CEPC Detector R&D Project

4.2 Muon and pre-shower µRWELL-based detectors

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| Document Responsible: |  |
| Last saved by on |  |
| Revision number: | 2 |
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Change history

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| **Revision** | **When** | **What changed and why** |
| 1 | 17/12/2019 | First draft |
| 2 | 28/04/2020 | Second draft added simulation task and INFN Torino |
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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).

4.2 Muon and pre-shower detector : Project Objectives

The µRWELL technology, developed at LNF-INFN (*“The micro-Resistive WELL detector: a compact spark-protected single amplification-stage MPGD”, G. Bencivenni et al 2015\_JINST\_10\_P02008*), has been identified as a very promising technology to realize both the muon apparatus as well as the pre-shower. The muon detector will provide complete coverage for detecting very penetrating particles, most of them being muons, having traversed the calorimeter. The µRWELL based pre-shower system is used to identify and measure electromagnetic showers initiated in the material of the solenoid before reaching the calorimeter. The information from the pre-shower is essential to recover a good energy resolution from the dual readout calorimeter. µRWELL detectors can obtain a position resolution of the order of 50-60 um with a time resolution of about 5 ns. The muon detector does not need such a precise position resolution and µRWELL detectors with a larger strip pitch than what will be used for the pre-shower will be employed. For both the muon detector and the pre-shower system a modular structure of µRWELL detectors of dimensions of about 50x50cm2 is envisaged. These detector dimensions should be a good compromise between the industrial engineering and production and the large overall dimensions to be covered, especially for the muon detector.

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

We also anticipate that the simulation studies will be used to optimize the overall detector design.

4.2 : Sub-projects Description

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| **Project ID** | **Title** | **Description** |
| 4.2.1 | Industrialization of large size µRWELL detectors with bi-dimensional readout | The µRWELL technology has been extensively characterized in laboratory measurements and has undergone several beam tests and is now a rather mature detector technology. Its characteristic of high space and good time resolution, high efficiency and high gain with a single amplification stage have been clearly demonstrated.  The purpose of this task is to optimize the engineering design of the detector and bring the technology and know-how to industry for a future mass production. For this purpose, we have started a collaboration with the ELTOS company in Arezzo, Italy, more than 2 years ago. The ELTOS company is specialized in PCB production and has already produced the anodes and cathodes of several µRWELL prototypes in the past. The next step was to perform the coupling of the µRWELL kapton foil with the well scheme with the anode PCB. Eltos has already achieved this step for several small size (10x10 cm2) µRWELL prototypes with the original layout with a single resistive layer. Several other layouts of µRWELL detectors have been produced and tested subsequently. From the original single resistive layer, dubbed “low rate” version, capable of particle rates up to about 30-50 kHz/cm2, we have then moved to a design that allows higher particle rates, up to about 10 MHz/cm2. The first high-rate layout employed a two resistive-layer scheme, that proved effective but of difficult industrialization. For this reason, a new high rate layout based on a single resistive-layer scheme with a silver grid underneath the resistive layer has been designed. This layout, called SG2++, is the layout that we would now like to fully co-develop and produce with ELTOS. The final design is not very different from the original low-rate single resistive layer layout and has shown a particle rate capability exceeding 10 MHz/cm2. The next step we want to achieve is the production of larger size detector prototypes, ~30x25 cm2 and even 60x25 cm2, at affordable and competitive costs. |
| 4.2.2 | R&D on improved DLC+Cu sputtering | The Diamond Like Carbon (DLC) sputtering technique is what has been used until now to produce the resistive layer of the µRWELL kapton foils. All the recent µRWELL detector prototypes we have built employ this technique for their resistive layer.  An improved method, using a DLC+Cu sputtering technique to make the resistive layer, has been recently developed in collaboration with the USTC Hefei institute. The first high-rate detector prototypes of dimensions 10x10 cm2 built with this resistive layer, designed at LNF-INFN, have been built at CERN and tested showing a very high efficiency up to particle rates of 10 MHz/cm2 (*“The micro-RWELL layouts for high particle rate”, G. Bencivenni et al., 2019\_JINST\_14\_P05014*). The R&D on the DLC+Cu sputtering technology has been recently inserted in a common project of RD51 for realizing resistive layers for many different types of Micro Pattern Gas Detectors (MPGD). The next step will be to increase the size on which the DLC+Cu deposition can be made in order to finally reach detector sizes as reported above. |
| 4.2.3 | Optimization of the bi-dimensional readout | The charge produced by the passage of an ionizing particle through a µRWELL detector and then amplified by the WELL structure is then read capacitively by a readout layer patterned in the readout PCB and placed underneath the resistive layer of the detector. The readout layer can be built with a pixel-design or with a strip-design. The pixel-design has the advantage of providing bi-dimensional readout with a single readout layer. The strip-design allows to achieve even better spatial resolution by performing a convolution of the charge deposited in nearby strips. We have recently built the first small µRWELL detector, 10x10 cm2, with two readout layers with a strip design, the first layer placed at 90o degrees with respect to the following one, in order to be able to read the x and y coordinates independently. The design of such a detector has to be properly optimized to achieve a similar signal size and resolution for both coordinates. The next step is to increase the size of the detectors with the bi-dimensional readout up to sizes of about 30x30 cm2. The strip pitch is what determines mostly the possible spatial resolution of a µRWELL detector. For the pre-shower system we need a spatial resolution, in both x and y coordinates, of the order of (or better than) 100 µm. The strip pitch envisaged is therefore of 400 µm. For the muon system the requirement of spatial resolution can be relaxed and the envisaged strip pitch is 1.2-1.5 mm. |
| 4.2.4 | Simulation of a µRWELL-based muon detector | Implementation of this detector in a fast simulation context to study physics potential for tracks tagging and long lived particles identification. Development of a full simulation model in Geant4 to study more realistic performance and optimization of detector design. |

4.2 : CEPC Relationship

This R&D on µRWELL detectors is an integral part of the needed R&D program for the muon and pre-shower systems of the IDEA detector concept. IDEA has been proposed an accepted by both very large circular e+e- colliders proposed: CEPC in China and FCC-ee at CERN. The R&D is the same for both colliders.

4.2 : Project Schedule

Task 4.2.1 should be completed by 2024. Intermediate milestones will be the construction of smaller size µRWELL prototypes.

Task 4.2.2 should be completed by 2024.

Task 4.2.3 is a prerequisite for the completion of Task 4.1.1. It is scheduled to be completed towards the end of 2022-23 in order to be able to later achieve the construction of larger size prototypes.

Task 4.2.4 will run in parallel to the other three tasks until 2024. First results will however be available already in 2021.

4.2 : Funding Availability

Task 4.2.1 has received some funding (25 keuro) from INFN CSN1 for the construction of several medium/large size µRWELL prototypes by the end of 2020.

Task 4.2.2 has received some funding (8 keuro) from INFN CSN1 as co-funding of the RD51 project at CERN. A funding request has been placed by groups of INFN Frascati, Bologna and Ferrara within the framework of the AIDA++ proposal, specifically for the pre-shower and muon system of the IDEA detector. The expected funding, from the beginning of 2021 and for a period of 4 years, is around 120 keuro.

A request of 40 keuro has been also submitted to the AIDA++ proposal, for the development of an advanced machine-learning based track reconstruction algorithm for µRWELL detectors.

A further request of 100 keuro has been submitted to the AIDA++ proposal to develop a specific ASIC for pixelated µRWELL detectors. Completion of all these tasks is expected by the end of 2024.

We also received significant funding from another European project, Cremlin+, to build a cylindrical µRWELL detector to serve as the main tracker for the proposed Super Charm-Tau Factory of the Budker Institute for Nuclear Physics in Novosibirsk, Russia, to be developed and tested by groups from INFN Frascati and Ferrara.

4.2 : Leadership Arrangement

Paolo Giacomelli INFN Bologna

Gianluigi Cibinetto INFN Ferrara

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4.2 Muon and pre-shower detectors : Manpower Resources

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| **Type** | **Average FTE Expected** |
| Faculty | 2.0 |
| Postdoc | 1.5 |
| Students | 1.0 |
| Engineers | 0.3 |

Four INFN sections are involved in this R&D: Bologna, Ferrara, LNF and Torino.

Bologna can count on an undergraduate and a PhD student, and three faculty.

Ferrara can count on 3 PostDocs, 1 PhD student and two faculty.

LNF can count on 1 PhD student and three faculty members.

Torino can count on 1-2 faculty.