Decipher anisotropic flow in AA and p/dA collisions by AMPT

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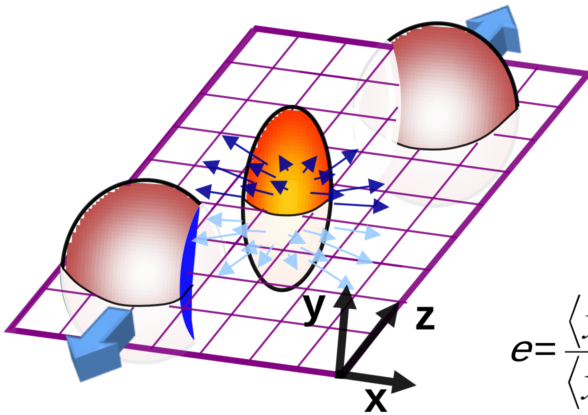
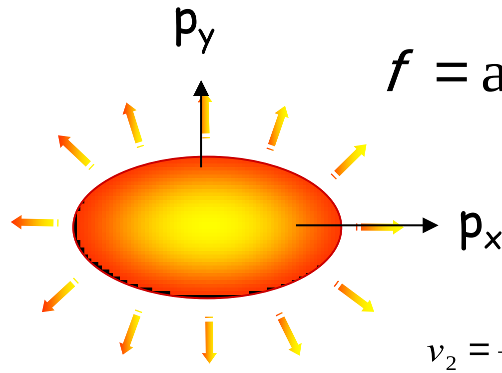
Elliptic flow



$$e = \frac{\langle y^2 \rangle - \langle x^2 \rangle}{\langle y^2 \rangle + \langle x^2 \rangle}$$

coordinate space anisotropy

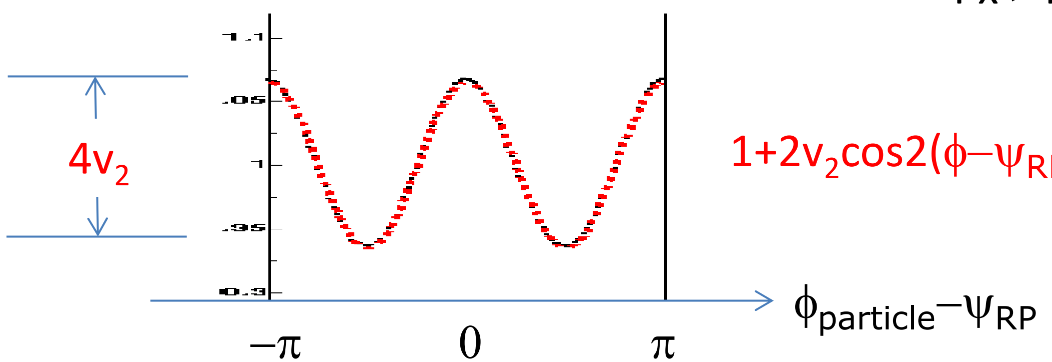


$$f = \text{atan}\frac{p_y}{p_x}$$

$$v_2 = \frac{\langle p_x^2 \rangle - \langle p_y^2 \rangle}{\langle p_x^2 \rangle + \langle p_y^2 \rangle}$$

momentum space anisotropy

Px > Py



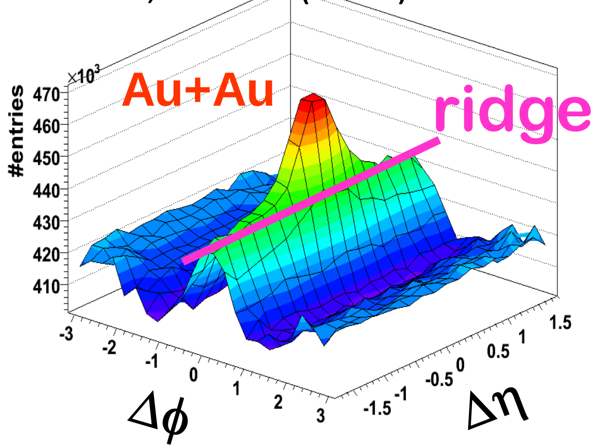
Triangular flow

- Two-particle angular correlations
- Elliptic flow subtracted

$dN/d\phi \sim 1 + 2v_2\cos2(\phi-\psi_2)$

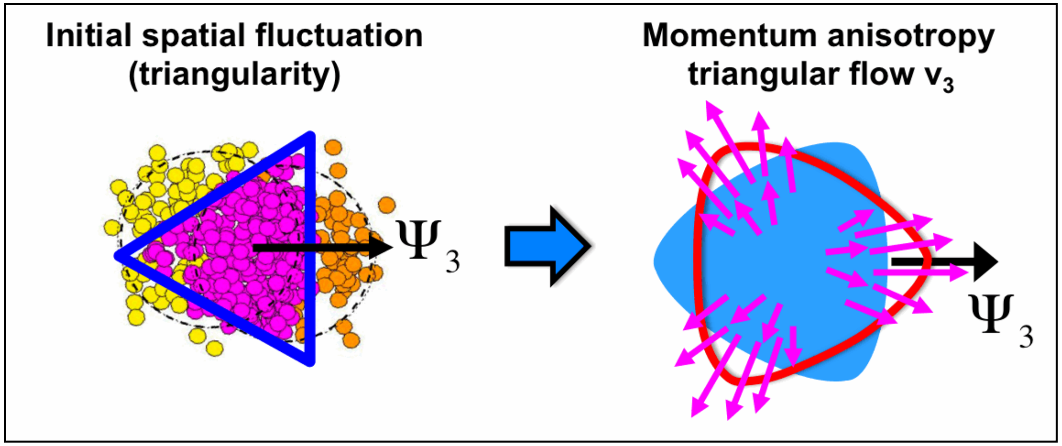
$dN/d\Delta\phi \sim 1 + 2v_2^2\cos2\Delta\phi$

STAR, PRC 80 (2009)

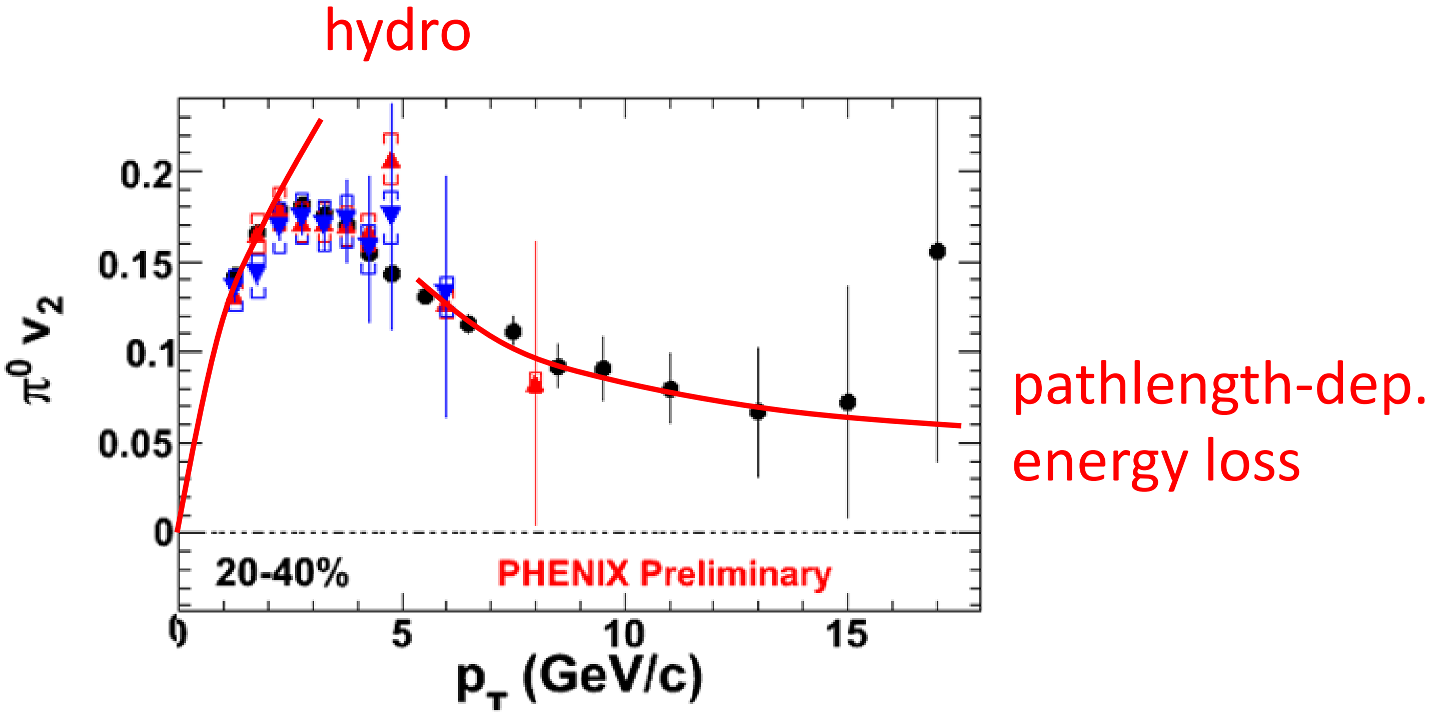


$$\eta = \frac{1}{2}\ln\frac{p+p_z}{p-p_z} = \ln\left(\tan\frac{\theta}{2}\right)$$

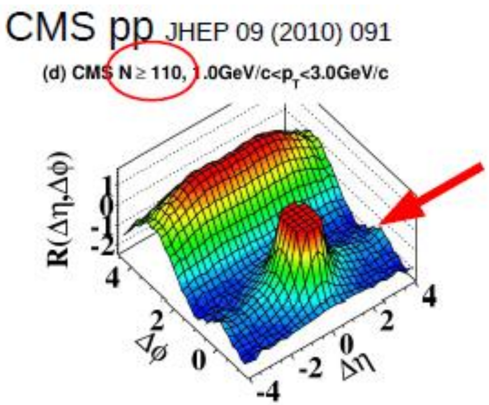
- Triangular flow

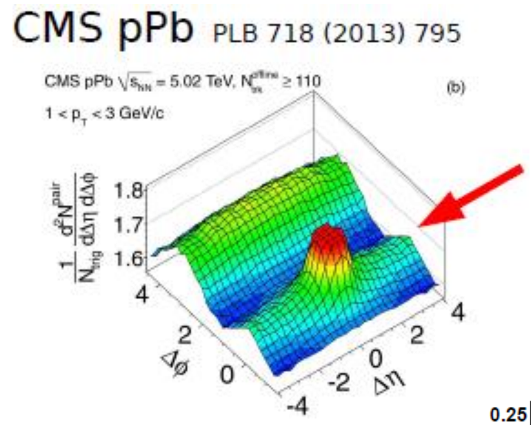


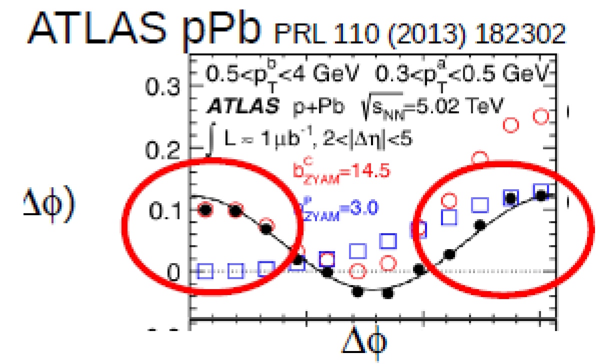
Our flow paradigm

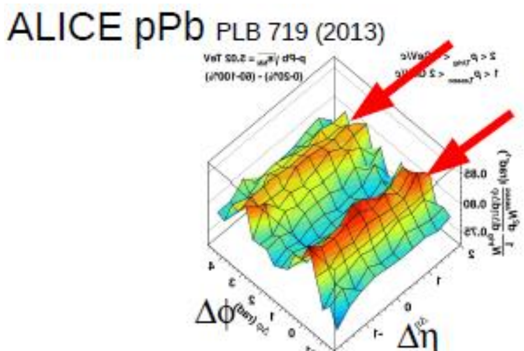


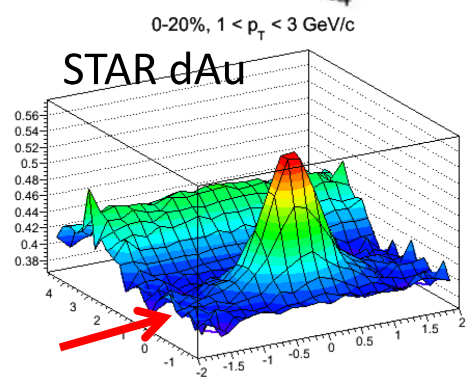
Ridge in small systems, and everywhere

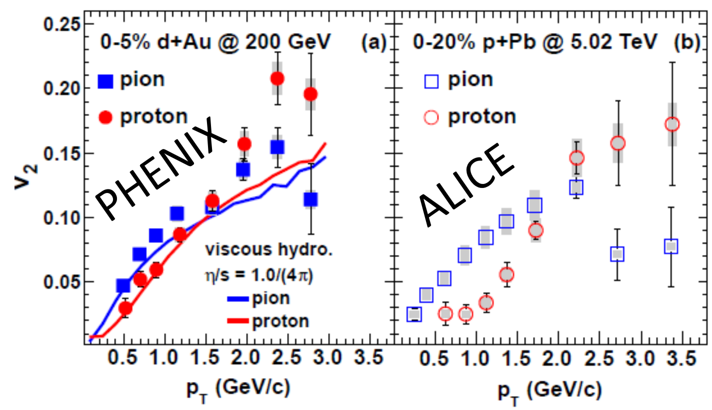


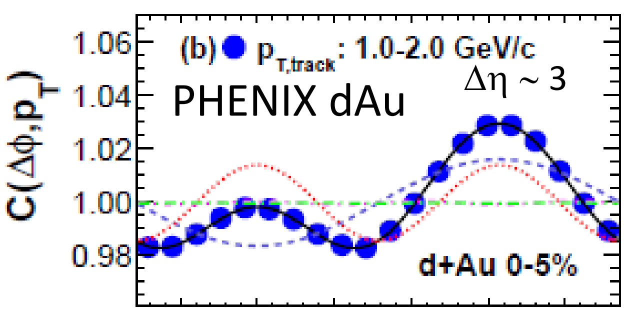


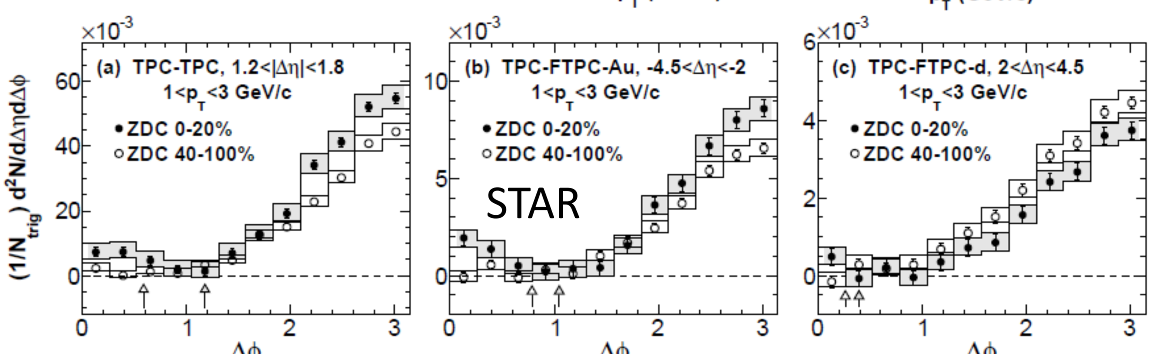




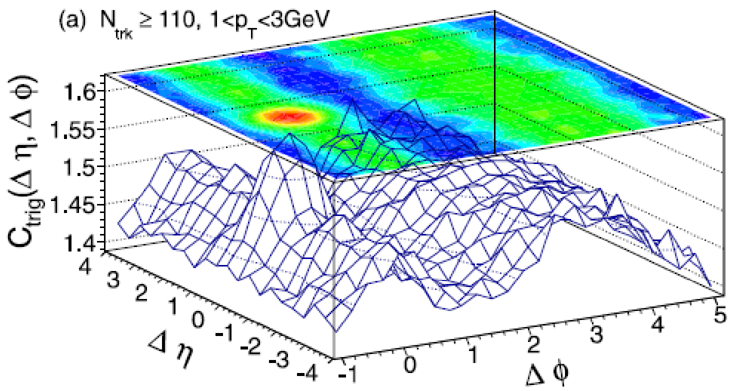


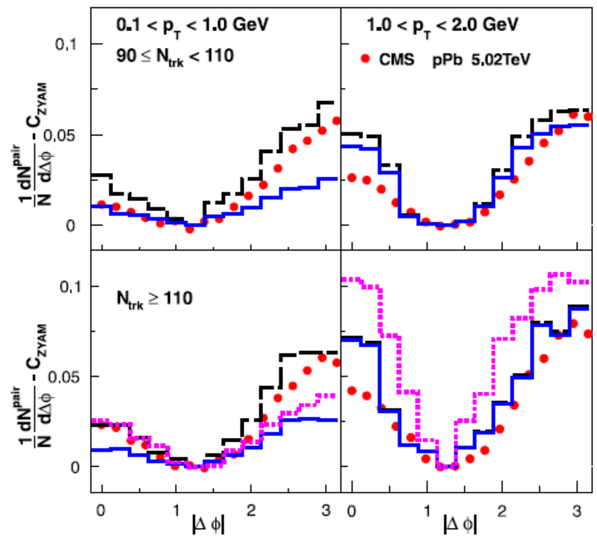




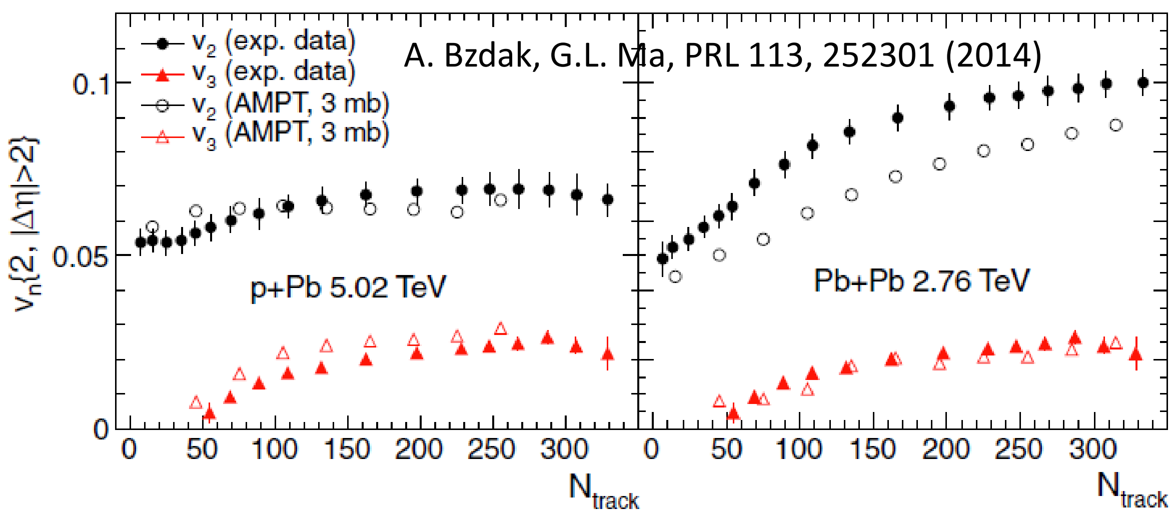


And hydro and transport can both describe it



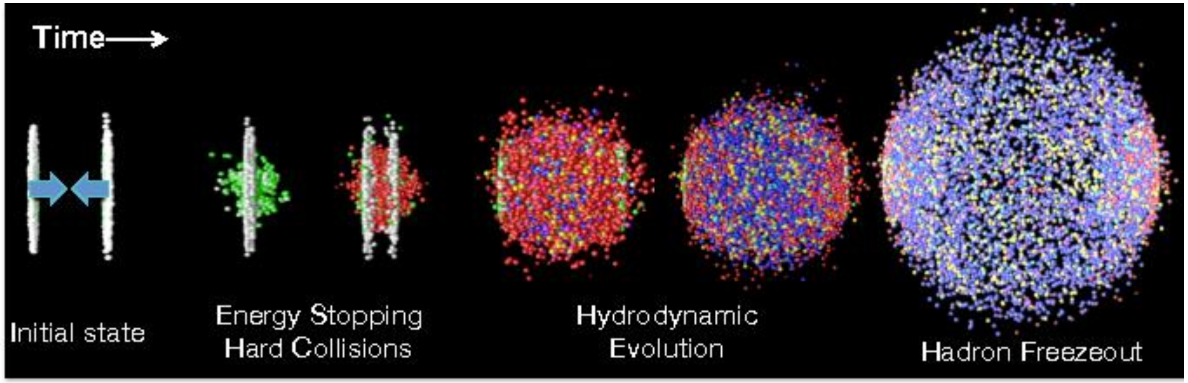


- Is hydro applicable to such small systems?
- Mean free path may be small relative to the size?

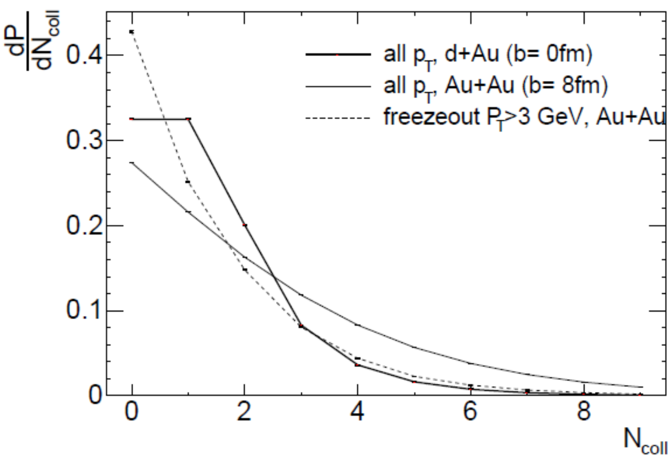


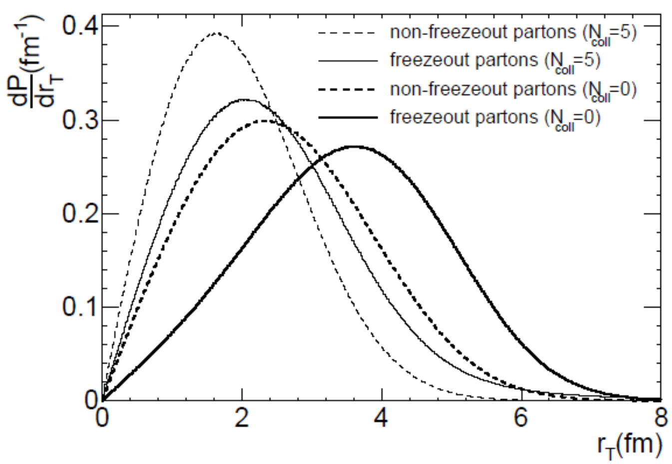
A. Bzdak, G.L. Ma, PRL 113, 252301 (2014)

Parton cascade history

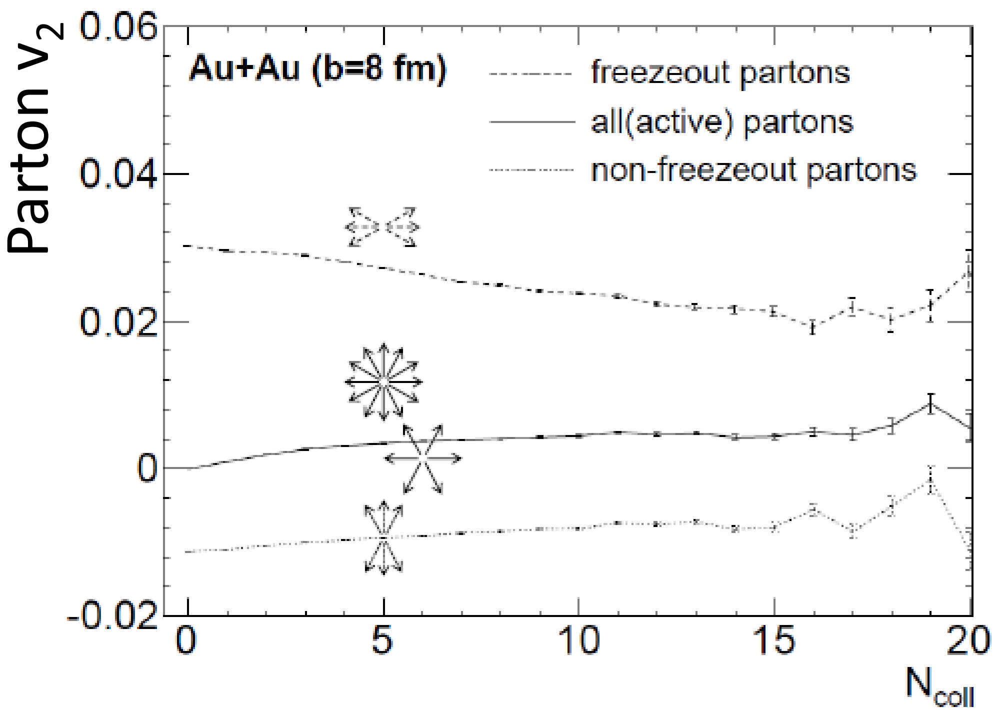


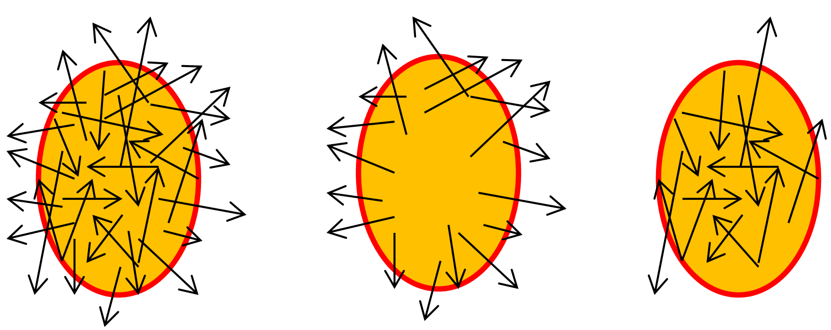
- Get into transport code
- Follow cascading history, microscopic interactions
- Investigate how parton v_n is generated





How is anisotropy developed?

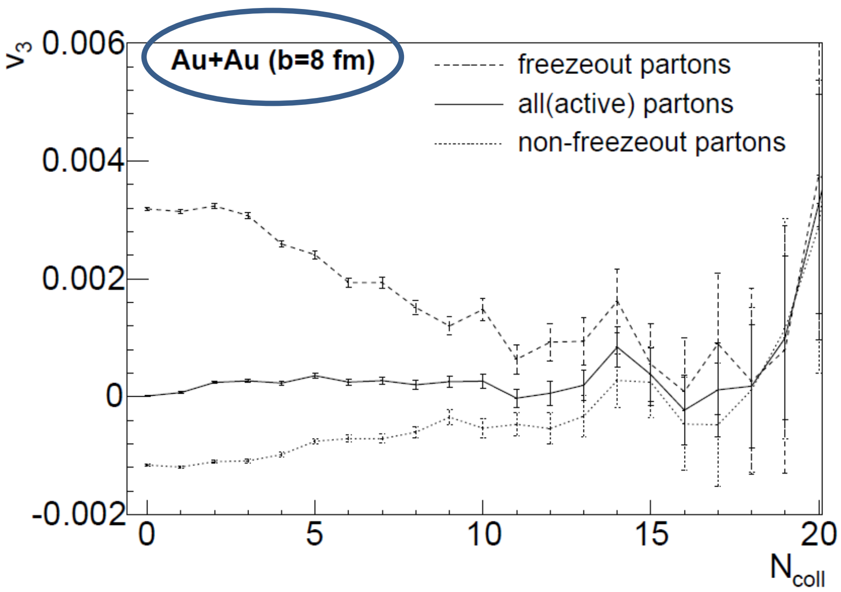




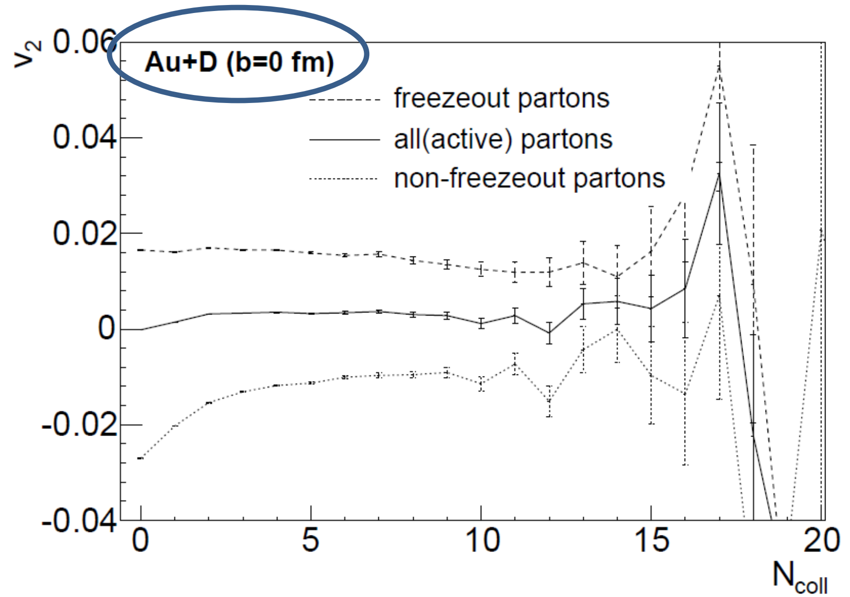
- Partons freeze out with large positive v_2, even when they do not interact at all.
- This is due to larger escape probability along x than y.
- Remaining partons start off with negative v_2, and become ~isotropic (v_2~0) after one more collision.
- Process repeats itself.
- Similar for v_3.
- Similar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

Similar for v_3, and d+Au

Similar for v_3



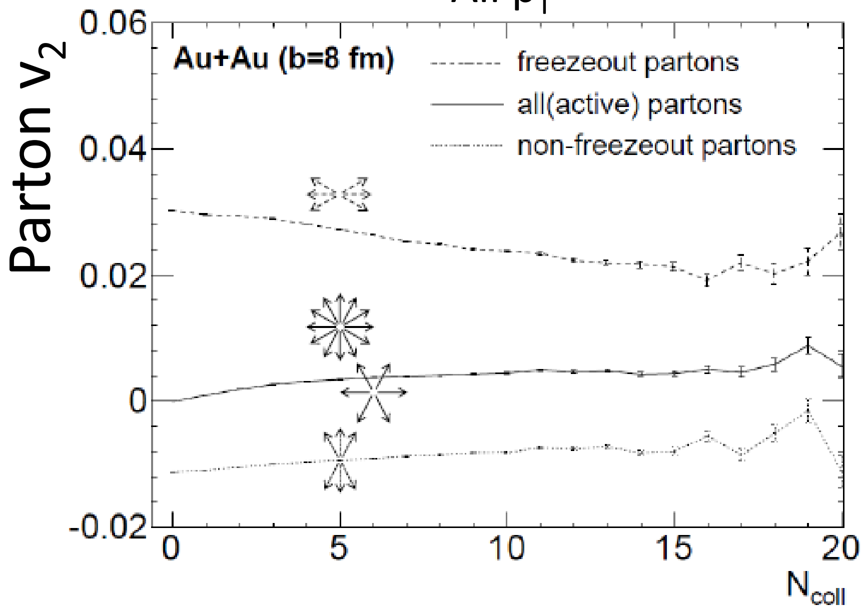
Similar for d+Au



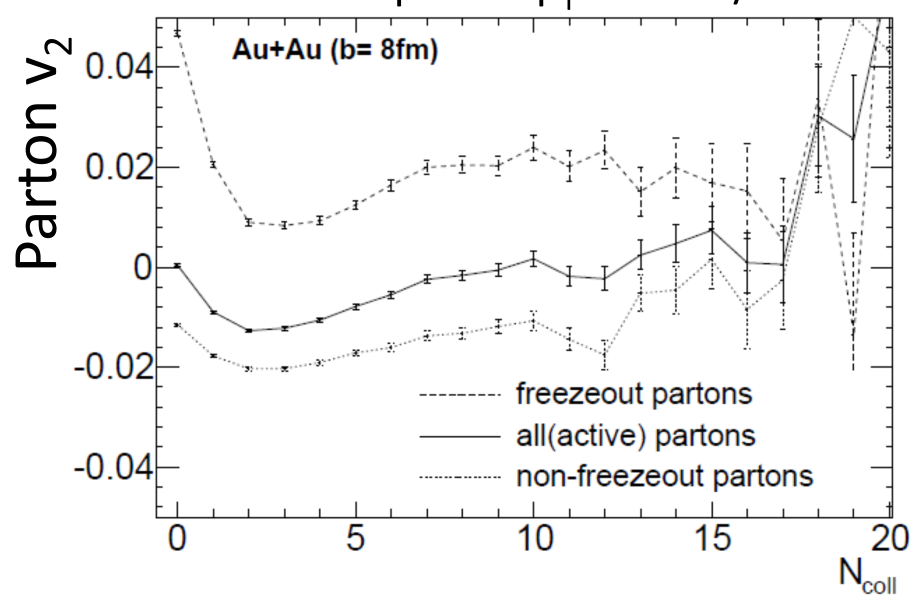
"Escape" mechanism

- Majority of v_n comes from the "escape" mechanism ("surface" emission).
- Considered to be responsible only for high-p_T v_n.
- Results suggest no fundamental difference between high-p_T and low-p_T.

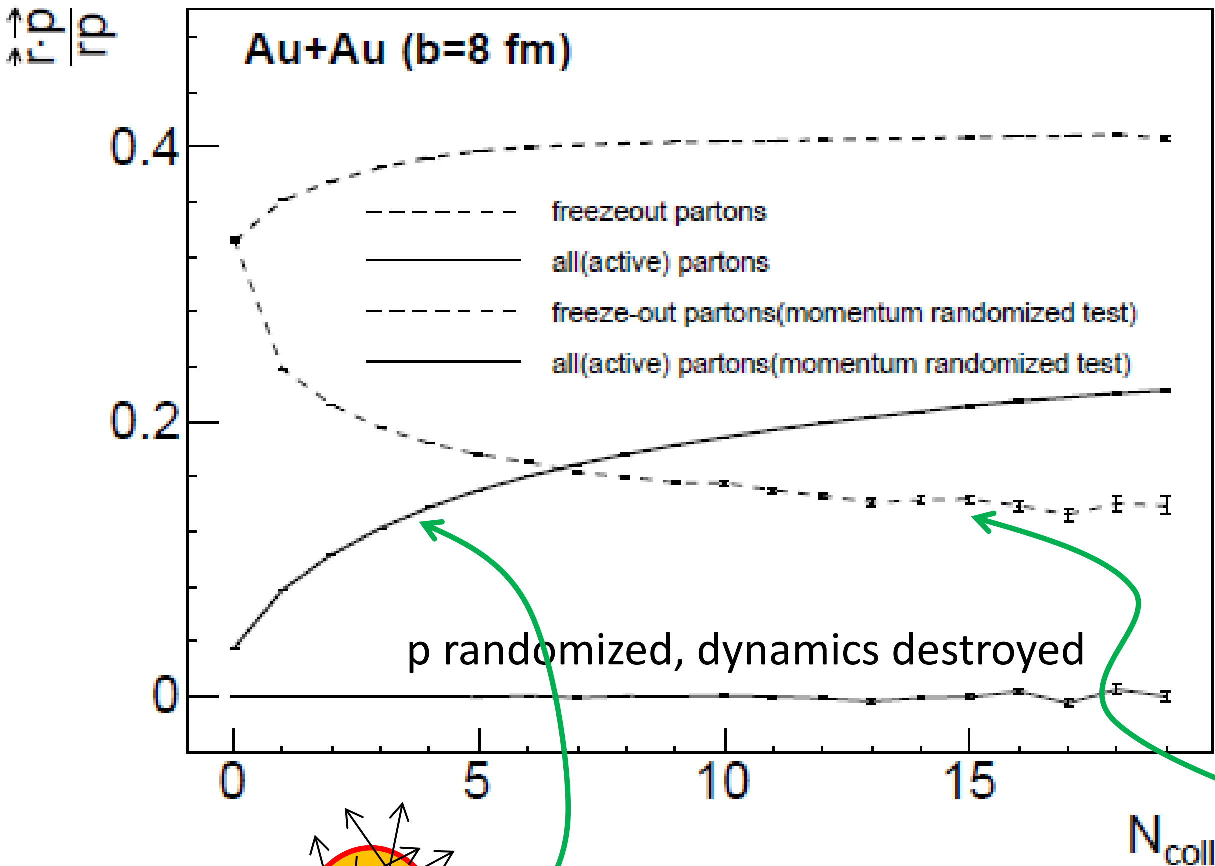
All p_T



Initial parton p_T > 2 GeV/c



Where are the dynamics?

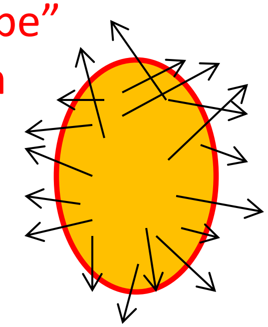


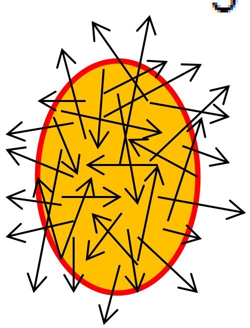
Strong r-p correlation

Increase purely from "escape" mechanism

Finite r-p correlation

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

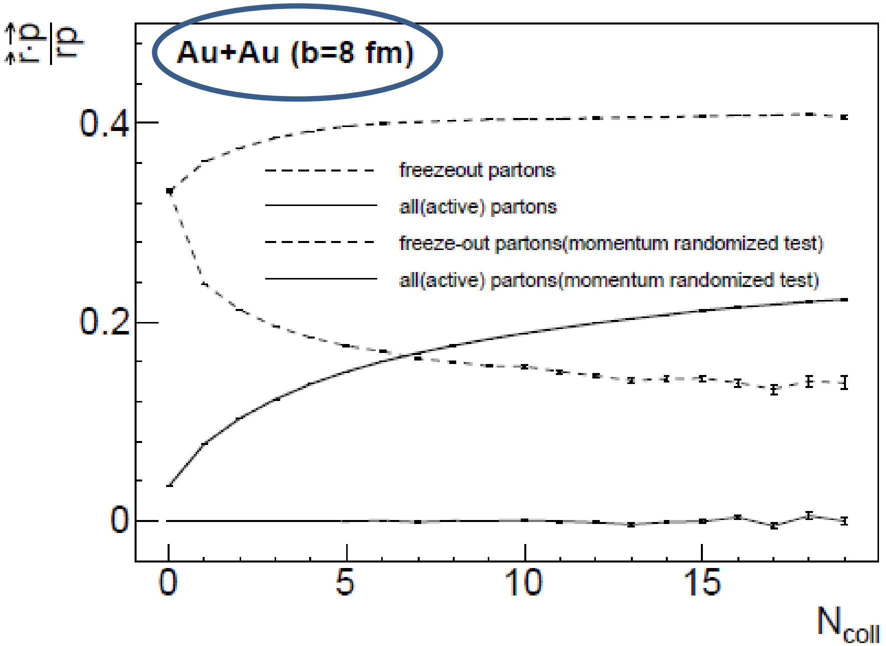


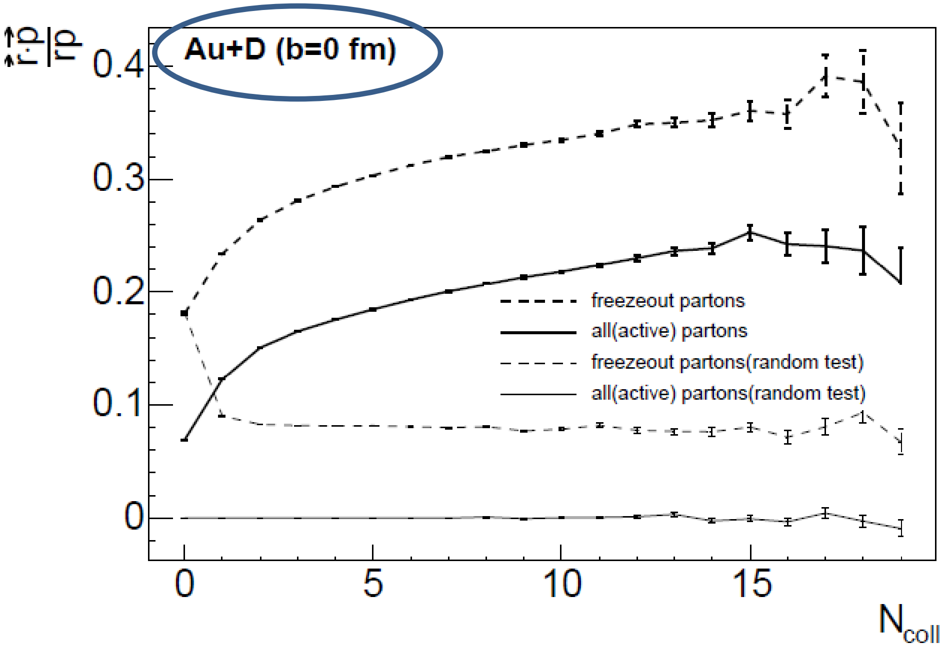


Collectivity

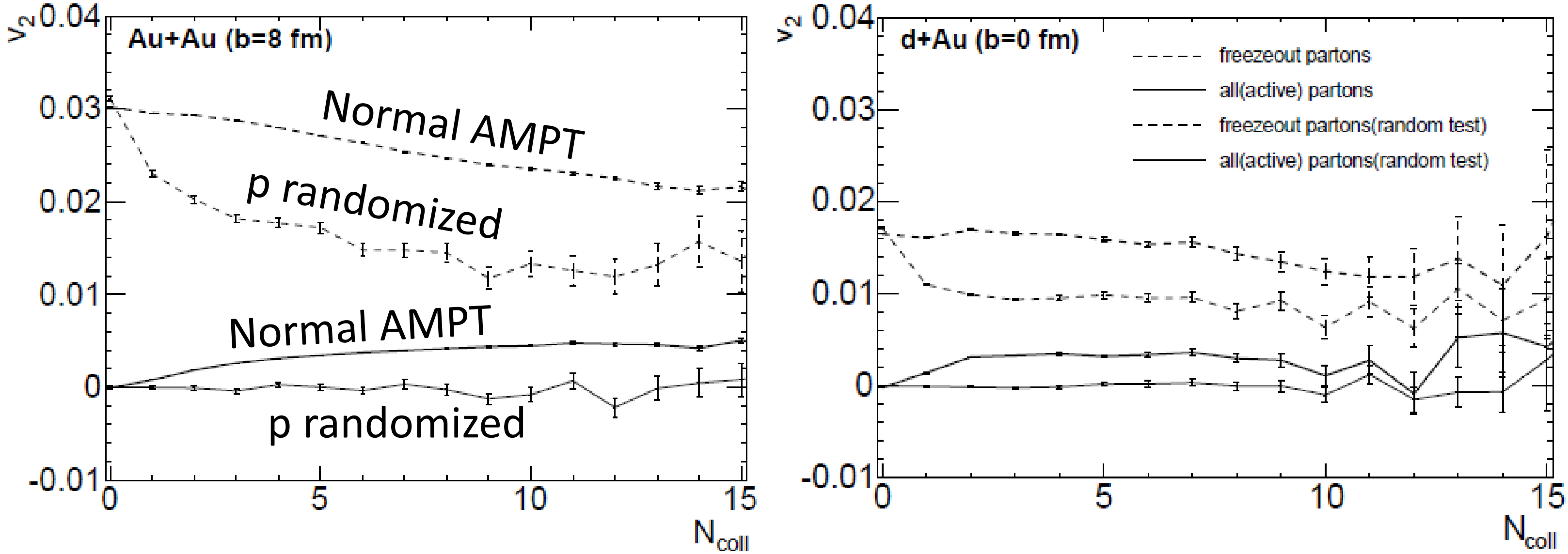
Collective motion, but not collectivity

Similar for d+Au





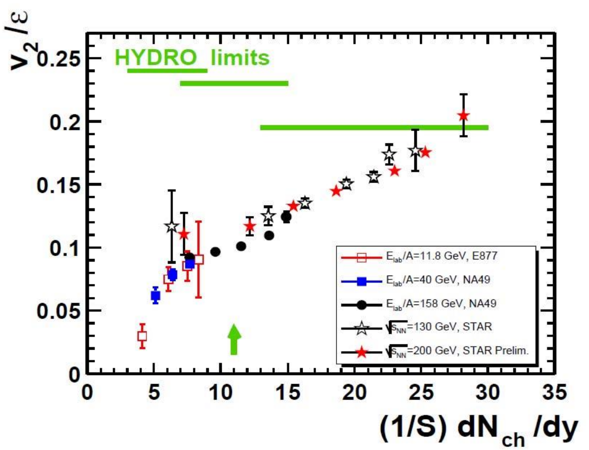
What's the punchline?

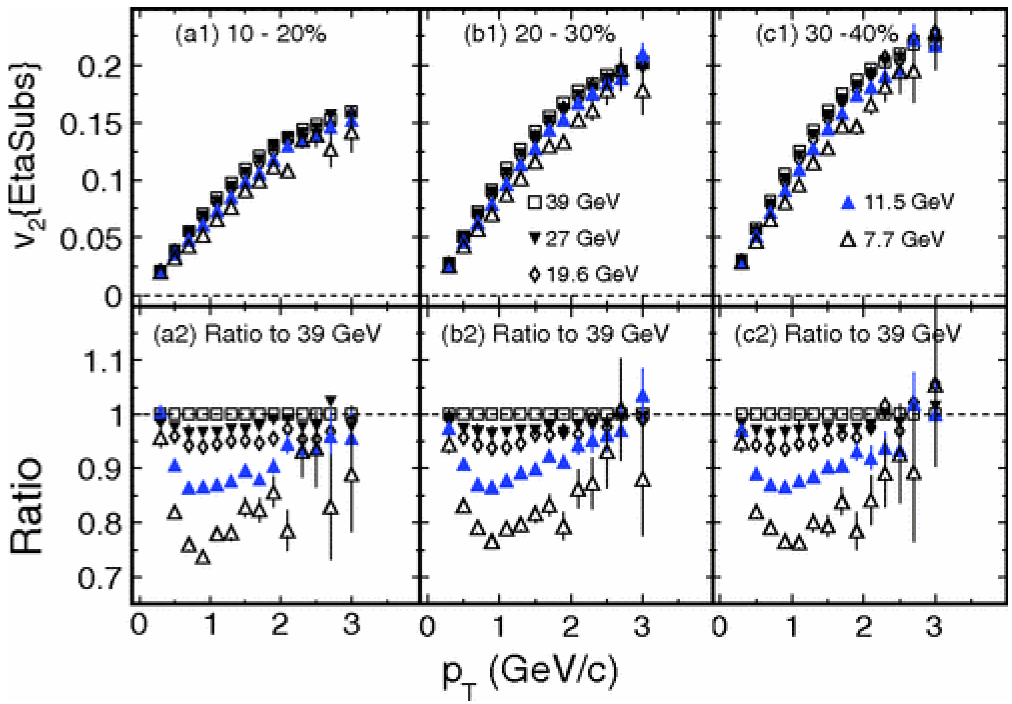


- Test case: Randomize parton azimuth after each scattering. Space-momentum correlations and dynamics are destroyed.
- Majority of flow comes from the final-step "escape" mechanism.
- Escape mechanism yields a slight larger v_2 in normal AMPT than the random case. The escape probability (the parton sees) differs in these two cases.
- The partons start with small v_2 before freezeout.
- This small v_2 is due to dynamics, result of hydrodynamics pressure push. It is this flow that is most relevant for sQGP physics. However it plays a minor role.

Hydrodynamics

- Hydrodynamics have pressure driven evolution only.
- Energy-momentum cell freeze-out controlled by local temperature/density.
- The escape mechanism is not obviously present in hydrodynamics.

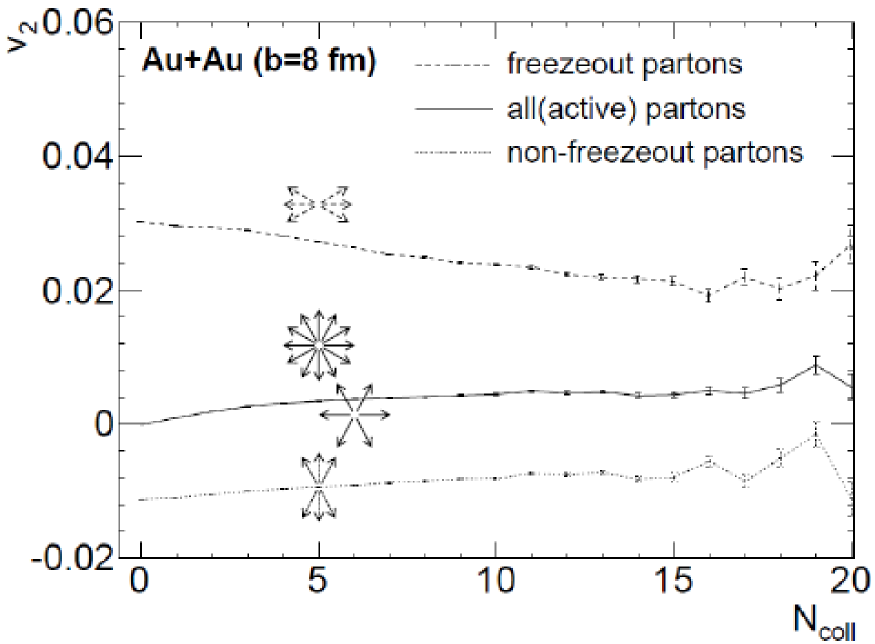




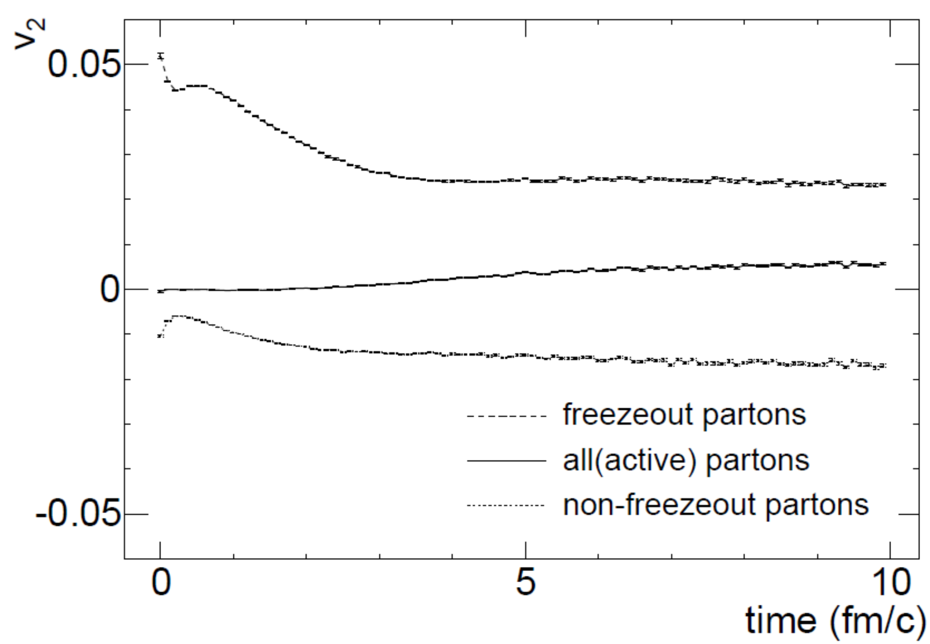
Which is real?

- Hydrodynamics describe data well.
  AMPT also describes data well.
  Which is more real? How to distinguish?
  - Pressure push generates radial flow
  - Escape mechanism does not generate radial flow

- Heavy-ion data closer to hydro, and small-system collisions closer to the escape mechanism?



v_2
0.06
0.04
0.02
0
-0.02
Au+Au (b=8 fm)
freezeout partons
all(active) partons
non-freezeout partons
0
5
10
15
20
N_{coll}



v_2
0.05
0
-0.05
freezeout partons
all(active) partons
non-freezeout partons
0
5
10
time (fm/c)