Testing and development of the data acquisition for the ALICE Experiment Fast Interaction Trigger (FIT) Detector at the CERN Large Hadron Collider

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Overview

The CERN Large Hadron Collider (LHC) (Figure 1) collides charged nuclei of atoms (Figure 3) to replicate the beginning of the universe: high-energy dense environments of quarks, gluons, and leptons. The resulting particles released from the collisions provide insight to the behavior of the universe millionths of a second after the Big Bang. Capturing information about the particles released from the collisions require extreme precision that is provided by a project the ALICE team (Figure 2) is collaborating on called the Fast Interaction Trigger (FIT). The FIT upgrades will replace the current triggers at the ALICE experiment (Figure 14), enabling selection of the most interesting collisions/events that require further analysis.

Our task is to become familiar with, edit the software for, and plot the results from a piece of equipment called the desktop digitizer. By using the digitizer to measure the signal from an Avalanche Photodiode (APD), a type of photon detector, CERN physicists will be able to use these methods for the micro-channel-plate photomultiplier (MCP-PMs) detectors involved in FIT. With the upgraded trigger detector, ALICE will be able make more accurate and precise measurements, furthering our knowledge about the high density matter from which our Universe evolved. CERN is where theory meets experiment for nuclear physics, and with new developments and upgrades such as FIT, yesterday's hypotheses can become tomorrow's knowledge.

Figure 1 (Above): A bird's eye view of CERN LHC, the tunnel 100 meters underground, that is 27 km in circumference. CERN's location is on the Franco-Swiss border. ALICE is one of the experiments involved at CERN.

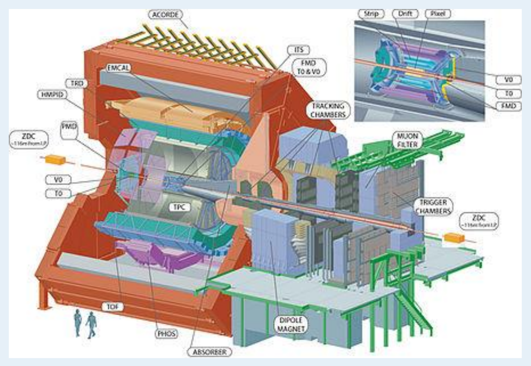


Figure 2 (Above): A cross section of the ALICE experiment's collision point. ALICE Physicists are interested in collisions that happen here.

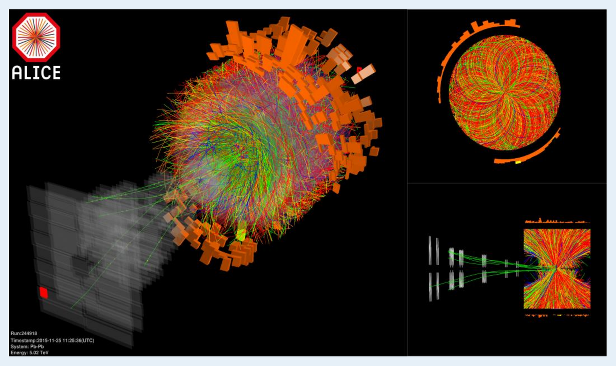


Figure 3 (Above): An ALICE Pb-Pb collision at CERN LHC. A mess of quarks and gluons is shown.

Introduction

At CERN LHC, the ALICE Collaboration team is working on upgrading the current model of triggers involved in the experiment. A trigger is what causes the detectors to begin detecting certain events or collisions. The new T0+ (Figure 13) and V0+ triggers will replace the outdated T0 and V0 and they are expected to be fast(on the scale of 30 picoseconds), selective(chooses which events are important), and accurate. A piece of equipment called the desktop digitizer (Figure 7) will be used, so its software needed to be edited. The digitizer needed to be experimented with and familiarized with before it is implemented in ALICE.

Our task is to use the materials presented later to develop and create a method used to acquire data using its software, Wavedump. This method of data acquisition will be used by ALICE physicists in charge of the triggers. Through our new method of acquiring data obtained from the APDs (Figure 6) in different locations, different pulse widths and different amplitudes (Figure 8) on a pulse generator (Figure 4), we were able to analyze how efficient, accurate, and correct the digitizer and our data acquisition method is.

Procedure

Goal:

- Develop and create a method for data acquisition on the digitizer.
- Use this method to characterize and measure the signals from 4 different APDs with different variables:
  - -- Pulse Generator's Pulse Width
  - -- Pulse Generator's Amplitude
  - -- APD's Location
- Plot the relationships of the data we acquired.
- Be able to use this method of data acquisition for different but similar materials.

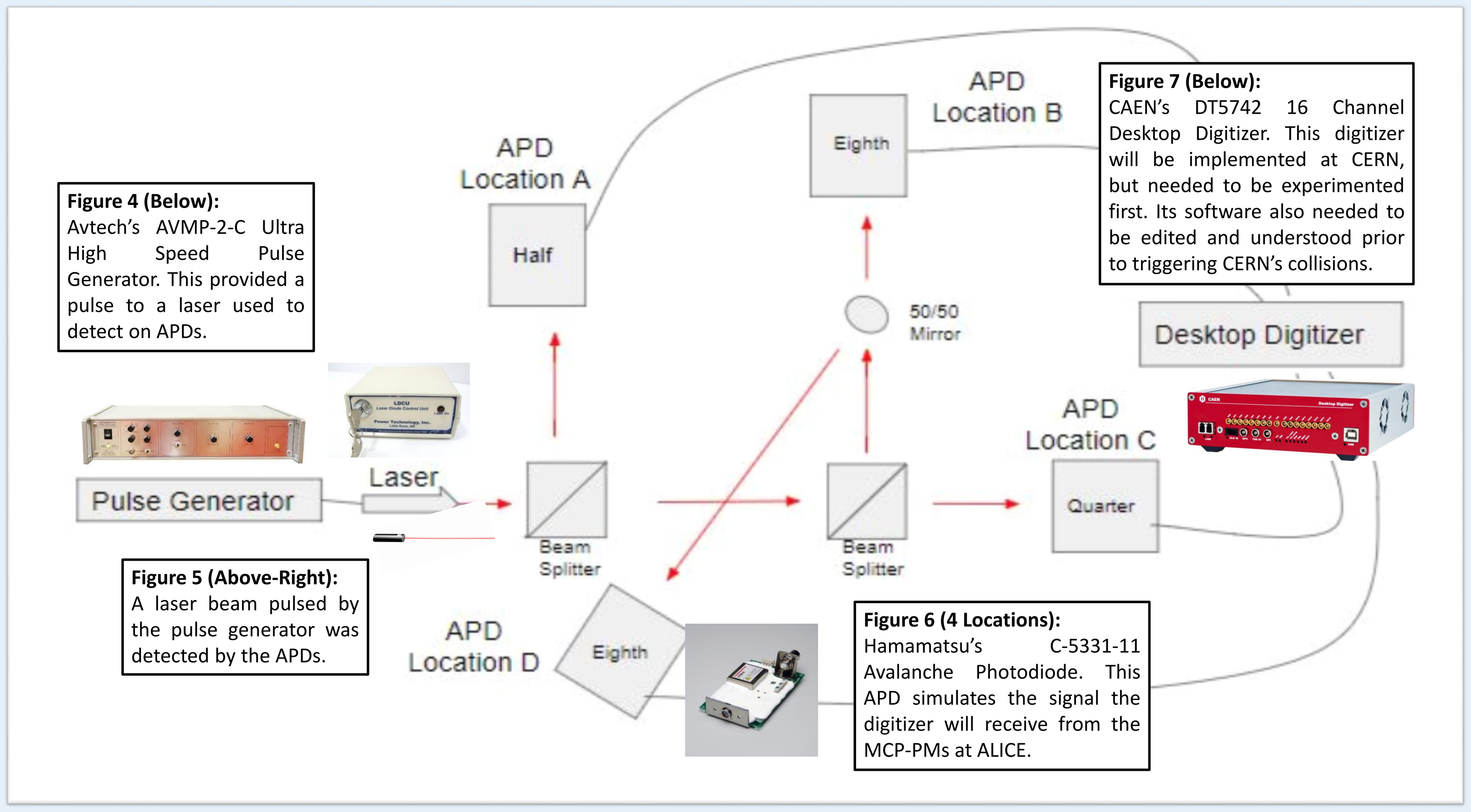


Figure 4 (Below): Avtech's AVMP-2-C Ultra High Speed Pulse Generator. This provided a pulse to a laser used to detect on APDs.

Figure 5 (Above-Right): A laser beam pulsed by the pulse generator was detected by the APDs.

Figure 6 (4 Locations): Hamamatsu's C-5331-11 Avalanche Photodiode. This APD simulates the signal the digitizer will receive from the MCP-PMs at ALICE.

Figure 7 (Below): CAEN's DT5742 16 Channel Desktop Digitizer. This digitizer will be implemented at CERN, but needed to be experimented first. Its software also needed to be edited and understood prior to triggering CERN's collisions.

Figure 8 (Above):
A simplified diagram of the setup to acquire APD data. The Pulse Generator sent a pulse signal to a laser which produced a pulsed beam. This pulse beam went through varying numbers of beam splitters and went to varying APDs. The APDs received different proposed amounts of the light beam. The signals from the APDs all went to the digitizer which processes their signals.

Analysis

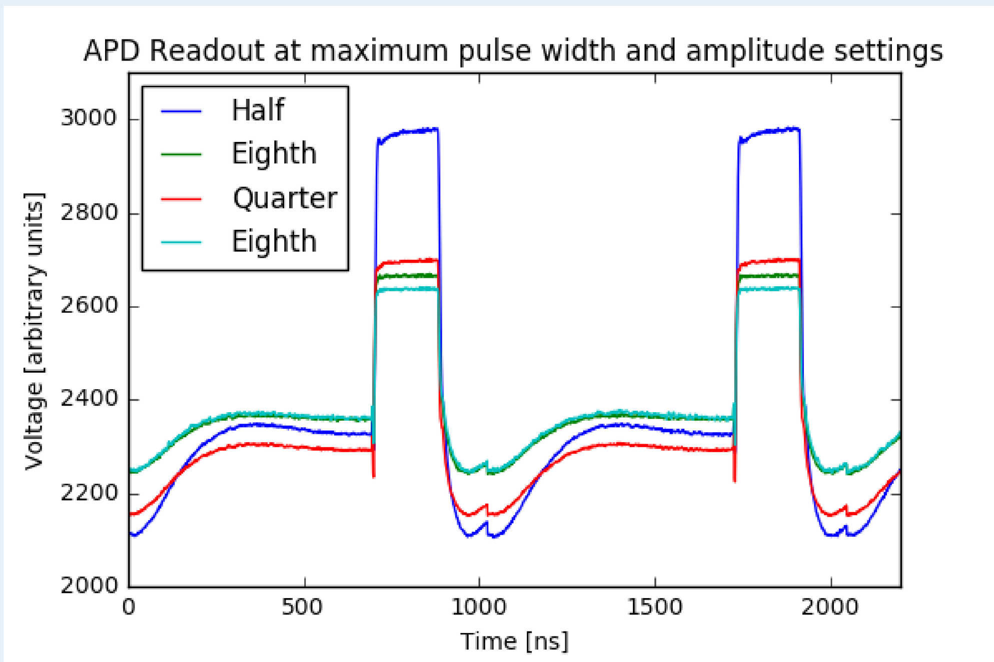


Figure 9 (Above): A raw waveform of the data acquired by the digitizer in the diagram like Figure 8. The different waves are the different APDs at the varying locations. The parameters for this run was Amplitude 10 and Pulse Width 10, at Standard Location: Channel 0: APD 1 at Location A (Half), Channel 1: APD 2 at Location B (First Eighth), Channel 2: APD 3 at Location C (Quarter), and Channel 3: APD 4 at Location D (Second Eighth).
*This was a plot not used by Wavedump, the Digitizer's Software.

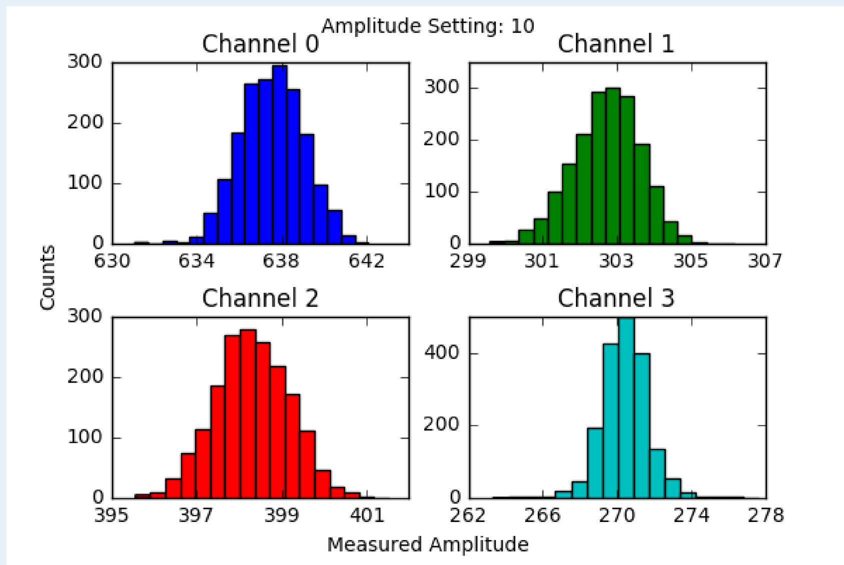


Figure 10 (Above): 4 Histograms for the 4 different Channels/APDs/Locations. This is to display the relative amplitudes of the pulses of the different APDs and how often a specific number of amplitude height appears. This also proves that the "Half" histogram, had the highest amplitude, the "Quarter" histogram had the second highest, and the two "Eighth histogram, had nearly equal amounts in amplitude.
This is for the same data acquired from Figure 9: Amplitude: 10, Pulse Width: 10 on the Pulse Generator, and at Standard Locations.

Results

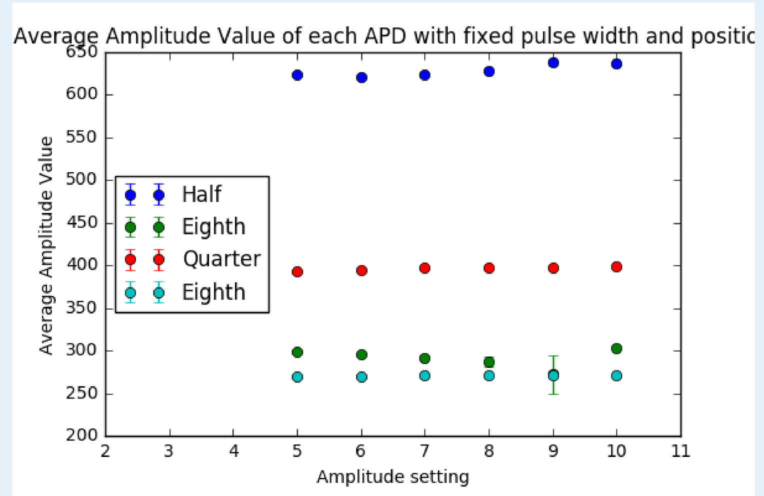


Figure 11 (Above): An error plot of the average amplitude of varying amplitude settings on the pulse generator. The pulse generator had a constant pulse width: 10, and standard locations, but this error plot includes all possible amplitude settings on the pulse generator the laser could process/the APDs could send signal of/ the digitizer could collect.

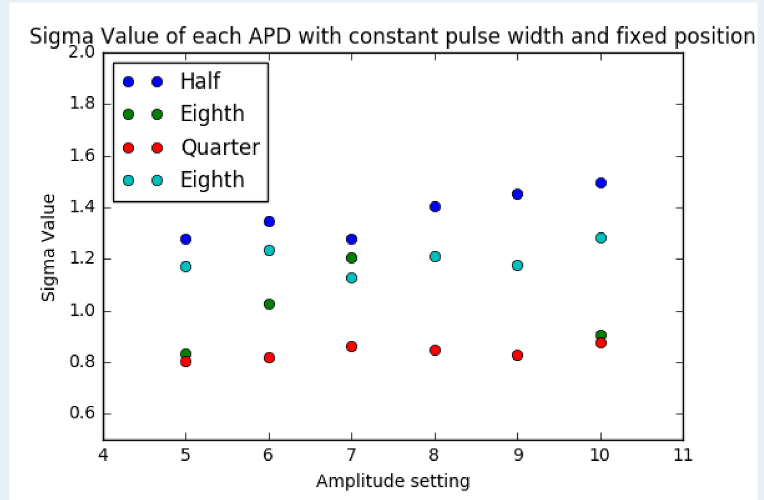


Figure 12 (Above): A plot of the standard deviations for each data set. Provided to show scale of error not able to be seen in Figure 11. Error at Amplitude setting 7, 8, 9 are probably due to error in the setup. This is also proving that our data acquisition method is good to use for ALICE.

The Upgrade and the Future

- Further testing on the Quartz Radiators (the sensors for the triggers), the MCP-PMTs, and the digitizer.
- Use newly made method to acquire data for MCP-PMTs, Quartz Radiators
- Any testing regarding the triggers or communication from its separate parts.
- Installation of the triggers at CERN.
- Success in finding more details and intricacies about the beginning of the universe.

Reconfiguration of C-Side Geometry

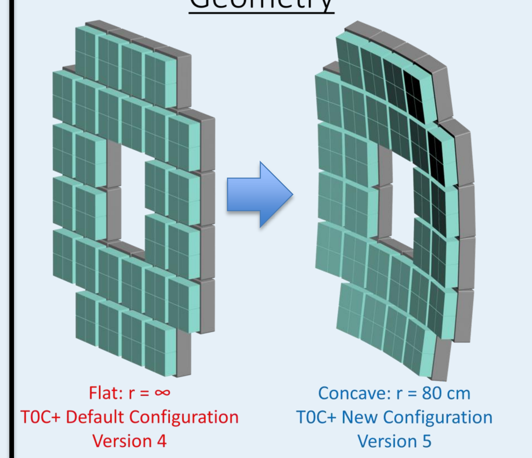
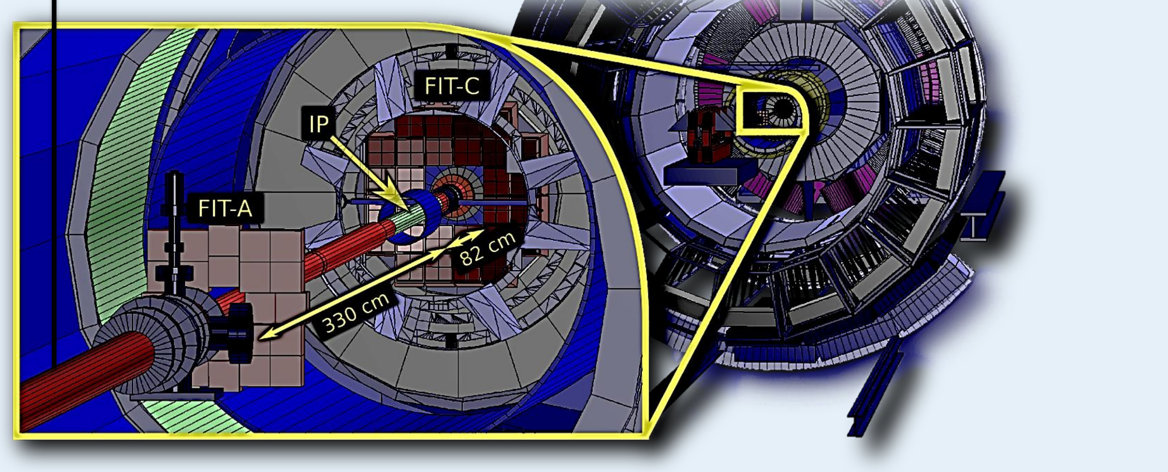


Figure 13 (Left): The T0C+ trigger. A pervious student involved in FIT ran simulations to find the best configuration concavity for most accurate results. Students involved next Summer will receive Quartz Radiators, MCP-PMTs, and a new laser to test their results using the same method on the Digitizer.

Figure 14 (Below): Installation of FIT triggers T0A+ and T0C+ will occur during CERN's Long Shutdown 2, during mid-late 2019. The figure shows the relative position to the Interaction Point(IP), where nuclei collide.



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