

30.6.17

Universal Strangeness Production and Color Deconfinement

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Joint work with P. Castorina and S. Plumari

Strangeness in Quark Matter

Utrecht/Netherlands, July 11, 2017

SQM Meetings: what is the effect of QGP formation on strange hadron production in high energy collisions?

Müller, Rafelski 1982

⇒ Empirical answer, leave theory as exercise.

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Relative Hadron Abundences in High Energy Collisions

Ideal gas of hadrons and resonances,
at temperature T , baryochemical potential μ .

In elementary collisions (pp, e^+e^-) up to RHIC energy and
in nuclear collisions up to SPS energies:
overprediction of strange hadron production.

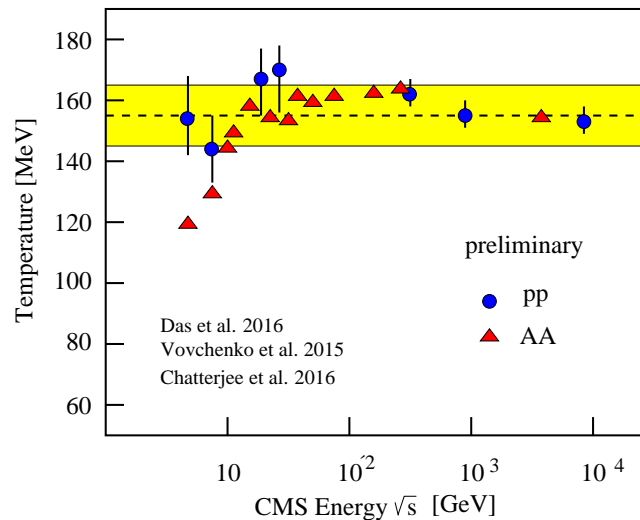
strangeness suppression factor γ_s , with γ_s^ν for hadrons with
 $\nu = 0, 1, 2, 3$ strange quarks

Letessier, Rafelski, Tounsi 1994

Ideal gas of hadrons and resonances, at temperature T ,
baryochemical potential μ , strangeness suppression γ_s ,
gives excellent agreement for abundances at all energies,
all collision configurations (e^+e^- , pp , pA , AA)

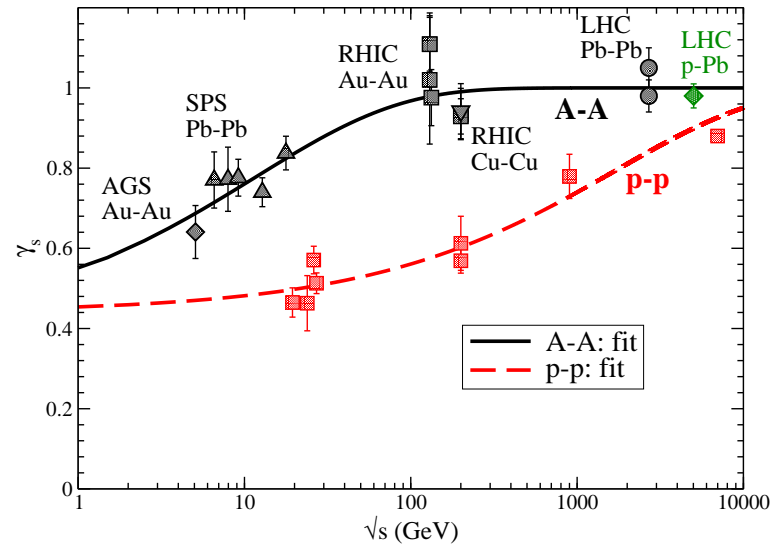
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For $\sqrt{s} \geq 10$ GeV, $T \simeq 160 \pm 10$ MeV, for pp and AA ,
 independent of μ , in accord with the color deconfinement
 temperature $T_c = 155 \pm 10$ MeV from lattice QCD.



For AA below 10 GeV, increasing μ , decreasing T .

Strangeness suppression as function of \sqrt{s} much stronger in pp than in AA :



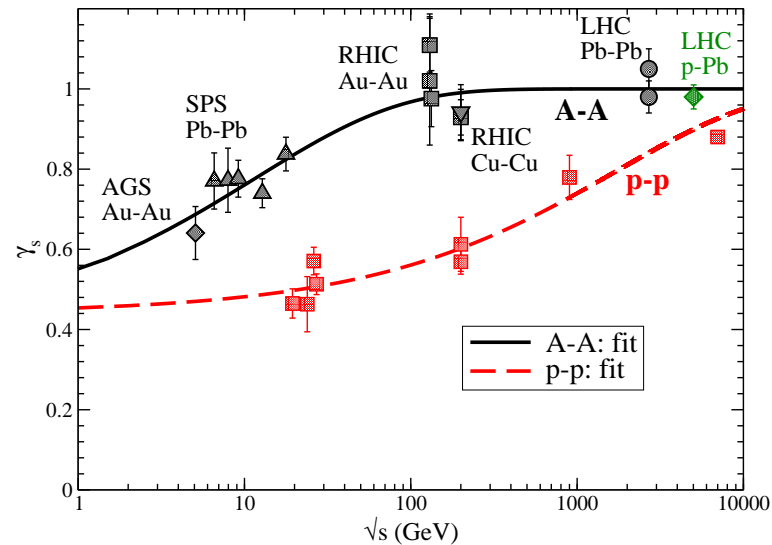
Becattini

fit curves for pp : $\gamma_s^p(s) = 1 - c_p \exp(-d_p s^{1/4})$,

for AA : $\gamma_s^A(s) = 1 - c_A \exp(-d_A \sqrt{A\sqrt{s}})$,

with $c_p = 0.5595$; $d_p = 0.0242$; $c_A = 0.606$, $d_A = 0.0209$.

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Is there a unified description of strangeness suppression?

Consider γ_s as function of pre-thermal or thermal variable.

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- color glass condensate: parton density in transverse plane

$$D = \frac{1}{A} \left(\frac{dN_h}{dy} \right)_{y=0}$$

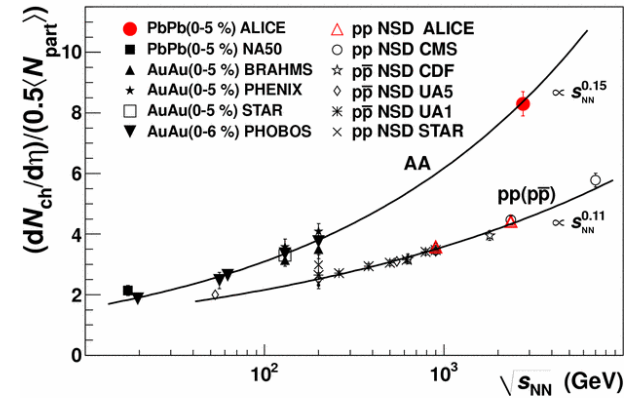
- 1d hydro (Bjorken) \Rightarrow initial entropy density s_0

$$s_0 \tau_0 \simeq \frac{1.5 A^x}{\pi R_x^2} \left(\frac{dN_{ch}}{dy} \right)_{y=0}^x, \text{ with } x \sim pp, pA, AA,$$

multiplicities measured and fitted:

$$\left(\frac{dN}{dy} \right)_{y=0}^{AA} = a_A (\sqrt{s})^{0.3} + b_A$$

$$\left(\frac{dN}{dy} \right)_{y=0}^{pp} = a_p (\sqrt{s})^{0.22} + b_p$$

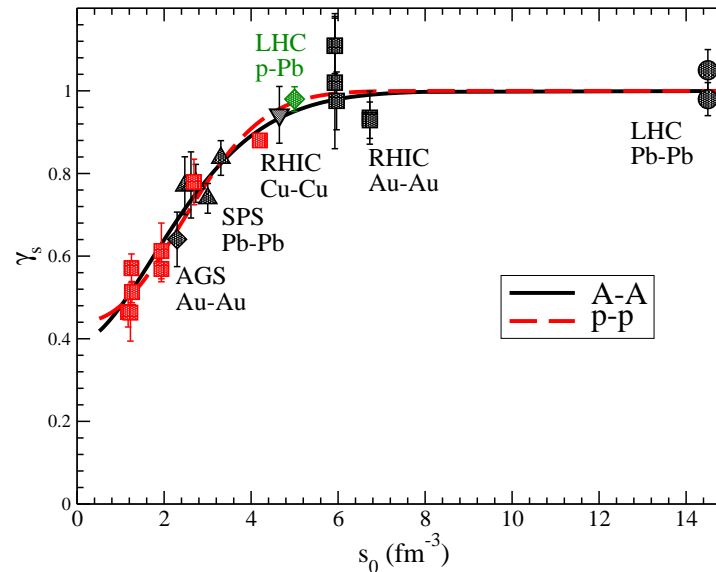


ALI-PUB-15

$$a_A = 0.7613, b_A = 0.0534; a_p = 0.797; b_p = 0.04123.$$

Now have strangeness suppression factor $\gamma_s(s)$ and initial entropy density $s_0(s)$; eliminate s to get $\gamma_s(s_0)$:

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as function of the initial entropy density, the pp and AA curves for γ_s coincide, all data fall on the same curve:

universal strangeness suppression

in particular: $\gamma_s \rightarrow 1$ also for high energy pp collisions

Castorina, HS 2016

Lattice QCD studies \Rightarrow initial entropy density vs. initial temperature T

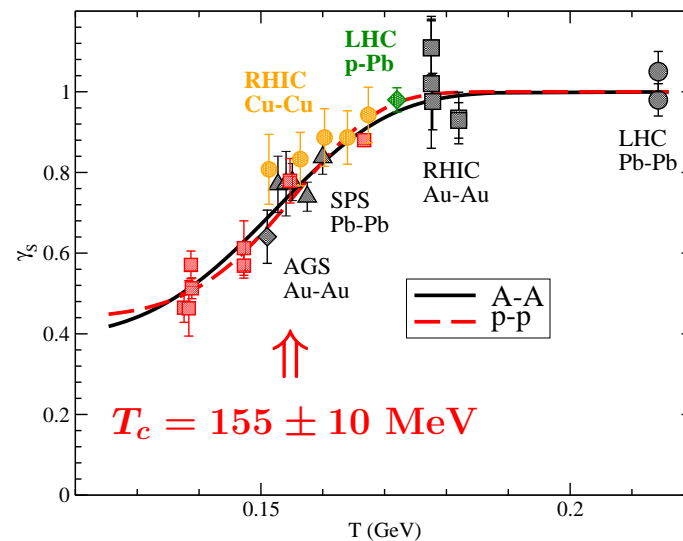
Bazazov et al. (HotQCD) 2014

obtain strangeness suppression factor $\gamma_s(T)$:

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Conclusion:

- Strangeness suppression is a universal function of initial thermal state.
- Strangeness suppression vanishes with the onset of color deconfinement.

Castorina, Plumari, HS 2017

Remaining theoretical questions:

- Why is there suppression in hadronic regime?
- Why does the suppression vanish with deconfinement?
- How can final state (freeze-out) provide information on initial state (thermalization)?

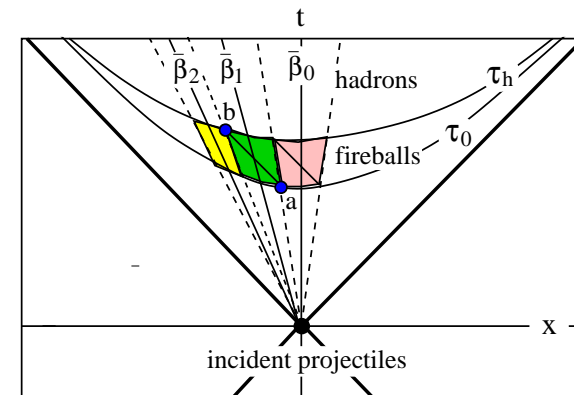
How can gas remember it was liquid an hour ago?

Local strangeness conservation $V_s < V \Rightarrow$ suppression of strangeness production.

Hamieh, Redlich, Tounsi 2000

Causality structure of production evolution \Rightarrow spatial restriction to strangeness conservation.

Castorina, HS 2013



Memory transmission:
canonical \rightarrow grand canonical ensemble?