Predictions for event-by-event flow harmonic distributions at RHIC

Leonardo Barbosa[1], Fernando G. Gardim[2], Frédérique Grassi[1], Matthew Luzum[1], Meera Vieira Machado[3] and Jacquelyn Noronha-Hostler [4]

[1]Universidade de São Paulo, São Paulo - Brasil

[2]Universidade Federal de Alfenas, Minas Gerais - Brasil

[3]Niels Bohr Institute, University of Copenhagen, Copenhagen - Denmark

[4]The State University of New Jersey, Pitscataway - USA

Introduction

Motivation

Great part of the uncertainty in our hydro models come from the fact we do not fully understand the initial conditions. Flow harmonic distributions are quite dependent of these initial conditions fluctuations giving us a good way to test these initial conditions models. Many models fail when trying do describe these quantities (e.g. MC-Glauber, MC-KLN [1, 2]). IP-GLASMA [3], EKRT[4], AMPT and TRENTO [5] provides satisfatory results. In this poster we show that NeXus also leads to reasonable results for LHC and show predictions for RHIC top energy for TRENTO and NeXus initial conditions.

Flow Harmonic Distributions

We can write the Fourier expansion of the particle distribution in terms of the azimuthal angle ϕ

$$\frac{dN}{p_T dp_T d\phi dy} = \frac{dN}{2\pi p_T dp_T dy}\left[1 + \sum_{n=-\infty}^{\infty} v_n e^{i(n(\phi-\Psi_n))}\right] \quad (1)$$

The coeficients v_n are called harmonic flow coefficients and it gives the magnitude of a certain type of anisotropy in the particle azimuthal distribution.Ψ_n gives us a orientation for these anisotropy components.

Eccentricities

The initial spatial anisotropies can be quantified in terms of the eccentricities $\epsilon_{m,n}$:

$$\epsilon_{m,n} e^{in\Phi_{m,n}} = -\frac{\int r dr d\phi r^m e^{in\phi} \rho(r,\phi)}{\int r dr d\phi r^m \rho(r,\phi)} \quad (2)$$

Where ρ is energy or entropy density and $\Phi_{m,n}$ is the participant angle. We give special attention to $\epsilon_{n,n}$ which, for simplicity, we call ϵ_n with $\Phi_{n,n} = \Phi_n$.

It is known that in a given centrality window for each event approximately $v_2 \propto \epsilon_2$ in non central collisions [6] [7], so it is reasonable that the scaled harmonic flow distributions follow the scaled eccentricities distributions, that is: $P(v_2/\langle v_2\rangle) \approx P(\epsilon_2/\langle \epsilon_2\rangle)$ that is true also for v_3 and ϵ_3. For v_4 and ϵ_4 an interesting feature can be mentioned: For non central collisions $v_4 \propto \epsilon_4$ does not hold as v_4 has a dependency not only with ϵ_4 but also with ϵ_2^2 [7].

NeXSPheRIO V-USPHYDRO

NeX**us** **S**moothed **P**article **h**ydrodynamic **e**volution of **R**elativistic heavy-**IO**n collisions

NeXSPheRIO is the code used in the simulations presented in this poster. It uses NeXus initial conditions, solves the 3+1 dimensional (it can be used 2+1 dimensions too) perfect fluid equations.

V-USPHYDRO solves 2+1 dimensional viscous (Temperature dependent bulk and shear viscosities) fluid hydrodynamics assuming longitudinal boost invariance, in this case using TRENTO initial conditions.

Since NeXSPheRIO solves perfect fluid equations we present our results as scaled harmonic flow distributions $P(v_n/\langle v_n\rangle)$, these scaled distributions should be independent of viscosity. [6]

Results

We present our results and compare them with experimental data for LHC energies, and present a prediction for RHIC top energy.

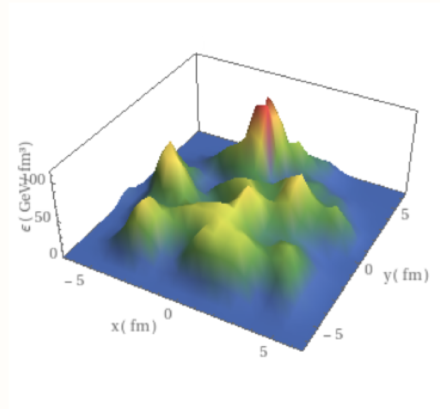

Figure 1: NeXus initial conditions. Picture reproced from arXiv:1712.03912 [nucl-th]

LHC

Here we show LHC energies scaled v_n and ϵ_n distributions from NeXSPheRIO compared with ATLAS data [2] in Fig 2, 3 and 4 at 20-25 % centrality window, where many other initial conditions models fail to describe data.

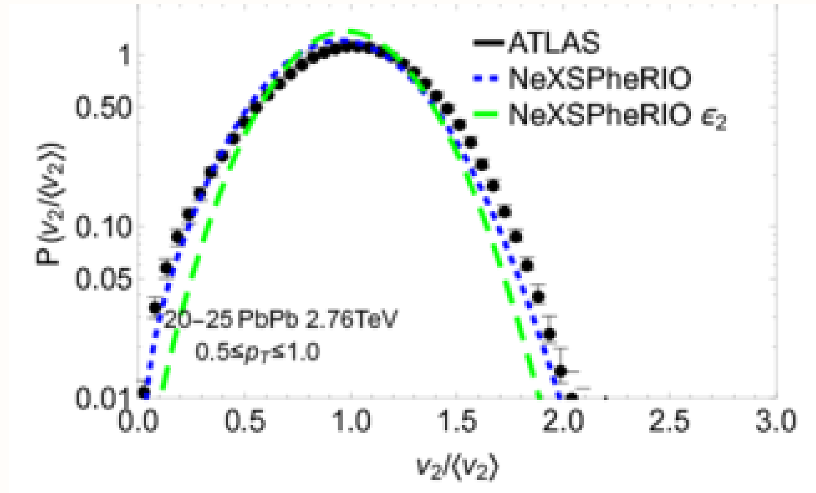

Figure 2: Scaled ϵ_2 and v_2 with $|\eta| < 1$ compared with ATLAS data [2] $|\eta| < 2.5$ in 20-25 % centrality windows and $0.5 < p_t < 1$ GeV in Pb+Pb collisions at 2.76 TeV.

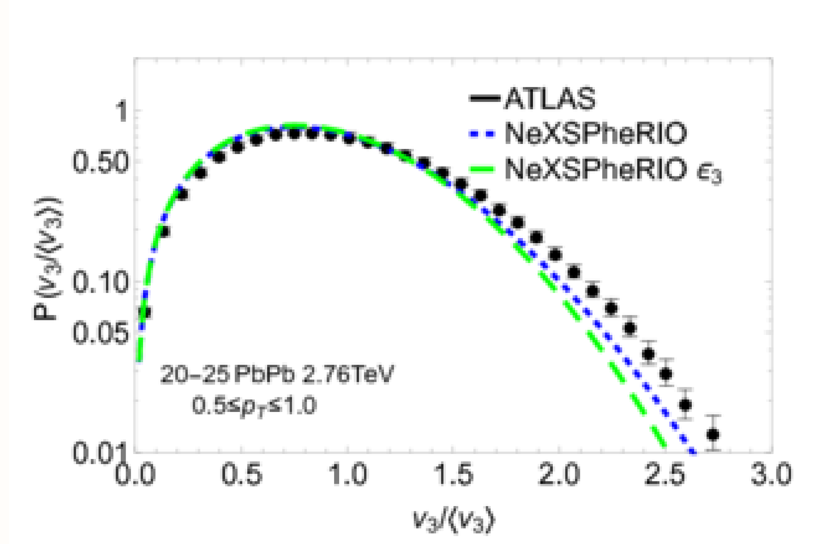

Figure 3: The same for scaled ϵ_3 and v_3

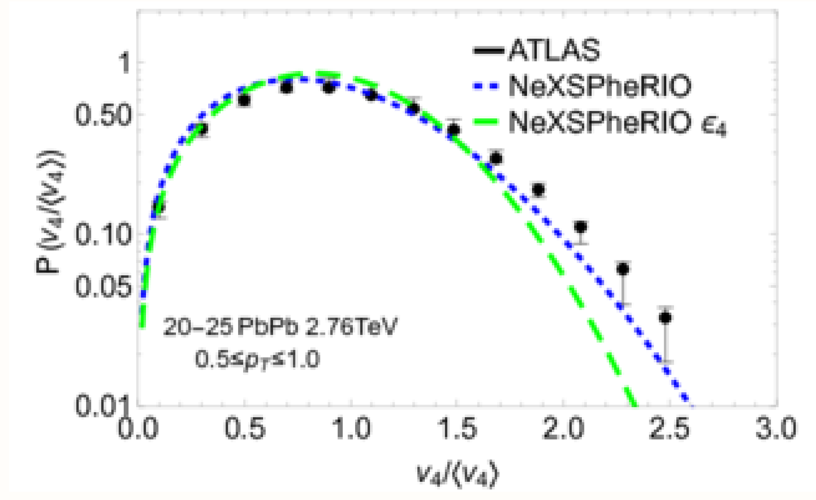

Figure 4: The same for scaled ϵ_4 and v_4

RHIC

Here we show predictions for RHIC top energy scaled v_n distributions from NeXSPheRIO (NeXus initial conditions) compared with data from V-USPHYDRO [8] (TRENTO initial conditions).

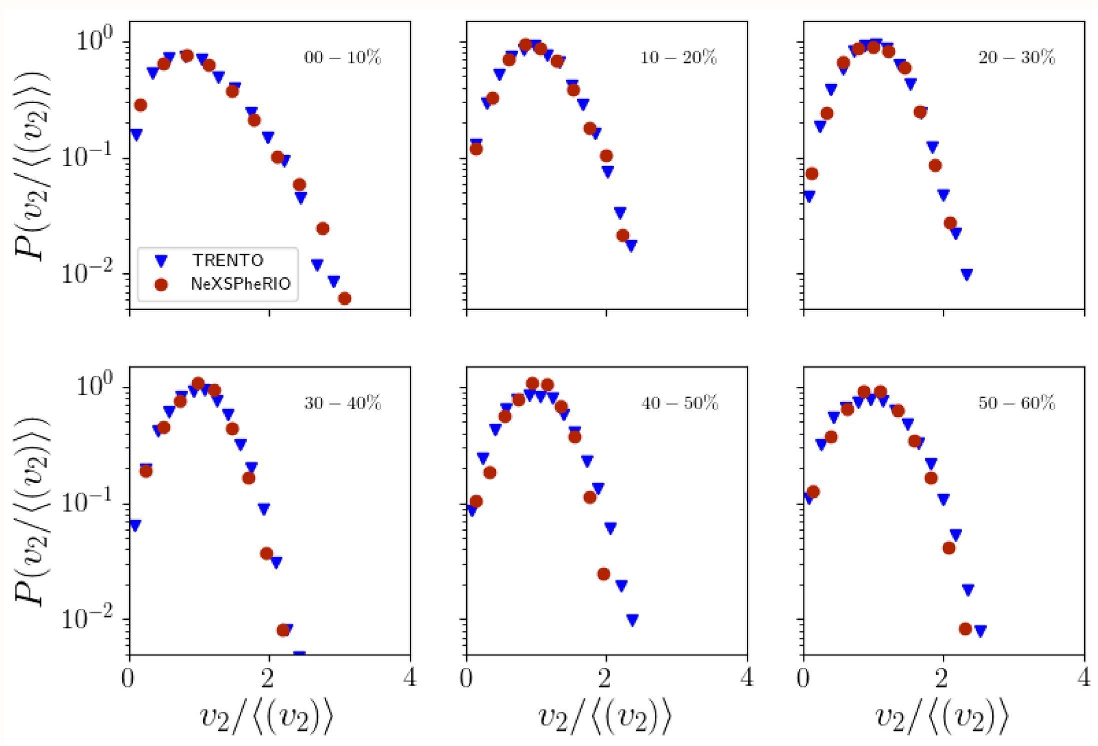

Figure 5: Scaled v_2 distributions with $|\eta| < 1$ from NeXSPheRIO (NeXus) for many centrality windows, compared with data from V-USPHYDRO (2+1 dimensions assuming longitudinal boost invariance (TRENTO))

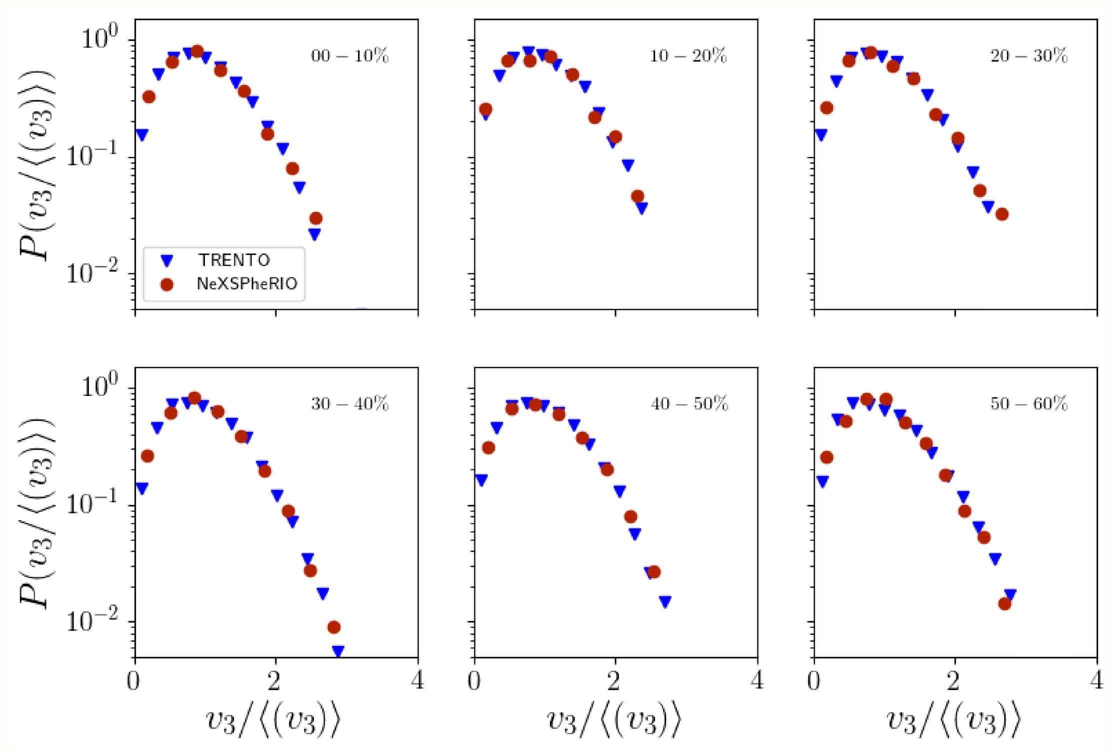

Figure 6: Same as in the previous figure but with v_3

Conclusions

RHIC energy data is in agreement with preliminary data from STAR collaboration presented on a poster at Quark Matter 2017 by Maowu Nie from Shangai Institute of Applied Physics Stony Brook University.

The eccentricities distribution depends little on energy scales. As mentioned in this poster for $n = 2,3$ $P(v_n/\langle v_n\rangle) \approx P(\epsilon_n/\langle \epsilon_n\rangle)$ and since TRENTO and NeXus give similar results for $P(v_n/\langle v_n\rangle)$ at LHC it is not very surprising that flow harmonic distributions are similar at RHIC

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