Strangeness production with ALICE at the LHC

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Outline

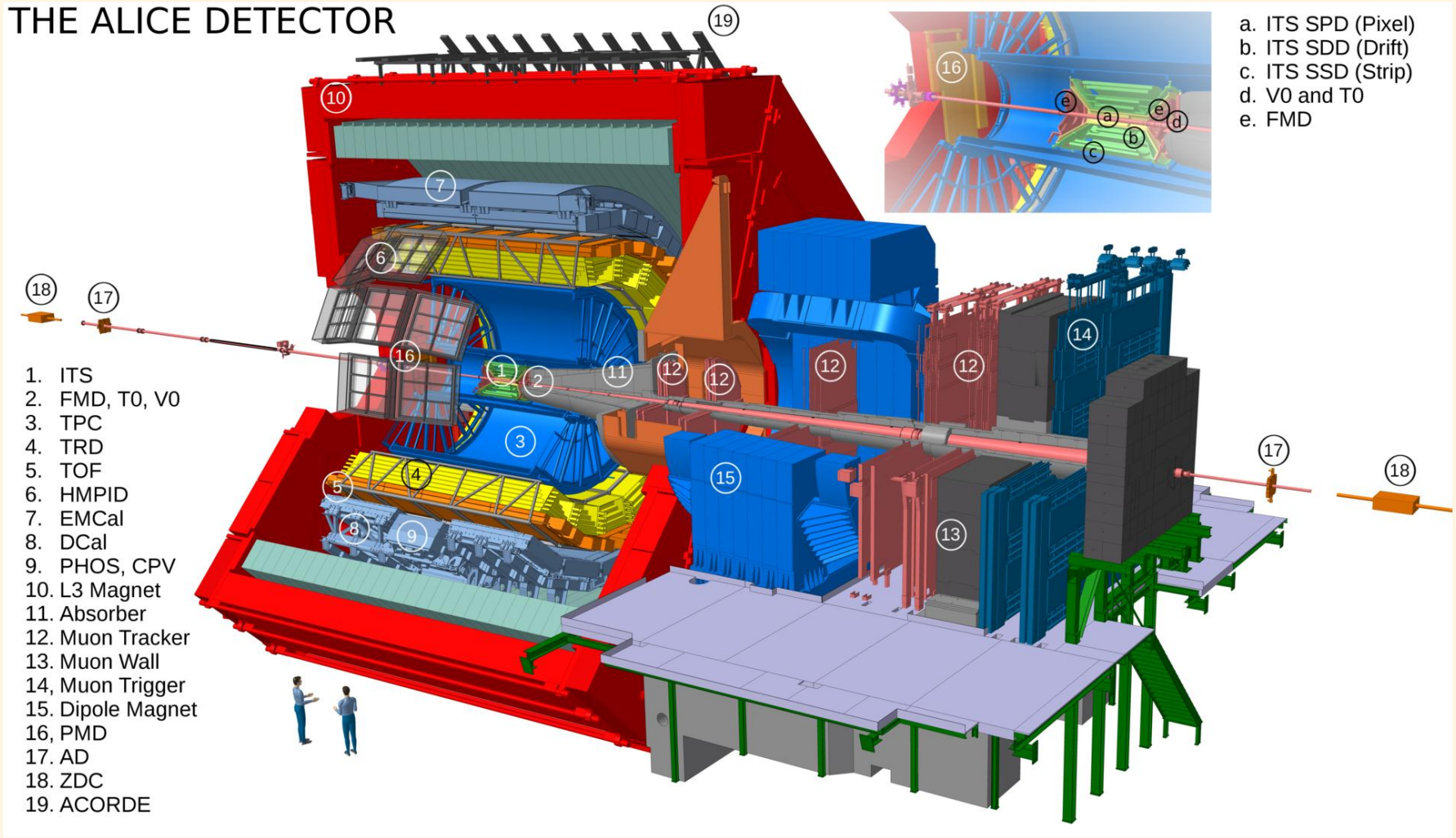
- Introduction
- ALICE Detector and PID
- Strange particle detection
- Strangeness production in pp, p-Pb, Xe-Xe and Pb-Pb collisions:
  - transverse momentum spectra
  - baryon-to-meson ratios
  - strangeness enhancement
- Conclusions

Introduction

ALICE is designed to study the physics of strongly interacting matter under extremely high temperature and energy density conditions to investigate the properties of the quark-gluon plasma (QGP). The Experiment has collected data from:

- **pp collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7, 8, 13 TeV**
  - Test QCD inspired models
  - Search for collective effects in small systems
  - Provide reference for p-Pb and Pb-Pb data
- **p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02, 8.16 TeV**
  - Discriminate between initial (cold nuclear matter) and final state (QGP) effects
  - Search for collective effects in small systems
  - Provide reference for Pb-Pb data
- **Xe-Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV**
  - Study the colliding system size dependence
- **Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76, 5.02 TeV**
  - Study QGP properties and its evolution

ALICE Detector



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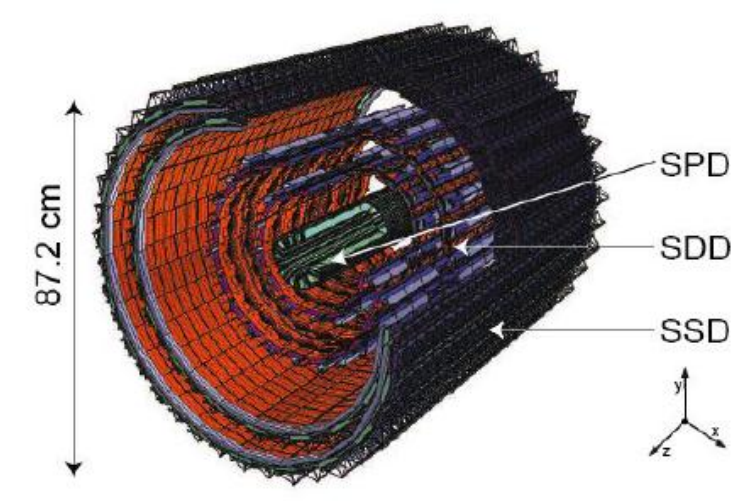

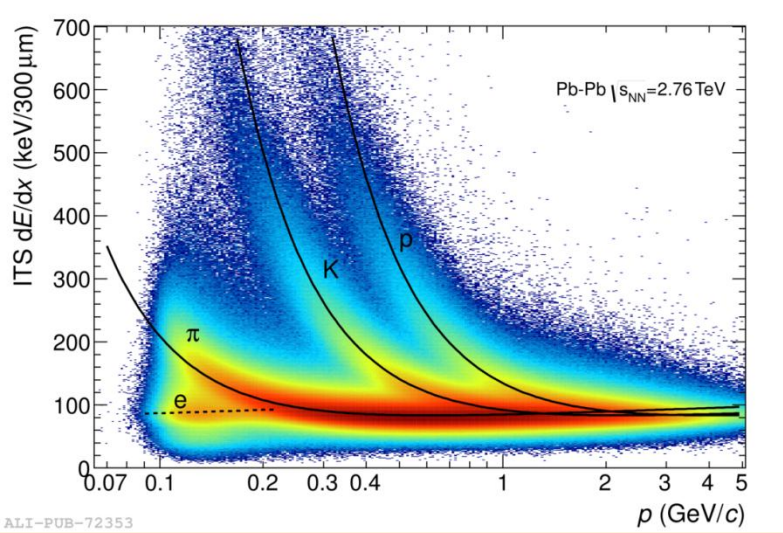

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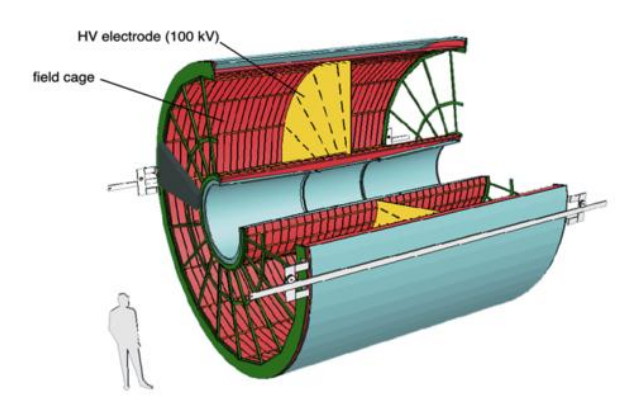
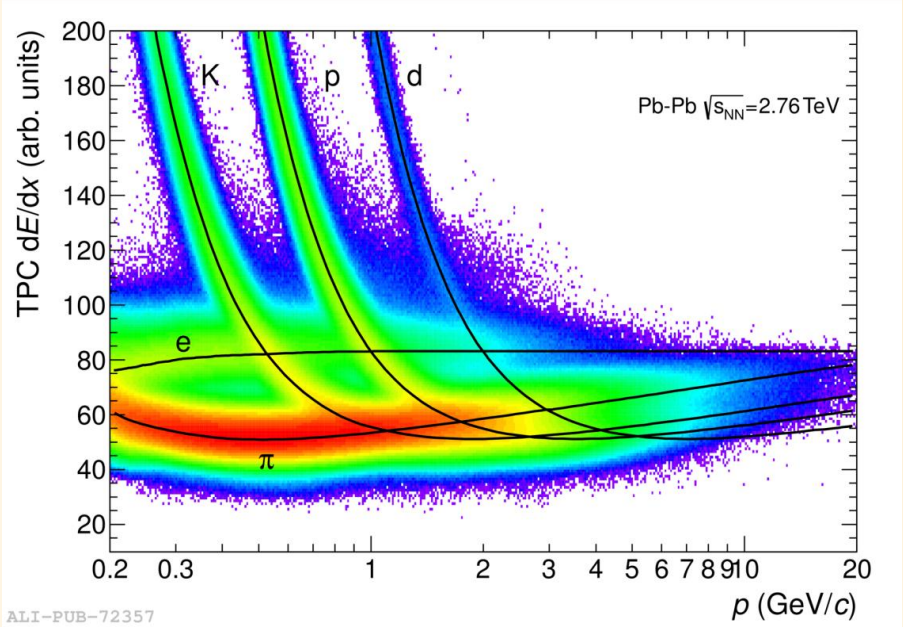
- Inner Tracking System:
  2 layers of Silicon Pixel Detector (SPD)
  2 layers of Silicon Drift Detector (SDD)
  2 layers of Silicon Strip Detector (SSD)
- Drift and Strip Detectors provide a measurement of the ionization energy loss
- PID to very low p_T:
  pions down to 100 MeV/c with stand-alone tracking

TPC



- PID via dE/dx in gas – Ar/CO_2 (90:10) – up to 159 samples
- Truncated mean dE/dx calculated and used for particle identification (PID) in a wide momentum range
- Largest π/K and K/p separation achieved at low p (< 2.0 GeV/c)



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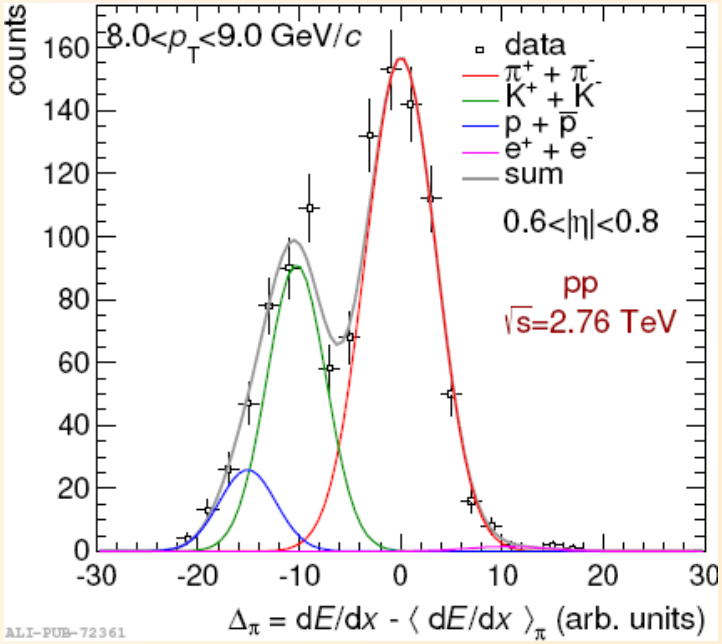
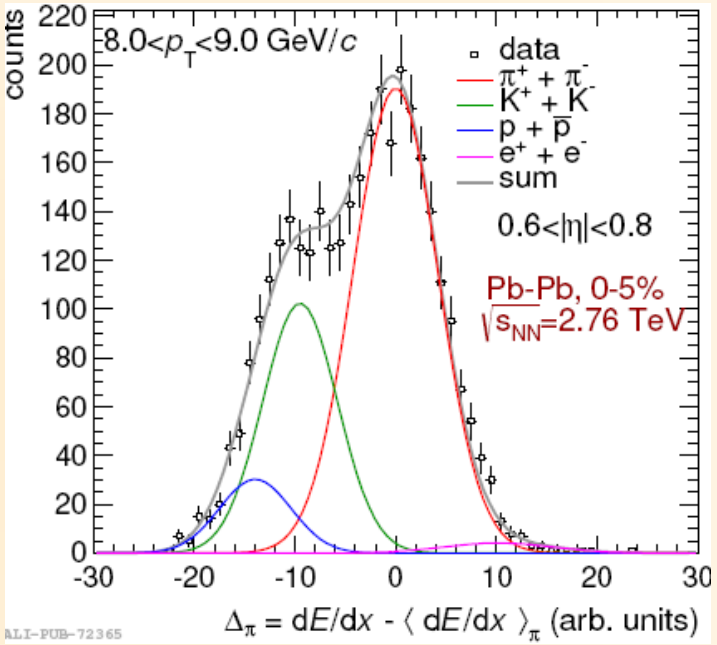
TPC





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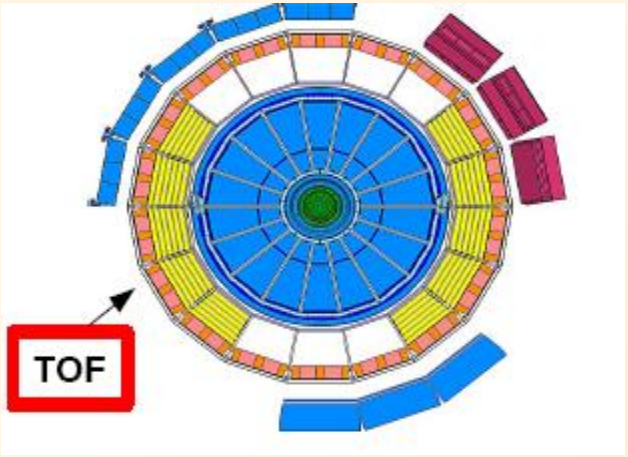
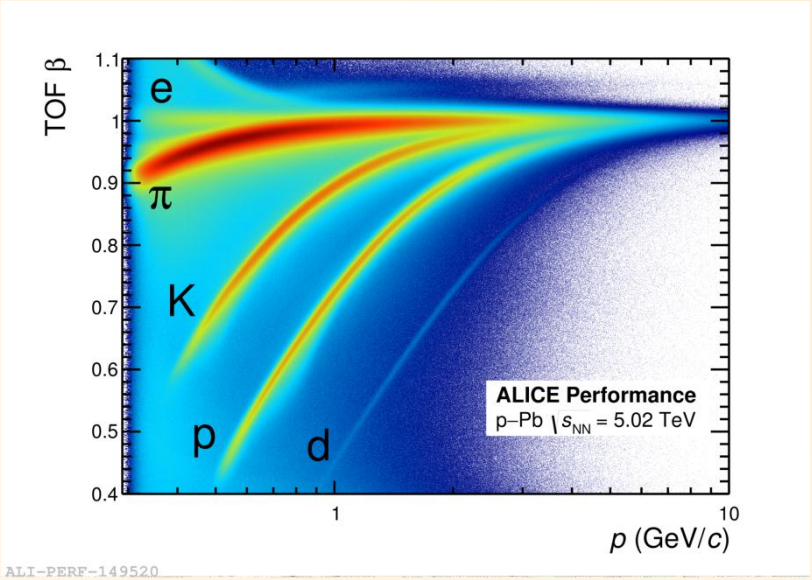
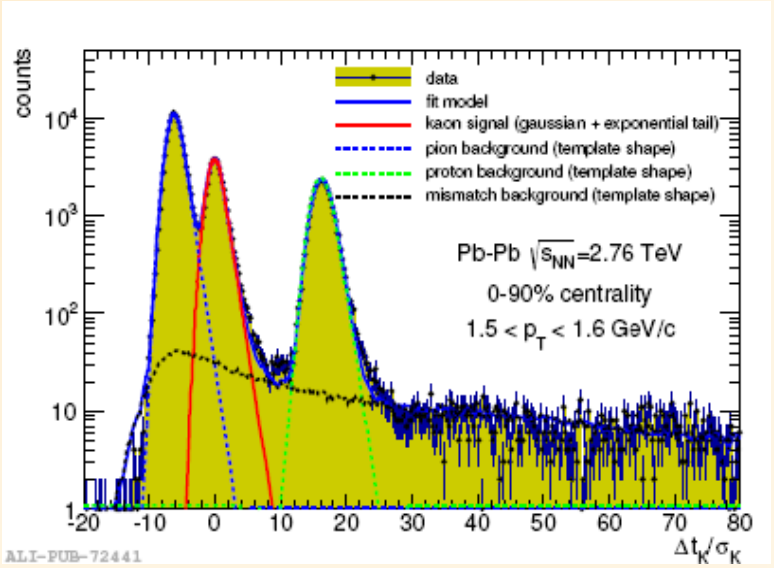
- At high p_T : particles separated on a statistical basis via multi-Gaussian fits

TOF

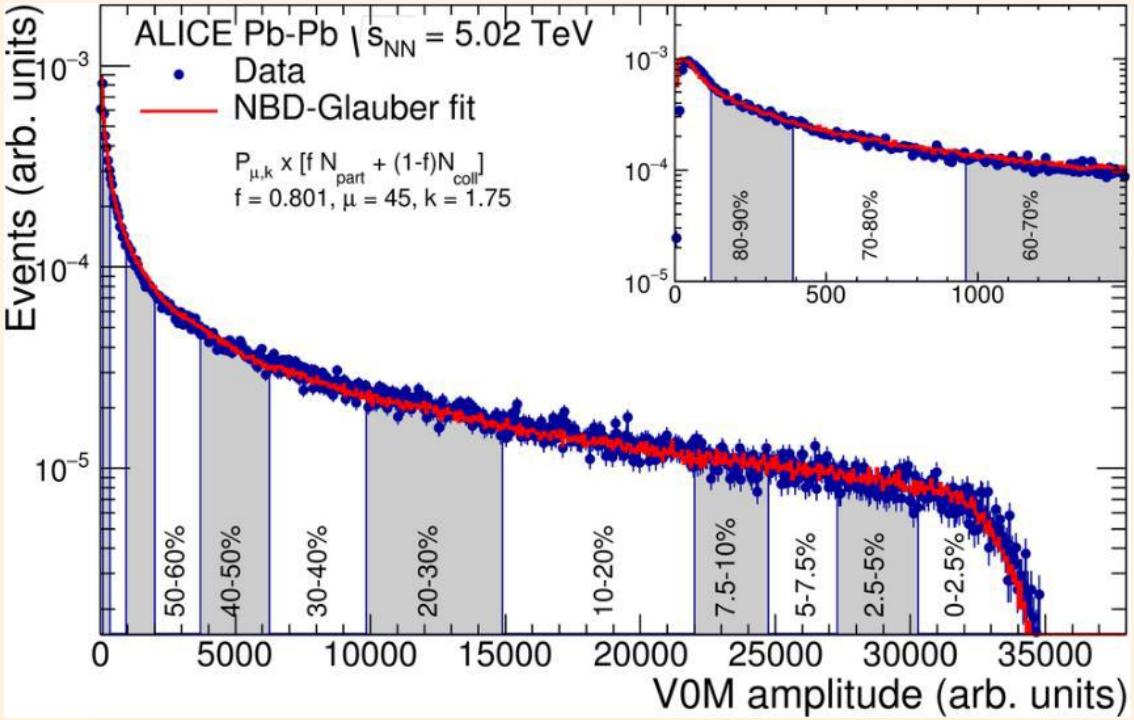


- Time - Of - Flight:
  Multigap Resistive Plate Chambers (MRPC)
  PID at intermediate momenta
- Resolution ~ 80 ps





Centrality Selection in Pb-Pb Collisions



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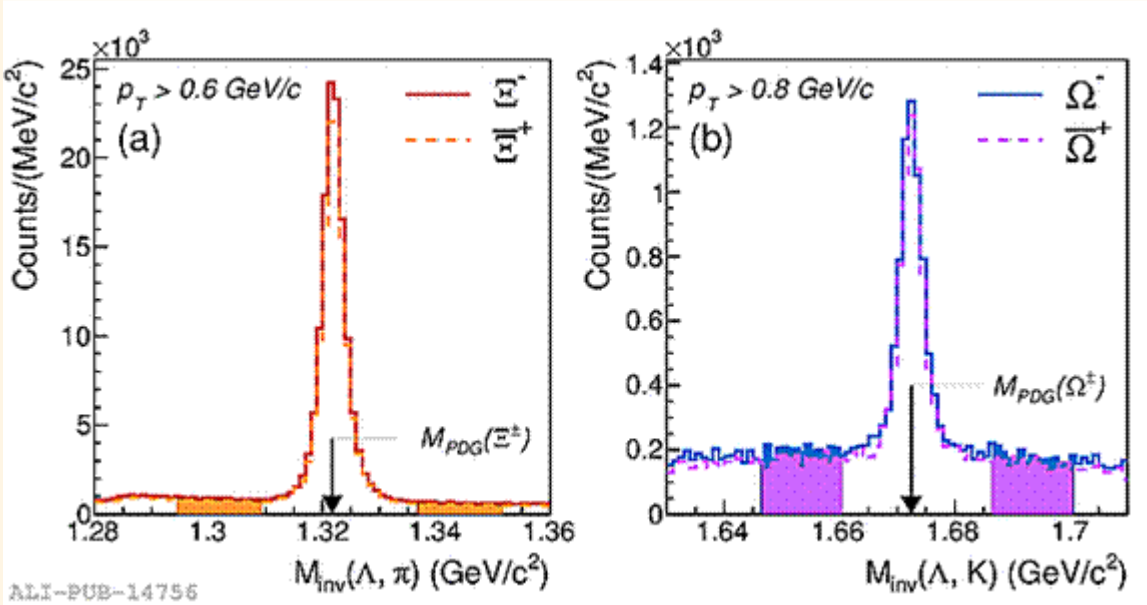
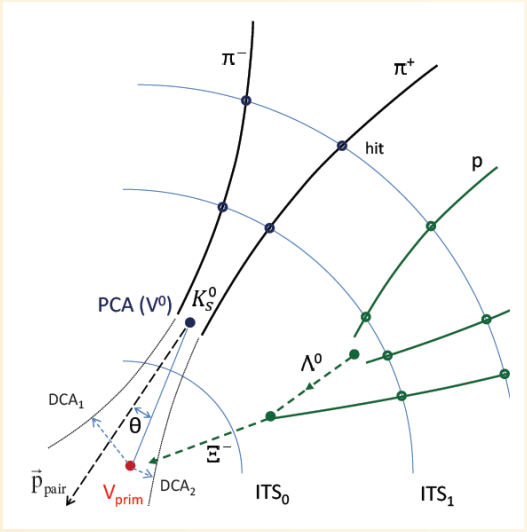
- Event centrality classes are defined based on the amplitude measured in the V0 scintillators placed at : $2.8<\eta<5.1$ (V0A) and $-3.7<\eta<-1.7$ (V0C)
- Curve: Glauber model fit to the measurement

Strange particle detection





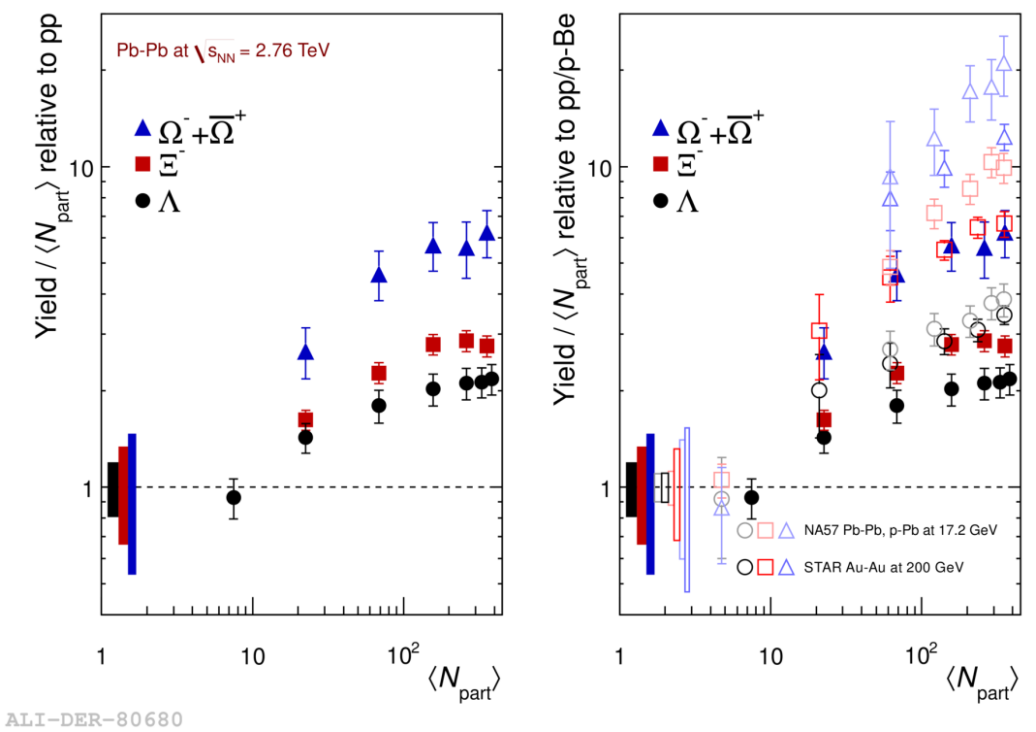
- Topological decay reconstruction
- Geometrical and kinematical selections
- Invariant mass analysis

$$K^0_S \rightarrow \pi^+ + \pi^- \text{ (B.R. 69.2\%)}$$
$$\Lambda \rightarrow p + \pi^- \text{ (B.R. 63.9\%)}$$
$$\overline{\Lambda} \rightarrow \overline{p} + \pi^+ \text{ (B.R. 63.9\%)}$$

$$\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^- \text{ (B.R. 63.9\%)}$$
$$\overline{\Xi}^+ \rightarrow \overline{\Lambda} + \pi^+ \rightarrow \overline{p} + \pi^+ + \pi^+ \text{ (B.R. 63.9\%)}$$
$$\Omega^- \rightarrow \Lambda + K^- \rightarrow p + \pi^- + K^- \text{ (B.R. 43.3\%)}$$
$$\overline{\Omega}^+ \rightarrow \overline{\Lambda} + K^+ \rightarrow \overline{p} + \pi^+ + K^+ \text{ (B.R. 43.3\%)}$$

Pb-Pb Collisions

Strangeness enhancement



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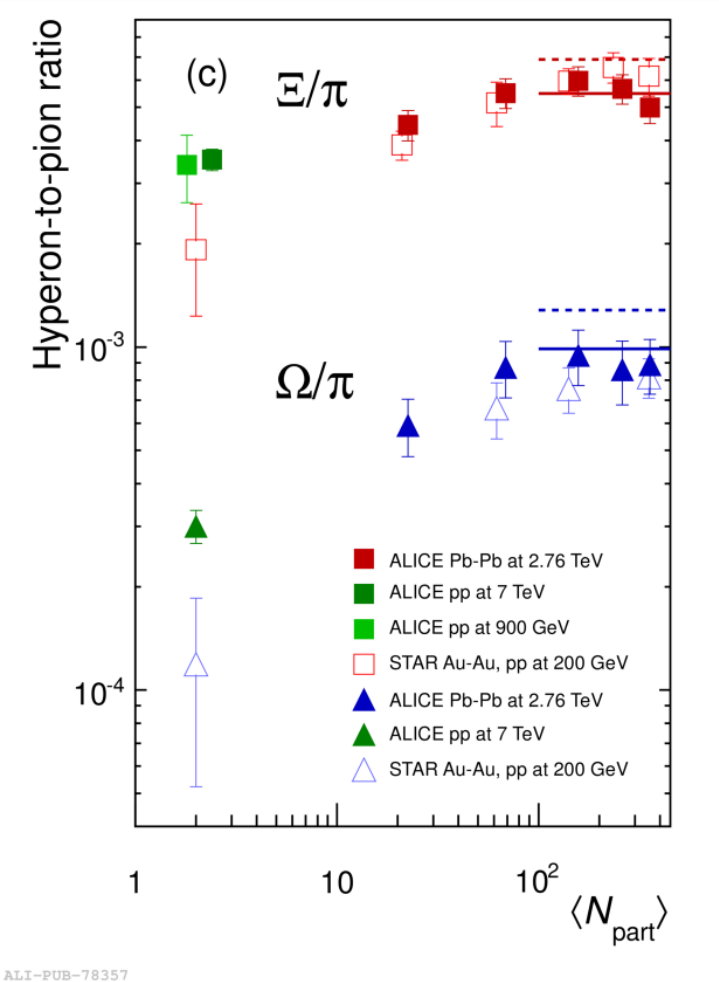
- Enhanced production of strange particles in A-A collisions w.r.t. pp
- Enhancement increases with the strangeness content of the particle
- Decreasing trend with increasing energy, as a result of (canonical) suppression in pp collisions

Strangeness enhancement



- In pp collisions the production of strangeness relative to pions is larger at the LHC
- Increase of strangeness production measured in Pb-Pb w.r.t. pp collisions
- Saturation of the ratios for large number of participants
- Values consistent with statistical hadronization models

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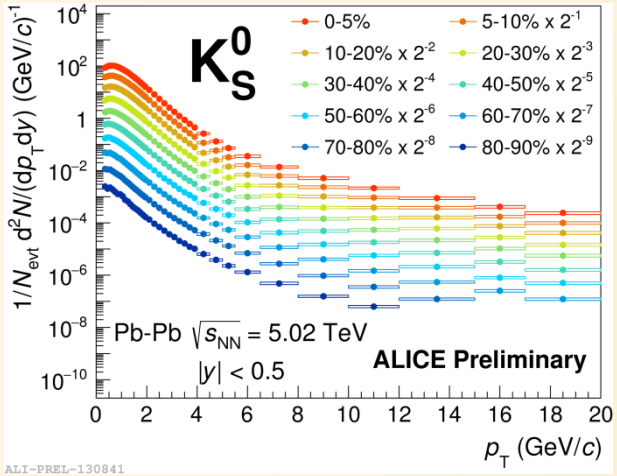
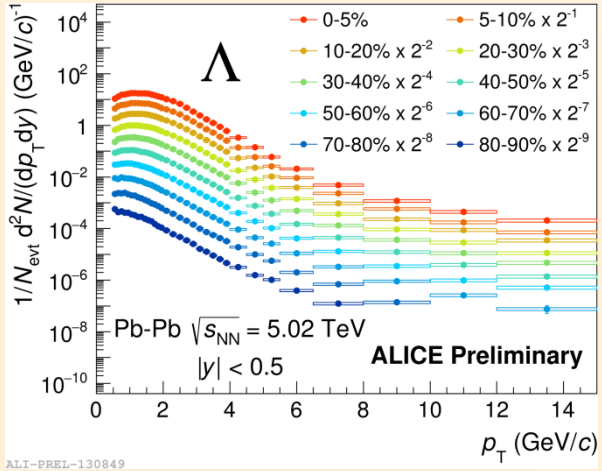
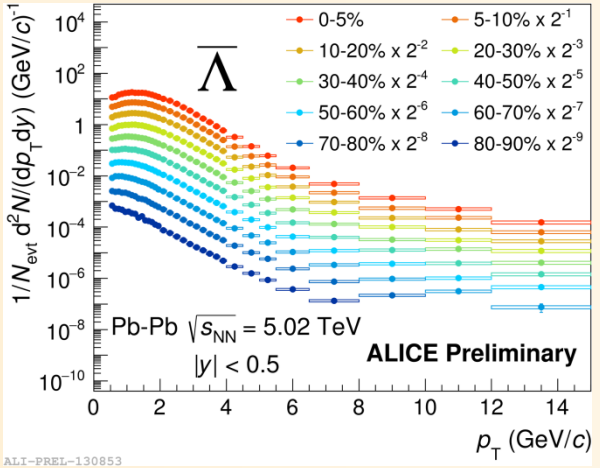
Transverse momentum spectra

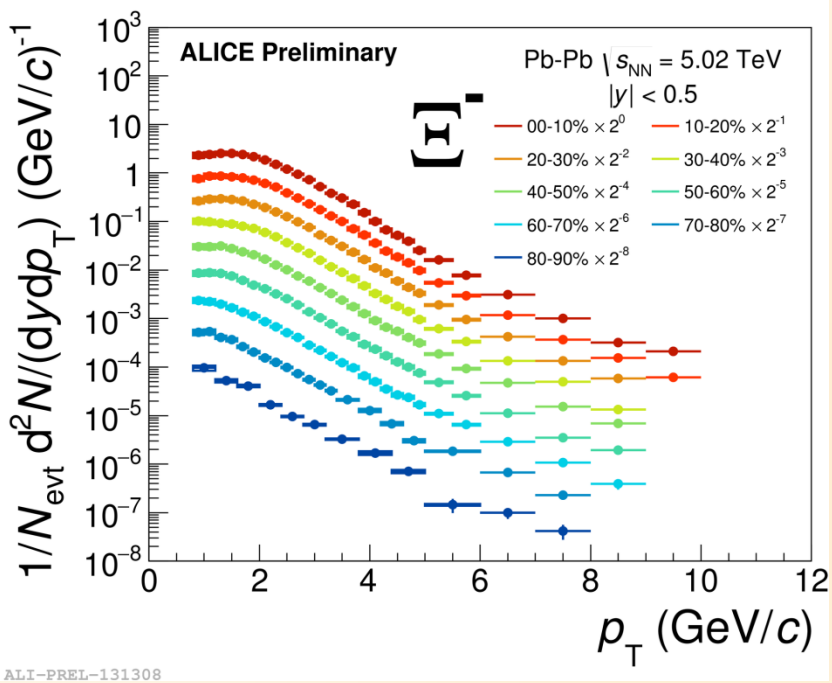


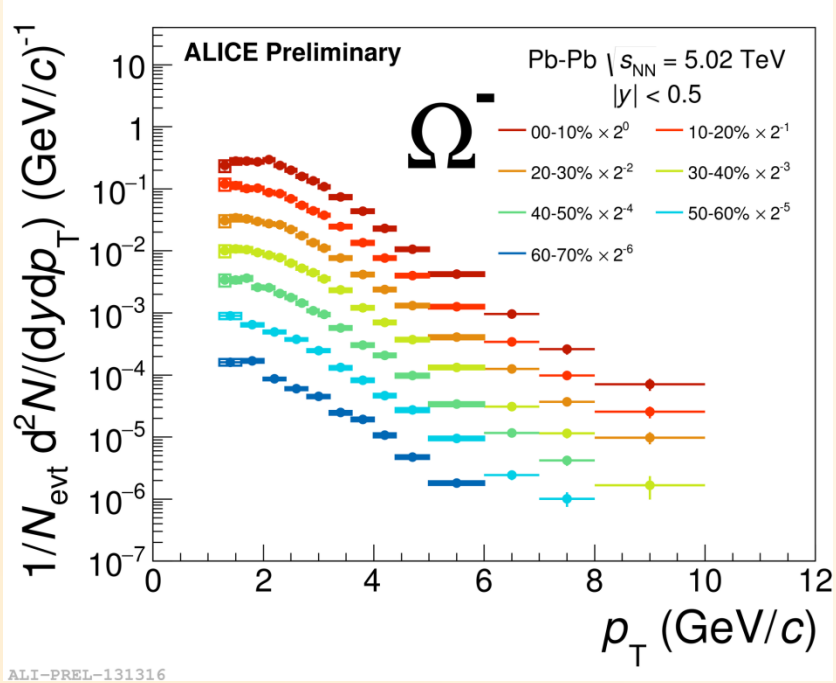




- Hardening of the spectra with increasing centrality
- More pronounced for heavier particles (radial flow)

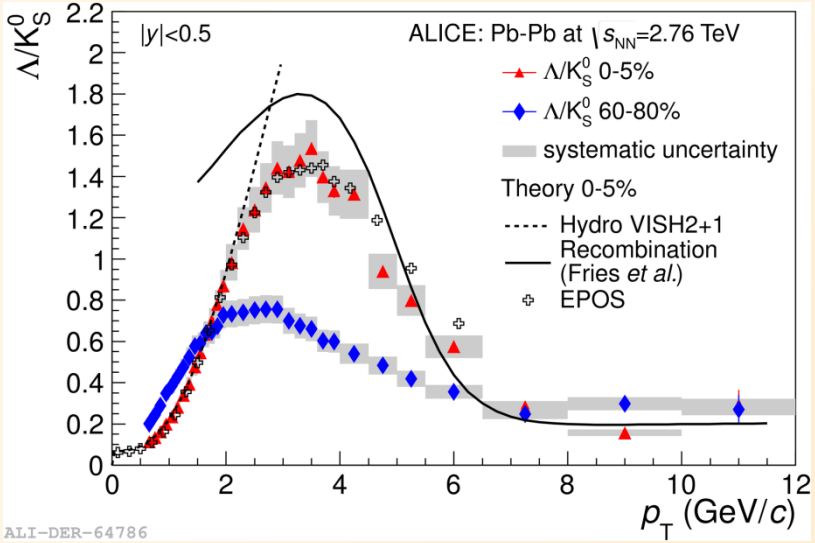
Transverse momentum spectra

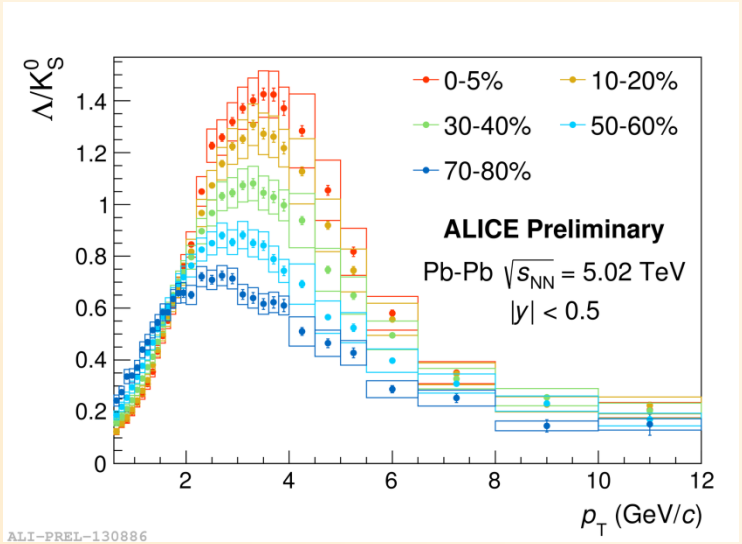




- Same pattern for multi-strange hadrons

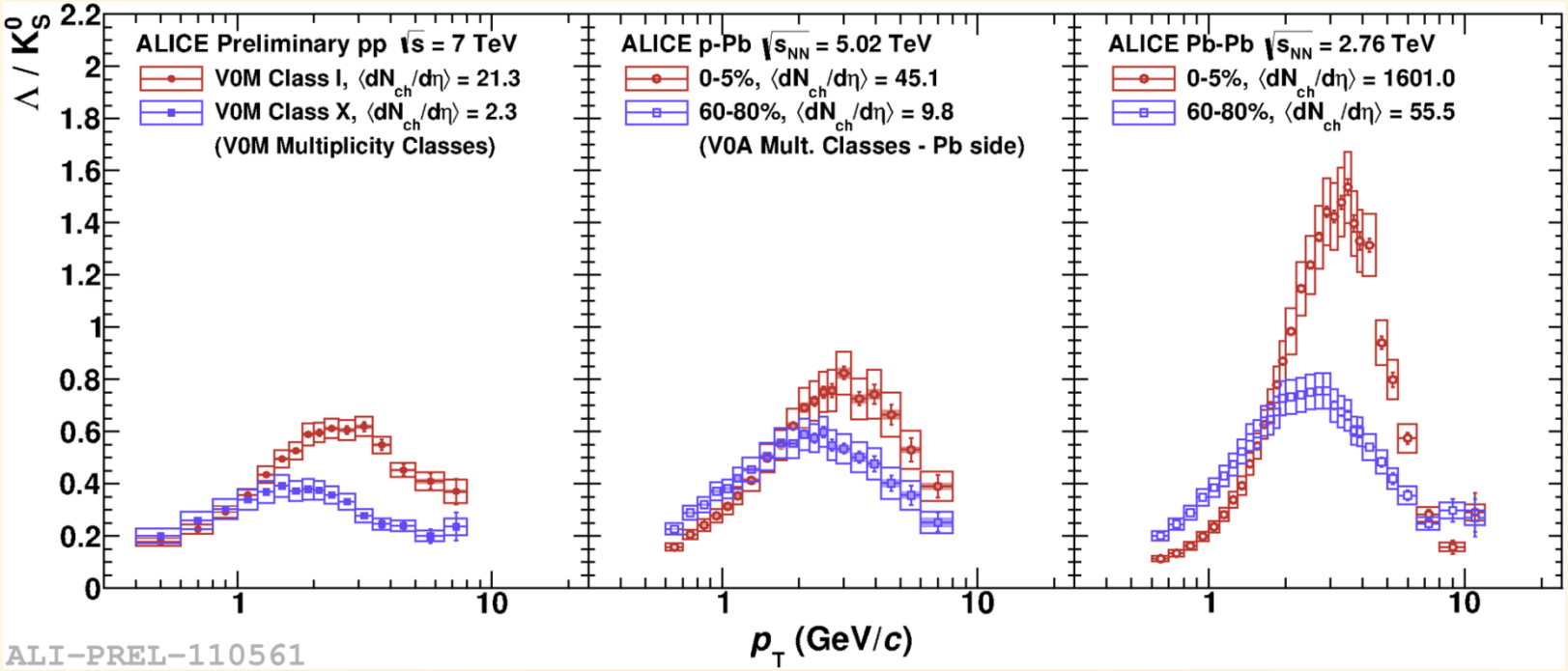
Baryon to meson ratios





- Same features in Pb-Pb collisions at both energies
- We observe a depletion at low p_T and an enhancement at intermediate p_T
- Recombination model approximately reproduces the shape but overestimates the baryon enhancement by about 15%
- EPOS describes the dependence over the entire p_T range

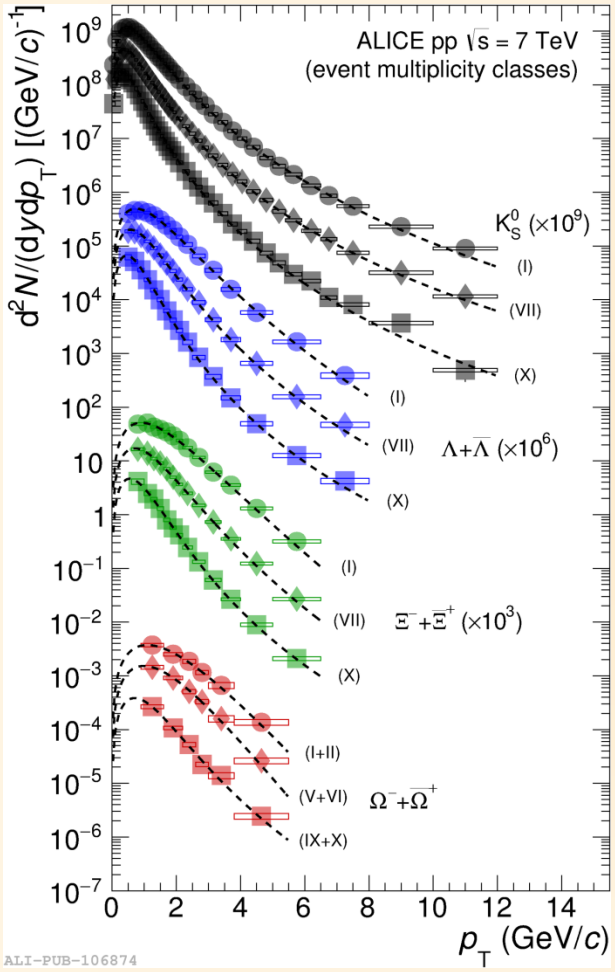
Baryon to meson ratios



- Similarities in the evolution across different systems
- We observe a depletion at low p_T and an enhancement at intermediate p_T

pp Collisions

Transverse momentum spectra



- Shape evolution similar to Pb-Pb
- Hardening of p_T spectra with increasing multiplicity
- Hardening more pronounced for higher-mass particles
- In Pb-Pb collisions such behavior explained by hydrodynamical models

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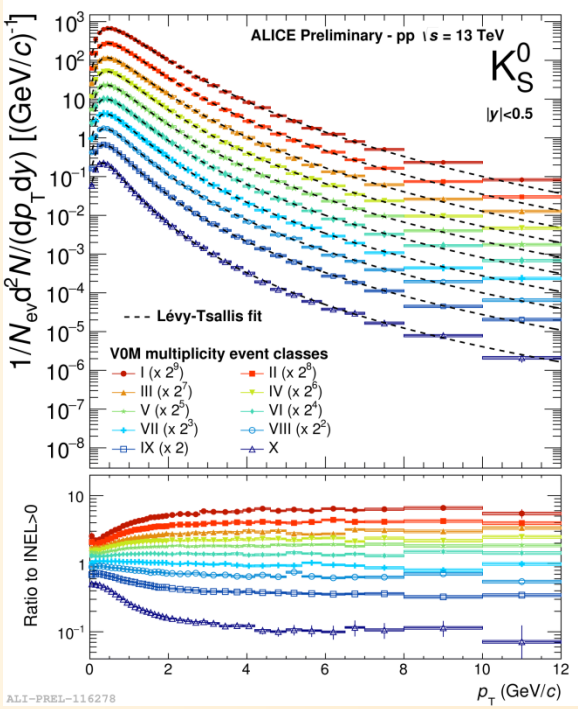
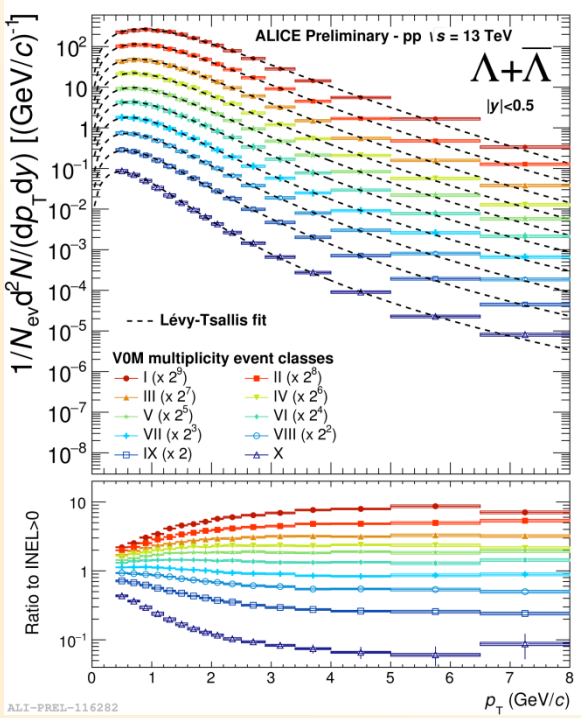
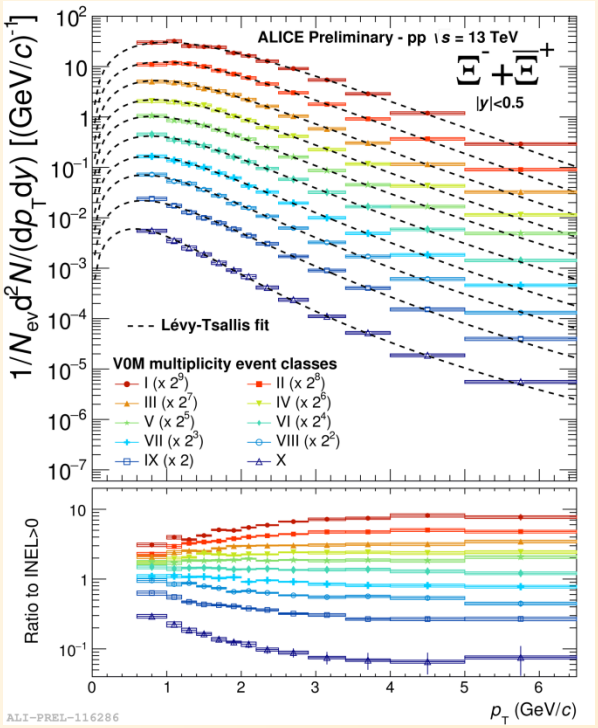
Transverse momentum spectra

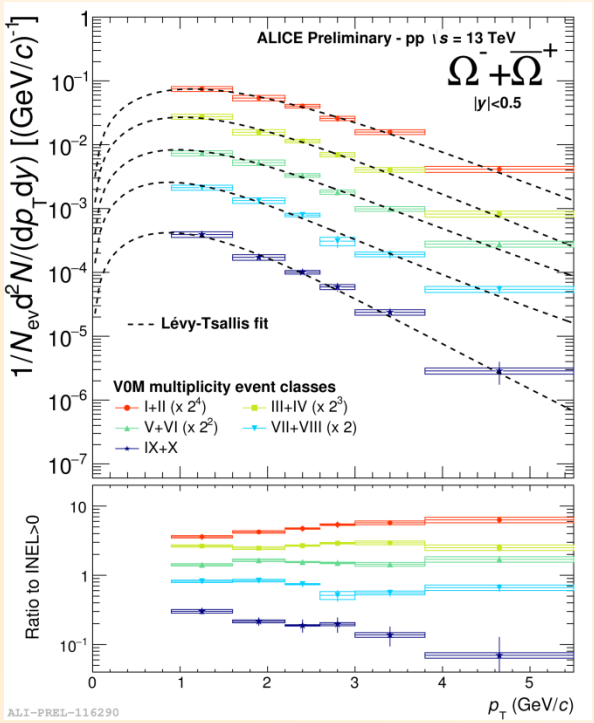




- Same pattern as observed in pp@7Tev

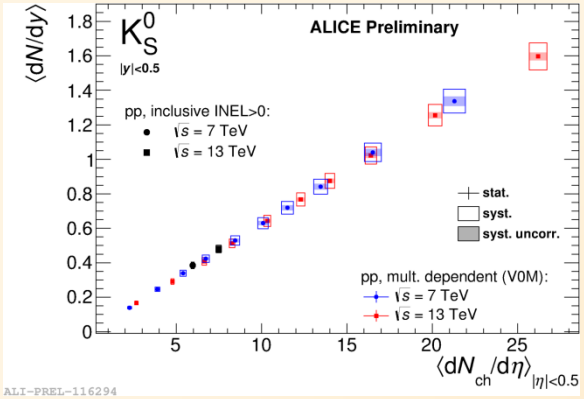
Transverse momentum spectra

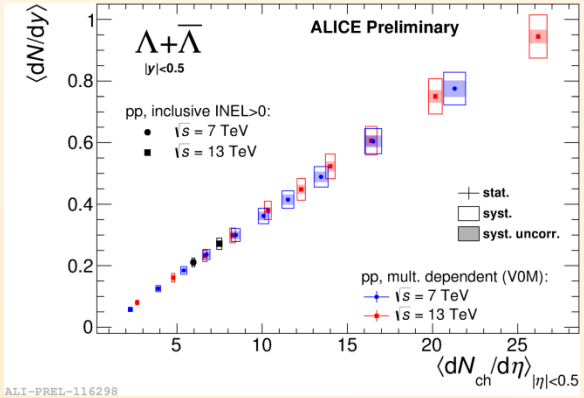


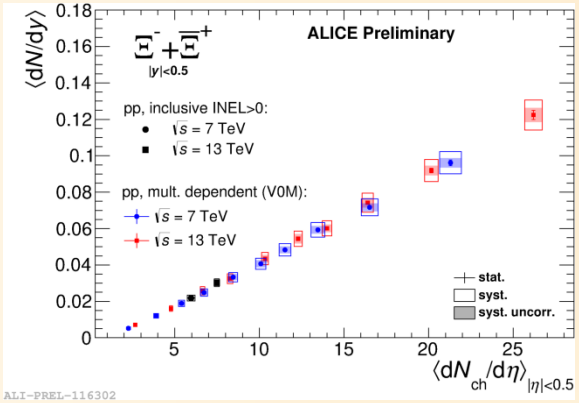


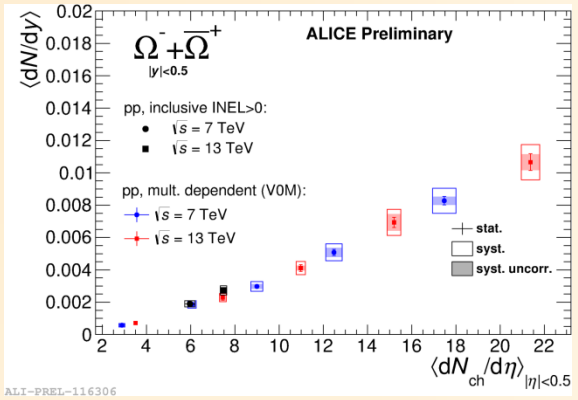
- Same pattern as observed in pp@7Tev

Strange particle yields



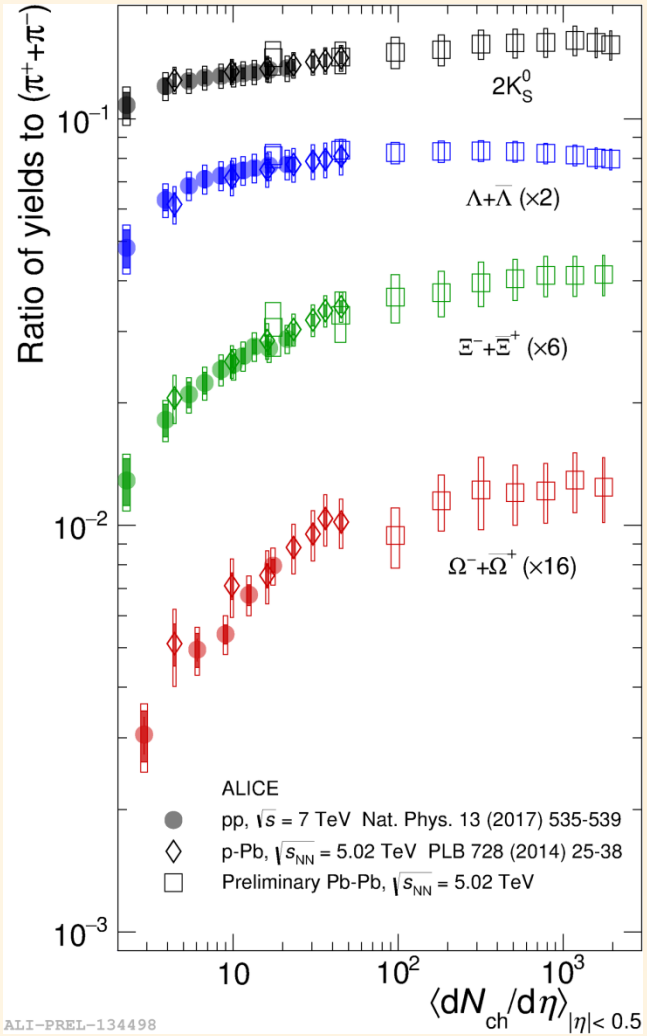






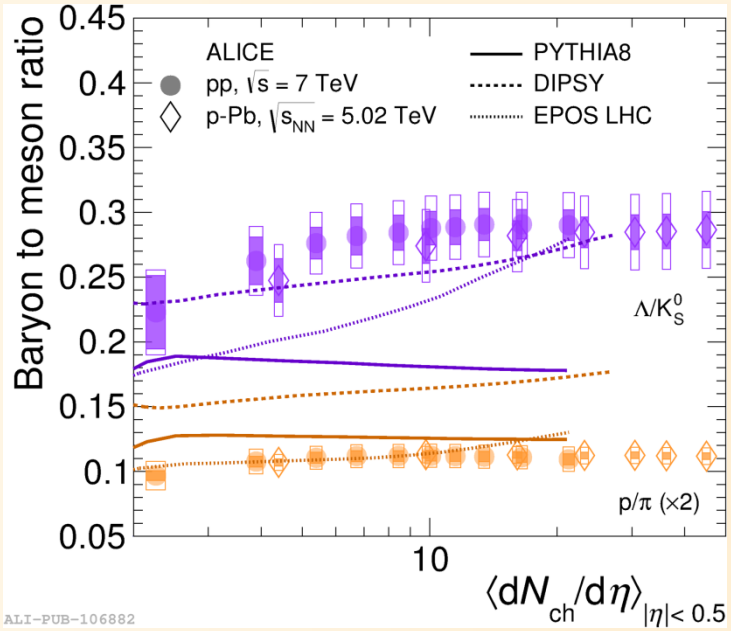
- Yields of strange hadrons increase linearly with the charged particle multiplicity
- Same trend in pp@7 TeV and pp@13 TeV
- The abundance of strange hadrons seems to be invariant with the collision energy

Strange-to-pion yields



- Enhancement of strange to non-strange hadron production from pp to most central Pb-Pb collisions
- Steeper slope with more strange content
- Almost saturated trend in most central Pb-Pb collisions for all particles
- Origin of strangeness production in Pb-Pb collisions driven by the final state rather than by the collision system or energy
- QCD inspired models fail to describe the data

Baryon-to-meson ratio



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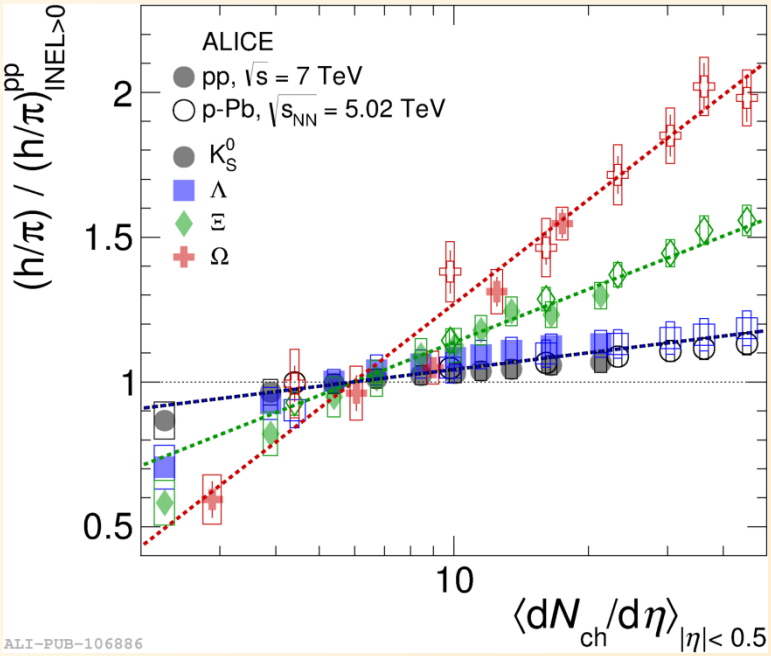
- Yield ratios do not change significantly with multiplicity → the observed enhanced production rates of strange hadrons w.r.t. pions is not due to the difference in the hadron masses
- None of the MC models can describe all particle ratios simultaneously

Strangeness enhancement



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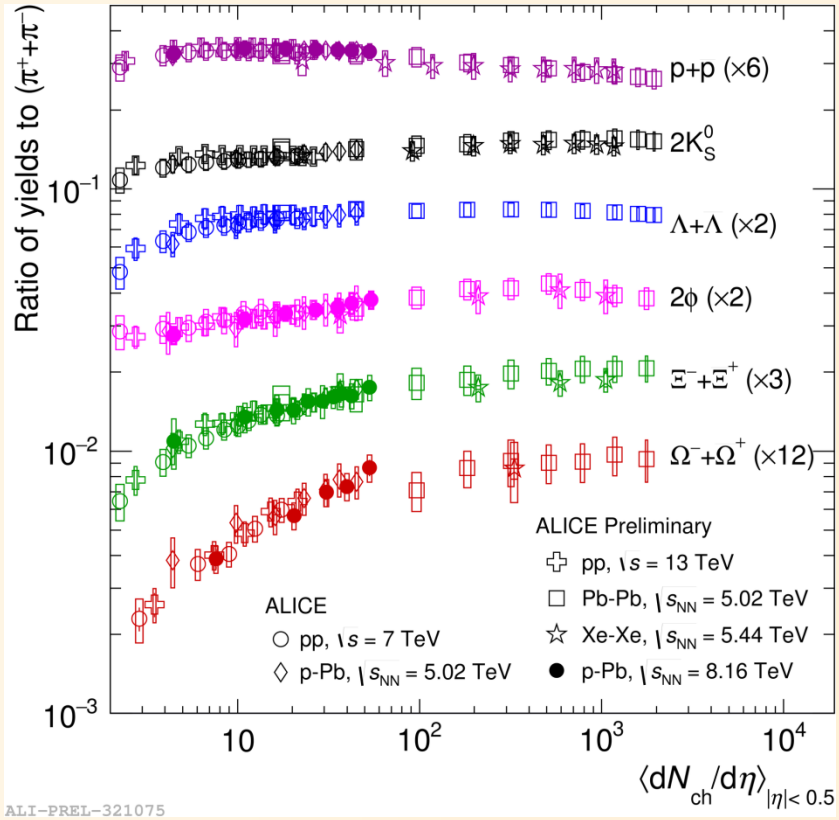
- Yield ratios to pions divided by the values measured in the inclusive pp sample
- The observed multiplicity dependent enhancement follows a hierarchy determined by the hadron strangeness

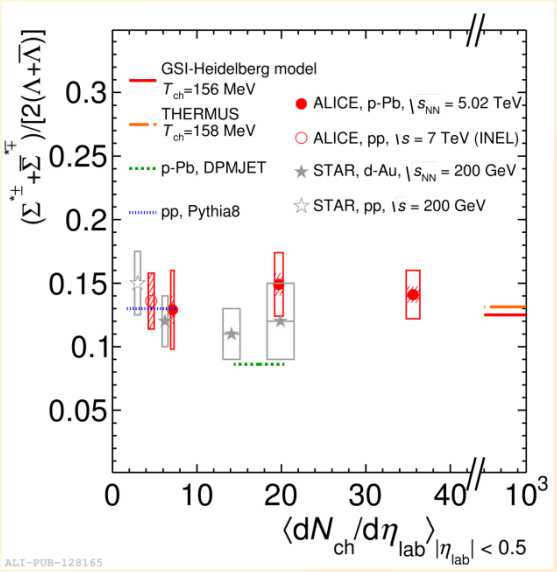
pp, p-Pb, Xe-Xe, Pb-Pb Collisions

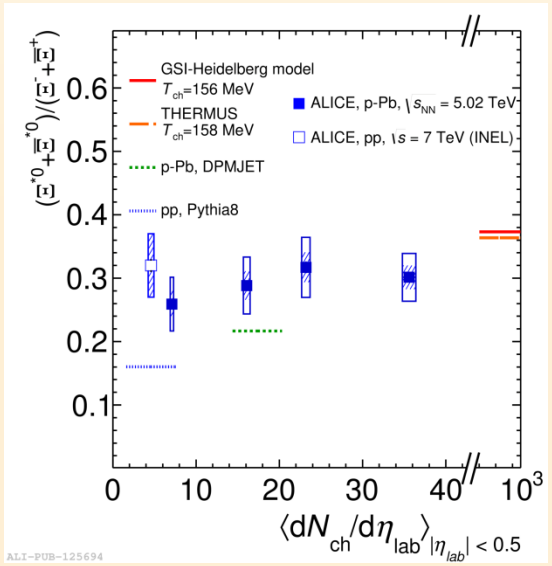
Strangeness enhancement

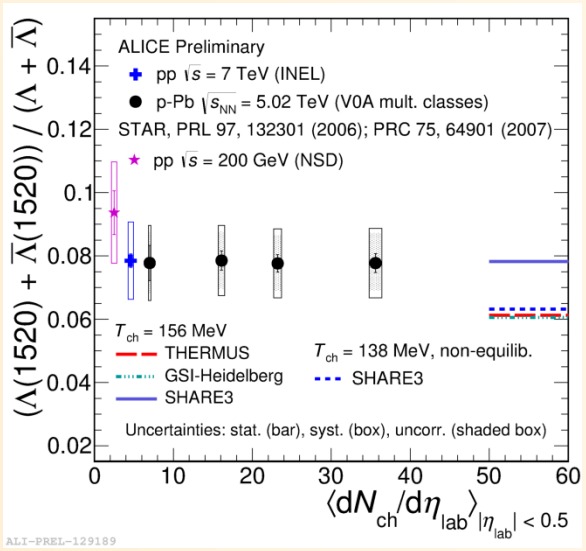


- Results from Xe-Xe@5.44 TeV collisions follow the trend observed in Pb-Pb collisions
- Strange particle production is collision energy independent at similar multiplicity

Strange resonance production







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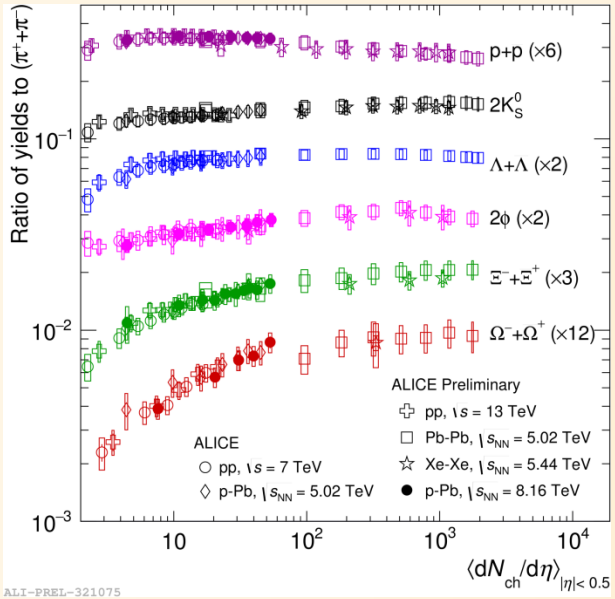
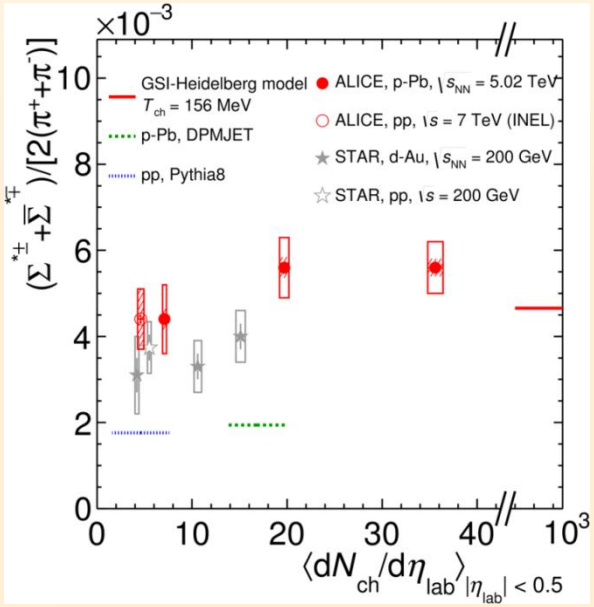
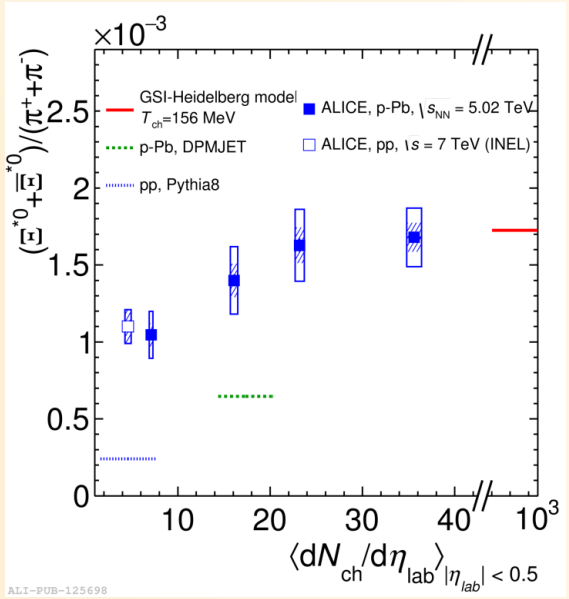
➢ For the small collision systems the ratio of baryonic resonance to stable particle with same strangeness content has no multiplicity dependence

Strangeness production







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- Increasing pattern depends only on strangeness content and not on particle mass: enhancement of higher mass resonances is the same as for the lower mass ground-state particle with the same strangeness content

Conclusions

- ALICE has measured strangeness production in pp, p-Pb, Xe-Xe and Pb-Pb collisions .
- In Pb-Pb collisions a hardening of strange hadron transverse momentum spectra is observed, with increasing centrality (radial flow).
- Similar effect measured in pp@7, 13 TeV collisions, with increasing multiplicity.

Conclusions

- Strangeness enhancement is observed in high multiplicity pp collisions.
- Strange-to-pion ratios evolve smoothly with charged particle multiplicity, regardless collisions system and energy.
- Strangeness enhancement has been studied with resonances. In small systems the enhancement as a function of multiplicity, is found to be driven by strangeness content.

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Thank you!