Energy and centrality dependence of resonance production with ALICE at the LHC

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Role of hadronic resonances

Several hadronic resonances studied via invariant-mass analysis with ALICE (ρ^0, ϕ, K^{*0}, $\Sigma^{*\pm}$, Λ^*, Ξ^{*0}) in all systems (pp, p-Pb, Pb-Pb and Xe-Xe) and at all energies from both Run I and Run II at LHC

Focus today on:

$\rho(770)^0 \to \pi^+ + \pi^-$ ($c\tau$ = 1.3 fm)

$K^{*0}(892) \to \pi^+ + K^-$ ($c\tau$ = 4.16 fm)

$\Lambda(1520) \to p + K^-$ ($c\tau$ = 12.6 fm)

$\phi(1020) \to K^+ + K^-$ ($c\tau$ = 46.2 fm)

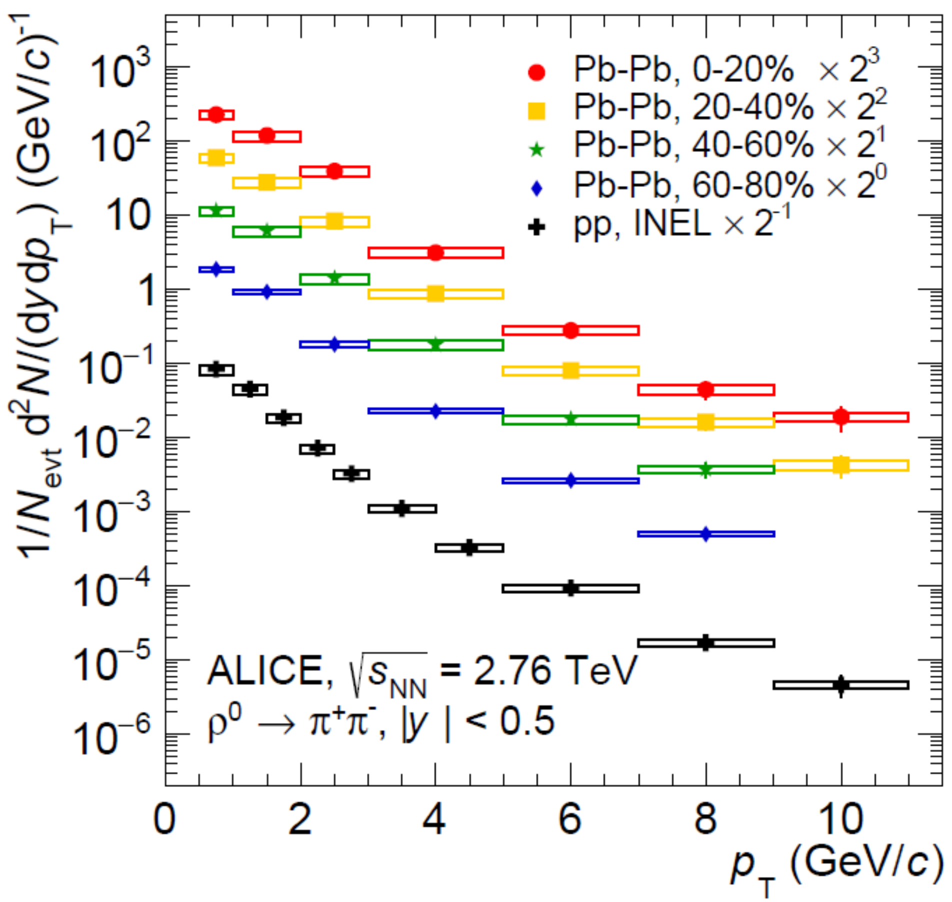
arXiv:1805.04365
arXiv:1805.04361
Phys. Rev. C 95 (2017) 064606
Eur. Phys. J. C 77 (2017) 389
Eur. Phys. J. C 76 (2016) 245
Phys. Rev. C 91 (2015) 024609
Eur. Phys. J. C 75 (2015) 1
Eur. Phys. J. C 72 (2012) 2183
Eur. Phys. J. C 71 (2011) 1594

Resonances play an important role in the study of the bulk properties of the system created in the collision (e.g. production mechanisms, late hadronic stage of the collision)

Transverse momentum spectra

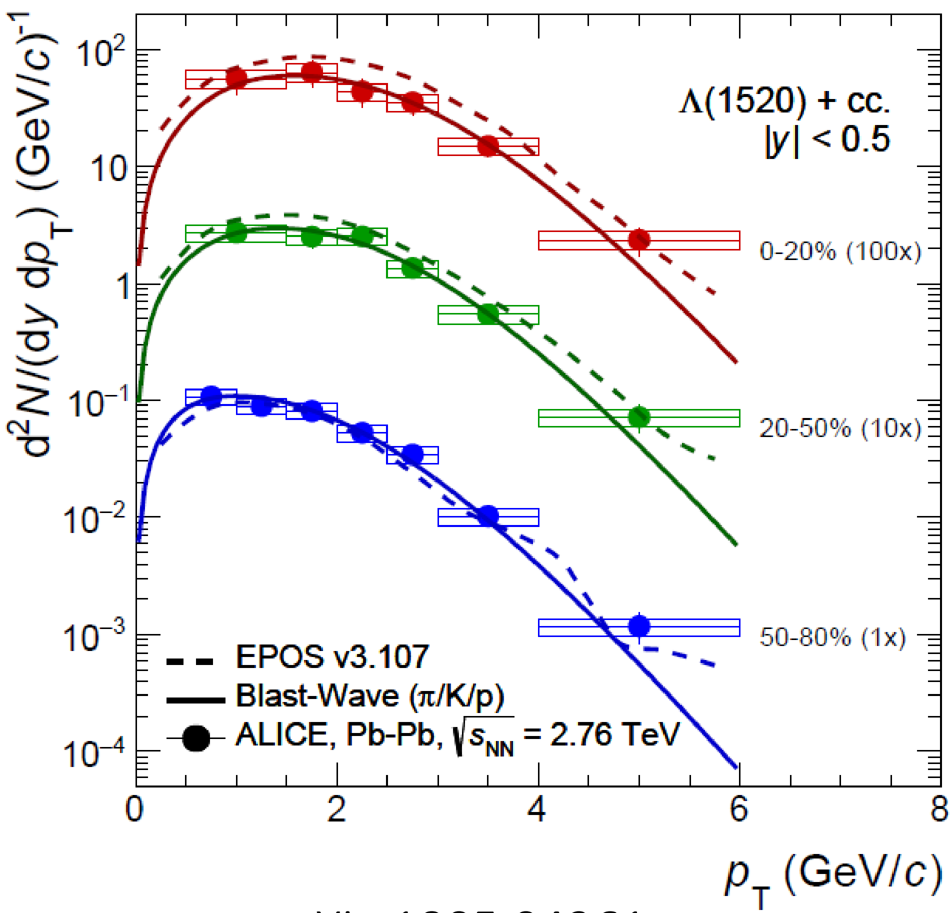
NEW

$\rho^0(770)$



arXiv:1805.04365

$\Lambda(1520)$



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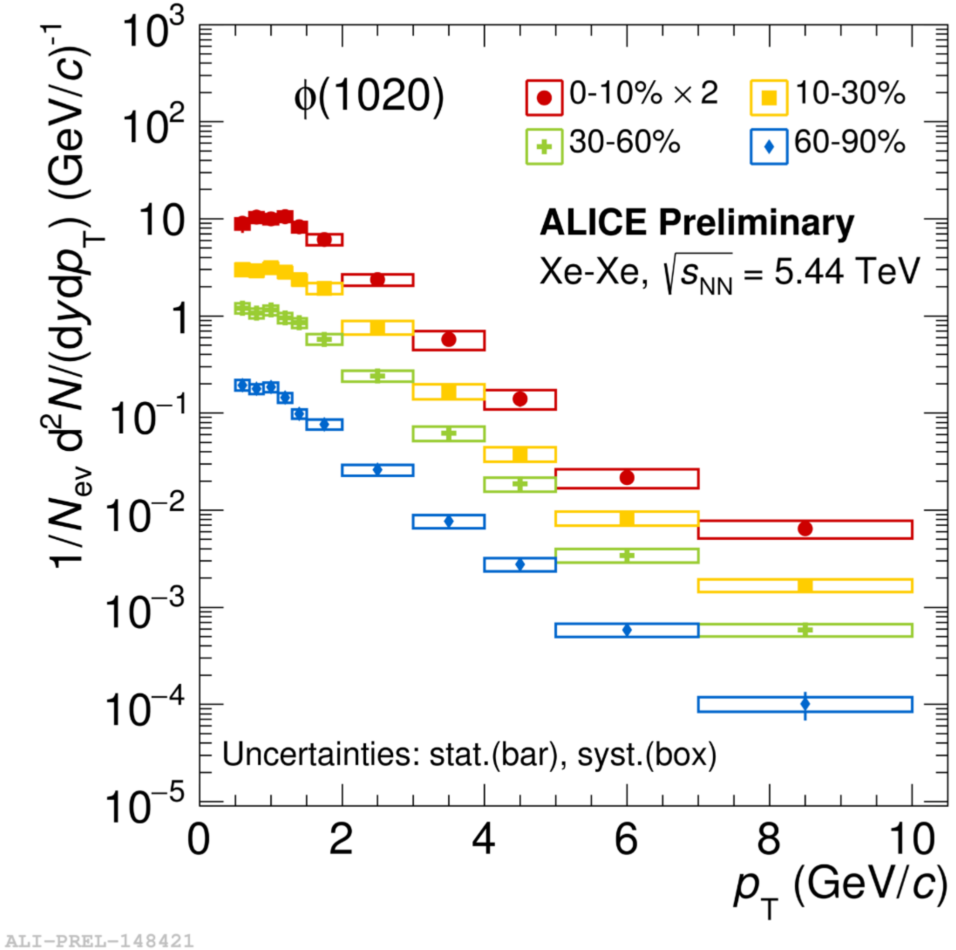
Transverse momentum spectra

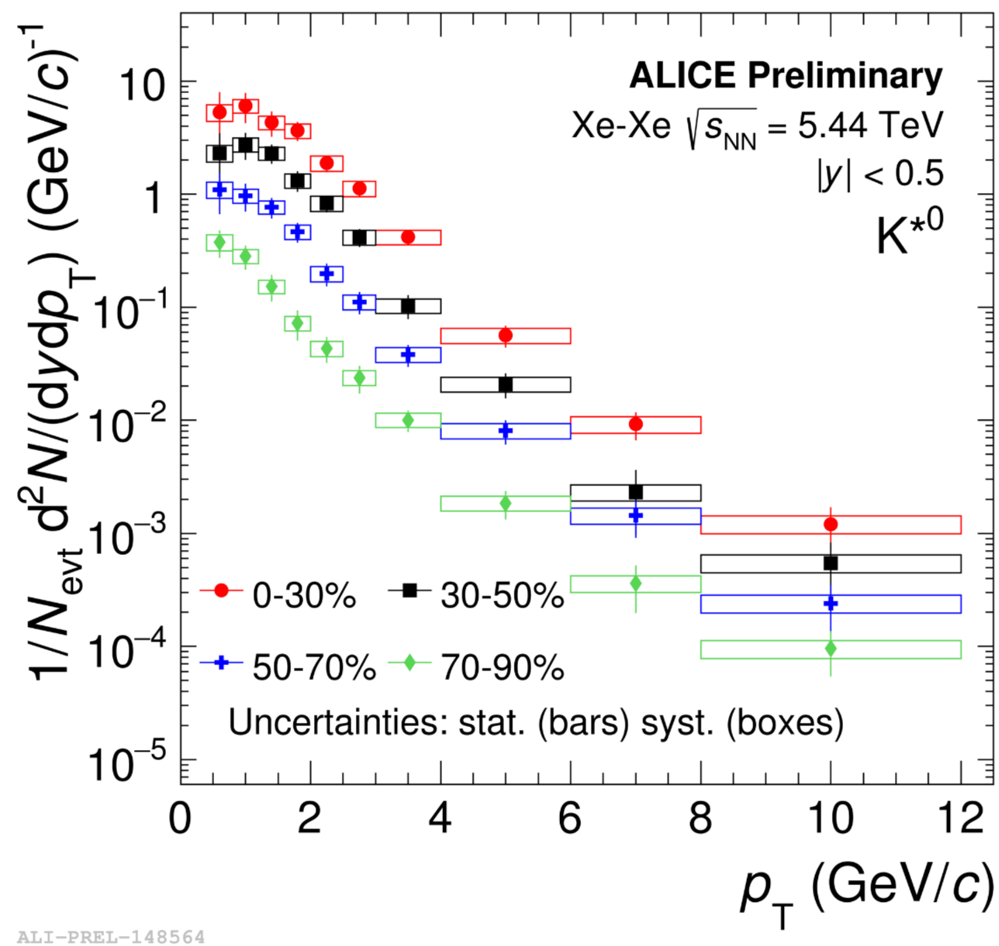
NEW

Xe-Xe

$\phi(1020)$



$K^{*0}(892)$



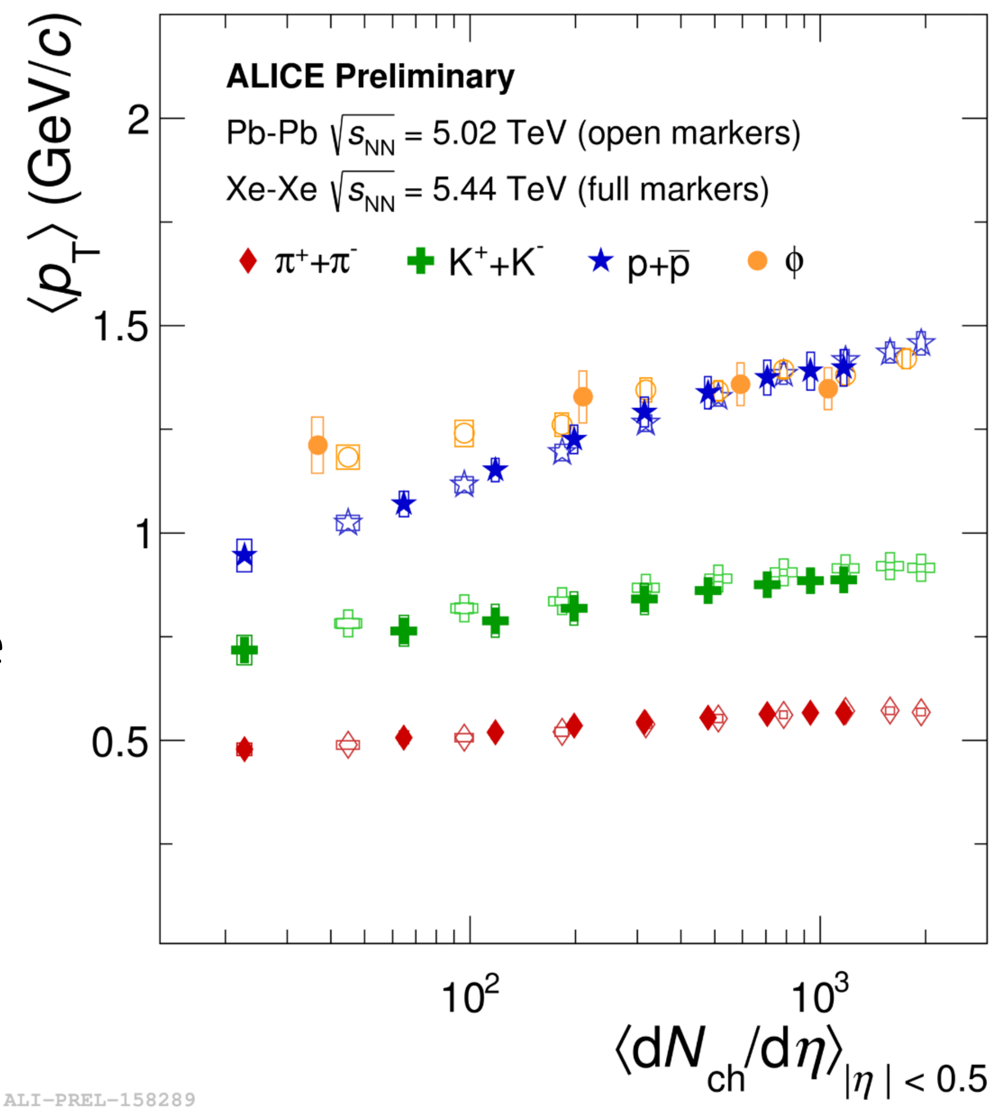
Mean transverse momenta

Mean transverse momenta provide first-order characterization of spectral shapes

New data in Xe-Xe for identified hadrons suggest a consistent picture between Xe-Xe and Pb-Pb

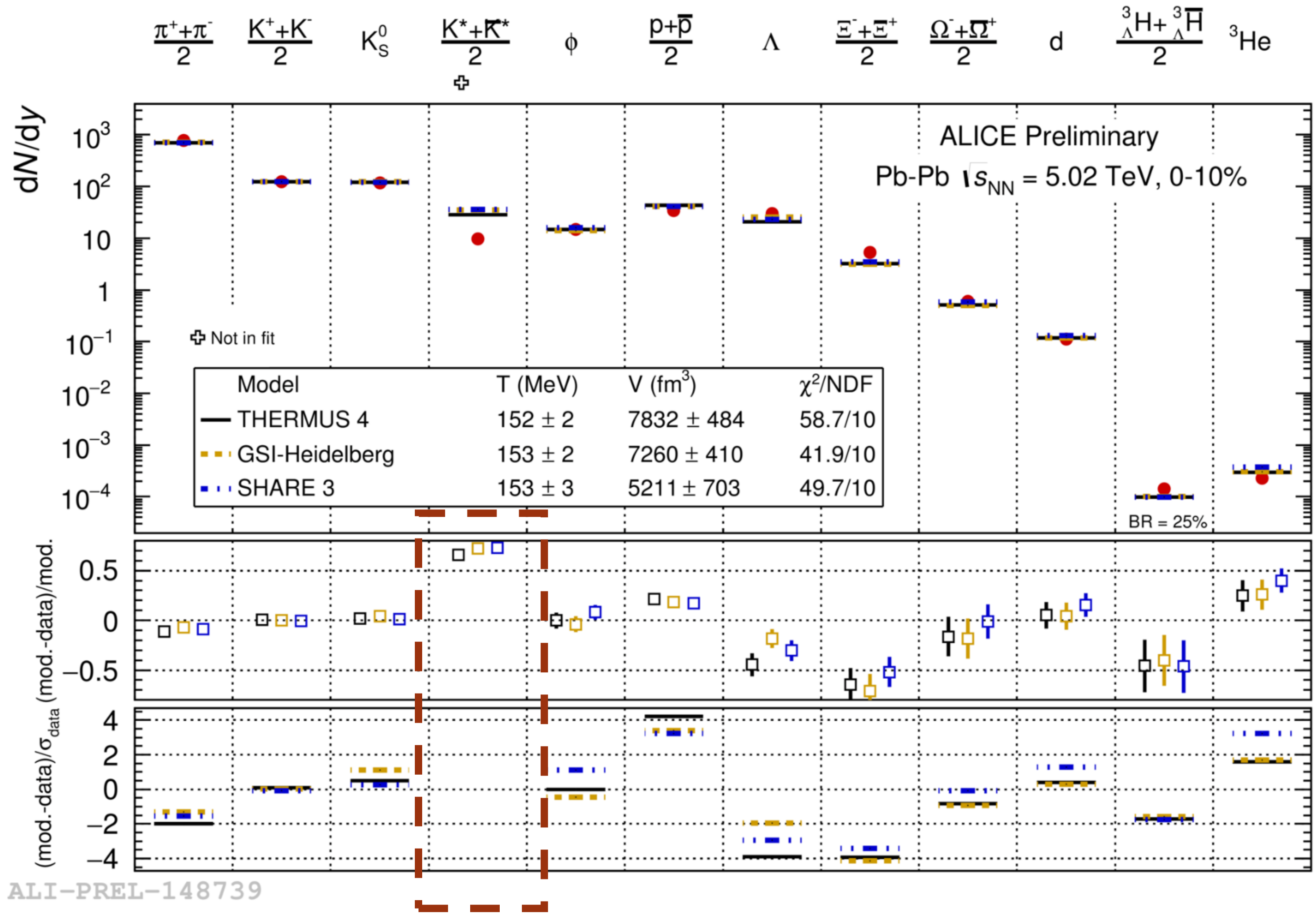
→ Hydrodynamics predicts only a weak dependence of the difference in $<p_T>$ between Xe-Xe and Pb-Pb (O(3%))
[G. Giacalone *et al.*, PRC 97, 034904 (2018)]

→ Mass scaling of $<p_T>$ observed in central Xe-Xe and Pb-Pb collisions



Mass scaling is tested comparing p and ϕ ($m_p \sim m_\phi$)

Thermal fit



Model	T (MeV)	V (fm^3)	χ^2/NDF
THERMUS 4	152 ± 2	7832 ± 484	58.7/10
GSI-Heidelberg	153 ± 2	7260 ± 410	41.9/10
SHARE 3	153 ± 3	5211 ± 703	49.7/10

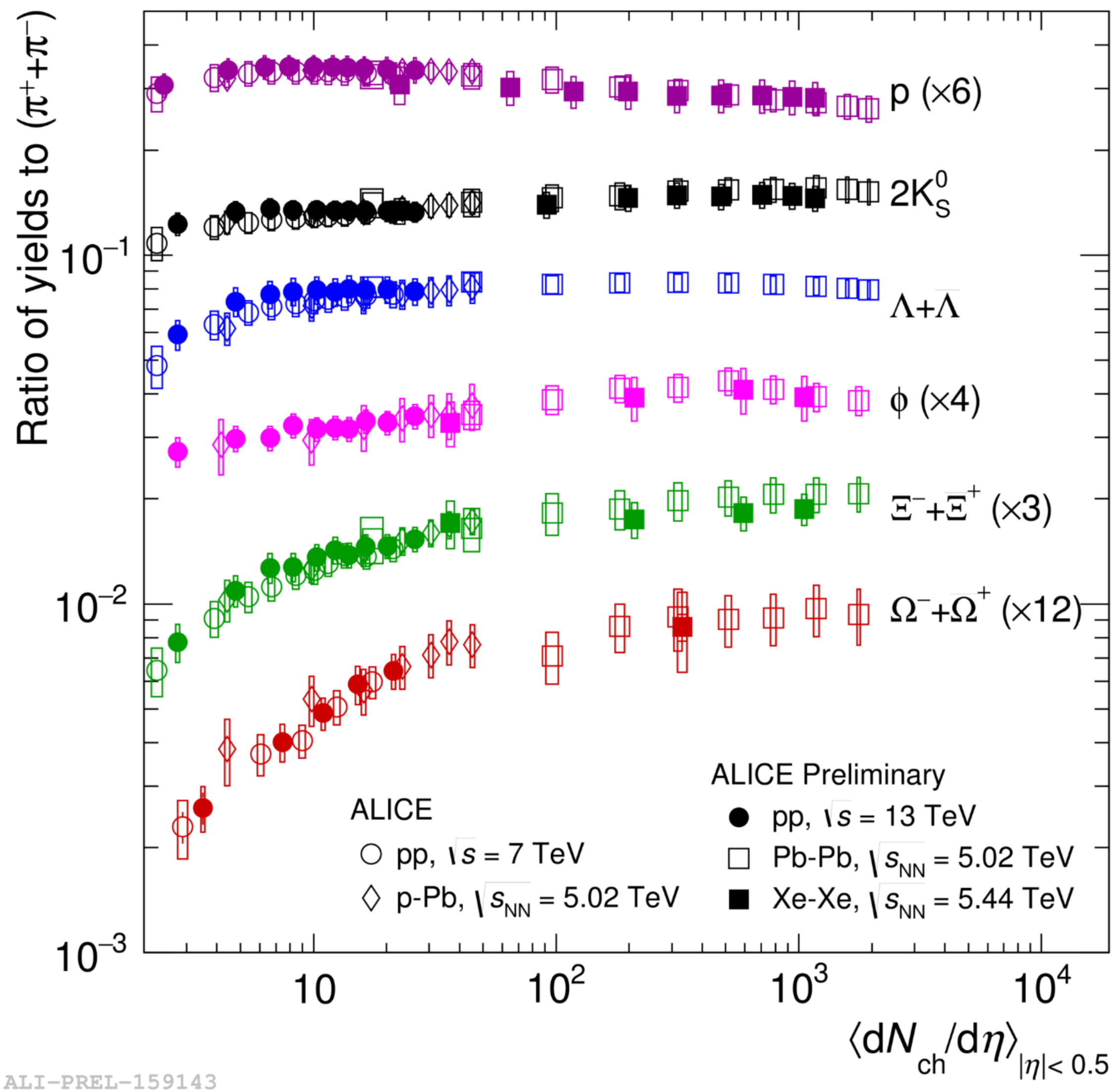
Statistical hadronization models describe hadron production assuming chemical equilibrium

Also at 5.02 TeV, yields of light flavor hadrons are qualitatively well described over 7 orders of magnitude

Deviation for short-lived K*^{0} resonance that suffers from rescattering in the late hadronic phase (excluded from fit)

THERMUS: Wheaton *et al.,* Comput.Phys.Commun, 180 84
GSI-Heidelberg: Andronic *et al.*, Phys. Lett. B 673 142
SHARE: Petran *et al.,* arXiv:1310.5108

Hadrochemistry as function of system size



Chemistry is driven by charged particle multiplicity, i.e. the size of the system

Smooth evolution of particle chemistry from small to large systems as function of charged particle multiplicity

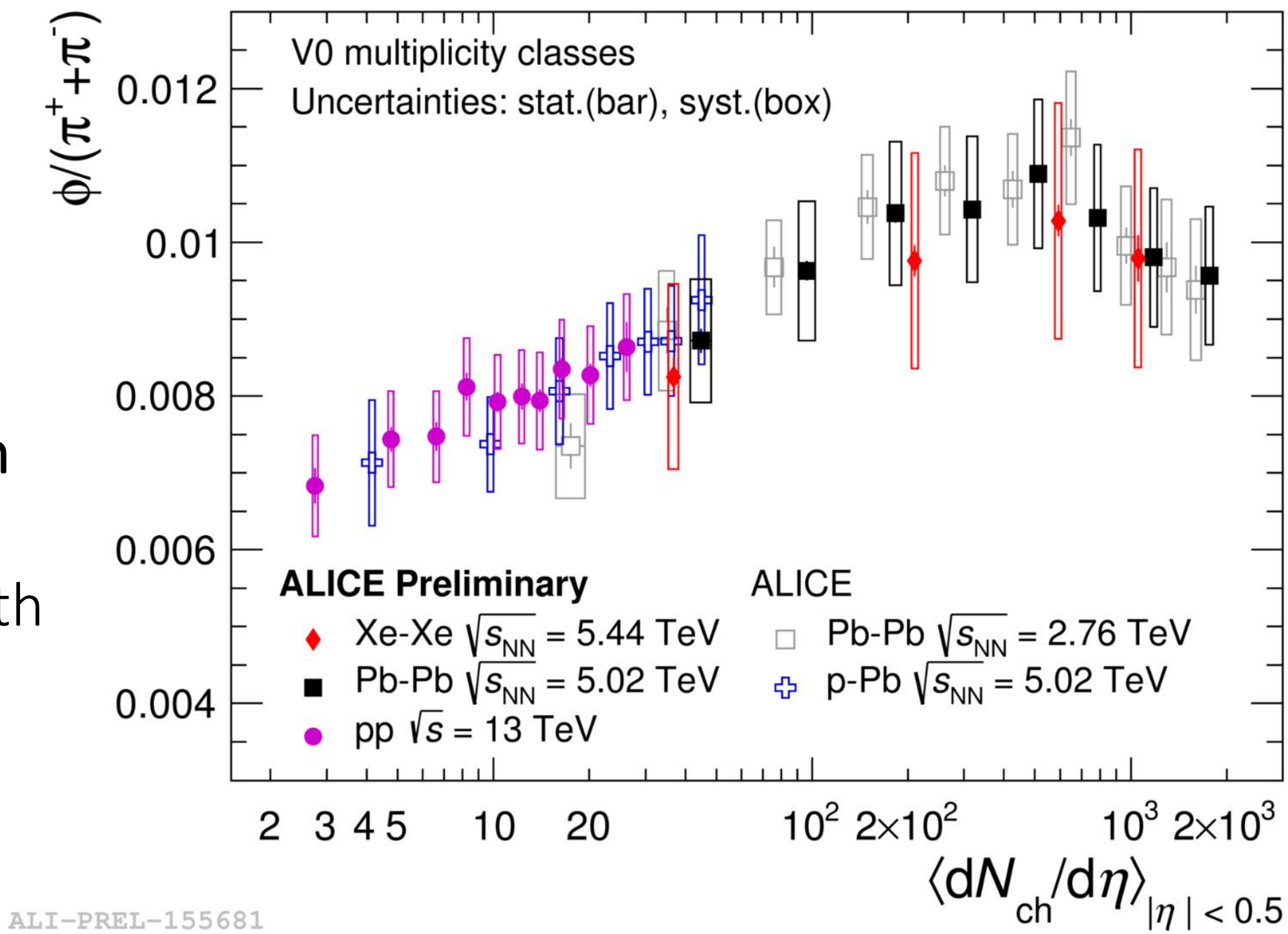
Increasing strangeness production with increasing multiplicity until saturation

Confirmed with new pp √s = 13 TeV and Xe-Xe data

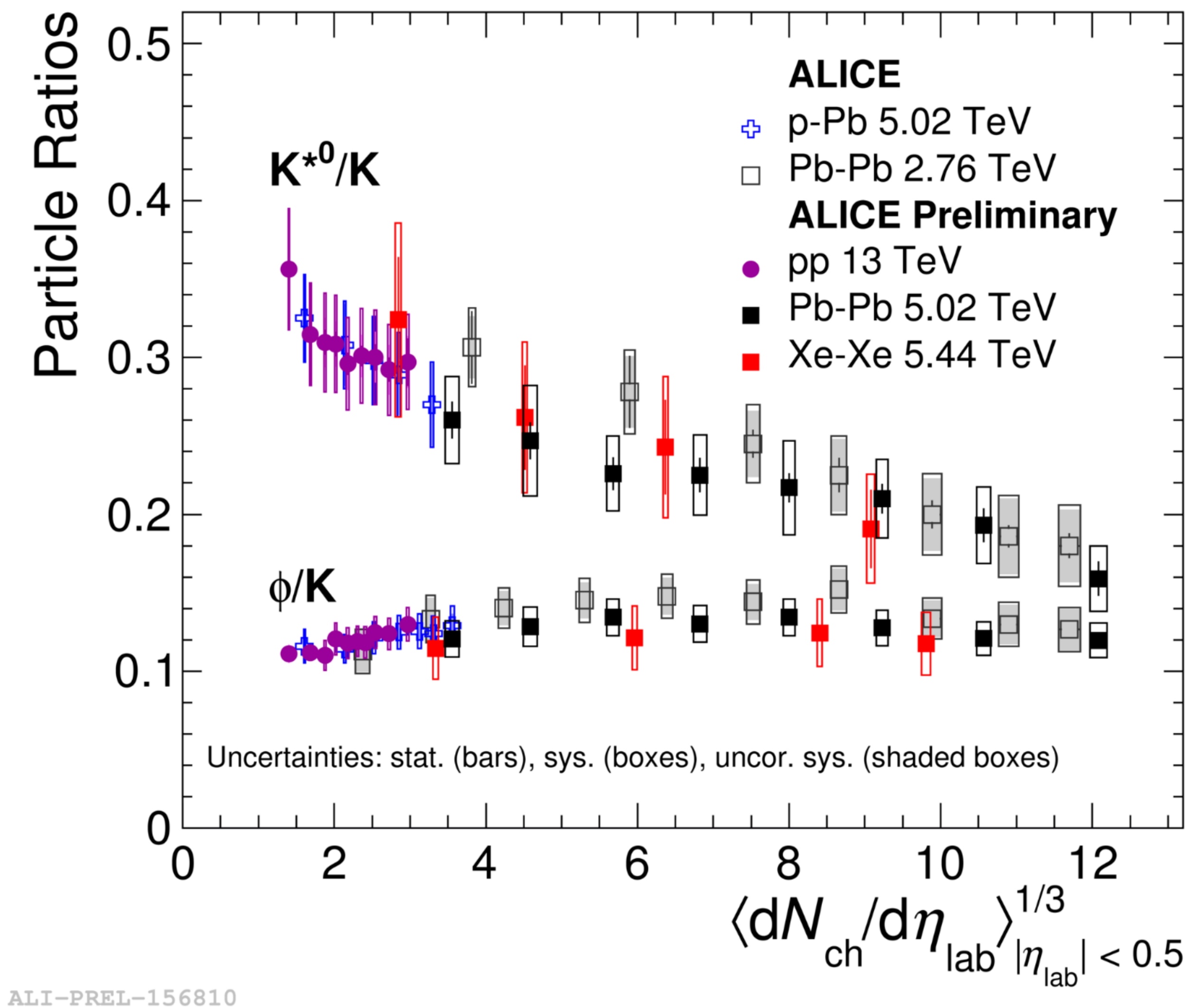
Role of ϕ

Significantly increasing trend of ϕ-meson to pion ratio with increasing multiplicity

Pivotal role of the ϕ-meson in the understanding of strangeness production with thermal-statistical, core-corona, and MC models



Suppression of K^{*0}



Re-scattering of the decay products and regeneration in the late hadronic stage of the collision

→ Modify the yields of reconstructed resonances
[G. Torrieri and J. Rafelski, Phys. Lett. B509 (2001) 239-245]

→ Effect depends on the lifetime of the resonance

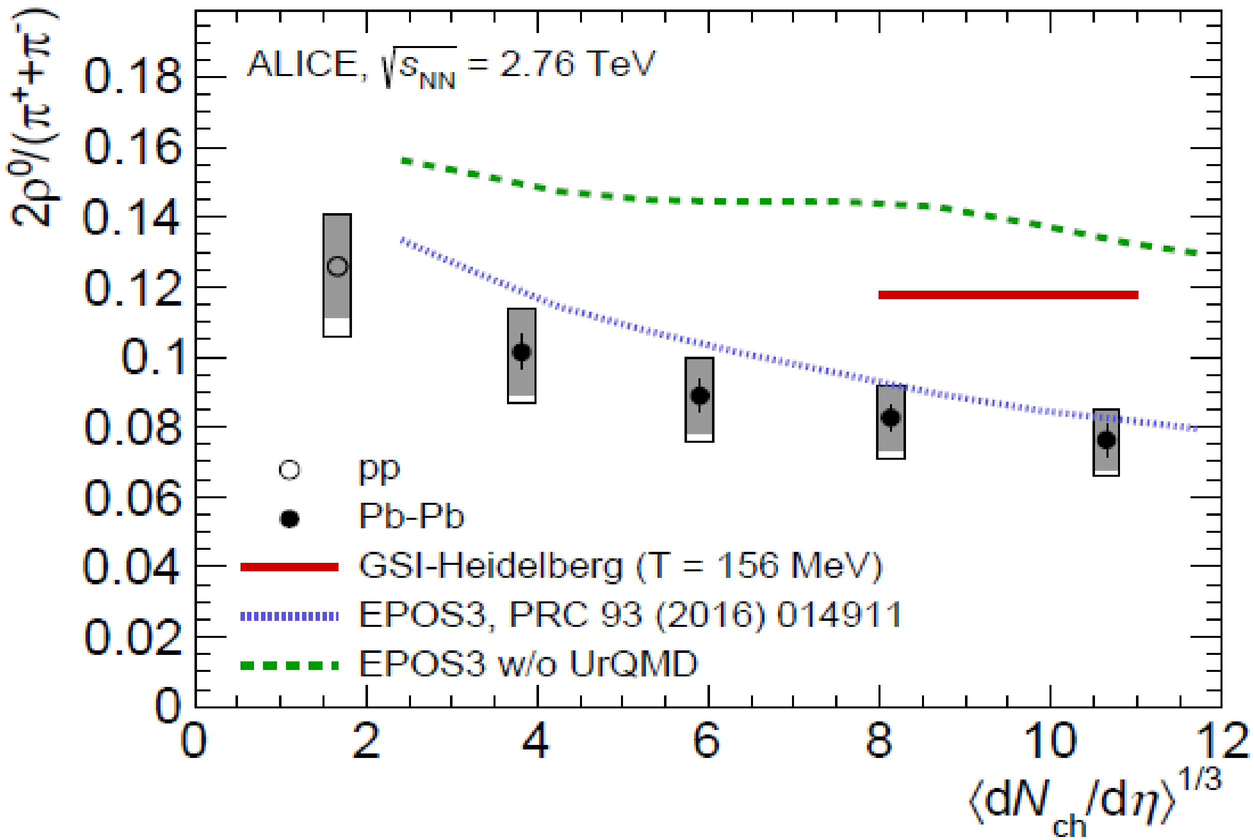
Suppression of ρ^0

The **ρ^0/π ratio shows a suppression** from pp to peripheral Pb–Pb and to central Pb–Pb collisions by about 40%.

The prediction of a grand-canonical thermal model with a chemical freeze-out temperature of 156 MeV is consistent with data only in peripheral collisions.

EPOS with UrQMD reproduces well the ρ^0/π ratio

arXiv:1805.04365



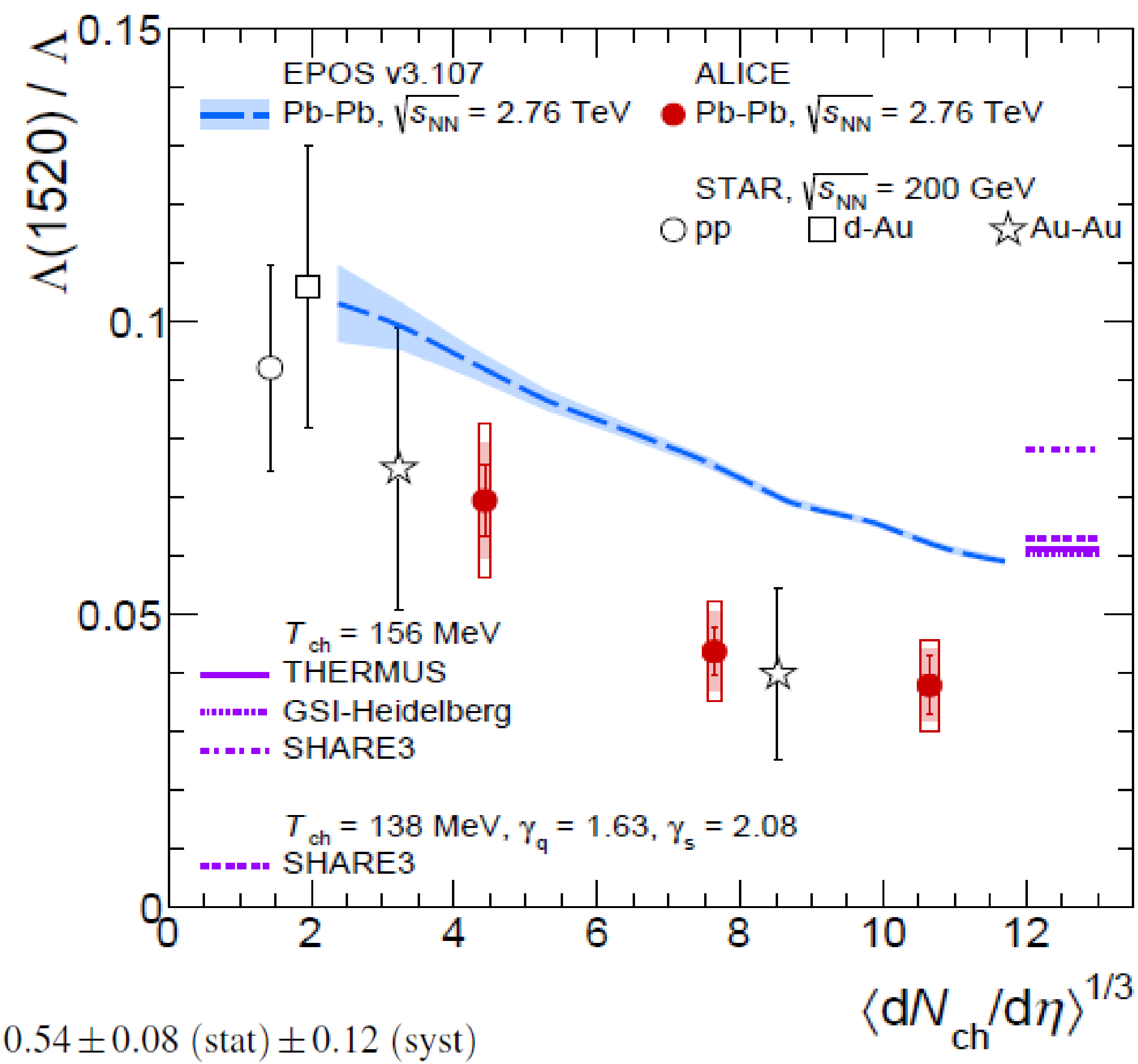
Suppression of $\Lambda(1520)$

arXiv:1805.04361

A decrease of the $\Lambda(1520)/\Lambda$ yield ratio with increasing charged-particle multiplicity is observed from peripheral to central Pb–Pb collisions.

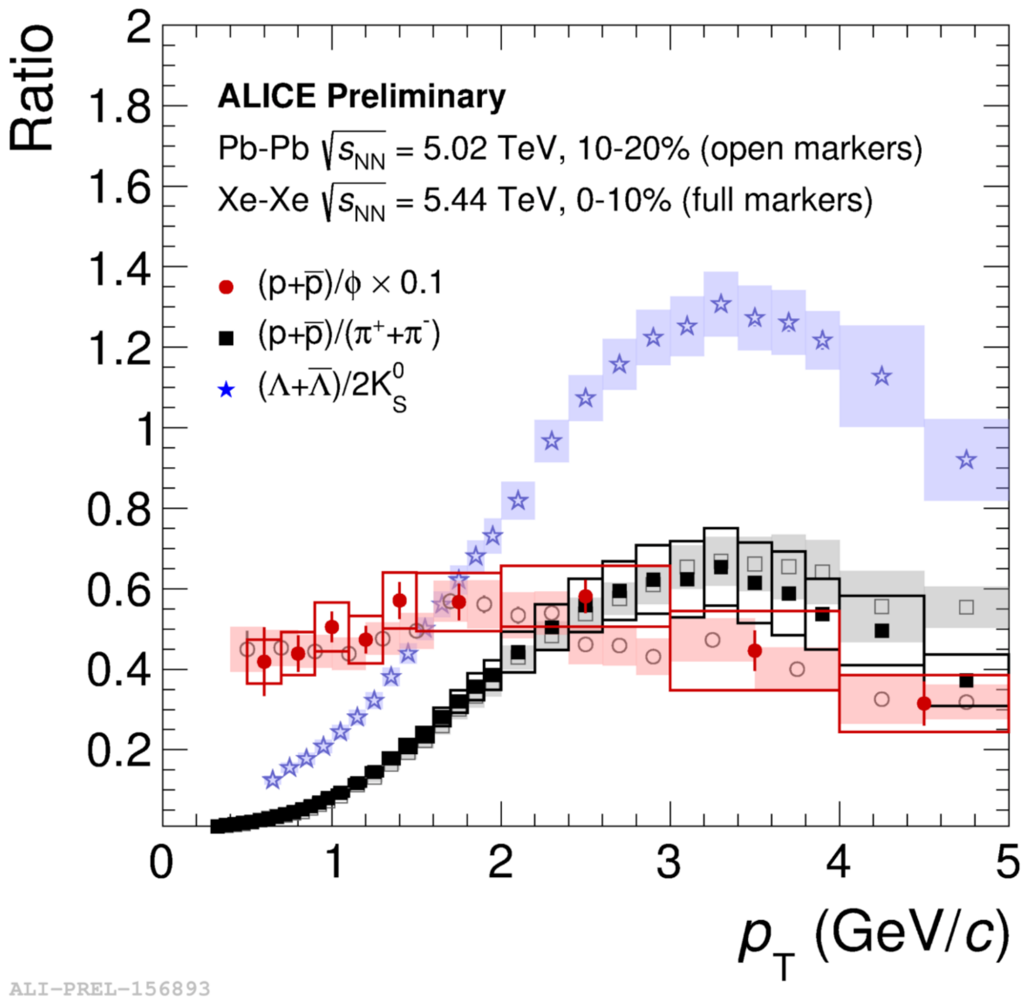
Evidence of suppression with a 3.1σ confidence level

EPOS3 systematically overestimates the data but describes the trend of the suppression well.



$$\frac{[\Lambda(1520)/\Lambda]_{0-20\%}}{[\Lambda(1520)/\Lambda]_{50-80\%}} = 0.54 \pm 0.08\ (\mathrm{stat}) \pm 0.12\ (\mathrm{syst})$$

Baryon-to-meson ratios



Baryon-to-meson ratios are a powerful tool to test hydro behavior and the role of recombination at intermediate p_T

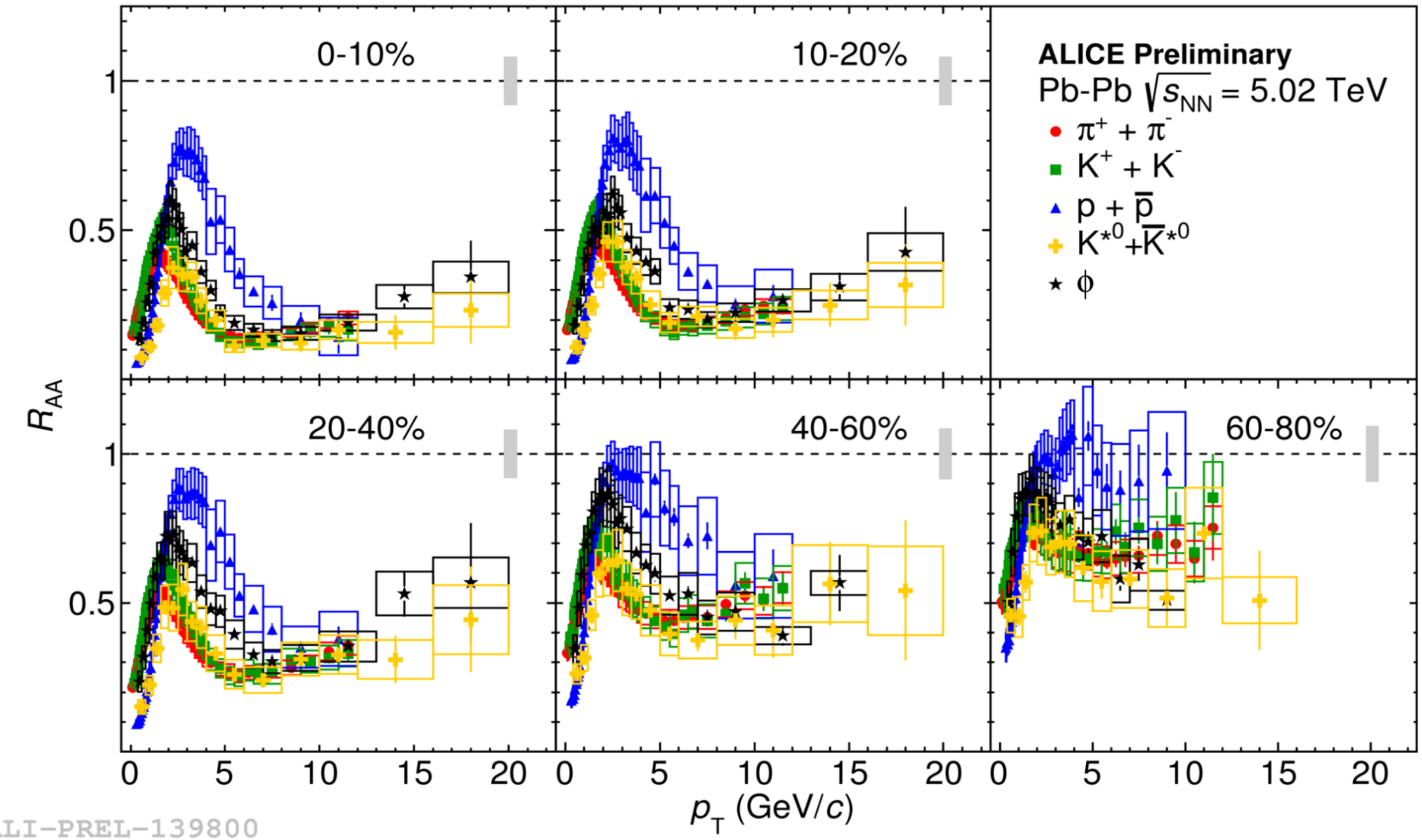
Behaviour in Xe-Xe confirms observations in Pb-Pb at 5.02 TeV (ratios compared at similar multiplicity)

The flatness of the p/ϕ ratio explained by models with recombination [V. Greco *et al.*, PRC 92 (2015) 054904]

Still an open point on whether recombination or flow determine the spectral shape at intermediate p_T

Centrality dependence of the nuclear modification factor

$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \times \frac{(d^2N/dy\,dp_T)_{AA}}{(d^2\sigma/dy\,dp_T)_{pp}}$$

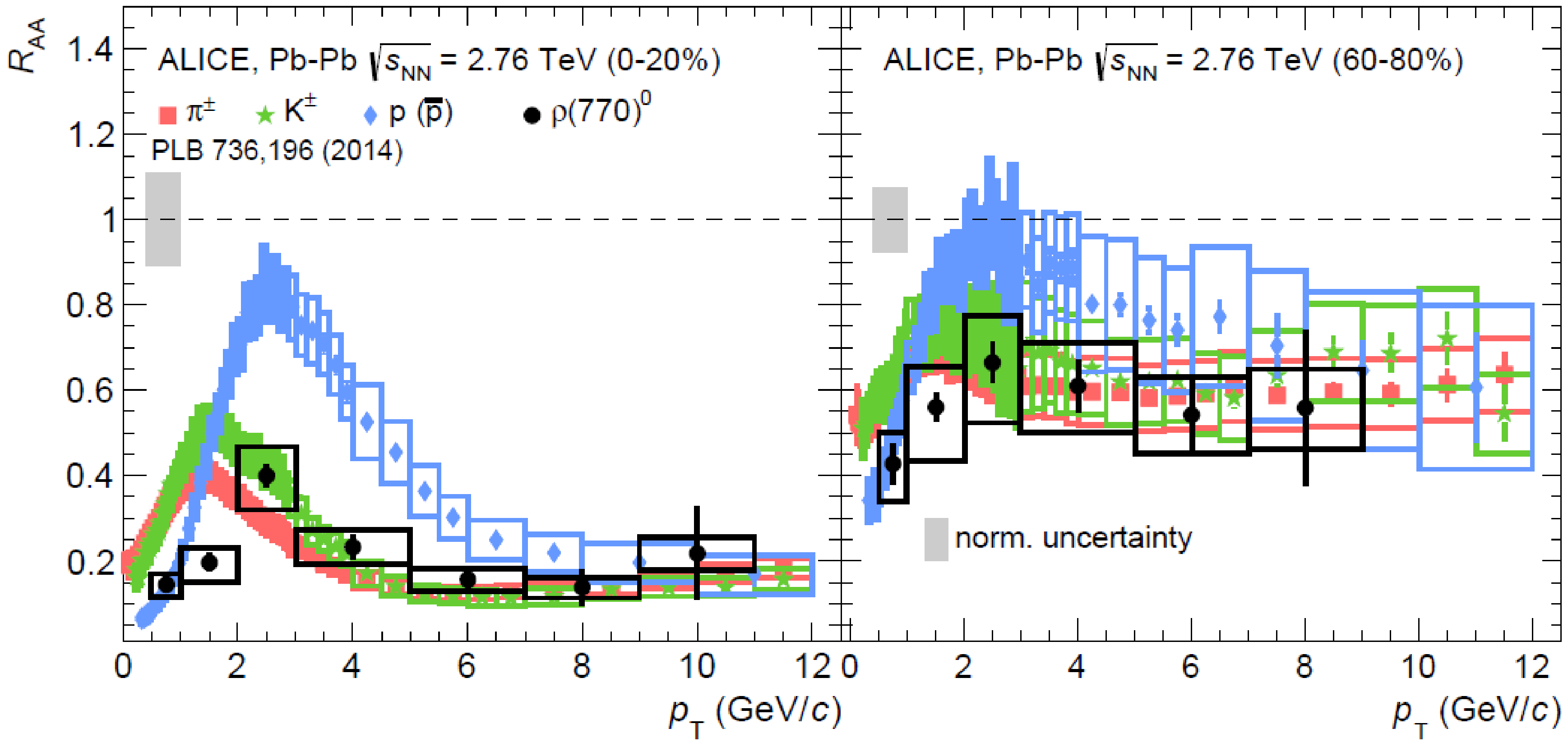


$R_{AA} < 1$ for all the centralities, **strong suppression for the most central collisions**

Similar behaviour of K*^{0} and ϕ to charged hadrons in all the centralities

Nuclear modification factor of ρ

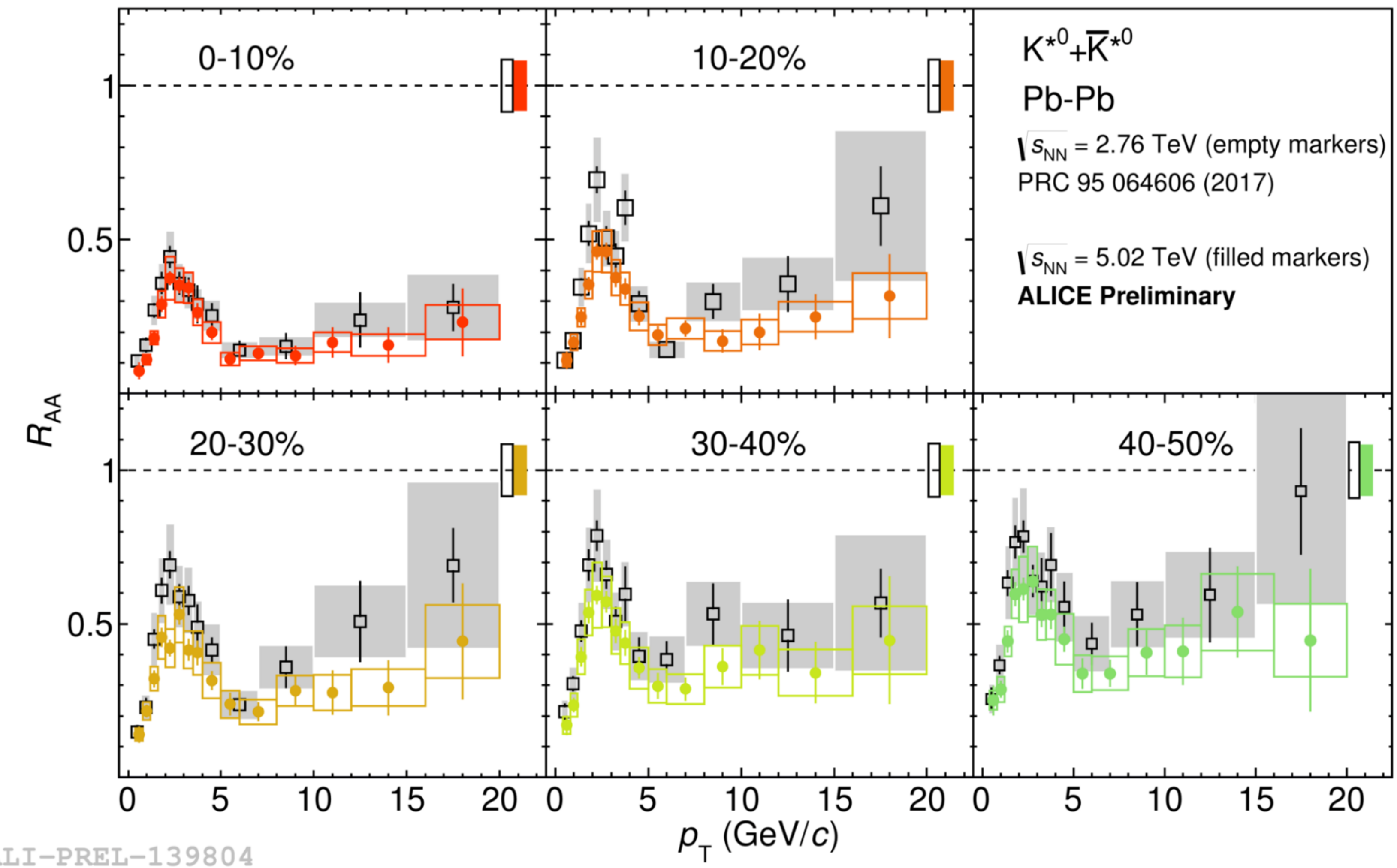
arXiv:1805.04365



All light-flavoured hadrons ($\pi^{\pm}$, $K^{\pm}$, p) and ρ-meson are equally suppressed at p_T > 8 GeV/c by a factor of 4-5

Suppression at high p_T is not dependent on hadron properties (mass, quark content or baryon number)

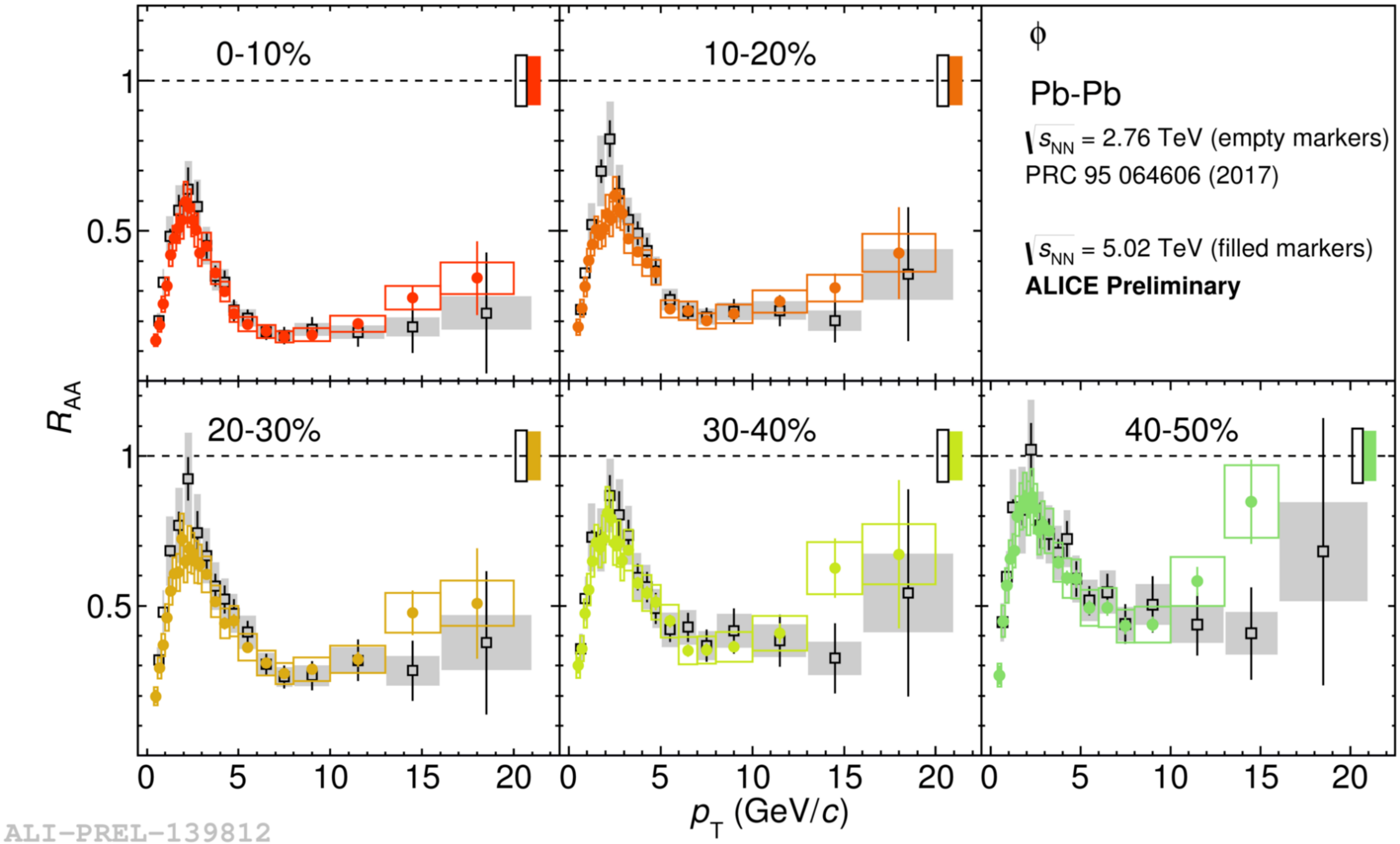
Energy dependence of the nuclear modification of K*



Similar behaviour in 2.76 and 5.02 TeV Pb-Pb collisions

No significant energy dependence observed for R_{AA}

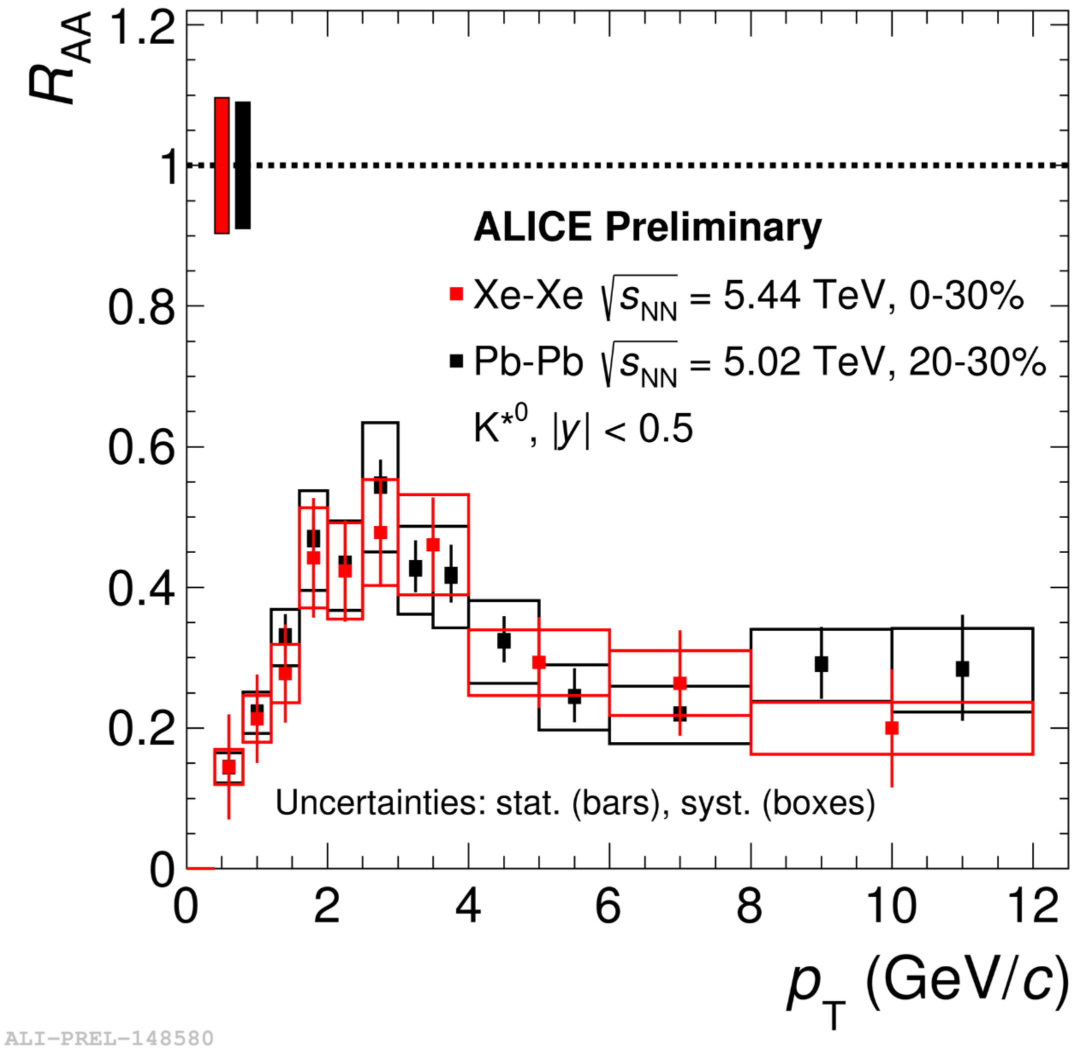
Energy dependence of the nuclear modification of φ



Similar behaviour in 2.76 and 5.02 TeV Pb-Pb collisions

No significant energy dependence observed for R_{AA}

Nuclear modification in Xe-Xe



R_{AA} in Pb-Pb at 5.02 TeV and Xe-Xe at 5.44 TeV are consistent within uncertainties once **compared at the same multiplicity** (and not just centrality percentile)

Conclusions

Role of resonances in the study of bulk properties

At similar multiplicity, no dependence with system nor energy

→ new Xe-Xe data follows trend observed in other systems

Suppression of ρ^0, K^{*0} and $\Lambda(1520)$ in most central collisions, while ϕ not suppressed

→ due to re-scattering in the late hadronic stage of the collision

→ qualitative description is obtained with EPOS+UrQMD

Nuclear modification factor of K* and ϕ