Sub Threshold strange hadron production in UrQMD

Jan Steinheimer

22.04.2016

Based on:

J. Steinheimer and M. Bleicher, J. Phys. G **43**, no. 1, 015104 (2016)

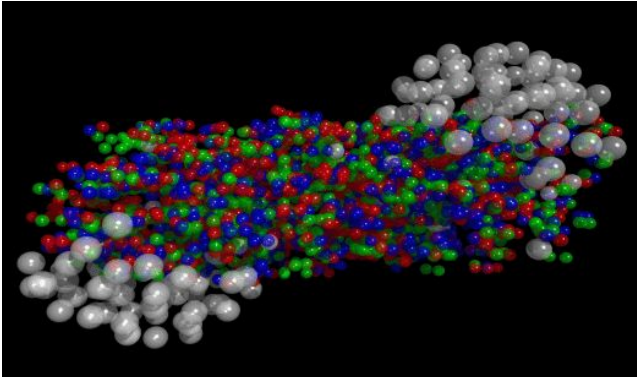
J. Steinheimer, M. Lorenz, F. Becattini, R. Stock and M. Bleicher, arXiv:1603.02051.

FIAS Frankfurt Institute for Advanced Studies

What is UrQMD?

UrQMD is a microscopic transport model

- Calculates the space-time trajectories of 'real' particles.



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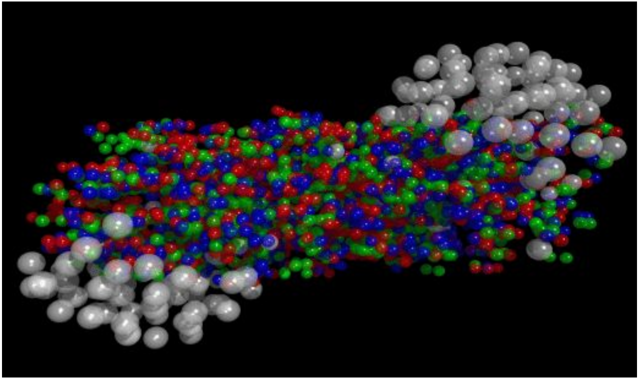

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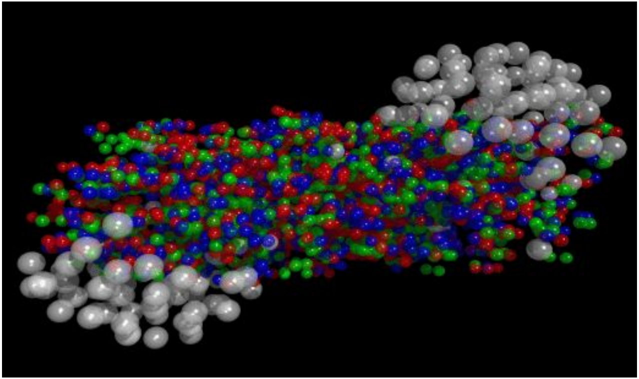
- No long range interactions like potentials.



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- Only $2 \leftrightarrow 2$, $2 \leftrightarrow 1$, $2 \rightarrow N$ and $1 \rightarrow N$ interactions allowed.
- Hadrons interact via scattering according to geometrical interpretation of cross sections.
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- Resonance decays according to PDG values + guesstimates.
- Detailed balance. (Violated in string excitations, annihilations and some dacays)

Strangeness Production in UrQMD

Strange particle production goes ONLY via

- Resonance excitation:
  - N+N→ X
  - N+M→ X
  - M+M→ X

Relevant channels:

1. $NN \to N\Delta_{1232}$
2. $NN \to NN^*$
3. $NN \to N\Delta^*$
4. $NN \to \Delta_{1232}\Delta_{1232}$
5. $NN \to \Delta_{1232}N^*$
6. $NN \to \Delta_{1232}\Delta^*$
7. $NN \to R^*R^*$

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N*(1650)	Δ(1232)
N*(1710)	Δ(1600)
N*(1720)	Δ(1620)
N*(1875)	Δ(1700)
N*(1900)	Δ(1900)
N*(1990)	Δ(1905)
N*(2080)	Δ(1910)
N*(2190)	Δ(1920)
N*(2220)	Δ(1930)
N*(2250)	Δ(1950)
N*(2600)	Δ(2440)
N*(2700)	Δ(2750)
N*(3100)	Δ(2950)
N*(3500)	Δ(3300)
N*(3800)	Δ(3500)
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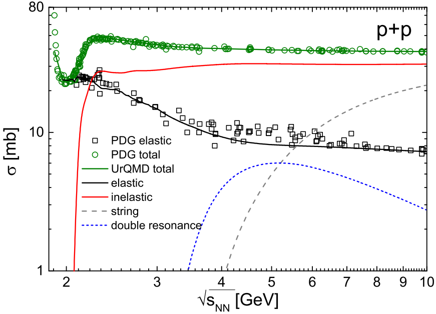

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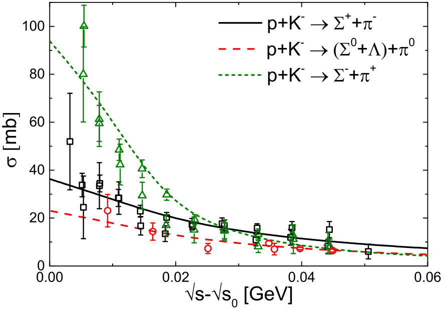
- String excitations

Not relevant at the beam energies considered here

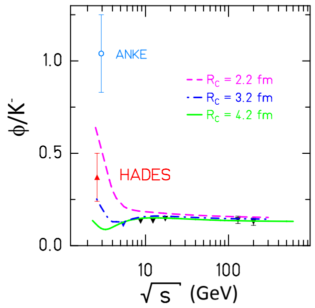
Strangeness exchange reactions

In addition Strange hadrons may be created in strangeness exchange reactions.



Motivation

Recent measurements on near and below threshold production.



ϕ production

HADES and FOPI reported unexpected large ϕ contribution to the K^- yield.

G. Agakishiev *et al.* [HADES Collaboration], Phys. Rev. C **80**, 025209

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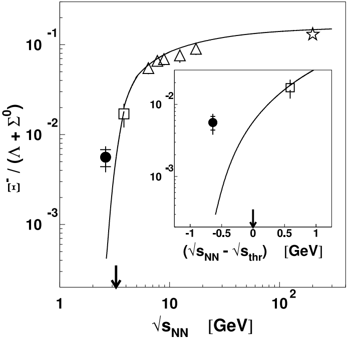

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Ξ^- yield, measured in Ar+KCl much larger than thermal model.
Confirmed in p+Nb → No Y+Y exchange!!

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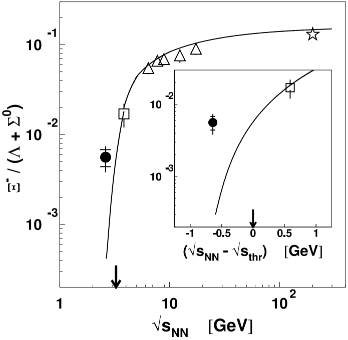

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Both particles are not well described in microscopic transport models and thermal fits are also not convincing.

G. Agakishiev *et al.* [HADES Collaboration], Phys. Rev. Lett. **103**, 132301 (2009)

The notorious $\phi + N$ cross section

Does the ϕ have a small hadronic cross section?

- The idea that the ϕ has a small hadronic cross section is not new.
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- The ϕ would be an important probe of hadronization.
- COSY and LEPS experiments have found large nuclear absorption cross sections

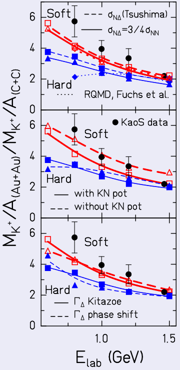
ANKE	SPring-8
14-21 mb	35 mb

M. Hartmann *et al.*, Phys. Rev. C **85**, 035206 (2012)
T. Ishikawa *et al.*, Phys. Lett. B **608**, 215 (2005)

The Kaon-Nuclean potential

An example

Comparisons of K^+ production in different size systems has lead to the conclusion, that the EoS of nuclear matter is soft.



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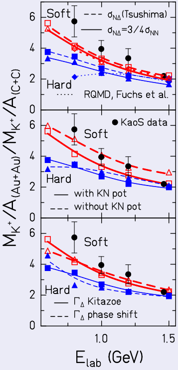

C. Hartnack, H. Oeschler and J. Aichelin, Phys. Rev. Lett. **96**, 012302 (2006)

Lots of work on strangenss

- P.Koch, B.Müller and J.Rafelski, Phys. Rept. 142, 167 (1986).
- J.Randrup and C.M.Ko, Nucl. Phys. A 343, 519 (1980)
- J.Aichelin and C.M.Ko, Phys. Rev. Lett. 55, 2661 (1985).
- W.Cassing, E.L.Bratkovskaya, U.Mosel, S.Teis and A.Sibirtsev, Nucl. Phys. A 614 , 415 (1997)
- C.Hartnack, H.Oeschler, Y.Leifels, E.L.Bratkovskaya and J.Aichelin, Phys. Rept. 510, 119(2012)
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First the ϕ

On the probability of sub threshold production

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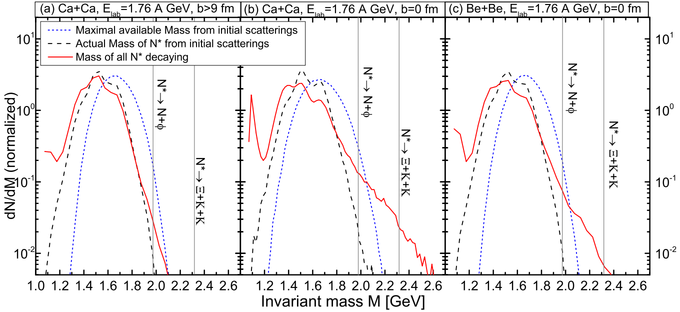

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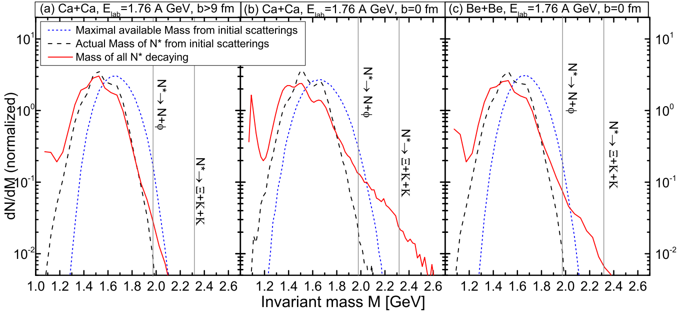
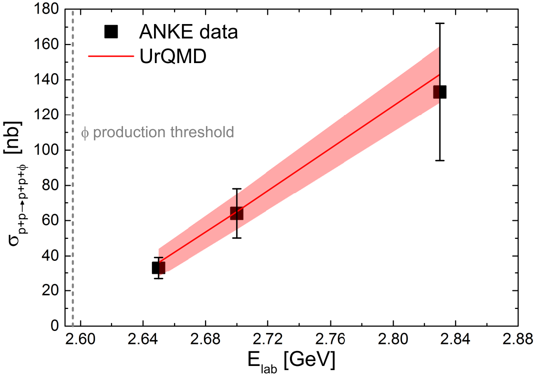


Why not introduce these decays for the less known resonances?

Fixing the $N^* \to \phi + N$ decay with p+p data

We use ANKE data on the ϕ production cross section to fix the $N^* \to N + \phi$ branching fraction.



Only 1 parameter

$\Gamma_{N^* \to N\phi}/\Gamma_{tot} = 0.2\%$

Fits all 3 points!

A. Sibirtsev, J. Haidenbauer and U. G. Meissner, Eur. Phys. J. A **27**, 263 (2006) [arXiv:nucl-th/0512055].

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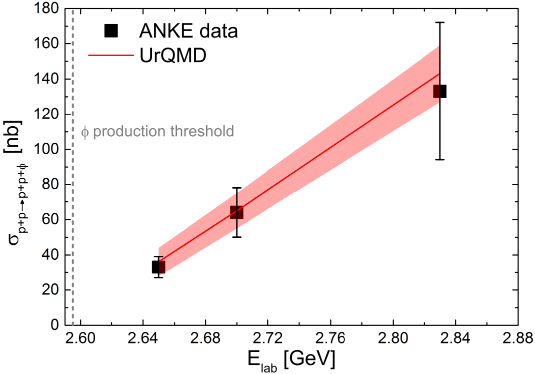

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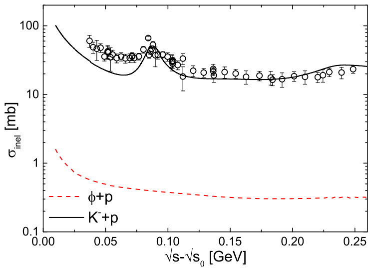
Branching fraction consistent with extracted OZI suppression (from ω/ϕ)
Y. Maeda *et al.* [ANKE Collaboration], Phys. Rev. C **77**, 015204 (2008) [arXiv:0710.1755 [nucl-ex]].

ϕ suppression in nuclear medium

Detailed balanca $\rightarrow$ absorption cross section

- $\phi + p$ cross section from detailed balance is very small.



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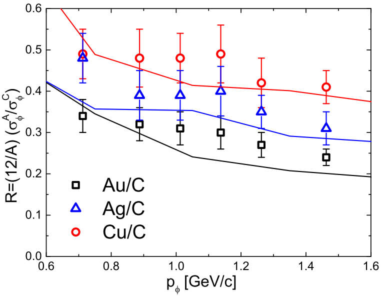

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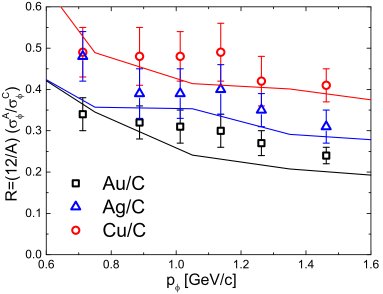

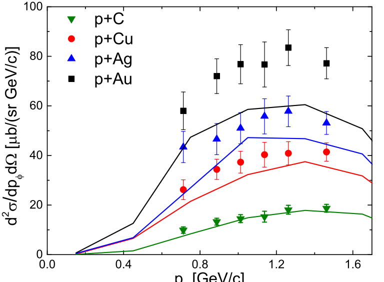

Based on: J. Steinhe

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- Still the transparency ratio is well reproduced. Remember: this is what lead to the 20 mb cross section from ANKE.
- Even the shape of the spectra looks good.
- Not 'absorption' of the ϕ, but of the mother resonance.
- Reactions of the type:
  $N^* + N \to N'^* + N'^*$
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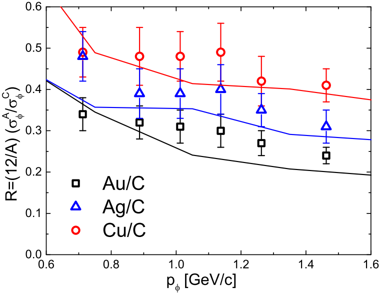
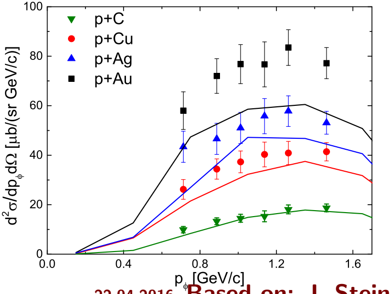
  where the mass of $N'^* < N*$ so no ϕ can be produced.





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ϕ production in nuclear collisions below the p+p threshold

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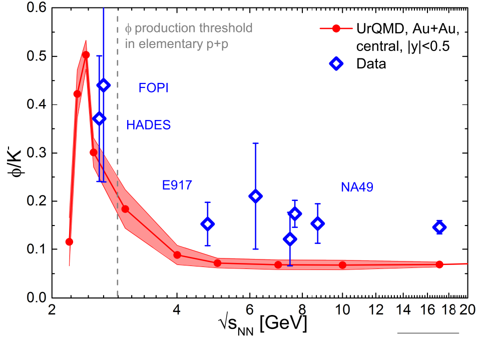

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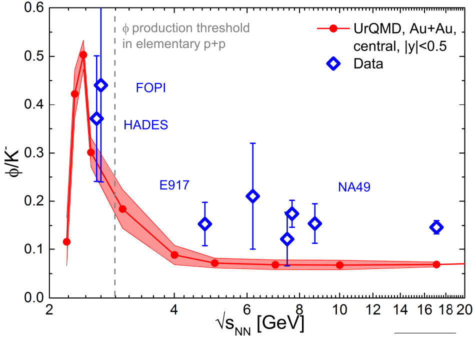

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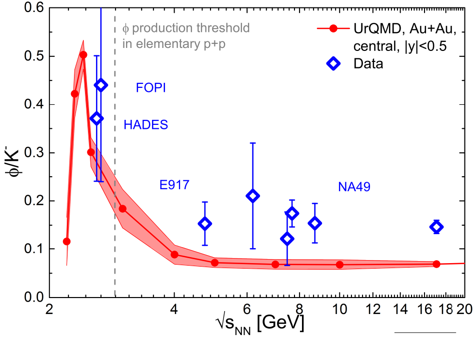

- Qualitative behavior nicely reproduced
- Predicted maximum at 1.25 A GeV
- High energies: too low due to string production
- HADES preliminary results for 1.23 A GeV, see H. Schuldes talk.

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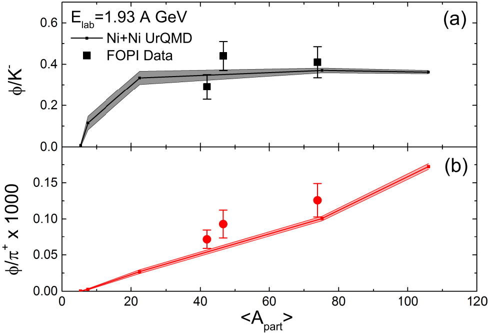
ϕ production in nuclear collisions below the p+p threshold

Even centrality dependence works well:



Data from: K. Piasecki et al., arXiv:1602.04378 [nucl-ex].

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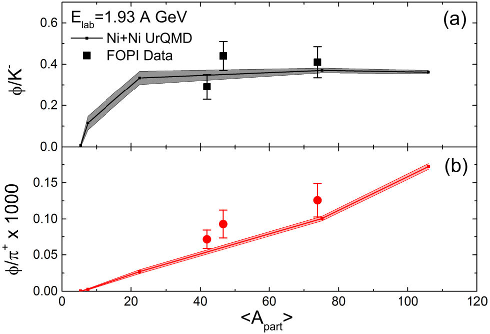

- Centrality dependence nicely reproduced.
- Good indicator for multi step production.

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About the Kaon potential

Kaon Potentials

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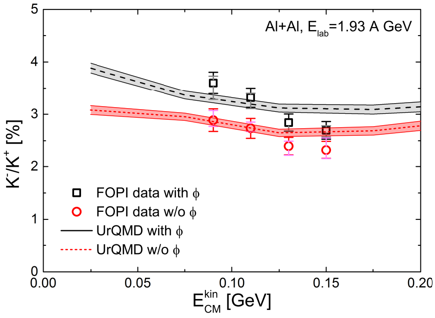

UrQMD results

- K^-/K^+ ratio as function of Kaon energy.
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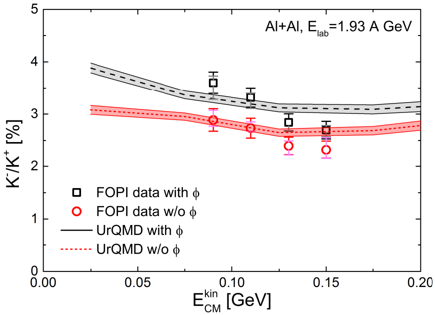

UrQMD results

- K^-/K^+ ratio as function of Kaon energy.
- With and without the ϕ the ratio is much closer to the data already as in a comparable HSD study.
- Can we make robust quantitative statements?

Based on: J. Steinhe

Now the Ξ

How to fix the $N^* \rightarrow \Xi^- + K + K$ decay?

No elementary measurements near threshold.

We use p+Nb at $E_{\mathrm{lab}} = 3.5$ GeV data $\rightarrow \Gamma_{N^* \rightarrow \Xi + K + K} / \Gamma_{tot} = 3.0\%$

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$\langle \Xi^- \rangle$	Ξ^-/Λ
$(2.0 \pm 0.3 \pm 0.4) \times 10^{-4}$	$(1.2 \pm 0.3 \pm 0.4) \times 10^{-2}$
UrQMD	
$\langle \Xi^- \rangle$	Ξ^-/Λ
$(1.44 \pm 0.05) \times 10^{-4}$	$(0.71 \pm 0.03) \times 10^{-2}$

Table: Ξ^- production yield and Ξ^-/Λ ratio for minimum bias $p + Nb$ collision at a beam energy of $E_{\rm lab} = 3.5$ GeV, compared with recent HADES results

Note:

G. Agakishiev *et al.*, arXiv:1501.03894 [nucl-ex].

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Note:

- Branching ratio seems large, however may be contributed to the limited number of heavy states in the model.

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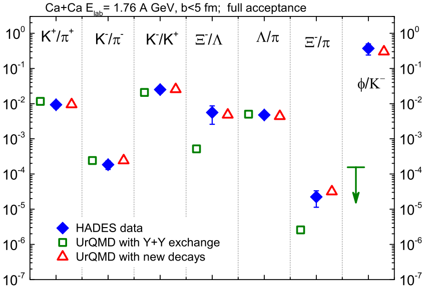
Ξ^- production in nuclear collisions below the p+p threshold



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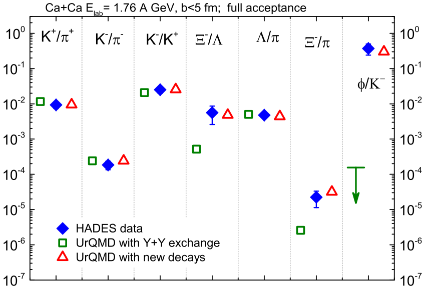

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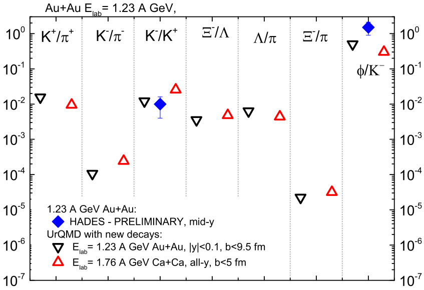
- Consistent with the p+Nb data.
- Indication for Ξ production from non-thermal 'tails' of particle production.
- All other strange particle ratios are also in line with experiment

Predictions for Au+Au at $E_{\mathrm{lab}} = 1.23$ A GeV

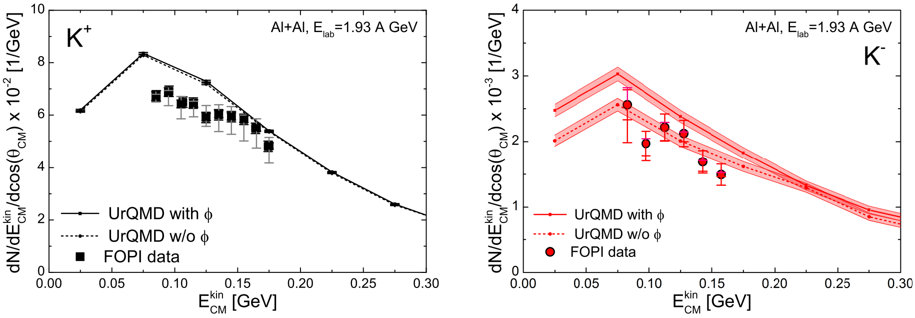


Ξ^-/Λ does not decrease much.

Summary

- We introduced a new mechanism of ϕ and Ξ production in elementary and nuclear collisions, through the decay of heavy resonances.
- We can nicely describe the ϕ and Ξ^- production in elementary and nuclear collisions near and below the ϕ production threshold.
- To successfully describe Ξ^- production in p+Pb and Ar+KCl reactions a large branching fraction of 10% is required.

Backup



K+
Al+Al, E_lab=1.93 A GeV
dN/dE_CM^kin/dcos(θ_CM) x 10^-2 [1/GeV]
E_CM^kin [GeV]
UrQMD with ϕ
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K-
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E_CM^kin [GeV]
UrQMD with ϕ
UrQMD w/o ϕ
FOPI data