Study of the ATLAS Tile Calorimeter LASER Calibration System Dynamic

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Introduction

The Large Hadron Collider (LHC) is a particle accelerator located at the Swiss-French border. At the LHC, two counter-rotating beams of hadrons will collide at energies comparable to those present moments after the Big Bang.[1] One of the experiments located at the LHC is ATLAS. A diagram of the components of ATLAS, including the tile calorimeter, is shown in figure 1.

In order to complete reliable physics analysis, the energy resolution should be as small as possible. Therefore, calibration is incredibly important. The LASER system is one of three hardware calibration systems of the ATLAS tile calorimeter.[2] A diagram of the LASER box is shown in figure 2. Our goal was to analyze data generated by the LASER system in order to calibrate the attenuation factor and the dynamic of the LASER filters.

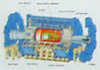

Figure 1. The ATLAS detector [1]

Figure 2. The ATLAS TileCal LASER box [2]

Data Samples and Event Selection

Samples were obtained from two modes: standalone and TDaq. In standalone, data was obtained from filters one, two, three, four, seven, and eight. In TDaq, data was obtained from filters one, four, and eight. In each case, LASER intensities of 14,000, 16,00, 18,000, 20,000, 22,000, 24,000, 26,000, 28,000 and 30,000 were used. Approximately 5,000 events were obtained for any given combination of filter and intensity.

Dynamical Range of the Wheel Filters

Plots of the mean energy of the PMTs of TileCal as a function of intensity were obtained in order to verify the dynamical range of the wheel filters. An example, from the 44th module of TileCal for filters one and four, is shown in figure 3. We could see that a large dynamical range, from a few MeV to many GeV, was covered.

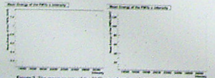

Figure 3. The mean energy of the PMTs as a function of intensity. On the right is filter one and on the left is filter four.

Attenuation Factor of the Wheel Filters

Each of the photodiodes in the LASER box has a pedestal value, which represents electronic background noise. To get the best value for the ADC count of the diode, the pedestal value must be subtracted from the ADC count. In order to determine the pedestal value, a pedestal run was taken. For each diode, a histogram of the ADC count for all events was made. An example histogram of the pedestal for diode three is shown in figure 4. The histograms for the diode ADC counts from the pedestal run were fit with Gaussians. The mean value of each Gaussian became the corresponding pedestal value for each diode.

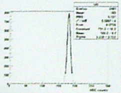

Figure 4. A histogram showing the electronic background noise for diode three. It was fit with a Gaussian. The mean of this Gaussian is the pedestal value for diode three.

The diodes should be linear. For each of the three diodes in every run, histograms of the diode ADC count minus the pedestal value were obtained. Then, they were plotted against each other and fit with lines to check diode linearity, as shown in figure 5. We found the diodes were linear.

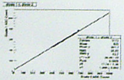

Figure 5. Diode 1 ADC count minus its pedestal value as a function of diode 2 ADC count minus its pedestal value for filter 1, intensity 26,000. As expected, the slope obtained, 1.096, was close to one with an offset, 17.74, close to zero.

To calculate the attenuation factor of the LASER filters, the mean diode ADC count and the ADC count of diode four were used, event by event, in the following manner:

$$attenuation = \frac{ADCcount_{diode4}}{MeanDiodeADCcount}$$

where the mean diode ADC count is defined as

$$MeanDiodeADCcount = \frac{\sum_{i=1}^{3}(ADCcount_{diode\,i} - pedestal_{diode\,i})}{3}$$

A summary of our results, in comparison with the expected values from the TileCal LASER web page in reference [3], is shown in table one. Expected values were not available for filters one and seven. Our results were within experimental uncertainties of those posted on the LASER web page.

Name	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Attenuation Factor from Data	0.115 ± 0.0002	0.251 ± 0.005	2.435 ± 0.058	[illegible] ± 0.155	[illegible] ± 0.007	0.517 ± 0.0002
Attenuation factor from LASER web Page	N/A	[illegible] ± 0.003	N/A	N/A	[illegible] ± 0.003	[illegible] ± 0.024

Table 1. A summary of the experimental attenuation factor of the LASER filters in comparison with the expected value from the TileCal LASER web page.

Problems Observed

Histograms of the mean energy of the PMTs as a function of mean diode ADC count for each filter were obtained to check the system linearity. Similarly, histograms of the calibration constant as a function of event number were obtained.

The mean diode ADC count and the mean energy of the PMTs of TileCal were obtained for every intensity and every filter. They were fit with Gaussians. The mean of each Gaussian, as well as corresponding errors, were recorded.

The mean values from the Gaussians were used to plot the mean energy of the PMTs as a function of mean diode ADC count for each filter. An example is shown in figure 6. Since the response of the diodes are linear, we expected plots of mean PMT energy as a function of mean diode ADC count to be linear. However, we found that these plots instead exhibited an S-shaped curve, regardless of the module or filter used. We postulated this could be due to a problem with the gate of the diodes.

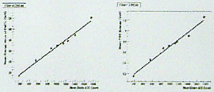

Figure 6. On the left is the mean energy of the PMTs as a function of mean diode ADC count for filter 4, where EBC44 denotes module 44 is being used to calculate the Energy of the PMTs. On the right is the mean PMT energy as a function of mean diode ADC count for module 44, filter 1. An unexpected S-shaped curve was observed, regardless of module or filter.

Histograms of the calibration constant as a function of event number were also obtained. The calibration constant was defined as

$$CalibrationConst = \frac{Energy_{PMT}}{MeanDiodeADCCount}$$

where $Energy_{PMT}$ refers to the energy from one PMT in one module of TileCal. We expected that when we plotted the calibration constant against the event number, we would see a horizontal line with no slope. An example of what we found is shown in figure 7. We observed slopes with significant values. For filters one and eight, the slope of the lines was of order of magnitude 10^{-6}. For filter four, the slope was significantly larger, ranging of orders of magnitude 10^{-3} to 10^{-4}. This suggests a dependence on frequency.

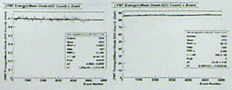

Figure 7. Calibration constants from the first PMT of the first module of TileCal as a function of event number. The left is for filter 1, intensity 20,000. The right is four filter 4, intensity 24,000.

Conclusions

We found a large dynamical range, from a few MeV to many GeV, was covered by the wheel filters. Furthermore, we found the LASER system intrinsic dynamic is of order 10 and does not depend on filter. Measurement of the attenuation factor for filters one, two, three, four, seven, and eight were within the range of experimental uncertainties in comparison to the values posted on the LASER web page. During the process of finding the dynamical range and attenuation factor of the wheel filters, many problems were observed. For instance, plots of PMT energy as a function of mean diode ADC count demonstrated an unexpected S-shaped curve. This non-linearity appears to have a significant influence on the LASER calibration constant stability. These problems are currently under investigation by the LASER group.

Literature Cited

[1] "The Large Hadron Collider." http://public.web.cern.ch/public/en/LHC/LHC-en.html. CERN, 2008.

[2] "A Short Introduction." http://atlas-tile-laser.web.cern.ch/atlas-tile-laser/LASERDescription.html. CERN, 2008.

[3] "Ongoing Work: LASER Instillation and Commissioning." http://atlas-tile-laser.web.cern.ch/atlas-tile-laser/LASERApplication_1.html. CERN, 2008.

Acknowledgments

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For Further Information

Please contact *meghan.shanks@drake.edu*. More information on projects related to ATLAS and the Large Hadron Collider may be found at http://public.web.cern.ch/public/en/LHC/ATLAS-en.html.
My paper on the calculation of the dynamic and attenuation factors of the LASER wheel filters may be found at http://www.um-cern-reu.org/links.html