PROCEEDINGS OF SCIENCE

The new ALICE Fast Interaction Trigger in LHC Run 3

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On the 5th of July 2022, the Large Hadron Collider (LHC) at CERN, Geneva, started the official data-taking of the current LHC run, Run 3, after a maintenance, upgrade, and commissioning period of about three and a half years. ALICE (A Large Ion Collider Experiment) has undergone many upgrades and improvements, one of which is the new Fast Interaction Trigger (FIT) detector. With its Cherenkov and scintillator arrays, FIT detects particles from proton and heavy-ion collisions in the forward regions of ALICE. It provides low-latency interaction triggers, precise interaction time, luminosity and background monitoring, and determination of multiplicity, centrality and event plane. FIT has performed well in both proton-proton and Pb-Pb collision runs: it shows good collision time and vertex reconstruction; provides a sophisticated interaction trigger menu; and has been giving critical feedback about luminosity and background to the LHC for online beam tuning. The performance of FIT is continuously improving thanks to upgrades to electronics, firmware and software. The installation and commissioning of FIT, its performance during the start of Run 3 and future development and outlook are presented.

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1. Introduction

ALICE (A Large Ion Collider Experiment), dedicated to the study of the quark-gluon plasma produced in ultra-relativistic heavy-ion collisions at the CERN LHC, has performed major detector upgrades to accommodate its extended physics program and to fully benefit from the LHC capabilities during the current and future LHC runs [1]. In the ongoing LHC Run 3, the Pb-Pb instantaneous luminosity has increased by a factor 5-6, and the Pb-Pb interaction rate has increased by a factor ~50 with respect to the previous run [2]. The planned amount of recorded minimum-bias events in Run 3 and 4 exceeds the minimum-bias statistics from Run 1 and 2 combined, by two orders of magnitude [1, 3].

2. The Fast Interaction Trigger

One of the ALICE upgrades for LHC Run 3 is the new Fast Interaction Trigger (FIT) [2–5]. FIT comprises five arrays of sensors grouped into three subdetectors, surrounding the beam pipe on both sides of the interaction point in the forward (high-rapidity) regions of ALICE. The FIT subdetectors are schematically depicted in figure 1.

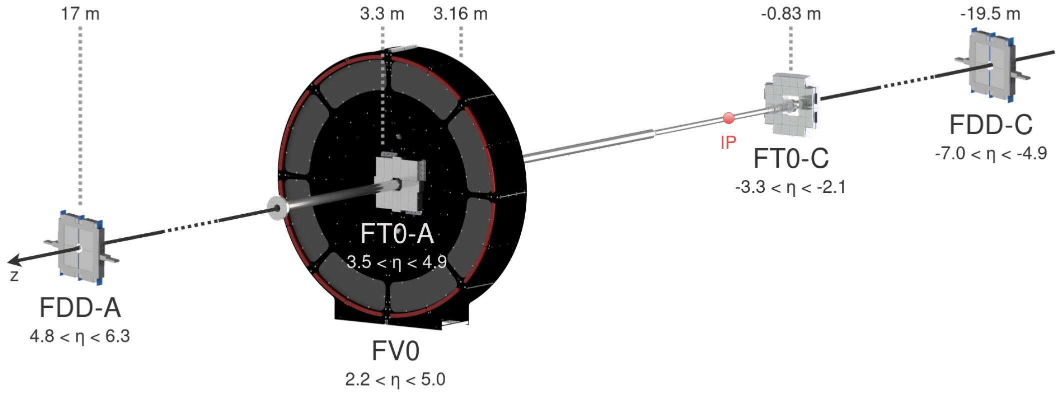

Figure 1: Schematic illustration of the FIT detector elements and their housing. The pseudo-rapidity coverage and distance from the interaction point of the detector elements are listed. For reference, the FV0 detector is about 1.5 m in diameter.

FT0 consists of two arrays of Cherenkov radiators, optically coupled to microchannel-plate-based photomultiplier tubes (MCP-PMTs), totaling 208 low-latency readout channels. FV0 and FDD utilize scintillator cells connected to PMTs via optical fibers [6, 7], extending the η-coverage of FIT to lower values with FV0's 48 detector cells on one side of the interaction point, and to higher values with FDD's four double layered detectors cells further away on both sides of the interaction point. Fully integrated custom front-end electronics provide fast digital signal readout [8].

FIT serves numerous vital purposes: it generates extensive and configurable trigger signals for both online and offline event tagging and background rejection; FT0 provides a precise interaction time used for time-of-flight-based particle identification; centrality and event plane are deduced based on the measured forward multiplicity; FDD tags diffractive physics events; and LHC depends on the background and luminosity monitoring of FIT for online beam tuning.

The installation of FIT was completed in July 2021 [9], after which its hardware and software were successfully tuned and commissioned for the upcoming data taking.

3. Performance

Between the first pilot beam of LHC Run 3 and the start of the Pb-Pb data taking, FIT profited from the nominal pp collisions at top-energy of $\sqrt{s}$ = 13.6 TeV, as well as from special calibration and stress-test runs, to further commission the detector. This while remaining fully operational and fulfilling its functions with great proficiency.

Also during the six-week-long Pb-Pb data taking of 2023, FIT proved excellent performance and operability, with only a scheduled downtime of about 30 minutes for FDD to fine-tune hardware settings.

FT0 reconstructs the collision time with an excellent resolution of 17 ps for pp collisions and down to 4.4 ps for Pb-Pb collisions. The resolution in the left plot of figure 2 is the standard deviation of the difference in primary-vertex-corrected average-time measurements from the two sides of the FT0 detector. The higher multiplicity in Pb-Pb versus pp collisions yields better time resolution. Furthermore, a time slewing correction is applied for Pb-Pb collisions.

Online, FT0 reconstructs the z-position of the collision vertex based on the time measurements with millimeter accuracy. This information is used to produce the vertex trigger. Offline, the ALICE tracking detectors reconstruct the vertex position (*primary vertex*) with micrometer precision. The FT0 online vertex shows a good correlation with the offline reconstructed primary vertex, as seen in the right plot of figure 2.

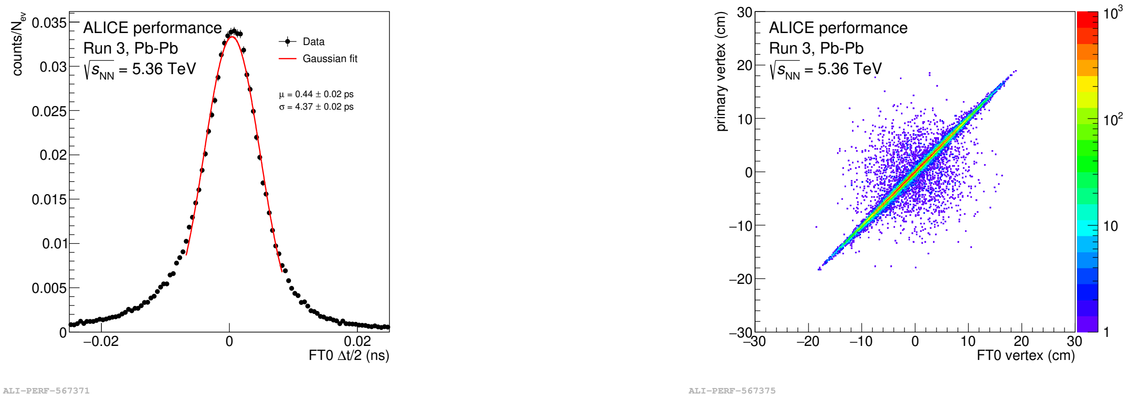

Figure 2: The FT0 time resolution (left), and the correlation between the FT0 vertex and the primary vertex (right).

The FDD detector provides complementary information about collision time and vertex position, as well as about background. This is especially useful for events with signals only in the very forward regions of ALICE. The correlation between the collision time and vertex, as measured by FDD for pp collisions and FT0 for Pb-Pb collisions, is shown in figure 3.

The total amplitude measured by FV0 and its strong correlation with the FT0-C total amplitude is shown in figure 4. This further demonstrates good and healthy performance of the detectors.

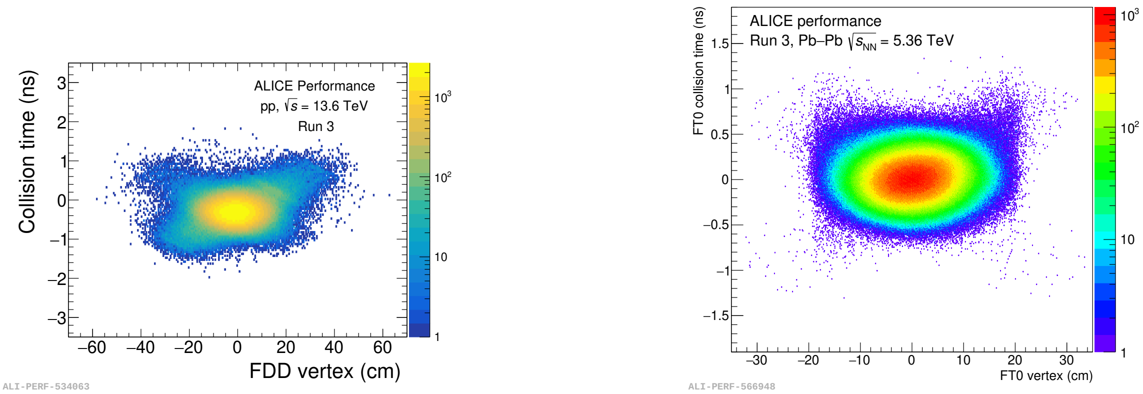

Figure 3: Correlation between collision time and vertex position as measured by FDD for pp collisions (left) and by FT0 for Pb-Pb collisions (right).

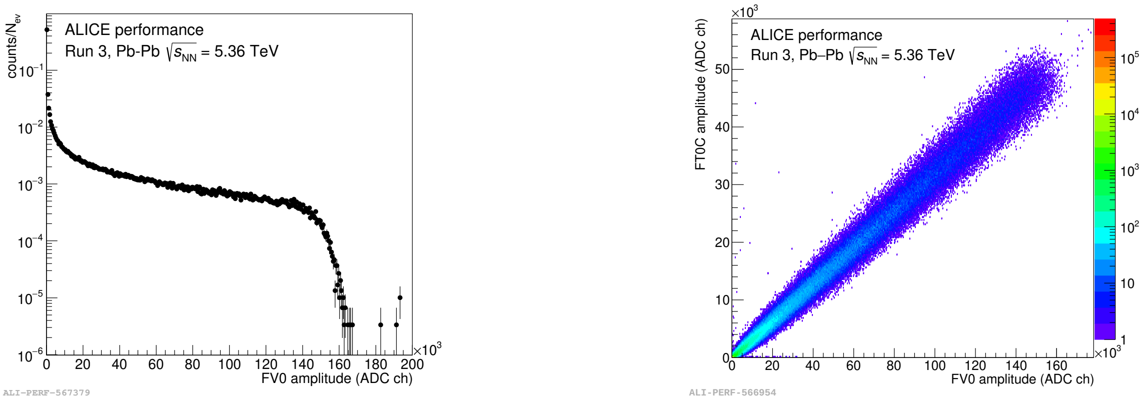

Figure 4: FV0 total charge distribution for Pb-Pb collisions (left) and correlation between the total charge of FT0-C and FV0 (right).

4. Summary and outlook

The greatly achieved installation, commissioning and operation of FIT to date, enabled and contributed to the successful first ALICE data taking of LHC Run 3.

The performance of FIT is continuously improving thanks to upgrades in electronics firmware and data processing software. Other future developments include detector operation automation, calibration and hardware maintenance to accommodate natural performance-degradation effects.

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