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Analytical Approach to Fundamental Properties of SiPMs at Cryogenic Temperatures

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Silicon photomultipliers are important in liquid argon detectors of short-baseline neutrino oscillation experiments. Furthermore, in spin-polarized proton and deuteron targets of photoproduction experiments, SiPMs are used for recoil identification down to absolute zero temperature.
For these and future applications a characterization over the full cryogenic temperature range is obligatory.

Based on physical principals, an analytical description of the temperature dependence of breakdown voltage and single-cell capacity was developed. It enables constant gain control from room down to liquid helium temperature.

To calculate the number of ionizations in the depletion layer and thereby the avalanche triggering probability, Wolff's theory for high electrical fields was adopted. This approach lead to predictions of the photon detection efficiency and the crosstalk probability.

Finally, the single-cell signal-to-noise ratio was investigated to find the optimum operational temperature. All these calculations were supported by analyzes of pulse height spectra and forward as well as reverse characteristic curve measurements.

Primary author: Mr BIROTH, Maik (Mainz University)

Co-authors: Dr THOMAS, Andreas (Institut für Kernphysik, Mainz); Prof. ACHENBACH, Patrick (Johannes Gutenberg-Universität Mainz(UMz)); Dr LAUTH, Werner (Institut für Kernphysik, Mainz)

Presenter: Mr BIROTH, Maik (Mainz University)

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