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The Fast Interaction Trigger Upgrade for ALICE

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On Behalf of the ALICE Collaboration †

The ALICE Collaboration is preparing a major detector upgrade for the second LHC long shutdown (2019–20). The LHC heavy-ion luminosity and collision rate from 2021 onwards will considerably exceed the design parameters of the present ALICE forward trigger detectors. Furthermore, the introduction of a new Muon Forward Tracker (MFT) will significantly reduce the space available for the upgraded trigger detectors. To comply with these conditions a Fast Interaction Trigger (FIT) has been designed. FIT will be the primary forward trigger, luminosity, and collision time measurement detector. The FIT will be capable of triggering at an interaction rate of 50 kHz, with a time resolution better than 30 ps, with 99% efficiency. It will also determine multiplicity, centrality, and reaction plane. FIT will consist of two arrays of Cherenkov radiators with MCP-PMT sensors and of a single, large-size scintillator ring. The arrays will be placed on both sides of the interaction point (IP). Because of the presence of the hadron absorber of the muon spectrometer, the placement of the FIT detectors will be asymmetric: one array at about 800 mm from the IP on the absorber side and and the other array together with the scintillator ring at around 3200 mm from IP on the opposite side. Scheduled for installation in 2020, FIT is in the midst of an intense R&D and prototyping period. The timing, amplitude and efficiency characteristics are determined with relativistic particles and with lasers. The ongoing Monte Carlo studies verify the physics performance and refine the geometry of the FIT arrays. This report gives a short description of FIT, a summary of the performance, and the outcome of the simulations and beam tests.

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1. Introduction

ALICE at the Large Hadron Collider (LHC) consists of a variety of detector systems for measuring hadrons, leptons, and photons. ALICE is designed to perform measurements of high-energy nucleus–nucleus collisions in order to study quark matter (QCD matter) [1] under extreme conditions. ALICE announced at the Quark Matter 2012 conference that the experiment produced quark–gluon plasma (QGP) with a temperature of about 5.5 trillion degrees, the highest temperature ever achieved in any controlled experiments thus far. The detector has successfully analyzed physics data from proton–proton, lead–lead, and proton–lead collisions during the past six years. A discussion of ALICE's physics program is in [2] and a list of publications in [3]. The experimental verification of the QGP and a comprehensive investigation of the properties of strongly interacting matter at high temperature are the principal objectives of the ALICE scientific program. Precise determination of the QGP properties, such as degrees of freedom, speed of sound, critical temperature, transport coefficients and equation of state, is the ultimate goal of ALICE.

2. ALICE Detector Upgrade

In order to fully exploit the scientific potential of the LHC injectors upgrade scheduled for the Long Shutdown 2 (LS2), the ALICE collaboration is undertaking a major initiative to extend its physics program. The improvement of the ALICE detector will enable detailed and quantitative characterization of the high density, high temperature phase of strongly interacting matter, together with the exploration of new phenomena in QCD. With the proposed timeline of initiating high-rate operation after the 2019–2020 LS2, the objectives of the upgrade plans will be achieved by collecting data into the 2020 decade. The study of the strongly interacting state of matter following LS2 will focus on rare probes and the study of their coupling with the medium and hadronization processes. These include heavy-flavour mesons and baryons, quarkonium states, low-mass dileptons, jets and their correlations with other probes.

To achieve the goals described above, high statistics and high precision measurements are necessary. Many of these measurements will involve complex probes at low transverse momentum, where traditional methods for triggering will not be applicable. Therefore, the ALICE collaboration is planning to upgrade the current detector by enhancing its low-momentum vertexing and tracking capability, and allowing data taking at substantially higher rates. The upgrade strategy is formulated under the assumption that, after the second long shutdown in 2019–2020, the LHC will increase its luminosity with lead beams reaching an interaction rate of 50 kHz, or instantaneous luminosities of $L = 6 \times 10^{27}$ cm^{-2} s^{-1}. In the proposed upgrade the ALICE detector is modified such that all interactions will be recorded. ALICE will then be in a position to accumulate 10 nb^{-1} of Pb–Pb collisions corresponding to about 10^{11} interactions. The planned upgrades will preserve the current particle identification capability while enhancing the vertex detectors, triggering and tracking capabilities. The main components of the ALICE upgrade are summarized in Fig. 1, and the details can be found in references [4, 5, 6, 7].

3. The Fast Interaction Trigger

The ALICE trigger upgrade strategy is based on collecting at least 10 nb^{-1} of Pb–Pb collisions

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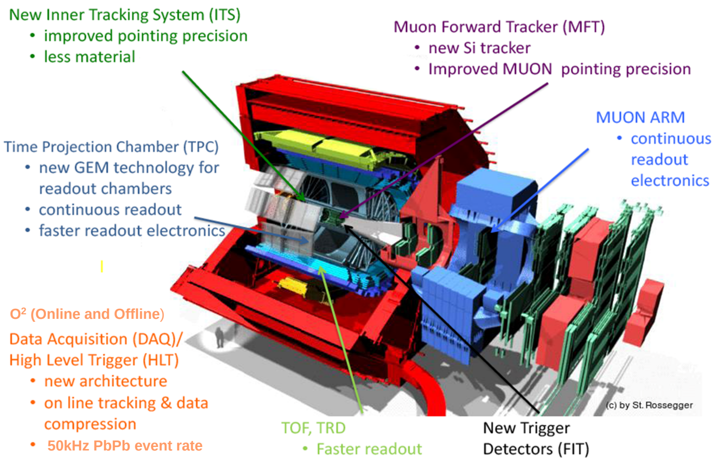

Figure 1: Summary and schematics of the ALICE detector upgrade.

at collision rates of 50 kHz, where each collision is sent to the online systems, either upon a Minimum Bias trigger or in a continuous fashion. In addition, we expect the collection of data at a collision rate of 200 kHz of 6 pb^{-1} of proton–proton collisions at the equivalent Pb–Pb nucleon energy as well as 50 nb^{-1} for p–Pb collisions.

To this end a Fast Interaction Trigger (FIT) [8] has been proposed to trigger beam-beam interactions with 99% efficiency and to provide a start signal for the rest of the ALICE detectors (Level-0 trigger) with a time resolution better than 30 ps. For the evaluation and rejection of beam-induced background and, in particular, beam-gas interactions the FIT detector will find the vertex location with a performance of at least 40 ps time resolution and 50% vertex efficiency for pp collisions, and 21 ps time resolution and close to 100% vertex efficiency for Pb–Pb central and semi-central collisions. Also, we expect that the FIT detector will be able to measure the reaction event plane and centrality. Finally, the FIT detectors will feed back to the LHC for luminosity monitoring.

The present ALICE detector employs two forward detector systems, the T0 [9] and the V0 [10] that provide minimum bias trigger, multiplicity trigger, beam-gas event rejection, collision time for TOF, online multiplicity and event plane determination. In order to adapt these functionalities to the collision rates of the ALICE upgrade, it is necessary to find a new solution with the Fast Interaction Trigger. The most natural approach to address the upgrade requirements for the FIT is increasing the acceptance of the current T0. However, it is not possible to use for the T0+ the detector setup that is now used for T0, i.e. a quartz + photo multiplier tube (PMT) because of space constrains allocated to the trigger detectors after installation of the MFT [6] . Instead, a new concept of an array of modules consisting of segmented quartz radiators coupled directly to a micro channel plate-PMT (MCP-PMT) is proposed. A rendering of the upgrade proposal for the trigger detectors is shown in Fig. 2.

3.1 The FIT detectors T0+ and V0+

Each T0+ module consists of a 2 cm thick quartz radiator coupled to a modified Planacon XP85012 MCP-PMT. The size of the radiator matches that of the photocathode with the active area spanning about 80% of the front surface of the sensor. To improve the performance at high particle multiplicities, the granularity of the sensors has been increased. The anode of the Planacon

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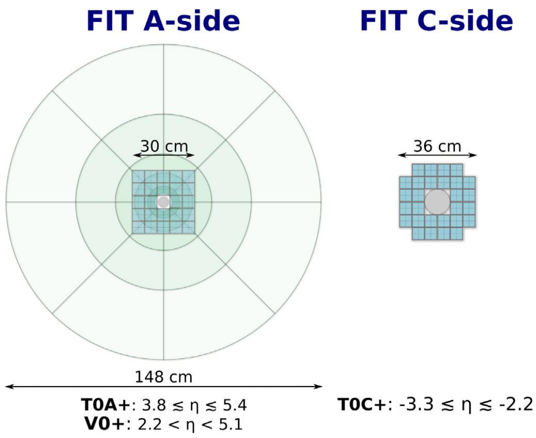

Figure 2: Scaled drawings of FIT components on both sides of the IP. The opening in the middle of the T0+ array on the C-side is needed to provide clearance for an R = 60 mm flange on the beam pipe.

consists of 64 sectors that operate independently, so that, the Cherenkov radiators can be subdivided to minimize optical crosstalk. Also, by subdividing the radiator into small sections, one increases the light loss due to multiple reflections from the inner walls. We have reached the best overall performance of T0+ modules by grouping the anodes and dividing the radiator into 4 sectors. During the prototype tests with 6 GeV/c pions and electrons from CERN PS, the 4-sector T0+ modules reach the time resolution of 25 ps (1 σ) and 25% amplitude resolution (FWHM).

The active part of the V0+ detector will be a 4 cm thick ring made of EJ204 scintillator plastic with an inner diameter of 8 cm and an outer diameter of 148 cm. The detector will be divided into five concentric rings and eight 45-degree sectors for a total of 40 elements. The light collection from the scintillators will be provided by 1 mm diameter optical fibers, assembled on a two dimensional grid with 5 mm pitch. The grid is looking directly at the scintillator while on the other side the fibers are bundled and, via a trapezoid light guide, are coupled to light sensors. The main impact of the V0+ scintillator ring will be on improved centrality and reaction plane resolution as well as added sensitivity for the detection of beam-gas events. As compared to the current V0 detector, the V0+ will have a 3.2 times larger active area, 25% more readout channels, and an improved time resolution. By the use of improved micro-PMTs, SiPM and/or with MCP-PMT sensors, the V0+ is expected to diminish aging problems and after-pulses observed in the current V0 detector. During the prototype tests with 6 GeV/c pions and electrons from CERN PS, the V0+ modules reached the time resolution of 220 ps (1 σ) and 35% amplitude resolution (FWHM), uniform across the area of the scintillator, when using fine mesh PMTs.

3.2 Performance Simulations

In addition to the tests at CERN PS, the performance of the detector was simulated with the AliRoot package and event generators. In particular, the response of the FIT for the trigger efficiency, the centrality resolution and the event plane resolution were studied. For the trigger efficiency events generated with PYTHIA 6 [11] for p-p collisions at $\sqrt{s}$=14 TeV were used. Simulations were performed with the HIJING event generator [12] for Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5 TeV. Figure 3 (left) shows the optimized T0+ efficiency as a function of primary particle multiplicity in p-p collisions. Figure 3 (right) shows the efficiency as a function of the impact parameter (cen-

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trality) for Pb-Pb collisions. The trigger conditions used for these calculations were a coincidence between the A and C detectors and OR coincidence. The efficiency obtained is within the expected parameters.

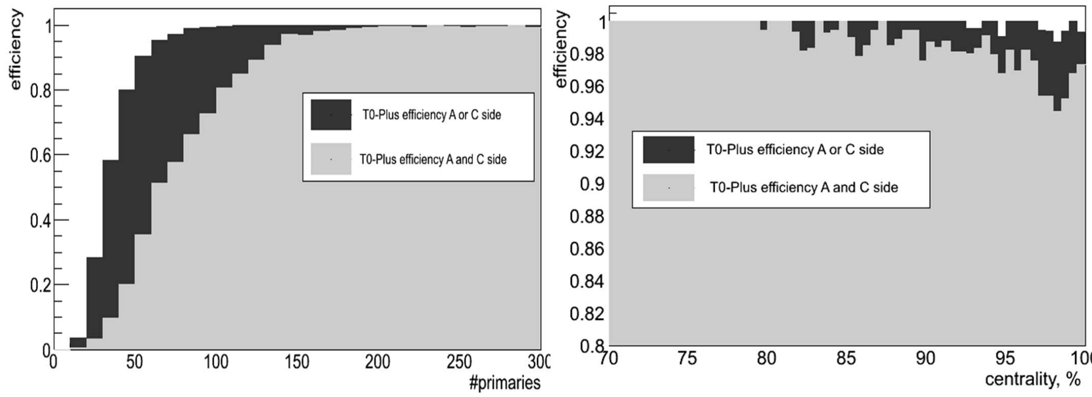

Figure 3: Simulated efficiency of the T0+ detector as a function of primary particle multiplicity for p-p collisions (left) and as a function of the event centrality for Pb-Pb collisions (right) [7] .

For the centrality resolution, in Fig. 4 (left), also a set of HIJING events for Pb-Pb collisions was used. The performance of the FIT upgrade is within the design parameters. Finally for the event plane resolution, in Fig. 4 (right), the hits in the sensitive detectors were used for the calculation of the event plane resolution following the method of reference [13]. The generator included as inputs the direct and elliptic flow distributions from data. The figure shows the event plane resolution for several current forward detectors and the upgrades. The simulations show that the event plane resolution calculated with the full FIT+MFT detector is equivalent to the resolution with the current detectors.

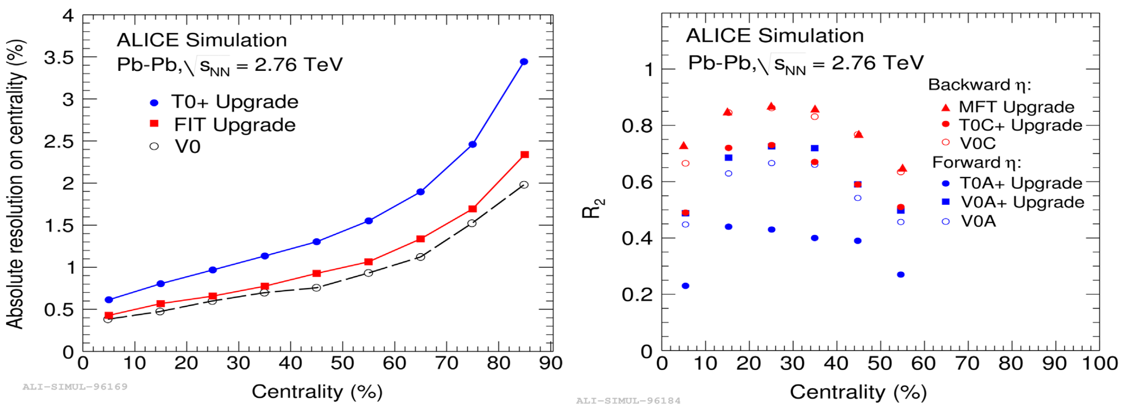

Figure 4: (Left) V0+ centrality resolution of FIT, solid dots only T0+ arrays, empty dots current V0, squares FIT consisting of both T0+ and V0+. (Right) The event plane resolution of FIT, the comparison is made separately for each side for MFT upgrade, V0, T0 and T0+ [8].

4. Conclusions

To exploit the full potential of the of the LHC in RUN 3, the ALICE experiment requires an upgrade. In order to carry out the precision measurements of rare probes one has to fully utilize

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high luminosity provided by the LHC after the LS2, and to collect 10 nb^{-1} at the collision rates of 50 kHz.

The strategy of this upgrade is to fully utilize high luminosity provided by the LHC after the LS2 in order to carry out measurements of rare and untriggerable probes. One of the elements of the upgrade, the FIT, is being currently developed. The time and amplitude resolution achieved by the detector prototypes have fulfilled the design expectations. The ongoing R&D concentrate on the electronics and implementation of the continuous readout for the FIT.

5. Acknowledgements

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