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Introduction to BESIII EMC sub-trigger system

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ABSTRACT

The Electromagnetic Calorimeter (EMC) sub-trigger system is one of the important parts of the trigger system of the BESIII spectrometer. Together with the conditions from the other sub-trigger systems, cluster-related and energy-related trigger conditions are provided to the Global Trigger system for effective selection of events interested and rejection of backgrounds. Total two types of PCB boards are designed to implement the whole functions, which are Trigger Cell and energy Block Adding (TCBA) and Energy Adding and Cluster Counting (EACC). Simulations and hardware arrangement of the EMC sub-trigger system are introduced in this paper.

1. Introduction

Trigger system is the central event selection and hardware control system of the BESIII [1]. Information from the different detector electronics is transported to the corresponding sub-trigger systems to generate various trigger primitives and conditions. Some information from the TOF, MDC and Electromagnetic Calorimeter (EMC) sub-trigger systems is transported to the Track Match sub-trigger system to generate the related trigger primitives and conditions. All of the trigger primitives and conditions are transported to the Global Trigger system to generate the Level 1 pass signal L1*, which is fanned out to the trigger systems and to all the electronics for data acquisition. The whole trigger system works in pipeline mode with a clock frequency of about 40 MHz. Fig. 1 shows the scheme of the trigger system.

2. Simulation of the EMC sub-trigger system

Simulation is the base of the hardware design of the trigger system. According to the characteristics of the EMC and taking into account the experiences of the other experiments, Trigger Cell (TC) is taken as the fundamental element in the simulation. A good TC should be large enough to contain most of the showered energy and not too large for accurate positioning of a shower. By means of simulation the sizes and energy threshold are determined, the cluster-related and energy-related trigger primitives and conditions are defined.

2.1. Determination of TC

From simulations [2], a 4×4 matrix TC is determined for the barrel EMC as shown in Fig. 2. For the endcap part, a TC is composed of 15 crystals.

The TC division of barrel and endcap is shown in Fig. 3. There are 330 TCs in the barrel and 64 TCs in both endcaps.

2.2. Energy threshold of the TC

A good energy threshold should be low enough to have a good trigger efficiency for the minimum ionization particles and not too low for effective rejection of background hits. A threshold of 80–100 MeV is determined as shown in Fig. 4.

2.3. Trigger efficiency of EMC trigger subsystem

Trigger efficiencies for some important physics channels are studied and the result is given in Table 1.

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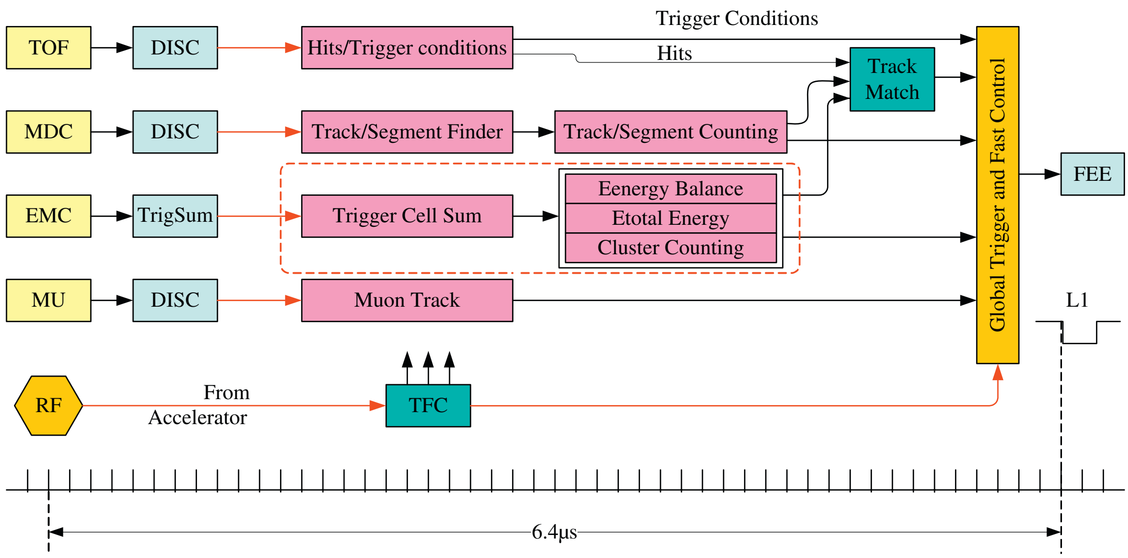

Fig. 1. Scheme of the trigger system.

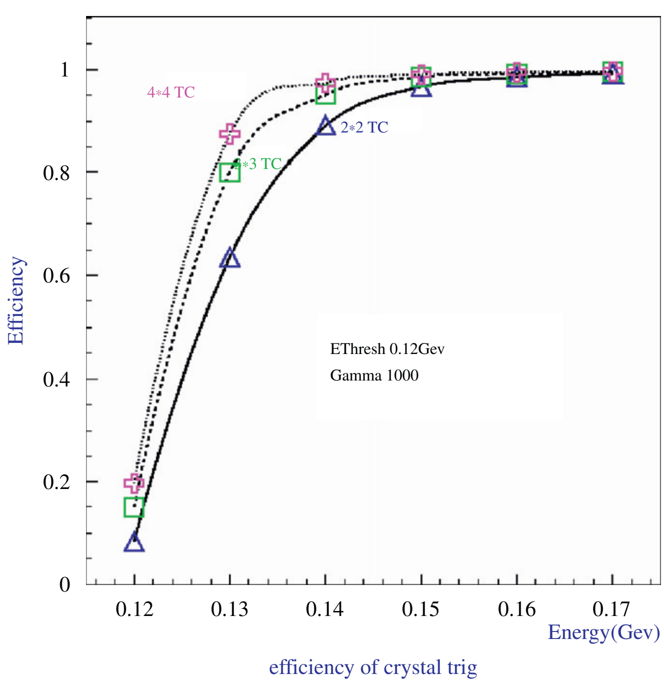

Fig. 2. Determination of the TC sizes.

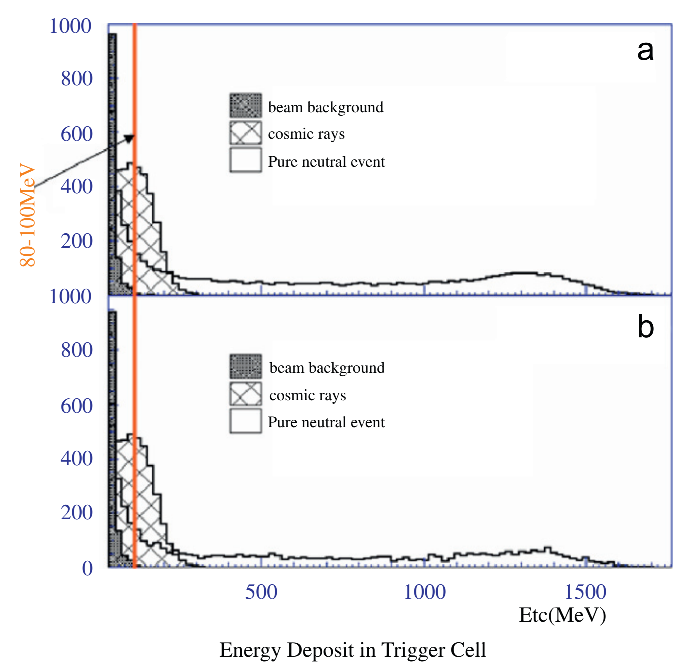

Fig. 4. Energy deposition in TCs.

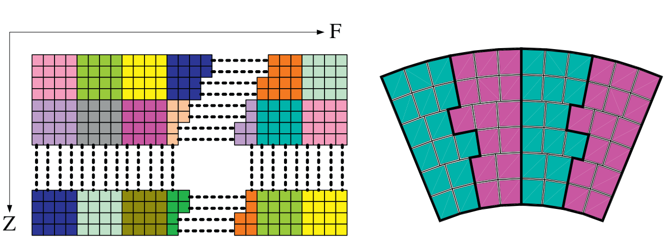

Fig. 3. TCs division (left: barrel; right: 1/8 endcap).

3. Trigger conditions of EMC trigger subsystem

EMC trigger primitives and conditions are based on two kinds of information [3]:

(1) the cluster information,
(2) the energy block information.

Table 1
United trigger efficiency of EMC trigger subsystem

	Combined EMC triggers (%)
Bhabha at 3.097 GeV	100
Radiative BB (3097 MeV)	100
$(3\gamma)J/\psi\to\gamma+\eta$	100
$(5\gamma)J/\psi\to\omega+\eta$	100
$J/\psi\to P+\bar{P}$	92.93
$J/\psi\to K^{+}K^{-}+\pi^{0}$	94.51
$J/\psi\to\gamma+\eta(1440)$	96.20
$J/\psi\to\rho+\pi$	90.87
$J/\psi\to\pi^{0}+P+\bar{P}$	96.20
$J/\psi\to$ anything	94.75
$\psi(2S)\to$ anything	96.67
$\psi(3770)\to$ anything	98.39

A detailed introduction will be presented below.

3.1. Isolated cluster finding

Several TCs may be fired by a showered particle. A cluster finding logic should be established to find out the TC that stands for the shower. From simulations and experiences of the other experiments, the logic of the isolated cluster finding [2] shown in Fig. 5 has been developed.

3.2. Definition of the energy blocks

Energy blocks are the basic components of the energy-related trigger primitives and conditions, and their definition is shown in Fig. 6. Twelve energy blocks are involved in barrel, which are named as BLK1, BLK2, ..., BLKC, and each endcap is an energy block, named as BLK West and BLK East.

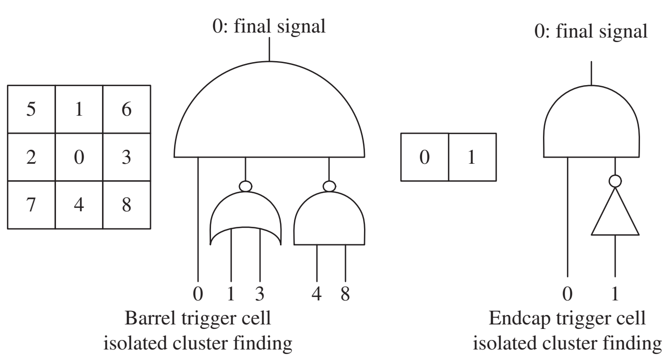

Fig. 5. Isolated cluster finding logic.

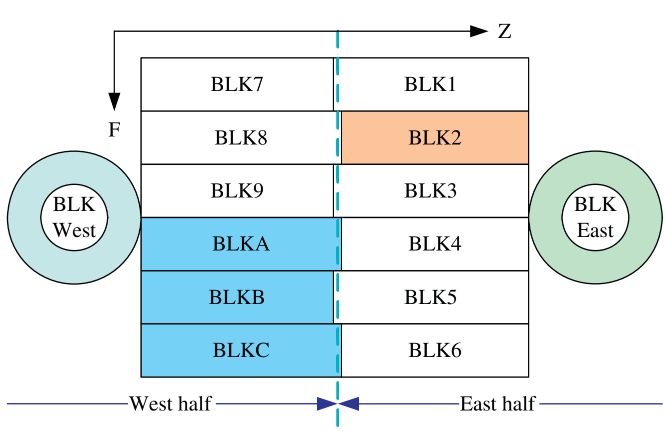

Fig. 6. Energy block definition.

Table 2
EMC cluster trigger conditions

Name	Comments
NClus⩾1	Cluster counts are greater than or equal to 1
NClus⩾2	Cluster counts are greater than or equal to 2
BclusBB	Back to back cluster in barrel
EblusBB	Back to back cluster in endcap
ClusPhiB	Barrel cluster balance at Φ direction
ClusPhiE	Endcap cluster balance at Φ direction
ClusZ	Each half at Z direction has at least 1 cluster

Table 3
EMC energy trigger conditions

Name	Comments
BEtotH	Total energy of barrel exceeds the high threshold
EEtotH	Total energy of endcap exceeds the high threshold
EtotL	Total energy of all EMC exceeds the low threshold
EtotM	Total energy of all EMC exceeds the middle threshold
BL_Z	Z direction energy balance (include barrel and endcap)
DiffB	Energy difference balance between each barrel half
DiffE	Energy difference balance between each endcap half
BL_BLK	Energy balance of barrel blocks
BL_EEMC	Energy balance between east and west endcap

3.3. Trigger conditions

Two types of trigger primitives are defined as shown in Tables 2 and 3. One is the cluster-related ones for shower positioning and counting, another one is the energy-related ones for energy balance and total energy decision. When a primitive is satisfied, the relevant condition signal is set active.

4. Hardware scheme of EMC trigger subsystem

The hardware scheme of the EMC sub-trigger system is shown in Fig. 7. Two types of PCB board are designed to fulfill the whole functions, which are 16 Trigger Cell and energy Block Adding (TCBAs) and 1 Energy Adding and Cluster Counting (EACC).

TCBA is the interface between the EMC front end electronics and EACC. Analog signals from TC in one energy block are sent to one of the TCBA boards. Data which represent the TC hits and total energy of the block are generated by this board and are sent to the EACC board with optical fibers.

4.1. Scheme of TCBA board

There are two main parts in TCBA board [3]: analog part and digital part. The scheme of TCBA is shown in Fig. 8.

When the analog TC signals from one energy block are fed to a TCBA board, they are processed in two parallel ways: generating a 30 bit TC cluster information by discriminators, and adding all the 30 analog signals to form a partial total energy signal, which is digitized (named "energy information") with a 10 bit FADC thereafter.

To determine the time information of the TCs accurately, a high-threshold discrimination and low-threshold timing logic is implemented in the discriminator.

All the TC information and the energy information are assembled in FPGA, and the clock frequency of FPGA is 40 MHz. Two steps are used to transfer the complete information (30 bit TCs information and 10 bit energy information) to EACC board.

4.2. Scheme of EACC board

EACC board scheme is shown in Fig. 9. All the trigger primitives are generated in the EACC board. The cluster and energy parts are processed independently.

Five main function modules are involved in the main FPGA of EACC board: "Data Distributor", "CSUM Logic", "ETOT Logic", "Data Storage Logic" and "Condition Shape Logic".

The module of Data Distributor selects the cluster and energy data from all block information, then send the cluster data to the module of CSUM Logic, at the same time, send the energy data to the module of ETOT Logic.

Two kinds of the job, cluster finding and trigger condition generating, are fulfilled by CSUM Logic. Seven trigger conditions are formed by the logic which are shown in Table 2.

The energy trigger conditions are produced by the module of ETOT Logic. Same as the cluster trigger conditions, there are two kinds of energy trigger conditions: total energy and block energy balance. The ETOT trigger conditions are shown in detail in Table 3.

The function of Data Storage Logic module is to save and readout the event data of interest. All the raw data received from TCBA board and all the trigger conditions generated by EACC board are stored in a temporary buffer in pipelined mode. When a Level 1 pass signal L1* arrives, the proper data are transferred to the global buffer, which will be readout by online readout in CBLT mode.

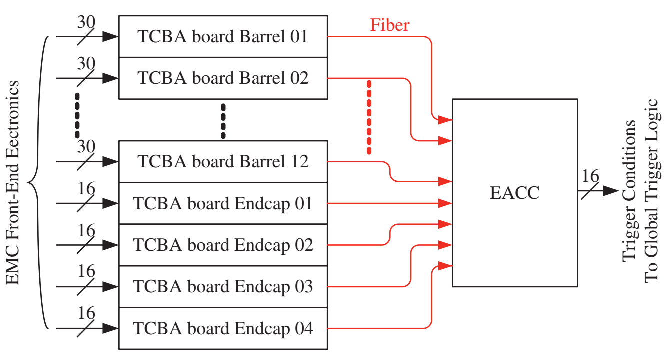

Fig. 7. Scheme of EMC sub-trigger system.

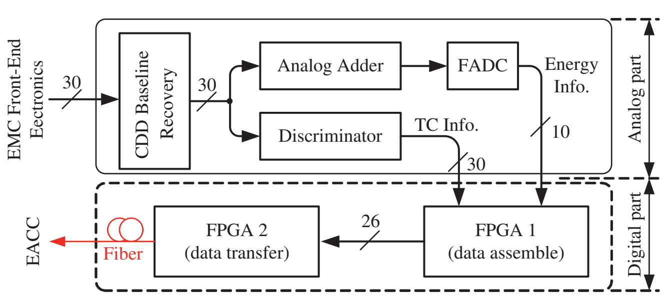

Fig. 8. Scheme of TCBA board.

Before the EMC trigger conditions feed to Global Trigger Logic, all the trigger signals must be shaped to a fixed width of about 300 ns. All the trigger conditions are sent out when the trigger condition NClus$\geqslant$1 for the alignment and timing considerations.

Two parts of the job are disposed in the module of VME interface and FPGA online configuration: One is to give the proper timing and acknowledgement signal during VME read and write process, and the other one is to configure the FPGA from VME bus or Flash Memory.

4.3. Technique adopted in EMC sub-trigger system

(1) FPGA online configuration technique.
As a part of hardware design in BESIII trigger system, online FPGA configuration technique [4] based on VME BUS can provide a flexible and reliable FPGA configuration method for the system. The scheme is presented in Fig. 10.
The FPGA configuration data are written to Flash Memory from VME bus before system is put in regular work. The configuration data can be loaded into FPGA automatically from Flash Memory when power is on. The FPGA can be reconfigured also from VME bus when necessary.

(2) RocketIO and optical fiber technique.
RocketIO and optical fiber technique [5] are used to reduce the number of cables and eliminate the common ground noise between the trigger system and the front end electronics systems.

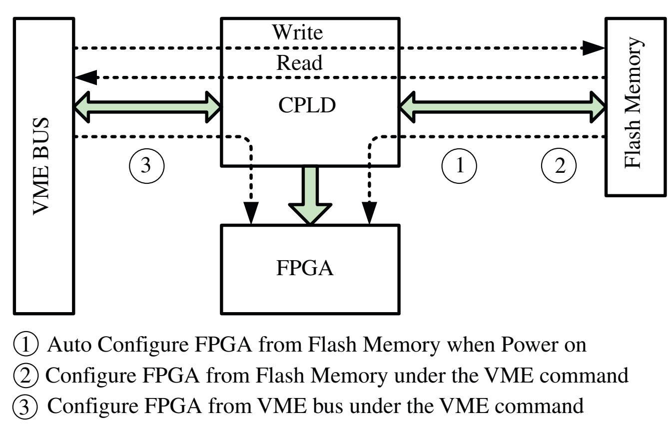

Fig. 10. Scheme of online FPGA configuration.

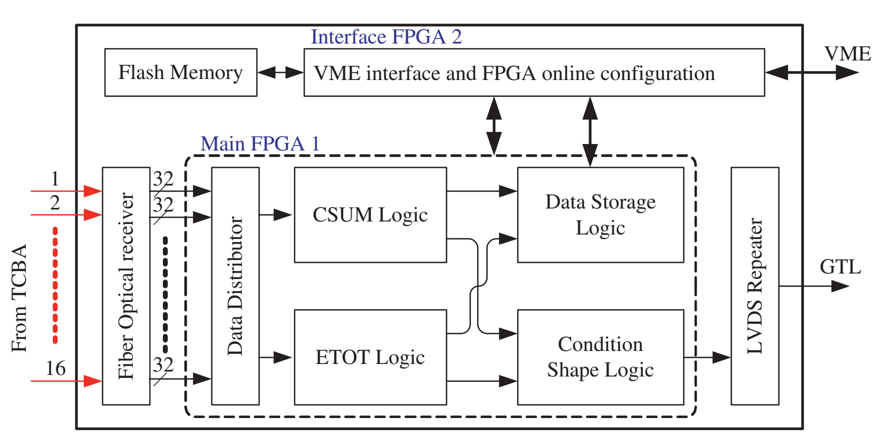

Fig. 9. Scheme of EACC board.

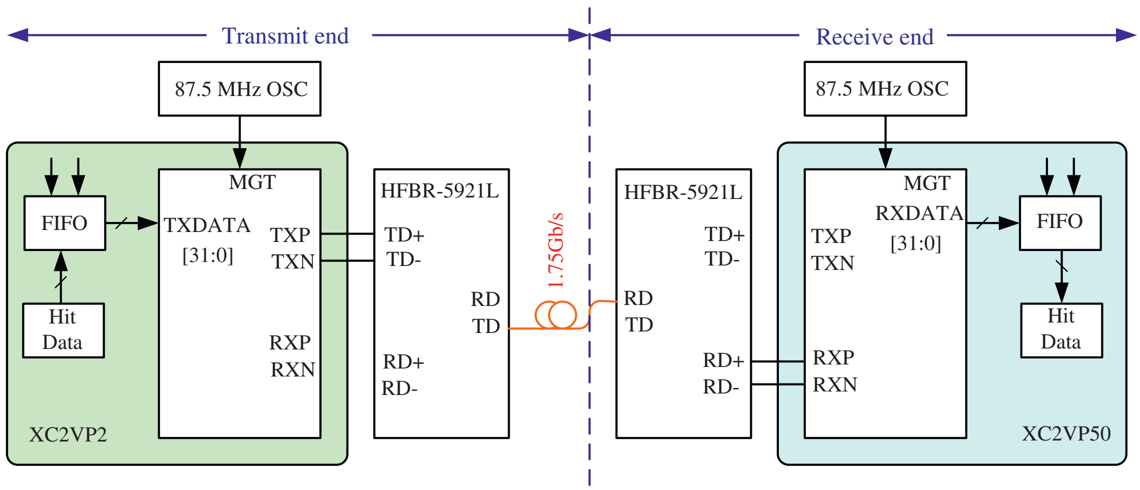

Fig. 11. Scheme of RocketIO and optical fiber technique.

The technique of optical fiber high-speed transmission is implemented based on RocketIO transceiver module embedded in VirtexII Pro series FPGA and optical transceiver module HFBR-5921L. The scheme of RocketIO and optical fiber technique is shown in Fig. 11.

5. Summary

The simulations, hardware and logic design of EMC sub-trigger system are finished carefully in the past years. This sub-trigger system can provide enough trigger conditions (e.g. energy trigger conditions, cluster trigger conditions) to satisfy the proper functions and high flexibility.

Furthermore, in order to enhance the performance of flexibility and reliability of the system, a lot of new techniques are adopted in system design.

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