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Advancing Space Telescope Capabilities: SiPM-based UV-Light Detection for Ultra High Energy Cosmic Rays

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The SiSMUV project aims to develop a compact modular UV detector based on SiPMs for use in space telescopes, targeting the study of fluorescence and Cherenkov signals produced by Ultra-High Energy Cosmic Rays (UHECRs). SiSMUV has the objective of incorporating into a monolithic block, state-of-the-art sensors and low-power read-out electronics, creating a complete end-to-end system, which can be easily interfaced with a PC for standalone operation or back-end electronics in the case of a more complex system. The Monolithic Photo-detection Block is defined as the combination of a matrix of SiPM, signal-processing front-end electronics, and a local intelligence.

Summary (500 words)

Space telescopes can detect Ultra High Energy Cosmic Rays by electronically recording the signals generated by Extensive Air showers (EAS) in the night side of the Earth's atmosphere. Astroparticle and High Energy Astrophysics space missions measuring light emission from EAS require the detection of very low photon fluxes. Characteristics of the latest SiPM are potentially optimal for this purpose. Their high intrinsic gain, low power consumption, low weight, and robustness against accidental exposure to light are significant for spaceborne multipixel imaging cameras, even though, some technological issues still need to be addressed. One key specification is achieving high Photon Detection Efficiency (PDE) in the UV range to accurately capture faint signals from UHECR showers. Recent advancements in SiPM technology have led to a significant increase in PDE, rivalling high-quantum efficiency PMTs. The requirements for a SiPM-based focal surface for UHECR detection include space qualification of SiPM arrays and the development of compact arrays compatible with low dead-area focal surfaces. Additionally, further development and space flight qualification of front-end ASICs to interface with the SiPMs are necessary.
SiSMUV's objectives include designing, constructing, and testing a compact modular UV detector integrated with low-power read-out electronics suitable for space applications. The ideal sensor and readout coupling consist of an array of SiPM paired with an ASIC, which acts as the multi-channel readout electronics, and an FPGA-based board to control a few such modules together and to implement trigger algorithm and data acquisition and processing in real-time. Challenges such as mechanical stress during launch, low power consumption, and operation in harsh environments are addressed through iterative design simulations and testing in thermal-vacuum chambers.
Integrating SiPM, FE Electronics and FPGA in a detector unit significantly reduces power consumption and mass, which is crucial for any space mission. Following testing of various components, the first prototype of the detector unit has been developed based on a 64-pixel MPCC from Hamamatsu, coupled with the Radioroc ASIC by Weeroc and a Xilinx Artix FPGA. The prototype has been designed to minimize crosstalk and signal loss to reduce background noise and improve energy resolution.
The use of Radioroc ASIC allows for channel-by-channel adjustment of SiPM high-voltage, enabling fine SiPM gain adjustment to correct for channel gain non-uniformity. Additionally, this ASIC can trigger at levels as low as 1/3 photoelectron, offering dual-gain energy measurement capabilities, and maintains 1% linearity in energy measurement up to 2000 p.e. Employing an FPGA to manage signal acquisition and processing allows

for the implementation of more complex trigger algorithms to reduce the impact of crosstalk on the acquired data, potentially utilizing machine-learning analysis tools.
In this contribution, we will show the functional characterization of the first prototype of the detector unit performance performed with an integrating sphere coupled with an LED, and the study of the dynamic in dark conditions (signal shape, gain, crosstalk, afterpulses) to measure PDE and timing performance.
The project showcases innovative advancements in SiPM technology and integrated read-out electronics, with potential applications in various scientific fields beyond astrophysics.

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