The Fast Interaction Trigger detector for the ALICE Upgrade

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Abstract. As a result of the LHC injectors upgrade after the Long Shutdown (2019-2020), the expected Pb-Pb luminosity and collision rate during the so called Runs 3 and 4 will considerably exceed the design parameters for several of the key ALICE detectors systems including the forward trigger detectors. Fast Interaction Trigger (FIT) will be the primary forward trigger, luminosity, and collision time measurement detector. It will also determine multiplicity, centrality, and reaction plane of heavy ion collisions. FIT is expected to match and even exceed the functionality and performance currently secured by three ALICE sub-detectors: the time zero detector (T0), the VZERO system (V0), and the Forward Multiplicity Detector (FMD). FIT will consist of two arrays of Cherenkov radiators with MCP-PMT sensors and of a single, large-size scintillator ring. Because of the presence of the muon spectrometer, the placement of the FIT arrays will be asymmetric: ~800 mm from the interaction point (IP) on the absorber side and ~3200 mm from IP on the opposite side. The ongoing beam tests and Monte Carlo studies verify the physics performance and refine the geometry of the FIT arrays. The presentation gives a short description of FIT, triggers and readout requirement for the ALICE Upgrade, a summary of the performance, and the outcome of the simulations and beam tests.

1. Introduction
The ALICE (A Lange Ion Collider Experiment) [1] at CERN LHC (Large Hadron Collider) is dedicated to the study of the strongly-interacting medium with high temperature and energy density produced in ultra-relativistic heavy-ion collisions. The ALICE schedules a major upgrade of its apparatus for the long shutdown 2 of the LHC 2019-2020. The objective of the upgrade is to improve the tracking precision and efficiency, in particular in the low-momentum range, to improve the readout and triggers capabilities of the experiment, to fully exploit the LHC luminosity and collision rate for heavy ions after the LHC injectors upgrade. The ALICE upgrade strategy is based on collecting >10 nb−1 of Pb-Pb collisions at luminosities up to \( L = 6 \times 10^{27} \text{ cm}^{-2} \text{ s}^{-1} \) corresponding to collision rates of 50 kHz, where each collision is shipped to the online systems, either upon a Minimum Bias trigger or in a self-triggered, continuous fashion. Letter of Intent [2] considers in addition the collection of 6 pb−1 of pp collisions at the equivalent Pb-Pb nucleon energy as well as 50 nb−1 of p-Pb collisions, both at a levelled collision rate of 200 kHz. As part of this upgrade the cluster of three ALICE forward detectors: V0, T0, and FMD (Forward Multiplicity Detector) [3, 4] will be replaced by a single trigger detector Fast Interaction Trigger (FIT) [5]. The main components of the ALICE upgrade are summarized on figure1.
2. The Fast Interaction Trigger

FIT will consist of two arrays of Cherenkov quartz radiators with MCP-PMT sensors and of a scintillator ring. Because of the functional and operational similarity to the current ALICE T0 detector, the upgraded Cherenkov arrays are referred to as T0+. Accordingly, in reference to V0 \cite{3}, the scintillator ring is called V0+. This system will provide triggers for the whole experiment. It is also will be used to measure beam luminosity, charged particle multiplicity and azimuthal distribution. The knowledge of the charged particle multiplicity is essential for the evaluation of the centrality of nucleus-nucleus collisions, the measure of the azimuthal distribution is important for defining the collision reaction plane. Particle identification via the time-of-flight technique is an important feature of the ALICE detector. The measurement of the time-of-flight of the tracks is based on the TOF (Time-of-Flight detector) while the event collision time will be determined using information coming from both the TOF and the FIT detectors. The FIT detector will be also able to monitor online the luminosity providing a fast feedback to the ALICE and the LHC. The required functionality of FIT also includes separation of beam-beam interactions from background events such as beam-gas interactions, either at the trigger level or in offline analyses.

2.1. T0+ detector

The T0+ detector will consist of two arrays of Cherenkov modules T0A+ and T0C+, positioned around the beam pipe at 3200 mm and –820 mm on the opposite sides of the interaction point (IP). T0A+ array and T0C+ array will have 24 and 28 of T0+ modules, respectively. Figure 2. shows the scaled drawings of the FIT components, pseudorapidity coverage and FIT inside of ALICE detector. Each T0+ module consists of a 2 cm thick quartz radiator coupled to a modified Planacon XP85012 MCP-PMT. The choice of Planacon XP85012 was based on its performance, compact size (28 mm thick) and a large surface of photocathode (53 x 53 mm²) with respect to the overall face area of 59 x 59 mm² of the unit. The XP85012 MCP-PMT has a multi-anode structure (8 x 8 anodes array), which enables segmentation into 64 independent pixels. We have reached the best overall performance of T0+ modules by grouping the anodes and dividing the radiator into 4 sectors. The standard PCB at the back of the Planacon was replaced by a custom-made PCB designed by our collaboration. It eliminated the common output and matched (within 1 mm) the lengths of the traces connecting anode
sections to the connectors for 4 coaxial signal cables. The modification of the Planacon XP85012 was implemented at the factory. The modification was very successful as illustrated on figure 3. As a result of the modification, the time resolution has improved from 30 to 22 ps and due to the reduced capacitance, the amplitude of the output signal increased by a factor of two for the same HV value applied to the MCP. During the prototype tests with 6 GeV/c pions and muons from CERN PS, the T0+ modules routinely reach the time resolution of 22 ps (1 sigma) and 25% amplitude resolution (FWHM).

Figure 2. Left: a scaled drawing of FIT components with dimensions in cm and indicated pseudorapidity coverage. Right: integration of FIT inside of the ALICE detector.

Figure 3. Amplitude spectra and time resolution of different readout channels of the standard MCP-PMT (left) and modified MCP-PMT (right).

2.2 V0+ detector
The introduction of the new Muon Forward Tracker (MFT) will significantly reduce the space available for FIT on the absorber side. Due to the space restrictions, V0+ will be placed only on the A-side, in the close proximity of the T0A+. V0+ will consist of five rings segmented into eight equal sections (figure 2). The active part of the V0+ detector will be made of a 4 cm thick EJ204 plastic scintillator with the inner diameter 8 cm and the outer diameter 148 cm. The final choice of the light sensors has not yet been made. The considered options include a modified Planacon XP85012 MCP-PMT and micromesh PMT.
3. FIT trigger and readout concepts.
The upgraded ALICE trigger system supports the read-out of triggered and continuously readout
detectors. The Central Trigger Processor (CTP) will provide LM,L0,L1 trigger signals. The LM signal
is produced by the FIT, with a latency (425ns) that is compatible with the timing requirements of the
wake-up signal for the readout of the other ALICE detectors. At nominal operation, this is the only
trigger contributor and L0, L1 are simply delayed copies of the LM signal. FIT trigger and readout
electronics is developed as integrated system based on a CFD (Constant Fraction Discriminator), on-
board TDC/ADCs and FPGA processors which allow digital trigger processing and continues readout
(figure 4). Processing the trigger algorithm in the digital domain allows flexibility during
commissioning and operation.

![Figure 4](image)

**Figure 4.** Digital trigger processing and estimated LM trigger latency.

4. Conclusion.
FIT prototype tests at CERN PS have shown that it is possible to build a new forward detector,
complying with the space limitations, offering improved time resolution and reliability and retaining
the required efficiency. The ongoing research concentrates on the digital trigger and continuously
readout electronics.

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