$p_\perp$ fluctuations and correlations

Piotr Bożek

AGH University of Science and Technology, Kraków

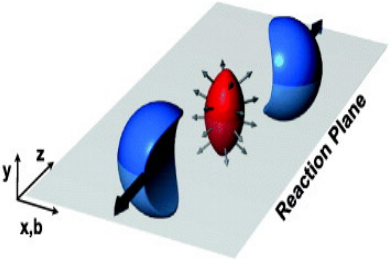
with: W. Broniowski, arXiv: 1701.09105
and S. Chatterjee, arXiv: 1704.02777

AGH

NATIONAL SCIENCE CENTRE
POLAND

asymmetry in the transverse plane at finite impact parameter

eccentricity - $\epsilon_2 = -\frac{\int dxdy(x^2-y^2)\rho(x,y)}{\int dxdy(x^2+y^2)\rho(x,y)}$



Snellings 2011

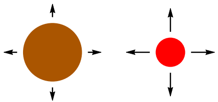
larger gradient and stronger flow in-plane - $v_2 > 0$ - **elliptic flow**

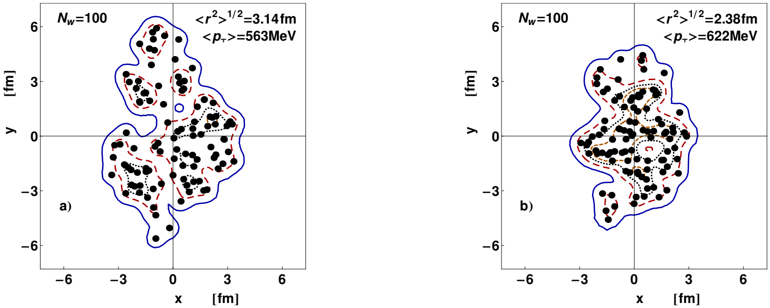
$$\frac{dN}{d\phi} \propto 1 + 2v_2 cos(2\phi)$$

$$\epsilon_2 + \mathrm{HYDRO\ RESPONSE} \longrightarrow \mathrm{v}_2$$

Event Plane (Reaction plane) must be reconstructed in each event

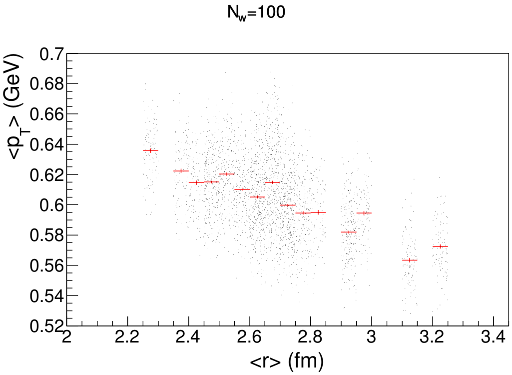
Size fluctuations $\leftrightarrow$ $p_\perp$ fluctuations





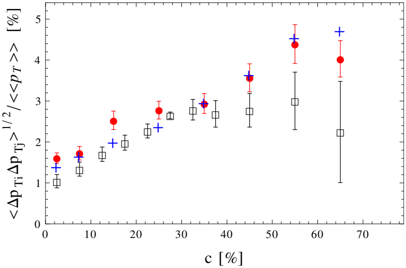
proposed by Broniowski et al. Phys.Rev. C80 (2009) 051902 : two-shots calculation

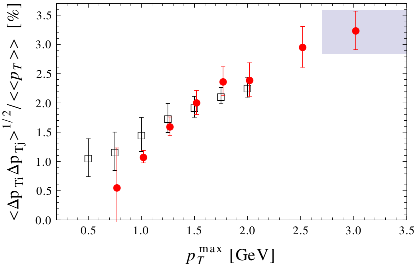
Physical and statistical fluctuations



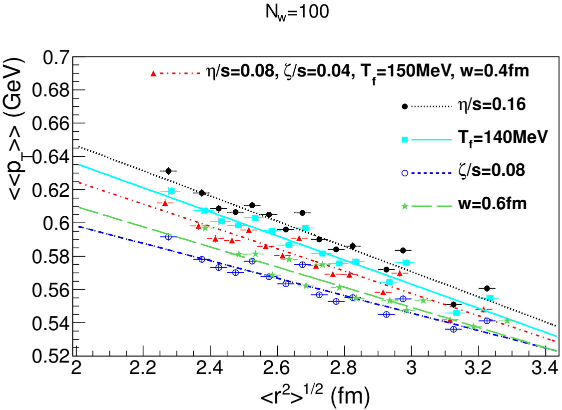
$$C_{p_\perp} = \frac{\frac{1}{N(N-1)}\sum_{i\neq j}\langle (p_i - \langle\langle p\rangle\rangle)(p_j - \langle\langle p\rangle\rangle)\rangle}{\langle\langle p_\perp\rangle\rangle^2}$$

PHENIX data vs. hydro.





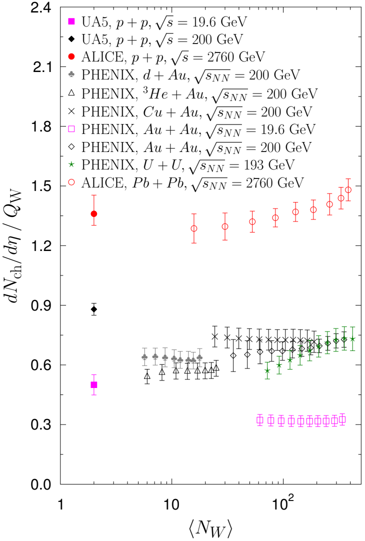
Viscosity effects on hydro response



$$\frac{\Delta p}{p} \simeq 0.4 \frac{\Delta r}{r}$$

- size fl. $\leftrightarrow$ $p_\perp$ fluctuations
- hydro. response not modified by
    - viscosity
    - T_F
    - smearing
    - core-corona
    - P_{tot} conservation
    - centrality def.
- too much fluctuations?

Wounded quark model in AA

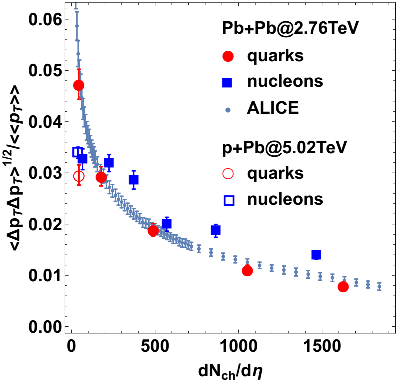


- very good (full) scaling at LHC
- approximate scaling at RHIC

LHC - 3 partons , RHIC - 2 partons ?

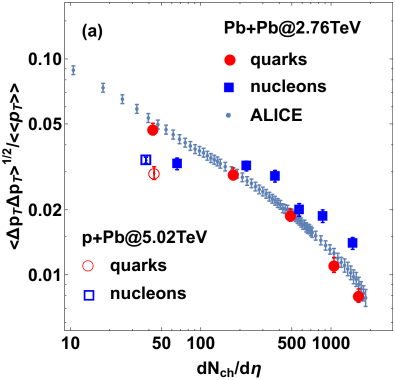
PB, W. Broniowski, M. Rybczyński, PRC 2016

$p_\perp$ fluctuation quark Glauber model initial conditions



Quark Glauber model gives better description of initial volume fluctuations

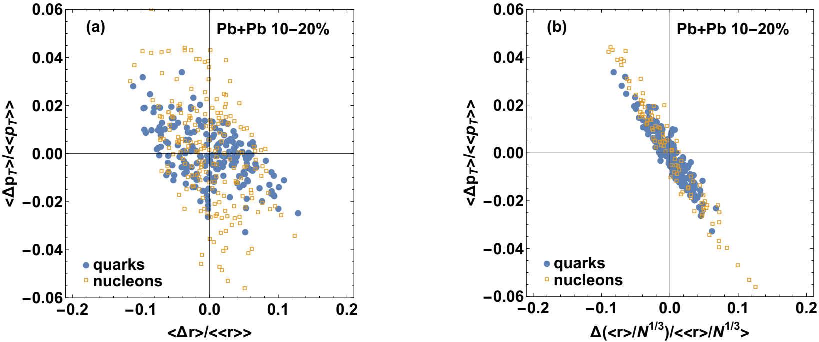
Same in log scale



more than simple $N^{-1/2}$ scaling

both experiment and theory $\longrightarrow$ not minijets

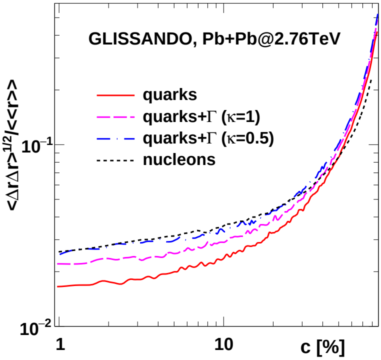
Size - $p_\perp$ correlation



$\frac{N_q^\alpha}{<r>}$ - predictor of the final $p_\perp$

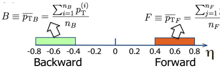
consistent with predcitor of Mazellauskas-Teaney, PRC 2016

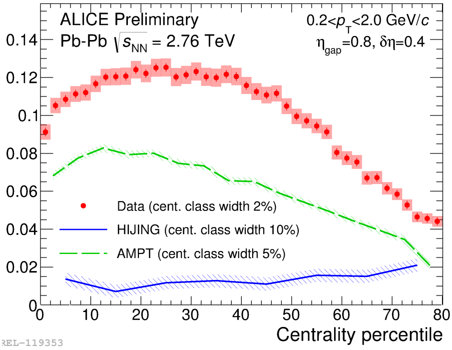
Caution - additional fluctuation may change the results



$p_\perp - p_\perp$ correlation in rapidity - ALICE preliminary

$$b_{\text{corr}} = \frac{\langle FB\rangle - \langle F\rangle\langle B\rangle}{\langle F^2\rangle - \langle F\rangle^2}$$

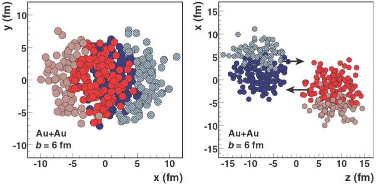




QM poster I. Altsybeev for ALICE

event generators have problems to reproduce data

Forward and backward assymetry

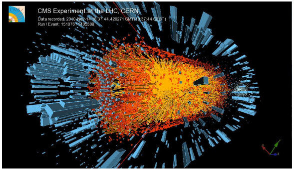


Ann.Rev.Nucl.Part.Sci. 57 (2007) 205

- Glauber Monte Carlo model $\longrightarrow$ different forward and backward distributions

- different fireball shape at forward and backward rapidities

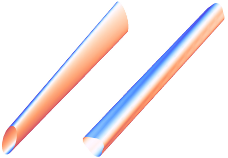
multiplicity-multiplicity correlations



dozens of years, hundreds of papers

many effects sum up ...

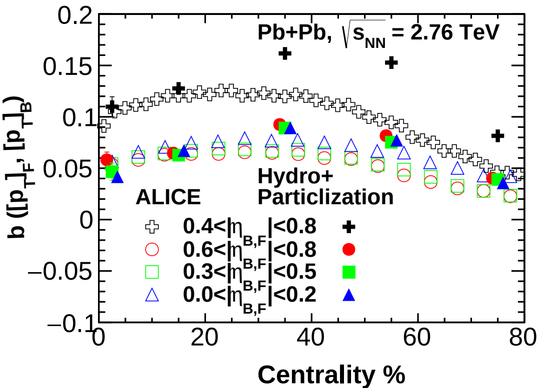
flow angle-flow angle correlations



PB, W. Broniowski, J.Moreira : 1011.3354

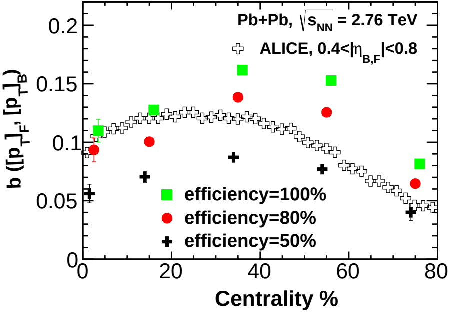
experiment and theory picks up momentum

$p_\perp - p_\perp$ correlation in rapidity - hydro



reasonable description of the data

$p_\perp - p_\perp$ correlation coefficient - ill defined



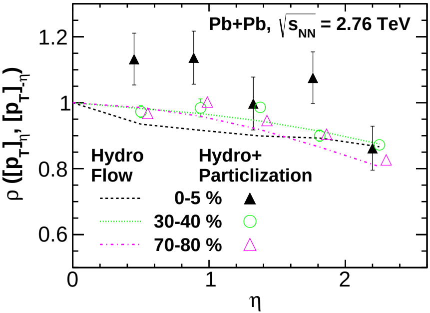
$$b = \frac{<[p_\perp]_A[p_\perp]_B> - <[p_\perp]_A><[p_\perp]_B>}{\sqrt{(<p_A^2> - <p_A>^2)(<p_B^2> - <p_B>^2)}} = \frac{\dots}{\sqrt{\frac{1}{n_A^2}\sum_{ij} p_i^A p_j^A \dots}}$$

sensitive to accepteance, particle multiplicity

dominated by statistical fluctuations!

$[p_\perp] - [p_\perp]$ correlation coefficient

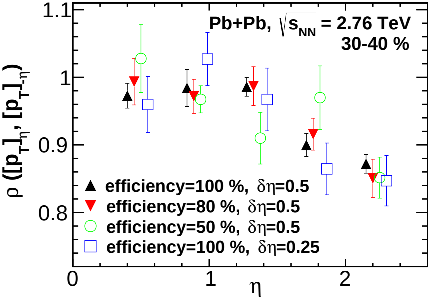
$$\frac{<[p_\perp]_A[p_\perp]_B> - <[p_\perp]_A><[p_\perp]_B>}{\sqrt{C^A_{p_\perp} C^B_{p_\perp}}} = \frac{\dots}{\sqrt{\frac{1}{n_A(n_A-1)}\sum_{i\neq j} p_i^A p_j^A \dots}}$$



$$\rho([p_T],[p_T]) \simeq 1$$

in the current model - strong correlations

$[p_\perp] - [p_\perp]$ correlation coefficient

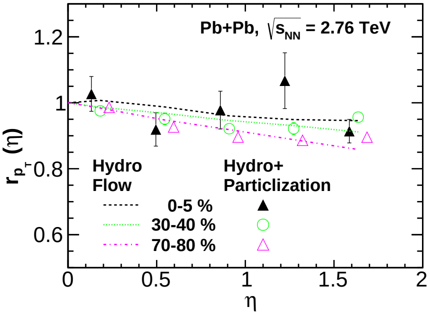


insensitive to acceptance, efficiency, mulitplicity

true measure of flow-flow correlations

3-bin measure of $[p_\perp]$ decorrelation

$$r_{p_T}(\Delta\eta) = \frac{Cov([p_T],[p_T])(\eta+\Delta\eta)}{Cov([p_T],[p_T])(\eta-\Delta\eta)}$$



Measure of $[p_T]$ decorrelation in pseudorapidity

Summary

- size fluctuations $\leftrightarrow$ $p_\perp$ fluctuations
- Glauber+hydro qualitatively consistent
- suggest scenarios with less fluctuations (quark Glauber model)
- $p_\perp$ correlations in η interesting
- strong $[p_\perp] - [p_\perp]$ correlations? - should be measured