Flow in small systems from parton scatterings

Guo-Liang Ma

Shanghai Institute of Applied Physics,
Chinese Academy of Sciences

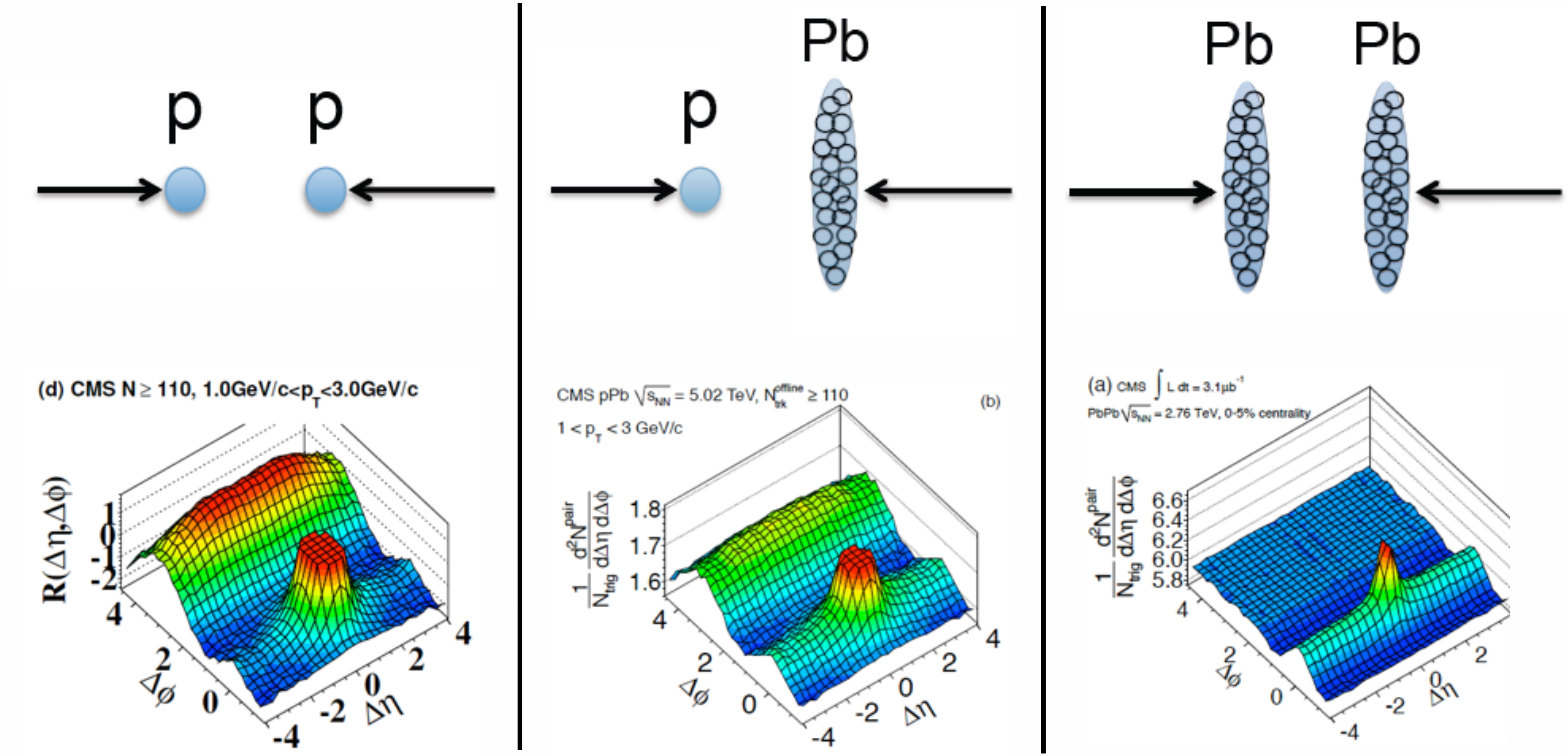
This work is in collaboration with Adam Bzdak(AGH).

[1] G.-L. Ma and A. Bzdak, Phys. Lett. B 739, 209 (2014) [arXiv:1404.4129].
[2] A. Bzdak and G.-L. Ma, Phys. Rev. Lett., 113, 252301 (2014) [1406.2804].
[3] G.-L. Ma and A. Bzdak, in preparation.

Outline

- **Introduction**
  - Motivation
  - AMPT model
- **Results**
  - Long-range correlation
  - Flow vn
- **Discussion**
  - Escape mechanism

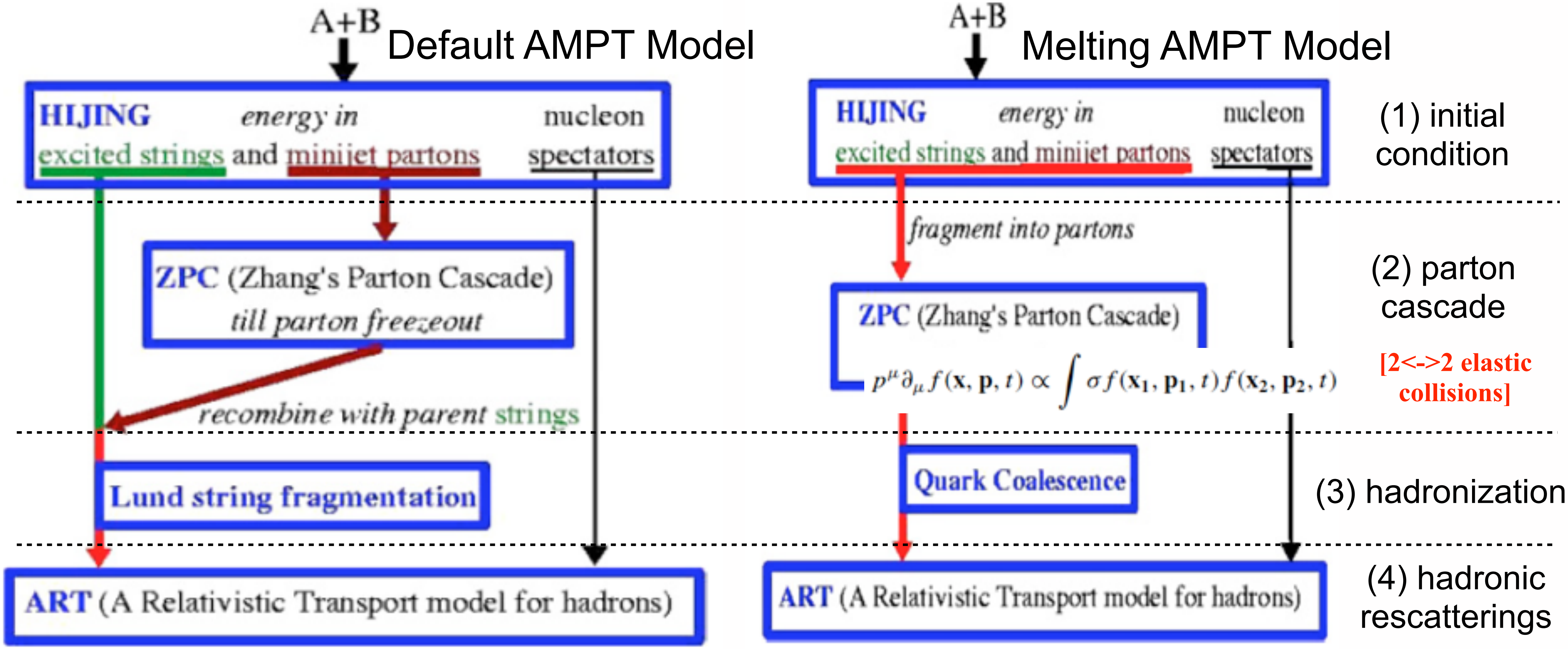
Long-range correlations in p+p, p+Pb, and Pb+Pb

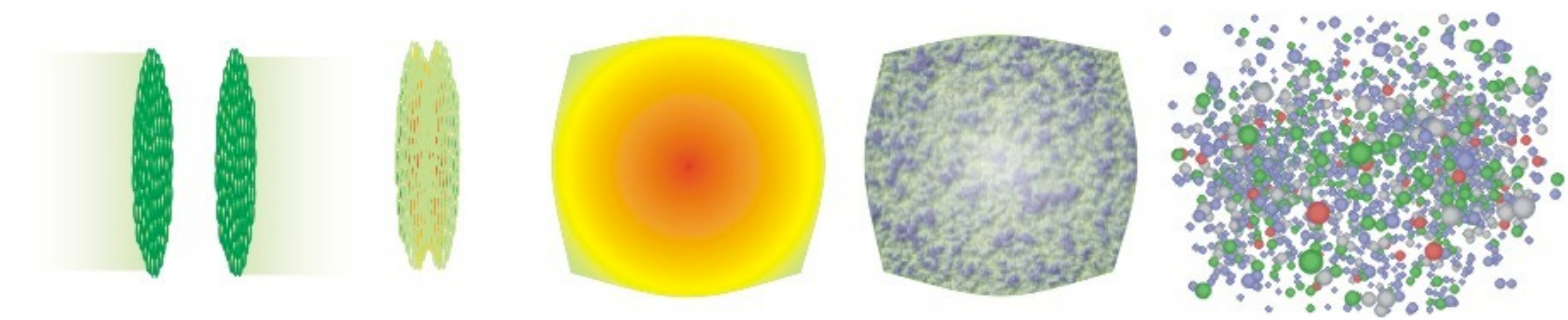


- Are the ‘ridges’ due to the same origin in p+p, p+Pb and Pb+Pb?

…

A multiphase transport (AMPT) model

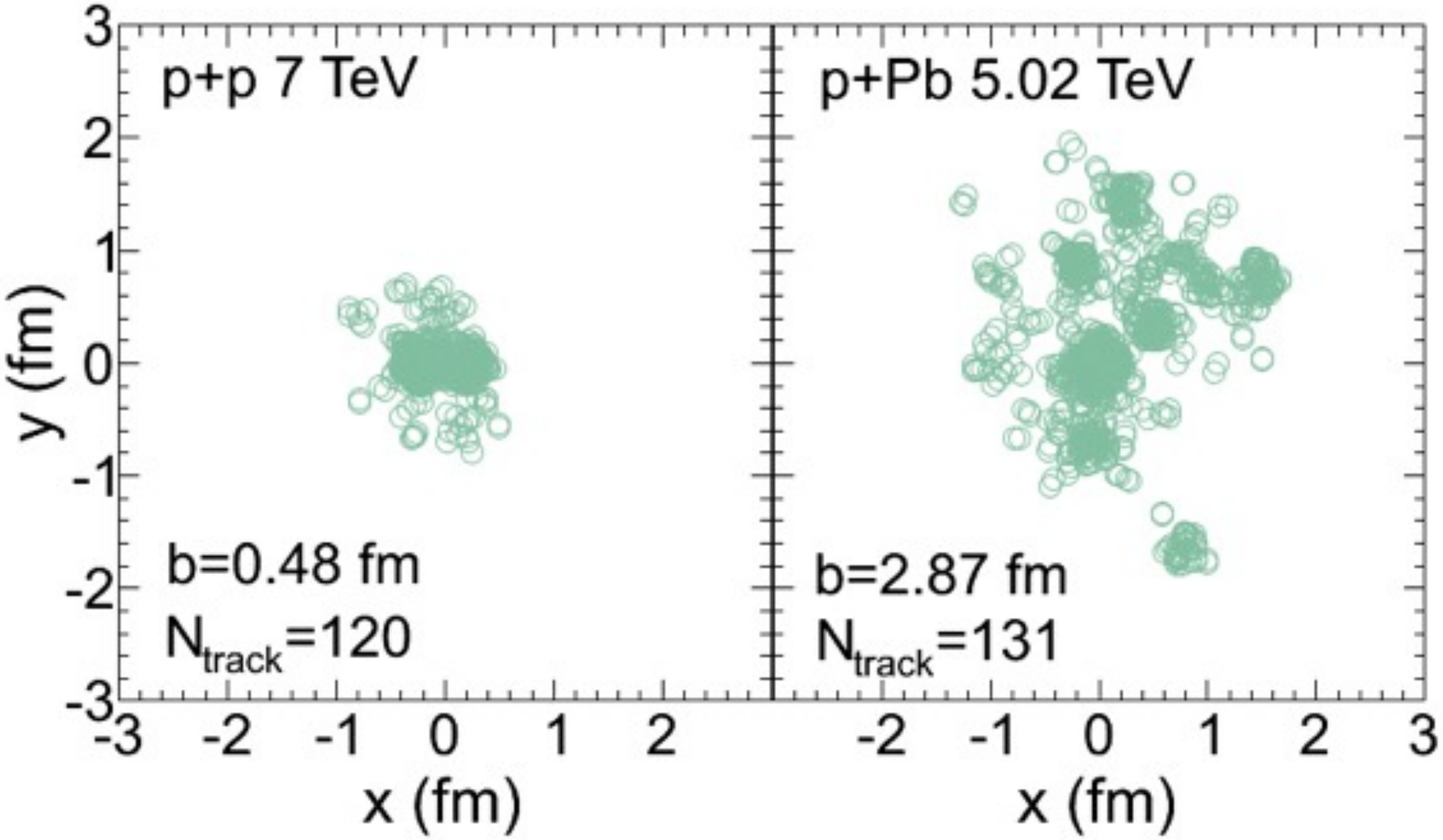


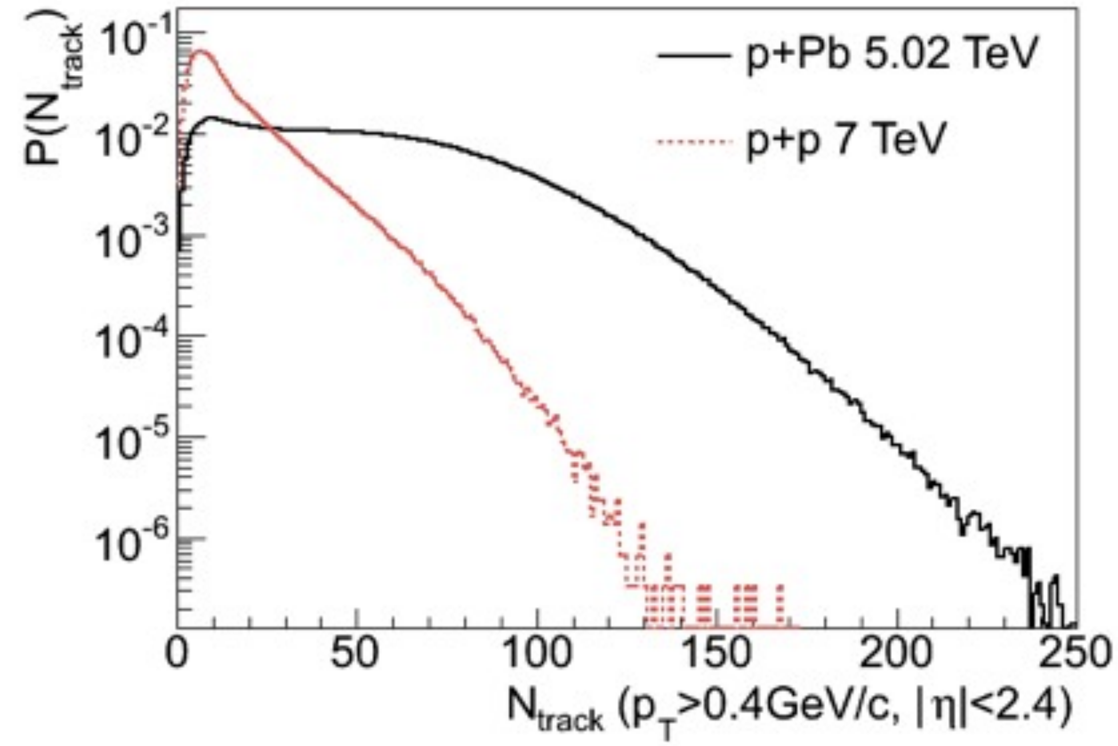


(1) initial condition (2) parton cascade (3) hadronization (4) hadronic rescatterings

p+p and p+Pb in the AMPT model

G.-L. Ma and A. Bzdak, PLB 739, 209 (2014)

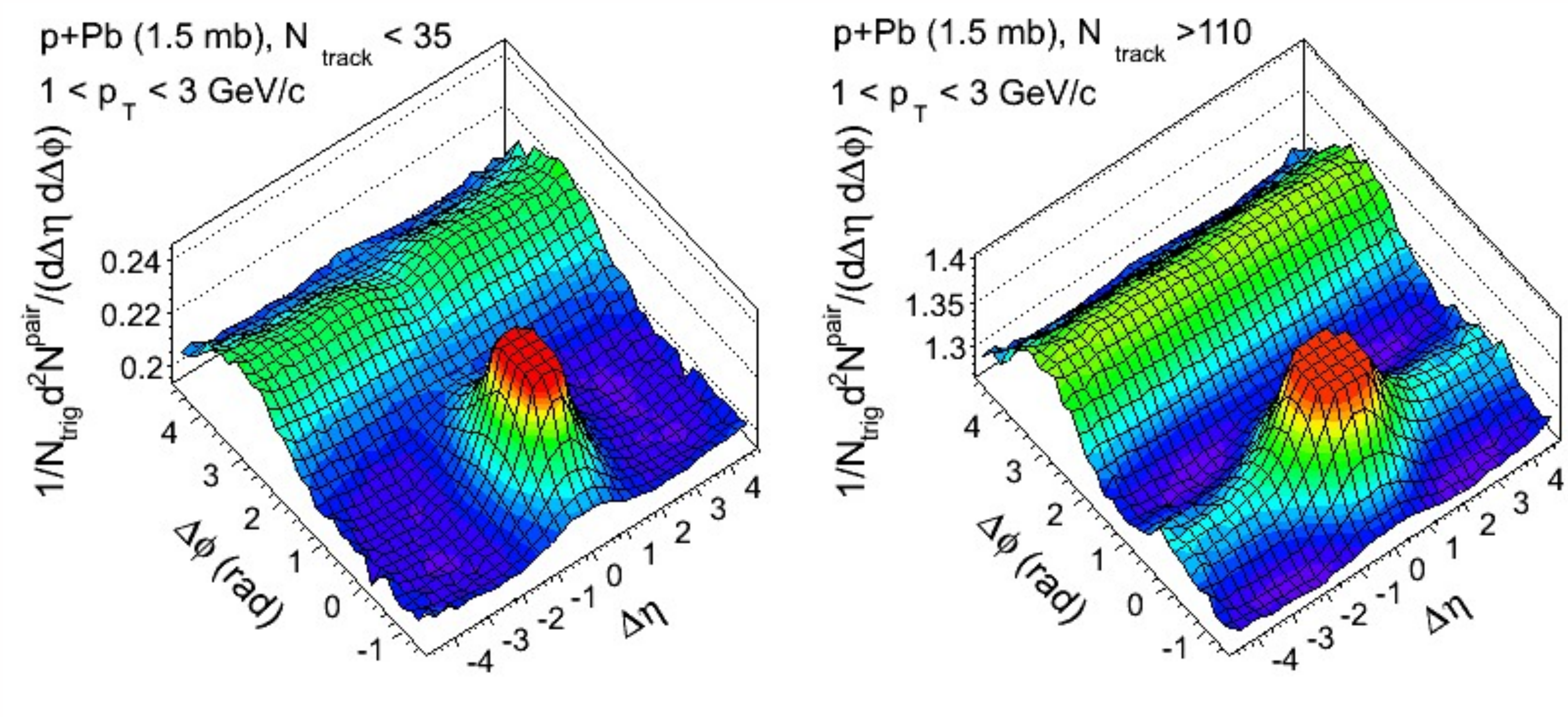




- One hot spot in p+p vs Several hot spots in p+Pb.
- 'Centrality' defined by using N_{track} distributions as the CMS.

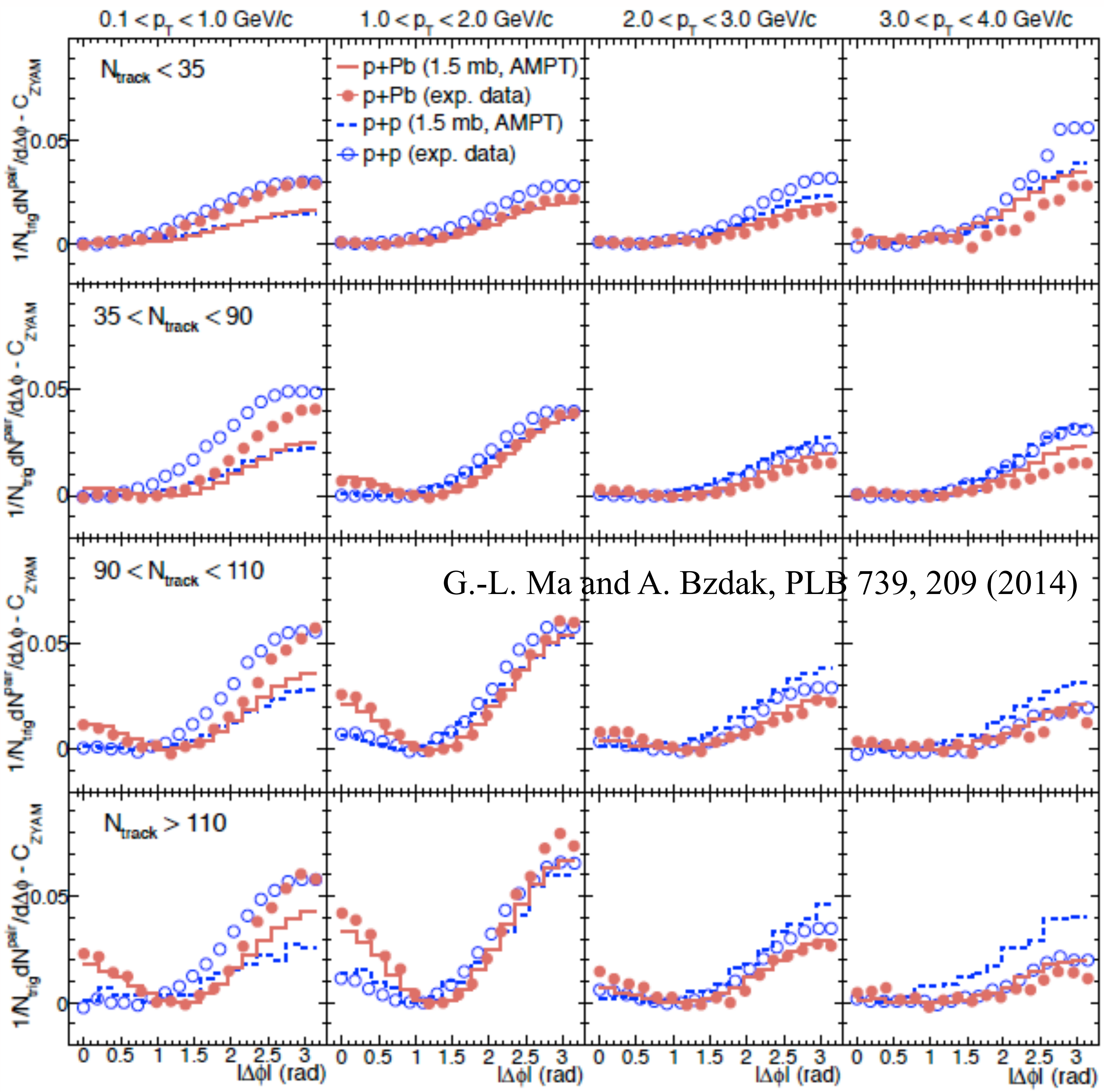
AMPT results on long-range correlations in p+Pb

G.-L. Ma and A. Bzdak, PLB 739, 209 (2014)



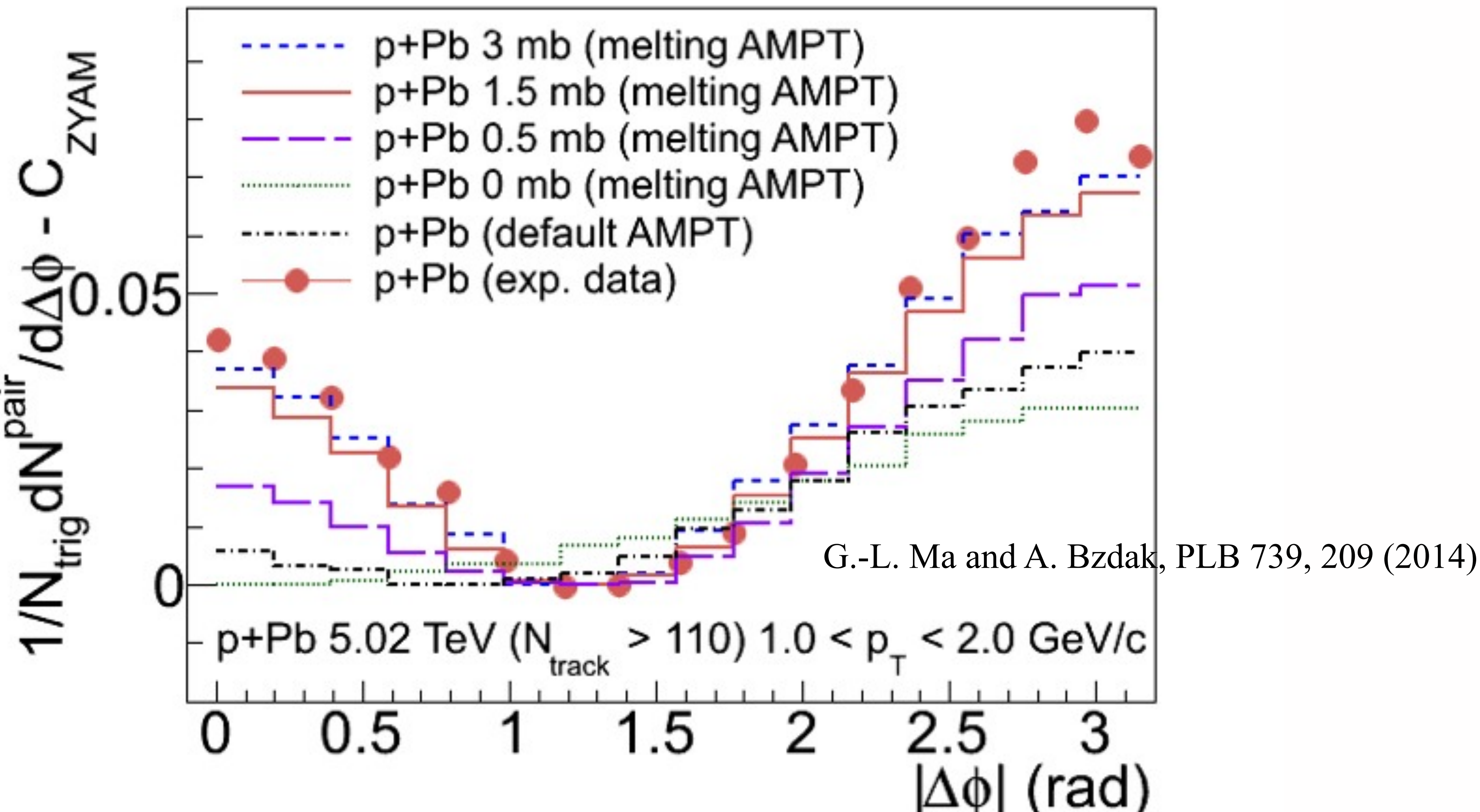
- No long-range correlation in low-multiplicity p+Pb.
- Clear long-range correlation in high-multiplicity p+Pb.

AMPT results on long-range azimuthal correlations in p+p and p+Pb



- The long-range two-particle azimuthal correlations in p+p and p+Pb are well reproduced by AMPT model (1.5mb).
- Long-range correlation ($\Delta\phi$~0) appears in high-multiplicity p+p and p+Pb.
- For signal strength, p+p <p+Pb.

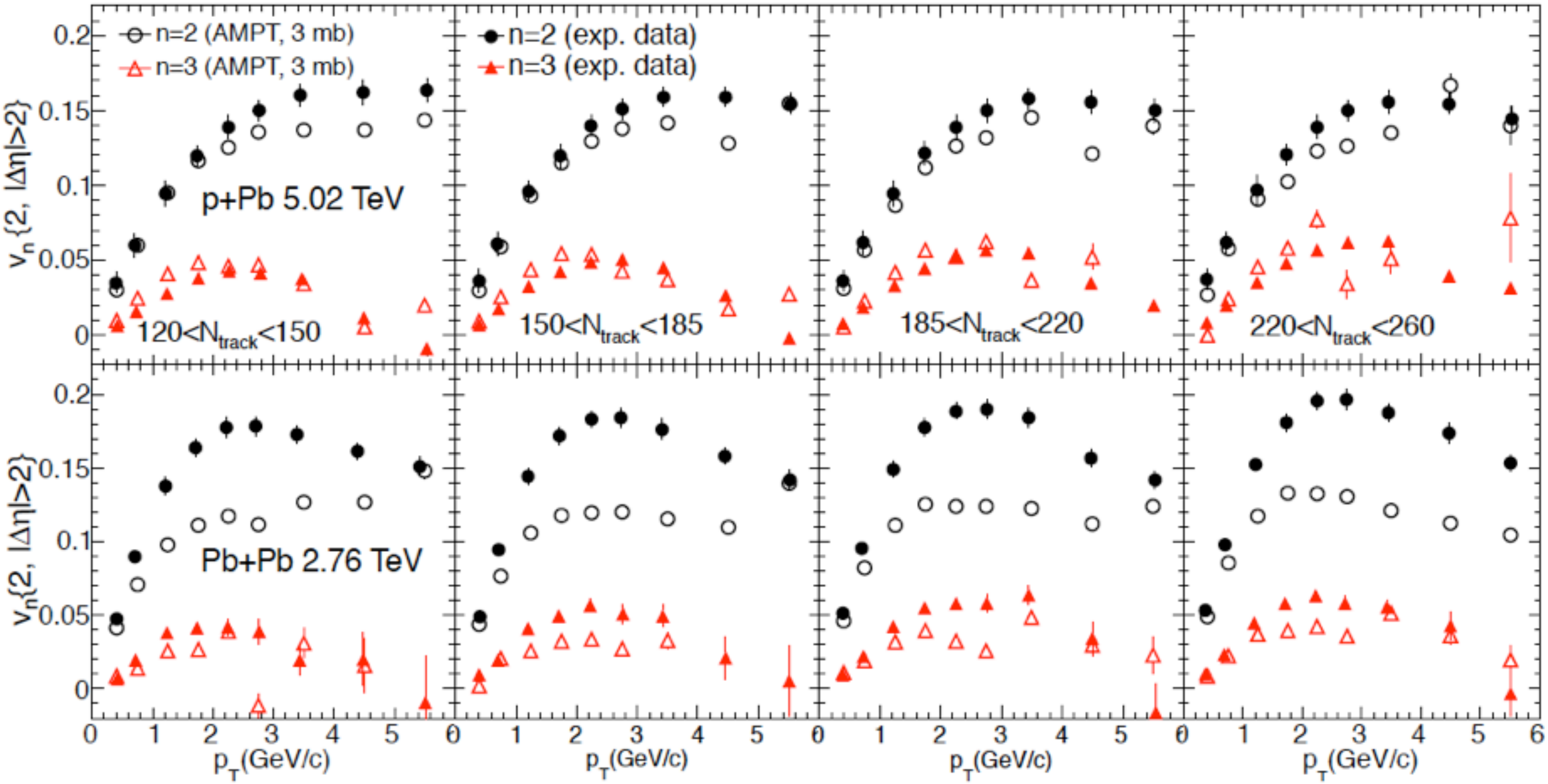
Cross section dependence of long-range correlation in p+Pb



- The two-particle correlations in p+Pb can be well described by σ=1.5-3 mb.
- The strength of the signal gradually increases with growing σ and the signal vanishes completely for σ = 0 mb.
- No visible long-range signal in the default AMPT model.
- Long-range signal comes from parton cascade.

AMPT results on vn(pT) in p+Pb vs Pb+Pb

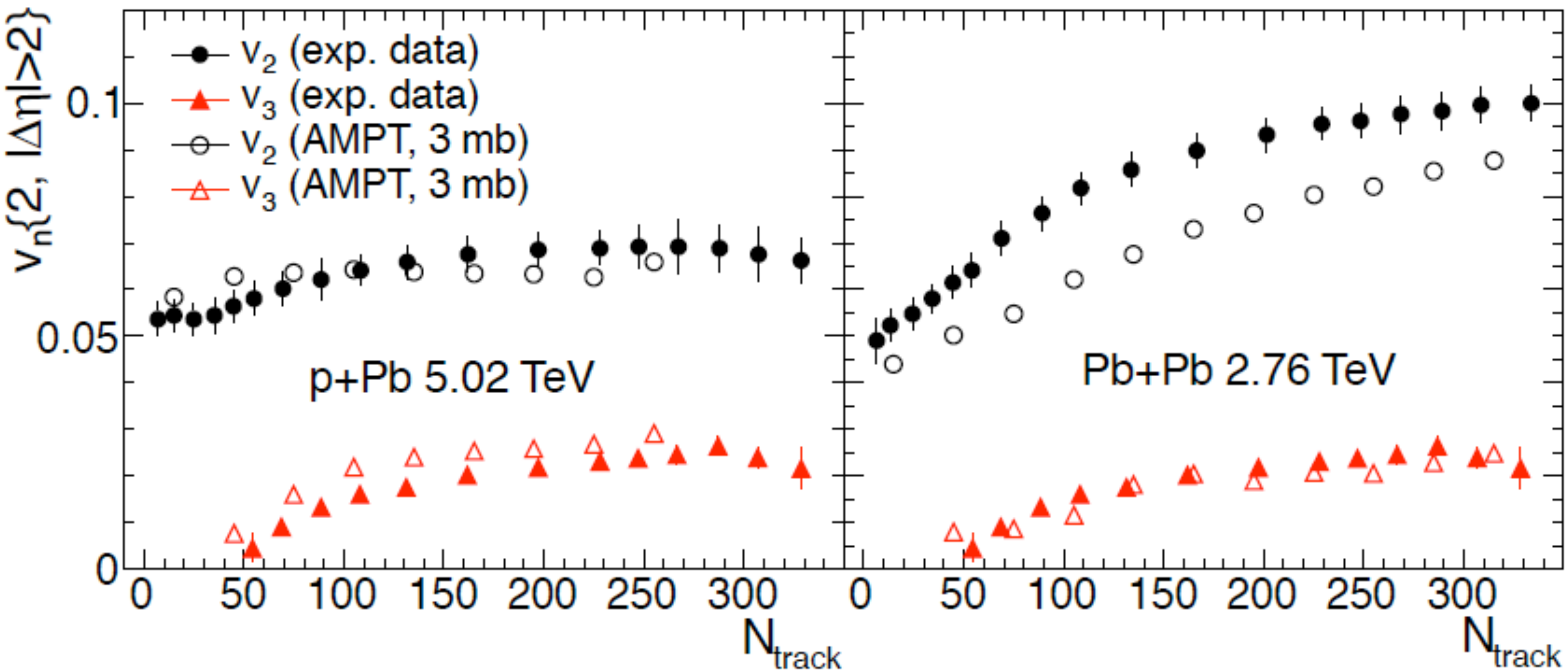
A. Bzdak and G.-L. Ma, PRL 113, 252301 (2014)



- For p+Pb, AMPT (3 mb) reproduces the measured v2 and v3.
- For Pb+Pb, AMPT (3 mb) reproduces the measured v3 for all pT, but underestimates v2 especially for high pT.

AMPT results on integrated vn

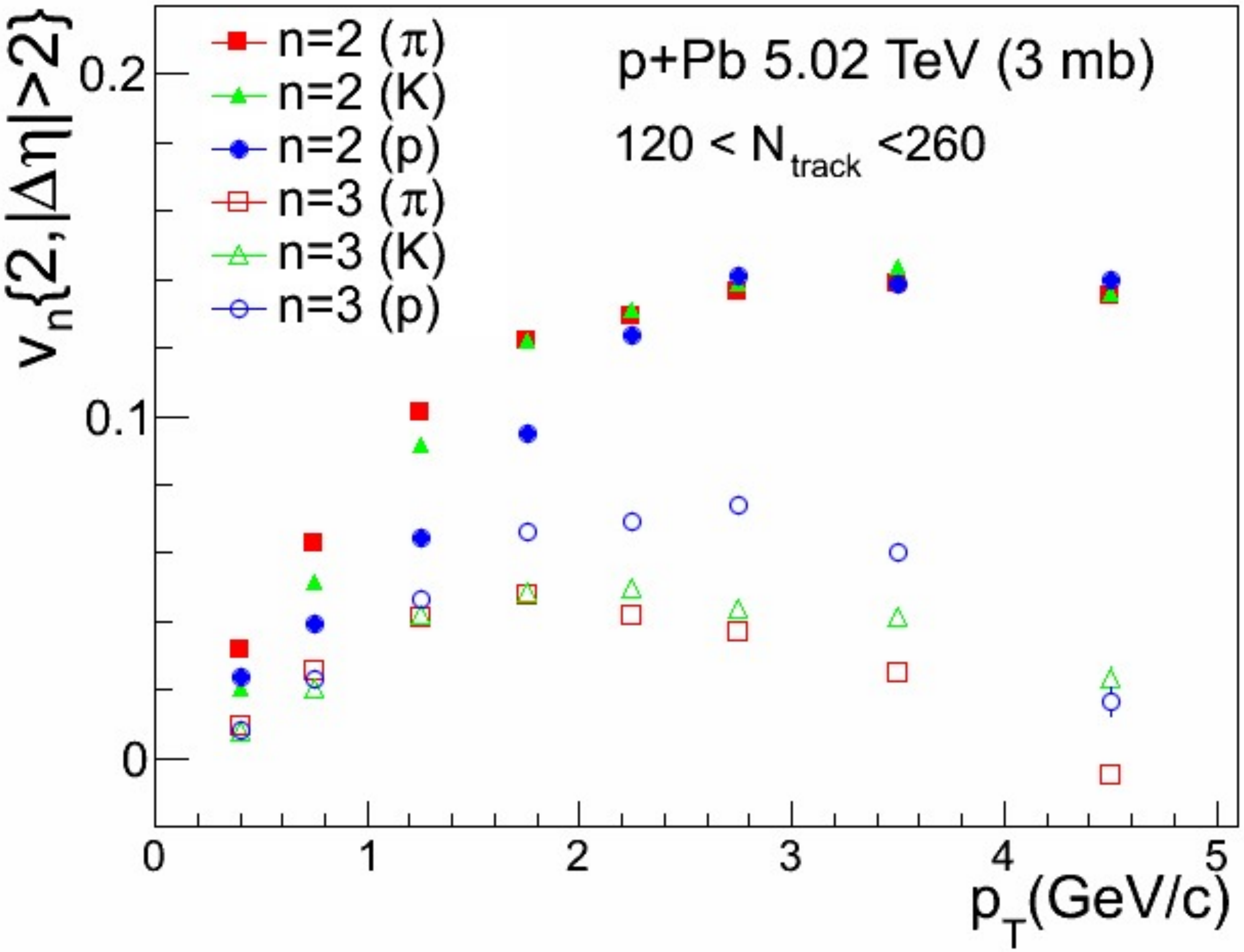
A. Bzdak and G.-L. Ma, PRL 113, 252301 (2014)

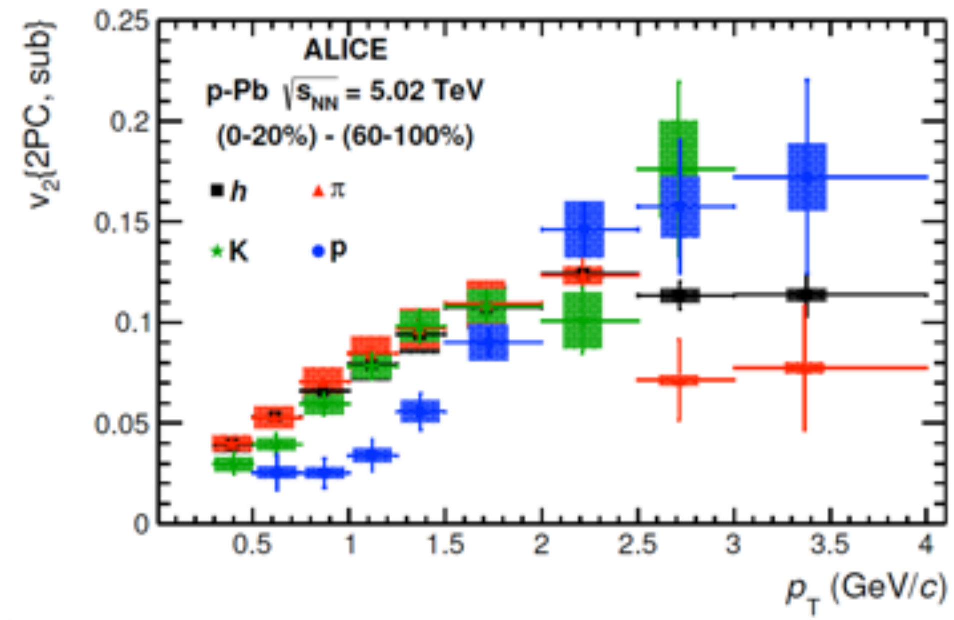


- For p+Pb, AMPT (3 mb) reproduces the integrated v2 and v3.
- For Pb+Pb, AMPT (3 mb) reproduces the integrated v3, but underestimates the integrated v2 by ~20%.
- AMPT (3 mb) shows similar v3 between p+Pb and Pb+Pb.

AMPT results on PID vn

A. Bzdak and G.-L. Ma, PRL 113, 252301 (2014)

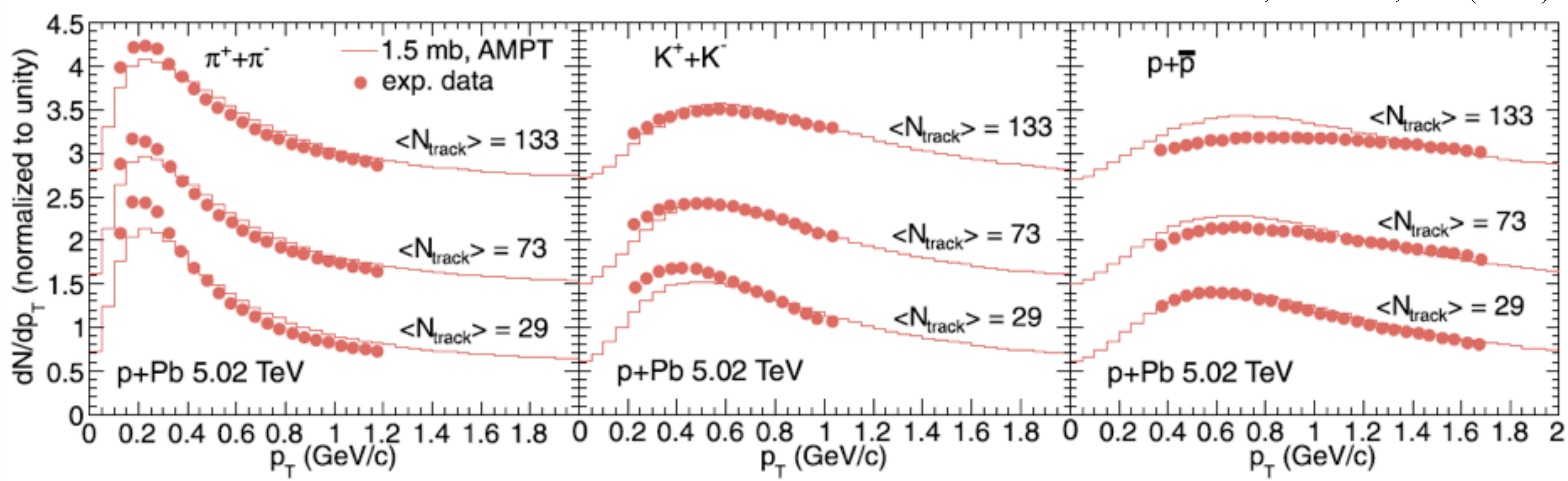




- The mass ordering of v2 is observed in p+Pb, as seen in data.
- No such a mass ordering of v3 in p+Pb.

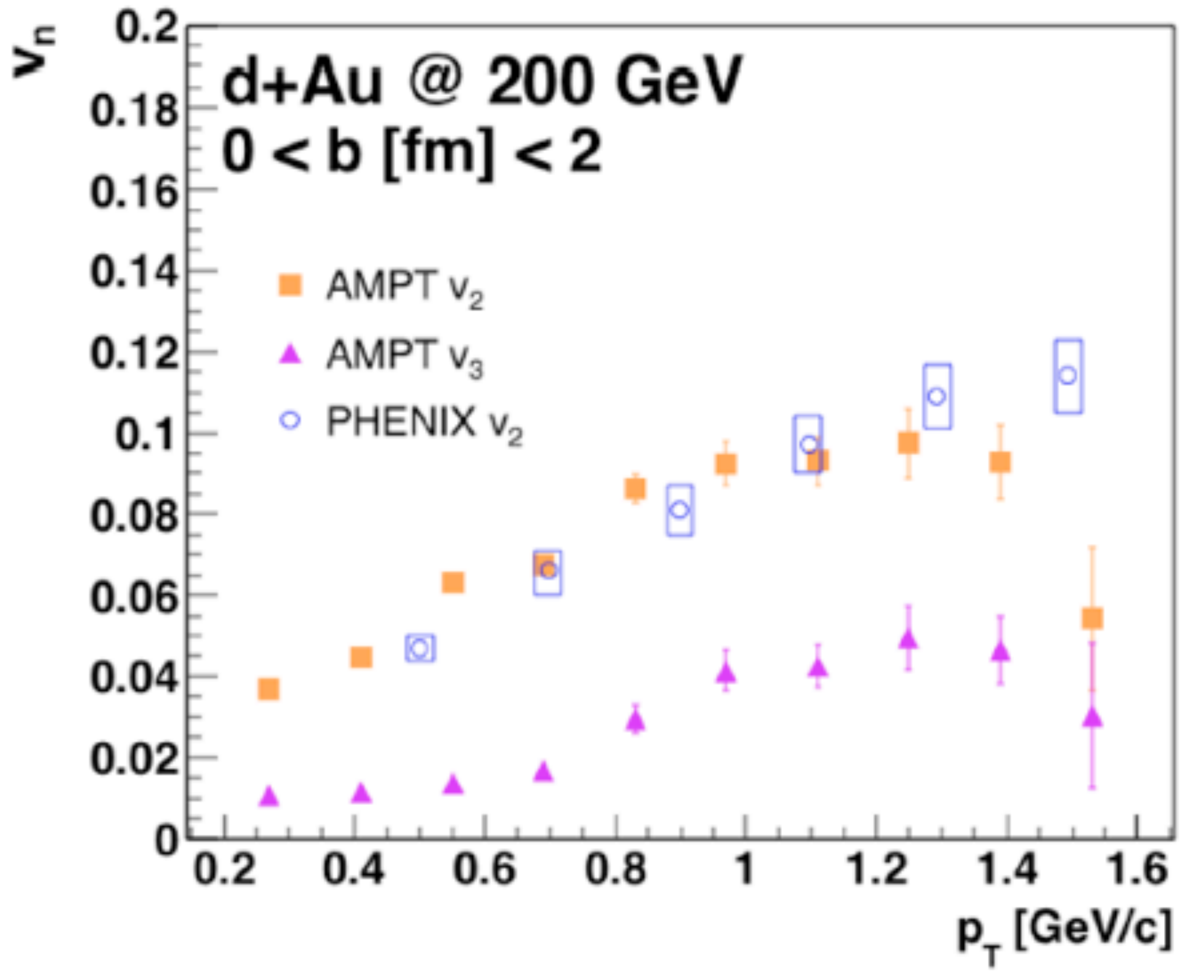
PID pT spectra in p+Pb

G.-L. Ma and A. Bzdak, PLB 739, 209 (2014)



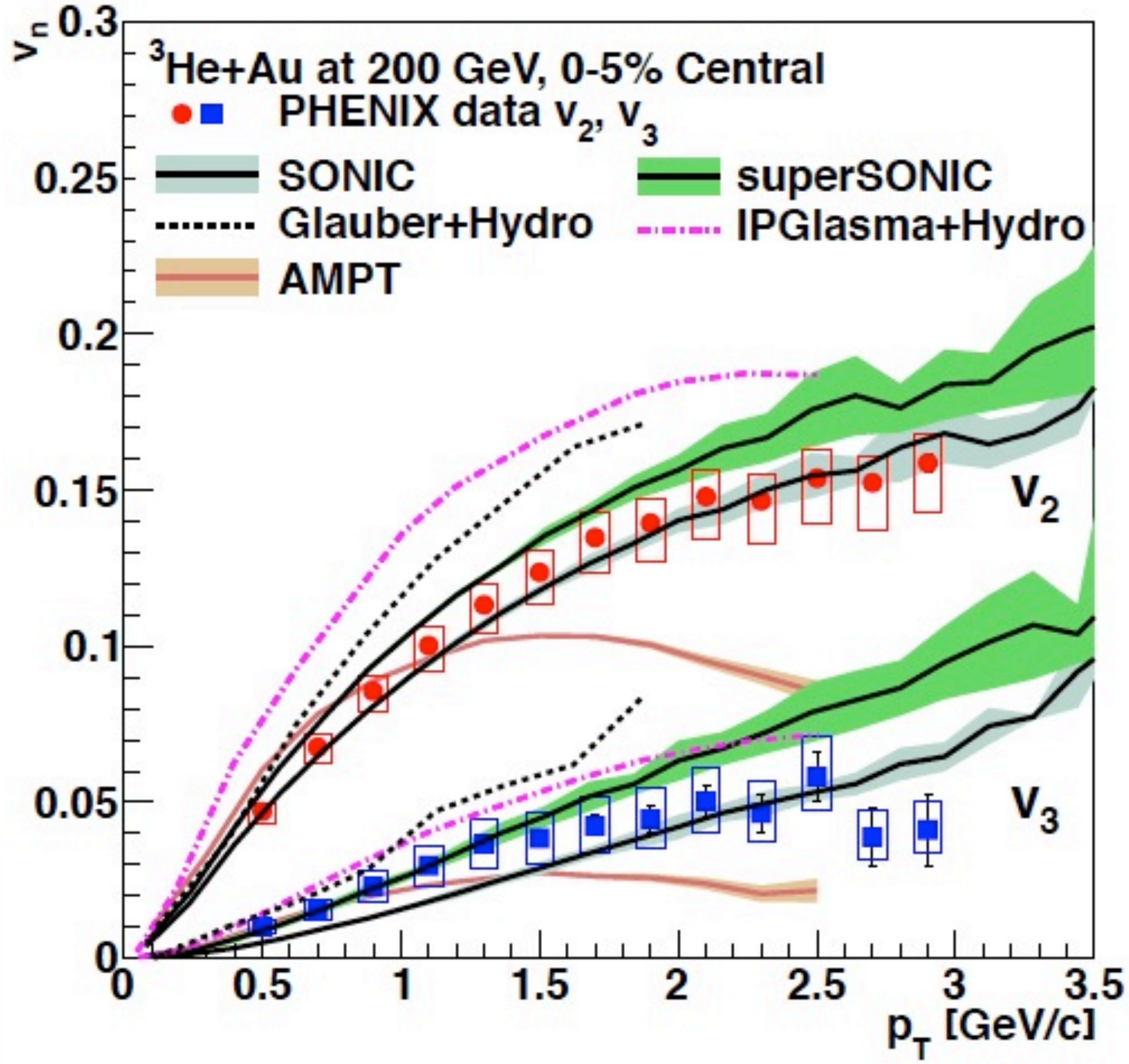
- The AMPT model reproduces the CMS data for pT spectra of pion, Kaon, and proton, within the accuracy of 20%.

AMPT results on d+Au and 3He+Au



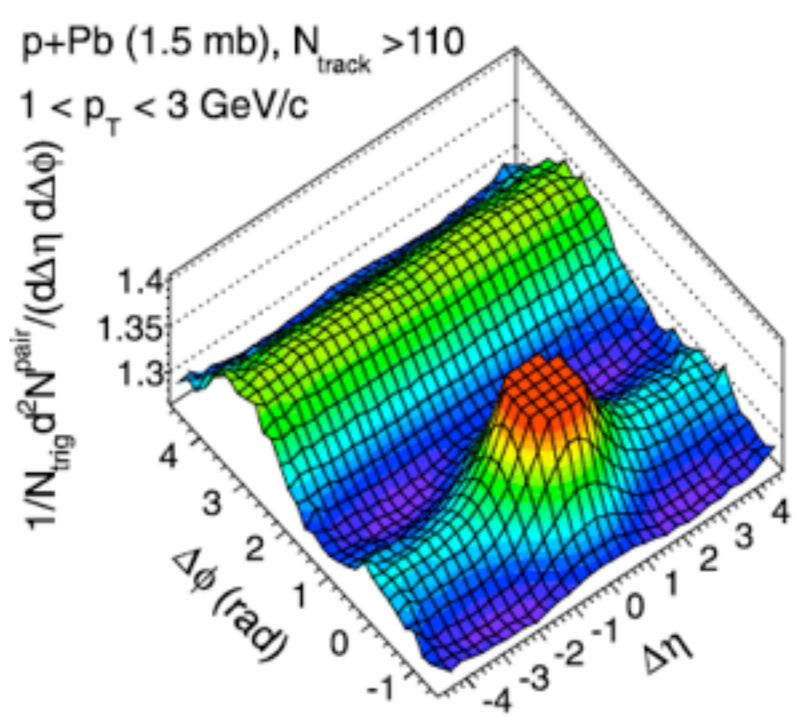
J.D. Orjuela Koop, A. Adare, D. McGlinchey, J.L. Nagle, arXiv:1501.06880

PHENIX, arXiv:1507.06273

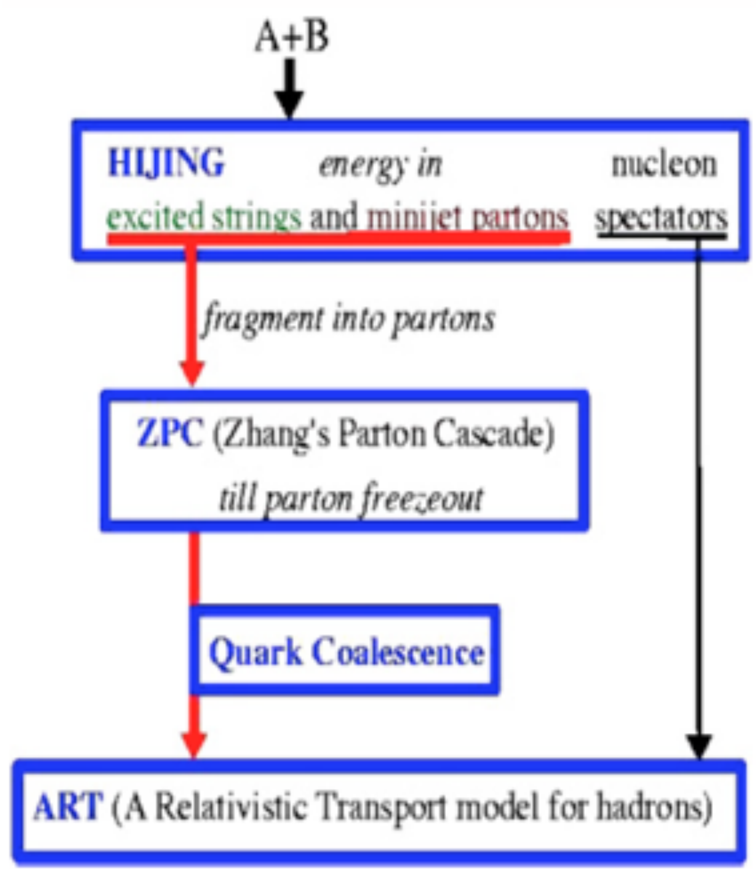


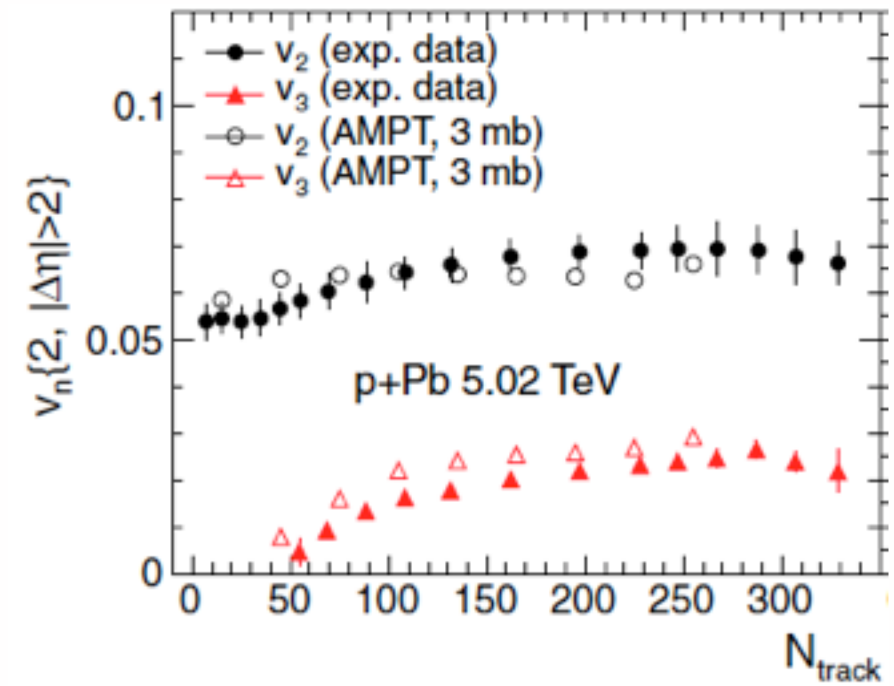
- The AMPT also can produce the low-pT vn in d+Au and 3He+Au at RHIC.

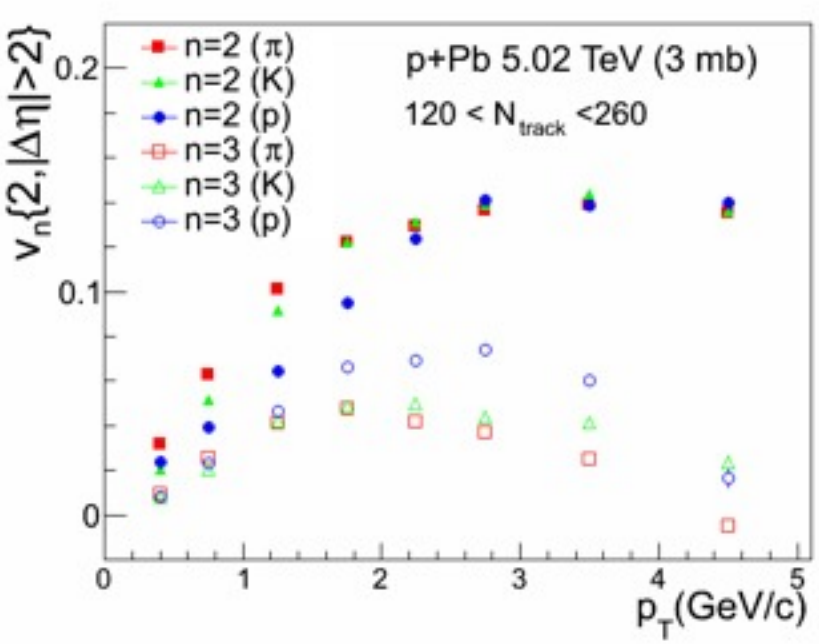
Physical mechanism?

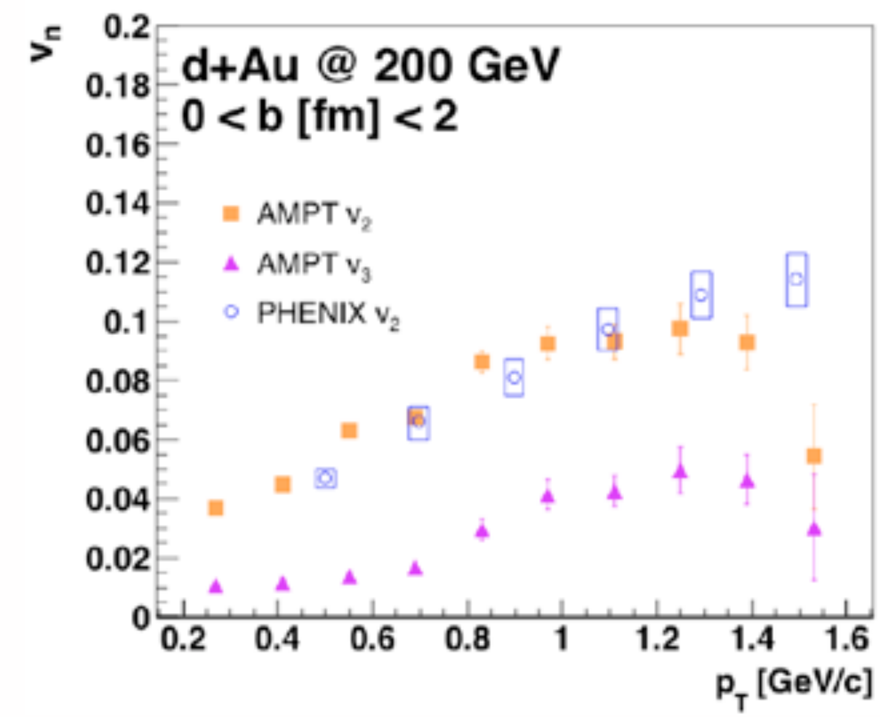


Melting AMPT Model

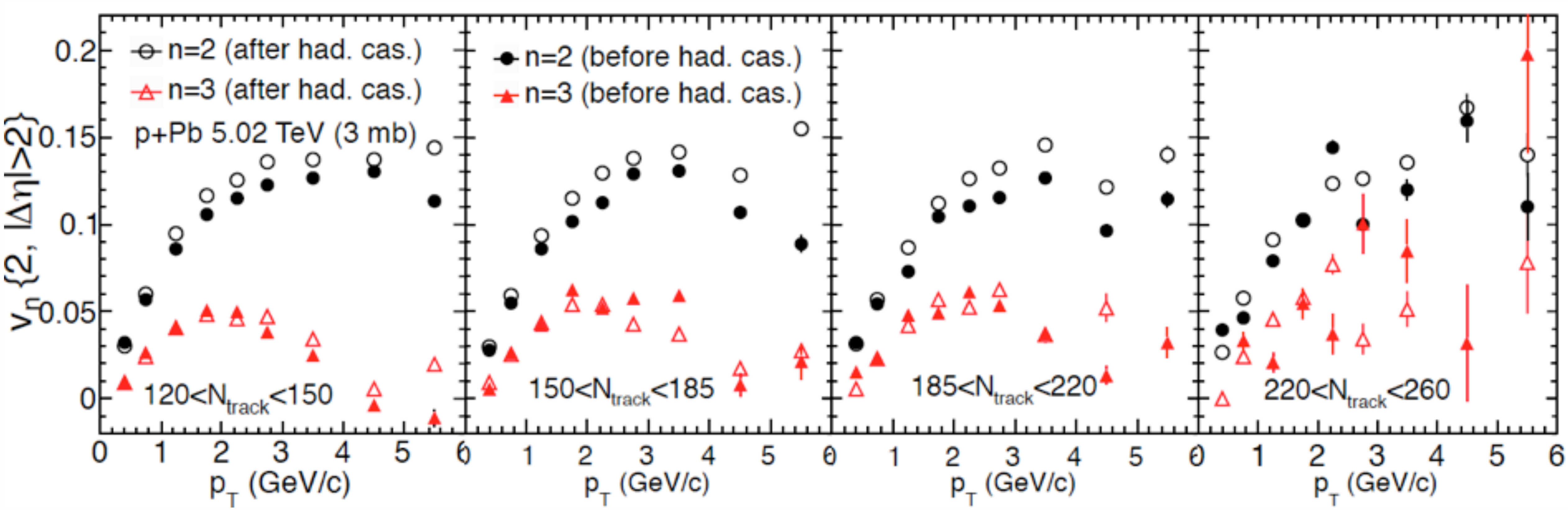






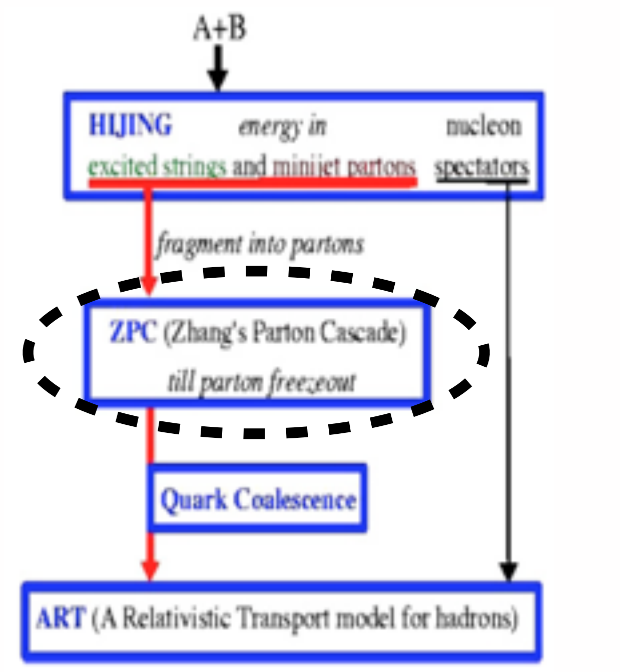


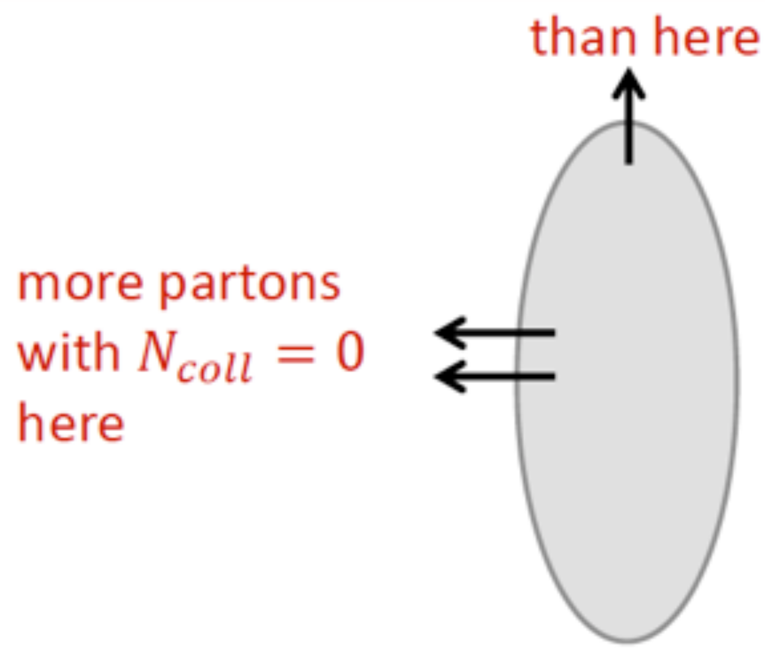
Hadron cascade effect?



- Hadron cascade shows a negligible effect on the p+Pb results.

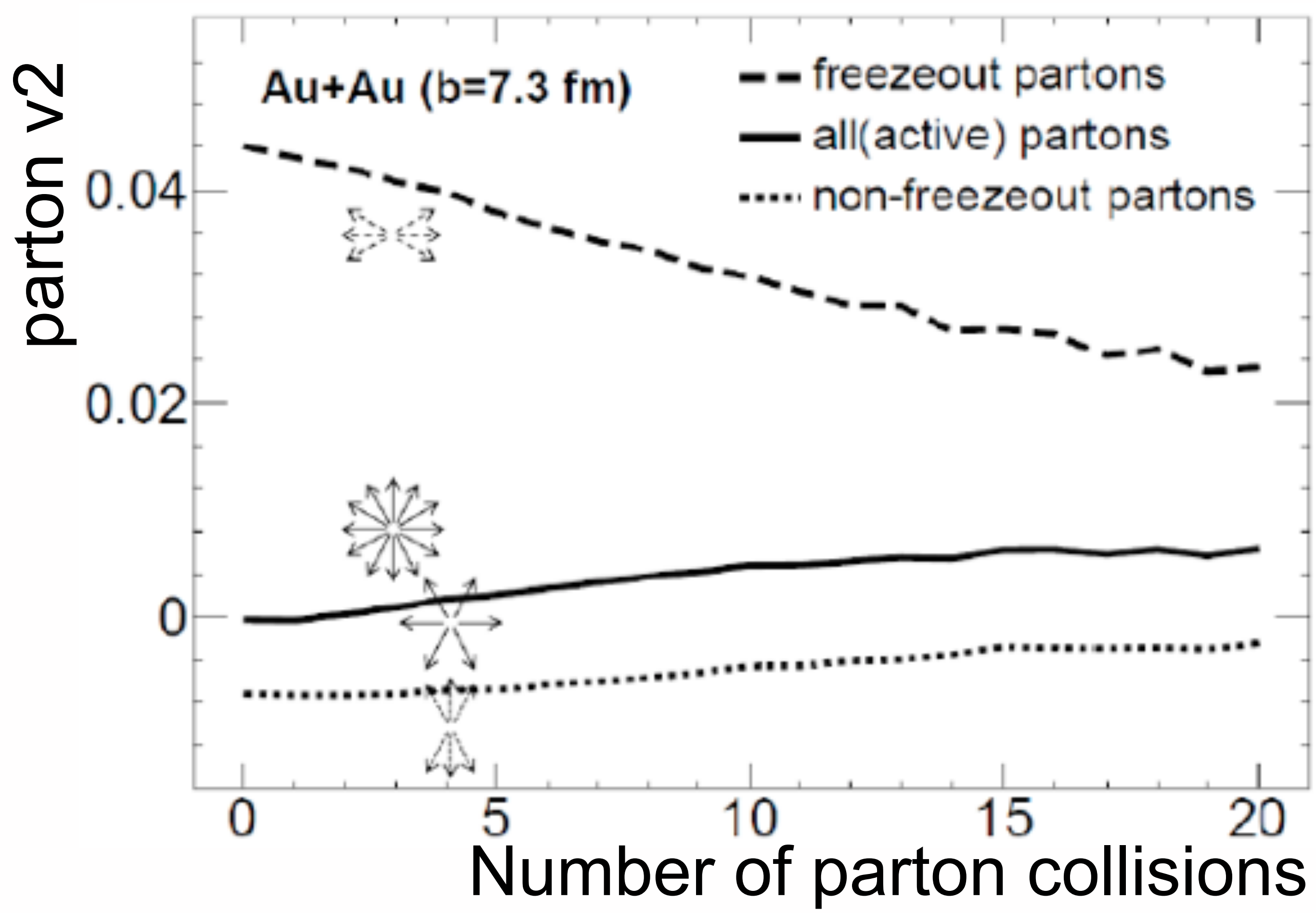
A possible explanation: escape mechanism





L. He, T. Edmonds, Z.W. Lin, F. Liu, D. Molnar, F. Wang, arXiv:1502.05572

larger probability for partons to escape along the short axis



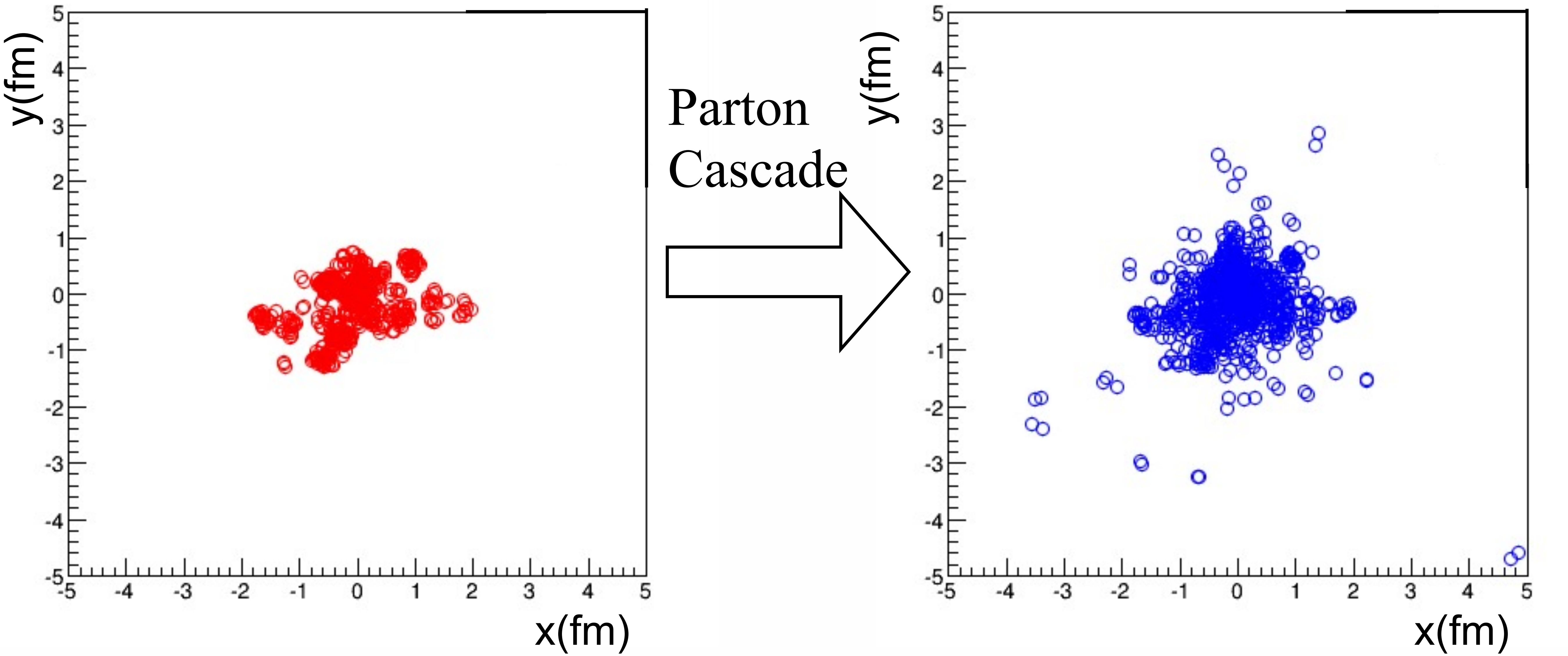
Features:

- Partons freeze out with large positive v2, even when they do not interact at all. It is just due to the initial geometry.
- Remaining partons start off with negative v2, and become ~isotropic (v2~0) after one more collision.
- The flow of active partons as a result of parton interactions or hydrodynamic-type pressure gradient is small.
- Similar for d+Au.

Initial and final parton distributions

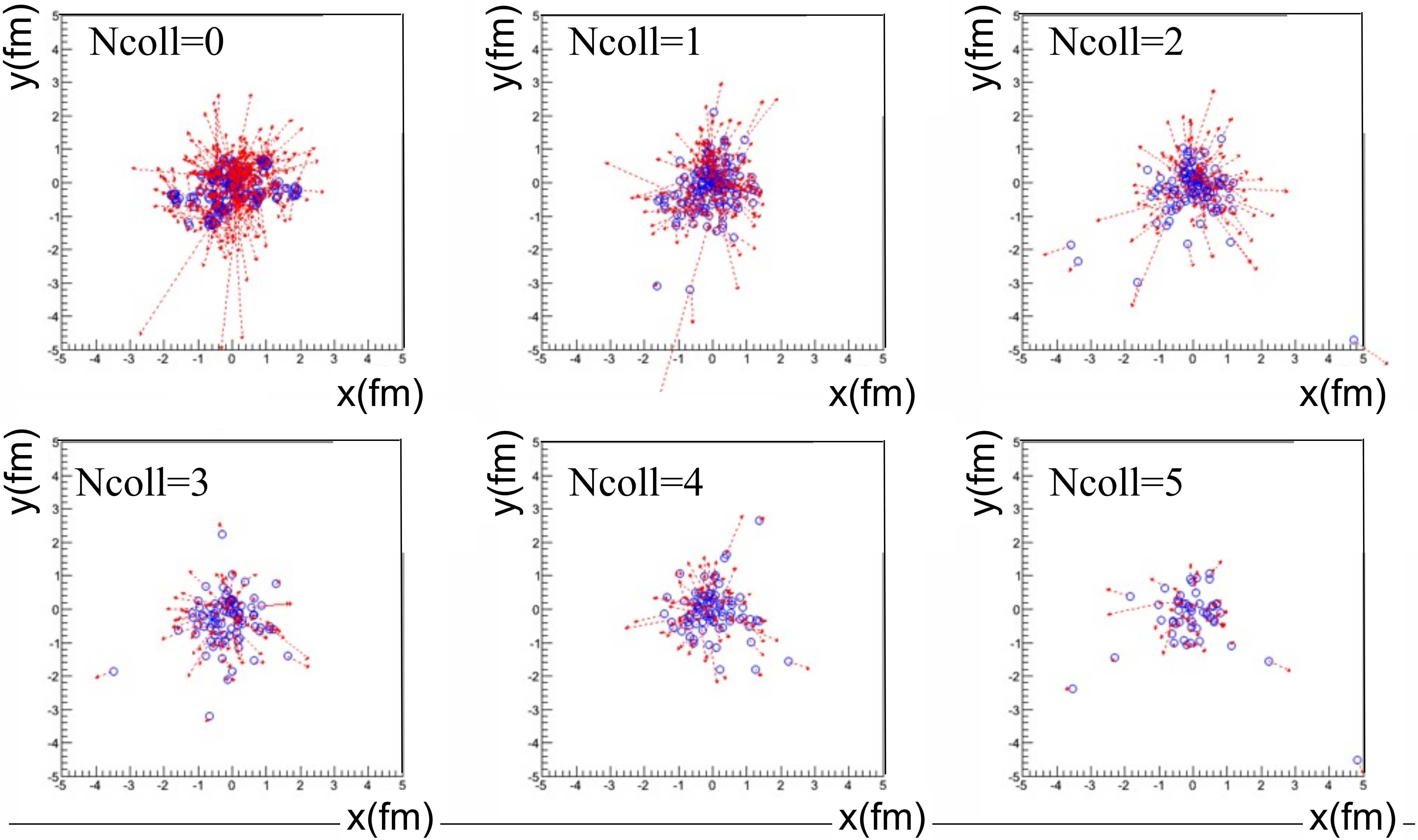
A p+Pb 5.02 TeV AMPT event (Ntrack=141)

initial partons final partons



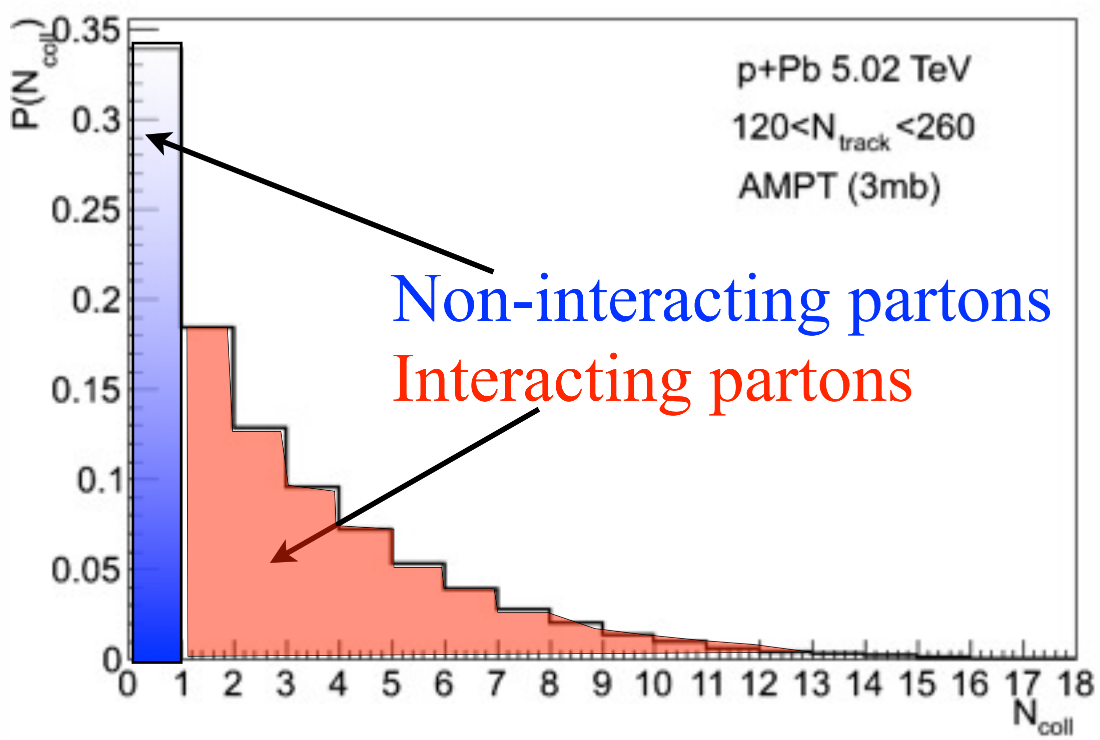
Final parton distributions with different Ncoll

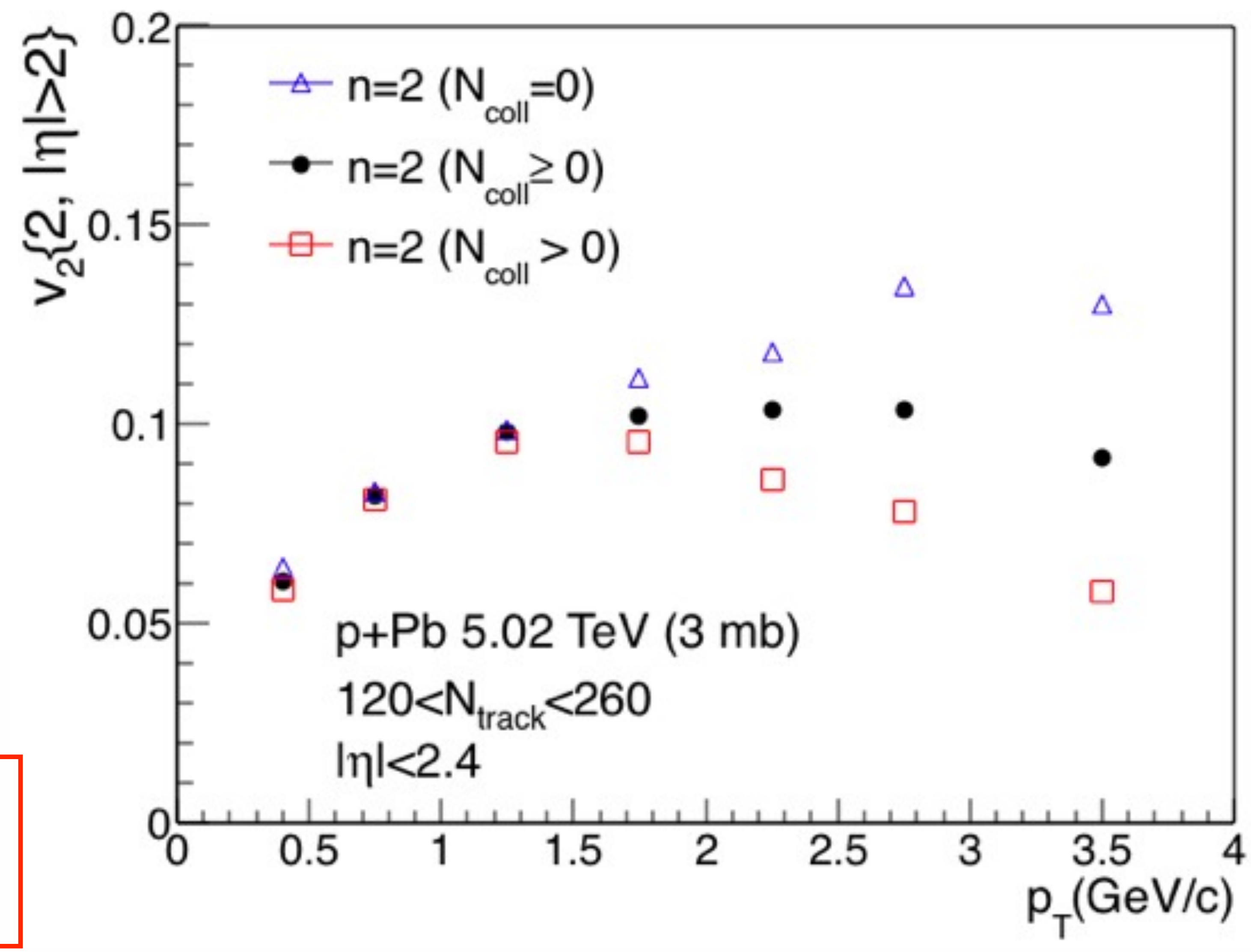
A p+Pb 5.02 TeV AMPT event (Ntrack=141)



Non-interacting parton v2 vs Interacting parton v2

Preliminary

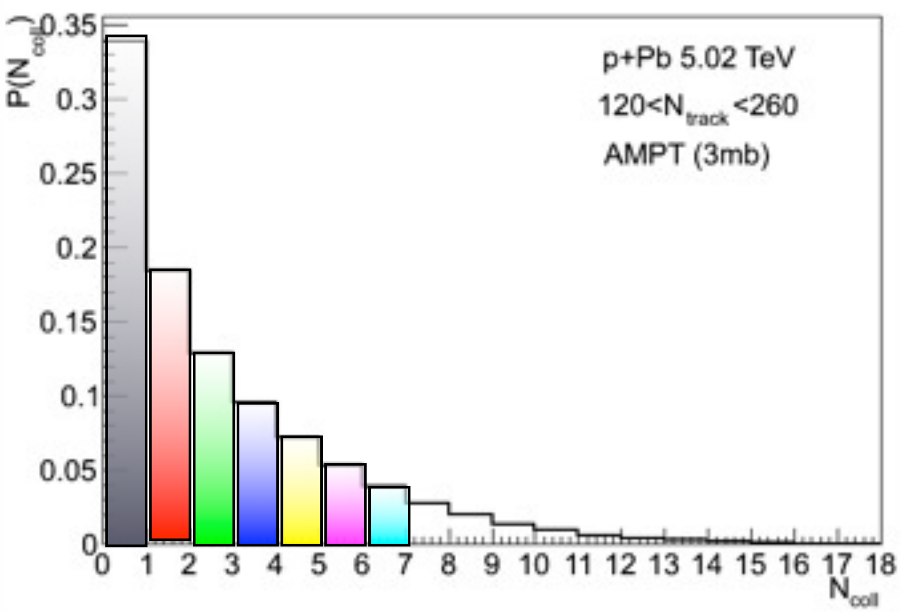




partons Ncoll>=0	=	Non-interacting partons Ncoll=0	+	Interacting partons Ncoll>0

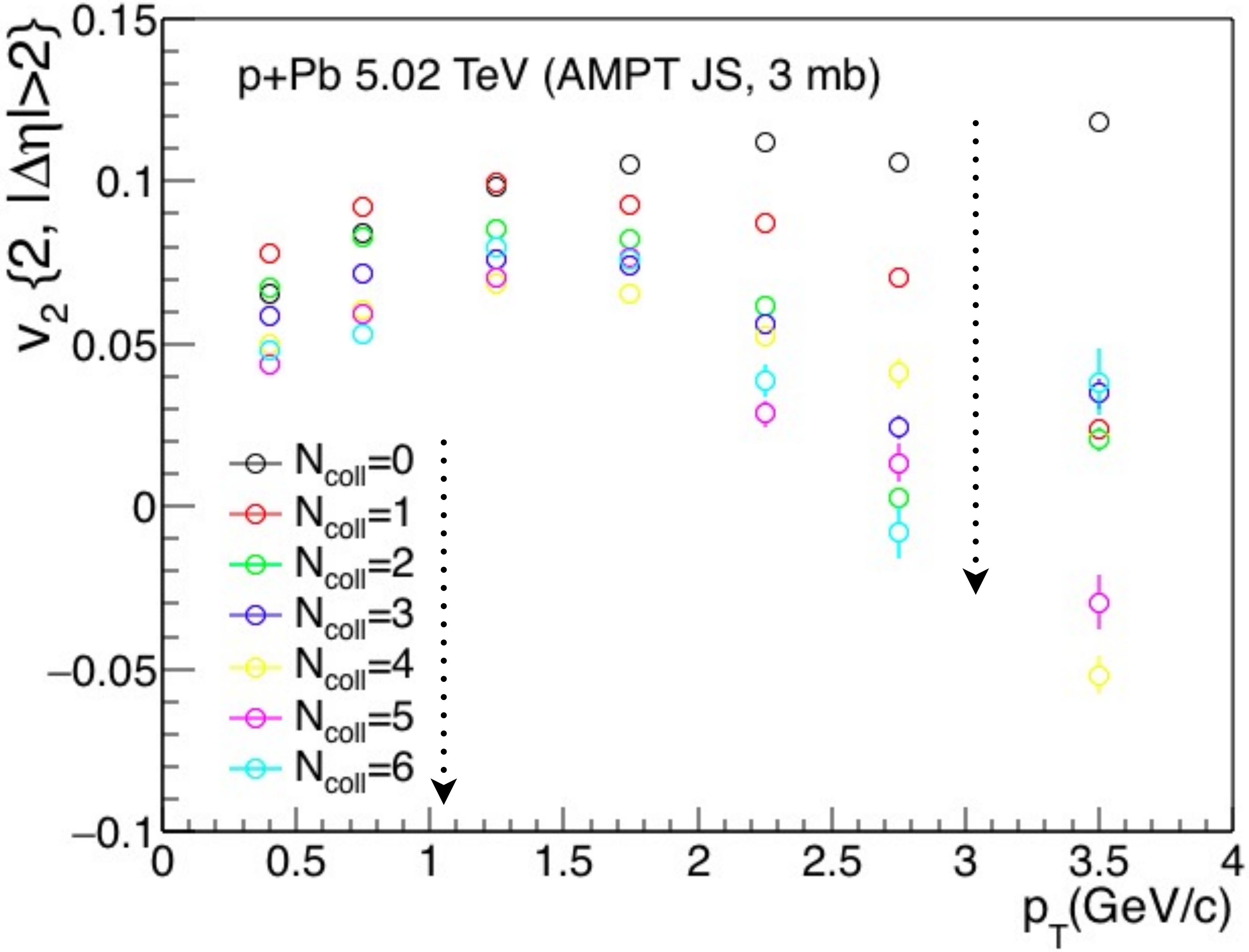
- Non-interacting parton v2 > Interacting parton v2 at high pT.

Different Ncoll parton v2



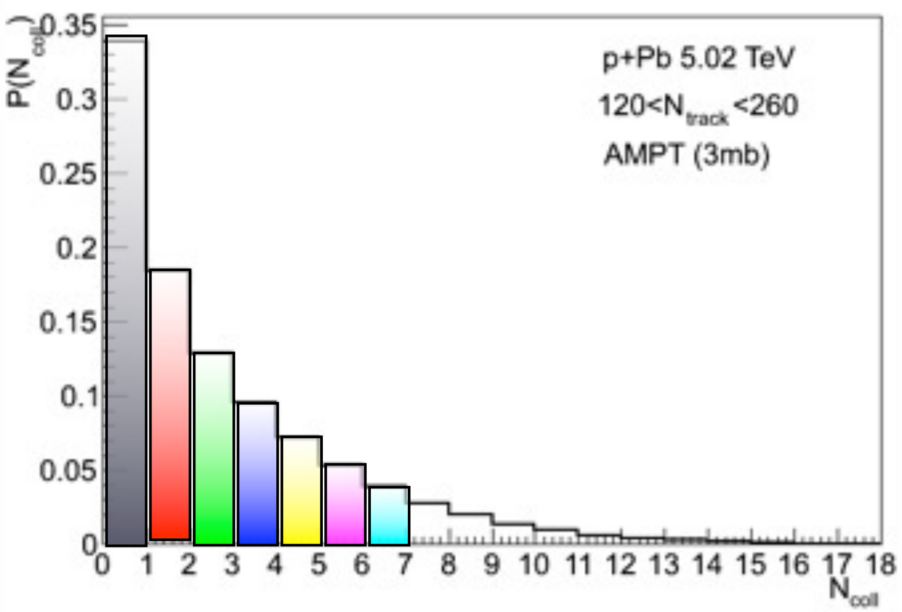
partons = Ncoll=0 + Ncoll=1 + Ncoll=2 + Ncoll=3 + Ncoll=4 + Ncoll=5 + Ncoll=6 + ...

Final parton state *Preliminary*



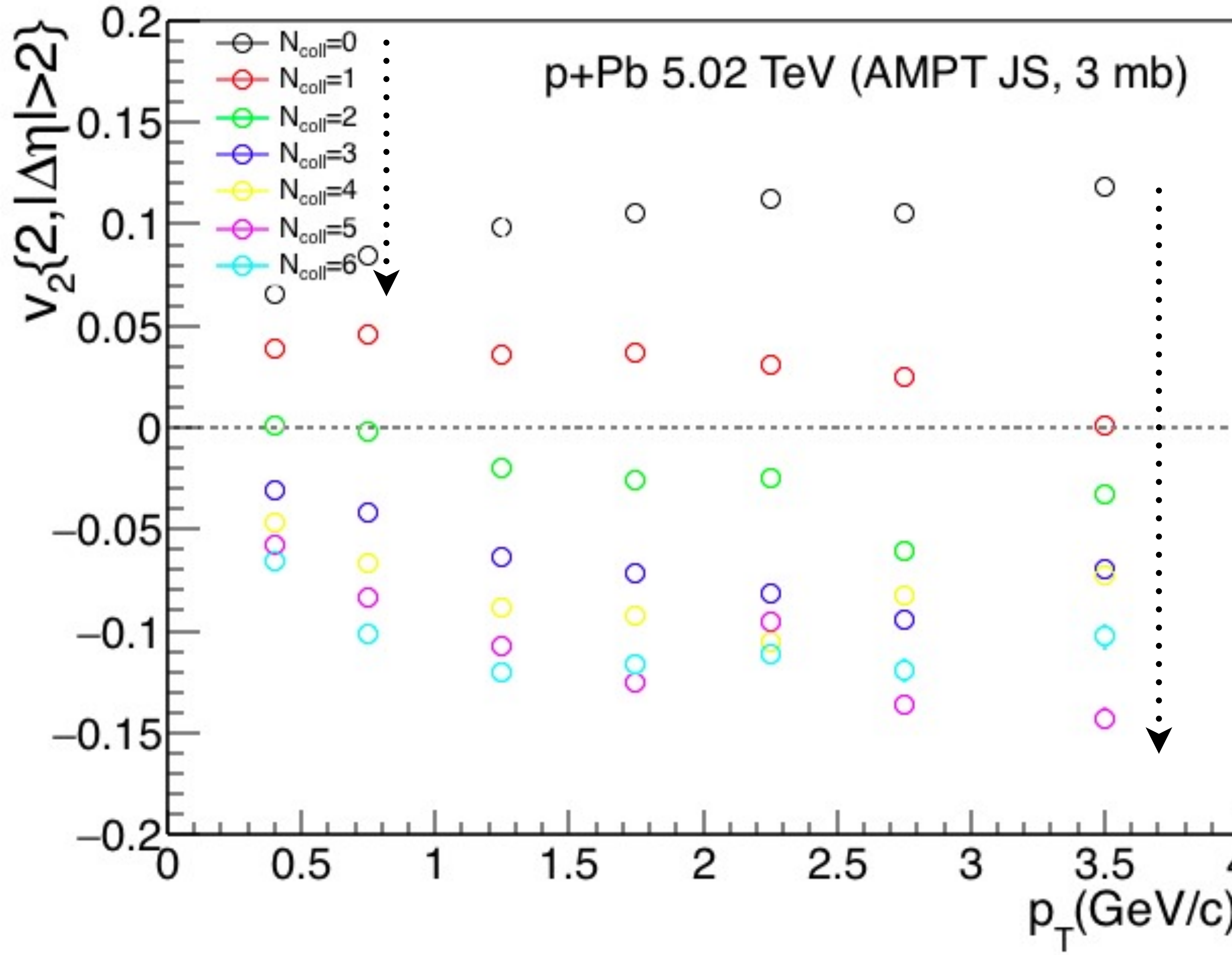
- v2 decreases with Ncoll in the final state.

Initial parton v2



partons = Ncoll=0 + Ncoll=1 + Ncoll=2 + Ncoll=3 + Ncoll=4 + Ncoll=5 + Ncoll=6 + ...

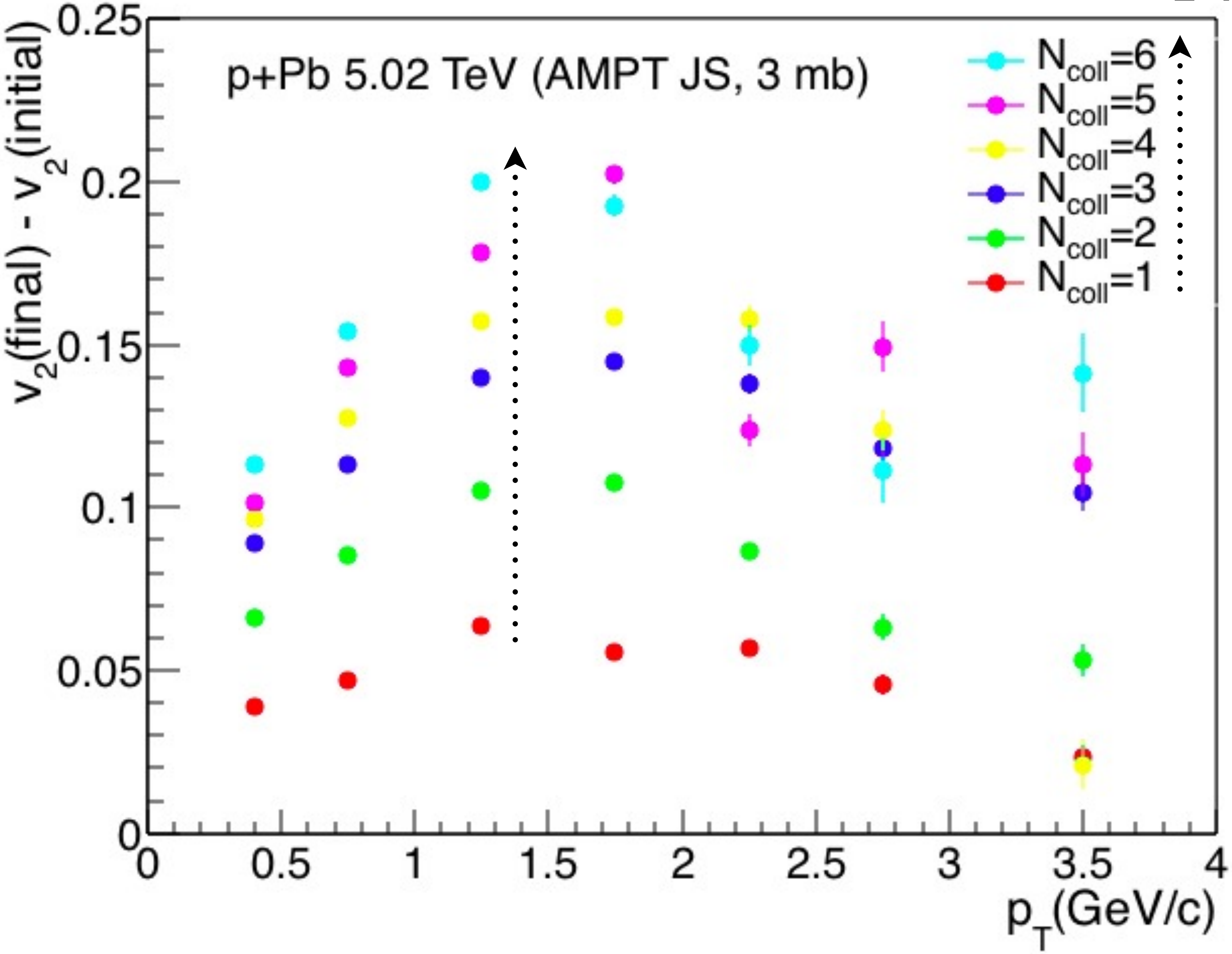
Initial parton state *Preliminary*



- v2 (small Ncoll)>0 and v2 (large Ncoll)<0, because the average v2 must be zero in the initial state.

Δv2 = (final v2 - initial v2) for partons

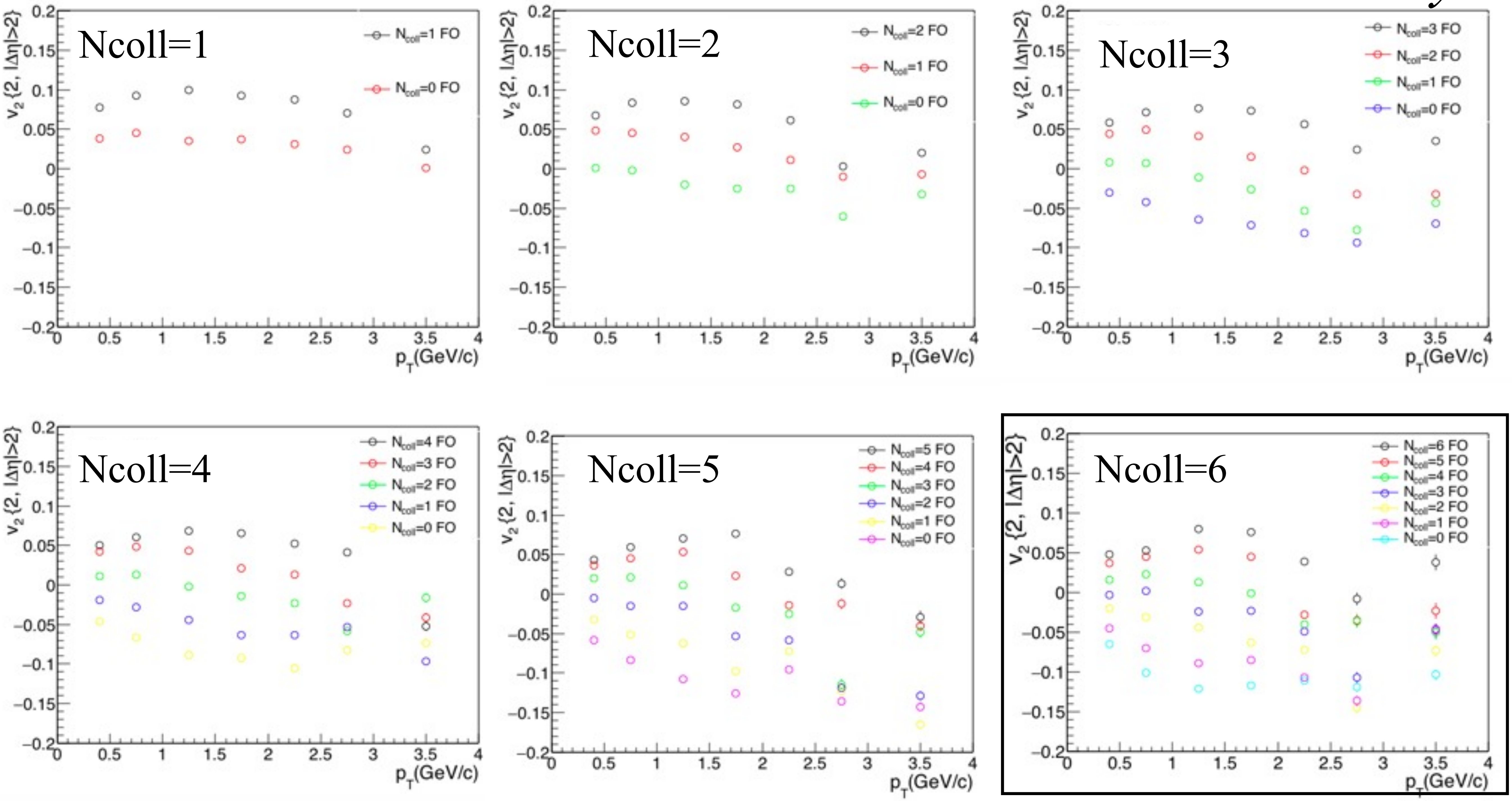
Preliminary



- Yes, more parton collisions generate larger Δv2.

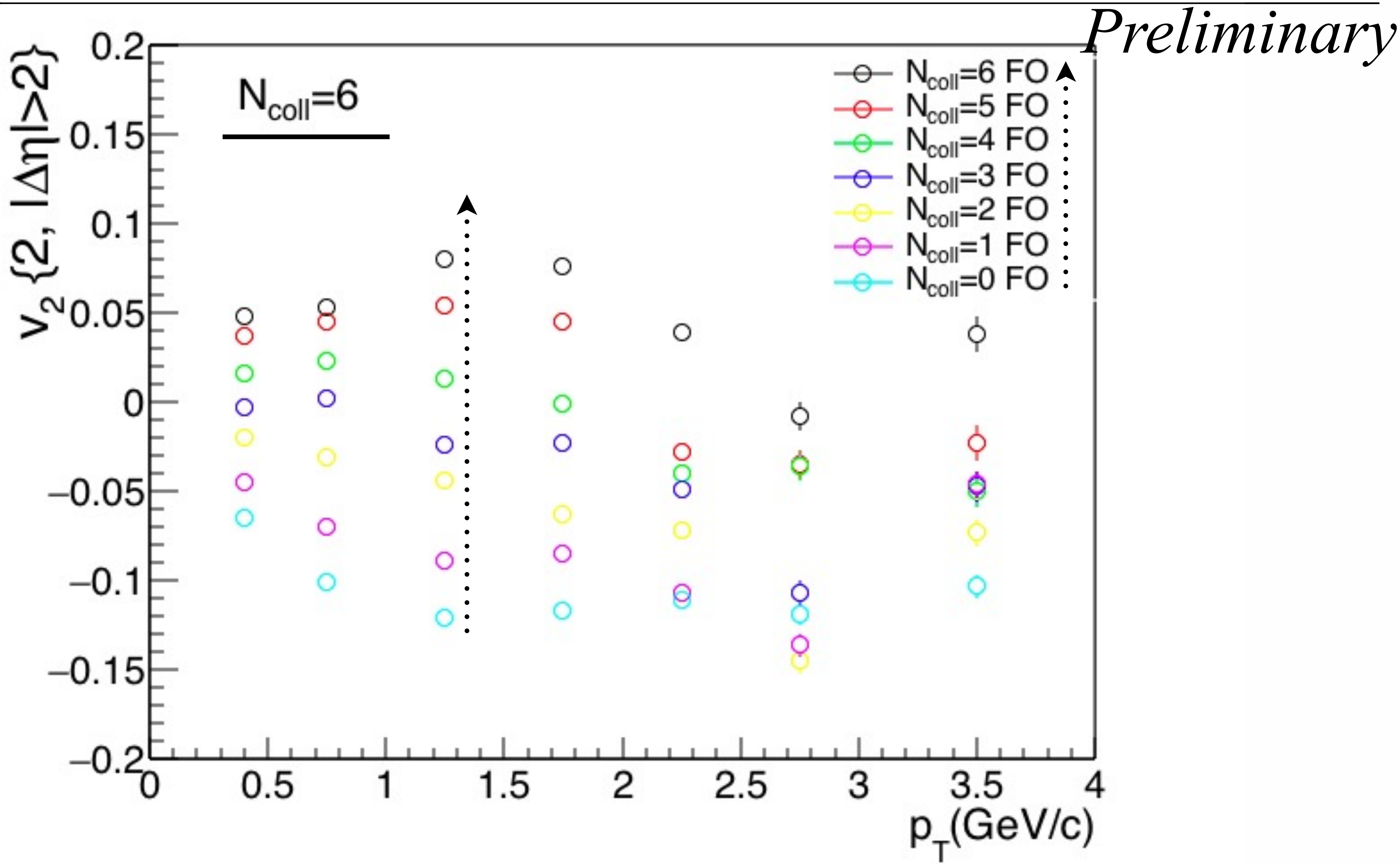
How do collisions generate Δv2?

Preliminary



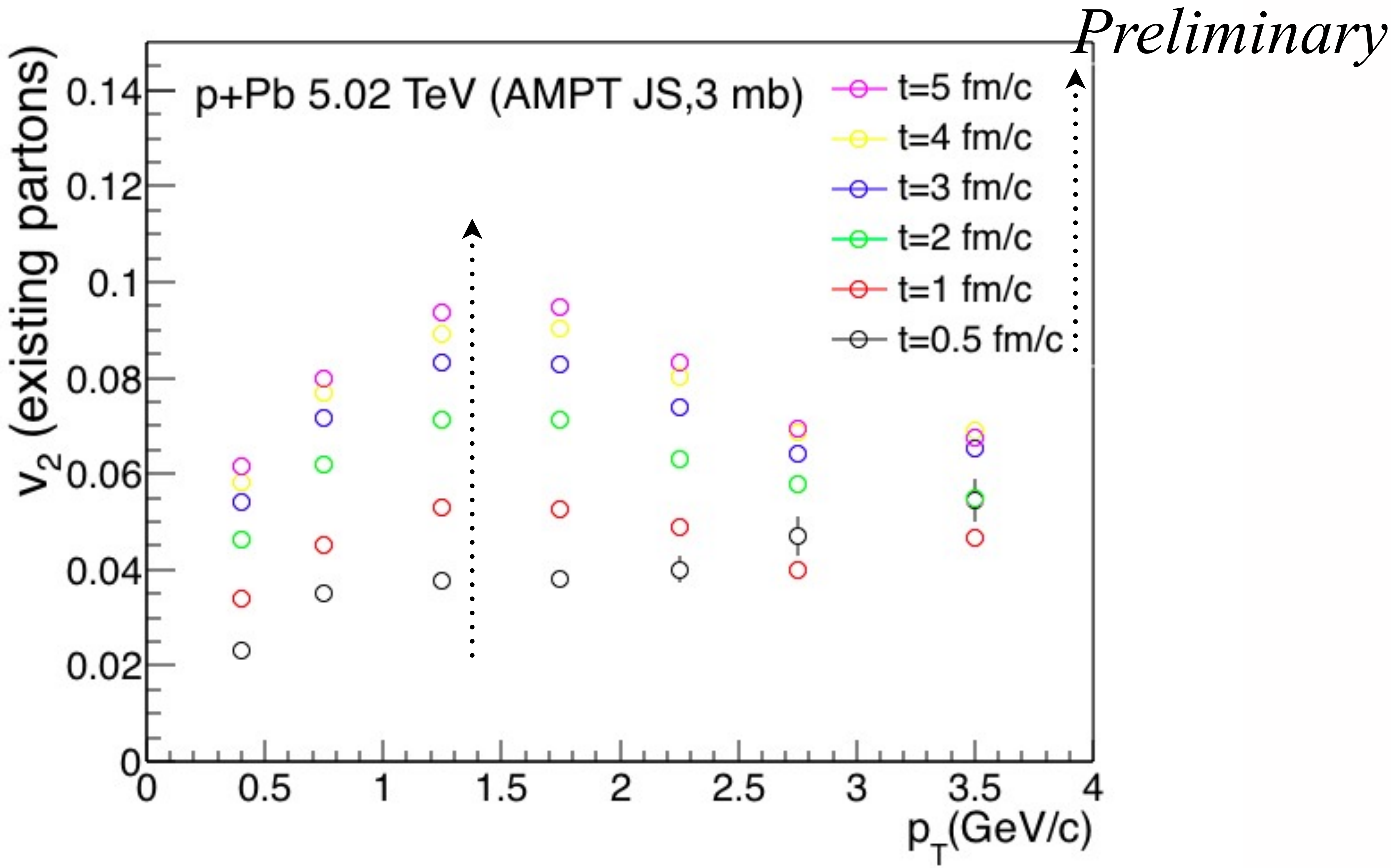
- Parton v2 is increased by subsequent parton collisions.

How do collisions generate Δv2?



- Parton v2 gradually increases from negative to positive through subsequent parton collisions.

Time evolution of parton v2



- Parton v2 increases with time, as more collisions happen with time.

Summary

- The elastic scattering of partons, with σ =1.5-3mb, naturally explains the long-range correlations in p+p and p+Pb.
- v3 are in a good agreement with the CMS data. v2 is very well described in p+Pb and underestimated for higher pT in Pb+Pb.
- The signals arise from parton cascade (under investigation).
  - In initial state, less-interacting partons (Ncoll=0 or 1) have positive v2, more-interacting partons (Ncoll>1) have negative v2.
  - In final state, parton collisions can generate v2 to interacting partons, which leads to a final positive v2.

Thanks!