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Medium-modified Jets and Initial State Fluctuations as Sources of Charge Correlations Measured at RHIC

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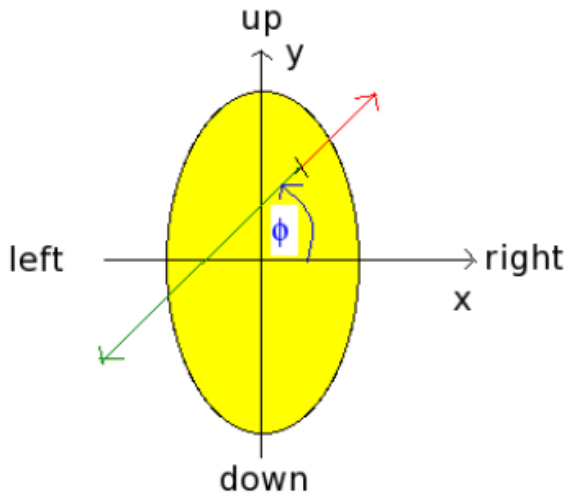
Thanks to: Thorsten Renk, Steffen A. Bass, Fuqiang Wang, Berndt Müller

Motivation

- Charge correlation measurement by STAR has been interpreted as a sign for local parity violation or the chiral magnetic effect
- Other Mechanisms might also exist:
  - Medium-modified Jets introducing asymmetries in particle production
  - S. Pratt in arXiv: 1002.1758 estimated effect of elliptic flow, momentum conservation and charge conservation
  - Initial State Fluctuations, 'Hot Spots', + dynamical evolution that generates coordinate-space-momentum-space correlation

  → State-of-art calculation to investigate these effects

Charged Particles in Different Hemispheres



LPV effects in UD. LR is null-reference.

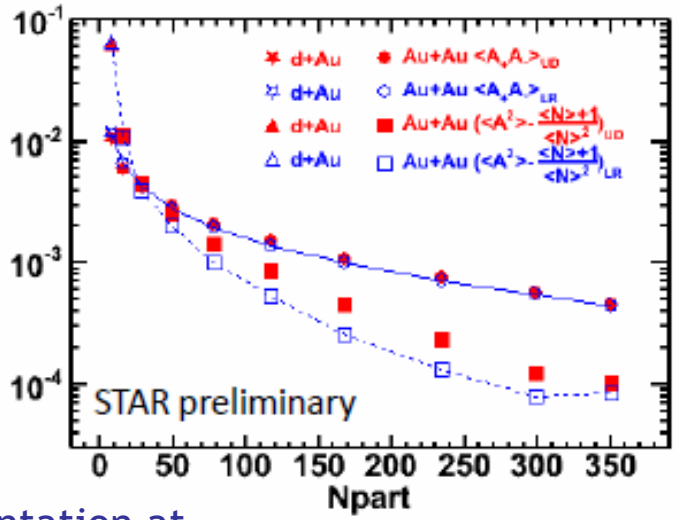
LPV expectations:

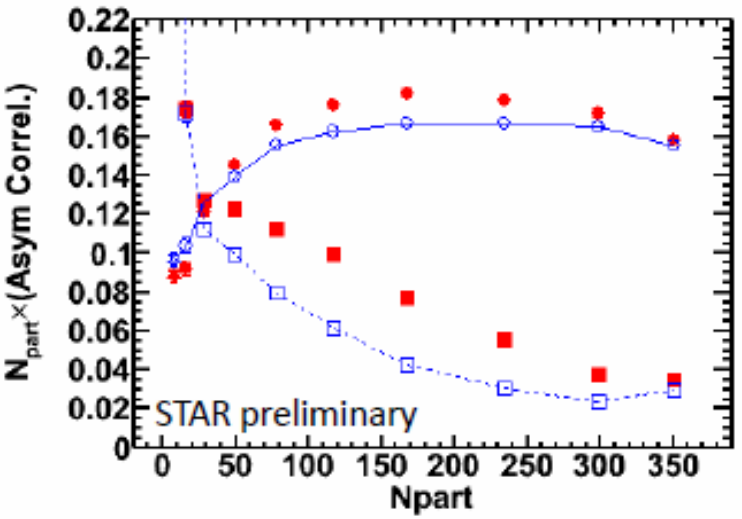
- A_{+UD} and A_{-UD} are anti-correlated
  → $\langle A_+A_-\rangle_{UD} < \langle A_+A_-\rangle_{LR}$
- Additional dynamical fluctuation broadens $A_{\pm UD}$ distributions
  → $\langle A_\pm^2\rangle_{UD} > \langle A_\pm^2\rangle_{LR}$

$$(A_{ud}^{+})^2 = \frac{(N_u^+ - N_d^+)^2}{(N_u^+ + N_d^+)^2}$$

$$(A_{ud}^{-})^2 = \frac{(N_u^- - N_d^-)^2}{(N_u^- + N_d^-)^2}$$

$$A_{ud}^{+/-} = \frac{(N_u^+ - N_d^+)(N_u^- - N_d^-)}{(N_u^+ + N_d^+)(N_u^- + N_d^-)}$$





From Quan Wang, Presentation at APS Meeting

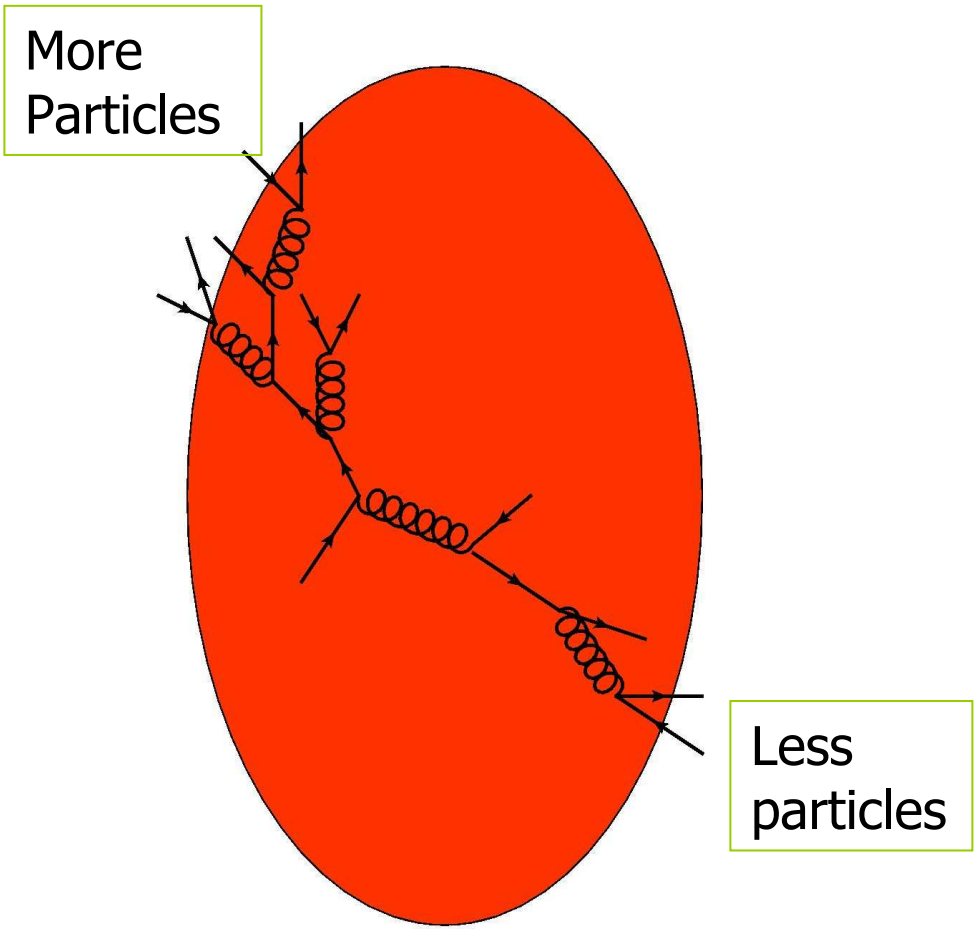
→ Finite correlation on the order of $1x10^{-3}$, UD > LR

Medium-Modified Jets

- Energy loss of a high energetic parton might lead to an asymmetry in the particle production
- The out-of-plane direction should be more modified because of longer average pathlength

→ leads to the correct up-down/left-right asymmetry

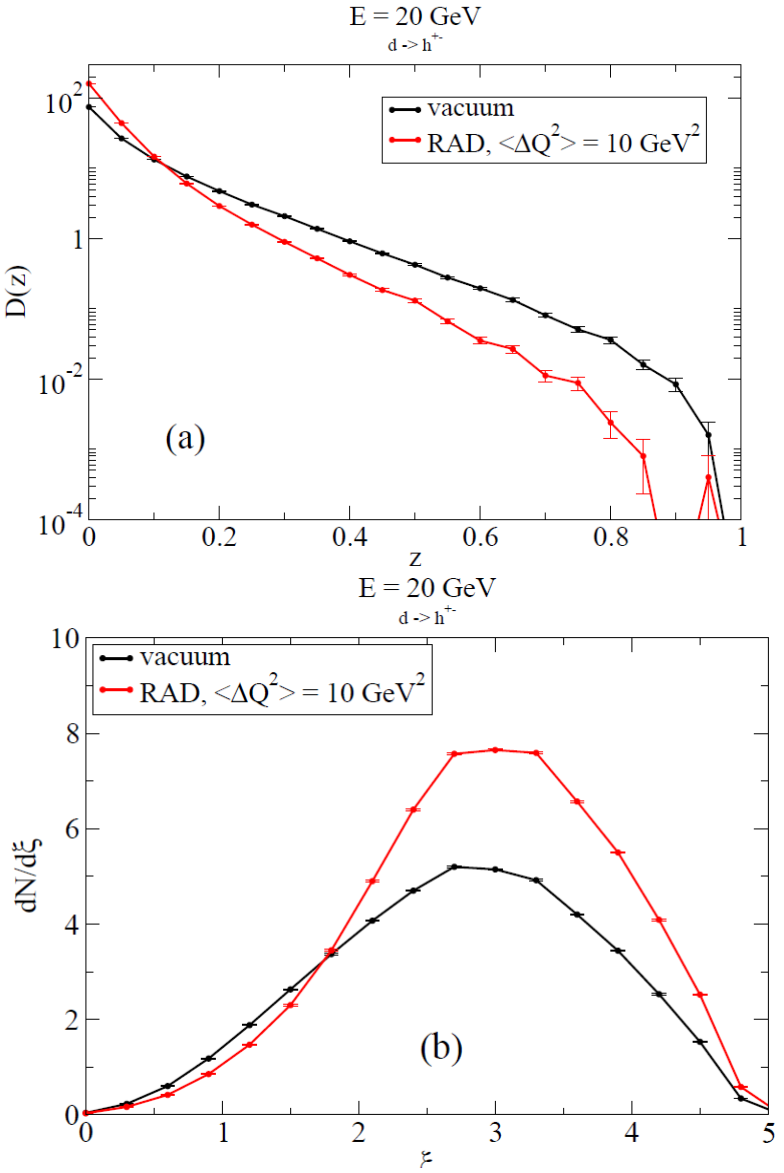
- Idea: Add jet events from YaJEM to UrQMD background



Model Overview

- YaJEM: Yet another Jet Energy-Loss Model
- Based on Pythia shower routine
- Event generator of medium-modified jets
- Here: 'RAD' scenario is applied
  - Initial parton acquires virtuality from the medium which leads to more branching
- Medium properties are taken from 3+1d Hydro (Nonaka/Bass)
- Background is simulated by hadronic transport approach (UrQMD)

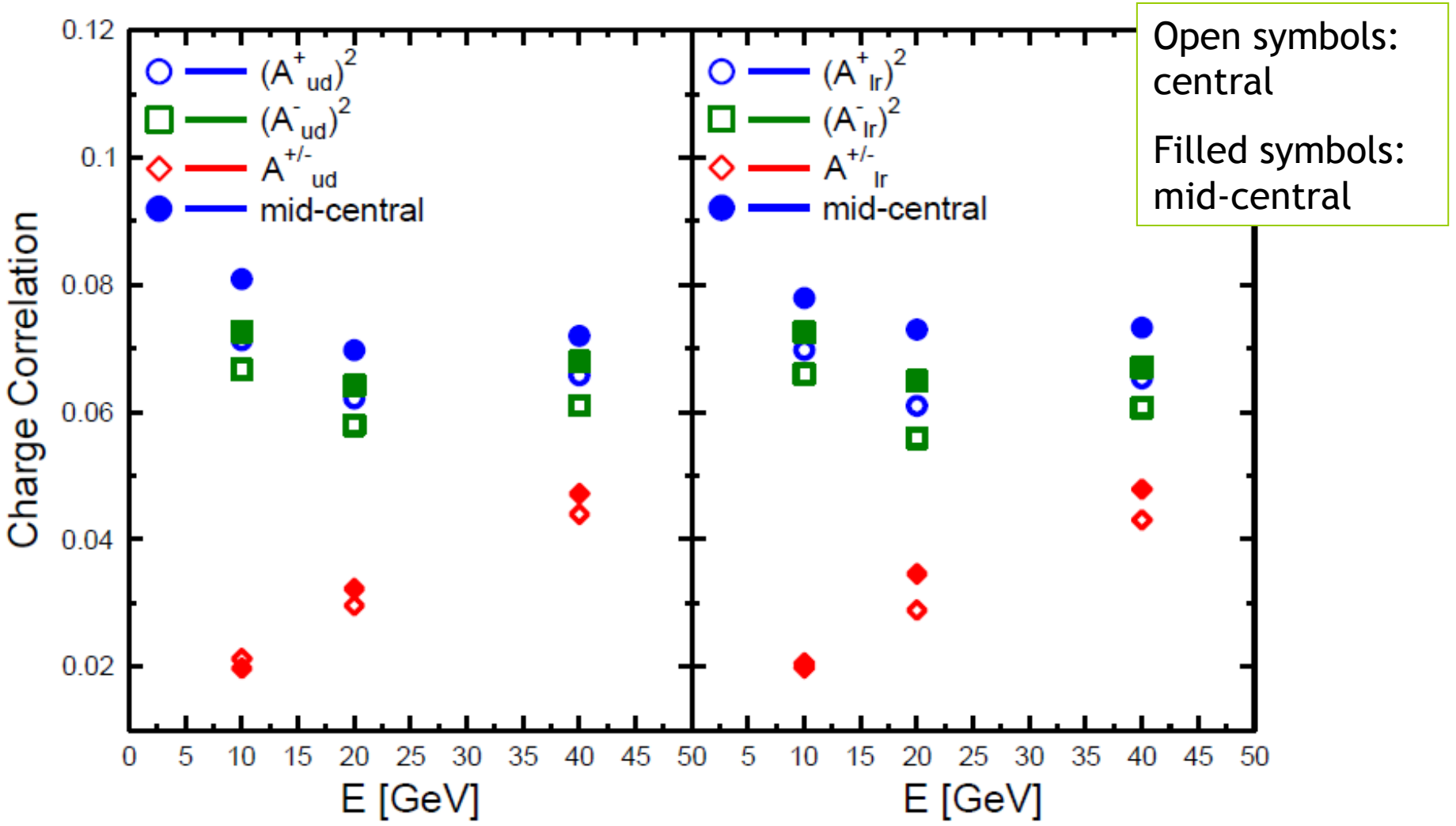
T. Renk, Phys.Rev.C78:034908,2008



Jet Sampling

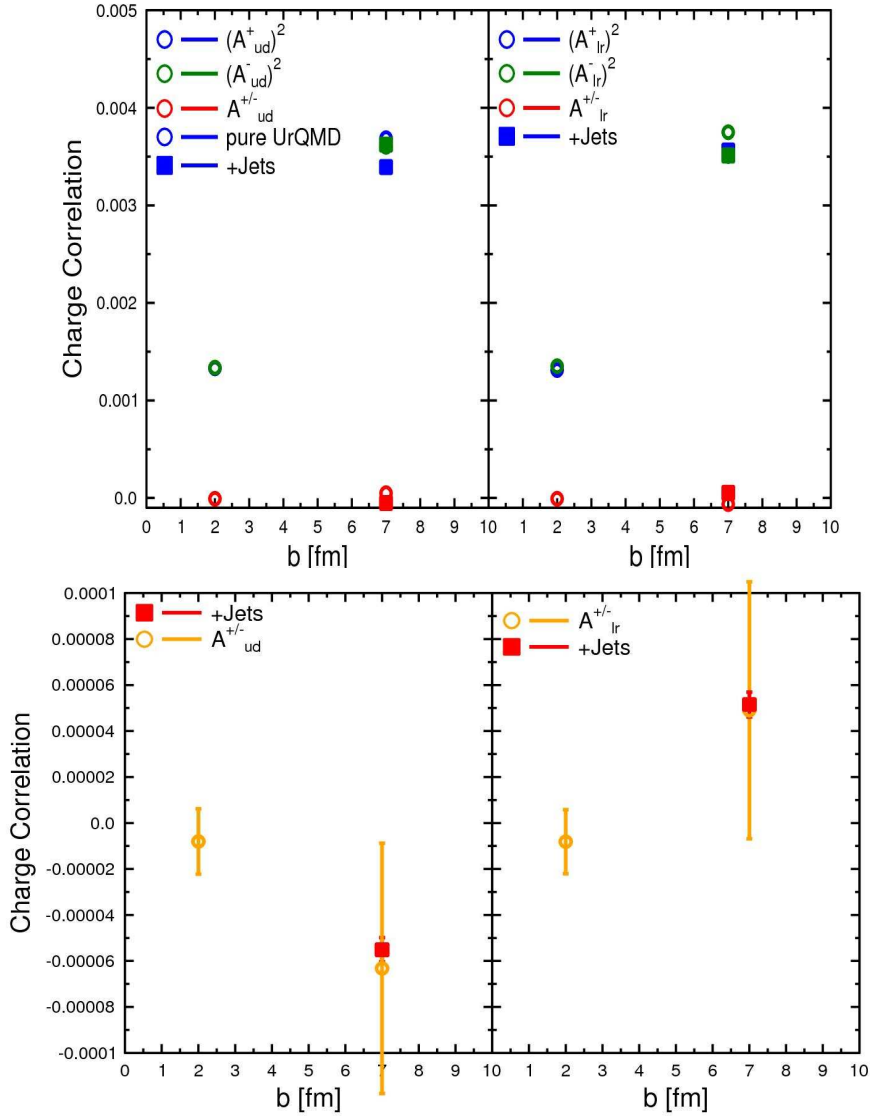
- Vertex position according to Glauber binary collision profile
- Arbitrary azimuthal angle ϕ between 0 and 2π
- Distribution of outgoing g-g/g-q/q-q events is taken into account
- Jet samples for three different initial parton energies: 10, 20 and 40 GeV
- Add event-by-event to UrQMD background with correct jet production probability extracted from PYTHIA

Coefficients for Jets only



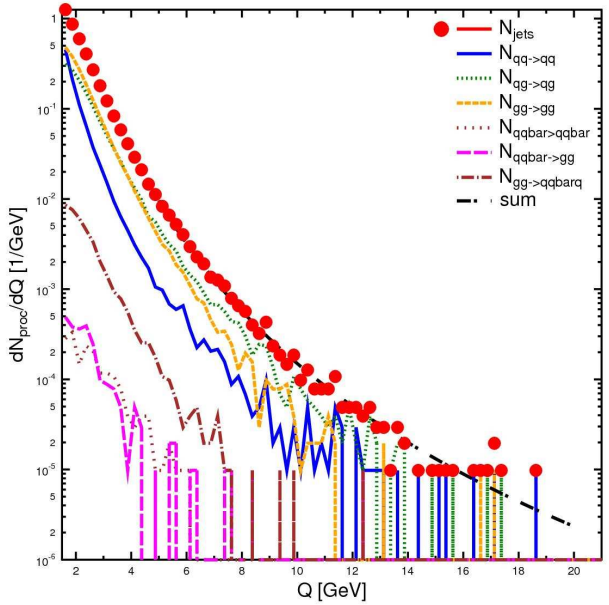
→ Finite resulting asymmetry is visible

Full Result



- UrQMD background shows no asymmetries

→ Lack of coordinate-momentum-space correlation



→ Jet production probabilities are too small to observe an effect

Initial State Fluctuations

- Space-momentum correlation in hydrodynamic evolution
- Initial 'Hot Spots' might introduce asymmetries in the charged particle production
- Elliptic flow and momentum conservation

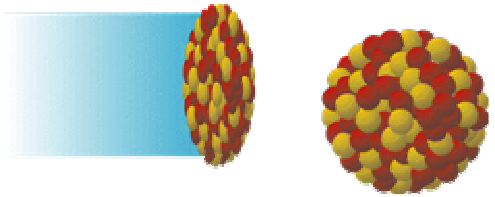
→ Hybrid approach takes that into account

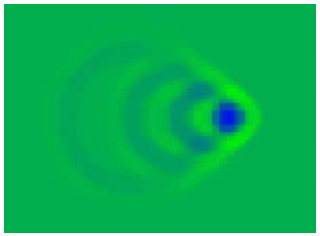
  - No strict local charge conservation due to sampling at Cooper-Frye transition

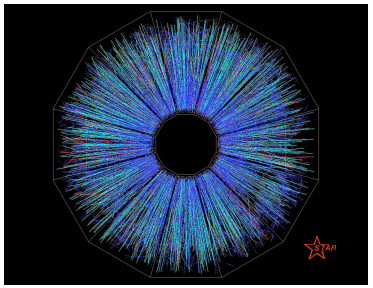
H.P. et al, PRC 78:044901,2008

The Hybrid Approach

- Full event-by-event setup with fluctuating initial conditions
- Restricted to midrapidity ($|y|<2$) observables at E_{CM}=200 AGeV
- Starting time has been chosen as t_{start}=0.5 fm/c







1) Non-equilibrium initial conditions via UrQMD

2) Hydrodynamic evolution

3) Freeze-out via hadronic cascade (UrQMD)

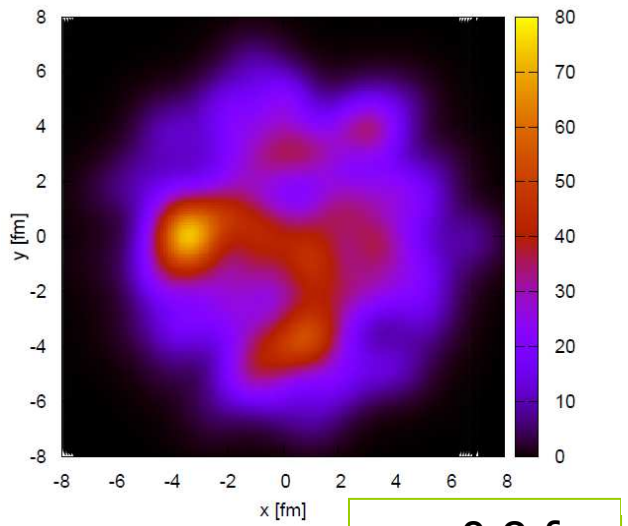
UrQMD-3.3p1 is available at http://urqmd.org

Initial State

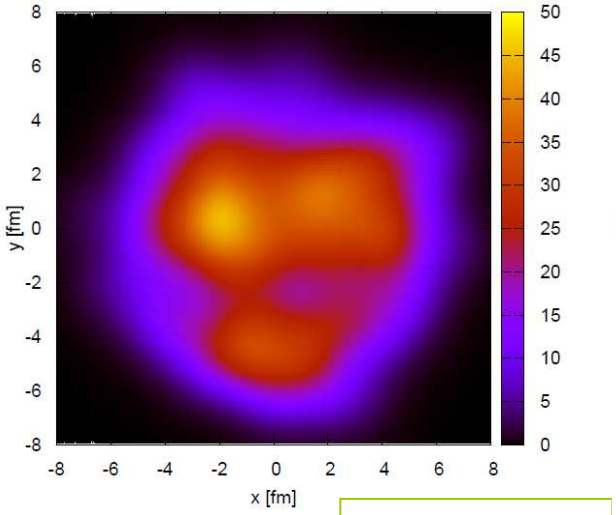
- Energy-, momentum- and baryon number densities are mapped onto the hydro grid using for each particle

$$\epsilon_{\rm cf}(x,y,z) = N \exp -\frac{(x-x_p)^2 + (y-y_p)^2 + (\gamma_z(z-z_p))^2}{2\sigma^2}$$

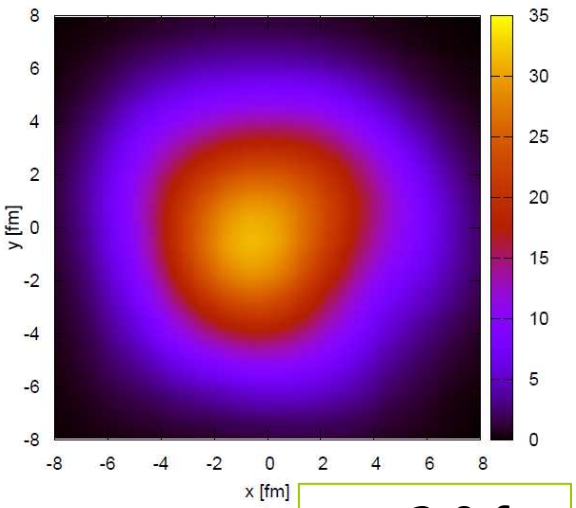
- **Event-by-event fluctuations** are taken into account
- Spectators are propagated separately in the cascade



σ = 0.8 fm



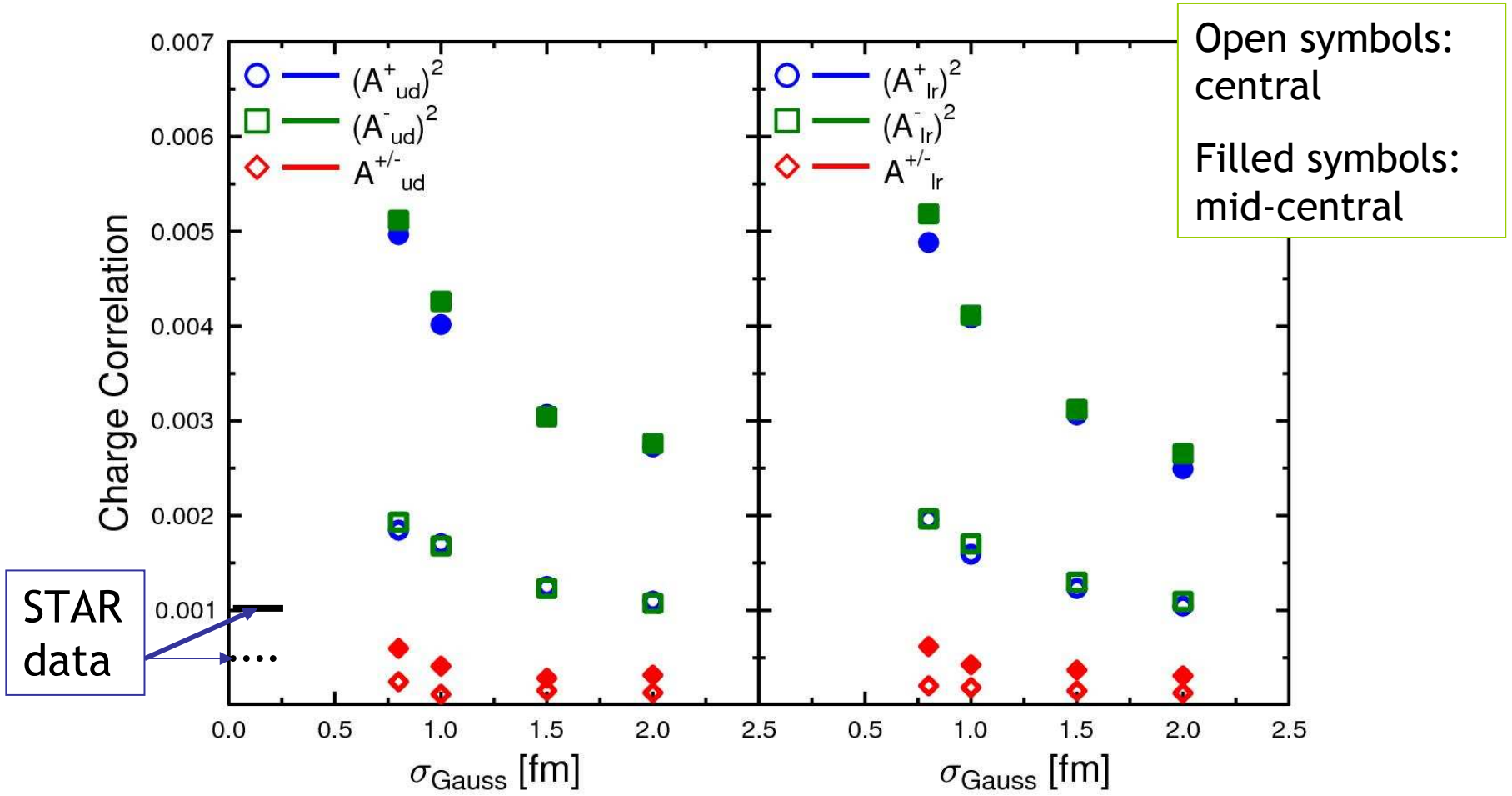
σ = 1.0 fm



σ = 2.0 fm

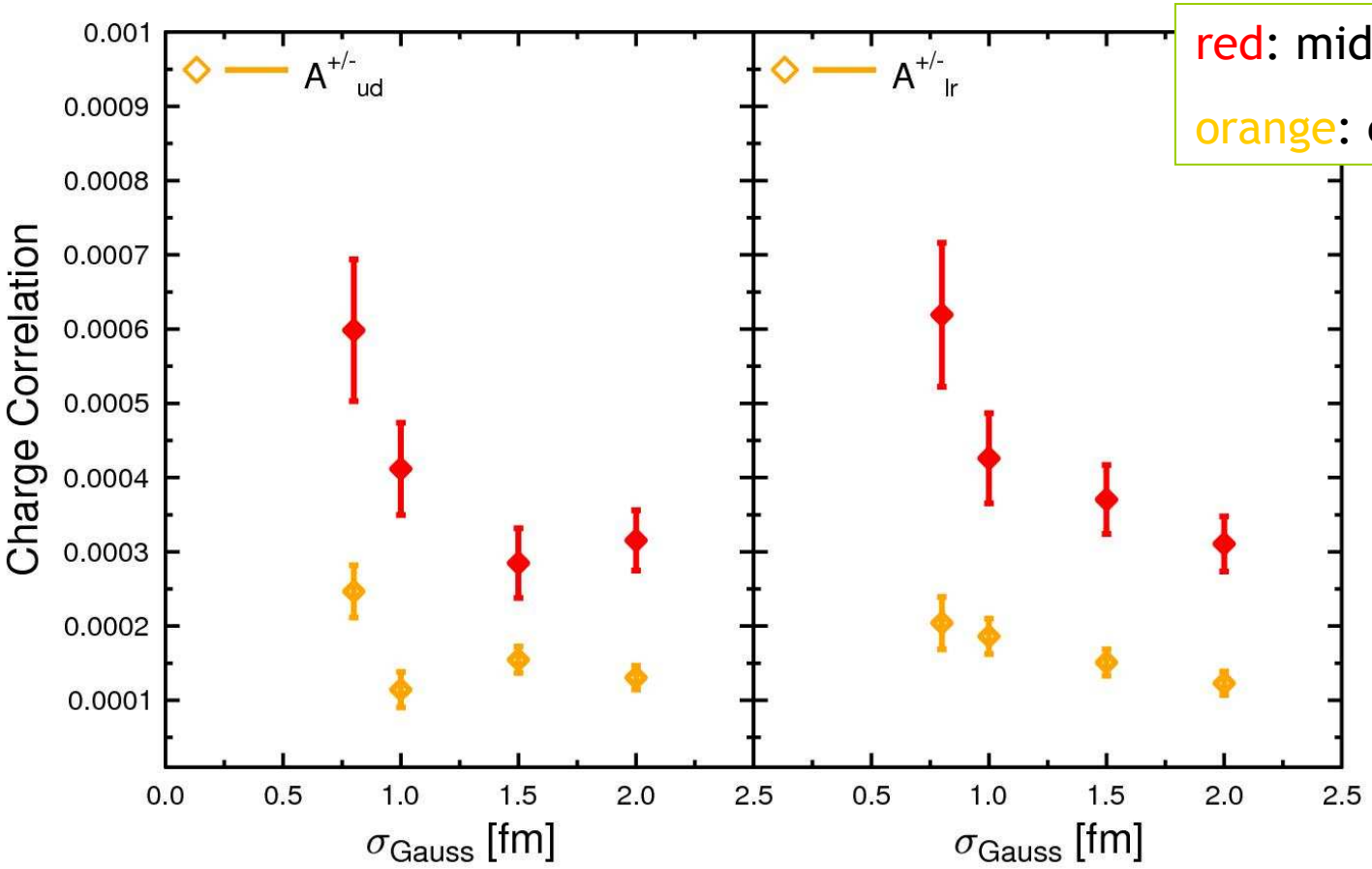
(J.Steinheimer et al., PRC 77,034901,2008)

Charged Particle Asymmetry



- Asymmetries are larger for mid-central collisions
- More granularity of initial state leads to higher correlation

Opposite Charge Correlation



→ Positively and negatively charged particles are preferably emitted in the same hemisphere

Conclusions

- Medium-modified jets are excluded as a source of the measured charged particle asymmetry
  - Detailed modeling shows that production probabilities are too small to observe the effect
- Initial state fluctuations and a hydrodynamic evolution that generates coordinate-momentum space correlations due to flow leads to results on the order of the experimental data
  - Possibility to explore initial state granularity?

→ These effects should be taken into account when looking at chiral magnetic effect