Design of Front-end Signal Processing for the Advanced Particle-astrophysics Telescope

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The Advanced Particle-astrophysics Telescope (APT) is a planned space-based observatory designed to detect and localize MeV transients such as gamma-ray bursts (GRBs) in real time. The goal is to enable concurrent, multi-messenger observation of transient GRBs from any direction with minimum delay. To keep latency low, the computational pipeline for detection and localization is fully onboard the instrument, which imposes significant size, weight, and power constraints. This poster describes the front end of the computational pipeline, which is designed to be deployed on a set of FPGAs. The front end computations perform event building for individual gamma rays, which includes pedestal subtraction, signal integration, centroiding, and data compression. Events are sent to the back end for reconstruction and localization.

We explore the use of high-level synthesis (HLS) techniques for efficiently implementing the first several pipeline stages. Pedestal subtraction is performed over 10 nanosecond samples, which are time-integrated in 2.56 microsecond event windows, driving low latency requirements for centroiding, which correctly identifies and locates around 60% of the interactions within the device. We investigate a number of lossless and lossy compression techniques for delivering data off the FPGAs for processing downstream (the back end of the computational pipeline) on traditional processor cores. We demonstrate that we can achieve at least 20× data compression with less than 0.02% loss of precision, enabling both individual signal intensity measurements and computed centroids for each event to be sent in real time. We extend the evaluation to characterize the impact of atmospheric background and gamma-ray pileup on a planned balloon-borne Antarctic demonstration mission.