The High Dynamics Readout of PMT for BGO Calorimeter

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Abstract. For one cell of BGO-EM energy deposition of electron/gamma with energy above TeV is between 0.5 MIPs and $10^5$ MIPs, the readout system need to cover this high dynamic range.

1. Introduction
The role of calorimeter is used to measure the energy of incident particle. In order to measure the energy deposited in calorimeter, readout system should be designed carefully. In this paper, the current status of readout test is reported.

2. The Experiment Setup
The block diagram for the calibration measurement is shown in Fig.1. The LED was driven by pulse generator (GEN). Optical fibers were used to transmit light from the LED to the PMT which was coupled with a BGO crystal. The photon intensity incident on the photocathode was tuned by changing the amplitude of the supply voltage or the pulse width of GEN. The analog signal from PMT was amplified by VA32 which is a charged sensitive amplifier.

2.1. Response Function of PMT
The PMT response function could easily be described by eq. (1). [1-2]

$$S_{idear} = P(n, \mu) \otimes G_n(x)$$

$$= \sum_{n=0}^{\infty} \frac{P_n e^{-\mu}}{n!} \frac{1}{\sigma_1 \sqrt{2\pi}} exp\left(-\frac{(x-nQ_1)^2}{2n\sigma_1^2}\right)$$  \hspace{1cm} (1)

Here the number of detected photoelectrons in PMT cathode follow a poisson distribution. The gaussian distribution describe the response of a multiplicative dynode system to a single photoelectron.

\hspace{1cm} while \hspace{0.5cm} n = 0 \hspace{1cm} Q_1 = Q_0 \hspace{1cm} \sigma_1 = \sigma_0  \hspace{1cm} (2)

There are some parameters:
1. $\mu$ is the mean photon-electrons number detected by PMT,
2. \( \sigma_1 \) is the single photon-electron spectrum's sigma,
3. \( Q_1 \) is the position of single photon-electron peak,
4. \( Q_0 \) is the pedestal position,
5. \( \sigma_0 \) is the pedestal width.

For more detailed expression, please see reference [1].

### 2.2. Single Photon-electron Spectrum

In order to test our PMT, we carried out several LED spectra that were measured by XP2262B PMT. Fig. 2 showed the output of XP2262B. we can see as the light intensity of LED increase, the mean photon-electron numbers increase too. The results of spectral processing are showed in Table 1. The spectrum were de-convoluted by means of a program based on the Minuit Minimization package using the eq. (1) as a fitting function.[2]

The position of XP2262B’s single photon-electron peak was confirmed. So we can calculate the gain of PMT. The results were showed in Table 2.

Fig.3 shows the LED spectra measured by R5611 PMT. The fitting function is eq. (1) too. from the fitting result, we get the mean photon-electron number is 4.4. The position of single photon-electron peak of R5611 is 24.4 channel of ADC. We also could calculate the gain of R5611 is \( 1.7 \times 10^5 \) under 800 High Voltage.
3. The Readout of PMT

In order to cover very high dynamic range (0.5 MIPs to $10^5$ MIPs). We read signal from three dynodes of R5611. Fig. 4 shows the relationship between dynode 7 and dynode 4. As the light intensity of LED increase gradually, the signal of dynode 7 and dynode 4 increase too. The signal of dynode is about 20 times that of dynode 4. The range for each readout channel was tested using LED. Fig. 5 shows the output range of dynode 7 and dynode 4.

Fig. 5 shows the cosmic ray test system. The random trigger that we just want to know the pedestal position. The result of dy7 and dy4 output were showed in Fig. 6. The signal of dy7 is
We put an absorber between crystal and PMT window to attenuate photons (like Fig. 7), ensuring the response of Dy7 to 0.5 MIPs is about 40 channels. So the dynamic range of Dy7 is 0.5 MIPs to 125 MIPs. According the correlation between Dynode 7 and dynode 4, we can know the output range is from 100 MIPs to 2500 MIPs. The results were shown in Table 3.

### Table 3. The Dynamic Range of Output Channel

|     | Dy7 | Dy4 |
|-----|-----|-----|
| Min(MIPs) | 0.5 | 100 |
| Max(MIPs) | 250 | 2500 |

4. Further Development

We should complete dynode readout studies, especially dynode 1. The ”absorber” should test carefully. We will try to test another output way — PD and APD.

5. Conclusion

We have presented response function of PMT. Use LED to test dynode output. Construct a cosmic ray test system to test the dynode output of muon.
Figure 6. The result of cosmic ray test.

Figure 7. Absorber between crystal and PMT.

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7. References
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