Azimuthal Anisotropies from AMPT

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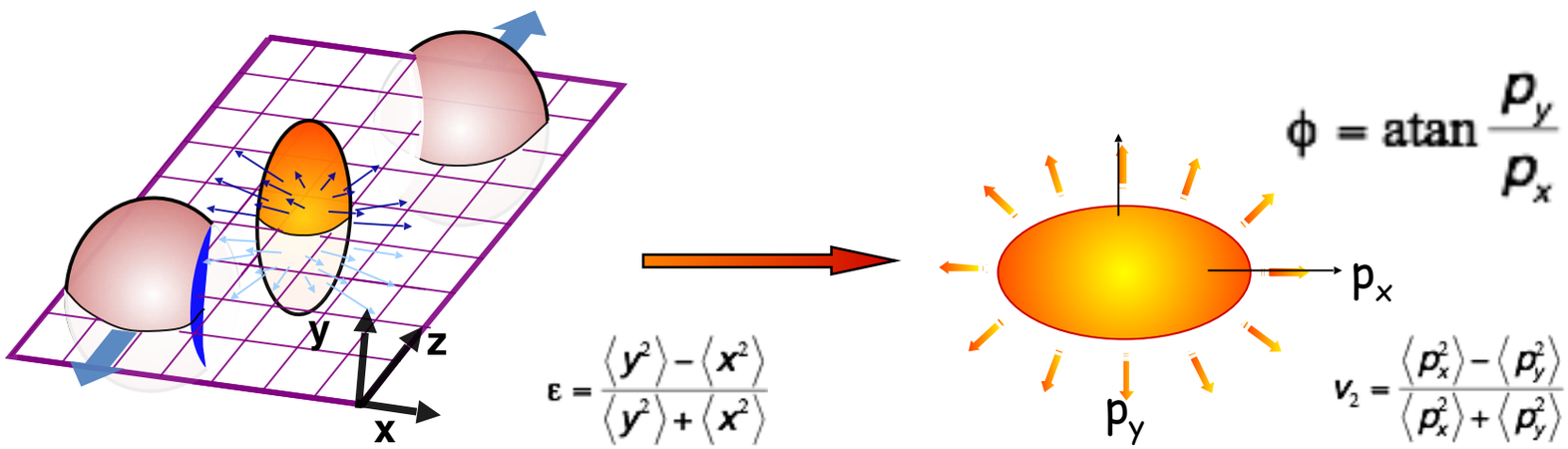
Mostly based on *arXiv:1502.05572:*
Liang He, Terrence Edmonds, Zi-Wei Lin, Feng Liu, Denes Molnar, Fuqiang Wang:
Anisotropic parton escape is the dominant source of azimuthal anisotropy in parton transport

OUTLINE

- Hydrodynamic vs. transport model
- Look at how v2 develops in AMPT
- Random test: try to gauge different contributions
- Conclusion and outlook

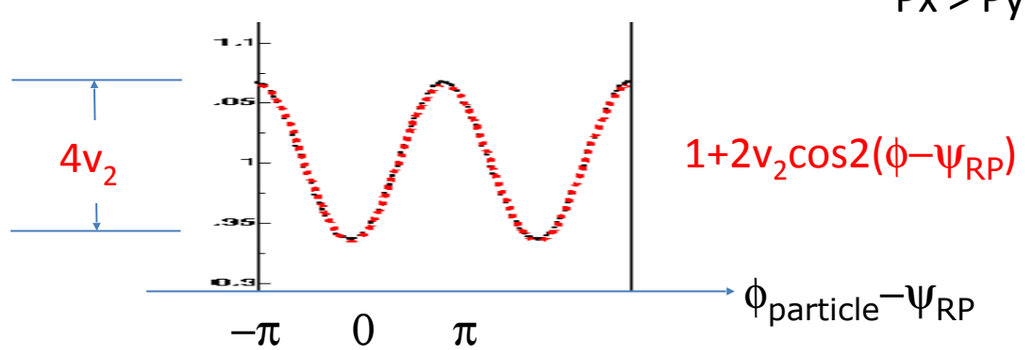
What's flow?



coordinate space anisotropy

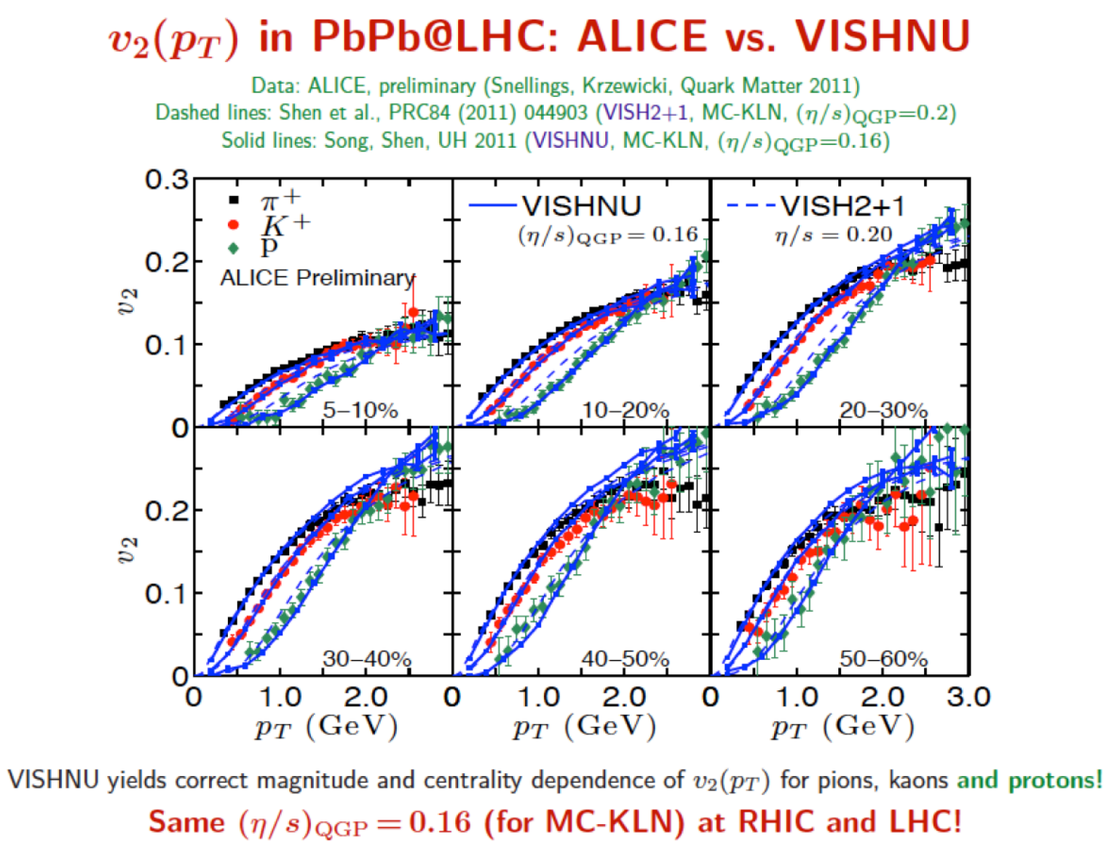
momentum space anisotropy

Px > Py



Hydrodynamic vs transport

Hydrodynamics has been very successful for global observables, especially flow v_n



Heinz, BES Workshop at LBNL 2014 using viscous hydrodynamics.

Transport model can also describe flow v_n :degree of equilibration is controlled by cross section σ

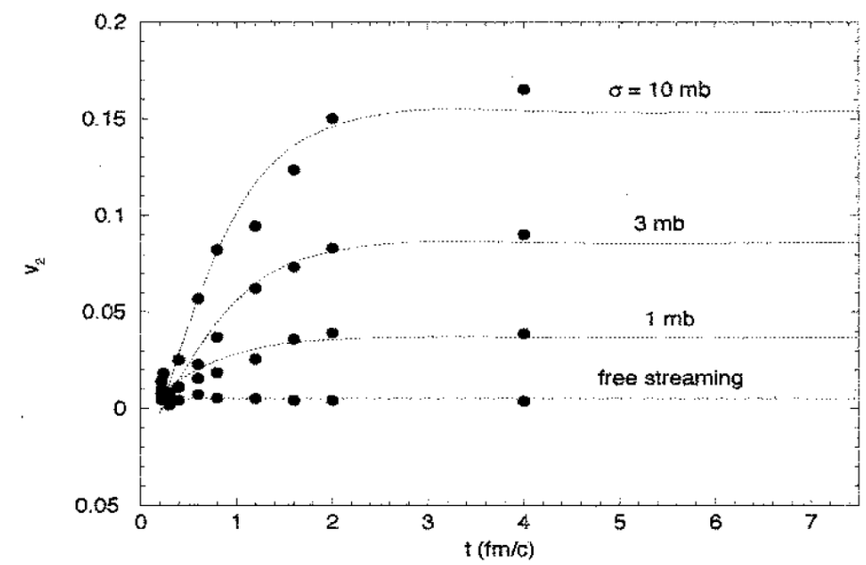
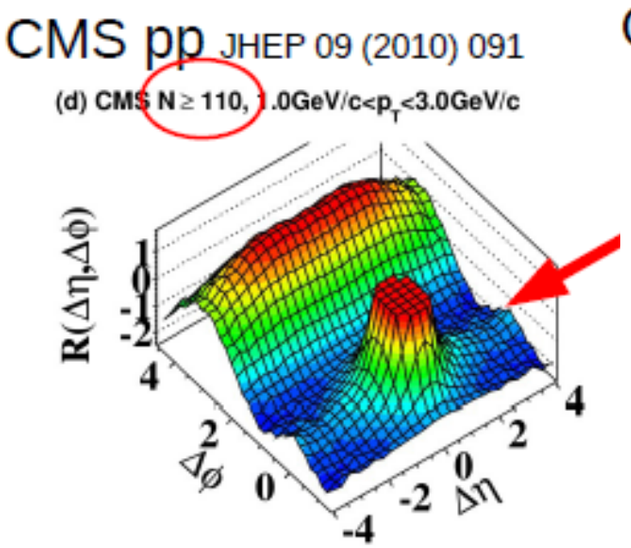
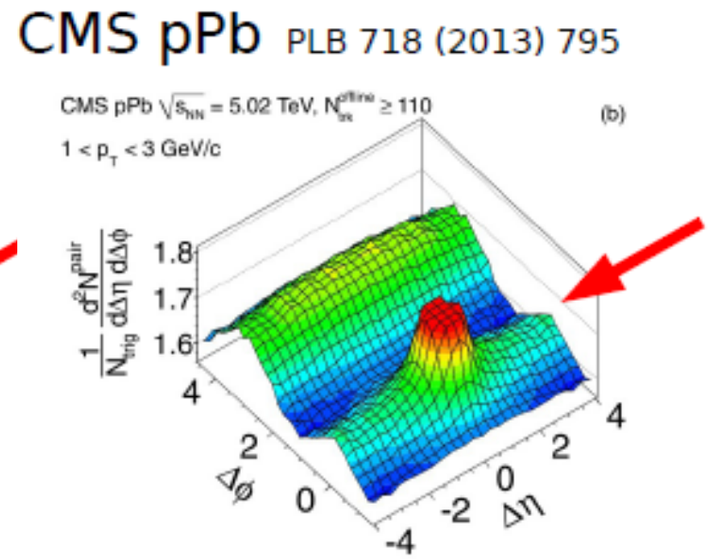


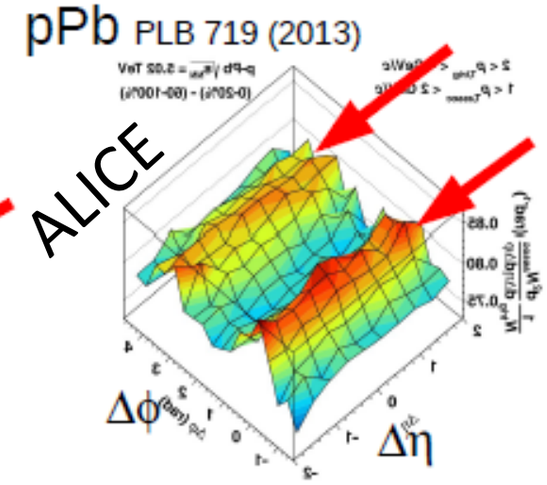
Fig. 1. Time evolution of v_2 coefficient for different effective parton scattering cross sections in Au-Au collisions at $\sqrt{s} = 200$ AGeV with impact parameter 7.5 fm. Filled circles are cascade data, and dotted lines are hyperbolic tangent fits to the data.

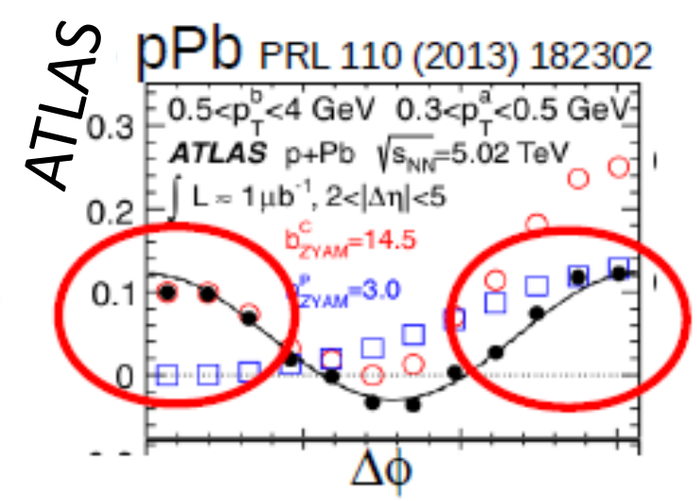
Zhang, Gyulassy and Ko, PLB (1999) using elastic parton transport.

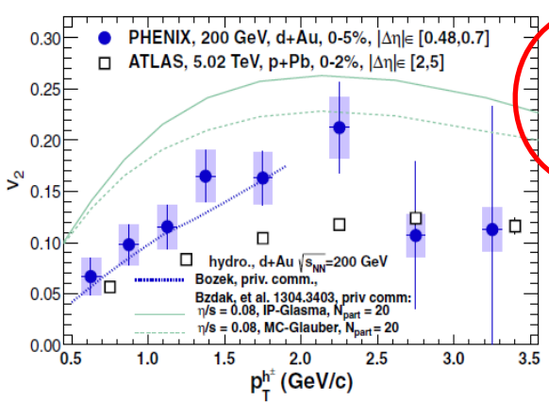
Question1: Flow in small system?

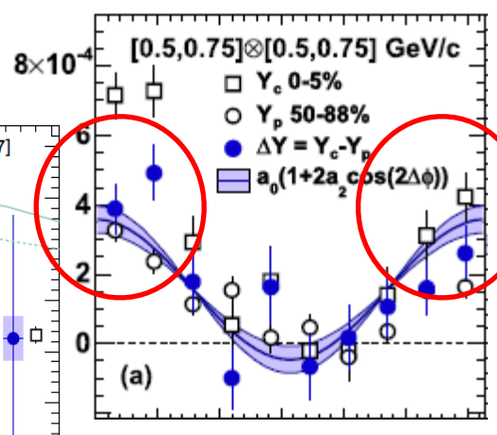


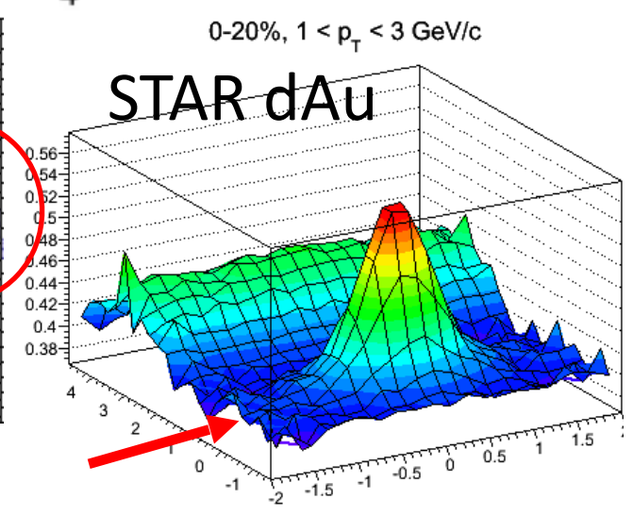


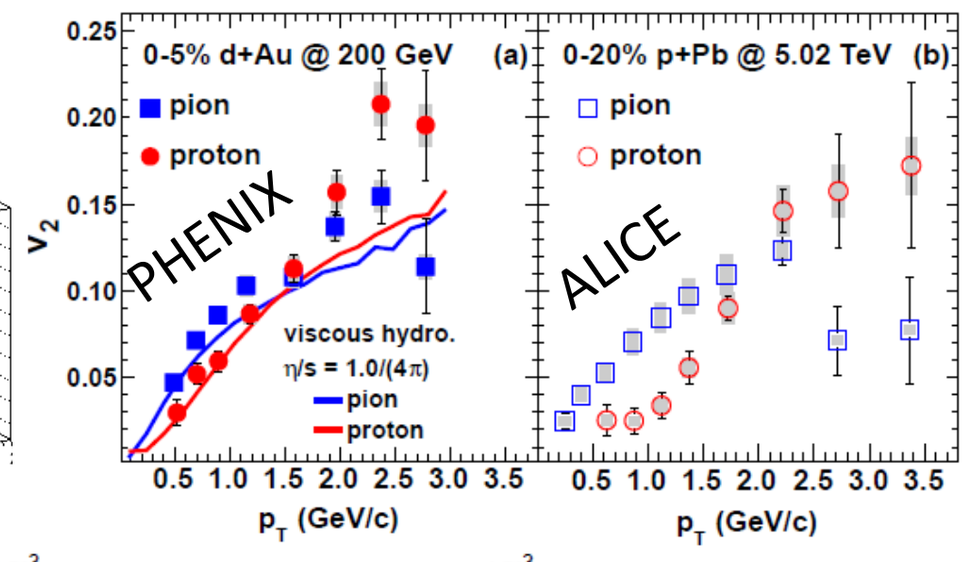


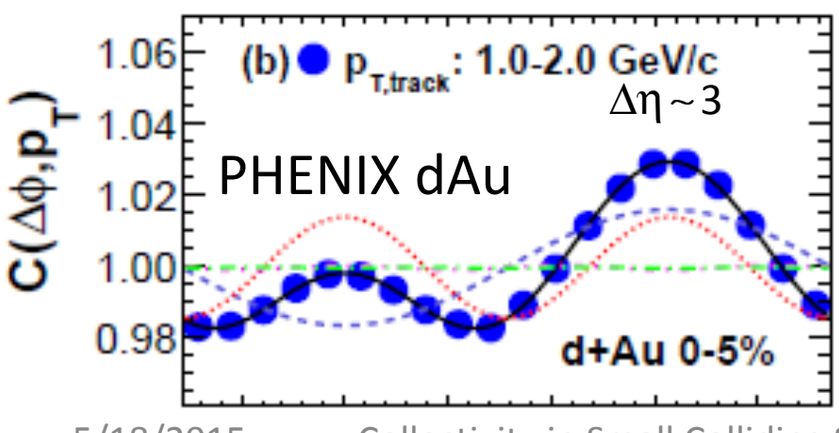


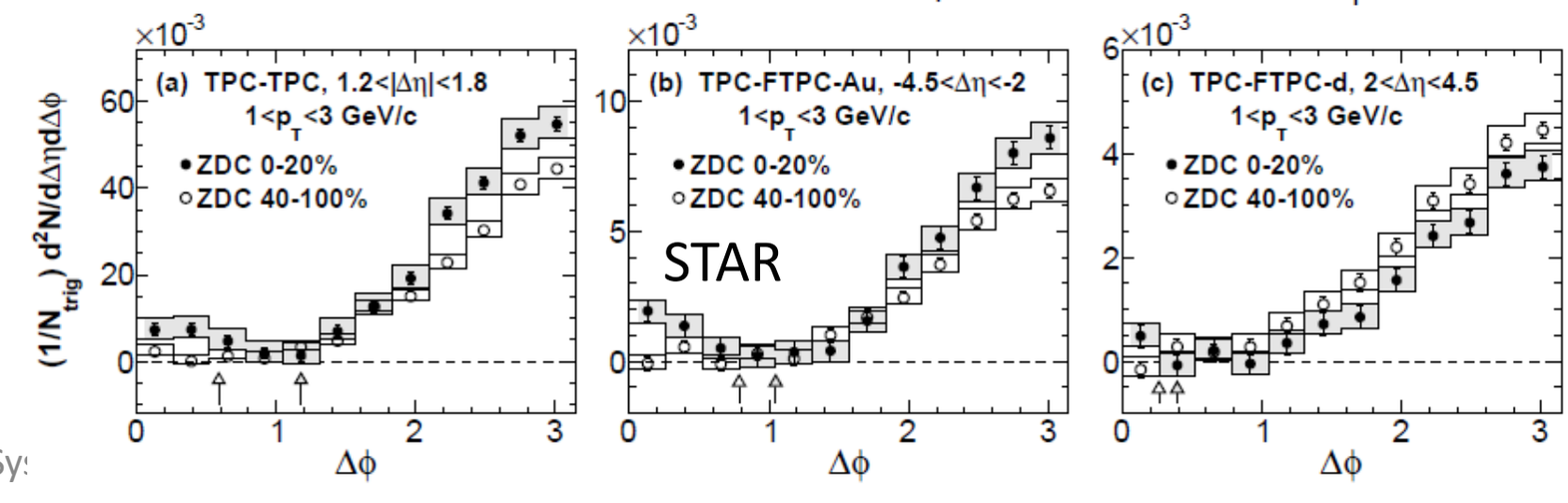




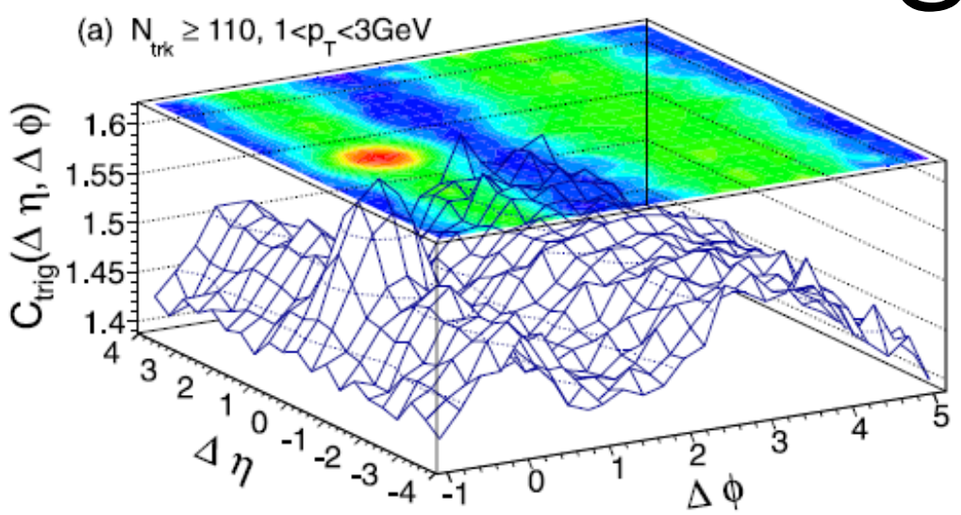


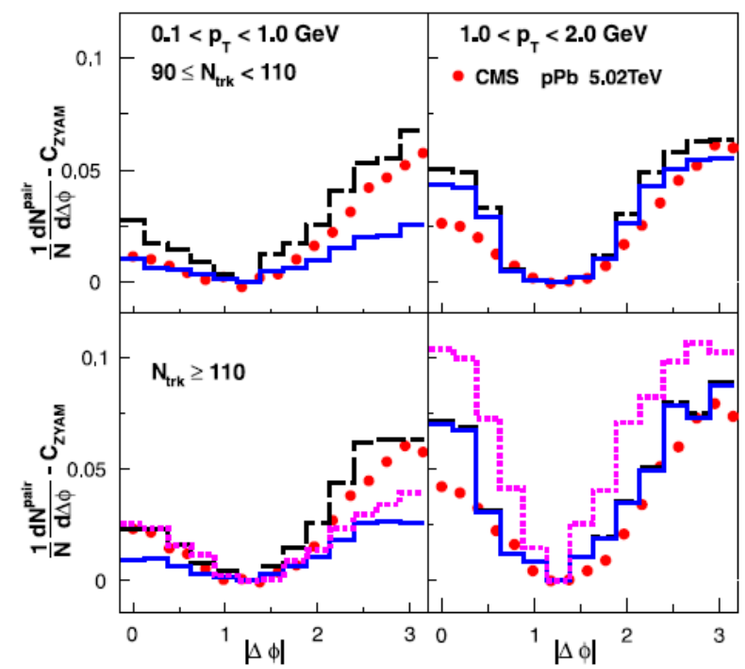




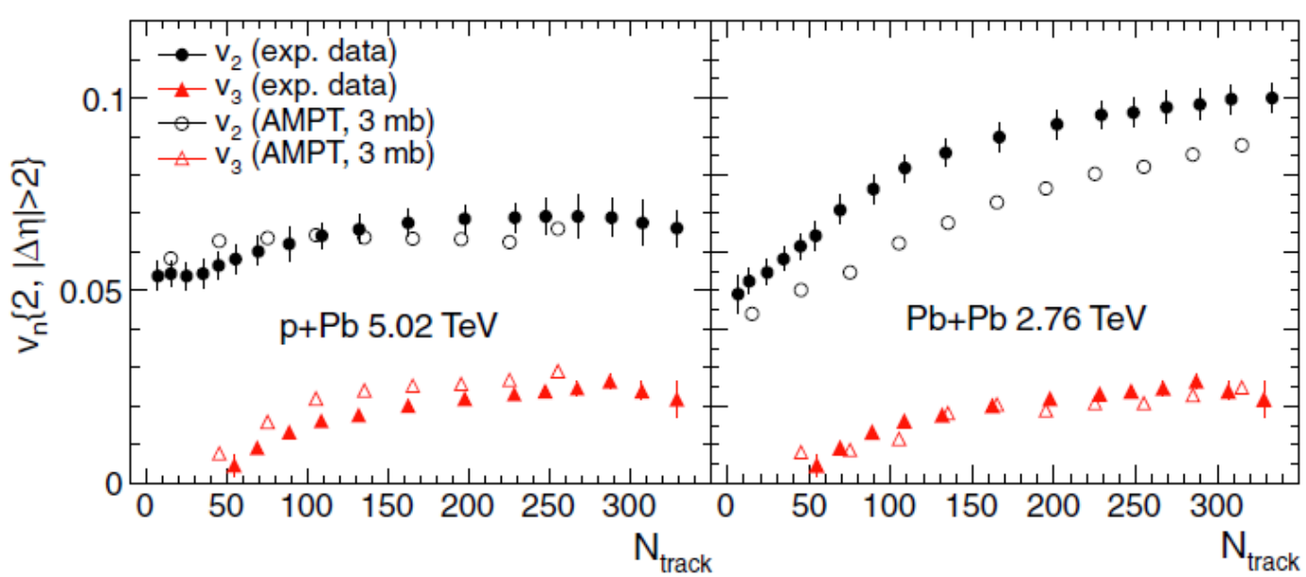


How to describe v2 in small system





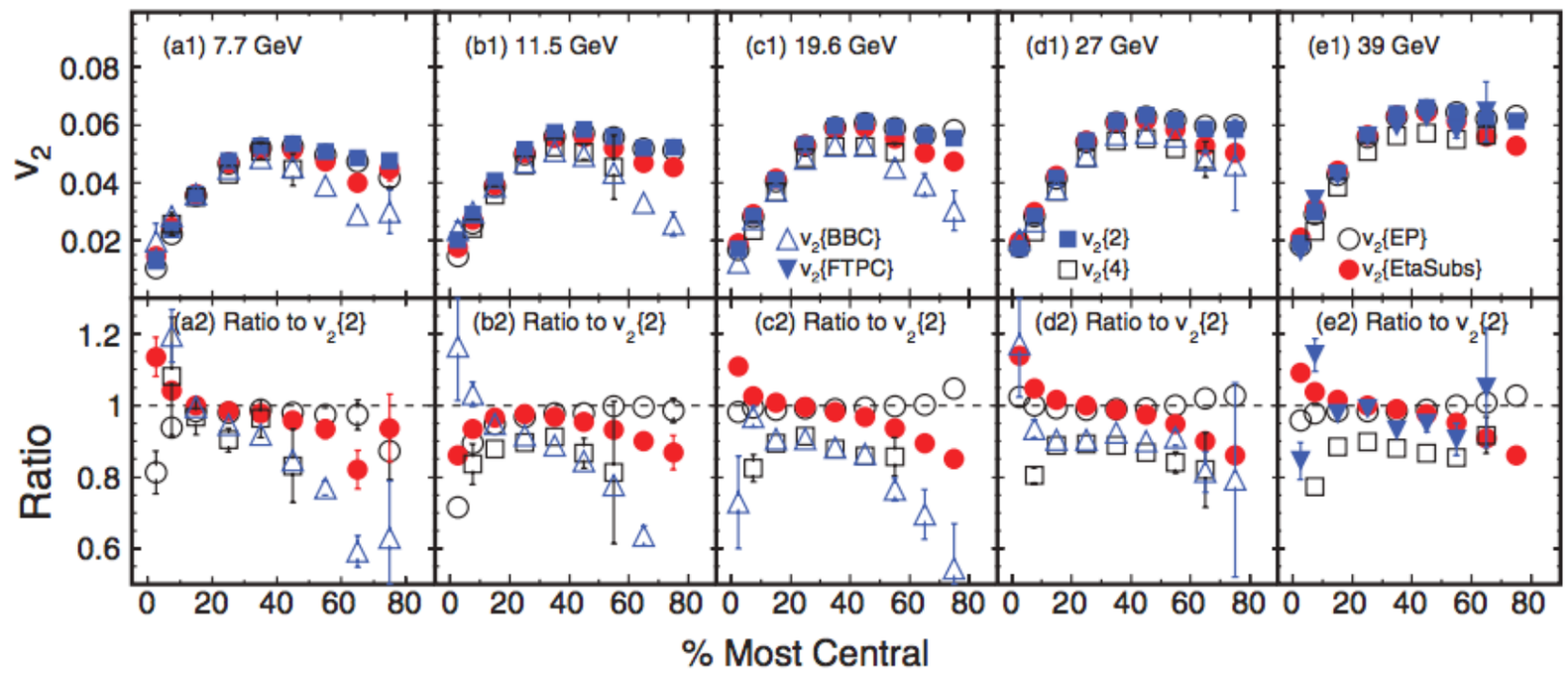
- Is hydro applicable to such small systems?
- Mean free path may be small relative to the size?

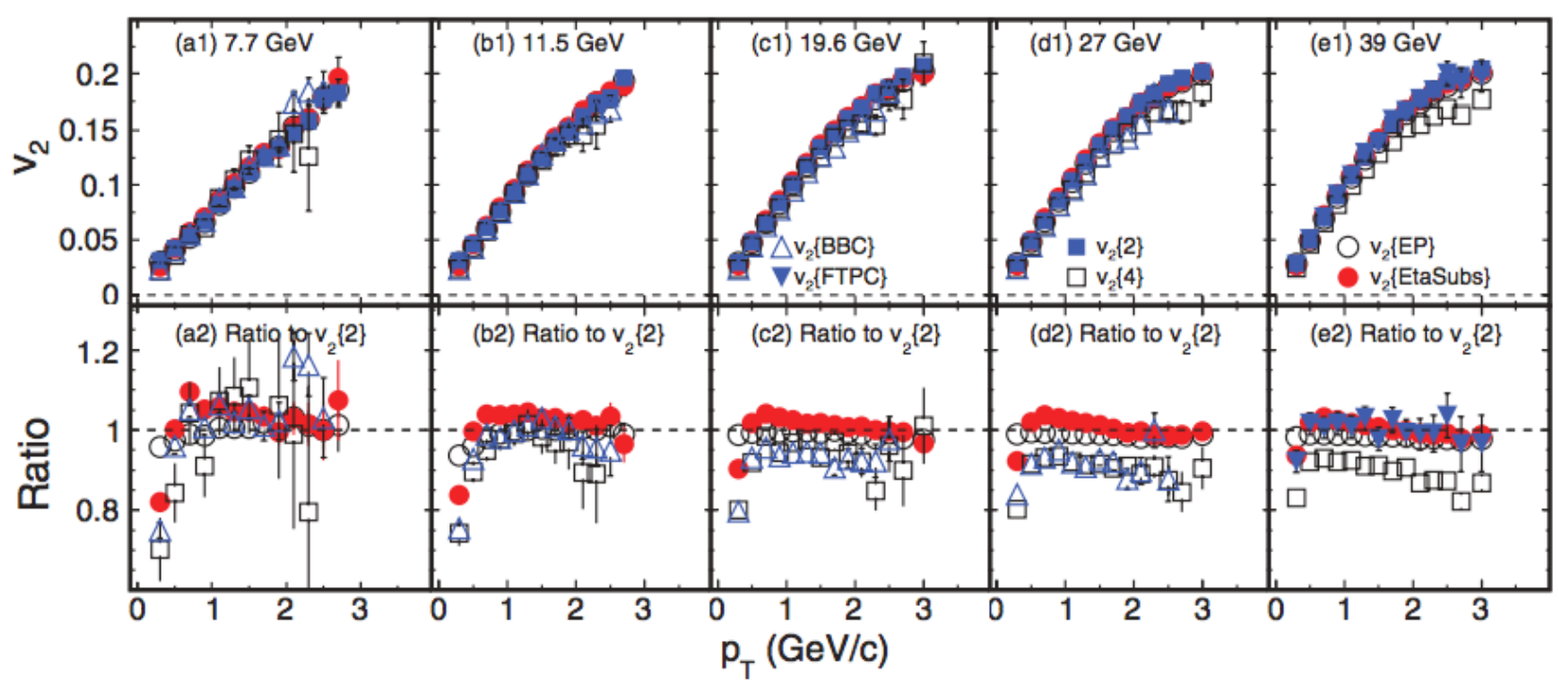


A. Bzdak, G.L. Ma, PRL 113, 252301 (2014)

Question2: v2 is independent with energy

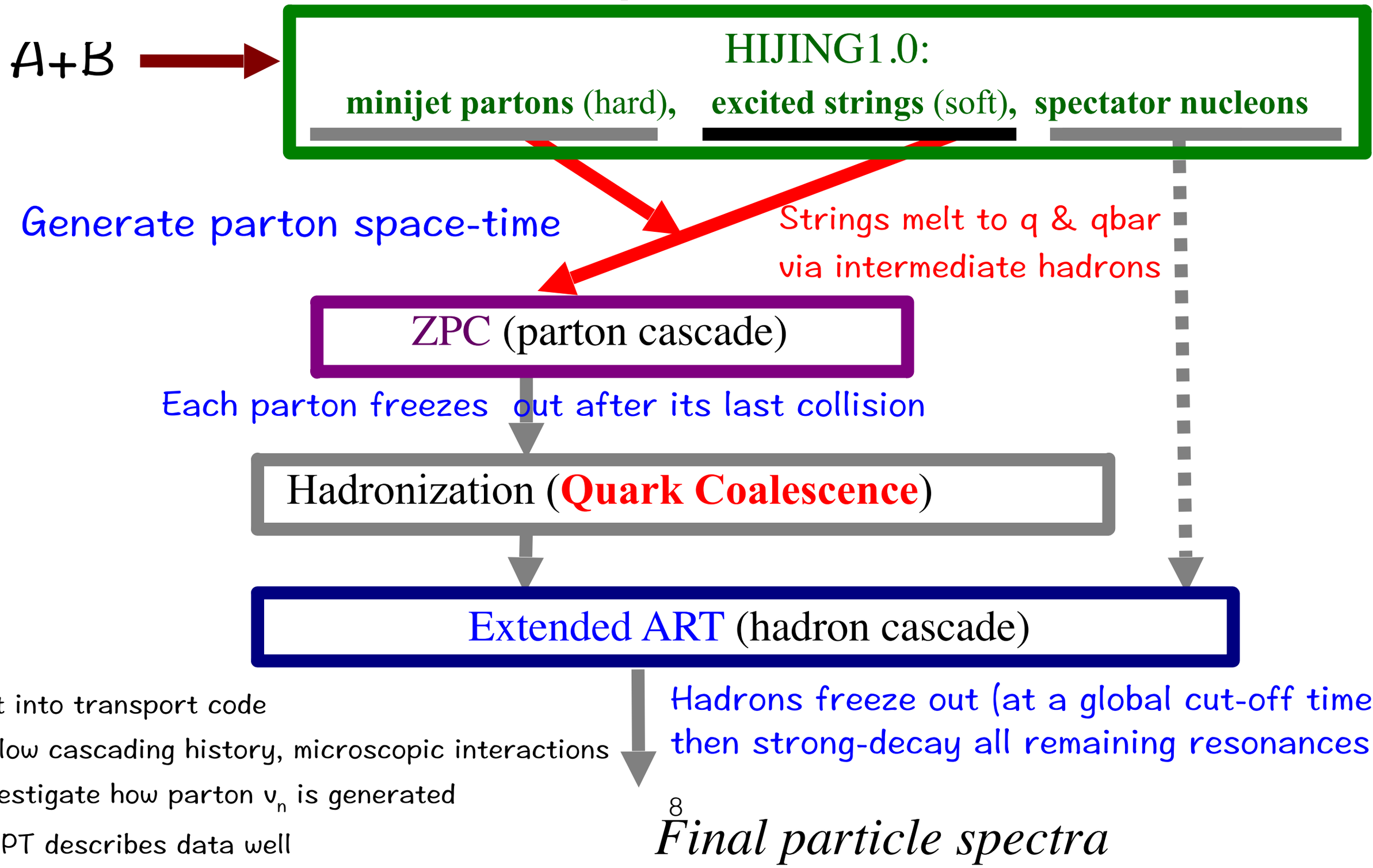
v2 in different energy scale is almost same. This is unexpected for hydrodynamic





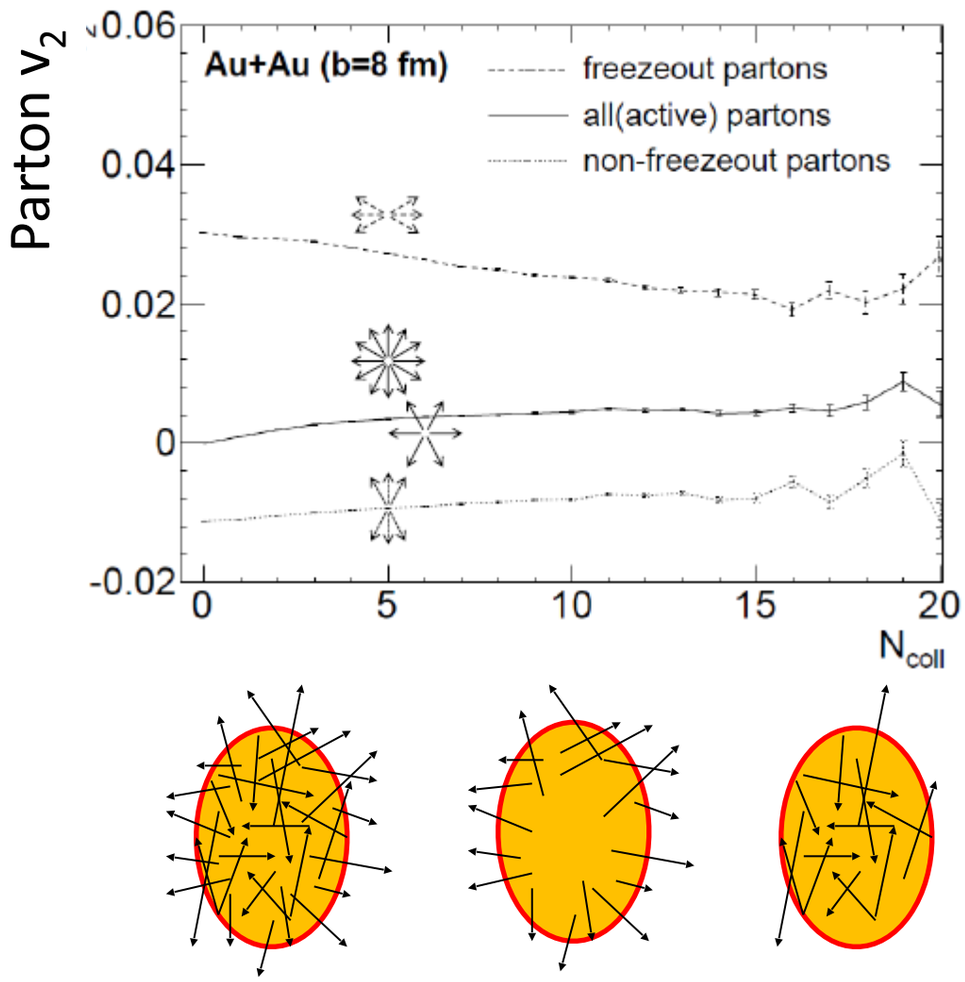
PhysRevC.86.054908

AMPT parton level



- Get into transport code
- Follow cascading history, microscopic interactions
- Investigate how parton v_n is generated
- AMPT describes data well

AMPT flow evolution



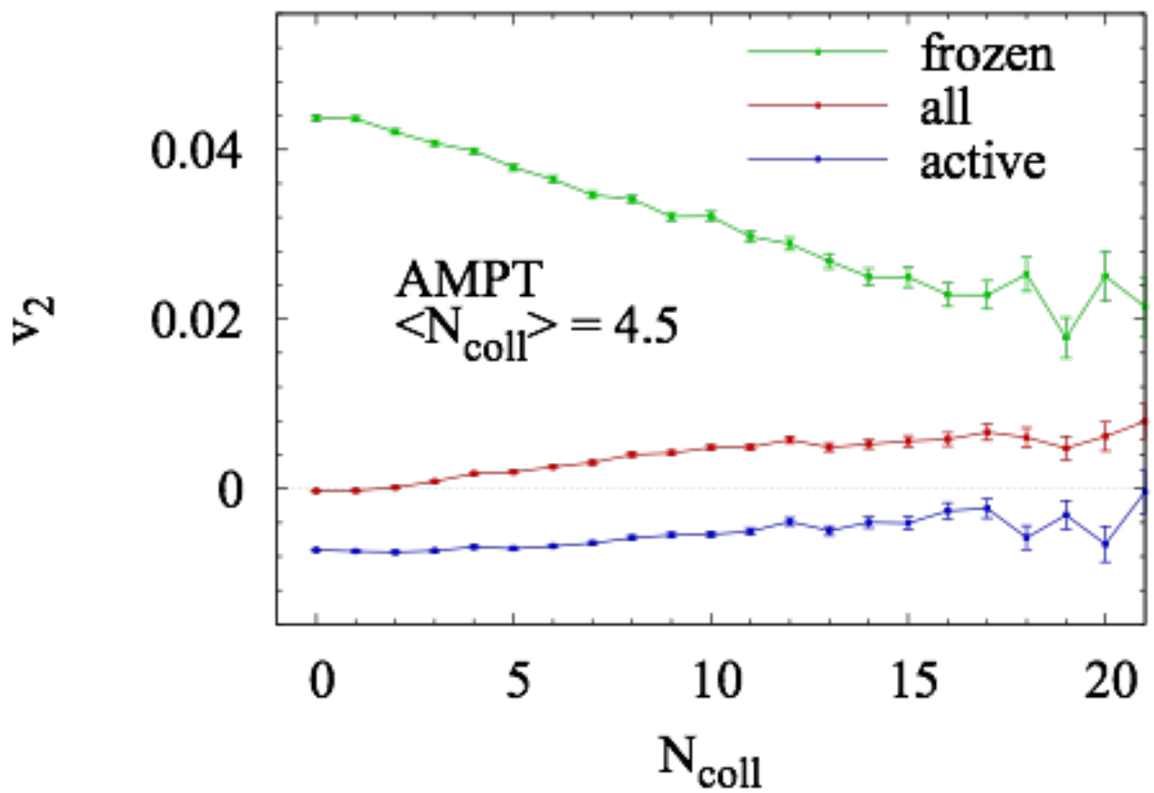
- Partons freeze out with large positive v_2, even when they do not interact at all.
- This is due to larger **escape probability** along x than y.
- Remaining partons start off with negative v_2, and become ~isotropic (v_2~0) after one more collision.
- Process repeats itself.
- Similar for v_3.
- Similar for d+Au collisions.

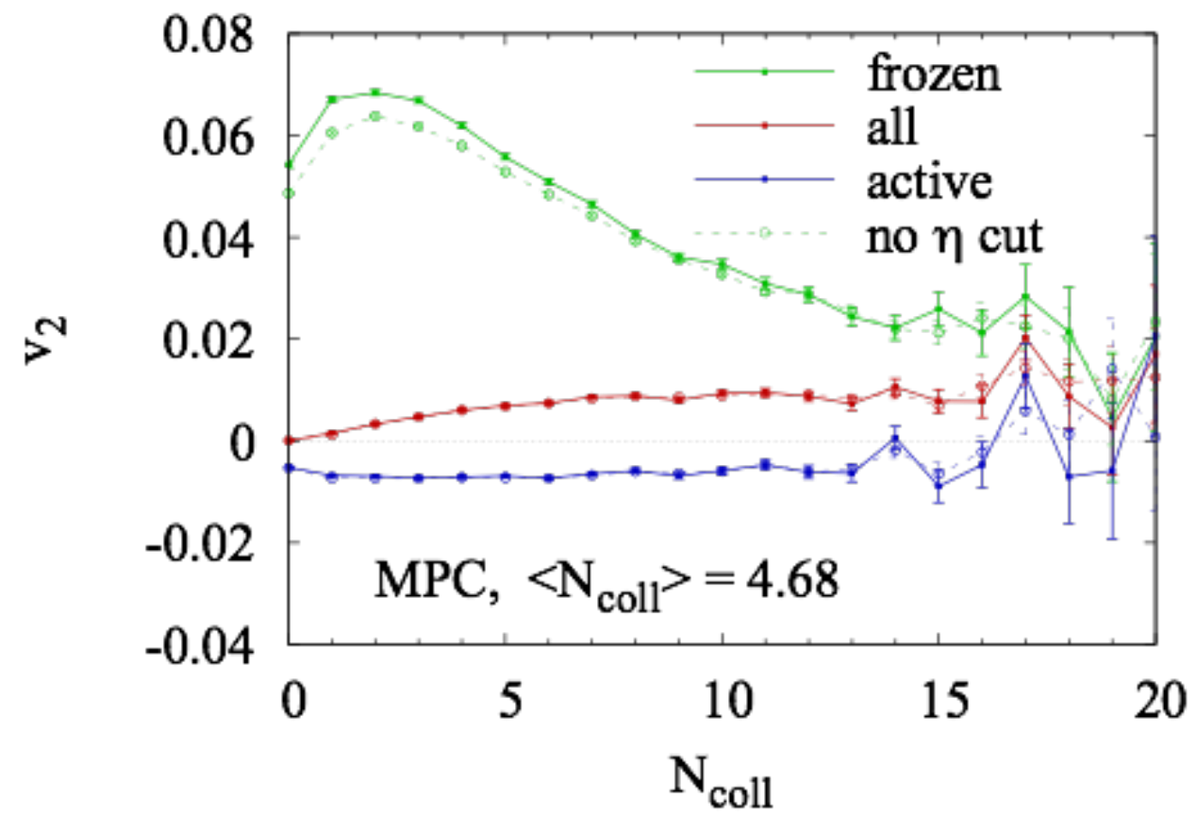
Same result for transport model

MPC gives essentially the same results at similar <Ncoll> as AMPT,

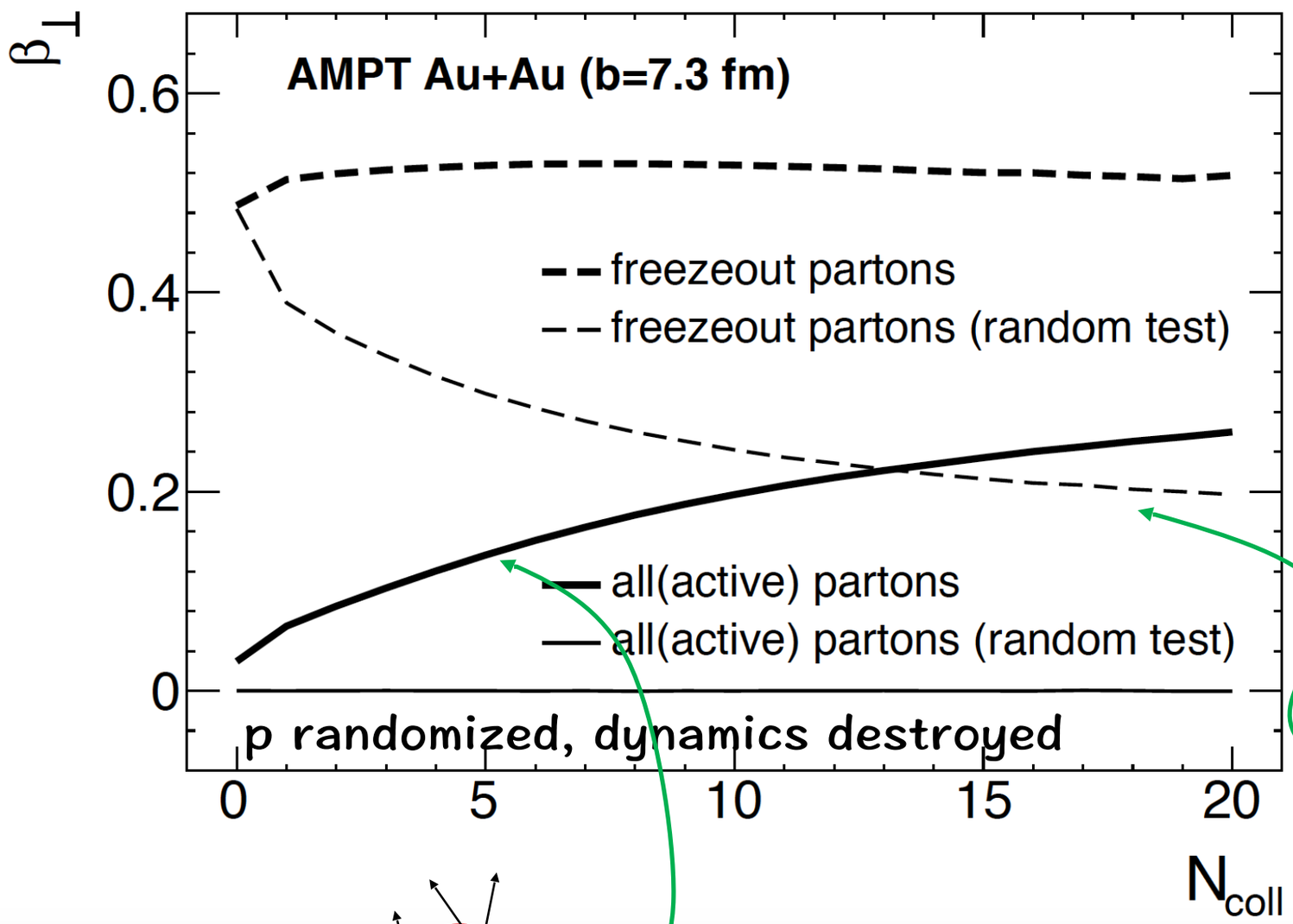
despite differences in

- parton initial condition (number density, P_T spectrum)
- dσ/dt, formation time, v2 magnitude, parton-subdivision.





Random AMPT

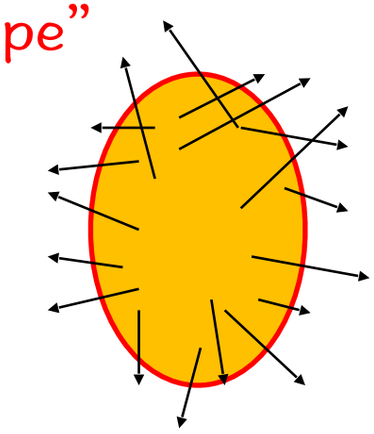


Strong r-p correlation

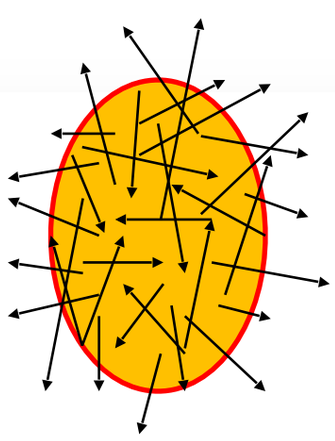
Increase purely from "**escape**" mechanism

Finite r-p correlation

r-p correlation purely from "escape" mechanism ("Surface" emission)

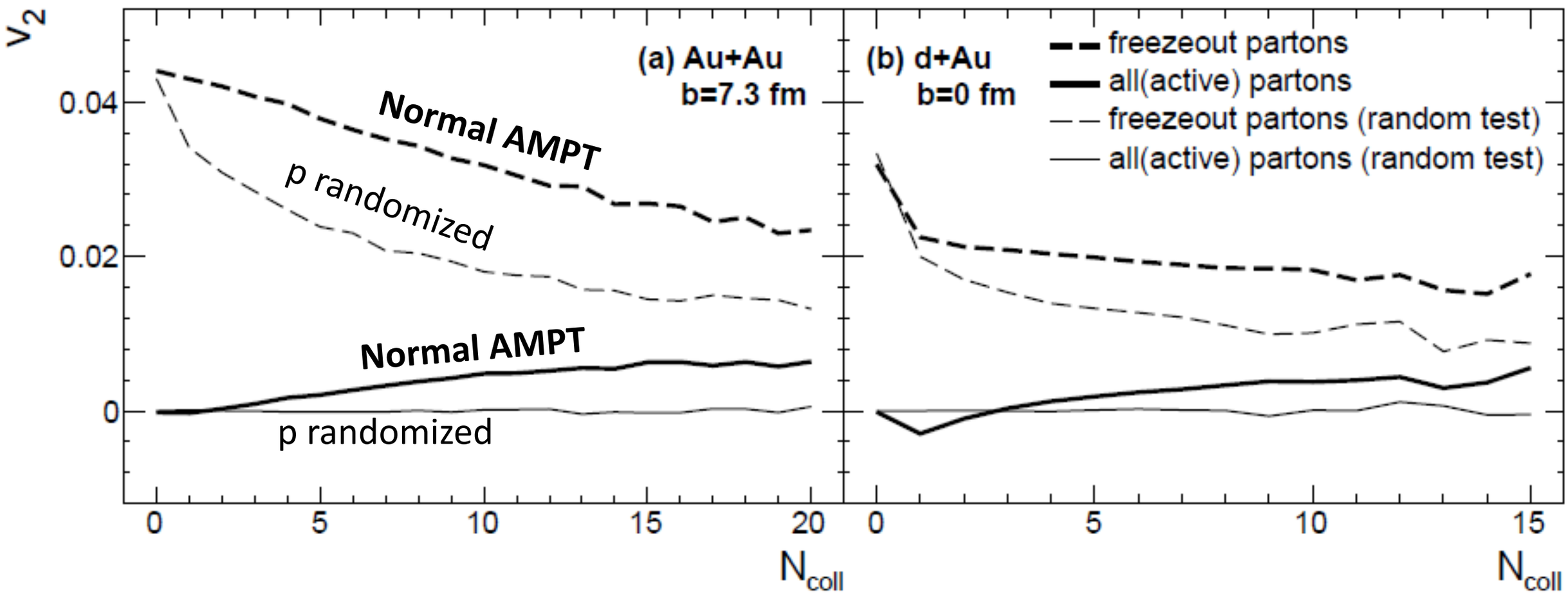


Collective motion, but not collectivity



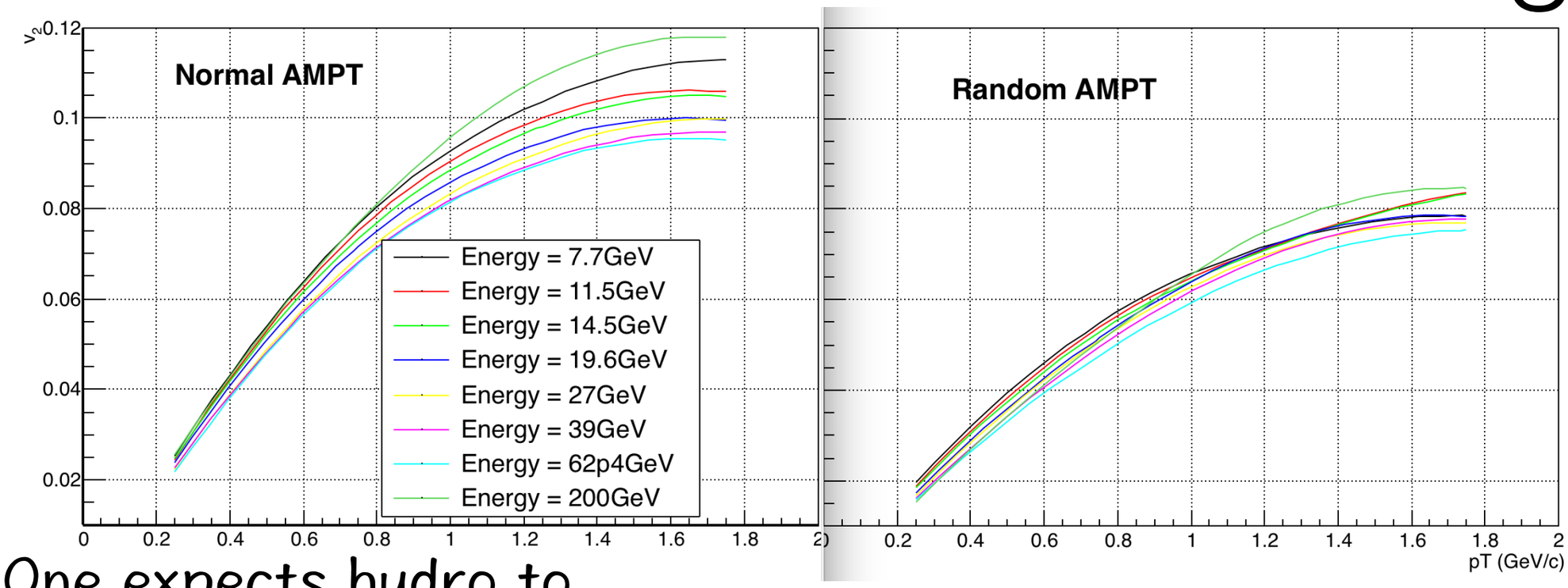
Collectivity

Hydro v2 vs. Escape v2

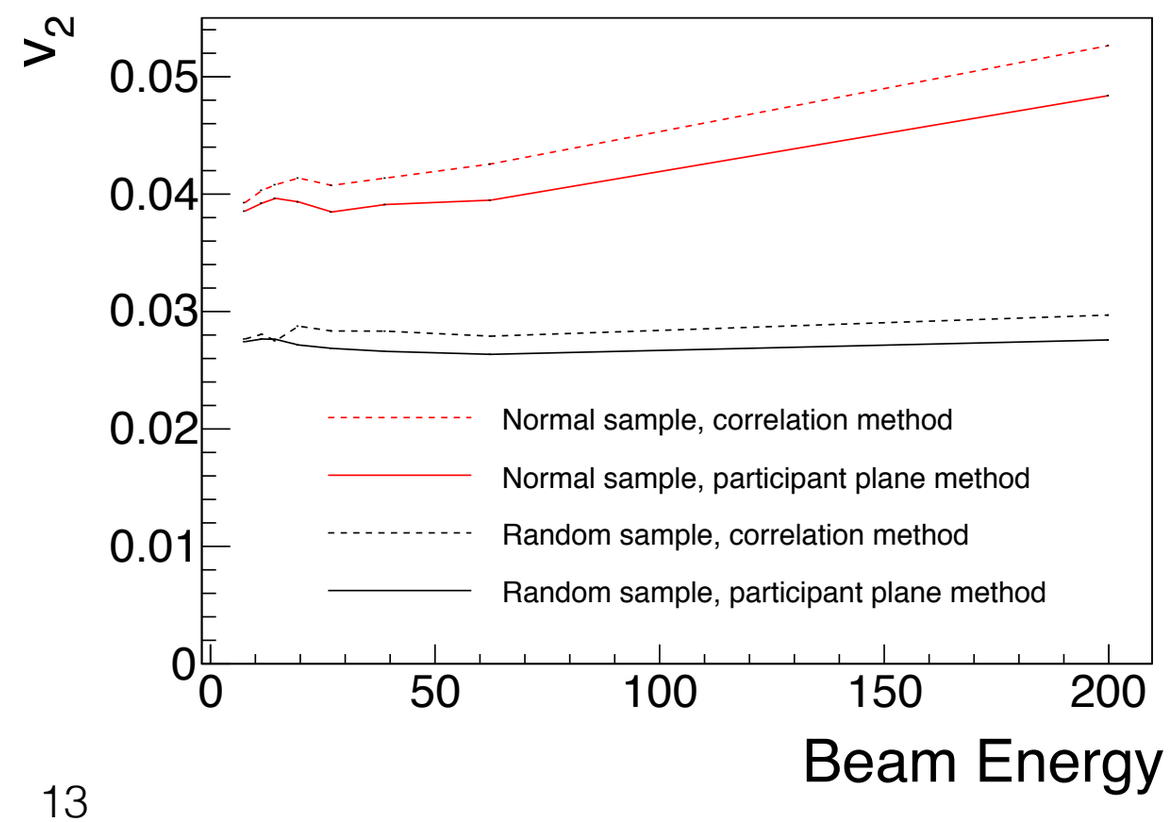


- Majority of anisotropy comes from the final-step "escape" mechanism.
- Escape yields a slightly larger v_2 in normal AMPT than in random case. The escape probability (parton sees) differs in these two cases.
- The partons start with small v_2 before escape (freezeout).
- This small v_2 is due to dynamics, result of hydrodynamic pressure push. It is this flow that is most relevant. However it plays a minor role.

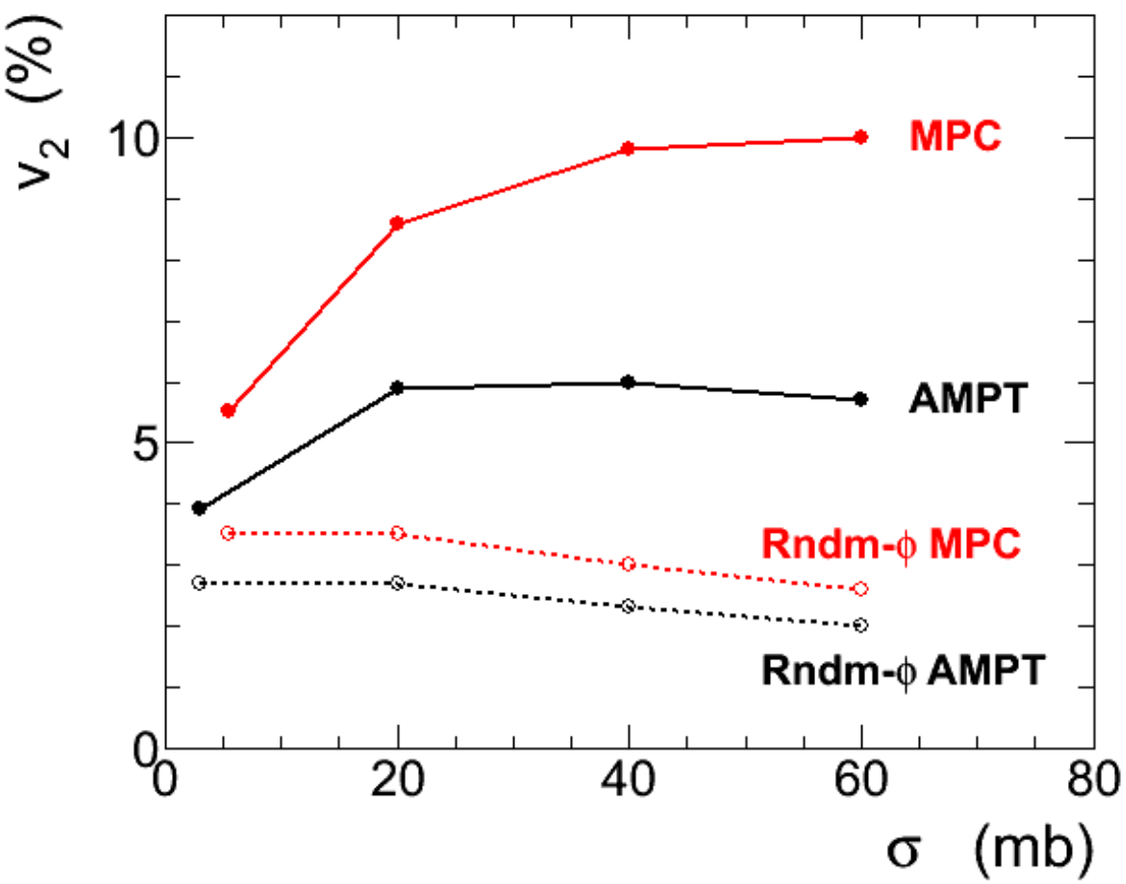
Hadron v2 in different energy

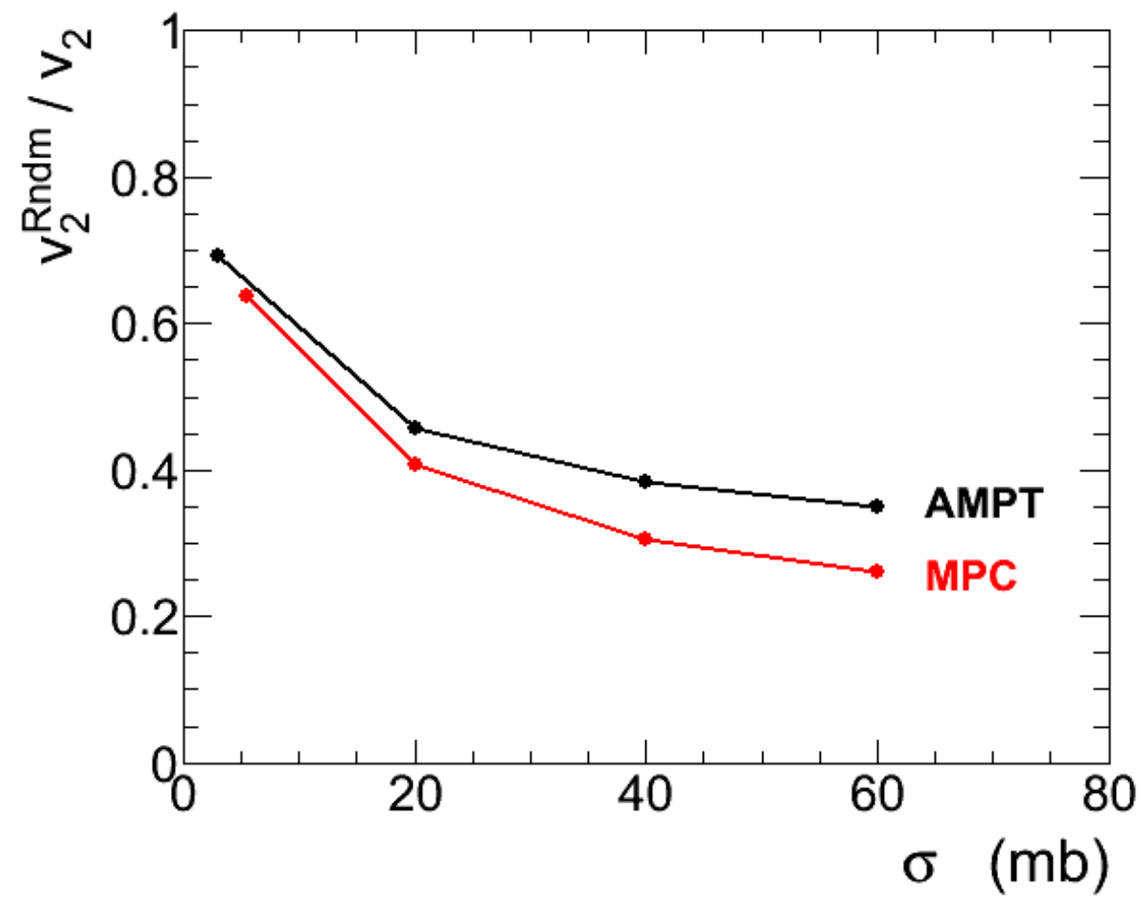


- One expects hydro to increase significantly with energy
- Energy "independence" may be an experimental evidence of "escape v2"
- The modest increase may be hydro to make up the remaining v2



v2 with different cross section





- Hydrodynamic flow will eventually dominate at large parton-parton cross sections (e.g. 60 mb), but unrealistic.
- The escape mechanism dominates at modest values of parton-parton cross sections.

Conclusion and outlook

- Escape mechanism can describe the anisotropic flow of both small system and large system.

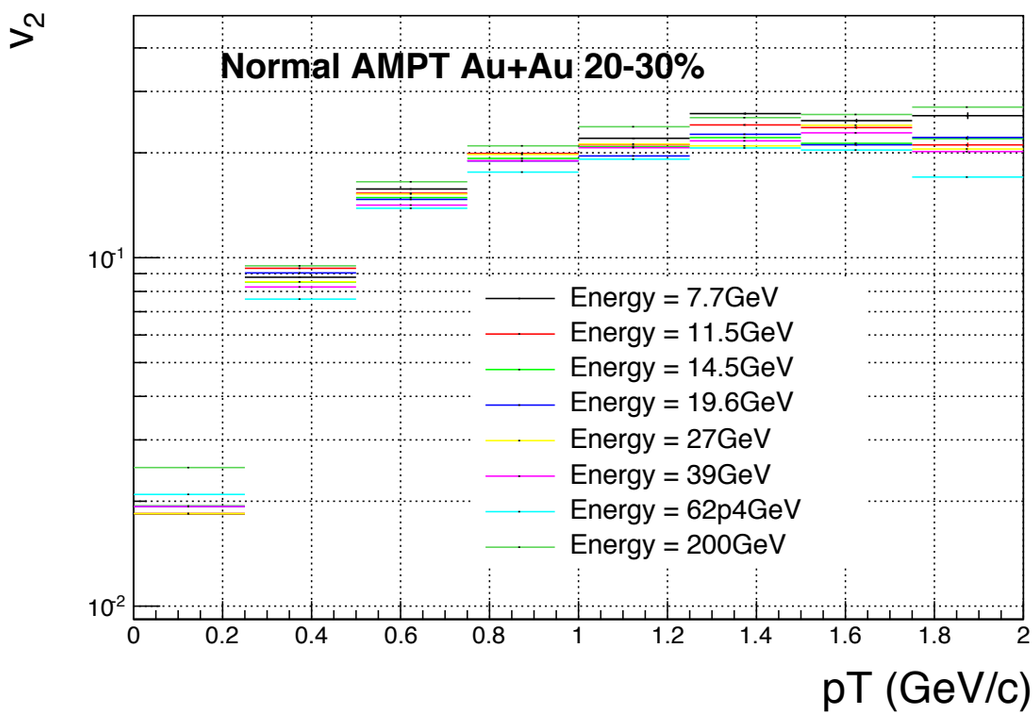
- Escape mechanism can explain the relationship between flow and energy.

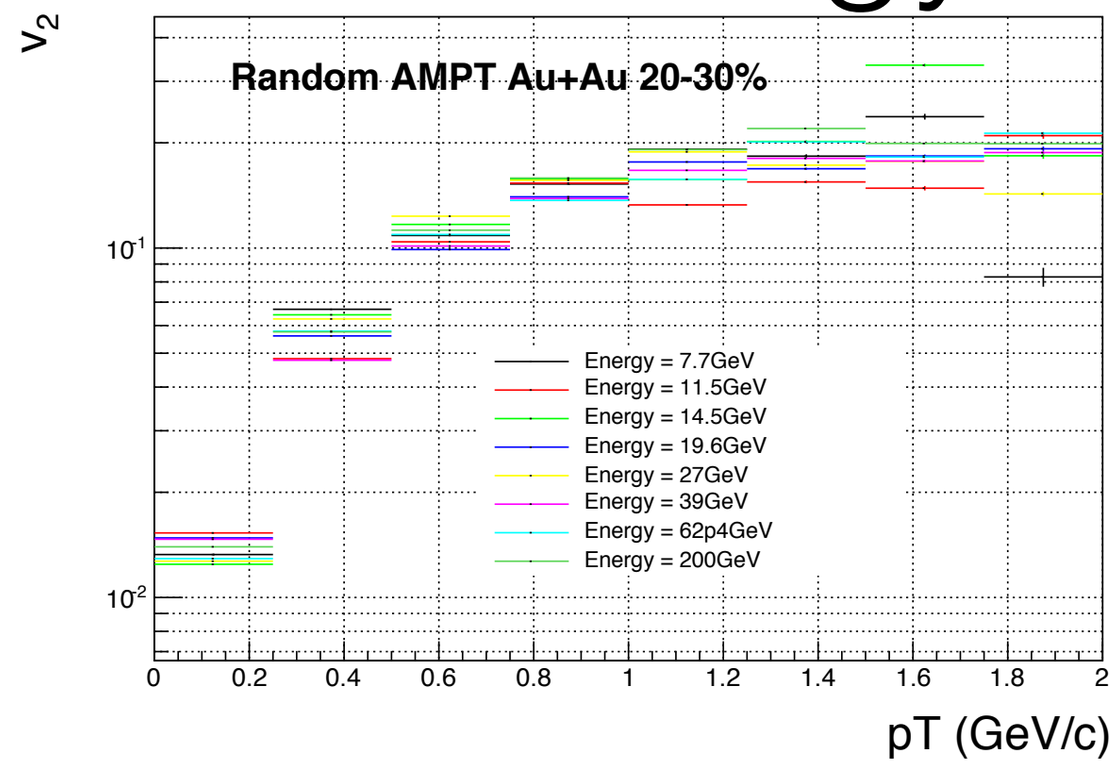
- Hydrodynamics needs to include escape mechanism.

Thank you!

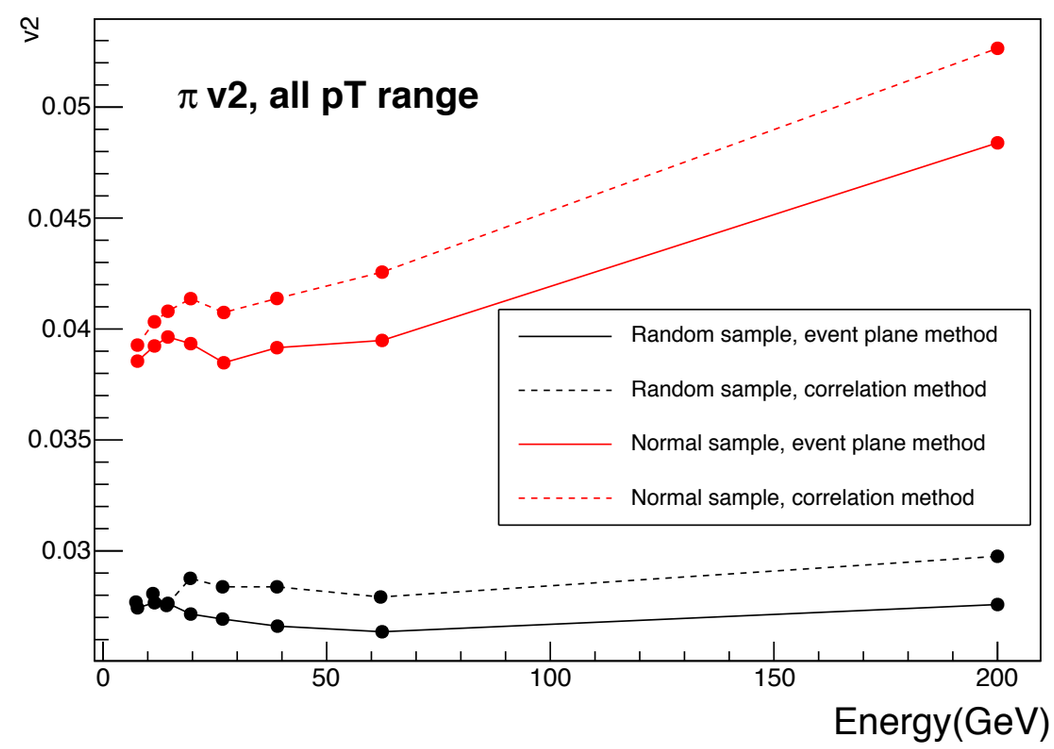
back up

Hadron v2 in different energy

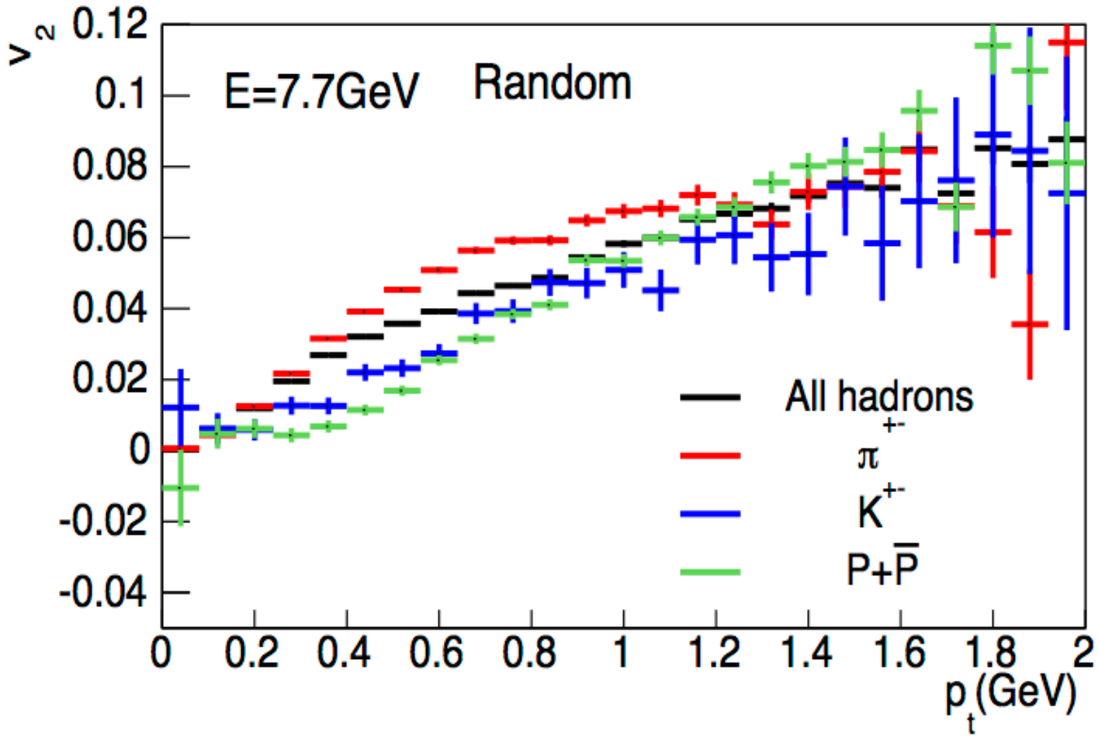


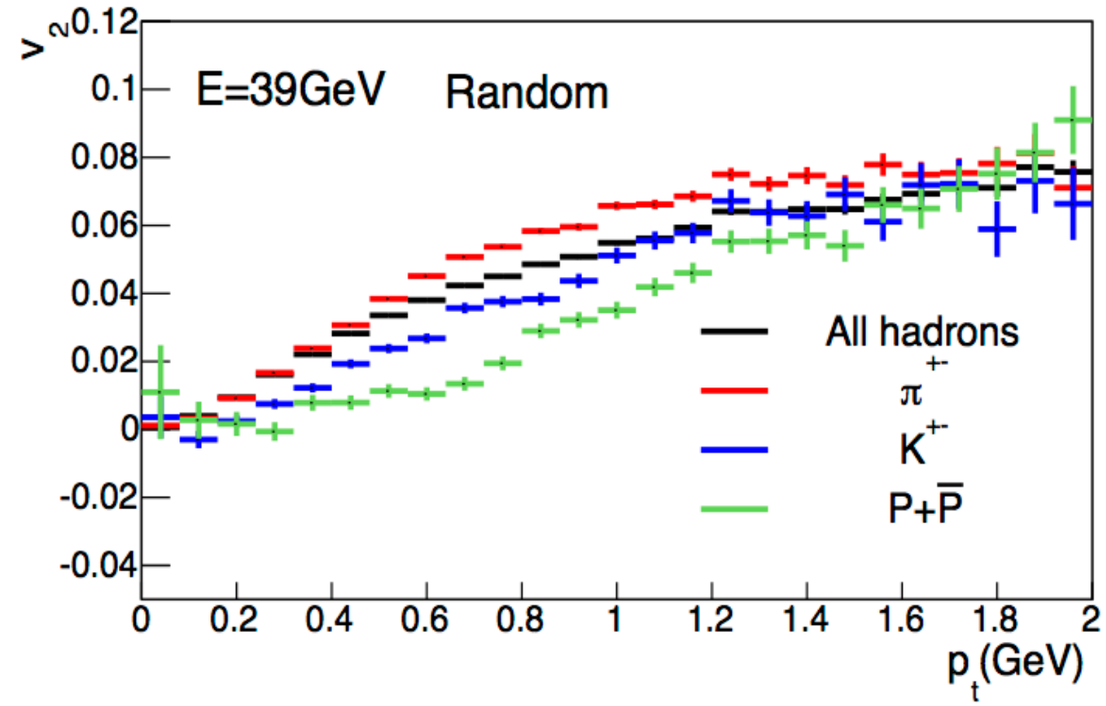


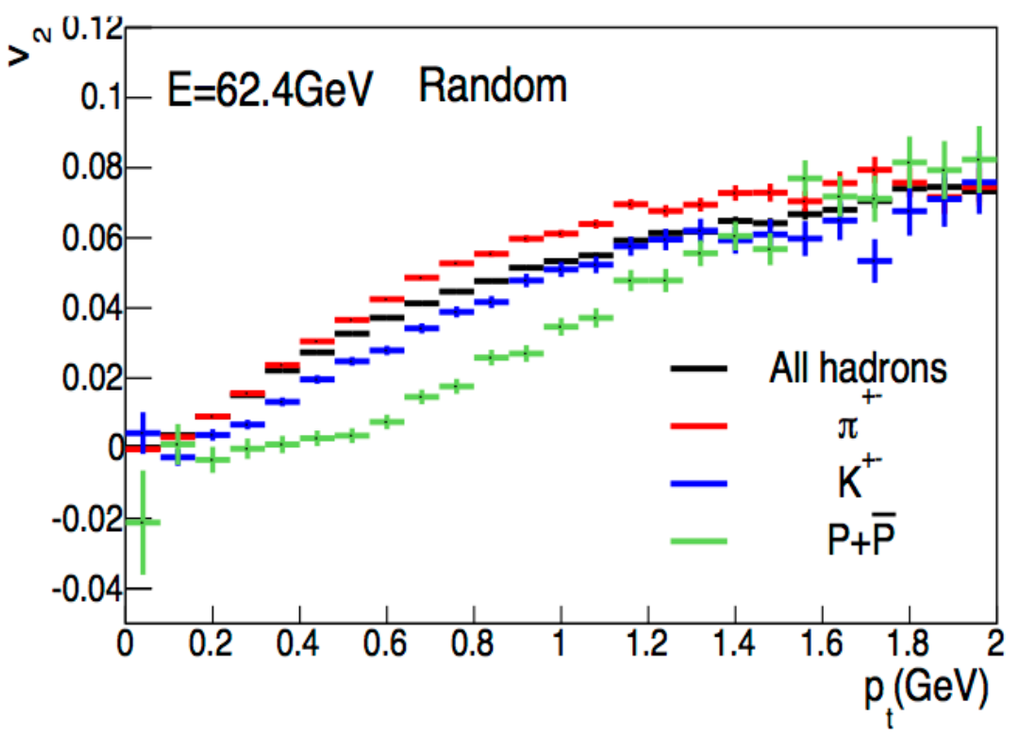
- Hydro v2 increases with energy
- Random AMPT is NOT related to energy
- AMPT result fits data well

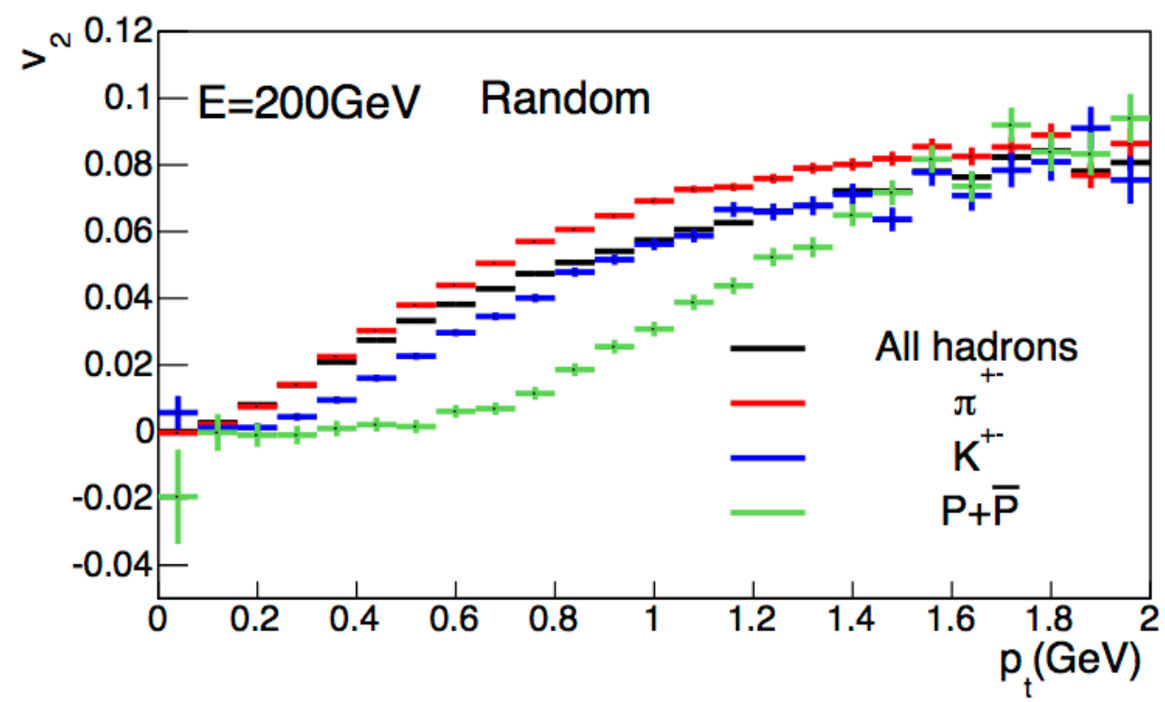


The V2 in Au+Au collisions with different hadrons



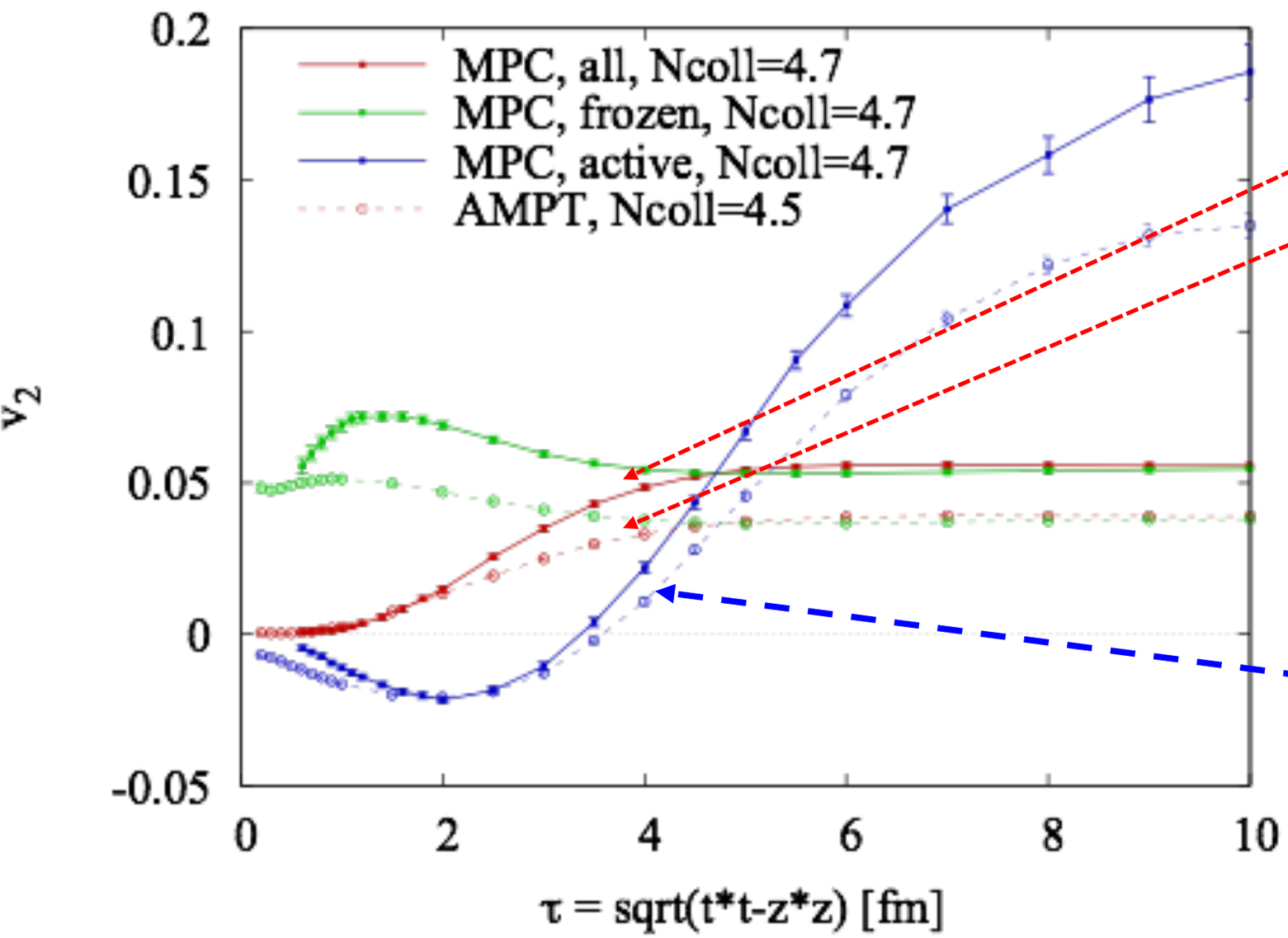






MPC model check

Time-dependence of 3 parton populations:
frozen partons, active partons, & all partons

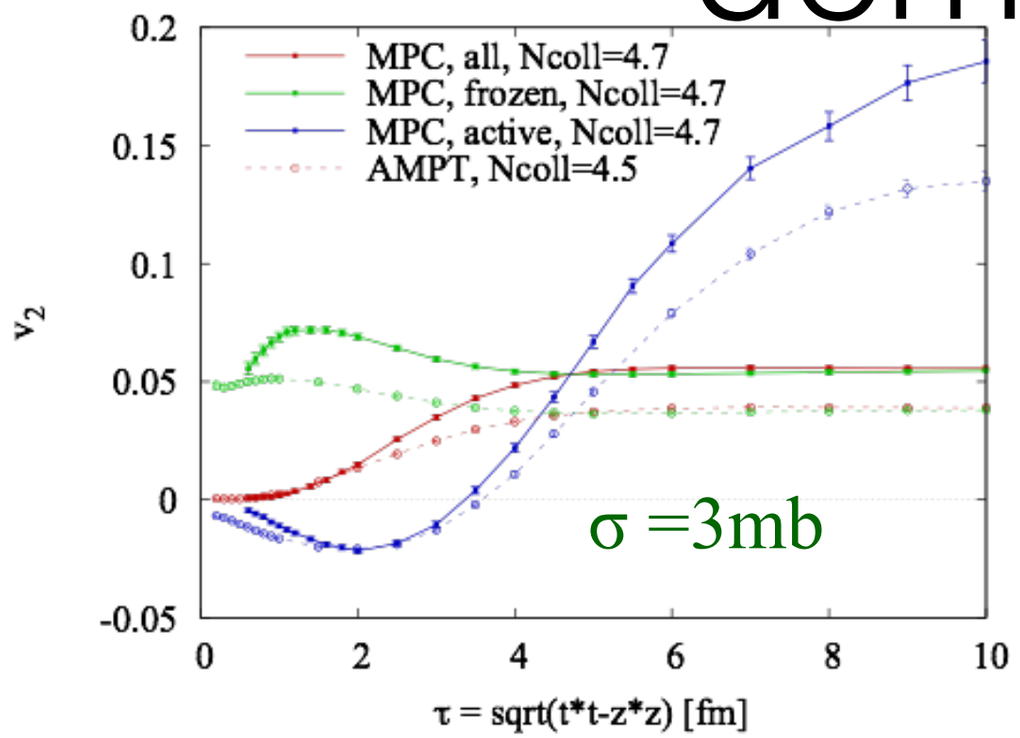


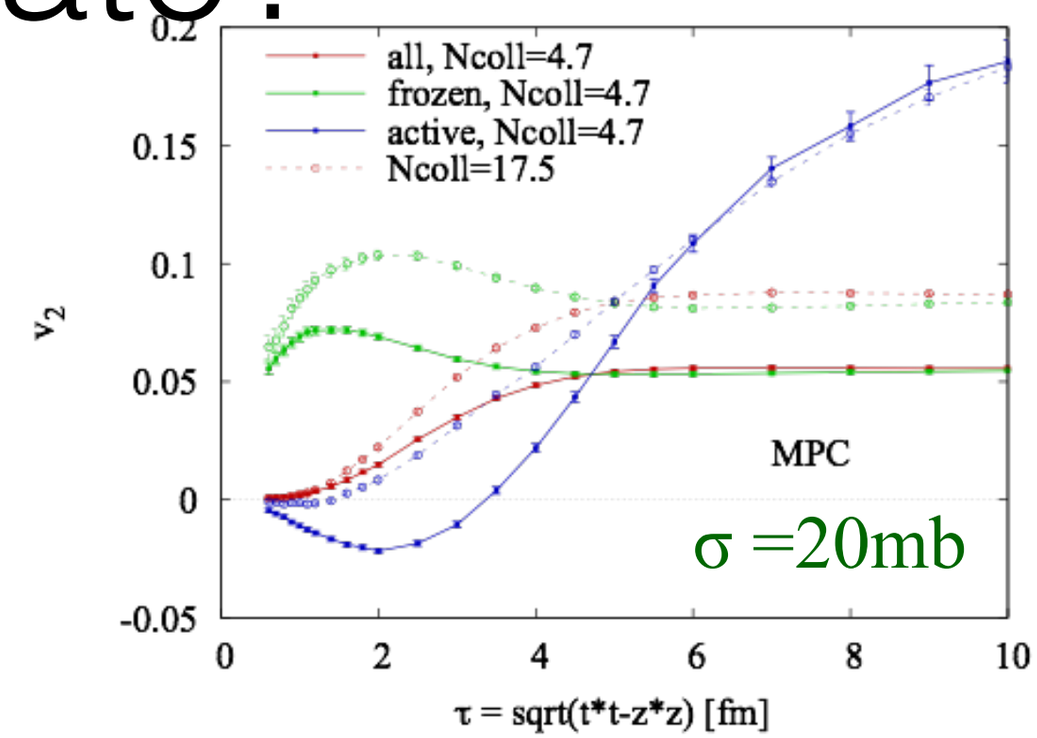
v2 of all partons gradually builds up within ~4 fm/c

v2 of active partons is small or negative during most of v2 build-up

MPC gives essentially the same results when taking a similar <Ncoll>

When will hydrodynamic dominate?



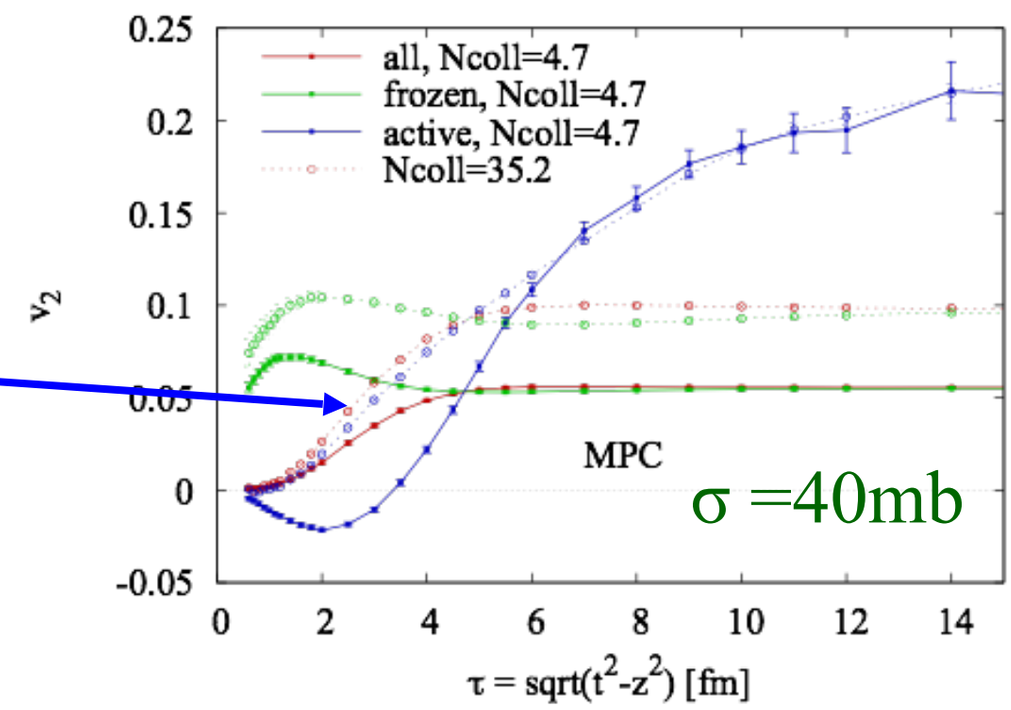


At very high <Ncoll> or σ :

v2 of active partons

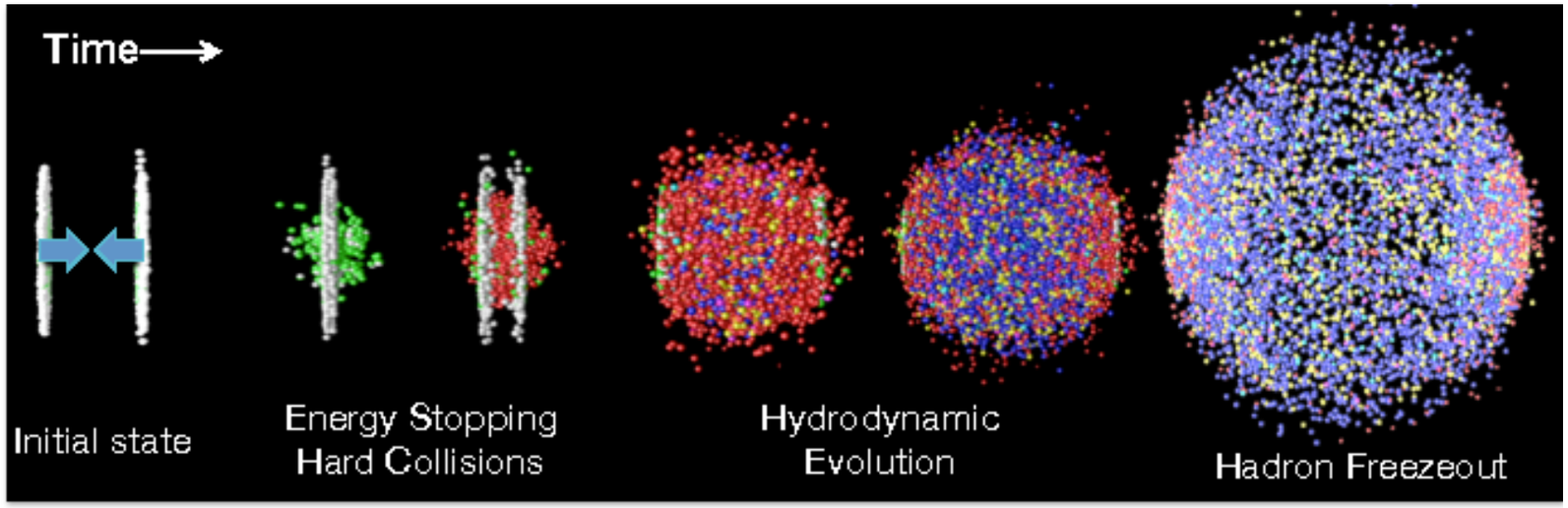
follows the total v2 closely

during the early v2 build-up



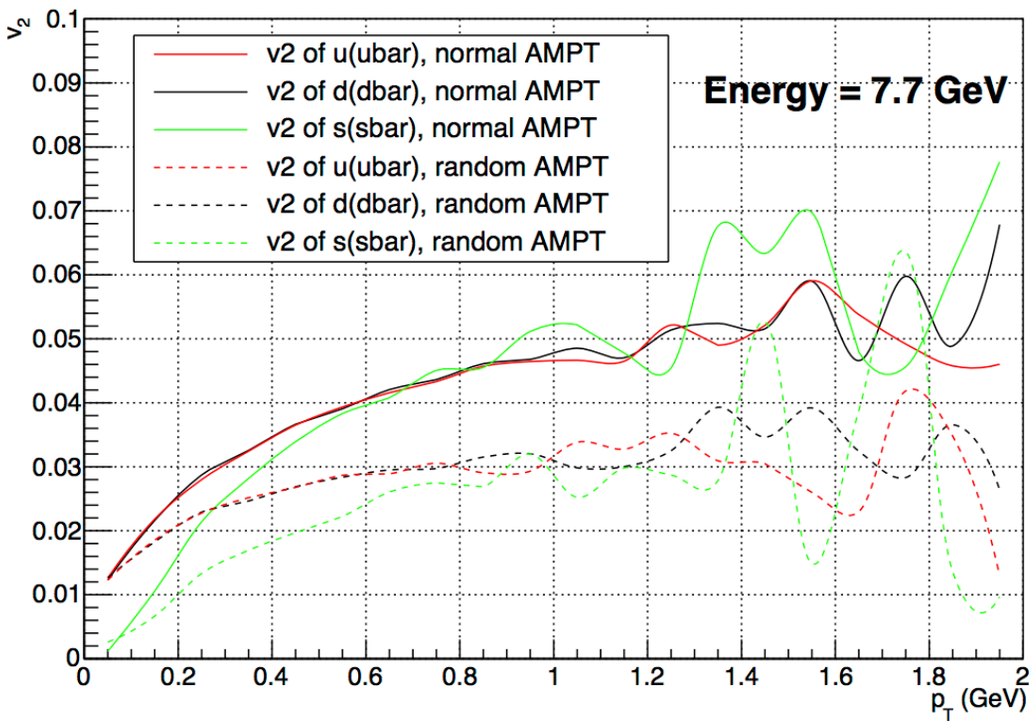
AMPT introduction

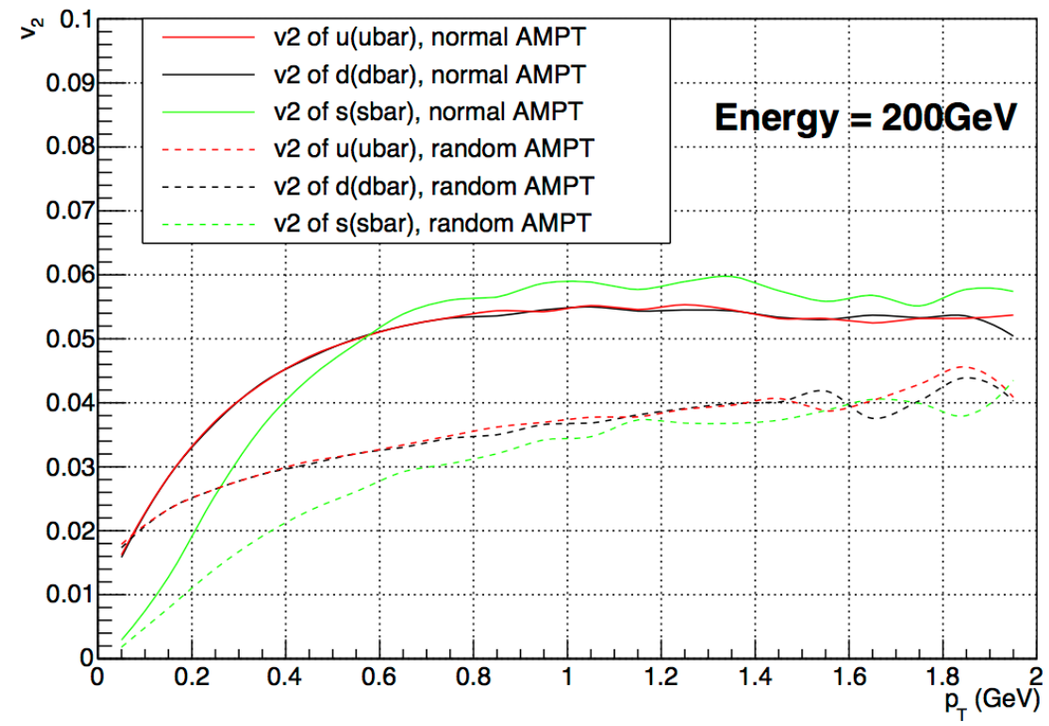
- AMPT: A Multi-Phase Transport (string melting turned on)
- Partons (quarks) liberated from nucleons and strings
- Parton cascading: elastic scattering with 3 mb cross-section
- Partons cease to interact: freeze-out, coalescence into hadrons

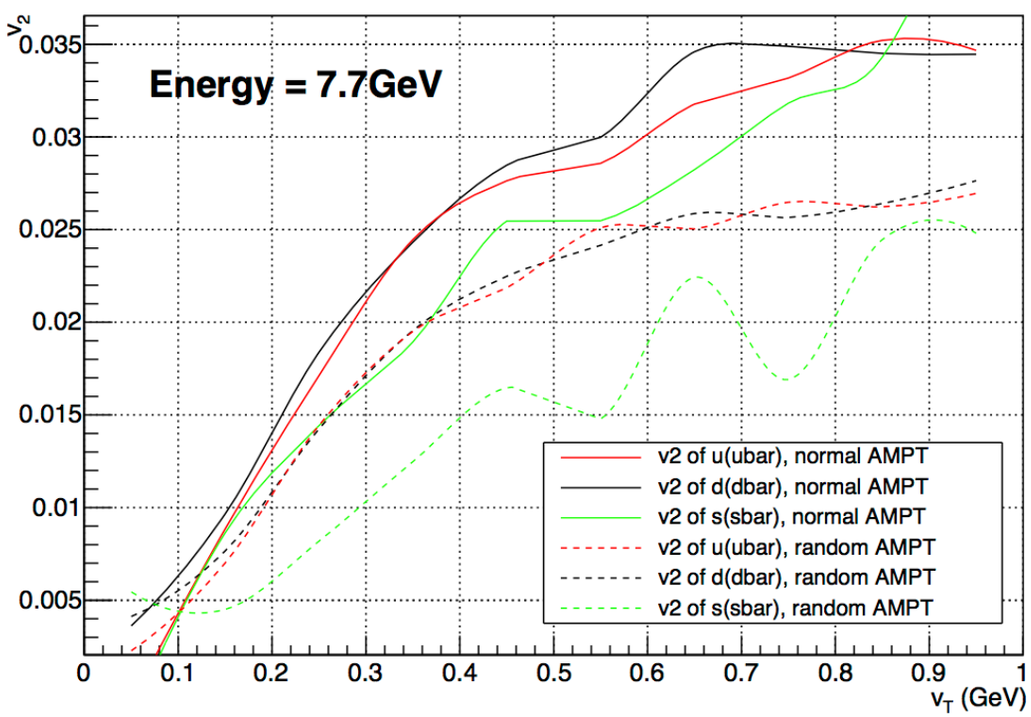


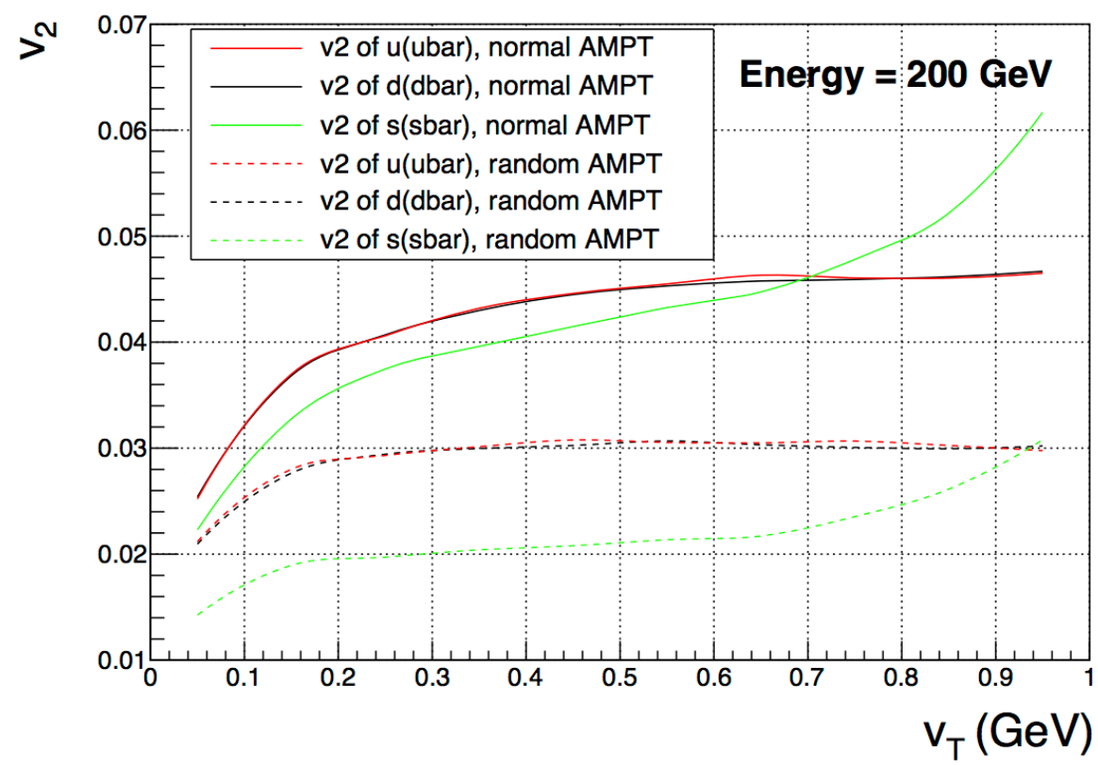
Why AMPT?

- Get into transport code
- Follow cascading history, microscopic interactions
- Investigate how parton v_n is generated
- AMPT describes data well


Energy = 7.7 GeV
v2 of u(ubar), normal AMPT
v2 of d(dbar), normal AMPT
v2 of s(sbar), normal AMPT
v2 of u(ubar), random AMPT
v2 of d(dbar), random AMPT
v2 of s(sbar), random AMPT
v_2
p_T (GeV)

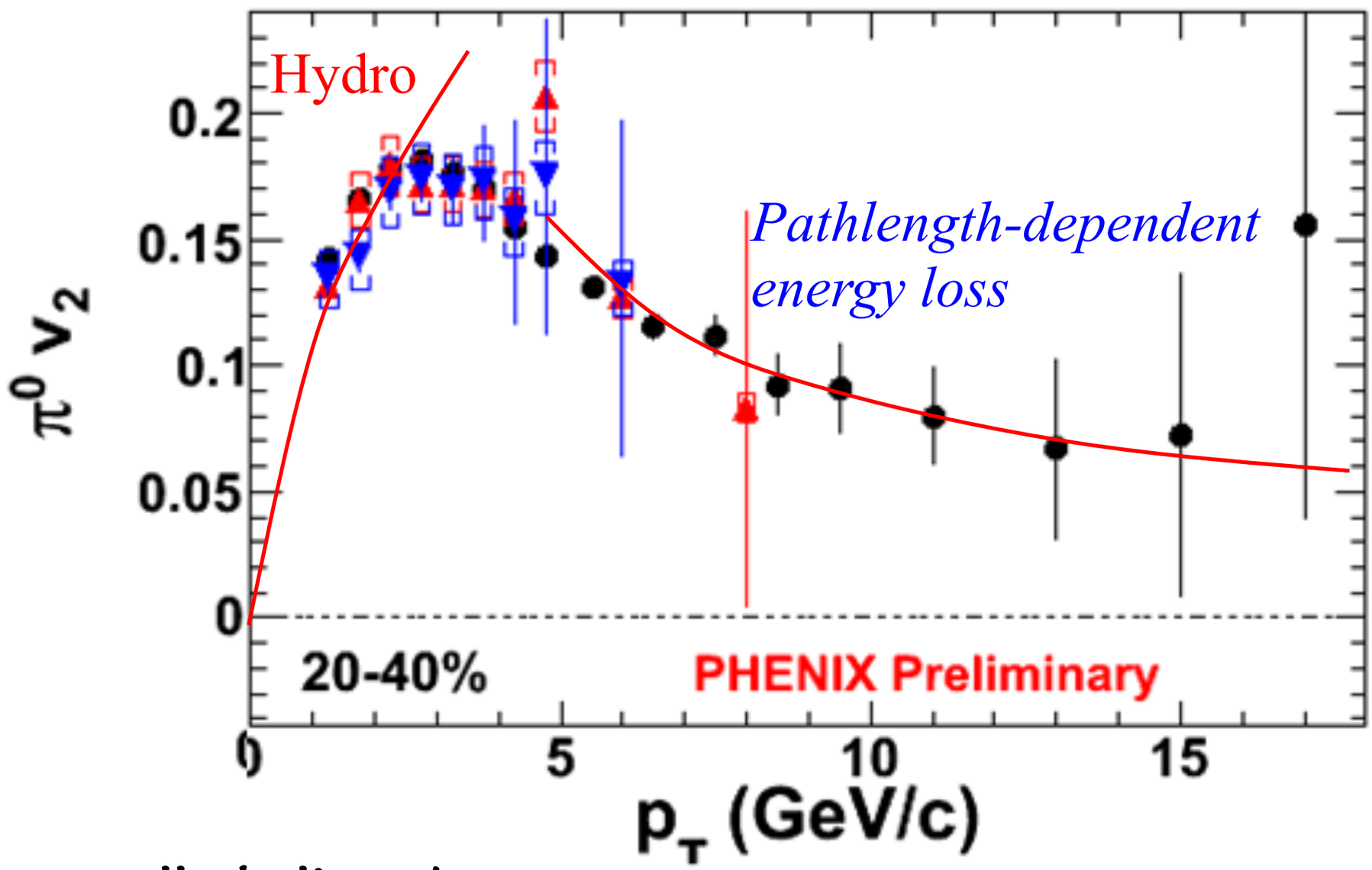

Energy = 200GeV
v2 of u(ubar), normal AMPT
v2 of d(dbar), normal AMPT
v2 of s(sbar), normal AMPT
v2 of u(ubar), random AMPT
v2 of d(dbar), random AMPT
v2 of s(sbar), random AMPT
v_2
p_T (GeV)


Energy = 7.7GeV
v2 of u(ubar), normal AMPT
v2 of d(dbar), normal AMPT
v2 of s(sbar), normal AMPT
v2 of u(ubar), random AMPT
v2 of d(dbar), random AMPT
v2 of s(sbar), random AMPT
v_2
v_T (GeV)


Energy = 200 GeV
v2 of u(ubar), normal AMPT
v2 of d(dbar), normal AMPT
v2 of s(sbar), normal AMPT
v2 of u(ubar), random AMPT
v2 of d(dbar), random AMPT
v2 of s(sbar), random AMPT
v_2
v_T (GeV)

Why do we use transport?

A different paradigm for high-p_T



It is generally believed:

high-p_T observables cannot be described by **hydrodynamics**,

one needs particle **transport** (plus **energy loss, fragmentation, etc**)

Summary of the comparison

Parton-parton σ	3 mb		24 mb		60 mb	
	Normal	*Random*	*Normal*	*Random*	*Normal*	*Random*
<Ncoll>	*4.6*	*5.6*	*14.2*	*23.9*	*19.9*	*37.8*
v_2	*3.7%*	*2.4%*	*5.9%*	*2.6%*	*5.4%*	*1.8%*
Escape contribution to v_2	*65%*		*44%*		*33%*	
Hydro contribution	*35%*		*56%*		*67%*	

	<Ncoll>	final v2	before <Ncoll>	before v2
Au+Au random	5.76	2.65%	5.8	2.7%
Au+Au normal	4.60	3.85%	4.5	3.9%
d+Au random	**1.39**	2.47%	**1.9**	2.5%
d+Au normal	1.15	2.65%	1.1	2.7%

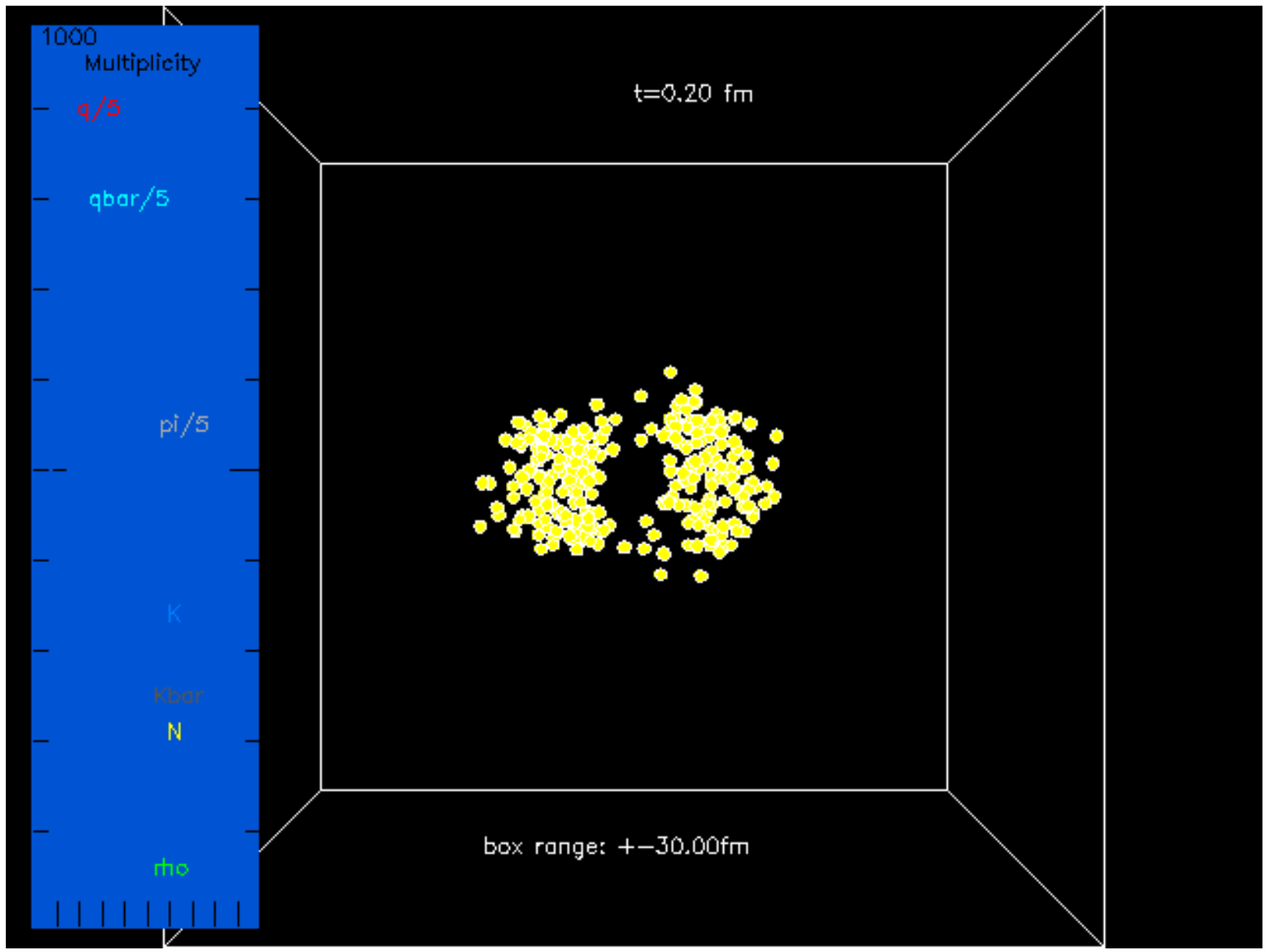
Summary

TABLE I: $\langle N_{\rm coll}\rangle$ and $\langle v_2\rangle$ of all final partons from the normal (first number in each column) and the azimuth-randomized transport model results (second number).

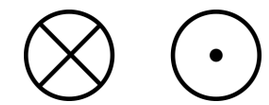
	AMPT d+Au (b=0 fm)		Au+Au (AMPT b=7.3 fm)			MPC Au+Au (b=8 fm)		
σ	3 mb		3 mb	20 mb	40 mb	5.5 mb	20 mb	40 mb
$\langle N_{\rm coll}\rangle$	1.1	1.9	4.5 5.6	13.2 21.7	17.1 31.6	4.4 5.4 (mid-y?)	16.4 xx	33.1 xx
$\langle v_2\rangle$	2.7%	2.5%	3.7% 2.4%	5.7% 2.5%	5.8% 2.2%			
$\frac{\langle v_2\rangle_{\rm random}}{\langle v_2\rangle_{\rm normal}}$	93%		65%	44%	38%	xx%	xx%	xx%

- Escape mechanism dominates
  - for small systems
  - and even for semi-central AuAu at RHIC
- Hydrodynamic collective flow
  - would dominates at very high σ or <Ncoll>

AMPT in parton level



Particle # vs time



Beam axes

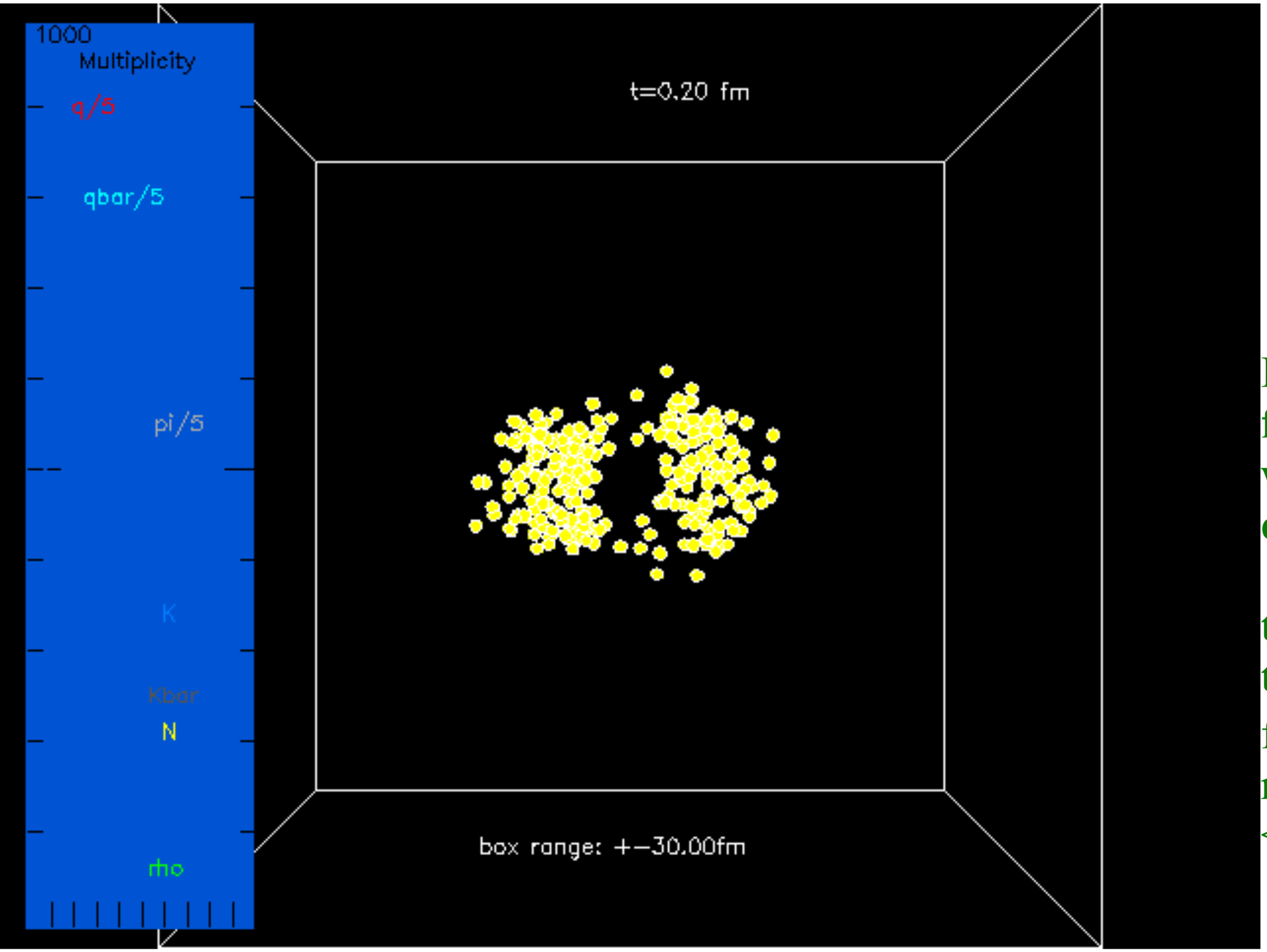
60fm-long box;

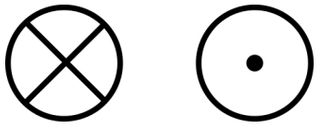
shows only formed particles.

1st frame: right after the primary collision, only spectator nucleons are formed.

Our Picture of v_n Development

A b=10 fm Au+Au event at 200AGeV from String Melting AMPT





Beam axes

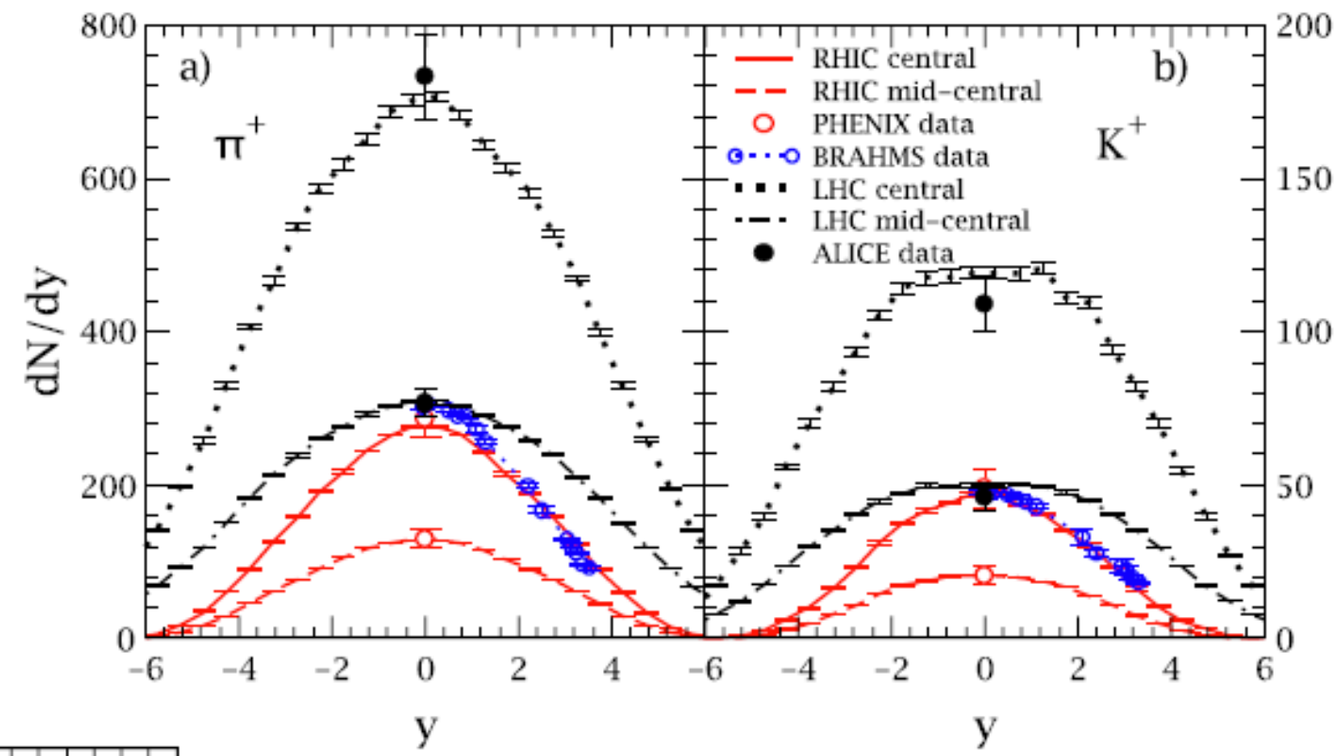
Particles freeze out with ϕ-dependent escape probability,

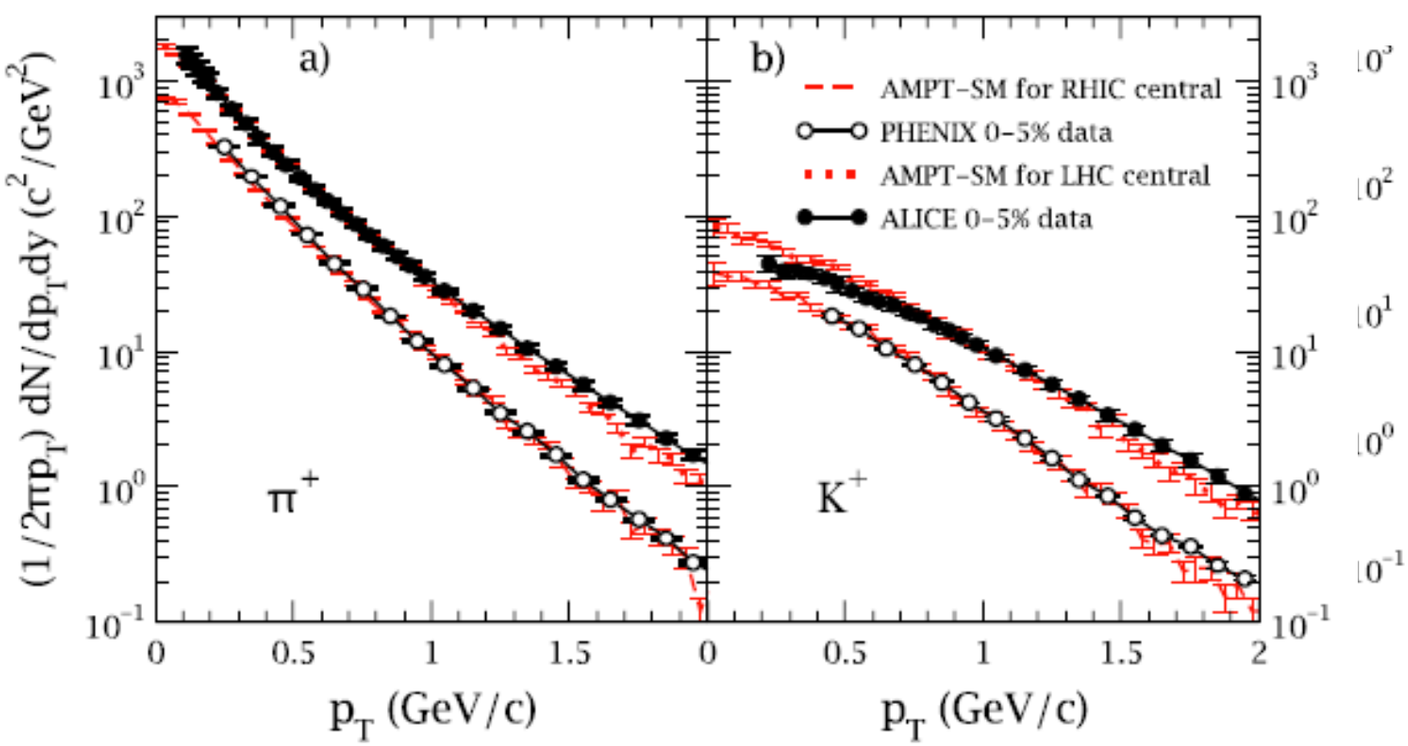
this dominates the final v_2

for collisions at relatively low <Ncoll>.

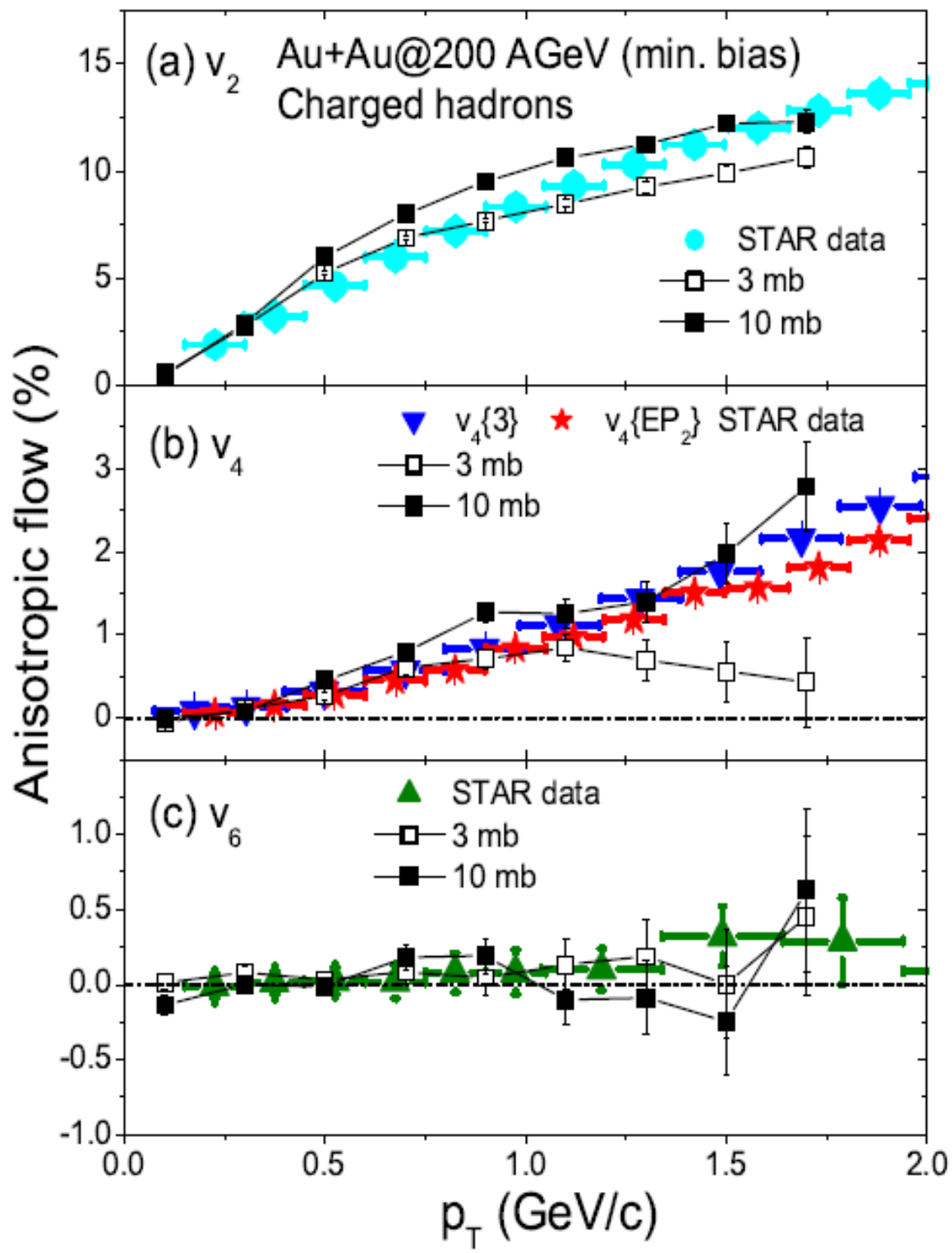
AMPT describes data

Z.-W. Lin, PRC90 (2014) 1, 014904



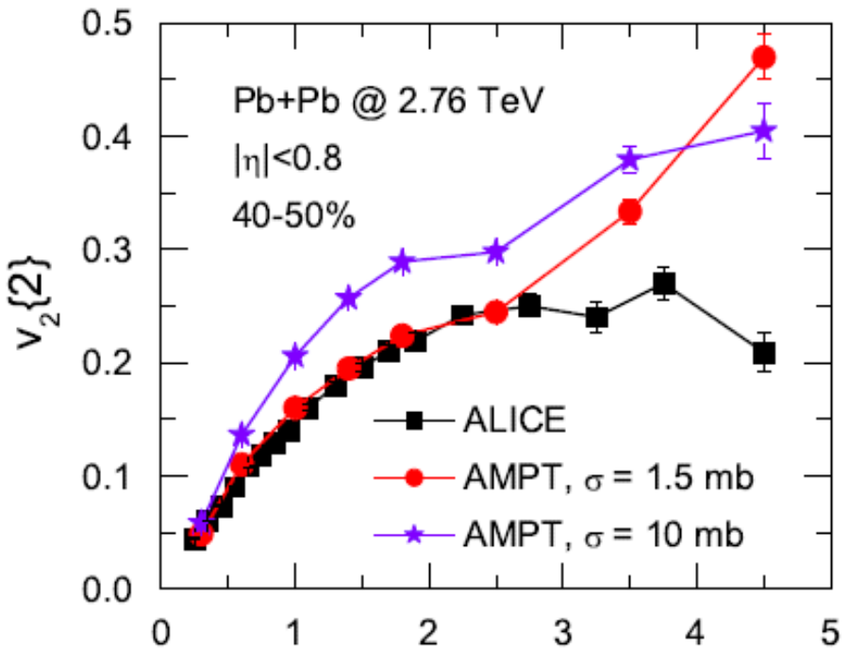


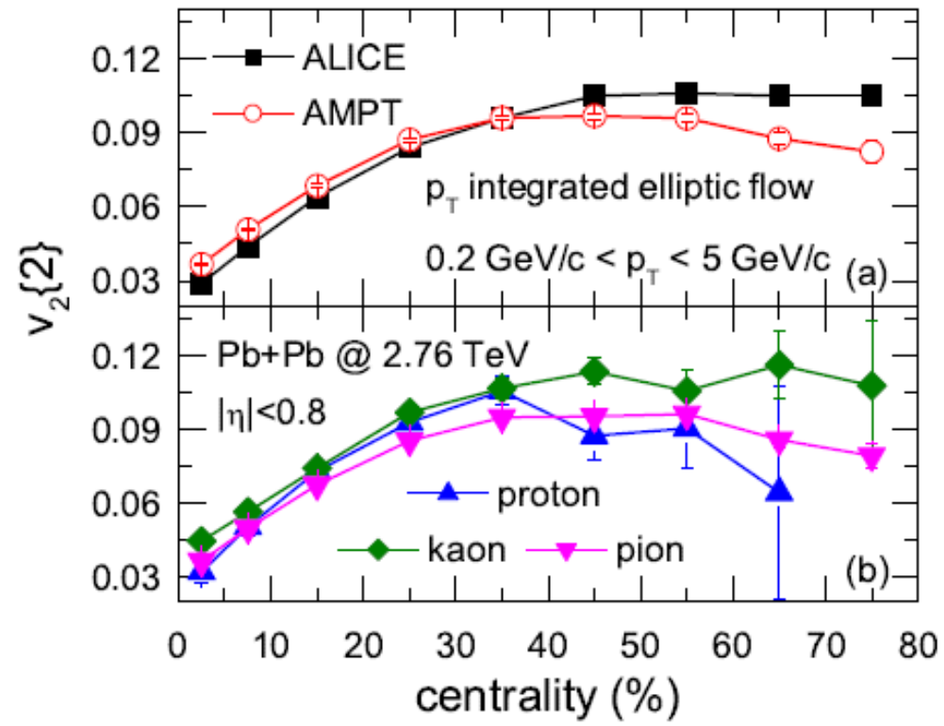
AMPT describes RHIC

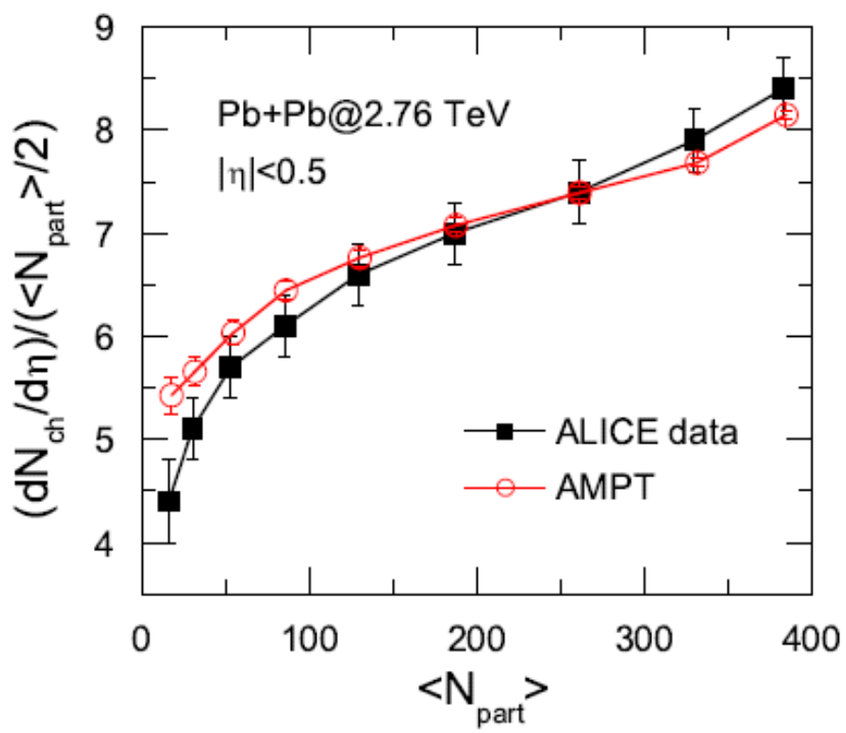


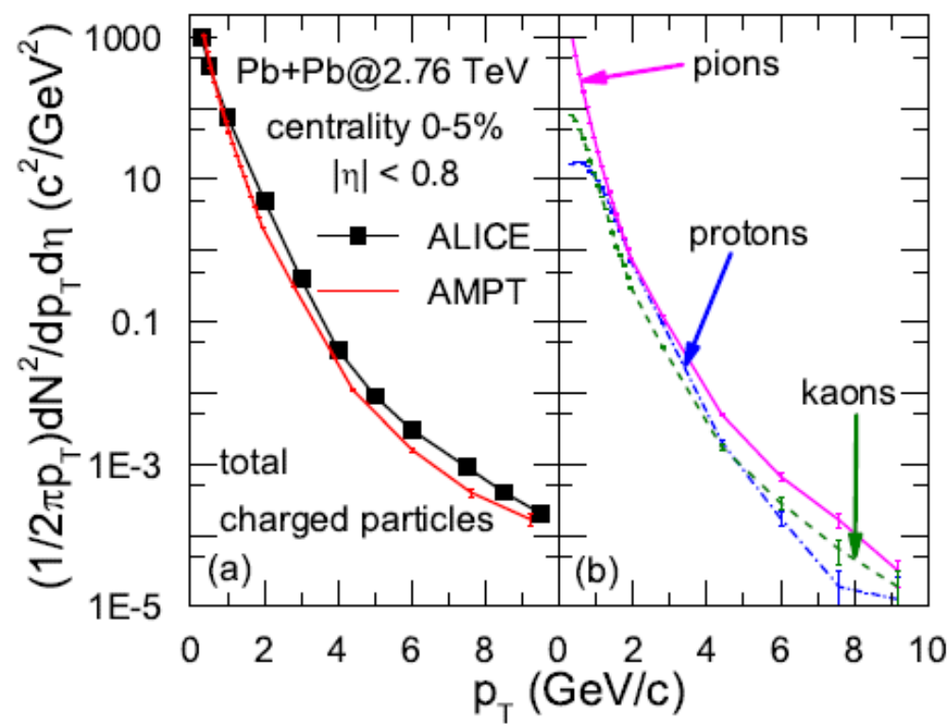
L.W.Chen, C.M. Ko, Z.-W. Lin, PRC69 (2004) 031901

AMPT describes LHC









J. Xu, C.M. Ko, PRC83 (2011) 034904