Importance of Granular Structure in the Initial Conditions for the Elliptic Flow

Y. Hama[1] R.P.G. Andrade[1] F. Grassi[1] W.-L. Qian[1]
T. Kodama[2]

[1]Instituto de Física, Universidade de São Paulo, Brazil

[2]Instituto de Física, Universidade Federal do Rio de Janeiro, Brazil

HDM 2008, **Mumbai India**

Outline

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1. Motivation
   - Fluctuating Initial Conditions
   - Granular Structure of IC
2. Fundamental tool: NeXSPheRIO
3. What is expected from the hot blobs?
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Hydrodynamic Model

In hydrodynamic approach of nuclear collisions, it is assumed that, after a complex process involving microscopic collisions of nuclear constituents, at a certain early instant a hot and dense matter is formed, which would be in local thermal equilibrium. Usually, this state is characterized by some initial conditions (IC), parametrized as smooth distributions of thermodynamic quantities and four-velocity.

Fluctuating Initial Conditions

- However, since our systems are small, important event-by-event fluctuations are expected in real collisions.
- In previous works, we introduced fluctuating initial conditions in hydrodynamics and studied several effects.
- In particular, we studied the fluctuations of v_2, where we showed that they are quite large.
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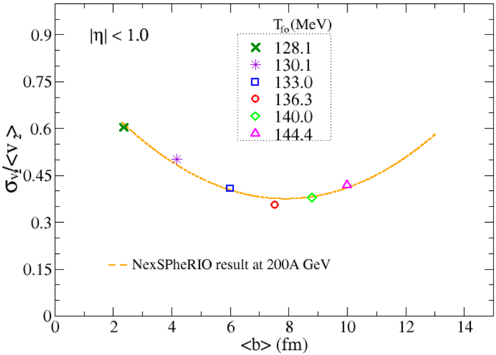
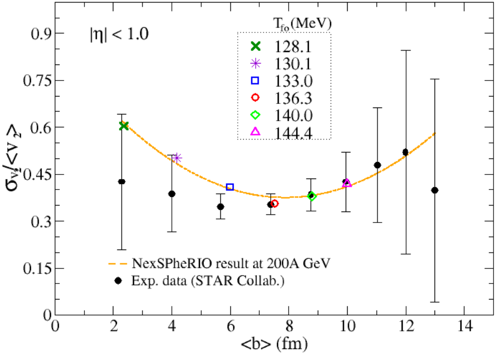
$\sigma_{v_2} / < v_2 >$



Curve: Y.H. *et al.*, arXiv:0711.4544 [hep-ph]

$\sigma_{v_2} / < v_2 >$ - Comparison with data (STAR Collab.)



Data: P. Sorensen [STAR Collab.], QM 2006, nucl-ex/0612021

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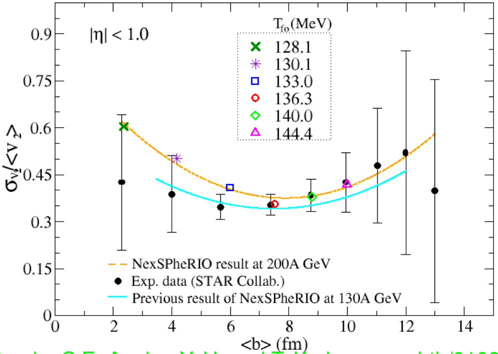

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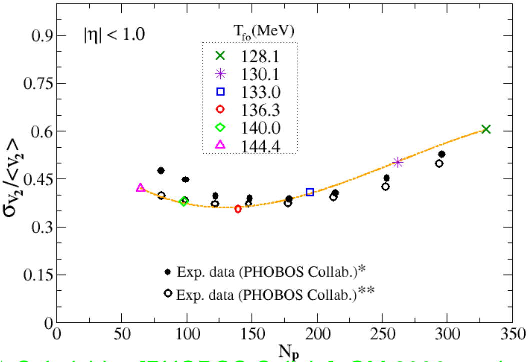
$\sigma_{v_2} / < v_2 >$ - Comparison with data (PHOBOS Collab.)

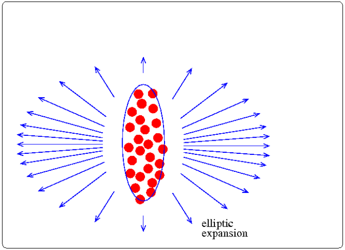


Data: * C. Loizides [PHOBOS Collab.], QM 2006, nucl-ex/0701049;
** B. Alver *et al.*, nucl-ex/0702036

Outline

Granular Structure of IC

The IC for high-energy nuclear collisions are not only event-by-event fluctuating but, if the thermalization is verified at very early time, they should have granular structure.



Granular Structure of IC

The main object of this talk is to show effects of such granular structure of IC on some observables, especially on the elliptic-flow parameter v_2.

Fundamental tool: NeXSPheRIO

SPheRIO

NeXSPheRIO is a junction of two codes.

SPheRIO (Smoothed Particle hydrodynamic evolution of Relativistic heavy IOn collisions) is used to compute the hydrodynamic evolution

- Smoothed Particle Hydrodynamics was originally developed in astrophysics and adapted to relativistic heavy ion collisions
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NeXus

NeXus is used to generate the initial conditions (IC)
[H.J. Drescher, F.M. Liu, S. Ostrapchenko, T. Pierog and K. Werner, *Phys. Rev.* **C65** (2002) 054902.]

- Its main advantage is that, once a pair of incident nuclei and their incident energy are chosen, it can produce, in the event-by-event basis, detailed space distributions of energy-momentum tensor, baryon-number, strangeness and charge densities, at a given initial time $\tau = \sqrt{t^2 - z^2} \sim 1$ fm.
- One important characteristic of such fluctuating IC is that each set of IC is highly irregular.
- Many simulators, based on microscopic models, show such event-by-event fluctuations. Here we use NeXus.

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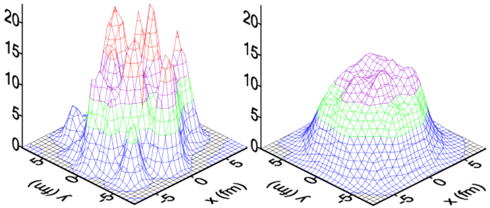
Initial Conditions

Energy density for central Au+Au collisions at 130 A GeV, given by NeXus simulator, at mid-rapidity

One random event | Average over 30 events



Fundamental tool: NeXSPheRIO

Method of analysis

In the present work, we perform two sets of computations:

1. First, we average over random NeXus events, obtaining smooth IC, which are used to compute the observables by using the SPheRIO code.
   This is similar to the usual hydro calculation.
2. In the second set, NeXSPheRIO is run many times and an average over final results is performed.
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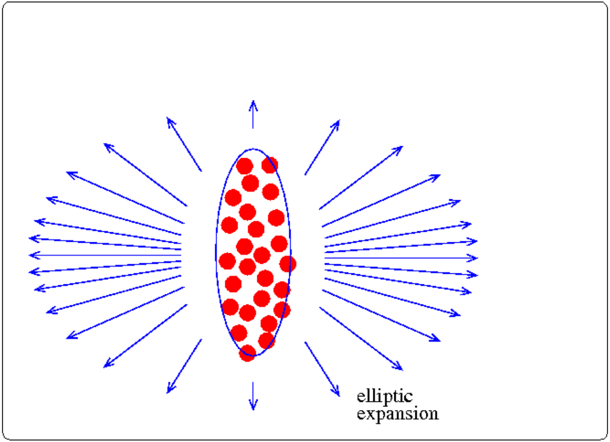

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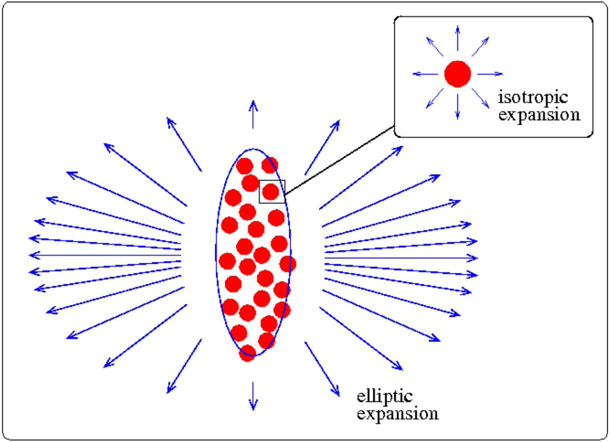
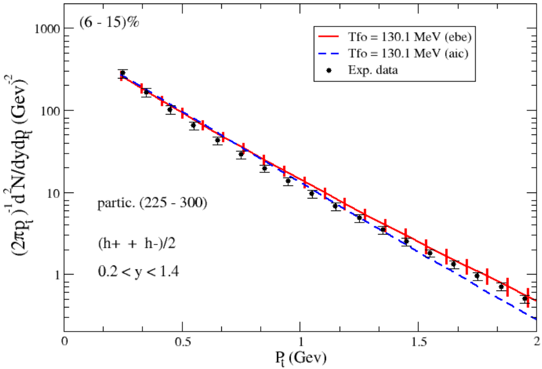


Outline

Results: p_T distribution



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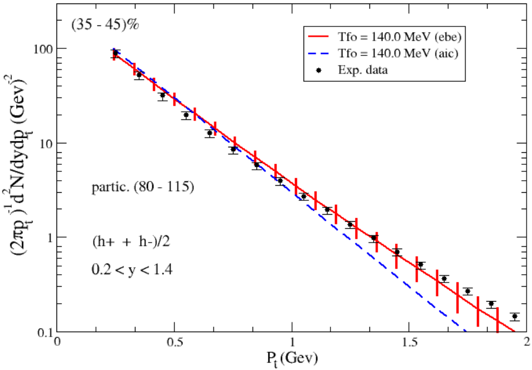

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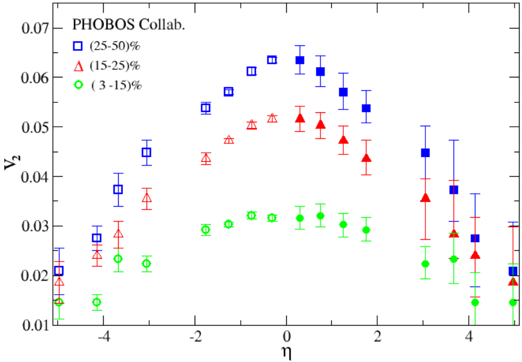
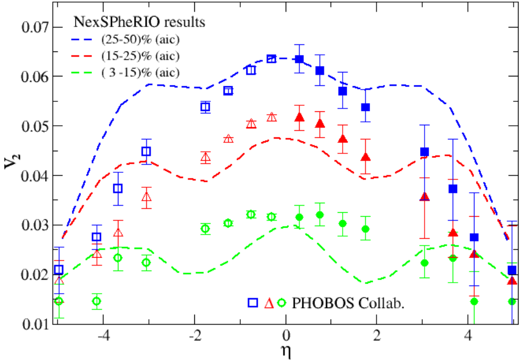
$< v_2 > (\eta)$ - Data



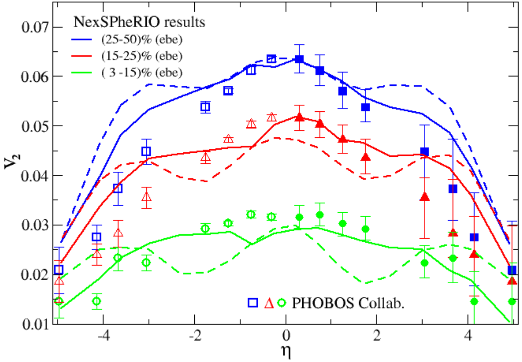
Data: PHOBOS Collab., B.B. Back *et al.* Phys.Rev. C**72** 051901 (2005)

Results: $< v_2 > (\eta)$ - Averaged (smooth) IC



Data: PHOBOS Collab., B.B. Back *et al.* Phys.Rev. C**72** 051901 (2005)

Results: $< v_2 > (\eta)$ - Fluctuating IC (with blobs)



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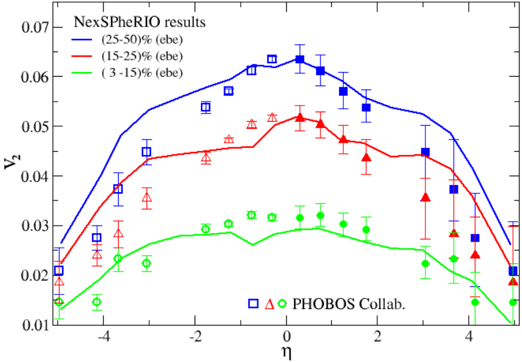

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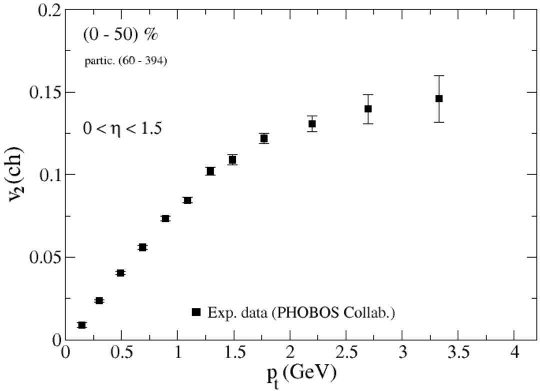
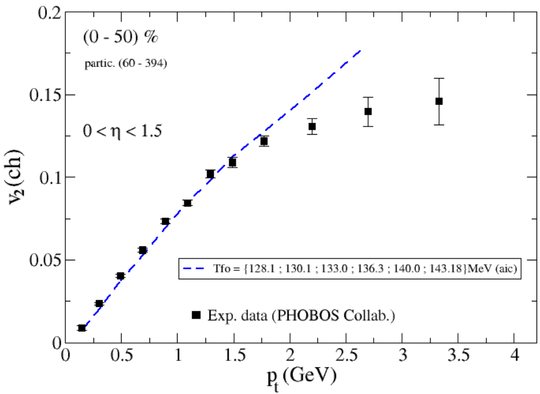
$< v_2 > (p_T)$ - Data



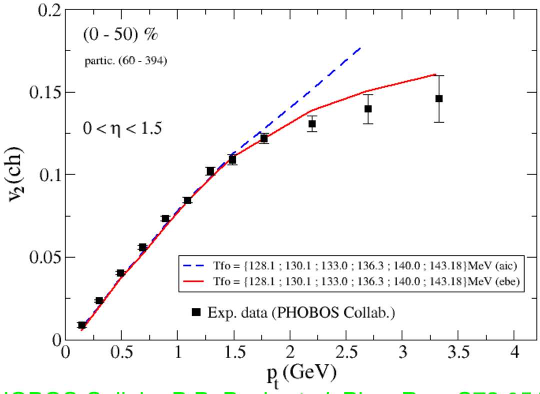
Data: PHOBOS Collab., B.B. Back *et al.* Phys.Rev. C**72** 051901 (2005)

Results: $< v_2 > (p_T)$ - Smooth IC



Data: PHOBOS Collab., B.B. Back *et al.* Phys.Rev. C**72** 051901 (2005)

Results: $< v_2 > (p_T)$ - Bumpy IC



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Summary

- Granular structure in the IC produces more high-p_T particles.
- Granular structure in the IC reduces the elliptic flow.
- This effect is enhanced where the average matter density is small. So, it decreases v_2 in the large pseudorapidity regions.
- As function of p_T, the mechanism becomes more effective as p_T increases, because those high-density blobs cause violent expansion, producing high-p_T particles.
- NeXSPheRIO, with fluctuating IC, reproduce approximately both the p_T-distribution and η-distribution of v_2 for different centrality windows.

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Outlook

The effect of continuous emission is being computed. Probably it makes the curve of v_2 at high-p_T even flatter and the η-distribution narrower.

Additional remarks - NeXSPheRIO

Previous Results - 1

NeXSpheRIO has been used to study a range of problems:

- effect of fluctuating initial conditions on particle distributions C.E. Aguiar *et al.* Nucl.Phys. A**698** 639c (2002)
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