



## RICH 2018

10th International Workshop on Ring Imaging Cherenkov  
Detectors, Moscow (Russia), 29 July - 4 August 2018

# *PID performance of the HMPID detector during LHC-RUN2*

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# Outline

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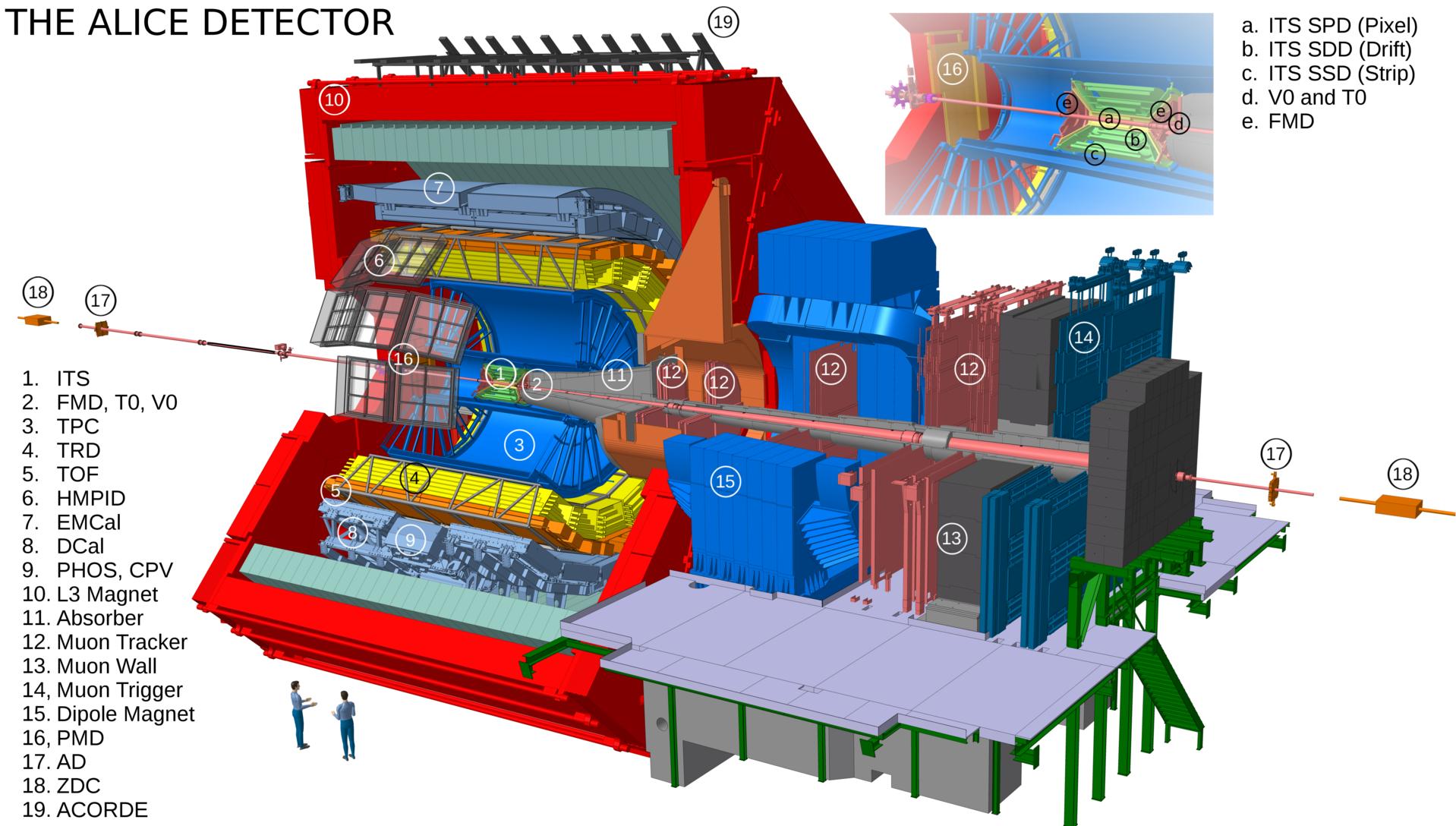


- ALICE apparatus
- HMPID description
- Detector stability
  - Number of detected photo-electrons (ph.e.).
  - Absorbed charge dose
- Pattern recognition performance
  - Low multiplicity events
  - High multiplicity events
  - Performance comparison between data with  $B = 0.5$  and  $0.2$  tesla
- Physics result highlights
- Conclusions

# ALICE apparatus



## THE ALICE DETECTOR



## THE ALICE DETECTOR



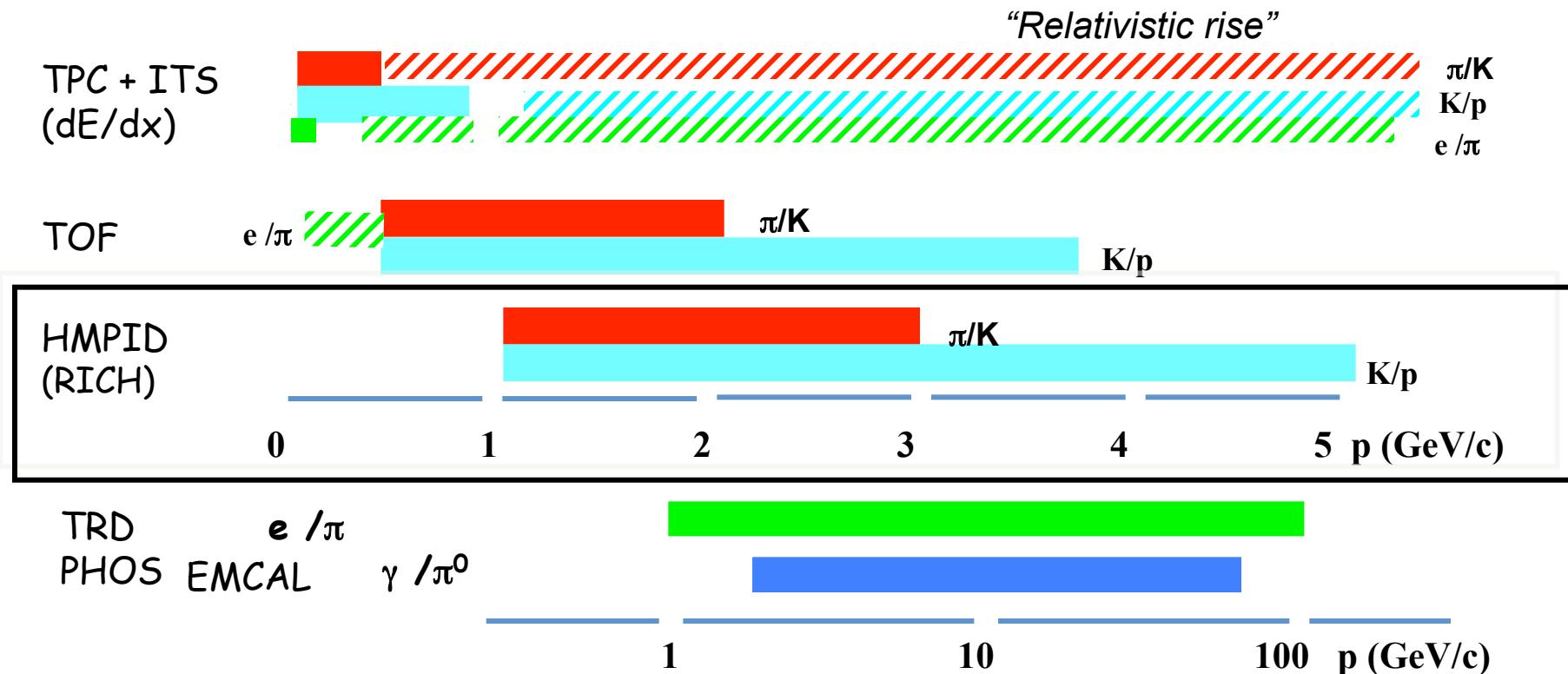
- a. ITS SPD (Pixel)
- b. ITS SDD (Drift)
- c. ITS SSD (Strip)

*ALICE exploits the combination of different particle identification (PID) techniques*

- Energy loss (ITS, TPC)
- Time of flight (TOF)
- Cherenkov radiation (HMPID)
- Transition radiation (TRD)
- Calorimeters (EMCal/DCal, PHOS)
- Topological PID

- 16. PMD
- 17. AD
- 18. ZDC
- 19. ACORDE

# Particle Identification in ALICE: momentum ranges



**Solid: track-by-track**

**Dashed: only statistical**

# HMPID detector description

The ALICE-HMPID (High Momentum Particle Identification Detector) 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  $C_6F_{14}$ ,  
 $n \sim 1.2989$  @ 175nm,  $\beta_{th} = 0.77$

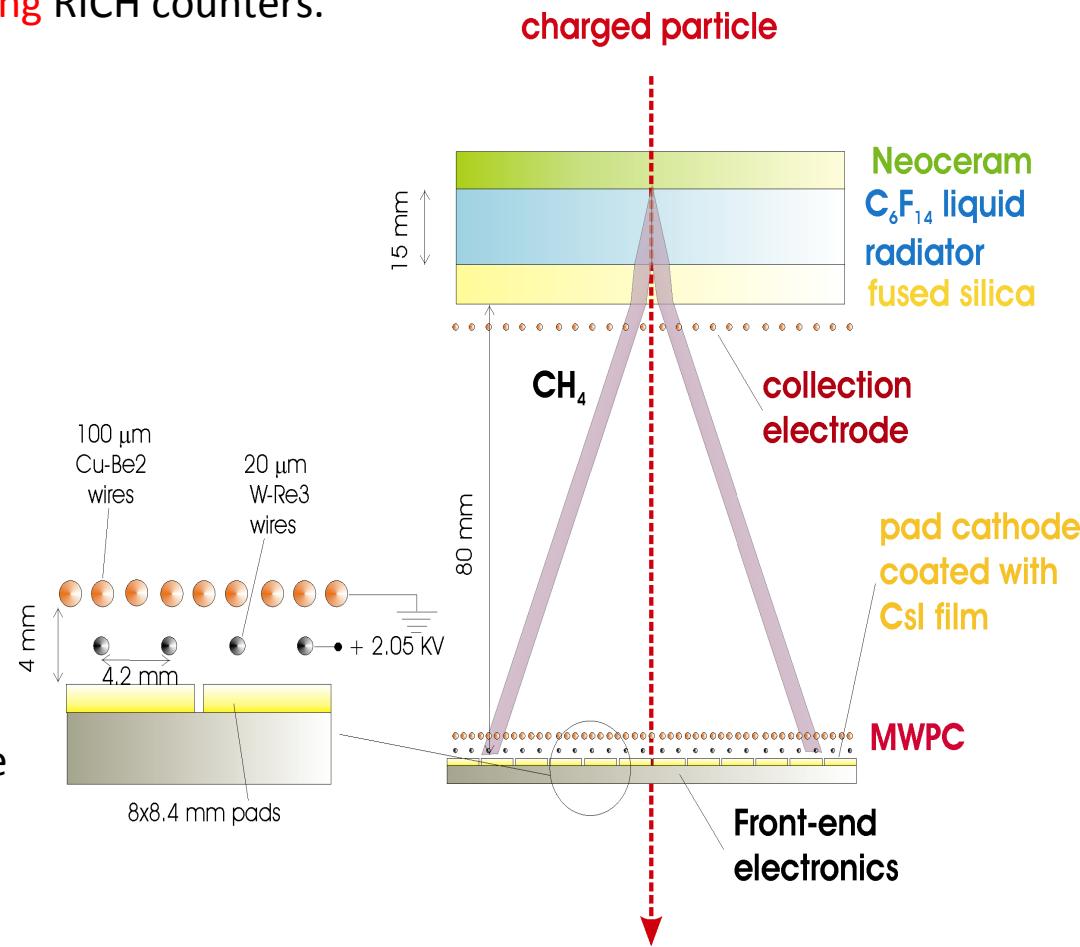
## PHOTON CONVERTER

Reflective layer of CsI  
 QE  $\sim 25\%$  @ 175 nm.

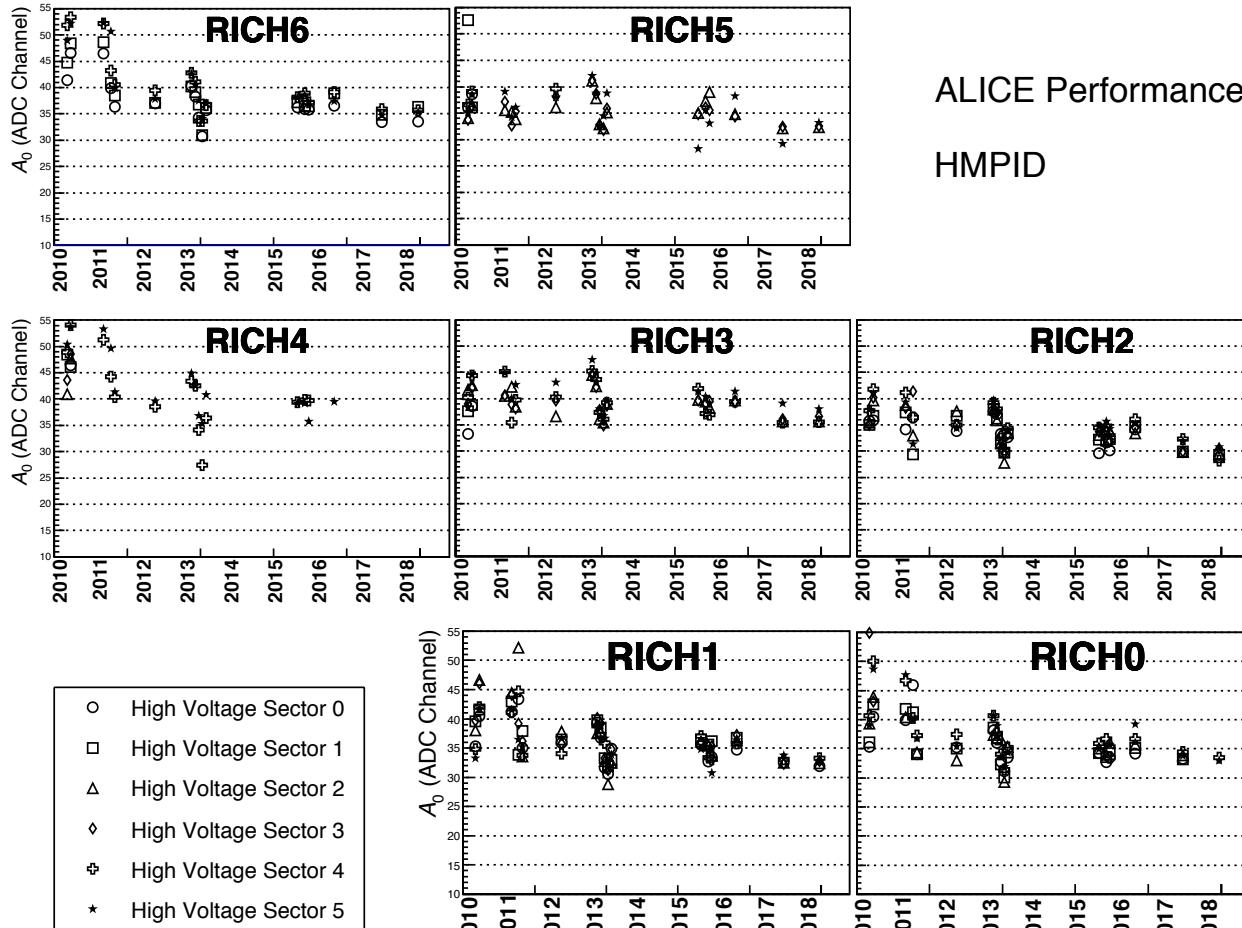
The largest scale (**11 m<sup>2</sup>**) application of CsI  
 photo-cathodes in HEP  
 $\approx 5\%$  of TPC acceptance

## PHOTOEL. DETECTOR

- MWPC with  $CH_4$  at atmospheric pressure (4 mm gap) **HV = 2050 V**.
- Analogue pad readout



# Detector stability: MWPCs gain



ALICE Performance

HMPID

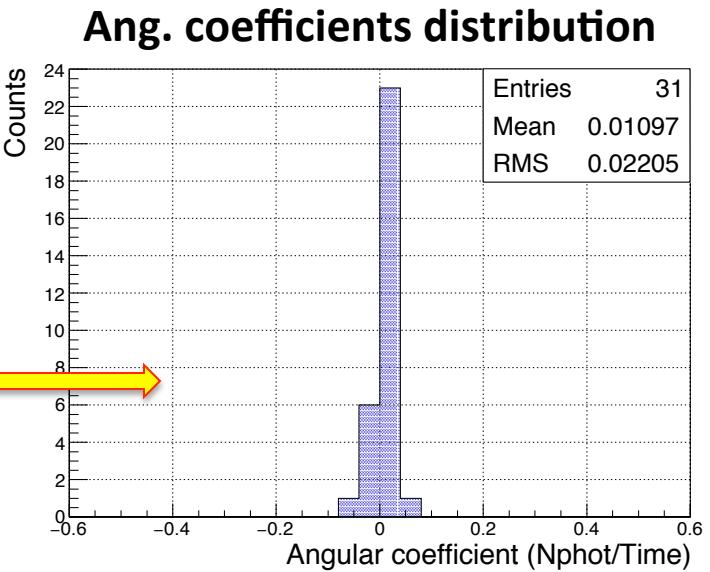
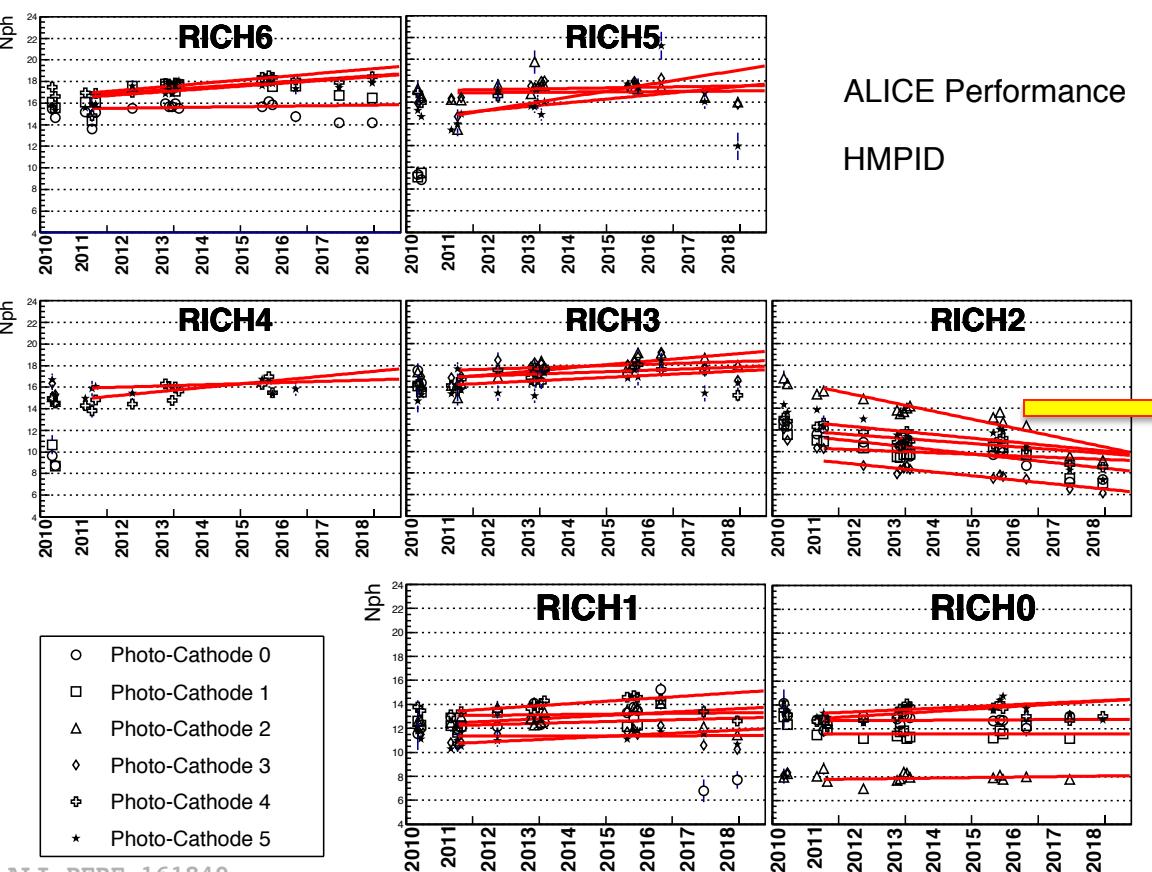
Photo-electron pulse  
height distribution



$$P(A) = \frac{1}{A_0} e^{-A/A_0}$$

- HV equalization (Sept. 2011) to set  $A_0 \approx 35$ ;
- Gain variations  $\approx \pm 15\%$ ;
- A reduction of 20% on  $A_0 \rightarrow$  photoelectron detection efficiency loss of 3% ( $A_{th}/A_0 \approx 4/35$ ) . **No effects on the PID performance!**

# Detector stability: number of detected ph.e.

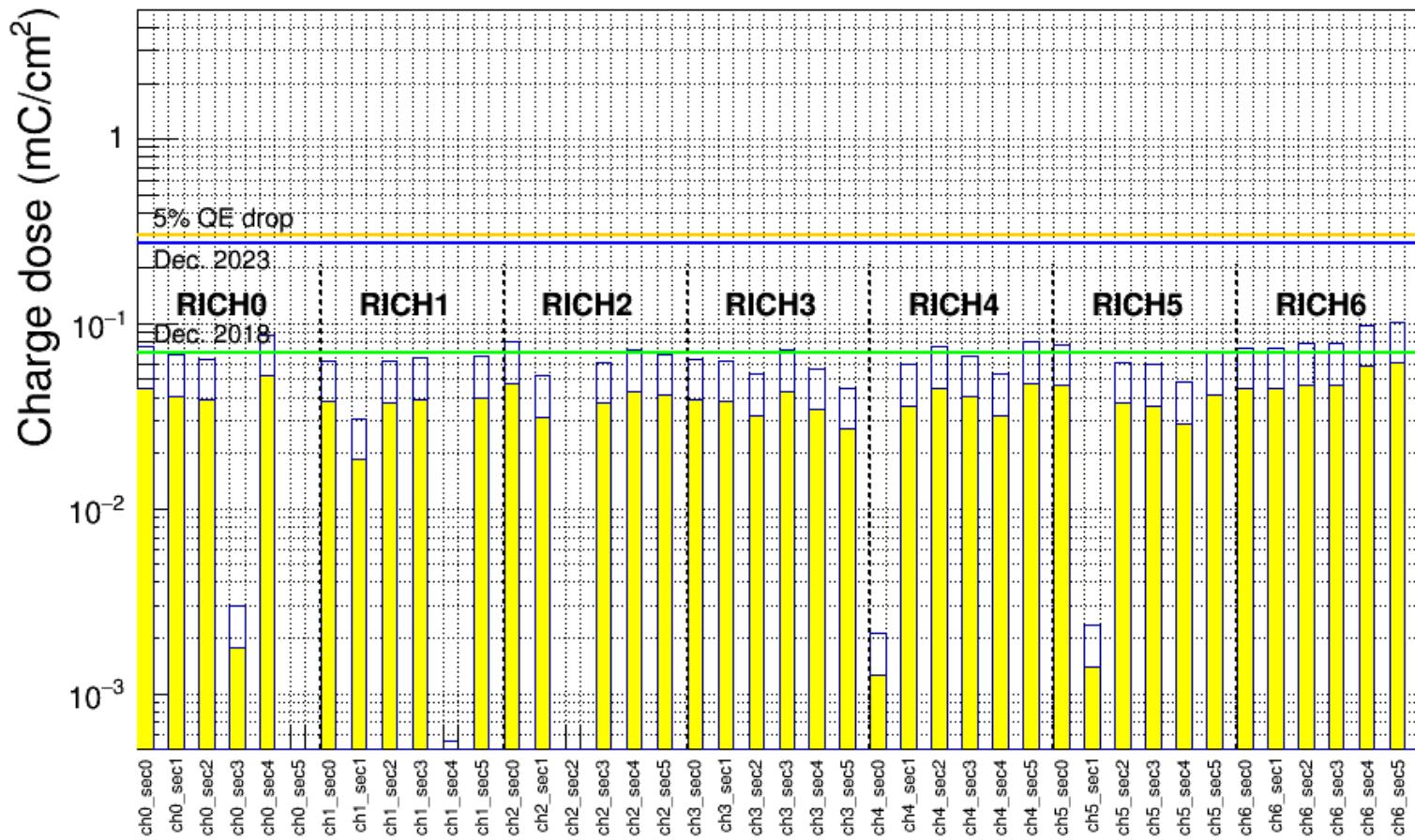


The distribution of the angular coefficients indicates no signs of ageing of the photocathodes!!

- Good  $N_{\text{ph}}$  stability infers a CsI QE stability;
- Except RICH2, where PC2 and PC3 show a drop of 30%. After cleaning, these PCs were re-evaporated during 2005, maybe procedure not optimised;
- Empty space between blobs represents LHC technical stops from 2010 up to 2015.

# Detector stability

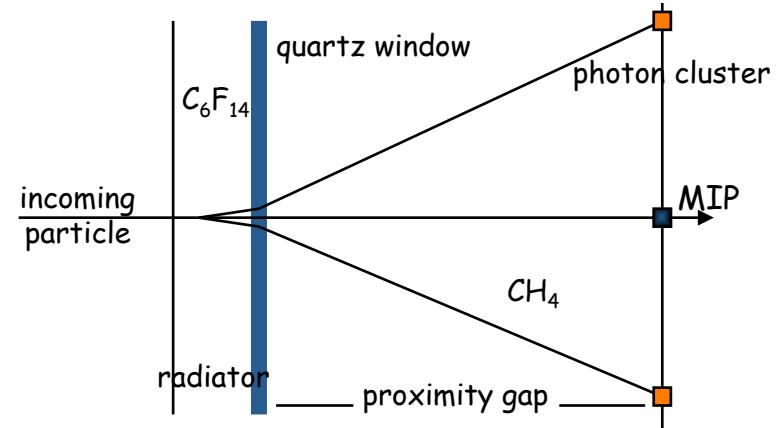
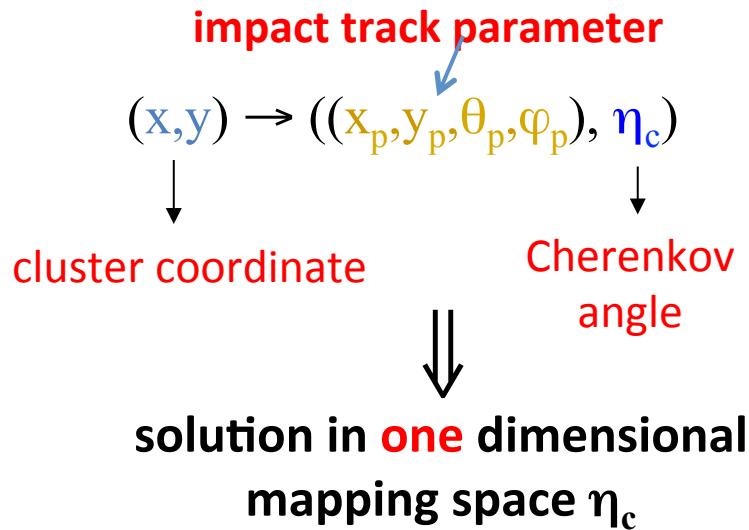
Absorbed charge dose for HV sector, period 2010 - 2017



Absorbed charge dose values for expected QE 5% drop,  $0.3 \text{ mC}/\text{cm}^2$  (yellow line), below the absorbed dose foreseen at the end of RUN3 (blue line)!

# Pattern recognition with the HMPID

- 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).



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

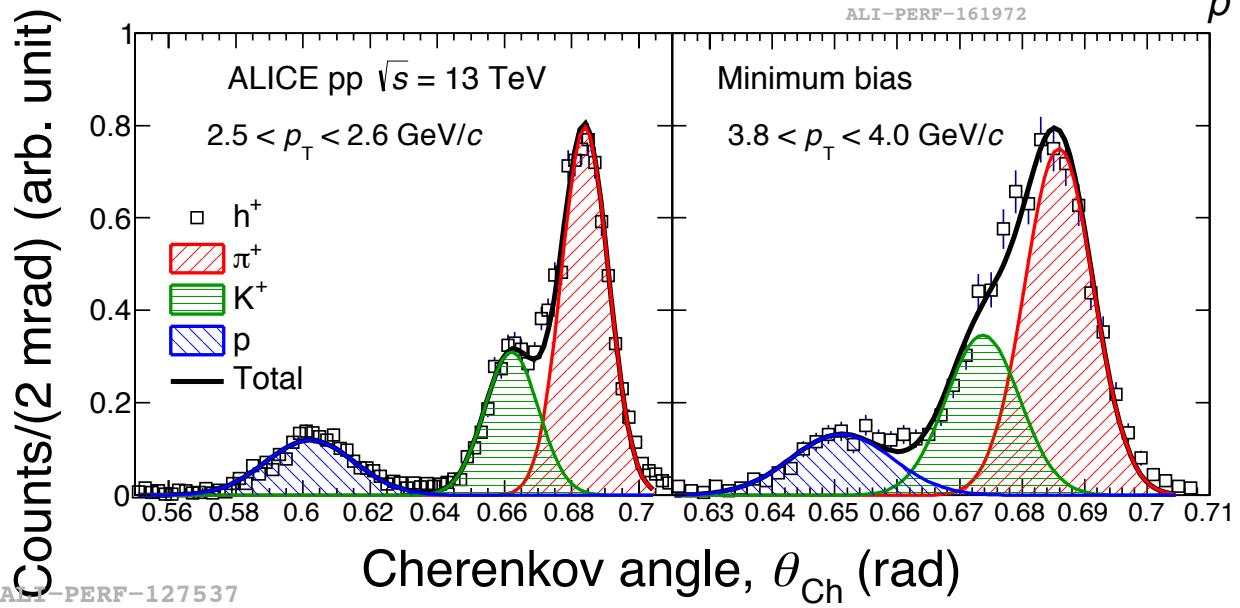
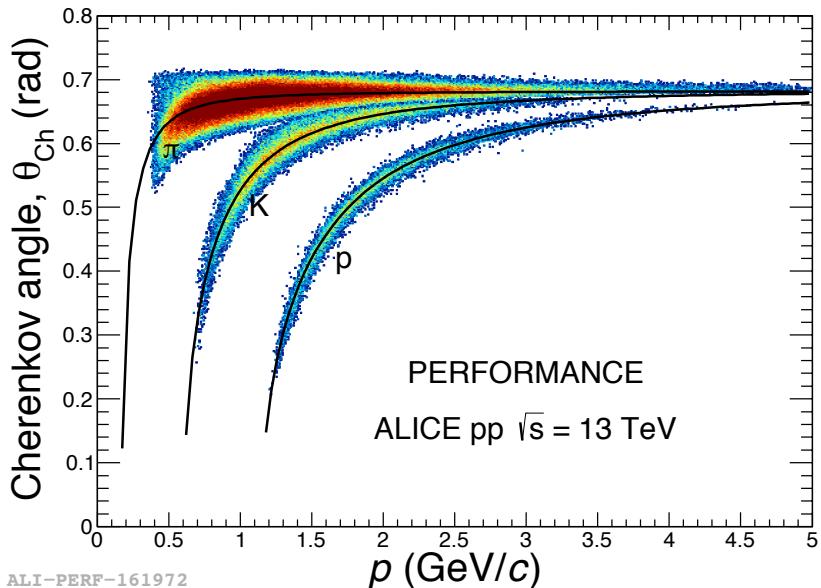
- The pattern recognition efficiency depends on **the chamber occupancy** (event multiplicity) and **track inclination** (magnetic field intensity).

# Low multiplicity events, $B = 0.5$ Tesla



pp at 13 TeV

Gaussian response function

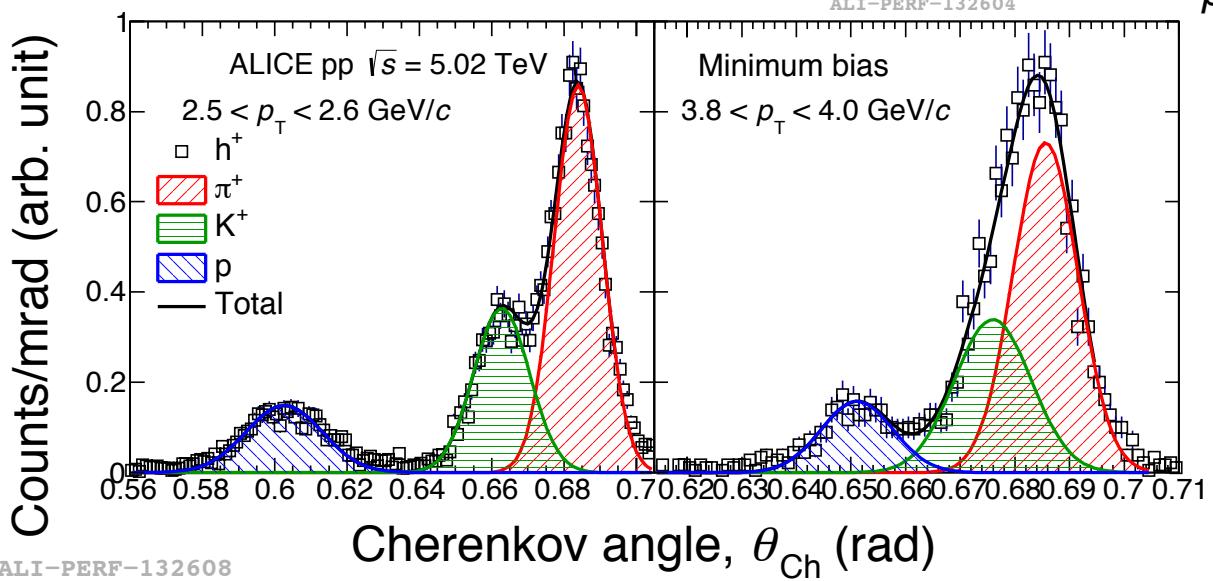
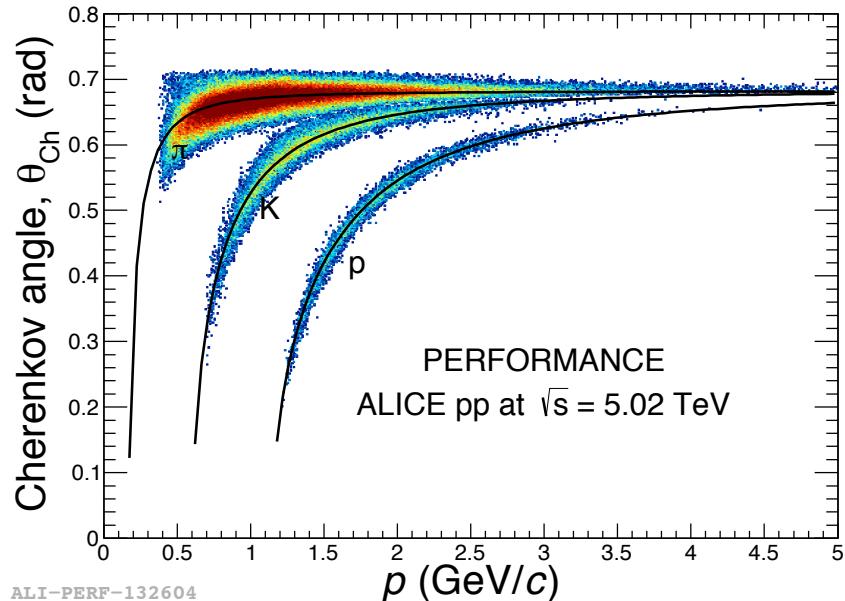


# Low multiplicity events, $B = 0.5$ Tesla



pp at 5.02 TeV

Gaussian response function

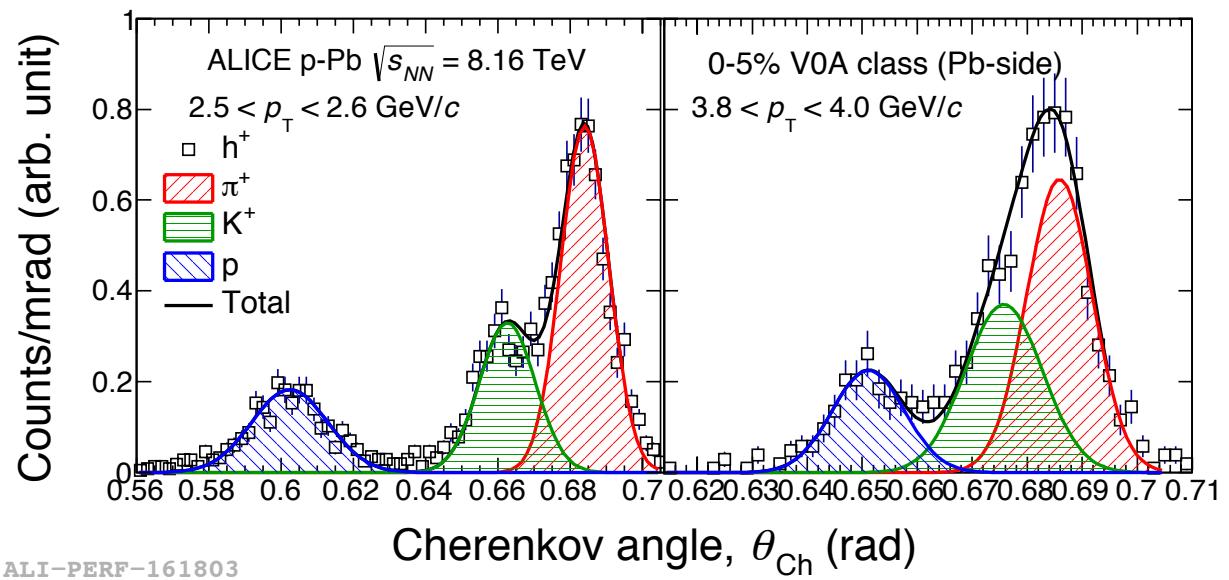
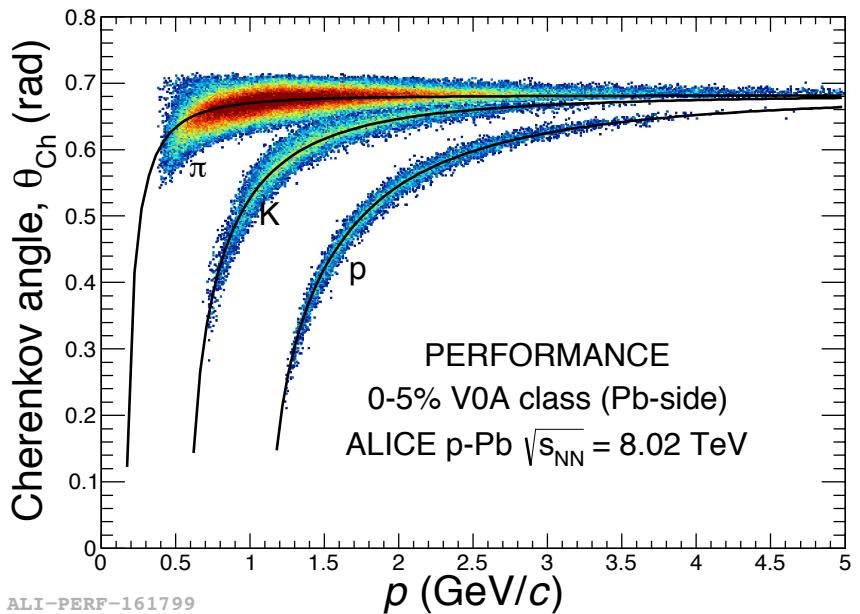


# Low multiplicity events, B = 0.5 Tesla



p-Pb at 8.16 ATeV

Gaussian response function

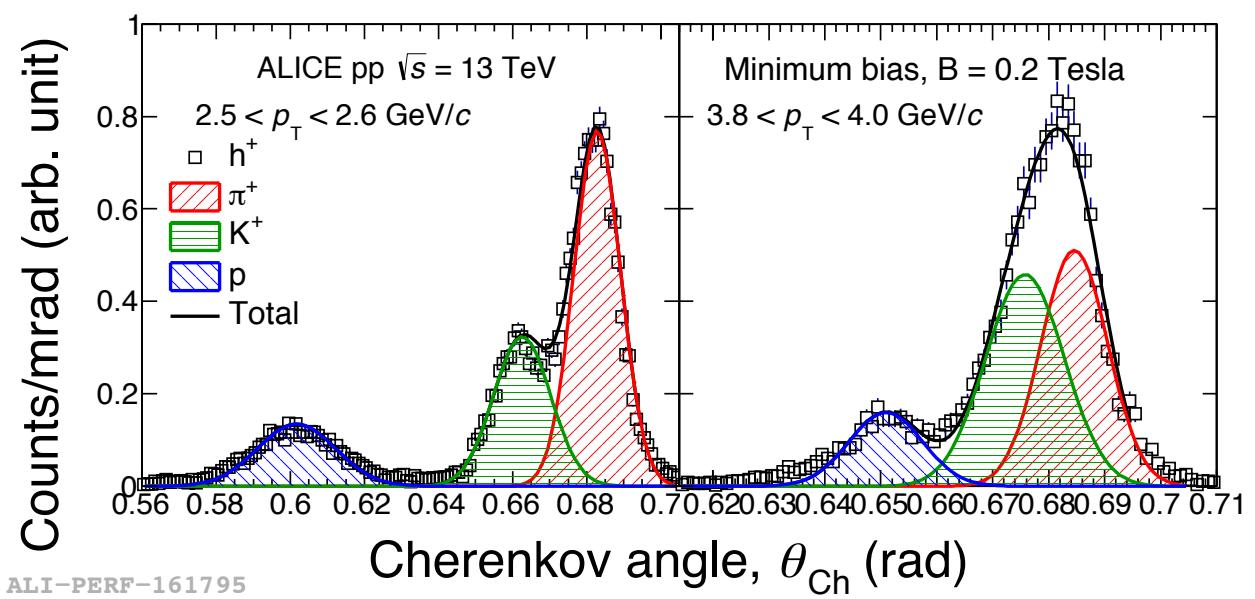
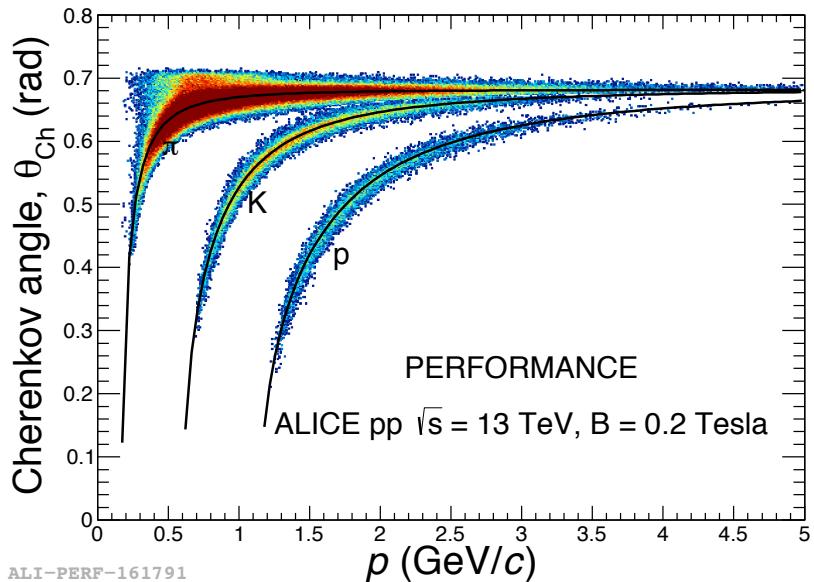


# Low multiplicity events, B = 0.2 Tesla

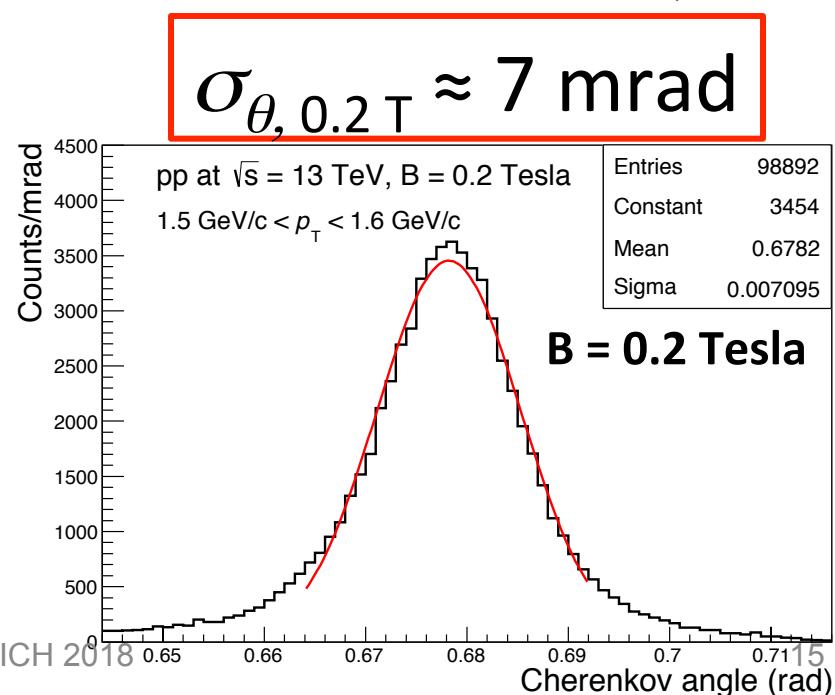
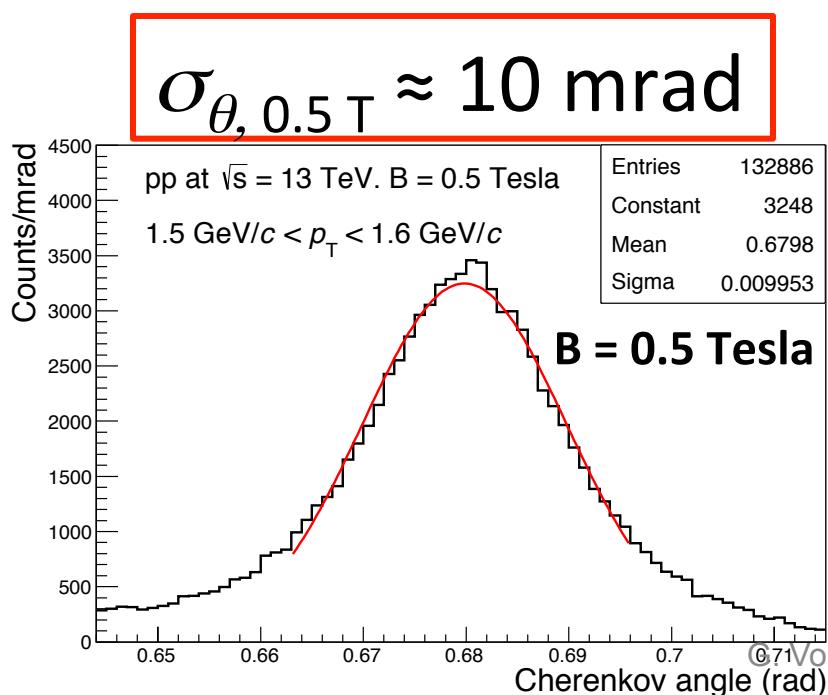
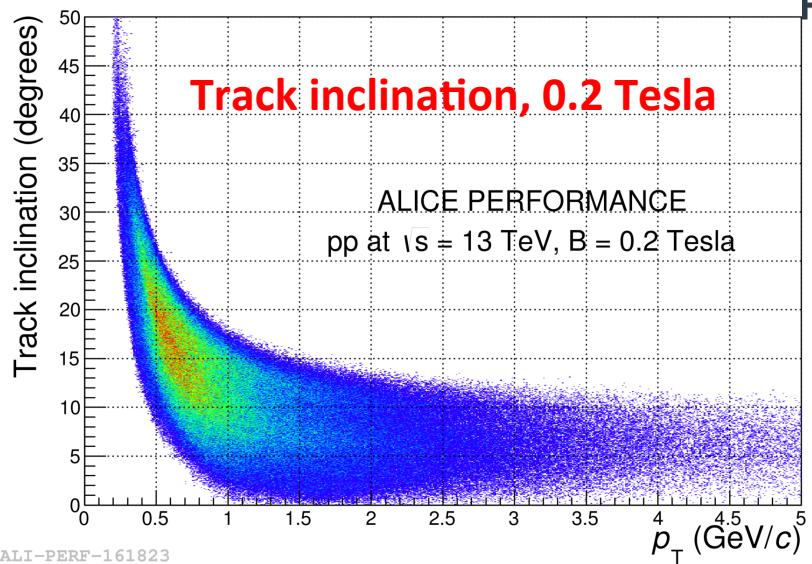
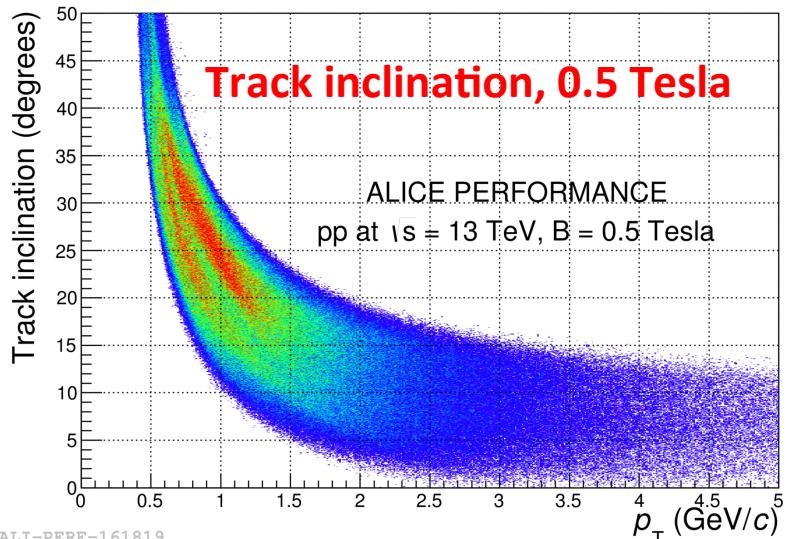


pp at 13 TeV  
B = 0.2 Tesla

Gaussian response function



# Low multiplicity events: B = 0.2 and 0.5 Tesla comparison

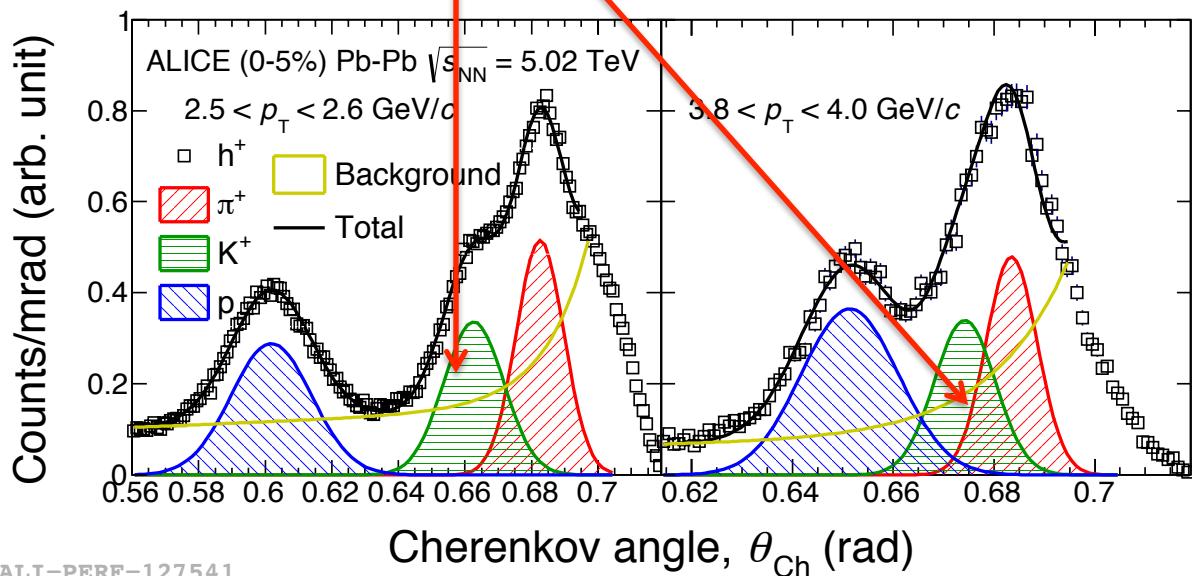
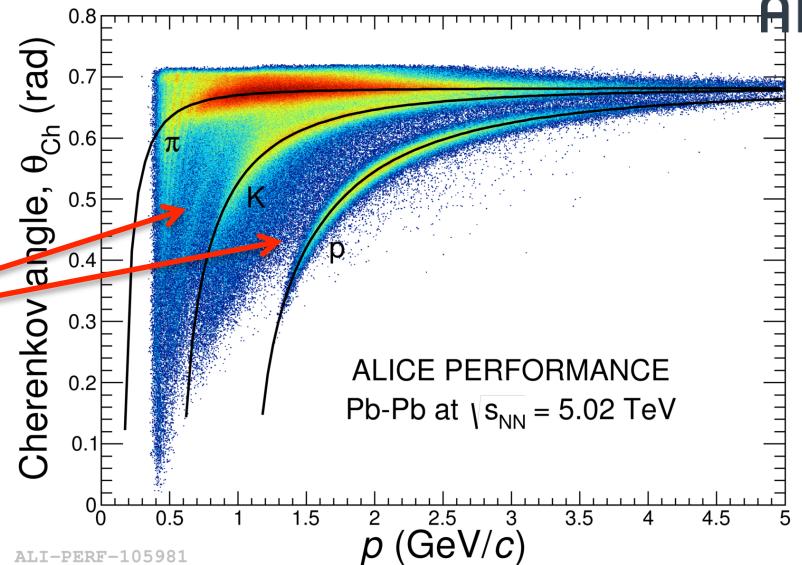


# High multiplicity events, $B = 0.5$ Tesla



## 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:

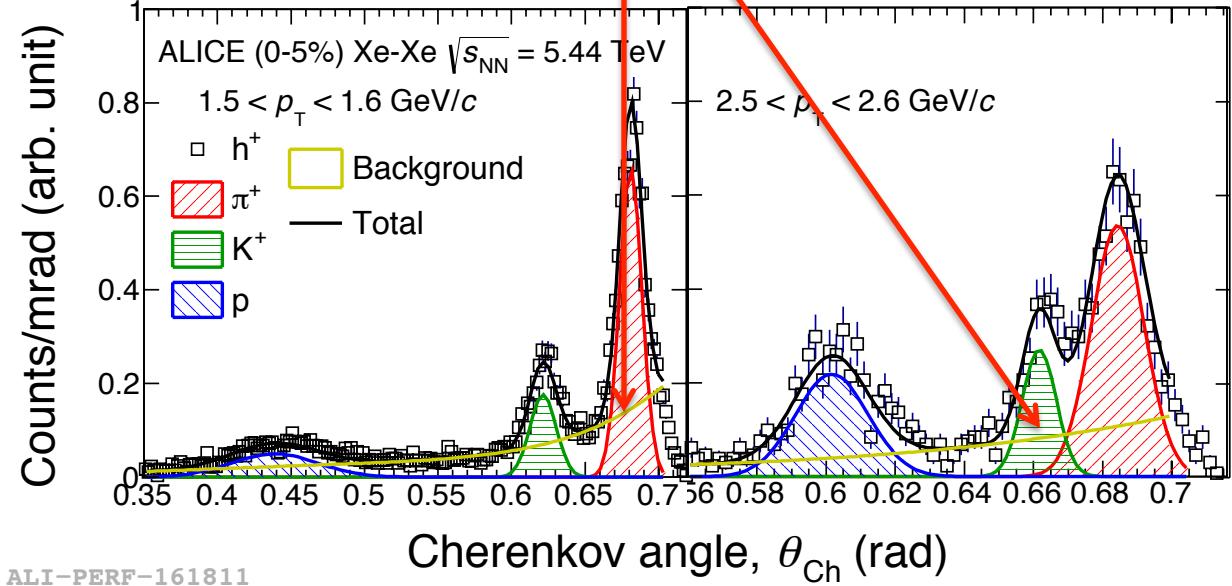
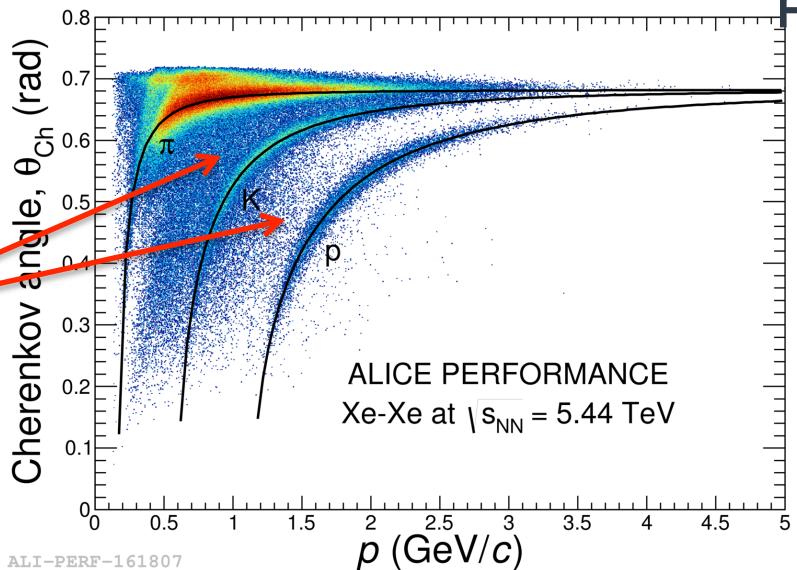
- larger is the angle value larger is the probability to find background.

# High multiplicity events, $B = 0.2$ Tesla

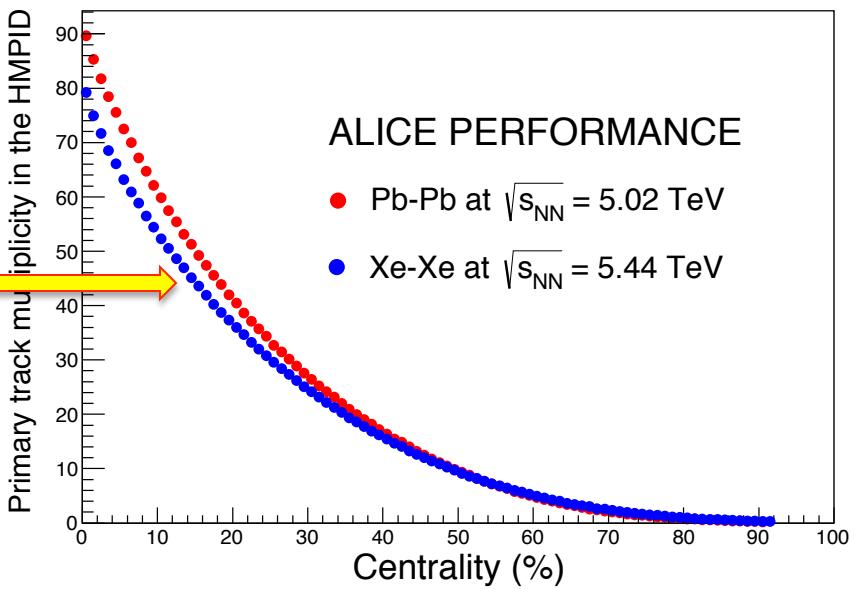
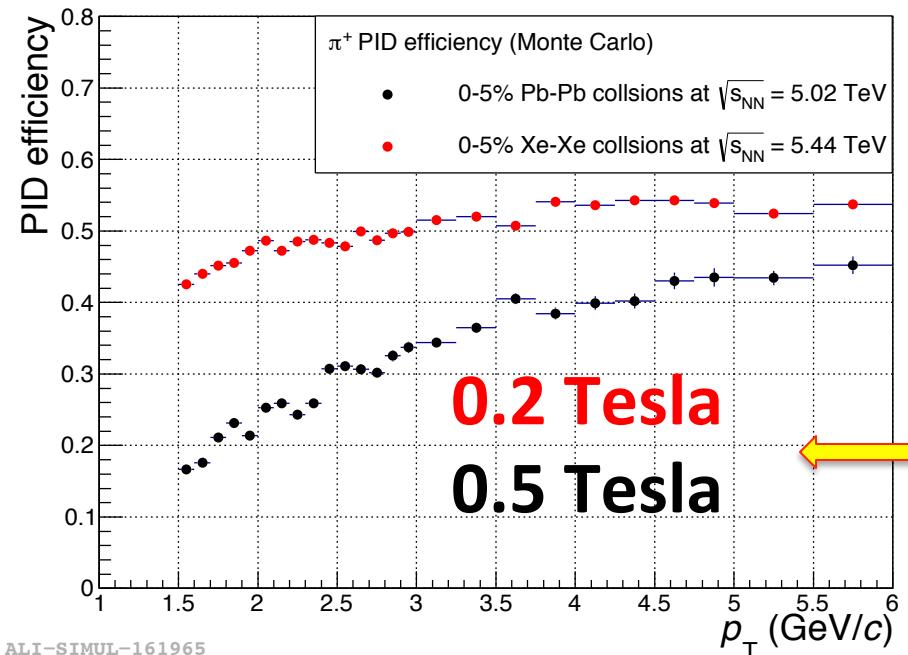


Xe-Xe at 5.02 ATeV

Mis-identified tracks  
(background)



## Primary track multiplicity in the HMPID acceptance



**PID efficiency**

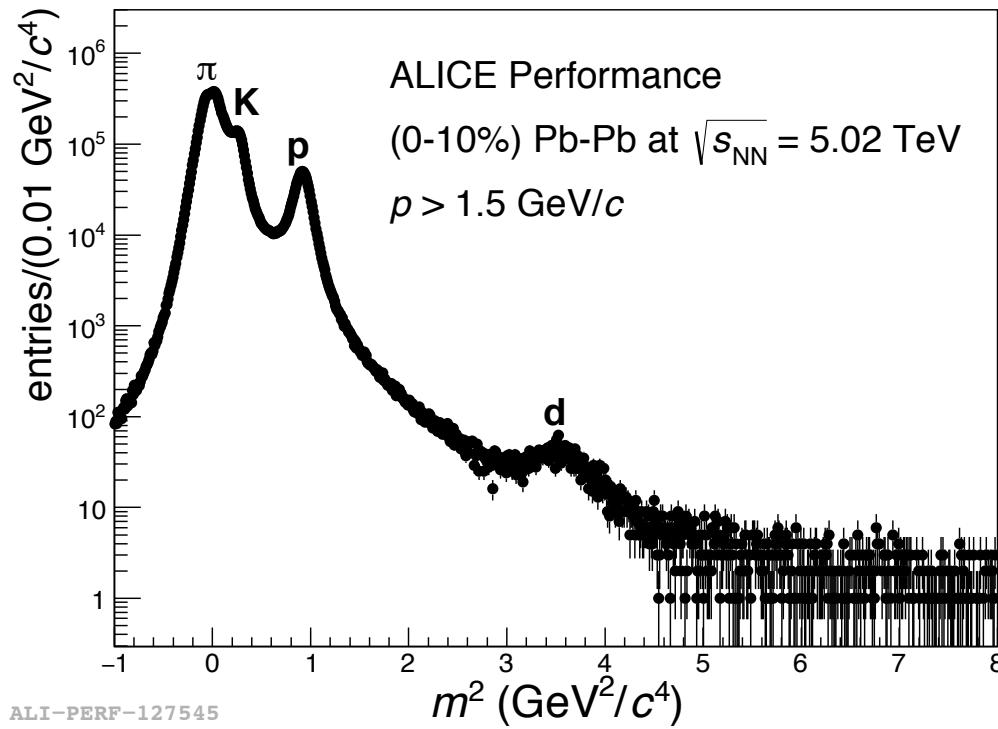
$$\varepsilon_{\text{PID}} = \frac{N(\text{signal})}{N(\text{signal and background})}$$

# Light nuclei PID



The signal over background ratio for deuterons in **central (0-10%) Pb-Pb collisions**, is large enough to be detected by the HMPID, by means of statistical unfolding on the **mass distribution (not on Cherenkov angle one!)**

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



ALI-PERF-127545

# Physics results

**Statistical unfolding:** 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:

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

$\langle \theta_i \rangle$  = means of the Cherenkov angle distributions

$\sigma_i$  = 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 known and fixed in the fitting.

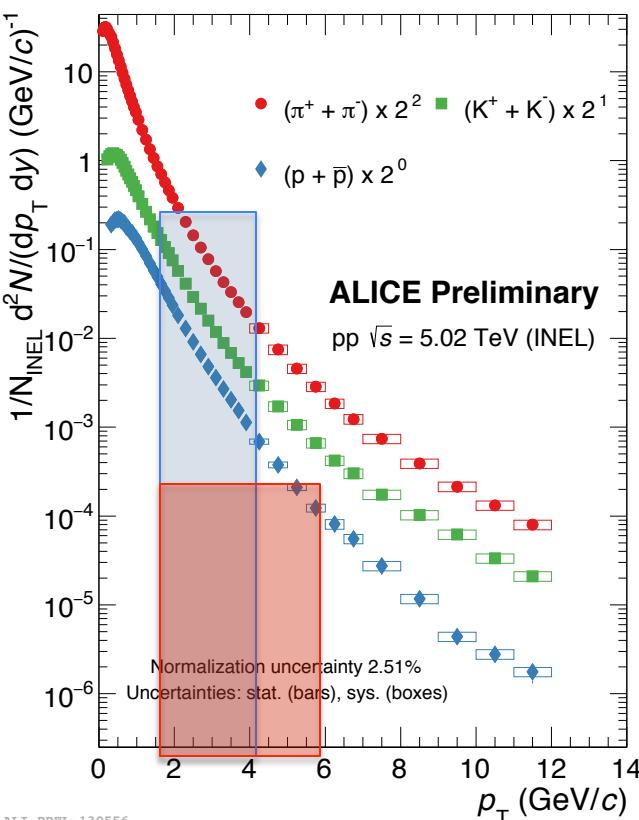
## high multiplicity events (central Pb-Pb collisions)

- The three Gaussian distributions in a given transverse momentum bins, are convoluted with the background distribution;
- In the yield extraction procedure, the background function has to be convoluted with the three-Gaussian one.
  - This represents a source of systematic errors on the yield evaluation.

# Physics results

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.

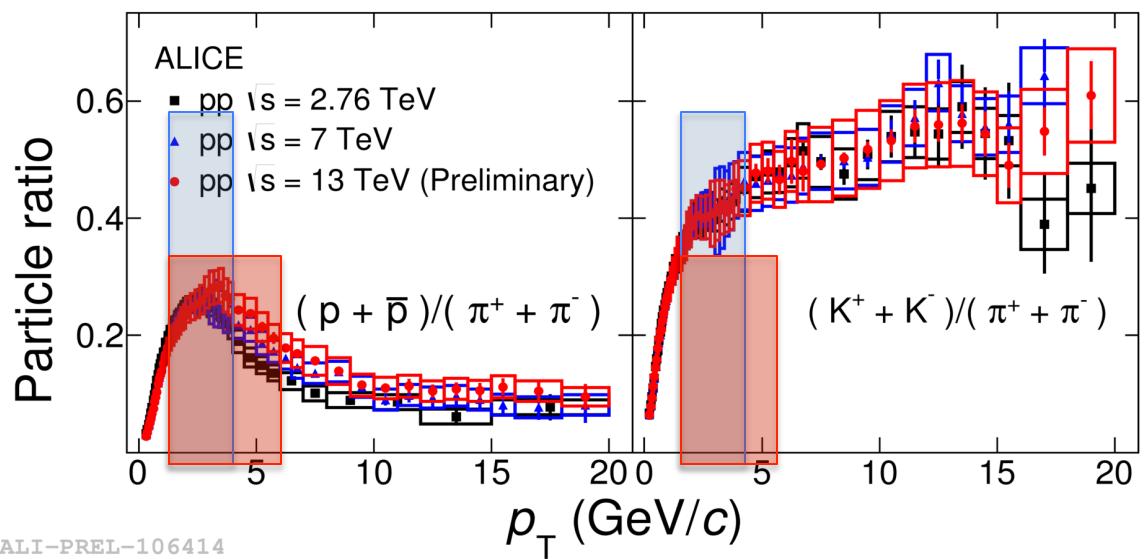
$p_T$  spectra in pp at 5.02 TeV



$\pi$ -K HMPID

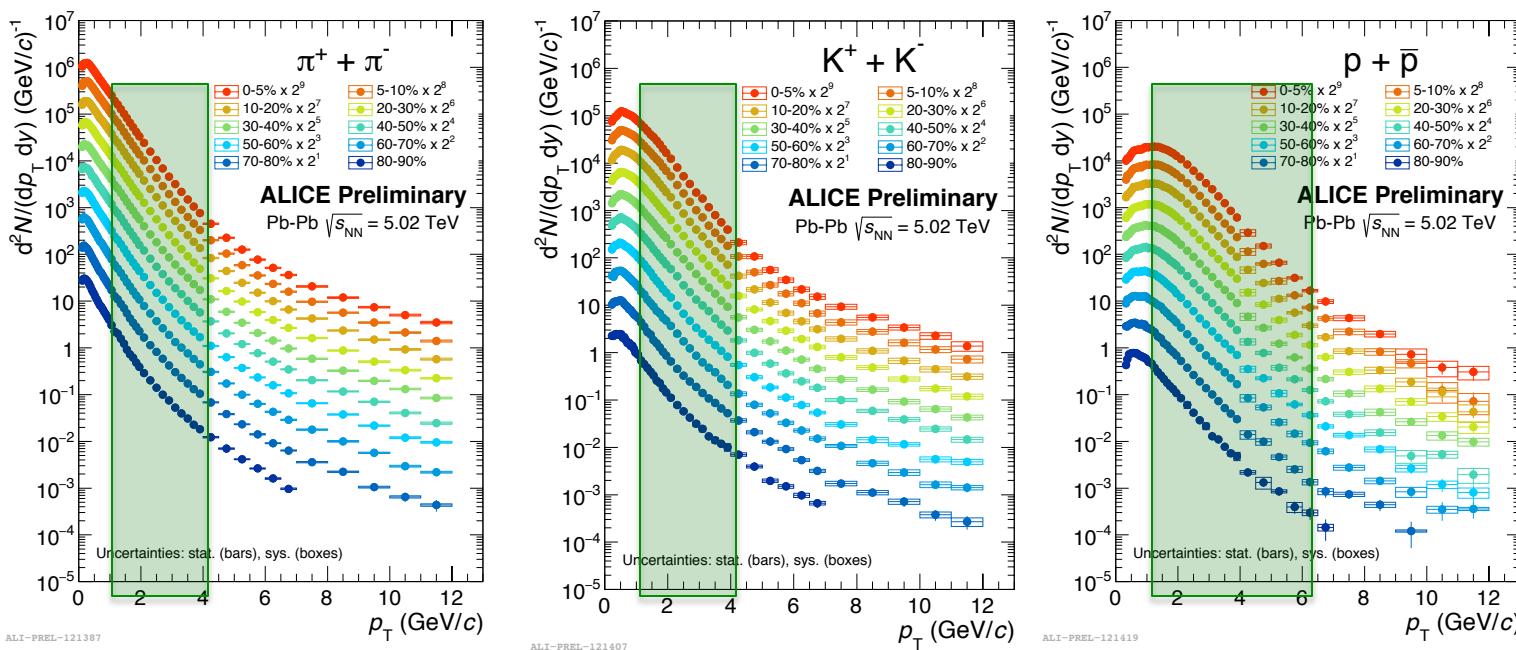
(anti-)p HMPID

Particle ratios vs  $p_T$  in pp at 13 TeV



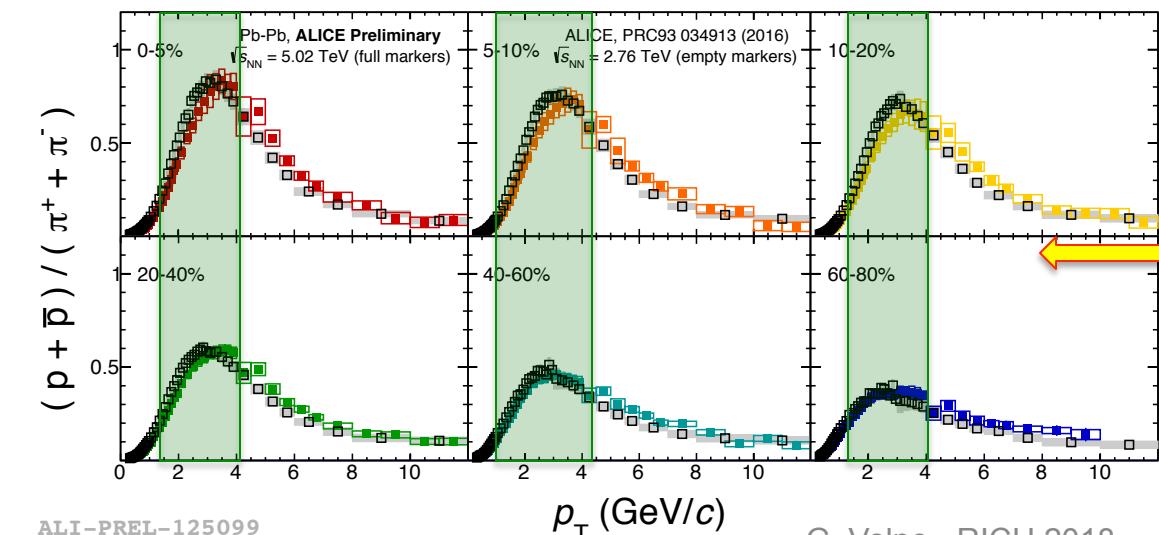


# Physics results



HMPID

$p_T$  spectra  
in Pb-Pb at  
5.02 ATeV



# Physics results

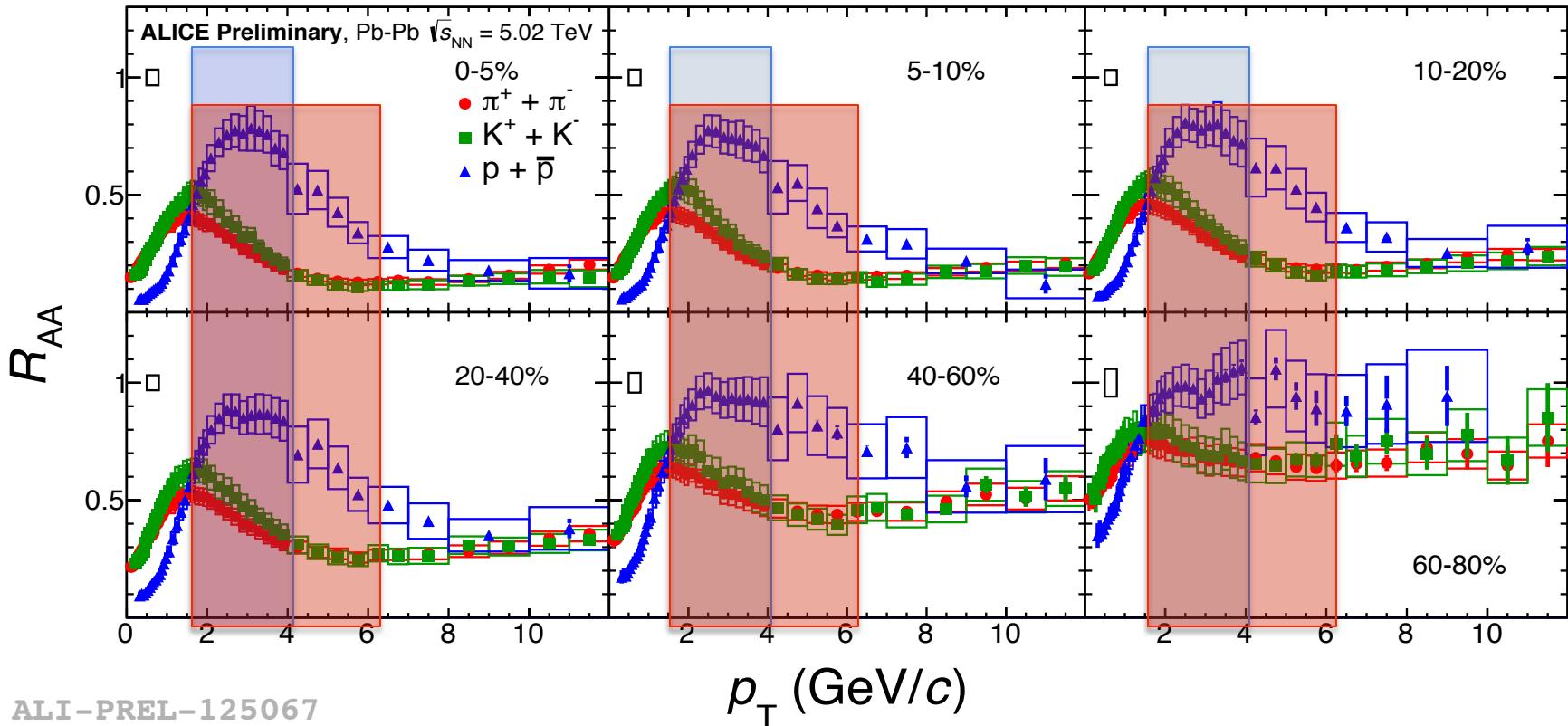


## Nuclear modification factor in Pb-Pb collisions at 5.02 ATeV

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

$\pi$ -K HMPID

(anti-)p HMPID



# Conclusions

- ❑ ALICE successfully collected the pp, p-Pb, Pb-Pb and Xe-Xe collisions data provided by LHC during RUN2 period.
- ❑ The HMPID detector presented so far **optimal PID performance**. Them have been studied in different environment conditions:
  - ❑ Event tracks multiplicity
  - ❑ Tracks inclination → magnetic field intensity
- ❑ In high multiplicity events ( central A-A collisions) the PID efficiency is lower than in the low multiplicity ones.
  - ❑ Source of systematic error on the yield evaluation.
- ❑ In the low magnetic filed data, the PID performance are even better, both in terms of **angular resolution** and **PID efficiency in the high multiplicity events**.
- ❑ By means **of statistical unfolding** HMPID provides charged hadrons production measurements, successfully participating to the ALICE physics program.
  - ❑ Highlights of the results from **LHC RUN2** data has been presented, more in the next future.
- ❑ Good perspective for the HMPID operation in HL-LHC RUN3.
  - ❑ **Light nuclei identification:** deuteron, triton,  ${}^3\text{He}$ ,  ${}^4\text{He}$ .

# 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**.

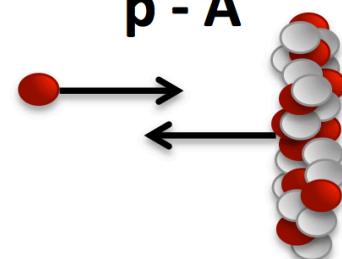
**p - p**



- pp 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, 2017).

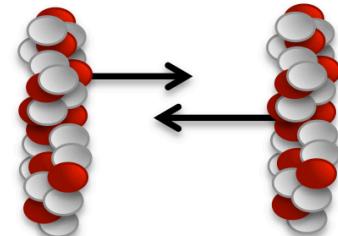
**p - A**



- p-A collisions:

- **initial state/cold nuclear matter.**
- collected p-Pb data at  $\sqrt{s_{NN}} = 5.02, 8.16$  TeV (2012, 2013, 2016).

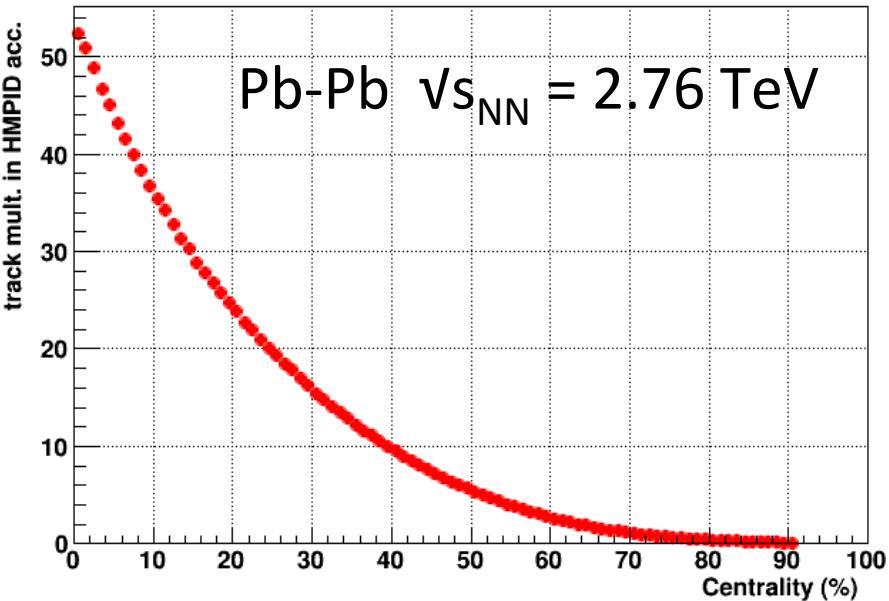
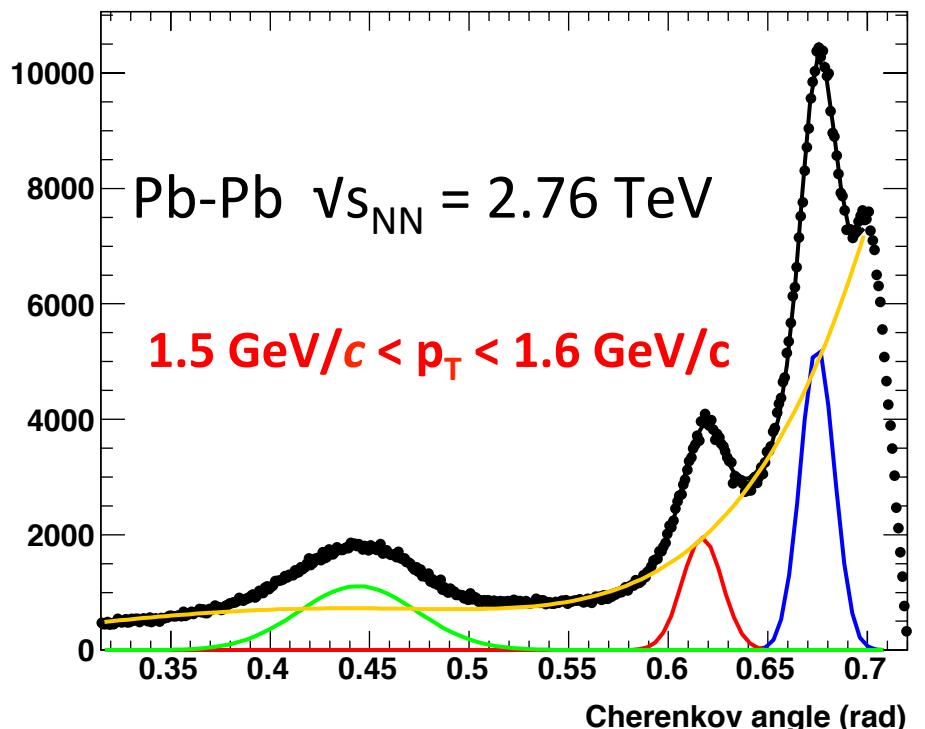
**A - A**



- A-A collisions:

- **quark-gluon plasma formation!**
- collected Pb-Pb data at  $\sqrt{s_{NN}} = 2.76$  TeV, 5.02 TeV (2010, 2011, 2015) and Xe-Xe data at  $\sqrt{s_{NN}} = 5.44$  TeV (2017).

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



# Charged hadrons spectra: Pb-Pb 2.76 ATeV

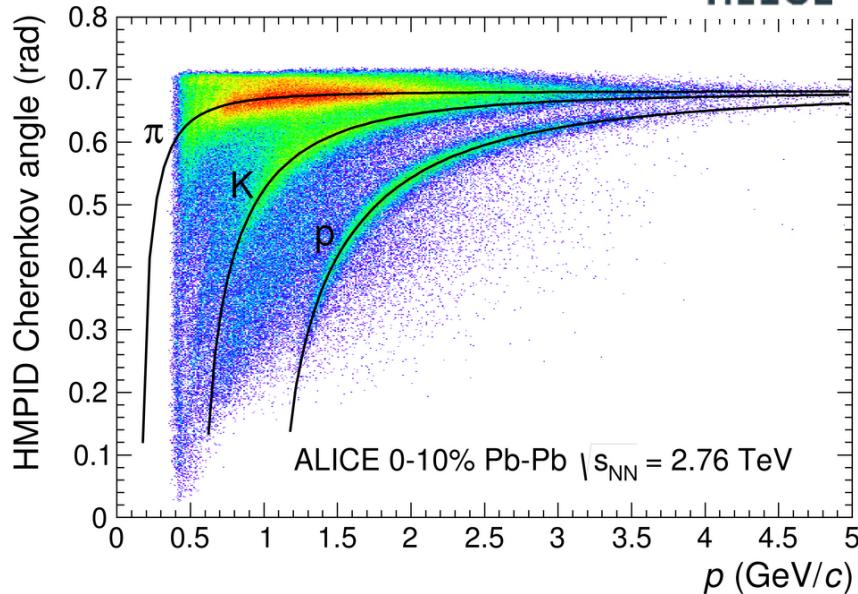


## Performance

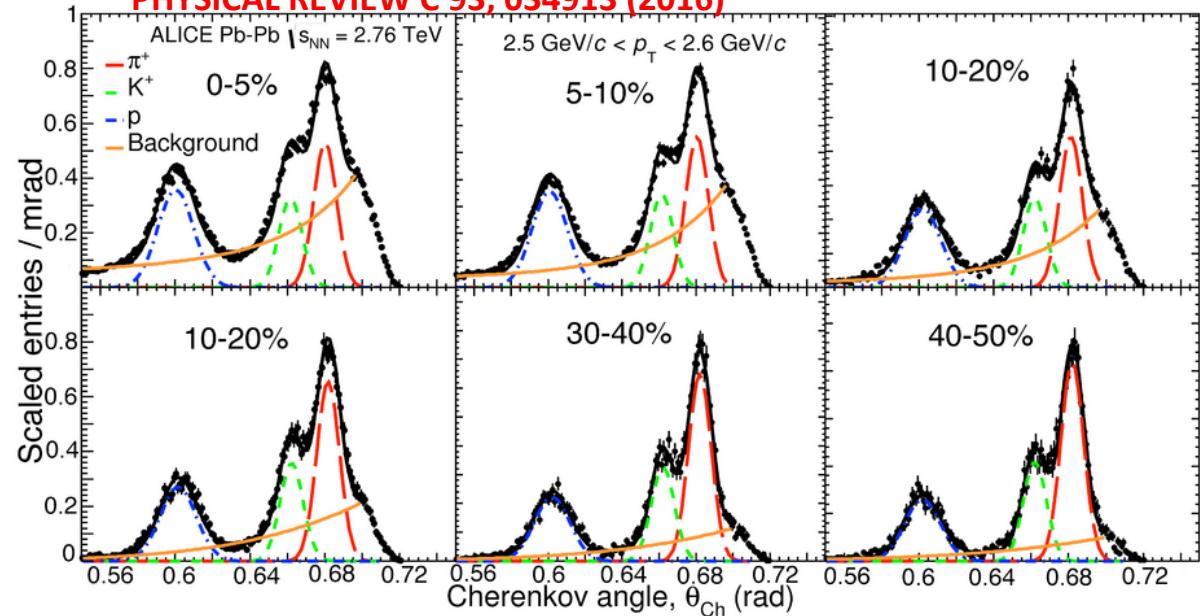
PID range

$$\pi/K \rightarrow 1.5 - 4 \text{ GeV}/c$$

$$p \rightarrow 1.5 - 6 \text{ GeV}/c$$



PHYSICAL REVIEW C 93, 034913 (2016)



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- H M P I D used in collisions centrality range 0-50%
- Centrality estimate based on V0 detector measurements.
- V0: trigger detector at forward rapidity.

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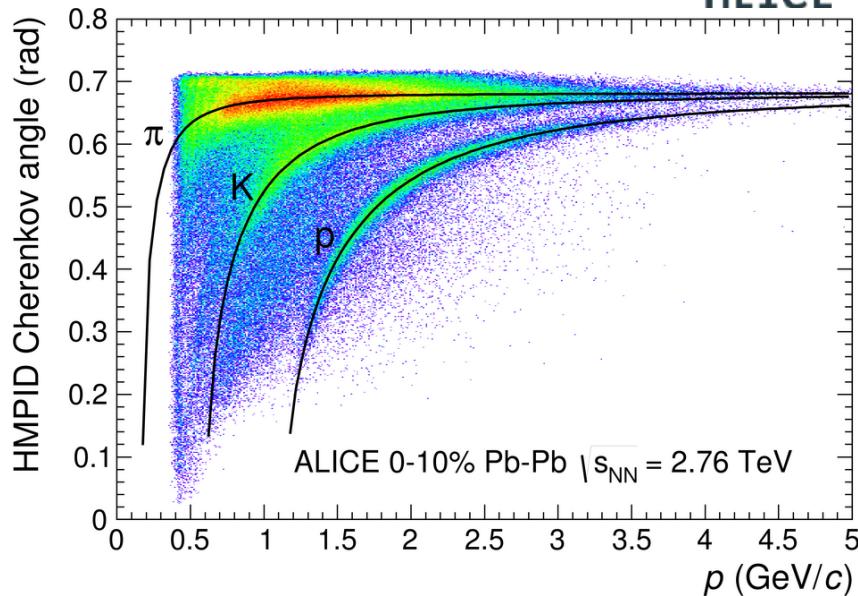
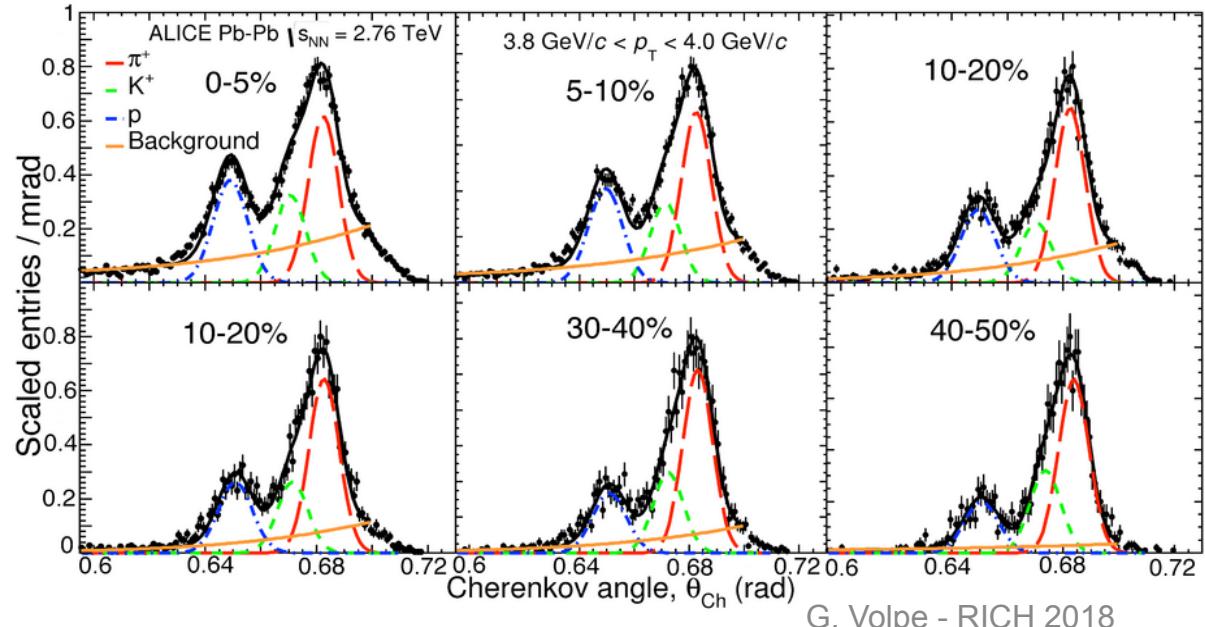
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