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Triggering with the ALICE TRD

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ABSTRACT

We discuss how a level-1 trigger, about 8 μs after a hadron–hadron collision, can be derived from the Transition Radiation Detector (TRD) in A Large Ion Collider Experiment (ALICE) at the LHC. Chamber-wise track segments from fast on-detector reconstruction are read out with position, angle and electron likelihood. In the Global Tracking Unit, up to 6 tracklets from a particle traversing the detector layers are matched and used for the reconstruction of transverse momentum and electron identification. Such tracks form the basis for versatile and flexible trigger conditions, e.g. single high-$p_\perp$ hadron, single high-$p_\perp$ electron, di-electron (J/Ψ, ϒ) and at least n close high-$p_\perp$ tracks (jet).

The need for low-latency on-line reconstruction poses challenges on the detector operation. The calibration for gain (pad-by-pad) and drift velocity must be applied already in the front-end electronics. Due to changes in pressure and gas composition an on-line monitoring and feedback loop for these parameters is required. First experiences on the performance were gathered from triggering in cosmic and pp runs.

1. Introduction

The design of the ALICE TRD was driven by the requirement for very good pion rejection in the high multiplicity environment of Pb–Pb collisions and by the goal to use the information for a fast trigger contribution. Many interesting probes, such as J/Ψ, ϒ, open heavy-flavour, have (semi-)electronic decay channels. For their analysis, good electron identification is of crucial importance. As these probes are rare, triggering is essential to record a sufficient sample of events. Covering $[-0.9,0.9]\times 2\pi$ in $\eta-\varphi$, the scope of the trigger extends beyond electron channels, e.g. to jets.

The detector is segmented into 18 super-modules in azimuth, each comprising 5 stacks of 6 layers of tracking chambers. Each chamber consists of a radiator, a drift volume and a multi-wire proportional chamber with pad readout [1]. In this design, a short drift could be combined with the possibility of local chamber-wise tracking. For efficient absorption of the transition radiation photons, Xe is used as the counting gas, with a 15% admixture of CO_2 as the quencher. The front-end electronics is mounted directly on the chambers. The general setup and performance of the TRD and its physics applications were discussed in other contributions at this meeting [2,3].

In Section 2, the general concept of the TRD triggers is described providing an overview of the steps involved. The subsequent section explains the on-line reconstruction in more detail. Sections 4 and 5 describe the simulation framework and the observed performance, respectively. In Section 6, a TRD trigger on jets is discussed.

2. TRD-based triggering

In ALICE, three levels of hardware triggers are used. At the first stage, level-0 contributions from fast detectors, such as scintillators and silicon pixel detectors, are evaluated by the Central Trigger Processor (CTP) to issue a level-0 trigger. The set of triggered detectors depends on the combination of fired trigger inputs. About 6.5 μs after a level-0 trigger the read out can be continued or aborted depending on the contributions to the level-1 trigger. So far, the ElectroMagnetic CALorimeter (EMCAL), the Zero-Degree Calorimeter (ZDC) and the TRD contribute at that level. After the drift time of the time projection chamber ($\sim$90 μs), the readout must be accepted or rejected by a level-2 decision. This mechanism is mainly intended for the rejection of events with too many pile-up interactions (past–future protection) but could also be used for more complex triggers. The trigger chain is completed by the High-Level Trigger (HLT) implemented in a computing cluster. It processes the data from all events which have been accepted at level-2. For an overview of possible rates at the different trigger stages see Table 1.

Data from the TRD become available only after the acquisition have been initiated by a level-0 trigger. Therefore, a high level-0 rate is needed to sample a large number of events with the TRD triggers. They are based on tracks which are reconstructed on-line from TRD data only. First, local track segments, so-called tracklets, are

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Table 1
Overview of the hardware trigger stages used in ALICE. The three hardware levels are followed by a computing cluster forming the High-Level Trigger [4].

Trigger	**Time** (μs)	**Rate** (kHz)
Level-0	~ 1.2	~ 100
Level-1	~ 7.7	~ 2.5
Level-2	~ 100	~ 1.5

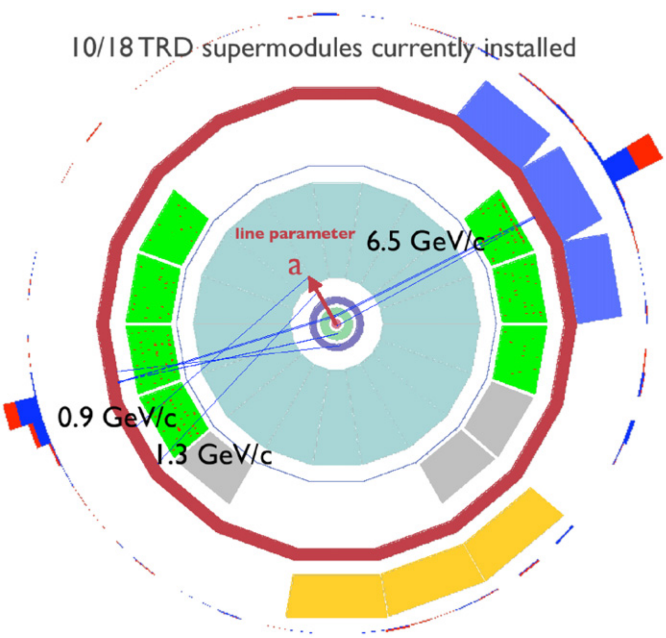

Fig. 1. An event display showing two back-to-back jets of about 45 GeV. The blue lines show the global tracks reconstructed as a straight line fits through the TRD tracklets. The line parameter a is used to extract the transverse momentum. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

calculated in every chamber. Those are shipped via optical links to the Global Tracking Unit (GTU). To achieve low latencies, all tracklets must be accepted without backpressure. The tracklet readout is sorted such that the matching can be performed as the data arrive. For found tracks, the transverse momentum is extracted from a straight line fit as the offset to the primary vertex.

By using the tracks as basis for the trigger decision, a variety of signatures can be used. A trigger on a single high-$p_\perp$ particle, on top of a level-0 condition based on TOF, has been used for cosmics data taking. In this way, a very pure sample of tracks could be provided for the analysis of very high momentum cosmic muons [5]. Asking for several tracks above a $p_\perp$ threshold in a small $\eta - \varphi$ area allows one to trigger on jets. The selection of identified electrons above a $p_\perp$ threshold allows one to enhance events with semi-leptonic decays of heavy flavour mesons. The di-electron signature shall be used to select events with electronic decays of J/Ψ or ϒ.

3. On-line reconstruction

3.1. Local tracking

When a charged particle traverses a TRD chamber (see Fig. 2) it deposits energy by ionisation of the gas in the active volume of the detector. Furthermore, highly relativistic particles with a Lorentz factor $\gamma \gtrsim 1000$ can emit transition radiation in the

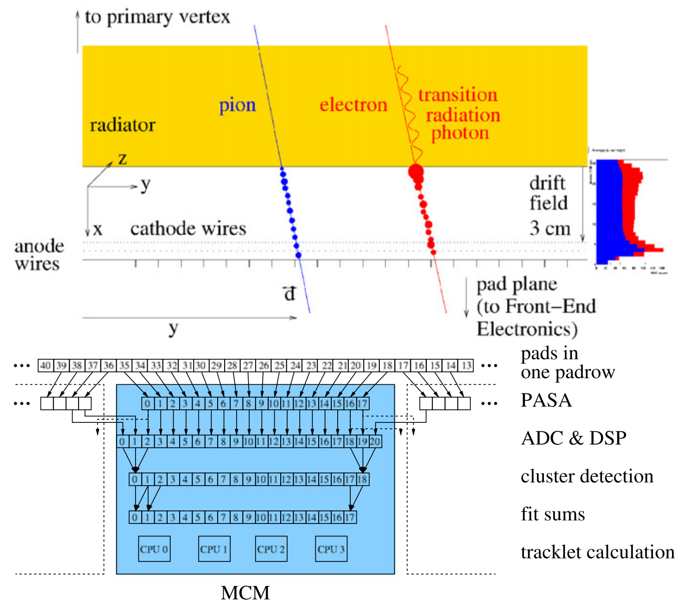

Fig. 2. Top: cross-section of a TRD chamber. Depending on its Lorentz γ a charged particle traversing the radiator can emit transition radiation which is absorbed within the drift region. Together with the electrons from ionisation of the gas the signal is detected in a MWPC. The pads are read out by front-end electronics mounted on the back of the chamber. Bottom: The processing of the pad signals. The charge-sensitive PASA feeds the ADCs in the TRAP. The edge channels are shared among adjacent chips. A preprocessor prepares the data for the final tracklet fit by the CPUs.

radiator material consisting of a fibre/foam sandwich [1]. Because of the high photoabsorption cross-section in Xe such a photon with X-ray energy is absorbed most likely close to the entrance to the drift volume. Except for very energetic particles, e.g. cosmic muons, the characteristic additional energy deposit at the end of the drift time can be exploited for the identification of electrons.

The electrons from ionisation of the gas drift towards an amplification region which is separated from the drift volume by a cathode wire grid. Induced signals are read out from a cathode pad-plane. Its granularity is fine in the transverse direction (~1 cm), while it is coarse along the beam direction (~10 cm). Therefore, the y-position (bending direction) can be determined accurately for individual clusters. To recover the z-position during off-line tracking, the pads are tilted by $\pm 2^\circ$ with the sign alternating from one layer to the next.

The signal from the pads is fed to the front-end electronics mounted on the backside of the pad plane. Groups of 18 channels are connected to a Multi-Chip Module (MCM) with two ASICs. The output of the charge-sensitive PreAmplifier and Shaping Amplifier (PASA) is fed to the TRAcklet Processor (TRAP). To avoid inefficiencies for the on-line tracking, the edge channels are shared between adjacent TRAPs as shown in Fig. 2. The signals are digitised by ADCs with a sampling frequency of 10 MHz. With a drift velocity around 1.5 cm/μs the full signal extends over 20 time bins. Typically, 24 time bins are read out to cover both the rising and falling edge of the signal, which are needed, e.g. for the drift velocity calibration.

The data pass through a chain of digital filters. A pedestal filter subtracts the channel-specific baseline as obtained over a long sampling period. A common baseline is added again to allow for the detection of undershoots created in later filter stages. Gain variations can be corrected for each of the 1.3 million channels by applying a correction

$$O_n(t) = \gamma_n \cdot I_n(t) + \alpha_n \quad (1)$$