Work on a large-area MRPC-based time-of-flight detector for high energy neutrons

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Abstract. The NeuLAND detector at the R$^3$B experiment of the future FAIR facility in Darmstadt aims to detect fast neutrons (0.2-1.0 GeV) with high time and spatial resolutions ($\sigma_t < 100$ ps, $\sigma_{x,y,z} < 1$ cm).

Here, development work on a possible NeuLAND solution based on the multigap resistive plate chamber (MRPC) technology is presented. In this hypothesis, the final detector consists of 50 consecutive MRPC stacks. Each stack contains a 4 mm thick anode made of iron converter material, with an additional 4 mm of converter material between two stacks. The secondary charged particles stemming from hadronic interactions of the high energetic neutrons in the converter will be detected in the MRPC's. A number of prototypes have been developed and built. They have been tested with a beam of single electrons, with picosecond time resolution at the superconducting linac ELBE (Dresden, Germany).

The present prototypes show good time resolution and efficiency. However, much better multihit capability is expected for a fully active cube of 2.5 $\times$ 2.5 $\times$ 3 m scintillator material, so this is the solution adopted for the NeuLAND detector in the meantime.

The New Large Area Neutron Detector (NeuLAND) is the successor of the Large Area Neutron Detector (LAND) at GSI [1]. NeuLAND should have three times better time and spatial resolution and greatly improved multineutron detection capability with respect to LAND. It is part of the future R$^3$B experiment at FAIR [2]. As first part of the R&D activity, the best parameters for the detector had been studied with 40 $\times$ 20 cm large prototypes [4]. Here, some preliminary findings from the development and study of 200 $\times$ 50 cm large prototypes are reported.

The center of the detector consists of 19 stainless steel anode strips (0.4 cm $\times$ 2.5 cm $\times$ 200 cm), which also serve as converters, converting the primary neutron to a secondary charged particle. On either side of the anode there is a standard MRPC glass-gap structure with two gas gaps, in order to detect the secondary charged particle. Semiconductive mylar sheets provide high voltage and ground to the glass. Further out on each side in the signal cathode made by copper strips for both side. The covers of the box are made from 2 mm stainless steel for conversion. For mechanical reasons, two such structures are built in one frame with a common gas volume. There is a the 2.5 mm gas gap between signal cathode and converter plate box that is needed to increase cathode impedance. Rubber lines kept the gas gap at its nominal thickness (figure 1).

For testing the response of the prototypes when irradiated with minimum ionizing particles, the electron beam of the 40 MeV Electron Linac with high Brilliance and low Emittance (ELBE)
facility\textsuperscript{1} at Helmholtz-Zentrum Dresden-Rossendorf, Dresden/Germany, has been used. The tests were performed with a low-intensity electron beam of 31 MeV kinetic energy, right above the energy for the minimum of ionization. As a time reference, the radio frequency (RF) signal of the electron source was used. A new mode of operation of the ELBE accelerator was used, called one electron mode. In this mode, the gate voltage of the electron gun is reduced much below usual operating in which most accelerated bunches are empty and the rest has only one electron per bunch \cite{3}. Two scintillators were used for trigger in coincidence with the RF signal. The flux of single electrons was 5-20 Hz/cm$^2$ for the present measurements, much higher than can be obtained with cosmic rays.

Hereafter, efficiency, resolution and cross-talks are defined as in Ref. \cite{4}. The number of gaps was chosen to be 2x2, because small prototype developments showed that this is enough to reach 90\% efficiency, while still avoiding the spark regime. The strip impedance is about 13 $\Omega$, defined by the geometry of detector and the limitation on the adopted strip width of 25 mm. In order to reach 50 $\Omega$ impedance, the strips should have a width of just 3-4 mm, which is unrealistic as it would require too many electronics channels. Because of this impedance mismatch there is an unavoidable reflection at 2 times the distance from the place of interaction to the far end of the strip, i.e. $2 + 1$ m for the case when the beam is in the center and $2 \times 7.5$ cm for the case when the beam is on the left side. On the figure 2 there are 2D plots (time over charge) for both cases. The amplitude difference for signal between the left (plot a and c) and right side (plot b and d) is just a difference in electronic amplification of that particular channel, it has no physical meaning. In principle, the system of strips is a complicate transmission lines system, and it shows the same behavior, i.e. the degradation of the signal with passed distance (plot c and d).

Due to the large width of 50 cm and the relatively thin housing of just 2 mm steel, the box bulged outward by 1.5 cm in the center. This can be a problem for mechanical stability of inner structure. Therefore, the gas volume was connected to a pump generating about 100 Pa

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Figure 1. Top: schematic view of one prototype. Bottom: side view of a full experimental module, which contains two detector units.
of underpressure inside the chamber, compensating the deformation.

The first beam-tests of full size prototypes (200 × 50 cm) show promising results for efficiency (>90%) and time resolution (σ < 100 ps) for the whole area of the detector. In 2012, a test with neutrons from the breakup of the deuteron at GSI (Darmstadt, Germany) will be done including mainly scintillator-based NeuLAND solutions, but for comparison also this prototype.

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