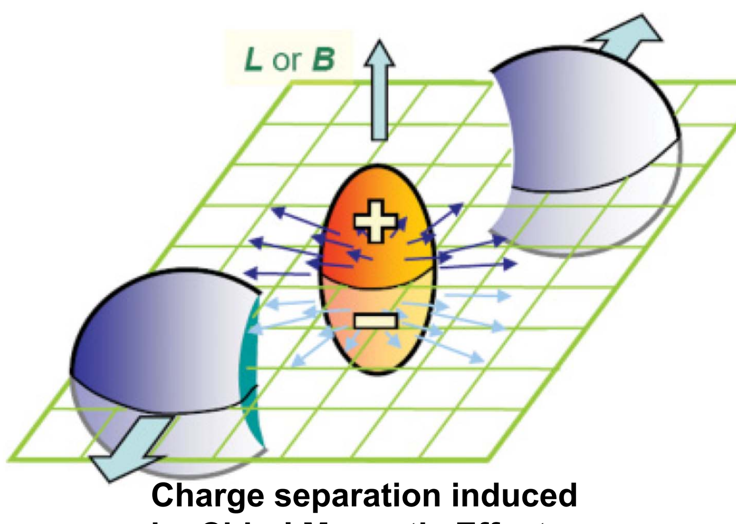
Effects of final state interactions on charge separation in relativistic heavy ion collisions

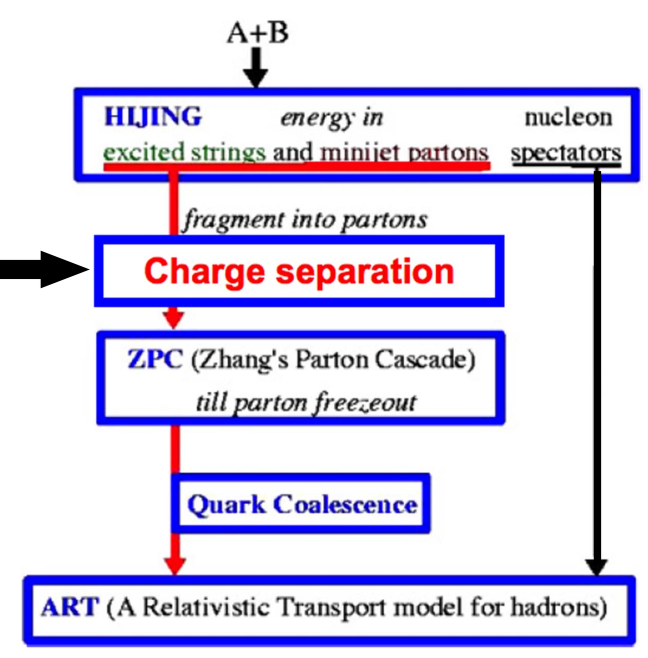
Guo-Liang Ma[1] and Bin Zhang[2]
[1]Shanghai Institute of Applied Physics, Shanghai, 201800, China
[2]Department of Chemistry and Physics, Arkansas State University, AR 72467-0419, USA

Abstract: Charge separation is an important consequence of the Chiral Magnetic Effect. Within the framework of a Multi-Phase Transport model, the effects of final state interactions on initial charge separation are studied. We demonstrate that charge separation can be significantly reduced by the evolution of the Quark-Gluon Plasma produced in relativistic heavy ion collisions. Hadronization and resonance decay can also affect charge separation. Moreover, our results show that the Chiral Magnetic Effect leads to the modification of the relation between the charge azimuthal correlation and the elliptic flow that is expected from transverse momentum conservation only. The transverse momentum and pseudorapidity dependences and the effects of background on the charge azimuthal correlation are also discussed.

(1) Introduction



Charge separation induced by Chiral Magnetic Effect



- The experimental results on charge separation are consistent with Chiral Magnetic Effect expectations.
- The AMPT model is a dynamical transport model that includes four different stages: initial condition, parton cascade, hadronization, hadron rescatterings.
- The Chiral Magnetic Effect is not built into the AMPT model. In order to separate a fraction of the charges initially, we switch the p_y values of a fraction of the downward moving u quarks with those of the upward moving u-bar quarks, and likewise for d-bar and d quarks.
- Resonance decays are implemented to ensure charge conservation and are included for the study of charge correlations.

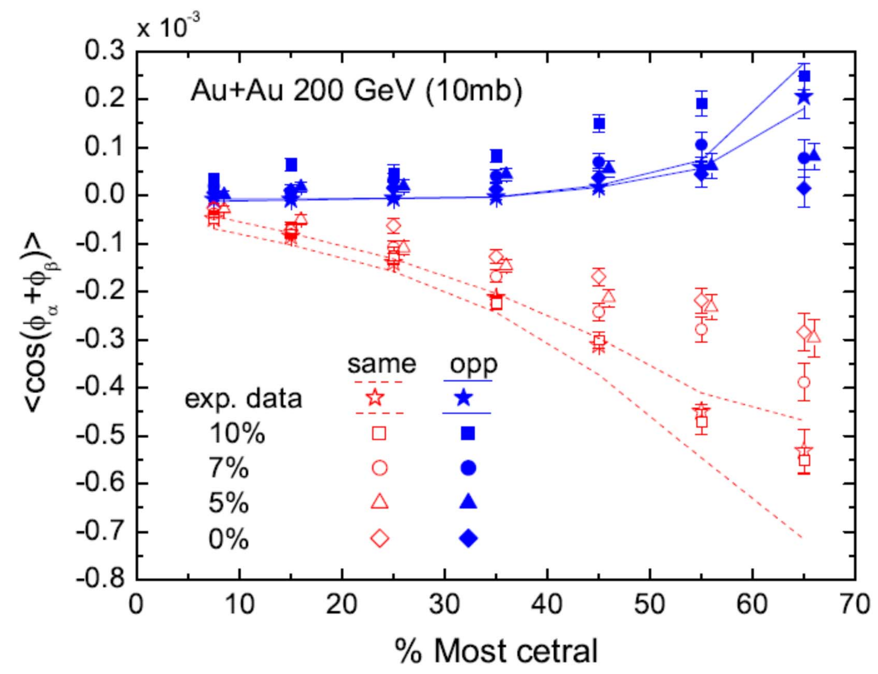
(2) Charge separation observables

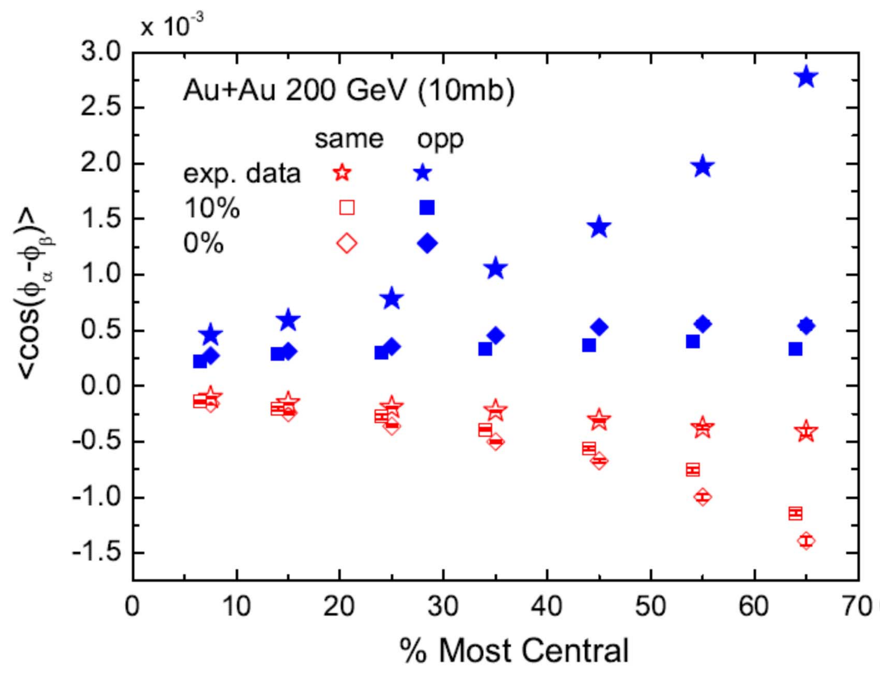
For $\langle\cos(\varphi_\alpha+\varphi_\beta)\rangle$:

- For same-charge, a percentage of 10% for initial charge separation can describe data well.
- For opposite-charge, it seems that initial charge separation is not necessary for all centralities except 60-70%.
- An initial charge separation of 10% can describe both the same-charge and opposite charge for 60%-70%.
- It might be challenging to observe an initial charge separation of 5% or less in the presence of strong final state interactions.

For $\langle\cos(\varphi_\alpha-\varphi_\beta)\rangle$:

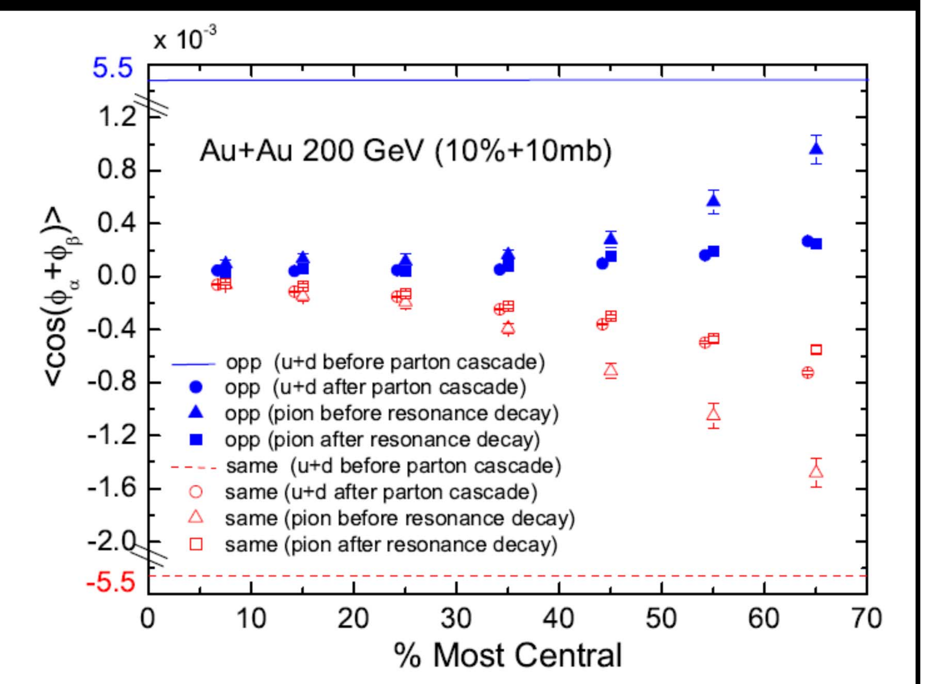
- The charge separation is not enough to make up for the large difference between the AMPT results and the experimental data, though the AMPT model gives the same trends as data.

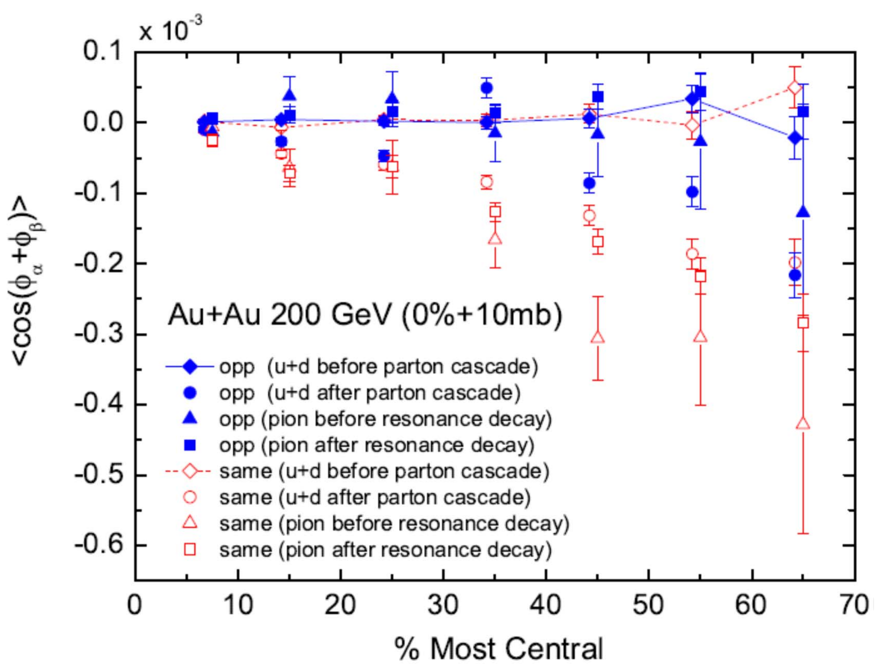




(3) Final state effects on charge separation

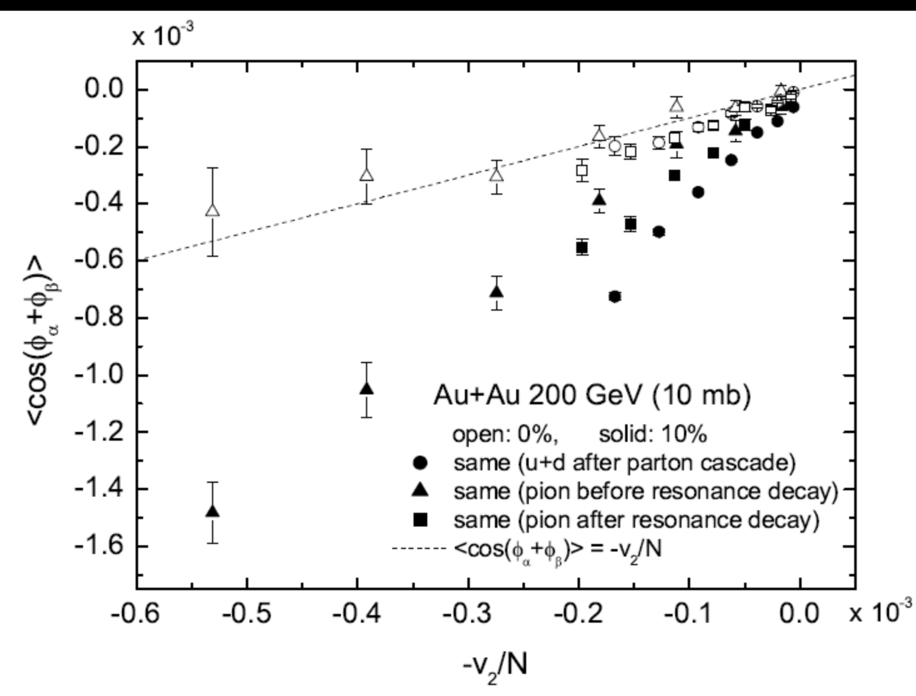
- With an initial percentage of 10% charge separation, the initial charge correlations are quite large.
- After strong parton cascade, charge correlations are significantly reduced especially for central collisions.
- The charge correlations are recovered partly from hadronization as coalescence reduces the number of particles while combining quarks into hadrons.
- Resonance decays reduce charge correlations in the hadronic phase.
- From a percentage of charge separation of 10% in the beginning, only 1-2% percentage remains at the end with more peripheral collisions having larger percentages.
- As a comparison, the charge correlations at different stages with no initial charge separation are shown for different centrality bins. The same-charge correlations are consistent with transverse momentum conservation expectations.

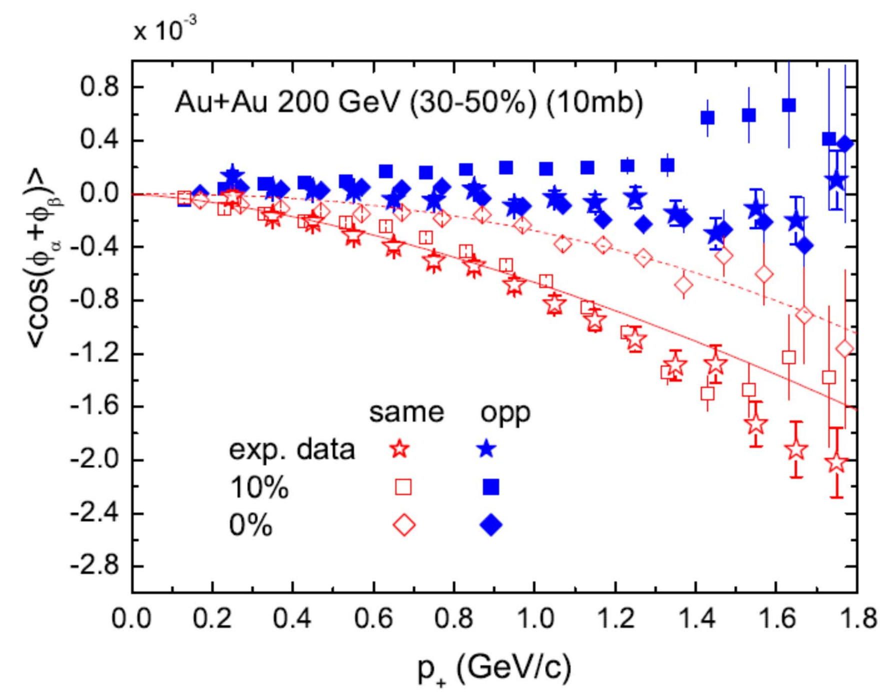




(4) Charge separation and trans. mom. cons.

- Recently, Bzdak et al. found that transverse momentum conservation can contribute to the charge correlations with magnitudes comparable to experimentally observed correlations.
- The AMPT results without initial charge separation are consistent with the expectation that $\langle\cos(\varphi_\alpha+\varphi_\beta)\rangle=-v_2/N$.
- The AMPT results with initial charge separation are much lower than the expected relation.
- Since the AMPT results with 10% initial charge separation can describe the same-charge correlation data, transverse momentum conservation can only partly account for the measured charge correlation data.
- The AMPT results without initial charge separation are consistent with the expectation from transverse momentum conservation, i.e. $\langle\cos(\varphi_\alpha+\varphi_\beta)\rangle \propto p_t^n$ (n=2 to 3). The power n deceases from 2.24 ± 0.27 to 1.54 ± 0.18 when 10% initial charge separation is included.





(5) Conclusions

In conclusion, final state interactions play an important role on charge separation in relativistic heavy-ion collisions. Parton cascade and resonance decay significantly reduce the charge separation from 10% in the initial state to 1-2% in the final state. Therefore, it is essential to take these final state effects into account for studies related to charge separation. Our results also suggest that mechanisms beyond transverse momentum conservation will be needed even for the description of the same-charge correlation. Other possible mechanisms certainly deserve further study for a satisfactory understanding of experimental data.

Acknowledgements:

We thank A. Bzdak, C.M. Ko, V. Koch, J. Liao, Y.G. Ma, F. Wang for helpful discussions and the U.S. National Energy Research Scientific Computing Center for providing computing resources. This work was supported by the NSFC of China, the Knowledge Innovation Project of Chinese Academy of Sciences (G.L.M.), and by the U.S. National Science Foundation (B.Z.).

Reference:

Guo-Liang Ma, Bin Zhang, arXiv:1101.1701 (doi:10.1016/j.physletb.2011.04.057).