Multiproduction and Early Universe Matter State

* Importance of investigation on early universe matter state
* Information collider Physics provides---Multiproduction
* Preliminary trials on

  Combination of the collider physics and cosmology
* Discussions

V.A.De Lorenci, R. Klippert(UNIFEI, BR), 李世渊 (山东大学)

- The universe is expanding.In early times it was more dense than it is today. The spacetime curvature becomes arbitrarily large around the initial 'singular' point, hence leaving room for arbitrarily large energetic processes as well as arbitrarily dense matter states to take place.
- The matter states of the largest densities that human being canproduce and study microscopically in laboratory are those produced in high energy collisions.It is then natural to discuss cosmology by evolving such states within the ramework of gravity dynamics.

Early universe matter state is the key point for early universe models

- **'Standard' FLRW: horizon, isotropy, flatness, initial singularity……**
- **Inflation**
- **Bouncing…**

$$G^{\mu\nu} = -\kappa T^{\mu\nu}$$

If based on the Einstein Gravity framework, one of the key thing to construct a model lies in the enenrgy-momentum tensor of the matter

The matter states of the largest densities that human being canproduce and study microscopically in laboratory

We concentrate on the multi-particle system produced just after the inelastic and non-diffractive hadronic/nuclear collisions at high energies. Without restricting (triggering) the transverse momenta to be large, this multi-particle process is responsible for the increasing of the total cross section with the collision energy, thus becoming dominant at very high energies. In relativistic heavy ion collisions, this kind of process is triggered and classified by the multiplicity of the produced hadrons. It is believed that the quark-gluon plasma is most probably produced for the largest multiplicity cases, as the evolution result from the multi-parton system produced in the collision. This kind of system is widely studied, e.g., under the terminology `glasma'. Though the global distribution (e.g., longitudinal) is very similar in hadronic and ear collisions, for the latter case, especially at the case of central collisions, the produced multi-parton system can be much more dense, with larger spacetime area, so that it may be taken as a `medium', representing a kind of matter state. Hence, we choose this multi-parton system in the heavy ion collisions with the largest multiplicities (central collisions) as the dominant matter state of a cosmological toy model describing a possible phase of the universe.

To explore the properties which can be extrapolated to energy to infinity
‘the central rapidity plateau’

Rewritten from PRD3,2195(1971)
"Theory of Pionization", Cheng&Wu

$$\frac{d\sigma}{dy d^2 \underline{p_T}} = \rho(y, \underline{p_T})$$

pp,AuAu,PbPb

$$\rho(y, \underline{p_T}) = \rho(-y, \underline{p_T}) \qquad (2)$$

$$\rho(y + \Delta y, \underline{p_T}) = \rho(-y + \Delta y, \underline{p_T}) \qquad (LT)$$

$$\rho(y + \Delta y, \underline{p_T}) = \rho(-y - \Delta y, \underline{p_T}) \qquad (1)$$

$$\forall \Delta y, \frac{\partial \rho}{\partial y} = 0, i.e., \frac{d\sigma}{dy d^2 \underline{p_T}} = \rho(\underline{p_T})$$

only input :

- **Equivalence of C system(1)**
- **Symmetry hypothesis(2)**
  (limiting hypothesis)

- **not dependent on the concrete dynamics (e.g. Lagrangian)**

- **H. Cheng, T.T. Wu, 1969,1971**
- **R. Feynman, 1969**

Energy momentum tensor of rapidity plateau put into Einstein equations

$$T^{\mu\nu} = \mathrm{diag}[\varepsilon(\tau), \mathrm{p}(\tau), \mathrm{p}(\tau), \mathrm{p}_3(\tau)];$$

$$\mathrm{d}s^2 = \mathrm{d}\tau^2 - A^2(\tau)\,[\mathrm{d}x^2 + \mathrm{d}y^2] - B^2(\tau)\,\mathrm{d}\eta^2$$

$$\begin{aligned} a^2 + 2ab &= \kappa\varepsilon, \\ \dot{a} + \dot{b} + ab + a^2 + b^2 &= -\kappa\bar{p}, \\ 2\dot{a} + 3a^2 &= -\kappa\bar{p}_3, \end{aligned}$$

$$a = \dot{A}/A, \; b = \dot{B}/B$$

$$\bar{p} = pA^2 \text{ and } \bar{p}_3 = p_3 B^2.$$

$$\dot{\varepsilon} + 2a(\varepsilon + \bar{p}) + b(\varepsilon + \bar{p}_3) = 0;$$

$$T^{\mu\nu}{}_{;\mu} = 0;$$

one need another input to fix the solution

solution-1: energy density of Glasma at t~0 as input

$$\varepsilon \propto 1/LnQ_s\tau$$

$$T^{\mu}{}_{\nu} = \mathrm{diag}\left[\varepsilon, \varepsilon, \varepsilon, \varepsilon\right]$$

$$\begin{aligned} \mathrm{d}s^2 \;=\; & \mathrm{d}\tau^2 - A_0^2 \exp\left[6\kappa\lambda\tau^2 L^2\right]\left(\mathrm{d}x^2 + \mathrm{d}y^2\right) \\ & -\tau^2\left(1 + 4\kappa\lambda\tau^2 L\right)\mathrm{d}\eta^2. \end{aligned}$$

running cosmological constant

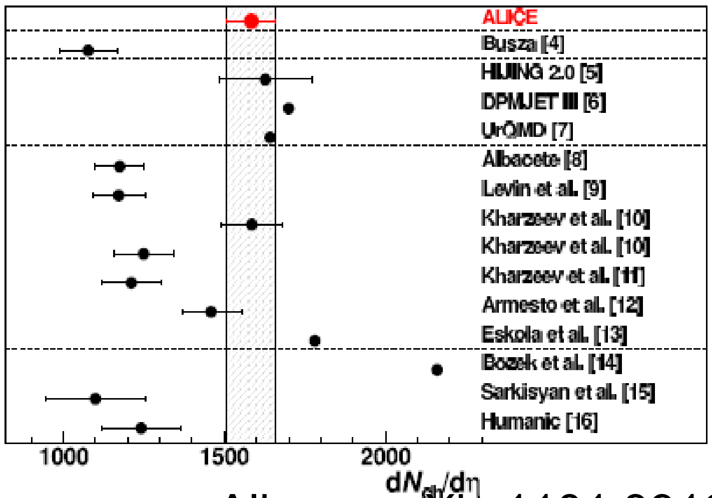
will not keep as 1/tau for large tau

- CGC: Effective field theory for hadron wave function and high energy collisions

F. Gelis et al, arXiv: 1002.0333

L. McLerran, arXiv: 1011.3203

......

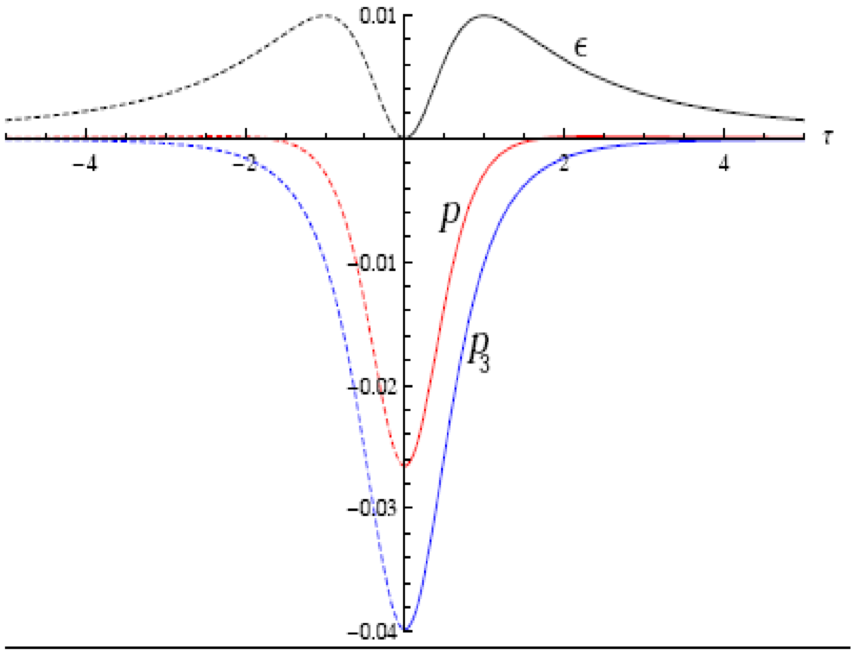


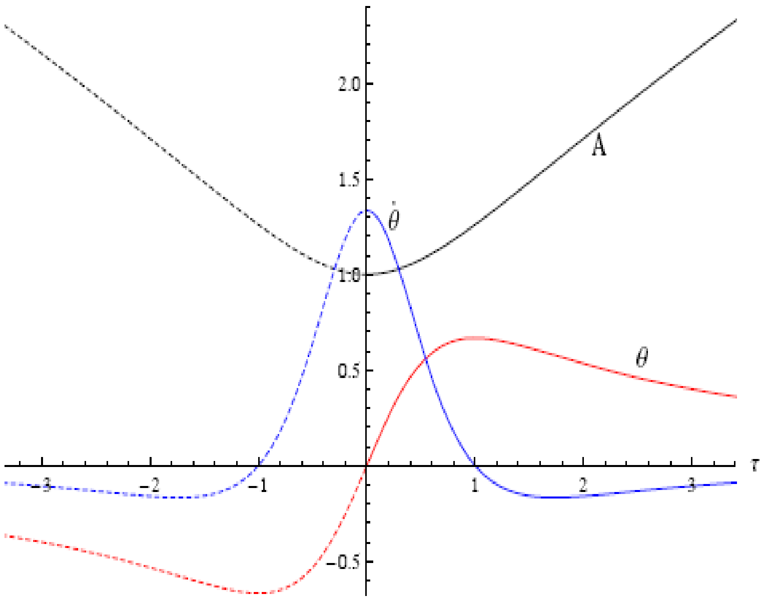
Alice， arXiv:1101.3916

solution-2: t~0 as Minkowski spacetime, enegy momentum conservation as input

$$
\begin{aligned}
A(\tau) &= A_0(1+\tau^2/\tau_0^2)^{1/3}, \\
B(\tau) &= \sqrt{3}\,\tau_0, \\
\varepsilon(\tau) &= \frac{4}{9\kappa\tau_0^2}\,\frac{\tau^2/\tau_0^2}{(1+\tau^2/\tau_0^2)^2}, \\
p(\tau) &= -\frac{2}{3\kappa A_0^2\tau_0^2}\,\frac{1-\tau^2/3\tau_0^2}{(1+\tau^2/\tau_0^2)^{8/3}}, \\
p_3(\tau) &= -\varepsilon(\tau)/\tau^2,
\end{aligned}
$$

time evolution of solution 2





Discussions

- **Interesting preliminary results indicate collider physics information can be used to construct bouncing models**
- **Further to applied to investigate the collisions of early universe，signal to be observed**
- **the averaged global properties employed；fluctuations and large scale structure (?)**
- the key problem is that how to employ the results of a Minkowski spacetime result (collision) in a general Riemann manifold for purpose of exploring geometry without the consistent framework of quantum gravity