Stability of the ALICE-HMPID detector in LHC Run 1 and 2 and PID performance in p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV

Gianbattista-Piero Nicosia

12th April 2019

University of Malta

Table of contents

Aim of the Thesis

The objectives of the project can be summerised as follows:

- Understand the functioning of the HMPID detector
- The study of the stabiliy of the HMPID detector over run periods 1 and 2
- The PID performance in the p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV

Note: During this presentation, the introductory part to the HMPID will be skipped.

Stability Studies

Detector stability

- The QE of the photocathodes cannot be directly measured from the LHC data, thus an indirect approach is adopted.
- The equation which models this approach is

$$\delta N_{ph} = \frac{\partial N_{ph}}{\partial QE}\delta QE + \frac{\partial N_{ph}}{\partial transparency}\delta transaprency + \frac{\partial N_{ph}}{\partial A_0}\delta A_0. \quad (1)$$

Parameters Studied

- The gas gain, A_0, per High Voltage (HV) sectors,
- The Most Probable Value (MPV) of the landau distribution of the Minimum Ionised Particle (MIP) cluster charge distribution per HV sectors,
- The average number of reconstructed photons, N_{ph}, per photocathodes.
- The transparency of the liquid radiator.
- CsI films ageing parameters.

Data Analysed

- The data analysed to update the stability detector were:
  - LHC18c, corresponding to data collected in April-May 2018;
  - LHC18f, corresponding to data collected in June 2018;
  - LHC18l, corresponding to data collected in July 2018;
  - LHC18o, corresponding to data collected in September 2018;
  - LHC18p, corresponding to data collected in October 2018;
- **The analysis of the last two data sets was merged due to low statistics with respect to the others.**
- The last analysis is of vital importance since they correspond to data which followed an increase of 10 V in the MWPC of the RICH2

Gas gain

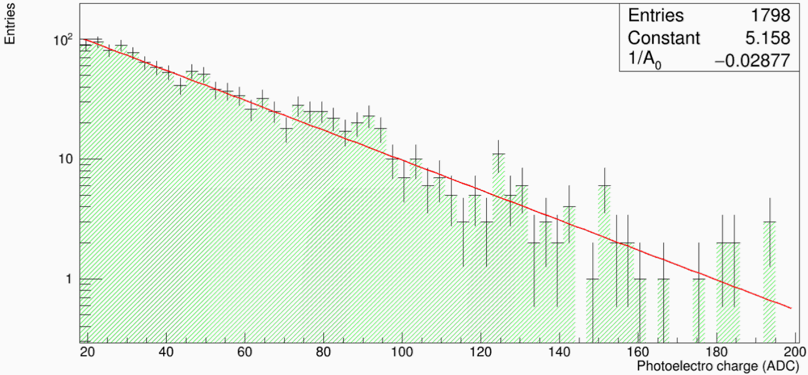
- The study of the gas gain is important and is based of the Furry distribution,

$$P(A) = \frac{1}{A_0} \exp\Big(- \frac{A}{A_0} \Big), \tag{2}$$

- It is importance since the detection efficiency is a function of the gas gain,

$$\epsilon_{det} = \exp\Big(- \frac{A_{th}}{A_0} \Big) \tag{3}$$

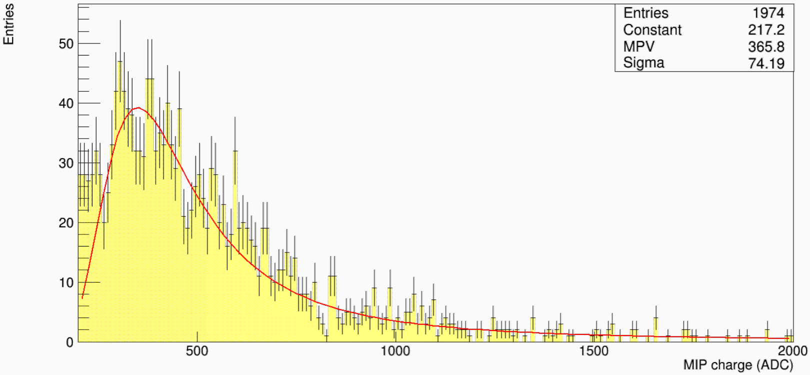
Singular Gas gain



Most Probable Value

- The study of the MPV of the MIP cluster charge distribution was also obtained in order to reinforce the stability study of the detector.
- The graphs obtained for the MIP cluster charge distribution are fitted with a Landau function.

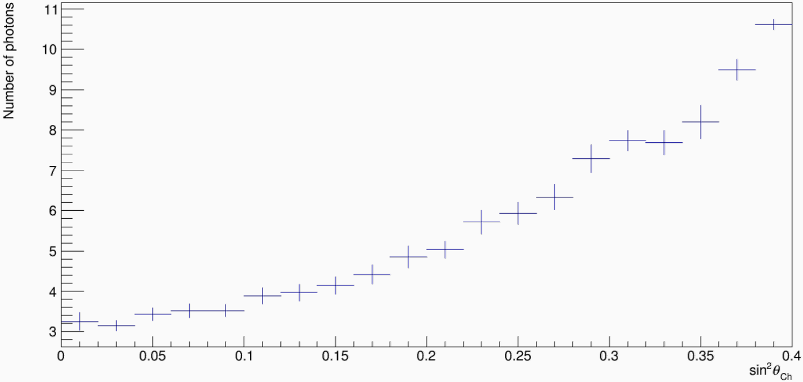
Singular MPV



Most Probable Value

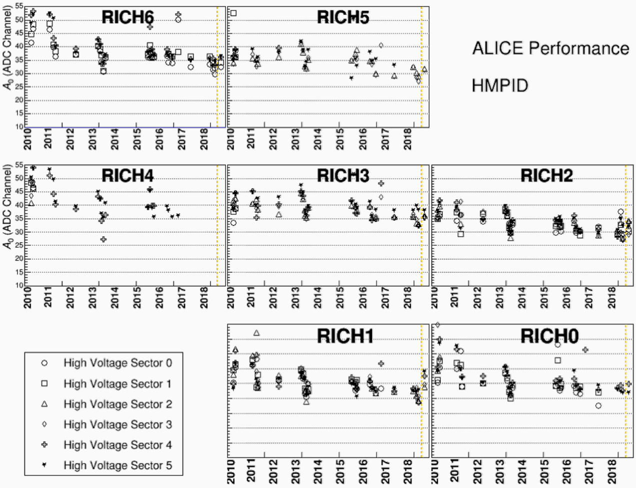
- The number of photons is given by
$$N_{ph} = LN_0 sin^2\theta_c, \tag{4}$$
where, L is the thickness of the radiator
- The number of photons were plotted against the sine squared of the Cherenkov angle, with a ring acceptance applied of >0.99.

Singular N_{ph}



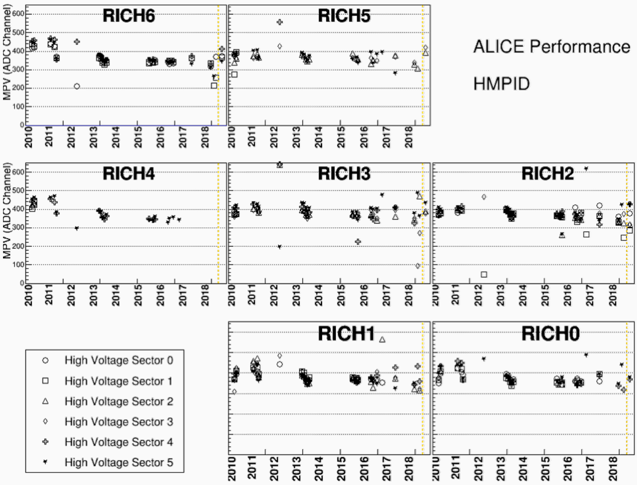
Gas gain

The gas gain remained constant throughout the years with a ±10% variation during the 8 years of operation.



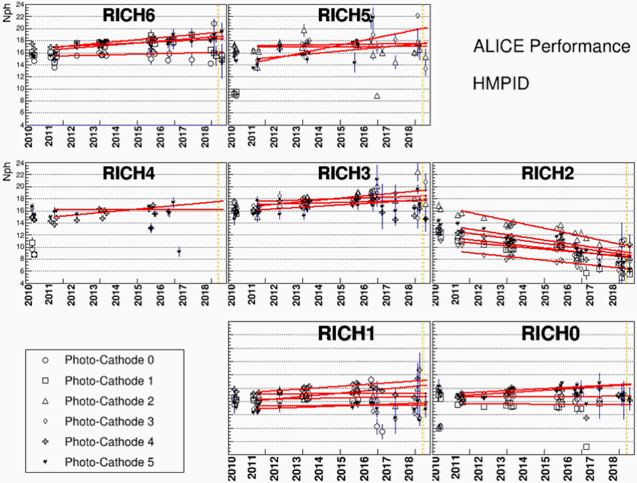
Most probable value

The values have also remained constant throughout the years.



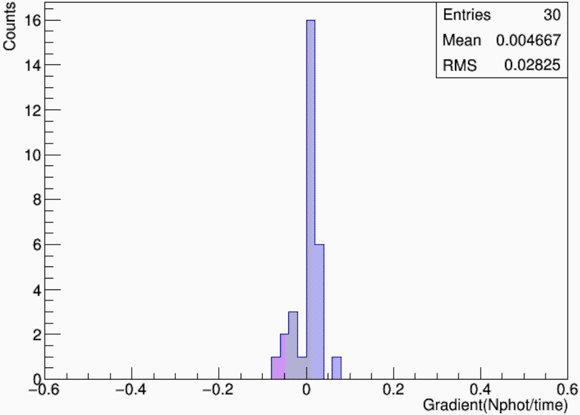
Number of photons

The negative slope in RICH2, indicates a 30% drop in photocathodes 2 and 3.



Angular coefficient

A mean slope of zero is implied by the distribution of the angular coefficients of the fitted straight line of the N_{ph} graphs.



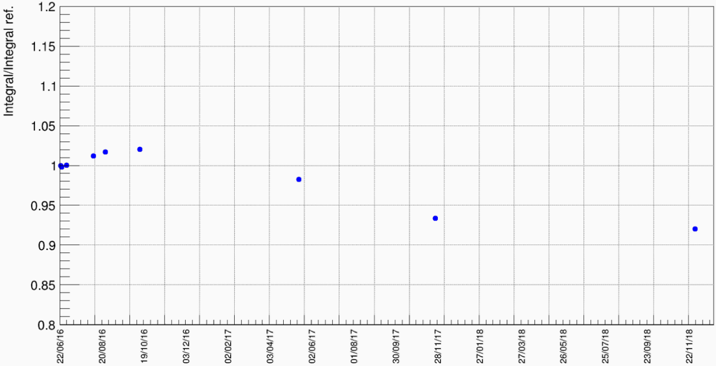
Transparency

- The yield of the Cherenkov photons of a relativistic particle passing through 10 mm of C_6F_{14} is approximately 6 nm^{-1} at 190 nm.
- This yield decreases according to an inverse square law

$$\frac{dN}{dx} \propto \frac{d\lambda}{\lambda^2}, Since some of the photons produced are absorbed by the liquid its \quad (5)$$

Transparency

An almost 10% drop was observed, but the liquid transparency is deemed to be constant.

- 

Parameters affecting CsI films

- Exposure to high photon flux.
- Specific charge dose from ion bombardment.
- Concentration of contaminants.

Specific Charge Dose

- The dissociation of the CsI molecules can be written as

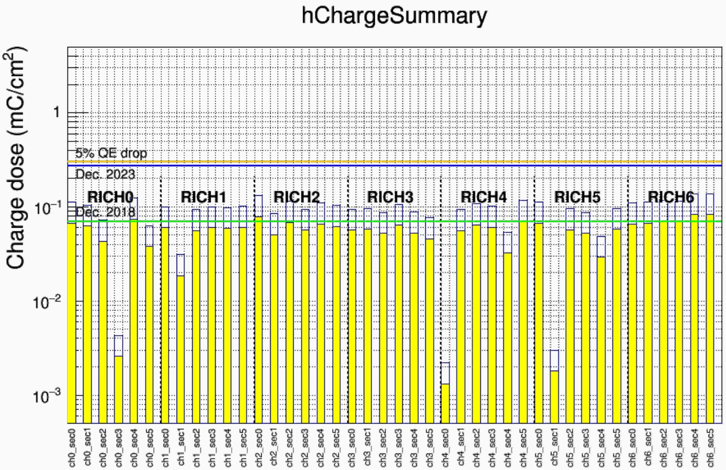
$$h\nu + CsI \rightarrow Cs^{+} + I + e^{-} \tag{6}$$

$$A^{+} + CsI \rightarrow Cs^{+} + I + A \tag{7}$$

- The photon flux required to damage the CsI photocathodes is in the order of 10^{11} $mm^{-2}s^{-1}$.
- With regards to the ion bombardment, this have been studied by monitoring the specific charge dose for the 42 photocathodes.

Specific Charge Dose

Prediction respected for 2018 and new prediction results in a further 5% QE drop.

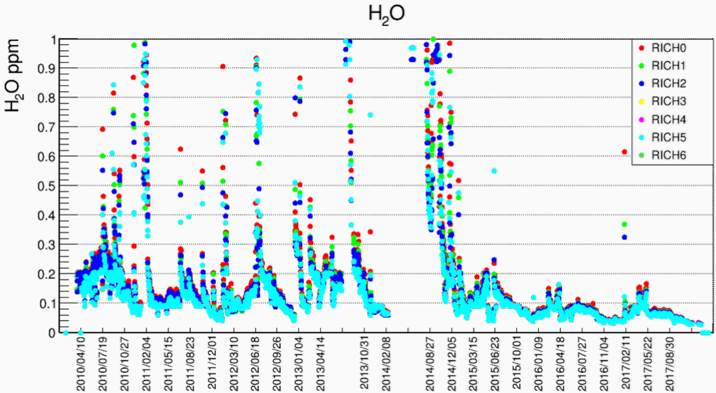


Contaminants

- The purity of the CsI film is of vital importance, since its purity affects the QE.
- The CsI compound is a very hygroscopic compound, meaning the exposure to humid air should be avoided.
- The major contaminants that may affect the CsI film are water and molecular oxygen, which would lead to complexation reactions.

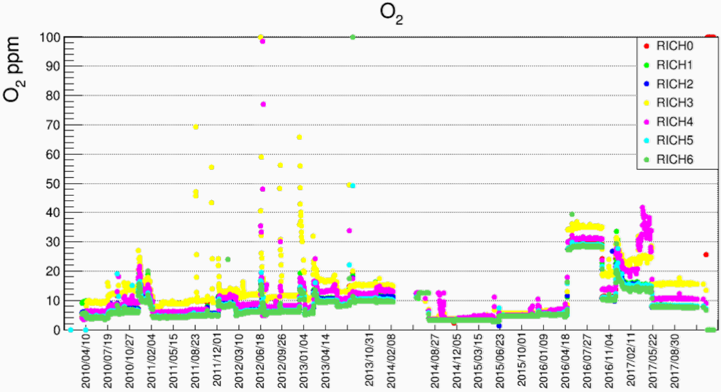
Water

The concentration have remained way below the 100 ppm.



Oxygen

The concentration have remained below the 100 ppm, but higher than water.



The RICH2 Problem

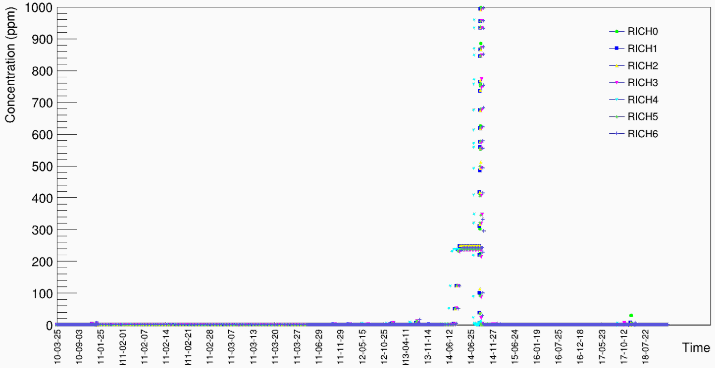
The problem

- The problem is the 30% drop observed in PC 2 and 3 and a more gentle drop in the rest of PCs.
- What exactly is going on in RICH2 is still under investigation, but it can be defined as an anomaly since:
  - It is the only module where a steep decrease in the detection number has been observed.
  - The CsI ageing parameters - contaminants and charge dose - are within the norm.
  - The other stability parameters are also in the norm.
- Two cases will be presented.

Contaminants

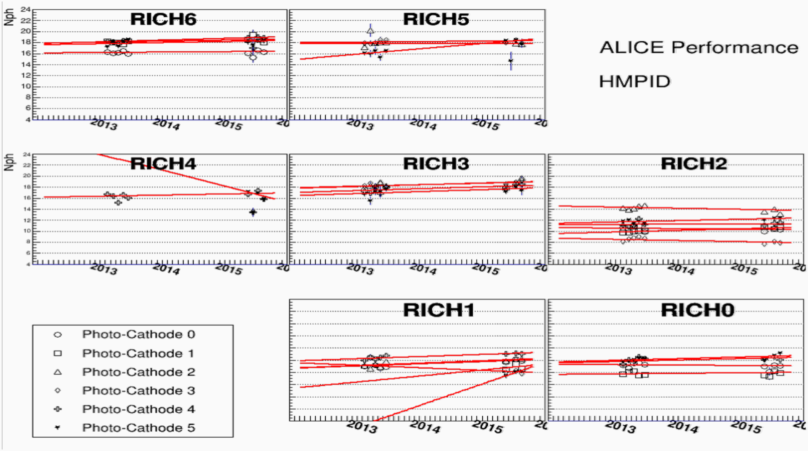
- During the analysis of the concentration of water, an anomaly was observed.
- A huge peak in the concentrations was observed in 2014, with ppm values up to a 1000.
- Hence, the hypothesis brought forward was that the high concentration would have ruined the CsI films.
- This hypothesis was studied by considering the values observed before and after 2014.

Water concentration



Comparison

No drop was observed after 2014.



Summary contamination

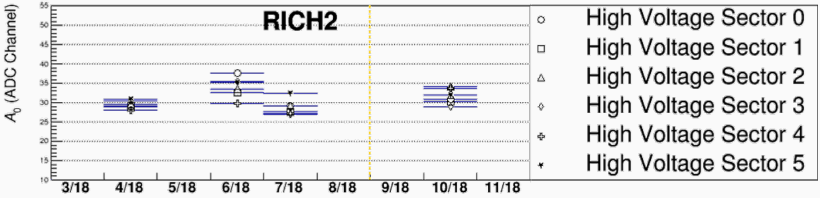
- The absence of a big drop after 2014 might result in two conclusions:
  - The peak is due to an anomaly within the spectrometer.
  - The strong peak did not affect the CsI films.
- With regards to the first conclusion, further confirmation will be given by my colleagues.
- If the colleagues were not to confirm the anomaly, then I strongly believe that a further investigation would be required.
- Further investigation since the time of exposure is over 10 days for an exposure of $\approx$ 250 ppm and a peak at a 1000 ppm.
- In this case a further investigation of the CsI films would be required.

Non-optimal re-evaporisation

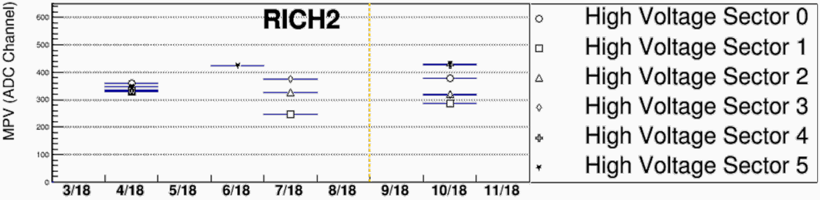
- The drop in RICH2 was believed to be due to a non-optimal re-evaporisation procedure of the photocathodes done in 2005.
- This hypothesis was set to test by increasing the voltage withing the MWPC by 10 V in the module.
- The increase in the voltage was done in late August 2018 and only two data sets were available for analysis - LHC18o and LHC18p

Gas gain

The increase in voltage brought about a significant increase in its values observed.

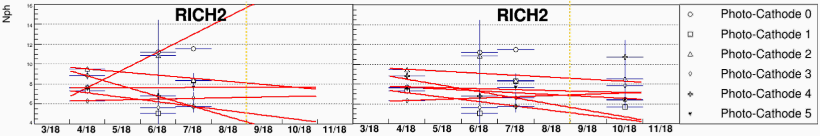


A slight increase was observed in the MPV, which helped to interrupt the beginning of a decreasing trend.



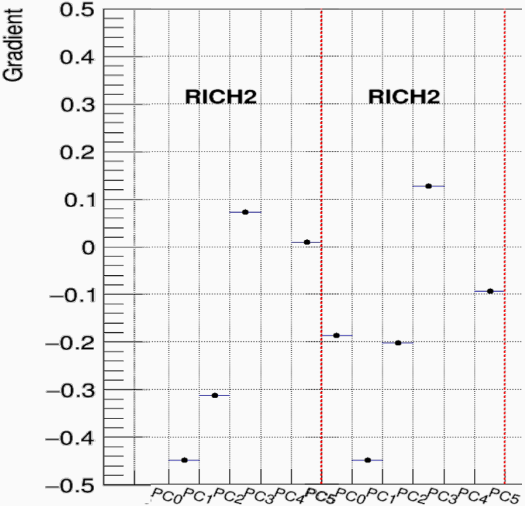
Number of photons

The increase in voltage has brought a slight increase in the values of the number of photons detected.



Angular coefficient

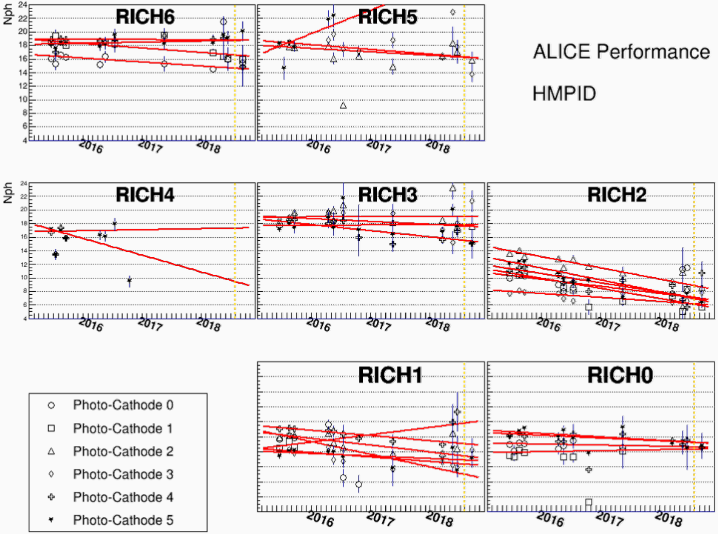
PCs 2 and 3 present an increase in the gradient therefore interrupting the 30% drop.



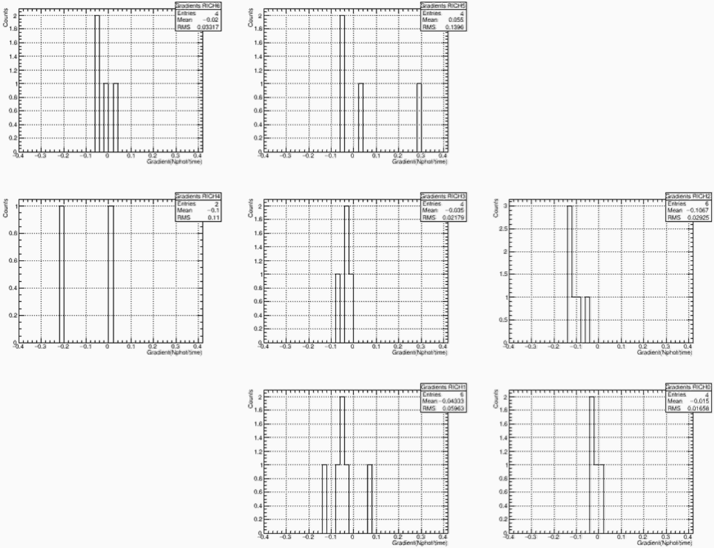
Summary increase in HV

- A full analysis cannot be done since the data point available are too little, BUT:
    - The 10 V increase is only a 0.5% increase with respect to the 2050V already applied.
    - This small increase seems to have stopped the 30% decrease present in PCs 2 and 3.
    - The small increase has also affected positively the number MPV and gas gain.
- A further increase of the voltage, keeping in mind the stability of the MWPC, should be fruitful for the detector.
- Therefore, it can be concluded that the outcome of the increase in HV is a positive one.

RICH2 or Run2 problem?



RICH2 or Run2 problem?



p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV

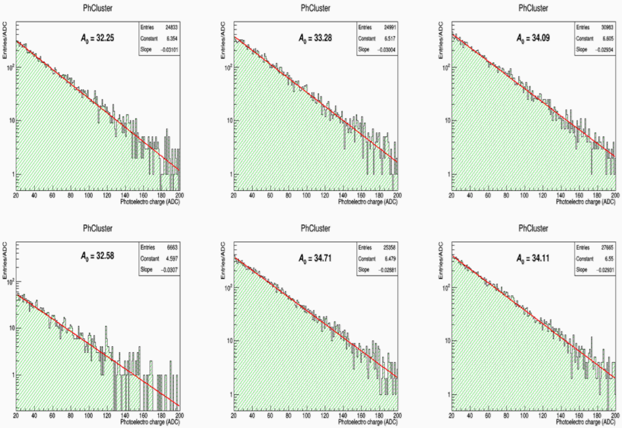
Stability in experiment

Before looking for the PID performance, the stability in this experiment was studied involving, as in the case of the general stability, the study of:

- The gas gain, A_0,
- The MPV, of the MIP cluster charge distribution,
- The number of photons, N_{ph}.

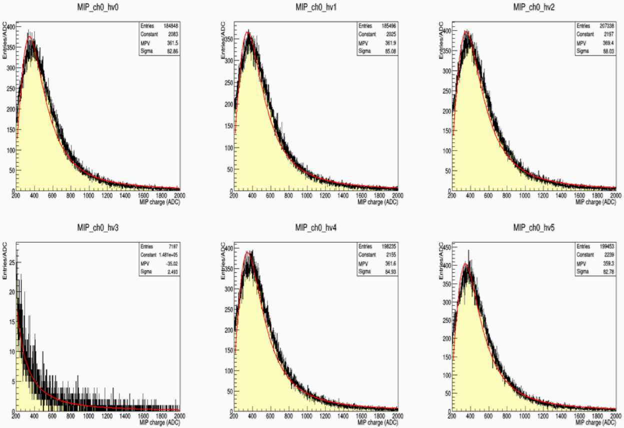
Gas gain

The following image shows Chamber 0 over the 6 HV sectors.



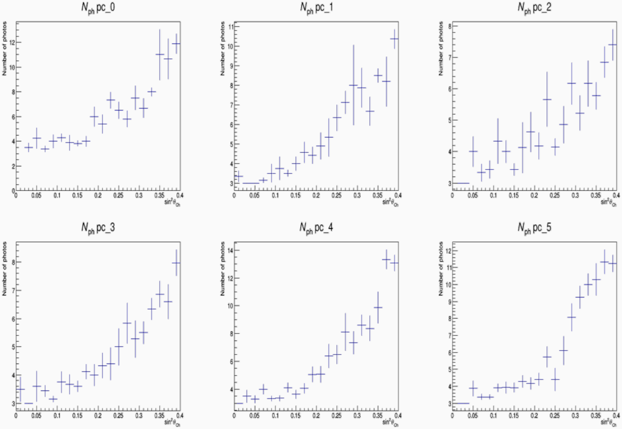
Most probable value

The following image shows Chamber 0 over the 6 HV sectors.



Number of photons

The following image shows photocathodes 0-5 of Chamber 0.

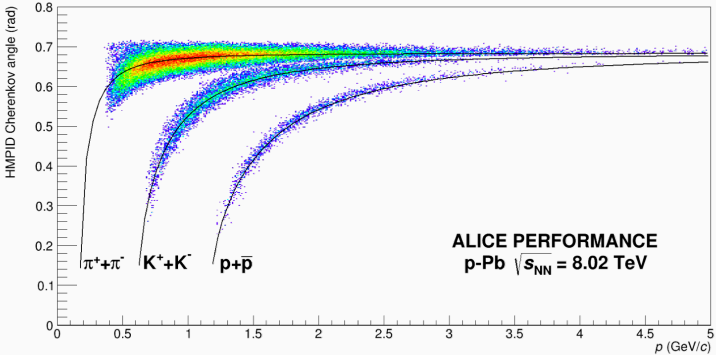


PID performance

- The results obtained from the stability showed that the detector was stable, thus increasing the reliability on the performance detector.
- The PID performance is studied by analysing scatter plots where the Cherenkov angle for the three particles is plotted against their momentum.
- A positive outcome is obtained when charged π and K and protons are distinguished with a 3σ separation, which is the main goal of the HMPID.

PID performance

The performance of the detector is excellent.



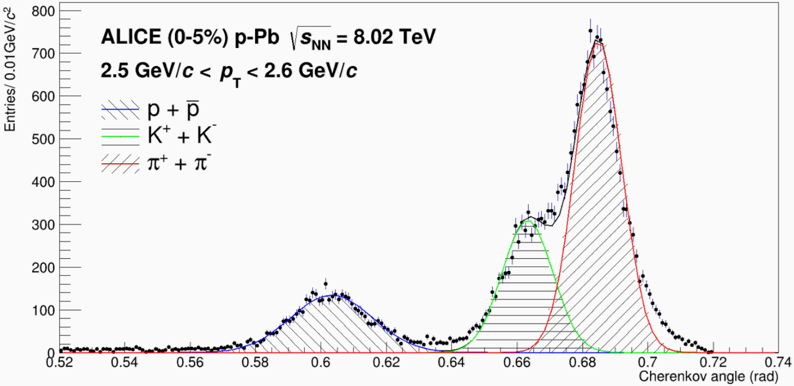
p-Pb collisions at $\sqrt{s_{\rm NN}}$ = 8.02 TeV

- The particle identification in this project was based on statistical basis, known as PID statistical unfolding and is based on

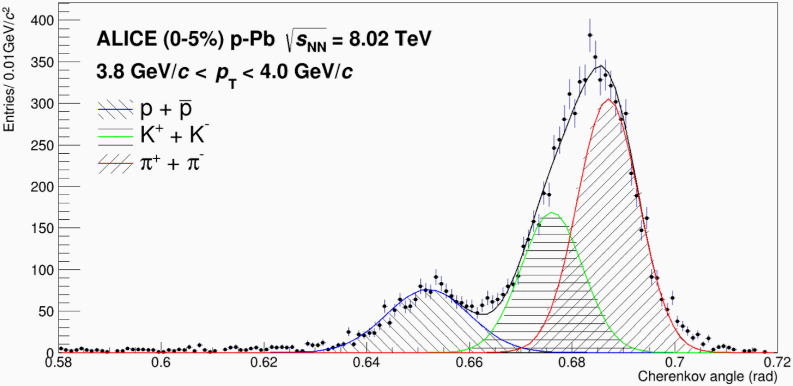
$$f(\theta) = \frac{Y_\pi}{\sigma_\pi\sqrt{2\pi}} e^{-\frac{(\theta - \langle\theta_\pi\rangle)^2}{2\sigma_\pi^2}} + \frac{Y_K}{\sigma_K\sqrt{2\pi}} e^{-\frac{(\theta - \langle\theta_K\rangle)^2}{2\sigma_K^2}} + \frac{Y_p}{\sigma_p\sqrt{2\pi}} e^{-\frac{(\theta - \langle\theta_p\rangle)^2}{2\sigma_p^2}} \tag{8}$$

- The analysis was based on the momenta and possible nature of the particle, and in a laboratory rapidity $-0.465 < y_{lab} < 0.035$.
- The transverse momenta were analysed as following:
  - 1.5 GeV $\leq p_T <$ 3.0 GeV in 100 MeV steps;
  - 3.0 GeV $\leq p_T <$ 5 GeV in 200 MeV steps;
  - 5 GeV $\leq p_T \leq$ 6 GeV in 500 MeV steps.

Particle identification



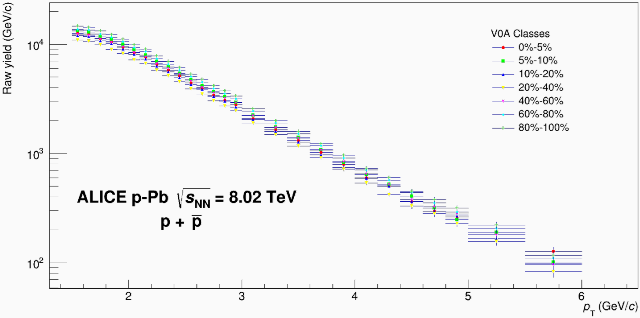
Particle identification



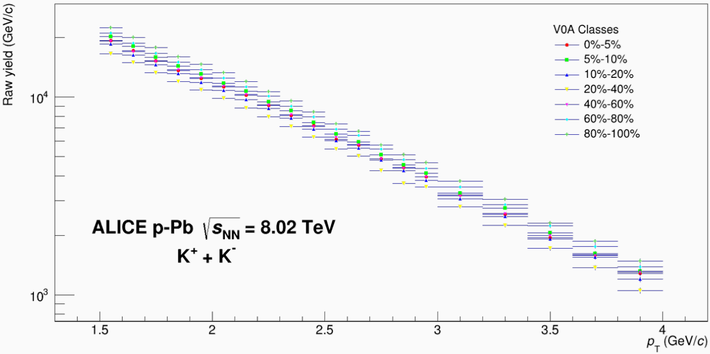
p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV

Raw Count

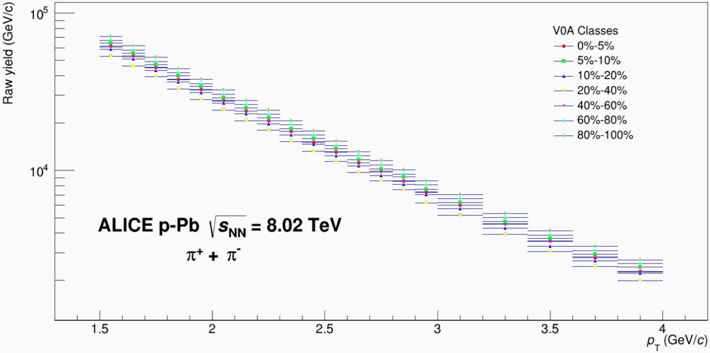
The PID statistical unfolding also provides the count of the particles present, which is obtained by integrating the Gaussians obtained experimentally and plotted against p_T



Raw Count


Raw yield (GeV/c)
10^4
10^3
V0A Classes
0%-5%
5%-10%
10%-20%
20%-40%
40%-60%
60%-80%
80%-100%
ALICE p-Pb $\sqrt{s_{NN}}$ = 8.02 TeV
$K^+ + K^-$
1.5
2
2.5
3
3.5
4
p_T (GeV/c)

Raw Count

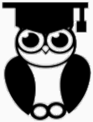


p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV

Conclusion

Conclusion

- The results obtained by the analysis were extremely important:
  - The overall stability of the HMPID detector is nearly optimal.
  - The cause to the RICH2 decrease has not yet been found, but an increase in the HV might result in a suitable solution.
  - A mild decrease pattern in the N_{ph} being detected in Run2 has been observed, but it should not be considered as worrying.
  - The PID performance during the p-Pb collisions at $\sqrt{s_{NN}}$ = 8.02 TeV was excellent and superlative physics results were obtained.
- Further studies have to be done to get to Run3 in "beast mode".

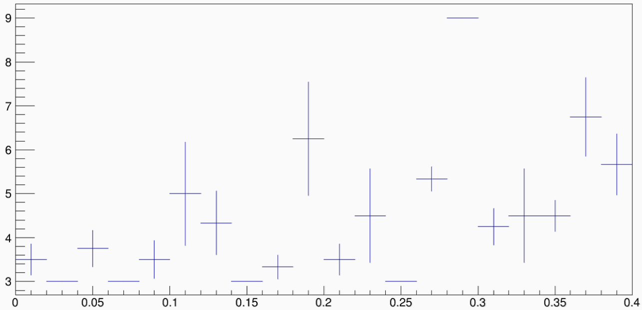


THANK YOU FOR YOUR ATTENTION!

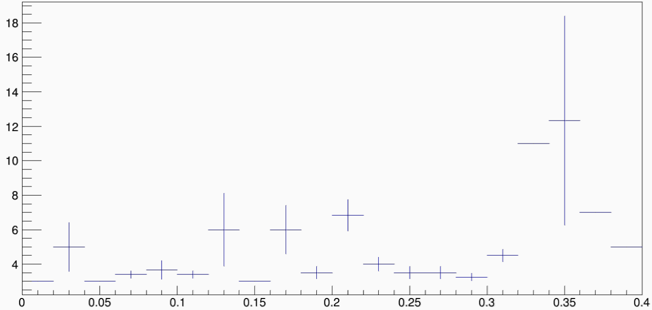
ANY QUESTIONS?

Appendix

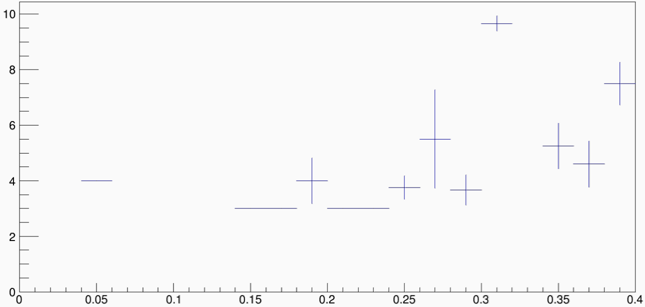
PC 12, Entries = 60



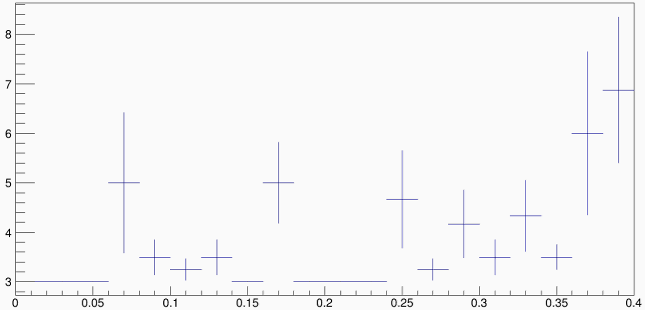
PC 13, Entries = 62



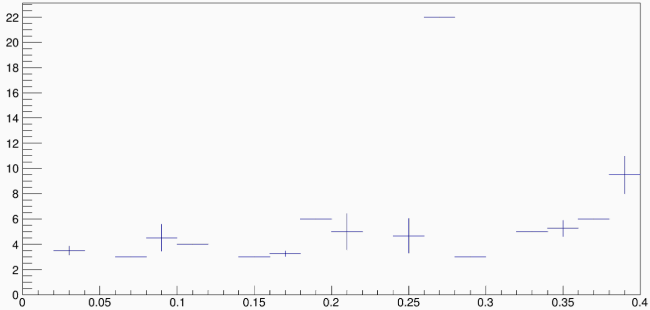
PC 14, Entries = 41



PC 15, Entries = 64



PC 16, Entries = 33



PC 17, Entries = 31