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uRANIA: μ-RWELL and sRPC for neutron detection

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Abstract: The goal of the uRANIA-V (μ-RWELL Advanced Neutron Imaging Apparatus) project is the development of an innovative thermal neutron detector based on micro-Resistive WELL (μ-RWELL) technology and surface Resistive Plate Counter (sRPC) technology. A thin layer of $^{10}B_4C$ on the cathode surface allows the thermal neutron conversion into ^7Li and α ions to be easily detected in the active volume of the device. These charged particles ionize the gas in the detectors and the readout measures the signal. Test results with different converter layouts show that a thermal neutron (25 meV) detection efficiency between $5 \div 10\,\%$ can be achieved with a single detector. A detailed comparison between the experimental data and the full simulation of the neutron physics and the detector behavior has been performed. Future applications of these technologies range from neutron diffraction imaging to radioactive waste monitor or radiation portal monitoring for homeland security. In this proceeding, the results of the neutron conversion optimization of the Boron thickness and the converted geometry will be discussed together with the development of new electronics integrated with μ-RWELL and sRPC. Experimental results and simulation measurements will be compared.

Keywords: Detector modelling and simulations I (interaction of radiation with matter, interaction of photons with matter, interaction of hadrons with matter, etc); Micropattern gaseous detectors (MSGC, GEM, THGEM, RETHGEM, MHSP, MICROPIC, MICROMEGAS, InGrid, etc); Neutron detectors (cold, thermal, fast neutrons); Resistive-plate chambers

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1 Gaseous detector technology applied to neutron detection

Neutrons play an important role in radioactive materials and the applications of neutron detectors can be found as monitors. Neutrons may interact with the detecting medium by neutron capture and the cross-section depends on the materials and the neutron energy. By means of a thin layer of ^{10}B facing the gas gap (i.e. sputtered on the cathode) it is possible to reveal thermal neutrons in a gaseous detector such as µ-RWELL or sRPC. Neutron and Boron interaction generates ^{7}Li and α ions, which are easily detected thanks to the ionization signal released in the gas. The µ-RWELL [1] is a resistive MPGD: compact, spark protected, and with a single amplification stage, the µ-RWELL_PCB, made by a multi-layer board: a high-density hole 50 µm polyimide foil with a 5 µm copper on the top, a thin Diamond-Like-Carbon (DLC) layer, and the readout. The gas volume between the cathode and the µ-RWELL_PCB is ionized when charged particles pass through and the primary electrons are collected on the amplification stage where the readout takes place. The sRPC [2] is a recent resistive plate counter based on surface resistivity electrodes: a thin DLC layer is used to suppress the sparks and it grants the detector operability. This novel detector changes completely the RPC manufacturing approach from bulk resistivity to surface resistivity. The detector is composed of two glass substrates and a 50 µm polyimide foil with a DLC layer on each side. The gap between the two DLC electrodes is 2 mm: here ionization and amplification occur simultaneously through an intense electric field.

2 Experimental measurements and simulation

The experimental measurements are performed at the HOTNES facility [3]: a calibrated thermal neutron source, relying on a moderated ^{241}Am-B source, placed in a cylindrical cavity delimited by polyethylene walls. The signal generated on the readout is measured with two different techniques: the current mode and the counting mode. The former monitors the current flowing to the resistive layer that is proportional to the electrons released in the gas and the detector gain. This technique is used for µ-RWELL only. The latter amplifies and discriminates the signal collected on the readout by means of custom electronics boards based on CREMAT CR-110. This technique allows tagging a single neutron conversion. Simulation tools, such as GEANT4 and Garfield++, are used to evaluate the neutron conversion for the different converted designs. The first optimization study is focused on the $^{10}B_4C$ thickness sputtered on the electrodes: planar cathodes with a thickness ranging from 1.5 µm to 4.5 µm are evaluated by means simulation then produced at ESS Detector Coatings Workshop in Linköping and tested together with the µ-RWELL_PCB with direct measurements at HOTNES. The complete scan of the $^{10}B_4C$ thickness shows that larger amounts of Boron can enhance the conversion efficiency, but if the thickness exceeds a certain value, the reaction products, α and ^{7}Li ions, cannot enter the gas volume, thus decreasing the detection efficiency. Furthermore, the detection efficiency is also dependent on the angle at which the neutron hits the $^{10}B_4C$ surface. As the angle shifts from perpendicular to almost parallel, the neutron path through the Boron layer becomes longer, resulting in an increase in conversion efficiency. The second phase of R&D increases the Boron converter surface by means of two approaches: the former is a folding structure on the cathode with a slope of 10° and variable width from 0.25 to 1 mm and 2.5 µm $^{10}B_4C$ thickness; the latter is a $^{10}B_4C$ coated metallic mesh inserted in the gas gap between the standard planar ($^{10}B_4C$

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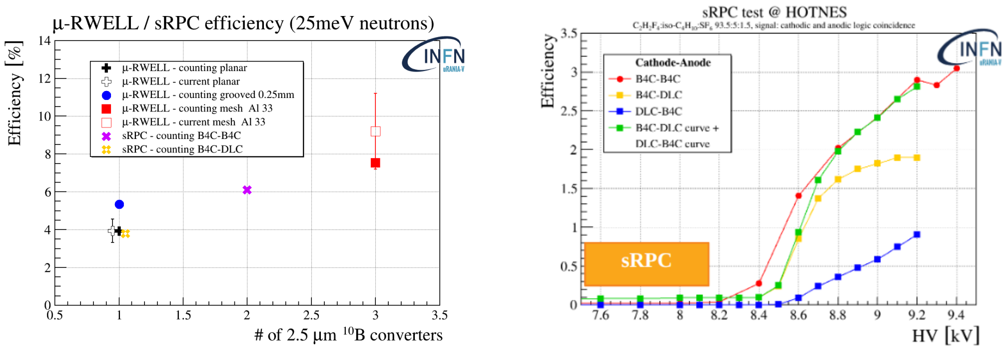

Figure 1. Neutron conversion efficiency is reported, on the left experimental data of three configurations (planar, mesh and groove) of µ-RWELL detector and two configurations of sRPC; on the right the detail of the HV scan with sRPC.

coated) cathode and the µ-RWELL_PCB. Both techniques increase the neutron conversion efficiency as reported in figure 1 left. The third phase of R&D is focused to keep good neutron detection with a low cost-effective impact and a simple manufacturing technique with a new detector: an sRPC with $^{10}B_4C$ coated sputtering on the cathode or on the anode or both electrodes. An HV scan reported in figure 1 right shows a comparison of the detection efficiency of the three detectors with results consistent between each other and with the simulations. The efficiency achieved with this technology is very promising thanks to the goodness of the results, the ease of manufacturing, and the production cost. The neutron capture cross-section depends on the neutron energy. As shown by GEANT4 simulations, with respect to the HOTNES spectrum, the detection efficiency for the thermal neutron (25 meV) increases by a factor of two, thus corresponding to a thermal neutron efficiency ranging from 5 to 10 %.

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