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Quality control of the readout electronics for the ADAPT Hodoscope

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Abstract. The "Advanced Particle–astrophysics Telescope" (APT) is a mission concept for a future space-based MeV-TeV observatory, that will combine a Compton and e^+e^- pair telescope. A small-scale prototype, the "Antartic Demonstrator for APT" (ADAPT), is currently being developed to fly on balloon in Antarctica during the local 2025-2026 flight season. Among its subdetectors there is a hodoscope that consists of four layers of interleaved scintillating fibers coupled to Silicon Photomultipliers (SiPMs). A multichannel electronics is essential for this kind of device: specifically the SMART (SiPM Multichannel ASIC for high Resolution Cherenkov Telescopes) ASIC, characterized by compactness, low cost, good level of integration of the electronics, will be employed for the amplification of signals coming from the SiPMs.

1 The Advanced Particle Telescope (APT) and the Antarctic demonstrator for APT

The Advanced Particle–astrophysics Telescope (APT) is a planned space-based observatory ($3\,\mathrm{m} \times 3\,\mathrm{m} \times 2.5\,\mathrm{m}$) designed for gamma–ray and cosmic–ray (CR) physics that will orbit around the second Sun–Earth Lagrangian point (L2). Thanks to its multiple layer tracker and imaging calorimeter, APT will be able to observe gamma rays at energies ranging from hundreds of keV up to a few TeV. [1]

The Antarctic Demonstrator for APT (ADAPT) is a prototype high-altitude balloon mission, scheduled to fly during the 2025-2026 summer window in Antarctica. It features only 1% of the total amount of material that will be used for APT. It will serve as a proof of concept for prompt Compton reconstruction and localization and will provide real-time positional alerts for gamma-ray bursts. The ADAPT detector stackup will consist of [2]:

- *SSDs*: Silicon Strip Detectors (SSDs) for CRs' charge identification located on top of the detector; they will provide a higher resolution charge measurement and will enhance Compton reconstruction for low-energy events;
- *ICCs*: Imaging CsI Calorimeter modules; 4 layers, each one consisting of 3×3 tiles of 15 cm × 15 cm × 15 mm of CsI(Na) crystals, with crossed 2×2 mm^2 WLS fibers with a SiPM readout to measure the position of the interaction and SiPM-based CsI edge detectors to measure the energy release;

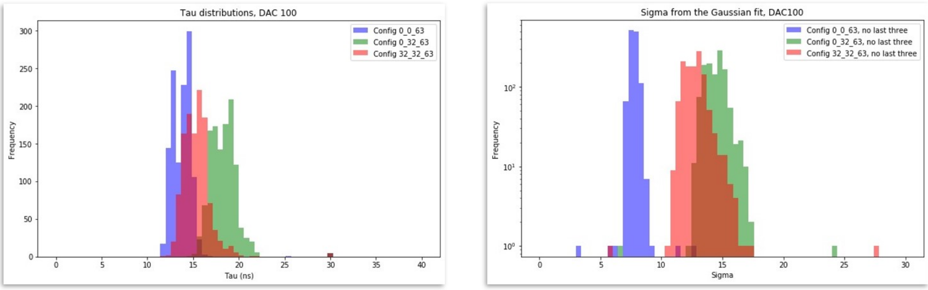

Figure 1. Left: recovery time from the exponential fit for the three different considered configurations at V_{DAC} 100; right: sigma from the fit for the three different considered configurations at V_{DAC} 100.

- *Hodoscope*: 4 layers of X-Y crossed scintillating fiber tracker modules, with interleaved 1.5 mm scintillating fibers and a SiPM readout;
- *Tail Counters*: 4 layers of CsI modules equipped with only edge detector readouts for energy measurements.

2 ADAPT readout electronics for Hodoscope and ICC

The SiPM readout for the Hodoscope and ICC will feature a high number of channels, hence a multichannel ASIC approach is essential to provide a compact and low power electronics. In particular, the readout electronics will consist of Hamamatsu SiPMs coupled to WLS or scintillating fibers, multiplexing boards to sum up 3 SiPMs and reduce the number of readout channels, a pre-amplification stage based on the 16-channel SMART ASIC [4] and a waveform digitizer for the SiPM signals.

2.0.1 Hodoscope SMART board

A custom electronics board was designed to serve as pre-amplification stage for SiPMs on the Hodoscope. These boards host 3 SMART ASICs, for a total of 48 readout channels. A total of 32 boards are necessary to readout the full ADAPT instrument.

The SMART ASIC has customizable parameters that allow adjustment of the preamplifier Gain (R), Bandwidth (C) and Pole ZERO compensation (PZ); moreover, the SiPM bias level can be adjusted for each channel (V_{DAC}).

After a prototyping phase, a total of 40 Hodo SMART boards were produced and tested for the full ADAPT instrument. Quality control tests were performed coupling the SMART inputs to Hamamatsu SiPMs S13360-2050VE 2×2 mm^2 operated at 57 V and illuminated with a pulsed LED. Different SMART configurations and bias DAC were tested.

We analyzed the outgoing signals from the board: for each channel, we calculated the mean waveform and performed both gaussian and exponential fits to measure the full width half maximum (FWHM) and recovery time of the pulses. Three different configurations of the parameters R, C and PZ were tested. Plots in Fig.1 show the distribution of the measured FWHM and recovery time for all channels.

As previously said, increasing the SMART VDAC value reduces the SiPM bias voltage, thus reducing the gain and signal amplitude. Therefore, we varied the V_{DAC} value for all channels, keeping the configuration at $R = 0$, $C = 32$ and $PZ = 63$. For each channel we plotted the amplitude vs the V_{DAC} and then performed a linear fit, as shown in Fig.2. The mean obtained value was -0.95 and the standard deviation 0.41.

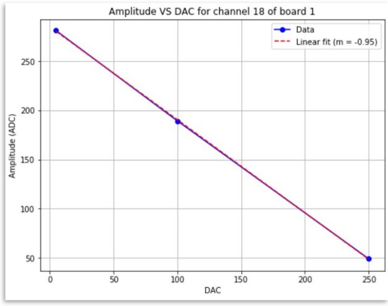

Figure 2. Amplitude vs V_{DAC} with linear fit

3 Summary and future perspectives

We produced and tested 40 SMART Hodo boards to equip the Hodoscope of the ADAPT instrument. The quality control tests showed that all parameters of the SMART ASICs could be properly tuned. Furthermore, the performed analysis showed that the ASIC perfomance was in agreement with expectations and suitable for the usage in the ADAPT instrument.

Acknowledgments

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