Study of identified particle production in high multiplicity pp collisions at √s = 13 TeV with ALICE at the LHC

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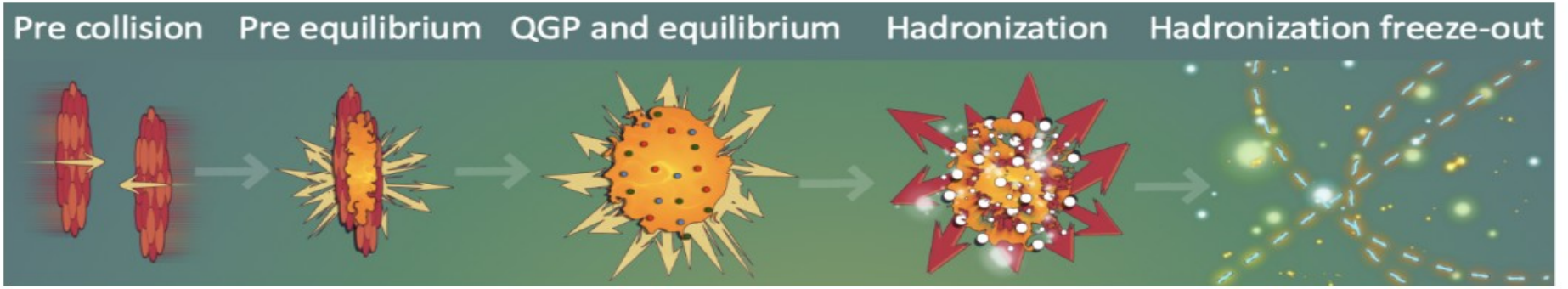
Outline

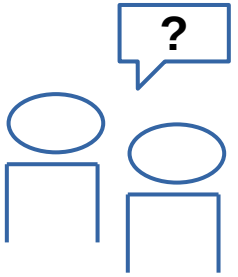
- **Introduction & Motivation**
- **ALICE detector**
- **Analysis details**
- **Results and discussion**
- **Summary**

Introduction & Motivation

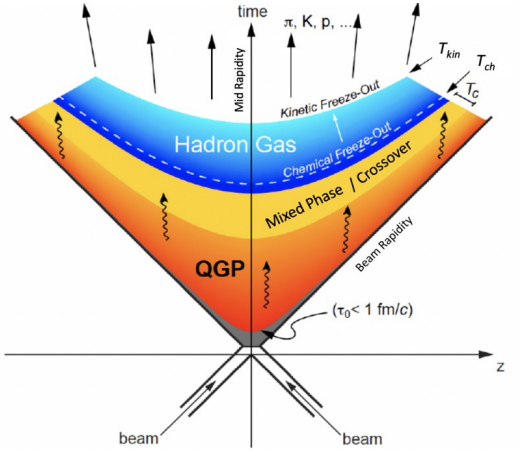
Quark-Gluon plasma (QGP): Hot and dense phase of matter having deconfined quarks and gluons.



- QGP formation at the LHC energy in AA collisions has been confirmed.



QGP formation in small system ?



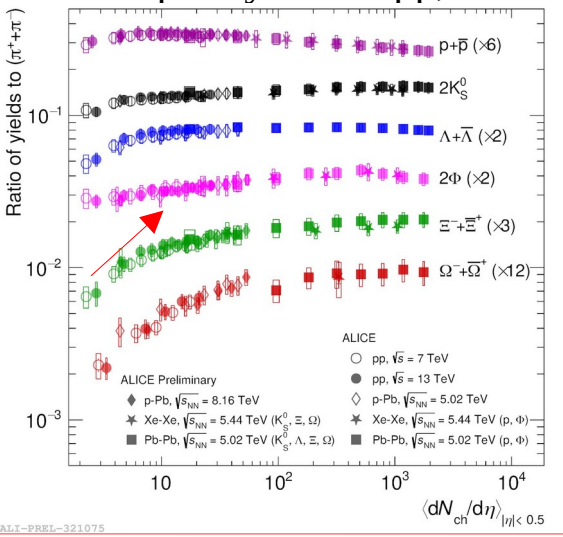
Space-time evolution of heavy-ion collisions

Introduction & Motivation

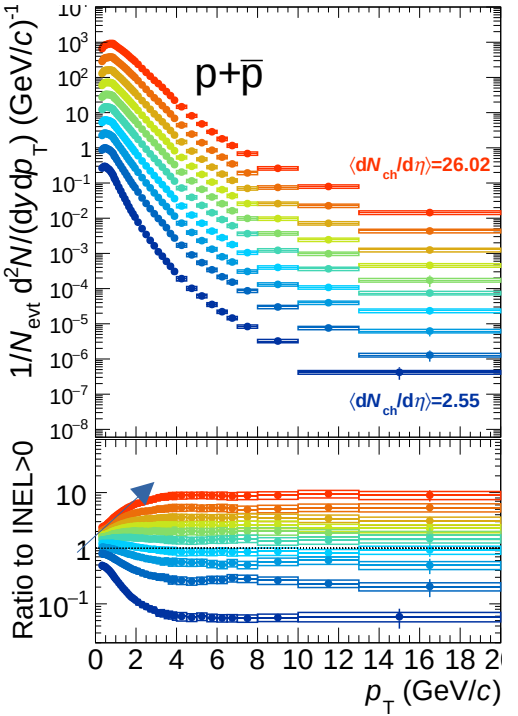
Why study identified hadrons in small systems ?

- Used as a tool to understand the particle production mechanism.
- Hardening of the transverse momentum (p_T) spectra / increase of $\langle p_T \rangle$ with multiplicity in pp collisions similar to heavy-ion collisions.
  - **Collective expansion / radial flow.**
- Smooth evolution of charged particles production with multiplicity across pp, pA, AA systems and saturation.
  - **Independent of collision system and energy**

- Stronger increase in the strange particle-to-pion ratio is observed with increasing strangeness content.



Increasing multiplicity

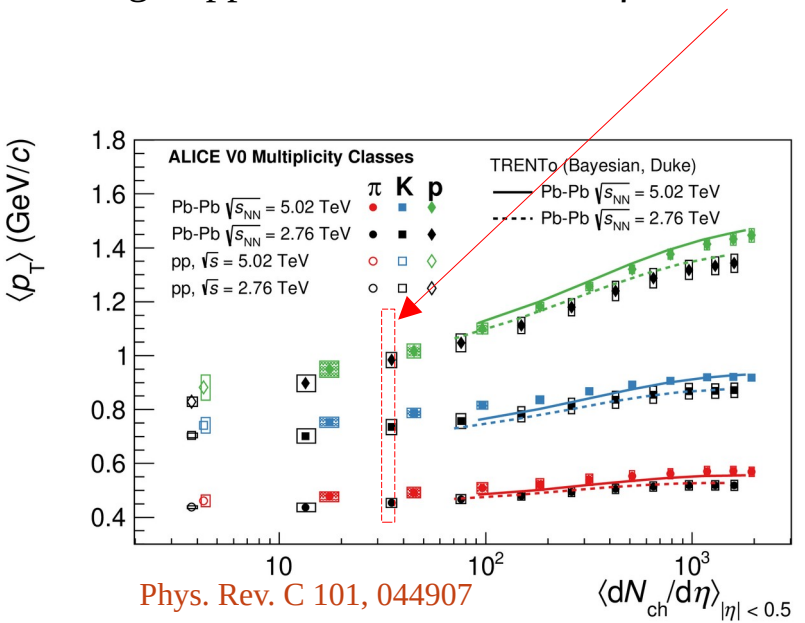


Eur. Phys. J.C (2020) 80:693

Introduction & Motivation

Why high-multiplicity pp collisions ?

- High-multiplicities in pp collisions at the LHC are comparable to those in p–Pb and peripheral Pb–Pb collisions.
- pp collisions with high multiplicities are useful for comparing different systems.
- This study will extend our understanding of pp collisions to $\langle dN_{ch}/d\eta \rangle = 35.8$.



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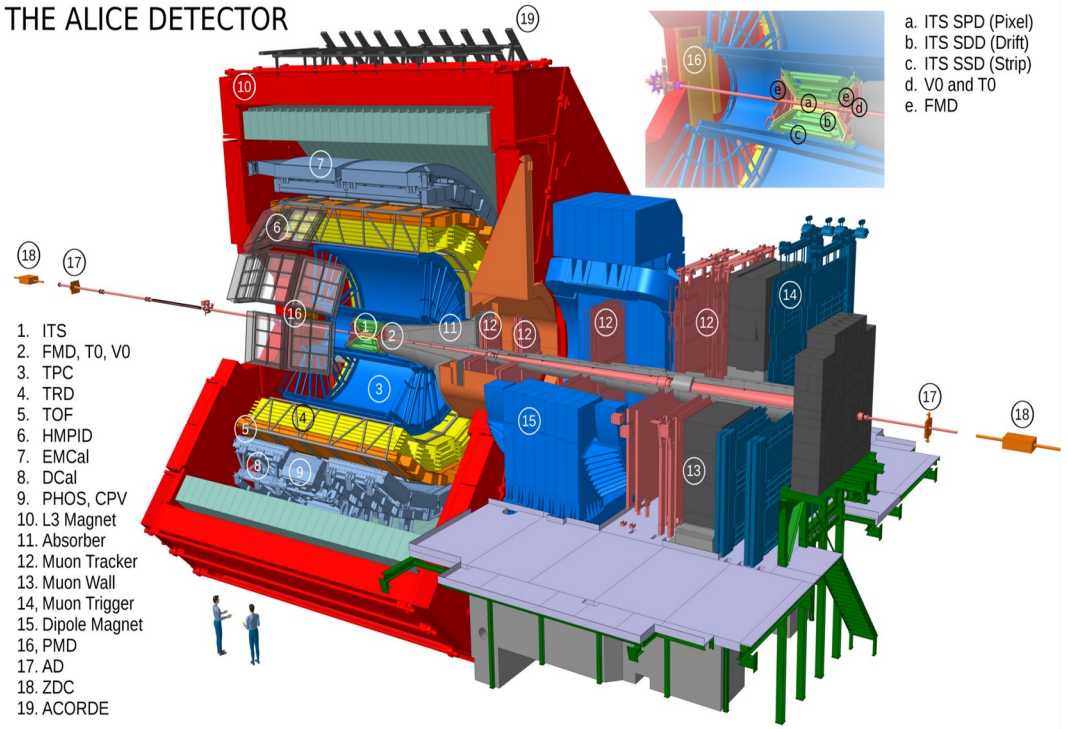
ALICE detector in Run 2



Inner Tracking System (ITS) |η| < 0.9 :

- Primary Vertex
- Tracking
- Particle Identification (PID) at low momentum

Time Projection Chamber (TPC) |η| < 0.8 :

- Tracking
- PID

Time of Flight (TOF) |η| < 0.9 :

- PID

Forward detector (V0):
V0A (2.8< η < 5.1) & V0C (-3.7< η <-1.7)

- Trigger, Multiplicity estimator

Analysis details

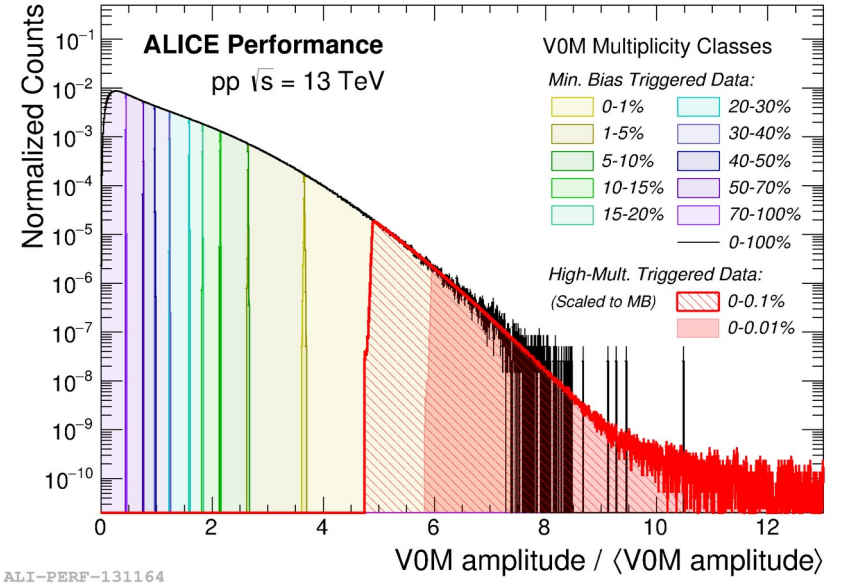
- pp collisions @ √s =13 TeV
- Year: 2016
- Particles studied: π, K and p

Event and track selection

- The data were recorded using high-multiplicity triggers.
- Standard track selection cuts are applied to ensure good quality of selected tracks.

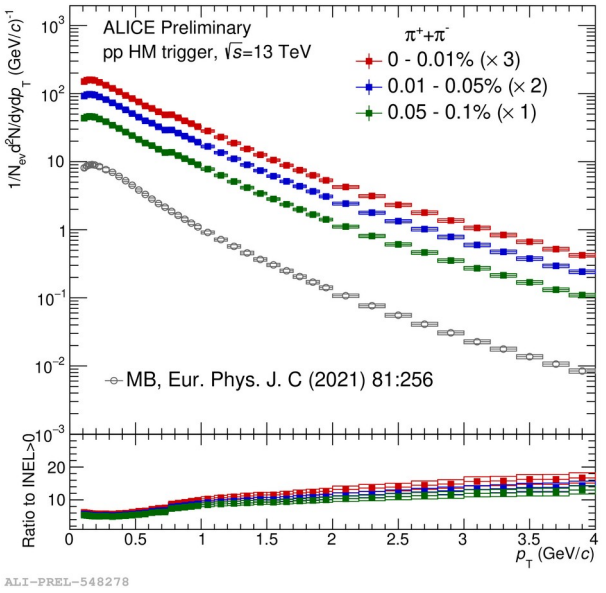
Multiplicity classes (in %)

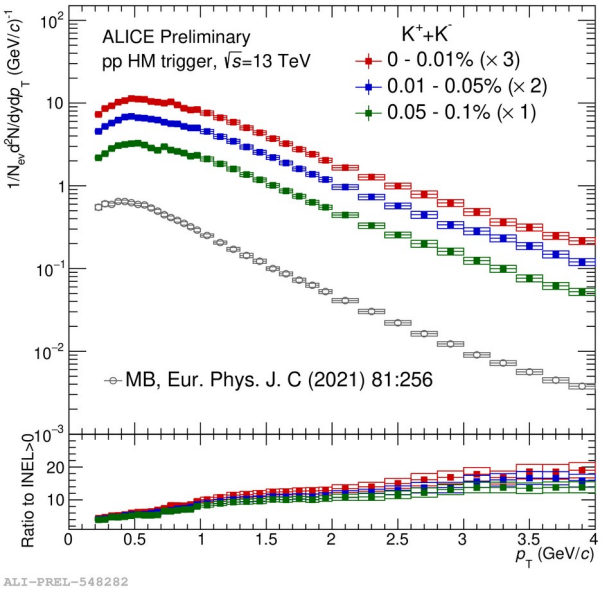
0-0.01(HM1), 0.01-0.05(HM2), 0.05-0.1(HM3)

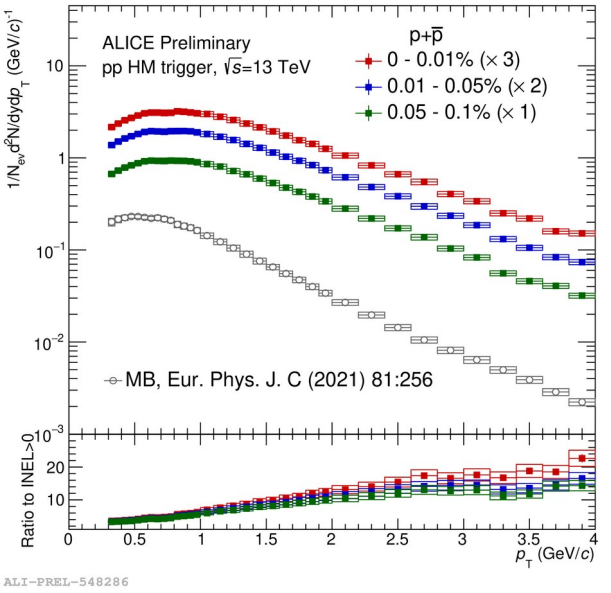


Analysis Region			
	p_T (GeV/c)		
	π	**K**	**p**
ITSsa	0.1-0.75	0.2-0.6	0.3-0.7
TPC-TOF	0.6-4.0	0.6-4.0	0.7-4.0

Transverse Momentum Spectra

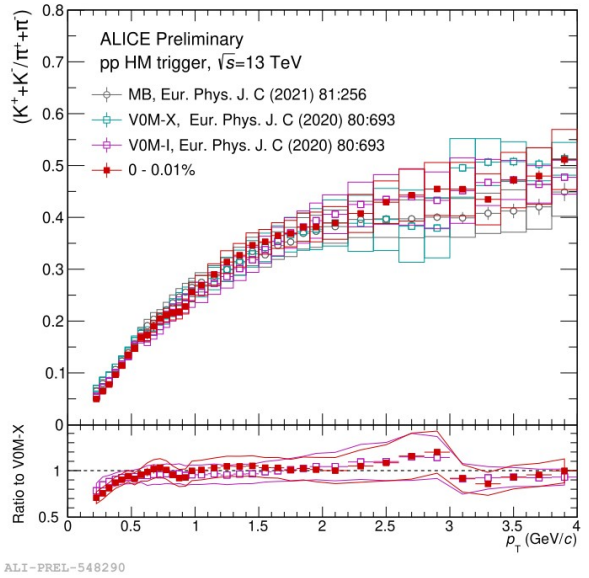


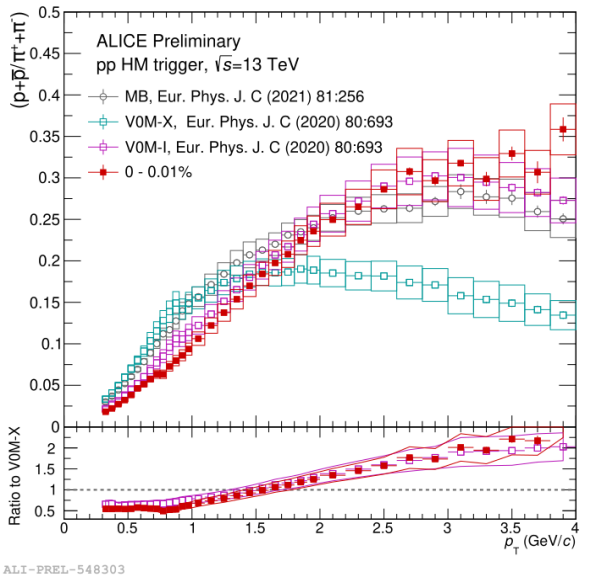




- Multiplicity dependent hardening is observed.
- The hardening of the p_T spectra with multiplicity is more pronounced for the heavier particles.
- p_T spectra of π, K and p for pp, @√s =13 TeV high multiplicity (HM) classes follow the trend of the published results.

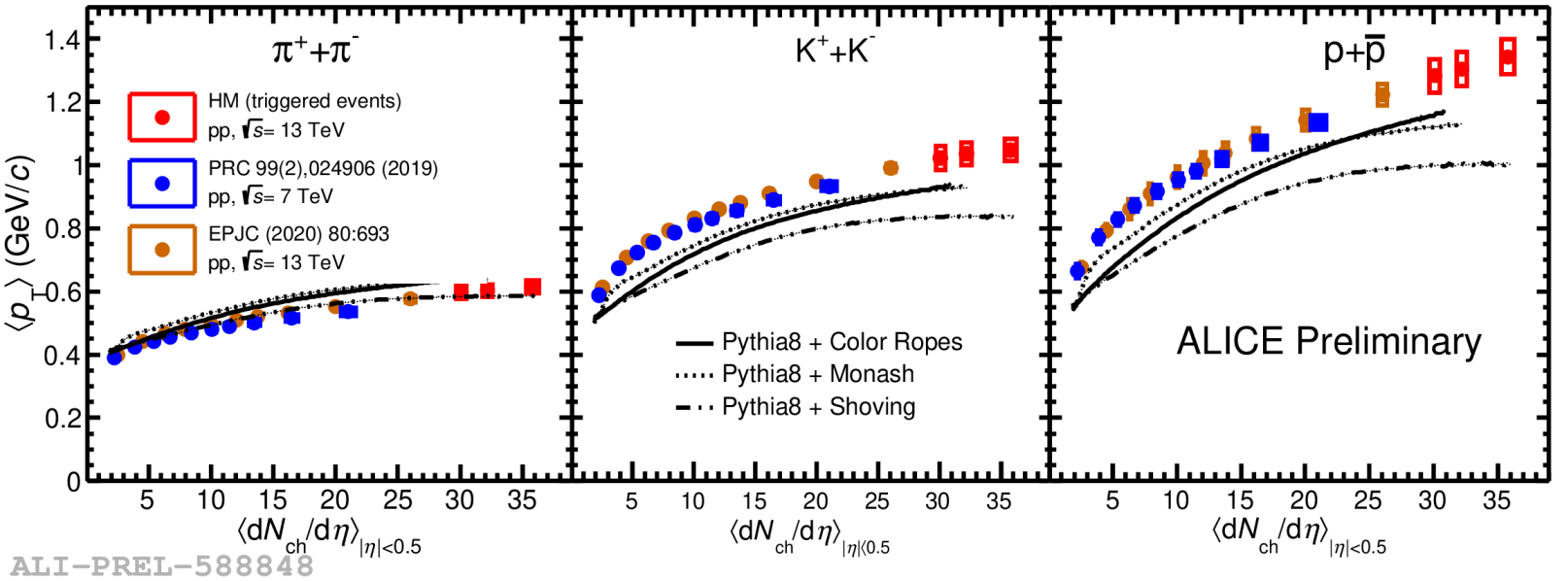
Particle ratios (K/π and p/π)





- K/π and p/π for HM1 (0-0.01%) multiplicity class are compared among different published pp events.
- High-multiplicity events shows the similar trends as compared with published V0M-I (0-0.92%) class.
- The ratio to V0M-X (64.5-100%) class shows a suppression of p/π ratio at low-p_T and enhancement at high-p_T (radial flow).

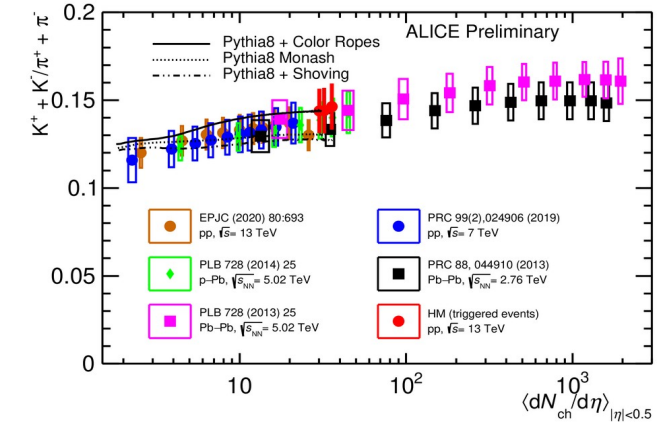
Multiplicity dependent average transverse momentum

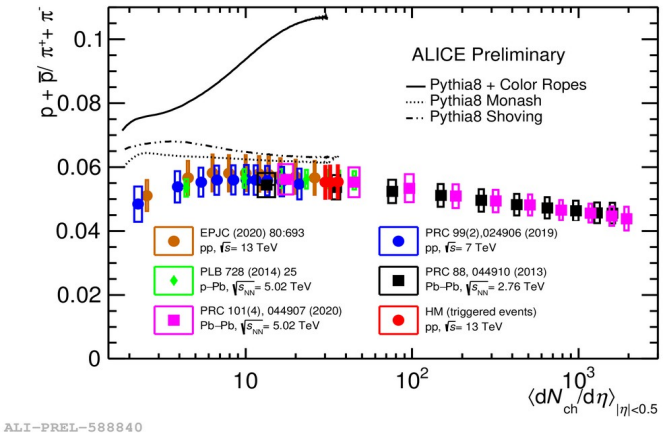


- The new results of $\langle p_T \rangle$ shows an increasing trend with the charged particle multiplicity.
- The increase is steeper with mass – **supports the picture of the collective evolution (radial flow).**
- The model qualitatively explains the multiplicity dependent trend of $\langle p_T \rangle$ for pions, kaons and protons.
- Quantitatively, pion $\langle p_T \rangle$ trend is well explained (by Pythia8 Shoving) but the kaon and proton are underestimated by the models.

Multiplicity dependent K/π and p/π ratios

- New measurements have extended the range of K/π and p/π ratios in pp collision to the high multiplicity i.e. $\langle dN_{ch}/d\eta \rangle = 35.8$.
- Increasing trend in the K/π ratio:
  Strangeness enhancement ?
- Decreasing trend in the p/π ratio:
  antibaryon-baryon annihilation.
  Physics Letters B 835, 137577 (2022)
- Smooth transition of ratio of the particles from pp to Pb-Pb collisions.
- The High-multiplicity results confirm the trends:
  Particle production is driven by the multiplicity, not by the system nor energy.
- Quantitative description of the K/π ratio is given by MC generator (Pythia8).
- Pythia8 with ropes are inconsistent with the measured multiplicity dependent p/π ratios.





Summary

- New results of π, K and p production as a function of transverse momentum in high-multiplicity pp collisions are presented.
- New measurements of high-multiplicity pp events extended the study in pp collisions to $\langle dN_{ch}/d\eta \rangle = 35.8$.
- Multiplicity-dependent hardening is observed, and it is more pronounced for heavier particles ⟶ Radial flow.
- Measured p_T–integrated particles yield ratios and $\langle p_T \rangle$ are consistent with the published multiplicity dependent trends by ALICE and show a smooth transition across different collision system sizes and energies, ⟶ hadron chemisty is driven by the multiplicity, not by the collison system nor energy.
- High-multiplicity collisions in small systems exhibit similar features as AA collisions.
- The predictions from MC generators quantitatively describe the K/π ratio, while qualitatively explaining the multiplicity-dependent $\langle p_T \rangle$ distrution of pions, kaons and protons. However, Pythia8 with Color Ropes overestimate the p/π ratio.

Thank you for your attention