

Production of π^0 , η and K^\pm measured with the ALICE detector at the LHC

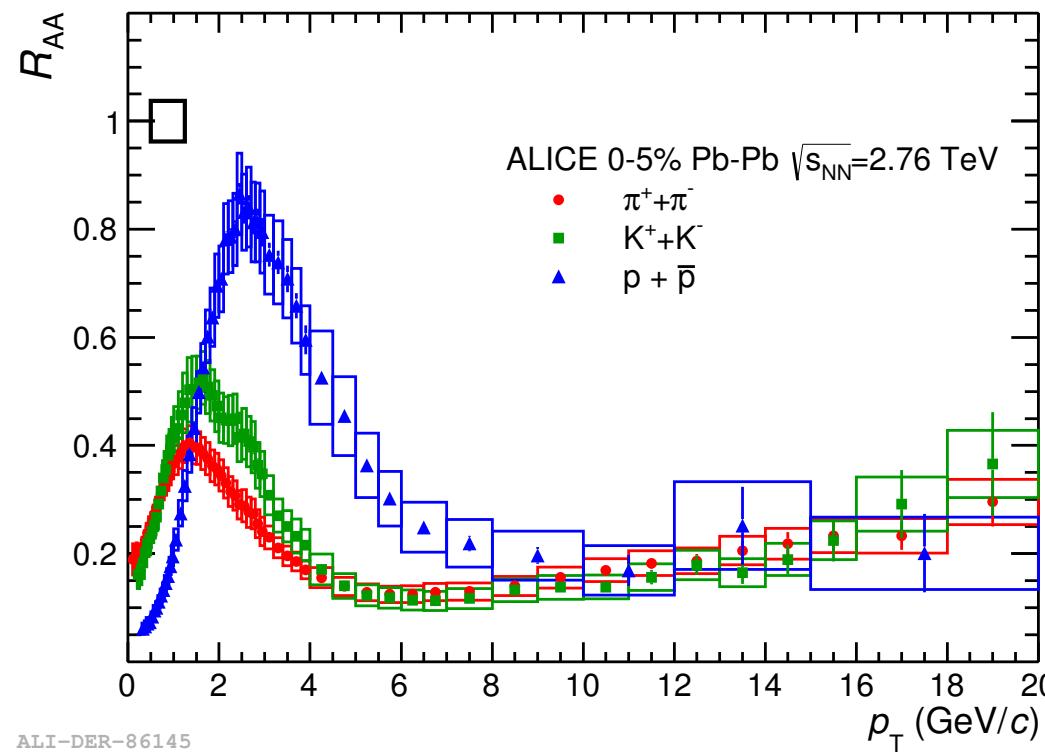
Astrid Morreale for the ALICE Collaboration

SUBATECH

June, 30 2016

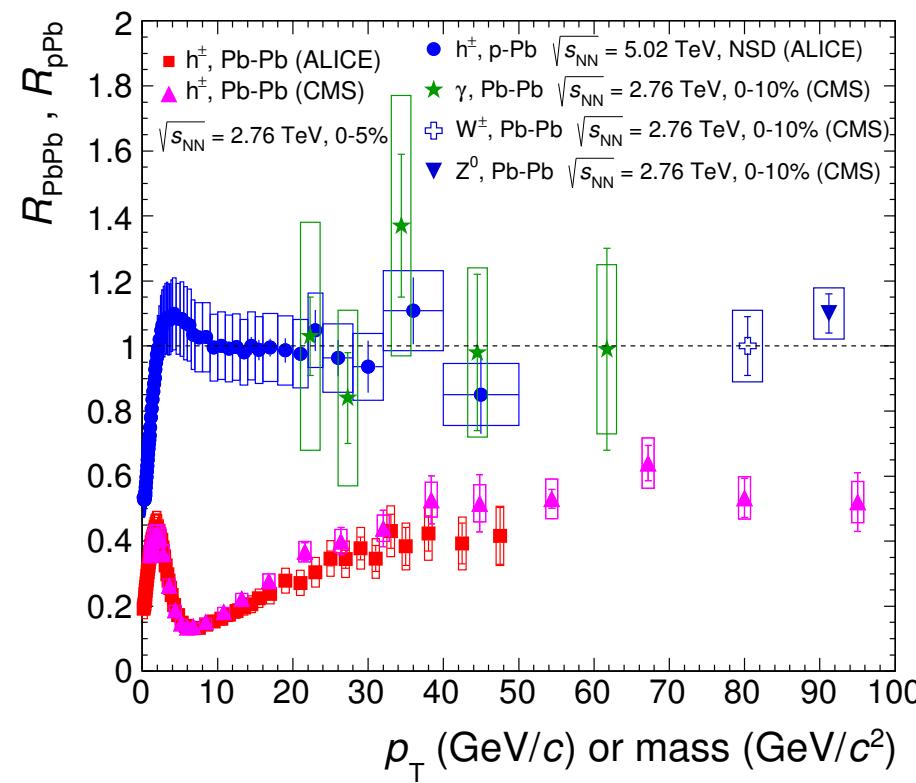
Strangeness in Quark Matter 2016, United States

- At low p_T , mesons give insight about bulk properties and collective effects.
- Particles with different masses will be affected differently by the collective motion of the medium.
- One expects a mass ordering of the R_{AA} at low p_T due to radial flow.



Light mesons as probes of the QGP

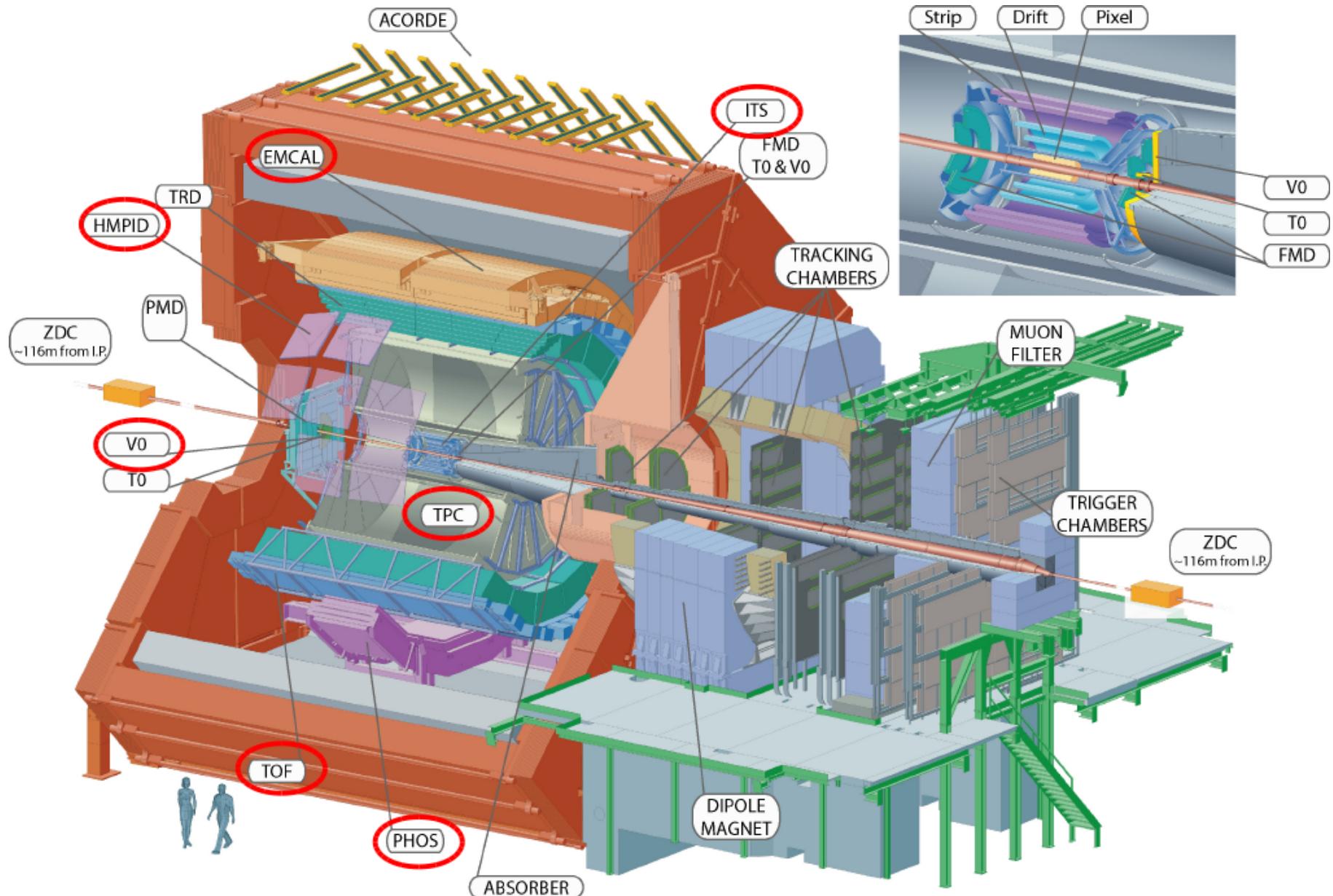
- High p_T hadrons result from the hadronization of partons created in initial hard scattering.
- The suppression of hadron production at high p_T in heavy-ion collisions is interpreted as energy loss of the scattered parton in the QGP.
- Gluons are expected to suffer a larger energy loss in the medium than quarks (casimir factor).
- This effect may give rise to differences in suppression patterns between π^0 and η .
- Expect larger energy loss of high p_T partons at higher \sqrt{s} , however due to a less steeply falling spectrum, for a given magnitude of partonic energy loss, **a smaller suppression** may be observed at high p_T .



- The apparatus and its PID techniques
- Invariant yields in pp
- Invariant yields in Pb-Pb
- The nuclear modification factor
- Particle ratios
- Conclusions

More on strangeness production measurements at ALICE see Domenico Colella's talk (Tuesday 14:40 Strangeness production I)

The ALICE experiment



Detectors relevant for this presentation: PHOS, EMCal, ITS, TPC, TOF, HMPID, V0.

Neutral meson detection

- Photon Conversion Method (PCM):

ITS and TPC ($X/X_0 = 11.4 \pm 0.5_{\text{sys}} \%$)

$|\eta| < 0.9, 0^\circ < \varphi < 360^\circ$.

8.5% conversion probability: small but compensated by a wide acceptance.

- PHOS calorimeter:

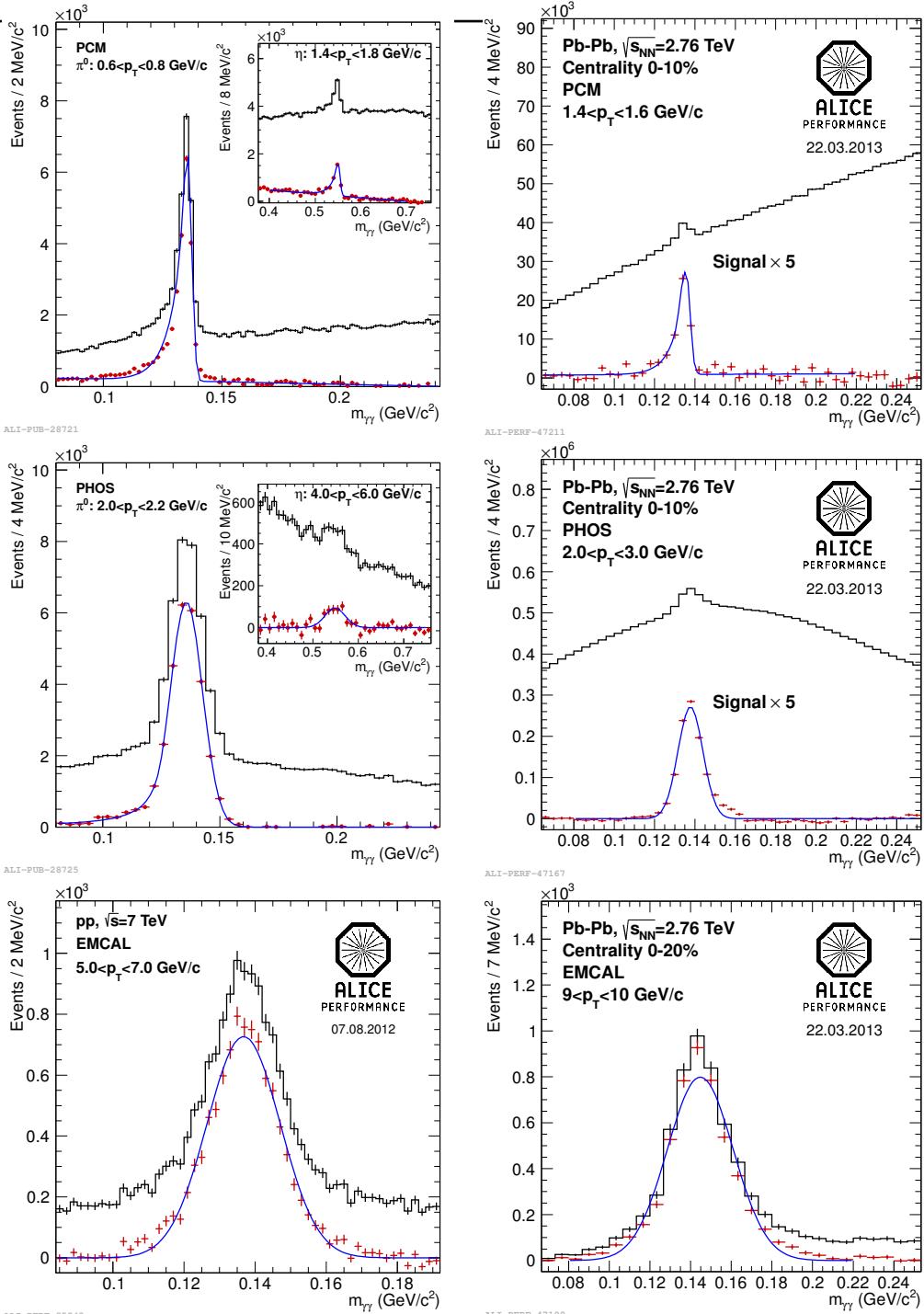
$|\eta| < 0.13, 260^\circ < \varphi < 320^\circ$

$$\frac{\sigma_{E(\text{GeV})}}{E} = \frac{1.8\%}{E} \oplus \frac{3.3\%}{\sqrt{E}} \oplus 1.1\%$$

- EMCal:

$|\eta| < 0.7, 80^\circ < \varphi < 180^\circ$.

$$\frac{\sigma_{E(\text{GeV})}}{E} = \frac{4.9\%}{E} \oplus \frac{9.4\%}{\sqrt{E}} \oplus 1.3\%$$



- PID is done via the specific energy loss (dE/dx) of particles traversing the TPC gas.

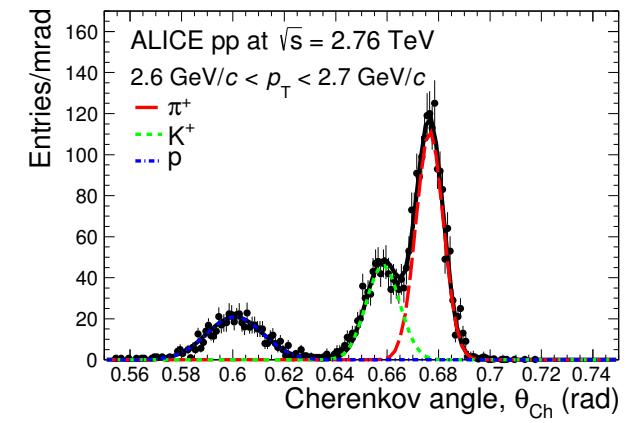
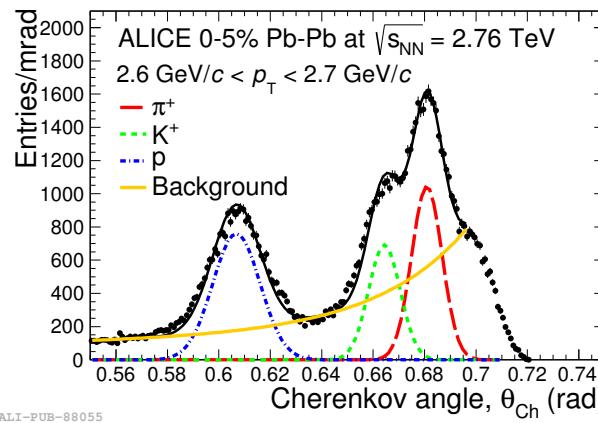
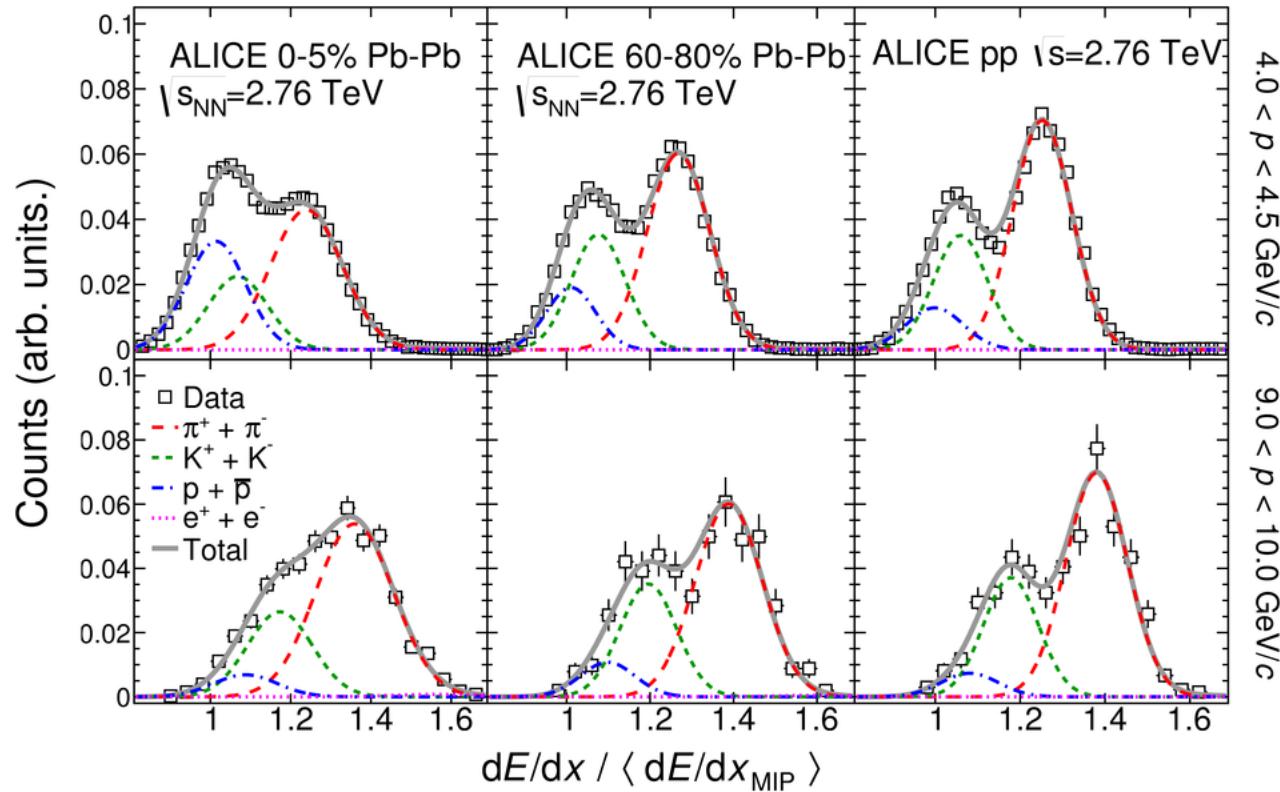
- Figure: dE/dx distributions

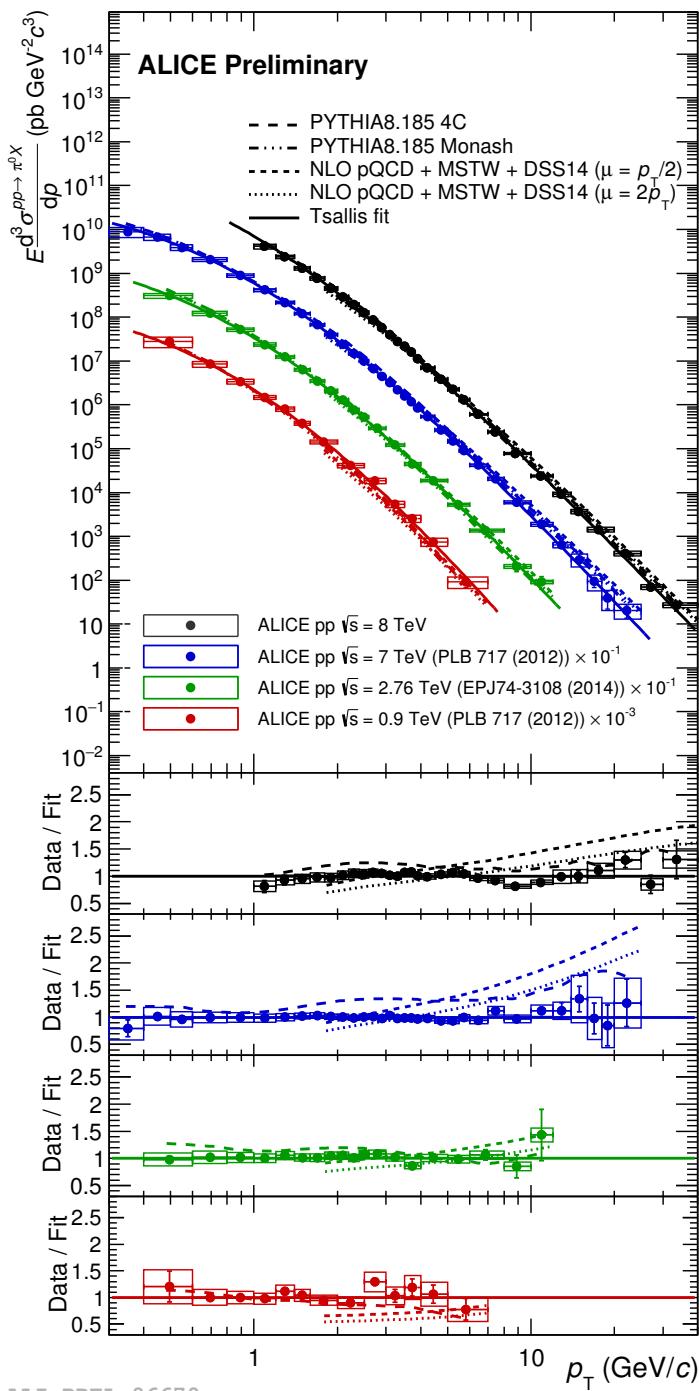
Signals are fitted to a sum of four Gaussian functions (solid line).

Electron fraction is below 1%.

- PID is improved at $p_T < 4 \text{ GeV}/c$ (K^\pm) with the use of the TOF and the HMPID

- Figure: Distributions of the Cherenkov angle measured in the HMPID for positive tracks in pp collisions





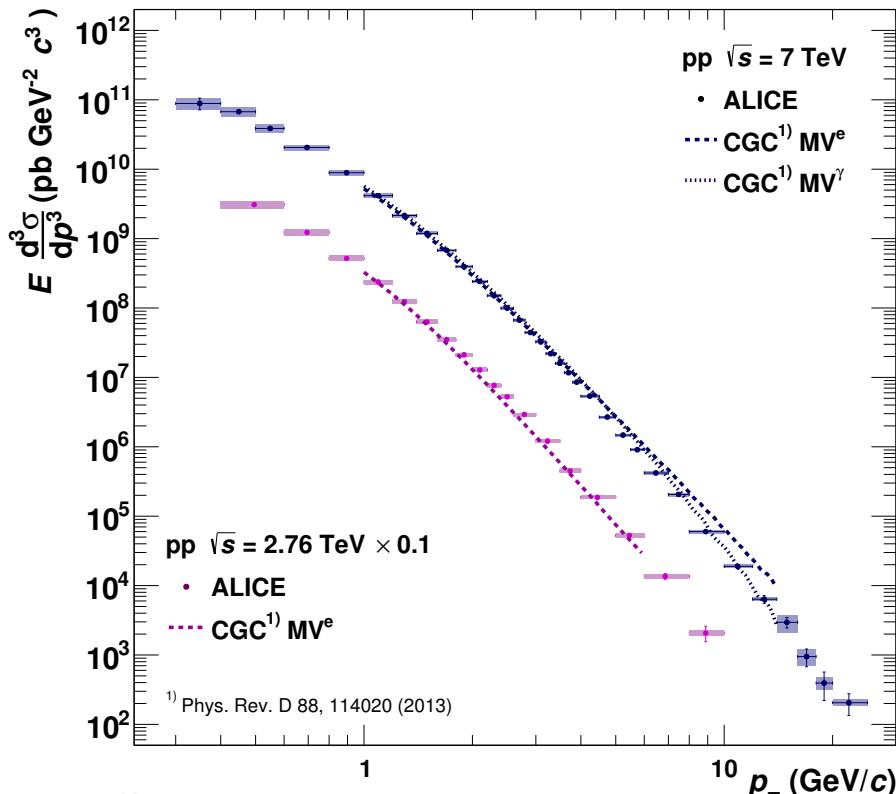
- Invariant yields at four \sqrt{s}
- Power law dependence at high p_T

\sqrt{s} (TeV)	n
0.9	7.0 ± 2.0
2.76	6.0 ± 0.5
7.0	6.0 ± 0.1
8.0	5.9 ± 0.1

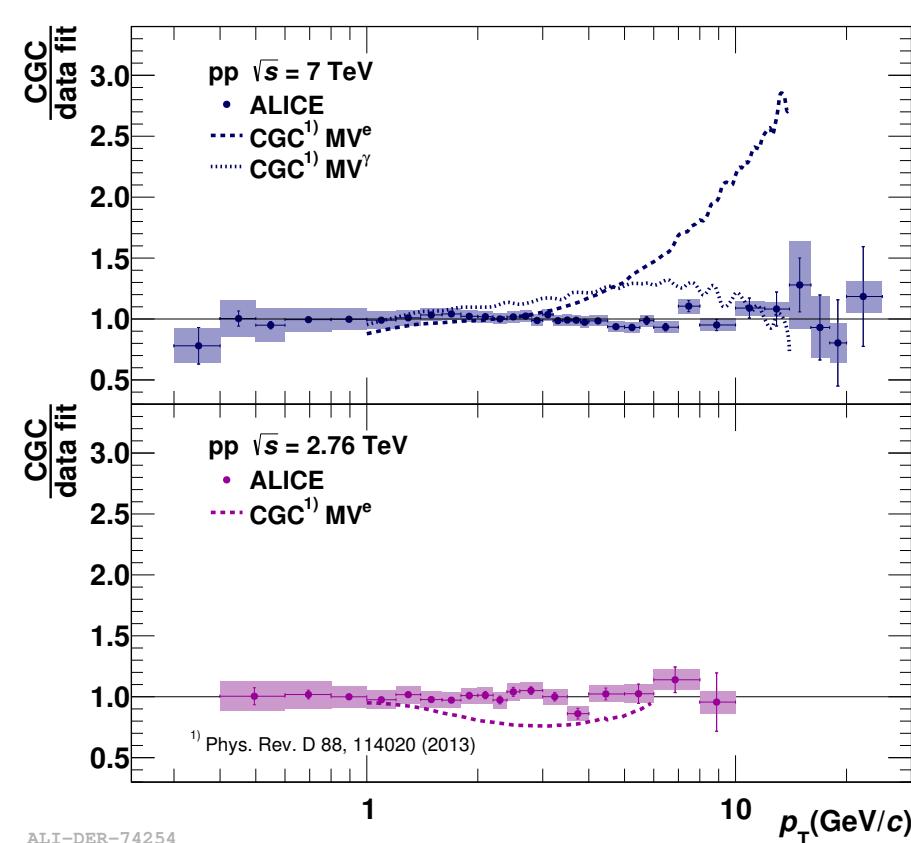
To be compared to $n = 8.22 \pm 0.1$ at RHIC ($\sqrt{s} = 0.2$ TeV)

- NLO pQCD calculations (*Phys. Rev. D91 (2015) 1*) describe the magnitude of π^0 production
- Increasing discrepancy with increasing p_T and \sqrt{s} .
- PDF: MSTW, fragmentation functions: DSS14

PLB 717 (2012) 162; Eur. Phys. J. C74 (2014) 10, 3108;
arXiv:1512.05250



ALI-DER-74237



ALI-DER-74254

CGC aims at describing strong interacting systems in the high energy limit: non-linear phenomena, gluon recombination.

Comparisons could give insights to the initial state gluon distributions.

Model describes ALICE data in the p_T region of 1-10 GeV/c , NPA931(2014).

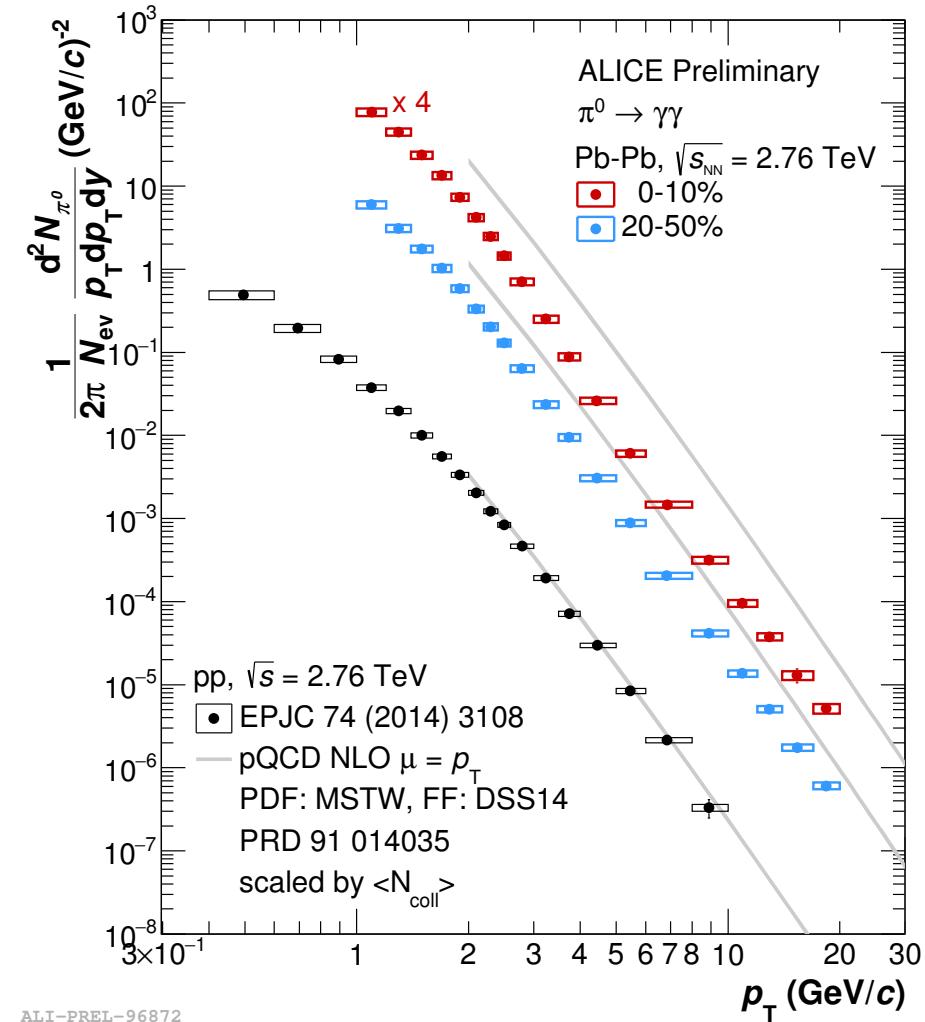
MV^y and MV^e: Parametrizations based on the McLerran-Venugopalan model.

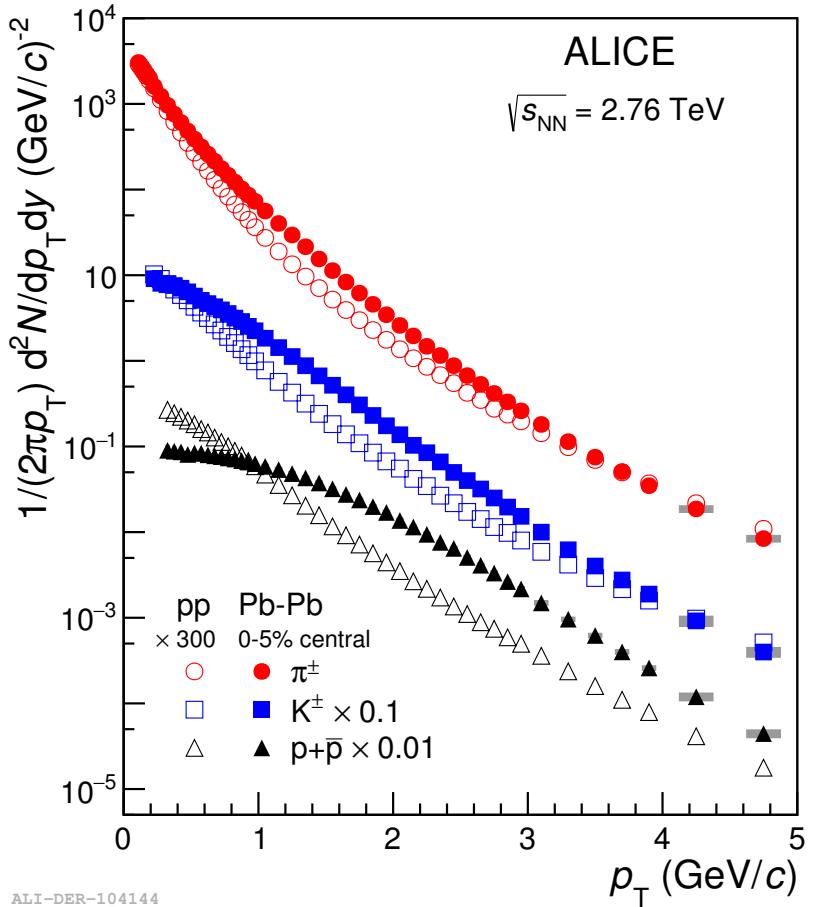
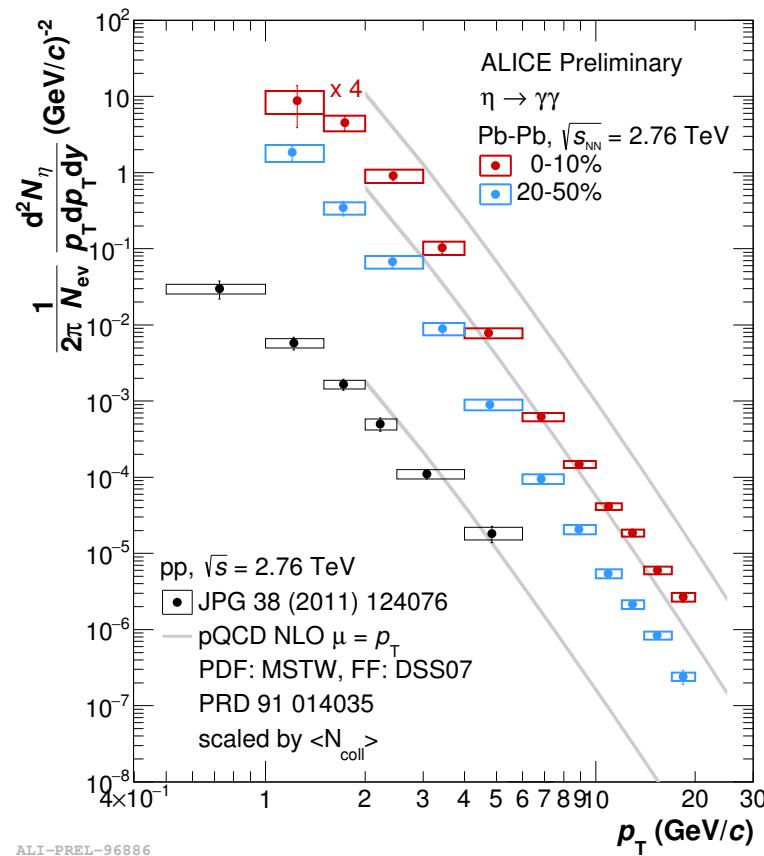
$\sqrt{s} = 7 \text{ TeV}$: PLB 717 (2012) 162; $\sqrt{s} = 2.76 \text{ TeV}$: Eur. Phys. J. C74 (2014) 10

π^0 invariant yields in Pb – Pb collisions compared to pp

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- π^0 measured in two centrality classes compared to pp *arXiv:1512.05250*.
- Up to ten times more statistics with respect to previously published data: *Eur. Phys. J. C74 (2014) 10, 3108*.
- p_T reach extended to 20 GeV/c with respect to previous result.
- Comparisons to NLO pQCD pp predictions (*Phys. Rev. D91 (2015) 1*) scaled by N_{coll}



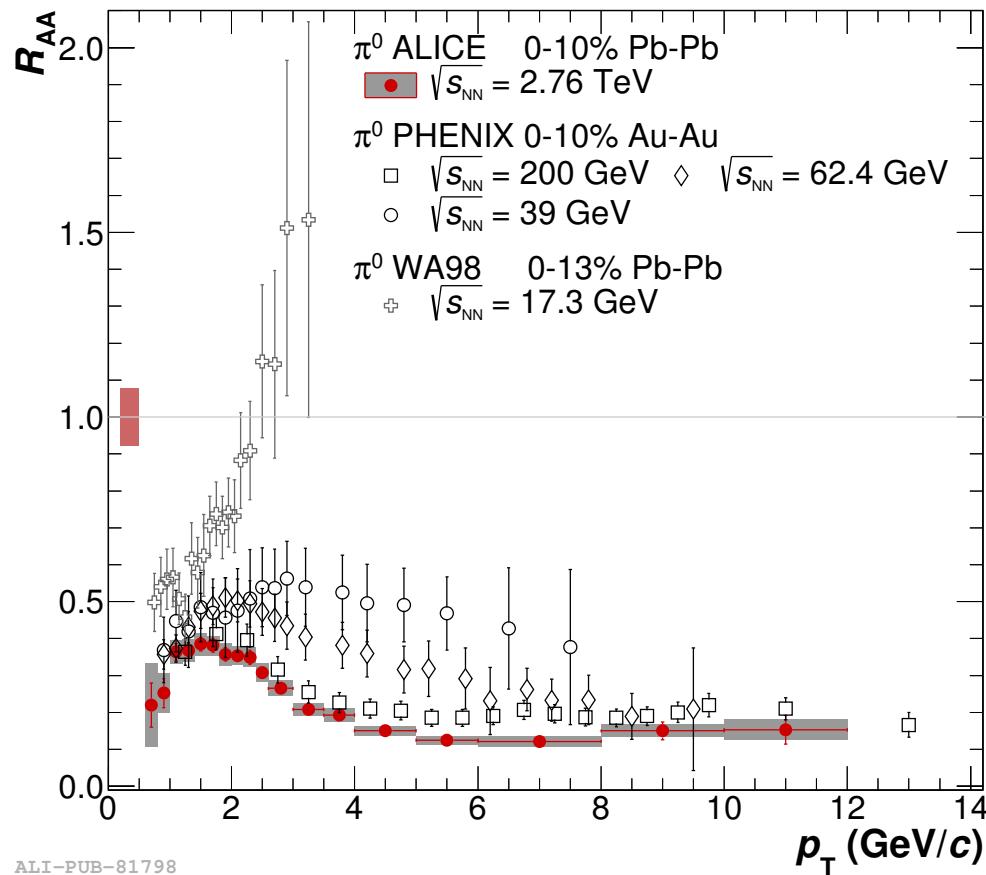


- Left: **First Pb-Pb η measurement** at the LHC.
- η in two centrality classes compared to pp *arXiv:1512.05250*.
- Comparisons to NLO pQCD pp predictions (*Phys. Rev. D91 (2015) 1*) scaled by N_{coll}
- Right: K^\pm and π^\pm in the 0-5% centrality class compared to pp (zoom to the low p_T region) : mass hierarchy (radial flow). *Phys. Lett. B 736 (2014) 196-207*.

- $R_{AA}(p_T) = \frac{1}{N_{coll}} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$
- Measured to quantify nuclear effects in A-A collisions
- Production in A-A is compared to production in scaled pp collisions
- Number of binary nucleon-nucleon collisions (N_{coll}) is taken from Glauber Monte Carlo simulations.
- R_{AA} contains both initial and final state effects.
 - Initial state: i.e. Cronin, nuclear shadowing.
 - Final state: collisional and radiative energy loss.

$\pi^0 R_{AA}$ (2010), in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV for the 0 – 10% class in comparison to corresponding measurements at lower energies.

The π^0 is ideal for this comparison due to world data being available at wide \sqrt{s} energies.



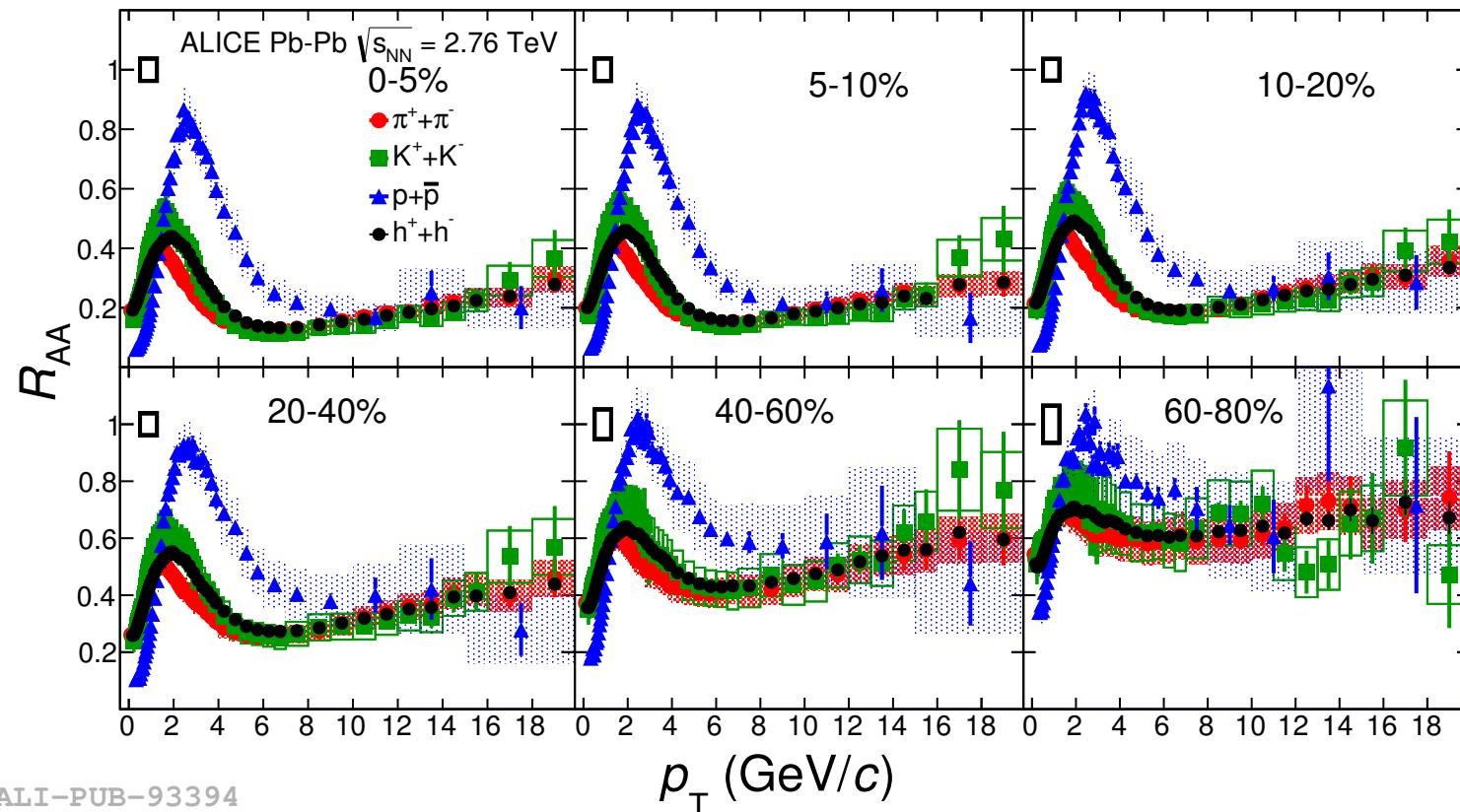
- $\pi^0 R_{AA}$ at LHC lower than at RHIC
- Similarities observed between the R_{AA} shape at $\sqrt{s_{NN}} = 2.76$ TeV and $\sqrt{s_{NN}} = 200$ GeV.
- Onset of suppression between $\sqrt{s_{NN}} = 17.3$ GeV and $\sqrt{s_{NN}} = 39$ GeV

ALICE: *Eur. Phys. J.* C74 (2014) 10.

PHENIX: PRL109,152301 (2012), 1204.1526

PHENIX: PRL101, 232301 (2008), 0801.4020

WA98:PRL100, 242301 (2008), 0708.2630

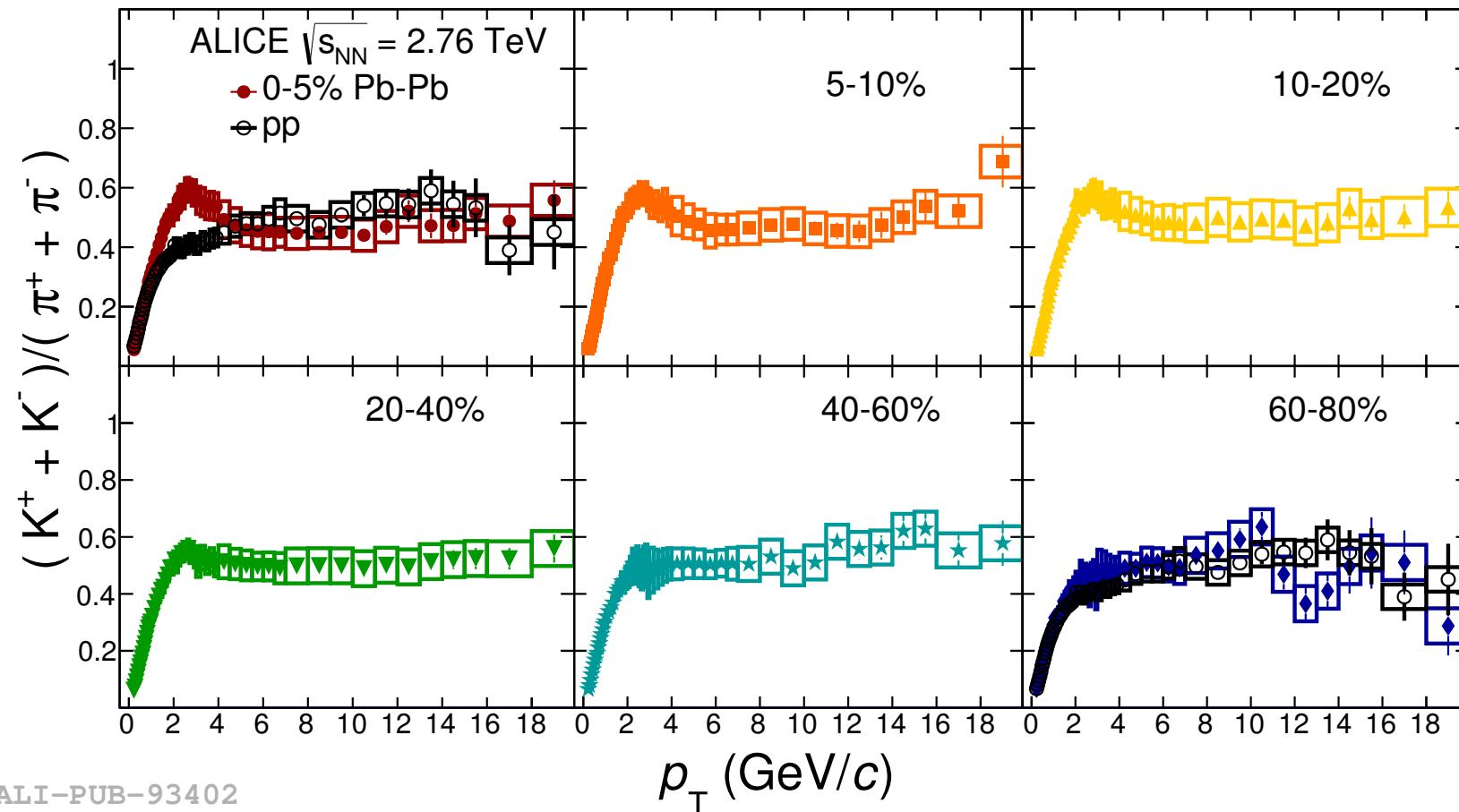


- Figure: R_{AA} in six centrality classes.

Large suppression in central Pb-Pb collisions.

60-80%: $R_{AA} \sim 0.6$ for $p_T > 6$ GeV/c

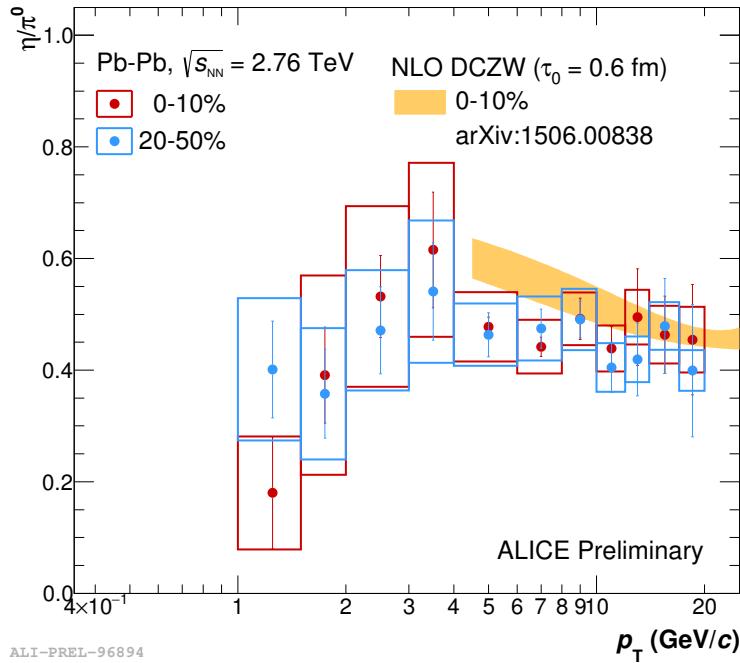
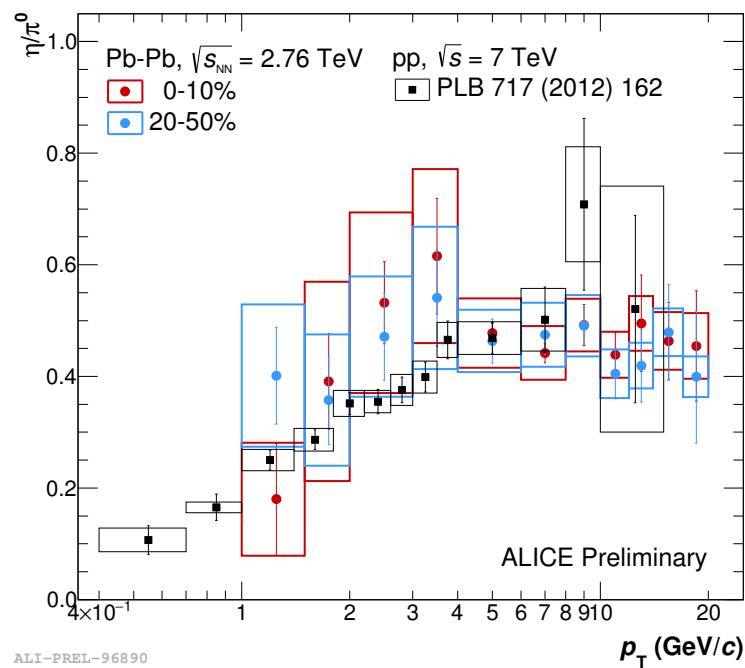
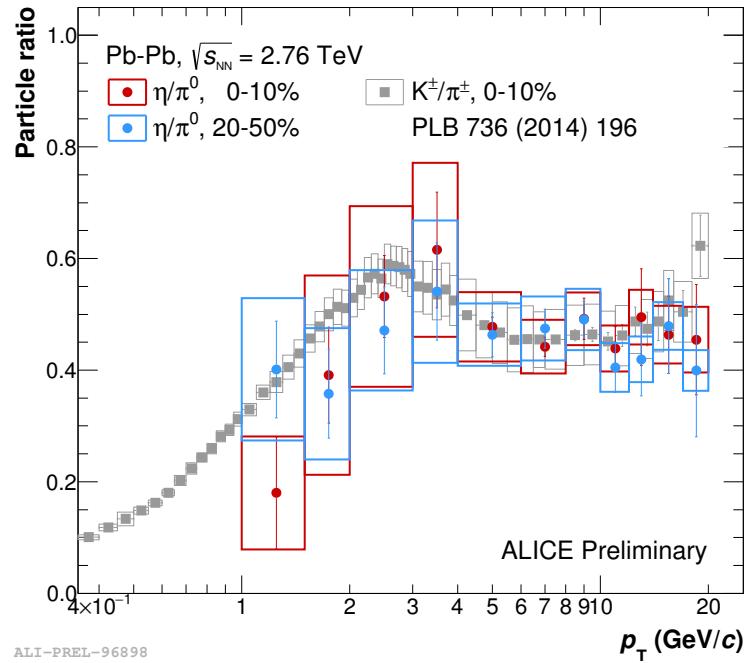
0-5%: $R_{AA} \sim 0.1$ for $p_T > 6$ GeV/c



- Clear enhancement of kaons at $2 < p_T < 4$ GeV/c that depends on centrality (radial flow).
- At $p_T > 4$ GeV/c the relative ratio seems constant in all centralities (fragmentation).
- Phys. Rev. C 93 (2016) 034913

Particle ratios in Pb-Pb collisions (2)

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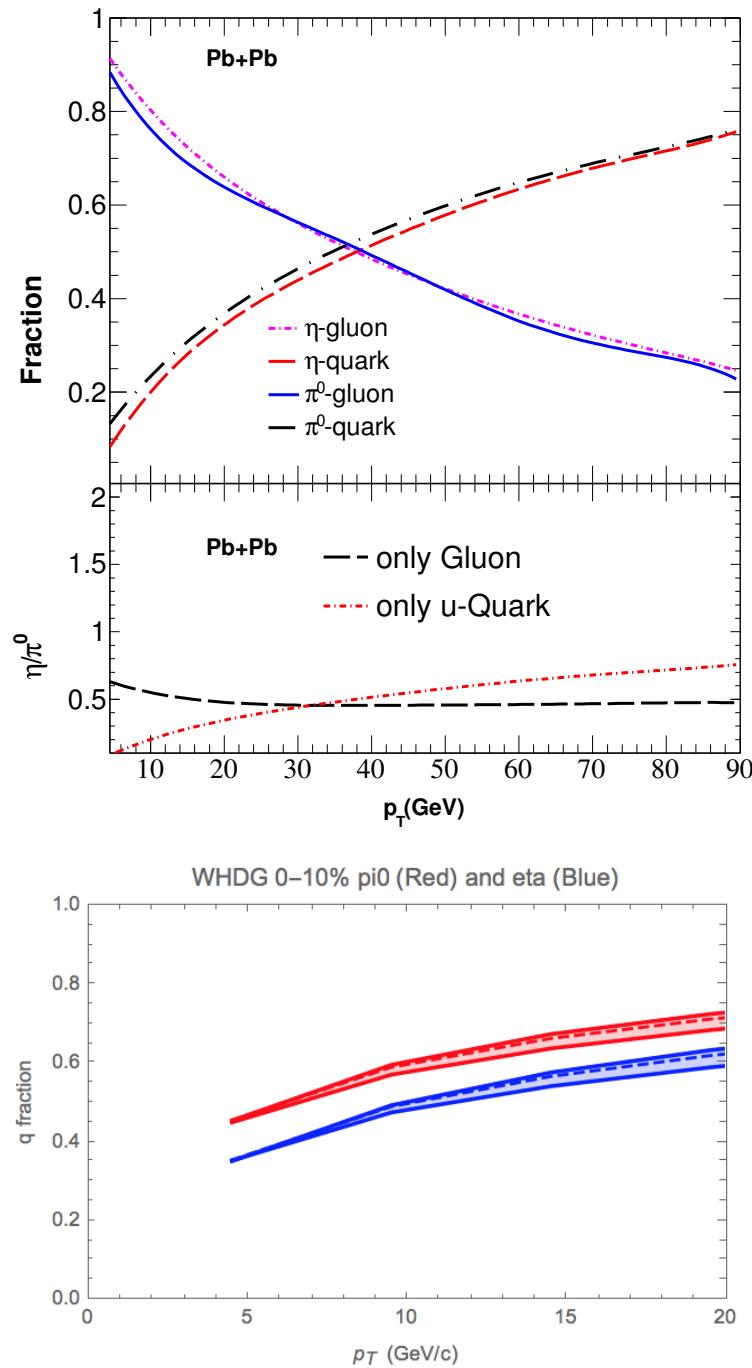
- η/π^0 in two centrality classes compared to: K^\pm/π^\pm in the same $\sqrt{s_{NN}}$, η/π^0 in pp collisions at $\sqrt{s} = 7$ TeV.
- Trend and magnitude consistent with the K^\pm/π^\pm measurement (PLB 736 (2014) 186).
- Jet quenching predictions by Wei Dai et al (PLB750 (2015) 390-395) describe the ratio within the current uncertainties.

- ALICE measures neutral and charged mesons in a wide p_T range thanks to complementary detectors.
- π^0 , η and K^\pm invariant yields have been measured by ALICE.
- π^0 's magnitude is well described by NLO pQCD calculations (pp collisions), however, there is a growing discrepancy as a function of p_T and with increasing \sqrt{s} .
- A suppression of π^0 and K^\pm is observed via R_{AA} which is p_T dependent (radial flow, jet quenching).

While the shape of the π^0 's R_{AA} is comparable between RHIC and LHC energies, at the LHC we see a stronger suppression.

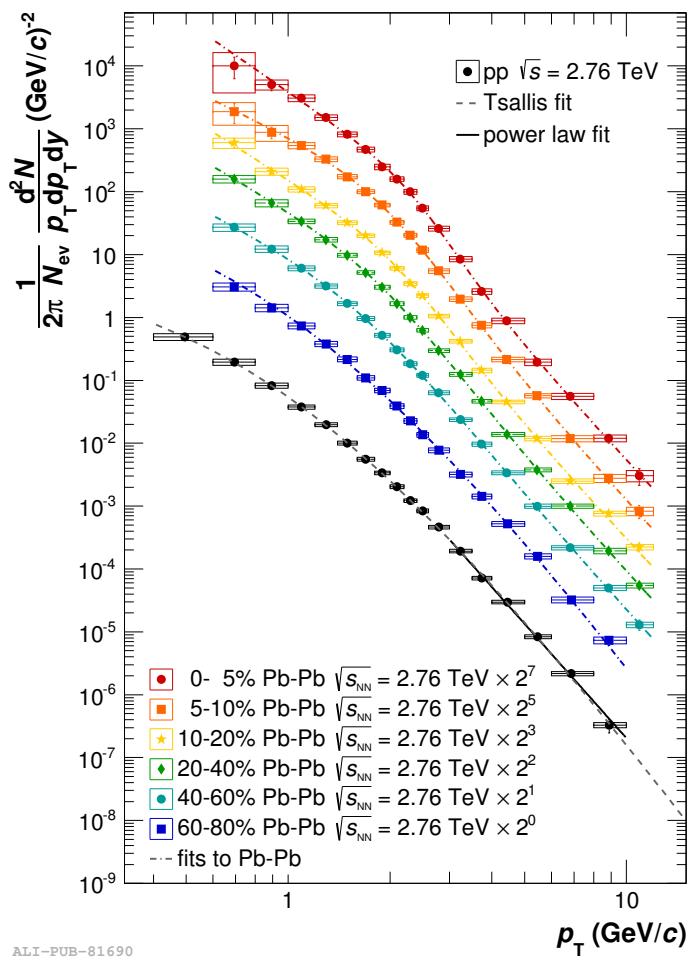
- We have presented the first measurement of η in Pb-Pb at the LHC.
- K^\pm/π^\pm reaches a constant value for $p_T > 4 \text{ GeV}/c$. For p_T below 4 GeV/c an enhancement is observed which is centrality dependant.
- η/π^0 reaches a constant value for $p_T > 4 \text{ GeV}/c$. For p_T below 4 GeV/c it is consistent with the pp and K^\pm/π^\pm ratio.
- At high p_T no significant differences are seen in the particle ratios between Pb – Pb and pp.

Backup



Partonic contributions to π^0 η production in Pb-Pb collisions at $\sqrt{s} = 2.76\text{TeV}$ and ALICE kinematics.
Figure courtesy of Wei Dai (PLB750 (2015) 390-395)

Partonic contributions to π^0 (red) and η production in Pb-Pb collisions at $\sqrt{s} = 2.76\text{TeV}$ and ALICE kinematics. Figure courtesy of William Horowitz



ALI-PUB-81690

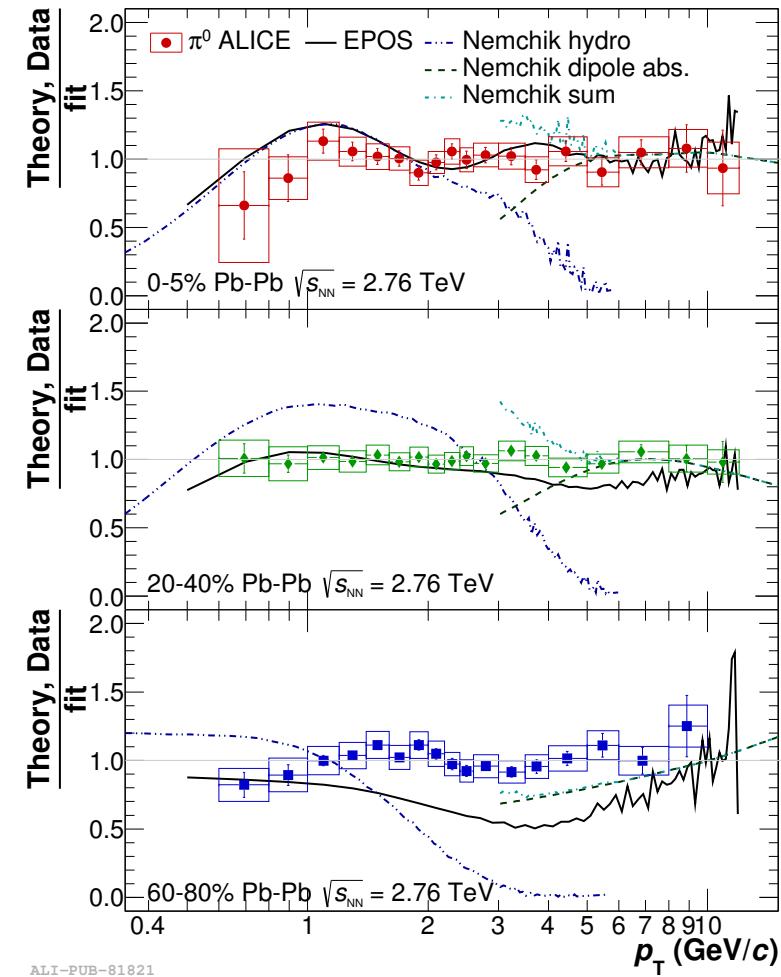
π^0 yields measured in six centrality classes

(*Eur. Phys. J. C*74 (2014) 10, 3108).

- EPOS: *Phys. Rev. C*85, 064907 (2012):

Low p_T : Hydrodynamic flow

High p_T : Energy loss of string segments

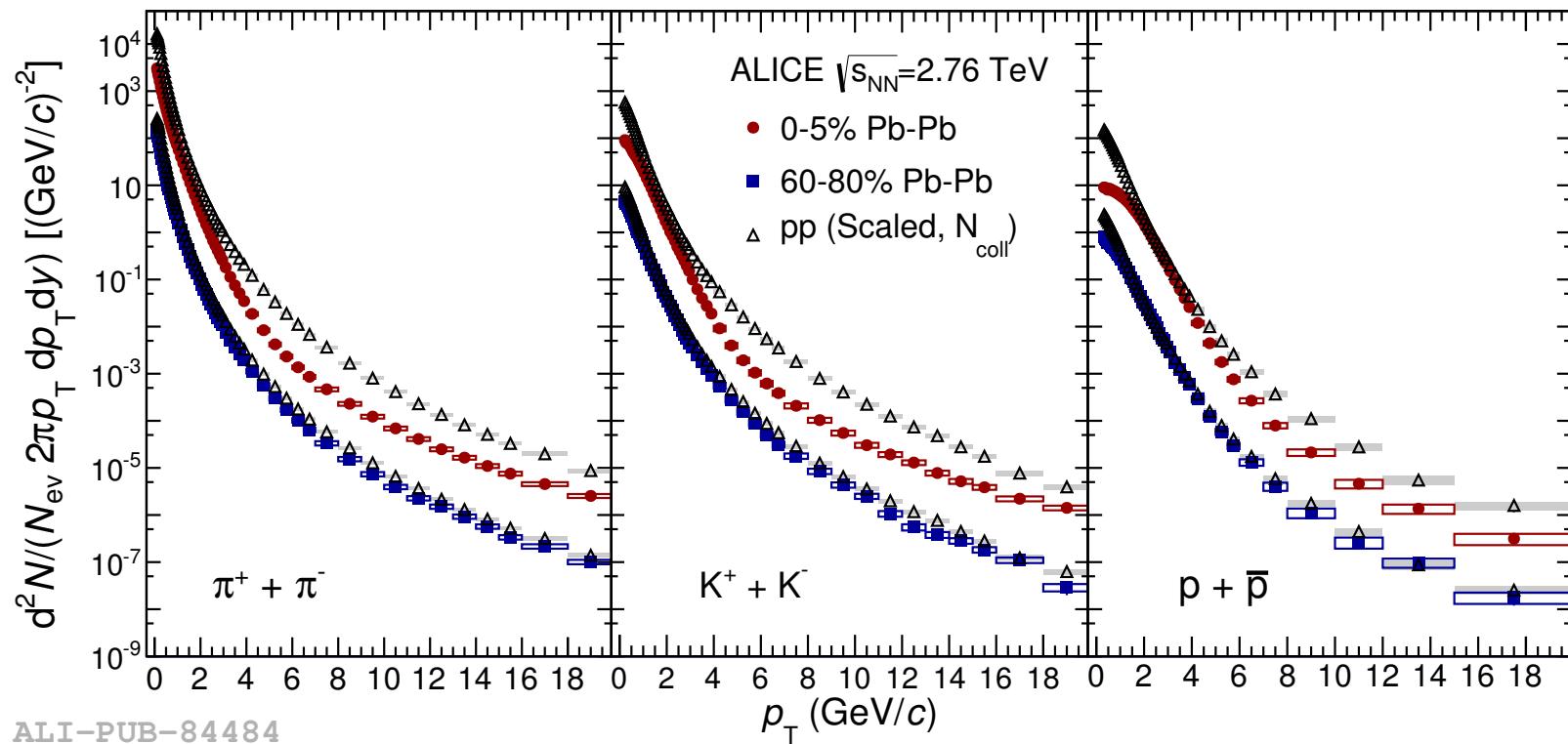


- Nemchik (PRC86, 054904, 2012):

Low p_T : Hydrodynamic description

High p_T : Color dipole absorption

red: central, blue: peripheral centrality class



left : π^\pm ; middle: K^\pm ; right: $p\bar{p}$

Phys.Lett. B736 (2014) 196-207