Performance of the ALICE PHOS trigger and improvements for RUN 2

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ALICE (A Large Ion Collider Experiment)

**ITS**: Inner Track System; **TPC**: Time Projection Chamber; **TRD**: Transition Radiation Detector

**TOF**: Time-Of-Flight; **V0**: Veto 0; **PHOS**: PHOton Spectrometer
ALICE trigger system

- Two kinds of detectors – triggering detectors and readout detectors
  - Triggering detectors provide trigger inputs to the trigger system.
  - Readout detector records data taken during physics runs
  - PHOS is both the triggering detector and the readout detector.
- Three levels of triggers – 24 L0-trigger inputs, 24 L1-trigger inputs and 12 L2-trigger inputs
  - L0 provides an early track on events of interests, L1 provides further information of these events, and L2 decides whether these events should be recorded.
  - PHOS is now contributing L0-triggers to the ALICE trigger system
  - PHOS L1-trigger is being developed and tested in lab

CTP: Central Trigger Processor
LTU: Local Trigger Unit
PHOton Spectrometer (PHOS)

| Array of crystals | APD + preamplifier | trigger logic |

Front-end electronics

readout

L0/L1 triggers

Signal to ALICE DAQ
PHOS trigger working scheme

• **Trigger generation path:**
  CSP signal → 2x2 analog-sum → TRU (local L0 decision) → TOR (final L0 decision)

• **Data recording path:**
  CSP signal → Shaper with two gains → ALICE DAQ controlled by RCU
Technical requirements

Ideally, L0-trigger outputs should fulfill three requirements:

• Trigger decision should be made according to the peak value of the analog-sum signal
  - To ensure that the threshold comparison is based on the most accurate value

• Duration of 25 ns (bunch spacing)
  - Long trigger pulse would lead to missed photons

• Arrive at the CTP at a fixed time
  - CTP only accepts triggers arriving at a fixed time
Technical limitations

• TRU works at 20 MHz (requirement is 40 MHz)
  - Can not assure that the trigger decision is made according to the peak of analog-sum signal
  - Trigger pulse is at least 50 ns
  - Trigger arriving time varies due to TRU clock shift

Lijiao Liu, University of Bergen, 2011
Trigger scheme selection

• Performance of two trigger scheme were compared
  I. Short scheme: keep the first clock cycle when the signal is over threshold.
  II. Long scheme: keep the trigger as long as the signal is over threshold.

Lijiao Liu, University of Bergen, 2011
Performance analysis

• Is the trigger operating as expected?
  – Rejection factor
  – PHOS trigger rate

• How many triggers are fake ones?
  – Trigger purity

• How many photons does PHOS miss?
  – Trigger efficiency
Rejection factor

- **Rejection factor** = \( \frac{N_{MB}}{N_{PHOS}} \)
  - \( N_{MB} \) is the number of events triggered by minimum bias trigger
  - \( N_{PHOS} \) is the number of events triggered by PHOS
Rejection factor

- Remains reasonably stable during runs of the same threshold \( \rightarrow \) PHOS trigger is working as expected
- \( 346@2\text{GeV}, \ 3845@4.3\text{GeV} \)
  - \( N_{PHOS} \frac{1}{\alpha} \) \( \text{Threshold} \)
  - \( N_{MB} \) keeps on the same level
- Rejection factor \( \propto \) Beam luminosity
PHOS trigger rate

- Remains reasonably stable during runs of the same threshold → PHOS trigger is working as expected

- 127Hz@2GeV, 17Hz@4.3GeV
  - The number of events with photons whose energy is over threshold is in negative proportion to threshold

- Trigger rate ∝ Beam luminosity
  - There are more photons in the collisions of beams with high luminosity than that in the collision of beams with low luminosity
**Trigger purity**

- **Trigger Purity** = \( \frac{N_{\text{real PHOS}}}{N_{\text{all PHOS}}} \)
  - \( N_{\text{real PHOS}} \) is number of real PHOS triggers
  - \( N_{\text{all PHOS}} \) is the number of all PHOS triggers

- 0.36@2GeV, 0.17@4.3GeV
  - Triggered events@2GeV is more than triggered events@4.3GeV
  - Noise could be regarded as constant

- Trigger purity \( \frac{1}{\propto} \) Beam luminosity

Energy Spectrum

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![Graphs showing PHOS trigger purity and Beam Luminosity](chart.png)
Trigger efficiency

- In principle, \( \text{Trigger efficiency} = \frac{N_{\text{PHOS}}}{N_{\text{PHOS Over Thr}}} \)
  - \( N_{\text{PHOS}} \) is the number of events triggered by PHOS.
  - \( N_{\text{PHOS Over Thr}} \) is the number of events with clusters whose energy is over PHOS threshold.

- In calculation, \( \text{Trigger efficiency} = \frac{E_{\text{PHOS}}}{E_{\text{PHOS Over Thr}}} \)
  - \( E_{\text{PHOS}} \) is the energy spectrum of PHOS triggered events
  - \( E_{\text{PHOS Over Thr}} \) is the energy spectrum of all the events that should be triggered by PHOS

- Two factors that mainly affect trigger efficiency
  - Boundary effect
  - Noise during data recording
Boundary effect

- **Boundary effect**: energy deposited by photons at the boundary of TRUs could not be fully reconstructed, therefore, their corresponding events might be missed by PHOS.

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Trigger efficiency

(a) Energy spectrum (all branches)

(b) PHOS trigger efficiency (all branches)

(c) Energy spectrum (cut noisy branches)

(d) PHOS trigger efficiency (cut noisy branches)
PHOS upgrade

- Deficiencies in PHOS:
  - TRU working at 20 MHz but not the ideal 40 MHz
  - Noisy channels

- Replacing PHOS-TRU with EMCAL-TRU
  - Same prototype
  - FPGA -> 40 MHz sampling frequency

- Replacing PHOS-TOR with EMCAL-STU
  - Same prototype
  - DDL link included -> direct interface to DAQ

- Replacing GTL bus with P2P bus + SRU
Conclusion

• PHOS trigger is working as expected

• Trigger efficiency is approximately 0.9 by removing noisy branches.

• Trigger purity varies with threshold voltage. Generally, 0.36 @ 2GeV and 0.17 @ 4.3GeV

• Upgrade is needed due to TRU working frequency and noisy channels. After the upgrade, PHOS is expected to reach an interaction rate of approximately 50 KHz for RUN2.
Thank you for listening !!!