Strangeness production at SIS energies

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Abstract

- New hadronic transport model SMASH [1] to describe heavy-ion collisions
- Important for all stages of collisions at SIS energies and late stages at RHIC and LHC energies
- Strangeness production via two mechanisms: resonances and forced thermalization

SMASH

- **S**imulating **M**any **A**ccelerated **S**trongly-interacting **H**adrons
- Goal: Standard reference for hadronic systems with vacuum properties
- Use cases: Nuclear collisions, infinite matter calculations, afterburner for hydrodynamic simulations
- Perturbative treatment of dileptons and photons

Transport approach

- Microscopic simulation of colliding particles
- Solve relativistic Boltzmann equation for particle species i

$$p^\mu \partial_\mu f_i(x,p) = C^i_{\text{coll}}$$

- Point-like test particles
- SMASH:
  - Geometric collision criterion
  - Only $2 \leftrightarrow 2$ and $2 \leftrightarrow 1$ hadronic reactions
  - 56 mesons and 60 baryons (+ anti particles)

References

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Strangeness production

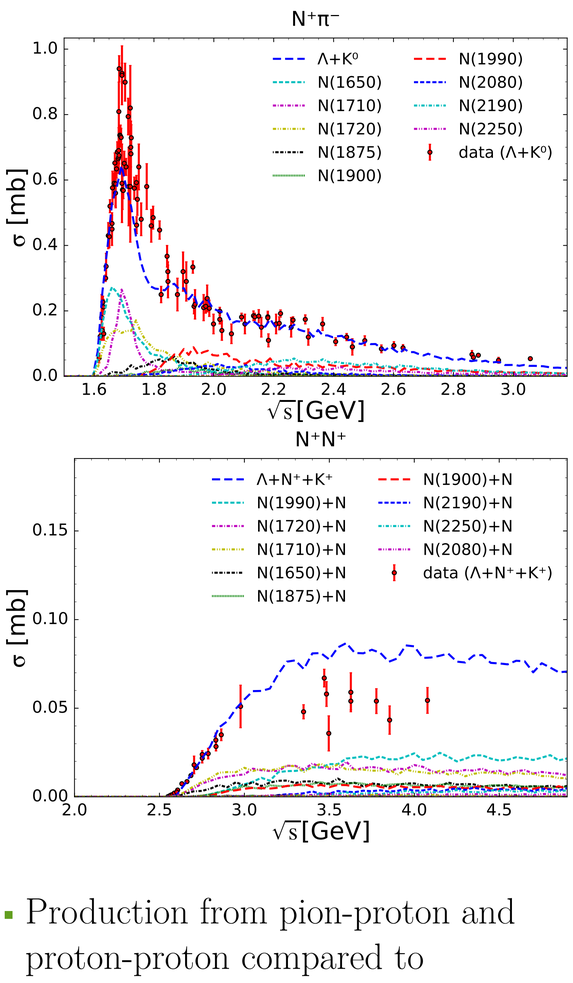
- Strangeness exclusively produced during collision ⇒ interesting probe for studying evolution of the reaction
- Production channels for strange particles ($Y \in \{\Lambda, \Sigma\}$):

$$NN \to NN^*, N\Delta^* \to NYK$$
$$\pi Y \leftrightarrow Y^* \leftrightarrow \bar{K}N$$
$$N^* \to \phi N \to \bar{K}KN$$

- Kaons and 11 kaonic resonances (+ anti particles)
- Λ, Σ, Ξ, Ω and 28 resonances (+ anti particles)

Nucleon resonances

- Important for hyperon and kaon production
- Cross section calculated from resonance masses, decay widths and branching ratios
- Resonance properties constrained by PDG data on branching ratios and exclusive cross sections



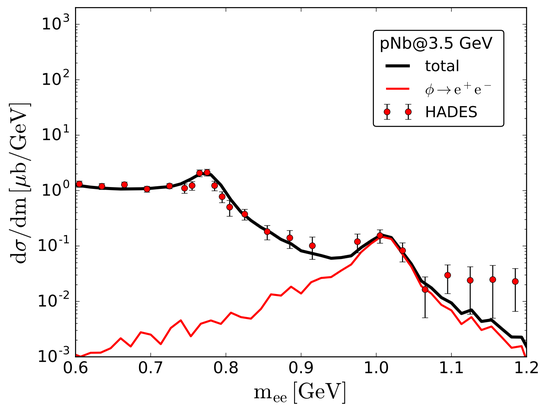
- Production from pion-proton and proton-proton compared to experimental data
- Both governed by same $B^* \to \Lambda K$ branching ratios
- Peaks of different B^* clearly visible
- Tuned to describe exclusive cross section and branching ratio data
- Similar procedure for Σ (not shown)

Hyperon resonances

- Important for antikaon production via strangeness exchange
- Constrained by PDG branching ratios, total and exclusive $\bar{K}N$ cross sections

Meson resonances

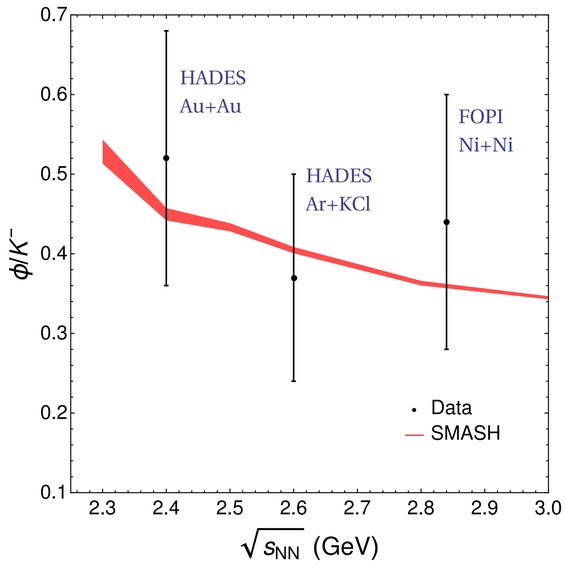
- Important for antikaon production via decays
- ϕ production cross section only measured at threshold



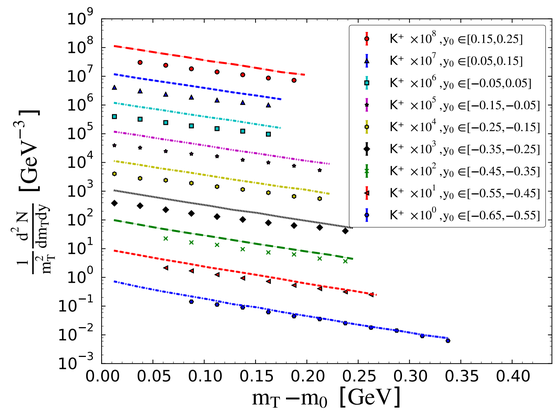
- Dilepton spectrum in p-Nb measured by HADES at 3.5 GeV [3] provides tighter constraints
- Production modeled via $N^* \to \phi N$ (not directly measured):

$$\Gamma(N^* \to \phi N)/\Gamma(N^* \to X) = 0.5\%$$

Strangeness in large systems

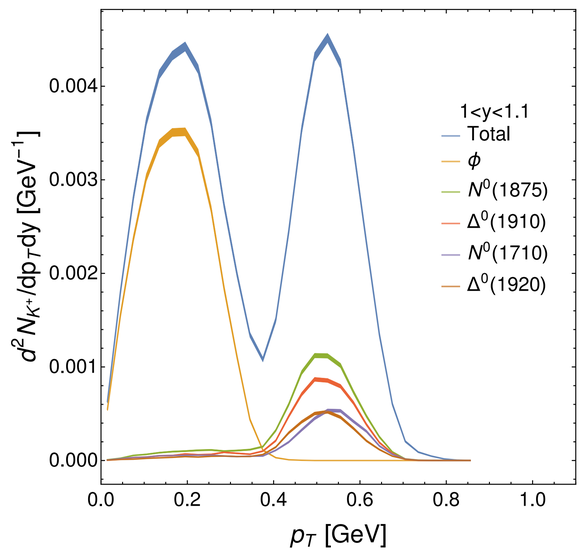


- ϕ/K^- ratio measured by HADES [2] in Au+Au collisions at $E_{\text{kin}} = 1.5A$ GeV compared to SMASH
- Underestimated, but large experimental error



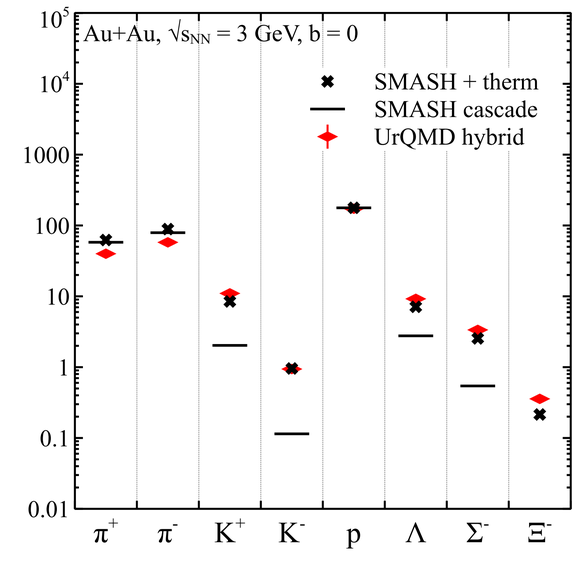
- SMASH K^+ transverse mass spectrum in Au-Au at $1.23A$ GeV compared to HADES results [5]
- Overestimated kaons hint at in-medium effect missing in SMASH?

Pion beam



- Predictions for K^+ transverse momentum spectra in $\pi^- C$ at 1.7 GeV and $1.0 < y < 1.1$
- Sensitive to resonance properties
- Second peak artifact of resonance approach?

Forced thermalization



- Resample particles from thermal distribution in regions above critical energy density [4]
- Strangeness enhancement similar to hybrid approaches including a hydrodynamic evolution, while avoiding typical interface problems

Conclusion

- Low-energy strangeness production can be modeled via resonances and forced thermalization
- Exclusive cross section and dilepton spectra provide good constraints
- Pion beam sensitive to resonance properties

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