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The ALICE-HMPID detector: performance and contributions to ALICE physics program

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Particle identification

- Particle identification is achieved knowing its mass and its charge.

- the mass is given at least two of the three correlated quantities: momentum, kinetic energy and velocity.

$$p = mc\gamma\beta$$

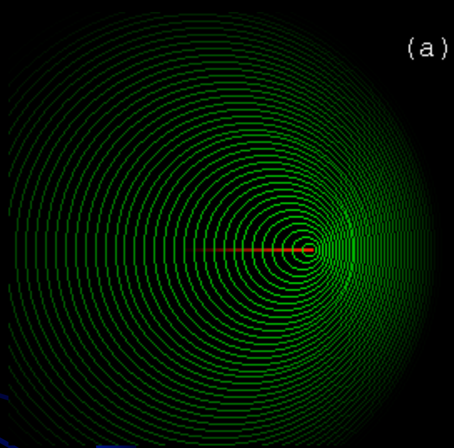
- the deflection of the particle trajectory in a suitable static magnetic field provides the charge sign and the momentum value.

- the velocity is achieved by means of one of the following methods: energy loss, time of flight (TOF), detection of Cherenkov radiation and detection of transition radiation.

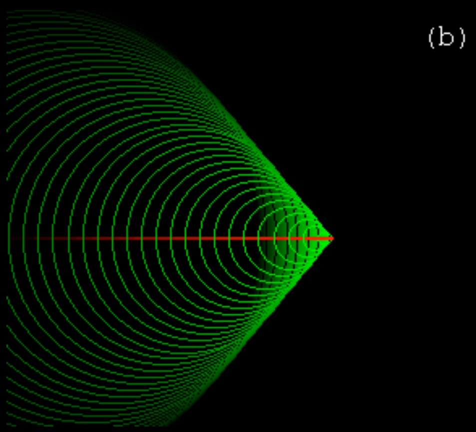
Cherenkov radiation

The Cerenkov electromagnetic radiation, is emitted by charged particles passing through a transparent dielectric medium at a speed greater than the speed of light in that medium.

$v<c/n$



$v>c/n$

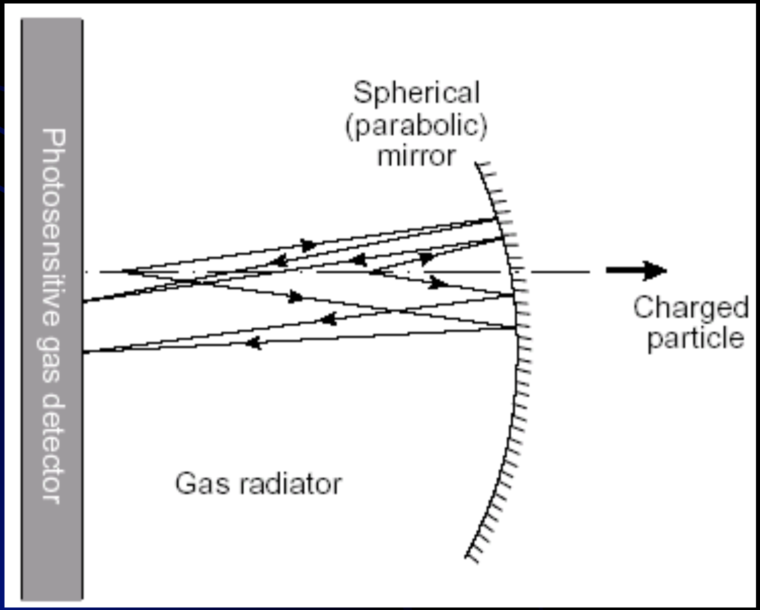


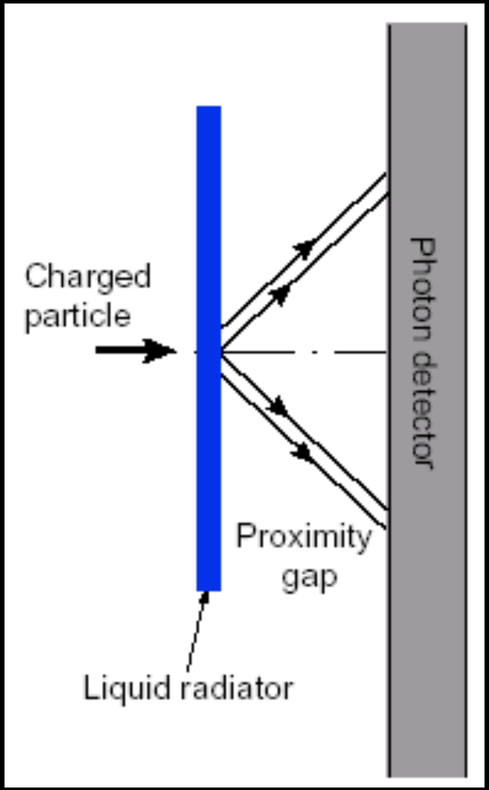
$$\cos\theta_c = \frac{c}{nv} = \frac{1}{n\beta}$$

Cherenkov radiation – RICH counters

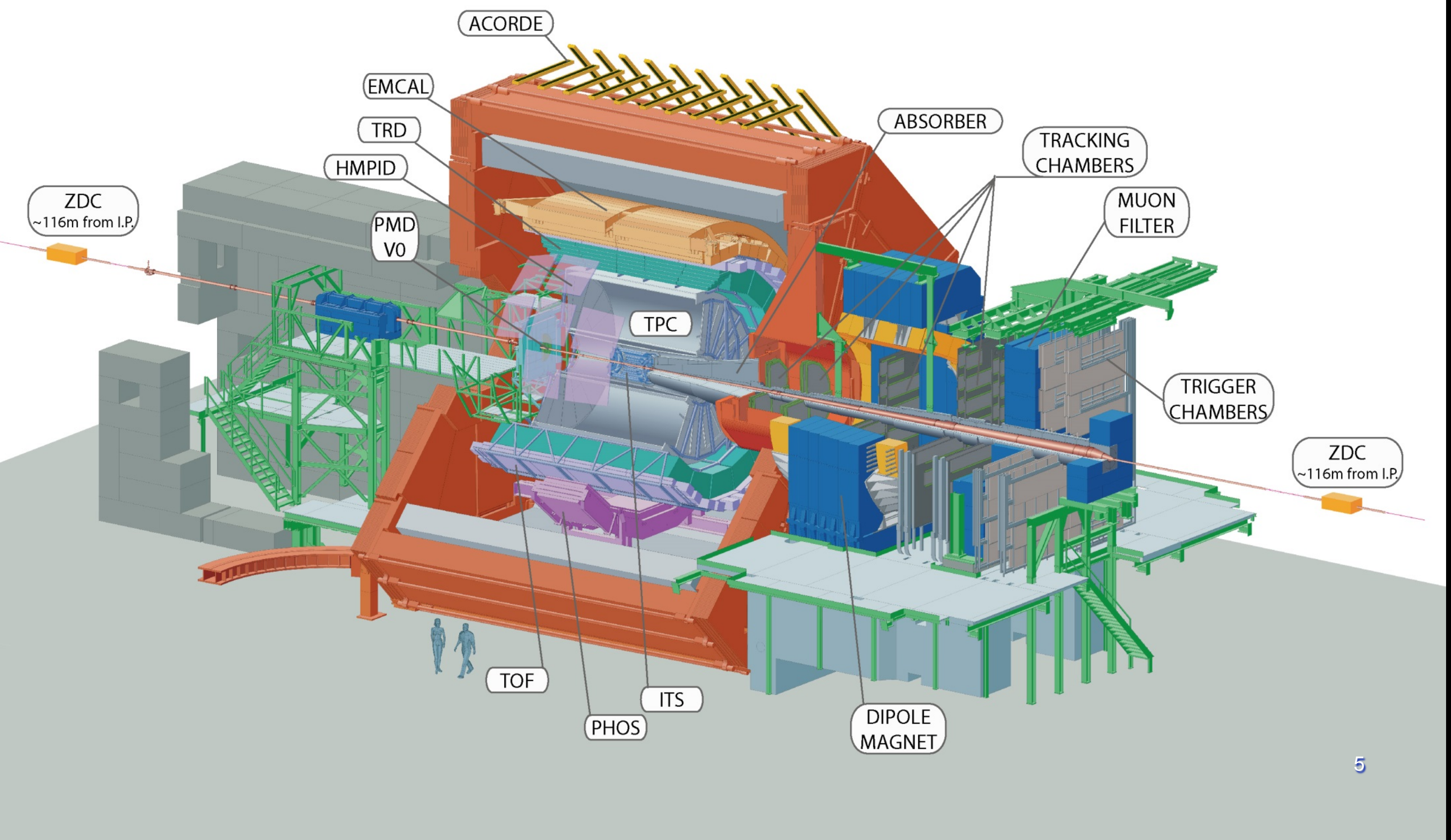
- A RICH (Ring Imaging Cherenkov) counters which allow simultaneous measurement of the values of β for several particles of different known momentum by determining the position of a certain number of Cherenkov photons.

- In a RICH detector, Cherenkov radiation, emitted from several particles in the same event, is transmitted through an optics, that could be either focusing with a spherical (or parabolic) mirror or not focusing (proximity-focusing), onto a photo-detector that converts photons into photoelectrons with high spatial and time resolutions.

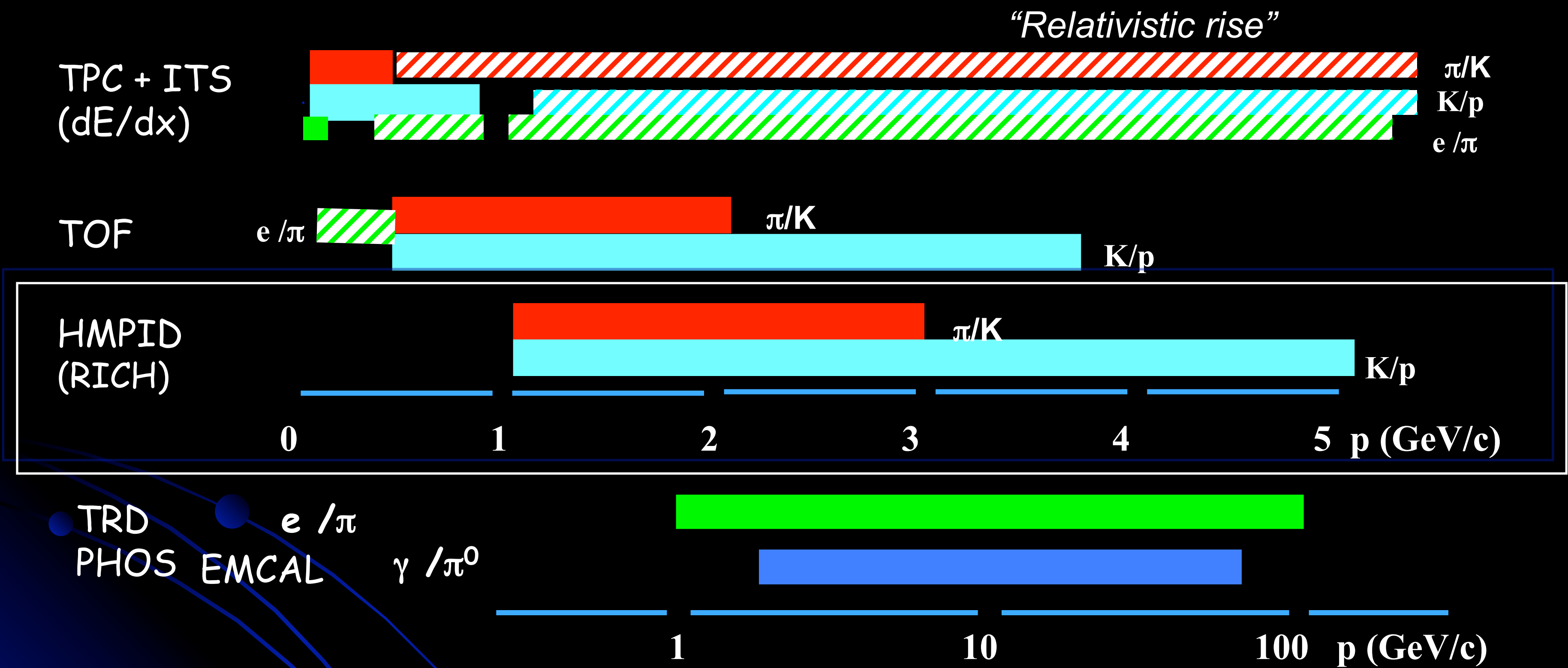




The ALICE Experiment



Particle identification in ALICE

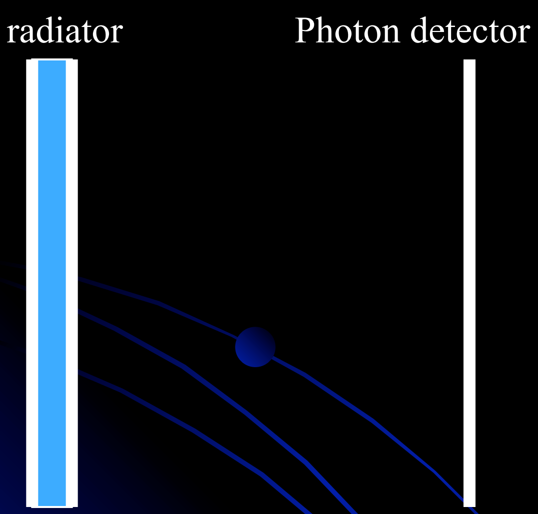


Solid: track-by-track

Dashed: only statistical

The ALICE-HMPID detector

- ALICE-HMPID (High Momentum Particle Identification Detector) performs charged particle track-by-track identification by means of emission Cherenkov angle measurement and of the momentum information provided by the tracking devices.
- It consists of seven identical proximity focusing RICH counters



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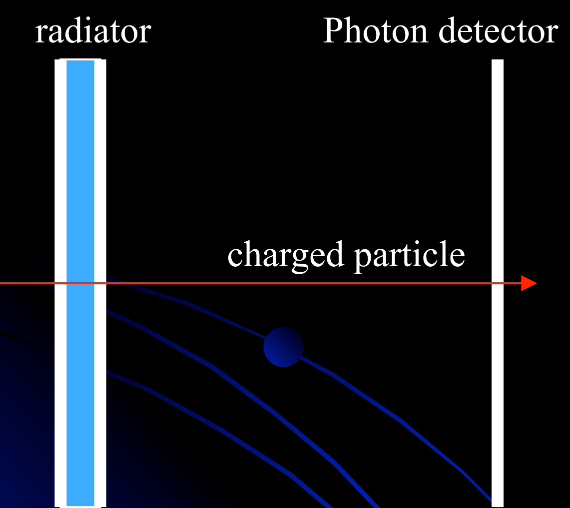

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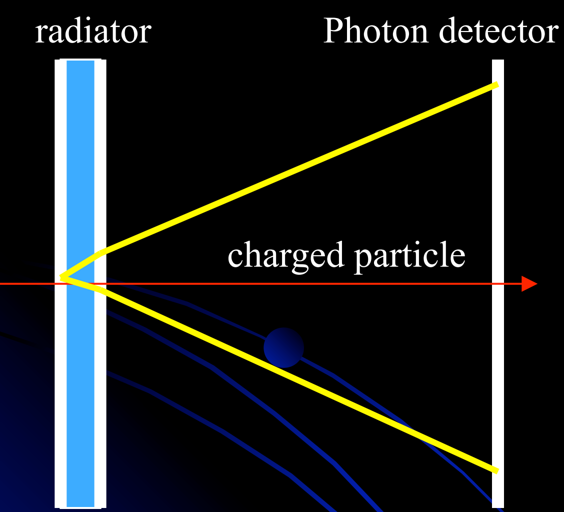

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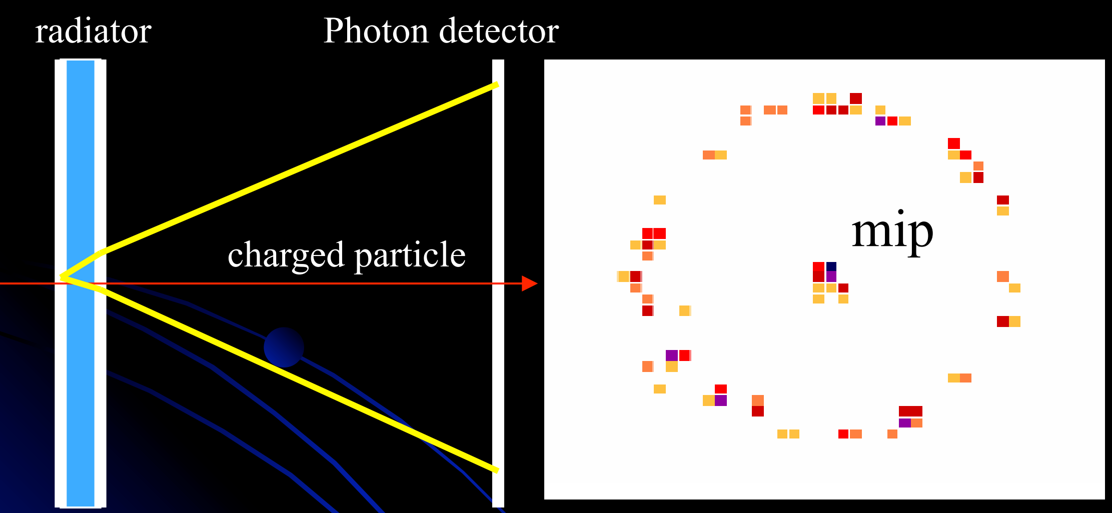

$$\cos\theta_c = 1/n\beta$$

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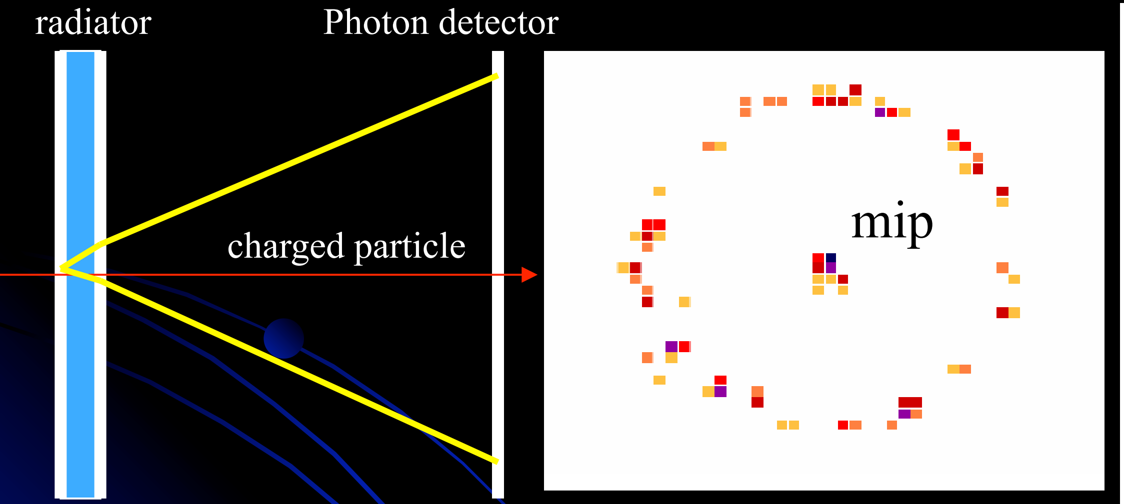
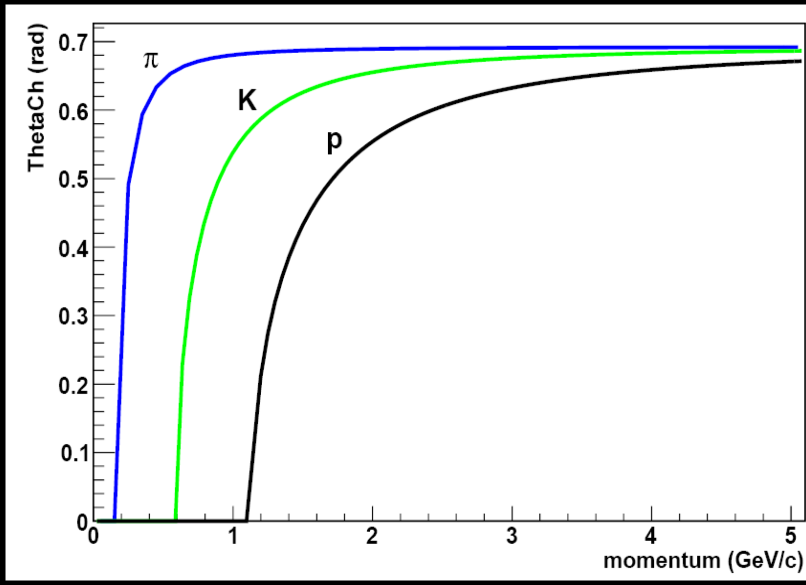




HMPID detector description

PID RANGE

- $1 < p < 3$ GeV/c π-k

- $2 < p < 5$ GeV/c p

RADIATOR

15 mm liquid C_6F_{14},
n ≈ 1.2989 @ 175nm, β_{th} = 1.21

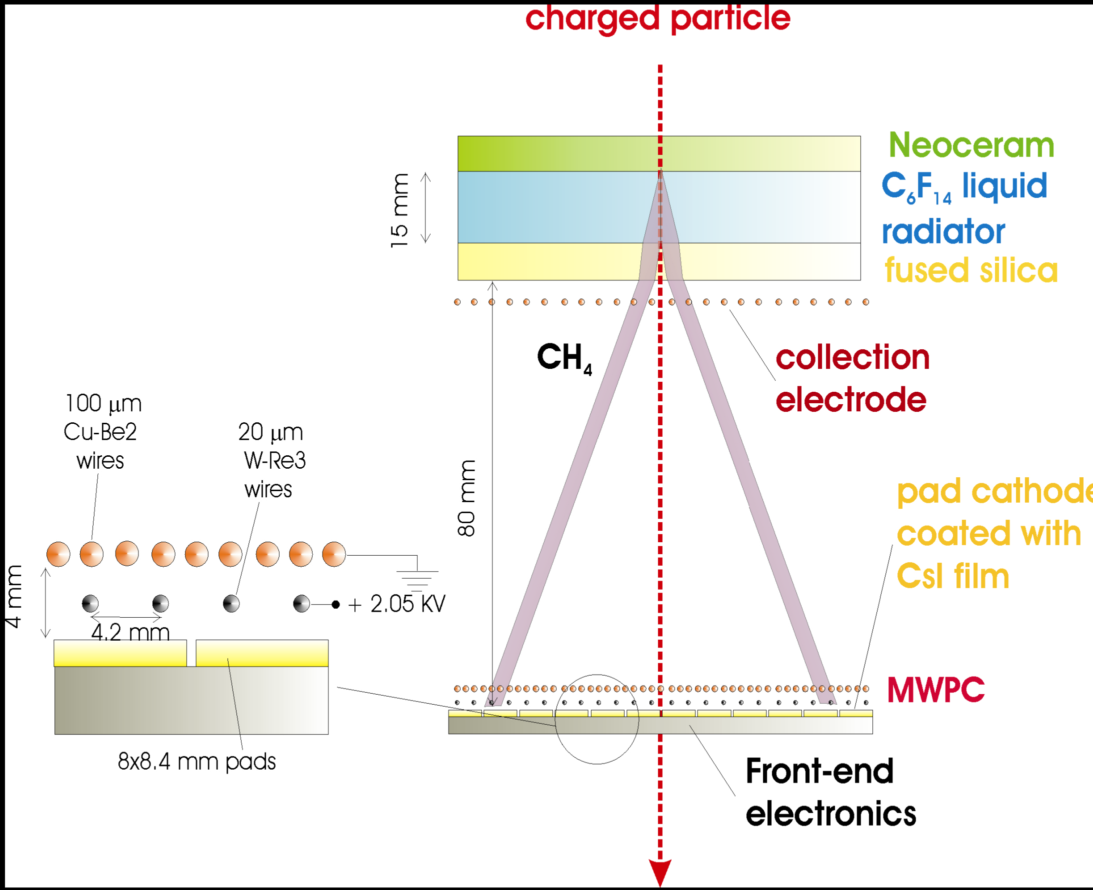
PHOTON CONVERTER

Reflective layer of CsI
QE ~ 25% @ 175 nm.

PHOTOELECTRON DETECTOR

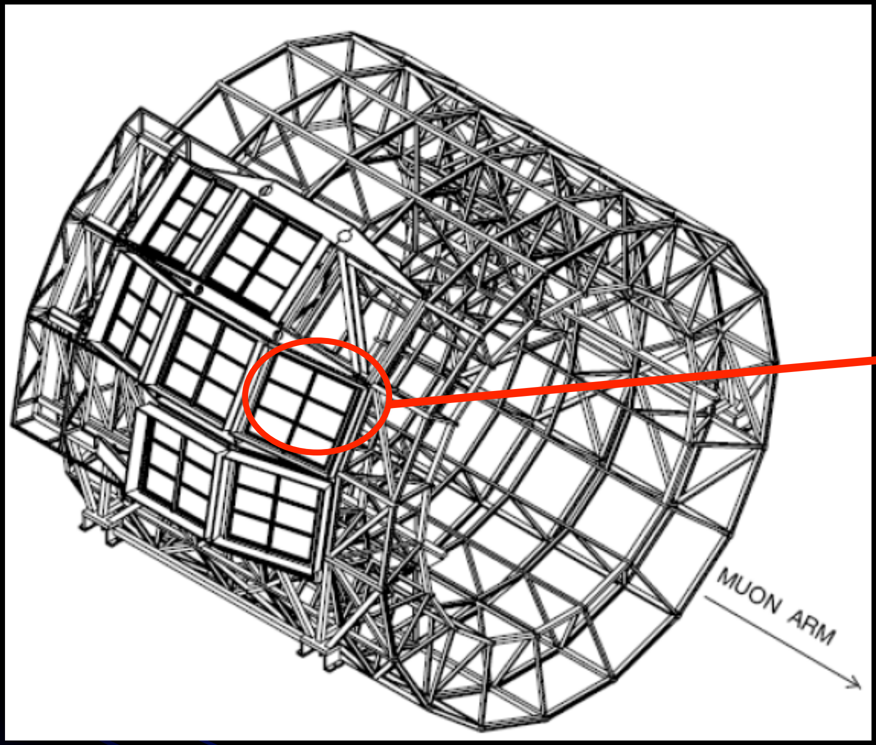
- MWPC with CH_4 at atmospheric pressure (4 mm gap) HV = 2050 V.

- Analogue pad readout

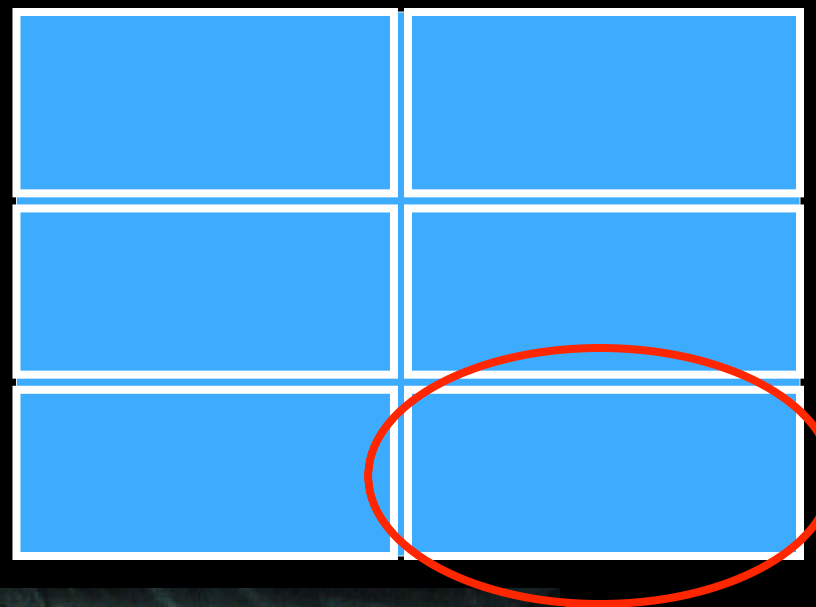


The largest scale (11 m²) application of CsI photo-cathodes in HE/HI-P!

HMPID detector description

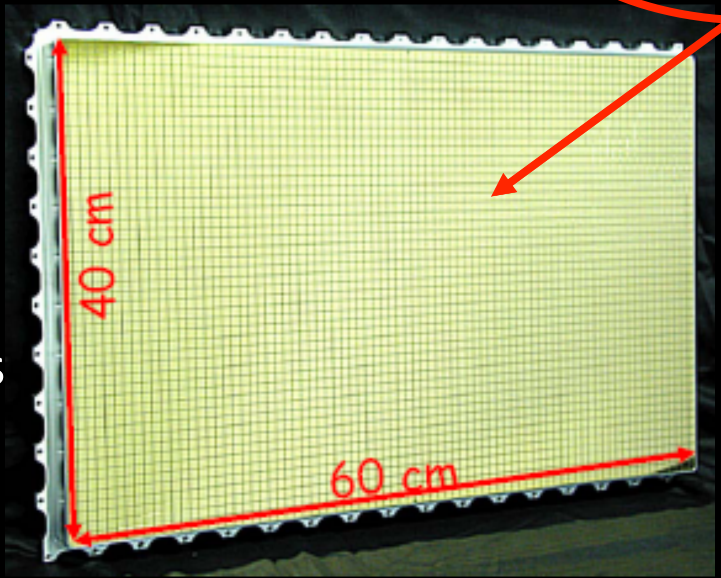


Six photo-cathodes per module



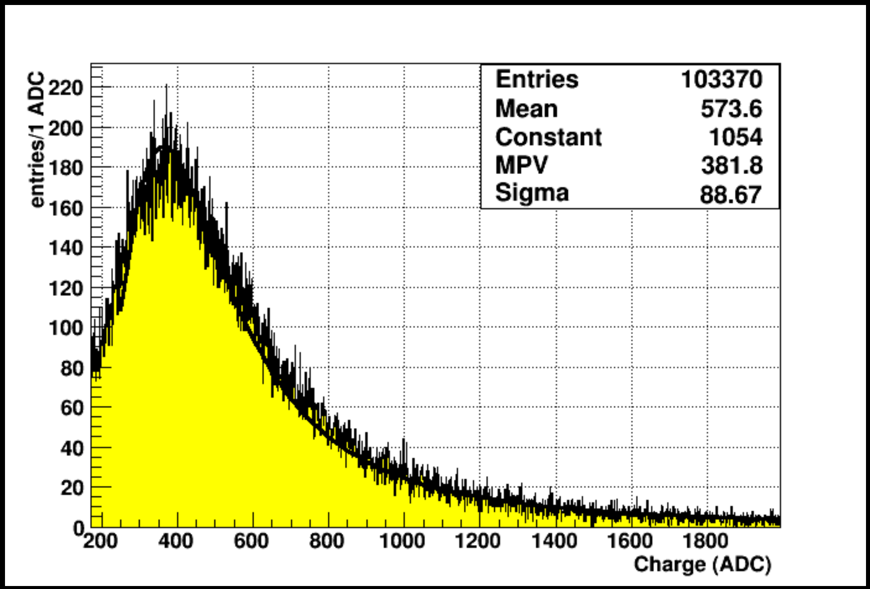
- active area of ≈11 m^2
- $|n| < 0.5$

CsI photo-cathode is segmented in 0.8x0.84 cm pads

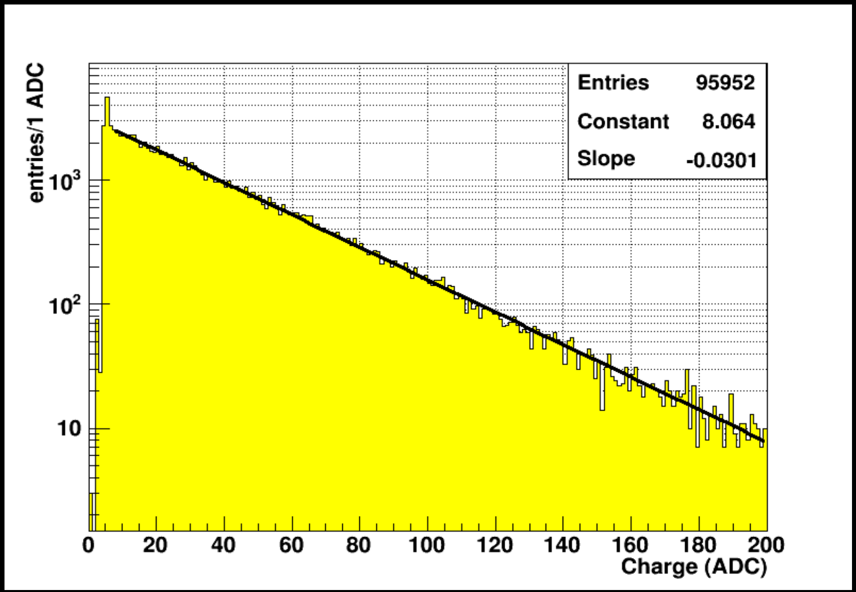


Gain monitoring per HV sectors

MIP charge distribution



Single electron pulse high distribution



Stability Gas gain value is a critical parameter for the:

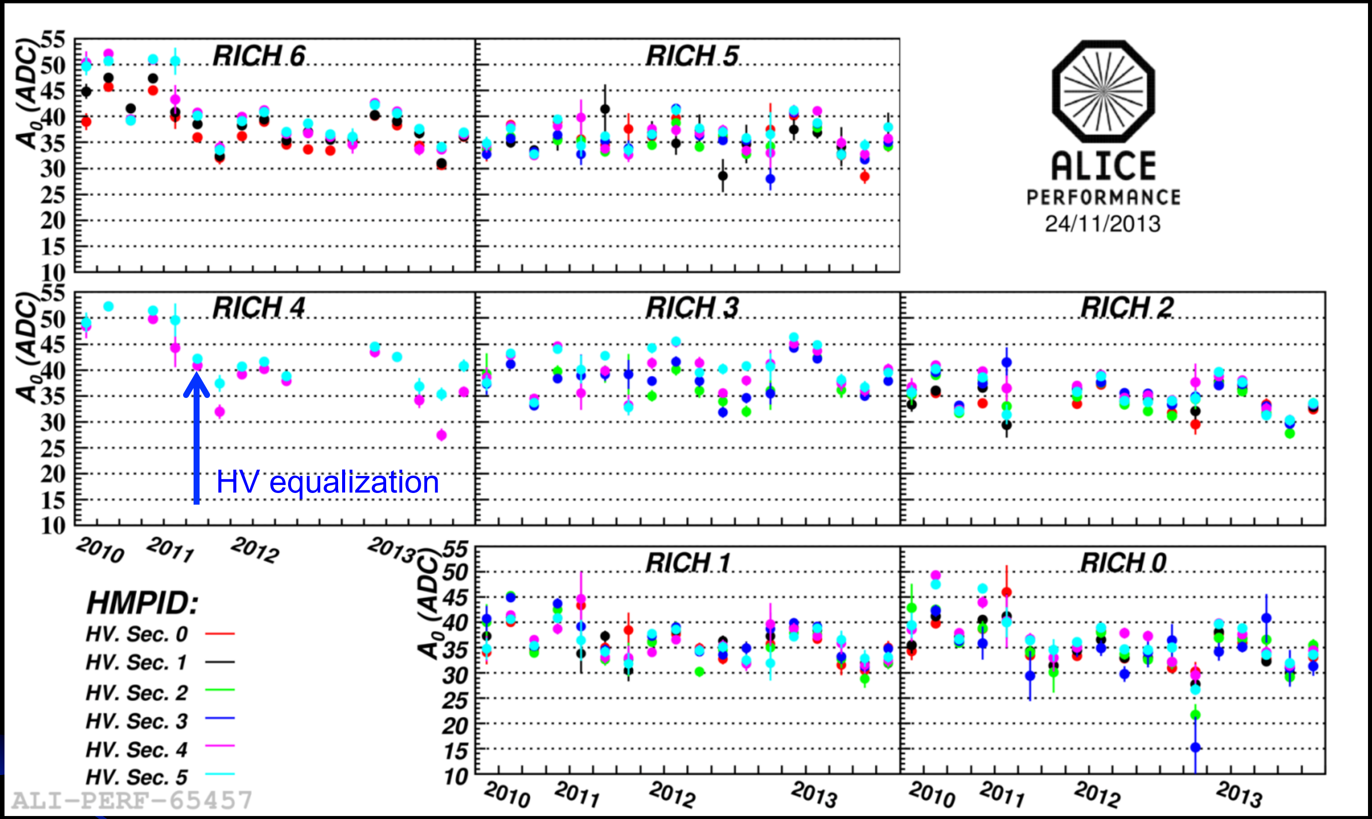
- Photon feedback;
- CsI ageing by avalance ions.

Actual value ≈ 4 10^4 (HV=2050 V)

- Invers of the slope (changed of sign) gives <spe ph> in ADC channels, the A_0 of the Furry distrib. In this case = 33 ADC chs.;
- $s_{\text{electronic noise}}$ = 1 ADC ch 1000 e-;
- cut applied on the bkg: A_{th} =4 ADC chs.

Actual e_{sped} ≈ 90%

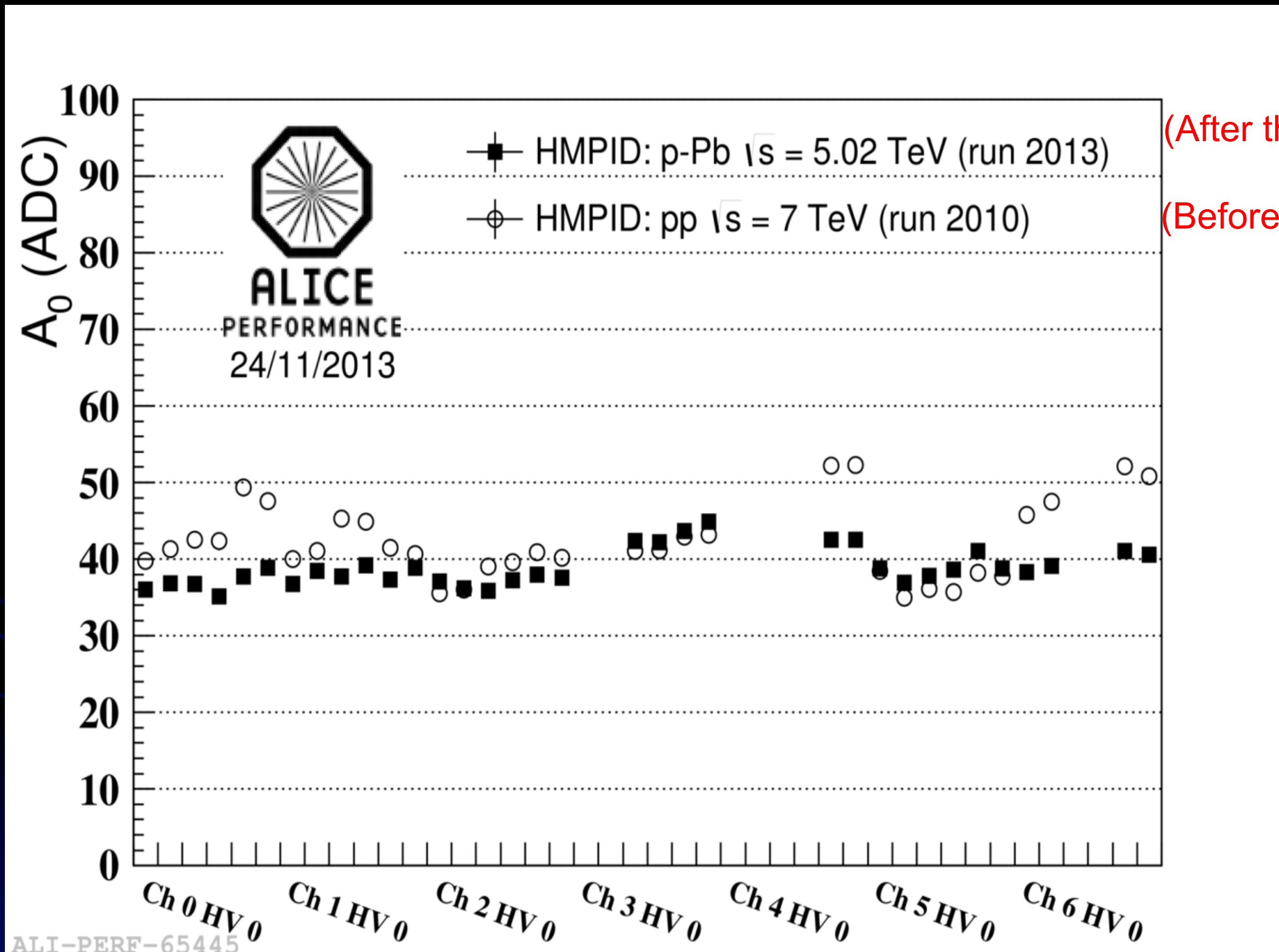
HV equalization and A_0 stability



- Trend views of the gas gain stability;
- Equalization of 42 HV sectors during LHC11 d-e periods to get $A_0 \approx 35$;
- Gas gain variations vs. time after the equalization ≈ ± 15%
- A reduction of 20% for A_0 results in a a single photoelectron detection efficiency loss of 3%
- no effect on the PID performances, and this thanks to the $A_0 / A_{th} \approx 35/4$;

Work done by Laszlo Olah

A0 spread for HV sector

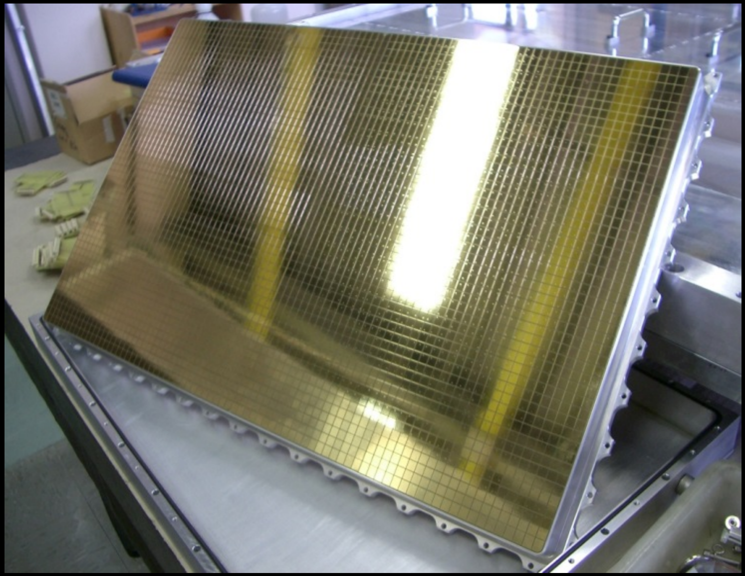


(After the HV equalization)

(Before the HV equalization)

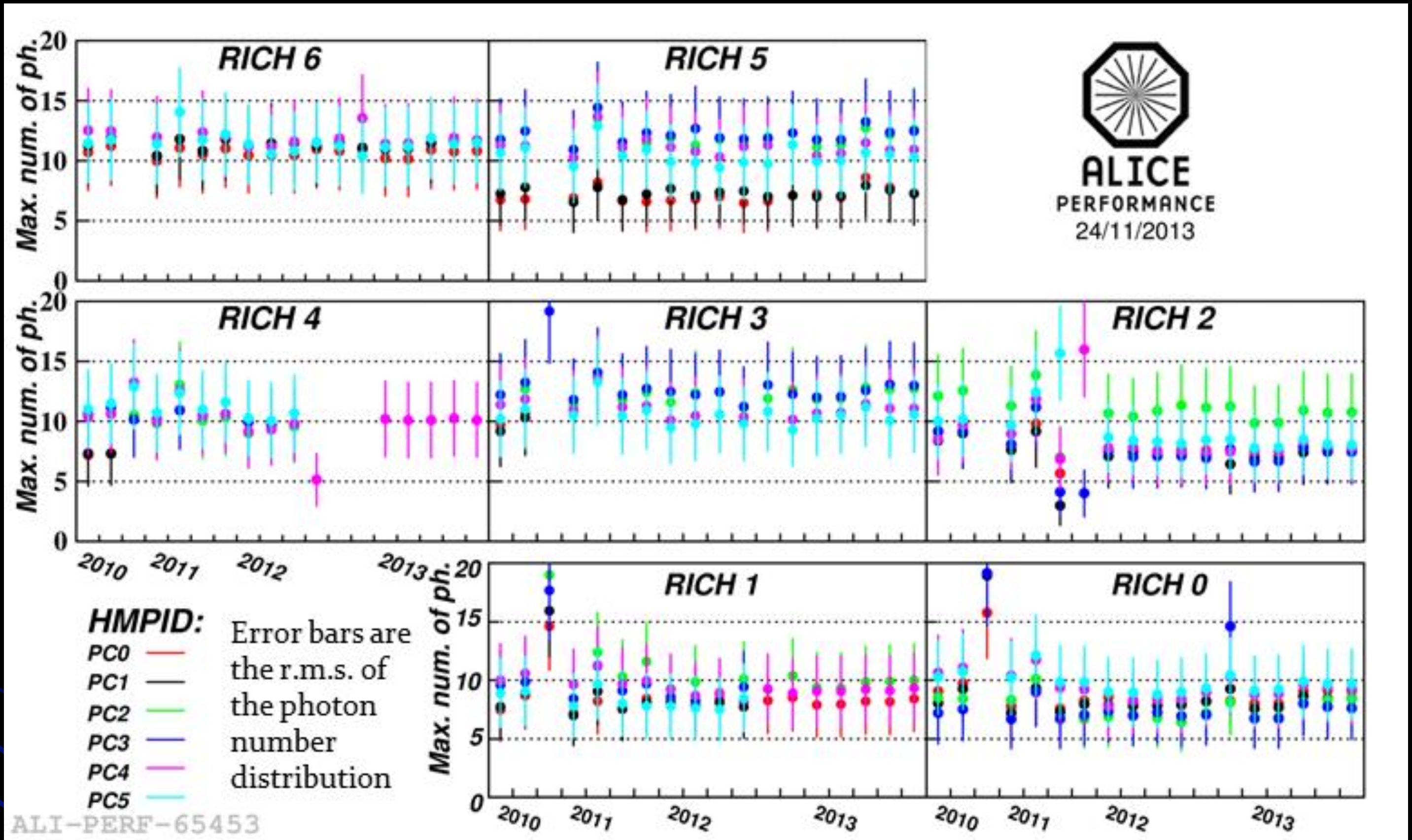
Preliminary study on the Q.E. stability of CsI photocathodes

- A direct measurement of the CsI Q.E. from data is not possible, convolution of several factors;
- Monte Carlo procedure for extracting the CsI Q.E. from data and compare with that at the production time of the photocathodes, is under way.
- Meanwhile here is proposed an indirect way to check the stability of CsI Q.E. via the number of detected Cherenkov photons $\mathbf{N_{\check{C}.ph;}}$
- The results are already normalized to the C_6F_{14} transparency and gas gain;



- One out of six pad photocathodes installed in each RICH module;
- 8x8.4 mm2 pads visible;
- CsI not yet evaporated.

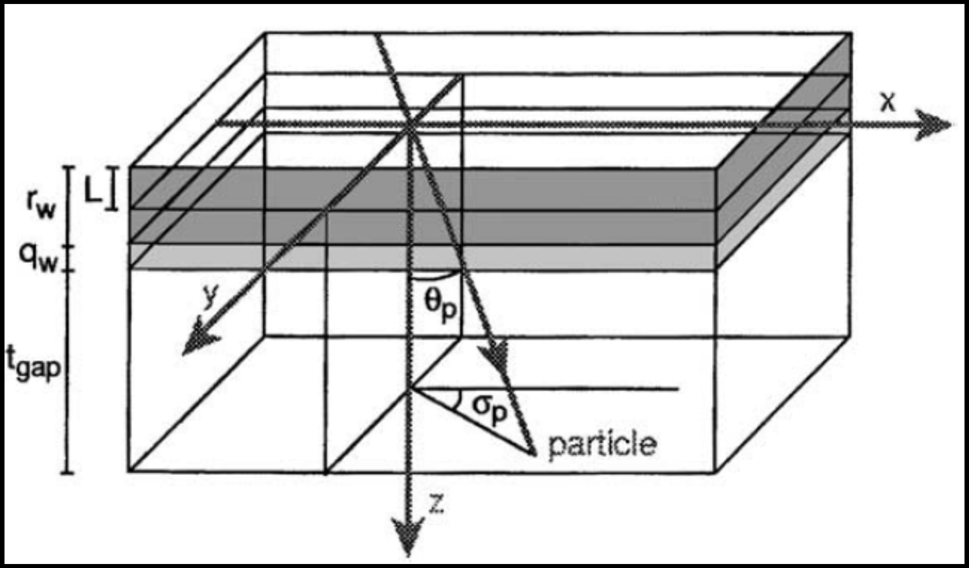
Stability of the detected number of photons



- Average number of reconstructed photons per track at saturated Č angle per photocathode.
- The gas gain normalization has been applied. C_6F_{14} transparency: no impact;
- to preserve enough statistics, also no fully contained rings are accepted;
- **Absence of loss trend on $N_{Č.ph.,}$, confident that no CsI Q.E. loss has taken place;**

Work done by Laszlo Olah

Pattern recognition procedure



The measurement of the photon angle in the HMPID requires the tracks to be extrapolated from the central tracking devices of ALICE (ITS, TPC) and associated with the corresponding cluster of the minimum ionizing particle in the HMPID cathode plane.

Starting from the cluster centroid (or the hit pad position) one has to reconstruct the angle under which the photon causing it could have been emitted if belonging to the chosen track. The procedure implemented to achieve such a result is called ''backtracing''.

Pattern recognition procedure

Background subtraction algorithm - Hough transform method

• The Hough Transform Method (HTM) is an efficient implementation of a generalized *template matching* strategy for detecting complex patterns in binary images.

• In the case of the Cherenkov pattern recognition, the starting point of the analysis is a bidimensional map with the impact point (x_p, y_p) of the charged particles, hitting the detector plane with known incidence angles (θ_p, ϕ_p), and the coordinates (x, y) of hits due to both Cherenkov photons and background sources.

• A "Hough counting space" is constructed for each charged particle, according to the following transform:

$$(x, y) \rightarrow ((x_p, y_p, \theta_p, \phi_p), \eta_c)$$

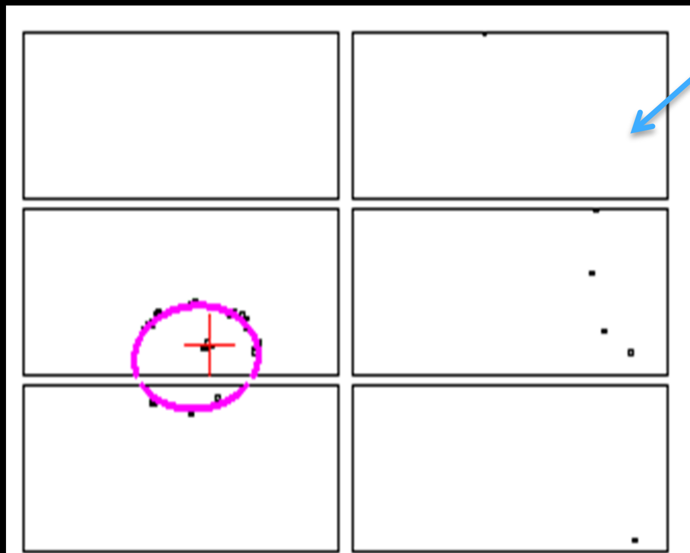
• (x_p, y_p, θ_p, ϕ_p) is provided by the tracking of the charged particle, so the transform will reduce the problem to a solution in a one-dimensional mapping space.

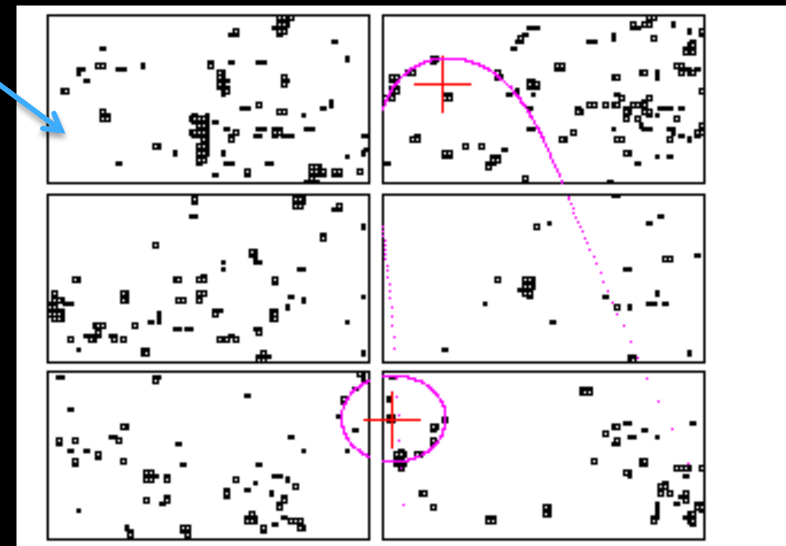
• A η_c bin with a certain width is defined.

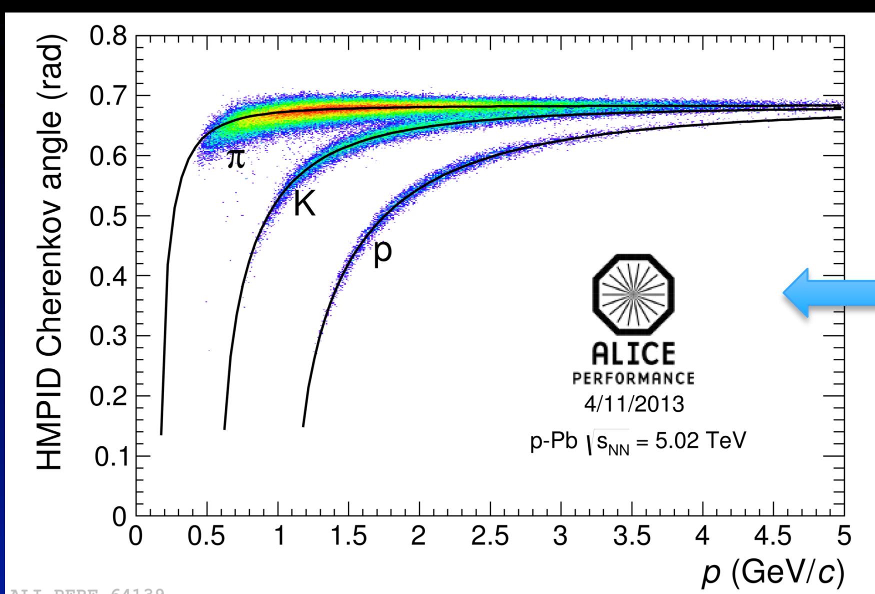
• The Cherenkov angle θ_c of the particle is provided by the average of the η_c values that fall in the bin with the largest number of entries.

Pattern recognition procedure

pp collisions | 2D Event display | Pb-Pb collisions







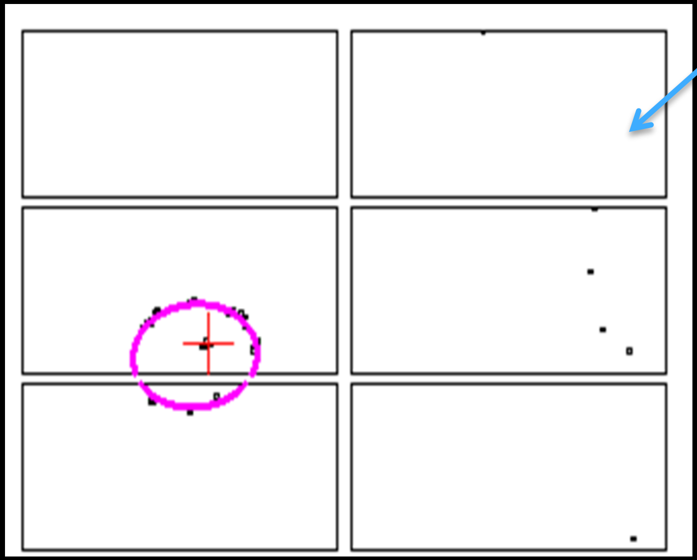
Cherenkov angle vs track momentum

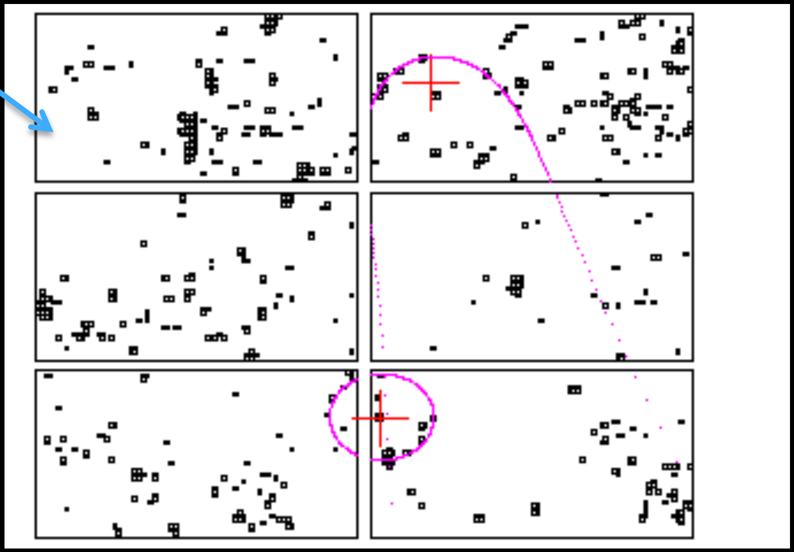
Pattern recognition procedure

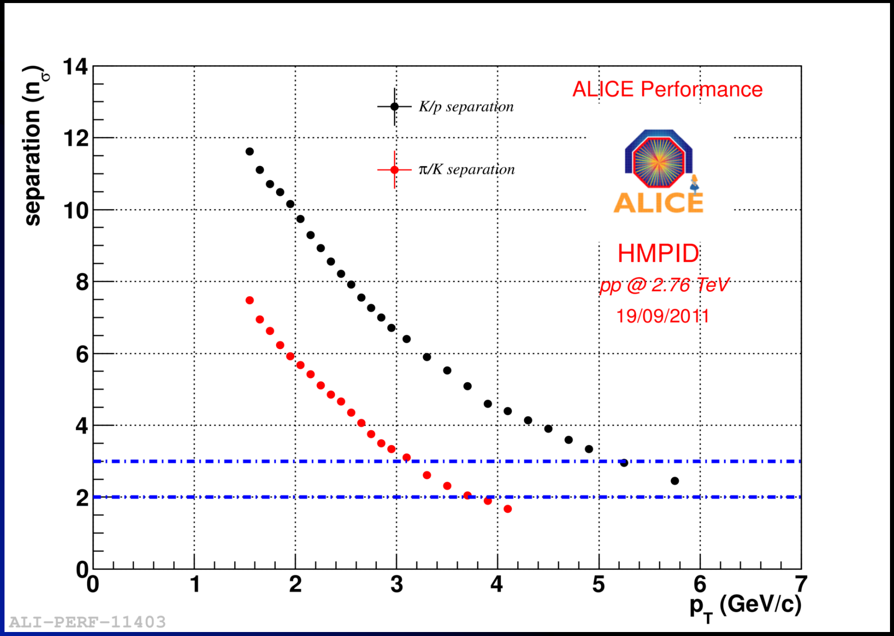
pp collisions

2D Event display

Pb-Pb collisions







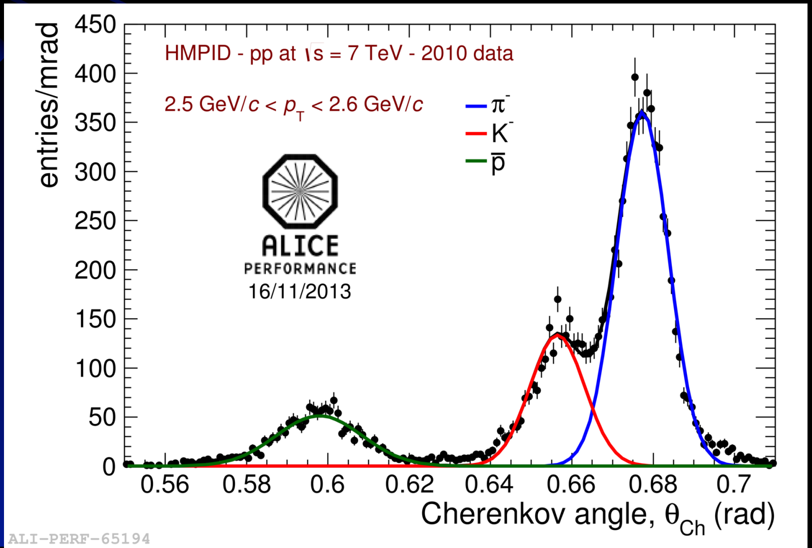
$$sep_{ij}(p_T) = \frac{\langle \theta^i_{Ch} \rangle - \langle \theta^j_{Ch} \rangle}{(\sigma_i + \sigma_j)/2}$$

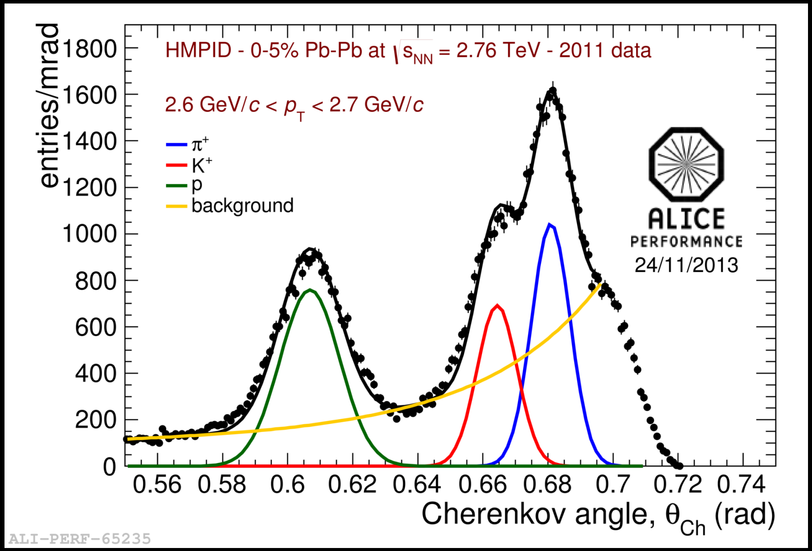
Particle identification – statistical unfolding

In pp collision events the background is negligible, so we extract the particle yields from a three-Gaussian fit to the Cherenkov angle distribution in a narrow transverse momentum range. The function used is the following:

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

In case of the most central Pb-Pb collisions (0 – 10 % of centrality) due to the high particles multiplicity, the three Gaussian distributions in a given transverse momentum bins are convoluted with a background distribution that increases with the Cherenkov angle value. It is due to mis-identification in the high occupancy events, larger is the angle value larger is the probability to find background (background uniformly distributed on the chamber plane).



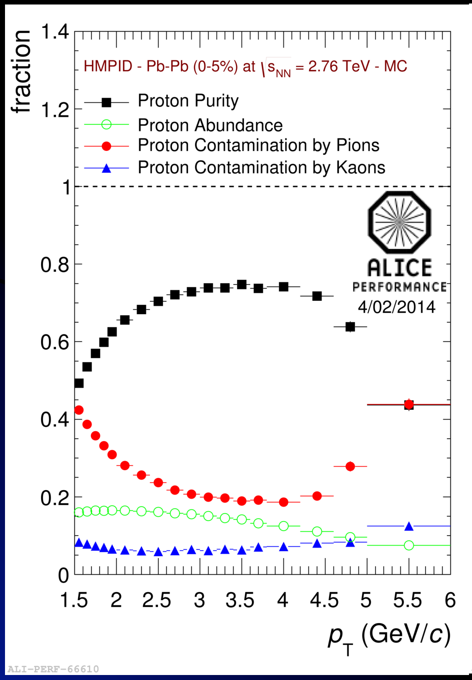


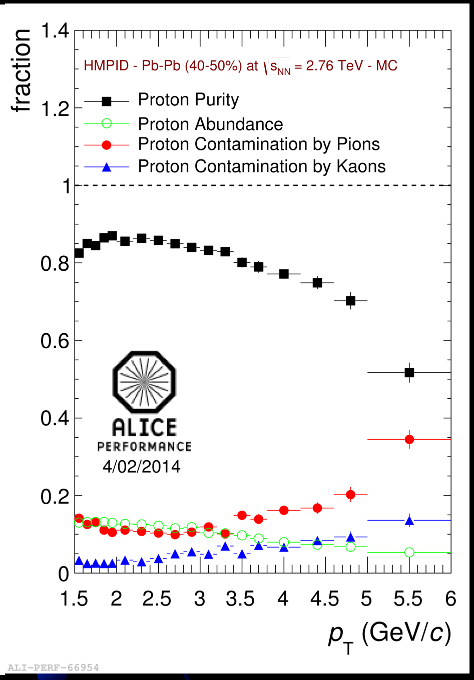
Particle identification – on track-by-track basis

In the case of particle identification on track-by-track basis from the knowledge of the expected Cherenkov angle value and the expected theoretical standard deviation, for each track and the corresponding measured emission angle it is possible to calculate the values of two PID estimators: the probability to be one of the charged hadron specie, the difference between the measured angle value and the expected theoretical one in sigma units

$$|N_\sigma| < 2$$

$$N^i_{sigmas} = \frac{\left|\theta_{exp} - \theta^i_{theor}\right|}{\sigma^i}$$





$$p_i = \frac{N^t_{id}(i)}{N_{id}(i)} \qquad c_i = \frac{N^w_{id}(i)}{N_{id}(i)}$$

p_i = purity, c_i = contamination

$N_{id}(i)$ = number of particles identified as type i

$N_{id}^t(i)$ = number of true particles of type i identified as type i

$N_{id}^w(i)$ = number of non-type i particles identified as particles of type i

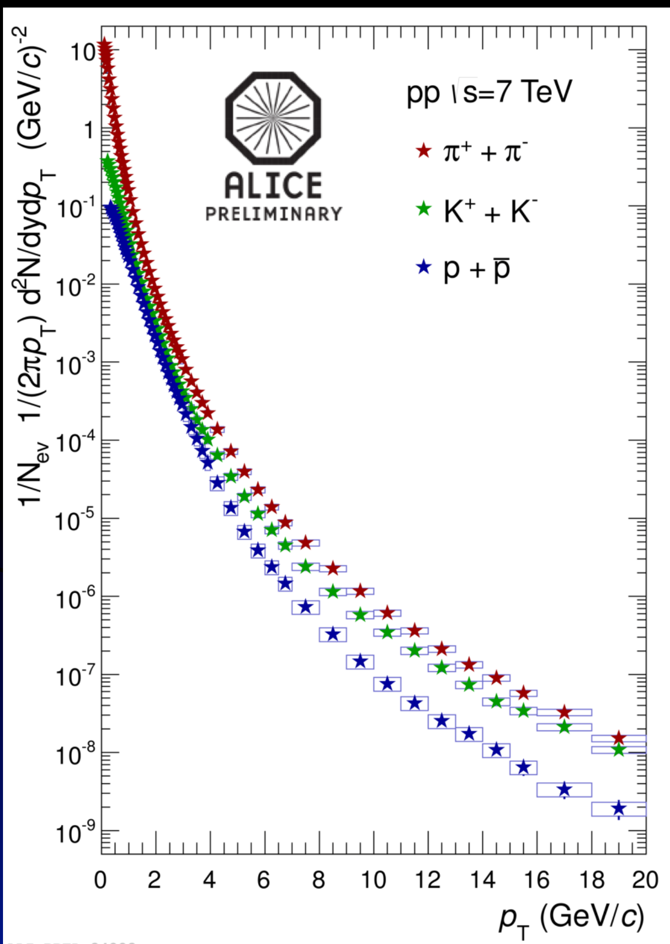
HMPID physics program

- Identified particle yields and ratios vs. p_T (p/p, $\bar{p}/\pi$, K/π) at midrapidity in pp, p-Pb an Pb-Pb at different energy collisions

- Jet physics:
  - jet fragmentation with the identification of particles in the jet
  - Study the flavor of the leading particle

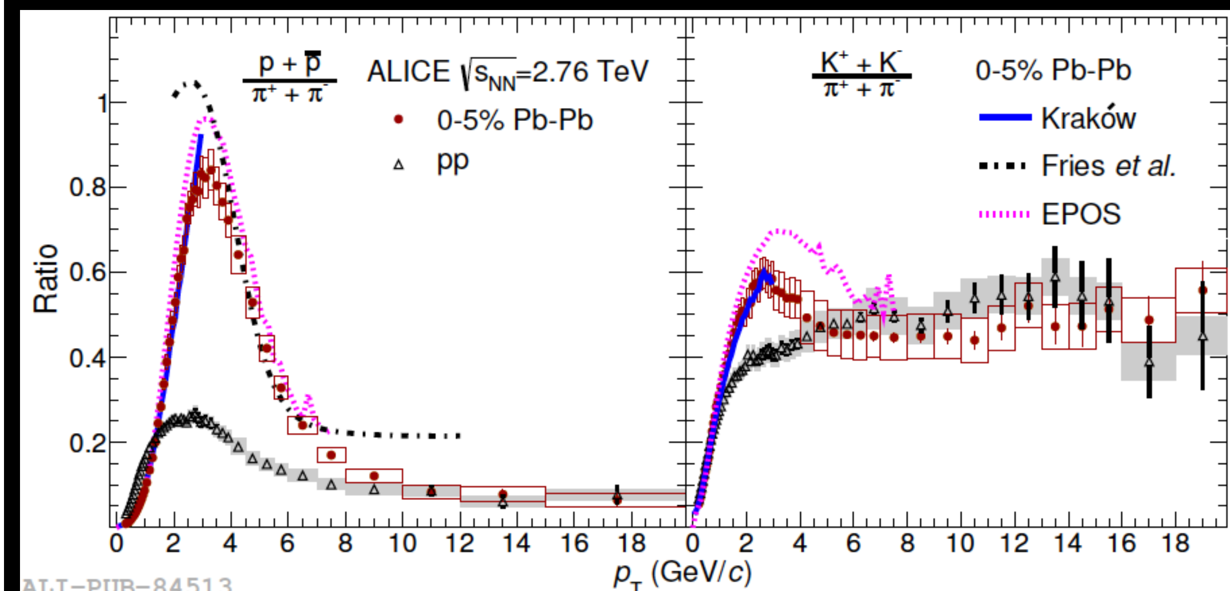
- Identified particles correlation
- Light nuclei (deuteron) production
- Resonances production such as $\phi(1020) \rightarrow K^+K^-$

Contributions to ALICE physics program



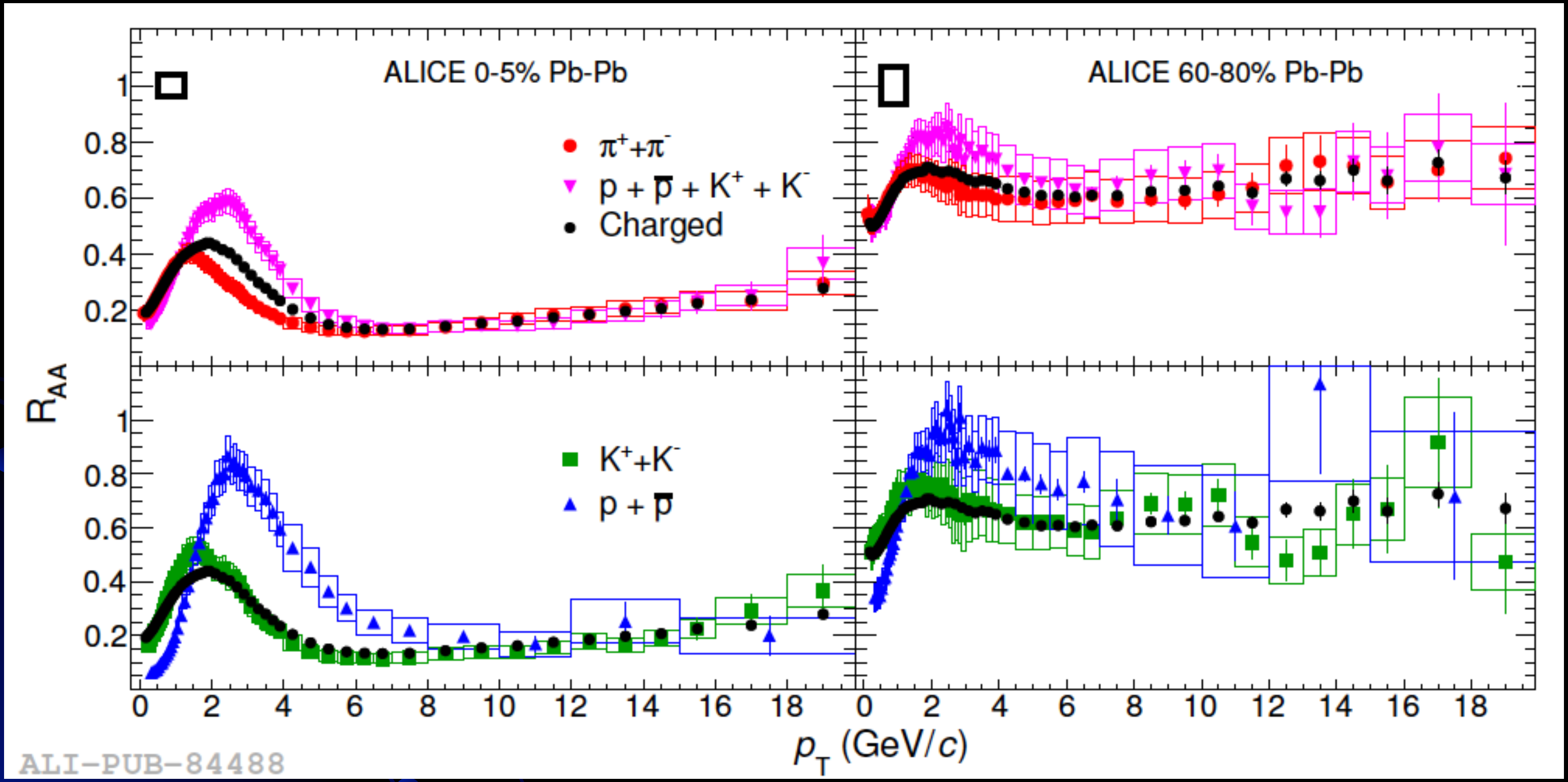
Combining the with the information provided by ITS, TPC, TOF and HMPID, pions, koans and protons pT spectra have been measured in a wide momentum range in the following collisions systems:

- pp at √s = 7 TeV, 2.76 TeV
- Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV
- p-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV



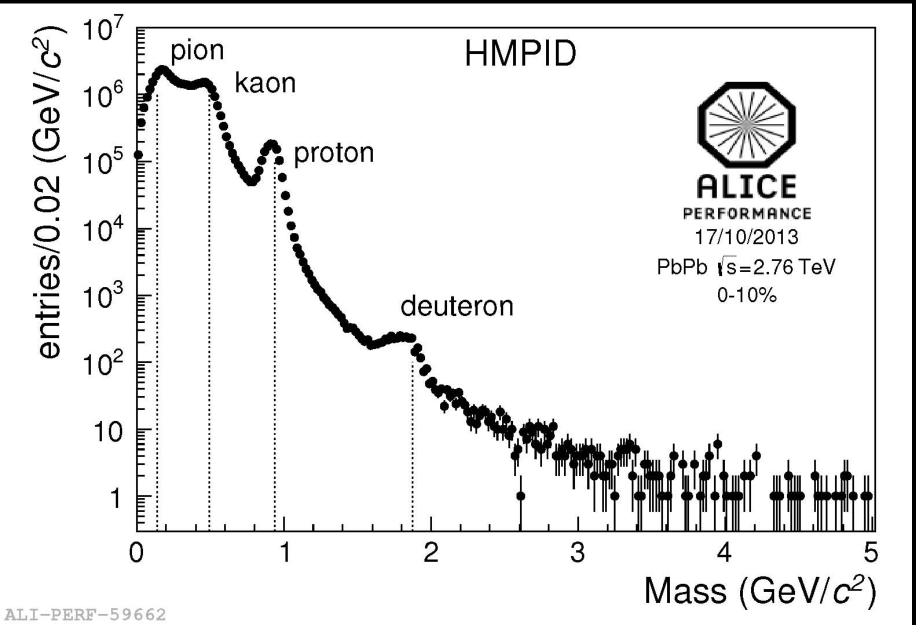
Contributions to ALICE physics program

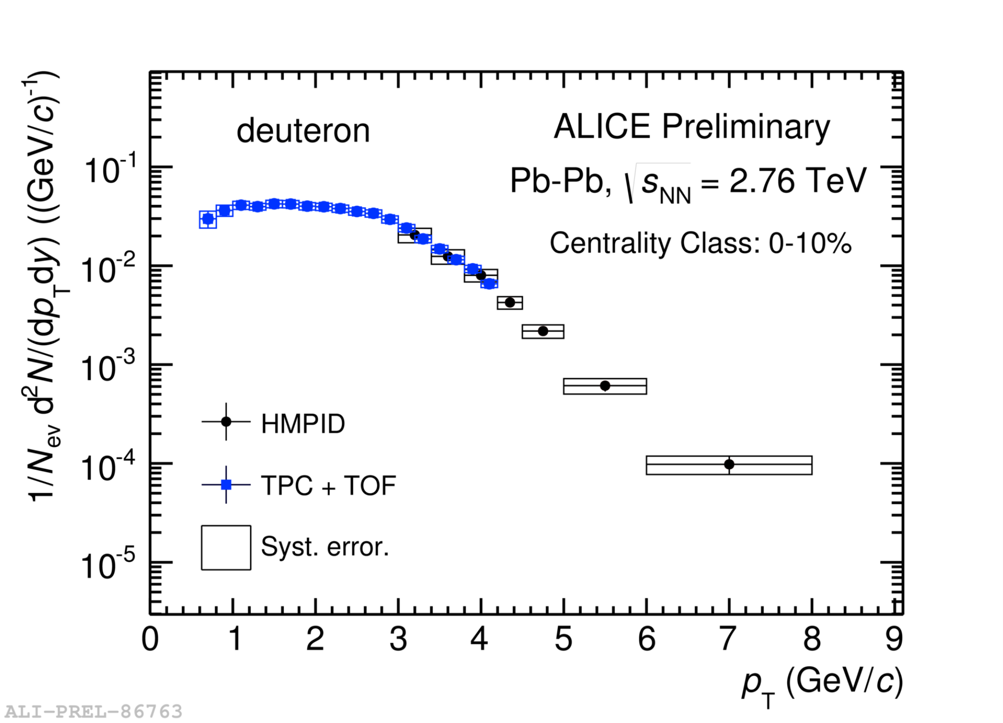
$$R_{AA} = \frac{AA}{\text{rescaled pp}} = \frac{d^2N_{AA}/dp_T dy}{\langle N_{coll}\rangle d^2N_{pp}/dp_T dy}$$



Contributions to ALICE physics program

In central Pb-Pb collsions the deuteron (anti-deuteron) p_T spectra has been evaluated.





Summary

- The Good detector stability during 2010-2013 have provide stable PID performances;

- The HMPID successfully contributes to the ALICE physics program:
  - identification of charged hadrons in the intermediate momentum range;

  - With Track by Track PID in Pb-Pb collisions, physics studies with HMPID on the identified particle correlations are ongoing.

- No loss of detected $N_{\check{C}.ph}$ observed, good perspectives for the CsI Q.E. up to 2021 (LHC Run3);

Backup

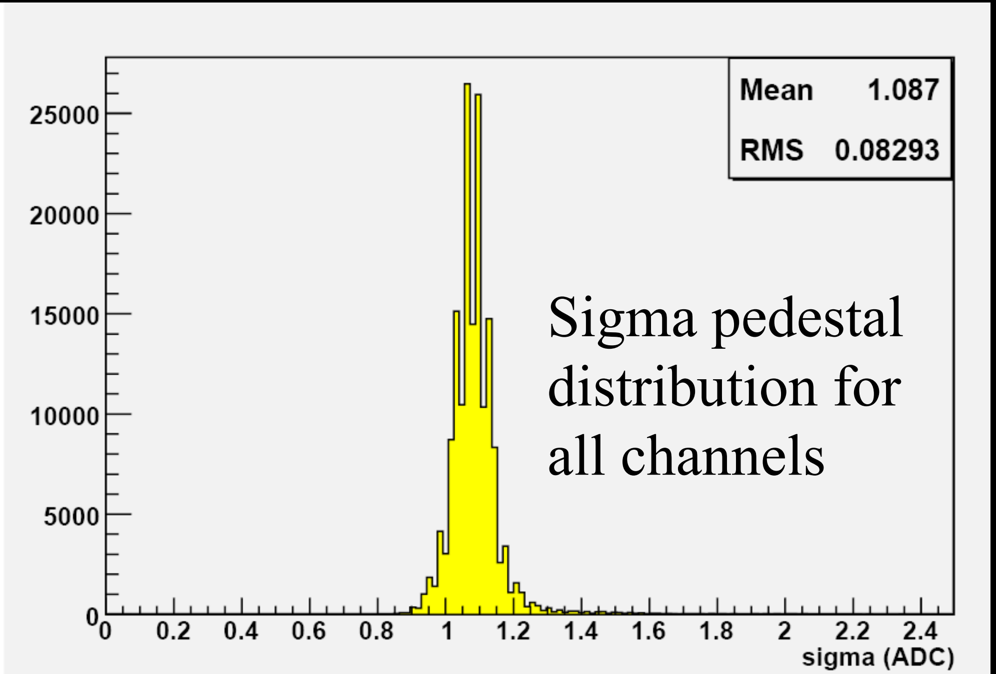
HMPID detector description

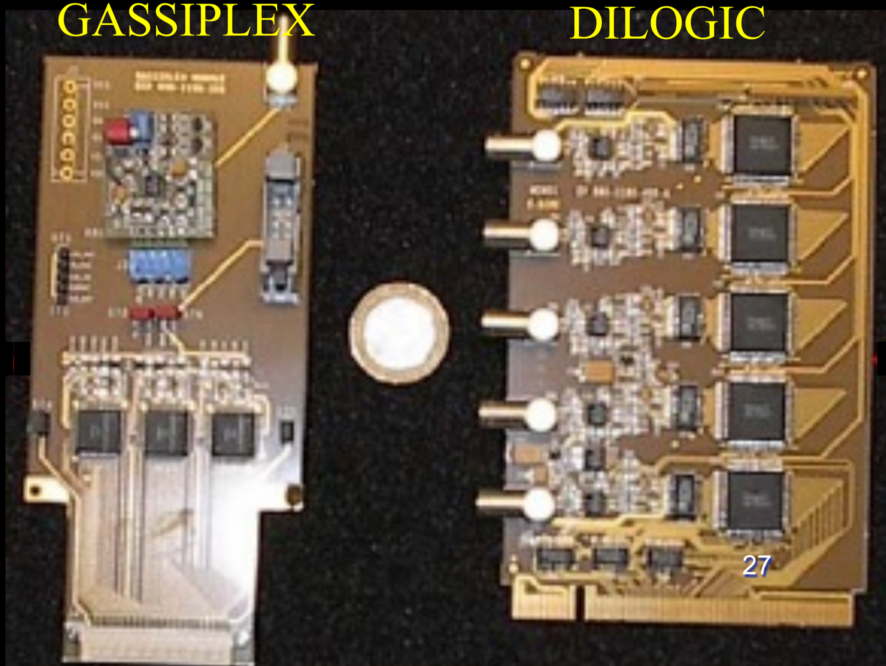
• FEE and RO electronics is based on GASSIPLEX and DILOGIC chips developed within the HMPID project

• GASSIPLEX: 16-channel analogue multiplexed low-noise signal processor, the noise level is 1000 e^-, dead/noisy pads are less than 200 out of 161280

• DILOGIC: individual threshold and pedestal setup

• 42 photo-cathodes are segmented into 3840 pads with individual analog readout.





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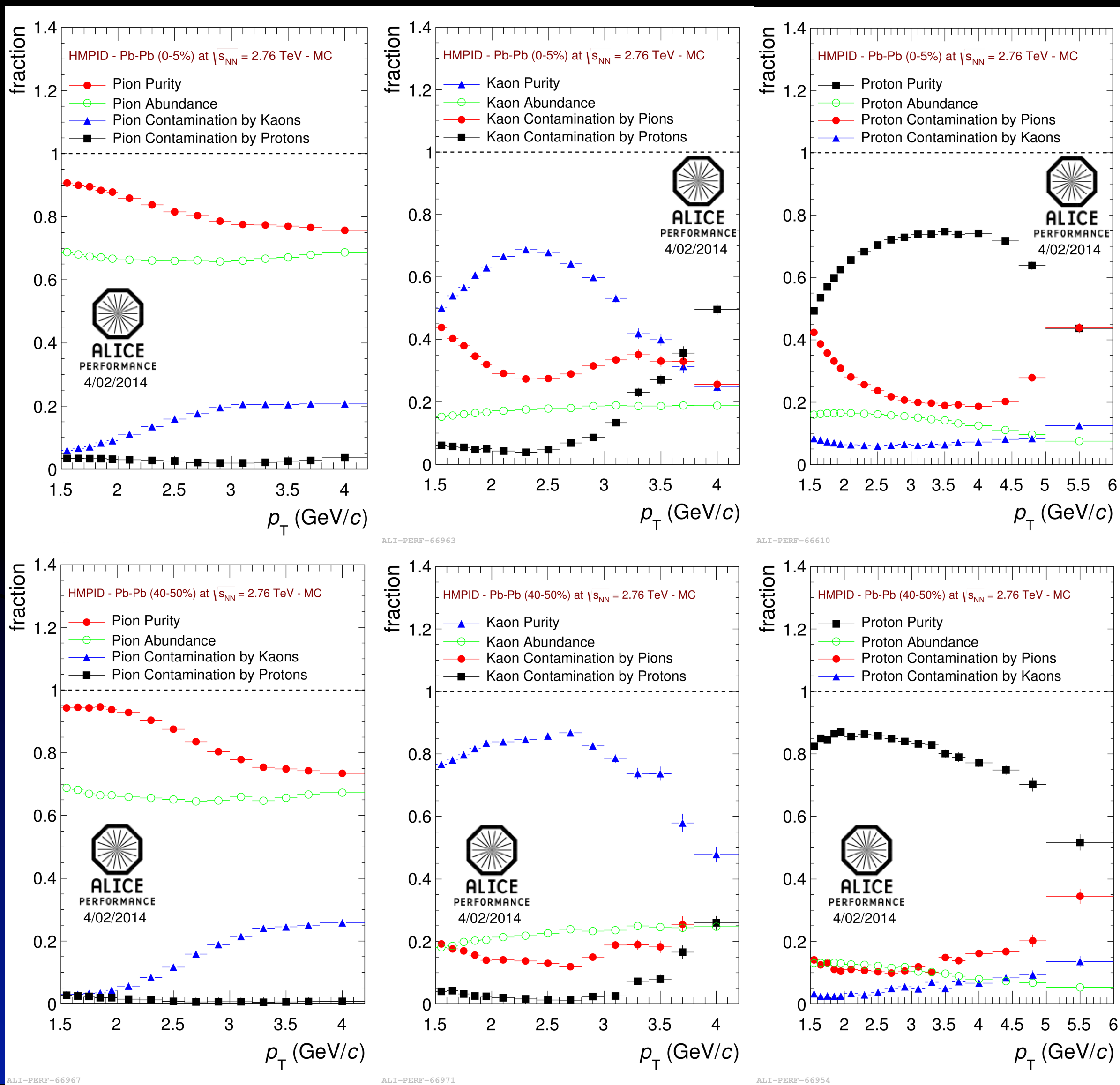
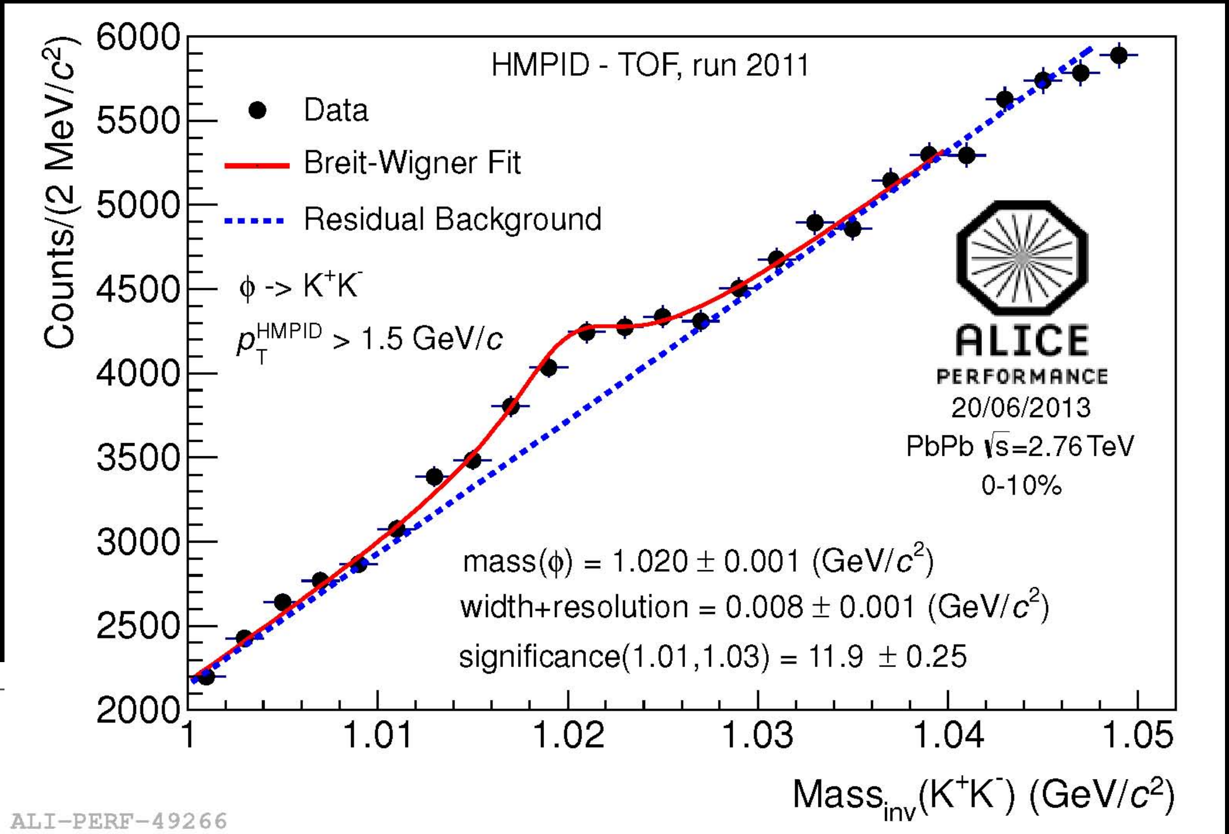
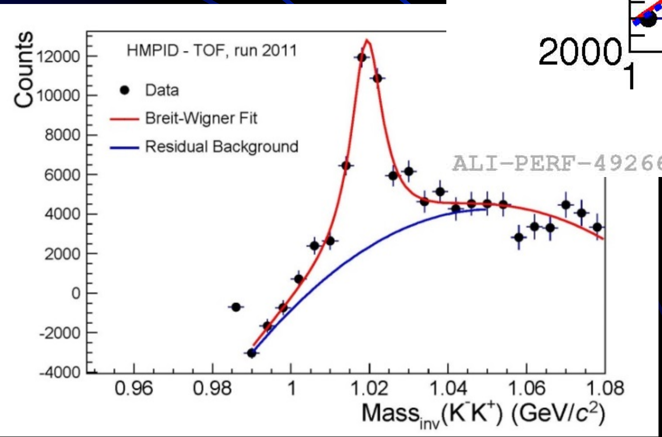


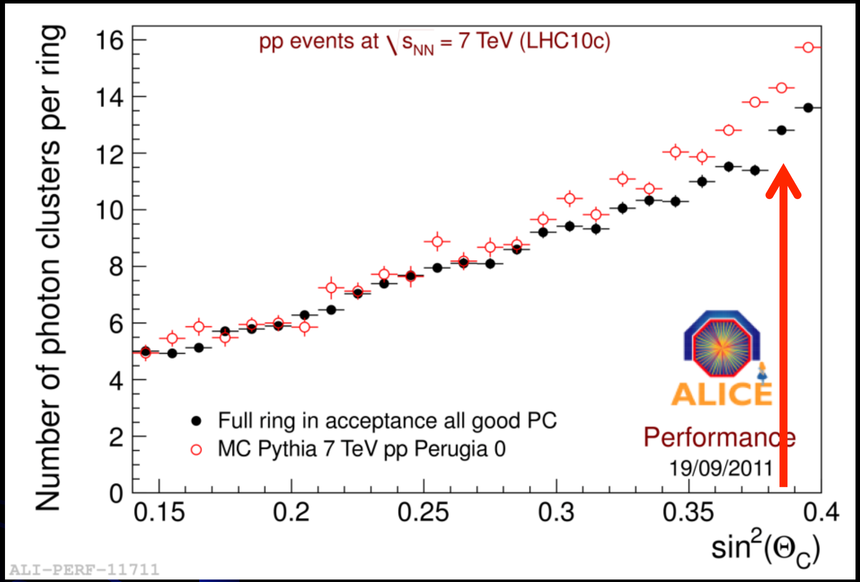
HMPID performance: $\phi(1020) \rightarrow K^+K^-$

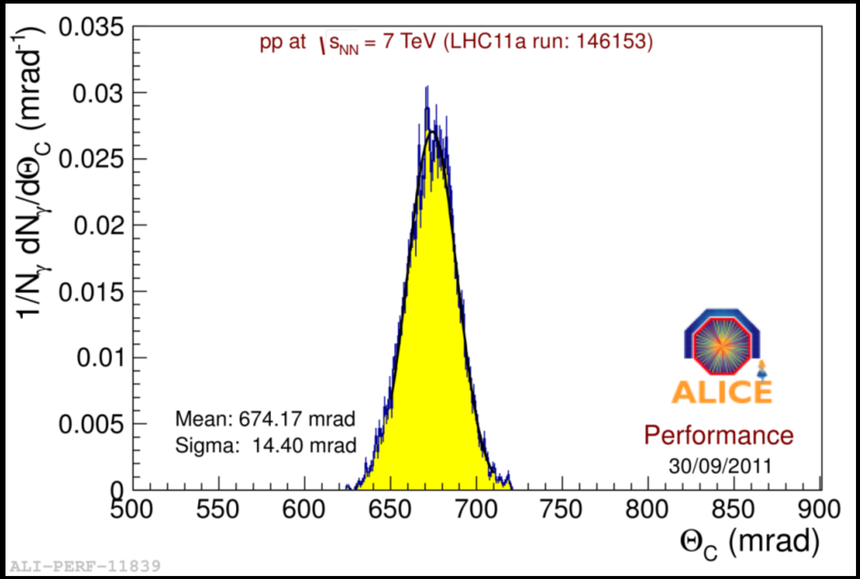
- One charged kaon identified with TOF outside the HMPID acceptance (to increase statistics)





$N_{\check{C}.ph.}$ vs. $\sin^2\theta$ and single-photon Č angle resolution





- Number of photon clusters per ring vs. $\sin^2\theta$,
- The number of photon clusters per ring is extracted from rings fully contained on the photocathode;
- Data set: LHC 10b period. B)

- The single-photon Cherenkov angle resolution is extracted for charged π at saturation (p > 1.5 GeV/c);
- no cut is applied on the incident track angle.