A Large Ion Collider Experiment

NEW RESULTS RELATED TO QGP IN SMALL SYSTEMS WITH ALICE

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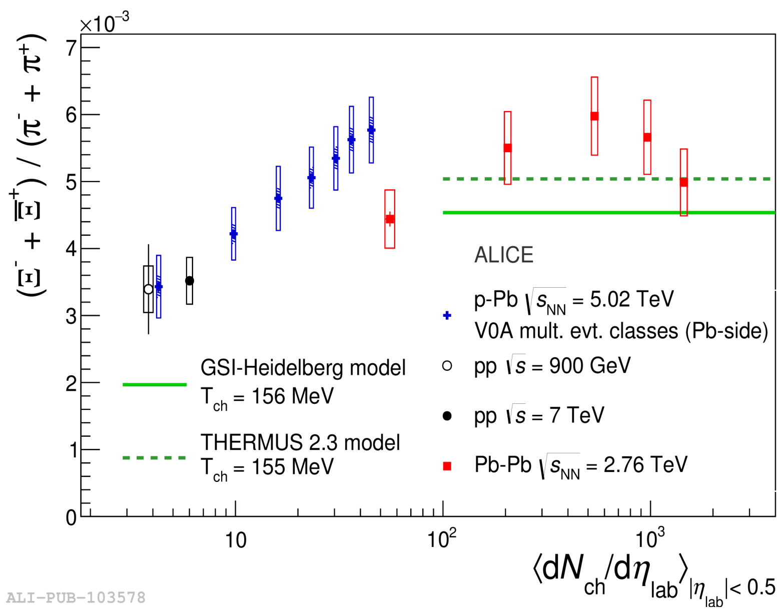
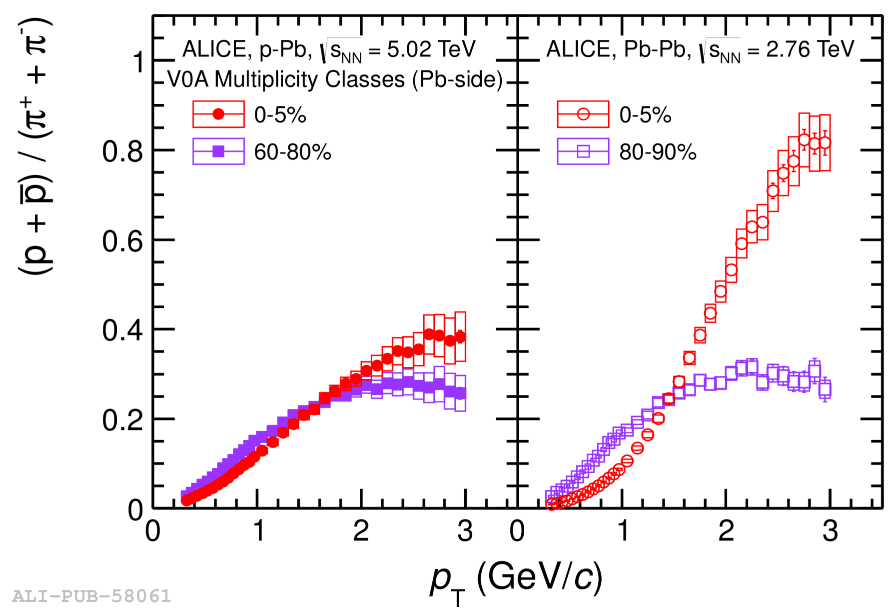
Introduction and Motivation

Motivation

- pA and AA: qualitatively same features in several observables of bulk particle production
- AA:
  - Strangeness enhancement/canonical suppression in small systems
  - Baryon/meson ratio enhancement
- pA:
  - Progressive release of canonical suppression with increasing system size/strangeness enhancement
  - Baryon/meson ratio qualitatively similar to AA

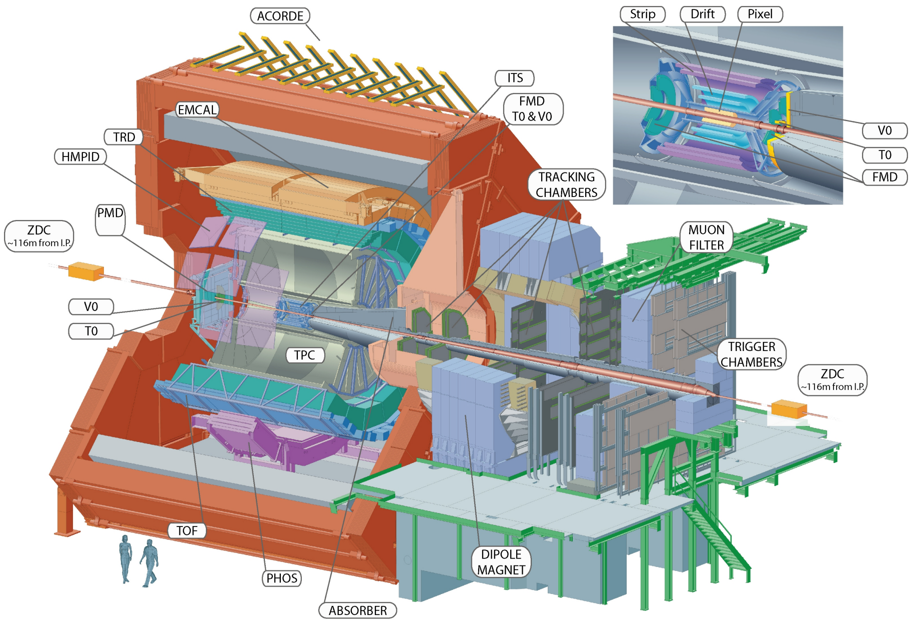


[Phys. Lett. B 758 (2016) 389-401]



[Phys.Lett. B728 (2014) 25-38]

PID & Multiplicity estimation



Detectors used for PID:

- Inner Tracking System (ITS)
  - also: trigger, tracking, vertex
- Time Projection Chamber (TPC)
  - also: tracking
- Time-Of-Flight (TOF)

Multiplicity estimation:

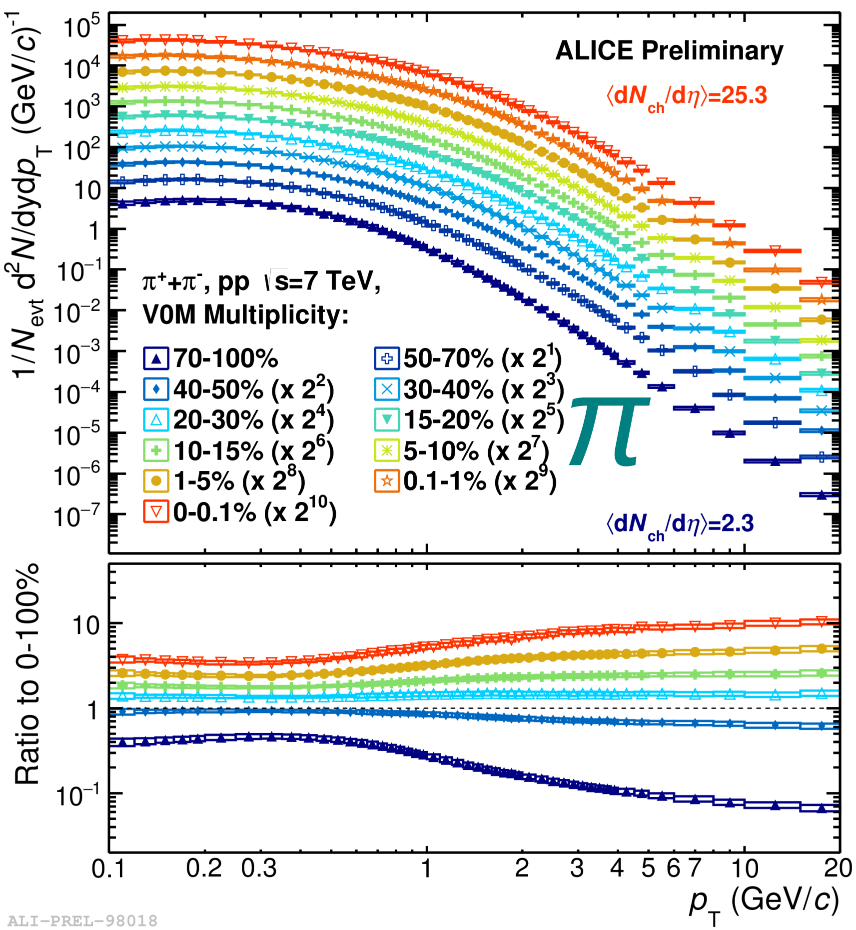
- V0M – multiplicity estimator at forward rapidities
  - Two plastic scintillators:
    V0A ($2.8 < \eta < 5.1$)
    V0C ($-3.7 < \eta < -1.7$)
  - V0M = V0A + V0C
  - Used in order to minimize the auto-correlation biases

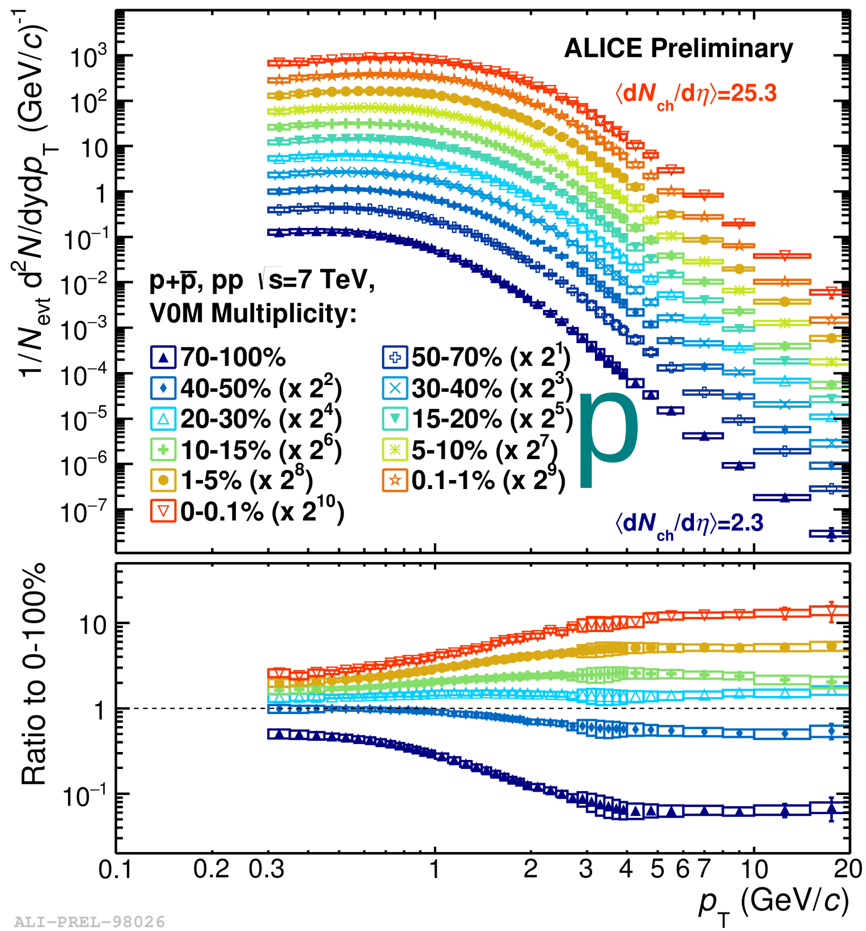
RESULTS

p_T-differential spectra – pp at √s = 7 TeV

Measure a comprehensive set of light-flavoured particles in a wide p_T range, interested in radial flow and chemical composition of events

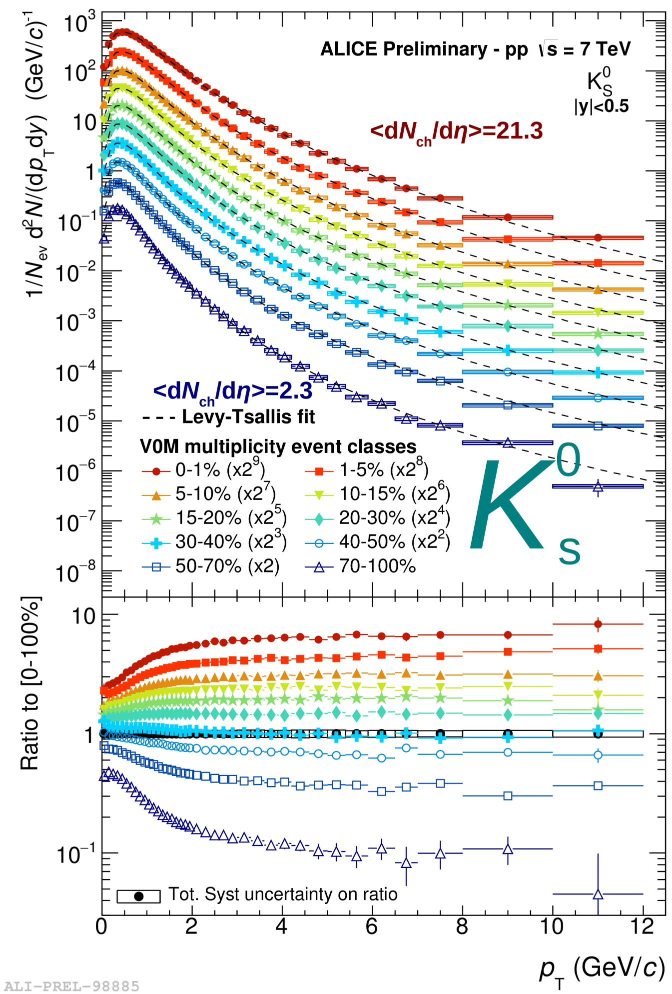
- Hardening with increasing multiplicity
- Flattening at high p_T

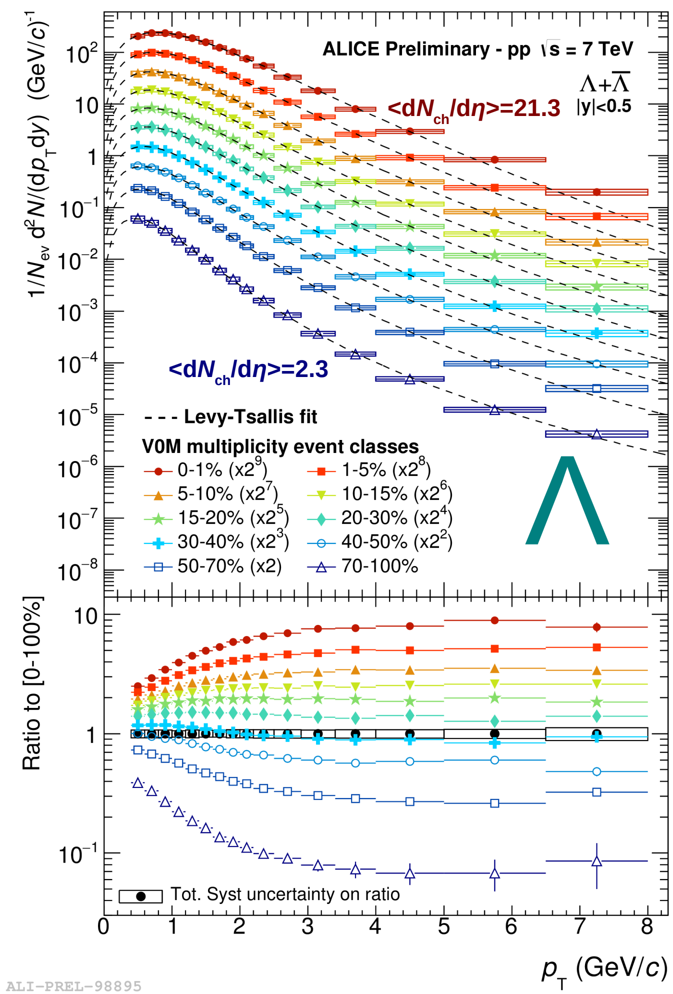




p_T-differential spectra – pp at √s = 7 TeV

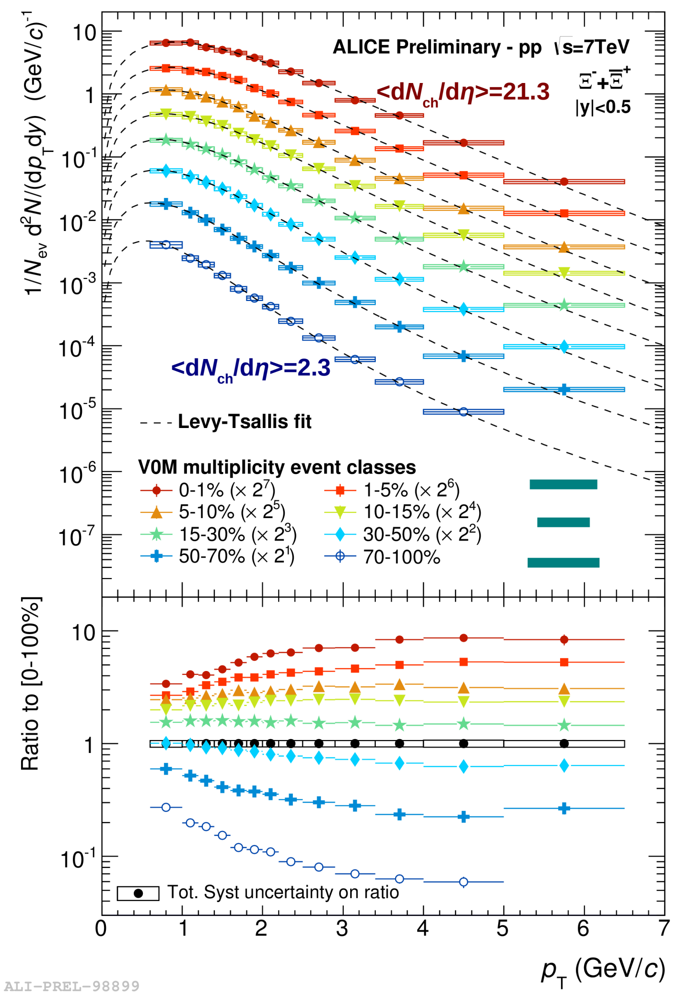
Similar effects for strange-hadron spectra

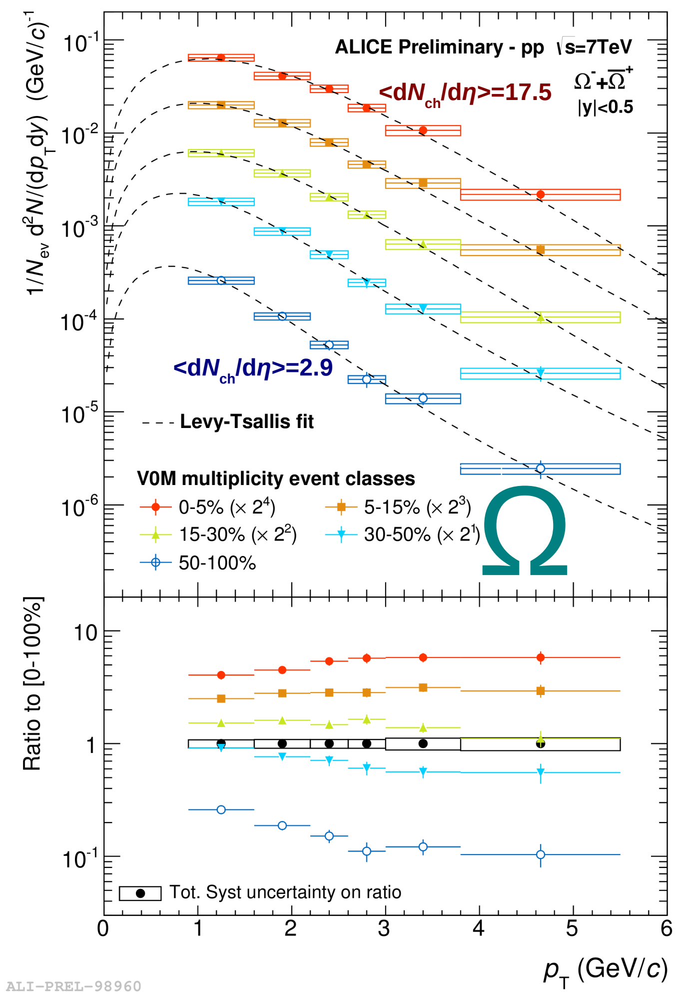




p_T-differential spectra – pp at √s = 7 TeV

And multi-strange hadrons



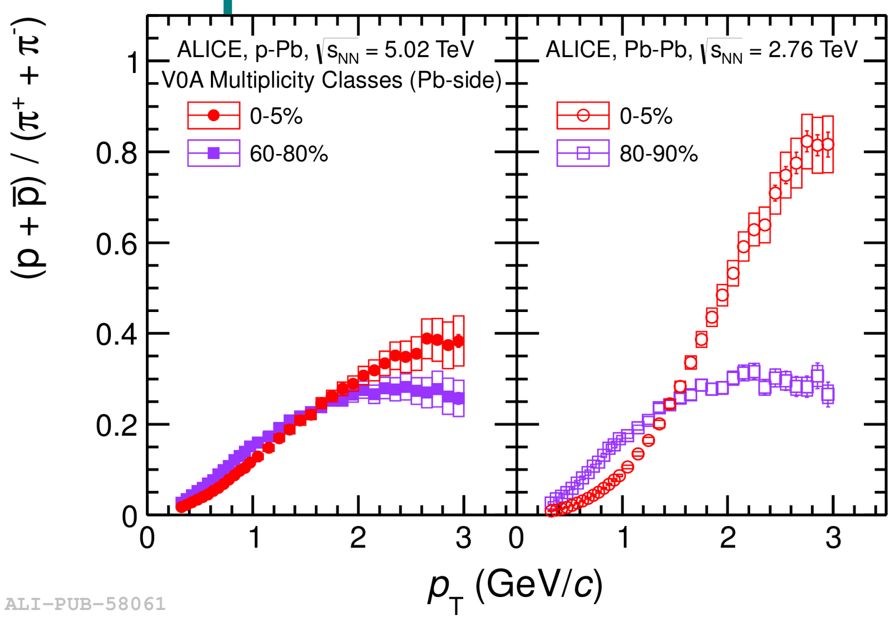


p_T-differential ratios vs. multiplicity

Baryon/meson ratios:

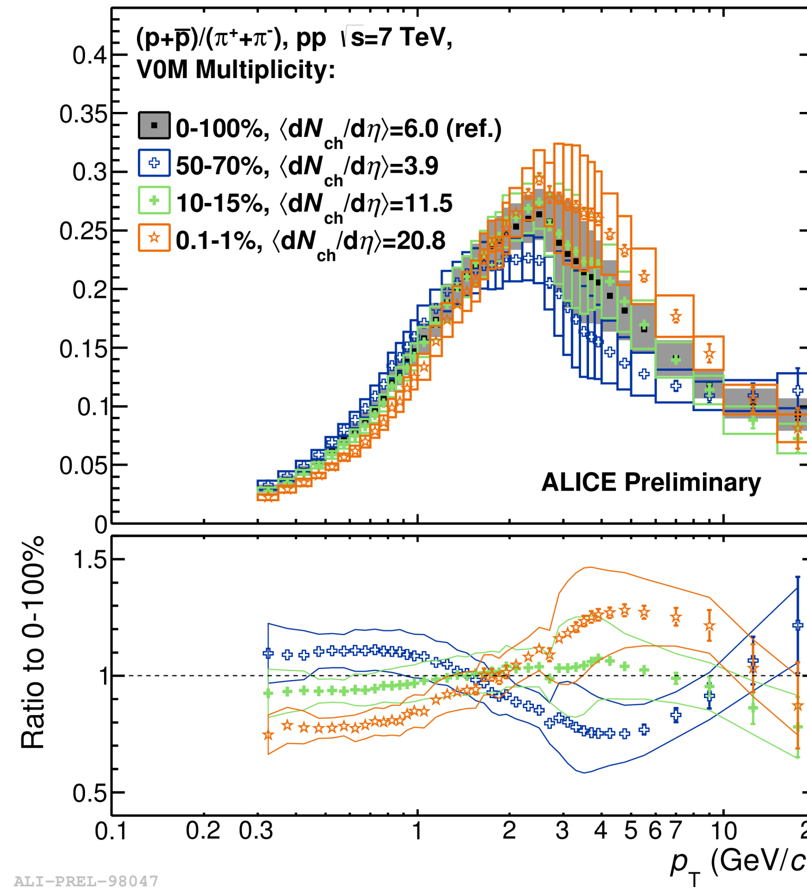
- Qualitatively similar trends in all systems
- Depletion at low p_T, enhancement at intermediate
- Different magnitudes, but also different multiplicity densities

p-Pb Pb-Pb



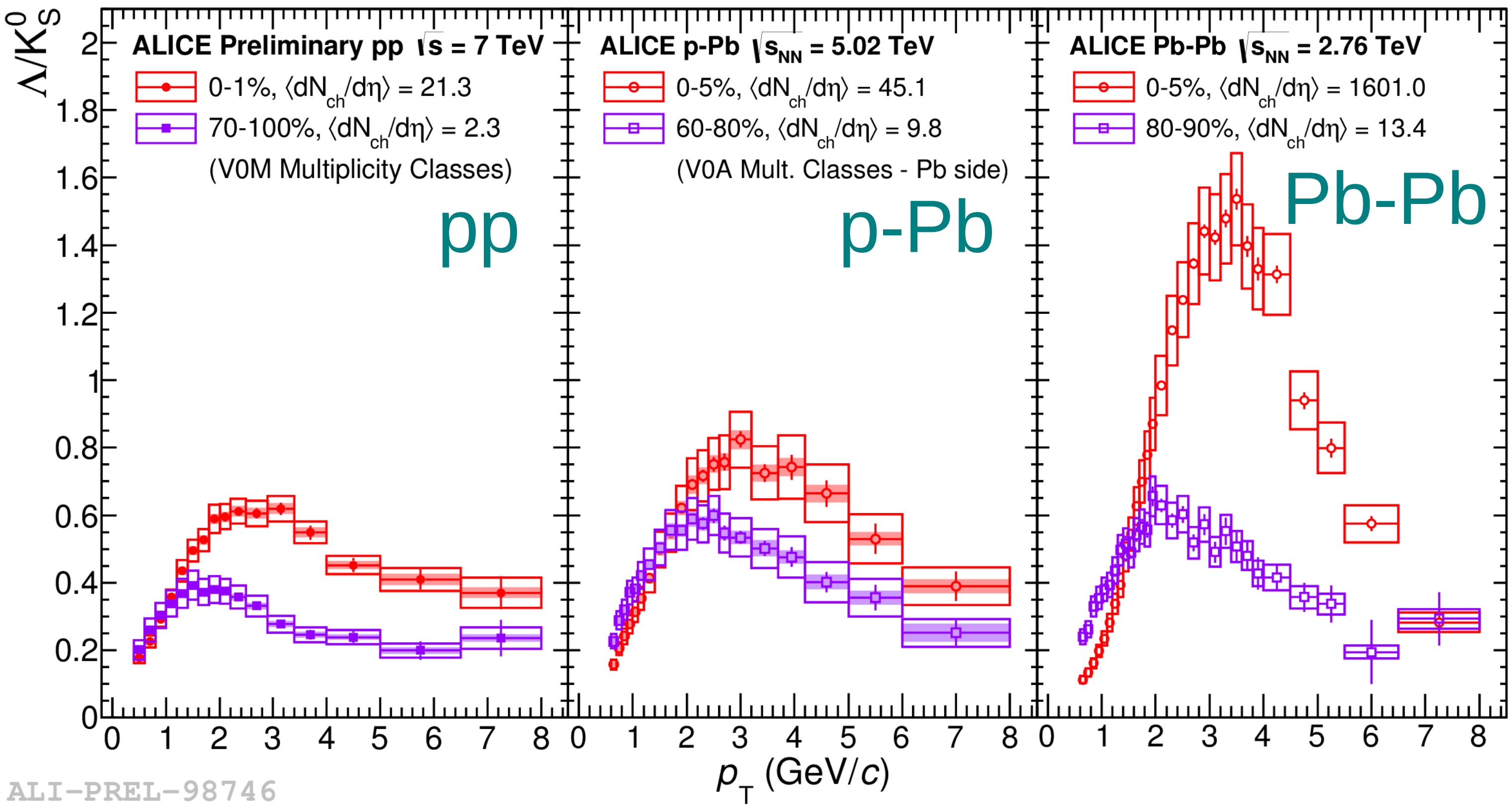
[Phys.Lett. B728 (2014) 25-38]

pp



p_T-differential ratios vs. multiplicity

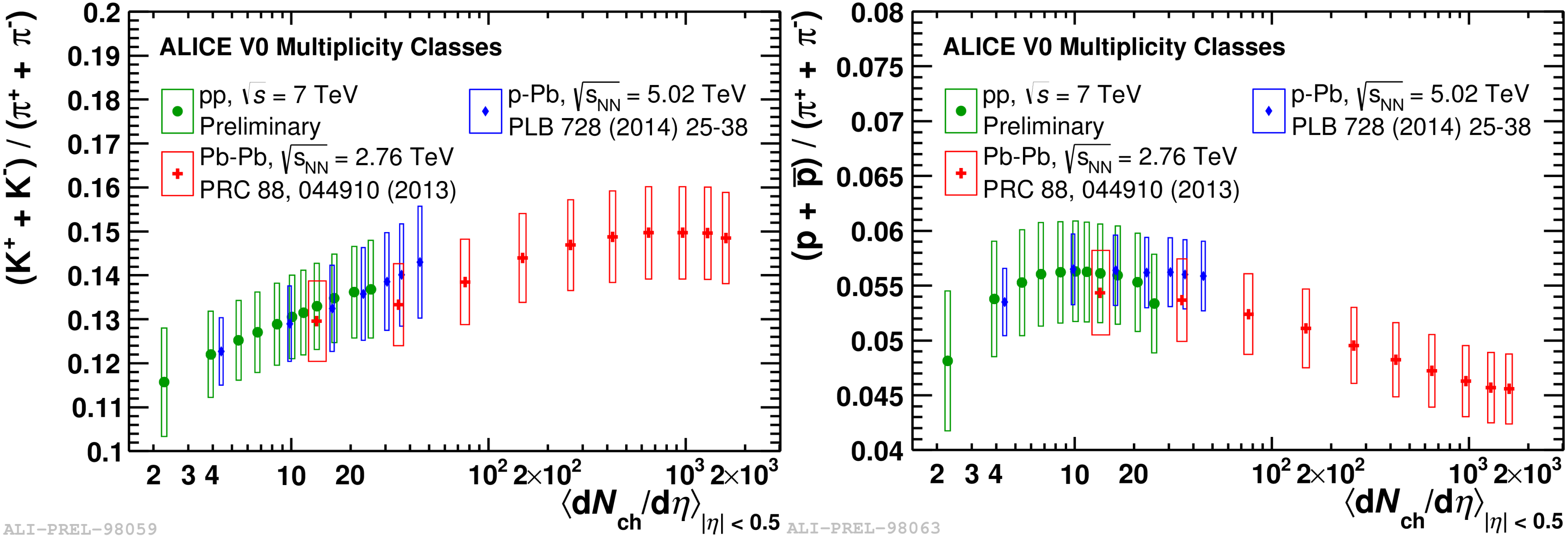
- Enhancement in Pb-Pb explained by coalescence/radial flow, but also seen in p-Pb and pp
- Mass ordering in Pb-Pb is described by hydrodynamical evolution of the system, which may require a fireball in local thermal (kinetic) equilibrium



p_T-integrated yield ratios vs. multiplicity

Integrated yield ratios: comparison between systems

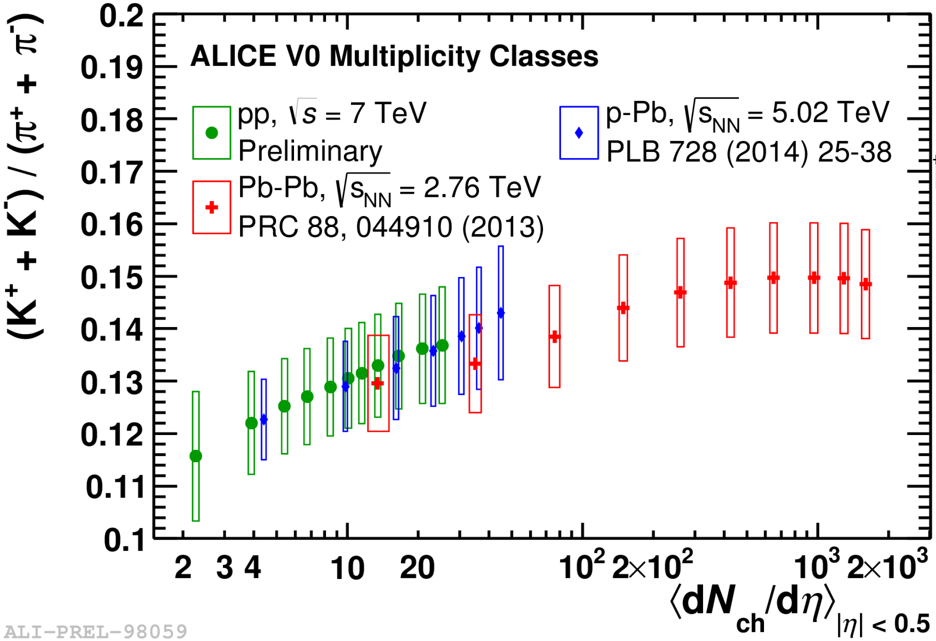
- Both *K/π* and p/*π* ratios consistent between different colliding systems for similar dN_{ch}/dη

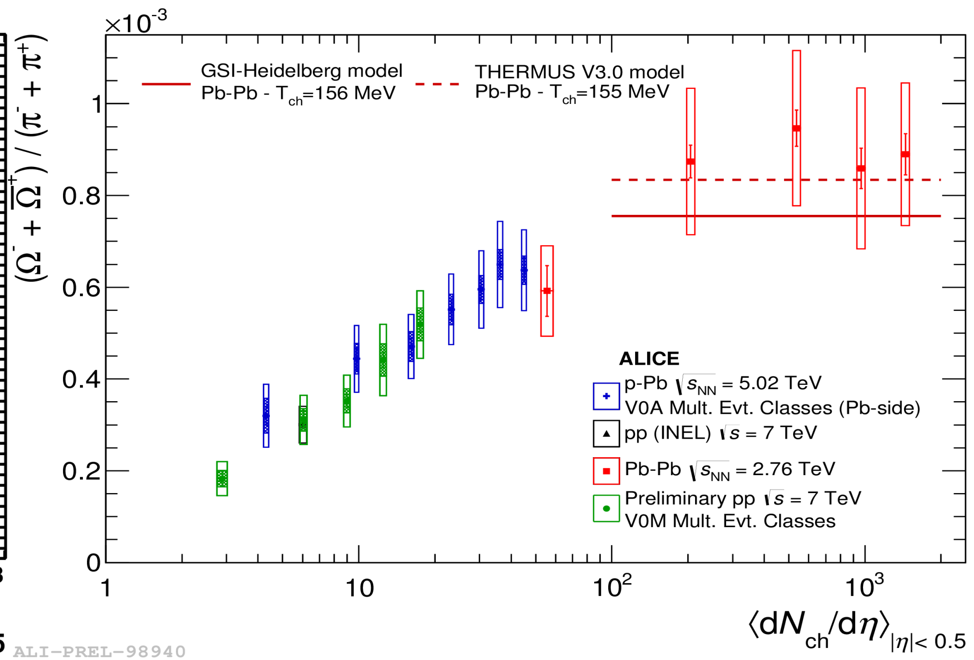


p_T-integrated yield ratios vs. multiplicity

Integrated yield ratios: comparison between systems

- Both *K/π* and p/*π* ratios consistent between different colliding systems for similar dN_{ch}/dη
- Similar behaviour for multi-strange baryons
- Particle composition seems to be driven by dN_{ch}/dη



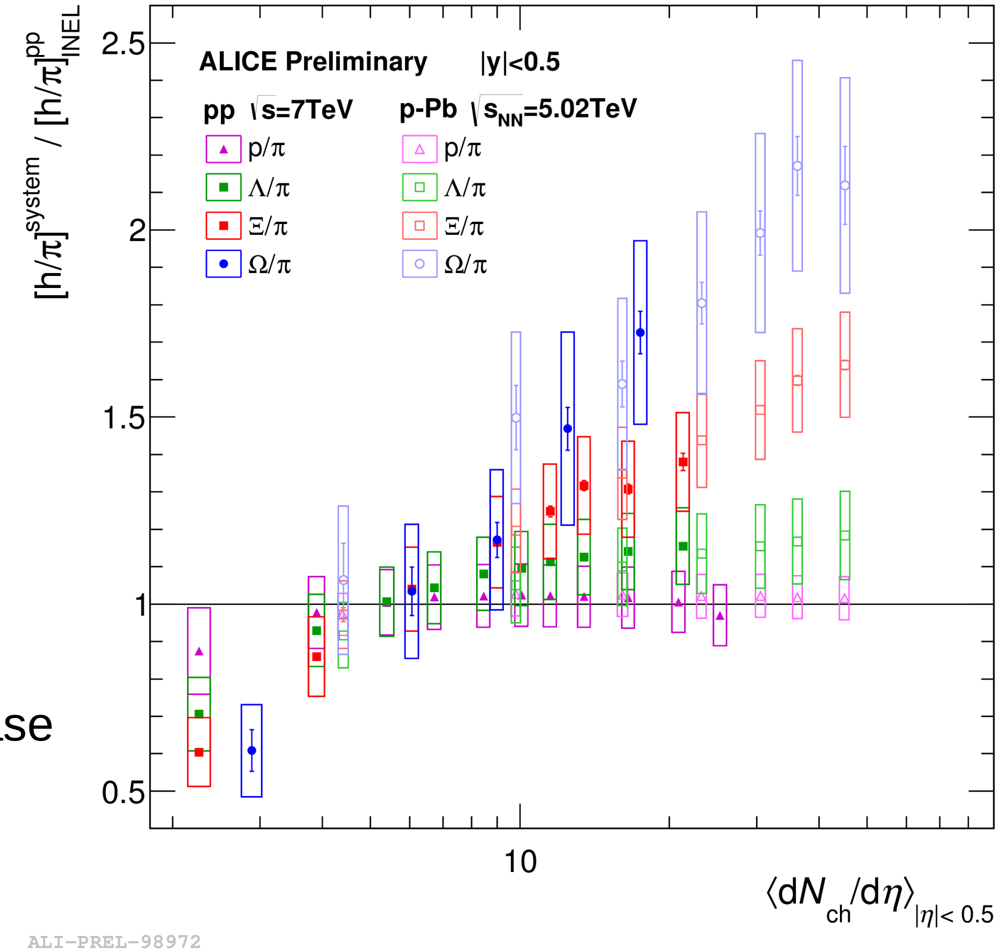


Baryon-to-meson ratios: pp & p-Pb comparison

pp and pA ratios normalized to multiplicity-integrated ratios:

- Protons: consistent with unity
  - Enhancement not related to baryon number
- Slope increases with strangeness content

Strangeness-related increase of ratio vs. multiplicity



Comparison to Thermal Model calculations

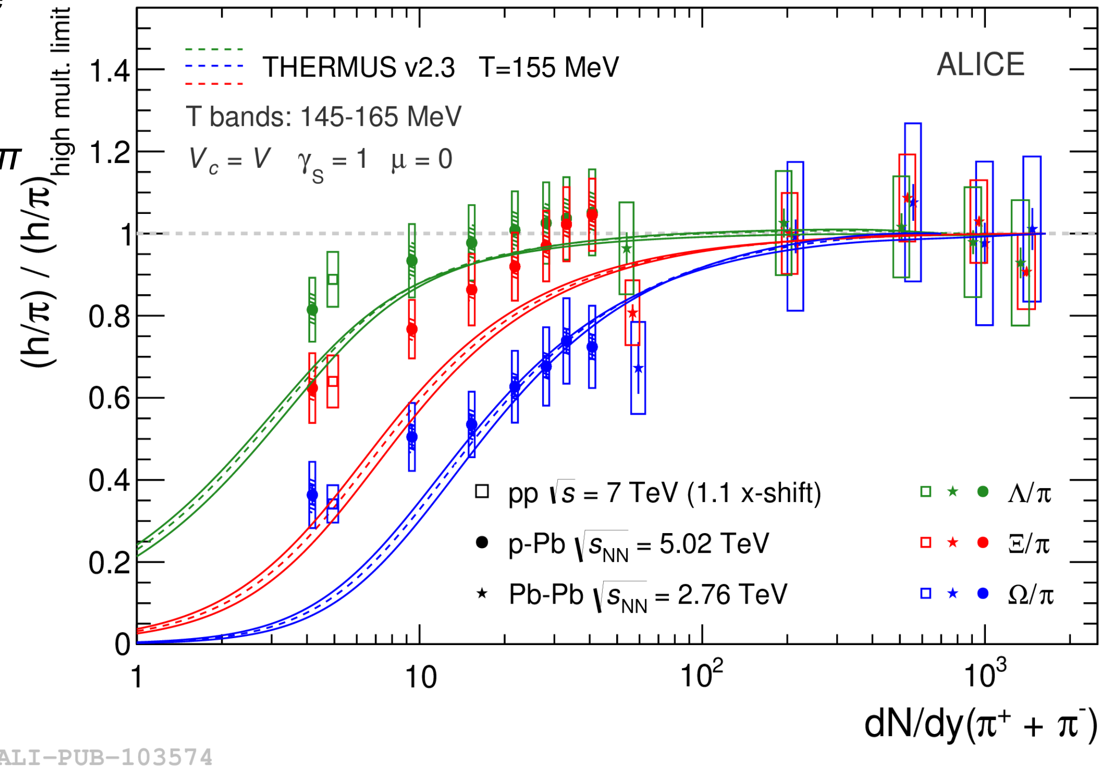
Another look into pp and pA

- *Λ/π, Ξ/π, Ω/π* approaching grand canonical saturation in same predicted way

- Consider strange hadron to *π* ratio at high multiplicity limit

- Trend for *Λ/π, Ξ/π, Ω/π* roughly described by THERMUS

- Reminder: Trends not reproduced by existing Pythia tunes



[Phys.Lett. B758 (2016) 389-401]

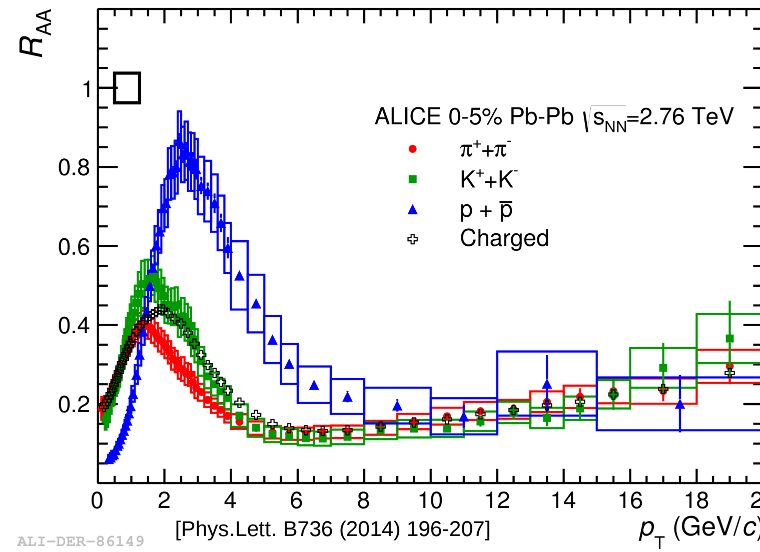
Nuclear Modification Factor

Pb-Pb:

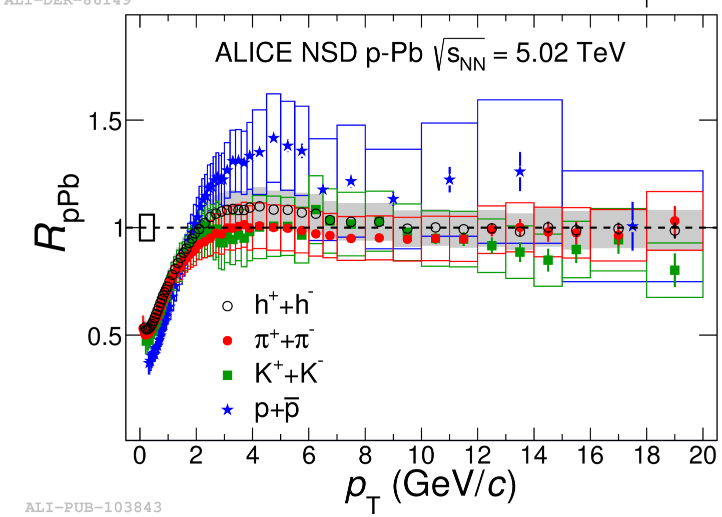
- Mass-ordered suppression of soft hadrons
- Species-independent suppression of hard particles

p-Pb

- No suppression above $p_T \approx 2$ GeV/c
- Consistent with unity for all species above $p_T \approx 6$ GeV/c
- Cronin peak/mass ordering?



[Phys.Lett. B736 (2014) 196-207]



[arXiv:1601.03658]

Summary

Summary

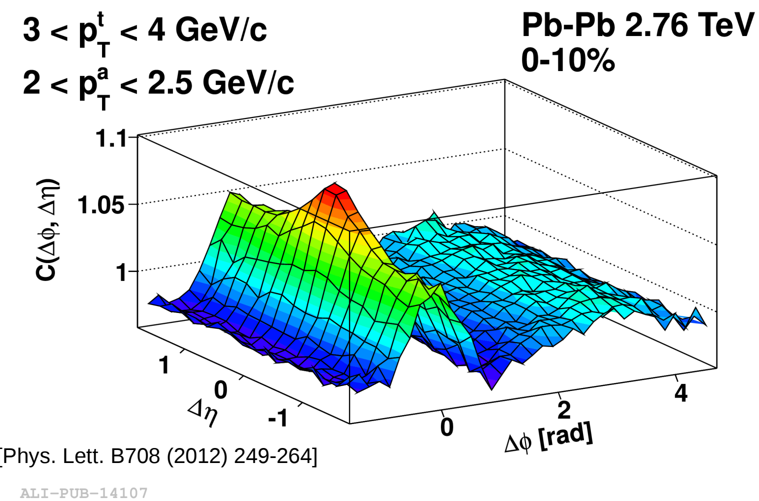
The production of identified hadrons as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV has been measured and reported

- Measured p_T-differential hadron spectra harden with multiplicity
- Ratios of p_T-differential spectra to minimum bias flatten out at high p_T
- p_T-differential baryon-to-meson ratios show significant evolution from low to high multiplicity; same qualitative behaviour observed in p-Pb and Pb-Pb collisions
- Strange-hadron to pion ratios:
  - Qualitatively similar among pp and p-Pb
  - Enhanced strange particle production with multiplicity observed
- Suppression of high p_T hadrons present in Pb-Pb, not in p-Pb

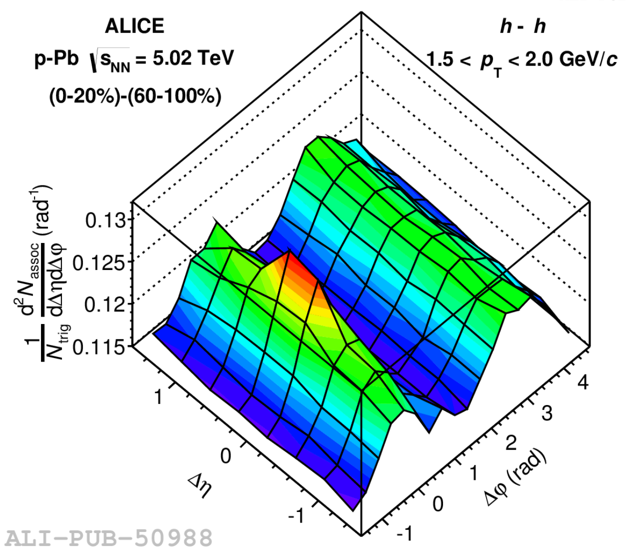
Backup

The ridge

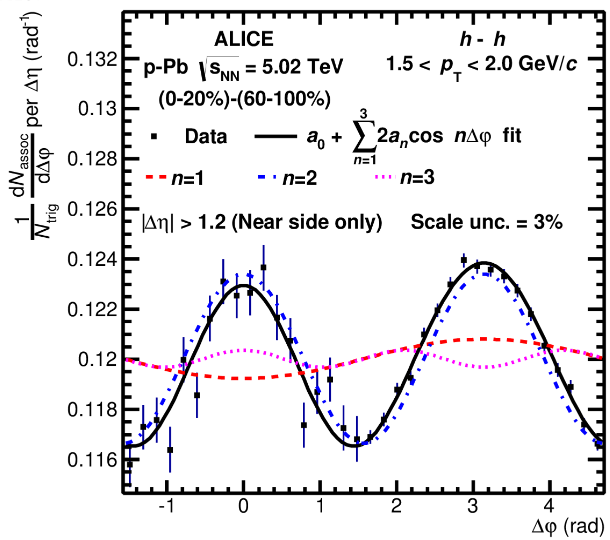
- Also, double-ridge
  (but not in this talk)



[Phys. Lett. B708 (2012) 249-264]



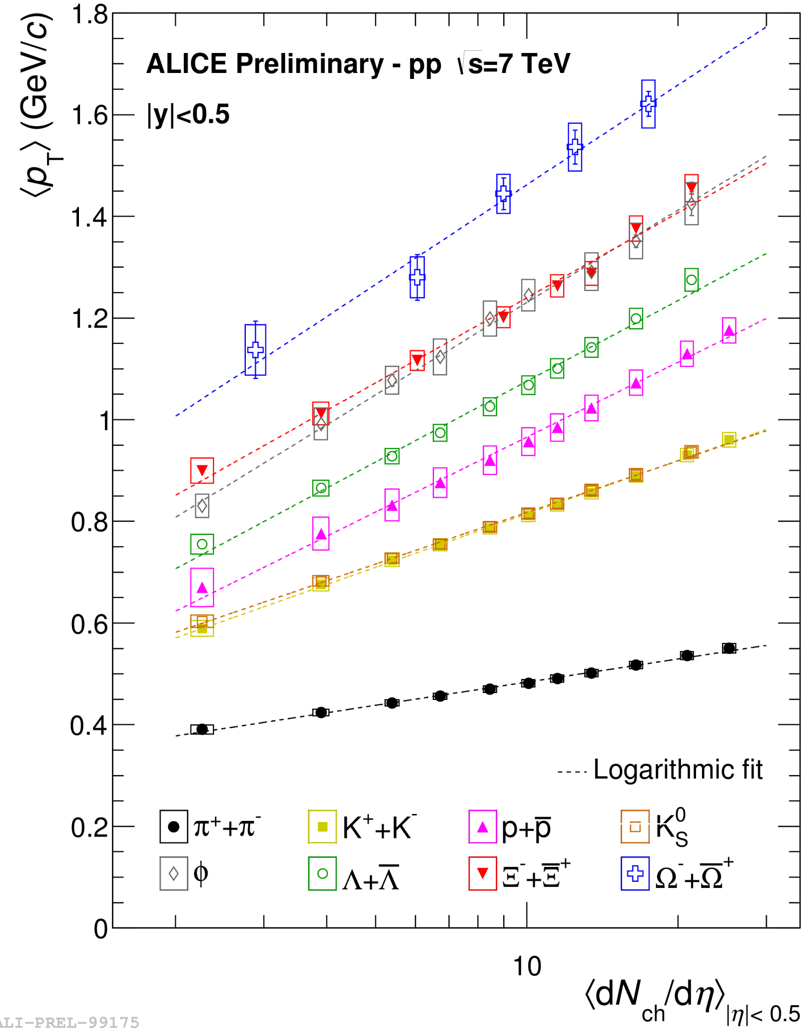
Phys.Lett. B726 (2013) 164-177



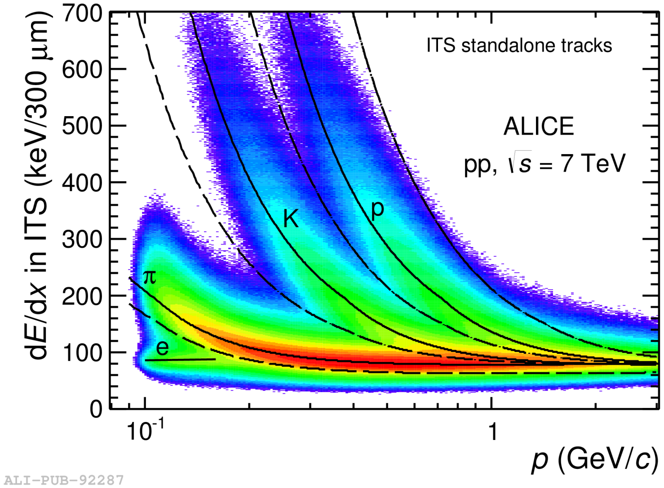
$<p_T>$ vs. multiplicity

The hardening of spectra can be quantified by looking at the $<p_T>$ as a function of multiplicity

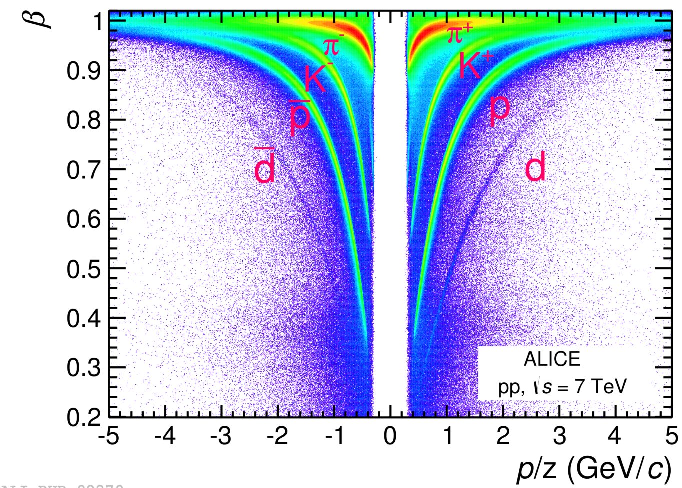
- Rising trend of $<p_T>$ with multiplicity for all identified particles
- Mass ordered
- Logarithmic fit to guide the eye



ITS, TPC and TOF performance in √s = 7 TeV pp collisions



[Eur.Phys.J. C75 (2015) no.5, 226]



[Eur.Phys.J. C75 (2015) no.5, 226]

ITS:

π: [0.1 – 0.6] GeV/*c*

K: [0.2 – 0.6] GeV/*c*

p: [0.3 – 0.6] GeV/*c*

TPC:

π: [0.2 – 0.5] GeV/*c*

K: [0.25 – 0.6] GeV/*c*

p: [0.4 – 0.8] GeV/*c*

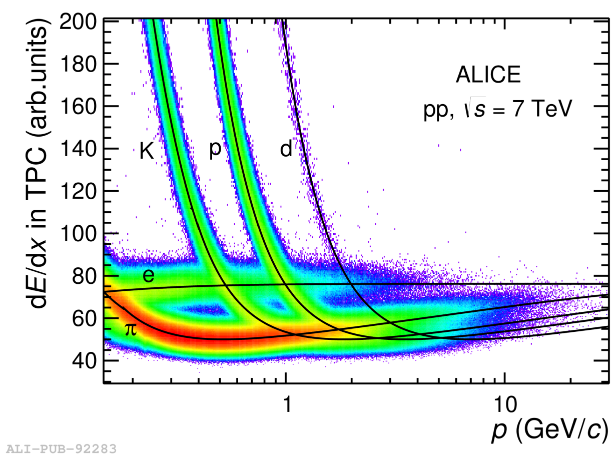
+ relativistic rise

TOF:

π: [0.5 – ~3] GeV/*c*

K: [0.6 – ~3] GeV/*c*

p: [0.8 – ~4] GeV/*c*



[Eur.Phys.J. C75 (2015) no.5, 226]

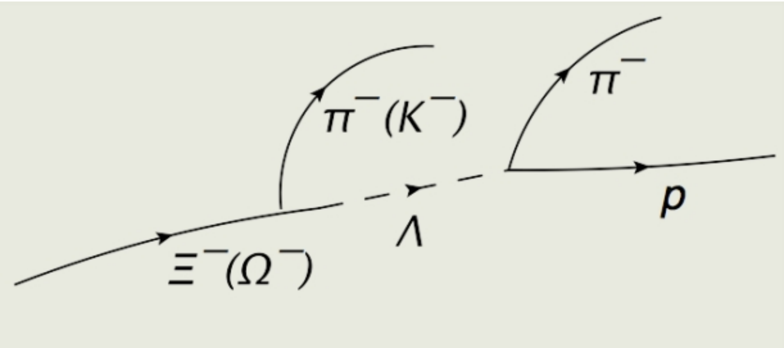
Topological PID

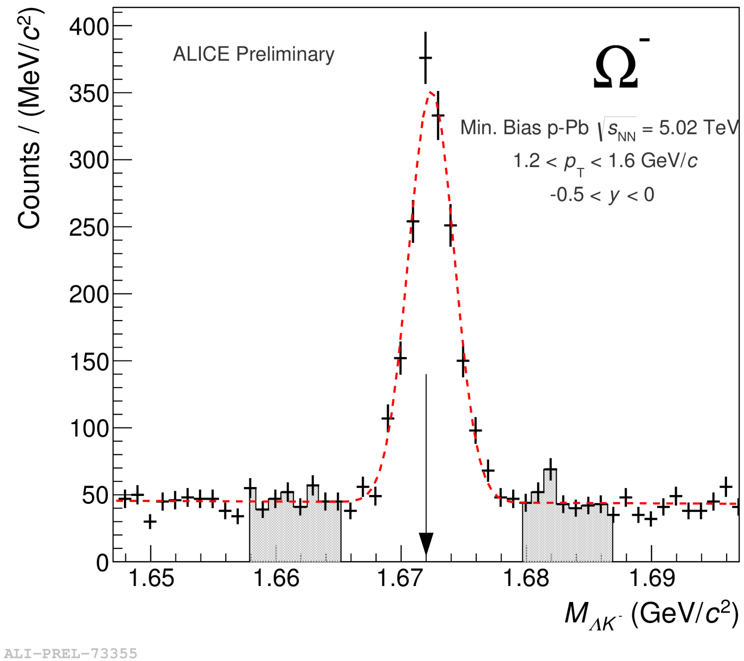
- Topological PID of weakly decaying strange baryons:

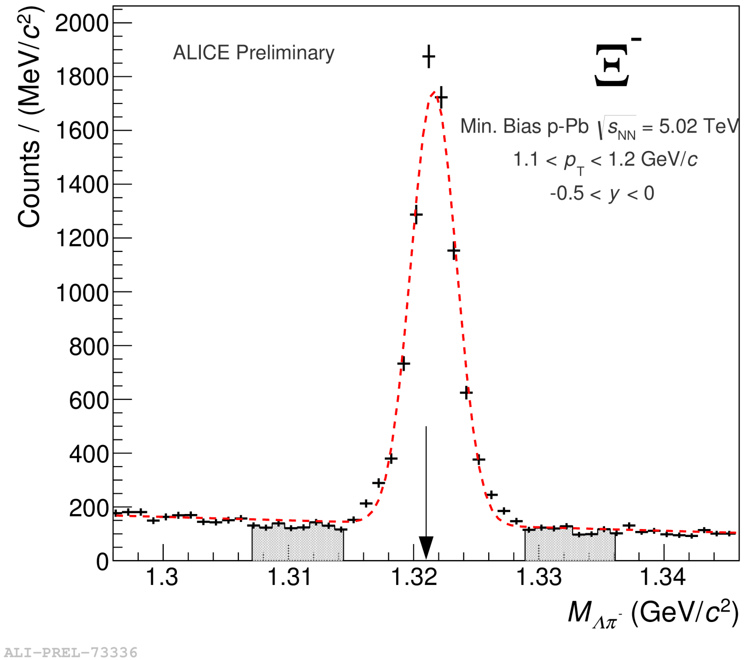
  Λ = |uds>

  Ξ = |dss>

  Ω = |sss>







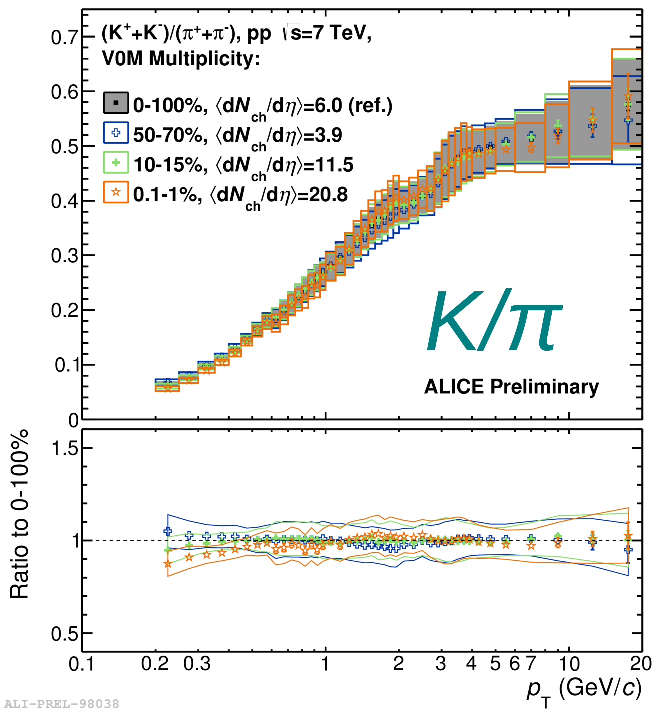
$\langle dN_{ch}/d\eta \rangle$ in V0M bins

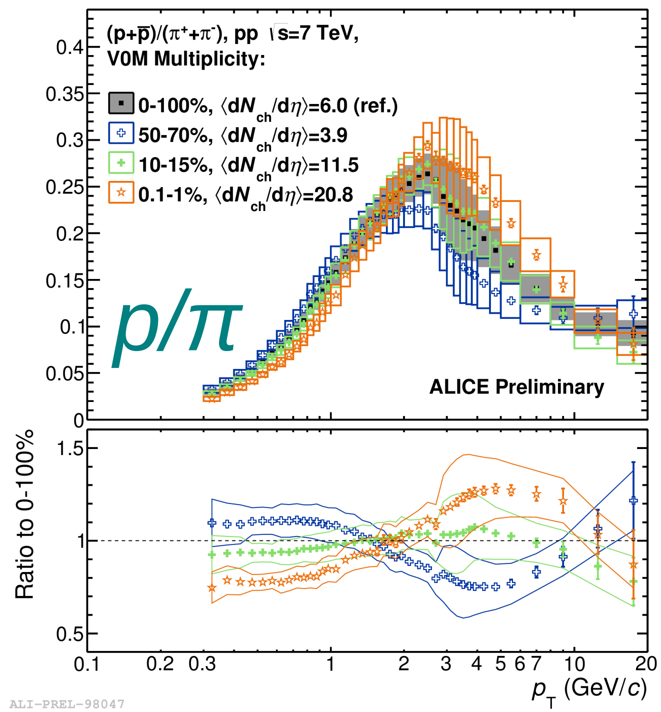
V0M (%)	$\langle dN_{ch}/d\eta \rangle$	V0M (%)	$\langle dN_{ch}/d\eta \rangle$
0 - 0.1	25.3 ± 0.8	0.1 - 1	20.8 ± 0.6
1 - 5	16.5 ± 0.5	5 - 10	13.5 ± 0.4
10 - 15	11.5 ± 0.3	15 - 20	10.1 ± 0.3
20 - 30	8.4 ± 0.3	30 - 40	6.7 ± 0.2
40 - 50	5.4 ± 0.2	50 - 70	3.9 ± 0.1
70 - 100	2.3 ± 0.1	0 - 100	6.0 ± 0.2

p_T-differential ratios vs. multiplicity

K/π, p/π ratios:

- *p/π* shows much stronger variation with multiplicity than *K/π*
  - Mass ordering

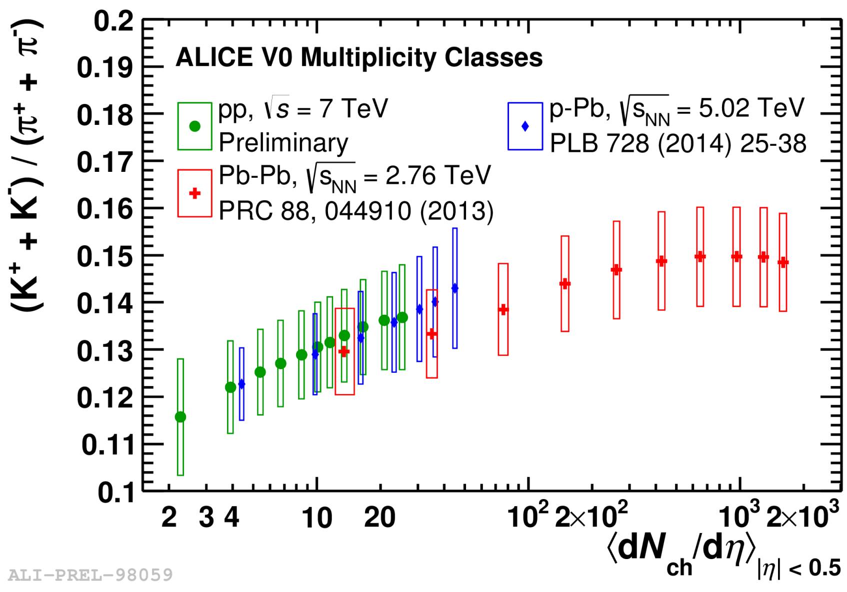


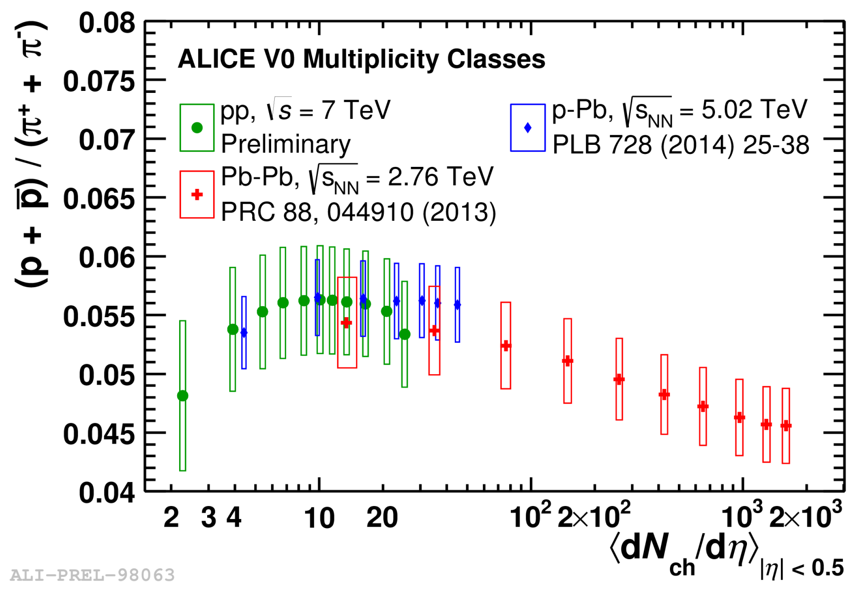


Integrated yield ratios vs. multiplicity

Integrated yield ratios: comparison between systems

- Levy-Tsallis fits to p_T-differential spectra (serves as extrapolation to p_T = 0; negligible contribution from $p_T \rightarrow \infty$ extrapolation)
- Both K/π and p/π ratios consistent between different colliding systems for the simmilar $dN_{ch}/d\eta$



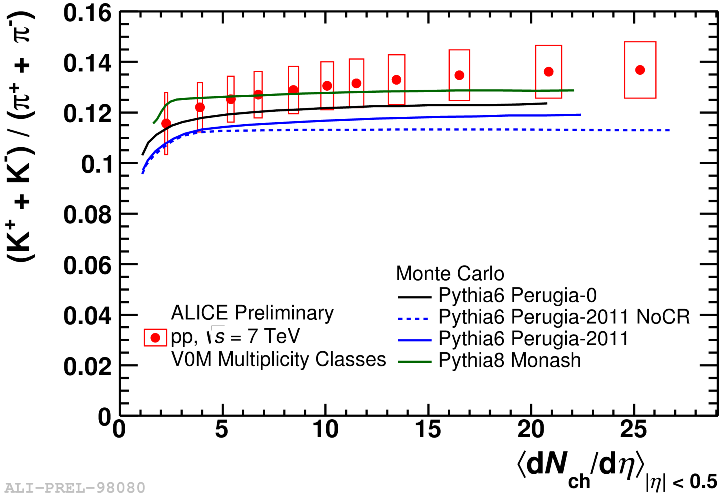


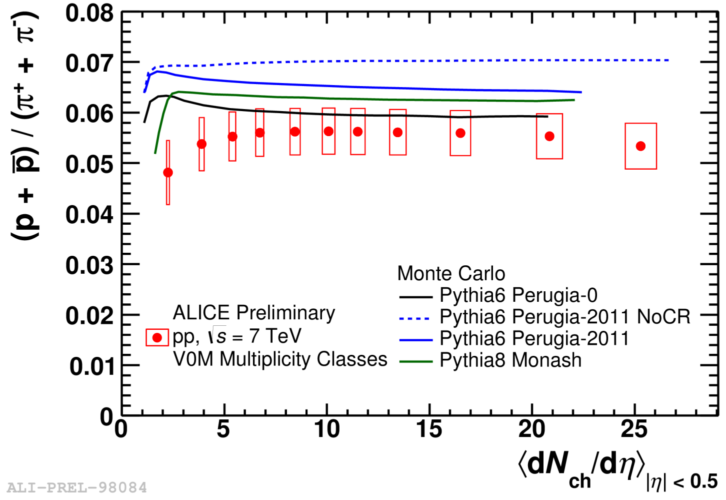
***Multiplicity uncorrelated errors are not shown here, but will be included in the forthcoming publication

Comparison to MC event generators

Integrated yield ratios:

- 4 different Pythia tunes were used
- Color reconnection has similar effect in all tunes
- None of the tunes can describe both *K/π* and *p/π* ratios quantitatively. This holds for tunes with and without color reconnection





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Comparison to MC event generators

Ratios vs. multiplicity in pp:

- Smooth trend pp → pA → AA with multiplicity
- Λ/π and Ξ/π reach predicted GC saturation values
- Ω/π stays below
- Pythia 6 & 8 do not describe the data
- Color reconnection has little impact on predicted multiplicity dependence of strangeness production