HMPID plenary meeting

Contribution of the HMPID to the ALICE physics program and its integration in the O^2 framework

13/12/2018

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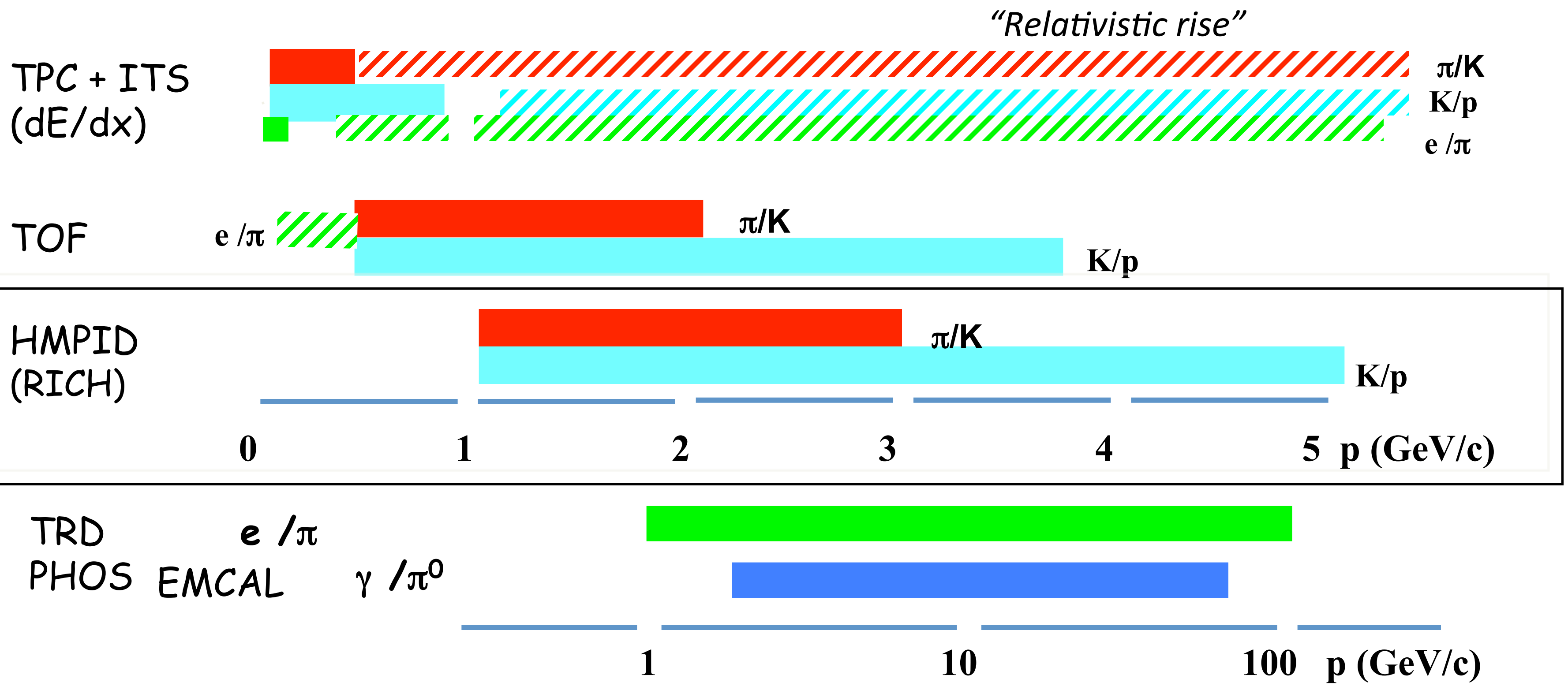
Outline

- PID procedure with the HMPID
- Identified charged hadrons spectra
- Deuterons identification
- Particle correlation study
- PID perfomance
  - High vs low multiplicity events
  - B= 0.2 vs 0.5 T magnetic field intensity
- HMPID integration in RUN3

Particle Identification in ALICE: momentum ranges



Solid: track-by-track

Dashed: only statistical

PID procedure with HMPID

Identification on statistical basis: low multiplicity events

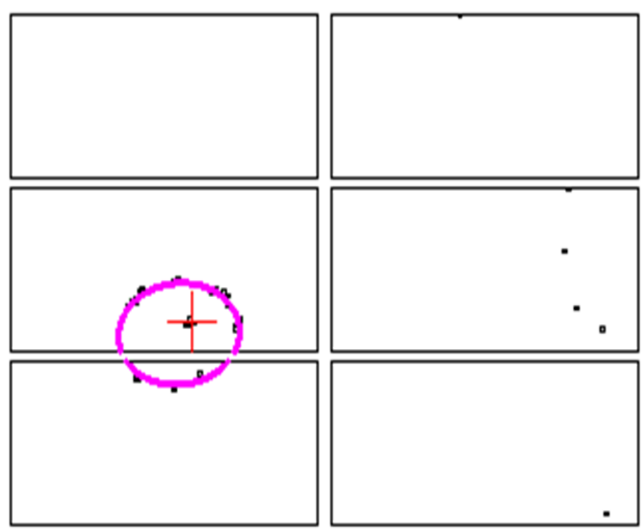
the particle yields are evaluated from a three-Gaussian fit to the Cherenkov angle distribution in a narrow transverse momentum range. The function used is the following:

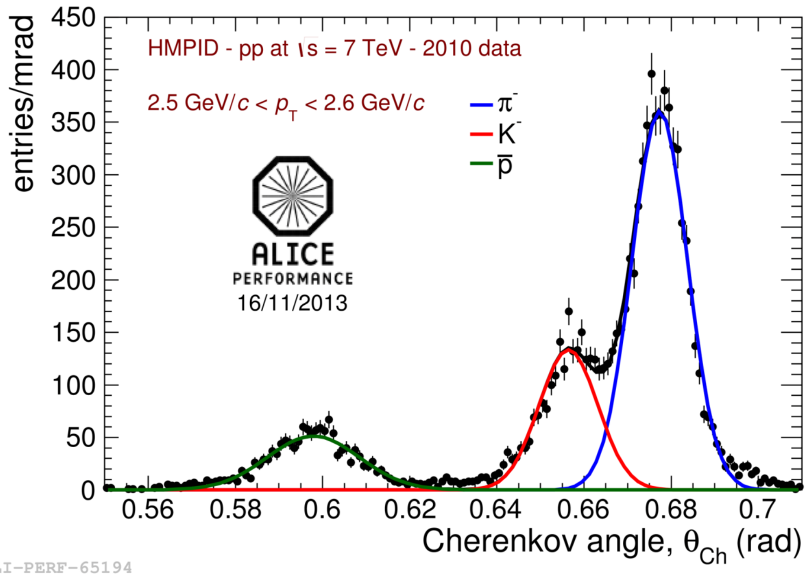
$$f(\theta) = \frac{Y_\pi}{\sigma_\pi\sqrt{2\pi}} e^{-\frac{(\theta-\langle\theta_\pi\rangle)^2}{2\sigma_\pi^2}} + \frac{Y_K}{\sigma_K\sqrt{2\pi}} e^{-\frac{(\theta-\langle\theta_K\rangle)^2}{2\sigma_K^2}} + \frac{Y_p}{\sigma_p\sqrt{2\pi}} e^{-\frac{(\theta-\langle\theta_p\rangle)^2}{2\sigma_p^2}}$$

$<\theta_i>$ = means of the Cherenkov angle distributions
σ_i, = standard deviation of the Cherenkov angle distributions.
Y_i = integral of the single Gaussian functions

- 9 parameters to be calculated, the three mean values, the three sigma values and the three yields.
- Mean and sigma values are know and fixed in the fitting.

pp event display



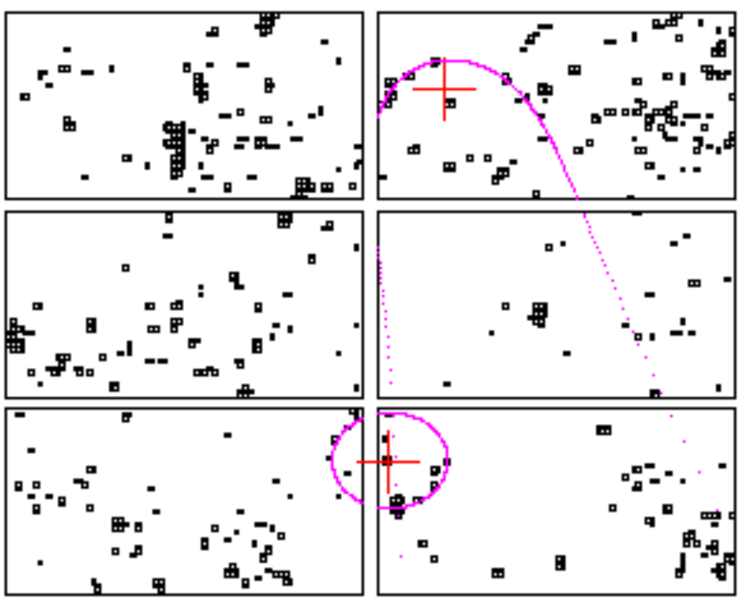


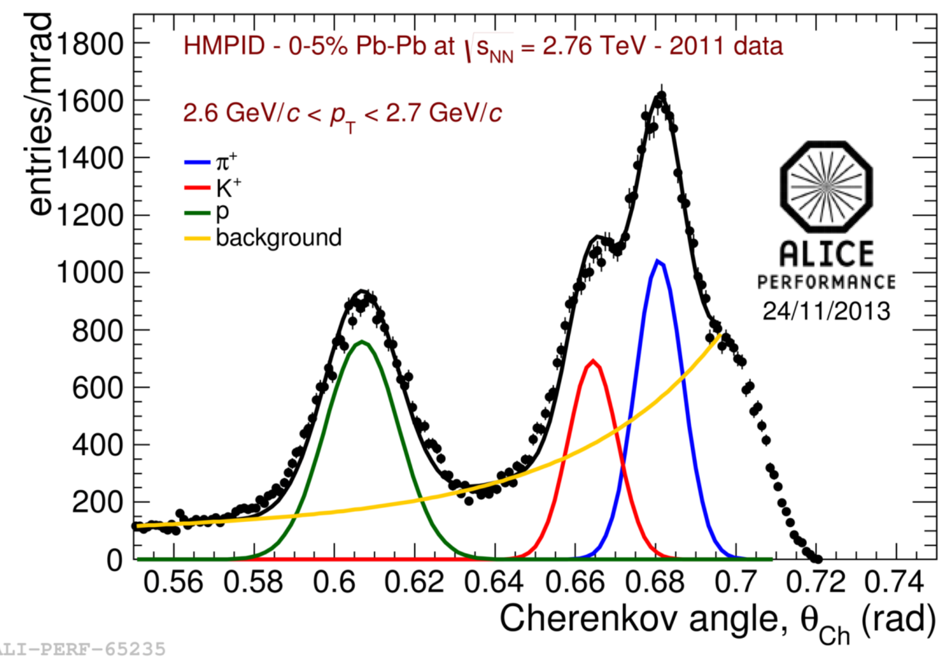
PID procedure with HMPID

Identification on statistical basis: high multiplicity events (central Pb-Pb collisions)

- the three Gaussian distributions in a given transverse momentum bins are convoluted with a background distribution;
- Such distribution 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;
- In the yield extraction procedure the background function has to be convoluted with the three-Gaussian one.

Pb-Pb event display

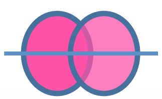




PID procedure with HMPID

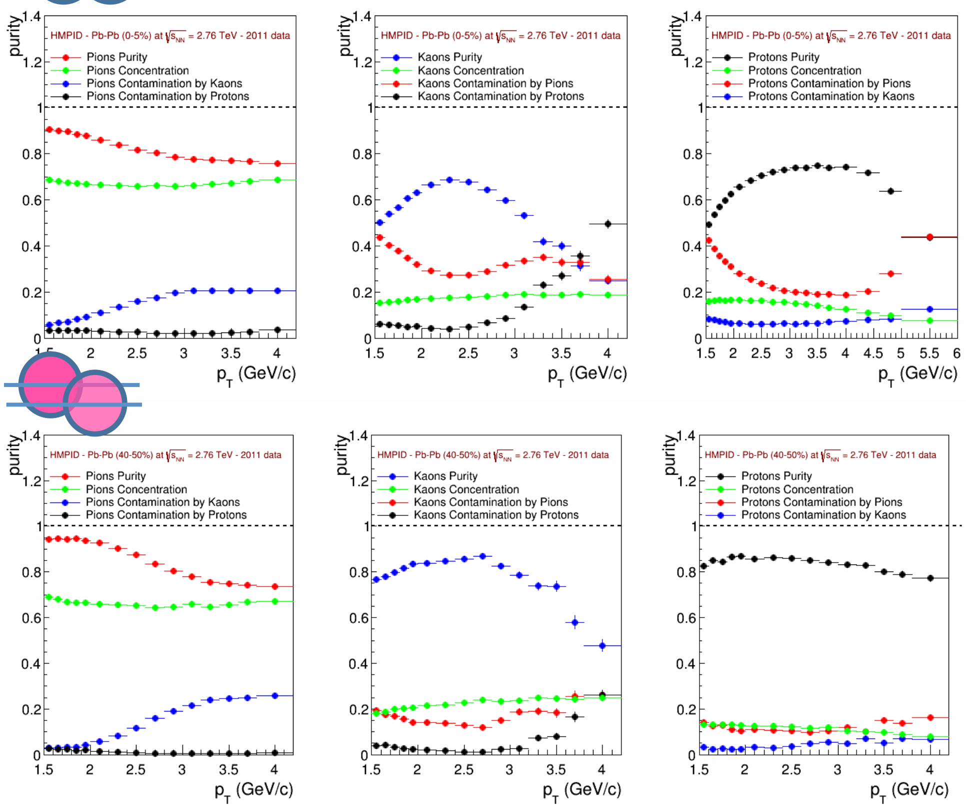
Identification on track-by-track basis

- From the knowledge of the expected Cherenkov angle value and the expected theoretical standard deviation, 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;



$$N_{sigmas} < 2$$

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



$$p_i = \frac{N^{t}_{id}(i)}{N_{id}(i)} \qquad c_i = \frac{N^{w}_{id}(i)}{N_{id}(i)}$$

$$i = \pi, K, p$$

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

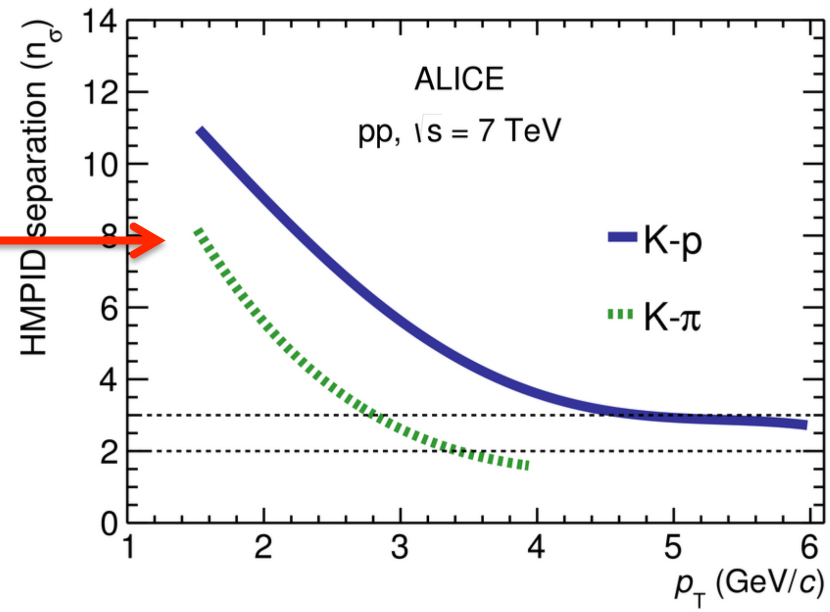
ALICE charged hadrons yields evaluation strategy

- To measure the production of pions, kaons and protons over a wide p_T range, results from five different independent PID techniques/detectors, namely ITS, TPC, TOF, HMPID and kink-topology (for kaons), are combined.

- In their overlap p_T regions the spectra from the different PID techniques are consistent within uncertainties:
  - the results are combined in the overlapping ranges using a weighted mean with the independent systematic uncertainties as weights.

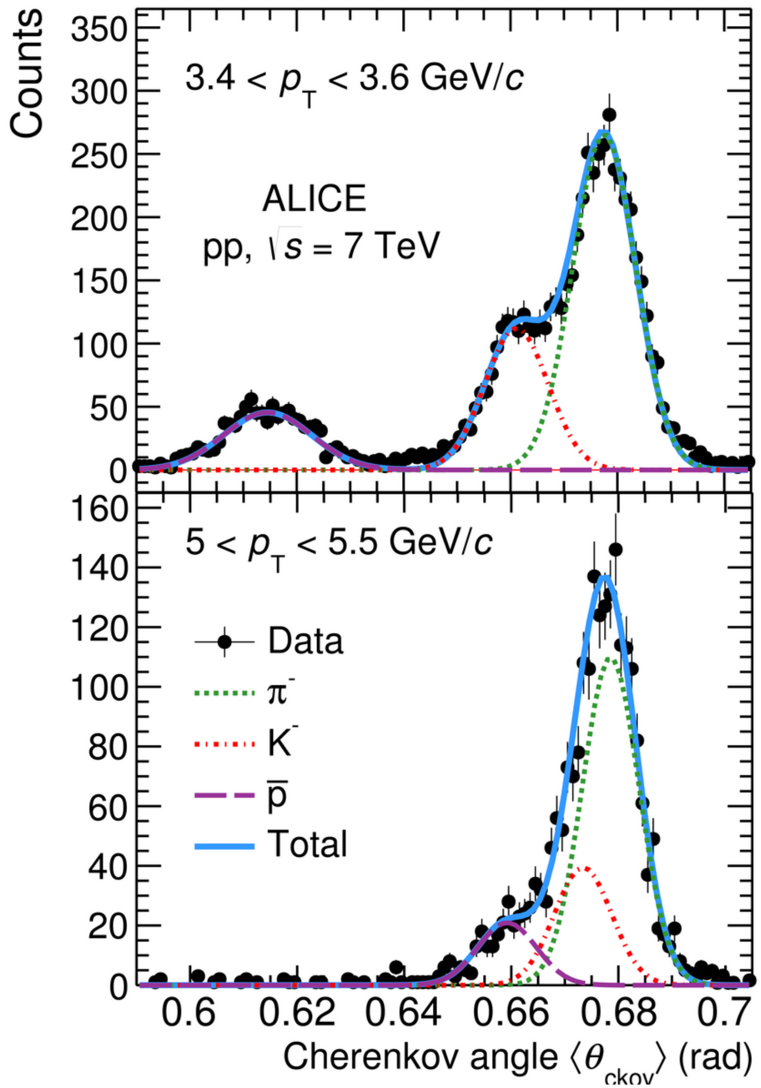
- The HMPID constrains the uncertainty of the measurements in the transition region between the TOF and TPC relativistic rise methods (around p_T = 3 GeV/c). It both improves the precision of the measurement and validates the other methods in the region where they have the worst PID separation.

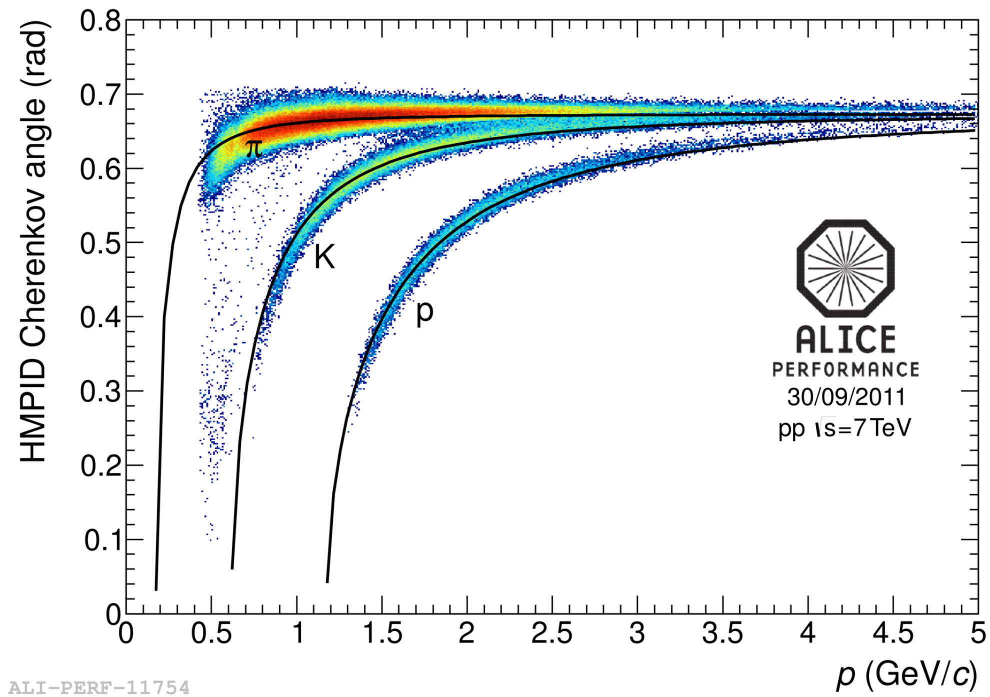
HMPID separation power in σ unit as a function of p_T



Charged hadrons spectra: pp 7 TeV

Eur. Phys. J. C (2015) 75:226





PID range

π/K → 1.5 – 3 GeV/c

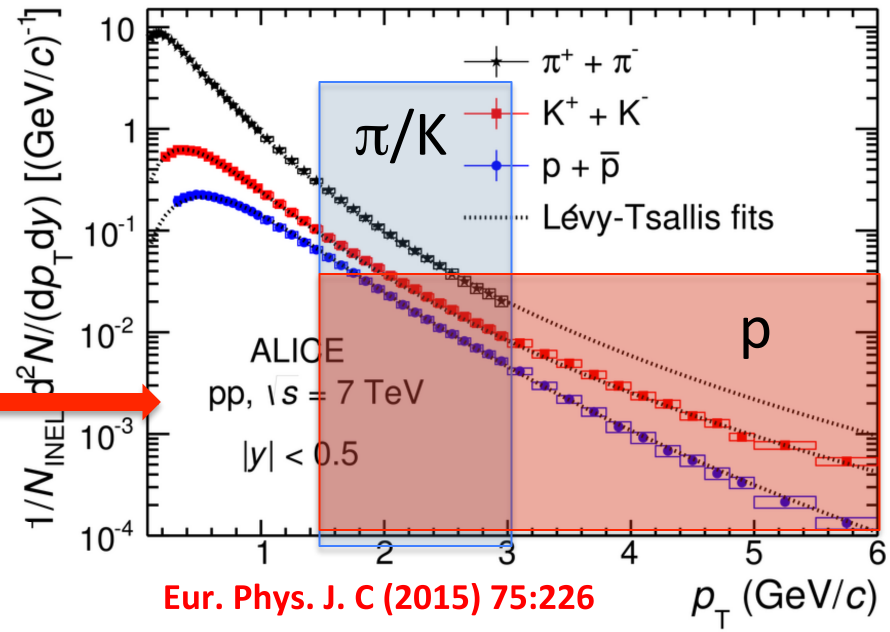
P → 1.5 – 6 GeV/c

Charged hadrons spectra: pp 7 TeV

π/K HMPID

p HMPID

π, K and p spectra, resulting from the combination of the information provided by 5 different analyses (dE/dx, TOF, Cherenkov, kinks topology for kaons).



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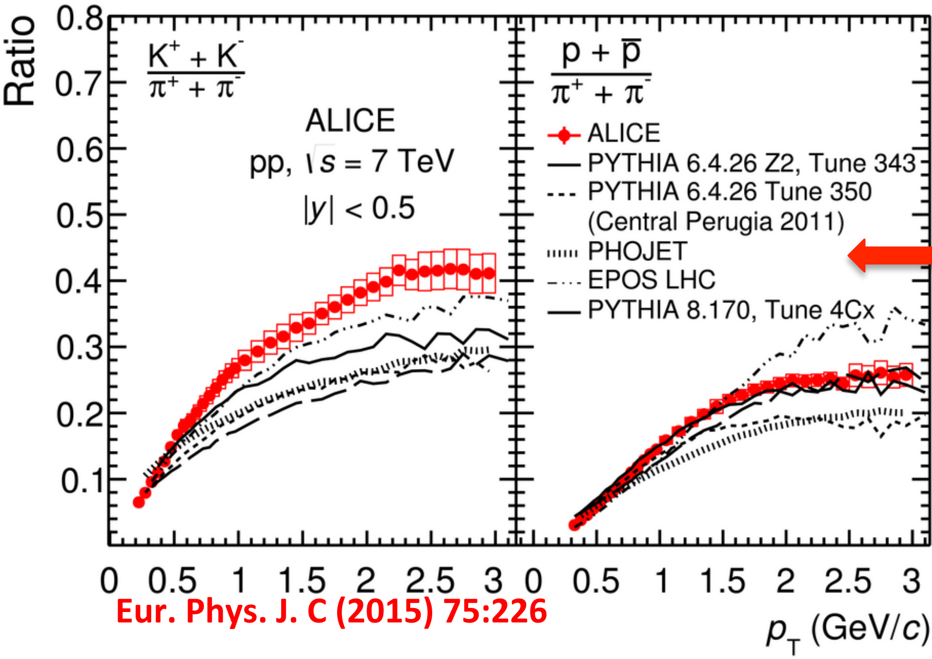
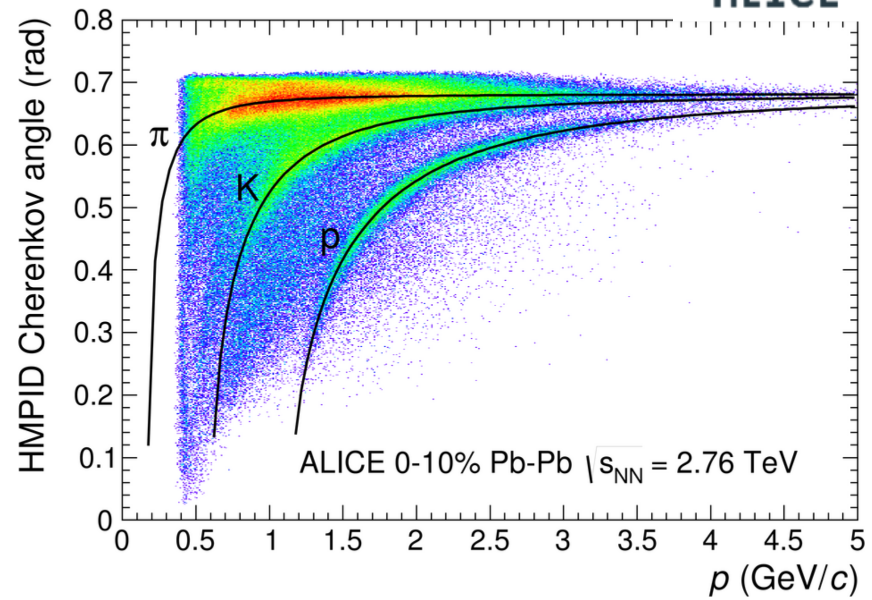


Eur. Phys. J. C (2015) 75:226

- $(K^+ + K^-)/(\pi^+ + \pi^-)$ and $(p + p)/(\pi^+ + \pi^-)$ ratios as a function of p_T compared with some event generators.
- $(K^+ + K^-)/(\pi^+ + \pi^-)$ ratio increases from 0.05 at p_T = 0.2 GeV/c up to 0.45 at p_T ~ 3 GeV/c with a slope that decreases with increasing p_T.

Charged hadrons spectra: Pb-Pb 2.76 ATeV

Performance

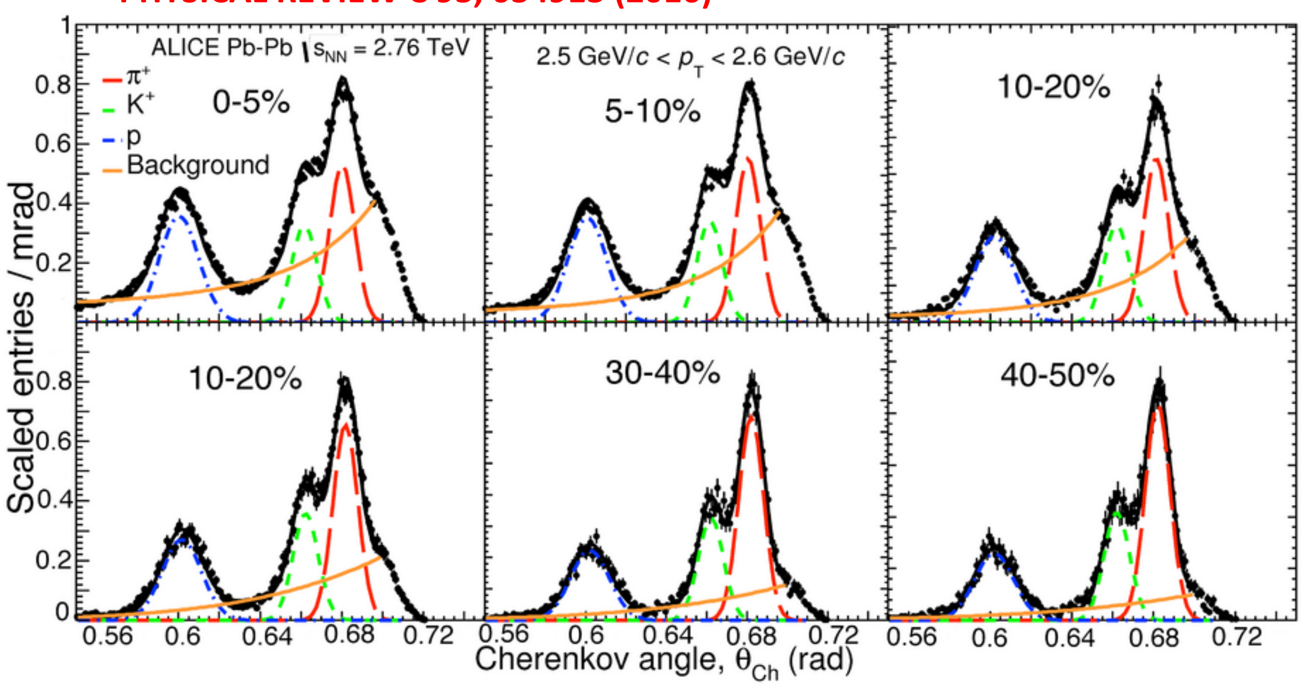


PID range

π/K → 1.5 – 4 GeV/c

p→1.5 – 6 GeV/c

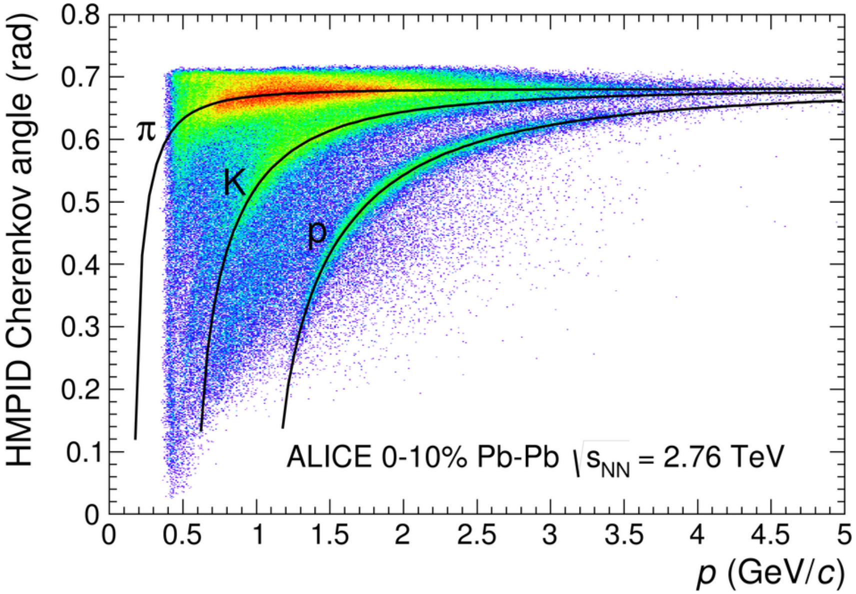
PHYSICAL REVIEW C 93, 034913 (2016)



- HMPID used in collisions centrality range 0-50%
- Centrality estimate based on V0 detector measurements.
- V0: trigger detector at forward rapidity.

Charged hadrons spectra: Pb-Pb 2.76 ATeV

Performance



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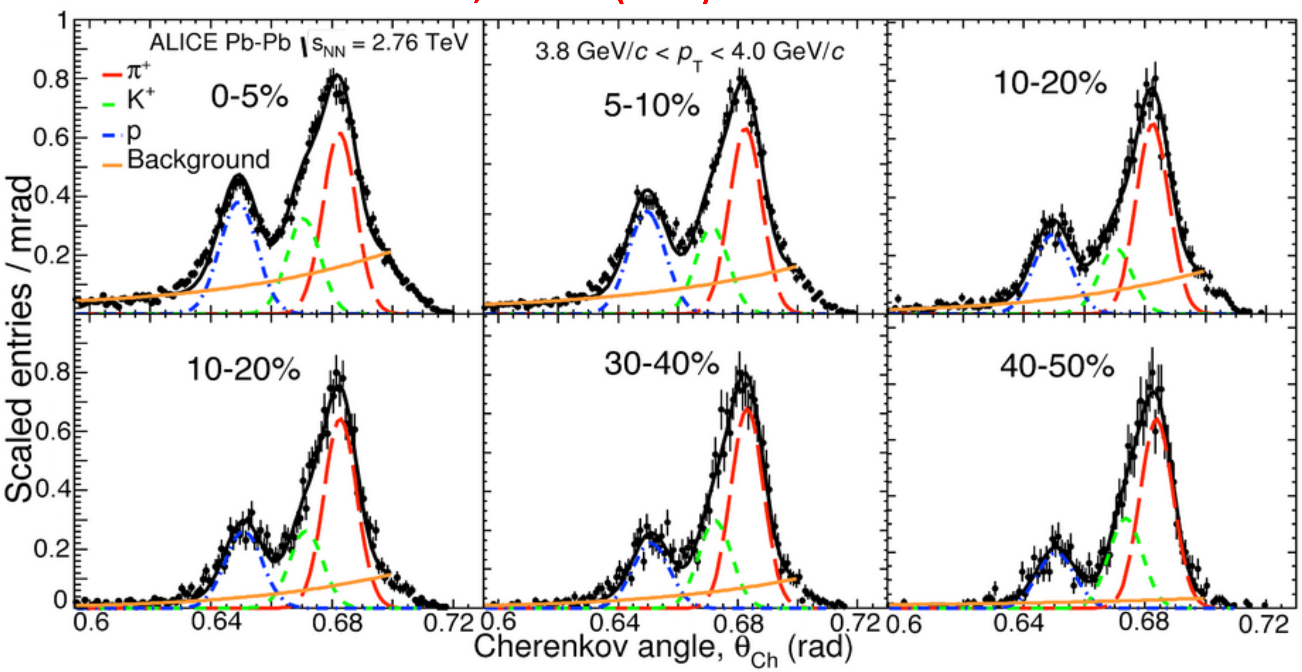
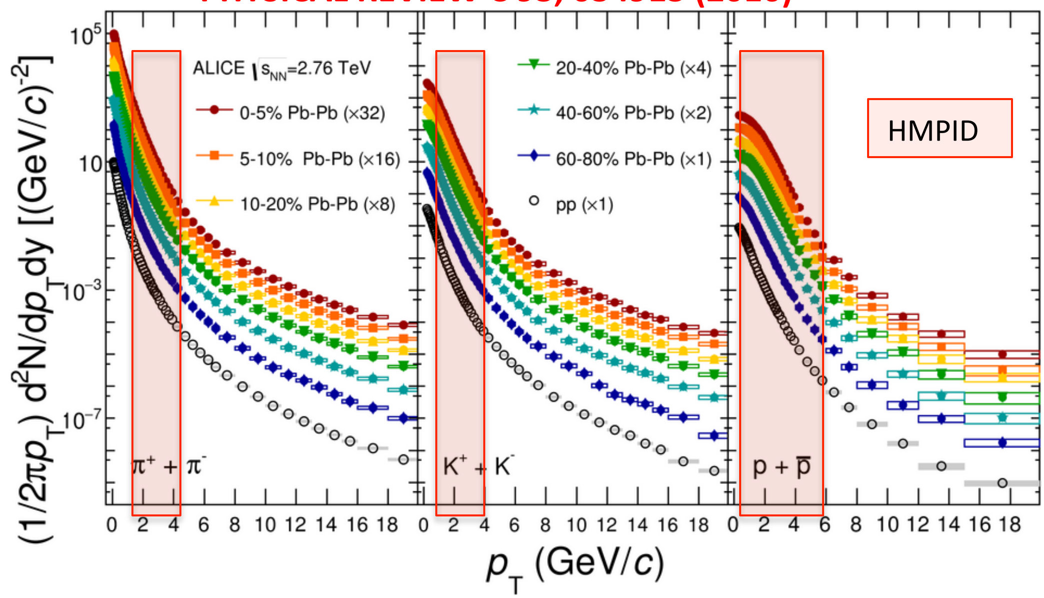


- HMPID used in collisions centrality range 0-50%
- Centrality estimate based on V0 detector measurements.
- V0: trigger detector at forward rapidity.

Charged hadrons spectra: Pb-Pb 2.76 ATeV

- For $p_T < 3$ GeV/c a hardening of the spectra is observed going from peripheral to central events. This effect is mass dependent and is characteristic of hydrodynamic flow.
- For high p_T (>10 GeV/c) the spectra follow a power law shape as expected from pQCD.

PHYSICAL REVIEW C 93, 034913 (2016)



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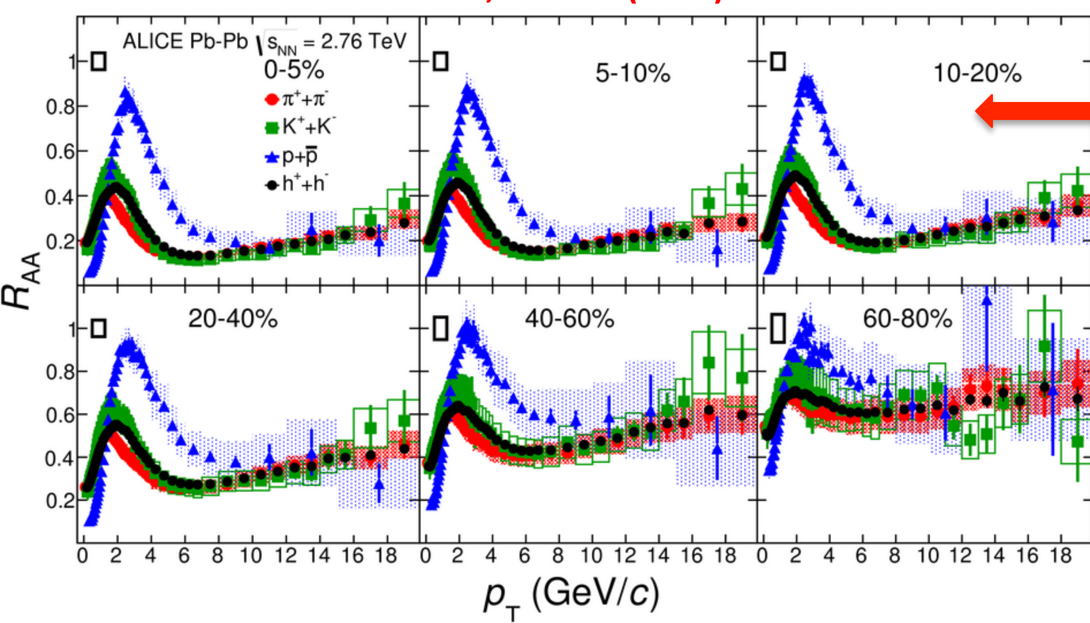


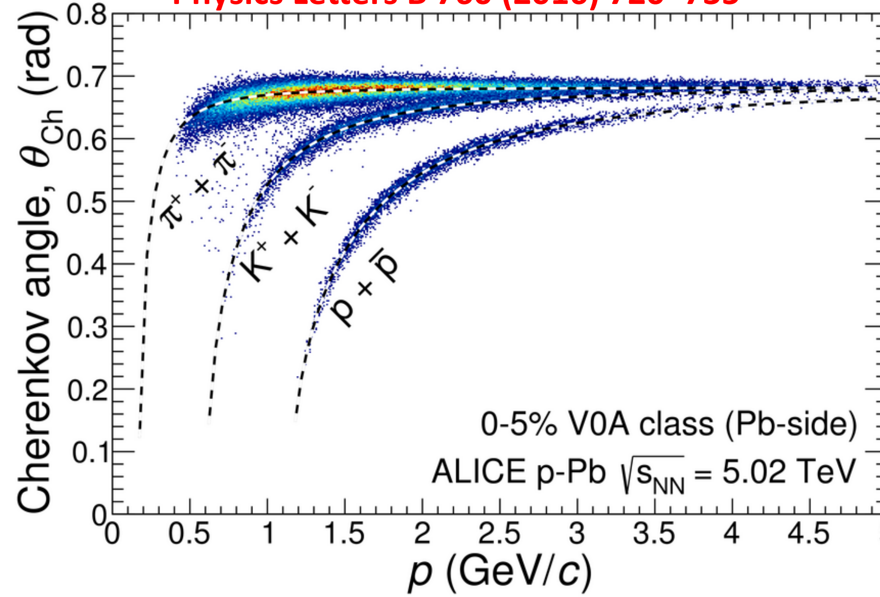
$$R_{AA} = \frac{d^2N^{AA}_{\rm id}/dy\,dp_{\rm T}}{\langle T_{AA}\rangle d^2\sigma^{\rm pp}_{\rm id}/dy\,dp_{\rm T}}$$

- For $p_T <\approx 8 - 10$ GeV/c: R_{AA} for π and K are compatible and are smaller than R_{AA} for p.
- At high p_T: R_{AA} for π, K and p are compatible.

Charged hadrons spectra: p-Pb 5.02 TeV

Performance

Physics Letters B 760 (2016) 720–735

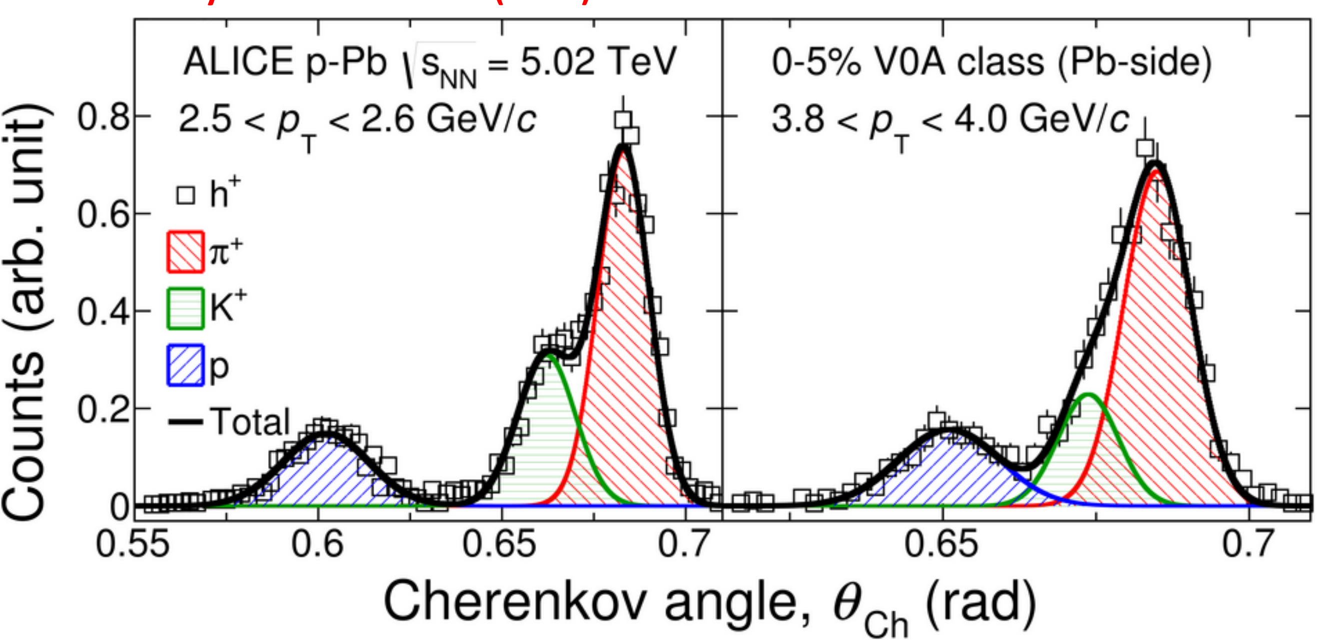


PID range

π, K: 1.5 – 4 GeV/c

p: 1.5 – 6 GeV/c

Physics Letters B 760 (2016) 720–735

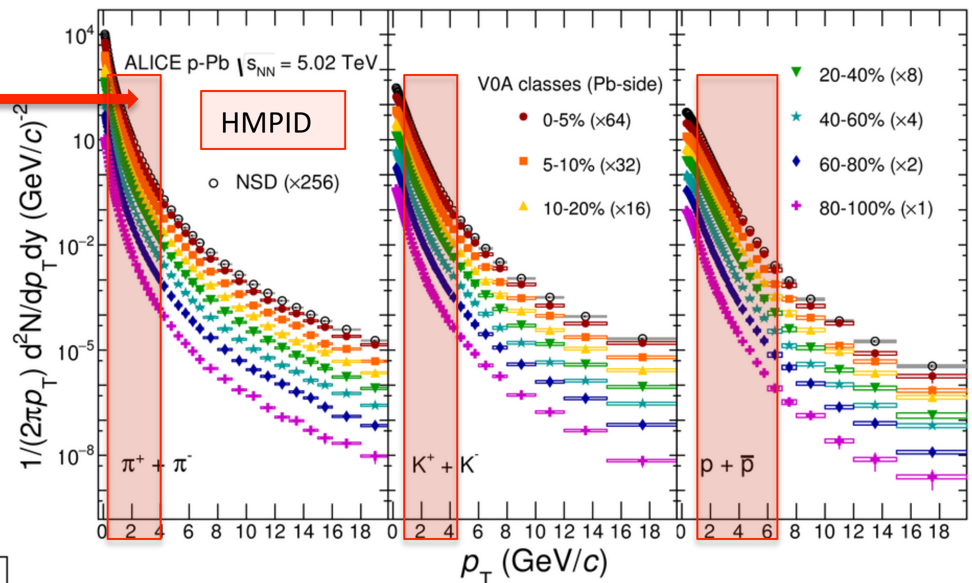


- HMPID used in collisions multiplicity range: 0 – 100 %
- multiplicity estimate based on V0 detector measurements.

Charged hadrons spectra: p-Pb 5.02 TeV

Physics Letters B 760 (2016) 720–735

- Hardening with multiplicity and particle mass
- Reminiscent of observed effects in Pb-Pb Attributed to radial flow/recombination (Indication for collective effects in p-Pb?!)



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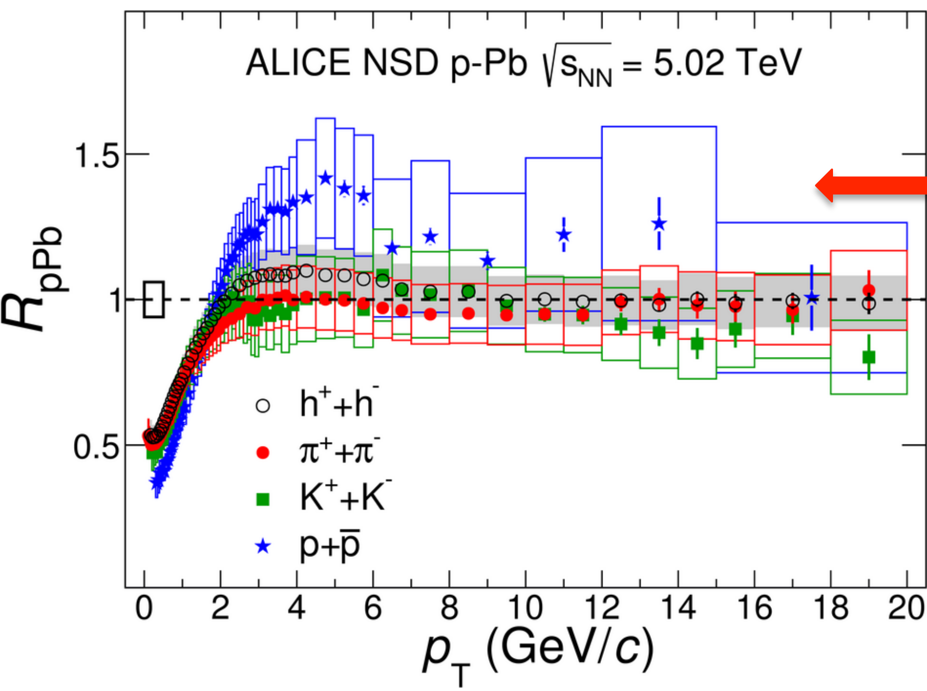
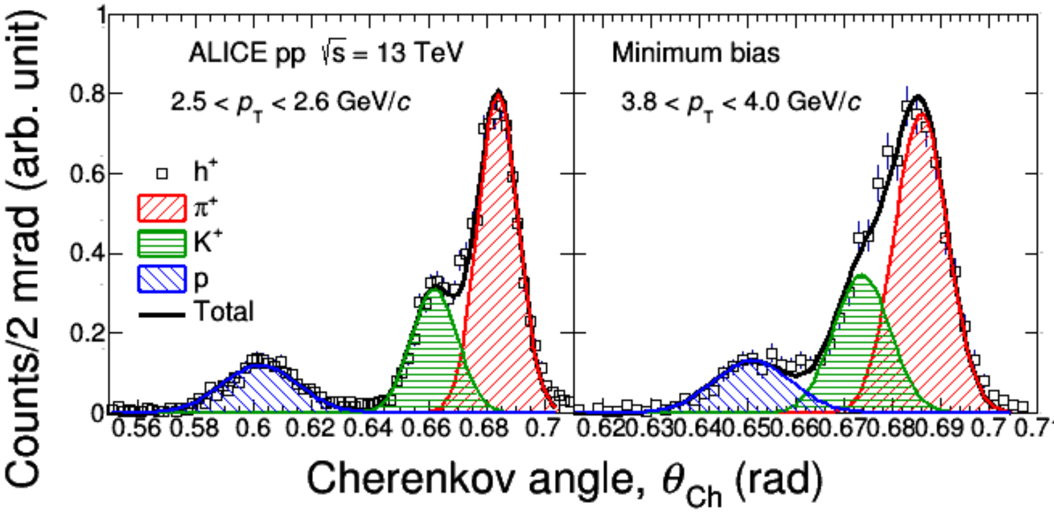


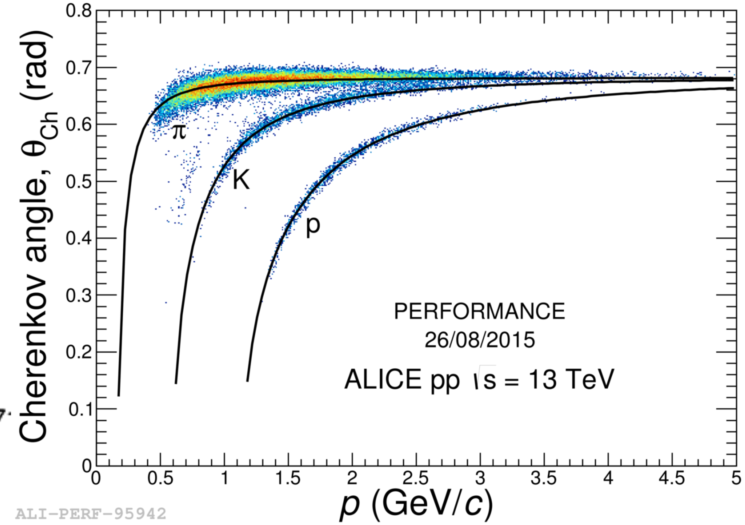
$$R_{pPb} = \frac{d^2N_{pPb}/dy\,dp_T}{\langle T_{pPb}\rangle d^2\sigma_{pp}^{INEL}/dy\,dp_T}$$

- Protons show peak at intermediate p_T
- R_{pPb} of π and K not show peak and flat above 2 GeV/c
- mass ordering in the Cronin peak, strong enhancement of protons
- no suppression at high p_T (> 8-10 GeV/c)

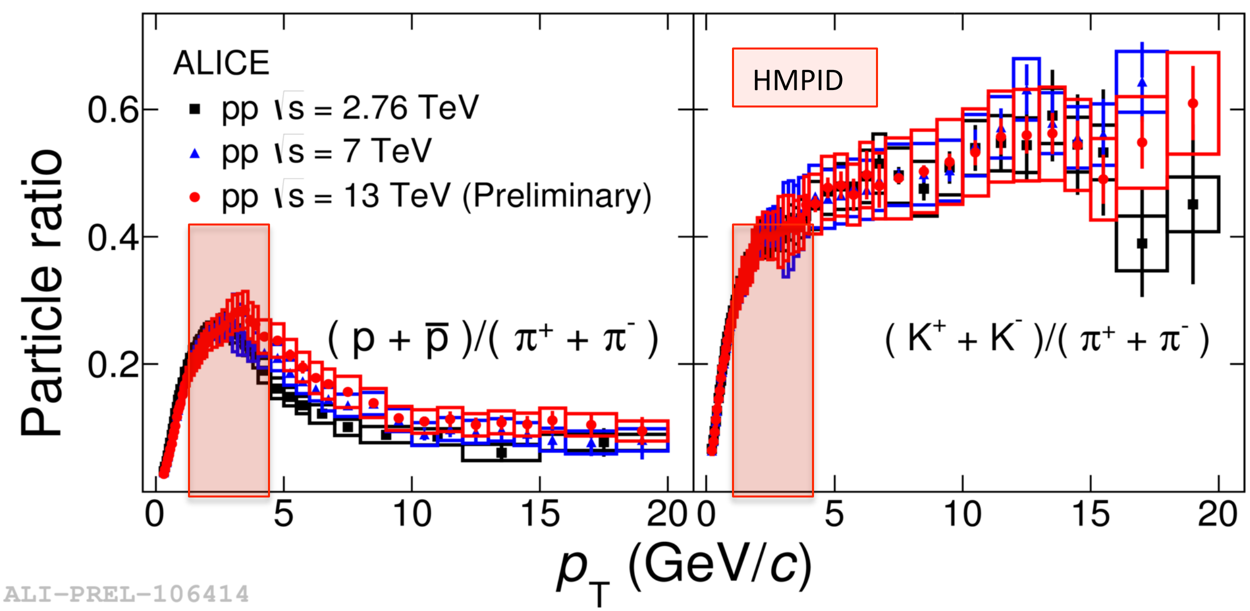
Charged hadrons spectra: pp 13 TeV

Performance





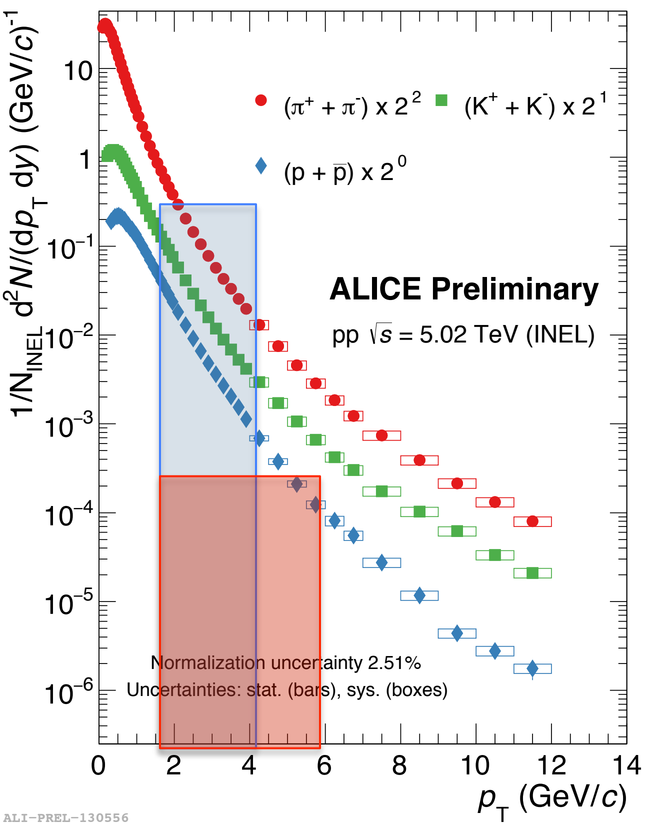
Results



- **p/π ratio** shift towards higher p_T for higher $\sqrt{s}$
- **K/π ratio** no significant modifications

Charged hadrons spectra: pp 5.02 TeV

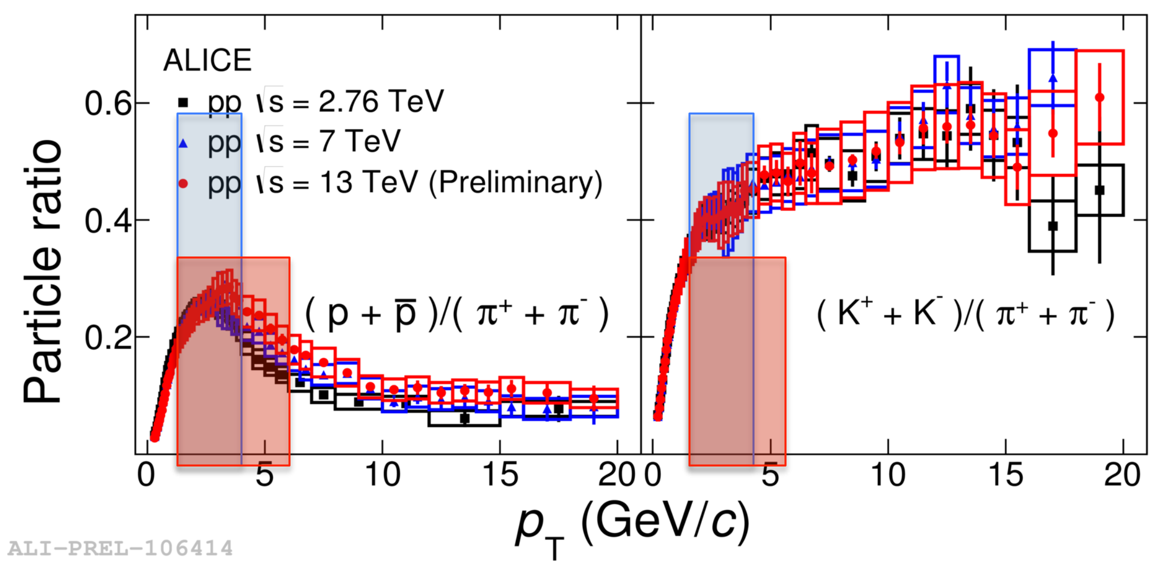
p_T spectra in pp at 5.02 TeV



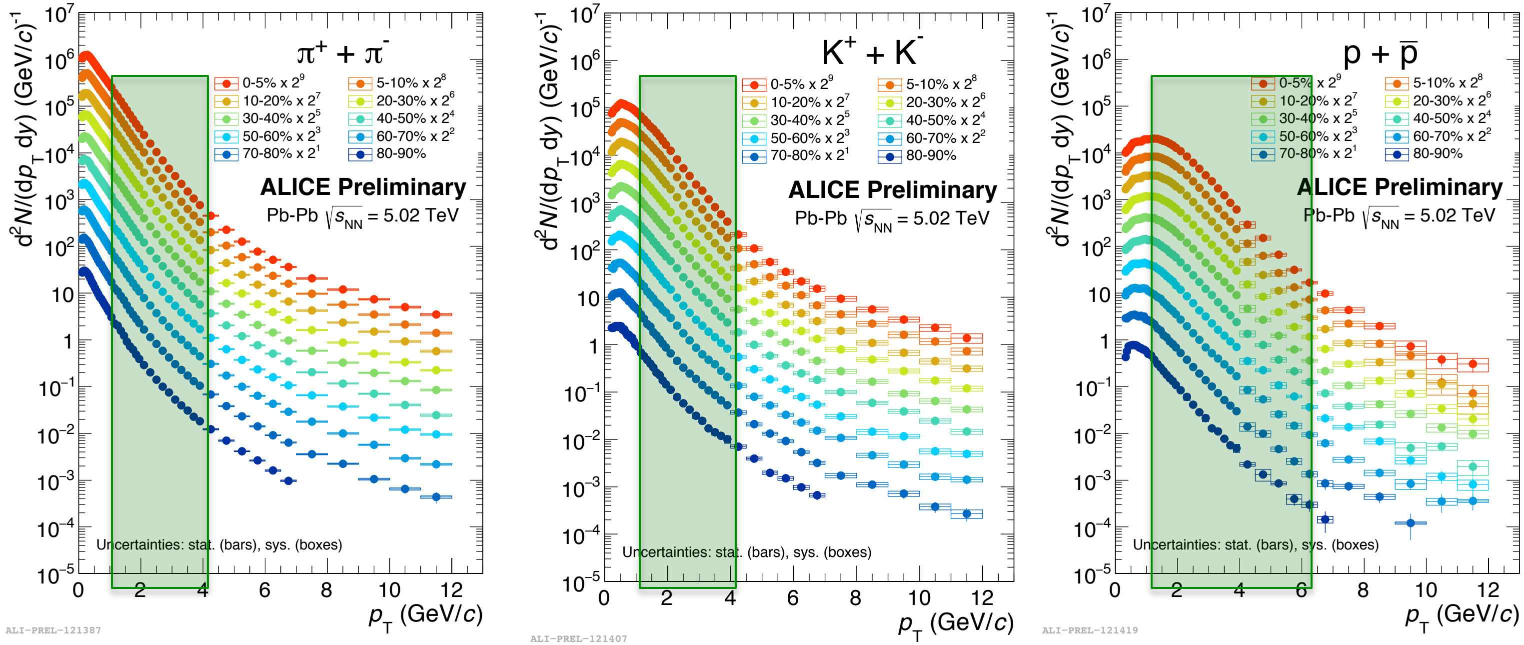
π-K HMPID

(anti-)p HMPID

Particle ratios vs p_T in pp at 13 TeV

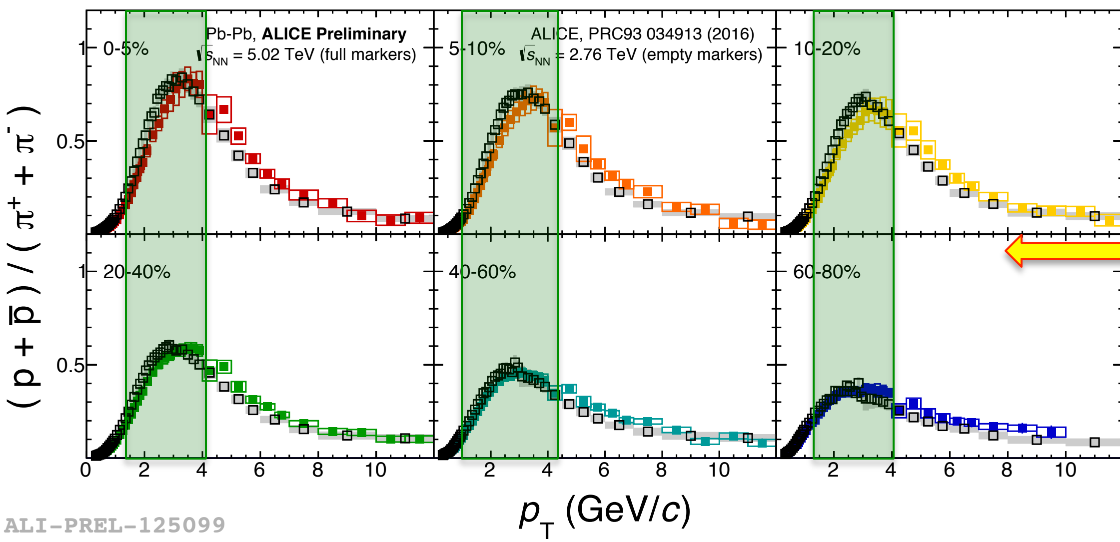


Charged hadrons spectra: Pb-Pb 5.02 TeV



HMPID

p_T spectra in Pb-Pb at 5.02 ATeV



proton/pion ratio

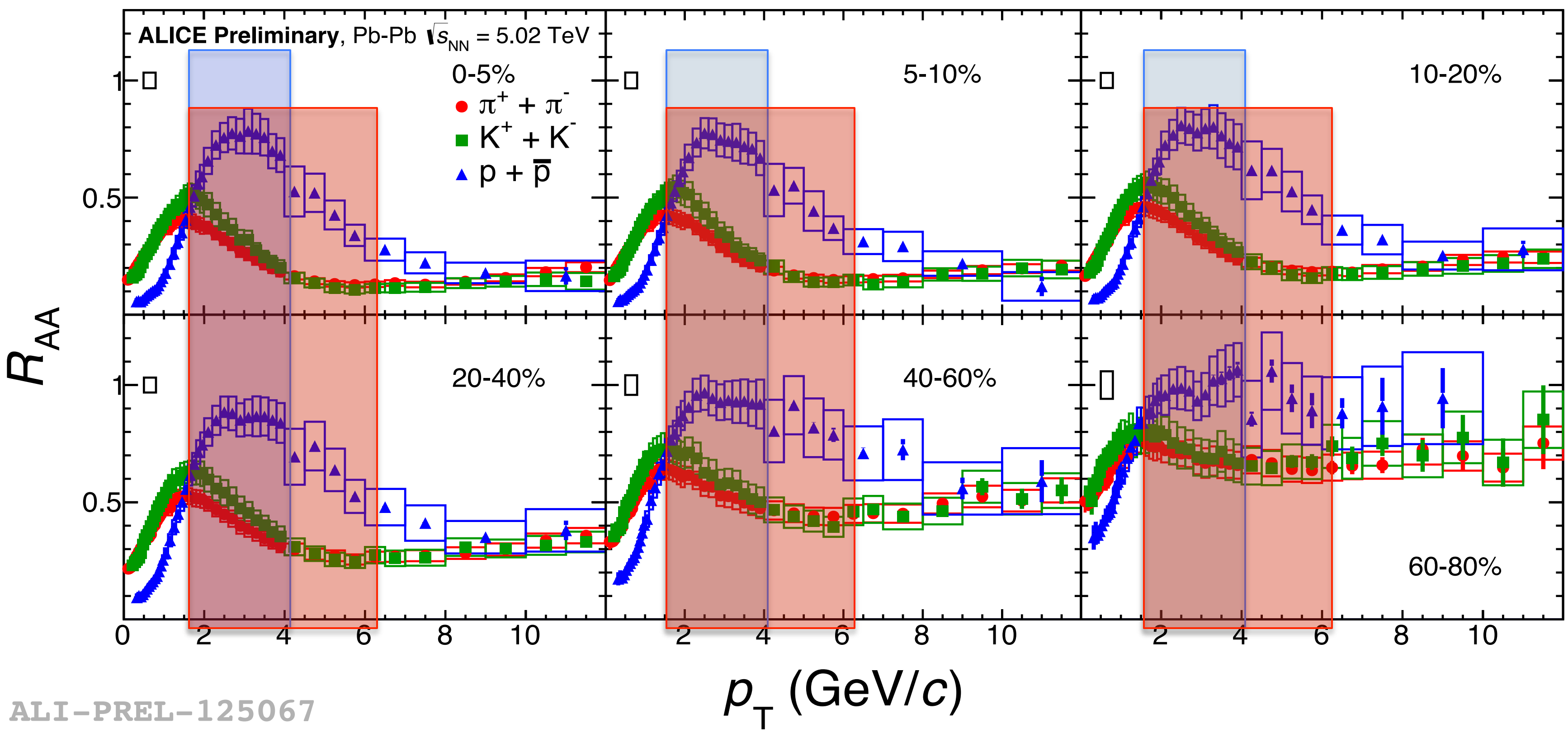
Charged hadrons spectra: Pb-Pb 5.02 TeV

Nuclear modification factor in Pb-Pb collisions at 5.02 ATeV

$$R_{AA} = \frac{d^2N_{\rm id}^{AA}/dy\,dp_{\rm T}}{\langle T_{AA}\rangle d^2\sigma_{\rm id}^{\rm pp}/dy\,dp_{\rm T}}$$

π-K HMPID

(anti-)p HMPID

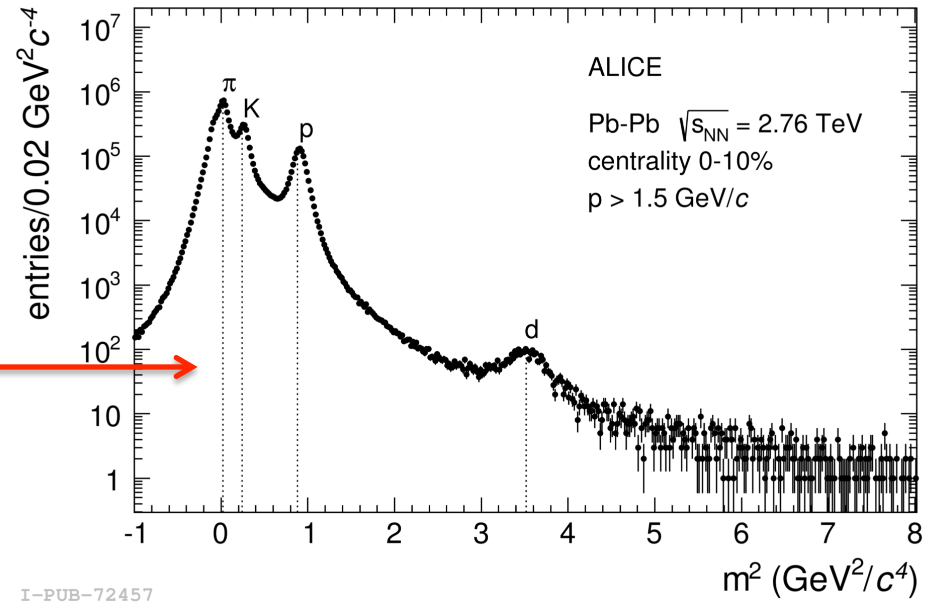


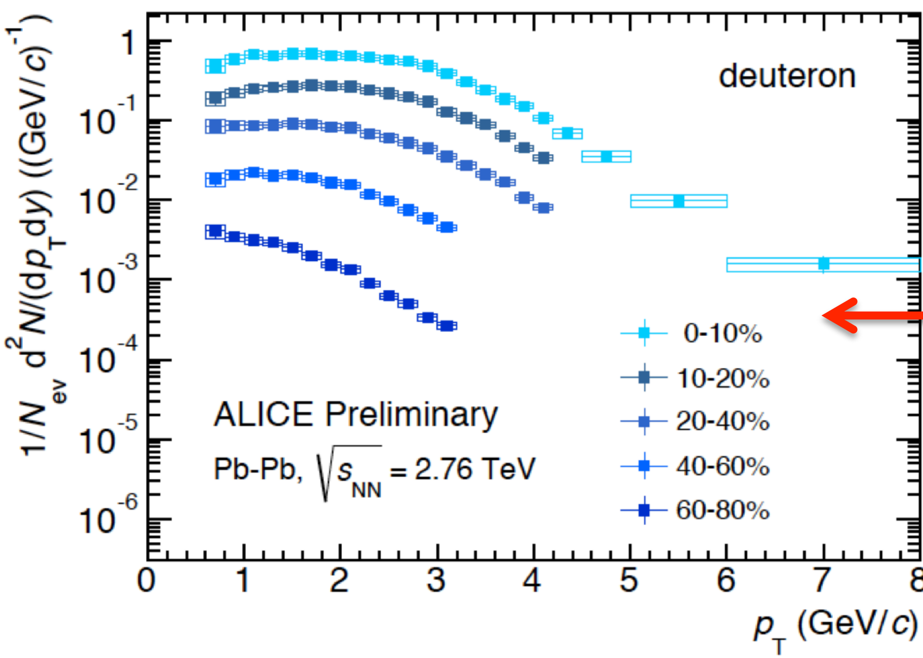
Deuteron identification in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV

Deuterons yield is not enough to allow measurements in HMPID but in central (0-10%) Pb-Pb collisions, by means of statistical unfolding on the mass distribution (not on Cherenkov angle one!)

$$m^2 = p^2(n^2\cos^2\theta_{ckov} - 1)$$

n = refractive index





I-PUB-72457

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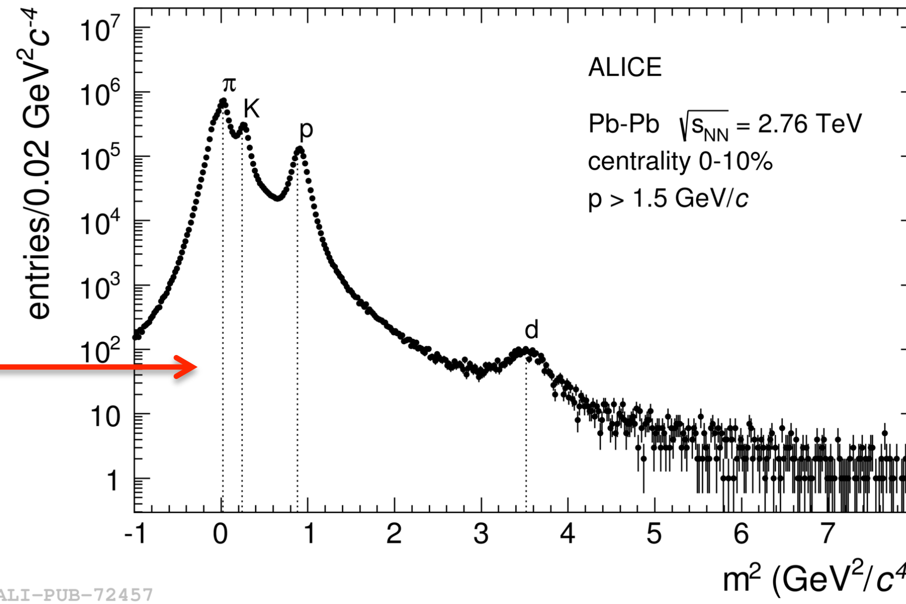
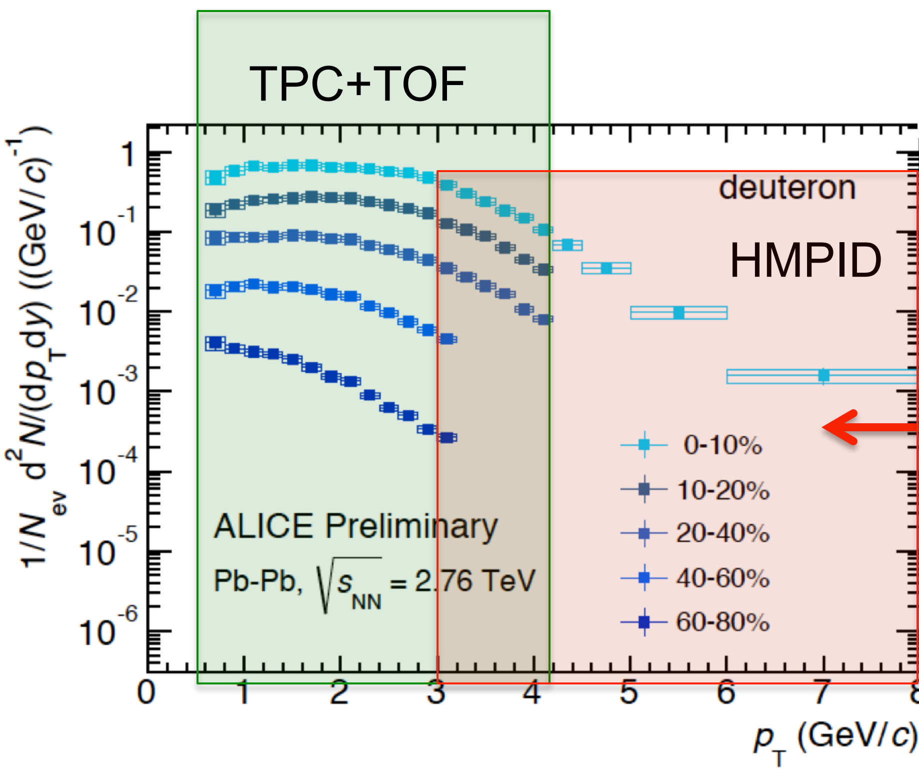


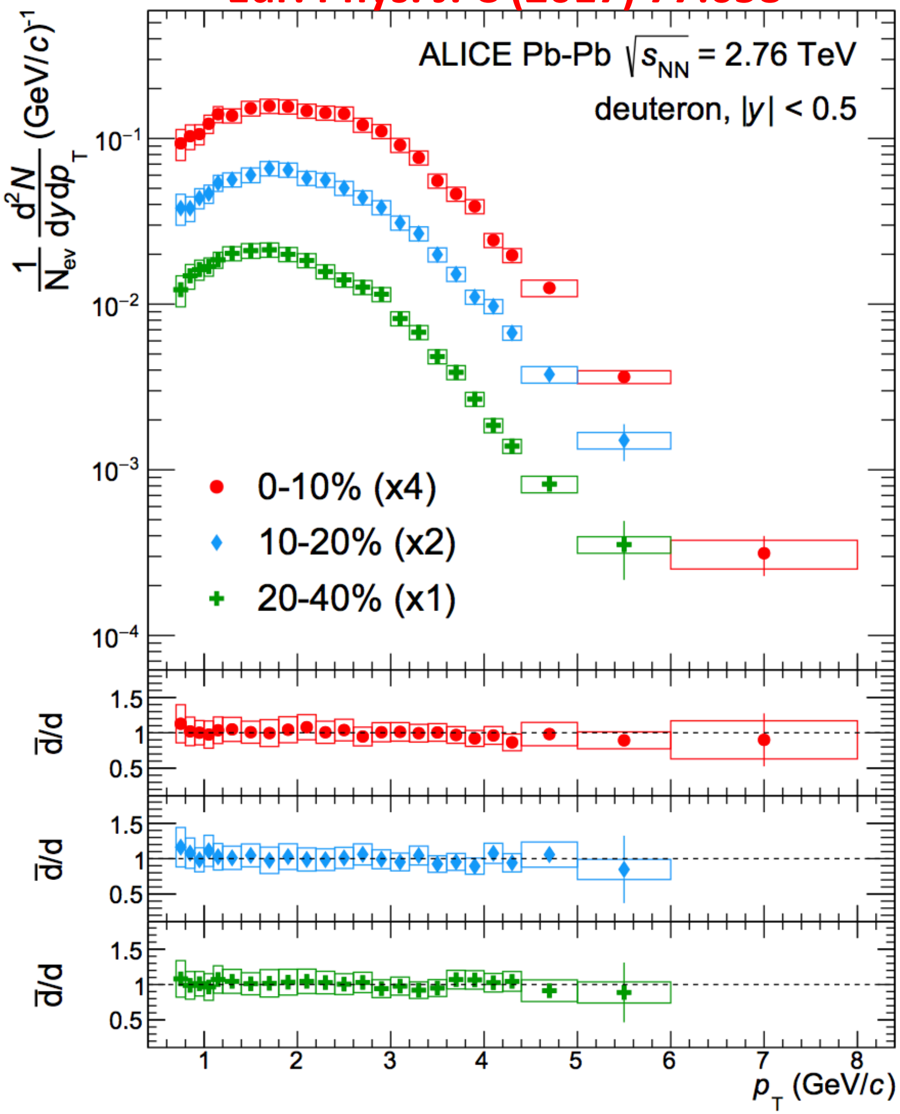


Deuteron spectra in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV

Good matching with TPC+TOF measurements!

Deuteron identification in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV

Eur. Phys. J. C (2017) 77:658



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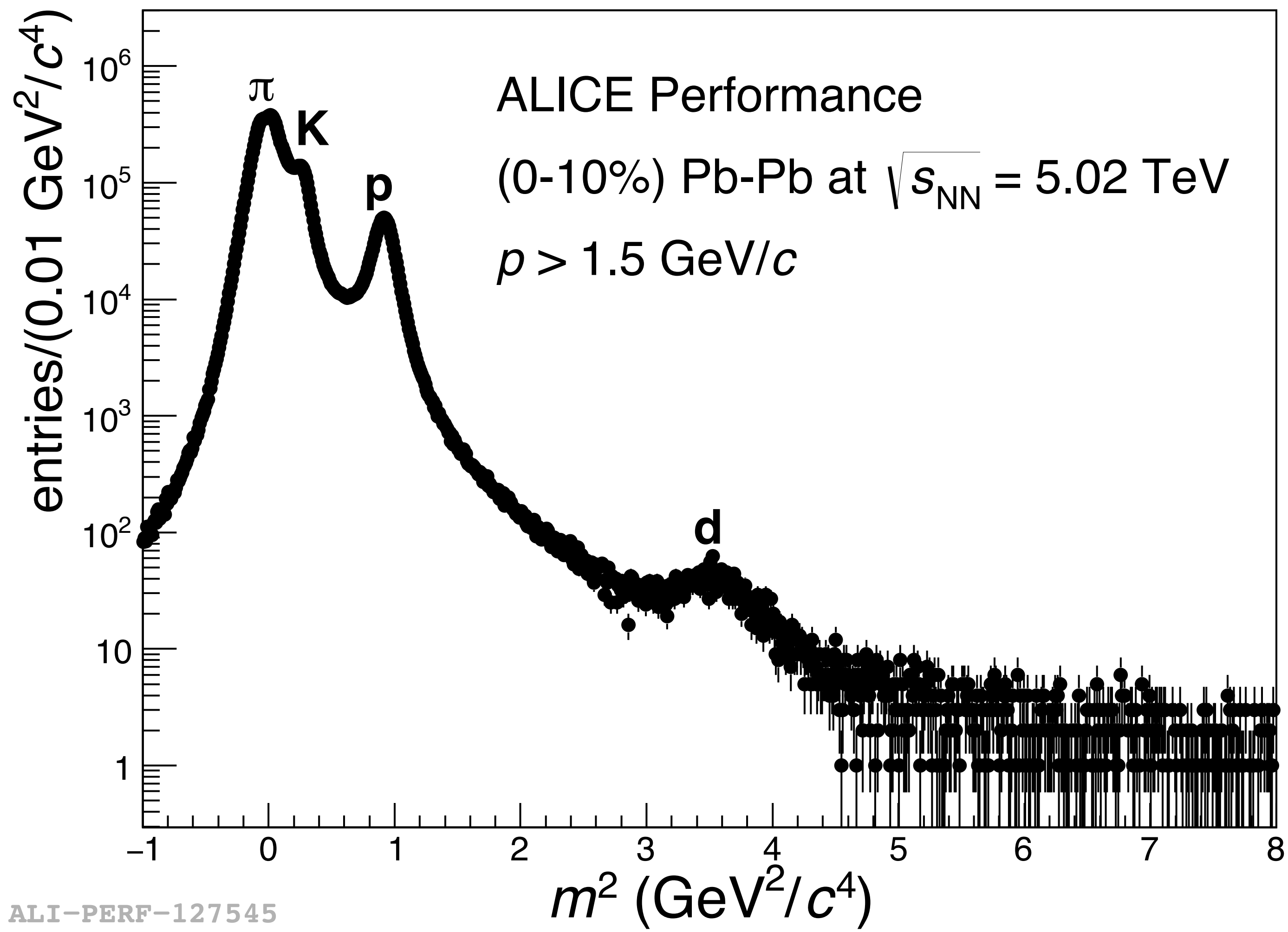
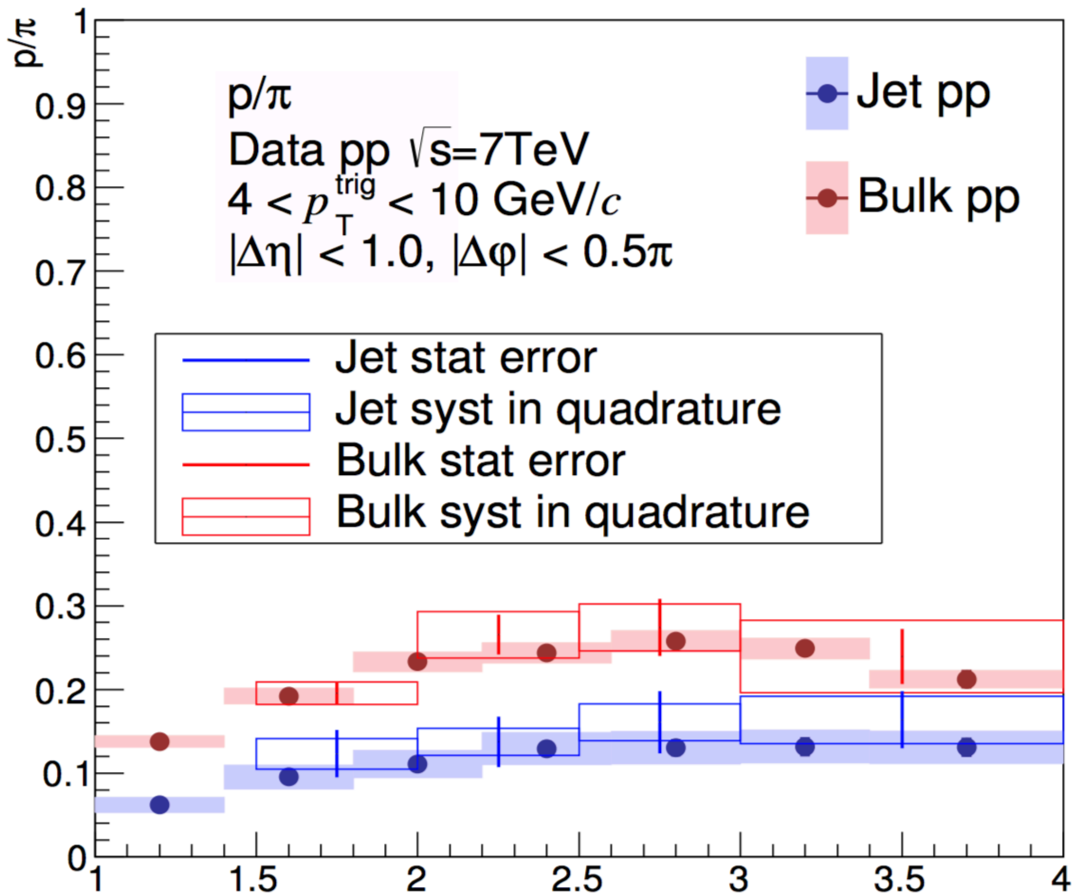


Identified particles correlation study

- In pp collisions at 7 TeV, identified particle correlation study has been performed, correlating one trigger particle in the full TPC acceptance with one identified in the HMPID acceptance.
- In this way the p/p ratio in the bulk and in the jets has been evaluated



Pattern recognition performance

- A primary track extrapolated from the internal tracking devices has to match with a MIP cluster. This is mandatory for an efficient reconstruction in events with high occupancy in the HMPID
- For each cluster in the event, the Cherenkov angle is evaluated (if exists).

impact track parameter

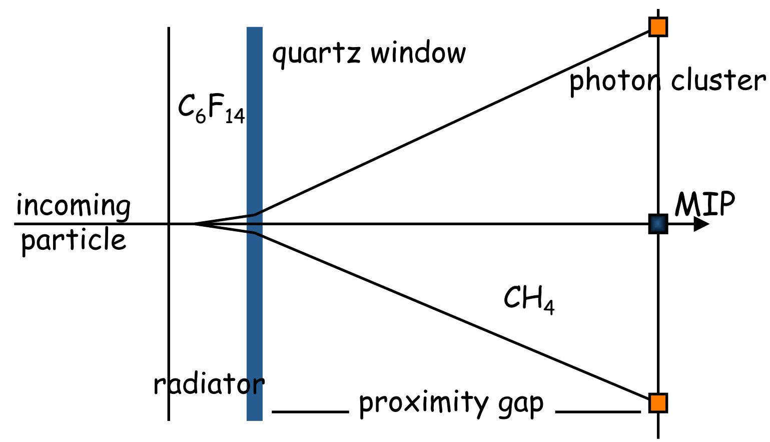
$$(x,y) \rightarrow ((x_p,y_p,\theta_p,\varphi_p), \eta_c)$$

cluster coordinate

Cherenkov angle

$\Downarrow$

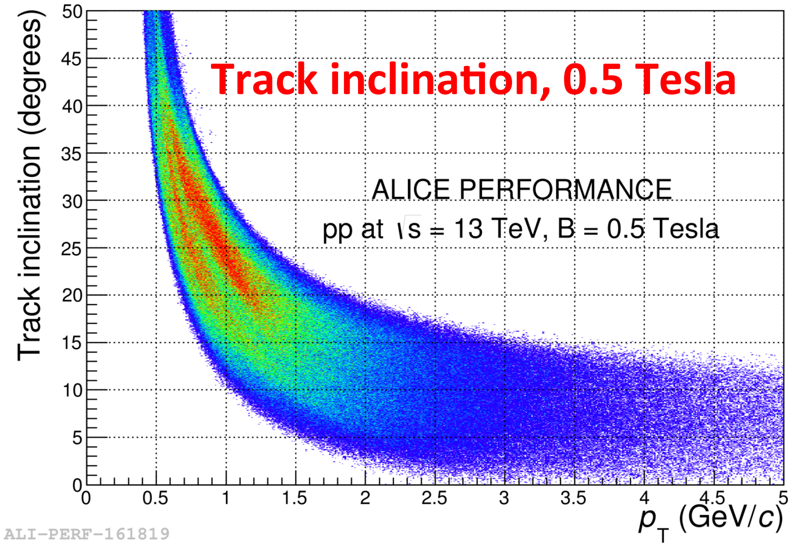
solution in one dimensional mapping space η_c

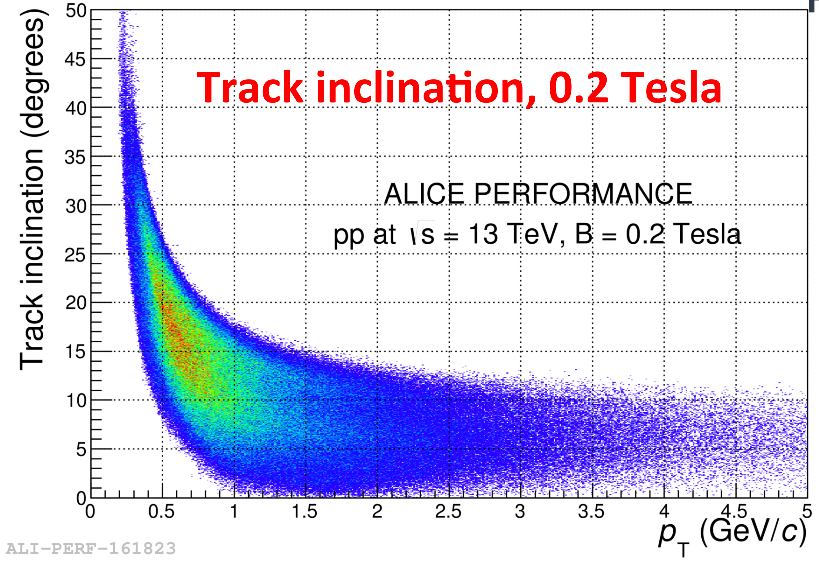


The pattern recognition (based on Hough Transform) tends to find the "best" pattern (according to the impact track parameter) with the highest number of photon candidates

- The pattern recognition efficiency depends on the chamber occupancy (event multiplicity) and track inclination (magnetic field intensity).

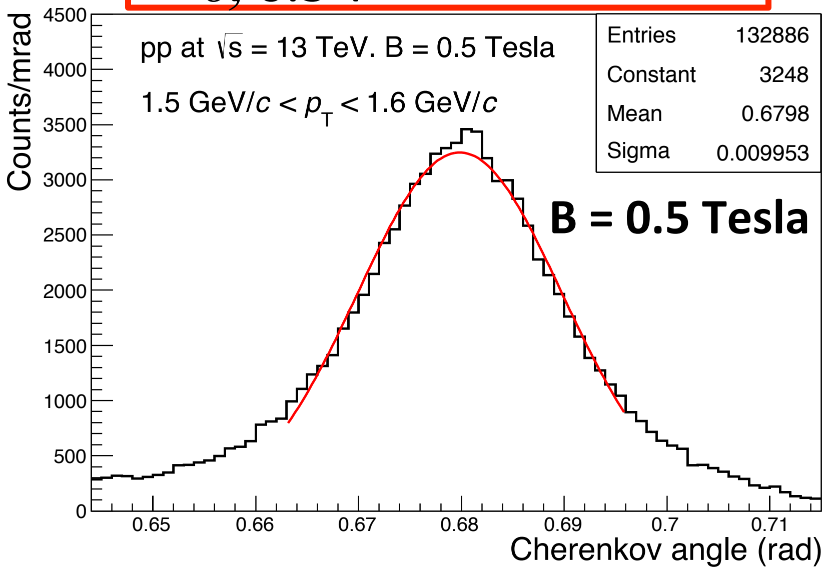
Low multiplicity events: B = 0.2 and 0.5 Tesla comparison

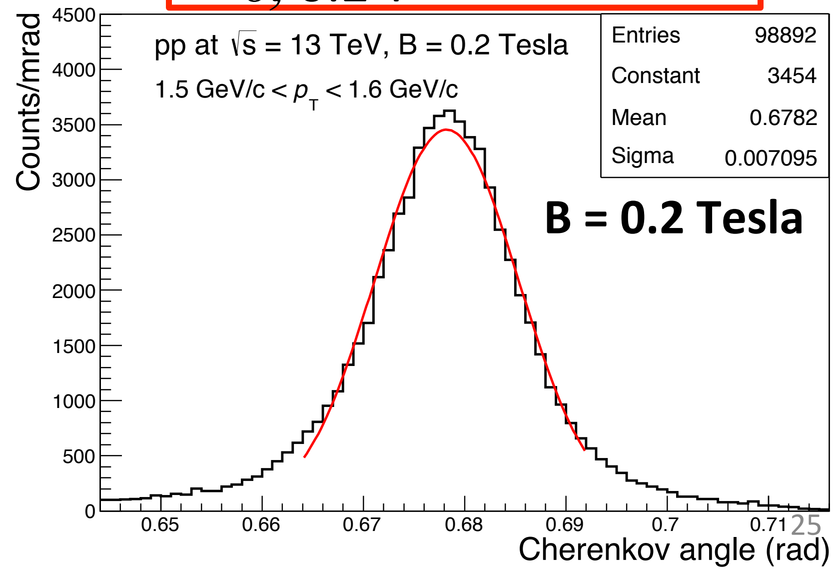




$\sigma_{\theta,\,0.5\,\mathrm{T}} \approx 10$ mrad

$\sigma_{\theta,\,0.2\,\mathrm{T}} \approx 7$ mrad

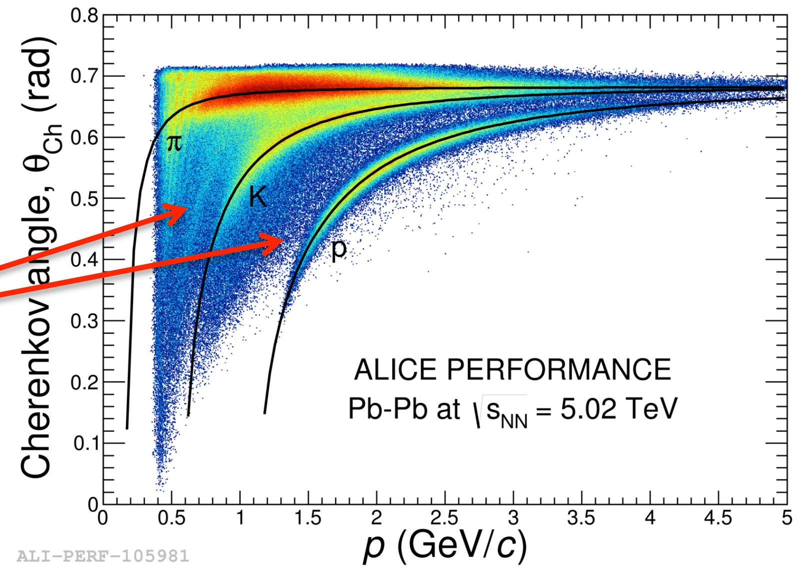


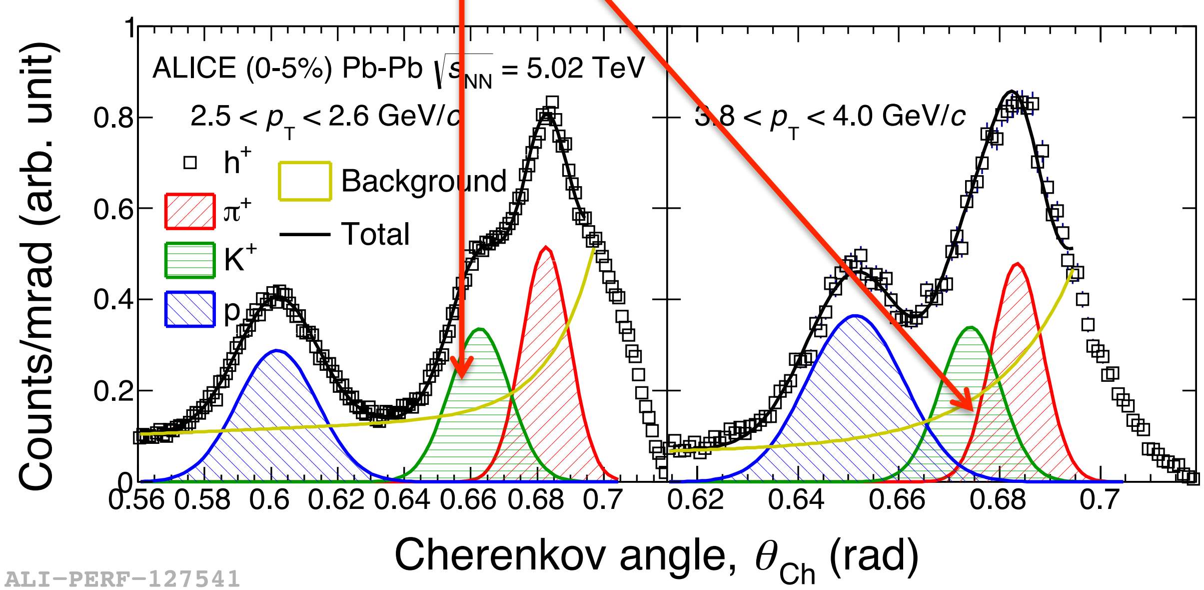


High multiplicity events, B = 0.5 Tesla

Pb-Pb at 5.02 ATeV

Mis–identified tracks (background)





background distribution increases with the Cherenkov angle value;

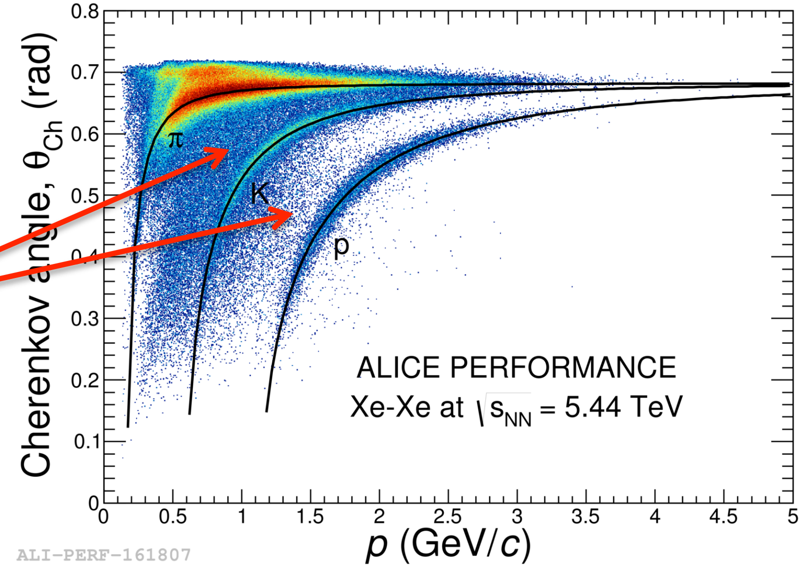
It is due to mis-identification in the high occupancy events:

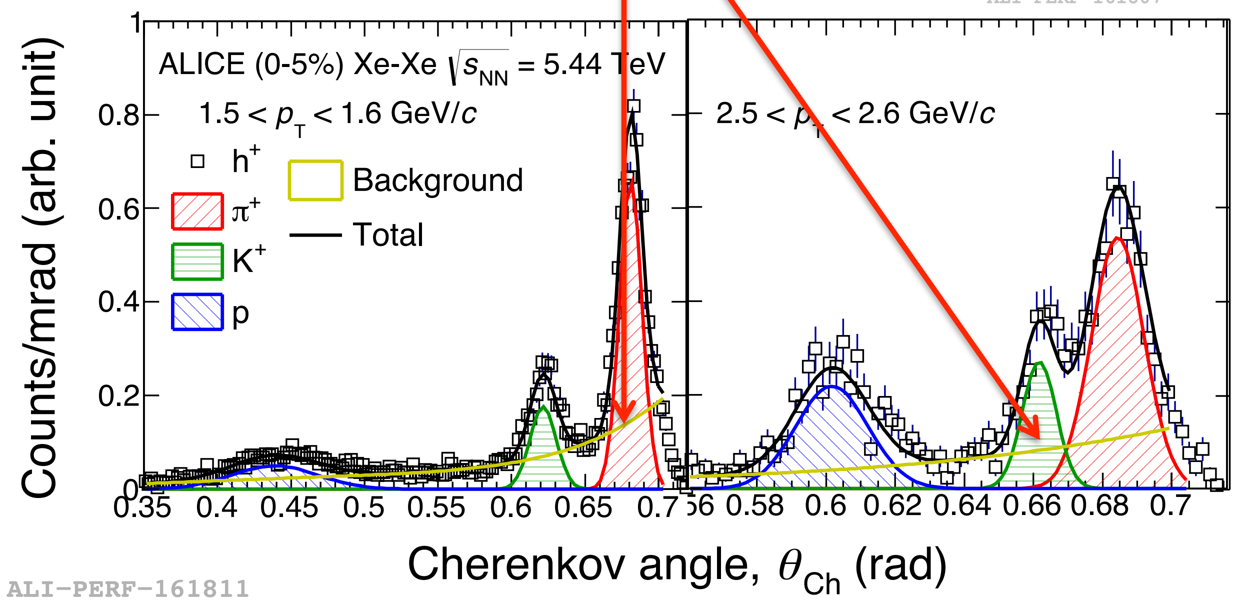
- larger is the angle value larger is the probability to find background.

High multiplicity events, B = 0.2 Tesla

Xe-Xe at 5.02 ATeV

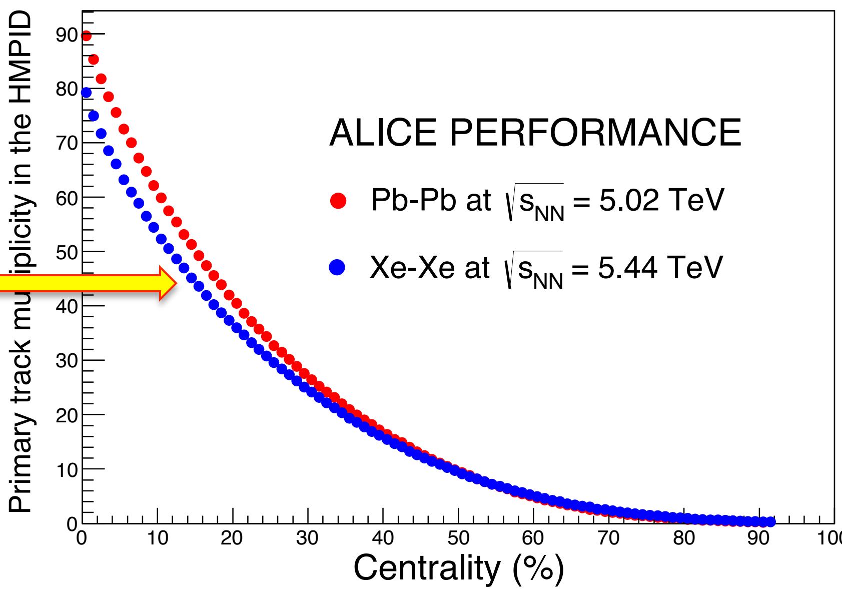
Mis–identified tracks (background)

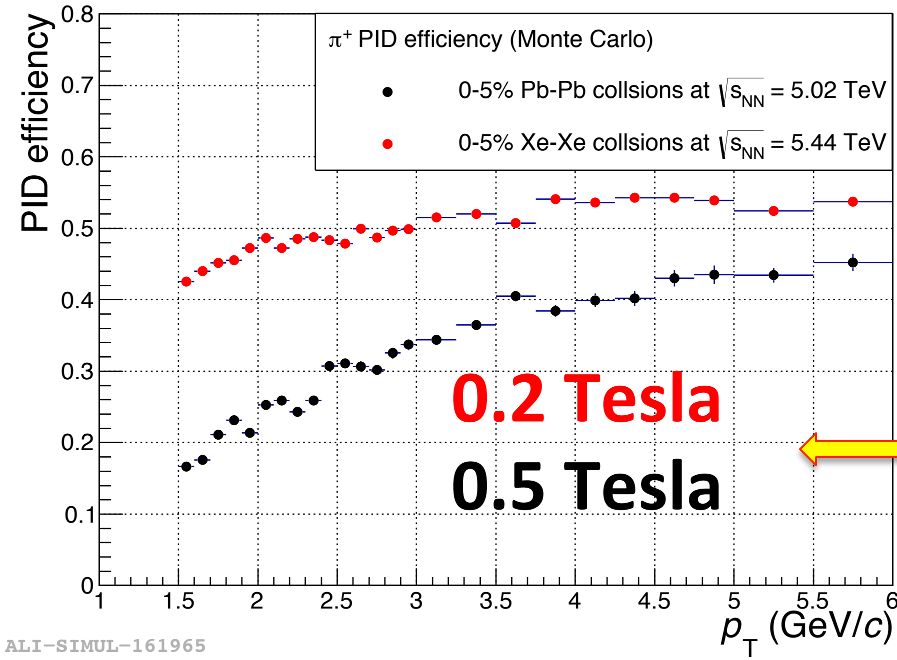




High multiplicity events: B = 0.2 and 0.5 Tesla comparison

Primary track multiplicity in the HMPID acceptance





PID *efficiency*

$$\varepsilon_{\mathrm{PID}} = \frac{N(\text{signal})}{N(\text{signal and background})}$$

ALICE papers with HMPID measurements contribution

- Production of charged pions, kaons and protons at large transverse momenta in pp and Pb-Pb collisions at sqrt(s_(NN)) = 2.76 TeV
  - publication link: http://www.sciencedirect.com/science/article/pii/S0370269314004973

- Measurement of pion, kaon and proton production in proton-proton collisions at sqrt(s) = 7 TeV
  - publication link: 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
  - Publication link: 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
  - publication link: http://www.sciencedirect.com/science/article/pii/S0370269316303914 .

ALICE papers with HMPID measurements contribution

- Measurement of deuteron spectra and elliptic flow in Pb-Pb collisions at √sNN = 2.76 TeV at the LHC
  - publication link: https://link.springer.com/article/10.1140%2Fepjc%2Fs10052-017-5222-x

- Measurement of π, K and p yield associated with a high-p_T trigger particle in pp, p-Pb and Pb-Pb
  - publication link: IN PROGRESS?

- Production of light flavor hadrons in pp collisions at √s = 13 TeV at the LHC
  - publication link: IN PROGRESS

- Production of π,K,p in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV
  - publication link: IN PROGRESS.

HMPID integration in RUN3

HMPID integration in O^2 framework

Introduction

- The HMPID detector will be not upgraded/modified for RUN3
  - Only firmware upgrade is foreseen to increase the read-out rate

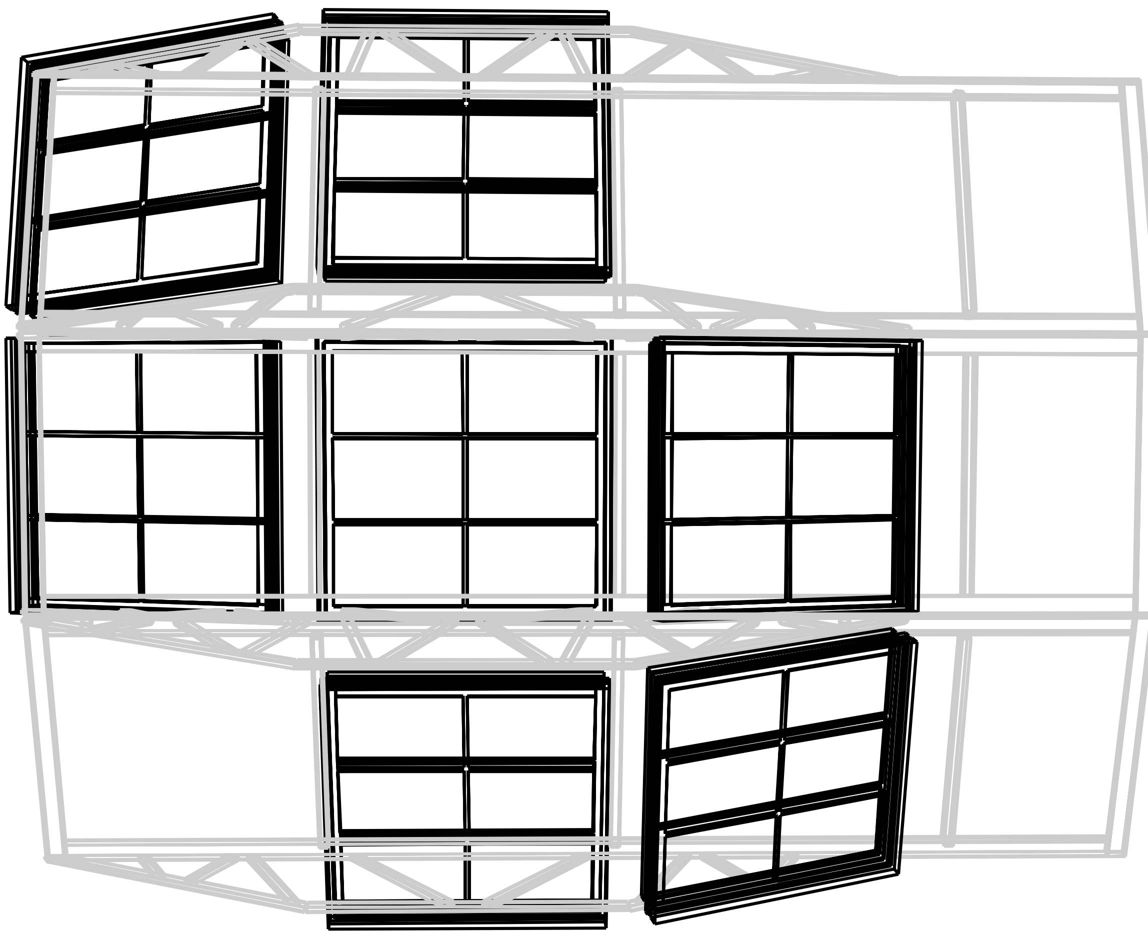
- The current AliRoot simulation, reconstruction and calibration code has to be can be migrated to the new framework

HMPID simulation in O^2

HMPID Geometry in O^2

- Geometry implemented and committed

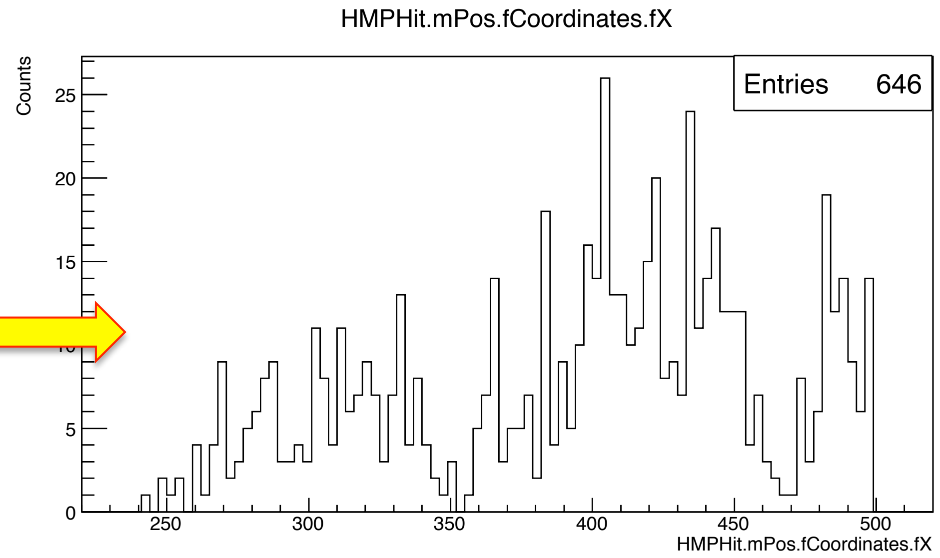
Chambers + cradle

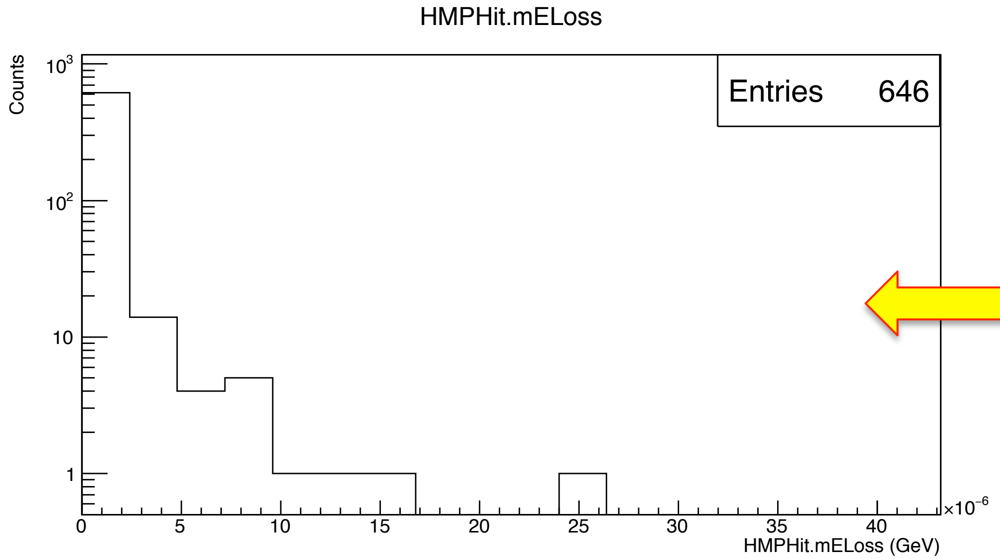


HMPID simulation in O^2

Implemented and committed definition of the **HMPID hit**

Hits X coordinates





Hits energy

HMPID simulation in O^2

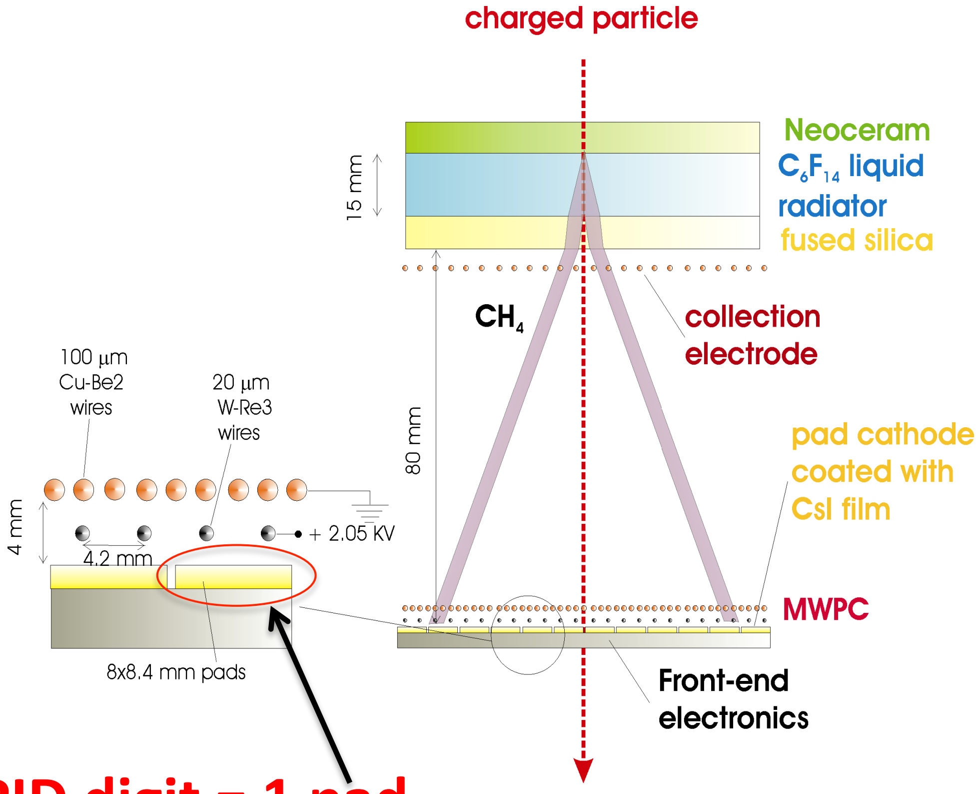
Basic HMPID digitizer workflow

Basic DPL digitizer workflow for the HMPID implemented and committed:

- rudimentary digits and first conversion from hits
- Digitizer class
- DPL components for digitization

The following steps need to be done:

- Complete the hits → digits conversion
  - consider cross talk (hit influencing multiple pads)
  - implement digit pileup + zero suppression
- finish IO of digits
- add treatment of MC labels



1 HMPID digit = 1 pad

HMPID simulation in O^2: schedule

Task	Status	Manpower
Geometry and base classes	**DONE**	G. Volpe
Hits creation	**DONE**	G. Volpe
Digitization	Started, to be completed → January 2019	G. Volpe
Simulated data compatible with timeframe	March 2019	G. Volpe

HMPID reconstruction in O^2: schedule

Task	To be completed	Manpower
Clusterization (from raw data and Monte Carlo)	May 2019	G. Volpe
Reconstruction (Cherenkov angle calculation from tracks information)	June 2018	G. Volpe
Calibration (chamber gain and refractive index using DCS information)	June/July 2019	G. Volpe

Conclusions

- ALICE successfully collected the pp, p-Pb and Pb-Pb collisions data provided by LHC.
  - Inclusive hadrons spectra are relevant tools to study the properties of the medium created in the high energy collisions

- HMPID detector presented so far optimal PID performance, successfully participating to the ALICE physics program
  - by means of statistical unfolding HMPID data constrains the charged hadrons measurements in the p_T region around 3 GeV/c where other technique present poor capability.
  - Results from LHC RUN1 and RUN2 data has been presented

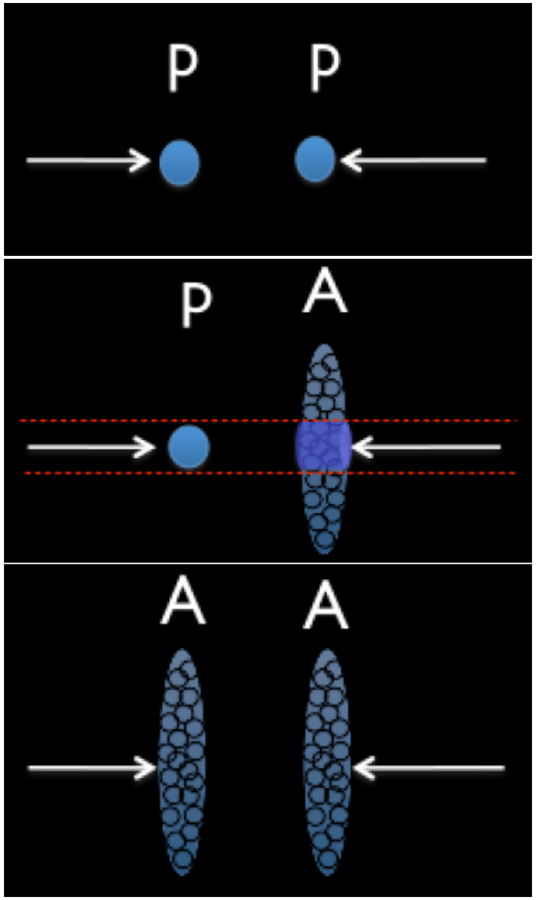
- Track-by-track identification with HMPID is exploited for two particle correlation study to evaluate protons/pions ratio in the bulk and jets

- Implementation of simulation, reconstruction and calibration code in the new O^2 framework is ongoing

Backup

ALICE goal

ALICE is designed to study the physics of strongly interacting matter under extremely high temperature and energy densities to investigate the properties of the quark-gluon plasma.



- Proton-proton collisions:
  - high energy QCD reference.
  - collected pp data at $\sqrt{s}$ = 0.9 TeV, 2.76 TeV, 7 TeV, 8 TeV, 13 TeV (2009, 2010, 2011, 2012, 2016,2016)
- proton-nucleus collisions:
  - initial state/cold nuclear matter.
  - collected p-Pb data at $\sqrt{s_{NN}}$ = 5.02 TeV (2012, 2013)
- nucleus-nucleus collisions:
  - quark-gluon plasma formation!
  - collected Pb-Pb data at $\sqrt{s_{NN}}$ = 2.76 TeV, 5.02 TeV (2010, 2011, 2015)

ALICE has measured the yields of produced charged pions, kaons and protons in a wide momentum range and in several colliding systems.

HMPID performance

•The ALICE-HMPID (**H**igh **M**omentum **P**article **I**dentification **D**etector) performs charged particle track-by-track identification by means of the measurement of the emission angle of Cherenkov radiation and of the momentum information provided by the tracking devices.

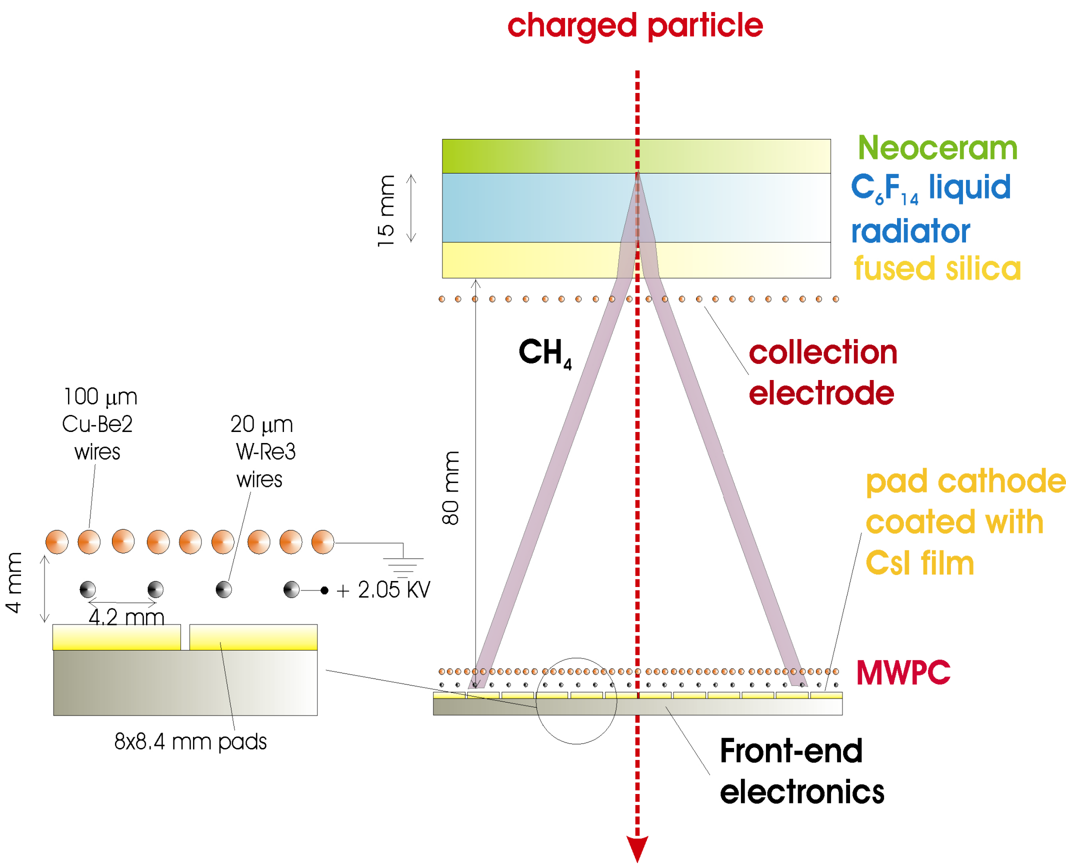
• It consists of seven identical proximity focusing RICH counters.

RADIATOR
15 mm liquid C_6F_{14},
n ~ 1.2989 @ 175nm, β_{th} = 0.77

PHOTON CONVERTER
Reflective layer of CsI
QE ~ 25% @ 175 nm.
The largest scale (11 m^2) application of CsI photo-cathodes in HEP
≈ 5 % of TPC acceptance

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

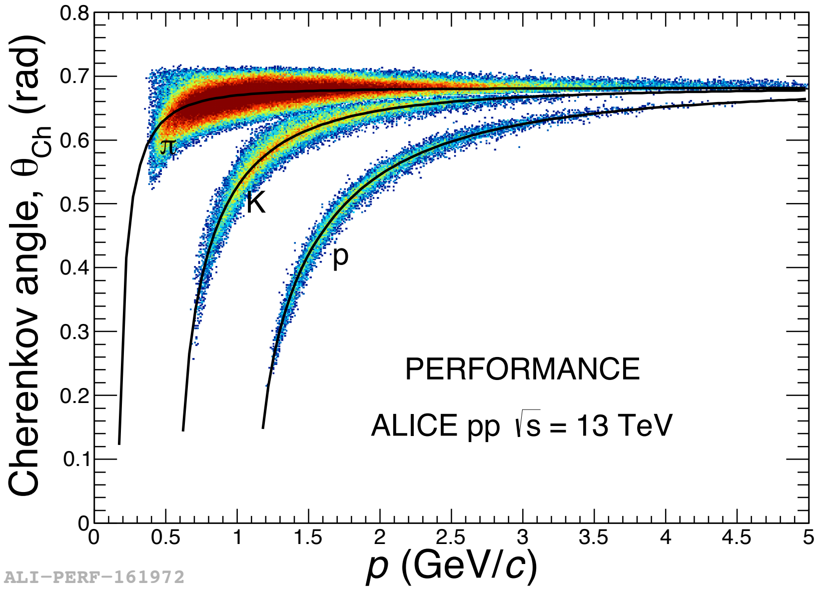
- Analogue pad readout

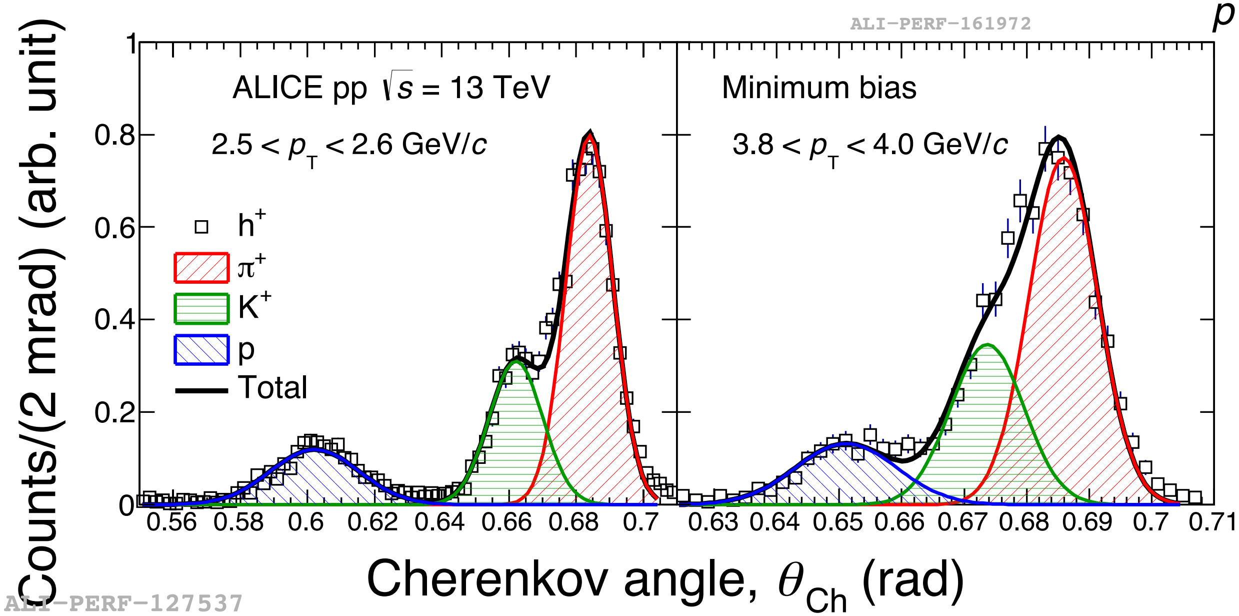


Low multiplicity events, B = 0.5 Tesla

pp at 13 TeV

Gaussian response function

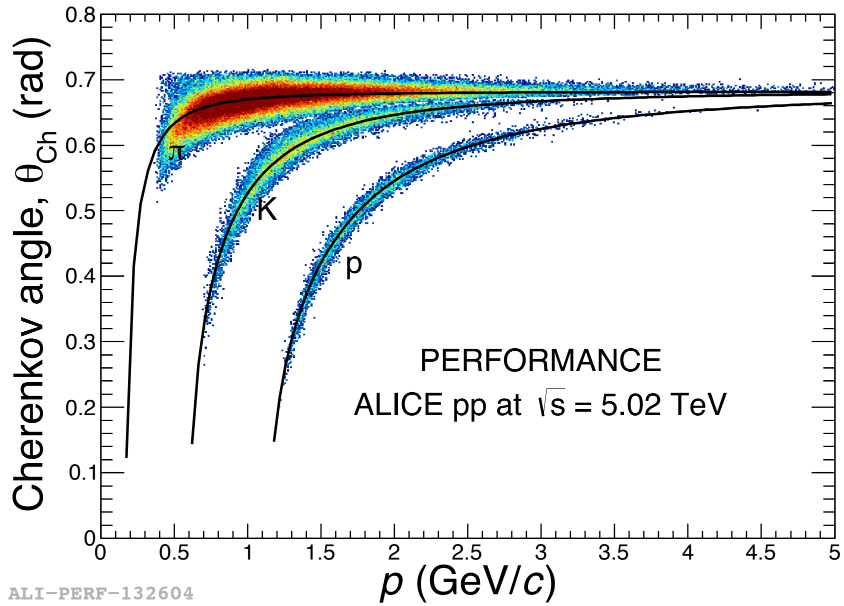


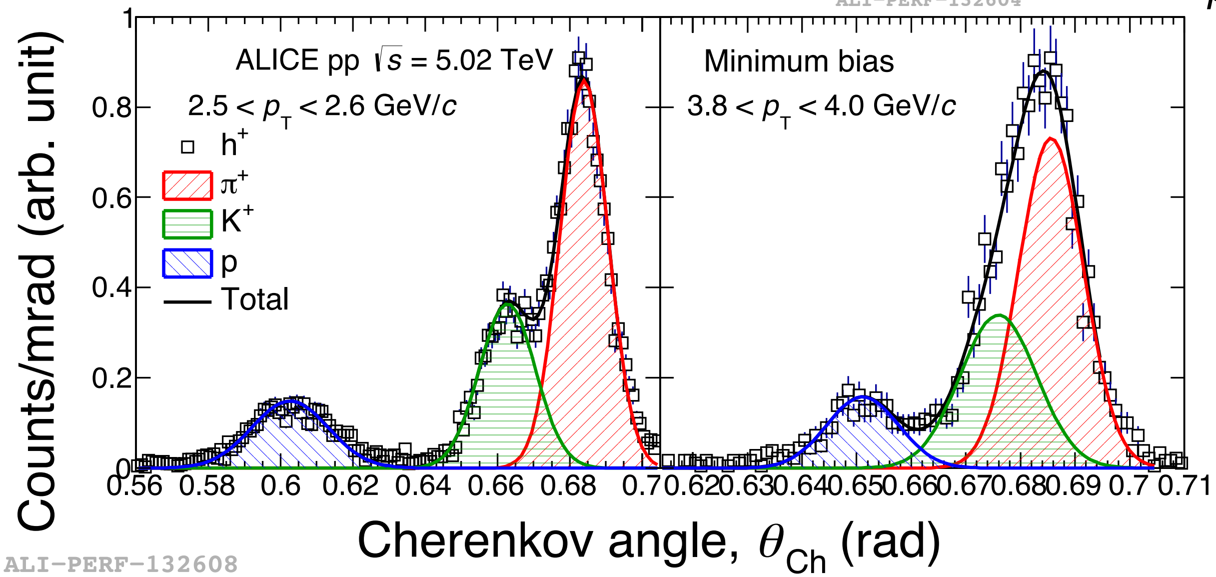


Low multiplicity events, B = 0.5 Tesla

pp at 5.02 TeV

Gaussian response function

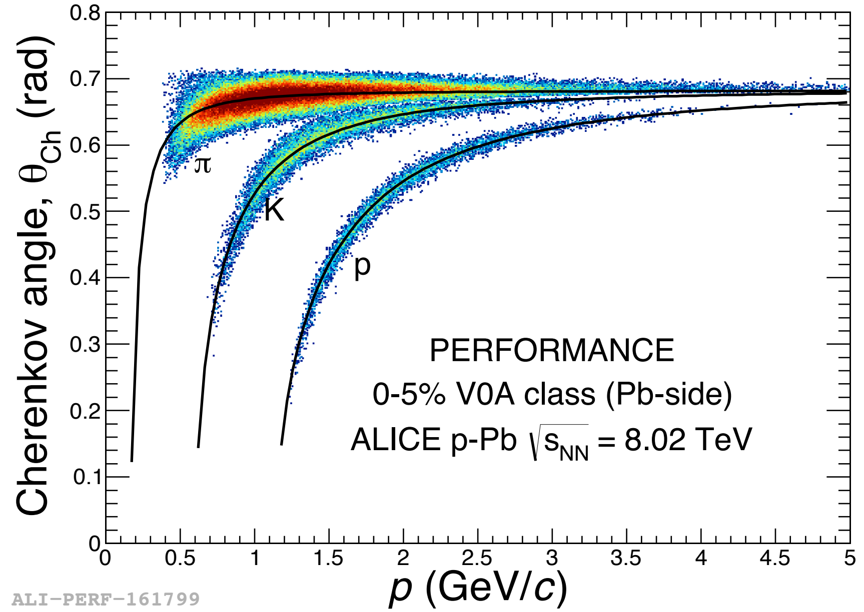


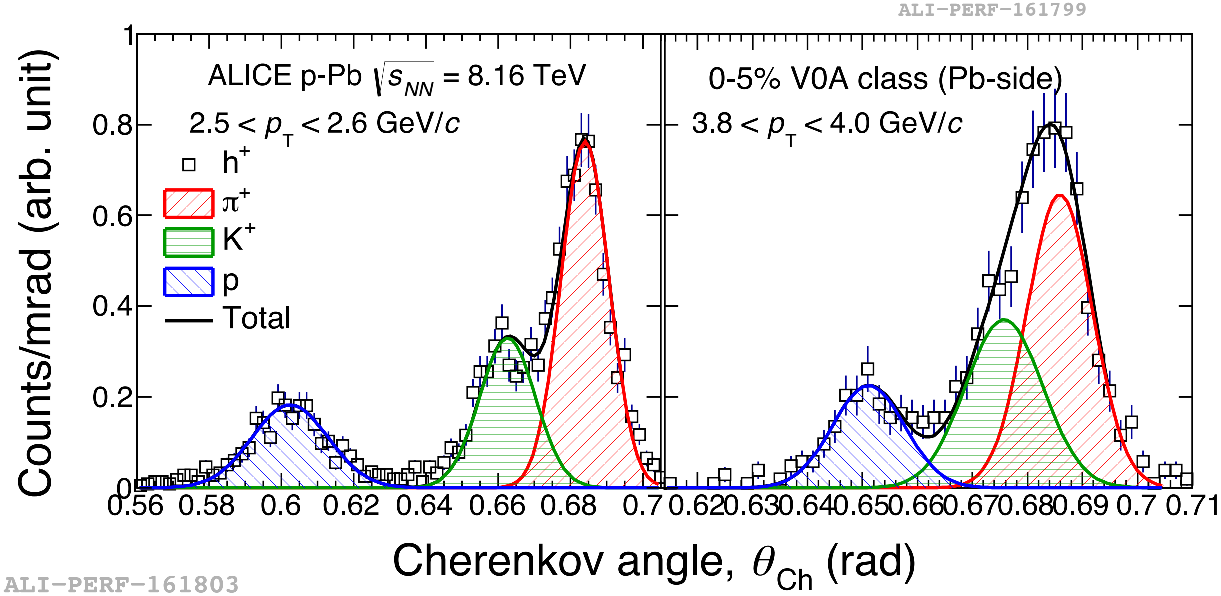


Low multiplicity events, B = 0.5 Tesla

p-Pb at 8.16 ATeV

Gaussian response function





Low multiplicity events, B = 0.2 Tesla

pp at 13 TeV

B = 0.2 Tesla

Gaussian response function