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# Construction progress of Detector of Unusual Cosmic-ray casKades

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**Abstract.** 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, may even be 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 Detector of Unusual Cosmic casKades, is to detect and verify the existence of unusual cosmic events. Moreover, it can help innovate EAS (Extensive Atmospheric Shower) analysis methods. This poster aims to highlight developments of the detector system, instrument calibrations and other activities conducted at Clayton State University.

## 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 Detector of Unusual Cosmic casKades (DUCK) [1, 2] is to detect and verify the existence of unusual cosmic events [3]. Moreover, it can help innovate EAS (Extensive Atmospheric Shower) analysis methods and participate in other collaborations such as CREDO [4]. This article aims to highlight the construction progress of the detector system, instrument calibrations and other activities conducted at Clayton State University.

The current design for DUCK system [5, 6] consists of four main detectors under construction, with the prototype [7] already completed and tested. Individual detectors [8] consist of the 1x1x0.05m EJ200 Eljen [9] scintillator and the Hamamatsu [10] H11284-30 photomultiplier tubes (PMT) that are connected to the CAEN [11] DT5730 Flash Analog-to-Digital Converter (FADC). The Hamamatsu 1.3 mm$^2$ Multi-Pixel Photon Counter (MPPC) photosensors are used as secondary detectors for the calibration purposes only. The schematic is shown in Figure 1.

## 2 Design of 3D Parts

For the small parts of each detector, such as the top piece in the Figure 1, the PMT holder and the MPPC fiber ferrule, the 3D printing technology is used. A special design was made by students for all the parts mentioned. Figure 2 shows the design and printing process for the PMT holder part, and the designs of the MPPC optical ferrule and the detector outer casing top piece that holds the PMT holder and the walls together.

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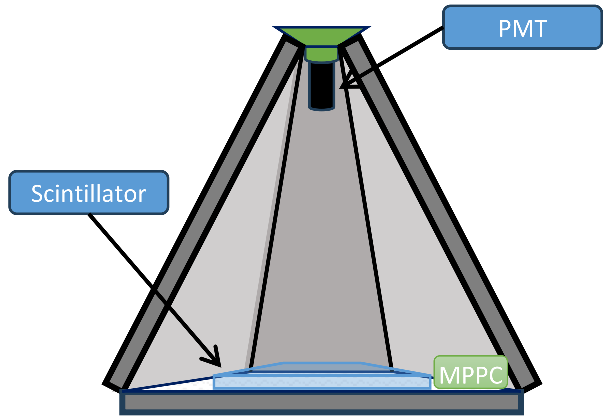


**Fig. 1.** General design of the DUCK detection module prototype.

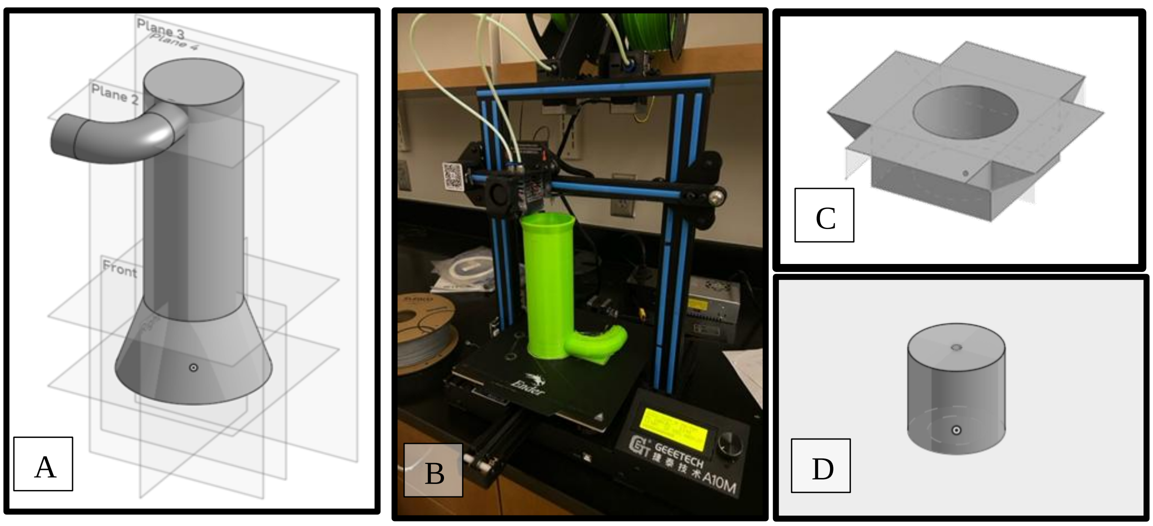


**Fig. 2.** **A**: Design of the PMT holder. **B**: PMT holder being printed. **C**: Detector case top piece. **D**: MPPC fiber ferrule.

**Fig. 3.** Detector module 1. The 3D printed PMT holder is at the top, shown before covered by light-tight cover.

In Figure 3, the 3D printed PMT holder is mounted onto the completed detector module 1. Figure 3 also shows the high voltage supply for the PMT, and low voltage power supply that powers the high voltage supplies for both the PMT and the MPPC. The entire MPPC module with the high voltage power supply is inside the detector enclosure.

## 3 ROOT-based File Format

The data acquisition (DAQ) method is implemented using the CERN ROOT analysis framework [12]. 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 [12]. 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. The schematic is outlined in Figure 4.

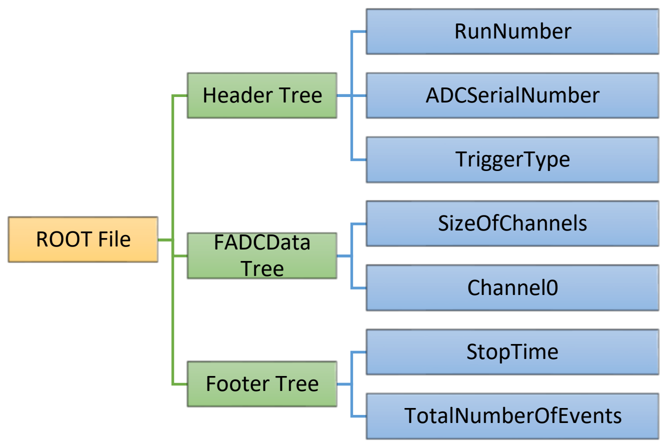


**Fig. 4**: The TTree structure of a data file. The root node defines the structure and branches represent specific parameters.

- 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.

## 4 DAQ Software

A specialized software was developed for the purposes of controlling DT5730 ADC, and for the data collection [12]. The software was designed to consider the 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.

The software offers a real time display as seen in Figure 5, from where the controls are adjusted, and data can be observed. The software was in part developed and evaluated by the students during the additional project activities [13, 14].

## 5 Conclusions and Future Plans

Currently, Detector module 1 has been fully completed and it is under testing and calibration. The DAQ software and file format for the detector data have been implemented and are functioning. The future plans are listed below.

Hardware construction plans:

- Complete construction of Module 2, 3, and 4
- Run calibration on Modules 1-4 and assess response to a single ionizing particle using cosmic rays
- Analyze data collected from Module 1 to validate data obtained from the prototype module

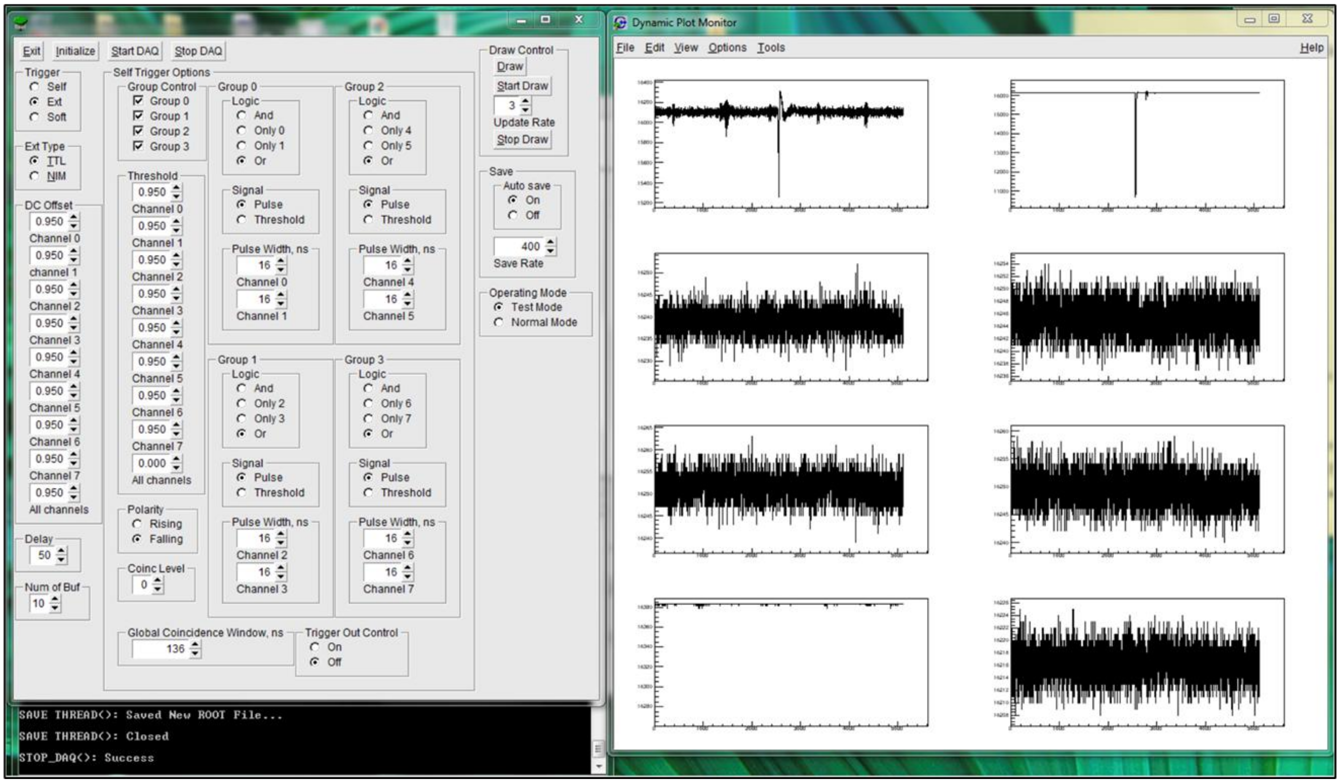


**Fig. 5.** (Right) DAQ control Panel interface. (Left) Data display showing live data from FADC channels 0 to 7.

Software development plans:

- Introduce and adapt new methods for better and more robust ACD-DAQ control
- Write detailed software documentation
- Develop command-line interface for more dynamic DAQ operations

Development of the command-line interface program:

The current software only allows for the execution of commands through the GUI, as highlighted in Figure 5. The purpose of the new command-line interface (CLI) is to enable the execution of ADC and DAQ controls within a terminal, while maintaining the ability to execute commands through GUI. The control program will be written in Python 3 and will utilize task queuing as the primary method of task execution. It will communicate with the DAQ using the CLI and use Python's subprocess library to manage ADC-DAQ software execution.

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