Energy and centrality dependence of resonance production in heavy-ion collisions at the LHC

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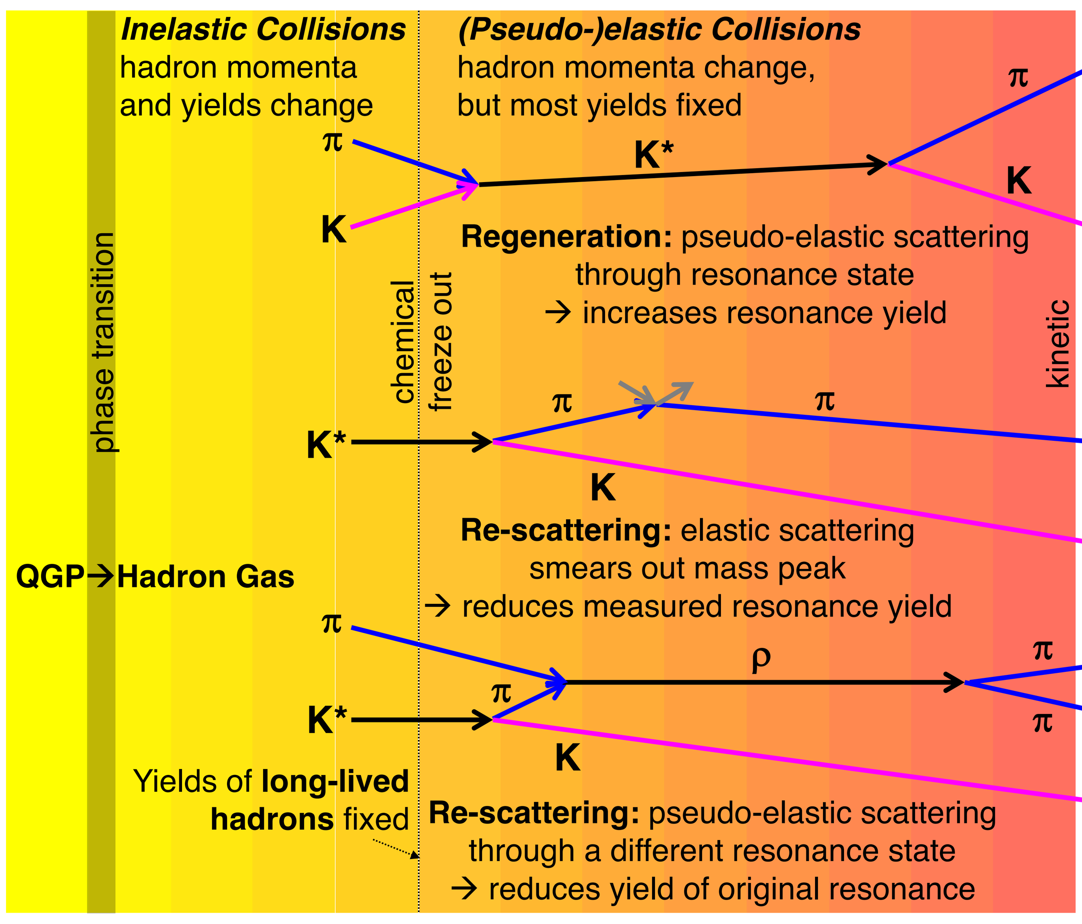
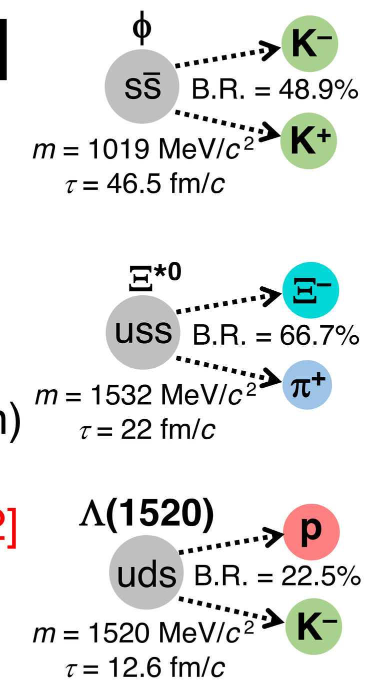
1. Motivation

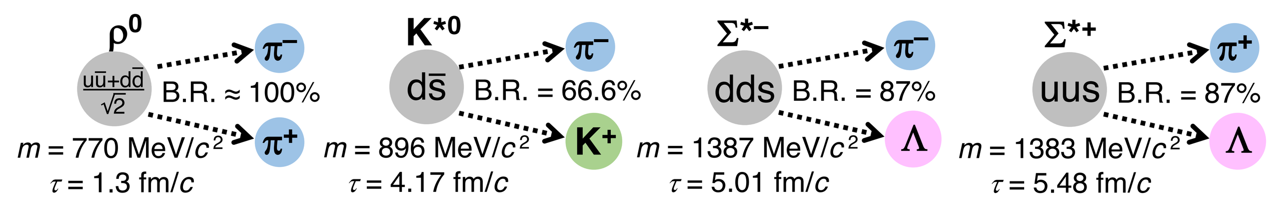
Hadronic resonances can be used to study...
- **Strangeness production** (enhancement, canonical suppression)
- **In-medium energy loss**
- Elliptic flow
- Effects that shape hadron p_T spectra (hydrodynamics, recombination, ...)
- Modification of lineshapes (*e.g.*, chiral symmetry restoration)
- **Spin alignment** [1]
- Properties of the **hadronic phase**
  Regeneration and re-scattering change resonance yields. Final yields depend on chemical freeze out **temperature**, hadronic phase **lifetime**, resonance lifetimes, and hadronic scattering cross-sections



2. Resonances Studied

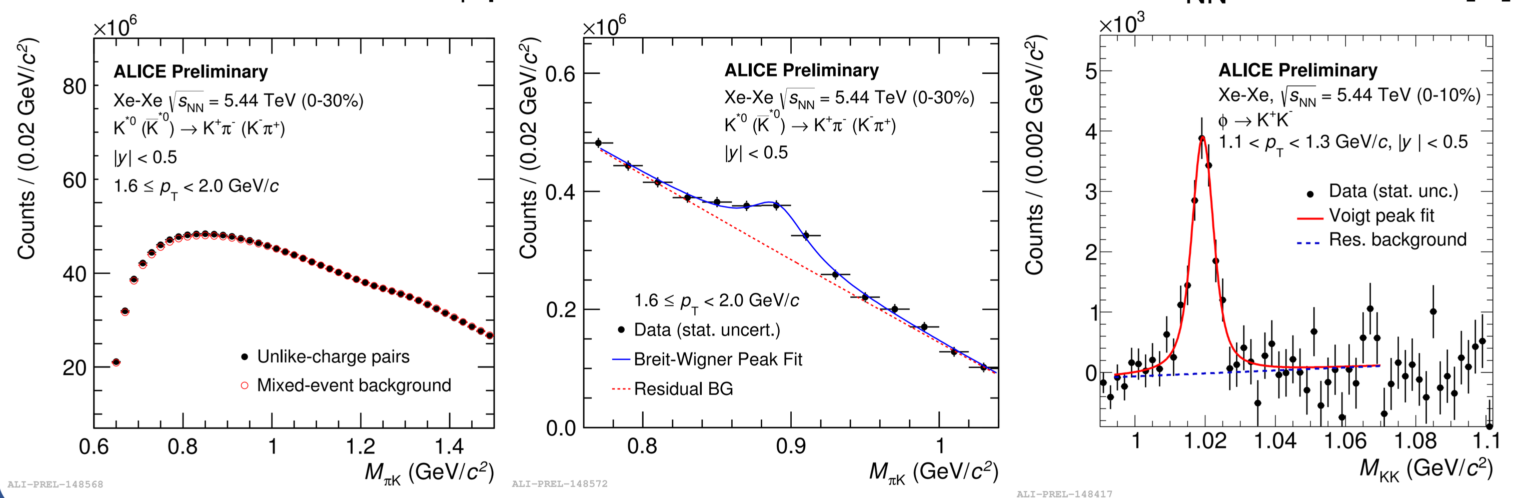
- Light-flavor hadronic resonances
- Variety of masses
- Different lifetimes: 1.3–46.5 fm/c
  On the order of the lifetime of the fireball
- Baryons & mesons
- Different strangeness content (0, 1, 2, hidden)
- Reconstruct common hadronic decay modes
- Measured in pp, p–Pb, Pb–Pb, and Xe–Xe [2]
- Compared to ground-state hadrons
- Future studies of $K^{*\pm}$, $f_0(980)$, Σ^0, $\Xi(1820)$





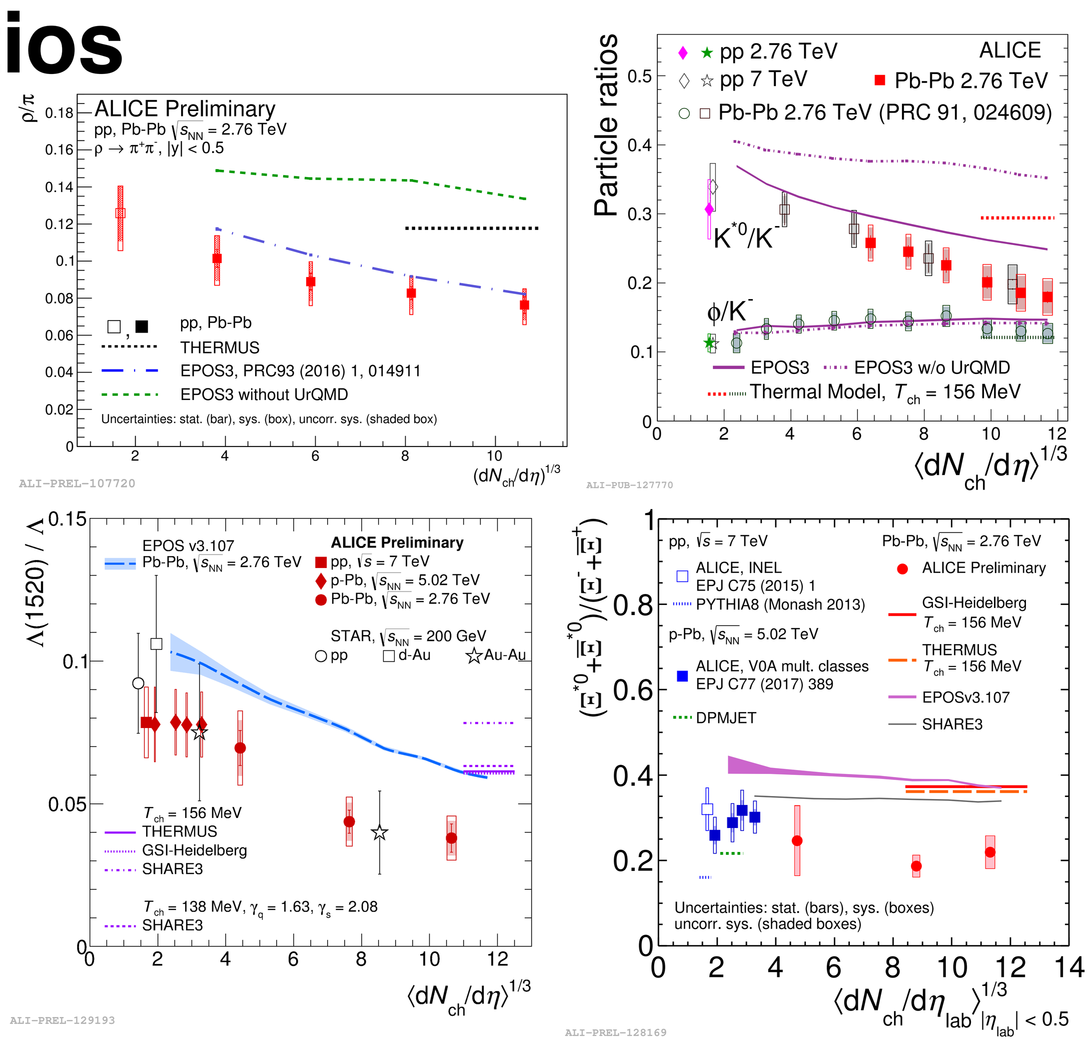
3. Resonance Reconstruction

- Find invariant-mass distribution of pairs of decay products
- Combinatorial background: like-charge pairs or event mixing
- Describe residual background (correlated pairs) with function or cocktail
- Describe peak with Breit-Wigner or Voigtian peak
  Voigitan: convolution of Breit-Wigner and Gaussian, accounts for detector resolution
- **New results:** K^{*0} & ϕ production in Xe–Xe collisions at $\sqrt{s_{NN}}$ = 5.44 TeV [2]



4. Particle Yield Ratios

- Ratios of p_T-integrated resonance yields to long-lived hadrons
- Plotted as function of charged-particle multiplicity at mid-rapidity
  →proxy for **system size**
- **Suppression** of ρ^0, K^{*0}, & $\Lambda(1520)$ w.r.t. pp and thermal model values
  →suggests re-scattering of decay products in hadronic medium
  →Hint of K^{*0} suppression in high-mult. pp and p–Pb collisions
- **No suppression** of ϕ
  →lives longer, decays outside fireball
- Possible **weak suppression** of Ξ^{*0} w.r.t. pp collisions
- Measurement of $\Sigma^{*\pm}$ in progress, no suppression seen by STAR [5]
- Ratios do not depend on energy (RHIC→LHC) or collision system
- Suppression trends qualitatively described by EPOS [6]
  →includes scattering effects modeled with UrQMD



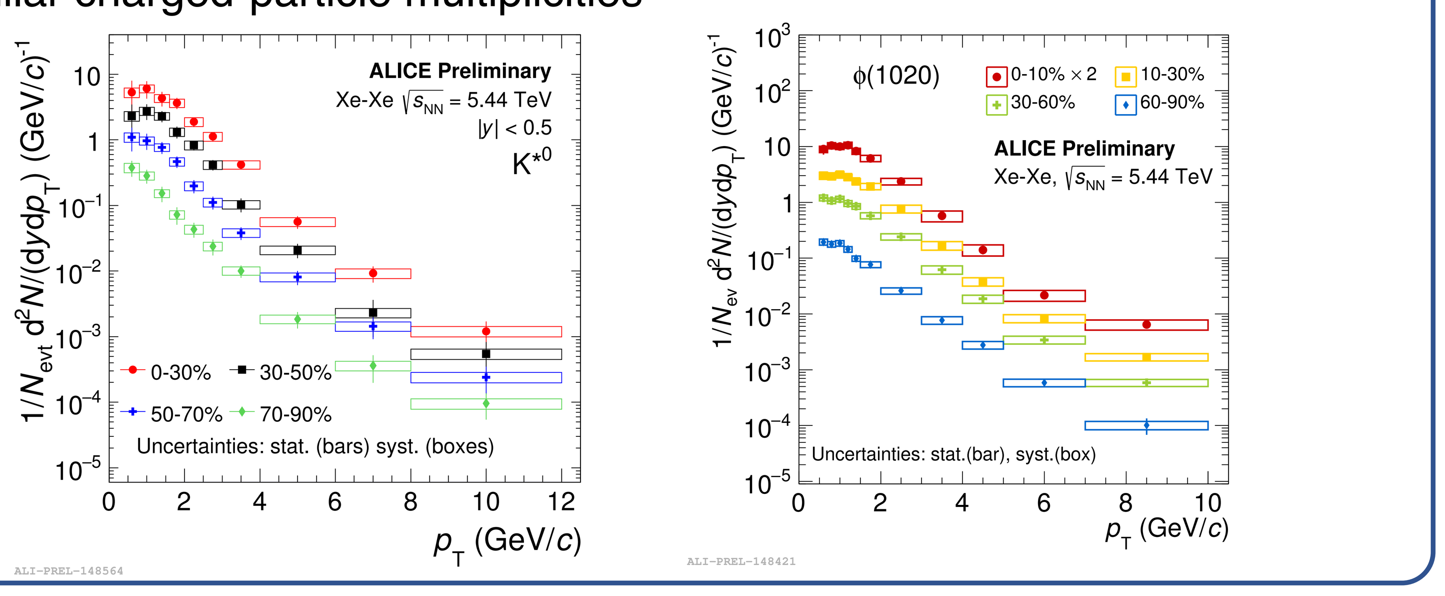
Not suppressed in d–Au (STAR) — Not suppressed in Au–Au (STAR) — Not suppressed

Resonance:	ρ^0	Δ^{++}	K^{*0}	$\Sigma^{*\pm}$	$\Lambda(1520)$	Ξ^{*0}	ϕ
Lifetime (fm/c):	1.3	1.69	4.17	5	12.6	22	46.5

Suppressed — Possible weak suppression

5. New: K^{*0} & ϕ in Xe–Xe Collisions

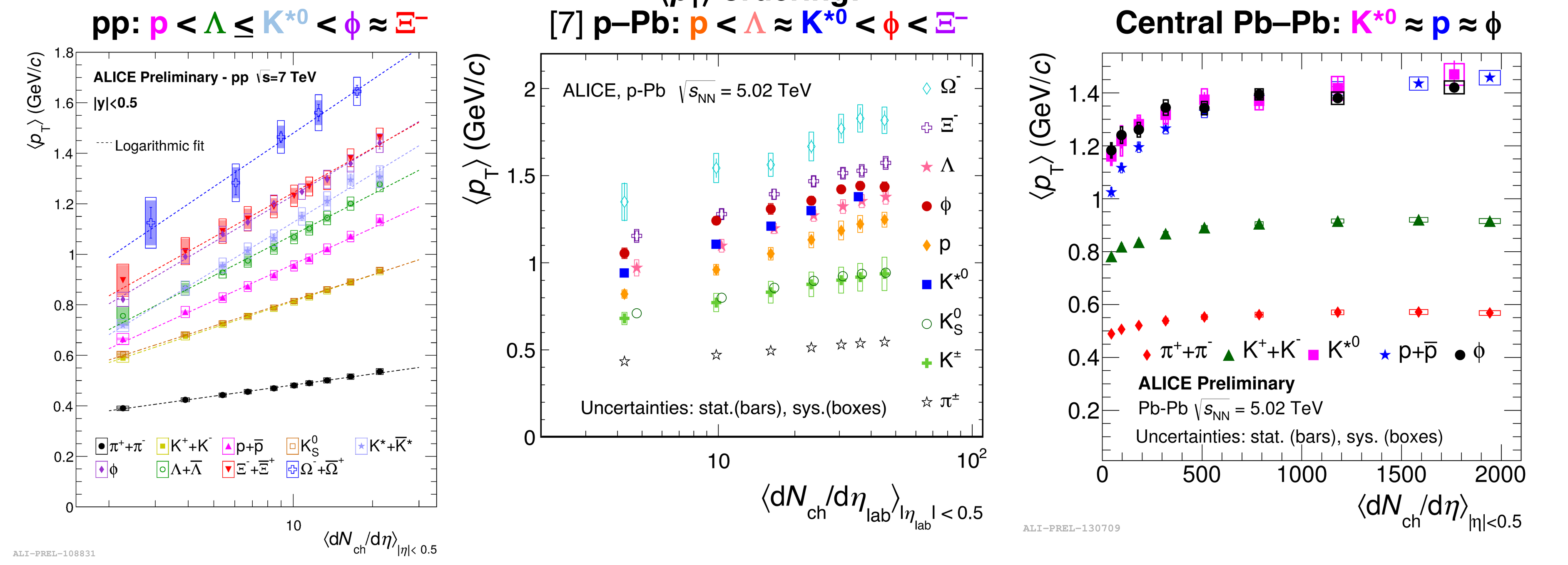
- 1.3 M collisions recorded in 2017 [2]
- K^{*0} (ϕ) extracted in multiple centrality classes up to p_T = 12 (10) GeV/c
- Yields and mean p_T values consistent with those in Pb–Pb collisions for similar charged-particle multiplicities



6. Mean Transverse Momenta

- Mass ordering of $\langle p_T \rangle$ values in central Pb–Pb collisions
  K^{*0}, p, and ϕ have similar $\langle p_T \rangle$ values: consistent with hydrodynamic behavior
- Mass ordering broken for smaller collision systems (pp, p–Pb, peripheral Pb–Pb)
  Resonances different from long-lived particles? Baryon-meson differences?

$\langle p_T \rangle$ ordering:
pp: $p < \Lambda \leq K^{*0} < \phi \approx \Xi^-$ — [7] p–Pb: $p < \Lambda \approx K^{*0} < \phi < \Xi^-$ — Central Pb–Pb: $K^{*0} \approx p \approx \phi$



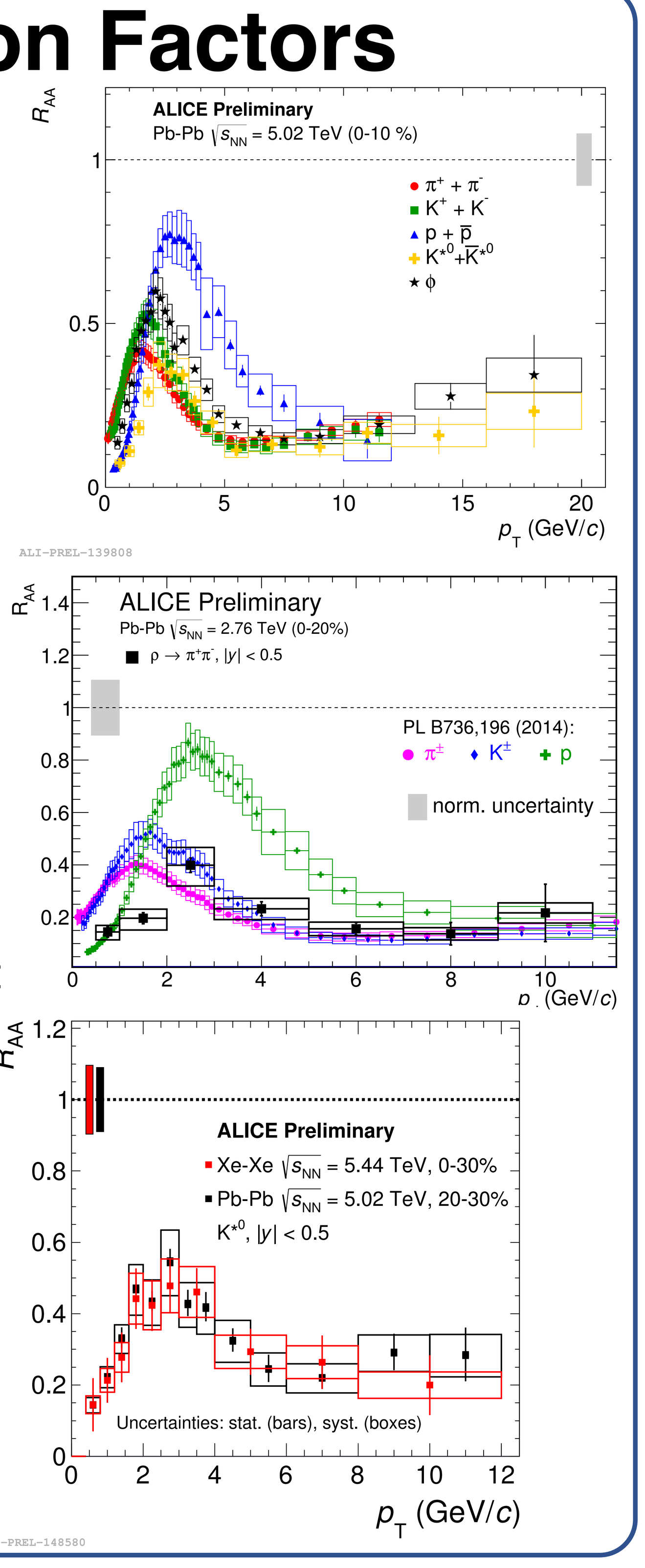
7. Nuclear Modification Factors

High p_T
- All light-flavor hadrons (and D mesons) suppressed by similar amounts
- Q_{pPb} for K^{*0} consistent with unity

Intermediate p_T
- Baryon-meson splitting
- Mass ordering among mesons
- Differences between p and ϕ are due to differences in the pp reference spectra

Low p_T
- Hints that ρ^0 and K^{*0} suppressed more than other mesons → re-scattering?

Other Observations
- No significant change in R_{AA} values of K^{*0} and ϕ at LHC energies (2.76→5.02 TeV)
- K^{*0} R_{AA}, R_{cp} in Xe–Xe & Pb–Pb consistent



8. Summary

- Centrality-dependent suppression of ρ^0, K^{*0}, & $\Lambda(1520)$ may be due to re-scattering of their decay products in the hadronic phase; qualitatively described by EPOS with UrQMD
  New papers on ρ^0 & $\Lambda(1520)$ in Pb–Pb to be released soon (arXiv:1805.04365 & 1805.04361)
- K^{*0} and ϕ in Xe–Xe collisions: consistent with Pb–Pb measurements for similar system size
- Mass ordering of $\langle p_T \rangle$ for central Pb–Pb, violated for smaller collision systems
- Comparison of resonance R_{AA} values to long lived hadrons:
  No species dependence at high p_T, baryon-meson splitting at intermediate p_T
- Forthcoming measurement of $\Sigma^{*\pm}$ will give a complete picture of resonance suppression

References:

[1]: R. Singh (ALICE), QM 2018 (15 May)
[2]: F. Bellini (ALICE), QM 2018 (16 May)
[3]: ALICE, *PRC* **91** 024609 (2015)
[4]: ALICE, *PRC* **95** 064606 (2017)
[5]: STAR, *PRC* **78** 044906 (2008)
[6]: A. G. Knospe *et al.*, *PRC* **93** 014911 (2016)
[7]: ALICE, *EPJC* **76** 245 (2016)

Related Contributions at QM 2018:
Talks: A. K. Dash, 14 May — D. S. De Albuquerque, 15 May

Posters:
- A. Lorenzo: $f_0(980)$ in pp
- K. Garg: $K^{*\pm}$ in pp
- P. Sahoo: $K^{*\pm}$ in pp
- A. Khuntia: K^{*0} in pp
- D. Mallick: K^{*0} and ϕ in p–Pb
- S. Tripathy: ϕ in pp