The centrality dependence of elliptic flow at LHC

H-J Drescher[1], A Dumitru[2] and J-Y Ollitrault[3]

[1] Frankfurt Institute for Advanced Studies (FIAS), Johann Wolfgang Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

[2] Institut für Theoretische Physik, Johann Wolfgang Goethe-Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

[3] Service de Physique Théorique, CEA/DSM/SPhT, CNRS/MPPU/URA2306, CEA Saclay, F-91191 Gif-sur-Yvette Cedex.

E-mail: `ollitrault@cea.fr`

Abstract. We present predictions for the centrality dependence of elliptic flow at mid-rapidity in Pb-Pb collisions at the LHC.

The centrality and system-size dependence of elliptic flow (v_2) provides direct information on the thermalization of the matter created in the collision. Ideal (non-viscous) hydrodynamics predicts that v_2 scales like the eccentricity, ε, of the initial distribution of matter in the transverse plane. Our predictions are based on this eccentricity scaling, together with a simple parameterization of deviations from hydrodynamics [1]:

$$v_2 = \frac{h\varepsilon}{1 + K/0.7}, \tag{1}$$

where the scale factor h is independent of system size and centrality, but may depend on the collision energy; The Knudsen number K can be expressed as

$$\frac{1}{K} = \frac{\sigma}{S}\frac{dN}{dy}\frac{1}{\sqrt{3}}. \tag{2}$$

It vanishes in the hydrodynamic limit. dN/dy is the total (charged + neutral) multiplicity per unit rapidity, S is the transverse overlap area between the two nuclei, and σ is an effective (transport) partonic cross section.

The model has two free parameters, the "hydrodynamic limit" h, and the partonic cross section σ. The other quantities, ε, S, dN/dy, must be obtained from a model for the initial condition. Here, we choose the Color Glass Condensate (CGC) approach, including the effect of fluctuations in the positions of participant nucleons, which increase ε [2]. The model provides a perfect fit to RHIC data for Au-Au and Cu-Cu collisions with $h = 0.22$ and $\sigma = 5.5$ mb [1].

We now briefly discuss the extrapolation to LHC. The hydrodynamic limit h is likely to increase from RHIC to LHC, as the QGP phase will last longer; however, we do not have a quantitative prediction for h. We predict only the centrality dependence of v_2, not its absolute value. Figure 1 is drawn with $h = 0.22$.

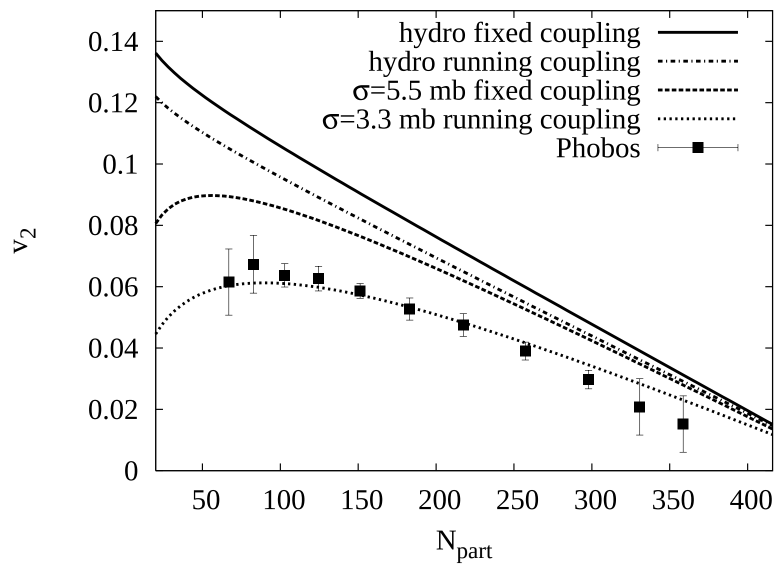

Figure 1. v_2 as a function of $N_{\rm part}$ at mid-rapidity for Pb-Pb collisions at LHC ($\sqrt{s_{NN}} = 5.5$ TeV). ——and — · · —: ε scaling ($K = 0$ in (1)); - - - -and · · · · · ·: incl. incomplete thermalization, with two values of the partonic cross section. ■: PHOBOS data for Au-Au collisions at RHIC [3]. The vertical scale is arbitrary (see text).

The second parameter is σ, which parameterizes deviations from ideal hydrodynamics, i.e., viscous effects. We consider two possibilities: 1) $\sigma = 5.5$ mb at LHC, as at RHIC. 2) $\sigma \sim 1/T^2$ (on dimensional grounds, assuming that no non-perturbative scales arise), where the temperature $T \sim (dN/dy)^{1/3}$. This gives the value 3.3 mb in figure 1.

The remaining quantities (S, dN/dy and ε) are obtained by extrapolating the CGC from RHIC to LHC, either with fixed-coupling (fc) or running-coupling (rc) evolution of the saturation scale Q_s. The multiplicity per participant increases by a factor of 3 (resp. 2.4) with fc (resp. rc). The eccentricity ε is 10% larger with fc (solid curve in figure 1) than with rc (dash-dotted curve) evolution. Deviations from hydrodynamics (the K-dependent factor in Eq. (1)) are somewhat smaller than at RHIC: v_2 is 90% (resp. 80%) of the hydrodynamic limit for central collisions if $\sigma = 5.5$ mb (resp. 3.3 mb). Our predictions lie between the dashed and dotted curves, up to an overall normalization factor. The maximum value of v_2 occurs for $N_{\rm part}$ between 60 ($\sigma \approx$ const.) and 80 ($\sigma \sim 1/T^2$).

Elliptic flow will be a first-day observable at LHC. Both its absolute magnitude and its centrality dependence are sensitive probes of initial conditions, and will help to improve our understanding of high-density QCD.

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