Tests of timing silicon photomultipliers for NeuLAND*

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It is investigated whether NeuLAND may be re-instrumented with semiconductor based photosensors. Tests with an 11 cm long slab of RP-408 plastic scintillator and a PiLas 45 ps laser diode system show time resolutions of σ = 100 ps.

The NeuLAND time-of flight detector for 1 GeV neutrons will consist in its final configuration of 30 double planes of 100 scintillator bars (RP-408) each. Each bar of $270\times5\times5\,\text{cm}^3$ must be read out at each end. Thus altogether 6000 timing photomultipliers of 1” diameter are needed [1]. In order to limit their cost impact, it is being investigated whether parts of NeuLAND may be (re-)instrumented with semiconductor-based photosensors, so-called Silicon Photomultipliers (SiPMs).

Previous experiments using the one-electron-per-bunch mode of the superconducting electron accelerator ELBE have shown that nearly full efficiency can be reached even when instrumenting one NeuLAND bar with just one $3\times3\,\text{mm}^2$ SiPM [2]. However, in those first tests the charge resolution did not allow to separate single photons, and the time resolution did not fulfill the required $\sigma \leq 150$ ps.

Electronics and preamplifier

Subsequently some improvements were made in the electronics circuits. For the timing, both a digital constant-fraction algorithm based on the recorded waveforms in a 12-bit 1 GHz, 2.5 GS/s digital oscilloscope and a constant fraction discriminator developed in house with a threshold of just 7 mV were tested and found to give satisfactory results.

* Supported by NupNET NEDENSAA (BMBF 05 P 09 CRFN5), GSI F&E DR-ZUBE, and by the Helmholtz Association Detector Technology and Systems Platform (DTSP).
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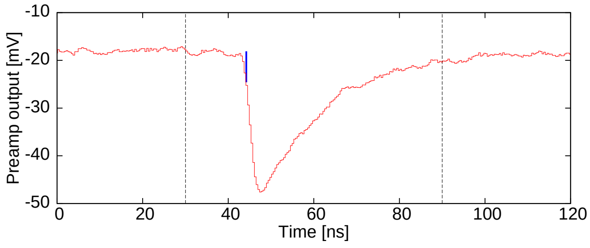

Figure 1: Waveform for a signal generated by a 421 nm 45 ps PiLas laser diode in a $3\times3\,\text{mm}^2$ Hamamatsu MPPC. The 60 ns wide integration window for the QDC is shown.

Due to the scarcity of commercial preamplifiers for SiPMs, a new preamplifier was developed in-house. It is based on a common-emitter circuit with a discrete complementary Darlington transistor with a bandwidth of 2 GHz and an input impedance of 25 Ω. There is no overshoot of the amplified signal as in some other SiPM preamplifiers, enabling to integrate the current pulses with a QDC. The gain of the output signals is 15-25, controlled by varying the supply voltage from 5-12 V. The rise time of the output signals is about 650 ps (fig. 1).

Preliminary results and outlook

The preliminary spectra shown a clean separation between single photons on the charge axis and have a slight time walk (fig. 2). The typical resolution is now σ = 100 ps for the time difference between the detected signal and the PiLas laser reference signal when using the in-house developed electronics and even 60-80 ps when adding a PS 775 fast amplifier. Future tests will show whether the satisfactory timing capability will also be maintained when exciting the scintillator with minimum ionizing electrons from ELBE.

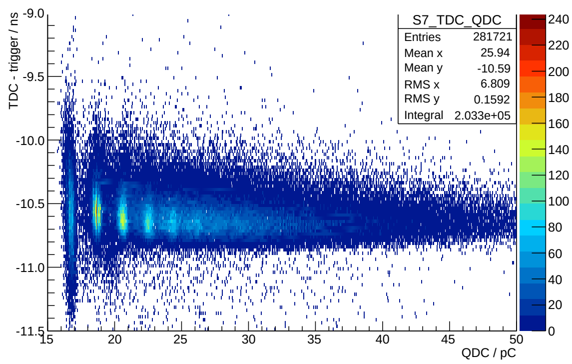

Figure 2: Time versus charge for the PiLas illuminating the RP-408, which is, in turn, read out by the MPPC. The pedestal (17 pC) and peaks for 1-4 photons can be seen.

References

[1] NeuLAND@R3B: A Fully-Active Detector for Time-of-Flight and Calorimetry of Fast Neutrons, NeuLAND Technical Design Report, http://www.fair-center.de/fileadmin/fair/experiments/NUSTAR/Pdf/TDRs/NeuLAND-TDR-Web.pdf

[2] T. Reinhardt *et al.*, GSI Scientific Report 2012, SR2012-PHN-ENNA-EXP-62

 doi:10.15120/GR-2014-1-NUSTAR-KR-11