Multiplicity dependence of strange particle production in proton-proton collisions with the ALICE detector

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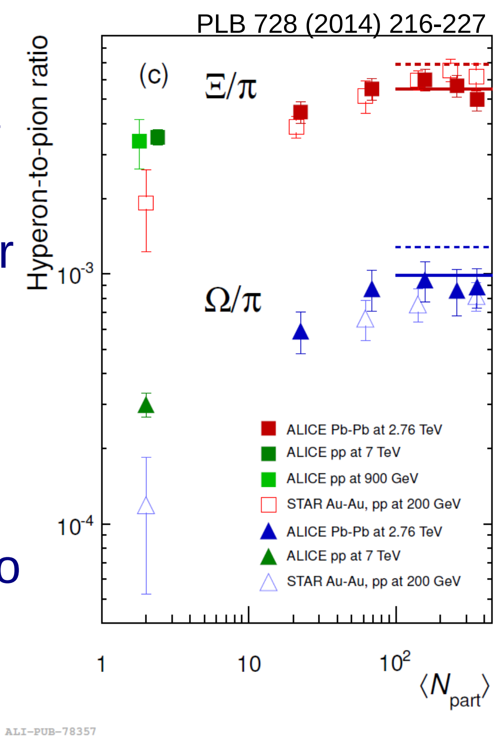
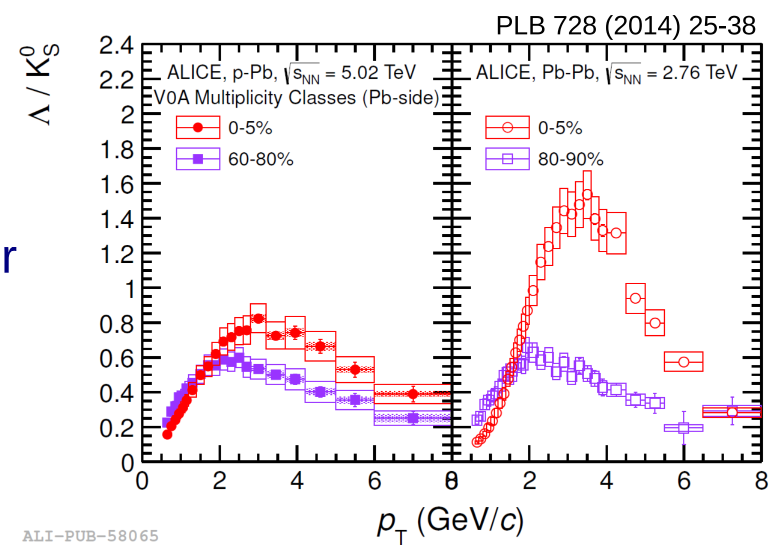
Outline

- Physics motivations
- The ALICE detector
  - multiplicity selection
- Detection of strange particles in ALICE
- Results: multiplicity dependence of
  - p_T-differential spectra
  - $\langle p_T \rangle$
  - Λ / K^0_S ratio as a function of p_T
  - Particle ratios
- Conclusions and Outlook

Physics motivation

- A-A collisions:
  - “Strangeness enhancement” originally proposed as a signature for the deconfinement[1]
  - “Baryon anomaly” observed in the strangeness sector
- p-A collisions:
  - Important for the correct interpretation of A-A results (disantangle final from initial-state effects)
  - Several multiplicity-dependent studies (e.g. Λ/K^0_S ratio vs p_T) show an evolution with multiplicity which is qualitatively similar to the one observed in A-A
- pp collisions:
  - Small system: no collectivity or deconfinement expected
  - Minimum bias pp used as a reference for “large” systems





[1] J. Rafelski and B. Muller, “Strangeness Production in the Quark–Gluon Plasma,” Phys. Rev. Lett. 48 (1982) 1066.

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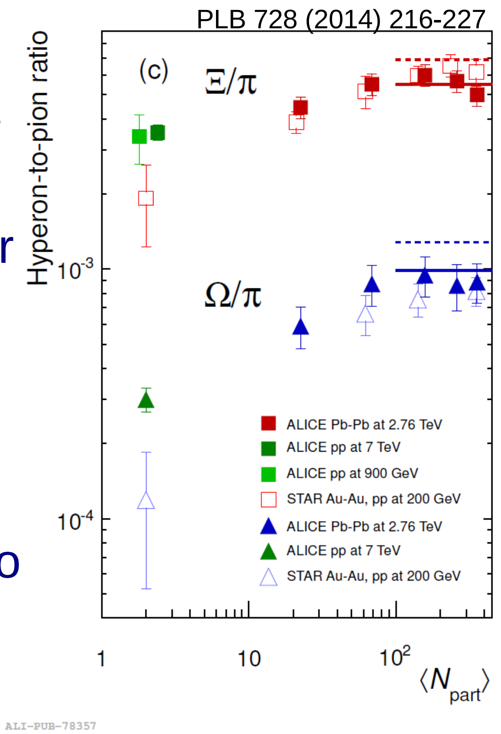
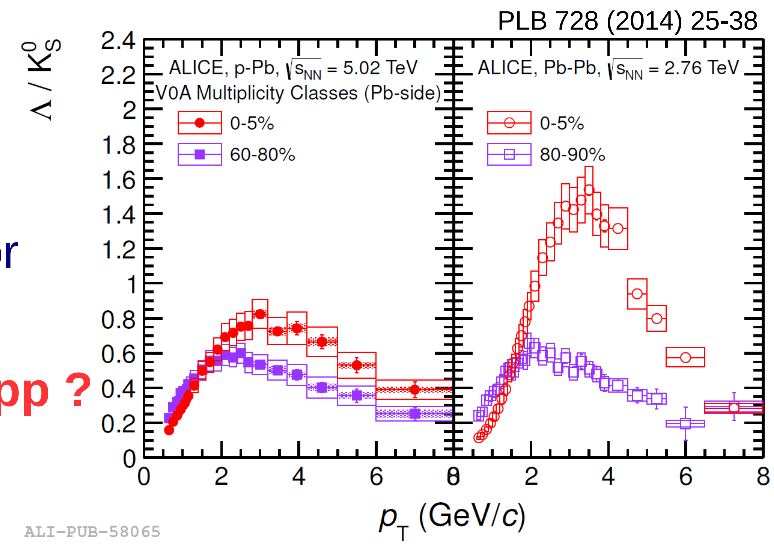
- pp collisions:
  - Small system: no collectivity or deconfinement expected
  - Minimum bias pp used as a reference for "large" systems
  - **Is there a multiplicity dependence in pp ?**





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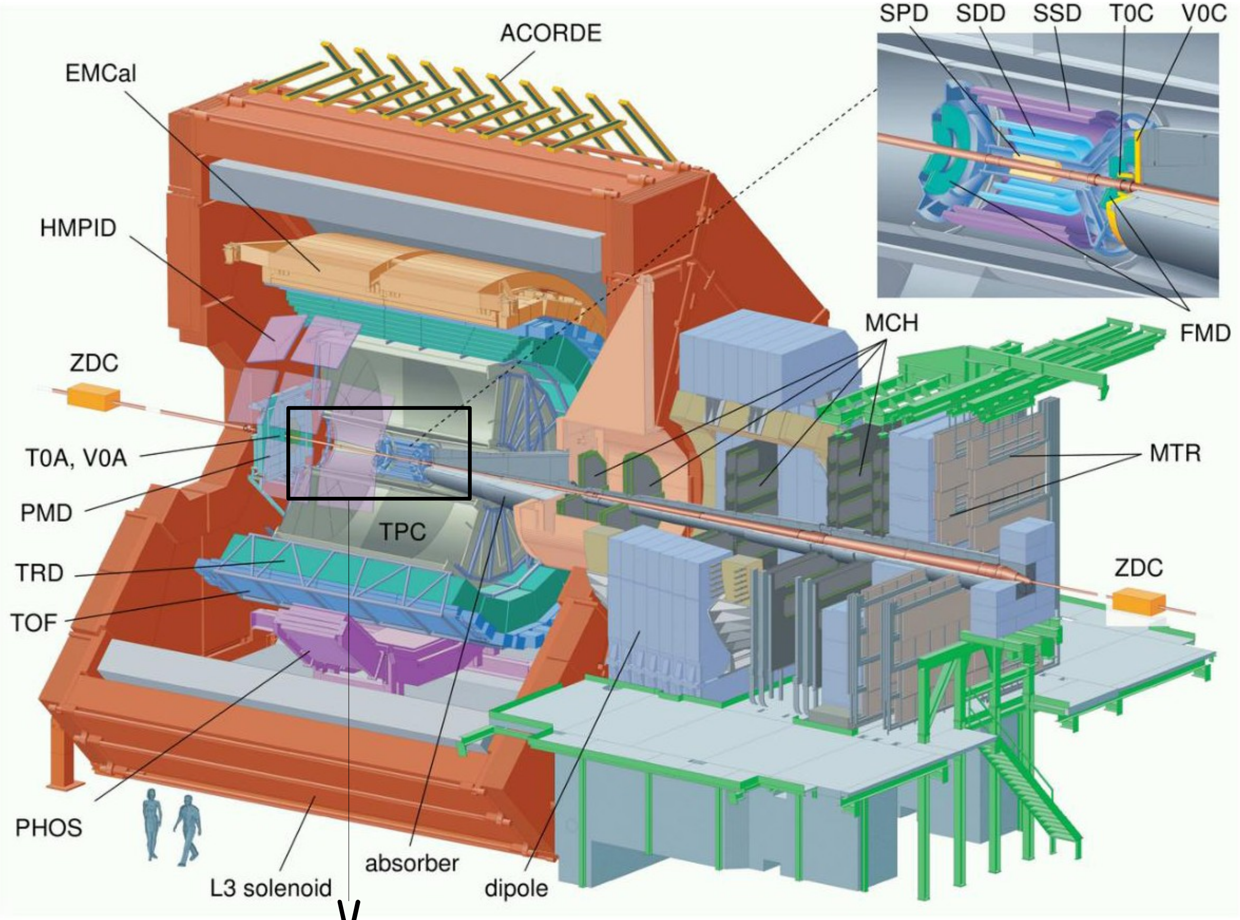
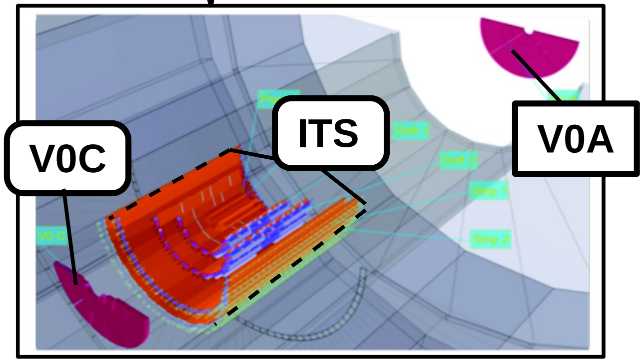
The ALICE detector





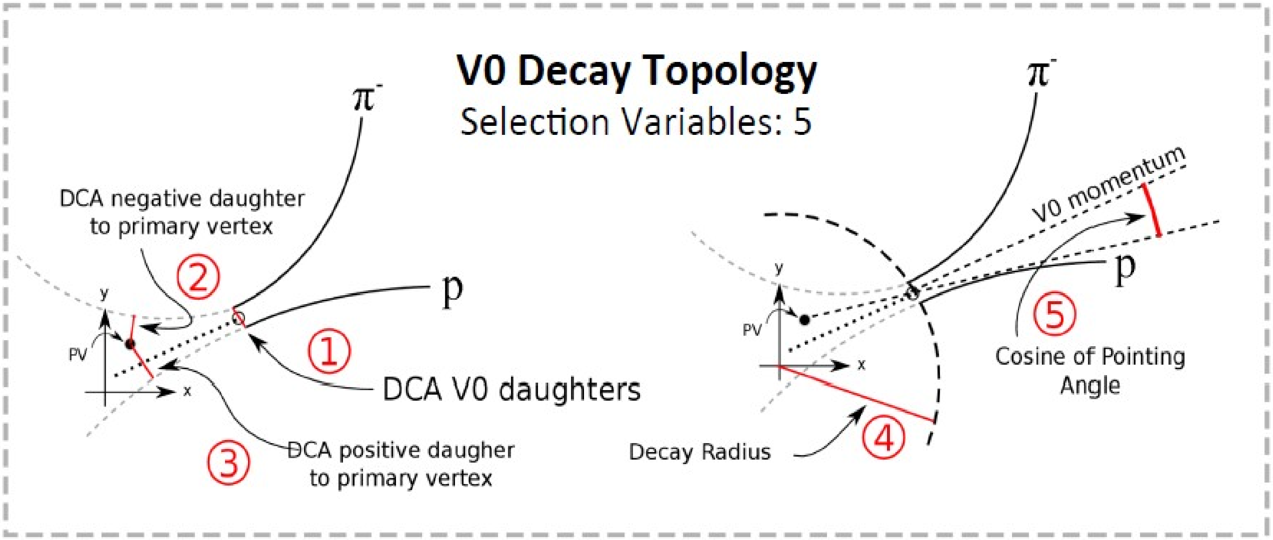
Main detectors employed for the analysis:

- **ITS (|η|<0.9):**
  - 6 layers of silicon detectors based on three different technologies (pixel, drift, strip)
  - primary vertex, tracking, PID (via dE/dx)
- **TPC (|η|<0.9):**
  - Gas-filled (Ne/CO_2) cylindrical barrel; MWPC used for the read-out
  - tracking (up to 159 points/ track), PID (via dE/dx)
- **V0**
  - Forward arrays of scintillators placed on either side of the interaction region (2.8 < η < 5.1 and -3.7 < η < -1.7)
  - trigger, beam gas rejection, **multiplicity estimation**

- Event selection performed via percentiles of the V0M amplitude distribution (V0A+V0C)
- $\langle dN_{ch}/d\eta \rangle$ estimated as the average number of primary charged tracks in |η|<0.5

Detection of strange particles

- Strange particles are identified through their specific decay topologies:



Single-strange partcles:

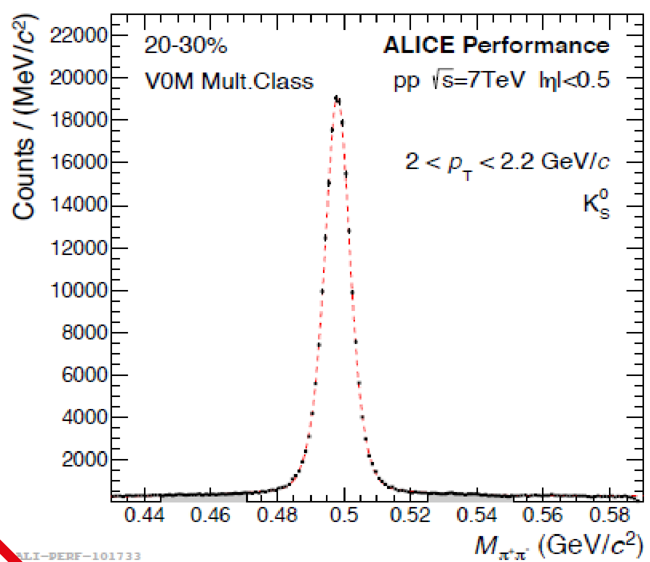
- $K^0_S \rightarrow \pi^+\pi^-$

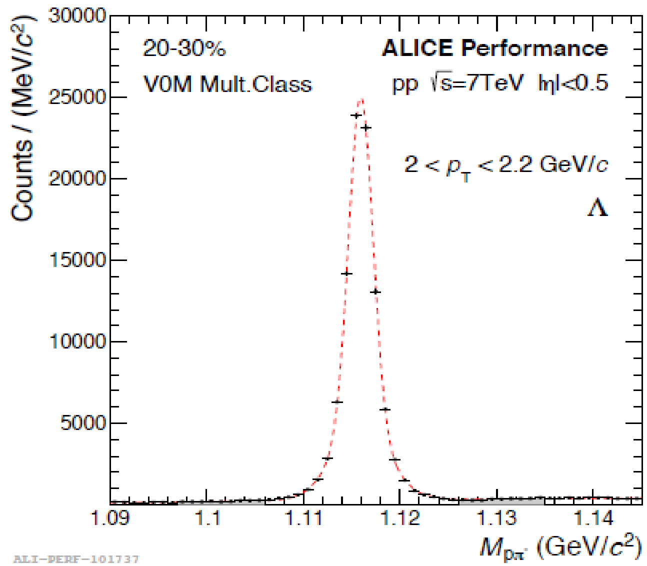
(B.R. 69.2 %, cτ = 2.68 cm)

- $\Lambda \rightarrow p\,\pi^-$

$\overline{\Lambda} \rightarrow \overline{p}\,\pi^+$

(B.R. 63.9 %, cτ = 7.89 cm)

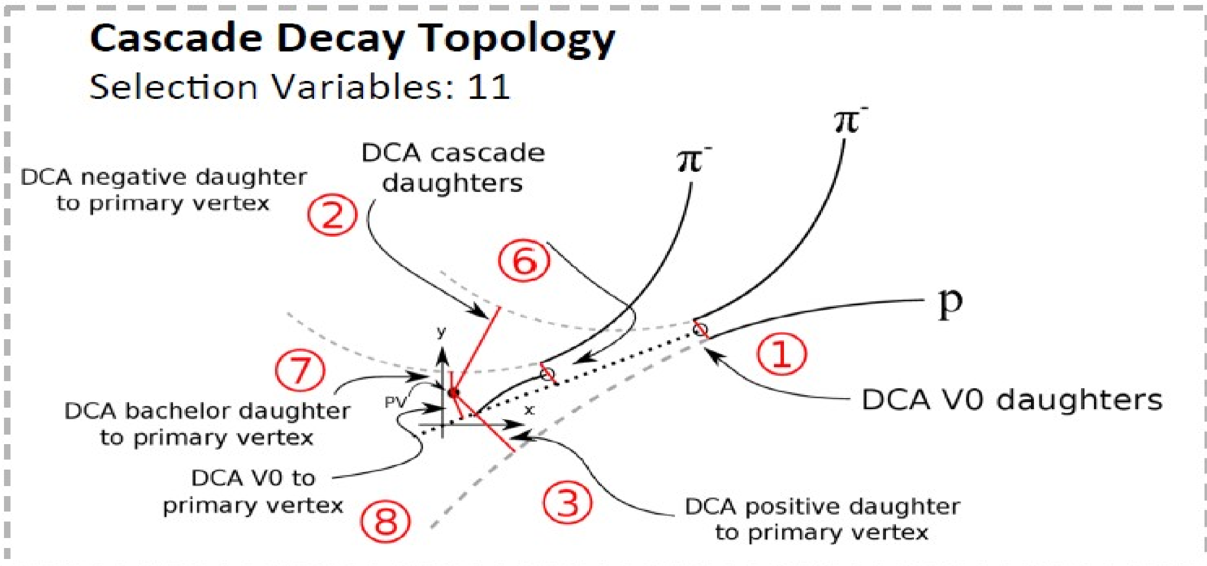




- Cuts tuned in order to optimize S/B
- Yields extracted by bin counting technique

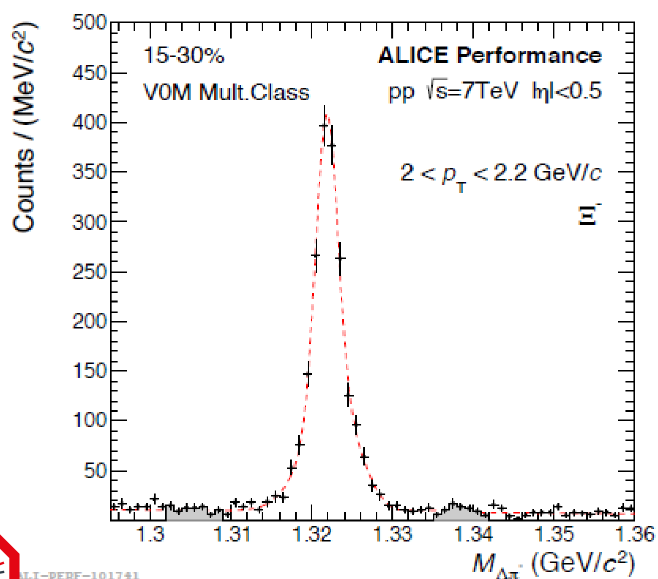
Detection of strange particles

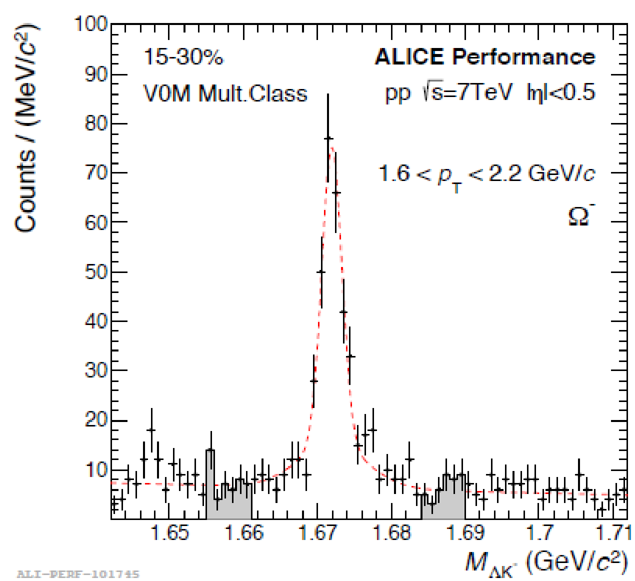
- ✔ Strange particles are identified through their specific decay topologies:



Multi-strange partcles:

- ✔ $\Xi^- \rightarrow \Lambda\ \pi^-$
  $\overline{\Xi}^+ \rightarrow \overline{\Lambda}\ \pi^+$
  (B.R. 99.9 %, $c\tau$ = 4.91 cm)
- ✔ $\Omega^- \rightarrow \Lambda\ K^-$
  $\overline{\Omega}^+ \rightarrow \overline{\Lambda}\ K^+$
  (B.R. 67.8 %, $c\tau$ = 2.46 cm)

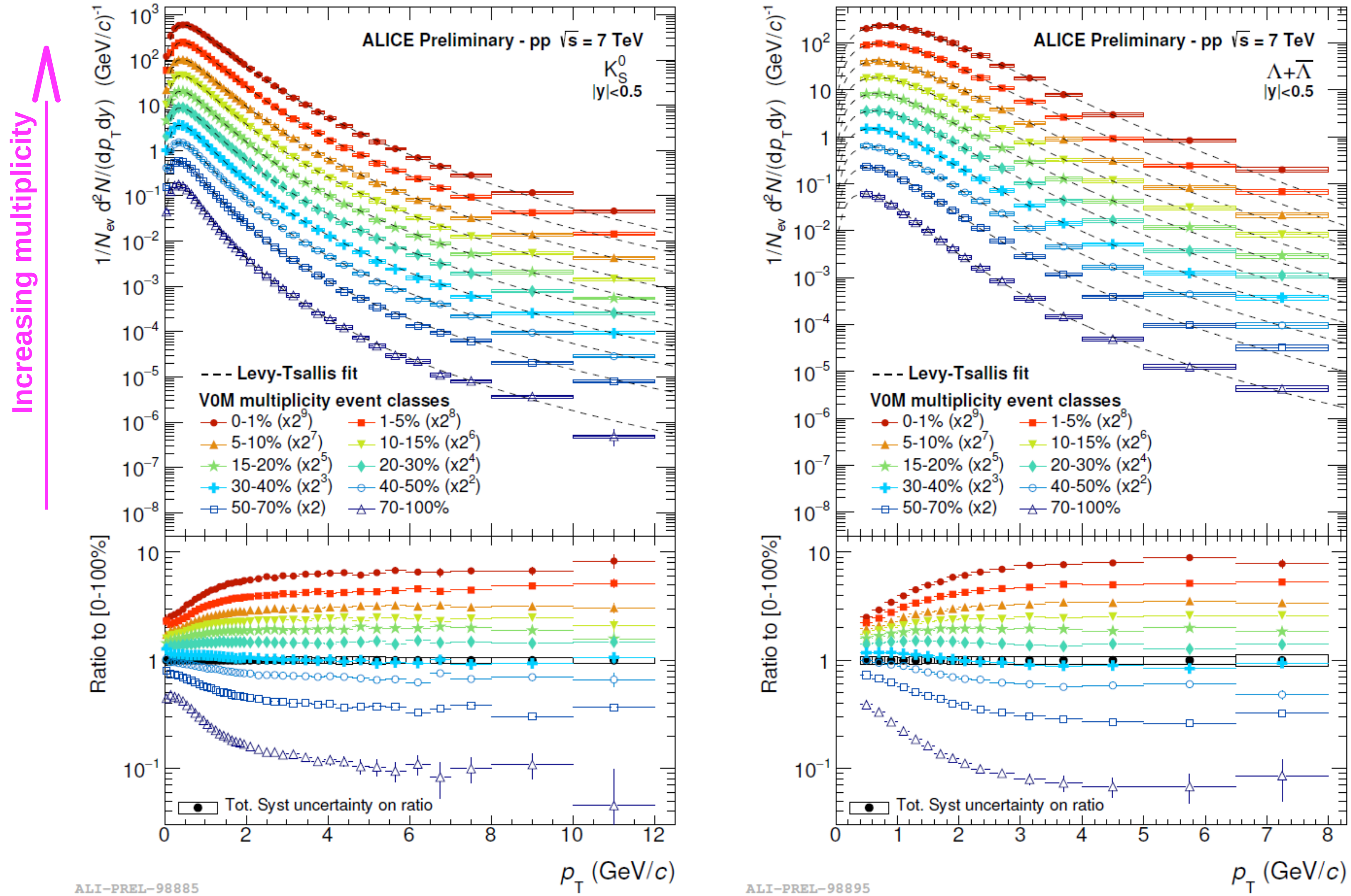




- ✔ Cuts tuned in order to optimize S/B
- ✔ Yields extracted by bin counting technique

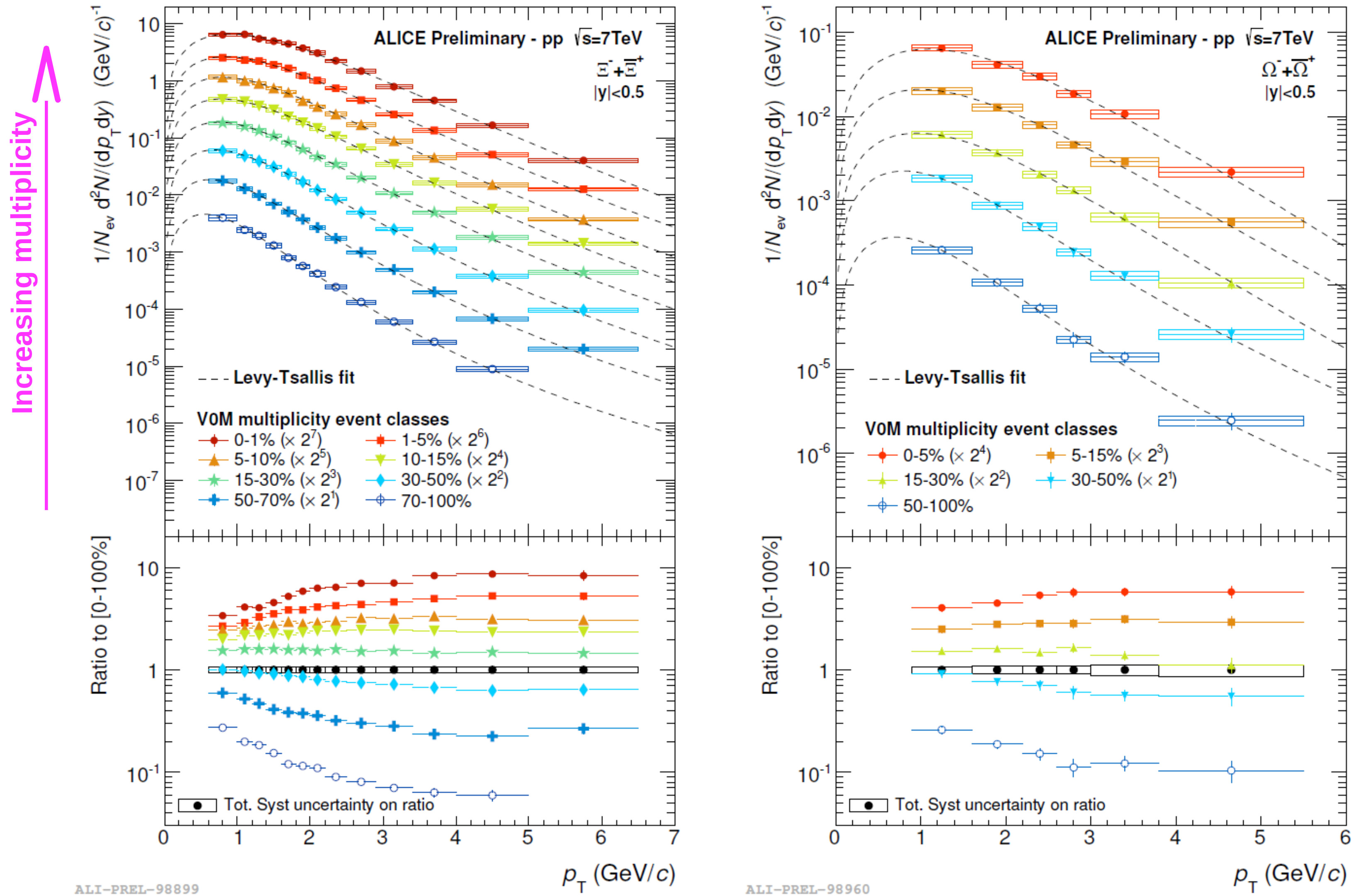
Results

p_T-differential spectra (I)



- Spectra become harder at higher multiplicities
- Ratios to integrated (over multiplicity) spectra show a saturation above p_T ~ 3 GeV/c

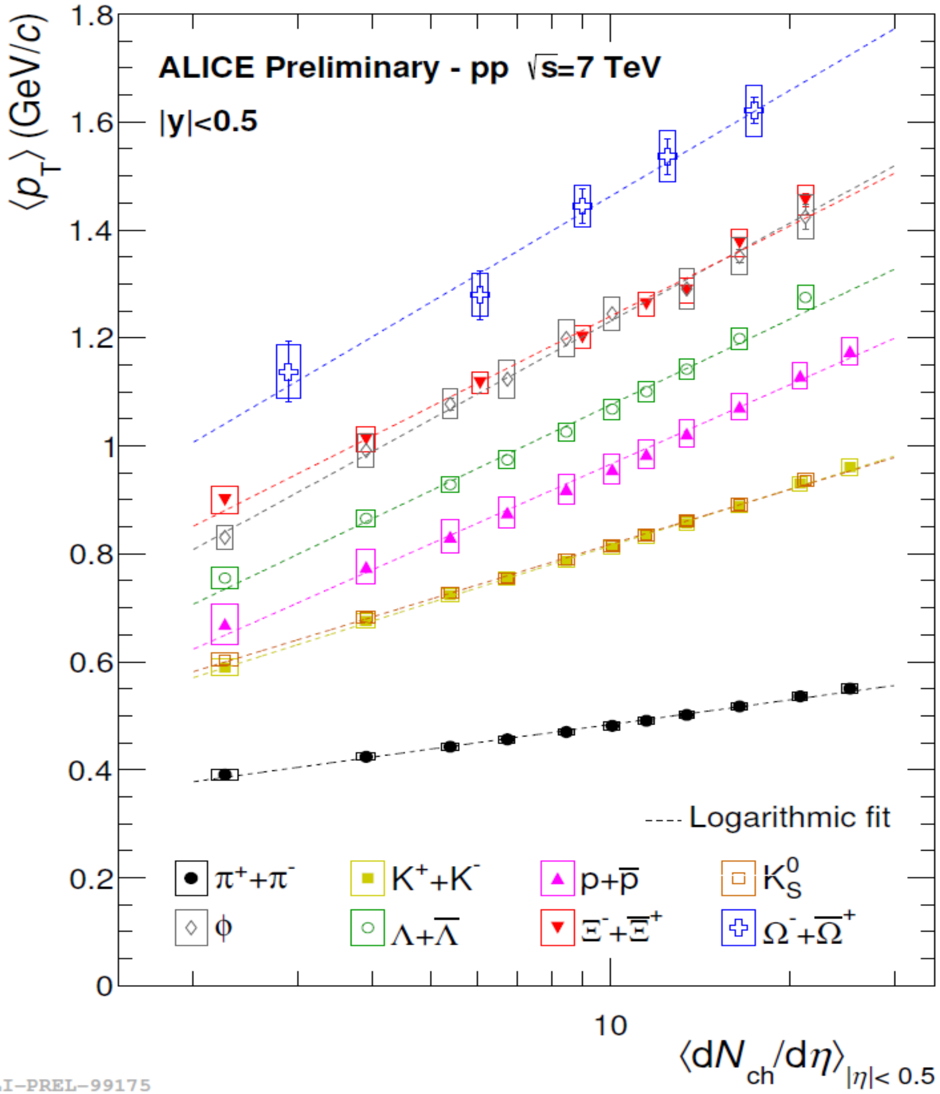
p_T-differential spectra (II)



- ✔ Spectra become harder at higher multiplicities → similar results for multi-strange hadrons
- ✔ Ratios to integrated (over multiplicity) spectra show a saturation above $p_T \sim 3$ GeV/c

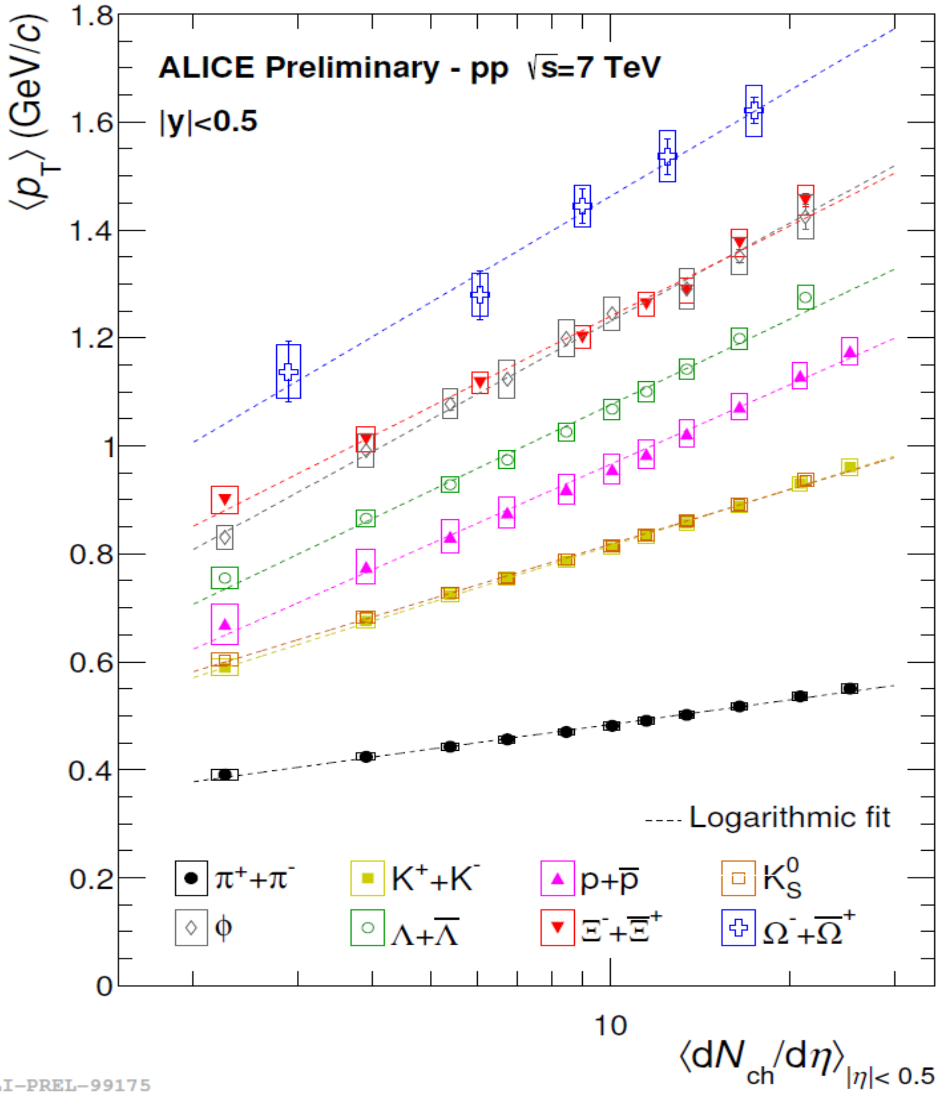
→ Levy-Tsallis fits used to get $\langle p_T \rangle$ and dN/dy vs multiplicity (extapolation down to p_T=0)

$<p_T>$ vs multiplicity



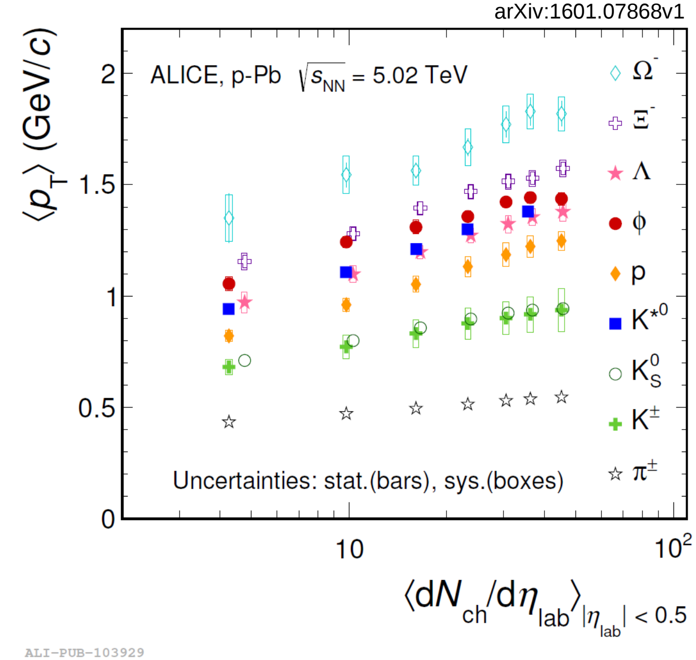
- Increasing of $\langle p_T \rangle$ as a function of multiplicity as a direct consequence of the hardening of the spectra
- Stronger increasing trend for heavier particles

$\langle p_T \rangle$ vs multiplicity

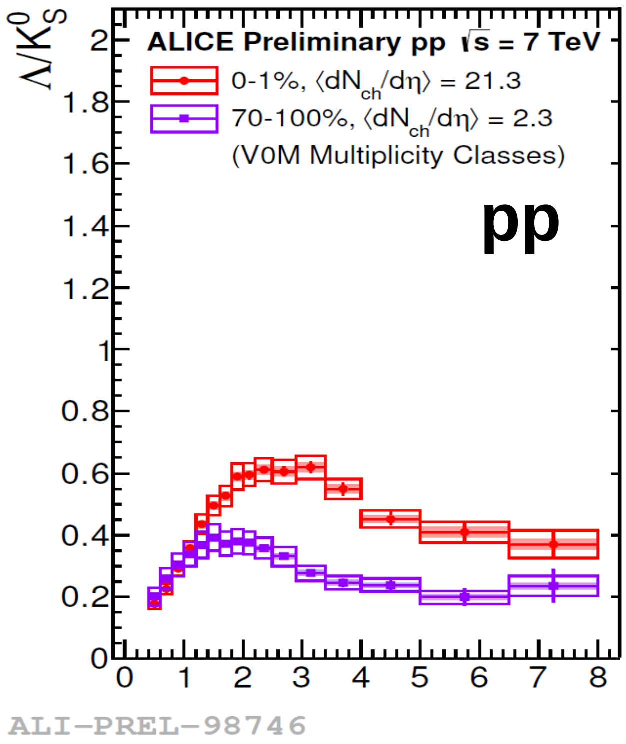


- Increasing of $\langle p_T \rangle$ as a function of multiplicity as a direct consequence of the hardening of the spectra
- Stronger increasing trend for heavier particles
- Similar behaviour observed in p-Pb / Pb-Pb as a function of multiplicity / centrality

arXiv:1601.07868v1



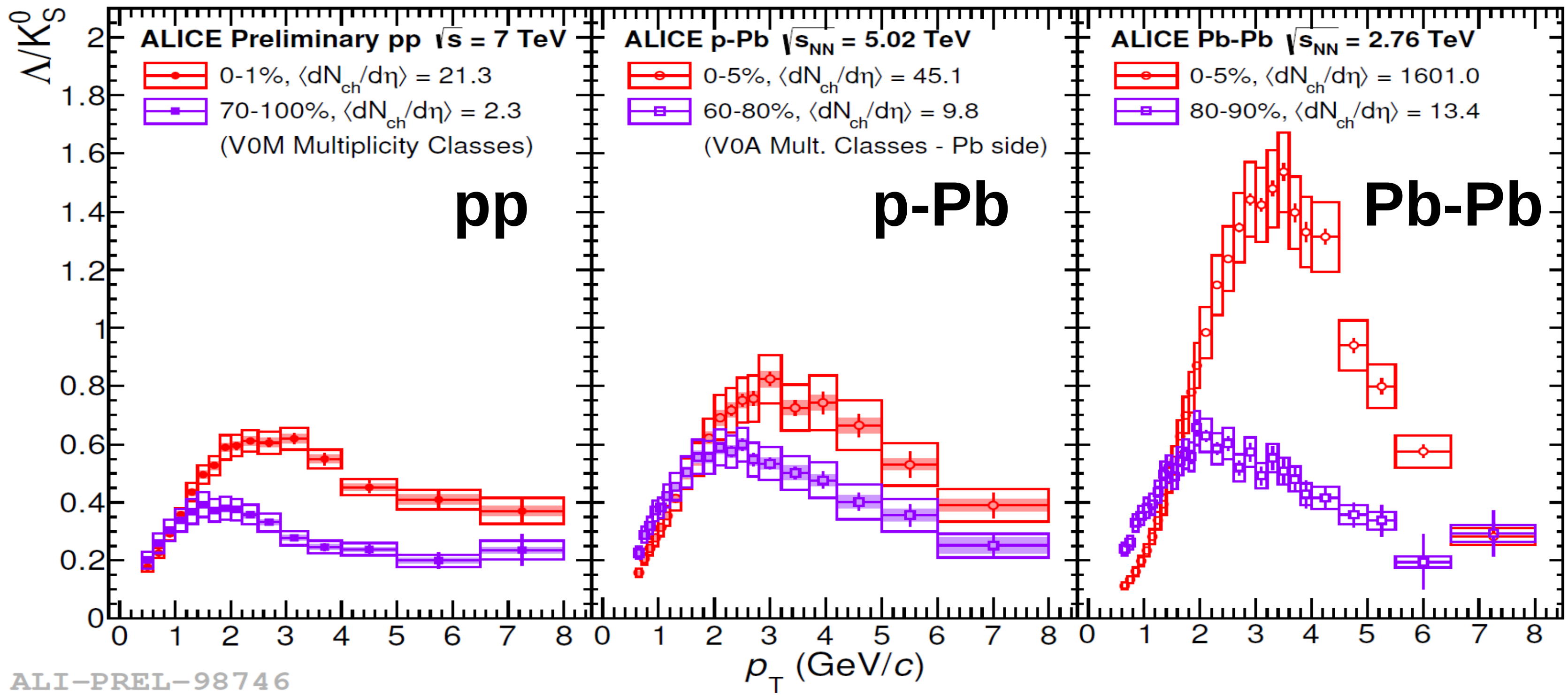
Λ / K^0_S vs p_T



- Significant enhancement observed for Λ / K^0_S at intermediate p_T (~3 GeV/c)
- Maximum shifted towards higher p_T as the multiplicity increases

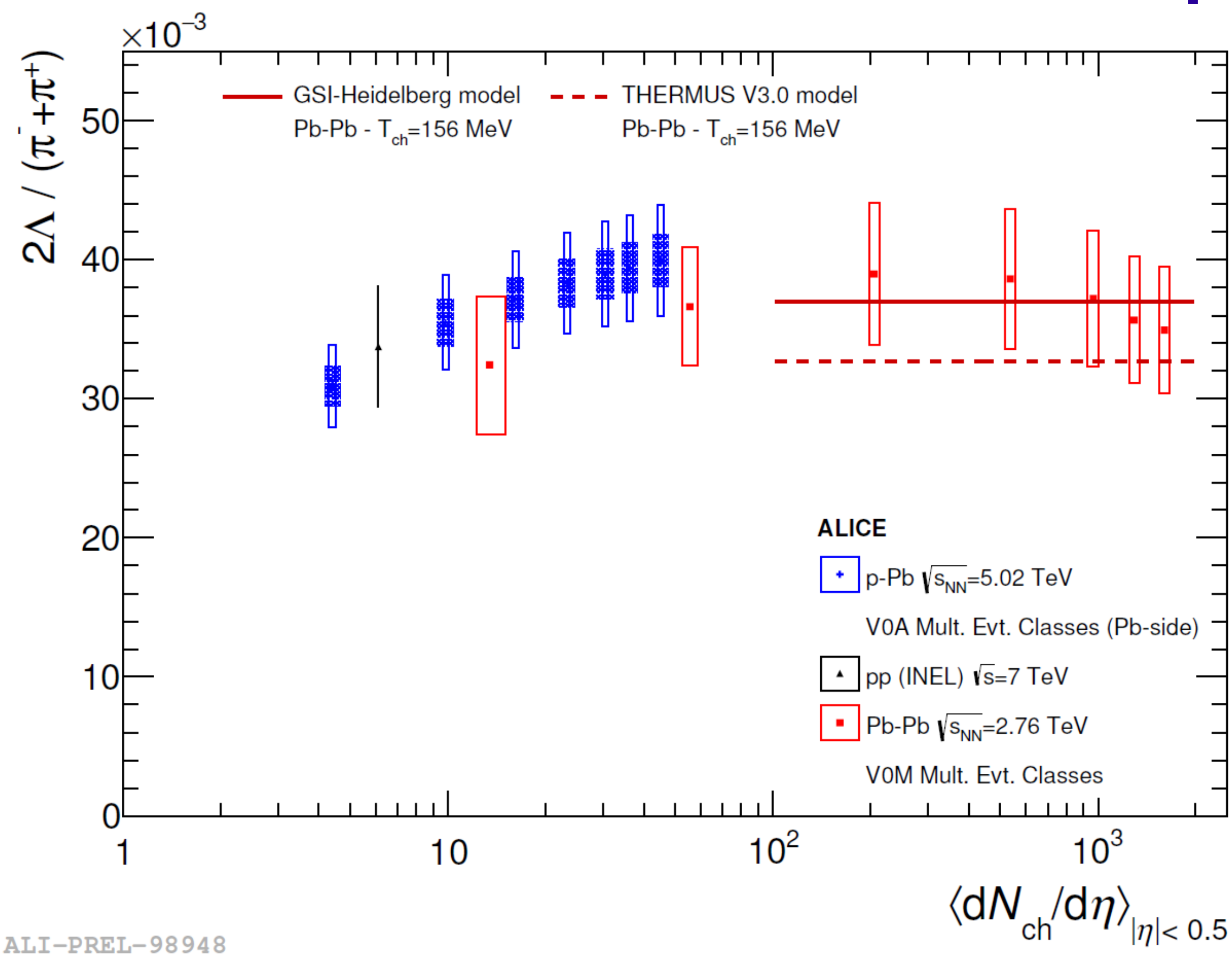
Λ / K^0_S vs p_T

[p-Pb, Pb-Pb: PLB 728 (2014) 25-38, PRL 111 (2013) 222301]



- Significant enhancement observed for Λ / K^0_S at intermediate p_T (~3 GeV/c)
- Maximum shifted towards higher p_T as the multiplicity increases
- Qualitative similar behaviour observed in p-Pb and Pb-Pb → in Pb-Pb this is generally discussed in terms of collective flow and / or quark recombination
- The magnitude of the effect looks larger in Pb-Pb moving from more peripheral to more central events, but also the corresponding ⟨$dN_{ch}/d\eta$⟩ increase is relatively large (~10^2)

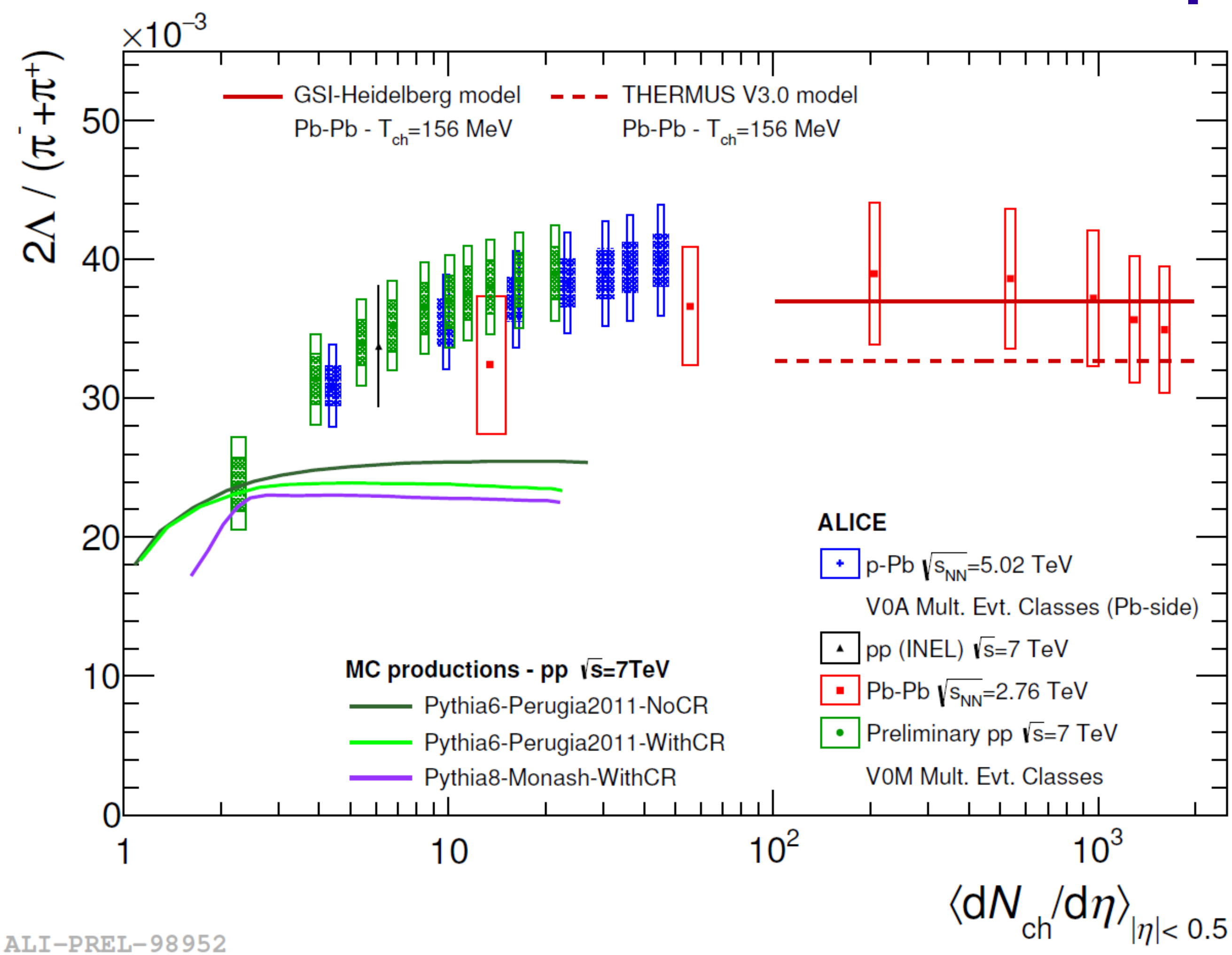
Λ/π ratio vs multiplicity



Shaded areas: uncorrelated (vs multiplicity) systematics

- ✔ Increasing trend for both **Pb-Pb** and **p-Pb** as a function of multiplicity
  - ✔ reach Gran Canonical (GC) saturation limit in p-Pb
- ✔ Good agreement with minimum-bias **pp**

Λ/π ratio vs multiplicity

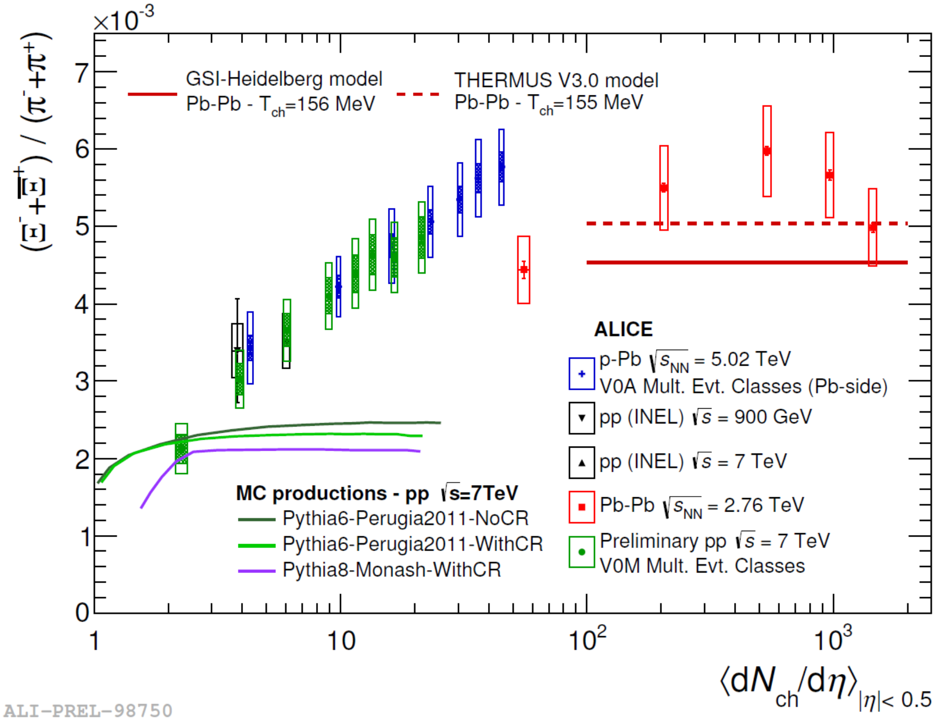


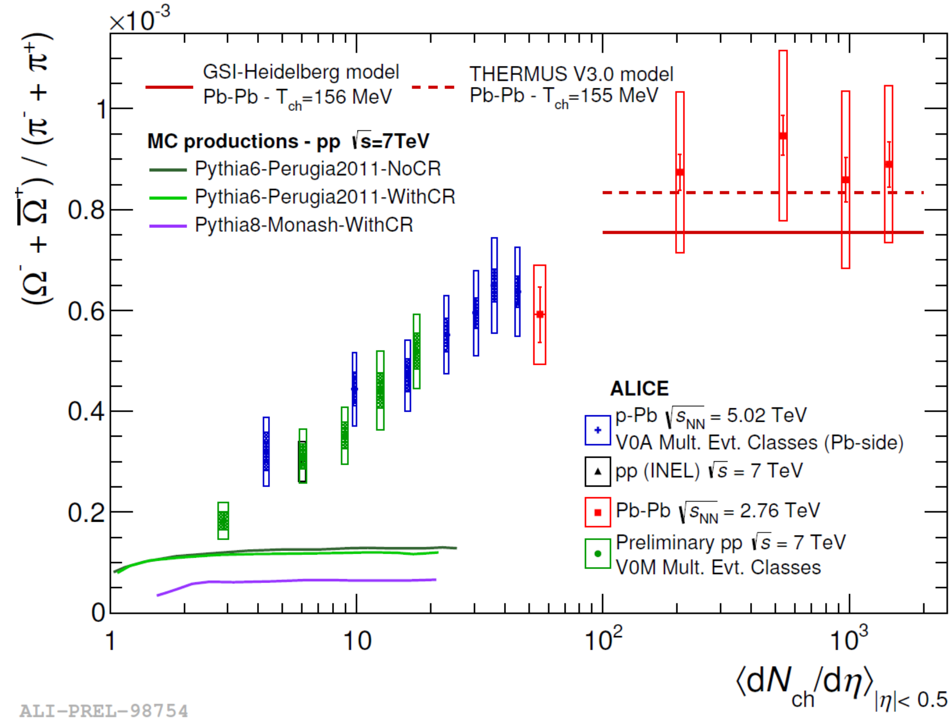
Shaded areas: uncorrelated (vs multiplicity) systematics

- Increasing trend observed also for **pp** as a function of multiplicity
- Excellent agreement for **pp** and **p-Pb** vs multiplicity
- Pythia6 / Pythia8 with and without Color Reconnection are not able to reproduce the observed enhancement

- Increasing trend for both **Pb-Pb** and **p-Pb** as a function of multiplicity
  - reach Gran Canonical (GC) saturation limit in p-Pb
- Good agreement with minimum-bias **pp**

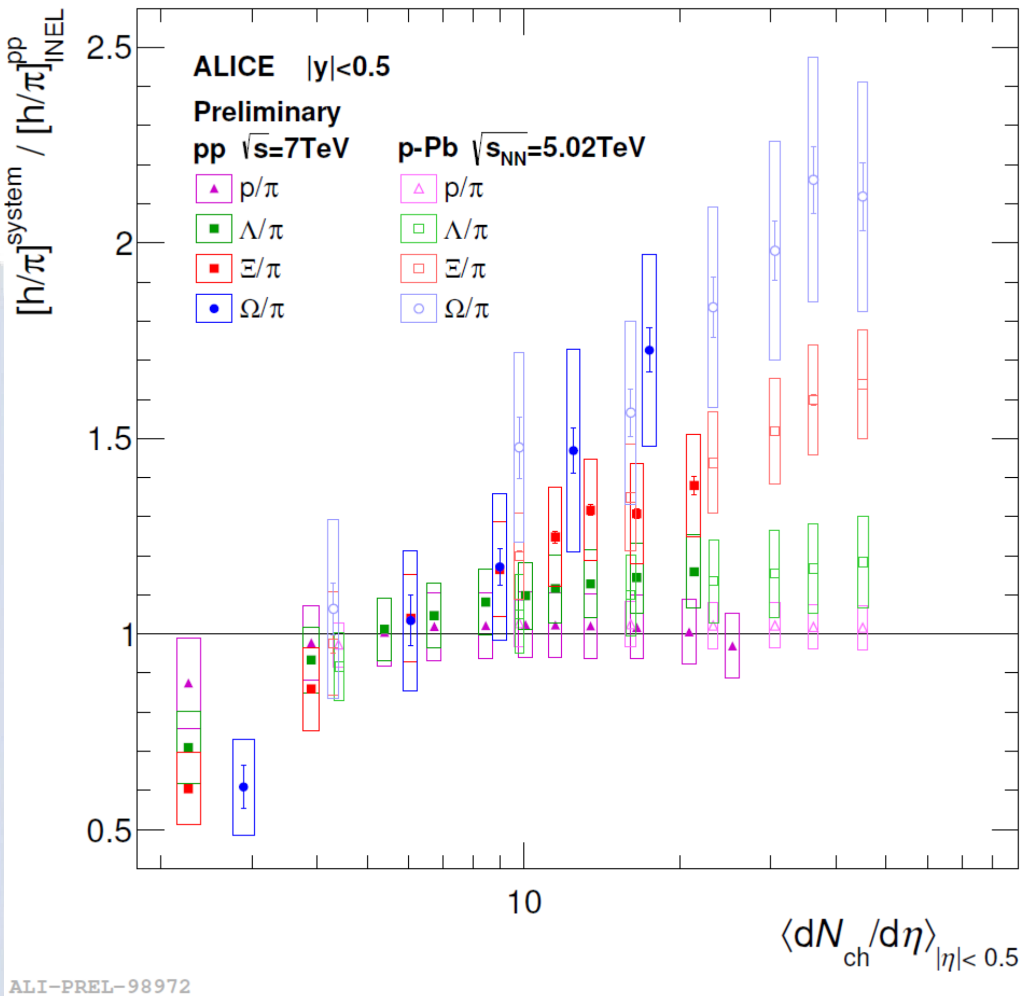
Ξ/π and Ω/π ratios vs multiplicity





- Increasing trend for **p-Pb** as a function of multiplicity
  - Ξ / π ratio exceeds the GC saturation limit at high multiplicity
  - Ω / π stays below the GC prediction
- Very good agreement between **pp** and **p-Pb** vs multiplicity
- Clear rise with multiplicity for multi-strange baryons, as already observed for the Λ / π
- Pythia6 / Pythia8 tunes don't reproduce the observed trend

Self-normalized Baryon/π ratio vs multiplicity



Baryon / π ratio as a function of multiplicity normalized to the corresponding minimum bias value for pp and p-Pb

- ✔ Similar results in pp / p-Pb
- ✔ p / π doesn't show any multiplicity dependence
- ✔ Strange baryon over π ratios increase as a function of multiplicity
  - ✔ Enhancement related to the strangeness content rather than to the baryon content
- ✔ Relative increase with multiplicity larger for baryons with a larger strangeness content

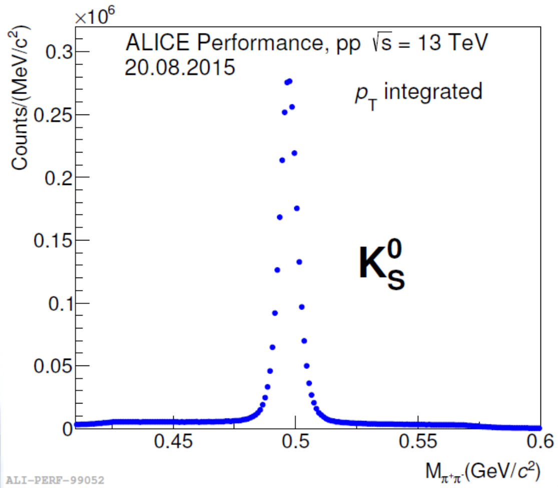
Conclusions

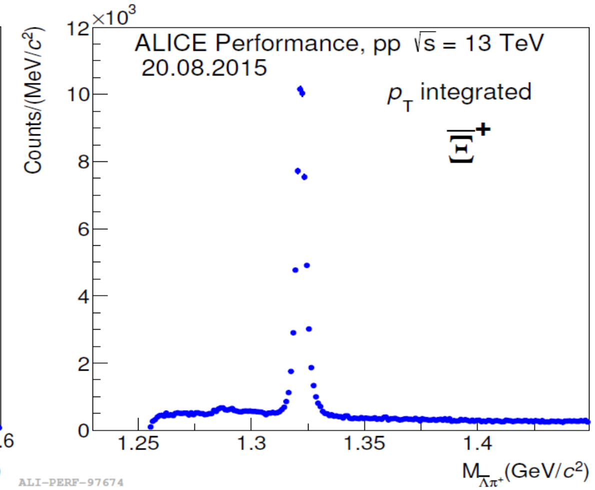
Multiplicity dependence of strange and multi-strange particle production studied by the ALICE Collaboration in pp @ 7 TeV

- ✔ Hardening of p_T spectra at high $\langle dN_{ch}/d\eta \rangle$
  - ✔ corresponding increase observed for the $\langle p_T \rangle$
- ✔ Λ / K^0_S ratio at high $\langle dN_{ch}/d\eta \rangle$ enhanced at intermediate p_T
  - ✔ qualitative similar behaviour observed in p-Pb and Pb-Pb
- ✔ Strange particle over π ratios (Λ/π, Ξ/π, Ω/π) exhibit an increasing trend as a function of multiplicity
  - ✔ Baryons with a larger strangeness content show a faster increase with $\langle dN_{ch}/d\eta \rangle$
  - ✔ Pythia 6 and Pythia 8 (even with Color Reconnection) are not able to reproduce the observed enhancement

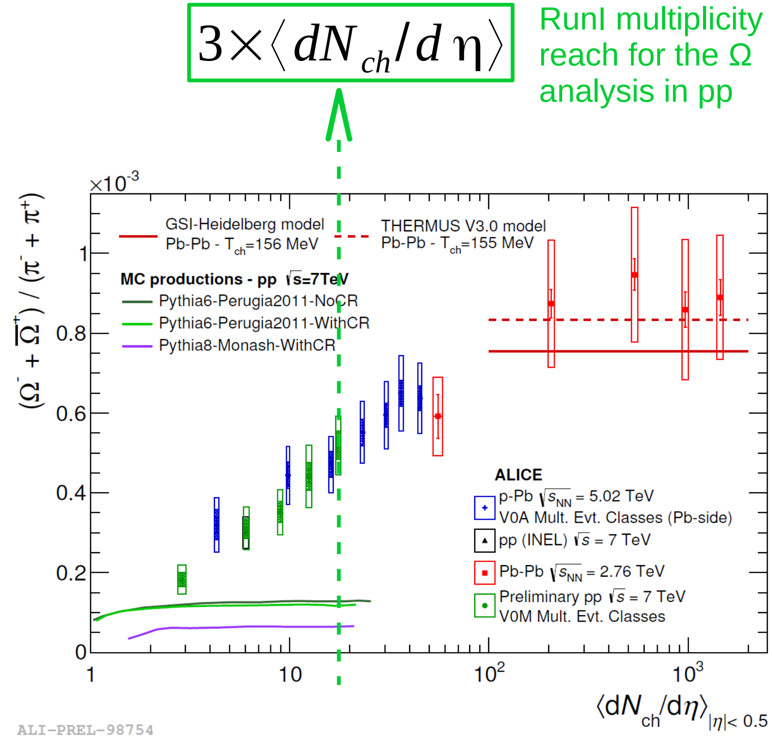
Outlook: pp @ 13 TeV

- ✔ Analysis on Run II data is ongoing...





- ✔ Main goal of RunII analysis: extend multiplicity reach → useful to understand trends at very high multiplicity
  - ✔ e.g. multi-strange baryon / π ratios: continuous increase ? saturation ?
- ✔ Large sample of high-multiplicity triggered events already available up to **~10 times the average multiplicity** based on data collected during 2015 (trigger rejection factor ~10^{-3}) → even larger trigger rejection factor foreseen for 2016 (~$3 \cdot 10^{-4}$)



RunI multiplicity reach for the Ω analysis in pp

Thank you!