Trigger System of BESIII

Zhen'An LIU*, Wenxuan GONG, Yanan GUO, Dapeng JIN, Lu LI, Yunpeng LU, Qiao QIAO, Ke WANG, Shujun WEI, Hao XU, Yueyuan ZHANG, Dixin ZHAO, Inst. of High Energy Physics, Beijing 100049, China. Email:liuza@ihep.ac.cn

Abstract-- **The trigger system of Beijing Spectrometer III, part of the upgrade of Beijing Electron Positron Collider, has been designed and implemented, and is ready for installation. This paper describes briefly the system components, its characteristics, and some technical issues. The system consists mainly of four parts: MDC(Drift chamber) tracking subsystem, EMC (ElctroMagnetic Calorimeter) subsystem, TOF (Time of Flight) subsystem and Global Trigger. Some highlights in designing of this system includes: Trigger scheme optimization with software simulation; Optical transmission between trigger and FEEs to realize isolation with FEEs to avoid ground loop current interference; designed with most latest FPGA(Xilinx Spartan 3, VirtexII Pro...) for simplicity, high reliability and easy maintenance and hence smaller system; FPGA in-system programming or firmware online downloadable via onboard, panel connector and/or VME bus for modification flexibility during commissioning. Different from the usual fix delay data transmission from FEE to trigger, the RocketIO has been used as SEDES.**

I. Overview

The Beijing Spectrometer (BES) has been accumulating data with good performance at the Beijing Electron Position Collider (BEPC) since its construction in 1989. To get a larger data sample for charm physics study with better systematic error, the National Laboratory of BEPC decided to upgrade the colliding machine to have a luminosity of 10^{33} $cm^{-2}s^{-1}$ with two order of magnitude higher (to be called BEPCII), and to rebuild the BES spectrometer as BESIII with new techniques. The design and mass production have been finished and will be installed by the end of year 2007. This paper addresses the general consideration, technology to be used and the principle of trigger in the design of the trigger system of BESIII.

The storage ring of BEPCII has been upgraded from single ring of BEPC to double ring with one collision point at the same position of present BESII [1]. The beam will have multi-bunch structure with most likely continuous bunches 8ns apart. The BESIII detector [1] consists from inner to outer of Main Drift Chamber (MDCIV), Time of Flight counter (TOF), Electromagnetic Calorimeter (EMC), Super-conducting Magnet (SC), and Muon Counter (MUC).

The number of good events at J/psi peak is estimated to 2000/s, and cosmic-ray backgrounds and beam loss backgrounds are estimated as 2000/s and 125M/s respectively, and the maximum throughput of DAQ system is 4k/s, so the rejection ratios for cosmic ray and beam loss backgrounds should be better 10:1 and 10000:1 respectively, to get a trigger rate of 4000/s.

II. The principle of BES-III trigger

The purpose of a trigger system is to select physics interested events from enormous backgrounds and to suppress backgrounds to a level that the DAQ system can sustain. The BESIII DAQ is quite safely designed for a maximum throughput of 4000 good events per second. The trigger system must therefore reduce the rate of various backgrounds and bhabha events discussed above down to 2000 Hz while keeps high efficiency for J/ψ and ψ' (2S) decays.

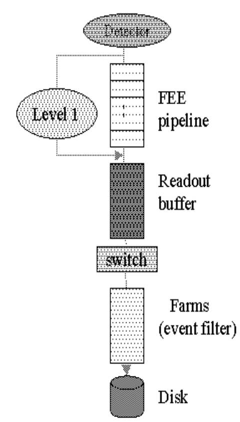

Fig. 1. BESIII event flow

A. Requirement of BES-III trigger(pipelining)

The aim for a trigger system design is to keep the total dead time as small as a few percentage, which corresponds to an acceptable loss of luminosity as it is in BESII. Formerly this is achieved by designing a trigger system with levels. The lowest level is very fast and reduces much of the backgrounds, but does not introduce dead time. High level is slow but because the rate is low so the dead time introduced is low. But this scheme can not be used in BESIII because we face different constrains.

Unlike in BEPC where the bunch spacing is 800ns which leaves trigger system enough time to process various sub-detector signals and make decision before next collision, in BEPCII the bunch spacing is only 8ns, it is not possible to generate a trigger in such short time.

This situation is further complicated by the fact that the arrival time of the Time of Flight (TOF) signal has an intrinsic spread of 30ns due to the different decay products of the J/ψ and ψ' resonance with different momenta and due to different hitting position at the scintillater which makes it not possible to identify a single bunch.

1-4244-0867-9/07/$20.00 ©2007 IEEE.

The TOF signals will be ready in 30ns after the collision. While in the drift chamber, the drift time is about 400ns, only after that time the wire signals can be used for trigger. Again in the electromagnetic calorimeter of CsI, because of its slow rising time and trailing time, only after 1.5μs calorimeter signal can be used for trigger.

Pipeline must be used in trigger to overcome these constrains. From these constrains we know that it is not possible to determine in hardware from which bunch an event originated. This fact gives us the freedom to set trigger sampling period several times longer than the bunch spacing, easing considerably the design of the pipeline components. The period will be chosen as 25ns which is 3 times the bunch spacing, so the signals from different sub-detectors will be binned into 25ns wide time slices and be processed in each pipeline step.

B. BES-III trigger

Considering all the above mentioned constrains and requirement, the BESIII trigger system will be in two level scheme, level 1 for hardware trigger and level 2 for software event filter as shown in Figure 1. The signals from different sub-detectors are splitted into two, one is digitized and stored in the pipeline buffer in front-end electronics (FEE), the other is used in the level 1 hardware trigger to be processed to make a trigger decision. There is a latency between the level 1(L1) trigger signal and the originating event time. We set the trigger latency as 6.4μs. When there is an L1 signal, the DAQ moves the data in the FE pipeline buffer to readout buffer, and packs them into an event, and send them to farm machine where the level 2 filter filters the backgrounds events further (this paper does not cover).

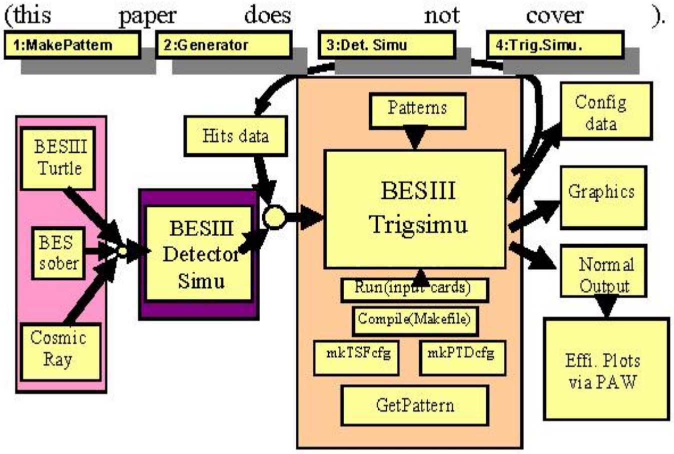

Fig.2 Simulation blockgram

C. Scheme optimization

Signals from sub-detectors are used to form the trigger system. As we have a unique MDC layer arrangement (less number of axial layers, not good Symmetry, neither uniformly arranged axial layers, nor well separated axial and stereo layers) and a unique EMC crystal numbers (number of crystals not devisable by 4 for Trigger-Cells in Barrel, hard to form Trigger-Cells in End-caps), a simulation has been done(Fig.2.) to study and compare deferent schemes and find a best one with high efficiencies, high background rejection. Track patterns, energy thresholds, etc are also determined for hardware design reference. Simulation results shows that the final scheme is acceptable (Fig.3).

Events generated and simulated with Geant	Trigger efficiency(%)/background rate
Bhabha @3.097Gev	100
Radiative BB(3.097GeV)	100
J/ψ → γ η → 3γ	99.99
J/ψ → ω η → 5γ	99.99
J/ψ → $K^+K^-\pi^0$	99.69
J/ψ → P Pbar	99.91
J/ψ → anything	99.80
J/ψ (2S) → anything	99.50
J/ψ (3770) → anything	99.90
Lost beam backgrounds	1.85kHz
Cosmic-ray backgrounds	86Hz

Fig. 3 Simulation results

III. IMPLEMENTATION

A. System Overview

A schematic view of the BES-III trigger system is shown in Fig. 4. Electronic signals from sub-detectors are received and processed by the appropriate circuits in separate VME crates to yield basic trigger primitives such as the hit count in TOF, the track count in the drift chamber, as well as the cluster count and topology in the electromagnetic calorimeter. The information from these sub-systems is correlated by global trigger logic (GTL) which generates an L1 strobe every time a valid trigger condition is satisfied. The L1 signals are distributed by the fast control to the data acquisition at FEEs. The trigger system is isolated via optical fibers to avoid interference caused by ground loop current.

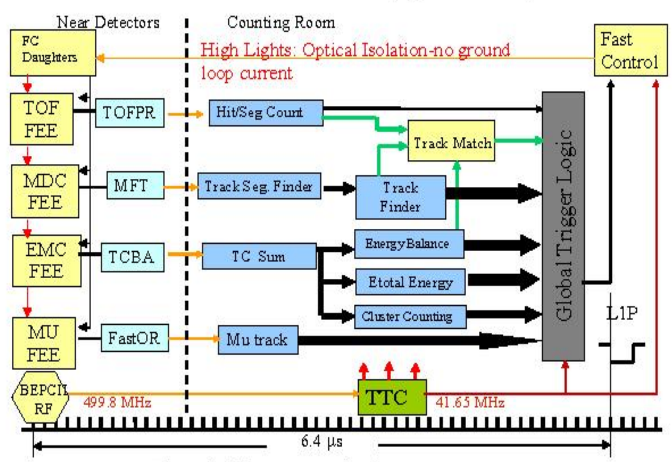

Fig. 4. Diagram of trigger system

B. MDC Tracking

There will be axial and stereo layers of sense wires in MDC-IV. The tracking component of the MDC-IV trigger use only axial wires. The hit signals from FEE discriminators is stretched to 500ns and then be sampled by the system clock

CLK40. 32 of sample hit signals in one clock are serialized by a 8/10 SEDES in a RocketIO in FPGA and sent out via a optical transceiver in 1.75Gbps. Signals are recover in another optical transceiver on tracker board and deserialized by RocketIO to 32 channels. The tracking circuitry in FPGA examines the complete set of 2312 wires, 16 axial layers (4 super layers each with 4 layers), for all possible valid patterns caused by tracks having transverse momentum greater than 120 MeV/c. The tracker consists of 2 parts: segment-finding and track-finding. Track in inner 3 superlayers forms short tracks and track in 4 full superlayers forms long tracks(Fig.5).

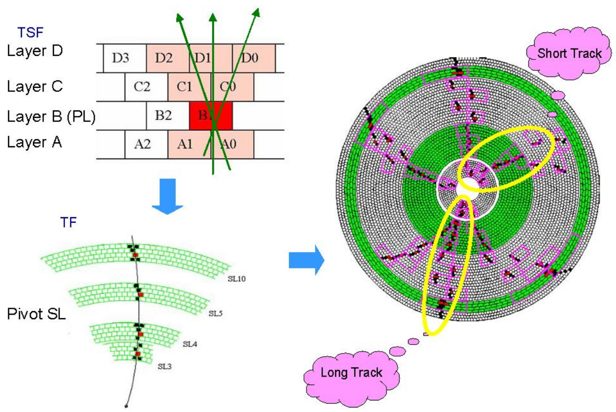

Fig. 5 MDC track finding

C. Electromagnetic calorimeter

The BES-III electromagnetic calorimeter comprises 5280 CsI crystals in the detector barrel part, arranged 44 along the beam(θ) by 120 in azimuth(φ) and 1024 in Endcap part. For

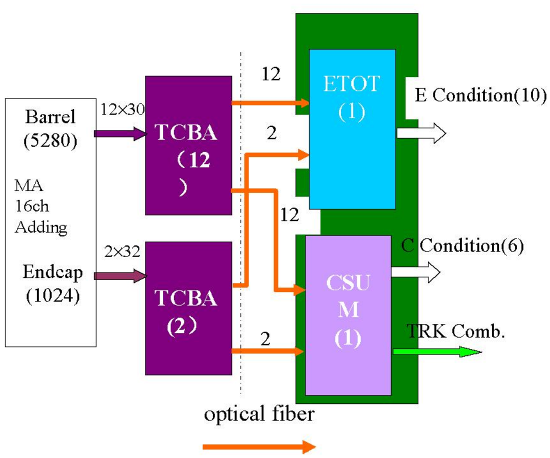

Fig 6 EMC trigger

the triggering, the signals from 16 crystals (4θ × 4φ) are summed in barrel as basic trigger Cell(TC), therefore there are 30 × 11 trigger cells(fig.6). The summed signal in a trigger cell (cell sum) is discriminated to extract a timing information after base line restoration. A block energy sum is also formed and digitized with Flash ADC. The TC data is sent via optical fiber to CSUM module with a cluster finding is made. The digitized data from FADC is sent to ETOT where a total energy cut is made.

D. Time of Flight

The Time of Flight counter of BES-III consists of 88 scintillators in one layer. Photo multiplier signals are discriminated first and then the number of hits is calculated and back to back match is also checked for bhabha events(fig.7). These hits are matched with MDC tracks, and ECAL clusters. The matched number of tracks are used in the final decision.

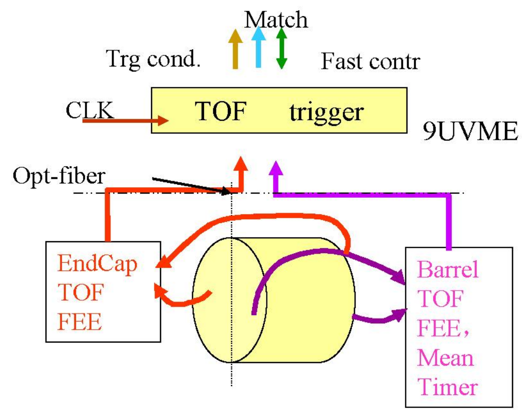

Fig. 7 TOF trigger

E. Trigger Timing and Control

The RF frequency of storage ring of BEPC-II is 499.8MHz. The system clock CLK40 is derived from this clock by a division of 12. To have a fix phase lock to the first bunch of the train, a pickup signal from beam crossing detector on the ring is used for synchronization(fig.8). CLK40 is the pipeline clock and all the processing of the sub-detectors signals in FEE and trigger system is under control of this clock.

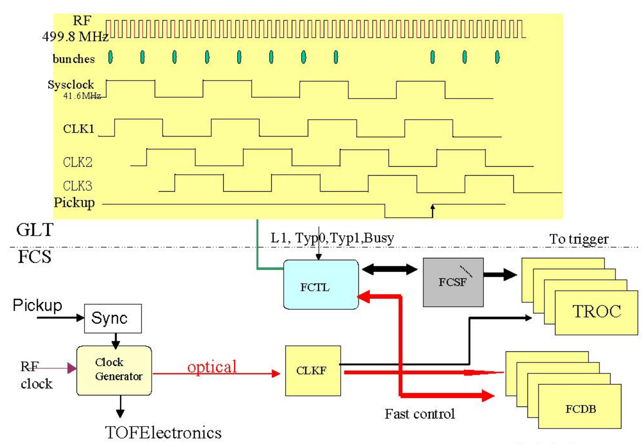

Fig.8 Timing and control

F. Global Trigger Logic

The primitive signals from sub-trigger are fed to the Global Trigger Logic(GTL). They are matched there to define a valid event trigger L1. The L1 signal is synchronized to the trigger pipeline clock to have a fixed latency of 6.4μs with collision.

IV. Project Status

The final design of the trigger system has been finished in 2006 and mass production has been finished. The installation will be done by the end of 2007.

V. Summary

The design of BESIII trigger system has been presented. The system design is under guidance of simulation and the optical data link have been used for high speed data transmission of 1.75Gbps and system isolation with FEE to prevent interference caused by ground loop current. Most latest FPGAs, like Xilinx Spartan 3, VirtexII Pro are used in board design, so simplicity and high reliability and easy maintenance are realized in the system. In-system programming are implemented via on board and panel connector and also via VME backplane bus for easy modification.

VI. Acknowledgment

The author gratefully recognize and thank Dr. S.X.WU of University of Boston, Dr. J.Y.Wu and Dr. Tiehui LIU of FermiLab, for their deep discussion on BESIII trigger system
.

VII. References

[1] The BEPC-II/BES-III Proposal.
[2] The KLOE Collaboration, ‘The KLOE trigger system, Addendum to the technocal Proposal,” LNF 96/043.
[3] S.Mori, S.Stanic,”The Belle Detector”, KEK Progress Report 2000-4
[4] C.Bebek,G.Crawford,et.al. CLEOII trigger system, NIM A302(1991) 261-276
[5] CLEO-III Detector Proposal, CLNS-94/1277. Cornell University, Wilson Lab.
[6] 1994 CLEO-III Detector Status Report, CBX 94-73. Cornell University, Wilson Lab.
[7] The CLEO III Detector Status Report, CBX 96-93
[8] R.M.Hans,C.L.Plager,M.A.Selen and M.J.Haney,”The CLEO-III Trigger:Axial and Stereo Tracking”, IEEE Trans. Nucl. Sci., (to appear in vol. 48, no. 3, 2001) R.M.Hans,C.L.Plager,M.A.Selen and M.J.Haney,”The CLEO-III Trigger:Axial and Stereo Tracking”, IEEE Trans. Nucl. Sci., (to appear in vol. 48, no. 3, 2001)
[9] G. D. Gollin, J. A. Ernst, J. B. Williams, and M. J. Haney, “The CLEO-III trigger: analog and digital calorimetry,” *IEEE Trans. Nucl. Sci.*, accepted for publication (to appear in vol. 48, no. 3, 2001).
[10] M. A. Selen, R. M. Hans and M. J. Haney, “The CLEO-III trigger: decision and gating,” *IEEE Trans. Nucl. Sci.*, accepted for publication (to appear in vol. 48, no. 3, 2001).