Physics for HMPID in run 3

GDC and G. Volpe
On the behalf of the HMPID collaboration

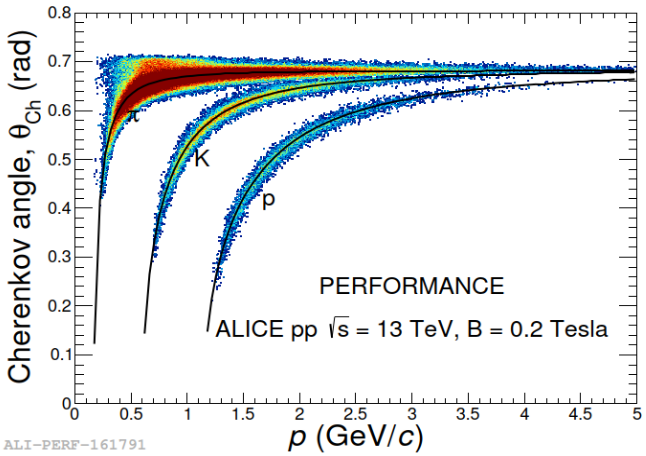
With the contribution of :

A. Dainese, F. Bellini, S. Bufalino, A. Caliva', M. Colocci, A. Festanti, M. Van Leeuwen, A.P. Kalweit, R. Shahoyan and M. Weber.

HMPID in the ALICE upgrade LoI 2012

- 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);

- short description of the physics tasks was given: "Its excellent PID capabilities can be exploited for physics and to constrain the charged hadron identification by the dE/dx measurement of the TPC in the overlapping momentum range".



Detector Status

- HMPID is taking data at <95%> of the TPC run time;
- Stable number of Cherenkov photon /pattern at θ_{max} (N_{ph});
- no evidence of CsI photocathodes ageing, total charge dose within expectation for 2018; Exist margins to operate till 2023;
- Actual Event rate 4.5 kHz in pp (~10 KHz Run-3) and 3.5 kHz in Pb-Pb (~6 KHz Run-3);
- RO and FEE card failures since 2006: stable at 0.1%;
- 4 leaking C_6F_{14} radiator vessels (out of 21) excluded from the hydraulic circuit;
- 6 HV sectors (out of 42) excluded from DCS;
- Detector acceptance: 65% of the initial ones;
- No major problems with other sub-systems (cooling, HV-LV PS, C_6F_{14} recirculation/transparency and DCS);
- EOR statistics:

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

Physics cases

- Light nuclei identification
  - Deuteron in pp collisions in the momentum bin 10 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 spectra up to 7 GeV/c;
  - 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 $\rho \rightarrow e^+e^-$);

- pions, kaons and protons PID in lighter nuclei collisions (O or Ar);

- Experiment alignment.

Present baseline lumi requirements and schedule

- ALICE L_{int} requirements (Upgrade LOI):
  - Pb-Pb: 10/nb @0.5T + 3/nb @0.2T
  - pp 5.5 TeV: 6/pb (4e11 events)
  - p-Pb: 50/nb
  - pp 14 TeV: introduced in 2015 (O^2 TDR)
- ATLAS/CMS:
  - Pb-Pb: 13/nb
  - pp 5.5 TeV: 300/pb (equivalent NN lumi of 10/nb Pb-Pb)
  - p-Pb: no lumi limitations
- LHCb:
  - Committed to participate in all runs, but no specific lumi requests up to now

Year	System	$\sqrt{s_{NN}}$ (TeV)	L_{int} pp: (pb^{-1}) p–Pb: (nb^{-1}) Pb–Pb: (nb^{-1})	$N_{collisions}$
2021	pp Pb–Pb	14 5.5	0.4 2.85	$2.7 \cdot 10^{10}$ $2.3 \cdot 10^{10}$
2022	pp Pb–Pb	14 5.5	0.4 2.85 **0.2T**	$2.7 \cdot 10^{10}$ $2.3 \cdot 10^{10}$
2023	pp pp	14 5.5	0.4 6	$2.7 \cdot 10^{10}$ $4 \cdot 10^{11}$
2027	pp Pb–Pb	14 5.5	0.4 2.85	$2.7 \cdot 10^{10}$ $2.3 \cdot 10^{10}$
2028	pp Pb–Pb p–Pb	14 5.5 8.8	0.4 1.4 50	$2.7 \cdot 10^{10}$ $1.1 \cdot 10^{10}$ 10^{11}
2029	pp Pb–Pb	14 5.5	0.4 2.85	$2.7 \cdot 10^{10}$ $2.3 \cdot 10^{10}$

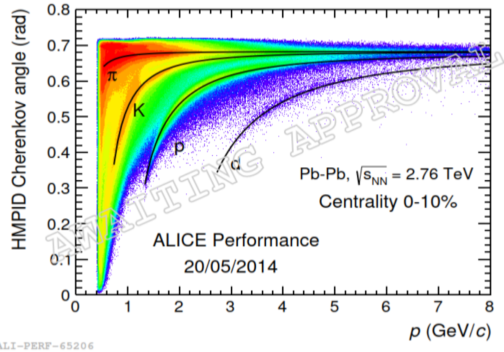
Updated (years) from ALICE O^2 TDR, CERN-LHCC-2015-006

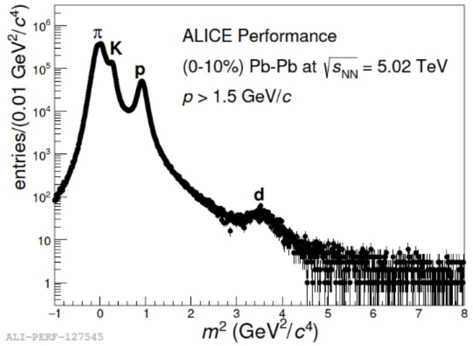
Andrea Dainese

light nuclei detection in Run-3

- **In pp,**
- in Run-3, with 2.4 10^{10} events in HMPID, the **10 GeV/c** momentum bin for the **deuteron** can be filled in.This spectrum extension is of interest t in the quest of establishing the composition of the X(3872) particle.

- **In Pb-Pb,**
- In Run-1, HMPID filled in the 8 GeV/c momentum bin for deuteron in 0-10% centrality interval;
- In 2018 , with 150 M events (0-10% centrality), the deuteron momentum bin at **10 GeV/c** can be filled in.
- In 2022, with B=0.2 T and ~300 M central events in HMPID, also the **12 GeV/c** bin (with 2 sigma separation) can be filled in. Contribution in other centalities, possible;
- Triton and ^{3}He spectra up to 7 GeV/c using central collisions can also be measured. Cross-check with TPC-TOF mesurement to be done.





Establishing the composition of the X(3872) particle

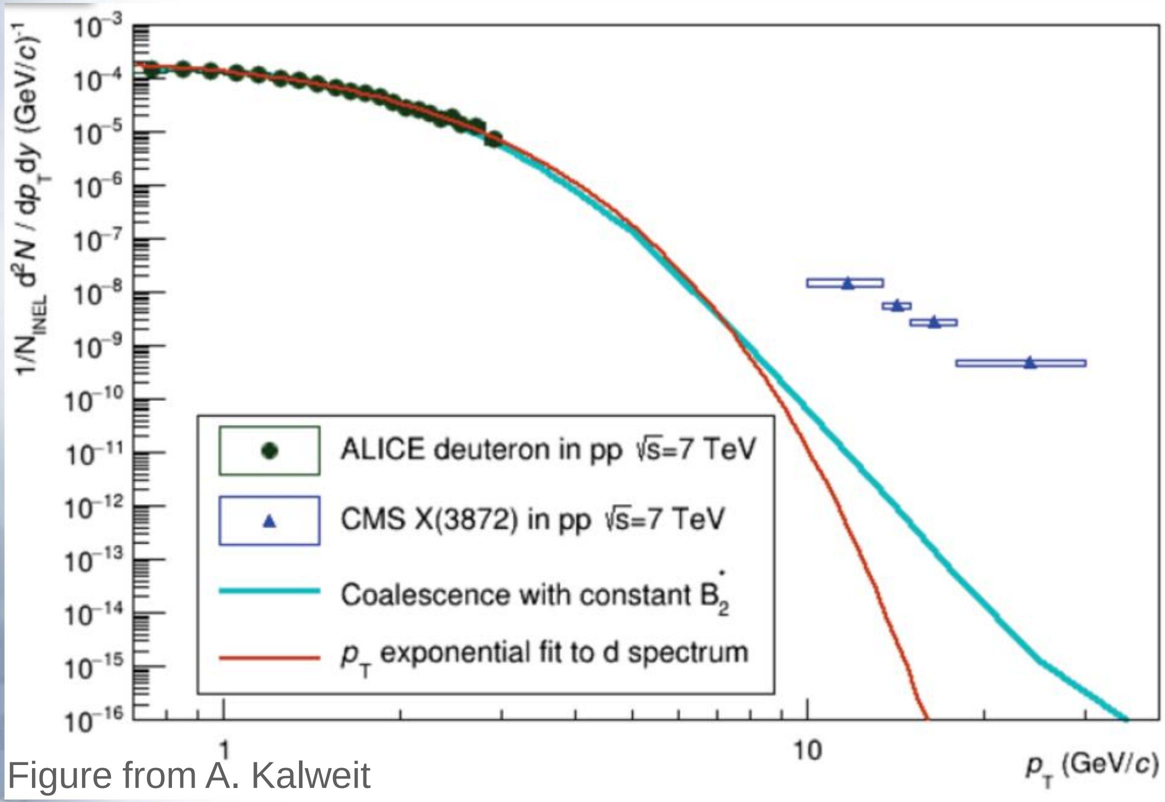
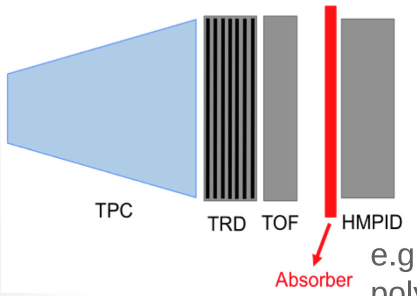


Figure from A. Kalweit

absorption cross section for anti-protons and light anti-nuclei

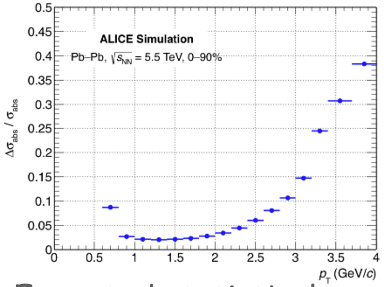
- Interesting for multi-baryon states production;
- To reduce the systematic uncertainties in the (anti-)deuteron (and anti-^{3}He) yield measurement;

$$N = N_0 \times e^{-\frac{\Delta x}{\lambda_i}} \quad with \ \lambda_i = \frac{A}{\rho N_A \sigma_h}$$

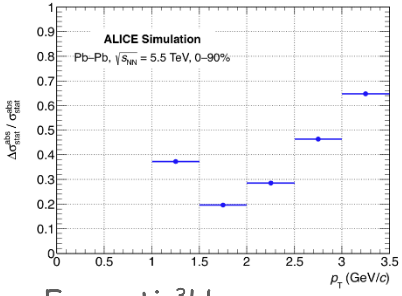


e.g.: 25 cm thick polyethylene slab (1/3 λ_i)

$$N_A^{HMPID} = (N_{A,present}^{TPC} \times\ 0.05\ \times f) \times \epsilon\ \times 10$$



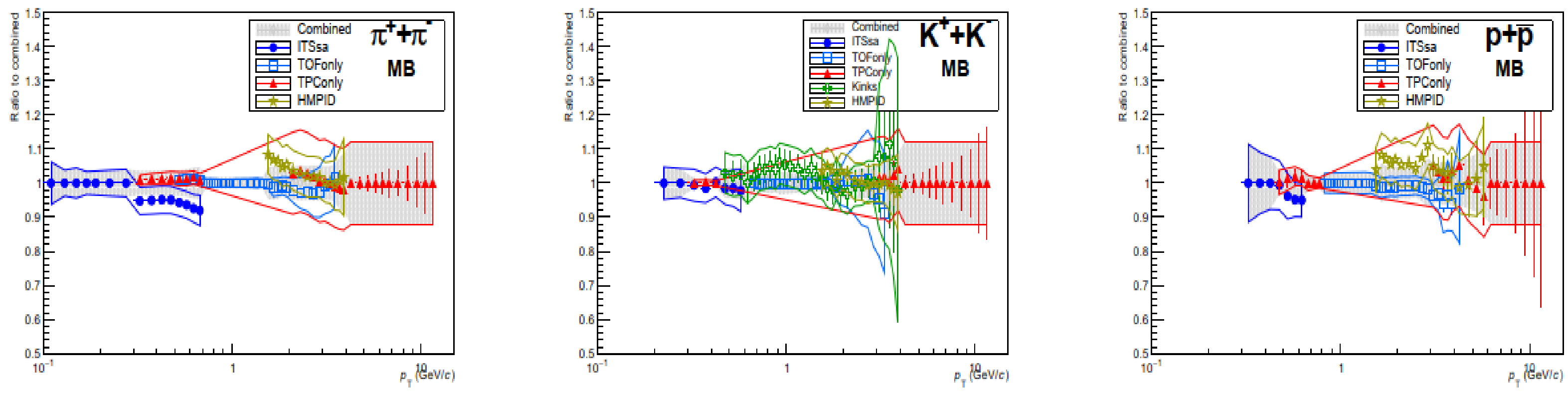
Expected statistical precision for anti-deuteron



For anti-^{3}He

PID cross-calibration of HMPID-TOF-TPC

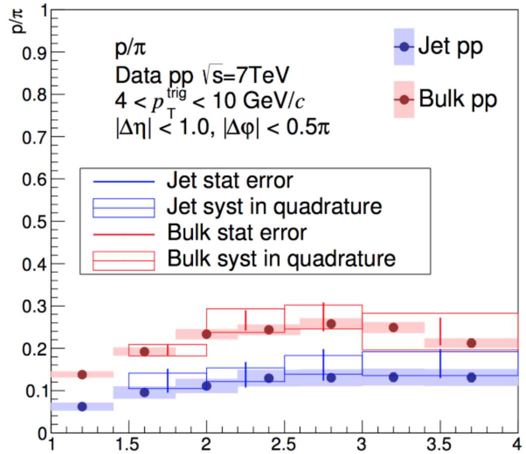
- collision energies in Run-3 different from Run-2, no published spectrum that can be used for precise benchmarking;
- HMPID can select with 3 sigma separation samples of π, K and p in the range 1-5 GeV/c;
- HMPID overlaps TPC and TOF, with uncertainties smaller than the TPC and also of the highest-pT TOF points



(a) $\pi^{+}+\pi^{-}$: Ratio to combined (b) $\pi^{+}+\pi^{-}$: Ratio to combined (c) $\pi^{+}+\pi^{-}$: Ratio to combined

Identified particles correlation study

- in pp collisions at 7 TeV, an internal note on one trigger particle in the full TPC acceptance with one identified in the HMPID acceptance was prepared;
- In Run-3 this study can be completed crosschecking with a ten times higher event statistics in the HMPID;



Proton-over-pion p/π ratio as measured with the HMPID detector. Empty rectangles (combined sys. and stat. errors) represent the points measured with the HMPID. The ratio is measured in jet and bulk and in the figure, it is compared with correlation analysis using TOF templates [1] not yet published. The results agree within statistical and systematic errors

Additional tasks

Details in the posted documents:

- **Pions, kaons and protons PID in lighter nuclei collisions;**
- Experiment alignment;
- **Combinatorial background reduction for the topological identification;**

Backup slides

RICH module Geometry

Proximity-focusing geometry;

$\cos\theta = 1/n\beta$

Cherenkov Radiator

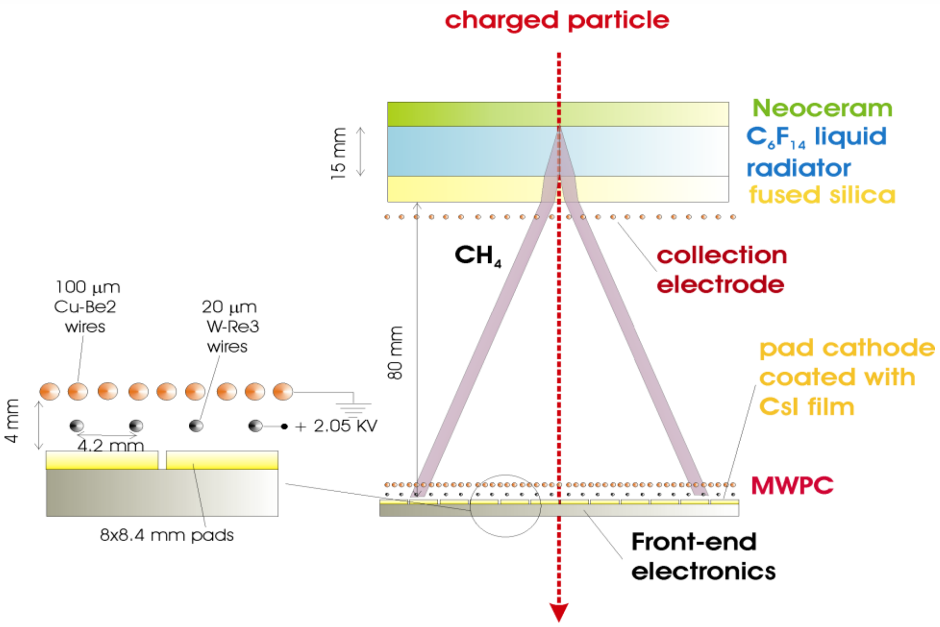
- 15 mm C_6F_{14}; n=1.2989 @ 175 nm;

Photon converter:

- 300 nm thick reflective layer of CsI; QE ≈ 25% @ 7.1 eV (175 nm)

Photoelectron detector:

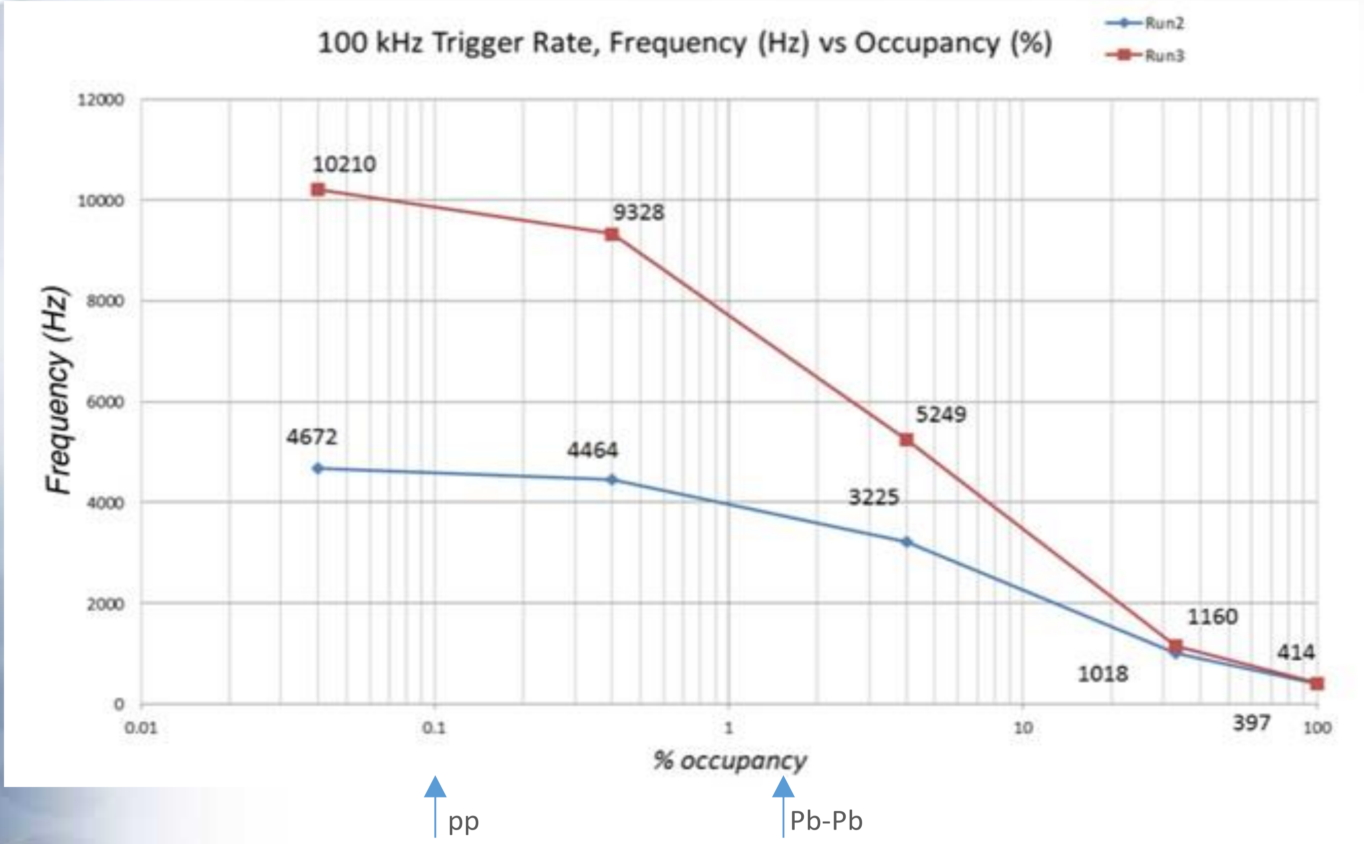
- MWPC 2,2-2.5 mm asymmetric gap with CH_4 at atmospheric pressure, gas gain ≈ 4 10^4 ;
- analogue pad read-out (pad size = 8x8.4 mm^2), total number of channels ≈ 160 K.



Perspective during 2019-2023

- HMPID will not be removed from the actual experiment location;
- Only development/procurement of new software components (RO firmware, DCS…) and external HV-LV and trigger modules;
- Lab. test set-up with: CTP-LTU, RO electronics and blade server for Run3 with new C-RORC running at bld. 581;
- No extra costs or manpower required, respectively in the ordinary M&O budget and ordinary maintenance.
- No tasks with critical time dead line;

Event RO rate



HMPID in the trigger sys.

- Preparation of two trigger Fan-in/out modules for LM and Busy LVDS signals;
- VME standard for power only, Ethernet for IPBus Control with remote programmable delay line (1 ns step) and input/output enable/disable features (Malta Univ). Prototype to be tested Oct 2017 at blb 581, final modules to be built;
- Short document for the HMPID integration in the Run3 trigger and O2 environments already submitted;
- No extra cost are expected, Dept. nano-micro electr. (Uni Malta) will provide these modules and the relevant manpower.

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ALICE CERN

DRAFT ALICE-HMPID-2016-001

Proposal for the HMPID *modus operandi* in DAQ and Trigger new schemas during Run 3

G. De Cataldo, J.L. Gauci

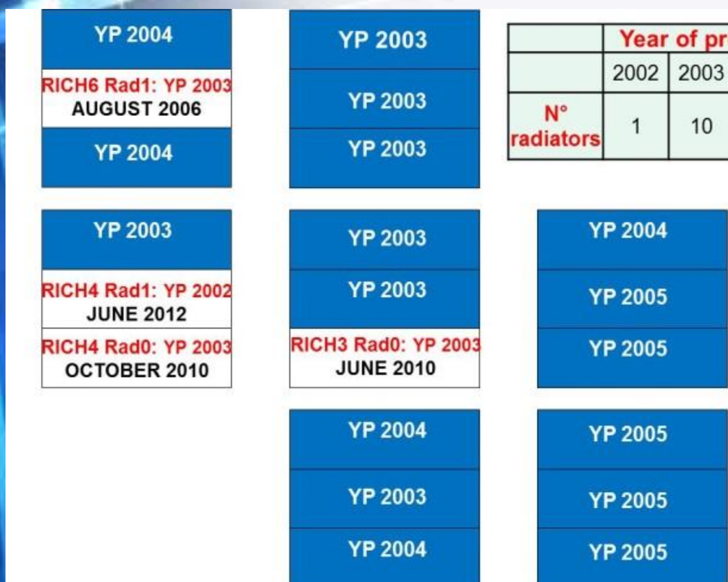
CERN, EP Department

Version 2, Nov. 15th, 2016

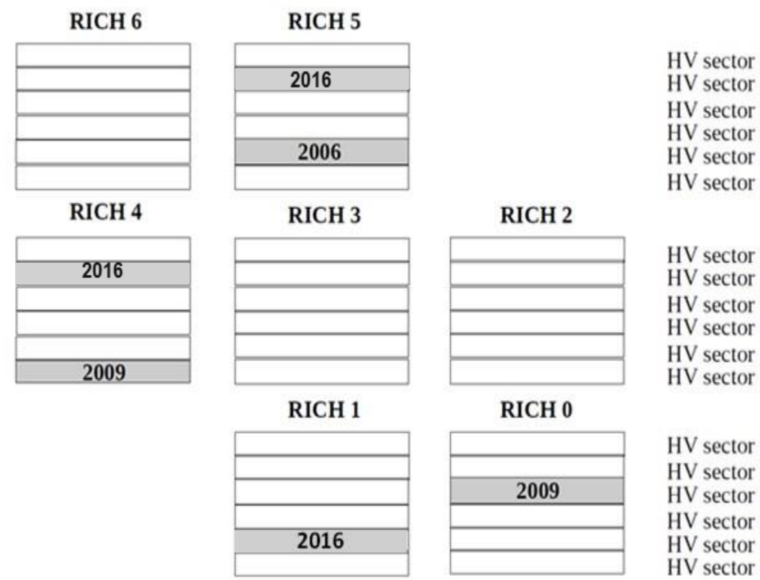
Abstract

The aim of this document is to propose the operation conditions making the HMPID compliant with the Trigger and DAQ schemas in the LHC Run3 period. The collision rate in Pb-Pb is expected to be 50 KHz. In ALICE there will be: a) continuously read-out detectors, b) triggered detectors with upgraded electronics and c) triggered detectors with not upgraded electronics (DDL1 and C-RORC based detectors). The HMPID will belong to the c) type.

Detector Status

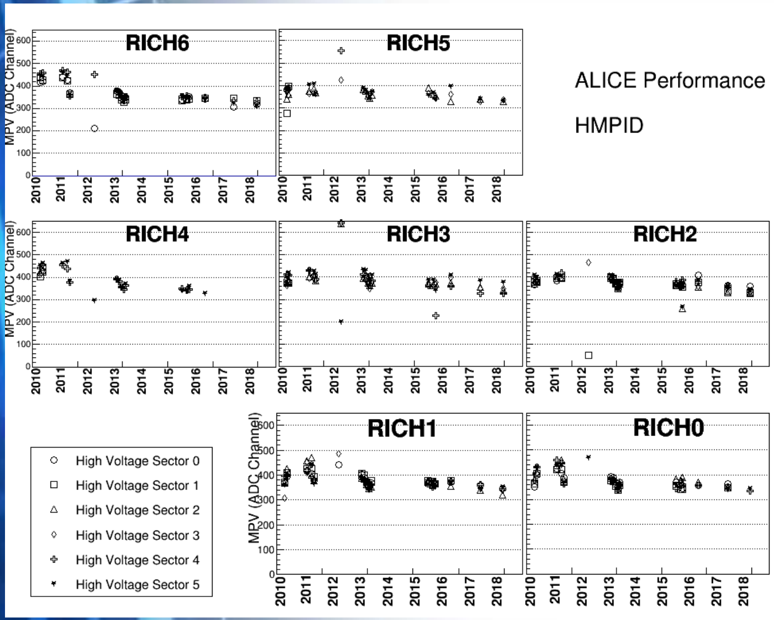


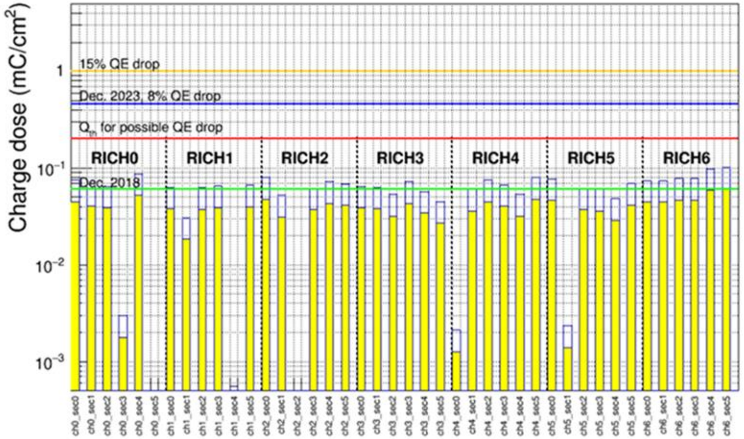
	Year of production YP			
	2002	2003	2004	2005
N° radiators	1	10	5	5



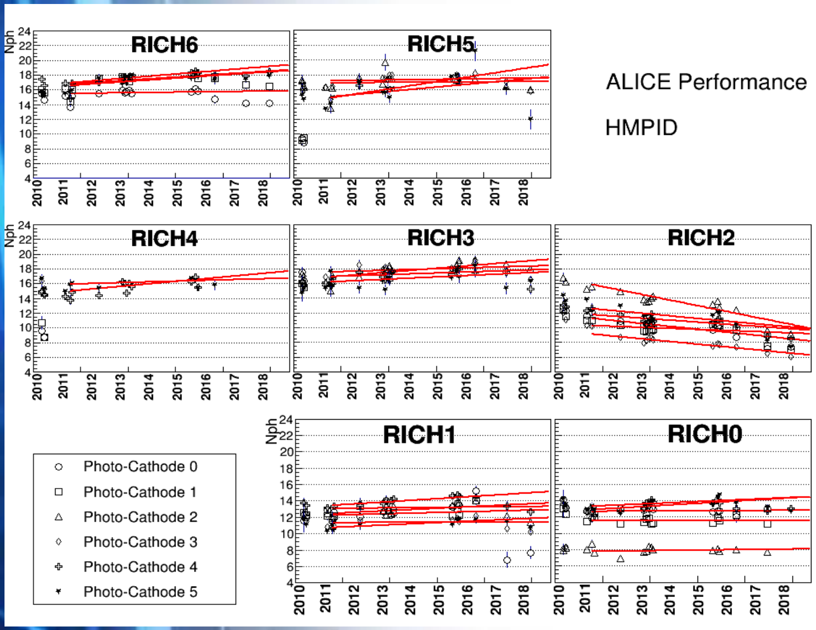
Layout of the radiator vessels with the year of production and the date (in black) when the leaks manifested. The interaction point is behind the figure plane.

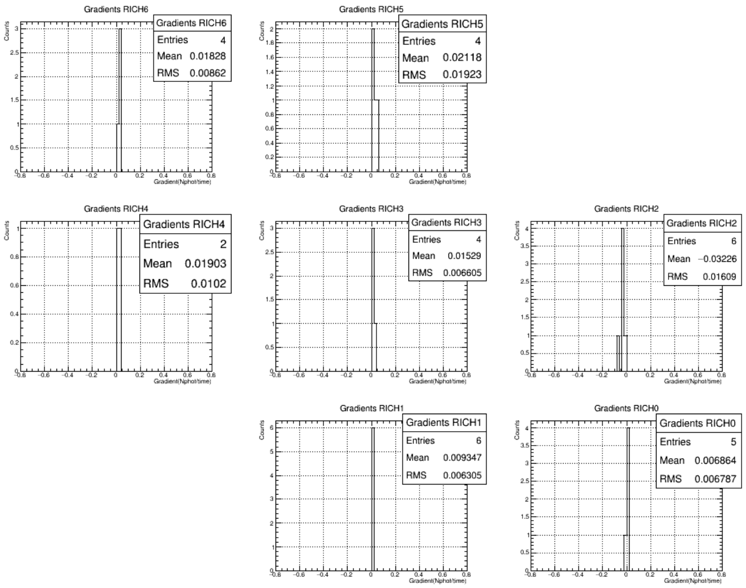
Gas gain stability





Nph stability





CsI ageing in HL_LHC

- According to NIM A 553 (2005) 187-195 and NIM A 574 (2007) 28-38, on a charge dose of ~0.5 mC/cm^2, a CsI QE-drop of ~8% is expected;

- No major degradation on PID performance expected (actual <Nph>~14) ;

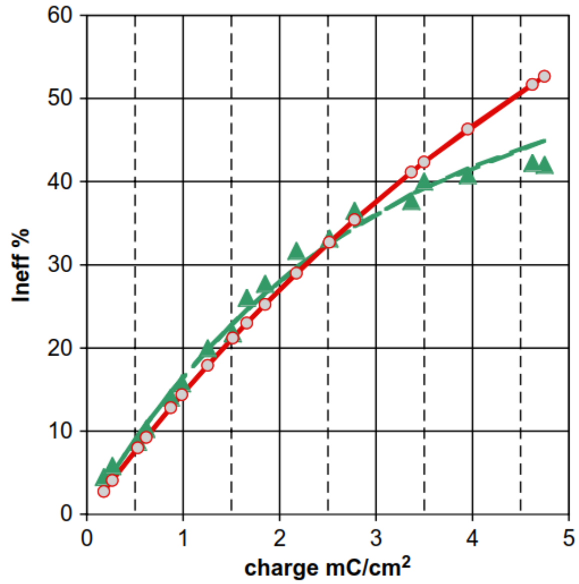
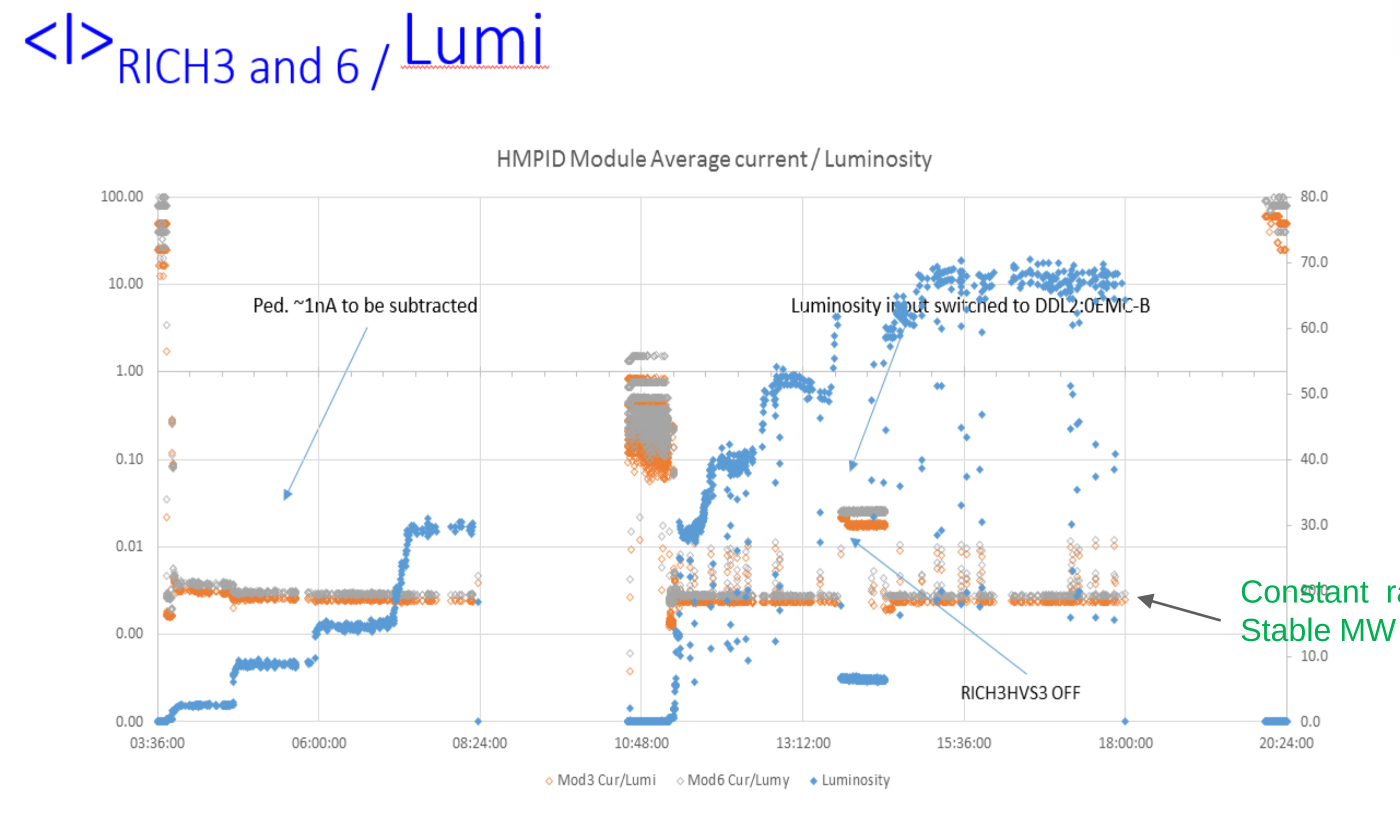


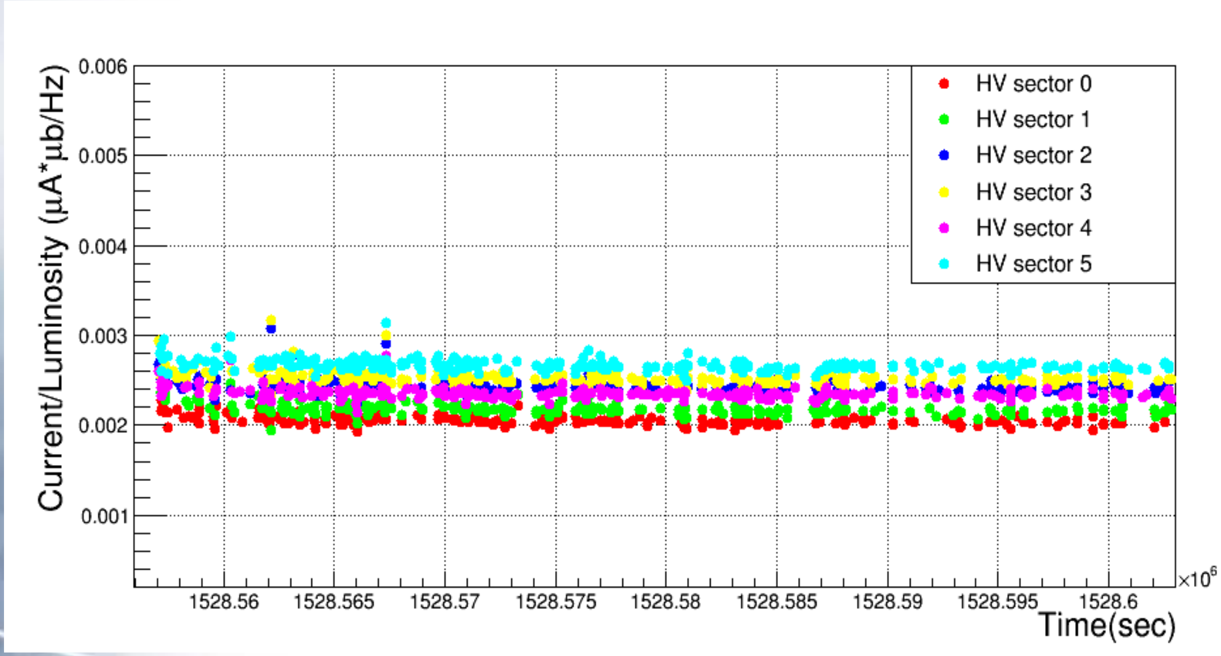
Fig. 7. Triangles: Inefficiency measured along a *X*-charge profile in position 2, first scan. Fits according to Eqs. (3) and (4), respectively dots and line.

HMPID in HL test 05 Sept 2017

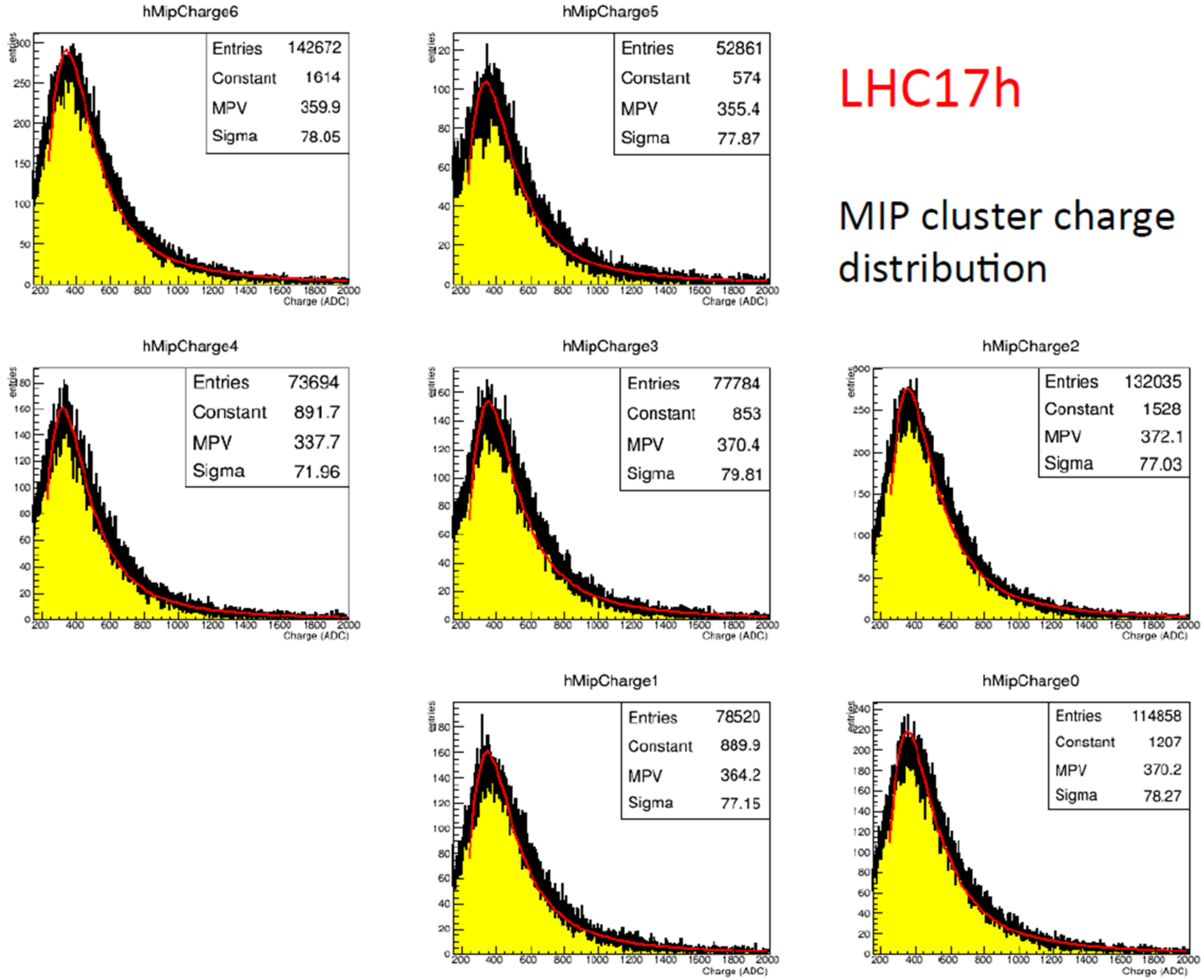


Constant ratio then
Stable MWPC gain.

June 2018: HL Run-3 equivalent test:



June 2017: dE/dx distributions



LHC17h

MIP cluster charge distribution

HMPID contribution to ALICE papers

- Production of charged pions, kaons and protons at large transverse momenta in pp and Pb-Pb collisions at sqrt(s_(NN)) = 2.76 TeV (http://www.sciencedirect.com/science/article/pii/S0370269314004973)
- Measurement of pion, kaon and proton production in proton-proton collisions at sqrt(s) = 7 TeV (http://link.springer.com/article/10.1140/epjc/s10052-015-3422-9?wt_mc=alerts.TOCjournals)
- Centrality dependence of the nuclear modification factor of charged pions, kaons, and protons in Pb-Pb collisions at sqrt(s_(NN)) = 2.76 TeV (http://journals.aps.org/prc/abstract/10.1103/PhysRevC.93.034913)
- Multiplicity dependence of charged pion, kaon, and (anti-)proton production at large transverse momentum in p-Pb collisions at sqrt(s_(NN)) = 5.02 TeV (http://www.sciencedirect.com/science/article/pii/S0370269316303914)
- Measurement of deuteron spectra and elliptic flow in Pb-Pb collisions at √sNN = 2.76 TeV at the LHC. (https://arxiv.org/abs/1707.07304) http://aliceinfo.cern.ch/ArtSubmission/node/3691
- Measurement of π, K and p yield associated with a high-pT trigger particle in pp, p-Pb and Pb–Pb collisions at the LHC. IN PROGRESS.
- Measurement of π, K and p pT spectra in pp collisions at √s = 13 TeV at the LHC. IN PROGRESS.
- Identified charged particle spectra in Pb-Pb data 2015 √sNN = 5.02 TeV . IN PROGRESS.

Technical papers and Public Note

Pattern recognition and PID procedure with the ALICE-HMPID

CrossMark

Giacomo Volpe
European Organization for Nuclear Research (CERN), Geneva, Switzerland
On behalf of the ALICE Collaboration

ARTICLE INFO ABSTRACT

The ALICE–HMPID performance during the LHC run period 2010–2013

CrossMark

Giacinto De Cataldo *
INFN Bari, Via Orabona 4, 70126 Bari, Italy
On behalf of the ALICE c

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C_6F_{14} radiator
CsI photocathode
Accumulated charge dose
PID

RICH2013

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The High Momentum Particle IDentification (HMPID) detector PID performance and its contribution to the ALICE physics program☆

Giacomo Volpe[a,b,*], On behalf of the ALICE Collaboration
[a] Dipartimento Interateneo di Fisica "M. Merlin", Bari, Italy
[b] Sezione INFN, Bari, Italy

Performance of the High Momentum Particle IDentification detector of ALICE during the LHC run period 2015-2016

G. De Cataldo, on behalf of ALICE collaboration
INFN Bari, Via Amendola 4, 70126 Bari Italy

RICH2016

Abstract

In the period June 2015- September 2016 the LHC has delivered pp and Pb-Pb collisions respectively at $\sqrt{s}$ =13 TeV and $\sqrt{s_{NN}}$ = 5.02 TeV for a total integrated luminosity in ALICE of 14 pb^{-1}. The High Momentum Particle IDentification detector (HMPID) is part of the ALICE experiment. It is based on seven Ring Imaging Cherenkov (RICH) modules, 1.3×1.3 m^2 each, with a proximity focusing geometry. The Cherenkov photon detection is achieved by pad segmented photocathodes, coated with 300 nm thick Caesium Iodide layer, installed in multiwire

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ALICE

CERN

ALICE-INT-2017-xx
24 May 2017

Performance of the ALICE-HMPID detector during the LHC run period 2010-2015 and perspectives

F. Barile[1], G.G. Barnaföldi[4], D. Di Bari[2], J. Briffa[6], M. Davenport[3], G. De Cataldo[1], A. Dell'Olio[2], D. Dell'Olio[2], A. Di Mauro[3], A. Franco[1], P. Martinengo[3], M. L. Minervini[7], E. Nappi[1], L. Oláh[4], G. Paic[5], F. Piuz[3], C. Pastore[1], S. Pochybova[4], I.Sgura[1], M. Tangaro[2], G. Valentino[6], J.S.Van Beelen[3], G. Volpe[2].

1. Istituto Nazionale di Fisica Nucleare, Sezione di Bari, Bari, Italy;
2. Dipartimento Interateneo di Fisica "M. Merlin" and Sezione INFN, Bari, Italy;
3. European Organization for Nuclear Research (CERN), Geneva, Switzerland;
4. Wigner Research Centre for Physics, Hungarian Academy of Science, Budapest, Hungary;
5. Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico City, Mexico;
6. Information and Communication Technology Department, Malta University, Malta;
7. Moved to private company.

Abstract

In this note the performance of the ALICE High Momentum Particle IDentification (HMPID) detector during the LHC run period 2010-2015, is presented. The HMPID can identify with three sigma separation charged π and K in the momentum range 1-3 GeV/c and protons in the range 1.5-5 GeV/c. It consists of 7 Ring Imaging Cherenkov modules (RICH), 1.3 × 1.3 m^2 each. The detection of Cherenkov UV photons is achieved by multiwire proportional chamber (MWPC) with CsI pad segmented photocathodes, for a total active area of 10.3 m^2. The Cherenkov radiator used is the liquid C_6F_{14} (perfluorohexane) with n=1.2989 at λ=175 nm.

The detector stability with emphasis on the CsI quantum efficiency stability and the Particle Identification performance (PID), by both statistical and track-by-track approaches, are presented.

The contribution of the HMPID to charged hadrons and deuteron identification will be shown.

Finally the perspective of the detector operation during the High Luminosity LHC period (2020-2023) is briefly discussed.

https://aliceinfo.cern.ch/Notes/node/474

HMPID contribution to the physics

http://aliceinfo.cern.ch/ArtSubmission/node/3691 (EPJ)

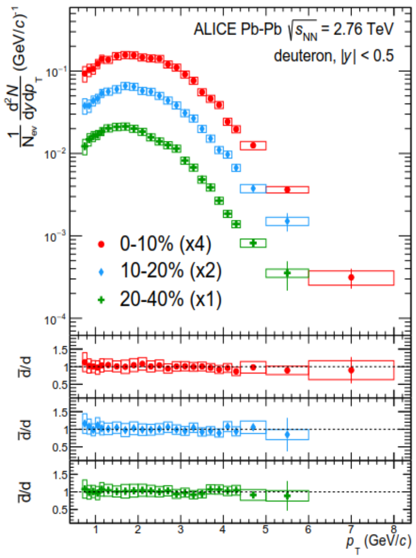

Fig. 3: In the upper panel the deuteron p_T spectra are shown for the three centrality intervals extended to high p_T with the TOF and HMPID analyses. In the lower panels the ratios of anti-deuterons and deuterons are shown for the 0–10%, 10–20% and 20–40% centrality intervals, from top to bottom. The ratios are consistent with unity over the whole p_T range covered by the presented analyses.

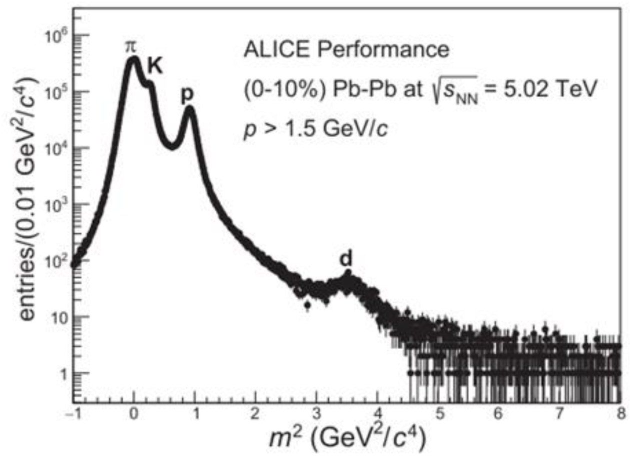

Fig. 8. Particle squared mass distribution obtained from the Cherenkov angle measured in the HMPID combined with the momentum information provided by the ALICE tracking devices, in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

RICH2016

G. Volpe

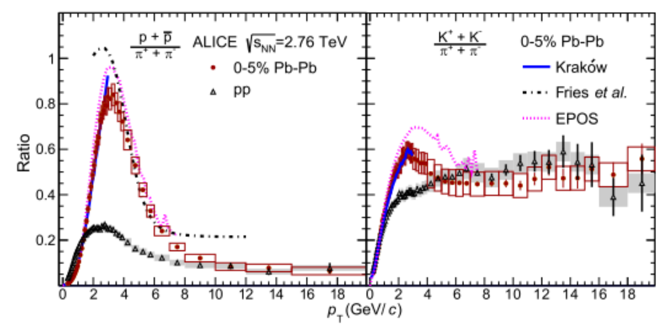

Fig. 7. Kaon to pion and proton to pion ratios as a function of p_T in minimum bias pp collisions and in the most central Pb–Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. Statistical and systematic uncertainties are displayed as vertical error bars and boxes, respectively. The theoretical predictions refer to Pb–Pb collisions..

Institutions and people involved

- INFN Bari, It:
  - G. Volpe, A. Franco, C. Pastore (not full time) A. Dell'Olio (electr. Tech.) and GdC;
- CERN team
  - A. Di Mauro (consultancy)
- Uni of Malta, Malta
  - Dep of Info. & Comm. Tech. Microelectronics and nanoelectr.
    - E. Gatt, O. Casha, J.L Gauci (PhD), C.Seguna (PhD, CPV-HMPID@50kHz);
  - Dep of Computer science
    - G. Valentino, J. Briffa;
  - Dep of Physics;
    - C. Sammut, G.P. Nicosia (Master student)
- Wigner inst. Budapest:
  - G. Barnafoldi, A. Futo and O. B. Visnyei (not full time, master student);