NEW DEVELOPMENTS FOR THE ALICE TRIGGER

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Abstract

The addition of a Transition Radiation Detector (TRD) to the ALICE setup, coupled with a better understanding of the requirements of the front-end electronics, have led to a major re-appraisal of the central trigger system for the ALICE detector. The previous system was reviewed at the LEB Workshop in 1996. In the new system, the principal rate reduction in Pb-Pb collisions comes after 5.5 microseconds, in order to wait for the decision of the TRD. Data transfer to the data acquisition system is initiated after a positive level 2 decision, 100 microseconds after the event takes place.

1. INTRODUCTION

The last twelve months have seen considerable activity in all aspects of the design of the ALICE detector, resulting in the production of a series of Technical Design Reports (TDRs). This process has led to a number of improvements for the interface between the detectors and the data acquisition system, which in turn implies modifications to the trigger system. The overall layout of the ALICE detector is shown in fig. 1

Fig. 1 The ALICE detector.

The ALICE trigger detectors are listed in Table 1, together with their functions. The Forward Multiplicity Detectors (FMD) and Zero Degree Calorimeters (ZDC) define an interaction inside a specified vertex region with given centrality; the dimuon and dielectron triggers select those events which also contain dimuon or dielectron pairs respectively. The function of the FMD, ZDC and dimuon trigger detectors has been described in previous LEB workshops **[1, 2],** and is not given here.

Table 1. ALICE trigger detectors.

DETECTOR	*Decision Time*	*DATA*	*FUNCTION*
FMD	≤ 500 ns	μ_{ch}, t_0	Define interaction diamond Beam-gas interaction rejection Centrality
ZDC	~1.5 μs	$E_{forward}$	Centrality
DIMUON (DM)	≤ 600 ns	$P^t_{t\mu}$	Selection of dimuon pairs above p_t cut
DIELECTRON (TRD)	~5.5 μs	P^t_{te}	Selection of dielectron pairs above p_t cut

Recently, a major new detector, a Transition Radiation Detector (TRD) **[3]** has been proposed for ALICE. This device will identify dielectrons in the same acceptance window as the Time Projection Chamber (TPC). It also provides a dielectron trigger. The detector complements the dimuon arm, allowing ALICE to study a wide range of aspects of dilepton production for masses above ~1 GeV.

The structure of this paper is as follows. The Transition Radiation Detector is described briefly in section 2. Section 3 reviews the protocol for non-triggering detectors in ALICE, and section 4 gives some conclusions.

2. THE TRANSITION RADIATION DETECTOR

The ALICE Transition Radiation Detector (TRD) consists of 18 (φ) x 4 (θ) sectors each consisting of six layers. In total there are about six hundred thousand readout channels. It forms a barrel between the TPC and the Time of Flight (TOF) system.

The principle of the Transition Radiation Detector (TRD) is to exploit the radiation produced when a relativistic charged particle crosses the boundary between two media with different refractive indices. The photons are in the soft X-ray range, with energies of about 2 to 30 keV. In order to increase the number of transition radiation photons, a stack of foils is used.

A schematic diagram of a TRD of a similar type to that proposed for ALICE is shown in fig. 2.

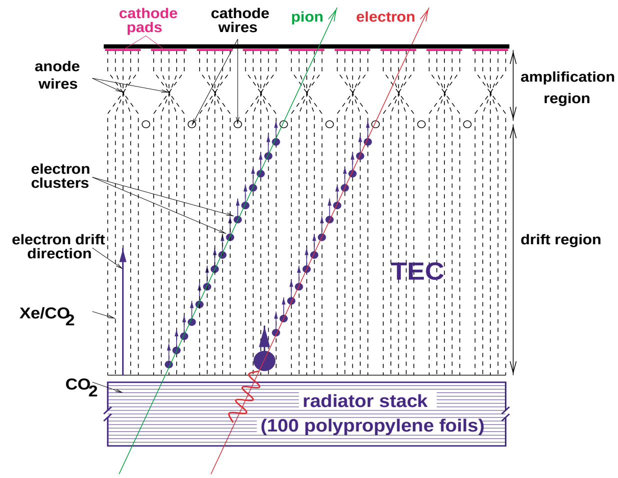

Fig. 2 T.R.D. principle.

The transition radiation photons are absorbed in a time expansion chamber (TEC), which is a wire chamber with a xenon-based gas mixture. The electrons created by the transition radiation tend to deposit most of their energy near the entrance window of the TEC, and thus the resulting electrons appear at the end of the drift time window for a passing charged particle.

The time structure of the transition radiation electrons allows the TRD to be used as a triggering detector. The idea is to identify tracks above a given momentum in the TRD, which can be done as their deflection in a magnetic field is small, and thus their ionization is associated with a small number of readout pads - typically one. The observation of a track with the characteristic TR pulse at the end of the drift time flags an electron. The occupancy of the TEC pads is being selected so as to avoid overlapping tracks in a given pad while minimizing the mean number of pads to be associated with a given pulse.

The pattern-recognition operations are nonetheless complex compared with those performed in the other ALICE trigger detectors, and therefore the TRD trigger algorithm takes longer than that for any other trigger detector. The decision is contributed to the ALICE level 1 trigger, which comes 5.5 microseconds after the time of the interaction. In order for the TRD trigger to be able to analyze as many interactions as possible, it means that the level 0 (L0) strobe to ALICE detectors, which in general are not pipelined, must be essentially a minimum bias trigger in Pb-Pb interaction mode. The strategies to be adopted in the other running modes are still under discussion.

3. ALICE TRIGGER-DAQ PROTOCOL

ALICE events are very large, which poses a challenge for the Data Acquisition System. The event sizes for the different detectors are given in Table 2

Table 2. ALICE detector event sizes

DETECTOR	SUBDETECTOR	N°. of Channels	Event Size (Mbyte)	Max. Readout Time (μs)
ITS	PIXEL	14.4×10^6	0.140	200
	SDD	192×10^3	1.500	≤1000
	SSD	2.6×10^6	0.160	≤1000
RPC		500×10^3	30.0 ÷ 36.0	2000
TOF	PPC	160×10^3	0.150	≤1000
PHOS		37×10^3	0.022	≤1000
HMPID	RICH	145×10^3	0.120	≤1000
	Scint. TOF	8×10^3	0.005	≤1000
MUON		1.0×10^6	0.100	200
TRIGGER		700	0.115	200
TOTAL			≈ 33 ÷ 39	

It may be seen that the overall data volume is dominated by the TPC readout.

The mean readout rates are chosen to match the required data taking rates. A special effort has been made to shorten the readout times for the pixels, the dimuon arm and the trigger detectors in order to allow these detectors to read out by themselves, independently of the rest of the detector.

Two factors govern the read-out rates. There is a limitation on the global data flow rate from the ALICE detector, and there is a requirement that the data transfer time from the front-end to the data acquisition system should not be long, so as to avoid excessive dead time. The scheme described in the ALICE Technical Proposal envisaged fast data links between the front end and the data acquisition system, with buffering in the counting room (in "Front-End Digital Crates") where there are less space limitations. It has been found that this leads to inefficient use of the optical links (Digital Data Links or DDLs) between the front-end and the counting room, given the low physics event rate in ALICE during Pb-Pb running.

The favoured solution is to introduce front-end buffering; events are only transferred after the final (level 2) trigger decision, thus reducing data traffic in the DDL, and the transfer proceeds asynchronously, thus allowing the DDL to be used more efficiently. The number of buffers is chosen so as to ensure that buffer saturation occurs rarely, while keeping low the total number of DDLs (each with a 100 MByte/s transfer rate).

The new demands posed by front-end buffering and the timing of the TRD trigger signal mean that the trigger signal sequence given in the ALICE Technical Proposal has had to be revised.

In the current ALICE protocol, there are four signals sent to each detector, and one sent back from the detector to the central trigger. The signals are listed in Table 3, and their timing is illustrated in fig. 3.

Table 3. ALICE trigger levels.

SIGNAL	Latency (μs)	Medium	Partecipating Trig. Detector	ACTION
LØ	1.2	Fast Coax. Cable NIM)	F.M.D.	STROBE to some detectors (T/H F.E. electronics)
L1	5.5	TTC (optical)	T.R.D. + ALL	STROBE + Trig. Number + Data Transfer to Multi-Event Register
L2a	100	Coax. Cable	ALL	Data Transfer to Multi-Event FIFO
L2r	≤ 100	Coax. Cable	ALL	Reject Event in the Multi-Event Register
BUSY		Coax. Cable		

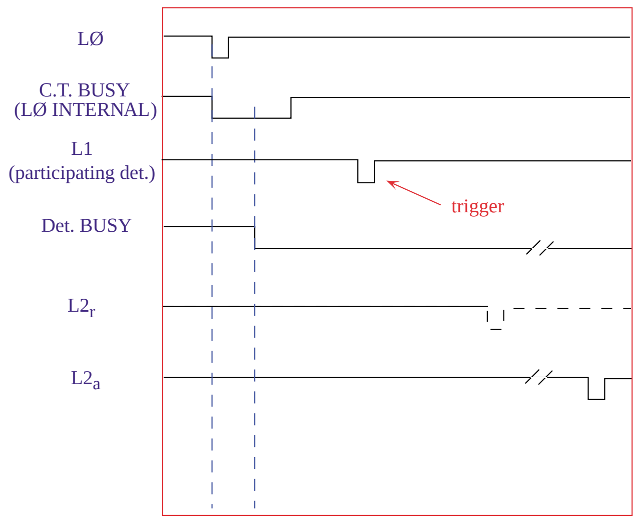

Fig. 3. Timing of ALICE trigger signals.

Level 0 serves as an early strobe to detectors; at this point rough vertex cuts and beam gas rejection can be applied. The FMD also delivers information on event centrality, which is employed at level 1. In addition, dimuon events can be identified at this stage, 1.2 μs after the collision.

At level 1, information from the ZDC and the TRD are also available; this information is enough to make a final event selection. For this reason, a substantial rate reduction can be made at this stage, and event identifiers are allocated. It is sent 5.5 μs after the collision. Trigger levels 0 and 1 have fixed latencies, and so the absence of a signal means it was not accepted.

The main purpose of level 2 is to apply past-future protection. Owing to the very high event multiplicity in ALICE (dN/dy ~ 8000), it is not possible to perform track reconstruction in cases when two events overlap (pile-up). The time window in which events can overlap is quite large, and extends to twice the drift time of the TPC, i.e. 200 µs. At the nominal luminosity for Pb-Pb collisions, $L = 10^{27}\ cm^{-2}\ s^{-1}$, the probability of pile-up is 63%. The central trigger logs, bunch-crossing by bunch-crossing, all cases in which an interaction has occurred, and will veto any event for which there has been a previous interaction within 100 µs (past protection). It will also abort any trigger for which a second interaction is detected for a period of up to 100 µs after the interaction has taken place (future protection). Unlike L0 and L1, two types of L2 are sent: a level 2 *reject*, ($L2_r$) can be sent at any time up to the full past-future protection interval, while a level 2 *accept*, ($L2_a$) cannot be issued until the full interval has elapsed.

It is a feature of the ALICE experiment that each detector is treated independently. A physics trigger can be issued if all the detectors required for it are not busy. Each detector contributes a BUSY signal to the central trigger. A BUSY signal should be set as soon as a detector receives an L0 trigger and the detector holds this signal until it is again ready to record an event.

Event numbers are issued at level 1 (L1) when the event rates are reduced to close to their final level.

Event numbering in ALICE is complicated by the fact that not all detectors need take part in a given event, which means that trigger numbers will not be sequential. ALICE uses the RD-12 TTC system to distribute event numbers. For this reason, bunch-crossing numbers, which are distributed to all detectors, are used to identify events. As the bunch-crossing counter uses 12 bits, it is not large enough to identify events uniquely over a range of more than about 100 µs.

For this reason, the bunch crossing is augmented by an *orbit number*. One LHC orbit takes 88 µs. By adding a 32 bit orbit counter, the time over which an event can be identified uniquely can be extended to about 100 hours. The orbit number is not automatically counted on the TTCrx chip. Instead, it can be transmitted, using the TTC B channel, and kept, off the chip, in a 32 bit register.

The inter-relation between the trigger system and the front end buffering is illustrated by the simple data flow model in figure 4.

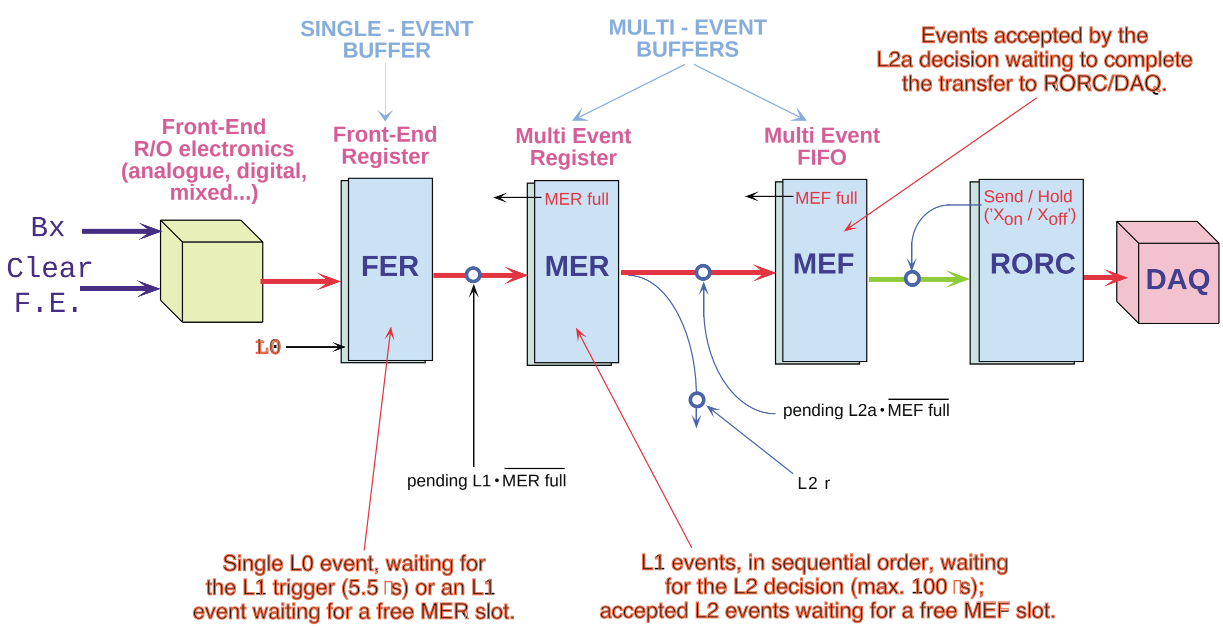

Fig 4 Conceptual buffering scheme for an ALICE detector system.

Data flow is from left to right. Data are produced in the sub-detectors, and are stored in a front-end register (FER) on receipt of an L0 signal. If there is no L1 signal (L0 timed out) the register is freed. On receipt of an L1 signal, which means a positive L1 decision, the data are transferred to a Multi-Event Register (MER), awaiting the L2 decision. Data in the MER can either be rejected or selected for transfer to DAQ. Following receipt of a level 2 accept ($L2_a$), the data cannot any longer be rejected. This is indicated in the figure by a transfer from the MER (from which events can be discarded) to the MEF, a Multi-Event FIFO (from which they cannot). Once in the Multi-Event FIFO, the data must be transferred to the RORC, as soon as data traffic on the DDL will allow.

Each of the data transfers can be halted if the buffering space ahead of it is full. Thus, the transfer across the DDL is controlled by the X_{on}/X_{off} signal, transfer to the Multi-Event FIFO can only go ahead if there is space in the

FIFO, and transfer to the MER can only take place if there is space in it.

The way this scheme is implemented in a given detector may vary from one case to another, but logically the functions described above should be present.

4. CONCLUSIONS

The requirements for the ALICE trigger have been revised in the light of the introduction of front-end buffering in detectors, and in order to accommodate the TRD. The latency for the earliest (L0) trigger is unchanged in the new scheme, but the latency for L1 becomes 5.5 µs. Buffering allows a more efficient use of the DDLs and reduces the overall data flow in the detector.

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