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ALICE-France in LHC runs 3+4 and the ALICE 3 upgrade project

Summary

The **ALICE experiment** has undergone a complete upgrade of its readout electronic and data acquisition system during the last Long Shutdown of the LHC (LS2). During this period, all detectors Readout and Front-end electronics have been upgraded to be able to cope with the increase of the luminosity and the new data taking paradigm based on continuous readout, opposite to the triggered-event one exploited in Runs 1 and 2. The Muon Spectrometer, composed of the Muon Chambers (MCH) and the Muon Identifier (MID), has been upgraded accordingly. In addition, two novel detectors were installed, namely the Muon Forward Tracker (MFT) and the Inner Tracking system (ITS2), both based on the CMOS silicon pixel technology. These 4 projects profit from a strong involvement from the French teams as IN2P3 projects. In **Part A** of this report it will be shown that, during the last period of 5 years, *i)* the ALICE-France community successfully exploited the data collected during Run 1 and 2, publishing important physics results improving our understanding of high density hadronic physics and the characterization of the Quark Gluon Plasma phase, leading at the same time *ii)* the finalization of the LS2 upgrade program culminating in the installation and the commissioning of the ITS2, MFT, MCH and MID, in preparation of Run 3. These upgrades have been carried out within the planned time and budget constraints, adapting on the fly to worldwide conditions such as the Covid pandemic. To fully exploit the next Run 4, the upgrade project of ITS3 has been presented to the scientific council of IN2P3 in October 2022. The physics potential corresponding to the exploitation of the upgraded detectors in Runs 3 and 4 will be discussed, as well as implications of the French IN2P3 teams within those projects.

The current ALICE detector will end its operation with Run 4. Beyond that limit, the aging of the detector will make its exploitation not useful anymore for a competitive physics program at the LHC. However, in order to continue exploiting the full potential of LHC as a heavy-ion collider in Run 5 and Run 6, the ALICE collaboration has proposed a new dedicated heavy-ion experiment, based on a next-generation detector implementing cutting-edge technologies for vertexing, tracking, particle identification, and readout. Such a new experimental program, unique and complementary to the heavy-ion scientific programs of the other LHC experiments, is being developed under the name of ALICE 3. The ALICE IN2P3 groups of Grenoble, Lyon and Strasbourg, already aiming at joining the ITS3 upgrade project for the LS3, also aim, in the longer term, at joining the ALICE 3 project with a common physics program and a significant technical implication. In **Part B** of this report the physics program of the ALICE 3 project will be discussed, together with the conceptual design of the envisaged sub-detectors. The discussions about a possible implication of IN2P3 are still ongoing, and the three laboratories interested in the project are working to define a common technical implication, which should arguably exploit the experience gained in the development of the ITS3 project (under approval at the IN2P3).

1. Bottom line of ALICE in Run 2 [2015-2018]

The analysis of the LHC Run 2 data has seen the French teams of the ALICE Collaboration involved on several fronts. Their contributions can be grouped into four main areas: i) study of production mechanisms and collective effects in the heavy quark sector; ii) specific hadro- and photo-production mechanisms for the ($c\underline{c}$) and ($b\underline{b}$) bound states, their modification in the deconfined medium, and their dependence on the charged-particle multiplicity; iii) multiplicity-dependent strangeness production; iv) hard or electroweak probe measurements. In an important fraction of the measurements performed, the analyses were carried out as a function of the charged particle multiplicity, with the aim of highlighting the role of the latter as an effective scaling parameter, determining the deviation of the observed effects from the vacuum reference, independently of the collision mode size.

The measurements concerning the production of hadrons containing heavy quarks (*c* and *b*), in the first place the dependence on the transverse momentum and the azimuthal asymmetries, give precious indications for the determination of the transport properties of the QGP, the characterization of the hadronization mechanisms for heavy quarks in a deconfined medium, and the determination of the corresponding parameters. Among the key measurements in this field, carried out with the participation of French teams, we can mention the demonstration of the absence of collective flow for the ϒ meson in Pb-Pb collisions, the first time that such a behavior is observed for a hadron in nuclear collisions at LHC energies, the first measurement of the elliptic flow of jet-associated particles in p-Pb, and the measurement of collective phenomena in pp and p-Pb collisions where no significant volume of QGP is expected to be produced. The study of the evolution of the meson/baryon ratios as a function of the multiplicity of charged particles, and the comparison of the production rates of different species of charm and beauty mesons or baryons, offer an important contribution to the characterization of the hadronization mechanisms of heavy quarks.

- *Search for collectivity with azimuthal J/ψ-hadron correlations in high multiplicity p-Pb collisions at 5.02 and 8.16 TeV* - PLB 780 (2018) 7-20 [arxiv:1709.06807]
- *J/ψ azimuthal anisotropy at forward rapidity in Pb-Pb collisions at 5.02 TeV* - JHEP 1902 (2019) 012 [arxiv:1811.12727]
- *Measurement of ϒ(1S) elliptic flow at forward rapidity in Pb-Pb collisions at 5.02 TeV* - PRL 123 (2019) 19, 192301 [arxiv:1907.03169]
- *Azimuthal anisotropy of jet particles in p-Pb and Pb-Pb collisions at 5.02 TeV* - submitted to PRL [arXiv:2212.12609]/ proceedings : [arXiv:2110.15852]

- *Measurements of azimuthal anisotropies at forward and backward rapidity with muons in high-multiplicity p-Pb collisions at 8.16 TeV* - submitted to PLB [arXiv:2210.08980]
- *J/ψ-hadron correlations at midrapidity in pp collisions at 13 TeV* - to be submitted to JHEP
- *Observation of a multiplicity dependence in the p_T-differential charm baryon-to-meson ratios in proton-proton collisions at 13 TeV* - submitted to PLB [arXiv:2111.11948]
- *Inclusive heavy-flavour production at central and forward rapidity in Xe-Xe collisions at 5.44 TeV* - PLB 819 (2021) 136437 [arXiv:2011.06970]
- *Production of muons from heavy-flavour hadron decays at high transverse momentum in Pb-Pb collisions at 5.02 TeV* - PLB 820 (2021) 136558, [arXiv:2011.05718]
- *Measurement of prompt D^0, D^+, D^{*+}, and D^+_s production in p-Pb collisions at 5.02 TeV* - JHEP 2019 (2019) 92 [arXiv:1906.03425]
- *Measurement of inclusive charged-particle b-jet production in pp and p-Pb collisions at 5.02 TeV* - JHEP 2022, 178 (2022) [arXiv:2110.06104]
- Production of muons from heavy-flavour hadron decays in pp collisions art 5.02 TeV- JHEP 09 (2029) 008, arXiv:1905.07207

Beyond the measurements concerning the evidence of flow and correlation phenomena involving heavy flavors, quarkonia measurements allow to address fundamental questions concerning the production mechanisms of cc and bb bound states in a hadronic collision environment, the role of photoproduction mechanisms, and the existence of dissociation and regeneration mechanisms in the presence of a deconfined medium. Measurements in this field are mainly focused on the analysis of the evolution of the quarkonia production rate with the multiplicity of charged particles or the transverse momentum, from pp collisions to Pb-Pb collisions.

- *Centrality and transverse momentum dependence of inclusive J/ψ production at midrapidity in Pb-Pb collisions at 5.02 TeV* - PLB 805 (2020) 135434 [arXiv:1910.14404]
- *ϒ production and nuclear modification at forward rapidity in Pb–Pb collisions at 5.02 TeV* - PLB 822 (2021) 136579 [arXiv:2011.05758]
- *Multiplicity dependence of ϒ production at forward rapidity in pp collisions at 13 TeV* - submitted to PLB [arXiv:2209.04241]
- *Inclusive quarkonium production in pp collisions at 5.02 TeV* - submitted to EPJC [arXiv:2109.15240]

- *Measurement of ψ(2S) production as a function of charged-particle pseudorapidity density in pp collisions at 13 TeV and p-Pb collisions at 8.16 TeV with ALICE at the LHC* - submitted to JHEP [arXiv:2204.10253]

- *J/ψ production as a function of charged-particle multiplicity in p-Pb collisions at 8.16 TeV* - JHEP 2020 (2020) 162 [arXiv:2004.12673]

- *Photoproduction of low-p_T J/ψ from peripheral to central Pb-Pb collisions at 5.02 TeV* - accepted by PLB [arXiv:2204.10684]

Measurements of the production of particles containing an s-quark play an essential role in the characterization of the thermalization and hadronization mechanisms of quarks in a dense hadronic medium. Indeed, the mass of the s quark being intermediate between those of the light quarks u and d and the heavy quarks c and b, it is extremely interesting to study how the interaction of this quark with the hadronic environment evolves as a function of the complexity of the created system, quantified by the multiplicity of charged particles. On the one hand, the production rate of the s quark is strongly suppressed in very low multiplicity collisions, whose environment is close to that of vacuum, compared to predictions based on a thermodynamic approach; on the other hand, in the most energetic nuclear collisions the s quark participates in the thermalization phase which characterizes the evolution of the volume of QGP created, its production rate finding the thermodynamic equilibrium with the production rates of the light u and d quarks.

- *Enhanced production of multi-strange hadrons in high-multiplicity proton-proton collisions* - Nature Physics *13*, 535-539 (2017) [arXiv:1606.07424]

- *Multiplicity dependence of (multi-)strange hadron production in proton-proton collisions at 13 TeV* - EPJC 80, 167 (2020) [arXiv:1908.01861]

- *Energy dependence of φ meson production at forward rapidity in pp collisions at the LHC* - EPJC 81 (2021) 772 [arXiv:2105.00713]

- *φ meson production at forward rapidity in Pb-Pb collisions at 2.76 TeV* - EPJC 78 (2018) 559 [arXiv:1804.08906]

Finally, measurements with hard or electroweak probes such as high-p_T particles or jets, isolated photons, and Z and W bosons, which are not very sensitive to the presence of hot or cold hadronic matter, allow us to establish a reference for measurements of effects related to the presence of a deconfined medium, to probe the partonic distribution functions (PDFs) of the nuclei involved in collisions, or to test perturbative QCD computations in a near vacuum environment.

- *W boson production in p-Pb collisions at 8.16 TeV and Pb-Pb collisions at 5.02 TeV* - accepted by JHEP [arXiv:2204.10640]

- *Z boson production in p-Pb collisions at 8.16 TeV and Pb-Pb collisions at 5.02 TeV* - JHEP 09 (2020) 076 [arXiv:2005.11126]
- *Measurement of Z°-boson production at large rapidities in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV* - PLB 780 (2018) 372-383 [arXiv:1711.10753]
- *Measurement of the inclusive isolated photon cross section in pp at 7 TeV* - EPJC (2019) 79: 896 [arXiv:1906.01371]
- *Measurement of charged jet cross section in pp collisions at 5.02 TeV* - PRD 100, 092004 (2019) [arXiv:1905.02536]
- *Multiplicity dependence of charged-particle jet production in pp collisions at 13 TeV* - EPJC (2022) 82: 514 [arXiv:2202.01548]

2. Upgrades during Long Shutdown 2 [2019-2021] for ALICE

The ALICE experiment has been approved for the two upcoming data-taking campaigns at the LHC, Runs 3 [2022-2025] and 4 [2029-2032]. At the beginning of 2022, the collaboration completed the installation of major upgrades that will remain in place for the next ten years. This includes the time projection chamber with novel GEM-equipped readout planes (TPC-2) [TPC-TDR], and, as far as some French teams are concerned, the inner trackers based on silicon pixel sensors, positioned at central rapidity (ITS2) [ITS2-TDR] and at forward rapidity (MFT) [MFT-TDR]. Installed downstream of the MFT, the muon spectrometer consists of muon chambers (MCH) and muon identifier (MID), both essentially led by French teams. The electronic readout [RO-TDR] of the muon spectrometer was completely revisited to accommodate the triggerless/continuous readout now enforced in the experiment, the master piece of such an upgrade strategy hinging on the so-called Common Readout Unit cards integrated in the completely new online-offline software environment [O^2-TDR]. The EMCal detector [EmCal-perf], partially designed and built by IN2P3 groups, was not significantly involved in the LS2 upgrade program and will not be discussed in what follows; it should be mentioned, however, that some of the French groups will continue exploiting its data and assure calibration activities during Runs 3 and 4.

2.1 Inner Tracking System, version 2 (ITS2)

The ITS2 consists of 7 coaxial layers divided into 2 groups: the 3 internal layers installed closest to the beam pipe (r_{pipe} = 1.82 cm) at distances $r_{\mathrm{L0}} \approx 2.3$ cm, $r_{\mathrm{L1}} \approx 3.2$ cm et $r_{\mathrm{L2}} \approx 3.9$ cm, and the 4 outer layers positioned between $r_{\mathrm{L3}} \approx 19.5$ cm et $r_{\mathrm{L6}} \approx 39.3$ cm. The 7 layers are instrumented to cover a range of pseudorapidity *at least* equal to $|\eta| < 1.3$ (see Tab. 1.1 in [ITS2-TDR]). The detector is composed of a set of pixelated monolithic active sensors (MAPS) exploiting a **180-nm CMOS** technology, following an ALPIDE architecture specially developed for this purpose. The whole ITS2 accounts for about 10 m² of active silicon surface, segmented into 12.5 billions pixels of about 27x29 µm² each. The main characteristics of the detector are listed in the first column of Tab. B.1 of this document. The ITS2 will already increase for the LHC Run 3 the detection efficiency of charged particles at low transverse momenta (e.g. at p_T = 0.1 GeV/c, $\varepsilon_{\text{tracking ITS-1}}(h^{\pm}) \approx 10$ % vs. $\varepsilon_{\text{tracking ITS-2}}(h^{\pm}) \approx 60$ %, see Fig. 7.12 in [ITS2-TDR]).

The IPHC group in Strasbourg participated and participates to the ITS2 project on several fronts:

- The design of the ALPIDE chip [VCI-2016] equipping the ITS2 was partially carried out in Strasbourg (C4pi, PICSEL)
- The *module* assembly, for which the IPHC was one of the 5 sites in charge in the ALICE collaboration (a module consists of 2x7 sensors positioned, glued and wire-bonded on a flexible printed circuit); 585 functional modules, defining about 25% of the grand total of modules, have been produced, between November 2017 and May 2019, requiring 4.5 FTE (C4pi, ALICE-IPHC).
- Technicians and engineers further committed themselves at CERN during the installation, to cable the various parts of the detector and set up its operation (implement detector slow control and cooling); they followed, intervened and/or co-organised aspects related to the electronic connection-reconnection during the various ITS2 relocations, from Meyrin to LHC point-2 ground to the underground ALICE cavern (C4pi, PICSEL, ALICE-IPHC).
- In parallel with the activity on the hardware side, Iouri Belikov from the IPHC ALICE team has been in charge (since the time of the ITS2 TDR, in 2013) of the software working group dedicated to detector simulations, tracking and reconstruction with the ITS2 (international group of about 50 persons in the collaboration).

2.2 Muon Forward Tracker (MFT)

The MFT is designed to add in Run 3 vertexing capabilities to the muon spectrometer (MCH + MID), improving the sensitivity of muon measurements (increasing the signal/background ratio) especially at low p_T, and providing offset information for charm-beauty separation. The MFT consists of two half-cones each containing five detection half-disks installed along the beam axis between −460 mm and −768 mm away from the interaction point, covering the pseudo-rapidity range $-3.6 < \eta < -2.5$. The basic detection element is the aforementioned ALPIDE silicon pixel sensor, developed for both ITS2 and MFT. The 936 silicon pixel sensors of the MFT are assembled, using the same technology as for the ITS2, on 280 ladders of 2, 3, 4 or 5 sensors each. The read-out electronics, common to both ITS2 and MFT, has been jointly developed by the two projects. [MFT-TDR].

The MFT and associated services have been installed in the ALICE cavern in December 2020. The year 2021 was dedicated to the integration and commissioning of all components into the central ALICE data taking and more specifically the Detector Control System (DCS), Readout, Quality Control and Data Compression with the synchronous reconstruction successfully validated by the Run with Pilot Beam at $\sqrt{s}$ = 900 GeV. In 2022, the MFT entered in production phase running at 500 kHz and 1 MHz interaction rate for proton-proton collisions.

Subatech-Nantes, IP2I-Lyon and LPC-Clermont carried out important roles in the MFT design, conception, production, assembly, installation and integration:

- IP2I-Lyon: Mechanical support, disk assembly and characterization, Readout System and Firmware, Slow Control (ALF-FRED), installation
- Subatech: Mechanics and integration of half disks and half cones, ladder design, Power Supply Unit, cooling system, Slow Control (ALF-FRED), MFT-MCH track matching, Commissioning
- LPC-Clermont: Geometry integration into simulation, ladder assembly, installation, commissioning.

French teams have a leading role in the management of the project with Guillaume Batigne (Subatech) as deputy project leader and System Run Coordinator in 2023, Sarah Porteboeuf-Houssais (LPC) as Data Run Coordinator and System Run Coordinator in 2021, Rafael Pezzi (Subatech + Brasil) as software coordinator and System Run Coordinator in 2022. Antonio Uras (IP2I) was the MFT Physics Coordinator until January 2023.

2.3 Muon spectrometer

The ALICE forward muon spectrometer studies the complete spectrum of heavy quarkonia (J/ψ, ψ(2S), ϒ(1S), ϒ(2S), ϒ(3S)) and weak bosons via their decay in the $\mu^+\mu^-$ channel, as well as low-mass vector mesons, and single muons from heavy flavor decays. It provided a wealth of results during Runs 1 and 2, corresponding to approximately 50 publications. The spectrometer acceptance covers the pseudorapidity interval $2.5 \leq \eta \leq 4$ and the resonances can be detected down to zero transverse momentum. The invariant mass resolution is of the order of 70 MeV/c^2 at the J/ψ mass, and about 100 MeV/c^2 close to the ϒ(1S). During the Long Shutdown 2, the front-end electronics of both MCH and MID have been upgraded. The software has been fully redesigned in the new Online-Offline (O^2) framework. Both detection systems are now integrated in the global ALICE data taking, with very good performances in terms of readout stability and efficiency.

Muon chambers (MCH)

The MCH is composed of 5 tracking stations (2x5 Multi-Wire Proportional Chambers) complemented with an absorber system. The total number of detectors is 156 (140 slats and 16 quadrants) with overlaps to avoid dead zones. The tracking system covers a total area of about 100 m^2 for about 1.1×10^6 readout channels.

IJCLab took in charge the production of the Dual Sampa cards for the whole project, coordinating the production of 19300 FEE cards via a manufacturer. In addition to the Dual Sampa production, a complete test bench was designed (mechanics and software) to be given to the manufacturing company allowing the complete testing and validation of all boards. The new FEE required a complete redesign of station-1 large PCB interfacing the FEE to the readout SOLAR crates, *i.e.* DAQ. Hence the routing, prototyping and production of 11 different boards. In addition, quadrants were reworked, opened, cleaned and validated with X-ray sources, to better cope with the high intensity expected in Pb-Pb collisions. Technicians and engineers have been involved in the installation and cabling of station 1 on-site and also participated in the station-2 installation. Readout cabling and commissioning were carried out by physicists of the group. The upgrade project started in 2013 and ended in 2021 involving up to 6 FTE.

Subatech played a crucial and leading role in the development and delivery of the fully O^2-integrated MCH software. The triggerless data taking implies a major rewriting and testing of existing code. The laboratory took charge of about 85% of the MCH software preparation for Run 3, including the simulation, clusterization, reconstruction and calibration codes. In addition, a Subatech physicist is in charge of the software maintenance and commissioning, since O^2 updates are still released on a weekly basis. On the technical side, Subatech participated in the installation and commissioning of stations 3, 4 and 5 and committed a dedicated engineer with a specific expertise to the repair of slat detectors. These maintenance operations are still ongoing on demand, when slat detectors are repaired and exchanged.

Christophe Suire (IJCLab) is the project leader of MCH and Laurent Aphecetche (Subatech) is the MCH-O^2 coordinator.

Muon Identifier (MID)

The MID is composed of 72 Resistive Plate Chambers (RPCs) arranged in 2 stations of 2 planes each for a total surface of about 150 m^2 and about 21×10^3 readout channels. The MID (for Muon Identification) is the upgrade of the MTR (for Muon Trigger) project: the front-end electronics was fully replaced in order to include an amplification phase with the aim of reducing the working voltage of the RPCs and, consequently, the aging process. The readout electronics was fully replaced as well, in order to allow for triggerless continuous acquisition.

These improvements result in a completely new system from the point of view of data acquisition. The reconstruction of the detector, which was previously based on the trigger algorithm, was changed as well and now includes clustering and tracking in the 4 RPC planes.

French institutes have a major role in the upgrade. The LPC-Clermont is in charge of the Front-End electronics (FEE) with the design, production and installation of the FEE with amplifications (FEERIC) and of the distribution of the thresholds. A total of 2384 FEERIC cards were installed. The threshold distribution is currently based on the Xbee wireless protocol, which will be further replaced by WiFi at the next winter shutdown. The institute is also responsible for the quality control monitoring of the detector.

Subatech-Nantes is in charge of the design, production, installation and slow control of the readout electronics. A total of 16 crates, each consisting of 16 local cards, 1 regional card and 1 J2 bus for the communications of the local and regional cards have been installed and commissioned. The laboratory also developed the quasi totality of the simulation and reconstruction software. It also took care of the integration of the different components in the data acquisition framework, from DAQ to online track segment reconstruction for online event display.

French teams have a leading role in the project with Pascal Dupieux (LPC-Clermont) who coordinated the MID upgrade up to the end of its installation in ALICE cavern, Diego Stocco (Subatech-Nantes) as current deputy project leader of the MID and Baptiste Joly (LPC-Clermont) who ensured a two-years presence at CERN as a CERN Project Associate for the integration and commissioning of the FE and readout electronics.

2.4 Online-Offline Common Readout Unit (O^2 CRU)

Starting in 2018, the LPSC gradually took over the responsibility for the firmware of the Common Readout Unit (CRU) acquisition card of the ALICE experiment. This electronics is a common service used by 10 sub-detectors of the ALICE experiment. This firmware has been reworked and lightened in order to free up FPGA hardware resources (from 43% to 29% for the logic modules used). In 2019, the ITS2 and TPC detectors, which are the most demanding in terms of CRU usage, have started their commissioning phase. This required continuous support as well as corrections where necessary. In addition, major but missing functionalities have been added, *i.e.* i) flow control for *continuous* reading as ALICE will work mainly in the absence of a specific trigger, ii) the addition of a trigger mode (for testing but also for the transition phase with non-updated detectors during the long LS2), as well as iii) the remote update of the firmware (about 500 cards to maintain in operation).

3. Commissioning the ALICE-2 experiment and 2022 data taking

The installation and integration of the ALICE upgrades have been completed in time by the end of 2021. The next step was then the full integration into the ALICE data taking infrastructure including the Central Trigger Processor, Detector Control System, Readout and acquisition, Synchronous processing and Data Compression, Online Quality Control, all supervised by the Online-Offline (O^2) software. The ALICE data taking is not based anymore on the concept of "physics event" but on the one of "Time Frame" which includes all raw data from all detectors during 11.6 ms. The Time Frames are then compressed based on online reconstructions (compression factor of about 20). The readout is continuous for most of the detectors, replacing the trigger mode of Runs 1 and 2. This makes the ALICE experiment in Run 3 (ALICE-2) a complete new experiment from the point of view of the readout and data acquisition, which required dedicated commissioning to ensure a good data sanity and quality.

This detector integration has been performed over 2021 and 2022 with regular milestones given by the ALICE collaboration (Milestone Weeks) or by the Machine with the 2021 and 2022 Pilot Beam at injection energy ($\sqrt{s}$ = 0.9 TeV). At the first data taking at $\sqrt{s}$ = 13.6 TeV (05 July 2022), ITS2, MFT, MCH and MID were included in all steps of the data taking showing good performances. Examples of Quality Control graphical displays are highlighted in Appendix α. During July and August, ALICE initiated a ramp-up phase (correlated with LHC beam intensity ramp-up) where the ALICE data taking moved from initial 10 kHz up to 1 MHz. The baseline proton-proton data taking is at 500 kHz where about 800 collisions are included in a Time Frame, the total ALICE raw Readout is about 600 GB/s, compressed down to about 30 GB/s of data stored. The muon tracking and matching is part of the asynchronous reconstruction but is running online for quality control and event display purposes. All the detectors, and more specifically the ITS2, MFT, MCH and MID have shown a very good availability in data taking with stable running conditions. The calibration runs are integrated into the flow of operations, either in standalone running (noise and pedestal runs) or during the acquisition for online calibrations (ITS2). The detectors are now converging toward the finalization of alignment studies which will allow the first physics outcome. As a preparation for Pb-Pb data taking, regular high-rate scans are organized up to 4 MHz of visible interaction rate. 3.5 MHz pp interaction rate corresponds to the equivalent track load on the detectors of 50 kHz Pb-Pb and allows the commissioning of the hardware and an appropriate understanding of the ability of the full system chain to sustain Pb-Pb data taking. In 2022, 34 pb^{-1} integrated luminosity was delivered to ALICE and half is under final reconstruction. Performance and first physics plots are under preparation. As mentioned above, a fraction of the beam time was devoted to commissioning in pp collisions and to Pb-Pb preparation, as well as special runs for calibrations and alignment.

In 2022, the LHC operations were cut due to two major external events :

- Failure of the LHC cooling system which lead to a downtime of 3 weeks;
- Energy crisis in Europe which leads to an anticipated stop by two weeks.

As a consequence, the LHC program was revised. 2022 was devoted to pp data taking and Pb-Pb data taking is postponed to 2023 with an extended program of 5 weeks instead of 4 initially planned. This strategy allows the ALICE experiment to keep the initial target of 6.5 nb^{-1} thanks to a reduced set-up time and better performance of the machine on long running time. During 2022 a Pb-Pb test beam at top energy was organized to validate the RUN 3 running conditions with slip stacking and crystal collimation. ALICE commissioned all detectors and collected approx. 1.1 Million events with very stable running conditions.

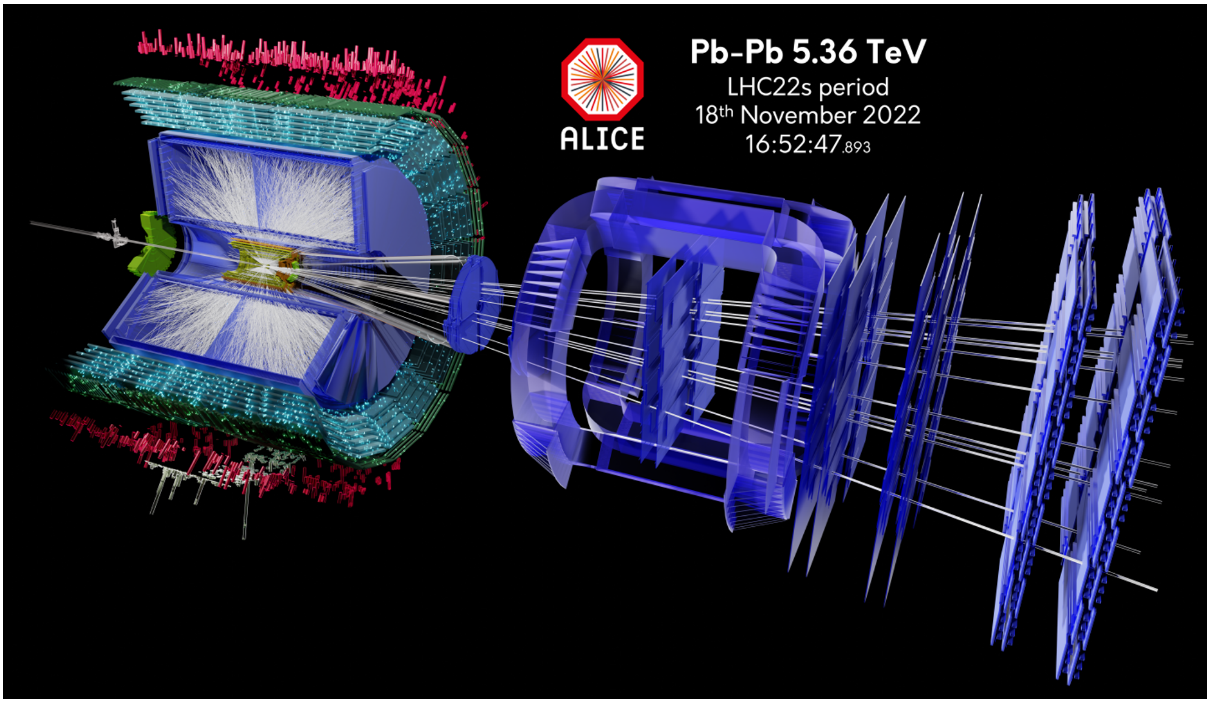

Figure A.1 - Event display of Pb-Pb collisions at $\sqrt{s}$ = 5.36 TeV collected for one event during Run 3 (2022 Pb test beam) by ALICE 2. The display shows tracks reconstructed in the central barrel and in the forward arm.

4. Upgrades during Long Shutdown 3 [2026-2028] for ALICE

4.1 The Inner Tracking System 3 (ITS3)

The goal of the ITS3 upgrade program is to replace the 3 innermost layers of the current tracker ITS2. The new layers will sit at closer radii (r ranging from 1.8 to 3 cm) and will be made of hypergranular (O[20x20 µm²]) and ultra-thin (≤ 0.05% X_0 per layer) sensors, of which most of the assembly is performed directly on the silicon substrate, i.e. at the stage of silicon lithography at the foundry, with sensor suture of sub-units (stitching). This results in detection units that cover each a large functional area (O[10x27 cm²] ≈ O[wafer]). Such thin sensors are flexible and can therefore be bent to shape an almost perfectly cylindrical layer geometry.

IPHC Strasbourg has already contributed to the ITS3 effort since 2019 and would like to expand their commitments, be they on simulations, on reconstruction as well as on instrumental grounds (chip design, integration). Teams in IP2I Lyon and LPSC Grenoble also aim at joining the project, progressively, in a proportionate manner with respect to their resources. **A detailed plan has been presented at the session of CS IN2P3 in October 2022: the conclusions of the review process should be delivered by the end of February 2023.**
Through recent (ITS2 and MFT) and future (ITS3) tracker upgrades, the three ALICE groups of IP2I, IPHC and LPSC wish to form a common research axis within the collaboration, with synergies on the instrumental level and with a community of interests on the front of the data exploitation and of the data analysis. These tighter bonds between teams and look towards a common horizon is of strategic interest for the continuation of the research program over the coming decade, exploiting the opportunities offered by the ALICE 3 project (see Part B), involving three clearly intertwined aspects (defining a multi-differential analysis approach):

- the particle identification (e.g. mesons vs. baryons)
- the correlated productions between central and forward rapidities

the physics dependences as a function of the parton flavor (*g + u + d,s,c,b*)

The ITS3, together with existing ITS2 and MFT projects of the ALICE experiment, respond to common interests of the IN2P3 teams from Strasbourg, Grenoble and Lyon altogether, around the physics of dense hadronic matter. The "joint" exploitation of these detectors will allow in Run 4 [2029-2032] to establish a coherent scenario of the physics of collectivity, combining the main research topics addressed by the groups, ranging from the study the response of the medium according to the quark flavors, the question of the meson vs. baryon productions, or the interaction between the created medium and the parton showers.

Quite some key opportunities relate to technical aspects and skills to be fostered via ITS3 for the IN2P3 :

- ITS3 will be a unique opportunity in the decade to come to tackle and master the 65-nm technology node for a "large"-scale project in HEP, paving the road towards silicon tracker of next generations, not only for ALICE but also other experiments (ALICE 3 at the LHC or the experiments foreseen at future facilities like FCC-ee and ILC)

- Along a similar line, ITS3 will be an effective test bench for mastering specific techniques of general interest, that are active-silicon bending and stitching at the wafer level.

The effectiveness of ITS3 detector will open unprecedented physics roads for the ALICE collaboration. The detector will be more accurate spatially, closer to beam interaction point and lighter than the already improved ITS2 inner layers. This will enable better efficiency, while keeping fake hit rate under control, better determination of distance of closest approach. Those aspects are for instance vital for a better characterisation of the event activity and for studies related to the heavy-flavor sector in QCD. Event multiplicity, jet activity, strangeness, charm and beauty will be at the core of the program for the French community, in particular, but more generally for the whole ALICE collaboration in Runs 3 and 4. This will maintain IN2P3 on high grounds, with acute visibility, at the forefront of the LHC experiment.

4.2 FOCAL and ALICE Fixed-target

At the Run 4 horizon, it should be mentioned that the ALICE Collaboration itself foresees possibly two other upgrades: FoCal and ALICE-FT. The installation of the FoCal (Forward Calorimeter) will open the way to new measurements at very forward rapidity, providing the opportunity to study the low-x region with the search for possible gluon saturation effects predicted by the color glass condensate model, and the study of the modifications of gluon (n)PDFs at small-x and Q^2. Even if IN2P3 does not foresee any technical implication in the FoCal project, interested people in the French community may still be involved during Run 4 in the analyses based on the data collected by the detector.

The fixed-target program in ALICE (CERN-PBC-Notes-2019-004) would provide further insight on the high-x gluon, antiquark, and heavy-quark content of the colliding nucleons and nuclei. This activity is supported by an ANR JCJC assigned to L. Massacrier (IJCLab). The project was recently discussed in the ALICE MB and, given the planned upgrades of ALICE, the MB concluded that the collaboration cannot afford to allocate the necessary resources for the project.

5. Timeline in LHC run 3 [2022-2025] and run 4 [2029-2032]

The current planning for LHC campaigns over the next decade is not fully settled. A likely timeline is given in Fig. A.2 below. The next decade will cover two LHC runs of 3-4 years each. Each year typically restarts around March with beam recommissioning, then moving, around middle spring, to proton beams typically accelerated up to maximum energy (6.8 TeV in 2022), delivering collisions at $\sqrt{s}$ = 13.6 TeV, meant for physics in the experiments. Towards the late fall of the year, a dedicated data taking should take place for 3-5 weeks, with typically Pb-Pb collisions with $\sqrt{s_{NN}}$ around 5 TeV [arXiv:1812.06772]. pp campaigns at an energy different from the top energy will be covered during such periods typically, also including further p-Pb data. Special runs of O-O and p-O, for short periods (*O*[day(s)]), are foreseen in 2024. One should not forget that ALICE also takes data in pp collisions at 13.6 TeV, the top LHC energy in Run 3. In a first stage, the pp data taking will focus on the collection of Minimum Bias events (500 kHz); it will later move to a data skimming approach via software trigger, meant to inspect integrated luminosities of about 200 pb^{-1} and focus on i) high-multiplicity events ii) diffractive events and iii) rare signals such as production of light nuclei (d,t,^{3}He,^{4}He…) or of heavy-flavour jets [ALICE-PUBLIC-2020-005].

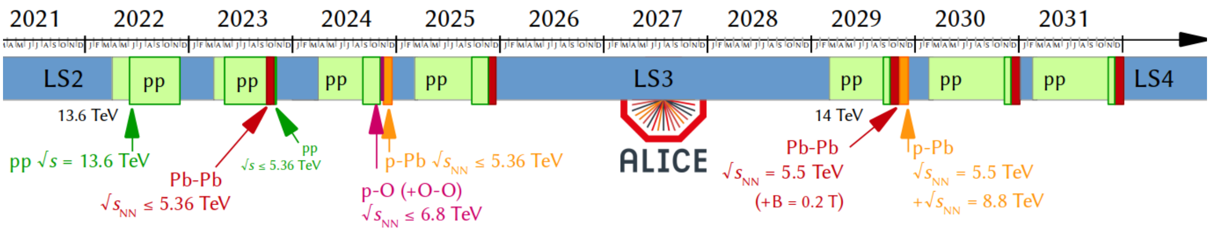

Figure A.2 - Tentative overview of the LHC campaign planning for Run 3 [2022-2025] and Run 4 [2029-2031(2032)], as currently anticipated from the ALICE experiment perspective. See LHC updates at *lhc-commissioning.web.cern.ch*. As far as it is foreseen in January 2023, the colliding energies ($\sqrt{s_{NN}}$) for pA and AA periods are not yet fully settled: their schedule will depend on collimation and training quench performances, still to be assessed.

6. Involvement of IN2P3 teams in Run 3 and Run 4

The priority of the teams involved in ITS2, MFT, MCH, MID and EMCal is i) to ensure the maintenance and operations of the detectors they are in charge of, until the end of Run 4, as well as ii) to exploit the full physics output. Due to natural aging of teams members as well as few scientific transitions to other field, a decrease of approximately 25% of permanent physicist human resources is expected towards the early Run 4 (2029) (cf. Table A.1). The French groups will pursue their implication in the analysis of the data collected by the ALICE detector during LHC Runs 3 and 4, exploiting the information coming from the upgraded detectors, a fundamental asset to open new opportunities for the physics program of the experiment.

More specifically, the data collected at forward rapidity with the muon spectrometer will profit for the first time from the information offered by the MFT on the offset of the tracks at the primary vertex, and the possibility of reconstructing secondary vertices corresponding to the decay of long-lived particles: the two main examples are the separation, in the $\mu^+\mu^-$ channel, between prompt J/ψ and J/ψ coming from the decay of B mesons, and the separation of the open charm and open beauty production in the semi-muonic decay channel. The French groups are expected to keep the leadership in these analyses in Runs 3 and 4, thanks to a major involvement in the dedicated working groups and their role in the operation of the MFT and MUON detectors. The data collected at mid-rapidity will profit from the better spatial resolution offered by the ITS2, for the reconstruction of the primary and secondary vertices, allowing for a better rejection of the background and a higher efficiency in the reconstruction of the decay chains of charm and beauty hadrons, especially at low p_T (0-2 GeV/c). These performances will be further improved in Run 4 thanks to the installation of the ITS3 (replacement of the three innermost layers of the ITS2). The French groups will have an active role in the corresponding physics analyses, the main goal being the study of the hadronization and energy loss mechanisms of heavy flavors in the medium. Measurements correlating observables at mid and forward rapidity will also be possible, opening the possibilities to new probes with respect to Run 2. Both at forward- and mid-rapidity, the expected statistics will allow for a significant improvement of the sensitivity for any measurement addressing multiplicity-dependent effects, with the goal of investigating the origin of collective behaviour. In that respect, after Runs 1 and 2, charged-particle multiplicity in events has already been identified as an effective scaling parameter driving the deviation of the observed effects from the vacuum reference. The Run 3 and Run 4 follow-up implies then the scrutiny of the event activity itself and its correlations with each probe or particle species of interest, in any of the collision systems which will be available in Runs 3 and 4.

Team	**"M&OA" (2022)**		**Due service work FTE/year (2022)**	**Main detector activities in Runs 3 *(+ Run 4)***	**"M&OA" *(projected end Run 3, 2026)***		**"M&OA" *(projected early Run 4, 2029)***	
IJClab Orsay	4 + 1	5	1.5	MCH, O²	4 + 1	5	4 + 1	5
IPHC Strasbourg	5 + 1	6	1.5	ITS2 *(+ ITS3)*	4 + 1	5	4 + 1	5
IP2I Lyon	3 + 0	3	0.75	MFT *(+ ITS3)*	2 + 0	2	2 + 0	2
LPC Clermont	2 + 5	7	1.75	MID, MFT	2 + 5	7	1 + 4	5
LPSC Grenoble	2 + 2	4	1	readout, DPG *(+ ITS3)*	2 + 2	4	2 + 1	3
Subatech Nantes	7 + 2	9	2.75	MID, MCH, MFT	4 + 2	6	3 + 2	5
TOTAL	23 + 11	34	9.25		18 + 11	29	16 + 9	25

Table A.1 - Inventory of the workforce per ALICE France team, for current year (2022) and *projected* for the coming years (rest of LHC Run 3 [2022-2025], future Run 4 [2029-2032]). It accounts for announced departures (research migration and retirements - some of the retired scientists could however get the status of emeritus) but it does *not* include possible new recruitments (it should be noted, however, that a CRCN profile ALICE-IP2I has been identified as a priority for the CNRS competition in 2023). In order to provide a coherent picture, post-docs are *excluded* from the count, and only permanent staff persons are considered; the first number corresponds to researcher positions, the second to university positions. M&OA corresponds to ALICE authors with a PhD; as a function of their number, each team owes a certain amount of service work for the experiment operation itself and/or for ALICE collaboration functioning (2022 : 0.25 FTE/year/ M&0A, including post-doc though).

1. Scientific incentives

Despite the remarkable results achieved in the last decades in investigating how strongly-interacting matter behaves under extreme conditions, and characterizing the phase transition between partonic and hadronic matter, our current knowledge is still limited in a number of broad topics, and additional investigations are needed towards a clear and coherent framework, providing a comprehensive answer to the key questions in the field:

- What are the conditions for the onset of a QGP phase, and how does the QGP evolve through hadronization?
- What are the limits of the applicability of hydrodynamics to the evolution of a QGP volume, and how collective effects in small collision systems should be interpreted?
- How can we connect the microscopic picture of the QGP, in terms of partonic degrees of freedom (short wavelength), to the picture of a strongly-coupled liquid (long wavelength)?
- How does the energy density profile of a QGP volume, created in an ultra-relativistic heavy-ion collision, relate to the parton distributions in the colliding nuclei?
- To what extent can we explain the emergence of the thermal equilibrium which characterizes the hadronization phase in the evolution of a QGP volume?
- How do the transport properties of a QGP, and the thermodynamics of its transition to hadronic matter, depend on the net baryonic density of the medium? Is there a critical point in the region of the QCD phase diagram that heavy ion collisions can explore, beyond the crossover characterizing the transition at vanishing net baryonic density?

The experimental heavy-ion programs planned for the 2022-2032 decade will be crucial in moving from an exploratory to a precision and quantitative stage in the investigation of the big questions in the field listed above. **As indicated by the available performance studies and projections, however, a continuation of these programs in the 2030s seems unavoidable to complete the picture of QCD as a multi-particle theory, pushing forward the experimental investigations, and driving the theoretical developments.** At the low-energy frontier, the experimental landscape will be characterized by the continuation of the programs at the FAIR, NICA, and possibly the SPS facilities. **At the high-energy frontier, the main opportunities will come from the continuation of the heavy-ion program of the four main experiments at the LHC in Run 5 and Run 6, as also outlined in the recommendations of the European Strategy for Particle Physics (CERN-ESU-013): "Europe should maintain its capability to perform innovative experiments at the boundary between particle and nuclear physics, and CERN should continue to coordinate with**

NuPECC on topics of mutual interest". These programs will be complemented by the operation of the electron-ion collider at BNL, which will provide details about the initial stages of the collisions by investigating the quark and gluon PDFs of the colliding nuclei. **More recently, the LHCC recommended the upgrades of ALICE and LHCb to complement the ATLAS and CMS Phase II Upgrades for a full exploitation of HL-LHC: "These will enable the exploration of new probes in heavy ion collisions by the ALICE experiment, and a significant increase in the scientific reach in heavy flavor physics for the LHCb experiment."**

In the context of the continuation of the LHC heavy-ion program in Run 5 and Run 6, the end of the expected lifetime of the ALICE detector opens new opportunities for the design of a new dedicated heavy-ion experiment, based on a next-generation detector implementing cutting-edge technologies for vertexing, tracking, particle identification, and readout. Such a new experimental program, unique and complementary to the heavy-ion scientific programs of the other LHC experiments, and designed to take advantage of the full physics potential of the HL-LHC, is being developed under the name of ALICE 3.

2. Scientific program and detector concept

As a next-generation, dedicated heavy-ion detector at the LHC, ALICE 3 is designed to span a broad and ambitious physics program involving both precision and exploratory measurements, from proton-proton to Pb-Pb collisions, with the final goal of improving our understanding of how complex hadronic systems form and behave, and how their properties connect to the fundamental parameters of QCD.

The core of this program involves measurements aiming at characterizing the properties of deconfined matter and its interaction with matter and radiation: interaction of heavy quarks with the medium, formation and dissociation of bound states inside the medium, emission of electromagnetic radiation from the medium, characterization of the fundamental QCD symmetries in the medium. On top of that, other measurements will exploit the specific environment offered by the deconfined phase of hadronic matter to explore the frontiers of QCD in terms of exotic multi-quark and hadronic molecule states, or even search for signals of physics beyond the Standard Model.

The French laboratories aiming at participating in the ALICE 3 project (IPHC, LPSC, IP2I-Lyon) have identified a common scientific program based on heavy-flavor measurements, allowing for the study of the interaction of heavy quarks with the medium and the characterization of the mechanisms driving the formation and dissociation of bound states inside the medium. One of the members of the IP2I-Lyon is currently co-convener of the ALICE 3 Working Group dedicated to heavy-flavor observables, and actively participated in the preparation of the Letter of Intent of the project.

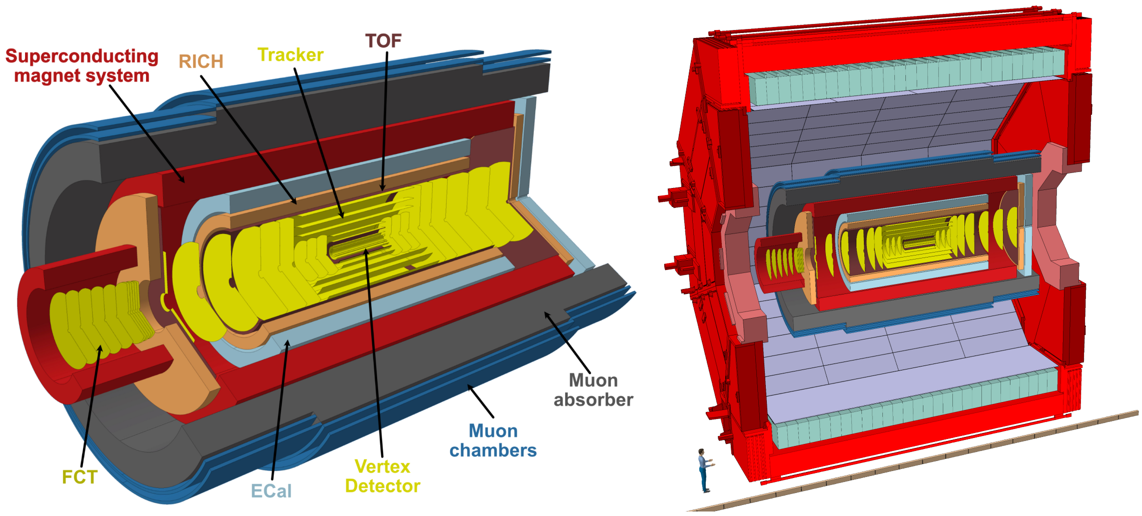

Figure B.1: Conceptual design of the ALICE 3 detector and its position inside the L3 magnet yoke in the ALICE cavern (ALICE3 LoI).

To pursue this physics program, a novel detector is proposed (see Fig. B.1), with high read-out rate, superb pointing resolution and excellent tracking and particle identification over a large acceptance, using advanced silicon detectors. To optimize the pointing resolution, the first tracking layer must be placed as *close* as possible to the interaction point, and to provide the larger aperture required for the beams at injection energy, the vertex detector must be *retractable*. In the proposed apparatus, the three first barrel detection layers are constructed from wafer-scale CMOS Active Pixel Sensors thinned to ~30 µm, bent into cylinders to minimize the material (ITS3 approach), and assembled with the corresponding endcaps. An outer tracker with barrel and endcap layers provides a relative momentum resolution of 1-2% over a large acceptance ($r_{\text{barrel}} \in [3.75;80]$ cm, $z_{\text{discs}} \in [77;400]$ cm) by measuring about 10 space points. The large active area of the outer tracker (approximately 66 m²) requires the exploitation of commercially available high-volume production processes, ranging from CMOS technology for the sensors to highly automated bonding techniques for module integration. For particle identification, a time-of-flight detector and a ring-imaging Cherenkov detector cover a broad momentum range, both relying on novel silicon timing and photon sensors. R&D programs are being set up to push current technological limits of silicon sensors for tracking, timing, and photon detection. Photon detection and lepton identification at higher momentum are provided by an electromagnetic calorimeter and a muon identifier, both of which exploit established detector technologies. A forward conversion tracker measures photons at very low transverse momentum ($p_{\text{T}} > 2$ MeV/c), through their conversion into electron-positron pairs at forward rapidity.

In order to maximize the impact of the physics program, further improvement of the luminosities available with ion beams at the LHC should be explored. Preliminary studies show that the current limits stem from effects in the injector chain, which could be alleviated with ion species lighter than Pb (section 1.3 ALICE3 LoI). Additional simulations and machine development studies are needed to refine the luminosity projections and to determine the optimal ion species for the A-A program. Smaller collision systems, including high statistics proton-proton collisions, also provide the opportunity to study collective effects and the approach to thermal equilibrium. The requirements for operation with additional systems, such as p-A and O-O, will be evaluated based on the results from LHC Run 3 and 4.

3. History and schedule

A first version of what is now the ALICE 3 project had been proposed in 2018 under the name of ANGHIE (A Next-Generation Heavy-Ion Experiment). A document summarizing the scientific motivations of the project and the main concepts of the foreseen detector (arXiv:1902.01211) had been submitted as a contribution to the discussions for the Update of the European Strategy for Particle Physics. In 2019-2021, additional discussions within the ALICE Collaboration and the international QGP community took place: it became rapidly clear that the physics case for a next-generation heavy-ion experiment at the LHC could be further broadened, implying in turn a more ambitious detector concept. At the same time, the ALICE Collaboration adopted the project as its own project for Run 5 and beyond (the current ALICE 2 detector being not suited for operation beyond Run 4, as already remarked) and, coherently, the name ALICE 3 was chosen. In 2021-2022, an intense effort in terms of performance studies allowed the different working groups to identify and characterize the most relevant physics cases for the ALICE 3 scientific program, further constraining the detector concept. These efforts allowed the Collaboration to deliver a first version of the Letter of Intent (CERN-LHCC-2022-009), reviewed by the collaboration and endorsed by the Collaboration Board on 28 January 2022. The LHCC review process started in October 2021, with a very positive report of the LHCC Review Panel being addressed mid-March 2022 (LHCC-149). The tentative schedule of the project is the following (see also Fig. B.2):

- **2023-25:** selection of technologies, small-scale proof of concept prototypes (≈ 25% of R&D funds)
- **2026-27:** large-scale engineered prototypes (≈ 75% of R&D funds) → Technical Design Reports
- **2028-31:** construction and testing
- **2032:** contingency
- **2033-34:** Preparation of cavern and installation of ALICE 3

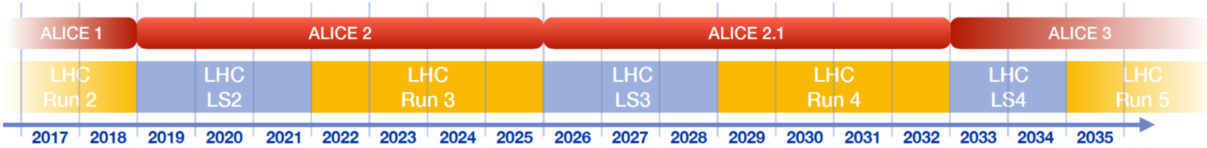

Figure B.2: Timeline of the ALICE operations at the LHC (phases 2, 2.1 and 3) (ALICE3 LoI, p.174).

The LHCC recently proposed a road map towards the finalization of the ALICE 3 project (as a part of the “Phase IIb Upgrades of ALICE and LHCb”), closely modeled after the ATLAS & CMS Phase-II approval process (CERN-LHCC-2015-007), and structured according the following steps:

- **In the first step**, the overall scope and cost for the entire ALICE 3 upgrade program will be defined, with the possibility to maintain different options which may depend on technical issues and/or on funding availability.

- **In the second step**, the detailed technical design reports (TDR) for the various subsystems will be reviewed. These TDRs will naturally come at different times depending on the maturity of the projects, and will be reviewed individually, with the requirement that each fit in the overall approved plan for scope and cost (Project Baseline).

- **In the third step**, the final design and construction readiness of the major detector components will be reviewed. As in the second step, different subsystems, and in some cases also different elements of subsystems, will be ready at different times, and will be reviewed accordingly, with the requirement that they are compatible with the overall construction and installation plan (Start of Construction).

- **In the fourth step**, the end of the Phase IIb upgrade project is marked by the completion of the installation of all upgraded subsystems. The possible need of additional reviews at this point (Start of Operations or Project Completion), beyond the scrutiny throughout the upgrade project provided by the LHCC and its subcommittees, will be defined at a later stage.

4. Current situation

With respect to the roadmap defined by the LHCC towards the installation of the PHASE IIb Upgrades, the ALICE 3 project has already fulfilled the first part of step 1, with the submission of the ALICE3 Letter of Intent (CERN-LHCC-2022-009), favorably reviewed by the LHCC, detailing the following elements:

- Physics motivation and performance.
- Detailed description of each element of the upgrade.
- Plan and schedule for remaining R&D, prototyping etc.
- Plans for technology selection, where applicable.
- Current estimates of approximate total CORE project costs, and schedule, in the appropriate detail to complete this step of the review.

The ALICE 3 project has now entered the second part of step 1, with the preparation of a *Scoping Document* supporting the Letter of Intent. The starting point of the Scoping Document is the extent defined in the Letter of Intent, and one of the main goals is to establish a plausible cost scenario in close exchange between the relevant stakeholders (Funding Agencies, CERN management, experiments, review bodies). The Scoping Document will include:

- Detector scoping options matched to the established cost ranges of the Phase IIb upgrade program, with estimates of cost, person power and the needed funding profile, as well as expected M&O costs.
- An overview of the R&D, construction and installation schedules. Demonstration of sufficient schedule contingency with respect to a full installation of the upgrades in LS4 is essential.
- Information on the availability of the required appropriate human resources, technical infrastructure and laboratory capacity in the collaboration to carry out the project with sufficient contingency.
- A preliminary top-level project management plan setting out the project organization, key milestones (including project phases and review strategy), deliverables, and risk analysis.
- A list of expected Technical Design Reports (TDRs) and an overall plan with milestones and schedule for producing them.
- An analysis of the impact of different scenarios on the physics performance.

Together with the Scoping Document, it is agreed that the ALICE Collaboration will also provide a separate, confidential document containing a preliminary funding plan, which takes into account inputs on the likely scale of funding from the Funding Agencies involved, with the “money-matrix” expected from such agencies. It is understood that the coverage of the full funds will likely not be available at this point, and that the collaborations may continue to expand in the process towards the TDRs.

5. Resources and means

A first estimation of the cost of the ALICE 3 detector (core cost without R&D and man power) has been prepared for the Letter of Intent, see Table B.1. The IN2P3 follows with interest the development of the ALICE 3 project. **The IN2P3 laboratories of Strasbourg, Lyon and Grenoble, currently participating in ALICE, have expressed their interest in participating in the R&D of ALICE 3. These 3 laboratories are setting up a plan starting with a close collaboration within the ITS3 project (see section 4.1 of Part A) with the aim of following up to ALICE 3. Their participation in ALICE 3 would focus on the R&D and construction of the silicon layers, with the idea to concentrate the efforts of the French community on a single sub-project.**

While this plan looks reasonable to the IN2P3 management according to the preliminary discussions, the specific ALICE 3 implication and the size of the corresponding contribution still have to be defined in quantitative terms. This process has currently started and will imply dedicated discussions in the next months with the Directors of the interested laboratories, aiming at defining the available human resources in the technical services: these discussions will converge towards a technical proposal illustrating the plans for the IN2P3 contribution to the detector R&D and construction. **This document is likely to be finalized in the next few months, but it is already possible to estimate that, in a baseline scenario where the activity on the ALICE 3 project will proceed in parallel with the ITS3 upgrade and the exploitation of the Run3+Run4 data, the human resources needed by the three interested groups in terms of permanent researchers should by no means be inferior to the ones which allowed, in the past years, the successful preparation of the Upgrades of the Long Shutdown 2 in parallel with the exploitation of the Run1+Run2 data. This corresponds to 5.5 FTE at IPHC (currently 4.5, 3.5 at the 2024 horizon if excluding new recruitments), 4 FTE at LPSC (currently 3, 2.5 at the 2027 horizon if excluding new recruitments), and 4 FTE at IP2I-Lyon (currently 2, expected to rise to 3 at the end of 2023 according to the results of the CNRS competition).**

System	Technology	Cost (MCHF)
Tracker	MAPS	30.5
TOF	Monolithic timing sensors (integrated gain layer)	14.8
	Hybrid LGADs	26.4
RICH	Aerogel and monolithic SiPMs	20.9
	Aerogel, analog SiPMs + read-out	34.0
ECal	Pb-Sci sampling and $PbWO_4$	17.0
Muon ID	Steel absorber, scintillator bars, SiPMs	7.0
FCT	MAPS (solenoid and dipoles)	2.3
	MAPS (solenoid and separate dipole for FCT)	5.3
Magnets	Superconducting solenoid + FCT magnet	25.0
	Superconducting solenoid and dipoles	40.0
Computing	Data acquisition and processing	6.0
Common items	Beampipe, infrastructure, engineering	15.0
Total		**141.4**

Table B.1: Estimates of ALICE 3 *core* cost (p.175 section 5 of ALICE3 LoI).

Appendix α. Selected performance plots from the upgraded detector commissioning

This Appendix includes a selection of performance plots from the detector commissioning during 2022. All plots are part of the Online Quality Control monitoring tool.

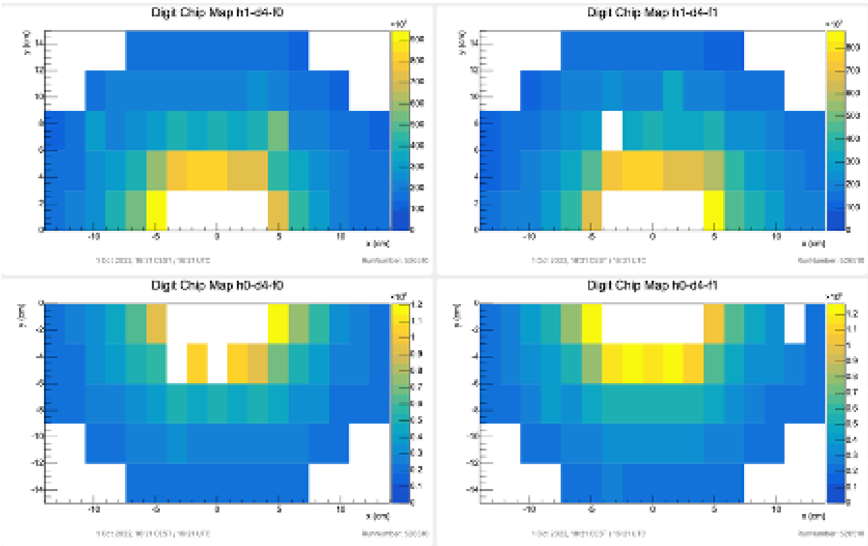

Figure α.1 - **MFT** DIgit Occupancy of the disk 4 (the furthest disk from interaction point), top and bottom half-disk, both faces. The Digits are reconstructed online. The occupancy is radially increasing with respect to the beam position, as expected. The 4 white squares indicate problematic ALPIDE chips. These plots are part of the Online Quality Control Monitoring. The example displayed here was collected during a 1-MHz data taking.

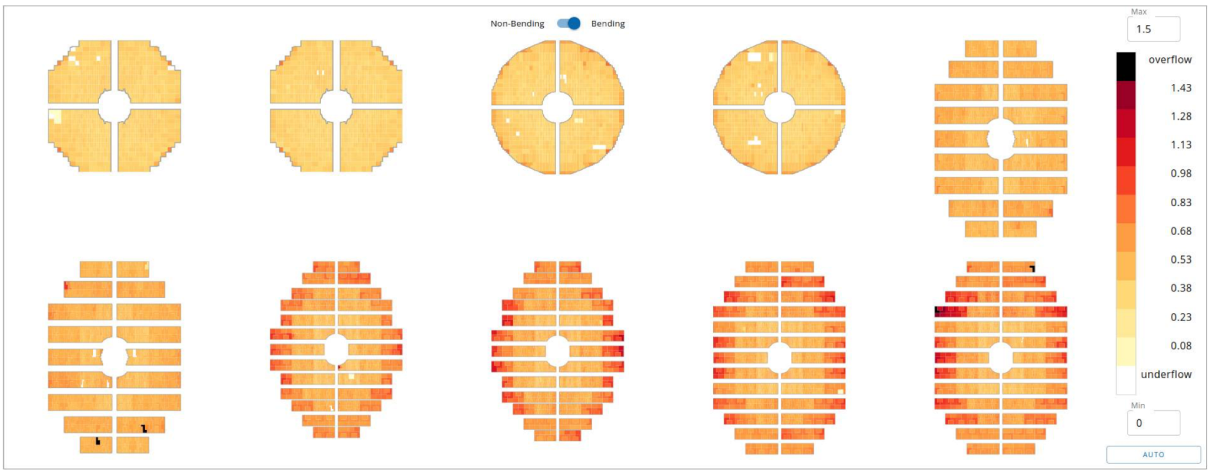

Figure α.2 - **MCH** noise measurement. All channels noise is below 1.5 ADC which is excellent. This graphical tool, MCH Viewer, was developed by Subatech.

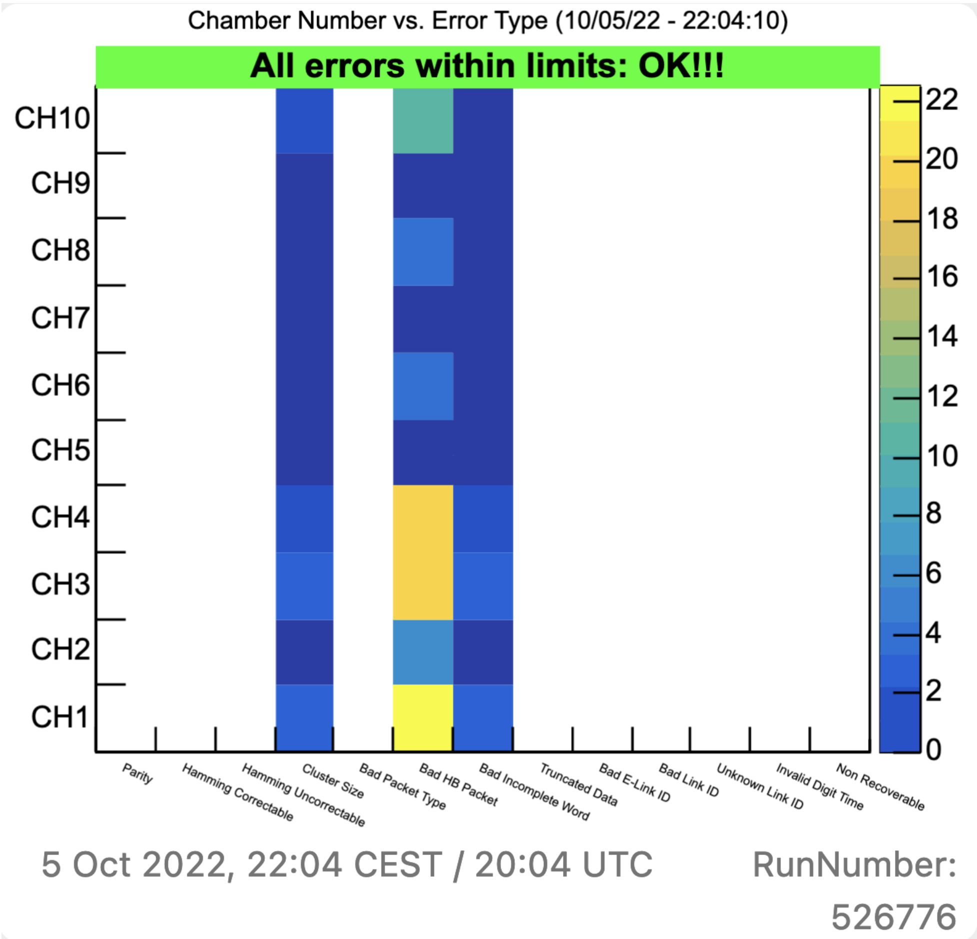

Figure α.3 - **MCH** online quality monitoring of number errors for each chamber per run type.

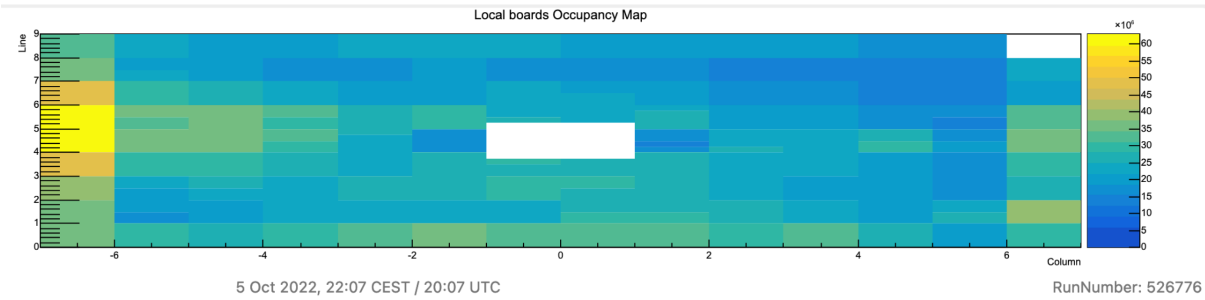

Figure α.4 - **MID** online quality monitoring of local-board occupancy map.

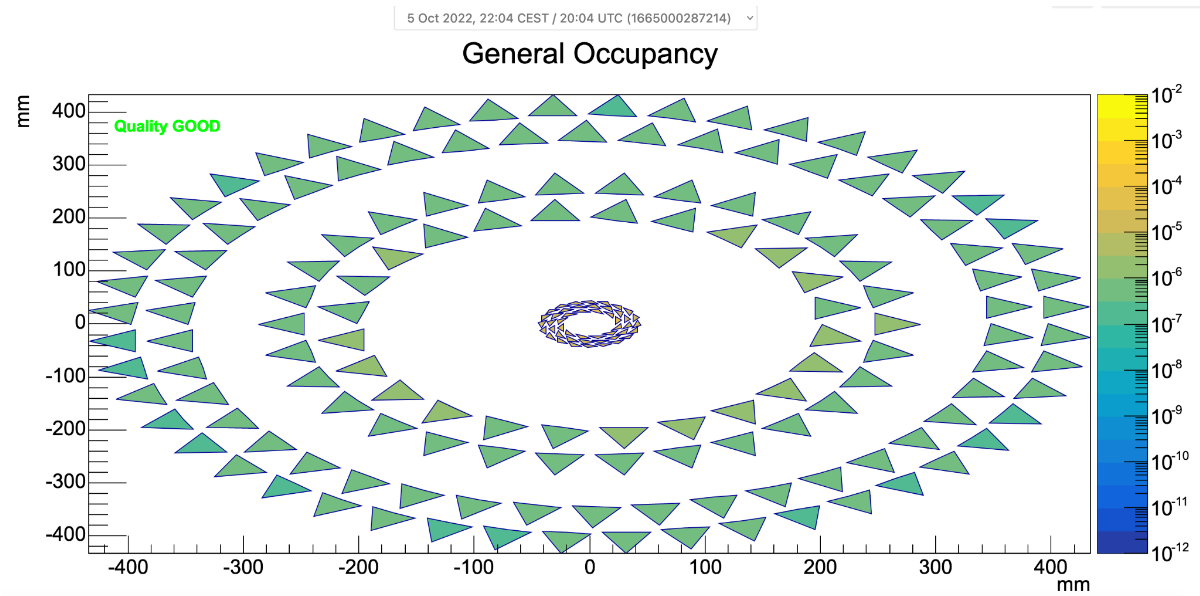

FIgure α.5 - **ITS2** online quality monitoring of ALPIDE chip occupancy.

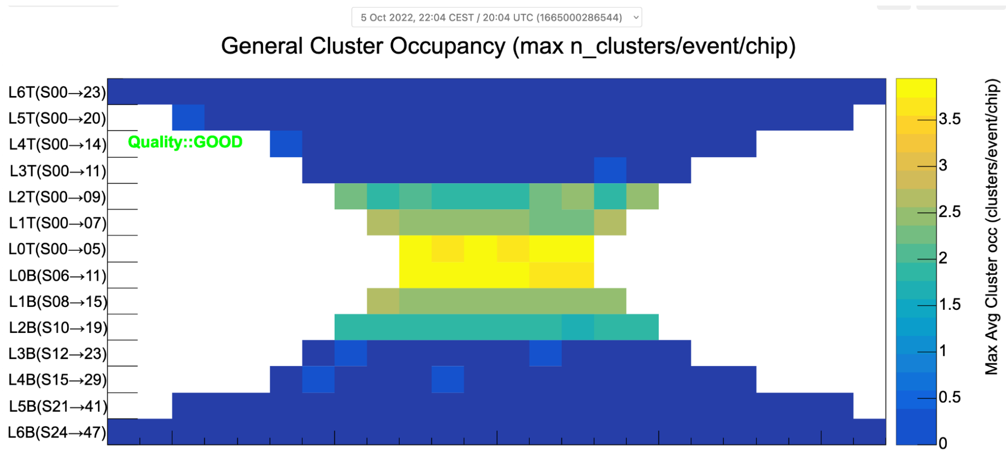

Figure α.6 - **ITS2** online quality monitoring of reconstructed cluster occupancy per layer.

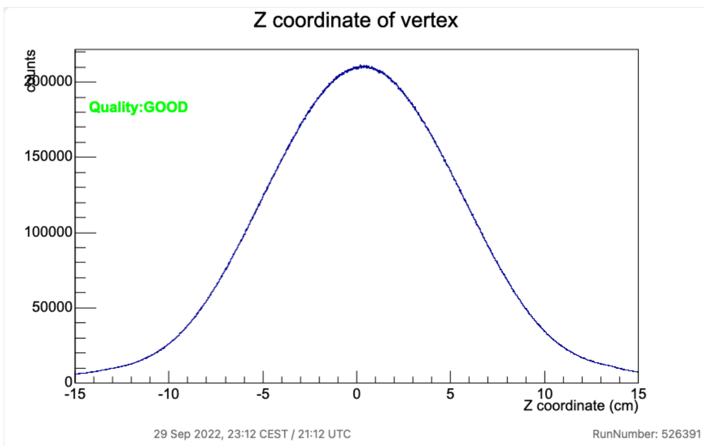

Figure α.7 - **ITS2** online quality monitoring of the position of the collision vertex along *z* axis.