Probing heavy-ion collision evolution with resonances in ALICE at the LHC

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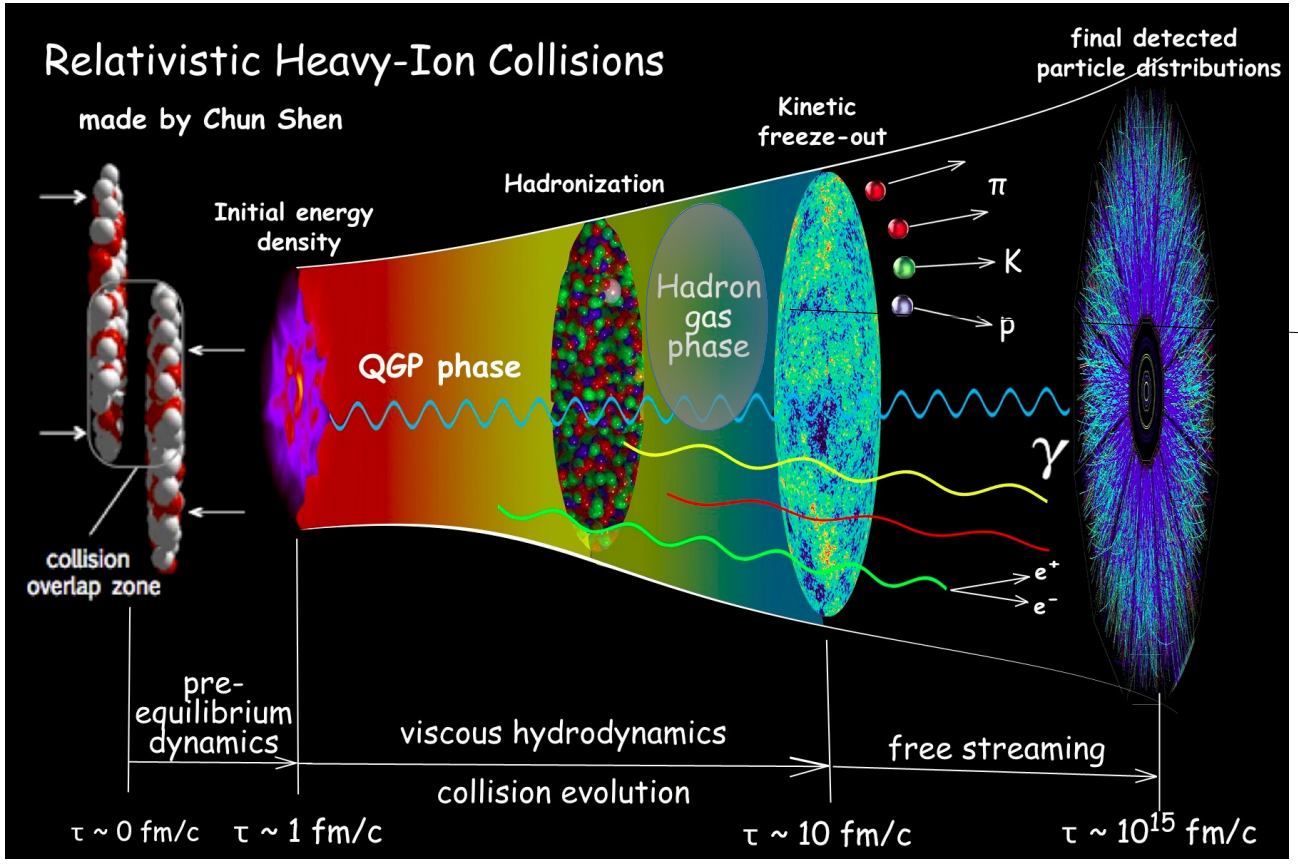
Introduction



FOCUS OF THIS TALK

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

Motivation

☑ Resonances: Short lived particles which decay via strong interaction ($\tau_{res} \sim 10^{-23}$ s)

Lifetime (fm/*c*): $\rho^0(1.3) < K^{*\pm}(4.0) < K^{*0}(4.16) < \Sigma^{*\pm}(5.0\text{-}5.5) < \Lambda^*(12.6) < \Xi^{*0}(21.7) < \varphi(46.2)$

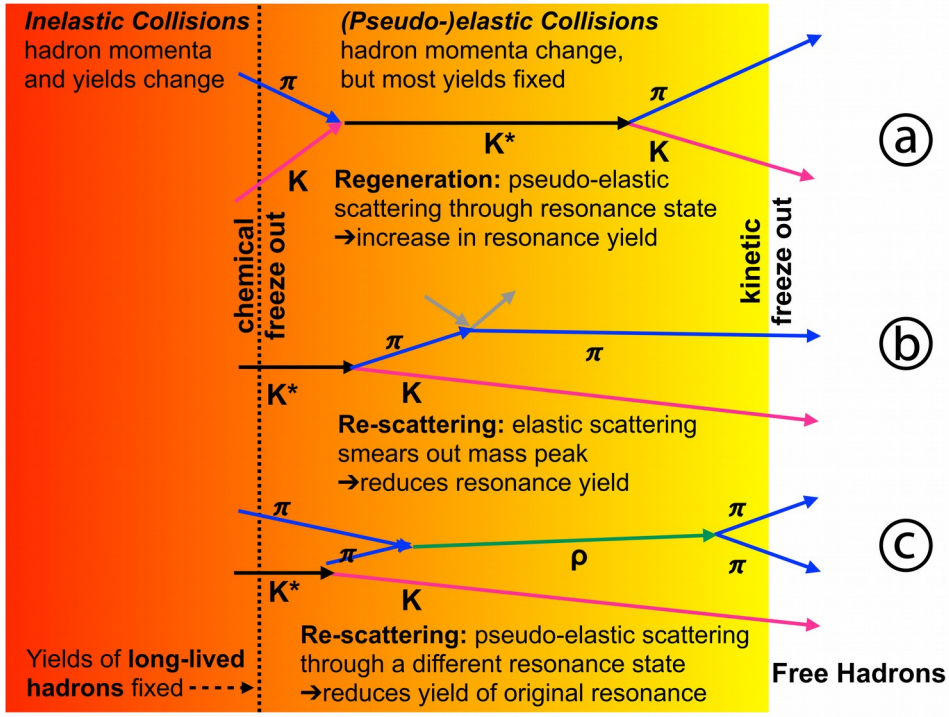
☑ **Lower limit of the hadronic phase lifetime can be extracted**

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

Regeneration (a): Enhances yield

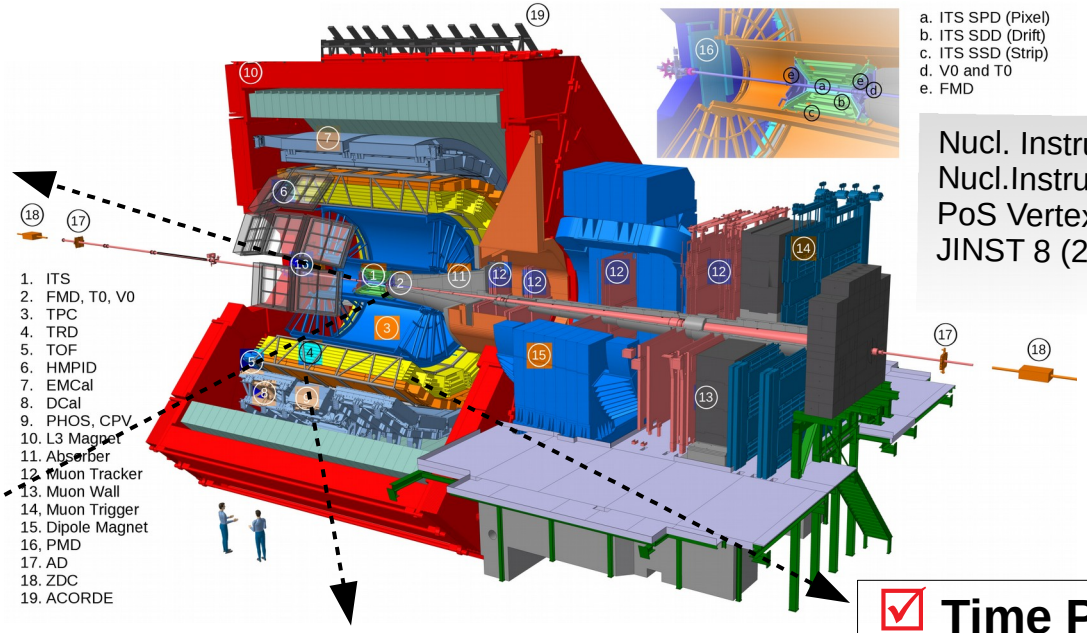
Rescattering (b & c): Reduces yield

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



ALICE detector

☑ **Inner Tracking System (ITS) (|η| < 0.9)**
- Tracking
- Vertexing
- Particle identification (PID)



Nucl. Instrum. Meth. A j.nima.2004.07.127
Nucl.Instrum.Meth.A 535 (2004) 197-200
PoS Vertex2016 (2017) 002
JINST 8 (2013) P10016

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

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

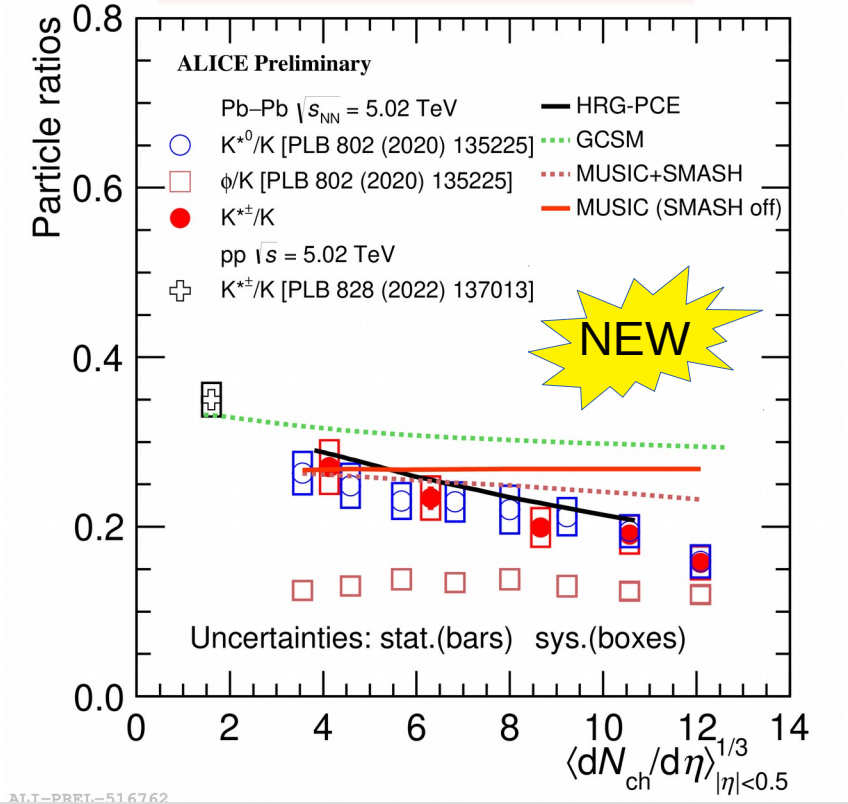
☑ **Time Projection Chamber (TPC): (|η| < 0.9)**
- Primary vertex and tracking
- Momentum measurement
- Particle Identification (PID) through d*E*/d*x*

Particle ratios K*/K

τ(K*⁰) = 4.16 fm/*c*

τ(K*±) = 4 fm/*c*

τ(φ) = 46.2 fm/*c*



- ☑ K*⁰,±/ K ratio decreases with increasing system size
- ☑ Statistical Hadronization Model (SHM) predictions overestimate the measurements
- ☑ HRG-PCE model best describes the experimental data
- ☑ φ/K is constant across multiplicities
- ☑ Evidence of rescattering effects in K*

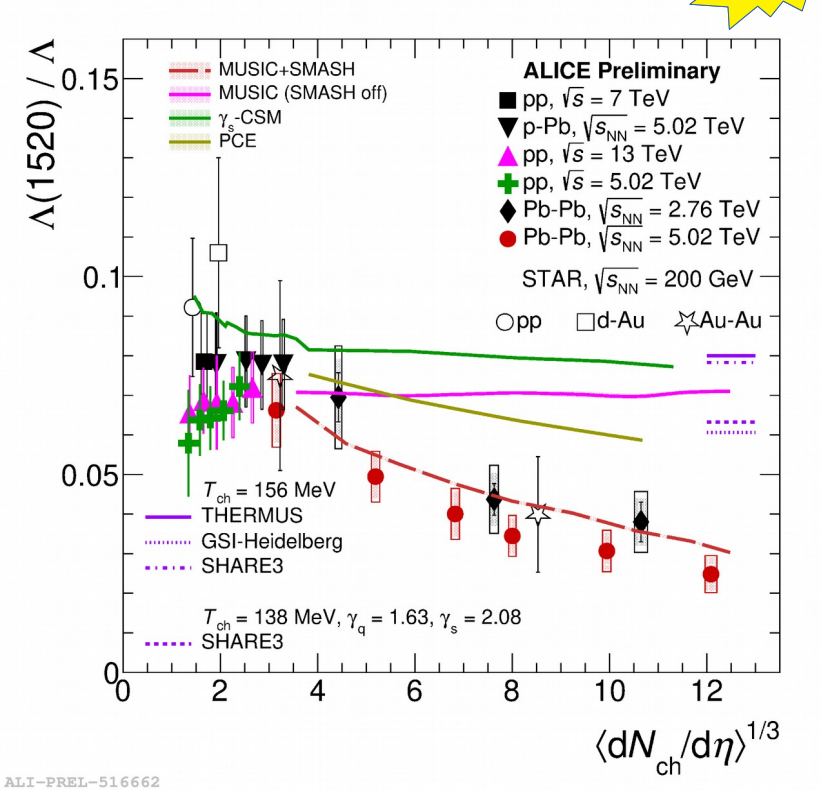
MUSIC: D.Oliinychenko, arXiv:2105.07539
PCE: A.Motornenko, Phys.Rev.C 102 (2020) 2, 024909
GCSM: V.Vovchenko, Phys.Rev.C 100 (2019) 5, 054906

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

Particle ratio Λ*/Λ

τ(Λ(1520)) ≈ 12 fm/*c*

NEW

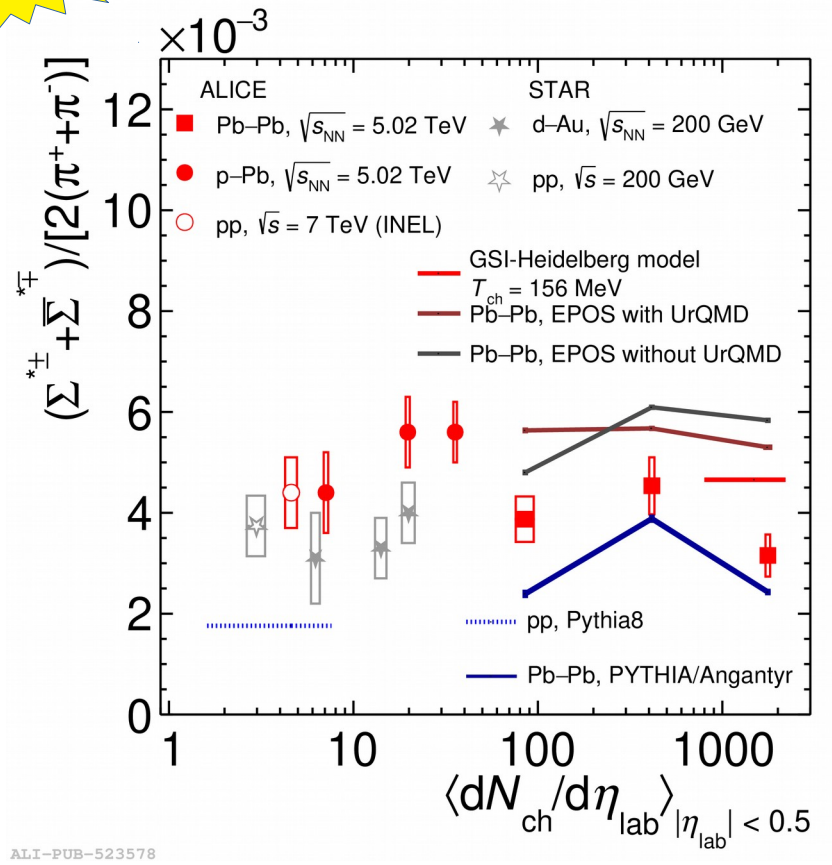


- ☑ Λ(1520)/Λ ratio decreases with increasing system size
- ☑ Λ(1520) lifetime is 3 times larger than that of K* but still suppressed
- ☑ SHM predictions overestimate the experimental data
- ☑ Hydrodynamic model (MUSIC) with hadronic afterburner (SMASH) best describes the measurement
- ☑ Evidence of rescattering effects

Particle ratios Σ*/π

NEW

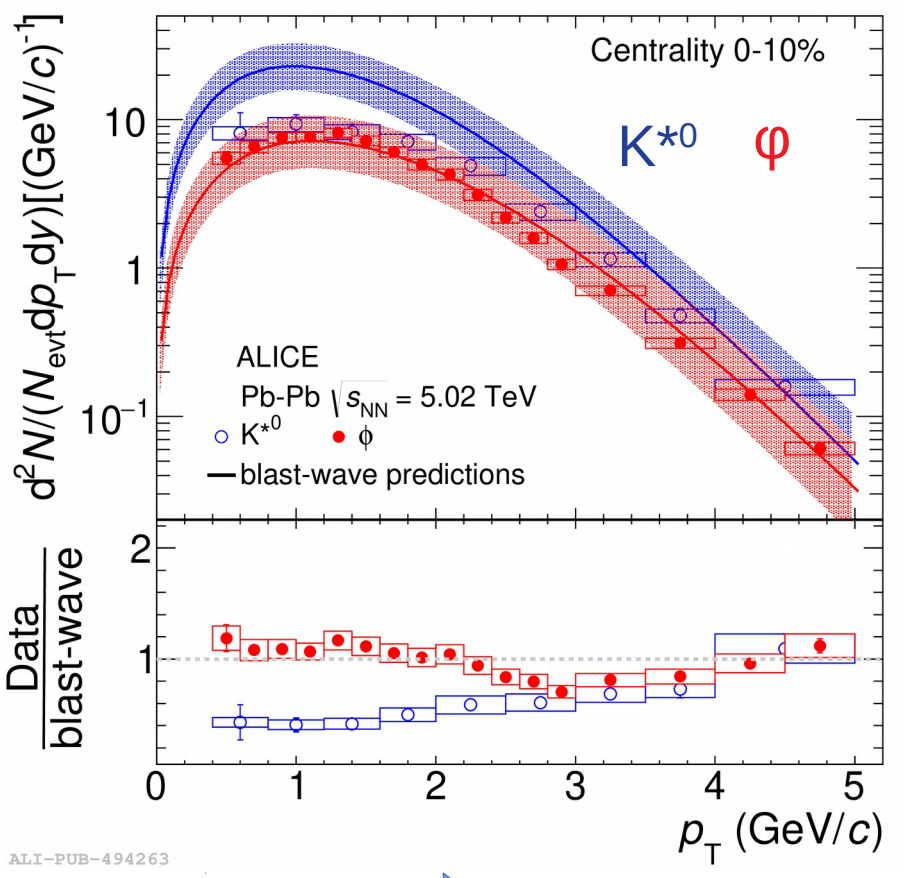
τ(Σ*±) ≈ 5.5 fm/*c*



- ☑ Suppression of Σ*±/π± yield ratio in central Pb–Pb collisions wrt pp and p–Pb collisions
- ☑ Both thermal model and EPOS + UrQMD overestimate the measurements
- ☑ 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



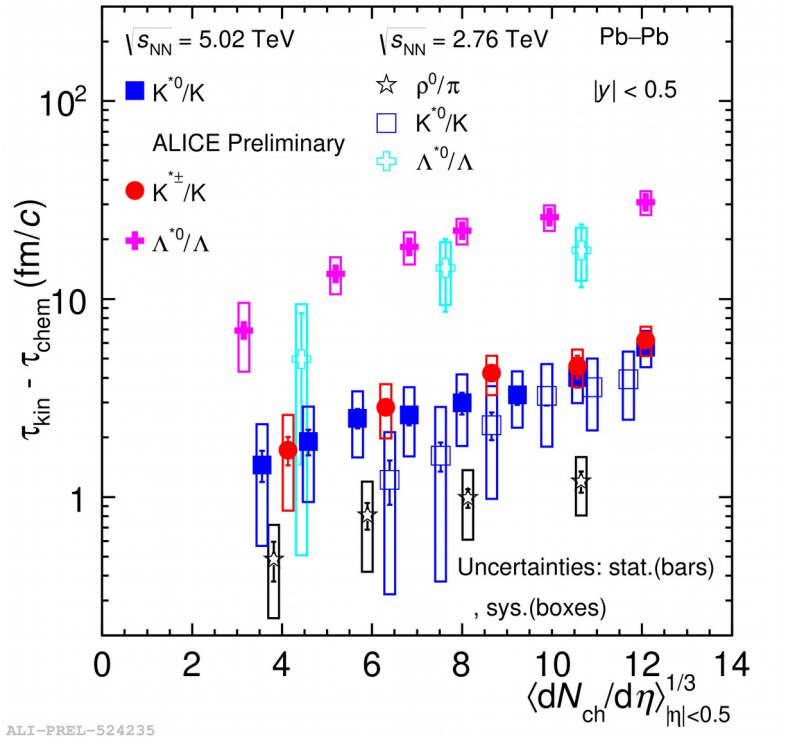
- ☑ Blast wave model (from π, K, p): No rescattering effect
- ☑ Suppression of K*0 in central Pb–Pb collisions at low p_T (< 3 GeV/c)
- ☑ No suppression is seen for φ

Ref: arXiv:2106.13113

Rescattering effect is a low p_T phenomenon

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