CEPC Detector Discussion and Q&A

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International Advisory Committee Meeting
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International Detector R&D Review Committee (IDRC)

Suggestions and next steps:

Discussion with IDRC chair → suggestions on how to proceed

- Concern that, given the current international situation, effectively there are no proposals from international community specifically to work at CEPC and it is difficult to imagine such proposals will materialize in the near future, therefore, the charge to this committee is not actionable
  - Observation: This might not be exactly correct since most detector R&D work for FCC-ee directly applies to CEPC. It is possible that, for certain communities, getting the support of this International Committee would be advantageous — this seems to be the situation with our Italian colleagues

- Suggest to change the charge of the committee to become more technical covering a technical evaluation of all detector R&D being done towards the CEPC — hence, closer to the International Accelerator Review Committee charge

- Re-evaluate the committee membership in light of this new, more technical, charge, and in particular, investigate the availability of the current committee members to still serve in such committee

Given that this committee was created following an IAC recommendation, we would like to discuss these possible changes with you

Suggestions for a new charge:

- The IDRC will advise on matters related to the CEPC detector R&D, including the Machine-Detector Interface, and the compatibility of the detector technologies proposed with the high-luminosity operation of the accelerator at the Z, WW, ZH, and tt-bar production threshold energies.
- The IDRC will evaluate international proposals for detector R&D relevant to the CEPC, and produce a short report with its findings.
- The IDRC reports to the Project Director.
- Later, this committee is expected to evolve into an experimental committee (similar to LHCC) to evaluate the Letters of Intent for the CEPC Detectors submitted by the proponents of the International Detector Collaborations
- The committee should have external members including 2-3 IAC members.
- The committee should meet at least once a year and a report should be provided at the IAC meeting.

Current committee membership:

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

Interaction with ECFA

Participation in ECFA detector working groups

How to better contribute to the ECFA effort?

- Jianchun Wang and Haijun Yang are serving as CEPC contact people at ECFA-WG3
- First ECFA-WG3 meeting on Oct. 25, 2022 aiming to Detector R&D Theme (DRDT) study
- Update of the European Strategy for Particle Physics: "…. The community should define a global detector R&D roadmap that should be used to support proposals at the European and national levels. "
  - Organised by ECFA, a roadmap should be developed by the community to balance the detector R&D efforts in Europe, taking into account progress with emerging technologies in adjacent fields.

ECFA-WG3 Contacts

Group	contact 1	contact 2
ILD	Karsten Buesser	Ulrich Einhaus
SiD	Marcel Stanitzki	Andrew White
CLICdet (+CLD)	Dominik Dannheim	
CLD (+CLICdet)		Frank Simon
IDEA	Margherita Primavera	Romualdo Santoro
LAr	Nicolas Morange	Brieuc François
CEPC	Haijun Yang	Jianchun Wang
TF1 Gas	Riccardo Farinelli	Maxim Titov
TF3 Si	Daniela Bortoletto	Didier Contardo
TF4 PD/PID	Neville Harnew	Peter Krizan
TF6 Calo	Gabriella Gaudio	Vincent Boudry
TF7 Ele	Dave Newbold	Federico Faccio
TF8 Mech	Frank Hartmann	Werner Riegler

Extra Slides

CEPC International Detector R&D Review Committee (IDRC)

Committee proposed by CEPC IAC

Initial Charge and Goals

Evaluate International proposals for detector R&D relevant to the CEPC

Independent organ to evaluate the importance and suitability of worldwide detector R&D proposals for CEPC and produce short report with findings.

Reviews and endorses the Detector R&D proposals from the international community, such that international participants can apply for funds from their funding agencies and make effective and sustained contributions

Later, this committee is expected to evolve to evaluate the Letters of Intent for the CEPC Detectors submitted by the proponents of the International Detector Collaborations

CEPC International Detector R&D Review Committee (IDRC)

Goals for original meeting, provided to committee:

Provide an overview of the on-going detector R&D linked to the CEPC

Solicit input regarding the directions one should take in the near future

Suggest: Short report with the opinion of the committee regarding the current R&D program and future directions

Outcome of original review: Report with main recommendation to produce:

1) Document with a coherent list of the on-going of R&D activities, such that the presence of gaps and overlaps can be determined and addressed — DONE
2) Updated CDR document within 12-18 months
3) A conservative full-detector concept, potentially deliverable on an aggressive time scale, should be specified by the CEPC Management and adopted as the baseline for the CDR update

We, the CEPC management and IAC, didn't agree with the production of another "CDR" document in this timescale, due to the large amount of resources required. Instead, the decision was to move forward with the R&D for a 4th detector

Events after first meeting:

- IDRC expressed concern that the schedule presented to them (with detector TDRs in 2023) was not realistic and prompted the problematic recommendations
- Follow-up IDRC meeting in 2020, planned for Marseille, was cancelled due to COVID
- A document with the summary of on-going R&D activities was produced and sent to the IDRC chair, as requested by the IDRC

- Since the last IAC meeting in 2021:
  - An updated version of the document with the summary of R&D activities was produced and sent to the IDRC
  - Two attempts to organize a meeting in 2022 were made by the IDRC chair, but unfortunately it was not possible to secure the presence of enough committee members
  - Given the current international situation, the chair has suggested a modification to the committee charge that we would like to discuss

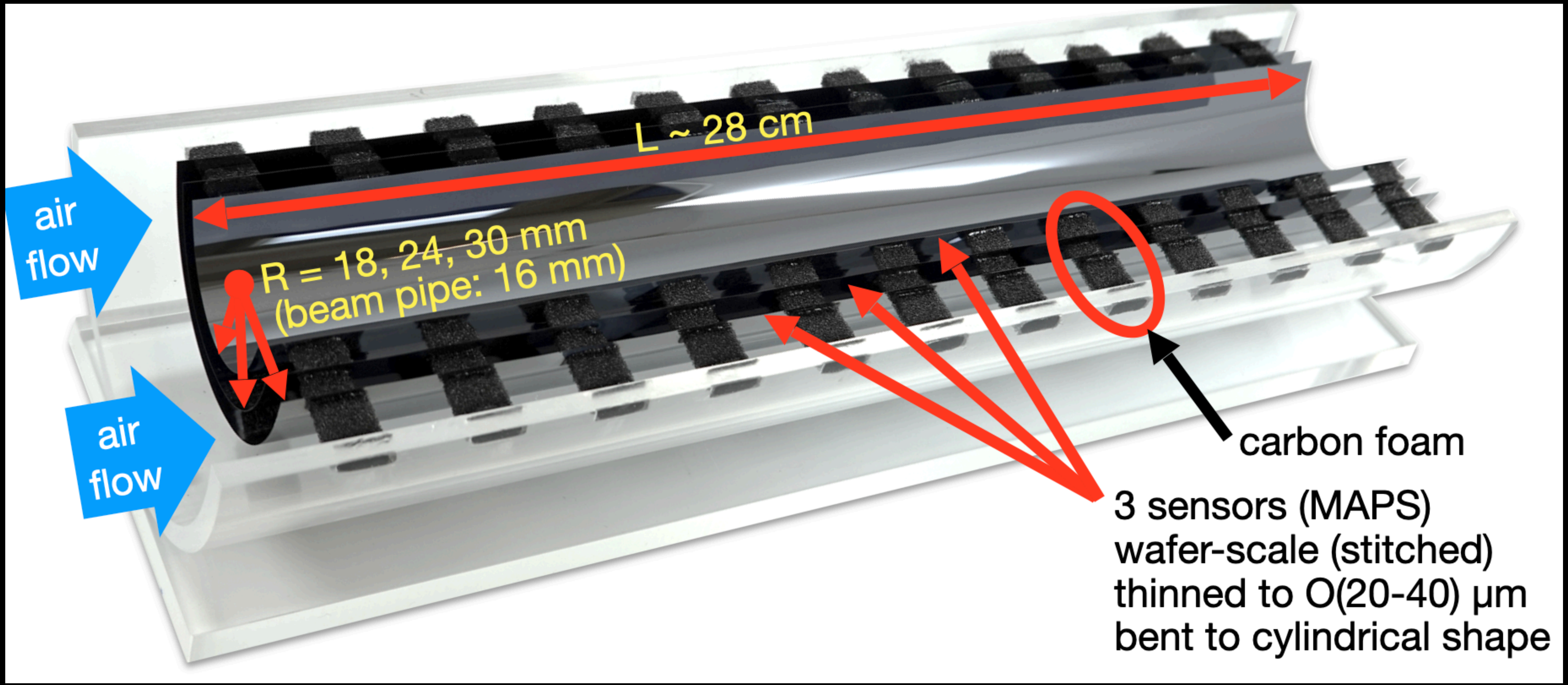
Document with summary of on-going R&D activities updated in early 2022

Contents

Key R&D Issues Moving Forward

Some key R&D topics moving forward

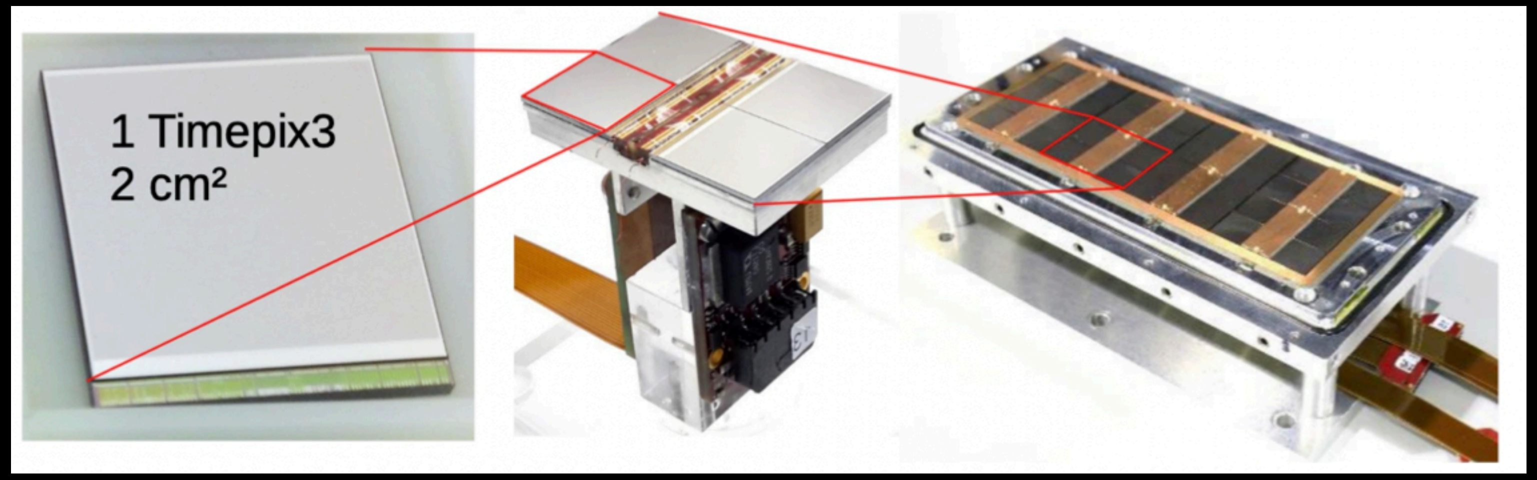
- Machine Detector Interface
- Luminosity meter (LumiCal) - continue integration in beampipe development
- Silicon Vertex
  - Continue to explore low-material budget solutions, cooling integration and performance optimization
  - Major issue: Sensor technology and availability in China
  - Curved silicon, as in ALICE ITS3, should be considered but it has lots of challenges that would need to be solved in a tight timescale



Some key R&D topics moving forward

Trade off: Transparency <—> reliability/resolution

- Tracker
  - Time Projection Chamber
    - Evaluate the Pixel TPC possibility



  - Drift Chamber
    - Demonstrate it can cope with the high increased rates at the Z pole? Enough resolution?
    - Demonstrate PID capabilities with cluster counting
    - Continue mechanical design and stability analysis
  - Full silicon tracker → still need manpower increase to exploit this option
    - Continue Silicon Tracker prototype collaboration
    - Need to add detector for particle identification — drift chamber is an option
    - Consider adding timing Silicon layer
      - AC-Coupled Resistive Silicon Detector (RSD)
      - Trench-isolated LGAD (TI-LGAD)

Some key R&D topics moving forward

- Calorimetry
  - Cost versus physics performance
  - ECAL
    - Finalize evaluation of the crystal calorimeter option
    - Cooling of PFA calorimeter versus performance
  - HCAL
    - Finalize evaluation of Scintillator Steel option
    - Study glass hadronic calorimeter has an alternative
    - Cooling and mechanics studies
  - Dual Readout
    - Demonstration using full size prototype

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- Muon System optimization
  - Optimize number of layers
  - Optimize design for industrialization and cost

CEPC Project timeline

CEPC Project Timeline

2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037

Accelerator	Technical Design Report (TDR)	2023
Accelerator	Engineering Design Report (EDR) R&D of a series of key technologies Prepare for mass production of devices though CIPC	2023
Accelerator	Civil engineering, campus construction	2026
Accelerator	Construction and installation of accelerator	2027
Detector	New detector system design & Technical Design Report (TDR)	2028
Detector	Detector construction, installation & joint commissioning with accelerator	2028
Detector	Experiments operation	2036
International Cooperation	Further strengthen international cooperation in the filed of Physics, detector and collider design	
International Cooperation	Sign formal agreements, establish at least two international experiment collaborations, finalize details of international contributions in accelerator	2026

Sub-detectors and Key techs

Table 3.2: All sub-detectors and the key technologies

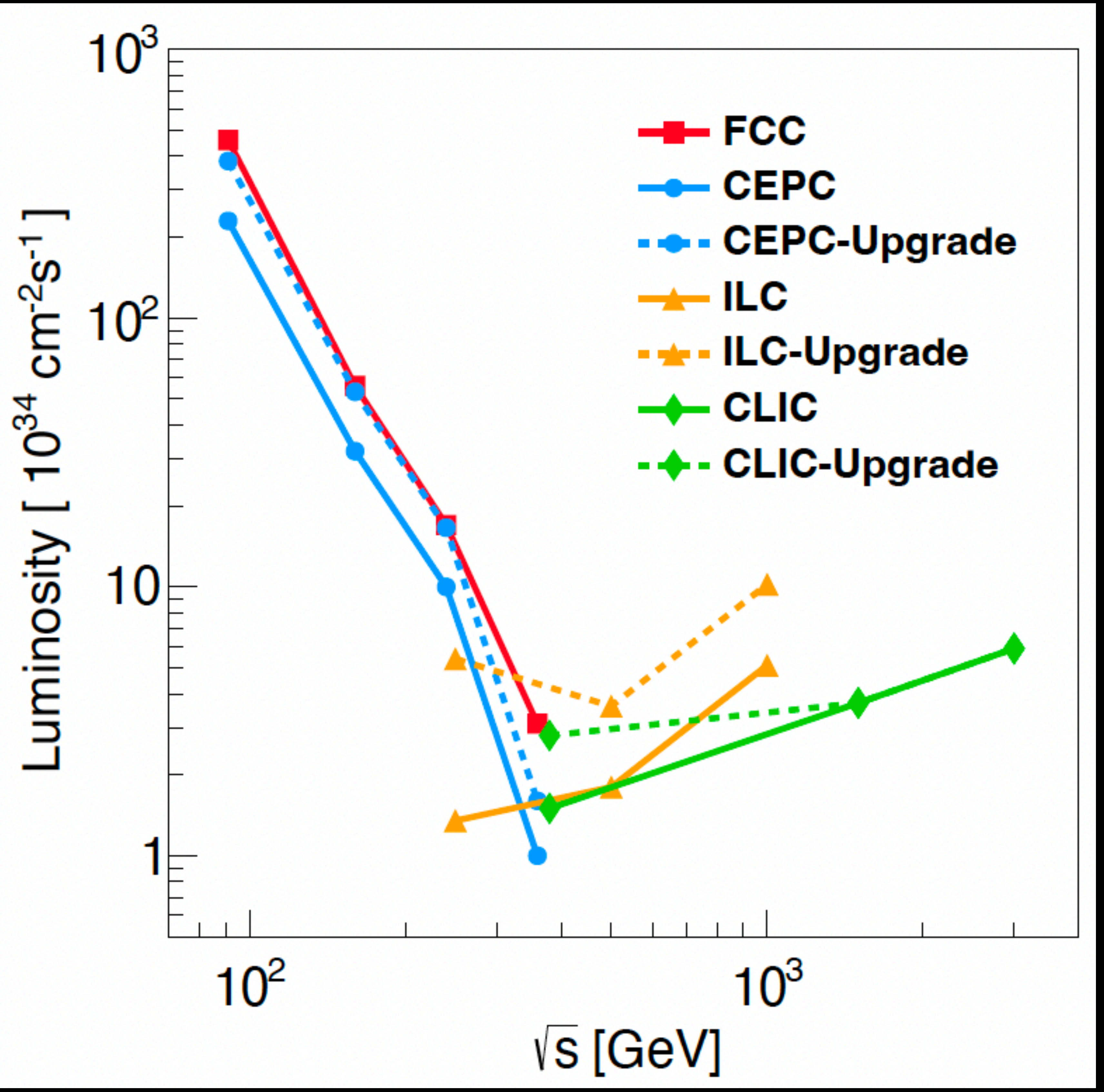
Sub-detector	Key technology	Key Specifications
Silicon vertex detector	Spatial resolution and materials	$\sigma_{r\phi} \sim 3\ \mu$m, $X/X_0 < 0.15\%$ (per layer)
Silicon tracker	Large-area silicon detector	$\sigma(\frac{1}{p_T}) \sim 2 \times 10^{-5} \oplus \frac{1\times10^{-3}}{p\times\sin^{3/2}\theta}(\mathrm{GeV}^{-1})$
TPC/Drift Chamber	Precise dE/dx (dN/dx) measurement	Relative uncertainty 2%
Time of Flight detector	Large-area silicon timing detector	$\sigma(t) \sim 30$ ps
Electromagnetic Calorimeter	High granularity 4D crystal calorimeter	EM energy resolution $\sim 3\%/\sqrt{E(\mathrm{GeV})}$ Granularity $\sim 2 \times 2 \times 2$ cm^3
Magnet system	Ultra-thin High temperature Superconducting magnet	Magnet field $2-3$ T Material budget $< 1.5X_0$ Thickness <150 mm
Hadron calorimeter	Scintillating glass Hadron calorimeter	Support PFA jet reconstruction Single hadron $\sigma_E^{had} \sim 40\%/\sqrt{E(\mathrm{GeV})}$ Jet $\sigma_E^{jet} \sim 30\%/\sqrt{E(\mathrm{GeV})}$

CEPC TDR Parameters (upgrade version)

	Higgs	W	Z	ttbar
Number of IPs	2			
Circumference [km]	100.0			
SR power per beam [MW]	50			
Half crossing angle at IP [mrad]	16.5			
Bending radius [km]	10.7			
Energy [GeV]	120	80	45.5	180
Energy loss per turn [GeV]	1.8	0.357	0.037	9.1
Piwinski angle	5.94	6.08	24.68	1.21
Bunch number	415	2162	19918	58
Bunch spacing [ns]	385	154	15(10% gap)	2640
Bunch population [10^{10}]	14	13.5	14	20
Beam current [mA]	27.8	140.2	1339.2	5.5
Momentum compaction [10^{-5}]	0.71	1.43	1.43	0.71
Phase advance of arc FODOs [degree]	90	60	60	90
Beta functions at IP (bx/by) [m/mm]	0.33/1	0.21/1	0.13/0.9	1.04/2.7
Emittance (ex/ey) [nm/pm]	0.64/1.3	0.87/1.7	0.27/1.4	1.4/4.7
Beam size at IP (sx/sy) [um/nm]	15/36	13/42	6/35	39/113
Bunch length (SR/total) [mm]	2.3/3.9	2.5/4.9	2.5/8.7	2.2/2.9
Energy spread (SR/total) [%]	0.10/0.17	0.07/0.14	0.04/0.13	0.15/0.20
Energy acceptance (DA/RF) [%]	1.7/2.2	1.2/2.5	1.3/1.7	2.3/2.6
Beam-beam parameters (xx/xy)	0.015/0.11	0.012/0.113	0.004/0.127	0.071/0.1
RF voltage [GV]	2.2 (2cell)	0.7 (2cell)	0.12 (1cell)	10 (5cell)
RF frequency [MHz]	650			
Beam lifetime [min]	20	55	80	18
Luminosity per IP[10^{34}/cm²/s]	8.3	26.6	191.7	0.8

Higher SR power of 50MW: Luminosity increase ~66%.

CEPC accelerator white paper for Snowmass21, arXiv:2203.09451



Projects overview: R&D schedule

PBS	Task Name	Start	Finish	Duration
	CEPC Detector R&D Project	**2020/5/7**	**2026/12/31**	**1736 days**
1	**Vertex**	**2020/5/7**	**2023/12/29**	**952 days**
1.1	Vertex Prototype	2020/5/7	2023/12/29	952 days
1.2	ARCADIA CMOS MAPS	2020/5/7	2023/12/29	952 days
2	**Tracker**	**2020/5/7**	**2024/12/31**	**1214 days**
2.1	**TPC Module and Prototype**	**2020/5/7**	**2021/12/31**	**432 days**
2.2	**Silicon Tracker Prototype**	**2020/5/7**	**2023/10/31**	**909 days**
2.3	**Drift Chamber Activities**	**2020/5/7**	**2024/12/31**	**1214 days**
3	**Calorimetry**	**2020/5/7**	**2024/12/31**	**1214 days**
3.1	**ECAL Calorimeter**	**2020/5/7**	**2024/12/31**	**1214 days**
3.1.1	Crystal Calorimeter	2020/5/7	2021/12/31	432 days
3.1.2	PFA Sci-ECAL Prototype	2020/5/7	2024/12/31	1214 days
3.2	**HCAL Calorimeter**	**2020/5/7**	**2023/4/28**	**777 days**
3.2.1	PFA Digital Hadronic Calorimeter	2020/5/7	2022/12/30	692 days
3.2.2	PFA Sci-AHCAL Prototype	2020/5/7	2023/4/28	777 days
3.3	**Dual-readout Calorimeter**	**2020/5/7**	**2024/12/31**	**1214 days**
4	**Muon Detector**	**2020/5/7**	**2024/12/31**	**1214 days**
4.1	Scintillator-based Muon Detector Prototype	2020/5/7	2023/12/29	952 days
4.2	Muon and pre-shower µRWELL-based detectc	2020/5/7	2024/12/31	1214 days
5	**Solenoid**	**2020/5/7**	**2026/12/31**	**1736 days**
5.1	LTS solenoid magnet	2020/5/7	2025/12/31	1475 days
5.2	HTS solenoid magnet	2020/5/7	2026/12/31	1736 days
6	**MDI**	**2020/5/7**	**2023/12/29**	**952 days**
6.1	LumiCal Prototype	2020/5/7	2021/12/1	410 days
6.2	Interaction Region Mechanics	2020/5/7	2023/12/29	952 days
8	**Software and Computing**	**2020/5/7**	**2024/12/31**	**1214 days**