[1]Multiplicity dependence of charged pion, kaon, and (anti)proton production at large transverse momentum in p-Pb collisions at 5.02 ATeV

Gyula Bencedi (Wigner RCP, Hungary)
on behalf of the ALICE Collaboration

Fisica de Altas Energias Seminario
27/01/2016

[1] arXiv:1601.03658v1 [nucl-ex] (ALICE Collaboration)

Contents

- Motivation
- Particle Identification in ALICE
- Measurement of pi/K/p production at high p_T as a function of event multiplicities in p-Pb collisions
- Calculation of pp reference spectrum at 5.02TeV
- Nuclear modification factor $\boldsymbol{R_{pPb}}$ for pi/K/p in non-single diffractive events (NSD)
- Summary

Motivation I

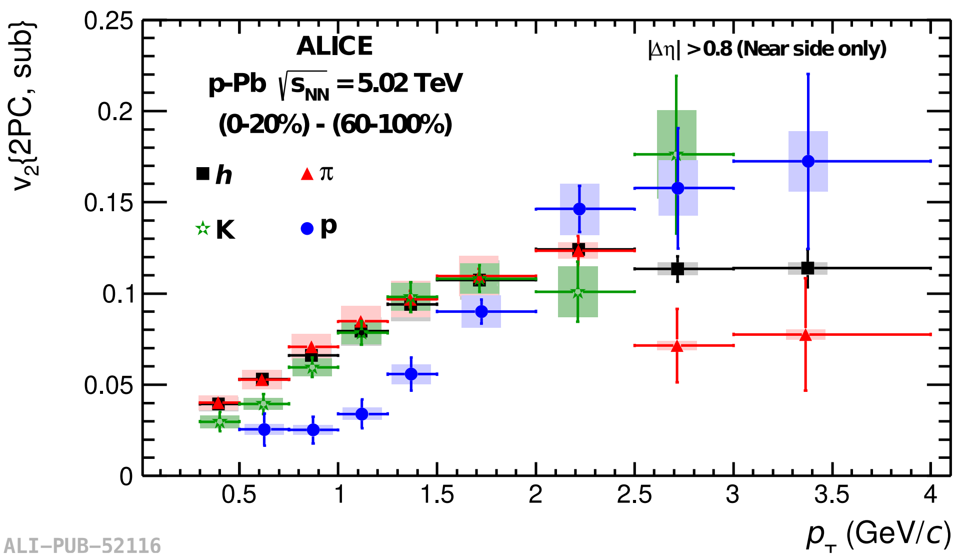
- p-A collisions: control measurement (beside pp collisions) in order to better understand heavy ion collisions, i.e. disentangle initial- and final state effects
- At high p_T (final state effects)
  - **study** **parton energy loss** mechanisms in QGP
- At intermediate p_T (initial state effects)
  - obtain higher precision in the existing measurements (ITS, TPC, TOF)
  - **study** **Cold Nuclear Matter effects** (e.g. Cronin enhancement) and modification of particle ratios (p/pi and K/pi) by flow-like effects
  - Importance of parton recombination ◄——► hydrodynamical descritpion
- At low p_T (flow-like behaviours)
  - **study** hydrodynamical description of the particle production

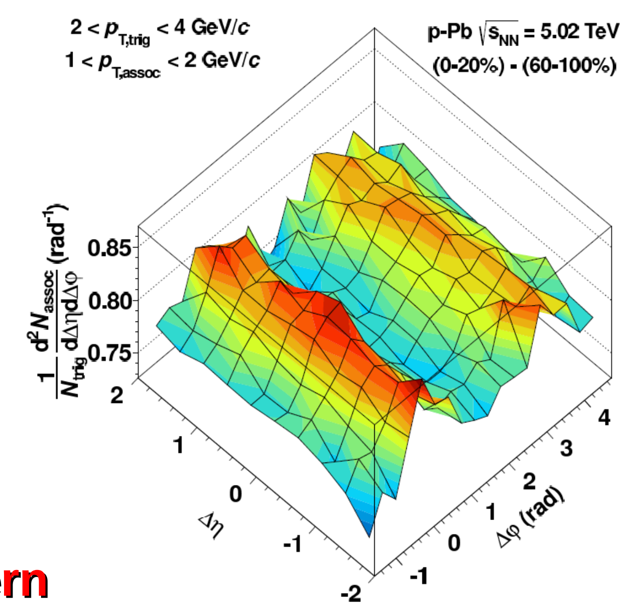
Motivation II

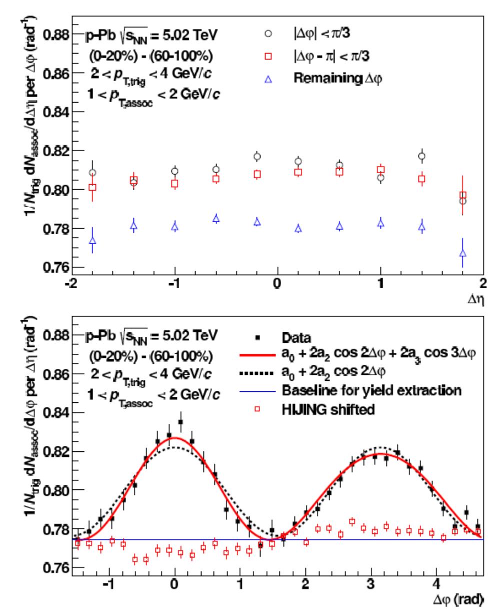
- **Heavy-ion collision → sQGP formed**
  - **Features of sQGP are collective flow and opacity of jets**

- **Collective behaviours are observed as azimuthal anisotropy**

- **Double ridge structure**, long-range angular correlations **in p-Pb** collisions at **high multiplicity** (near- and away side)
- **Flow-like patterns** observed
- **Mass ordering** and crossing is qualitatively **similar** to observations in **A-A collisions** at low p_T can be described by hydrodynamic models







Qualitatively similar to elliptic-flow pattern observed in heavy-ion coll.

ALICE, PLB 719 (2013) 29-41; ALICE, PLB 726 (2013) 164-177; ALICE, PLB 728 (2014) 25-38; CMS, PLB 718 (2013) 795

Motivation II

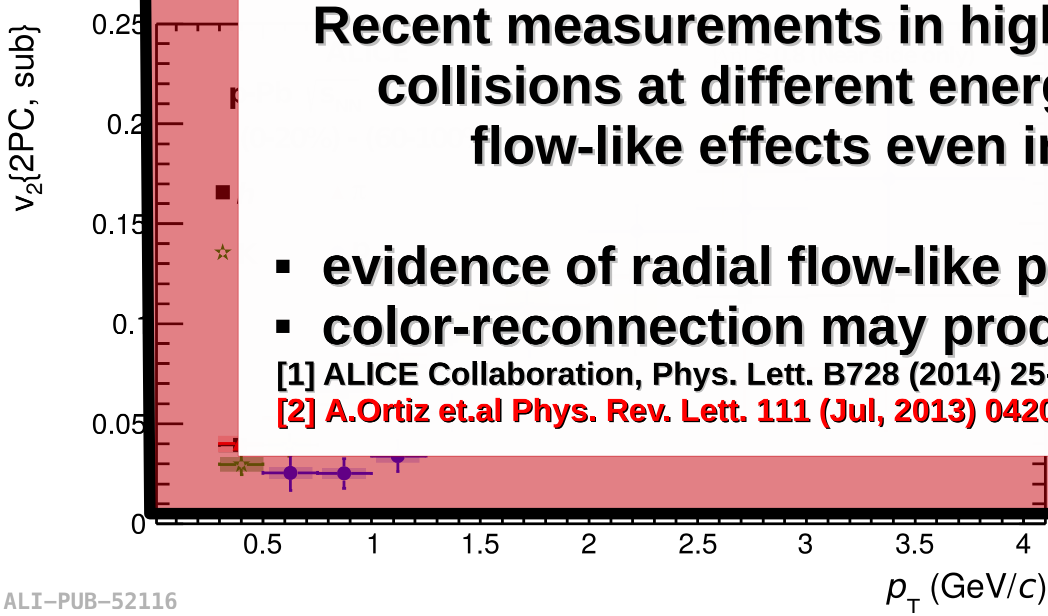
- **Heavy-ion collision → sQGP formed**
  - **Features of sQGP are collective flow and opacity of jets**
- **Collect**
- **Double r**
  (near- an
- **Flow-like**
- **Mass ord** ... be described
  by hydro

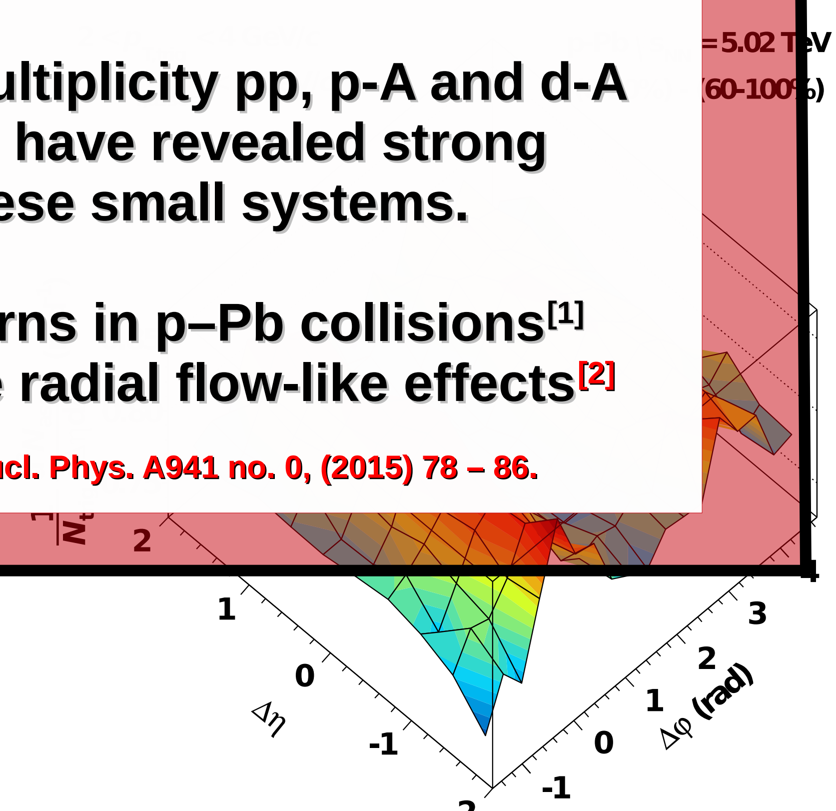
The interpretation of these sQGP properties requires comparisons with reference measurements like pp and p-A collisions.

Recent measurements in high multiplicity pp, p-A and d-A collisions at different energies have revealed strong flow-like effects even in these small systems.

- **evidence of radial flow-like patterns in p–Pb collisions[1]**
- **color-reconnection may produce radial flow-like effects[2]**

[1] ALICE Collaboration, Phys. Lett. B728 (2014) 25–38
[2] A.Ortiz et.al Phys. Rev. Lett. 111 (Jul, 2013) 042001, Nucl. Phys. A941 no. 0, (2015) 78 – 86.

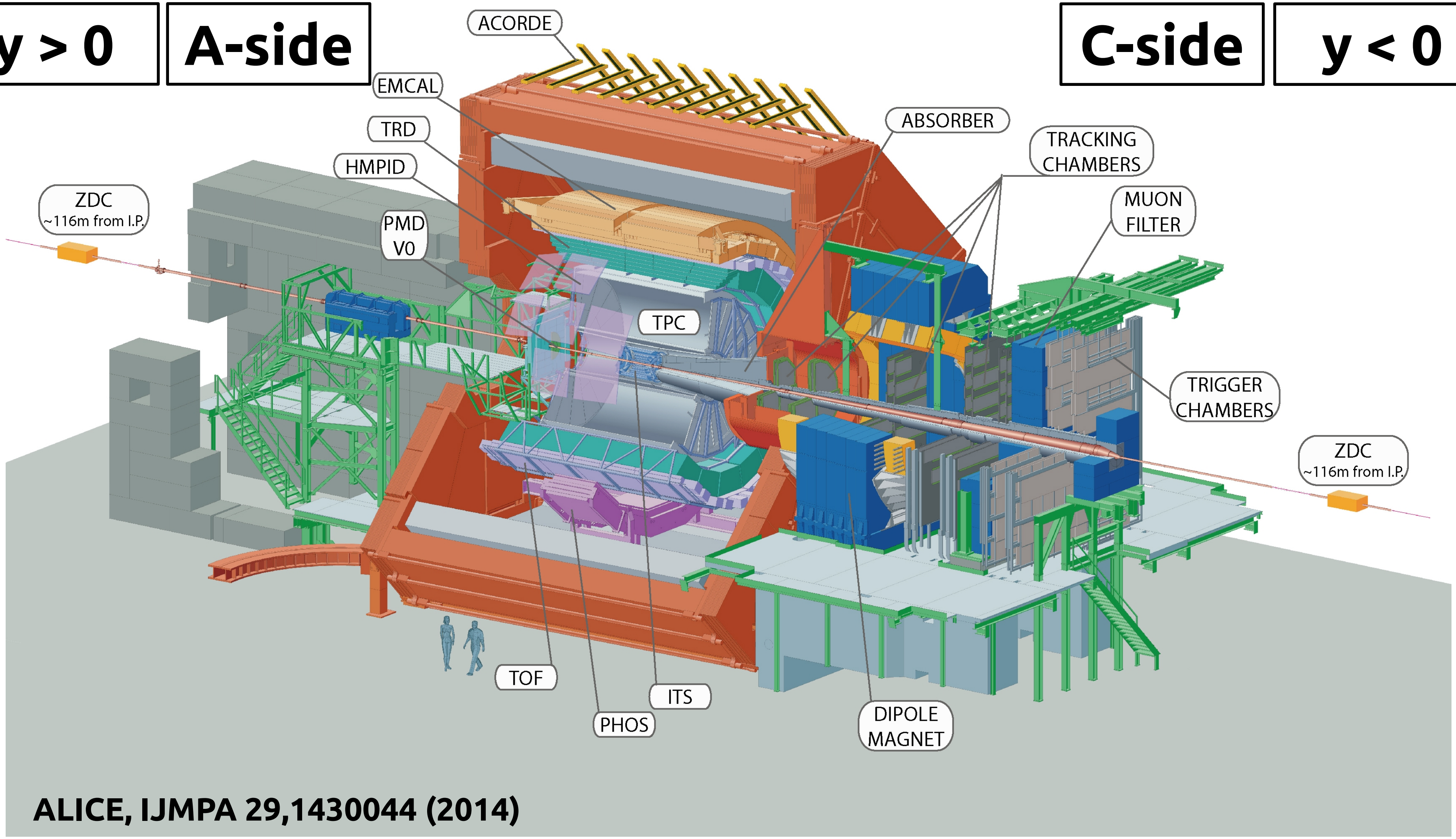




ALICE, PLB 719 (2013) 29-41
ALICE, PLB 726 (2013) 164-177
ALICE, PLB 728 (2014) 25-38
CMS, PLB 718 (2013) 795

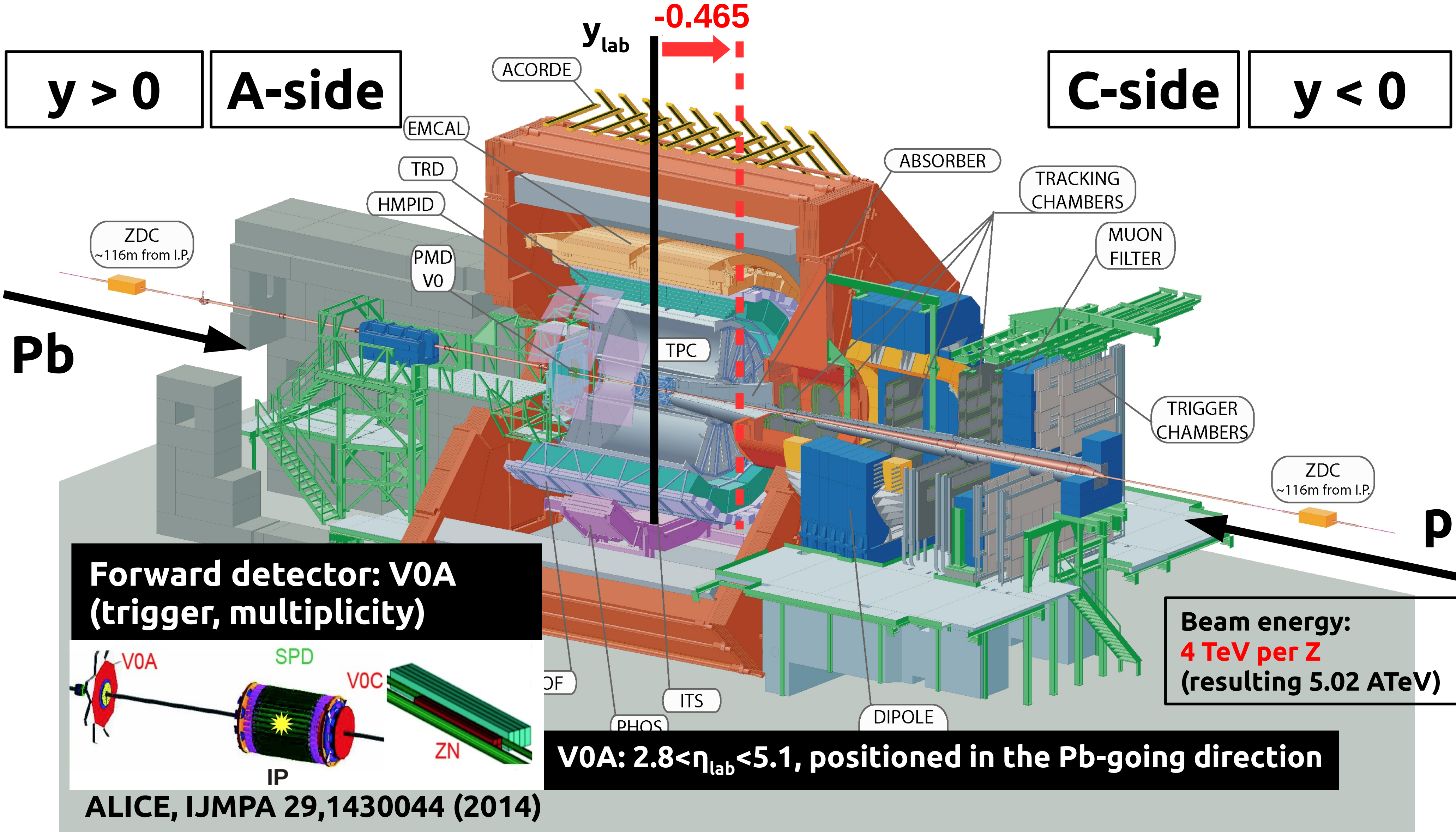
The ALICE apparatus

y > 0 | A-side | C-side | y < 0



ALICE, IJMPA 29,1430044 (2014)

The ALICE apparatus



Forward detector: V0A (trigger, multiplicity)

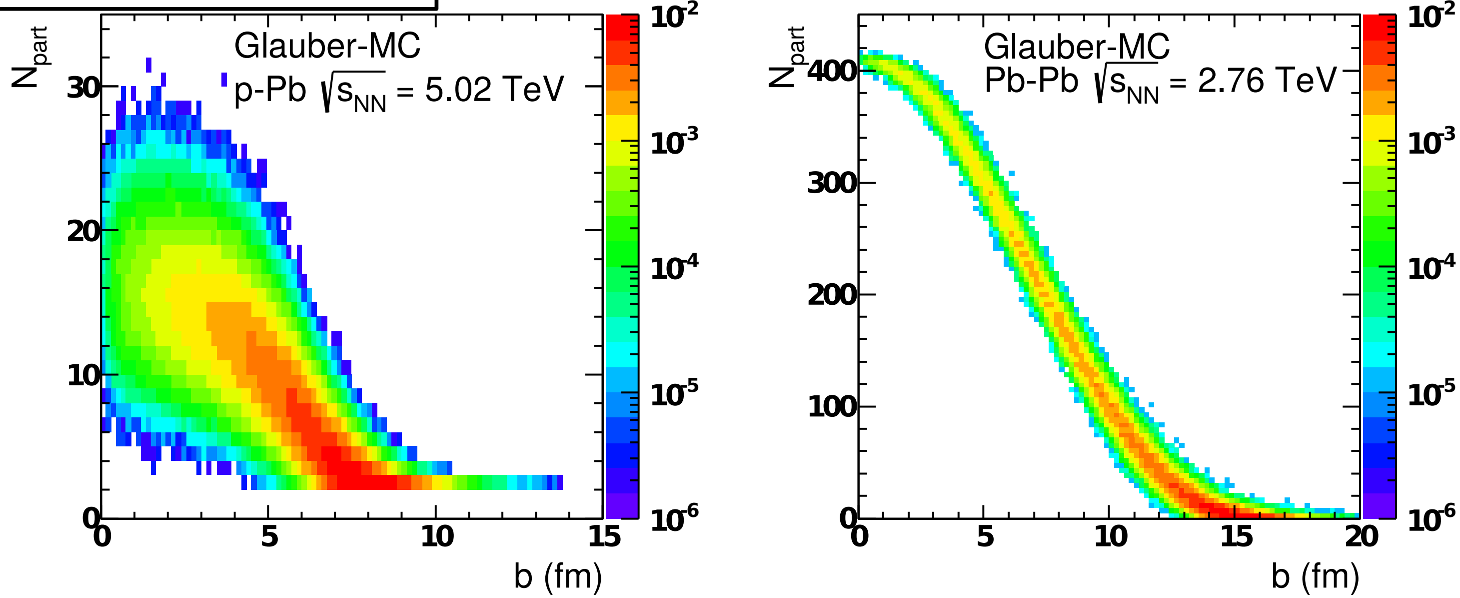
Beam energy:
4 TeV per Z
(resulting 5.02 ATeV)

V0A: $2.8<\eta_{lab}<5.1$, positioned in the Pb-going direction

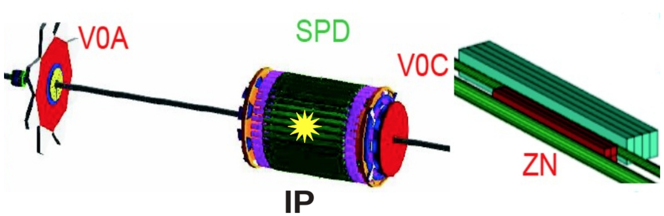
ALICE, IJMPA 29,1430044 (2014)

Multiplicity estimation: V0A

ALICE PRC 91 (2015) 064905



- For small systems there is a weak correlation between the *impact parameter (b)* and the *number of participants (N_{part})*
- For this reason particle production is studied in event multiplicity classes
  V0A estimator is used (as in the first ALICE publication on identified hadron production in p-Pb collisions)



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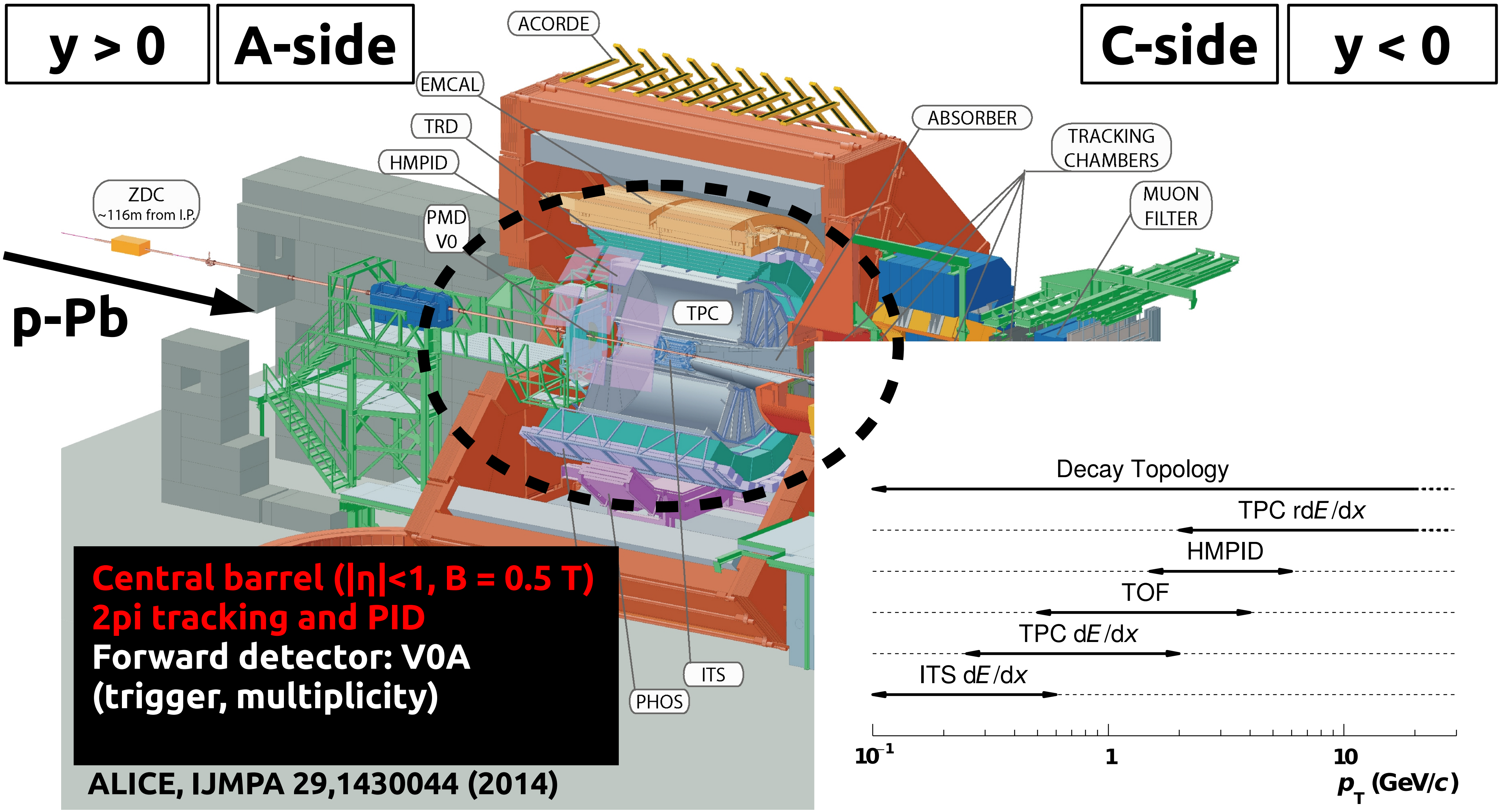
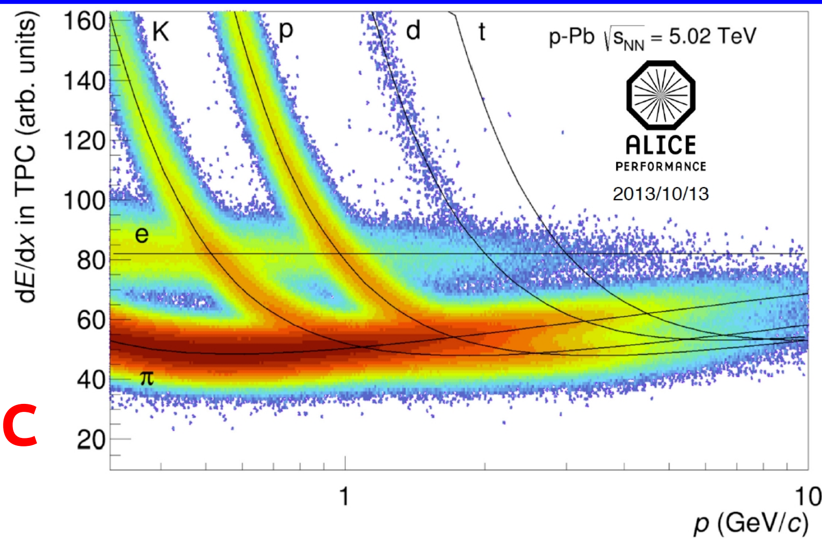


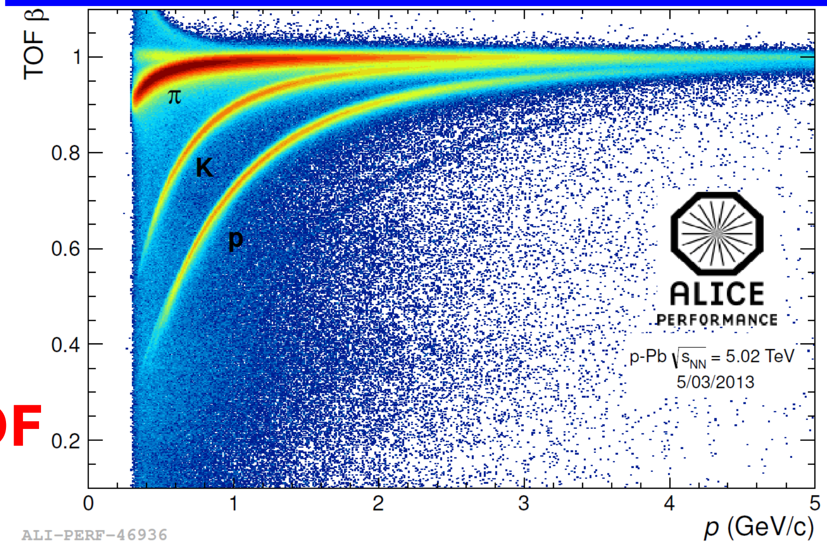
Particle Identification

- **Track-by-track ID (n-σ cut) in the $1/\beta^2$ region**
- **PID in the relativistic rise using statistical approaches**



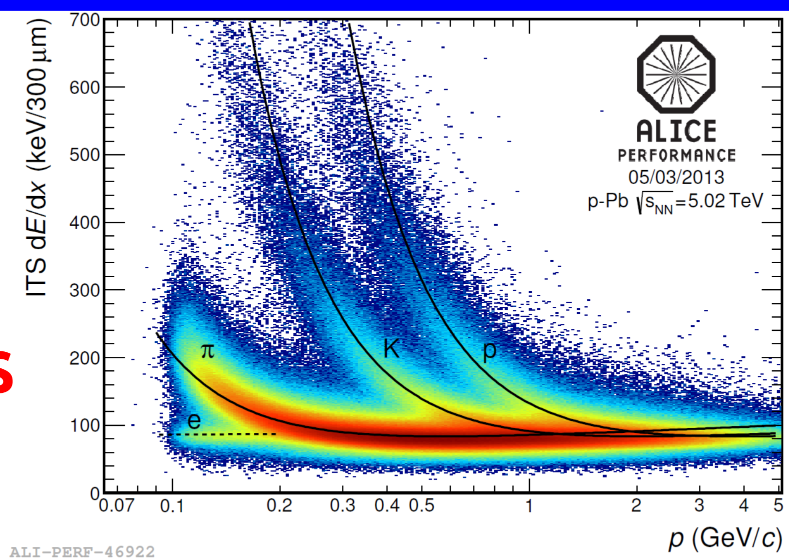
TPC

Dedicated to charged hadron Identification in the intermediate momentum region



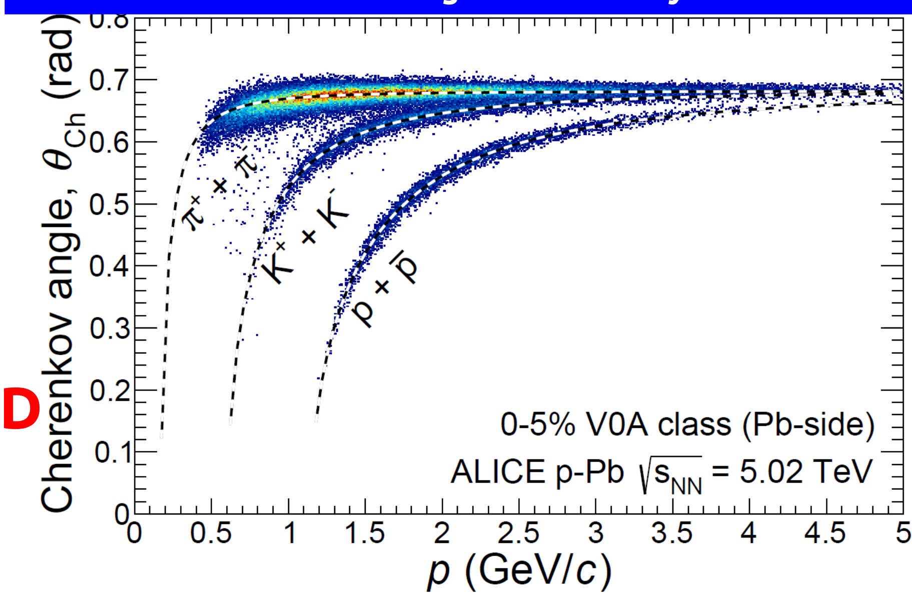
TOF

- **Tracking + standalone reconstruction: PID via d*E*/d*x* from SDD and SSD analog read-out**
- **Standalone tracking in the low-p_T region (down to 100MeV/*c*)**



ITS

Particle Identification using RICH technique in the intermediate momentum region on track-by-track basis



HMPID

Particle Identification

- Track
- PID i

TPC

dE/dx in TPC (arb. units)

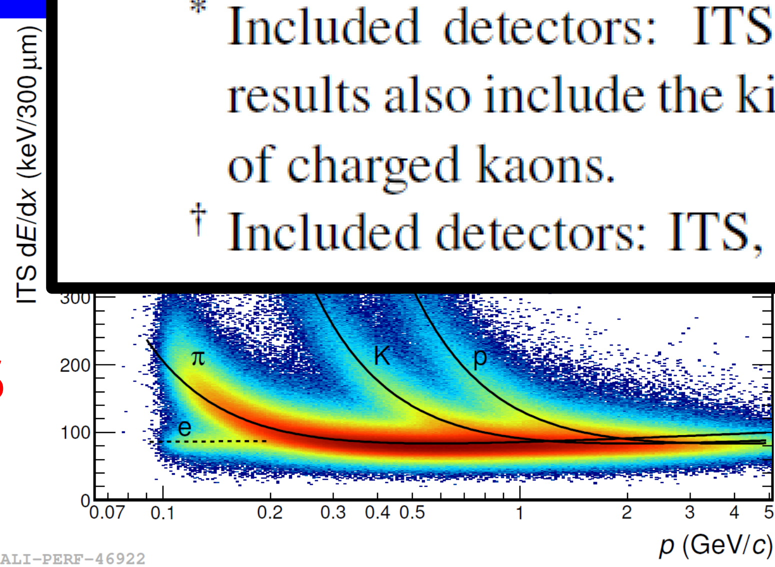
- Track and S
- Stand

	Analysis	$\pi^+ + \pi^-$	$K^+ + K^-$	$p + \bar{p}$
pp	Published [38]*	0.1 – 3.0	0.2 – 6.0	0.3 – 6.0
pp	TPC dE/dx rel. rise	2 – 20	2 – 20	3 – 20
p–Pb	Published [30]†	0.1 – 3.0	0.2 – 2.5	0.3 – 4.0
p–Pb	HMPID	1.5 – 4.0	1.5 – 4.0	1.5 – 6.0
p–Pb	TPC dE/dx rel. rise	2 – 20	2 – 20	3 – 20

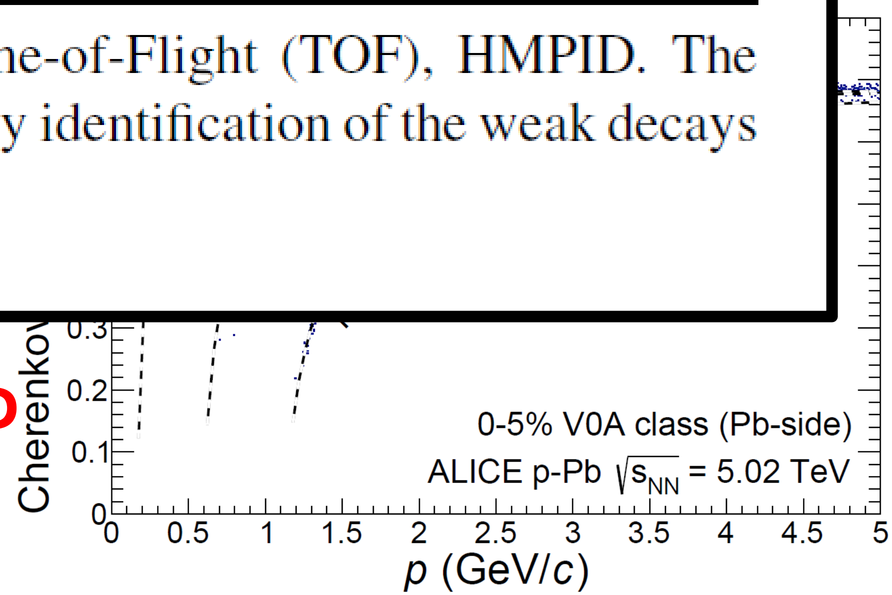
* Included detectors: ITS, TPC, Time-of-Flight (TOF), HMPID. The results also include the kink-topology identification of the weak decays of charged kaons.

† Included detectors: ITS, TPC, TOF.

ITS

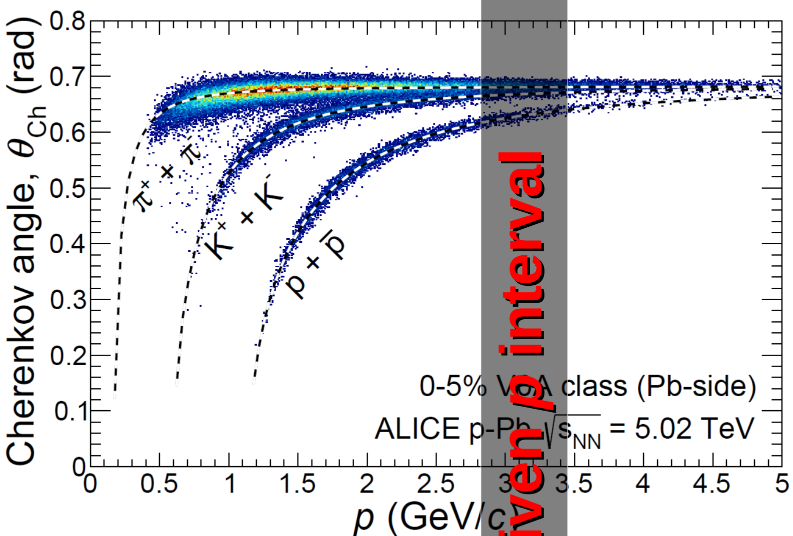


HMPID

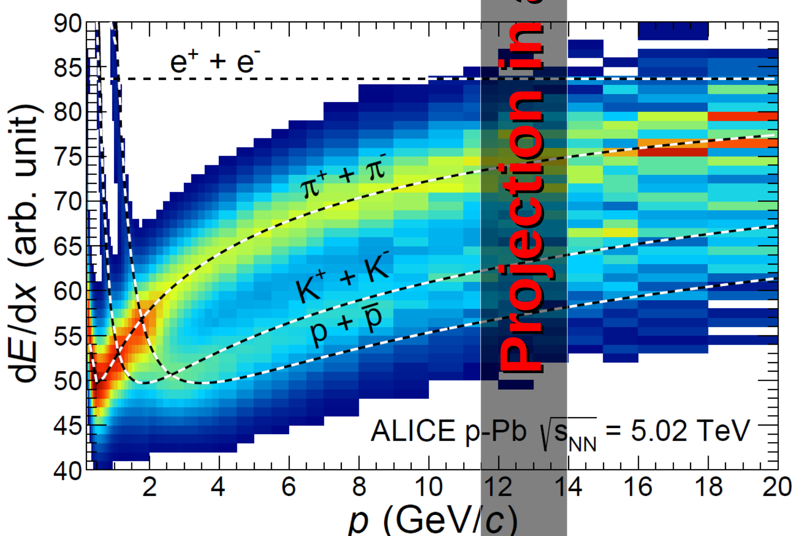


Performance of PID

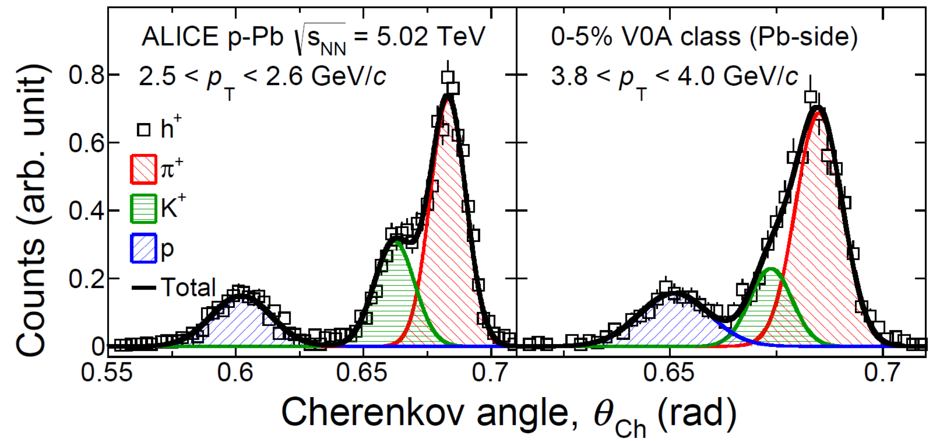
HMPID

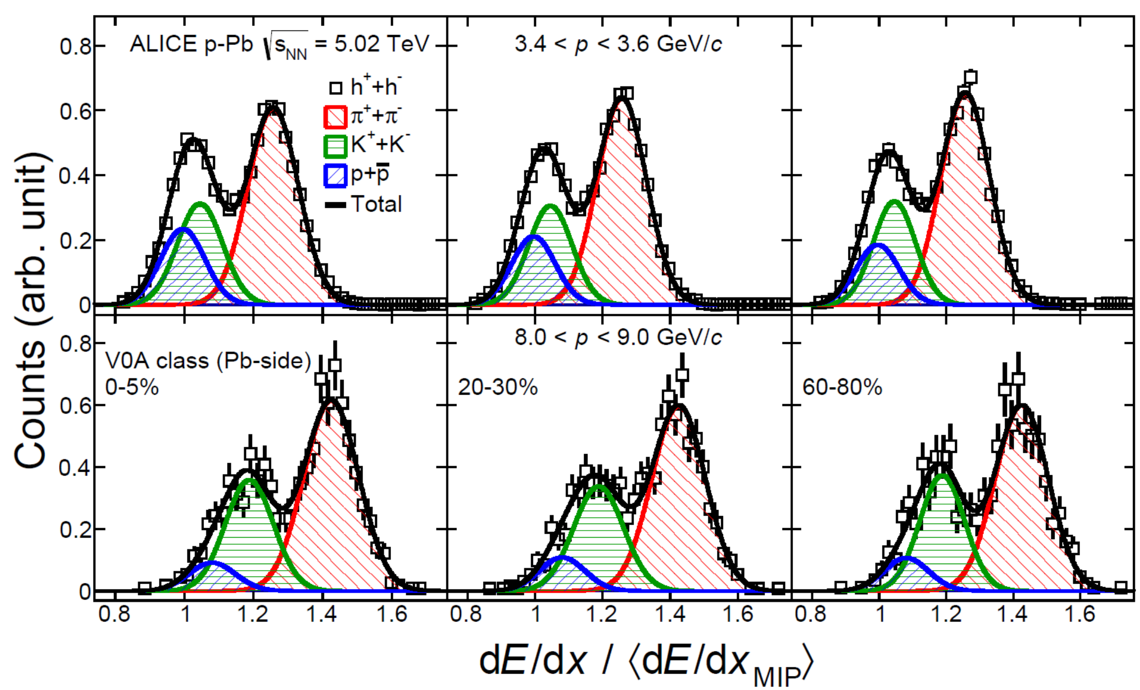


TPC



Projection in a given p interval

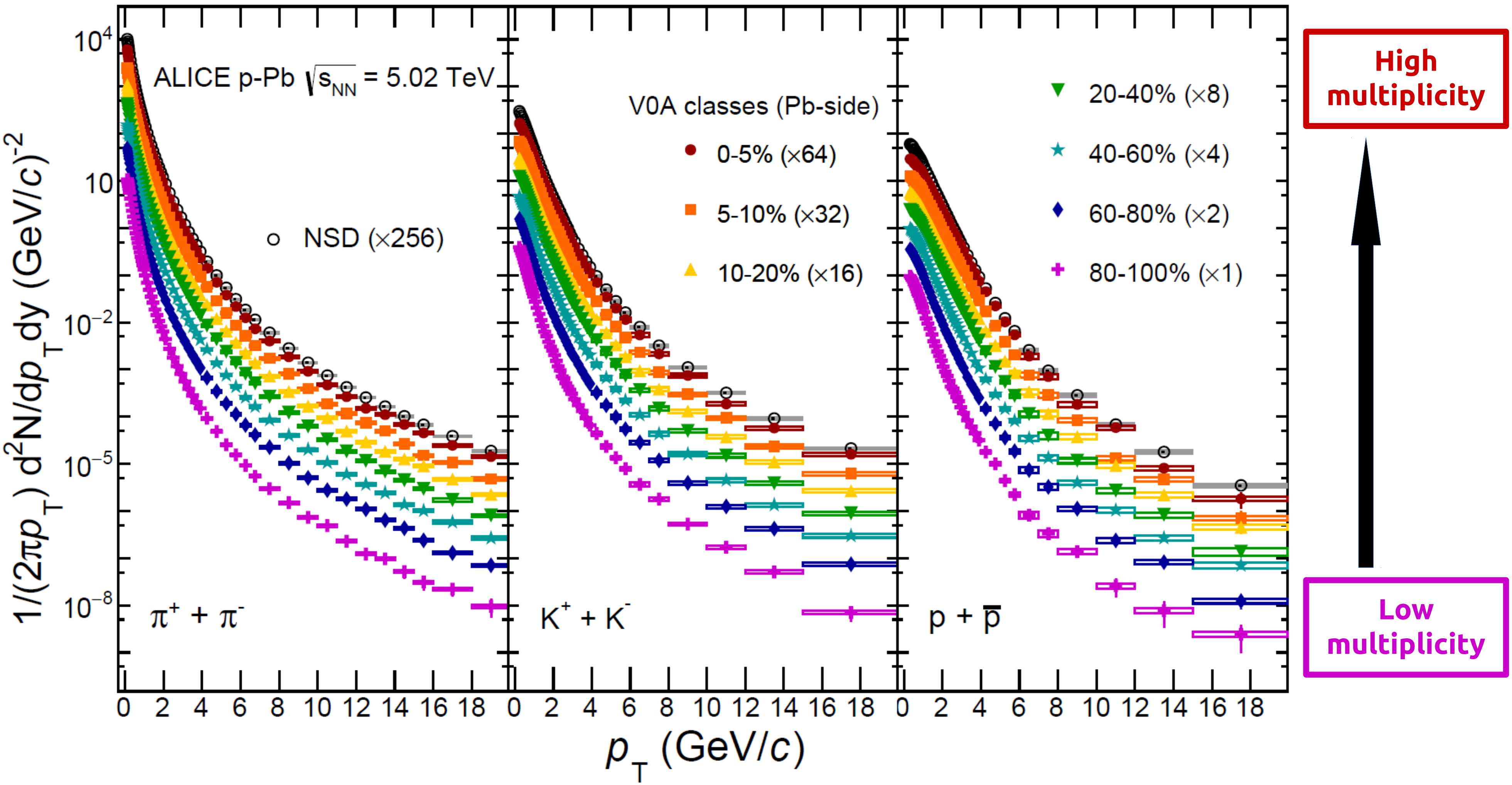




pi/K/p production at high p_T as a function of event multiplicity

Multiplicity dependence of pi/K/p spectra

p-Pb @ 5.02ATeV



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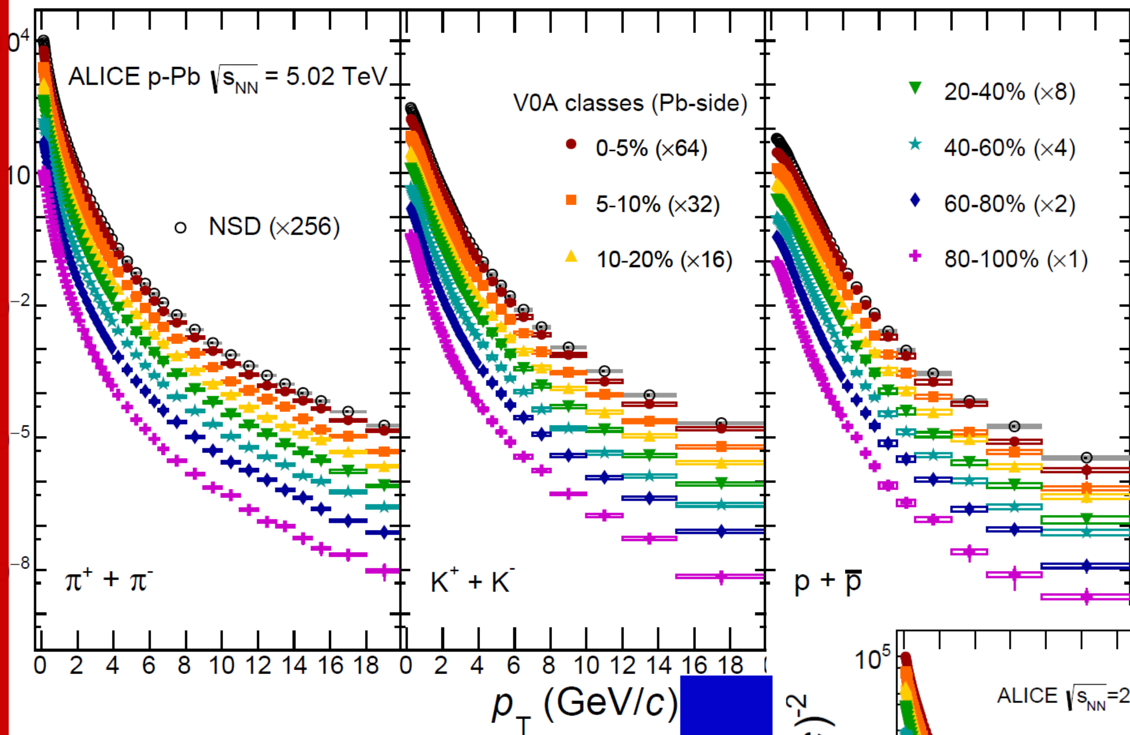
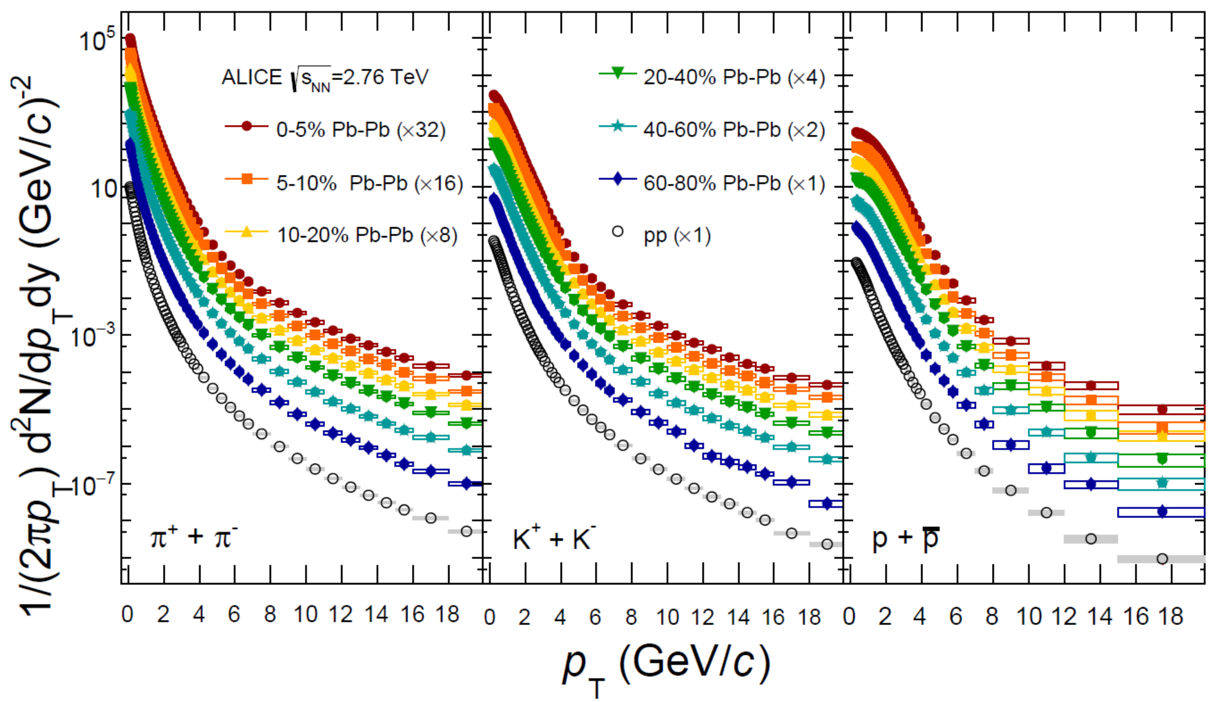


Similarities to Pb-Pb results are observed:

- A multiplicity- and mass-dependent **flattening of the p_T spectra** at low p_T (< 2 GeV/c)
- Hardening the p_T spectra at high p_T with increasing multiplicity

Pb-Pb @ 2.76ATeV

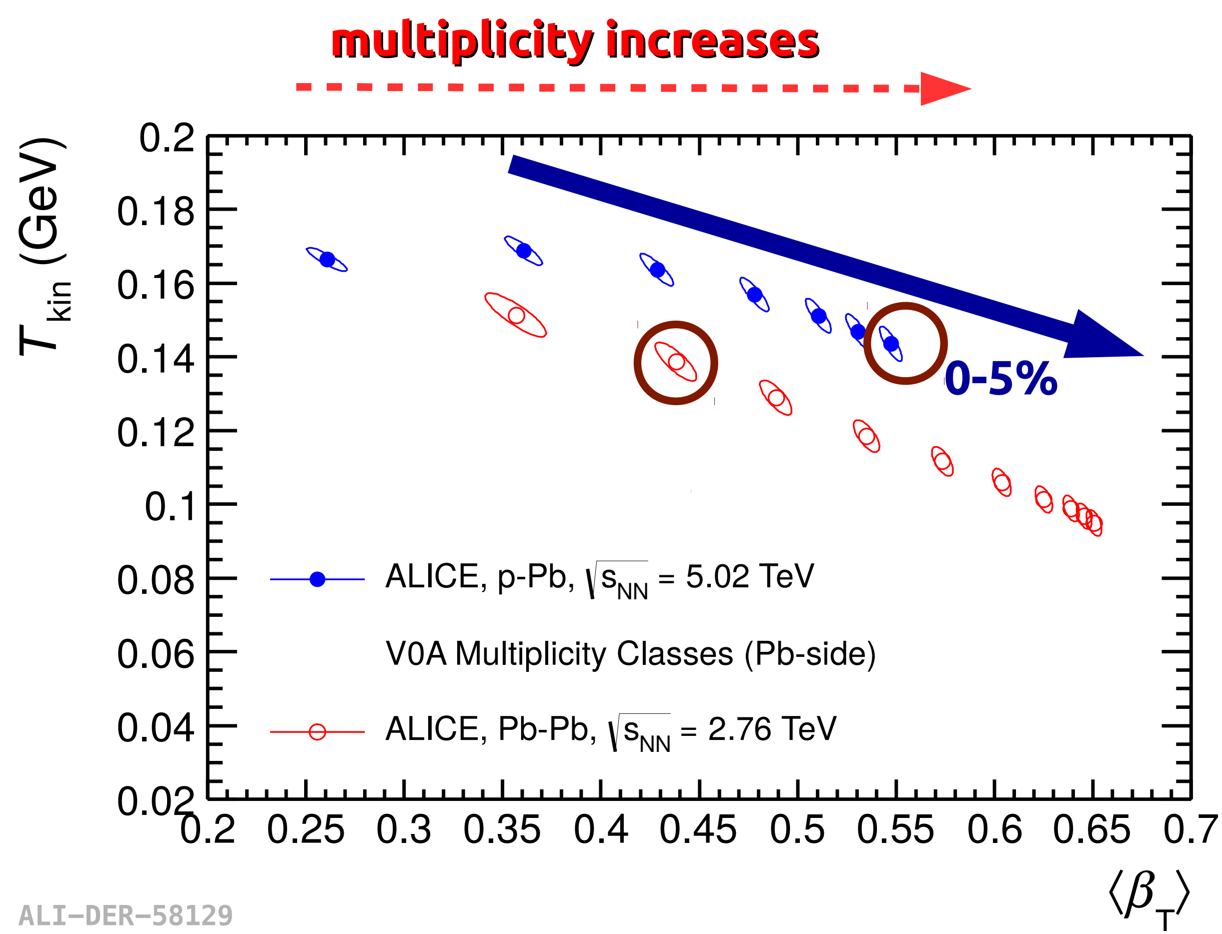


At low p_T

the **flattening** and **mass ordering** of the p_T spectra can be **studied** by applying simultaneous **Blast-Wave** fits

Blast wave fits to the spectra

The **flattening** and m**ass ordering** of the p_T spectra can be **studied** by applying simultaneous **Blast-Wave** fits to pi, K, p, K^0_s and Λ p_T spectra in V0A multiplicity classes



- **Qualitatively similar behavior** observed **for p-Pb** and Pb-Pb collisions
- **Larger radial flow parameter** obtained **in p-Pb** than in Pb-Pb collisions at similar multiplicity
  - → consequence of selection bias of harder events?
  - → consequence of stronger radial gradients? (**Phys.Rev. C88 (2013) 4, 044915**)

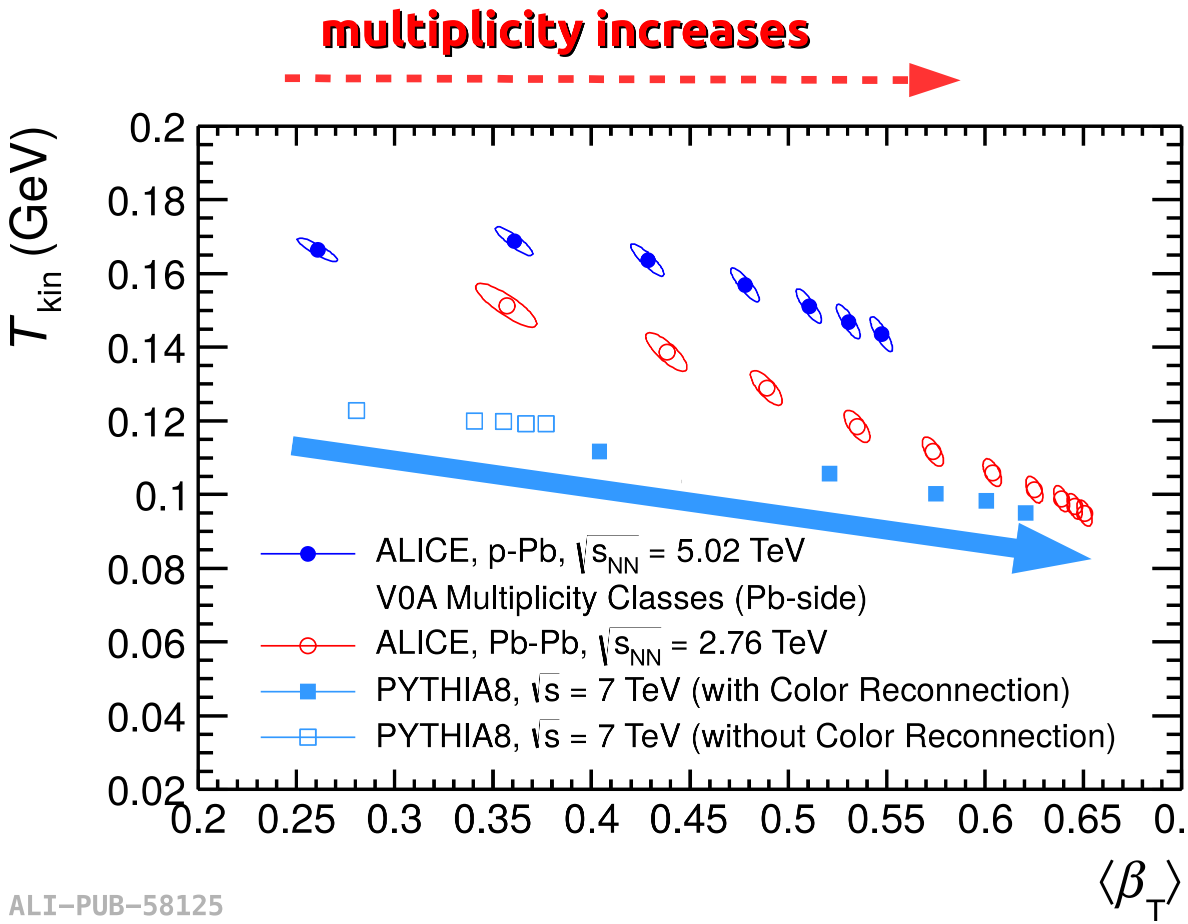
- In p-Pb data there is a presence of flow-like effects
- In Pb-Pb strong radial flow is observed **Phys. Rev. Lett. 109 (2012) 252301**

Blast wave fits to the spectra

The **flattening** and mass **ordering** of the p_T spectra can be **studied** by applying simultaneous **Blast-Wave** fits to pi, K, p, K^0_s and Λ p_T spectra in V0A multiplicity classes

- Simulated pp events (PYTHIA8, CR) without hydrodynamical expansion of the system show similar trend to those observed in p-Pb and Pb-Pb collisions

A. Ortiz *et al.* PRL 111 (2013) 4, 042001



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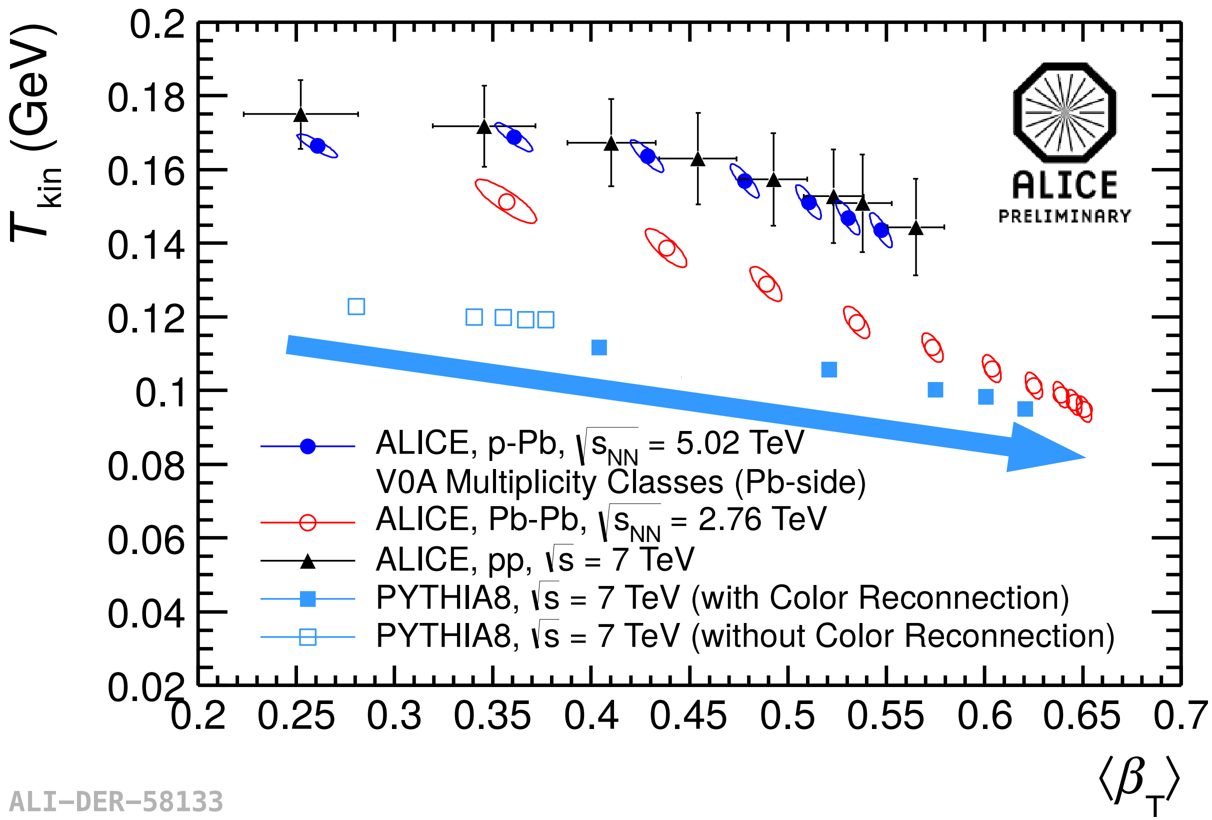
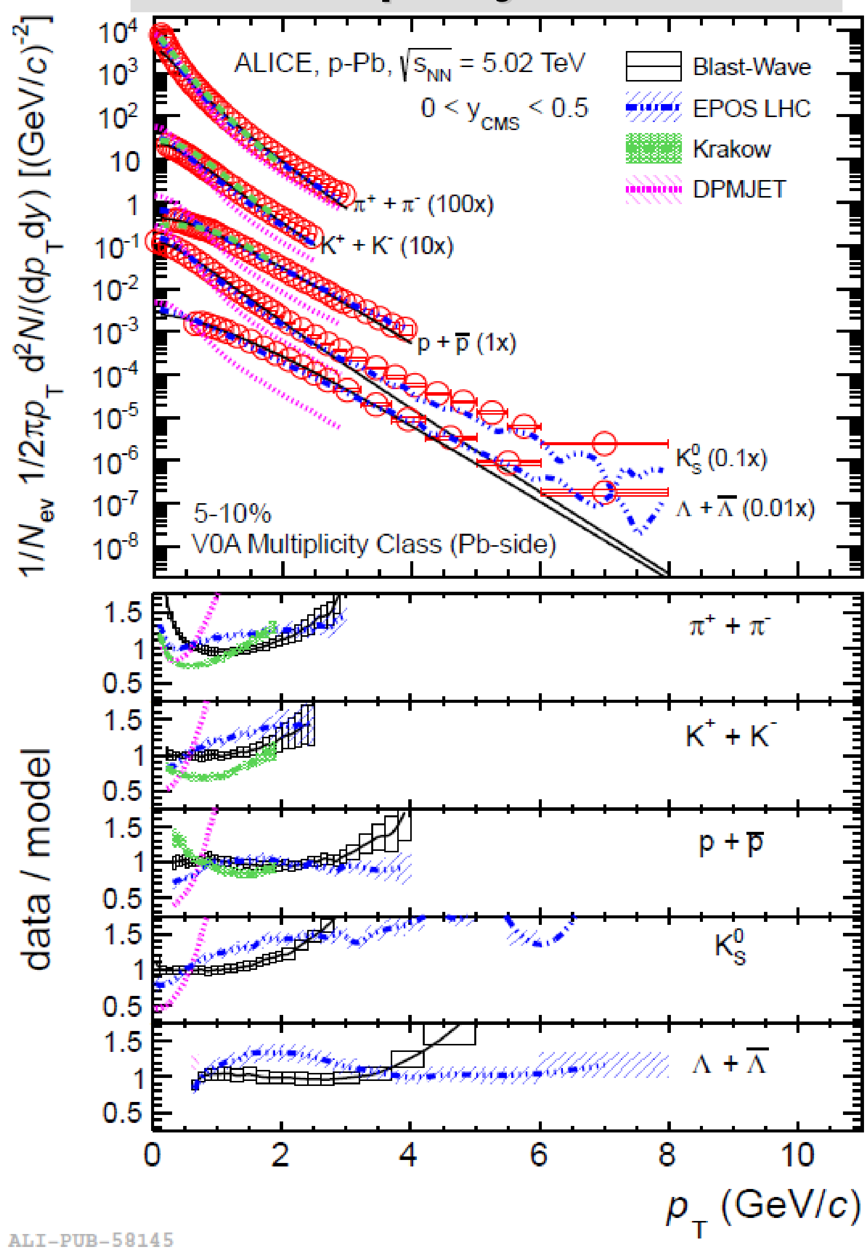
multiplicity increases



pp collisions exhibit flow-like behavior

Blast wave fits to the spectra

V0A Multiplicity Class: 5-10%



The p_T spectra in high multiplicity pp and p-Pb collisions show a clear evolution with multiplicity
→ this effect is well known from heavy ion collisions

- models, e.g. the Kraków **hydro**dynamic **model**, **reproduce** the **kaon** and **pion spectra** fairly well **below 1 GeV/*c***
- A **deviation for higher p_T** might show the **limit of hydro**dynamical models. The data could indicate the onset of a non-thermal (hard) component, which is not dominated by the flow-boosted thermal component in more peripheral collisions
- **Models** incorporating **final state effects,** such as EPOS, give **good description** of the data

- **Common kinetic freeze-out** describes the spectra in high multiplicity p-Pb collisions
- This feature is **also observed in pp** events simulated with PYTHIA8

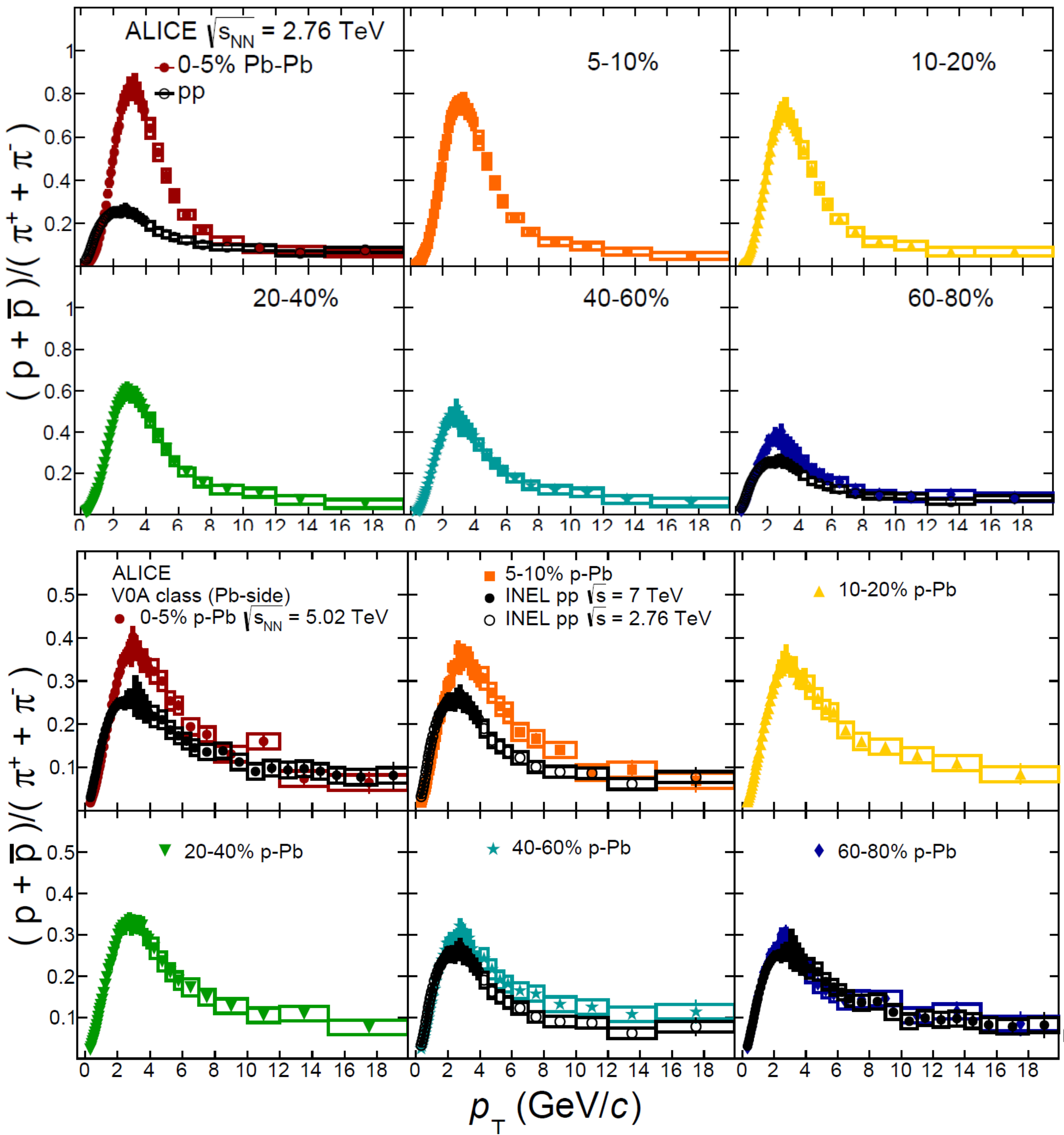
Transverse momentum and multiplicity dependence of particle ratios

proton-to-pion and kaon-to-pion

Particle ratios, K/pi and **p/pi**

Pb-Pb @ 2.76ATeV

p-Pb @ 5.02ATeV

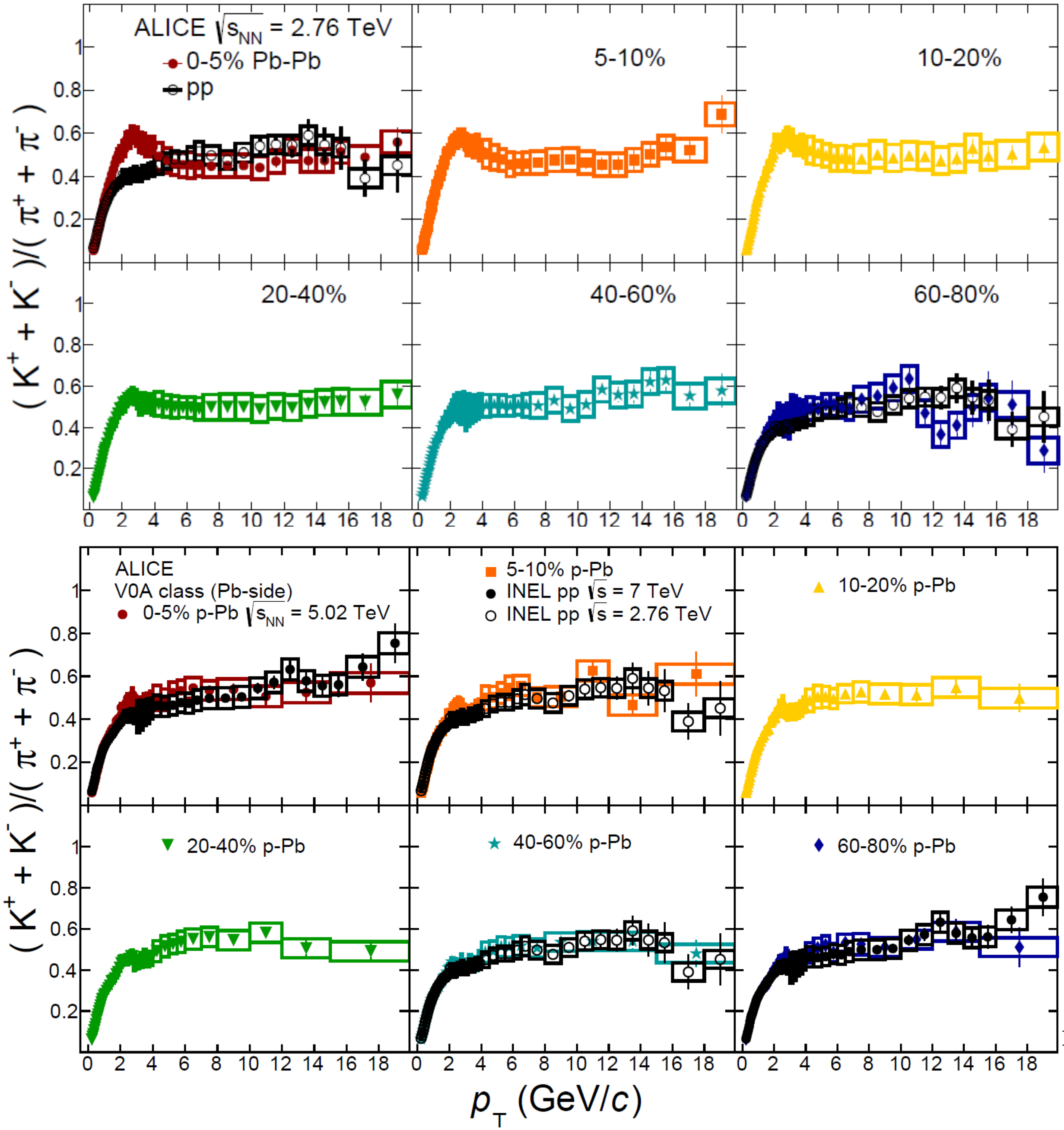


- **Proton-to-pion ratios**
  - **Strong mutliplicity dependence observed for p_T < 10 GeV/c**
  - **Qualitatively similar to Pb-Pb**
  - **At high p_T similar behaviour to pp at 2.76TeV and pp at 7TeV**

Particle ratios, K/pi and p/pi

Pb-Pb @ 2.76ATeV

p-Pb @ 5.02ATeV



- **Kaon-to-pion ratios**
  - **No dependence with multiplicity**
  - **Similar to those of pp at 2.76TeV and 7TeV**

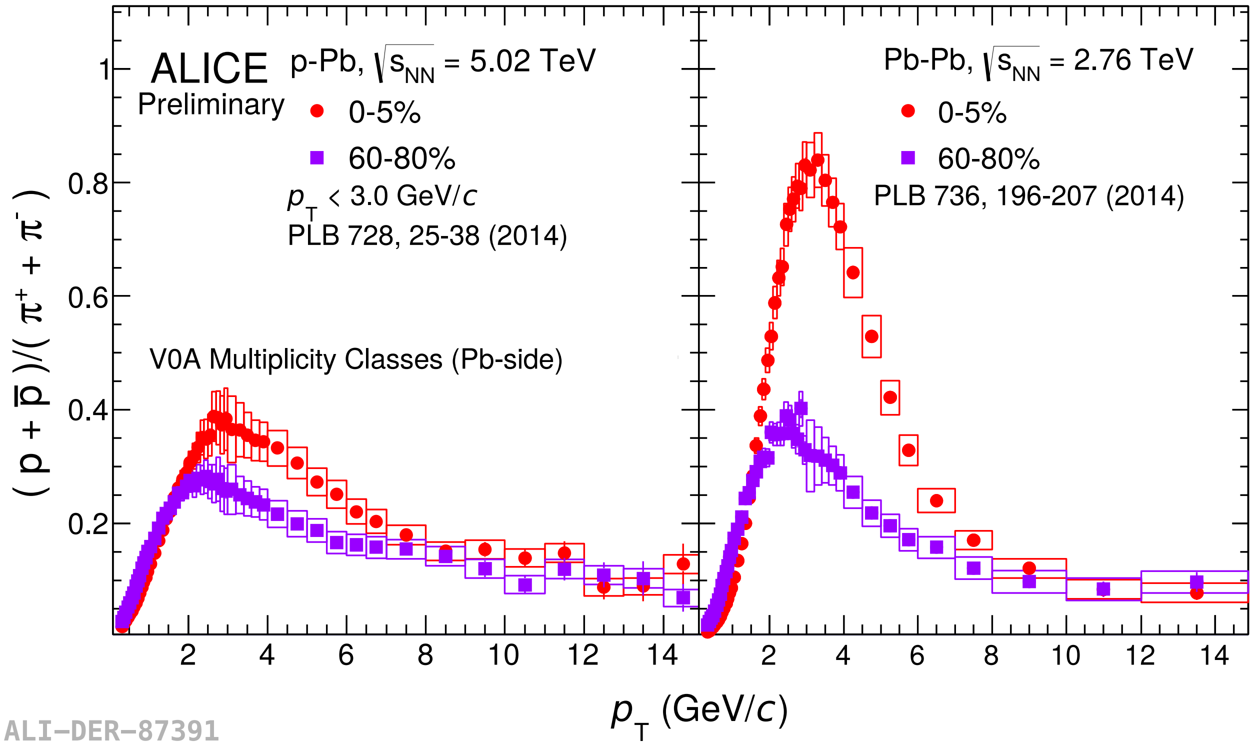
rio

Multiplicity dependence of kaon/pion and proton/pion particle ratios

- **At intermediate p_T** (2<p_T<10 GeV/c), the **proton-to-pion ratio increases with event multiplicity** (and a corresponding depletion at low p_T)

- The behavior of this **increase** is qualitatively **similar to** that observed in **Pb-Pb** collisions
  → its multiplicity dependence for $p_T \leq 1$ GeV/c is a feature of radial flow

- **At high p_T** (>10 GeV/c) the particle ratios in **p-Pb and Pb-Pb** are **consistent**



p_T integrated
kaon/pion and proton/pion particle ratios

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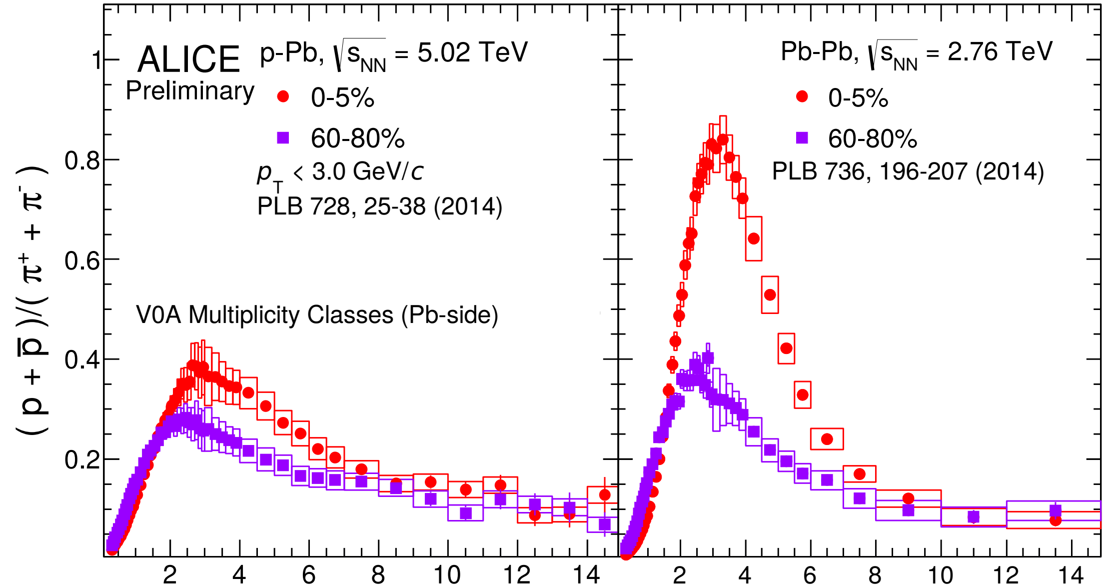
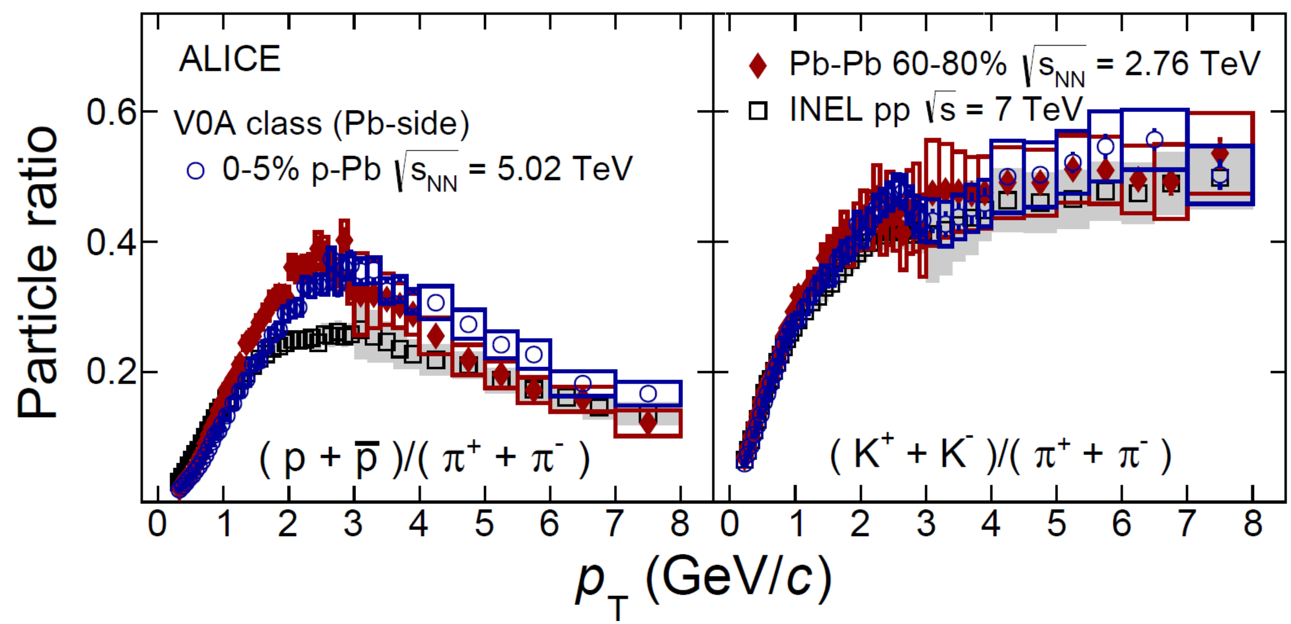
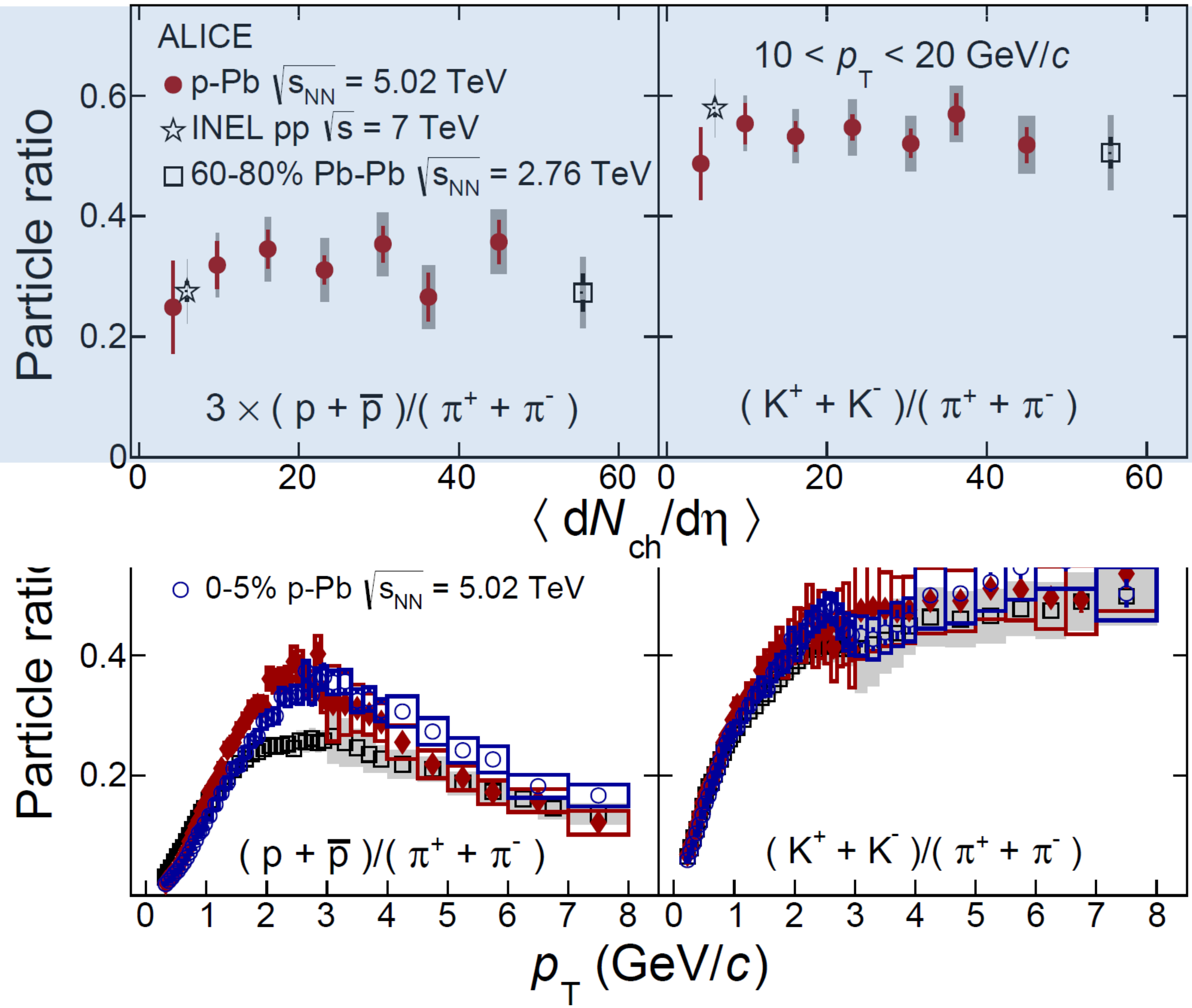




p_T integrated kaon/pion and proton/pion particle ratios

- **At intermediate p_T** (2<p_T<10 GeV/c) the **p_T integrated to-pion ratios are**
  - **independent of event multiplicities**
  - **Independent of system size**



The nuclear modification factor $\boldsymbol{R}_{\mathbf{pPb}}$ for pi/K/p

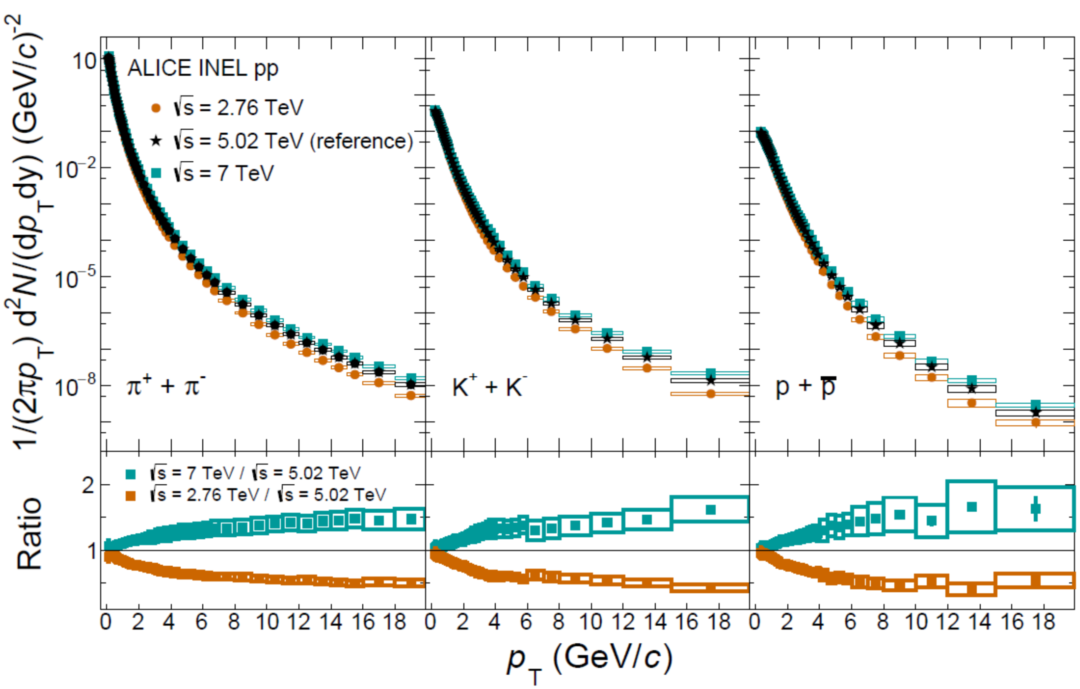
$$R_{\mathrm{pPb}} = \frac{\mathrm{d}^2 N_{\mathrm{pPb}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{pPb}} \rangle \mathrm{d}^2 \sigma_{\mathrm{pp}}^{\mathrm{INEL}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}$$

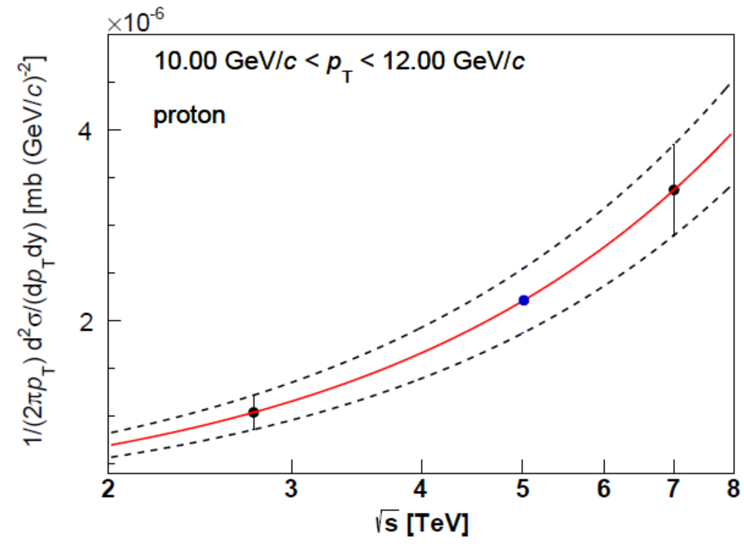
$$\langle T_{\mathrm{pPb}} \rangle = \langle N_{\mathrm{coll}} \rangle / \sigma_{\mathrm{NN}} = 0.0983 \pm 0.0035\ \mathrm{mb}^{-1}$$

In order to quantify particle specie dependence of nuclear effects comparison to reference pp at the same energy is needed

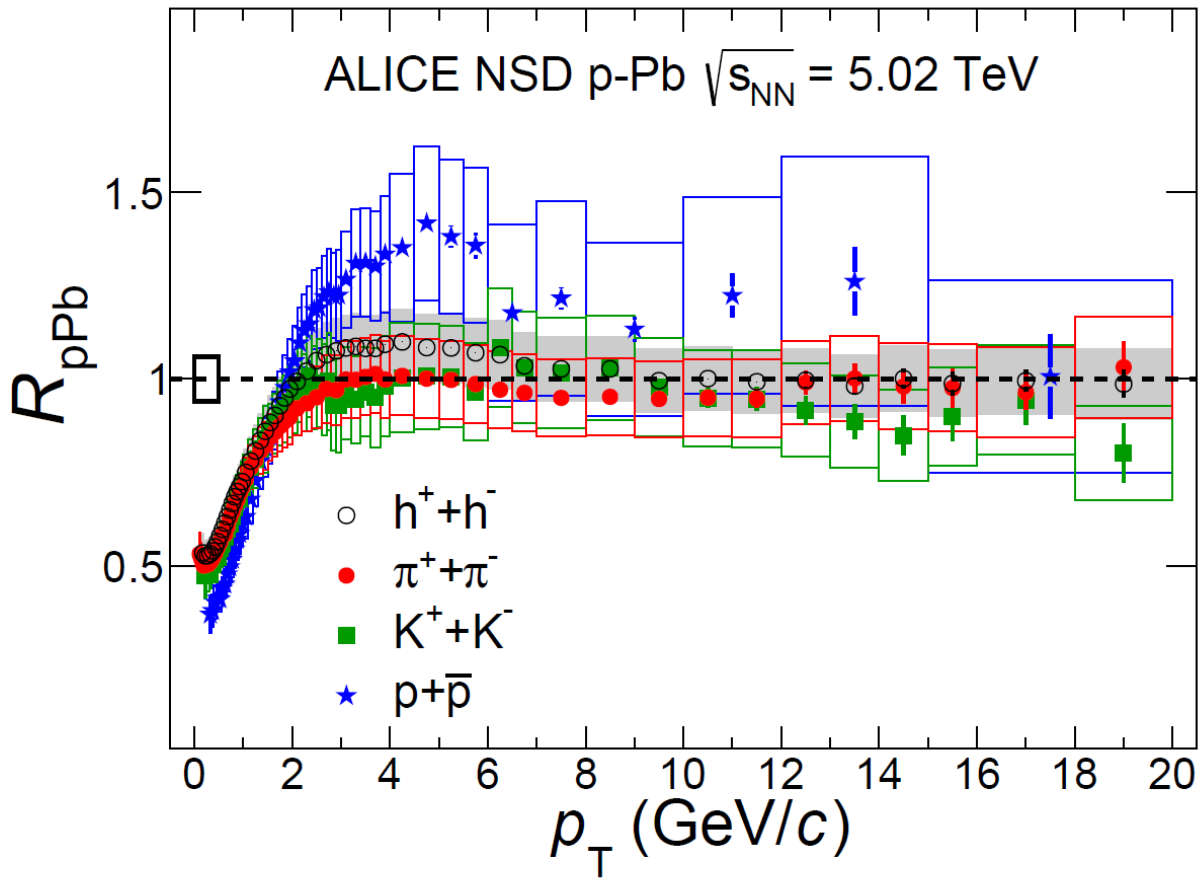
The nuclear modification factor R_{pPb} for pi/K/p – calculation of pp reference spectrum at 5.02TeV

- No measurement was available in pp at 5.02TeV
- Constructed from pp 2.76TeV and pp 7TeV (measured up to 20GeV/c)
- The invariant cross section $d^2\sigma_{pp}^{INEL}/dy dp_T$ is interpolated bin-by-bin (p_T) assuming $\alpha \cdot \sqrt{s}^{\beta}$ dependence





The nuclear modification factor R_{pPb} for pi/K/p



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

- **Measured for NSD events**
  - Nuclear overlap $<T_{pPb}>$ is not measured yet in mult. classes
- **No pp measurement at 5.02 TeV**: it has to be interpolated between existing measurements
- **At intermediate p_T** the **proton R_{pPb}** shows a **Cronin-like enhancement**, while pions and kaons show little or no nuclear modification
- **At higher p_T** the pion, kaon and proton R_{pPb} are consistent with **unity**

It has been proposed that in d-Au collisions the recombination of soft and shower partons in the final state could explain the behavior of the nuclear modification factor at intermediate pT

Summary

- **p-Pb and Pb-Pb** collisions have very similar **behavior** in many ways
- p-Pb: p_T spectra show flow-like behavior
- p-Pb: **multiplicity dependence of the proton-to-pion** ratio *vs.* p_T is qualitatively **similar** to the **centrality evolution** of this ratio **in Pb-Pb** collisions
- Cronin-like enhancement observed for protons at intermediate p_T (initial state effects); no nuclear modification at high p_T

Backup slides

Combined spectra