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A four-dimensional timing RPC neutron detector concept

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A detection technology for thermal neutrons combining hybrid double gap timing resistive plates chambers lined with a 10B enriched solid neutron converter (10B-RPCs) is being developed at LIP-Coimbra [1]. Our previous studies performed on neutron beamlines at ILL (Institut Laue-Langevin) and FRMII (Research Neutron Source Heinz Maier-Leibnitz) have already demonstrated the feasibility of 10B-RPC based neutron detectors, capable of a detection efficiency to thermal neutrons above 50% and a spatial resolution in 2D better than 250 µm FWHM [2]. In this work we present a concept of a detector with four-dimensional readout capability (XYZ and time), called nRPC-4D, based on the 10B-RPCs. Application for this type of detector is foreseen in ToF (time-of-flight) neutron diffraction/ reflectometry, energy- and time-resolved neutron imaging, as well as in other applications requiring simultaneous readout of neutron event position and time.
The basic design of a nRPC-4D detector consists of several timing 10B-RPCs, stacked on top of each other. Such a multilayer configuration is required to surpass low detection efficiency of a single layer of the 10B4C neutron converter, oriented normally to the neutron incidence direction [1]. The optimal number of 10B-RPC detection units depends on the range of neutron wavelengths and the specific requirements of a particular application. From a simulation-based optimization of a nRPC-4D detector with ten 10B-RPCs units we compute a detection efficiency of ˜ 60% for a neutron pencil beam (4.7 Å) with normal incidence at the center of the detector [3]. The timing 10B-RPCs are designed to act as standalone and versatile detection units, making a nRPC-4D detector straightforward to build and maintain, and adapt to different applications with specific sets of requirements. A 10B-RPC unit has a double gap configuration and is formed by two resistive anode plates made from 0.3 mm thick float glass, and a 0.3 mm thick aluminium cathode plate between them, all parallel to each other and separated by PEEK spacers defining two 0.28 mm wide gas gaps (see Figure 1). The glass plates are lined on the face opposite to the gas gap with a thin layer of resistive ink used to apply uniform potential across the entire anode active area. The aluminum plates, with an area of 190×190 mm2, are coated on both sides with a 0.4 to 2.3 µm thick layer of B4C (10B enrichment level > 97%). The 10B4C coatings were made in the ESS Detector Coatings Workshop. To read both X and Y event coordinates, a thin polyamide (25 µm thick) flexible printed circuit board (FPCB), with one array of parallel signal pick-up strips (1 mm pitch, 0.3 mm wide) on each side and orthogonal to each other, is placed at the top and bottom of the 10B-RPC unit (see Figure 1). To reduce the number of electronic channels, the X strips of each FPCB with the same index are interconnected, and read by the same electronic channel. The same applies to Y strips. The Z coordinate of a neutron event (position of the neutron capture along the stack), and the neutron ToF are defined using the cathode signal of the triggered 10B-RPC unit. Due to the fast (sub-ns) timing properties of RPCs [4] and the short flight time (˜ 1 ns) of thermal neutrons through a 10B4C layer before capture, an nRPC-4D detector should be able to determine the ToF up to sub-microsecond precision.
Here we present the configuration of an nRPC-4D detector and describe its working principles. We also report results of the preliminary tests of the timing 10B-RPC units, performed on the BOA neutron beamline at Paul Scherrer Institut. The experimental results demonstrate the capability of the 10B-RPC units to determine the XYZ position of the neutron events and the ToF. They also show that the correlation between the amplitudes of the signals from the X and Y strips allow to identify the gas gap of the 10B-RPC where an event has occurred (see Figure 2, Left and Center). In Figure 2 (Right) the neutron wavelength spectrum at BOA beamline computed from the ToF values is shown. The results validated the design of the 10B-RPC units for a detector prototype that is currently being built, and prove that the nRPC-4D detector concept is suitable for Time-of-Flight neutron diffraction/reflectometry and energy- and time-resolved neutron imaging.

[1] L.M.S. Margato and A. Morozov 2018 JINST 13 P08007, DOI: 10.1088/1748-0221/13/08/P08007
[2] L.M.S. Margato et al 2020 JINST 15 P06007, DOI: 10.1088/1748-0221/15/06/P06007

[3] L.M.S. Margato, et al., Nucl. Instr. Methods A, 2023, https://doi.org/10.1016/j.nima.2023.168267
[4] A Blanco et al 2012 JINST 7 P11012, DOI: 10.1088/1748-0221/7/11/P11012

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