

Theoretical study on the formation of high energy density states in heavy ion collisions

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In my PhD work I studied equilibrium and non-equilibrium descriptions of high energy heavy ion collisions.

1. We have found a new analytic solution to the hydrodynamic equations of fireball expansion. I calculated the scale factor and the entropy [1].
2. I developed a non-equilibrium model of the hadronization of quark matter created in heavy ion collisions (MICOR). I compared its predictions to other models [2]. By extracting the model parameters from the momentum spectra of the ϕ and Ω particles, I got a prediction to the ρ meson that matches the experimental results [3]. When I applied the model for the description of charm meson creation (D and J/ψ), it turned out that the initial state cannot be described with one collective flow, the heavier charm quarks “lag behind” light and strange quarks, their transverse flow velocity remains smaller [4].
3. I developed a particle cascade program to solve the Boltzmann equation of the secondary interactions between hadrons [5, 6, 7]. It became more general than the problems I studied, it is able to simulate any transport model, it can be used as a parton cascade, moreover it supports the subdivision method for the correction of Lorentz invariance violation. With the GROMIT program I solved the following problems:

- In the “pion wind” problem I found that for large cross sections or large initial densities, the final momentum spectra has a strong dependence on the λ subdivision. Using constant 40 mb cross sections, the inverse slope of the transverse momentum spectra of nucleons is 20% smaller in the $\lambda = 1$ case than the “real” value that we would get from the exact solution of the Boltzmann equation, in the Lorentz invariant limit. By increasing the subdivision to $\lambda = 16$, we get a good approximation.
- Secondary interaction simulation of the resonance gas generated by the MICOR hadronization model. The coalescence model completed with the secondary hadronic interactions was also able to describe the pion and proton spectra. Another result is that in the resonance gas created by quark coalescence, collisions are rare enough and most cross sections are small enough for the Lorentz invariance violation of the cascade algorithm to be negligible. Thus subdivision is not necessary in this problem.
- Study of parton energy loss in RHIC Au+Au collisions, at $\sqrt{s_{NN}} = 130$ GeV energy. $2 \rightarrow 2$ scattering and $2 \rightarrow 2 + \text{final state radiation}$ processes of quarks and gluons have been taken into account. As a consequence of these processes, the particle momentum distributions change, the high momentum component is decreased (“quenching”). The transverse energy is decreased with an amount depending on the cross sections. Two different hadronization mechanisms have been compared that lead to different final state hadron distributions. The Lund string fragmentation model needed larger parton cross sections to reproduce the experimental pion spectra than the independent fragmentation model [7].

I performed these studies as a member of the RHIC Transport Theory Collaboration (RTTC). Our aim is to develop transport models describing high energy heavy ion collisions, using our universal code.

References

- [1] P. Csizmadia, T. Csörgő, B. Lukács: *New analytic solutions of the non-relativistic hydrodynamical equations*, Phys. Lett. **B443** (1998) 21-25
- [2] P. Csizmadia, P. Lévai, S. E. Vance, T. S. Biró, M. Gyulassy, J. Zimányi: *Strange hyperon and antihyperon production from quark and string-rope matter*, J. Phys. **G25** (1999) 321-330
- [3] P. Csizmadia, P. Lévai: ϕ , Ω and ρ production from deconfined matter in relativistic heavy ion collisions at CERN SPS, Phys. Rev. **C61** (2000) 031903
- [4] P. Lévai, T. S. Biró, P. Csizmadia, T. Csörgő, J. Zimányi: *The production of charm mesons from quark matter at CERN SPS and RHIC*, J. Phys. **G27** (2001) 703-706
- [5] P. Csizmadia and P. Lévai, *The MICOR hadronization model with final state interactions*, J. Phys. **G28** (2002) 1997-2000
- [6] S. Cheng, S. Pratt, P. Csizmadia, Y. Nara, D. Molnár, M. Gyulassy, S. E. Vance, B. Zhang: *The effect of finite-range interactions in classical transport theory*, Phys. Rev. **C65** (2002) 024901
- [7] Y. Nara, S. E. Vance, P. Csizmadia, *A study of parton energy loss in Au+Au collisions at RHIC using transport theory*, Phys. Lett. **B531** (2002) 209-215