Anisotropic flow measurements in MPD experiment using two- and three-particle correlation scalar product method

Petr Parfenov, Vinh Ba Luong, Dim Idrisov, Arkadiy Taranenko, Alexander Demanov

NRNU MEPhI

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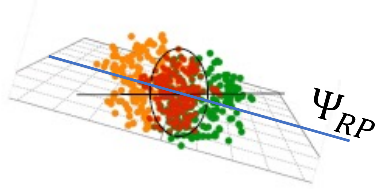
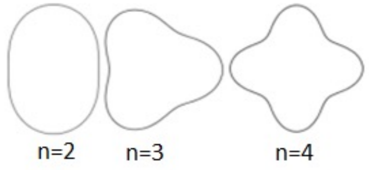
Outline

- Anisotropic flow at energies from LHC to NICA
- Scalar product (SP) method implementation
- Comparison of elliptic flow using 2- and 3-particle correlation SP method
- Summary and outlook

Anisotropic flow at RHIC/LHC





Spatial anisotropy:

$$\varepsilon_n = \frac{\sqrt{\langle r^2 \cos n\varphi \rangle^2 + \langle r^2 \sin n\varphi \rangle^2}}{\langle r^2 \rangle}$$

φ – azimuthal angle of nucleon
ϕ – azimuthal angle of produced particle

Momentum anisotropy:

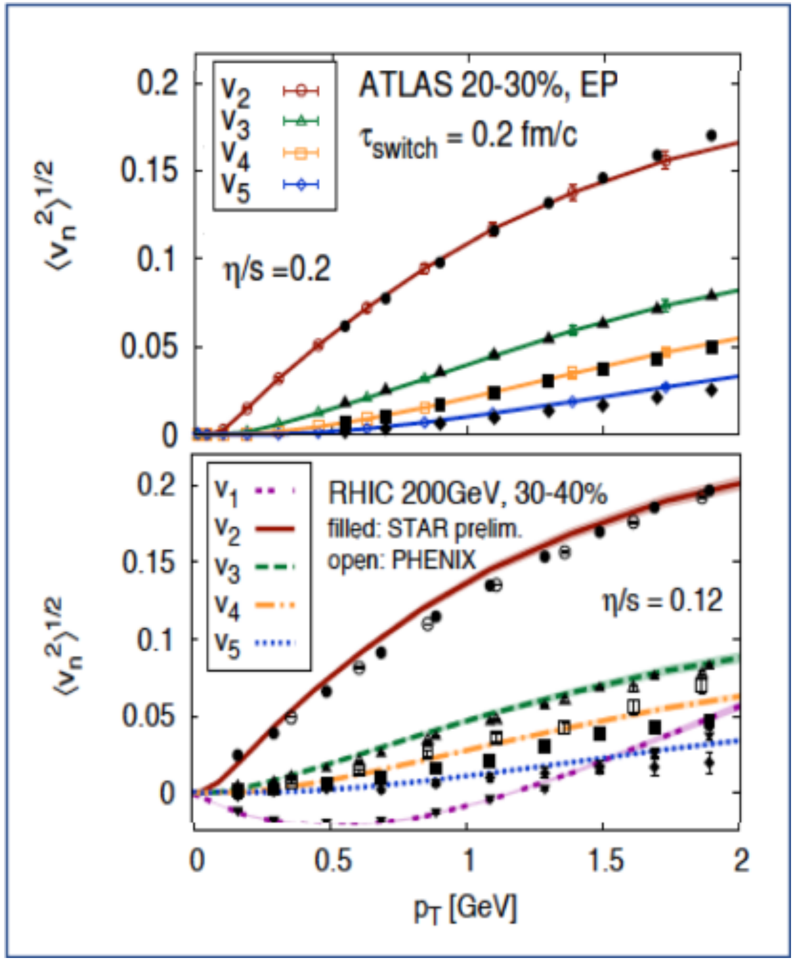
$$\frac{dN}{d\phi} \propto 1 + 2\sum_{n=1} \boldsymbol{v_n} \cos[n(\phi - \Psi_{RP})]$$

$$v_n = \langle \cos[n(\phi - \Psi_{RP})] \rangle$$

v_1 - directed flow
v_2 - elliptic flow

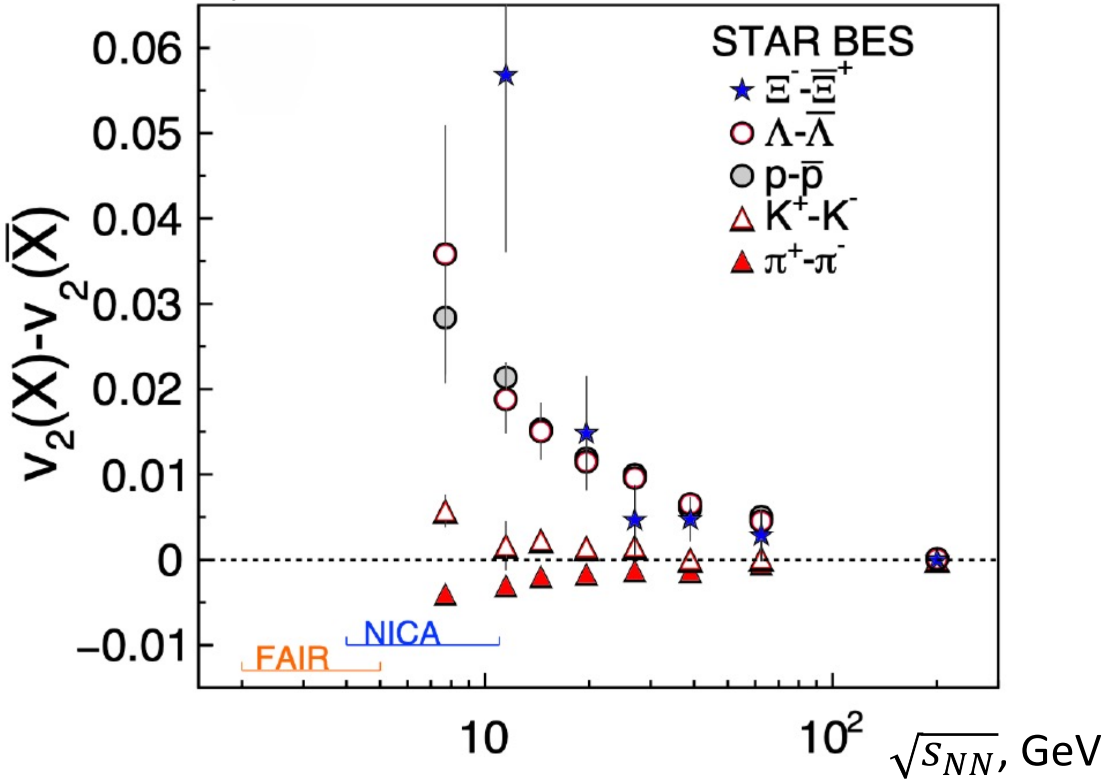
- Initial eccentricity (and its attendant fluctuations) ε_n drives momentum anisotropy v_n with specific viscous modulation
- $\boldsymbol{v_n (p_T, centrality)}$ sensitive to the early stages of collision:
  - Important constraint for transport properties: EOS, η/s, ζ/s, etc.

Gale, Jeon, et al., Phys. Rev. Lett. 110, 012302

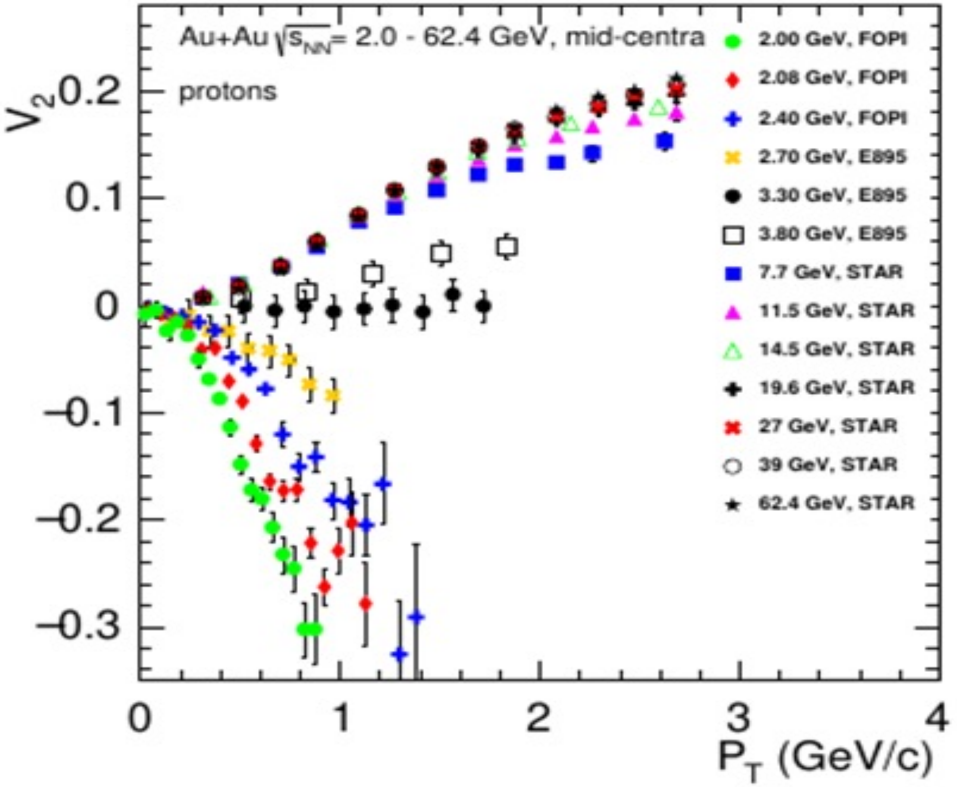


Anisotropic flow at STAR BES and NICA energies

EPJ Web Conf. 204 (2019) 03009
Phys. Rev. C 88 (2013) 14902



Taranenko et. al., Phys. Part. Nuclei **51** (2020), 309–313



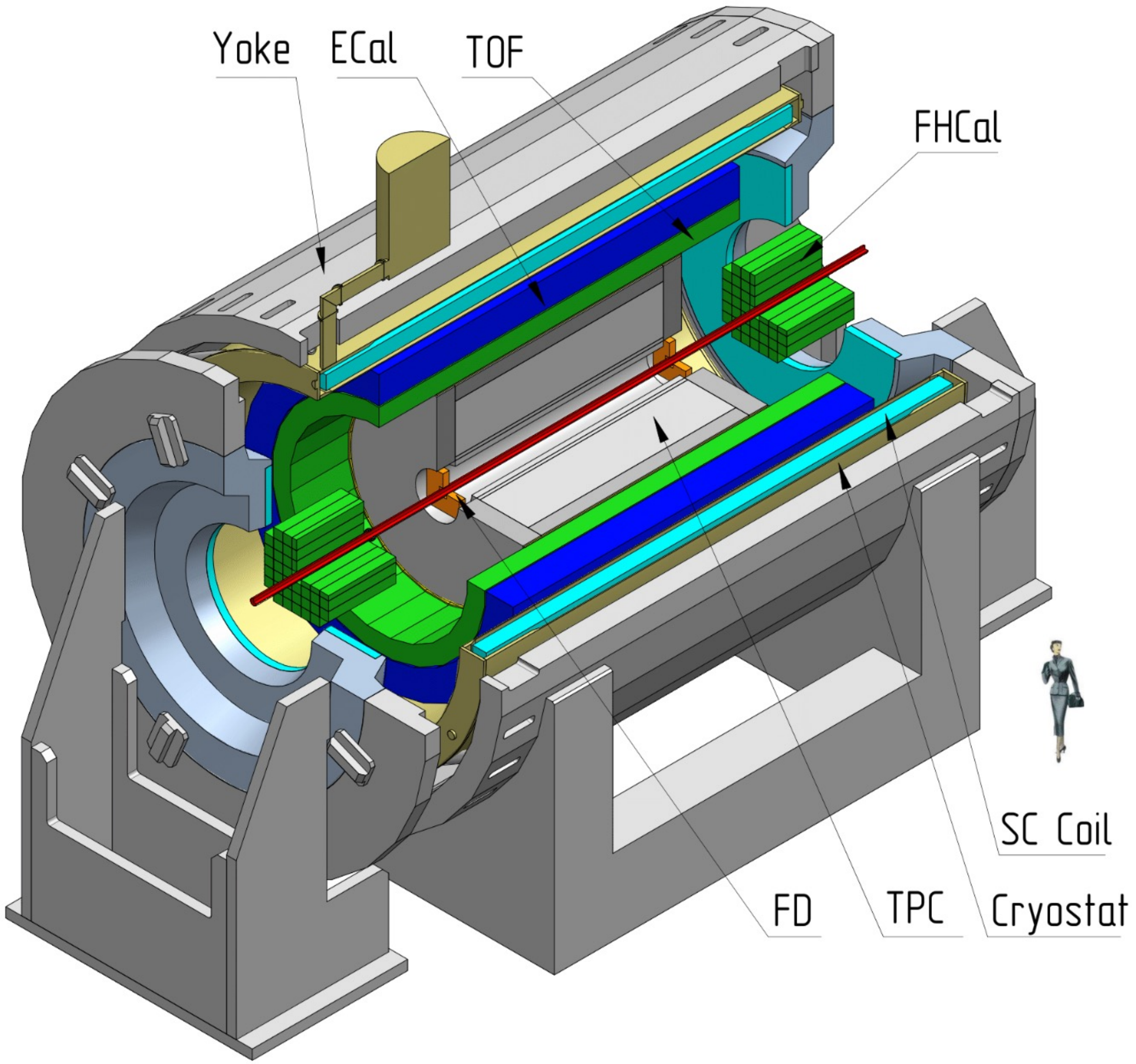
Strong energy dependence of the difference in v_2 of particles and antiparticles

Anisotropic flow at NICA energies is a delicate balance between:

I. **The ability of pressure developed early in the reaction zone** **and**

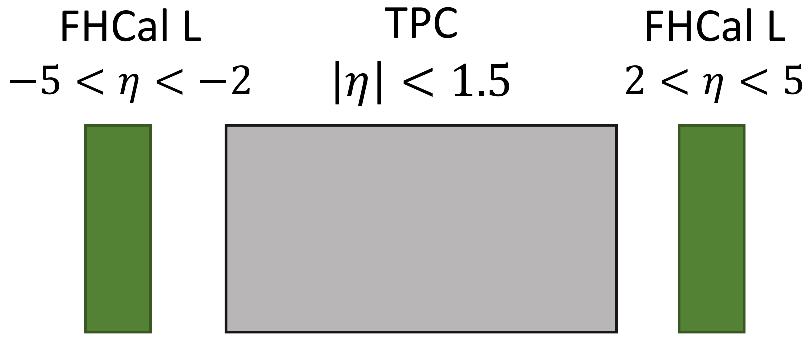
II. **The passage time for removal of the shadowing by spectators**

MPD experiment at NICA



Multi-Purpose Detector (MPD) Stage 1

- **Symmetry plane**
  - FHCal ($2 < |\eta| < 5$) or TPC ($|\eta| < 1.5$)
- **Time projection chamber (TPC)**
  - Tracking of charged particles within ($|\eta| < 1.5, 2\pi$ in ϕ)
  - PID at low momenta
- **Time of flight (TOF)**
  - PID at high momenta



Scalar product (SP) method

Unit particle vector u_n and event flow vector Q_n:

$$u_n = e^{in\phi}, \qquad Q_n = \sum_{j=0}^{M} u_n^j = \sum_{j=0}^{M} e^{in\phi_j}$$

Where:

- ϕ – azimuthal angle of the particle
- M – particle multiplicity in the given set of particles (subevent)

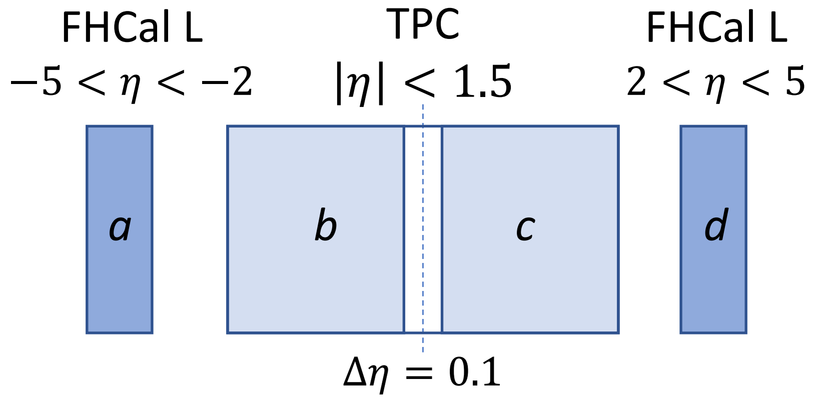
2-particle correlation:

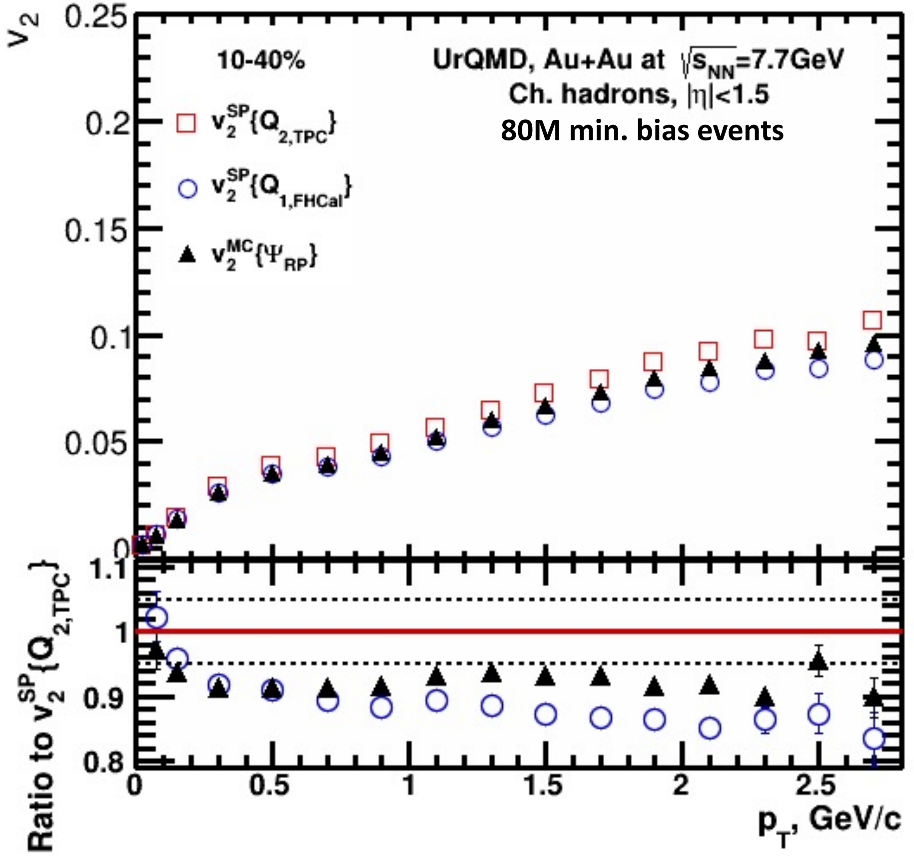
$$v_2^{SP}\{Q_{2,\mathrm{TPC}}\} = \frac{\langle u_2^{b,c} Q_2^{c,b*} \rangle}{\sqrt{\langle Q_2^c Q_2^{b*} \rangle}} \approx v_2 + \mathcal{O}\left(\frac{1}{v_2 M}\right), \qquad \delta \sim \frac{1}{M}$$

3-particle correlation:

$$v_2^{SP}\{Q_{1,\mathrm{FHCal}}\} = \frac{\langle Q_1^a Q_1^d u_2^{b,c*} \rangle}{\langle Q_1^a Q_1^{d*} \rangle} \approx v_2 + \mathcal{O}\left(\frac{1}{(v_2 M)(v_1 M)}\right), \qquad \delta \sim \frac{1}{M^2}$$

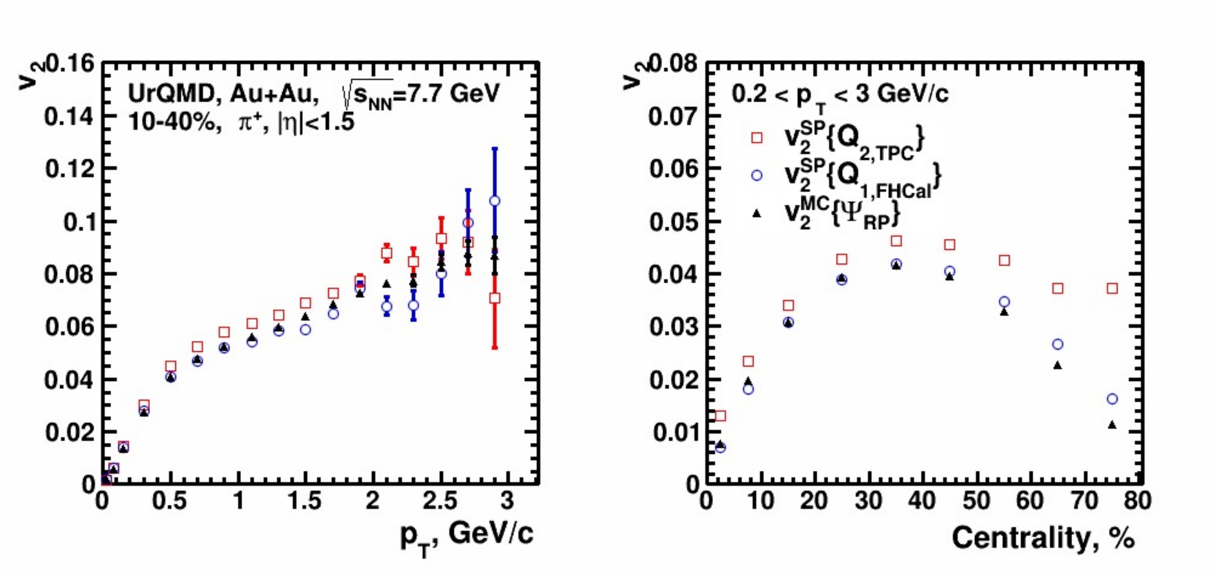
SP method based on 3-particle correlation has a stronger suppression of non-flow contribution δ

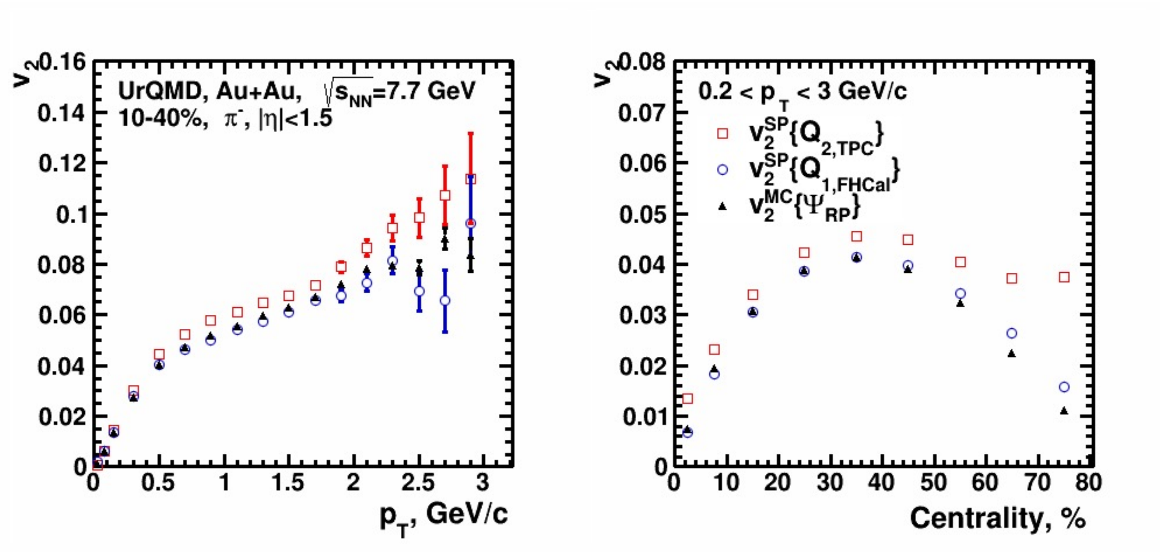


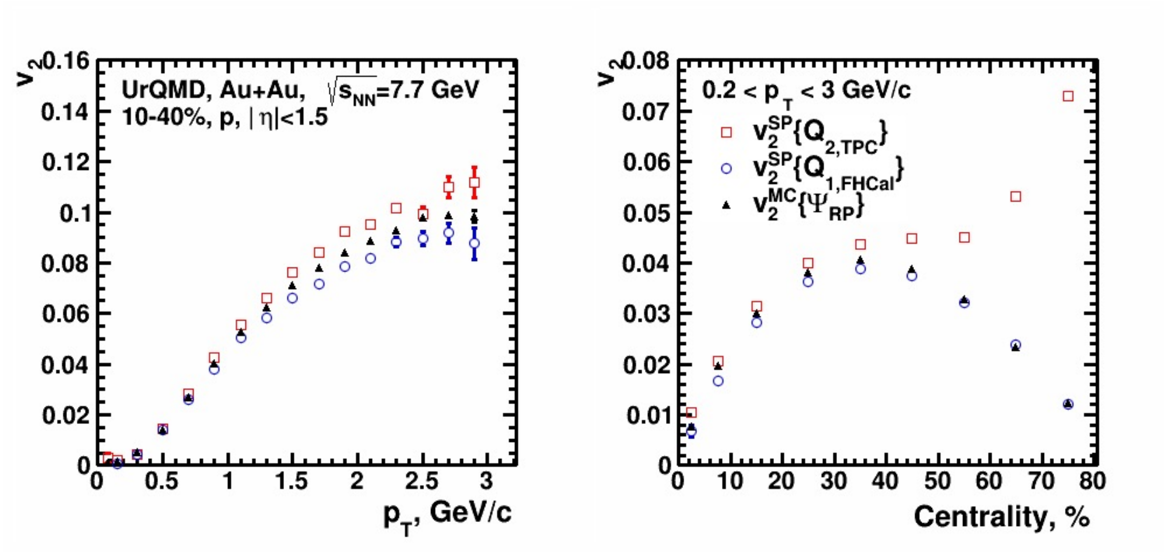


I. Selyuzhenkov and S. Voloshin, Phys. Rev. C 77 (2008) 034904
N. Borghini, P.M. Dinh, J.Y. Ollitrault, Phys.Rev. C 66 (2002) 014905

Comparison of the SP methods







- UrQMD 3.4, Au+Au, $\sqrt{s_{NN}} = 7.7$ GeV, 80M min. bias events
- Centrality determination: impact parameter selection based on the MC-Glauber method (see Idrisov's talk)
- Track selection:
  - $0.05 < |\eta| < 1.5$
  - $p_T < 3$ GeV/c
  - PDG based particle idetification

SP method based on 3 particle correlation can be used to study flow in peripheral collisions

Summary

- **v_2 at NICA energies shows strong energy dependence**
  - There's a lack of differential measurements of v_2 at NICA energy range
- **Comparison of SP methods for v_2 measurements:**
  - Method that uses 3 particle correlation has a stronger non-flow suppression and can be used for flow measurements in case of peripheral collisions
  - Additional difference can be attributed to the flow fluctuations (see Luong's talk)

ToDo:

- Implementation of the SP based on 3 particle correlation for the fully reconstructed data in MPD (NICA)

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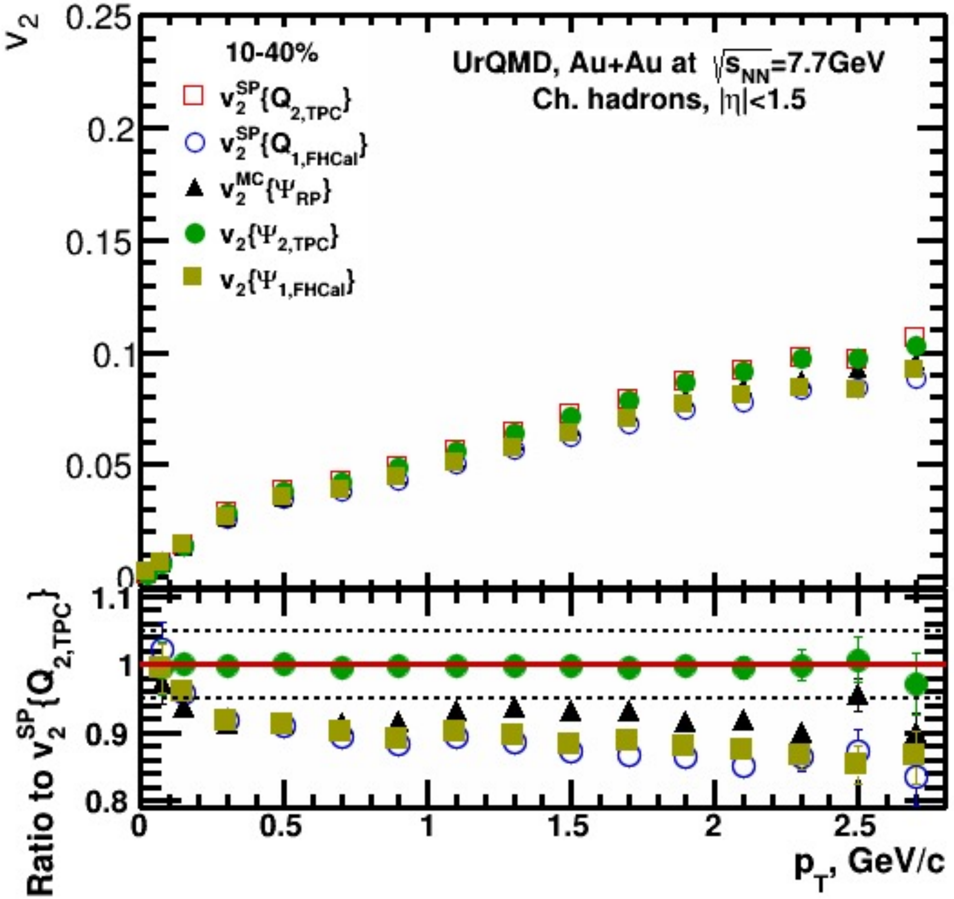
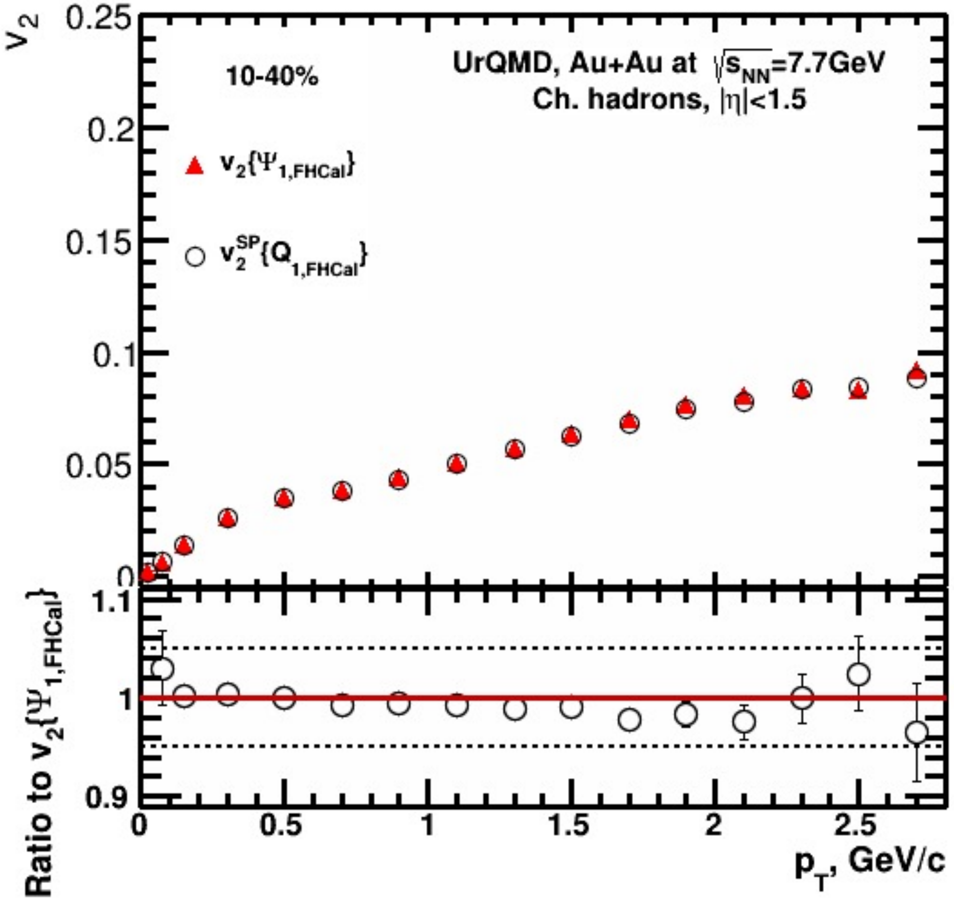
Thank you for your attention!

Backup slides

SP vs EP methods





$$v_2^{SP}\{Q_{2,TPC}\} \approx v_2\{\Psi_{2,TPC}\} > v_2^{MC}\{\Psi_{\mathrm{RP}}\} \geq \boldsymbol{v_2^{SP}\{Q_{1,FHCal}\} \approx v_2\{\Psi_{1,FHCal}\}}$$