XLV International Symposium on Multiparticle Dynamics
Wildbad Kreuth, 4-9 Oct 2015

ALICE

Multiplicity dependence of strange and multi-strange hadron production in pp collisions at √s=7 TeV measured with the ALICE experiment

Rafael Derradi de Souza

For the ALICE Collaboration

UNICAMP – Brazil

UNICAMP

FAPESP
FUNDAÇÃO DE AMPARO À PESQUISA DO ESTADO DE SÃO PAULO

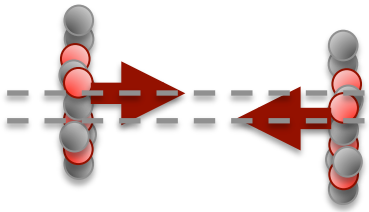
(supported by FAPESP Grant 2014/09167-8)

Outline

- Introduction
  - *A-A, p-A and pp systems*
- The ALICE Experiment
- Multiplicity Selection
  - *Forward rapidity estimator*
- Strange Hadron Measurements
  - K^0_S, Λ, Ξ *and* Ω
- Results
- Summary

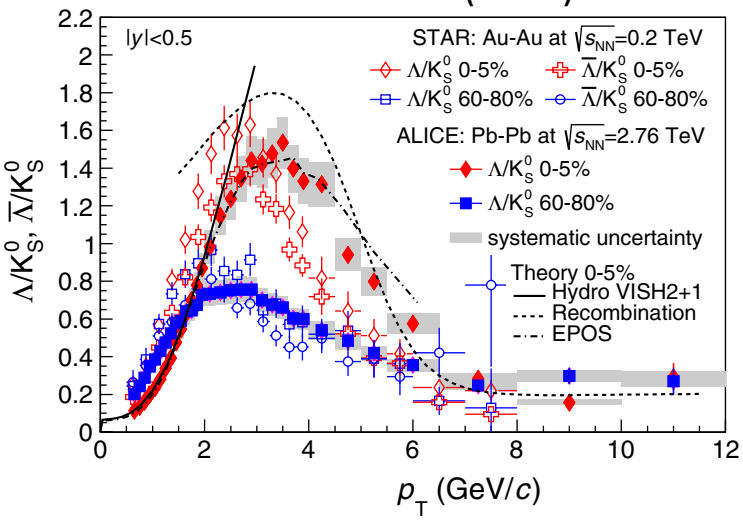
Introduction: A-A, p-A and pp

A-A:



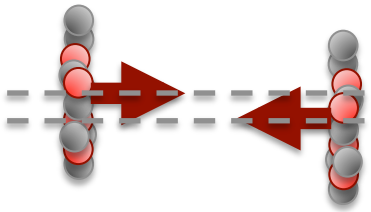
- Large system: *deconfinement/ QGP scenario*
- Strangeness enhancement
- Λ/K^0_S enhancement at intermediate p_T

PRL 111 (2013) 222301



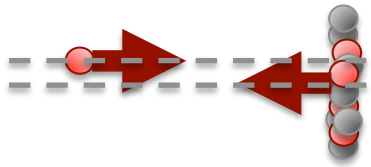
Introduction: A-A, p-A and pp

A-A:



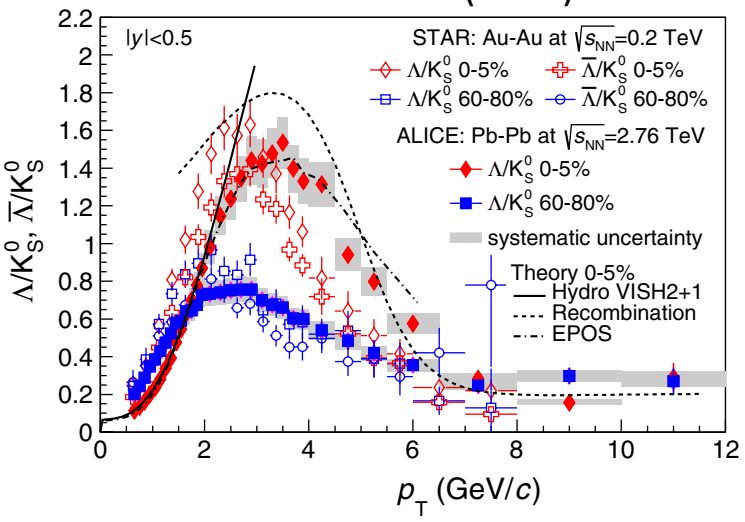
- Large system: *deconfinement/ QGP scenario*
- Strangeness enhancement
- Λ/K^0_S enhancement at intermediate p_T

p-A:

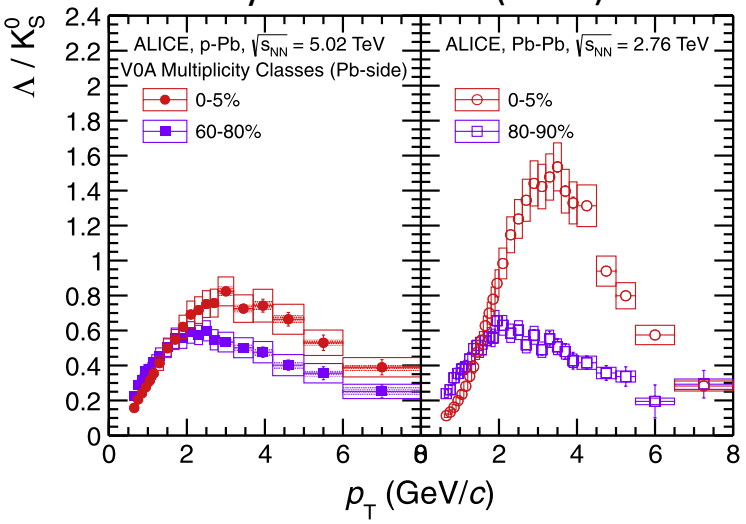


- Intermediate system: *suited to explore the transition between A-A and pp*
- Progressive release of canonical suppression
- Λ/K^0_S qualitatively similar to A-A

PRL 111 (2013) 222301

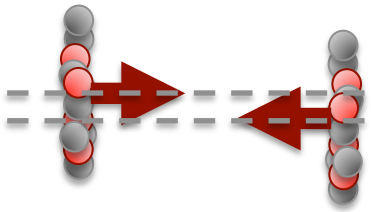


Phys. Lett. B 728 (2014) 25-38



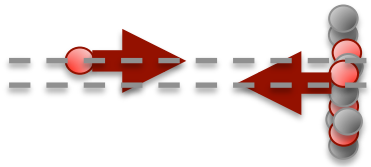
Introduction: A-A, p-A and pp

A-A:



- Large system: *deconfinement/ QGP scenario*
- Strangeness enhancement
- Λ/K^0_S enhancement at intermediate p_T

p-A:

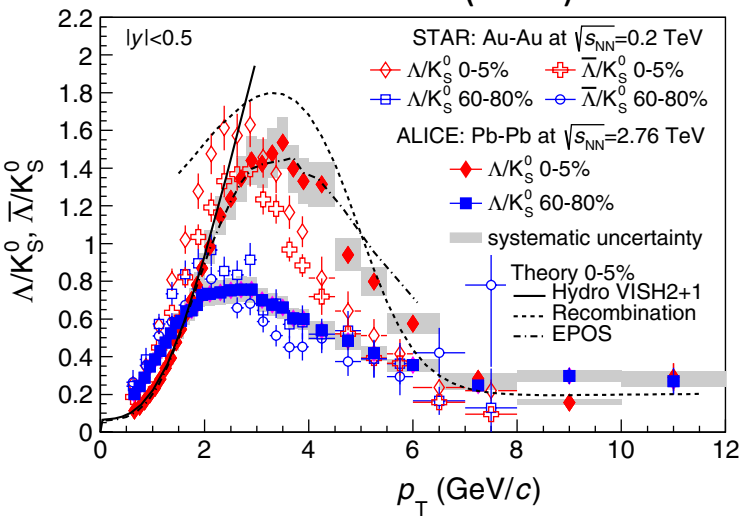


- Intermediate system: *suited to explore the transition between A-A and pp*
- Progressive release of canonical suppression
- Λ/K^0_S qualitatively similar to A-A

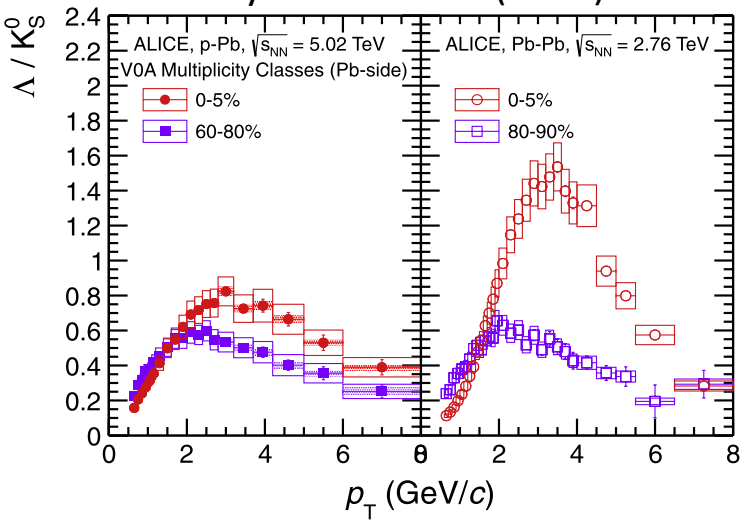
pp:

- Small system: *no collectivity or deconfinement expected*
- Reference for A-A *(hadron gas)*

PRL 111 (2013) 222301

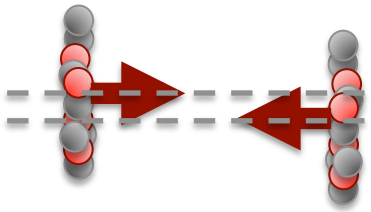


Phys. Lett. B 728 (2014) 25-38



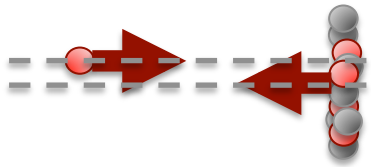
Introduction: A-A, p-A and pp

A-A:



- Large system: *deconfinement/ QGP scenario*
- Strangeness enhancement
- Λ/K^0_S enhancement at intermediate p_T

p-A:



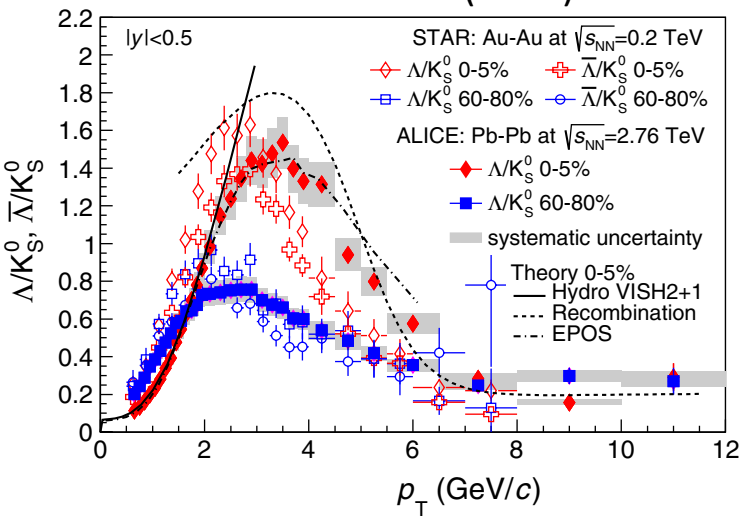
- Intermediate system: *suited to explore the transition between A-A and pp*
- Progressive release of canonical suppression
- Λ/K^0_S qualitatively similar to A-A

pp:

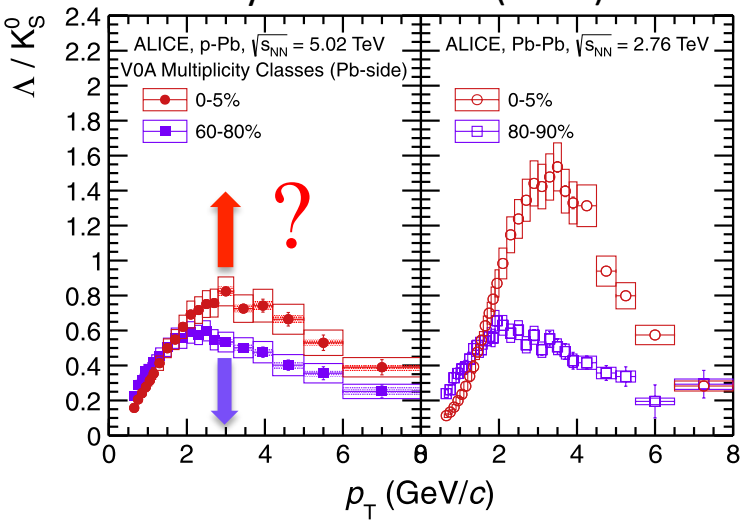
- Small system: *no collectivity or deconfinement expected*
- Reference for A-A *(hadron gas)*

What about multiplicity dependence in pp?

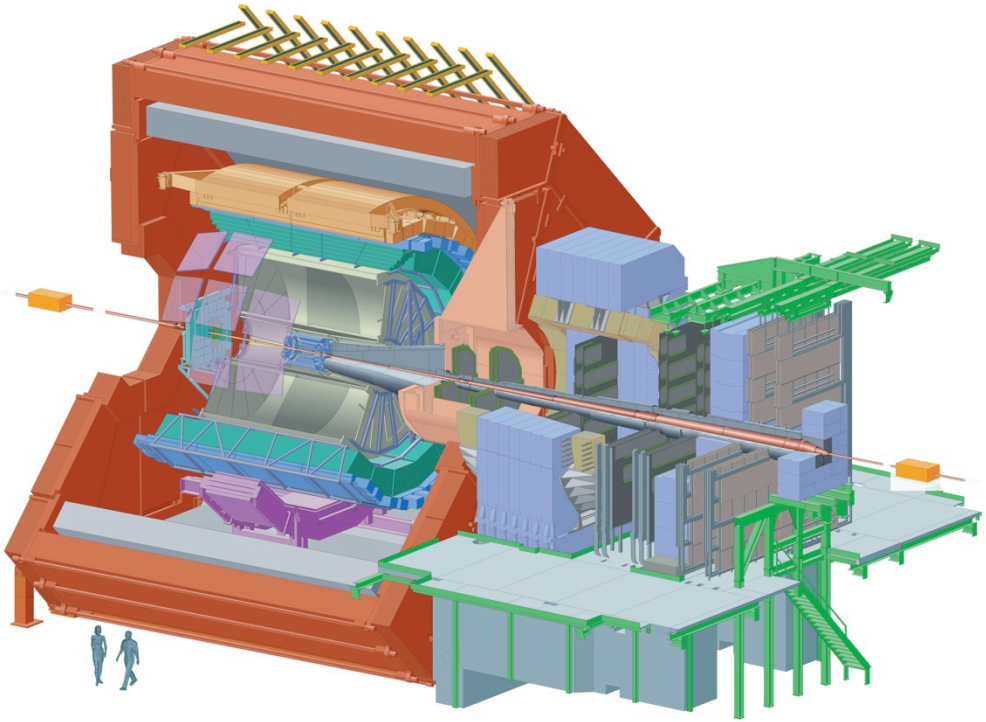
PRL 111 (2013) 222301



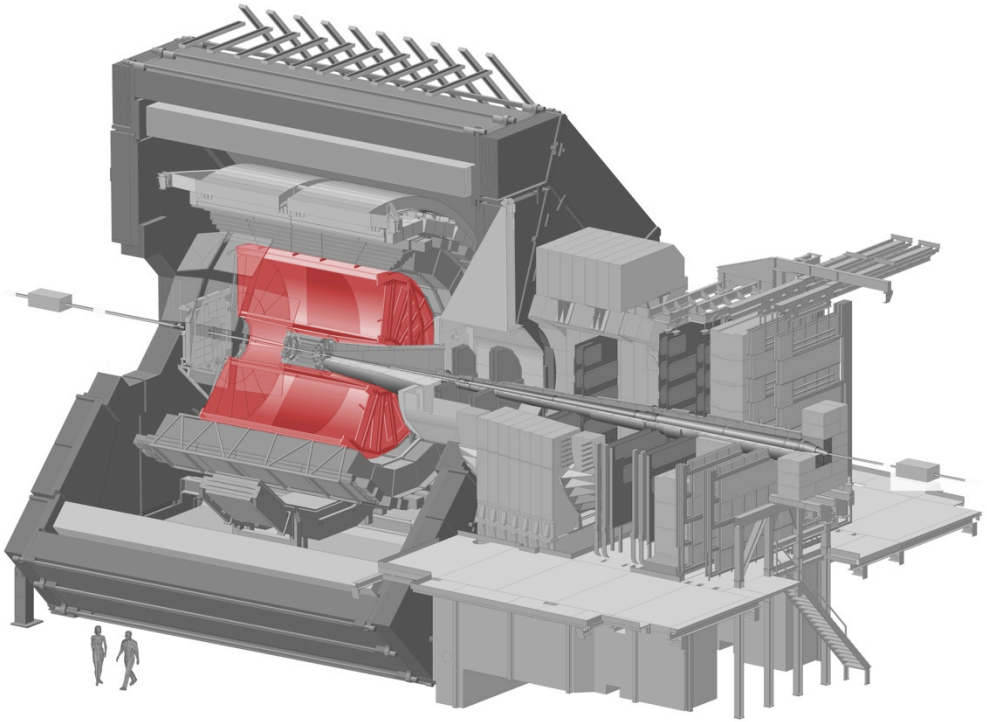
Phys. Lett. B 728 (2014) 25-38



The ALICE Experiment



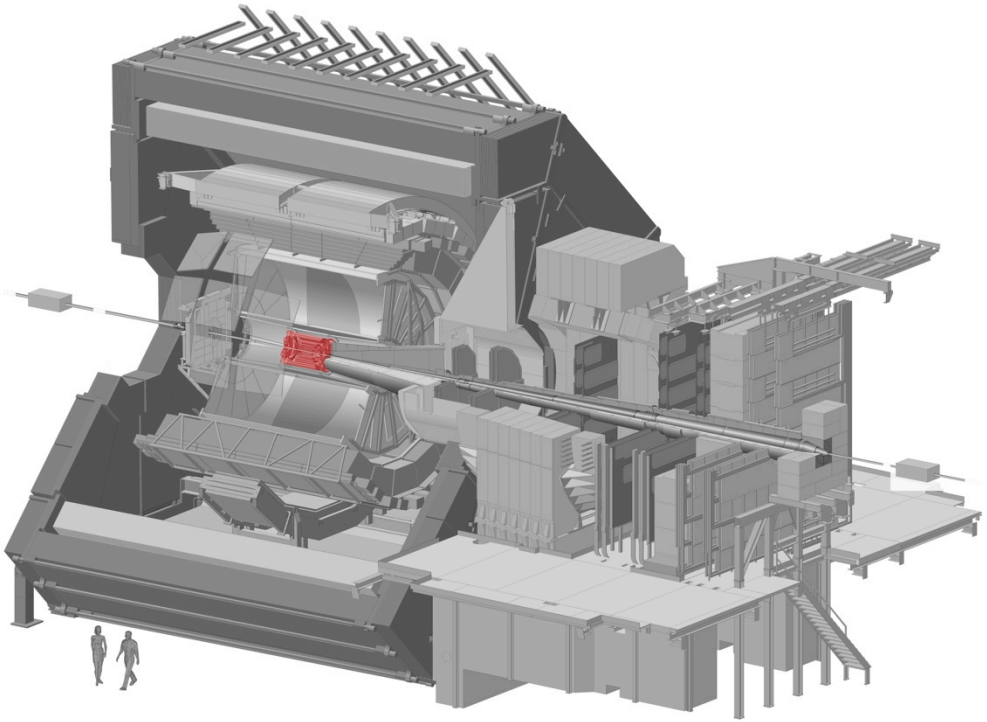
The ALICE Experiment



Detectors used in this analysis:

TPC ($|\eta|<0.9$)
- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)

The ALICE Experiment

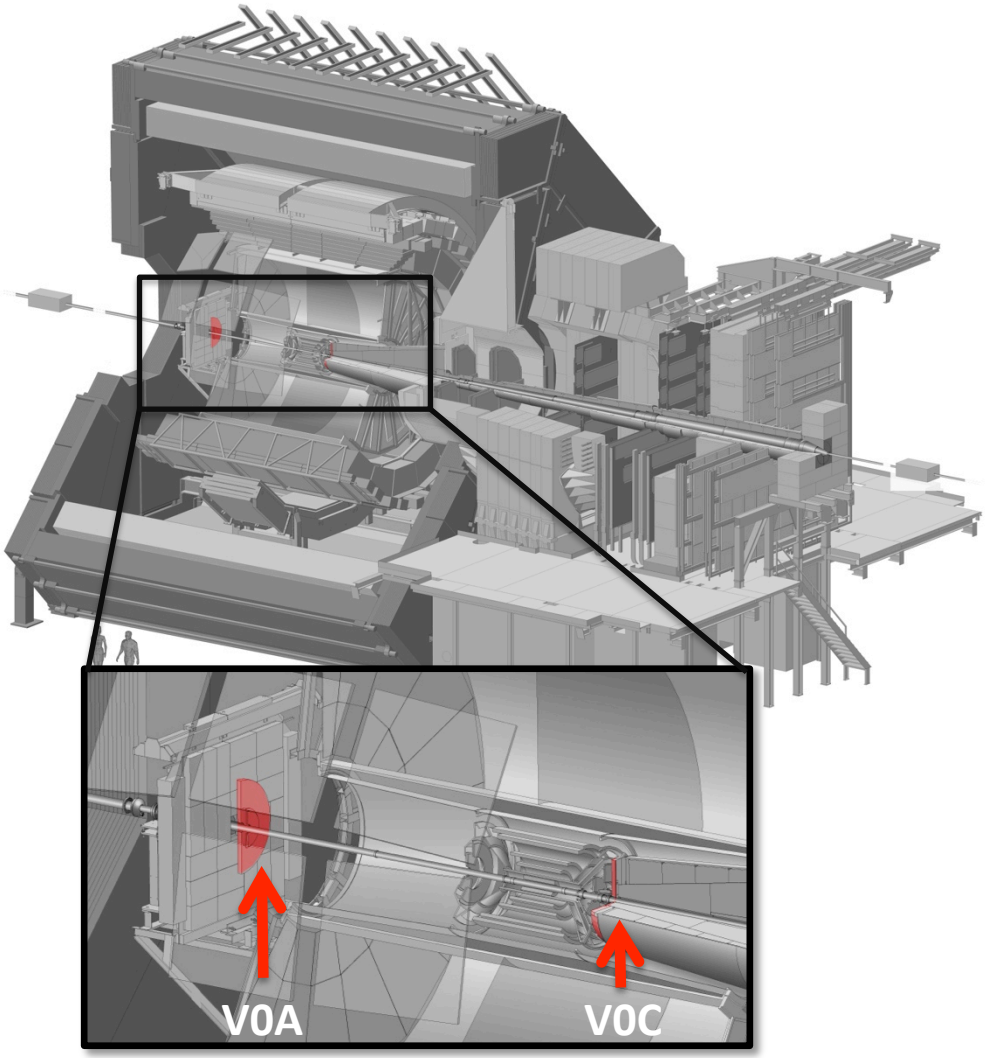


Detectors used in this analysis:

TPC ($|\eta|<0.9$)
- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)

ITS ($|\eta|<0.9$)
- 6 Layers of silicon detectors
- Trigger, tracking, vertex, PID (dE/dx)

The ALICE Experiment



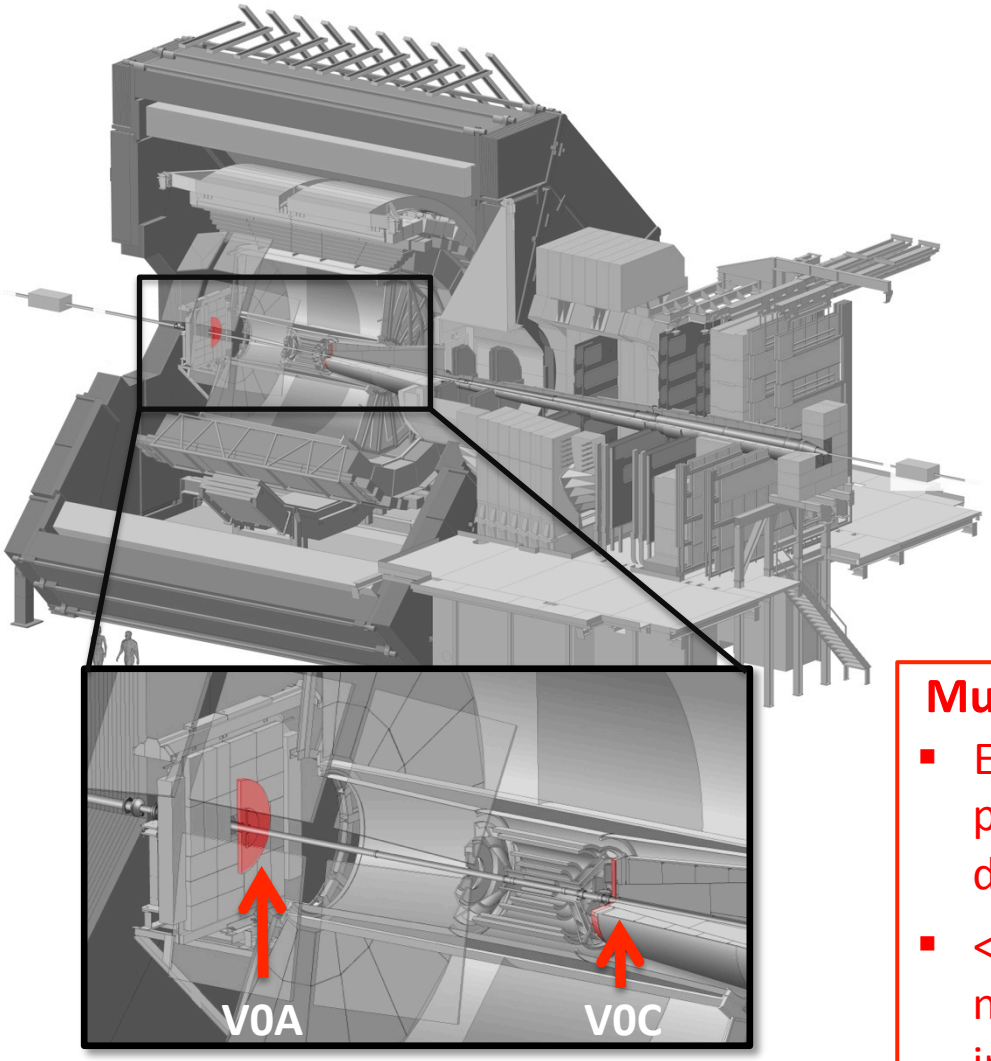
Detectors used in this analysis:

TPC (|η|<0.9)
- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)

ITS (|η|<0.9)
- 6 Layers of silicon detectors
- Trigger, tracking, vertex, PID (dE/dx)

V0 [V0A (2.8<η<5.1) & V0C (-3.7<η<-1.7)]
- Forward arrays of scintillators
- Trigger, beam gas rejection
- *Multiplicity estimation*

The ALICE Experiment



Detectors used in this analysis:

TPC (|η|<0.9)
- Gas-filled ionization detection volume
- Tracking, vertex, PID (dE/dx)

ITS (|η|<0.9)
- 6 Layers of silicon detectors
- Trigger, tracking, vertex, PID (dE/dx)

V0 [V0A (2.8<η<5.1) & V0C (-3.7<η<-1.7)]
- Forward arrays of scintillators
- Trigger, beam gas rejection
- *Multiplicity estimation*

Multiplicity Selection

- 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 $|\eta|<0.5$

Strange Hadron Measurements

V⁰'s (single-strange hadrons)

$$K^0_S \to \pi^+ + \pi^- \quad \left(\frac{d\bar{s} - s\bar{d}}{\sqrt{2}} \right)$$

- **B.R.:** 69.2%
- **cτ:** 2.68 cm
- **mass:** 497.61 MeV/c²

$$\Lambda \to p + \pi^- \quad [\,uds\,]$$
$$\bar{\Lambda} \to \bar{p} + \pi^+ \quad [\,\bar{u}\bar{d}\bar{s}\,]$$

- **B.R.:** 63.9%
- **cτ:** 7.89 cm
- **mass:** 1115.68 MeV/c²

Cascades (multi-strange hadrons)

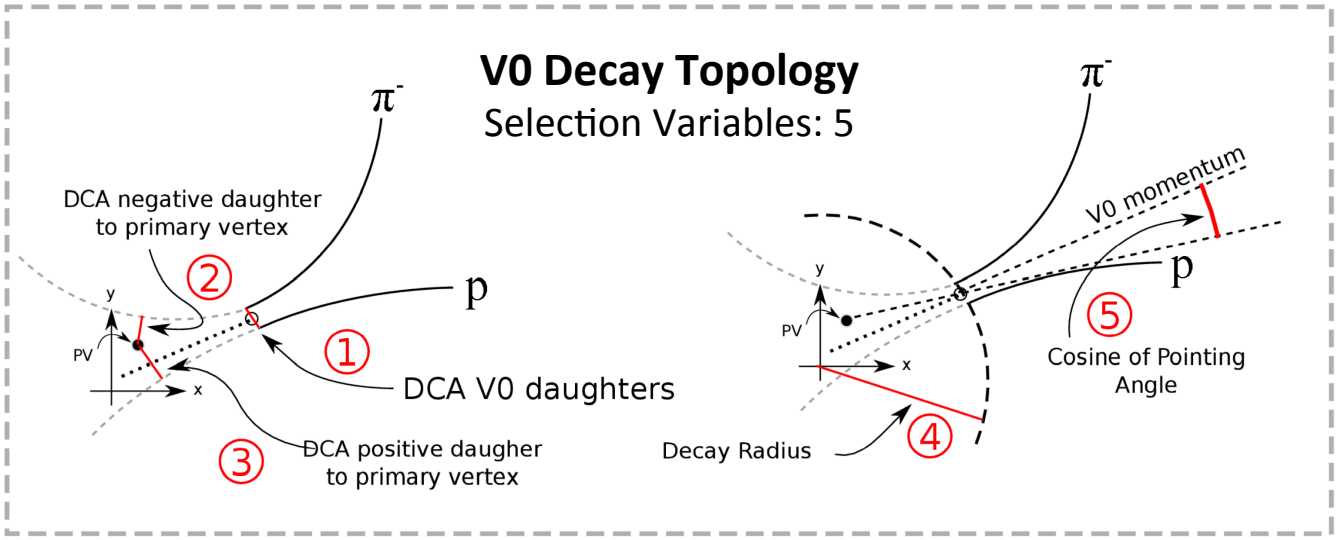
$$\Xi^- \to \Lambda + \pi^- \quad [\,dss\,]$$
$$\bar{\Xi}^+ \to \bar{\Lambda} + \pi^+ \quad [\,\bar{d}\bar{s}\bar{s}\,]$$

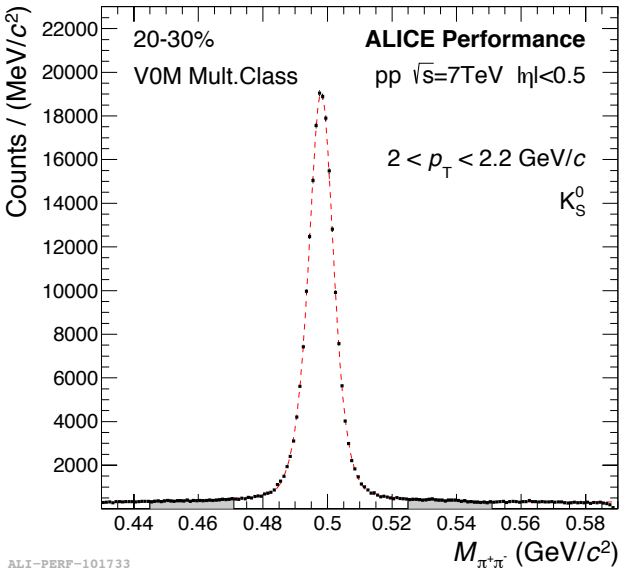
- **B.R.:** 99.9%
- **cτ:** 4.91 cm
- **mass:** 1321.71 MeV/c²

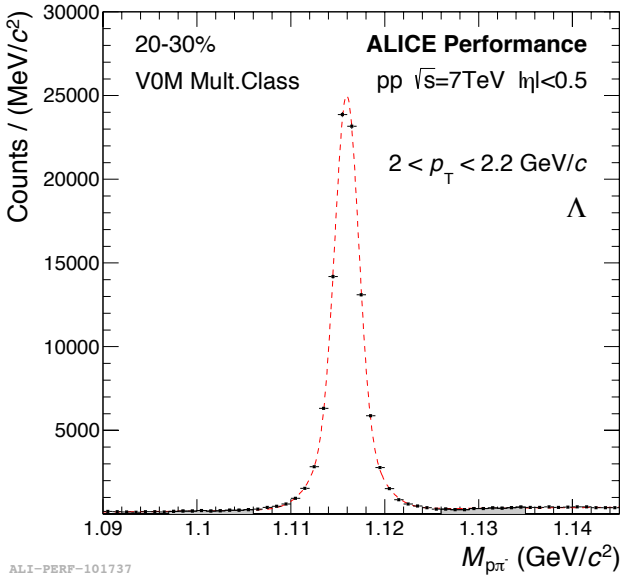
$$\Omega^- \to \Lambda + K^- \quad [\,sss\,]$$
$$\bar{\Omega}^+ \to \bar{\Lambda} + K^+ \quad [\,\bar{s}\bar{s}\bar{s}\,]$$

- **B.R.:** 67.8%
- **cτ:** 2.46 cm
- **mass:** 1672.45 MeV/c²

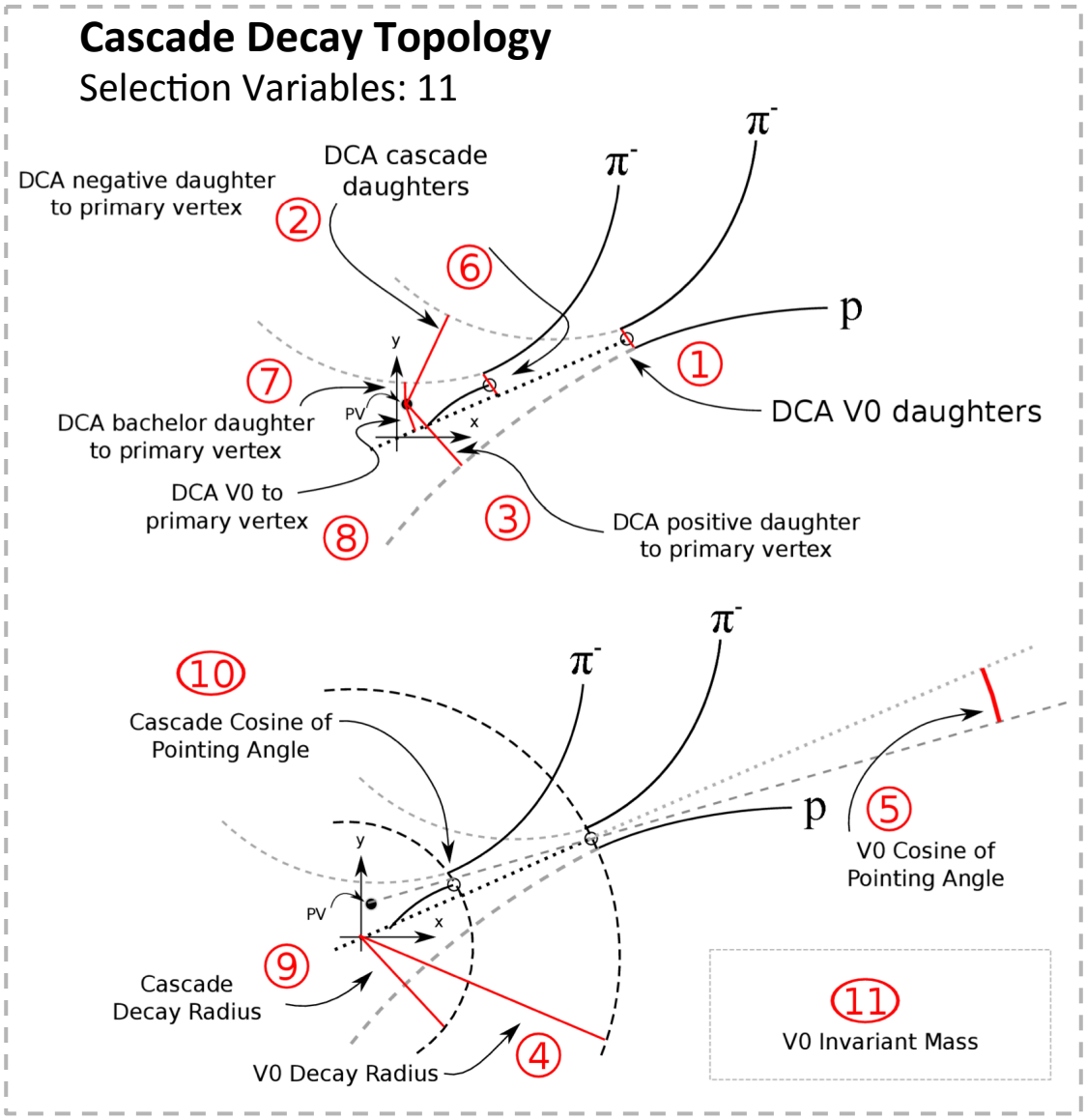
Strange Hadron Measurements

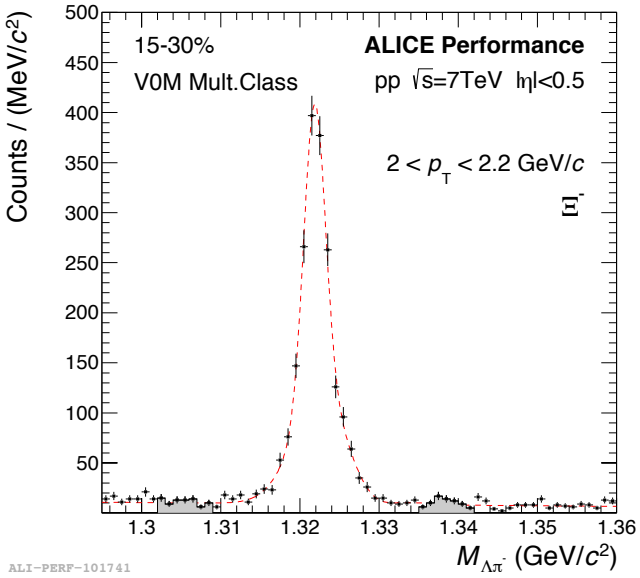


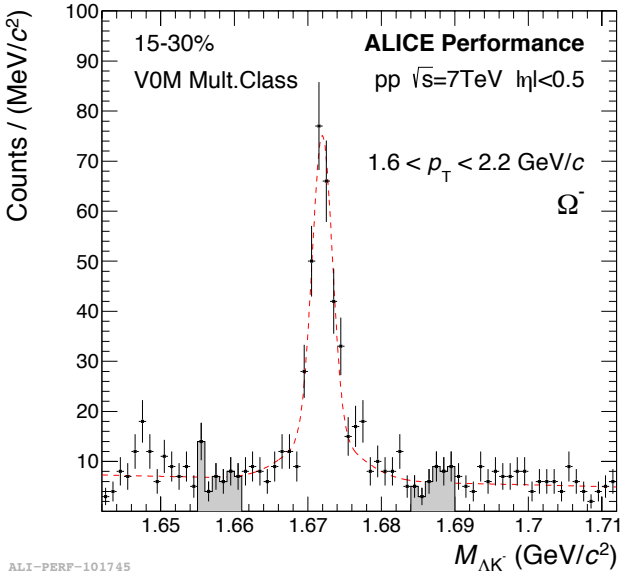




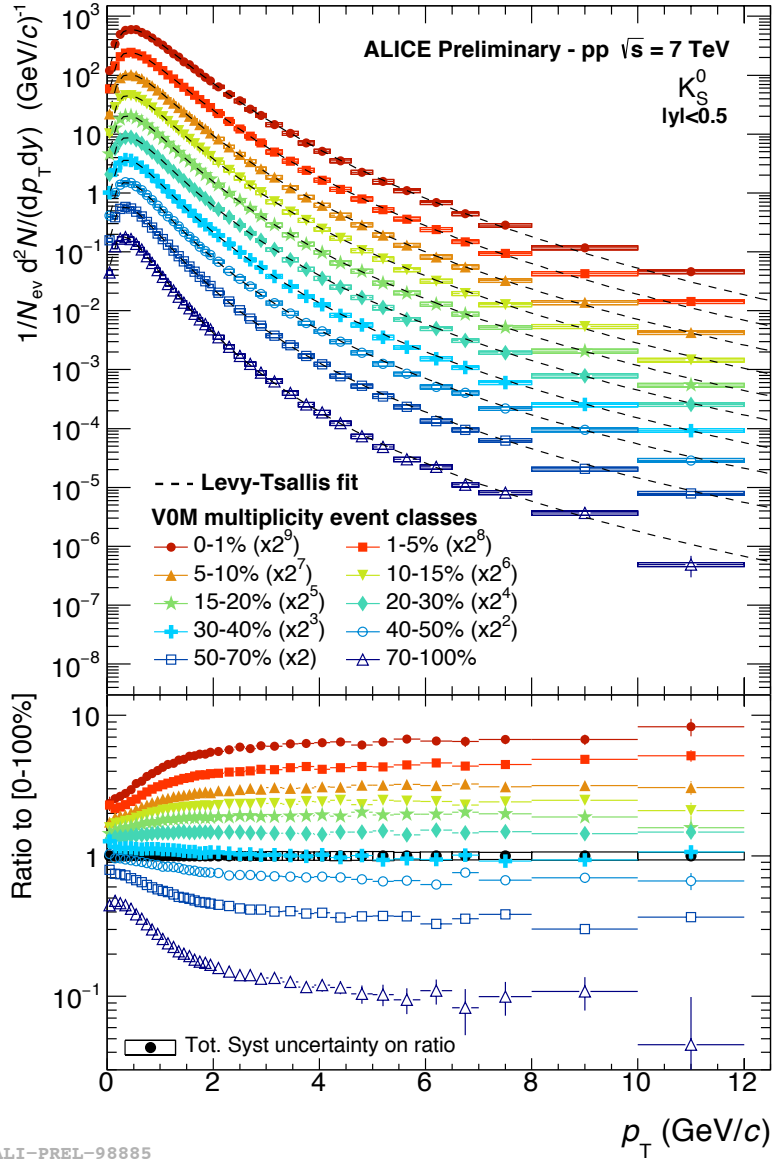
Strange Hadron Measurements

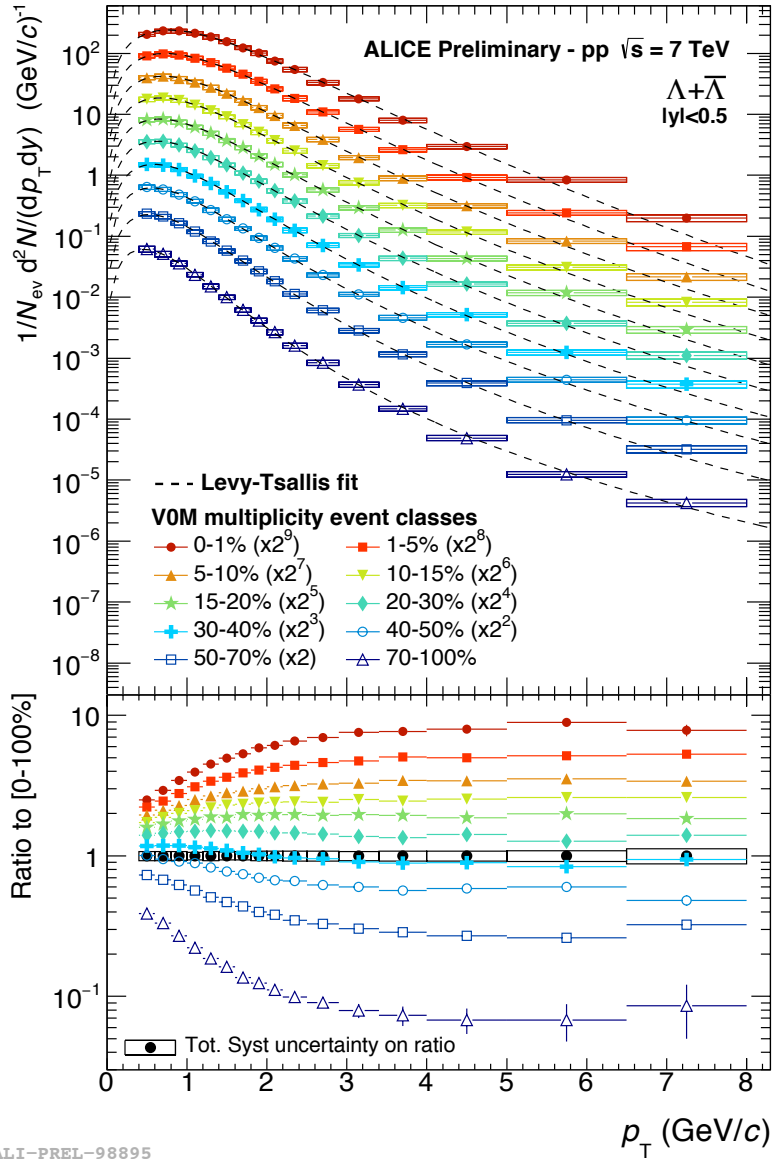




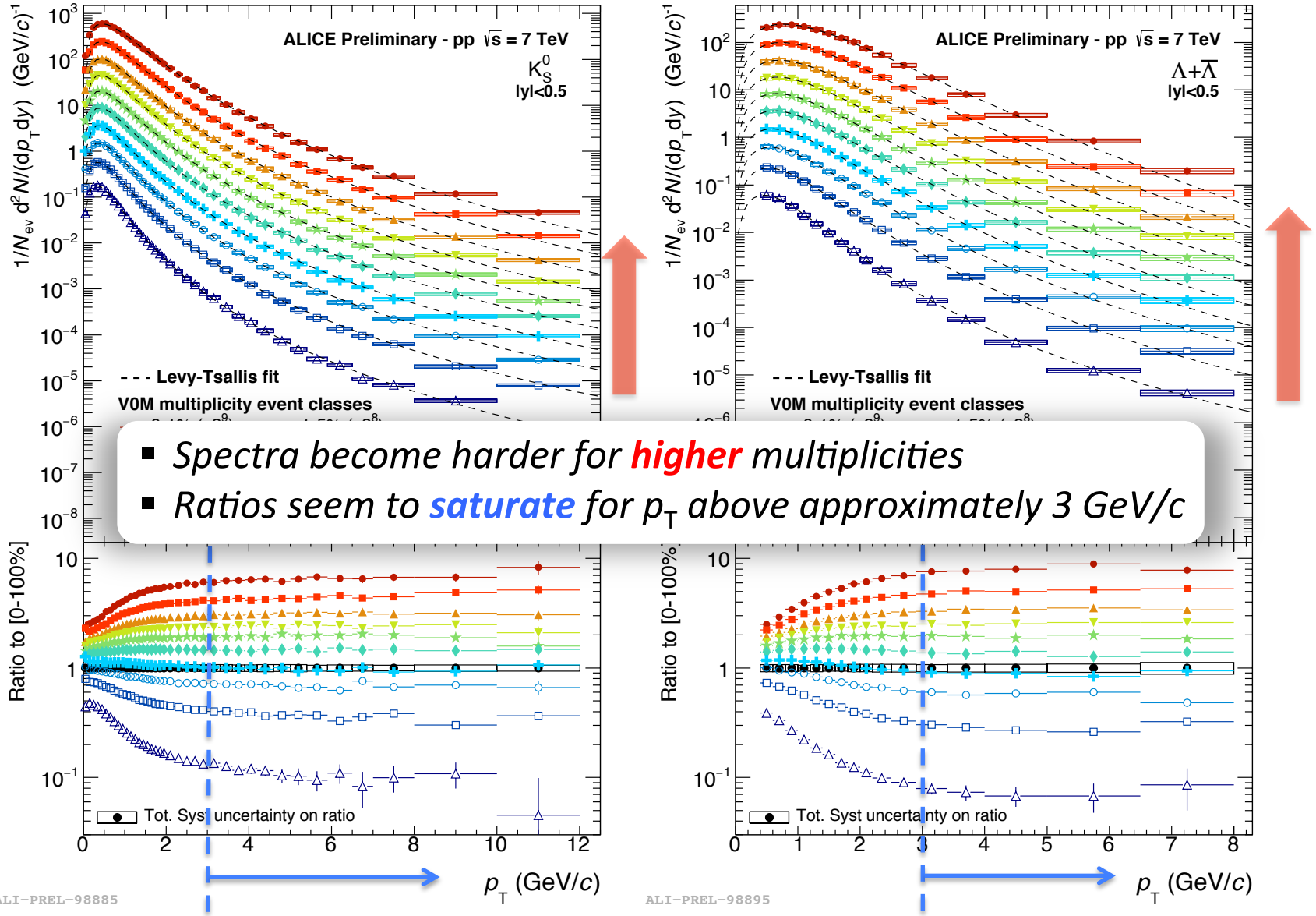


Results: p_T Spectra (I)



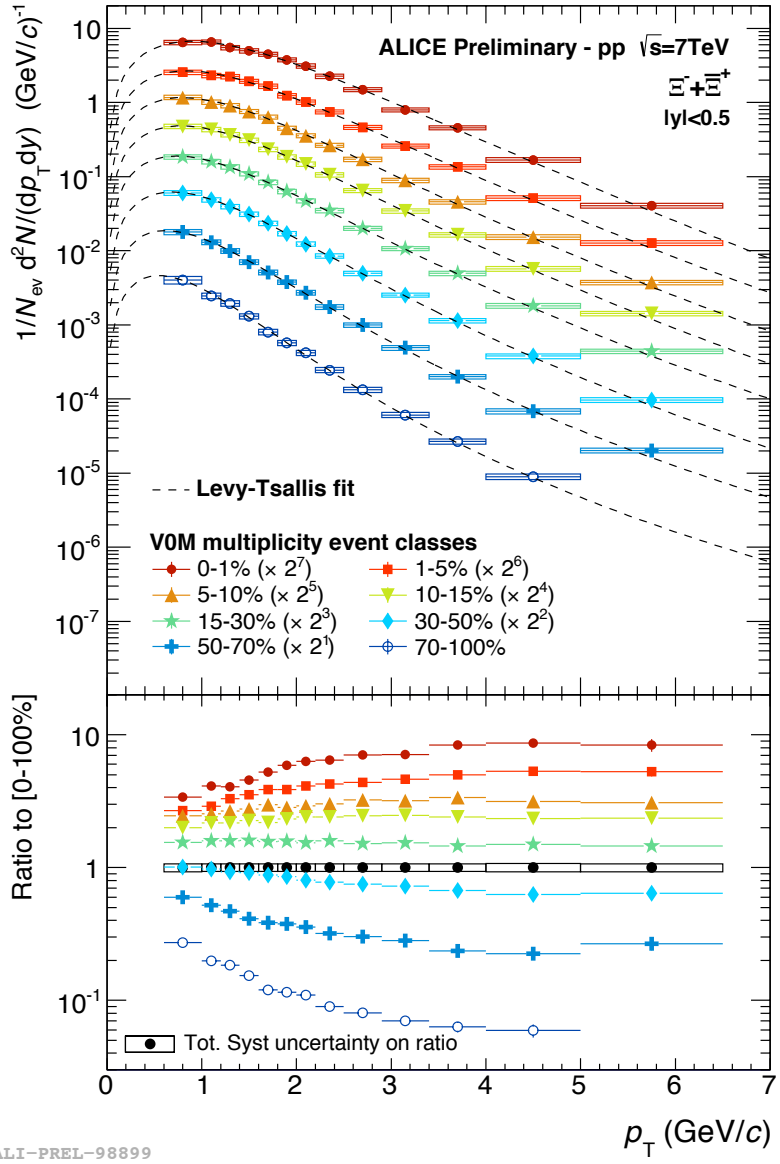


Results: p_T Spectra (I)

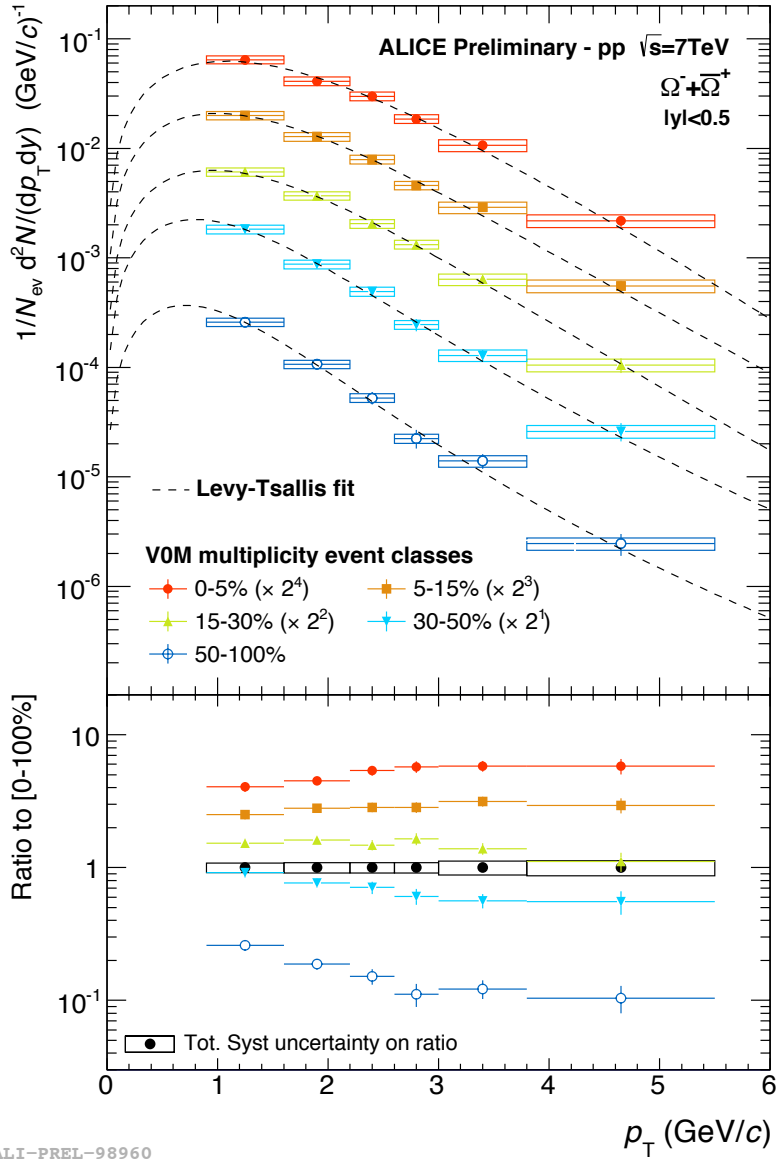


- *Spectra become harder for **higher** multiplicities*
- *Ratios seem to **saturate** for p_T above approximately 3 GeV/c*

Results: p_T Spectra (II)

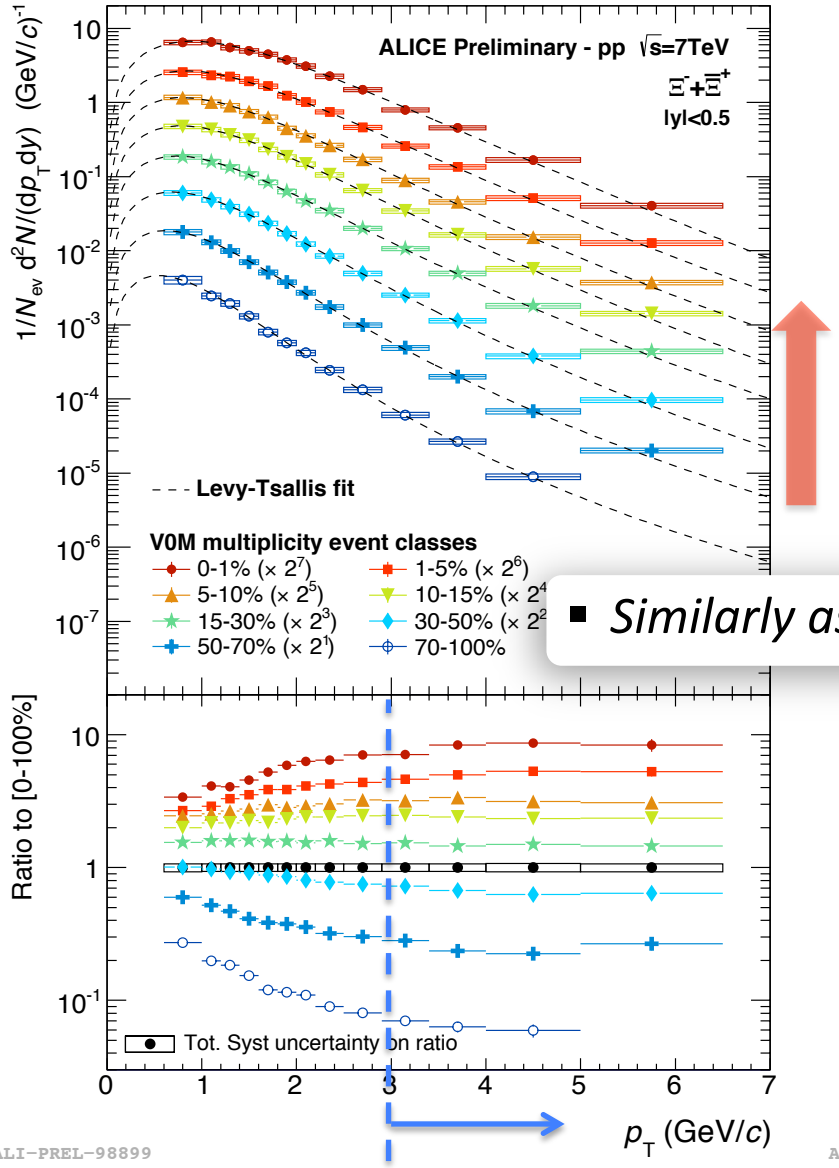


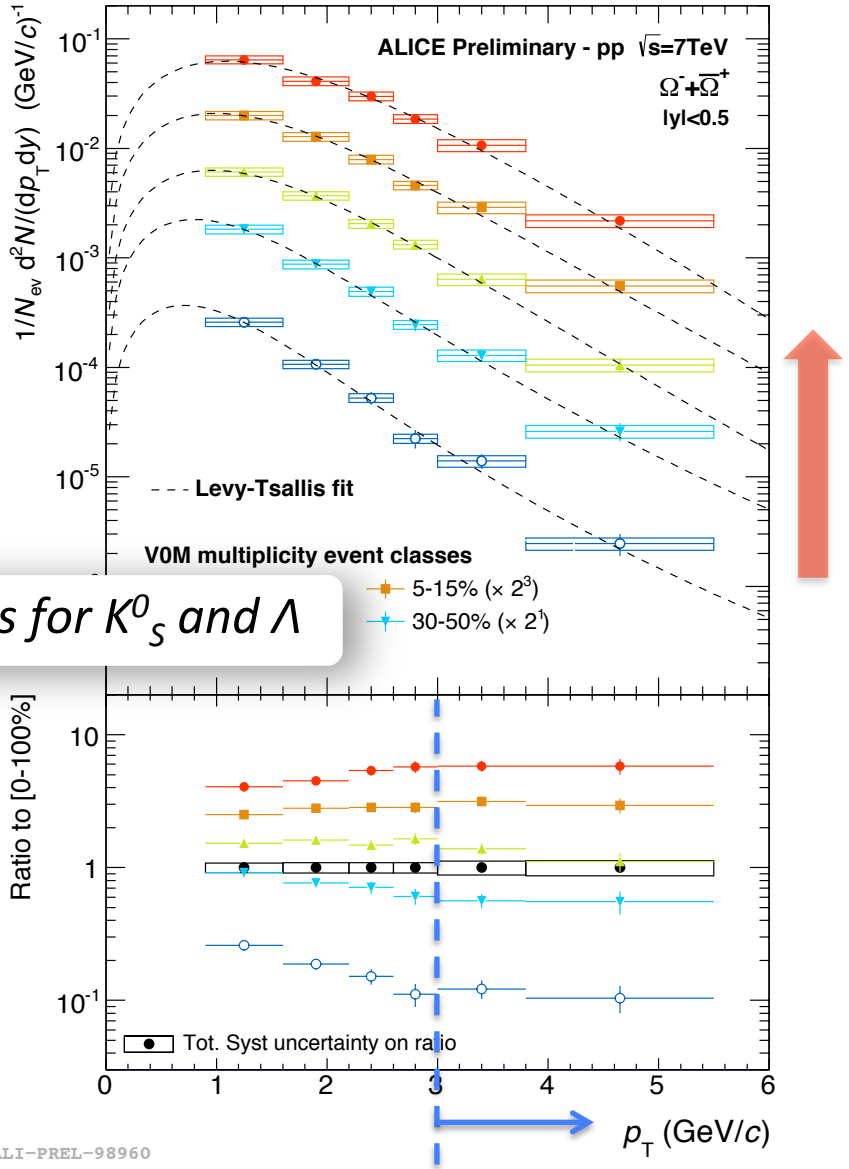
ALI-PREL-98899



ALI-PREL-98960

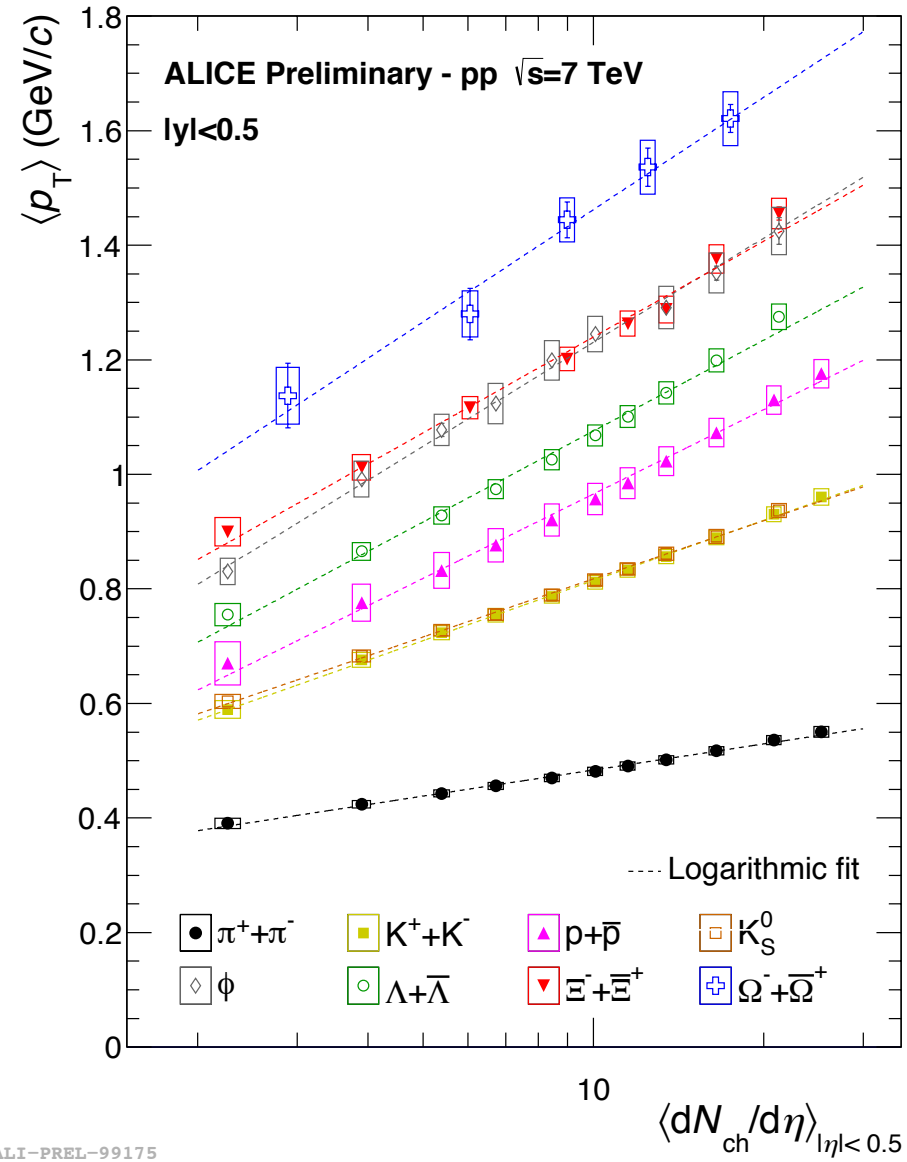
Results: p_T Spectra (II)





- *Similarly as for K^0_S and Λ*

Results: $\langle p_T \rangle$



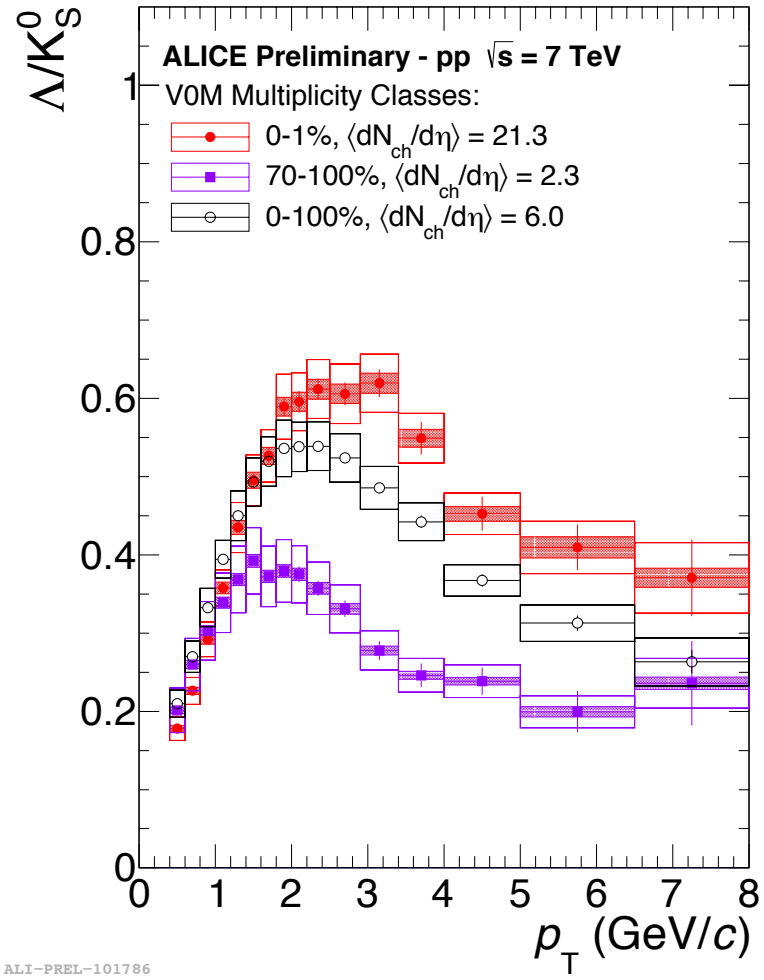
ALI-PREL-99175

Rising trend of $\langle p_T \rangle$ as a function of multiplicity for all identified particles

(dashed lines are logarithmic fits to guide the eye)

The dependence of the $\langle p_T \rangle$ with multiplicity shows the "*hardening*" of the spectra clearly

Results: Λ/K^0_S vs p_T in pp



Λ/K^0_S as a function of p_T for highest (0-1%) and lowest (70-100%) multiplicity selections compared to the multiplicity-integrated (0-100%) selection

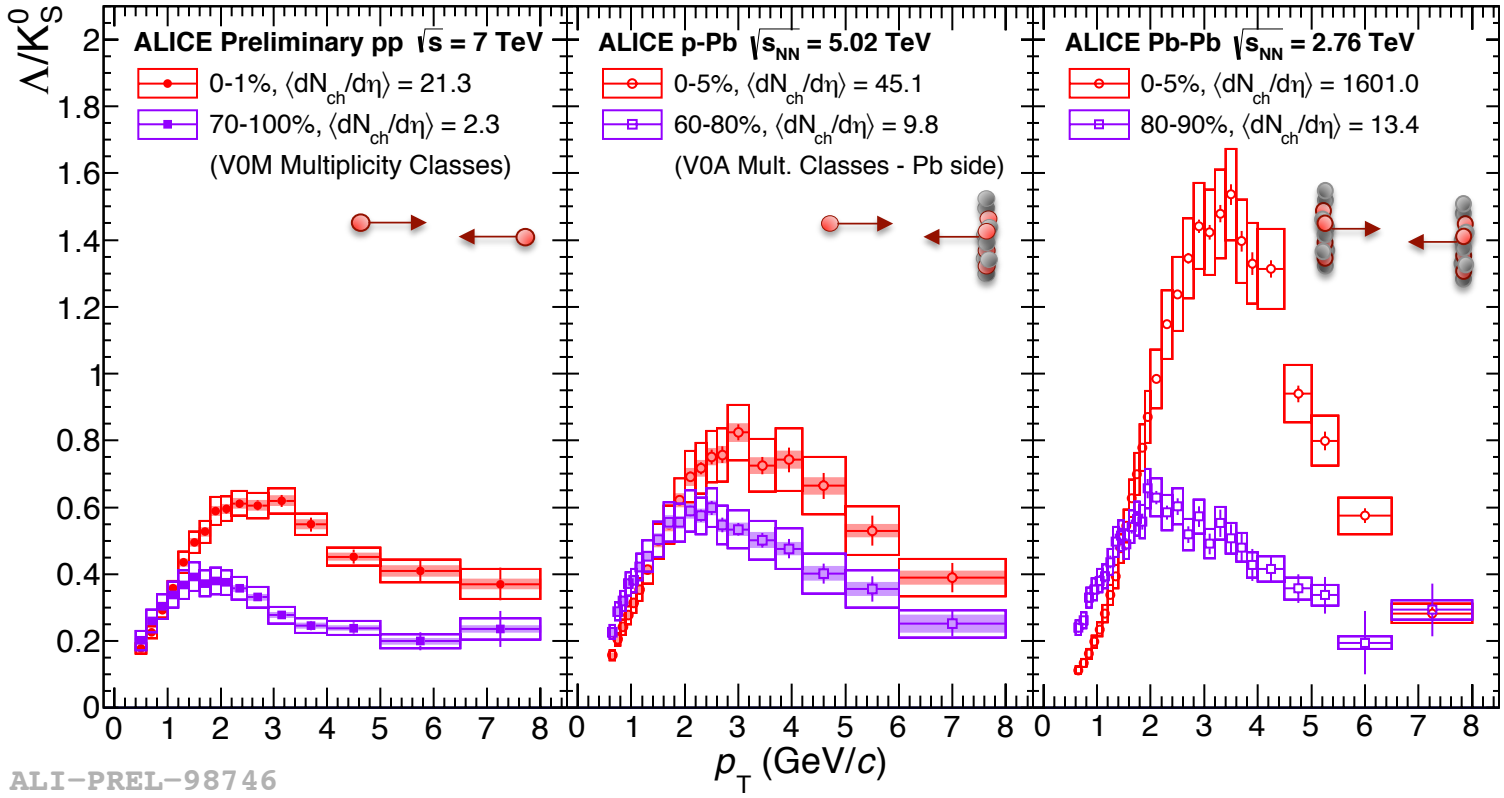
➔ Clear separation between highest and lowest multiplicity selections

➔ The position of the maximum is shifted

➔ The trend observed for the multiplicity-integrated case seems closer to the one observed for the highest multiplicity selection

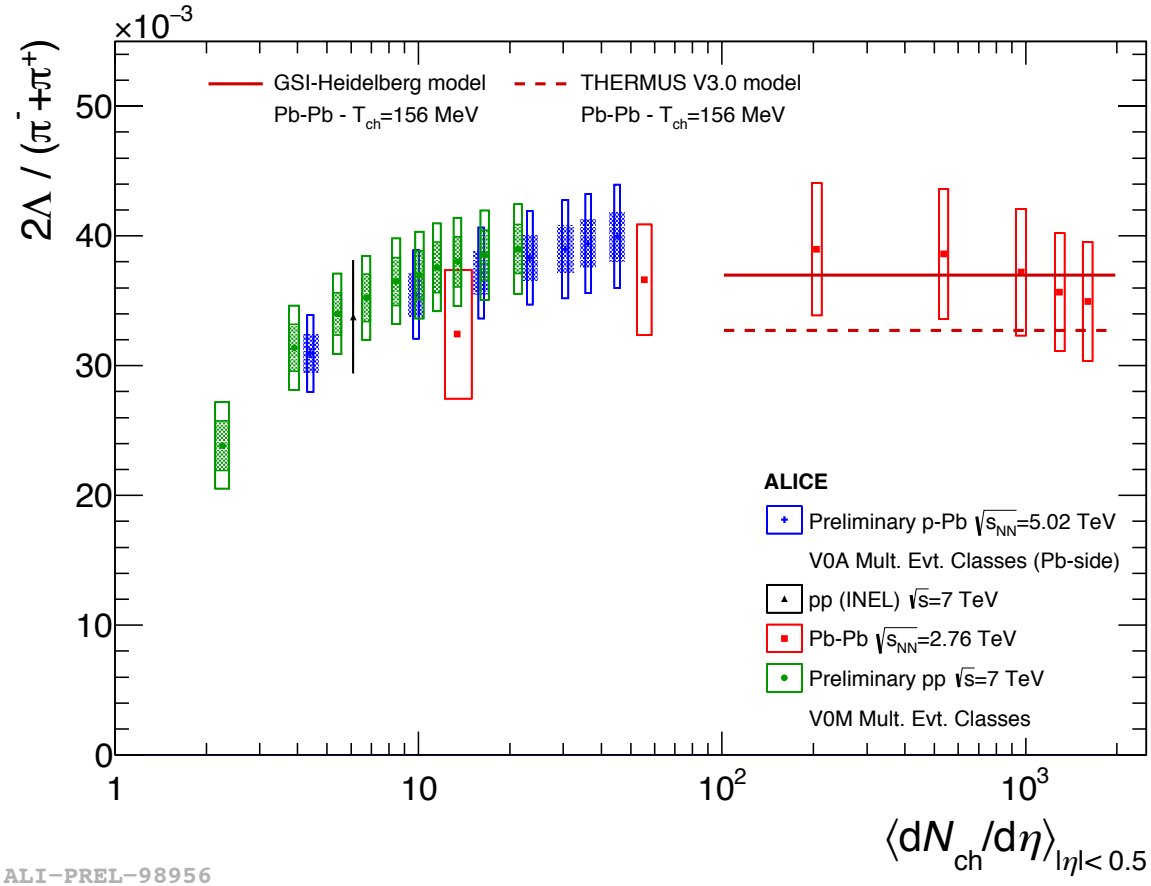
Results: Λ/K^0_S vs p_T in pp, p-Pb, Pb-Pb

p-Pb, Pb-Pb: ALICE, PLB 728 (2014) 25-38



The dependence of the ratio with the event multiplicity in pp seems qualitatively similar to what is observed for p-Pb and Pb-Pb

Results: Λ/π vs multiplicity in pp

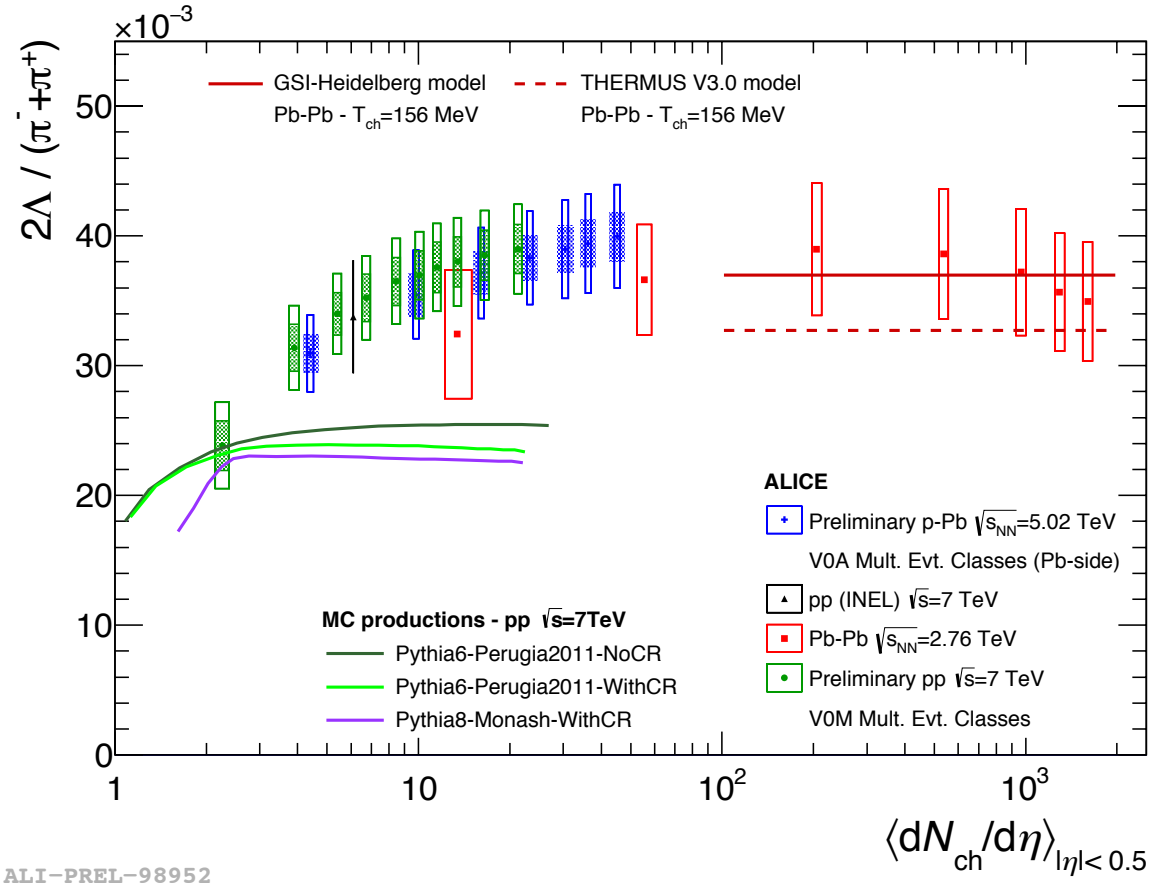


Consistent behavior observed between the results from pp and p-Pb

Good agreement with pp INEL at low multiplicities

GC saturation value reached in the higher multiplicities

Results: Λ/π vs multiplicity in pp



Consistent behavior observed between the results from pp and p-Pb

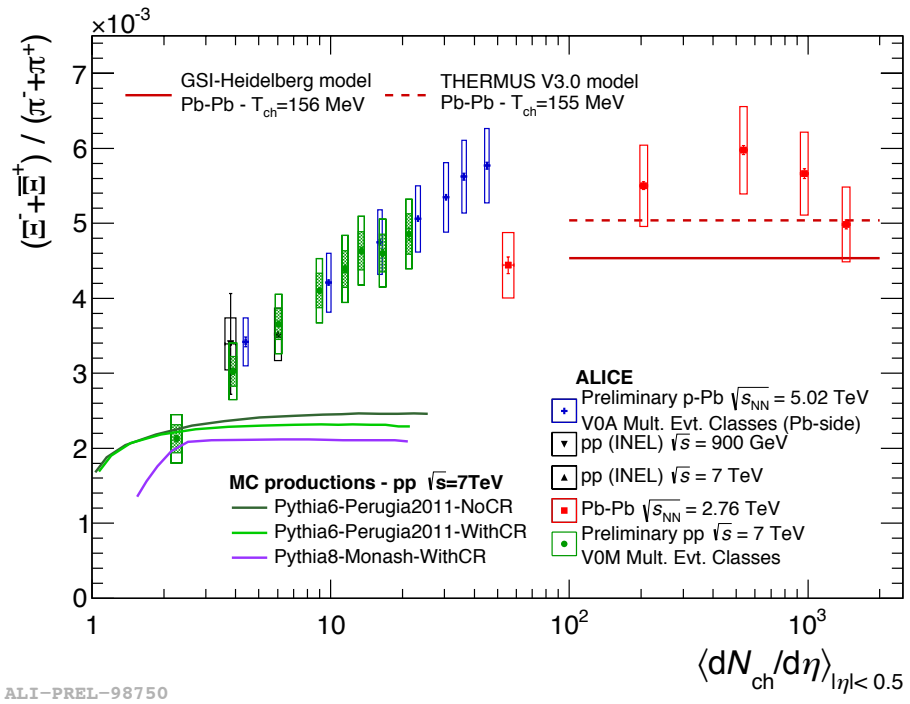
Good agreement with pp INEL at low multiplicities

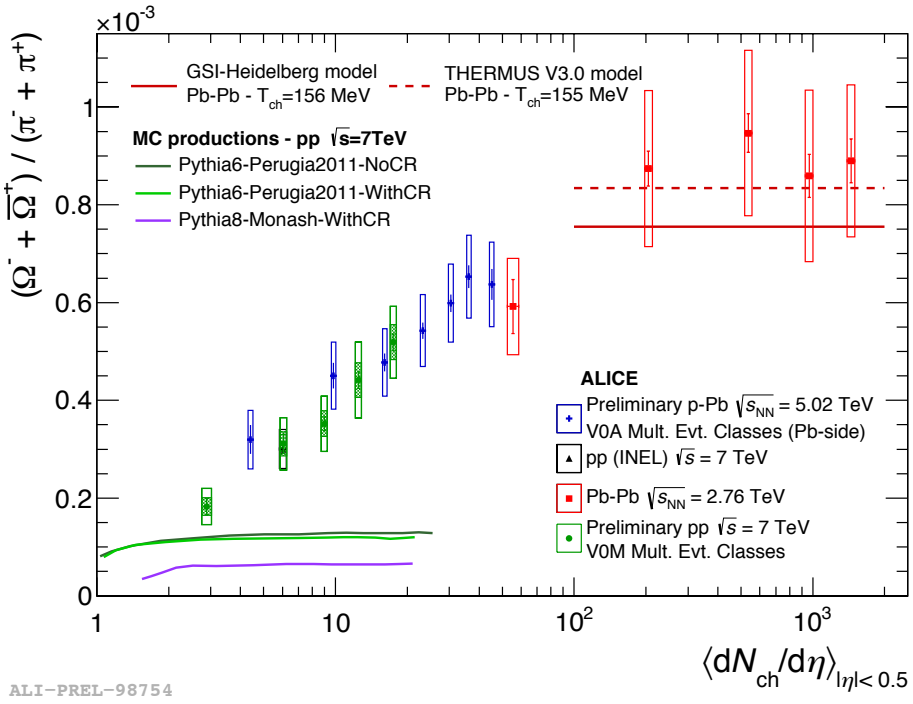
GC saturation value reached in the higher multiplicities

Pythia 6 and **8** predictions using several tunes show ***strong disagreement*** with the observed trend in pp collisions

Effects of color reconnection (CR) in the simulation does not produce significant changes

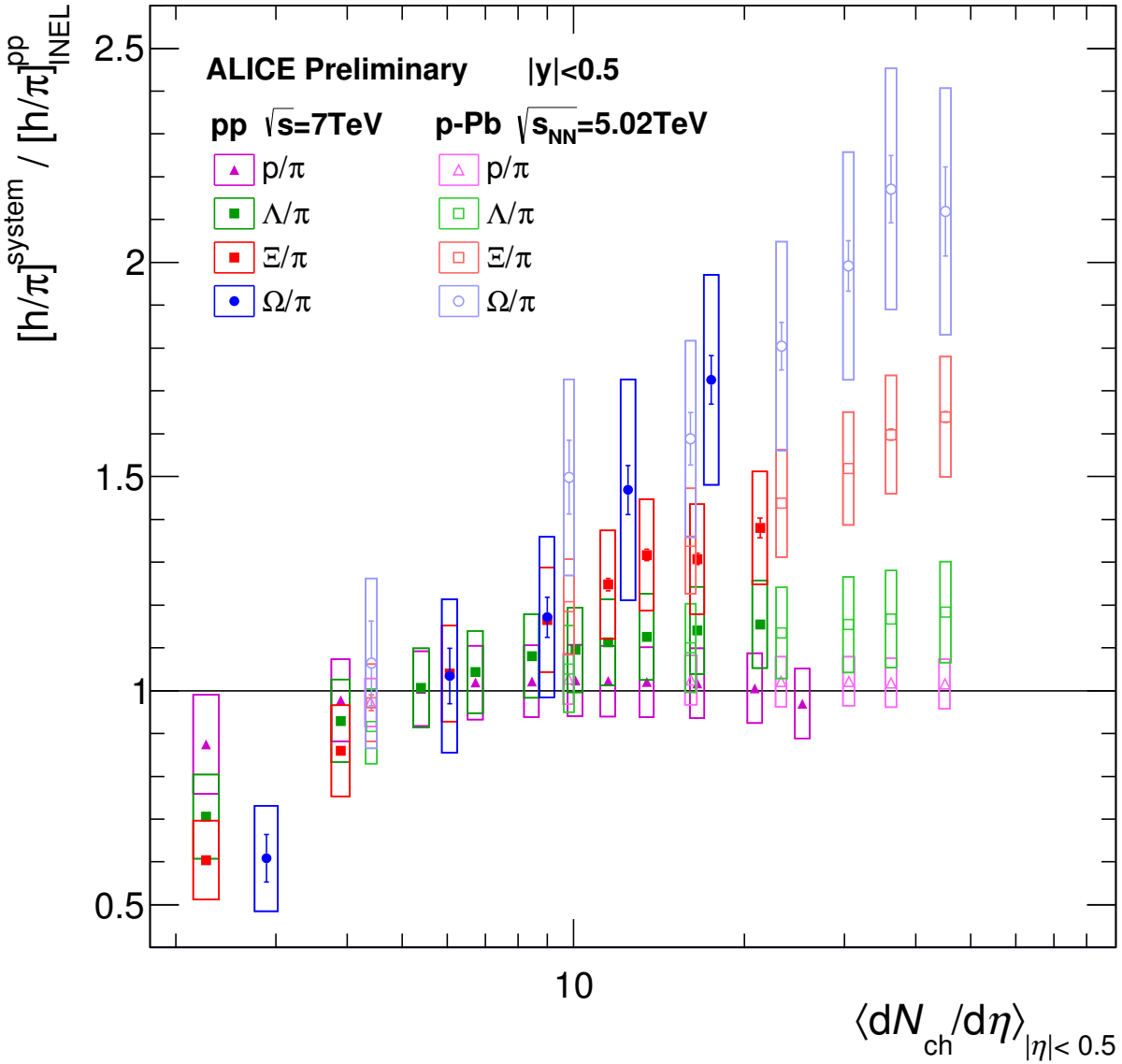
Results: Ξ/π and Ω/π vs mult. in pp





- Similarly to what was shown for Λ/π, the trends observed for pp and p-Pb are very similar
- **Pythia 6** and **8** predictions also show ***strong disagreement*** with the observed trend for Ξ/π and Ω/π
- Comparing to thermal model predictions (THERMUS/GSI-Heidelberg models), Ξ/π seems to reach the GC saturation value but Ω/π stays below

Results: pp and p-Pb scaled by pp_{INEL}



The relative increase with multiplicity is more pronounced for baryons with higher strangeness content

The observed increase seems to be strangeness-related rather than baryon-related since for protons the ratio remains constant up to the highest $\langle N_{ch} \rangle$ probed

ALI-PREL-98972

Summary

- Measurements of **strange and multi-strange hadrons** have been performed **as a function of charged-particle density in pp collisions** at √s = 7 TeV with the ALICE experiment
- The **spectra shape** are observed to **become harder** as one selects on higher multiplicity events
- The trend of Λ/K^0_S vs p_T for different multiplicity selections observed in **pp** is **similar** to the corresponding observations in **p-Pb** and **Pb-Pb**
- Increase of yield ratios (Λ/π, Ξ/π, Ω/π) with multiplicity also follows the **same trend observed in p-Pb**
- Comparisons with **predictions** from Monte Carlo generators Pythia 6 and 8 show strong **disagreement** for all cases

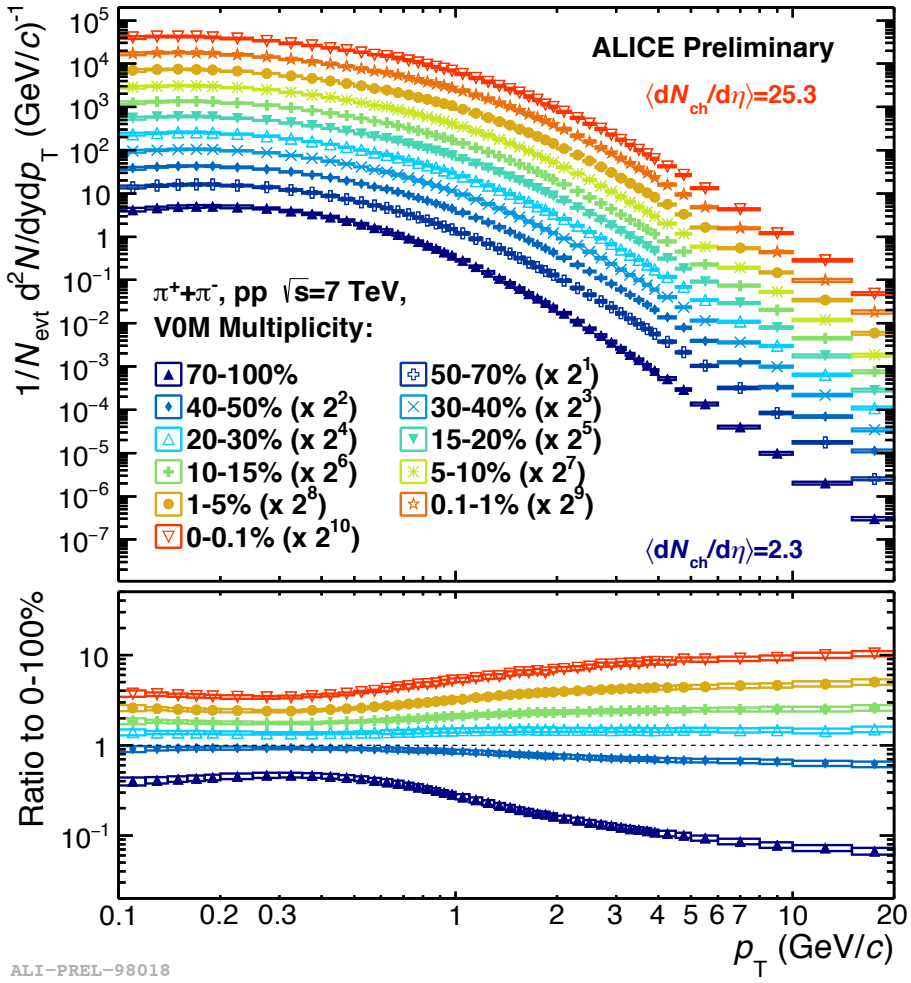
Thank you for the attention!

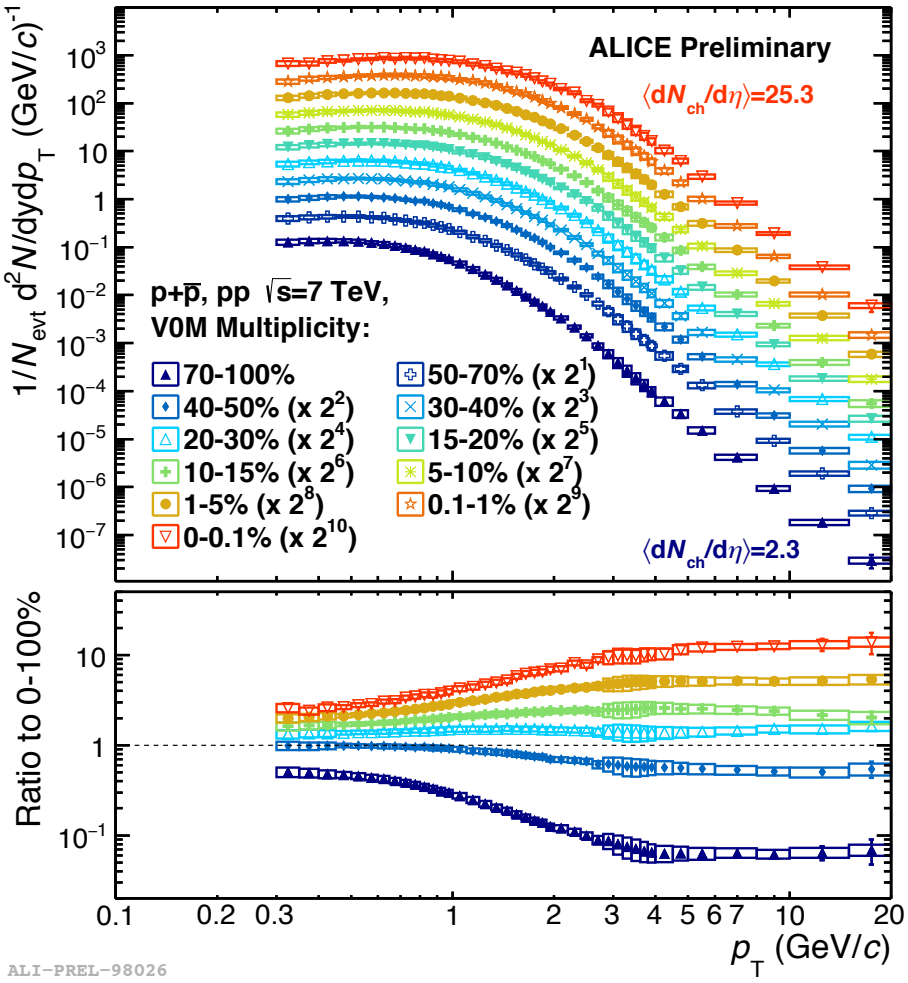
Backup

(backup) Multiplicity Selection Classes

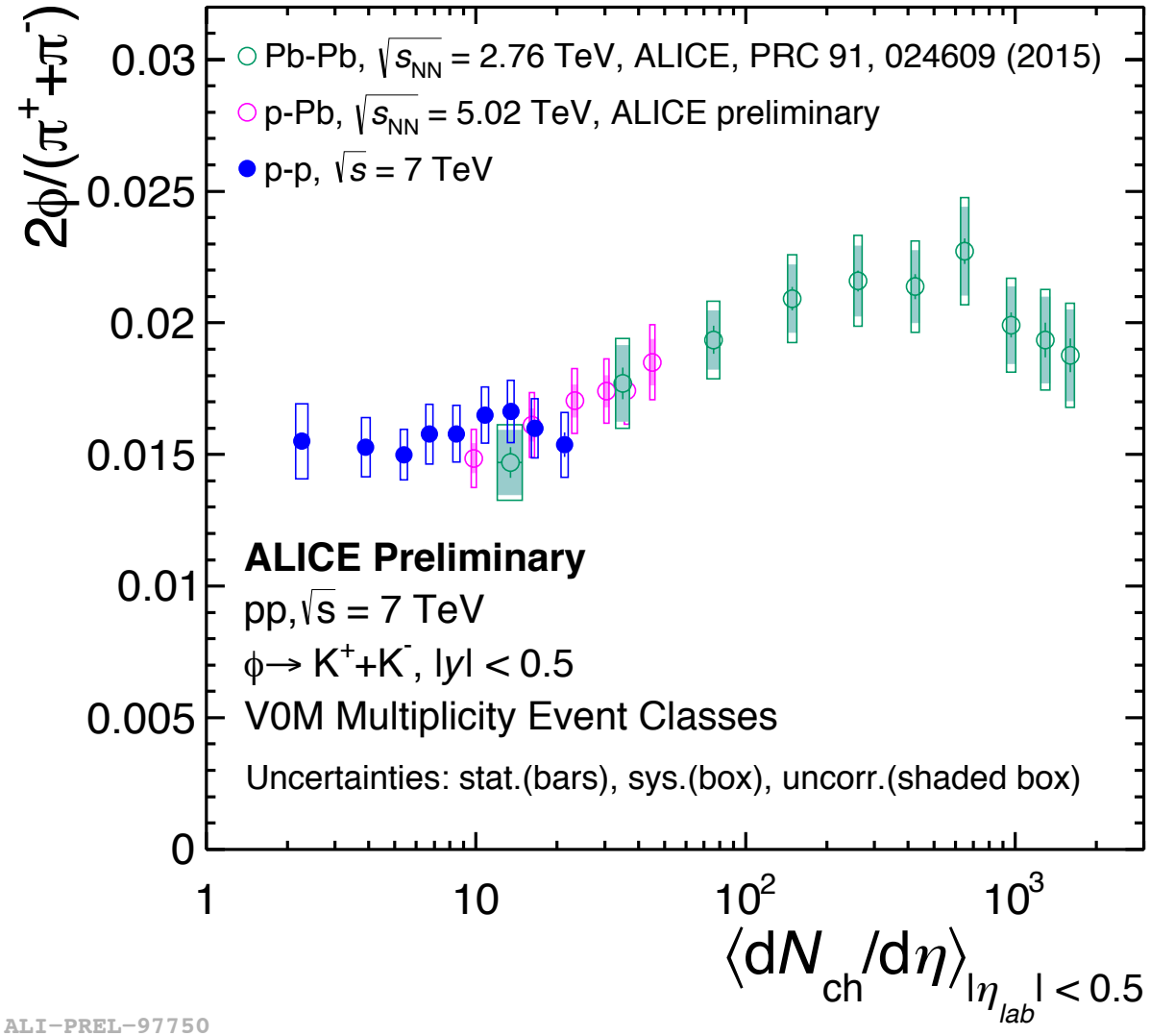
K^0_S and Λ		Ξ		Ω	
V0M Classes	**$\langle dN_{ch}/d\eta \rangle_{\lvert\eta\rvert<0.5}$**	**V0M Classes**	**$\langle dN_{ch}/d\eta \rangle_{\lvert\eta\rvert<0.5}$**	**V0M Classes**	**$\langle dN_{ch}/d\eta \rangle_{\lvert\eta\rvert<0.5}$**
0 – 1%	21.29±0.04±0.64	0 – 1%	21.29±0.04±0.64	0 – 5%	17.47±0.02±0.52
1 – 5%	16.51±0.01±0.50	1 – 5%	16.51±0.01±0.50		
5 – 10%	13.46±0.01±0.35	5 – 10%	13.46±0.01±0.35	5 – 15%	12.48±0.01±0.38
10 – 15%	11.51±0.01±0.35	10 -15%	11.51±0.01±0.35		
15 – 20%	10.08±0.01±0.30	15 – 30%	8.99±0.01±0.27	15 – 30%	8.99±0.01±0.27
20 – 30%	8.45±<0.01±0.25				
30 – 40%	6.72±<0.01±0.21	30 – 50%	6.06±<0.01±0.19	30 – 50%	6.06±<0.01±0.19
40 – 50%	5.40±<0.01±0.17				
50 – 70%	3.90±<0.01±0.14	50 – 70%	3.90±<0.01±0.14	50 – 100%	2.89±<0.01±0.14
70 – 100%	2.26±<0.01±0.12	70 – 100%	2.26±<0.01±0.12		

(backup) π and p spectra

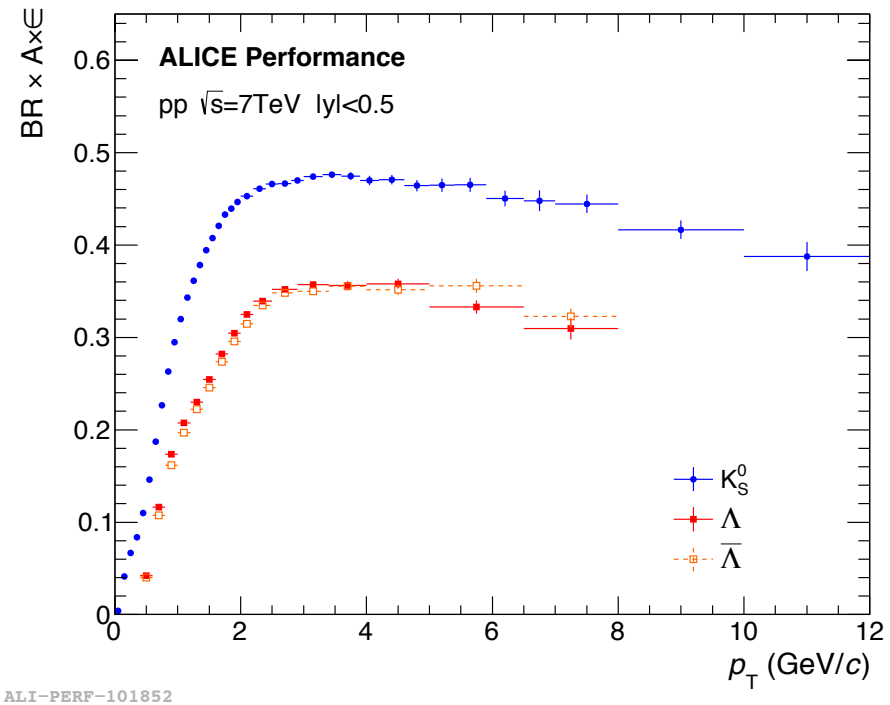




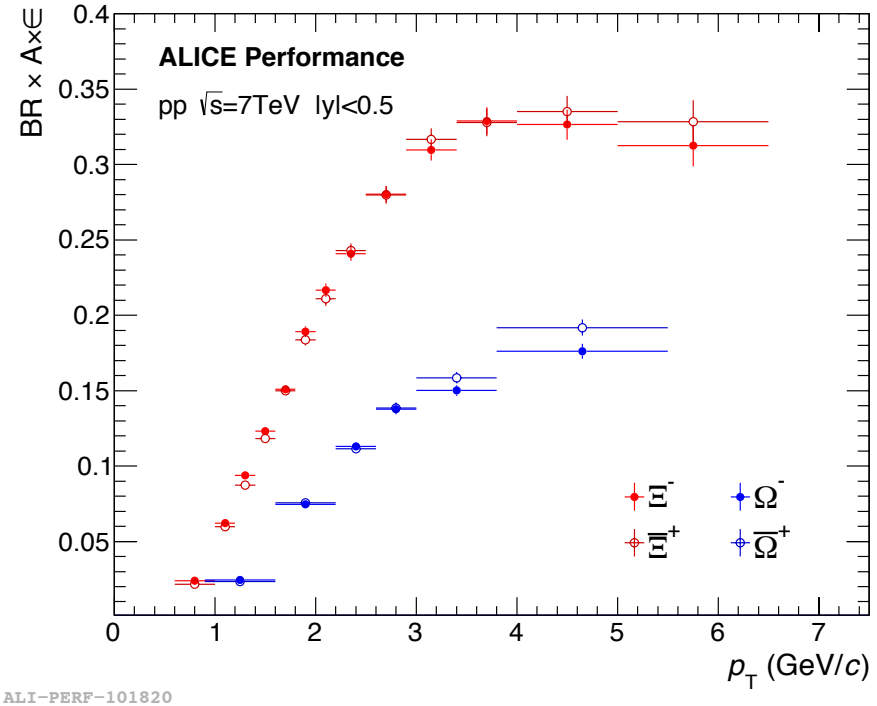
(backup) 2ϕ/(π⁺+π⁻) vs multiplicity



(backup) Acceptance × Efficiency



ALI-PERF-101852



ALI-PERF-101820