2007 APCTP Workshop on

"Frontiers in Nuclear and Neutrino Physics"

HIC: ALICE, The Wonderland

(more or less personal view)

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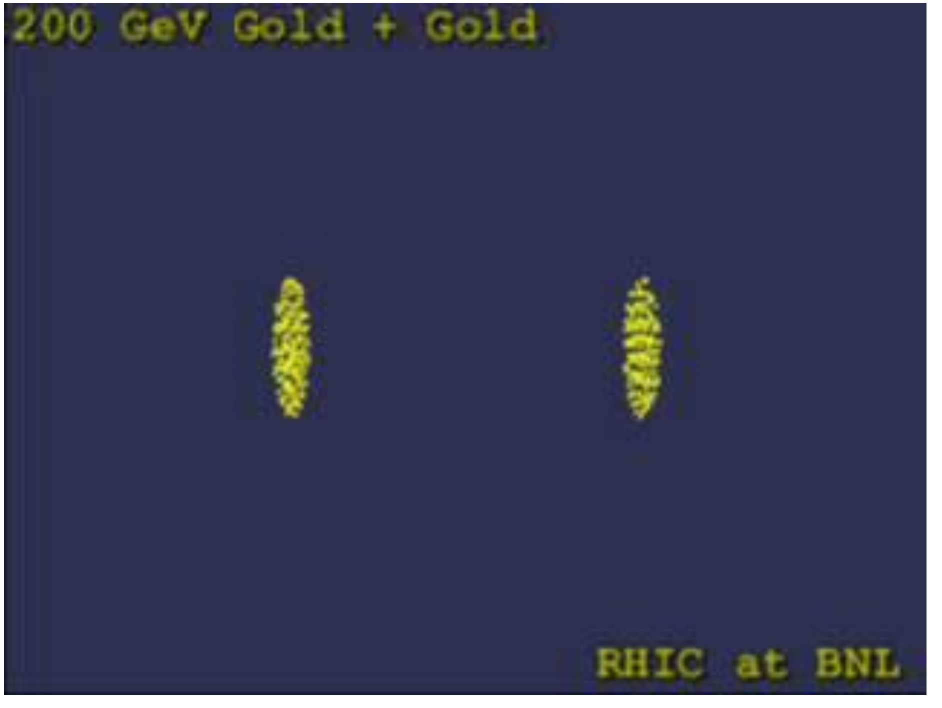
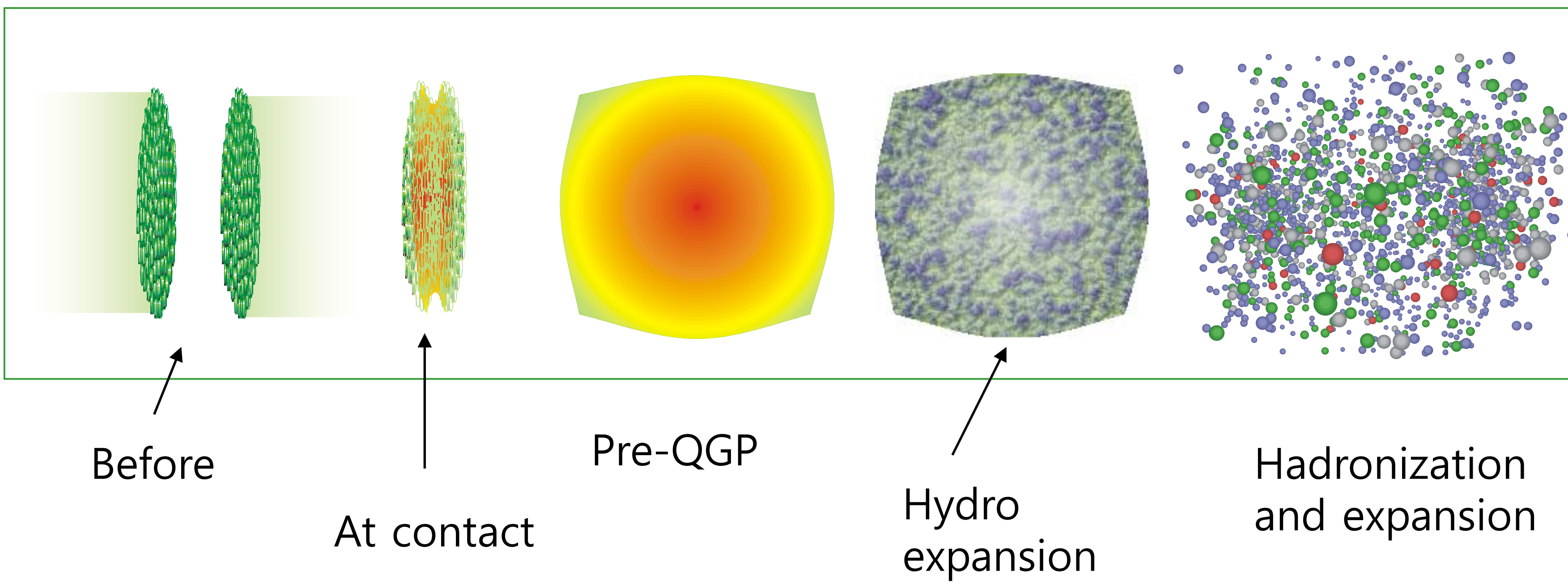
Feb. 26-28, 2007

I. Introduction

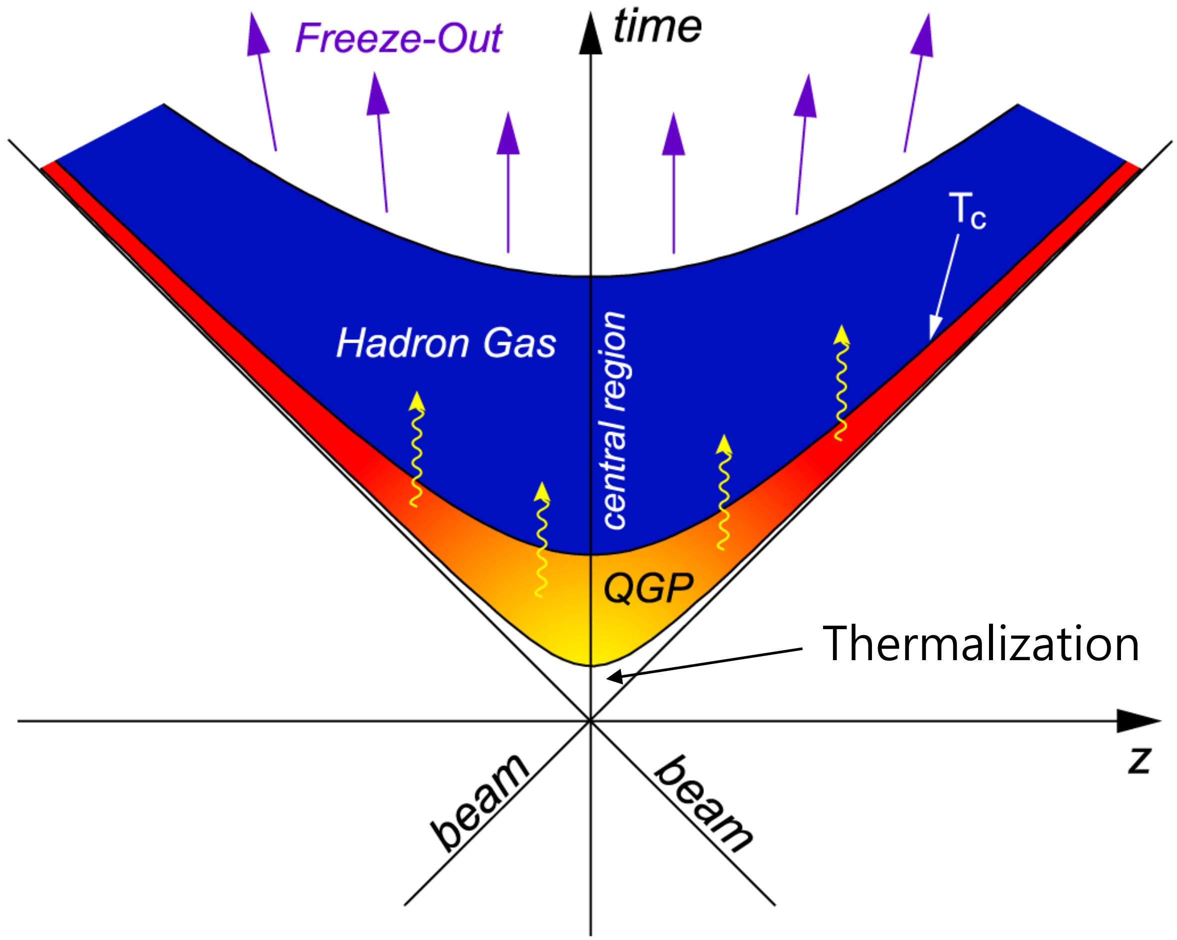
- HIC(heavy ion collision) Simulation (Au-Au from BNL)



- Schematic Time evolution 1:



- Schematic Time evolution 2:



- Basic data:

	RHIC	LHC
E_cm	200 GeV	5.5 TeV
A	Au(197)	Pb(207)
R	6.4 - 7 fm	6.5-7.1 fm
gamma	100	2750
X(=p_d/p_p)	10^-2 - 10^-3	10^-3 – 10^-4
Q_0	1-2 GeV/c	2-3 GeV/c

II. Before the collision

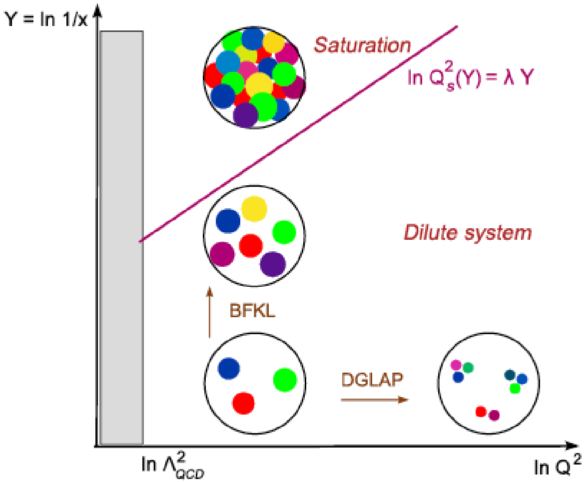
- At Rest:
  - R = 1.1 A^1/3 fm
  - Nucleon distribution: see textbook on nuclear physics
    - Wood-Saxon model
    - Shell model
    - Liquid-drop model
    - Constant density (Sharp-edge) model

  - Parton distribution:
    - DIS(ep) scattering: See Halzen and Martin

- At high speed:
  - Lorenz contraction with gamma factor.
  - Partons may overlap to become CGC(color glass condensate).

- In general, the parton distribution of a nucleon:
  - Momentum distribution:
    - CTEQ
    - GRV
    - MRST
    - And so on…: there is website providing the code.
  - No specific space distribution:

- Nucleon distribution within nuclei:
  - EKS : see Eskola
  - And so on…
- Thus,
  - CTEQ X EKS with space distribution
  - GRV X EKS with space
  - ….
- Once we know one distribution at given scale, we can use BFKL or DGLAP equations.



- Recent development of distribution (CGC): See excellent reviews by McLerran, Venugopalan, Mueller, Blaizot etc.
  - Main idea:
    - High x parton: sources of Weizacker-Williams field
    - But those fields overlap and fuse together
  - Problems:
    - Gluon only.
    - At rest, those nucleons are independent. At high speed, they entangle and fuse. But, we know they should be related by LT and LT cannot explain the entanglement.

III. At Contact

- Two viewpoints:
  - Parton collision: See Eskola
    - Two (projectile and target) distributions overlap
    - Partons collide each other
      - P_t > Q_0 : escape from parent nucleon
      - P_t < Q_0 : stay in the nucleon
    - Q_0 : perturbative regime
  - CGC shattering: see Krasnitz
    - Two CGCs smash and give birth to virtual partons
    - Equation of motion:

$$[D_\mu, F^{\mu\nu}]^a = J^{\nu,a} \qquad J^\nu = \rho_1\,\delta(x^-)\delta^{\nu+} + \rho_2\,\delta(x^+)\delta^{\nu-}$$

- 4 different kinds of partons:
  - High p_t and high p_z: jets
  - High p_t and low p_z : jets, will travel through medium
  - Low p_t and high p_z : mostly valence partons
  - Low p_t and low p_z : soft partons, medium

  - NOTE: the collision time is very short
    - ~ 0.14 fm/c at RHIC
    - ~ 0.005 fm/c at LHC
  - Tentative thermalization time is 0.6 - 1 fm/c

IV. Formation of QGP: Just after a collision

- Very difficult subjets. But we can make scenarios
- Hawking-Unruh Radiation: Born to be thermal: see Khazeev et al. or Satz
  - Hawking Radiation: near the event horizon, radiation escape with thermal temp. T ~ g/2pi
  - Unruh radiation: From the equivalence principle, the accelerating particle also radiates with T ~ a/2pi
  - Thus strongly decelerating partons while overlapping radiate in thermal, T ~ a/2pi.
  - We know that the nucleons become transparent as the collision energy goes high.

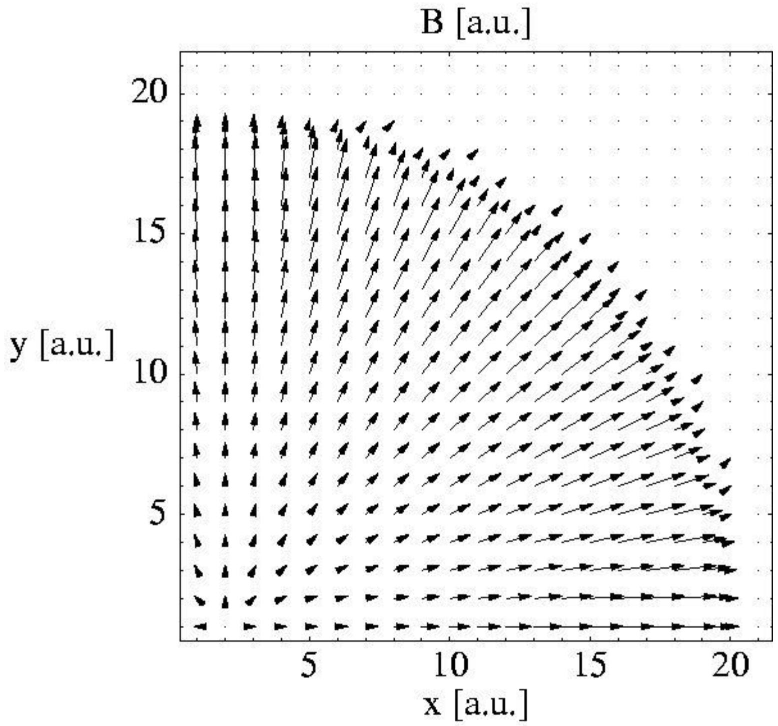
- Bottum-up scenario: see Mueller at al.
  - Soft partons thermalized first
  - Hard parton thermalized
  - Time scales have been given.
- Collision scenario: see parton cascade
  - Partons collide each other to become thermal
  - Shuryak claims one collision per parton is enough.
  - No collective effects of soft partons

- Weibel Instability : See Mrowczynski
- Color Force Explosion: personal view
  - High p_t or high p_z (most likely valence quarks) quickly escape from the system
  - Color charge unbalance in the system
  - Substantial color force will exert each other
  - We need to look at the ep collision if there is explosion!!
- And so on :

V. Hydro expansion

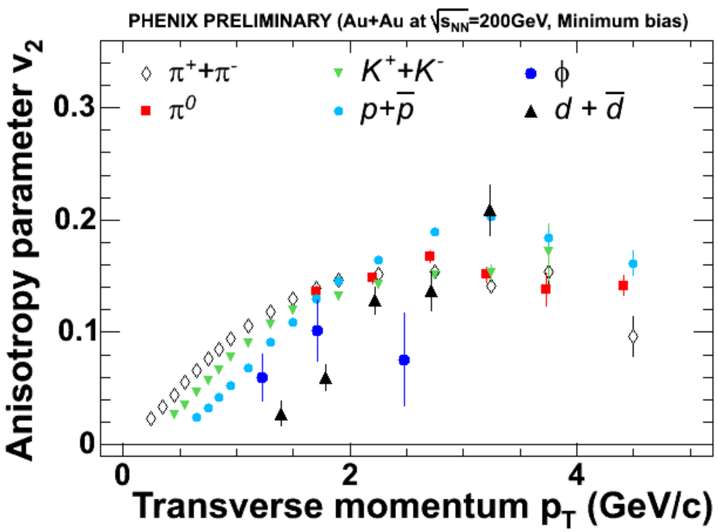
- There are many groups working on the subjects: Japanese group (Hirano, Nonaka, and so on), Yonsei group, …
- 1D, 2D, 3D hydro
- Recently analytic solutions have been sought and found:
  - 1D: Bjorken expansion
  - 2D:
  - 3D: ellipsoidal Hubble-like expansion, see Csorgo

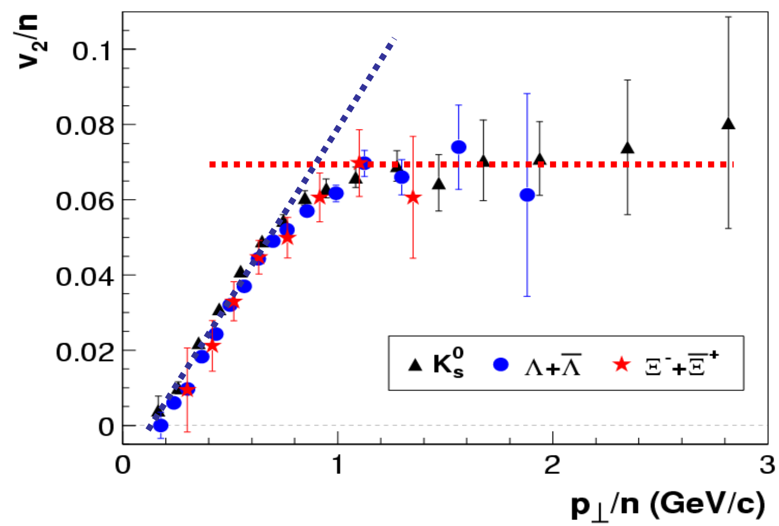
An example of Hubble-like expansion



- This means that, with small viscosity,
  - The expansion is more or less free motion in particle point of view. Thus a collisionless transport theory may works fine.
  - While they run free, less virtual partons eat higher virtual partons to become constituent partons (quarks or antiquarks only): see valon theory by Hwa.

We look at v2 : see Lacey
Very different v2 aline nicely with constituent quarks or antiquarks: which means 1) hadrons have common partons, 2) the elements are constituent partons.





VI. Hadronization

- Two ways to make hadron:
  - Recombination method:
    - Cooper and Frye:
    - Fries, Muller, Nonaka, and Bass:
    - Greco, Ko, and Levai:
  - Fragmentation method:
  - Unified view : see Majumder, based on field theory

VII. Hadron Evolution

- UrQMD works fine
- And so on ….

VIII. Conclusion

Thanks for attention