(Harmonic moments of) the gluon density distribution in AA collisions

Yasushi Nara (Akita International Univ.)

- Introduction
- Monte-Carlo version of kt-factorization with rcBK (MCrcBK)
- Eccentricities

ISMD 2011 Miyajima in Hiroshima 2011/9/26-30 (9/28)

Hydrodynamics and inputs

- Initial condition:

  thermalization time
  initial energy density
  (flow profile)
- Equation of state:

  ideal gas EoS, lattice QCD
- freezeout:

  Hadron cascade after burner
  (hadronic dissipative effects)
- Dissipative effects

Purpose: test uncertainties of the initial conditions.

Initial transverse geometry for hydro initial conditions

Glauber model

$$\frac{dN}{d^2\boldsymbol{x}_\perp dy} \sim N_{part,1}(\boldsymbol{x}_\perp) + N_{part,2}(\boldsymbol{x}_\perp)$$

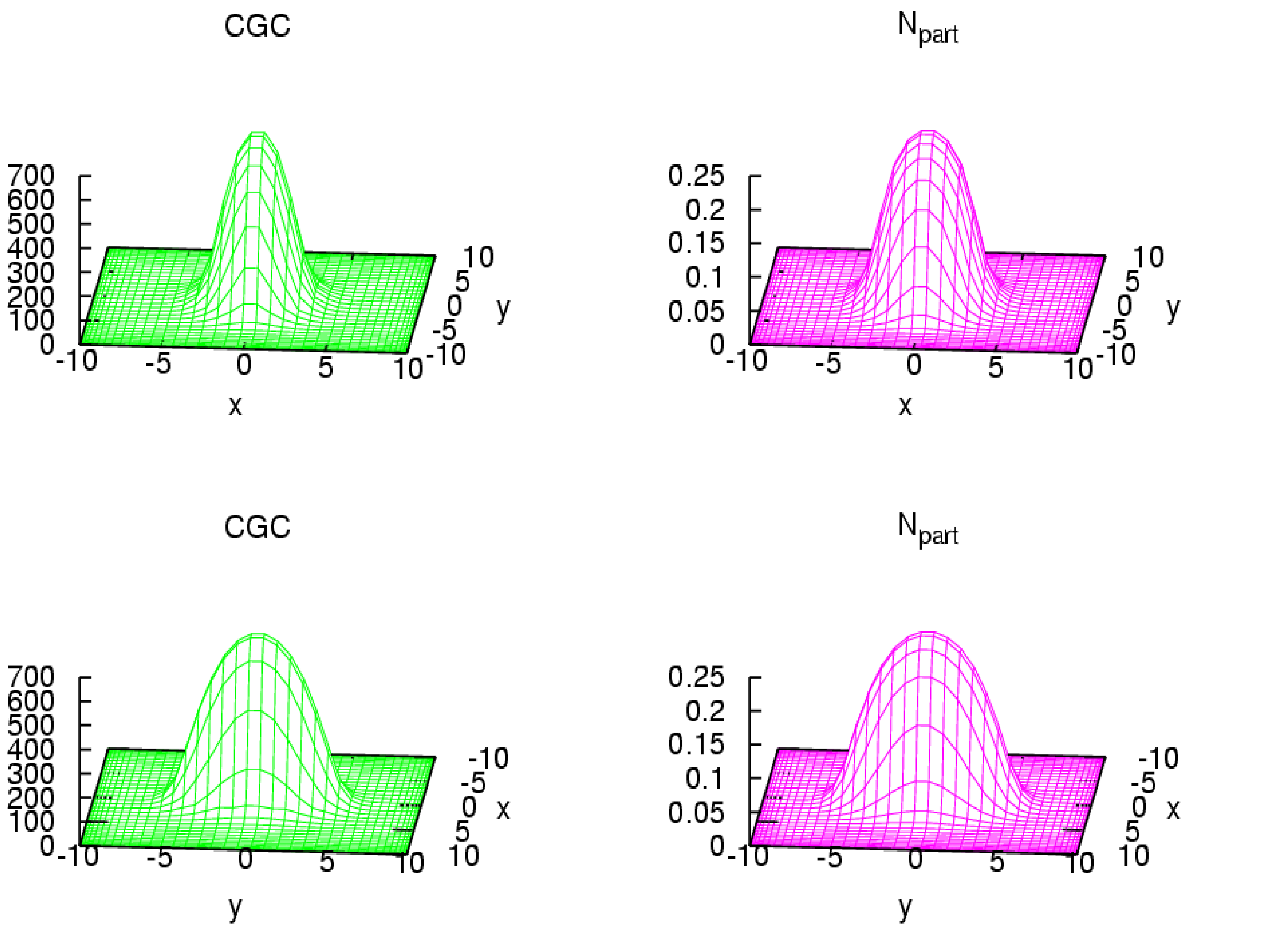
Initial energy density or entropy is taken from Wounded nucleon model:
number of participants or collision scaling.

kT factorization (KLN -Color Glass Condensate)

$$\frac{dN_g}{d^2x_t dy} = \frac{4\pi N_c}{N_c^2-1}\int\frac{d^2p_t}{p_t^2}\int d^2k_t \alpha_s \phi(x_{1,}k_t^2)\phi(x_{2,}(p_t-k_t)^2)$$

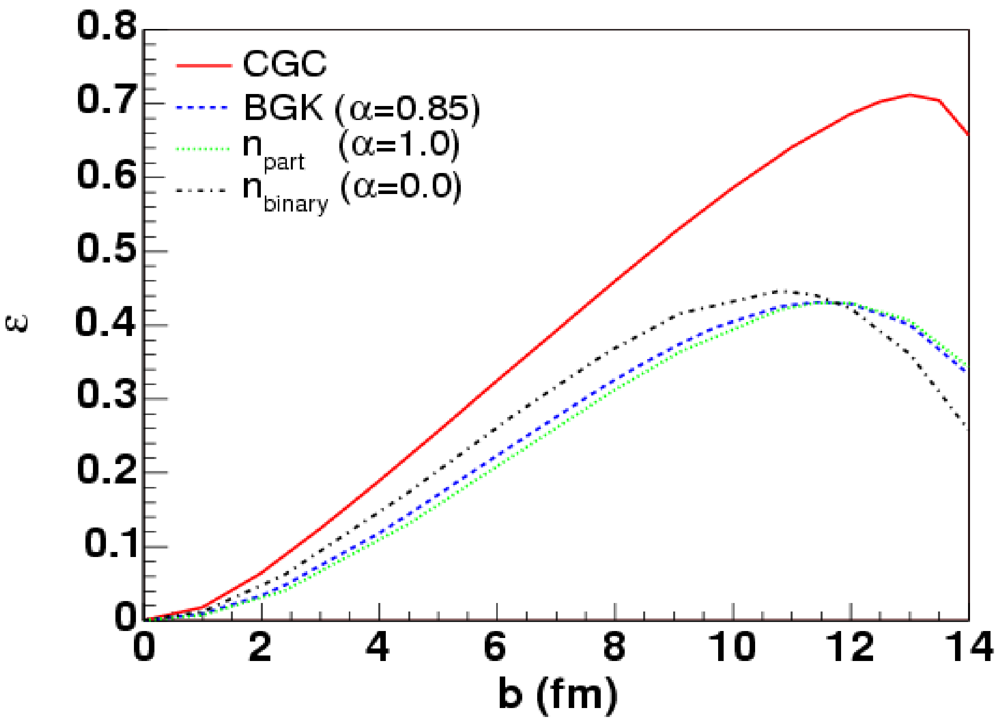
$$\frac{dN}{d^2\boldsymbol{x}_\perp dy} \sim \min\{N_{part,1}(\boldsymbol{x}_\perp), N_{part,2}(\boldsymbol{x}_\perp)\}$$

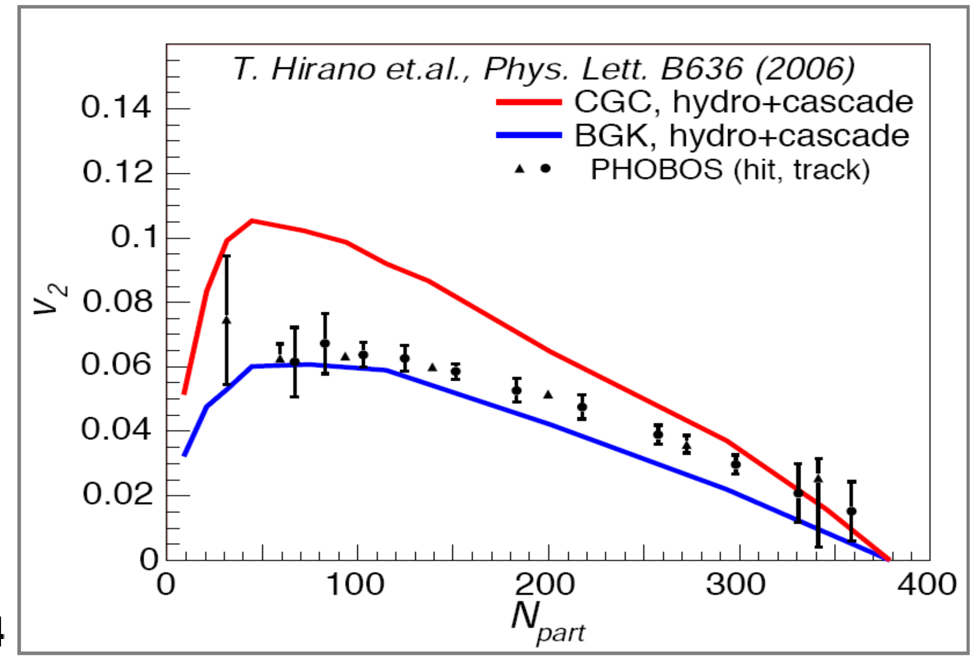
Densities for Au+Au b=8fm



Large v2 in CGC because of

$$\varepsilon_{CGC} > \varepsilon_{Glauber}$$





$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle x^2 + y^2 \rangle}$$

$$v_2 \equiv \langle \cos(2\phi) \rangle = \left\langle \frac{p_x^2 - p_y^2}{p_x^2 + p_y^2} \right\rangle$$

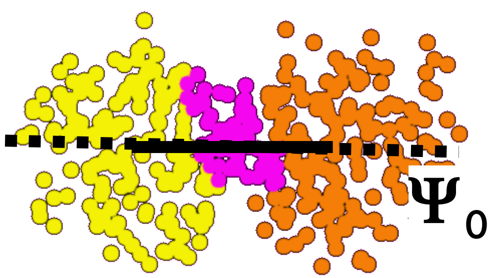
Purpose: improvement of the model and look at higher order eccentricities

Eccentricity fluctuations

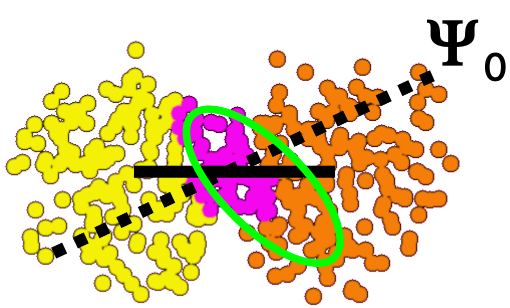
Event-by-event fluctuations in the shape of the initial collision zone may be important.

Specifically fluctuations in the nucleon positions.

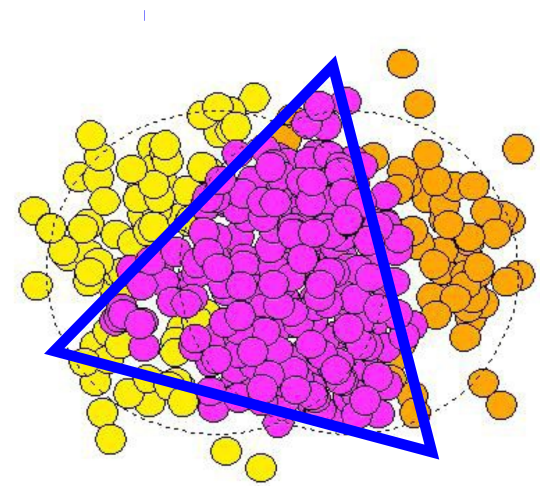
B Alver and G Roland, Phys. Rev. C 81, 054905 (2010)



$$\epsilon_{\mathrm{std}} = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$



$$\langle \epsilon_{\mathrm{part}} \rangle = \frac{\sqrt{(\sigma_y^2 - \sigma_x^2)^2 + 4\sigma_{xy}^2}}{\sigma_y^2 + \sigma_x^2}$$



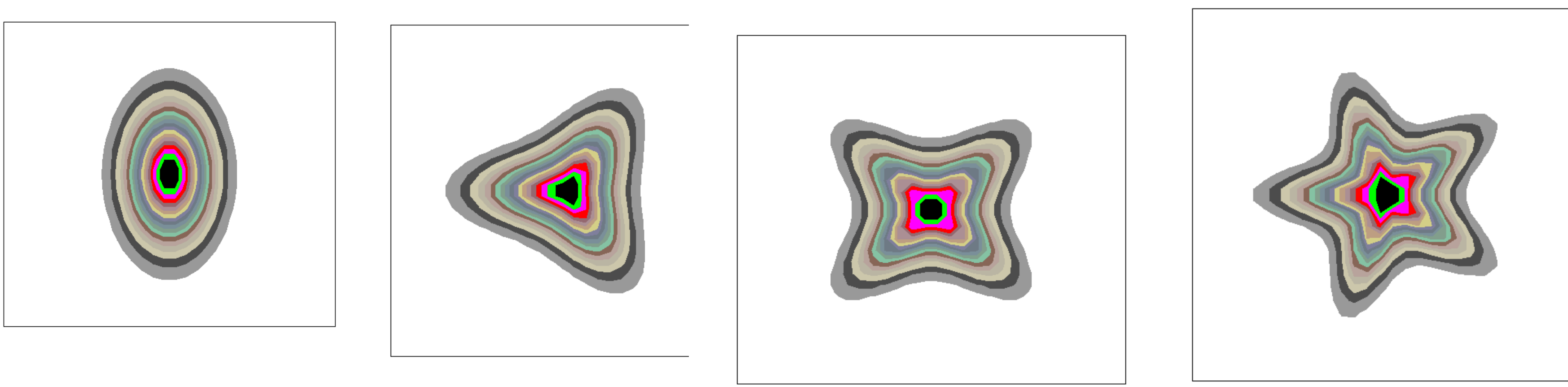
$$\sigma_x^2 = \langle x^2 \rangle - \langle x \rangle^2, \quad \sigma_y^2 = \langle y^2 \rangle - \langle y \rangle^2, \quad \sigma_{xy}^2 = \langle xy \rangle - \langle y \rangle \langle x \rangle$$

R.S.Hollis (PHOBOS) nucl-ex0707.0125

Higher order Eccentricities

$$\epsilon_n = \frac{\sqrt{\langle r^2 \cos(n\phi)\rangle^2 + \langle r^2 \sin(n\phi)\rangle^2}}{\langle r^2 \rangle}$$

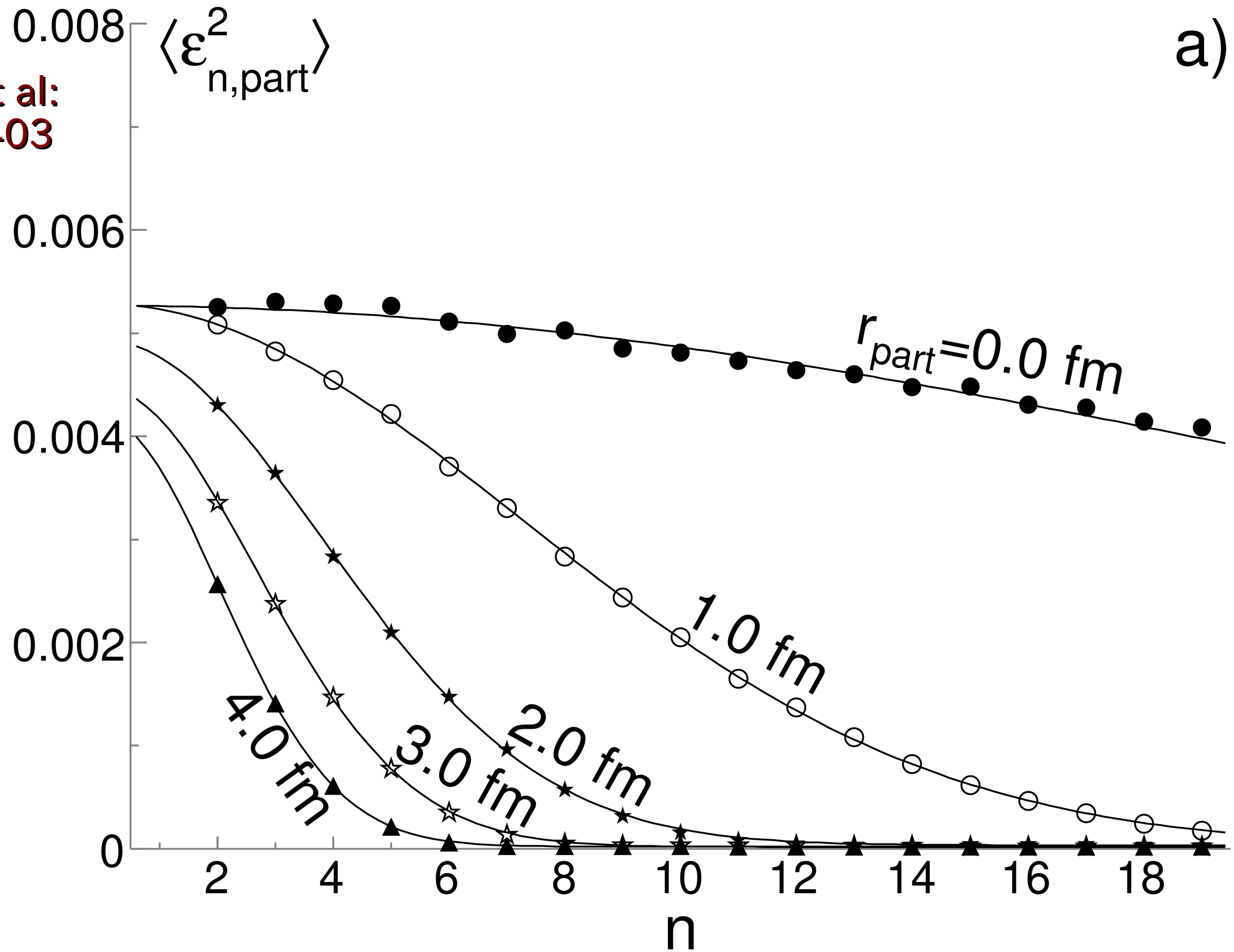
$$r^2 = x^2 + y^2,\ x = r\cos(\phi),\ y = r\sin(\phi)$$



$$e(r,\phi) = e_0 \exp\left[-\frac{r^2}{2\sigma^2}(1 + \epsilon_n \cos(n\phi))\right]$$

Higher-order moments and the length scale of fluctuations (analogy: CMB)

P. Sorensen et al: arXiv:1102.1403



Monte-Carlo implementation

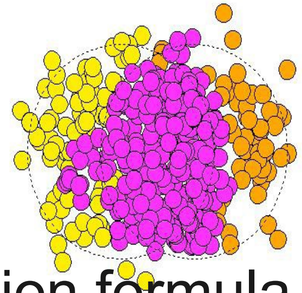
- Sample A and B nucleons according to the Woods-Saxon distribution.
- Collision: NN collision probability $P(b) = 1 - \exp[-kT_{pp}(b)]$

$$T_{pp}(b) = \int d^2 s T_p(s) T_p(s-b)$$

k is fixed by the relation $\sigma_{in} = \int d^2 b\,(1 - \exp[-kT_{pp}(b)])$

- Local density of valence charges at each grid point:

$$T_p(r) = \frac{1}{2\pi B} \exp[-r^2/(2B)]$$



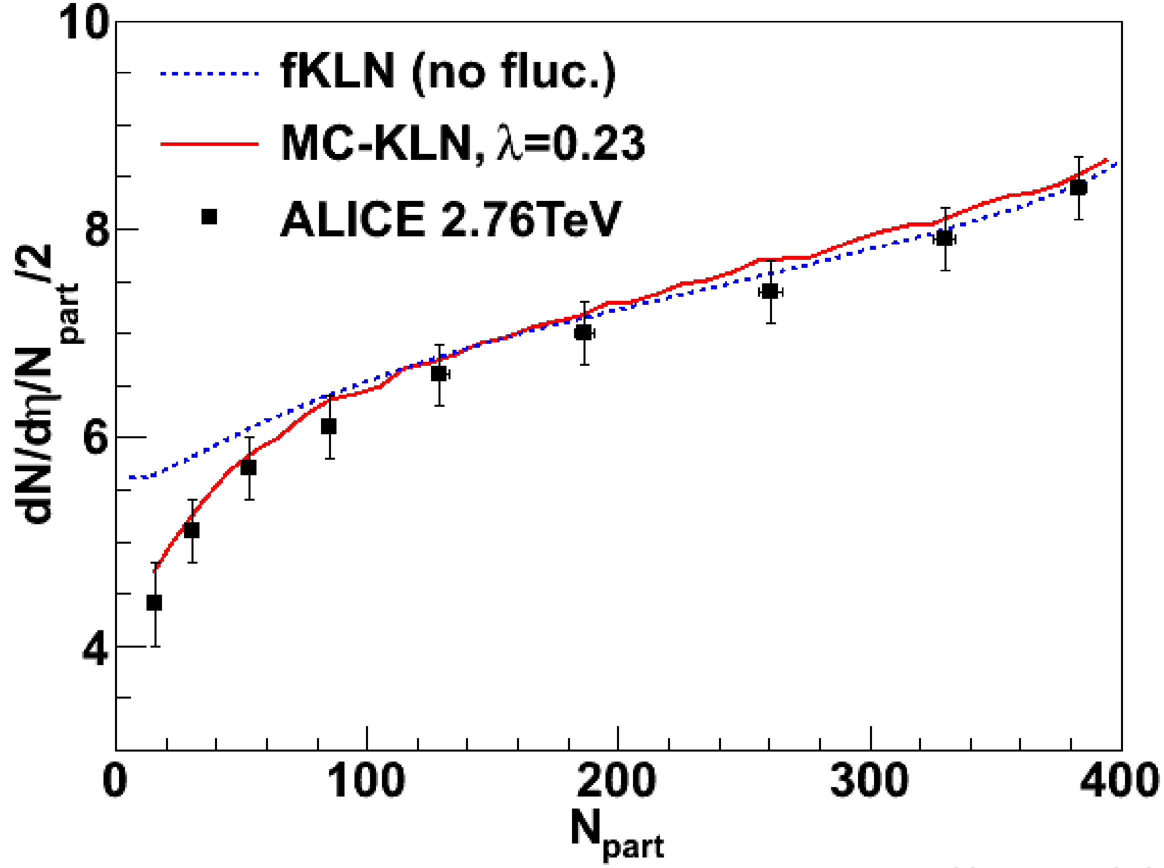
- For each generated configuration: apply the k_t-factorization formula at each transverse grid point.

$$\frac{dN_g}{d^2 x_t\, dy} = \frac{4\pi N_c}{N_c^2 - 1} \int \frac{d^2 p_t}{p_t^2} \int d^2 k_t\, \alpha_s\, \phi(x_1, k_t^2)\, \phi(x_2, (p_t - k_t)^2)$$

$$\varphi(k, x, b) = \frac{C_F}{\alpha_s(k)\,(2\pi)^3} \int d^2\mathbf{r}\; e^{-i\mathbf{k}\cdot\mathbf{r}}\, \nabla^2_{\mathbf{r}} \mathcal{N}_G(r, Y = \ln(x_0/x), b)$$

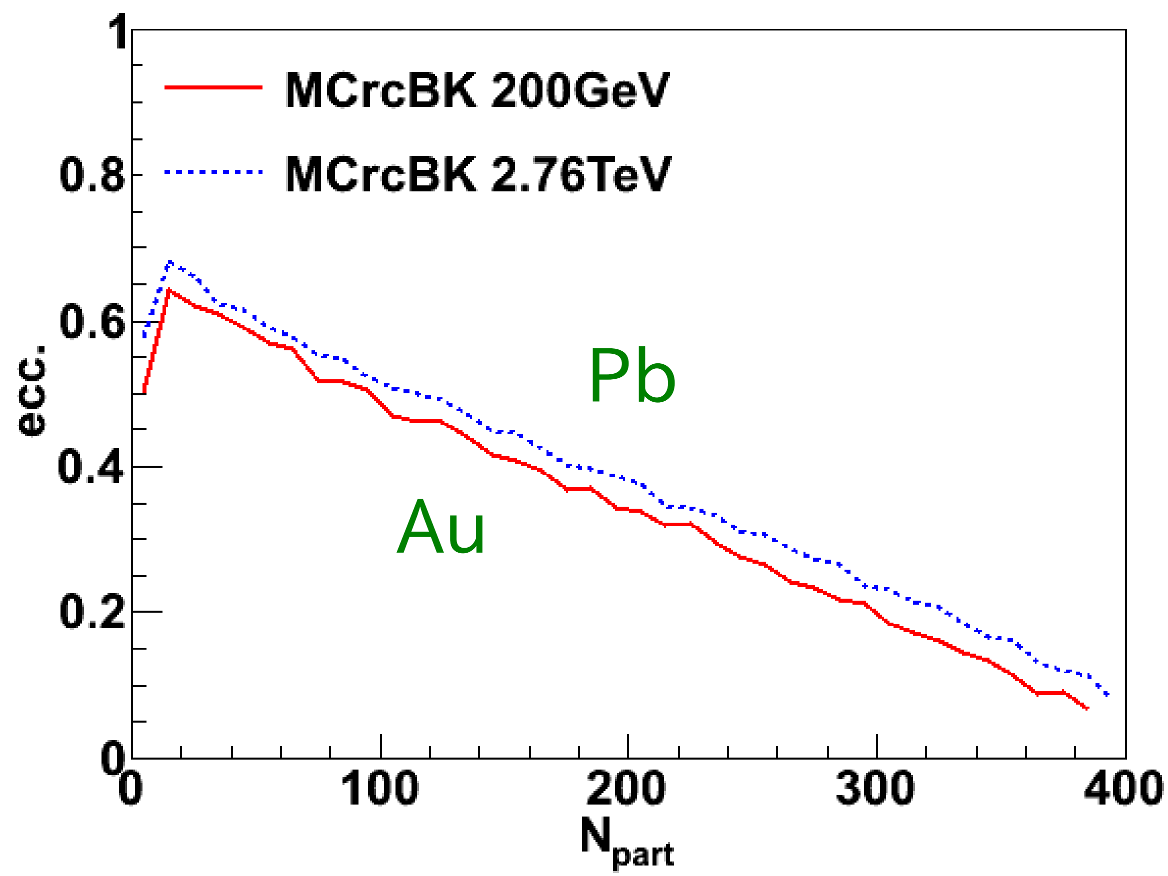
http://physics.baruch.cuny.edu/node/people/adumitru/res_cgc

centrality dependence at LHC energy



The effect of fluctuation is seen in peripheral collisions (Npart < 100).

eccentricity from MCrcBK



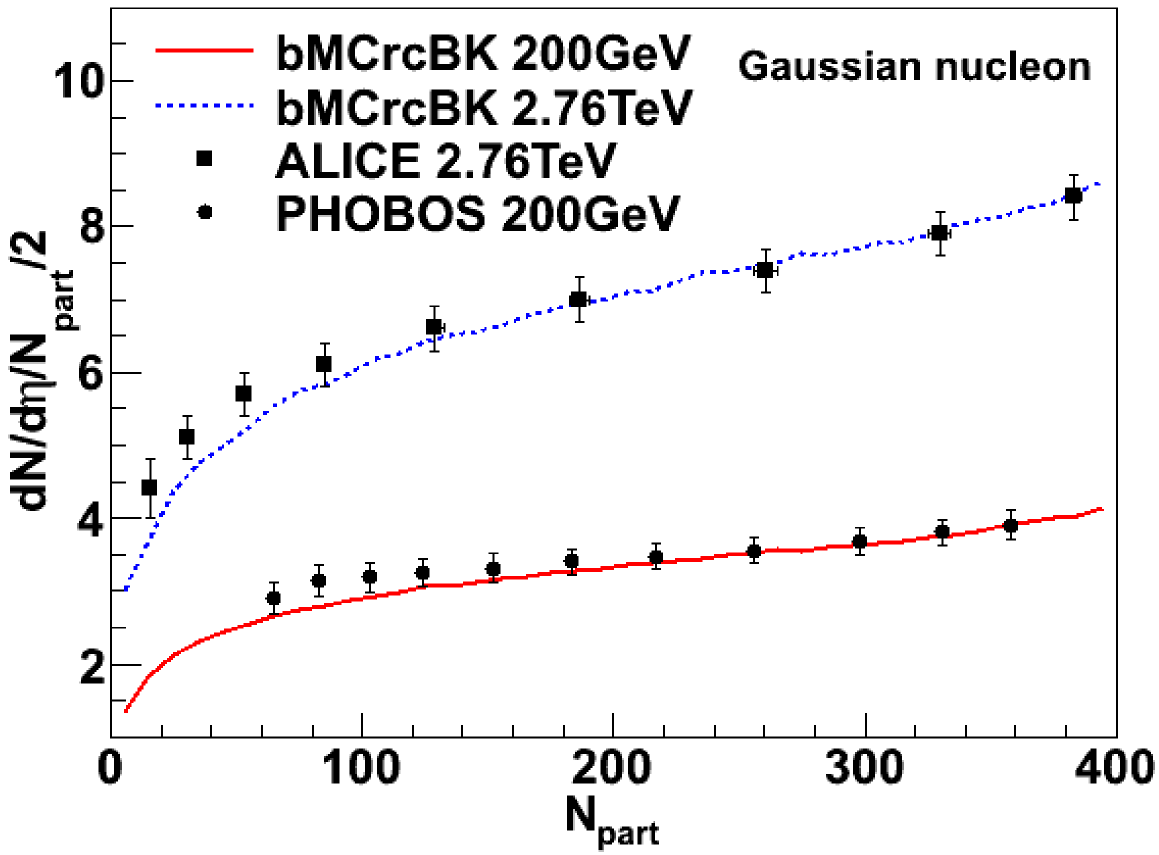
No incident energy dependence for eccentricity ε_2

MCrcBK with Gaussian nucleon with MV initial condition

$$\mathcal{N}(r, Y=0) = 1 - \exp\left[-\frac{r^2 Q_{s0}^2}{4} \ln\left(\frac{1}{\Lambda r} + e\right)\right]$$

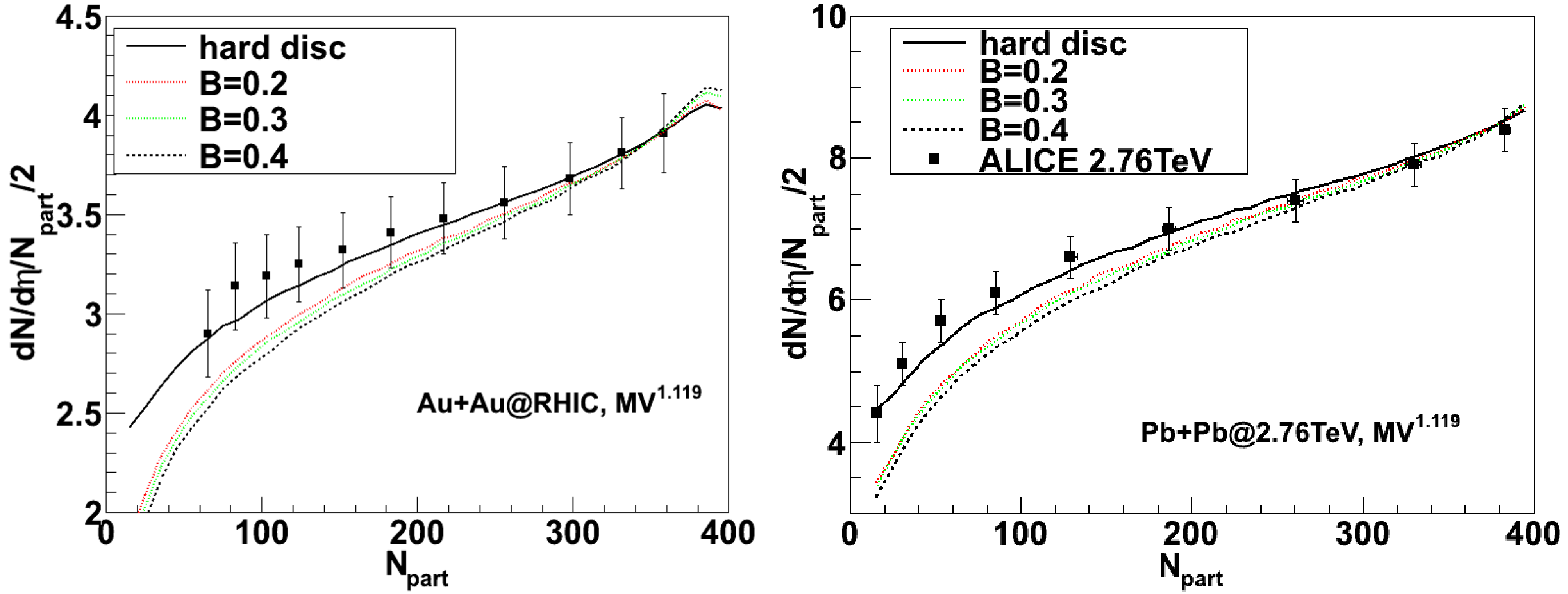
$$Q_{s0}^2 = 0.2\,\mathrm{GeV}^2$$

$$\Lambda = 0.2\mathrm{GeV}$$

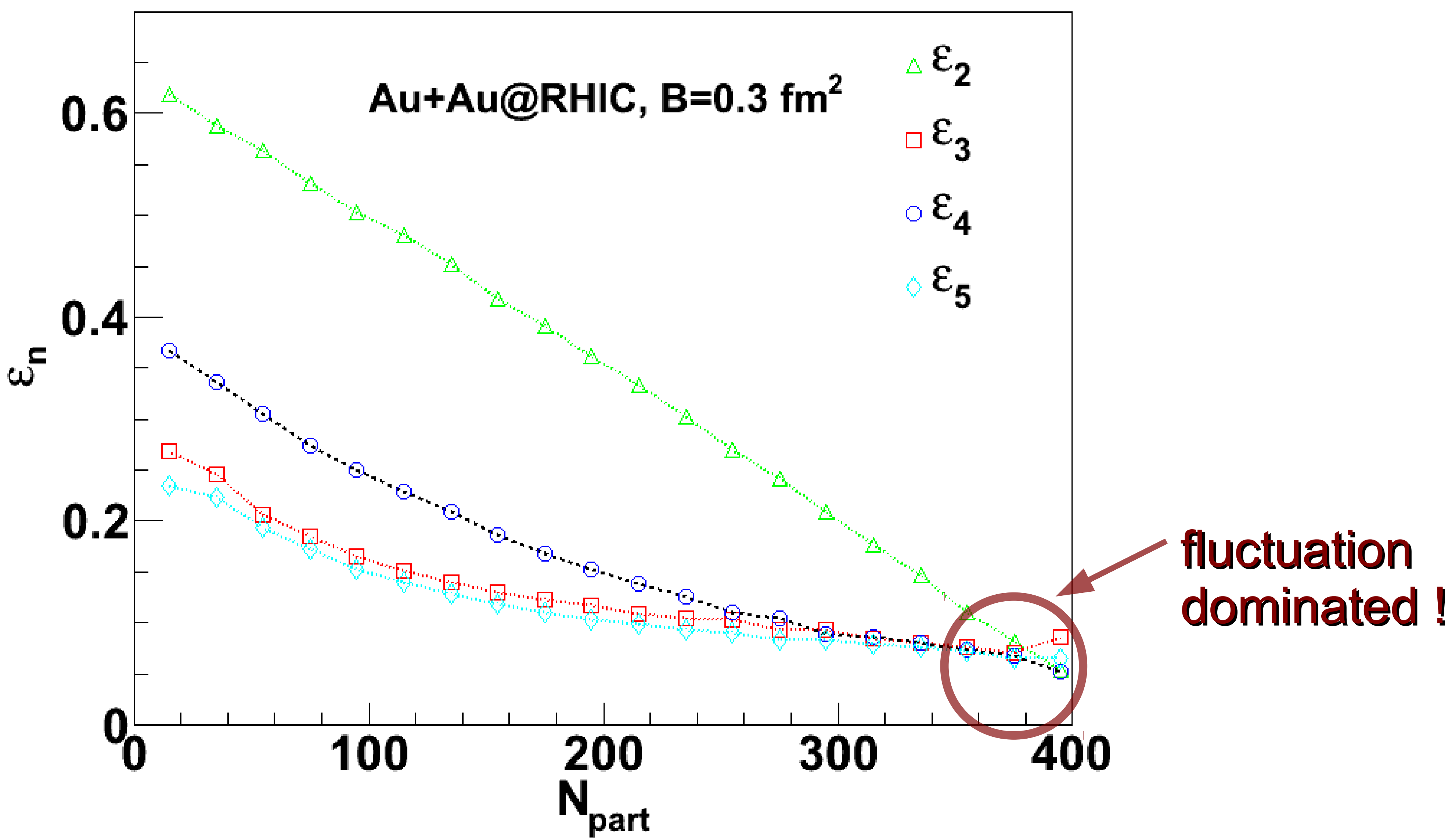


MCrcBK with $MV^{1.119}$ initial conditions

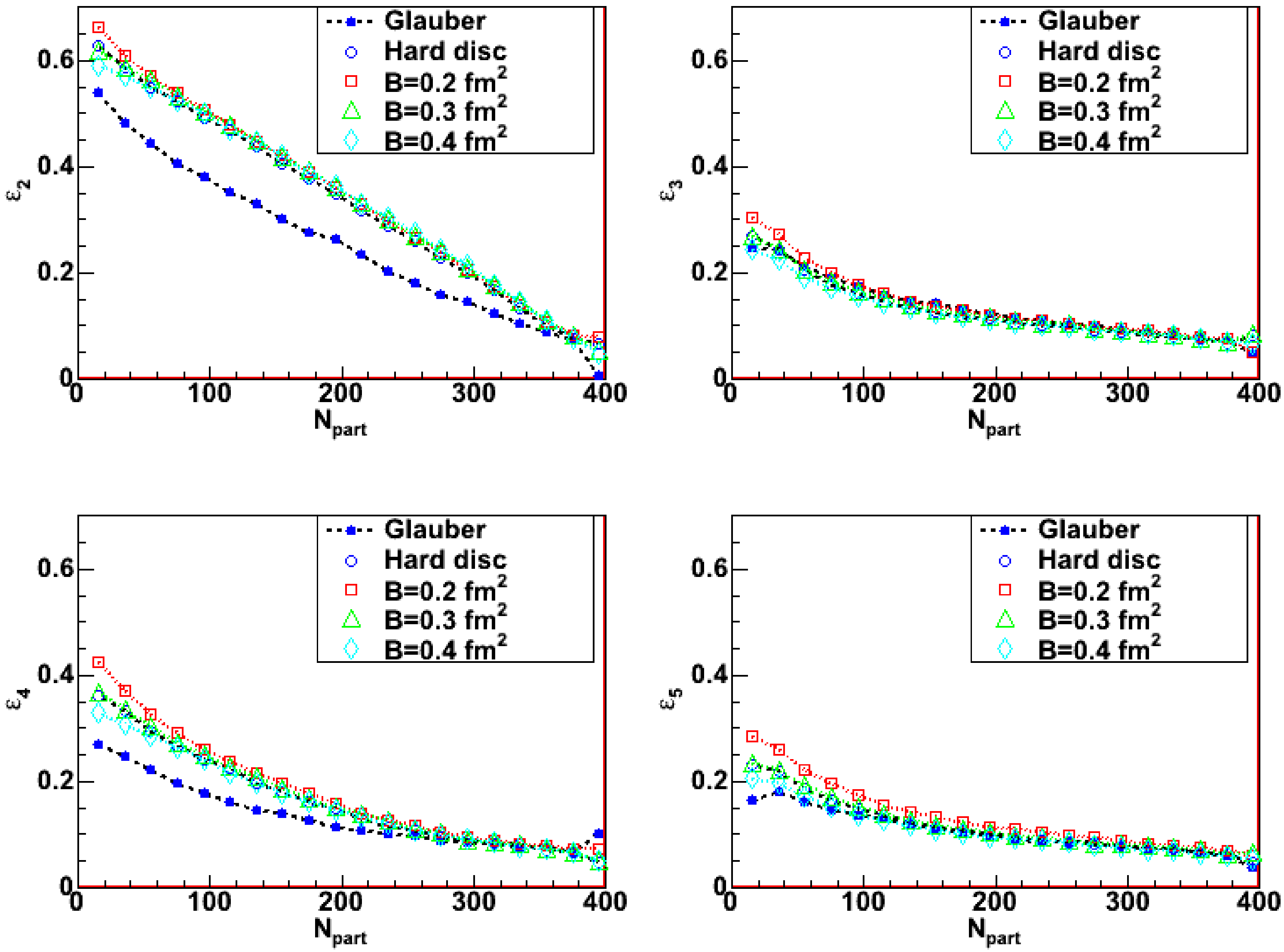
$$\mathcal{N}(r, Y=0) = 1 - \exp\left[-\frac{(r^2\,Q_{s0}^2)^\gamma}{4}\,\ln\left(\frac{1}{\Lambda\,r}+e\right)\right] \qquad \begin{aligned}\gamma &= 1.119\\ Q_{s0}^2 &= 0.168\,\mathrm{GeV}^2\end{aligned}$$



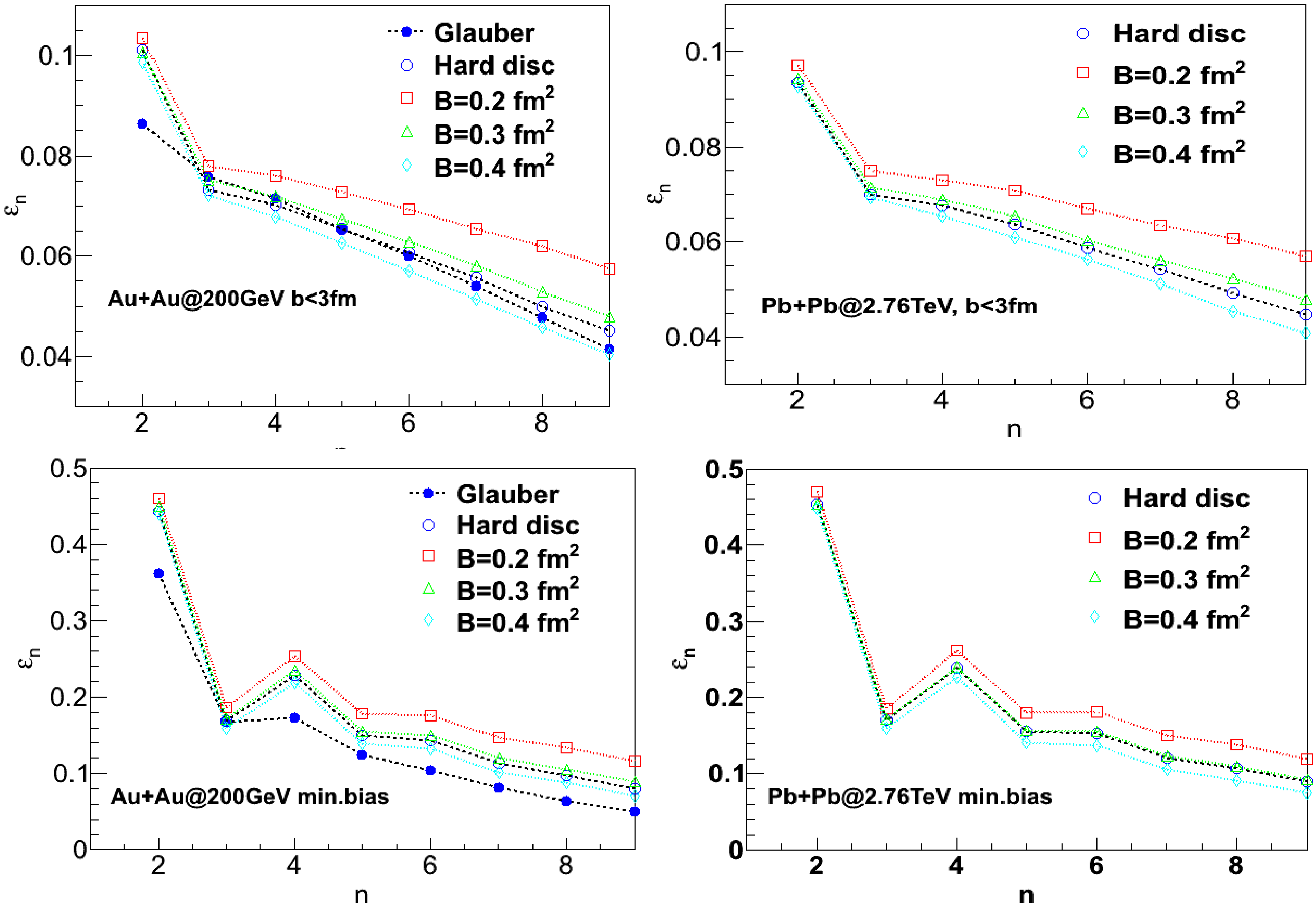
Centrality dependence of Eccentricities



Eccentricity coefficients at RHIC



Eccentricity as a function of order



Summary

- We compute higher order eccentricities from Monte Carlo version of kt-factrization formula with rcBK small-x evolution
  - Fluctuations affect multiplicities at low N_{part}
  - MCrcBK prediction on centrality dependence of dN/deta at LHC is consistent with ALICE data.
  - Gaussian profile of large-x sources:
    higher moments of eccentricity increase as Gaussian width decreases