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The μ-RWELL technology for the preshower and muon detectors of the IDEA detector

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ABSTRACT

The IDEA detector concept has been designed to operate at a future large circular e^+e^- collider, like FCC-ee or CEPC. The IDEA detector has an innovative design with a central tracker enclosed in a superconducting solenoidal magnet. Going outwards, a preshower system followed by a dual readout calorimeter is foreseen. In the iron yoke, that closes the magnetic field, are then located three stations of muon detectors. The preshower and muon detectors are based on the μ-RWELL technology that inherits the best characteristics of the GEM, in particular the layout of the amplification stage, and Micromega detectors, that inspired the presence of a resistive stage. To profit of the industrial production capabilities of this technology, a modular design has been adopted for both systems: the μ-RWELL *tile* will have an active area of 50×50 cm^2, but with a pitch between the readout strips of 400 μm for the preshower and about 1 mm for the muon system. Other requirements are: a spatial resolution of the order of 100 μm for the preshower and a reasonable total number of front-end channels for the muon system. To optimize the resistivity and the strip pitch, we have built a set of prototypes with active area of 5×40 cm^2 and 40 cm long strips. The DLC resistivity is ranging from 10 to 80 MΩ/□. All these detectors have been exposed in October 2021 to a muon beam at the CERN SPS. The very positive results obtained pave the way for a completely new and competitive MPGD tracking device for high energy physics experiments.

1. FCC-ee collider and IDEA detector

A high luminosity and high energy lepton collider, Future Circular Collider (FCC-ee), installed on a 100 km tunnel has been proposed to serve the worldwide community with a scientific capability beyond the current state of art [1]. Combining novel elements with past and present lepton colliders, the FCC-ee design achieves outstandingly high luminosity. This will make the FCC-ee an instrument to study the heaviest known particles (Z, W and H bosons and the top quark) to improve the precision measurements in literature and the sensitivity to new physics. Two complementary detector designs have been proposed: the "CLIC-Like Detector" (CLD) and the "International Detector for Electron-positron Accelerators" (IDEA). The structure of IDEA is shown in Fig. 1 and it comprises a silicon pixel vertex detector, a large volume wire chamber and a silicon micro-strip detector for the tracking volume, a low mass superconducting solenoid coil, a preshower detector, a dual-readout calorimeter and muon chambers within the magnet return yoke.

The layout of the tracking volume is optimized to reduce the material budget and obtain a position resolution of 20 μm in the silicon detectors. The transverse moment resolution was estimated through simulations to be $\sigma(1/p_t) \approx \ a \oplus \ b/p_t$, with a $\approx 3 \times 10^{-5}$ GeV^{-1} and b $\approx 0.6 \times 10^{-3}$ [1]. Outside the magnet coil, the preshower is used to tag charged particles and photons after 1 X_0 of lead and it provides a position measurements matched with the calorimeter, resulting in an

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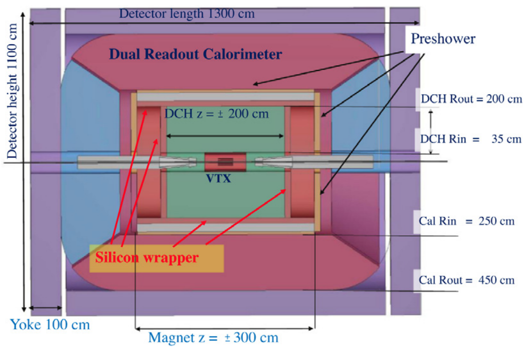

Fig. 1. A schematic layout of the IDEA detector.

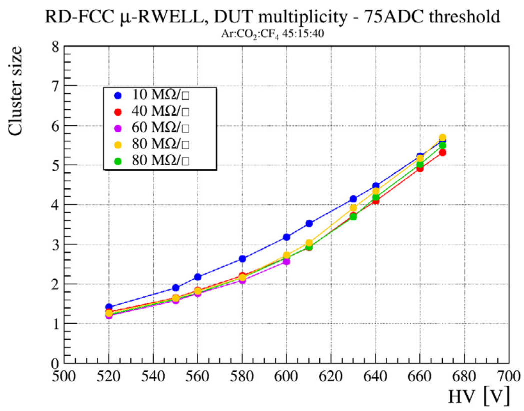

Fig. 2. Number of signal strips as a function of the HV on the amplification stage for different DLC resistivity of the DUTs.

improvement of the reconstruction performance. The interplay between the preshower and the calorimeter has been evaluated in a combined testbeam and the preliminary results are shown in [2].

2. μ-RWELL technology

Large tracking and tagging areas are needed both for the preshower and the muon system. Straightforward choices are the Micro Pattern Gaseous Detectors (MPGDs), in detail the micro-Resistive well (μ-RWELL) technology: a single-amplification stage resistive MPGD [3]. The detector amplification element is realized with a single copper-clad polyimide foil micro-patterned with a blind hole (well) matrix and embedded in the readout Printer Circuit Board (PCB) through a thin Diamond-Like-Carbon (DLC) sputtered resistive film. The DLC suppresses the transition from streamer to spark, allows to achieve large gains (10^4) with a single amplification stage and improves the detector performance through the charge dispersion effect [4]. A spatial resolution of 50 μm and an efficiency above 97%–98% have been measured with muons in a testbeam in the North Area SPS at CERN while a rate capability up to 10 MHz/cm^2 has been achieved in another testbeam with pions at PSI [5,6].

3. μ-RWELL optimization and summary

The preshower and the muon chamber of the IDEA detector will share the same technology but require a different optimization. The preshower needs a high spatial resolution to tag the incoming particles, while the muon detector covers more than 4000 m^2 of surface with a spatial resolution of few mm and a restrained number of channels.

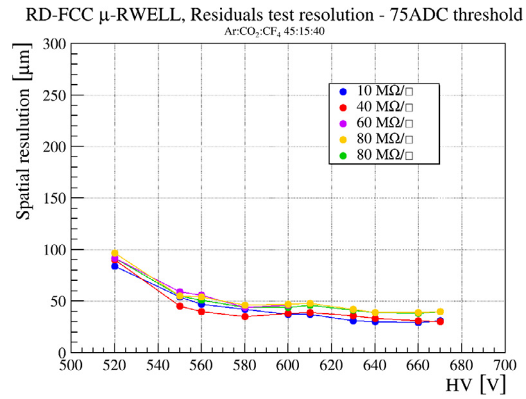

Fig. 3. Core spatial resolution as a function of the HV on the amplification stage for different DLC resistivity of the DUTs.

A different resistivity in the DLC impacts on the induced charge distribution on the readout: the smaller the resistivity, the wider the charge distribution. The DLC optimization, together with the readout granularity, impact the detector performance and its layout. A testbeam was performed in the H8 test line of the CERN North-Area using a muon beam of 140 GeV/c momentum and a set of detectors under tests (DUTs) with 5 × 40 cm^2 active area, resistivity values between 10 and 80 MΩ/□ and an Ar/CO_2/CF_4 (45/15/40) gas mixture. Two detectors with a resistivity of 80 MΩ/□ are used to evaluate systematic contribution in the measurements. The DUTs performance have been evaluated by mean of a tracking system built up by six well tested μ-RWELL detectors: three upstream and three downstream. The results of a preliminary analysis show a wider charge distribution for the DUT with 10 MΩ/□ resistivity, evaluated by the cluster size in Fig. 2, and a reduced charge dispersion in the range 40–80 MΩ/□. The core spatial resolution of the DUTs is evaluated with a Gaussian fit of the DUT position and an extrapolation from the tracking system. This resolution is better than 100 μm in a large voltage range and for all the resistivity tested, as shown in Fig. 3. The DLC resistivity characterization will continue with further studies and analysis. Up to now, only the 10 MΩ/□ resistivity shows a sizeable impact on the charge distribution, while for higher values the cluster size spread is more compact and no significant effect on the core spatial resolution was observed. The collected data will be used to tune a complete μ-RWELL simulation to be implemented in the IDEA software framework for extended evaluation of the experiment potential [7].

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