TDR
Editing Organization

Tuesday CEPC TDR Meeting
June 03, 2025

Joao Guimaraes

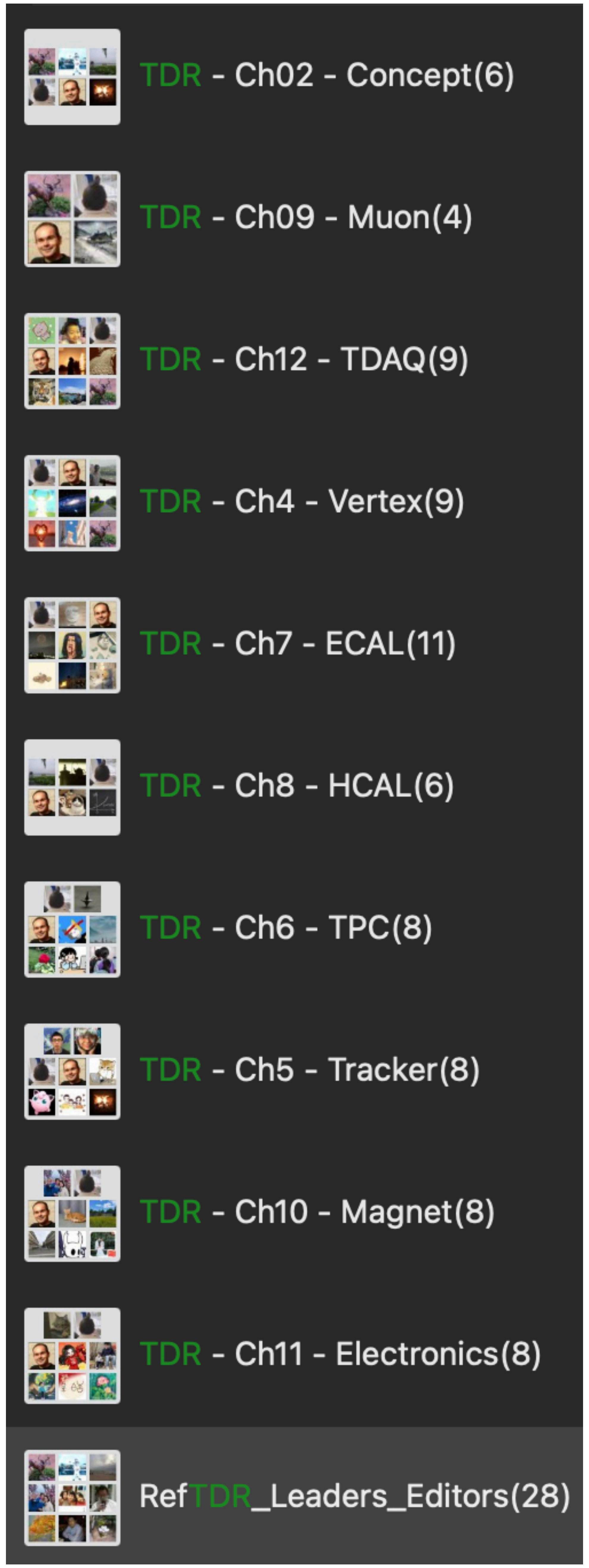
Outline

- Keeping track of modifications — overall situation
- Plots formats → sample plots
- Length of chapters
- Symbol consistency and glossary
- Organization of overall tracking and calorimetry → Detector Concept Chapter

Keeping track of modifications

- **Created WeChat new chats for several chapters:**
  - Try to keep discussion relative to your chapter within the corresponding chat
- General announcements still to RefTDR_Leaders_Editors
- Feedback is appreciated, so that i know you are working on something and when you plan to finish

- **Spreadsheet monitoring the status moved by Zhaoru to IHEP docs:**
  - https://docs.ihep.ac.cn/link/ARF4C648FCA57D4CF281A8E821A110229E
  - 文件名： Status of TDR.xlsx
  - 文件路径： AnyShare://ZHANG Zhaoru(zhangzr)/CEPC Det TDR/Status of TDR.xlsx
  - Please fill in your input now, and **keep it updated** as we move along
  - Information will be added by myself as well to give feedback on the parts that have been processed



Keeping track of modifications

Blue section of the spreadsheet is for chapter leaders

			Chapter leaders							
Chapter	Overall Complete	Chapter structure	Updated date	Tables		Figures			Text	
			Ready for check	Unified format	Significant digits	Change to pdf	Unified Macro	Enlarge the font size	Symbols	Glossary
Executive summary	80%	100%		100%	100%		100%	100%	100%	
1 Introduction	80%	100%		100%	100%		100%	100%	100%	
2 Concept of CEPC Reference Detector	90%	100%		90%	90%	90%		90%		
3 MDI and Luminosity Measurement	90%	90%		90%	80%	90%		70%	70%	
4 Vertex Detector	90%	100%		100%	95%	50%		70%	80%	
5 Silicon Trackers	100%	100%		100%		80%			90%	
6 Pixelated Time Projection Chamber	95%	100%		100%	100%	100%		80%	95%	95%
7 Electromagnetic calorimeter	90%	90%		90%	90%	50%		80%		
8 Hadronic calorimeter	90%	100%		90%	90%	70%		80%	90%	
9 Muon Detector	95%	100%		100%		75%		80%		
10 Detector magnet system	70%	70%		90%	100%	10%		100%		
11 Readout Electronics	90%	100%		100%	100%	60%		80%	100%	
12 Trigger and Data Acquisition	95%	100%	Jun. 2rd	100%	100%	100%	100%	100%	100%	
13 Offline software and computing	95%	100%		100%	100%	100%	100%	100%	95%	95%
14 Mechanics and integration	80%	80%		100%	80%	100%		70%	90%	
15 Detector and physics performance	80%	80%		100%		70%			100%	
16 Timeline and Future Plans										
17 Reference detector costing										
18 Summary										

People overly optimistic - try to be critical (100% should mean ready to be printed)

Keeping track of modifications

Yellow section of the spreadsheet is for chapter review editors (english) appointed by Jianchun

Chapter	Chapter Review Editors	
	Name	Status
Executive summary		
1 Introduction		
2 Concept of CEPC Reference Detector	Mingshui	80%
3 MDI and Luminosity Measurement	Manqi	60%
4 Vertex Detector	Mingyi	90%
5 Silicon Trackers		
6 Pixelated Time Projection Chamber	Mingyi	70%
7 Electromagnetic calorimeter	Manqi	50%
8 Hadronic calorimeter	Jianbei	
9 Muon Detector	Weidong	
10 Detector magnet system	Haijun	
11 Readout Electronics	Zheng	80%
12 Trigger and Data Acquisition	Zheng	85%
13 Offline software and computing	Gang	
14 Mechanics and integration	Jingbo	80%
15 Detector and physics performance	Weidong	85%
16 Timeline and Future Plans	Jianbei	
17 Reference detector costing		
18 Summary		

	Chapter	Chapter Leader(s)	Responsible Editors	
1	Introduction	Joao Costa / Gang Li	-	
2	Concept of Ref-Detector	Haijun Yang / Mingyi Dong	MSC	
3	MDI and Luminosity Measurements	Haoyu Shi	MQR	
4	Vertex Detector	Zhijun Liang / Jerome ?	MYD	
5	Silicon Trackers	Qi Yan	-	
6	Gaseous Tracker	Huirong Qi / Nicola De Filippis	MYD	
7	Electromagnetic Calorimeter	Yong Liu / Hwidong Yoo	MQR	
8	Hadron Calorimeter	Sen Qian	JBL	**TCZ**
9	Muon Detector	Xiaolong Wang / Pavel Pakhlov	WDL	*JCW JGC*
10	Superconducting Solenoid Magnet	Feipeng Ning	HJY	
11	Readout Electronics	Wei Wei	ZW	
12	Trigger and Data Acquisition	Fei Li	ZW	
13	Software and Computing	Weidong Li	GL	
14	Mechanics and Integration	Quan Ji	JBY	
15	Detector and Physics Performance	Mingshui Chen	WDL	
16	Construction Cost	Miao He	JBL	
17	Future Plans	Gang Li / Miao He / JCW	-	

Please indicate how far have you read and when you will be finished

People editing TDR latex directly?

Keeping track of modifications

Green section is for Joao's feedback

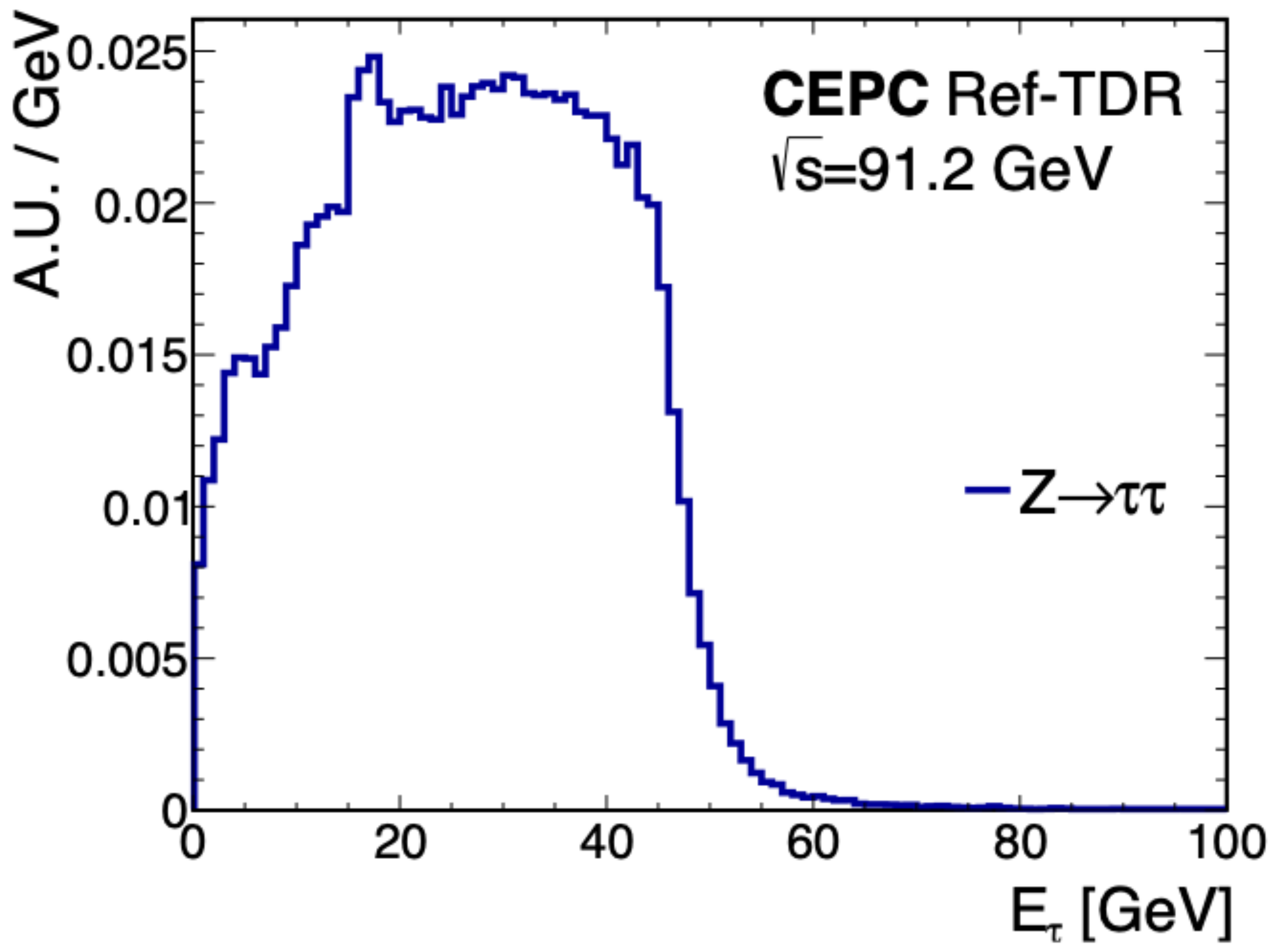
	Joao									
Chapter	Overall structure									
	Introduction	Introduction Quality	Overall complete	Chapter Structure	Page	Length	Tables to fix	Figures to fix	References	Comments
Executive summary					14	2				
1 Introduction	Yes	Needs references to sections		NA	16	13				
2 Concept of CEPC Reference Detector	No	0	70%	NA	29	12	2.1,		Need mor r	All collider in
3 MDI and Luminosity Measurement	No	0	80%	80%	41	42	left justify fi	Some lumical figures are too small		
4 Vertex Detector	No	0	80%	80%	83	52	some tables	some Figures are not qu		Need to rear
5 Silicon Trackers	Yes	OK, but needs expansion to cover sections	90%	95%	135	41	The positior	The positions of some fi		Too long. Th
6 Pixelated Time Projection Chamber	Yes	Need to reorganize			176	119				
7 Electromagnetic calorimeter	Yes	Needs expansion of references to sections	80%	80%	295	70				Checked
8 Hadronic calorimeter	No	0		90%	365	54				
9 Muon Detector	No	0	70%	50%	419	43				
10 Detector magnet system	Yes	Needs to expand to cover sections			462	57				
11 Readout Electronics	No	Use the introduction and remove the title, then it needs reference to sections	80%		519	60		fig11.4, 11.5, 11.9, 11.1		It is too muc
12 Trigger and Data Acquisition	Yes	Perhaps too long, needs to expand to cover sections	90%		579	52				
13 Offline software and computing	Yes	Very good → Excellent :-)			631	61				
14 Mechanics and integration	Yes	Needs to expand to cover sections			692	50				
15 Detector and physics performance	Yes	Use the introduction and remove the title, then it needs reference to sections	85%	90%	742	55		Figure 13, Figure 14, Figure 15, Figu		
16 Timeline and Future Plans					797	1				
17 Reference detector costing					798	2				
18 Summary					800					

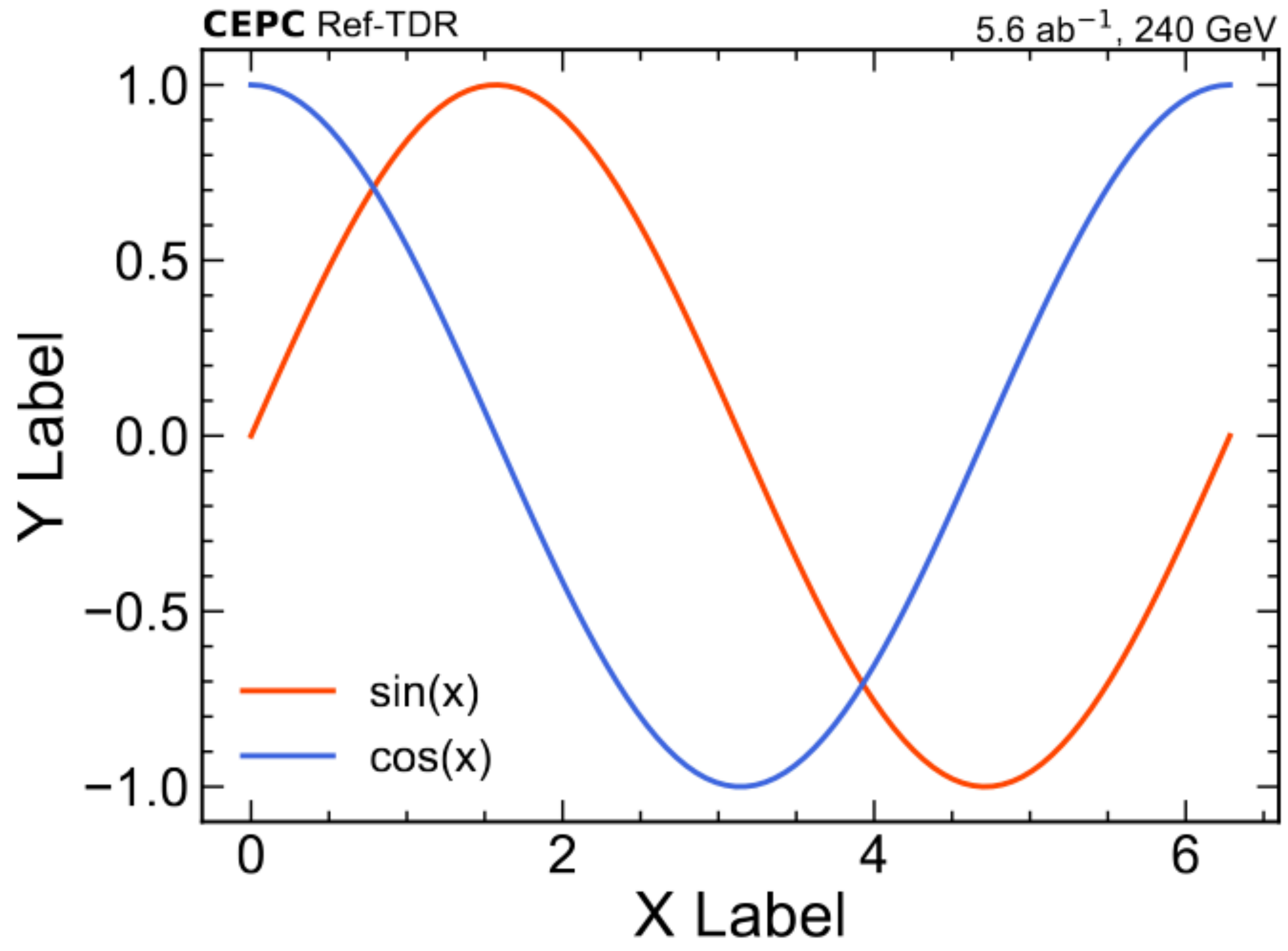
Check this section and get back to me if you need clarifications on something

Plot formats → sample plots

by Zhang Yang and Kaili

- Templates with instructions at: https://latex.ihep.ac.cn/project/68347a429cc3e0db27dacfc4
- Python code: Gitlab: https://code.ihep.ac.cn/zhangyang98/cepc-style
- ROOT style file for CEPC: ~zhangkl/cefs/plot/CEPCStyle.h



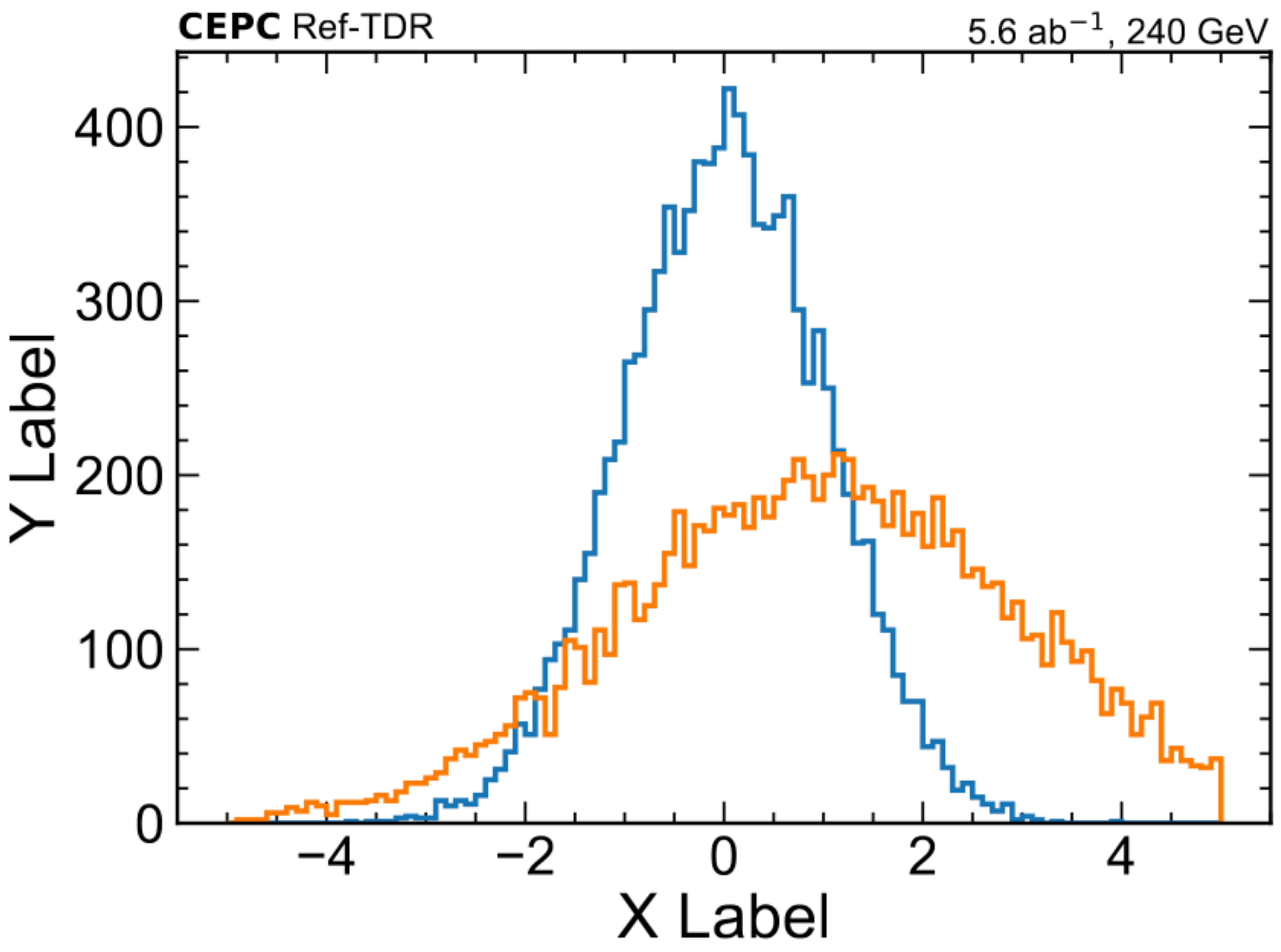


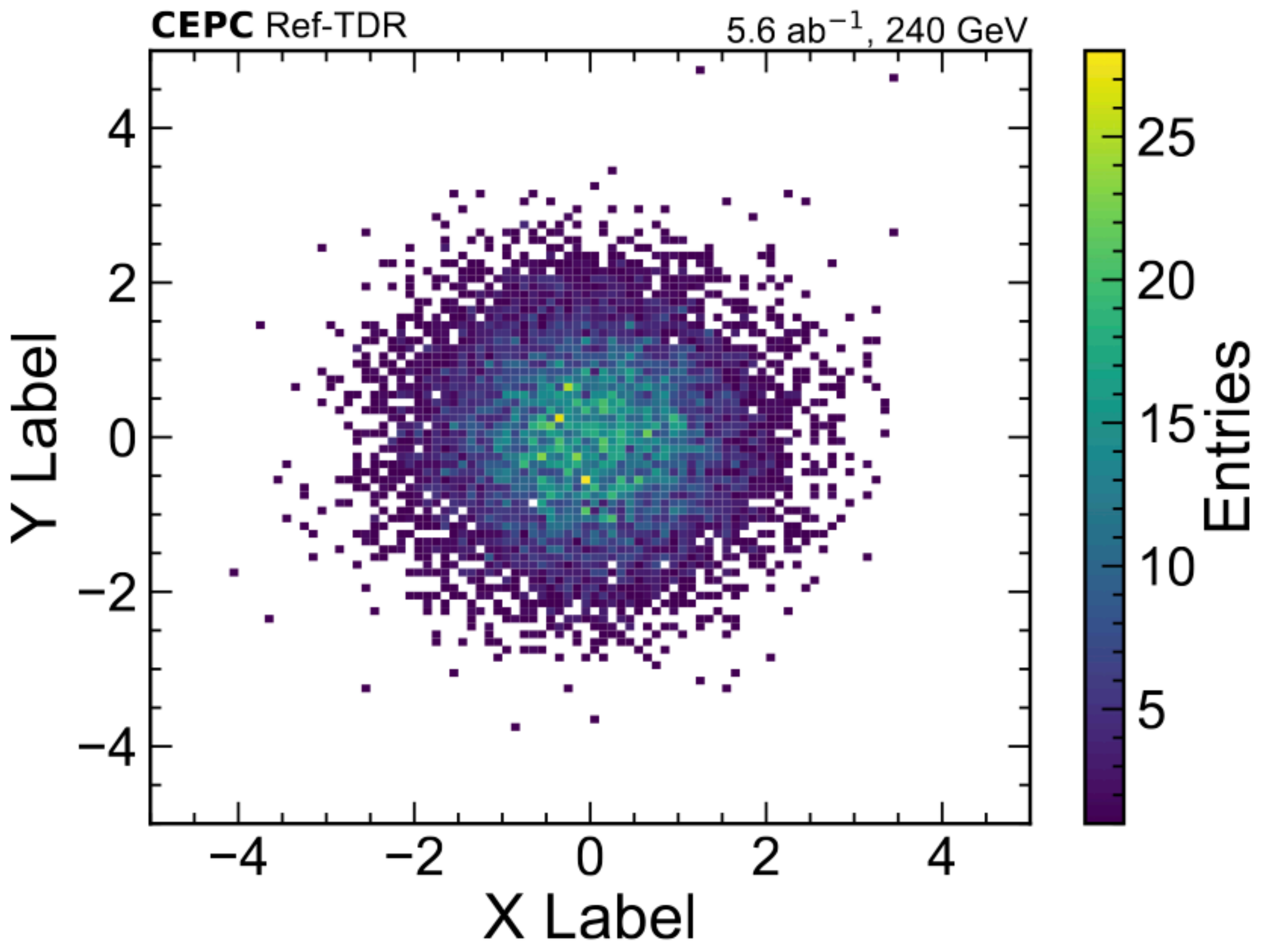
Most important: keep proportions of the text large compared to the plot

Plot formats → sample plots

by Zhang Yang and Kaili Zhang

- More sample plots from python
  - Fonts and styling a little different between root and python





Label for plots: **CEPC** Ref-TDR

Length of Chapters

- Document currently has 800 pages, this twice as big as CDR
- Really need to decide on a total length
- Some chapters look good but a bit too long:
  - Silicon Tracker: 106 pages
  - Electromagnetic calorimeter: 70 pages
  - Offline software and computing: 61 pages
  - Readout electronics: 60 pages
  - Detector magnet system: 57 pages
  - TPC: 54 pages

Chapter	Page	Length
Executive summary	14	2
1 Introduction	16	13
2 Concept of CEPC Reference Detector	29	12
3 MDI and Luminosity Measurement	41	42
4 Vertex Detector	83	52
5 Silicon Trackers	135	106
6 Pixelated Time Projection Chamber	241	54
7 Electromagnetic calorimeter	295	70
8 Hadronic calorimeter	365	54
9 Muon Detector	419	43
10 Detector magnet system	462	57
11 Readout Electronics	519	60
12 Trigger and Data Acquisition	579	52
13 Offline software and computing	631	61
14 Mechanics and integration	692	50
15 Detector and physics performance	742	55
16 Timeline and Future Plans	797	1
17 Reference detector costing	798	2
18 Summary	800	

Symbols unification

- Being led by Zhaoru and Tao Lin

- File with physics/math symbols to be used by all: **cepcphysics.sty**

- **Unit Symbols**:
  - Unit symbols should be written in **non-italic** font, especially when they appear in equations. Use `\mathrm{}` for units in equations.
  - Add a space between numbers and units, e.g., `1~mm`.
  - Use unit symbols exclusively, e.g., do not use "meters" or "microns".
- **Energy Units**:
  - Replace **GeV**, **TeV**, **MeV**, etc., with `\GeV`, `\TeV`, `\MeV`.
  - The `cepcphysics.sty` file defines these terms; reference them using `\` + the term.
- **Particle Names**:
  - **H**, **Z**, **W** should be written in **uppercase italics**. Use `\Hboson`, `\Zboson`, etc., to replace them (refer to the definitions in `cepcphysics.sty`).
  - Check other particles, such as **pi**, **K**, etc., and use the `.sty` file definitions, `\` + the term.
- **Variable Names**:
  - Replace **p_T**, **E_T**, **Missing E_T**, etc., with the definitions from the `.sty` file.

- Add your own symbols to the file and let Zhaoru and others know

Glossary

- Being led by Zhaoru and Tao Lin
- First version of glossary added at end of TDR, albeit without page numbers yet
- Tao Lin working to add it to all chapters via a script

Glossary

AAI Authentication and Authorization Infrastructure
AC Alternating Current
AC-LGAD AC-coupled Low Gain Avalanche Detector
ADC Analog-to-Digital Convert
AFE Analog Front-End
AHCAL Analog HCAL
AI Artificial Intelligence
ALDD Array Laser Diode Driver ASIC
ALP Axion-Like Particle
ALPs Axion-Like Particles
APD Avalanche Photodiodes
APDs Avalanche Photodiodes
APEP Associated Proton Beam Experiment Platform
AR Augmented Reality
ASIC Application Specific Integrated Circuits
ASICs Application-Specific Integrated Circuits
ASTC Aluminum stabilized Stacked REBCO Tape Cable
ASU Active Sensor Unit
ATCA Advanced Telecommunications Computing Architecture
ATIA Array Transimpedance Amplifier ASIC

BAU Baryon Asymmetry of the Universe
BE Back-end Electronics
BEE Backend Electronics
BEPCII Beijing Electron-Positron Collider
BESIII Beijing Spectrometer
BGB Beam Gas Brems
BGC Beam Gas Coulomb
BGO Bismuth Germanate
BMR Boson Mass Resolution
BOSS BES III Offline Software System
BPMs Beam Position Monitors
BR Branching Ratio
BSC Beam Stay Clear
BSM Beyond the Standard Model
BSO Bismuth Silicate
BTH Beam Thermal Photon

Introduction(s)

Chapter 13 Offline software and computing

The development of the CEPC software (CEPCSW) [1] is based on several foundational HEP software packages, including the Gaudi [2] software framework for event processing, EDM4hep [3] for the event data model, DD4hep [4] for detector description, Geant4 [5] for simulation, and ROOT [6] for data analysis. A key aspect of this endeavor is the development of CEPC-specific software, designed to meet the experiment's unique requirements. The core software will be introduced in Section 13.1, while the applications for simulation, reconstruction, analysis, and visualization will be described in Sections 13.2, 13.3, and 13.4, respectively.

To tackle the growing complexity of data processing tasks, emerging technologies are being actively explored. Research and development efforts focus on areas such as concurrent computing, machine learning, and quantum computing, which will be discussed in Section 13.5.

Grid computing technology, successfully implemented in the LHC experiments, connects computing and storage resources distributed across laboratories worldwide, facilitating the processing and analysis of EB-level data. Leveraging this technology, we have established a distributed computing infrastructure (DCI) to support detector R&D activities. On this prototype, the latest Grid computing technologies are being investigated and evaluated to ensure robust support for the experiment's future operations. These aspects will be discussed in Sections 13.7 and 13.10.

In the current project, the software and computing team is responsible for providing the core software, including the framework, various services, data management, and computing systems. The development of detector-specific algorithmic code for simulation, calibration, and reconstruction is a shared responsibility between the software and computing team and the sub-detector teams. Close collaboration with the physics group ensures the smooth development of global event-reconstruction code and software tools for physics analysis.

Chapter 12 Trigger and Data Acquisition

While collision rates reach tens of megahertz, the actual Higgs production rate remains vanishingly small—a fundamental discrepancy that demands a trigger and data acquisition (TDAQ) system capable of identifying rare physics events within an overwhelming background of non-interesting processes. This system must achieve real-time event selection while preserving the integrity of critical physics signals.

This chapter presents the technical design of the CEPC reference detector's TDAQ system. Subsequent sections address critical topics including system requirements and overall architectural design as Section 1, hardware trigger implementations as Section 2, software-based high-level triggers as Section 3, trigger simulations and algorithms as Section 4, data acquisition infrastructure as Section 5, and integrated run control with online monitoring systems as Sections 6 and 7.

Chapter 7 Electromagnetic calorimeter

The CEPC electromagnetic calorimeter (ECAL) plays a critical role in precision measurements of Higgs and flavour physics. It is a high-granularity homogeneous calorimeter with dense scintillating crystals. Based on the Particle Flow Algorithms (PFA), it aims to achieve an unprecedented jet energy resolution and excellent electromagnetic (EM) performance, which will enable the accurate reconstruction of Higgs decaying into photons and jets as well as EM showers of meson decays involving with photons.

The primary objective of the ECAL is to identify and reconstruct EM showers, even in the presence of near-by particles, while also serving as the first section for hadronic showers. To ensure superior separation of near-by particle showers, the ECAL is highly segmented both longitudinally and transversely. Based on detailed simulation optimisations, the granularity of the longitudinal and transverse segmentations is at the level of X_0 (radiation length) and R_M (Moliere Radius), respectively. The ECAL design emphasises maximum possible hermeticity, modularity and scalability.

This chapter is organised as follows: Section 7.1 first introduces the ECAL, followed by the ECAL design in Section 7.2 and key technologies in Section 7.3. Dedicated R&D activities and performance studies will be discussed in Section 7.4 and Section 7.5. ECAL backup options will be listed in Section 7.6 and summary and prospects will be presented in Section 7.7.

Most people seem to have misunderstood the request

Check the CDR and these chapters for good examples

Introduction(s) — bad examples — Need changes

Chapter 3 Machine Detector Interface and Luminosity Measurement

3.1 Overview

The Machine-Detector Interface (MDI) represents one of the most complex challenges associated with the CEPC project. Specifically, it must address all relevant issues pertaining to both the machine and the detector. This chapter outlines key topics including the layout of the MDI region, the beam pipe, the cryogenic module, the beam induced backgrounds, and the luminosity measurement detectors . The compact and complex design of the CEPC MDI fulfils constraints from both the machine and the detector, which is still under optimization. The future plan will be discussed in Section 3.5.

A conmmon layout is designed for all CEPC operation modes as shown in Figure 3.1. The MDI region spans approximately 14 m (± 7 m from the Interaction Point) in length within the Interaction Region (IR) and encompasses various components, including the detector, luminosity calorimeter(LumiCal), central beam pipe, cryogenic modules, and supporting items such as bellows, flanges, etc. The interface between the machine and the detectors extends beyond the detector's acceptance, which is 99%. The accelerator components housed within the detector must not interfere with the detector devices, and after optimization, they occupy a conical space with an opening angle of 10 mrad. The crossing angle between electron and positron beams is 33 mrad in the horizontal plane, and the superconducting final focusing system, which including the three magnets QDa, QDb and QF1, is situated 1.9 m from the Interaction Point. The double layer central beampipe witn 20 mm inner diameter has been chosen. The design and parameters of the central beampipe and MDI cryomodule will be presented in Section 3.2. The luminosity measurement at the CEPC combines the silicon detector, LYSO and Diamond, which will be discussed in detail in Section 3.4.

The study on beam induced backgrounds are critical to CEPC. Currently, the estimation of the beam induced backgrounds is based on the experiences at Beijing Electron-Positron Collider(BEPCII) and Third Generation of Beijing Spectrometer(BESIII) with taken both the single beam and luminosity related backgrounds into account. The detailed discussion of the beam induced background will be presented in Section 3.3.

Chapter 4 Vertex Detector

4.1 Physics requirements

The vertex detector is a key component of the CEPC detector and is primarily aimed at the first decade of CEPC operation, operating at both the Higgs factory and the low-luminosity Z-pole runs. It plays a critical role in identifying and reconstructing heavy-flavor hadrons and τ leptons, enabling robust b- and c-tagging and precise vertexing crucial for probing the Higgs couplings, studying flavor-changing neutral currents, and searching for new particles that may manifest as displaced vertices or long-lived decays. Precision vertexing also enhances the sensitivity to subtle effects in electroweak and flavor physics, sharpening tests of the Standard Model and potentially revealing new phenomena.

Chapter 5 Silicon Trackers

5.1 Introduction

The CEPC is designed to operate across a wide energy region, including Z-pole (91 GeV), W^+W^- threshold (160 GeV), the energy maximizing ZH production (240 GeV), and $t\bar{t}$ threshold after upgrade (360 GeV). In High Lumi Z mode, the luminosity reaches $\mathcal{L} = 192 \times 10^{34}\ \mathrm{cm^{-2}s^{-1}}$ at 50 MW, with a 23 ns interval between bunch crossings. These demanding operational and physics conditions impose stringent requirements on the CEPC

Chapter 6 Pixelated Time Projection Chamber

6.1 Overview

The CEPC gaseous tracker has been designed to optimize physics performance while respecting operational constraints [1]. The operational environment is relatively benign compared to that in a hadron collider [2]. The magnetic field needs to be at least 3T to confine electron pairs from bremsstrahlung within the beam pipe. In a circular collider, the beam collision timing structure is in a continuous mode at the nanosecond level. The

Chapter 8 Hadronic calorimeter

8.1 Overview

Hadronic calorimeter (HCAL) is employed in the CEPC detector system to provide an energy measurement of hadronic jets with excellent resolution and hermetic coverage. To fully exploit the potential of physics program for Higgs and electroweak physics, all possible final states from decays of intermediate vector bosons, Z, W and the Higgs boson need to be reconstructed and well identified with high sensitivity. In particular, to clearly identify hadronic final states of $H \to ZZ^* \to 4j$ and $H \to WW^* \to 4j$, the energy resolution of the calorimetry for hadronic jets needs to be pushed beyond today's limit. In order to distinguish the hadronic decays of W and Z bosons, a 3-4% invariant mass

Chapter 9 Muon Detector

9.1 Physics and Performance Requirements

The Muon Detector, shown in Fig. 9.1, consists of iron plates and active detector elements outside the superconducting solenoid. The iron plates function as the magnetic flux return for the solenoid. The dodecagonal Barrel covers the polar angle range from 48.6° to 133.2°, while the Endcaps extend this coverage from 8.1° to 171.9°. Each Barrel or Endcap sector comprises six detector layers and seven iron plates. With a magnetic

Chapter 11 Readout Electronics

11.1 Introduction

The readout electronics system plays a crucial role in processing the output signals from all sub-detectors of the reference detector. This involves signal amplification, analog-to-digital conversion, and processing signals from millions of detector channels, as well as buffering these signals and interfacing with the trigger system. Additionally, the system [illegible] [illegible]

Chapter 14 Mechanics and integration

This chapter introduces the mechanical layout of the CEPC reference detector, details the boundaries and constraints of each sub-detector and the connections among them. The interface design requirements and installation scheme of each sub-detector are given, as well as the uniform installation tooling taken into consideration of the maintenance and upgrades of the sub-detectors in the future. The design of the supporting auxiliary facilities is given to meet the cooling and electronics requirements of each sub-detector. The design of the installation layout in the underground experimental hall for the whole detector and the layout of the auxiliary hall for the ancillary facilities are given.

Examples from CDR

DETECTOR MAGNET SYSTEM

The CEPC detector magnet is an iron-yoke-based solenoid to provide an axial magnetic field of 3 Tesla at the interaction point. A room temperature bore is required with 6.8 m in diameter and 8.3 m in length. This chapter describes the conceptual design of the magnet, including the design of field distribution, solenoid superconducting coil, cryogenics, quench protection, power supply and the yoke. In the end of this chapter, the R&D Section 6.5 brings up other concept options and some reach projects. The compensating magnets designed to minimize the disturbance from the detector solenoid on the incoming and outgoing beams are briefly discussed in Section 9, and in more detail in the CDR accelerator volume, Chapter 9.2 [1].

6.1 MAGNETIC FIELD DESIGN

TRACKING SYSTEM

The CEPC physics program demands a robust and high performance charged particle tracking system. Charged particles are used directly in physics analyses; they are input to determine primary and secondary vertices; and they are crucial input to particle flow calorimetry.

The tracking system has two major components. The vertex detector has excellent spatial resolution and is optimized for vertex reconstruction. The main tracker is optimized for tracking efficiency and resolution required for the CEPC physics program.

This Chapter introduces all tracking system options of the detector concepts discussed in this report. Section 4.1 describes the CEPC baseline vertex detector and the inner tracker. An outer tracking system, composed of a Time Projection Chamber (TPC), a silicon external tracker and a forward tracking detector, is discussed in Section 4.2. This system, together with the vertex detector and the inner tracker from Section 4.1, composes the tracking system of the baseline detector concept which is represented in Figure 4.1. Section 4.3 discusses in some detail the option of a full-silicon tracker that could substitute the tracking system of the CEPC baseline detector concept. Finally, in Section 4.4 a Drift Chamber Tracker is proposed as an option for the CEPC main outer tracker. This chamber, together with a layer of silicon microstrip detectors that surrounds it in both barrel and forward/backward regions, and the inner vertex detector, constitute the tracking system of the CEPC alternative detector concept.

4.1 VERTEX DETECTOR

MUON DETECTOR SYSTEM

For the baseline detector concept, muons are identified primarily in the the PFA-oriented calorimeters and their momenta are measured in the tracking system. An outermost muon detector system is envisioned to provide redundancy, aid muon identification in busy environments and reduce backgrounds. Embedded in the solenoid flux return yoke, the detector is designed to identify muons with high standalone efficiency ($\geq 95\%$) and purity for muon p_T down to $\sim 3\,\mathrm{GeV}$ over the largest possible solid angle. While the design is driven by the identification, the muon detector could provide standalone measurements of the muon momenta as well.

The muon detector will significantly improve the identification of muons produced inside jets such as those from B hadron decays. Moreover, the detector can compensate for leaking energetic showers and late showering pions from the calorimeters, which could help to improve the jet energy resolution [1]. It can also aid in searches for long-lived particles that decay far from the IP, but still inside the detector.

This Chapter presents design considerations and technology options for the CEPC muon detector. Section 7.1 introduces the conceptual design. Both the Resistive Plate Chamber (RPC) and an innovative type of Micro Pattern Gas detector (MPGD), the μ-RWELL detector, are being considered. The main difference between the two technologies lies in the position resolution and the cost. Details are presented in Section 7.2 for the RPC technology and in Section 7.3 for the μ-RWELL technology. Though not described here, other gas detectors such as Gas Electron Multiplier (GEM), MicroMegas and Monitored Drift Tubes (MDT) are also possible options. Section 7.4 briefly describes the future R&D program.

CALORIMETRY

A calorimetry system is employed in the CEPC detectors to provide hermetic coverage for high-resolution energy measurements of electrons, photons, taus and hadronic jets. Section 5.1 provides an overview of the calorimetry systems being considered. Two distinct approaches are being pursued: particle-flow and dual-readout calorimeters. The current baseline detector concept adopts the particle flow approach. Section 5.2 introduces design considerations for these calorimeters. It is followed by the description of the corresponding particle flow oriented electromagnetic calorimeter (ECAL) in Section 5.3, and hadronic calorimeter (HCAL) in Section 5.4. Different technology options are described in both cases. The technology options that have been integrated into the full detector simulation are silicon-tungsten for the ECAL and steel-GRPC for the HCAL. The dual-readout calorimeter concept, described in Section 5.5, is an integral part of IDEA, the alternative detector concept for the CEPC.

5.1 OVERVIEW

Please check the CDR, specially for your chapter, for some guidance regarding style and formatting

Not suggesting to copy content!!

Chapter Structure

Chapter X:				
X.	**1**	**Overview**		What are we going to build? **Design**, expected performance ("requirements")
X.	**2**	**Detailed Design**		
X.	**2.**	**1**	**Detailed design**	
X.	**2.**	**2**	**Challenges and critical R&D**	
X.	**3**	**Key Technologies to address challenges**		
X.	**4**	**R&D and prototypes**		
X.	**5**	**Simulation and Performance**		
X.	**6**	**Alternative Solutions**		Can be either backup or more advanced solution (demonstrate backup solutions are in hand and that their possible selection still meet the requirements)
X.	**7**	**Summary and Future Plan**		
X.	**8**	**(Cost table and justification)**		Eventually to be moved to a common chapter

- Sections should not have more than 4 numbered subsection levels x.y.z.w
- If using AI, editors need to read the AI output and finalize the text themselves. Cannot blindly use AI output. Also, AI usage should be minimized to correct english, NOT write sections from scratch
- Captions should be long and describe plot, not just a title

Calorimetry and tracking

- Handling of **Calorimeter and Tracking** optimization and performance is tricky
  - CDR and other TDRs have one chapter for each Calorimetry and Tracking, not individual chapter for each sub-detector
  - Solution:
    - Chapter 2 should justify in more detail the choices for the calorimeters and tracking and how things fit together — no other better place
    - Chapter 5 should not talk about all tracking, vertexing and TPC
    - Chapter 15 needs to cover the integrated **object** performance covering tracking and calorimetry

New version of Chapter 2 from 4 am to be evaluated :-)

The end

Summary of status

As evaluated by the chapter editors

Chapter	Overall Complete (%)	Chapter structure	Tables		Figures	
			Unified format	Significant digits 有效数字	Change to pdf format	Enlarge the font size in figure
Executive summary						
1 Introduction						
2 Concept of CEPC Reference Detector						
3 MDI and Luminosity	90%	100%				
4 Vertex Detector	90%	100%	90%	95%	50%	70%
5 Silicon Trackers	100%	100%				
6 Pixelated Time Projection Chamber						
7 Electromagnetic calorimeter	95%	100%	95%	95%	50%	95%
8 Hadronic calorimeter	90%	100%	90%	90%	50%	80%
9 Muon Detector						
10 Detector magnet system	100%					
11 Readout Electronics	100%	100%	90%	90%	50%	80%
12 Trigger and Data Acquisition						
13 Offline software and computing	100%	100%	100%	100%	90%	90%
14 Mechanics and integration	100%					
15 Detector and physics performance						
16 Timeline and Future Plans						
17 Detector Costing						

Table styles

- Many different styles were present → should to make it as uniform as possible
  - Think about how to better display the information
  - Tables with many small numbers might not convey very useful information → sometimes it is better to split into multiple tables

Proposal that you should implement

Table 7.7: Deformation and stress in various directions of the composite frame under self-weight

Parameter	Values for T700	Reference Value/Range
Deformation (mm)	0.025 mm	Row 1, Cell 3
Fiber direction stress (MPa)	2.3/-5.6	1600/-900
Lateral stress (MPa)	0.12/-0.12	22/-120
In-plane shear stress (MPa)	0.18	20

But don't do it blindly

Adjust text or format to make reasonable tables

Table 4.9: Estimates of power consumption of the Left-End Block (LEB). All values are for 27 °C temperature and 1.2 V power supply voltage.

Components	Clock Block	Data Aggregat	Data Encoder	Serializer	Slow&Power control	LEB Total
Power [mW]	36	120	80	32	80	348

Table styles

Table 5.11: Estimation of the OTK stave material contributions

Estimation of OTK stave material contributions					
Functional unit	Component	Material	Thickness [μm]	X_0 [cm]	Radiation Length [% X_0]
Sensor Module	PCB metal layers	Cu		1.436	0.200
	PCB Insulating layers	Polyimide		28.41	0.070
	Sensor	Silicon	300	9.369	0.320
	Glue		100	44.37	0.023
	Other electronics				0.100
Structure	Carbon fiber facesheet	Carbon fiber	300	26.08	0.115
	Cooling tube wall	Titanium	200	3.560	0.169
	Cooling fluid	Water		35.76	0.105
	Graphite foam+Honeycomb	Allcomp+Carbon fiber	6000	186	0.322
	Carbon fiber facesheet	Carbon fiber	300	26.08	0.115
	Glue	Cyanate ester resin	200	44.37	0.045
Total					1.584

Text is too small

Split row titles into two rows:

- one row with name
- one row with unit

- Tables **cannot** be screenshots or images of tables
  - Likely this happens to tables that we didn't produce ourselves → make sure to reference all such cases
  - Still, please reproduce the tables properly into the document

Significant figures/digits (有效数字)

- Significant digits in a number represent the significance we know that value with.
  - Don't use more digits than what represents our knowledge. Too many figures makes text and tables difficult to read and scientifically incorrect

Table 6.7: K/π separation powers for ML-based and traditional algorithms. The ML-based algorithm has a rough 10% improvement for momentum range from 5.0 to 20.0 GeV/c.

	Momentum (GeV/c)						
	5.0	7.5	10.0	12.5	15.0	17.5	20.0
ML alg.	4.605σ	4.688σ	4.471σ	4.198σ	3.844σ	3.523σ	3.200σ
Traditional alg.	4.259σ	4.332σ	4.125σ	3.891σ	3.590σ	3.346σ	2.955σ

Figures style, formatting and files

- **Images, plots and figures in the TDR need to be of the highest quality**
  - File format need to be scalable (pdf or eps) - not png and definitively not jpeg
    - Some high quality png and jpeg might work but it is not guaranteed because they are not scalable, it depends how their dimensions are changed and ultimately edited
    - **Change all figures to PDF as much as possible**
    - Some plots in jpeg format really look bad
- All text inside the figures needs to be readable.
  - If text is too small either:
    - Increase the text
    - Increase the size of the figure
    - Remove the figure (if the text cannot be read, probably the figure is not important)
- Figures should be large and easily understandable
- Don’t make ridiculously small plots

Figures style, formatting and files

- These are ridiculously small plots

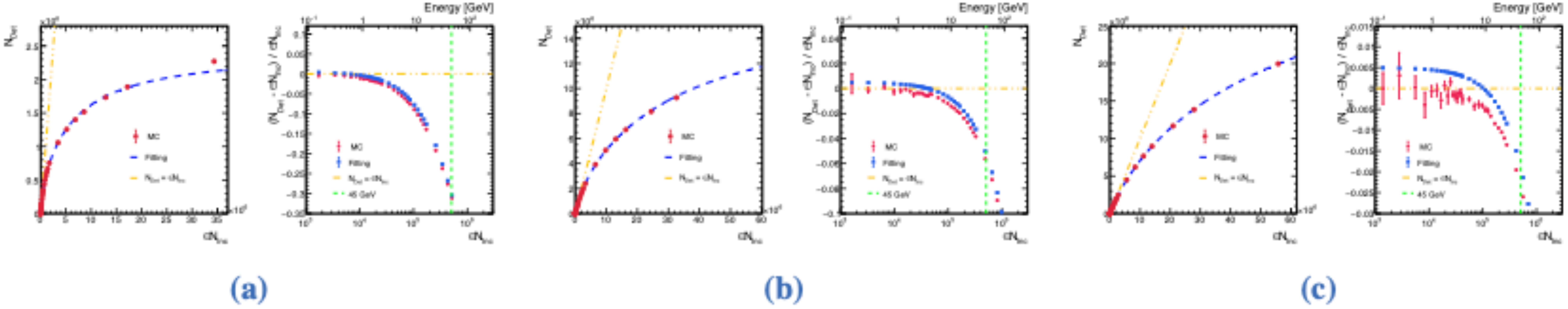


Figure 7.40: Simulated responses of SiPMs to BGO ($1.5\times1.5\times40$ cm^3) scintillation light: (a) HAMAMATSU S14160-3010PS, (b) NDL EQR10 11-3030D-S, and (c) NDL EQR06 11-3030D-S. In the figures, the red points represent the simulation results, the blue dashed line corresponds to the fitting functions [16].

Figures style, formatting and files

- A little larger but still unacceptable

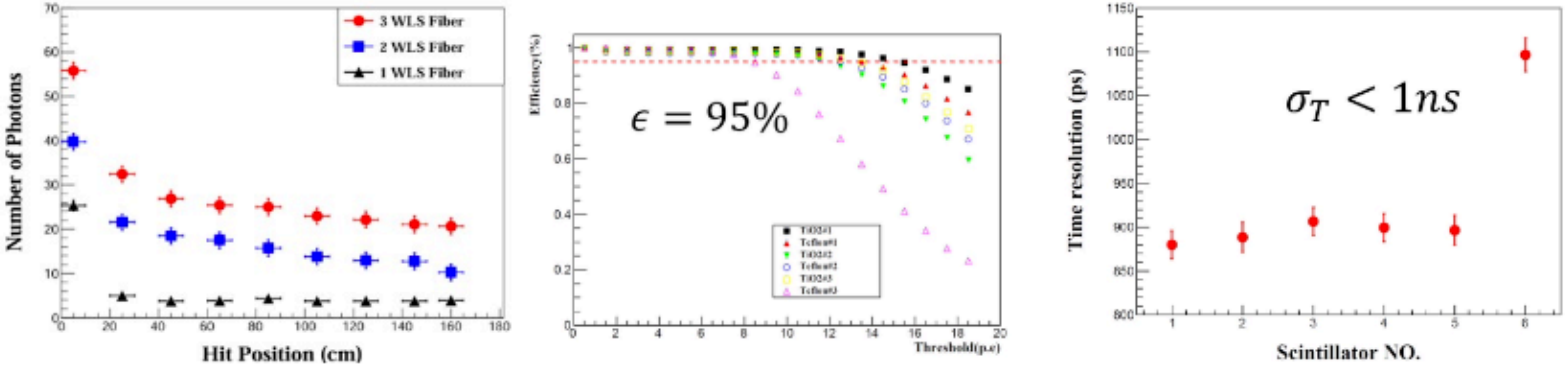
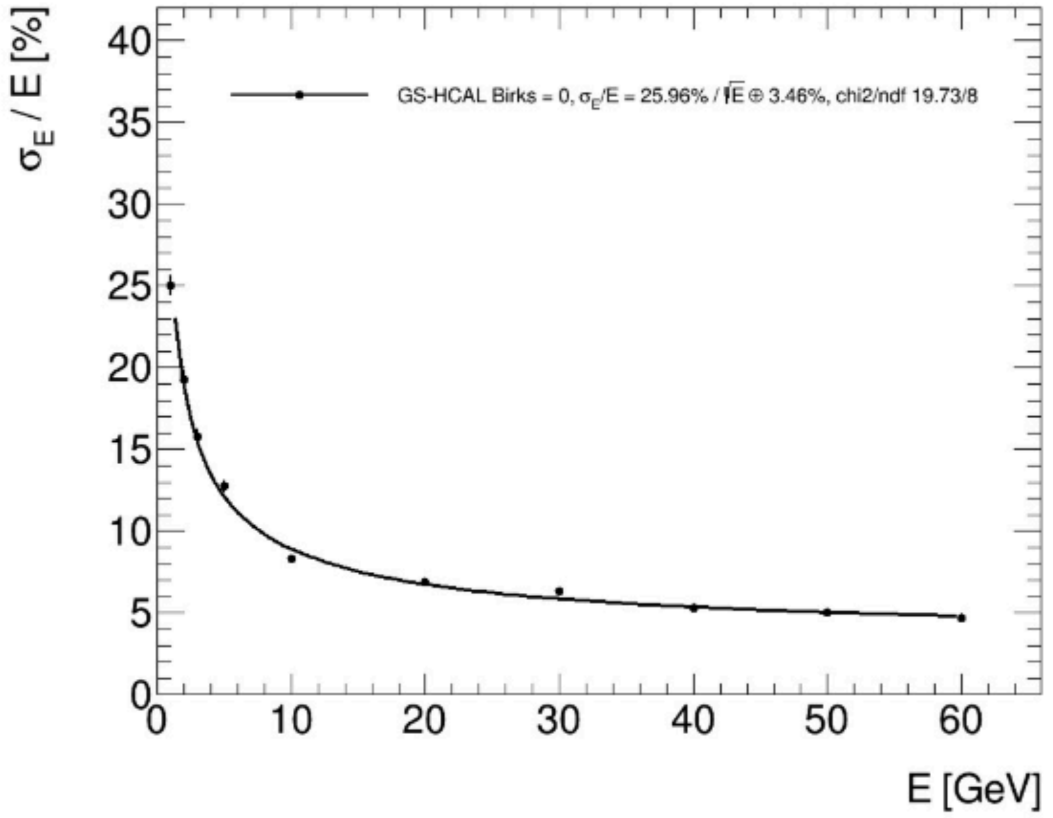


Figure 9.7: The performance of the new scintillators with a hole in the cosmic ray test. The left plot shows the N_{pe} of the photon collection. The middle plot shows the efficiency, and the right one shows the time resolution.

- It seems like one technique used to reduce the number of pages was to reduce the size of the plots!!
  - This was not what anyone had in mind :-)
- Please revert back to larger figures and **reduce the text!**

Figures style, formatting and files

- More tiny font figures



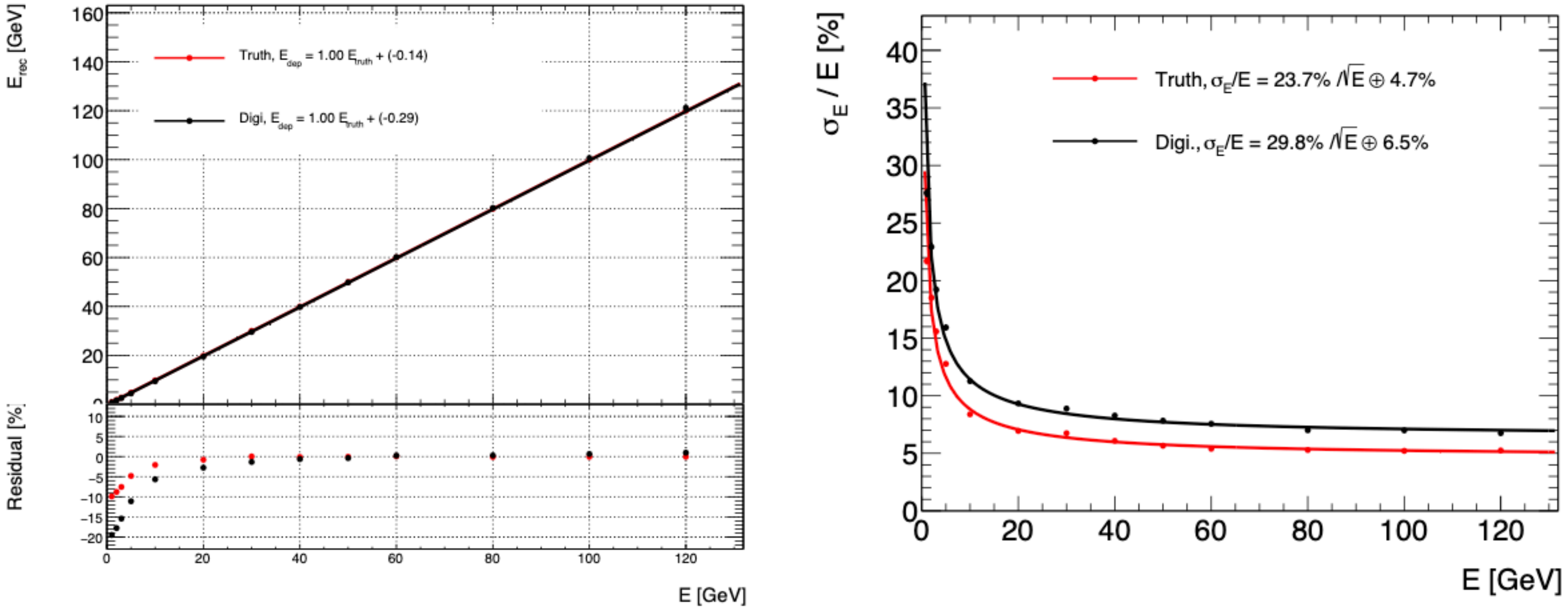


Figure 8.40: Energy linearity and energy resolution of GS-HCAL with the digitization model.

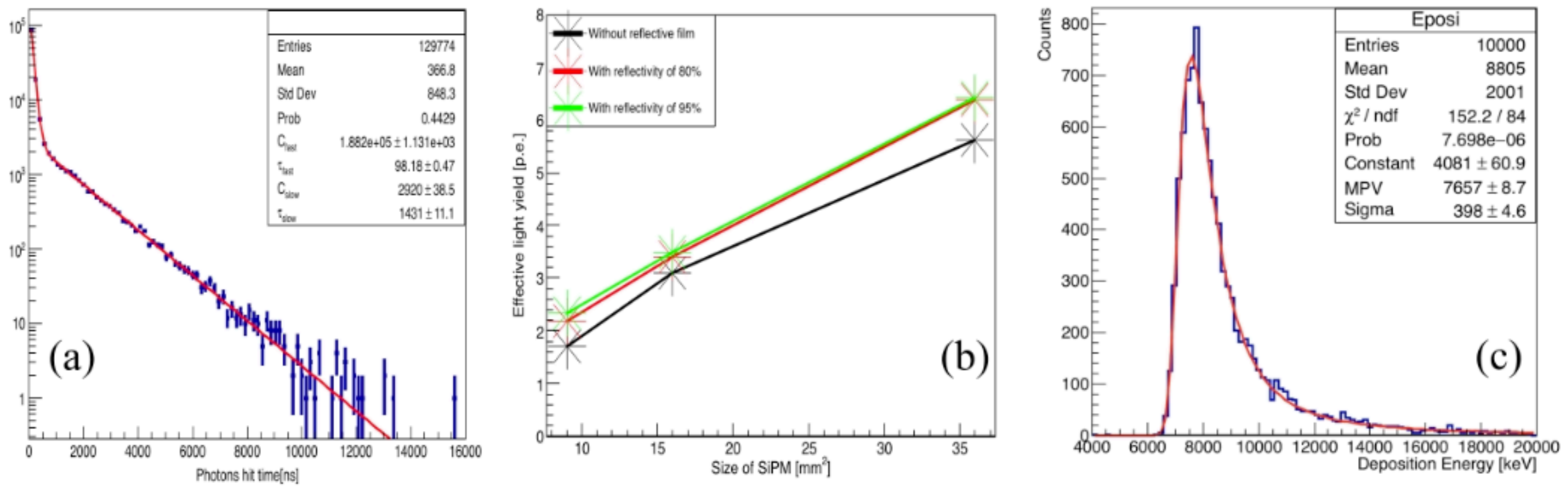


Figure 8.30: The results checked to validate the physical process in simulation, (a) Signal decay time (fast and slow components), (b) Effect of wrapping film with different reflectivity, (c) Muon deposited energy in GS cell (10mm thick).

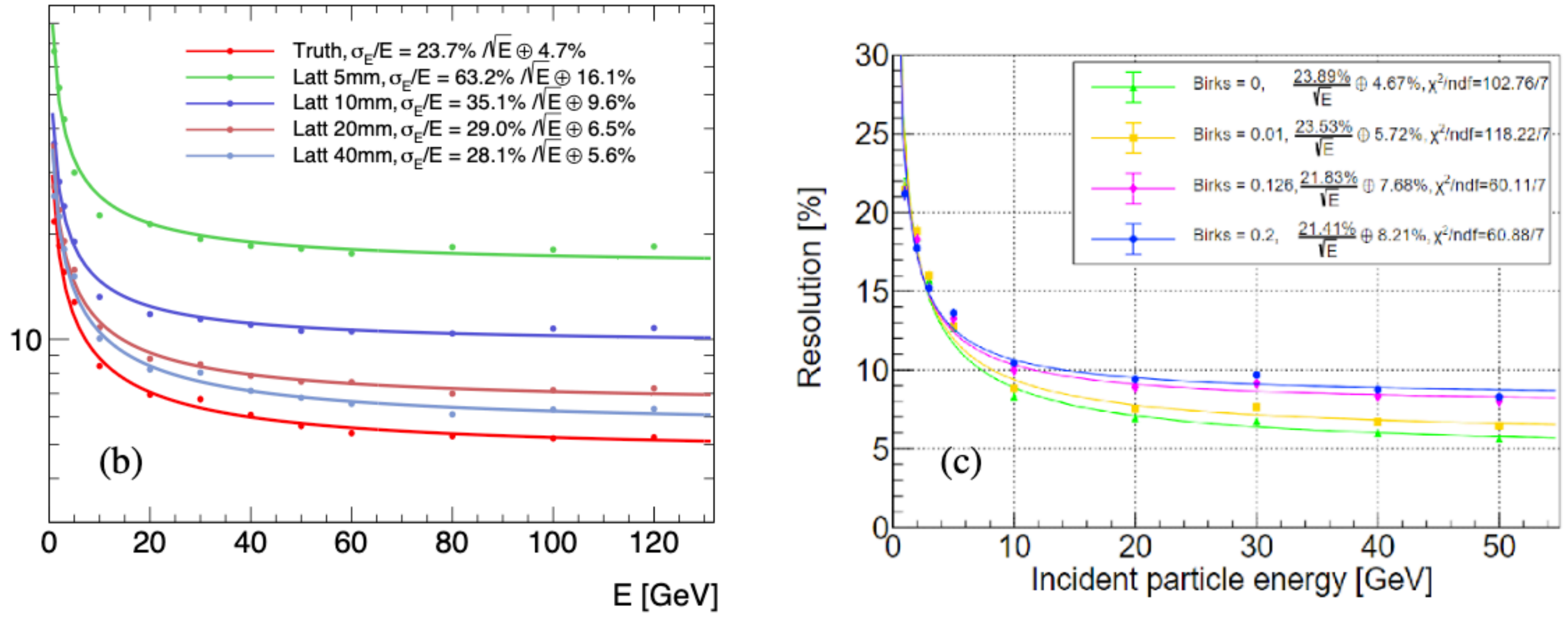


Figure 8.42: The simulated energy resolution with varies of (a) light yield and energy threshold, (b) glass scintillator attenuation lengths, (c) Birk's constants.

Figures style, formatting and files

- Template for plot making
  - Will suggest a baseline template for plots
  - Try to keep plots as consistent as possible
  - It is understood that needs to be some exceptions

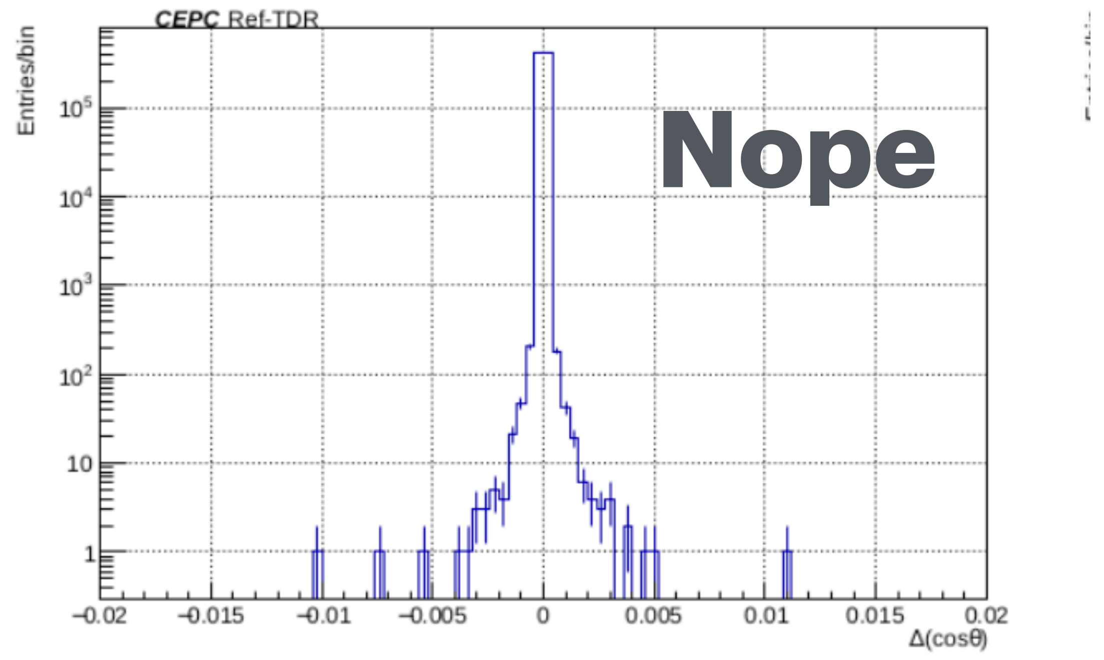
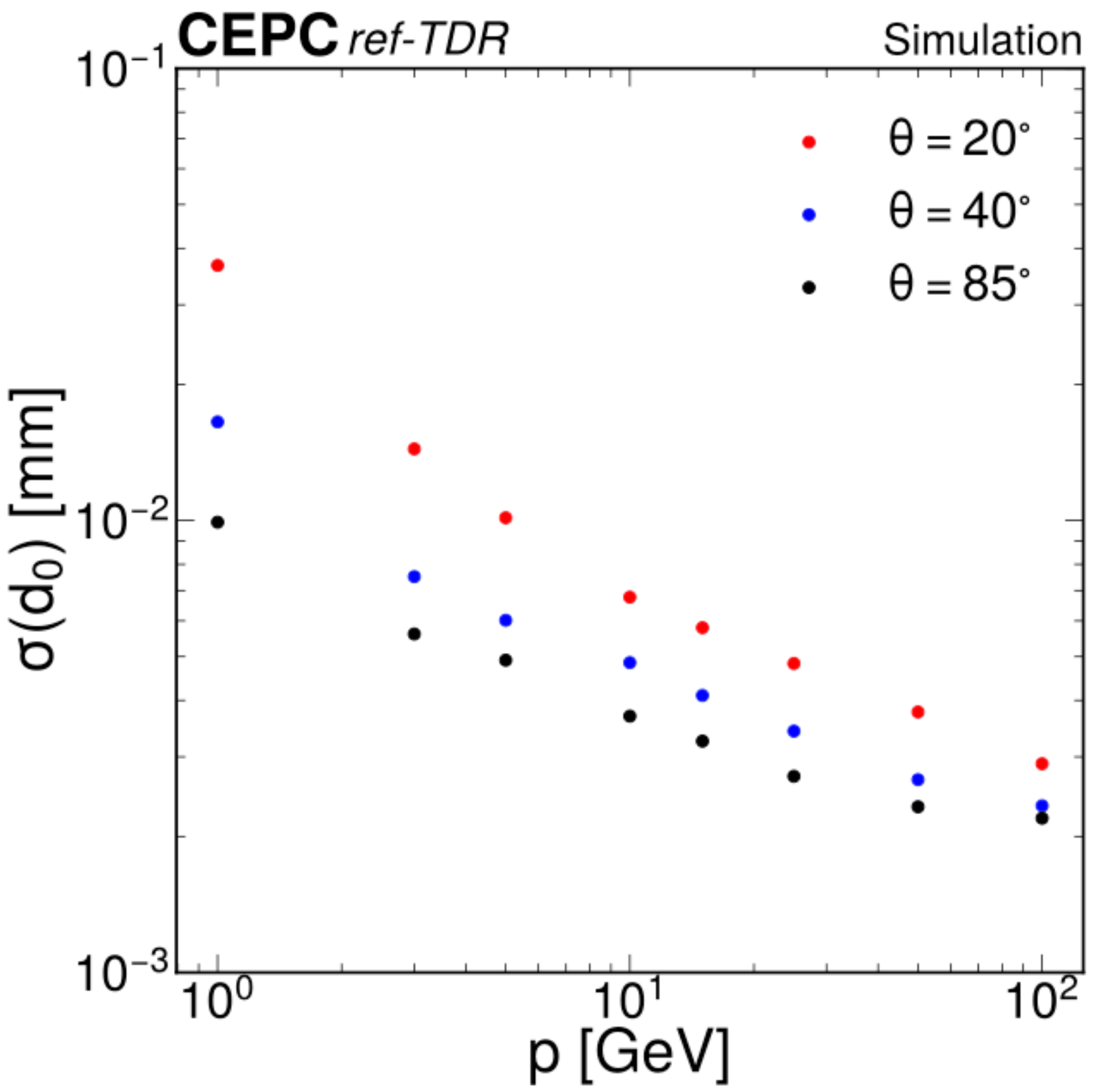
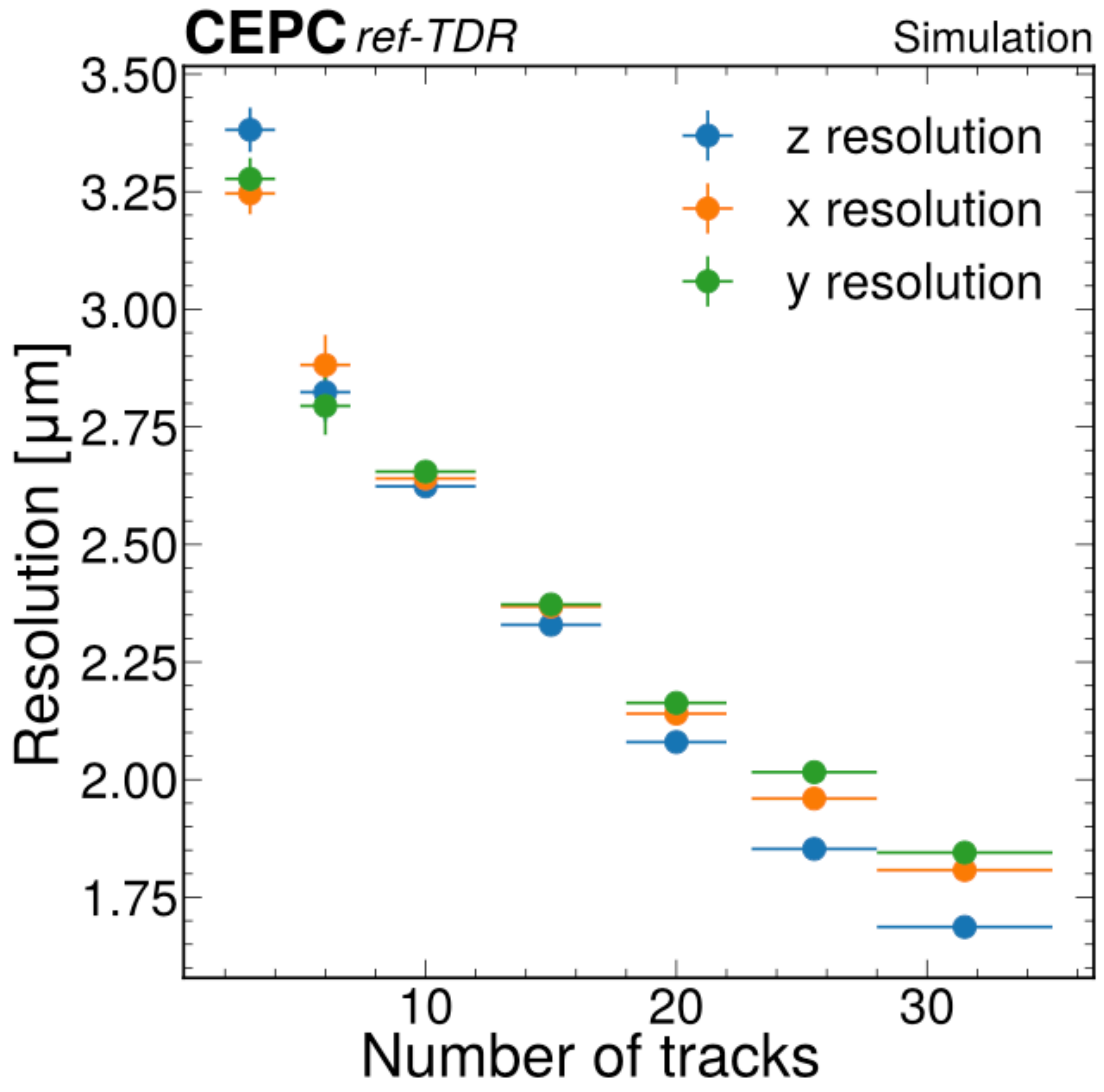
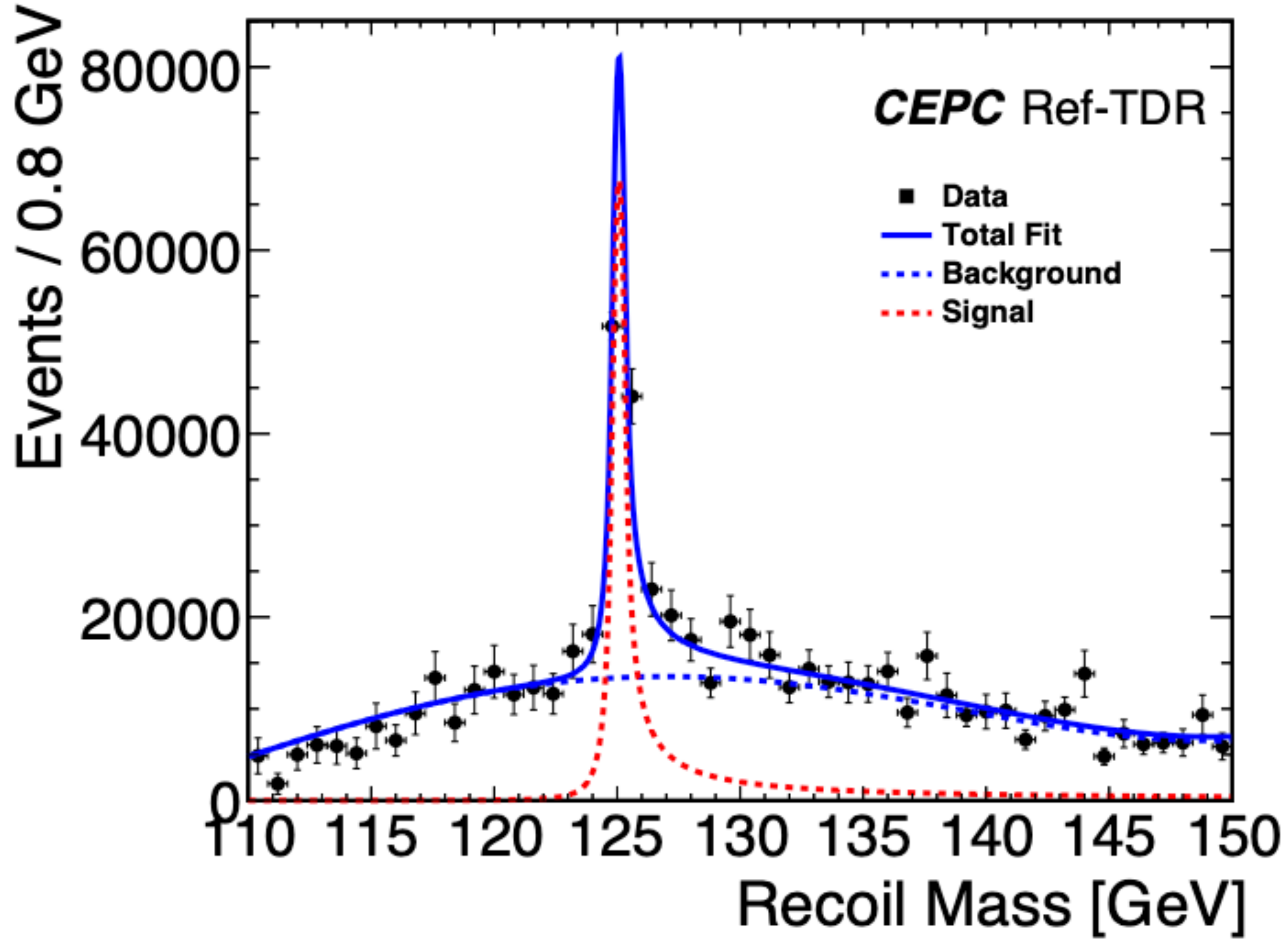


Figure 15.28: (Left) The difference between the μ^- cos(θ)
function of the angular resolution of PFOs. (Right) The differe

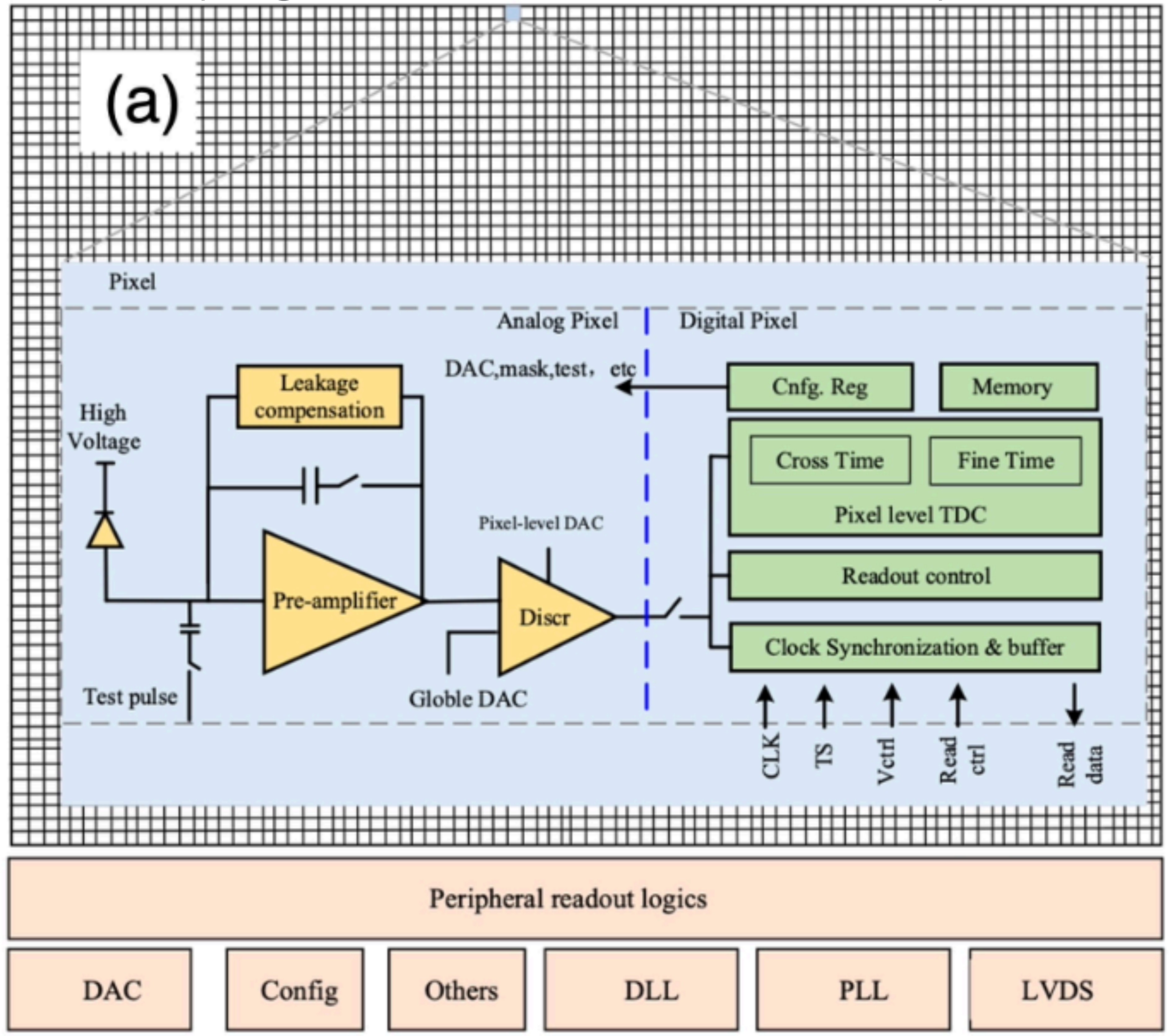






Figures style, formatting and files

- Example of a figures that requires either to be displayed larger, or be simplified with larger text, or removed
  - This size is 1/2 page size, but this figure is in the TDR as <1/6th of a page → not readable in the printed version



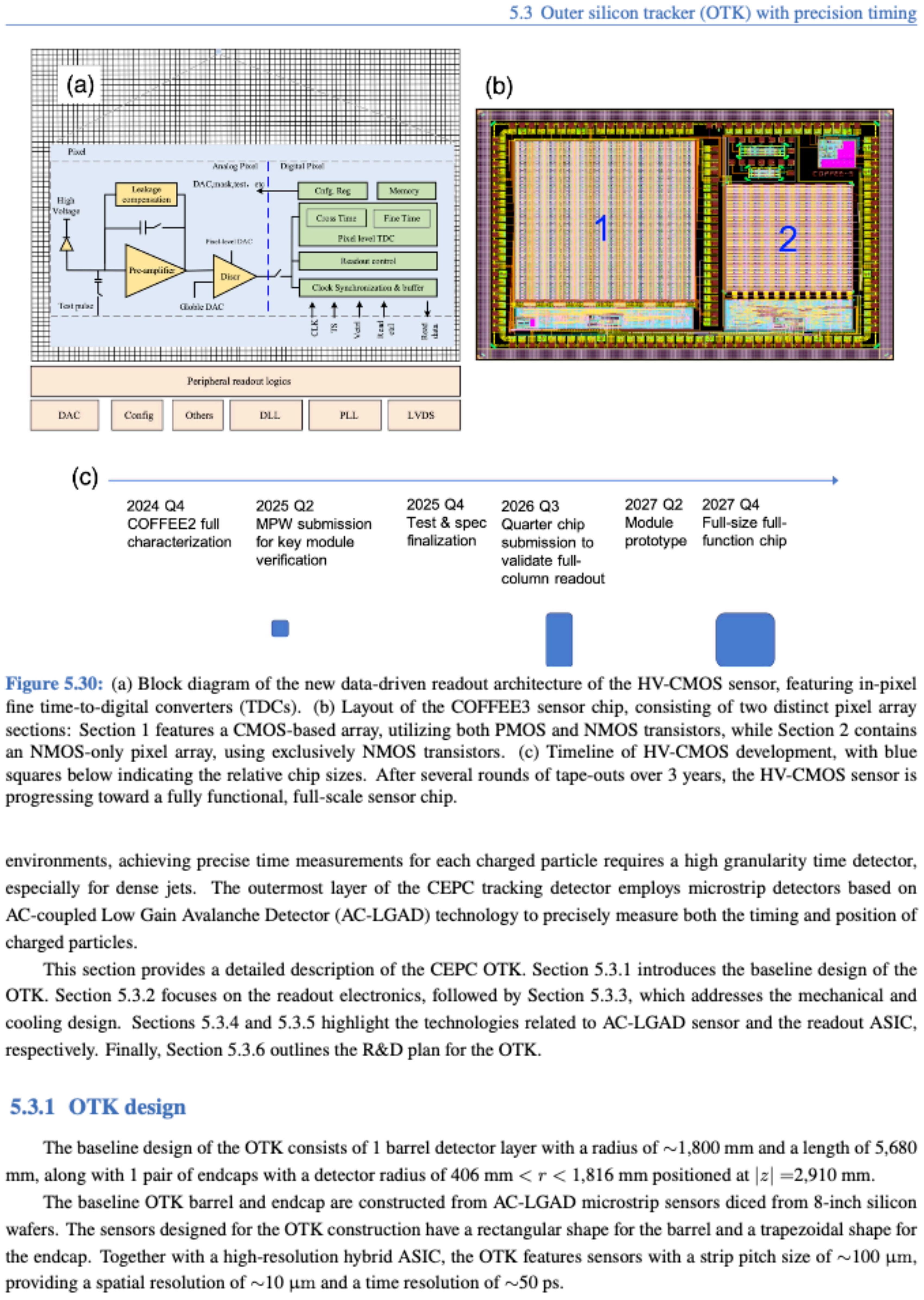


Figure 5.30: (a) Block diagram of the new data-driven readout architecture of the HV-CMOS sensor, featuring in-pixel fine time-to-digital converters (TDCs). (b) Layout of the COFFEE3 sensor chip, consisting of two distinct pixel array sections: Section 1 features a CMOS-based array, utilizing both PMOS and NMOS transistors, while Section 2 contains an NMOS-only pixel array, using exclusively NMOS transistors. (c) Timeline of HV-CMOS development, with blue squares below indicating the relative chip sizes. After several rounds of tape-outs over 3 years, the HV-CMOS sensor is progressing toward a fully functional, full-scale sensor chip.

environments, achieving precise time measurements for each charged particle requires a high granularity time detector, especially for dense jets. The outermost layer of the CEPC tracking detector employs microstrip detectors based on AC-coupled Low Gain Avalanche Detector (AC-LGAD) technology to precisely measure both the timing and position of charged particles.

This section provides a detailed description of the CEPC OTK. Section 5.3.1 introduces the baseline design of the OTK. Section 5.3.2 focuses on the readout electronics, followed by Section 5.3.3, which addresses the mechanical and cooling design. Sections 5.3.4 and 5.3.5 highlight the technologies related to AC-LGAD sensor and the readout ASIC, respectively. Finally, Section 5.3.6 outlines the R&D plan for the OTK.

5.3.1 OTK design

The baseline design of the OTK consists of 1 barrel detector layer with a radius of ∼1,800 mm and a length of 5,680 mm, along with 1 pair of endcaps with a detector radius of 406 mm $< r <$ 1,816 mm positioned at $|z|$ =2,910 mm.

The baseline OTK barrel and endcap are constructed from AC-LGAD microstrip sensors diced from 8-inch silicon wafers. The sensors designed for the OTK construction have a rectangular shape for the barrel and a trapezoidal shape for the endcap. Together with a high-resolution hybrid ASIC, the OTK features sensors with a strip pitch size of ∼100 µm, providing a spatial resolution of ∼10 µm and a time resolution of ∼50 ps.

Figures style, formatting and files

- The detector concept picture in the TDR
  - Two pictures side by side…. some text impossible to read, impossible to understand each component
    - Quality of the file is also very poor

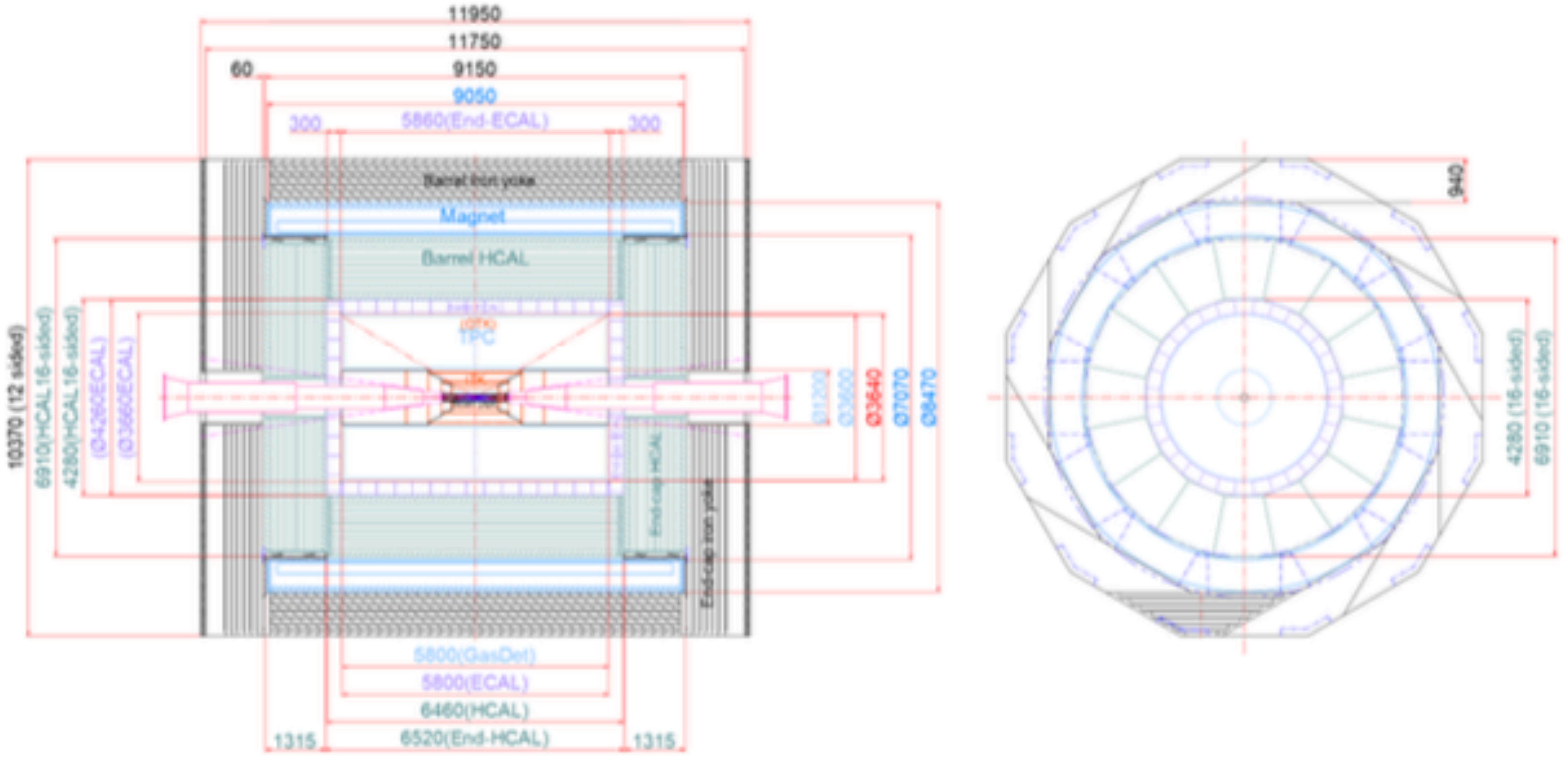
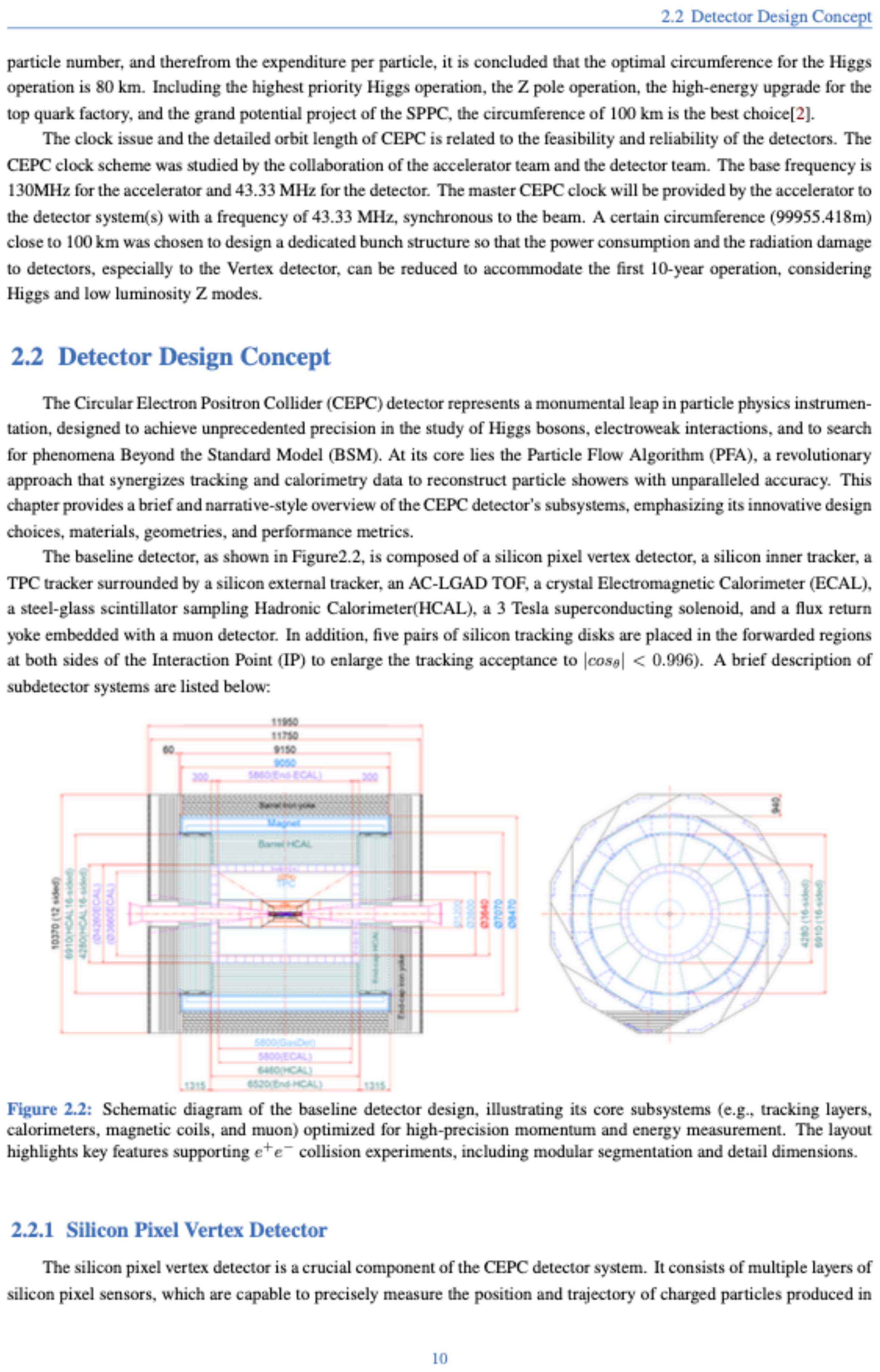


Figure 2.2: Schematic diagram of the baseline detector design, illustrating its core subsystems (e.g., tracking layers, calorimeters, magnetic coils, and muon) optimized for high-precision momentum and energy measurement. The layout highlights key features supporting e^+e^- collision experiments, including modular segmentation and detail dimensions.



2.2 Detector Design Concept

particle number, and therefrom the expenditure per particle, it is concluded that the optimal circumference for the Higgs operation is 80 km. Including the highest priority Higgs operation, the Z pole operation, the high-energy upgrade for the top quark factory, and the grand potential project of the SPPC, the circumference of 100 km is the best choice[2].

The clock issue and the detailed orbit length of CEPC is related to the feasibility and reliability of the detectors. The CEPC clock scheme was studied by the collaboration of the accelerator team and the detector team. The base frequency is 130MHz for the accelerator and 43.33 MHz for the detector. The master CEPC clock will be provided by the accelerator to the detector system(s) with a frequency of 43.33 MHz, synchronous to the beam. A certain circumference (99955.418m) close to 100 km was chosen to design a dedicated bunch structure so that the power consumption and the radiation damage to detectors, especially to the Vertex detector, can be reduced to accommodate the first 10-year operation, considering Higgs and low luminosity Z modes.

2.2 Detector Design Concept

The Circular Electron Positron Collider (CEPC) detector represents a monumental leap in particle physics instrumentation, designed to achieve unprecedented precision in the study of Higgs bosons, electroweak interactions, and to search for phenomena Beyond the Standard Model (BSM). At its core lies the Particle Flow Algorithm (PFA), a revolutionary approach that synergizes tracking and calorimetry data to reconstruct particle showers with unparalleled accuracy. This chapter provides a brief and narrative-style overview of the CEPC detector's subsystems, emphasizing its innovative design choices, materials, geometries, and performance metrics.

The baseline detector, as shown in Figure2.2, is composed of a silicon pixel vertex detector, a silicon inner tracker, a TPC tracker surrounded by a silicon external tracker, an AC-LGAD TOF, a crystal Electromagnetic Calorimeter (ECAL), a steel-glass scintillator sampling Hadronic Calorimeter(HCAL), a 3 Tesla superconducting solenoid, and a flux return yoke embedded with a muon detector. In addition, five pairs of silicon tracking disks are placed in the forwarded regions at both sides of the Interaction Point (IP) to enlarge the tracking acceptance to $|cos_\theta| < 0.996$). A brief description of subdetector systems are listed below:

Figure 2.2: Schematic diagram of the baseline detector design, illustrating its core subsystems (e.g., tracking layers, calorimeters, magnetic coils, and muon) optimized for high-precision momentum and energy measurement. The layout highlights key features supporting e^+e^- collision experiments, including modular segmentation and detail dimensions.

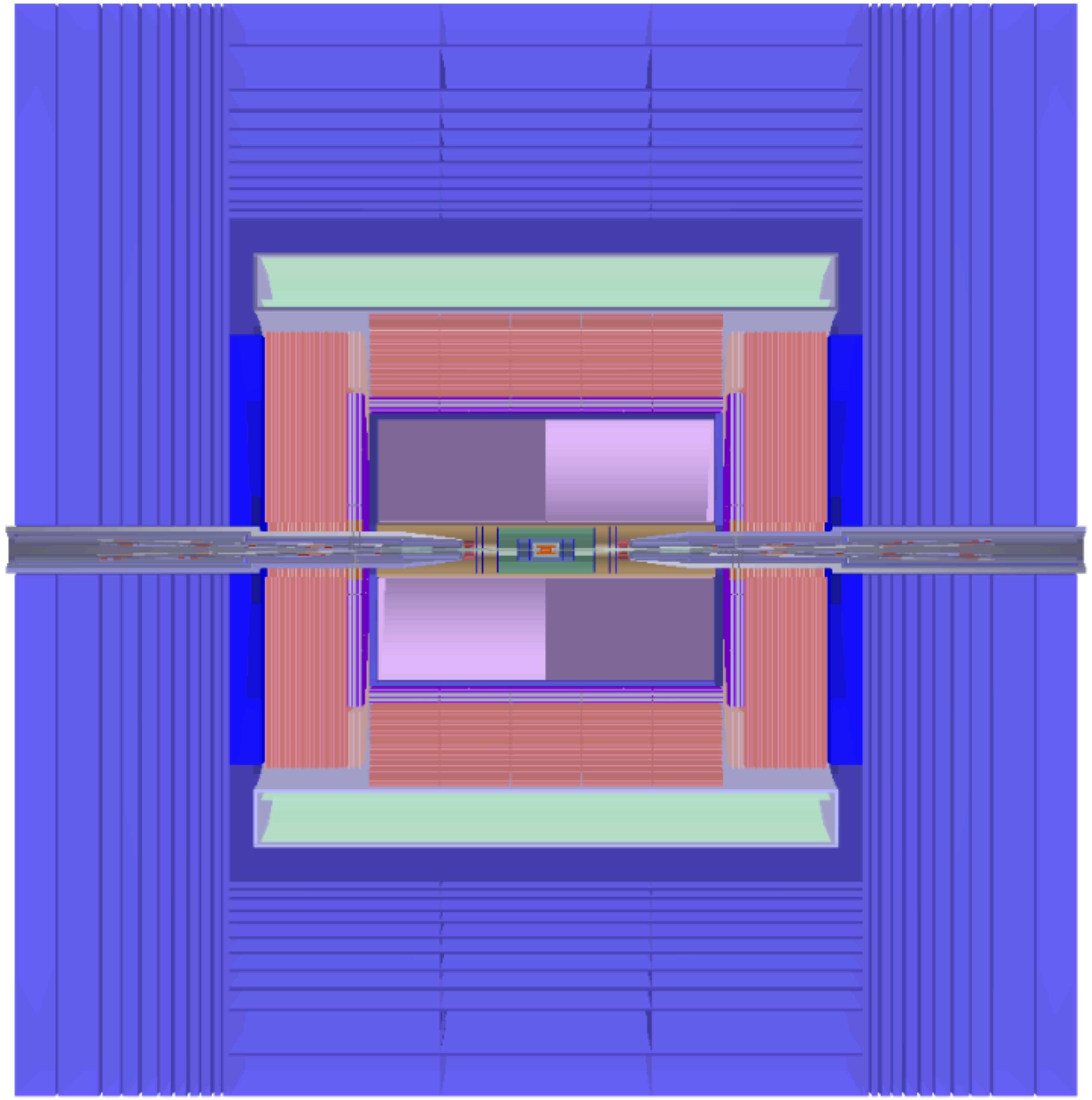
2.2.1 Silicon Pixel Vertex Detector

The silicon pixel vertex detector is a crucial component of the CEPC detector system. It consists of multiple layers of silicon pixel sensors, which are capable to precisely measure the position and trajectory of charged particles produced in

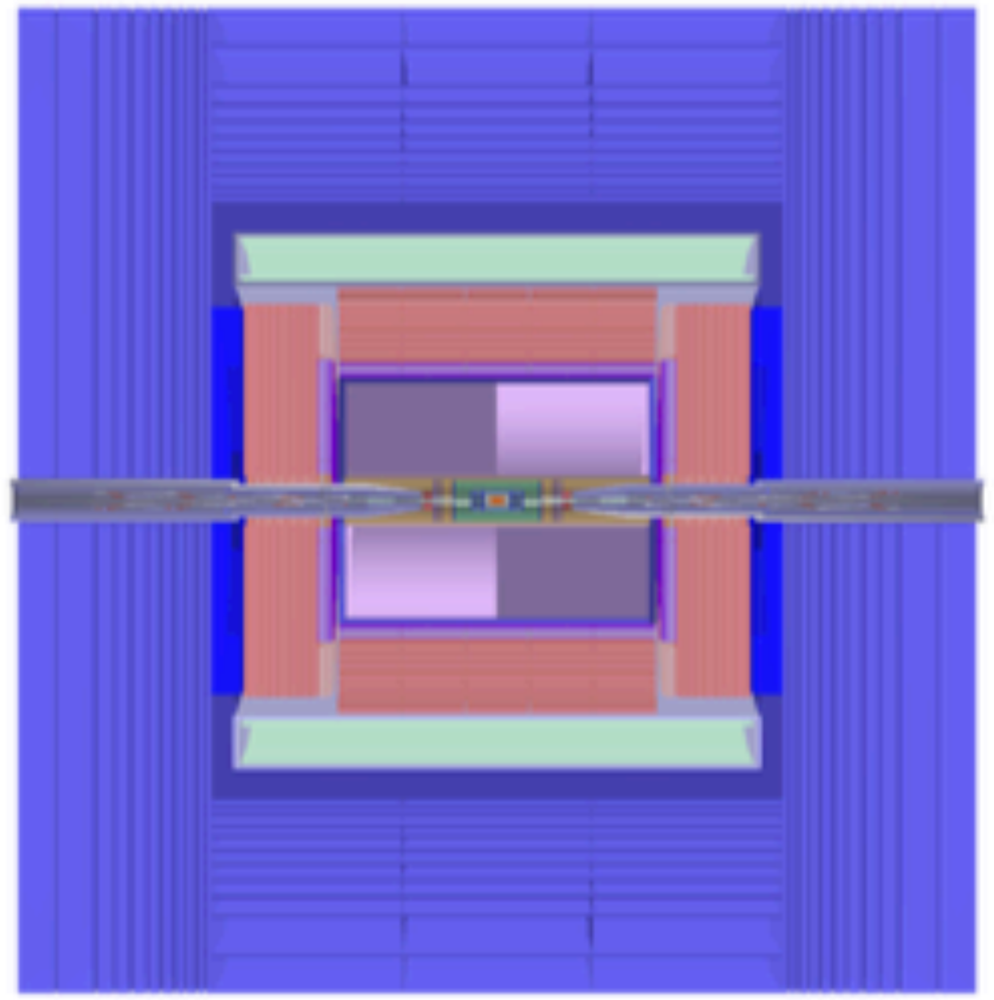
10

Figures style, formatting and files

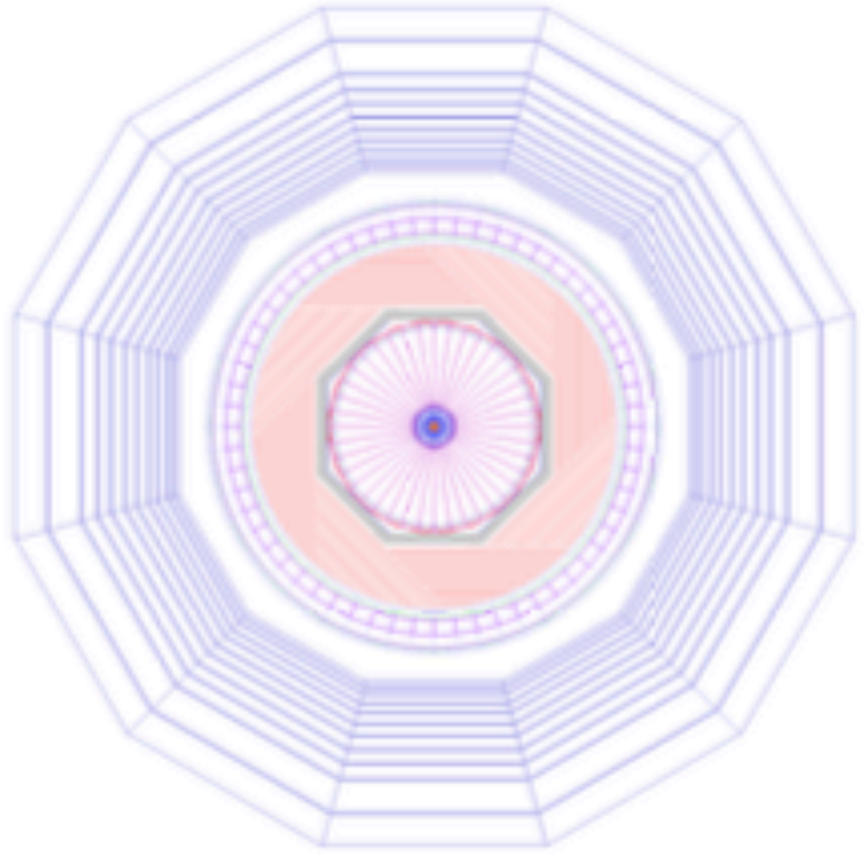
- The detector concept picture in the CDR
  - One full page (still not perfect but visible) → we did had a lot of steel :-)



DETECTOR CONCEPTS 131



(a)



(b)

Figure 3.8: The (a) r–z and (b) r–ϕ view of the baseline detector concept. In the barrel from inner to outer, the detector is composed of a silicon pixel vertex detector, a silicon inner tracker, a TPC, a silicon external tracker, an ECAL, an HCAL, a solenoid of 3 Tesla and a return yoke with embedded a muon detector. In the forward regions, five pairs of silicon tracking disks are installed to enlarge the tracking acceptance (from $|\cos(\theta)| < 0.99$ to $|\cos(\theta)| < 0.996$).

Figures need to take whatever size is required to express the message

Comparing the CDR with the TDR

CDR

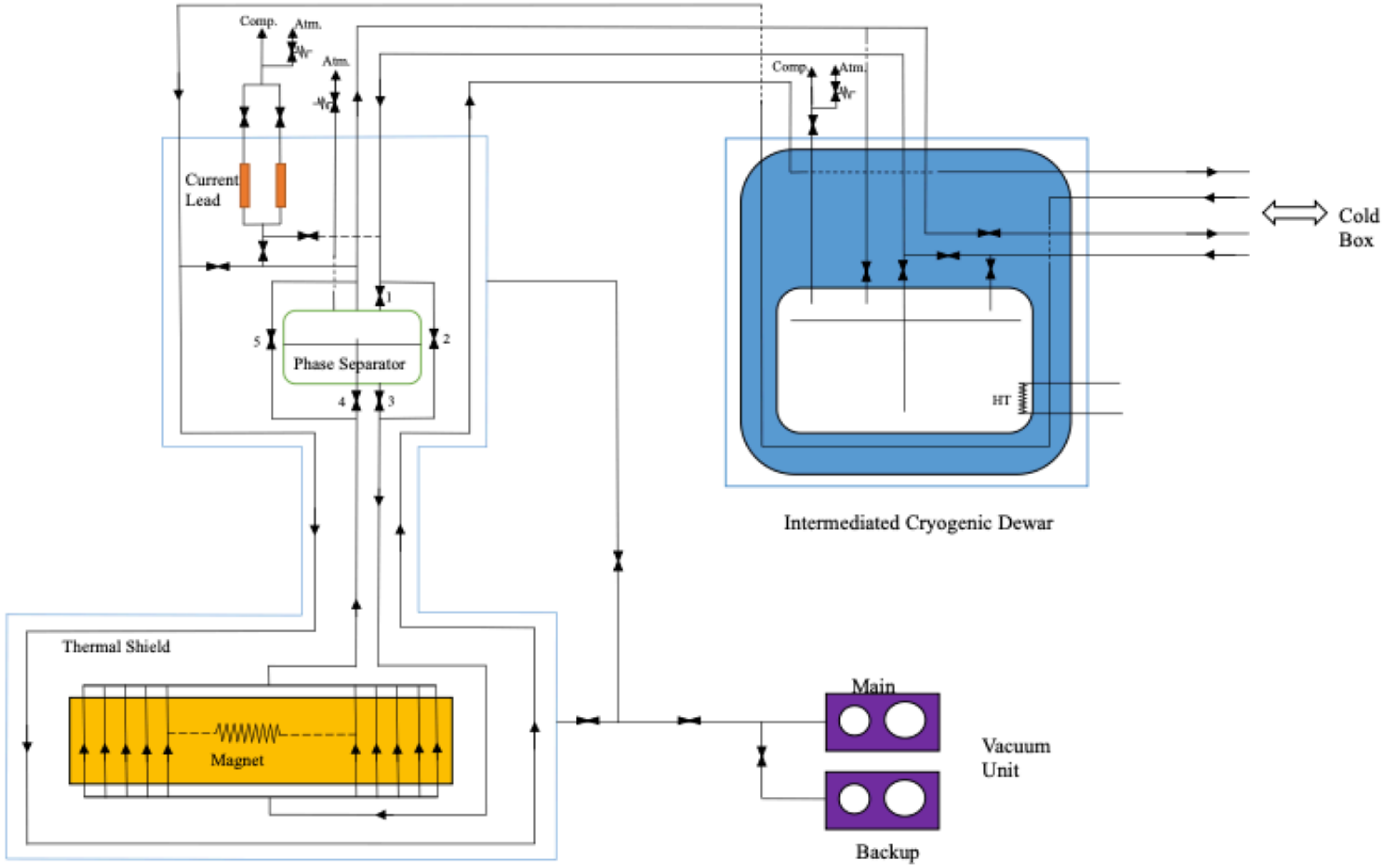


Figure 6.5: Thermosiphon cooling circuit. The CEPC detector magnet cryogenic system is composed of two sub-system: the external system and the inner system. The external system includes cold box and intermediate Dewar; the inner system includes coil cooling circuit and phase separator. The cryogenic sequences include cooling down, normal operation, energy dump and warming up. The first operation mode is the cooling down process by forced flow helium from 300 K to 100 K and to 4.5 K. The second operation mode is the normal operation process in thermosiphon flow condition, which is the main working mode for the magnet. The third one is the energy dump process, which is divided into fast discharge, slow discharge and post quench re-cooling. The last operation mode is the warming up.

TDR

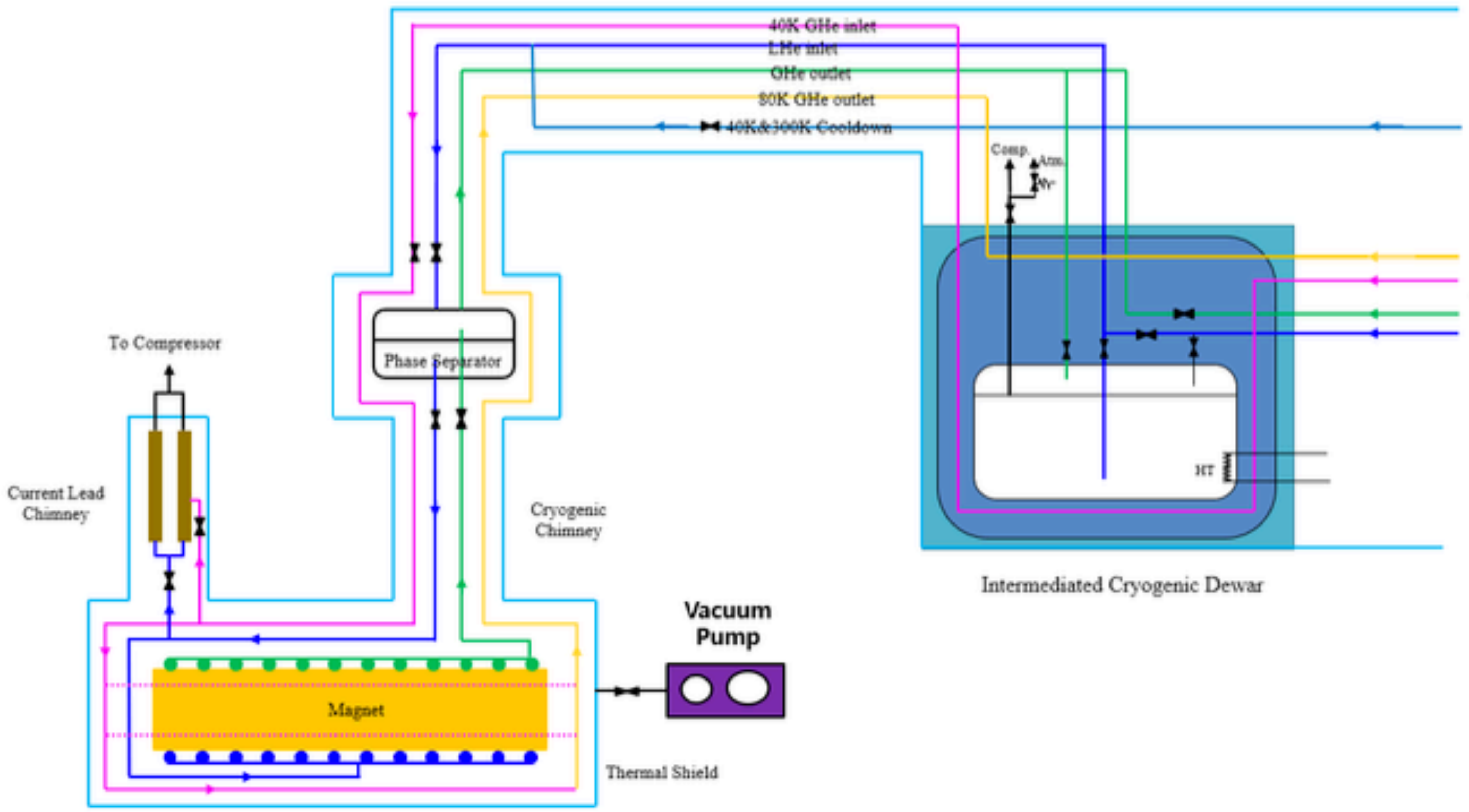


Figure 10.51: Coil cryogenic circuits

Provide proper captions

(still **tiny** font and symbols… there are valves in this picture)

Family photos are not acceptable

Avoid group photos with accomplishments... they are not scientific or technical

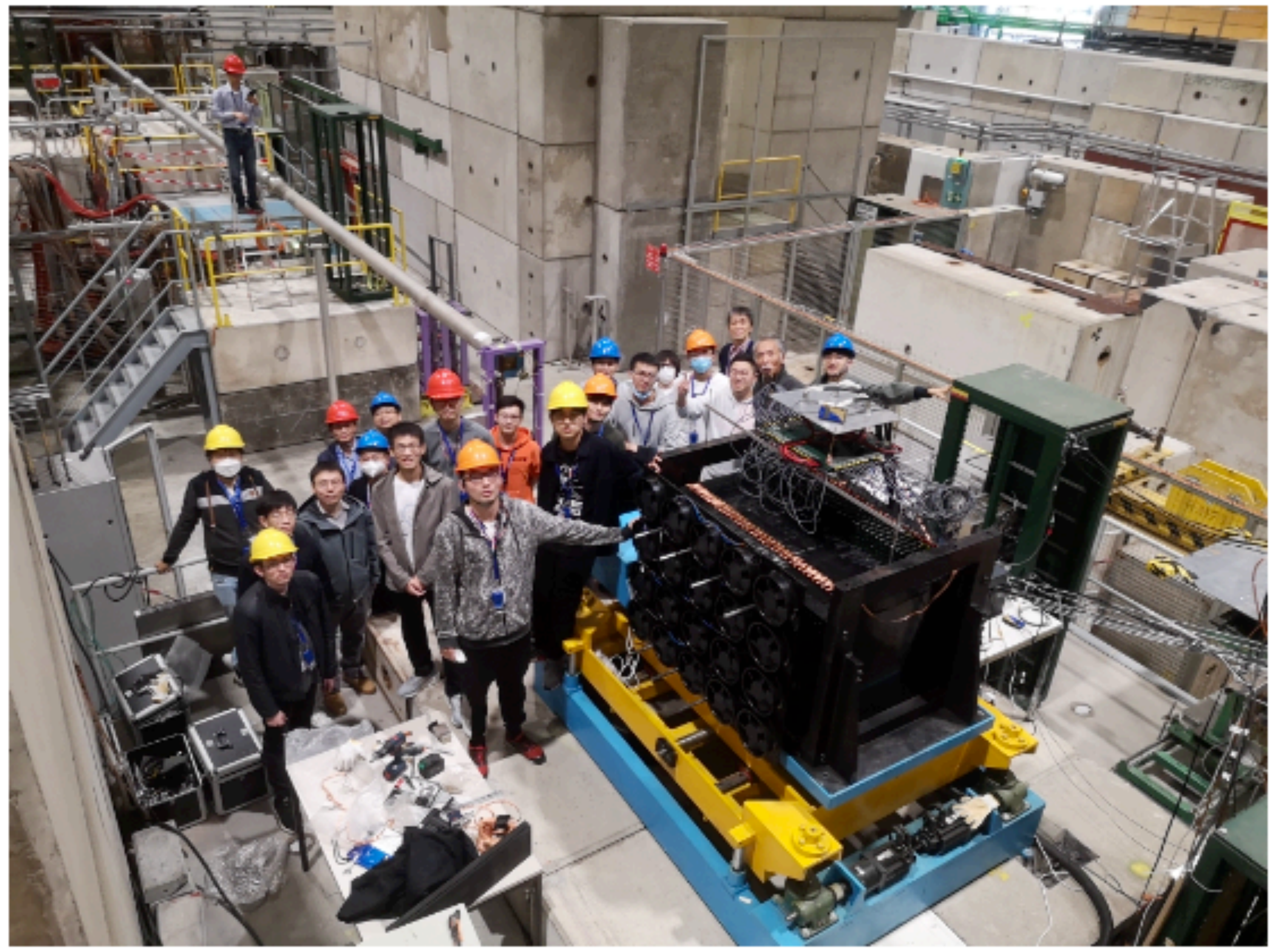


Figure 8.51: AHCAL prototype at CERN beamline with a group of colleagues from China, Japan and Israel.

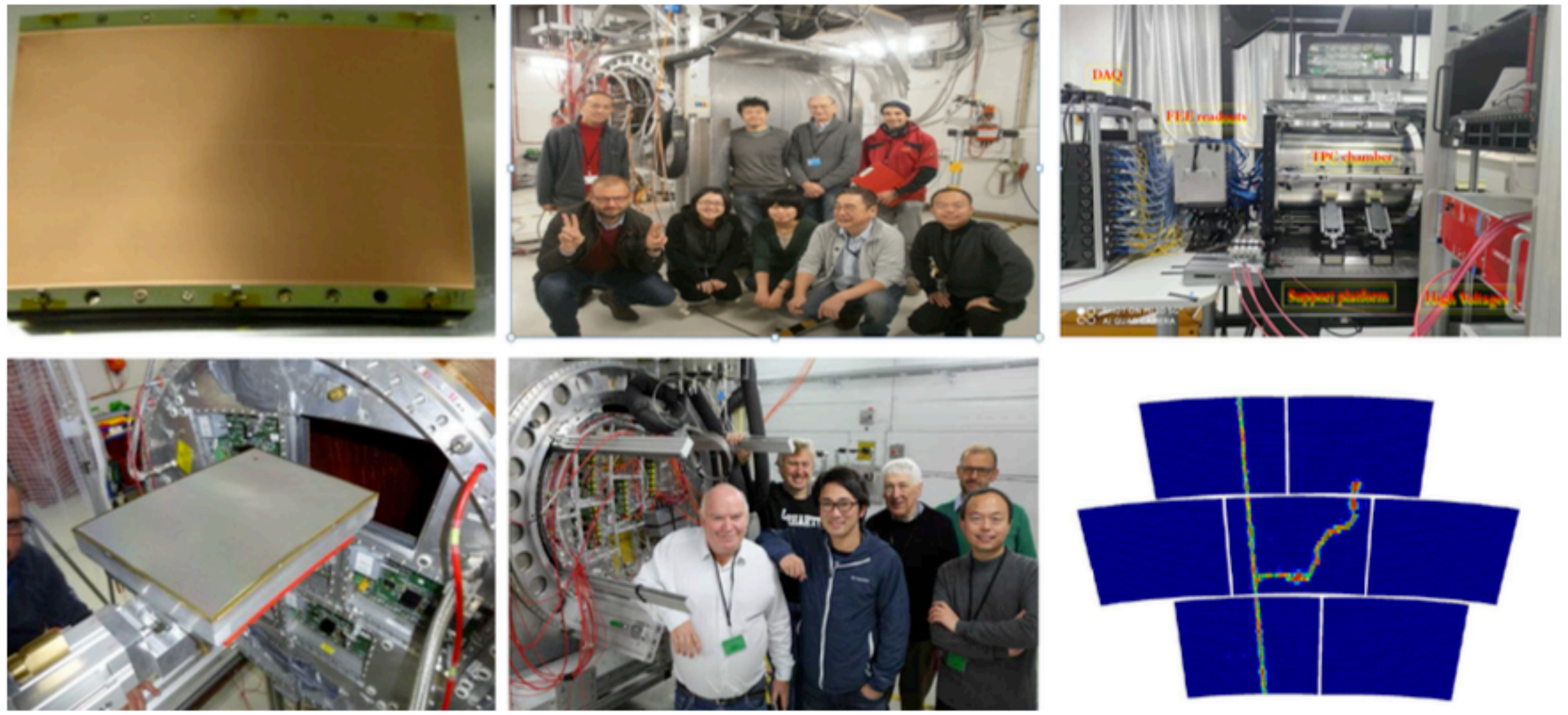


Figure 6.20: Beam tests of TPC prototype at DESY in LCTPC international collaboration, the performance of the prototype was evaluated in a beam test using 5 GeV electrons from several R&D groups in the collaboration.

In particular if these pictures include some of our reviewers! These people didn't consent to be in the TDR

Six images collected in one figure without explanations is not scientific. Pictures should have a technical purpose to be included in the TDR → either explain explicitly what is the image, or remove it

Test beams work can be expressed in words, results and papers, ... not group pictures

Figures style, formatting and files

- There are some “strange figure”
  - Figures need to be scientific and technical in nature

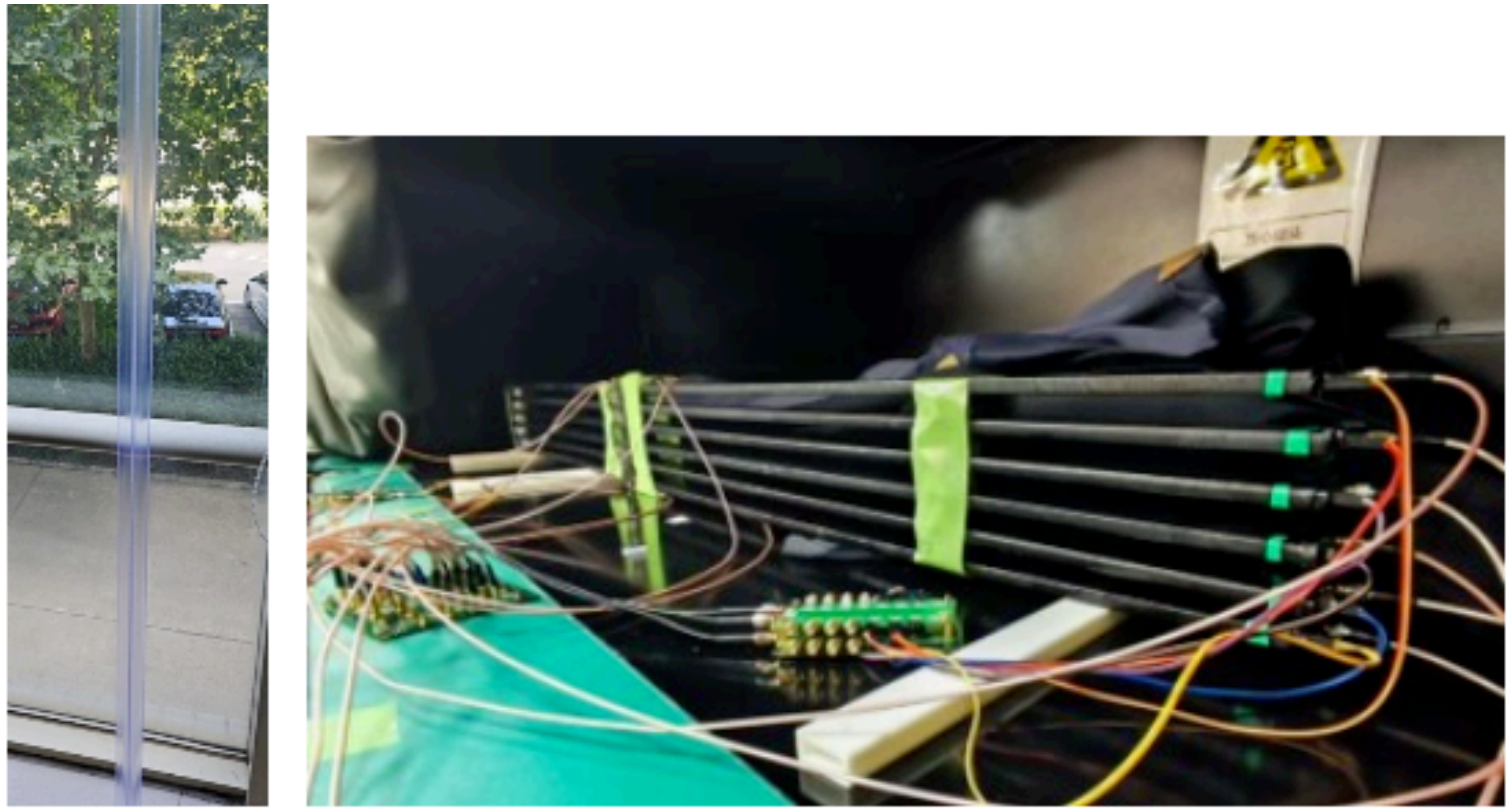


Figure 9.6: The new scintillator strip with a hole for embedding WLS fiber and the cosmic ray test. The left picture shows a strip without a coating reflection layer. The right picture shows the cosmic ray test on six strips with a length of 1.65 m.

There is a **parking lot** in this picture that seems to be taken from a balcony without any explanation

Better to **remove ALL such pictures**, otherwise 1) improve picture; 2) explain technical and scientific value

Other format issues

- **Symbol and format consistency**
  - Need to use the power of Latex to make sure the symbols and other format issues are kept uniform throughout the document
    - New Latex style file provided that ALL chapter editors should use: **cepcphysics.sty**
      - This guarantees that:
        - Particle names: H, Z, W, etc… are used consistently… they are NOT now
        - Units: GeV, keV, TeV are used correctly
        - Also, variables like p_T, Missing ET, ET, etc…
        - Journal names
      - We will work with you to add more symbols specific to the CEPC into this file → fill free to add and let us know
- **Glossary**
    - Latex provides tools to create glossaries → avoid repetitive definition of names and provides a list of symbols at the end
    - Done for the CDR at the last minute, as requested by reviewers at the time
      - Will implement this and let you know what to do (with help from Zhaoru)

Glossary from CDR

Glossary

CP Charge-Parity 57, 58

ADC Analog-to-Digital Convert 155

AFE Analog Front-End 155

AHCAL Analog HCAL 194, 208

ALP Axion-Like Particle 29, 33

ASIC Application Specific Integrated Circuits 155

ASU Active Sensor Unit 200

ATCA Advanced Telecommunications Computing Architecture 269

BAU Baryon Asymmetry of the Universe 51, 57

BE Back-end Electronics 206

BMR Boson Mass Resolution 124

BSM Beyond the Standard Model 297

CDR Conceptual Design Report 1, 2, 116, 388

CEPC Circular Electron Positron Collider 1

CMOS Complementary Metal-Oxide-Semiconductor 146

CPS CMOS Pixel Sensors 167

DAQ Data AcQuisition 267

DCH Drift CHamber 175

DEPFET Depleted P-channel Field Effect Transistor 147

DHCAL Digital HCAL 194

DLC Diamond Like Carbon 262

DM Dark Matter 35

DR Dual Readout 224

DSP Digital Signal Processors 155

EB Event Builder 272

EBM Event Building Manager 272

ECAL Electromagnetic Calorimeter 130, 300, 304

EDM Electric Dipole Moment 333

EEC Energy-Energy Correlation 65

EFT Effective Field Theory 10

EIT Endcap Inner Tracker 170

EOT Endcap Outer Tracker 170

EQR SiPM SiPM with Epitaxial Quenching Resistors 222

ETD Endcap Tracking Detector 165

EW ElectroWeak 315

EWPT ElectroWeak Phase Transition 20, 21

EWSB ElectroWeak Symmetry Breaking 20

FE Front-End 206

FEA Finite Element Analysis 250, 251, 256

FPGA Field-Programmable Gate Array 222, 253

FST Full-Silicon Tracker 115

FTD Forward Tracking Detector 165

FV Fiducial Volume 290

GEM Gas Electron Multiplier 153, 160, 161

GEM-MM hybrid Gas Electron Multiplier and Micro-Mesh Gaseous Structure 153, 160, 161, 162, 163

Summary of status

- https://docs.qq.com/sheet/DQkxVTmhpRkdhQUJq?tab=000001&_t=1748241620462&nlc=1

Chapter	Overall Complete (%)	Chapter structure	Tables		Figures	
			Unified format	Significant digits 有效数字	Change to pdf format	Enlarge the font size in figure
Executive summary	Will update to keep track of glossary and symbols updates					
1 Introduction						
2 Concept of CEPC Reference Detector						
3 MDI and Luminosity	90%	100%				
4 Vertex Detector	90%	100%	90%	95%	50%	70%
5 Silicon Trackers	100%	100%				
6 Pixelated Time Projection Chamber						
7 Electromagnetic calorimeter	95%	100%	95%	95%	50%	95%
8 Hadronic calorimeter	90%	100%	90%	90%	50%	80%
9 Muon Detector						
10 Detector magnet system	100%					
11 Readout Electronics	100%	100%	90%	90%	50%	80%
12 Trigger and Data Acquisition						
13 Offline software and computing	100%	100%	100%	100%	90%	90%
14 Mechanics and integration	100%					
15 Detector and physics performance						
16 Timeline and Future Plans						
17 Detector Costing						

Other Issues

Summary of status: Chapter Introduction

Chapter	Introduction	Quality (first impressions)
Executive summary		
1 Introduction	Yes	Poor, needs expansion
2 Concept of CEPC Reference Detector	No	
3 MDI and Luminosity	No	
4 Vertex Detector	No	
5 Silicon Trackers	Yes	OK, but needs expansion to cover sections
6 Pixelated Time Projection Chamber	No	
7 Electromagnetic calorimeter	Yes	Good
8 Hadronic calorimeter	No	
9 Muon Detector	No	
10 Detector magnet system	Yes	Not the right level of detail. Needs to expand to cover sections
11 Readout Electronics	No	
12 Trigger and Data Acquisition	Yes	Perhaps too long, needs to expand to cover sections
13 Offline software and computing	Yes	Very good → Excellent :-)
14 Mechanics and integration	Yes	Needs to expand to cover sections
15 Detector and physics performance	No	
16 Timeline and Future Plans		
17 Detector Costing		

Quick personal understanding of status

Chapter	Overall	Quality (first impressions)
Executive summary	OK	Can be improved but good enough for now
1 Introduction	50%	Should follow the description in backup. More details overall and references
2 Concept of CEPC Reference Detector	50%	Expand to include justification for the concept and tracker and calorimeter integration
3 MDI and Luminosity	?	Need to read
4 Vertex Detector	80%	Does not follow proposed structure. Needs improvements
5 Silicon Trackers	80%	Too wordy. Introduction does not follow structure. Need re-ordering. Optimization. Figures
6 Pixelated Time Projection Chamber	70%	Does follow structure. Seems to need work
7 Electromagnetic calorimeter		Does not follow structure. Overview should cover baseline design
8 Hadronic calorimeter	?	Totally re-written, much improved → need to read in detail
9 Muon Detector		Does not follow structure. Text can likely be further reduced
10 Detector magnet system	70%	Comments already provided. Needs more work overall.
11 Readout Electronics		Some too small figures. Does not follow structure. Likely diving into too much details
12 Trigger and Data Acquisition		Looks good. Needs to reference to detectors. Not sure it does
13 Offline software and computing	95% ?	Looks good but need to check details. A bit long
14 Mechanics and integration		Much improved relative to last version
15 Detector and physics performance		Object performance still not clear. Needs work
16 Timeline and Future Plans		
17 Detector Costing		

Introduction Chapter Outline

- Overview of the context for the CEPC, link to the accelerator TDR, and overview of full TDR document
- Chapter 1.1: Physics Case (~5 pages)
  - Higgs, electroweak, QCD physics, flavor physics, new physics searches, outlook for top physics at upgraded
- Chapter 1.2: Collider and Experimental Environment
  - Operation modes (do we talk about upgrades?)
- Chapter 1.3: Detector concept and TDR organization
  - Detector challenges
- Chapter 1.4: Performance and physics benchmarks
  - Summary table of physics benchmarks, reference chapter
- Chapter 1.5: Future plans and outlook (2 paragraphs)

Chapter 1.1: Physics Case

- CEPC precision frontier
- Higgs boson and electroweak symmetry breaking
  - Naturalness
  - Electroweak phase transition
- Exploring new physics
  - Exotic Higgs boson decays, Exotic Z boson decays, Dark matter and hidden sectors, Neutrino connection, Extended Higgs sector
- QCD precision measurement
  - Precision α_s determination, Jet rates at CEPC, Non-global logarithms, QCD event shapes and light quark Yukawa coupling
- Flavor Physics with the Z factory of CEPC
  - Rare B decays, Tau decays, Flavor violating Z decays

Introduction Chapter Goals

- Overview of the full TDR document
- Overview of the current context for the CEPC
- Brief Physics Case → mostly references to the White Papers
- Collider and Experimental Environment
- Brief introduction of the detector concept and explanation about the R&D stages and extensions
- Brief summary of performance and physics benchmarks
- Future plans and outlook (2 paragraphs)

Suggest to change name of chapter from "Physics Goal and Requirements" to simply "Introduction"

In addition, we need a brief Executive Summary

Summary of status

Chapter	Overall Complete (%)	Chapter structure	Tables		Figures	
			Unified format	Significant digits 有效数字	Change to pdf format	Enlarge the font size in figure
Executive summary						
1 Introduction						
2 Concept of CEPC Reference Detector						
3 MDI and Luminosity	90%	100%				
4 Vertex Detector	90%	100%	90%	95%	50%	70%
5 Silicon Trackers	100%	100%				
6 Pixelated Time Projection Chamber						
7 Electromagnetic calorimeter	95%	100%	95%	95%	50%	95%
8 Hadronic calorimeter	90%	100%	90%	90%	50%	80%
9 Muon Detector						
10 Detector magnet system	100%					
11 Readout Electronics	100%	100%	90%	90%	50%	80%
12 Trigger and Data Acquisition						
13 Offline software and computing	100%	100%	100%	100%	90%	90%
14 Mechanics and integration	100%					
15 Detector and physics performance						
16 Timeline and Future Plans						
17 Detector Costing						