Detection of Fast Neutrons for R^{3}B at FAIR*

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The R^{3}B project at the FAIR facility at GSI aims for investigations of unstable nuclei by means of reactions with high-energy radioactive beams in inverse kinematics [1]. The physics program of this project includes studies of reactions involving the emission of neutrons with projectile-like velocities. In order to perform kinematically complete measurements, a high energy neutron detector is required. For this purpose, the high resolution neutron time-of-flight spectrometer NeuLAND is being developed.

The desired neutron momentum resolution of NeuLAND is $\Delta p/p = 10^{-3}$, which is similar to that for the measurement of charged particles. Since the neutron flight path will range from 10 to 35 m, this momentum resolution can be reached at a time-of-flight resolution of $\sigma_t < 100$ ps and a position resolution of $\sigma_{x,y,z} \simeq 1$ cm. For measurements involving the maximum flight length of 35 m, an invariant-mass resolution of about $\Delta E = 30$ keV at 1 MeV above the neutron threshold can be achieved for medium-mass nuclei at beam energies of about 500 MeV per nucleon. The design parameters also ask for a neutron detection efficiency of more than 90%.

The existing neutron detector LAND [2] uses organic scintillator as detection medium and iron as passive converter. With this configuration, a time resolution of about $\sigma_t \leq 250$ ps and a position resolution of $\sigma_{x,y,z} \simeq 3$ cm is observed. For NeuLAND, the feasibility of using multigap Resistive Plate Chambers (RPC) is being investigated, since they offer time resolutions down to 50 ps for minimum ionizing particles. Neutrons that interact with the iron converter will produce hadronic showers, dominated by protons at various energies. Since up to now, the response of RPCs to non-minimum ionizing particles is not well known, a test experiment with proton beams has been carried out at KVI in Groningen (Netherlands).

Two different RPC types have been investigated during this experiment with proton beams at 190 MeV, 120 MeV, and at several energies between 80 and 30 MeV. The first RPC, built by the FOPI collaboration [3], was a 90 $\times$ 4.6 cm^2, 2 $\times$ 4 gap RPC (220 μm gaps), with a 16-strip anode. The second RPC was a shielded 2 $\times$ 2 gap RPC [4], a technology also foreseen for the HADES RPC TOF wall, provided by LIP-Coimbra and composed of five 60 $\times$ 2 cm^2 structureless electrodes that define 300 μm gaps. The standard RPC gas mixture was used for both RPCs with a total gas flow of approximately 3.6 l/h. Typical high voltage values were -9.5 kV for the FOPI RPC and +6.25 kV for the LIP-Coimbra RPC. A 5 mm round collimator was placed in front of the setup, and the beam rate was kept at 100-200 counts per second. Futhermore, two plastic-scintillator counters were used for the trigger logic and time reference.

Figure 1 shows the time spectrum of strip 4 of the FOPI RPC for 120 MeV protons and an operating voltage of -9.5 kV. A time resolution of $\sigma_t \simeq 45$ ps was observed. The time resolution stays at reasonable values ($\sigma_t \simeq 60$ ps) down to the lowest possible energy for the given setup ($E_{prot} \simeq 30$ MeV). In case of the FOPI RPC efficiency, we could determine a lower limit of 90% for all proton energies used.

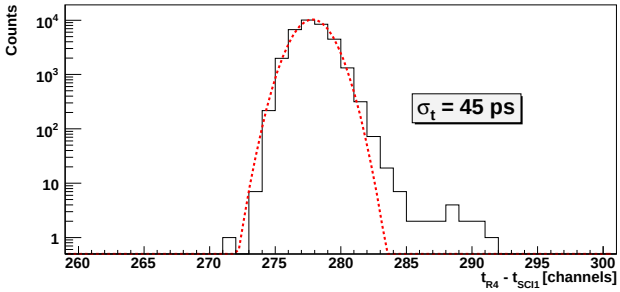

Figure 1: Time resolution of a FOPI RPC strip with 120 MeV protons. TDC conversion factor $\simeq$ 40 ps/channel.

Although the electronic readout was optimized for the FOPI RPC, the measurement with the LIP-Coimbra RPC yielded time resolutions of $\sigma_t \simeq$ 80-100 ps and efficiencies of nearly 100%.

These results demonstrate the feasibility of the neutron detection concept using converter plus RPCs for charged-particle detection. A dedicated prototype adapted to the NeuLAND concept and geometry will be developed and tested in the near future.

References

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