Color Confinement and Strangeness Production

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Joint work with P. Castorina and S. Plumari

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QCD Phase Boundary and Heavy Ion Collisions:

“normal” hadrons are on this side of boundary

possible tool to check boundary: effect of QGP formation on strange hadron production in high energy collisions?

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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

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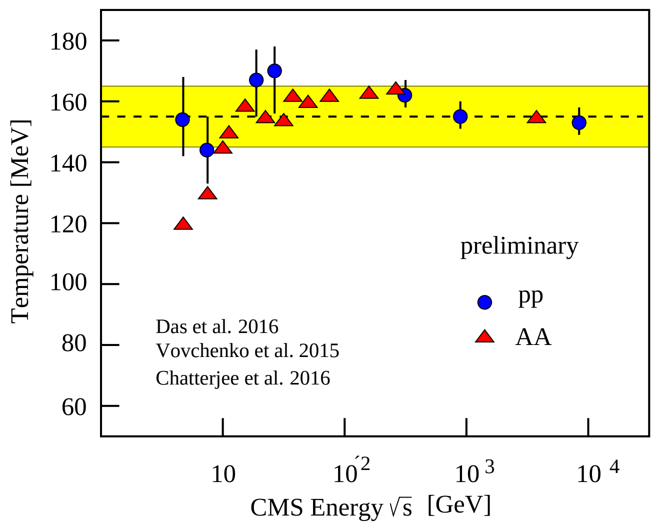
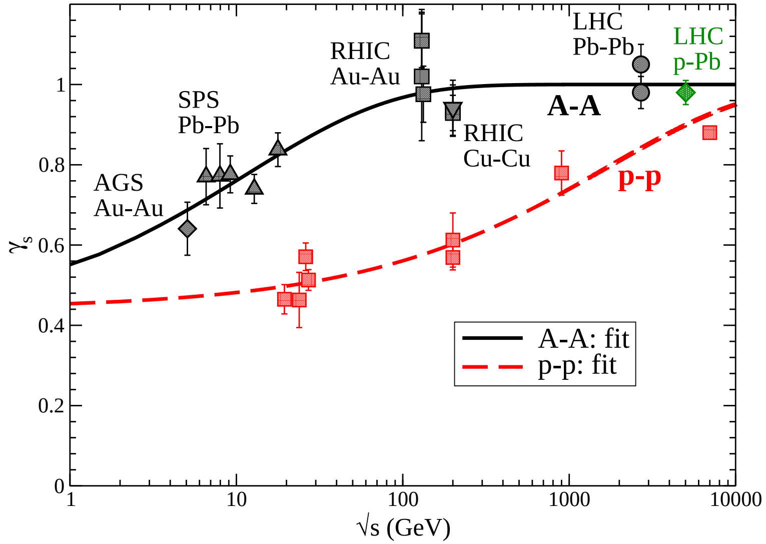
For $\sqrt{s} \geq 10$ GeV, $T \simeq 160 \pm 10$ MeV, for pp and AA, independent of μ, in accord with the color deconfinement temperature $T_c = 155 \pm 10$ MeV from lattice QCD.



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: $\gamma_s^p(s) = 1 - c_p \exp\left(-d_p s^{1/4}\right)$,
for AA: $\gamma_s^A(s) = 1 - c_A \exp\left(-d_A \sqrt{A\sqrt{s}}\right)$,
with $c_p = 0.5595$; $d_p = 0.0242$; $c_A = 0.606$, $d_A = 0.0209$.

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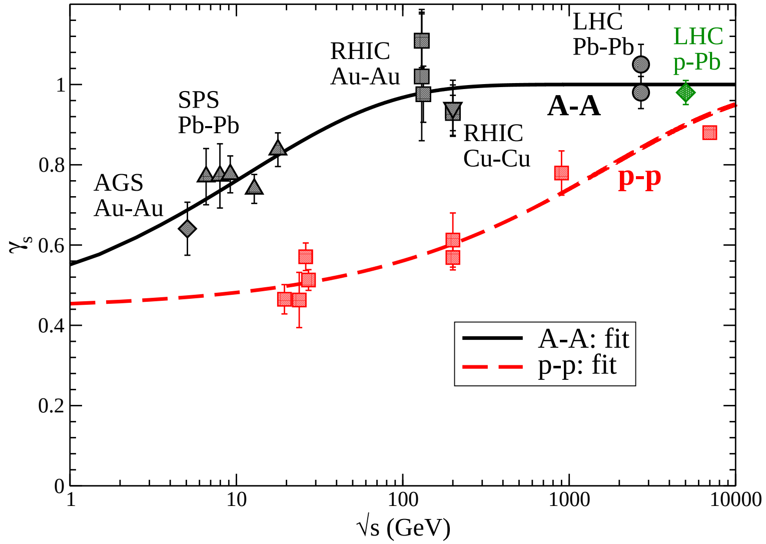

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Is there a unified description of strangeness suppression?

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

Castorina, Plumari, HS 2016/2017

• color glass condensate: parton density in transverse plane

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

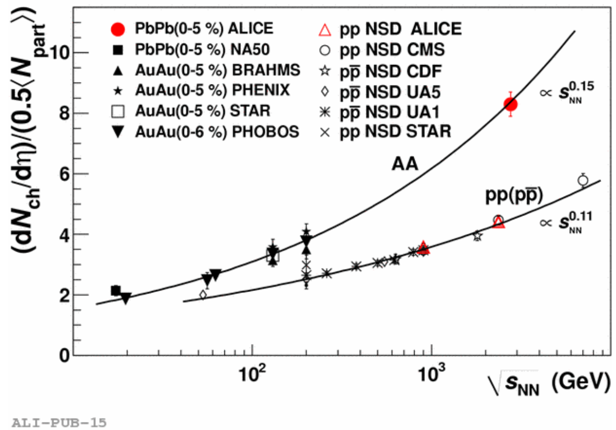
• 1d hydro (Bjorken) $\Rightarrow$ initial entropy density s_0

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

multiplicities measured and fitted:

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

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



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

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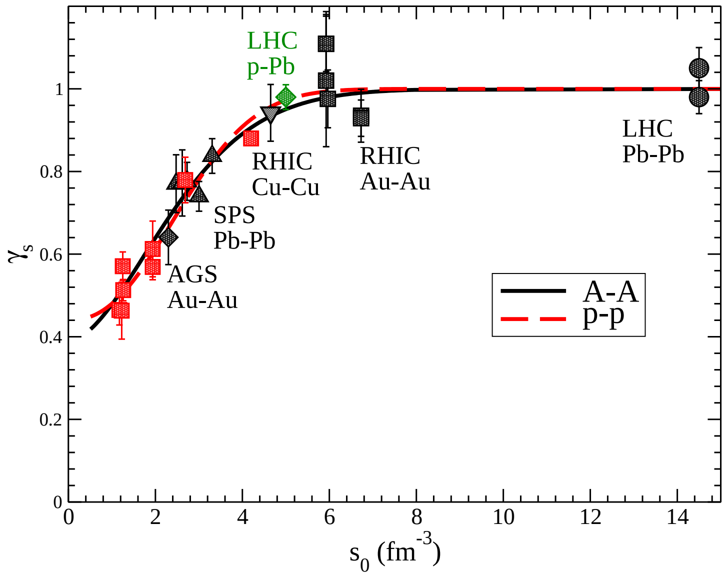

as function of the initial entropy density, the pp and AA curves for γ_s coincide, all data fall on the same curve:

<u>universal strangeness suppression</u>

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

Castorina, HS 2016

Lattice QCD studies ⇒ initial entropy density vs. initial temperature T Bazazov et al. (HotQCD) 2014

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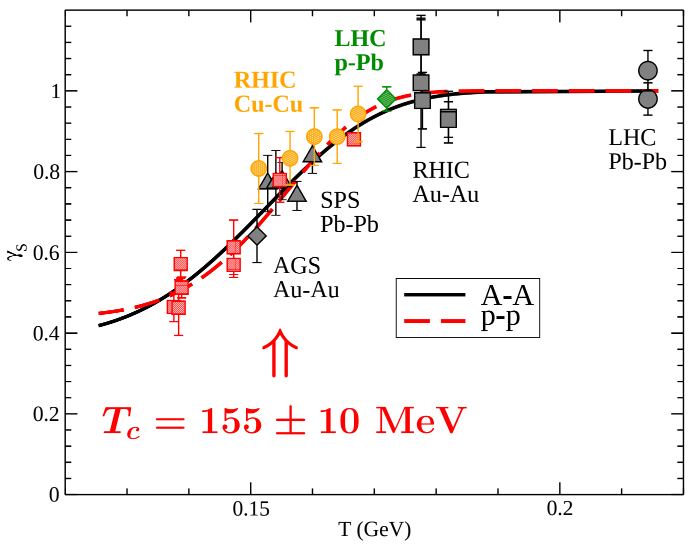


<u>Conclusion</u>:

• 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)?

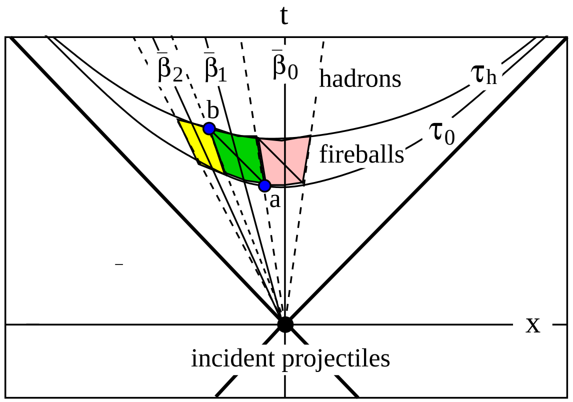
How can gas remember it was liquid an hour ago?

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?