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32-channels mixed-signal processor for the tracking system of the GAPS dark matter experiment

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This work aims to describe the experimental performance of a module consisting of four Lithium-drifted Silicon (Si(Li)) detectors and their readout electronics, which is the main component of a tracker in an upcoming balloon experiment. The activity is carried out within the GAPS (General AntiParticle Spectrometer) collaboration, whose scientific objective is the indirect detection of dark matter, through the detection of antiparticles present in low-energy cosmic-rays. The balloon flight is expected from McMurdo station in Antarctica in 2024. The main object of this study is the analysis of the readout electronic performance, with particular focus on the noise.

Summary (500 words)

The GAPS experiment aims to detect indirect signatures of dark matter through the identification of cosmic antimatter particles. The instrument is composed of two structures. One is the silicon tracker, which acts both as a stopping material for the incident particle and as of X-ray spectrometer and charged particle tracker for the interaction products. The other one is the Time-of-Flight system which provides the energy scale and the instrument trigger. The tracker of the first flight is composed by 10 layers of two different types. The upper 7 layers are made by 6x6 modules. Every module consists of four 8-strip Si(Li) detectors, a readout ASIC and a FrontEnd Board (FEB), which electrically connects the detectors with the ASIC and powers them. Each tracker layer is organized in rows: a row is made up of 6 modules in cascade connection via Flex-Rigid PCBs which allows the transmission of both the signals to and from the ASICs, and the low voltage power supplies. The lower 3 layers are composed by 6x6 dummy modules. The latter emulate the presence of a real module: they consist of 4 disks having the same size and weight as the detectors and a FEB populated only by passive components which emulate the power consumption of the readout electronics. The readout ASIC designed for the Si(Li) detectors is called SLIDER32 (32-channels Si(LI) DEtector Readout) and was fabricated in a 180nm CMOS technology. It includes 32 analog readout channels and integrates, as a first stage, a charge preamplier with dynamic signal compression to cover the wide detection range required by the experiment (20 keV - 100MeV). The second stage of the channel is a unipolar semi-Gaussian time-invariant filter with 8 selectable peaking times, ranging from 300 ns to 1.8 µs. 600 ASICs were fabricated and individually tested to select the 300 with the best performance. During the selection, particular emphasis has been paid to the electronic noise. The goal is to obtain an energy resolution below 4 keV FWHM, for low energy signals (up to a few tens of keV) in order to be able to distinguish X-rays of interest for the experiment. The characterization included a 40 pF capacitor at each input to account for the detector capacitance. After the production of the boards, a second characterization phase was carried out to assess that mounting SLIDER32 onto the FEB did not affect its performance. A power consumption of 7.2mW per channel has been obtained. A chain of 6 FEBs in cascade was also characterised in order to emulate a full single row. All the electronics, i.e. FEBs, dummy FEBs and FRB, underwent one thermal cycle in a climate chamber (from -40 ℃ to 60 ℃). A very high yield was obtained on all the tested PCBs (from 86% to 100 %).

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