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

Marion Sudvarg (msudvarg@wustl.edu, www.sudvarg.com)
Meagan Konst, Thomas Lang, Diana Pacheco-Garcia, Roger Chamberlain, Jeremy Buhler, James Buckley
For the APT collaboration

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.

For a mission overview, see Poster 103.45, “The ADAPT Mission”

APT will have 20 layers of 3x3m CsI:Na scintillating crystal
Orthogonal 2mm wavelength shifting (WLS) fibers are bonded to the top and bottom of each layer
Each layer is also coupled with orthogonal scintillating-fiber tracker hodoscopes

Pedestal Subtraction
ADC count contribution from analog memory pedestal must be subtracted
Two incident gamma-ray photons arriving during the same readout window result in pileup
Our simulator models the pileup effects of short GRB time profiles and anisotropic atmospheric background for a balloon-borne Antarctic demonstration mission

Signal Integration
4 integrals over subsets of 256 samples (2.56 μs) to capture complete time profile of CsI scintillation

Centroids sent from >80 FPGAs to CPU performing backend computation

Compress integrated fiber intensities to send to CPU in addition to centroids for later analysis

Represent 20-bit fiber data as 16-bit values. For intensity values up to 1 million, error remains less than 0.02%

Compress data, send to CPU
CPU decompresses data from each FPGA, then combines & recompresses
High flux events:
• 62.42 MeV/cm²
• 5.2×10⁶ detected events
• Total compressed size: 42 MB

High flux events:
• 14.36 MeV/cm²/s
• 1.12×10⁹ detected events/s
• Data rate (FPGA array to CPU): 830 Mbps

For more details, see poster 103.29, “Prompt, Accurate Localization of Gamma-Ray Bursts in the Advanced Particle-astrophysics Telescope”

Event Reconstruction
Centroids from each individual gamma ray are combined and used to reconstruct Compton angles

GRB Localization
Resulting annuli describing PDF of incoming source direction are intersected to infer a common source