Current status and performance of the BESIII electromagnetic calorimeter

Jian Fang, Zhigang Wang

Institute of High Energy Physics, Chinese Academy of Science, Beijing 100049, China

wangzhg@ihep.ac.cn

Abstract. The design and construction of the BESIII electromagnetic calorimeter is introduced briefly. Radiation dose of CsI(Tl) crystals is monitored and history graph of integral dose of crystals is showed. LED-fiber system is used for monitoring the EMC light output, and large decrease of light output of several crystals is discussed. BESIII electromagnetic calorimeter works very well and its performance reach the design value.

1. Introduction

Beijing Electron Positron Collider II and Beijing Spectroscopy III (BEPCII/BESIII) [1] is a major upgrade of BEPC/BESII. The BESIII detector is equipped with a CsI(Tl) crystal based electromagnetic calorimeter (EMC) [2] which plays an important role in the BESIII physics. In this paper, we present an introduction of the design of the BESIII EMC, the work status and performance of it.

2. BESIII Electromagnetic Calorimeter

BESIII EMC is based on CsI(Tl) crystals, with a designed energy resolution of 2.5% and a position resolution of 6 mm for 1 GeV showers. The EMC consist of barrel and endcap parts as shown in Figure 1. In the barrel, there are 120 sectors in phi direction, each consist of 44 crystals in z direction. The number of barrel crystals is 5280 in total. The crystals are 28 cm long, and typical size of the crystal is 5.2 cm by 5.2 cm in the front surface and 6.5 cm by 6.5 cm in the rear face. In the endcap, the crystals with similar dimensions as those in the barrel are arranged in 6 rings in radial direction. There are total of 960 crystals in two endcaps. In order to minimize the dead material and gap between the crystals, the crystals are suspended from the support girder.
Two photodiodes are attached to the back face of every crystals, the photon sensors are Hamamatsu S2744-08 (1 cm × 2 cm) photodiodes. Each diode is readout by one preamplifier [3]. The signals from the preamplifier are set to the main amplifier, the shaping time of the amplifier is 1 us. Then the signals are digitized in a Q module. The noise of the electronics is required to be less than 1100 electrons, equivalent to shower energy of 220keV. The readout units are housed in an Al box. The crystals are held by 4 screws drilled into the crystal, then mounted to the support structure. There are fibers emitting light from LED to each crystal for monitoring purpose.

3. Operation Experience

In order to ensure the safety of the crystals from the radiation, the radiation dose is carefully monitored by RadFET [4]. RadFET is an acronym for RADIATION-SENSING FIELD-EFFECT TRANSISTOR based on the metal-oxide-silicon p-channel structure. It is an integrating dosimeter which measures dose by virtue of the field effect caused by space charge trapped in an inorganic insulator. The RadFET probes are distributed at a radius close to crystal position, in the barrel 10 probes are positioned along the Z direction at one phi angle. There are 4 rows of probes at phi of 0, 90, 180 and 270 degrees, and there are 40 probes in barrel. In the endcap, each side placed 4 probes along the radius direction at one phi, and probes are placed in phi direction of 0, 90, 180 and 270 degrees, there are 32 probes in total in the endcap. The integral dose accumulated from beginning of collision to March 2012 is showed in Figure 2. The integral dose in the center of barrel is large than that at two ends. The integral dose at west endcap is larger than that at east. Integral dose accumulated from August 2008 to March 2012 is calculated. According to the design, the allowed radiation dose per year should be less than 200rads at crystals.
There is a LED-fiber system used to monitor the crystals light output during the EMC assembling and during data taking. Each crystal is connected to one fiber, it is used to check modules quality, monitor radiation hardness and EMC performance. The LED-fiber unit is composed of LED, light mixer and fiber bundle. The light intensity can be adjusted to simulate the energy deposited in crystal from 10 MeV to 2.5 GeV. There are two independent reference to monitor the light variances of each LED. The instability of the LED-fiber system is less than 1% in a run.

There are 76 LED-fiber units. According to the structure of EMC, 60 LED-fiber units in barrel, each serves 88 crystals, 16 units in endcap, each serves 60 crystals. Before assembly of super module, each cell is examined by LED-fiber system, if light output < 80% of PMT data, it will opened to check PD-crystal gluing and preamplifiers and so on. During data taking, the system serves to find out bad channels and monitor the performance of the EMC, including the gain reduction by radiation in each crystal. Relative decrease of light output measured by LED-fiber monitor is shown in Figure 3. In most of the crystal the light output decrease is less than 10%. There are 26 crystals light output decrease exceed 10%, among them 11 crystals exceed 20%. The result is agreement with the offline calibration by Bhabha data. Suddenly decrease of light output of some crystals has been found. This case has appeared before installation, and was confirmed that it was caused by loose gluing of PD to crystal. There is a crystal, it’s light output decreased to only 20%, this may be caused by total drop of PDs from crystal. All these crystal damages can be recovered by offline calibration. So far, there is no dead channel in EMC.

![Figure 2. The integral dose of RadFET over four years](image-url)
Every crystal is read out by two photodiodes. The two preamplifier outputs are received by two differential amplifiers and then go through a switching stage with two selections. Normally the selection A+B that sums the two photodiode outputs is used. If one photodiode or preamplifier lost, the selection 2A or 2B that boosts the signals by a factor of two is used. There are 10 crystals read out by one PD.

There is a water flow system used to control the temperature of the calorimeter in a suitable range. Water flow system of barrel operate normally and the maximum, minimum and average temperature of the barrel calorimeter over six months is showed in Figure 4. As a precaution of leakage, water flow system of endcap is stopped in 2009, the maximum temperature is blow 29 degree.

Gas-filled system was used to keep the calorimeter in a dry environment. It prevent the CsI(Tl) crystal from deliquescence and maintain the humidity in a suitable range. The gas of the system was changed from dry Nitrogen to freeze-dried compressed air and the humidity of crystals over six months is showed in Figure 5.

4. EMC Performance
In BESIII, Bhabha events are used to calibrate the gain of each crystal. From the Bhabha data, we can get energy peak and resolution of each crystal channel at 1.5 GeV. Those checks are shown in Figure 6 and Figure 7, respectively. It can be seen that data and MC results agree very well after the calibration with Bhabha. The energy resolution for $e^+e^-\rightarrow e^+e^-$ is $\sim$2.3% at the center-of-mass energy 3.097 GeV in barrel and 4.1% in endcap. At the same time the performance of the calorimeter has no degradation after 3 years running.
5. Conclusion

The performance of BESIII CsI(Tl) calorimeter is very good. All the 6240 channels are working well. The light output of the crystals is monitored by the LED-fiber system. The temperature and humidity control system are running normally. The performance observed meets the design requirements, and has no degradation after 3 years running.

References

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