On Hypernuclear State in High Energy Heavy Ion Collisions

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Content

- NA-49 results:
  - Strange to non-strange yield ratio: ‘horn’ effect
  - Spectra of kaons
- Models describing the ‘horn’ effect.

My proposal:

Action-Reaction mechanism in **HIC**:

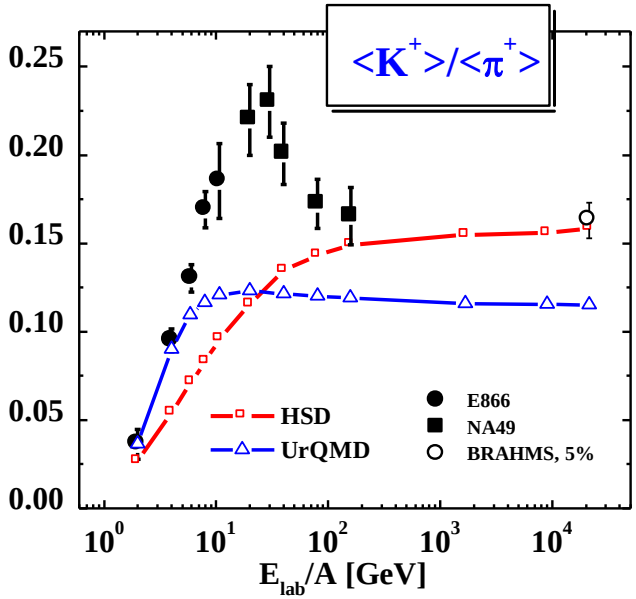
- **Initial state**
- **Overlap time**
- Discussion

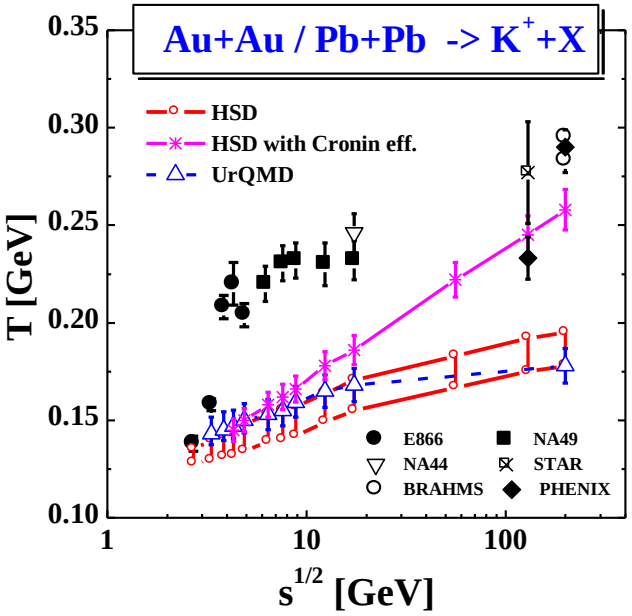
K/π and Λ/π ratio in central Pb-Pb collisions (**NA49**)

Clear evidence for horn structure in K^+/pi^+ and Lambda/pi+

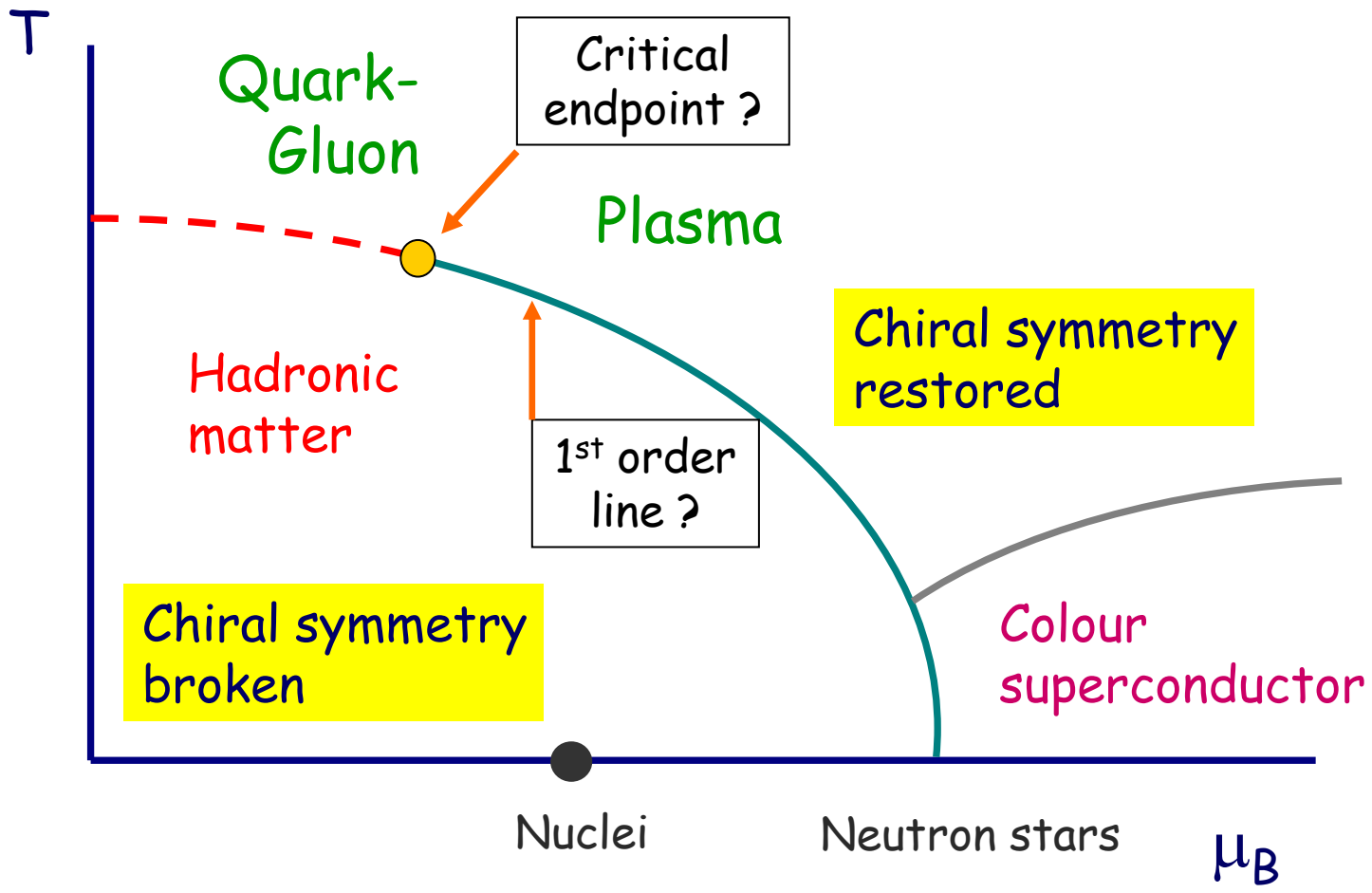
No horn structure in K^-/pi^-

Transport models fail to describe exp. data





Mixed Phase? Critical Endpoint?



Models

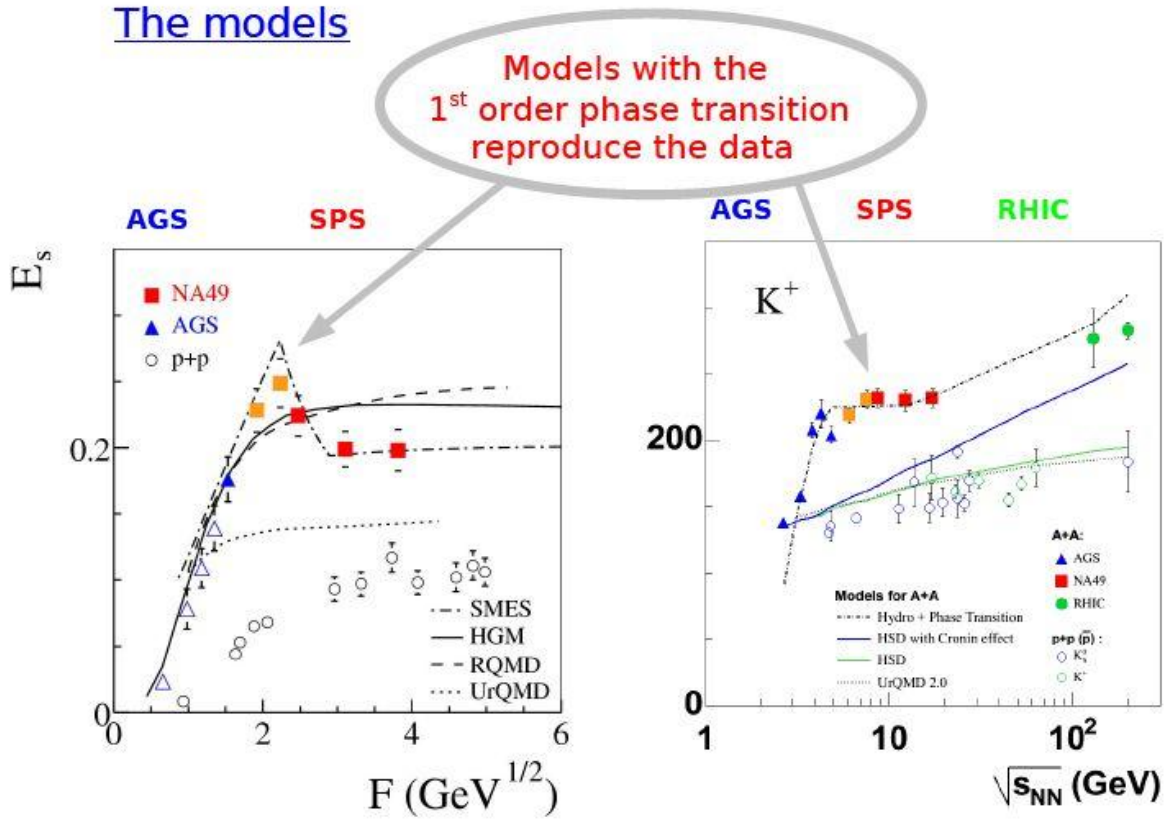
SMES *M. Gazditzki, M. Gorenstein*

Thermal-Statistical Model *P. Brawn-Munzinger, et al.*

Hadronic Kinetic Model *E. Kolomeitsev, B. Tomasic*

Models

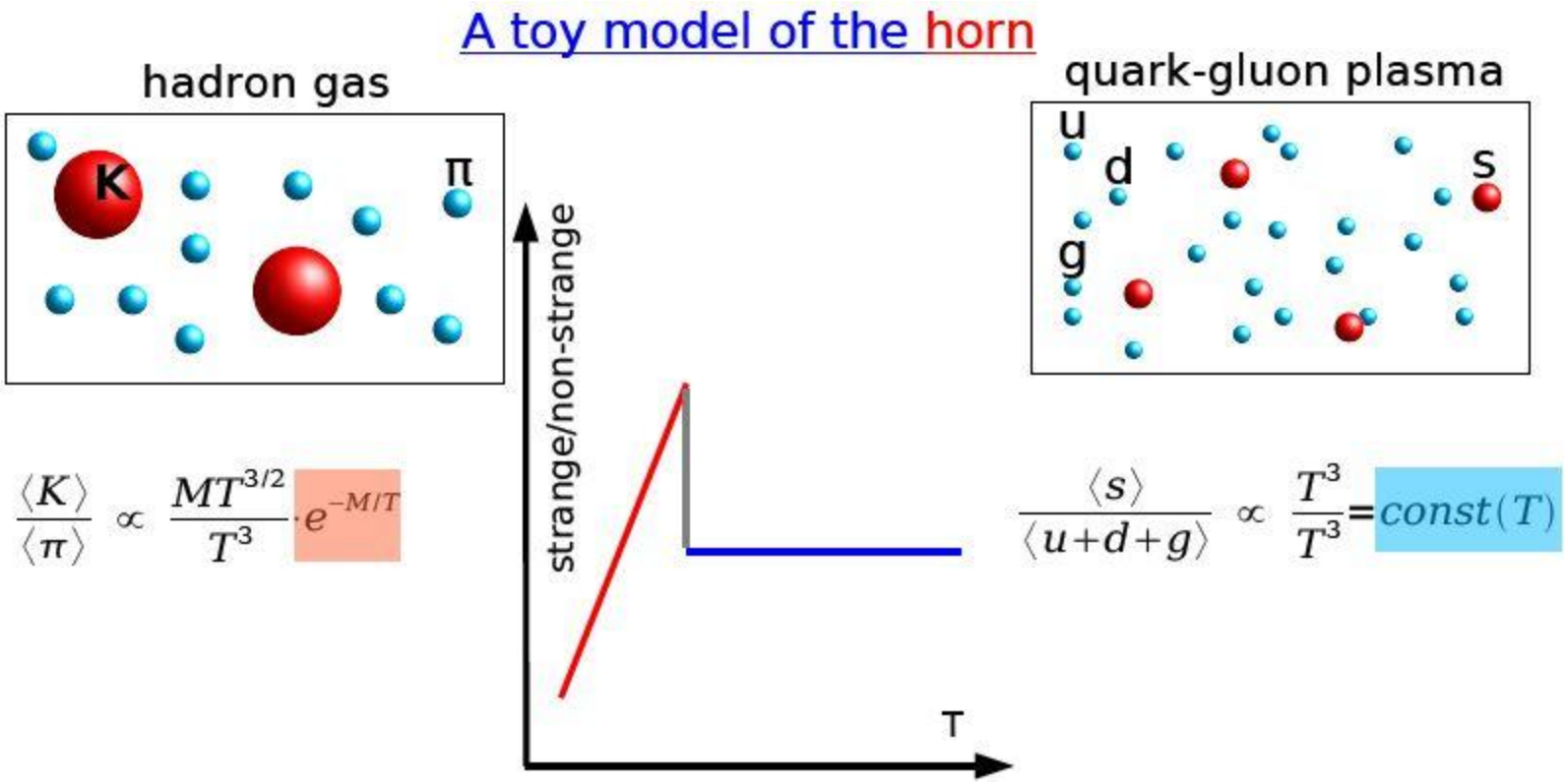
SMES *M. Gazditzki, M. Gorenstein*



$$E_S = (\langle \Lambda \rangle + \langle K + \overline{K} \rangle) / \langle \pi \rangle$$

Models

SMES *M. Gazditzki, M. Gorenstein*

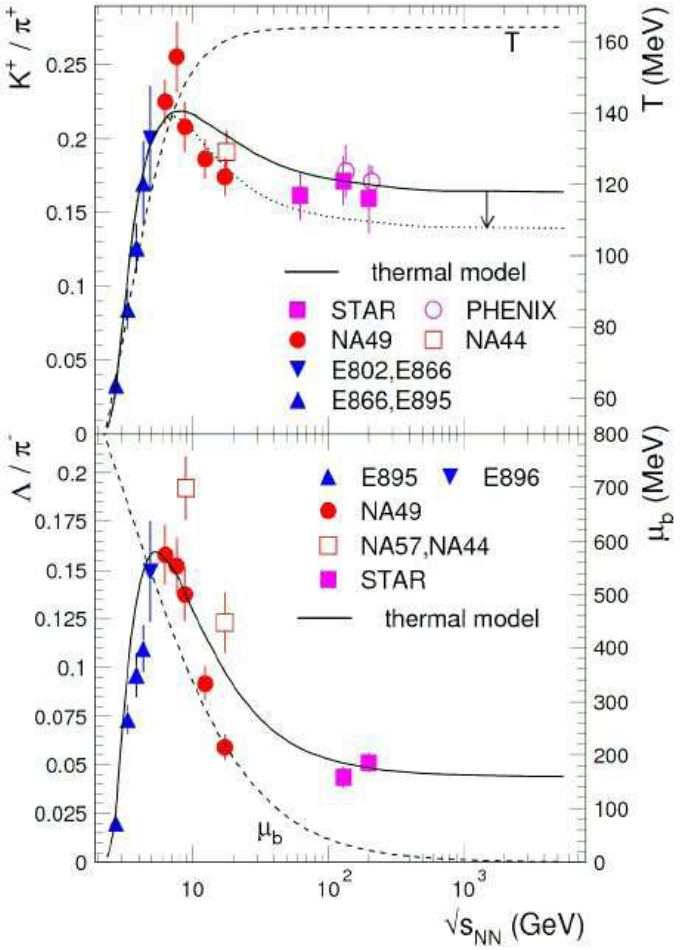


Models

Thermal-Statistical Model *P. Brawn-Munzinger, et al.*

„Horn“ is described as an interplay between QGP phase boundary and the higher resonance spectrum.

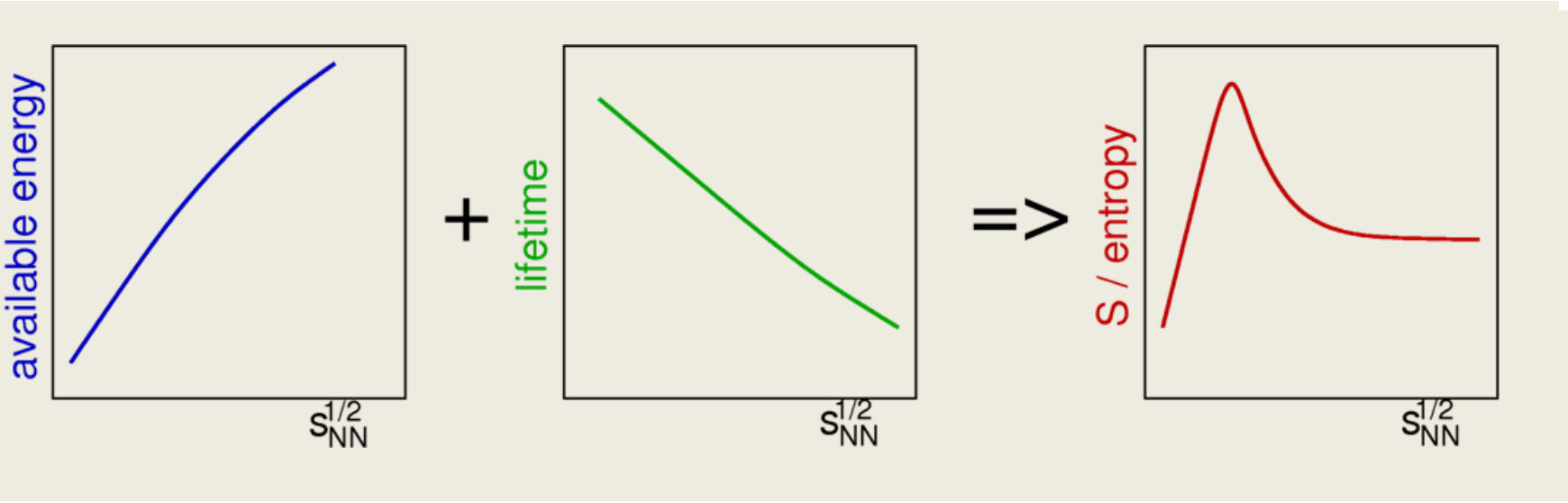
Higher resonances in conjunction with additional pions from the sigma describes “horn” structure well



Models

Non-equilibrium Kinetic Model *E. Kolomeitsev, B. Tomasik*

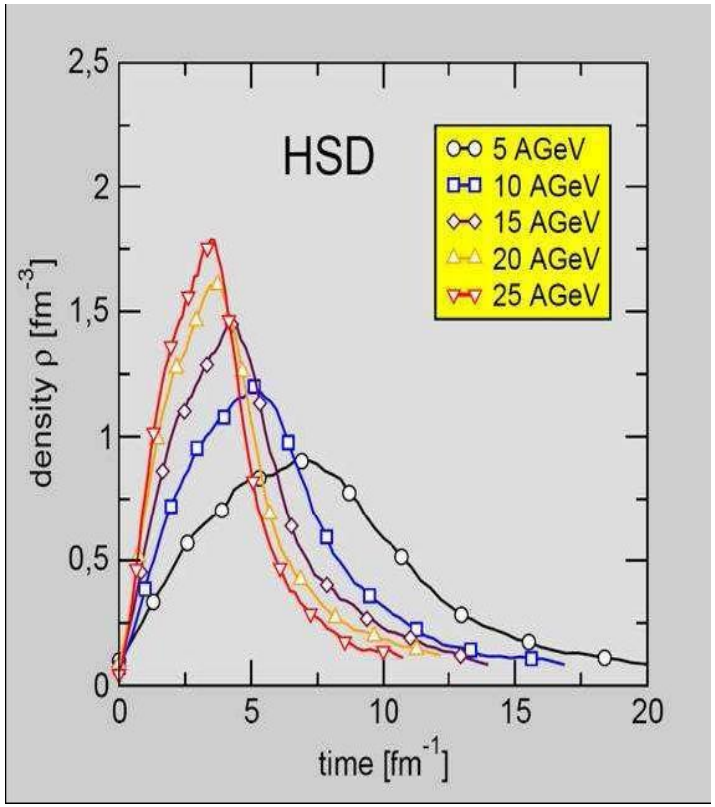
energy vs. time



Action-Reaction Mechanism in HIC

Baryon density evolution

At NICA energies ρ/ρ_0 ~ 5 - 10

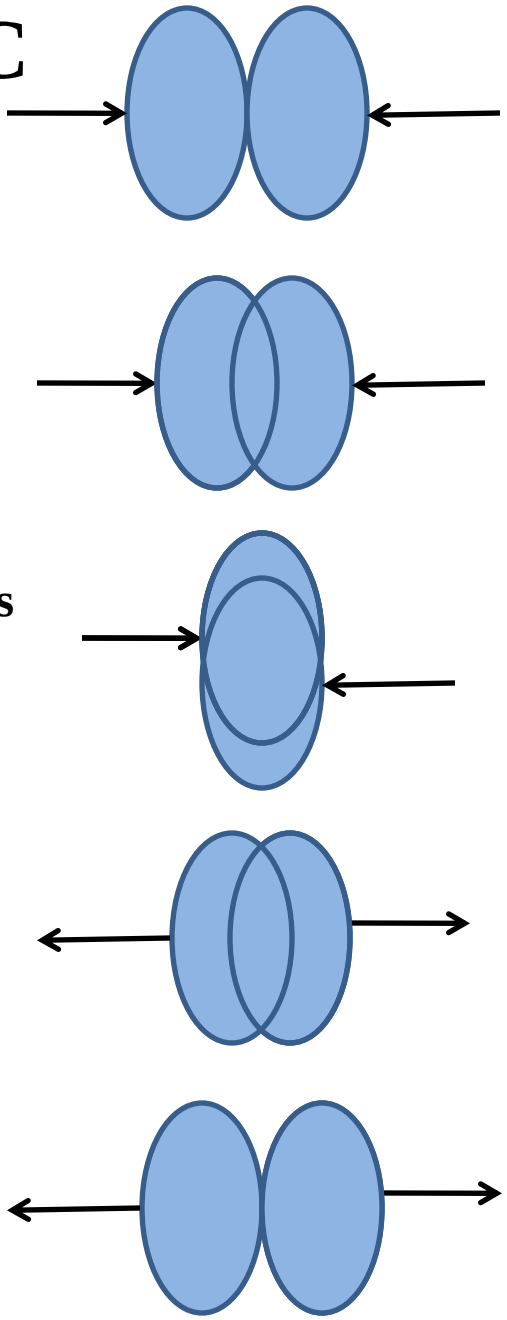


- **At NICA energies ρ/ρ_0 ~ 5 – 10.**

- **In overlap region nucleons are suppressed and forced to occupy much less space volume.**

- **Overlap time:**

$$\tau_O = 2R_A/(\gamma v)$$



Action-Reaction Mechanism in HIC

Conjecture 1:

In dense nuclear matter the baryon number conserves locally (nucleon is a topological soliton).

How can baryons conserve their identity in a smaller volume inside a suppressed medium?

Answer : according to action-reaction mechanism.

Conjecture 2:

- **With a definite probability nucleons in the overlap region transform into hyperons (the heavier quark content of a baryon the less the spatial dimensions of it)**

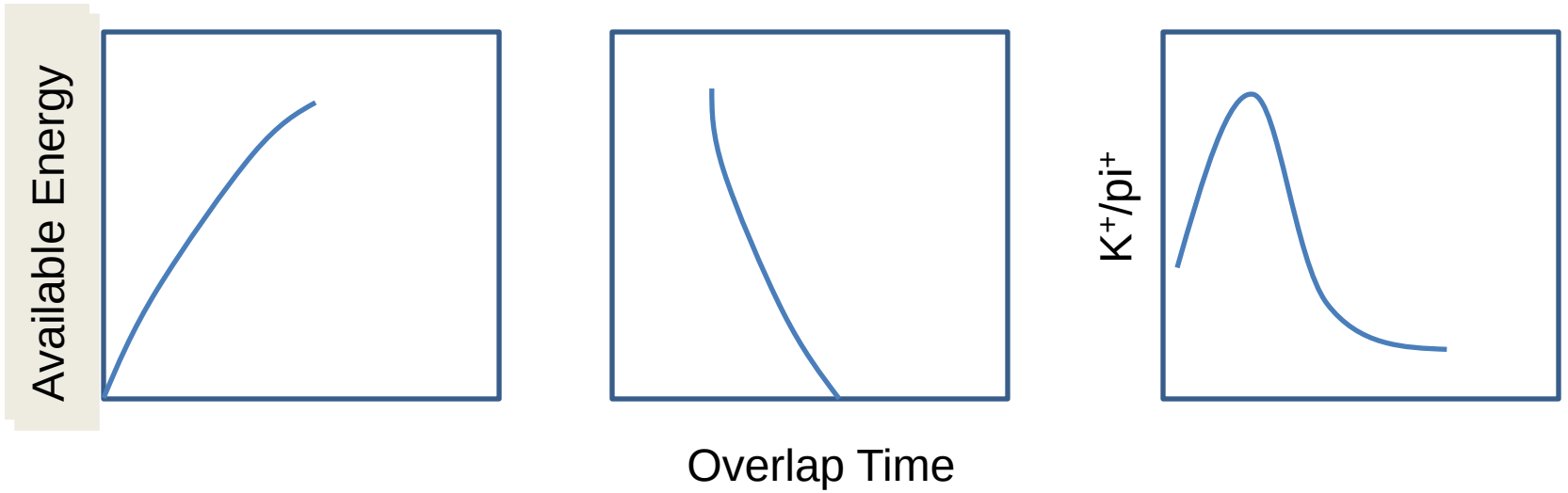
$$p, n \rightarrow \text{hyperons} + \text{kaons}$$

Conjecture 3:

- **All spins of quarks both in hyperons and kaons should be parallel (hyperons and kaons oppose to the external suppression)**

Action-Reaction Mechanism in HIC

Energy vs. time



Proton Transformations

$$p = (uud), \quad n = (ddu), \quad u, d \to s$$

$$\left.\begin{aligned} p(uud) &\to \Sigma^{+*}(uus) + K^{0*}(d\bar{s}) \\ &\to \Sigma^{0*}(uds) + K^{+*}(u\bar{s}) \end{aligned}\right\} \begin{aligned} S &= -1 \\ I &= 1 \end{aligned}$$

$$\left.\begin{aligned} &\to \Xi^{-*}(dss) + 2K^{+*}(u\bar{s}) \\ &\to \Xi^{0*}(uss) + K^{0*}(d\bar{s}) + K^{+*}(u\bar{s}) \end{aligned}\right\} \begin{aligned} S &= -2 \\ I &= \frac{1}{2} \end{aligned}$$

$$\left.\begin{aligned} &\to \Omega^{-}(sss) + 2K^{+*}(u\bar{s}) + K^{0*}(d\bar{s}) \end{aligned}\right\} S = -3, \; I = 0$$

$$K^{0/+*} \to K^{0/+} + \pi^{0}$$

Neutron Transformations

$$n(ddu) \rightarrow \Sigma^{-*}(dds) + K^{+*}(u\bar{s}) \qquad \left.\begin{array}{l} S = -1 \\ I = 1 \end{array}\right\}$$

$$\rightarrow \Sigma^{0*}(uds) + K^{0*}(d\bar{s})$$

$$\rightarrow \Xi^{0*}(uss) + 2K^{0*}(d\bar{s}) \qquad \left.\begin{array}{l} S = -2 \\ I = \frac{1}{2} \end{array}\right\}$$

$$\rightarrow \Xi^{-*}(dss) + K^{0*}(d\bar{s}) + K^{+*}(u\bar{s})$$

$$\rightarrow \Omega^{-}(sss) + 2K^{0*}(d\bar{s}) + K^{+*}(u\bar{s}) \qquad \left.\begin{array}{l} \\ \end{array}\right\} S = -3,\ I = 0$$

$$K^{0/+*} \rightarrow K^{0/+} + \pi^{0}$$

Hyperon Resonances Decay

$$\Sigma^{0*} \rightarrow \Lambda + \pi^0 \quad 88\%$$
$$\rightarrow \Sigma^0 + \pi^0 \; 12\%$$
$$\Sigma^{+*} \rightarrow \Lambda + \pi^+ \quad 88\%$$
$$\rightarrow \Sigma^+ + \pi^0 \; 12\%$$

$$\Xi^{0*} \rightarrow \Xi^0 + \pi^0$$
$$\Xi^{-*} \rightarrow \Xi^{-0}$$

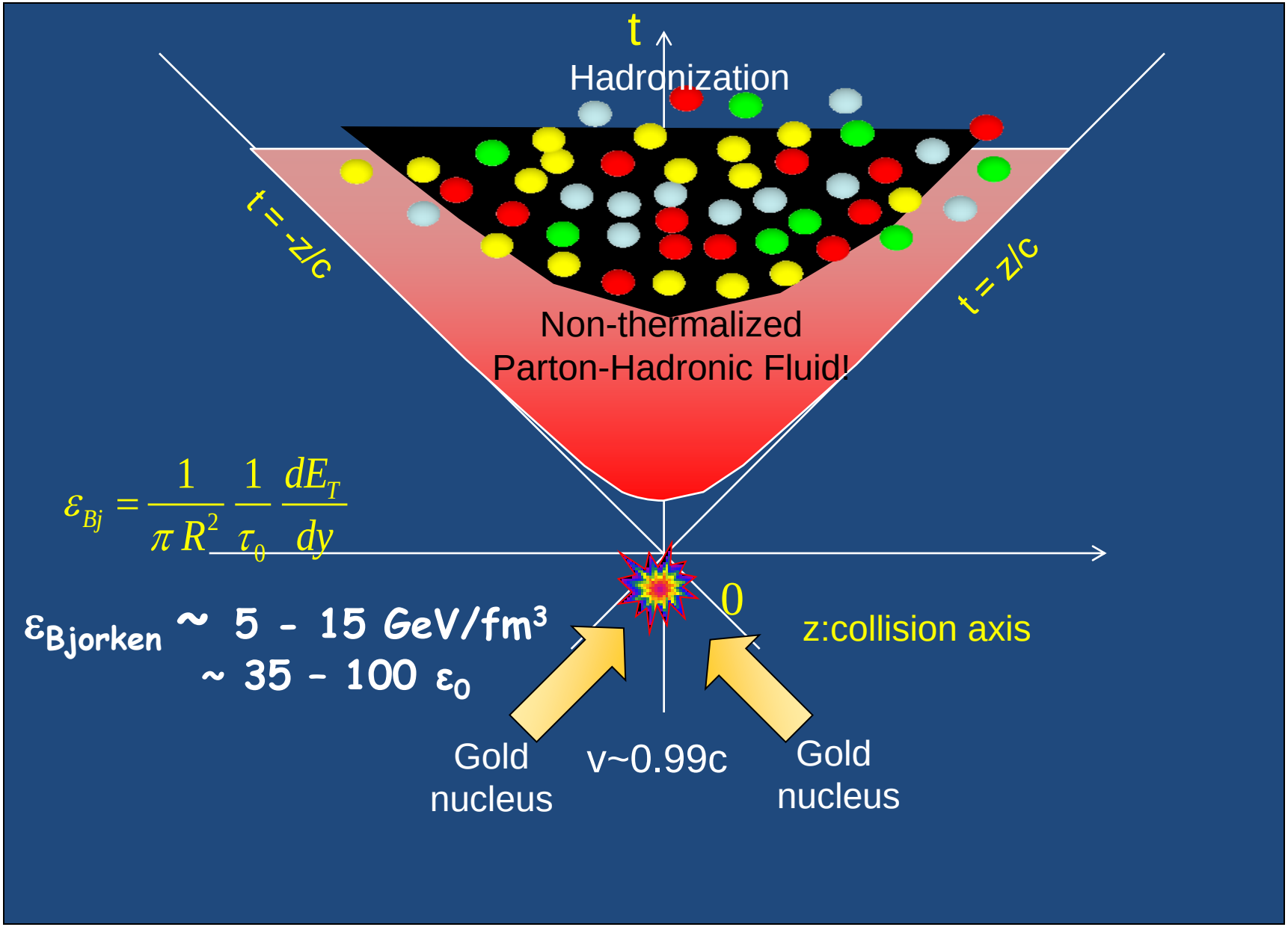
$$\Omega^- \rightarrow \Lambda + K^- \quad 68\%$$
$$\rightarrow \Xi^0 + \pi^- \quad 24\%$$
$$\rightarrow \Xi^- + \pi^0 \quad 8\%$$

Action-Reaction Mechanism at RHIC and LHC

Early stage of the fireball evolution:

- Very high medium density

- Predominant production of (heavy) vector resonances at the early (high density) stage of the fireball evolution.


t
Hadronization
t = -z/c
t = z/c
Non-thermalized
Parton-Hadronic Fluid!
$\varepsilon_{Bj} = \frac{1}{\pi R^2}\frac{1}{\tau_0}\frac{dE_T}{dy}$
$\varepsilon_{Bjorken}$ ~ 5 - 15 GeV/fm^3
~ 35 - 100 ε_0
0
z:collision axis
Gold nucleus
v~0.99c
Gold nucleus

Conclusions

Consequences of the AR mechanism:

- **Bad News**
- **Good News**

Conclusions

Bad News

Early stage of the fireball evolution:

- Predominant production of (heavy) vector resonances at the early (high density) stage of the fireball evolution.
- Perhaps, this impacts the fireball the features of the ideal liquid.

QGP at FAIR and NICA and even at RHIC and LHC energies is not realized:

- No room for the 1st order phase transition and critical point.
- No room for dynamical fluctuations
- P or CP invariance is not violated neither at NICA and FAIR nor at RHIC and LHC.

Conclusions

Good News

The most observables and effects can be explained using the proposed mechanism.

To test it quatitatively one needs to implement it into the transport (URQMD, HSD, QGSM) and hybrid models.

Parameters:

- **reaction time;**
- **probability of transition of nucleon to hyperon + kaon.**

Conclusions

Good News

The most interesting physics is expected at NICA, FAIR, low energy region of SPS:

- The Isobar- and hyperon- nuclear states (application to physics neutron stars)
- Enhancement yield of (multi)strange baryons
- Correlations between strange baryons and kaon
- Effects of the Strong magnetic field:
  - ✓Polarization of (multi)strange particles
  - ✓Vorticity effects
  - ✓Skewness/asymmetry of particle emissions

"Entities must not be multiplied beyond necessity"

Occam,
Franciscan friar

Thanks for your patience

Current quark states in bound nucleons are **suppressed**

Bound Nucleon, N^*

$$\left|N^*\right\rangle = c_1\left|q_1q_2q_3\right\rangle + c_2\left|q_1q_2q_3\bar{q}q\right\rangle + c_3\left|q_1q_2q_3g\right\rangle + \ldots$$

suppressed

Nucleons inside nuclei are in constituent state!

Color Transparency “Breaking”
in quasielastic scattering

p+A → pp+X at $\theta_{cm}=90^0$

Observable:

$$T = \sigma^A/(Z\,\sigma^N)$$

Color transparency :

$T \rightarrow 1$