Talk: A. Calivà, Tue, 17:30
Talk: P. Ganoti, Wed, 11:50

EXPLORING THE HADRONIC PHASE OF ULTRARELATIVISTIC HEAVY-ION COLLISIONS WITH RESONANCES IN ALICE

ENRICO FRAGIACOMO

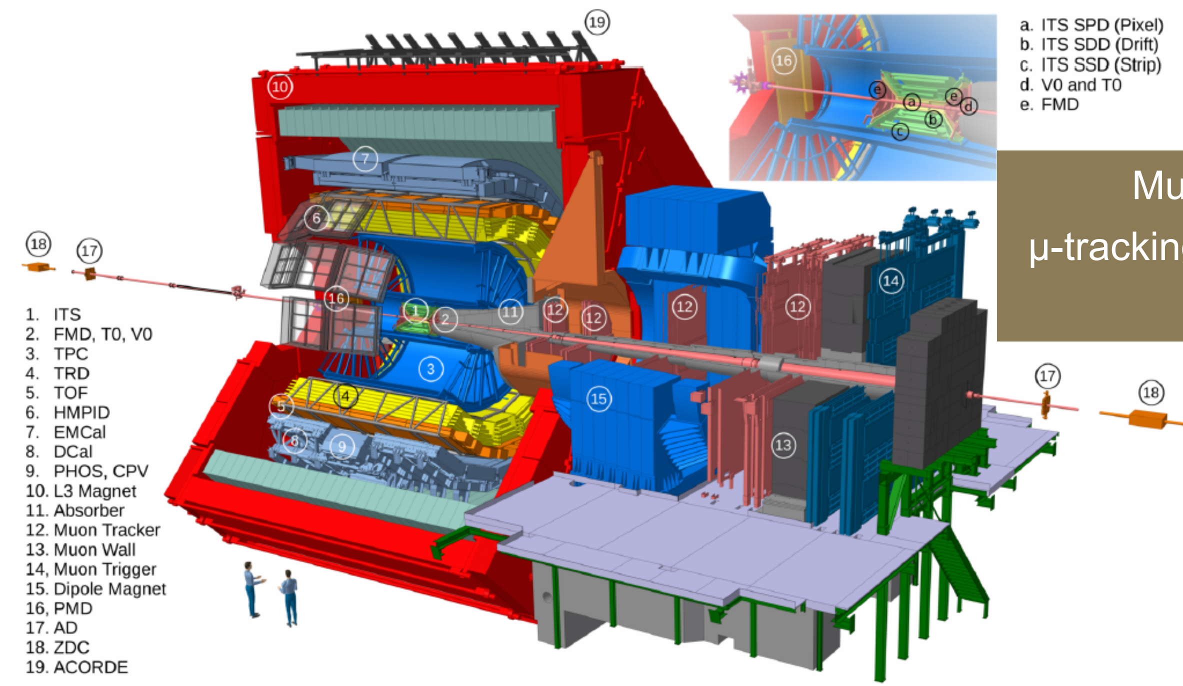
INFN - SEZIONE DI TRIESTE

NSTAR 2022

S. MARGHERITA LIGURE, 17-21 OCTOBER 2022

THE ALICE DETECTOR

Excellent track momentum resolution and PID



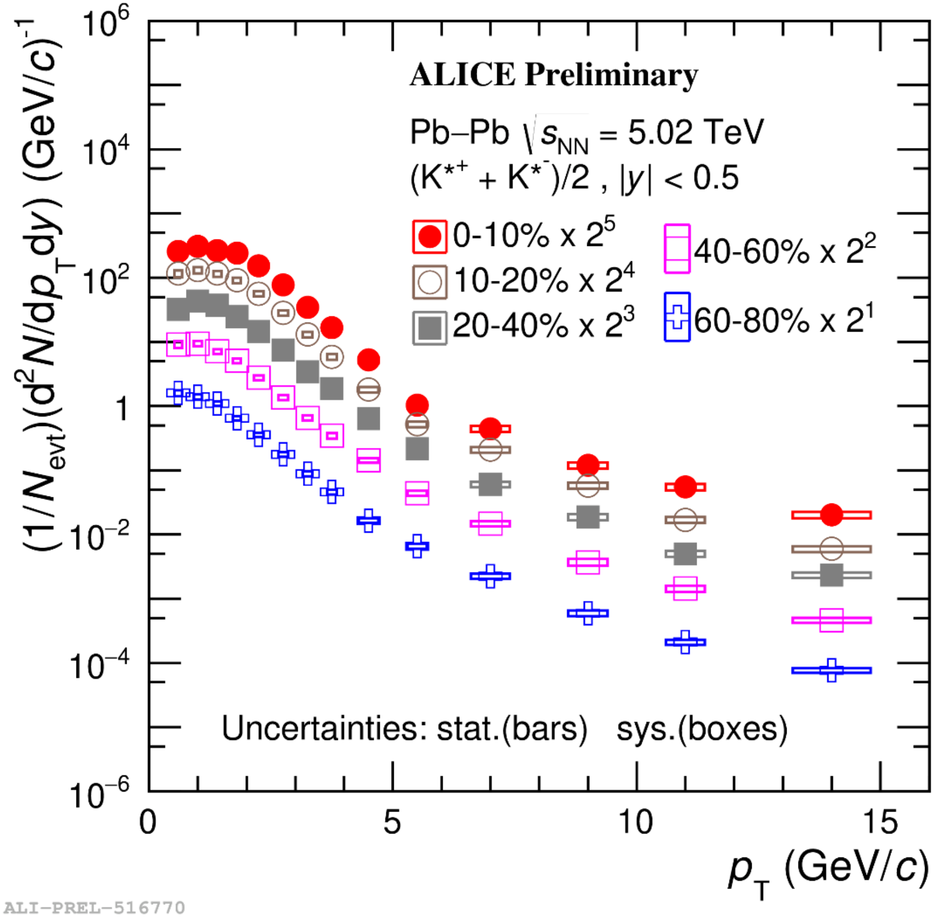
Muon spectrometer:
μ-tracking and trigger chambers
$-4 < \eta < -2.5$

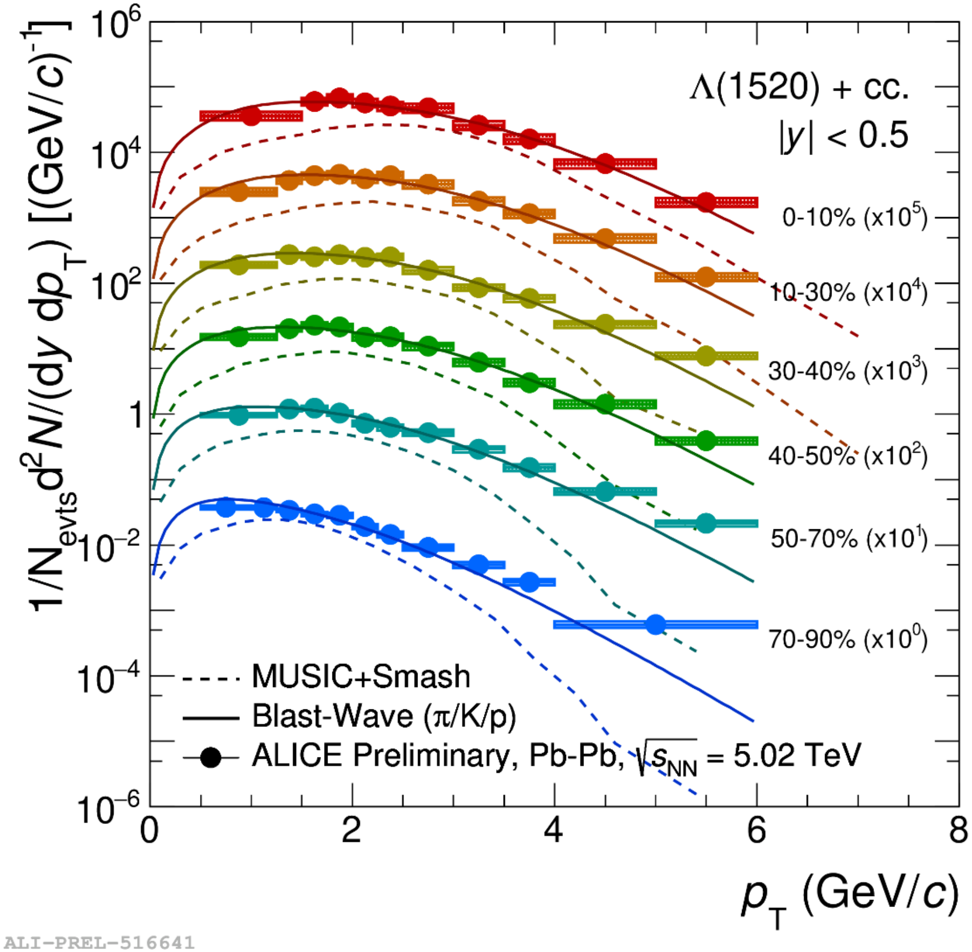
Central barrel:
vertexing, tracking, PID, EM calos
$|\eta| < 0.9$

Forward detectors:
multiplicity, trigger, centrality, time zero

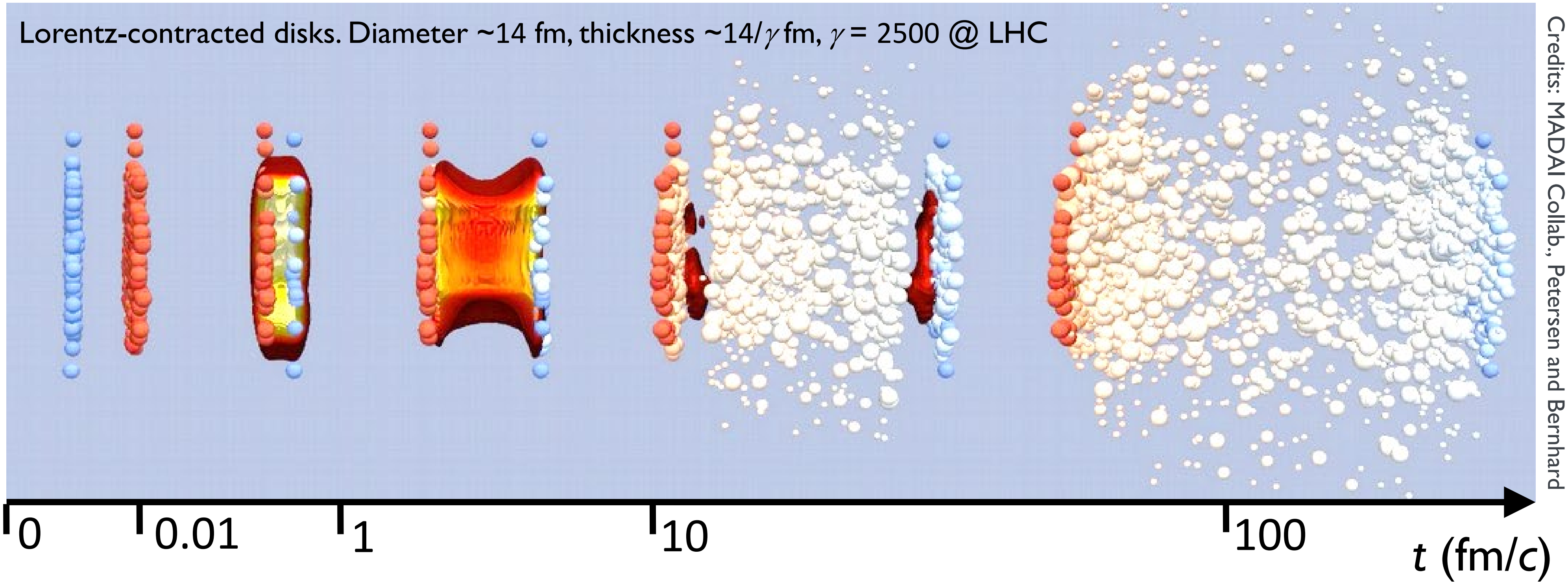
TRANSVERSE MOMENTUM SPECTRA

Excellent track momentum resolution is critical to reconstruct hadron resonances down to p_T below 1 GeV/c

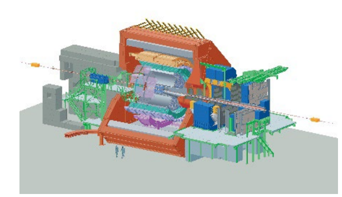




COLLISION EVOLUTION



Initial stage nPDF, saturation, shadowing	Gluon and quark-pair creation All heavy quarks created at this stage	QGP: deconfined nuclear matter expanding hydrodynamically	Hadronization and chemical freeze-out Inelastic collisions cease	Kinetic freeze-out Elastic collisions cease Free streaming particles to the detectors

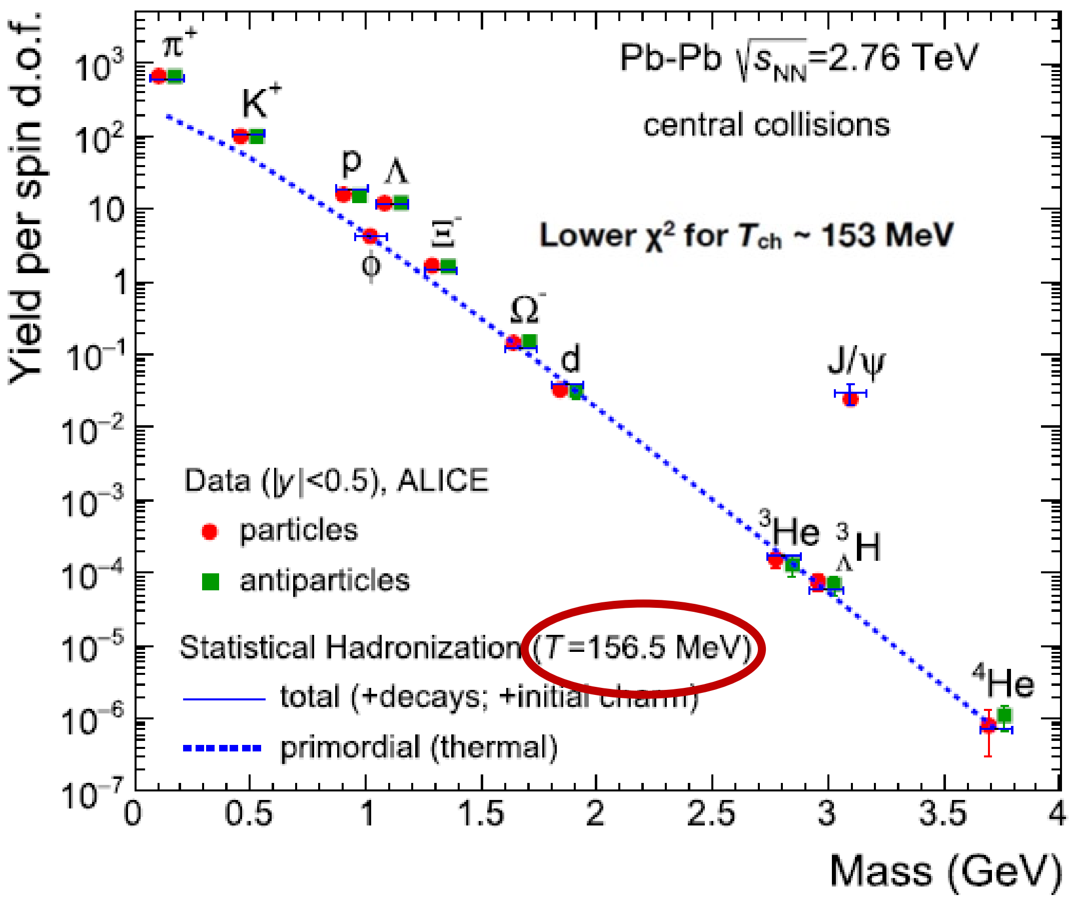


QGP phase

Hadron gas phase

TEMPERATURE AT CHEMICAL FREEZE-OUT

Statistical Hadronization Model (SHM)



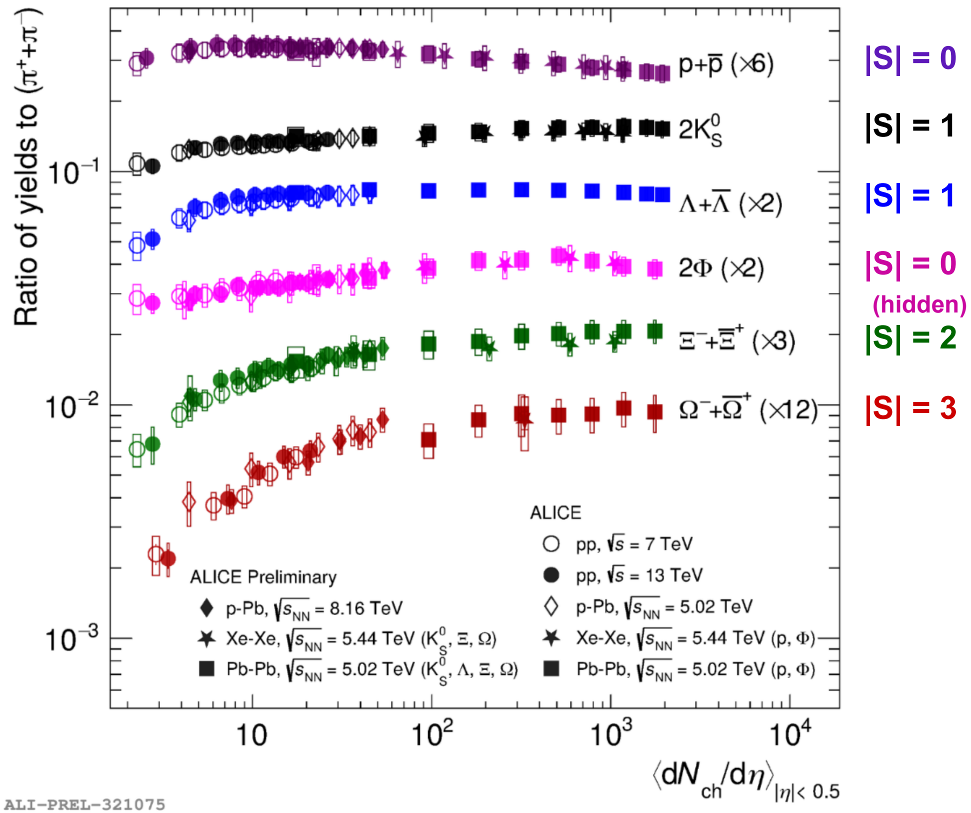
A.Andronic et al., Physics Letters B 797 (2019) 134836

- At hadronization the system is close to thermal equilibrium
- A rapid hadrochemical freeze-out takes place at the phase boundary
- Hadron abundances described by SHM over 9 orders of magnitude!
- Note that also loosely bound objects (light nuclei and hyper-nuclei) and heavy-flavour hadrons (J/ψ) are described by SHM

Total yields include contributions from resonance decays!

HADROCHEMISTRY

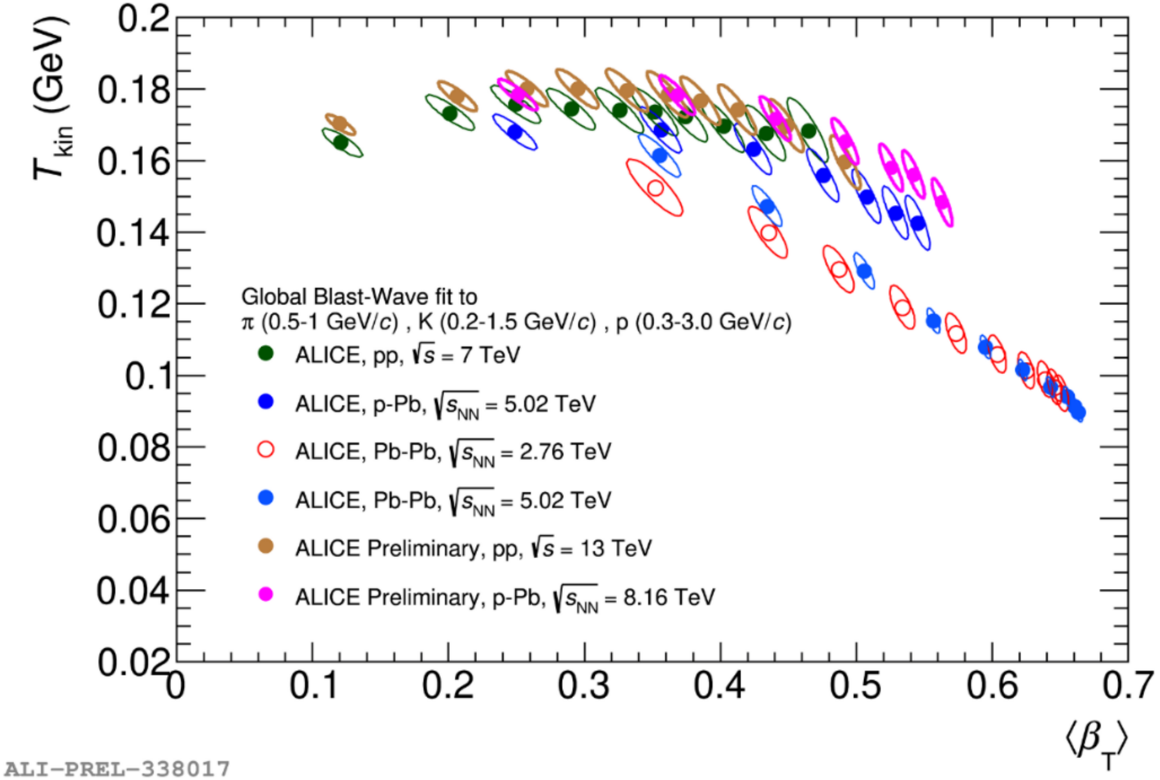
Nat. Phys **13,** 535–539 (2017)



Common particle production mechanism for all systems?

- **Smooth evolution of particle production from small to large systems** vs. charged-particle multiplicity
- Strangeness production increasing with multiplicity until saturation (grand-canonical plateau) is reached
- Steeper increase for particles with more strangeness content
- High-multiplicity pp: same hadrochemistry as larger (p-Pb, peripheral Pb-Pb) systems

TEMPERATURE AT KINETIC FREEZE-OUT



Boltzmann-Gibbs Blast-Wave fits are used to determine parameters of the radial flow:

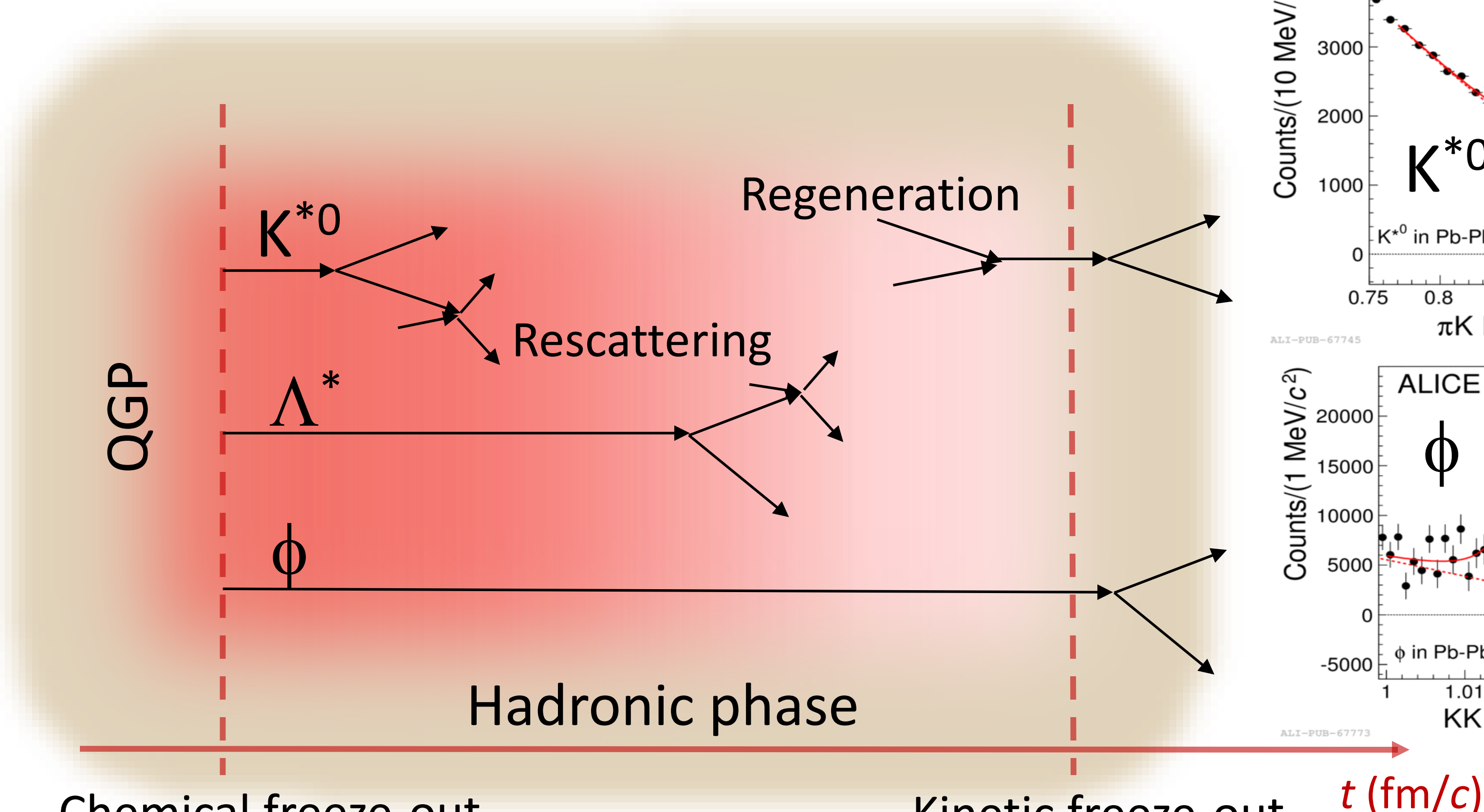
- T_{kin} – kinetic freeze-out temperature
- $<\beta_T>$ - transverse flow velocity

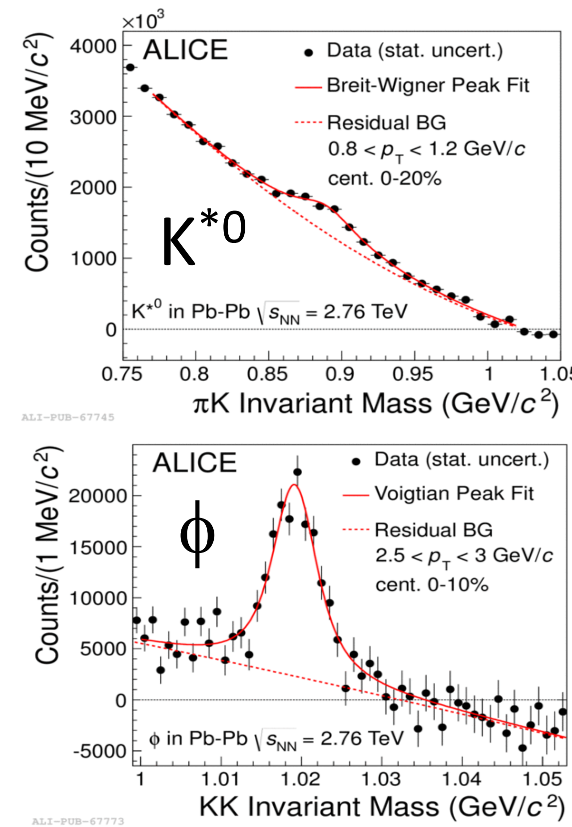
Fit parameters are extracted from simultaneous fits to π, K, p spectra

Results are sensitive to fitting range!

RESONANCES IN THE HADRON GAS

Re-scattering (elastic or pseudo-elastic scattering of the decay products) and regeneration modify the yield of reconstructible resonances



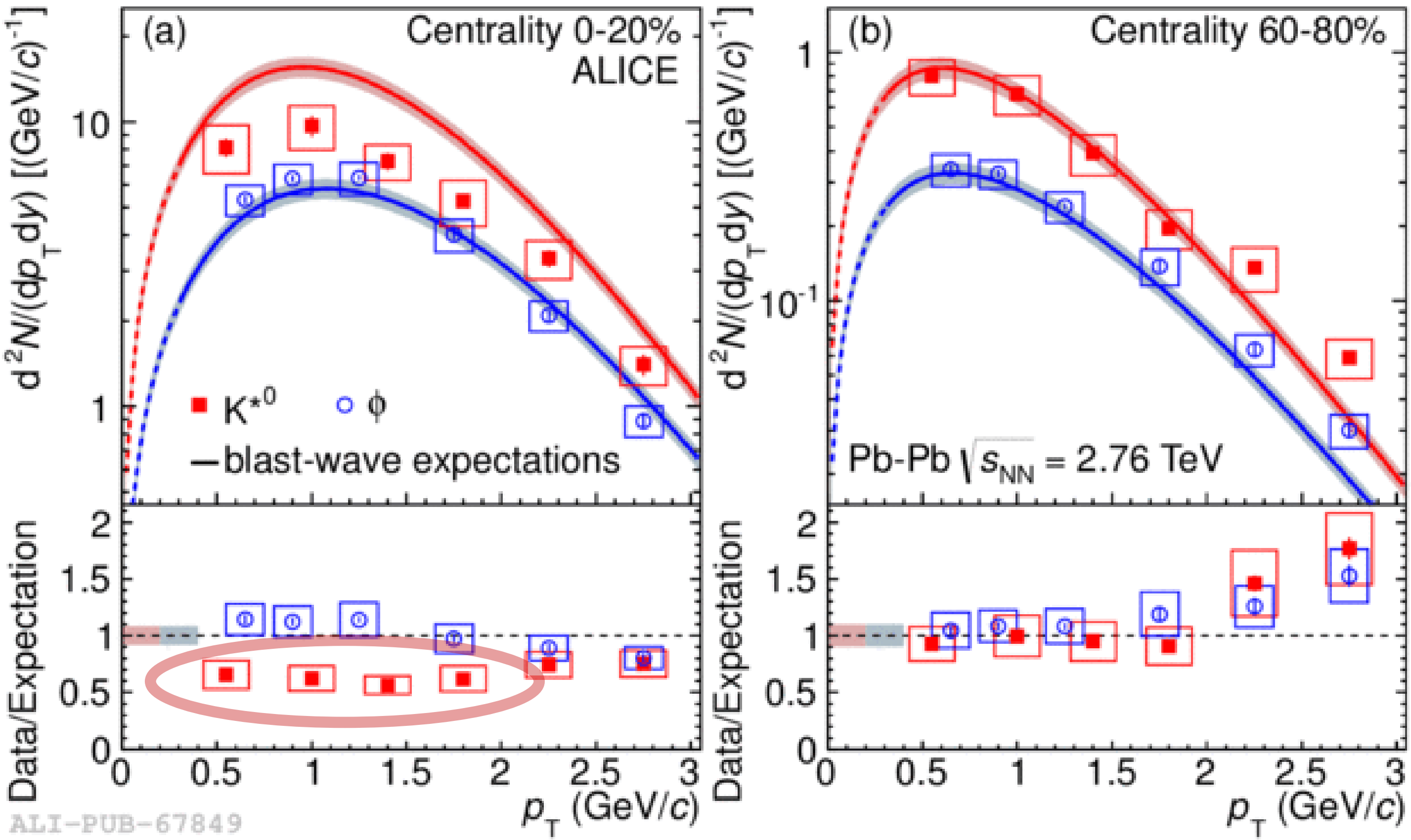


Chemical freeze-out
(→ Particle yields)

Kinetic freeze-out
(→ Spectral shapes)

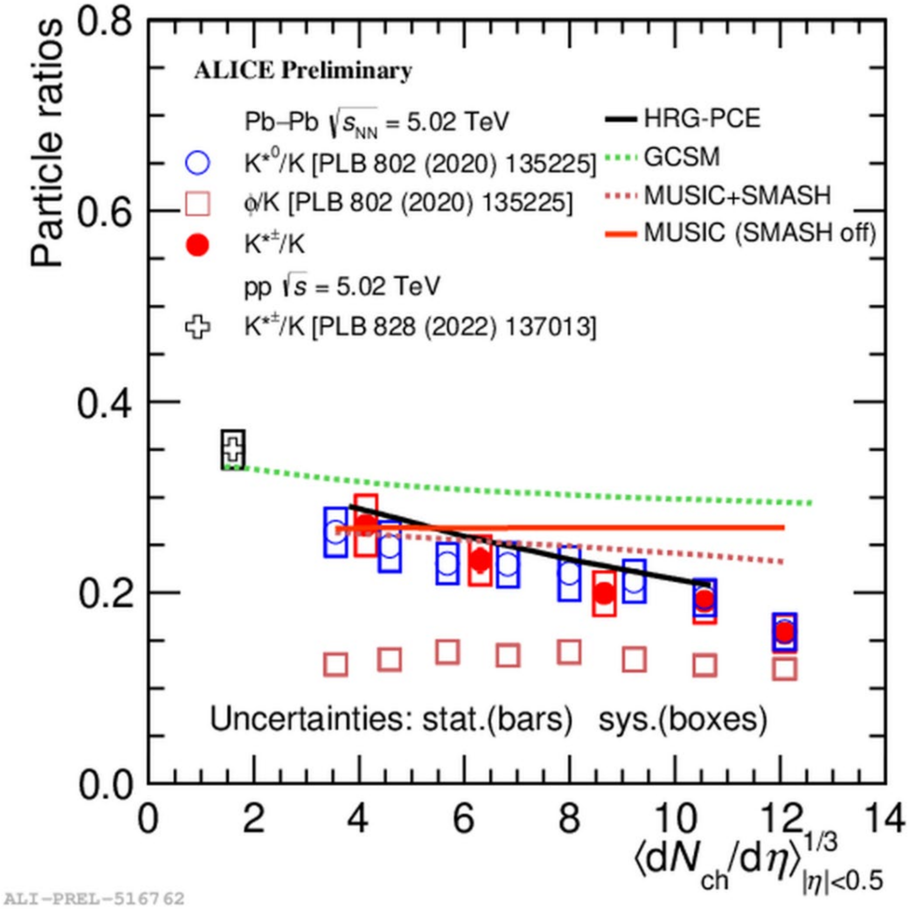
p_T-SPECTRA WITH PREDICTIONS

- Curves are obtained with a simultaneous fit to π/K/p distributions
- Curves are normalized to the measured K^- yield times the K^{*0}/K^- (ϕ/K^-) ratio from the thermal model (T = 156 MeV)



RATIO K*/K

$\tau(K^{*0})$ = 4.16 fm/c



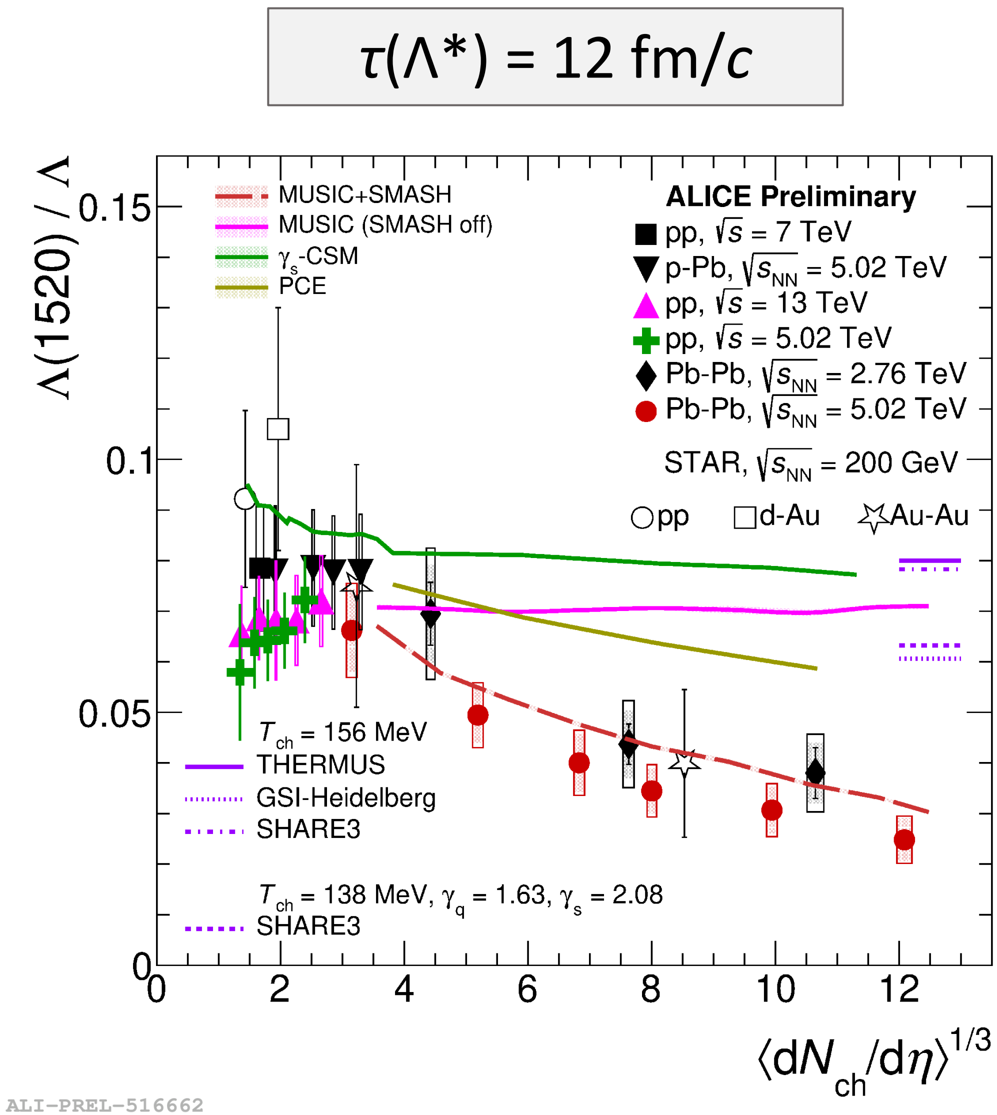
$K^{*\pm}$/K shows a ~55% suppression going from peripheral Pb–Pb collisions to most central Pb–Pb

- consistent with the rescattering of the daughters as the dominant effect
- models with rescattering effect (MUSIC+SMASH and HRG-PCE) qualitatively describe the data

$K^{*\pm}$ measurement is consistent with previous results for K^{*0}

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

RATIO Λ*/Λ



Λ*/Λ shows a ~ 70% suppression going from peripheral Pb–Pb collisions to most central Pb–Pb

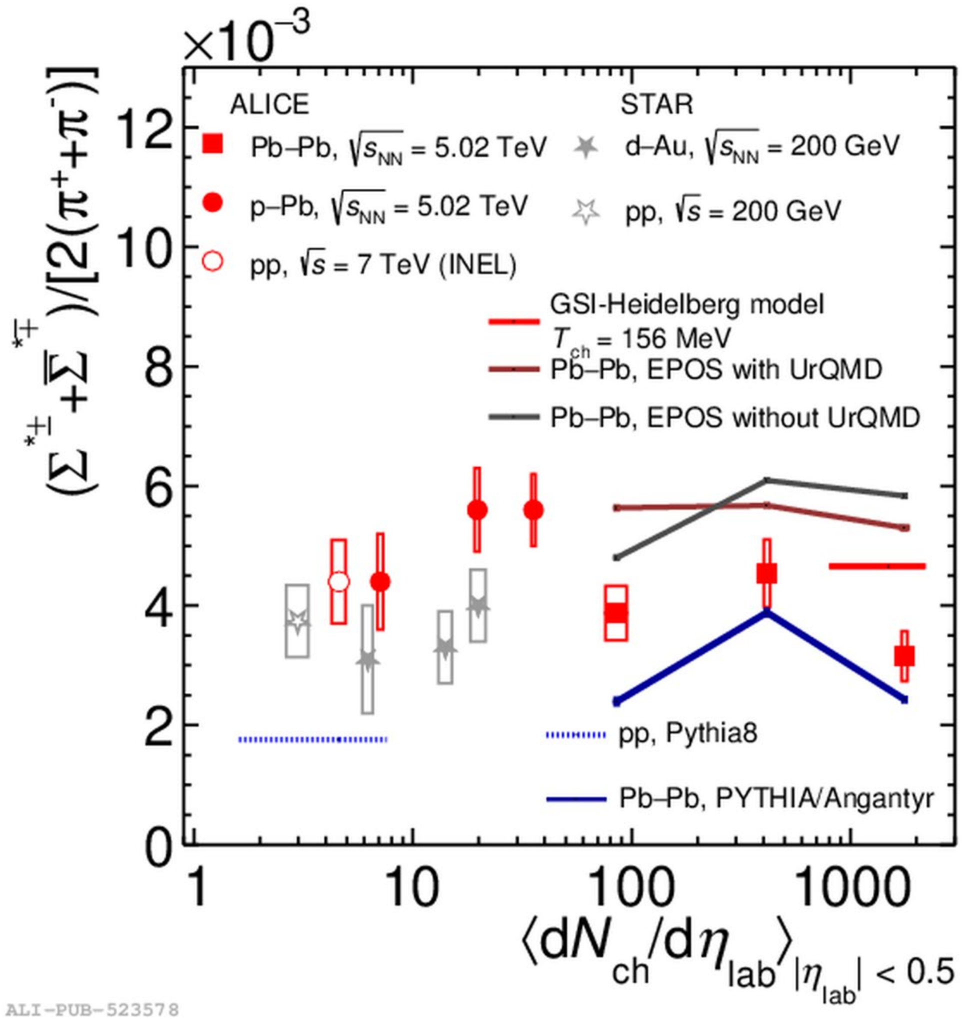
- consistent with the rescattering of the daughters as the dominant effect
- it is larger than ~ 55% for $K^{*\pm}$ although $\tau(\Lambda^*) = 3\,\tau(K^*)$

➢ **MUSIC-SMASH reproduces the multiplicity suppression trend**

➢ thermal models overestimate the ratio in central Pb–Pb collisions

RATIO Σ^*/π

$\tau(\Sigma^*) = 5$ fm/c

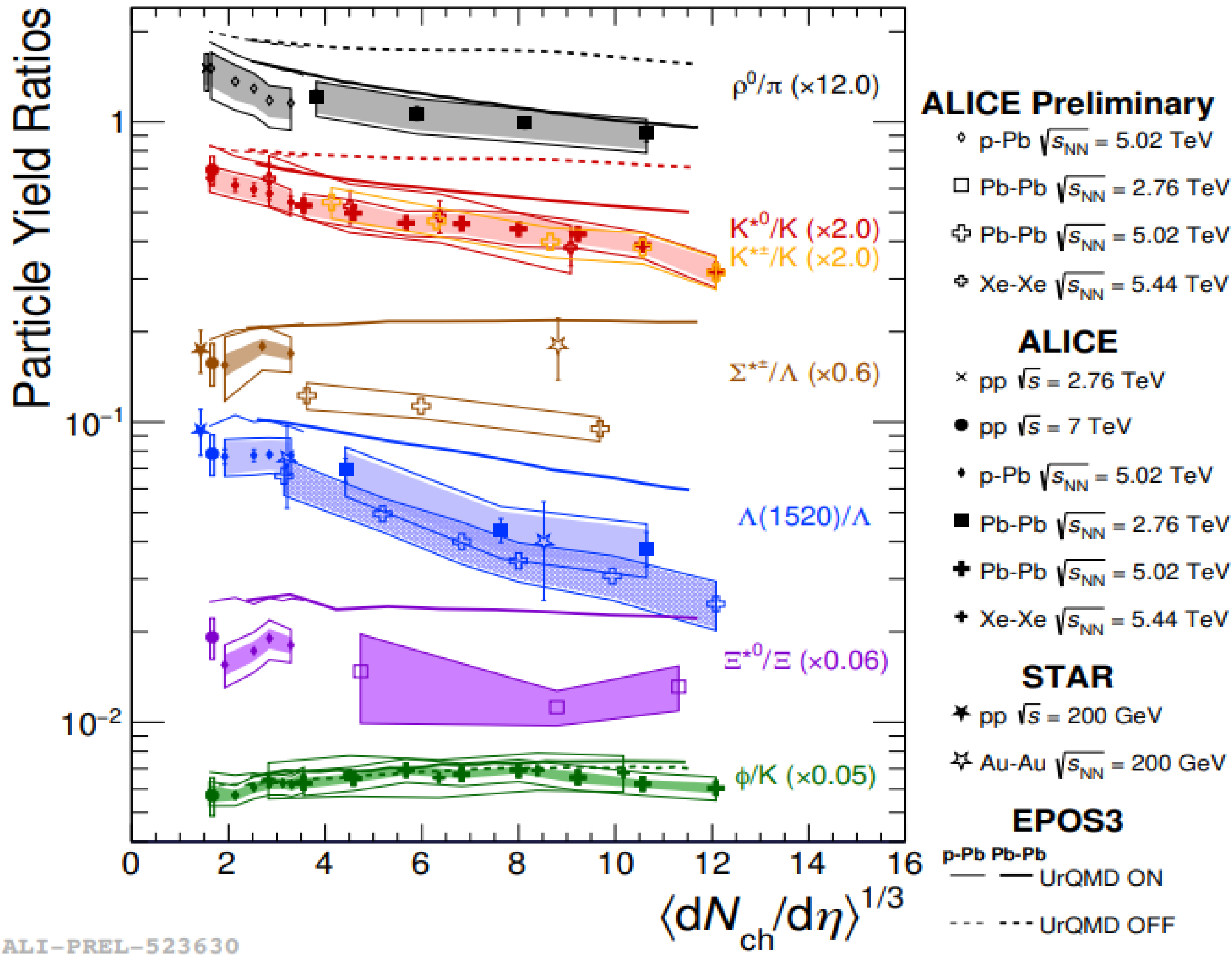


- Suppression of $\Sigma^{*\pm}/\pi^{\pm}$ yield ratio in central Pb–Pb collisions wrt pp and p–Pb
- Thermal model and EPOS + UrQMD overestimates the measurement
- Suppression at a level of 3.6σ in 0-10% central Pb–Pb collisions with respect to statistical thermal model

arXiv:2205.13998

SUMMARY OF PARTICLES RATIOS

	$c\tau$ (fm)
ρ	1.3
K*	4.2
Σ*	5.5
Λ*	12.6
Ξ*	21.7
ϕ	46.2

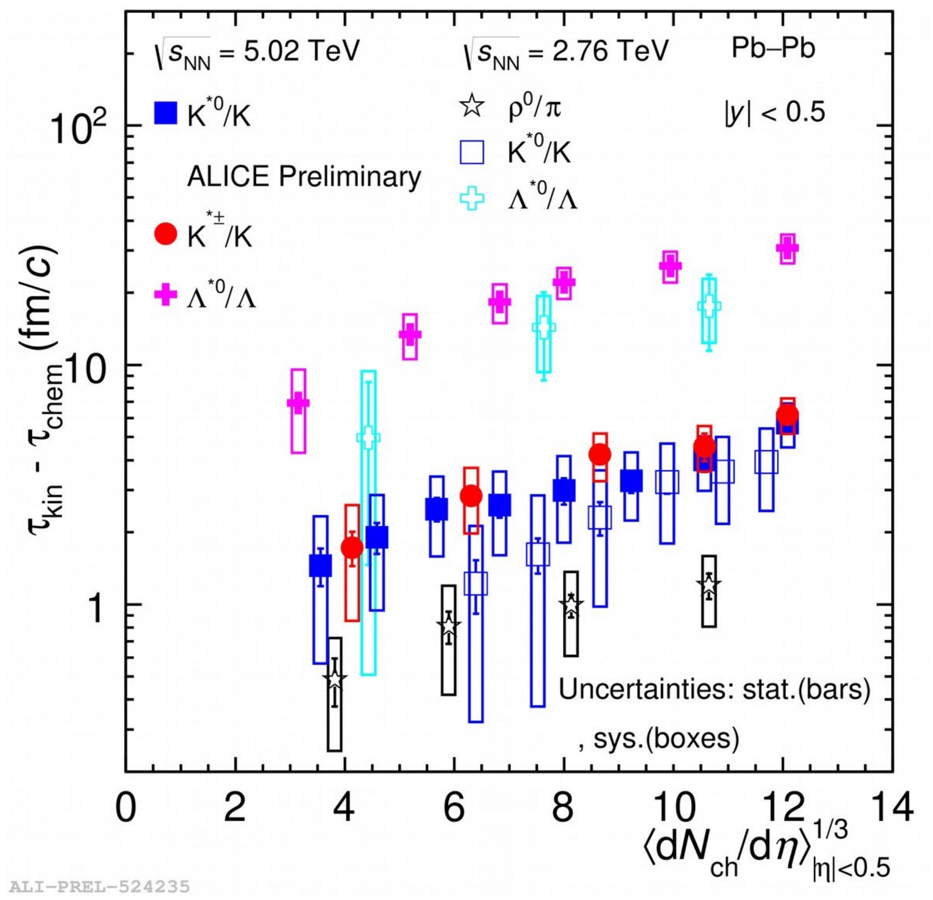


MEASURING LIFETIME OF HADRONIC PHASE

Estimation of lower limit of the timespan between chemical and kinetic freeze-out by exponential law:

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

- r_{kin} = measured yield ratios in Pb–Pb collisions
- r_{chem} = measured yield ratios in pp collisions
- τ_{res} = lifetime of resonance



<u>Assumptions:</u>

i) Simultaneous freeze-out for all particles

ii) Negligible regeneration

Lifetime of hadronic phase smoothly 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
- ✓ Lower limit of hadronic phase lifetime is obtained
- ✓ Lifetime of hadronic phase smoothly increases with multiplicity

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