The v_2 fluctuations in NeXSPheRIO

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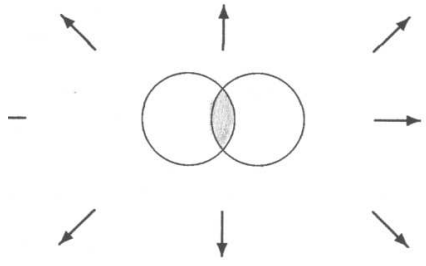
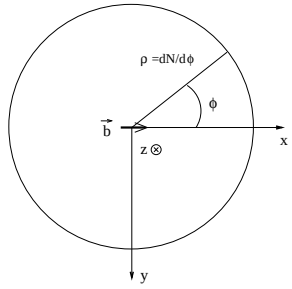
Outline

Objective

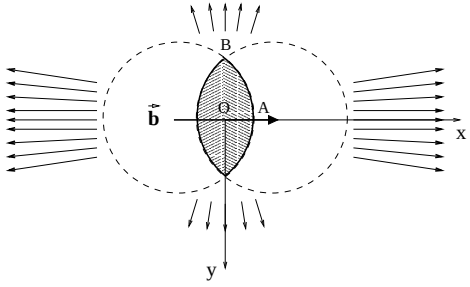
If a nucleus-nucleus collision

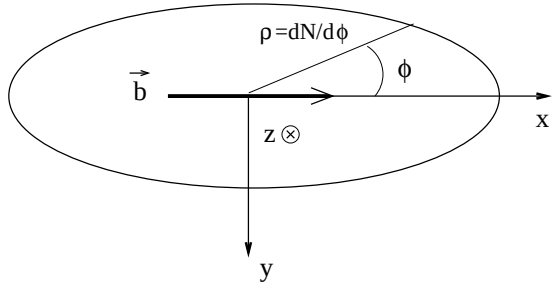
- is a number of *independent nucleon-nucleon collisions* $\Rightarrow$ the momentum distribution is isotropic





- leads to *thermalized matter* (in overlap region) $\Rightarrow$ the momentum distribution is stretched





v_2 = measure of this stretching, so teaches about IC, thermalization, etc

Why study v_2 fluctuations?

$\langle v_2 \rangle$ teaches about IC, thermalization, etc, on an average basis.

Fluctuations give information on an event-by-event basis.

It is a more detailed tool.

To do hydrodynamics with e-b-e fluctuations, we use NeXSPheRIO.

What is 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
  C.E.Aguiar, T.Kodama, T.Osada & Y.Hama, J.Phys.G27(2001)75;
  Y.Hama, T.Kodama & O.Socolowski Jr. Braz.J.Phys. 35(2005)24
- Advantage: incorporates any geometry in the initial conditions

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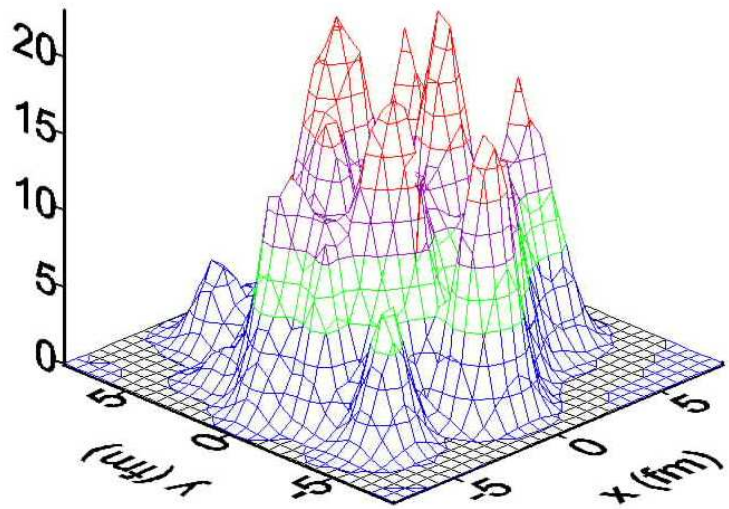
What is NeXSPheRIO?

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.]



$\eta = 0$ slice for initial energy density of a central RHIC collision with several high density peaks (in GeV/fm^{-3}). (In usual hydrodynamic approach, one assumes some highly symmetric and smooth IC.)

NeXSPheRIO is run many times and an average over final results is performed.

This mimics experimental conditions.

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)
- energy dependence of the kaon effective temperature M. Gaździcki *et al.* Braz.J.Phys. **34** 322 (2004); Acta Phys. Pol. B**35** 179 (2004)
- interferometry at RHIC O. Socolowski Jr. *et al.* Phys.Rev.Lett., **93** 182301 (2004); Acta Phys. Pol. **B36** 347 (2005)
- transverse mass distributions at SPS for strange and non-strange particles F. Grassi *et al.* J.Phys. G**30** S1041 (2005)
- effect of the different theoretical and experimental binnings R.Andrade *et al.* Braz.J.Phys. **34** 319 (2004)
- effect of the nature of the quark-hadron transition and of the particle emission mechanism Y. Hama *et al.* QM05 proceedings, Nucl.Phys. A**774** 169 (2006)
- how to relate the hydro-computed and experimental $\langle v_2 \rangle$ R. Andrade *et al.*, Phys.Rev.Lett. **97** 202302 (2006)
- Strange particles at RHIC:W.L.Qian, this meeting
- $\langle v_2 \rangle$: this talk

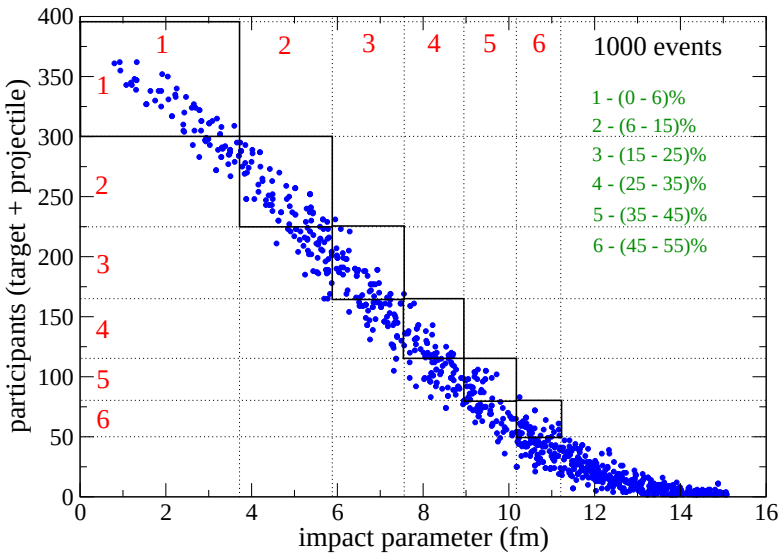
Results for averaged quantities

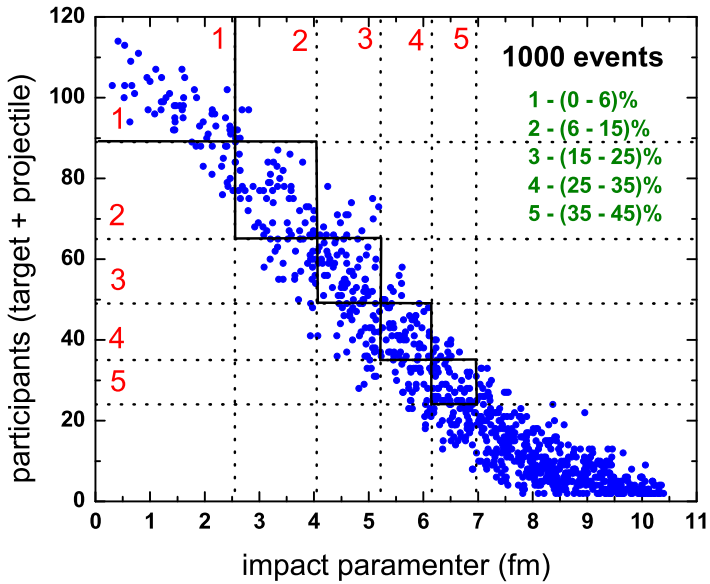
The version of NeXSPheRIO used here has an eos with a critical point

Y. Hama *et al.* QM05 proceedings, Nucl.Phys. A**774** 169 (2006)

and incorporate strangeness conservation.

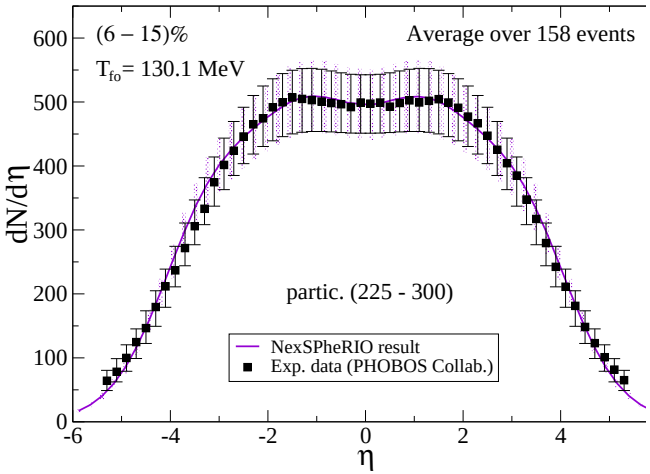
Centrality windows are defined *as experimentally*, using participant number and not impact paremeter R.Andrade *et al.* Braz.J.Phys. **34** 319 (2004)

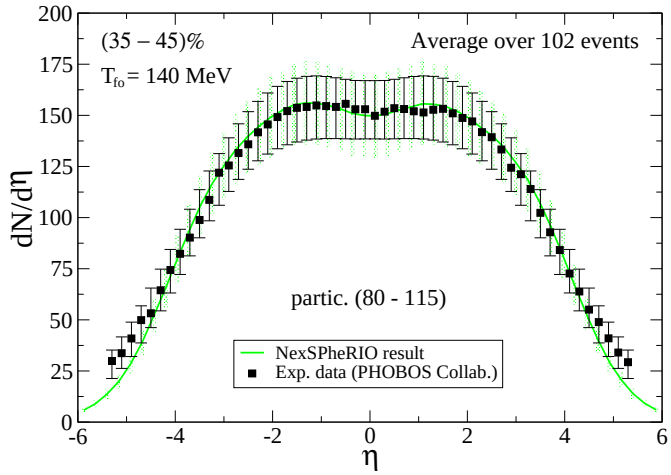




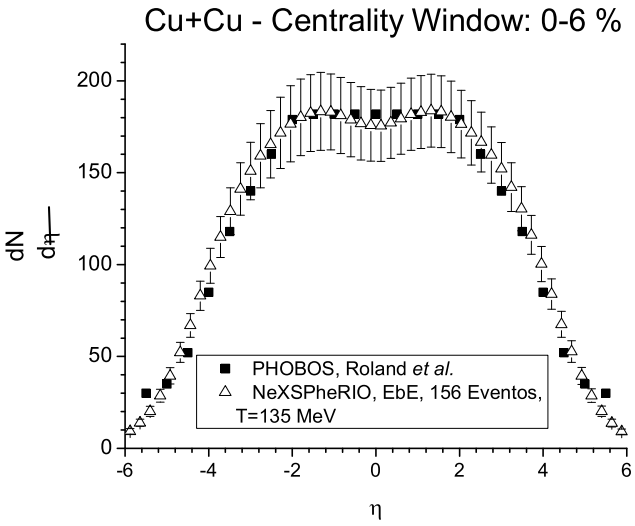
NeXus centrality windows for: left) Phobos Au+Au data, right) Phobos Cu+Cu data.

NeXus IC are normalized by an η-dependent factor to reproduce $dN_{ch}/d\eta$ in each centrality window (Au+Au) and most central windows (Cu+Cu).



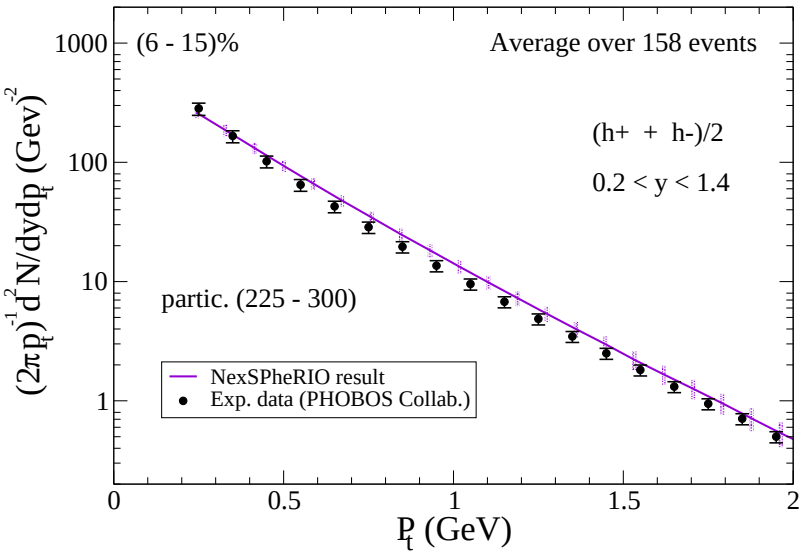


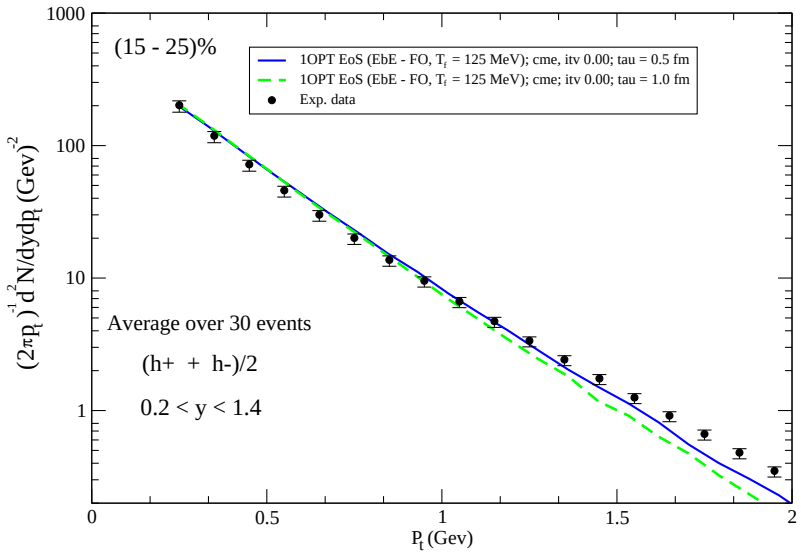
NeXSPheRIO and Phobos Au+Au data



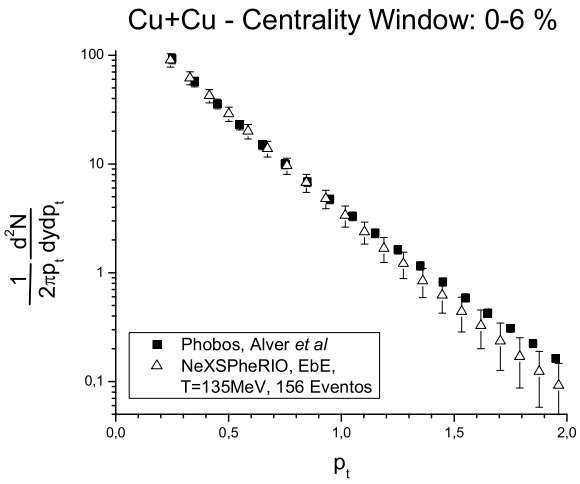
NeXSPheRIO and Phobos Cu+Cu data

$T_{f.out}$ is fixed (mostly) by $dN_{ch}/p_t dp_t$ and depends on the centrality window (i.e. number of participants).



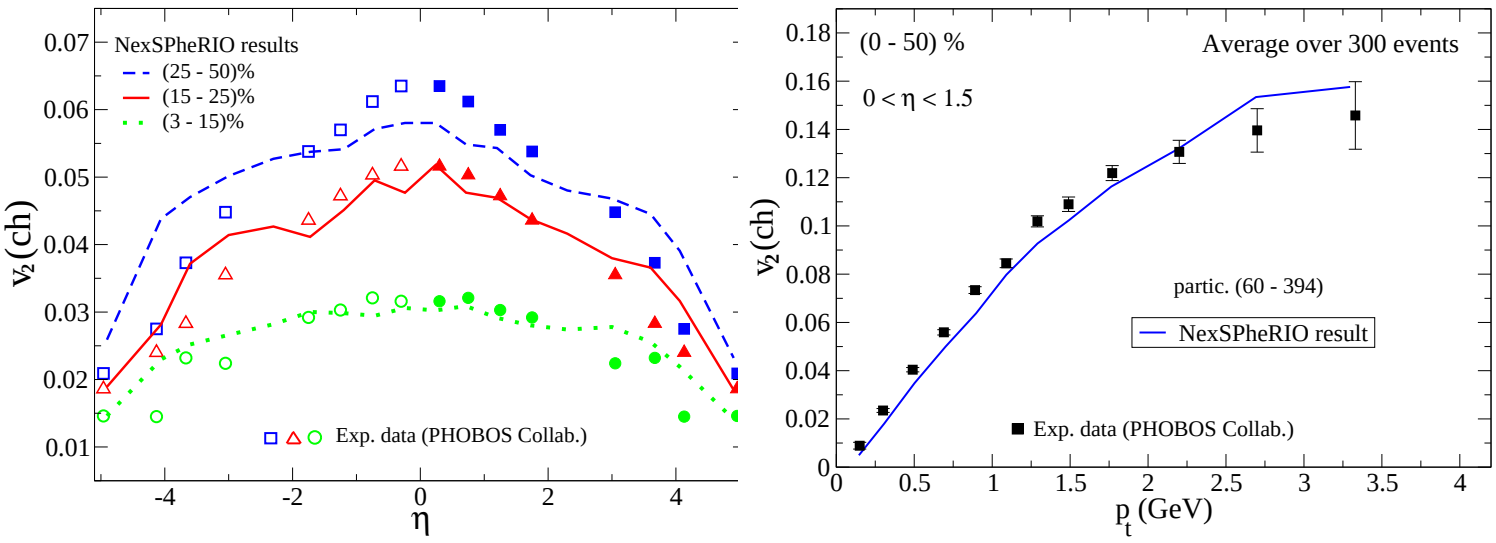


NeXSPheRIO and Phobos Au+Au data.



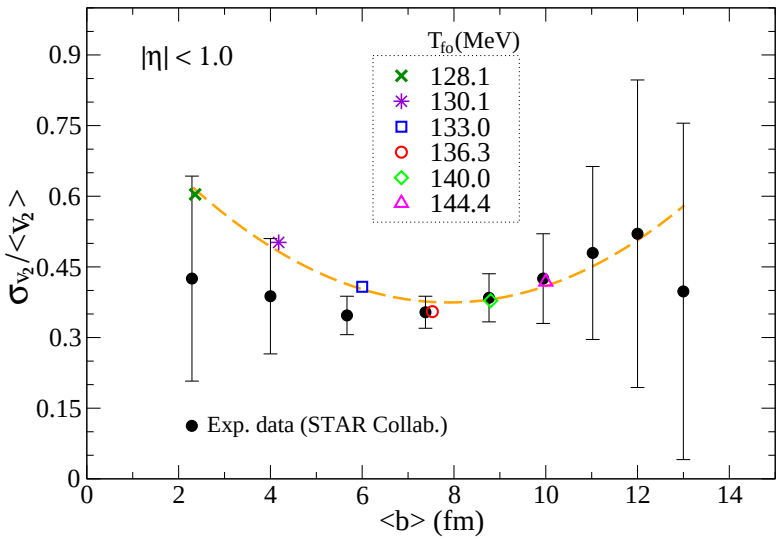
NeXSPheRIO and Phobos Cu+Cu data.

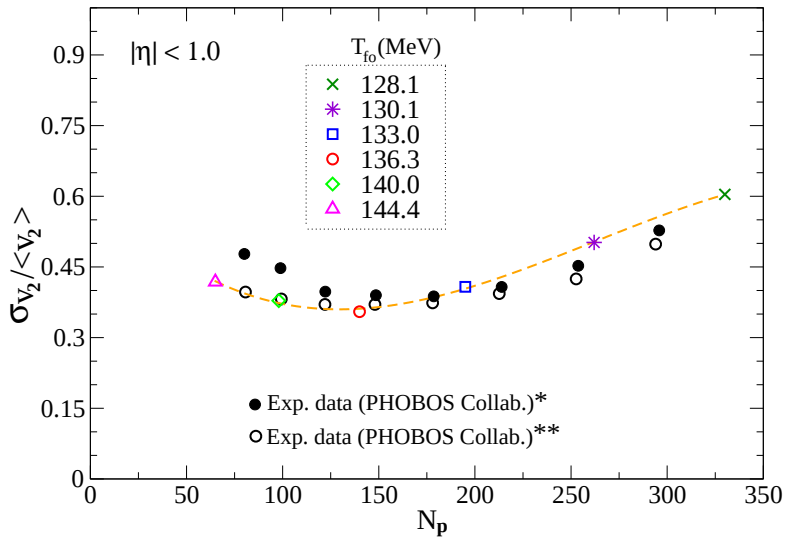
Elliptic flow is computed in the event plane and not reaction plane to compare with data R. Andrade *et al.*, Phys.Rev.Lett. **97** 202302 (2006)



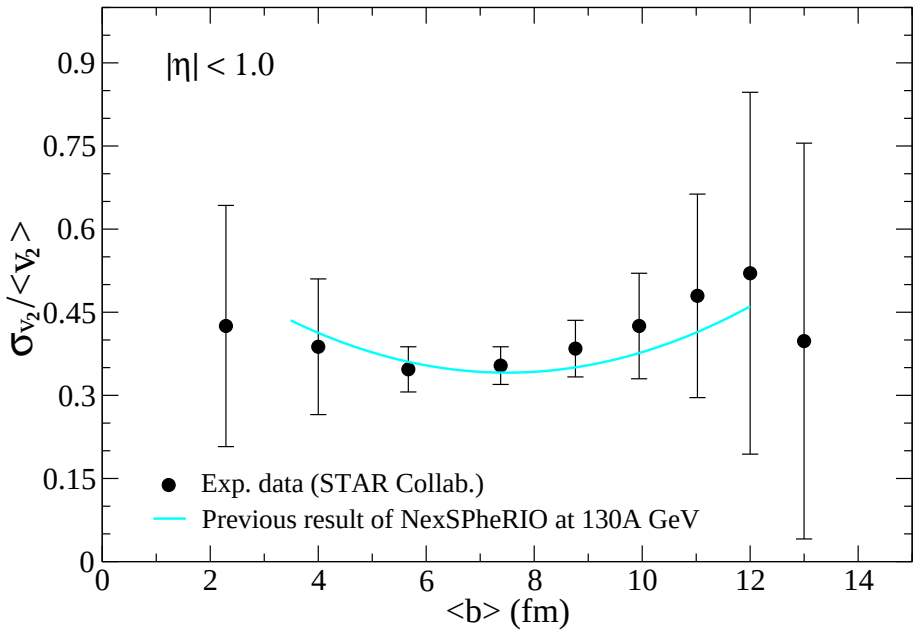
Results for e-b-e quantities: v_2 fluctuations

Results on v_2 fluctuations were shown at QM06. NeXSPheRIO results agree well with them: left) Star right) Phobos.



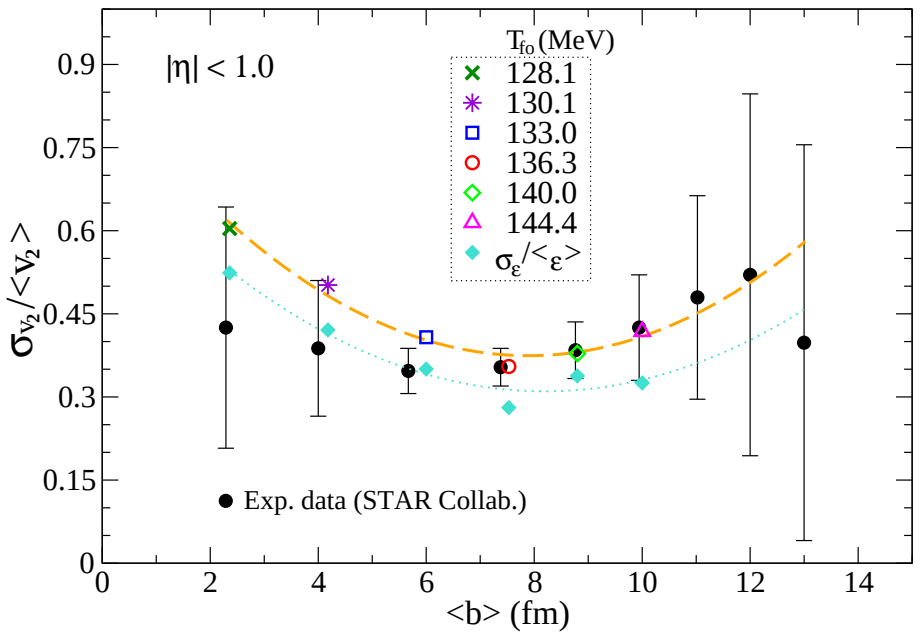


In fact, the correct order of magnitude of these fluctuations (at $\sqrt{s} = 130\,GeV$) was predicted by NeXSPheRIO C.E. Aguiar *et al.* Nucl.Phys. A**698** 639c (2002)



Where do these fluctuations come from?

Compare them with $\sigma_{\epsilon_{participant}} / \epsilon_{participant}$.

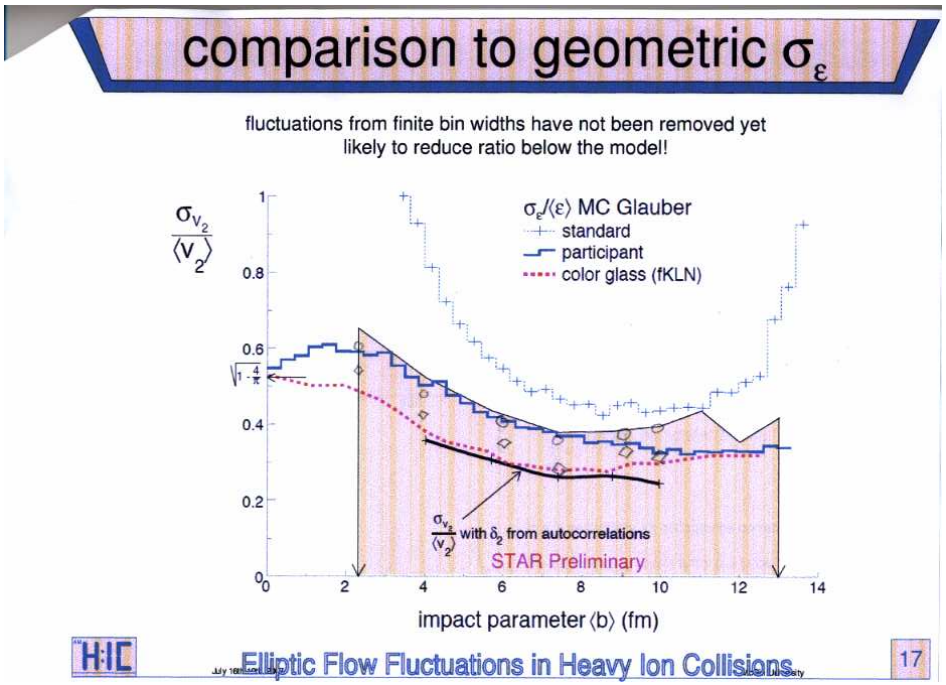


Preliminary*:
$\sigma_{v_2}/\langle v_2 \rangle$ is a little higher than $\sigma_{\epsilon_{participant}}/\epsilon_{participant}$
$\Rightarrow$ NeXus initial conditions are the main source of v_2 fluctuations. The emission process in SPheRIO would provide the rest.
In this case, it might be interesting to study the v_2 fluctuations together with other fluctuations, such as multiplicity ones.

*This is prelimimary because additional checking is necessary on how to compute the eccentricity (what matter to include) and the emission process sensitivity to number of Monte-Carlos.

Newest results on v_2 fluctuations

More recent results by Star (P.Sorensen, Montreal meeting, july 2007, http://www.physics.mcgill.ca/etd-hic/schedule.html) indicate that 1) the QM results are an upper limit for $\sigma_{v_2}/\langle v_2 \rangle$ (top of redish area) 2) there are also other reasons to expect that this upper limit will be decreased.



From previous figure, if the upper limit on v_2 fluctuations really gets lower

- standard Glauber type models would be excluded
- NeXSPheRIO would be exluded (the circles)
  (too much fluctuations in NeXus I.C.? in particle emission? failure of ideal hydro?)
- the CGC curve is a $\sigma_{\epsilon_{participant}}/\epsilon_{participant}$ curve Drescher and Nara, arXiv:0707.0249 [nucl-th].
  It may have difficulties as well because 1) when coupled with hydro, the particle emission process would lead to a higher $\sigma_{v_2}/\langle v_2 \rangle$ 2) the low value of $\sigma_{\epsilon_{participant}}/\epsilon_{participant}$ comes from the large value of the eccentricity, this in turn when coupled with hydro, usually leads to too high v_2 Hirano et al. Phys. Lett. B636 (2006) 299.

All models seem to be on the verge of consistent with v_2 fluctuations

Summary

- Results from NeXSPheRIO are in agreement with RHIC charged particle data in the various centrality windows for $dN/d\eta$, $dN/p_t dp_t$, $v_2(\eta)$ and $v_2(p_t)$ for Au+Au and Cu+Cu.
- v_2 fluctuations from NeXSPheRIO agree with QM Star and Phobos results.
  Preliminary: v_2 fluctuations from NeXSpheRIO come mostly from the I.C., being increased somewhat by particle emission.
- If v_2 fluctuations data decrease, many models may have problems.
  $\Rightarrow$ v_2 fluctuations seem a good way to constrain models.

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