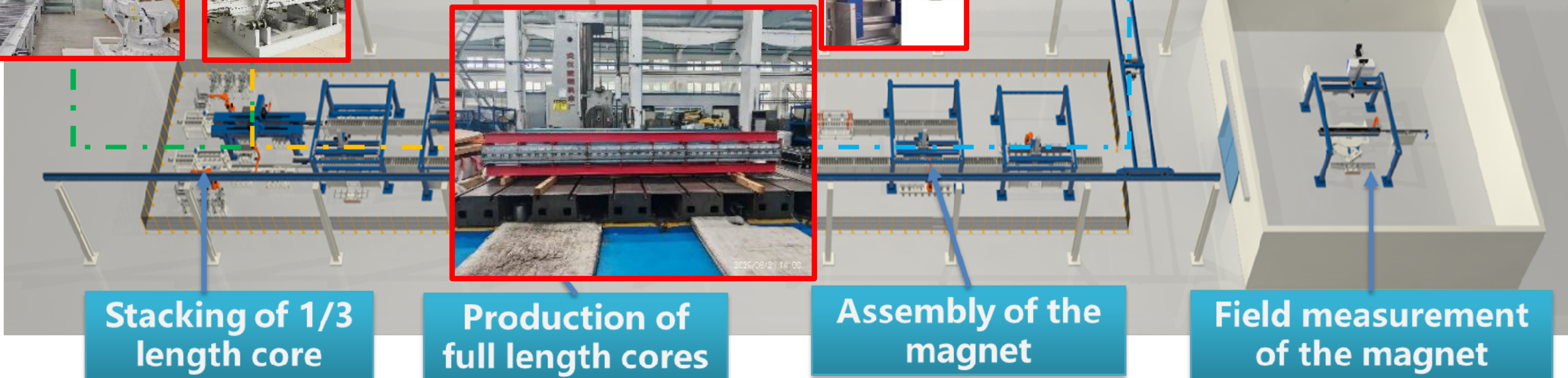
CEPC Booster Magnet Automatic Production Line in EDR



4 booster magnets fabricated per day



~15000 dipole magnets in the CEPC booster

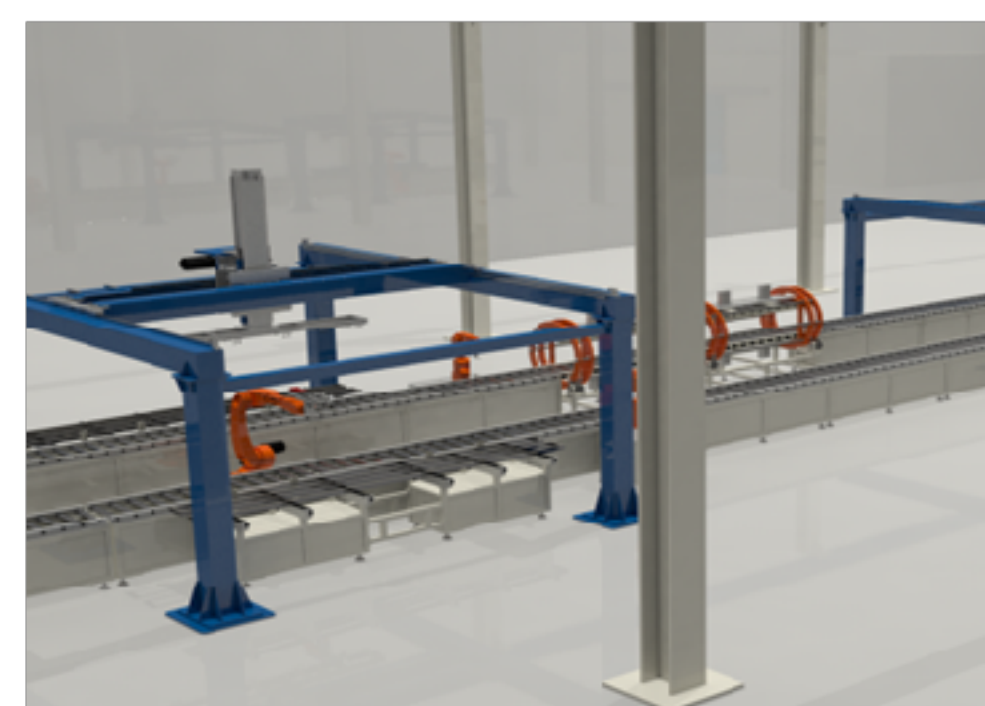
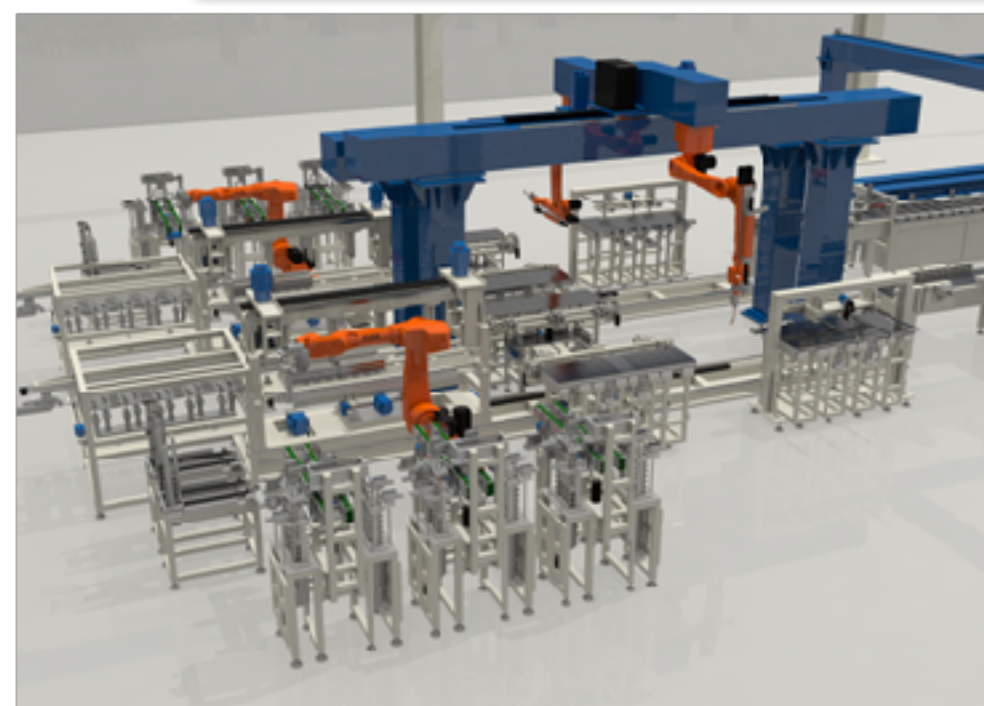


Stacking of 1/3 length core

Production of full length cores

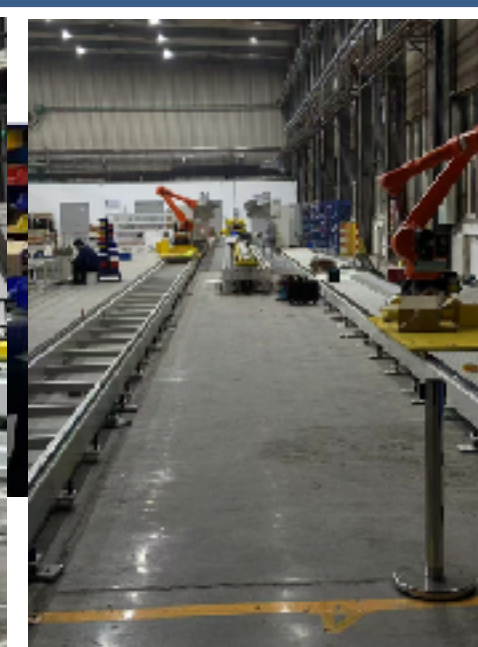
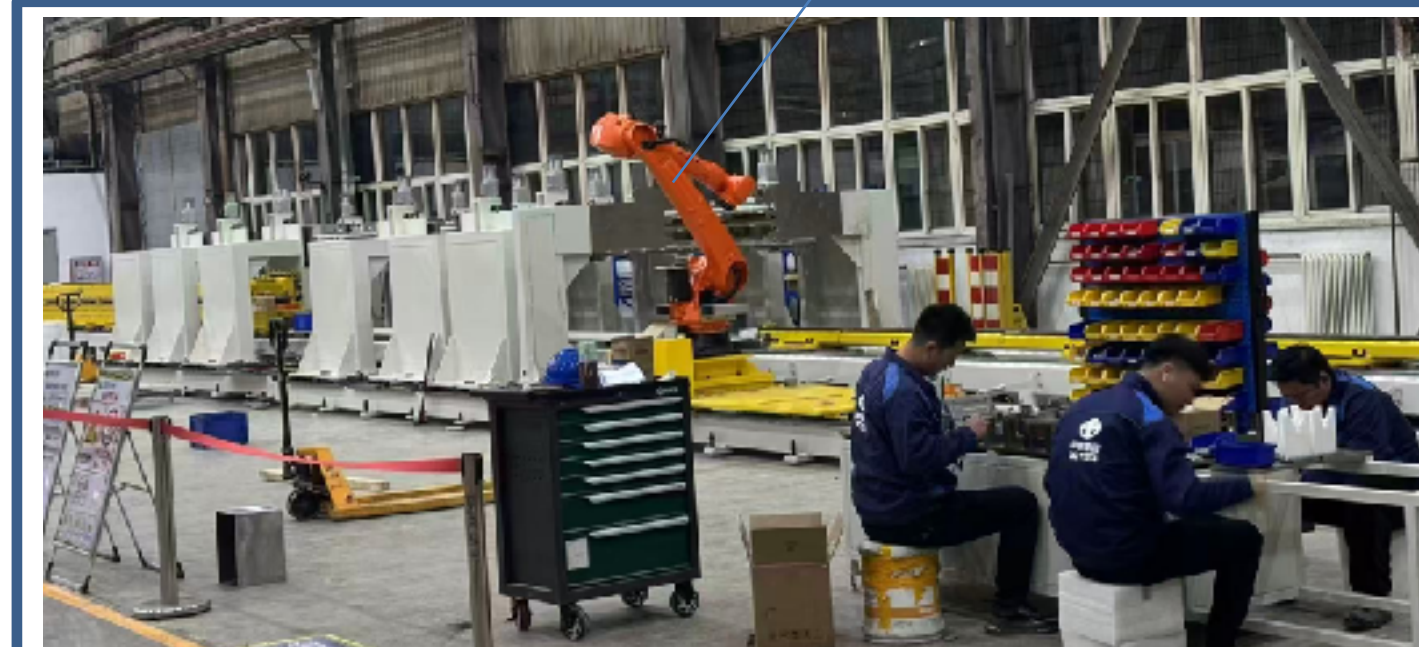
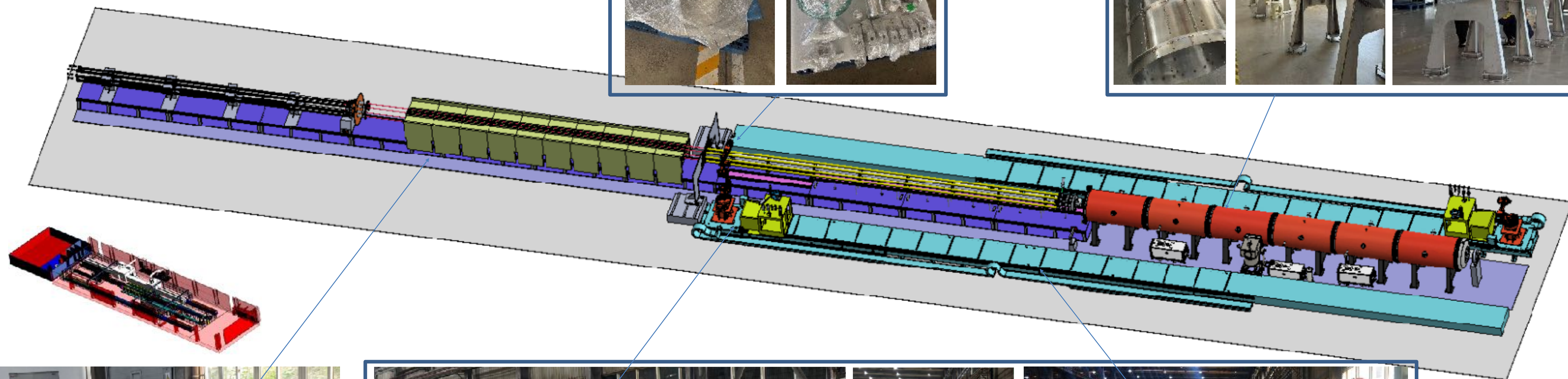
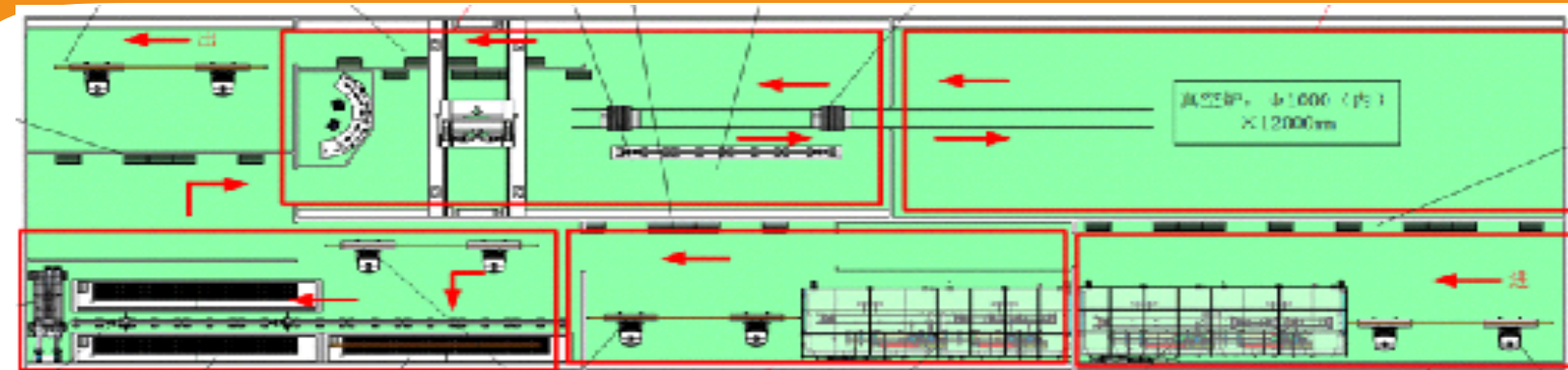
Assembly of the magnet

Field measurement of the magnet



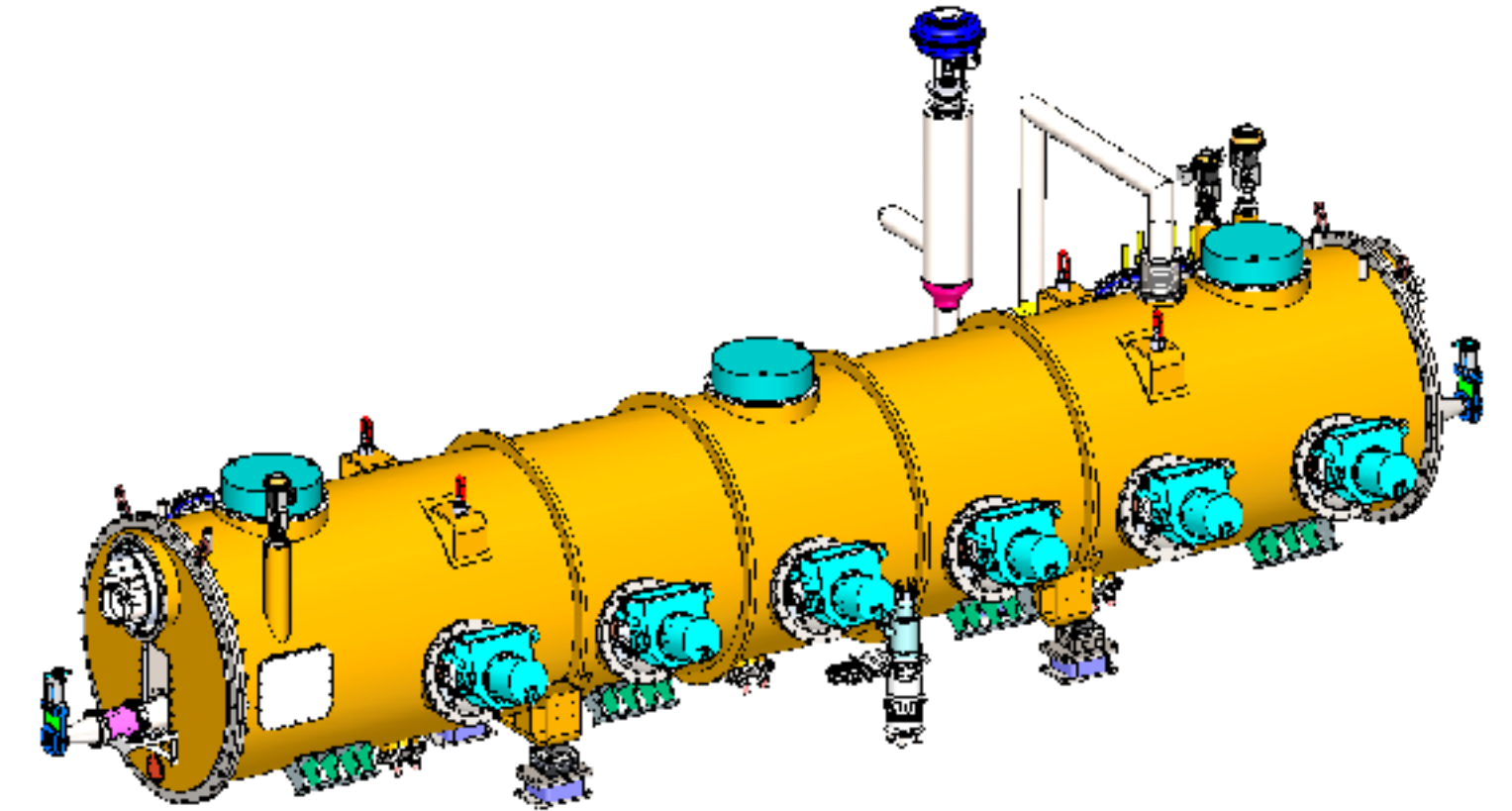
Status: under construction, to be completed in 2025~2026

CEPC NEG Coated Vacuum Chamber (200km) Automatic Production Line in EDR

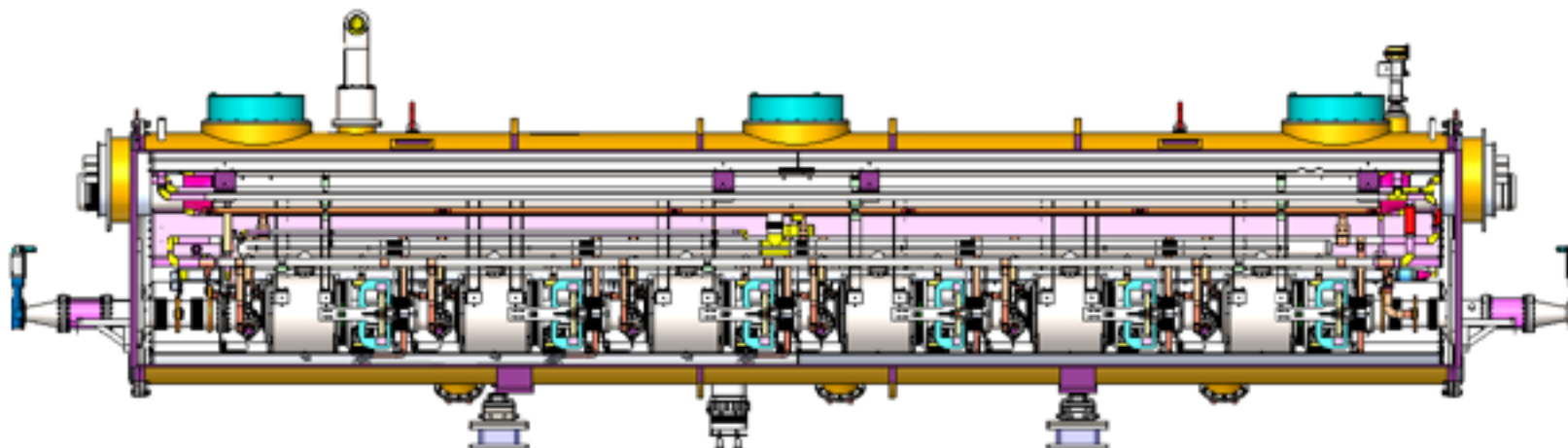
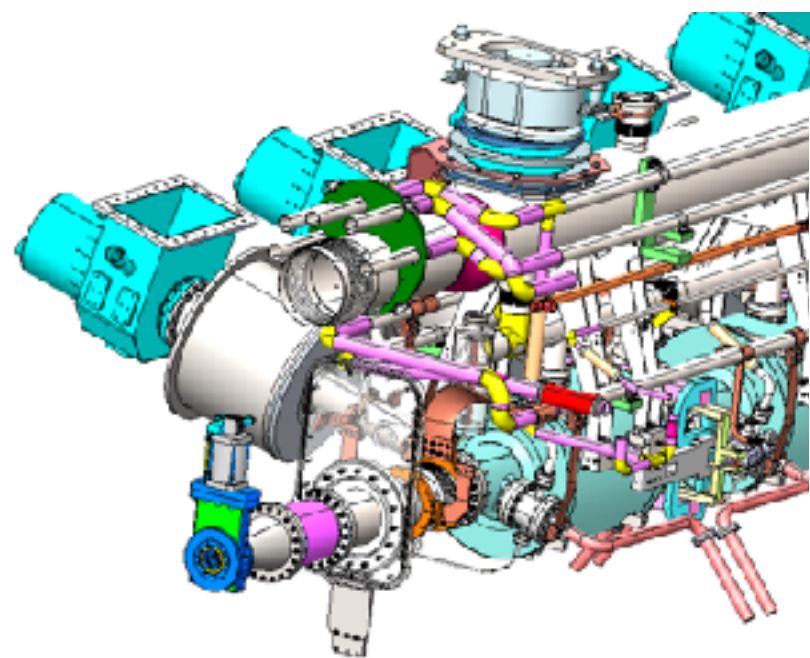
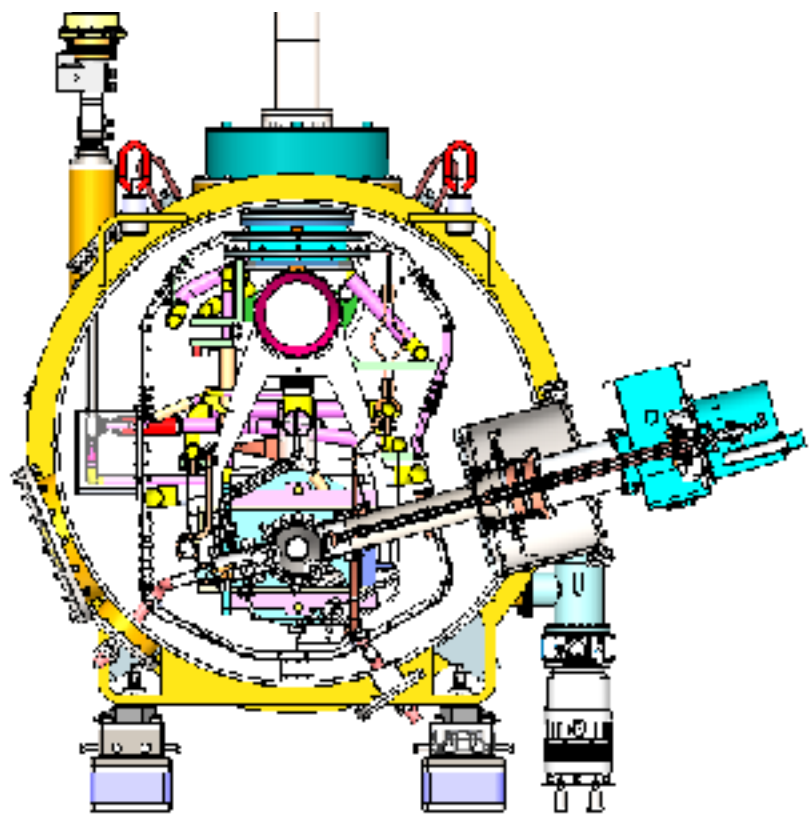


The main components of vacuum oven for NEG coating have been manufactured and under are now being assembled. **Status: under construction, to be completed in 2025~2026**

CEPC 650MHz SRF Development in EDR



CEPC collider ring 650MHz 2*cell short test module has been completed in TDR phase



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**

Status: under construction, to be completed in 2026

BEPCII-based PWFA Test Facility Development Status

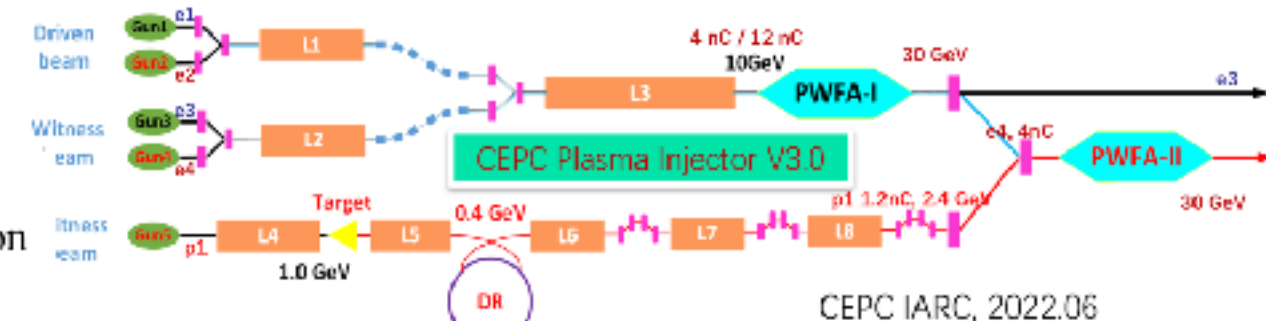
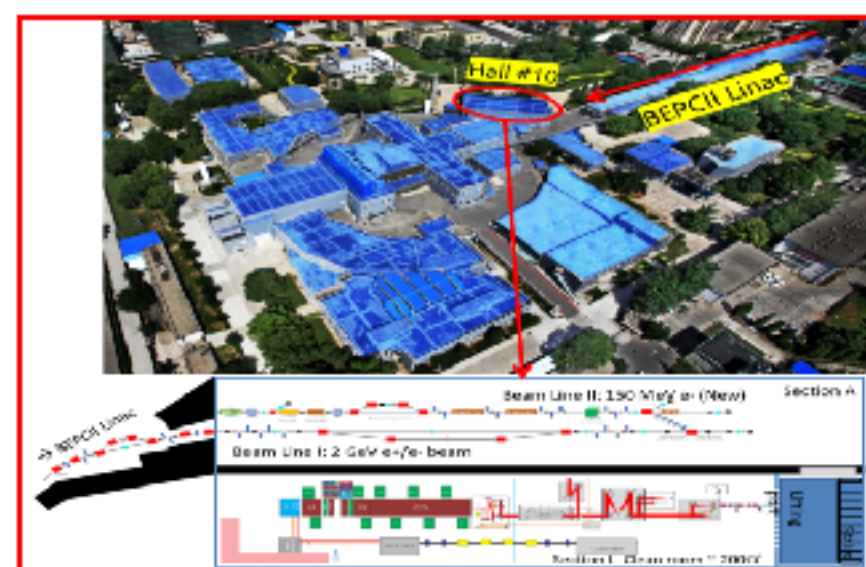


CEPC Plasma Injector (alternative option) and TF Plan

CEPC plasma injector scheme:

From 10 GeV $\rightarrow$ 30 GeV $\rightarrow$ $TR \geq 2$

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



Phase I (Year0-Year2)

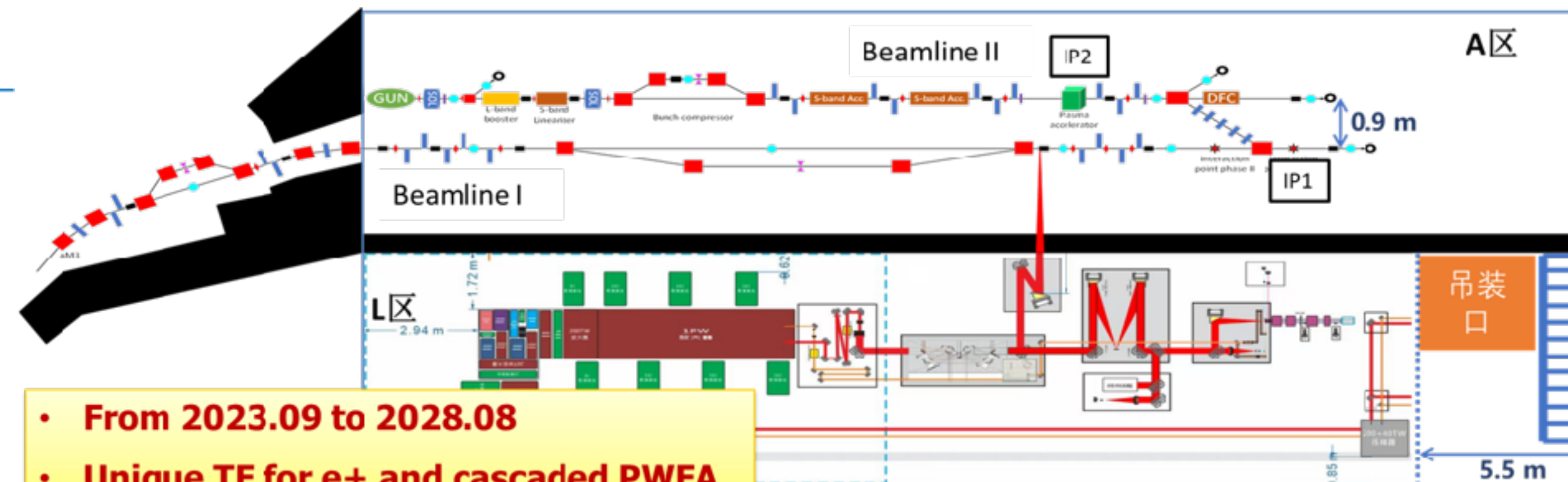
1. Re-design and install transport beamline system, optimize the e⁻/e⁺ beam quality
2. Clean room and high power installation 200TW
3. Beam instrumentation
4. RF Gun platform
5. Commissioning

Phase II (Year3-Year4)

1. Re-design and install transport beamline system, optimize the e⁻/e⁺ beam quality (1PW + 20/40 TW)
2. Clean room and high power installation 200TW
3. Beam instrumentation
4. RF Gun platform
5. Commissioning

• Positron and electron acceleration
• Cascading acceleration
• Future linear collider technologies (possible application)

PWFA/LWFA TF based on BEPC-II Linac and HPL has been founded by CAS 90M RMB in Sept. 2023
Under development in the experimental hall #10 of BEPC-II

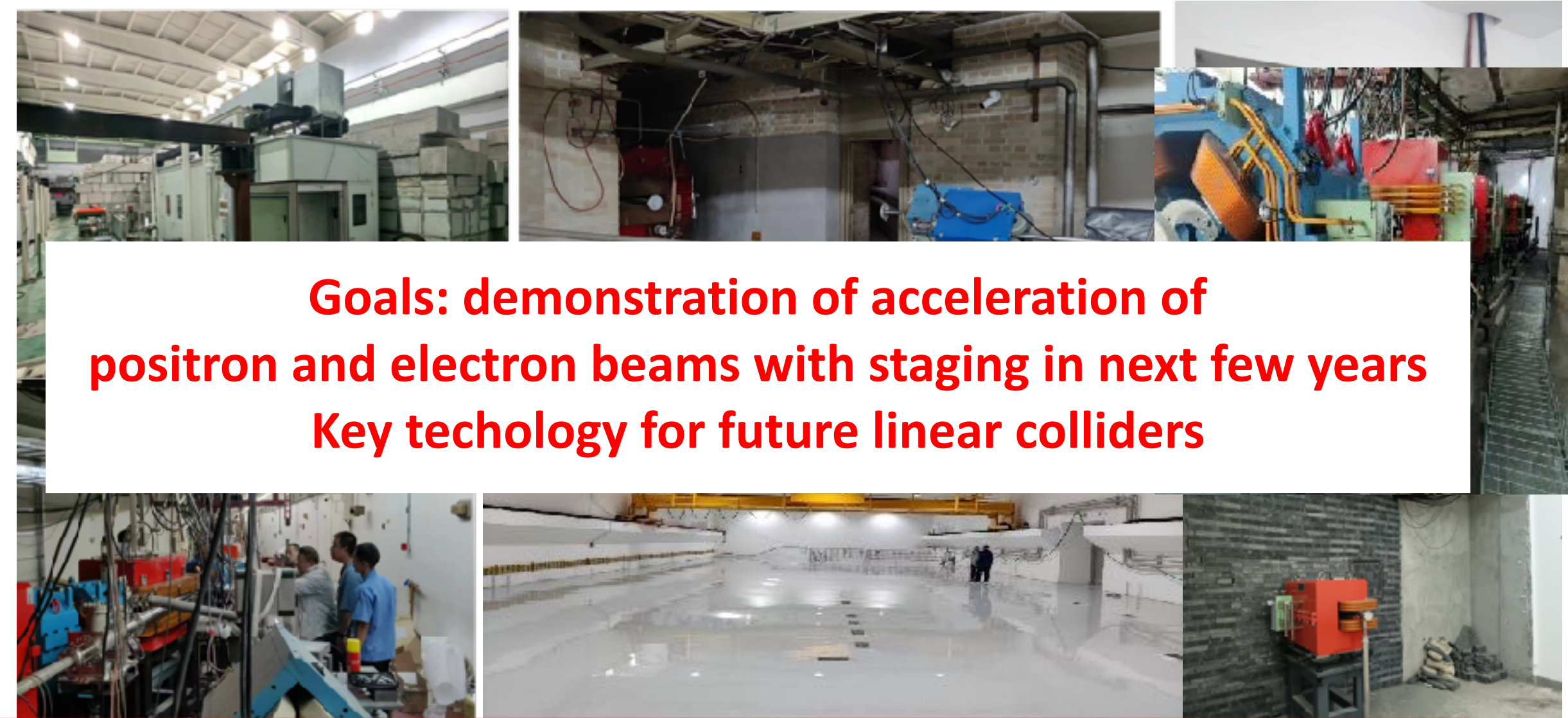
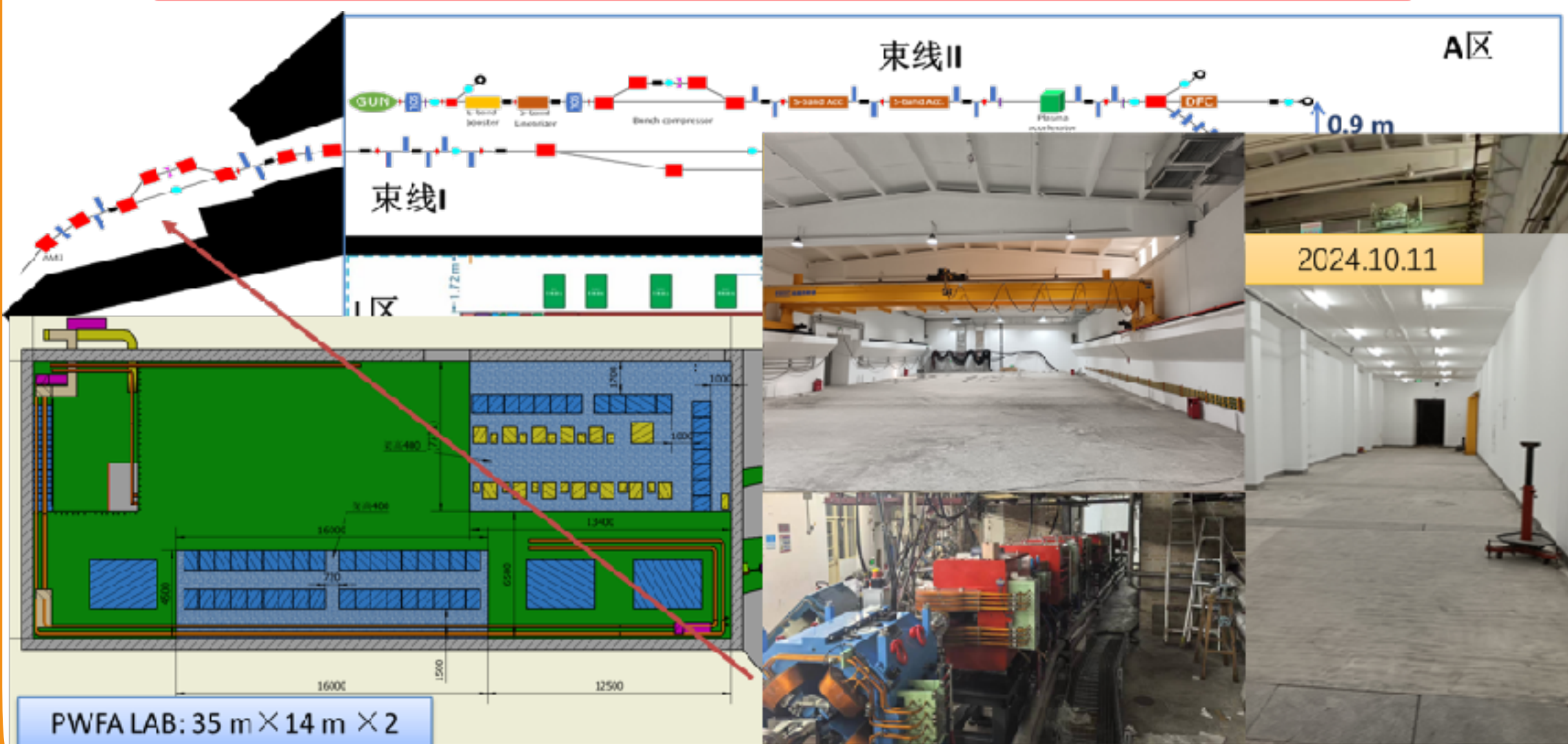


- From 2023.09 to 2028.08
- Unique TF for e⁺ and cascaded PWFA

Beam quality

Beamline I

Parameters	Unit	BL-I e ⁻ (AM3)	BL-I e ⁻ (IP1)	BL-I e ⁺ (AM3)	BL-I e ⁺ (IP1)	BL-I e ⁻ (IP1, block)	BL-I e ⁺ (IP1, block)
Energy	GeV	2	2	2	2	2	2
Charge	pC	2000	2000	100	100	9.4	0.2
bunch length	ps	10	1	10	1	~1	~1
Geo. emittance	mm-mrad	0.1/0.1	0.1/0.1	0.4/0.4	0.4/0.4	0.011/0.005	0.04/0.02
RMS beam size	μm	-	150/150	-	300/300	30/40	54/76

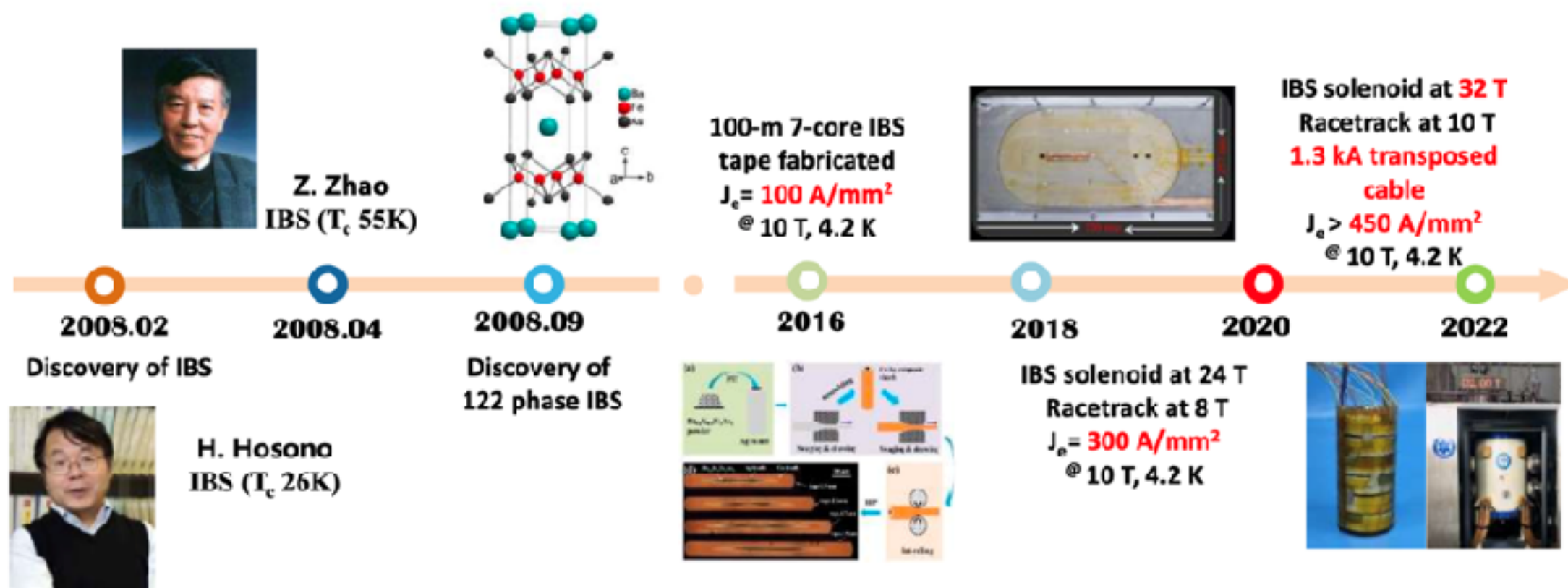


Goals: demonstration of acceleration of positron and electron beams with staging in next few years
Key techology for future linear colliders

Advanced Technologies Development in Progress



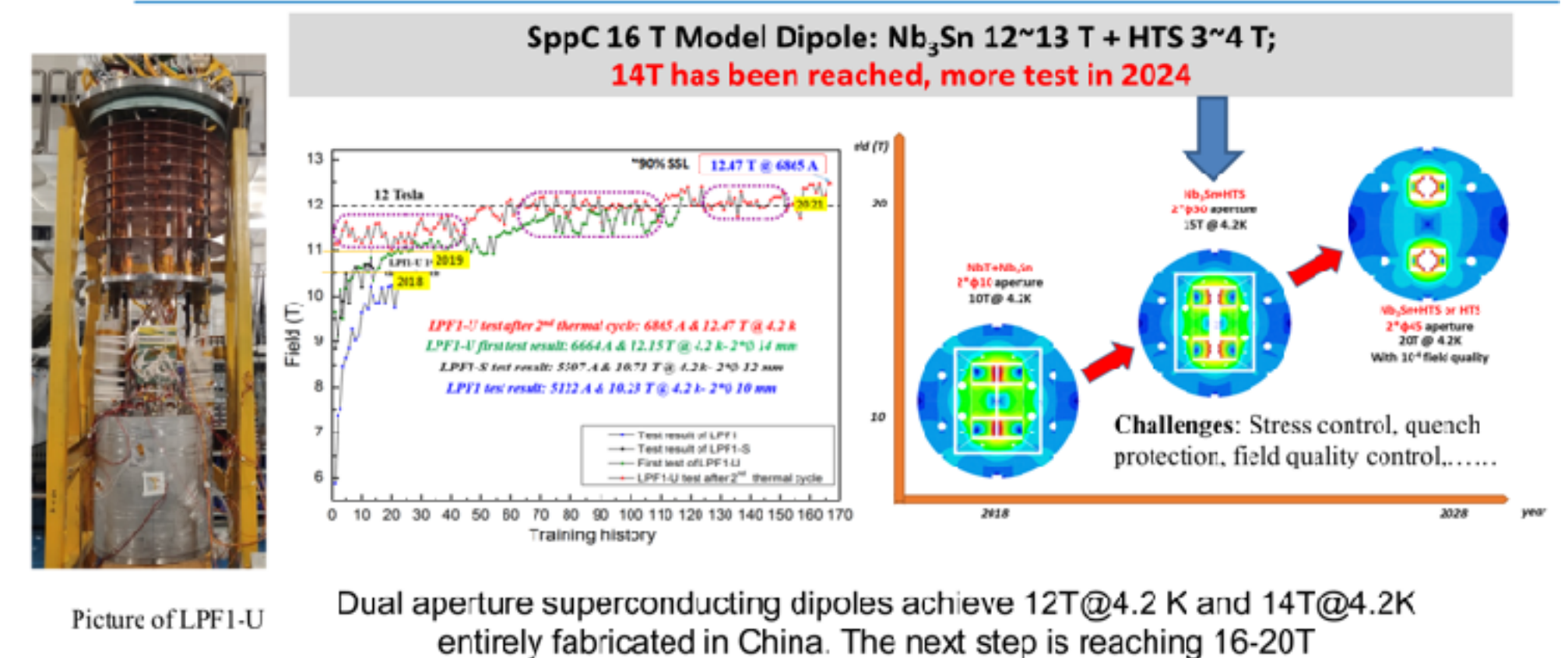
IBS Technology for High Field Magnets



J_c of IBS expected to be similar as ReBCO in 5 years with better mechanical properties and lower cost



SppC HF Magnet Development



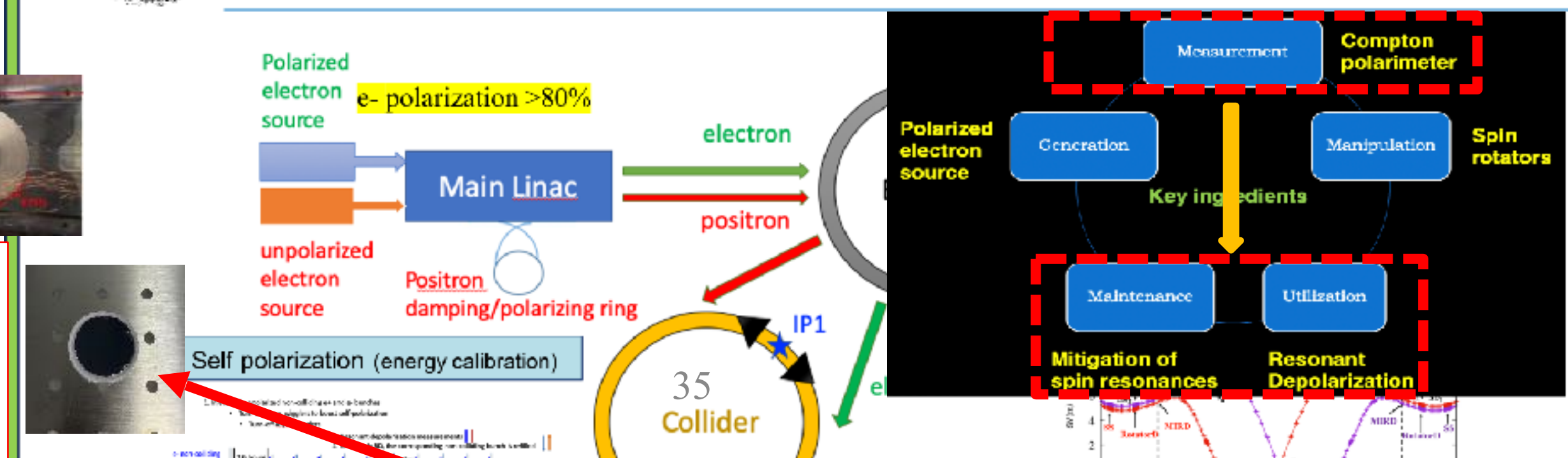
CEPC Accelerator EDR Scope, Plan and Status - J. Cao

The CEPC IARC Meeting in 2024, Sept. 18-20, 2024, IHEP

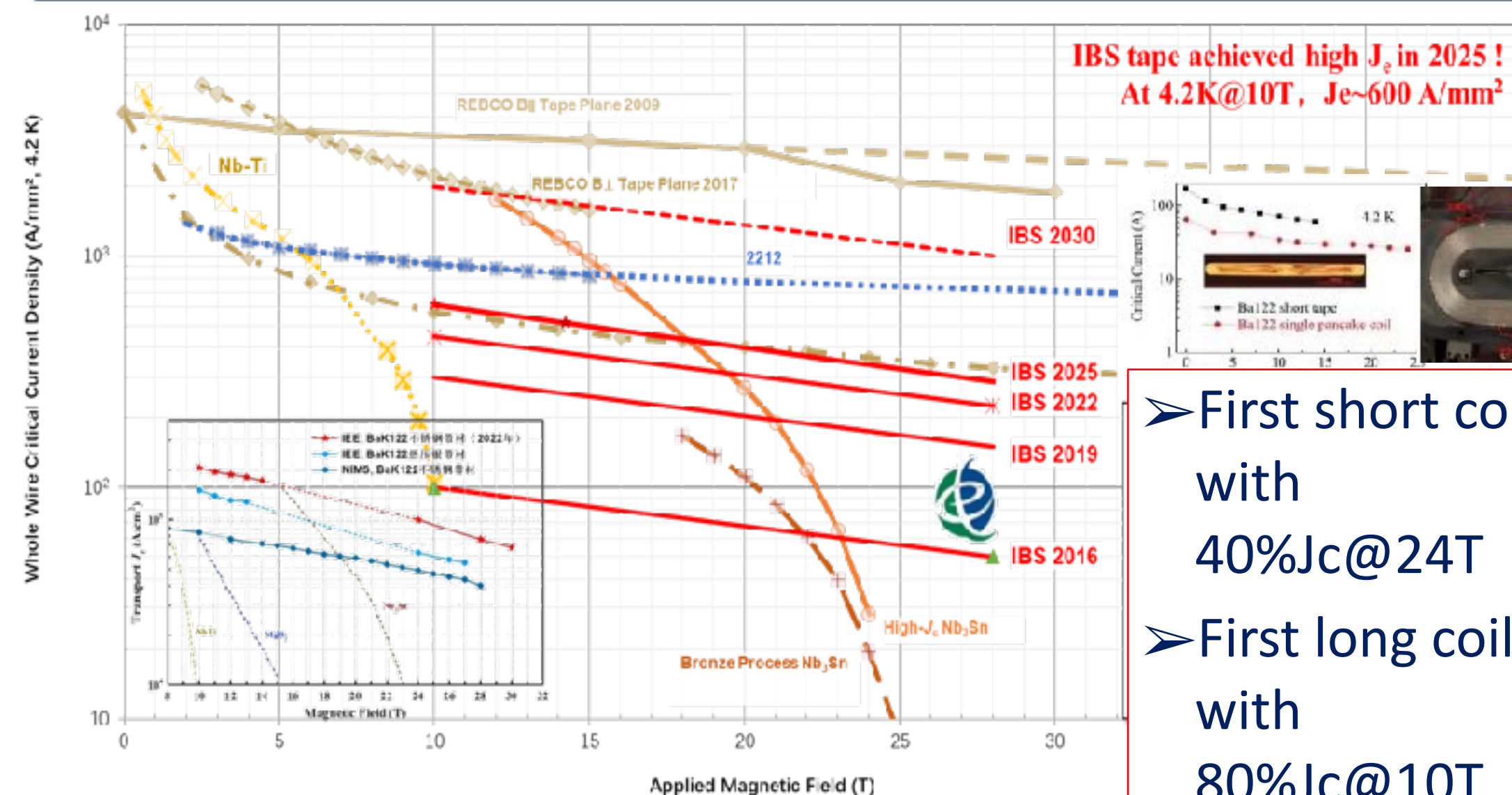
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CEPC Polarized Beam Studies(alternative option)



Polarized electron cathode chip (diameter ~5cm) has been fabricated in June 2025: Polarization of 85%, for 1ns laser (780nm) pulse length, several nC polarized electron charge will be obtained with the expected cathode lifetime ~6 months



- First short coil with 40% J_c @24T
- First long coil with 80% J_c @10T

According to the progresses from 2016-2025, it is expected that the IBS could reach the technical requirements for SppC/FCChh around 2035

The CEPC Reference Detector

Steps Towards Reference Detector TDR



October 2025

2015

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

Preliminary CDR

The CEPC-SPPC Study Group

March 2015

2018

IHEP-CEPC-DR-2018-02

IHEP-EP-2018-01

IHEP-TH-2018-01

CEPC

Conceptual Design Report

Volume II - Physics & Detector

CDR

The CEPC Study Group

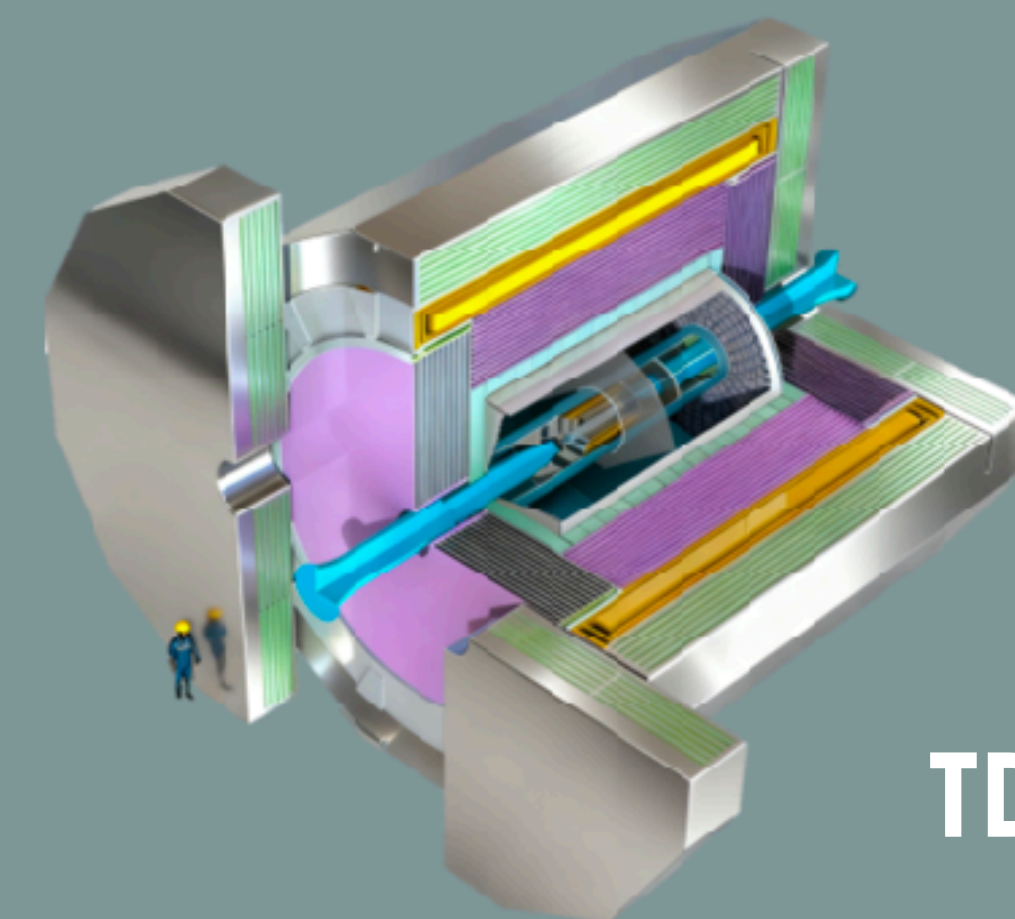
October 2018

IHEP-CEPC-DR-2025-01
IHEP-EP-2025-01

CEPC Reference Detector Technical Design Report

Version: v1.0.1 build: 2025-11-02 11:13:11+08:00

<https://arxiv.org/abs/2510.05260>



TDR

~1500 authors

The CEPC Study Group
October, 2025

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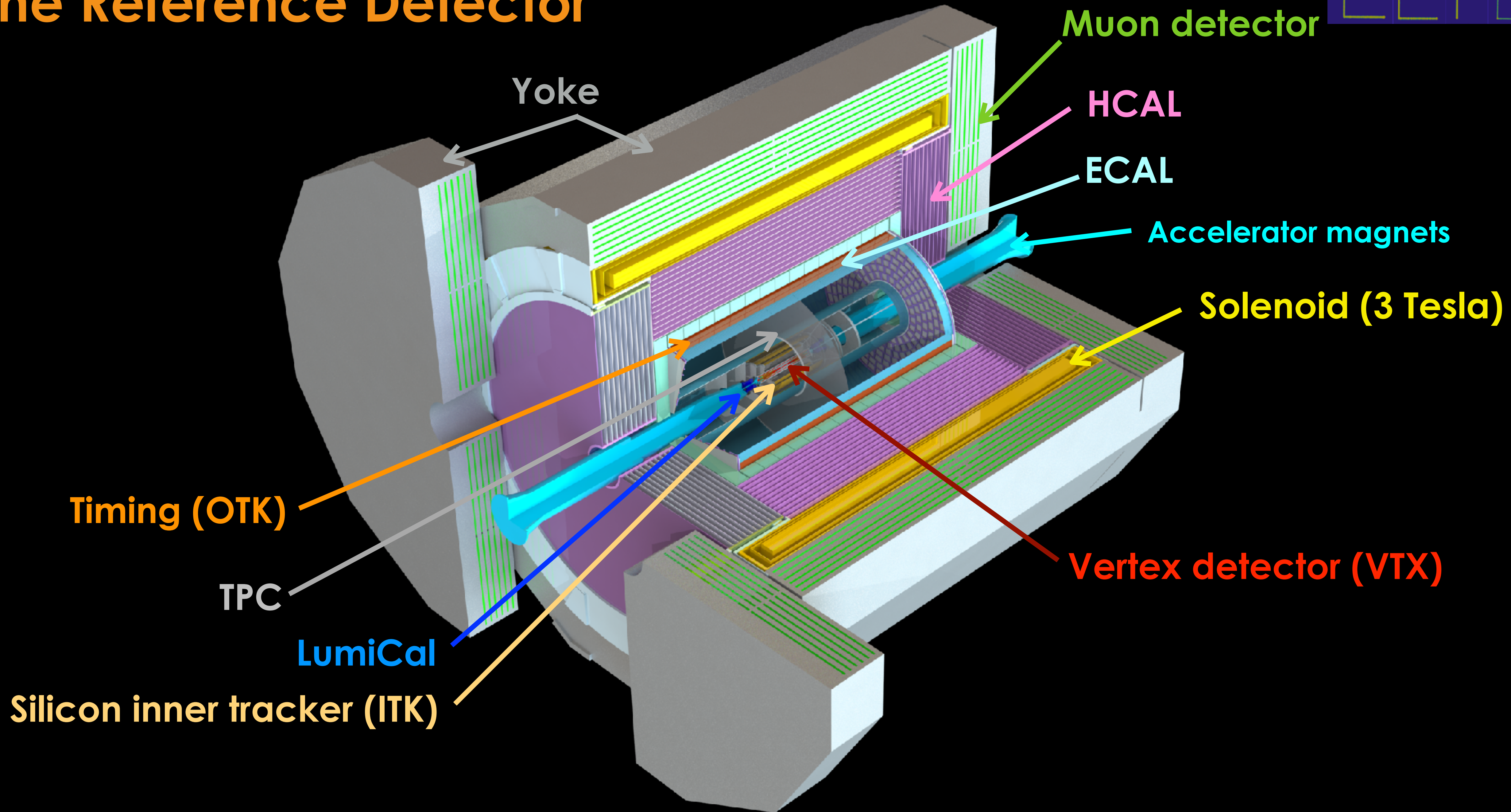
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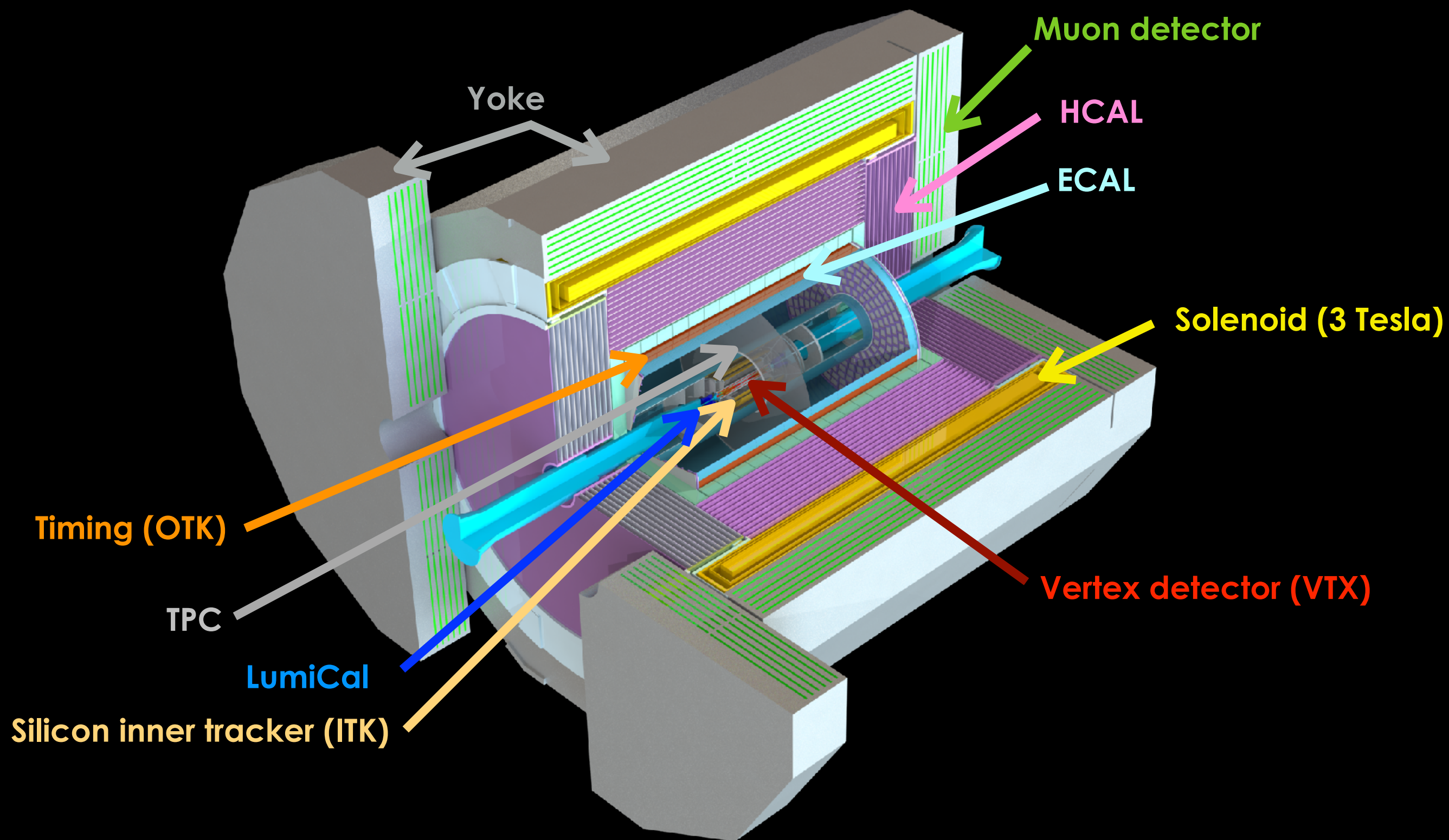
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The Reference Detector



The Reference Detector



Main goal of CEPC Reference Detector TDR

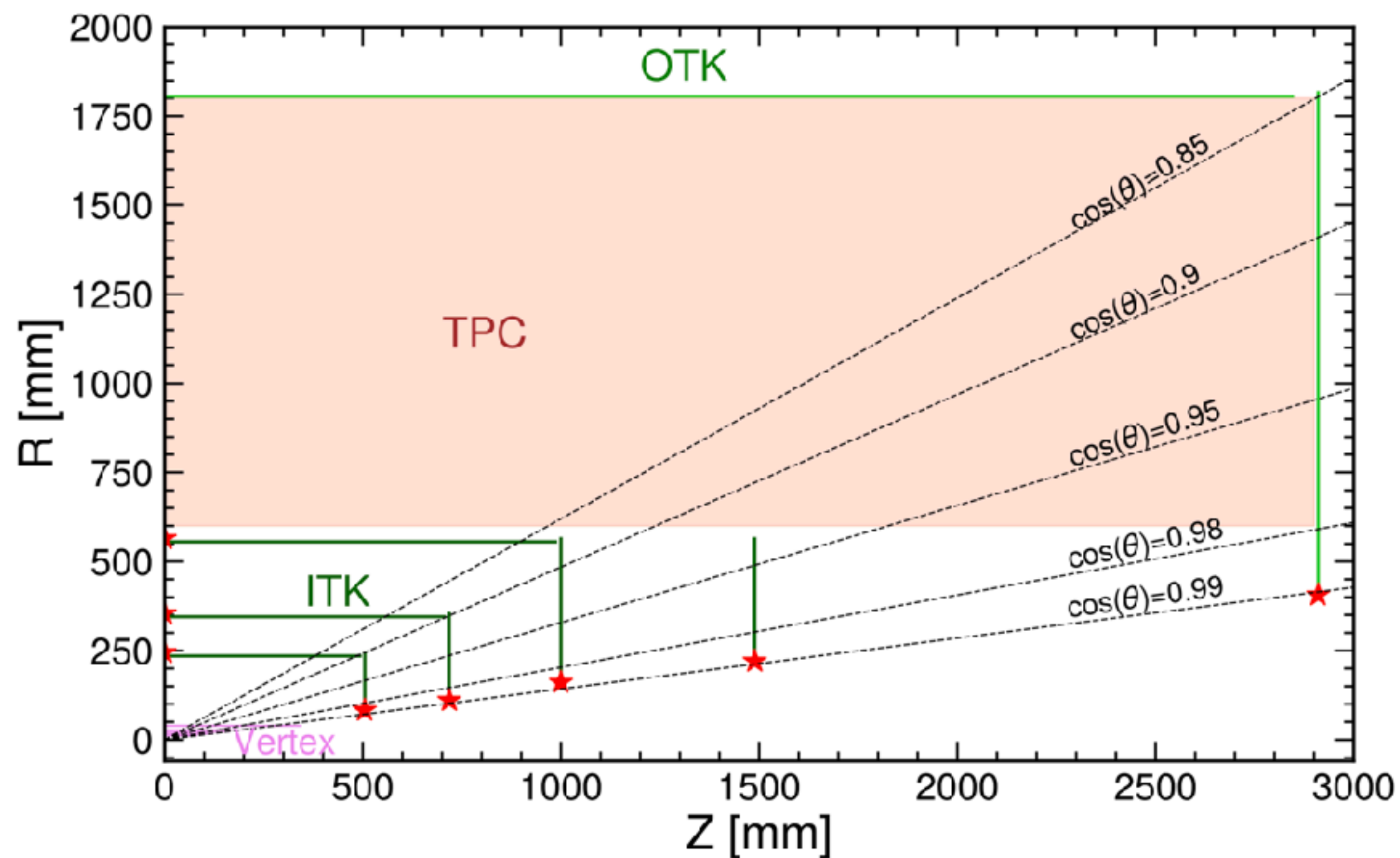
Demonstrate readiness for construction of detector for baseline scenario

A detector that could be constructed and commissioned within a decade

Sub-system	Technologies
Beam pipe	Beryllium, ϕ 20 mm
LumiCal	Silicon tracker + LYSO crystals
Vertex	Si Pixels: CMOS MAPS+stitching
Inner tracker (ITK)	Si Pixels: CMOS MAPS 55-nm
Gas detector	TPC with high granularity
Outer tracker (OTK)	AC-LGAD $\rightarrow$ TOF
ECAL	4D transverse crystal bars
HCal	Glass scintillator, SiPM + Fe
Magnet	LTS Solenoid
Muon	Plastic scintillator bars, SiPM
TDAQ	Conventional
Back-end electronics	Common

The Tracking System

Silicon tracker inside a Time Projection Chamber (TPC) with a timing layer outside



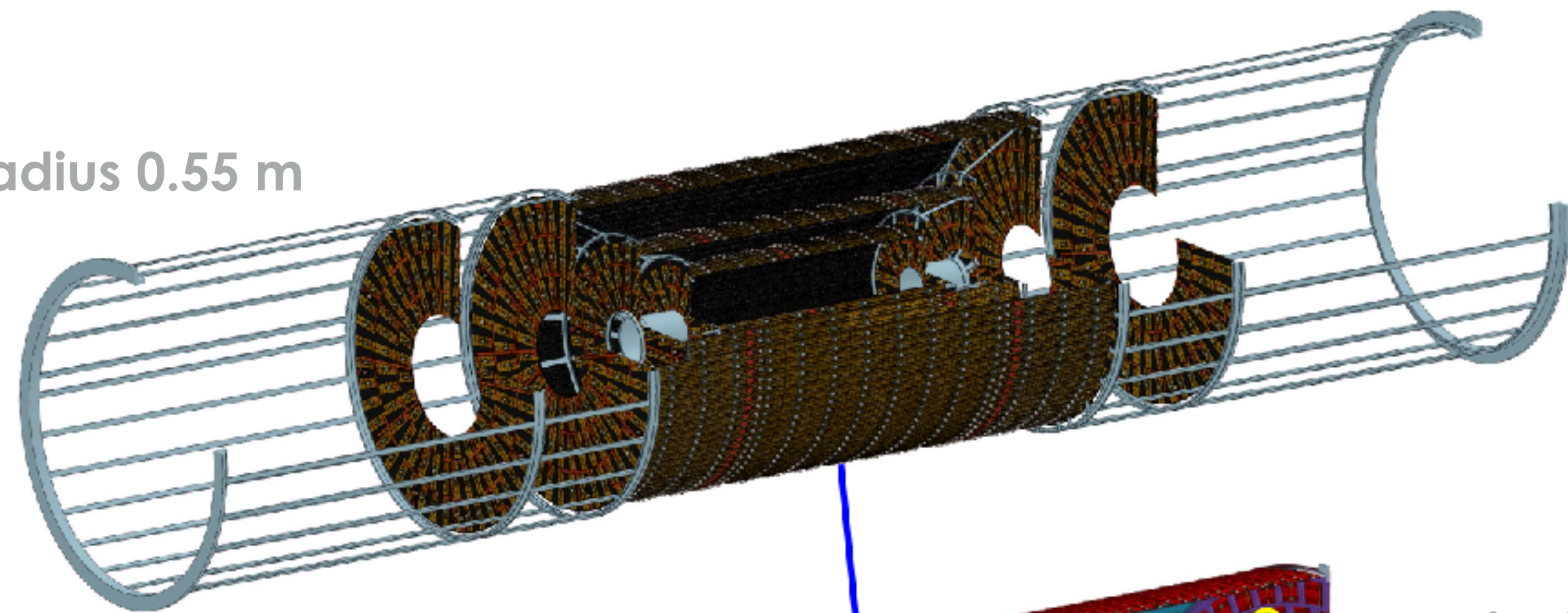
Measurands

Coverage
Recon. efficiency
Resolution in barrel
Resolution in endcap

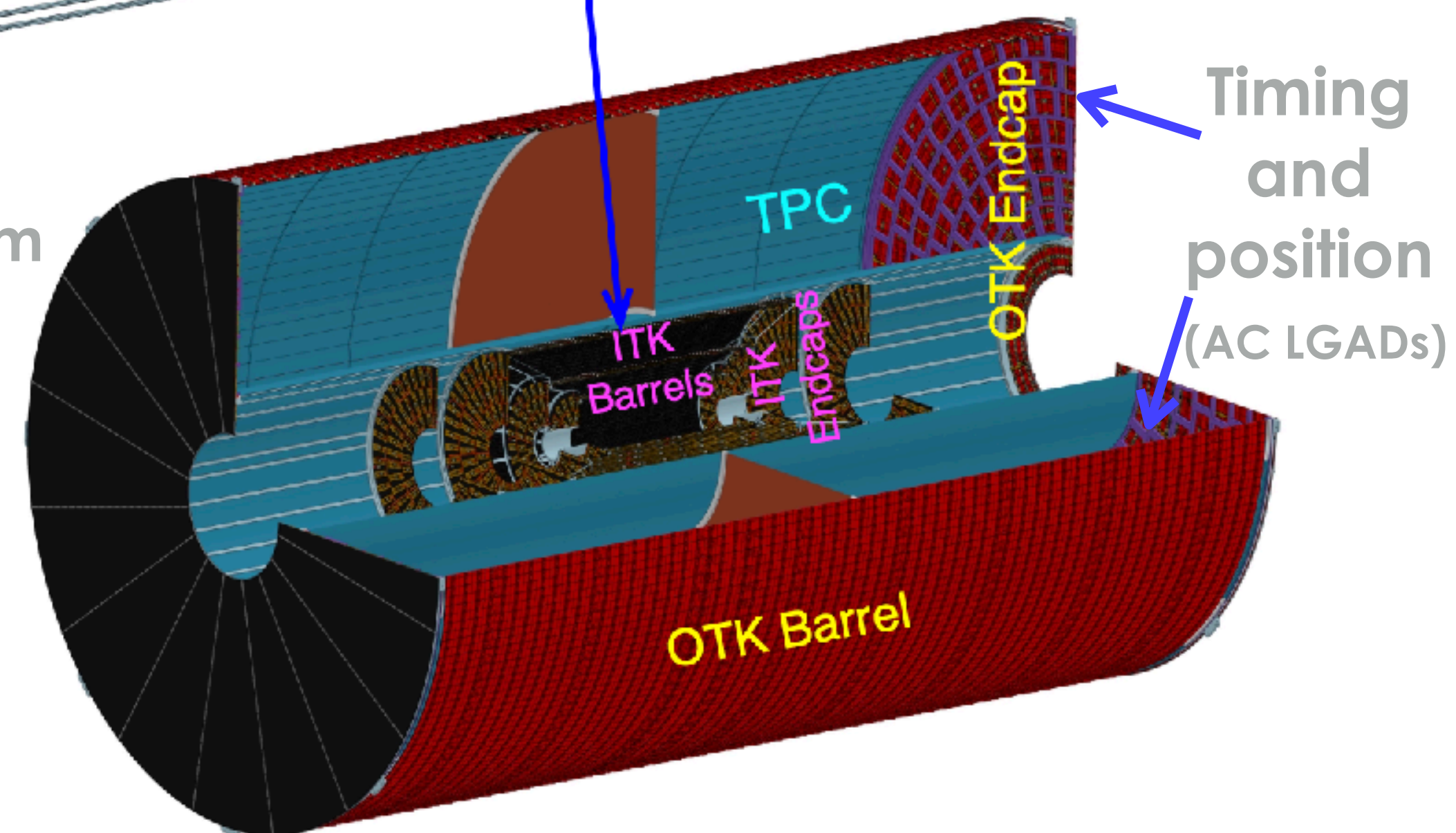
Performance requirement

$|\cos \theta| \leq 0.99$
 $\geq 99\%$ ($p_T > 1 \text{ GeV}/c$)
 $\sigma_{p_T}/p_T < 0.3\%$ ($|\cos \theta| \leq 0.85$)
 $\sigma_{p_T}/p_T < 3\%$ ($|\cos \theta| > 0.85$)

Radius 0.55 m



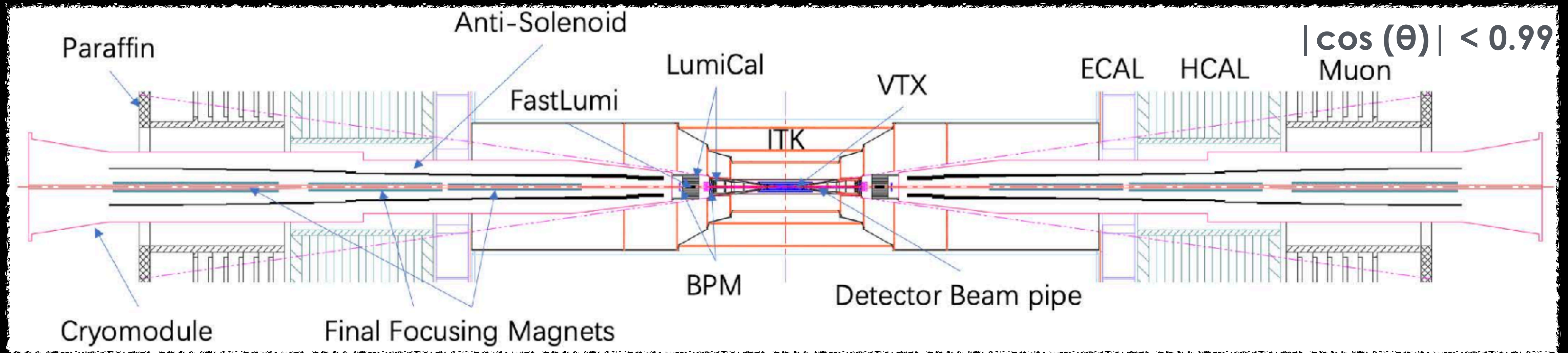
Radius 1.8 m



Interaction Region: Machine Detector Interface

Likely the most challenging component of the project

Critical to deliver the maximum luminosity without affecting detector performance



Accelerator magnets
well inside the detector volume

Beryllium beam pipe $\phi_{\text{out}} = 20 \text{ mm}$

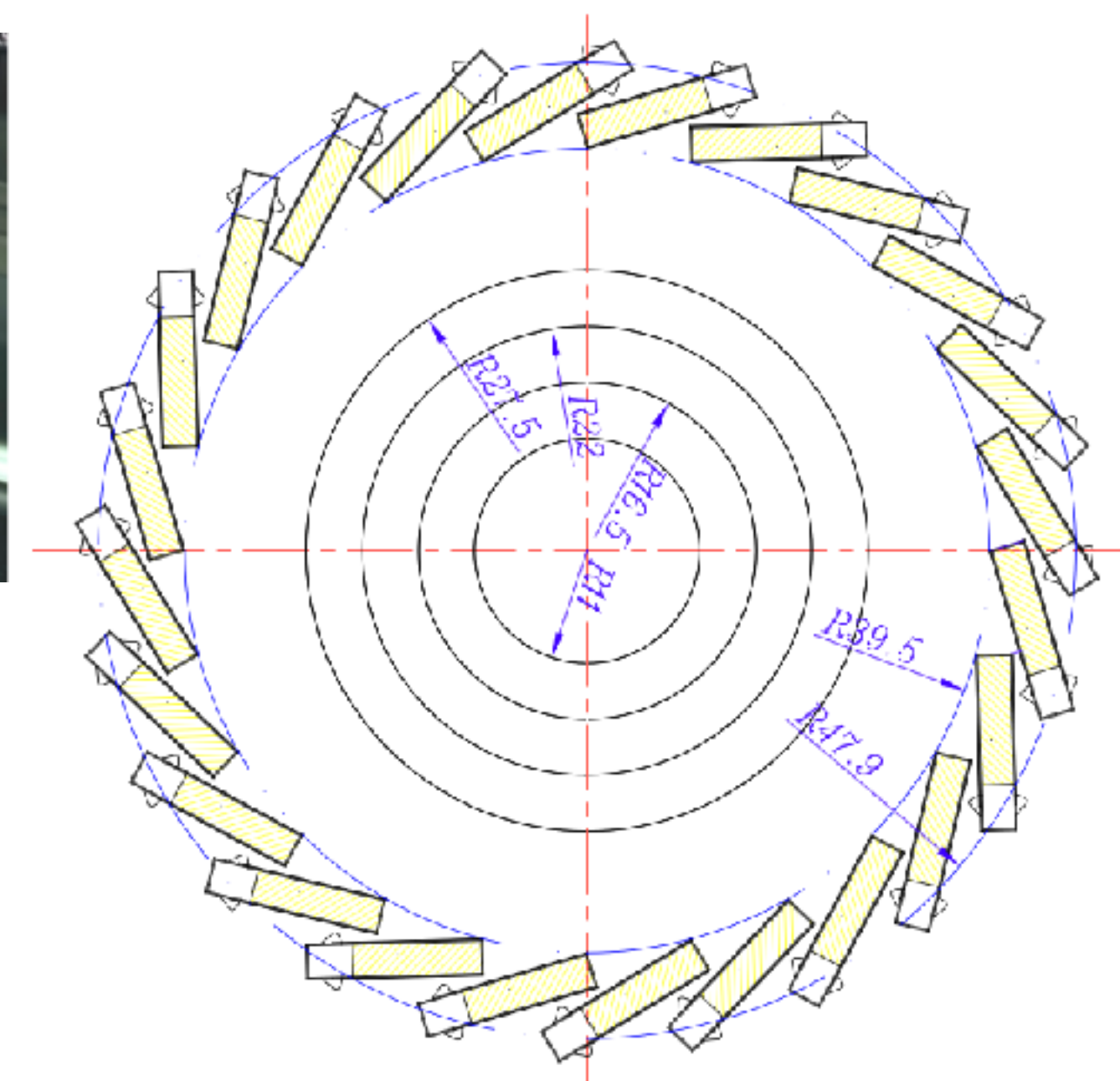
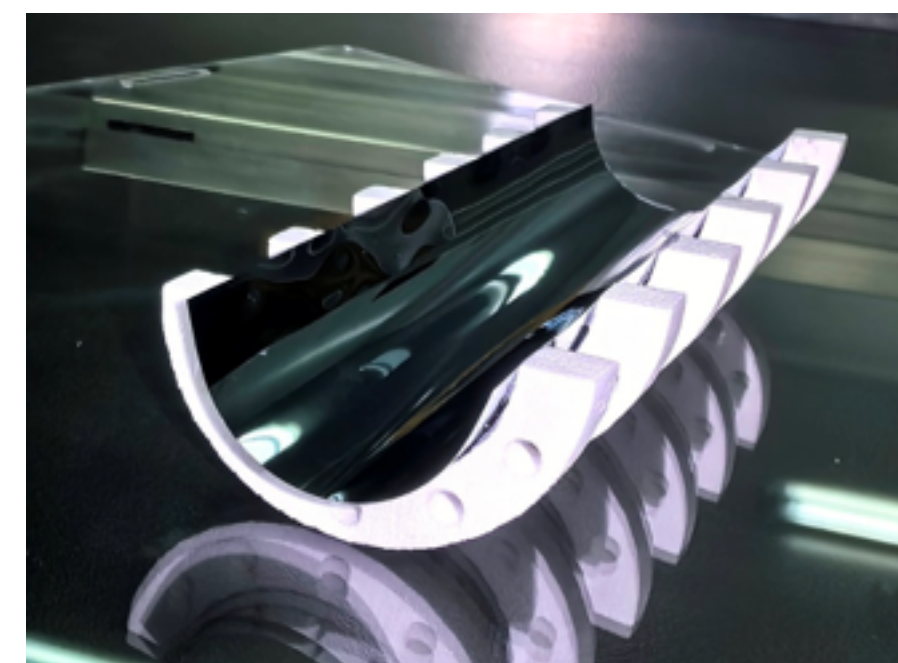
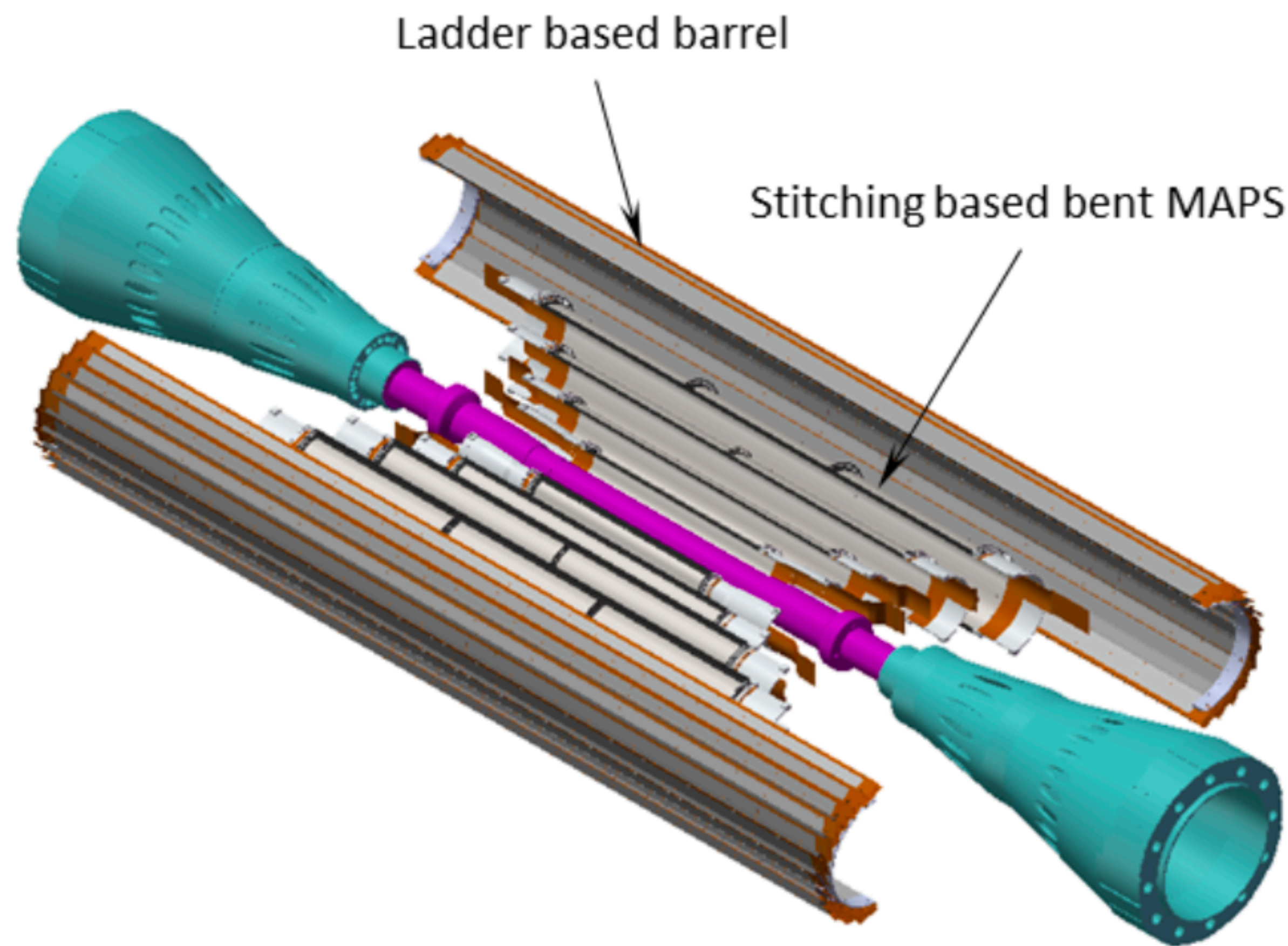
Two walls: 0.15 - 0.2 mm thick

Water coolant

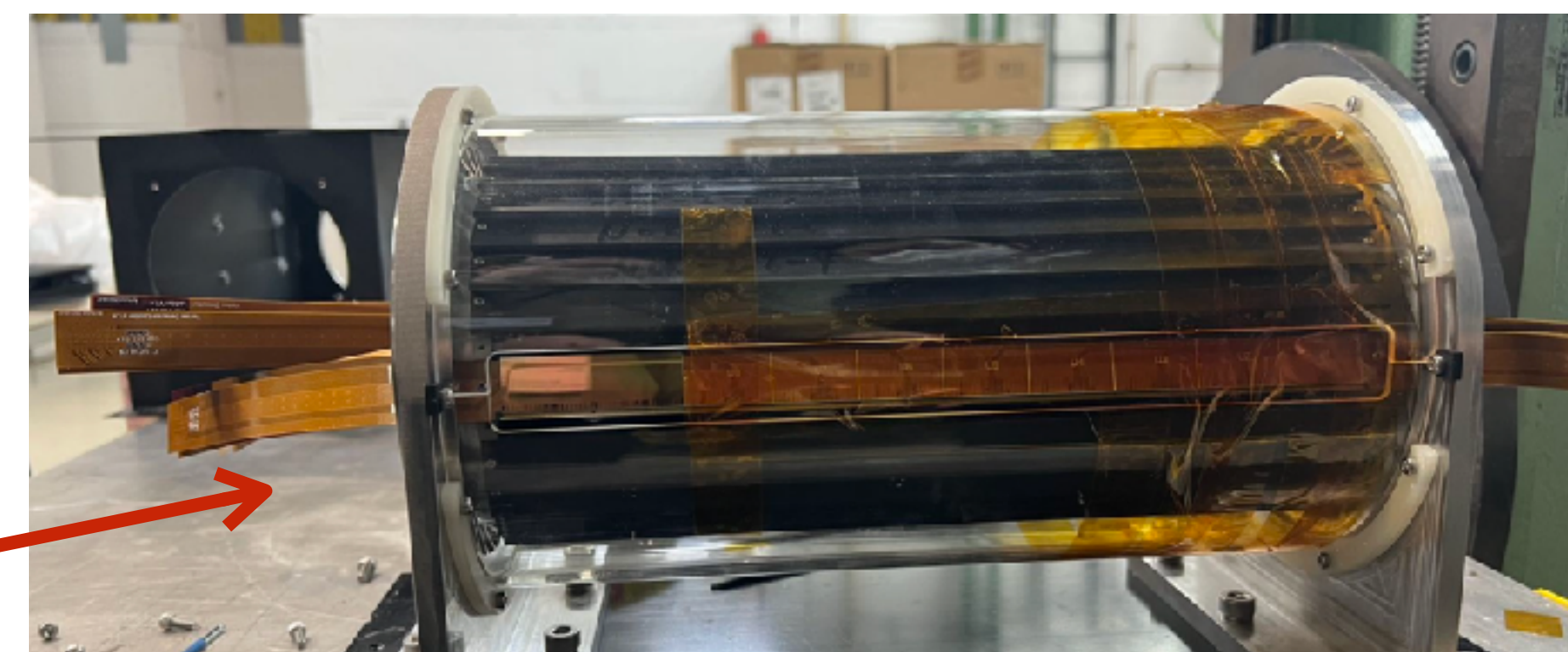
Vertex detector mounted around the beam pipe

The Vertex Detector

Four layers of bent silicon wafers + one layer with standard ladders



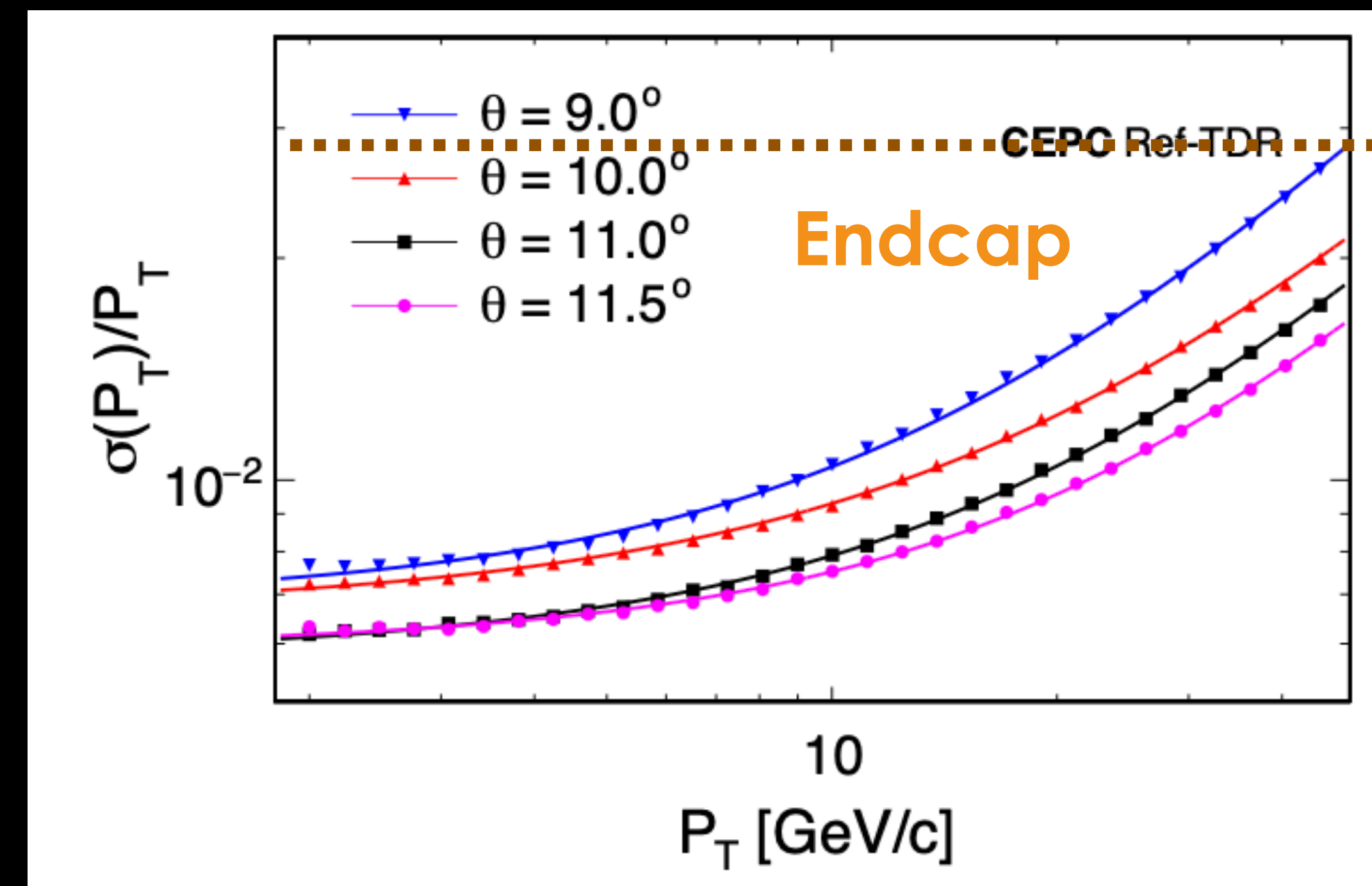
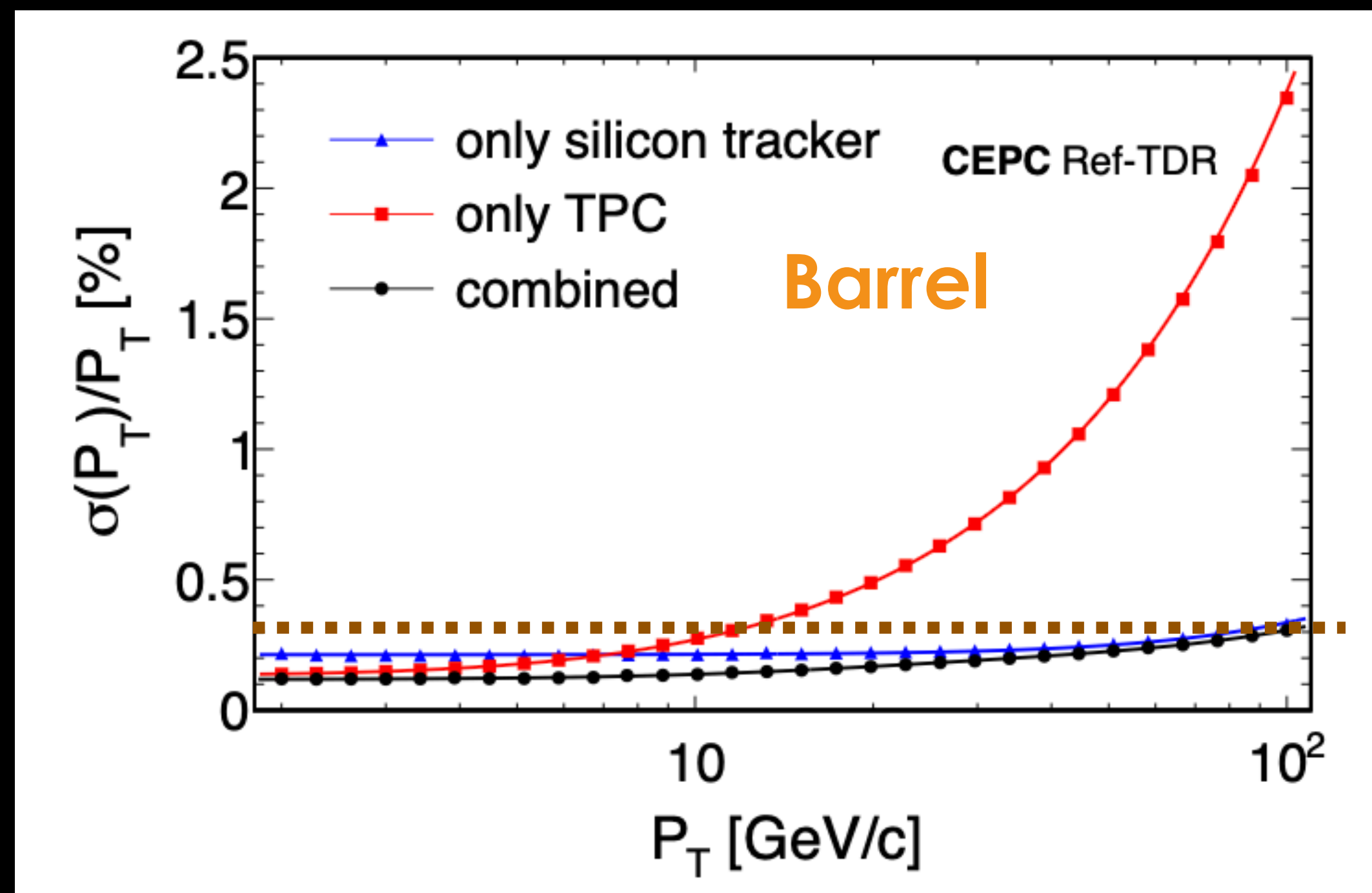
Prototype of standard prototype
(no bending layers)



Tracking Performance

Transverse momentum resolution

Physics objects	Measurands	Detector subsystem	Performance requirement
Tracking	Coverage	Tracker	$ \cos \theta \leq 0.99$
	Recon. efficiency		$\geq 99\%$ ($p_T > 1 \text{ GeV}/c$)
	Resolution in barrel		$\sigma_{p_T}/p_T < 0.3\%$ ($ \cos \theta \leq 0.85$)
	Resolution in endcap		$\sigma_{p_T}/p_T < 3\%$ ($ \cos \theta > 0.85$)

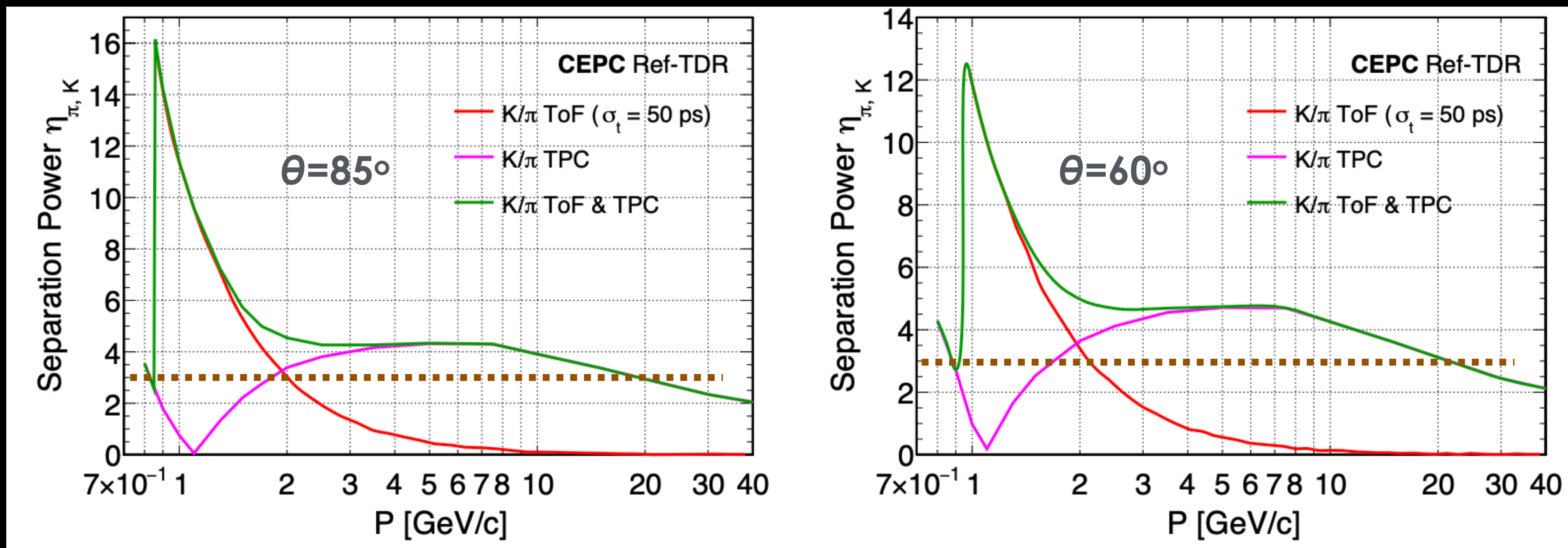


Resolution of different detectors at 85°

Resolution of the combined tracker at different polar angles

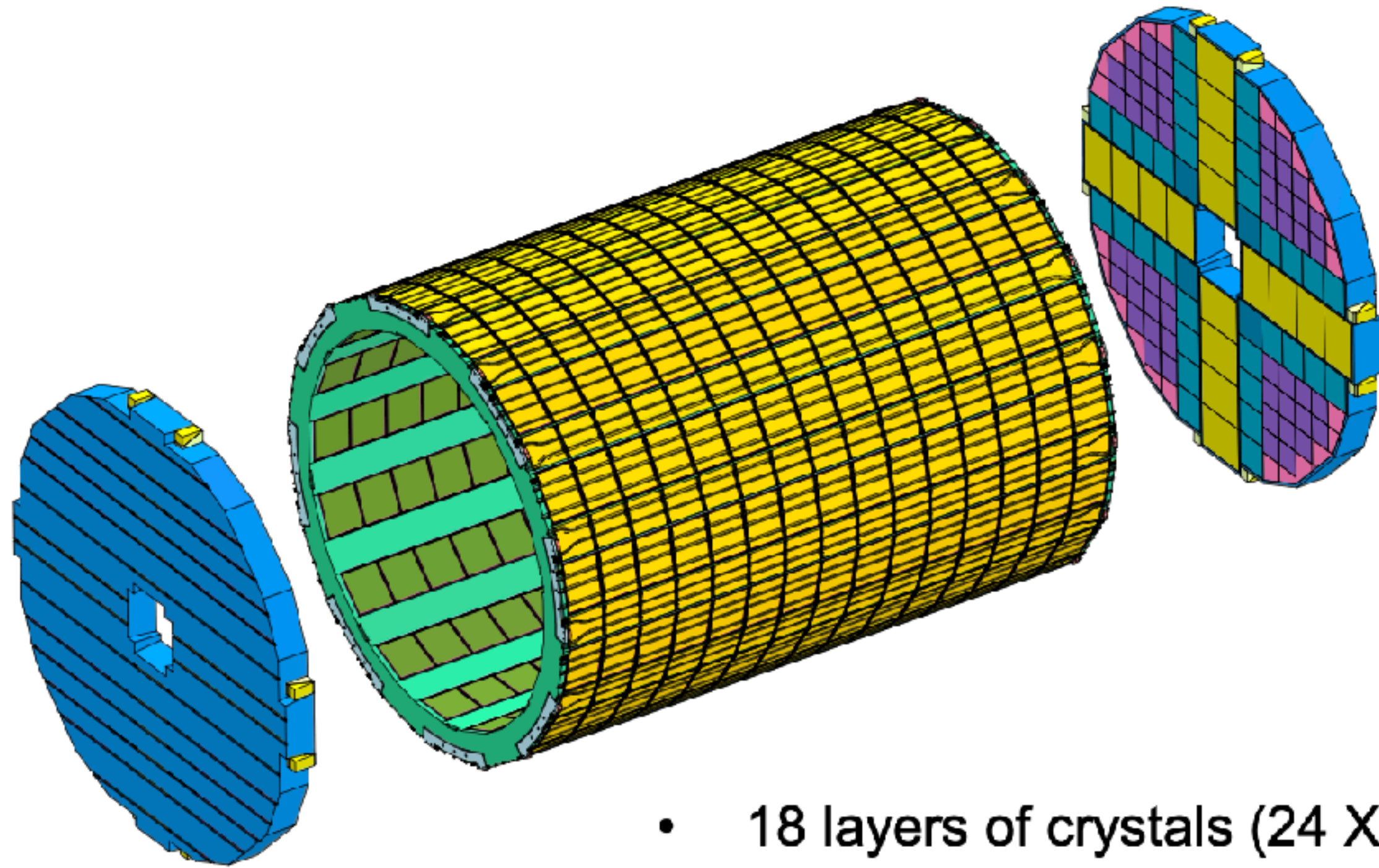
Particle Identification

K, pion separation using **TPC-only**, **OTK-only** and **TPC+OTK** measurements

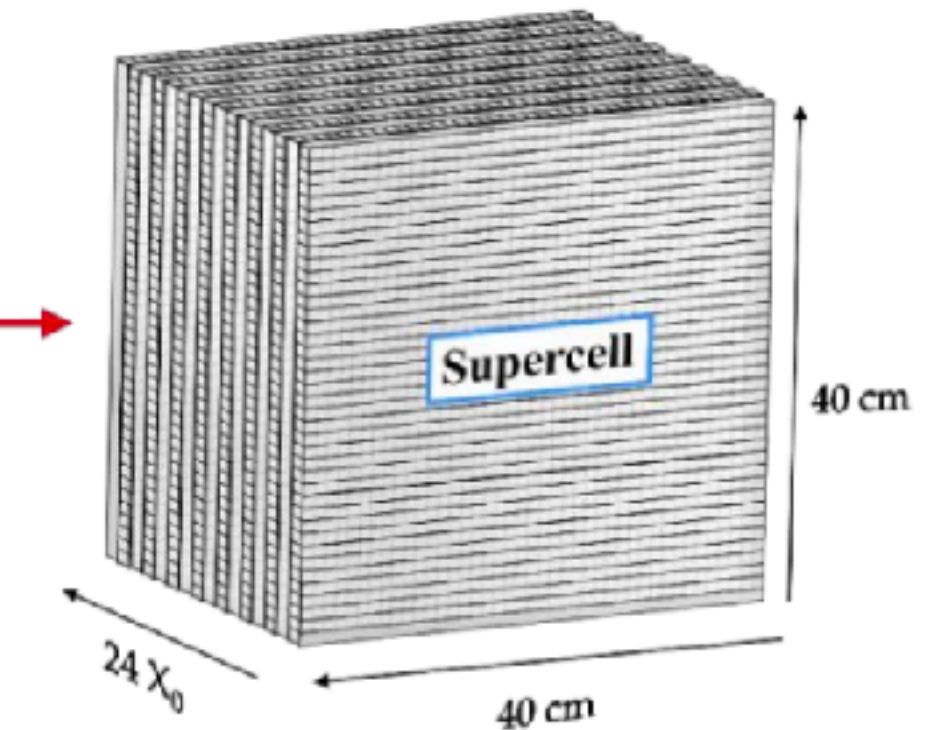
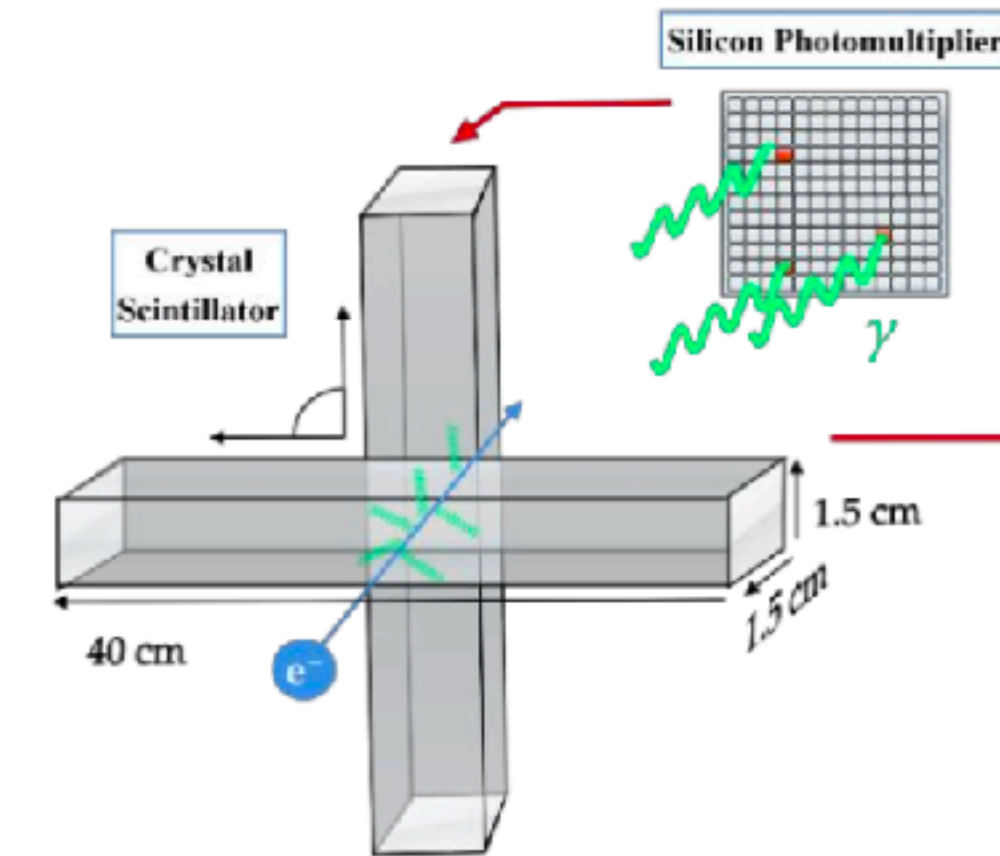
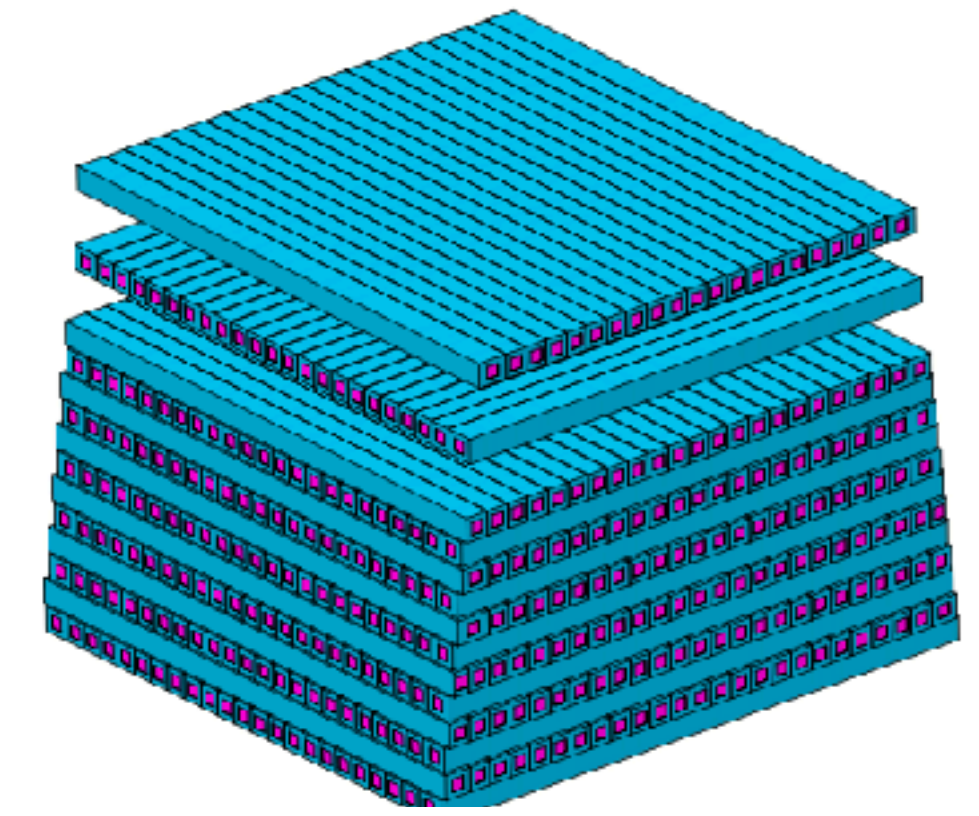
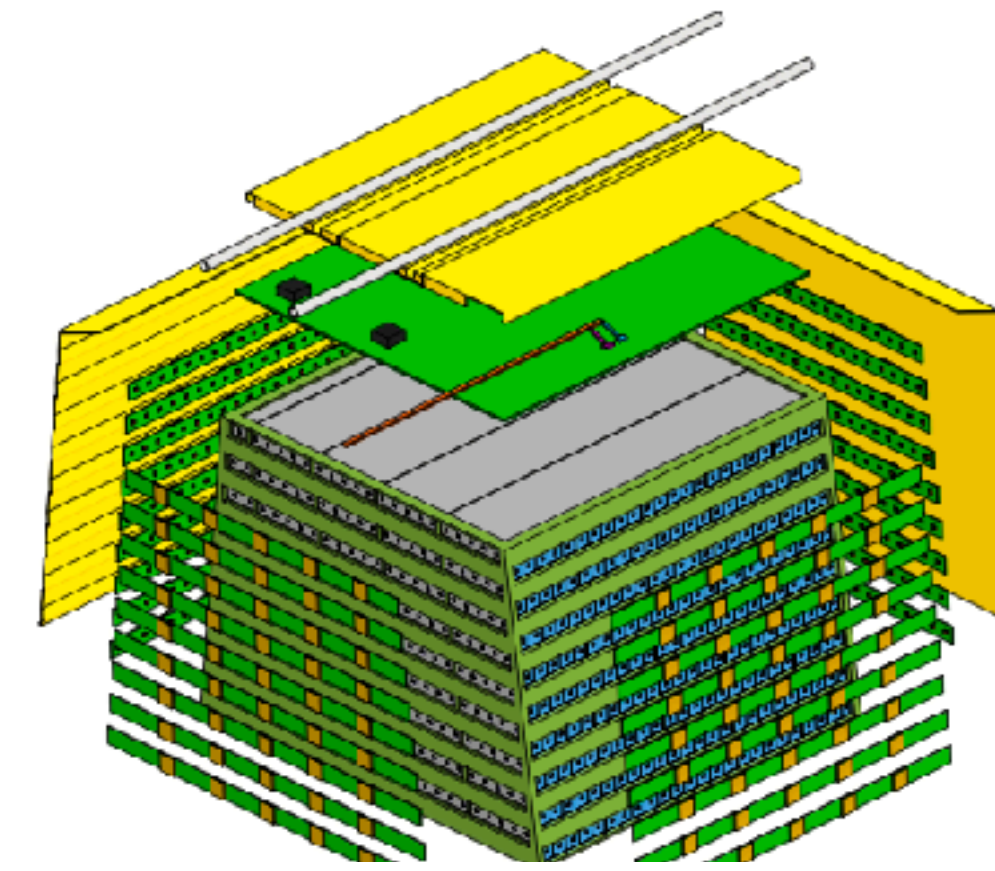


Separation power larger than 3 up to 20 GeV

A crystal electromagnetic calorimeter

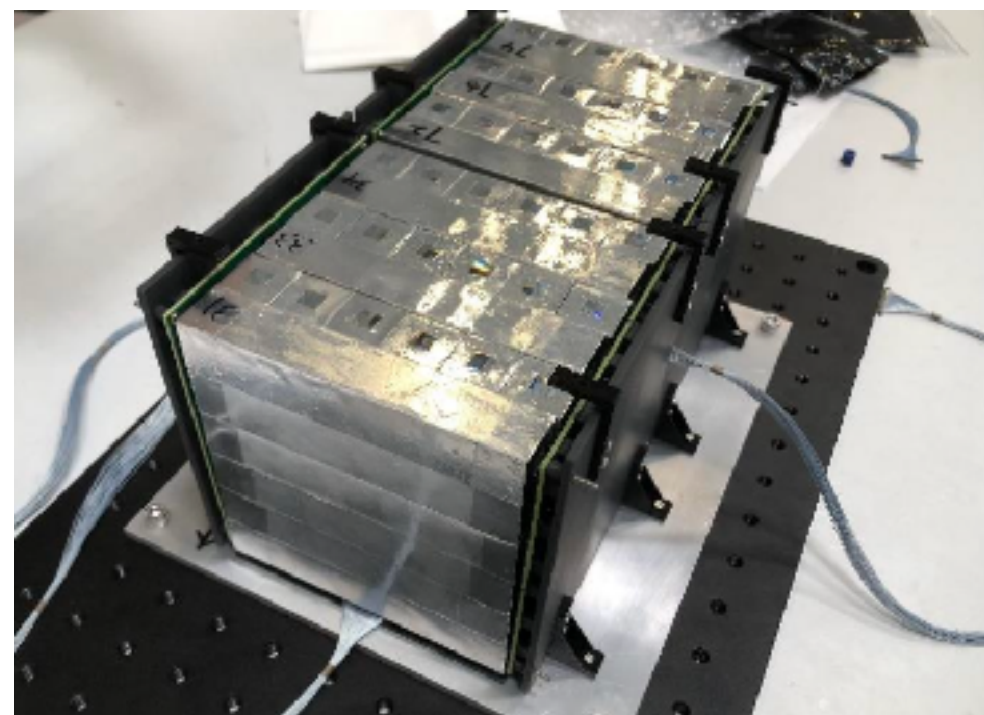


- 18 layers of crystals ($24 X_0$)
- Barrel: 32 towers per ring, 15 rings
- Endcap: 224 modules
- Total: 24m^3 BGO, 571k channels



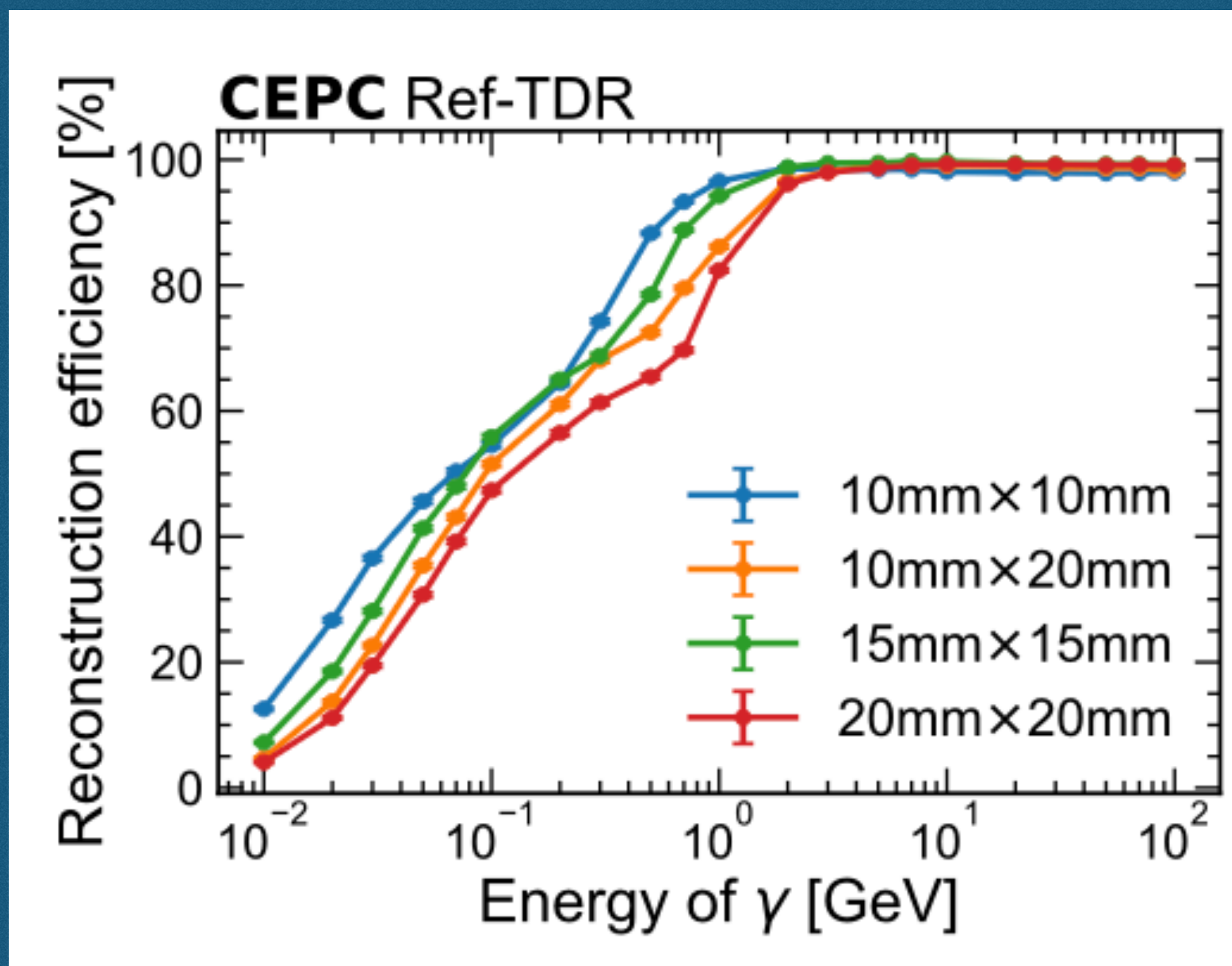
Superb energy resolution but not cheap

$$\sigma_E/E \leq 3\%/\sqrt{E(\text{GeV})} \oplus 1\%$$

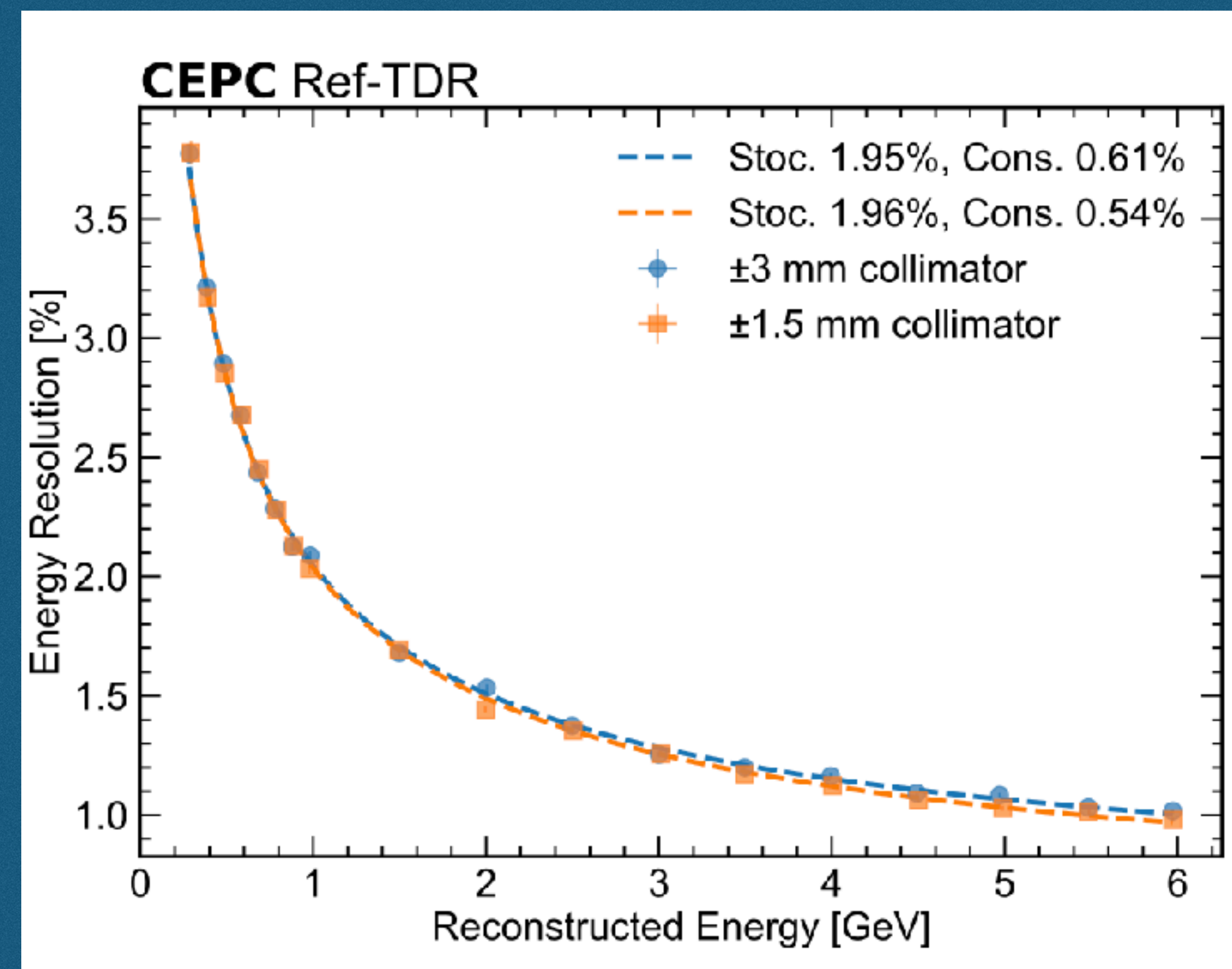


A crystal electromagnetic calorimeter

Crystal bar granularity was optimized for a balance between physics performance, crystal production, cost and design constraints.



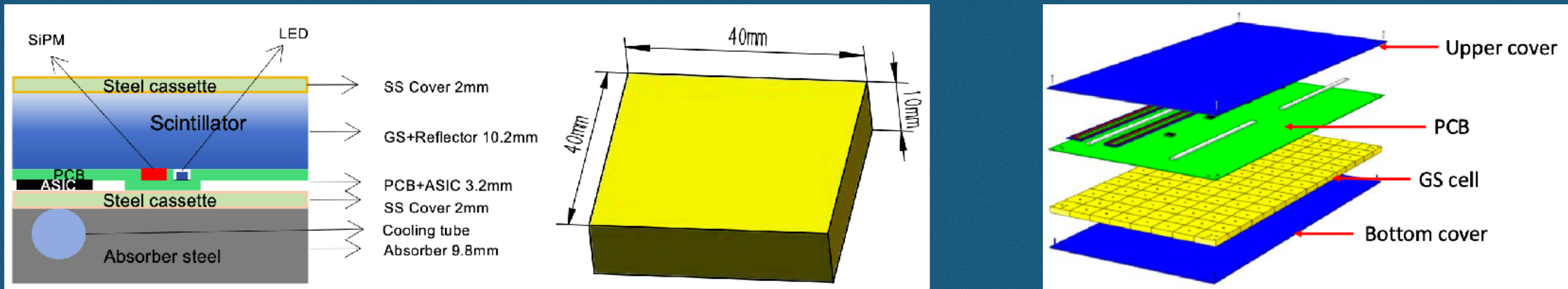
ECAL prototype in test beam:
EM energy resolution better than
 $2\%/\sqrt{E(\text{GeV})} \oplus 1\%$



The Hadronic Calorimeter

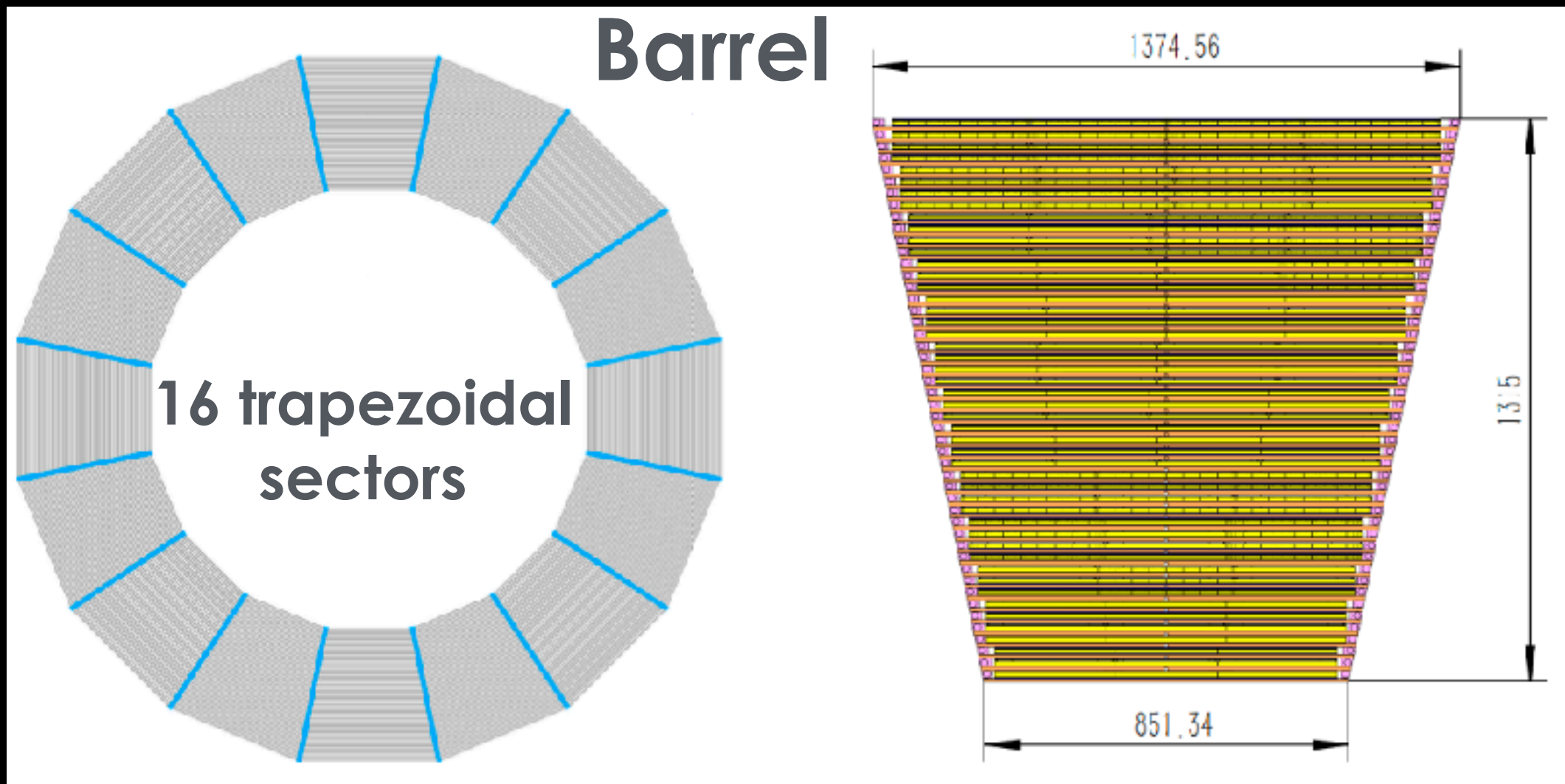
GS-HCAL: a glass scintillator calorimeter

Single layer structure



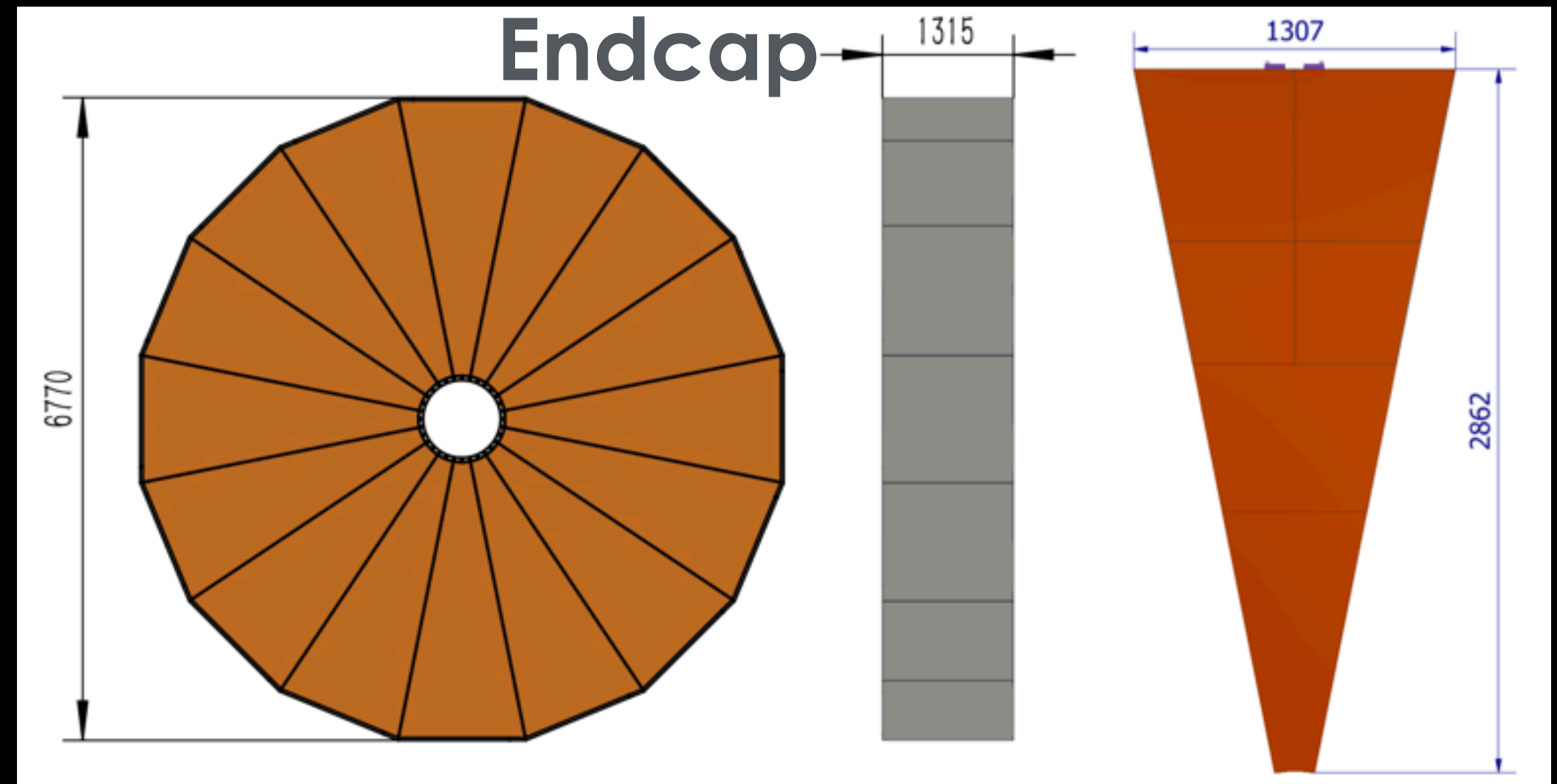
48 layers stacked per module

Barrel



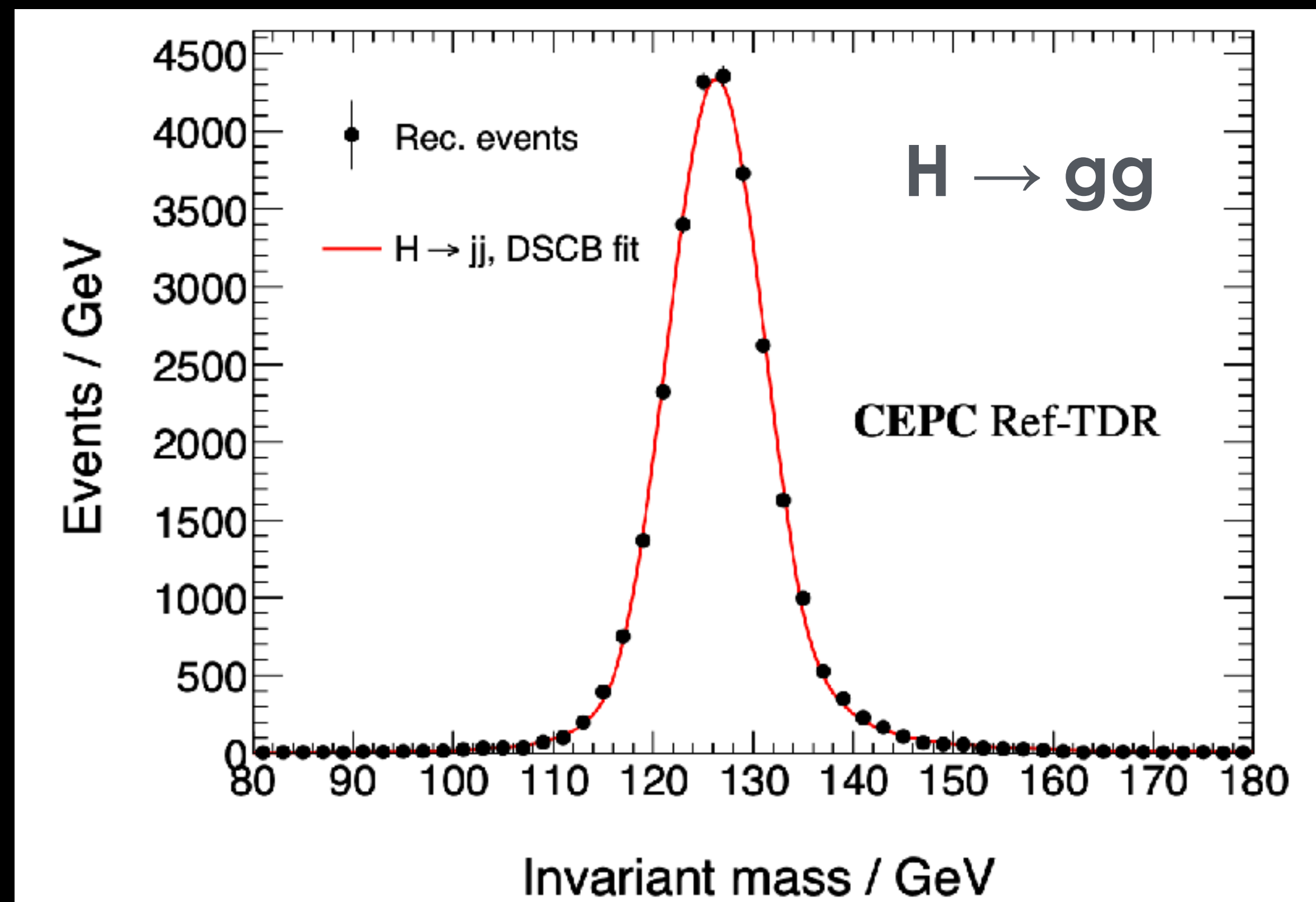
955 tons

Endcap



362 tons/endcap

PFA detector performance on simulation events
(includes tracker, ECAL, HCAL)



Higgs boson invariant mass resolution
(BMR) = 3.88%

Detector International Review Committee (IDRC)



International Committee composed of 19 experts in detector physics

Name	Affiliation	Country/Region
Daniela Bortoletto (chair)	Oxford	UK
Colin Gay	UBC	Canada
Bob Kowalewski	U Victoria	Canada
Burkhard Schmidt	CERN	CERN
Liang Han	USTC	China
Paul Colas	Saclay	France
Christophe De La Taille	OMEGA, CNRS	France
Cristinel Diaconu	CPPM	France
Roman Poeschl	IJCLab	France
Maxim Titov	Saclay	France

Name	Affiliation	Country/Region
Frank Gaede	DESY	Germany
Anna Colaleo	INFN, Bari	Italy
Tommaso Tabarelli de Fatis	INFN Milano-Bicocca	Italy
Roberto Tenchini	INFN, Pisa	Italy
Akira Yamamoto	KEK	Japan
Hitoshi Yamamoto	Tohoku U., Valencia	Japan
Gregor Kramberger	IJS	Slovenia
Ivan Villa Alvarez	Santander	Spain
James Brau	Oregon	USA

Three review meetings were held from October 2024 to September 2025

The CEPC International Detector Committee Meeting in 2024

Oct 21-23, IHEP

THE CEPC INTERNATIONAL DETECTOR COMMITTEE MEETING IN 2025

APR 14-16, IHEP

CEPC International Detector Review Committee Meeting

Sep. 2025, Beijing

Final report outcome

In summary, the CEPC detector programme is entering a decisive stage. A significant portion of the technical groundwork is complete, but the coming years must **consolidate the design through focused R&D, integrated prototyping, and system validation**. By sustaining momentum in innovation while deepening international cooperation, the collaboration will be well positioned to deliver **a technically mature and scientifically powerful detector system**—one capable of serving as the basis for the two international experiments that will define the CEPC physics era.

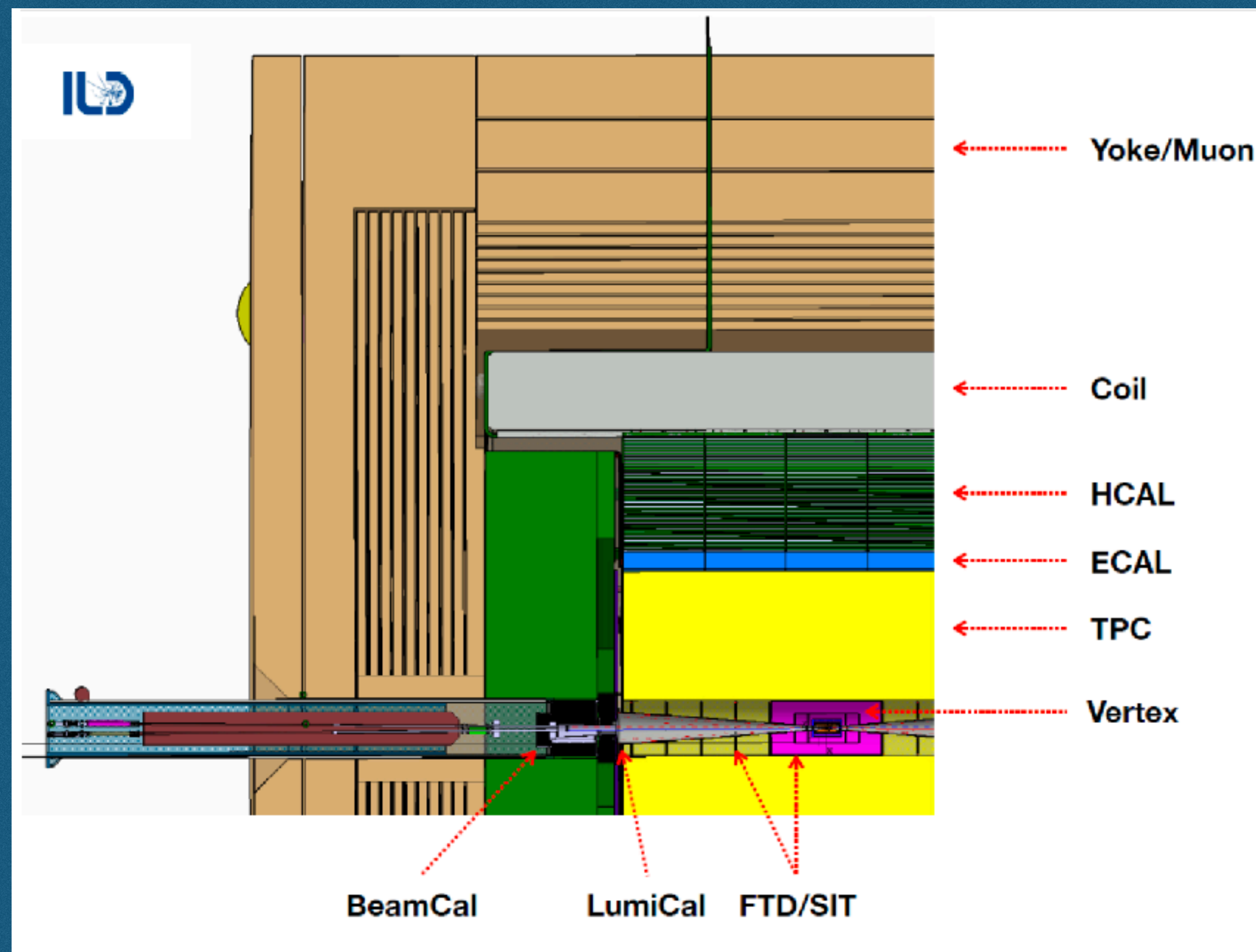
Readiness for construction after R&D and engineering preparations

With sector/module demonstrators, thermal and mechanical mock-ups, full DAQ chains, and formal design/production reviews (FDR/PRR), the project can credibly achieve production readiness. The Ref-TDR supports early industrial engagement; **remaining work is system-level validation and final down-selection on an agreed schedule**.

Alternative Detector Concepts in the TDR

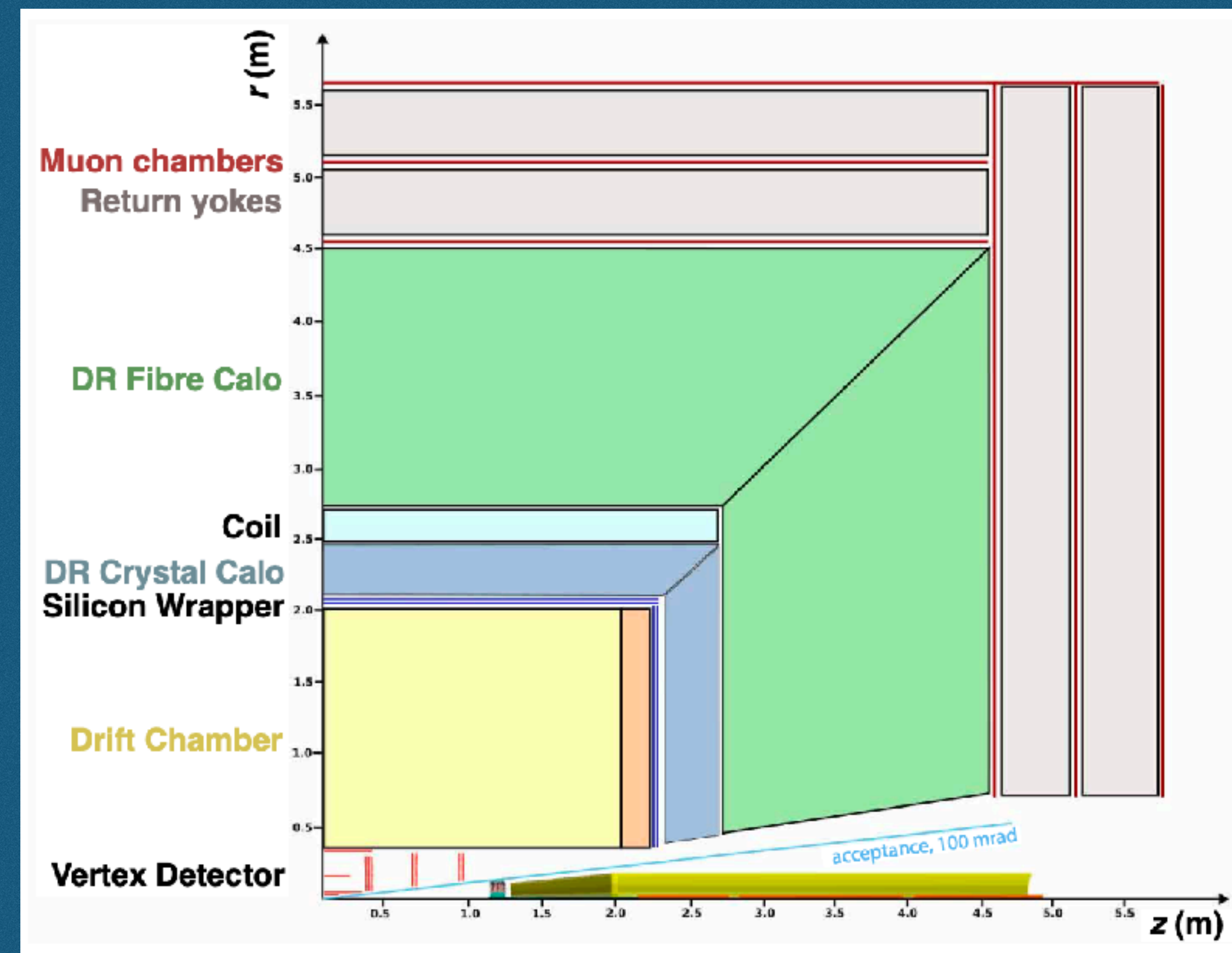
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ILD: International Large Detector



Chapter 18

IDEA: Innovative Detector for Electron-positron Accelerator

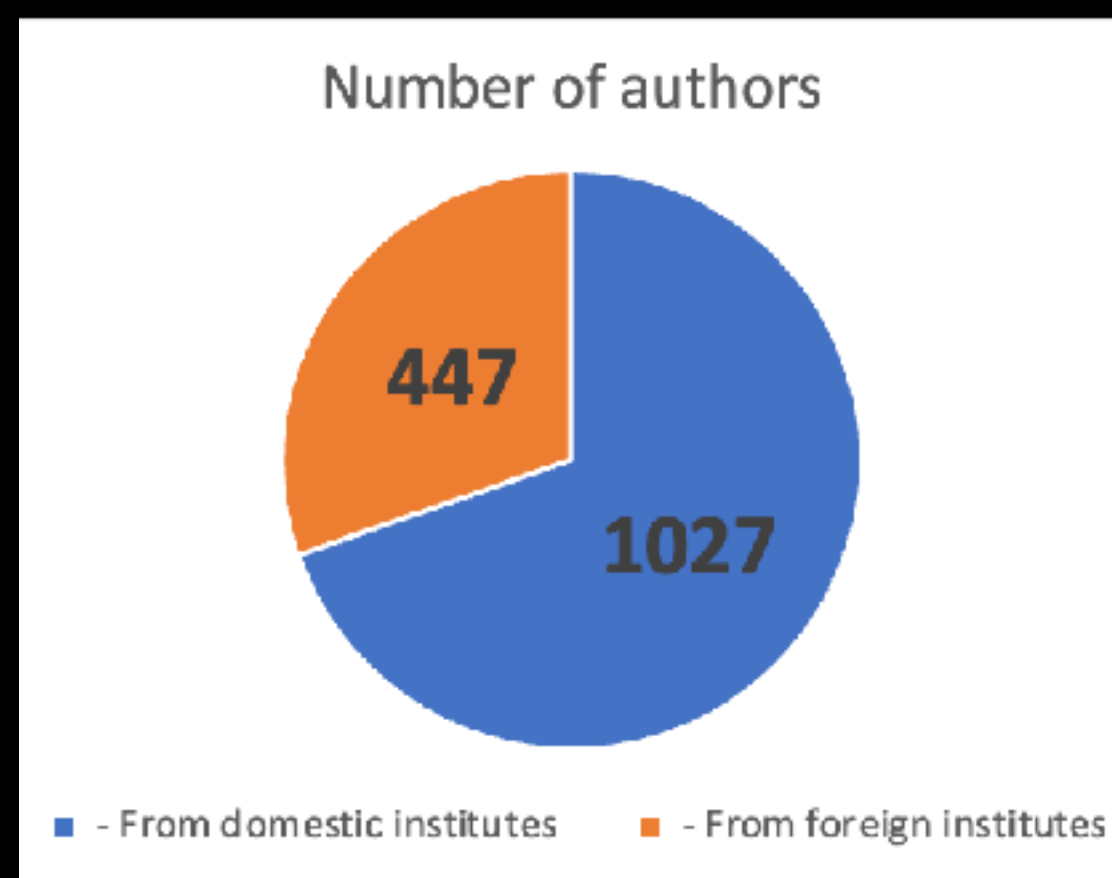


Chapter 19

Final two detectors will result from international proposals

Reference Detector TDR Authorship

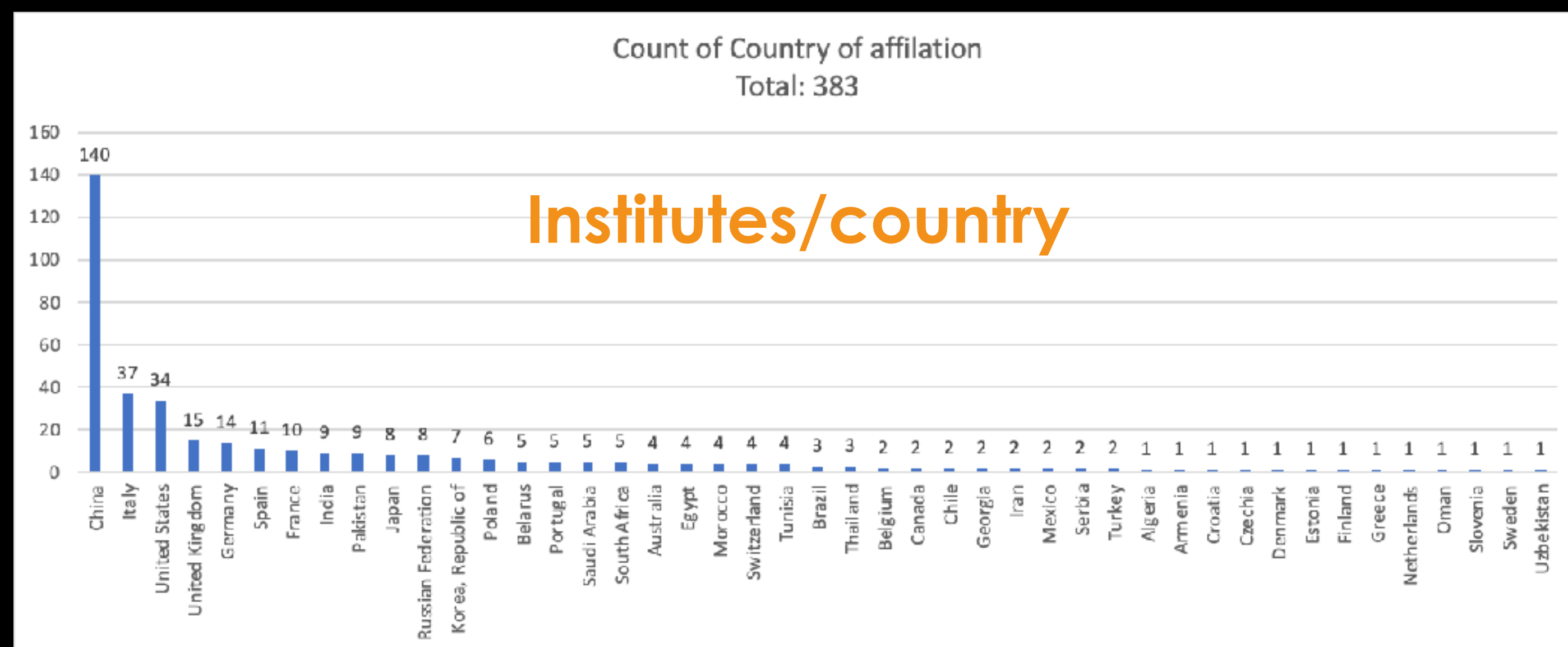
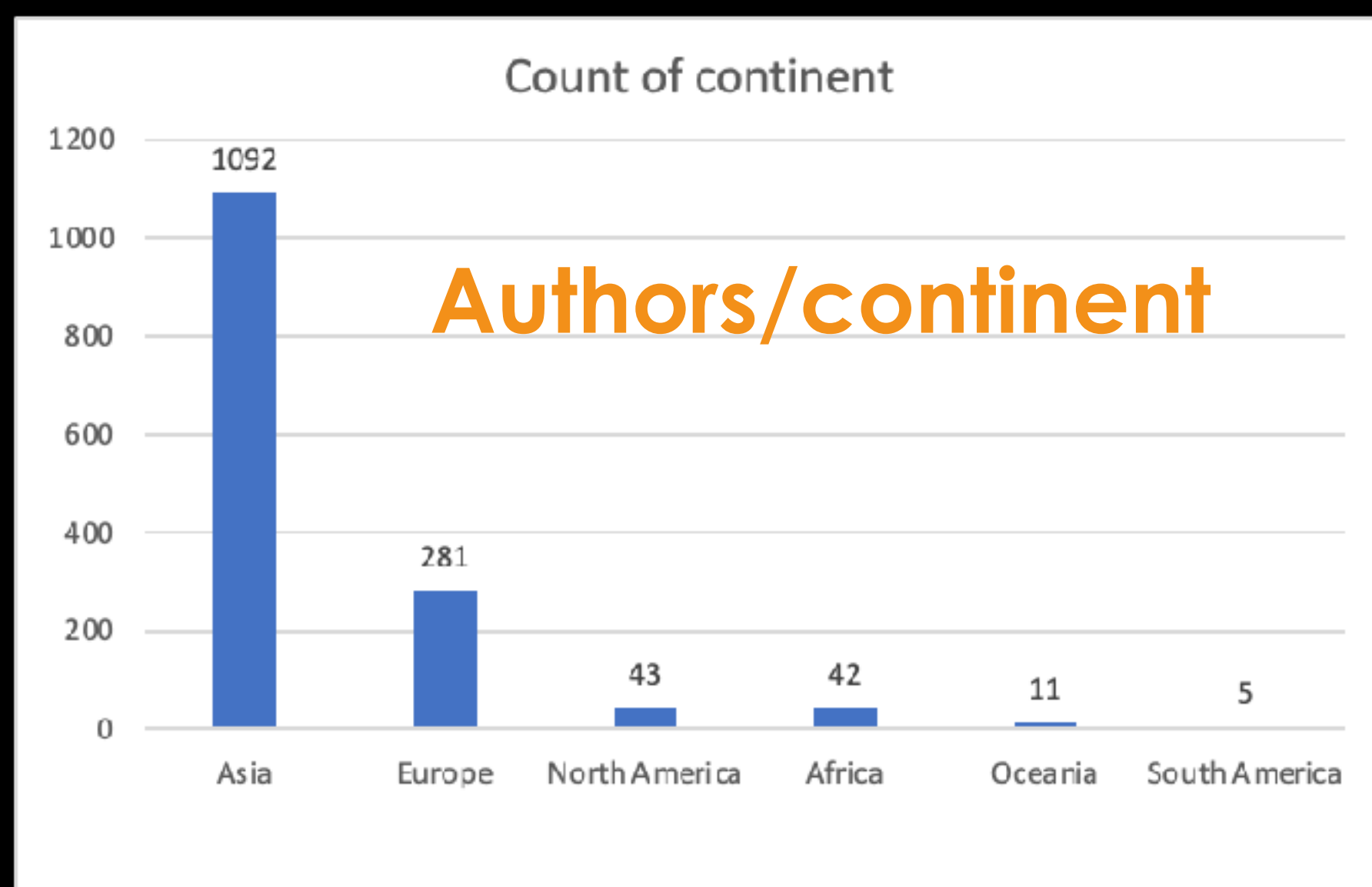
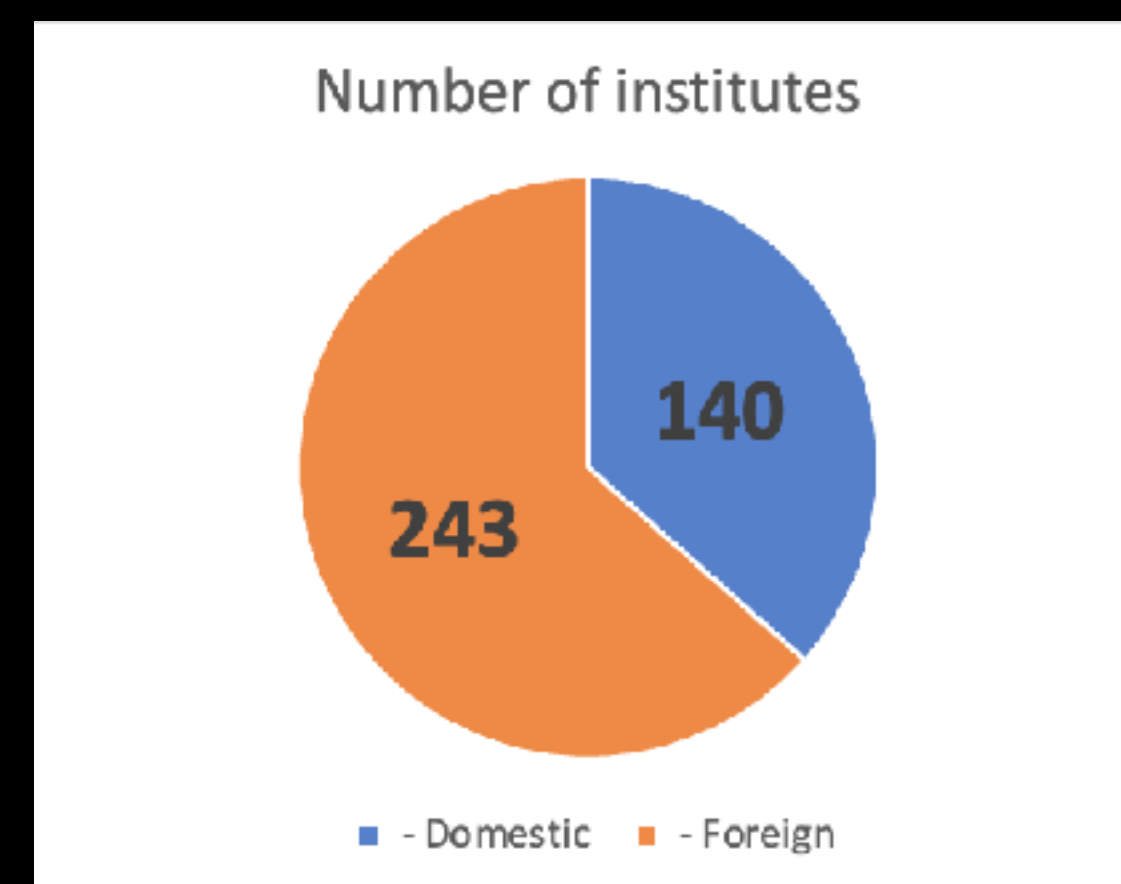
30% authors from foreign institutes



1493 authors { 383 institutions
43 countries

~30% increase relative to accelerator TDR and CDR

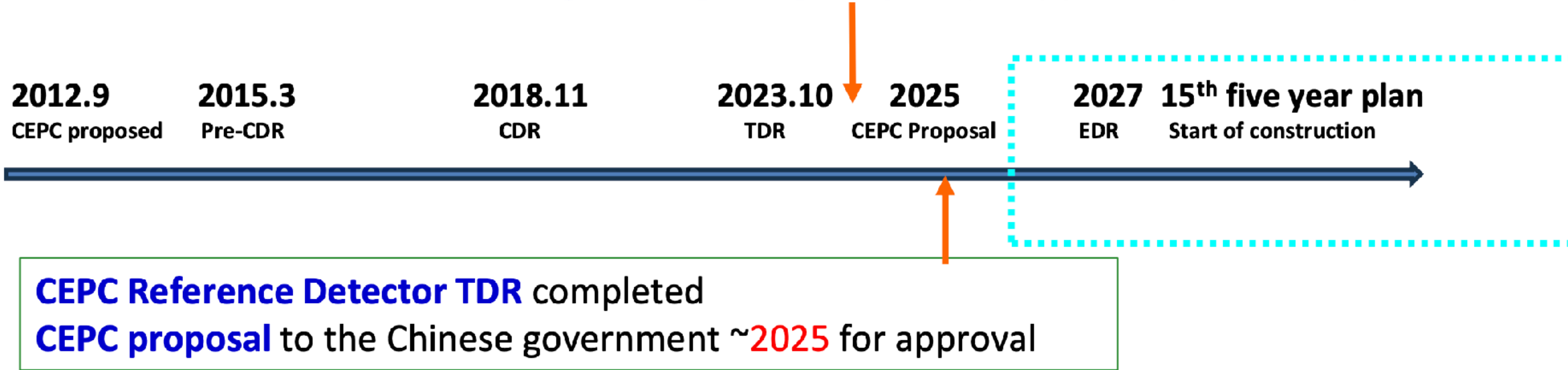
63% foreign institutes



CEPC Milestones and Timeline



CEPC accelerator entered the **Engineering Design Report (EDR)** phase (**2024-2027**);



Unfortunately, the Chinese Academy of Sciences did not support the submission of the CEPC proposal for government approval

CEPC Host Lab **IHEP** and its Large Science Facilities



HERD (2027) on Chinese Space Station 57

GECAM
Gravitational wave EM Counterpart All-sky Monitor

Huairou Campus
HEPS High Energy Photon Source

IHEP, Beijing Campus
BEPC Beijing Electron-Positron Collider
IHEP Plasma Accelerator Test Facility

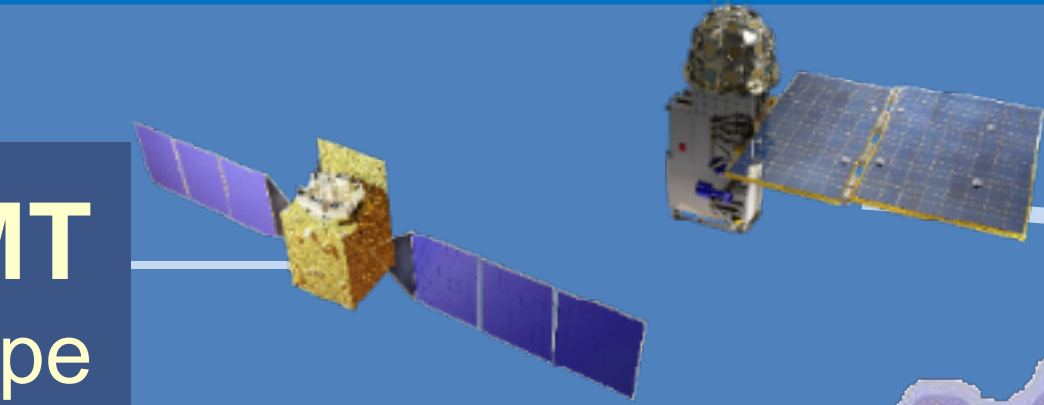
Jinan Campus



HUNT, underwater in south China Sea

Daya Bay (retired)
Daya Bay reactor Neutrino Experiment

Dongguan Campus
CSNS China Spallation Neutron Source



HXMT

Insight Hard X-ray Modulation Telescope



CEPC-SppC



YBJ (retired)

International Cosmic Ray Observatory



AliCPT

Ali CMB Polarization Telescope



LHAASO

Large High-Altitude Air Shower Observatory



JUNO

Jiangmen Underground Neutrino Observatory



CEPC Host Lab **IHEP** and its Large Science Facilities



HERD (2027) on Chinese Space Station

HXMT

Insight Hard X-ray Modulation Telescope

GECAM

Gravitational wave EM Counterpart All-sky Monitor

IHEP directorate group statement

IHEP, as a leading high energy physics lab, will continue to pursue **high energy frontier** particle physics research, **cutting edge technology** development, and the CEPC

LHAASO

Large High-Altitude Air Shower Observatory



Daya Bay (retired)

Daya Bay reactor Neutrino Experiment



JUNO

Jiangmen Underground Neutrino Observatory



Dongguan Campus

CSNS China Spallation Neutron Source

The main duty and task of IHEP is to pursue the energy frontier explorations through advanced colliders

The CEPC Plan

Townhall meeting of **Chinese institutional representatives** during the CEPC-2025 Workshop, Guangzhou (November 8, 2025)



- Representatives from Chinese institutes and universities **unanimously** agreed:
 - Continue to pursue CEPC in China
 - Enhance cooperation with CERN on future Higgs factory

The CEPC Plan



The CEPC remains an international project seeking to be approved by the government for construction at the earliest opportunity

The CEPC Study Group intends to continue advancing the critical and innovative R&D projects identified by the various international review and advisory committees, to position well the CEPC for approval in 2030 within China's 16th Five-year Plan

The CEPC Plan



- IHEP and the CEPC Study Group will continue to carry out the critical work outlined in the TDR documents:
 - Accelerator engineering design
 - Detector R&D
- IHEP will apply for approval of the CEPC project for the 16th Five-Year Plan in 2030,
 - unless, the FCC is officially approved for construction before
 - In such case, IHEP will join FCC

International Collaboration

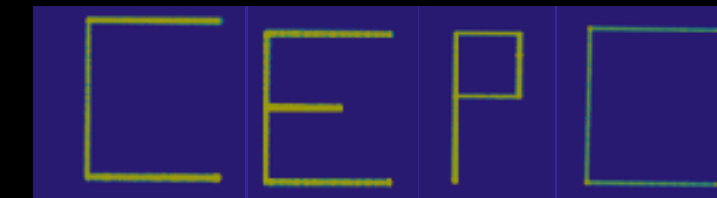
- Integration into European R&D Framework

Sub-system	DRD	Sub-system	DRD	Sub-system	DRD
Pixel Vertex Detector	3	Electromagnetic Calorimeter	6	Superconducting Solenoid	
Inner Silicon Tracker	3	Hadron Calorimeter	4, 6	Mechanical and Integration	8
Outer Silicon Tracker	3	Machine Detector Interface	8	General Electronics	7
Gas Tracker (TPC / DC)	1	Luminosity Calorimeter		Trigger and DAQ	7
Muon Detector	1 (RPC)	Fast Luminosity Monitor	3	Offline Software	Key4hep

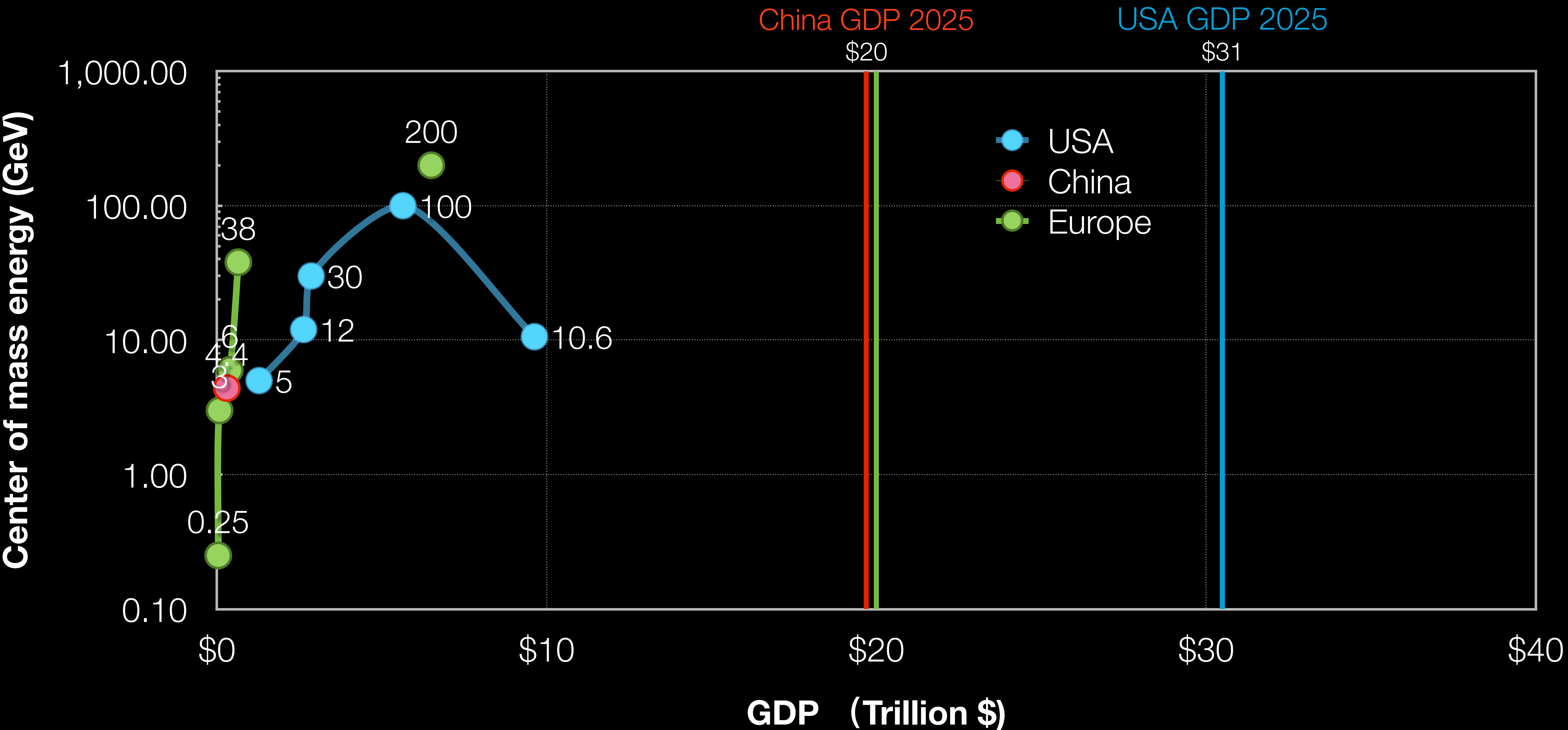
In addition, we will continue to do research towards future colliders:

- **Iron-based superconducting HTC cables and magnets for preparation of SPPC/FCC-hh**
- **Plasma Wake Field Accelerators (PWFA) for future very high energy linear colliders → can be used as injector of CEPC**

Electron/positron colliders: It is not the cost....



Center of mass energy versus GDP of electron colliders



Final remarks

The Reference Detector TDR was finished in October 2025

<https://arxiv.org/abs/2510.05260>

The Detector is a innovative and challenging concept, with still interesting R&D to be pursued

Focus will shift into consolidating the designs and validation with larger scale prototypes

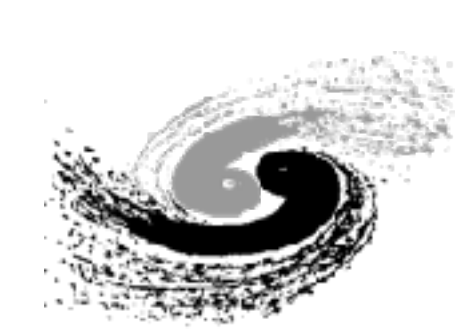
The CEPC Accelerator Engineering Design has progressed well

CEPC will complete EDR around 2027 and continue preparations to apply for construction within the 16th five year plan around 2030's

International efforts towards Higgs factories are common endeavors of humankind, and the final goals should be reached with persistence and endurance

Engagement between research communities of potential projects will benefit everyone with the goal of continuing to explore the **high-energy frontier**

The end



CEPC Key System EDR Progresses-1

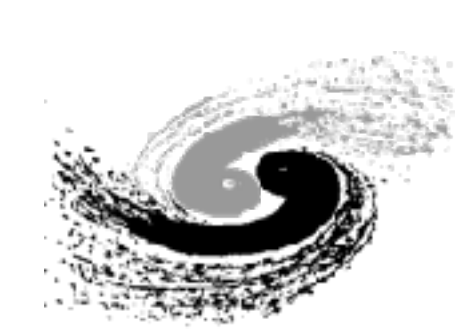
68

CEPC Accelerator Key System EDR Progresses

- 2025 March 20, CEPC booster magnet automatic fabrication line ready for construction (under construction, to be completed in 2025-2026)
- 2025 April 17, CEPC polarization cathode material and test facility ready for fabrication
- 2025 April 25, CEPC vacuum chamber NEG coating automatic fabrication line ready for construction (under construction, to be completed in 2025-2026)
- 2025 April 28, 650MHz full size cryomodule ready for construction (under construction, to be completed in 2025-2026)
- 2025 Feb. CEPC accelerator survey started (99.955428km)
- 2025 July, CEPC accelerator components, vertical shafts (10) and horizontal access tunnels (12) naming systems are decided
- 2025 July, CEPC booster detailed installation scheme studies started

CEPC Accelerator Key System EDR International Mini Reviews (Required by IARC)

- 2025 April 24, CEPC alignment and installation EDR international mini review
- 2025 May 14,15, CEPC cryogenic system (+650MHz cryomodule) EDR international mini review
- 2025 May 29, CEPC booster dipole and sextupole combined magnet EDR international mini review
- 2025 June 9-10, CEPC MDI EDR international mini review
- 2025 June 9-10, CEPC EDR site geological feasibility study review
- 2025 July 31, CEPC vacuum chamber type EDR international mini review



CEPC Accelerator EDR Key Progresses-2

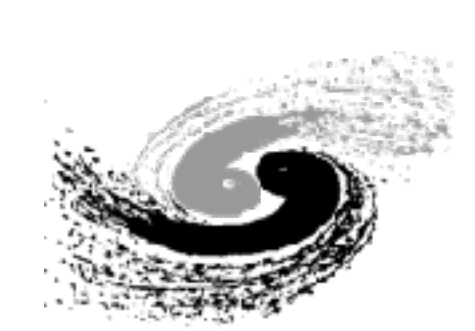
69

-2024 Dec 9, CEPC EDR site geological study and civil engineering design tasks Have been assigned to “PowerChina HuaDong Engineering Corporation Limited (HDEC)”

-2025 June 9-10, CEPC site geological study and site selection choice review meeting was held and CEPC Xinmi Site of Henan province was recommended as the proposed construction site to Chinese government, and more detailed studies will be completed by the end of 2025.

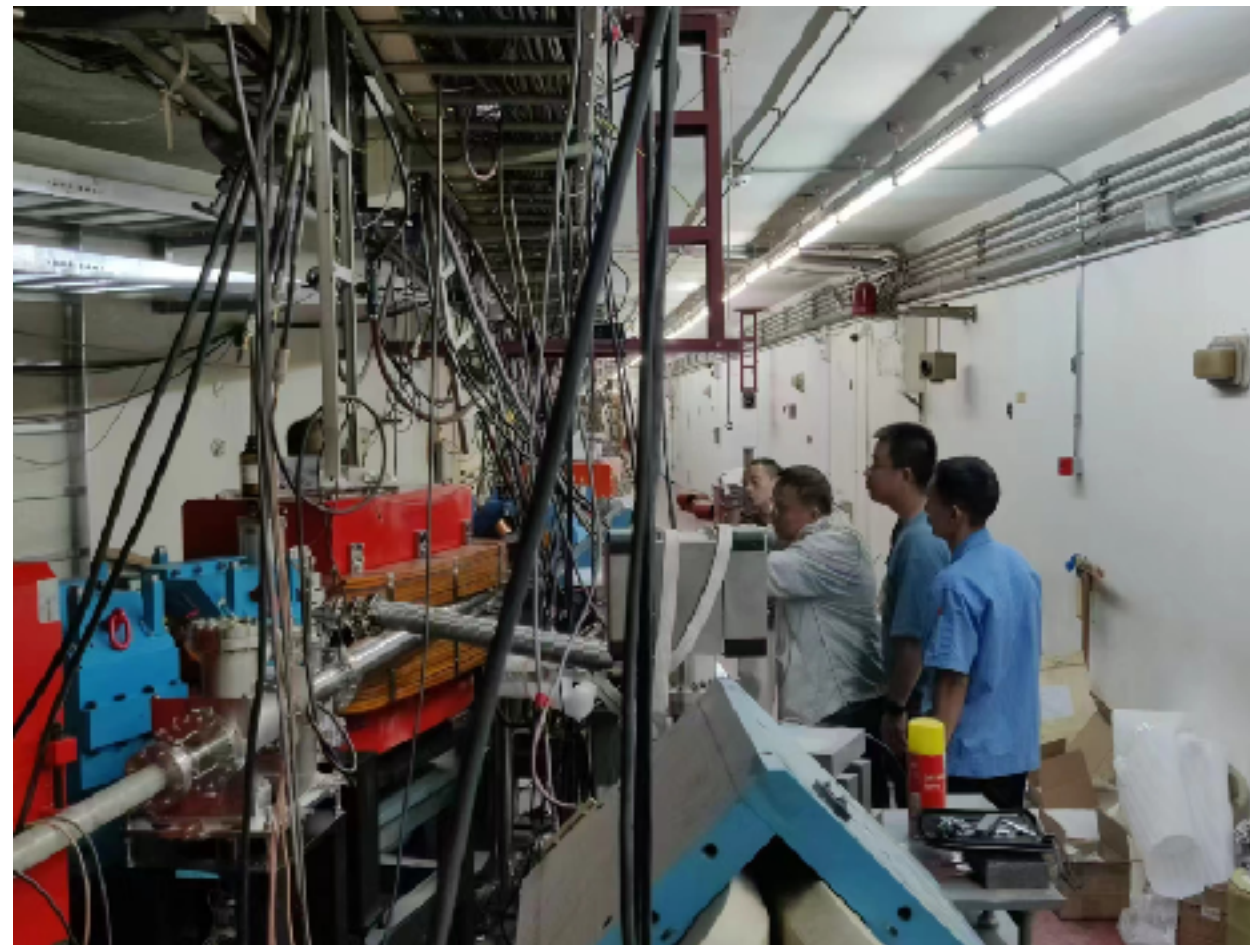
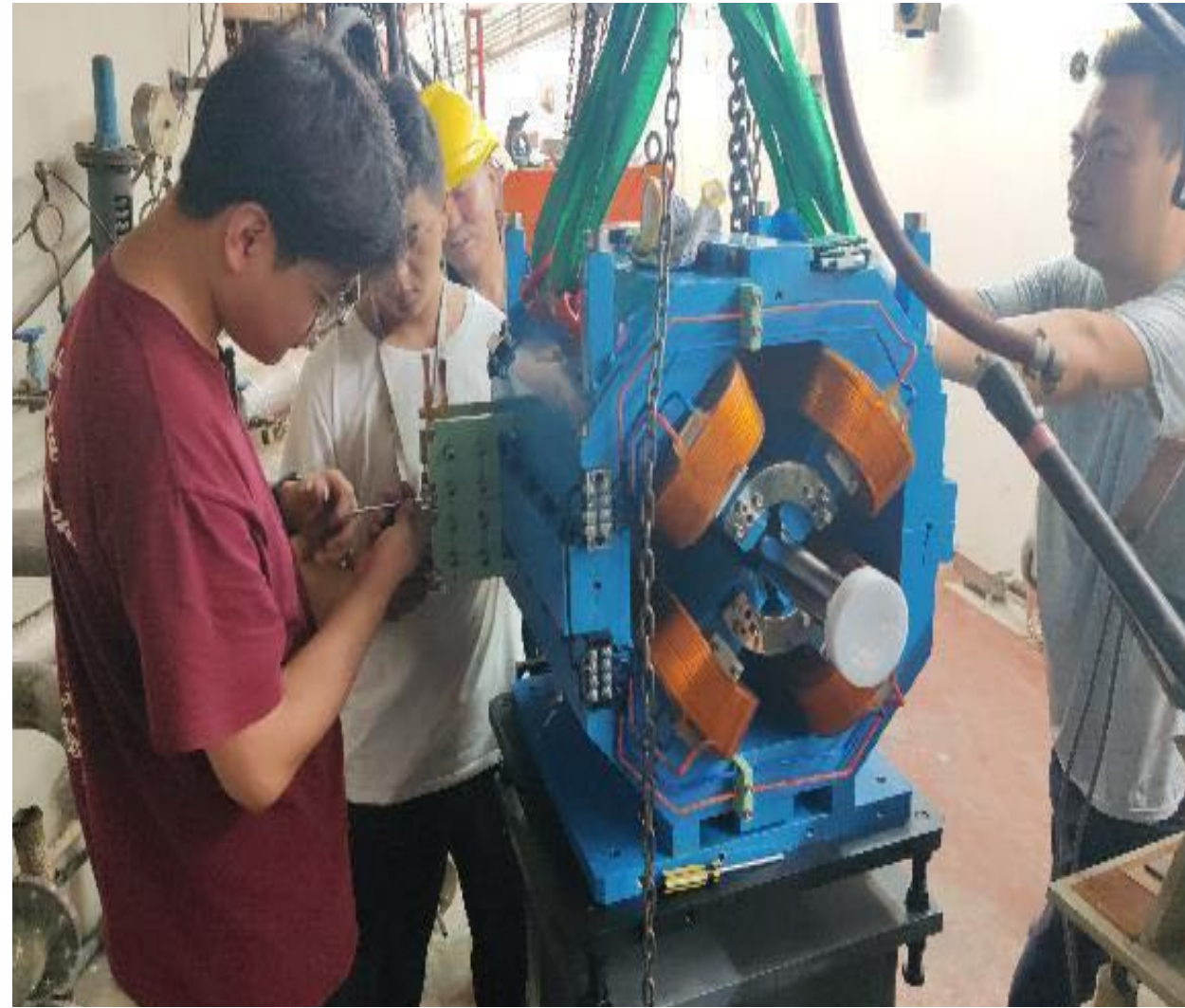
-2025 Sept . 5, CEPC EDR accelerator and civil engineering cost have been updated.

-2025 Sept. 8, CEPC accelerator/auxiliary facilities TDR/EDR progresses and site geological study/selection/civil engineering design status and progresses have been included in the CEPC Proposal for the 15th five-year-plan to Chinese government, which has been presented at CAS selection meeting



BEPCII-based PWFA Test Facility - beamline installation

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PWFA-BL 1 from BEPCII

PWFA-BL 2 from L-Band RF gun

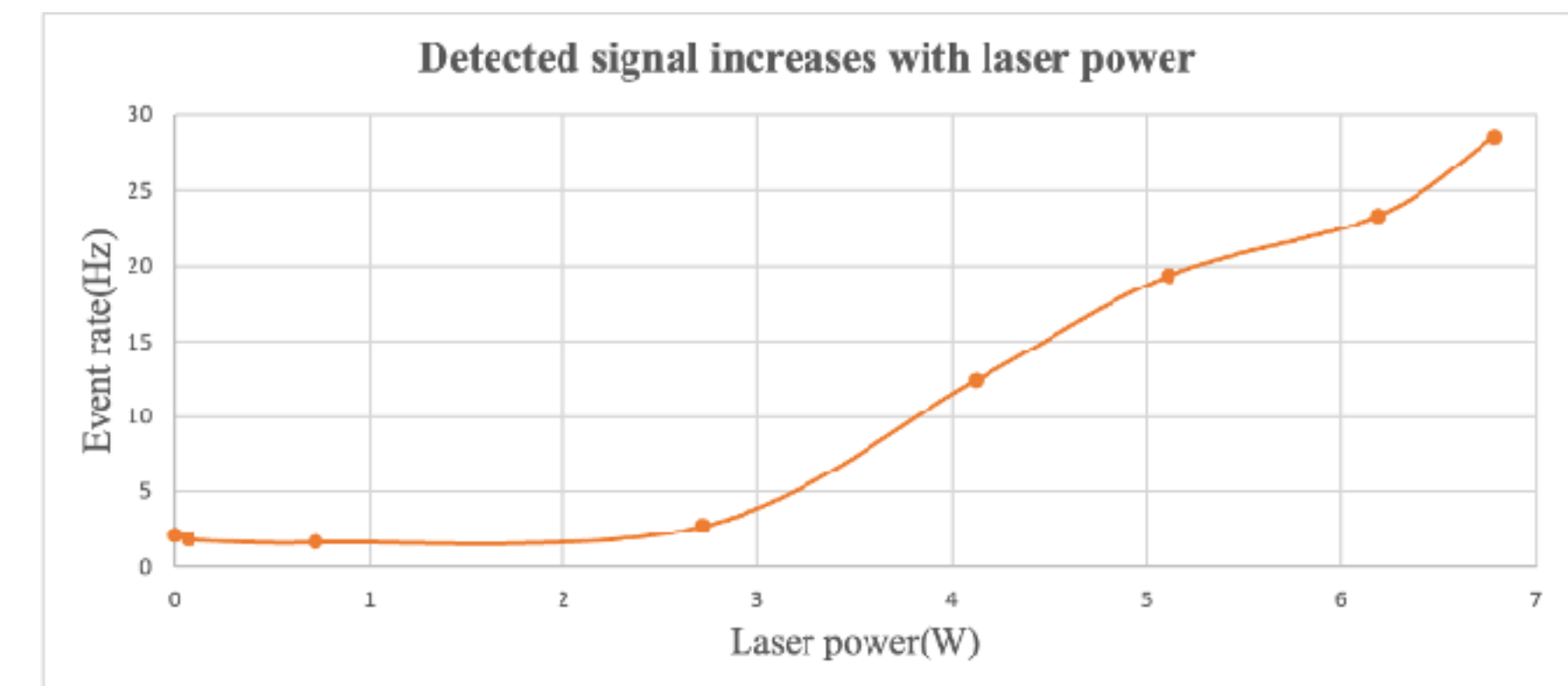
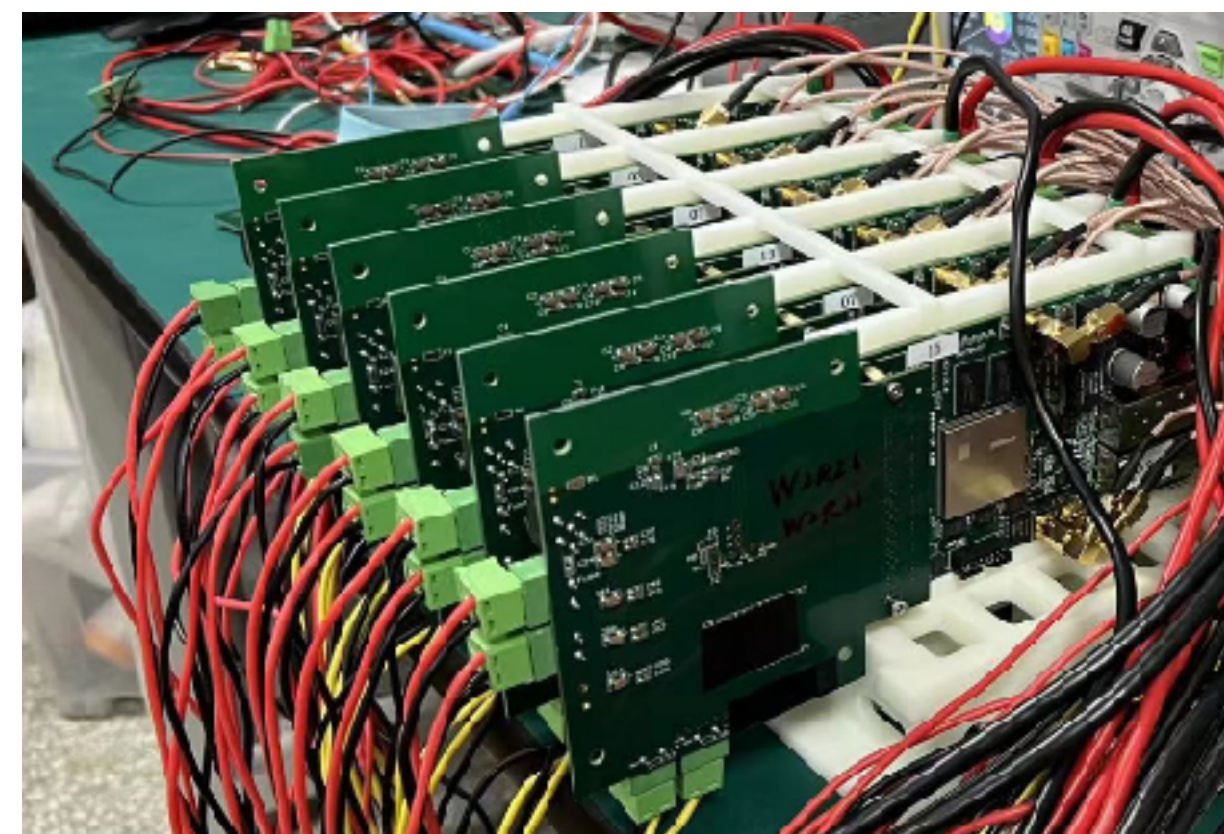
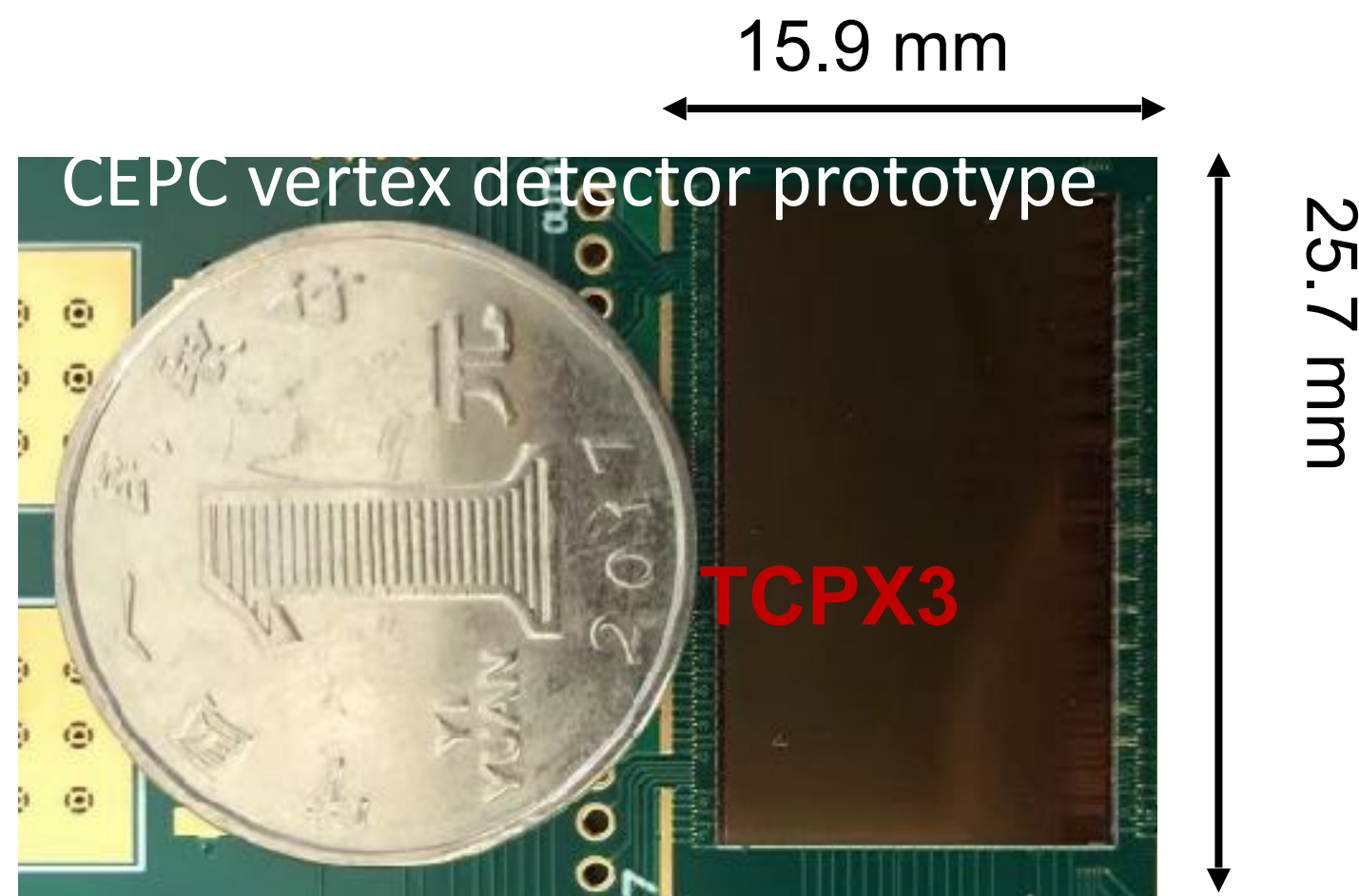
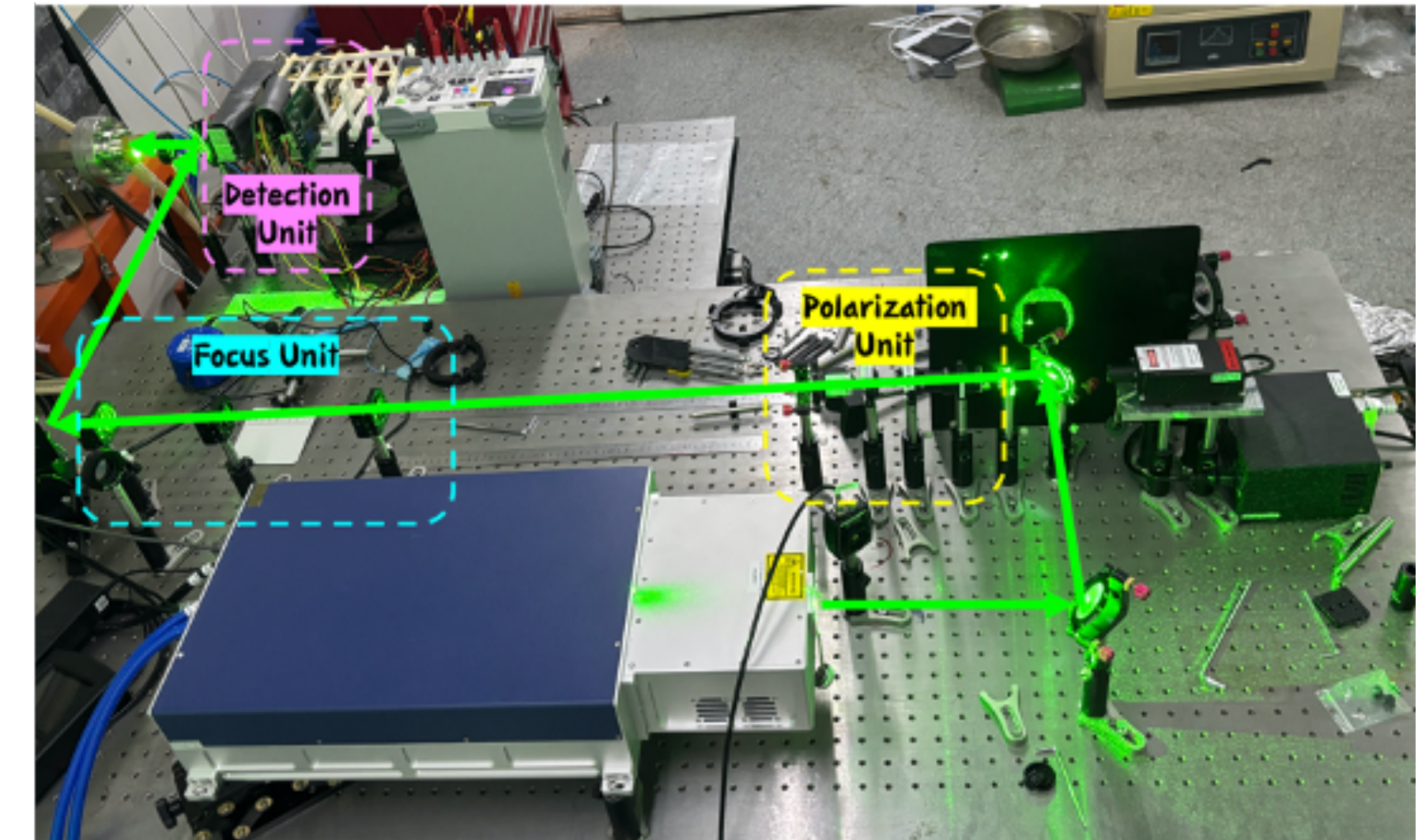
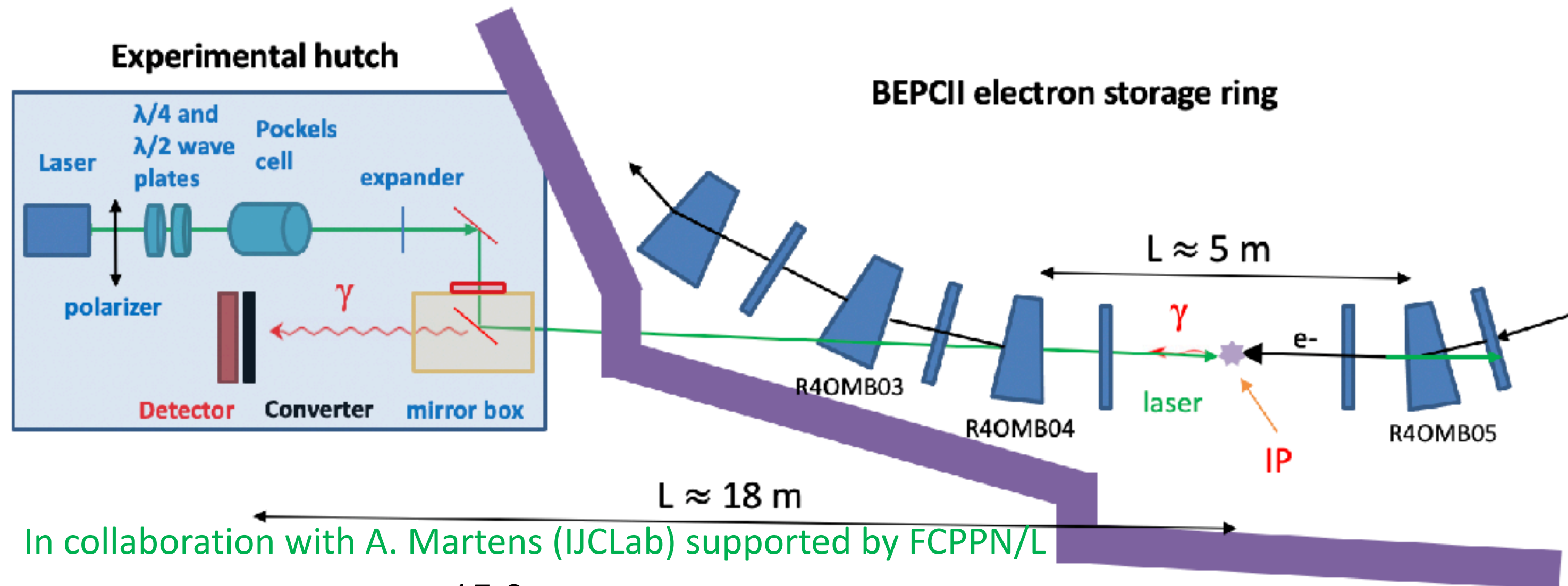
PWFA-BL 1 from BEPCII will have first beam in Nov. 2025

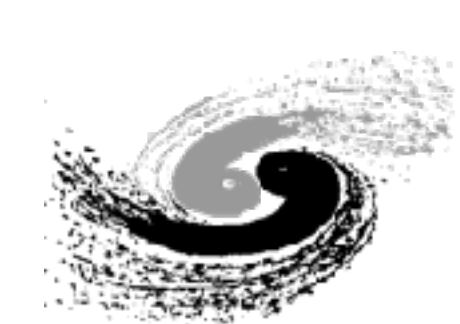
CEPC Polarization in Preparation Study

-Compton Polarimeter at BEPCII-U

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- A Compton polarimeter is now under commissioning at BEPCII-U
 - Simulated performance: $\sim 1\%$ stats uncertainty within 20 second
 - Ready for tuning of laser-electron collision $\rightarrow$ backscattered gamma signal from laser-electron collision has been observed





CEPC in ESPPU 2026

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Physics Preparatory Group

Karl Jakobs (chair) **Xinchou Lou (IHEP)**

Gianluigi Arduini	Fabio Maltoni
Thomas Bergauer	Jocelyn Monroe
Tommaso Boccali	Hugh Montgomery
Anadi Canepa	Rogério Rosenfeld
Cristinel Diaconu	Mike Seidel
Pilar Hernandez	Yuji Yamazaki
Gino Isidori	



Open Symposium on the European Strategy for Particle Physics June 23-27, Venice, Italy

June 24

14:30 - 15:05 **Yifang Wang (IHEP Beijing)**

Status and plans for the realisation of the Circular Electron Positron Collider (CEPC) and other large-scale projects in China
Sala Perla, Palazzo del Casinò

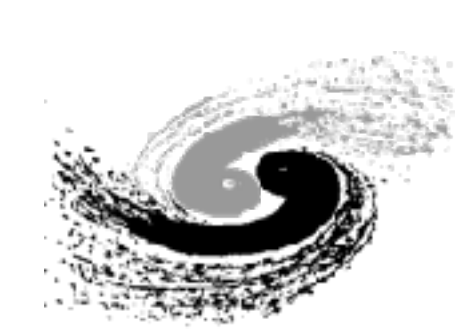
<https://agenda.infn.it/event/44943/overview>

CEPC-SppC participate actively in the 2026 update of the European Strategy for Particle Physics (ESPPU 26) with two input documents:

- 1) **The Circular Electron Positron Collider (CEPC)**
An input to the European Strategy for Particle Physics - 2026 update
Contact persons: **Jie Gao, Miao He, Dou Wang, and Jianchun Wang**
- 2) **High Performance and Cost Effective Superconducting Accelerator Magnet R&D at IHEP**
Contact persons: **Chengtao Wang, Rui Kang, Chunyan Li, Yingzhe Wang, Juan Wang and Qingjin Xu**

On July 6, 2025, **China Association for Science and Technology (CAST)** delivered publicly the **top ten frontier scientific questions**, where “**Higgs particle properties and the origin of masses**” are among the top ten questions (the second) and CEPC is mentioned in association with replying this question

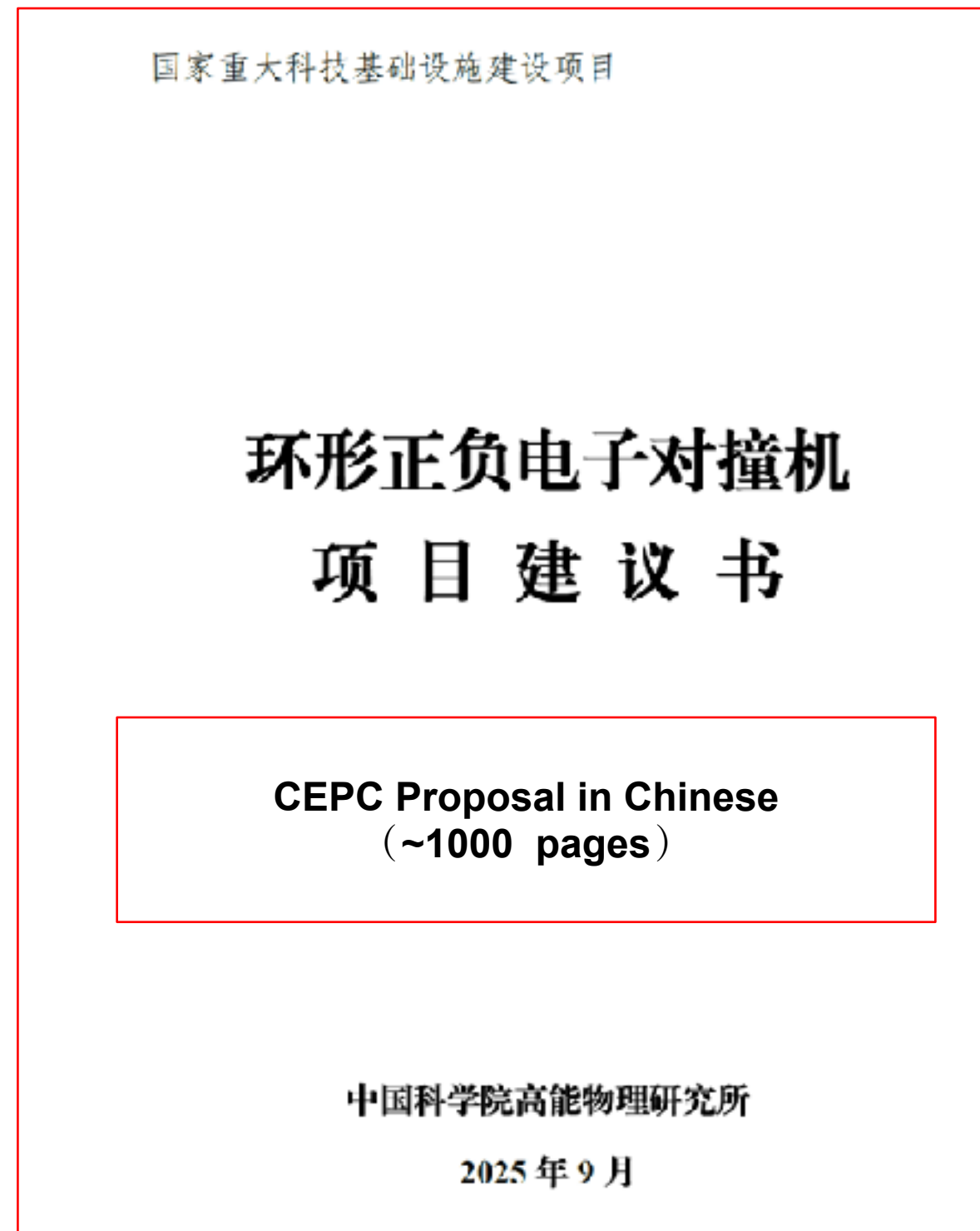
https://www.cast.org.cn/xw/BWTJ/art/2025/art_0f20c8a62cfe4584b13a53271ae73837.html



CEPC Proposal Preparation (2025) and Beyond

73

The CEPC Proposal (in Chinese) has been submitted for China's "15th five-year-plan" process in 2025 to CAS in Sept 2025



Due to the CEPC proposal has not been selected by CAS in 2025, CEPC will continue to complete EDR around 2027 and prepare for the application For construction during the 16th five year plan (2030-2035)

Concerning CEPC entering construction preparation phase 2026-2027, CEPC civil engineering design based on EDR site and geological conditions will be put to high priority with components' industrial mass production and installation preparations

CEPC accelerator overall survey, components' naming system, electronic management system (DeepC), BIM design, and AI applications in all CEPC systems, etc. have been started...

On July 6, 2025, **China Association for Science and Technology (CAST)** delivered publicly the **top ten frontier scientific questions**, where "Higgs particle properties and the origine of masses" are among the top ten questions (the second) and CEPC is mentioned in association with replying this question

Enhanced international and national collaborations and preparation for establishment of the construction team, long term personnel training, CEPC headquarter at EDR site will be put forward in close collaboration with local government

CEPC Baseline Operation Scenario

Operation mode	$\sqrt{s}$ (GeV)	SR power (MW)	$\mathcal{L}$ ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	$\int \mathcal{L}/\text{year}$ (ab^{-1})	Years	Total $\int \mathcal{L}$ (ab^{-1})	Event yields
H	240	30	5	0.65	15	10	2.0×10^6
Z	91	12.1	26(*)	3.2	4	13	5.6×10^{11}
W^+W^-	155-170	30	16	1.2	1	1.2	$1.0 \times 10^7(\dagger)$

Main goal of CEPC Reference Detector TDR

Demonstrate readiness for construction of detector for baseline scenario
A detector that could be constructed and commissioned within a decade

After CEPC project approval:

- 1) **Two** CEPC detectors will be selected among international proposals
- 2) **International Collaborations** will lead those detector designs and produce corresponding TDRs adapted to the final operational scenarios

Physics Requirements

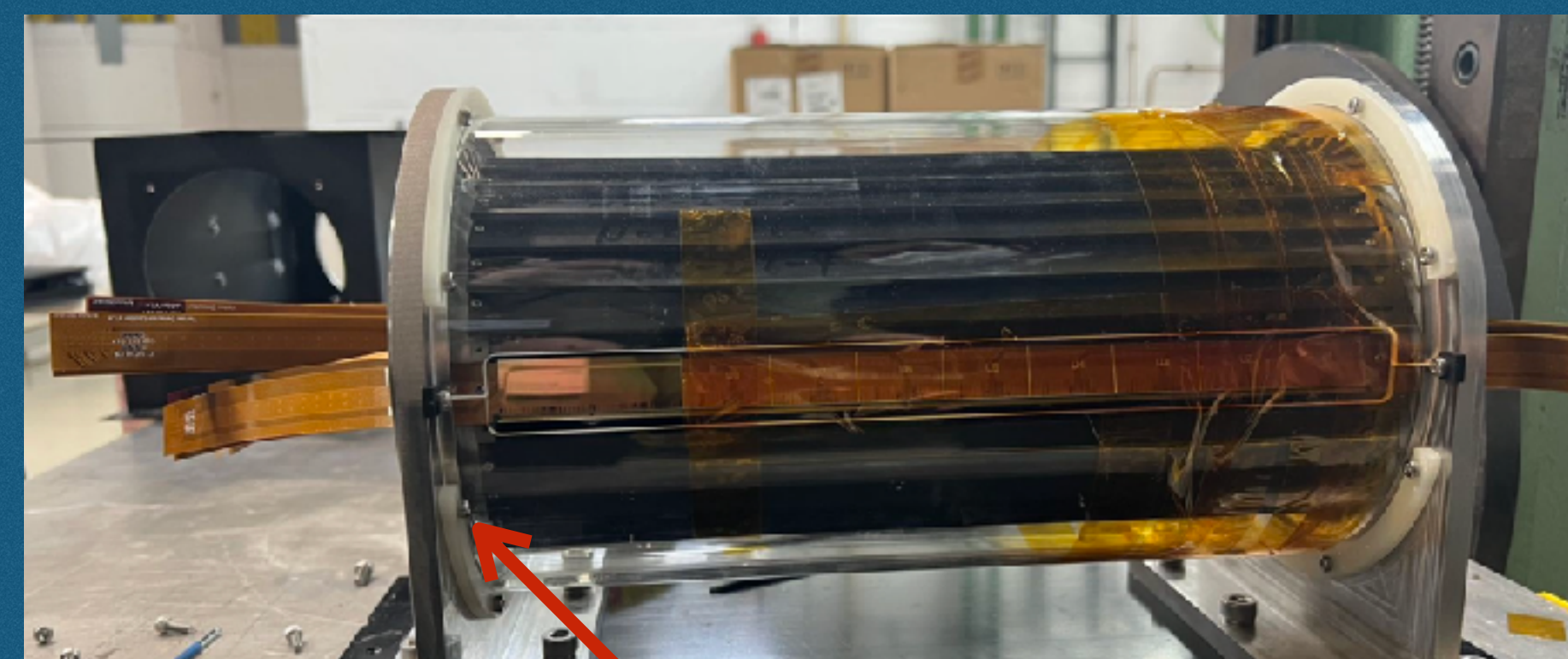
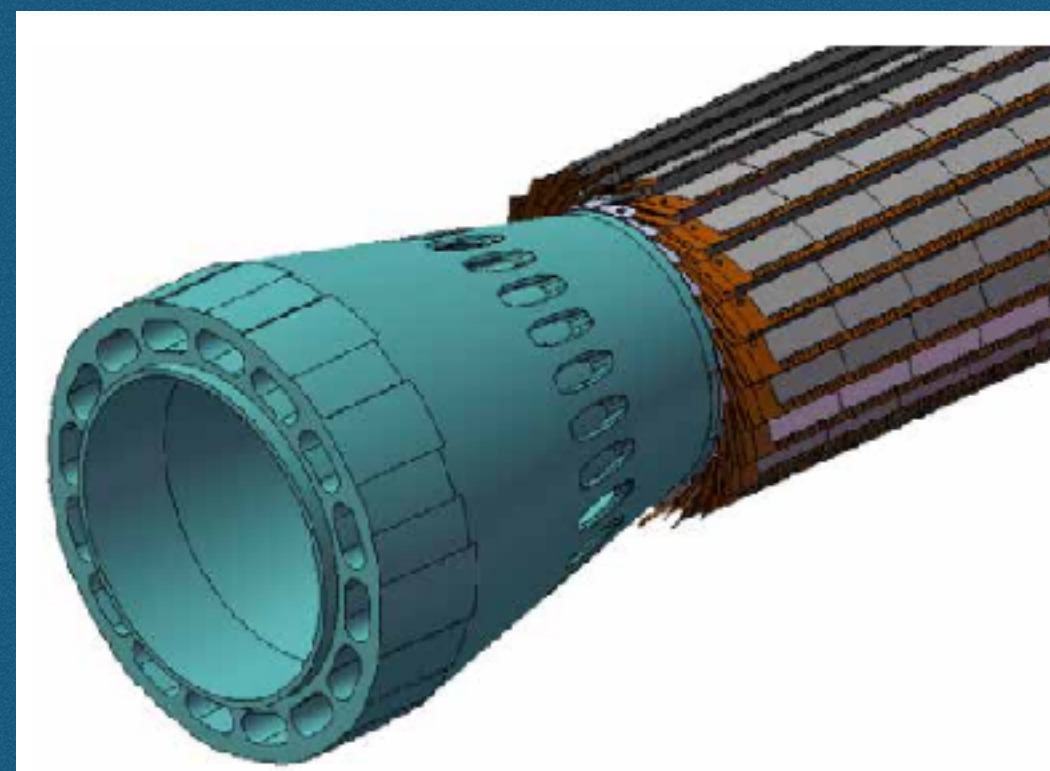
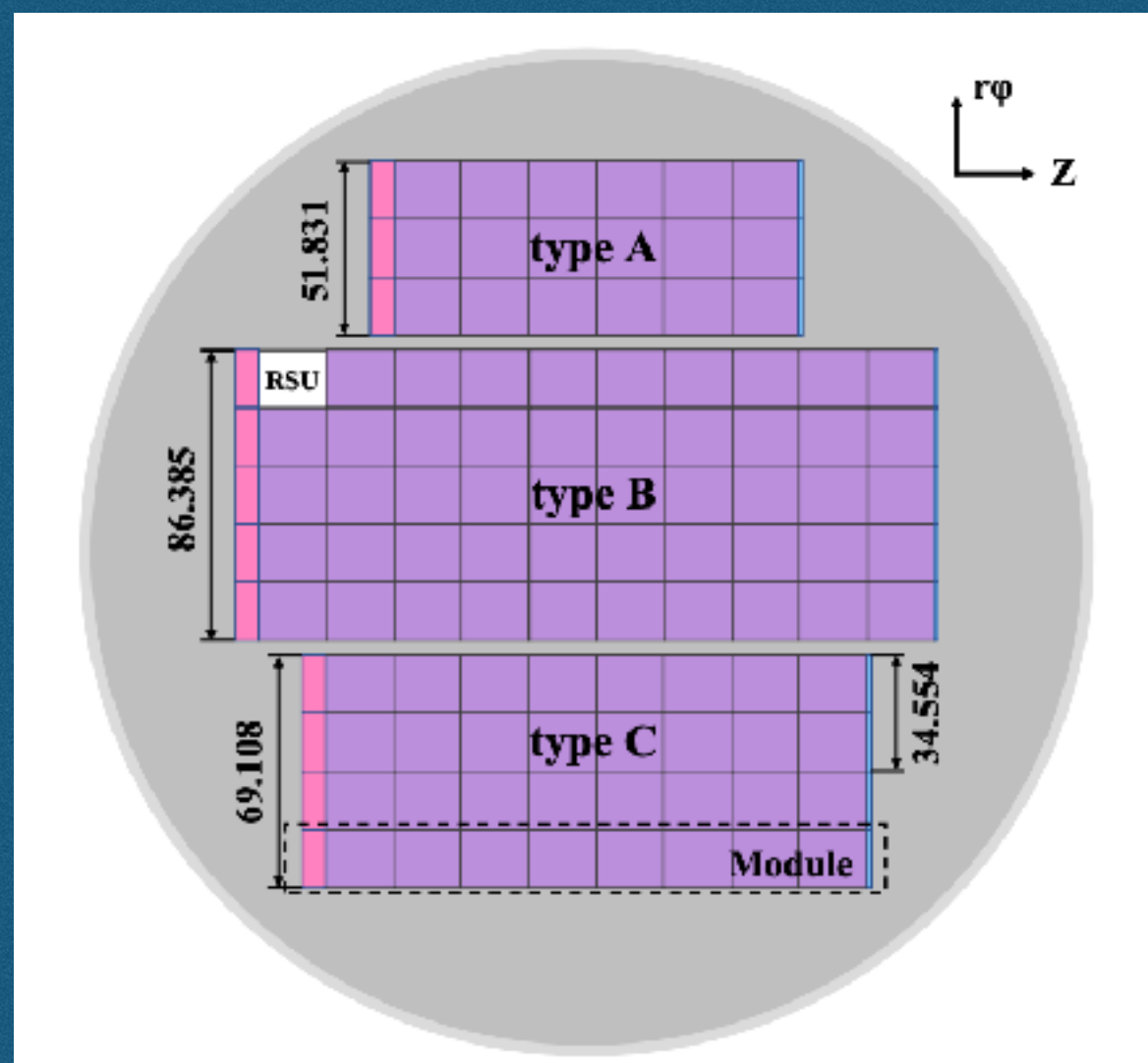
Parameter	Requirement
Single-point resolution per layer	$\leq 5 \mu\text{m}$
Detector material budget	$\leq 0.9\% X_0$
Angular coverage	$ \cos \theta < 0.99$
Beam pipe material budget	$< 0.5\% X_0$
Detector occupancy	$< 1\%$

Design Parameters

Parameter	Design
Spatial Resolution	$\sim 5 \mu\text{m}$
Detector material budget	$\sim 0.8\% X_0$
First layer radius	11.1 mm
Power Consumption	$< 40 \text{ mW/cm}^2$ (air cooling requirement)
Time stamp precision	100 ns
Fluence	$\sim 2 \times 10^{14} \text{ Neq/cm}^2$
Operation temperature	$\sim 5^\circ\text{C}$ to 30°C
Readout electronics	Fast, low-noise, low-power
Mechanical Support	Ultralight structures
Angular Coverage	$ \cos \theta < 0.99$

The Vertex Detector

Unit	Beam pipe	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
$\bar{X}_0$ (X_0)	0.454%	0.067%	0.059%	0.058%	0.061%	0.280%	0.280%

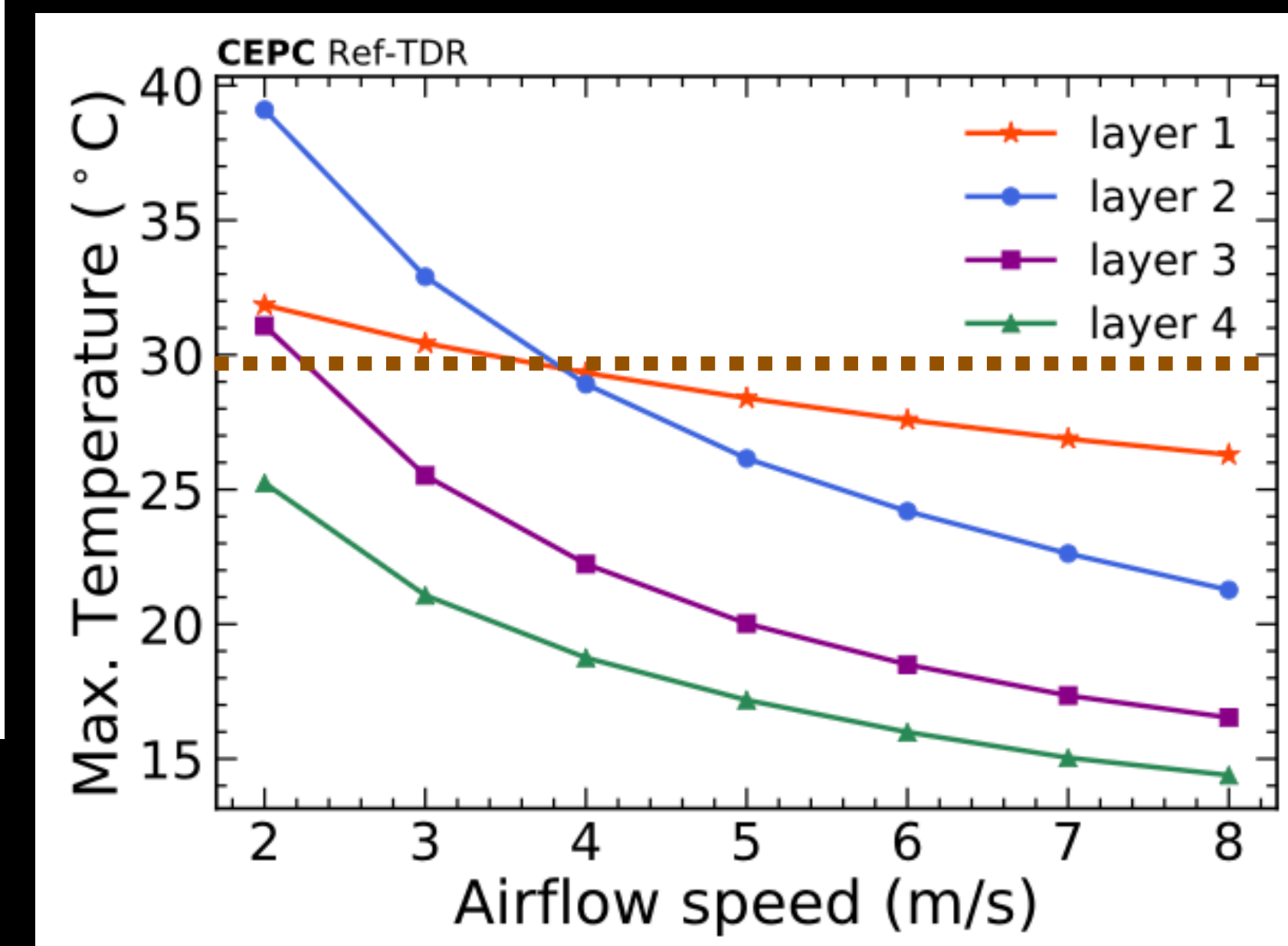
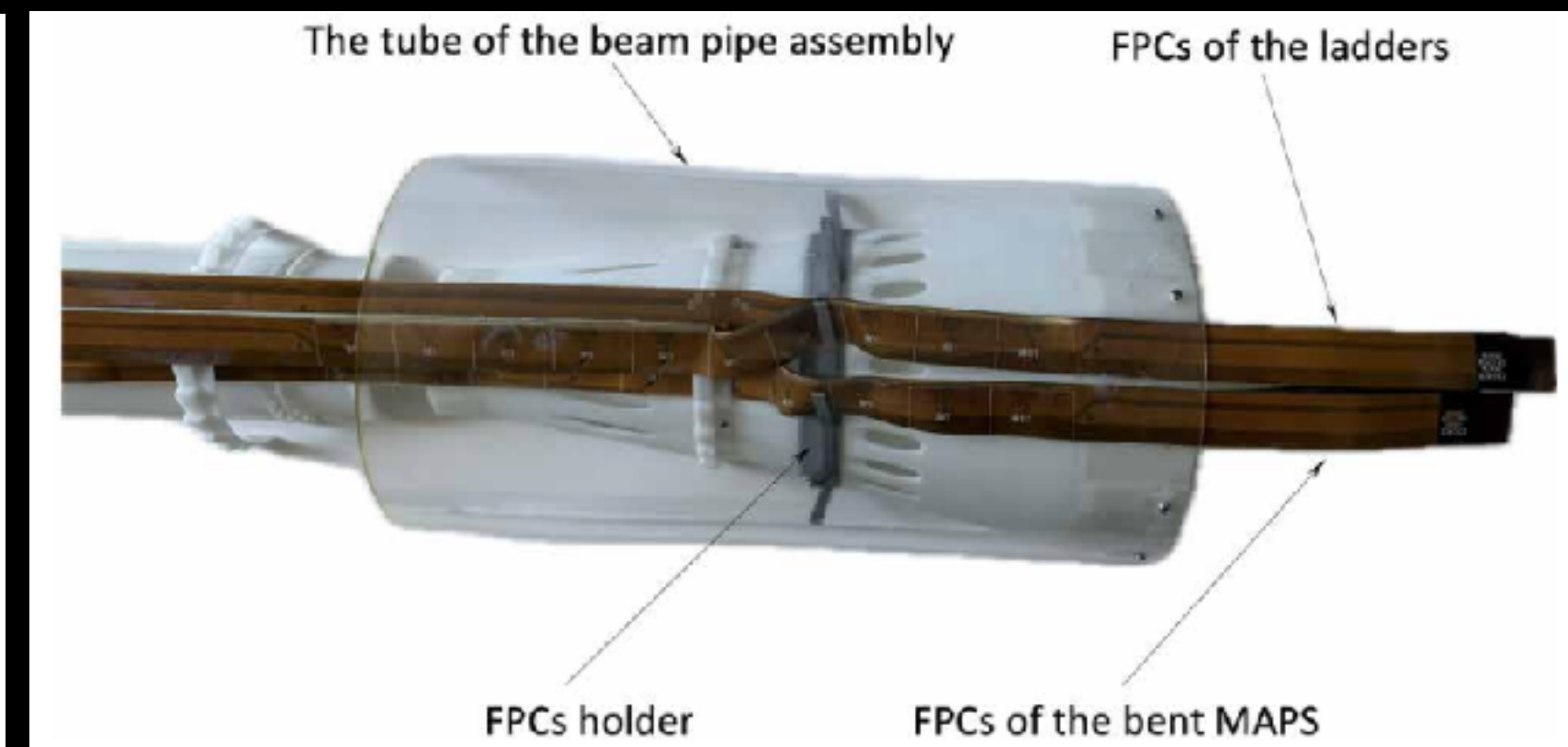
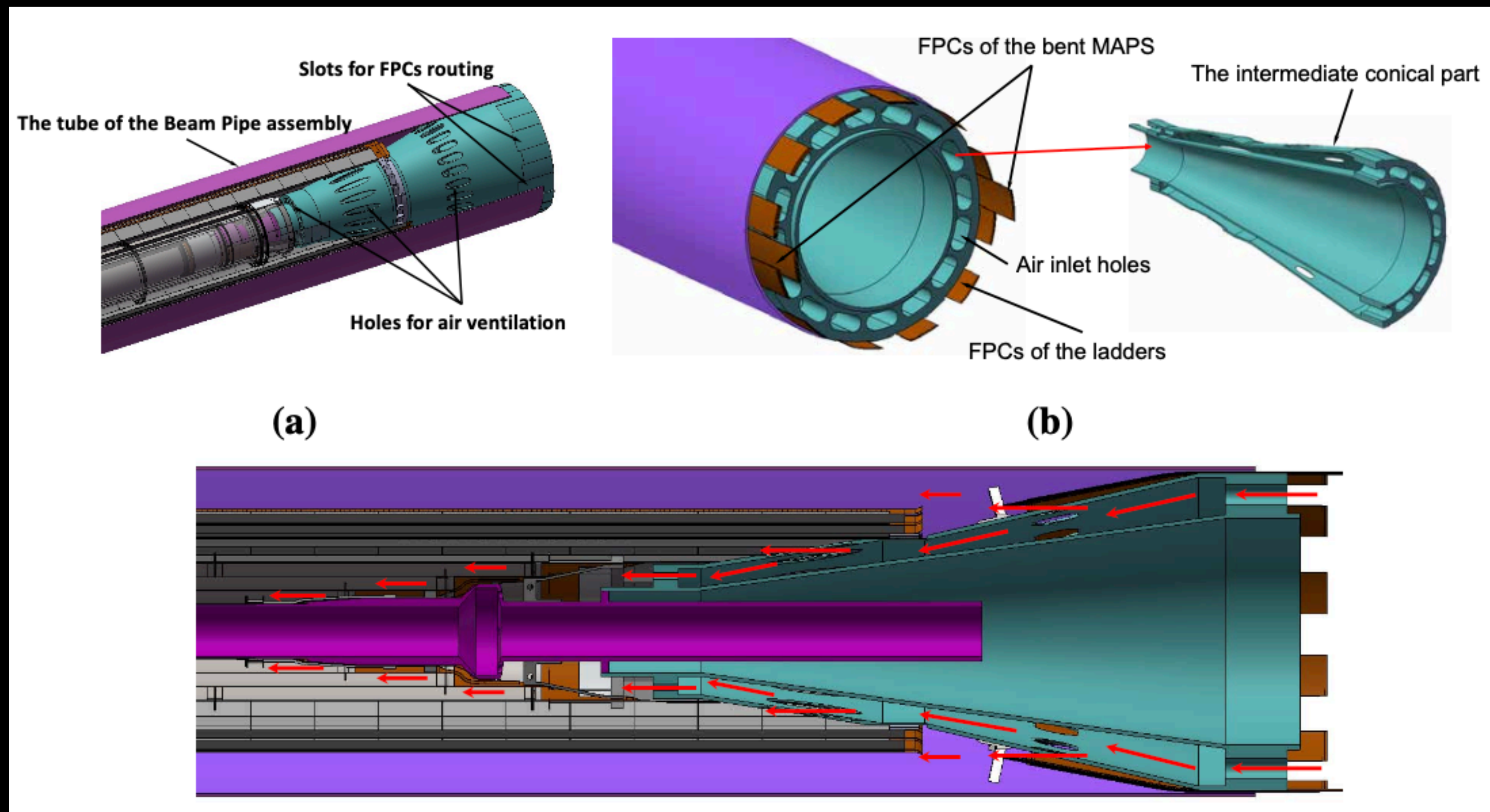


Prototype of standard vertex
(no bent layers)

Technology: Tower Partners Semiconductor Co. (TPSCo) 65 nm MAPS
Alternative: Huali Microelectronics Corporation (HLMC) 55 nm MAPS

The Vertex Detector: Mechanics and Cooling

Dummy mock-up



- Airflow speed of 7 m/s, equivalent to a total flow rate of 3500 L/min
- Required to keep temperature safely below 30 °C

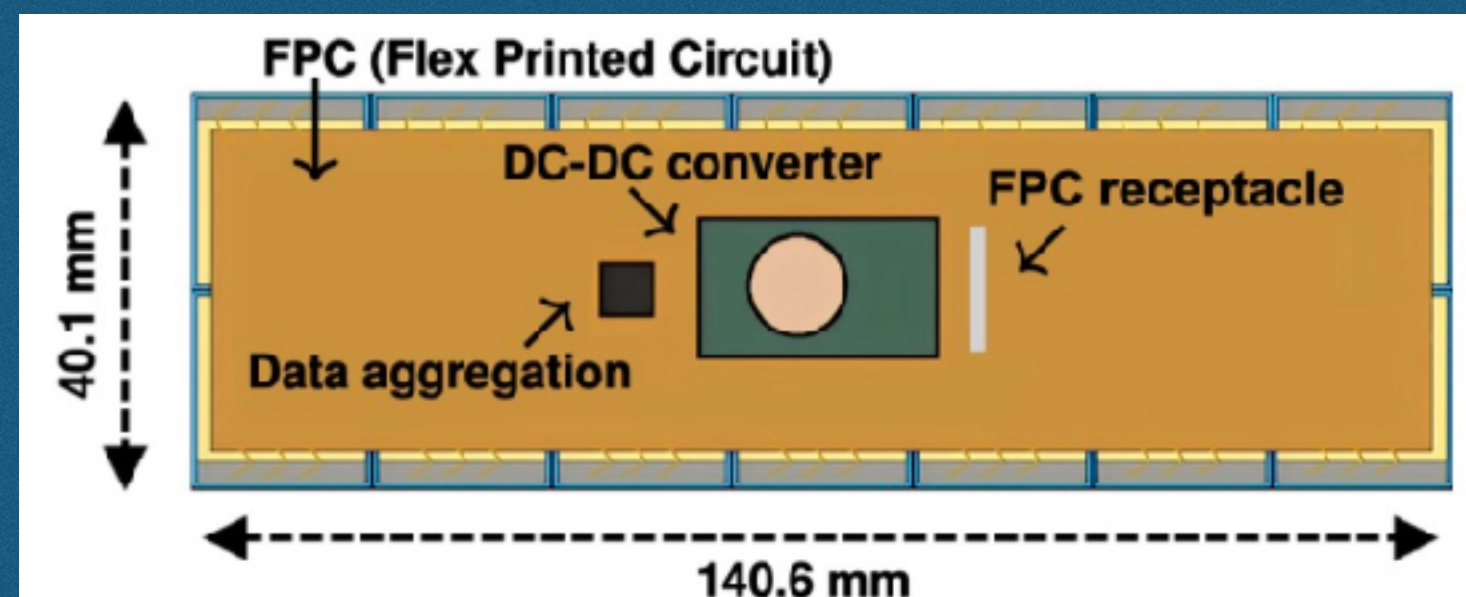
The Inner Silicon Tracker (ITK)

Monolithic HV-CMOS pixel sensors fabricated using a 55 nm CMOS process

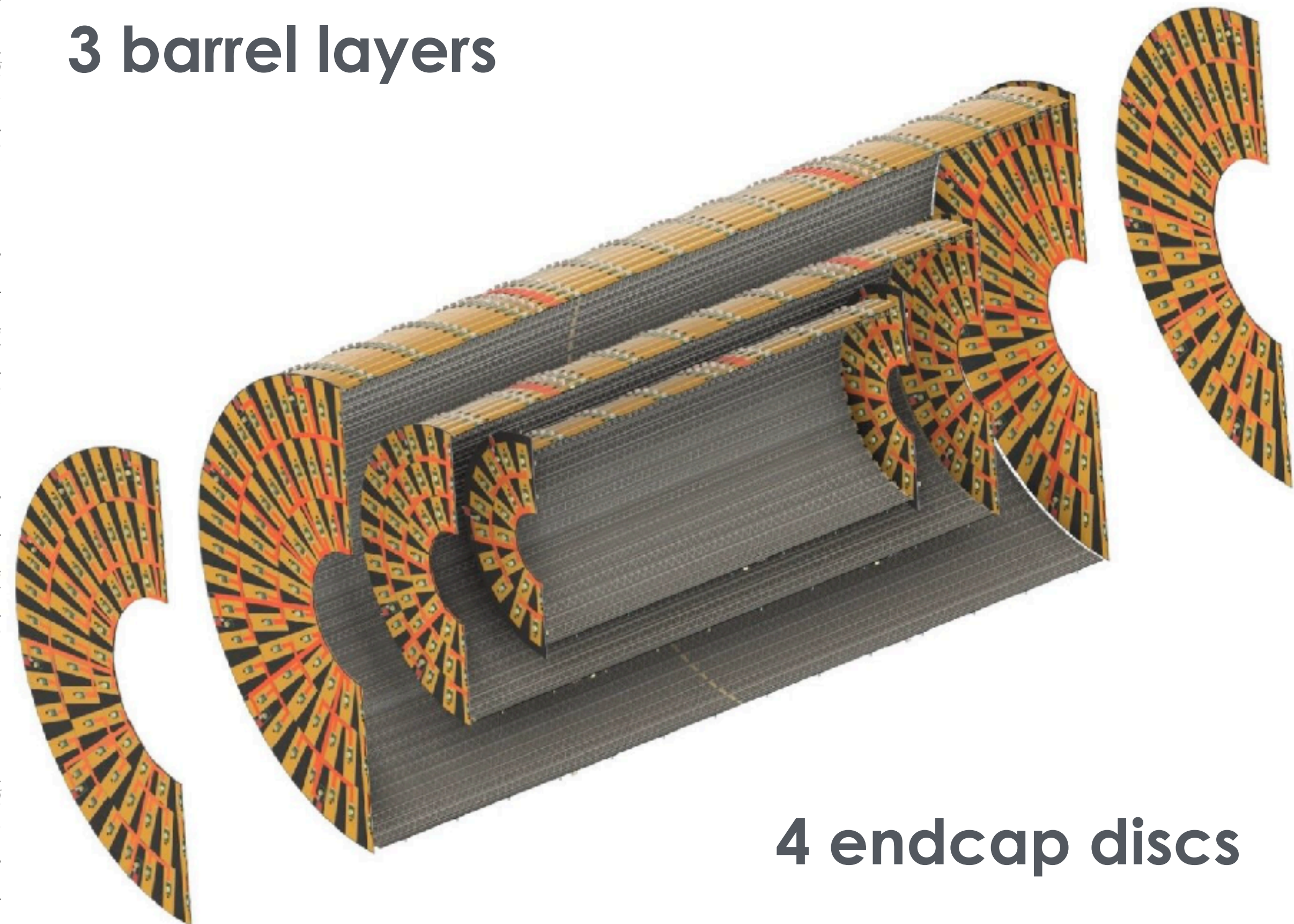
Sensor key parameters

Parameter	Value
Sensor size	2 cm × 2 cm (active area: 1.74 cm × 1.92 cm)
Sensor thickness	150 μm
Array size	512 × 128
Pixel size	34 μm × 150 μm
Spatial resolution	8 μm × 40 μm
Time resolution	3–5 ns
Power consumption	200 mW/cm ²
Technology node	55 nm

Module
with
14 sensors



3 barrel layers

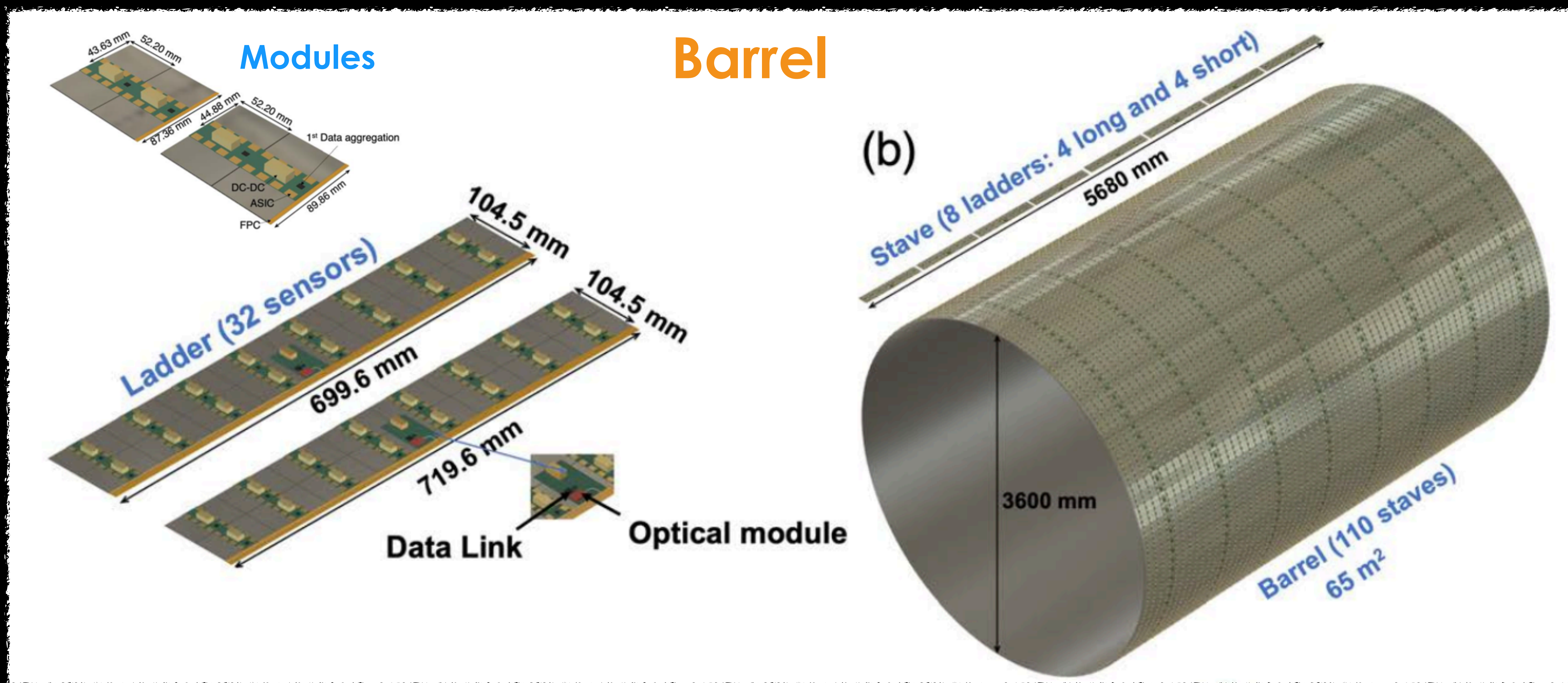


4 endcap discs

The Outer Tracker (OTK)

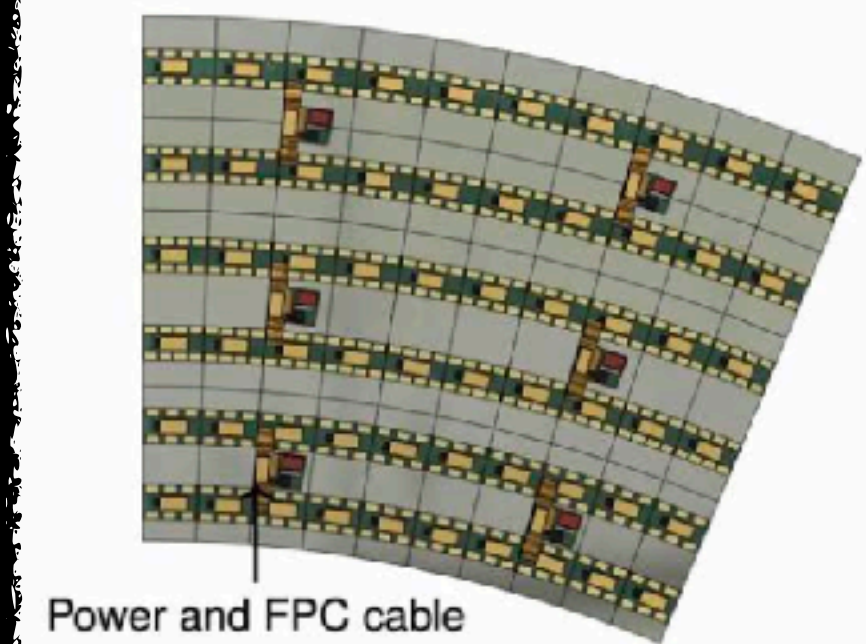
Designed to provide a spatial resolution of $\sim 10 \mu\text{m}$ and a time resolution of $\sim 50 \text{ ps}$

Using microstrip AC-LGAD technology to cover $\sim 85 \text{ m}^2$

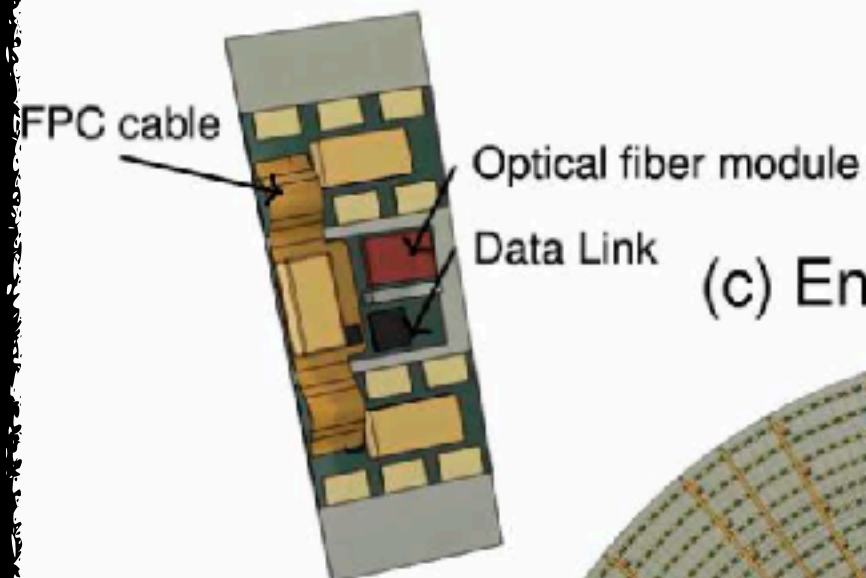


The Outer Tracker (OTK)

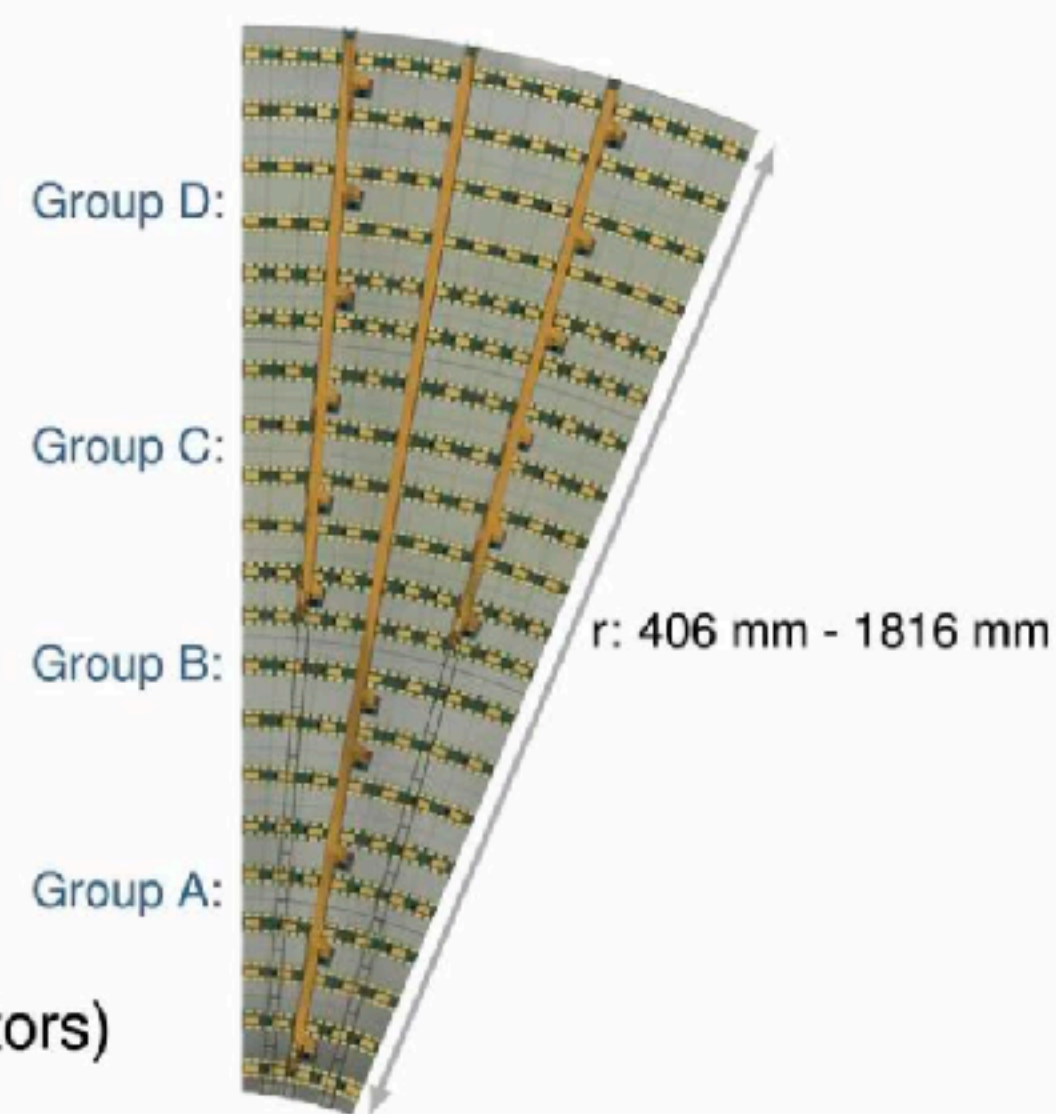
(a) Group C Sensors:



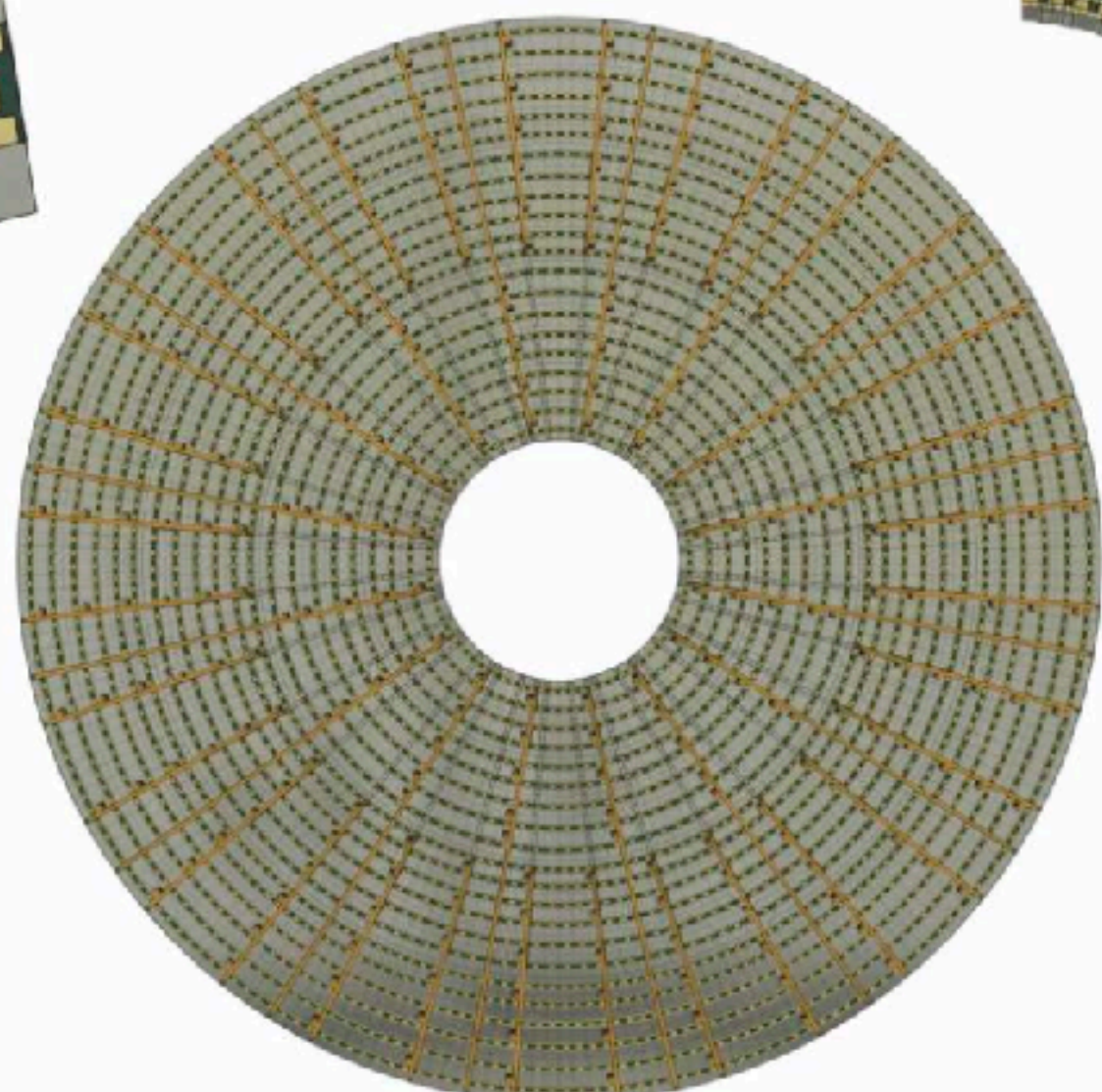
2 Sensor module:



(b) 1/16 Sector:

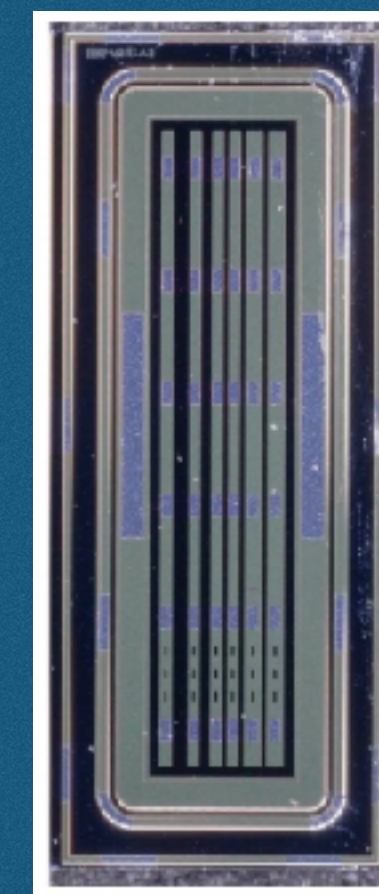
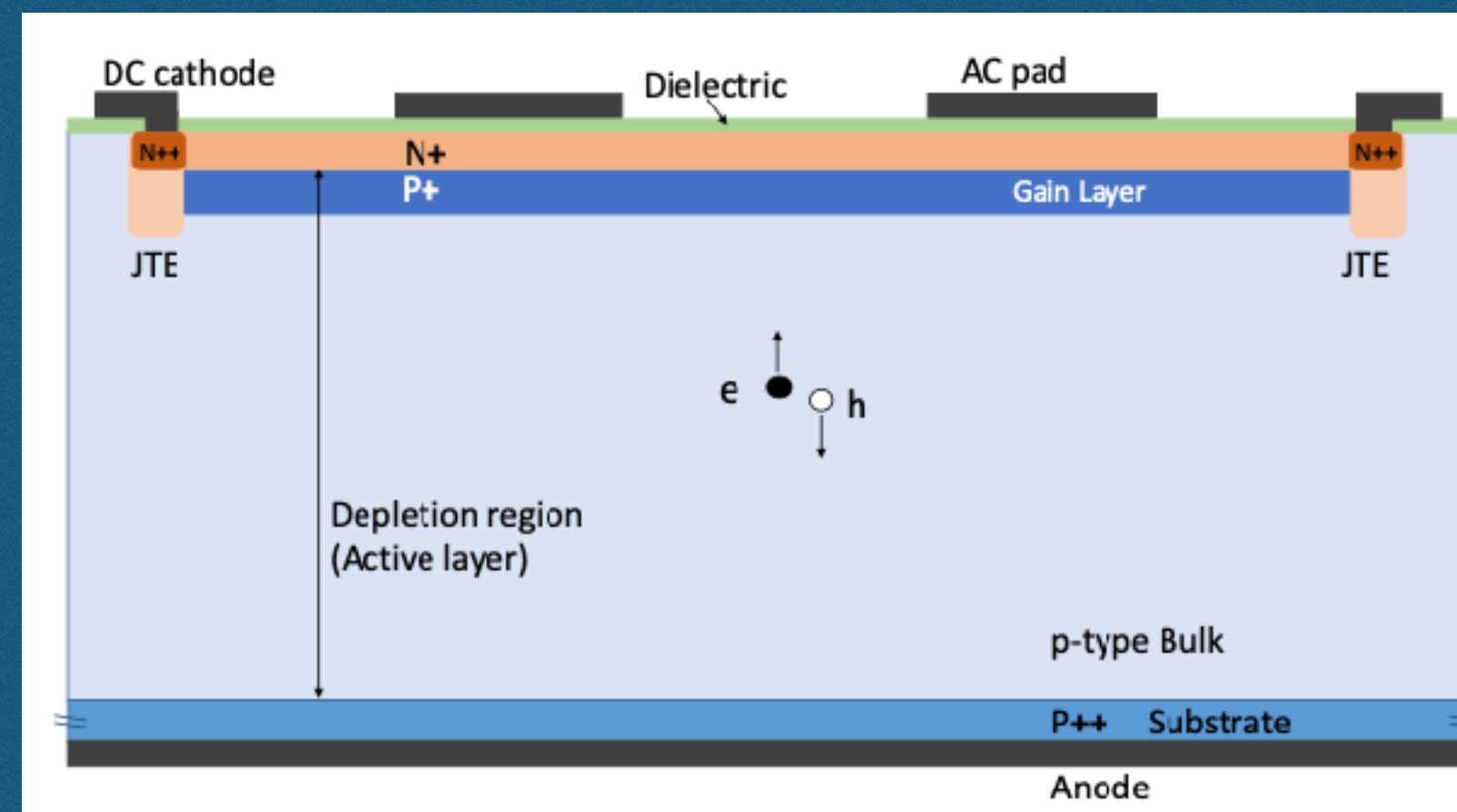


(c) Endcap (16 Sectors)

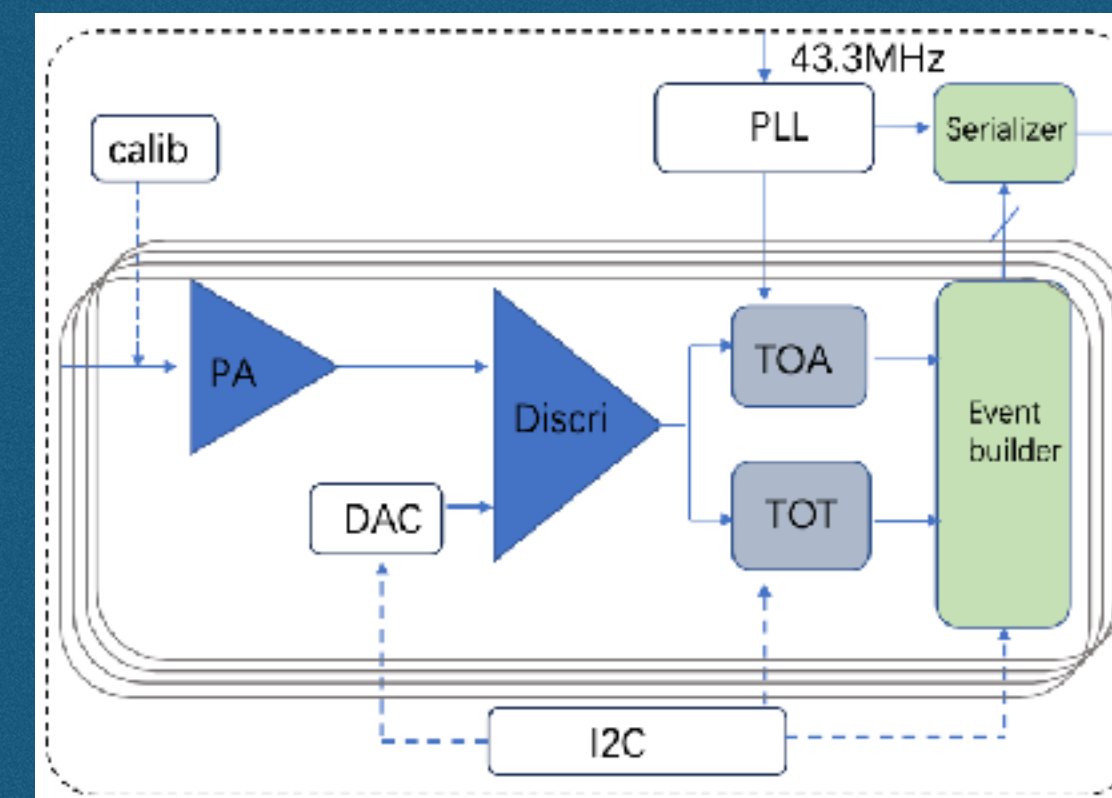


Endcap

AC-LGAD development:



LATRIC: LGAD Readout Chip (LGAD Timing and Readout Integrated Chip)



The Time Projection Chamber (TPC)

Detailed mechanical design:

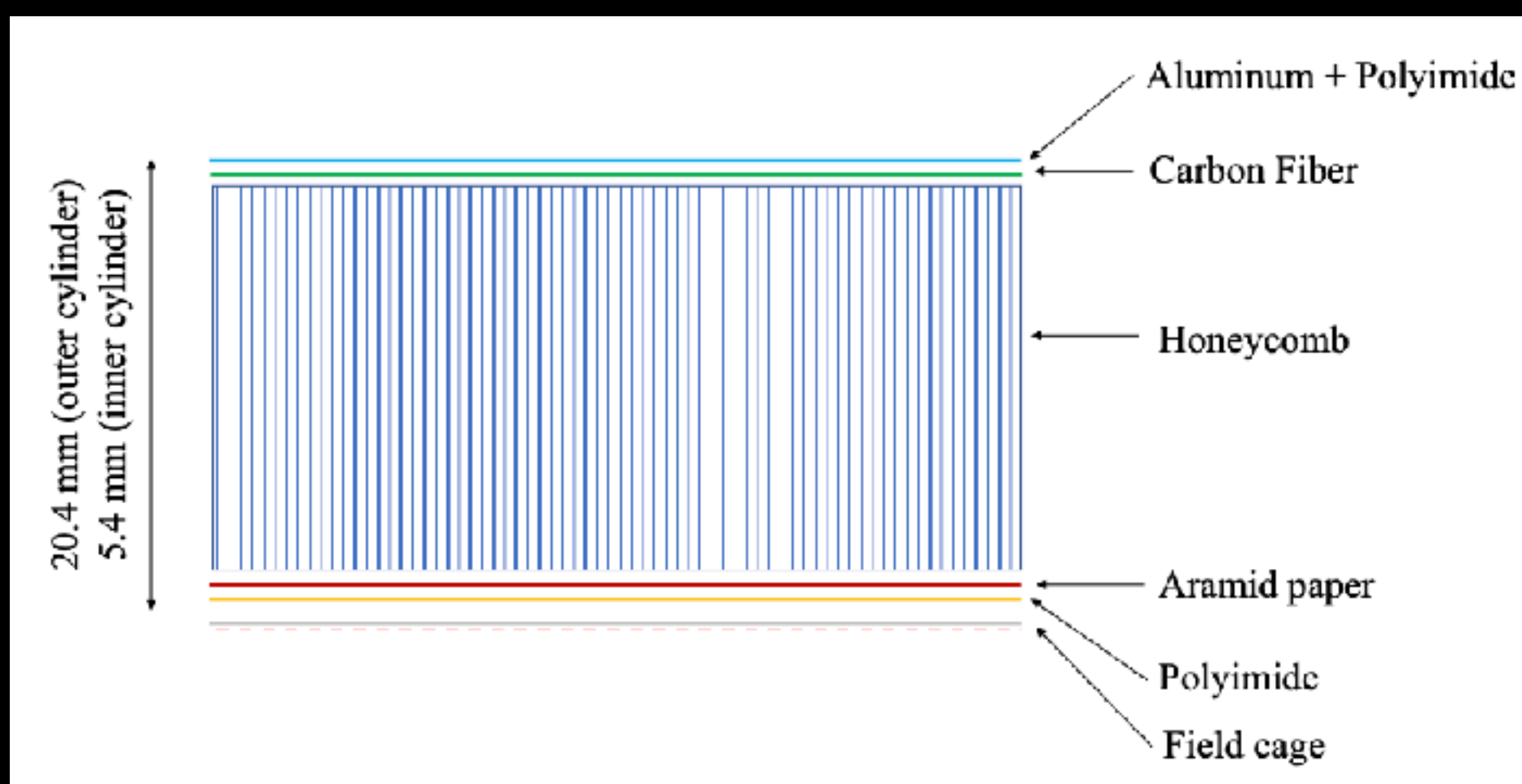
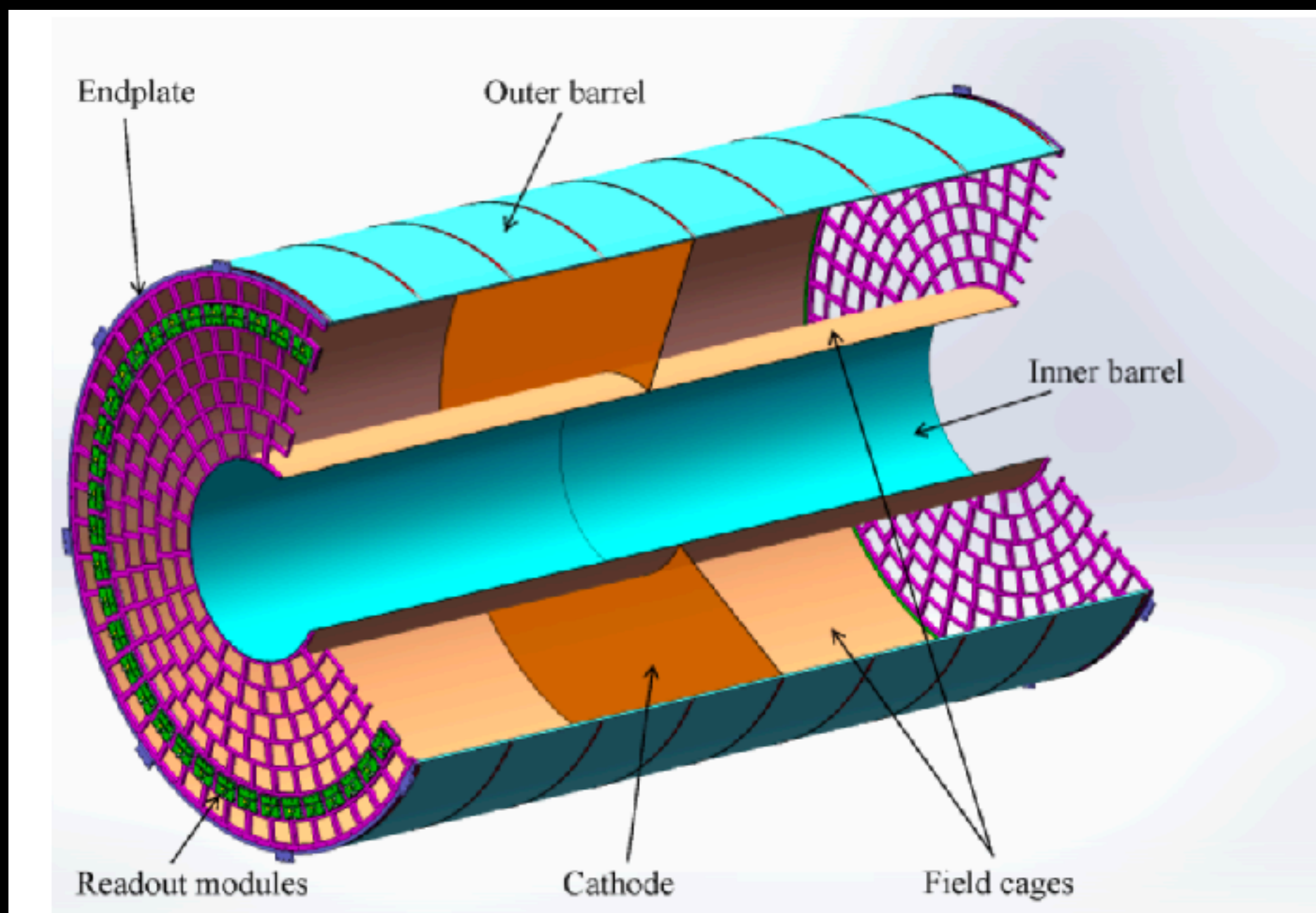


Table 6.1: Critical parameters of the TPC.

Parameters	Values
Length (outer dimensions)	5800 mm
Radial extension (outer dimensions)	600–1800 mm
Cathode potential	-63,000 V
Gas mixture	T2K: Ar/CF ₄ /iC ₄ H ₁₀ = 95/3/2
Drift velocity	~ 8 cm/μs
Maximum electron drift time	~ 34 μs
Readout detector	Double-mesh Micromegas
Pad size	500 μm × 500 μm
Gas gain	~ 2000
Readout modules per endplate	244
Cooling	Water cooling circulation system

Material budget estimation of the TPC barrel

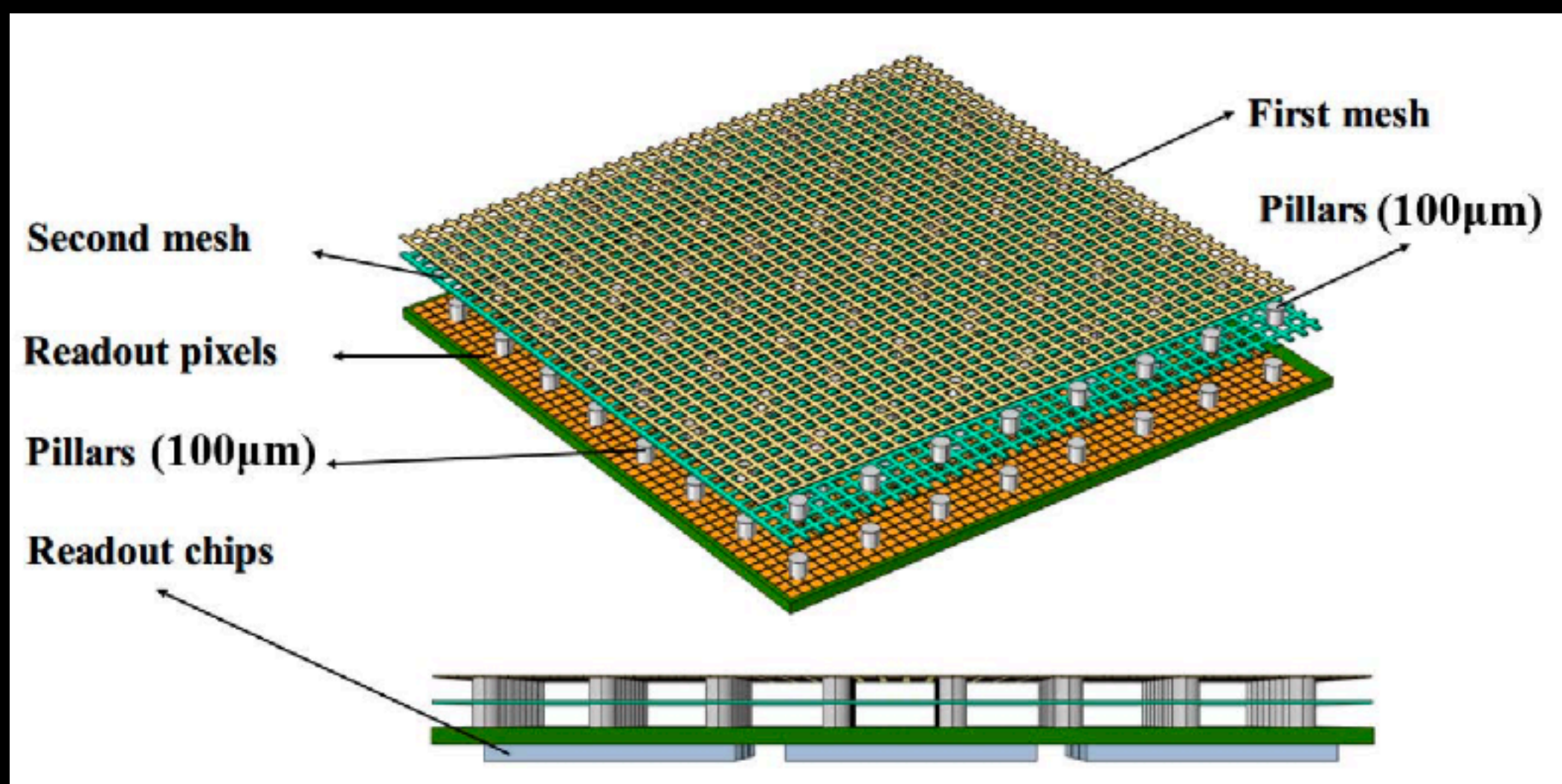
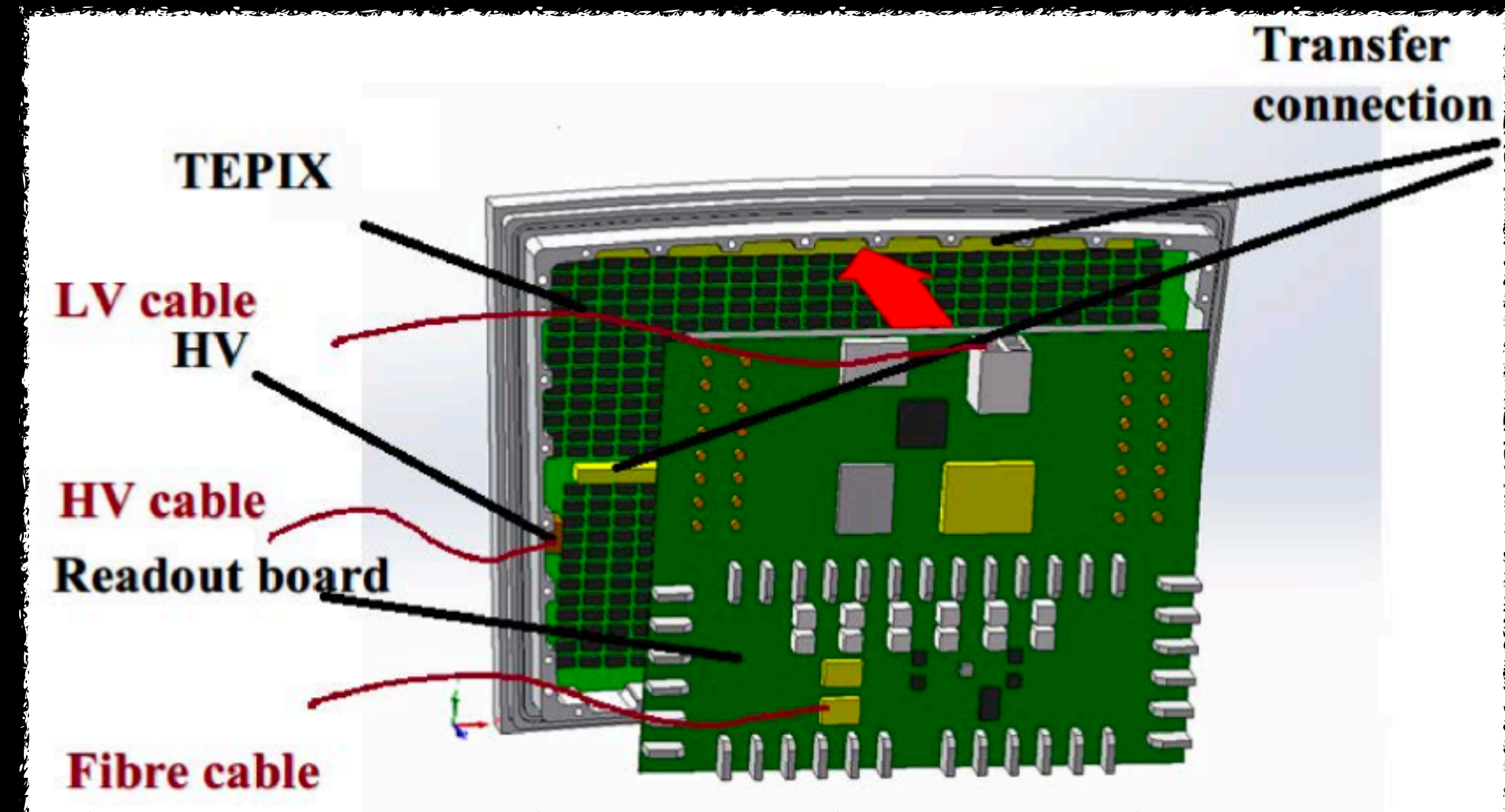
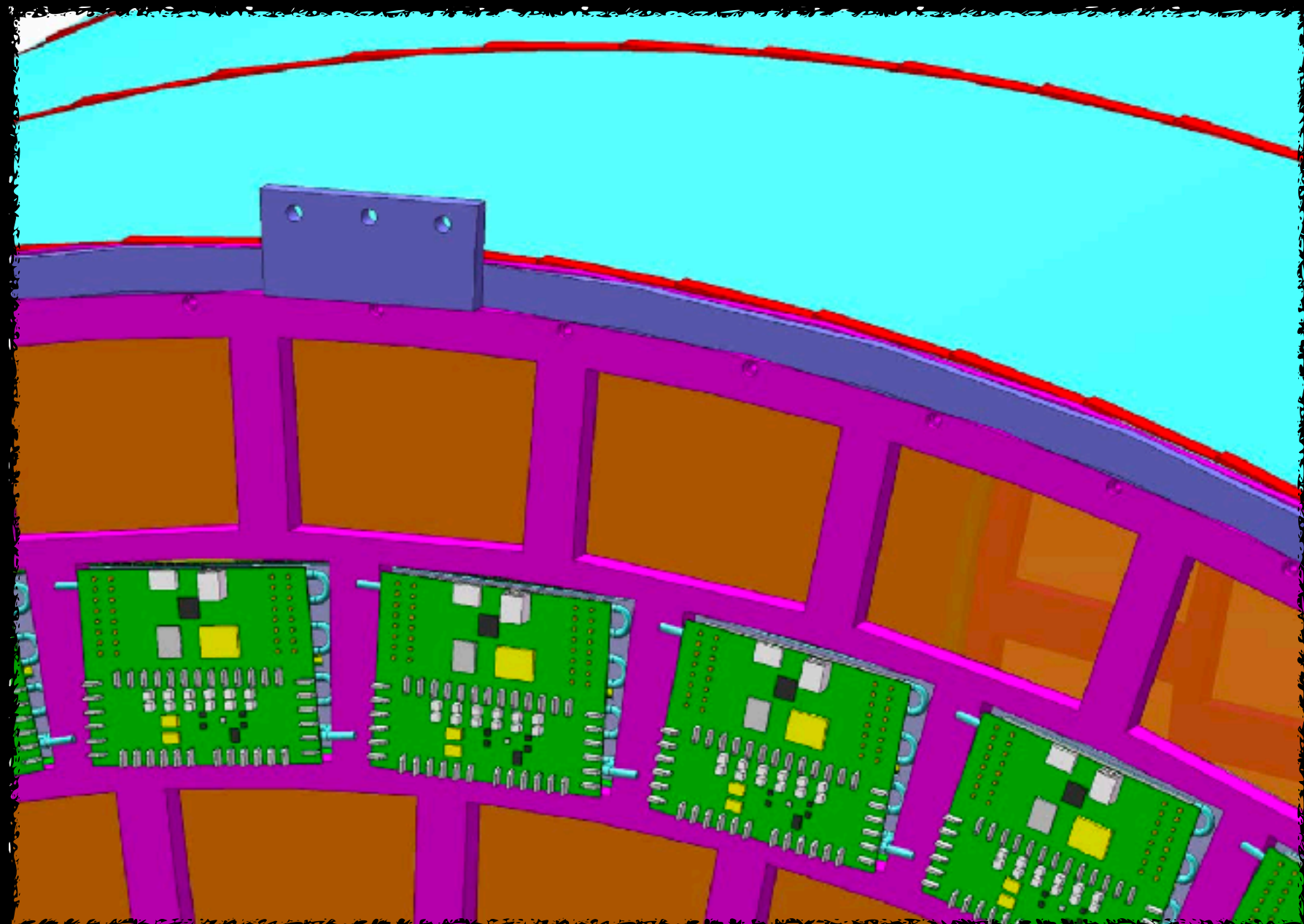
TPC outer wall: 0.69%

TPC inner wall: 0.45%

High granularity readout:

Pad size: 500 μm × 500 μm

The Time Projection Chamber (TPC) - Readout



244 detector modules per endplate

TEPIX: Low-power readout ASIC ($<100 \text{ mW/cm}^2$)
One ASIC for 256 small pads

Double mesh micromegas readout board

The CEPC Reference Detector embraces PFA Calorimetry,
using the full detector for ultimate performance

Physics objects	Measurands	Detector subsystem	Performance requirement
Leptons (e, μ)	PID efficiency Mis-ID rate	Tracker, ECAL HCAL, Muon	$\geq 99\%$ ($p > 5 \text{ GeV}/c$, isolated) $\leq 2\%$ ($p > 5 \text{ GeV}/c$, isolated)
Photons	PID efficiency Mis-ID rate Energy resolution	ECAL, HCAL	$\geq 95\%$ ($E > 3 \text{ GeV}$, isolated) $\leq 5\%$ ($E > 3 \text{ GeV}$, isolated) $\sigma_E/E \leq 3\%/\sqrt{E(\text{GeV})} \oplus 1\%$
Hadronic jets	Energy resolution Mass resolution	Tracker ECAL, HCAL	$\sigma_E/E \sim 30\%/\sqrt{E(\text{GeV})} \oplus 4\%$ BMR $\leq 4\%$
Jet flavor tagging	b-tagging efficiency c-tagging efficiency	Full detector	$\sim 80\%$, mis-ID of uds $< 0.3\%$ $\sim 50\%$, mis-ID of uds $< 1\%$

**Benchmark
physics
requirements**

A crystal electromagnetic calorimeter



Significant R&D on Silicon Photomultipliers (SiPM) and Readout Electronics

An issue common to ECAL, HCAL and Muon Detectors

The **SiPM** is required to have:

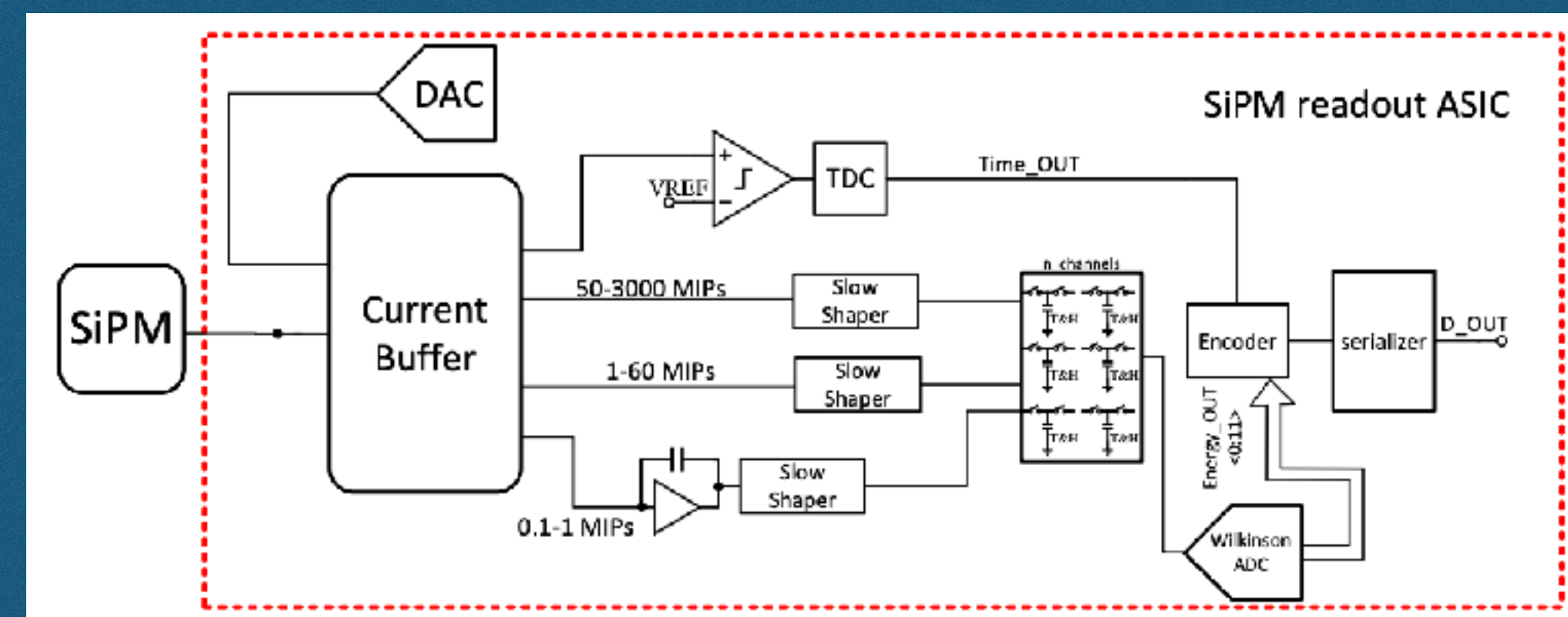
- high dynamic range
- moderate Photon Detection Efficiency (PDE)
- acceptable Dark Count Rate (DCR)

SiPM Type	NDL EQR06	NDL EQR10	HPK S14160-3010PS
Pixel Pitch μm	6	10	10
Pixel Quantity in $3 \times 3 \text{ mm}^2$	244,719	90,000	89,984
Pixel Gain	8×10^4	1.7×10^5	1.8×10^5
Typical peak PDE	30 % (at 420 nm)	36 % (at 420 nm)	18 % (at 460 nm)
Typical DCR (20 °C)	2.5 MHz	3.6 MHz	700 kHz
Inter-pixel Crosstalk	12 %	N/A	< 1 %
Terminal Capacitance (pF)	45.9 pF	31.5 pF	530 pF

selected candidates

New ASIC

SIPAC: SiPM ASIC for Calorimeter
(to be commonly used)

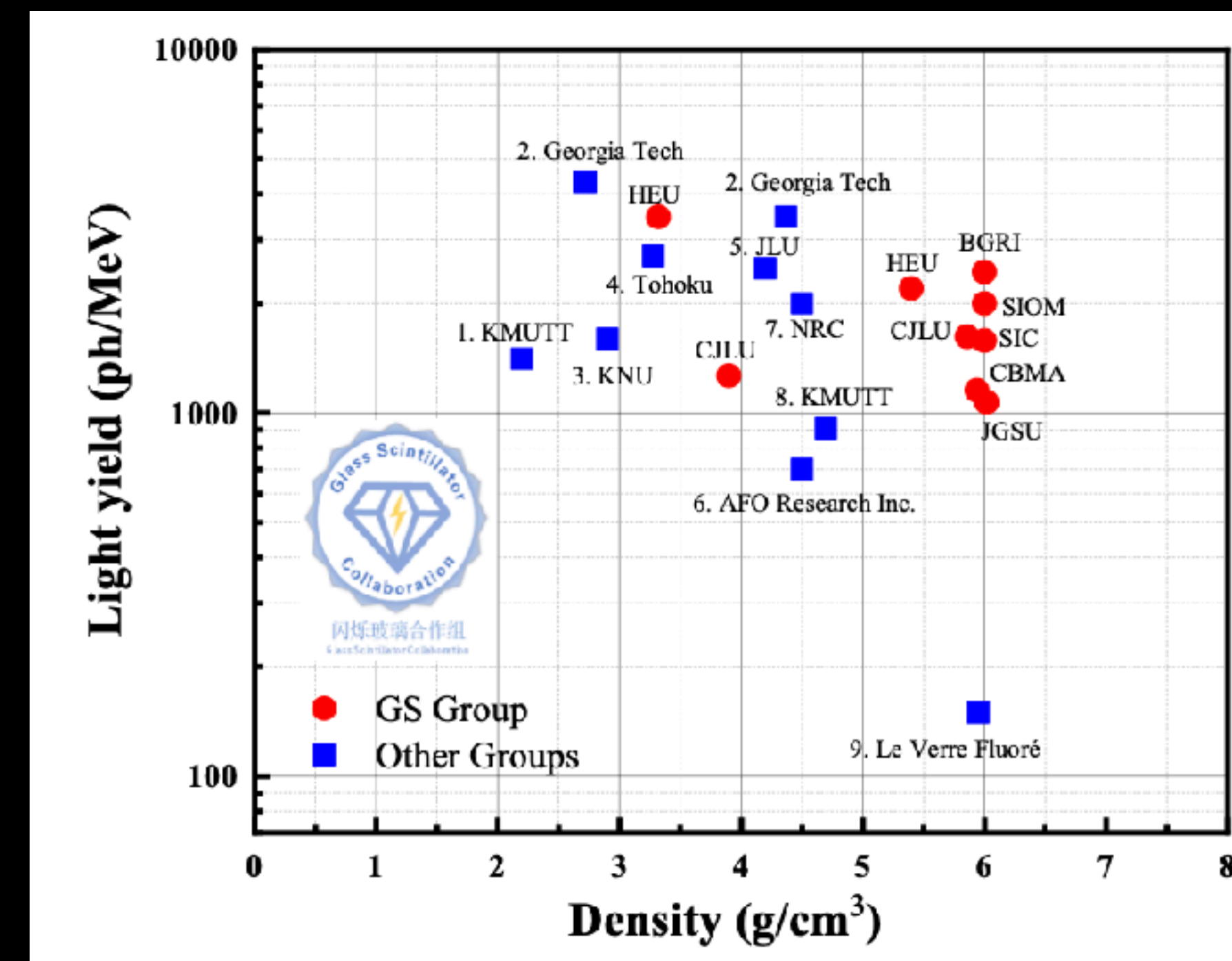
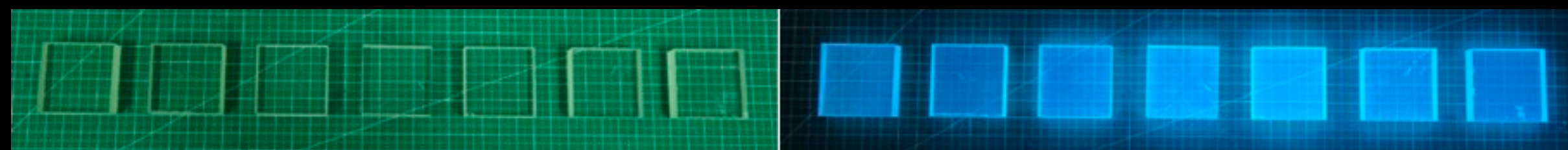


The Hadronic Calorimeter: Glass Scintillation

Using Gadolinium Fluoro-Oxide (GFO) glass

Key parameters	GFO glass	BGO	DSB Glass
Density (g/cm ³)	6.0	7.13	4.2
Melting point (°C)	1250	1050	1550
Radiation length (cm)	1.59	1.12	2.62
Molière radius (cm)	2.49	2.23	3.33
Nuclear interaction length (cm)	24.2	22.7	31.8
Z _{eff}	56.6	71.5	49.7
dE/dx (MeV/cm)	8.0	8.99	5.9
Emission peak (nm)	400	480	430
Refractive index	1.74	2.15	
Light yield (ph/MeV)	~ 1500	7500	2500
Energy resolution (% at 662 keV)	~ 23	9.5	
Scintillation decay time (ns)	~ 60, 500	60, 300	90, 400

Sample size of 5 × 5 × 5 mm³



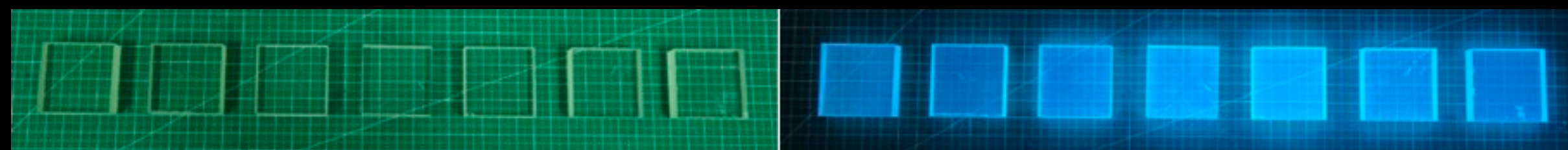
Goal is **high light yield**, **large density** and lower attenuation length

The Hadronic Calorimeter: Glass Scintillation

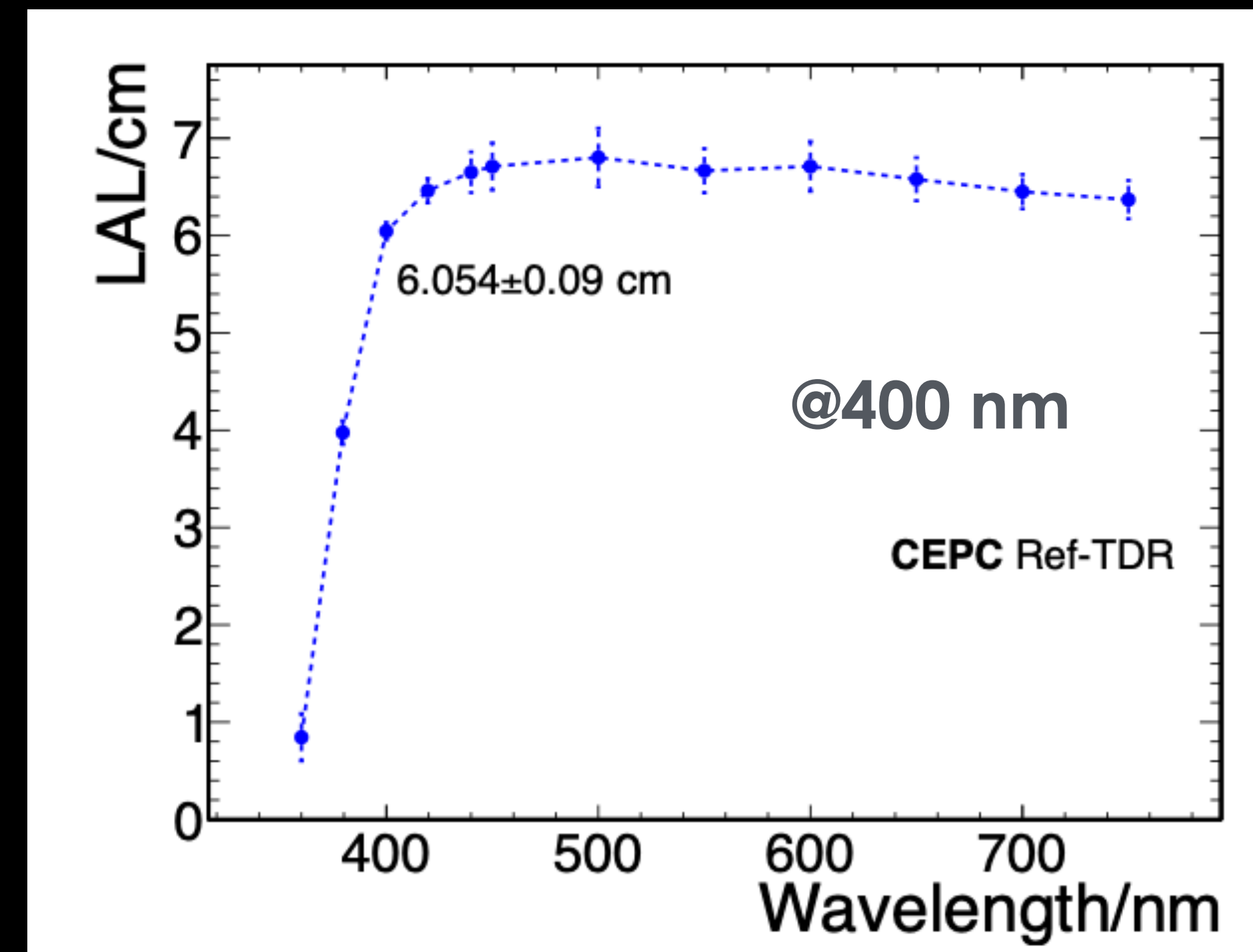
Using Gadolinium Fluoro-Oxide (GFO) glass

Key parameters	GFO glass	BGO	DSB Glass
Density (g/cm ³)	6.0	7.13	4.2
Melting point (°C)	1250	1050	1550
Radiation length (cm)	1.59	1.12	2.62
Molière radius (cm)	2.49	2.23	3.33
Nuclear interaction length (cm)	24.2	22.7	31.8
Z _{eff}	56.6	71.5	49.7
dE/dx (MeV/cm)	8.0	8.99	5.9
Emission peak (nm)	400	480	430
Refractive index	1.74	2.15	
Light yield (ph/MeV)	~ 1500	7500	2500
Energy resolution (% at 662 keV)	~ 23	9.5	
Scintillation decay time (ns)	~ 60, 500	60, 300	90, 400

Sample size of 5 × 5 × 5 mm³



Best GFO GS sample

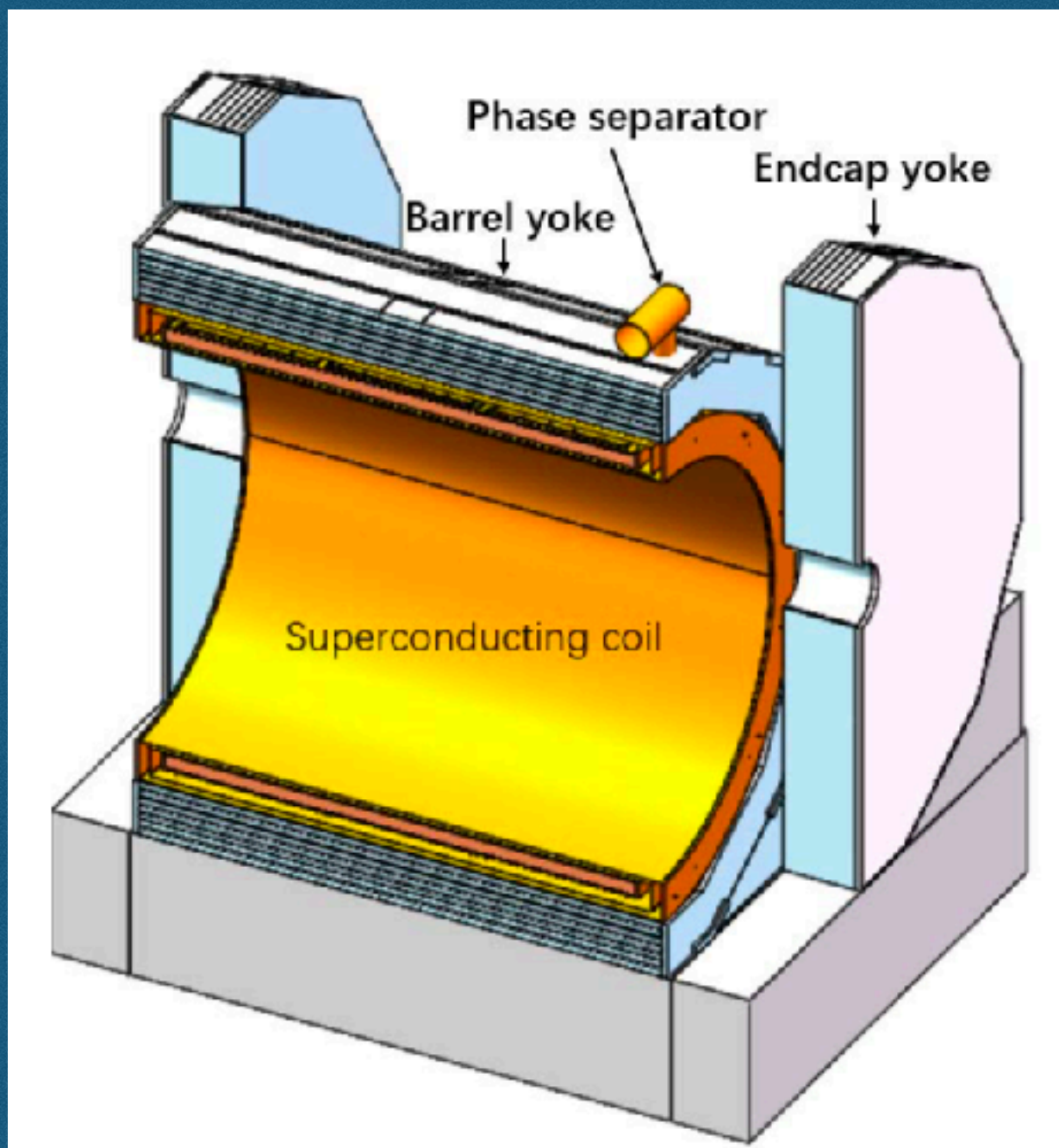


Goal is high light yield, large density and **lower attenuation length**

The Magnet System: Superconducting Solenoid

Chapter 10

LTS: Low-temperature SC



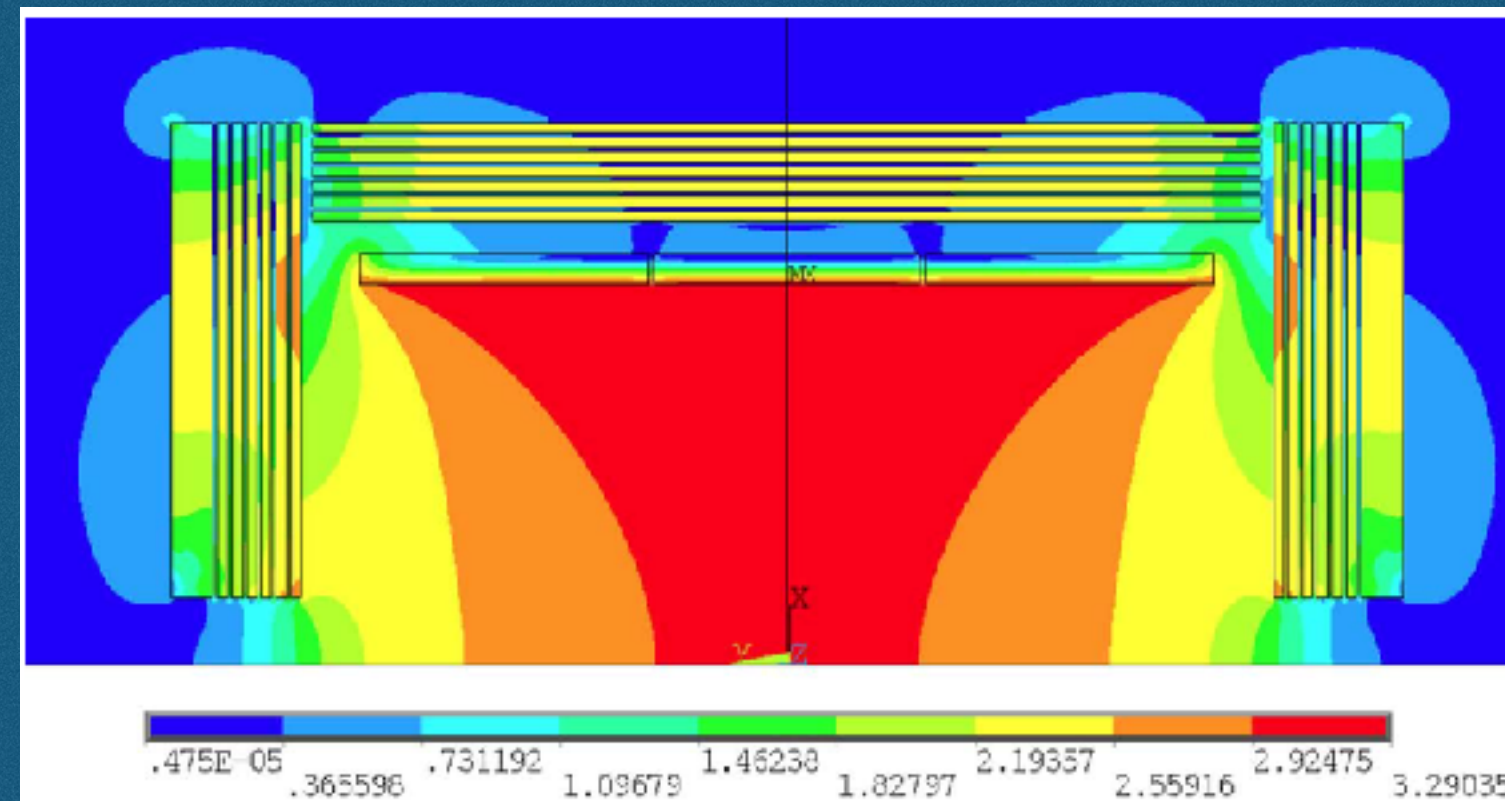
Coil $\phi_{\text{inner}} = 7.3 \text{ m}$
Coil $\phi_{\text{outer}} = 7.92 \text{ m}$
Coil length = 8.15 m

Operational conditions:

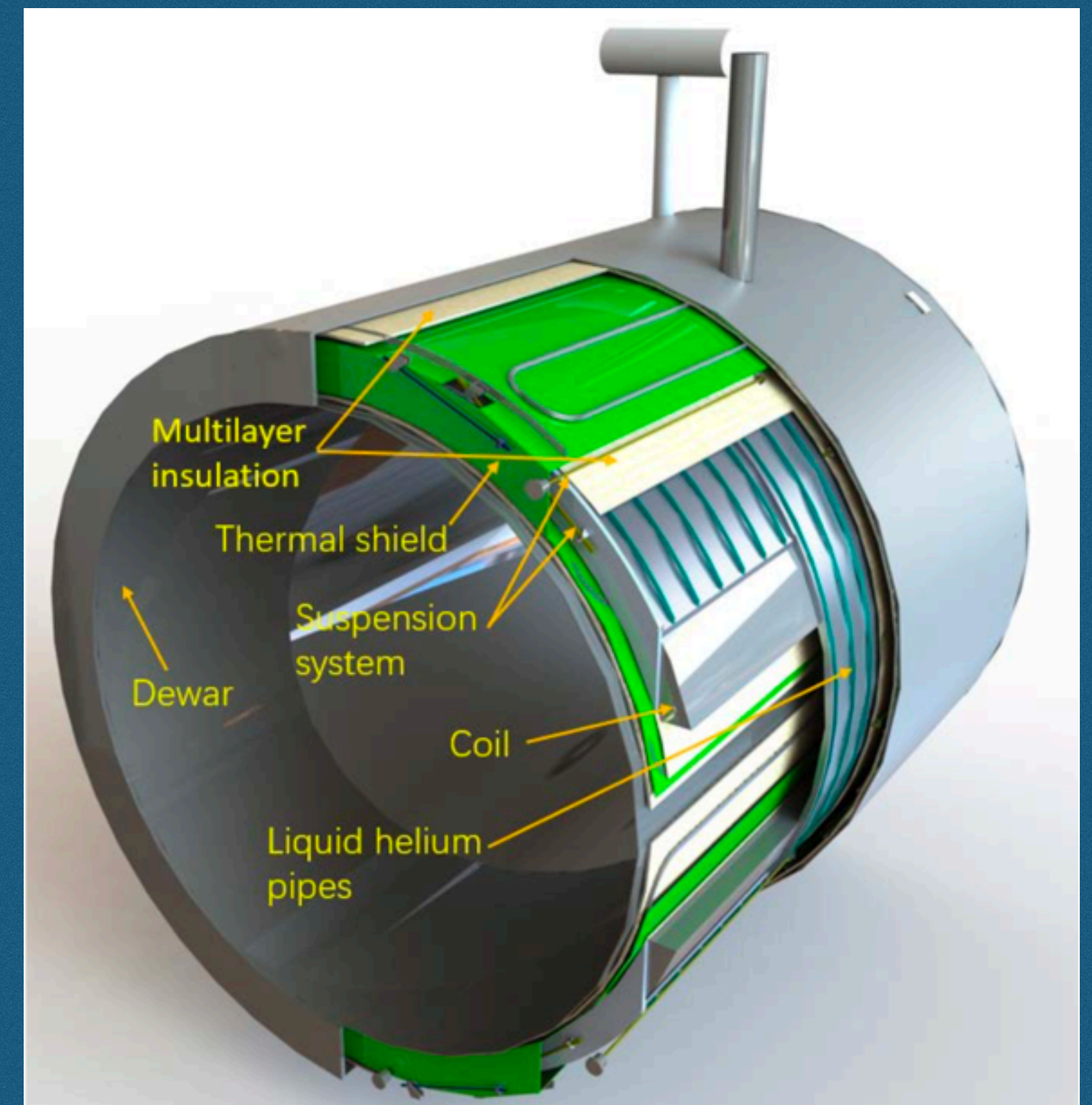
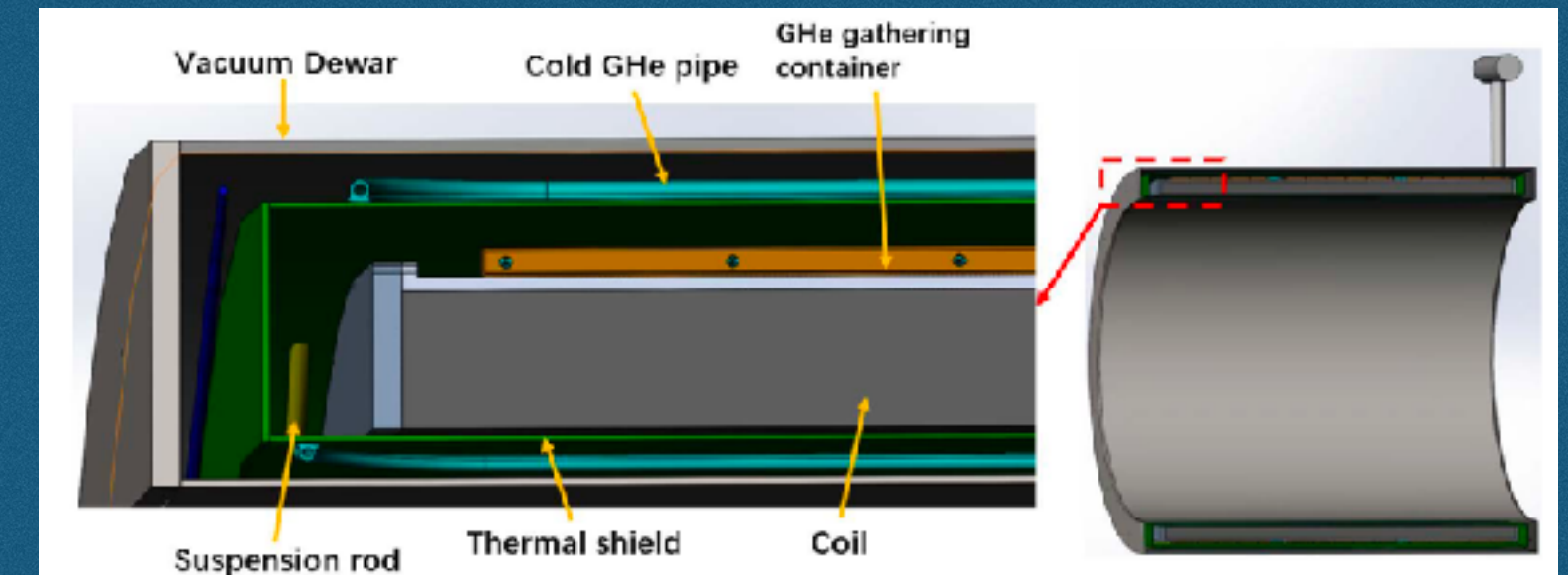
Central magnetic field: 3 T
Temperature: 4.5 K
Current: 17 kA

Magnetic field uniformity

~7% as required by TPC



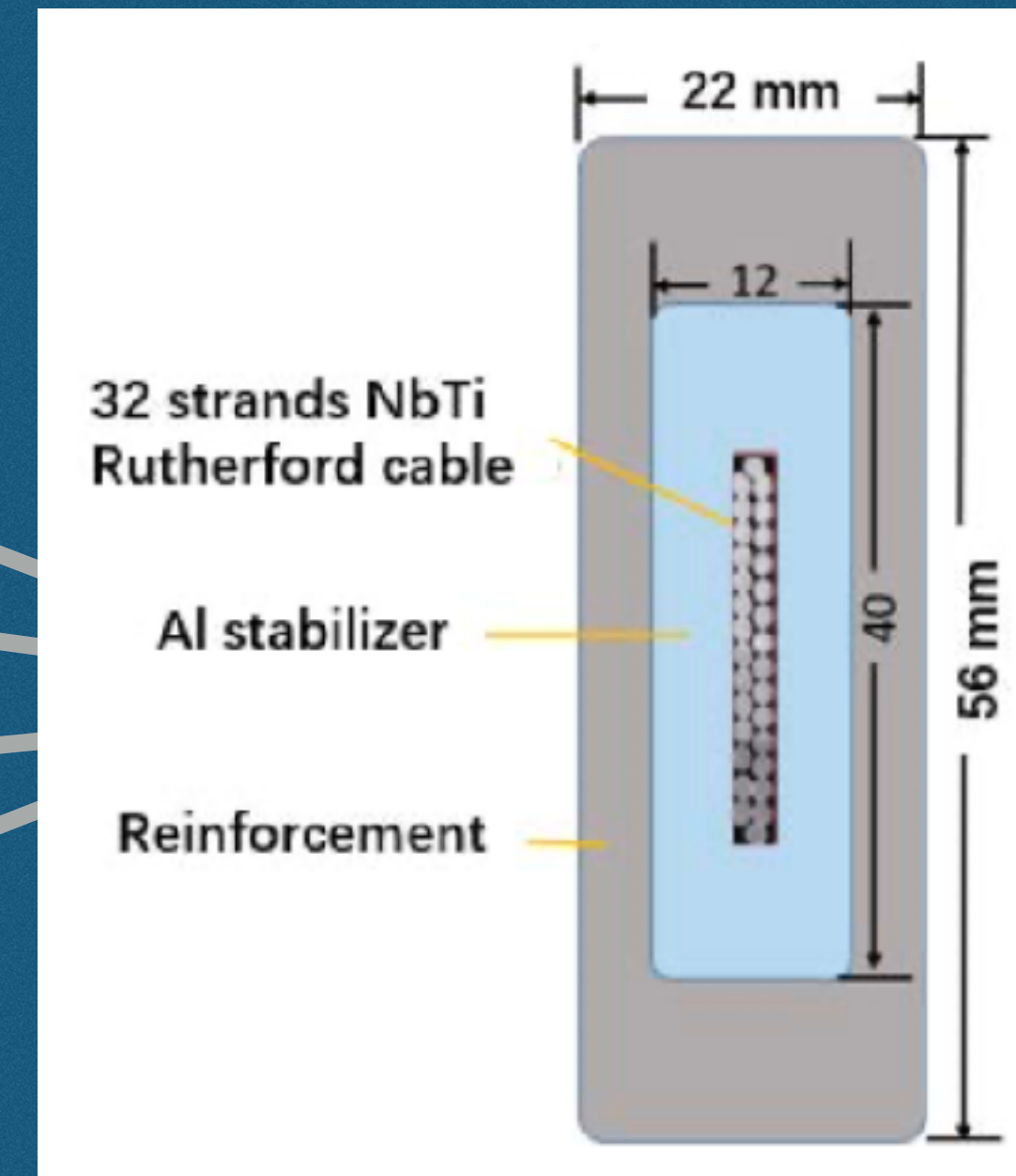
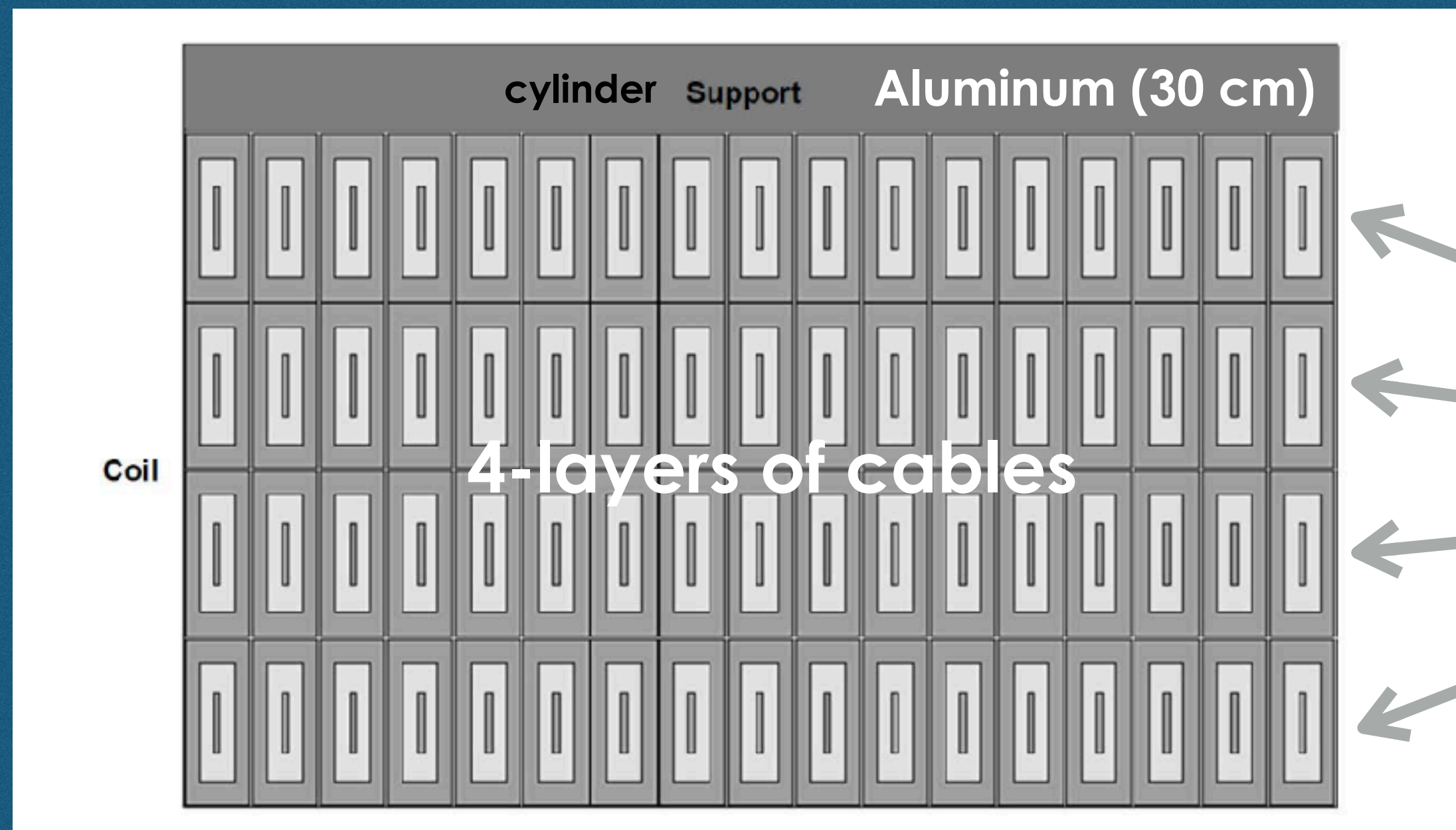
Detailed mechanical design



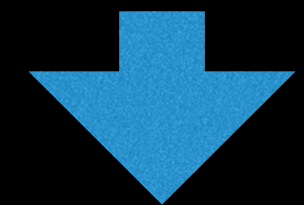
The Magnet System: Superconducting Solenoid

Aluminum Stabilized Superconducting Cable

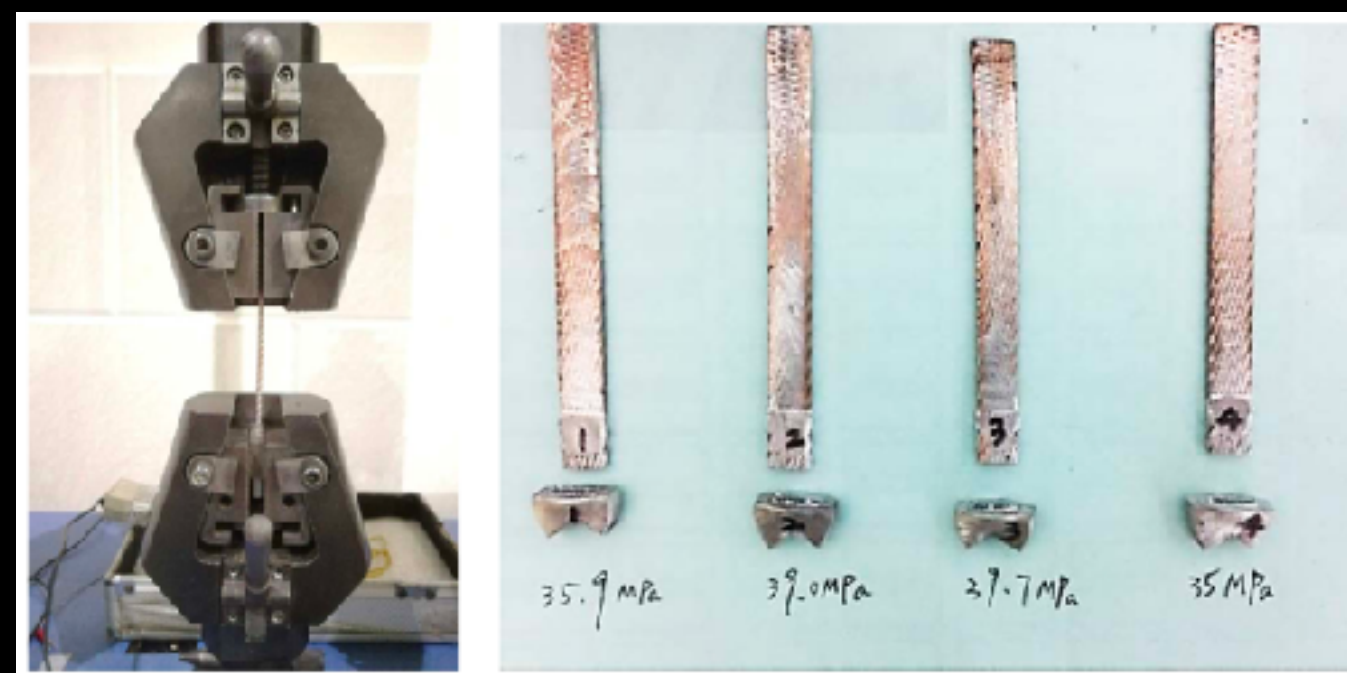
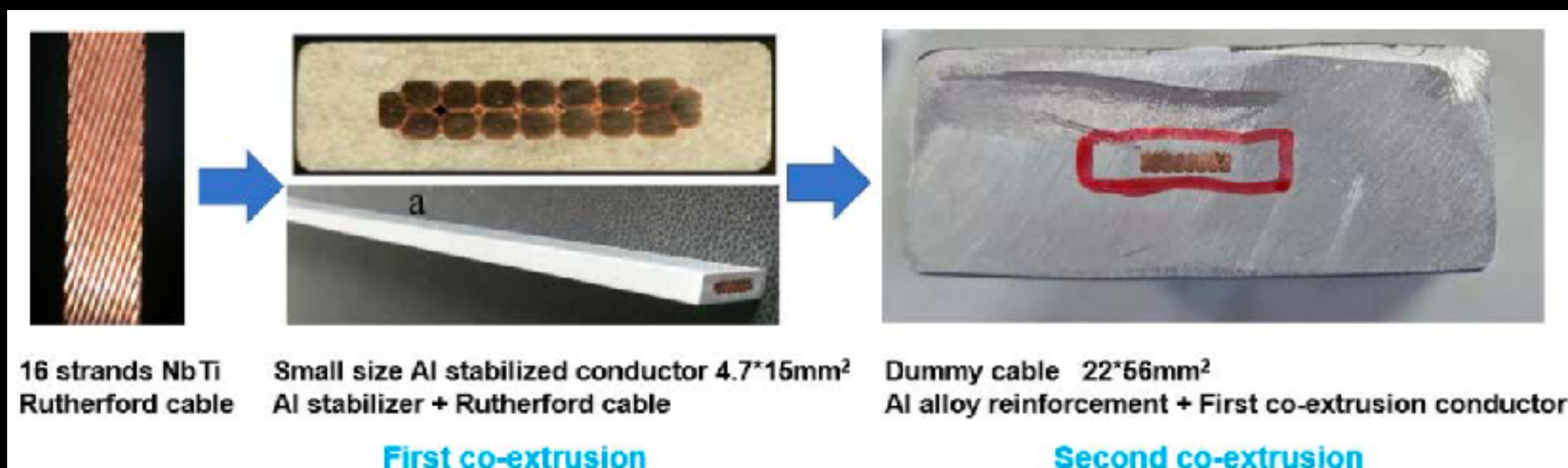
Aim to produce a thin solenoid puts pressure on the design of superconducting cable



Requires double extrusion cables for sufficient strength to survive stress energized under cold

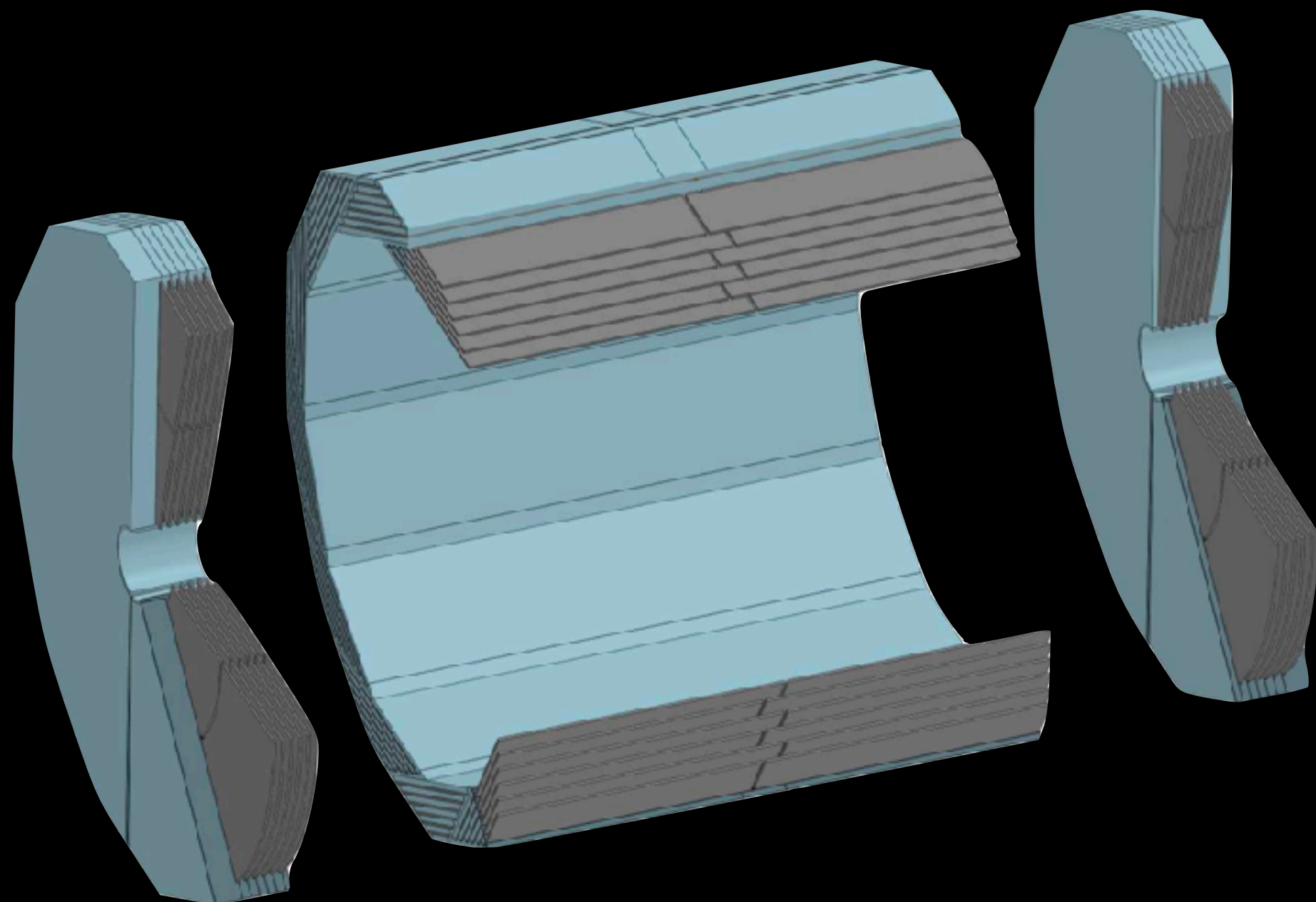


Complex cable under development

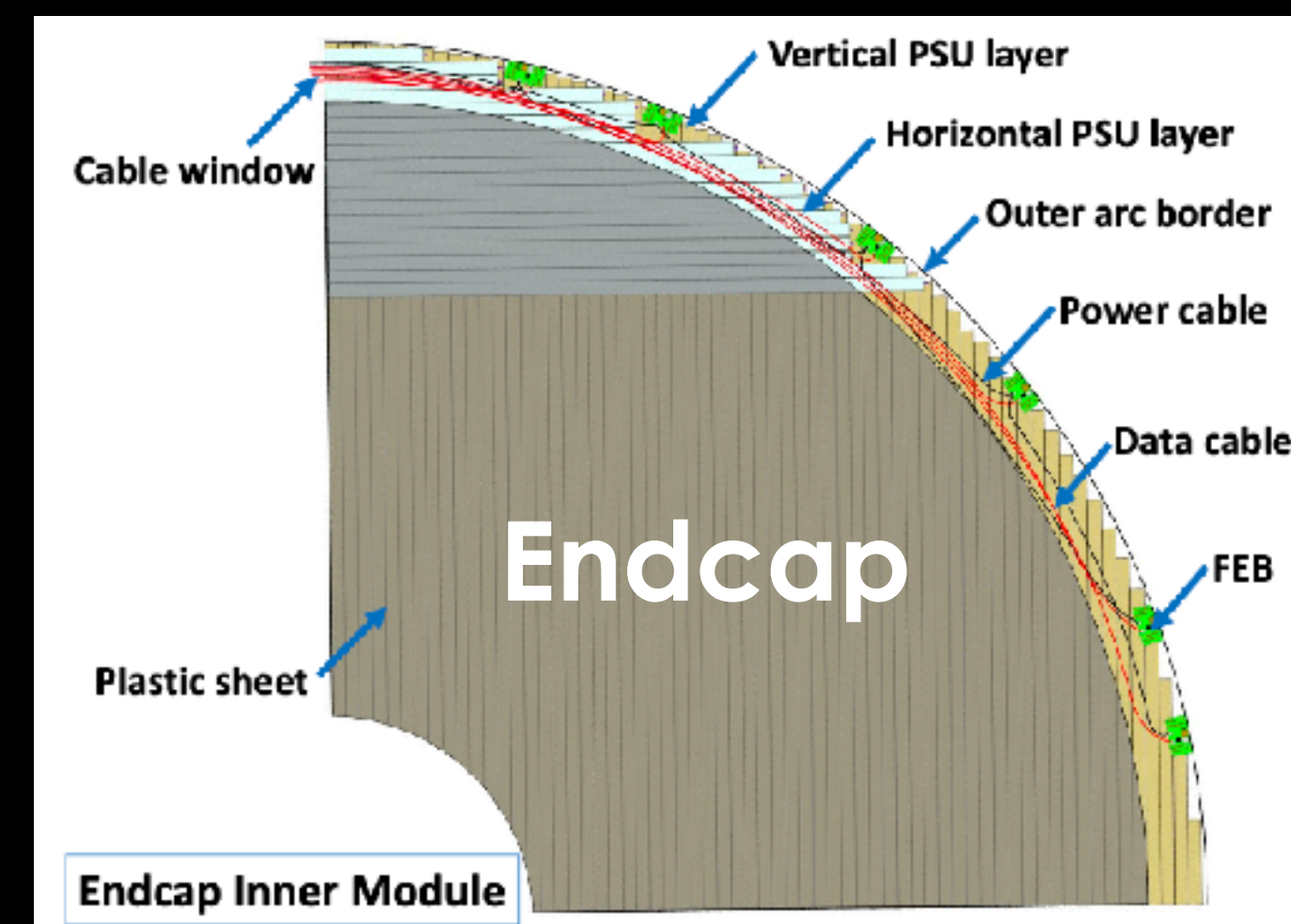
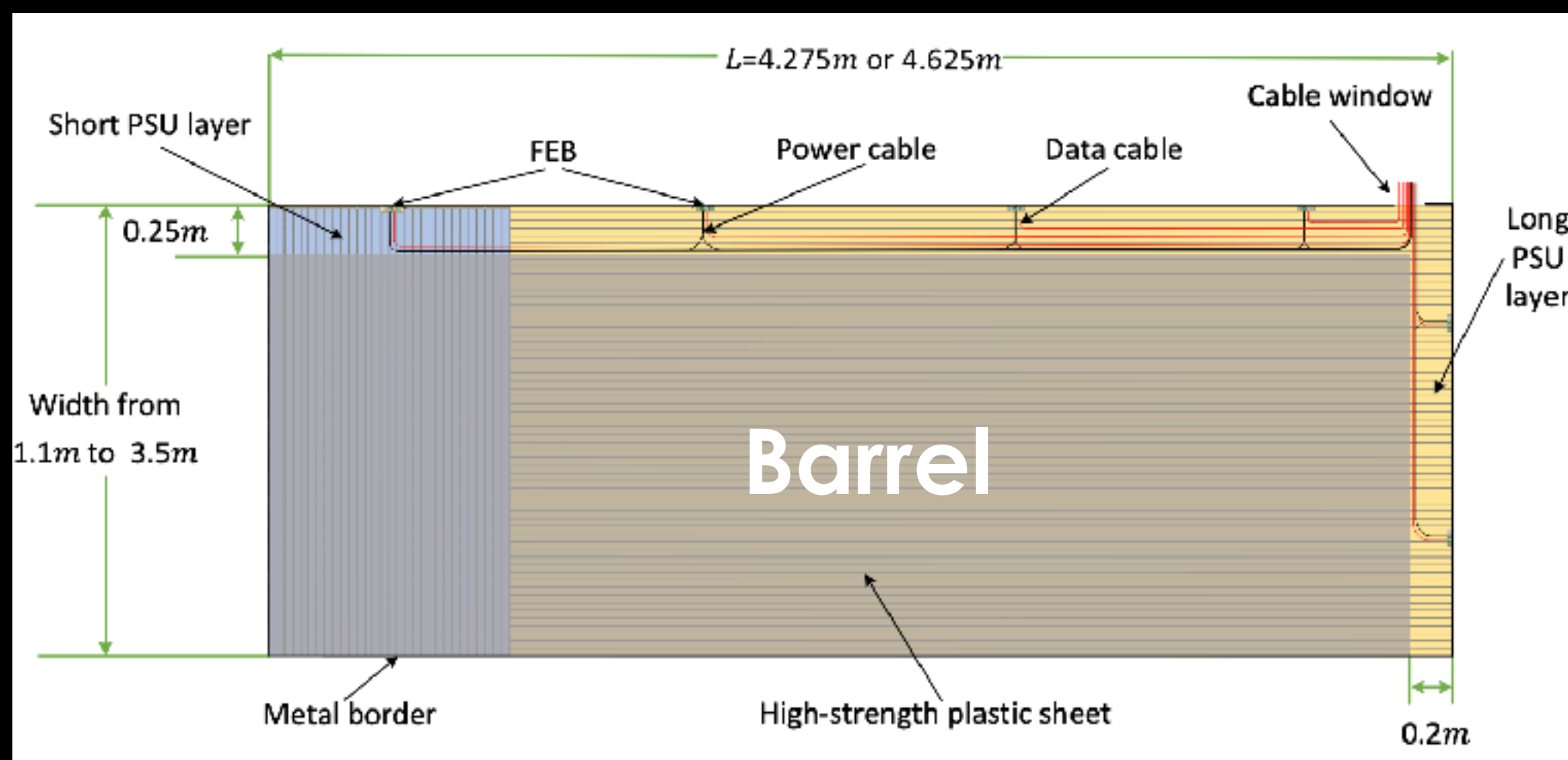


250-m dummy cable produced and tested

6 layers of plastic scintillator strips embedded in the iron Yoke

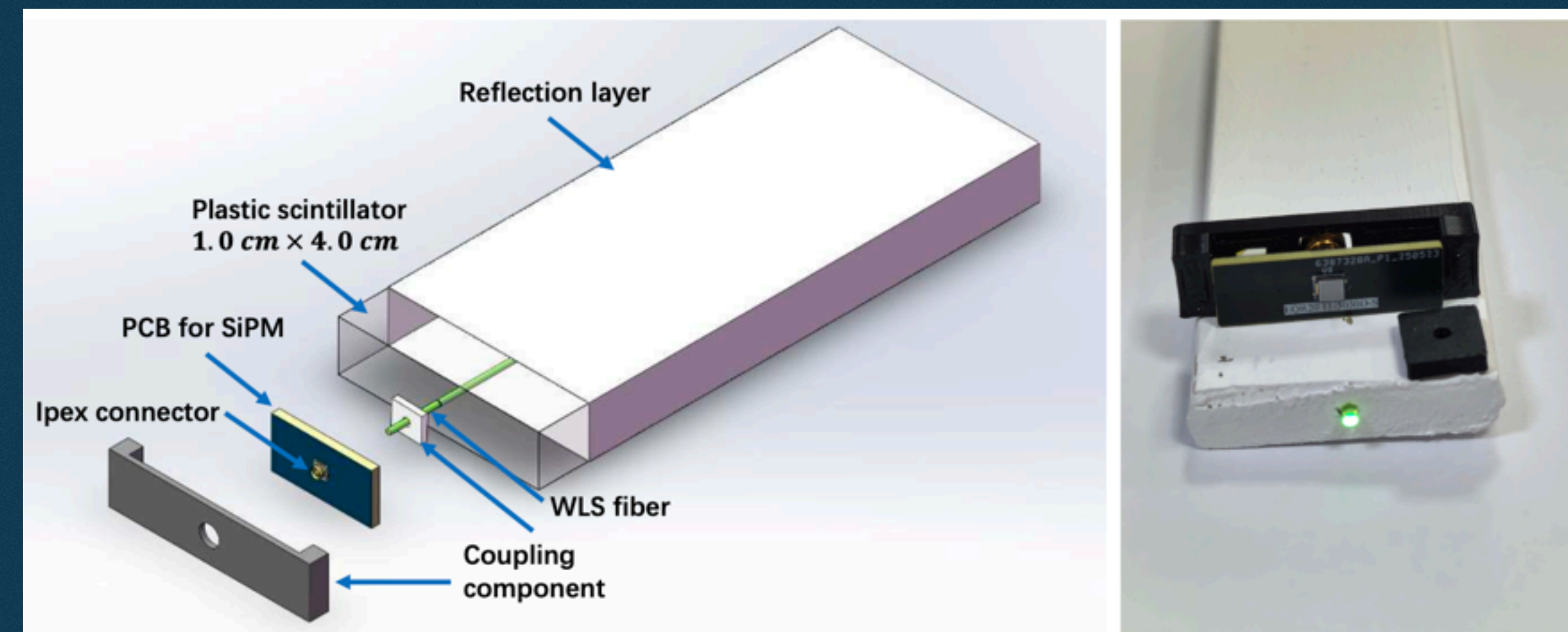
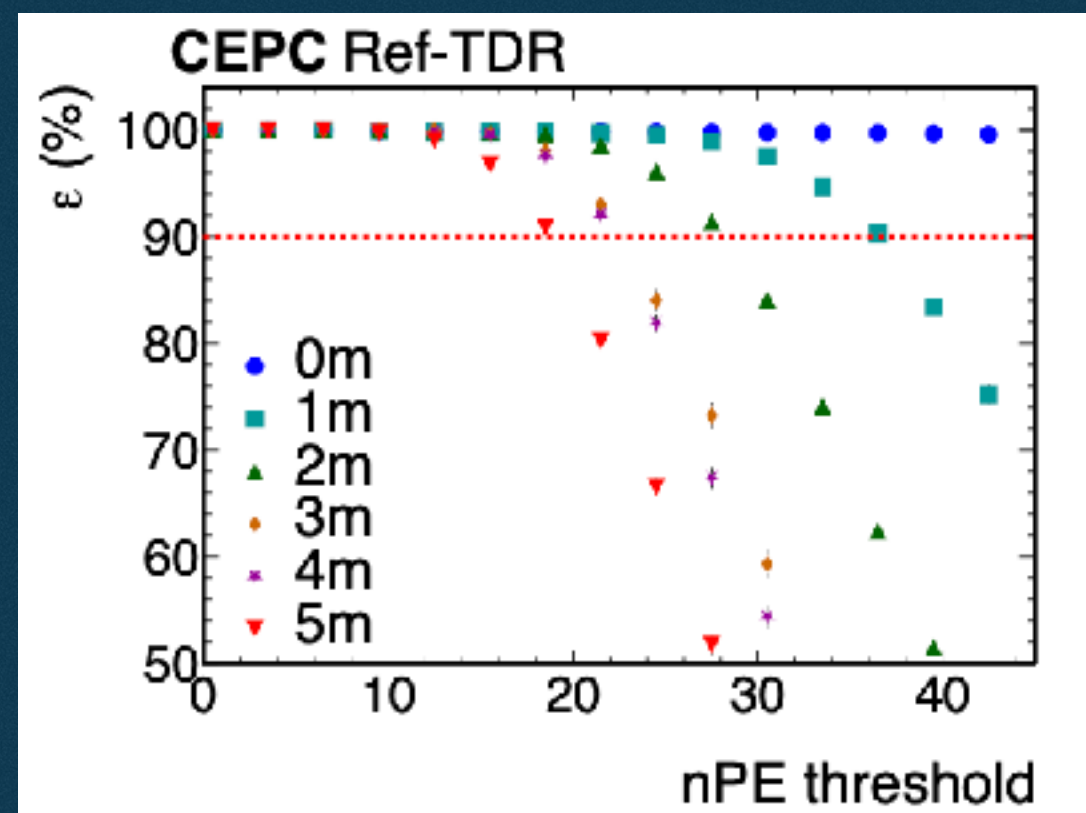
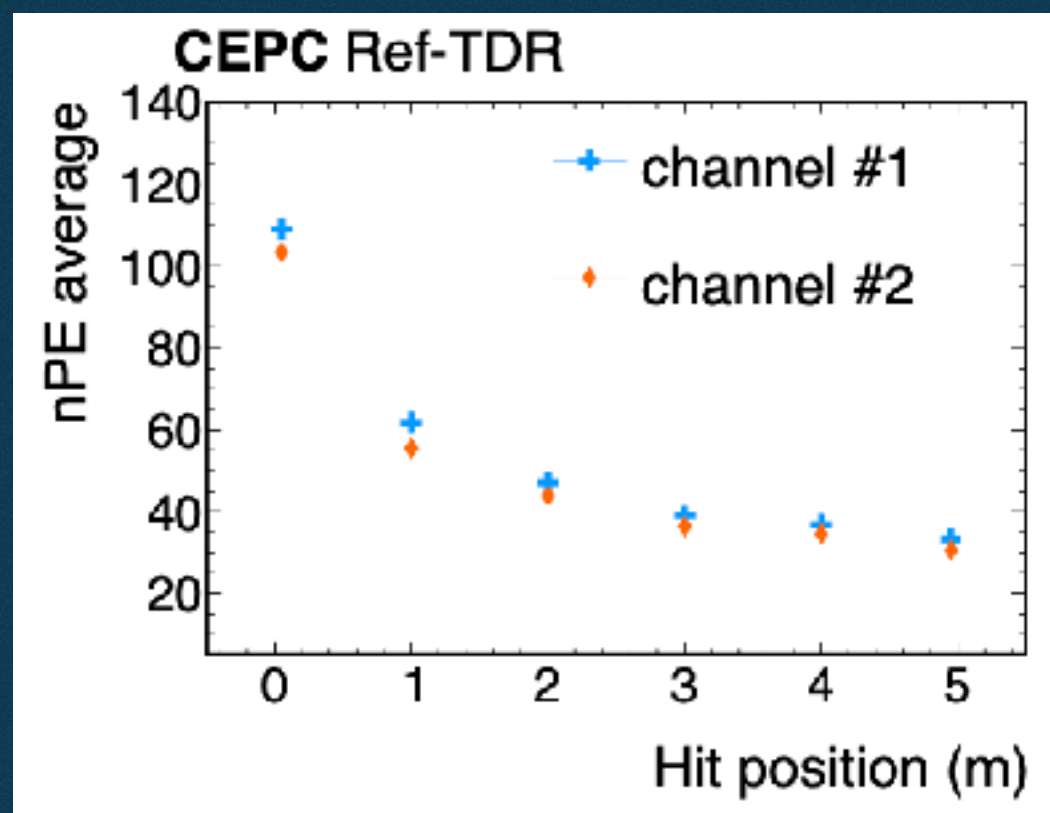


- Solid angle coverage: $> 98\% \times 4\pi$
- μ identification efficiency: $> 95\%$
- $\pi \rightarrow \mu$ fake rate: $< 1\%$
- Spatial resolution: ~ 1 cm
- Time resolution: ~ 1 ns
- Rate capability: 50 Hz/cm^2



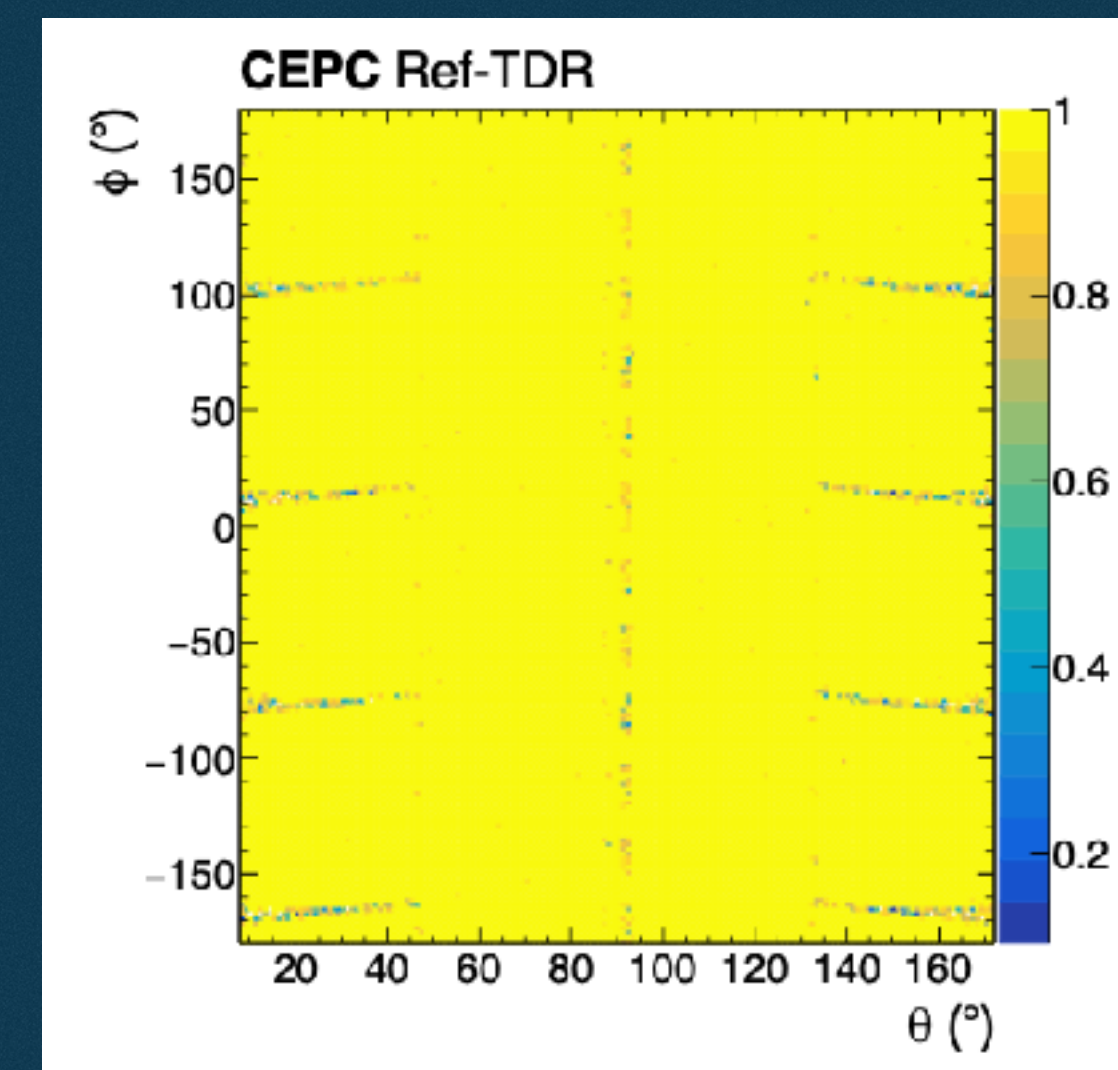
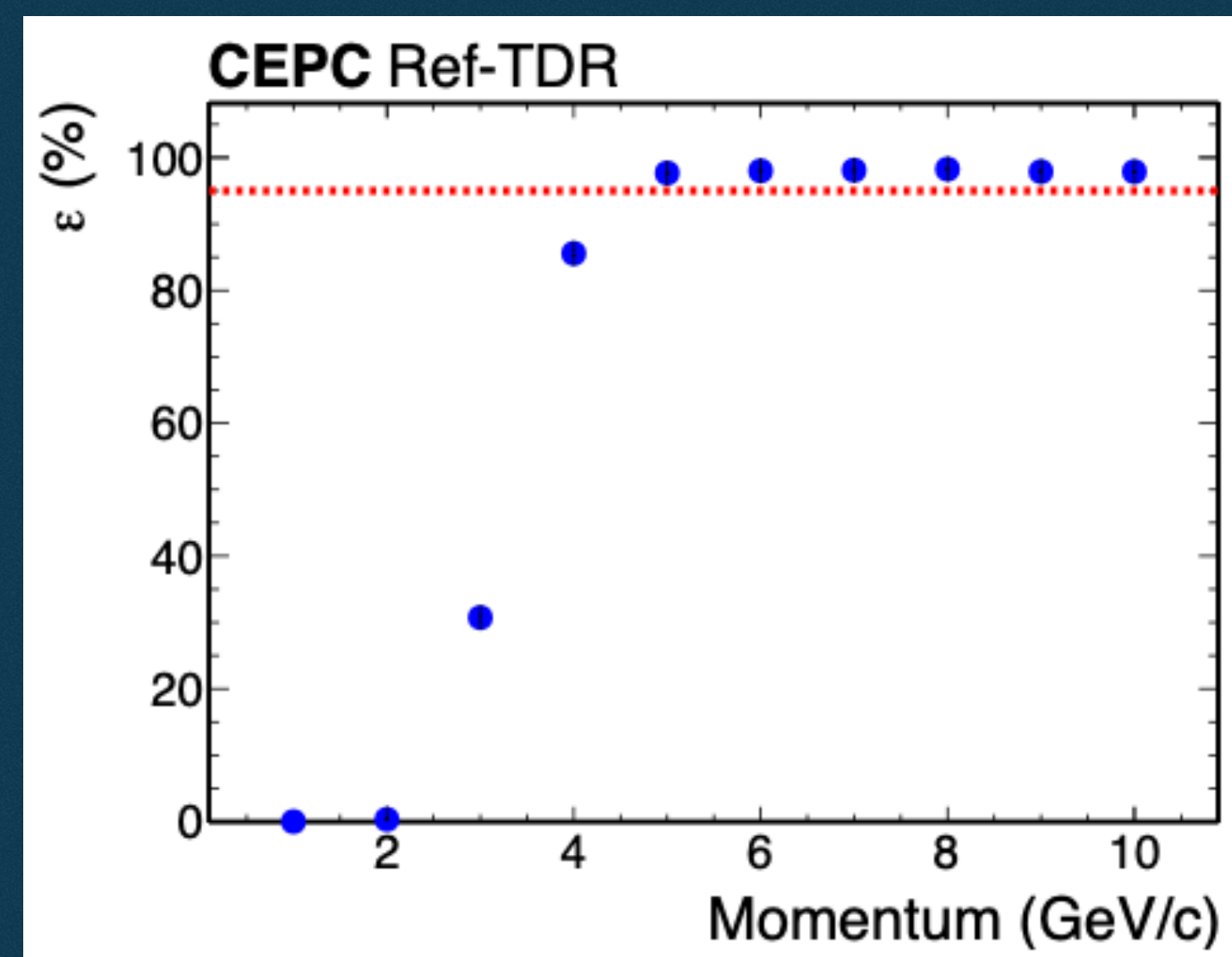
The Muon Detector

Extensive R&D on SiPM and long plastic scintillator strips with WLS fibers

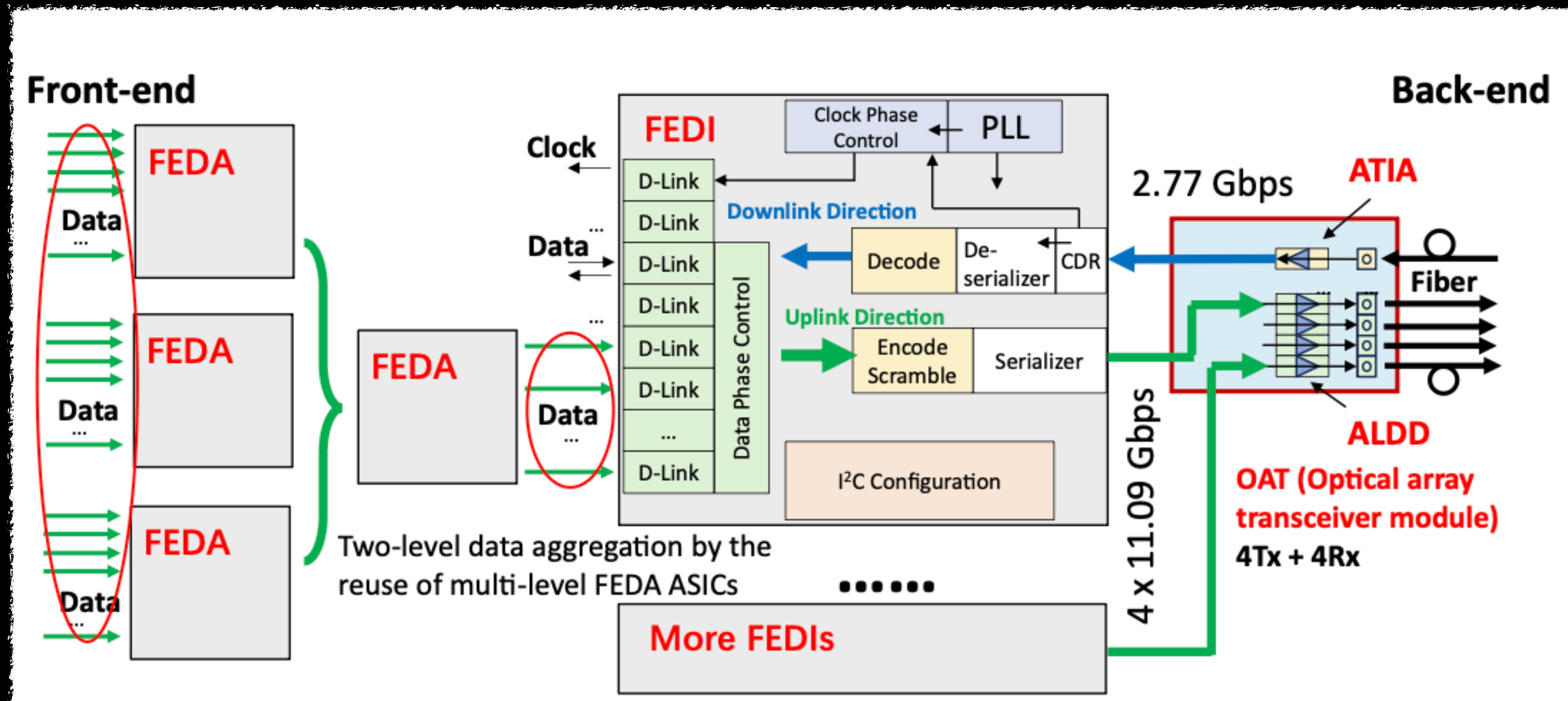


5 meter strips with >90% efficiency

Standalone muon detector efficiency
~98% for muons above 4.5 GeV/c

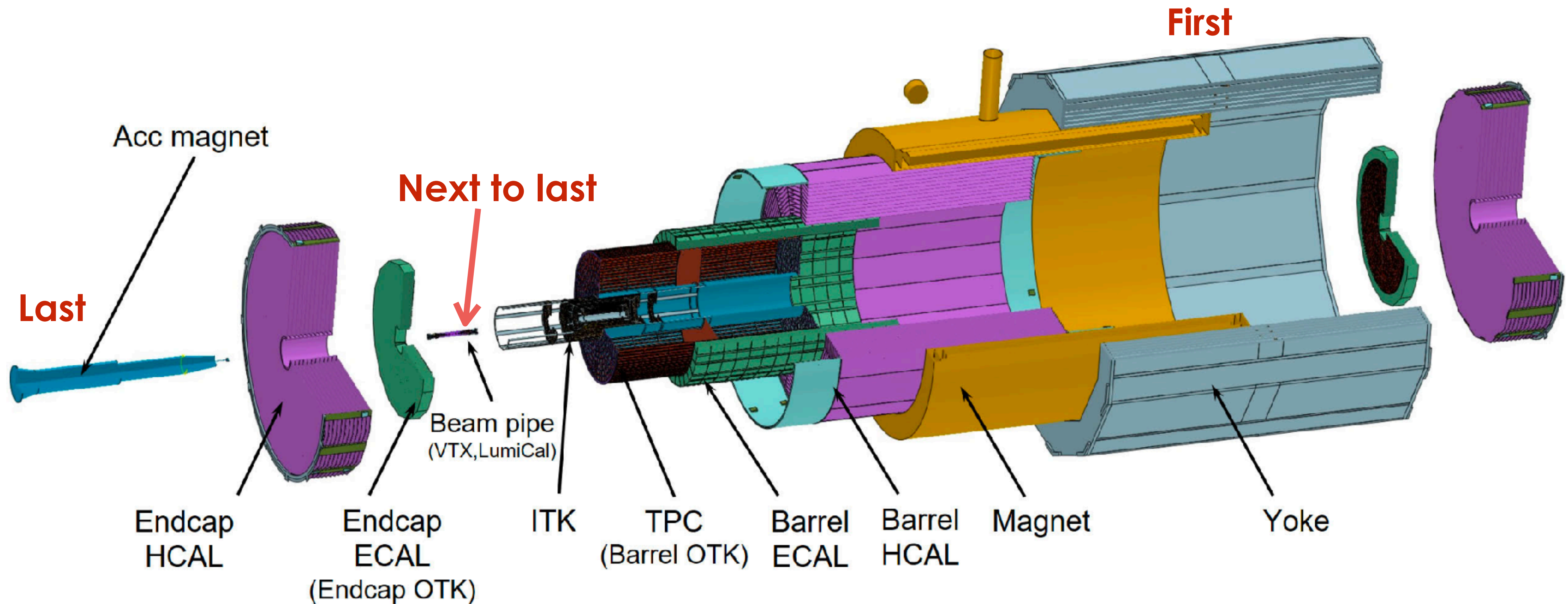


Significant effort put into defining common infrastructure, such as, the architecture of the data interface



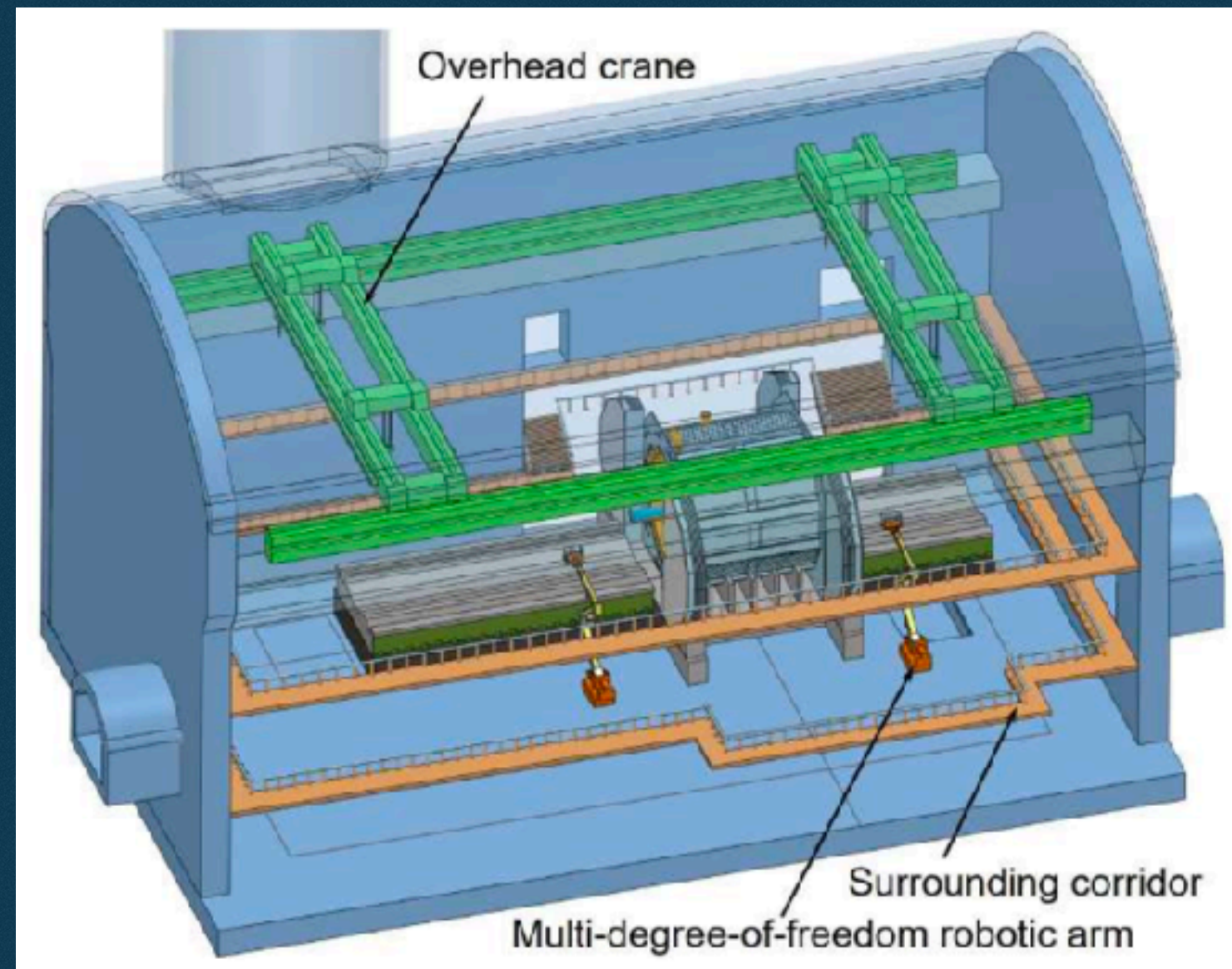
The data interface has a custom Optical Array Transceiver (OAT), and ASICs including: the Front-End Data Aggregator (FEDA), Front-End Data Interface (FEDI), Array Laser Diode Driver (ALDD), and Array Transimpedance Amplifier (ATIA)

Installation will proceed from outside inwards

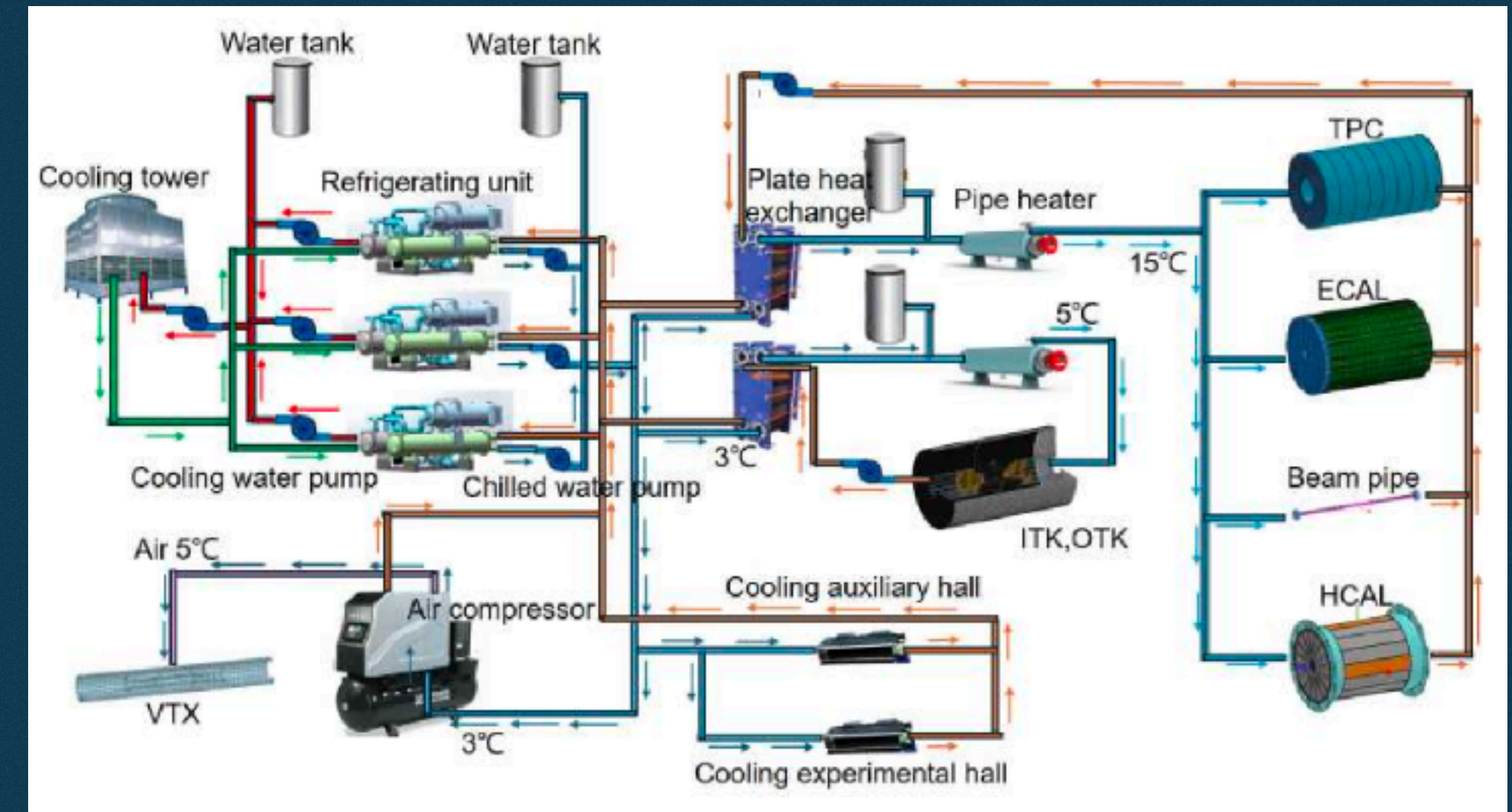


Layout of underground halls

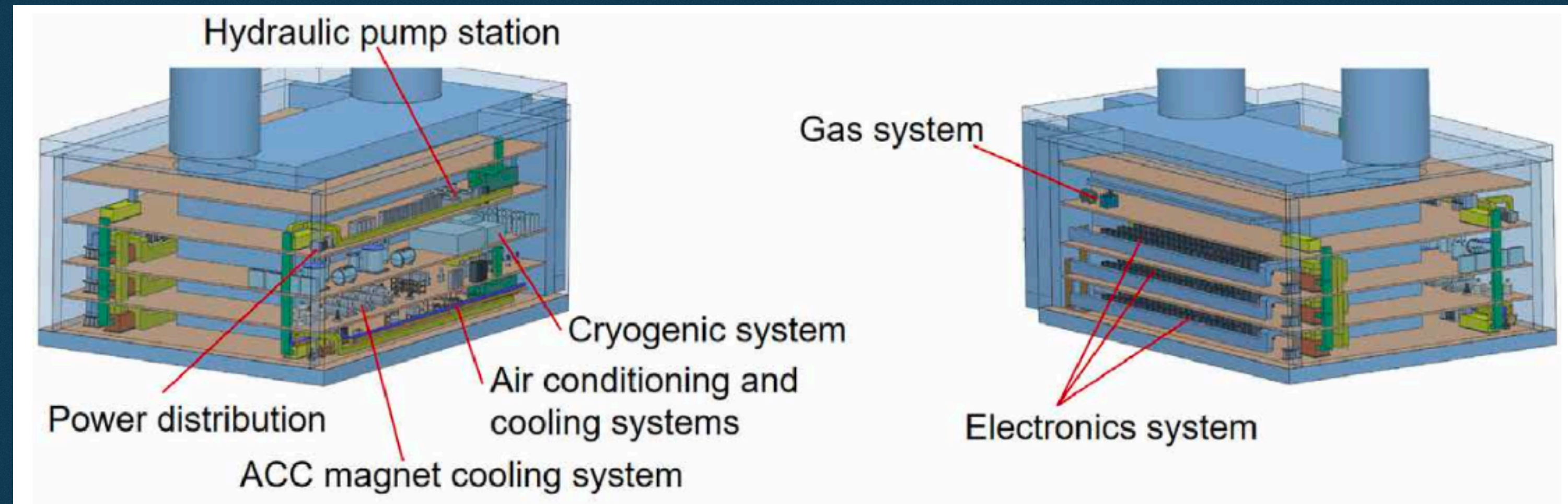
Collision hall



Cooling system



Auxiliary halls and facilities



Detector Cost



- **Detector total cost estimate: 333 MCHF**
 - Includes 3% installation cost, but no contingency
 - Includes projection for cost evolution in next 5-10 years

System	Cost (MCHF)
The Reference Detector	333.3
Machine detector interface and luminosity measurement	1.8
Vertex detector	4.5
Silicon tracker	29.7
Time projection chamber	6.2
Electromagnetic calorimeter	115.0
Hadron calorimeter	68.3
Muon detector	2.5
Detector magnet system	22.0
Readout electronics	19.3
Trigger and data acquisition	12.2
Offline software and computing	23.1
Mechanics and integration	28.9

Cost drivers

1. Crystal calorimeter
2. Hadronic calorimeter
3. Silicon tracker

Review by IDRC

The cost evaluation for the reference detector to be **well structured, robust**, and consistent with **comparable assessments** from other large-scale experimental projects