Final results on the pi/K/p production in pp and Pb—Pb collision at 5.02 TeV

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V Congreso de la Red Mexicana Científica y Tecnológica para ALICE-LHC

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Outline

- Motivations
- PID with the TPC of ALICE
- Status of the paper: “Production of charged pions, kaons, (anti)protons in Pb—Pb and minimum bias pp collisions at 5.02 TeV”
- Conclusions

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Motivations to do PID in ALICE

- The p_T distributions of pi/K/p allow to study the bulk properties and dynamical evolution on the created system in heavy-ion collisions.

- The high p_T spectra of hadrons (> 10 GeV/c) can be used as proxies for jets to get insight into mechanisms of medium-induced energy loss.

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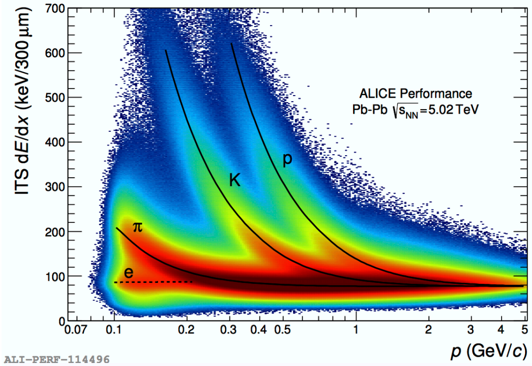

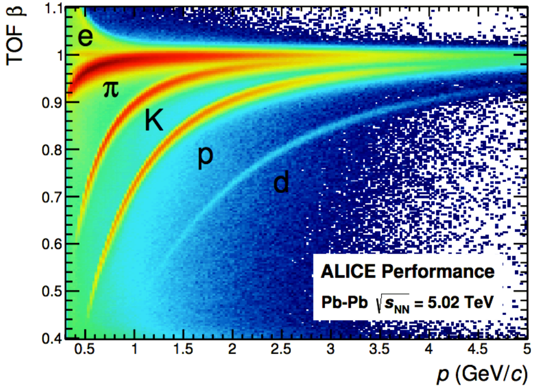

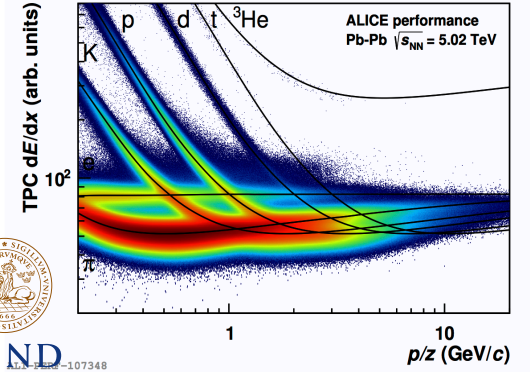

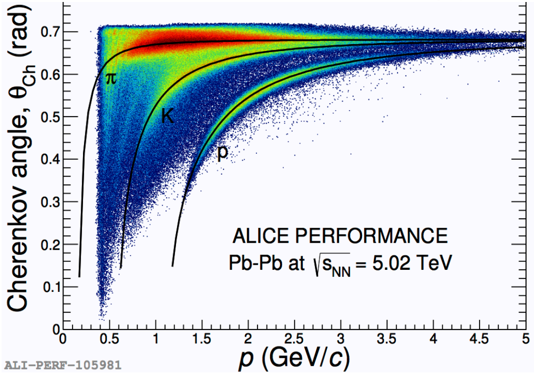

$\pi^{\pm}$	$K^{\pm}$	$p(\bar{p})$
ITS		
0.1 - 0.8	0.2 - 0.6	0.3 - 0.8
TPC (low p_T)		
0.3 - 0.7	0.25 - 0.45	0.4 - 0.8
TPC (high p_T)		
3 - 12	4 - 12	4 - 12
TOF		
0.6 – 2.5	1.0 – 2.5	0.8 – 4
HMPID		
1.5 - 4	1.5 – 4	1.5 - 6
Kinks		
-	0.2-5.0	-
Measured in GeV/*c*		

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$$\frac{\mathrm{d}^2 N_{\bar{\mathrm{p}}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}y} = J f_{\bar{\mathrm{p}}}\, C_{\mathrm{FD}} \left(C_{\mathrm{Mat}} \frac{\epsilon_{\mathrm{ch}}}{\epsilon_{\bar{\mathrm{p}}}} \right) \times \left(\frac{\mathrm{d}^2 N_{\mathrm{ch}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\eta} \frac{1}{\epsilon_{\mathrm{ch}}} \right)_{|\eta|<0.8}$$

*Example for $\bar{\mathrm{p}}$

J: Jacobian transformation ($\eta \rightarrow y$)

$f_{\bar{\mathrm{p}}}$: Particle abundances

C_{FD}: Feed-down correction

C_{Mat}: Geant-Fluka correction

$\frac{\epsilon_{\mathrm{ch}}}{\epsilon_{\bar{\mathrm{p}}}}$: Relative efficiency correction

$\frac{\mathrm{d}^2 N_{\mathrm{ch}}}{\mathrm{d}p_{\mathrm{T}}\mathrm{d}\eta}$: Inclusive charged particle p_{T} spectrum

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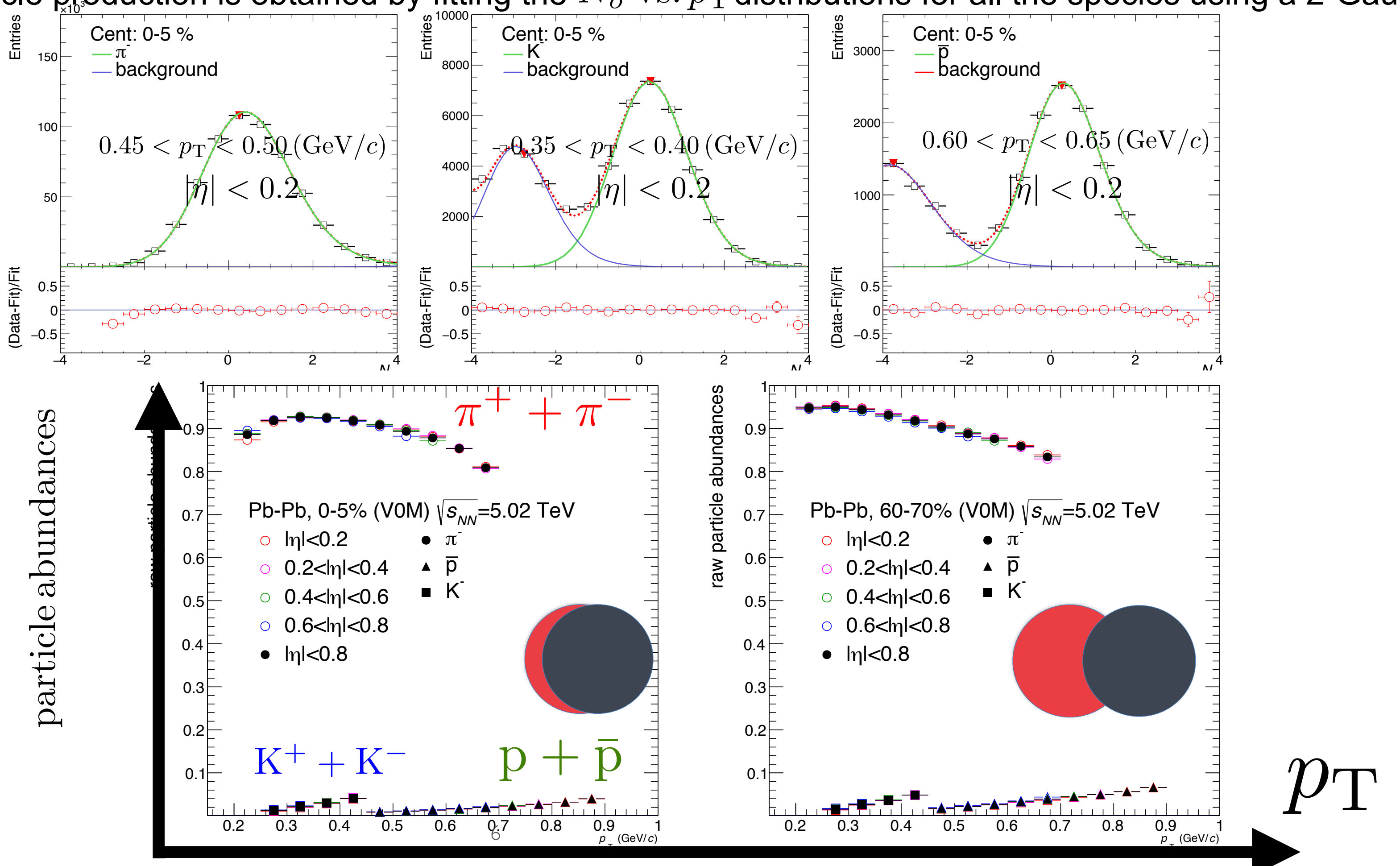
Low p_T analysis

The particle production is obtained by fitting the N_σ vs. p_T distributions for all the species using a 2-Gaussian function



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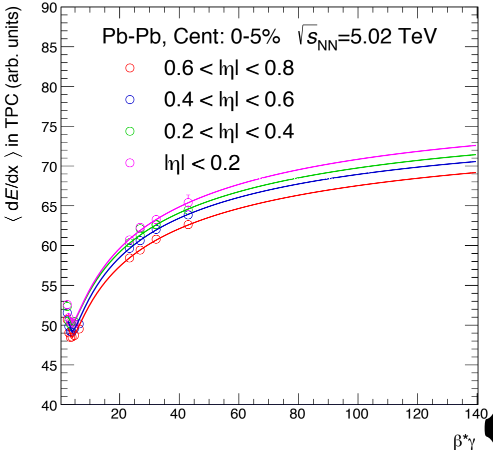
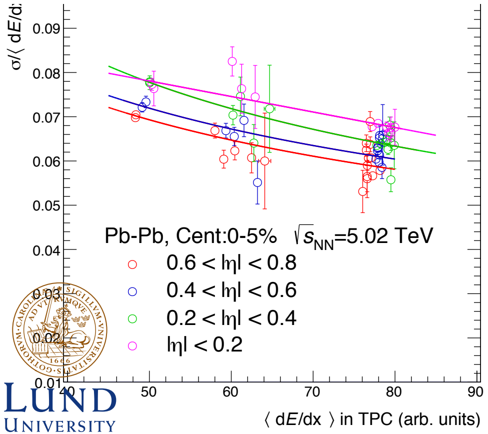
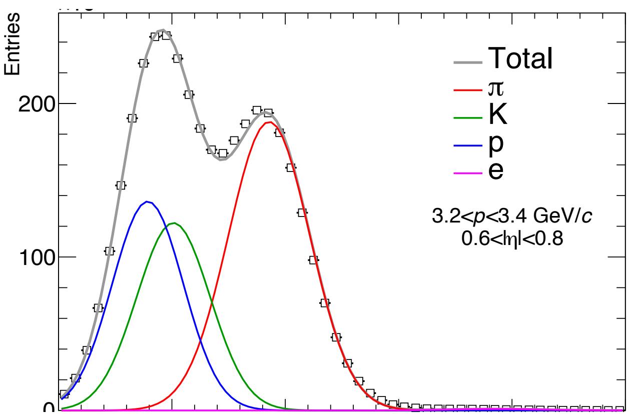
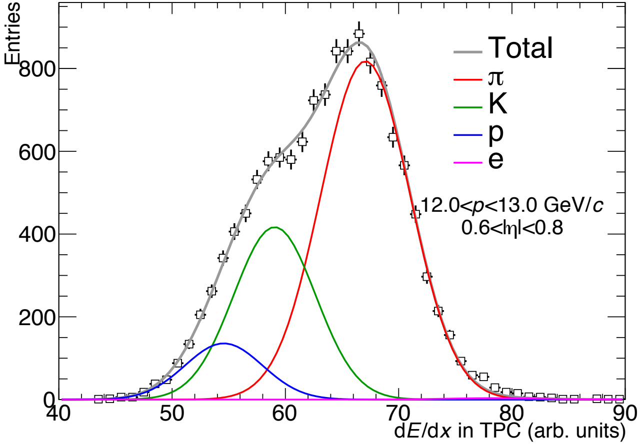
High p_T analysis

1. The extraction of the yields begins with the parameterization of the Bethe-Bloch and resolution curves.
2. The TPC signal is fitted to a four-Gaussian function, in which $\langle \mathrm{d}E/\mathrm{d}x \rangle$ and $\sigma_{\langle \mathrm{d}E/\mathrm{d}x \rangle}$ are extracted from the BB and resolution curves.









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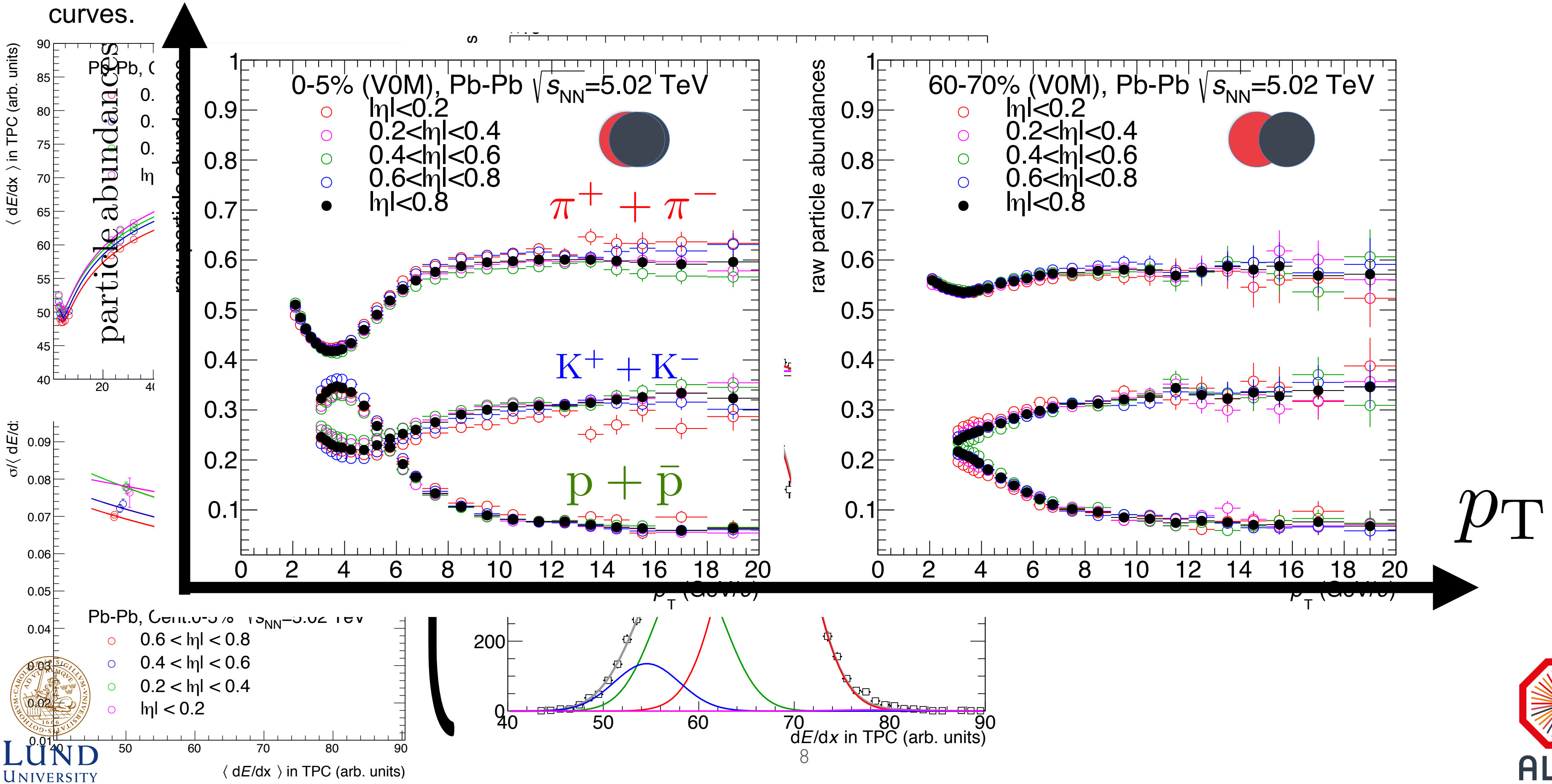
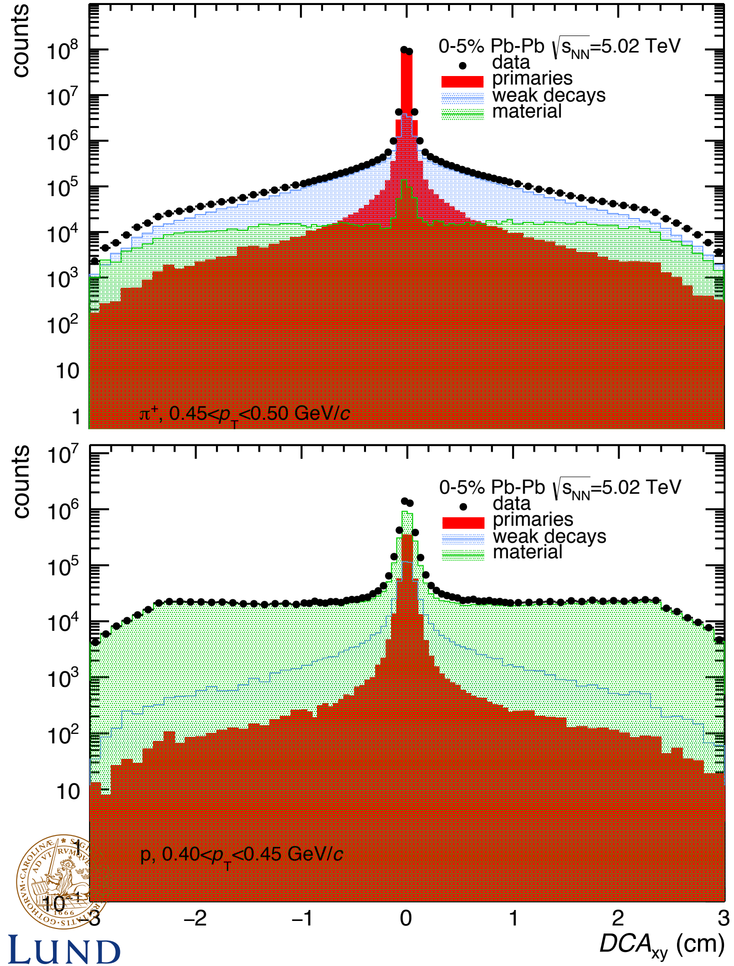
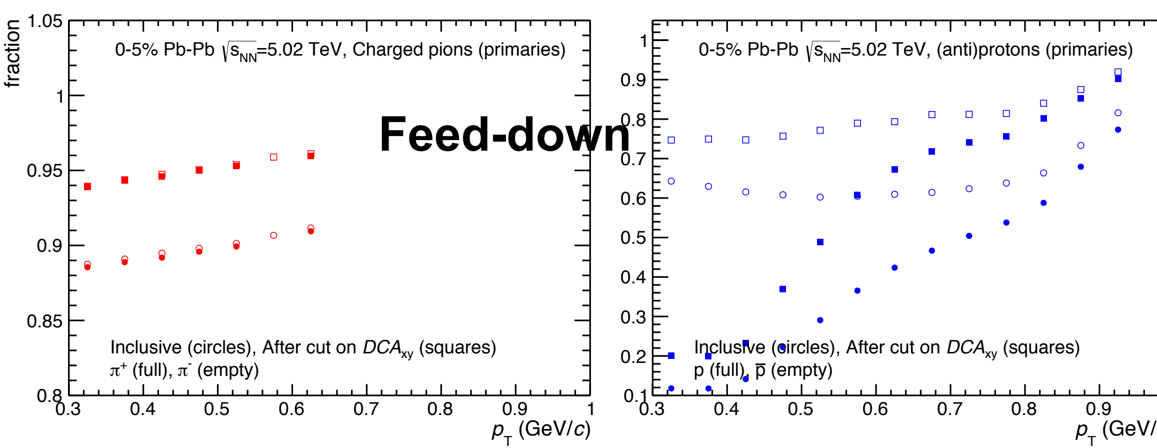
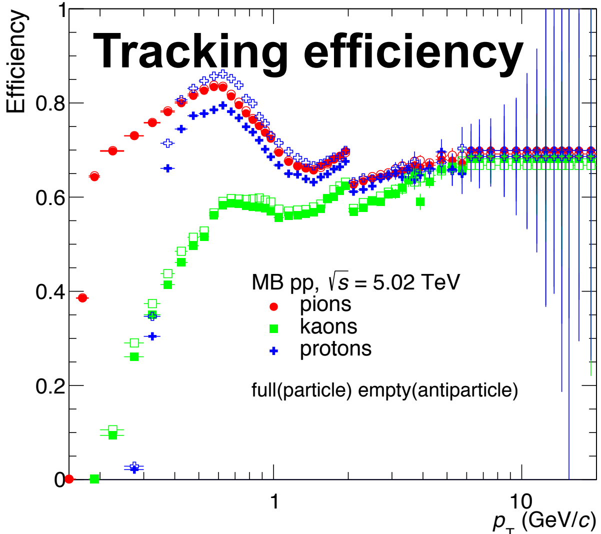


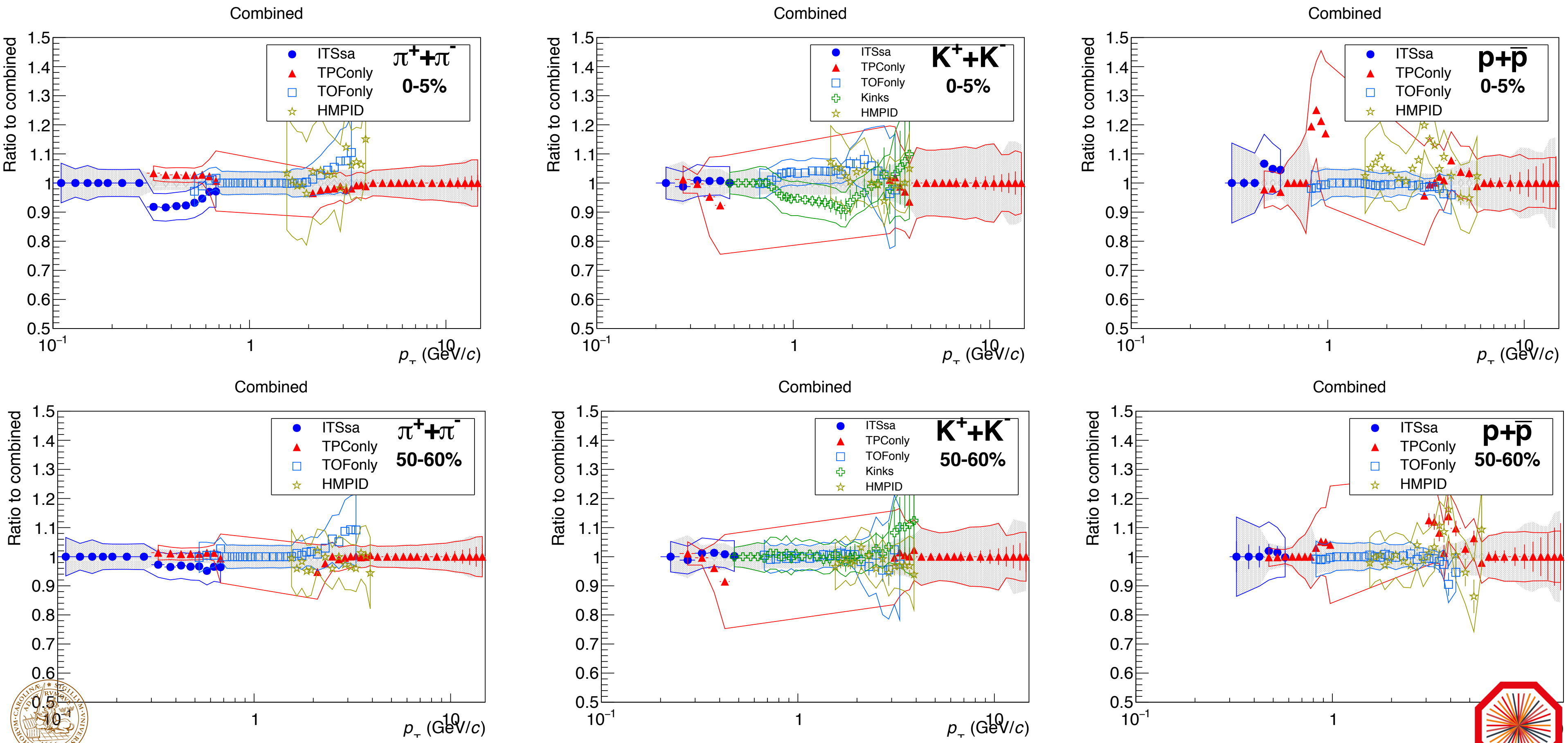
Corrections







Comparison of individual analysis to combined spectra



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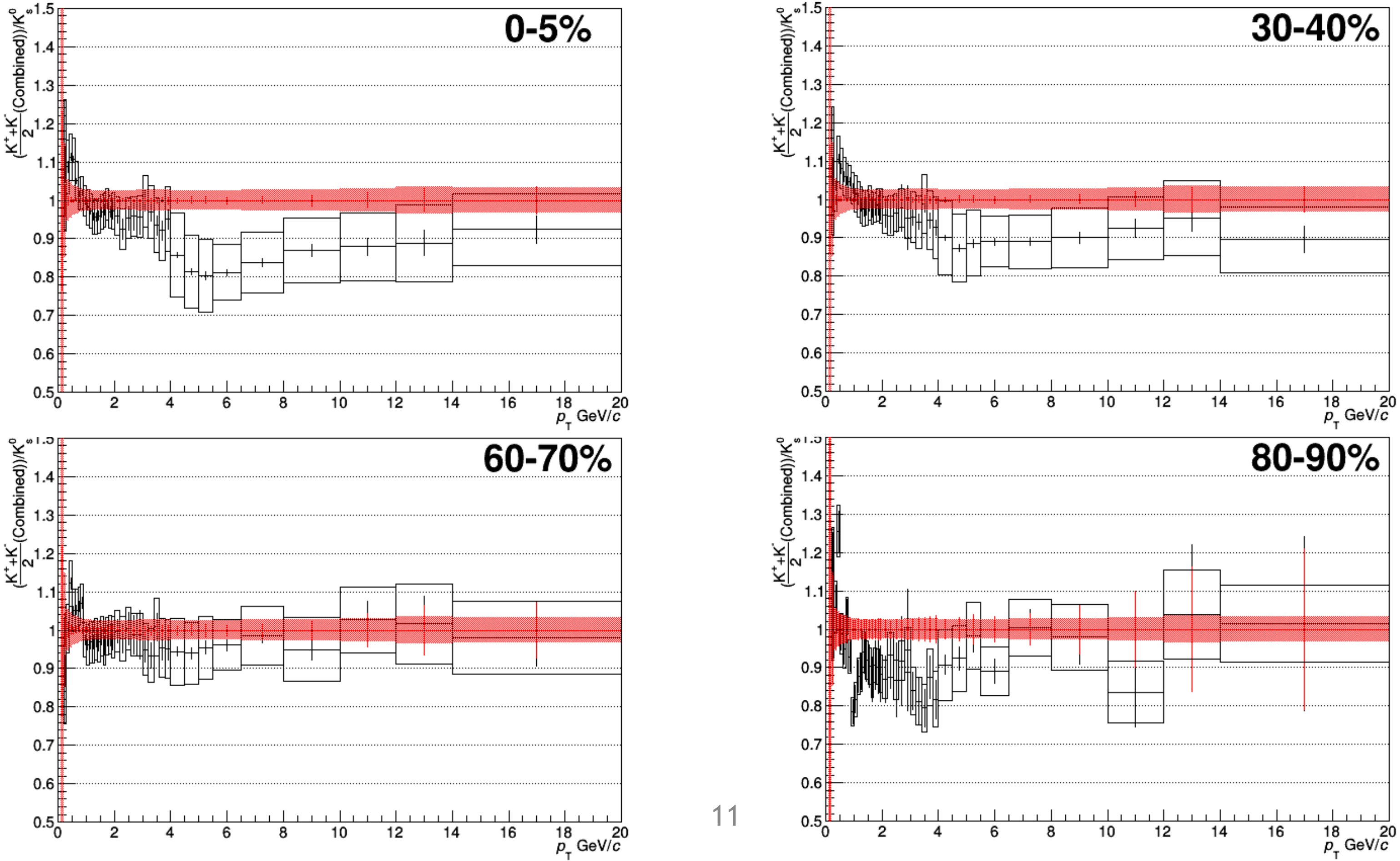
$$\left(\frac{K^+ + K^-}{2}\right)_{\text{Combined}} / K^0_s$$



Production of charged pions, kaons (anti)protons in Pb—Pb and minimum bias pp collisions at 5.02 TeV

Feb. 2017 | May | Aug. | Sept. | Mar. 2018 | Sept.

Approved results by the ALICE collaboration

https://indico.cern.ch/event/433345/sessions/210506/#20170208

https://indico.cern.ch/event/517784/sessions/223846/#20170516

Approved by PB

https://indico.cern.ch/event/578078/sessions/219502/#20170919

1st Iteration with IRC

PWG-LF meeting

Paper ready ~ late October

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Production of charged pions, kaons (anti)protons in Pb—Pb and minimum bias pp at collisions at 5.02 TeV

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP-2018-XXX
25 May 2018

Production of charged pions, kaons and (anti)protons in Pb–Pb and minimum bias pp collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

ALICE Collaboration*

Abstract

In this paper, the mid-rapidity ($|y| < 0.5$) production of $\pi^{\pm}$, $\mathrm{K}^{\pm}$ and $\mathrm{p}(\bar{\mathrm{p}})$ in Pb–Pb and minimum bias pp collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV is presented. The invariant yields are measured over a wide transverse momentum (p_{T}) range from hundreds of MeV/c up to 20 GeV/c. The results in Pb–Pb collisions are presented as a function of the collision centrality. The comparison of the p_{T}-integrated particle ratios, i.e. proton-to-pion and kaon-to-pion ratios, with analogous measurements in Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV show no significant energy dependence. However, particle ratios as a function of p_{T} show distinctive maxima at $p_{\mathrm{T}} \approx 3$ GeV/c in central Pb–Pb collisions. Their positions slightly depend on energy, in particular for the proton-to-pion ratio. The blast-wave analysis of the p_{T} spectra gives an average transverse expansion velocity of $\langle \beta_T \rangle \approx 0.663 \pm 0.004$, indicating that radial flow is slightly higher than that measured at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV ($\langle \beta_T \rangle \approx 0.651$). Using the pp reference spectra measured at the same collision energy of 5.02 TeV, the nuclear modification factors for the different particle species are derived. Within uncertainties, the nuclear modification factor is particle species independent for $p_{\mathrm{T}} > 10$ GeV/c and compatible with measurements at $\sqrt{s_{\mathrm{NN}}} = 2.76$ TeV. The results are compared with theoretical predictions.

*See Appendix A for the list of collaboration members

ID number: 3828

e-group: alice-paperdraft-id3828

PWG: PWG-LF (Light Flavour Spectra)

Format: Regular Paper

Approved by PB: 30 August, 2017

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Particle production at low p_T

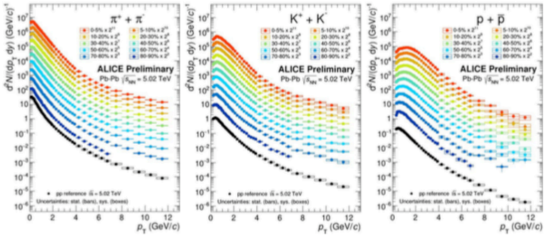


Fig. 3: Transverse momentum spectra of pions (left), kaons (middle) and protons (right) measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV for different centrality classes. Scale factors are applied for better visibility. The results are compared with the spectra measured in minimum-bias pp collisions at $\sqrt{s} = 5.02$ TeV. Statistical and systematic uncertainties are displayed as error bars and boxes around the data points, respectively.

3.1 Particle production at low transverse momentum

In order to quantify the centrality dependent change of the spectral shapes at low p_T (< 2-3 GeV/c) the Boltzmann-Gibbs blast-wave function [66], reported in Eq. 3 has been simultaneously fitted to the charged pion, kaon and (anti)proton spectra.

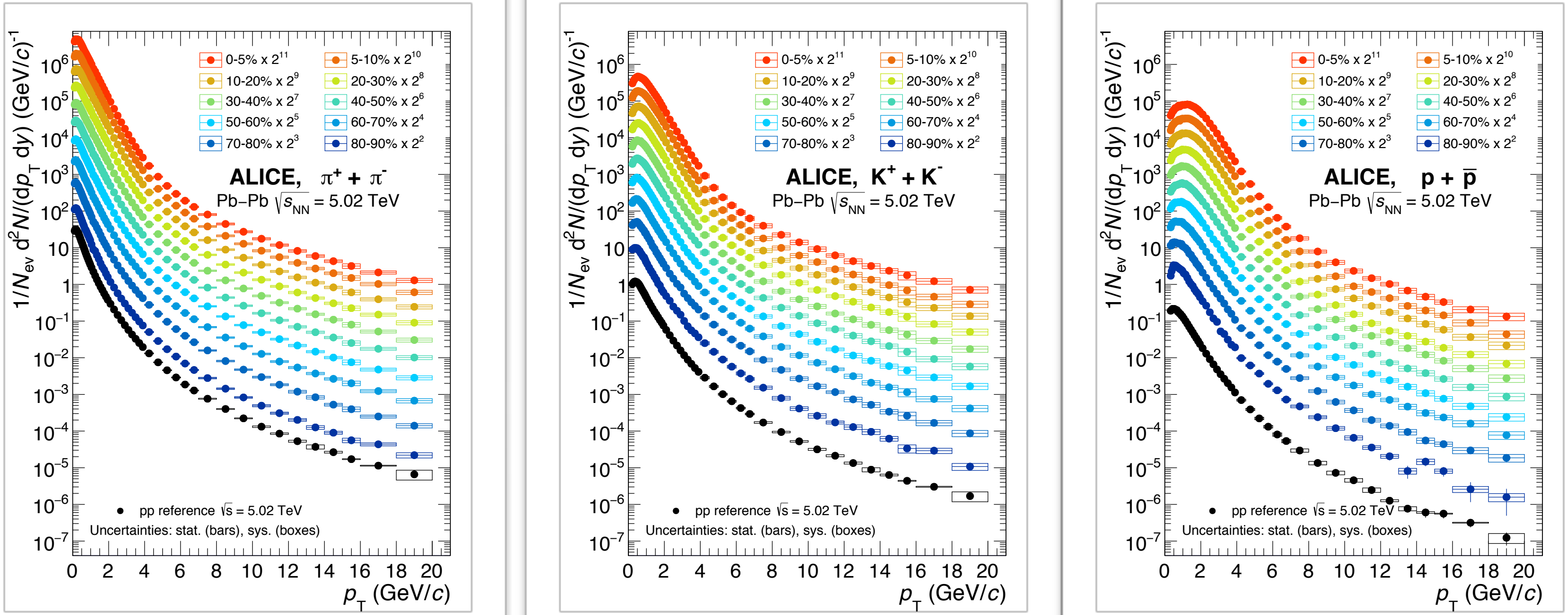
$$E\frac{d^3N}{dp^3} \propto \int_0^R m_T I_0\left(\frac{p_T \sinh(\rho)}{T_{kin}}\right) K_1\left(\frac{m_T \cosh(\rho)}{T_{kin}}\right) r\,dr \tag{3}$$

The blast-wave function is a three parameters simplified hydrodynamic model where the velocity profile ρ is given by:

$$\rho = \tanh^{-1}\beta_T = \tanh^{-1}\left(\left(\frac{r}{R}\right)^n \beta_s\right) \tag{4}$$

where β_T is the radial expansion velocity, m_T the transverse mass ($m_T = \sqrt{m^2 + p_T{}^2}$) and T_{kin} the temperature at the kinetic freeze-out. Although the absolute values of the parameters have a strong dependence on the fitting range used in the analysis, it still makes sense to compare the evolution of the parameters with $\sqrt{s_{NN}}$ when the fits are done within the same p_T intervals. In the present analysis we used the same p_T intervals employed in a previous publication [15], namely, $0.5-1$ GeV/c, $0.2-1.5$ GeV/c and $0.3-3$ GeV/c for charged pions, kaons and (anti)protons, respectively. Figure 4 shows the ratios of the spectra to the combined fits for all the centrality classes and particle species. If the behavior of the spectra over the full p_T range would be purely hydrodynamic, then the fitted functions determined within a limited p_T range would be expected to describe the spectral shape in the full p_T range. This is only observed for the proton and kaon p_T spectra in 0-20% Pb–Pb collisions. A different situation is observed for pions where, due to their smaller masses and feed down from resonance decays, the agreement with the model is worse than that observed for kaons and (anti-)protons. The p_T threshold at which the function deviates from the data increases with increasing the impact parameter, indicating the need for more sophisticated hydrodynamic implementations.

Particle production at low p_T



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- The full p_T spectra is a combined result of independent PID techniques: ITS, TPC,TOF, HMPID and kaons identification from kinks.
- Going from peripheral to central Pb-Pb collisions the spectra exhibit a flattening at low p_T (~ 1 GeV/c), the effect is more pronounced for heavier particles. This behavior is consistent with the presence of radial flow.

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Intermediate p_T

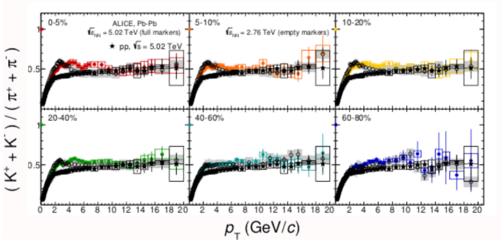

Fig. 8: Centrality dependence of the K/π ratio as a function of transverse momentum, measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ and 2.76 TeV. The ratio in pp collisions at $\sqrt{s} = 5.02$ TeV is also show. The statistical and systematic uncertainties are shown as error bars and boxes around the data points, respectively.

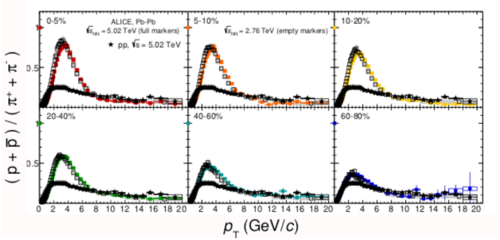

Fig. 9: Centrality dependence of the p/π ratio as a function of transverse momentum, measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ and 2.76 TeV. The ratio in pp collisions at $\sqrt{s} = 5.02$ TeV is also show. The statistical and systematic uncertainties are shown as error bars and boxes around the data points, respectively.

Figure 9 shows the proton-to-pion (p/π) ratio as a function of p_T. The ratios measured in heavy-ion collisions exhibit a pronounced enhancement with respect to minimum-bias pp collisions, reaching a value of about 0.9 at $p_T = 3$ GeV/c. This is reminiscent of the increase in the baryon-to-meson ratio observed at RHIC in the intermediate p_T region [74]. Such an increase with p_T is an intrinsic feature of hydrodynamic models, where it is due to the mass ordering induced by radial flow (heavier particles are boosted to higher p_T by the collective motion). It should be noted, however, that this is also suggestive of the recombination picture as discussed in the introduction. However, since recombination is a baryon effect, it would not explain the bump which is also observed in the kaon-to-pion ratio. Because in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV the radial flow was found to be higher than at $\sqrt{s_{NN}} = 2.76$ TeV, we can

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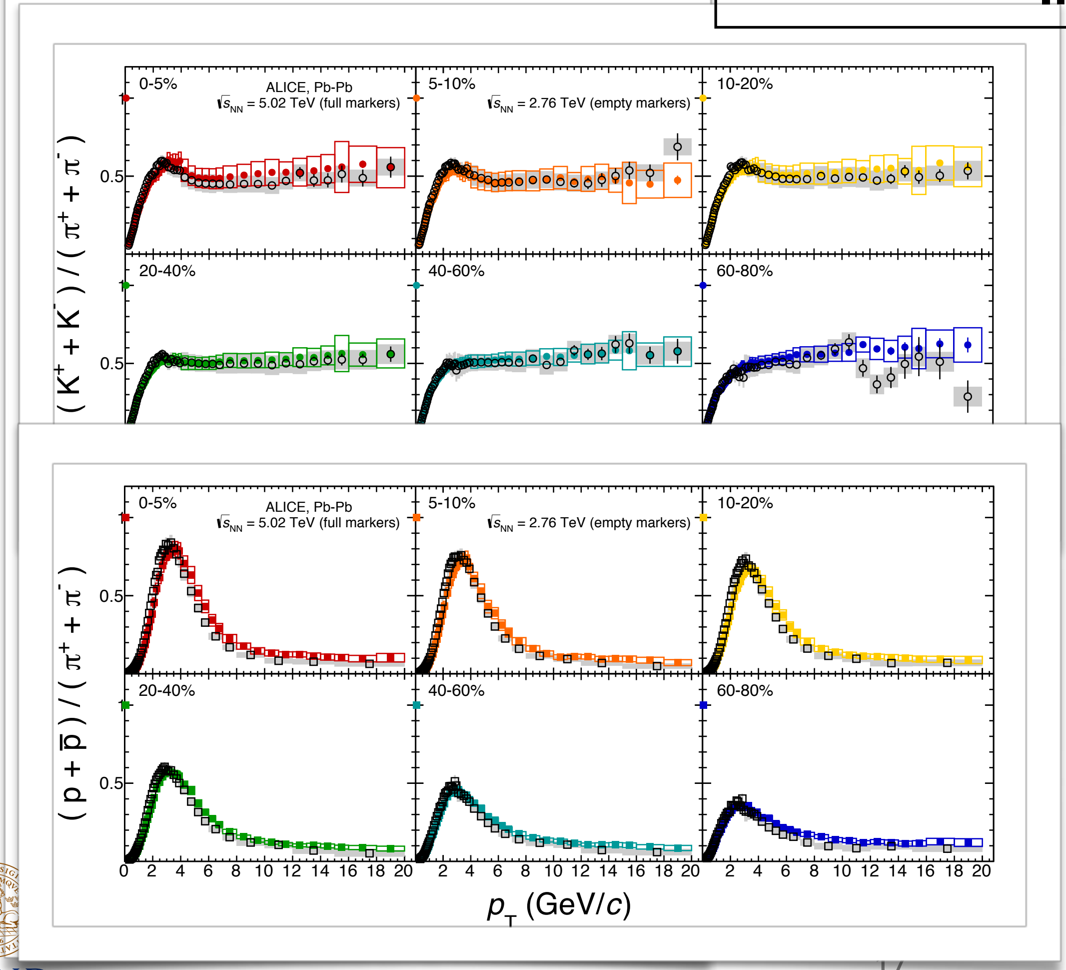
Intermediate p_T



- In the proton-to-pion ratio, the shift of the peak toward higher values of p_T indicates a signature of stronger radial flow compared to Pb—Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV.

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Particle production at high p_T

understand that the p/π bump is located at higher p_T in 5.02 TeV data. Finally, both particle ratios for $p_T > 10$ GeV/c become similar to 2.76 TeV and behave like those in pp collisions, suggesting that vacuum-like fragmentation processes dominated there [27].

3.3 Particle production at high transverse momentum

Figure 10 shows the centrality dependence of R_{AA} as a function of p_T for charged pions, kaons and (anti)protons. For $p_T < 10$ GeV/c protons appear to be less suppressed than kaons and pions, consistent with the particle ratios shown in Fig. 9. At larger p_T (>10 GeV/c) all particle species are equally suppressed; so despite the strong energy loss observed in the most central heavy-ion collisions, the particle composition and ratios at high p_T are similar to those in vacuum. This suggests that jet quenching does not produce signatures that affect the particle species composition for the leading particles. It is worth mentioning two interesting features of the unidentified-charged particle production [75] which has been measured up to 300 GeV/c [37]. Firstly, as seen in the identified particle results a gradual approach of R_{AA} to unity is observed going from central to 60-80% Pb–Pb collisions. Secondly, for central Pb–Pb collisions the results for unidentified charged particles gives an R_{AA} which reaches unity for p_T higher than 100 GeV/c. The second effect can not been seen in the pion, kaon and (anti-)proton analysis due to the limited p_T reach. However, based on inclusive charged particle R_{AA} results, the R_{AA} of identified particles is also expected to increase up unity for very high p_T.

Concerning the behavior of the identified-particle R_{AA} for peripheral Pb–Pb collisions, namely, the apparent presence of jet quenching ($R_{AA} < 1$) though for similar particle densities in smaller systems (like p-Pb collisions) no jet quenching signatures have been reported [76]. It has been argued that peripheral A-A collisions can be significantly affected by event selection and geometry biases [77] leading to an apparent suppression for R_{AA} even if jet quenching and shadowing are absent. The presence of the biases in heavy-ion data has been confirmed by means of the measurement of R_{AA} for very peripheral Pb–Pb collisions [78]. All hard probes should be similarly affected [77], in particular the leading pions, kaons and protons reported in the present paper.

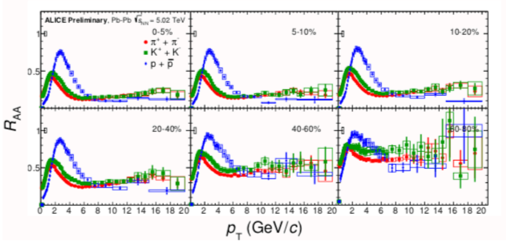
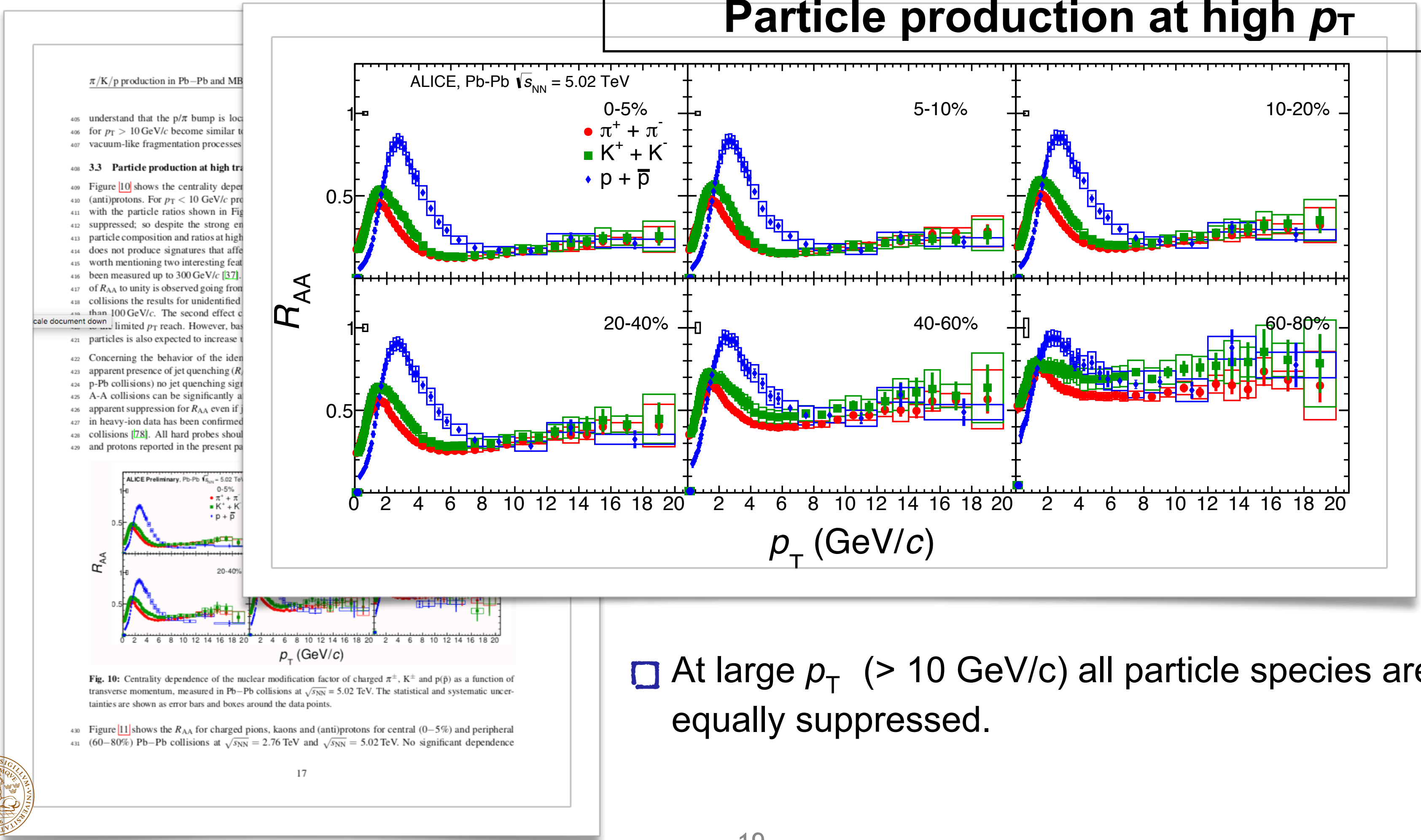


Fig. 10: Centrality dependence of the nuclear modification factor of charged $\pi^{\pm}$, $K^{\pm}$ and p($\bar{p}$) as a function of transverse momentum, measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The statistical and systematic uncertainties are shown as error bars and boxes around the data points.

Figure 11 shows the R_{AA} for charged pions, kaons and (anti)protons for central (0–5%) and peripheral (60–80%) Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 5.02$ TeV. No significant dependence

Particle production at high p_T



- At large p_T (> 10 GeV/c) all particle species are equally suppressed.

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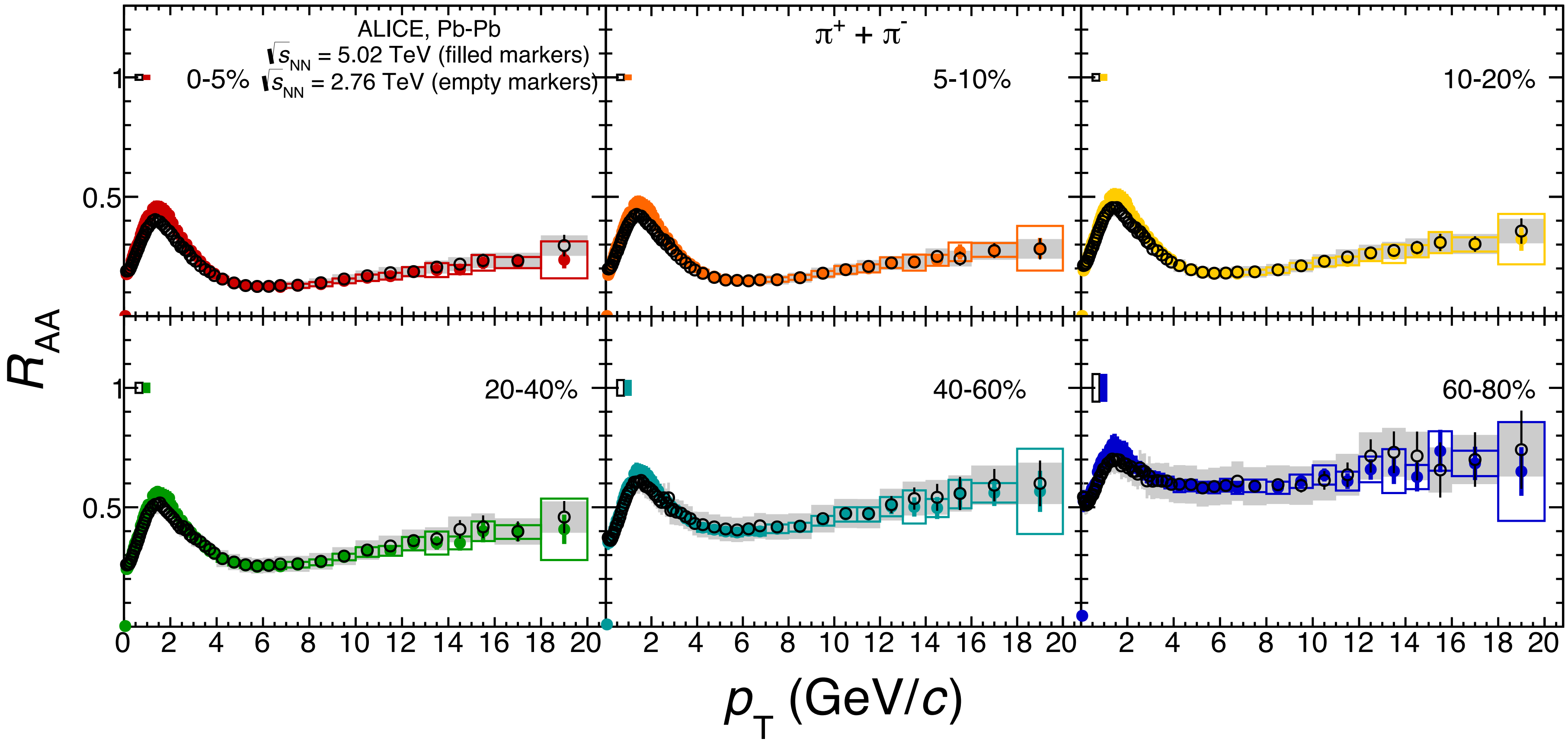
Conclusions

- We have observed an increase of radial flow compared to Pb—Pb collisions at 2.76 TeV.

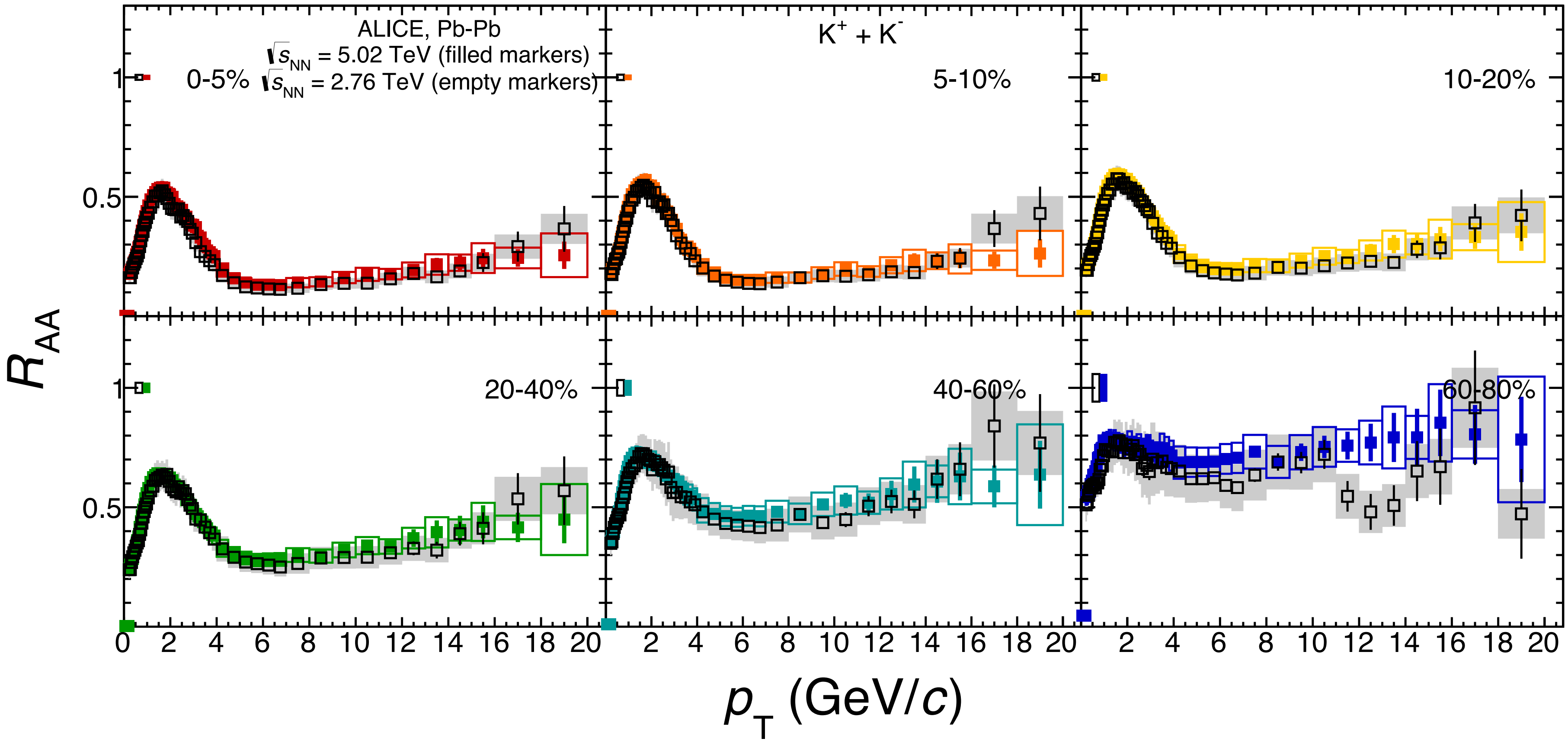
- No significant evolution of nuclear modification at high-p_T with the center of mass energy is observed.

- The publication of the “Production of charged pions, kaons, (anti)protons in Pb—Pb and minimum bias pp collisions at 5.02 TeV” paper is approaching fast !!

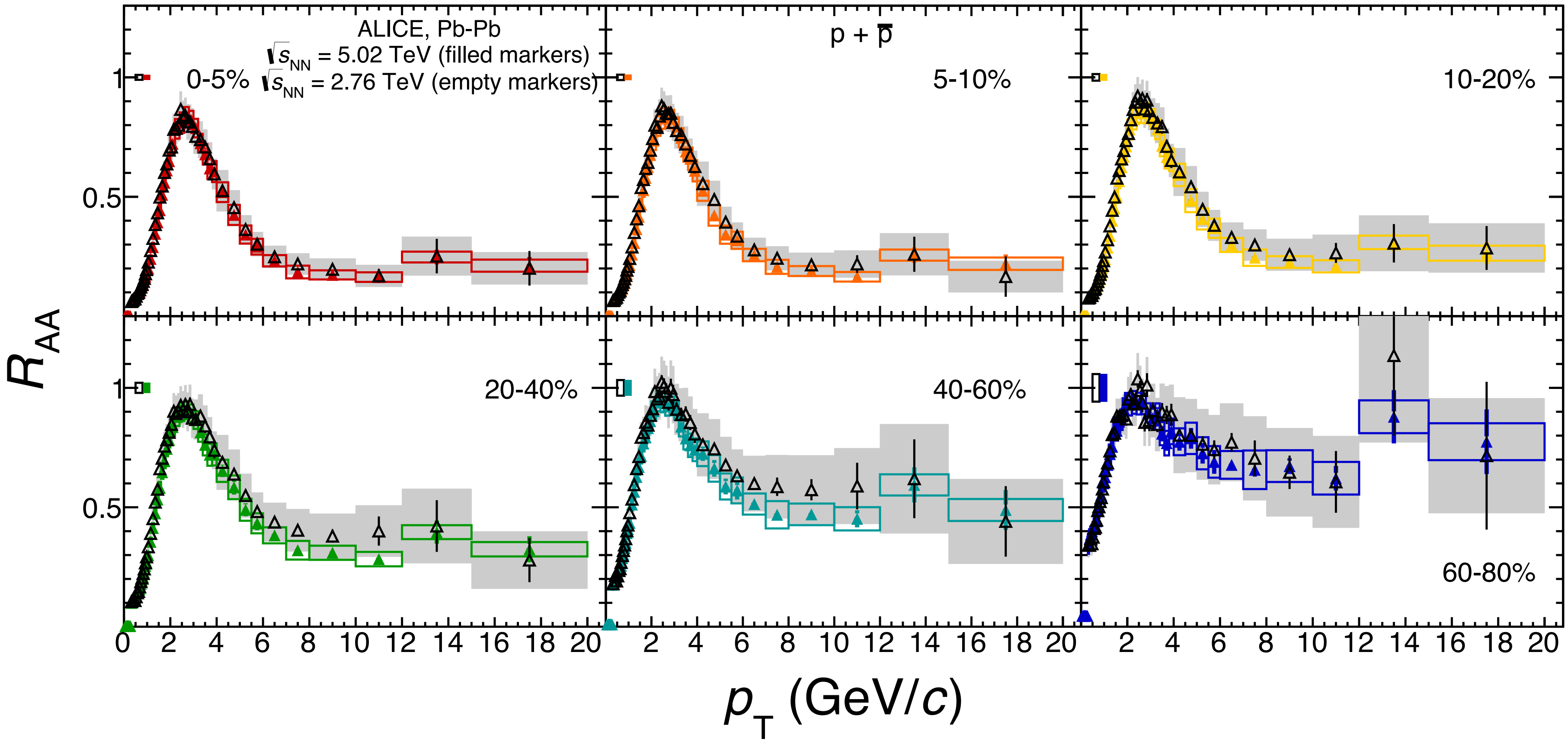
Backup

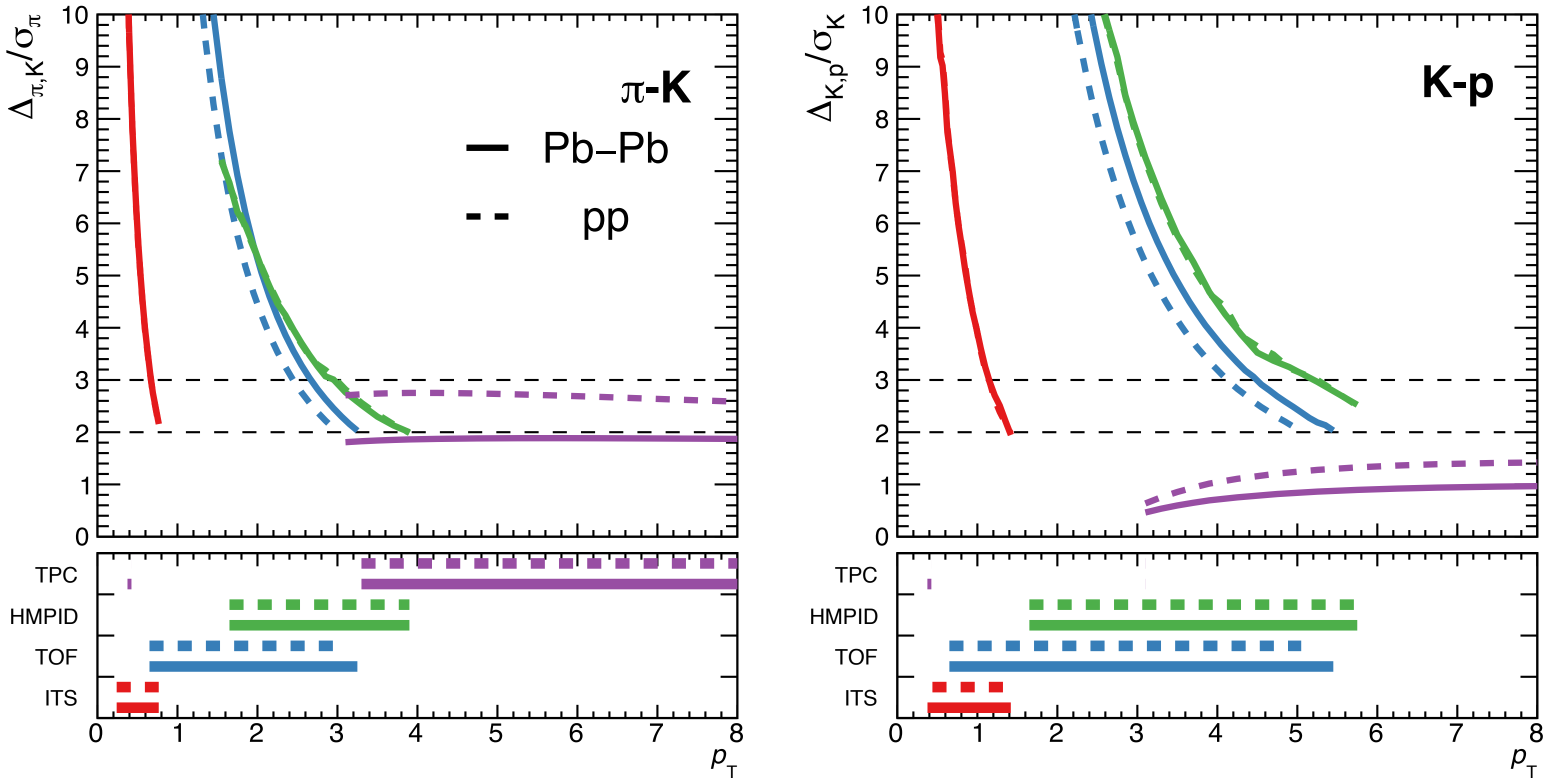


ALICE, Pb-Pb
$\sqrt{s_{NN}}$ = 5.02 TeV (filled markers)
$\sqrt{s_{NN}}$ = 2.76 TeV (empty markers)
$\pi^{+} + \pi^{-}$
0-5%
5-10%
10-20%
20-40%
40-60%
60-80%
R_{AA}
p_{T} (GeV/c)



ALICE, Pb-Pb
$\sqrt{s_{NN}}$ = 5.02 TeV (filled markers)
0-5%
$\sqrt{s_{NN}}$ = 2.76 TeV (empty markers)
$K^+ + K^-$
5-10%
10-20%
20-40%
40-60%
60-80%
R_{AA}
p_T (GeV/c)


ALICE, Pb-Pb
$\sqrt{s_{NN}}$ = 5.02 TeV (filled markers)
$\sqrt{s_{NN}}$ = 2.76 TeV (empty markers)
p + $\bar{p}$
0-5%
5-10%
10-20%
20-40%
40-60%
60-80%
R_{AA}
p_T (GeV/c)
0.5
1
0
2
4
6
8
10
12
14
16
18
20



❖ Separation power of hadron identification.

Power low exponent