

NeuLAND - from double-planes to the demonstrator *

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NeuLAND [1] is one key building block of the R³B experiment which will be commissioned and will perform first physics runs in Cave C at GSI prior to moving to its final destination in the NUSTAR high-energy cave at FAIR. During 2014, the NeuLAND (new Large-Area Neutron Detector) demonstrator has been assembled and tested with fast neutrons from high-energy Coulomb break-up, fragmentation and fission reactions using various isotopes. The demonstrator comprises five so-called double-planes and thus 1/6 of the total NeuLAND detector. Here, we report on the assembly and testing stages of the demonstrator, beam test experiments, and the overall status of the NeuLAND project.

Three GSI test beam times gave the opportunity to investigate the response of NeuLAND to fast neutrons. In the following we report on the different configurations during these experiments and present first, preliminary results.

In a beam time aiming to test various R³B components comprising the active target ACTAR [2] and various beam tracking detectors during April 2014, one NeuLAND double-plane (front-face 250×250 cm², 2×5 cm depth) was exposed to fast neutrons originating from (Coulomb) breakup of ⁵⁸Ni at 500 to 800 AMeV. The 200 NeuLAND photomultipliers (PMTs) were read out using the former LAND electronics TacQuila [3], also for the high-voltage (HV) supply commercial modules, inherited from the former neutron detector LAND, were used. The NeuLAND double-plane was located about 10 m downstream from the target, primary beam and fast beam-like projectile fragments were bent away using the ALADIN magnet and

identified by a system of tracking detectors. In order to cope with the large material budget along the beamline, caused by various detectors, tested simultaneously, a very thick Pb target (6 mm) served as a source for neutrons and fast gammas to be detected by NeuLAND. The preliminary results from this test comprise a typical time resolution of $\sigma_t = 100\text{--}150$ ps, derived from prompt γ -rays produced at the target, which is compatible with the design goals for NeuLAND. Due to the downstream fragment beam path being in air and the insertion of multiple tracking detectors, a lot of background caused by high-energy protons was detected in the first layer of the NeuLAND double-plane. These findings allowed to cross-check detailed background simulations for future experiments and stimulated a design study for a veto detector for the full size NeuLAND detector.

During summer, the NeuLAND demonstrator support frame at Cave C was sequentially equipped with additional double-planes, see Figure 1. The assembly comprised four double-planes read-out with TacQuila electronics and one double-layer (technically two single layers were built) read out with a prototype of the designated NeuLAND electronics TAMEX [4]. The demonstrator has an active volume of 250×250×50 cm³ and a weight of more than 4 tons. It comprises 500 individual scintillator bars, 1000 PMTs with their HV supplies and their read-out electronics. The slow control of parameters like thresholds or HV settings was implemented in EPICS and graphical user interfaces (GUIs) were adapted accordingly.

Two GSI beam times were carried out using the NeuLAND demonstrator. At the beginning of October, a beam time with several R³B components was carried out comprising besides NeuLAND also a CALIFA demonstrator, Silicon Tracker ladders and various silicon- and scintillator-based tracking detectors for heavy ions [5].

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Figure 1: The first NeuLAND double-plane in its frame in Cave C (left), NeuLAND double-plane no. 4 on its way to Cave C (middle, photo: G. Otto) and the demonstrator support frame after insertion of the fourth double-plane (right).

Both fragmentation reactions from the ^{48}Ca beam impinging at 450 to 650 AMeV on a carbon target and Coulomb break-up on lead were used to produce fast neutrons for NeuLAND. These data, dominated by one- and two-neutron events are important inputs for the further development of simulation and analysis tools. Figure 2 illustrates a 3D-view of a two-neutron event inside the detector volume.

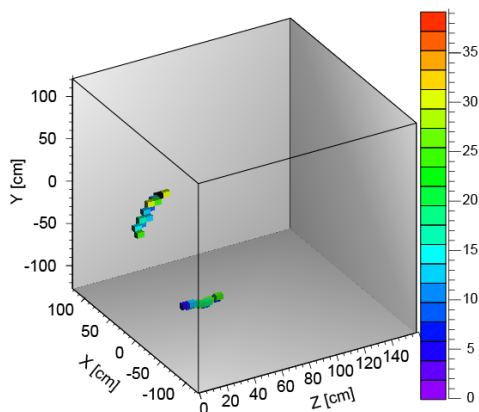


Figure 2: A measured two-neutron event is displayed in the detector volume (depth 40 cm for the TacQuila read-out double-planes). The neutrons impinge at the front face ($Z=0$), a veto condition on the first layer ensures the detection of neutrons and suppresses (background) protons. The colour code represents the energy deposit measured in the corresponding scintillator bars.

Only ten days later the NeuLAND demonstrator joined the SOFIA experiment. Figure 3 displays the hit distributions in the 4 double-planes read out with TacQuila electronics. All 400 submodules were functional and well calibrated. Due to the SOFIA fragment trigger, only a minor amount of background is observed at low x-values,

originating mostly from secondary particles produced by the projectile fragments on their flight path behind the ALADIN magnet. The analysis of the neutron data will focus on the patterns and multiplicities found as a function of the fission fragment masses measured with SOFIA.

After the successful completion of the GSI beam times, four NeuLAND double-planes and their electronics were crated for the transport to RIKEN, Japan. Logistics challenges due to the oversize of the transport box ($401 \times 344 \times 128 \text{ cm}^3$ and 5.75 tons) were overcome and the detector arrived safely at RIKEN in January 2015. The NeuLAND double-planes have been installed and taken into operation at the SAMURAI setup [6] and will be used in beam times in conjunction with the NEBULA detector [7].

As a next step towards the final detector, the pre-series for the future NeuLAND HV distribution system, an in-kind contribution from PNPI Gatchina, has arrived at GSI and is currently being taken into operation. The pre-series comprises 200 channels in four slim modules with a form-factor allowing the on-board assembly on the NeuLAND double-planes. Within this distribution system, supplied by one HV primary power, each HV channel can be downregulated individually.

The ongoing, stepwise construction and commissioning of the detector is carried out by a collaborative consortium of the University groups of Darmstadt, Frankfurt, Köln, and the GSI RB team. The major part of the construction cost is funded via the BMBF Verbundforschung.

References

- [1] NeuLAND webpage, https://www.gsi.de/de/work/fairgsi/rare_isotope_beams/r3b/neuland.htm
- [2] G. Alkharov et al., Test of an R^3B Active Target prototype with a beam of ^{58}Ni , contribution to this annual report
- [3] K. Koch et al., A New TAC-Based Multichannel Front-End

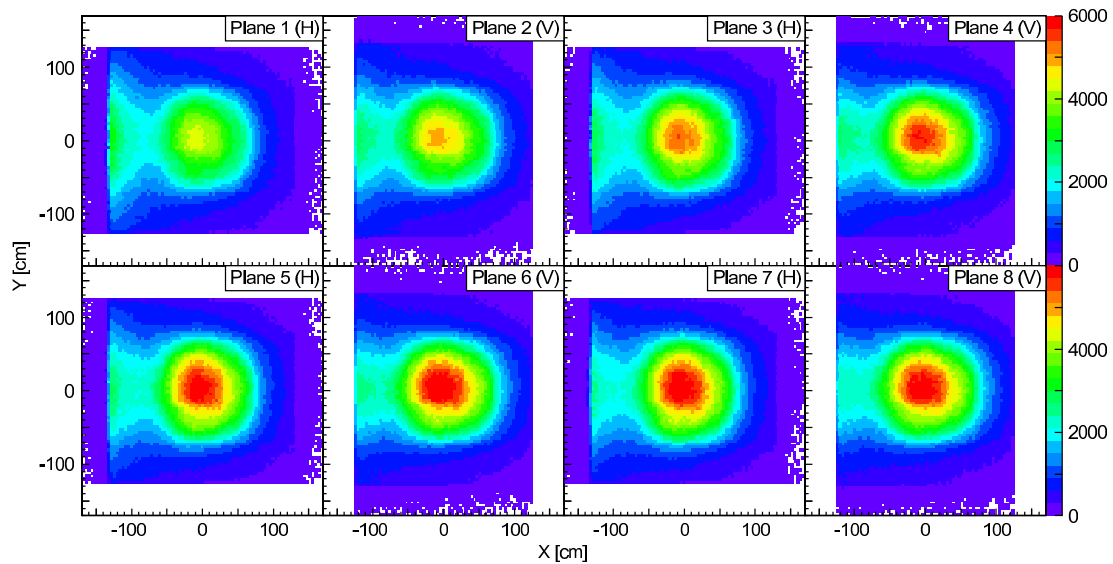


Figure 3: Spatial hit distributions, perpendicular to the beam axis measured in 4 double-planes (8 alternating horizontal and vertical single layers) of the NeuLAND demonstrator, starting with the first horizontal layer in the upper left corner up to the fourth vertical layer in the lower right corner. These spectra were obtained for reactions of ^{238}U beam on a lead target at 700 AMeV.

Electronics for TOF Experiments With Very High Time Resolution, *IEEE Trans. Nucl. Sci.* **52**, 745 (2005)

- [4] C. Ugur et al., A Compact Readout System for the R³B High-Resolution Neutron Time-of-Flight Spectrometer (NeuLAND), contribution to this annual report
- [5] M. Heil et al., In-beam test of a new TOF wall for the R³B setup, contribution to this annual report
- [6] T. Kobayashi et al., SAMURAI spectrometer for RI beam experiments, *NIMB* **317**, 294 (2013)
- [7] Y. Kondo et al., Calibration methods of the neutron detector array NEBULA, *RIKEN Accel. Prog. Rep.* **45**, 131 (2012)