TileCal D-cells Trigger Output Measurement

Daiki YAMAGUCHI (PH-ADE-CA)

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Abstract

I report my work which I have done in CERN Summer Student Programme. I have participated in Level One Tile Endcap Muon trigger group, in LHC ATLAS Experiment, and measured the features of some modules in Hadronic (Tile) Calorimeter. The result is presented in this report.

1 Introduction

I have participated in Level One Tile Endcap Muon trigger group during CERN Summer Student Programme. In this section, I will introduce the ATLAS experiment, the Tile Muon group and the goal of my work.

1.1 ATLAS Experiment and Tile Calorimeter

ATLAS [1] is a particle physics experiment at the Large Hadron Collider (LHC) at CERN that is searching for new discoveries in head-on collisions of protons of extraordinarily high energy. 3000 scientists in 174 universities and labs from 38 countries are participating in ATLAS experiment. ATLAS detector, shown in Figure 1, is 25 meters in diameter, 46 meters length, 7000 tones weight. It consists of Inner Detector, Electromagnetic (EM) Calorimeter, Hadronic Calorimeter, Toroid Magnets, and Muon Detectors.

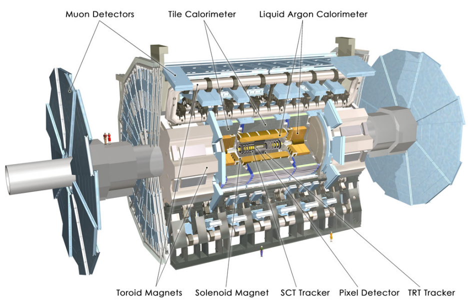


Figure 1: A computer generated cross-section of ATLAS detector, which is 25 meters in diameter, 46 meters length, 7000 tones weight. It consists of Inner Detector, Electromagnetic (EM) Calorimeter, Hadronic Calorimeter, Toroid Magnets, and Muon Detectors. Inner Detector is composed of Pixel Detector, SCT Tracker, and TRT Tracker.

Inner Tracker, Calorimeters, and Muon Detector are responsible for tracking charged particles, particle energy measurement, and muon identification and tracking, respectively.

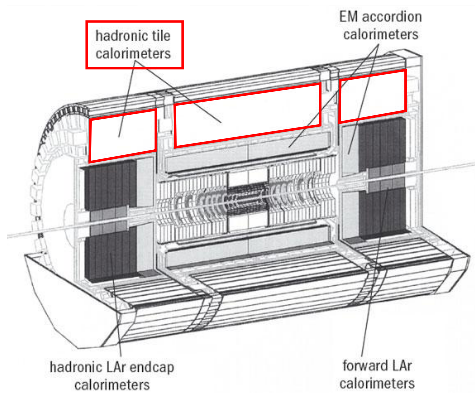


Figure 2: Electromagnetic (EM) Calorimeter and Hadronic Calorimeter, which consists of barrel and end-cap parts. The barrel part of Hadronic Calorimeter is Tile Calorimeter [2], composed of steel plates and scintillating tiles.

EM Calorimeter and Hadronic Calorimeter is shown in Figure 2. Hadronic Calorimeter consists of the barrel part and the endcap part. The barrel part is Tile Calorimeter [2], composed of steel and scintillator tiles (see Figure 4). More details about the Tile Calorimeter structure will be shown in section 1.2 and 1.3.

1.2 Level One Tile Endcap Muon trigger group

The main source of background in the endcap region of the level one muon trigger is due to low momentum protons emerging from magnets and shield in the foward region. With the increased luminosity after LHC upgrade, the fake muon rate will be quite high and has to be reduced to allow for important physics triggers in the limited level one trigger bandwidth. In order to reduce them, muon is selected by requiring muon signals in the outer cells (D-cells) in the Tile Calorimeter, which are located before magnets and shields [3]. The selection allows to reduce fake muon rate efficiently. The group is very active to be ready by the restart of LHC physics programme in early 2015.

1.3 The purpose of my work

The study is limited to the pseudo-rapidity region $1.0 < |\eta| < 1.3$. This region is covered by the Tile Calorimeter exetended barrel [3]. Figure 1 shows the long barrel and extended barrel sections of it. Each calorimeter cell is connected to a pair of Photo Multiplier Tube (PMT), called L and R. PMTs are located in the outer radius girder in a so-called electronics drawer (Figure 2). Signals from PMTs are summed in analog way by the board called "adder" to form projective towers. Adder board has two outputs, hadron output and muon output. Hadron output is a sum of signals in each section, while Muon output is just a signal from one PMT connected to D-cell [5]. Until the year 2013, muon outputs were not used, but in order to reduce fake muon rate it will be necessary to use them. Therefore it is required to measure the following characteristics of the Tile muon trigger output signal, such as the gain, pedestal mean, and pedestal RMS, of EBA and EBC D-cells.

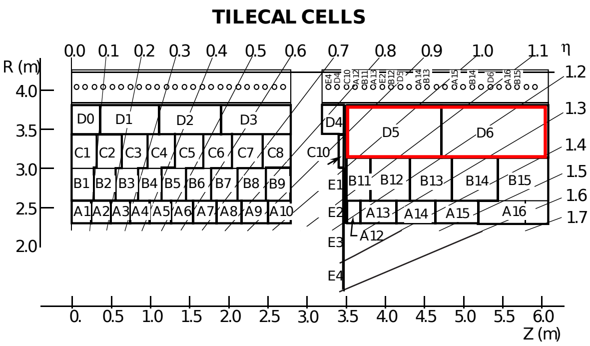


Figure 3: the long barrel and extended barrel sections of Tile Calorimeter is shown. One D-cell covers 1/64 in ϕ and 0.2 in η in the long barrel cells D0, D1, D2, and D3. D4, D5, and D6 is located in the extended barrel. D4 is not connected to Muon output. D5 covers from 0.85 to 1.20 in η, D6 covers from 1.05 to 1.40 in η [5].

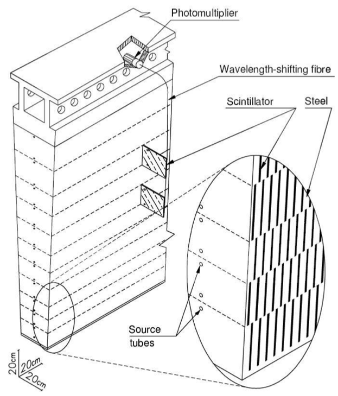


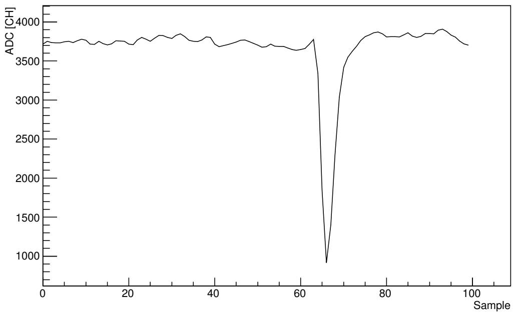
Figure 4: A part of Tile Calorimeter. Two sides of each cell are connected to independent PMT. PMT is located in the outer radius girder in a so-called electronics drawer [5].

2 Measurement procedure

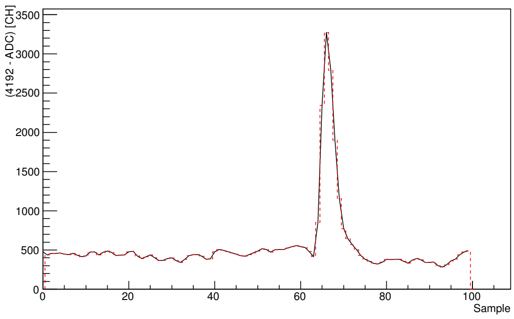
For the measurement, we use MobiDICK5 [6], which includes Fast Analog to Digital Converter (FADC) board. Analog signals from detectors are sampled and converted to digital values correspond to the pulse height in the board, and we can measure the signal. Our measurement procedure is the following:

- Use CIS (Charge Injection System) to inject test signals
- Inject six different charges from 0 to 15 pC.
- Read analog signals with 12 bit FADC
- Take 100 samples of 25 ns per event
- Store the data as text files
- Convert to ROOT Ntuple
- Calculate the gain, pedestal mean, and pedestal RMS.

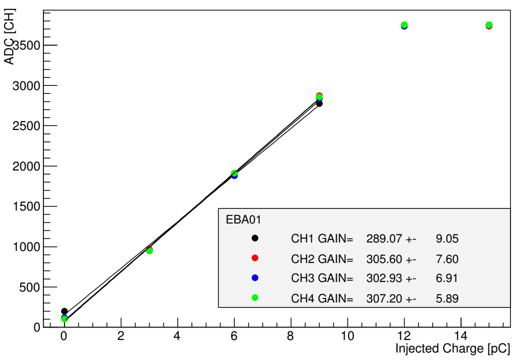
Figure 5 (a) shows the raw data obtained with MobiDICK5. At first, the raw data is turned upside-down by computing 4192 − ADCcounts, shown in Figure 5 (b). The data from 0 to 45 samples, where any signal does not exist, is used to calculate the pedestal value. The pulse height is calculated by subtracting the pedestal value from the maximum value. Filling the pulse height mean value every injected charge into histograms, I get the mean value every injected charge, and plot them as a function of injected charge, shown in Figure 5 (c). I fit them by a straight line to calculate the slope, which corresponds to the gain value. On the other hand, to calculate the pedestal mean and RMS, the data from 0 to 45 samples of all events and injected charges are filled into a histogram. Then, we can get the pedestal mean and RMS.



(a)



(b)

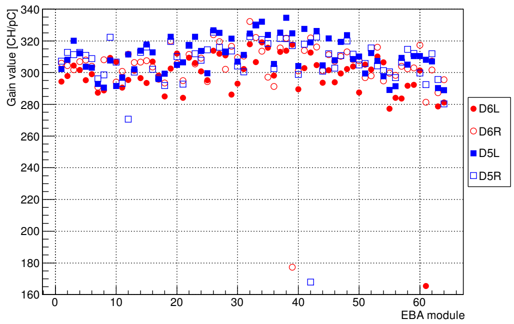


(c)

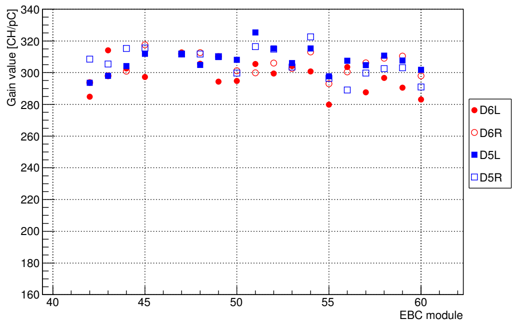
Figure 5: (a): The raw data of EBA01 gained with MobiDICK5 in USA15. (b): The data converted (a) by 4192 – ADCcounts. (c): The plot shows the plus height as a function of injected charge. Fitting the plot by a straight line, the gain value of each PMT can be gained.

3 First measurement

We measured all 64 EBA and 18 EBC D-cells modules from 1st Aug. to 15th Aug. The gain value, pedestal mean, and pedestal RMS obtained from the measurements are shown as a function of module number in Figure6, 7, and 8, respectively.

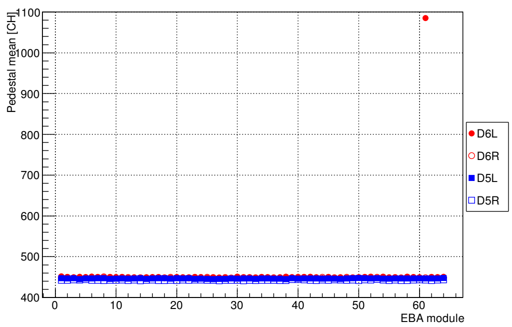


(a) EBA module

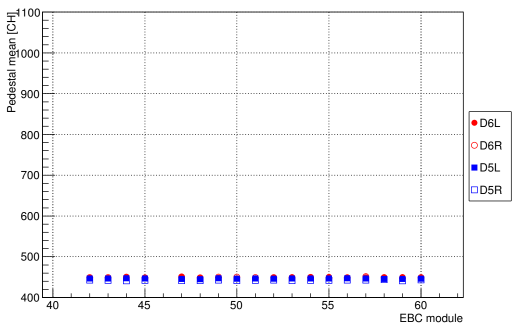


(b) EBC module

Figure 6: The gain value as a function of EBA module (a) or EBC module (b).

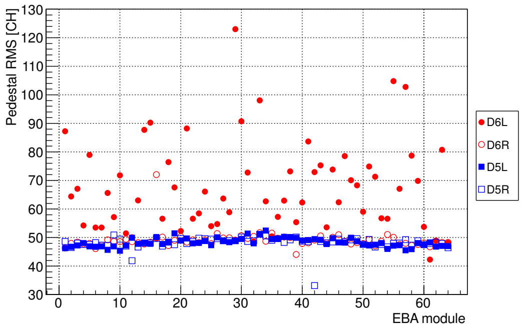


(a) EBA module

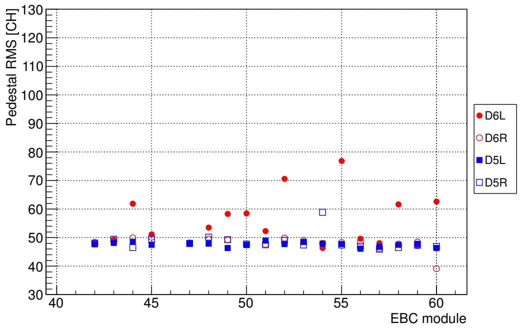


(b) EBC module

Figure 7: The pedestal mean as a function of EBA module (a) or EBC module (b).



(a) EBA module



(b) EBC module

Figure 8: The pedestal RMS as a function of EBA module (a) or EBC module (b).

Shown in Figure 6, the gain values of most EBA modules are around 305 [CH/pC], except some points. Almost all the pedestal means, shown in Figure 7, are around 450 ADC counts except D6L of EBA61. But the pedestal RMSs of most D6L are higher than D6R, D5R, and D5L. In case of D6L of all EBA modules, the average of the pedestal RMS is 67.4 ADC counts, while in case of the others, the average is 48.5 ADC counts. In addition, they are discrepant in D6L and D6R. It is necessary to figure out the cause and fix it as soon as possible. Therefore we stopped measuring EBC modules, and carried out detailed tests to solve the problems.

4 Detailed tests

4.1 Tests in USA15

To solve the problem, we measured a few modules in detail. Figure 4.1 shows the simple scheme of cabling from detectors.

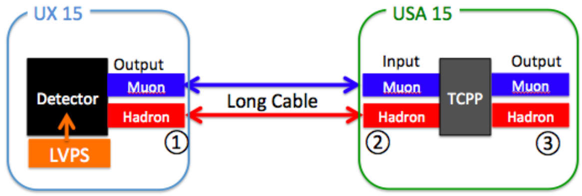


Figure 9: In UX15, ATLAS cavern, super drawers are equipped with Low Voltage Power Supply (LVPS), and have two output, Hadron output and Muon output. The two outputs are connected to TileCal Patch Panel (TCPP) rack in USA15 cavern. TCPP has also Hadron output and Muon output for triggers [2]. But Muon output has not been used for level one trigger until now.

We measured EBA21 at three different points. One is to measure it with MobiDICK5 connected to the detector directly (① in Figure 4.1). One is after the long trigger cable (② in Figure 4.1). The other one is after TCPP rack (③ in Figure 4.1). The results are summarized in Table 1.

Table 1: The result of EBA21. ①, ②, ③ mean the pedestal RMS gained by measurement with MobiDICK5 directly connected, after the long trigger cable, after TCPP rack, respectively, shown in Figure 4.1.

PMT	①	②	③
D5L	64.16	52.04	48.71
D5R	61.15	51.10	48.58
D6L	64.40	66.04	64.50
D6R	62.83	51.00	48.33

As you see from Table 1, the pedestal RMS of D6L after the long trigger cable is higher than that in UX15. It indicates that the long trigger cable has some problem. The next step is to swap the muon cable(blue line in Figure 4.1) and hadron cable(red line in figure 4.1). At first we measured EBA15 in normal condition, and then swapped the cables, and then measured it again. The result is shown in Table 2. In Table 2, the pedestal RMS of D6L before and after swapping the cables are higher than those of other PMTs. It indicates that the long trigger cable has no problem.

Table 2: The result of measurement of EBA15 before and after swapping the muon cable and the hadron cable.

PMT	No swap	after swap
D5L	50.67	50.72
D5R	51.59	51.01
D6L	92.16	91.09
D6R	50.09	51.43

Therefore, we changed the standard LVPS used in the detector to a portable power supply used by the maintenance team. We measured EBA15 at three points, same as measurement of EBA21 shown in Figure 9. The result is shown in Table 3. As you see in Table 3, the pedestal RMS of D6L with portable power supply are less than that with LVPS. We have found that LVPS has an influence in one channel.

Table 3: The result of measurement of EBA15 with LVPS or portable power supply used by maintenance.

PMT	LVPS	portable PS		
	UX15		before TCPP	after TCPP
D5L	63.73	61.86	57.71	46.98
D5R	61.62	60.62	61.17	47.63
D6L	115.3	59.94	58.45	48.81
D6R	63,51	62.34	58.64	47.73

It is required to compare with some modules equipped with old LVPS and new LVPS. The maintenance team has replaced old LVPS to new LVPS. I remeasured 10 modules with new LVPS in the same condition as the first measurement, and compared the pedestal RMS of modules with old and new LVPS. The result is shown in Figure 4.1, where OLD and NEW represent the pedestal RMS of EBA modules with old LVPS and new LVPS, respectively. In terms of D6L, the average of the pedestal RMS reduced by 8.6% comparing that with old LVPS. Therefore the replacement of LVPS is effective to reduce the noise, but it is not enough.

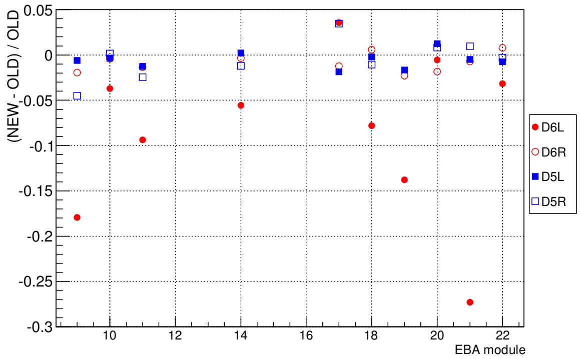


Figure 10: The comparison with modules equipped with old LVPS and new LVPS. OLD and NEW represent the pedestal RMS of EBA modules with old LVPS and new LVPS, respectively.

4.2 Test in the drawer lab

We thought that the cause may be due to delay cables [4] connected between PMTs and the adder board in the drawer. The reason is that the delay cable of D6L is especially longer than the other PMTs, shown in Table 4.

Table 4: The length of delay cables in the drawer [4].

PMT	Length [cm]
D5R	70
D5L	60
D6L	170
D6R	120

We needed to figure out the cause of D6L noise more precisely at laboratory level. There is EBC00 module in the drawer lab for some tests. We decided to use EBC00 equipped with new LVPS.

At first, we measured it before and after swapping the delay cables between PMT37 and PMT38, because PMT37 and PMT38 correspond to D6R and D6L, respectively. For the test, we took the connectors of delay cables from the board, and swapped the cables, as shown in Figure 4.2. But the results, shown in Table 5, are the pedestal RMS of D6R before swapping is higher than the other PMTs, while after swapping that of D6L is higher than the other PMTs. Therefore there is no difference between the pedestal RMS before and after the swapping of the cables.

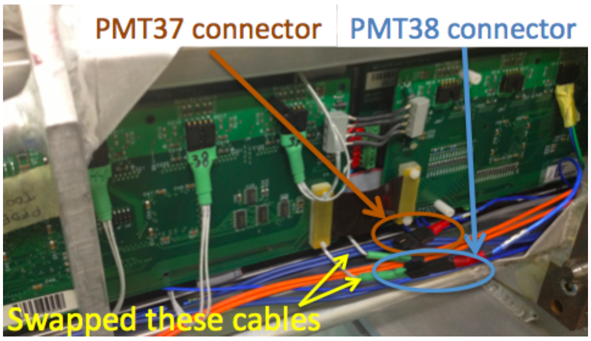


Figure 11: Scheme of PMT37 and PMT38 connectors in the drawer. Both connectors were unplugged, and the delay cables were swapped.

Table 5: The result of tests before and after swapping delay cables of D6R and D6L. The pedestal RMS is shown, in units of ADC counts.

PMT	before swapping	after swapping
D5R	49.5	49.6
D5L	48.1	48.8
D6L	49.5	51.2
D6R	55.0	49.6

As the next step, the connectors were put behind the boards, and then the measurement was started. The result is shown in Table 6. As you see, in case of putting PMT38 connector behind the board, the pedestal RMS of D6L becomes higher. Since all connectors in the drawer are the same, the cause of the noise should be the location of the connector in the drawer.

Table 6: The result of tests after putting the connectors behind the board. The pedestal RMS is shown, in case when only PMT37 connector is put behind the board, in case when only PMT38 connector is put behind the board, and in case both connectors are put behind the board. The unit is ADC counts.

PMT	only PMT37	only PMT38	both PMTs
D5R	49.2	45.8	49.4
D5L	48.5	42.3	48.6
D6L	49.9	46.9	49.6
D6R	63.6	45.5	69.3

The next step is to put PMT37 connector or both connectors in same way at the position where PMT38 connector was located originally. The result is shown in Table 7. When any of the connectors is located in this position, the noise is higher.

Table 7: The result of tests after putting the connectors at the position where PMT38 connector was located originally in the same way. The pedestal RMS is shown, in case only PMT38 connector is put at the position, and in case both connectors are put at the position. The units are ADC counts.

PMT	only PMT38	both PMTs
D5R	45.2	48.7
D5L	44.5	45.9
D6L	73.3	68.3
D6R	47.6	56.5

Then, we shielded the connectors by electrical conductive material(copper tape), put them behind the board (Figure 12), and remeasured it. The result is shown in Table 8. When the connector is shielded, the pedestal RMS is around 48 ADC counts, which is the same level as those of D5R and D5L. It means that shielding is effective to reduce the noise.

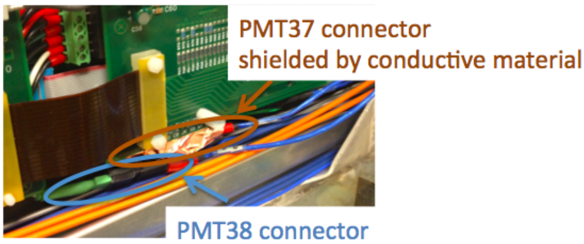


Figure 12: Scheme of PMT37 and PMT38 connectors in the drawer. Both connectors was unplugged, and the delay cables are swapped

Table 8: The result of tests after shielding by copper tape. The pedestal RMS is shown, in case only PMT37 connector is shielded, and in case both connectors are shielded. The unit is ADC counts.

PMT	only PMT37	both PMTs
D5R	48.0	49.0
D5L	48.3	48.6
D6L	54.8	48.8
D6R	48.4	47.9

In addition, I tested for PMT17 and PMT18 in the same way as that for PMT37 and PMT38. After the measurement of the pedestal RMS in normal condition, I shielded PMT17 and PMT18 connectors and put them back behind the board. The result is shown in Table 9. As you see in Table 9, all pedestal RMS are around 50 ADC counts. It indicates that PMT17 and PMT18 connectors are not necessary to be shielded.

Table 9: The result of tests for PMT17 and PMT18 after shielding the connectors by copper tape. The pedestal RMS is shown, in case of normal condition, and in case both connectors are shielded and put them back behind the board. The unit is ADC counts.

PMT	Normal	Shiled and put back
D5R	50.2	49.8
D5L	51.4	49.6
D6L	49.9	50.0
D6R	51.9	51.7

4.3 Summary

I summarize the result of D6L noise described in section 4.1 and 4.2. At first, since the noise is less in case of portable PS, LVPS has some effect upon some ground or power line on the board in the drawer. The effect of new LVPS is less than that of old LVPS. The effects on the line, which is something like electrical fluctuation or oscillation, generate the electromagnetic field near some part of the board, and on the lines in the connector the noise is induced by the field.

Therefore, shielding the connectors by electrical conductive material is effective to reduce the noise.

5 Conclusion

I was taking part in the Tile Muon Trigger group to use D-cell information for the Level 1 trigger in order to reduce the fake muon rate coming from protons emerging from the magnets and shields, and that in order to effectively use the D-cell information one has to characterize the hardware, by measuring the pedestal, noise and the gain of the D-cell muon trigger output.

For the measurement, we were using MobiDICK5, which includes FADC board. Analog signals obtained from using CIS are sampled and converted to digital values correspond to the pulse height in the board. We calculated the gain, the pedestal mean and pedestal RMS of PMTs by using the digital signal.

At first, we measured all 64 EBA modules and 18 EBC modules, and obtained the gain value, the pedestal mean, and pedestal RMS of these modules. But we had the problem that the pedestal RMS of D6L, corresponding to the noise of D6L, is higher than those of the other PMTs.

Secondly, we made the various tests in UX15 and USA15 to figure out the cause of the higher noise. As the result, we found that LVPS can have some effect to ground or power line on the board in the drawer of modules and induce the noise. But the effect of new LVPS are less than that of old LVPS.

Thirdly, we tested EBC00 more precisely in the drawer lab. The results indicates that the delay cable connectors can pick up noise from electromagnetic interference. We found a source of electromagnetic interference at the position in the drawer. The delay cable of EBC00 were moved from the normal position, and that was the reason for the higher noise on the D6R in this particular drawer.

There are two solutions for the noise reduction. One is keeping the connectors in reasonable distance from noisy spots in the drawer. But this is not always possible. The other is shielding the connectors by electrical conductive material. This is more effective.

References

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[6] MobiDick4 twiki page, `https://twiki.cern.ch/twiki/bin/viewauth/Atlas/MobiDick4`