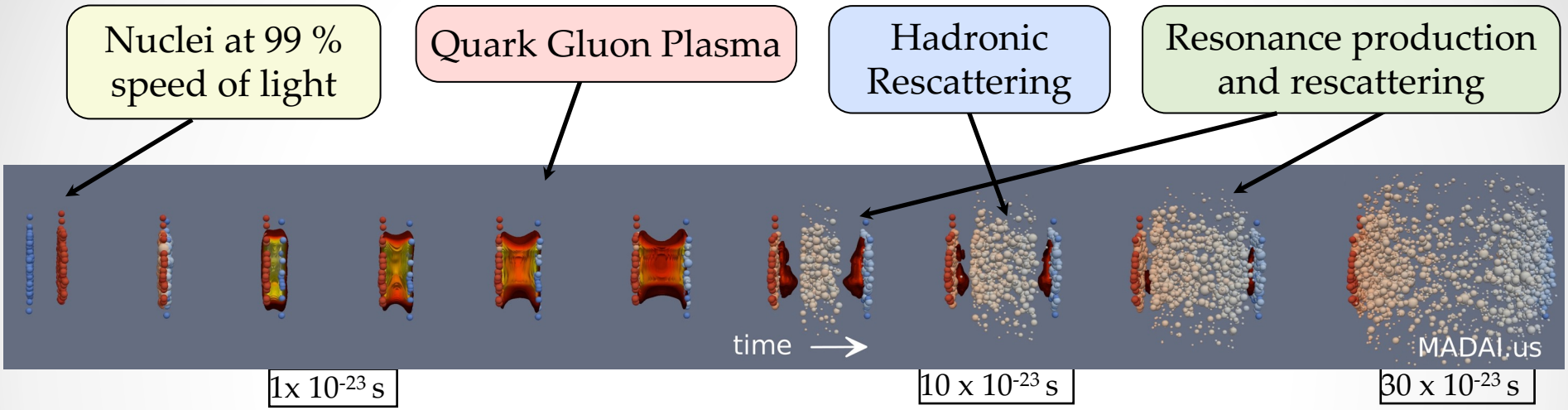
Resonance Studies in Heavy Ion Collisions

Lisa Engel

with Tom Reichert, Marcus Bleicher, Jan Steinheimer, Apiwit Kittiratpattana

Institut für Theoretische Physik, Goethe Universität – Frankfurt

Time Evolution of Heavy Ion Collisions

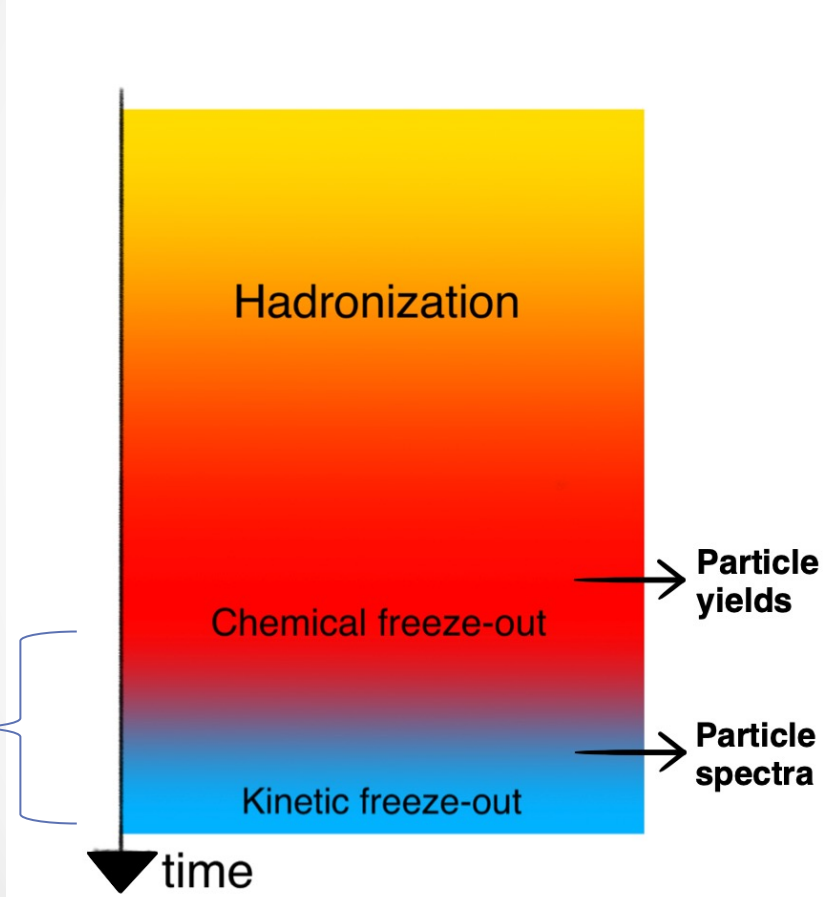


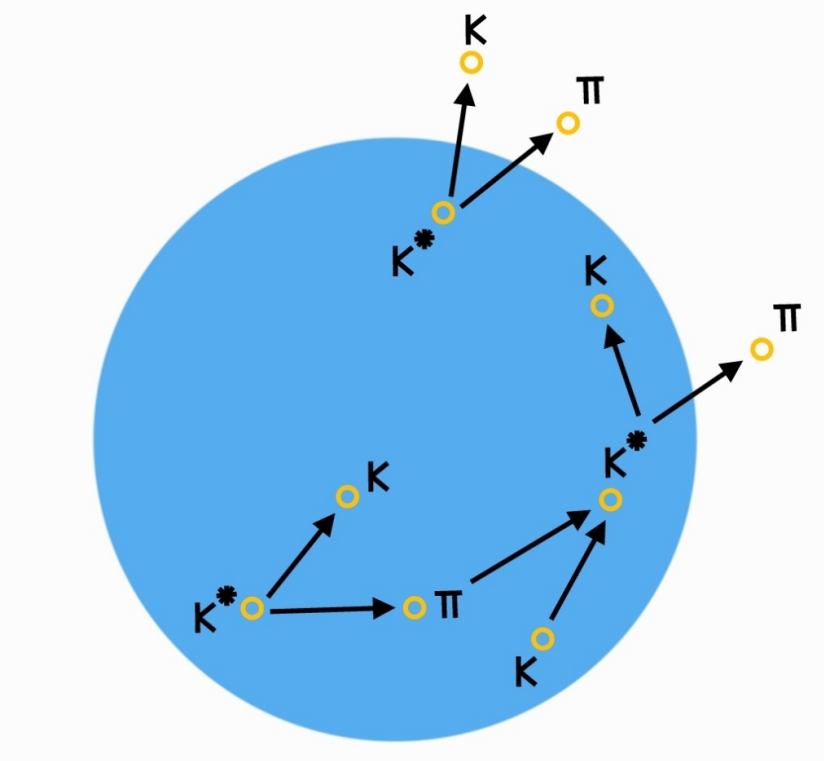
Nonequilibrium initial state dynamics → Relativistic Hydrodynamics/ Particle dynamics → Hadron Transport

Learn about the length of the hadronic rescattering stage using resonances

Figure adapted from H. Elfner, arXiv:1404.1763

Resonance reconstruction





Ultra-relativistic Quantum Molecular Dynamics (UrQMD)

Hadron cascade (standard mode)

- Based on the propagation of hadrons
- Rescattering among hadrons is fully included
- String excitation/decay at higher energies
- Provides a solution of the relativistic n-body transport eq.:

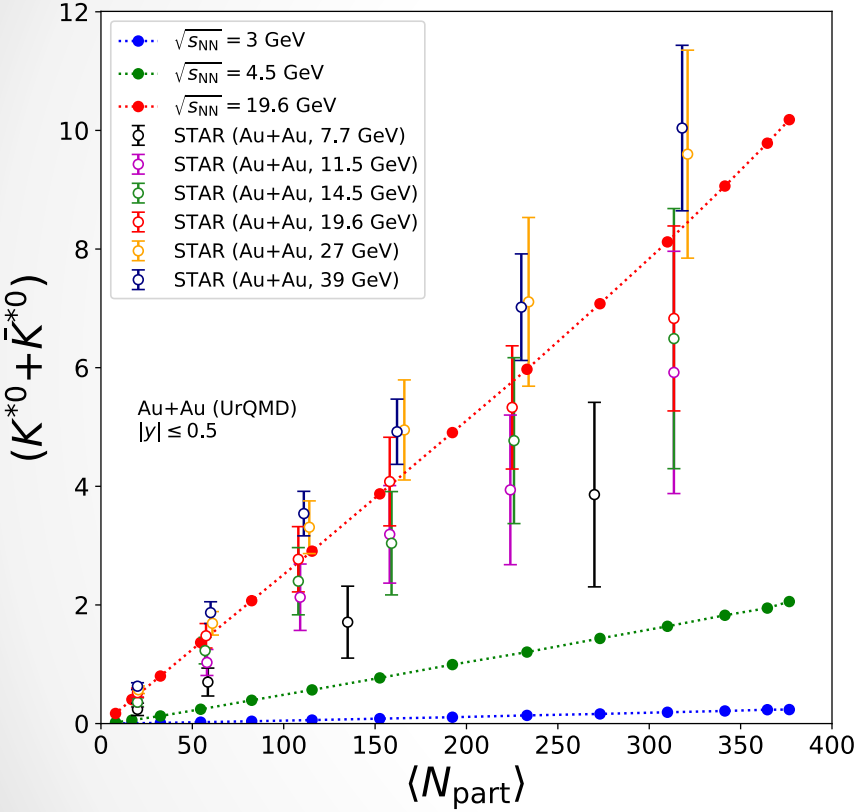
$$p^\mu \cdot \partial_\mu f_i(x^\nu, p^\nu) = \mathcal{C}_i$$

- "*Standard Reference*" for low and intermediate energy hadron and nucleus interactions

M. Bleicher et al, J.Phys. G25 (1999) 1859-1896

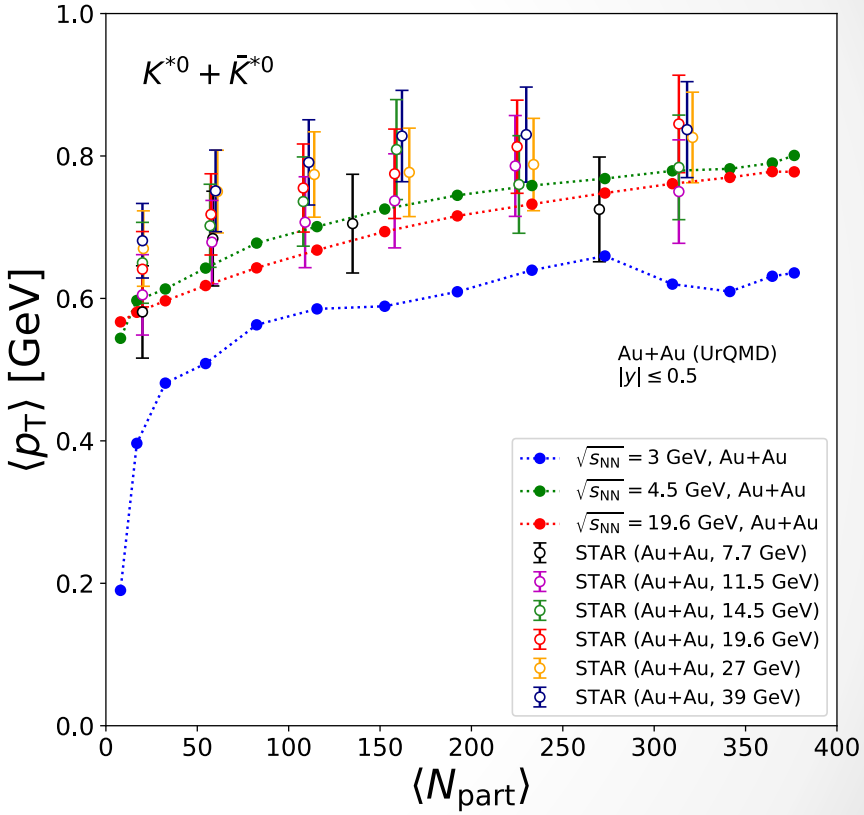
Energy and centrality dependence

K* Multiplicities



Yield increases with energy and centrality

K* mean p_T



p_T increases with centrality
No energy dependence for central reactions
→ absorption of low p_T daughters more relevant

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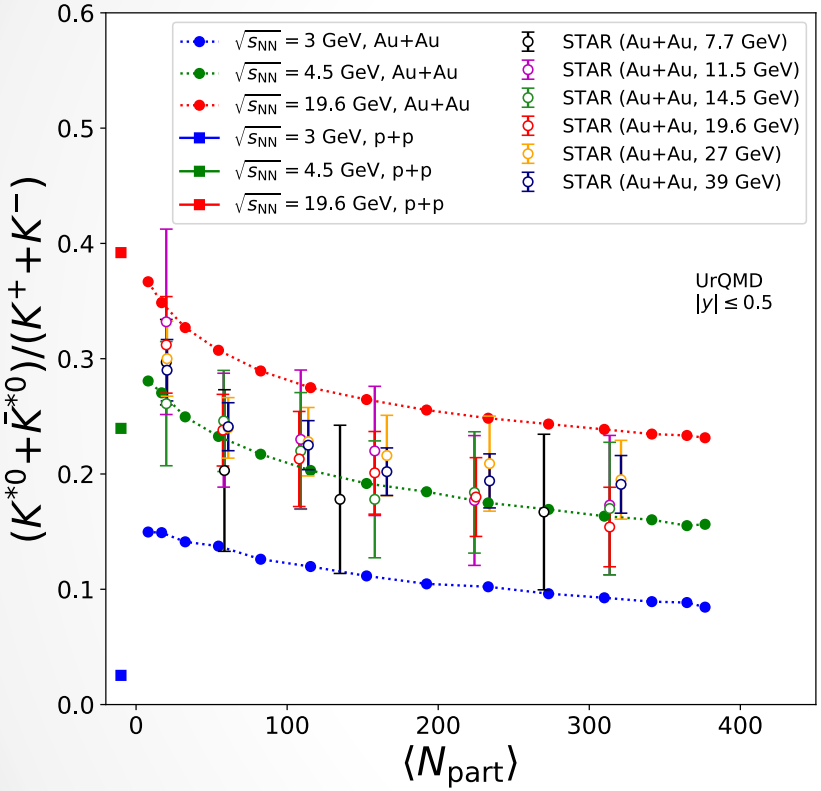
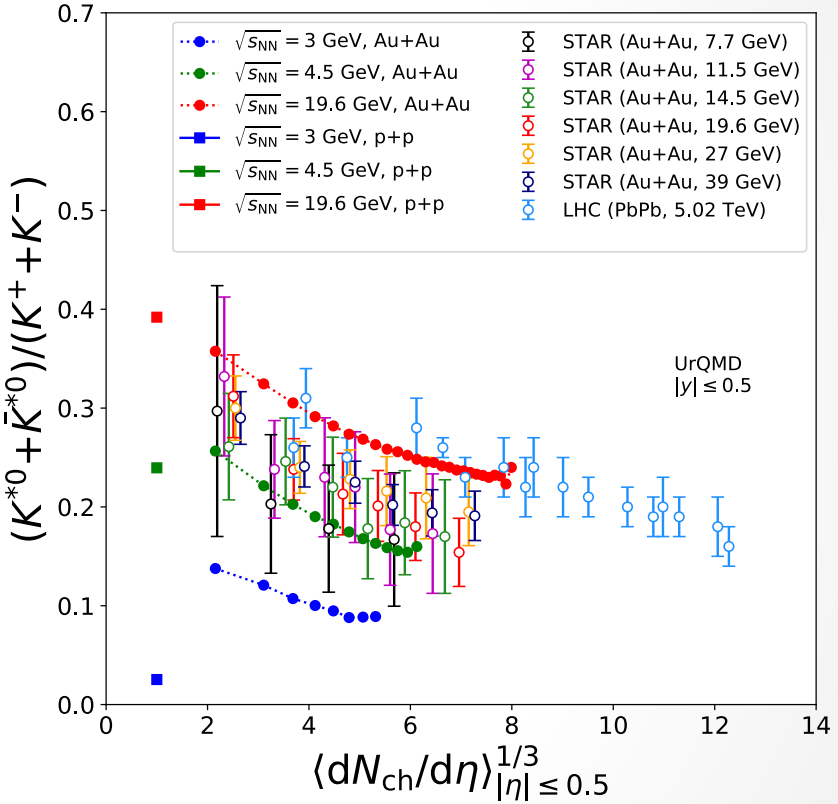
Ratio to ground state

Centrality dependence in terms of N_{part}



Centrality dependence in terms of N_{ch}



- Strong K* daughter absorption in central collisions observed at all energies
  Absorption seems stronger at lower energies than at LHC
- Low energies pp is not equal to peripheral AA (threshold!)

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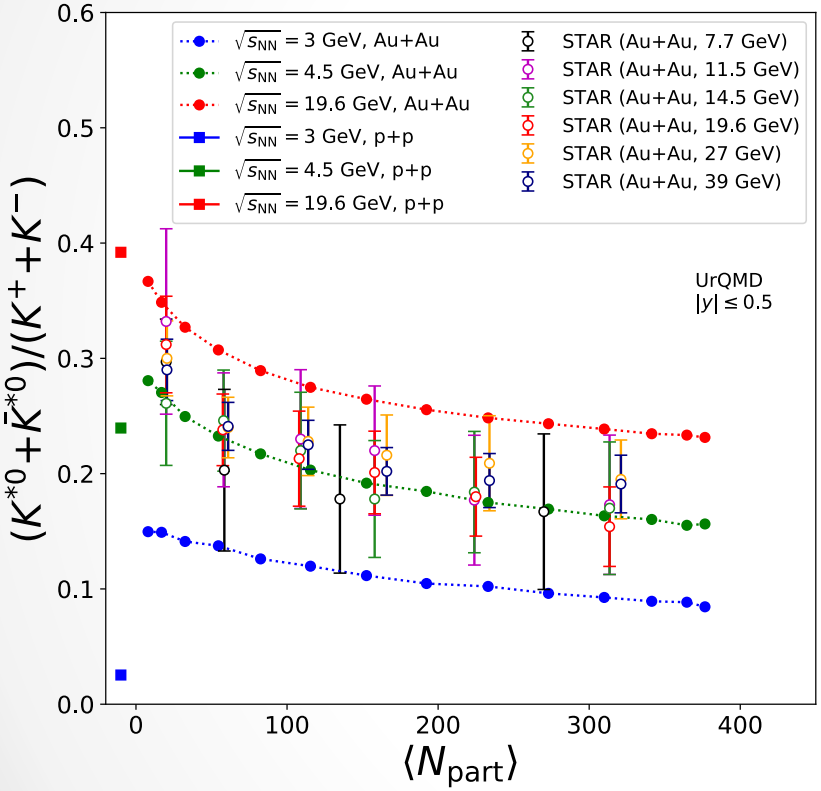
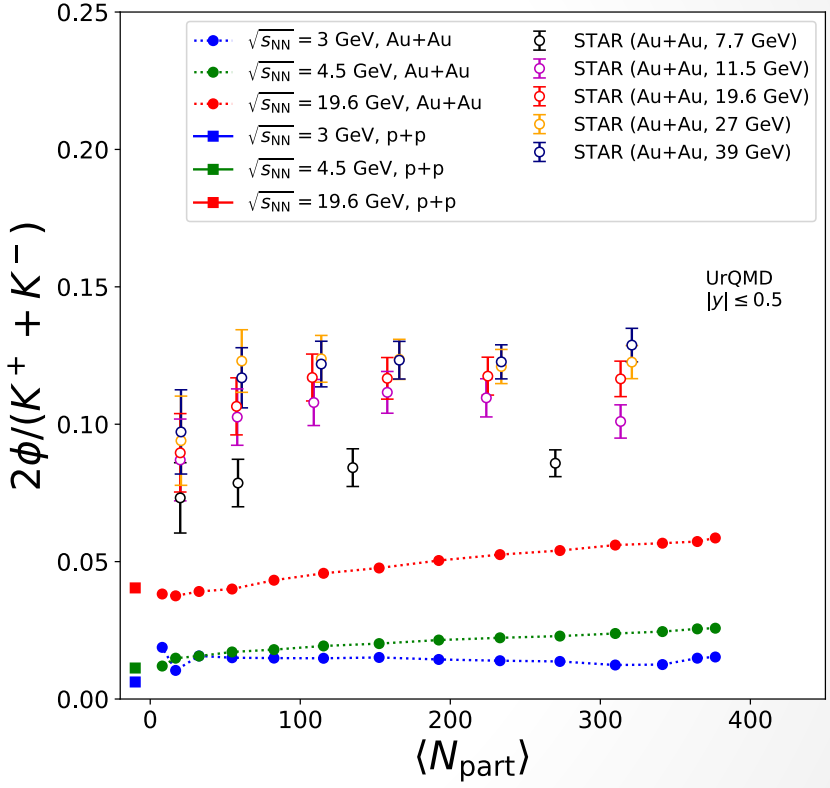
Comparison to ϕ meson

K*/K ratio



ϕ/K ratio



- No suppression of ϕ meson due to long live time
- Extraction of duration of hadronic stage possible

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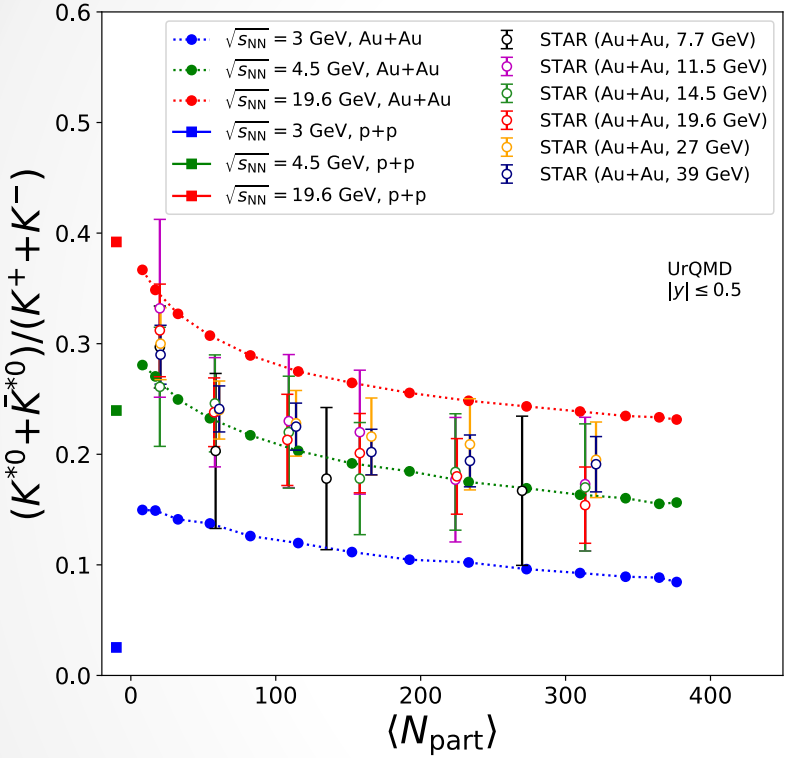
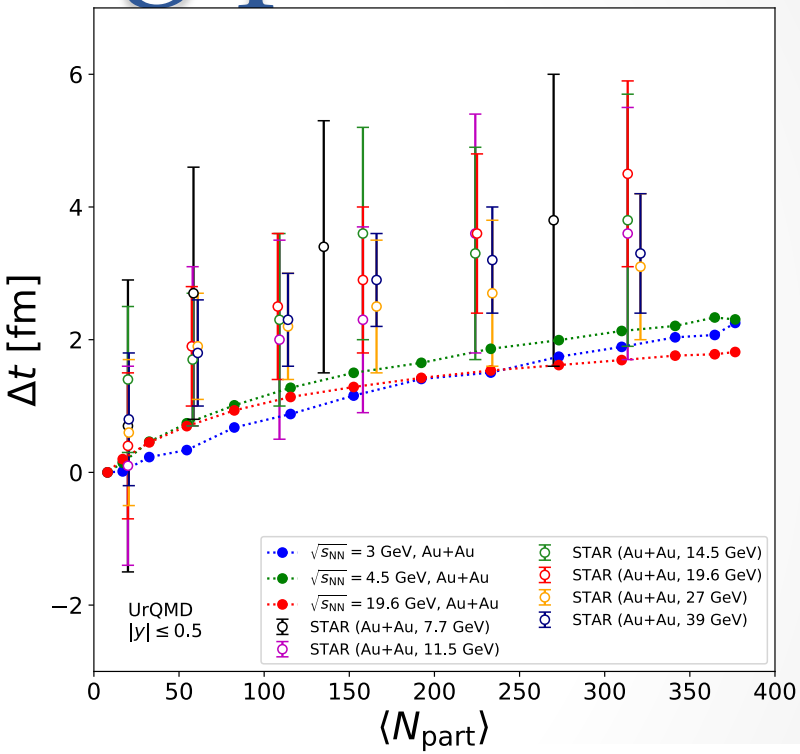
Lifetime of hadronic rescattering phase





$$\left(\frac{K^{*0}}{K}\right)_{\mathrm{KFO}} = \left(\frac{K^{*0}}{K}\right)_{\mathrm{CFO}} \times e^{-\Delta t/\tau_{K^{*0}}},$$

- Extraction of duration of hadronic stage possible
  → Lifetime in the order of 2 fm
- Assumption: $\left.\frac{K^*}{K}\right|_{CFO} \approx \left.\frac{K^*}{K}\right|_{pp}$ not valid below $\sqrt{s} \approx 20\ GeV$

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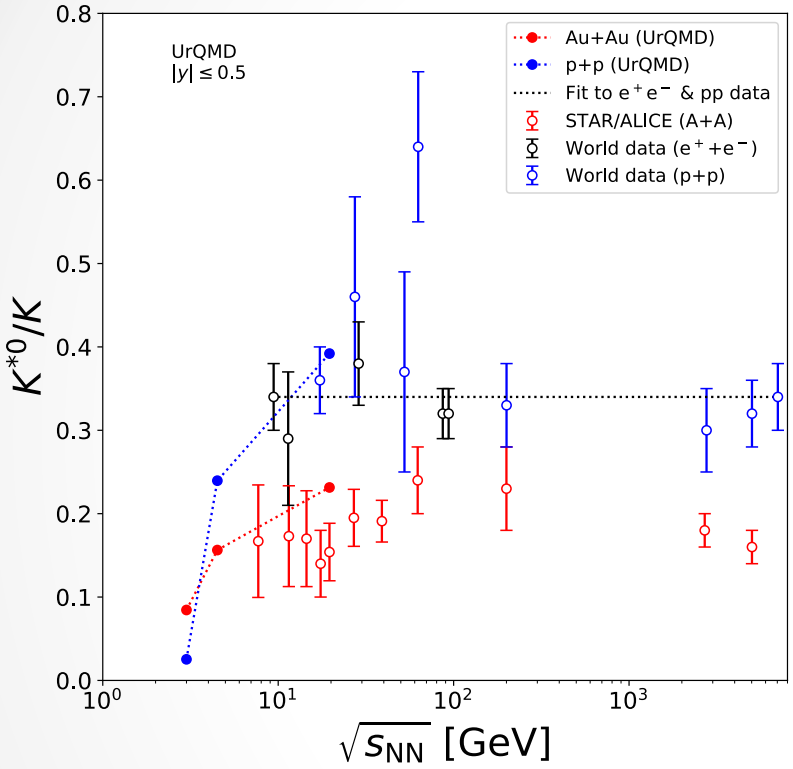
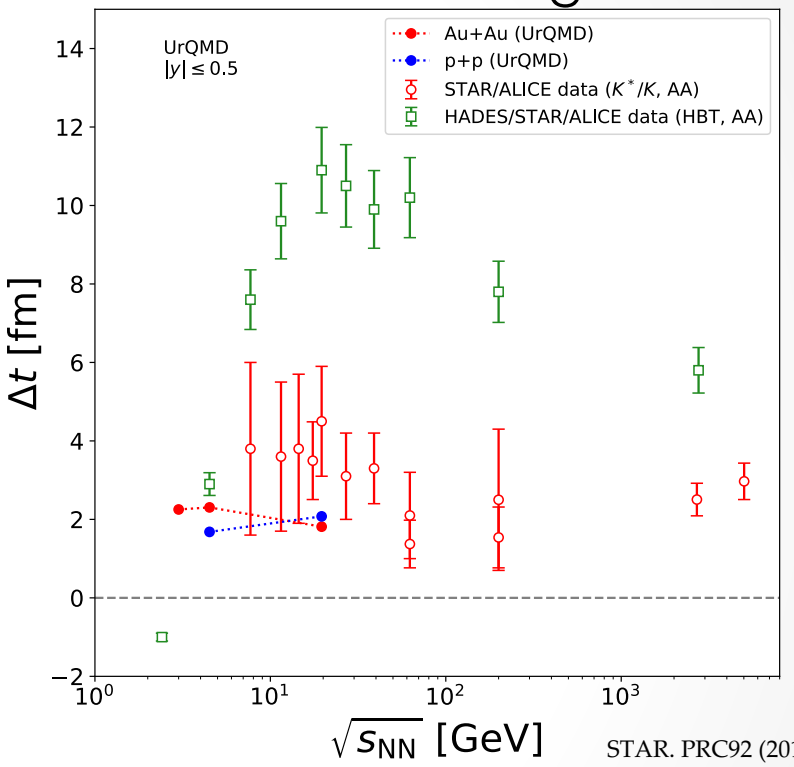
Energy dependence

Comparison



Extraction of duration of hadron stage



STAR. PRC92 (2015) 1,014904
PHENIX. NPA931 (2014) 1082-1087
ALICE. PoS WPCF (2011) 003
HADES. EPJA56 (2020) 5, 140

- Strong K* suppression present at all energies
- K*/K might have a local maximum around $\sqrt{s_{NN}}$ =100-200 GeV
  → compensation between strangeness production and daughter rescattering?
- Lifetime of hadronic stage might show local minimum at this energy?

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Summary

- Transport models are excellent tools to describe and explore the dynamics of matter in heavy ion collisions
- Hadronic rescattering phase suppresses K^* /K (short-lived resonances) ratio, while ϕ/K remains centrality-independent (long-lived resonance)
- Lifetime extraction hints at local minimum of hadronic phase around $\sqrt{s_{NN}}$ =100-200 GeV (while HBT data suggests a local maximum)
- Lifetime extraction breaks below $\sqrt{s} \approx 20\ GeV$