Electronics Development for the Cherenkov Telescope Array

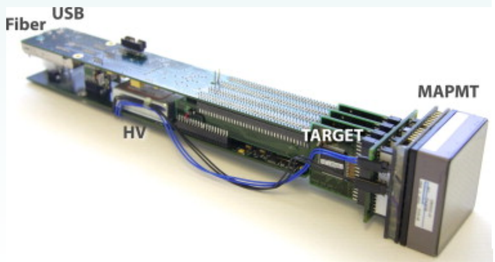
Margaret Murphy, Justin Vandenbroucke
Kavli Institute for Particle Astrophysics and Cosmology
SLAC National Accelerator Laboratory, Menlo Park, CA 94306

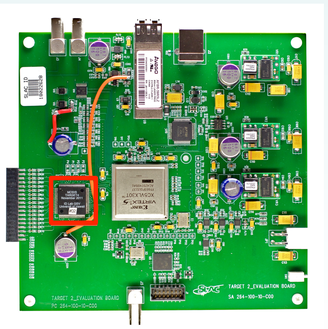
Introduction

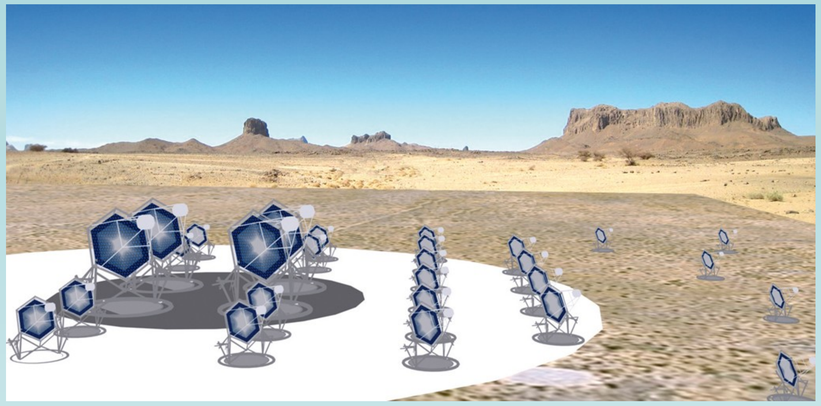
Gamma-ray astronomy, currently a large topic of study in astrophysics, could potentially lead to the identification and characterization of dark matter. Although there are several instruments already in place to study and capture gamma-rays, the Cherenkov Telescope Array (CTA) is in the planning and development stages and will be an order of magnitude more sensitive than existing instruments. CTA will be a ground based observatory that will study gamma-rays in the 10 GeV to 100 TeV energy range. CTA will collect and record images from particle showers that are initiated by gamma-rays entering the Earth's atmosphere. CTA will consist of many telescopes with thousands of photo-sensor channels per telescope. The TeV Array Readout with GSa/s sampling and Event Trigger (TARGET) chip was created to ensure high reliability and low cost per channel. TARGET consists of 16 sampling channels and readout can be triggered both by internal and external trigger signals.

TARGET 4

There have been several generations of TARGET and the most current in existence is TARGET 4. Four TARGET chips will be in each camera module of the telescopes of CTA however in the research and development stage TARGET 4 is tested on an evaluation board in the lab. Each telescope in CTA will be built with dozens of camera modules. The camera module to be used in the telescopes is shown below on the left. TARGET 4 and the evaluation board is shown below on the right; the TARGET 4 chip is outlined by the red rectangle.



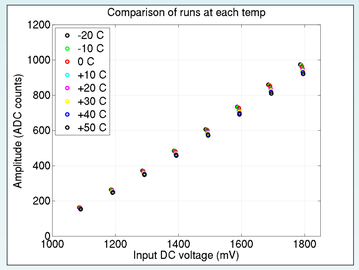


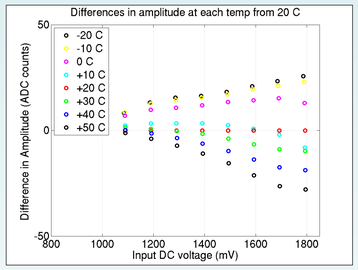


Above is a simulated image of the future Cherenkov Telescope Array. It will be located in a high desert where the atmosphere is typically thin and dry.

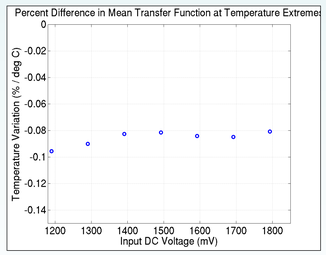
Temperature Dependence

TARGET converts an input voltage to digital. The transfer function is a relationship between the input voltage and the number of output analog to digital conversion counts (ADC counts). This transfer function was tested for temperature dependence and it found to vary by about a 0.1% per degree Celsius.





The top left image is a plot of the transfer functions at each temperature setting from -20 C to 50 C. The top right image is a plot of the difference between the transfer function at each temperature and the transfer function at 20 C. The bottom right image is a plot of the percent difference per degree Celsius among the transfer functions.



Transfer Function Optimization

One main goal was to optimize the range of the TARGET 4 transfer function. The goal was to achieve the largest ADC range as possible with a voltage range of 1.0-1.5 V. The parameters of the transfer function are controlled by 5 internal voltage settings. Each of the five voltages was adjusted over its full range one at a time while the other four voltages were left at the defaults. Afterwards, the transfer functions for each voltage were studied to determine the optimum range. The settings for each voltage that gave the optimal transfer function were chosen to be the new default settings.

The figure above is a plot comparing the transfer function achieved with the original defaults to the transfer function with the new defaults determined through multiple voltage scans.

Acknowledgements

Special thanks to Justin Vandenbroucke as collaborator and mentor and to Leonid Sapozhnikov, Stefan Funk, Gary Varner, Sonia Karkar, and Tobias Jogler as collaborators.

This material is based upon work supported by the S.D. Bechtel, Jr. Foundation and by the National Science Foundation under Grant No. 0952013. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the S.D. Bechtel, Jr. Foundation or the National Science Foundation. This project has also been made possible with support of the National Marine Sanctuary Foundation.

The STAR program is administered by the Cal Poly Center for Excellence in Science and Mathematics Education (CESaME) on behalf of the California State University (CSU).