# RESEARCH AND DEVELOPMENT OF DIAMOND BASED BEAM MONITORING AND DIAGNOSTICS SYSTEMS AT THE S-DALINAC*

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*Abstract*

In this contribution a field-programmable gate array (FPGA) based read-out concept for diamond based beam monitoring detectors will be introduced. Furthermore for research and development of diamond based detectors a test setup will be installed at the Superconducting Darmstadt Electron Linear Accelerator (S-DALINAC) of TU Darmstadt. The preparatory work, with particular focus on beam transport simulations will be shown.

## INTRODUCTION

For future experiments with the HADES [1] and CBM [2] detectors at the FAIR facility in Darmstadt, a radiation hard and fast beam detector is required. On one hand the detector should handle high current beams. Especially the CBM experiment plans to operate at up to $10^9$ ions/s. On the other hand the detector has to perform precise T0 measurements ($\sigma_{T0} < 50$ ps) and should offer beam monitoring capabilities. These tasks can be fulfilled by utilizing single-crystal Chemical Vapor Deposition (scCVD) diamond based detectors. This material is well known for its radiation hardness and high drift velocity of both electrons and holes, making it ideal not only as Time-of-Flight (ToF) detectors placed in the beam but also as luminosity monitors. Challenging is the detection of minimum-ionizing particles (MIPS) traversing the diamond detector. The very small induced charges and expected high rates require special emphasis to the read-out electronics. The recently developed technology of producing mono-crystalline diamond material, which is almost free of structural defects and chemical impurities and thus provides very high charge collection efficiency, allows for building detectors for MIP based on single-crystalline diamond material. With the help of stripped read-out electrodes or by arranging several diamond detectors in a mosaic, a position information can be obtained for beam monitoring purposes. An example of such a diamond based mosaic detector is shown in Fig. 1.

## TRB3 BASED BEAM MONITORING SYSTEM

A read-out concept for diamond based beam monitoring and diagnostic detectors is currently under development. It will be based on the already well established TRB3 (Trigger and readout board - version 3) platform [3, 4], developed at

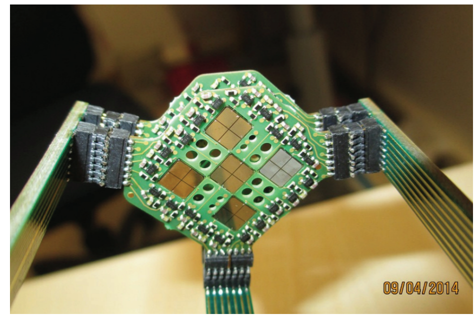


Figure 1: Diamond based mosaic detector which was located in front of the HADES target in a pion production beam time. An total area of 14 mm × 14 mm was covered. The first transistor based pre-amplification stage is located very close to the diamond material.

GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt. The board provides 260 high precision (RMS < 12 ps) multi-hit FPGA-TDCs and serves as a flexible data acquisition system (DAQ). The available comprehensive software package allows on-line monitoring capabilities including basic analysis. A large variety of front-end electronics is available in order to extend its functionality. One of those front-end boards is the PADIWA discriminator board. It is designed to discriminate 16 detector signals. Due to its flexible analog input stage, it is possible to adapt it to a wide range of detector signal specifications i.e. different Photomultiplier (PMT) types. A photography of the PADIWA board and the simplified read-out scheme is shown in Fig. 2. The input signals are amplified and afterward discriminated by misusing the low-voltage differential signaling (LVDS) input buffers of an FPGA. Thresholds can be set via pulse width modulation in combination with a low pass filter. The arrival time and the time-over-threshold (ToT) is encoded in the leading edge and the width of a digital pulse. The digital pulse is afterwards sent via differential lines to the TRB3 for time measurements.

The read-out concept was already successfully adapted in order to read out the Hodoscope detector in the HADES experiment, which is located at GSI Helmholtzzentrum für Schwerionenforschung (Darmstadt). The Hodoscope was placed behind the HADES spectrometer and was mainly used for beam-monitoring purposes during the beam-tuning. It consists of 16 stacked plastic scintillator rods with sizes of 10 mm × 5 mm × 100 mm. The scintillation light produced in the rods is read out from both sides by Hamamamtsu R3478 PMTs. The PADIWA-AMPS [5] front-end board (which is similar to the PADIWA board, with ad-

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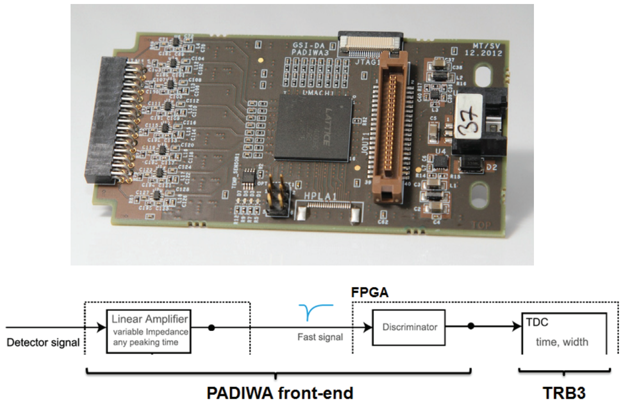
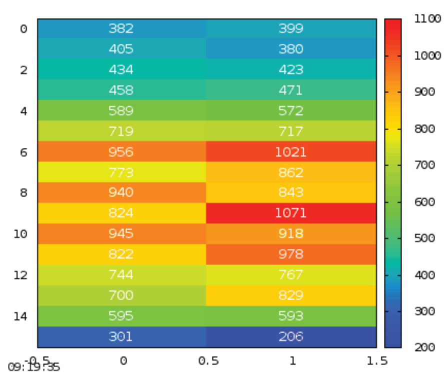
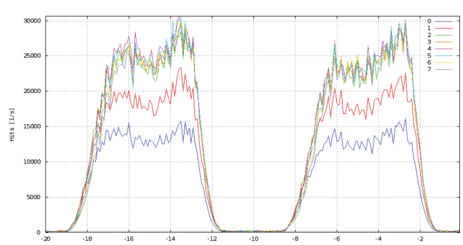



Figure 2: Upper panel: The PADIWA discriminator front-end board for the TRB3 platform. Lower panel: Simplified read-out scheme.




(a) Heat-map showing the hit-rate per second of all Hodoscope PMTs.



(b) Hit-rate of all Hodoscope PMTs over time.

Figure 3: During the beam-time the figures are displayed live in a web-browser. In the lower panel the spill structure of the pion beam is visualized.

ditional charge measurement capability), in combination with a TRB3 was adapted to the PMT signals. In Fig. 3 the on-line monitoring screen of the hit rate and the spill structure during the beam-time as seen by the Hodoscope is shown. Currently the concept is adapted to the signals of diamond based detectors. For that the analog stage has to be redesigned in order to adapt it to the specifications of the pre-amplifier of the diamond detector.

## DIAMOND DETECTOR TEST SETUP AT THE S-DALINAC

The Superconducting Darmstadt Electron Linear Accelerator (S-DALINAC) [6] of TU Darmstadt was currently upgraded with a third recirculation [7] which will allow an acceleration of electrons up to 130 MeV and the possibility to operate it in an energy recovery linac (ERL) mode. It has been shown that the accelerator can provide excellent beam conditions for research and development of diamond based detectors, especially for MIPS. The main aims are the development of new diamond based beam detectors and the investigation of its time and energy resolution. Radiation damage studies in diamond material are in great demand. Moreover it is foreseen to build up a permanent multi-purpose test setup at the S-DALINAC which is suitable for other tracking detectors i.e. drift-chambers or even radiation tests of read-out electronics. The test setup will be located in the E5 beam line in front of the NEPTUN experiment. For that an additional dipole magnet will be installed into the beam line. An additional pair of quadrupoles will be used to focus the electron beam on the detectors under test. Desirable beam parameters for detector tests are currents in the order of several nA and energies up to 130 MeV. The floor-plan is shown in Fig. 4.

### *Beam Transport Simulations*

Beam transport simulations have been performed using the XBEAM [8] software which was developed at TU Darmstadt. The software uses a matrix based code which calculates beam dynamics up to first (linear) order. The lattice from the extraction of the S-DALINAC to the NEPTUN experiment and the diamond detector test setup was simulated. The simulations must fulfill certain conditions. On one hand the beam envelope should fit the beam tube at every point. On the other hand the beam envelope should be minimized at the position of the NEPTUN target and the diamond detector test setup. In Fig. 5 the simulated beam envelope from the S-DALINAC extraction to the diamond detector setup is shown.

## SUMMARY AND OUTLOOK

In this contribution a FPGA based beam monitoring system was introduced. The system was already successfully adapted in order to read out PMT signals of the HADES Hodoscope. Currently the front-end electronic is adapted to diamond detector signals. Furthermore the current status of the preparatory work of a diamond detector test setup at S-DALINAC of TU Darmstadt has been shown. The beam transport simulations, which fix the position of the dipole and quadrupole magnets, are almost finished. The beamline and the diamond detector test set-up are expected to be installed in nearest future. A first commissioning of the beam-line is planned for the second half of 2017.

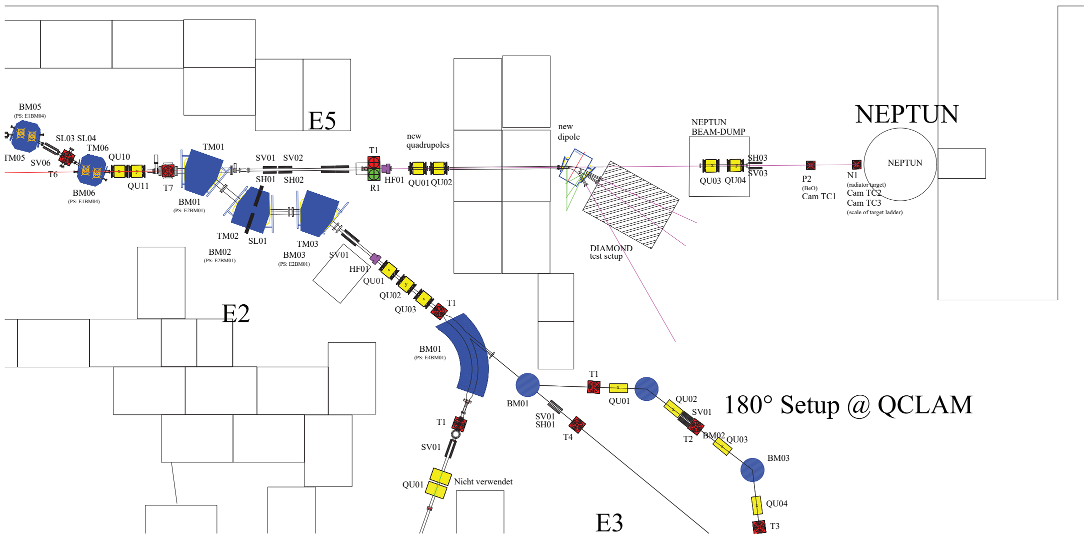



Figure 4: Floor-plan of the E5 beam line of the S-DALINAC. A dipole magnet will be installed and a pair of quadrupoles in order to focus the beam on the diamond detector setup.

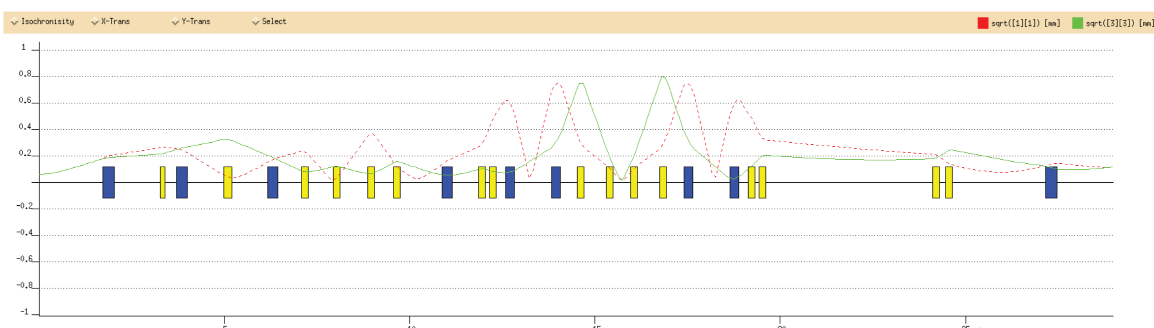


Figure 5: XBEAM simulation of the lattice from S-DALINAC extraction to the diamond detector test set-up. Dipoles are blue and quadrupoles are yellow. The envelope in x- (red) and in y-direction (green) is shown.

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