

# Multiplicity dependent study of pions, kaons, and protons production in pp, p-Pb and AA collisions with ALICE



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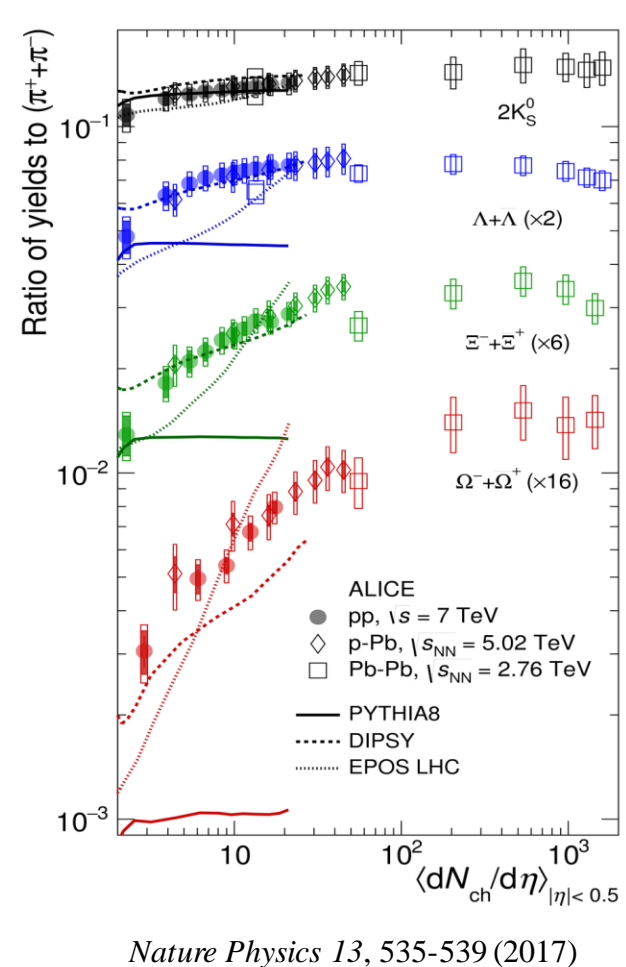
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## (1) Introduction and Motivation

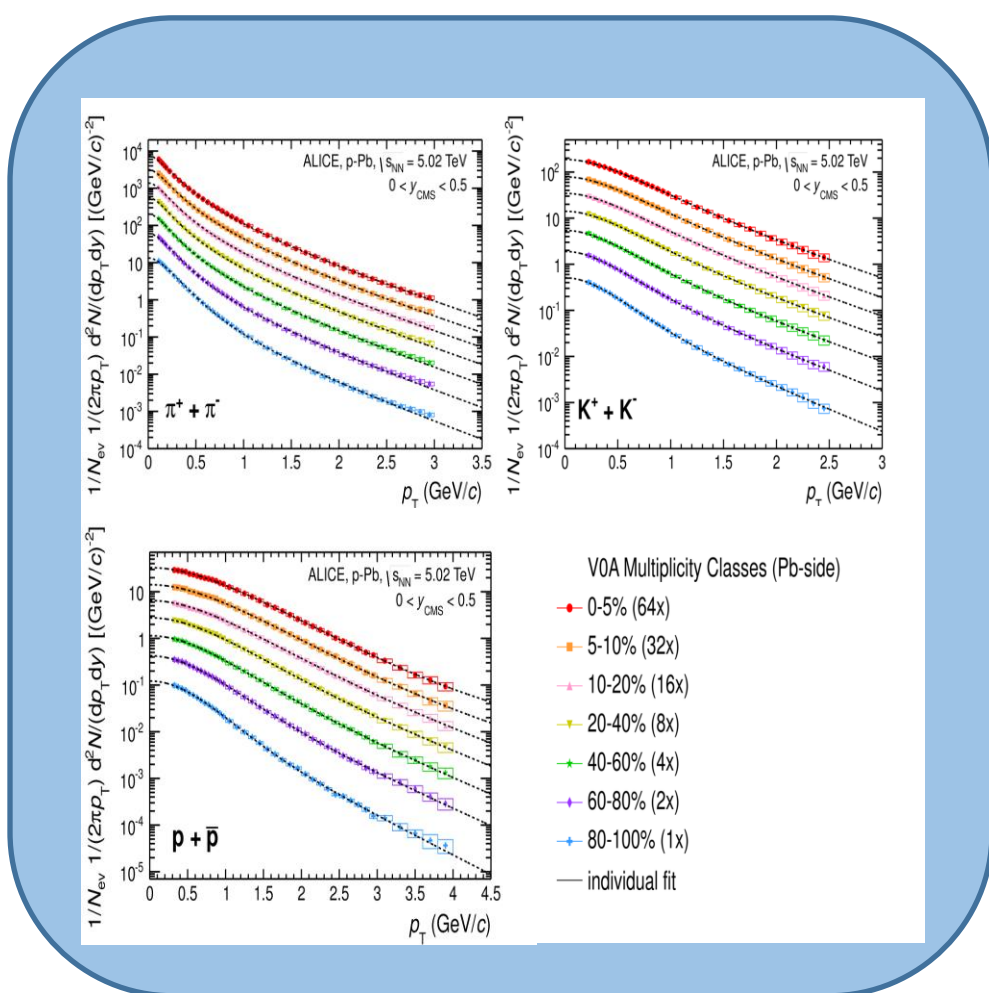
- Systematic measurements of the production of pions, kaons, and protons in pp collisions as a function of charged-particle multiplicity provide insight into the hadronization mechanism and emergence of collective effects such as radial flow.
- The multiplicity of the high-energy pp collisions at the LHC is comparable to that of p-Pb and peripheral Pb-Pb collisions.
- Identified particle spectra measured in relativistic heavy-ion collisions contain information about the collision dynamics and the entire space-time evolution of the system.
- Origin of strangeness enhancement with increasing multiplicity in small systems is still not understood.

### (Multi)-strange Hadron Enhancement



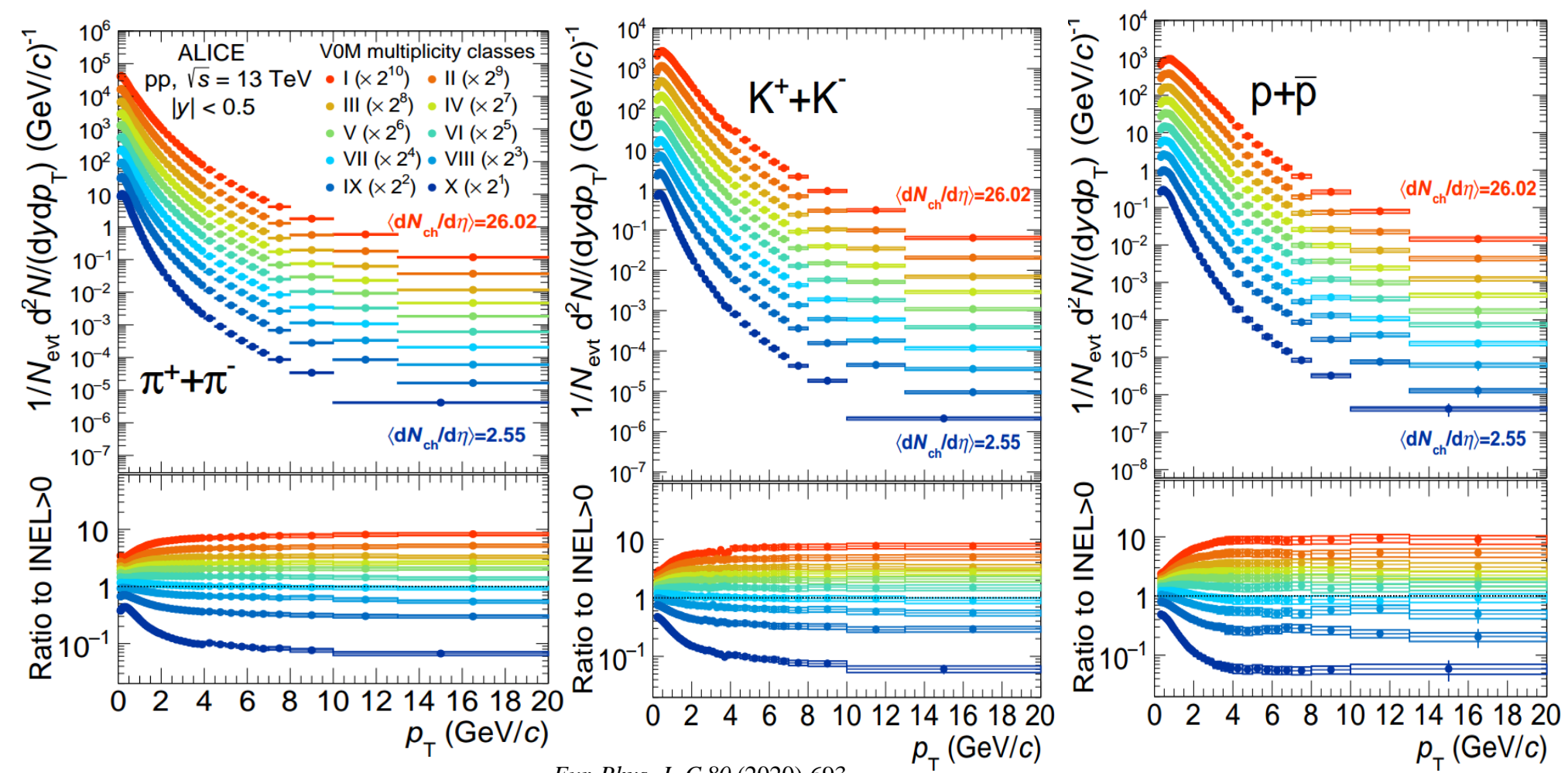
Nature Physics 13, 535-539 (2017)

### Mass dependent hardening of spectra



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

## (4) Particle Spectra



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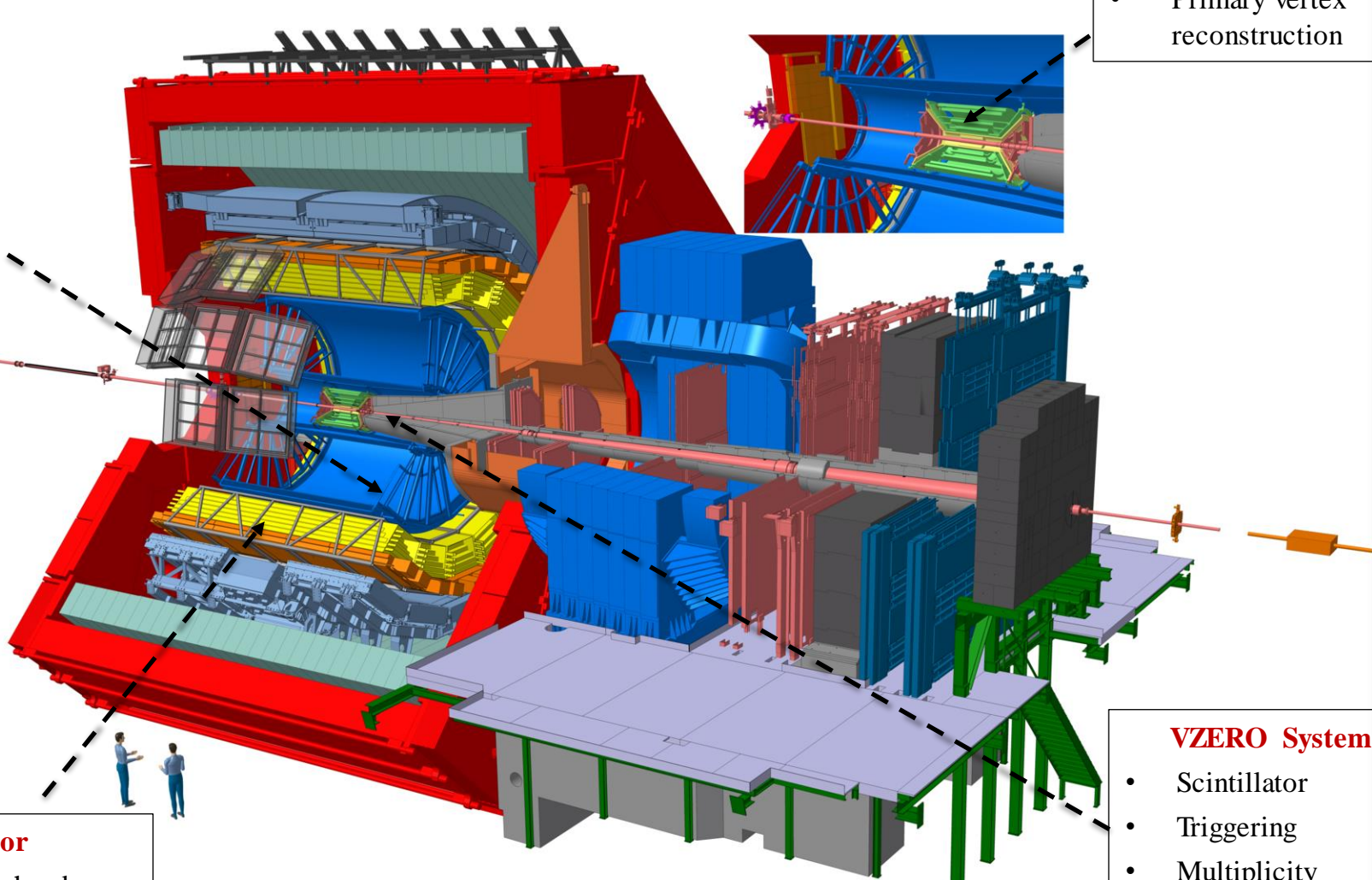
- The spectra become harder and the maximum of the distributions shifts toward higher values for increasing multiplicity (similar to the radial flow).
- At the higher  $p_T$  ( $\geq 8$  GeV/c) the slope of the spectra becomes independent of the multiplicity.
- The hardening of the spectra with multiplicity is more pronounced for the heavier particles.

## (2) The ALICE Detector System

- General-purpose experiment dedicated to studying the quark-gluon plasma.
- Tracking capabilities down to  $p_T \sim 100$  MeV/c.
- Excellent particle-identification capabilities over a broad momentum range.

### Time Projection Chamber

- Gas-filled detector
- Main tracking detector
- Particle identification via  $dE/dx$  measurement in the TPC gas.



### Inner Tracking System

- Six layers of silicon
- Trigger, tracking
- Primary vertex reconstruction

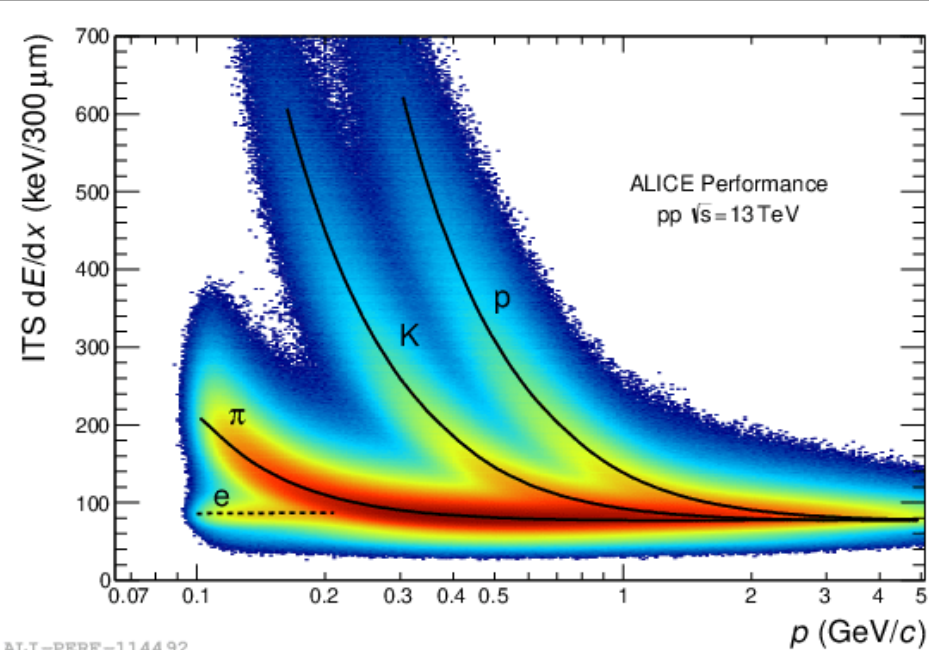
### VZERO System

- Scintillator
- Triggering
- Multiplicity estimator

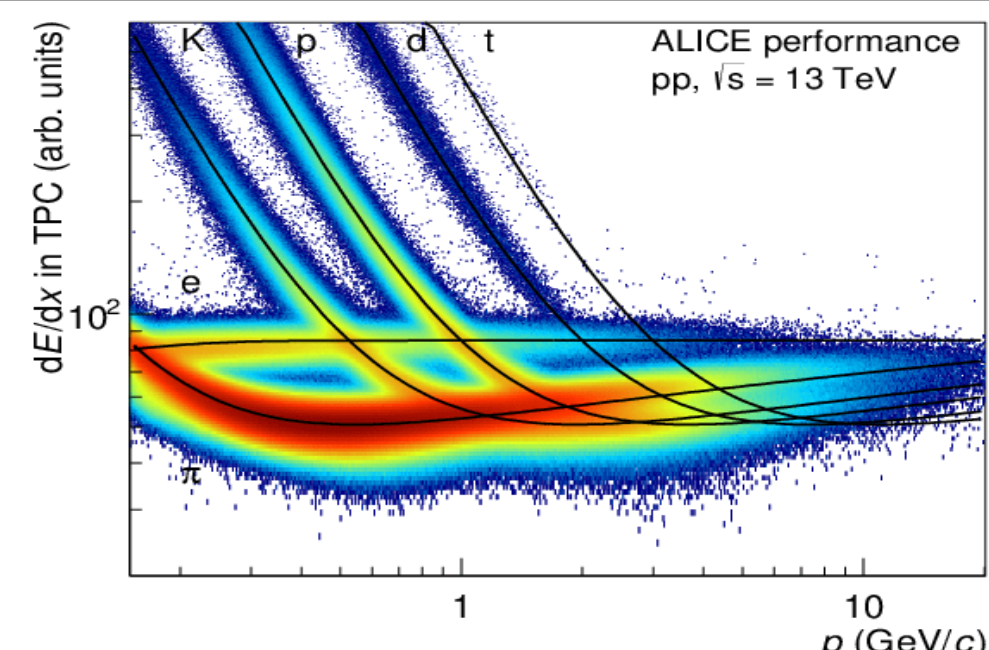
### Time of Flight Detector

- Multi-Gap resistive plate chamber
- Particle identification via time of flight

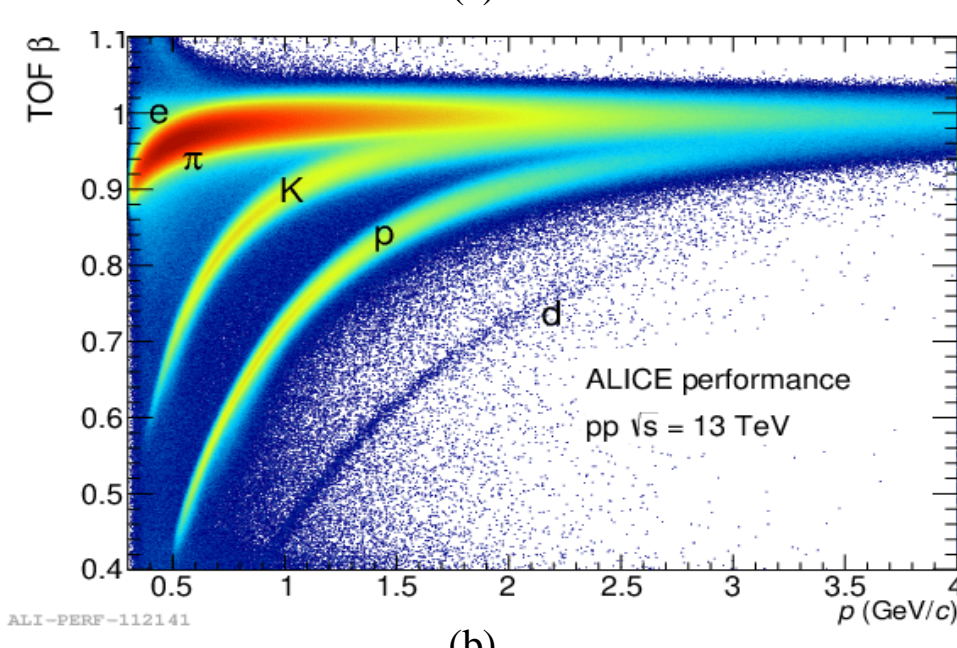
## (3) Particle Identifications



(a)



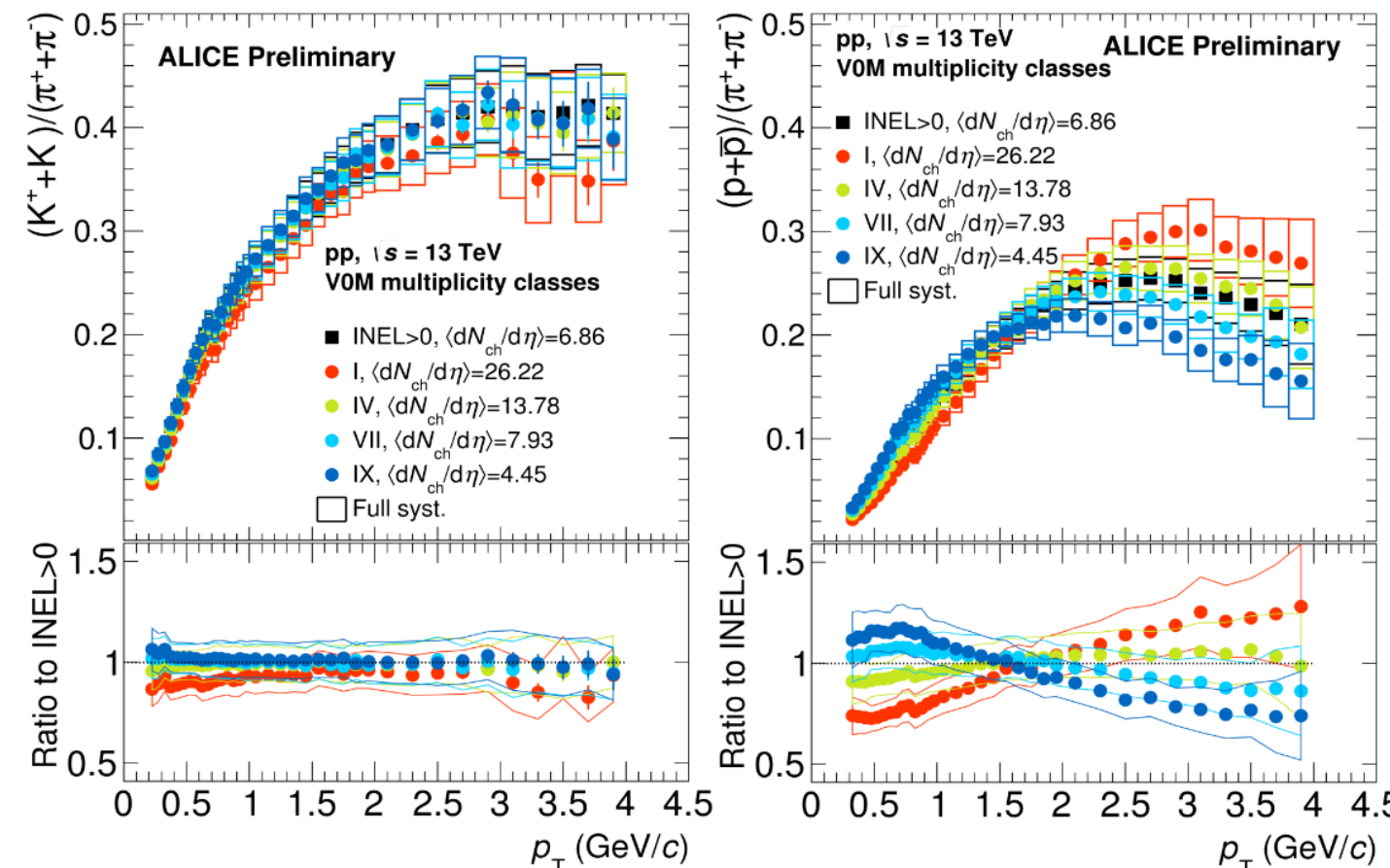
(b)



(c)

- Specific energy loss in the four outermost layers of ITS vs momentum.
- Specific energy loss in TPC gas volume vs momentum.
- TOF  $\beta$  vs momentum.

## (5) $p_T$ -Differential Particle Ratios

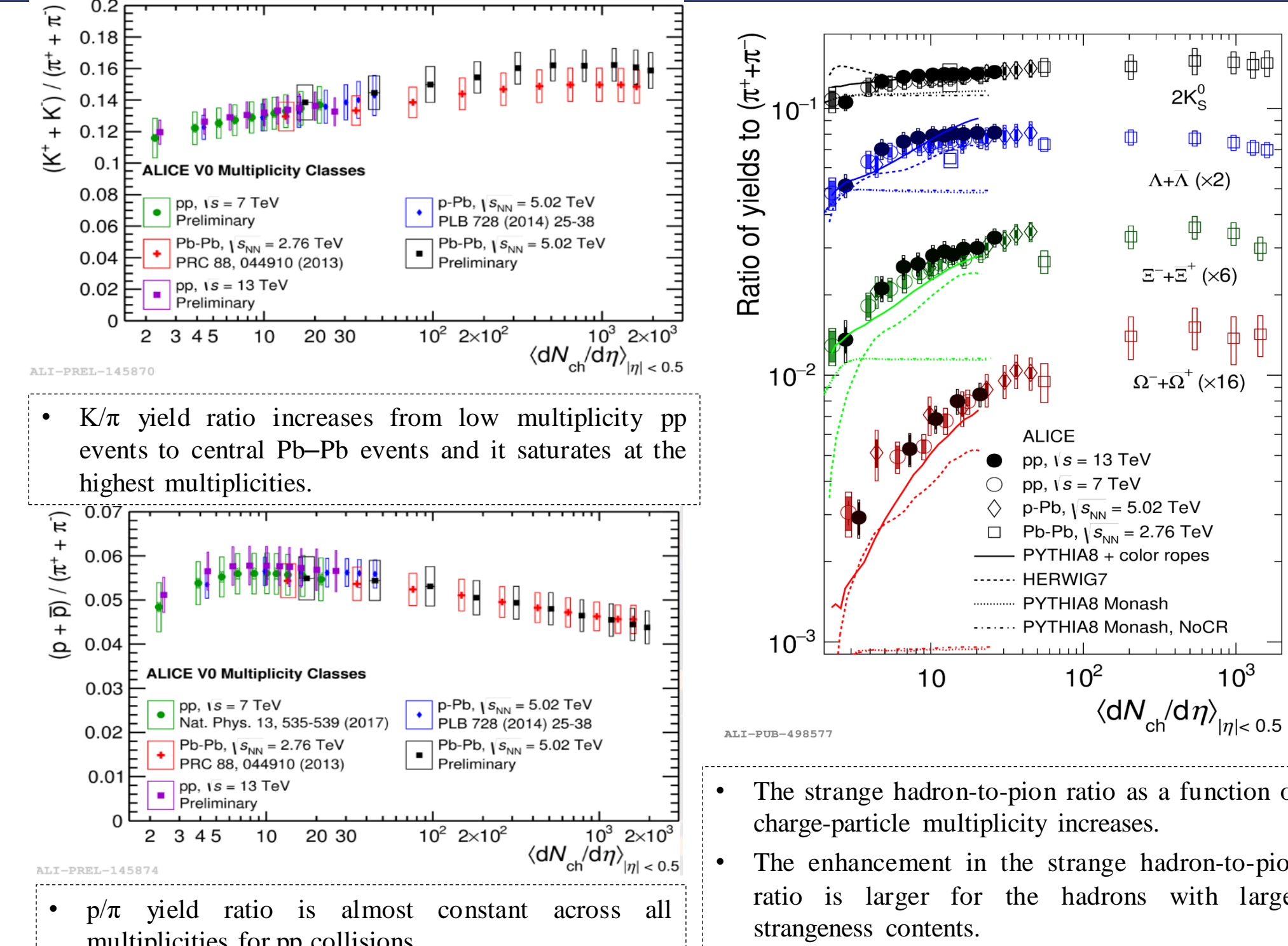


- The  $K/\pi$  ratio is independent of multiplicity.

- An enhancement in the  $p/\pi$  ratio for  $p_T > 2$  GeV/c is observed as the multiplicity class increases.

- The  $p/\pi$  ratio shows a peak which is shifted towards the higher  $p_T$  with increasing multiplicity (which also resembles as a radial-flow).

## (6) $p_T$ -integrated particle ratios



- $K/\pi$  yield ratio increases from low multiplicity pp events to central Pb-Pb events and it saturates at the highest multiplicities.

- $p/\pi$  yield ratio is almost constant across all multiplicities for pp collisions.

- The strange hadron-to-pion ratio as a function of charge-particle multiplicity increases.
- The enhancement in the strange hadron-to-pion ratio is larger for the hadrons with larger strangeness contents.

## (7) Conclusions

- $\pi$ ,  $K$  and  $p$  production as a function of transverse momentum in pp, p-Pb, Pb-Pb collisions is presented.
- Radial flow increases with multiplicity.
- Particle production is independent of the collision system and energy, it depends upon the multiplicity.
- Strangeness enhancement is observed as the multiplicity increases.

## (8) Outlook

- To study the collective effect (radial flow) and strangeness enhancement in pp collisions with fine, high multiplicity bins.

## (9) References

- [1] U. W. Heinz, arXiv:hepph/0407360 (2004)
- [2] ALICE: *Nature Physics* 13, 535-539 (2017)
- [3] ALICE: *Phys. Lett. B* 728 (2014) 25-38
- [4] ALICE: *Eur. Phys. J. C* 80 (2020) 693