XXIV QUARK MATTER
DARMSTADT 2014
A Large Ion Collider Experiment

ALICE

Light flavor hadron spectra at low p_T and search for collective phenomena in high multiplicity pp, p-Pb and Pb-Pb collisions measured with ALICE

Cristian Andrei* for the ALICE Collaboration
*IFIN-HH Bucharest, Romania

IFIN-HH

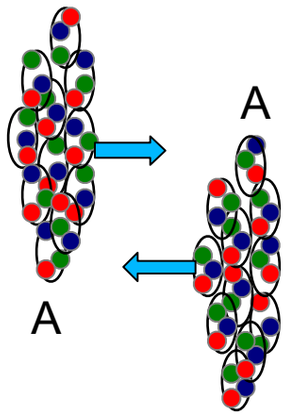
Outline

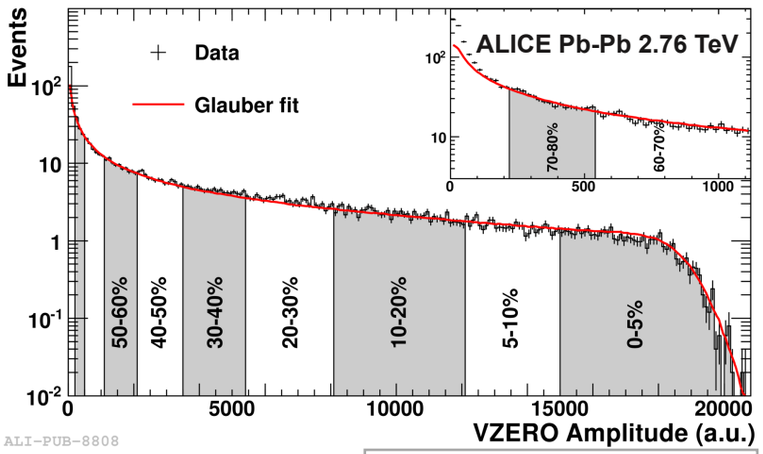
- Introduction
- ALICE PID performance
- Transverse momentum spectra of identified charged hadrons
- Spectra ratios - multiplicity dependence
- Relative yields – p_T and multiplicity dependence
- BGBW – fit results in terms of T-β and expansion profile
- Outlook

A-A, p-A, pp collisions

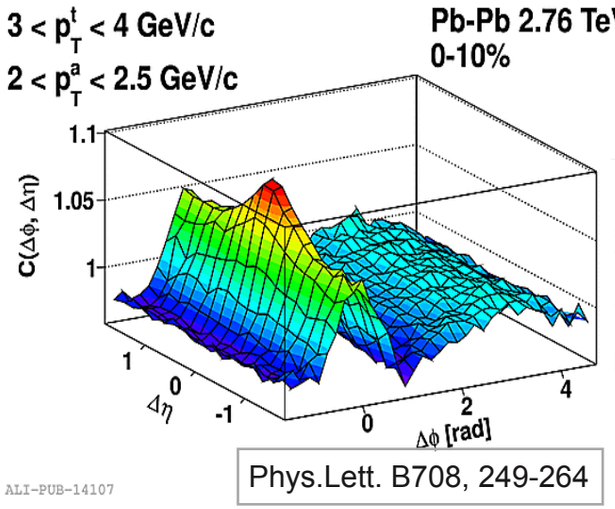
Similarities and differences

Centrality Selection

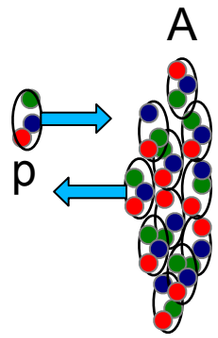


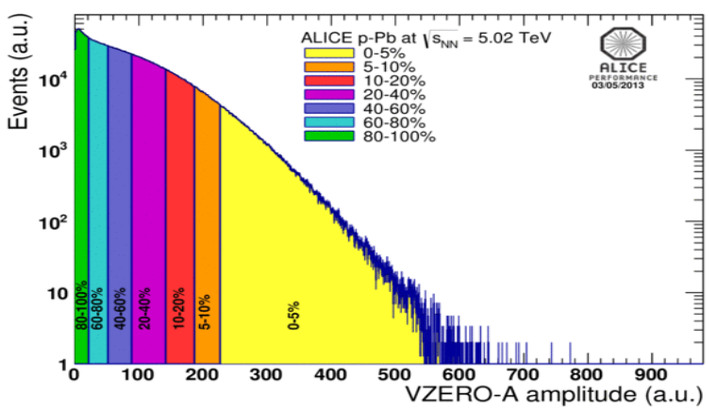


Phys. Rev. Lett. 106, 032301

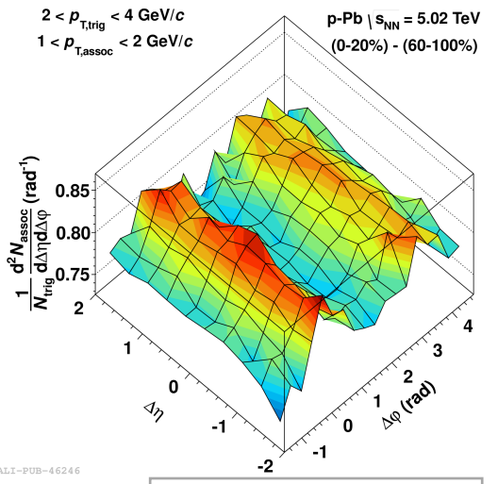


Phys.Lett. B708, 249-264

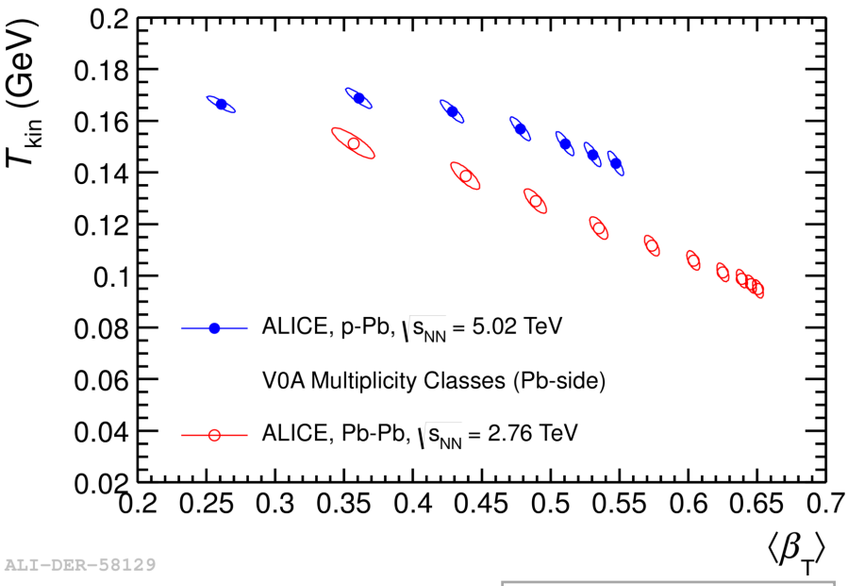




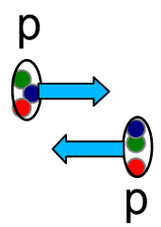
see L. Milano ID-245

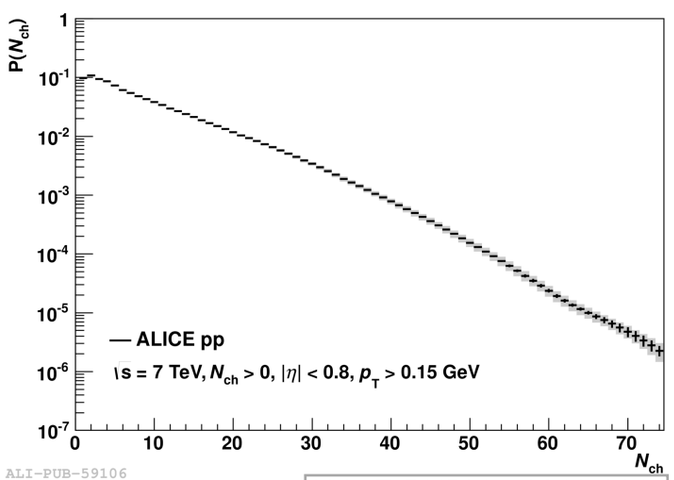


Phys.Lett. B719, 29-41

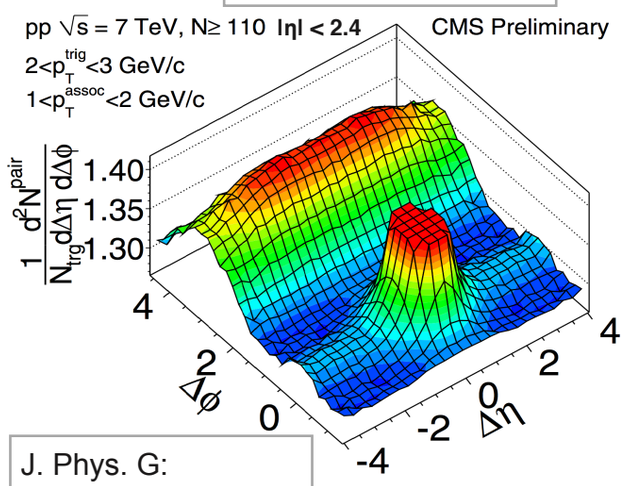


Phys.Lett. B728, 25-38





ALICE-PUBLIC-2013-001

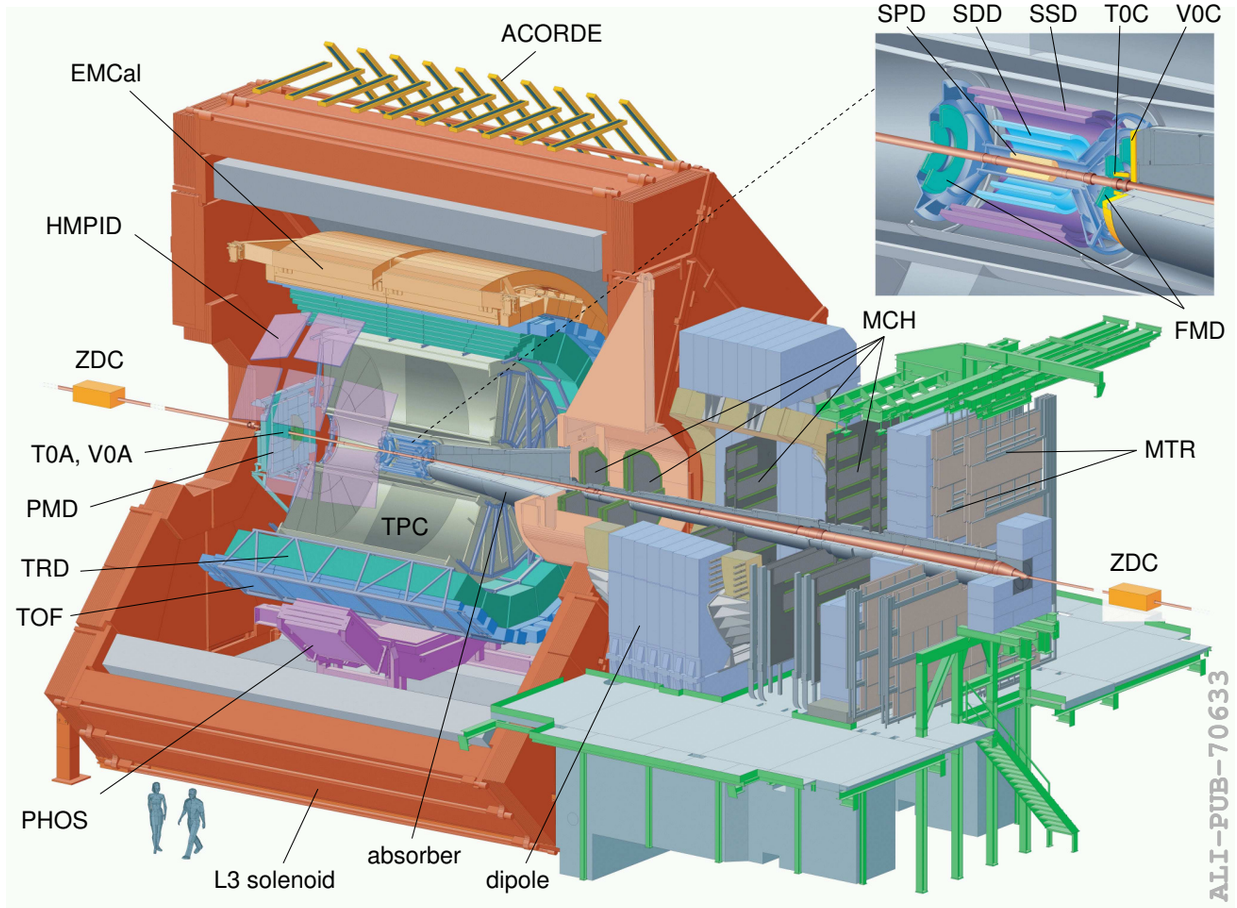


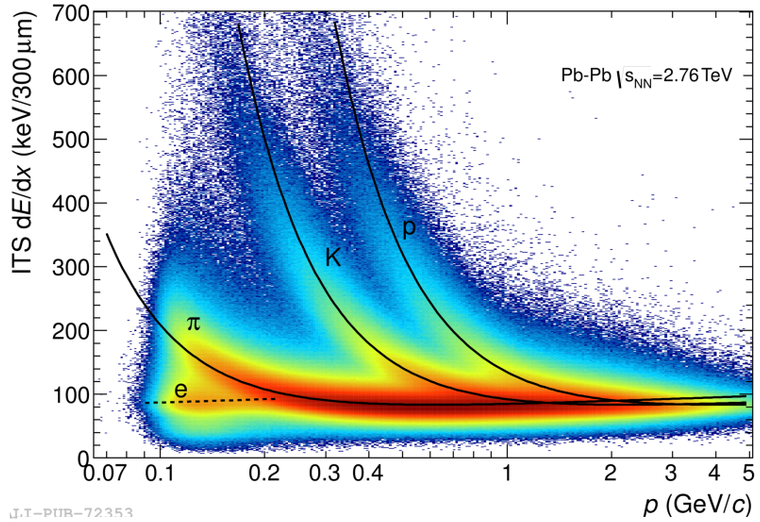
J. Phys. G: Nucl. Part. Phys. 38, 124051

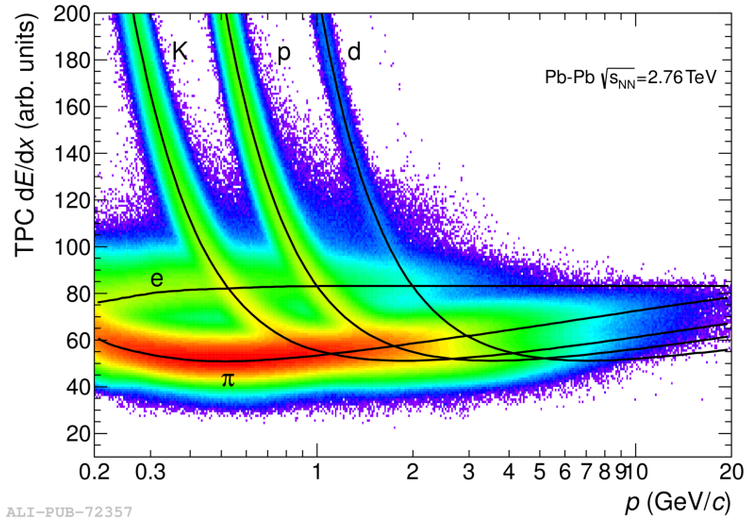
?

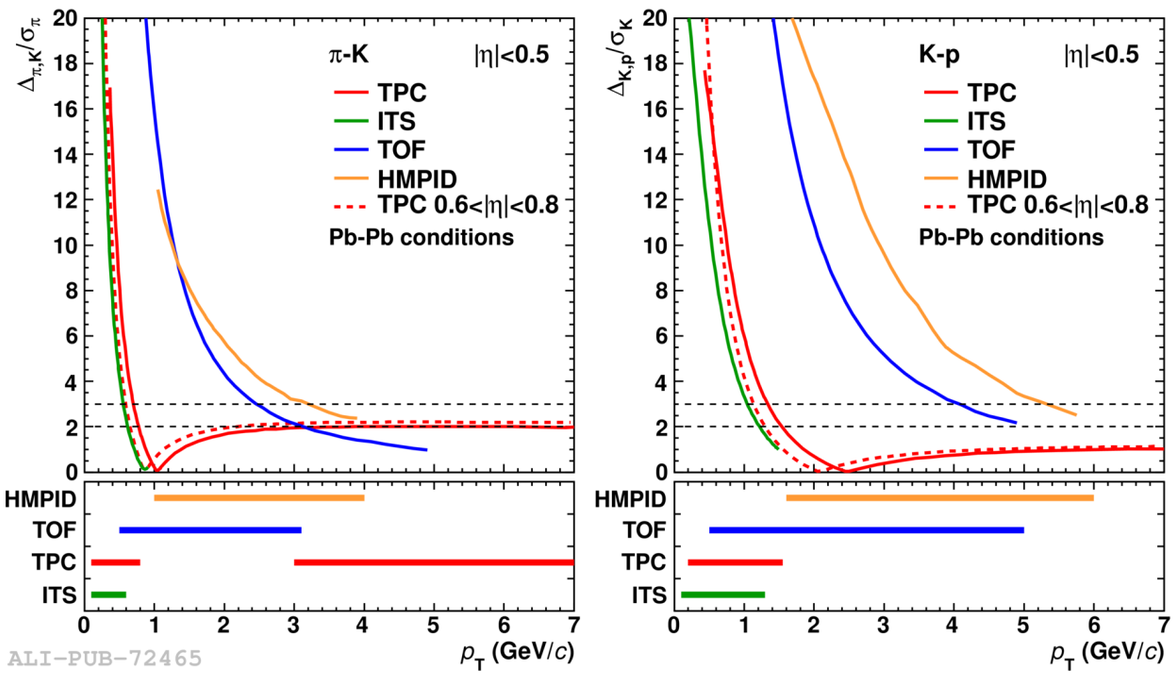
ALICE Experiment @ LHC

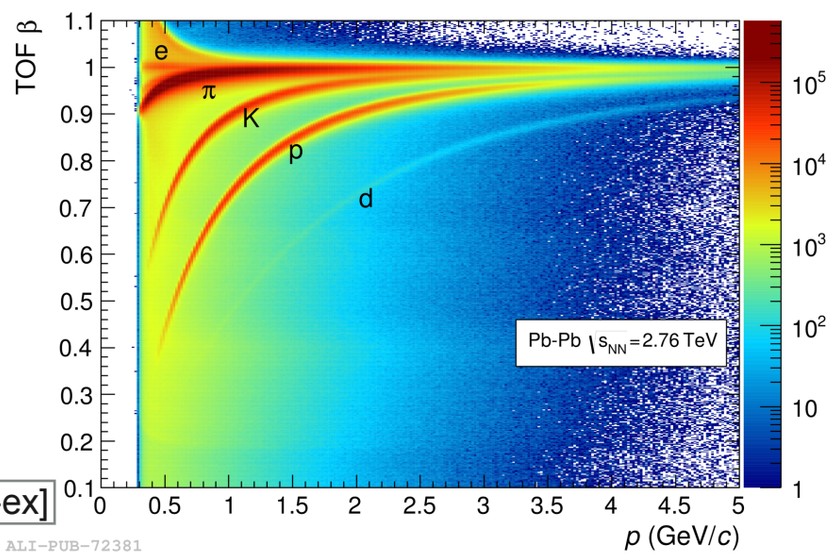
PID performance







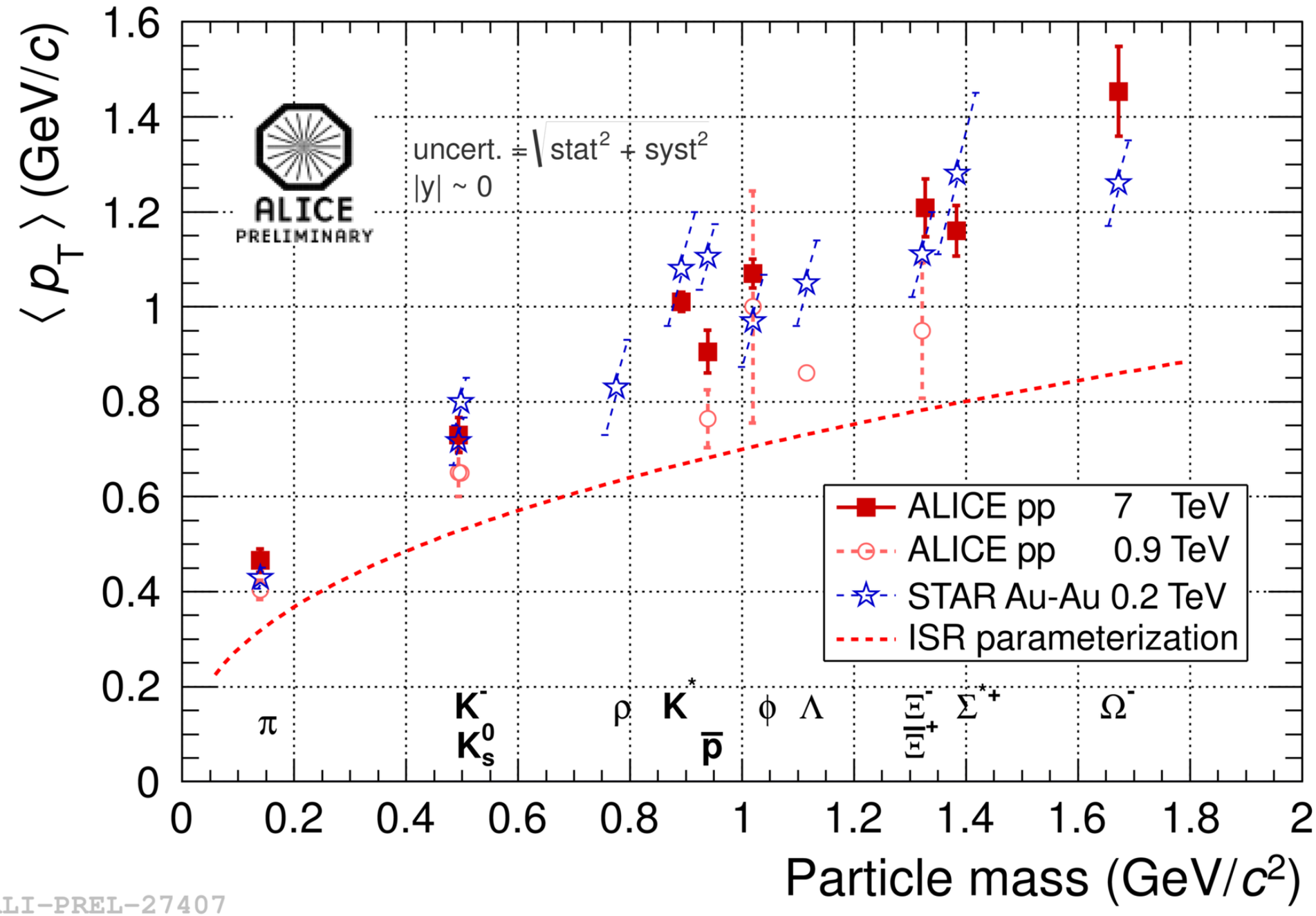




arXiv:1402.4476 [nucl-ex]

pp Minimum Bias

<p_T> - mass and energy dependence

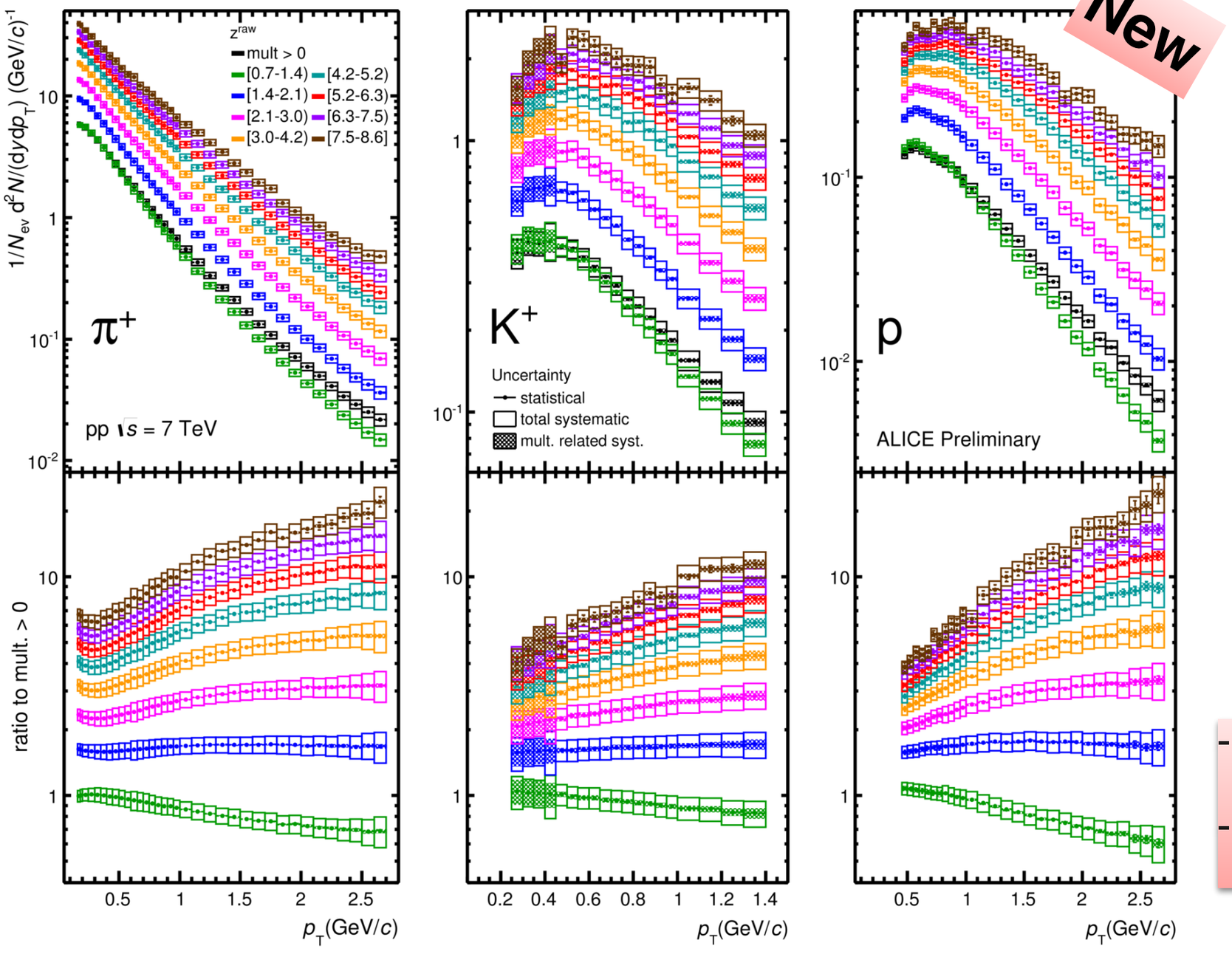


ALI-PREL-27407

- <p_T> vs mass for pp - the slope increases with the energy

pp 7 TeV
p_T spectra - multiplicity dependence

- N_{ch}^{raw} - multiplicity estimator with **|η| < 0.8** (global tracks, complementary ITS SA tracks, complementary tracklets)
- spectra obtained with **|y| < 0.5**
- 2010 data: 6x10^7 MB trigger events 3.8x10^6 HM trigger events 5.5x10^6 MC events



$$z^{raw} = \frac{(N_{ch}^{raw})_{limit}}{< N_{ch}^{raw} >_{mult>0}}$$

$$< N_{ch}^{raw} >_{mult>0} = 9.6, |\eta| < 0.8$$

N_{ch}^{raw}	z^{raw}
7 - 12	0.7 - 1.3
13 - 19	1.4 - 2.0
20 - 28	2.1 - 2.9
29 - 39	3.0 - 4.1
40 - 49	4.2 - 5.1
50 - 59	5.2 - 6.2
60 - 71	6.3 - 7.4
72 - 82	7.5 - 8.6

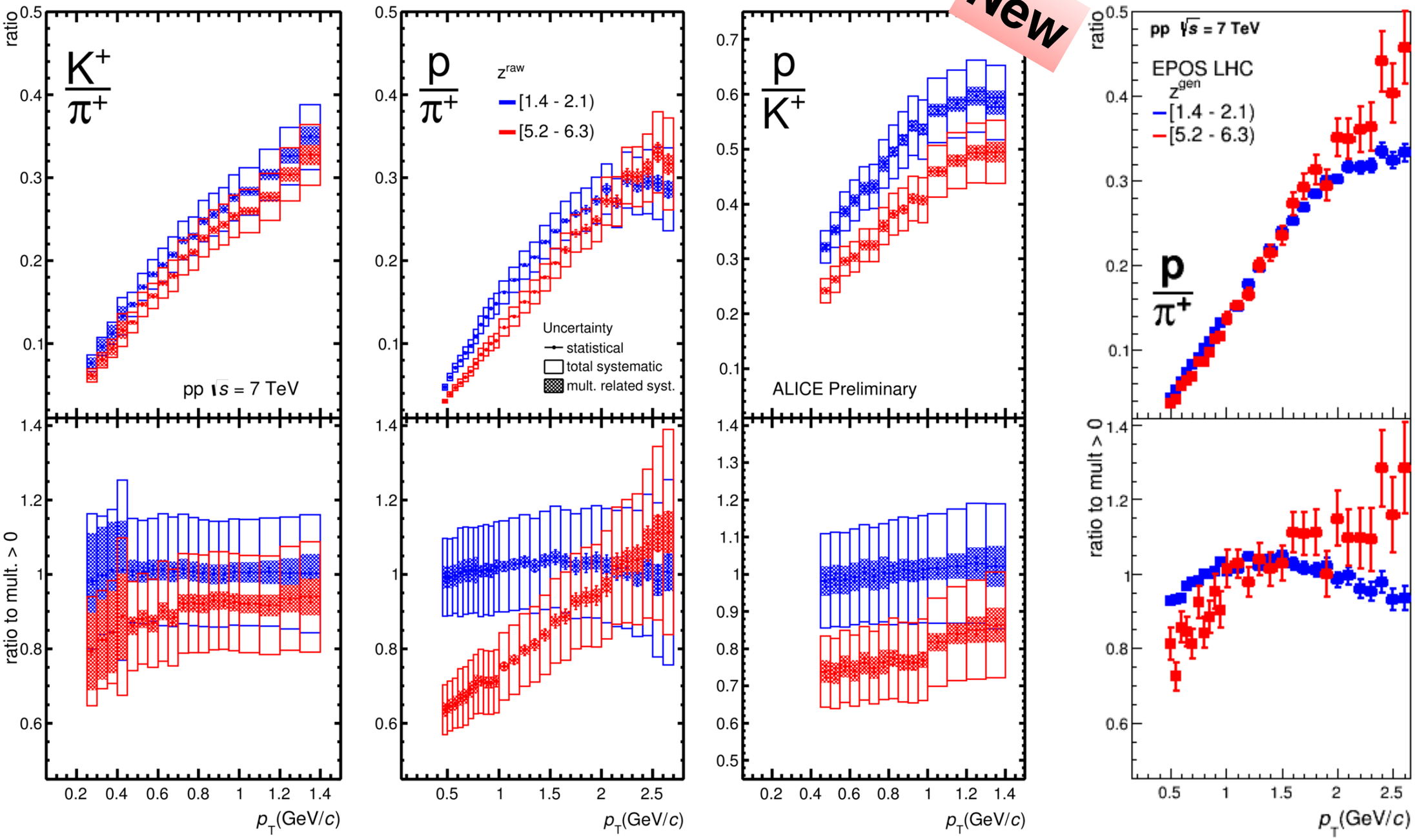
- spectra shape - multiplicity dependence
- low p_T depletion - multiplicity and mass dependence

ALI-PREL-81642

pp 7 TeV

Yield ratios as a function of p_T - multiplicity dependence

New



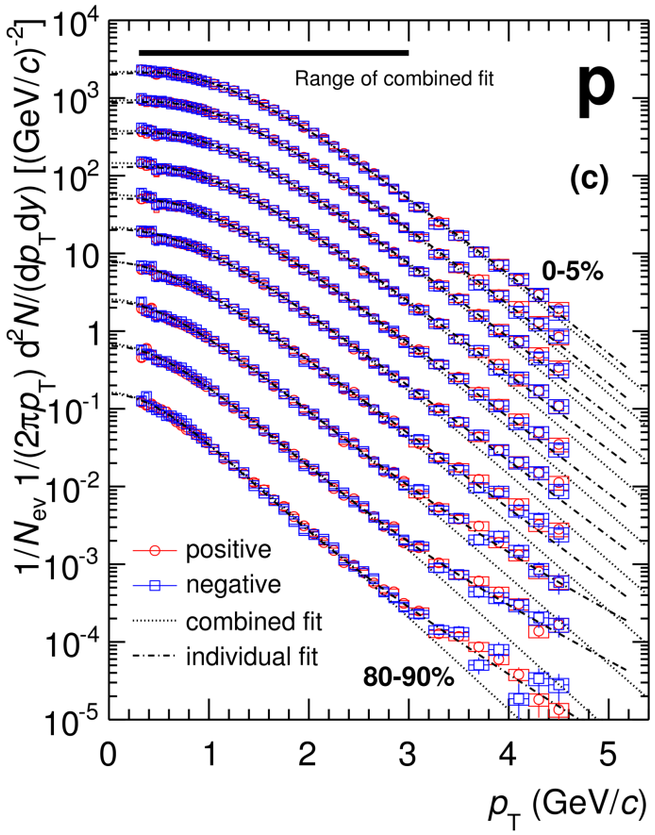
ALI-PREL-81635

- larger boost for heavier particles and high multiplicity
- qualitatively EPOS shows the same trend, similar with PYTHIA8 Tune 4C (CR)

pp, p-Pb, Pb-Pb comparison

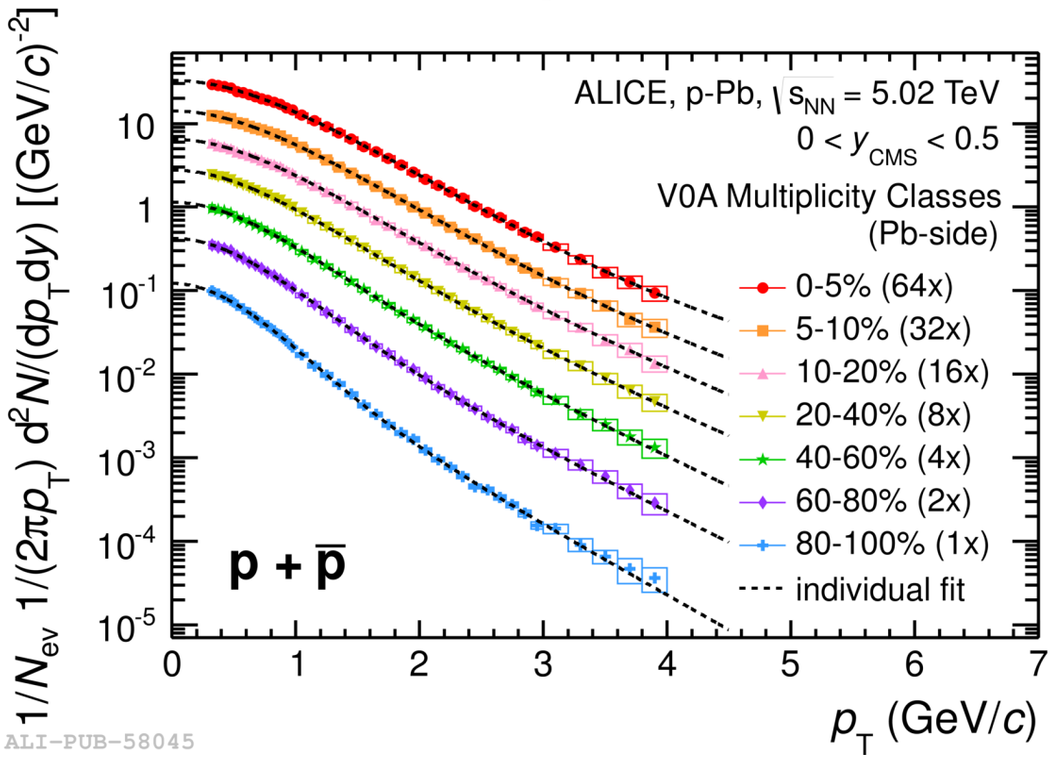
Invariant p_T distributions

Pb-Pb



Phys. Rev. C88, 044910

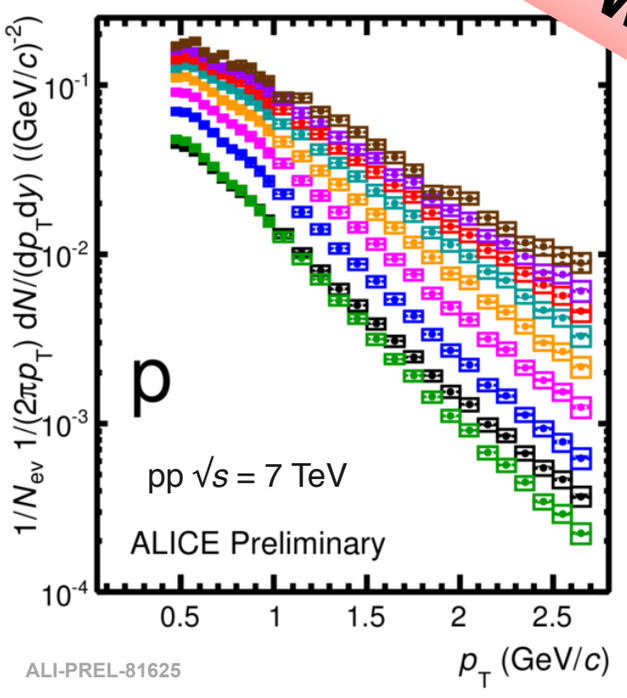
p-Pb



Phys.Lett. B728, 25-38

pp

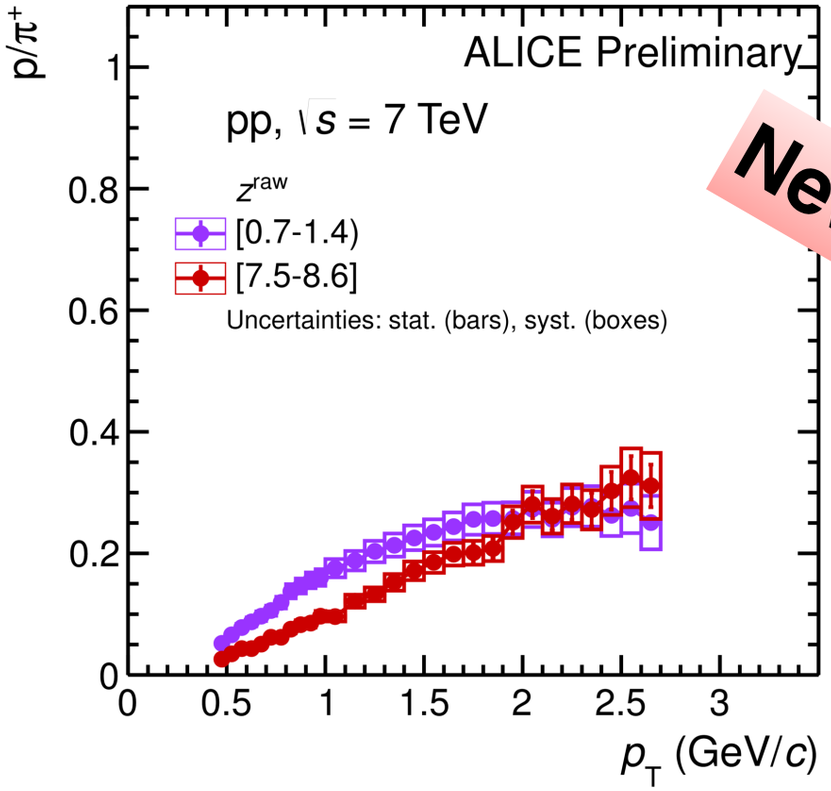
New



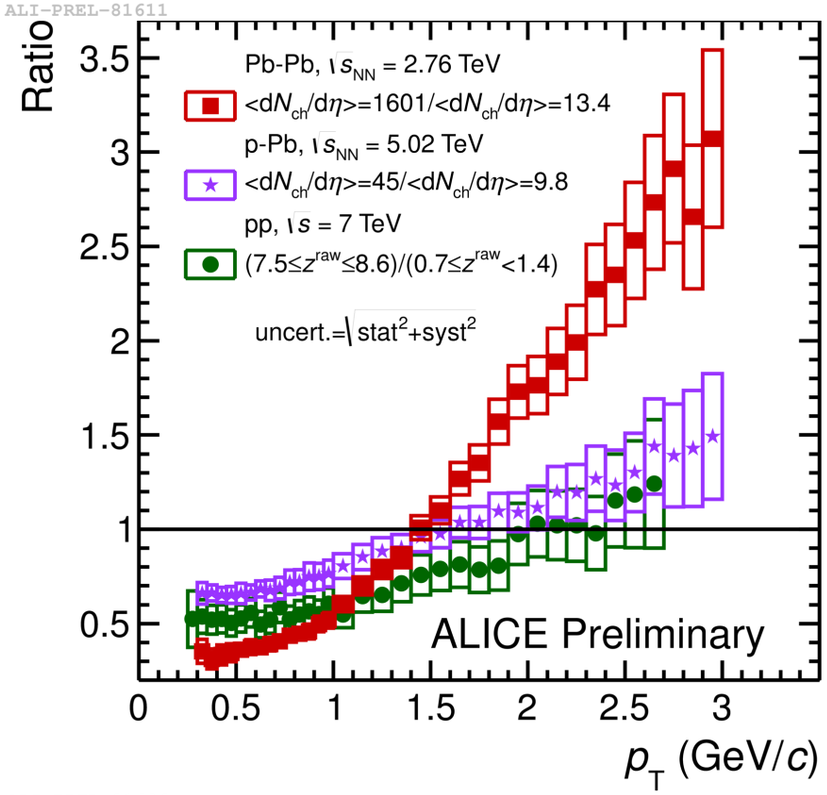
- a similar change in the shape of the distributions in the low p_T region, with increasing multiplicity is observed

pp, p-Pb, Pb-Pb comparison

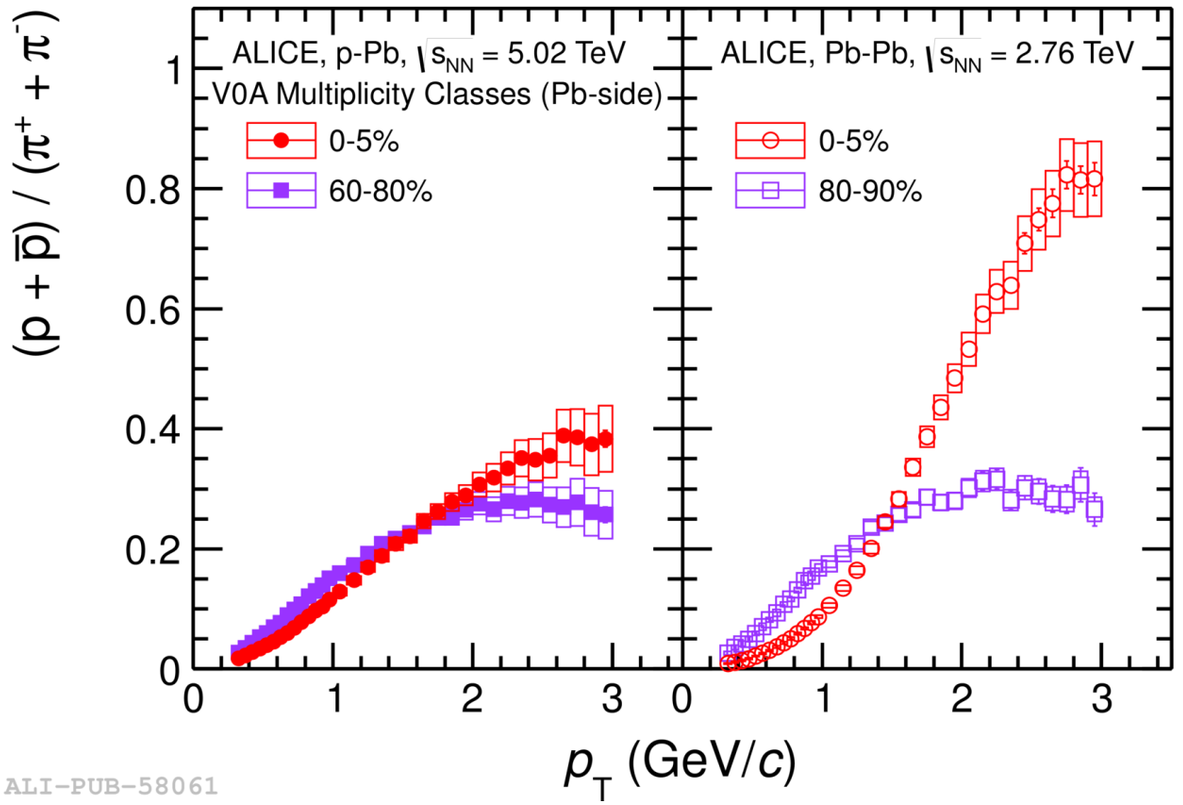
Yield ratios as a function of p_T - multiplicity dependence



ALI-PREL-81611



ALI-PREL-81606



ALI-PUB-58061

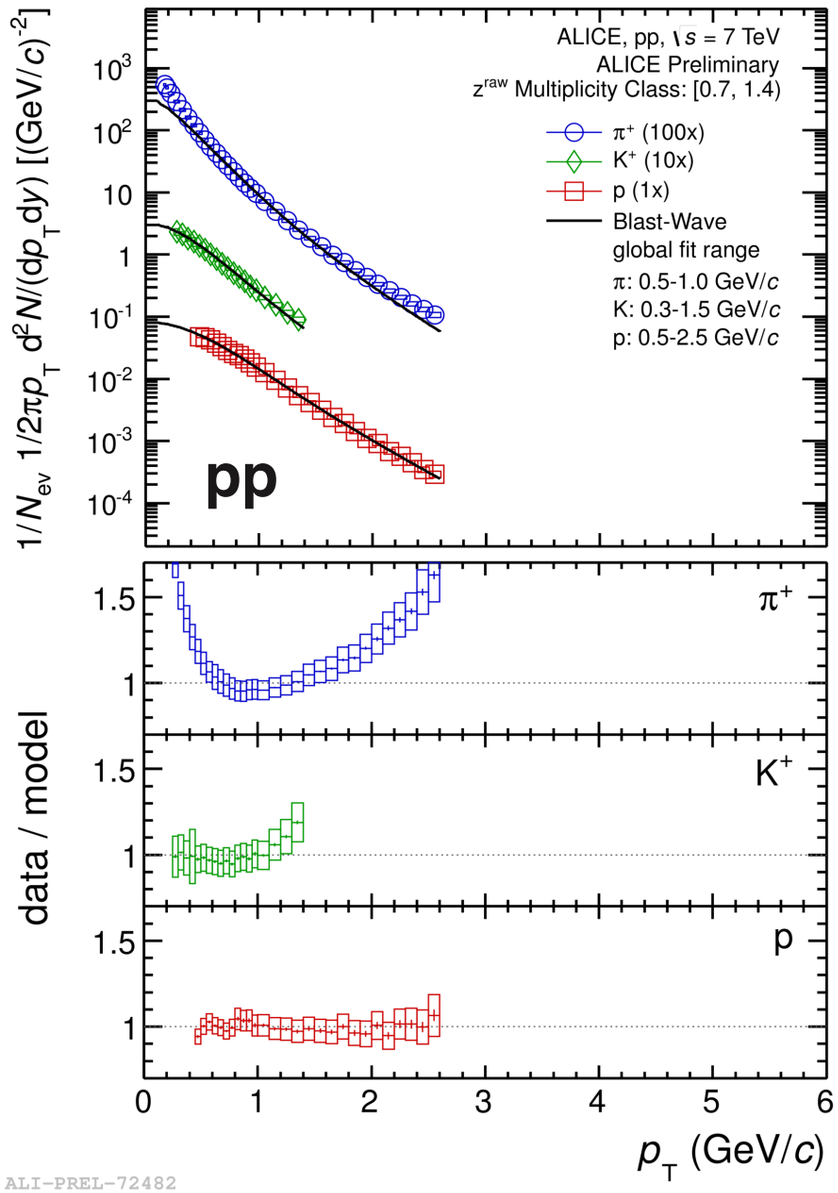
Phys. Lett. B 728, 25-38

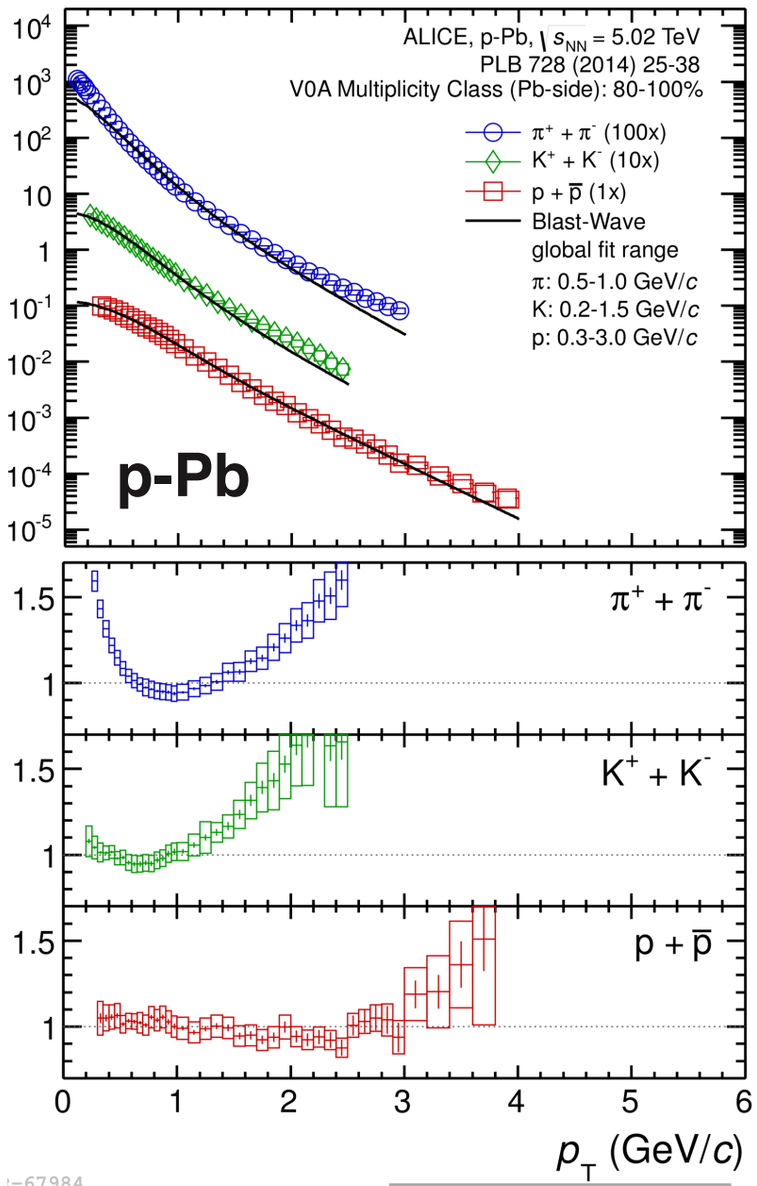
- the push of heavier particles towards larger p_T - present for all three systems
- the ratio to the lowest multiplicity bin for pp follows closely the p-Pb trend

pp, p-Pb, Pb-Pb comparison

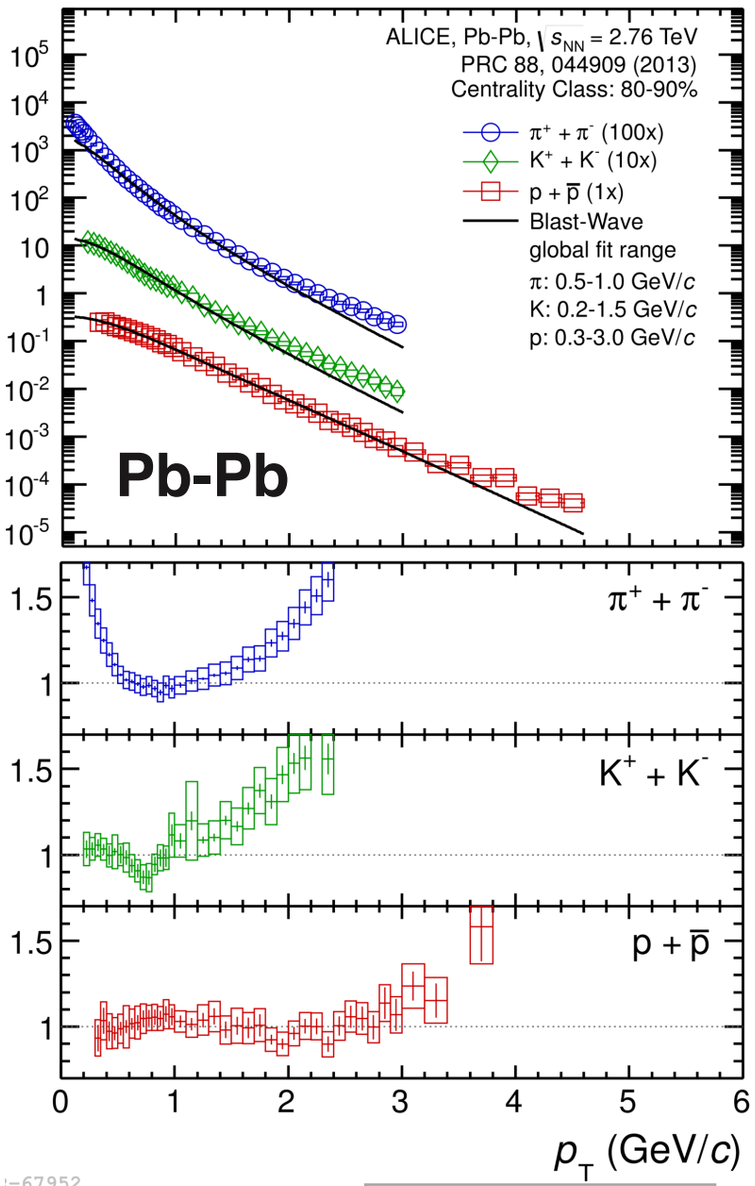
Boltzmann-Gibbs Blast Wave fits - fits quality - low multiplicity

$$E\frac{d^3N}{dp^3} \sim f(p_t) = \int_0^R m_T K_1(m_T cosh\rho/T_{fo}) I_0(p_T sinh\rho/T_{fo}) r dr \quad \text{where } m_T = \sqrt{m^2 + p_T^2};\ \beta_r(r) = \beta_s(\tfrac{r}{R})^n;\ \rho = tanh^{-1}\beta_r.$$





Phys. Lett. B728, 25-38



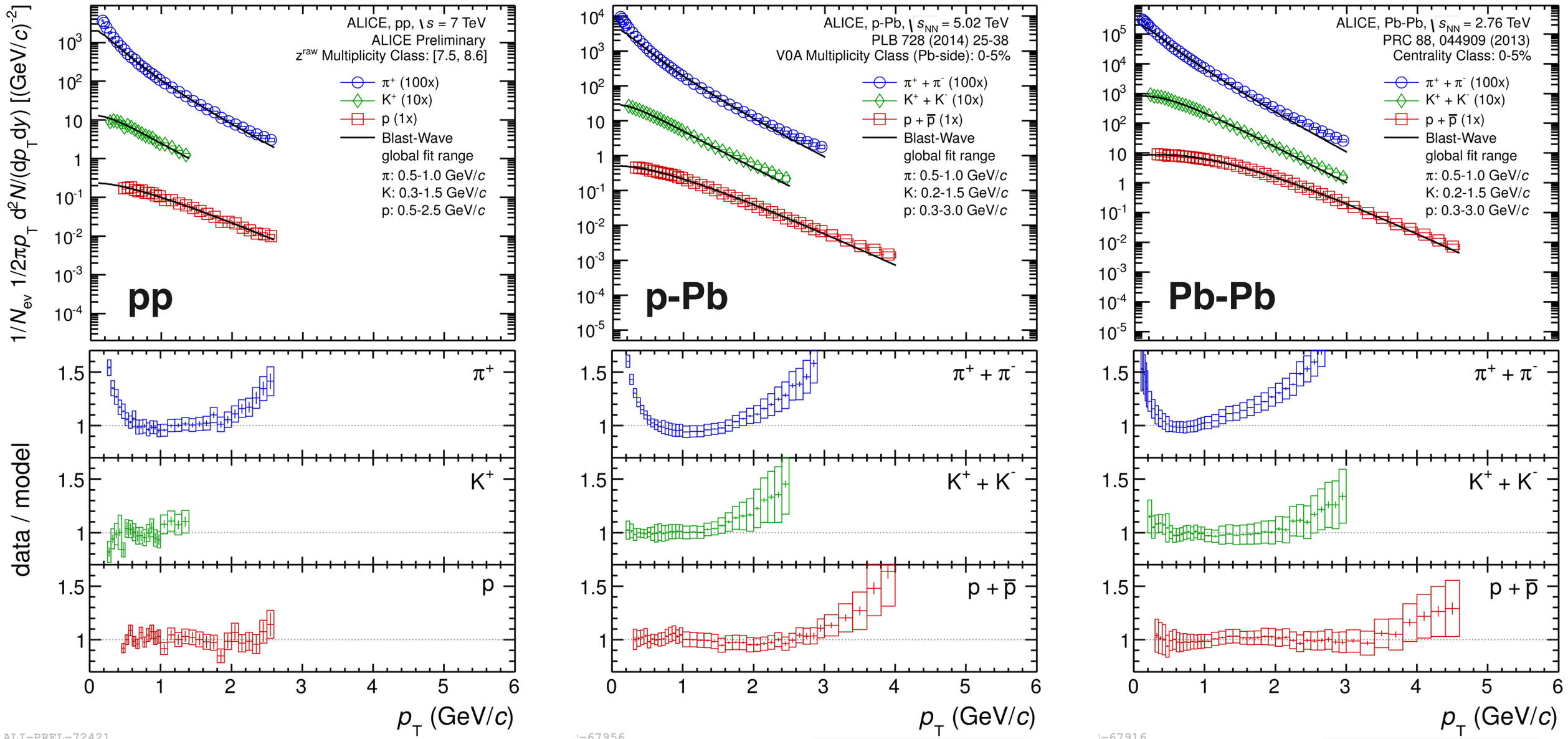
Phys. Rev. C88, 044910

- the fit quality, in the fit ranges, within the error bars, is comparable for all three systems

pp, p-Pb, Pb-Pb comparison

Boltzmann-Gibbs Blast Wave fits - fits quality - high multiplicity

$$E\frac{d^3N}{dp^3} \sim f(p_t) = \int_0^R m_T K_1(m_T cosh\rho/T_{fo}) I_0(p_T sinh\rho/T_{fo}) r dr \quad \text{where } m_T = \sqrt{m^2 + p_T^2};\ \beta_r(r) = \beta_s(\tfrac{r}{R})^n;\ \rho = tanh^{-1}\beta_r.$$



Phys. Lett. B728, 25-38

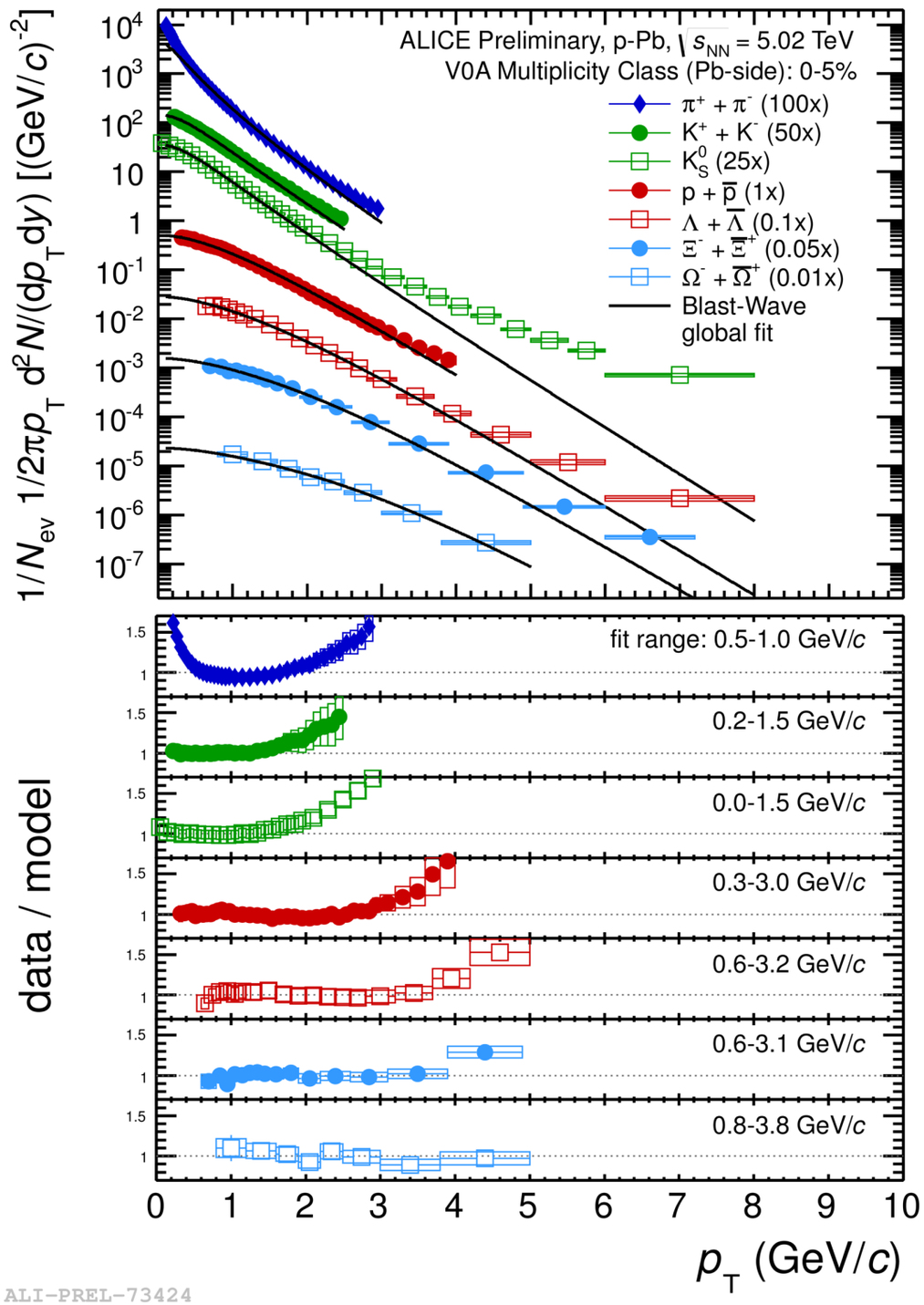
Phys. Rev. C88, 044910

- the fit quality, in the fit ranges, within the error bars:
  - is comparable and rather good for all three systems
  - improves going from low to high multiplicity

p-Pb 5.02 TeV

Boltzmann-Gibbs Blast Wave fits - fits quality - high multiplicity

$$E\frac{d^3N}{dp^3} \sim f(p_t) = \int_0^R m_T K_1(m_T cosh\rho/T_{fo}) I_0(p_T sinh\rho/T_{fo}) r dr \quad \text{where } m_T = \sqrt{m^2 + p_T^2};\ \beta_r(r) = \beta_s(\tfrac{r}{R})^n;\ \rho = tanh^{-1}\beta_r.$$

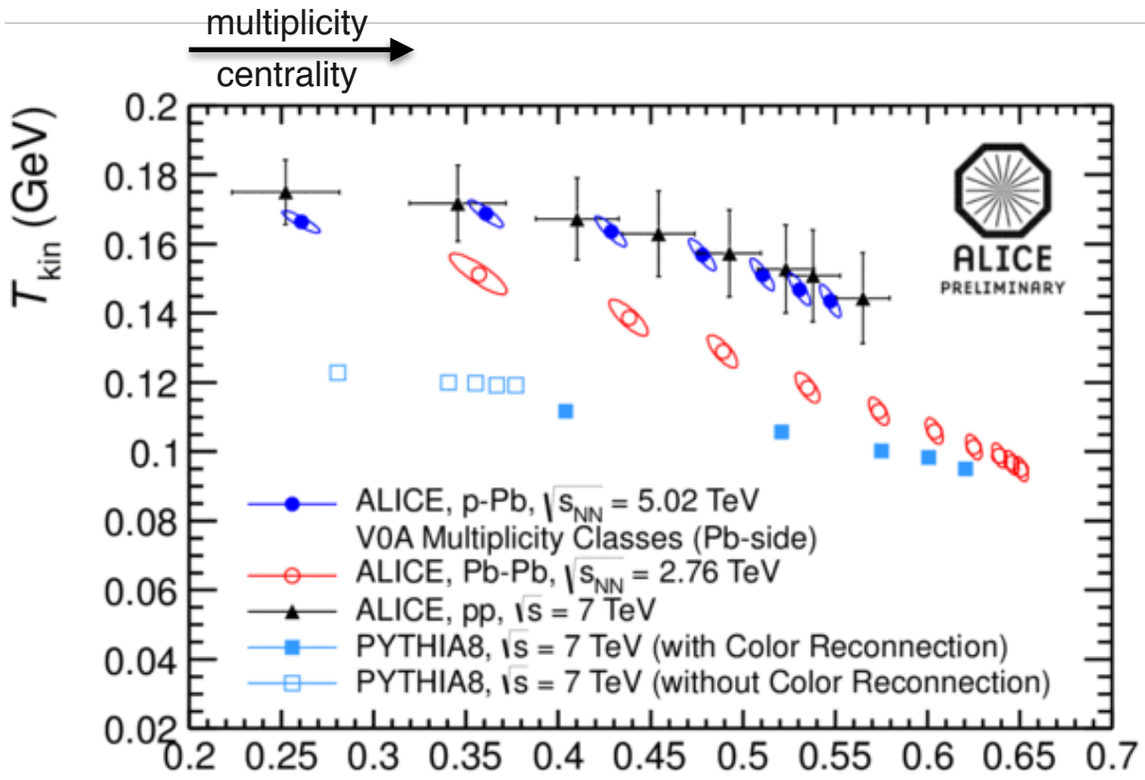


π
K
K^0_s
p
Λ
Ξ
Ω

- the p_T spectra follow the hydro shape on a larger p_T range for heavier particles

see D. Alexandre ID-207

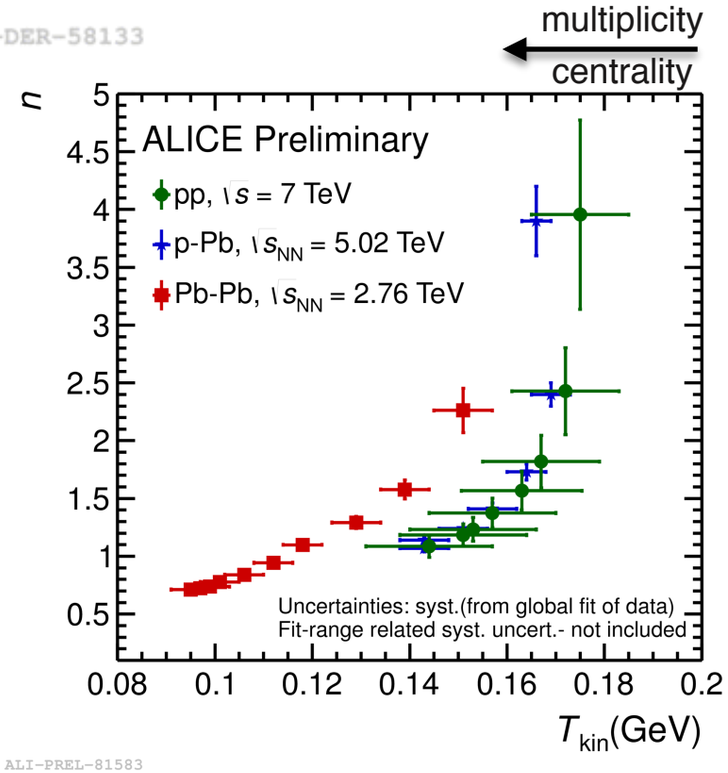
pp, p-Pb, Pb-Pb comparison
Boltzmann-Gibbs Blast Wave fits



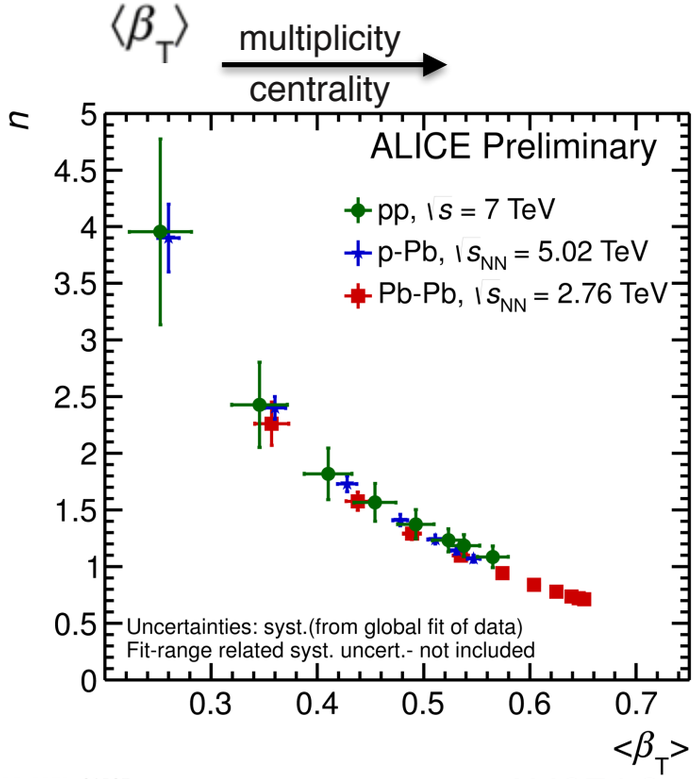
ALI-DER-58133

- similar trends in the T_{kin} - $<\beta_T>$ correlation for pp and p-Pb while systematically the values for Pb-Pb are lower and higher, respectively, with increasing multiplicity

- T_{kin} - $<\beta_T>$ correlation for pp is not reproduced by PYTHIA in absolute values; qualitatively PYTHIA-CR seems to indicate a similar trend as the experiment



ALI-PREL-81583



ALI-PREL-81587

- n - T_{kin} correlation
  - similar for pp and p-Pb
  - for Pb-Pb T_{kin} has lower values

- n - $<\beta_T>$ correlation
  - similar for the three systems

- towards high charged particle multiplicity expansion velocity approaches a linear dependence as a function of the position in the fireball(r)

Outlook

- Results on p_T spectra and their ratios as a function of multiplicity in pp collisions at 7 TeV measured by ALICE, are presented

- Similarities between pp, p-Pb and Pb-Pb systems, in terms of the multiplicity dependence of:
  - the relative yields as a function of p_T
  - T_{kin}, $<\beta_T>$ and expansion profile (n) extracted from BGBW fits

  are shown

- However, a conclusion about similar mechanisms for the three systems has to be taken with caution

- Theoretical investigations will give insight to the underlying physics of these new phenomena evidenced at LHC energies:
  - hydrodynamic approaches
  - parton based Gribov Regge theory (EPOS) + hydro
  - Color Glass Condensate
  - Color Reconnection

BACKUP

centrality - charged particle multiplicity density

p-Pb

Table 1
Definition of the event classes as fractions of the analyzed event sample and their corresponding $\langle dN_{ch}/d\eta \rangle$ within $|\eta_{lab}| < 0.5$ (systematic uncertainties only, statistical uncertainties are negligible).

Event class	V0A range (arb. unit)	$\langle dN_{ch}/d\eta \rangle$ $\lvert\eta_{lab}\rvert < 0.5$
0–5%	>227	45 ± 1
5–10%	187–227	36.2 ± 0.8
10–20%	142–187	30.5 ± 0.7
20–40%	89–142	23.2 ± 0.5
40–60%	52–89	16.1 ± 0.4
60–80%	22–52	9.8 ± 0.2
80–100%	<22	4.4 ± 0.1

Phys.Lett. B728, 25-38

Pb-Pb

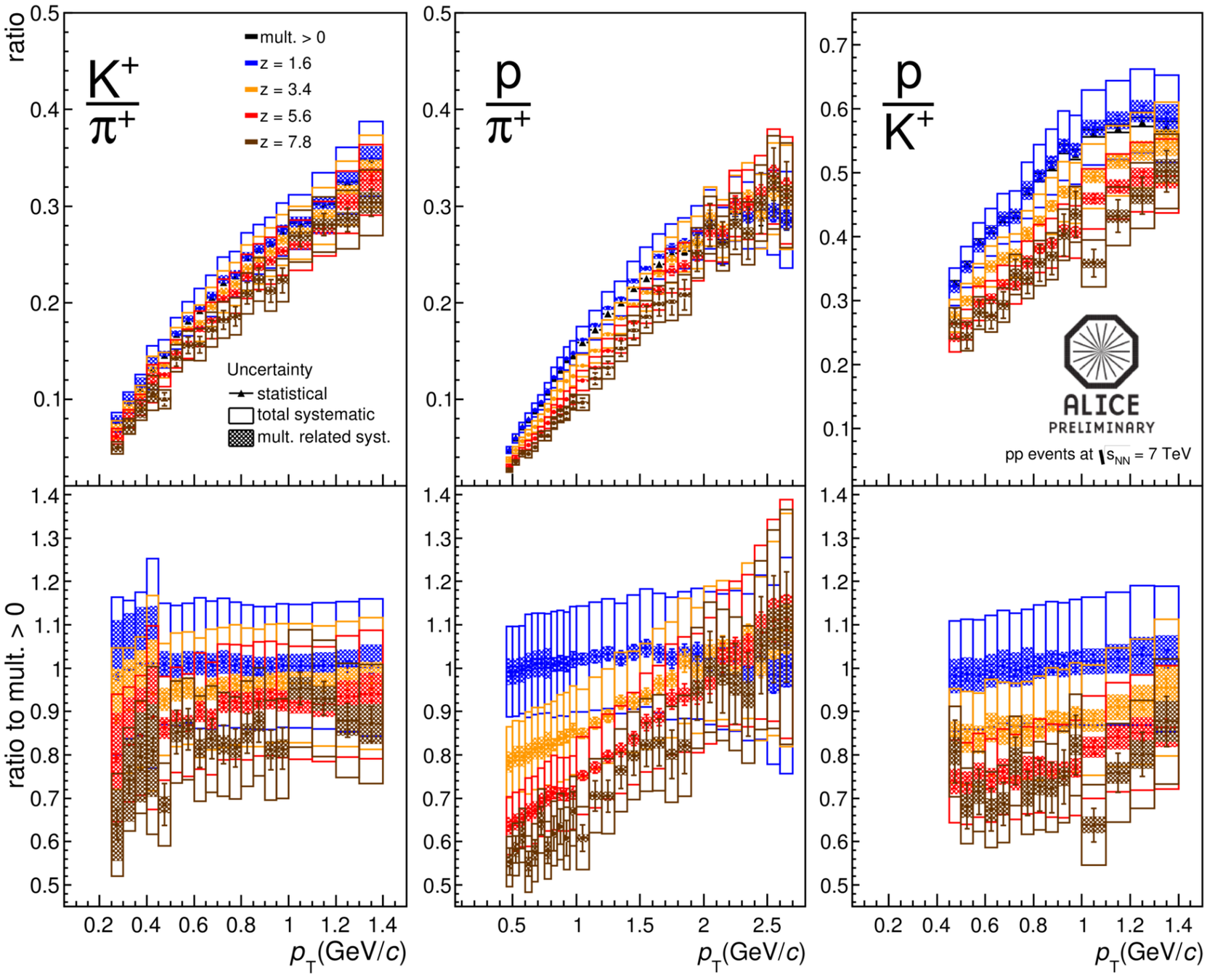
TABLE I. $dN_{ch}/d\eta$ and $(dN_{ch}/d\eta)/(\langle N_{part}\rangle/2)$ values measured in $|\eta| < 0.5$ for nine centrality classes. The $\langle N_{part}\rangle$ obtained with the Glauber model are given.

Centrality	$dN_{ch}/d\eta$	$\langle N_{part}\rangle$	$(dN_{ch}/d\eta)/(\langle N_{part}\rangle/2)$
0%–5%	1601 ± 60	382.8 ± 3.1	8.4 ± 0.3
5%–10%	1294 ± 49	329.7 ± 4.6	7.9 ± 0.3
10%–20%	966 ± 37	260.5 ± 4.4	7.4 ± 0.3
20%–30%	649 ± 23	186.4 ± 3.9	7.0 ± 0.3
30%–40%	426 ± 15	128.9 ± 3.3	6.6 ± 0.3
40%–50%	261 ± 9	85.0 ± 2.6	6.1 ± 0.3
50%–60%	149 ± 6	52.8 ± 2.0	5.7 ± 0.3
60%–70%	76 ± 4	30.0 ± 1.3	5.1 ± 0.3
70%–80%	35 ± 2	15.8 ± 0.6	4.4 ± 0.4

Phys.Rev.Lett. 106, 032301

pp 7 TeV

Yield ratios as a function of p_T - multiplicity dependence



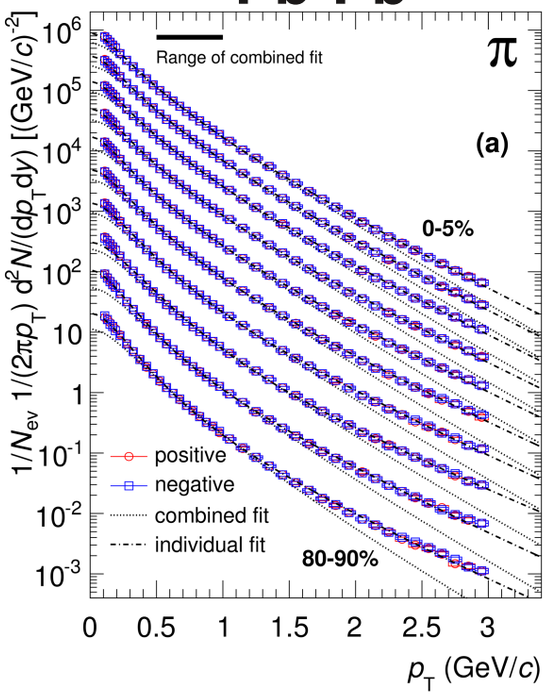
ALI-PREL-51119

- larger boost for heavier particles and high multiplicity

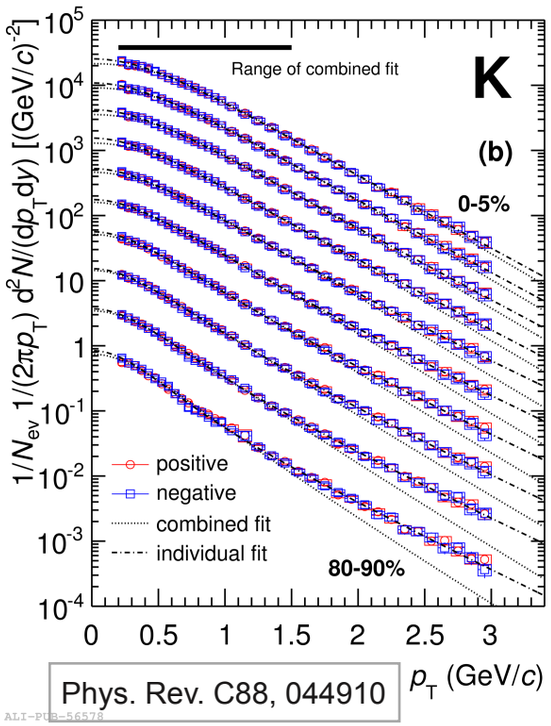
pp, p-Pb, Pb-Pb comparison

Invariant p_T distributions

Pb-Pb



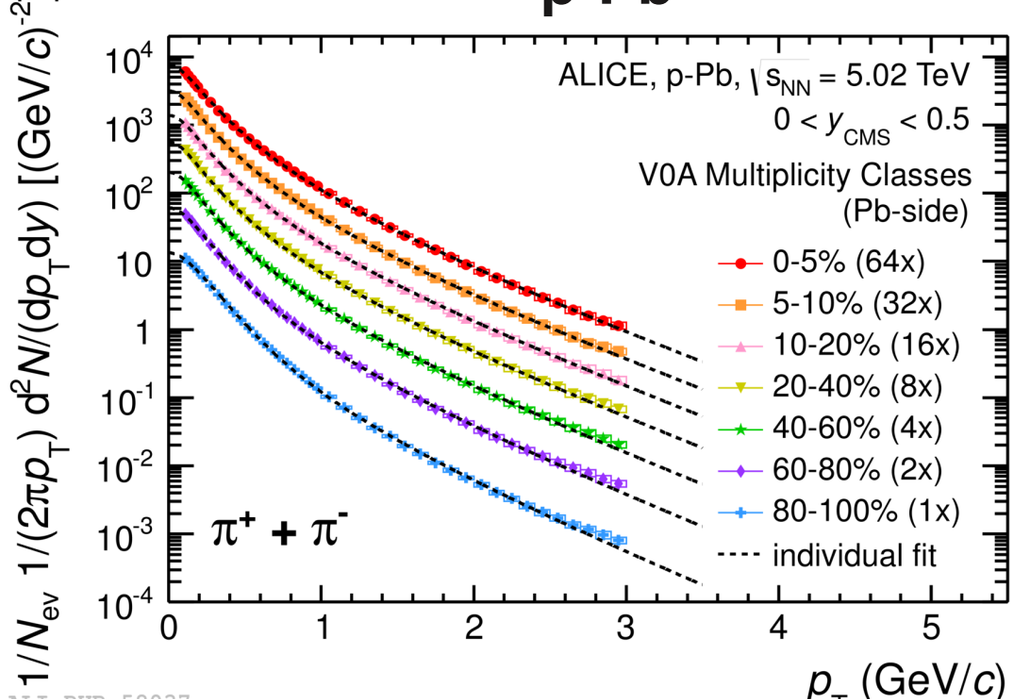
ALI-PUB-56574



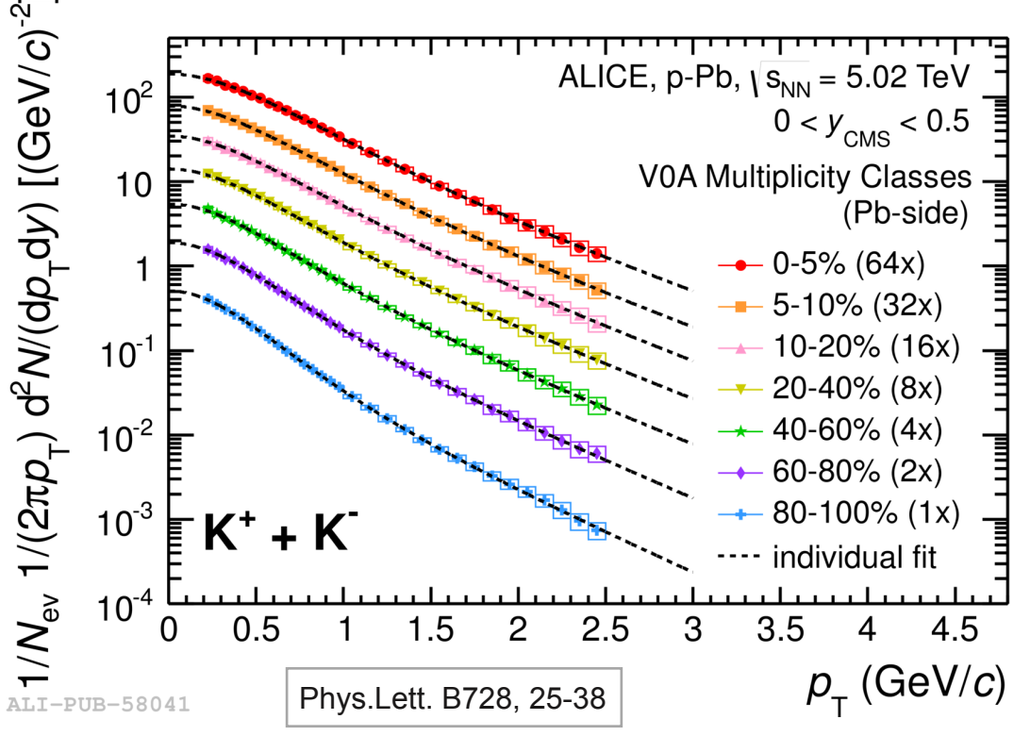
Phys. Rev. C88, 044910

ALI-PUB-56578

p-Pb



ALI-PUB-58037

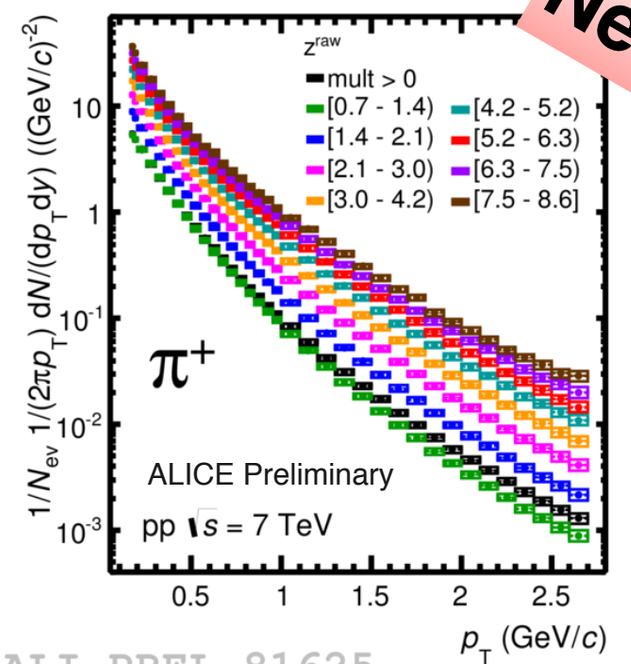


Phys.Lett. B728, 25-38

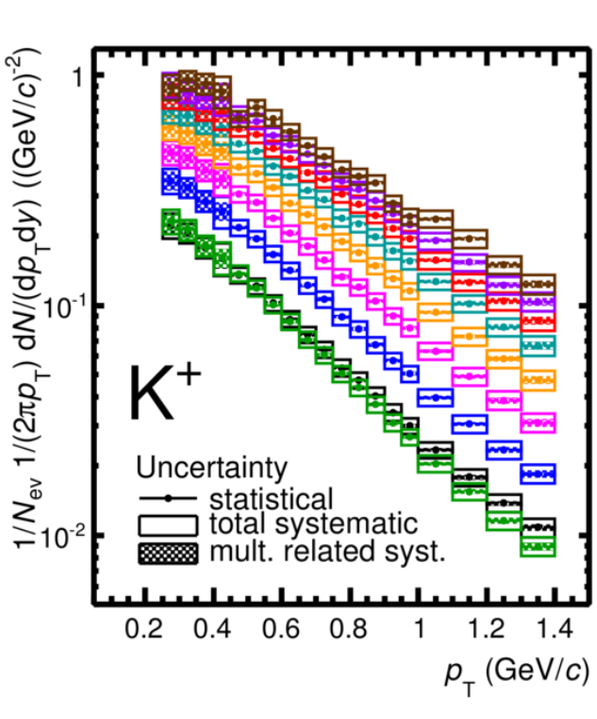
ALI-PUB-58041

pp

New

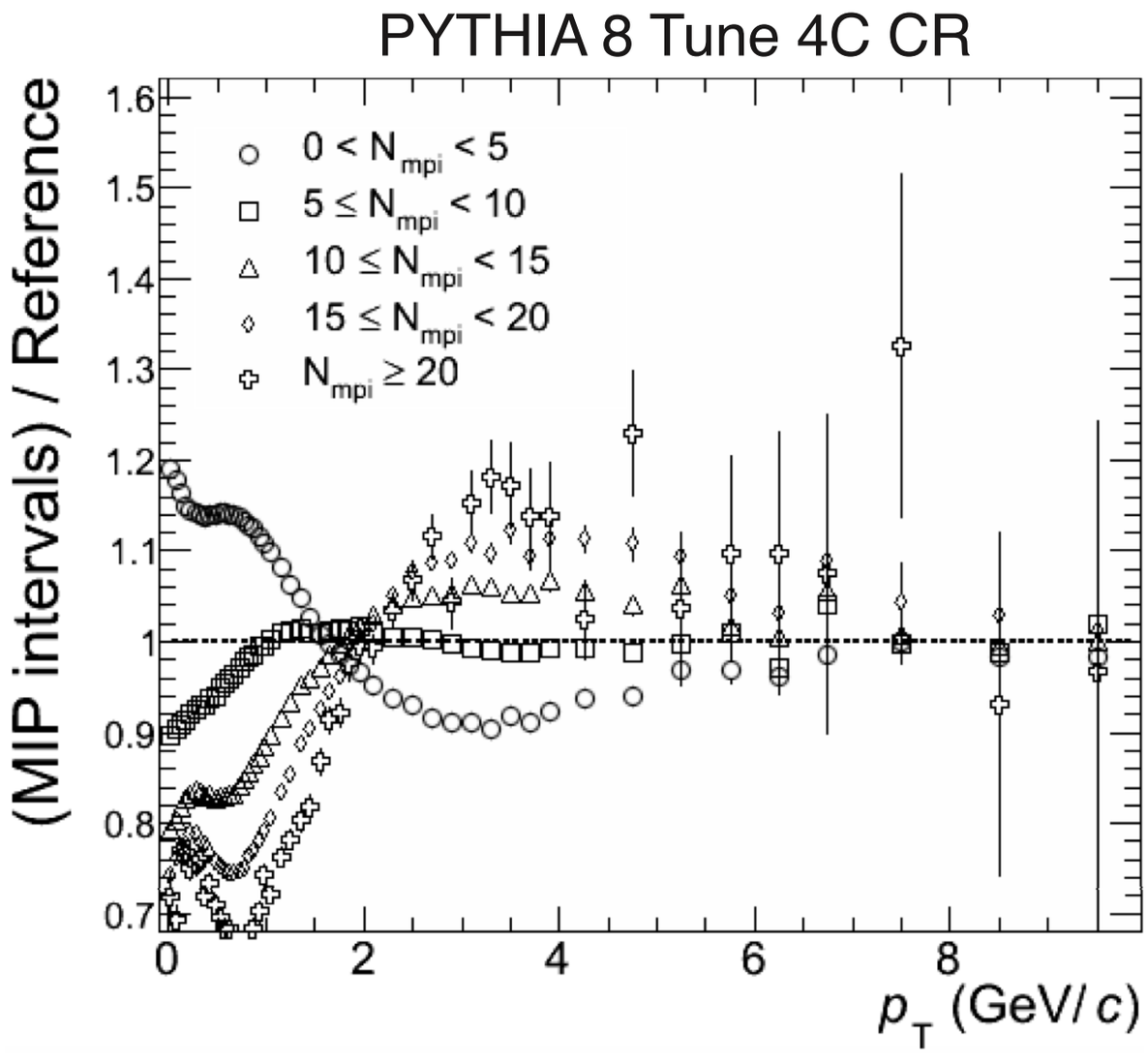


ALI-PREL-81625



- a similar change in the shape of the distributions in the low p_T region, with increasing multiplicity is observed

pp 7 TeV
PYTHIA - evolution of p/π with N_{MIP}



A. O. Velasquez et al.
Int.Conf. Initial Stage of High Energy Nucl.Coll.
Galicia, Spain, 8-14 Sept. 2013