Commissioning of the ALICE-PHOS trigger

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Abstract. The Photon Spectrometer (PHOS) of the ALICE experiment at LHC is a high-resolution electromagnetic calorimeter dedicated to the precise measurement of direct photon and neutral meson yields in p+p and Pb+Pb collisions at mid-rapidity in a $p_T$ range up to 100 GeV/c. A multi-level trigger system selects events of interest and reduces the overall data flow. PHOS generates two triggers: i) the Level 0 (L0) trigger for high luminosity p+p runs acting mainly as a spectrometer trigger and for selecting high $p_T$ photons in Pb+Pb and in p+p collisions; ii) the Level1 (L1) trigger corresponds to a more sophisticated shower analysis which refines the $p_T$ selection. The algorithms perform a pulse-shape analysis of the oversampled Avalanche Photo Diode (APD) signal followed by a sliding-window cluster finder. Both triggers are implemented in the firmware which, since SRAM-based FPGAs are used, can be changed on-line between runs. The trigger system was commissioned by cosmic rays and particles from interactions. The status of the trigger system and first results will be presented.

1. Introduction

ALICE (A Large Ion Collider Experiment) is an experiment designed for the study of nucleus-nucleus collisions at the Large Hadron Collider (LHC) \cite{ALICE1,ALICE2}. It mainly focuses on the study of physics of strongly interacting matter and the deconfined state of nuclear matter which is called Quark-Gluon Plasma (QGP).

The main goal of the PHOS detector \cite{PHOS} is to study photon physics. One of the main physics objectives is to search for thermal photons for the determination of thermal and dynamical properties of the initial phase of the collisions. The other main physics objective is to study jet quenching through the measurements of high $p_T\pi^0$ and $\gamma - jet$ correlation. According to predictions \cite{predictions} for heavy ion collisions, it is expected that thermal photons are in the energy range between 1 and 10 GeV. Therefore one of the two major requirements of the PHOS detector is to measure direct photons with good energy resolution in a $p_T$ range 100 MeV/c to 100 GeV/c. The other requirement is to survive in the high multiplicity condition with up to 8000 charged particles per rapidity unit. There are 17920 PWO crystals with the size of $22 \times 22 \times 180$ mm$^3$ in total for the PHOS detector, which is located at a distance of 460 cm from the interaction point. It covers 100$^\circ$ in the azimuthal angle and $-1.2 \cdots + 1.2$ in pseudo-rapidity.

2. The PHOS trigger and readout system

Three levels of triggers, L0, L1 and L2, are used for the reduction of overall dataflow and the selection of events in the ALICE experiment. L0, L1 and L2 are required to arrive at the front end electronics at 1.2 $\mu$s, 6.5 $\mu$s, and 88 $\mu$s respectively after the collisions take place. The
PHOS detector contributes to two levels of triggers: L0 and L1. Because of the tight timing requirements of the trigger, PHOS must send the L0 trigger to the Central Trigger Processor (CTP) within 800 ns after the time of the interaction.

PHOS consists of 5 modules and each module is equipped with $64 \times 56$ PWO crystals, 112 Front End Cards (FEC) \cite{5,6,7}, 8 Trigger Region Unit (TRU)\cite{8,9,10} and one Trigger OR unit (TOR) which is shared by all the modules. Each crystal has an Avalanche Photon Diode (APD) and a low noise Charge Sensitive Preamplifier (CSP) glued onto it. The PHOS components are divided into cold zone components at a temperature of $-25 ^\circ C$ and warm zone components. The FECs and TRUs are located below the crystals inside the warm part of the air-tight compartments, and the TOR sits outside the air-tight compartments.

2.1. The Front End Card

The FEC is designed to fit the layout of double rows of $2 \times 16$ PWO crystals. The dynamic range between 5 MeV and 80 GeV is implemented with two shapers of gain ratio $1:16$ and 10-bit ALTRO \cite{11} ASICs. Each 4 output signals from CSPs in matrix $2 \times 2$ are summed by an analog adder with a fast shaper property and the summed signal goes to the TRU via differential lines.

2.2. The Trigger Region Unit

Signals from Analog sum of 14 FECs are fed to one TRU where 14 8-channel ADCs with 12-bit resolution convert the analog signals to digital signals. The onboard FPGA deserializes the ADC values, subtracts pedestals and then uses a $4 \times 4$ crystals sliding window to find clusters. The L0 decision is made by a simple threshold trigger. Both the L0 and the cluster energies are transmitted serially to the TOR for further processing. In addition, the digitized 12-bit $2 \times 2$ sums, called trigger channel signals, are buffered in the FPGA according to ALTRO format for the comparison with the energy channels in the real ALTRO on the FEC. The TRUs can be configured and programmed remotely via a Detector Control System (DCS) \cite{12} card which is mounted on the the RCU card.

2.3. The Trigger OR

The TOR card, also with a DCS card, is connected to up to 40 TRU via differential cables. The FPGA configuration can be remotely configured and programmed with the DCS card. Its FPGA is responsible for the collection and processing of all the incoming trigger signals, including the L0 which is a simple logical OR of all the L0 trigger inputs from all the TRUs in the 5 modules. The L1 triggers are generated based on more sophisticated processing of the cluster energies only when the confirmed L0 is coming from the Local Trigger Unit (LTU)\cite{13}. There are one L0 trigger output and three L1 trigger outputs from the TOR to the CTP\cite{13}.

2.4. The overview of the PHOS trigger and readout system

Figure 1 shows the overview of the PHOS trigger and readout system. The signals coming from 32 PWO crystals go into one FEC. There are two data paths for the signals in the FEC, one of them consists of dual gain shapers and ALTROs to digitize the energy from each PWO crystal directly. The other is Analog sum.

The L0 trigger is generated in the TRU and ORed in the TOR, whereas the L1 triggers are generated in the TOR, both L0 and L1 triggers are delivered into the CTP for the combination and synchronization of information from all the triggering detectors in the ALICE, then the trigger related sequences that consist of combined and synchronized information are sent to the LTU, where the trigger related sequences are converted into proper format to deliver to the front end electronics via an optical fiber. The RCU decodes the trigger information and sends L1 strobe (i.e. confirmed L0 for PHOS) and L2 strobe(i.e. L2a ) to FEC. The ALTRO on the
3. Commissioning with cosmic ray and LED

The muons from cosmic rays deposit part of their energy when they traverse the PHOS detector, which can be used for trigger commissioning and calibration. Also each PHOS module is equipped with a LED Monitor System (LED MS), there is an individual LED on the top of each crystal. The brightness of the LED can be adjusted by setting different modes of amplitude: one-peak mode and grid-mode that gives a multi peak structure of the amplitude histograms. In addition, the illumination structure of the LED can be adjusted to different modes: four lines with each line covering $2 \times 64$ crystals, chess-like with four $2 \times 16$ crystals and point-like with $2 \times 4$ crystals.

3.1. The trigger channel noise test

The trigger channels were tested with both cosmic rays and LED MS at the CERN PHOS lab in August 2009. One PHOS module was used for the trigger channel test in 2009 at the lab. The one peak mode, 4 lines with $2 \times 64$ channels structure mode was set for the LED system. Figure 2 shows the pedestal of 4 trigger channels, Figure 3 shows the Root Mean Square (RMS) distribution of the pedestals from two TRU regions.

The LED calibration result is showed as Figure 4, the top part represents the matrix of energy channels on one module, the bottom part represents the matrix of trigger channels. One can see the good coincidence of energy channels and trigger channels in the figure. Figure 5 shows the cosmic rays calibration result of trigger channels, one can see that the energies of channels with hits are much higher than that of channels without hits. Therefore the trigger is expected to be issued by setting a threshold just above the noise. It is worth mentioning that the pedestal has

Figure 1. The dataflow of the PHOS trigger and readout system
been subtracted in the matrix of trigger channels already.

![Figure 2. Pedestal of four trigger channels](image)

![Figure 3. RMS distribution of the pedestals from two TRU regions](image)

![Figure 4. The energy channel matrix (top) and trigger channel matrix (bottom) with LED run](image)

![Figure 5. Trigger channels matrix with cosmic run (bottom) and two corresponding trigger channels (top)](image)

3.2. The L0 trigger performance test

A cosmic run was taken in 2010. In this run, the PHOS is both triggering detector and readout detector. Figure 6 shows the Minimum Ionizing Particle MIP distribution of a cosmic run, a relatively low threshold was set, one can see that the MIP peak is around 210 MeV. The PHOS detector has not been fully calibrated yet till then.

3.3. The L0 trigger purity test

When the muons from cosmic rays traverse the ALICE experiment, they produce tracks in the Time Projection Chamber (TPC). There is also energy deposited in the crystals when the muons hit the PHOS detector. In principle the number of MIP tracks and the number of hits are supposed to be identical. A cosmic run was taken in 2010. In this run, both the PHOS and the TPC were read out detectors, the PHOS detector was also a triggering
detector, a relatively low threshold around 180MeV was set. The trigger purity is calculated by the number of triggers with MIP TPC tracks /the number all PHOS triggers. In this run the purity was around 23% because the MIP energy was just above the threshold.

4. Commissioning with beam injection
The first beam injection was done in October 2009, the calibration of PHOS and the commissioning of trigger L0 is in progress during p+p collisions.

4.1. The L0 trigger timing Test
The timing test was done at P2 during p+p collisions in 2010. The Figure 7 shows the plot that has several histograms with signals from triggering detectors as a function of time in 25 ns units corresponding to bunch crossings, one can see that the PHOS L0 trigger arrives earlier than the benchmark OBPC and OBPA, which means the PHOS L0 trigger fulfills the timing requirement.

4.2. L0 trigger efficiency and fake trigger rate test
Trigger channel data is supposed to be compared with energy channel data for the analysis of trigger efficiency and fake trigger rate test, therefore both trigger channel data and energy channel information have been recorded already. The analysis of trigger efficiency and fake trigger rate is ongoing.

5. Conclusions
Three of five PHOS modules have been installed at P2, the pre-commissioning of the trigger electronics has been done at the lab with cosmic rays runs and LED runs. Global timing test of the trigger system has been done during p+p collisions, also some L0 trigger performance has been analyzed during p+p collisions. The analysis of trigger efficiency and fake trigger rate is ongoing.

The update of the firmware is being developed in order to improve the L0 trigger performance. The L1 trigger development is in progress and the commissioning is supposed to be done soon.
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