PROCEEDINGS OF SCIENCE

Progress of construction and calibration of main modules for the DUCK (Detector of Unusual casKades) system

Dmitriy Beznosko [a,*], Valeriy Aseykin [b], Alexander Dyshkant [c], Alexander Iakovlev [d], Oleg Krivosheev [e], Tatiana Krivosheev [a], Vladimir Shiltsev [c], Xuong Minh Tran [a] and Valeriy Zhukov [b]

a School of Sciences, Clayton State University,
2000 Clayton State Blvd., Morrow GA 30260 USA

b P. N. Lebedev Physical Institute,
Mitin street 3a, Almaty, 050020 Kazakhstan

c Department of Physics, Northern Illinois University,
1425 W Lincoln Hwy., DeKalb, IL 60115 USA

d Upper School Science Department, Woodward Academy,
1662 Rugby Avenue, College Park, GA 30337 USA

e Xcision Medical Systems,
9176 Red Branch Rd STE O, Columbia, MD 21045 USA

E-mail: dmitriybeznosko@clayton.edu

The Astroparticle field is actively searching for the origin and the nature of the Ultra-high energy cosmic rays from deep within the Universe as they carry the information from those regions and might also hint on possible new physics. This paper reports on the overall design and the ongoing construction and calibration of DUCK (Detector system of Unusual Cosmic-ray casKades), a new cosmic-rays detector at the Clayton State University campus with ns-level detection resolution. The main scientific importance for the DUCK project will be to contribute to the approach of cosmic ray event analysis using the full waveform and detector response width, and to an independent verification of the detection of the 'unusual' cosmic ray events that were reported by the Horizon-T detector system that may be indicating direction towards the novel physics possibilities.

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[*]Speaker

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1. Introduction

High Energy Physics (HEP) is a field that has still has many mysteries that need to be solved. An open question is about the origin and composition of the Ultra-high Energy Cosmic Rays (UHECRs). These cosmic rays originate well outside our planet, maybe even outside of the galaxy. They are messengers that could help us better understand the universe around us and provide insight into the fundamental building blocks of our universe.

The primary goal of the DUCK system [1, 2] is to detect and verify the existence of unusual cosmic events [3, 4]. Moreover, it can help innovate EAS (Extensive Atmospheric Shower) analysis methods. This poster aims to highlight development and construction of the detector system, instrument calibrations and other activities conducted at Clayton State University (CSU).

2. 3D Hardware Design

Using OnShape© CAD, the PMT Upper Shell (Figure 1a), PMT lower shell and Optic Fiber ferule for Module 1 were designed and 3Dprinted as show in in Figure 1b. The design was carried out by the student and the process was optimized with the following:

- Planes were used to manipulate where objects originate.
- Splicing was done using UltiMaker© Cura 5.3 after downloading the .stl file with the units in mm and quality set to fine, this is very important or the model won't be sliced properly.

(a) (b)

Figure 1. (a) PMT holder shell. (b) PMT holder printing.

3. Current Status of the Project

Modules #1 and #2 have been fully built, and all hardware components are now operational. Several new hardware additions were designed and implemented, including the PMT holder and mount, as well as PMT cable management. Two more modules are under construction. Initial calibrations are under progress currently.

A secondary photodetector was added using the Hamamatsu [5] MPPC sensor. The MPPC installation board is shown in Figure 2.

For the two detector modules, the MPPC boards are equipped with the Hamamatsu power supply C11204-01 for the MPPC photosensor. Powered by just 5V, it can produce the output up to 90V that covers MPPC range needed.

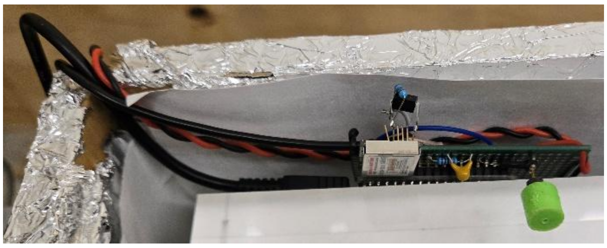

Figure 2. MPPC board.

However, the following issues were found while working with this power supply:

- COM-port communication only with outdated parity check
- On power loss – loses last setting, starts with default of 40V - added Arduino controller to initialize and monitor the power supply
- Old protocol, slow comm speed
- Unnecessarily complicated commands
- Needs to be 'reset' when loaded: short NC pin to ground, undocumented 'feature'
- No overload/short protection!

As a result, modules #3 and #4 will be outfitted with more robust power supplies. The modules themselves use Hamamatsu H11284-30 (former R7723) PMT as a primary photosensor, and these are powered by easy to use and robust C9619-01 power supply.

4. Software Efforts and File Format

A specialized software was developed for the purposes of controlling DT5730 ADC, and data collection [6]. The software was designed to consider speed, data readability, ADC control function, and real time display (with priority on data collection). The software uses TBB (threading blocks) library to delegate and handle task operation [7, 8].

The current version of the software offers a real-time display where the controls are adjusted, and data can be observed.

The data acquisition (DAQ) method is implemented using the ROOT analysis framework. ROOT's built-in file-writing tools are used to save the data as .root files. These ROOT files are binary and are designed to prioritize easy retrieval of information while maintaining a compact file size. They use a hierarchical structure for data organization, with data stored in tree-like structures that help track complex systems. The file consists of three parts: header, body, and footer. Each part contains a data tree (TTree), and each tree can hold multiple events. In practice, the header and footer typically contain a single event [6].

Header: The header's primary purpose is to define the parameters by which the DAQ was conducted. Parameters include sampling frequency, readout speed, trigger type, trigger polarity, etc.

Data: The body of the file contains 'events' - data from a detected cosmic event. The data recorded notes the size of a given event and data from each individual channel within the DAQ time window. The data is written after each trigger; this is done to reduce data loss in the event of malfunction.

Footer: The footer of the file is written at closing the file and contains important information for quality assurance. The footer notes the total number of cosmic events during physics run across all files at the moment when the current data file is closed.

5. Conclusion

For the hardware portion, the plans are to complete construction of Module 3 and 4, carry out the calibration of all modules through various tests, and conduct the separation curve test using modules 1 and 2.

For the software portion of the project, the future plans are to write the robust ADC-DAQ control that also gives possibility for remote operations. Add detailed software documentation. Development of command-line interface for more dynamic interaction and scripting possibility.

Acknowledgements

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