Search for collective phenomena in high multiplicity pp and p-Pb collisions with ALICE

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on behalf of the ALICE collaboration

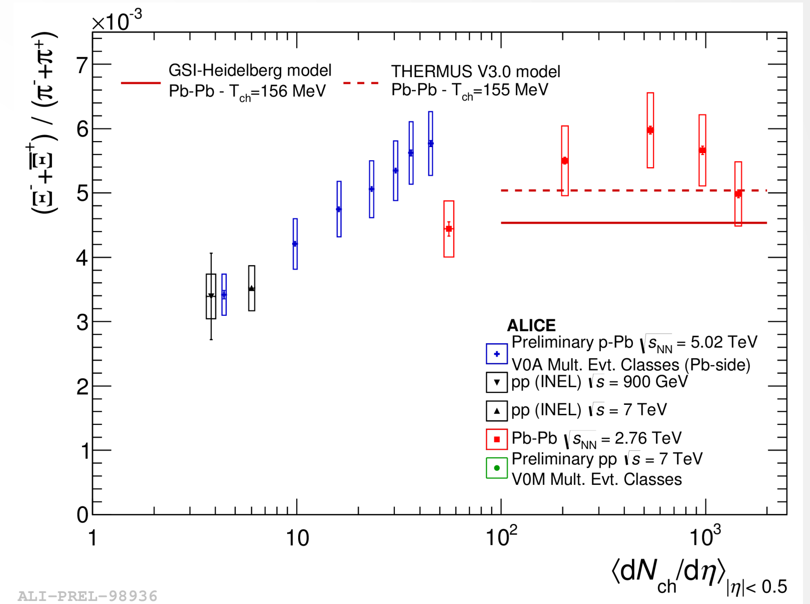
QCD challenges at the LHC: from pp to AA
Taxco, Mexico
2016-01-19

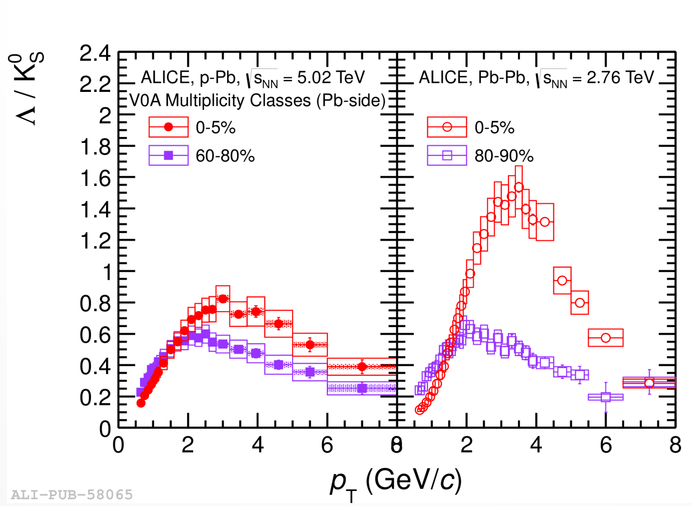
Outline

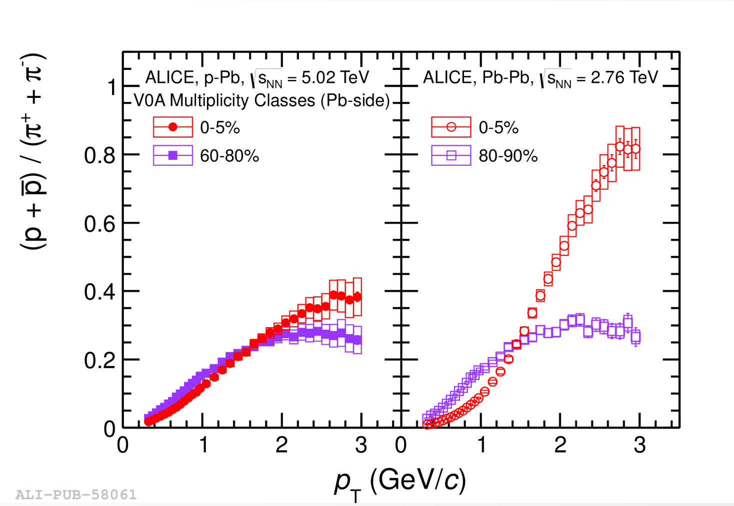
- Motivation
- Particle Identification in ALICE
- Results: π/K/p/Λ/Ξ/Ω spectra in multiplicity bins
- π/K/p/Λ/Ξ/Ω ratios vs. multiplicity: comparison among systems
- Comparison to MC event generators
- Comparison to thermal model calculations using the strangeness-canonical ensemble
- Summary

Motivation

- pA and AA: qualitatively same features observed
- AA:
  - Strangeness enhancement/canonical suppression in pp
  - Baryon/meson ratio enhancement
- pA:
  - Progressive release of canonical suppression with increasing system size/strangeness enhancement
  - Baryon/meson ratio qualitatively similar to AA







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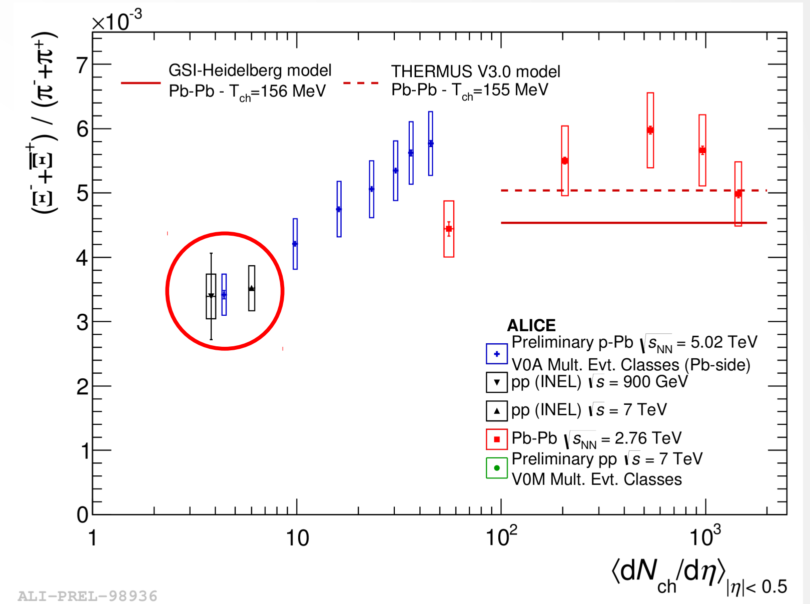
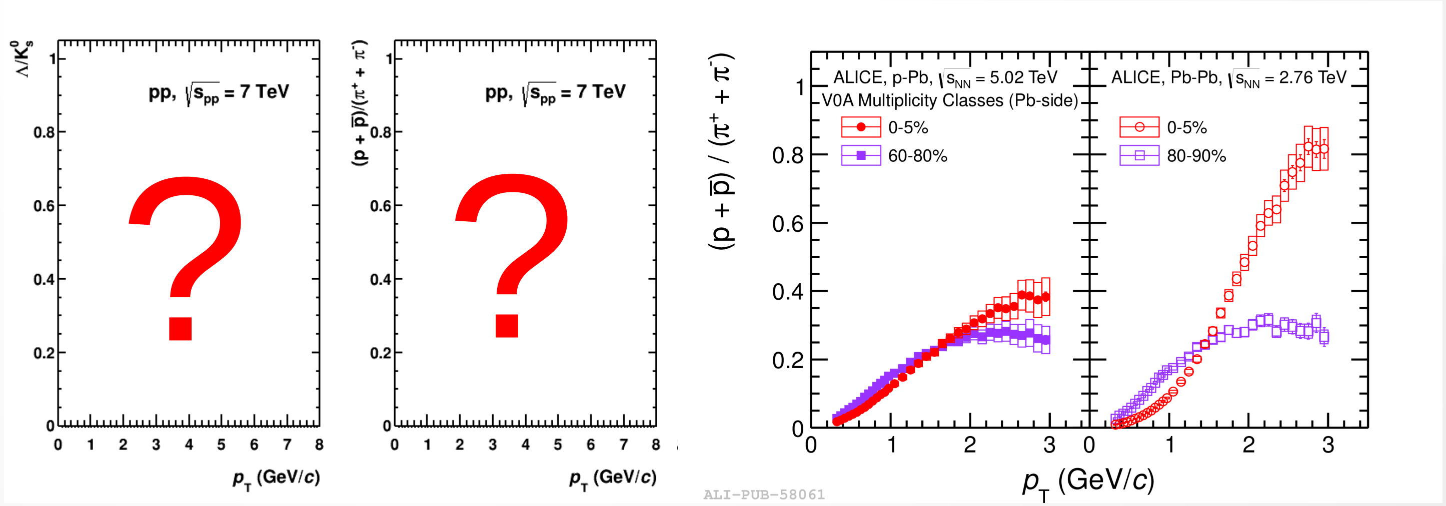
Motivation

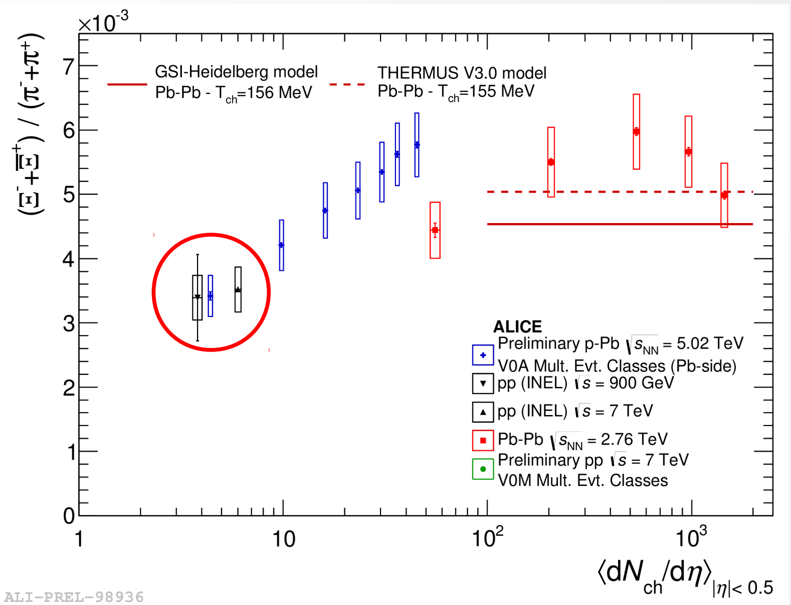
- What happens in pp?
  - Measured in √s = 900 GeV and 7 TeV, but...
  - MB <dN_{ch}/dη> is not high enough...

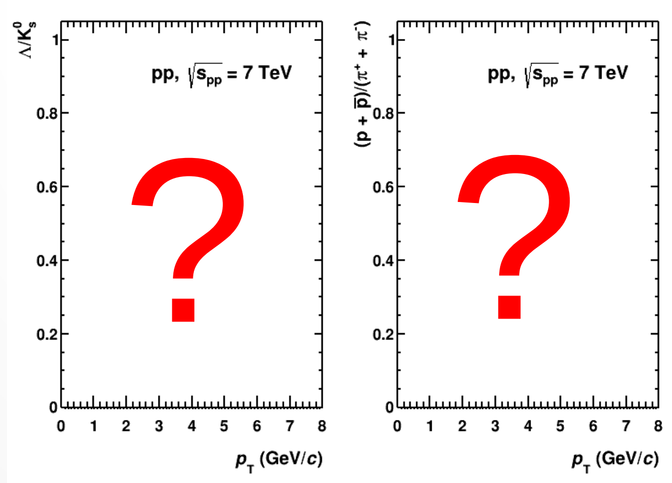


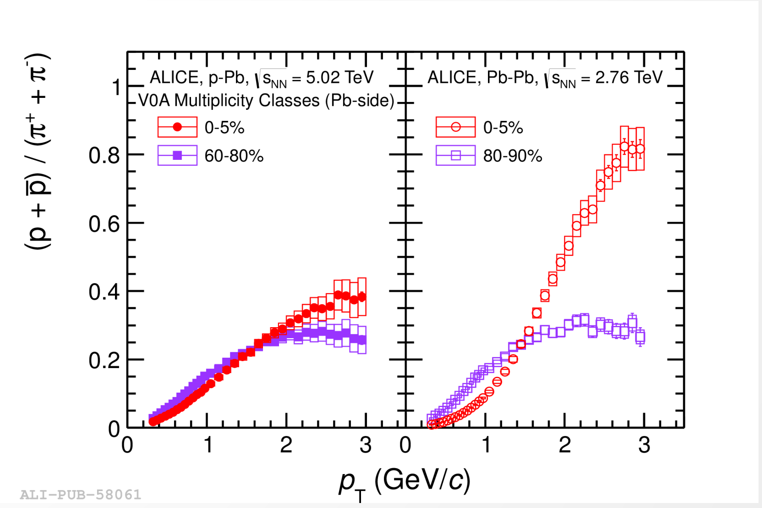


Motivation

- What happens in pp?
  - Measured in $\sqrt{s}$ = 900 GeV and 7 TeV, but...
  - MB $\langle dN_{ch}/d\eta \rangle$ is not high enough...
  - Select highest multiplicity events

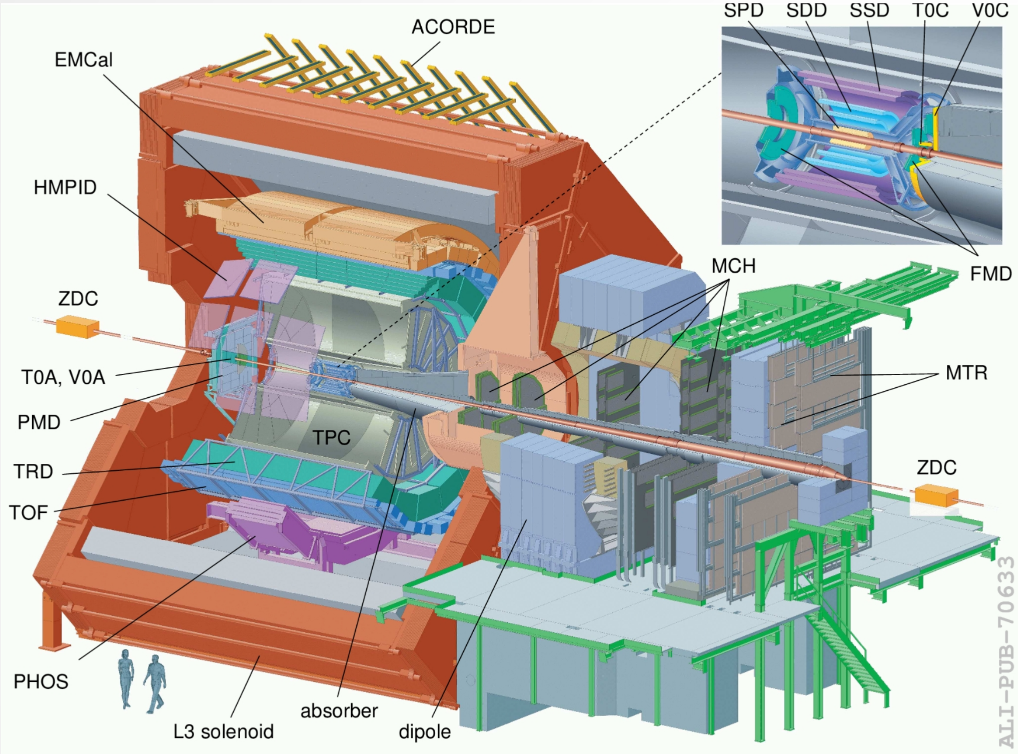






Particle Identification with ALICE

π/K/p PID



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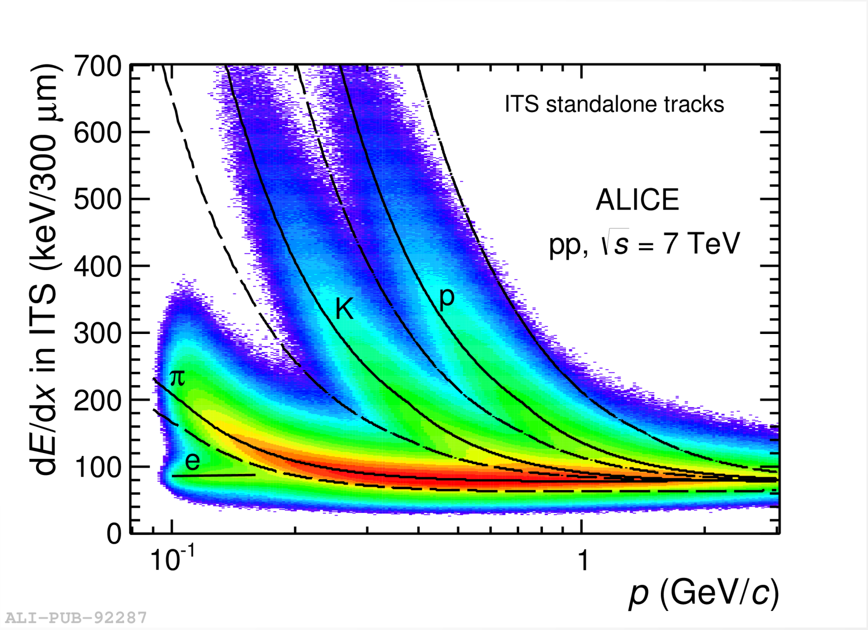
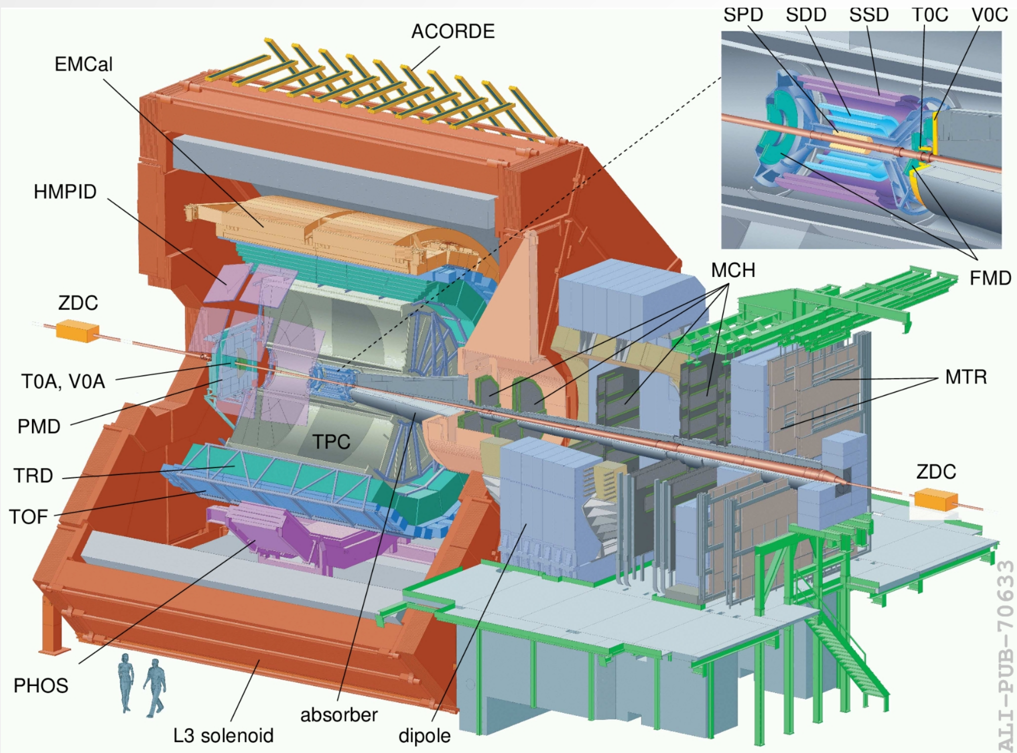
Detectors used for charged LF PID:

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

π: [0.1 – 0.6] GeV/c
K: [0.2 – 0.6] GeV/c
p: [0.3 – 0.6] GeV/c



π/K/p PID



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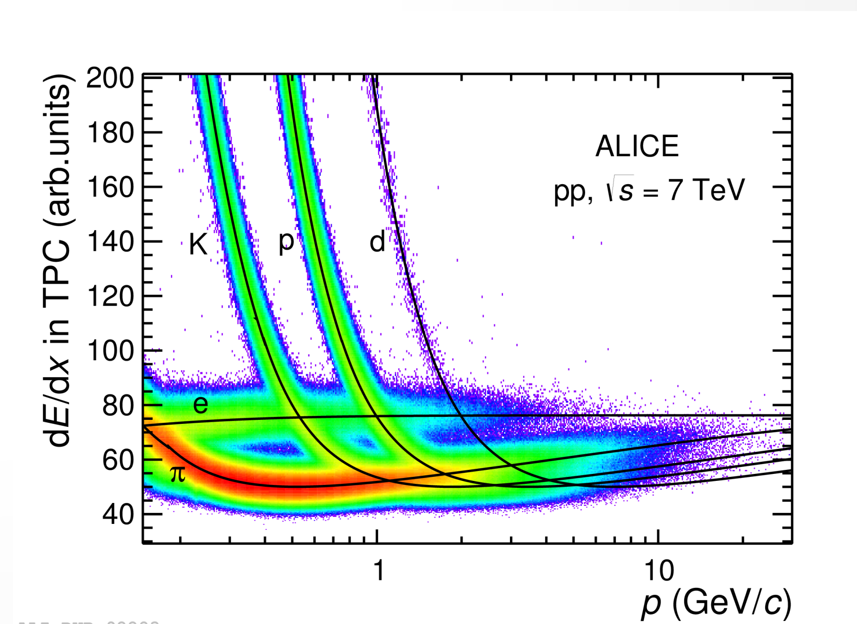
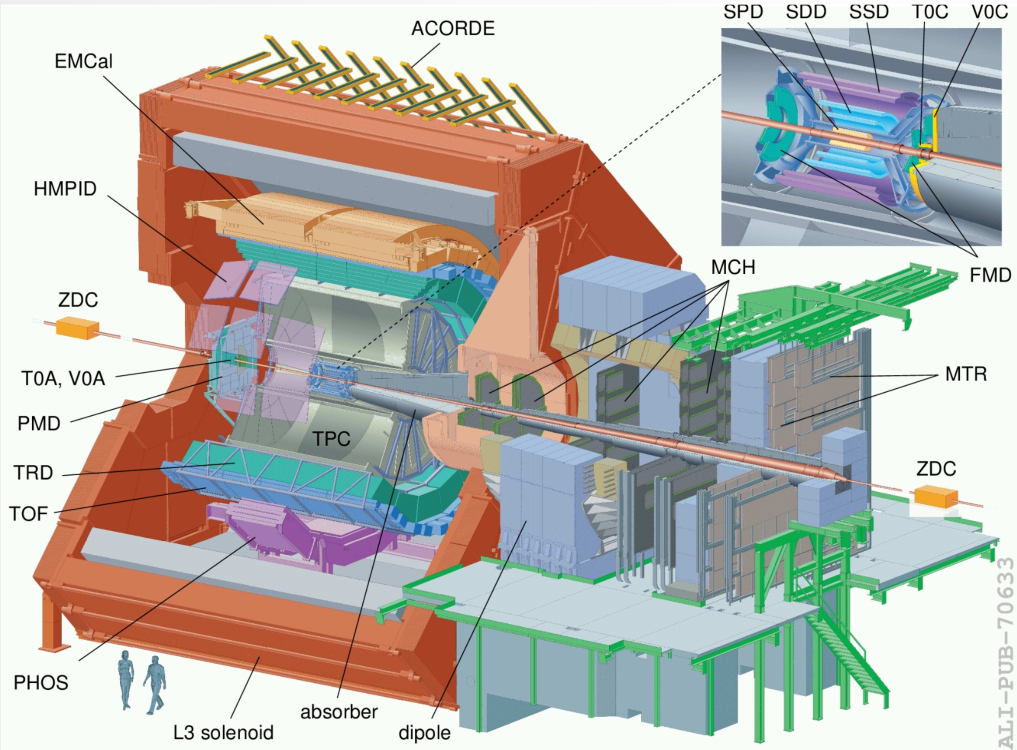
Detectors used for charged LF PID:

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

π: [0.2 – 0.5] GeV/c
K: [0.25 – 0.6] GeV/c
p: [0.4 – 0.8] GeV/c
+ relativistic rise



π/K/p PID



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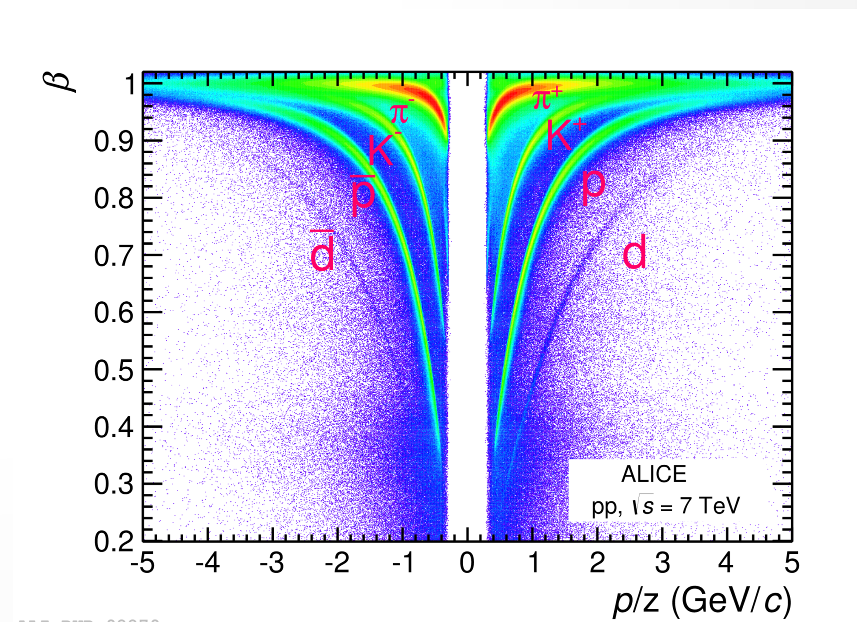
Detectors used for charged LF PID:

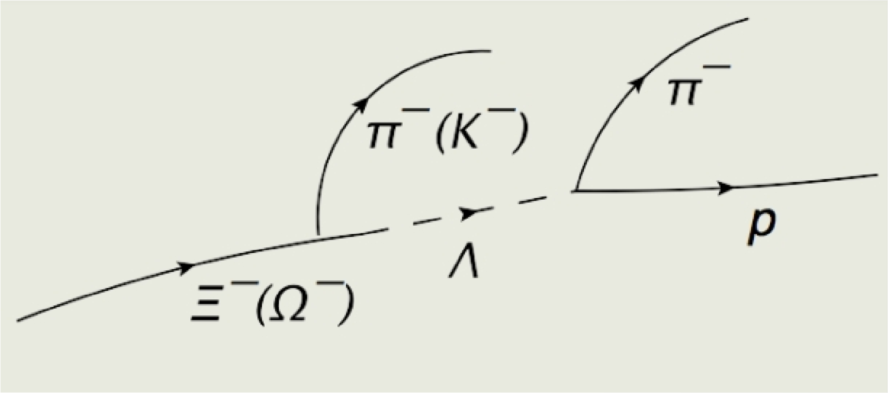
- Inner Tracking System (ITS)
  - also: trigger, tracking, vertex
- Time Projection Chamber (TPC)
  - also: tracking
- Time-Of-Flight (TOF)

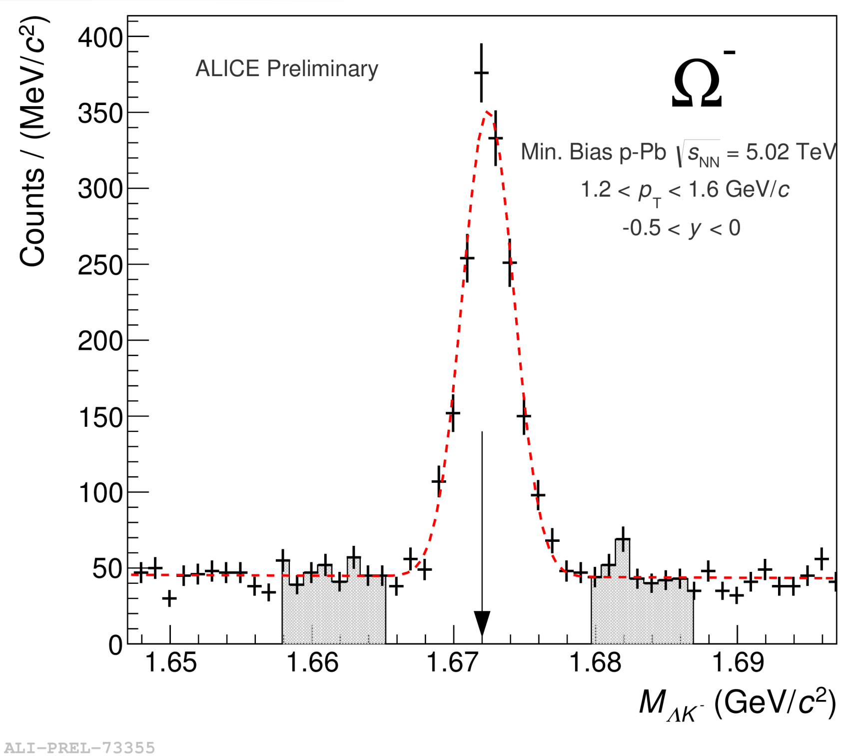
π: [0.5 – ~3] GeV/c
K: [0.6 – ~3] GeV/c
p: [0.8 – ~4] GeV/c

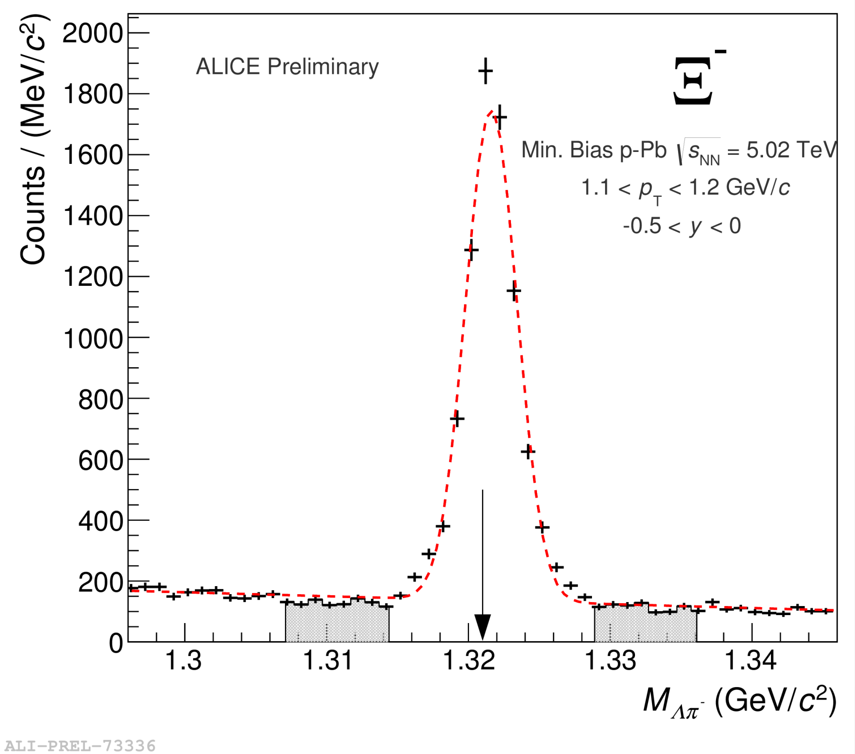


Strange baryon reconstruction

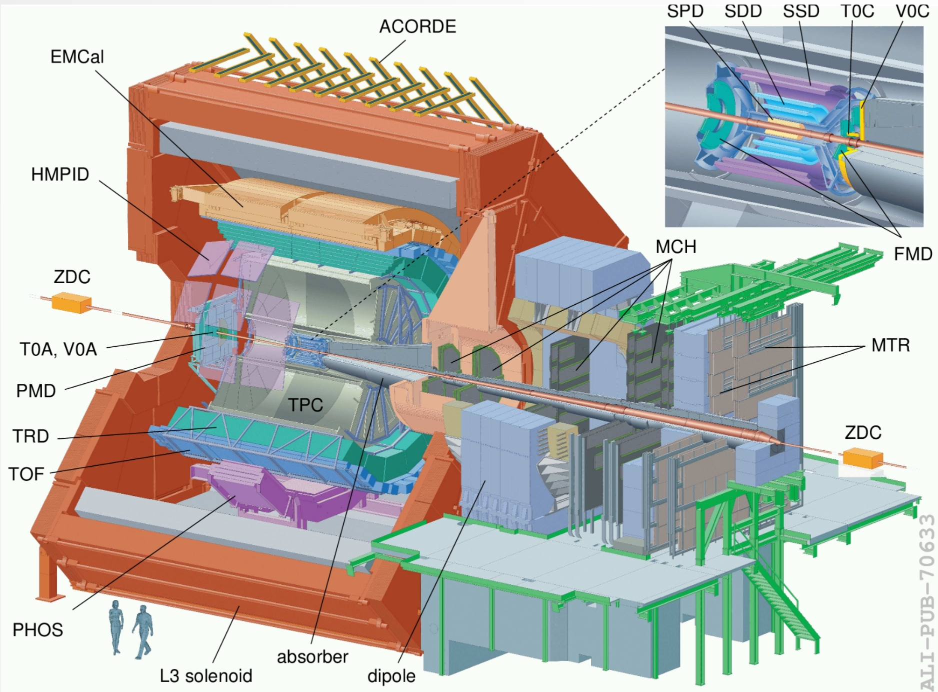
- Topological PID of weakly decaying strange baryons:
  - Λ = |uds>
  - Ξ = |dss>
  - Ω = |sss>







Multiplicity estimation



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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

Multiplicity estimation:

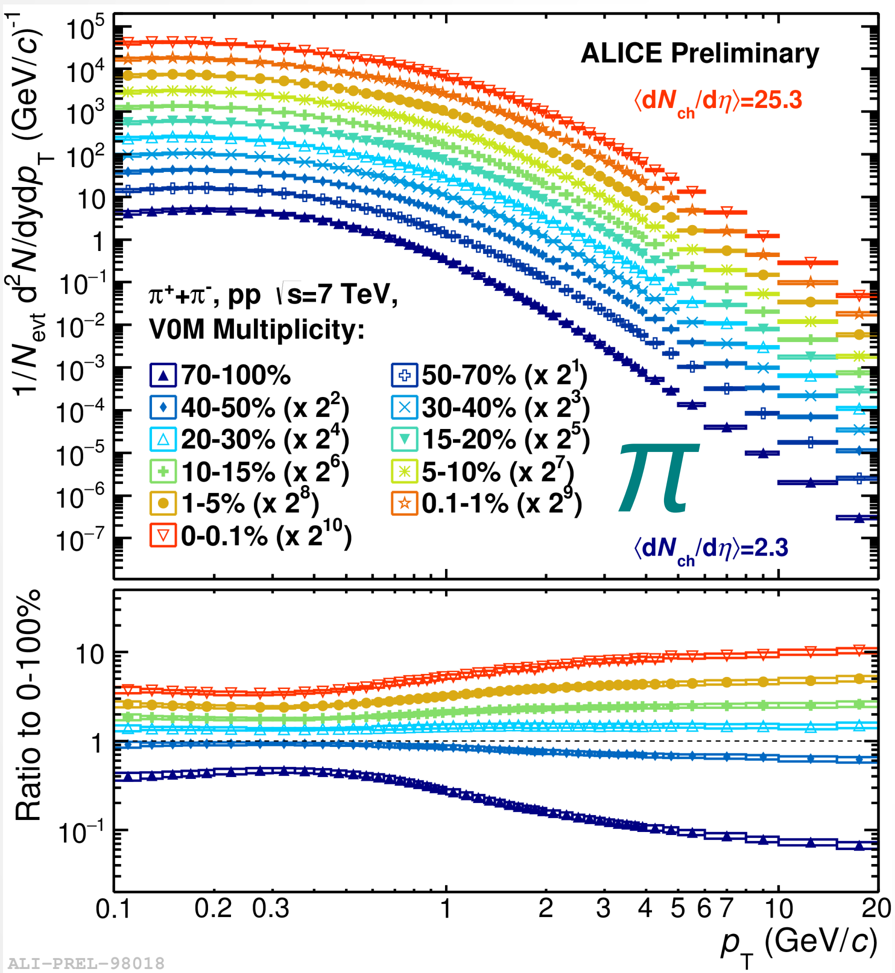
- V0M – multiplicity estimator at forward rapidities
  - Two plastic scintillators: V0A ($2.8 < \eta < 5.1$) and V0C ($-3.7 < \eta < -1.7$)
  - V0M = V0A + V0C
  - Only events with at least one charged particle at midrapidity are considered for event samples
  - For cross-checks, studies based on the average number of charged tracks at midrapidity ranges have been done, but auto-correlation biases have been observed

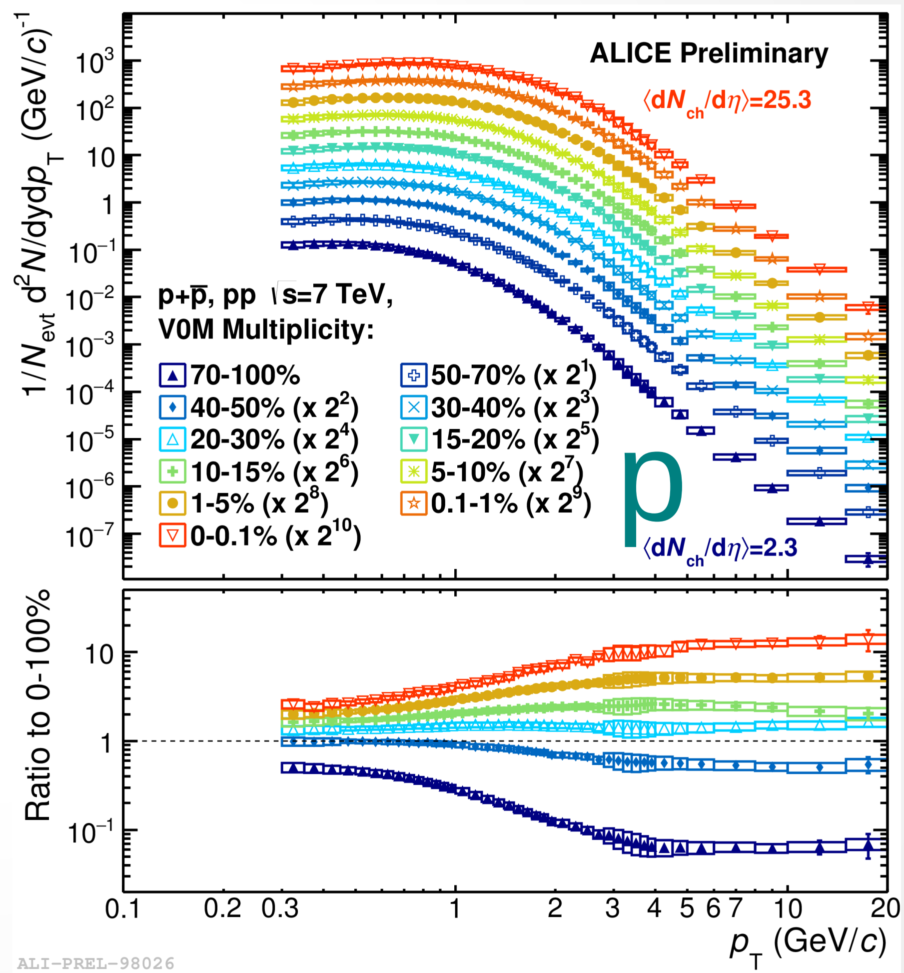
Results

π & p spectra vs multiplicity

- p_T-differential spectra in V0M multiplicity bins
- Ratio to inclusive spectra (INEL>0) (à la "R_{pp}")

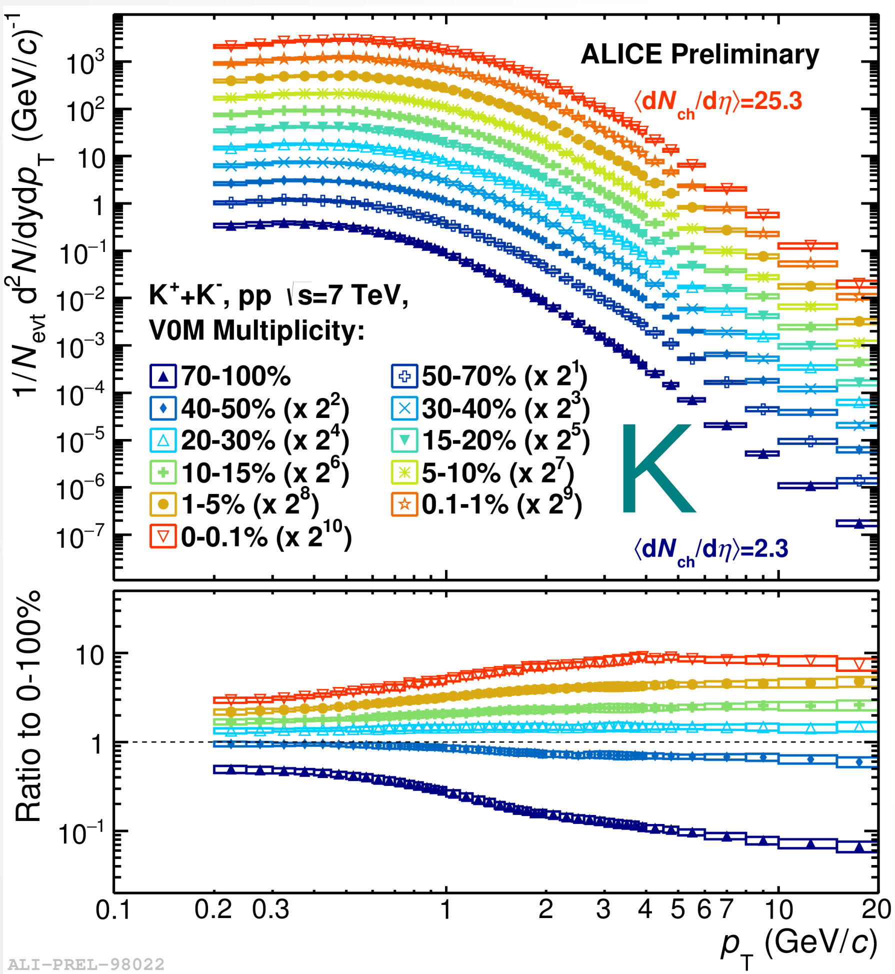
- Hardening with increasing multiplicity
- Flattening at high p_T (ratios to MB) – Multi-parton interaction (MPI) scaling?

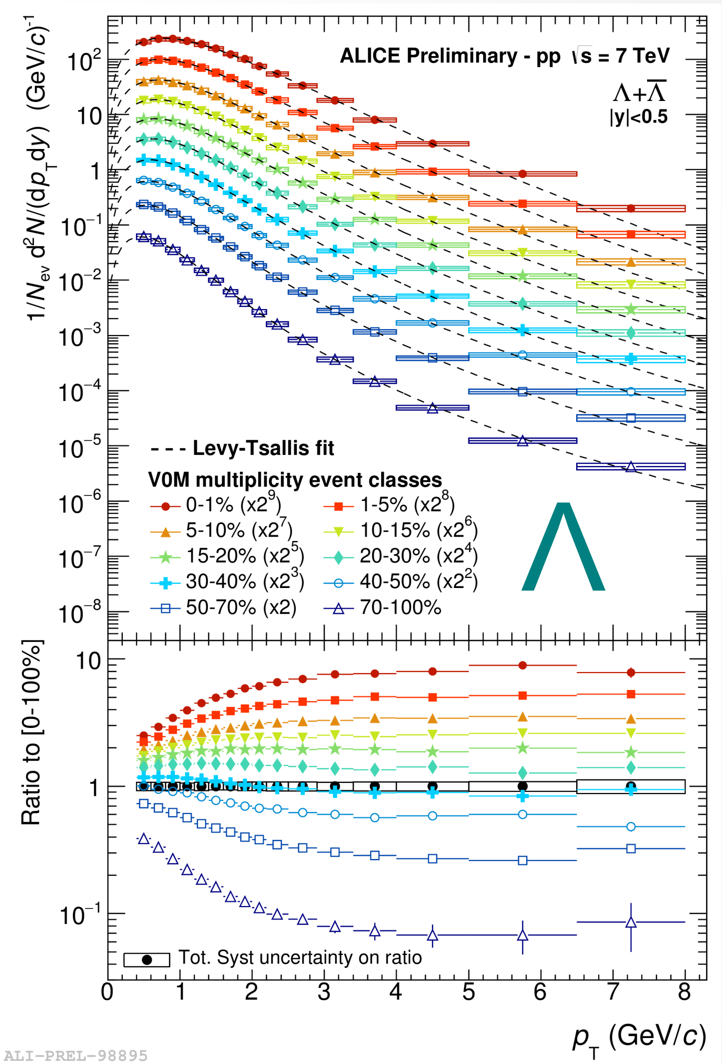




K & Λ spectra vs multiplicity

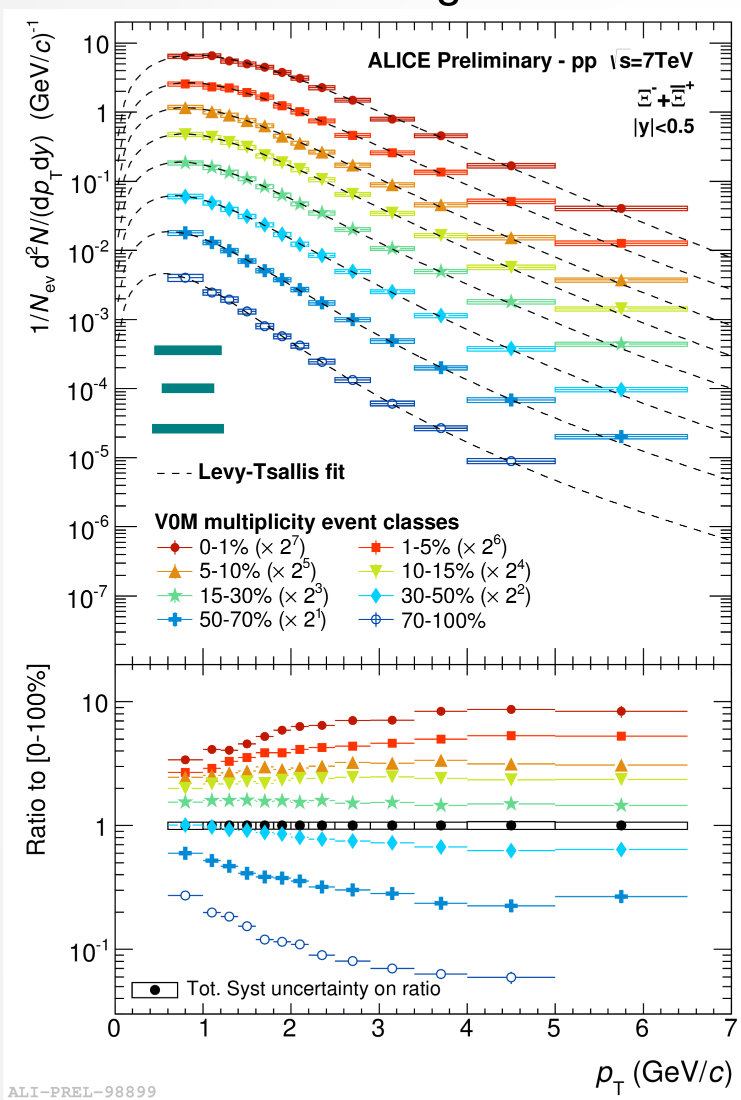
Similar effects seen in strange hadron spectra:

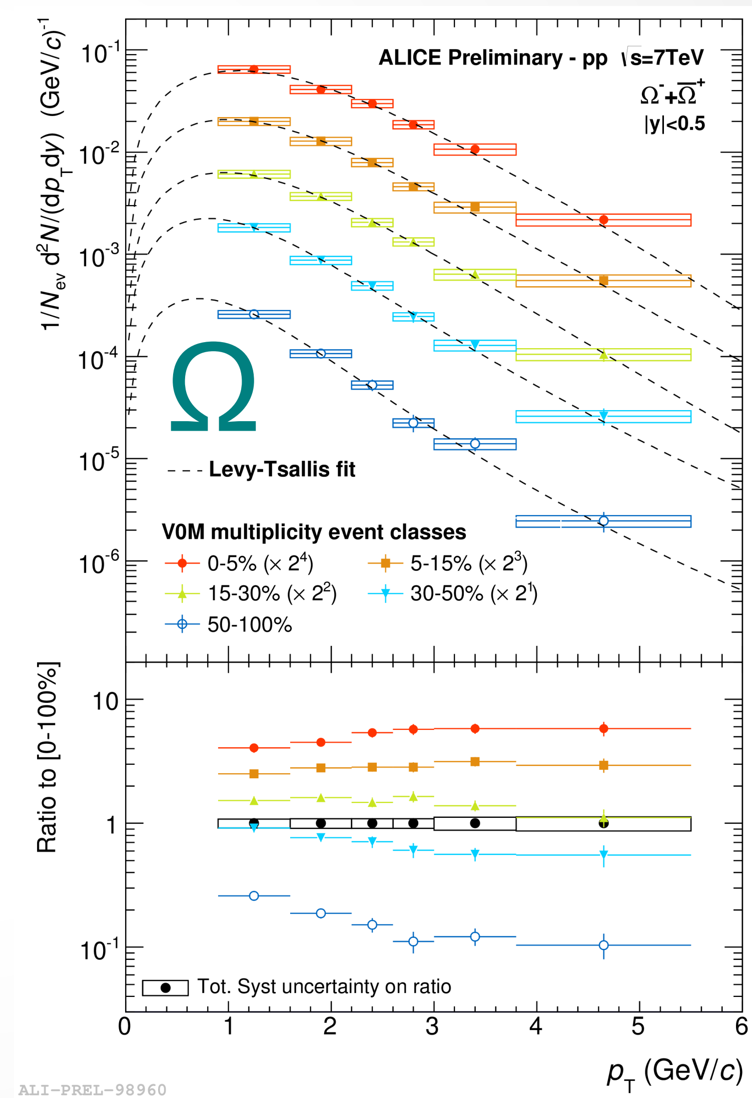




Ξ & Ω spectra vs multiplicity

And even for multi-strange hadrons:

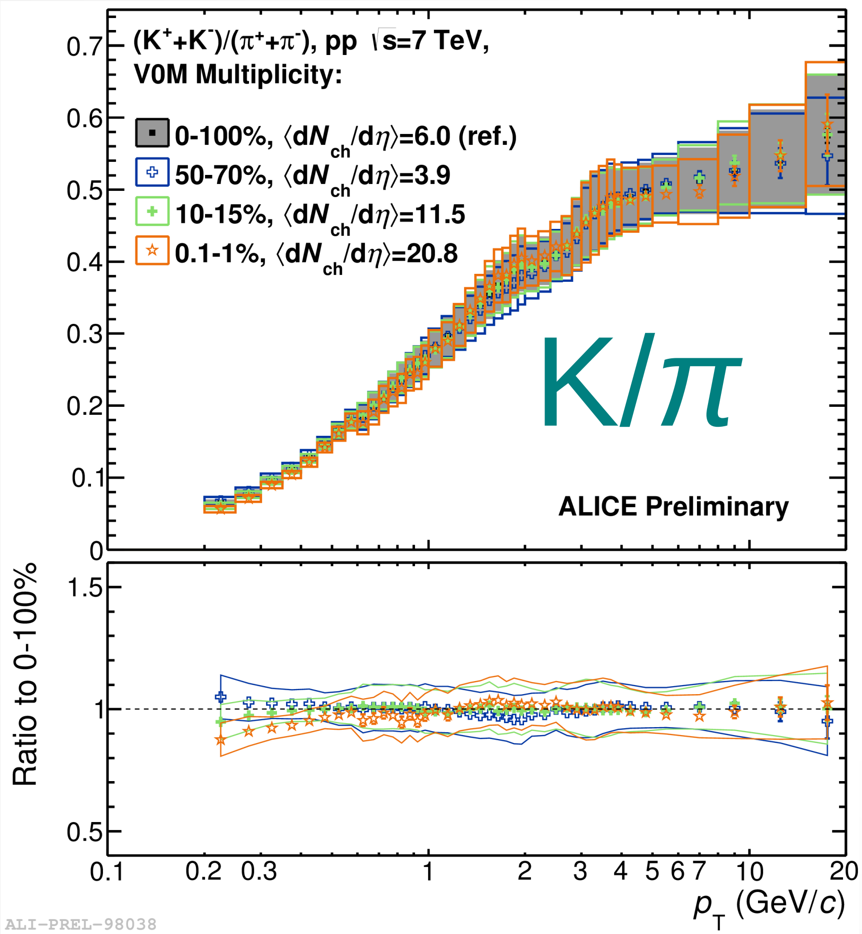


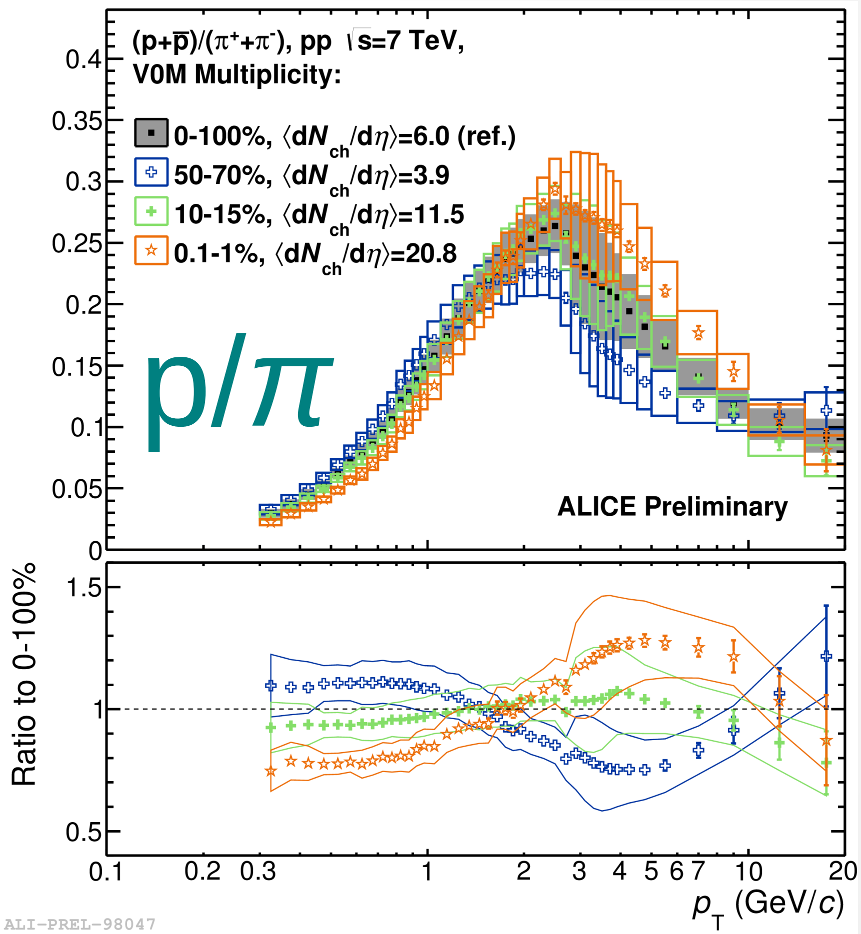


p_T-differential ratios vs. multiplicity

K/π, p/π ratios:

- p/π shows much stronger variation with multiplicity than K/π
  - Mass ordering
- But there is more...

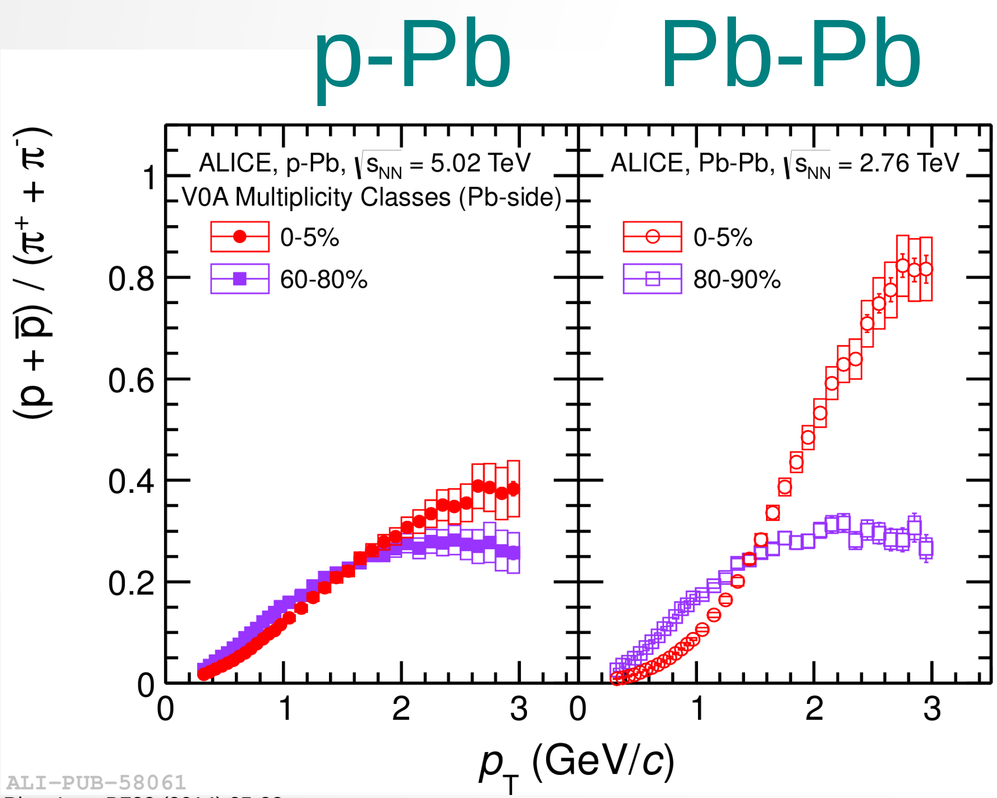




p_T-differential ratios vs. multiplicity

Baryon/meson ratios:

- Qualitatively similar trends in all systems
- Crossing point ~ 1.5 GeV/*c*
- Different magnitudes, but note different multiplicity densities



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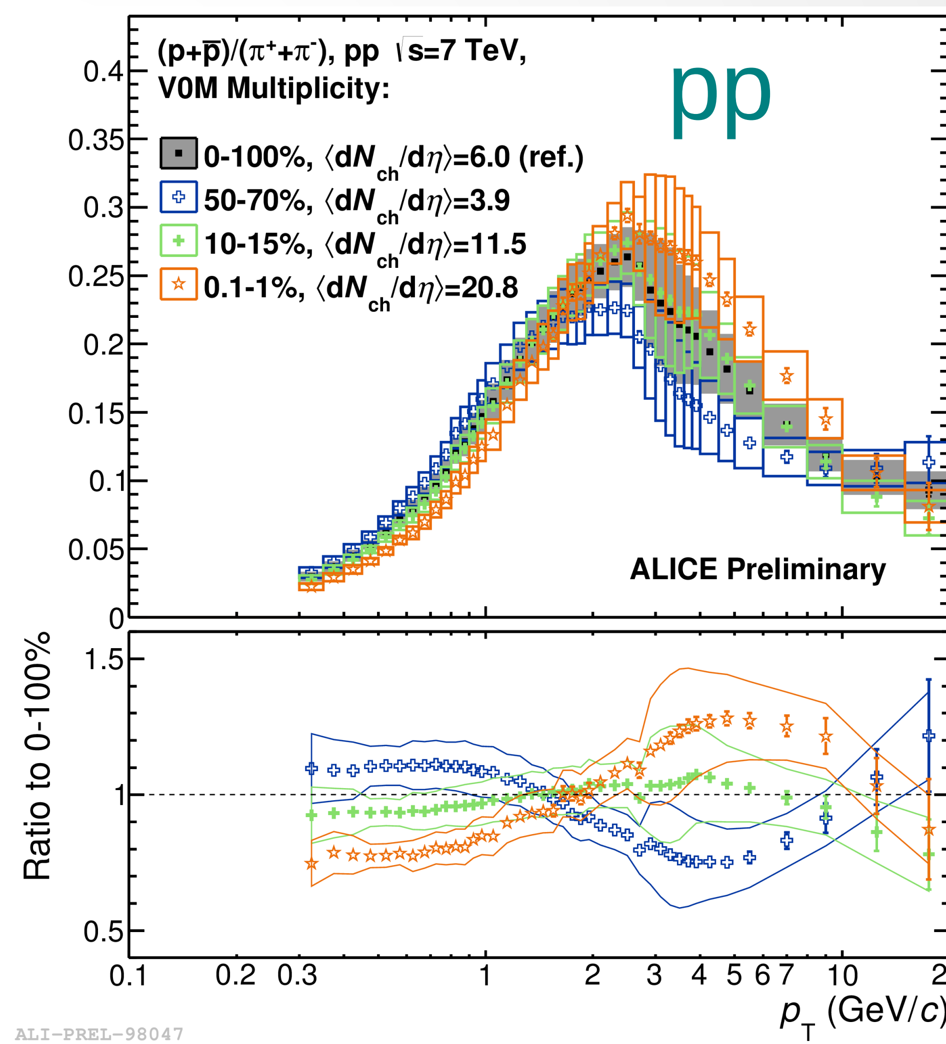
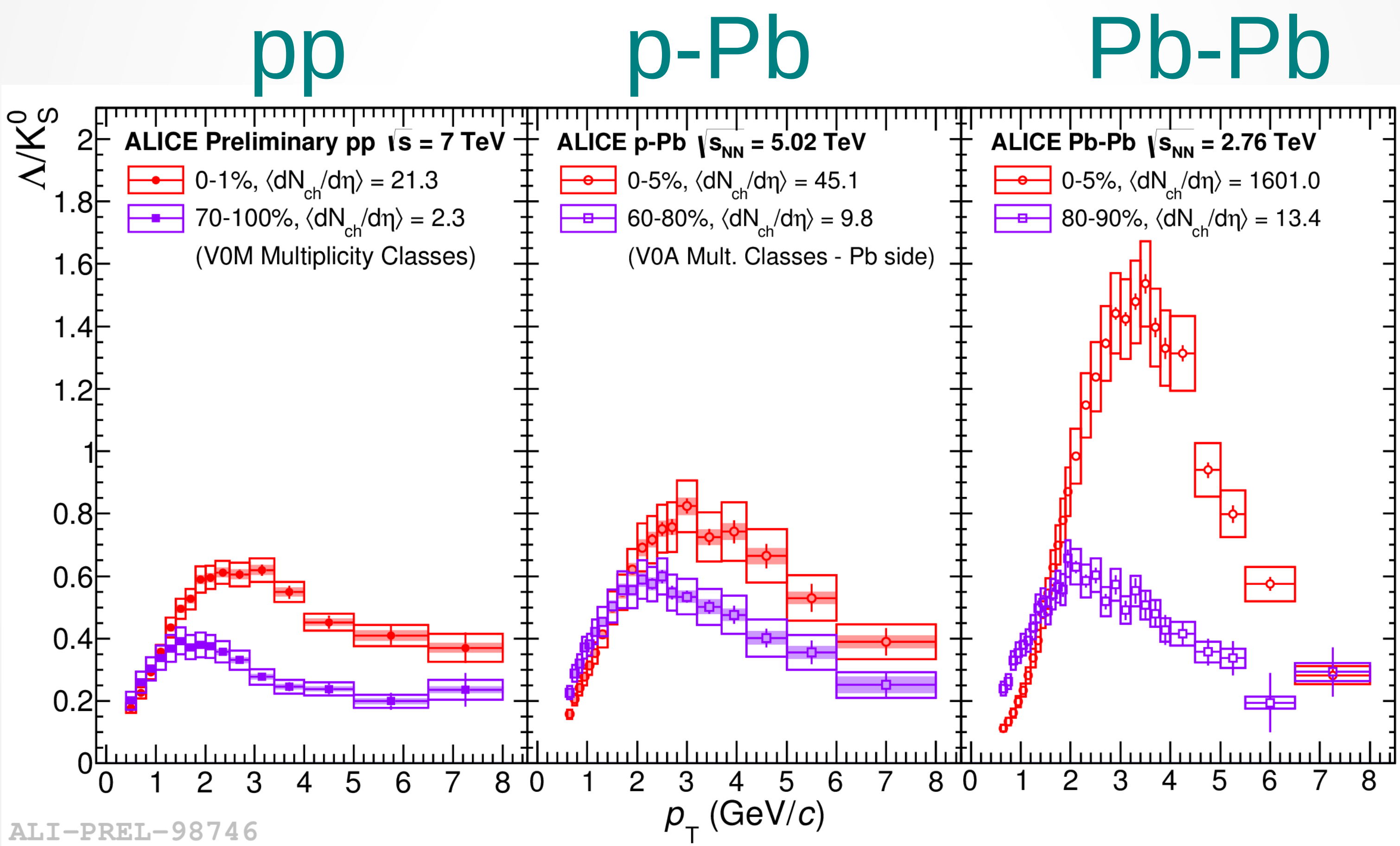


p_T-differential ratios vs. multiplicity

Strange baryon/meson ratios:

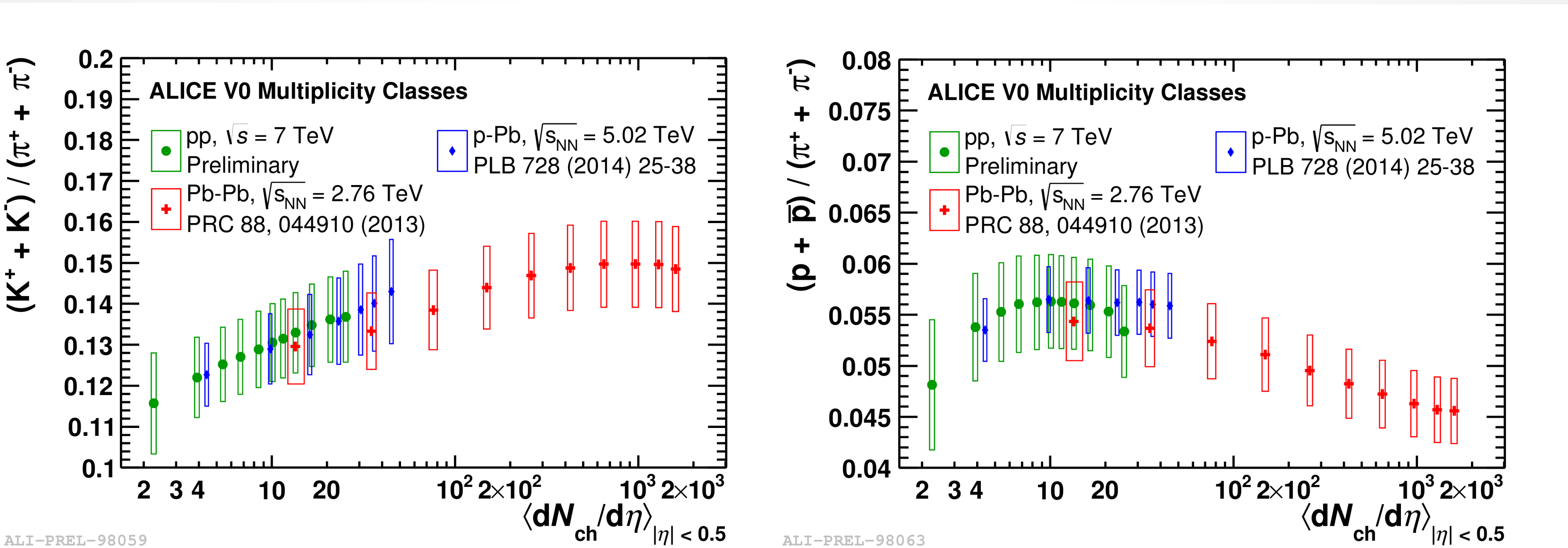
- Same trends for strange hadrons!



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 $p_T \to \infty$ extrapolation)
- Both K/π and p/π ratios consistent between different colliding systems for the similar $dN_{ch}/d\eta$

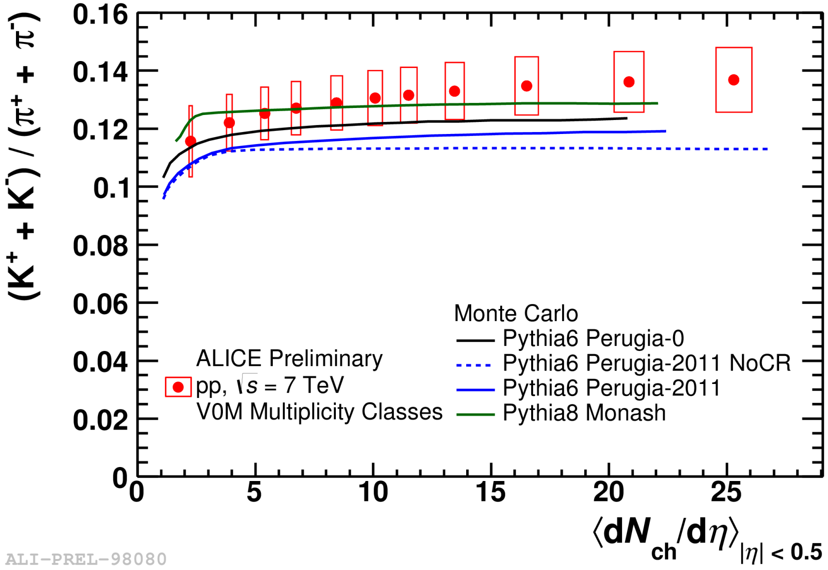


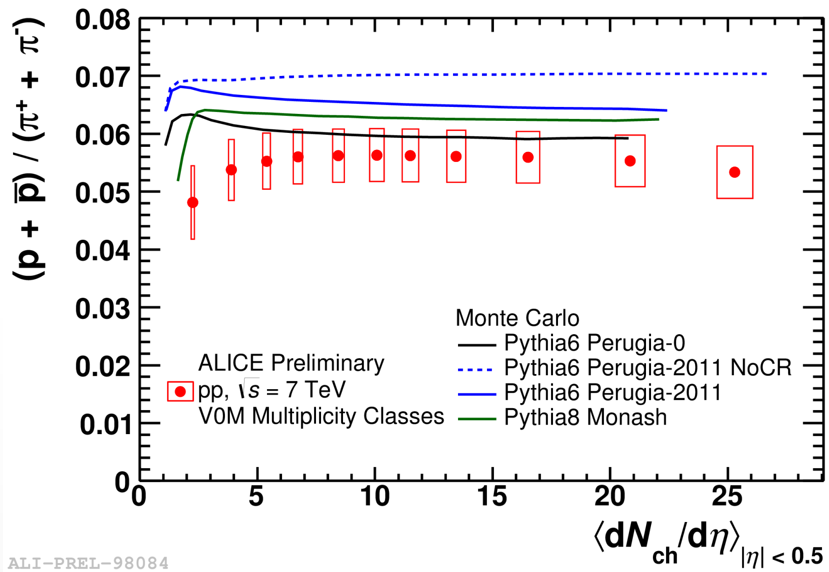
***Multiplicity uncorrelated errors are not shown here, but will be included in the forthcoming publication

Comparison to MC event generators

Integrated yield ratios:

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

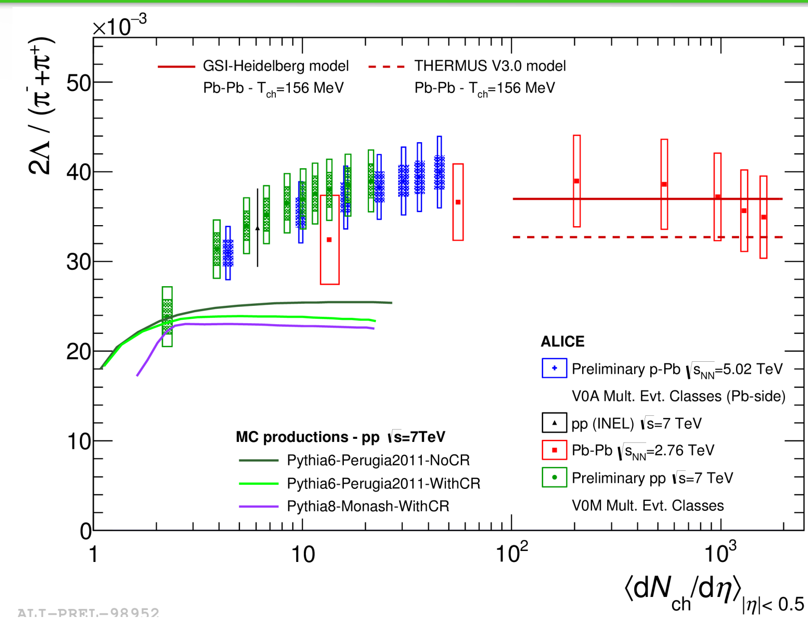




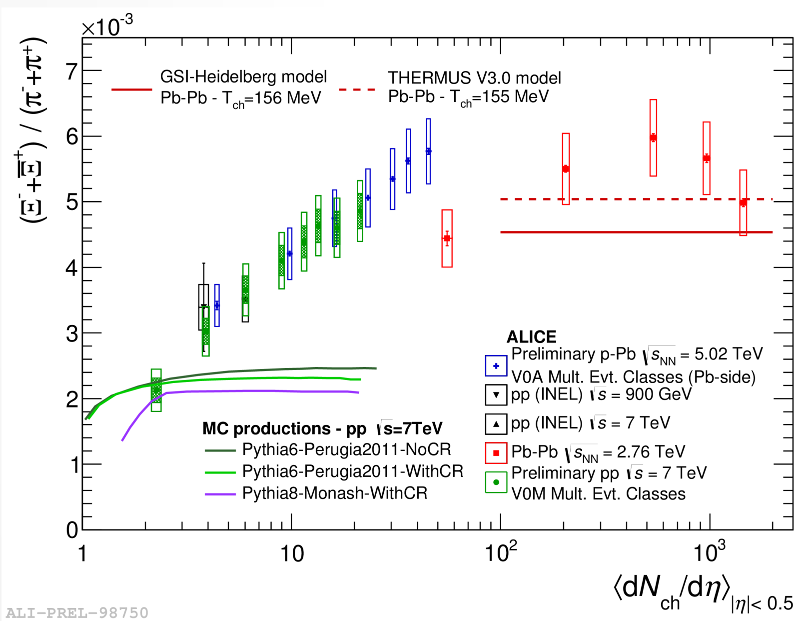
Comparison to MC event generators

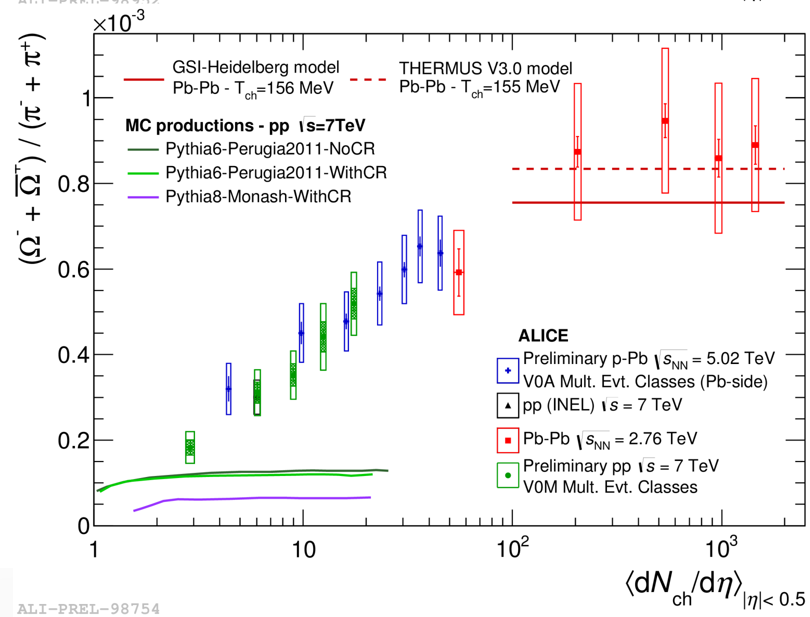
Ratios vs. multiplicity in pp:

- Smooth trend in pp → pA → AA with multiplicity
- Λ/π and Ξ/π reach predicted grand canonical 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



MC tunes do not show rise in multiplicity, while data does!



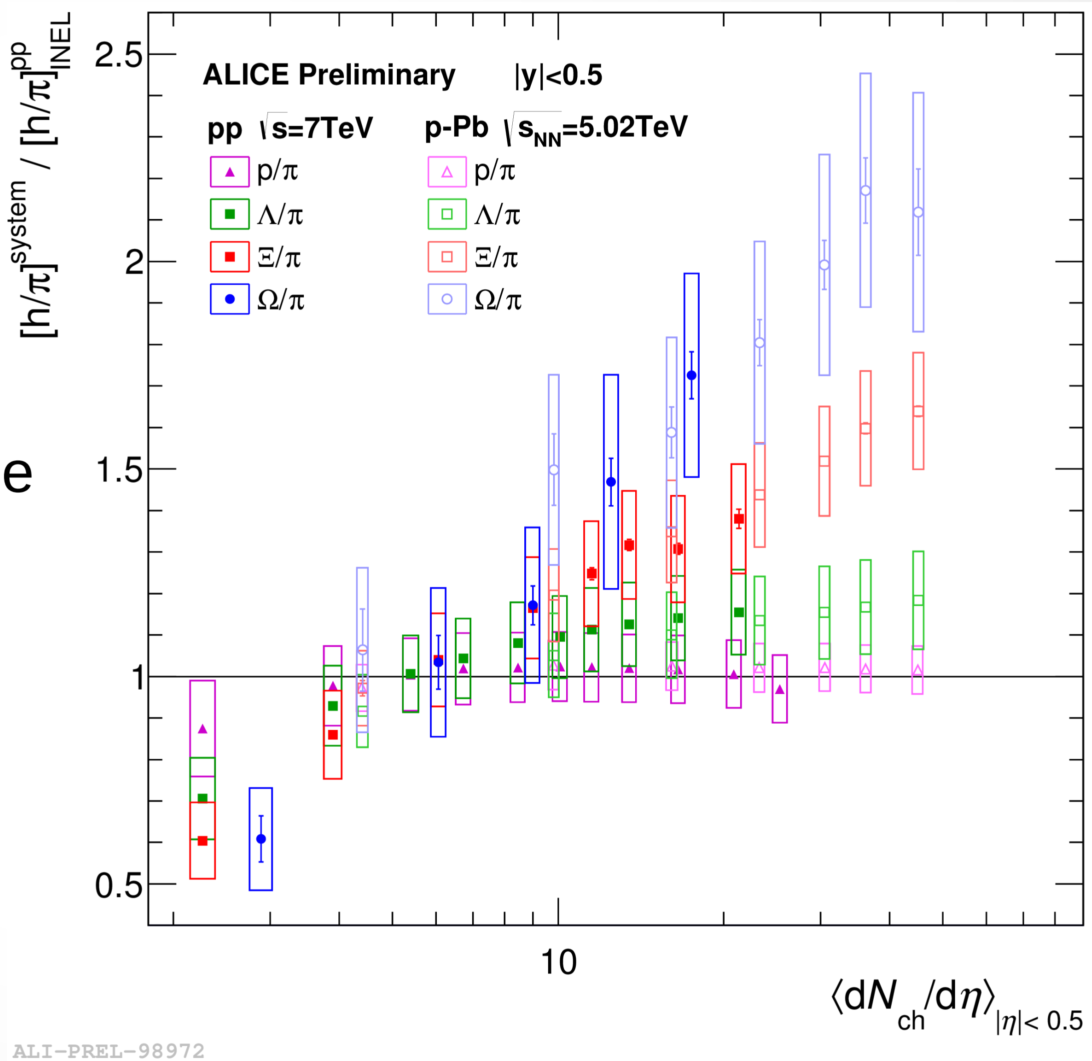


Baryon-to-pion ratios: comparison to pp_{INEL}

pp and pA ratios normalized to pp_{INEL}

- Protons: consistent with unity in considered multiplicity range
- Slope increases with strangeness content, not related to baryon number related increase

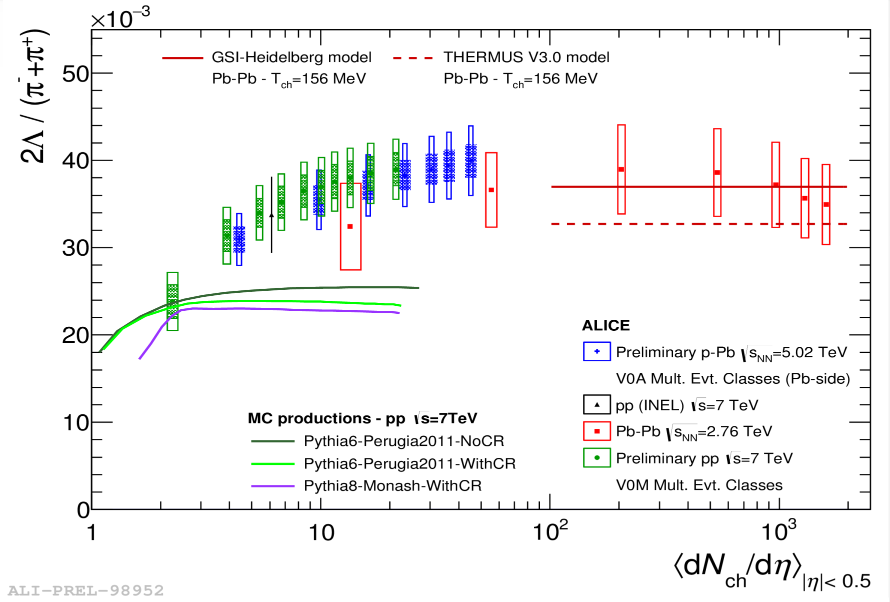
→ Strangeness-related increase of ratio vs. multiplicity

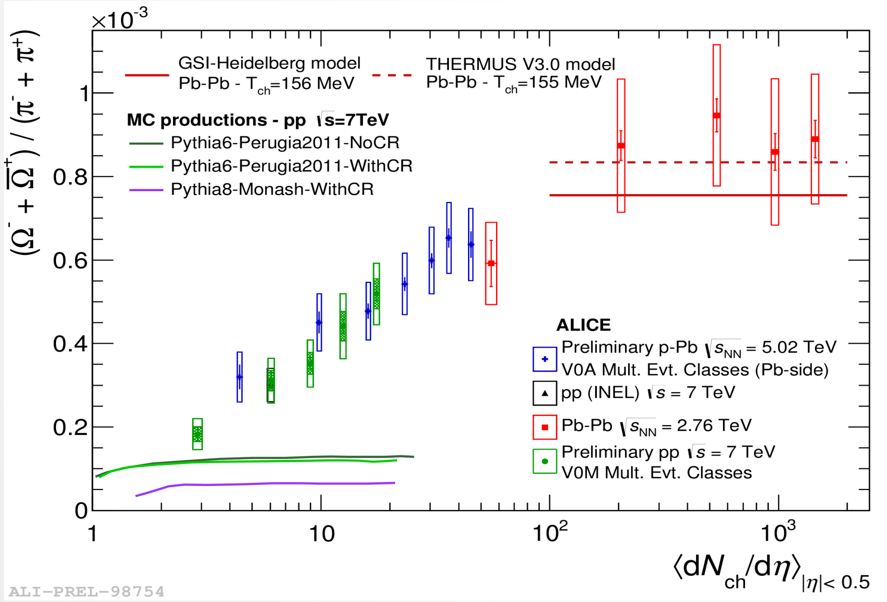


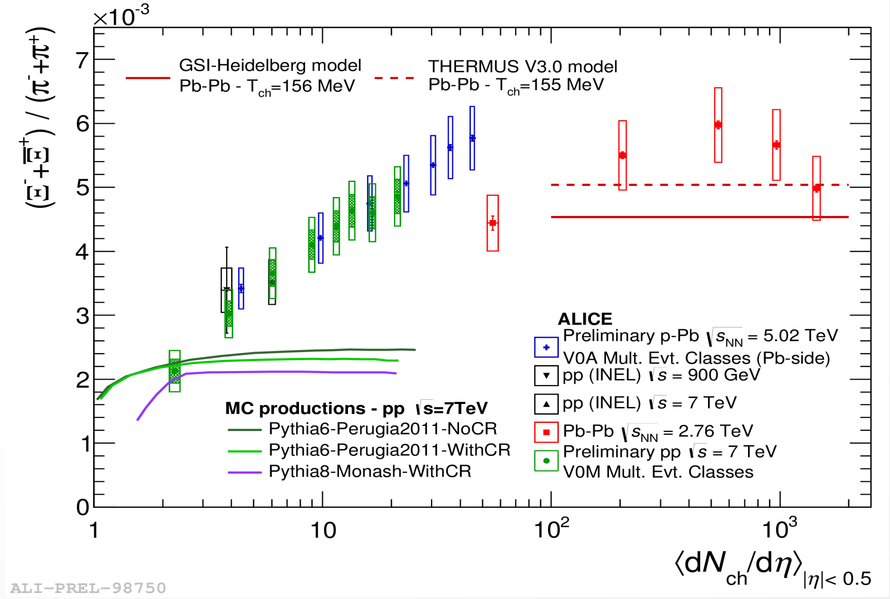
Comparison to thermal model calculations using strangeness-canonical ensemble

Another look into pp and pA

- Λ/π, Ξ/π, Ω/π approaching grand canonical saturation limit in a similar way







Comparison to thermal model calculations using strangeness-canonical ensemble

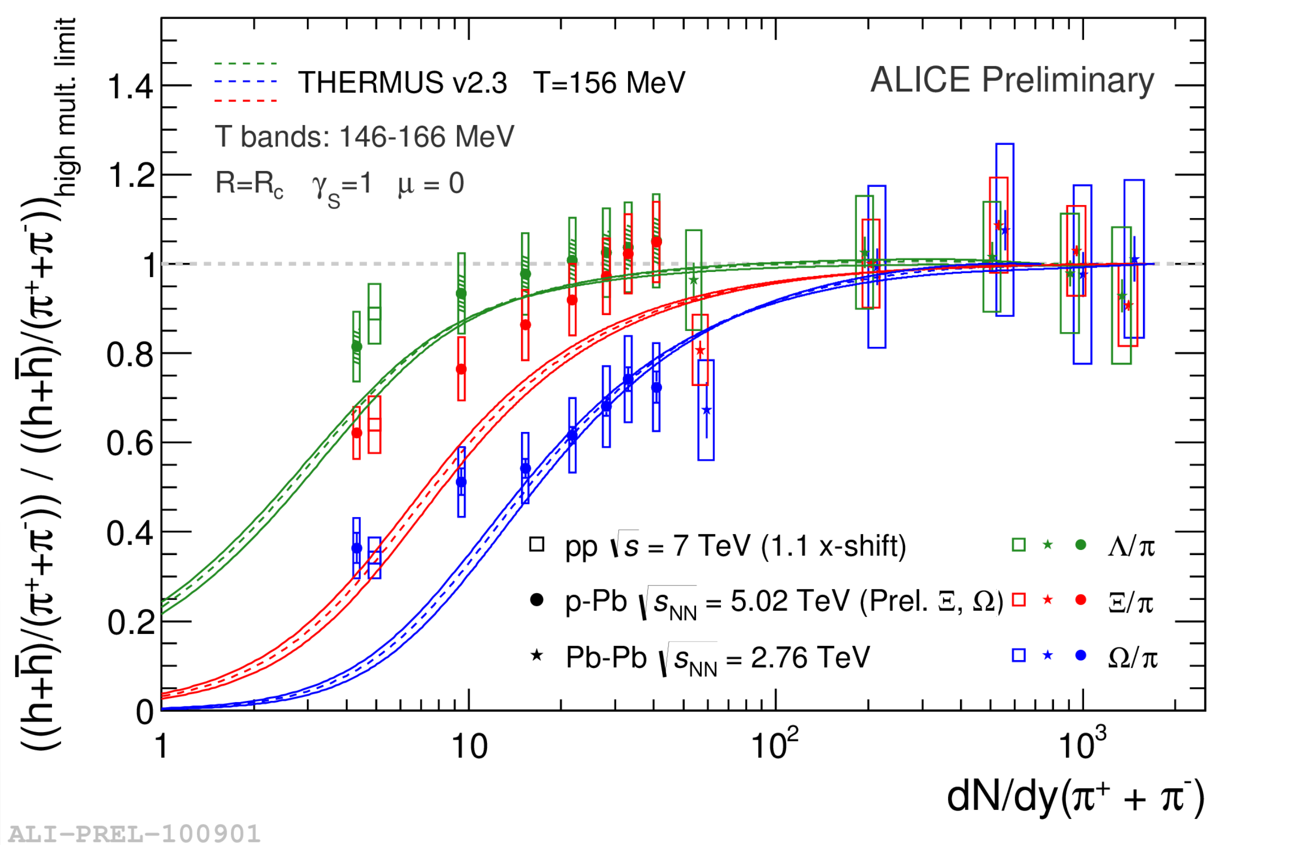
Another look into pp and pA

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

- Consider strange hadron to π ratio at high multiplicity limit
- Trend for Λ/π, Ξ/π, Ω/π described by THERMUS (qualitatively)

Recap:

- Measuring the ratios in pp allows us to test the validity of QCD-based event generators (Pythia, Dipsy, etc.). It is one of the goals of this workshop to see how well they can describe the strangeness enhancement while keeping p/π ratios flat.
- *Macroscopic* models (e.g. Thermal model) are well suited to describe the data



Summary

Identified hadron production as a function of event multiplicity in pp collisions at $\sqrt{s}$ = 7 TeV has been measured and reported by the ALICE collaboration

- Measured p_T-differential hadron spectra harden with multiplicity
- Ratios of p_T-differential spectra 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
  - Trends not reproduced by Pythia 6 & 8

Backup

$\langle dN_{ch}/d\eta \rangle$ vs. V0M

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
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40 - 50	5.4 ± 0.2	50 - 70	3.9 ± 0.1
70 - 100	2.3 ± 0.1	0 - 100	6.0 ± 0.2

Particle Identification in ALICE

π/K/p: 5 different analysis, combined into one:

Analysis	PID Technique	p_T Range (GeV/c)			Analysis Region
		π	K	p	
ITS stand-alone	n-σ cuts on ITS	$0.1 - 0.6$	$0.2 - 0.6$	$0.3 - 0.6$	$\lvert y \rvert < 0.5$
Bayesian PID	Bayesian probability	$0.2 - 2.5$	$0.3 - 2.5$	$0.5 - 2.5$	$\lvert y \rvert < 0.5$
TPC-TOF	n-σ cuts on TPC and TOF	$0.25 - 1.2$	$0.3 - 1.2$	$0.45 - 2.0$	$\lvert y \rvert < 0.5$
TPC-TOF Fits	n-σ fits to TPC and TOF	$0.25 - 2.5$	$0.3 - 2.5$	$0.45 - 2.7$	$\lvert y \rvert < 0.5$ (TPC) $\lvert \eta \rvert < 0.2$ (TOF)
TPC Template Fits	TPC dE/dx Template Fits	> 2.0			$\lvert \eta \rvert < 0.8$

$<p_T>$ 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