The HMPID in Run3

Abstract

Since the preparation of the LoI on the ALICE upgrading (Sept 2012), the HMPID was in the list of the detectors to take data during the period 2021-2023 (Run-3). At that time a short description of the physics reasons was given.
In this document the physics and technological reasons supporting the continuation of the detector operation in the period 2021-2023, are expanded and complemented.
The HMPID can identify charged hadrons in the momentum interval 1-5 GeV/c. The stability and the potential on the PID the detector can still provide, are presented.
Thanks to the available expertise, the detector operation will require limited resources. Moreover the limited data size produced doesn't add significant overhead to the O^2 system.
Finally, the upgrading activities started since 2012, and so far successfully under way, are also presented.

HMPID contribution to the ALICE physics during Run-1 and 2

The HMPID:

- has provided $\pi, K\ and\ p$ aboundancies, in pp collisions at $\sqrt{s}$= 2.76 and 7 TeV, in Pb-Pb collisions at $\sqrt{s_{NN}}$= 2.76 TeV and in p-Pb collisions at 5.02 TeV for a total of 4 published papers [1][2][3][4];
- Results in pp at $\sqrt{s}$= 13 TeV and Pb-Pb at $\sqrt{s_{NN}}$= 5.02 TeV are in publication phase;
- has provided deuteron identification (centrality interval 0- 10%) up to the momentum bin 8 GeV/c (the highest so far) for a published papers [5];
- two particle correlation study in pp collisions at $\sqrt{s}$= 7 TeV to extract the p/π ratio in jet and bulk is ongoing (see the analysis note [6]);
- is finalizing an internal note on the detector performance (stability and PID) during the period 2010-2015 [9];
- has presented several papers with the detector performance at detector conferences [10].

Contribution of HMPID to Run3 physics

HMPID in Run3 will increase its event read out rate by a factor of 10 thanks to the upgrading of the RO firmware. Therefore, it can contribute to the physics analysis with ten times the vent statistics collected during Run-1and 2. The physics subjects can be summarized as follow:

- Light nuclei identification
  - Deuteron in pp collisions in the momentum bin 10-12 GeV/c,

- Deuteron in Pb-Pb collision in the momentum bin 10-12 GeV/c, not only in central collision, and estimate of triton and helium samples;
- Measurement of (anti-)nuclei absorption cross section;

- PID cross-calibration of HMPID-TOF-TPC;
- Identified particle correlation study :
  - p/π ratio in the bulk and in the jets;
- reduction of combinatorial background in topological identification: $(e.g.: \Lambda_c^+ \rightarrow p + K^- + \pi^+$ and/or ρ → e^+e^-);
- Pions, kaons and protons PID in lighter nuclei collisions (O or Ar);
- Experiment alignment.

A more complete presentation of these analysis channels can be found in the attached document **HMPID contribution to the ALICE physics program in Run-3.**

PID cross-calibration of HMPID-TOF-TPC and alignment

- The TPC and TOF will undergo an upgrading program especially TPC that will replace the MWPC's with new GEM modules. At the beginning of Run3 HMPID will undergo only to the upgrading of the RO firmware. Therefore, it can select with 3 sigma separation samples of π, K and p in the range 1-5 GeV/c to be used for cross-calibration of TOF and TPC to probe the preliminary PID performance.
- The HMPID can also provide the impact points of tracks in the MWPC's (MIP clusters) at a distance of about 5 m from the collision point. They can be used as a good constraint in the global alignment especially to monitor the radial expansion or squeeze of the whole ALICE setup. During 2006 a survey of the seven MWPC's on the cradle, and of the cradle in ALICE was carried out. Permanent reference points were fixed on the MWPC's and on the cradle supporting the modules so, the HMPID position was precisely determined in the ALICE reference system. The precisions of the location of the MIP clusters is of the order of ±2 mm in the local HMPID X-Y pad plane (perpendicular to the radial direction) and ±3 mm (to be cross-checked) in the radial direction, respectively.

Stability and Ageing studies for detector development

- The HMPID with its 10.3 m^2 of active surface of CsI photocathodes is the largest RICH detector taking data on a collider experiment.
- The RICH counters are based on pad segmented, CsI photocathodes, installed in MWPC's for the detection of UV Cherenkov photons produced in the liquid C_6F_{14}. The CsI photocathodes were produced in the period 2001-2005 in a common facility at CERN for COMPASS and the HMPID projects.
  After 8 years of LHC operation (2010-2018) and after about 15 years from their production, the CsI photocathodes are showing a stable quantum efficiency (QE) and this in agreement with what expected from

the ageing studies carried out at the production time, using radioactive sources [11].
The scientific community is interested in exploring the stability of the PID performance of this technique based on a cheap solution for the Cherenkov photon detection w.r.t. vacuum-based photodetectors.
The detector operation during Run3 would provide then the suitable test bench to check the CsI stability. The charge dose at the end of Run3 (2023) is expected to be 0.3 mC/cm^2 (see later Fig. 2) and some loss on the CsI QE could appear above the limit of 0.2 mC/cm^2. From the ageing test results we expect a QE loss of 8% with no PID degradation, for a detector operation over 13 years (2010-2023).

The detector stability and the upgrading activities for the technological challenge in Run3

So far the detector has shown a very good stability and PID performance. Considering the HV sectors and the radiator vessels not providing data, the actual acceptance of the HMPID is about the 65 % of the total. Since the event topology requires only half photocathode for the pattern detection at the maximum Cherenkov angle, this acceptance reduction has no impact on the PID performance but only on the event statistics.

In Fig. 1 a good gas gain stability with ±10% of variation during 8 years of operation, is shown. On sept. 2011 a HV equalization was carried out resulting in a smaller gain spread per module.
In Fig. 2 the yellow bars show the charge dose on the CsI photocathodes expected till 2023 when a possible reduction of 8% the QE might be observed. In principle this could also be compensated by increasing the MWPC high voltage. However the QE reduction would not have impact on the PID performance.
Fig 3-4 show the monitored number of Cherenkov photons per pattern Nph at the maximum emission angle. Except in the RICH2 (2 re-evaporated photocathodes show a decrease of Nph), a good stability is observed in all the other modules, condition representing the stability of the CsI QE.

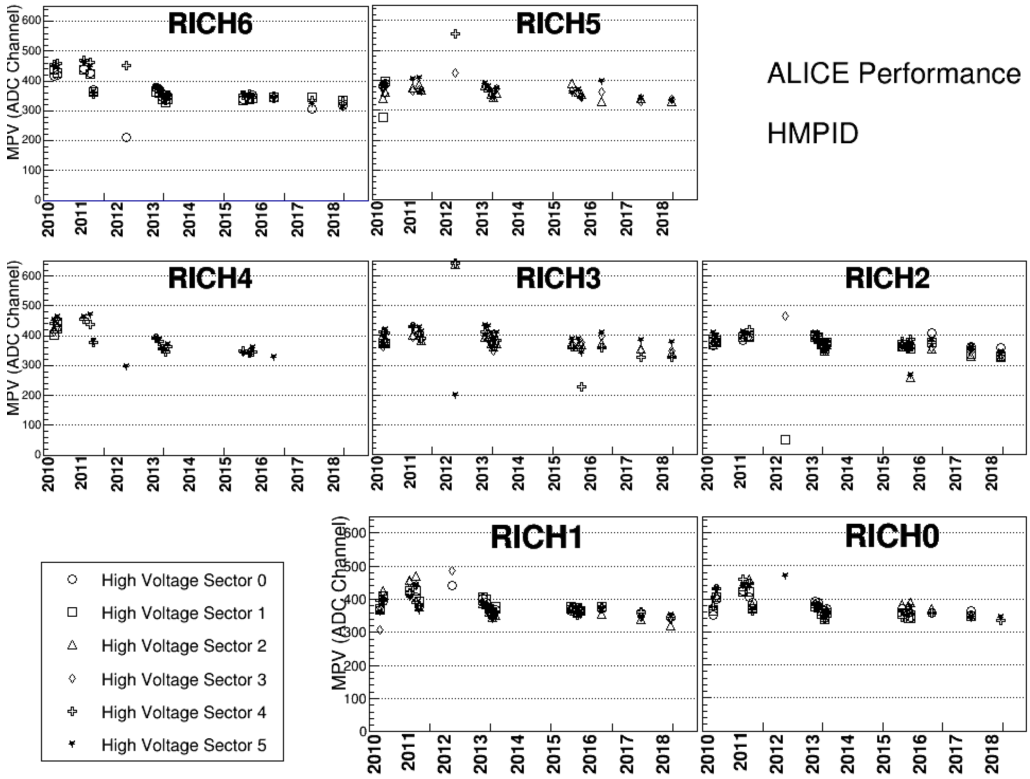

Figure 1 The most Probable Value of the landau distribution of the MIP vs. time. On Sept 2011 a HV equalization was carried out.

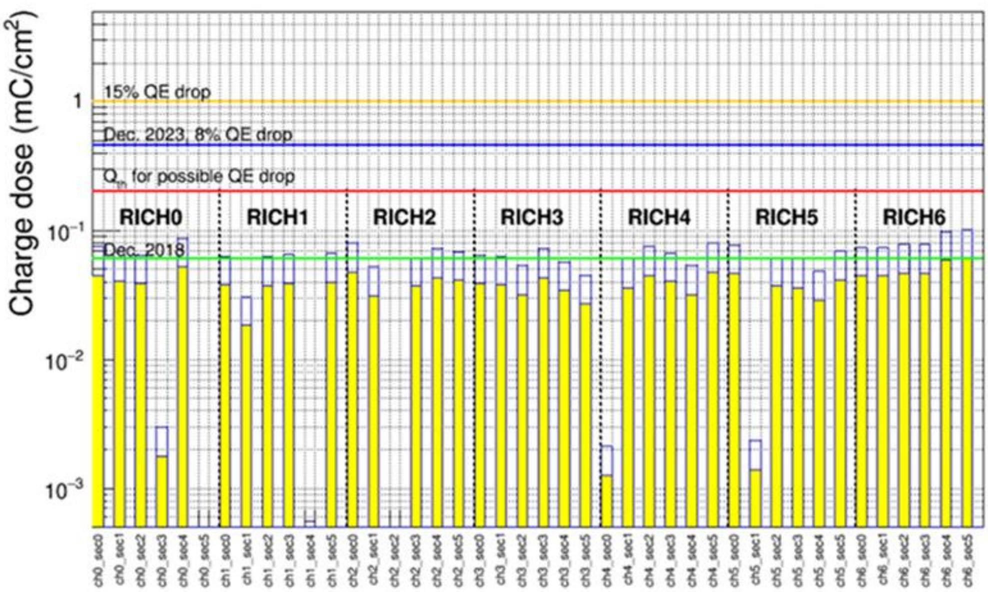

Figure 2. The yellow bars represents the charge dose on the CsI photocathodes untill end 2017. It is calculated integrating the 60% of the total anode current (upper bar profiles) flowing through the CsI photocathode.

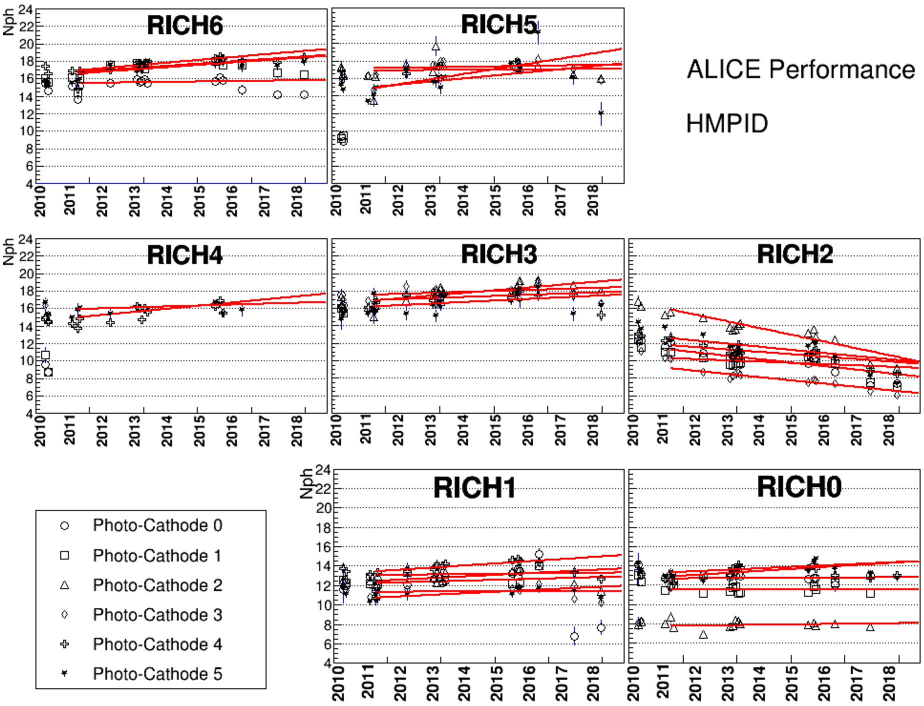

Figure 3. Nph, number of photons per pattern at the maximum Cherenkov emission angle (cosθ=1/n, with n refractive index of C_6F_{14}) in the period 2010-2018

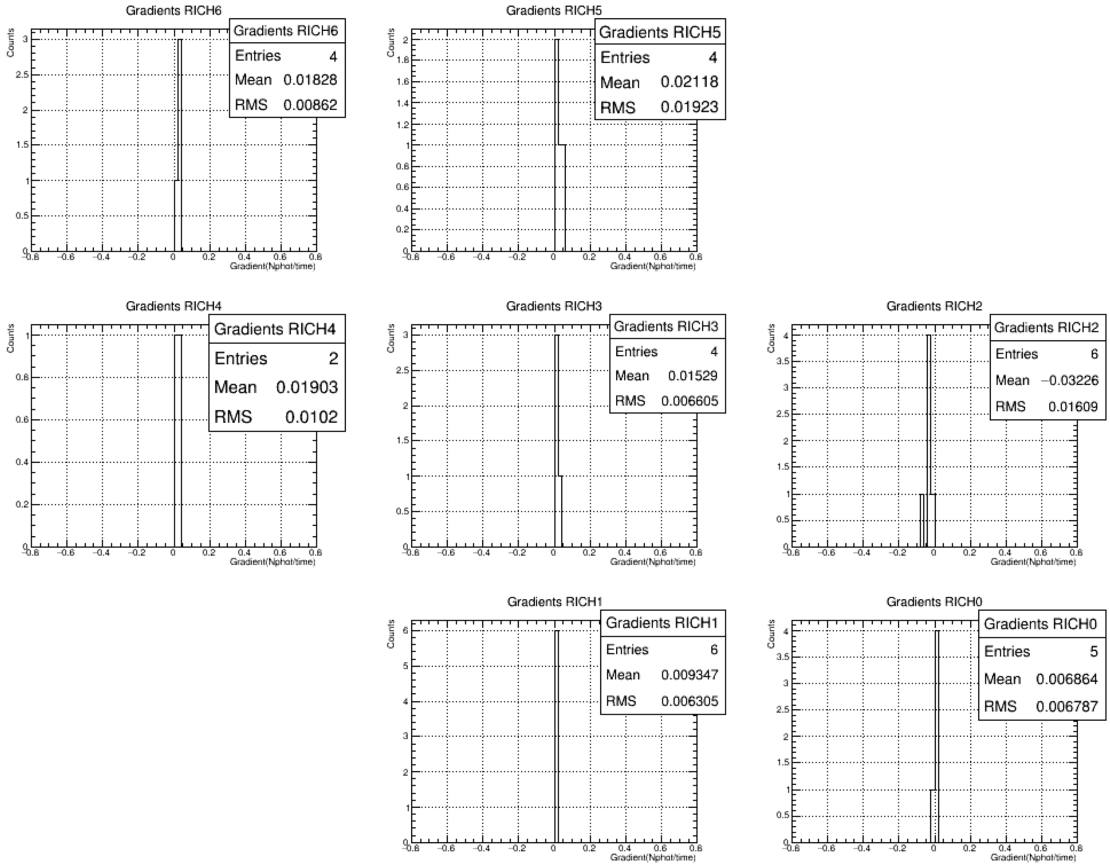

Figure 4. Distribution per RICH module of the angular coefficients of the fit of N_{ph}.

High Luminosity Run3 equivalent tests

HMPID so far has participated to all the high luminosity Run3 equivalent tests showing a good gas gain linearity. As an example in Fig. 5 and Fig. 7 are shown the test results of June 2018, respectively: the MWPC anode current, Luminosity and the ratio current/lumi. This last one remains constant up to 70 Hz/μb confirming the absence of gas gain saturation effects.

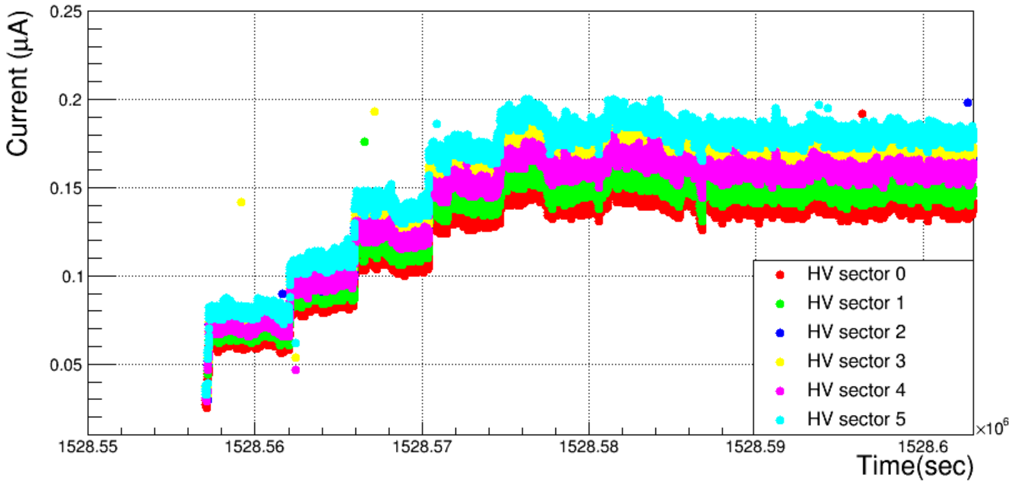

Figure 5 MWPC anode currents in RICH3

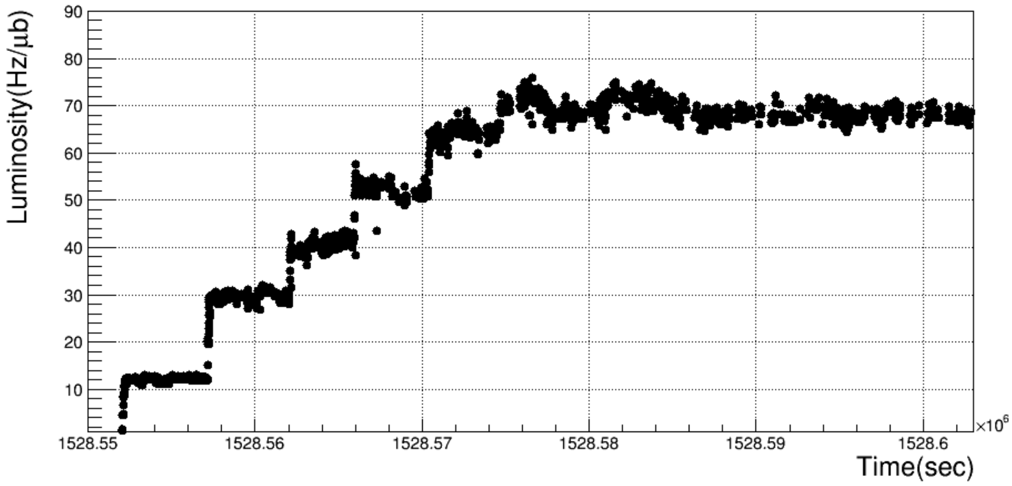

Figure 6 Luminosity monitoring in ALICE

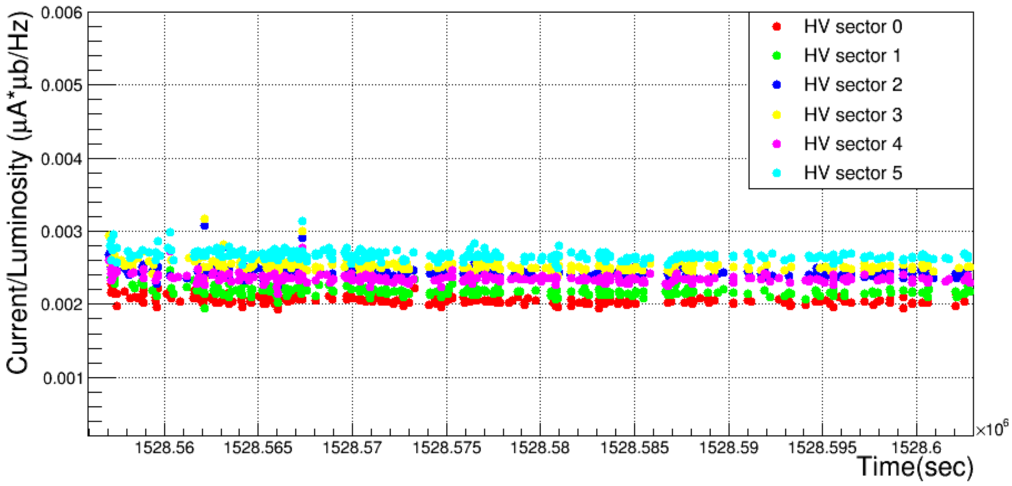

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Figure 7 Ratio of anode current over luminosity, constant up to 70 Hz/μb.

End of Run during Run2 caused by HMPID

The number of EOR during 2015-2018 caused by HMPID has been of the order of less than ~ 3% of good runs. An increase at ~10 % during 2018 is observed (tab.1). This is due to mainly the failing pause and reset commands (PAR command). A study of the reasons is underway and apparently they concentrate on one of the HMPID DAQ equipment. An improvement on the PAR procedure might be introduced. Finally, the dead time introduced with each EOR on the ALICE data taking is of the order of few minutes (STOP/START a new run), therefore a negligible amount of the total time of the about 200 runs per year.

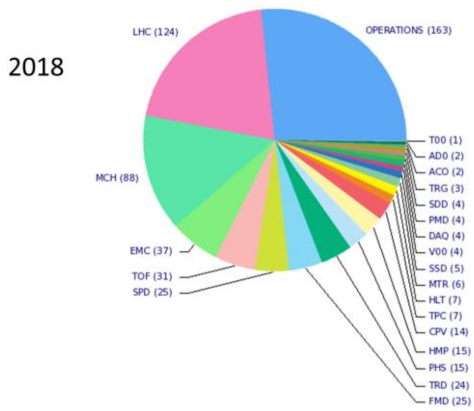

Figure 8

year	Operations	EOR
2015	**207**	**8**
2016	**273**	**4**
2017	**221**	**5**
2018	**163**	**15**

Table 1

Electronic Read-out and trigger for Run3

During LS1 HMPID has carried out an upgrading of the RO firmware. Using a preliminary version partially compliant with Run3 (L2 latency eliminated), the event read out rate has increased as shown in Fig. 9.
It allows for doubling the max event read out rate w.r.t. Run2, at the expected detector occupancy in pp and Pb-Pb collisions.
To carry out the PID, the HMPID requires the momentum measurement by TPC. So during Run1-2 it has been limited to taken data at about 800 Hz and 500 Hz respectively in pp and Pb-Pb runs. In Run3 HMPID will be able to exploit its full capabilities taking data at ~10 KHz and ~6 KHz respectively in pp and Pb-Pb (see red curve in Fig. 9). In both cases with a rate 10 times higher than Run1-2 and then with benefits for the event statistics.

The detector throughput at 6 KHz in Pb-Pb collisions is up to 22 Mbyte/s. This corresponds to about 10^{-4} of the full experiment throughput, a negligible overhead for the O^2 system.

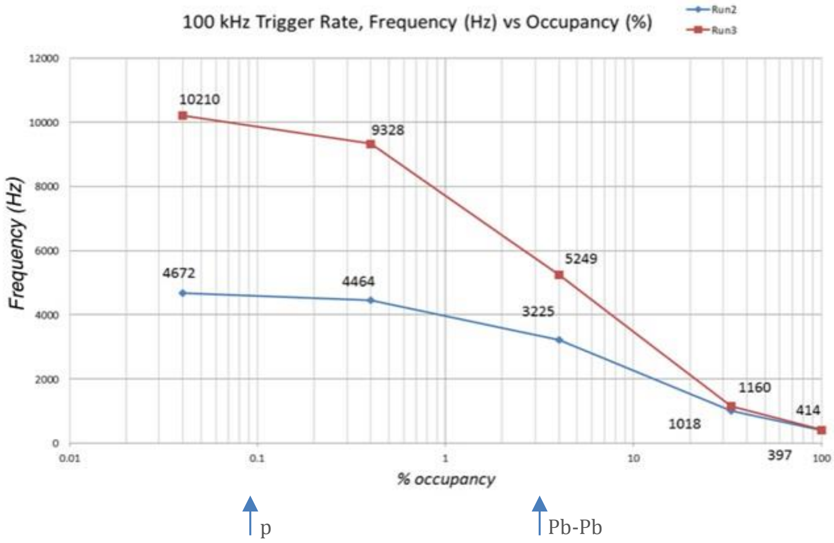

Figure 9 Event read out rate using a preliminary RO firmware, Run3 compliant (red line) where the L2 latency is eliminated.

With the collaboration of the CTP team, the integration in the new trigger schema has also been successfully carried out. HMPID, as triggered detector, will receive the standard LM-L1 trigger signals plus the asynchronous Heart Beat trigger message via B channel of the TTCrx for the event identification. A new LTU unit, Run3 compliant, will be delivered by the end of 2018 and installed in the HMPID electronic laboratory at CERN.
The design of the trigger fan-in/out module is already finalized [12, 13], the prototype tested (Fig. 10) and the first module produced in Malta will be delivered at CERN by the beginning 2019. This module will remotely be configurable and monitored by IP bus and connection to Internet.

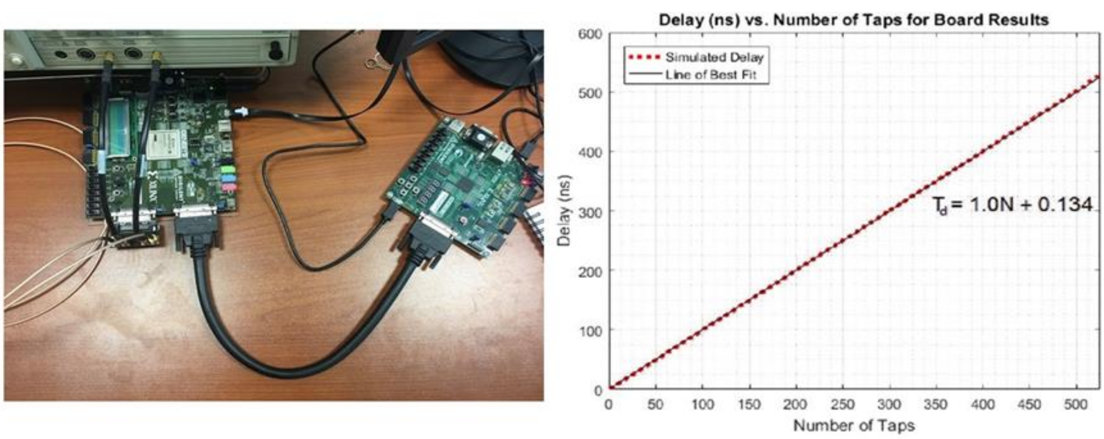

Figure 10. On the left panel, the prototype of the first Fan-in/out module implemented on a FPGA commercial card. On the right panel, the precision of the time delay that can be set to align the timing of the LM trigger and the requested peaking time of the GASSIPLEX FEE electronics.

Maintenance and Operations of the HMPID during Run3

The INFN is the main contributor of the project since 1990 in the collaboration RD26 first and now in ALICE (70% of M&O B budget).
If the CERN team, as second contributor, will not be able to contribute to the 30% of the M&O B budget, INFN can cover the full amount.
Using the spare modules and discontinuing the maintenance of infrastructures for the conservation in Ar of the spares CsI photocathodes, as from 2021 until 2023, a detector M&O B budget of the order of 60 KCHF instead of the actual 82 kCHF, will be requested.
The already available amount of the liquid Cherenkov radiator C_6F_{14} is enough to operate the detector until the end of Run3 so, no extra costs are expected for its procurement.
Finally, in 19th Nov. 2015 the previous spokesperson P. Giubellino signed with the Rector of the Malta University a MoU as Associate Member. Colleagues from the Faculty of Information and Communication science and Physics Department are collaborating in the HMPID project and with related INFN activities.

Conclusion

During Run 3 the HMPID can contribute in several way to the ALICE physics program, it can provide data samples of pion, K and protons for the cross-calibration and test of the PID performance of TPC and TOF and finally it can contribute to the experiment alignment monitoring the radial expansion/contraction of the full experimental set up.
The Scientific Community is also interested in exploring the technological challenge of the CsI photocathodes w.r.t. vacuum-based photodetectors.
Moreover, the HMPID is a key project of ALICE for the collaboration with the Malta University (MoU signed in Nov. 2015).
Finally, taking into account the detector stability and the successful upgrading activity under way, the HMPID collaboration consider there are evidences supporting the detector operation during the period 2021-2023.
A check of the detector status at the end of each year will be carried out. If it will not be fulfilling the stability requirements, then the impact on the global performance of the data-taking will be evaluated with the technical coordination and eventually the detector could be switched OFF.
As from 2021 until 2023, a detector M&O B budget of the order of 60 kCHF instead of 82 kCHF, will be requested.

Bibliography

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http://www.sciencedirect.com/science/article/pii/S0370269314004973

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[3] **Centrality dependence of the nuclear modification factor of charged pions, kaons, and protons in Pb-Pb collisions at sqrt(s_(NN)) = 2.76** http://journals.aps.org/prc/abstract/10.1103/PhysRevC.93.034913.

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