# Development of a SiPM-based readout-module for the characterization of various scintillator materials

Lukas Nies,* Hans-Georg Zaunick, and Kai-Thomas Brinkmann
*II. Institute of Physics, University of Giessen*

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In this paper we discuss a general approach to use SiPMs in different electrical configurations in combination with numerous scintillator materials for applications in nuclear instrumentation like calorimetry and timing. The "hybrid" configuration proposed by [1] was found to show fastest timing properties with several hundred ps response by combining the advantages of a large active area while avoiding high operation voltages and dark noise. A "parallel" configuration shows the largest light collection efficiency and is therefore suitable for energy measurements. Several calibration spectra were taken to measure the energy deposit of minimal ionizing cosmic muons in a 2cm thick $PbWO_4$ crystal. WORK IN PROGRESS

Modern photodetector applications encounter a large spectrum of different experimental environments. Prerequisites like working within strong magnetic fields, providing large intrinsic amplification, independence on high operation voltage, and space restrictions lead to the development of a new type of detectors, the semiconductor diodes. The *Silicon Photomultiplier* (SiPM) integrates a large number of *avalanche photodiodes* as microcells within a small space. With a large intrinsic amplification of up to $10^6$, the SiPM comes in many different packaging sizes and works mainly with low voltage between 25 V and 85 V. Its insensitivity to magnetic fields and single photon counting capability in combination with suited scintillators make SiPMs a valuable choice for modern challenging applications, i.e. *nuclear magnetic resonance imaging*, *positron emission tomography*, and high energy calorimetry and tracking.

The development of the scintillation tile hodoscope [1], short SciTil, for the *PANDA* detector at the future Facility for Antiproton and Ion Research (*FAIR*) at the GSI Helmholtz Centre for Heavy Ion Research in Germany [2] necessitated the development of a small-scale photo readout system insensitive to the magnetic field of the detector. The Wien group chose SiPMs due to previously mentioned properties. Coupling multiple SiPMs in an array increases the effective active area and, thus, enhances the photon detection efficiency.

In order to develop a general purpose SiPM array we designed in first iteration a principle circuit board (*PCB*) which is able to host either a "parallel" or "hybrid" configuration by just adding or removing some resistors and capacities on the back of the board. The signal is read out via a "bias-T" consisting of a resistor and a capacity which decouple the signal from the DC biasing.

Attached to a plastic scintillator, comparing the raw and normalized signal shapes of a single SiPM with an array of four diodes in either parallel or hybrid configuration shows the fundamental differences of the methods. The signal amplitude for the hybrid configuration is roughly $\frac{1}{\sqrt{N}}$ compared to the amplitude of a single SiPM, where $N$ stands for the number of SiPMs per array. Driving the SiPM in parallel mode does not affect the signal amplitude. With a few nanoseconds the hybrid configuration has a considerably faster rising edge in respect to the parallel configuration where the latter tends to get slower as the number of SiPMs per array increases. Hence, SiPM-arrays in hybrid configuration are more suitable for time measurements whereas the parallel configuration is useful for energy measurements.

In order to yield breakdown and operation voltages, the temperature dependent current-voltage characteristics were studied. For this, the different configurations were wrapped with opaque tape to prevent occurrence of photon induced currents and put in a programmable refrigerator. For different temperatures between $-25°C$ and $25°C$ the SiPM-boards were biased and the IV-curves were measured with a custom made high voltage distribution board designed for operating the avalanche photo diodes of the electromagnetic calorimeter barrel of the PANDA detector [4].

If a photo diode is driven in reversed bias mode the

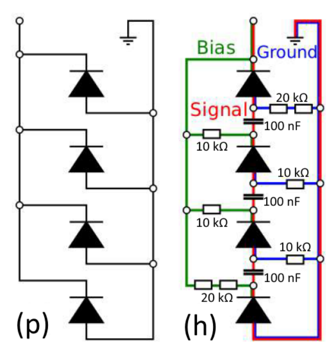


FIG. 1. Schematic of the two different SiPM configurations [3]. On the left is the "parallel" configuration, on the right is the "hybrid" configuration. The signal path is in red depicted, the bias current in green, and the ground in blue.

* Lukas.Nies@physik.uni-giessen.de

depletion layer between the p- and n-junction broadens and the built-in potential intensifies. At the breakdown voltage $U_{BD}$ electrons gain sufficient energy to create a self-sustained avalanche which leads to an exponential increase in current flowing. In order to find the optimal operation voltage $U_{OP}$ which is usually a few volts beyond breakdown, the minimum of the relative slope $\frac{dI}{dV}\frac{1}{I(V)}$ of the IV-curve was fitted.

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[3] S. Zimmermann (Austrian Academy of Sciences, Stefan Meyer Insitute for Subatomic Physics, 28th of March, 2017).

[4] C. Hahn, *Measurements on the radiation hardness of the high voltage subdistribution prototype of the Electromagnetic Calorimeter for the PANDA Experiment*, Master's thesis, Justus Liebig University (Mai 2017).