Deciphering Azimuthal Correlations in Relativistic Heavy-Ion Collisions

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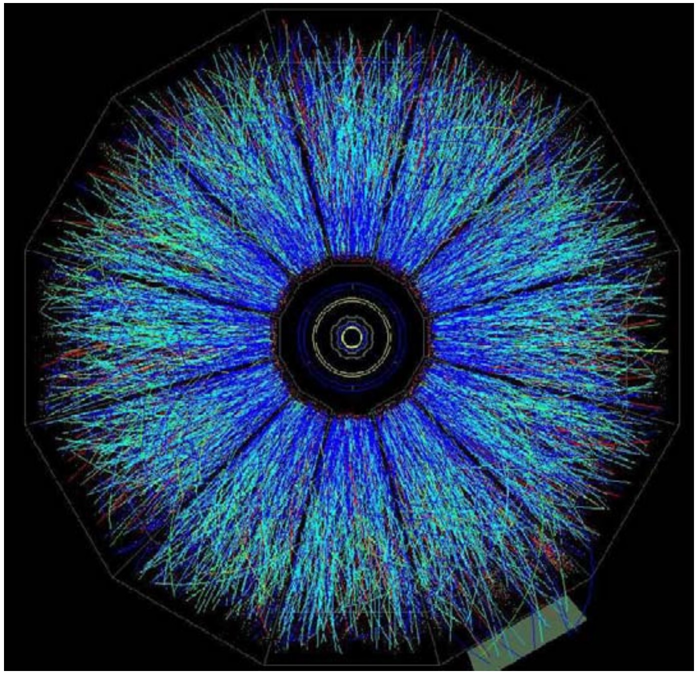
Various sources of azimuthal correlations



STAR experiment @ RHIC

$\mathrm{Au-Au}\ @\ \sqrt{s_{NN}} = 200\ \mathrm{GeV}$

- Jets
- collective flow
- collective flow fluctuations
- resonance decays
- p_{T} conservation
- . . . .

Integral fluctuation measure Φ

$$\Phi_\varphi = \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\overline{z^2}}$$

$z \equiv \varphi - \overline{\varphi}$ one-particle variable

$\overline{\cdots}$ inclusive average $\overline{z} = 0$

$Z \equiv \sum_{i=1}^{N} z_i = \sum_{i=1}^{N} \left(\varphi_i - \overline{\varphi}\right)$ event variable

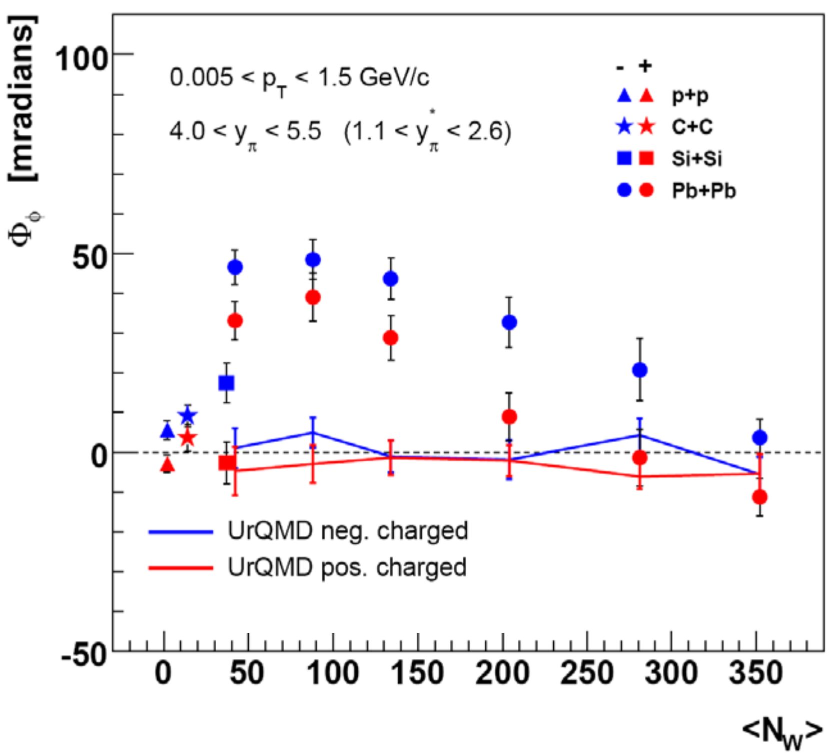
$\langle \cdots \rangle$ average over events $\langle Z \rangle = 0$

- ✓ $\Phi_\varphi = 0$ for no correlations
- ✓ Φ_φ strictly intensive

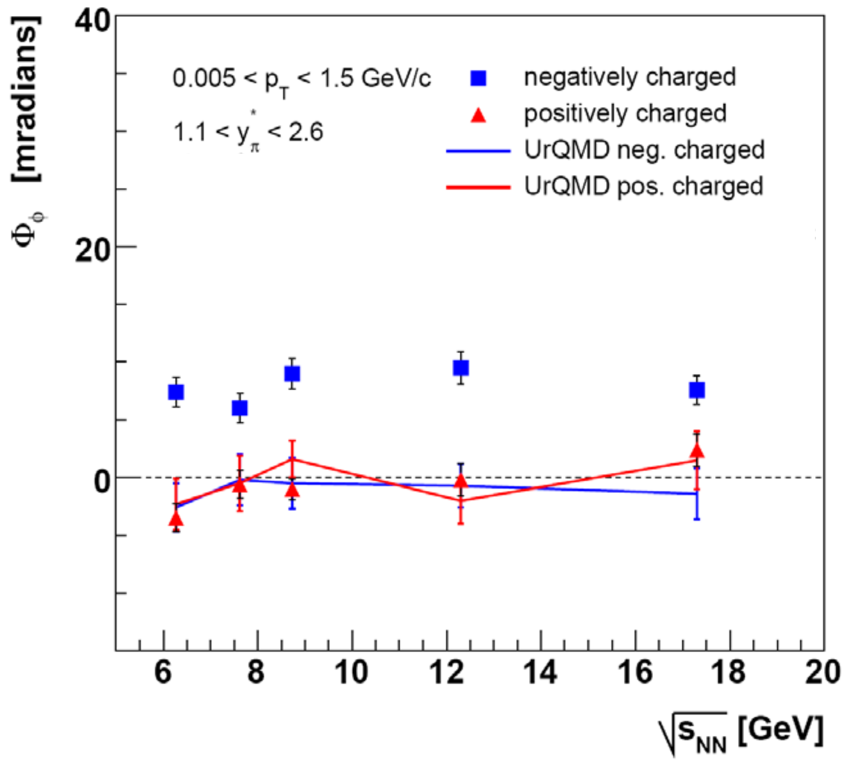
M. Gaździcki & St. Mrówczyński, Z. Phys. **C54,** 127 (1992)

NA49 preliminary data

A-A @ 158 *A*GeV



Most central Pb-Pb



T. Cetner & K. Grebieszkow [for NA49 Collaboration], arXiv:1008.3412[nucl-ex]

Modeling of azimuthal correlations

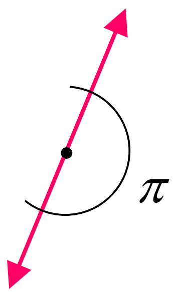
Sources of correlations which are modeled:

- resonance decays
- jets
- p_T conservation
- collective flow
- collective flow fluctuations

T. Cetner, K. Grebieszkow & St. Mrówczyński, Physical Review **C83**, 024905 (2011)

Resonance decays

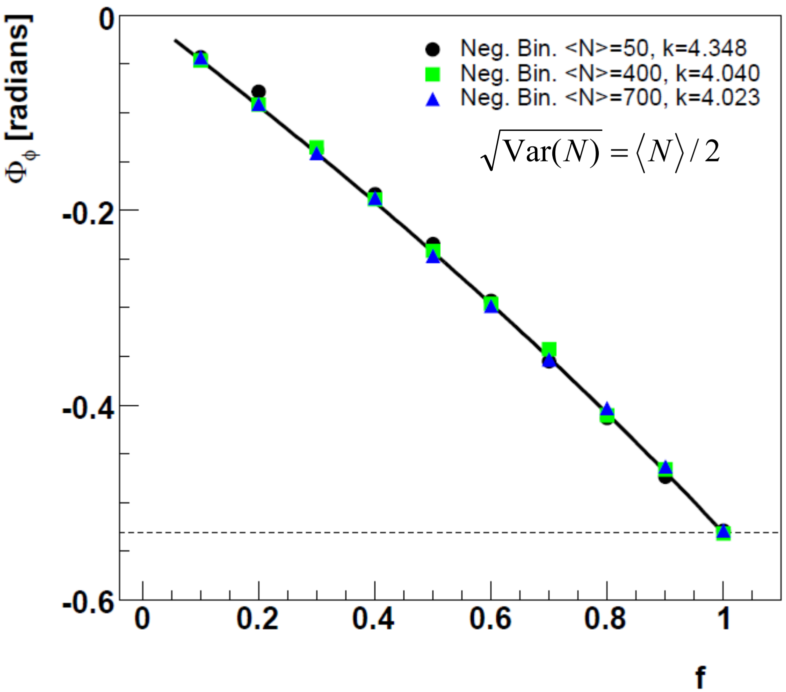
Toy Model



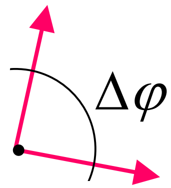
N_R heavy resonances decaying back to back and N_0 stable particles

f – fraction of particles coming from resonance decays, $f = \dfrac{2N_R}{2N_R + N_0}$

$$\Phi_\varphi = \frac{\sqrt{2-f} - \sqrt{2}}{\sqrt{6}}\pi$$



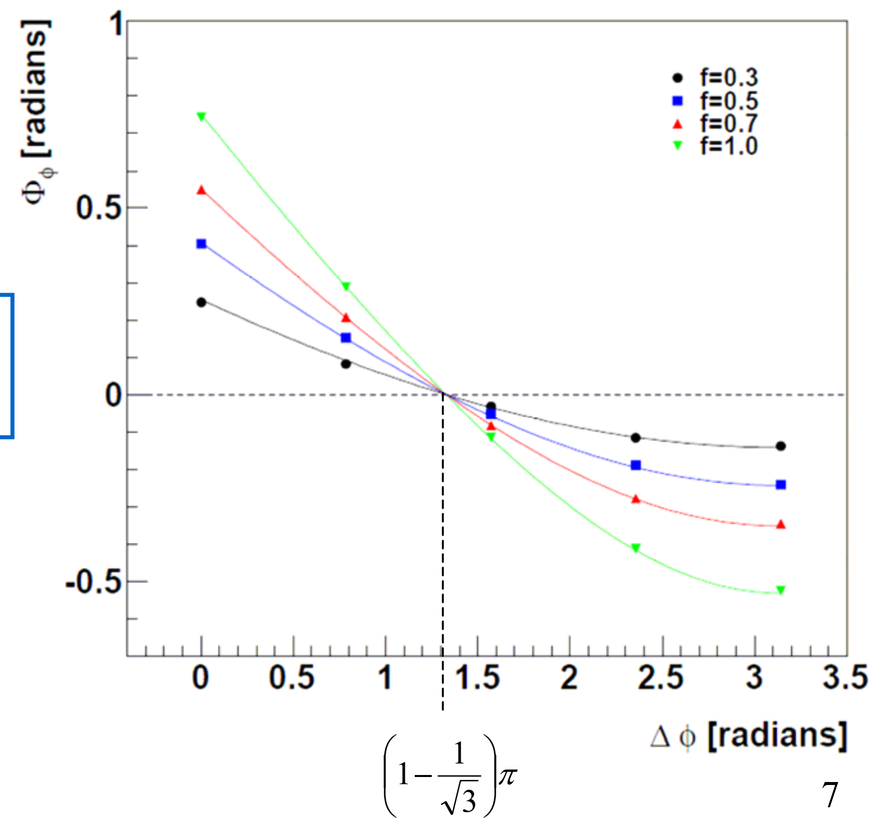
Resonance decays cont.



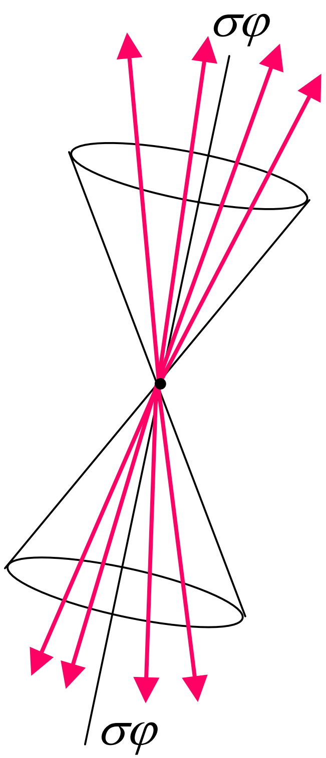
N_R resonance and N_0 stable particles

f – fraction of particles coming from resonance decays, $f = \dfrac{2N_R}{2N_R + N_0}$

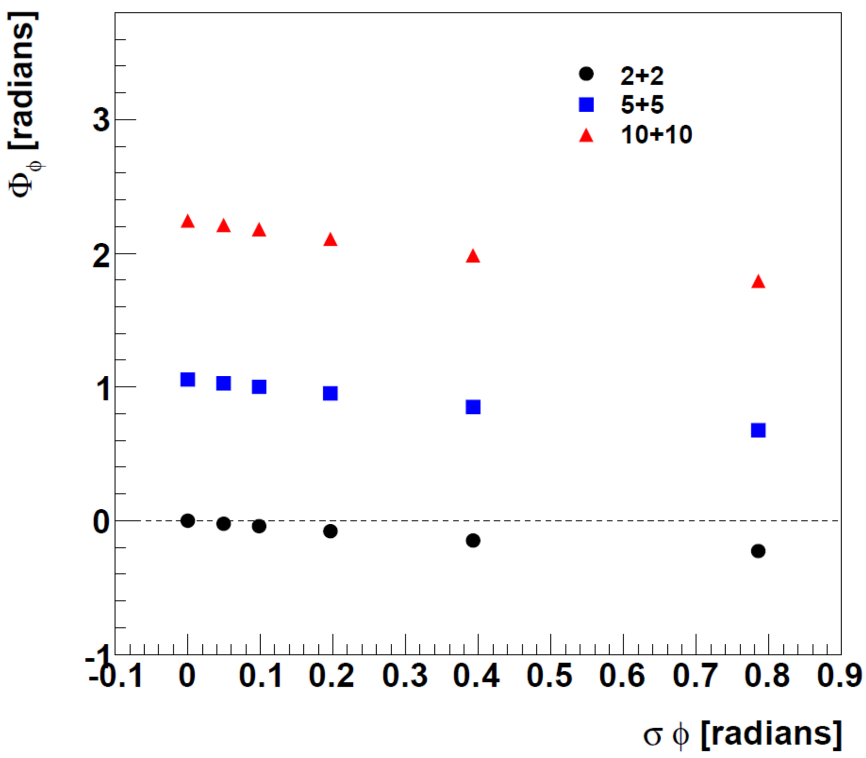
$$\Phi_\varphi = \sqrt{\frac{\pi^2}{3} + f\left(\frac{\pi^2}{3} - \pi\Delta\varphi + \frac{1}{2}(\Delta\varphi)^2\right)} - \frac{\pi}{\sqrt{3}}$$



Jets



σφ
σφ

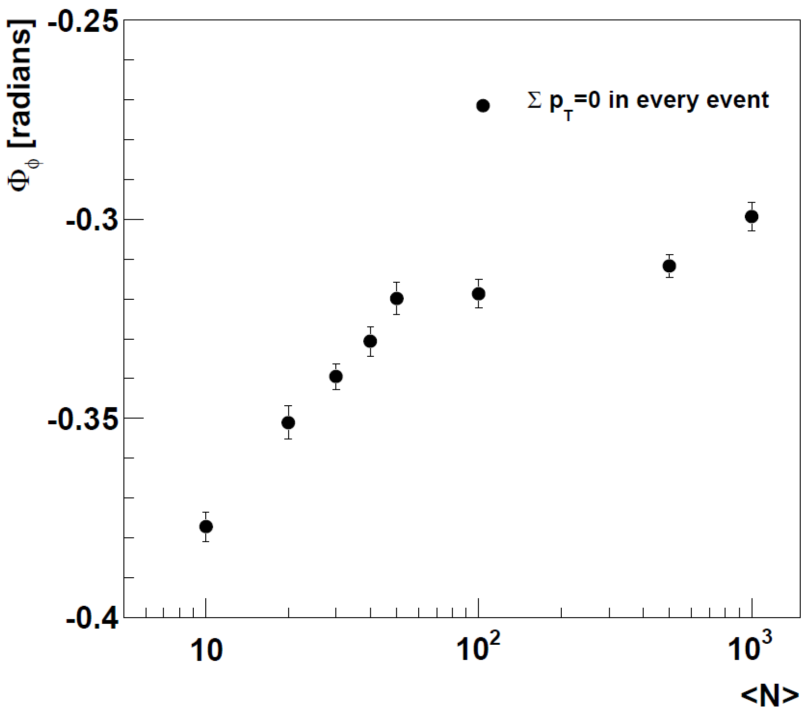


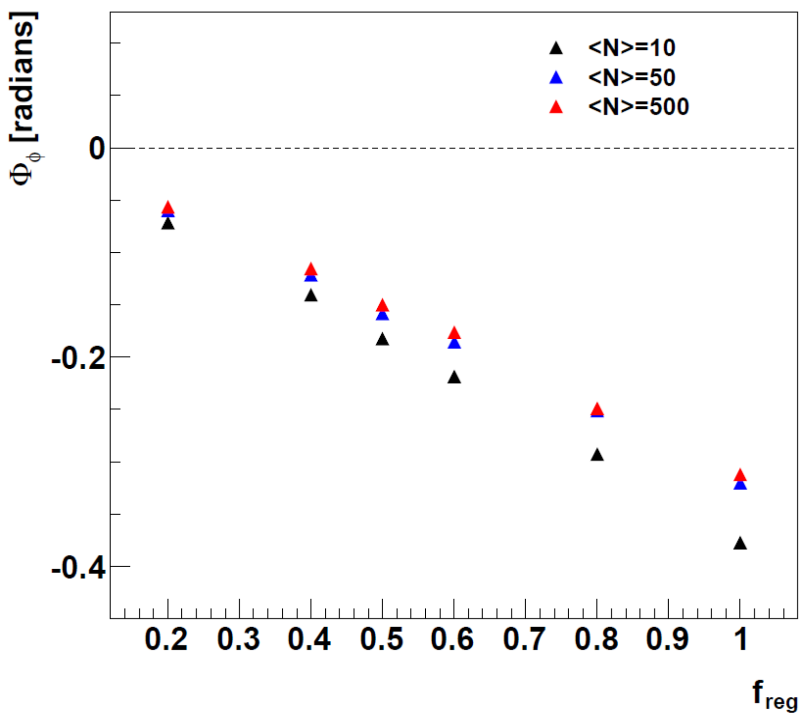
2+2
5+5
10+10
Φ_φ [radians]
σ φ [radians]
-1
0
1
2
3
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

p_T conservation

Monte Carlo model:

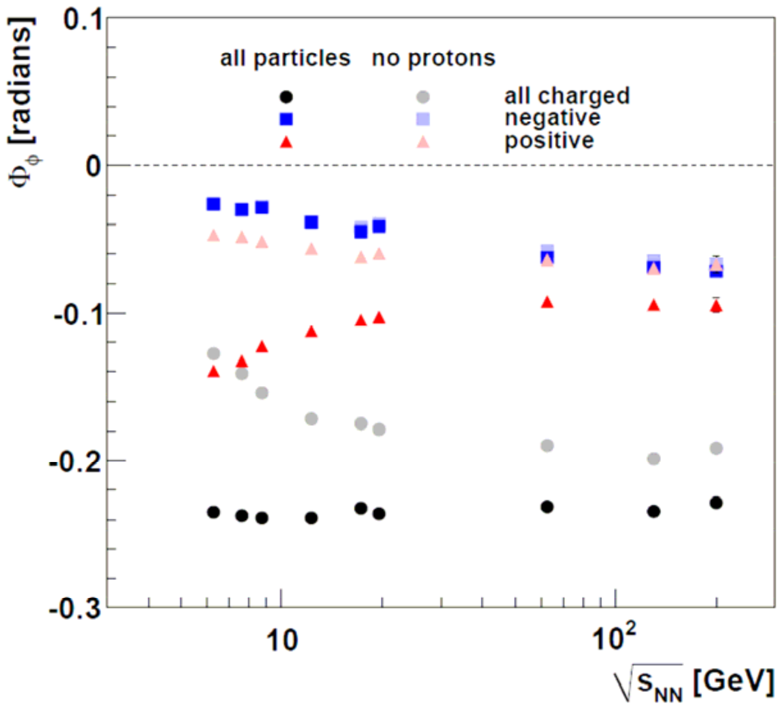
$$p_x \to p_x - \frac{1}{N}\sum_{i=1}^{N} p_x^i\,, \qquad p_y \to p_y - \frac{1}{N}\sum_{i=1}^{N} p_y^i$$



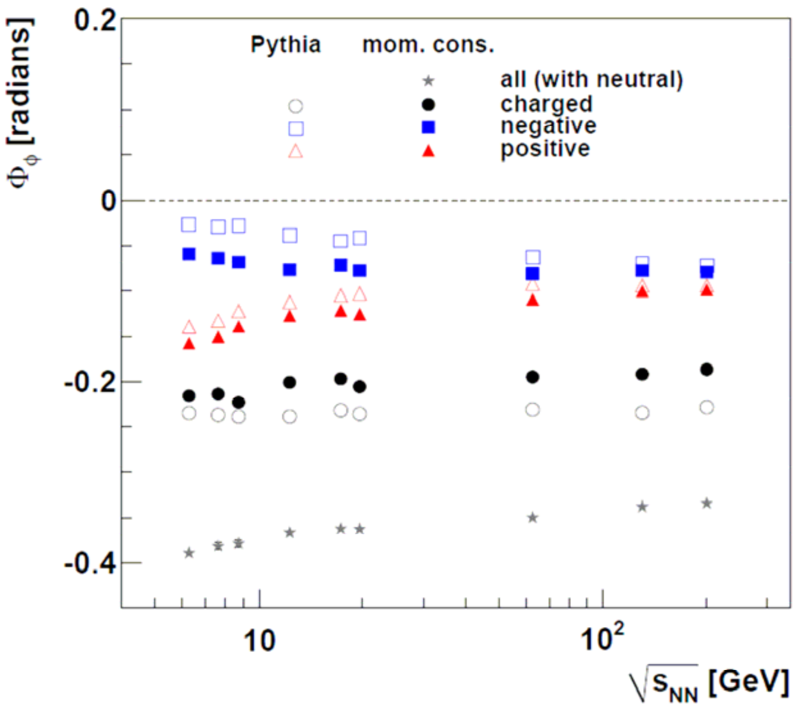


f_{reg} – fraction of registered particles

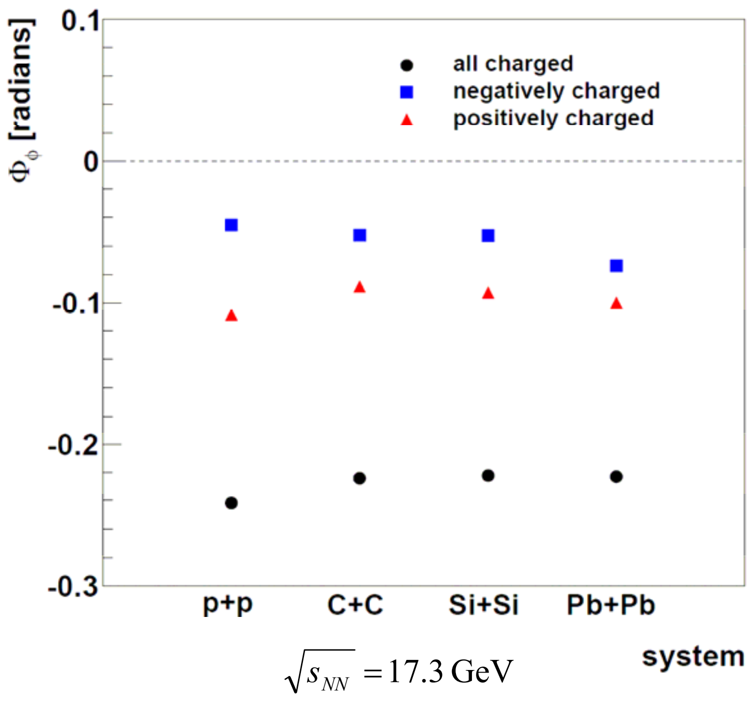
PYTHIA p-p data



PYTHIA vs. p_T conservation



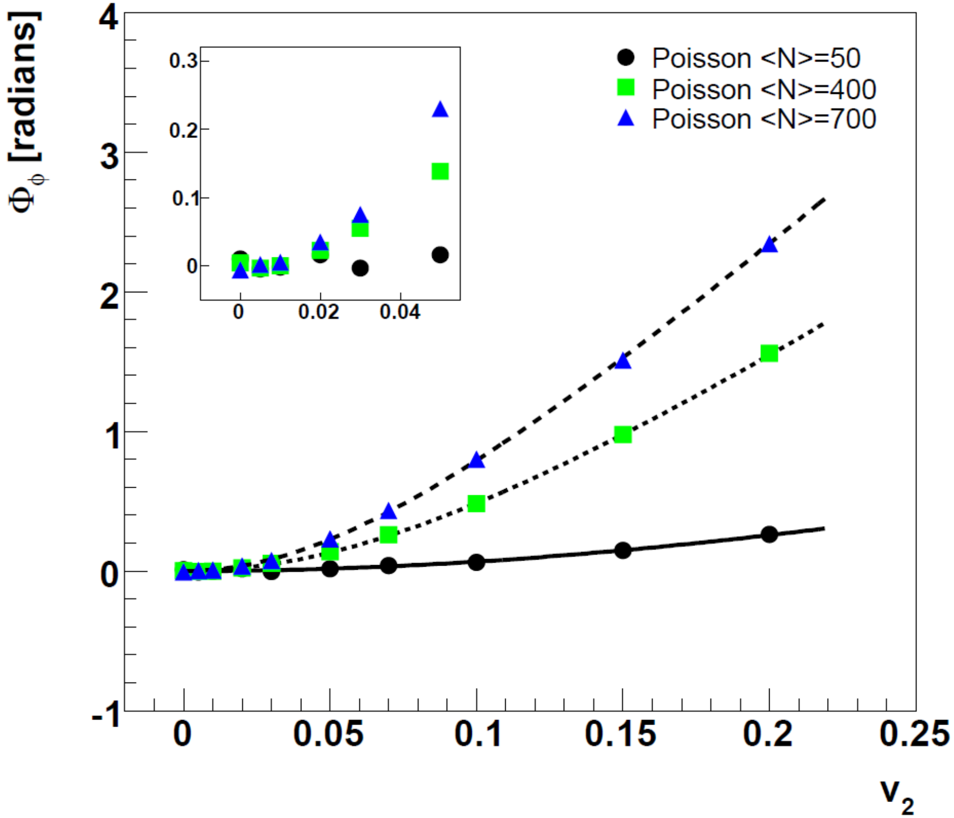
HIJING A-A data



Collective flow

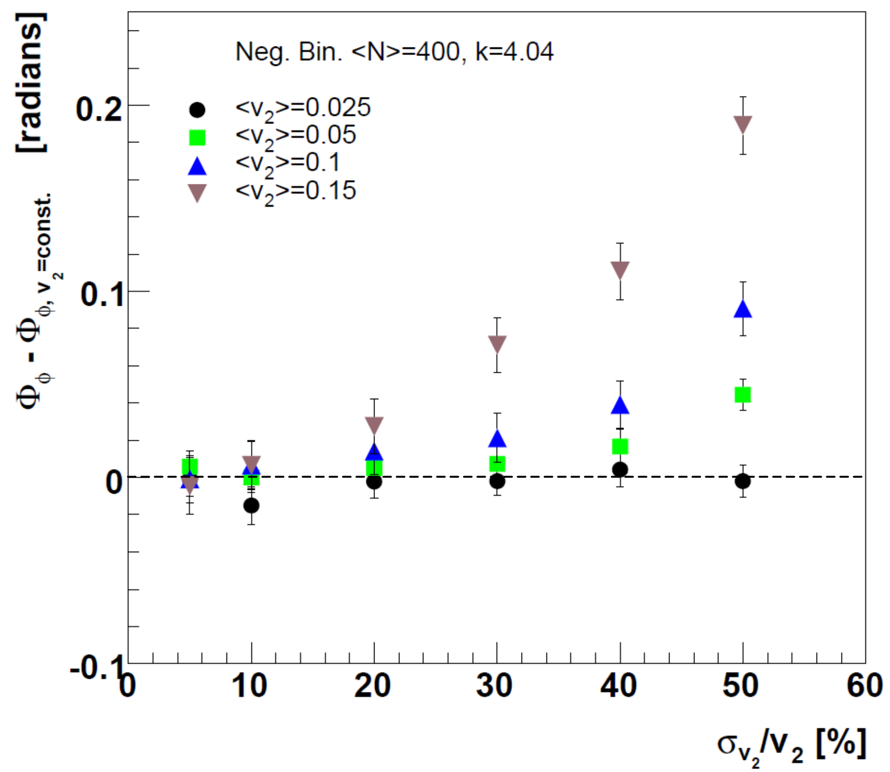
$$\Phi_{\varphi} = \sqrt{\frac{\pi^2}{3} + \frac{\langle N^2 \rangle - \langle N \rangle}{\langle N \rangle} S} - \frac{\pi}{\sqrt{3}}$$

$$S \equiv 2 \left\langle \sum_{n=1}^{\infty} \left(\frac{\mathrm{v}_n}{n} \right)^2 \right\rangle$$

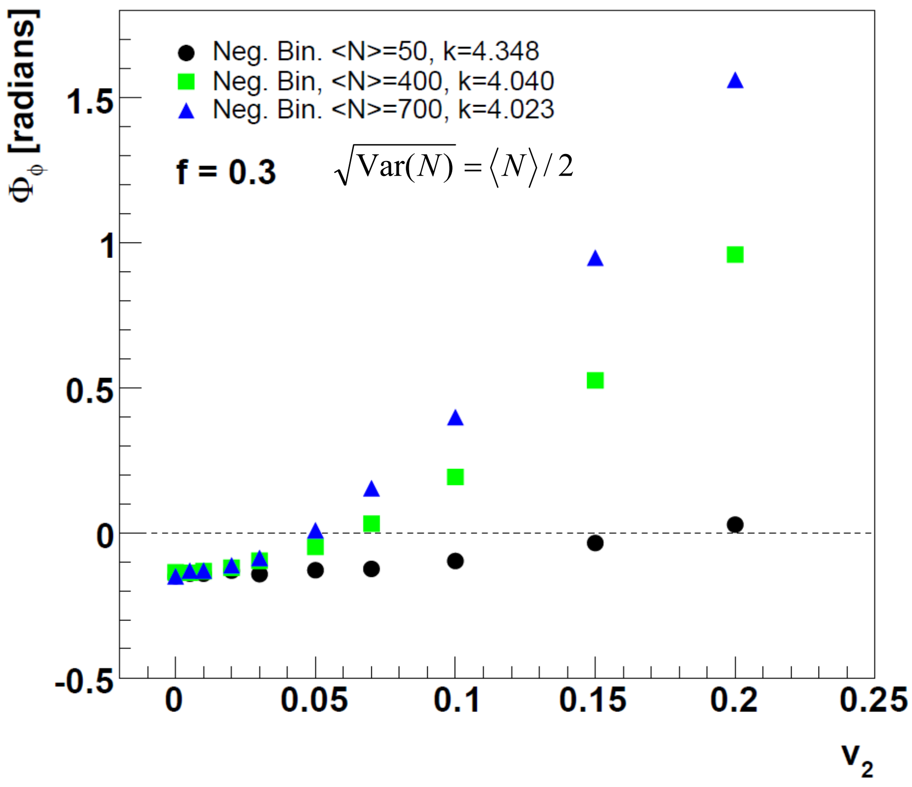


St. Mrówczyński, Acta Phys. Pol. **B31,** 2065 (2000)

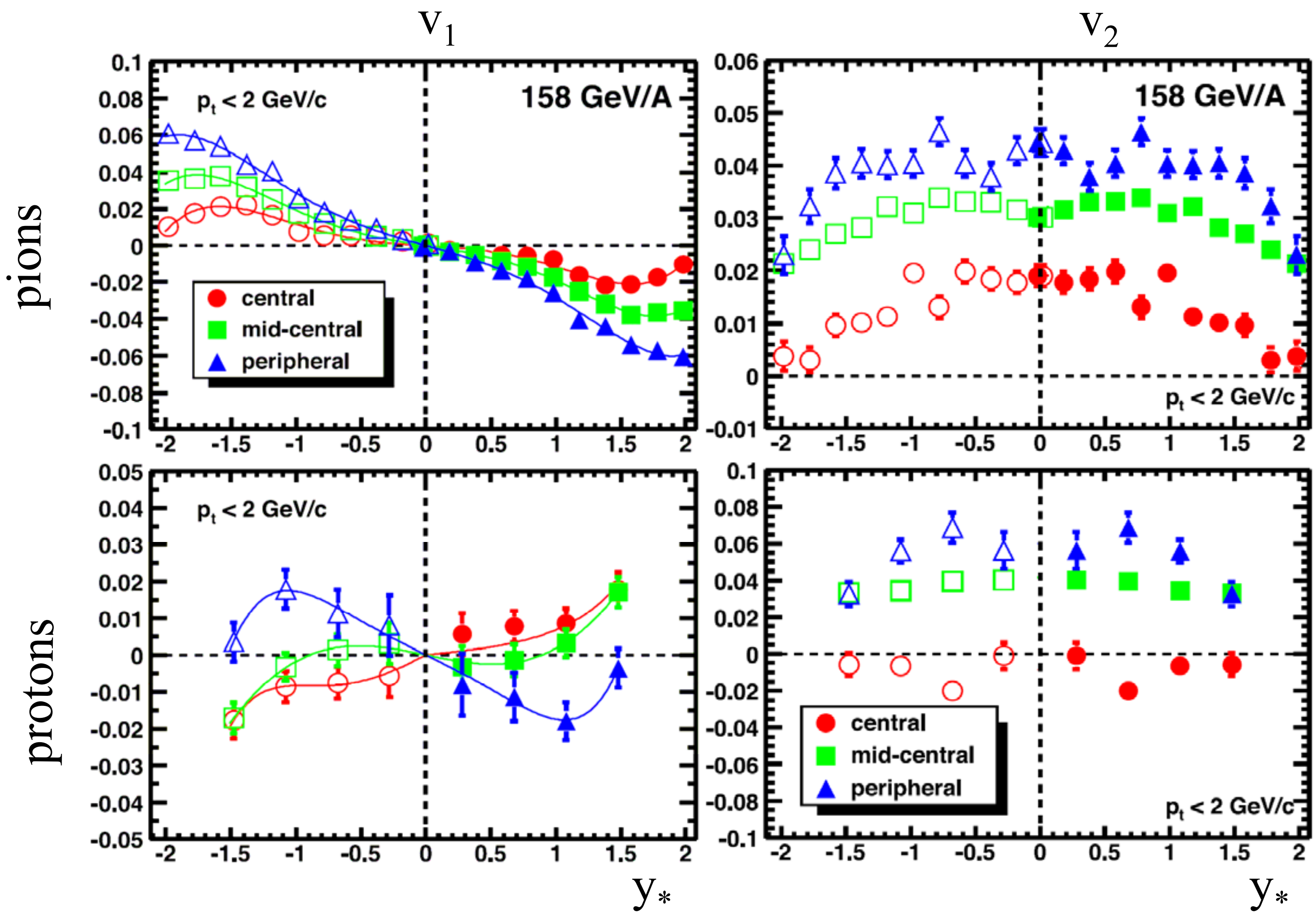
Collective flow fluctuations



Collective flow & resonance decays



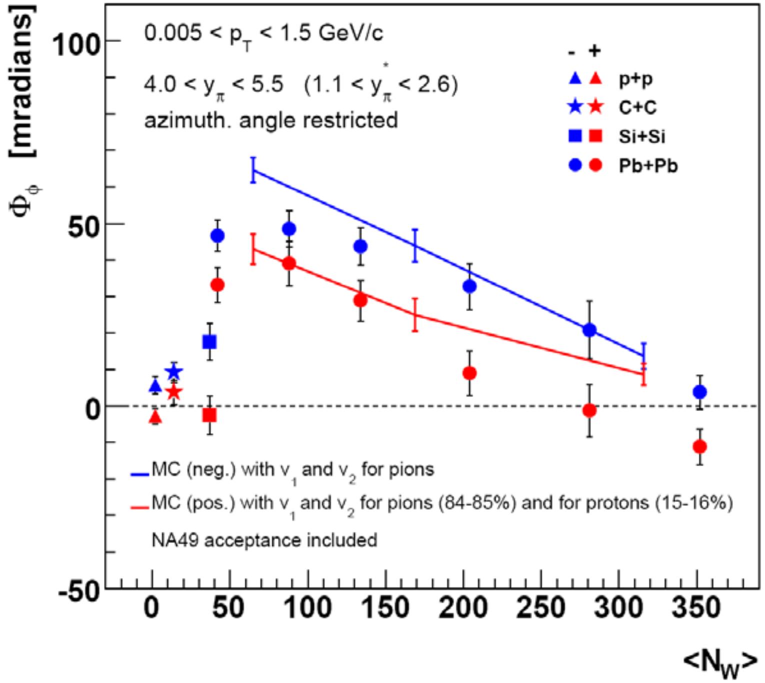
NA49 data on collective flow in Pb-Pb @ 158 GeV



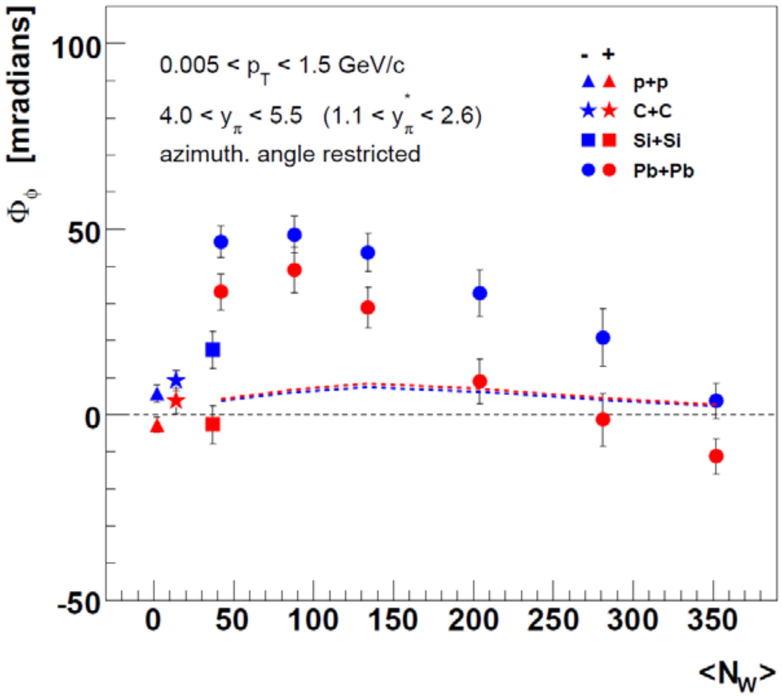
C. Alt et al. [NA49 Collaboration], Physical Review **C68**, 034903 (2003)

Measured v_1 & v_2 vs. NA49 data on Φ_φ

v_1 & v_2



v_2 only



$$\Phi_\varphi = \sqrt{\frac{\pi^2}{3} + \frac{\langle N^2 \rangle - \langle N \rangle}{\langle N \rangle} S} - \frac{\pi}{\sqrt{3}} \qquad S \equiv 2 \left\langle \sum_{n=1}^{\infty} \left(\frac{v_n}{n} \right)^2 \right\rangle$$

Thanks to Wojtek Broniowski!

Conclusions

- azimuthal correlations are dominated by collective flow
- no exotic source of strong correlations is seen