CEPC Detector R&D Project

3.2.1 PFA Semi-Digital Hadronic Calorimeter

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Change history

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| **Revision** | **When** | **What changed and why** |
| 1 | 12/18/2019 | First draft |
| 2 | 5/6/2020 | Second revision, add R&D and construction of RPC and RWELL |
| 3 | 1/13/2021 | Third revision, add manpower and some minor modifications |

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 **1.1** **Vertex Prototype**. 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).

3.2.1 : Project Objectives

High-granularity hadronic calorimeter concept is to play an essential role in PFA-based experiments such as CEPC. It allows to separate the deposits of charged and neutral hadrons and to precisely measure the energy of the neutrals. Although the contribution of the neutrals to the jet energy, around 10% on average, the performance is dominated by confusion of energy separation between charged and neutral hadrons, topological pattern recognition and energy information are important for correct track cluster assignment. High-granularity hadronic calorimeter is thus needed to achieve excellent jet energy resolution.

HCAL are sampling calorimeters with steel as absorber and scintillator tiles or gaseous devices with embedded electronics for the active part. The steel was chosen due to its rigidity which allows to build self-supporting structure without auxiliary supports (dead regions). The active detector element has very finely segmented readout pads, with 1cm×1cm cell size. For the entire HCAL, with ~100 m3 total volume, the total number of channels will be 4×107which is one of the biggest challenges for the HCAL system. A simple hit counting is already a good energy measurement for hadrons. In a Semi-DHCAL, each readout channel is used to register a ’hit’, instead of measure energy deposition, as in traditional HCAL. In this context, gas detectors (such as RPC, RWELL, RPWELL) become excellent candidates for the active element of a SDHCAL.

The objectives of the R&D projects are relative to four tasks listed in the following subsections.

3.2.2 Semi-Digital Hadronic Calorimeter : Sub-projects Description

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| **Project ID** | **Title** | **Description** |
| 3.2.1 | Sensitive detector R&D and construction | * To carry out R&D of sensitive detector RPC and RWELL/RPWELL * To construct large size RPC and RWELL/RPWELL * To design and construct readout electronics |
| 3.2.2 | Performance with jets in PFA and optimization | * To study performance of SDHCAL option for precision measurements of jets with PFA; * To provide comparisons with Analog HCAL (e.g. based on scintillator with SiPM), and also with different gaseous detector options; (e.g. energy resolution, cost budget); * To optimize PCB cell size to achieve descent jet energy performance with reduced power and cost. |
| 3.2.3 | Test Beam and performance study | * To involve the test beam and related data analysis to better understand performance of SDHCAL technological prototype. * To evaluate the performance of SDHCAL and ECAL using joint test beam data. |
| 3.2.4 | Active Cooling of SDHCAL (hardware and simulation) | * To establish thermal simulation program to optimize active cooling design * To develop small-scale prototypes with active cooling system, to evaluate its performance and validate simulation results. |
| 3.2.5 | Performance with timing information | * To study how additional timing information in hadronic showers can be made to improve particle identification, shower separation for PFA study. * To design and build a few modules of MRPC with good timing resolution (~100ps) * To make feasibility study of building a 5D HCAL prototype which include 3D position, amplitude, and timing. (part of AIDAnova project) |

3.2.3 Semi-Digital Hadronic Calorimeter : CEPC Relationship

This R&D on Semi-Digital Hadronic Calorimeter based on gaseous detector (eg. RPC, RWELL, RPWELL) is an essential part of the PFA based HCAL R&D program in the context of CALICE collaboration, especially for the high granularity HCAL to be designed for future lepton colliders such as ILC, CEPC and FCC-ee etc. This R&D effort is common for future lepton colliders.

3.2.4 Semi-Digital Hadronic Calorimeter : Project Schedule

Task 3.2.1 should be completed by 2021. Intermediate milestone will be the construction of large size RPC and RWELL/RPWELL detectors.

Task 3.2.2-3 should be completed by 2022, construction of a small prototype for test beam.

Task 3.2.4 should be completed by 2022.

Task 3.2.5 is part of AIDA2020 project, shall meet the schedule of AIDA2020.

3.2.5 Semi-Digital Hadronic Calorimeter : Funding Availability

Currently, CEPC detector R&D are supported by

* one MOST key project (2016-2021, ~2M RMB)
* one NSFC joint project (2019-2022) between China (~1.75M RMB) and Israel (~1.8M RMB).

We also received significant funding from another European project, Cremlin+.

3.2.6 Semi-Digital Hadronic Calorimeter : Leadership Arrangement

Haijun Yang SJTU, Shanghai, China

Imad Laktineh IPNL, Lyon, France

Shikma Bressler Weizmann Institute of Sciences, Israel

4.7 : Manpower Resources

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| **Type** | **Average FTE Expected** |
| Faculty | 2.1 |
| Postdoc | 1.75 |
| Students | 2.55 |
| Engineer | 0.25 |

Domestic Institutes:

\* Prof. Haijun Yang (SJTU), Faculty, FTE: 0.3

\* Prof. Jianbei Liu (USTC), Faculty, FTE: 0.3

\* Prof. Jun Guo (SJTU), Faculty, FTE: 0.2

\* Prof. Weihao Wu(SJTU), Faculty, FTE: 0.3

\* Dr. Francois Lagarde(SJTU), Postdoc, FTE: 0.5

\* Dr. Yanyun Duan(SJTU), Postdoc, FTE: 0.5

\* Daojin Hong(USTC), PhD student, FTE: 0.5

\* Qiuping Sheng(SJTU), PhD student, FTE: 0.5

\* Xi Wang(SJTU), PhD student, FTE: 0.5

\* Yifan Zhu(SJTU), PhD student, FTE: 0.3

International Institutes:

\* Prof. Imad Laktineh (IP2I, Lyon), Faculty, FTE: 0.2

\* Prof. Gerald Grenier (IP2I,Lyon), Faculty, FTE:0.1

\* Prof. Laurent Mirabito (IP2I, Lyon), CNRS, FTE:0.1

\* Prof. Shikma Bressler (Weizmann, Israel), Faculty, FTE: 0.3

\* Prof. Enrique Kajomovitz (IIT, Israel), Faculty, FTE: 0.3

\* Luca Moleri (postdoctoral fellow - 0.5 FTE)

\* Abhik Jash (postdoctoral fellow - 0.25 FTE)

\* Dan Shaked-Renous (PhD student - 0.5 FTE)

\* Darina Zavazieva (PhD student - 0.5 FTE)

\* Gil Cohen (leading technician - 0.25 FTE)