Exploring the hadronic phase of relativistic heavy-ion collisions with resonances in ALICE

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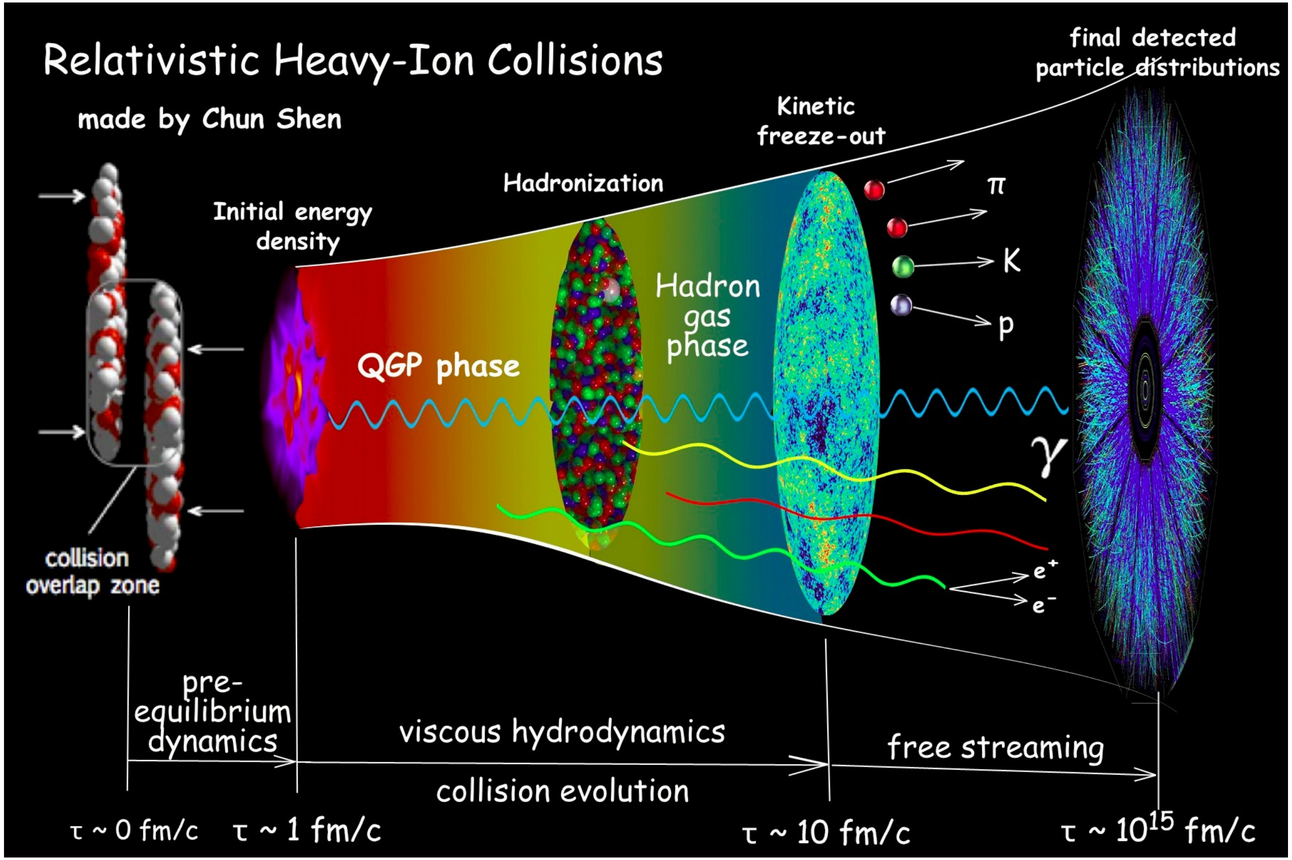
Introduction



How to probe the later stages of heavy-ion collisions?

Ref: https://u.osu.edu/vishnu/category/visualization/

Motivation

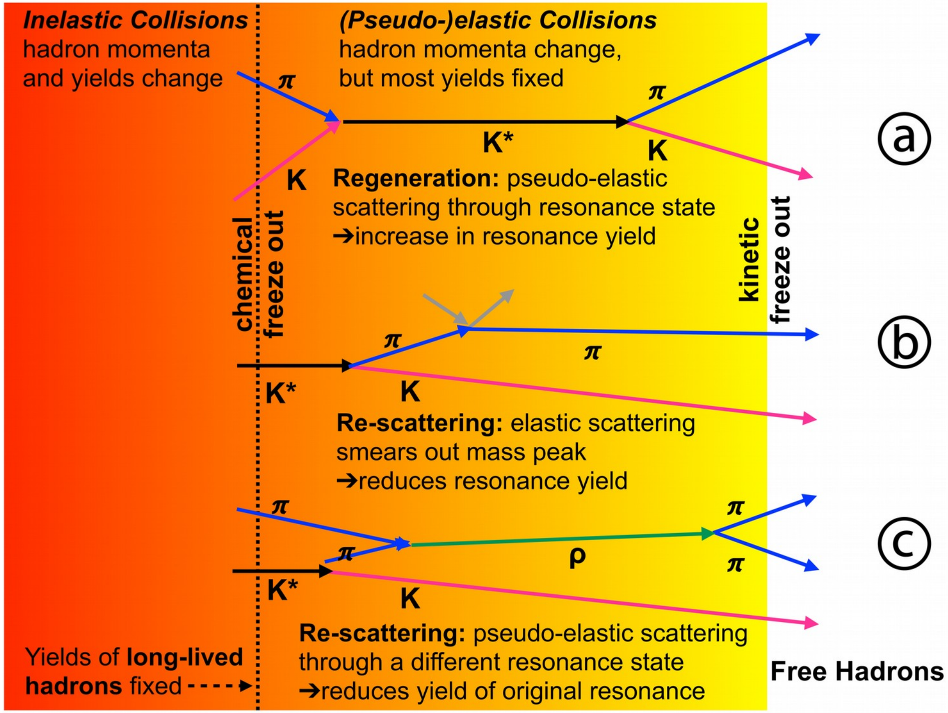
☑ Resonances: Short lived particles having lifetime comparable to that of hadronic phase

Lifetime (fm/*c*): ρ^0(1.3) < $K^{*\pm}$(4.0) < K^{*0}(4.16) < $\Sigma^{*\pm}$(5.0-5.5) < Λ^*(12.6) < Ξ^{*0}(21.7) < φ(46.2)

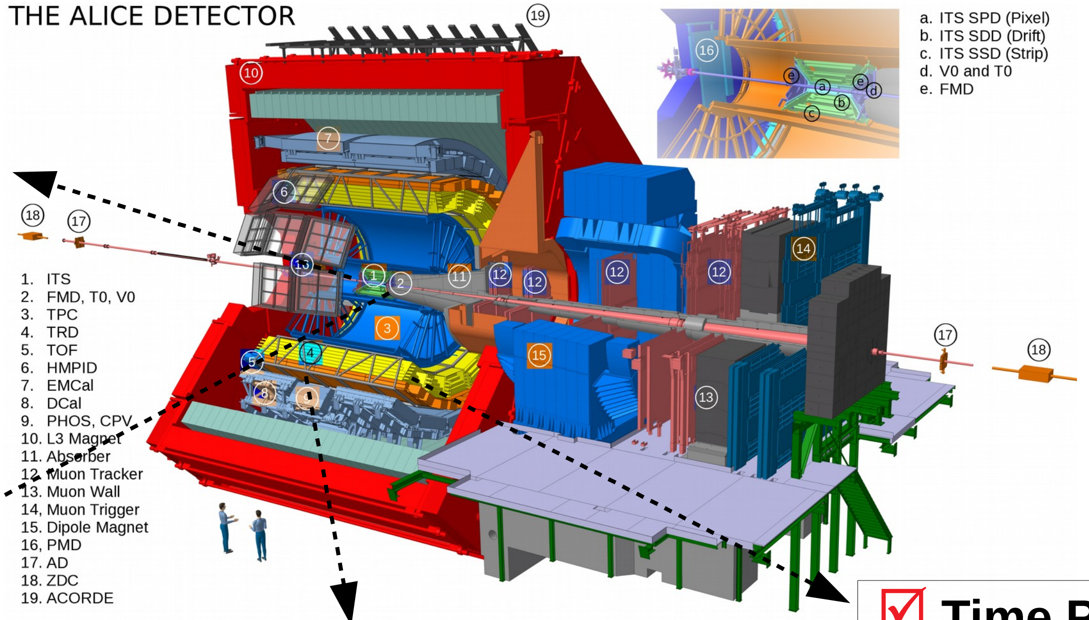
Regeneration (a): Enhances yield

Rescattering (b & c): Reduces yield

☑ **Can be studied from resonance to stable particle yield ratio with the same quark content**



ALICE detector



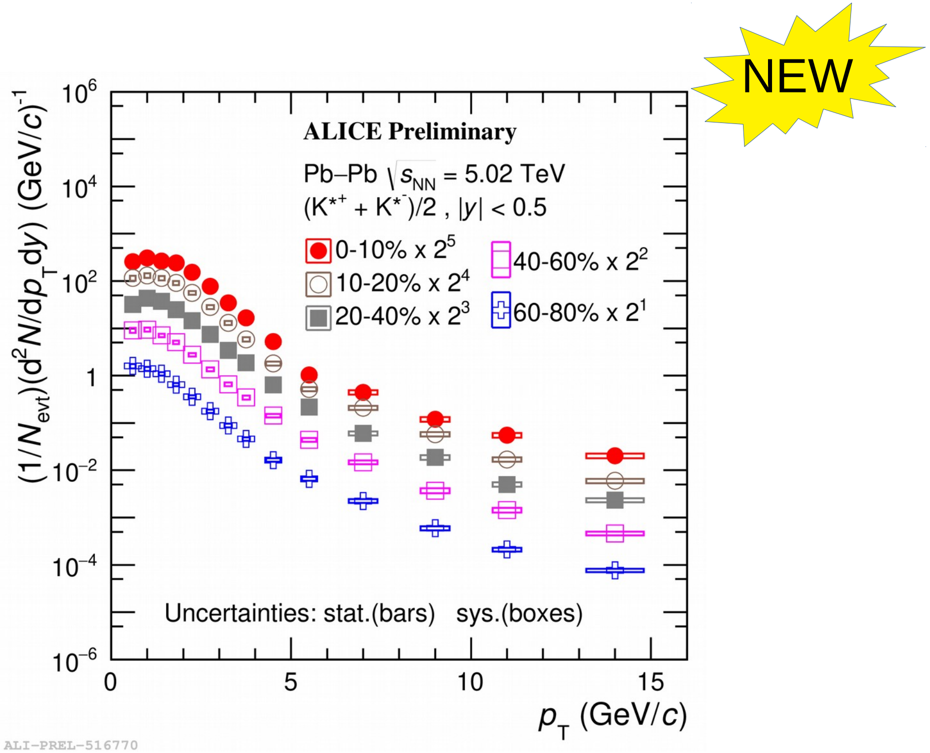
☑ **ITS ($|\eta| < 0.9$)**
- Tracking
- Vertexing
- Particle identification (PID)

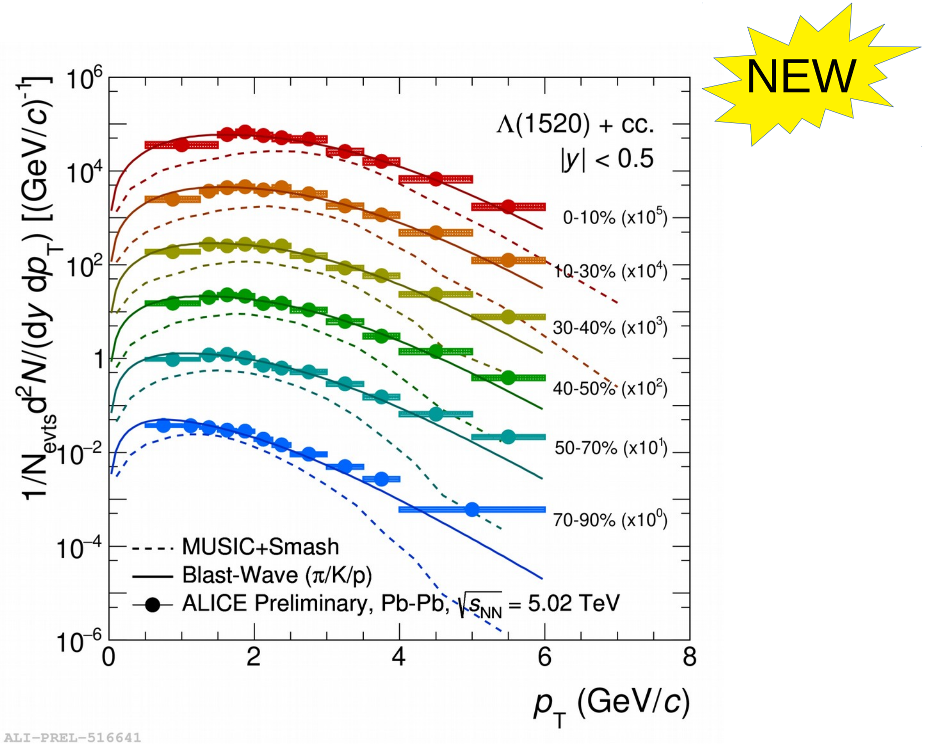
☑ **V0: V0A ($2.8 < \eta < 5.1$) & V0C ($-3.7 < \eta < -1.7$)**
- Trigger and centrality

☑ **Time Of Flight (TOF): ($|\eta| < 0.9$)**
- Particle identification through time of flight measurement

☑ **Time Projection Chamber (TPC): ($|\eta| < 0.9$)**
- Primary vertex and tracking
- Momentum measurement
- Particle Identification (PID) through dE/dx

Transverse momentum spectra of K*± and Λ (1520)

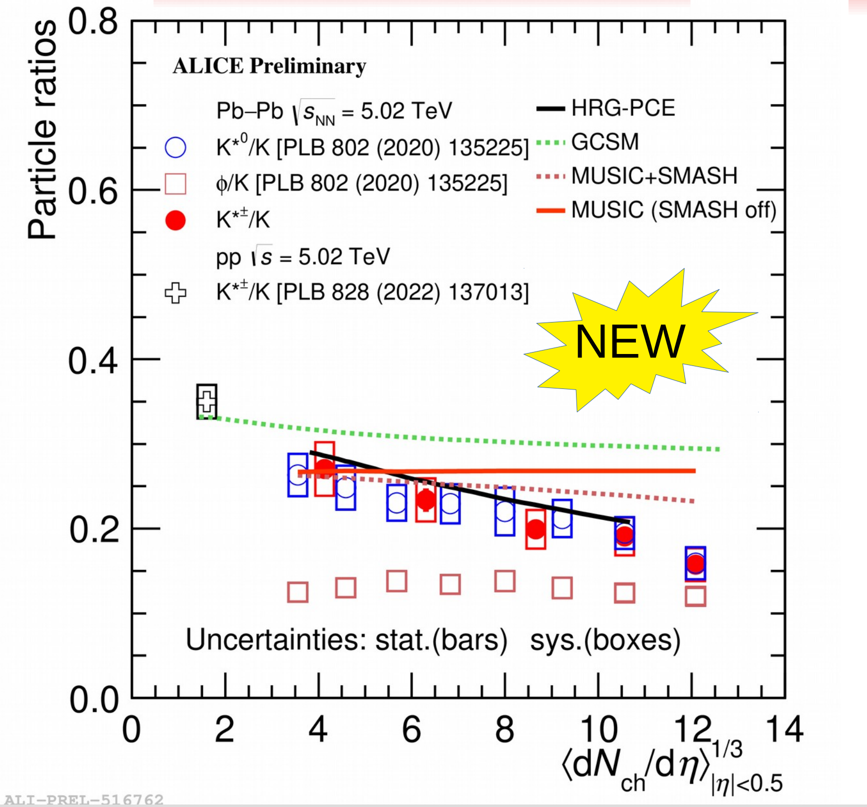




- ☑ Inverse slope of spectra increases with increasing multiplicity
- ☑ Λ*: Spectral shapes are in agreement with the Blast-Wave (from π,K,p)
- ☑ Λ*: MUSIC + SMASH afterburner prediction underestimate the measurements

Particle ratios K*/K

τ(K*⁰) = 4.16 fm/c — **τ(K*±) = 4 fm/c** — **τ(φ) = 46.2 fm/c**



- ☑ $K^{*0,\pm}$/ K ratio decreases with increasing system size
- ☑ Thermal model predictions overestimate the measurements
- ☑ Models with rescattering effects qualitatively describe the measurements
- ☑ φ/K is constant across multiplicities
- ☑ Evidence of rescattering effect in K*

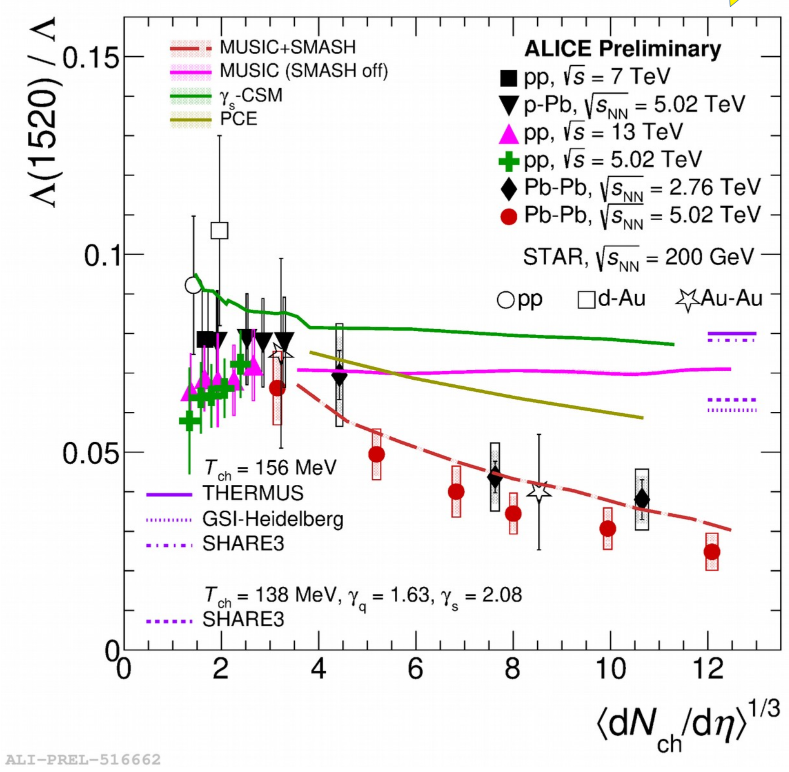
MUSIC: D.Oliinychenko, arXiv:2105.07539
PCE: A.Motornenko, Phys.Rev.C 102 (2020) 2, 024909
GCSM: V.Vovchenko, Phys.Rev.C 100 (2019) 5, 054906

$<dN_{ch}/d\eta>^{1/3}$: Proxy for system size

Particle ratio Λ*/Λ

τ(Λ(1520)) ≈ 12 fm/c

NEW



- ☑ Λ(1520)/Λ ratio decreases with increasing system size
- ☑ Λ(1520) has a lifetime 3 times more than that of K* but still more suppressed
- ☑ Thermal model predictions overestimate the experimental data
- ☑ MUSIC with hadronic afterburner SMASH qualitatively describe the measurements
- ☑ Evidence of rescattering effect

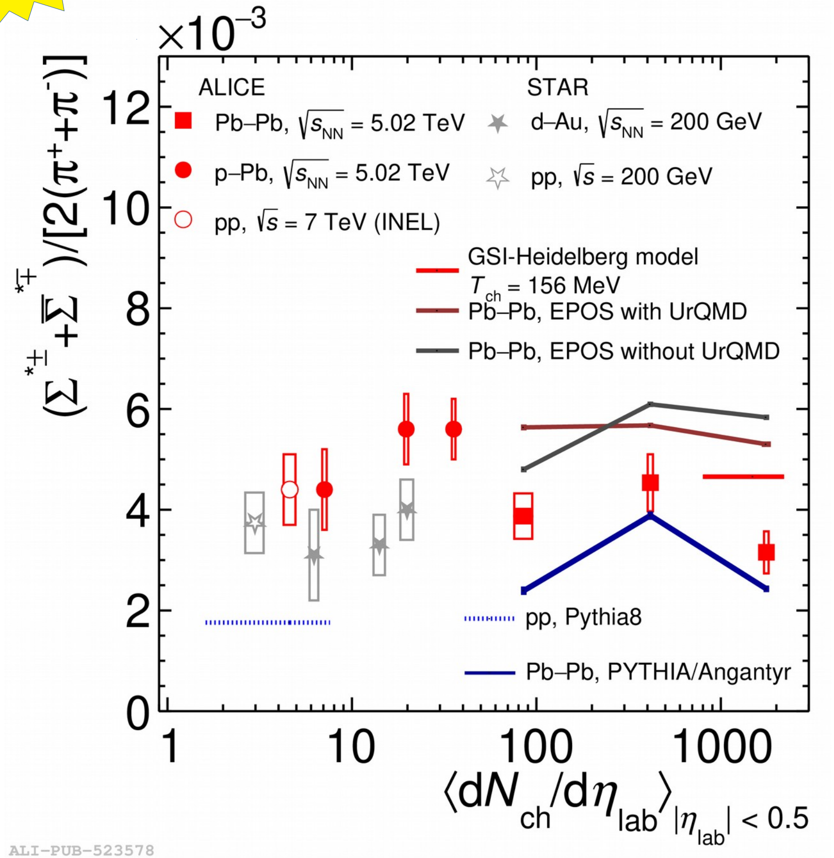
Posters by Neelima Agrawal, Sonali Pradhan

Talk by Nicola Rubini

Particle ratios Σ*/π

NEW

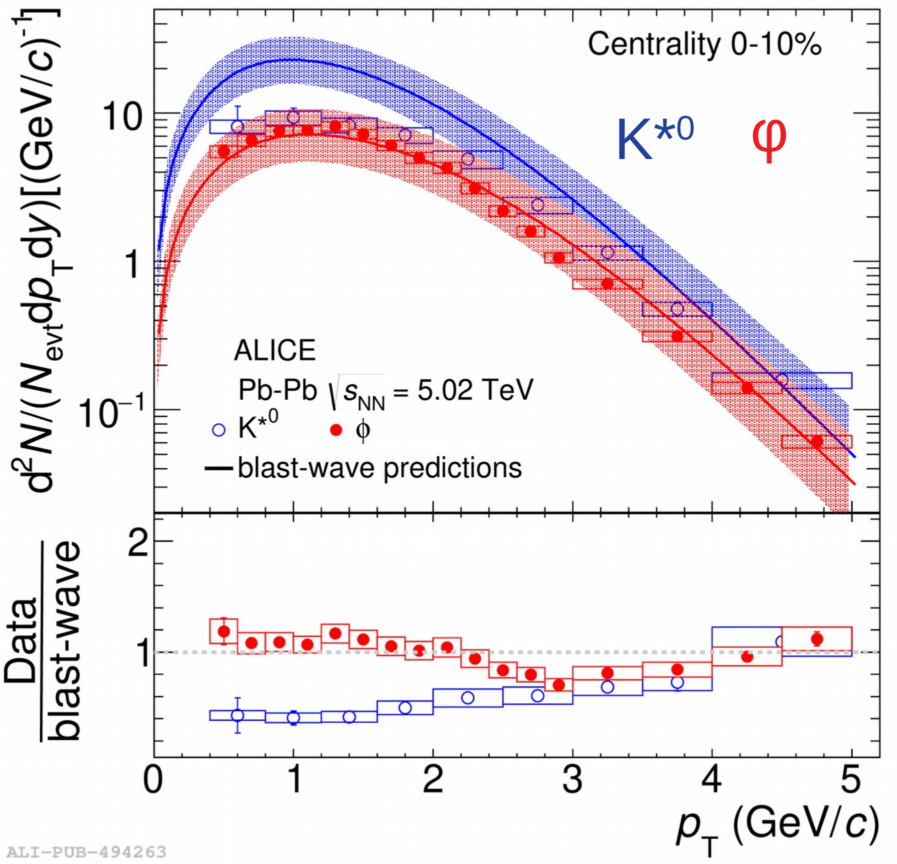
$\tau(\Sigma^{*\pm}) \approx 5.5$ fm/c



- ☑ Suppression of $\Sigma^{*\pm}/\pi^{\pm}$ yield ratio in central Pb–Pb collisions wrt pp and p–Pb
- ☑ Thermal model and EPOS + UrQMD overestimates the measurement
- ☑ Suppression at a level of 3.6σ in 0-10% central Pb–Pb collisions with respect to statistical thermal model

arXiv:2205.13998

Particle spectra

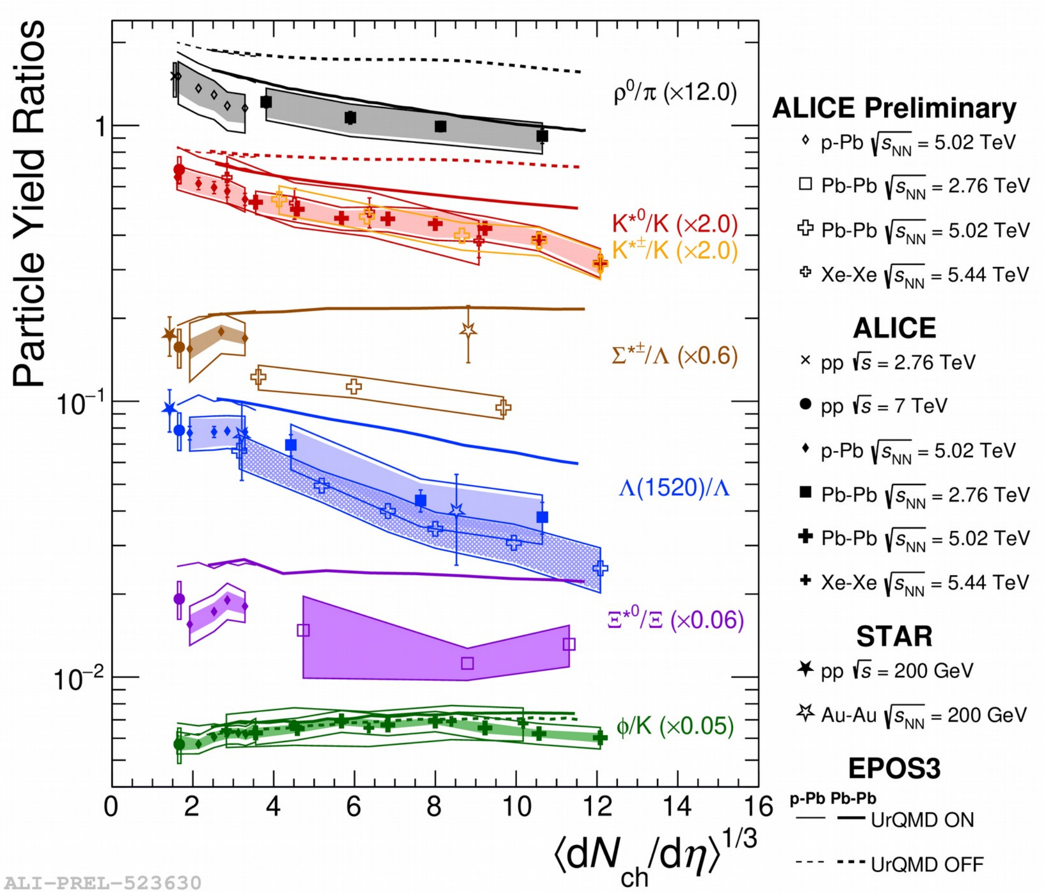


- ☑ Blast wave model (from π, K, p): No rescattering effect
- ☑ Suppression of K^{*0} in central Pb–Pb collisions at low p_T (< 3 GeV/c)
- ☑ No suppression is seen for φ

Ref: arXiv:2106.13113

Rescattering effect is a low p_T phenomenon

Overview of particle ratios



- ☑ Yield ratio of short lived resonances to stable particle shows suppression with increasing multiplicity
- ☑ EPOS with UrQMD qualitatively describe the measurements

Can we measure?

- ☑ Finite lifetime of hadronic phase
- ☑ Evidence of rescattering effects in hadronic phase

Hadronic phase lifetime

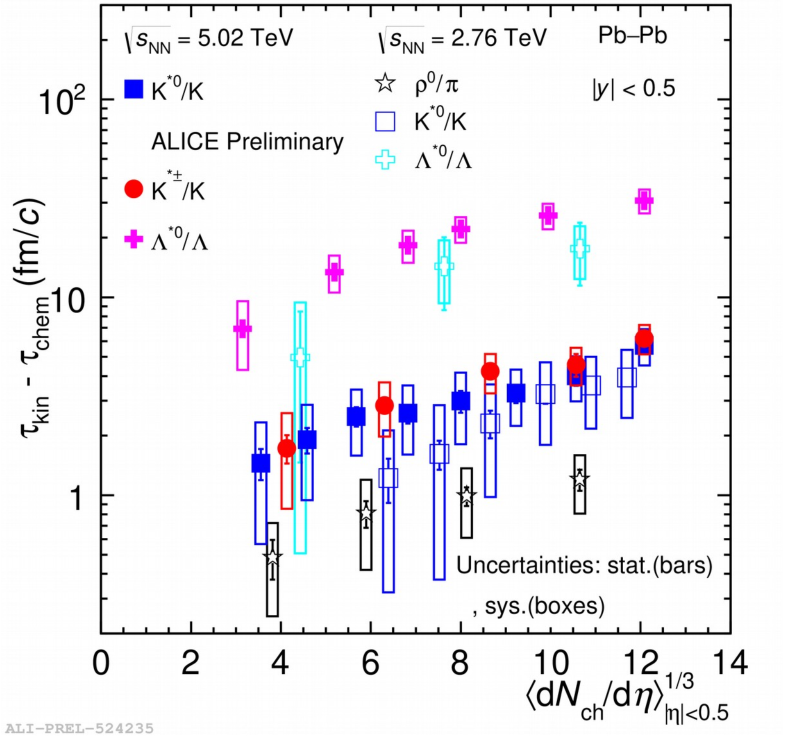
Lower limit of hadronic phase lifetime can be obtained from a simplistic approach

$$N_{kin} = N_{chem} \times \exp(-(\tau_{kin} - \tau_{chem})/\tau_{res})$$

Obtained from Pb-Pb

Obtained from pp

Lifetime of resonance



☑ Assumptions:

- No regeneration of decay products in the hadronic phase
- Simultaneous freeze-out of all particles

Lifetime of hadronic phase increases with multiplicity

Summary

- ☑ **ALICE** continues to measure a varied set of resonances with different lifetime, mass, quark content to probe the hadronic phase
- ☑ Dominance of **rescattering** effects over **regeneration** effects for short lived resonances in the hadronic phase
- ☑ Rescattering effects are dominant at low p_{T} (< 3 GeV/c)
- ☑ Lower limit of hadronic phase lifetime is obtained
- ☑ Lifetime of hadronic phase smoothly increases with multiplicity