Joint CATHIE-TECHQM workshop

Current Status of Ideal Hydro + Cascade Model

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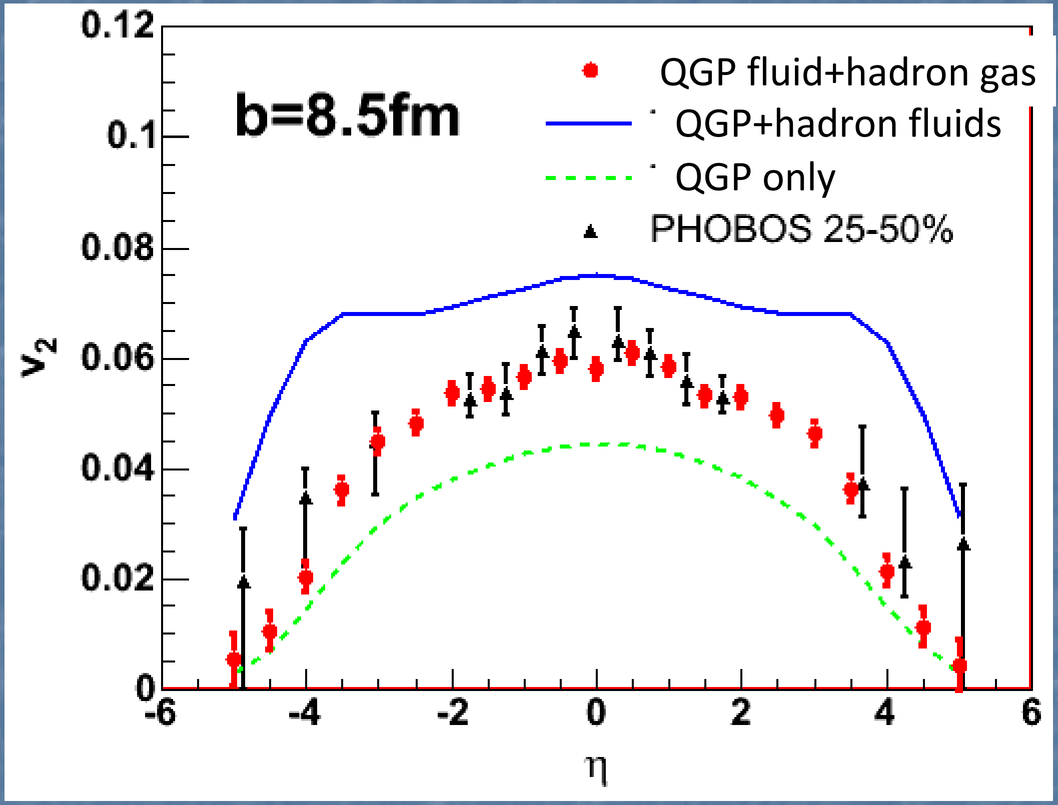
Outline

- Introduction
- Importance of hadronic dissipation
- Current status of dynamical modeling
- Summary

Introduction

- Hydrodynamics describes matter under local thermal equilibrium
  - Hydrodynamics is applicable in the intermediate stage.
  - Need modeling before and after hydro regime
    - Initial conditions
    - Freezeout
- Detailed analysis based on ideal hydro towards quantifying viscous effects

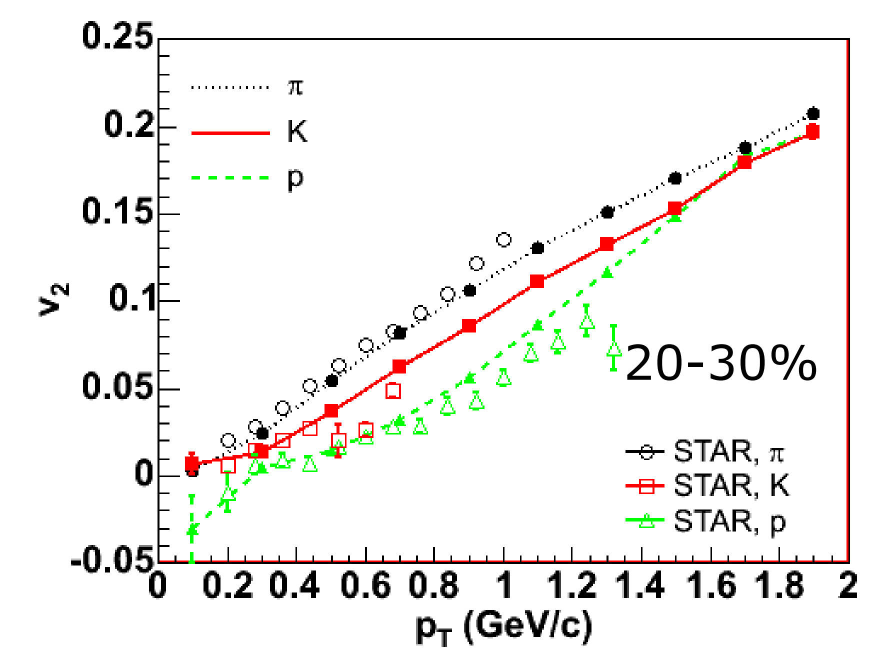
Importance of Hadronic Dissipation

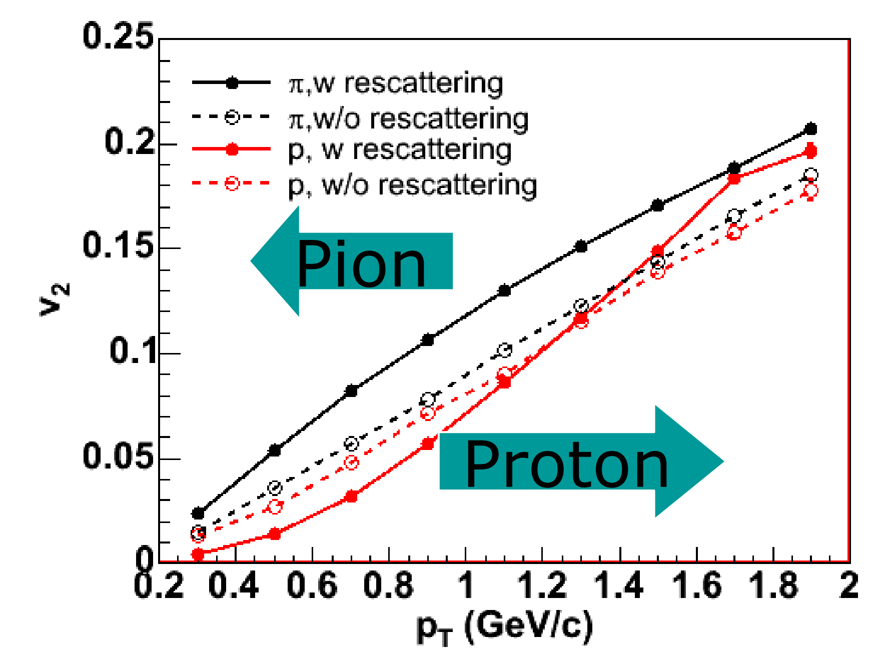


Suppression in forward and backward rapidity
Importance of hadronic viscosity

TH et al.,('05)

Mass Splitting = Hadronic effects



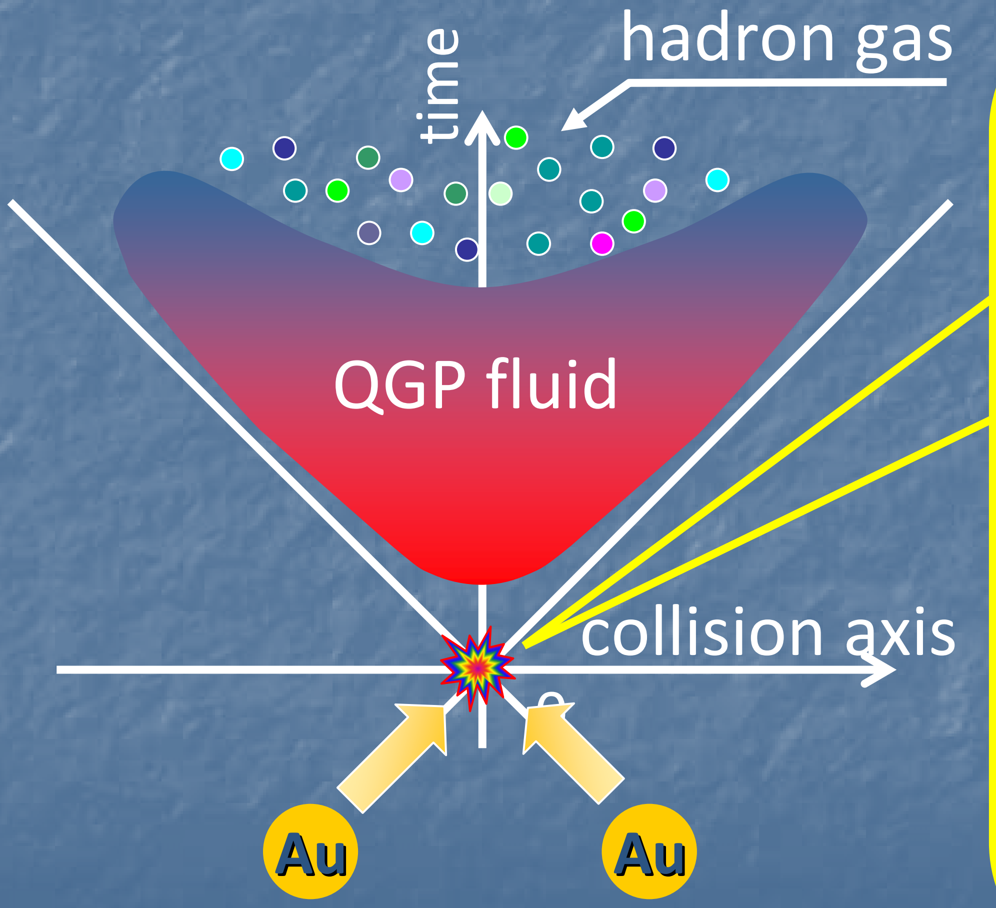


Mass dependence is o.k. from hydro+cascade.
When mass splitting appears?

Mass ordering comes from hadronic rescattering effect.
Interplay btw. radial and elliptic flows.

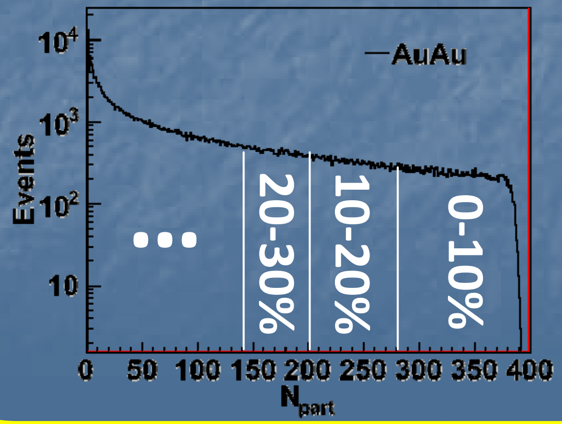
TH et al.,('08)

Current Status of Dynamical Modeling



Initial condition

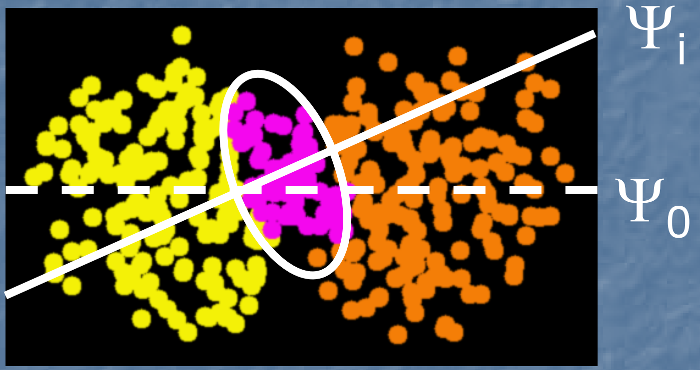
- Model*
    - MC-Glauber
    - MC-KLN (CGC)
- Participant eccentricity
- Centrality cut NEW



*H.J.Drescher and Y.Nara (2007)

Eccentricity Fluctuation

Adopted from D.Hofman(PHOBOS), talk at QM2006

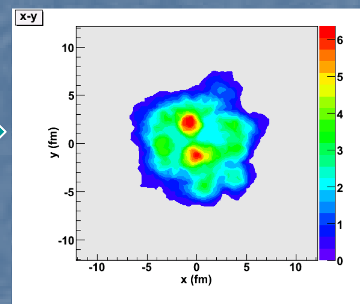


A sample event from Monte Carlo Glauber model

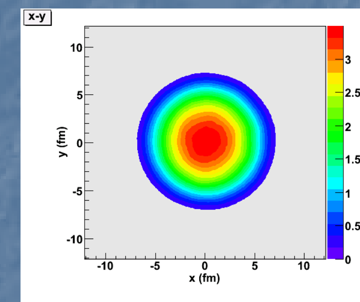
Interaction points of participants vary event by event.
→ Apparent reaction plane also varies.
→ The effect is significant for smaller system such as Cu+Cu collisions

Initial Condition with an Effect of Eccentricity Fluctuation

Throw a dice
to choose b

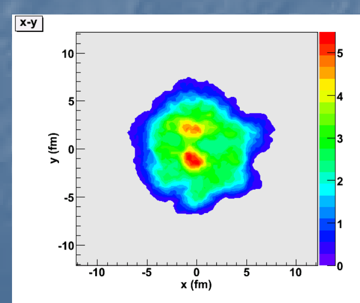


Without fluctuation effects

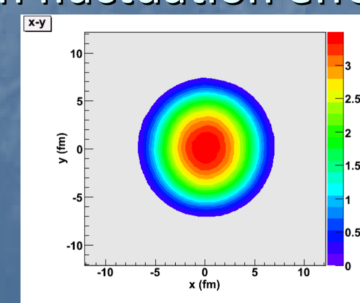


average
over events

Rotate each Ψ_i
to Ψ_{true}



With fluctuation effects

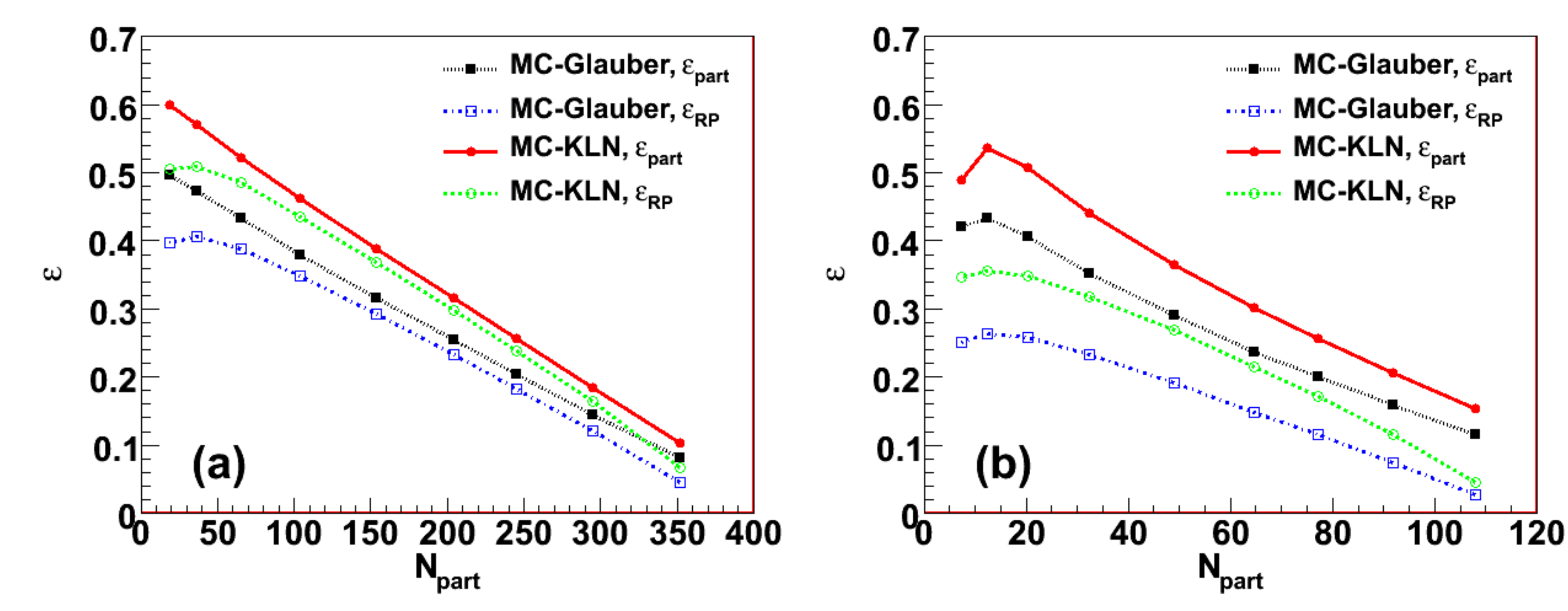


average
over events

E.g.)
N_{part}^{min}= 279
N_{part}^{max}= 394
in Au+Au collisions
at 0-10% centrality

Eccentricity with Fluctuation Effects

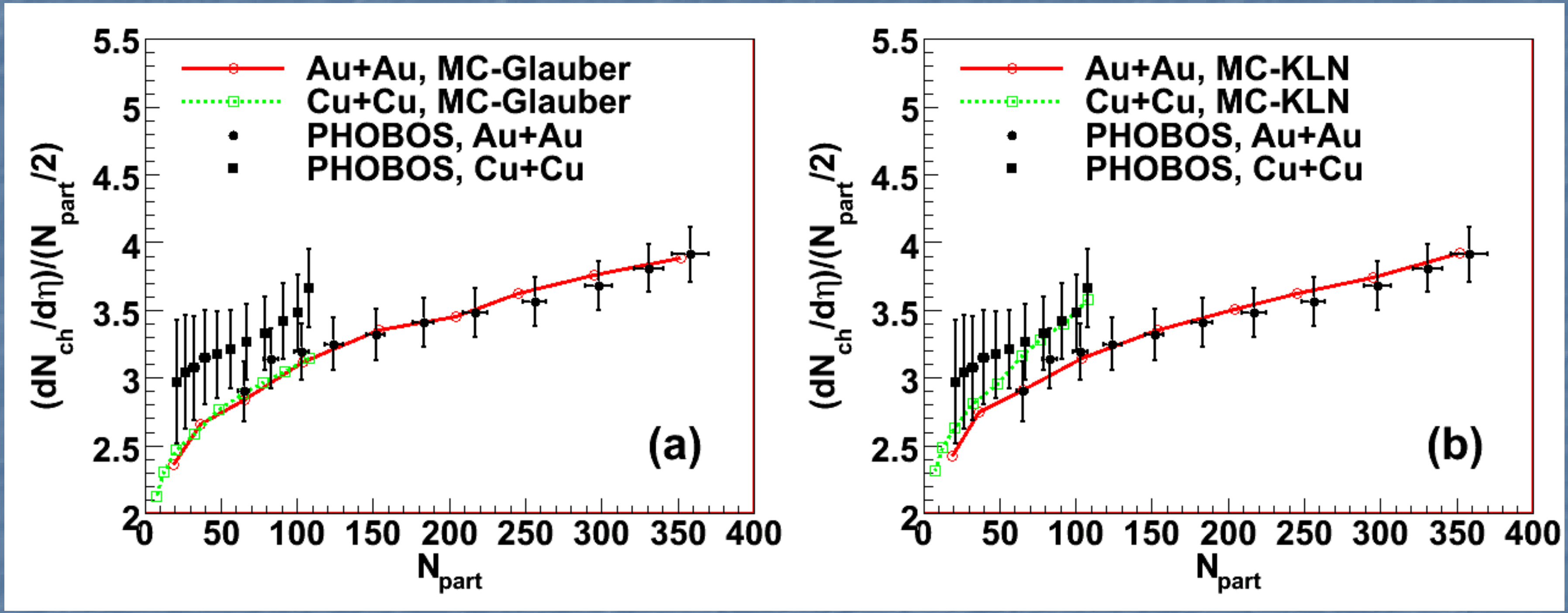
Au+Au　　　　　　　　Cu+Cu



Large fluctuation in small system such as Cu+Cu and peripheral Au+Au

Need these effects toward quantitative analysis

Inputs in Model Calculations

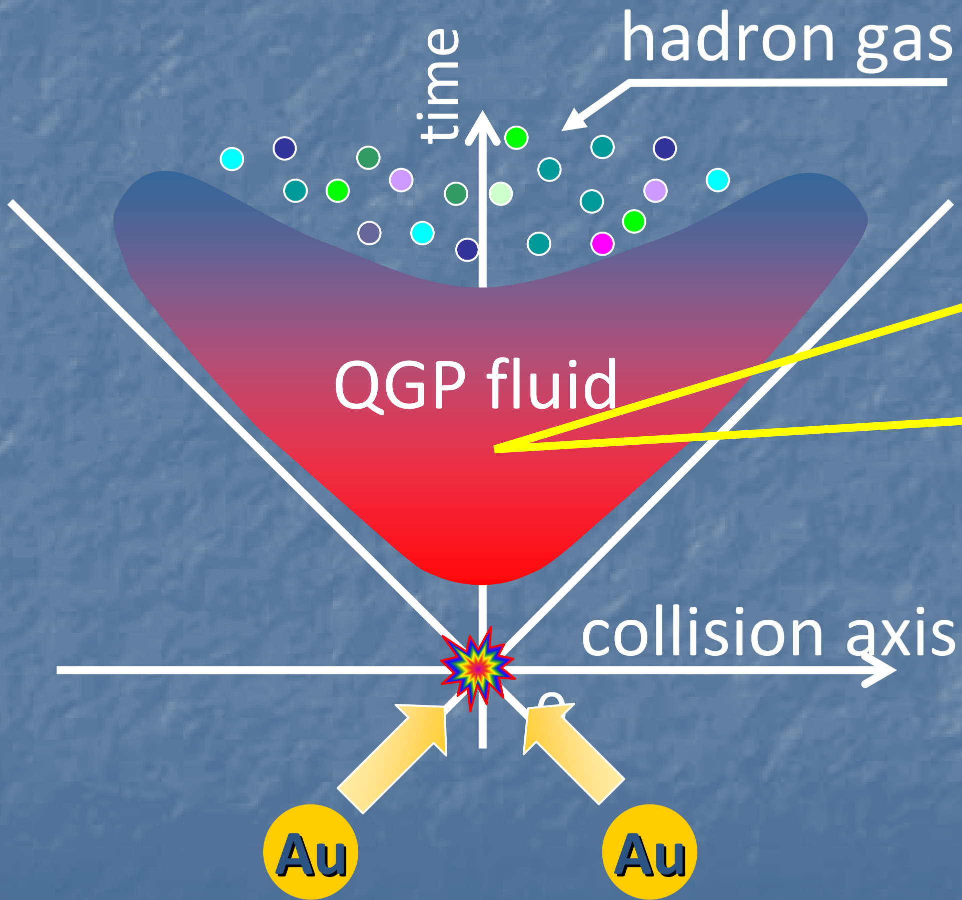


Parameters are fixed in Au+Au collisions

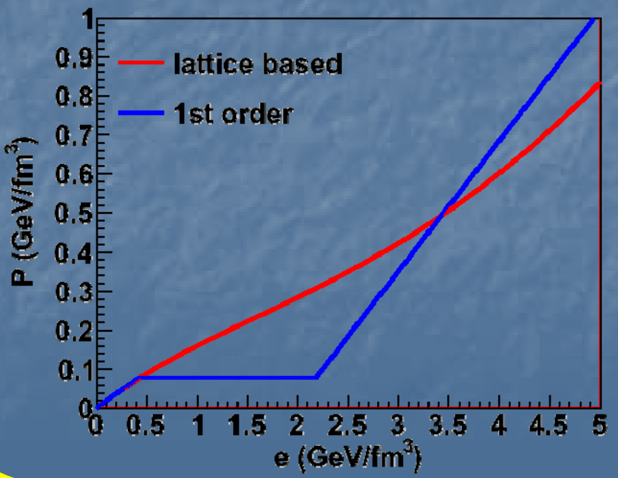
Glauber: $$\frac{dS}{d^2x_\perp} = C\left[\frac{1-\delta}{2}\frac{dN_{\rm part}}{d^2x_\perp} + \delta\frac{dN_{\rm coll}}{d^2x_\perp}\right]$$

KLN: standard parameters

Current Status of Dynamical Modeling

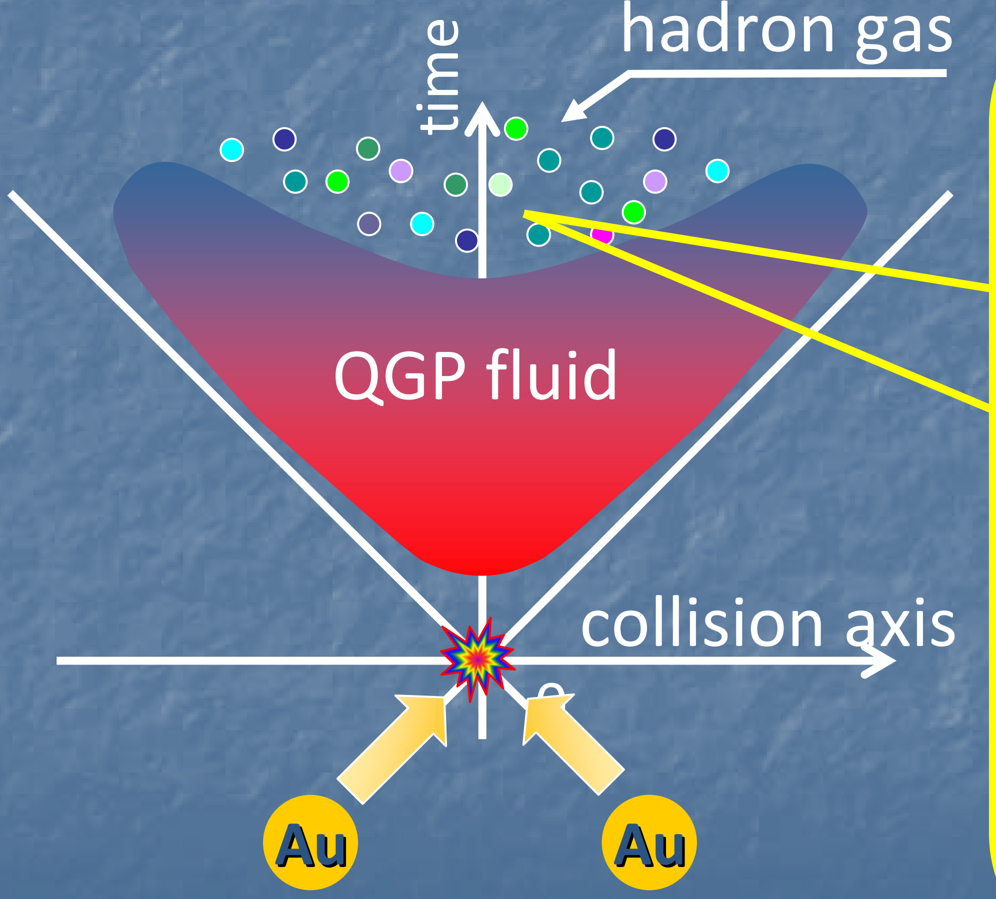


<u>Ideal Hydrodynamics*</u>
- Initial time 0.6fm/*c*
- Model EoS
  - lattice-based# NEW
  - 1st order



*T.Hirano(2002), #Lattice part : M.Cheng *et al*. (2008)

Current Status of Dynamical Modeling



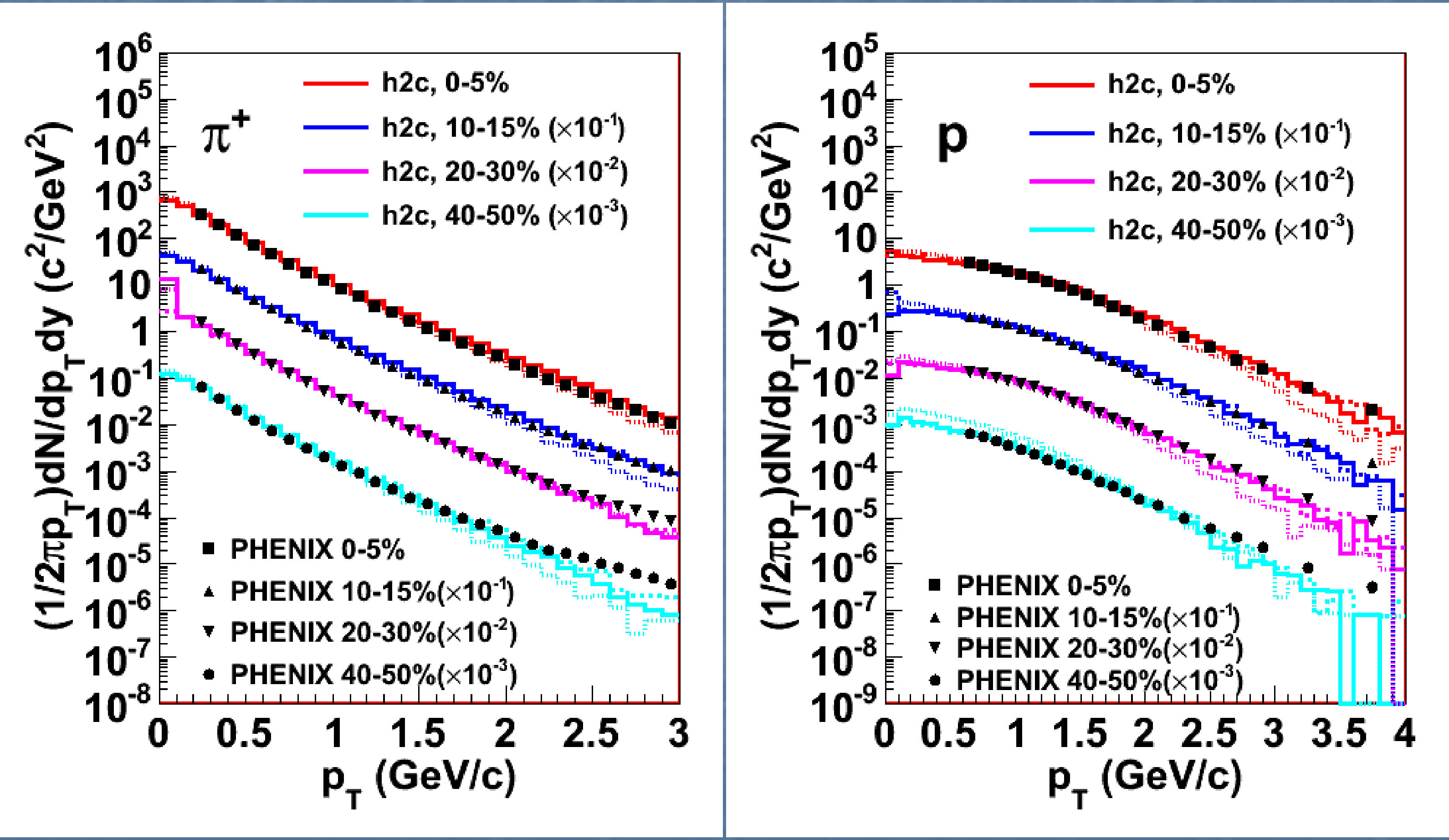
<u>Hadronic afterburner</u>

- Hadronic transport model, JAM*
- Switching temperature *T*=160 MeV

Note: We changed switching temperature from 169 MeV to 160 MeV to utilize lattice-based EoS which matches smoothly to a resonance gas model at this temperature.

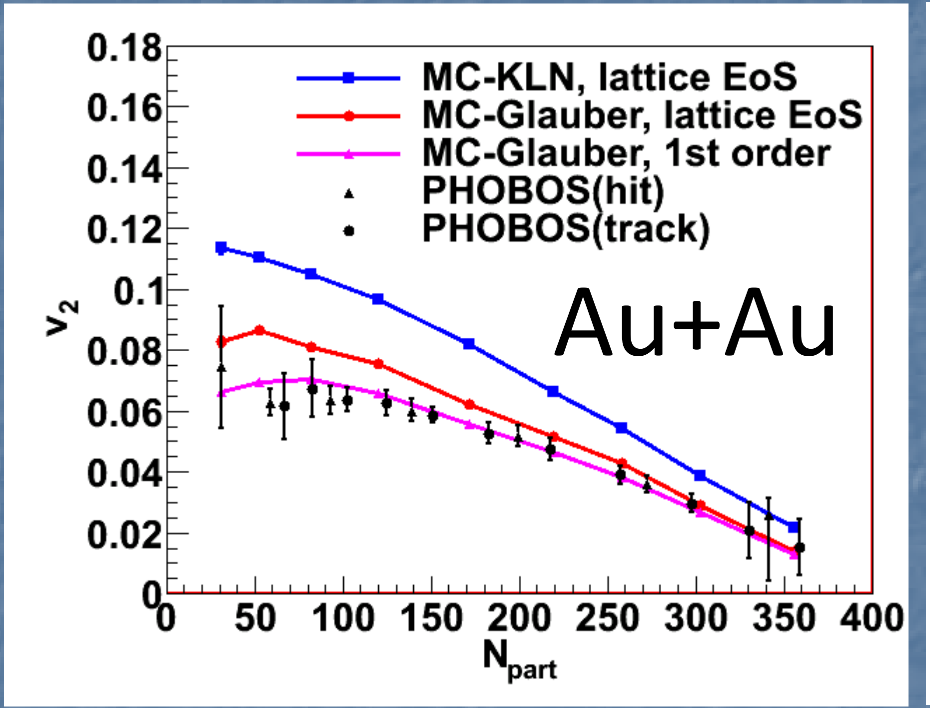
*Y.Nara et al., (2000)

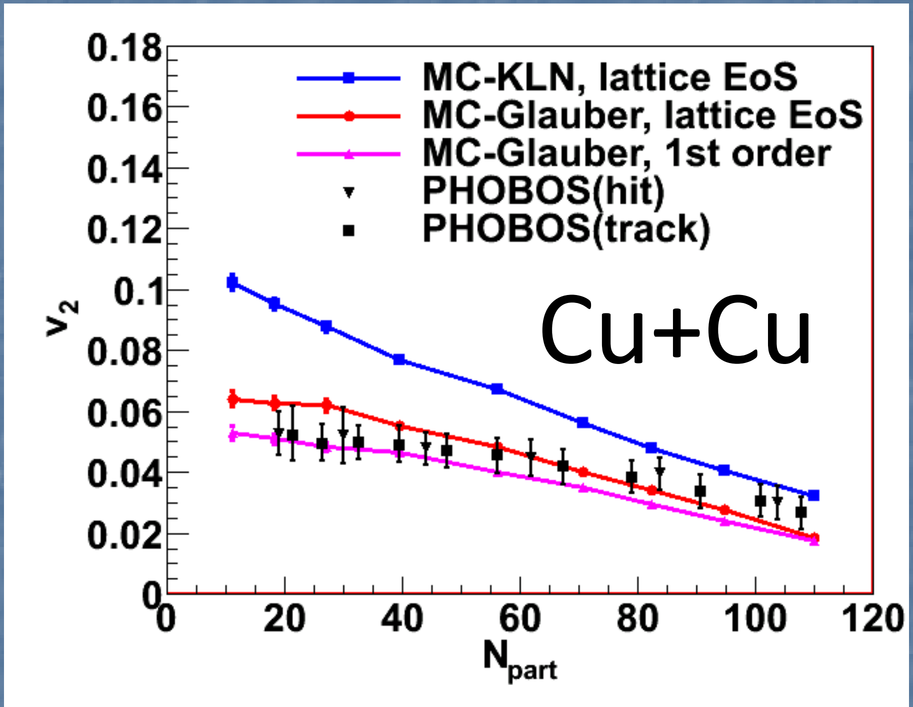
Current Status: p_T distribution



Hybrid model works well up to p_T~1.5 GeV/*c* (1st order, dotted) and 2-3 GeV/*c* (lattice-based, solid)

Current Status: Elliptic Flow

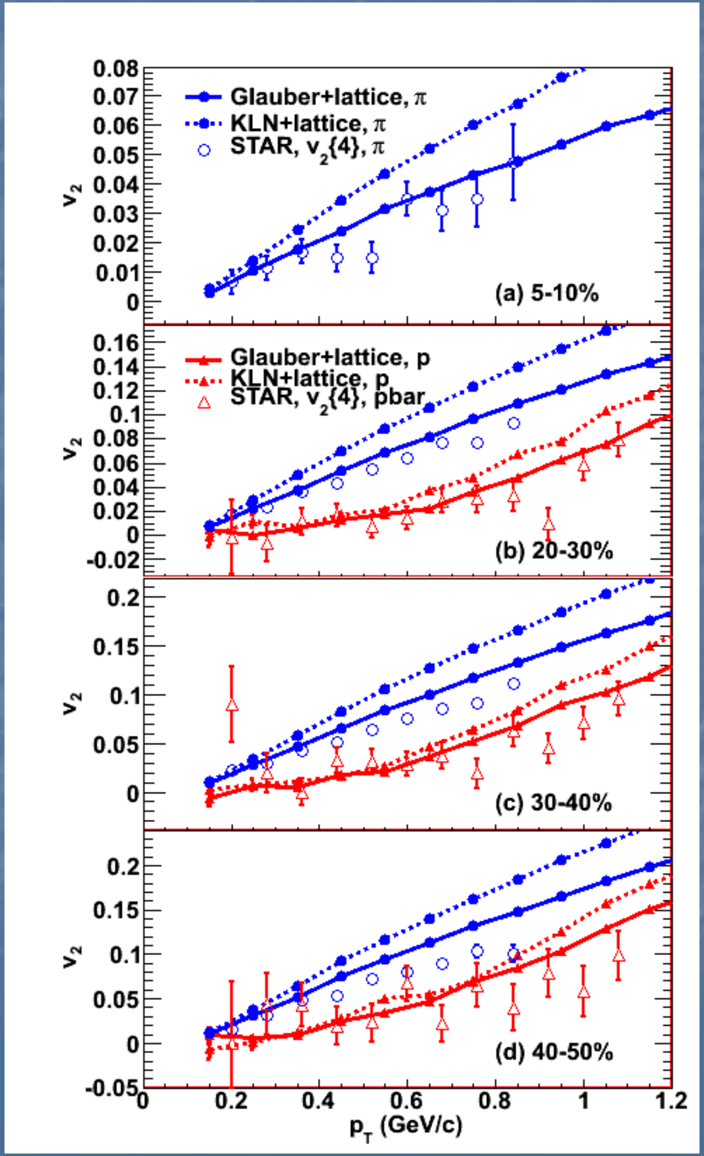




- 1st order EoS apparently leads to reproduction and might have mimicked viscosity.
- Highly sensitive to initial models.
- Perfect fluid and CGC, compatible?

→ Need more studies on initial condition and viscosity

Current Status: Differential Elliptic Flow



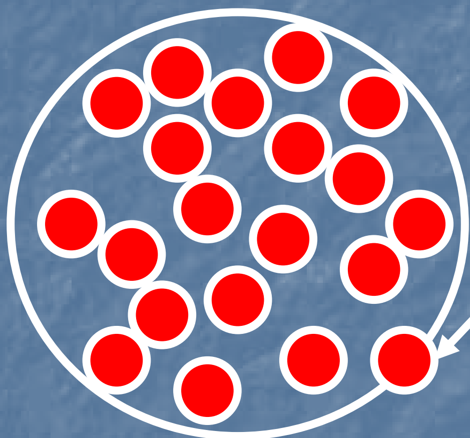
Au+Au 200 GeV

- Glauber/KLN+ lattice EoS
- Eccentricity fluctuation is essential in central collisions.
- Centrality dependence
  → OK for Glauber
- Viscosity would be needed for better description.
- Eager to see PID v_2 data with less errors and less non-flow effects in low p_T (<2 GeV/*c*) region.

Summary

- Initial condition (Glauber/KLN) + ideal hydro (lattice based EoS/1st order EoS) + hadronic afterburner (JAM)
- Within Glauber type initial conditions, the strong 1st order phase transition is unlikely to be realized. (Even tiny viscosity in the QGP reduces v2, therefore one would fail to reproduce data.)
- More studies are demanded for initial conditions.
- Future: Fluctuation (event by event) and correlation (ridge) in the longitudinal direction

Comment on Monte Carlo Approach



How do we consider this?

Naïve Glauber calculation:

$$\rho_{\rm WS}(\vec{x}) = \int \delta^{(3)}(\vec{x}-\vec{x}_0)\rho_{\rm WS}(\vec{x}_0)d^3\vec{x}_0$$

MC-Glauber calculation:

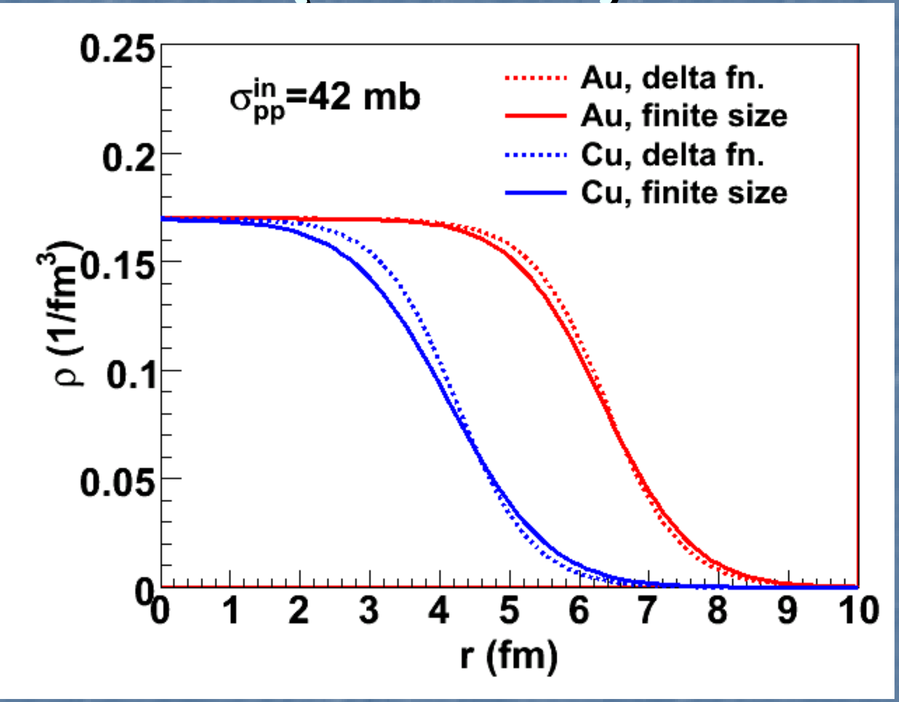
$$\rho_{\rm WS}(\vec{x}) \neq \rho(\vec{x}) = \int \Delta(\vec{x}-\vec{x}_0)\rho_{\rm WS}(\vec{x}_0)d^3x_0$$

Finite nucleon profile

$$\Delta(\vec{x}-\vec{x}_0) = \frac{\theta(r-|\vec{x}-\vec{x}_0|)}{V}$$

$$V = \frac{4\pi r^3}{3}, \quad r = \sqrt{\frac{\sigma_{pp}^{\rm in}}{\pi}}$$

Comment on Monte Carlo Approach (contd.)



→ Reduction of eccentricity by ~5-10%

→ Necessity of re-tuning parameters in Woods-Saxon density

→ We have retuned parameters.