Light-flavour hadron production in the smallest hadronic systems created in ALICE at the LHC

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for the ALICE Collaboration

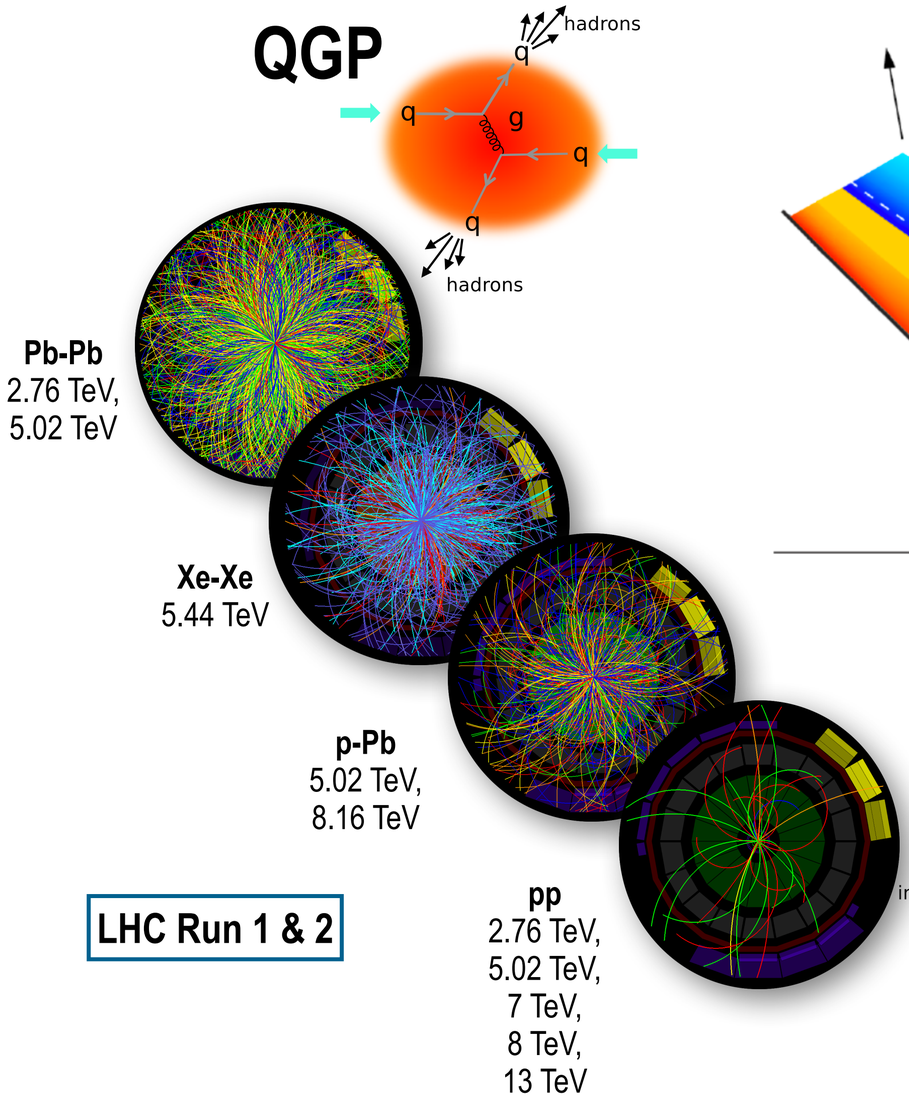
07/07/22

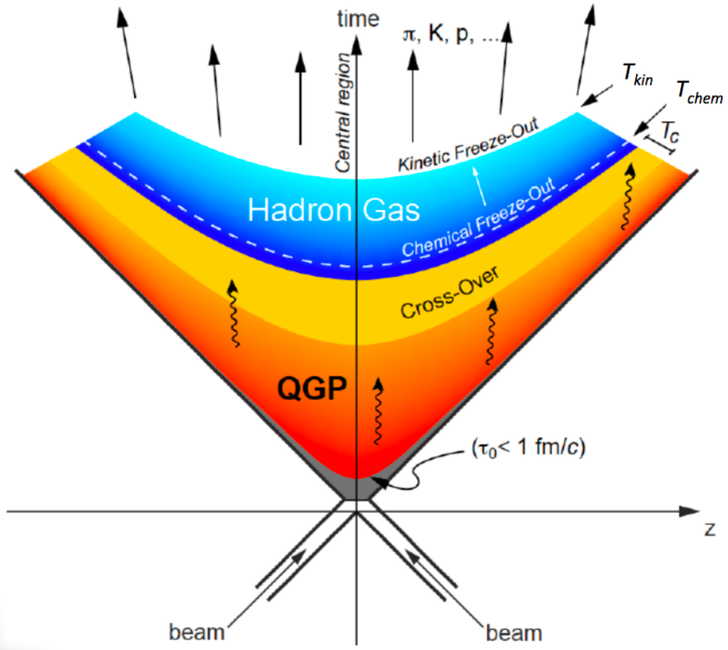
ICHEP 2022 BOLOGNA

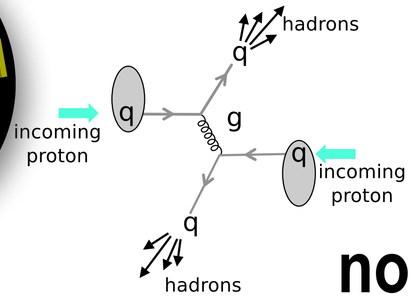
IKF
Institut für Kernphysik Frankfurt

ALICE

Introduction







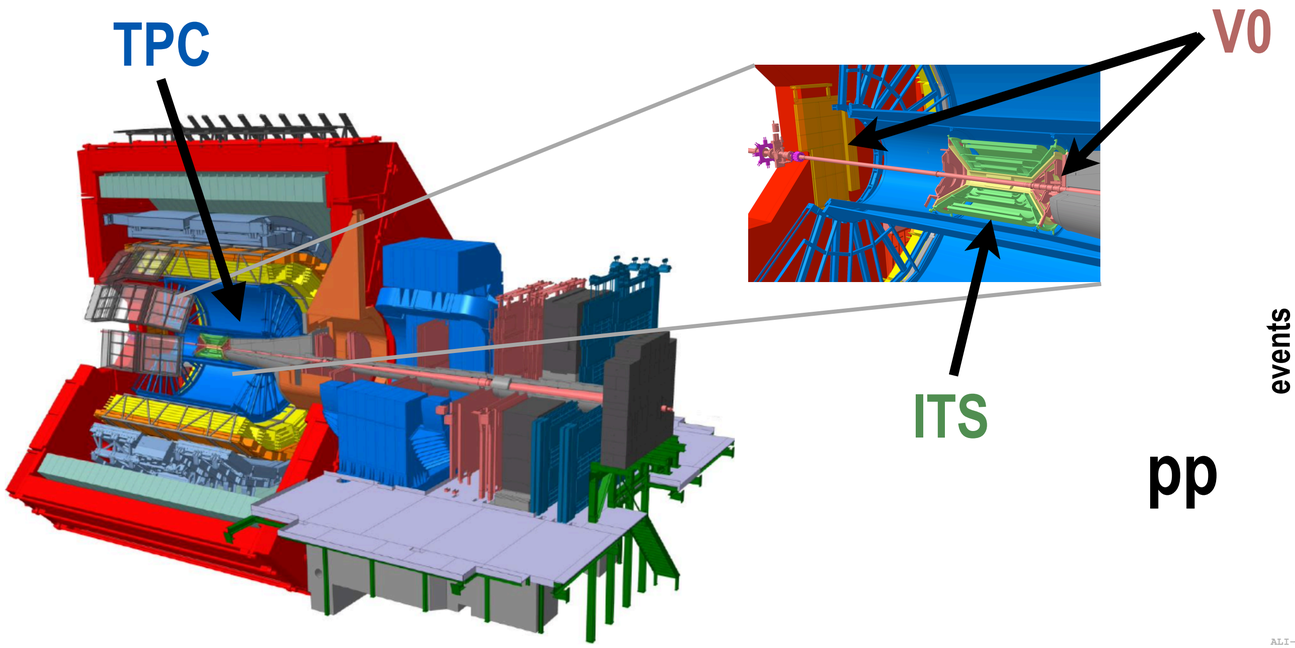
no QGP

- heavy-ion collisions allow to create a hot and dense deconfined medium of strongly interacting matter in the laboratory (quark-gluon plasma, QGP)
- it was found that some QGP-characteristic collective phenomena emerge also in smaller collision systems (pp, p-Pb)
- light-flavour hadrons (π, K, p,…) make up the bulk of particles produced in heavy-ion collisions

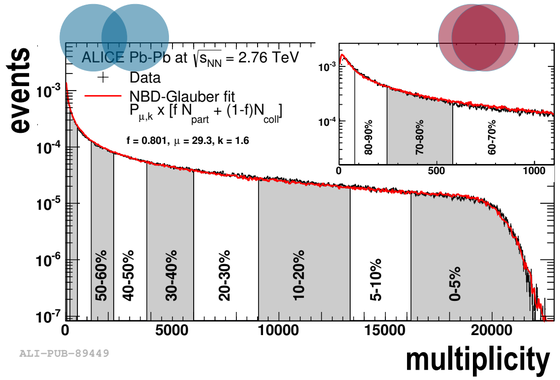
  → **perfect probes to study collective evolution of the system**

ALICE detector

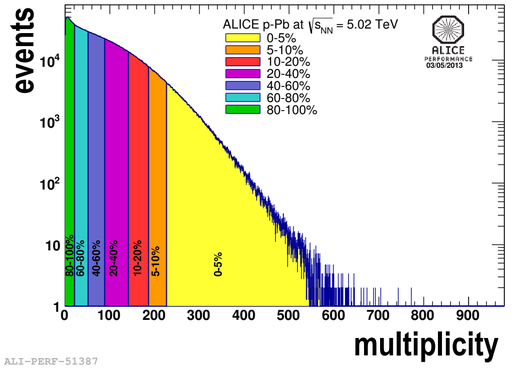
- dedicated heavy-ion experiment
- tracking capabilities down to p_T ~100 MeV/c
- charged-particle reconstruction with
  Inner Tracking System (ITS) and Time Projection Chamber (TPC)
- trigger and centrality / multiplicity selection with V0 system



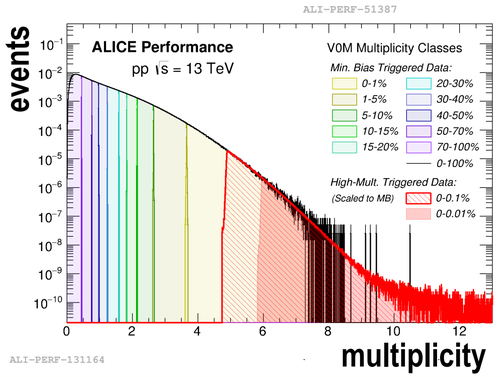
Pb-Pb



p-Pb



pp



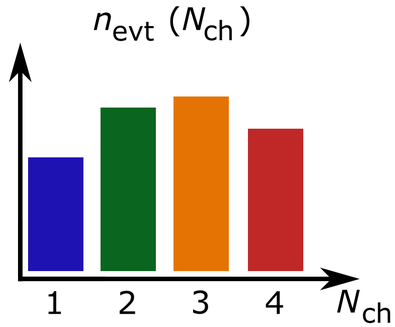
V0 multiplicity classes

Charged particle p_T spectra vs. N_{ch}

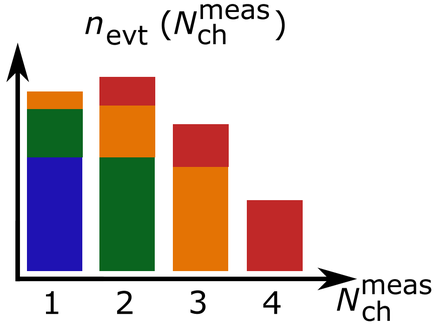
central-barrel multiplicity

- correlation of p_T spectra with true multiplicity cannot be measured directly due to detector effects
- raw observable:
  track yield as a function of track multiplicity
- sequential 2D-unfolding based on iterative D'Agostini method

  Nucl. Instr. Meth. Phys. Res. A 362 (1995) 487-498
- final observable:
  multiplicity and p_T differential invariant yield of primary charged particles

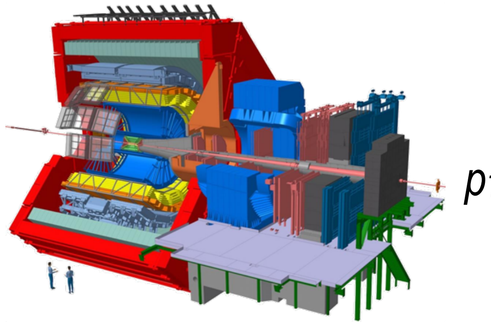


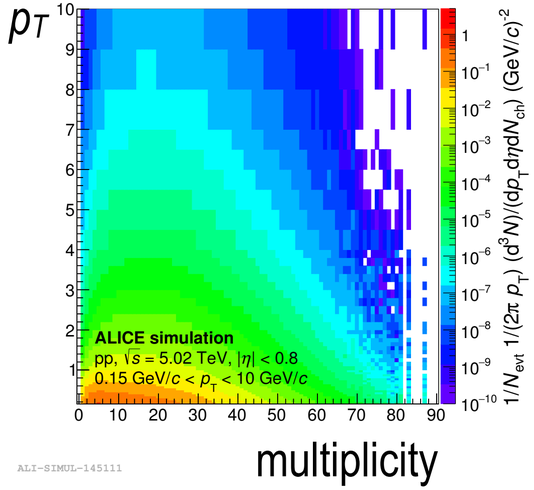
detector response



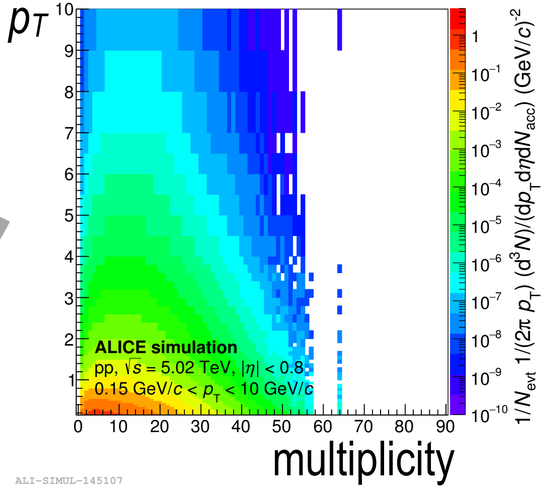
true

measured

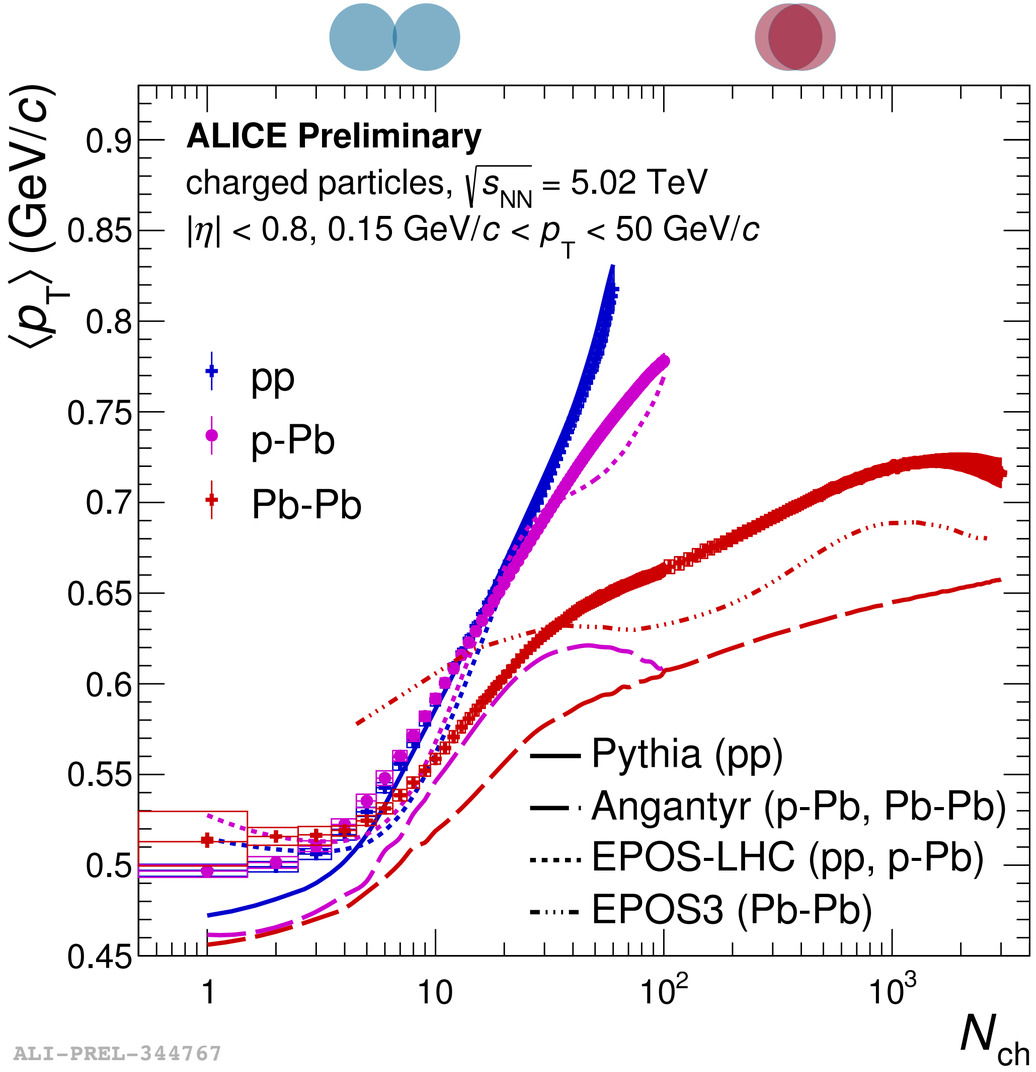




unfolding



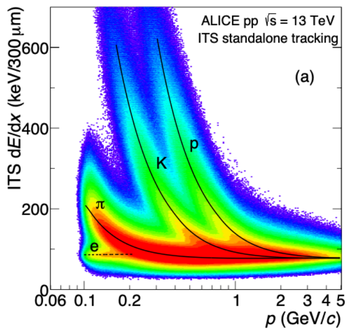
Charged particle mean p_T



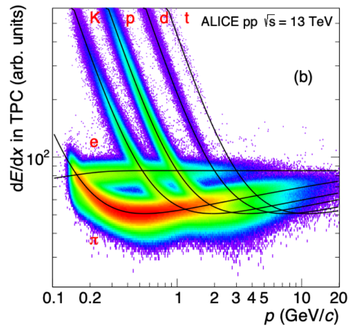
- charged hadron spectral shape evolution with highest possible granularity in multiplicity
- steeper rise in $\langle p_T \rangle$ for small systems (pp, p-Pb)
- **describing both large and small systems simultaneously still challenging for models**

PID with ALICE

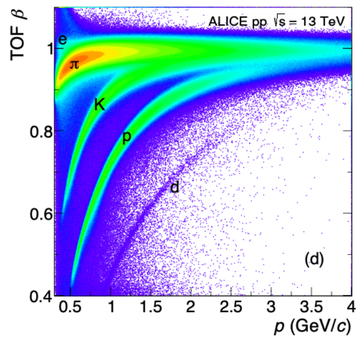
ITS



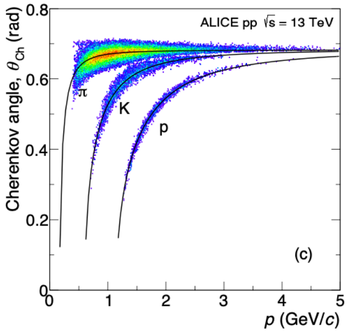
TPC

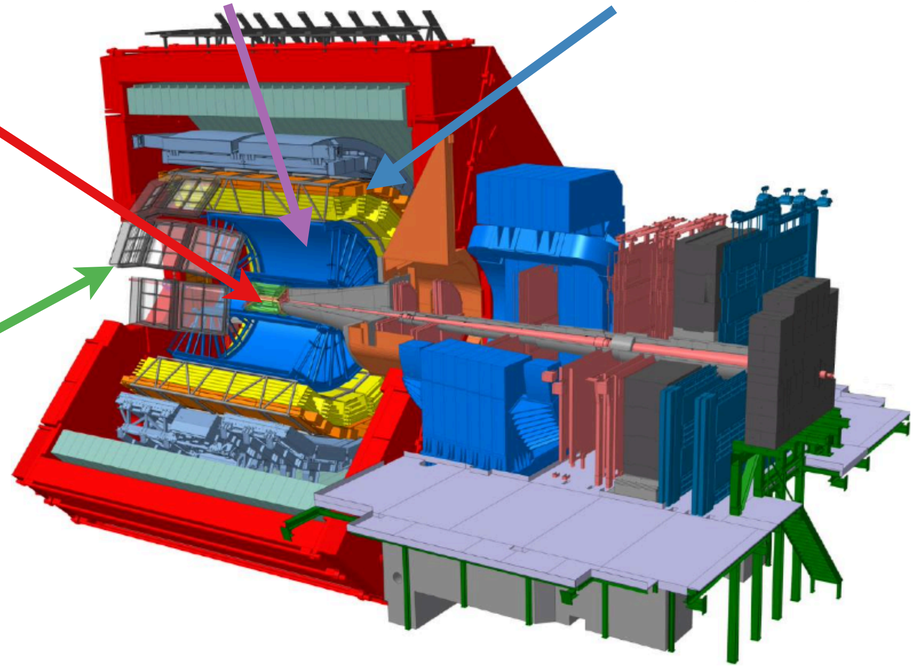


TOF

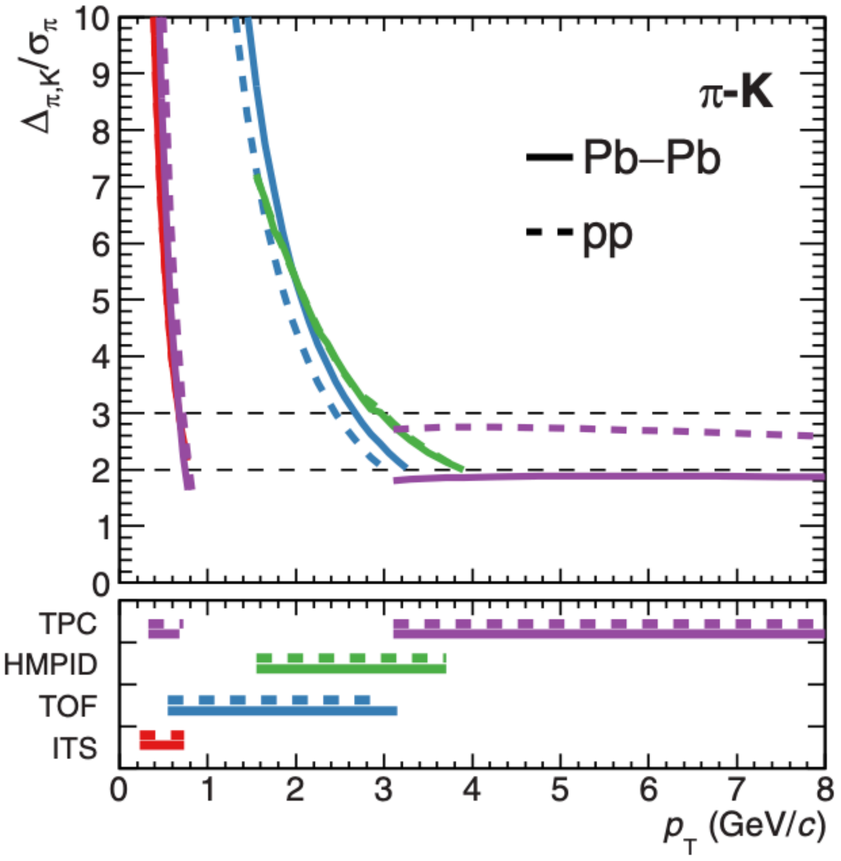


HMPID





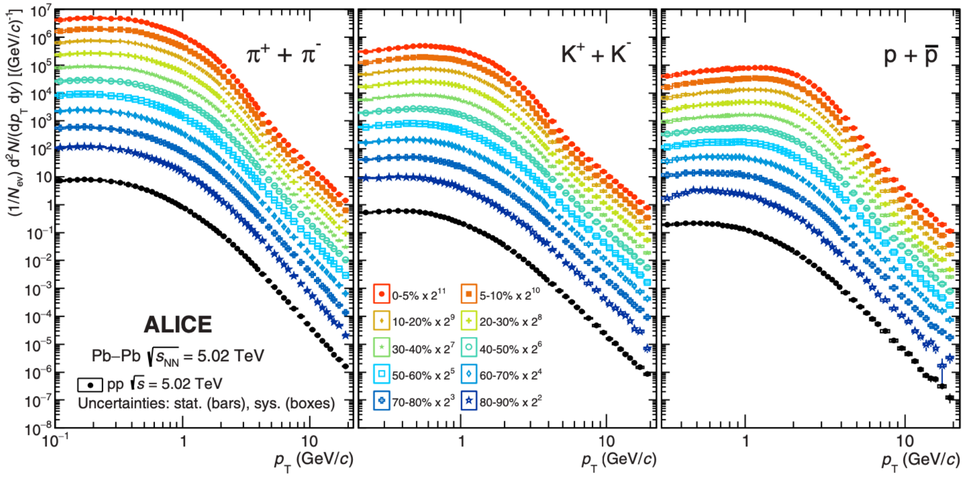
PID separation power

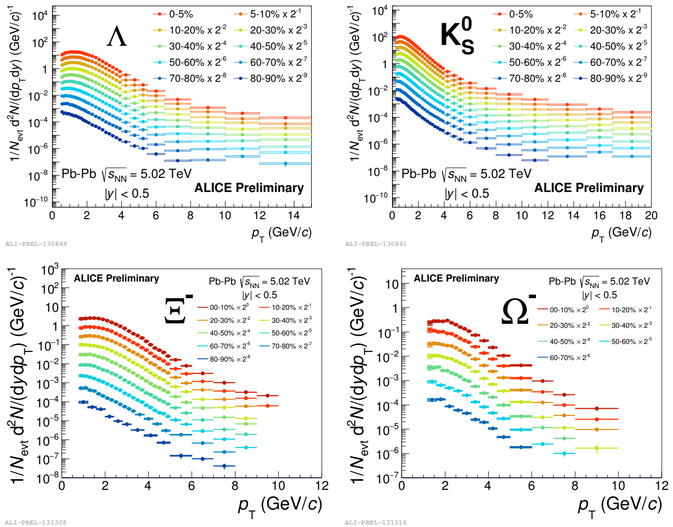


Phys. Rev. C 101, 044907

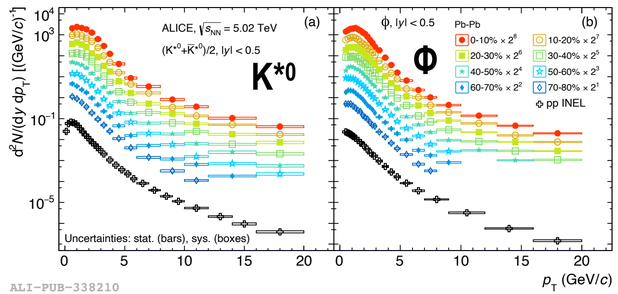
Particle production in Pb-Pb

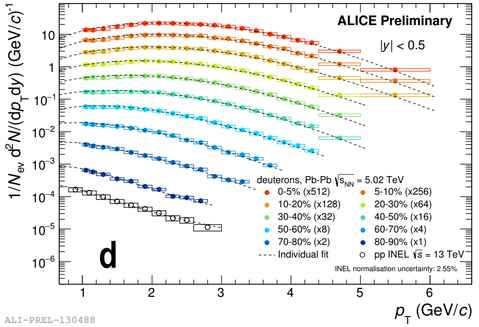
Phys. Rev. C 101, 044907



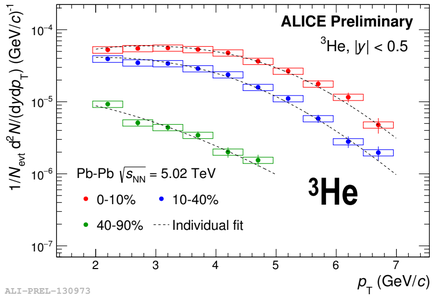


Phys. Lett. B 802, 135225



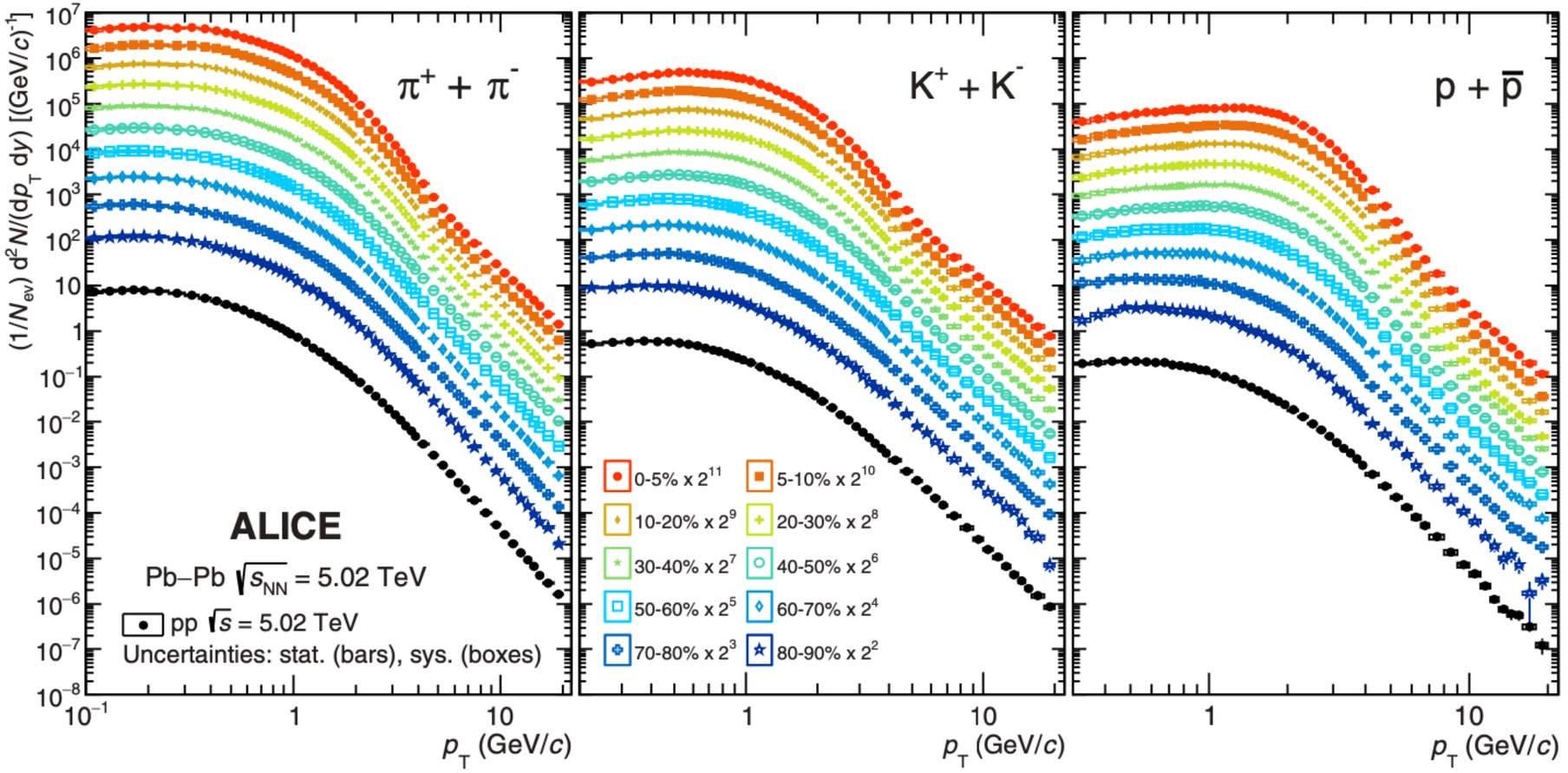


- precise p_T and centrality differential measurements of various light-flavour particle species at highest Pb-Pb collision energy
- complemented by a large number of multiplicity dependent measurements in pp and p-Pb



Particle production in Pb-Pb

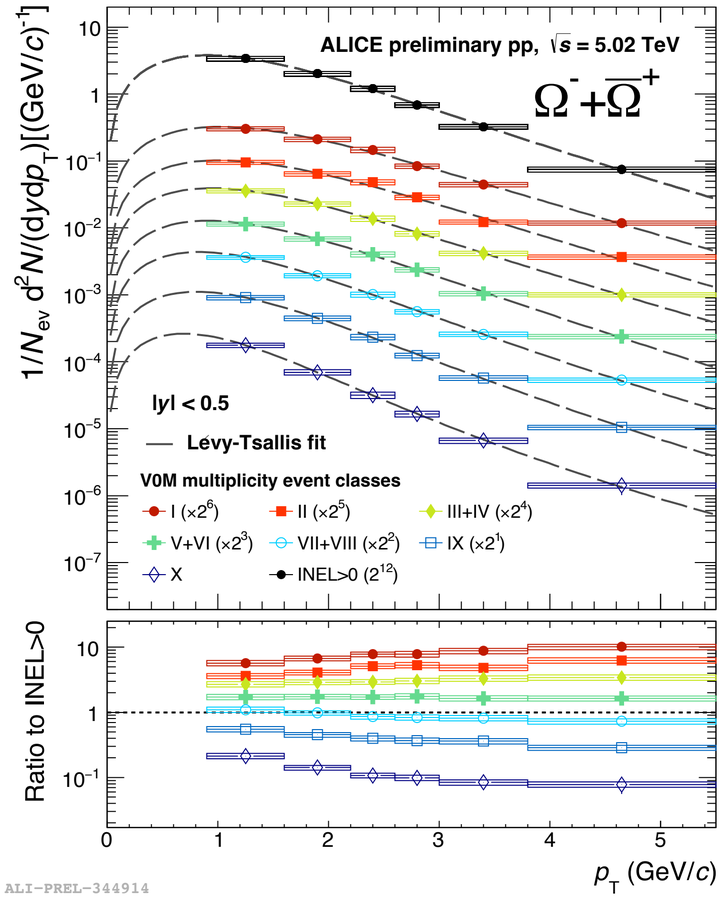
Pb-Pb

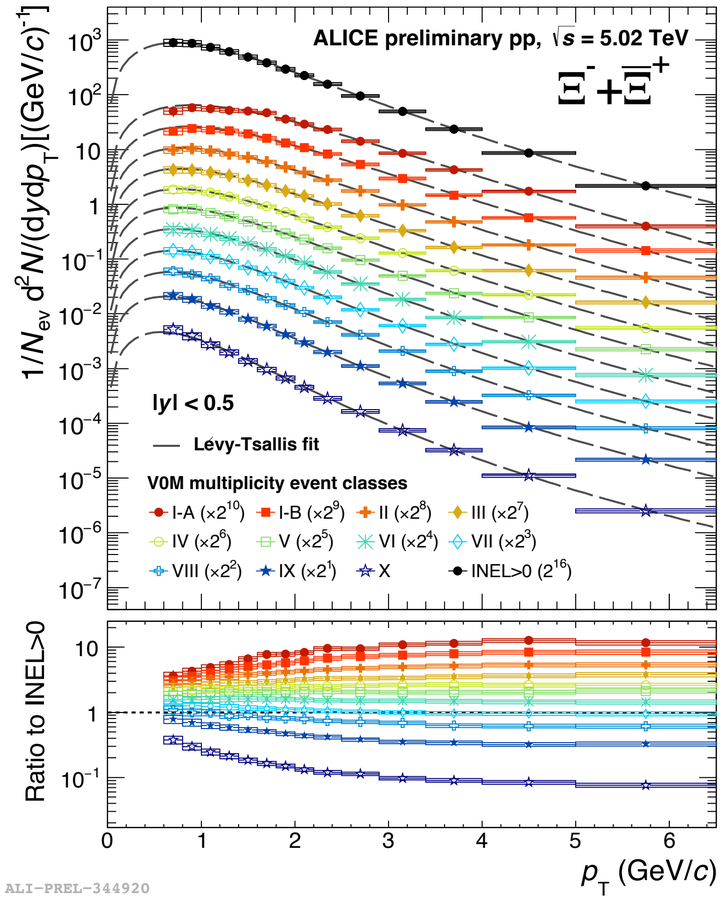


- flattening of spectral shape at low p_T more pronounced for heavier particles
  → **hint for collective movement (radial flow)**

Particle production in pp

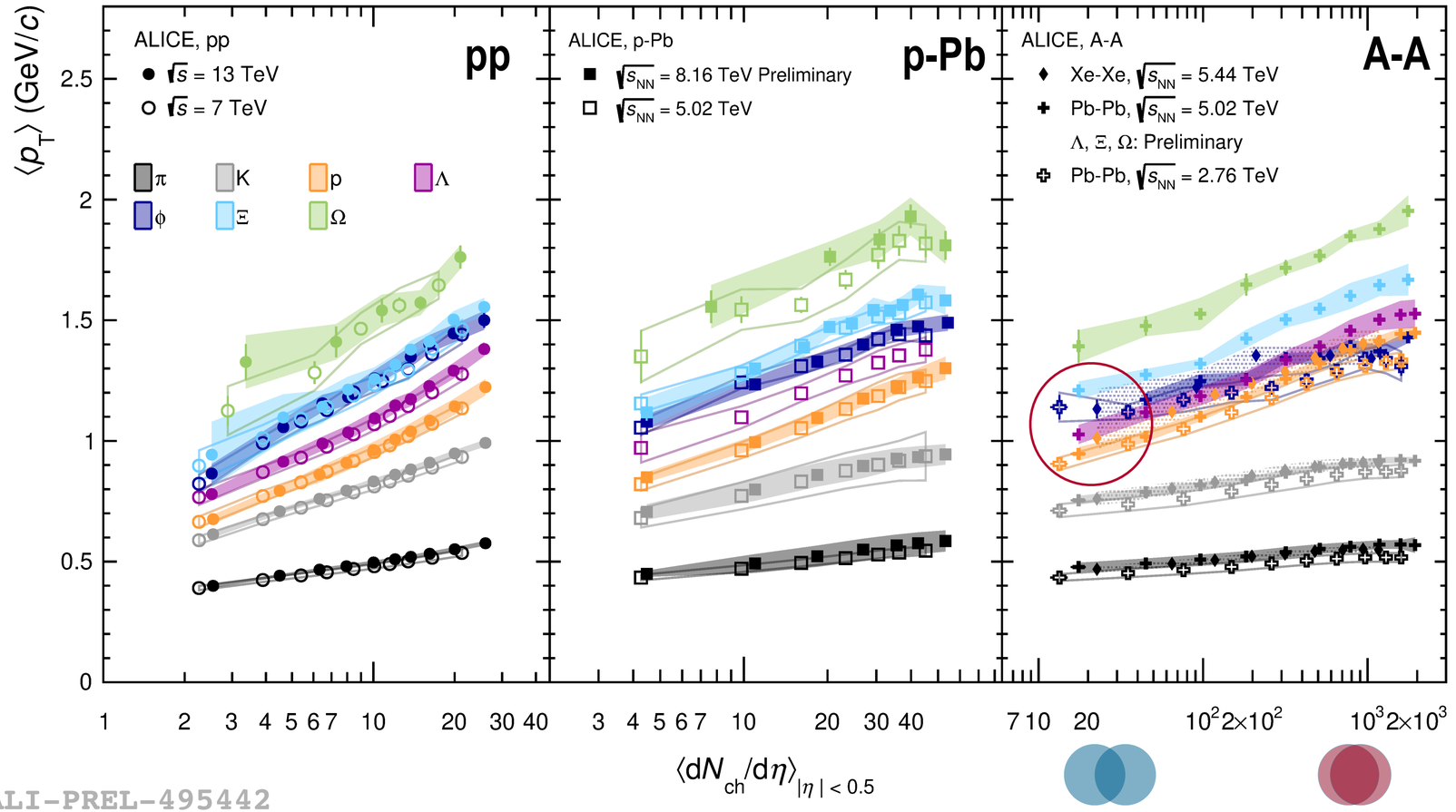
pp





- similar mass dependent hardening of spectra with increasing multiplicity observed in pp
- **lowest pp collision energy for multiplicity differential measurement so far: √s = 5.02 TeV**

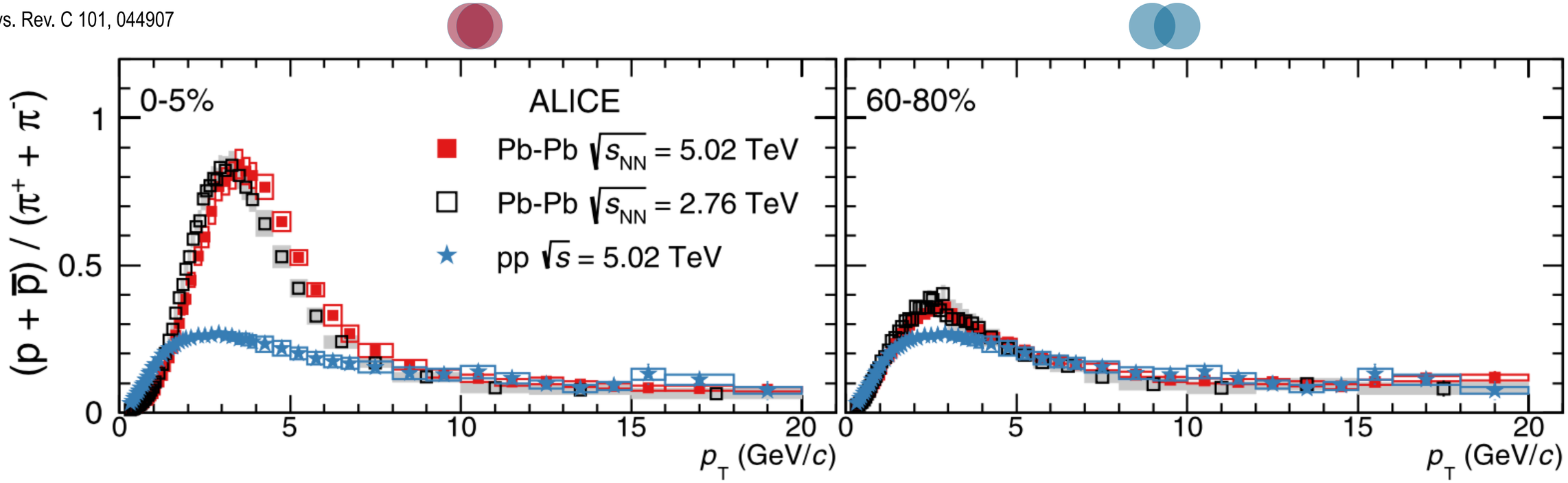
Mean p_T



- in central heavy-ion collisions particles with similar masses have similar <p_T> (hydrodynamic expansion)
  → **ϕ meson ($m_\phi \approx m_p$) mass ordering breaks down for peripheral collisions and in pp and p-Pb**

Baryon-to-meson ratios

Phys. Rev. C 101, 044907

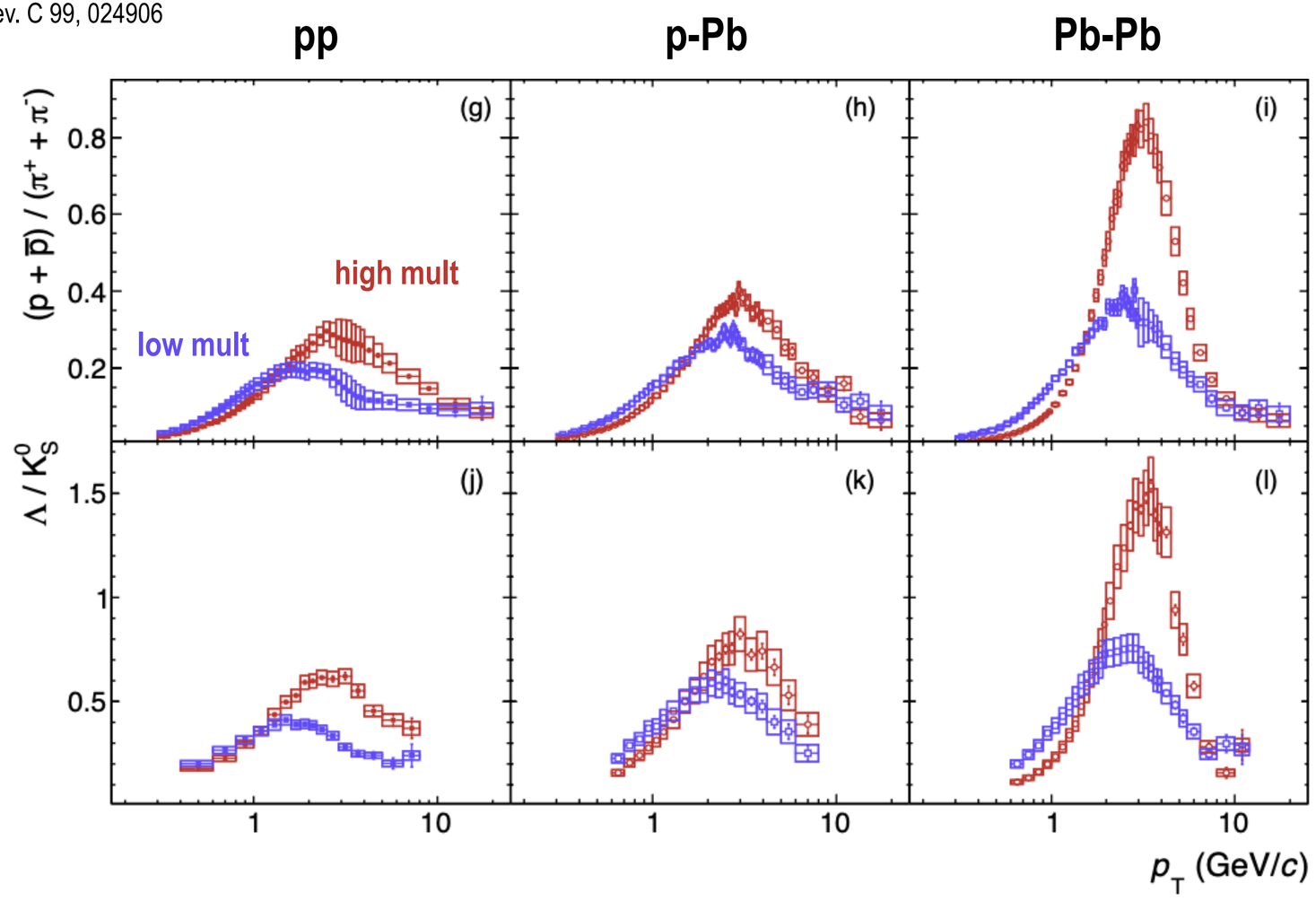


- significant enhancement of protons over pions at intermediate p_T for central collisions wrt. peripheral and pp
  → **heavier particles could be boosted to higher momenta by collective motion**

- peak in $\sqrt{s_{NN}}$ = 5.02 TeV slightly shifted toward higher p_T (consistent with larger radial flow)

Baryon-to-meson ratios

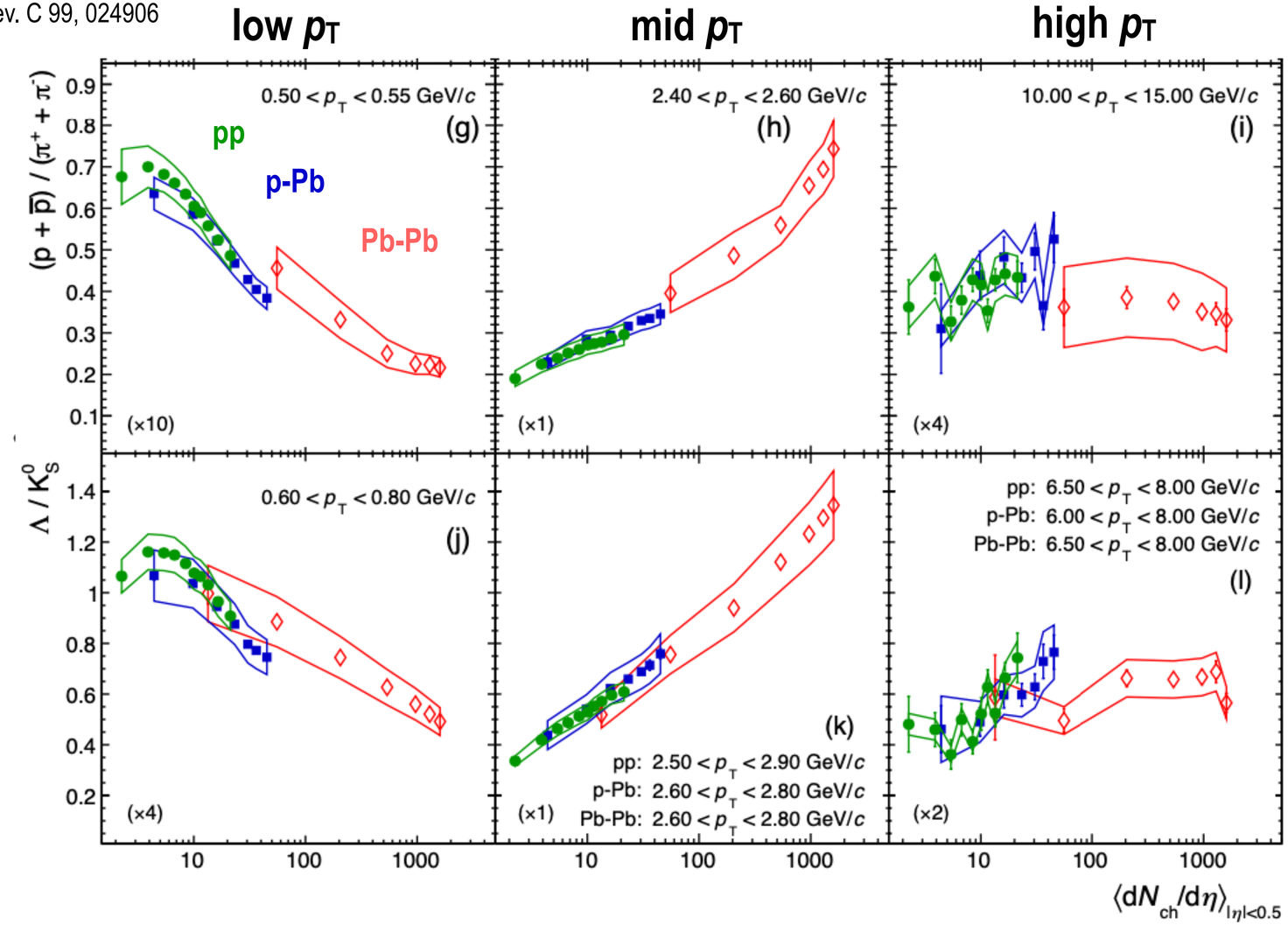
Phys. Rev. C 99, 024906



- p/π and Λ/K^0_s:
  - enhancement at intermediate p_T
  - depletion at low p_T
- qualitative similarities between systems when comparing high multiplicity with low multiplicity

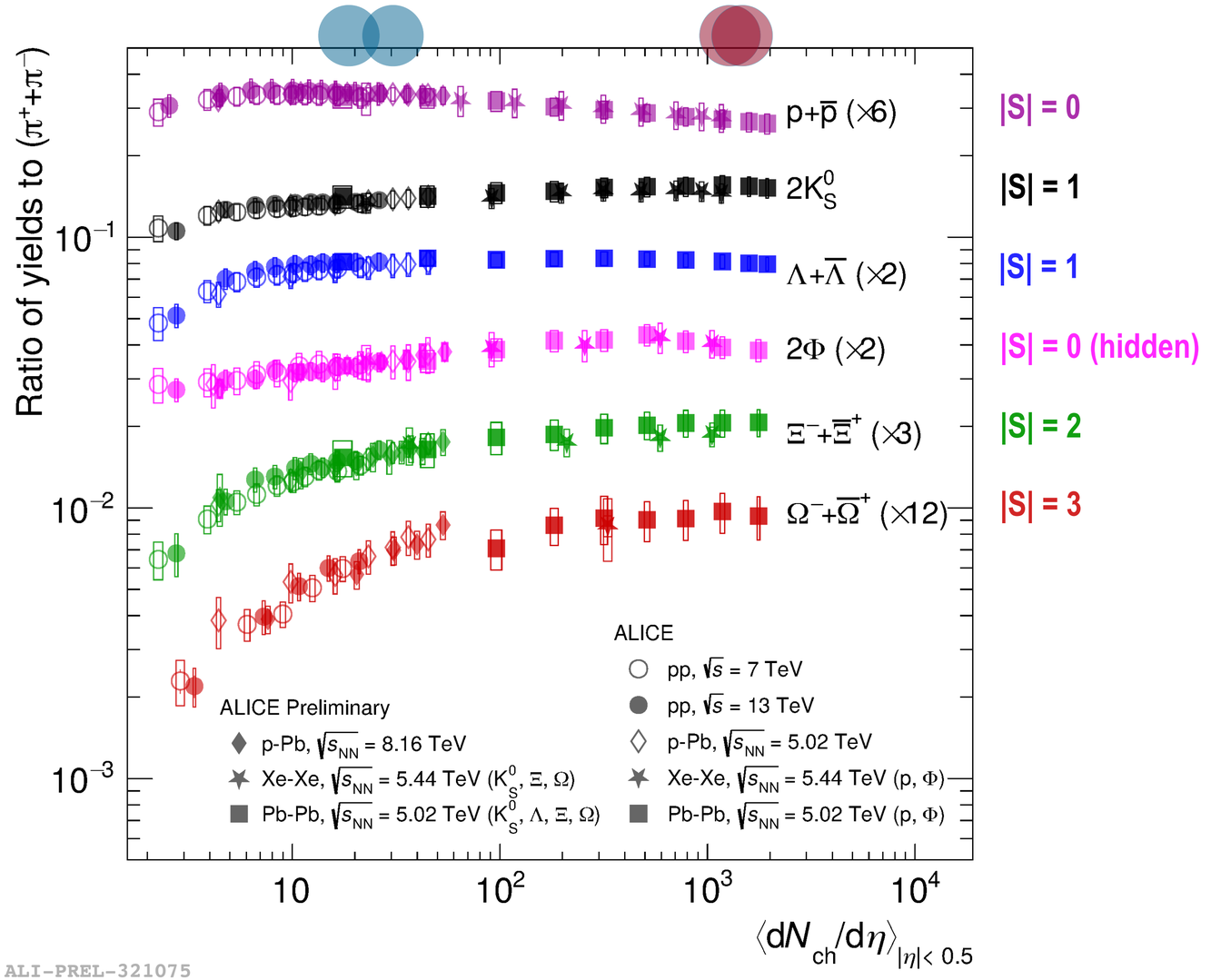
Baryon-to-meson ratios

Phys. Rev. C 99, 024906



- p/π and Λ/K^0_S:
  - enhancement at intermediate p_T
  - depletion at low p_T
- qualitative similarities between systems when comparing high multiplicity with low multiplicity
- smooth evolution with multiplicity between the systems within same p_T ranges
- **points toward common driving mechanism in all systems**

Integrated particle yields



|S| = 0

|S| = 1

|S| = 1

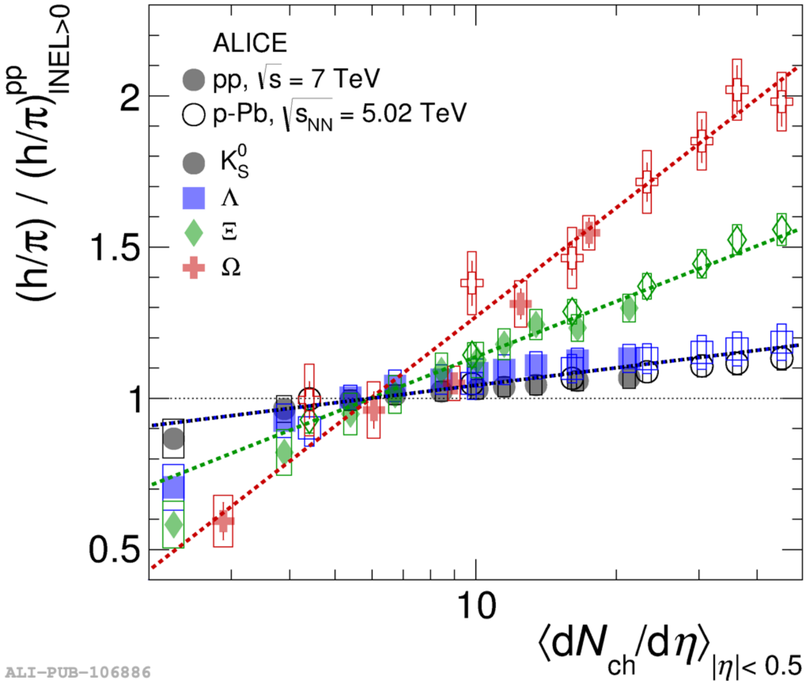
|S| = 0 (hidden)

|S| = 2

|S| = 3

ALI-PREL-321075

- hadron chemistry driven by multiplicity
- continuous evolution of strangeness production between different collision systems and energies
- magnitude of strangeness enhancement grows with strange quark content:



|S| = 3

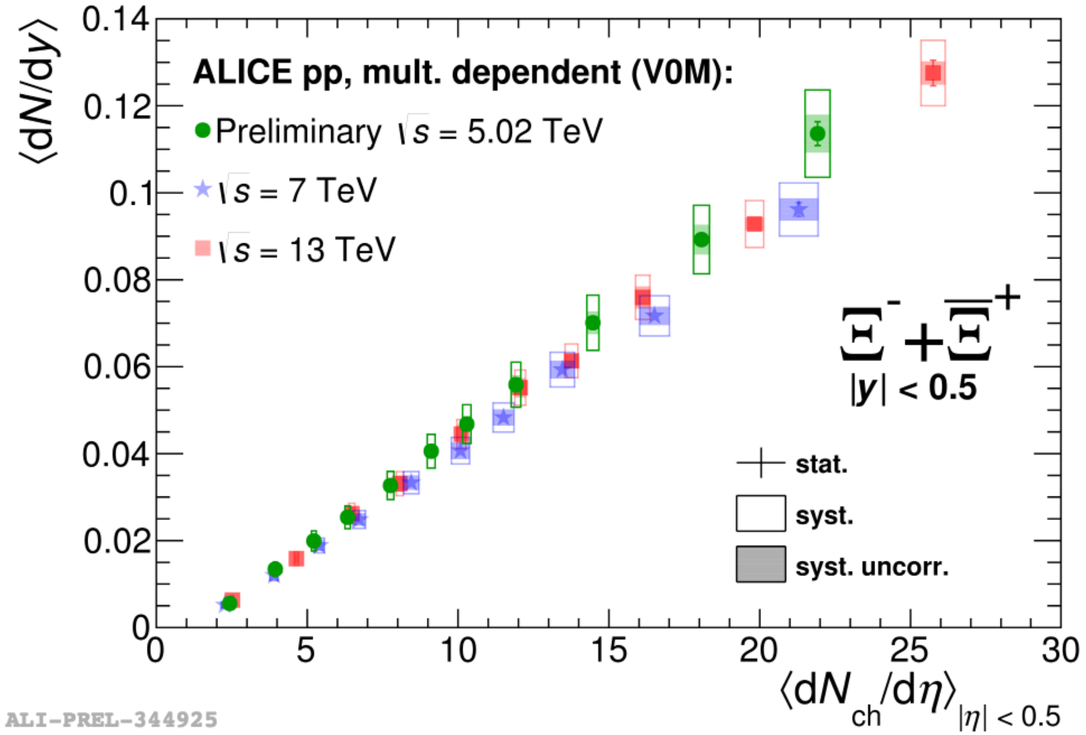
|S| = 2

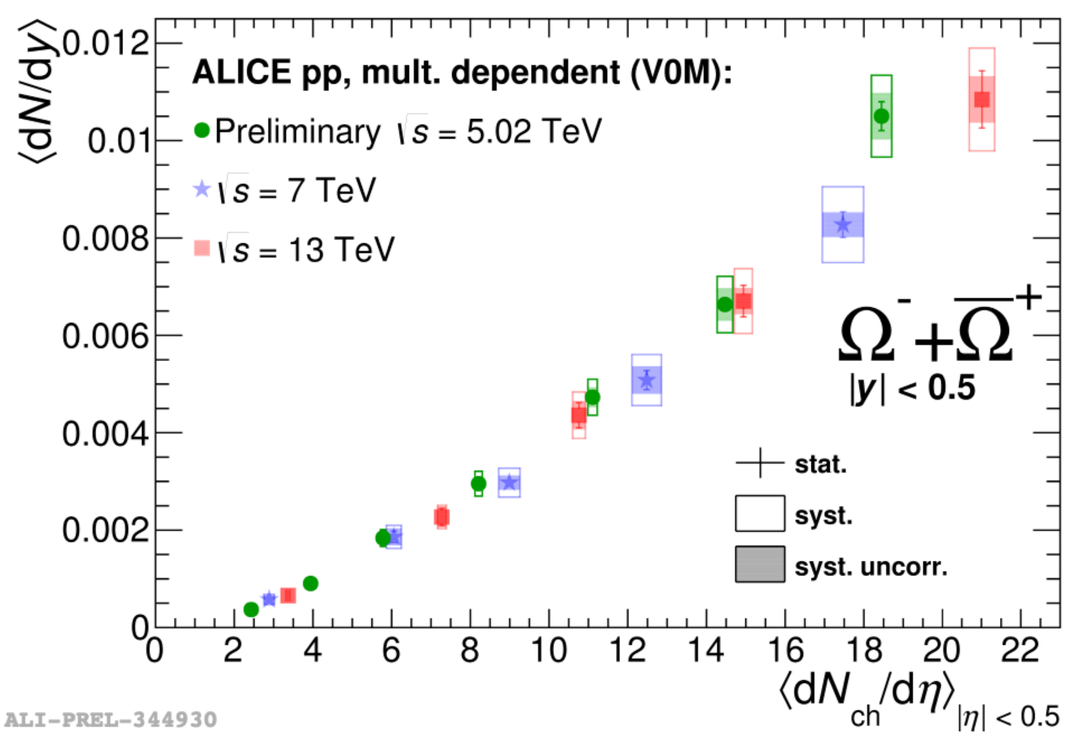
|S| = 1 |S| = 1

Nat. Phys. 13, 535–539

ALI-PUB-106886

Integrated particle yields

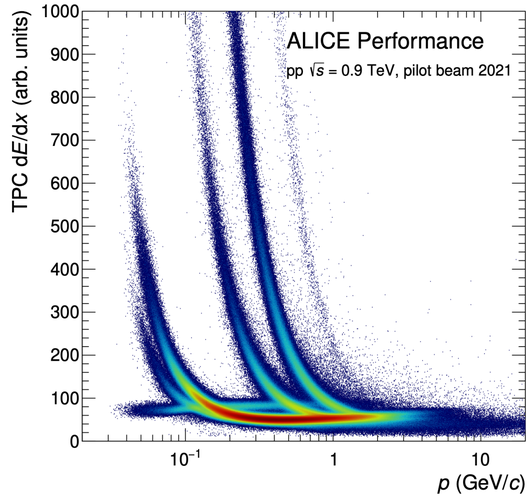




- latest measurements for pp collisions at √s = 5.02 TeV perfectly align with previous results and extend $\langle dN_{ch}/d\eta \rangle$ range to lower multiplicities

LHC Run 3 pilot beam: pp, 900 GeV

- after major Run 3 upgrade of ALICE:
  first pilot beam data taken for pp collisions at √s = 900 GeV
- PID performance of new detector very promising
- first analyses ongoing to measure light flavour hadron production
- hope to extend current measurements down to lowest multiplicities
- LHC Run 3 will also provide higher pp collision energies and exciting new collision systems (p-O, O-O)



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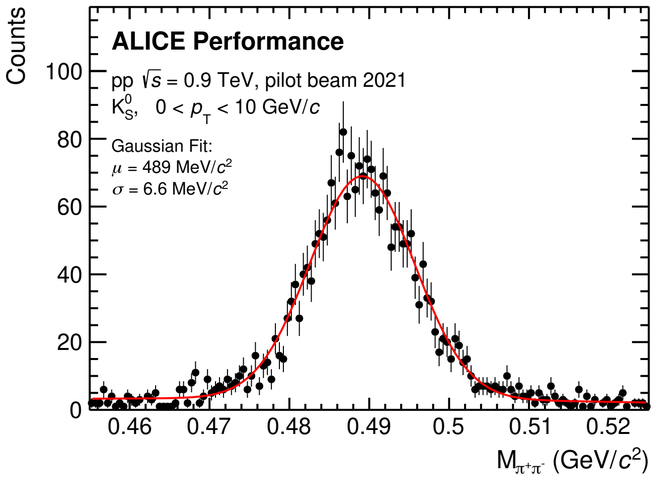

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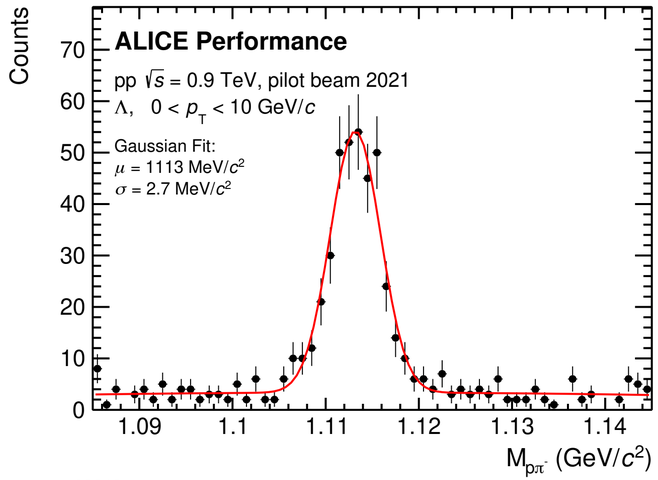
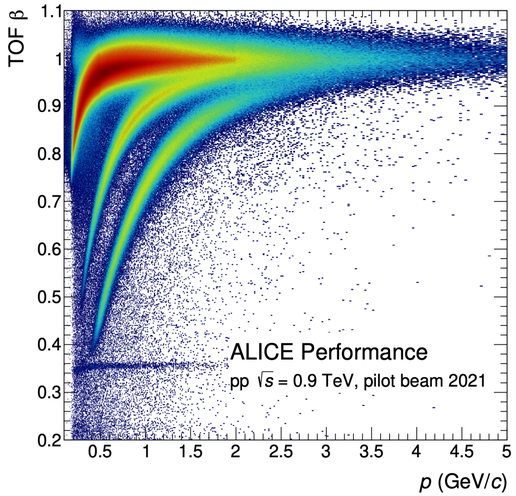


ALI-PERF-502948



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Conclusions and outlook

- simultaneous description of charged particle production as function of multiplicity for all collision systems still challenging for theoretical models
- ϕ-meson mass ordering of $\langle p_T \rangle$ not observed in p-Pb and pp collisions
- relative enhancement of p/π and Λ/K^0_S at intermediate p_T also present in high multiplicity pp and p-Pb
- smooth evolution of strangeness enhancement with multiplicity between systems
  → can we disentangle initial and final-state effects in pp collisions?

Francesca Ercolessi, Thursday 09:50

- ALICE on the verge of completing the full energy & system size scan of light flavour measurements for LHC Run 1 & 2
  → Run 3 has already started and will provide more exciting opportunities…

Aimeric Landau, Friday 09:18

stay tuned!