CEPC Detector R&D Project

1.1 Vertex Prototype

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Change history

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| --- | --- | --- |
| **Revision** | **When** | **What changed and why** |
| 1 | 12/12/2019 | First draft |
| 2 | 5/5/2020 | Completed the information |
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|  |  | < Add further lines to table as required > |

Readme first

1. Please do not delete or modify this section or its structure.
2. Only change text enclosed by (and including) angled brackets “< … >”.
3. Don’t change field directly, instead modify the document options, under File🡪 Properties (or similar)
   * Enter name of person that wrote the document in Document:Summary: Author
   * The project ID number, should follow the rules provided to you earlier. The number should be changed in Document:Custom: PBS.
   * The project name should be changed in Document:Summary: Subject.
4. In Section [*Project Objectives*](#ProjectObjectives) provide a brief description of the project goals, i.e. why and what is being produced, for PBS item . If this project includes identifiable sub-projects you can indicate them in the [*Sub-projects Description*](#SubprojectsDescription) Section, otherwise submit a separate document for each of them. The sub-project IDs are free for you to define.
5. Finally, remember to update the [*Change History*](#ChangeHistory).

: Project Objectives

The project is to build a full-size prototype for CEPC vertex detector. The prototype should fulfill the CEPC requirement, especially the requirement on spatial resolution, time stamping precision, material budget, power consumption, as well as readout data throughput in Higgs runs, Z pole runs and WW threshold scan runs.

: Sub-projects Description

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| **Project ID** | **Title** | **Description** |
| 1.1.1 | Pixel sensor R&D | Sensor R & D for CEPC vertex detector |
| 1.1.1.1 | CMOS pixel sensor R&D | Baseline sensor R & D: Monolithic sensor with CMOS imaging technology |
| 1.1.1.1.2 | MOST1 CMOS sensor | CMOS R&D with Rolling-shutter readout, supported by the first CEPC grant from Ministry of Science and Technology (MOST1). Aim to develop high resolution and low power consumption pixel sensor. |
| 1.1.1.1.1 | Full size CMOS sensor | Full size CMOS pixel sensor using priority readout (FEI3-like and ALPIDE-like) with full functionality to be used in a pixel vertex detector. It is designed to obtain 25ns time stamp and fast readout pixel sensor. |
| 1.1.1.2 | SOI pixel sensor R&D | Alternative sensor R & D: Aim to Develop high resolution and fast readout pixel sensor with 3D connection technology and SOI technology |
| 1.1.2 | Low-mass ladder | Build low-mass Ladder to satisfy CEPC requirements, including the support structure prototyping and ladder assembly with automatic robot. |
| 1.1.3 | Readout electronics and DAQ | Readout electronics and data acquisition for ladder and vertex detector. Design data acquisition system to handle data transmission rate in Higgs runs, Z pole runs and WW threshold scan runs. |
| 1.1.4 | Detector Layout  optimization | Use MC simulation to optimize the layout of vertex detector |
| 1.1.5 | Mechanical structure | Build a full-size low-mass mechanical structure for pixel detector |
| 1.1.6 | Detector integration | Install ladders on vertex detector structure, and integrated them into one system. |
| 1.1.7 | Detector test | Commissioning the detector system and perform beam test and study radiation hardness of the detetor. |

: CEPC Relationship

The project aims to build a full-size prototype for CEPC vertex detector in barrel region and verify the performance in terms of spatial resolution, time stamping precision, material budget, readout data throughput. For short term, this is standalone vertex prototype R & D project. In longer term, this prototype should be integrated with beam pipe structure and incorporated into machine-detector interface R & D.

: Project Schedule

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| **Project ID** | **Title** | **Schedule** |
| 1.1.1 | Pixel sensor R&D |  |
| 1.1.1.1 | CMOS pixel sensor R&D |  |
| 1.1.1.1.1 | Full size CMOS sensor | 2020: complete R & D for small-size full-functionality CMOS sensor using priority readout (FEI3-like and ALPIDE-like)  2021: complete R & D for full-size full-functionality sensor. |
| 1.1.1.1.2 | MOST1 CMOS sensor | 2020-2021: test engineering-run CMOS sensors with Rolling-shutter readout, verify its power consumption lower than 100 mW/cm2 and spatial resolution better than 5μm. |
| 1.1.1.2 | SOI pixel sensor R&D | 2021: develop high resolution SOI sensor  2023: use 3D connection technology to inter-connect the high resolution SOI sensor and fast readout chip |
| 1.1.2 | Low-mass ladder | 2020: first prototype of low-mass support structure of the Ladder.  2022: Assemble the first ladder prototype with full-size sensor |
| 1.1.3 | Readout electronics and DAQ | 2021：complete readout system for one ladder  2022: Readout system for vertex detector prototype |
| 1.1.4 | Detector Layout  optimization | 2020: finish the optimization of detector layout with CEPC MC simulation |
| 1.1.5 | Mechanical structure | 2021: Build a full-size low-mass mechanical structure for pixel detector. |
| 1.1.6 | Detector integration | By the end of 2022: complete the detector integration |
| 1.1.7 | Detector test | 2021: radiation hardness tests of single sensor, verify it can survive 1MRad total ionization does irradiation  2022: beam tests of single ladder  2023: beam tests of full-size prototype, verify its spatial resolution better than 5μm. |

: Funding Availability

The project is mainly supported by Ministry of Science and Technology(MOST).

The first CEPC grant from MOST (MOST1) is mainly to develop monolithic active pixel sensors with CMOS imaging technology and its frontend electronics for CEPC application. This sensor R & D is also supported by National Nature Science Foundation of China and IHEP innovation grant.

The second CEPC grant from MOST (MOST2) supports the R & D for a full-size CEPC vertex detector prototype.

Further, the alternative sensor development with SOI and National Nature Science Foundation of China.

1.1 Vertex Prototype: Leadership Arrangement

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| Funding agency |  | objectives of the project | anticipated schedule | funding available(MRMB)/ leadership arrangements | CEPC-specific development |
| Project ID |
| MOST1 | 1.1.1.1.2  MOST1 CMOS sensor | CMOS pixel | 2016-2021 | 5.0/IHEP+CCNU | Aim to develop high resolution and low power consumption pixel sensor |
| MOST2 | 1.1  Vertex prototype | Full-size vertex detector prototype | 2018-2023 | 12.0/IHEP+SDU+NWPU+NJU | Aim to build a full-size vertex detector prototype with 25ns time stamp and fast readout pixel sensor |
| NSFC | 1.1.1.1.2  MOST1 CMOS sensor | CMOS pixel | 2016-2022 | 1.1/IHEP | Aim to optimize the pixel sensing front-end |
| NSFC | 1.1.1.2  SOI pixel sensor R&D | SOI pixel | 2016-2023 | 4.0/IHEP | Aim to develop high resolution and fast readout pixel sensor with 3D connection technology |
| IHEP | 1.1.1.1.2  MOST1 CMOS sensor | CMOS pixel | 2015-2018 | 1.0(finished) | Aim to explore the CMOS process with optimization of sensing diode |

: Manpower Resources

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|  | objectives of the project | CEPC-specific development | Manpower resources | | |
| Faculty/  FTE | Engineer/  FTE | Student/  FTE |
| MOST1 | CMOS pixel | Aim to develop high resolution and low power consumption pixel sensor | 5 | 1 | 3 |
| MOST2 | Full-size vertex detector prototype | Aim to build a full-size vertex detector prototype with 25ns time stamp and fast readout pixel sensor | 14 | 2 | 13 |
| NSFC | CMOS pixel | Aim to optimize the pixel sensing front-end | 0.5 |  | 0.5 |
| NSFC | SOI pixel | Aim to develop high resolution and fast readout pixel sensor with 3D connection technology | 1.5 | 0.5 | 0.7 |
| IHEP | CMOS pixel | Aim to explore the CMOS process with optimization of sensing diode |  |  |  |