ALICE activity report 2020

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1 The ALICE experiment

The ALICE collaboration at CERN currently includes 39 countries, 175 institutions, and 1936 members. In turn, INFN participates with 12 groups for a total of about 200 physicists. The INFN-Frascati group is a very active contributor to the scientific output of the collaboration in terms of detector construction, operation and physics analysis. In fact, the INFN-Frascati group played a key role in the construction and operation of the ALICE electromagnetic calorimeters (the EMCAL and the DCAL), in the upgrade foreseen for RUN3 (2021-24) with the construction of 1/4 of the new Inner Tracker System (ITS) Outer Layers (OL), and in the operation of the entire ALICE detector (Run and Commissioning Coordination, 2013-15 and 2019-21).

This report briefly summarizes the results obtained in Frascati for the construction and describes the commissioning of the new ALICE Monolithic Active Pixel Sensors (MAPS) ITS which has replaced the old Run 1-2 device (based on hybrid pixel sensors, silicon strips, silicon drifts).

It is worth to remind that a production infrastructure for large area silicon sensors has been designed and installed at LNF and the group quickly developed the know-how needed fulfill the demand of an high yield and high efficiency production rates. The mass production of functional staves started in March 2018 and ended in June 2019 with a short tail of spares production at the end of 2019.

The assembly-storage cycles has been performed in two fully instrumented and optimized clean rooms of 42 m^2 (Class-10000, hosting a fast and flexible Mitutoyo Crysta Apex S 9206 Coordinate Measurement Machine (CMM) with a nominal resolution of 0.1 μm) and 25 m^2 (Class-100000), respectively.

The produced staves have been assembled on the surface at CERN and the commissioning of the inner and outer barrels started in June 2019. The INFN-Frascati group tooks part in the commissioning campaign by covering its quota of the 24/7 detector shifts for the second hald of 2019 and for the full 2020, at CERN and also remotely due to the COVID-19 emergency. The shift campaign ended in December 2020, leading the full detector to be ready for the installation at the ALICE point P2.

The installation of the new ITS into the ALICE cavern is scheduled in 2021, first the Outer Barrel and later the Inner Barrel.

The ALICE vacuum is expected to be closed by June 2021 and to have low intensity beam injected by last week September 2021 (week 39-40).

The INFN-Frascati group has been very active also for physics analysis and in particular for the extraction of the π, K, and p spectra from the newest high-energy data set of p-Pb collisions at 8.16 TeV, an essential reference analysis for any light flavor physics.

Since fall 2019 the INFN-Frascati group covered different roles of responsibility, having a leading role to the ALICE Run Coordination, being in charge of the global ALICE commissioning and data taking operations until 2021, and being an elected member of the Management Board of the ALICE experiment, participating by defaults also to the Physics and Technical Boards.

2 ALICE commissioning

Once the LHC entered Long Shutdown 2 (LS2), the ALICE activities focused on the upgrades: the old ITS and the TPC were extracted from the cavern in the first part of 2019. The old ITS was decommissioned and is now part of the permanent exhibition at the ALICE site (P2). The TPC was parked in the large clean room at P2 for the replacement of the MWPC end-caps with the new 4-foil GEM chambers. The replacement of the chambers and their services started in March and ended in June 2019. The new front-end electronics was installed in October 2019 and the new chambers have been tested with X-ray irradiation in November. The pre-commissioning phase started in December 2019 with sector-by-sector laser and cosmic runs.

The TPC has been fully commissioned on surface at CERN in 2020. The detector has been located inside the ALICE cavern and fully powered.

The two half-barrels of the other ALICE main tracking device - the new ITS - were fully assembled by the end of 2019 on the surface at CERN as shown in Fig. 1. The Inner Barrels were included in the readout and were routinely participating in threshold scans, fake-hit rates and cosmic runs. On the other hand, the Outer Barrels underwent a complete powering campaign and has been included in the running in August 2020.

The installation of the ITS in the cavern was initially scheduled in summer 2020, but it has been delayed due to the COVID situation. The Outer Barrel installation is now scheduled for March 2021 and the Inner Barrel in April. After that, there will be three weeks of ITS commissioning, while the start of the global ALICE commissioning is foreseen for June 2021.

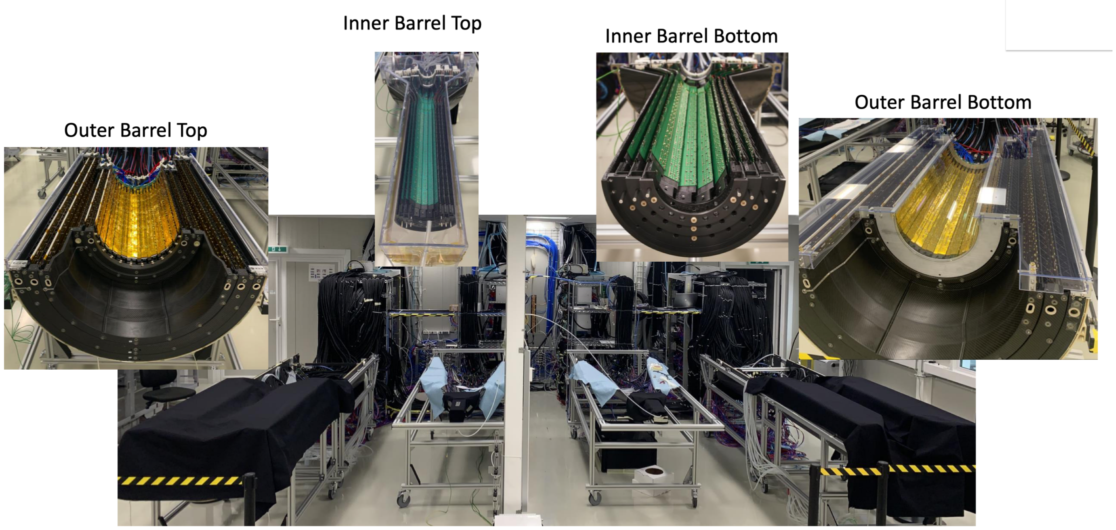

Figure 1: *The full ITS constructed in the clean room at the CERN Meyrin site. The Inner and Outer Barres can be seen in the center of the photo covered with a black tissue during commissioning data taking to avoid light induced noise. Details of the fully assembled inner and outer layers can be seen on the top photos.*

Despite some delay due to the COVID-19 emergency, the commissioning and installation of the remaining ALICE detectors during 2020 did match the milestones of the master schedule and is compatible with the LHC plans and will not be discussed in detail here. In 2021 the LHC will increase the luminosity of the heavy ion beams and deliver an instantaneous luminosity

$L = 6 \times 10^{27} cm^{-2} s^{-1}$ or higher. The upgraded ALICE detector is able to cope with the increased collision rates using the new GEM TPC and the MAPS ITS and will run at an interaction rate of 1 MHz during p-p operations and 50 kHz in Pb-Pb collisions.

As mentioned in the introduction, the INFN-Frascati group is in charge of the global ALICE commissioning and operation for the critical phase of the restart of the LHC after LS2.

3 Contribution to the ITS commissioning

The Frascati group provided 1/4 of the total Outer Barrel staves, with a sustained rate at LNF of 1 stave/week between the end of 2018 and June 2019 while the final production yield reached 97% (fraction of detector grade modules) for 29 produced staves (27 nominal staves + 2 spares). The 29 ITS staves assembled at LNF add up to total of 2.8 Gigapixels and can be considered one of the largest silicon pixel detectors currently existing in the world.

The INFN-Frascati group also developed a recovery procedure for damaged staves: since a stave is composed by 2 HS a tool was engineered at LNF to detach the already glued HS from the support to reuse the detector grade parts in a new stave.

The OL staves produced at LNF, together with the one produced in INFN-Torino, Nikhef, Daresbury and the ML staves produced in Berkeley have been assembled at CERN into the so called Half-Barrels (top and bottom). The two half-barrels have been connected to the cooling and readout electronics services on the surface (clean room of Bldg. 167 in Meyrin) where the commissioning started in mid 2019 and has been completed at the end of 2020, with some delay due to the COVID emergency. The surface commissioning of the ITS includes a powering campaign to assess the detector stability and continuous running of thresholds scans and noise runs to validate the number of bad or noisy pixels. Cosmic runs are routinely taken to validate the intrinsic alignment of the detector. The Frascati group has fulfilled its quota of the commissioning shifts at CERN for 2019 and has started to gain expertise in the detector operation.

As already mentioned in the past, in only three years (2016-2019) the INFN-Frascati group has successfully acquired and mastered the technological know-how for processing and producing large-area, small material budget, MAPS-based silicon tracking detectors. The production rate at LNF reached a sustained rate of 1 stave/week between the end of 2018 and June 2019 while the final production yield reached 97% (fraction of detector grade modules) for 29 produced staves (27 nominal staves + 2 spares). The 29 ITS staves assembled at LNF add up to total of 2.8 Gigapixels and can be considered one of the largest silicon pixel detectors currently existing in the world. The LNF site exceeded the production of the assigned nominal quota of detector grade staves and fulfilled the goals within the allocated time and with a high yield. In addition, spares have been produced and a technique to recover broken staves developed and applied. This technique has been also used by the CERN team during the test performed on surface. The group in 2020 was focused on the ITS surface commissioning.

The shifter teams were dedicated to the Inner Barrel monitoring and data taking and Outer Barrel monitoring. The full ITS commissioning period was in total of 63 weeks from 2019 week 21 to 2020 week 53 with only long stop from week 12 to week 34 in 2020 due to the COVID emergency. From week 39 in 2020 it was possible to do shifts also remotely, and the Frascati group fulfilled the assigned quota of 24/7 shifts, doing shifts at CERN by people on site and at LNF with remote shifts.

The Inner Barrel Top was fully commissioned in 2019 and January 2020, while the Inner Barrel Bot was commissioned in the first three months of 2020. The goal of IB detector on-surface commissioning readiness for 50 kHZ Pb-Pb running has been accomplished since March 2020. Three run types each hour for monitoring calibration (threshold tuning and stability), noise (system level, fake hit rate), and for measuring cosmic tracks have been performed in order to assess the detector stability, to validate the number of bad or noisy pixels and to validate the intrinsic alignment of the detector. Data transmission studies have been performed at nominal parameters (50 kHz, Pb-Pb) but also at trigger frequency up to 250 kHz. Dead pixels regions have been identified and recovered. The IB detector was ready for installation at the end of 2020.

The Outer Barrel detector has been fully commissioned in 2020. The commissioning started with a one-by-one stave verification and long term powering. Calibration, noise and cosmic studies have been done as for the IB detector. Stability test runs were taken also for all OB staves in order to find the noisy pixels of each stave in each run and compare them among runs to check the stability of the masks. Staves with a fake hit rate (FHR) $> 10^{-7}$/pixel/event have been investigated. The pixels with an occupancy $> 10^{-6}$ hits/event have been defined as noisy and considered as bad.

Tipical tracks for OB top and bottom obtained during the cosmic campaign are reported in Fig. 2. 7 millions cosmic events have been collected during data taking before Christmas 2020: from these data, an estimate of the OB detection efficiency and a measure of the spatial misalignment can be obtained.

Bandwidth tests have been carried out in order to verify robustness of the readout chain versus increasing data throughput. This has been accomplished with fake-hit rate run at increasing frequency (to increase the throughput), integration time of 100 s, with nominal voltage (with voltage drop correction), with different Trigger frequencies up to 100 kHZ.

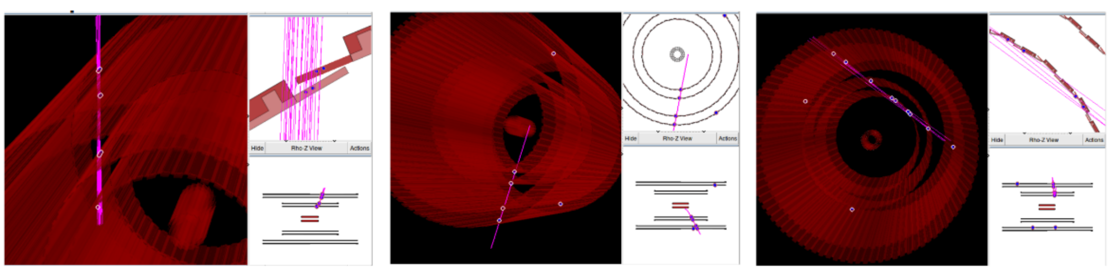

Figure 2: *Outer Barrels (OB) top and bottom cosmic candidates.*

4 Physics contribution

During 2020, the analysis activity has been devoted to the extension up to 20 GeV of the previously-approved measurement of light hadron spectra collected on ALICE data through p-Pb collisions at a center-of-mass energy $\sqrt{s_{NN}} = 8.16$ TeV. The extension of the p_T range proceeded through the inclusion of a new analysis performed with the *High Momentum Particle Identification Detector* (HMPID) and one performed by exploiting the *relativistic-rise* in the energy-loss signal measured with the *Time-Projection Chamber* (TPC), realized, respectively, in Bari and Copenaghen. Light-flavour spectra represent indeed an essential tool in understanding the underlying mechanisms in PbPb collisions. In fact, they allow to test the emergence of a deconfined phase - the so-called **Quark-Gluon Plasma** (QGP) - through the analysis of the spectral shape of hadron p_{T} distributions. From the latter, it is possible to extract the thermodynamic properties of the system created during the collision, as the kinetic freeze-out temperature and the fireball expansion velocity. However, some phenomena typically attributed to the emergence of a deconfined phase can be mimicked by alternative processes, as the ones known as *Cold Nuclear Matter effects*, as the modification of the parton distribution functions in the nuclear environment or shadowing effects.

These effects can be studied by analyzing p-Pb collisions, where no deconfined phase should appear, given the smaller energy density produced in the collision.

Frascati group, that performed the analysis at low-p_T, during 2020 has been responsible for the combination of the high-p_T analyses with the low-p_T ones. It led to the production of the new spectra - extended now up to 20 GeV - and to the extraction of the relevant observables related to the higher-p_T sector. In particular, the nuclear modification factor - both for Minimum Bias events and for the different multiplicity classes - has been extracted.

In view of these new results, a paper proposal is being presented at the ALICE Collaboration, and it is now in the final stage of the approval process.

Simultaneously to the finalization of the paper at 8.16 TeV, a new analysis has been started aiming at the measurement of pion, kaon and proton spectra on ALICE data collected through p-p collisions at a center-of-mass energy $\sqrt{s} = 5.02$ TeV. Frascati is responsible for this analysis in the low-p_T sector, focusing on the extraction performed through the *Inner Tracking System* (ITS), the *Time-Projection Chamber* (TPC) and the *Time-Of-Flight* (TOF).

The ITS analysis was also the subject of a Master Degree thesis; Frascati group, in fact, supervised the work of a master student (A. Pournaghi) at Sapienza Università di Roma, leading her to graduation on December 2020.

5 ALICE scientific output

The ALICE Collaboration has published 39 papers in 2020 and to date published 297 papers on international referred physics journals (Fig. 3).

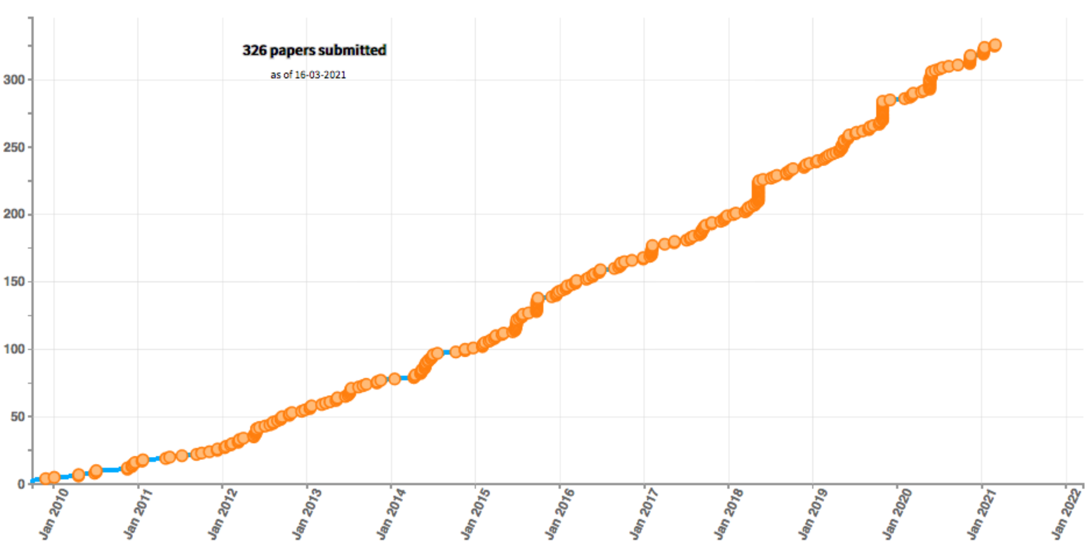

Figure 3: *Timeline of the total number of ALICE papers ("submitted" is to be intended as published+submitted) since the fist LHC beam at 900 GeV on November 23, 2009).*

The full list of ALICE publications can be found online at the link:
http://aliceinfo.cern.ch/ArtSubmission/publications