Anisotropic flow from Initial state geometry in pp collisions at LHC energies.

I. Bautista

CONACYT, Faculty of Physics Benemérita Universidad Autónoma de Puebla

Abstract

Anisotropic flow plays a crucial role to characterize the momentum anisotropy of the final state particles. In order to probe the properties of the system created in high multiplicity pp collisions at LHC energies, we study within the percolation color sources, the effects of initial state geometry, profile distribution, size and eccentricity fluctuations in pp collisions at the LHC energies. The results on the higher harmonic flow modes shown how the initial state geometry and the density of color string sources vary significantly the contribution of the higher flow modes (v_n) due to the size effect. The correlation of the higher flow harmonics with the corresponding η/s is compared with hydrodynamic calculations.

Introduction

Flow coefficients in relativistic heavy ion collisions at RHIC and LHC are now a well establish signature of hydrodynamic behavior of the strongly interacting Quark Gluon Plasma. v_2 is commonly assumed as an hydrodynamic response to the initial anisotropy ε_2 of the initial density profile. Also the statistical properties of anisotropic flow had been studied by several collaborations. Recently in high energy pp and pA an anisotropy azimuthal correlation has been observed in high multiplicity collisions similar to the one measured in AA collisions. The measured azimuthal structure is long range (namely ridge), also it has been found to be collective, correlating almost to all particles in the event. In the case of v_2 the values in pp and pPb seem to be independent of the multiplicity, also the mass dependence of identified particles in v_2 also suggest the production of particles from a collective moving source, which origin is still not completely determined. There are models of hydrodynamics, parton transport which assume an initial anisotropy in position or momentum space and uses strong final state interactions to transpose the final anisotropy in momentum space. Other models suggest the presence of strong interactions in the initial stage before particles are produced, in agreement with the ridge structure (initial interactions of gluons inside the projectile). Among the models which follow this scheme are CGC, glasma, color field domains, and also the String Pecolation Model (SPM) which is the framework on which we present a study on anisotropic flow from Initial state geometry in pp collisions at LHC energies.

Color String Percolation Model

Particle production sources on the String Percolation Model (SPM) are color strings stretching between the colliding hadrons. The stretched strings break and decay into new partons which produce new strings (Schwinger mechanism)[1-3].

By increasing the energy or the system size, the string density will increase and the strings will start to overlap to form macroscopic clusters. When a critical disc density $\zeta^t \simeq 1.12 - 1.5$ is reached (homogeneous or Woods-Saxon nuclear distribution profile), a connected system
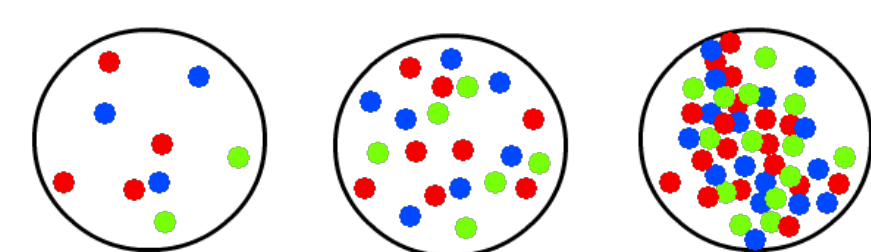

Figure 1: Representative scheme of cluster formation and percolation

is created which marks a phase transition. The transverse string density is defined as: $\zeta^t = \left(\frac{r_0}{R_p}\right)^2 N_s$

Another important parameter is the color reduction factor, which is the geometric scaling function that reduces the color production clusters with the energy and the number of participants. $F(\zeta^t) = \sqrt{\frac{1-e^{-\zeta^t}}{\zeta^t}}$

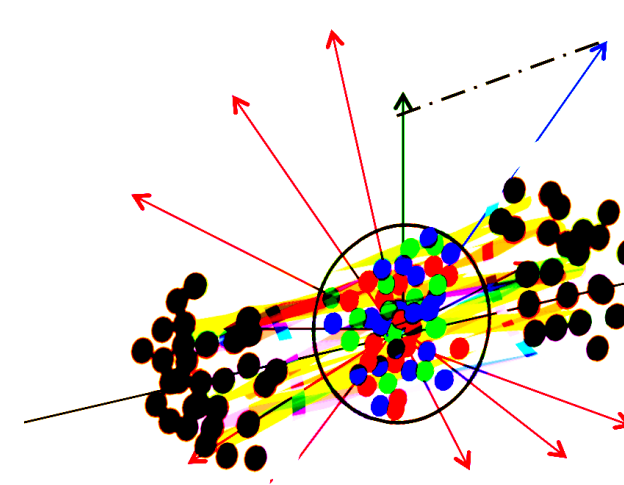### Monte-Carlo model bounded percolating system for different geometries

Figure 2: Representative scheme of the color string between partons.

To explore the effects on the initial geometry, we perform a study on the finite size effects on the string density order parameter, in the context of small collisions systems for different initial number of strings being different multiplicity classes, using 3 different profile functions.

We fix the number of strings and the geometry boundary, as we change the surface of the overlapping area, we get variations in the filling factor. So, the dimension of S can be written as a function of η, N and the geometry. For an n-sides regular polygon boundary, the string density is given by $\eta = \frac{4N\pi r_0^2 \tan(\pi/n)}{nl^2}$ where r_0 is the radius of the small discs or strings and l is the length of the sides of the regular polygon. So that the dimension of the regular polygon of n-sides witch confines the system is given by $l = \sqrt{\frac{4N\pi \tan(\pi/n)}{n\eta}} r_0$. To obtain ϵ_n, we use 2 different profile functions to distribute the strings in the different geometries, uniform and a Gaussian for a more realistic case. For ϵ_2 elliptic boundary, we use semi-axes given by $a^2 = \frac{r_0^2 N}{\eta\sqrt{1-\varepsilon^2}}$, $b^2 = \frac{r_0^2 N\sqrt{1-\varepsilon^2}}{\eta}$, being a and b are the major and the minor semi-axes, respectively, and ε is the eccentricity. Due to no periodic boundary condition for strings systems, to establish the emergence of the spanning cluster. Similarly, as in Ref. [4], we inscribe a polygon small enough so that its sides are at a distance equivalent to the string diameter $2r_0$ from the boundary. If there is a spanning cluster in the string system, then we compute the percolation probability as the rate between the number of strings belonging to the spanning cluster and the total number of strings in the system. With the Gaussian distribution function, defined as follow: $f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left[-\left(\frac{(x-x_0)^2}{\sigma_x^2} + \frac{(y-y_0)^2}{\sigma_y^2}\right)\right]$
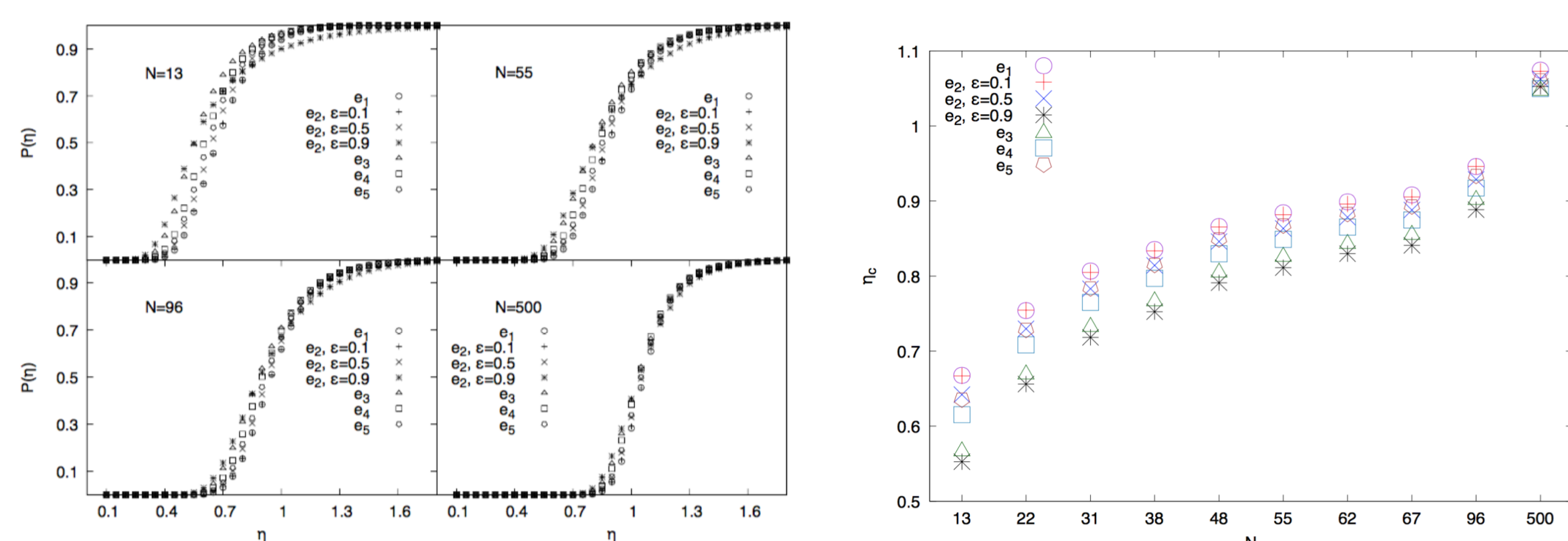

Figure 3: Left side shows the percolation probability dependence on the geometry of the initial state for systems in the Uniform model with N =13, 55, 96 and 500. Rigth side of the figure shows the percolation threshold dependence on the initial geometry state and the number of strings in the system.
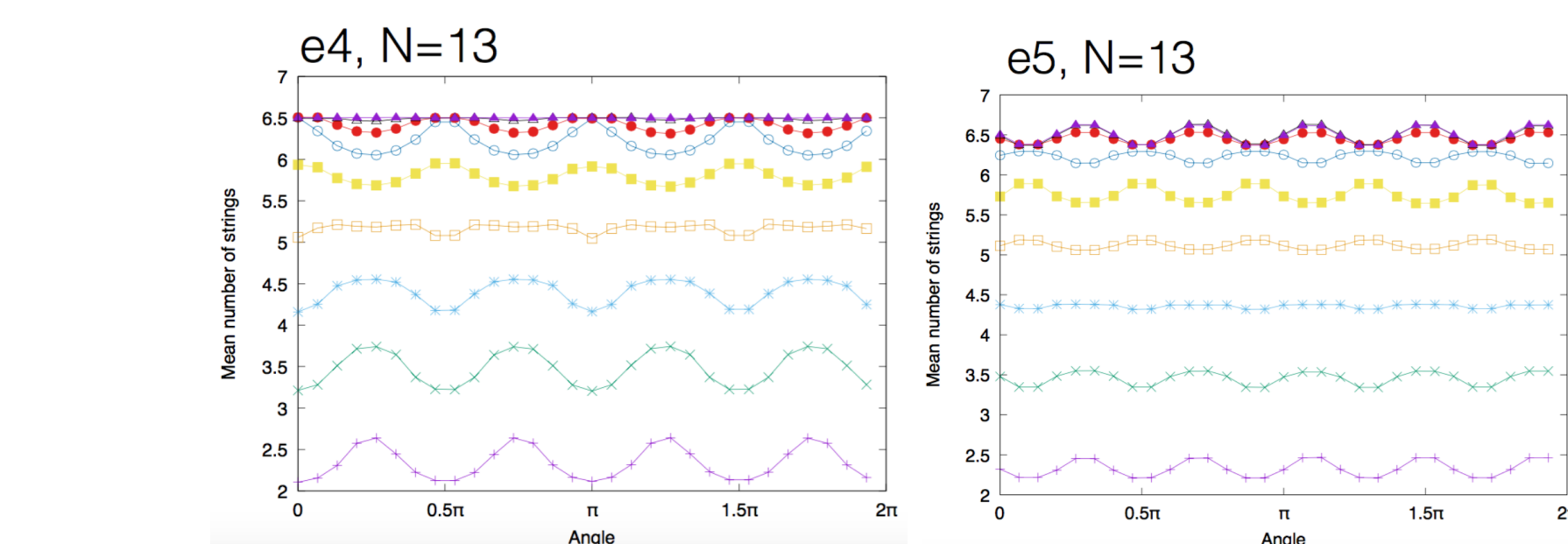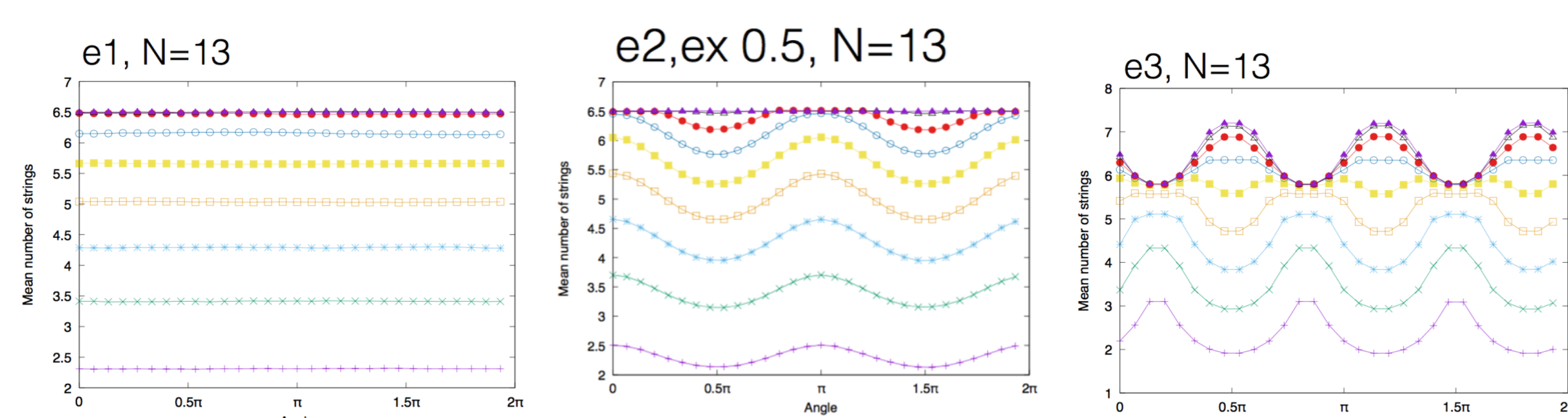

Figure 4: particle production dependence on the geometry of the initial state for systems.
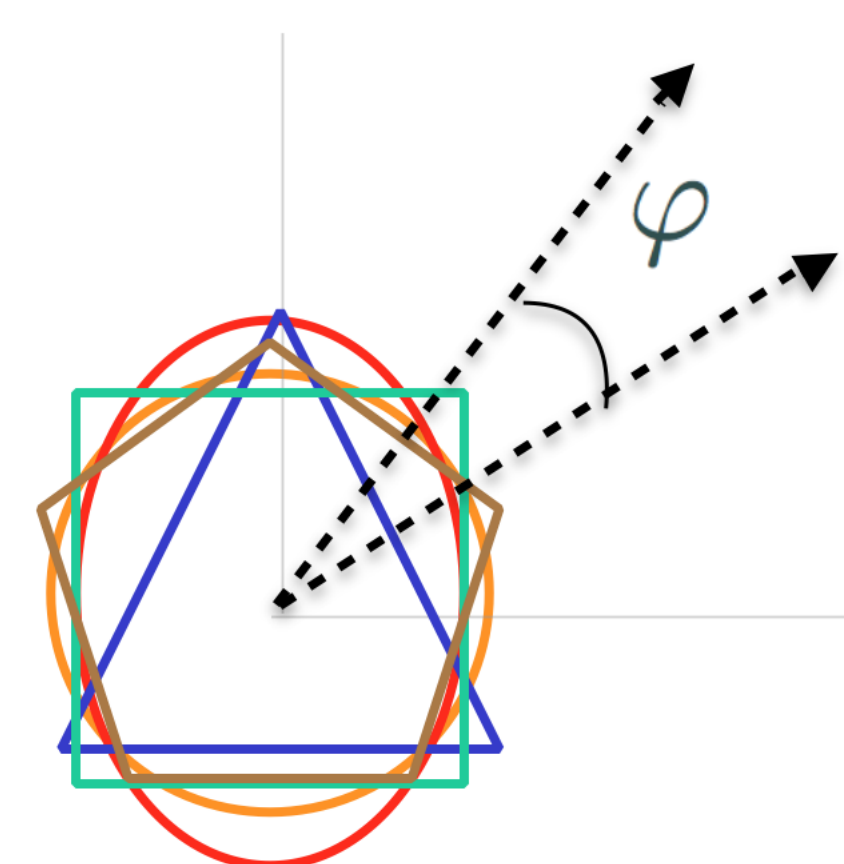
Now we can relate the particle production for the different initial geometry modes that are shown in the above figure to calculate the contribution due to geometry fluctuation of the initial anisotropy ε_n defined in a similar manner as in reference [5].

$$\varepsilon_n = \varepsilon_n e^{in\varphi_n} = \frac{\int r^n e^{n\varphi} \zeta^t(r,\varphi) r dr d\varphi}{\int r^n \rho(r,\varphi) r dr d\varphi} \quad (1)$$

Where ζ^t is the transverse string density, and with the usual polar coordinates in the transverse plane. By scaling to be able to comparethe trend with the prediction of n predictions from Monte-Carlo Glauber, IP-Glasma and the results from [4] for the fit to the ATLAS data.
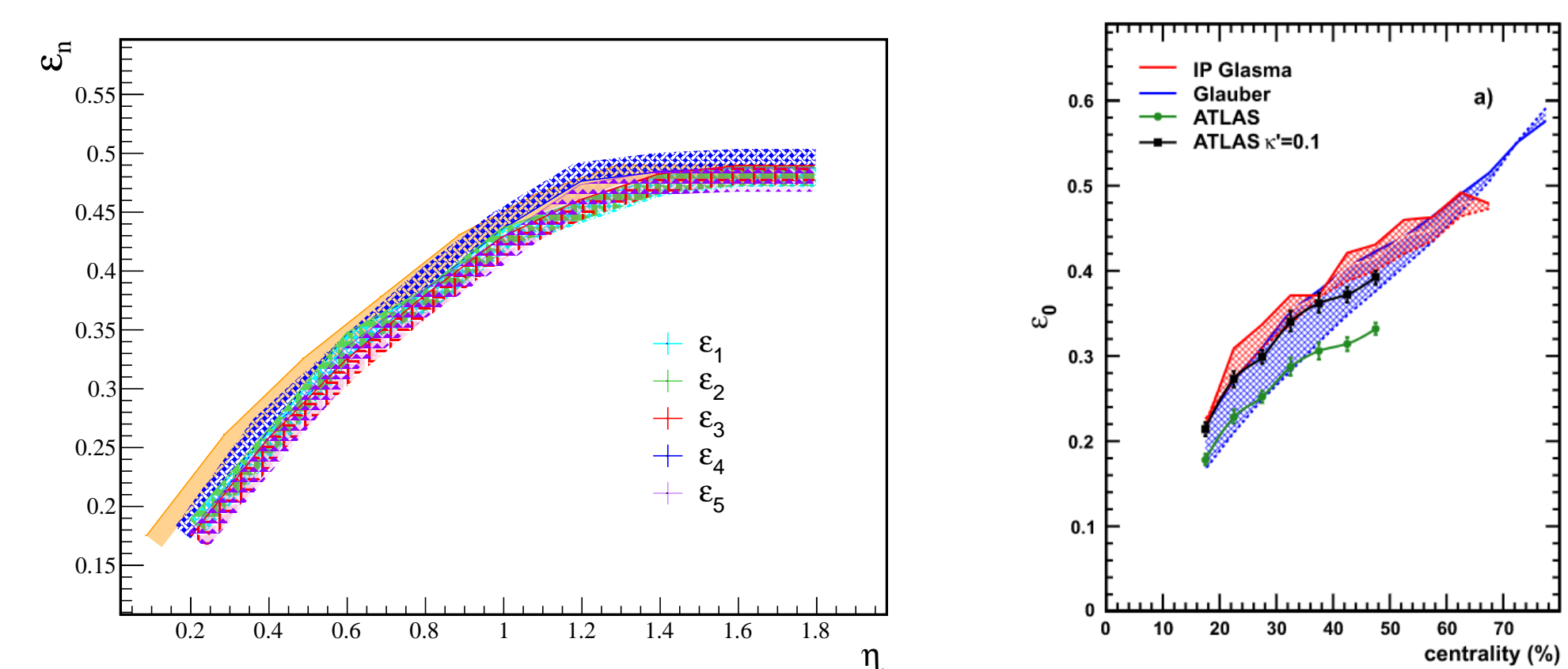

Figure 5: Scheme of azimuthal production for ϵ_n.

Figure 6: Comparison of the mean initial anisotropy ε_n with the calculation obtained in Ref. [5]. Note that we are comparing ε_n vs initial string density which is proportional to the centrality of the collision.

Note that for this model there is dependence on the temperature and so with the string density that due to the initial geometry is also modify for small collisions systems as shown in Figure.
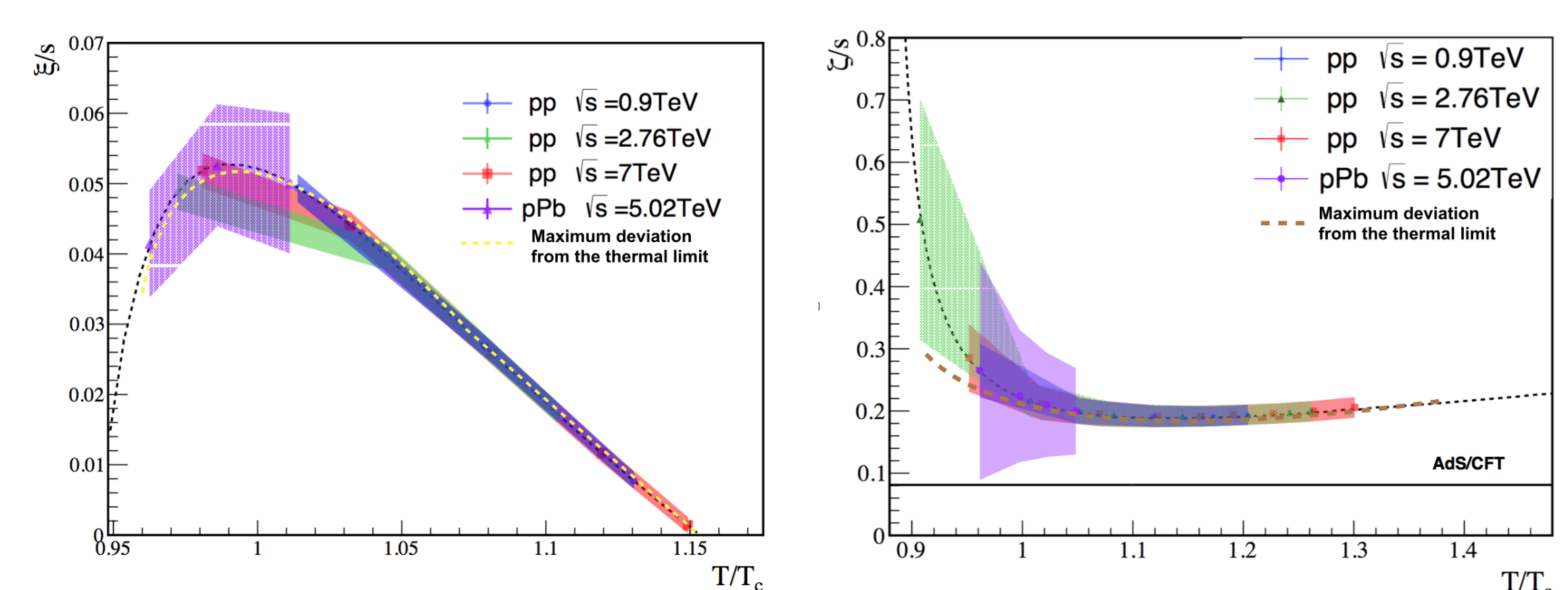

Figure 7: Maximum deviation for shear and bulk viscosity due to initial anisotropy.

Initial geometry effects shown to be significant on small symmetric collision systems, their contribution to the flow by the fluctuation of the initial anisotropy seem to have a universal trend, which can be correlated to the decrease for the less initial string populated systems on the shear viscosity but not for the bulk viscosity. This is expected as we will have an increase on the differences o the velocities of the edited particles generating resistance to the moving but not a change on the degree of compressibility, which is intrinsic for the created medium.

Conclusions

Initial geometry effects show to be significant on small symmetric collision systems, their contribution to the flow by the fluctuation of the initial anisotropy seem to have a universal trend, which can be correlated to the decrease for the less initial string populated systems on the shear viscosity but not for the bulk viscosity. This is expected as we will have an increase on the differences o the velocities of the emitted particles generating resistance to the moving but not a change on the degree of compressibility, which is intrinsic for the formed medium.

References

1. M. A. Braun, J. Dias de Deus, A. S. Hirsch, C. Pajares, R. P. Scharenberg and B. K. Srivastava, Phys. Rept. **599** (2015) 1
2. E. G. Ferreiro, F. del Moral and C. Pajares,Phys. Rev. C **69** (2004) 034901
3. I. Bautista, A. F. Téllez and P. Ghosh, Phys. Rev. D **92** (2015) no.7, 071504.
4. J. E. Ramrez, A. Fernndez Tllez and I. Bautista, Physica A **488** (2017) 8
5. L. Yan, J. Y. Ollitrault and A. M. Poskanzer, Phys. Lett. B **742** (2015) 290.