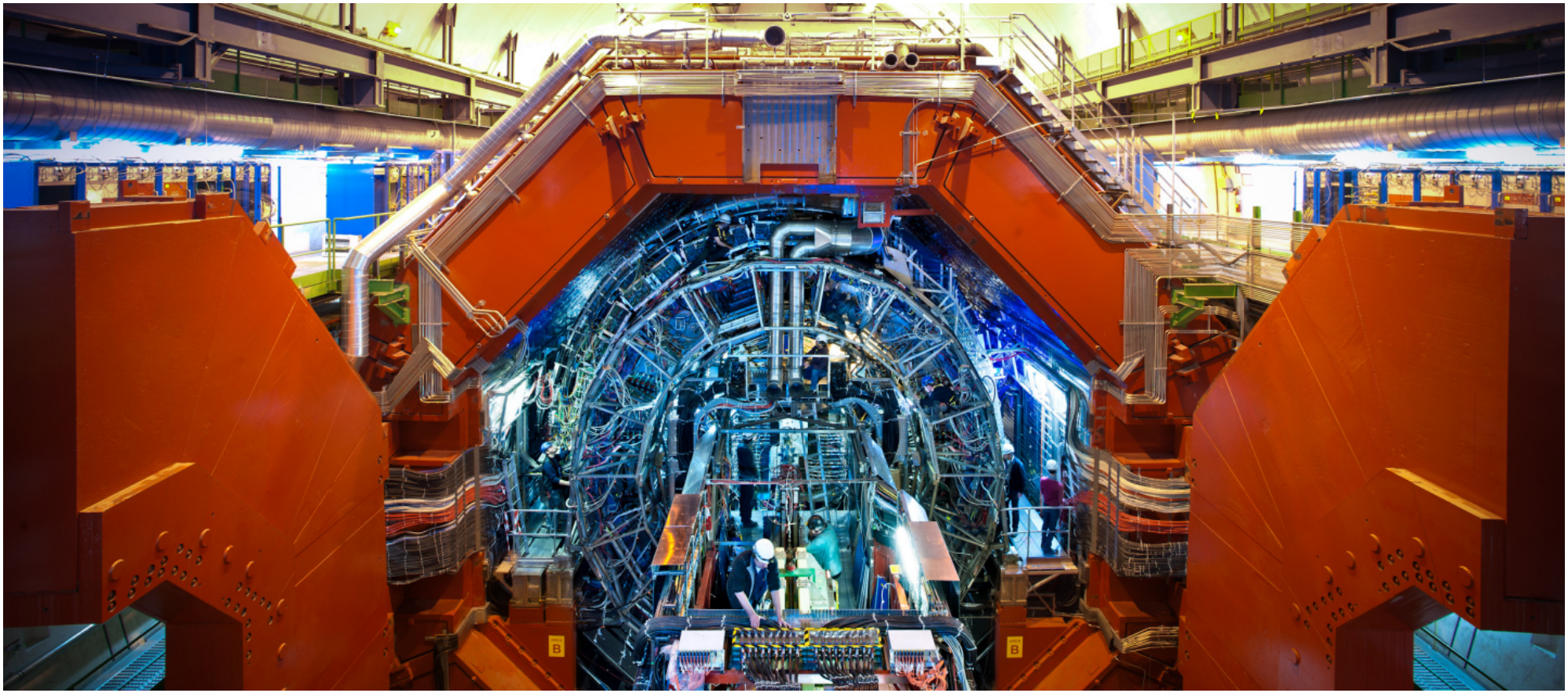


Multiplicity dependence of identified particle production in pp and p-Pb collisions measured with ALICE

Stefania Bufalino
Politecnico and INFN, Torino

8th International Workshop on Multiple Partonic Interactions at the LHC, Nov. 28th – Dec. 2nd , 2016

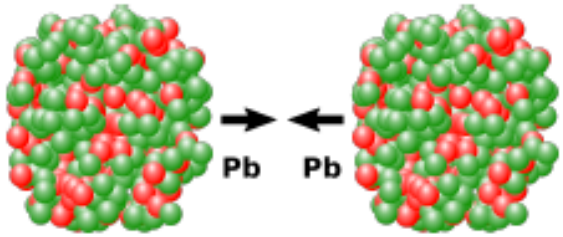
Outline

- Collision systems at the LHC
- Collectivity in small collision systems?
- The ALICE detector
  - PID techniques
  - Multiplicity estimation
- Results
  - Particle production in pp and p-Pb collisions
  - Radial flow
  - Blast Wave fits
  - Baryon-to-meson ratios
- Summary

Collision systems at the LHC

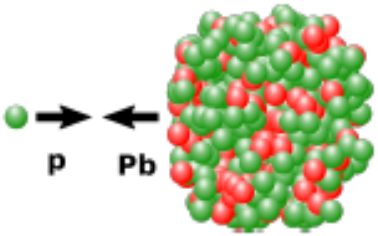
Study of hot and dense QCD matter

hydrodynamic evolution



Study of nuclear matter effects

intermediate system between the Pb-Pb and the pp



Reference for measurement in other systems

deconfinement not expected

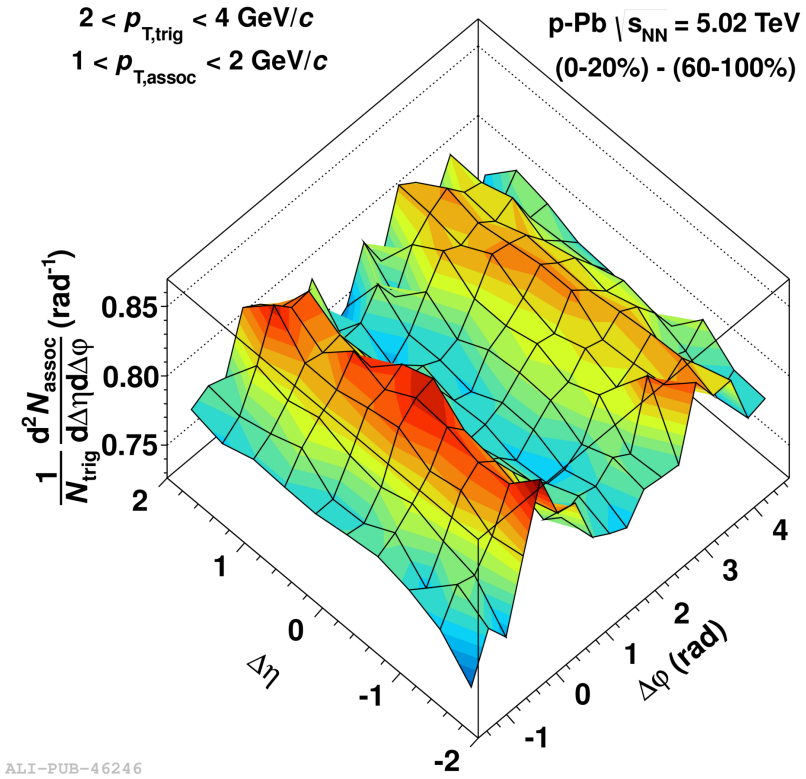
collectivity not expected

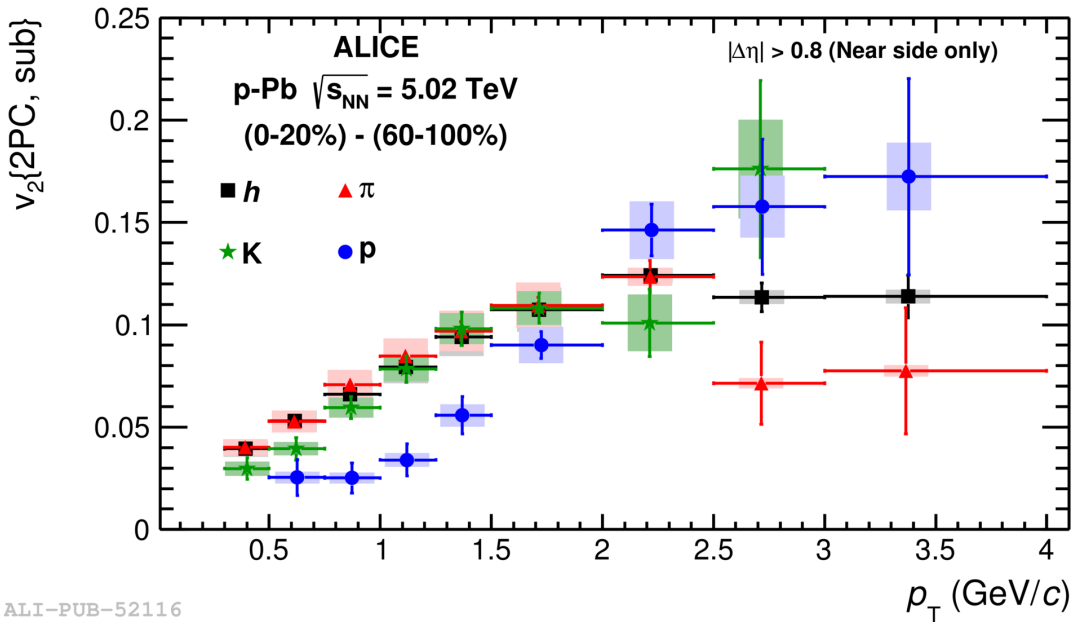
Collectivity in small systems?

So far, pp and p-A collisions were playing the role of control experiments

- disentangle the so-called cold nuclear matter effects from those attributed to the hot and dense QCD medium (sQGP) produced in central heavy-ion collisions

Striking findings in high multiplicity p-Pb events

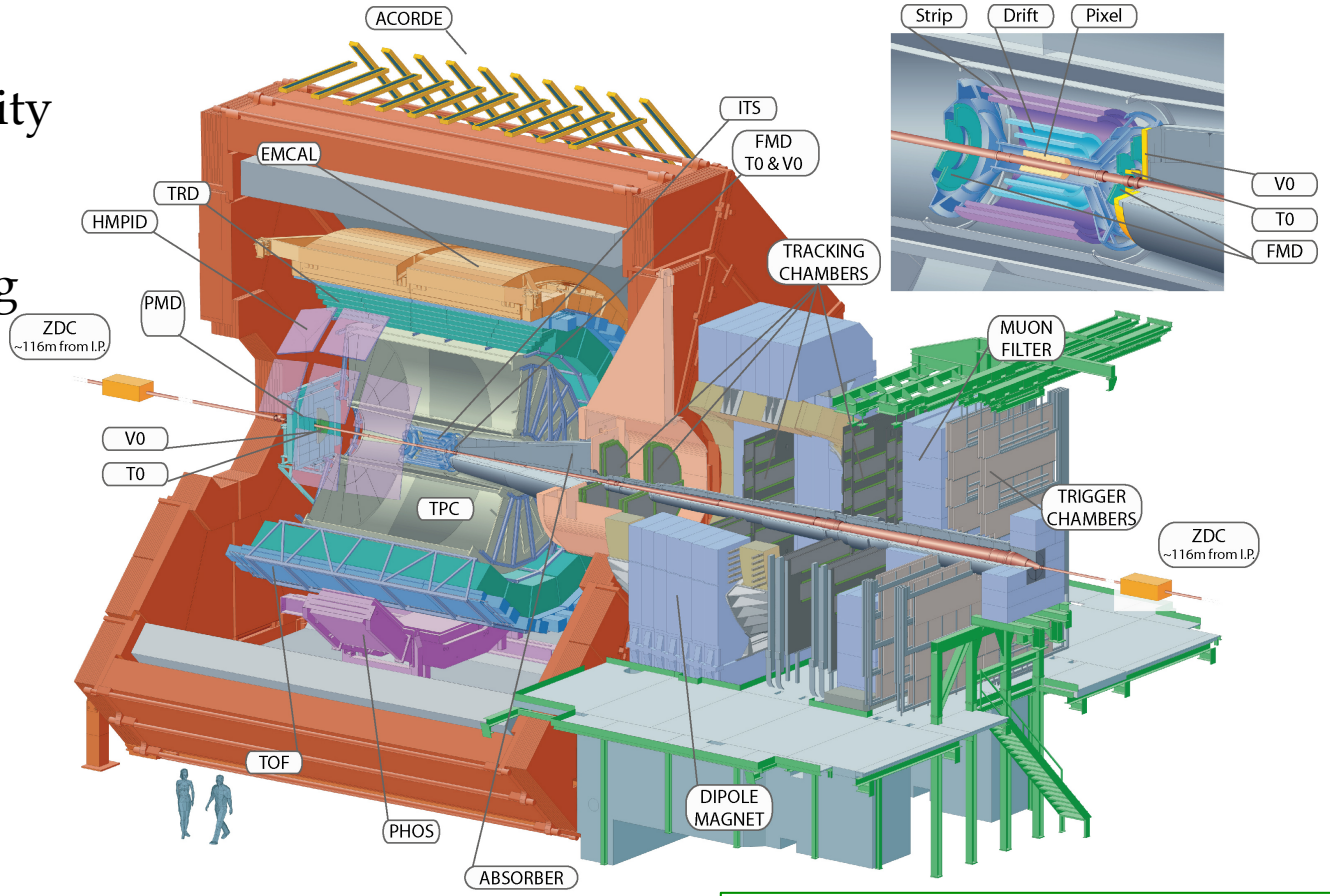




ALICE, PLB 719 (2013) 29-41
CMS, PLB 718 (2013) 795
ALICE, PLB 726 (2013) 164-177
ALICE, PLB 728 (2014) 25-38

The ALICE apparatus

- Moderate magnetic field (B = 0.5 T) in the midrapidity region
- Low momentum tracking down to $p_T \approx 100$ MeV/c
- High granularity to cope with the high occupancy
- Extensive Particle IDentification (PID) capabilities



More information:
ALICE, IJMPA 29, (2014) 1430044

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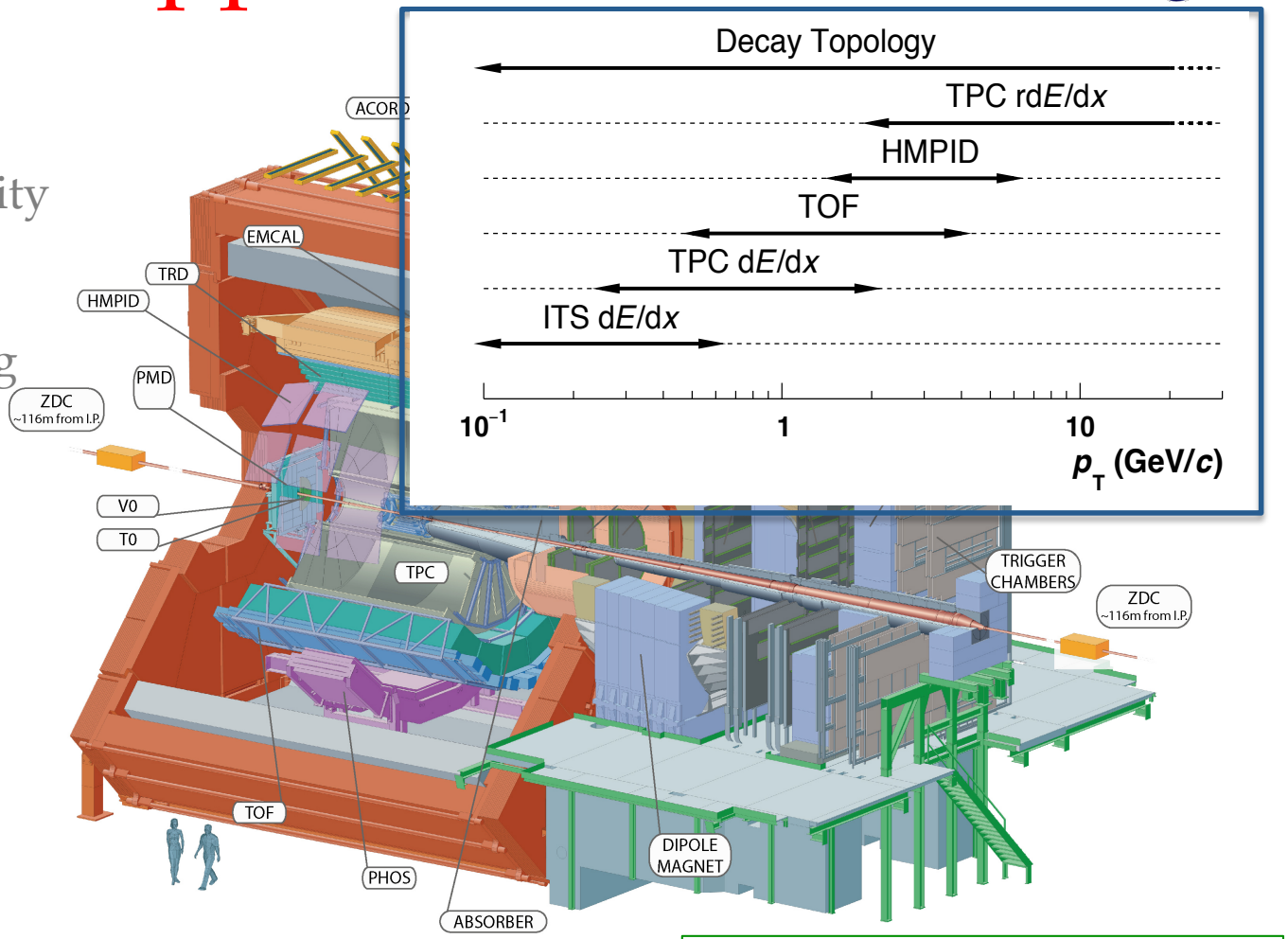
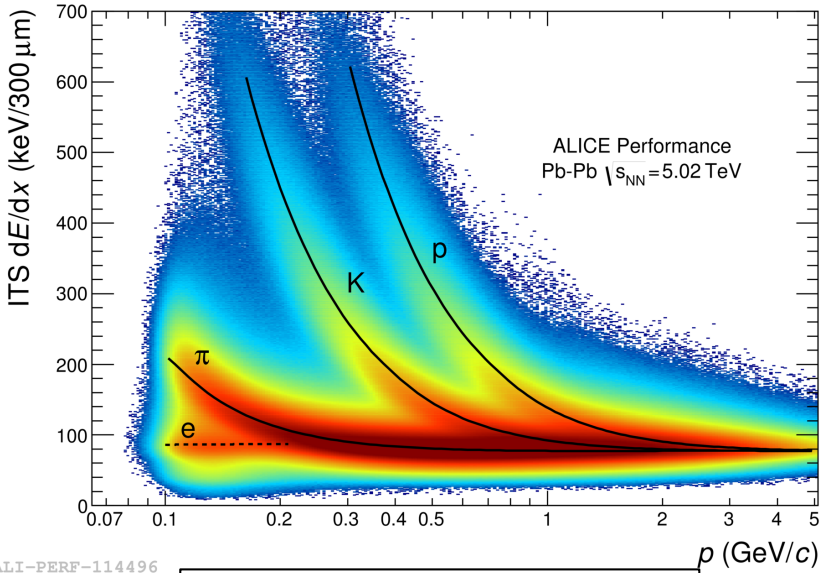


Central barrel:
2π tracking and PID
|η|<1, B = 0.5 T
(HMPID RICH: |η|<0.6, Δφ=57°)

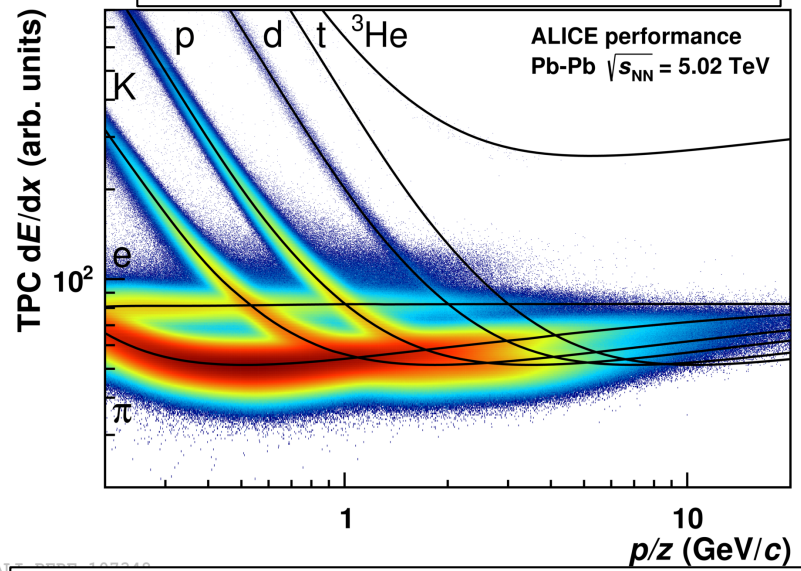
More information:
ALICE, IJMPA 29, (2014) 1430044

Particle identification

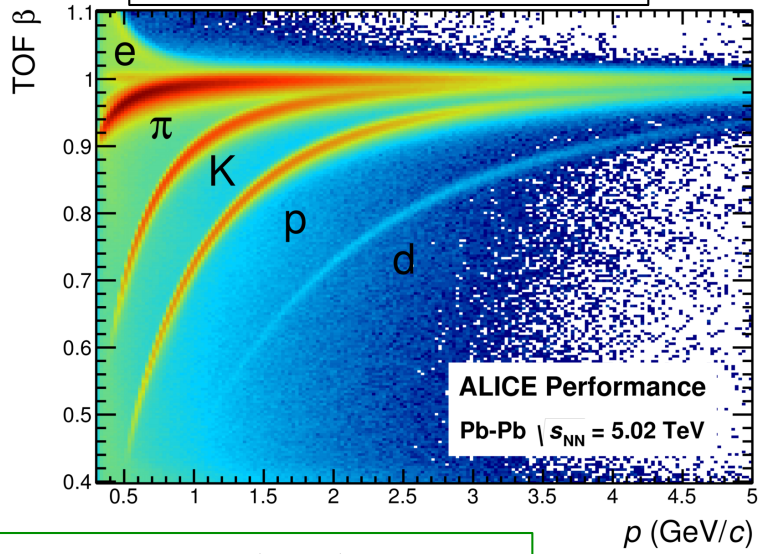
Inner Tracking System



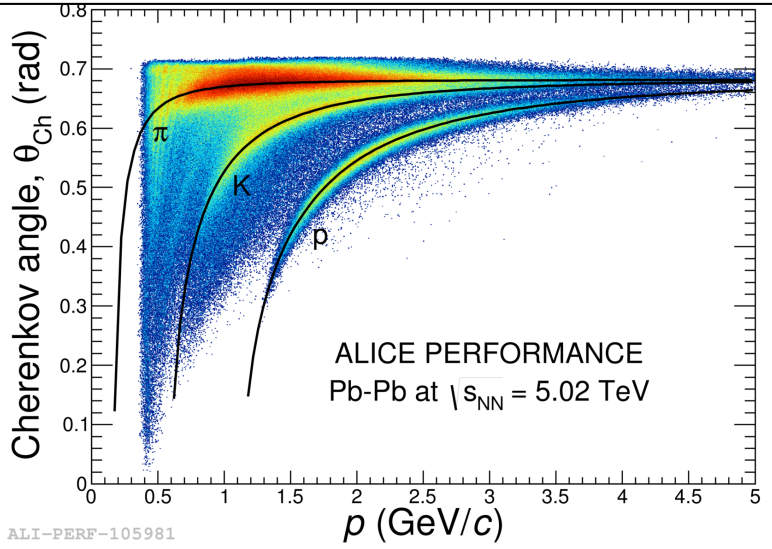
Time Projection Chamber



Time Of Flight



High Momentum Particle Identification



ALICE, IJMPA 29, (2014) 1430044

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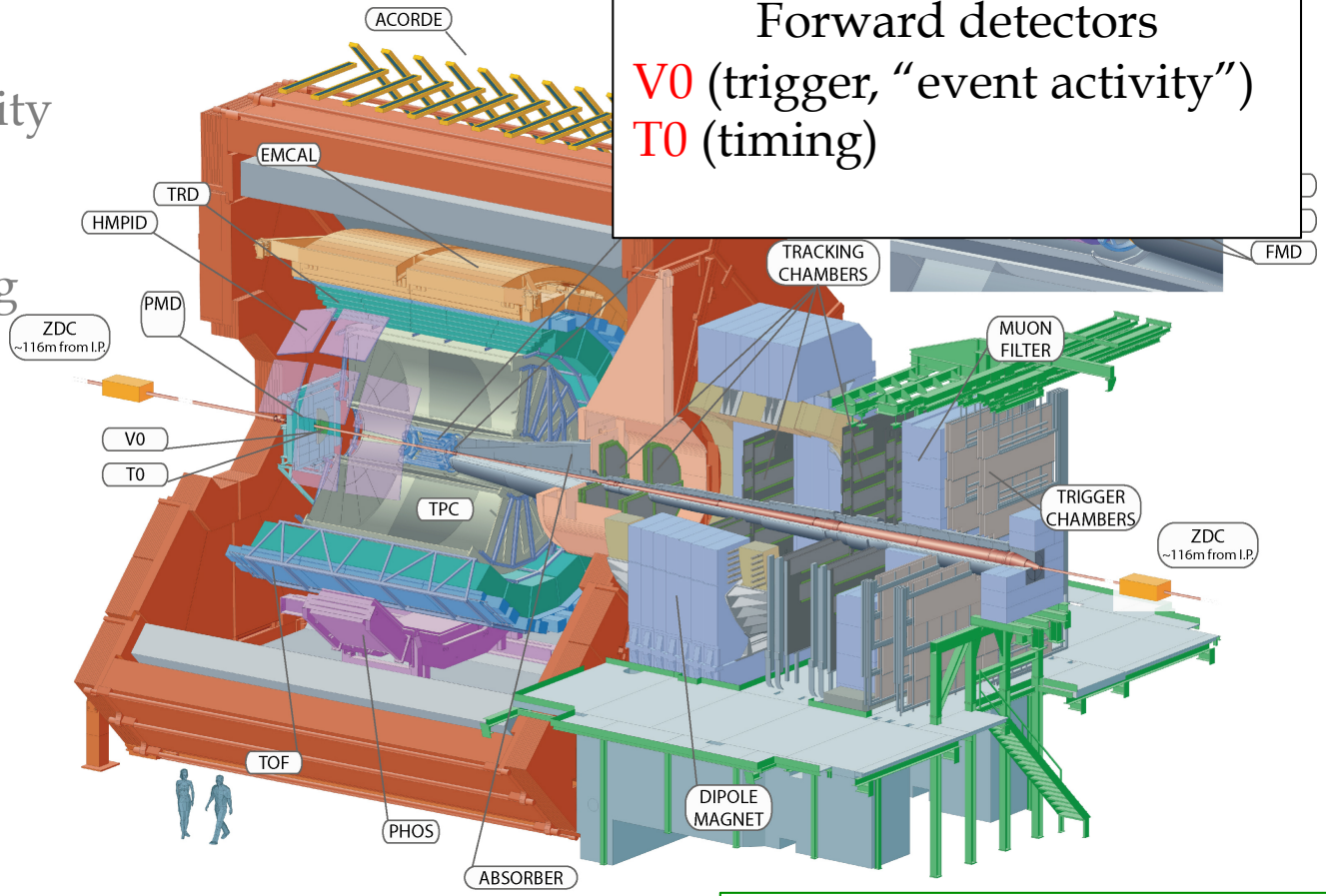
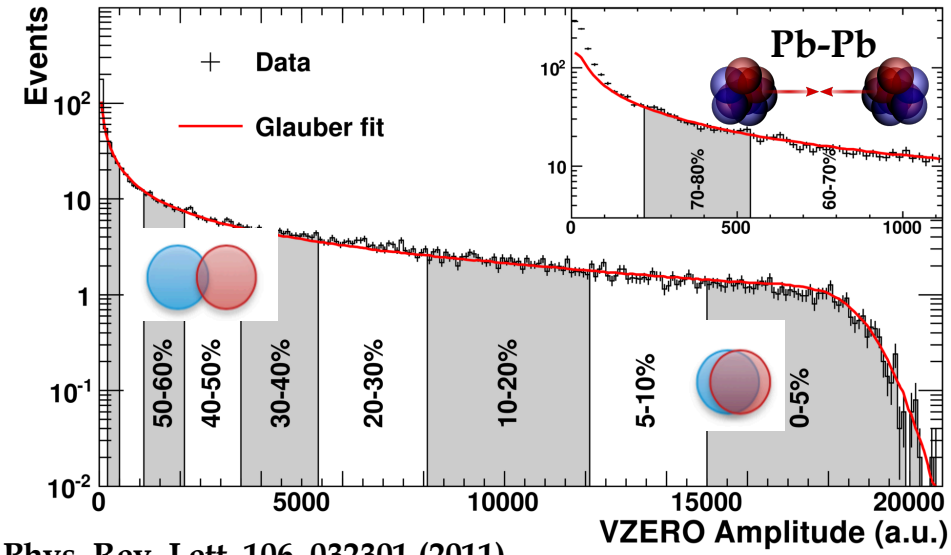


Forward detectors
V0 (trigger, "event activity")
T0 (timing)

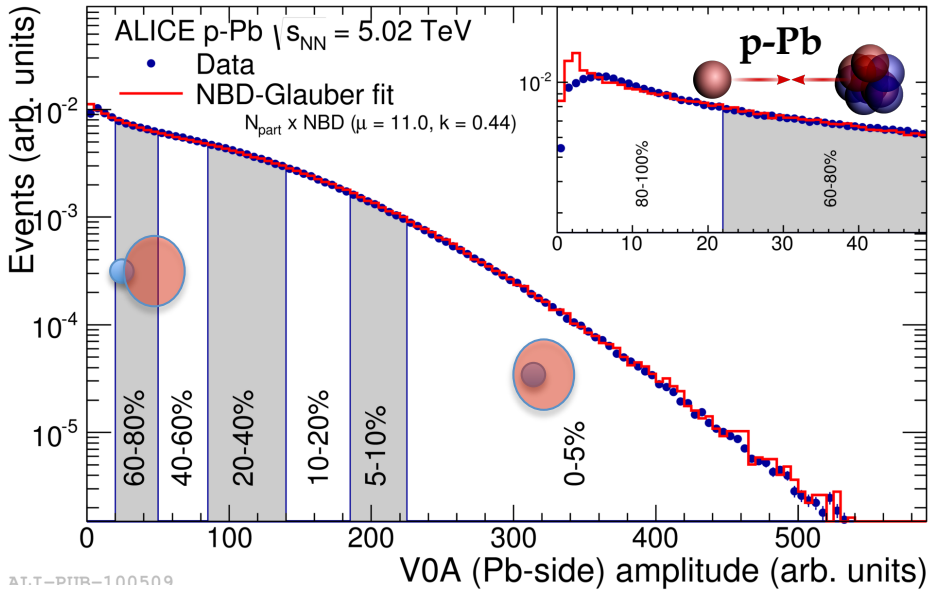
V0A detector:
2.8 < η < 5.1, positioned in the Pb-going direction

More information:
ALICE, IJMPA 29, (2014) 1430044

Multiplicity estimation



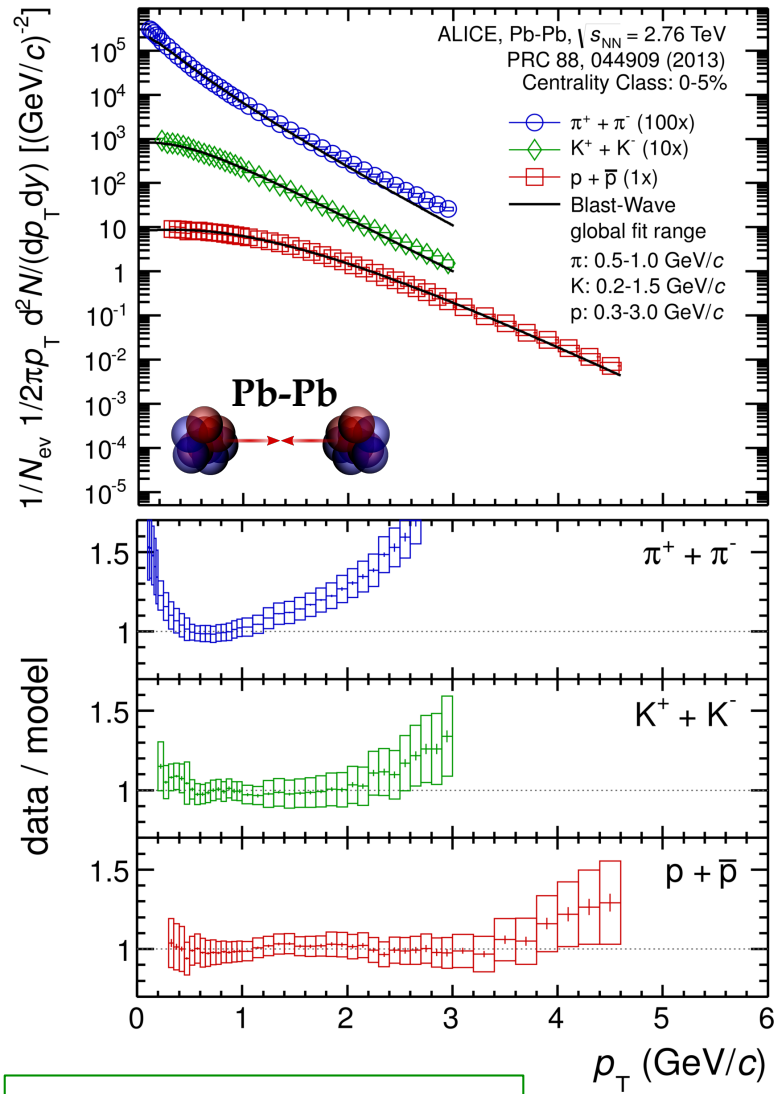
Phys. Rev. Lett. 106, 032301 (2011)



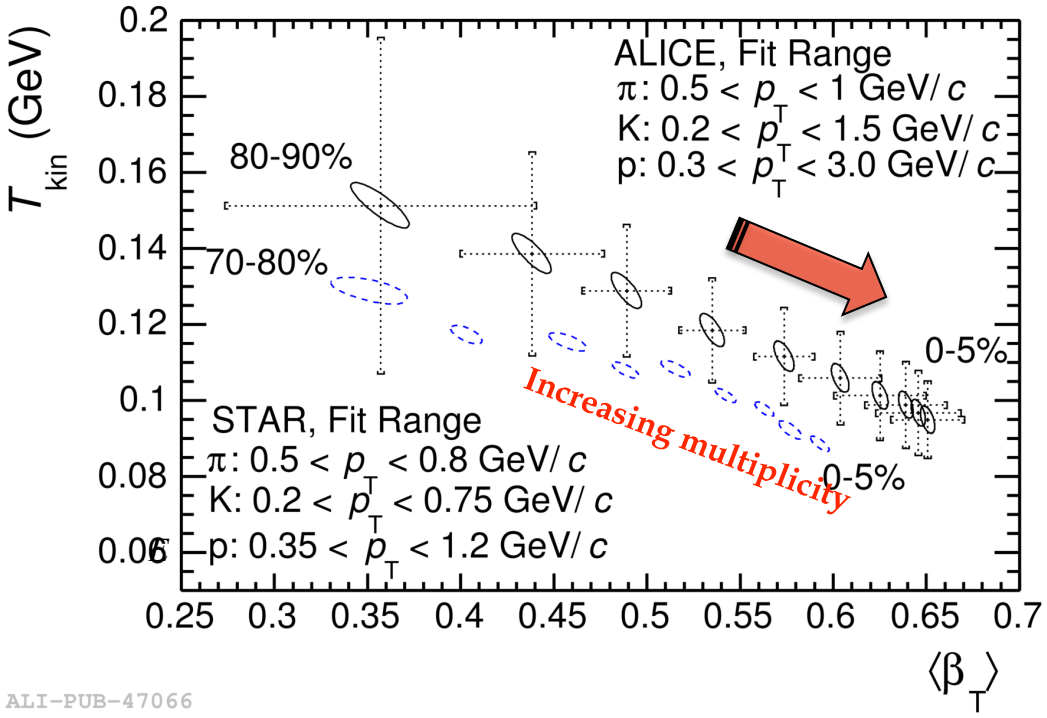
Phys. Rev. C 91 (2015) 064905

- Multiplicity is defined as the number of charged particles per event
- Linked through the impact parameter to the collision centrality in Pb–Pb
- ALICE measures the event activity at forward rapidity with the V0 detector
- Wide range of measured multiplicities
  - from $\langle dN_{ch}/d\eta \rangle \approx 2$ in pp
  - to $\langle dN_{ch}/d\eta \rangle \approx 1600$ in central Pb–Pb

Spectra evolution in Pb-Pb



Phys. Rev. C 88, (2013) 044910



ALI-PUB-47066

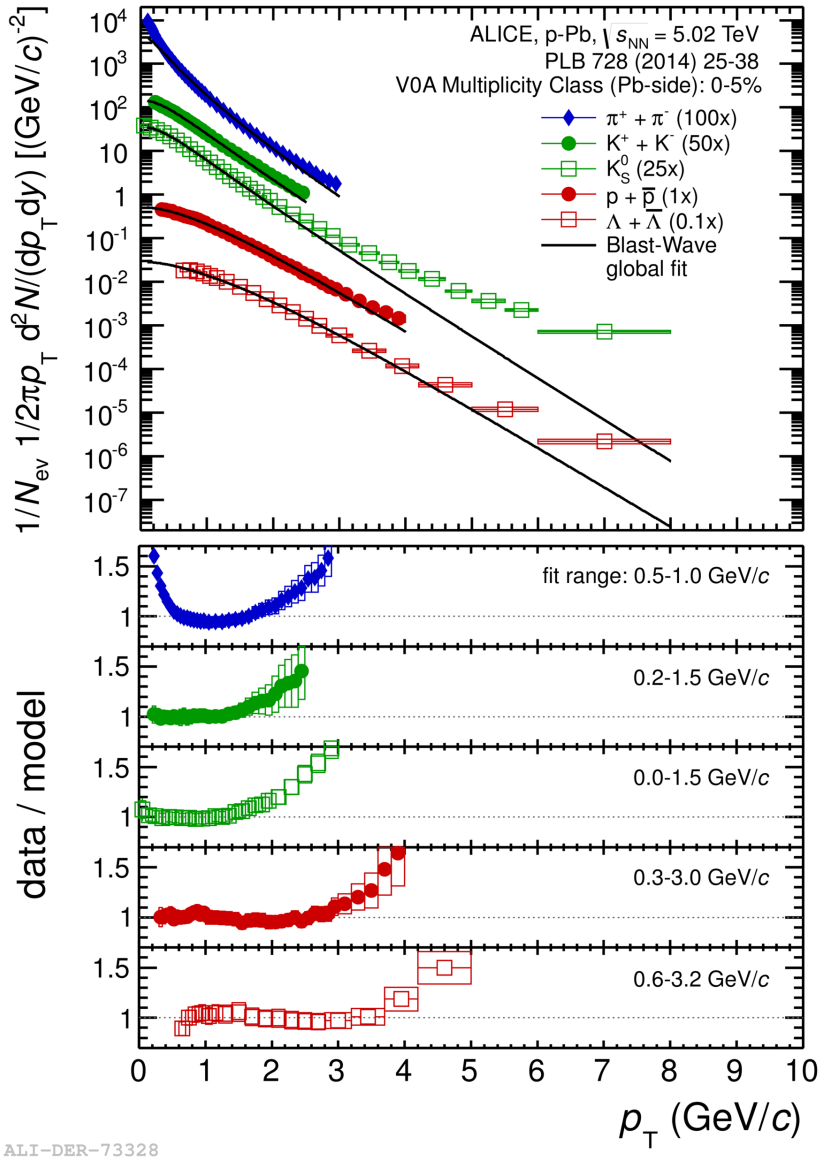
- Mass dependence of the spectral shape
  - **radial flow**
- Blast Wave
  - **simplified hydrodynamic model**
- Well described spectral evolution

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

Schnedermann, Sollfrank and Heinz Phys. Rev. C 48, 2462

Spectra evolution in p-Pb

V0A Multiplicity Class: 0-5%



The Blast-wave model is compared to the p_T distributions:

- parameters obtained from the simultaneous fit to π, K, p and Λ
- combined BW fit describes the spectra fairly well also in p-Pb

Common kinetic freeze-out describes the spectra in high multiplicity p-Pb collisions

In central heavy-ion collisions, the multistrange particles experience less transverse flow

PLB 728 (2014) 216-227
PRC 90 (2014) 054912

ALI-DER-73328

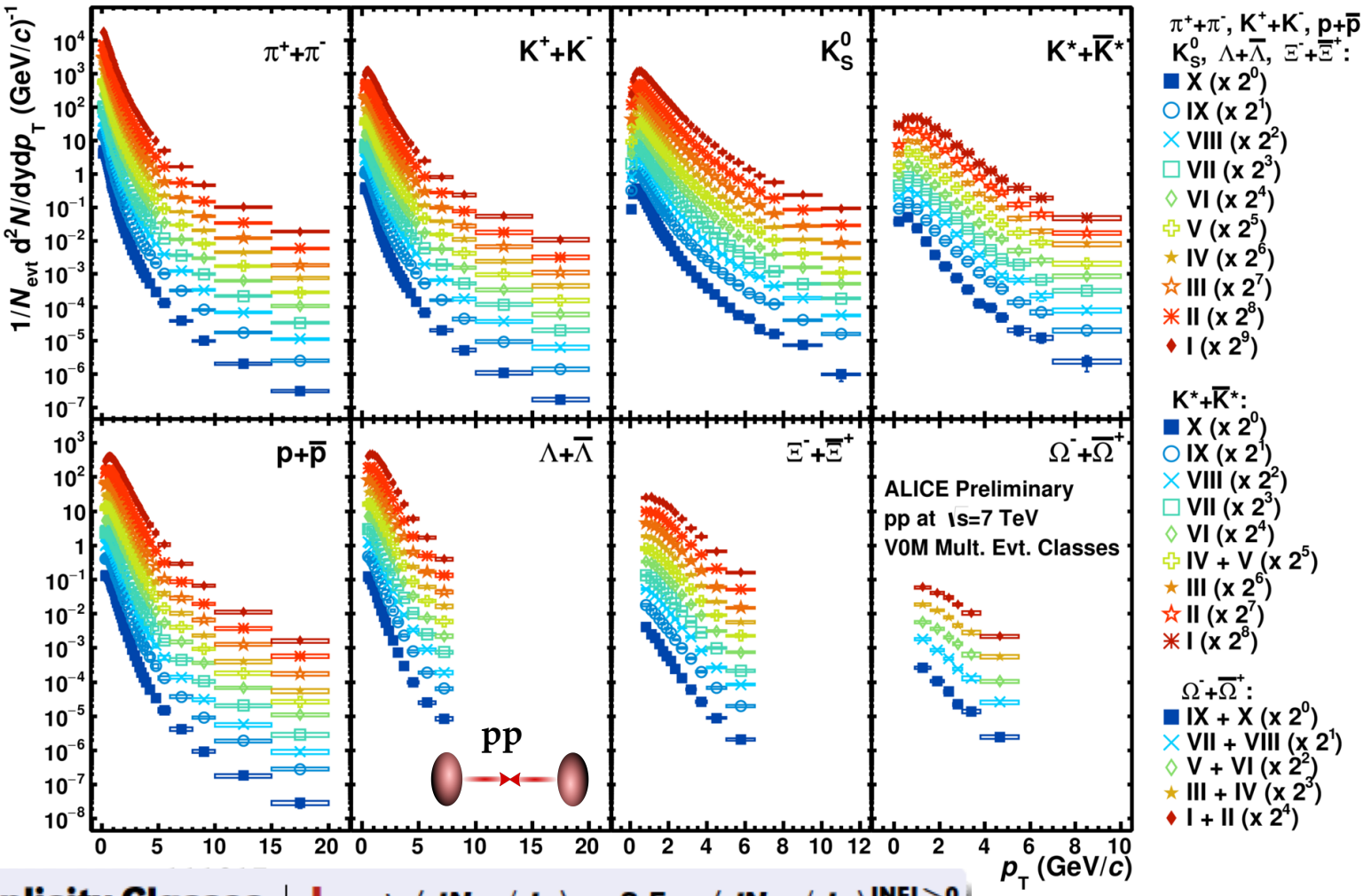
Spectra evolution in pp

Similarities to Pb-Pb results are observed:

multiplicity- and mass-dependent flattening of the p_T spectra at low p_T (< 2 GeV/c)

High multiplicity

Low multiplicity



V0M Multiplicity Classes

π K p K^0_s K^* Λ Ξ Ω

$\langle dN_{ch}/d\eta \rangle^{INEL>0} \sim 6.0$

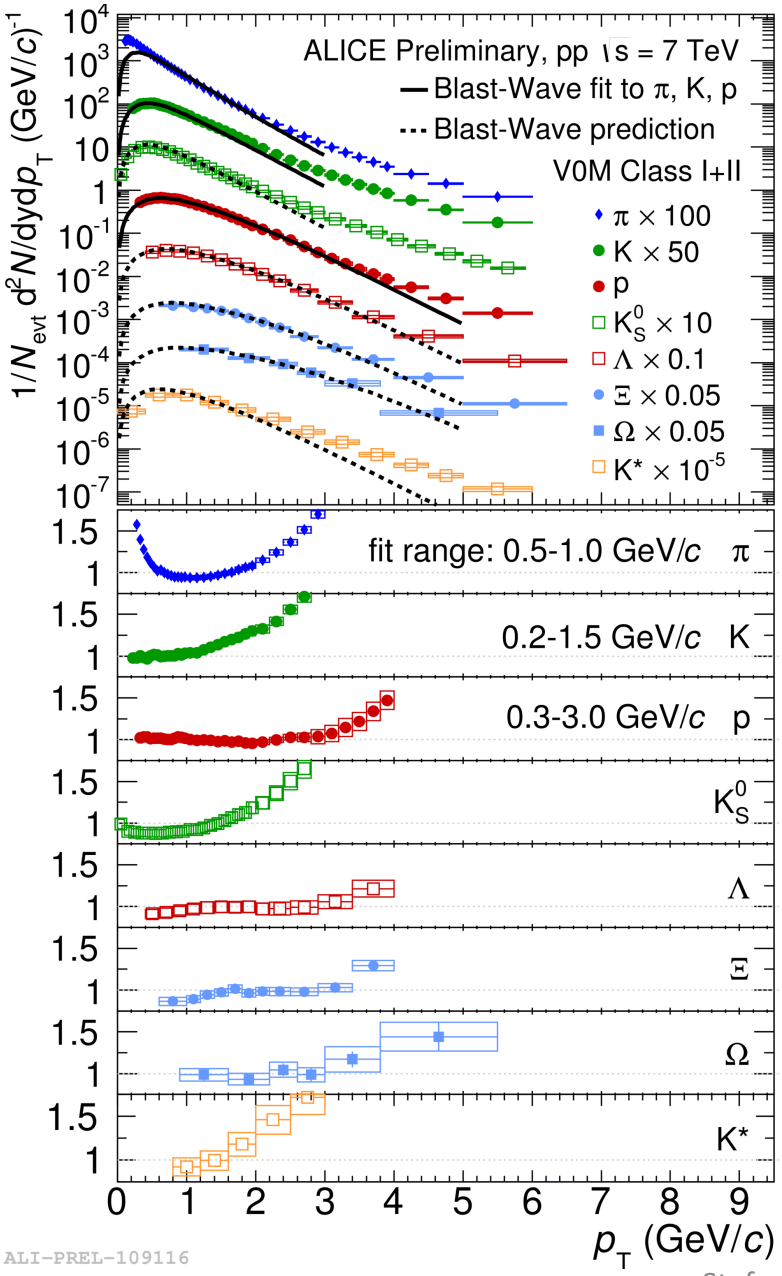
I $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 3.5 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$

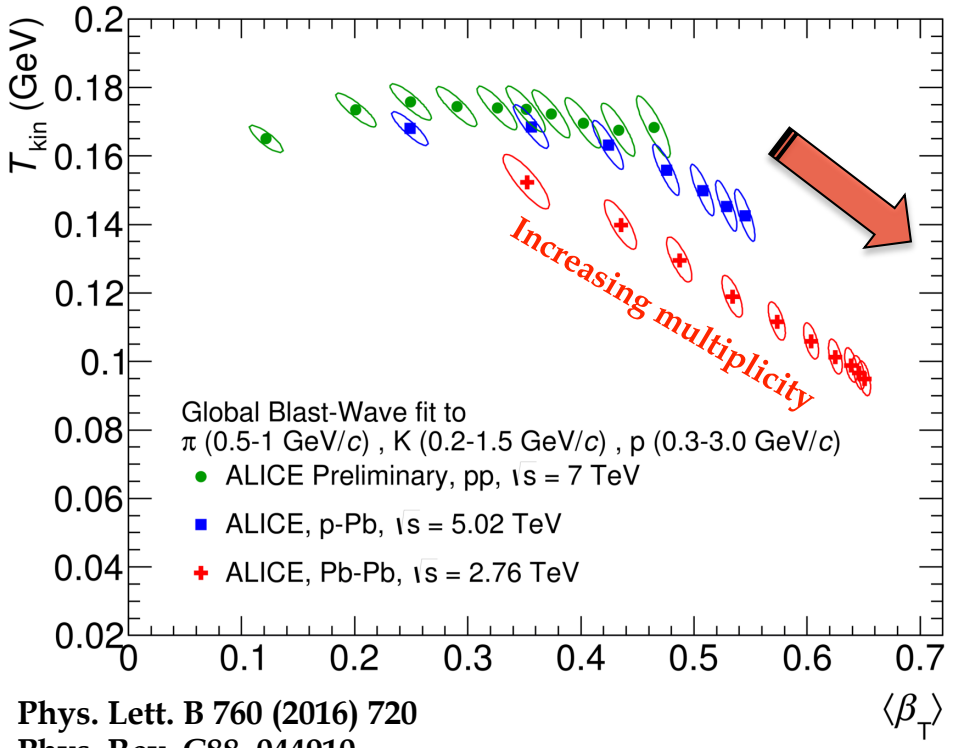
...

IX $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 0.7 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$

X $\rightarrow \langle dN_{ch}/d\eta \rangle \sim 0.4 \times \langle dN_{ch}/d\eta \rangle^{INEL>0}$

Blast Wave fit in pp





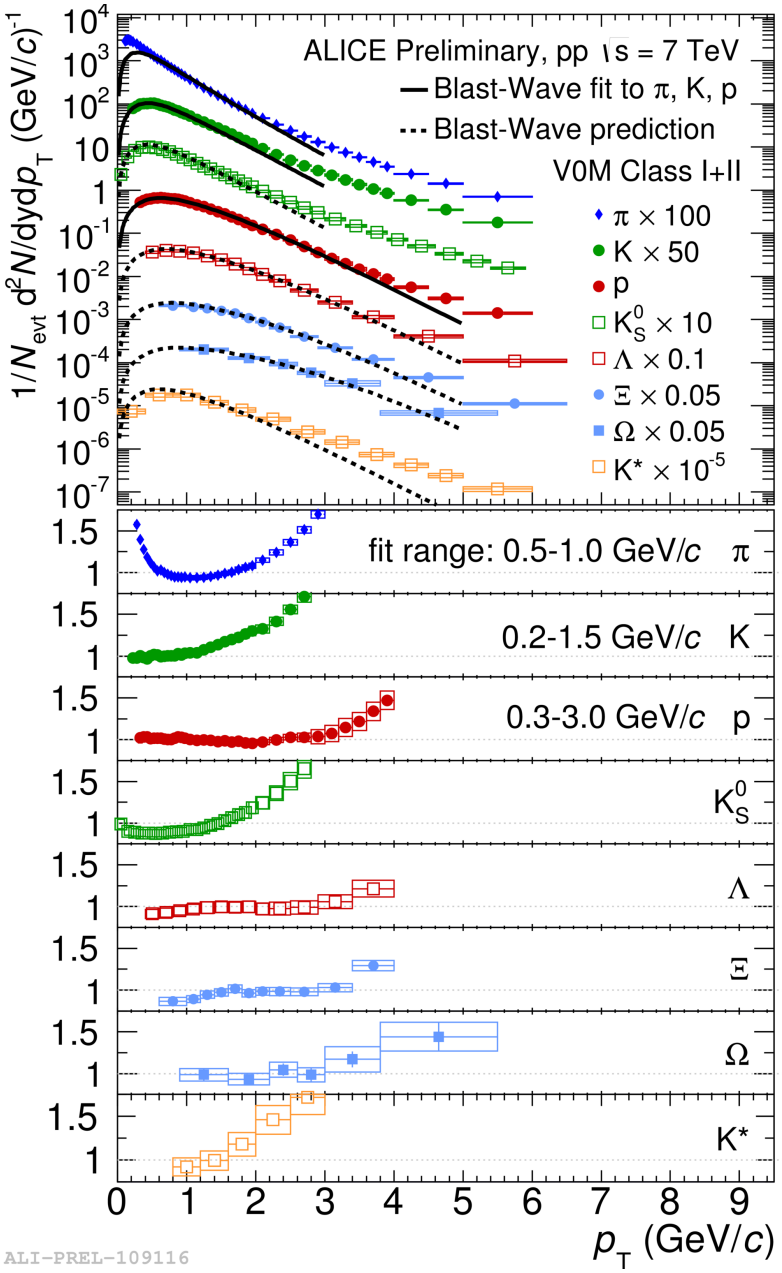
Phys. Lett. B 760 (2016) 720
Phys. Rev. C88, 044910

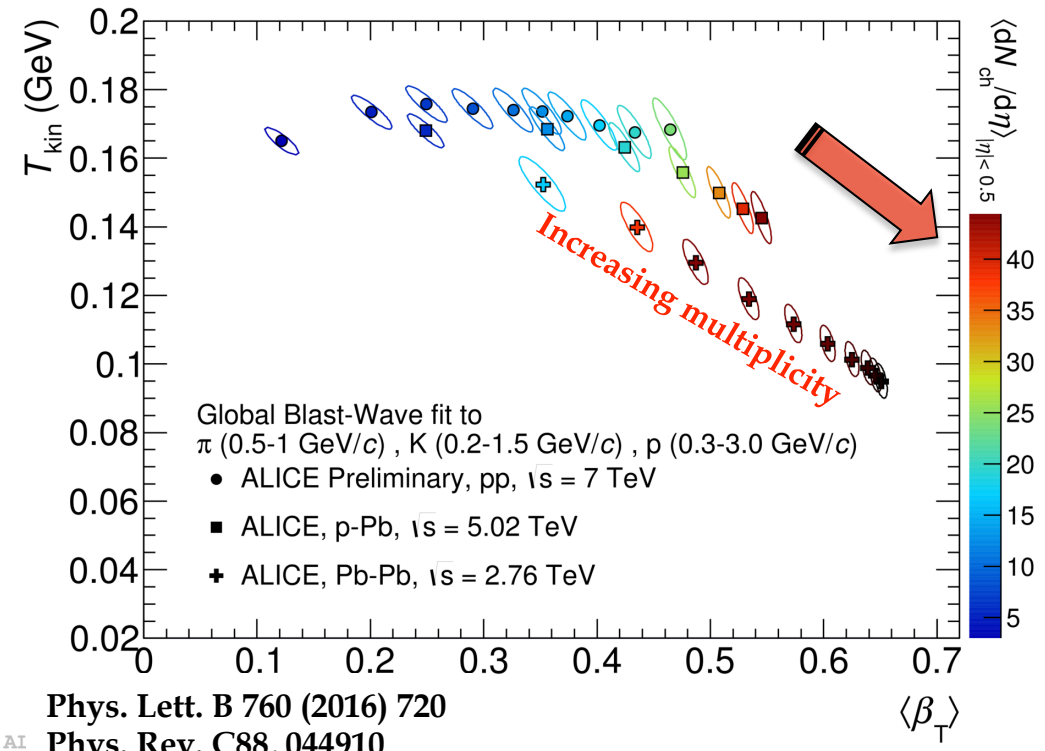
- V0M class I+II → highest multiplicity
- Simultaneous fit to the π, K and p spectra
- Hyperons follow the Blast Wave predicted with the π, K, p fit parameters

pp and p–Pb parameters follow the same trend

ALI-PREL-109116

Blast Wave fit in pp



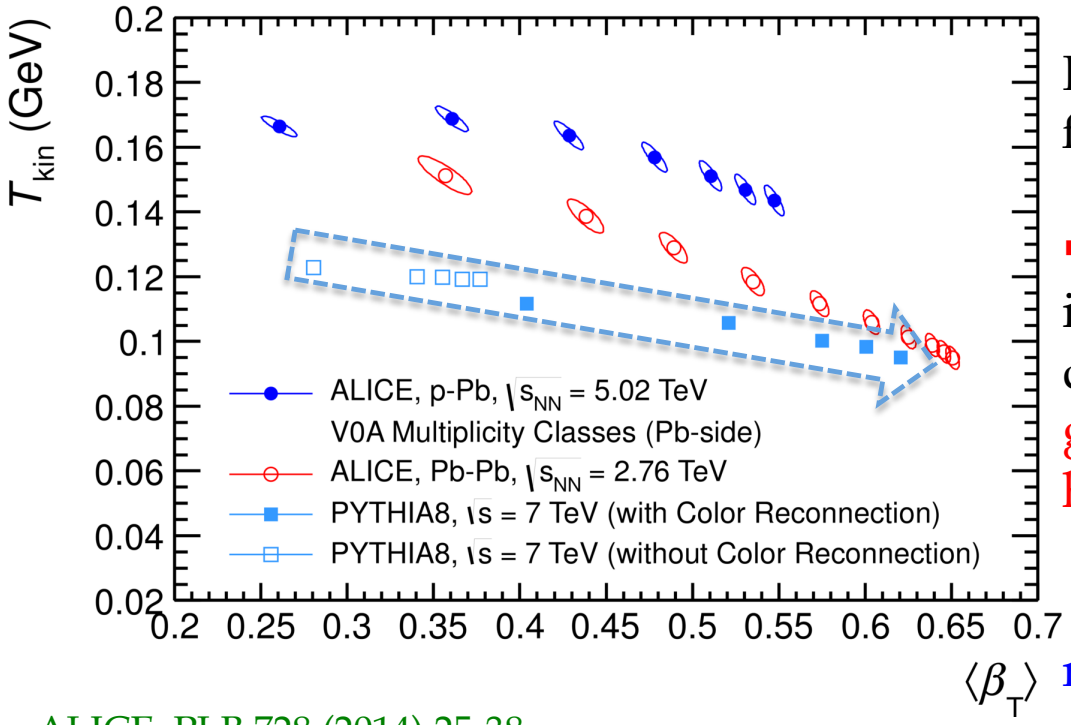


Phys. Lett. B 760 (2016) 720
Phys. Rev. C88, 044910

- Qualitatively similar behavior observed for pp, p-Pb and Pb-Pb collisions
- Larger radial flow parameter obtained in p-Pb than in Pb-Pb collisions for a similar multiplicity

Blast Wave fit results

Multiplicity evolution of the spectral shapes



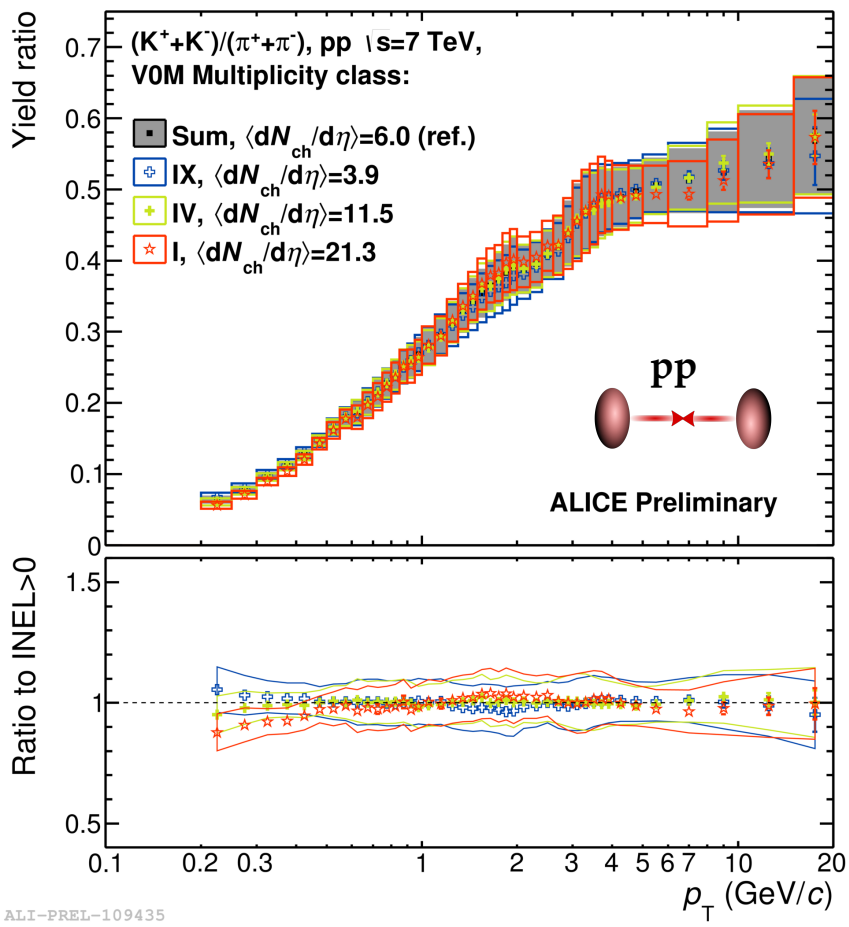
ALICE, PLB 728 (2014) 25-38

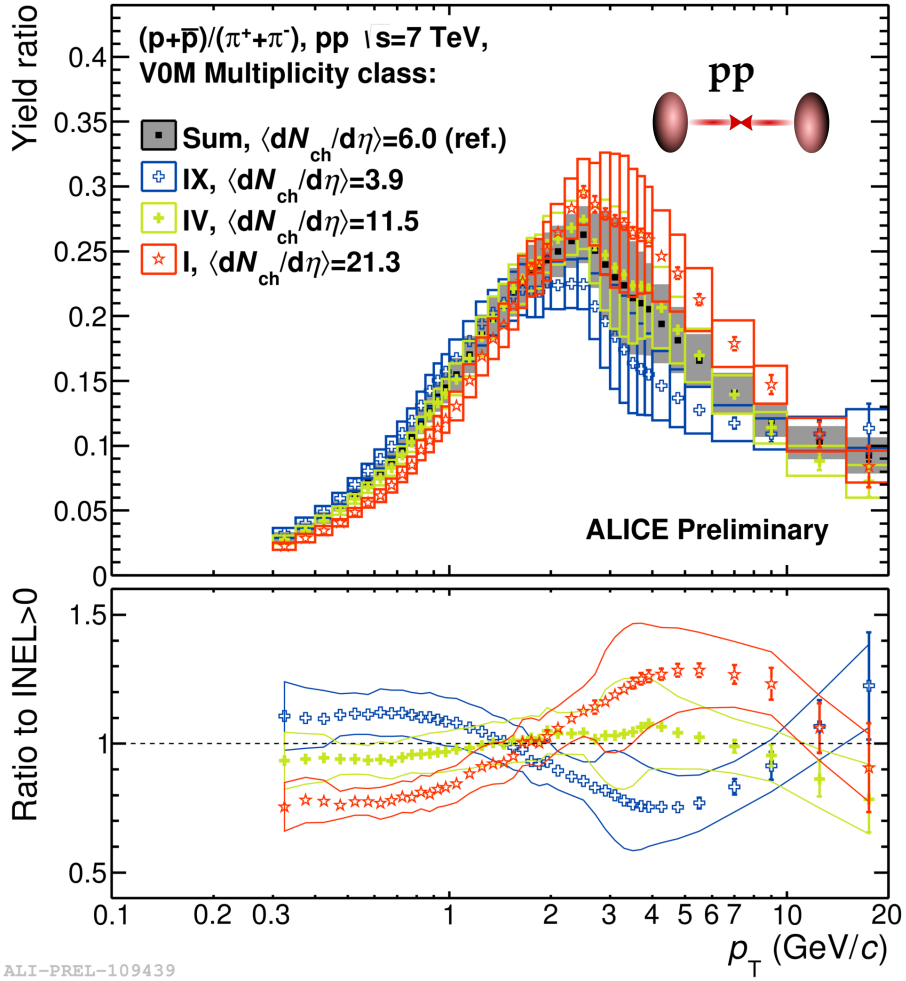
Results of the simultaneous Blast-Wave fit to π, K, p and Λ p_T spectra

- care needs to be taken with the interpretation because the model also describes the p_T spectra of pp events generated with Pythia 8, where no hydro expansion is assumed

→ other final state mechanisms can mimic the effects of radial flow!

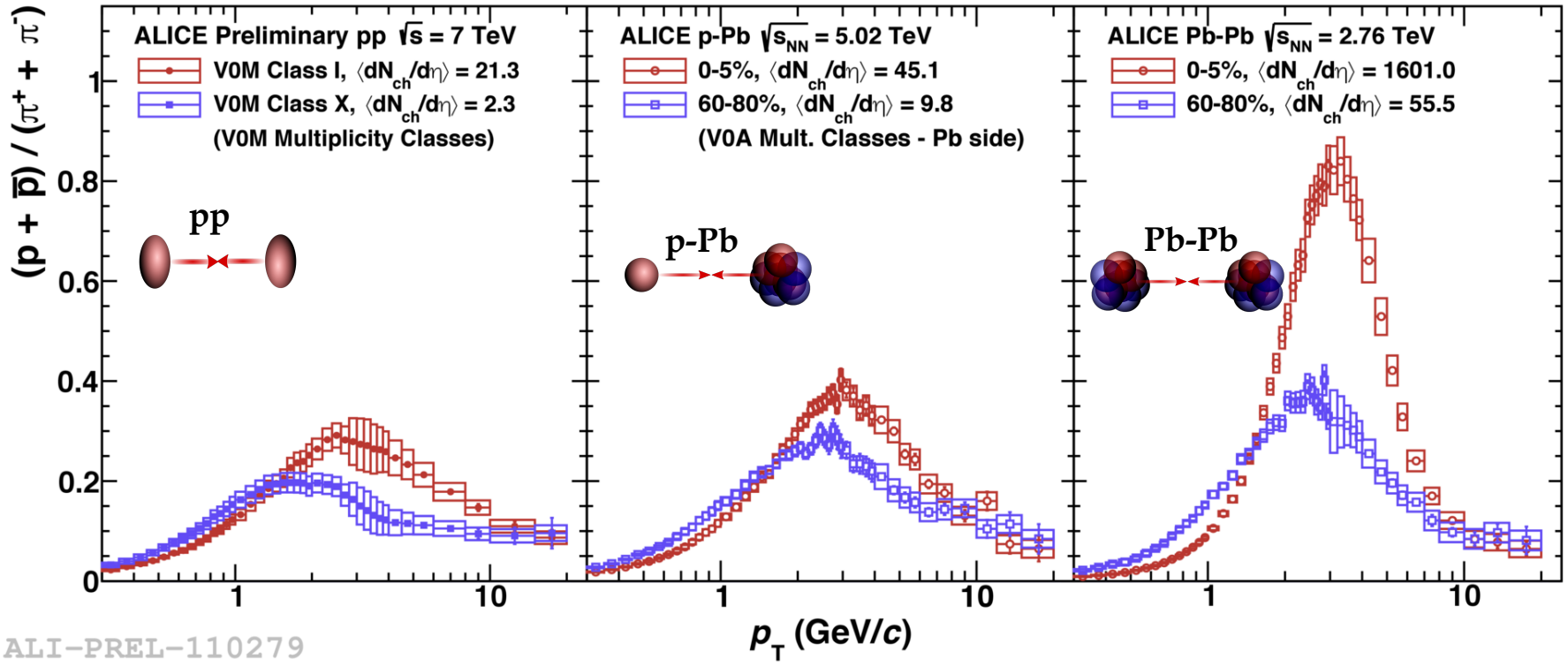
Baryon to meson ratio





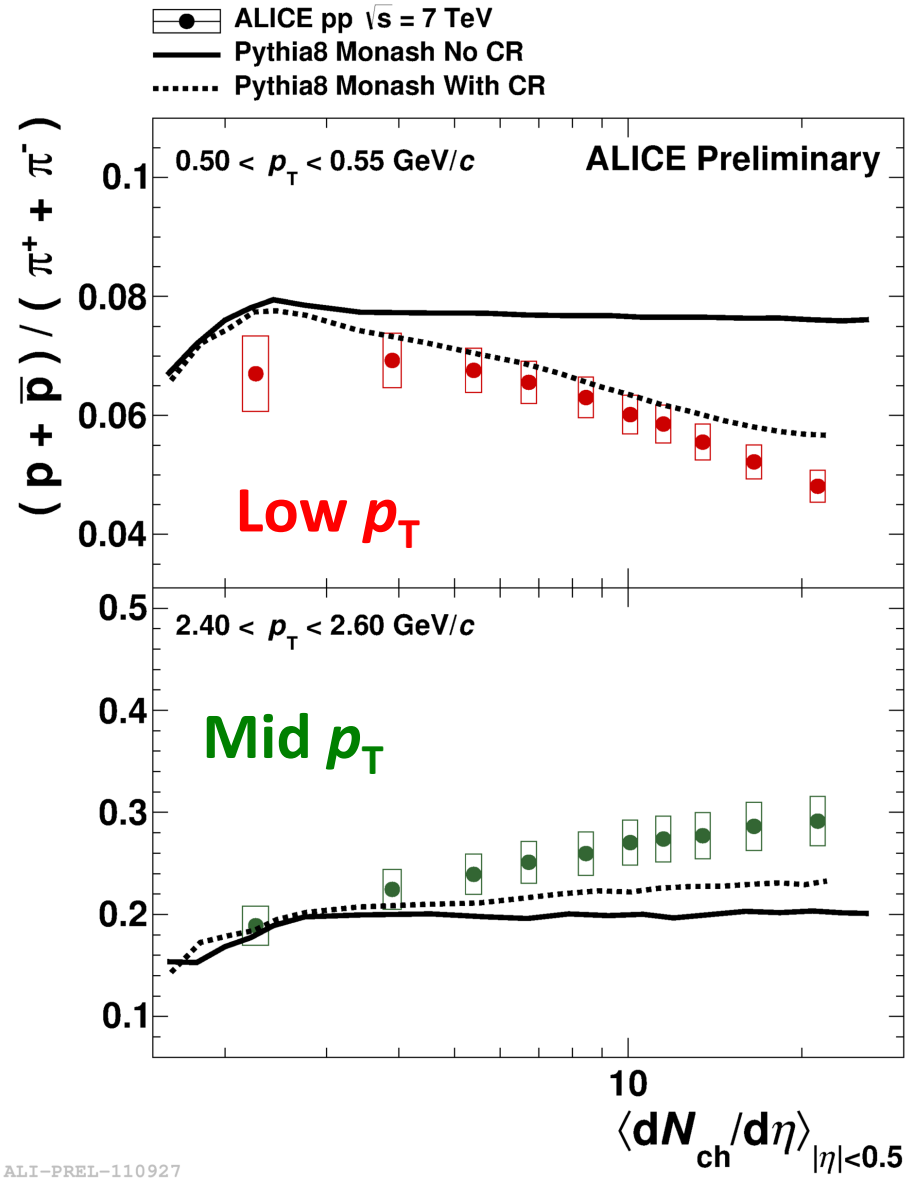
- No significant multiplicity evolution for the ratio K/π as a function of p_T
- Depletion at low p_T and enhancement at intermediate p_T for p/π

Baryon to meson ratio



- At intermediate p_T ($2<p_T<10$ GeV/c), the proton-to-pion ratio increases with event multiplicity
- The behavior of this increase is qualitatively similar to that observed in Pb-Pb collisions
- At high p_T (>10 GeV/c) the particle ratios in pp, p-Pb and Pb-Pb are consistent

Baryon to meson ratio vs multiplicity

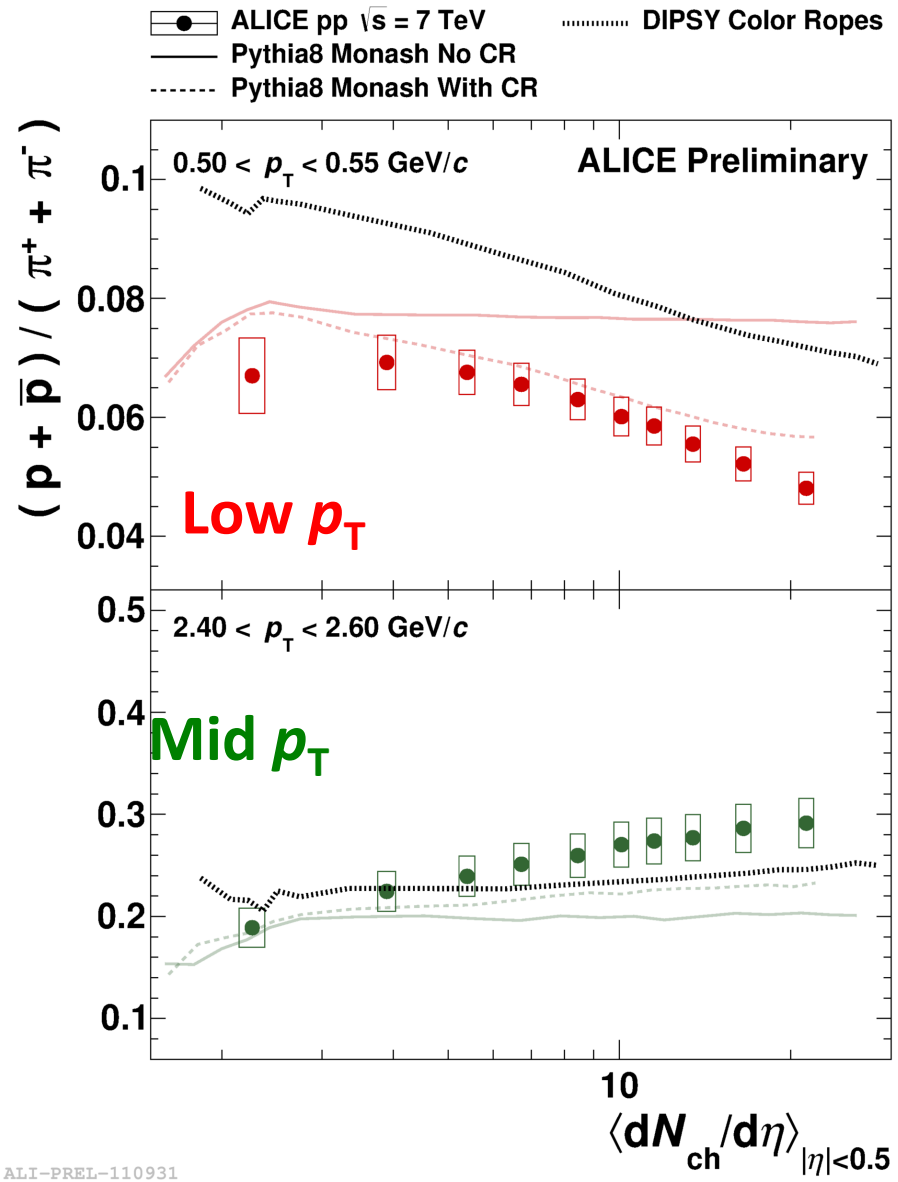


PYTHIA 8 with and without colour reconnection

→ colour reconnection describes qualitatively better the data

PYTHIA8 T. Sjöstrand et al., Comput.Phys.Commun. 178 (2008) 852867
DIPSY C. Flensburg et al., J. High Energ. Phys. (2011) 2011: 103
C. Bierlich et al., J. High Energ. Phys. (2015) 2015: 148
C. Bierlich et al., Phys. Rev. D 92, 094010
EPOS LHC T. Pierog et al., Phys. Rev. C 92, 034906 (2015)

Baryon to meson ratio vs multiplicity



PYTHIA 8 with and without colour reconnection

→colour reconnection describes qualitatively better the data

DIPSY:

→ Describes the measured trends in a qualitative way

→effect at low p_T overestimated

PYTHIA8 T. Sjöstrand et al., Comput.Phys.Commun. 178 (2008) 852867
DIPSY C. Flensburg et al., J. High Energ. Phys. (2011) 2011: 103
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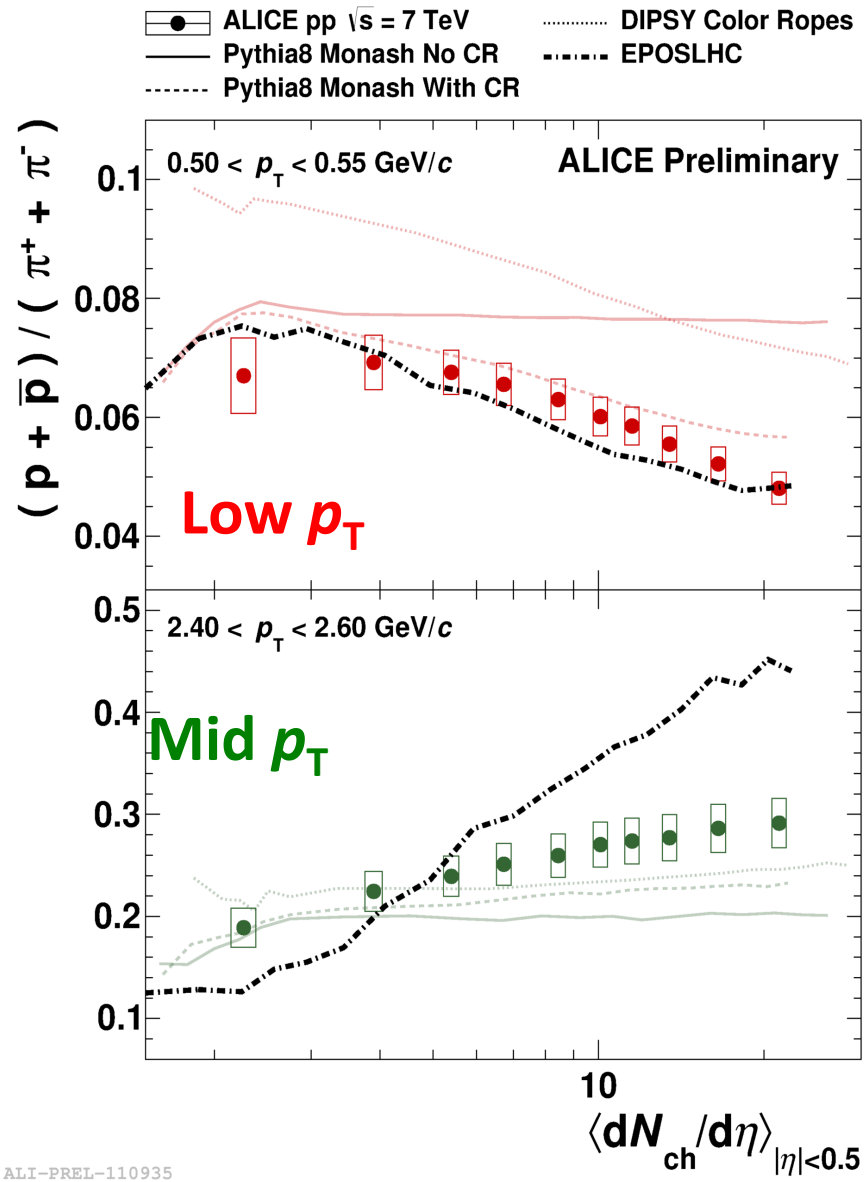

PYTHIA 8 with and without colour reconnection

→colour reconnection describes qualitatively better the data

DIPSY:

→ Describes the measured trends in a qualitative way

→effect at low p_T overestimated

EPOS LHC:

Collective radial expansion

→Describes only the trends for the low p_T

PYTHIA8 T. Sjöstrand et al., Comput.Phys.Commun. 178 (2008) 852867
DIPSY C. Flensburg et al., J. High Energ. Phys. (2011) 2011: 103
C. Bierlich et al., J. High Energ. Phys. (2015) 2015: 148
C. Bierlich et al., Phys. Rev. D 92, 094010
EPOS LHC T. Pierog et al., Phys. Rev. C 92, 034906 (2015)

Summary

- Several similarities between pp, p-Pb, and Pb-Pb collisions have been reported
  - collectivity, baryon/meson ratio,

    strangeness production **see Prabhakar Palni talk in this session**

- Predictions from Monte Carlo models show poor agreement with the measurements

- Further investigations are necessary to understand the underlying particle production mechanisms in smaller systems