Torque (pokrętność)

Wojciech Broniowski

Jan Kochanowski U., Kielce, and
Institute of Nuclear Physics PAN, Cracow

UJK, 27 January 2015

[research with P. Bożek, J. Moreira (PRC 83 (2011) 034911), A. Olszewski]

Outline

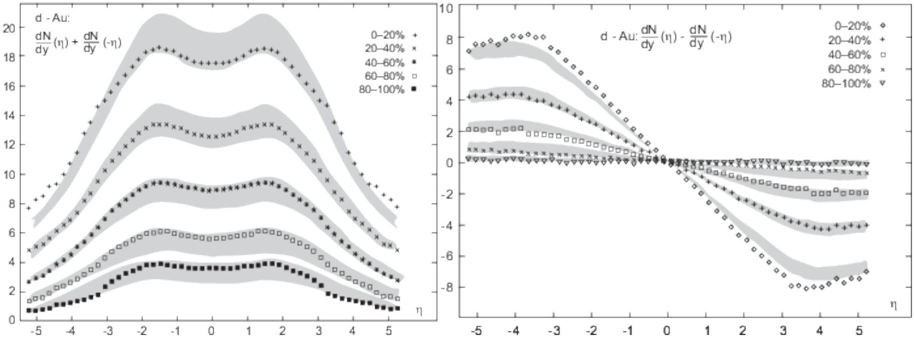
Correlations in rapidity

- Info on earliest stages
- Sensitivity to production mechanism
- Terra incognita
- On-going e-by-e studies

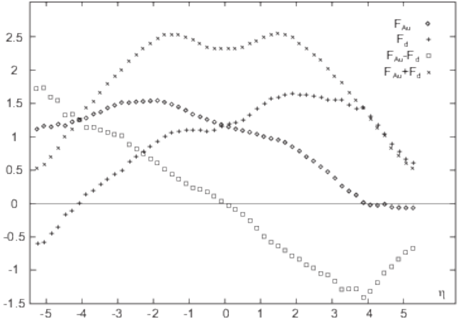
Outline

- Emission "triangles"
- Fluctuations $\rightarrow$ torque effect
- Decorrelation effects on freeze-out
- Measures of torque
- Principal Component Analysis

Białas & Czyż: d-Au from PHOBOS

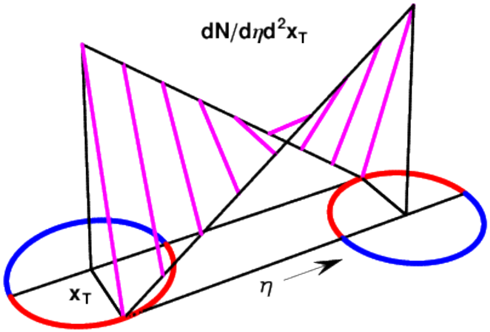


Białas & Czyż: d-Au from PHOBOS



A-A

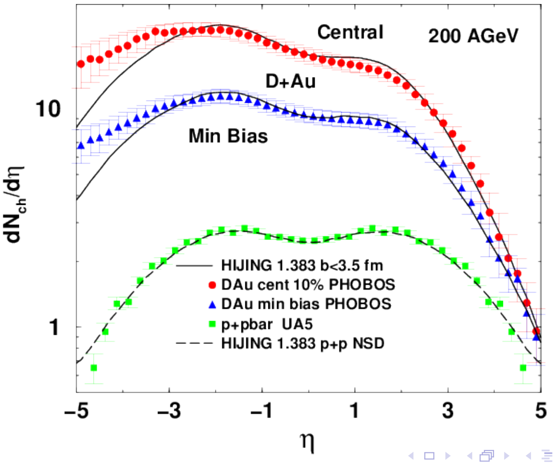
[Białas, Jeżabek (2004), Fiałkowski, Wit (2005), Adil, Gyulassy (2005)A. Adil, Gaździcki, Gorenstein (2006), Bzdak (2009), Białas, Zalewski (2010), Bzdak, Woźniak (2010), Bożek, Wyskiel (2010)]



[Adil, Gyulassy]

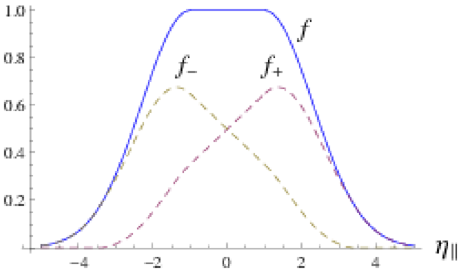
A-A

[Białas, Jeżabek (2004), Fiałkowski, Wit (2005), Adil, Gyulassy (2005)A. Adil, Gaździcki, Gorenstein (2006), Bzdak (2009), Białas, Zalewski (2010), Bzdak, Woźniak (2010), Bożek, Wyskiel (2010)]



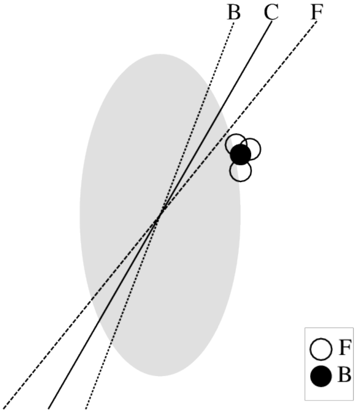
Parametrization (Bożek)

Initial (partonic) density:

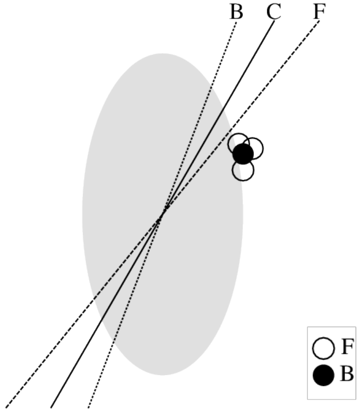


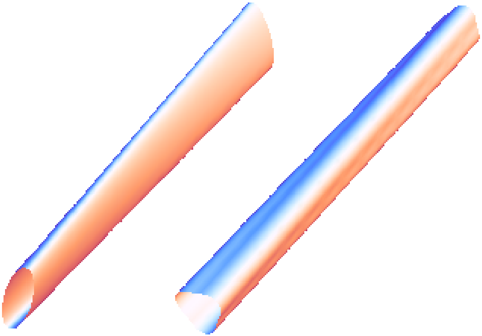
(for highest RHIC energy)

The torque effect



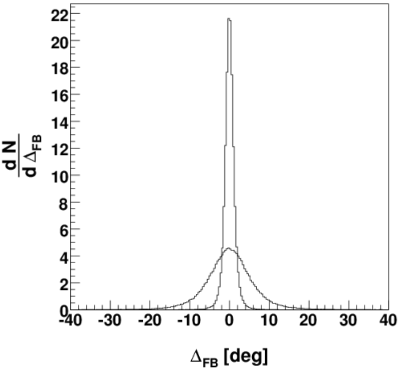
The torque effect



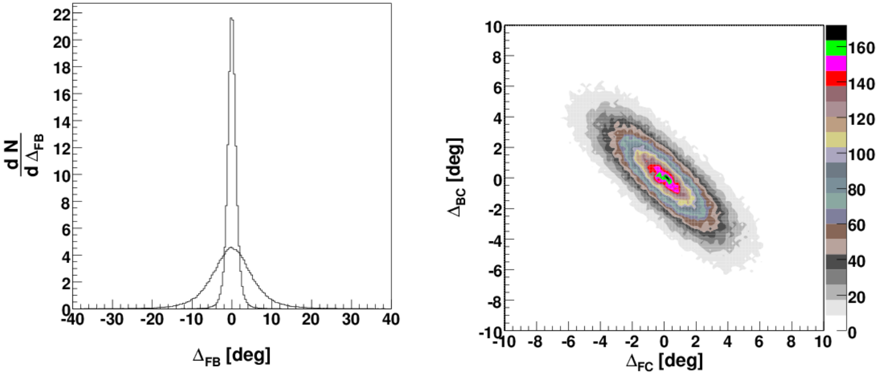


$$\Psi^{(k)} = \frac{1}{k}\arctan\left(\frac{\sum_{i=1}^{n} w_i r_i^2 \sin(k\phi_i)}{\sum_{i=1}^{n} w_i r_i^2 \cos(k\phi_i)}\right)$$

The torque effect



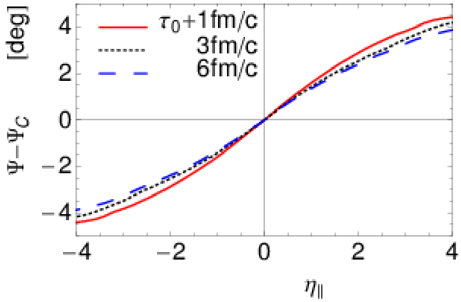
Distribution of the difference of the forward and backward torque angles for the elliptic deformation. The narrower and wider distributions correspond $\Delta\eta_{||} = 1$ and 5, respectively. Centrality 20-30%, mixed model for Au+Au collisions with $\alpha = 0.145$



Right: 2D distribution of the relative torque angles Δ_{FB} and Δ_{FC} for centrality 50-60% and $\Delta\eta_{\|} = 5$. The correlation coefficient is -0.61

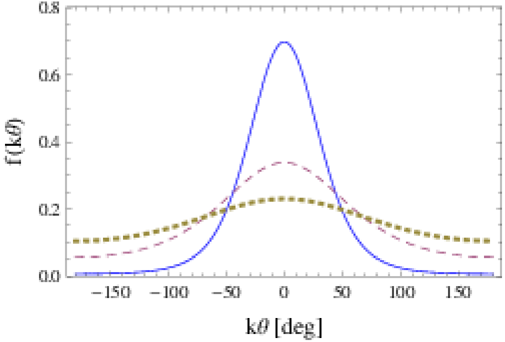
3+1D hydrodynamics

Assumed deterministic evolution down to freeze-out → correlations survive



Statistical hadronization

Finite no. of particle in a $\Delta\eta$ bin $\rightarrow$ fluctuations of the principal angle Θ



e-by-e distribution of $k\Theta$, $k = 2, 3, \ldots$, for $v_k = 5\%$ for several values of the event multiplicity n: 600 (solid), 100 (dashed), and 20 (dotted).

Statistical measures

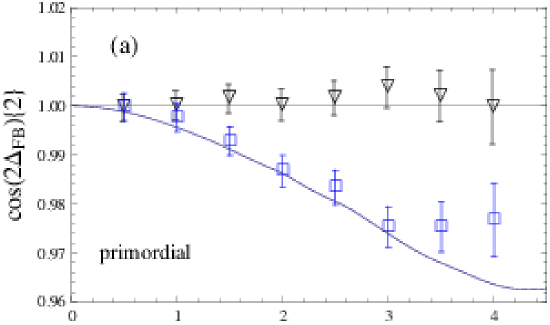
$$\cos(k\Delta_{FB})\{2\} \equiv \frac{\left\langle e^{ik(\phi_F-\phi_B)}\right\rangle}{\sqrt{\left\langle e^{ik(\phi_{F,1}-\phi_{F,2})}\right\rangle \left\langle e^{ik(\phi_{B,1}-\phi_{B,2})}\right\rangle}} = \langle\cos(k\Delta_{FB})\rangle_{\text{events}} + \text{nonflow}.$$

$$\cos(2k\Delta_{FB})\{4\} \equiv \frac{\left\langle e^{ik[(\phi_{F,1}+\phi_{F,2})-(\phi_{B,1}+\phi_{B,2})]}\right\rangle}{\left\langle e^{ik[(\phi_{F,1}-\phi_{F,2})-(\phi_{B,1}-\phi_{B,2})]}\right\rangle} = \langle\cos(2k\Delta_{FB})\rangle_{\text{events}} + \text{nonflow}$$

$$\left\langle e^{in(\phi_F-\phi_B)}\right\rangle = \frac{1}{N_{\text{events}}}\sum_{\text{events}}\frac{1}{n_F n_B}\sum_{i=1}^{n_F}\sum_{j=1}^{n_B} e^{ik(\phi_i-\phi_j)}$$

Results (one hydro event from averaged condition, $c = 20 - 25\%$)

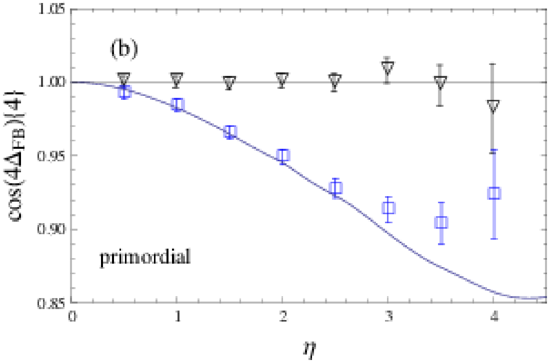
Primordial particles (no resonance decays):



triangles – no torque, squares – torque
line – fireball torque angle after hydro (no hadronization)

Results (one hydro event from averaged condition, $c = 20 - 25\%$)

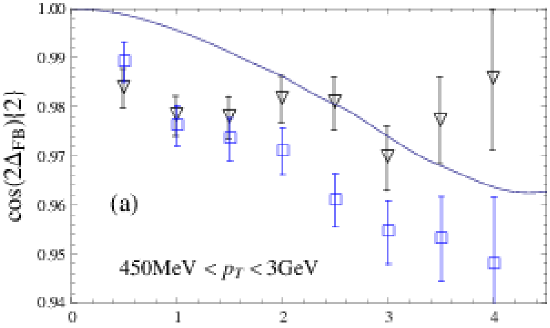
Primordial particles (no resonance decays):



triangles – no torque, squares – torque
line – fireball torque angle after hydro (no hadronization)

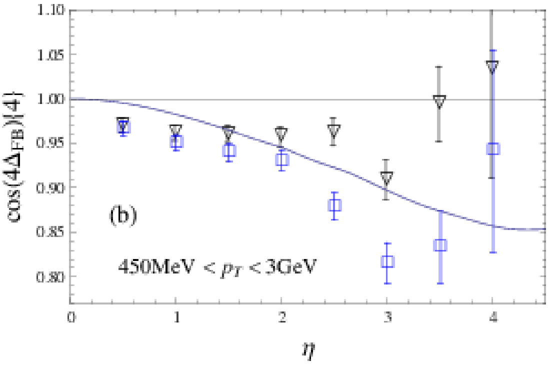
Results (one hydro event from averaged condition, $c = 20 - 25\%$)

Physical particles (with resonance decays):



Results (one hydro event from averaged condition, $c = 20 - 25\%$)

Physical particles (with resonance decays):



Principle Component Analysis (PCA)

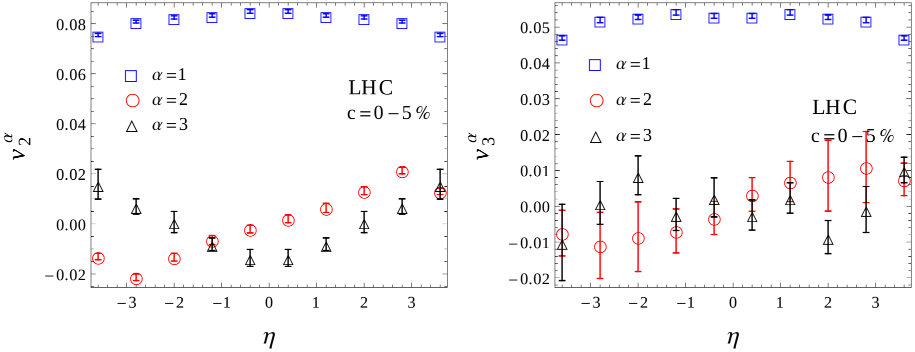
[standard multivariate method,
recalled by Bhalerao, Ollitrault, Pal, Teaney (2014)]

- Take N bins
- Evaluate $N \times N$ covariance matrix ρ
- Find eigenvectors and eigenvalues (principal system)
- If $\lambda_i \gg \lambda_j \to$ mode i much more collective than j

[white board drawings, relation to torque]

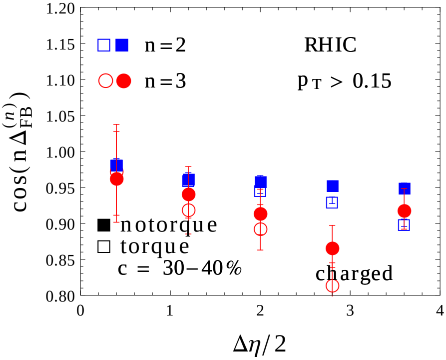
Results from PCA (sneak preview of AO work)

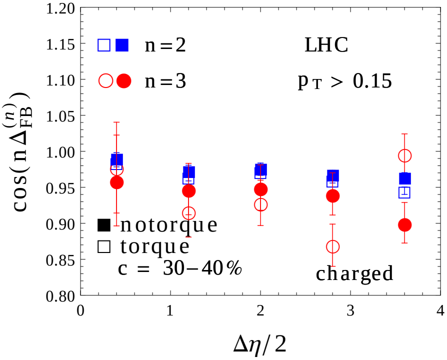
[work with P. Bożek and AO]



Results from PCA (sneak preview of AO work)

[work with P. Bożek and AO]





Summary and prospects

- Torque (FB flow correlations) ARE presently studied at LHC
- Origin: initial "triangles" and fluctuations
- Decorrelation form hadronization needs to be carefully analyzed (no-torque adds to torque)

(to be continued by AO)