Remote high voltage control for the ATLAS TileCal Cesium water activation monitor

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Abstract

The Tile Calorimeter of the ATLAS detector is calibrated using a radioactive source propelled by water through the calorimeter modules. To monitor a possible activation of the water, the signals are redirected to a photomultiplier and a multi-channel analyser to read out the energy distribution. A simple program to remotely manipulate the high voltage supply to the photomultiplier was written. With this program, the high voltage supply was varied in order to observe the behavior of the position of the energy peak of the source. At higher voltage, the distribution peaked at a higher channel number, which corresponds to a higher energy. The stability of the reading was also examined by taking data kept at a constant high voltage over 24 hours at 1 hour intervals, which could also correspond to change in temperatures on different times of the day.

Keywords: ATLAS, TileCal, calibration, activation monitor, remote high voltage, energy peaks

1 Introduction

The ATLAS detector is located at one of the four main collision points on the Large Hadron Collider. It is a general purpose particle detector with various calorimeters installed to measure the energies of the particles produced from proton-proton collisions. One of these is the Tile Calorimeter, or TileCal, which stops and measures hadrons and their constituents' energies. Figure 1(a) shows an anatomical diagram of the calorimeters of ATLAS. The TileCal has 64 modules across the $\phi-$direction (going in circle). Each of these module contains electronic chips and sensors responsible for reading the signals from the detected particles.

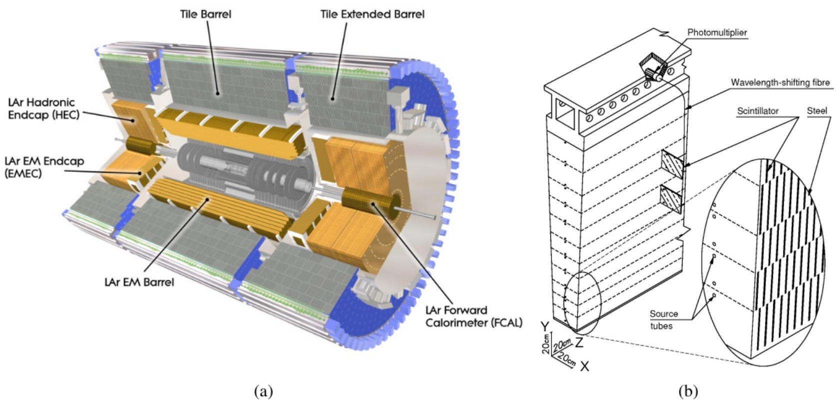


Figure 1: (a) The calorimeters in the ATLAS detector and (b) one slice of the tile calorimeter in the $\phi-$direction. Taken from [1].

Figure 1(b) shows that each module are divided into cells along each row. In order to make sure that the TileCal does its job precisely, it needs to be calibrated. In this case, it is done by taking a radioactive source, which will act as the signal as if it was the particle/s to be detected, and propelling it through each module of the TileCal, making sure that each cell is responding in the same way.

The method used to propel the source across the modules is by using water. Tubes are installed on the modules, along with the electronics, in order for water to flow while carrying the source. To avoid getting the water radioactive, or so called activation, the source is enclosed in a capsule. However, this does not ensure entirely that the water does not get activated. Hence, it is best to monitor the activity of the water used for the calibration system. In order to do this, a system of electronic equipment are used to quantify the energy released by the radioactive source.

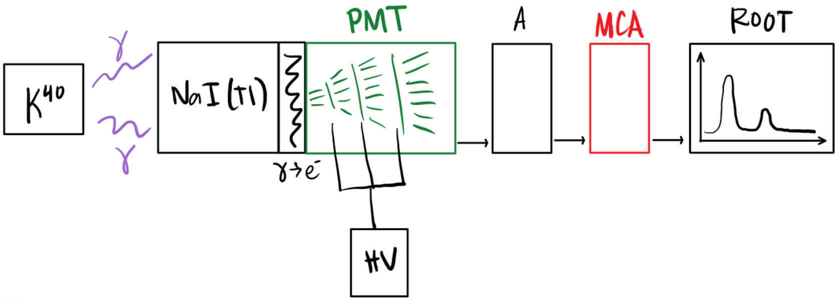


Figure 2: (a) Sketch of the process flow for collecting the energy distribution of the K-40 source.

Figure 2 shows the basic flow of signals that are read in order to produce a histogram of the energy spectrum. Typically, a Cs-137 source is used for the calibration, along with K-40 as the basis or reference for the energy values. In this paper, we only investigate the energy spectra of the K-40 source, without having the Cs-137.

The process starts as the radioactive source emits photons, particularly gamma rays, which are registered by the NaI(Tl) crystals that lights up when absorbing the gamma rays. This lighting up of the crystal is then detected by the photomultiplier (PMT), which converts the photons into electrons, and hence electrical signals. The spectroscopy amplifier (A) enhances these signals, and the multi-channel analyser (MCA) constructs the energy spectra collected as histogram in a `.root` file.

Notice that the high voltage supply is connected to the photomultiplier. Changing the voltage supply changes the energy spectrum collected. One sample histogram for the K-40 with 1000 V supply over two hours is shown in Figure 3.

2 Remote high voltage board control

The high voltage supply board for the photomultiplier is the CAEN1470. The high voltage board used in this project contains one board with two channels. These channels have various parameters whose value can be set and/or read. Some of the relevant parameters are listed in Table 1.

Table 1: Relevant parameters of the high voltage channel.

Parameter	Description
VSET	Set the voltage
VMON	Read the present voltage
MAXV	Set/Read the maximum voltage you can set with VSET
ISET	Set the current
IMON	Read the present current
STAT	Read the status of the channel (on, off, etc.)

The VSET parameter allows the user to set the voltage difference of the board. The CAEN1470 can accomodate up to 8000 V, but for safety reasons, there is another parameter called MAXV that can be set as a ceiling for VSET. It was set to 1000 V, which means that we can only set the voltage supply up to 1000 V for this project. ISET does the same for current, while VMON and IMON both get the actual voltage applied and current flowing in the board respectively. The STAT parameter gives whether the channel being used is turned on, off, or is in some state with a problem.

The high voltage board can be controlled either locally by manipulating manipulating the board settings using the front-panel buttons and switches, or remotely by connecting the board thru USB, Ethernet, RS485, RS232 interfaces, or stand-alone programs and libraries. In this project, it was connected to a PC using a USB cable, and controlled using Python with the PySerial package. When getting the value of the parameters, the board returns a string. For example, setting and getting the VMON value using the syntax

```
$BD:00,CMD:SET,CH:0,PAR:VSET,VAL:800\r
$BD:00,CMD:MON,CH:0,PAR:VMON\r
```

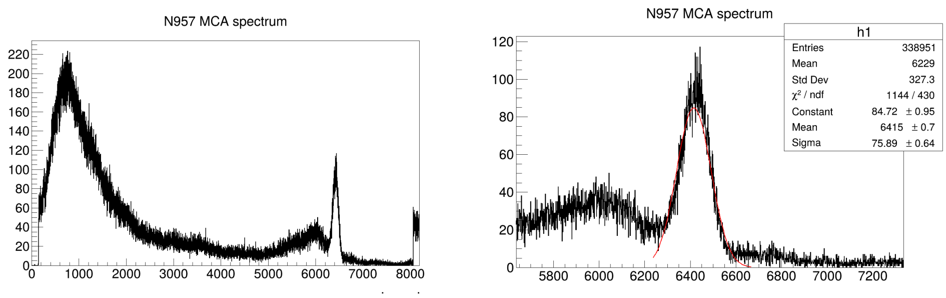
will return the value

```
#BD:00,CMD:OK,VAL:800.1
```

It would be useful to only take the actual value itself, which in this case is 800.1. To do this, we wrote simple functions in Python, shown below, to extract the value.

```
##########################################################################################
import serial
import time
from datetime import datetime

ser = serial.Serial(port='/dev/ttyUSB0',timeout=3,xonxoff=True)


def HVon(ch='0'):
        ser.write('$BD:00,CMD:SET,CH:{},PAR:ON\r'.format(ch))
        ser.readline()

def HVoff(ch='0'):
        ser.write('$BD:00,CMD:SET,CH:{},PAR:OFF\r'.format(ch))
        ser.readline()

def getVAL(par, bd='00',cmd='MON',ch='0'):
        ser.write('$BD:{},CMD:{},CH:{},PAR:{}\r'.format(bd,cmd,ch,par))
        s = ser.readline()
        l = len(s) - 18
        val = s[-l:]
        return val
        #### THIS RETURNS A STRING FOR NOW, SINCE DIFFERENT PARAMS GIVE DIFFERENT DATA TYPE

def setVAL(par, val, bd='00',cmd='SET',ch='0'):
        ser.write('$BD:{},CMD:{},CH:{},PAR:{},VAL:{}\r'.format(bd,cmd,ch,par,val))
        s = ser.readline()

##########################################################################################
```

3 Peak behaviors



(a) (b)

Figure 3: (a) Sample histogram of the K-40 energy spectrum at 1000 V for 2 hours, (b) fitted with a Gaussian distribution across the K-40 peak.

Again, Figure 3 shows a sample energy spectrum for K-40 with 1000 V supply over two hours. The $x-$axis of the plot corresponds to the channel of the MCA, which is proportional to the energy, while the $y-$axis shows the count of events. In this histogram, we see different peaks. The first peak we see on the lower energy scale is just background from the external environment. Another peak we can observe is the rightmost one. This is a pileup of overflows, that is, any energy reading that is “off-the-charts” are dumped among the last channels of the MCA and is disregarded. The remaining peak is the on of interest, which is the peak at around channel 6000-6600. This corresponds to the energy of the gamma rays released by the K-40 source. In order to estimate the position of the peak, a Gaussian curve is fitted across this distribution, in which the mean value represents the peak location.

If you observe carefully, there is actually another small peak to the left of this K-40 peak. However, this one is not in the scope of this project, and is recommended for further studies.

3.1 Mean position vs. voltage

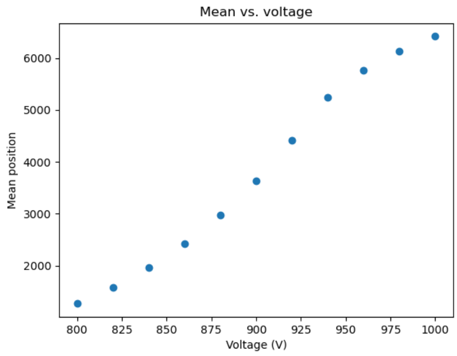
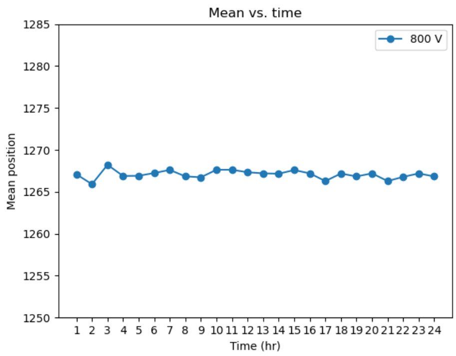


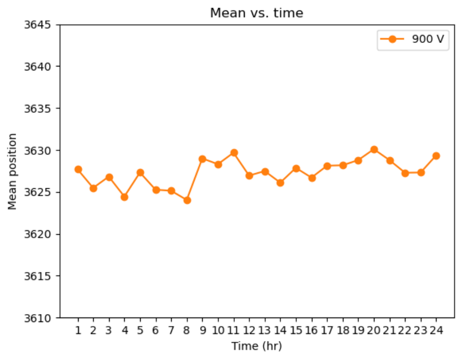
Figure 4: (a) Mean position of peak vs. voltage collected over a two-hour period.

By varying the high voltage supply from 800 V to 1000 V in 20 V steps, collecting data for two hours each, then fitting a Gaussian distribution and getting its mean across the K-40 peaks, we obtain a Mean position of peak vs. voltage plot shown in Figure 4. It is expected that higher voltage supply corresponds to higher channel number, which means higher energy reading.

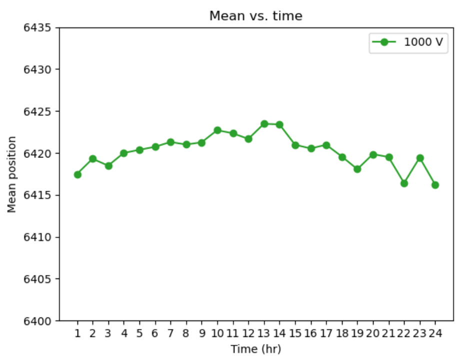
3.2 Mean position vs. time



(a)



(b)



(c)

Figure 5: Mean position of peak vs. time in hours at (a) 800 V, (b) 900 V, and (c) 1000 V.

Another point of interest is the stability of the source emission over 24-hour periods. By setting a fixed high voltage supply to the system, data was collected for every hour over one day to see the fluctuations on the mean position of the energy peaks. This was done for 800 V, 900 V, and 1000 V as shown in Figure 5. This could also correspond to the behavior of mean position with respect to temperature, since environment temperature varies during different times of the day.

4 Conclusion and recommendations

This high voltage control for the water activation monitor could be implemented with the actual Cs-137 source for the TileCal calibration in order to analyze its energy peak behavior. Having a remote control for the high voltage supply for the calibration system could prove to be more efficient as it would not be needed to proceed physically to the location of the board.

Moreover, this monitoring of water activation can also be used to detect the activation of nearby materials from the colliding particles.

References

[1] G. Blanchot et al., The Cesium Source Calibration and Monitoring System of the ATLAS Tile Calorimeter: Design, Construction and Results, *JINST* **15**, P03017 (2020), arXiv:2002.12800.