国家重点研发计划

高能环形正负电子对撞机关键技术研发和验证

所属专项：　大科学装置前沿研究

项目负责人：　João Guimarães da Costa

项目承担单位：中国科学院 高能物理研究所

Task Final Review Meeting: June 19-20, 2023

中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

国家重点研发计划

R&D and Verification of Key Technologies for a High Energy Circular Electron-Positron Collider

所属专项：　大科学装置前沿研究

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中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

University of Science and Technology of China 1958

Shanghai Jiao Tong University 1896

Shandong University 1901

Nanjing University 南京大学

Northwestern Polytechnical University 1938

任务分解和主要研究: Task Arrangement and Main Research

Task	Task Leader Institute	Research Content	Funds
Task 1: Accelerator	Yunlong Chi IHEP	Prototypes: low-field dipole magnet, vacuum pipe, RF shield bellows, HE separator. Beam polarization study	974万
Task 2: Silicon Detector	João Guimarães da Costa IHEP	Prototype: silicon tracker with high-resolution sensor, radiation resistant	1200万
Task 3: Hadronic Calorimeter	Jianbei Liu USTC	Prototype: imaging hadron calorimeter with scintillator + silicon photomultiplier tube (SiPM)	971万

Total funding: 3145 万

Agenda for the review

Today: Detector Tasks

Task 3: Calorimeter

9:00 AM → 9:10 AM	Leader welcome speech 承担单位领导致辞	10m
9:10 AM → 9:40 AM	Overview of project 项目总结汇报 Speaker: Joao Guimaraes da Costa	30m
9:40 AM → 12:00 PM	Task3 课题三：成像型强子量能器技术验证 papers and confere... / task3-self assess r... / 评审意见草稿-Grou... / 课题3-专家个人评...	
9:40 AM	Overview 课题三整体汇报 (20'+5') Speaker: Jianbei Liu (University of Science and Technology of China)	20m
10:00 AM	Group photo and Coffee break 合影+茶歇	
10:20 AM	Highlight of HCAL R&D 量能器技术研究亮点 (20'+5') Speaker: Yunlong Zhang (University of Science and Technology of China)	25m
10:45 AM	Analysis of beam test result 束流测试数据分析 (20'+5') Speaker: 禹坤 石 (中国科学技术大学) AHCAL Calibration ...	25m
11:10 AM	Discussion (Project group only) Main building A511	50m
11:10 AM	Discussion (Refrees only) 评委内部讨论与撰写评审意见	50m
12:00 PM → 2:00 PM	Lunch box 午餐	

Task 2: Vertex Detector

1:20 PM → 5:25 PM	Task2 课题二：硅径迹探测器关键技术验证 papers and confere... / Task2 self-assess... / 课题2-专家个人评... / 课题2评审意见草稿...	
1:20 PM	Lab visit 参观样机和实验室	40m
2:00 PM	Overview 课题二整体汇报 （20'+5'） Speaker: 梁志均 LIANG Zhijun	25m
2:25 PM	Sensor chip design and testing 传感器芯片设计与测试（20'+5'） Speaker: Ying ZHANG (IHEP)	25m
2:50 PM	Structure and assembly of detector prototype 探测器样机的结构与组装（20'+5'） Speaker: Jinyu Fu (高能所)	25m
3:15 PM	Coffee break	
3:35 PM	Analysis of beam test result 束流测试 (20'+5') Speaker: Shuqi Li	25m
4:00 PM	Discussion (Project group only) Main building A511	1h
4:00 PM	Discussion (Refrees only) 评委内部讨论与撰写评审意见	1h
6:00 PM → 7:00 PM	Dinner	

Agenda for the review

Tomorrow

Task 1: Accelerator

9:00 AM → 12:30 PM **Task1 课题一：高能环形正负电子对撞机加速器关键技术验证**

paperlist-acc.pdf | task1-self-assessm... | 评审意见草稿 Grou... | 课题1-专家个人评...

9:00 AM	**Brief overview** **Speaker**: Joao Guimaraes da Costa	15m
9:15 AM	**Sub-task 1：CEPC Booster Dipole Magnet Prototype (20'+5')** 子课题1：CEPC高精度二极磁铁原型机 **Speaker**: 文 康 (Accelerator Centor, IHEP)	25m
9:40 AM	**Sub-task 2：Prototype of CEPC vacuum system（20'+5'）** 子课题2：CEPC真空系统关键设备样机 **Speaker**: Haiyi 董海义 (高能所)	25m
10:05 AM	**Coffee break**	
10:25 AM	**Sub-task3: Electron positron electronic separator （20'+5'）** 子课题3：正负电子束静电分离器样机 **Speaker**: 斌 陈 (高能所)	25m
10:50 AM	**Sub-task 4: CEPC polirization study at Z-pole（20'+5）** 子课题4：CEPCZ能区极化束流的加速器物理研究与设计 **Speaker**: Zhe DUAN (高能所)	25m
11:15 AM	**Discussion（Project group only)** Main building A511	45m
11:15 AM	**Discussion（Refrees only）评委内部讨论与撰写评审意见**	45m

12:30 PM → 12:50 PM **Lunch box**

CEPC action plan since CDR → Context of this MOST project

Since 2019

Public release: November 2018

IHEP-CEPC-DR-2018-01
IHEP-AC-2018-01

CEPC

Conceptual Design Report

Volume I - Accelerator

arXiv: 1809.00285

The CEPC Study Group
August 2018

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

CEPC

Conceptual Design Report

Volume II - Physics & Detector

arXiv: 1811.10545

The CEPC Study Group
October 2018

First for a circular e^+e^- Higgs factory

Cement project with R&D towards:

(1) Accelerator TDR, planned for 2023 — just started review

(2) Detector technologies development and establishment of seeds for International Collaborations

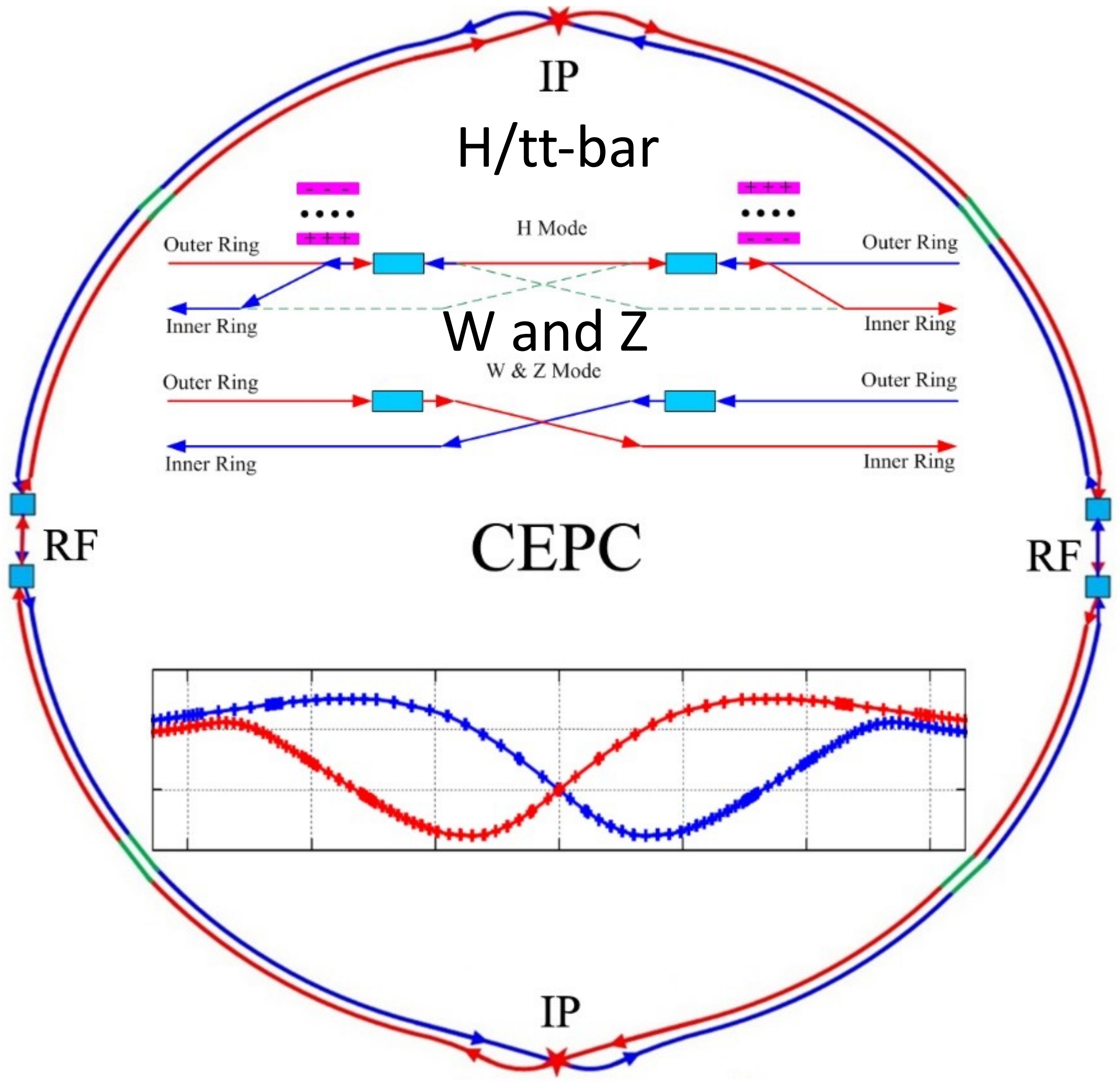
Identify challenges and devise solutions

Download from: http://cepc.ihep.ac.cn/

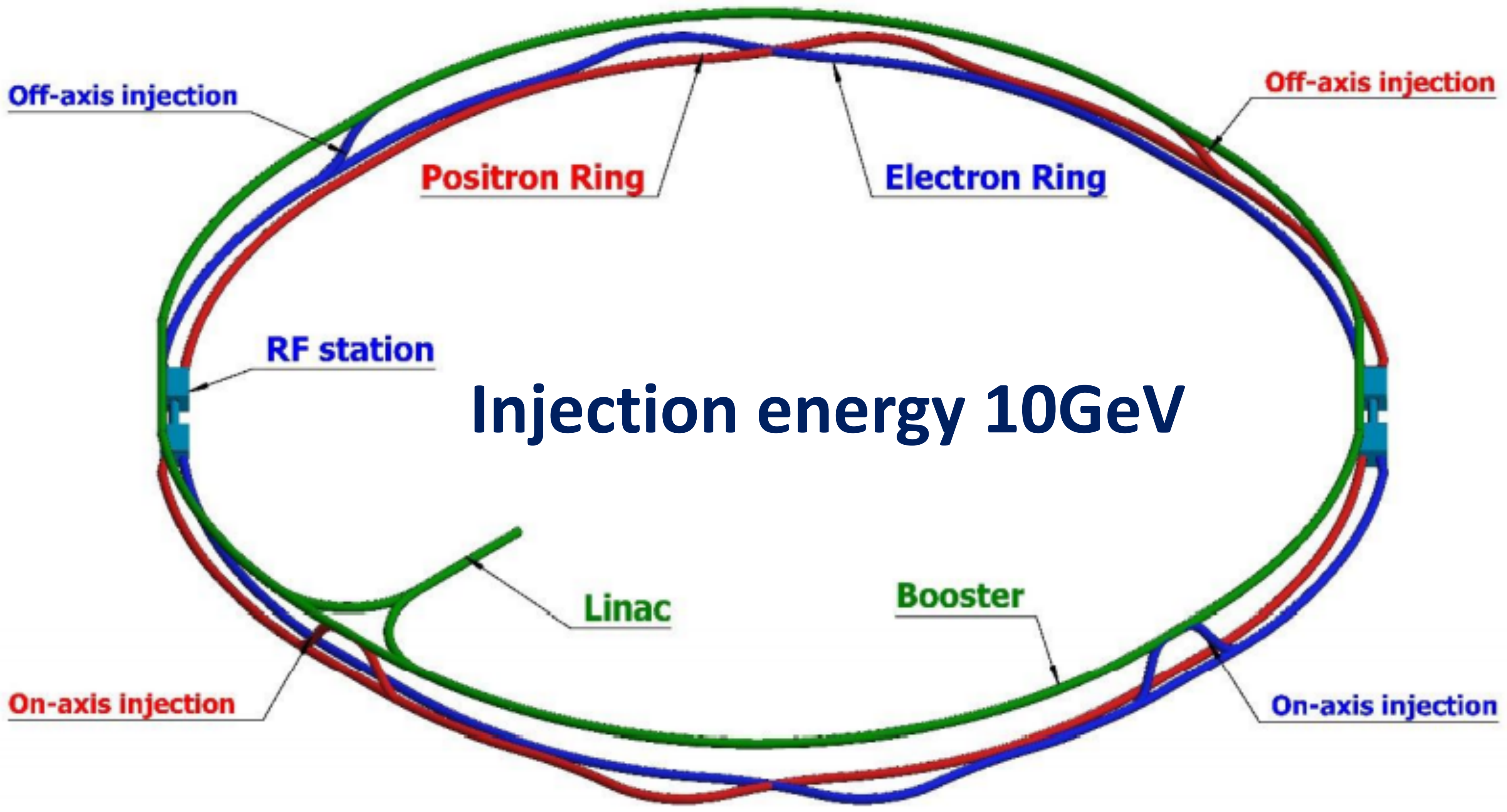
Circular Electron Position Collider (CEPC) - TDR Layout

CEPC as a Higgs Factory： H, W, Z, upgradable to tt-bar, followed by a SppC ~125TeV

30MW SR power per beam (upgradable to 50MW)



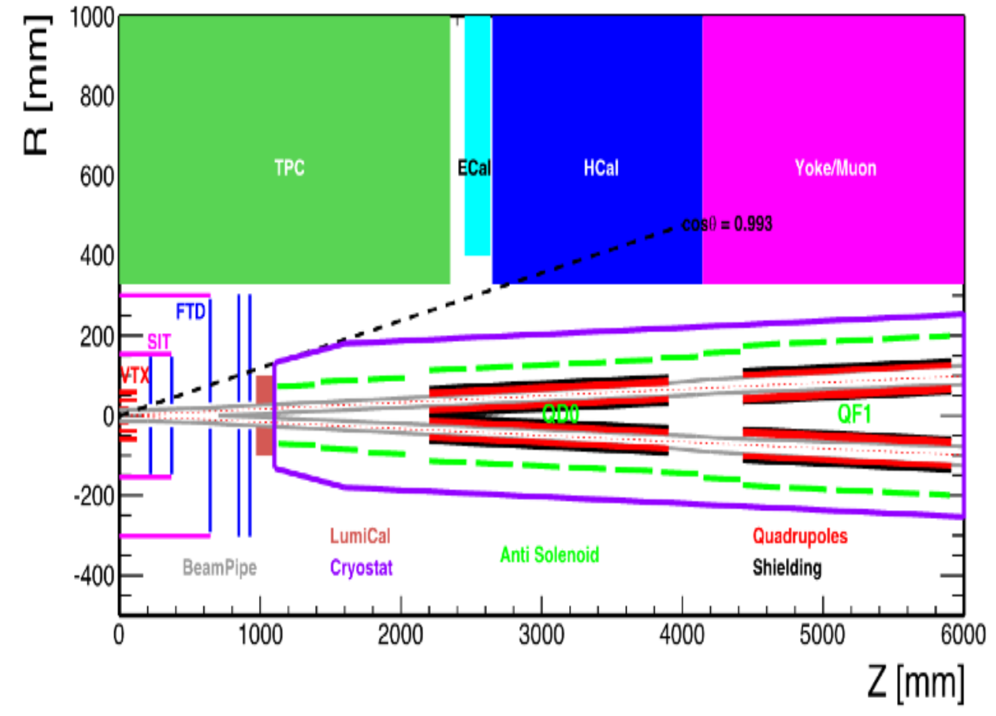
CEPC collider ring (100km)



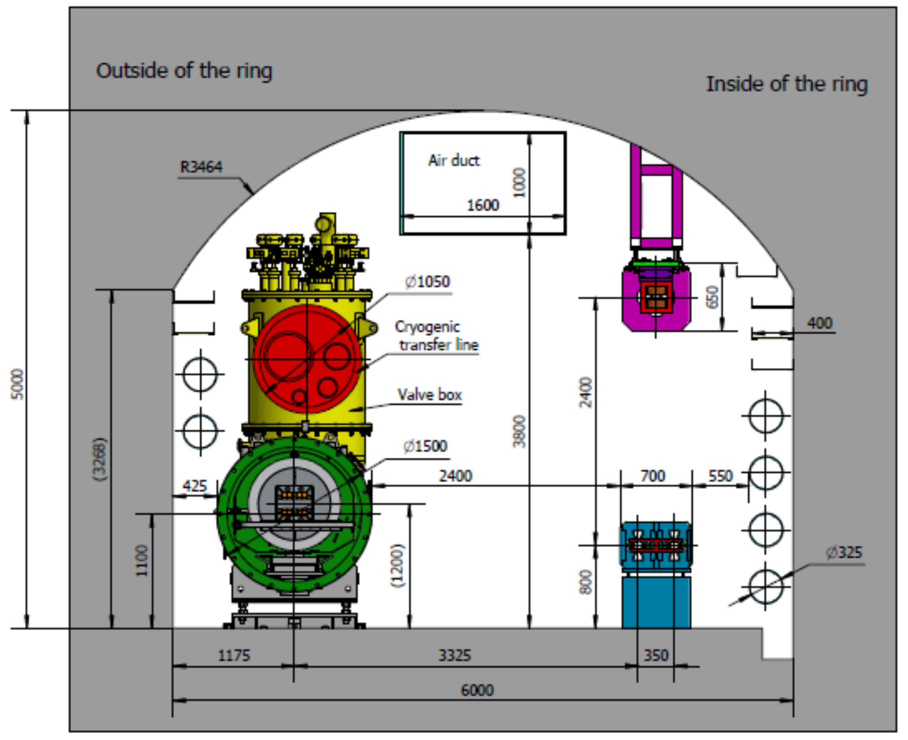
CEPC booster ring (100km)

Common tunnel for booster/collider & SppC

CEPC MDI



CEPC Civil Engineering



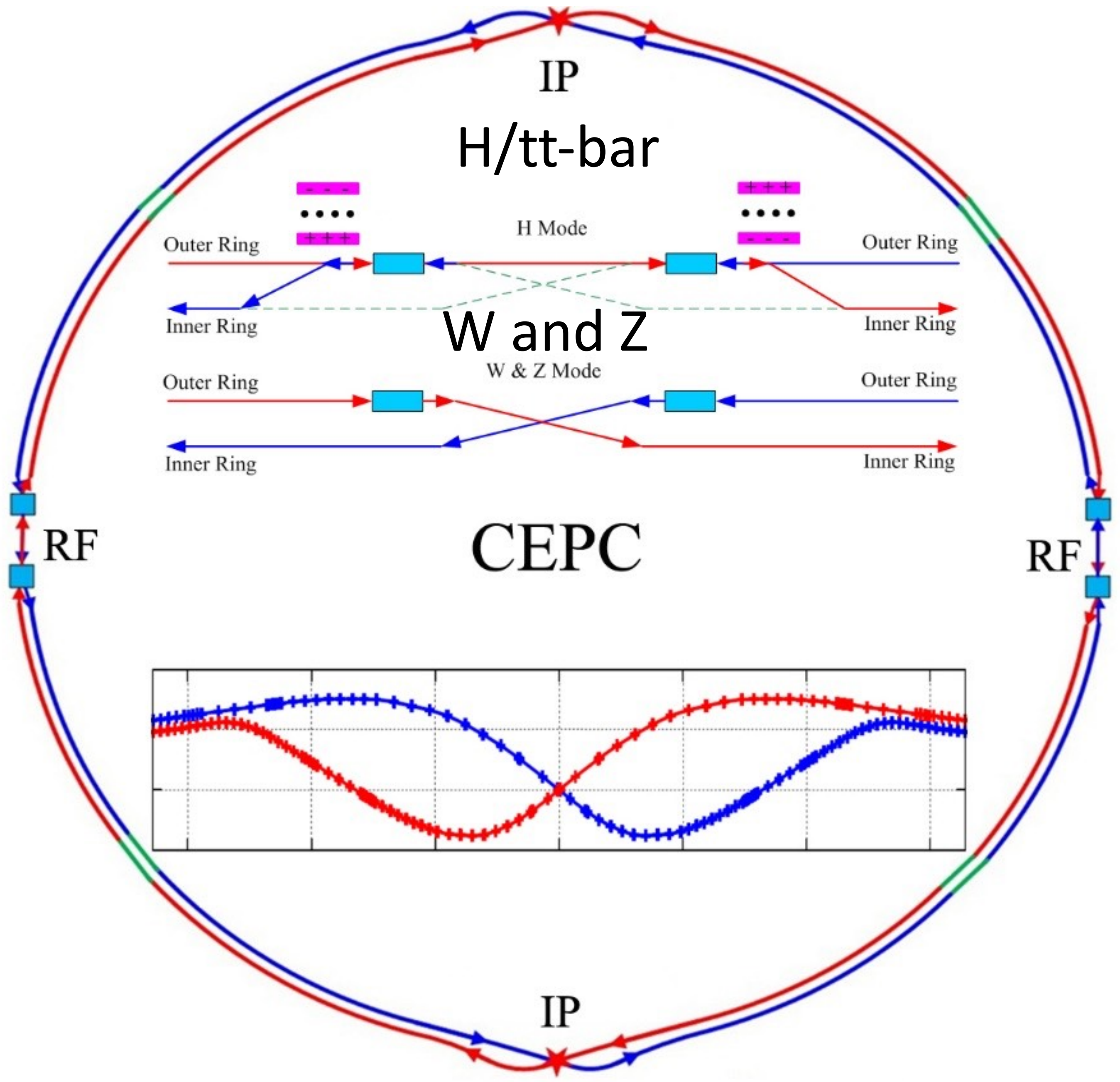
Critical aspects requiring prototyping: (this project)

- **Low-field dipole magnets for booster**
- **Electrostatic separator**
- **Vacuum system**

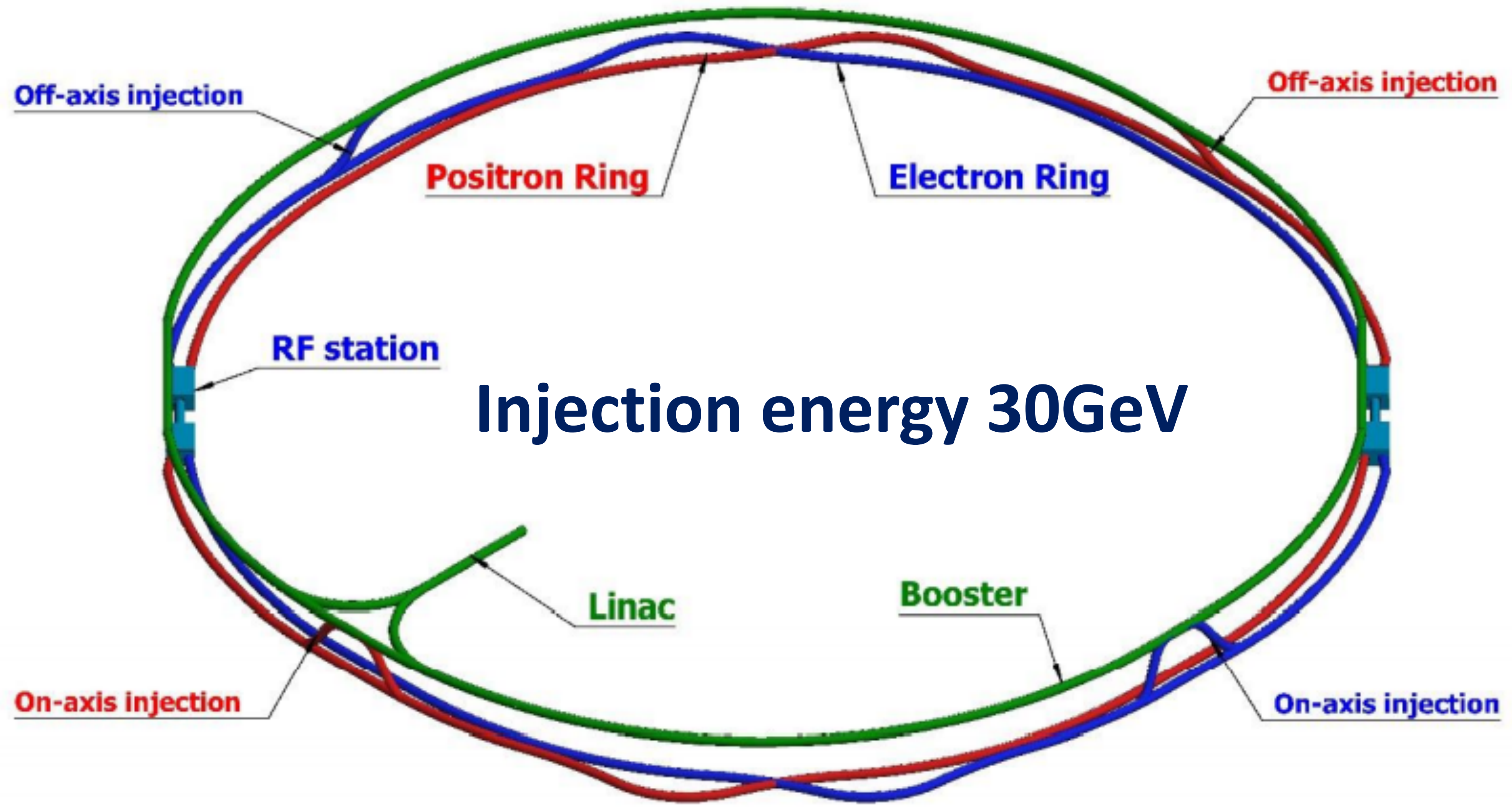
Circular Electron Position Collider (CEPC) - TDR Layout

CEPC as a Higgs Factory： H, W, Z, upgradable to tt-bar, followed by a SppC ~125TeV

30MW SR power per beam (upgradable to 50MW)



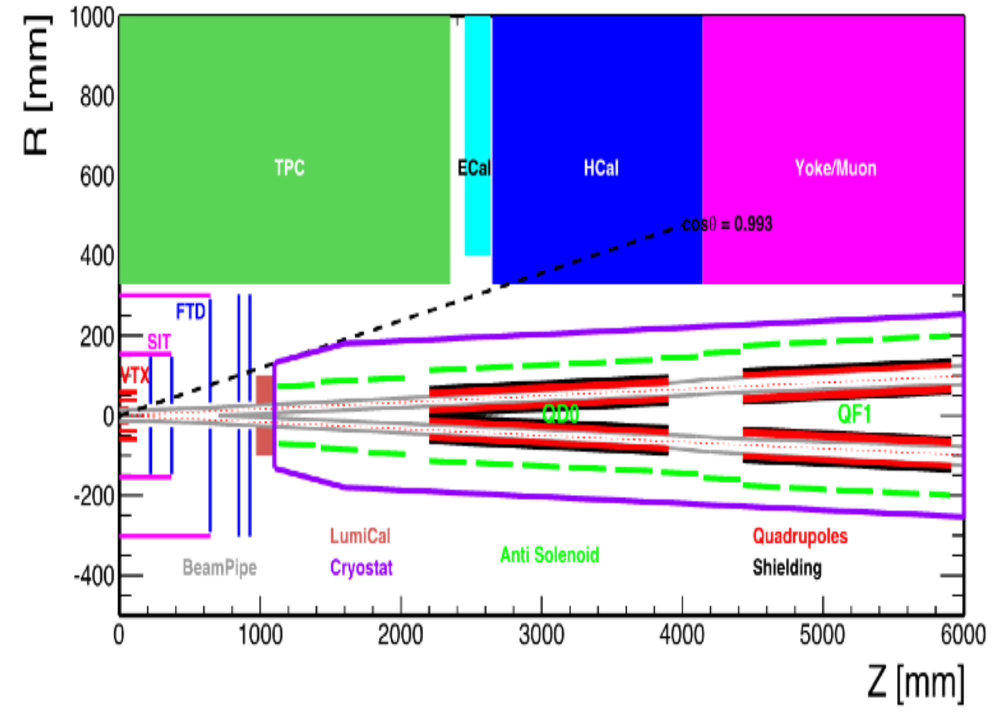
CEPC collider ring (100km)



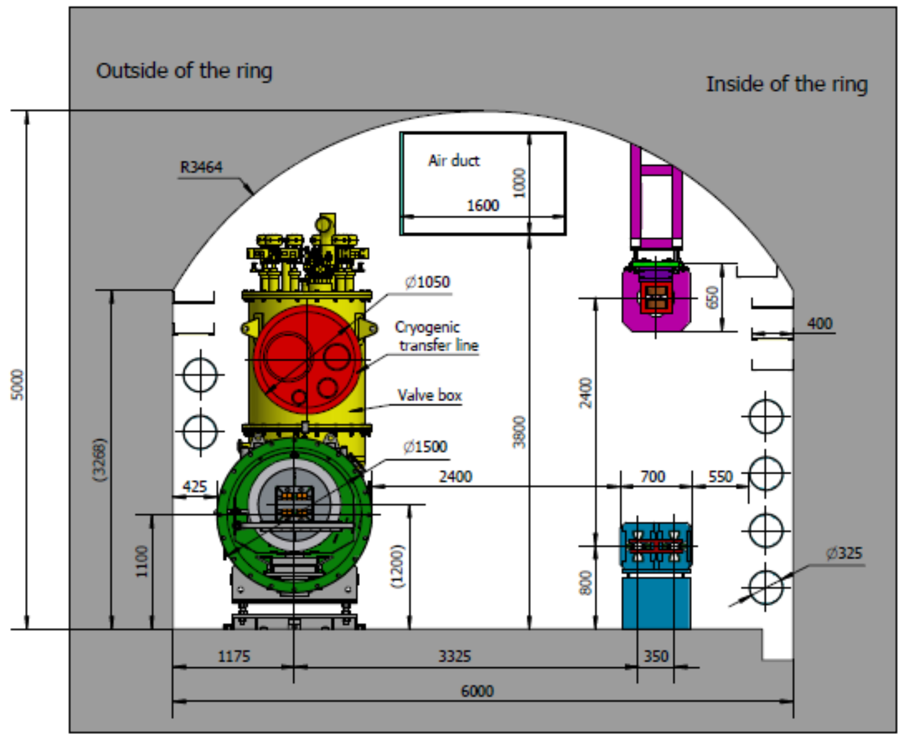
CEPC booster ring (100km)

Common tunnel for booster/collider & SppC

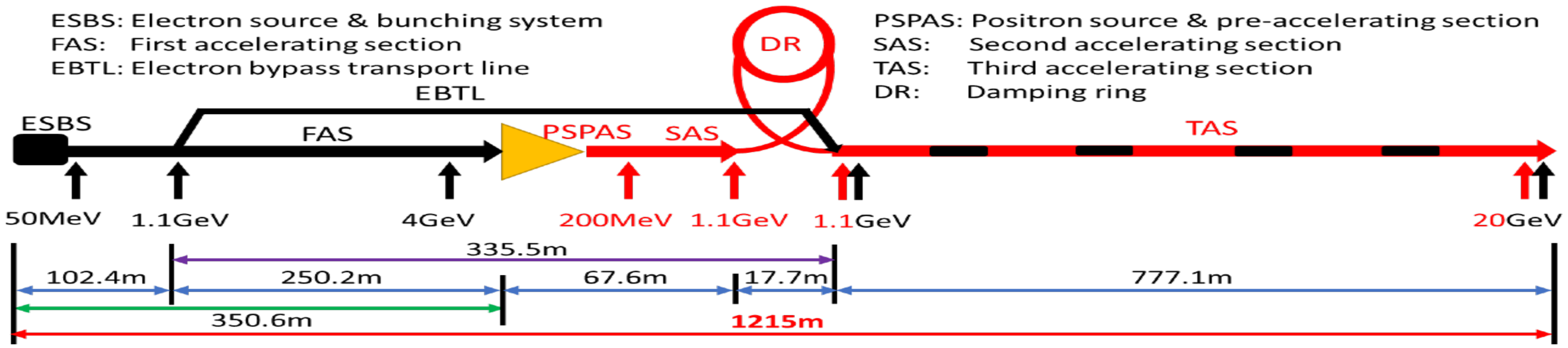
CEPC MDI



CEPC Civil Engineering



CEPC TDR S+C-band 30 GeV linac injector

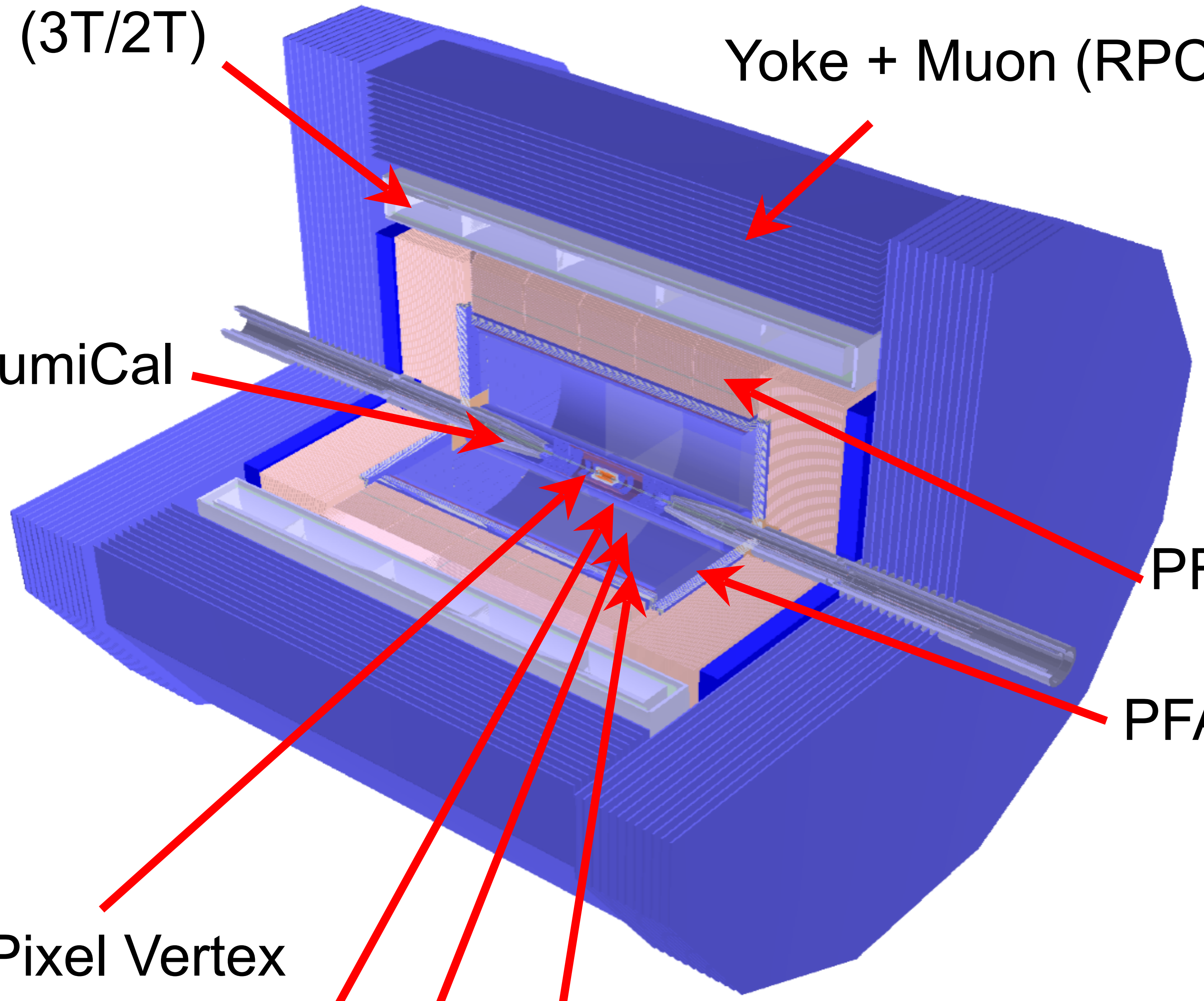


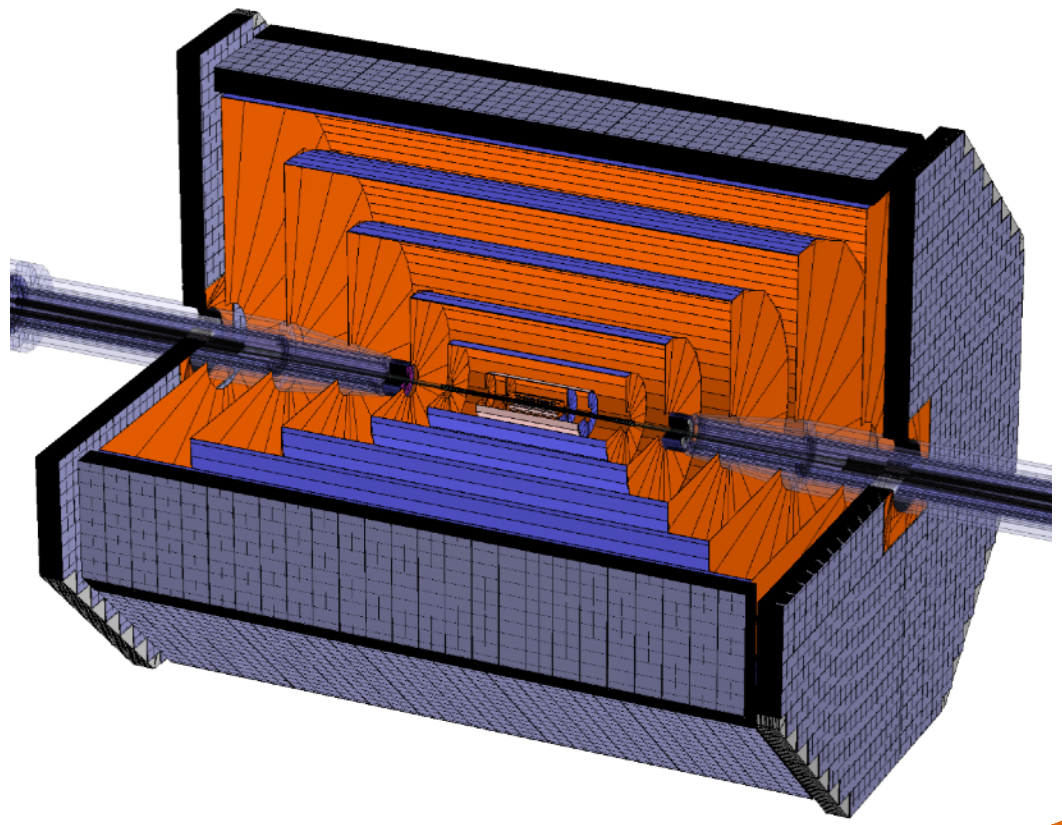
Operation mode		ZH	Z	W+W-	tt
		~240	~91.2	158-172	~360
L / IP [$\times 10^{34}$ $cm^{-2}s^{-1}$]	CDR (2018)	3	32	10	
	TDR (30MW)	5.0	115	16	0.5

CEPC Detector Concept Designs

CDR

(Baseline Design)
Particle Flow Approach



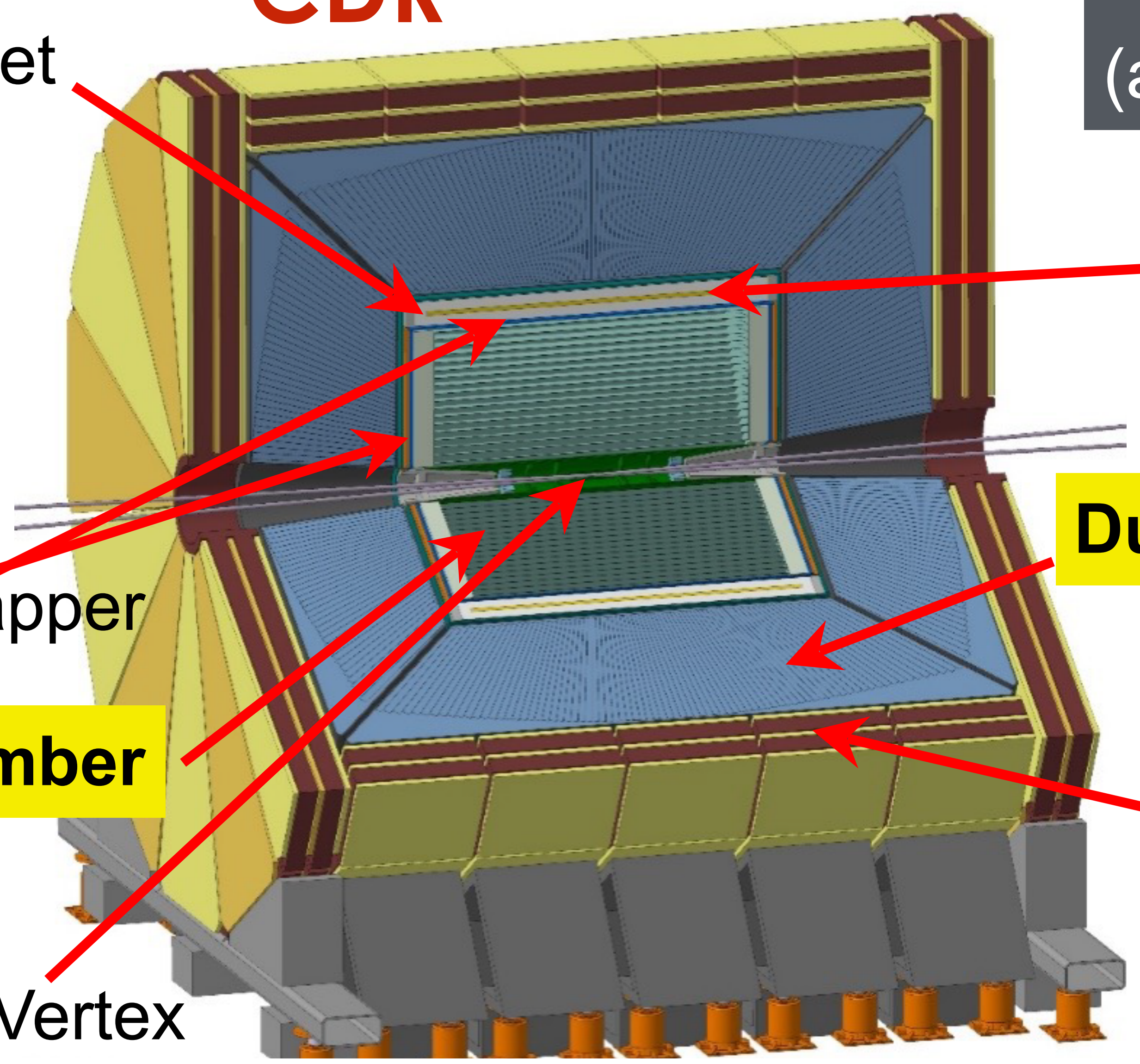


FST concept
(Full Silicon Tracker)

CDR

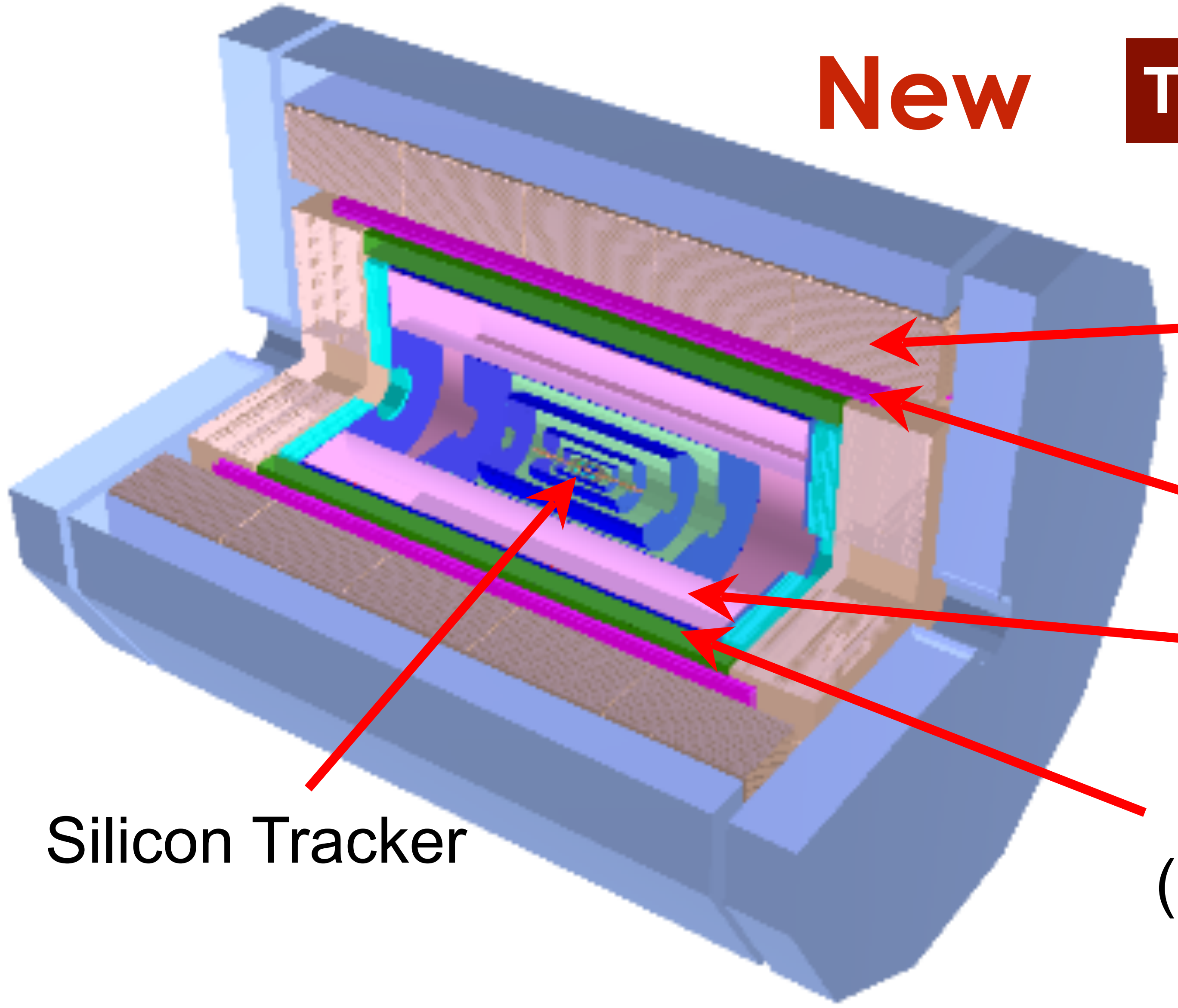
CDR

IDEA concept
(also proposed for FCC-ee)



New

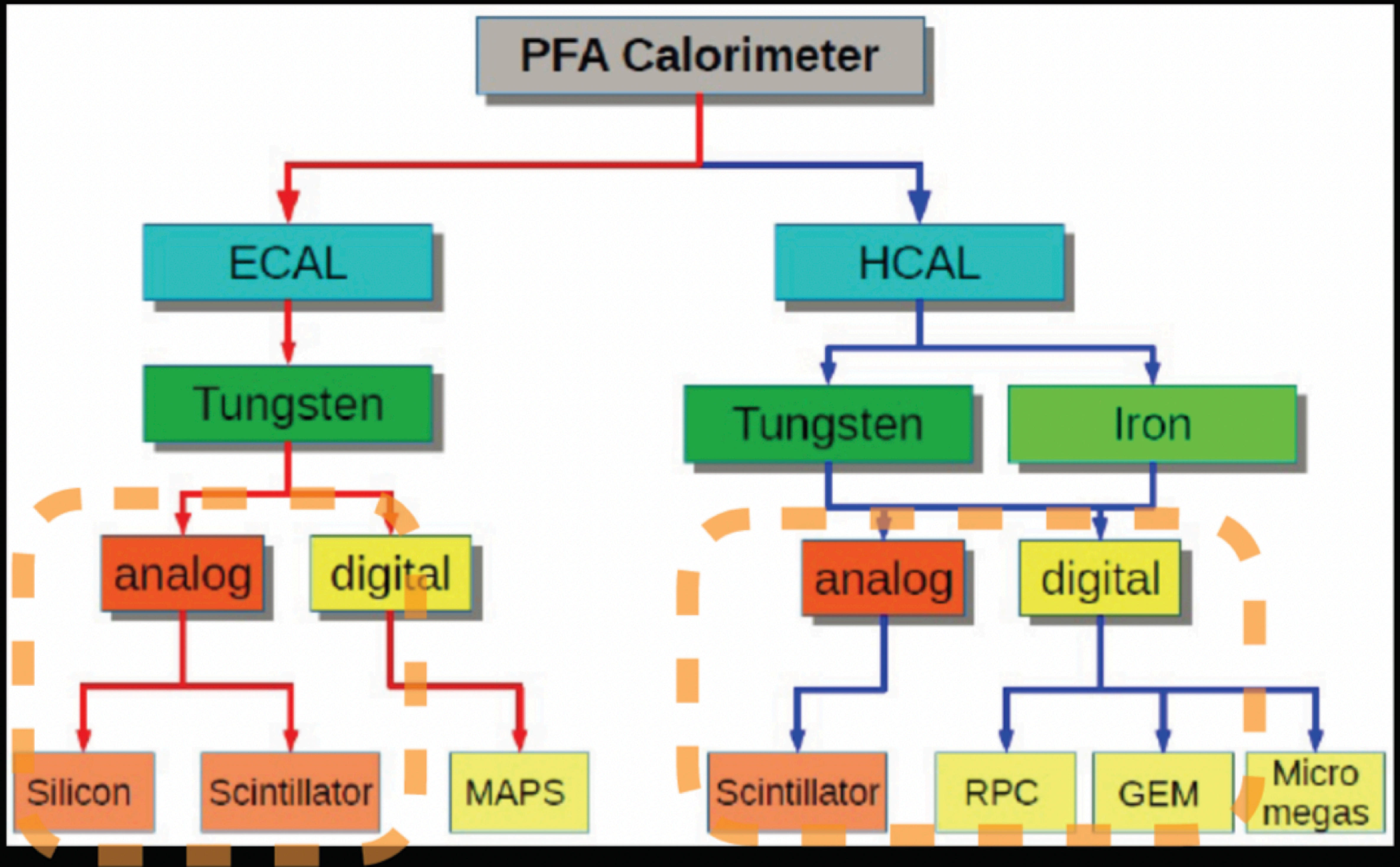
The 4th Concept



Calorimeter options

Chinese institutions have been focusing on Particle Flow calorimeters

R&D supported by **MOST**, **NSFC** and **IHEP** seed funding



High Granularity

Electromagnetic	ECAL with **Silicon** and Tungsten (LLR, France) ECAL with **Scintillator+SiPM** and Tungsten (IHEP + USTC)
Hadronic	SDHCAL with **RPC** and Stainless Steel (SJTU + IPNL, France) SDHCAL with **ThGEM/GEM** and Stainless Steel (IHEP + UCAS + USTC) HCAL with **Scintillator+SiPM** and Stainless Steel (IHEP + USTC + SJTU)

Newer Options

Some longitudinal granularity	**Crystal** Calorimeter (LYSO:Ce + PbWO) **Dual readout** calorimeters (INFN, Italy + Iowa, USA) — RD52

Testing of full size prototypes allow us to face challenges that are otherwise not visible:

- **Knowledge acquire in these projects can be put to use to construct the final accelerator or detectors, either using the same technology or similar technologies**

- **All prototypes in this project are at least being build in China for the first time, some are worldwide goals**

Task 1: Accelerator

Task 1: Low-field dipole magnet for CEPC Booster

When the beam injection is at 10 GeV, the CEPC Booster requires dipole magnets with a minimum field of only 31 Gs, and extremely small field error (uniformity 5×10^{-4})

There would be about 16000 of such dipoles, 4.7m long, to cover the 100 km

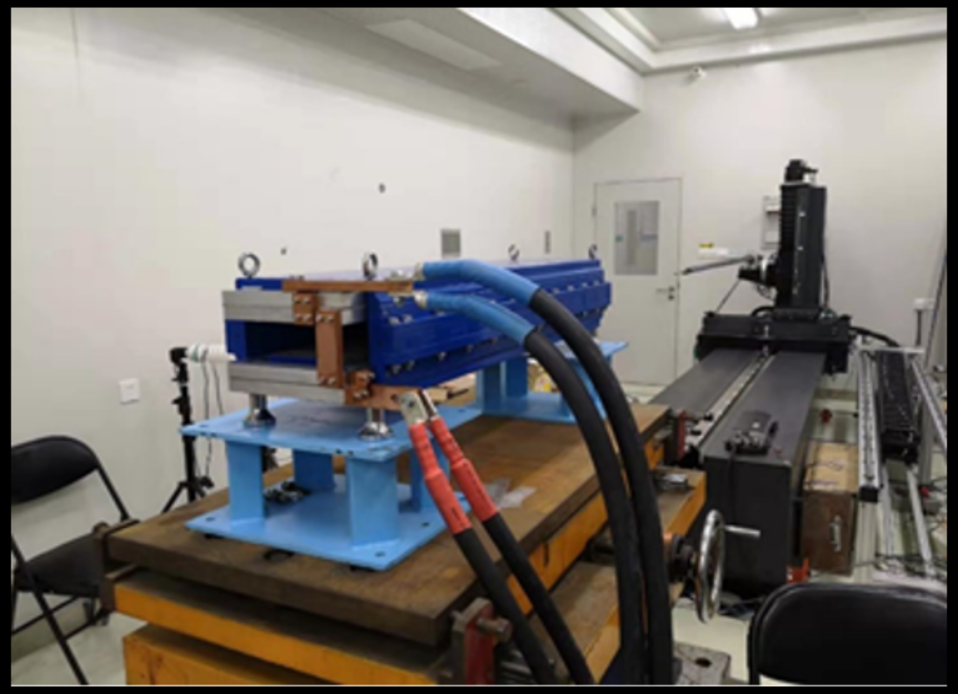
LEP: 170Gs → **World class: 120Gs** → **This project: 31Gs**

World leading

Two subscale prototypes were built

Cosine-Theta (CT) coil

iron-core dipole magnet



iron-core dipole magnet didn't satisfy requirements

↓

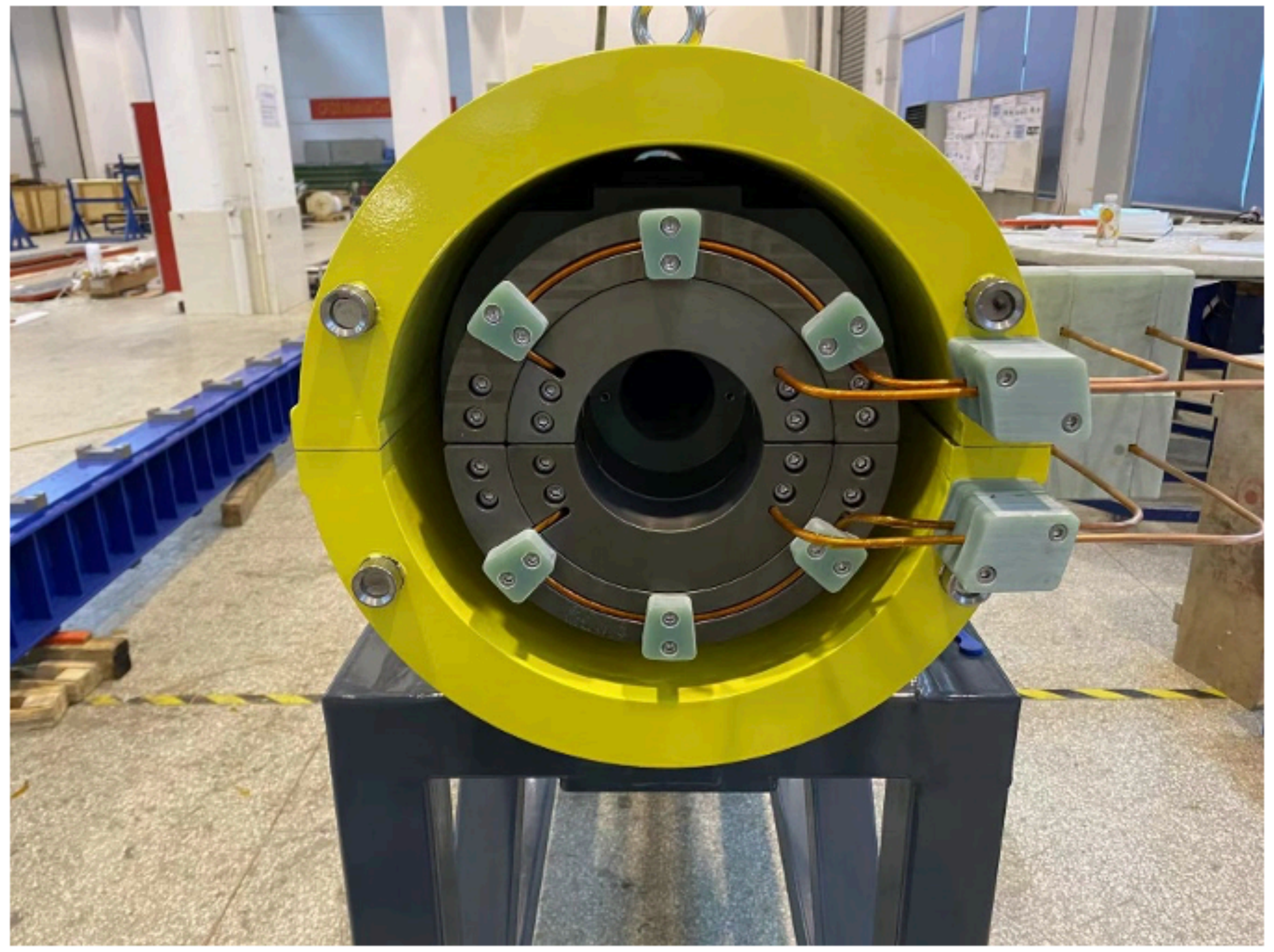
Built full-size CT coil magnet

Task 1: Low-field dipole magnet prototype for CEPC Booster

Full-scale prototype CT coil dipole magnet

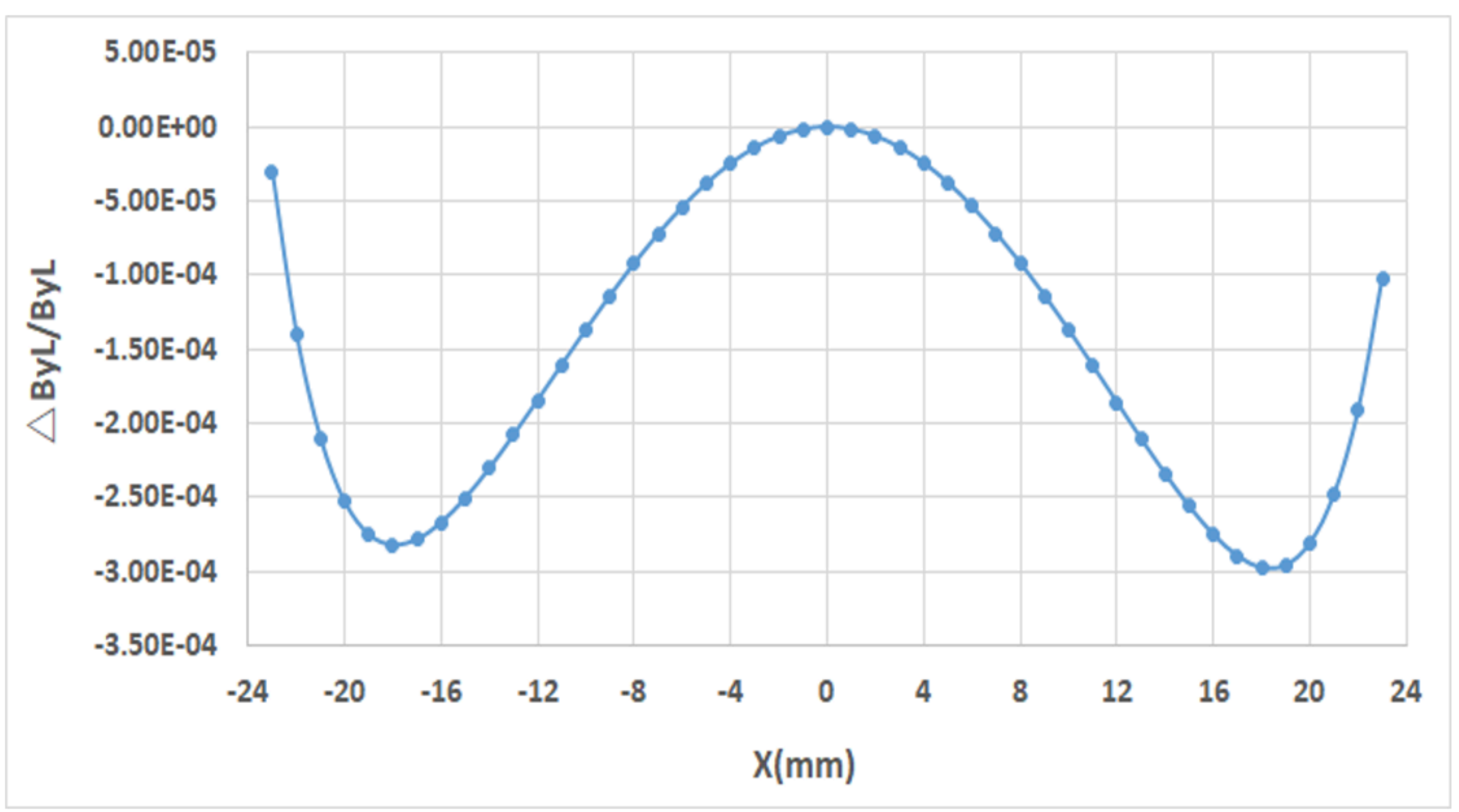
After some adjustments it can reach the requirements

✓ **The pictures of the finished CT coil dipole magnet**



Subtask	Indicator	Requirement	Result	Conclusion
High precision low-field dipole magnet prototype	Lowest field	<31 Gs	28.5 Gs	✓ Surpassed
	Field uniformity	$<5\times10^{-4}$	3×10^{-4}	✓ Surpassed

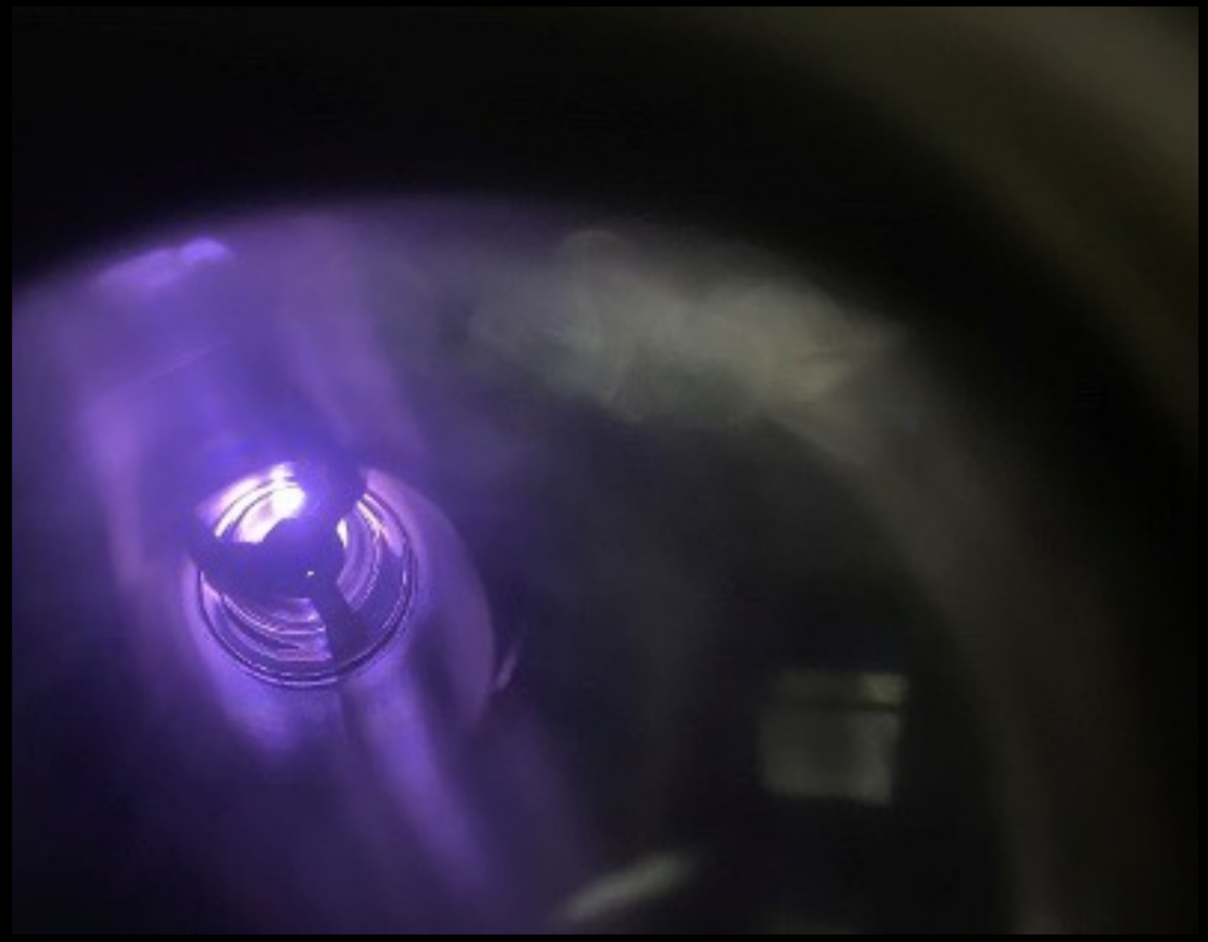
World leading

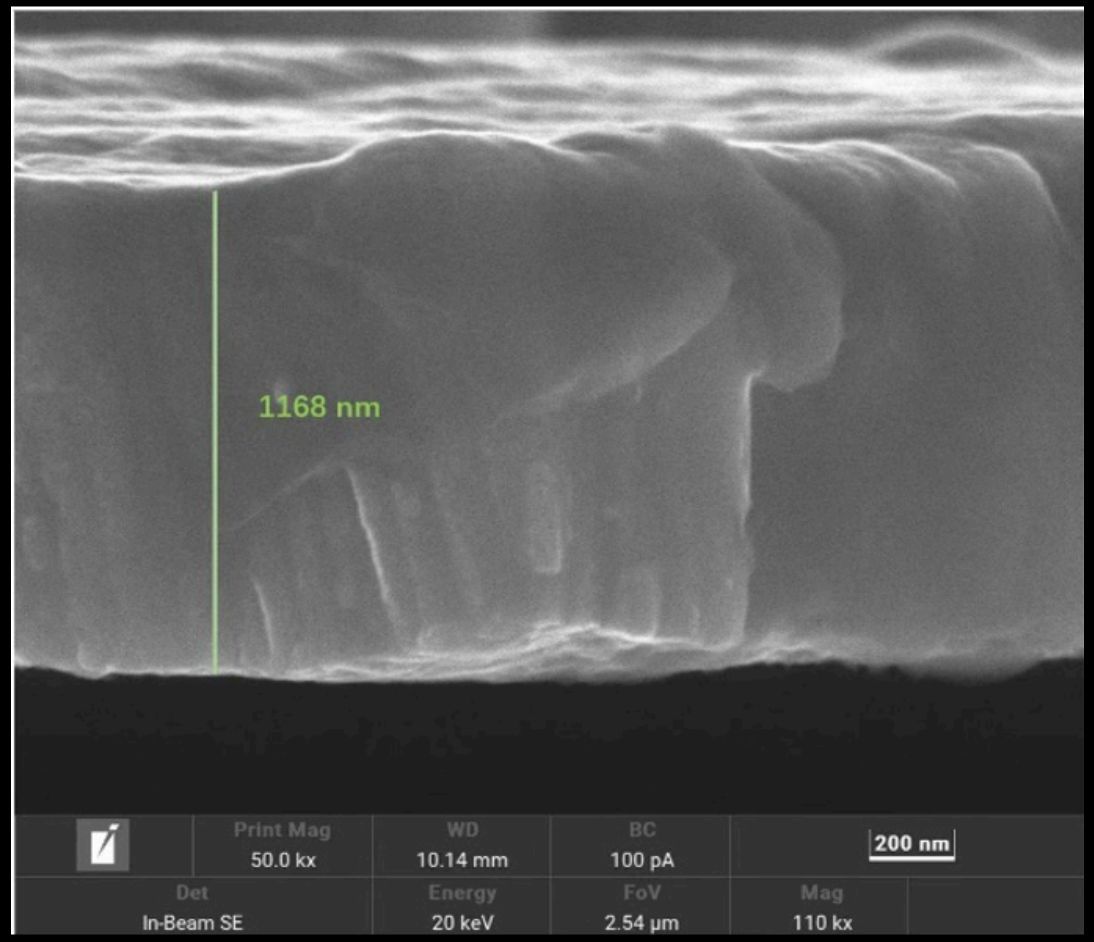


Task 1: Vacuum system and RF shielding bellows prototypes

Prototype 6-m log vacuum chambers for beampipe

Develop technique for NEG coating of the inside of the beampipe (using sputtering technique)

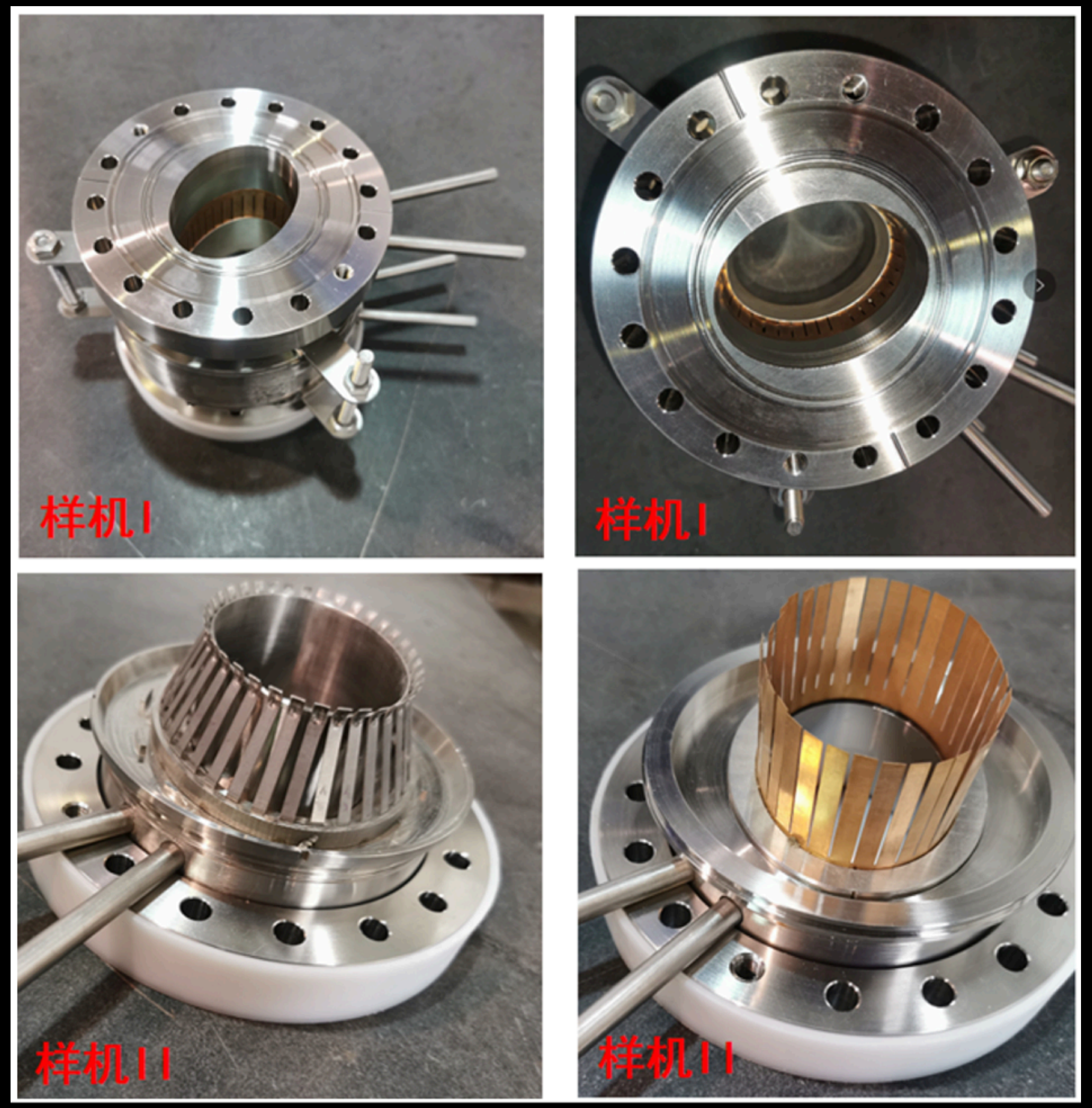




Coating done in sections for 6-m vacuum tube ultimately achieved good enough uniformity

7 patents developed for this work

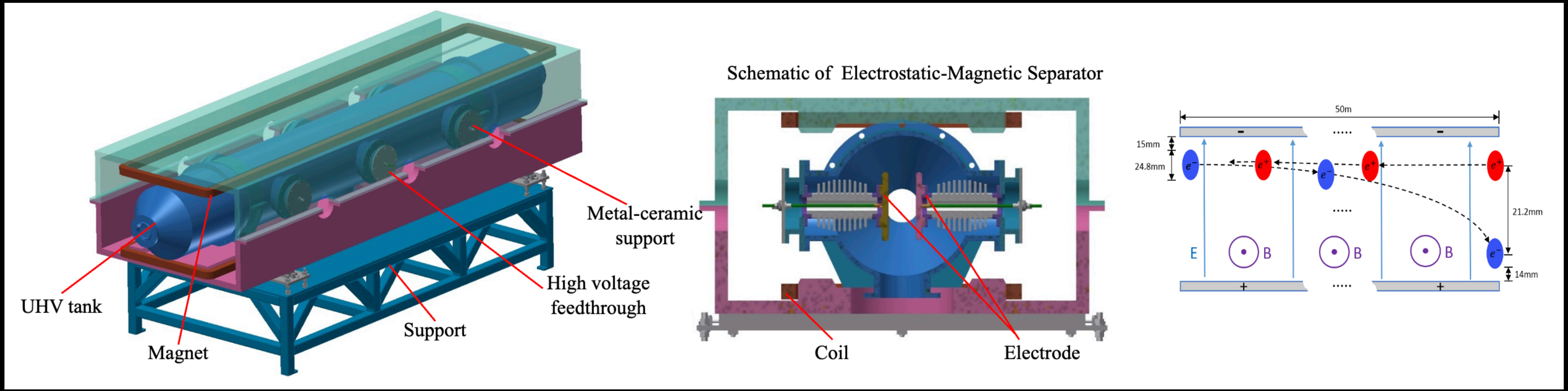
Subtask	Indicator	Requirement	Result	Conclusion	
High precision low-field dipole magnet prototype	Lowest field	<31 Gs	28.5 Gs	✓ Surpassed	World leading
	Field uniformity	$<5\times10^{-4}$	3×10^{-4}	✓ Surpassed	
Vacuum pipe and RF shielding bellow prototype	Vacuum degree	$< 2\times10^{-10}$ Torr	1.08 - 0.99 $\times10^{-10}$ Torr	✓ Surpassed	First in China
	Vacuum leakage	$< 2\times10^{-10}$ Torr.L/s	1×10^{-10} Torr.L/s	✓ Surpassed	
	RF shield bellows contact force	125±25 g/finger	123-135 g/finger	✓ Achieved	

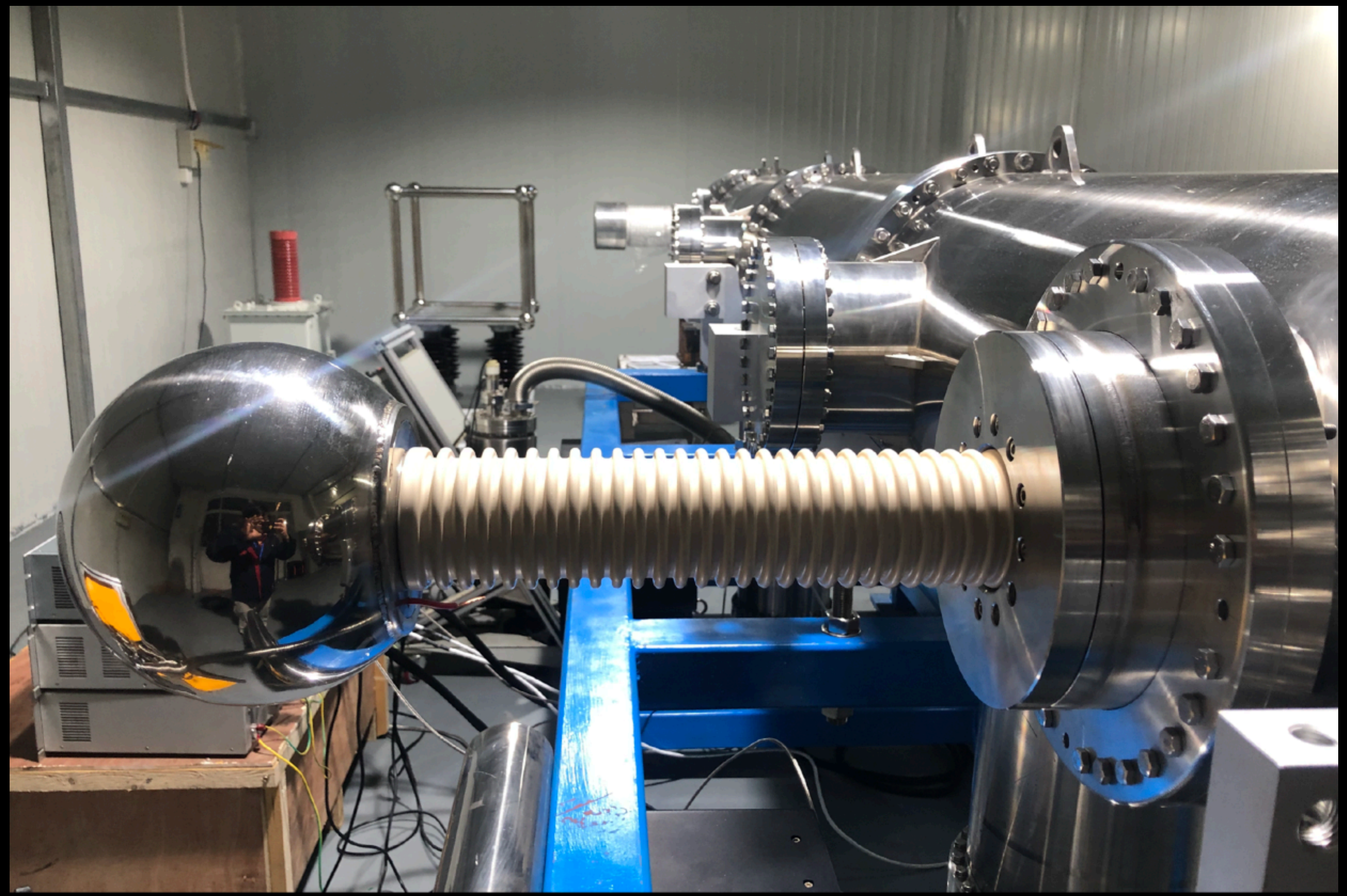


Task 1: Electrostatic separator prototype

The Electro-Magnetic Separator is a device consisting of perpendicular electric and magnetic fields.

One set of Electro-Magnetic Separators includes 8 units, total 32 units will be need for CEPC





Subtask	Indicator	Requirement	Result	Conclusion	
High precision low-field dipole magnet prototype	Lowest field	<31 Gs	28.5 Gs	✓ Surpassed	**World leading**
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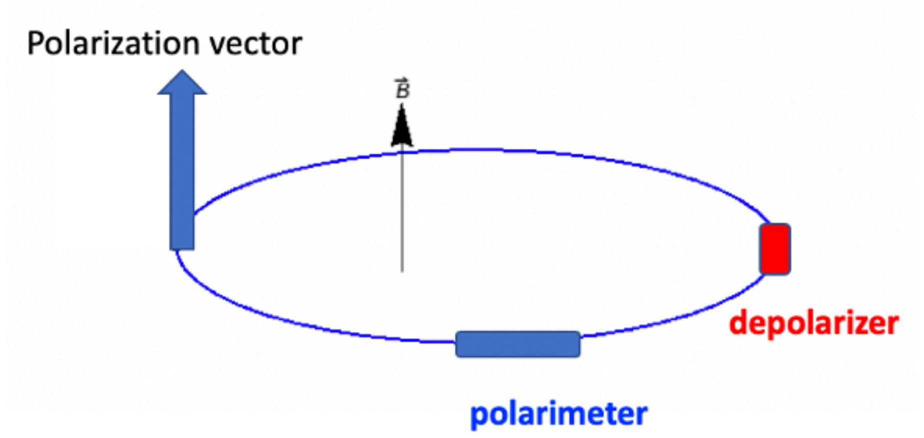
	Vacuum leakage	$< 2\times10^{-10}$ Torr.L/s	1×10^{-10} Torr.L/s	✓ Surpassed	
	RF shield bellows contact force	125±25 g/finger	123-135 g/finger	✓ Achieved	
High energy electrostatic separator prototype	Electric field	>2 MV/m @ ±110 kV	3.09 MV/m @ ±116 kV	✓ Surpassed	**First in China**
	Field uniformity	(1‰)10x10 mm²	(0.5‰)46x30 mm²	✓ Surpassed	
	Vacuum	$< 2.7\times10^{-8}$ Pa ($<2\times10^{-10}$ Torr)	$< 2.6\times10^{-8}$ Pa	✓ Achieved	

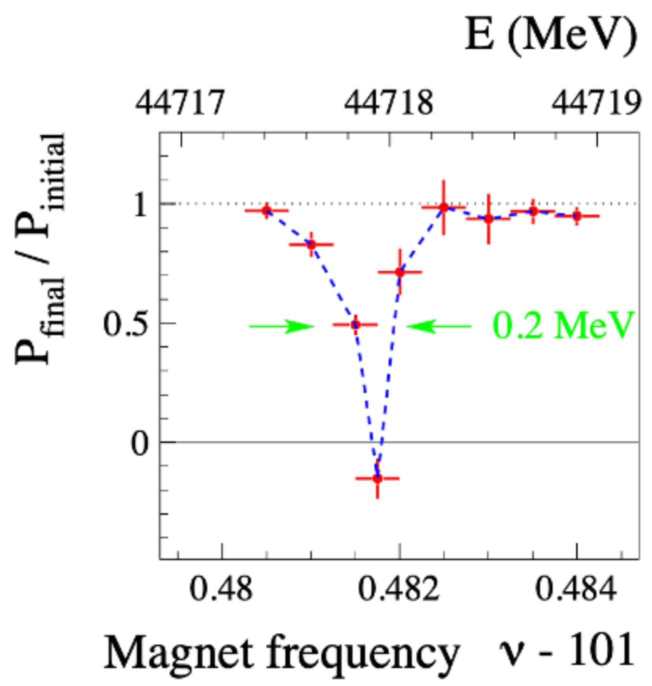
Task 1: Design of polarization at Z-pole

Considering both vertical and longitudinal polarization

Vertical polarization in the arc

- Beam energy calibration via the resonant depolarization technique (RD)
- Essential for precision measurements of Z and W properties
- At least 5% ~ 10% vertical polarization, for both e+ and e- beams

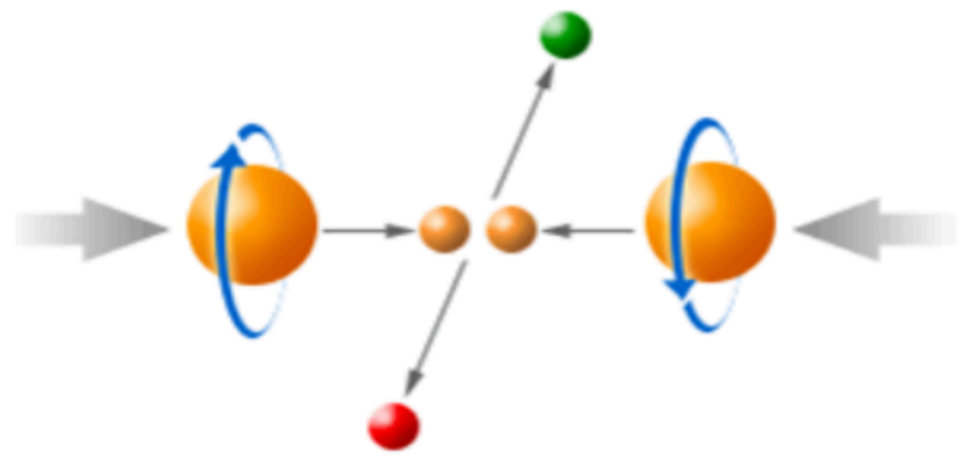




L. Arnaudon, et al., Z. Phys. C 66, 45-62 (1995).

Longitudinal polarization at IPs

- Beneficial to colliding beam physics programs at Z, W and Higgs
- Figure of merit: Luminosity * f(Pe+, Pe-)
- ~50% or more longitudinal polarization is desired, for one beam, or both beams



- FCC-ee (CERN) focuses on vertical polarization for beam energy calibration.
- Both aspects are being pursued at the CEPC.

Subtask	Indicator	Requirement	Result	Conclusion	
High precision low-field dipole magnet prototype	Lowest field	<31 Gs	28.5 Gs	Surpassed	World leading
	Field uniformity	$<5\times10^{-4}$	3×10^{-4}	Surpassed	
Vacuum pipe and RF shielding bellow prototype	Vacuum degree	$< 2\times10^{-10}$ Torr	1.08 - 0.99 $\times10^{-10}$ Torr	Surpassed	First in China
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	Field uniformity	(1‰)10x10 mm^2	(0.5‰)46x30 mm^2	Surpassed	
	Vacuum	$< 2.7\times10^{-8}$ Pa ($<2\times10^{-10}$ Torr)	$< 2.6\times10^{-8}$ Pa	Achieved	
Polarization design	Beam polarization	> 50%	$P_{avg} > 70\%$	Surpassed	World leading
	Beam lifetime	> 60 min	> 60 min	Achieved	

Achievement Presentation and Assessment Methods

项目目标[1]	成果名称	成果类型	对应的课题（任务）[2]	考核指标[3]				考核方式（方法）及评价手段[5]
				指标名称	立项时已有指标值/状态	中期指标值/状态[4]	完成时指标值/状态	
1. 开展CEPC增强器关键设备高精度低场二极磁铁、弯转真空盒、RF屏蔽波纹管和真空盒内表面镀吸气剂膜、高能正负电子束静电分离器的研制；开展CEPC在Z能区极化束流的加速	高精度低场二极磁铁 **Dipole Magnet**	☐新理论 ☐新原理 ☐新产品 ☐新技术 ☐新方法 ■关键部件 ☐数据库 ☐软件 ☐应用解决方案 ☐实验装置/系统 ■工程工艺 ☐标准 ☐专利 ■论文 ☐其他	课题1：加速器关键技术的研发和验证	高精度低场二极磁铁场强和均匀性	最低工作磁场127Gs，磁场均匀度5×10^{-4}	最低工作磁场60Gs，磁场均匀度5×10^{-4}	最低工作磁场31Gs，磁场均匀度5×10^{-4}	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告
	研制弯转真空盒、RF屏蔽波纹管和真空盒内表面 **Vacuum pipe**	☐新理论 ☐新原理 ☐新产品 ☐新技术 ☐新方法 ■关键部件 ☐数据库 ☐软件 ☐应用解决方案 ☐实验装置/系统 ■工程工艺 ☐标准	课题1：加速器关键技术的研发和验证	真空盒极限真空	5×10^{-10}Torr	3×10^{-10}Torr	2×10^{-10}Torr	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告

Assessment method and means of evaluation:

Expert review in the visit to prototype

Test report will be included in "CEPC accelerator key technology design report and testing report"

Achievement Presentation and Assessment Methods

器物理研究与设计。 2. 研制出硅径迹探测器原型机，并验证其空间分辨率达到3-5微米；设计出抗电离辐射总剂量达到 1MRad的硅探测器。 3. 完成对采用闪烁体作为灵敏层的成像型强子量能器技术方案的验证	镀吸气剂膜 **Vacuum pipe**	☐专利 ■论文 ☐其他		真空盒总漏率	5×10^{-10} Torr•L/s	3×10^{-10} Torr•L/s	2×10^{-10} Torr•L/s ✓	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告
	Bellows			RF屏蔽波纹管接触力	125±50g	125±30g	125±25g ✓	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告
	高能正负电子静电分离器 **Electrostatic separator**	☐新理论 ☐新原理 ☐新产品 ☐新技术 ☐新方法 ☐关键部件 ☐数据库 ☐软件 ☐应用解决方案 ■实验装置/系统 ■工程工艺 ☐标准	课题 1：加速器关键技术的研发和验证	静电分离器电场强度	1.8MV/m@±60kV 工作电压	完成静电分离器的初步设计，以实现：2MV/m@±110kV 工作电压的电场强度要求	2MV/m@±110kV 工作电压 ✓	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告

Assessment method and means of evaluation:

Expert review in the visit to prototype

Test report will be included in "CEPC accelerator key technology design and test report"

Achievement Presentation and Assessment Methods

Electrostatic separator	☐专利 ■论文 ☐其他		静电分离器电场均匀性	无	完成静电分离器初步设计，以实现(1‰)10×10 mm^2 的场均匀性	(1‰)10×10 mm^2 ✓	同行专家评议，静电分离器设计报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告
			静电分离器腔体真空度	6×10^{-10}Torr	完成静电分离器初步设计，以实现2×10^{-10}Torr的腔体真空度要求	2×10^{-10}Torr ✓	同行专家组现场测试，测试报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告
Polarization CEPC在Z能区极化束流运行时的整体物理设计	☐新理论 ☐新原理 ☐新产品 ☐新技术 ■新方法 ☐关键部件 ☐数据库 ☐软件 ☐应用解决方案 ☐实验装置/系统 ☐工程工艺 ☐标准 ☐专利 ■论文 ☐其他	课题 1：加速器关键技术的研发和验证	在Z能区极化束流的加速器物理研究与设计	已有不含极化插入件的lattice 设计	明确极化插入件的基本参数选择和精确能量测量的工作模式；模拟研究束流极化度大于50%的实现条件	束流极化度大于 50%，束流 寿命大于 60 分钟 ✓	同行专家评审，束流极化物理设计报告报告将写入高能环型正负电子对撞机加速器关键技术设计和测试报告

Assessment method and means of evaluation:

- Expert review in the visit to prototype
- **Test** report will be included in final report (1)

- Peer expert review
- **Design** report will be included in final report (1)

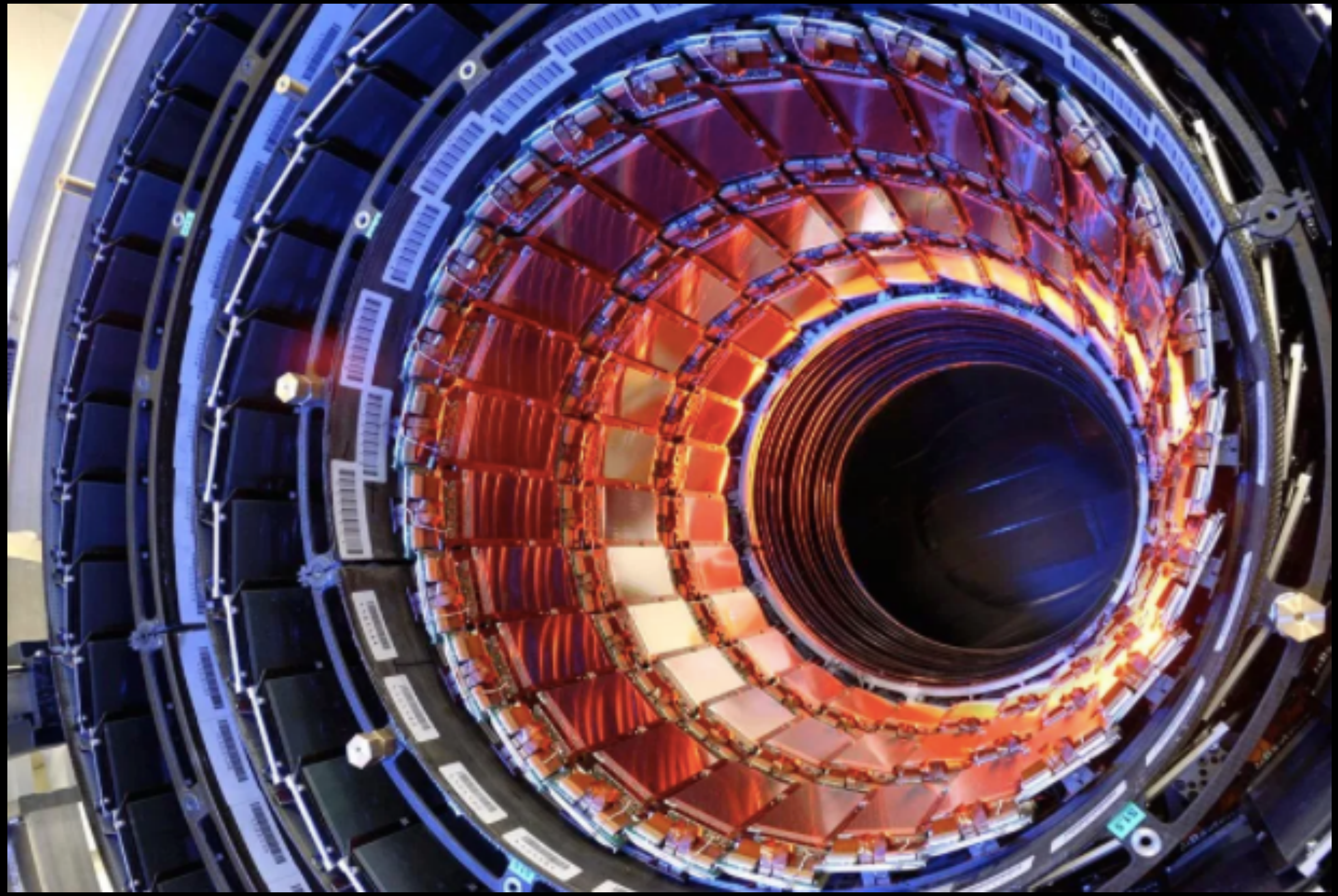
(1) Final report: "CEPC accelerator key technology design and test report"

Task 2: Vertex Detector Prototype

Task 2: Vertex Detector Prototype Research Goal

- **Produce a world class vertex detector prototype**
  - Spatial resolution 3~5 μm (pixel detector)
  - Radiation hard (>1 MRad)

Typical vertex tracker



Typical cost of such detectors: 350-700 MRB

Resolution

ATLAS/CMS upgrade (10-20 μm)

Alice upgrade (5~10 μm)

This project (3~5 μm)

World leading

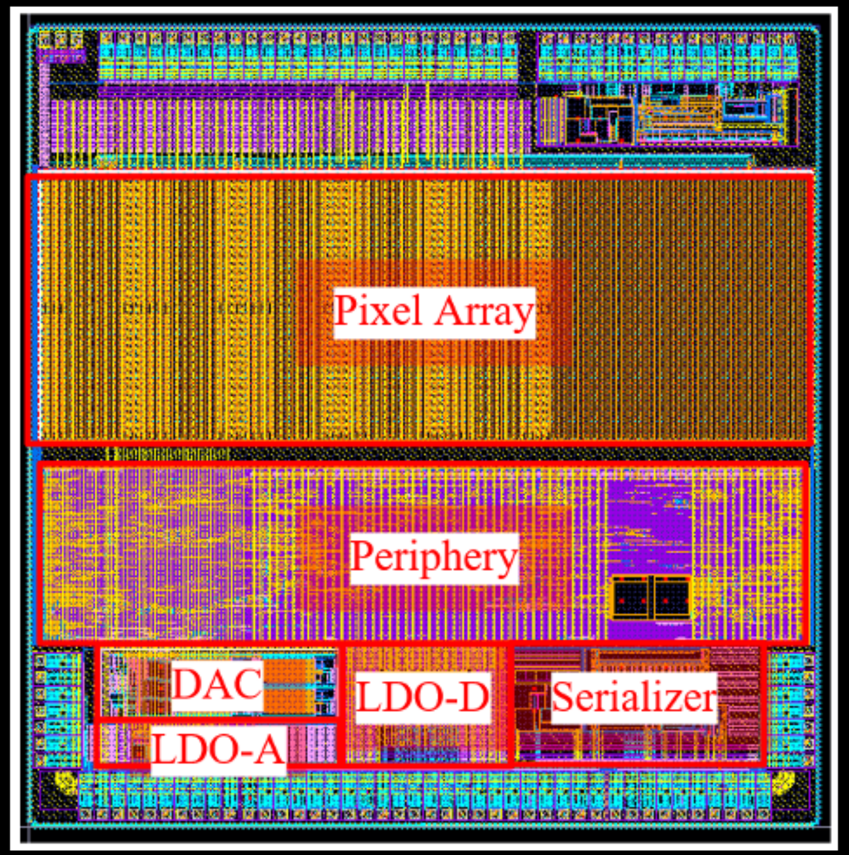
Key ingredient:

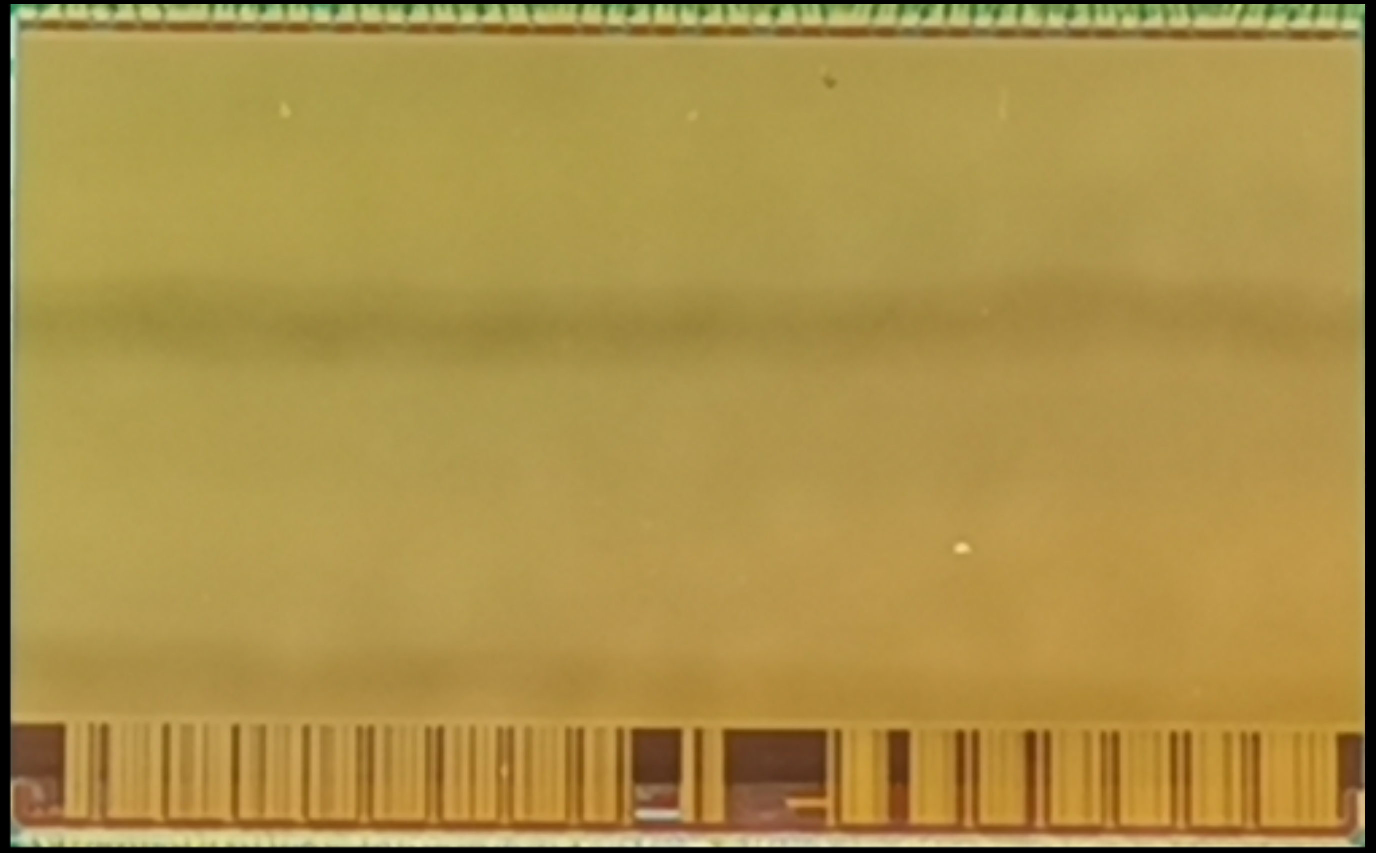
Full size sensor/ASIC ($2\text{-}4\ cm^2$)

Major goal: develop the know-how in China to be such advanced detectors

Task 2: Vertex Detector Prototype Development

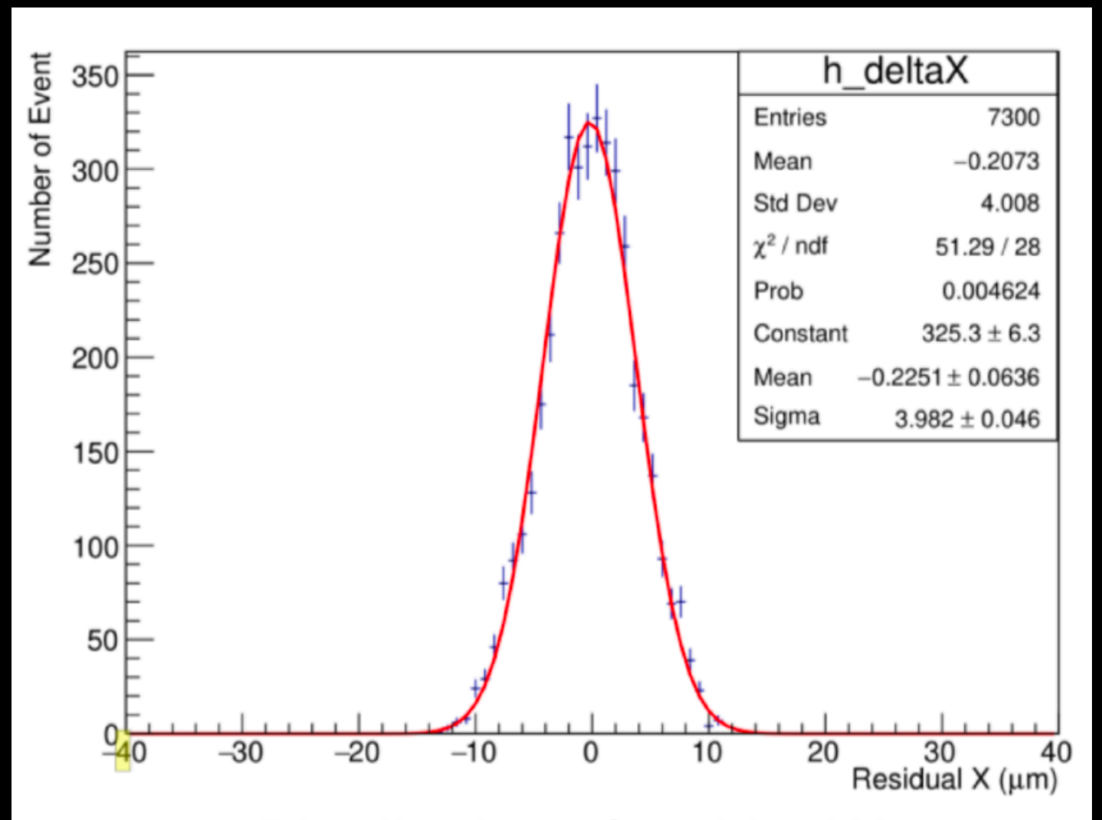
- **Developed first full-size CMOS monolith imaging sensor in China**, adequate for the production of this vertex detector and other silicon-based devices



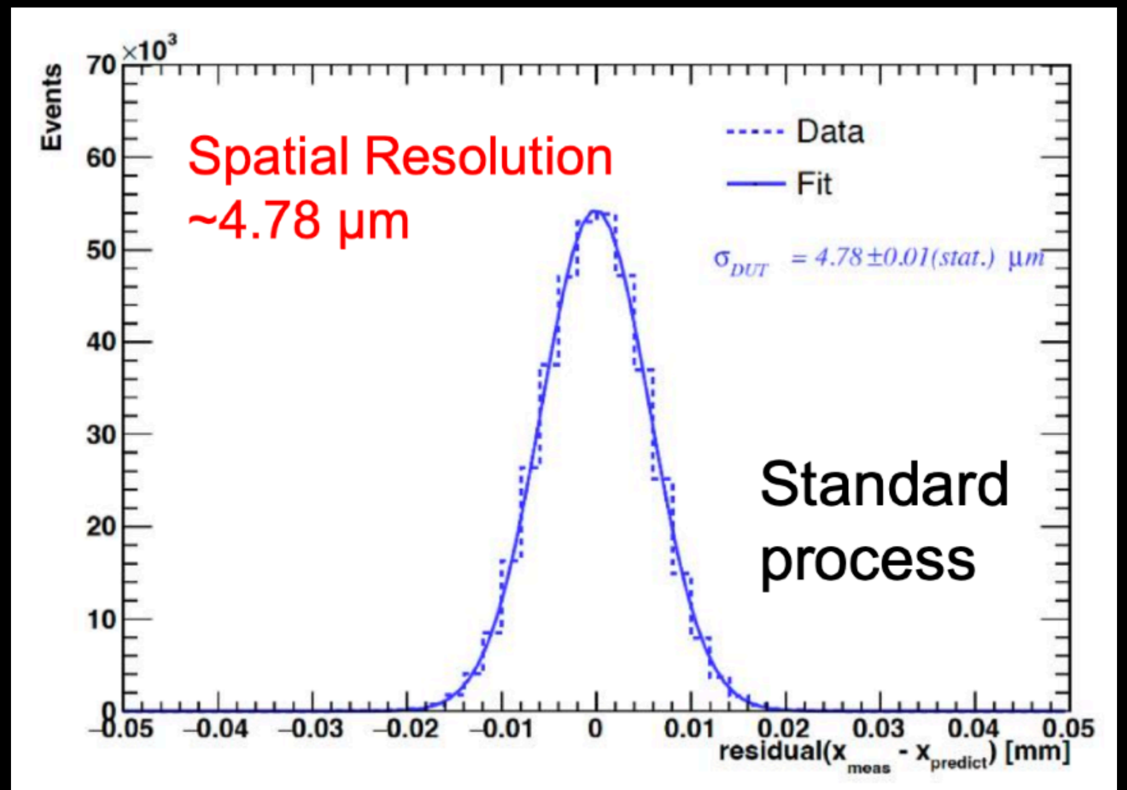


- Full size 1024×512 Pixel array, Chip Size：15.9 × 25.7 mm²
- 25×25μm² pixel size allowing high spatial resolution
- Process: Towerjazz 180nm
- Fast Periphery digital readout , high-speed data interface

- Resolution of < 5 μm demonstrated with:
  - laser tests on bench
  - test beam telescope
  - test beam with full size CEPC vertex prototype



Distribution of residual X

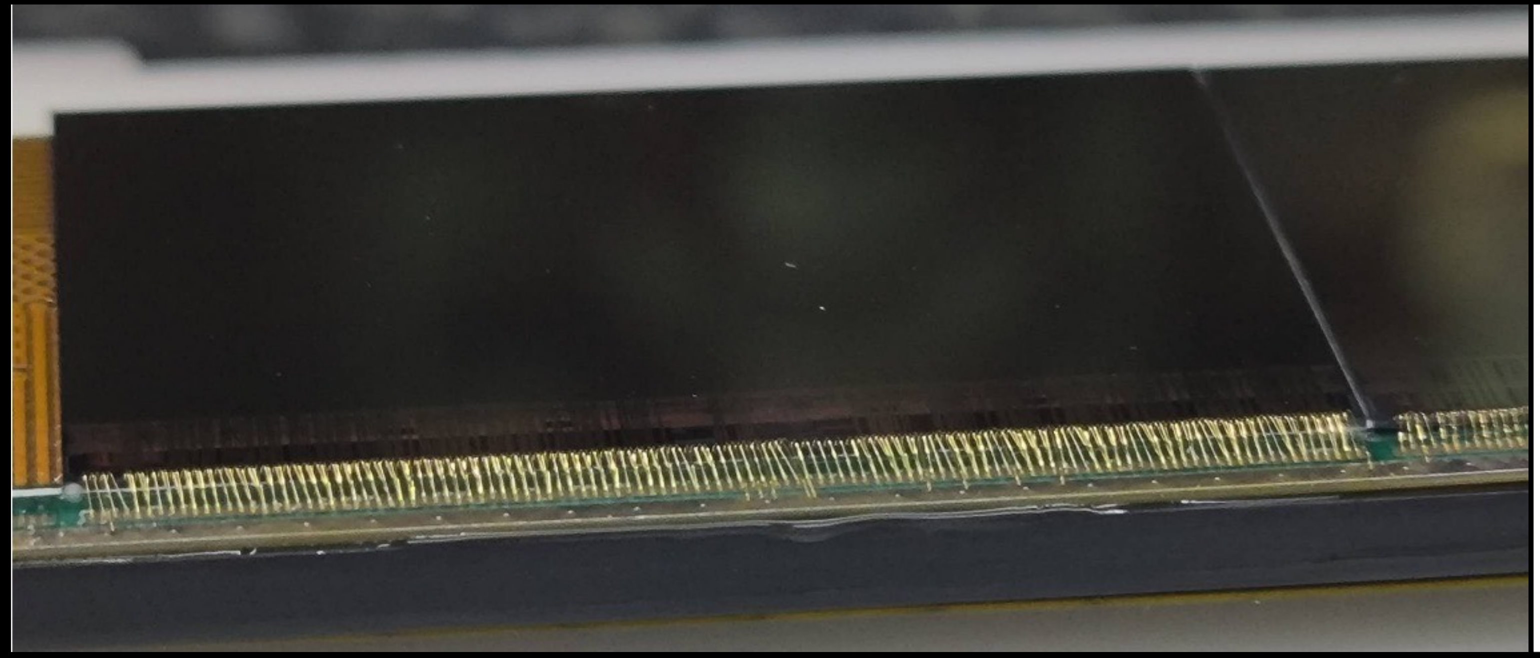


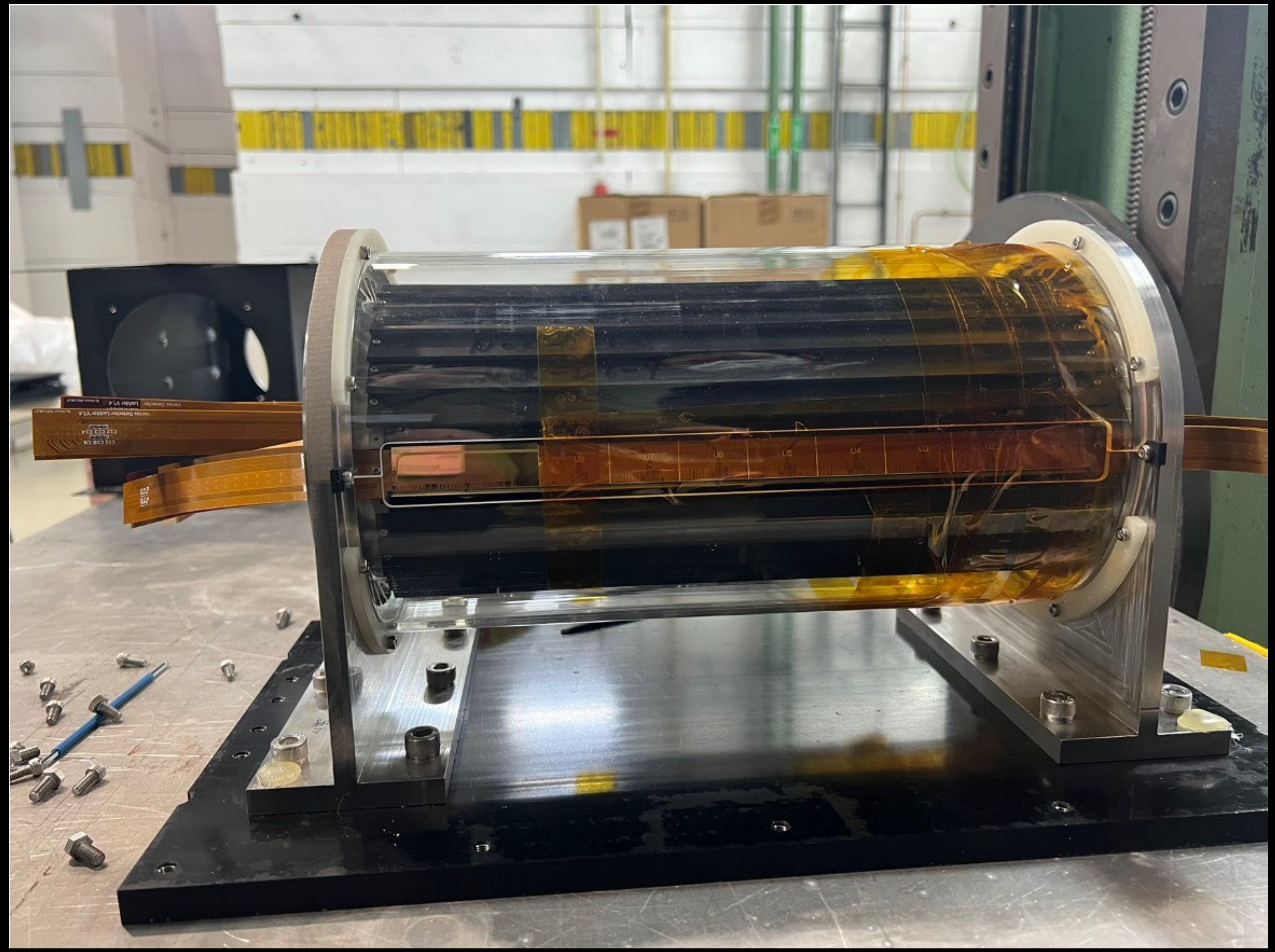
Distribution of residual X

Task 2: Vertex Detector Prototype Development

- **First in-depth full scale silicon vertex prototype developed in China** allowing for the studies of mechanical structures, low-mass materials, and cooling procedures

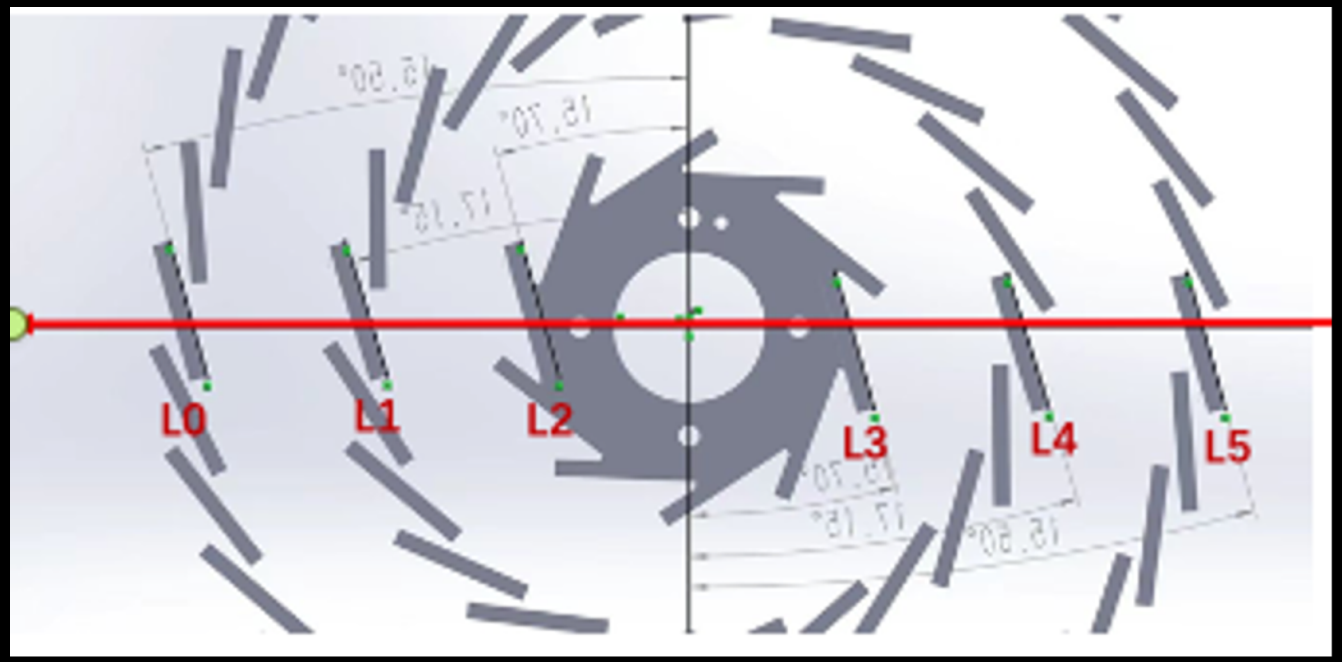
Full scale ladder





Vertex detector configuration for test beam

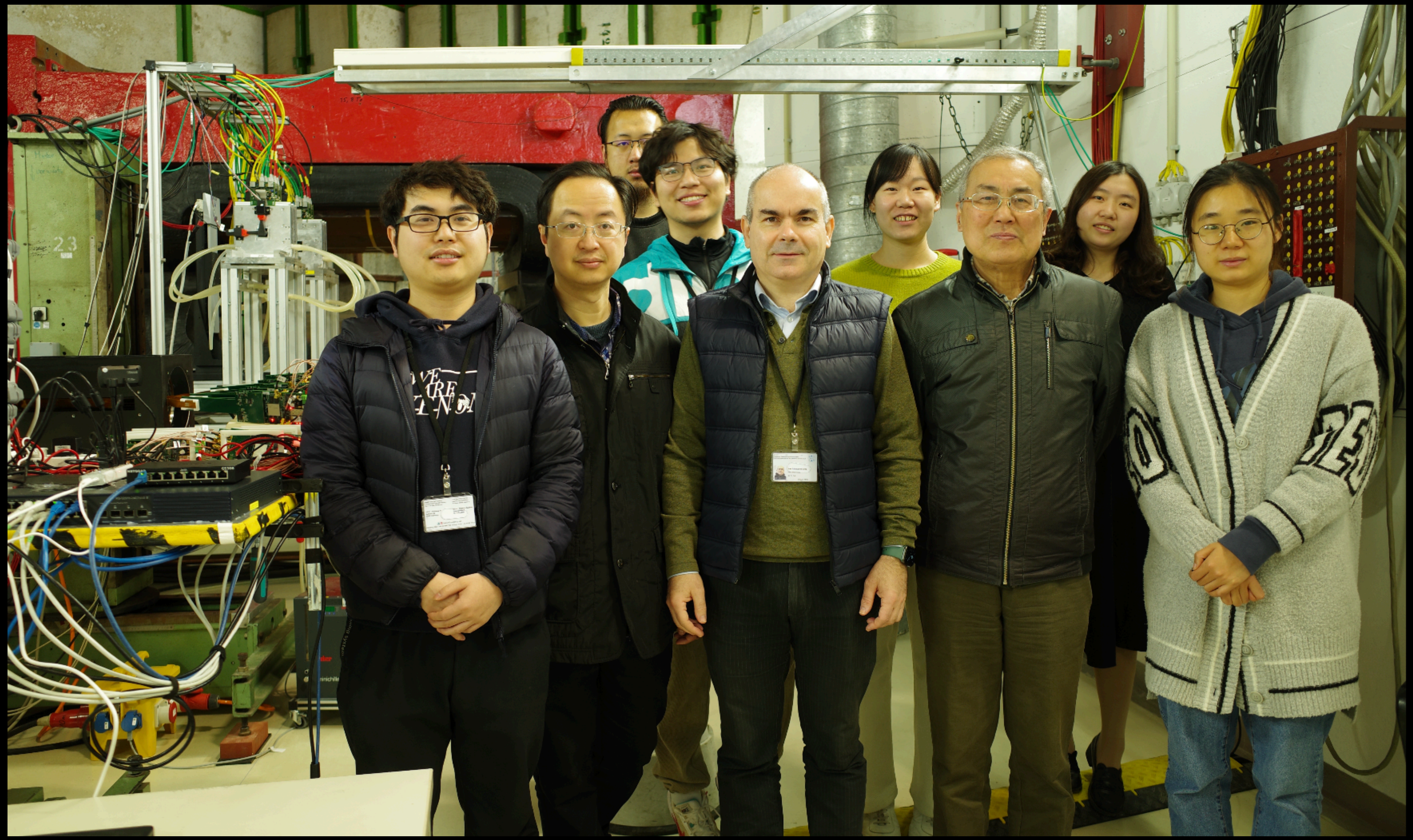
- Three double sided ladders in two sets, for a total of 12 layers
- Twice the layers that a particle would transverse in a real detector

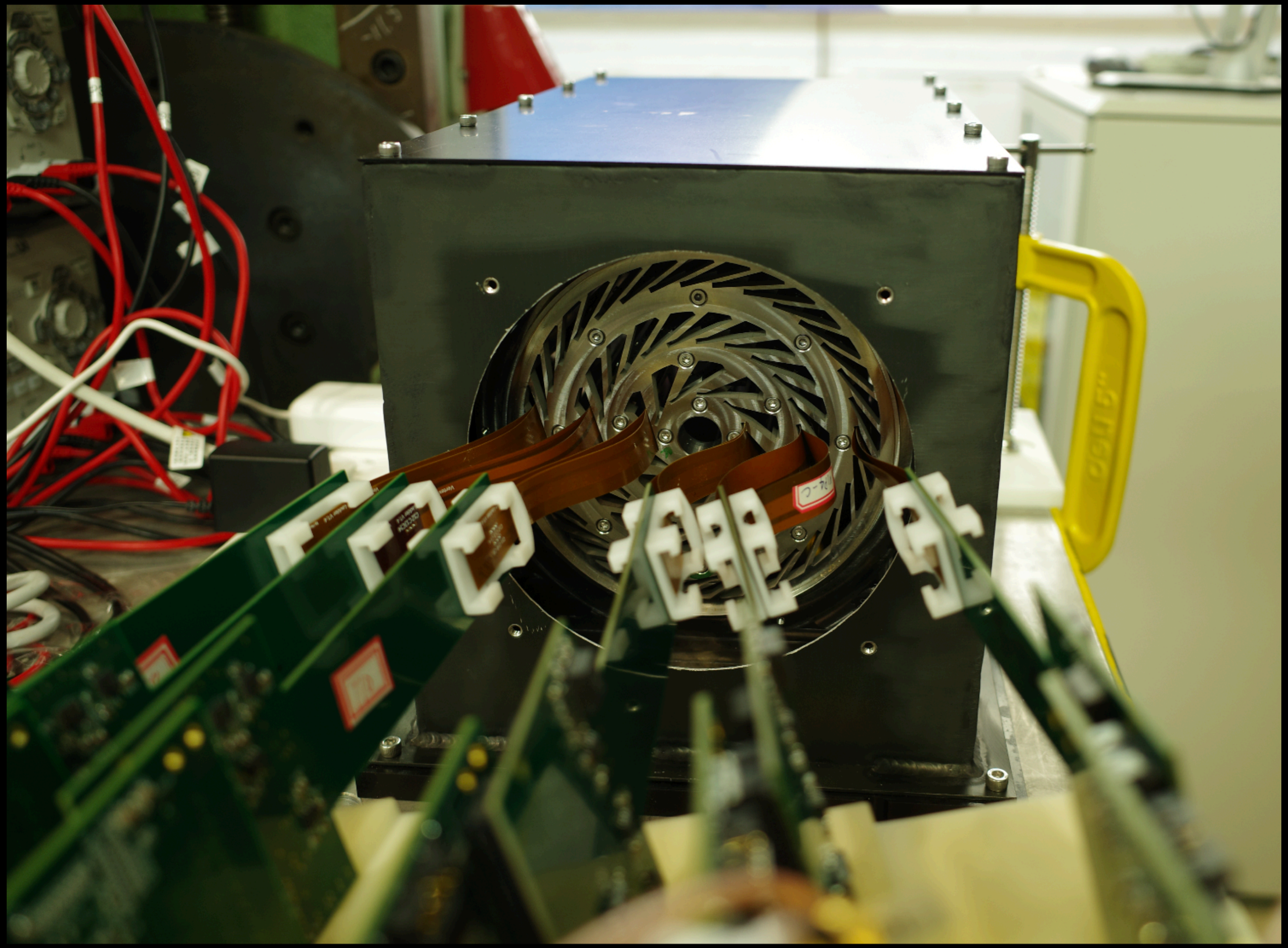


Task 2: Vertex Detector Prototype Test Beam

Two test beam events at DESY, Germany:

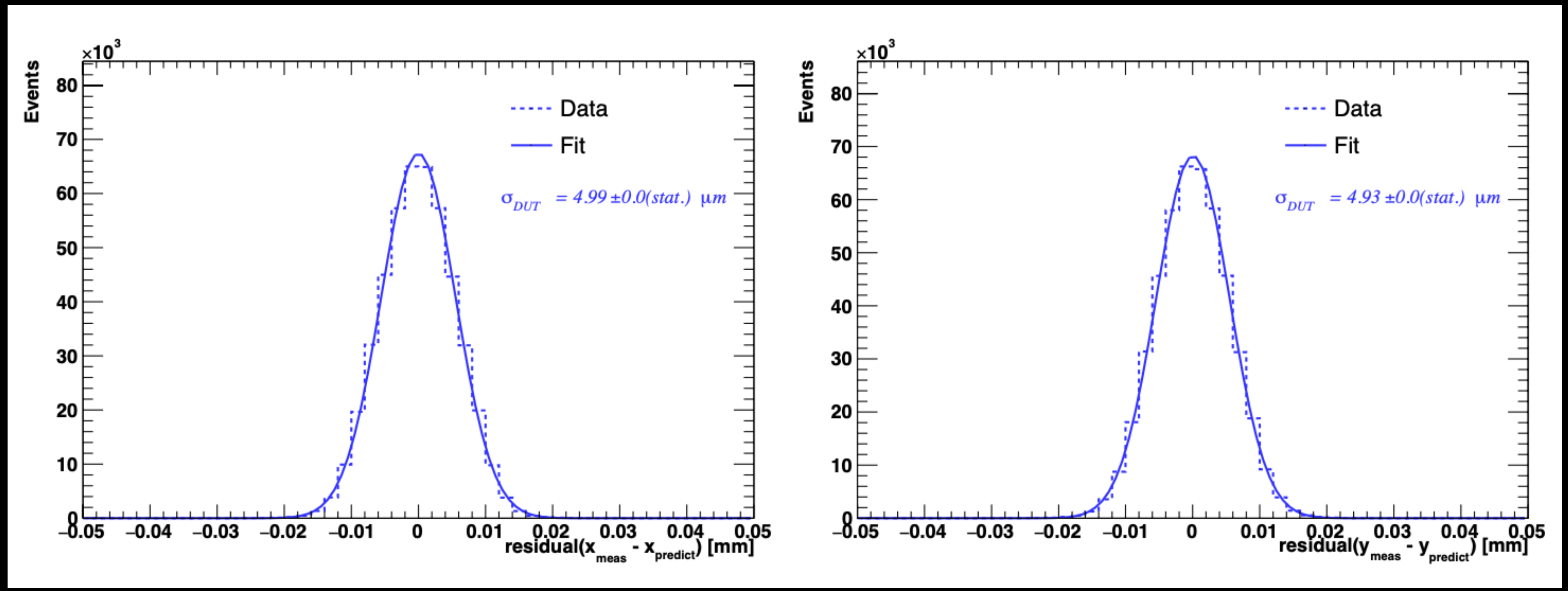
- December 2022
- April 2023





Prototype connected with readout electronics
12 layers of sensors visible

Resolution with full-size mechanical prototype



Achievement Presentation and Assessment Methods

Silicon Detector (研制出硅径迹探测器原型机)	□新理论 □新原理 □新产品 □新技术 □新方法 □关键部件 □数据库 □软件 □应用解决方案 ■实验装置/系统 □工程工艺 □标准 □专利 ■论文 □其他	课题2：硅径迹探测器关键技术验证	硅径迹探测器原型机的空间分辨率	无	研制出小型传感器芯片，像素单元尺寸小于或等于25微米×25微米。	3-5 微米 ✓	同行专家评审。(通过束流实验，离线分析数据获得空间分辨率。该测试结果写入原型机设计与测试报告，以供同行专家评审)
			所设计的抗辐照硅传感器能承受的总剂量	无	完成传感器的初步设计，通过仿真初步验证其抗辐照性能	1 MRad ✓	同行专家评审(提供传感器的设计与测试报告供专家评审)

Assessment method and means of evaluation:

- Peer expert review
- **Beam test** and offline analysis; report to be included in final report (2)

- Peer expert review
- Provide sensor **design** and **test** report for expert evaluation

(*) Final report: "CEPC Detectors Test Report"

Indicator	Requirement	Result		Conclusion	
Spatial resolution	3-5 μm	Laser test: x: 4.0 μm; y: 4.1 μm Beam test: x/y: 4.8 μm	✓	Achieved	**World leading**
Total ionization dose (TID)	> 1 MRad	> 3 MRad	✓	Surpassed	**First in China**

Task 3: Calorimeter Prototype

Task 3: HCAL Prototype Research Goals

- **R&D of SiPM based HCAL prototype**
  - **High energy resolution (60%√E/GeV⊕3%)**
  - **High linearity （non-linearity <3%）**
- **Initial prototype design**
  - **0.5×0.5 m^2 , 35 layer (4λ), 3×3cm^2 module**
  - **SiPM and scintillator coupling**
- **Actual prototype built**
  - **0.72×0.72 m^2 , 40 layer (4λ), 4×4cm^2 module**
  - **number of total channels: 12,960**

Typical HCAL

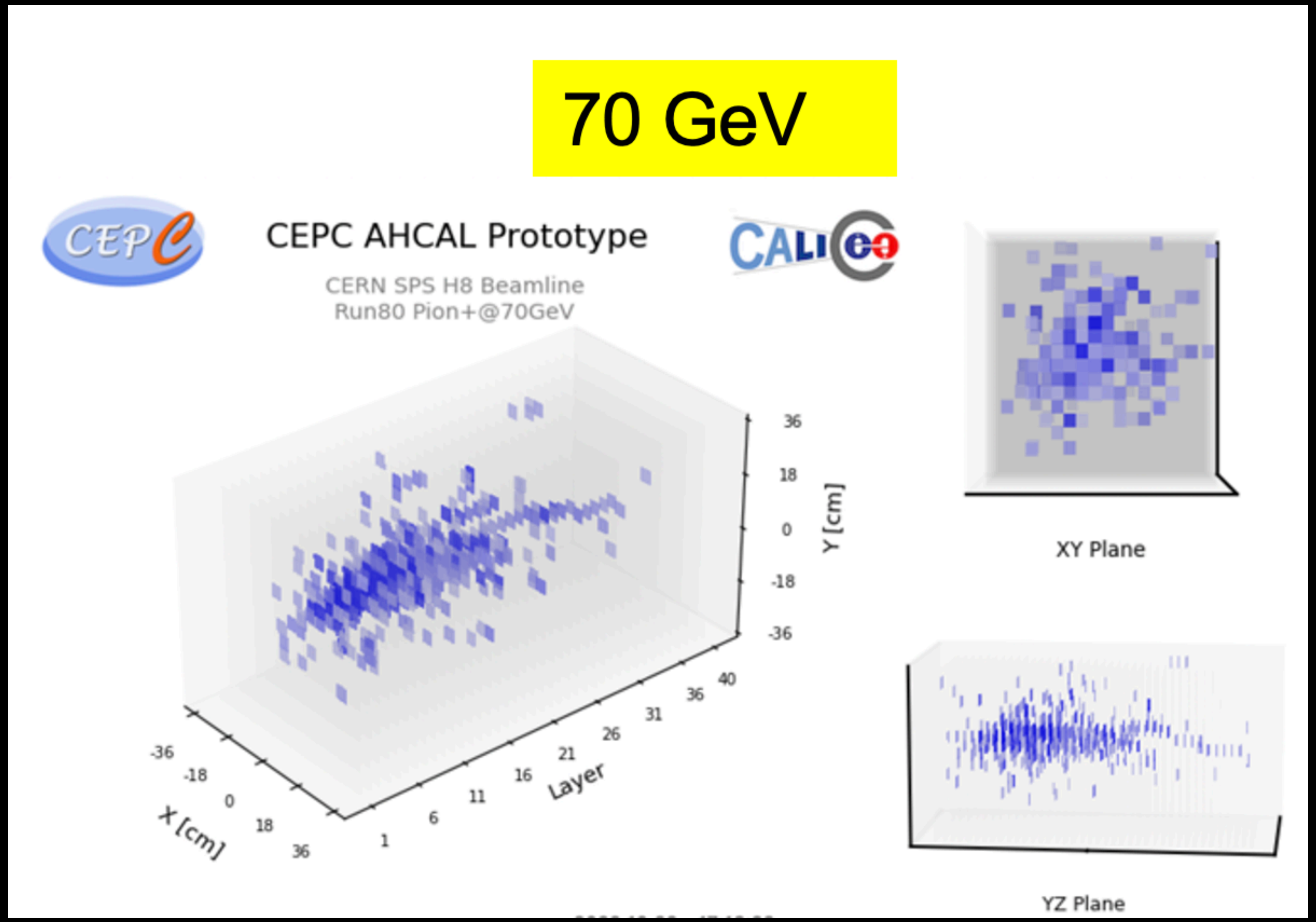
Automatic system developed to cope with the large number of channels

Task 3: HCAL Prototype Testing

Three test beam campaigns at CERN: Oct 2022, April 2023 and May 2023

HCAL prototype

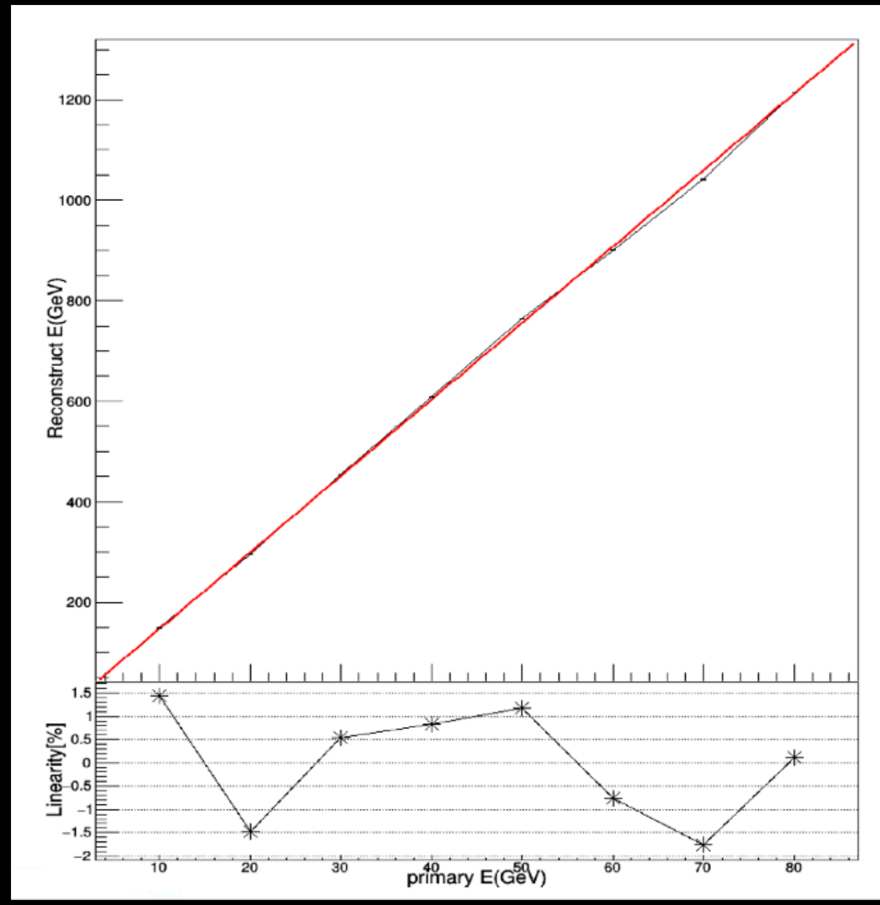
Pion event display

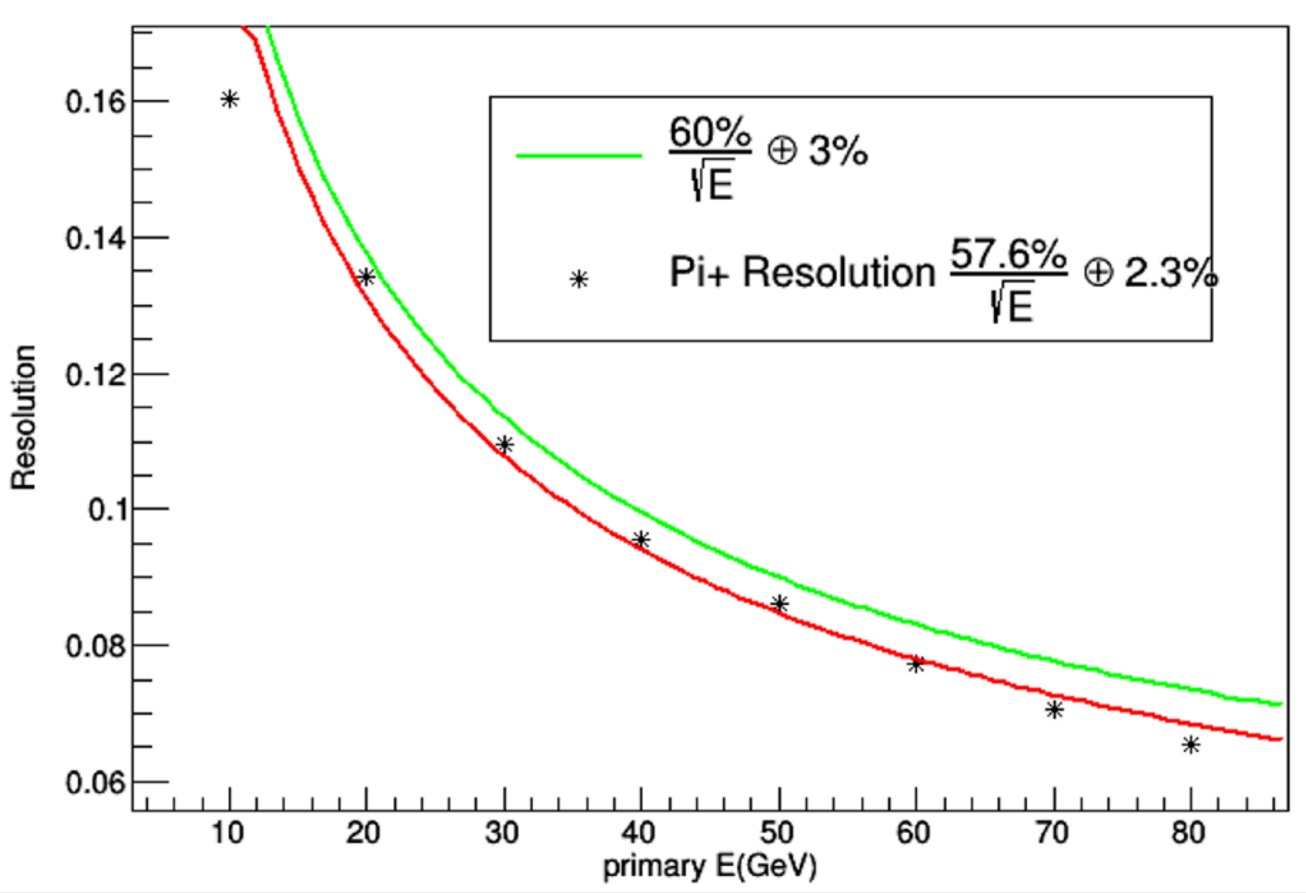


Team at CERN

65 million events collected in total

Linearity < 2%





Resolution

Achievements and Assessment Methods

Calorimeter	□新理论 □新原理 □新产品 □新技术 □新方法 □关键部件 □数据库 □软件 □应用解决方案 ■实验装置/系统 □临床指南/规范 □工程工艺 □标准	课题 3：成像型强子量能器技术验证	量能器能量分辨	无	完成原型机物理设计，模拟得到原型机能量分辨达到 $60\%/\sqrt{E/GeV} \oplus 3\%$ (10GeV<E<80GeV)	$60\%/\sqrt{E/GeV} \oplus 3\%$ (10GeV<E<80GeV) ✓	利用高能粒子束对原型机进行测试，离线分析测试数据获得性能指标。同行专家评审测试报告。
Calorimeter	■论文 □发明专利 □其他		量能器能量线性	无	完成原型机物理设计，模拟得到原型机能量线性达到 3%(10GeV<E<80GeV)	3%(10GeV<E<80GeV) ✓	利用高能粒子束对原型机进行测试，离线分析测试数据获得性能指标。同行专家评审测试报告。

Assessment method and means of evaluation:

- **Peer expert review**
- **Beam test and offline analysis; report to be included in final report (*)**

- **Peer expert review**
- **Beam test and offline analysis; report to be included in final report (*)**

(*) Final report: "CEPC Detectors Test Report"

Indicator	Requirement	Result	Conclusion	
Energy resolution	$60\%/\sqrt{E/GeV} \oplus 3\%$ (10 GeV < E < 80 GeV)	$(57.6\%)/\sqrt{E} \oplus 2.3\%$	✓ Surpassed	First in China
Energy linearity	3% (10 GeV < E < 80 GeV)	<2%	✓ Surpassed	First in China

International Collaboration

The pandemic made international collaboration much complicated, and prevented collaboration with UK and US institutes within the vertex detector project

Academic Achievements

	Accelerator	Vertex	Calorimeter	Total
Patents	8	3	1	12
Papers	11	5	8	24
Proceedings	2	1		3
Conferences	16	18	28	62
PhD Students	6	8	4	18
Master Students		23	3	26
Postdocs		2	1	3

小结

- All indicators have been achieved in the project
  - Several world-leading and china-first achievements were made
  - Long-lasting knowledge was acquired that will help us progress further in the future
- Details will follow in the next talks

谢谢

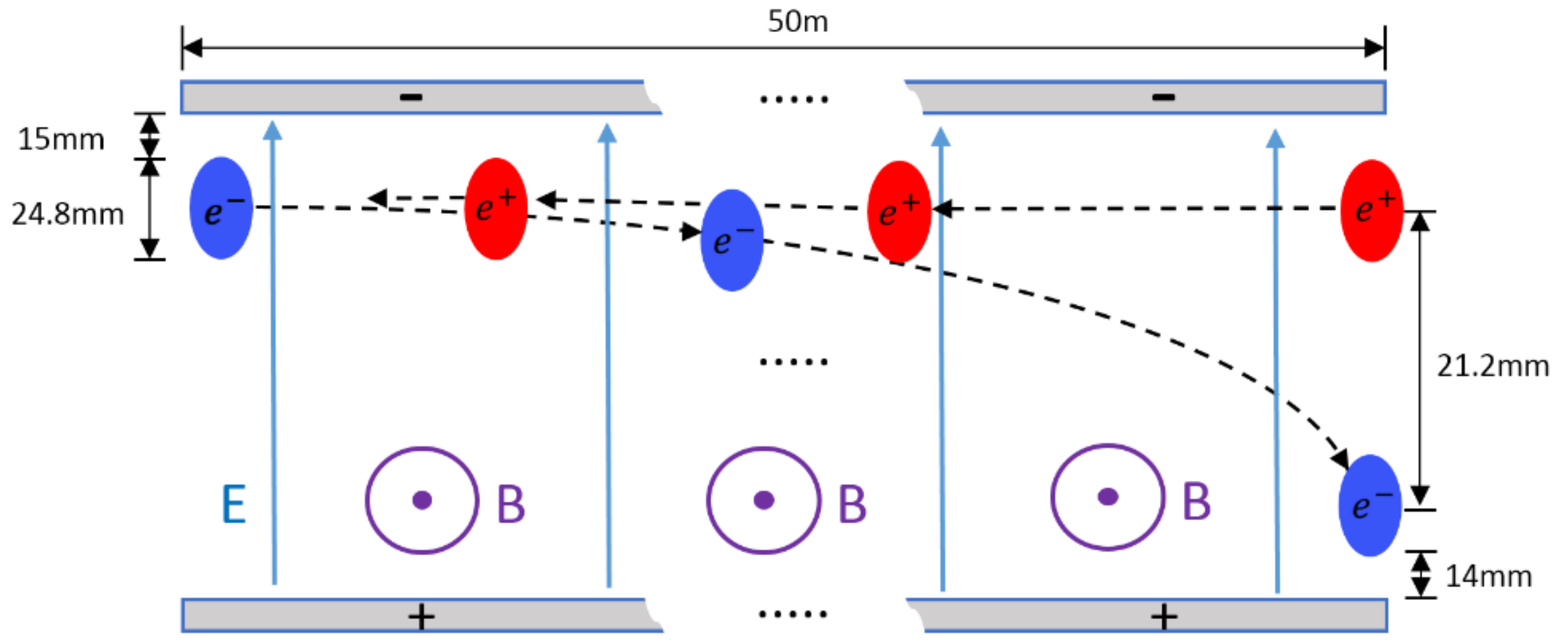
The end

Electrostatic Separator R&D

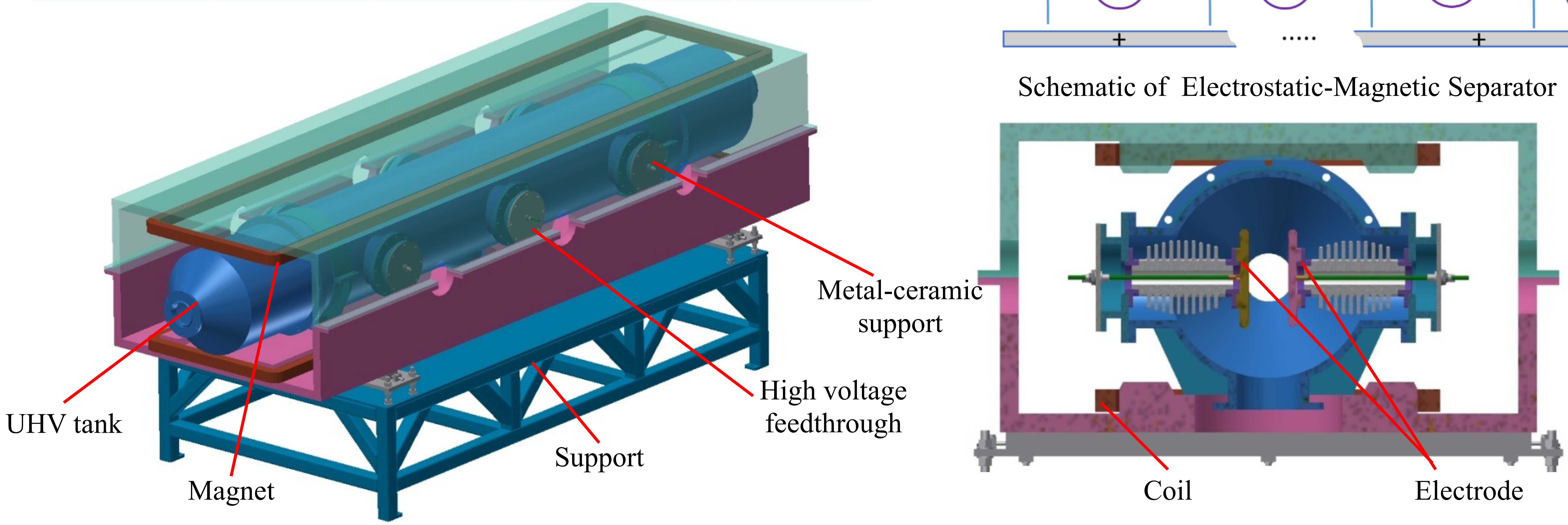
Introduction

- The Electro-Magnetic Separator is a device consisting of perpendicular electric and magnetic fields.
- One set of Electro-Magnetic Separators including 8 units, total 32 units will be need for CEPC.

	Filed	Effective Length	Good field region	Stability
Electrostatic separator	2.0MV/m	4m	46mm×11mm	5×10^{-4}
Dipole	66.7Gauss	4m	46mm×11mm	5×10^{-4}



Schematic of Electrostatic-Magnetic Separator



Structure drawing of Electrostatic-Magnetic Separator

Assessment Indicators of Science and Technology Report

序号	Report type	数量	提交时间	公开类别及时限
1	Annual technical progress report	1	2019 年 6 月	公开
2	Annual technical progress report	1	中期检查前	公开
3	Annual technical progress report	1	2021 年 6 月	公开
4	Annual technical progress report	1	2022 年 6 月	公开
5	Annual technical progress report - final report	1	结题验收前	公开
6	High Energy Circular Collider Detector Design Report	1	2021 年 4 月	公开
7	High Energy Circular Collider Detectors Test Report (task 2+3)	1	2023 年 4 月	公开
8	High Energy Circular Electron-Positron Collider Key Technology Design and Test Report	1	2023 年 4 月	公开

Project management organization

- **Risks and Response Measures**
  - There may be some risks in the implementation of this project, but they can be effectively avoided by different kinds of methods:
    - Intermediate small-scale prototypes
    - Strengthening international communication/collaboration
  - Examples:
    - Precision of accelerator dipole magnet can be explored and achieved by means of small prototype
    - Technical limit of coating for bending vacuum box and Detector design errors can be effectively avoided through international communication and learning from the experience of others
    - Due to the installation accuracy of detector and the delay risk of calorimeter packaging process, automatic control system and automatic packaging scheme can be used to ensure the accuracy and progress.
    - Chip embargo/submission rules: problem can be managed by integrating into international collaboration (e.g. ATLAS)

Project management organization - Initial Expert Team

- **MOST Project Responsibility Expert**
  - **Zhao Hongwei** (Institute of Modern Physics, CAS)
  - **Wang Qiuliang** (Institute of Electrical Engineering, CAS)
  - **Xu HongJie** (Shanghai Institute of Application Physics, CAS)
- **Expert Team (8 people)**
  - **Xu Nu** (Institute of Modern Physics, CAS)
  - **Tang Chuanxiang** (Tsinghua University)
  - **Lv Junguang** (Institute of High Energy Physics, CAS)
  - **Li Jin** (Institute of High Energy Physics, CAS)
  - **Gao Yuanning** (Peking University)
  - **Youjin Yuan** (Institute of Modern Physics, CAS)
  - **Hu Guo Chaoying** (IN2P3-CNRS-University of Strasbourg, IPHC)
  - **Zhentang Zhao** (Shanghai Institute of Applied Physics, CAS)