WA98 FEE Test for PHENIX/EMCal CERN Data Analysis

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1 Purpose

We performed a PHENIX/EMCal high energy beam test at CERN in 1998. In this test, we had expected to confirm that the EMCal has a linear energy response within 2% in the beam energy region between 10 to 80 GeV. For the lead–scintillator calorimeter (PbSc), we confirmed the linearity within 2% in the energy region higher than 15 GeV. But we found a deviation of 3 to 4% at the 10 GeV energy point [1]. This deviation could not be explained specifically by the effects of analysis processes, pedestal subtraction, high/low gain ratio, tower-by-tower gain adjustment, or correction of time and position dependence, etc. The deviation of beam energy itself could not explain it either [2].

The deviation could be observed even by investigating the energy deposit in one tower by selecting beam hit position. Figure 1 shows the deviations from the linear energy response for one tower (channel 54) by selecting events with beam hit position at the center of the tower without any time-dependent gain-drift correction in the low HV setting. The low HV setting at CERN is a setting to cover 80 GeV energy region. Its maximum energy coverage in the low gain output (about 800 counts) is 160 GeV. At 10 GeV energy point, there is a deviation about 3.5% after pedestal subtraction.

We observed 3 to 4% deviation also at the 10 GeV point in the normal HV setting. The normal HV setting at CERN is a setting to cover up to 64 GeV at the maximum energy coverage in the low gain output.

We need to know the reason why this deviation occurs. One possible reason is non-linearity of our readout system. The EMCal towers were readout by PMTs and the signals were processed by the CERN/WA98 FEE. The PMTs for the PbSc readout are FEU115M which are assured to be linear within 2% by the previous measurement described in Ref.[3]. We need to check the linearity of the CERN/WA98 FEE. We setup again the WA98 FEE at BNL in the same way used at the CERN test.

2 Setup

We tested the WA98 FEE which was used in the CERN test to readout the PbSc supermodule. As an input signal source, we used an arbitrary waveform generator (Tektronix AWG2020). It generated pulses with the function form

$$\exp(-t/5\text{nsec}) - \exp(-t/20\text{nsec})$$

which is shown in Fig.2 as a monitored picture using an oscilloscope.

The AWG2020 was operated in the external trigger mode triggered by a pulser at a repetition rate of about 10 Hz. To obtain small enough amplitude as the input signal, we used a variable attenuator and set it at $\times$ 0.5 attenuation or $\times$ 0.1 attenuation. Downstream of the attenuator, the signal was divided by a linear fan-in/fan-out NIM module (LeCroy 428F) into signals to the WA98 FEE and a signal to CAMAC ADC (LeCroy 2249W) for the monitoring purpose.

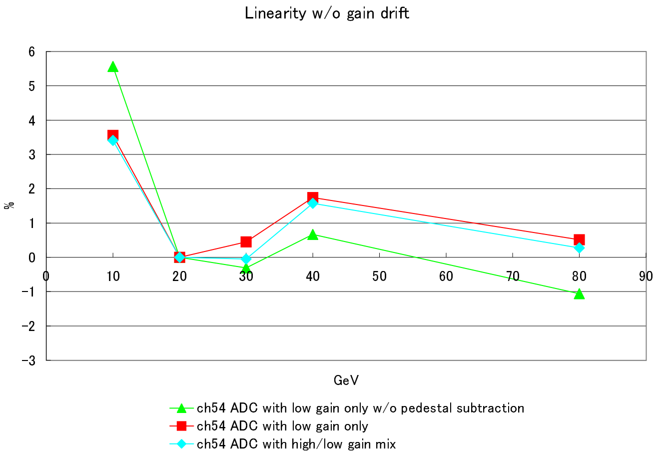

Figure 1: The deviations from the linear energy response for one tower (channel 54) by selecting events with beam hit position at the center of the tower in the low HV setting at CERN. Triangle points show the deviations without time-dependent gain-drift correction. Square points show the deviations after time-dependence correction by using low-gain output only. Diamond points show those by combining low-gain and high-gain outputs.

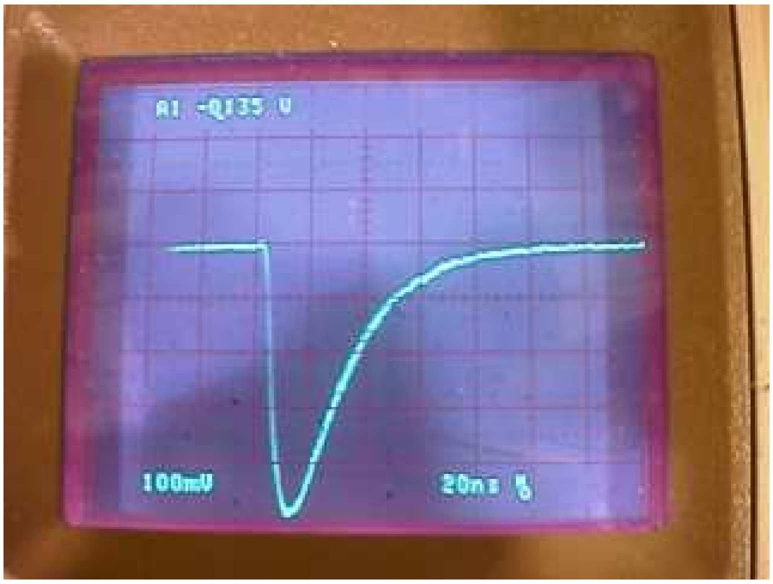

Figure 2: A monitored picture of the input signal generated by the AWG2020.

For the WA98 FEE, we need to adjust timings of the pre-sampling and the post-sampling by setting parameters $t2$ and $t1$ respectively. To make the relative timing of the pre-sampling and the post-sampling same as that at the CERN test, $t2 - t1 = 5$ is required. Figure 3 shows values of (pre-sampling - post-sampling) by setting several sets of $t2$ and $t1$ when some fixed charge was given. As a result, we set them at $t2 = 8$ and $t1 = 13$.

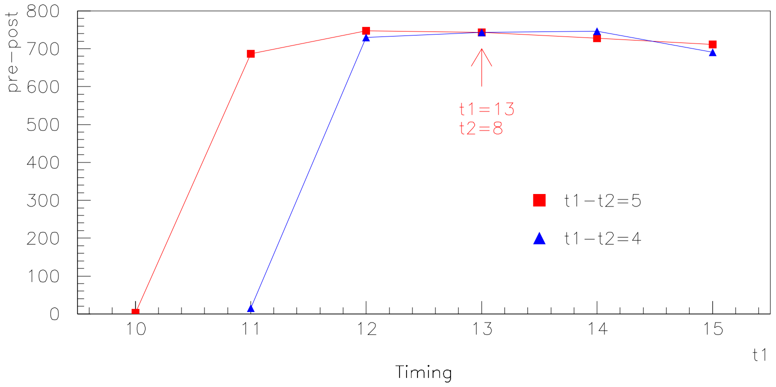

Figure 3: Values of (pre-sampling - post-sampling) by setting several sets of $t2$ and $t1$ for the WA98 FEE when some fixed charge was given.

3 Results

We took data of some channels of the WA98 FEE and one channel of CAMAC ADC for the divided AWG2020 signal, then compared them. The scatter plot of the WA98 FEE data and the CAMAC ADC data were fitted with linear line by fixing pedestal point of each data. Figure 4 shows the difference of the WA98 FEE data and the fitted value divided by the fitted value for the channel 54 of the WA98 FEE used in the analysis to make Fig.1. This ratio shows the deviation from the linear energy response. The origin in the figure corresponds to the pedestal point.

The results show linear behavior within 1% down to about 100 CAMAC ADC counts in the low gain output and down to about 50 CAMAC ADC counts in the high gain output. The 10 GeV energy point in the low HV setting at CERN which we have interest in corresponds to about 100 CAMAC ADC counts. The deviation of about 3.5% observed at CERN cannot be explained by the energy response of the WA98 FEE. The 10 GeV energy point in the normal HV setting corresponds to about 200 CAMAC ADC counts in the same figure. The energy response is also linear within 1% at this point.

Figure 5 shows the same kind of ratio by comparing the WA98 FEE data with the AWG2020 setting voltage. The 10 GeV point in the low HV setting corresponds to about 0.2 V and that in the normal HV setting corresponds to about 0.4 V. The differences of circle points and triangle points for the AWG2020 voltage value between 0.1 V to 0.6 V show non-linearity of the AWG2020 response for the setting voltage value, but the non-linearity is within 1%.

We also need to check the linearity of the CAMAC ADC for the result shown in the Fig.4. The CAMAC ADC data were compared with the AWG2020 setting voltage. Figure 6 shows the difference of the CAMAC ADC data and the linear-fitted value divided by the fitted value. There is 2% deviation at maximum in the region between 0.2 V and 0.4 V where we have interest in. Although this deviation can be one reason of the non-linear behavior shown in Fig.4 in the region between 100 to 200 CAMAC ADC counts, correction of this effect make +1% deviation at 100 CAMAC ADC counts in Fig.4 to −1% deviation. The result do not change.

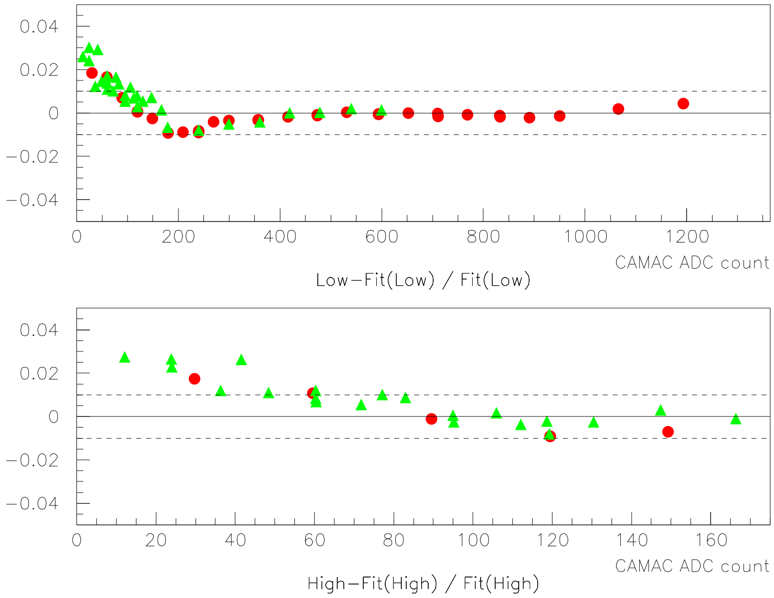

Figure 4: The differences of the WA98 FEE data and linear-fitted value of the WA98 FEE compared with the CAMAC ADC divided by the fitted value. The top figure shows this ratio in the low gain output of the WA98 FEE and the bottom figure shows that in the high gain output. Circle points show data taken by using $\times$ 0.5 attenuator setting and triangle points show those taken by using $\times$ 0.1 attenuator setting.

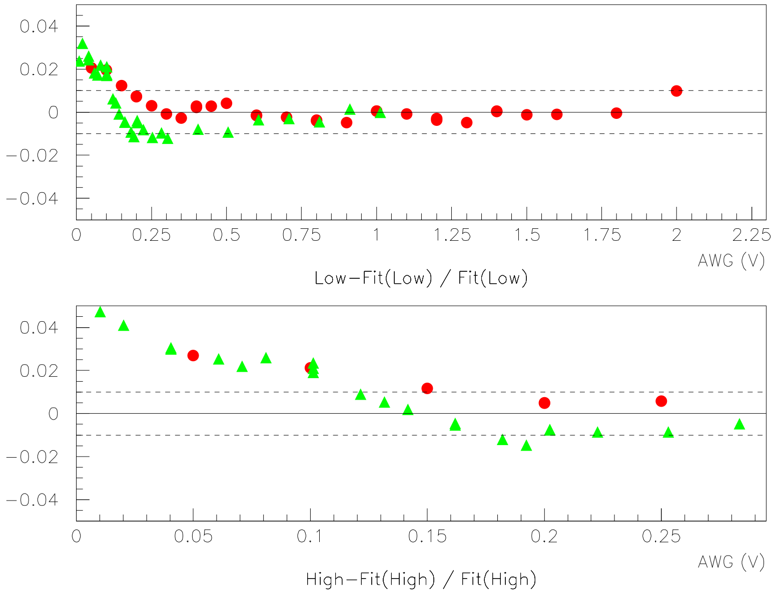

Figure 5: The difference of the WA98 FEE data and linear-fitted value of the WA98 FEE compared with the AWG2020 setting voltage divided by the fitted value. The top figure shows this ratio in the low gain output of the WA98 FEE and the bottom figure shows that in the high gain output. Circle points show data taken by using $\times$ 0.5 attenuator setting and triangle points show those taken by using $\times$ 0.1 attenuator setting. The AWG2020 voltage values of $\times$ 0.1 attenuator setting were normalized to those of $\times$ 0.5 setting by using observed normalized factor of these two settings.

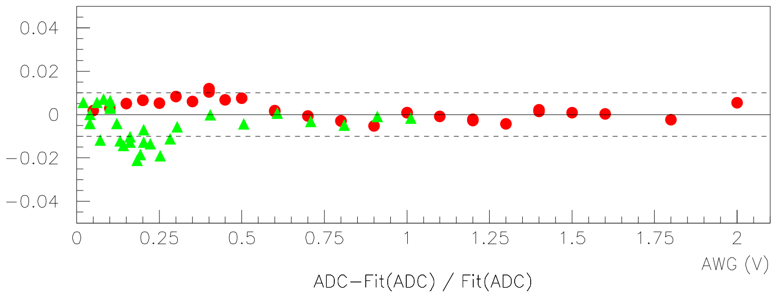

Figure 6: The difference of the CAMAC ADC data and linear-fitted value of the CAMAC ADC compared with the AWG2020 setting voltage divided by the fitted value. The AWG2020 voltage values of × 0.1 attenuator setting were normalized to those of × 0.5 setting by using observed normalized factor of these two settings.

4 Conclusion and Discussion about PHENIX FEE

From this test of the WA98 FEE we can conclude that we cannot explain the deviation of 3 to 4% at the 10 GeV energy point by the non-linear response of the WA98 FEE. As a conclusion of the CERN test, we confirmed that the PbSc has a linear energy response within 2% for the beam energy region between 15 to 80 GeV and we observed a deviation of 3 to 4% from the linear response, which cannot be explained by our knowledge. This deviation needs to be confirmed in the PHENIX setup by using the laser calibration system and physics signals, for instance, momentum-identified electron or π^0 mass peak position, and it must be calibrated to achieve known energy response within 2%.

The 10 GeV energy point corresponds to about 50 counts in the low gain output in the low HV setting and about 125 counts in the normal HV setting. This is at a critical point where we cannot use high gain output and we can get small counts in the low gain output. To achieve 2% measurement of 10 GeV energy, we need 1 to 2 counts accuracy as a result of the data processing. This energy region is the most difficult region to obtain accurate energy value.

The PHENIX FEE test at ORNL [4] showed the same level of linearity in the low gain output and much better linearity in the high gain output. Figure 7 shows the difference of the low gain output and 1-line and 2-line fitted value of the output compared with the input signal value divided by the fitted value. The signal value is converted to the energy scale in the 16 GeV maximum HV setting. The result by the 1-line fitting shows linearity within 0.5% down to almost 1 GeV and larger non-linearity under 1 GeV. The result by the 2-line fitting shows linearity within 0.5% in all measured region. We can compare the result with that of the WA98 FEE which showed linearity within 1% down to 10 GeV in the 160 GeV maximum HV setting (low gain HV setting at CERN). They are the same level.

Figure 8 shows the same kind of ratio in the high gain output. It shows linearity within 1% down to almost 40 MeV. In the test of the WA98 FEE, we showed linearity within 1% only down to 6 GeV in the 20 GeV maximum HV setting (low gain HV setting at CERN). The result of the PHENIX FEE test at ORNL is much better than this.

In the PHENIX FEE, the critical point corresponds to 1 GeV in the 16 GeV maximum HV setting. The energy region around 1 GeV is the most difficult region to achieve good energy accuracy. The PHENIX FEE has 16 times gain difference between the low gain output and the high gain output, while the WA98 FEE has 8 times difference. This will make the critical region wider than the WA98 FEE.

References

[1] H. Torii and Y. Goto, in preparation.

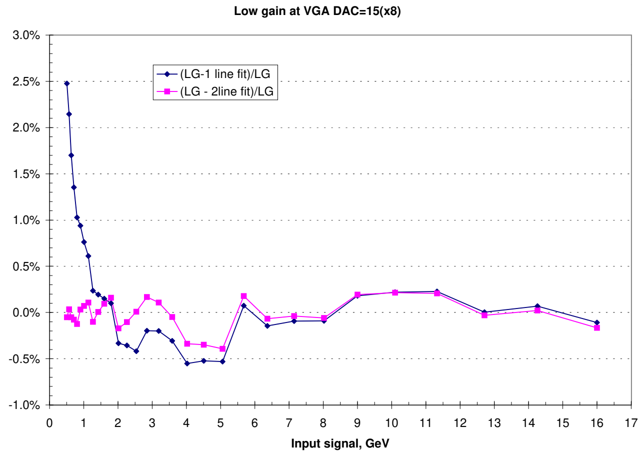

Figure 7: The difference of the PHENIX FEE low gain output and fitted value of the output compared with the input signal value divided by the fitted value. Diamond points show the result using 1-line fitting and square points show the result using 2-line fitting. The signal value is converted to the energy scale.

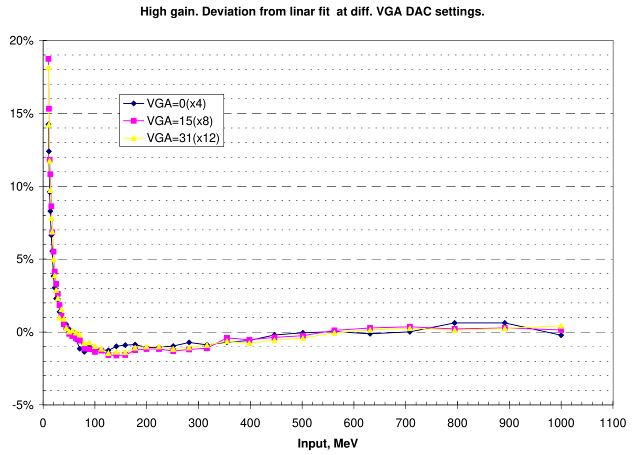

Figure 8: The difference of the PHENIX FEE high gain output and fitted value of the output compared with the input signal value divided by the fitted value. Those three lines show results for different VGA setting. The signal value is converted to the energy scale.

[2] G. Ambrosini et al., Eur. Phys. J. **C10** (1999) 605.

[3] G. David et al., IEEE Trans, Nucl. Sci. **42** (1995) 306.

[4] P. Stunkus et al., private communication