Stony Brook University | The State University of New York

My involvements with AMPT

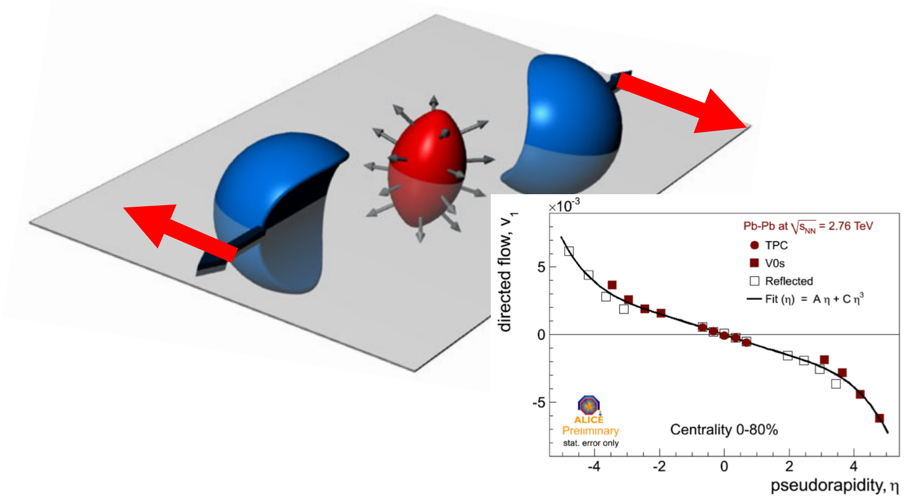
Jiangyong Jia, BNL and Stony Brook University

Dipolar flow from EbyE fluctuation of ε_1

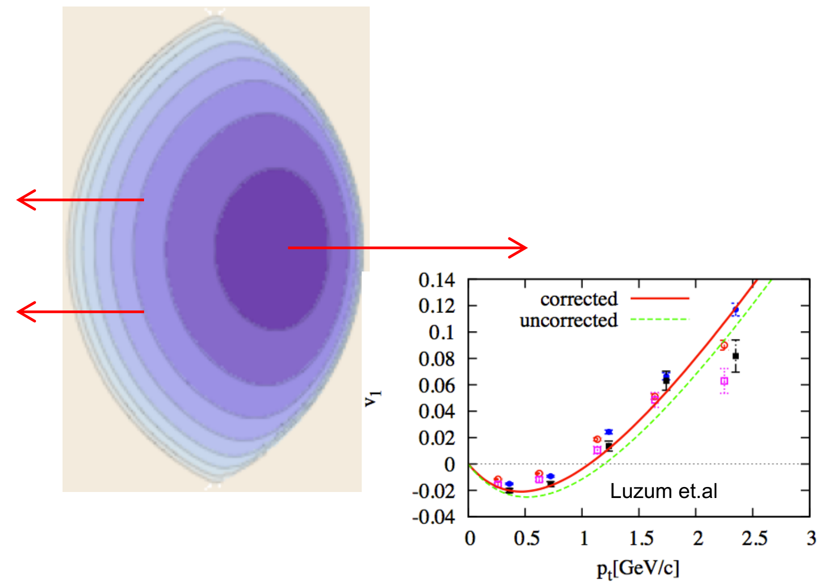
A study of the anisotropy associated with dipole asymmetry in heavy ion collisions 1203.3410

Jiangyong Jia[1,2], Sooraj Radhakrishnan[1] and Soumya Mohapatra[1]

Odd component: vanish at η=0



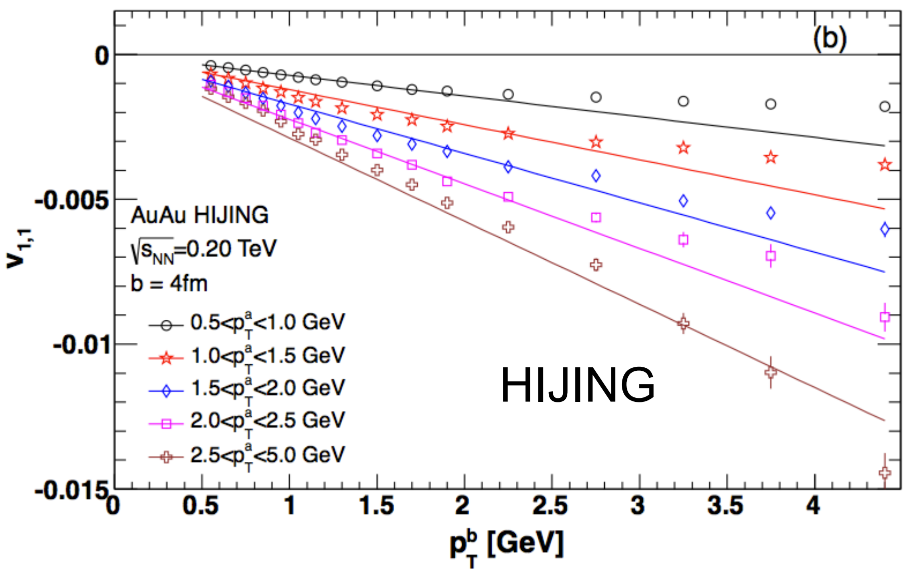
Even component: ~boost invariant in η



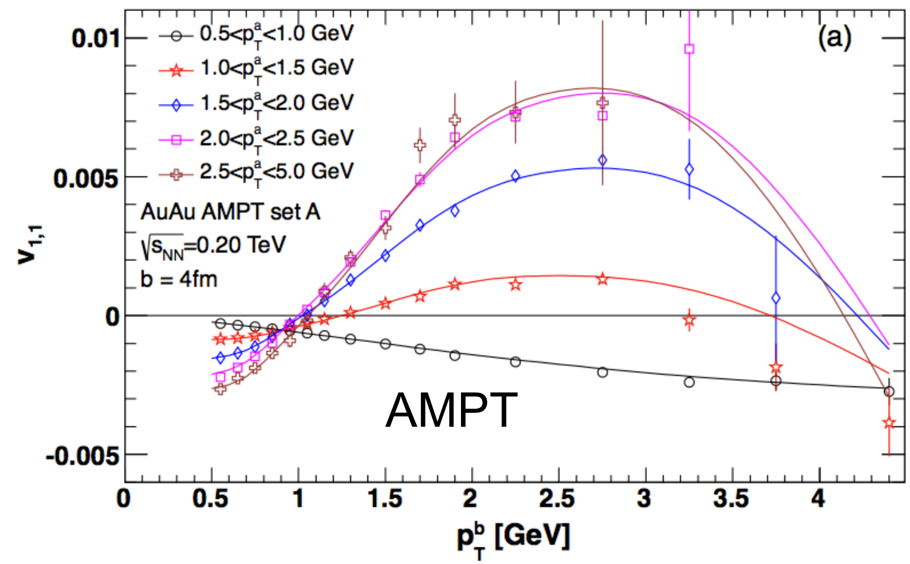
$$v_{1,1}(p_T^a, p_T^b) \approx v_1(p_T^a)v_1(p_T^b) - \frac{p_T^a p_T^b}{M\langle p_T^2\rangle}$$

Dipolar flow   Momentum conservation

Dipolar flow from AMPT

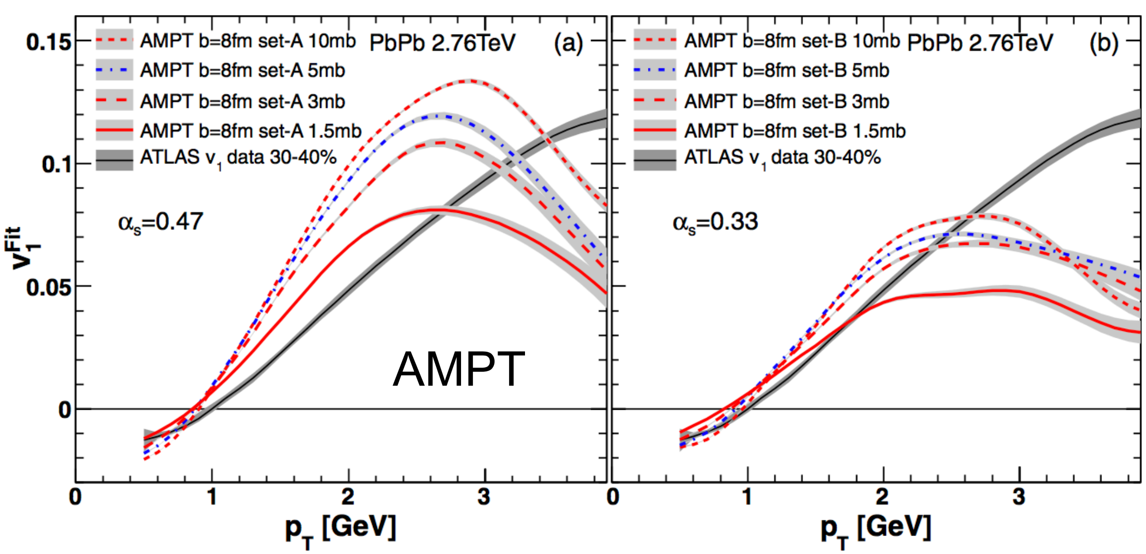


$$v_{1,1}(p_T^a, p_T^b) = -c p_T^a p_T^b$$



$$v_{1,1}(p_T^a, p_T^b) = v_1^{\mathrm{Fit}}(p_T^a) v_1^{\mathrm{Fit}}(p_T^b) - c p_T^a p_T^b$$

Sensitive to cross-sections

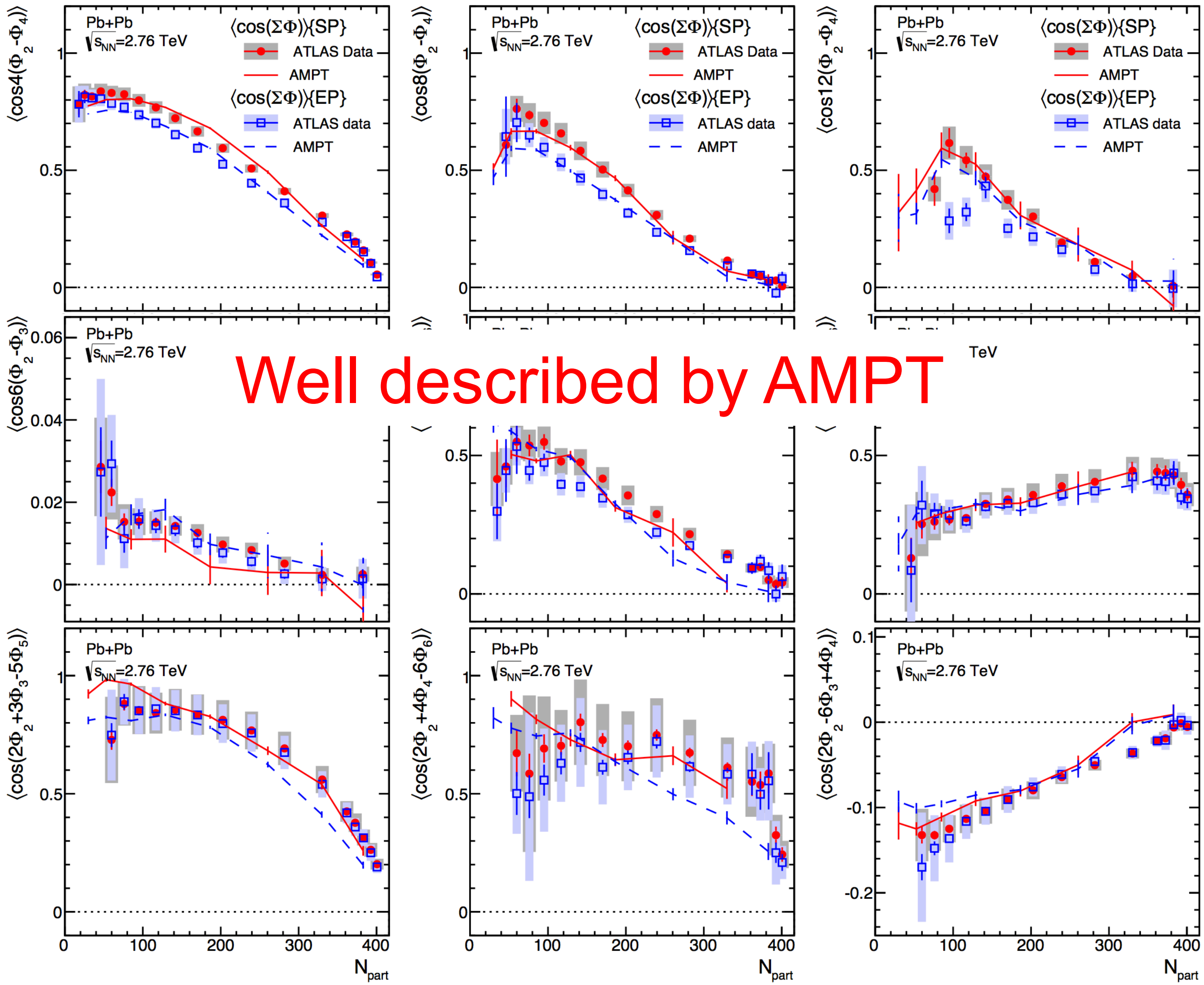


Event plane correlations: How are (ε_n,Φ_n^*) transferred to (v_n, Φ_n)?

- EP correlation probes into the initial ε_n correlation and final state mode-mixing

PHYSICAL REVIEW C **90**, 024905 (2014)

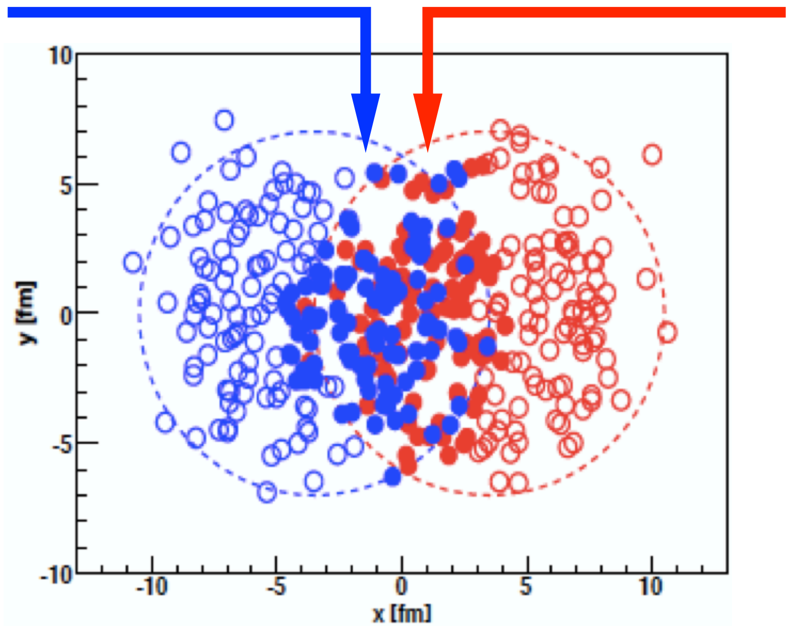
Measurement of event-plane correlations in $\sqrt{s_{NN}}$ = 2.76 TeV lead-lead collisions with the ATLAS detector



Three types of longitudinal correlations

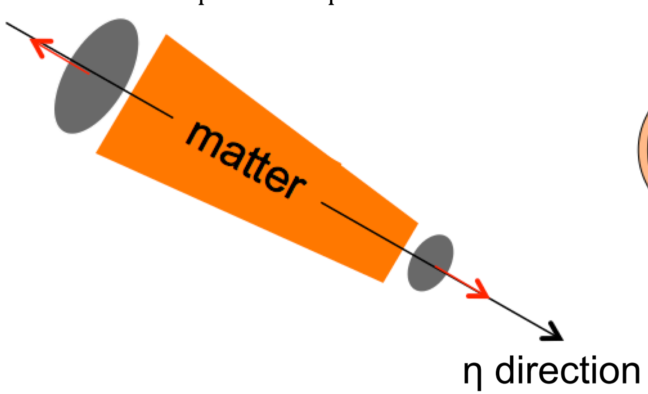
Fluctuation of sources in two nuclei → fluc. of size and transverse-shape

$N_{\mathrm{part}}^{\mathrm{F}}$ $\varepsilon_n^{\mathrm{F}} e^{in\Psi_n^F}$



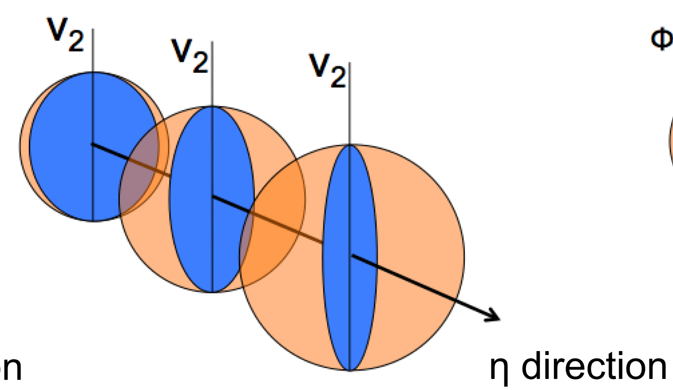
$N_{\mathrm{part}}^{\mathrm{B}}$ $\varepsilon_n^{\mathrm{B}} e^{in\Psi_n^B}$

(a) $N_{\mathrm{part}}^{\mathrm{F}} \neq N_{\mathrm{part}}^{\mathrm{B}}$



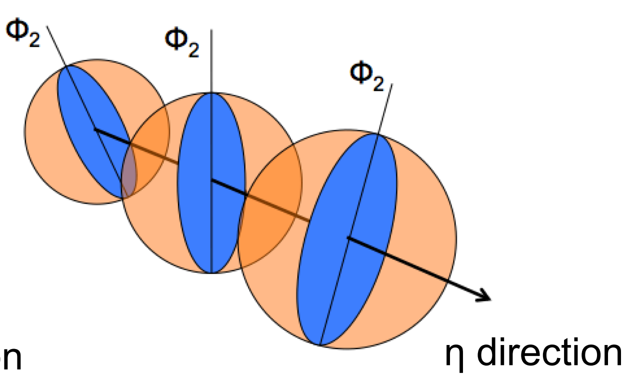
Asymmetry in multiplicity

(b) $\varepsilon_2^{\mathrm{F}} \neq \varepsilon_2^{\mathrm{B}}$



Asymmetry in flow magnitude

(c) $\Psi_2^{\mathrm{F}} \neq \Psi_2^{\mathrm{B}}$



Torque/twist of flow plane

Event shape engineering with AMPT

PHYSICAL REVIEW C **90**, 034905 (2014)

Method for studying the rapidity fluctuation and de-correlation of harmonic flow in heavy-ion collisions

Jiangyong Jia[1,2,*] and Peng Huo[1]

PHYSICAL REVIEW C **90**, 024910 (2014)

Elucidating the event-by-event flow fluctuations in heavy-ion collisions via the event-shape selection technique

Peng Huo (霍鹏),[1] Jiangyong Jia (贾江涌),[1,2,*] and Soumya Mohapatra[1,†]

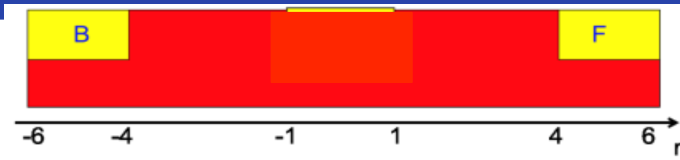
PHYSICAL REVIEW C **90**, 034915 (2014)

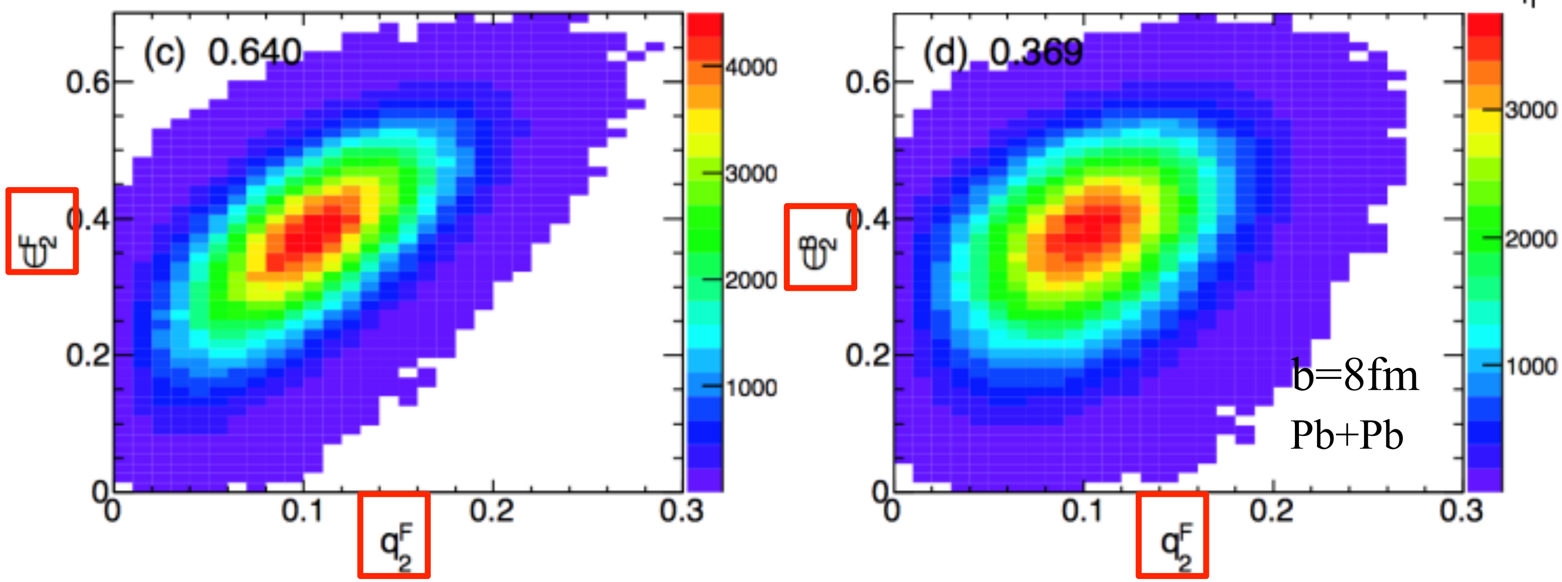
Forward-backward eccentricity and participant-plane angle fluctuations and their influences on longitudinal dynamics of collective flow

Jiangyong Jia[1,2,*] and Peng Huo[1]

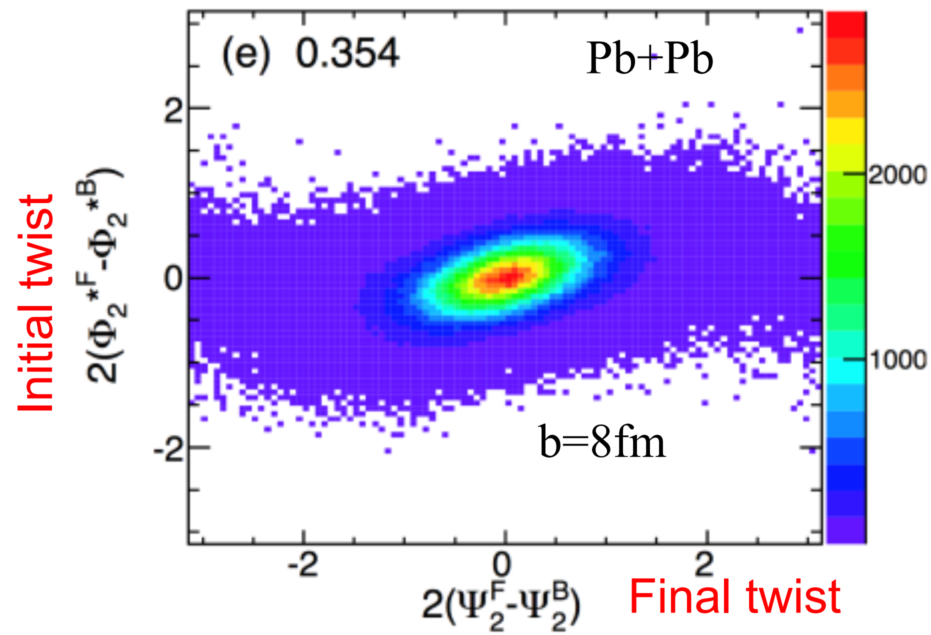
Event shape engineering with AMPT

q_2^F **more correlated with** ε_2^F **than** ε_2^B





Twist in initial geometry appears as twist in the final state flow



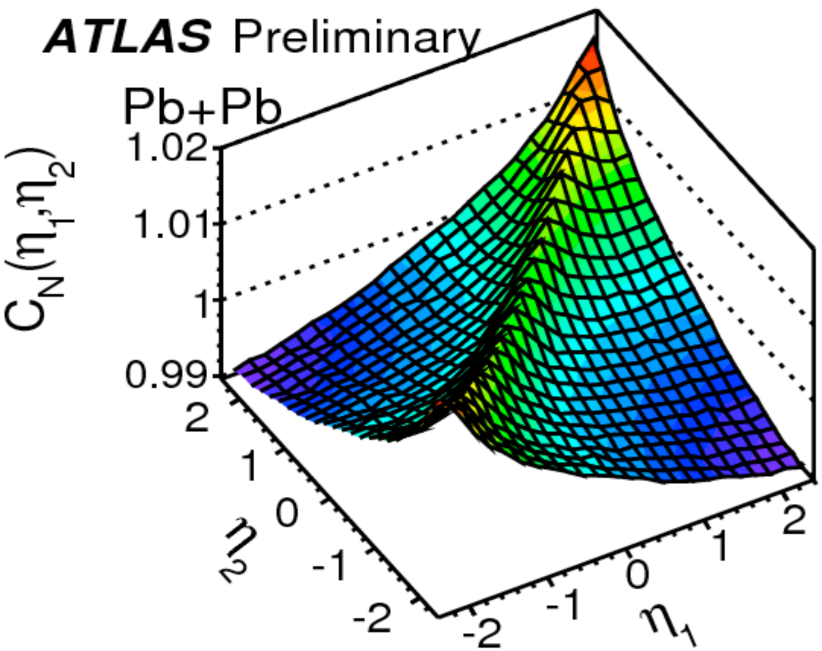
Longitudinal multiplicity fluctuations

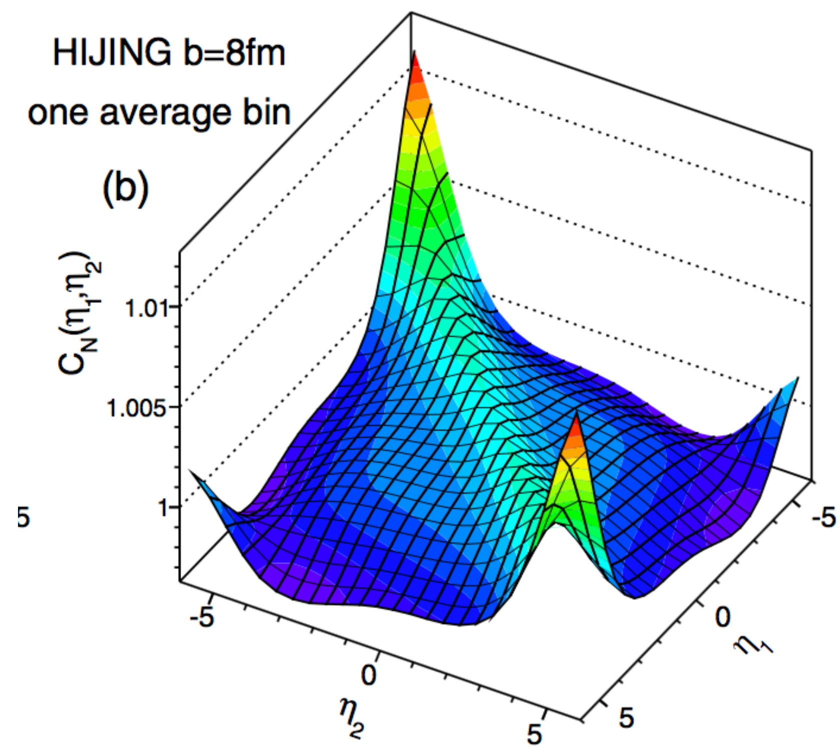
PHYSICAL REVIEW C **93**, 044905 (2016)

Forward-backward multiplicity fluctuation and longitudinal harmonics in high-energy nuclear collisions

Jiangyong Jia,[1,2,*] Sooraj Radhakrishnan,[1] and Mingliang Zhou[1,†]

$$C_N(\eta_1,\eta_2)=\frac{\langle N(\eta_1)N(\eta_2)\rangle}{\langle N(\eta_1)\rangle\langle N(\eta_2)\rangle}$$





Longitudinal multiplicity fluctuations from AMPT

PHYSICAL REVIEW C **93**, 044905 (2016)

Forward-backward multiplicity fluctuation and longitudinal harmonics in high-energy nuclear collisions

Jiangyong Jia,[1,2,*] Sooraj Radhakrishnan,[1] and Mingliang Zhou[1,†]

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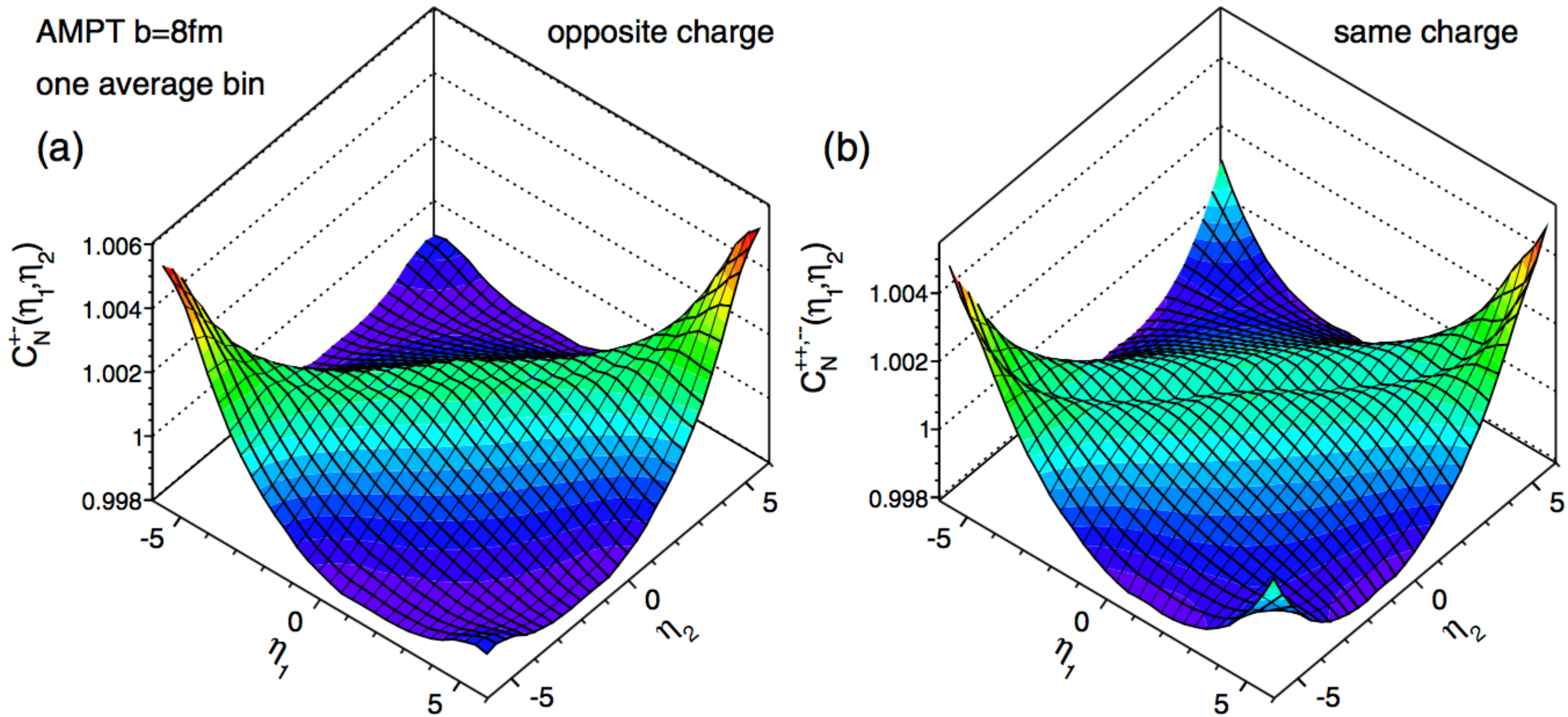
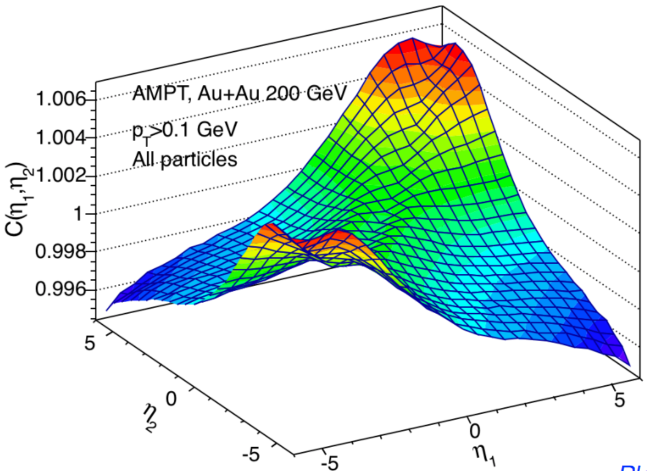


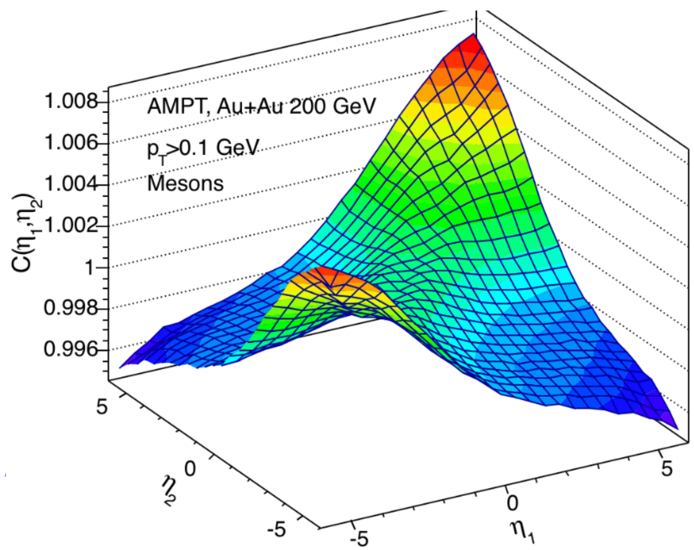
Peculiar dip in around $\eta_1 \sim \eta_2$ due to coalesce effects?

PID dependence from AMPT

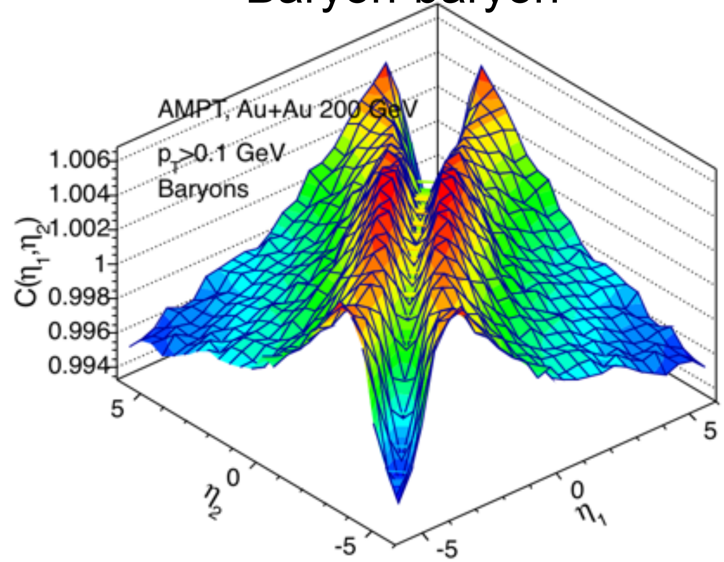
h-h



Meson-meson

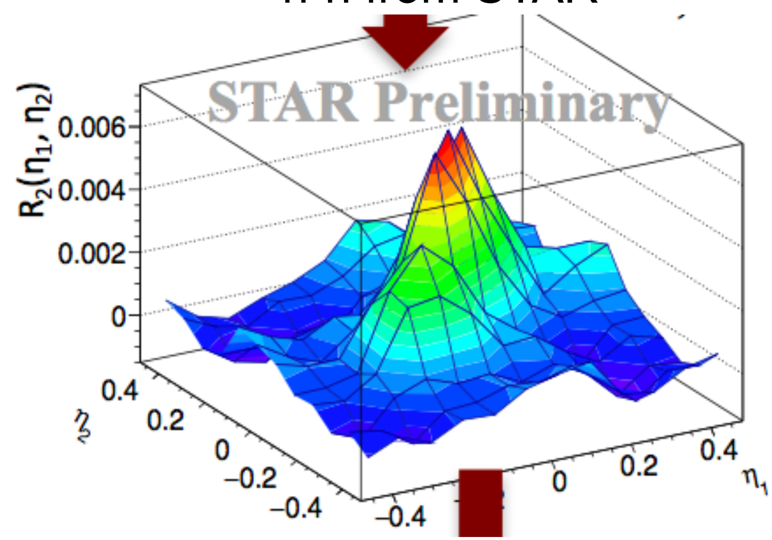


Baryon-baryon



- Baryons show a strong depletion in the short range region.
- Long-range correlations are consistent.

h-h from STAR



Coalesce mechanism?

Some thoughts on AMPT

- AMPT model has wrong short-wave length physics, but still appears to be a good effective long-wave length model.
  - Elastic scattering only, in principle not different from, e.g. cold atom system once the coupling is tuned.

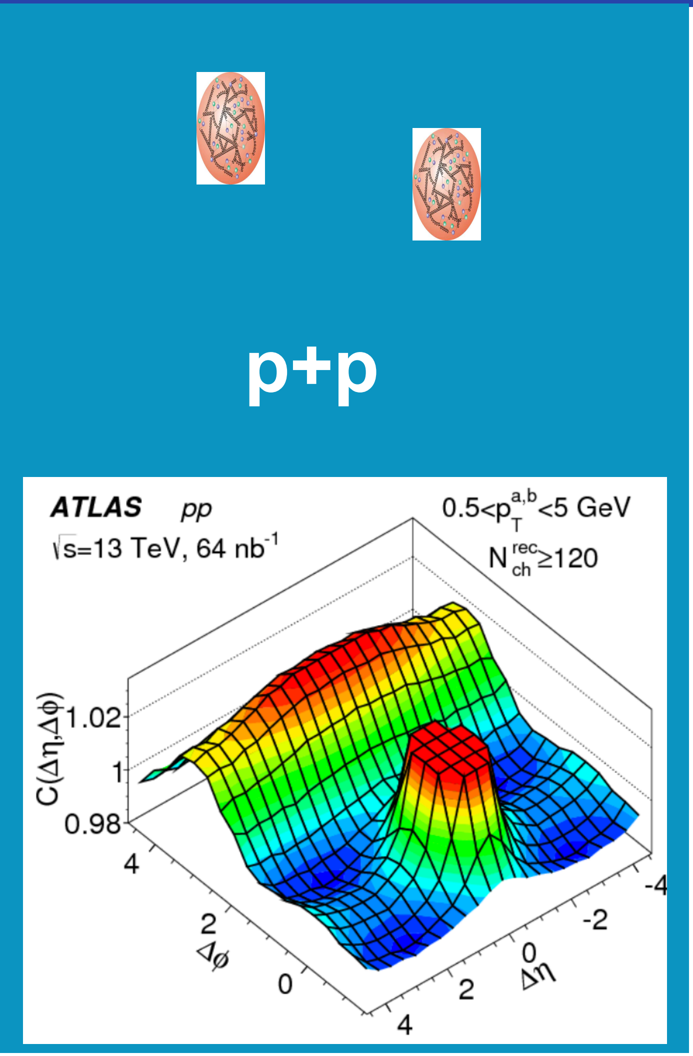
- Details of the transport mechanism must be reflected by the non-equilibrium corrections via transport properties.

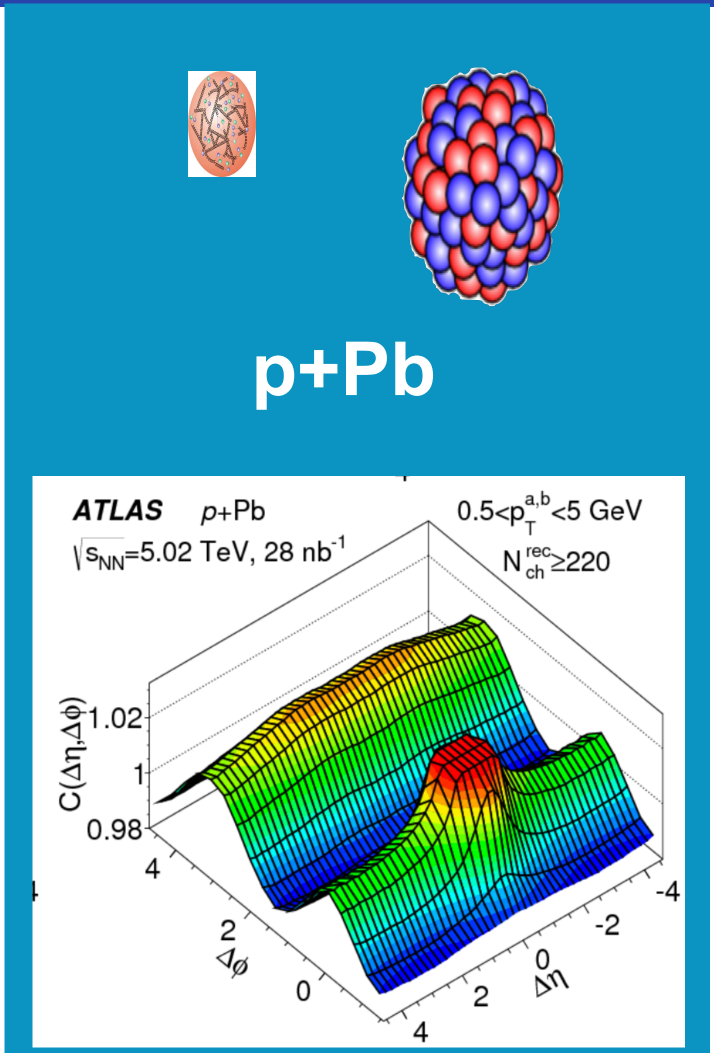
- It would be good to find out observables that are sensitive to these non-equilibrium corrections.
  - Higher p_T production and correlation, heavy quark diffusion?
  - Flow factorization breaking in p_T
  - Longitudinal flow and multiplicity dynamics.

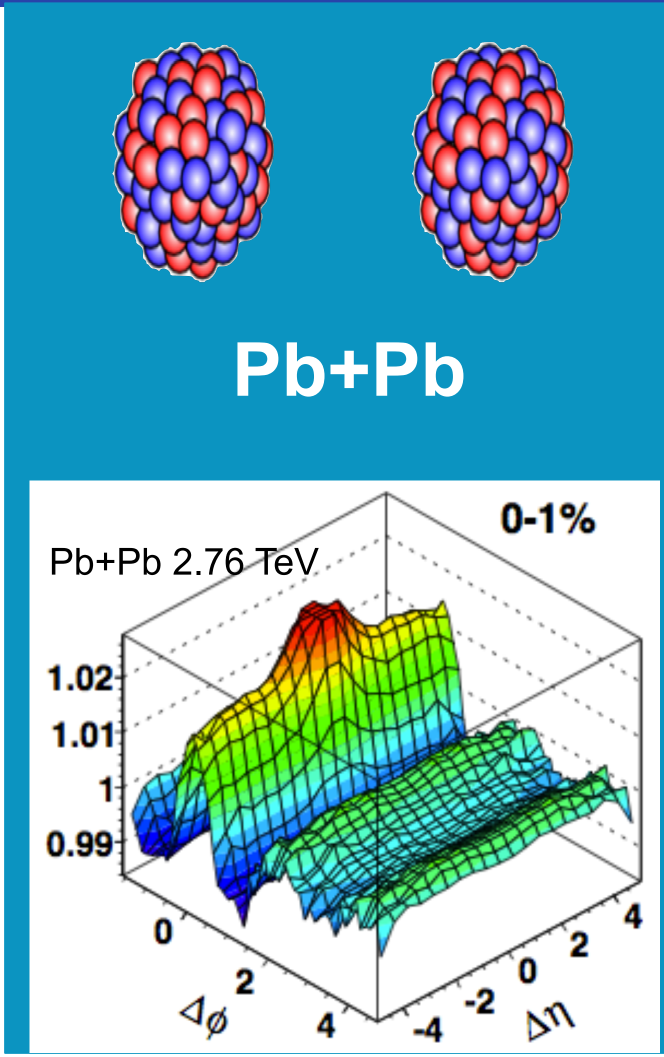
“Long-range collectivity” in small systems

- What is collectivity?
- How to distinguish initial and final state effects?

Long-range collectivity in different systems





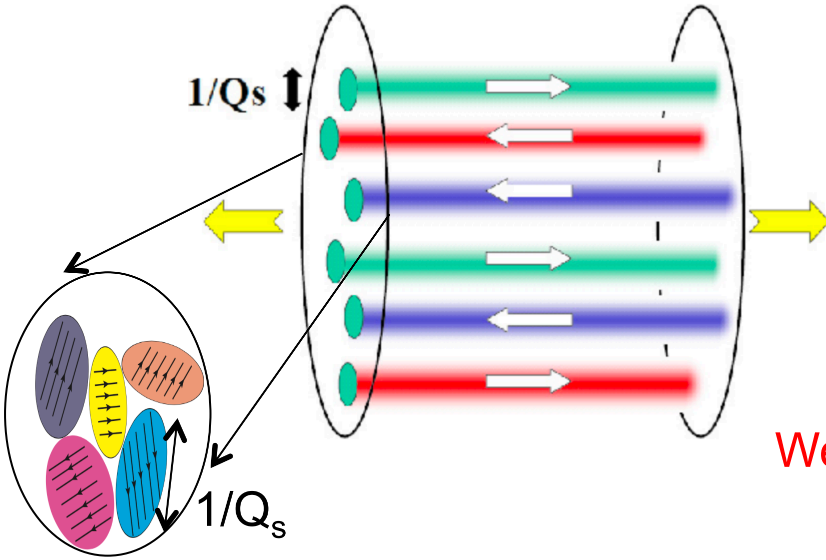


- Long-range correlation in momentum space comes
  - directly from early time t~0 (CGC)
  - or it is a final state response to spatial fluctuation at t=0 (hydro).

What is the timescale for emergence of collectivity?

Examples of initial vs final state scenarios

CGC



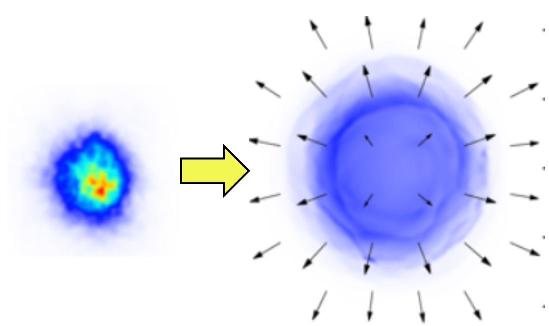
Domain of color fields of size $1/Q_s$, each produce multi-particles correlated across full η.

Uncorr. between domains, strong fluct. in Q_s

More domains, smaller v_n, more Q_s fluct, stronger v_n

Well motivated model framework, lack systematic treatment

Hydro



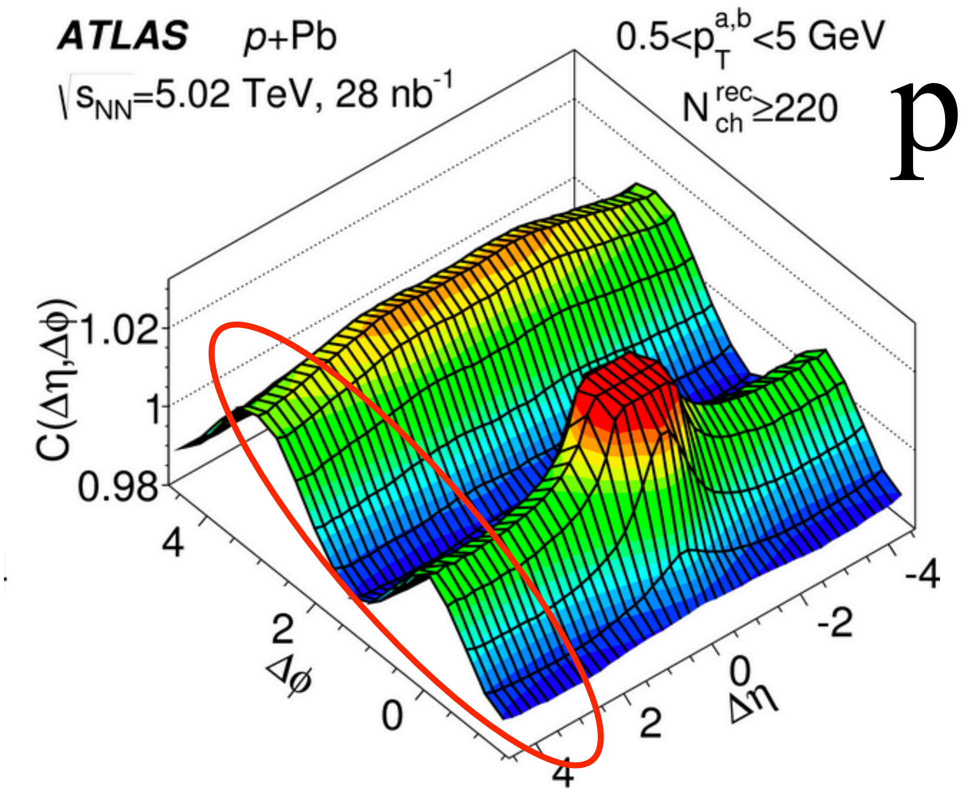
Hot spots (domains) in transverse plane e.g IP-plasma, boost-invariant geometry shape

Expansion and interaction of hot spots generate collectivity

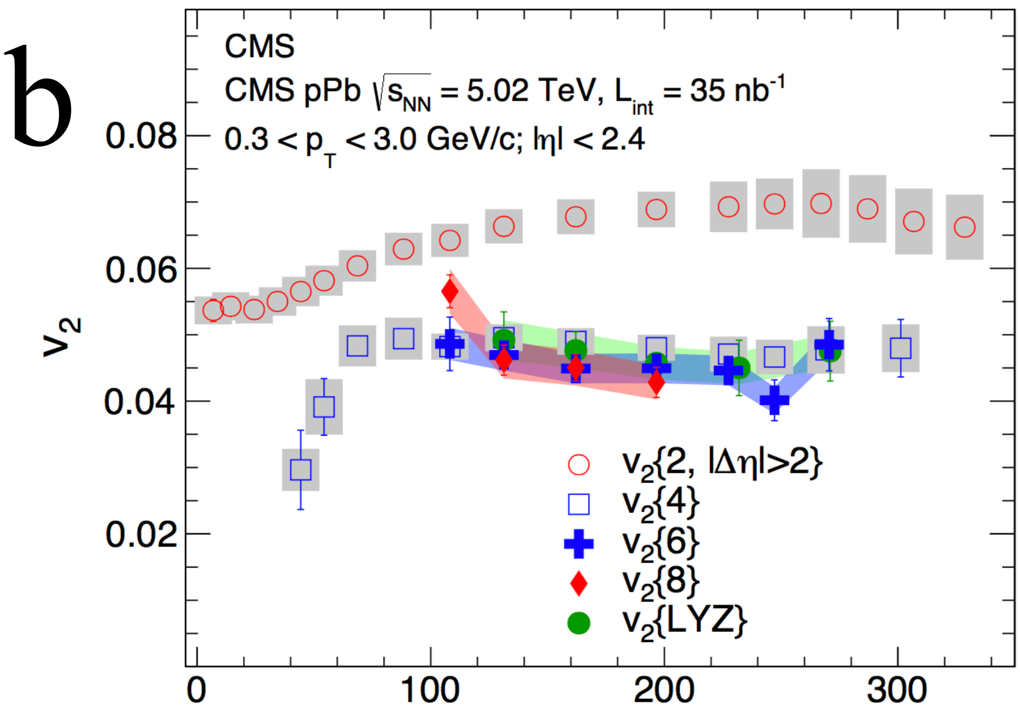
v_n depends on distribution of hot spots (ε_n) and transport properties.

Ongoing debate whether hydro is applicable in small systems

Features of collectivity in HM pPb



pPb

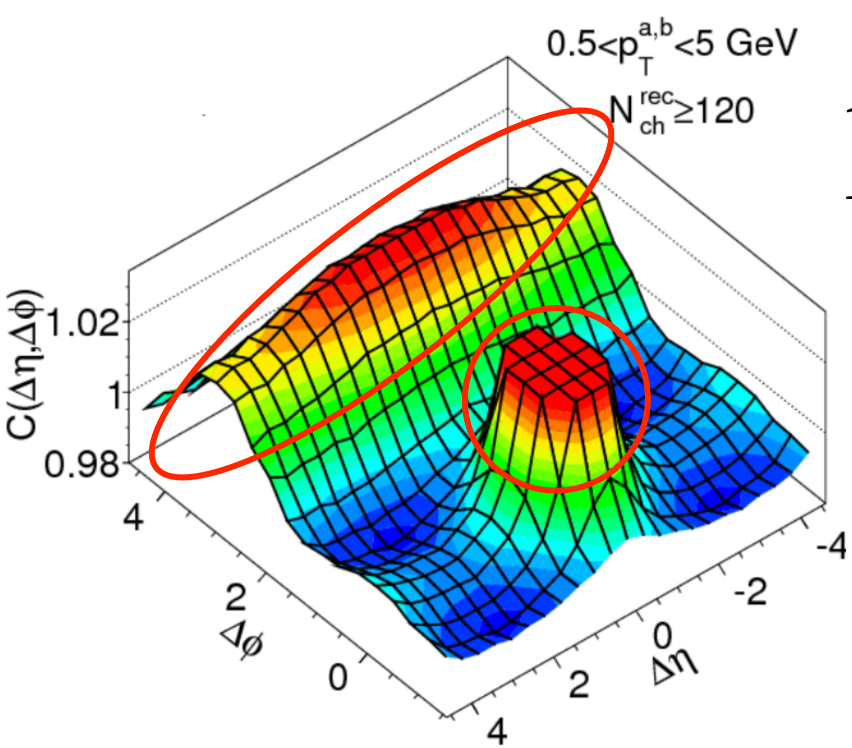


$v_2\{4\} \approx v_2\{6\} \approx v_2\{8\} \approx v_2\{\infty\}$

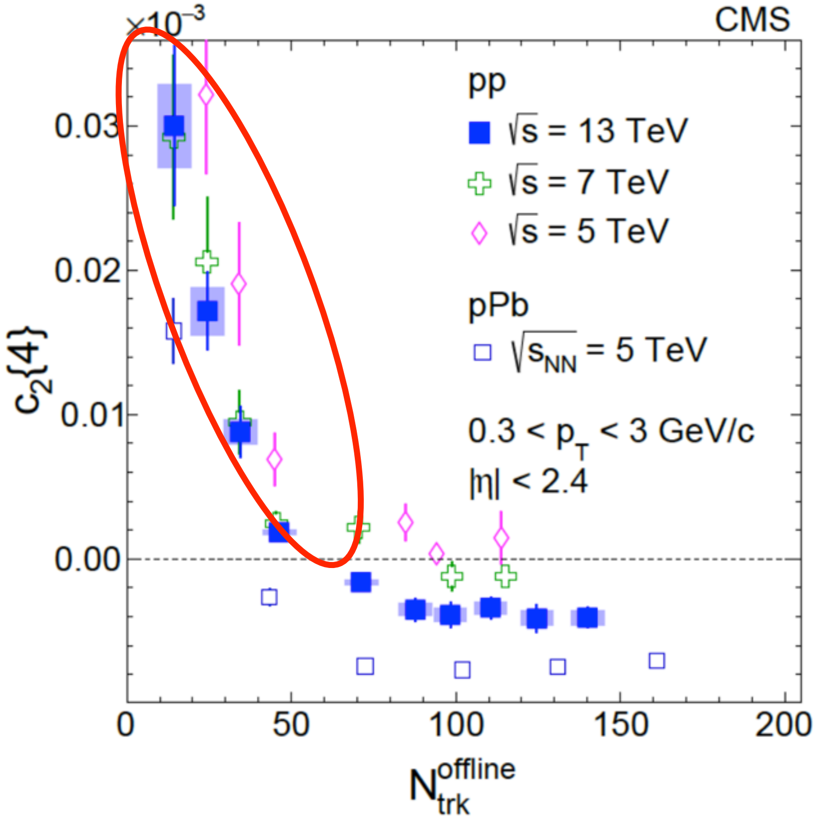
Long-range in η

Multi-particle signals

Features of collectivity in HM pp



pp



Long-range in η

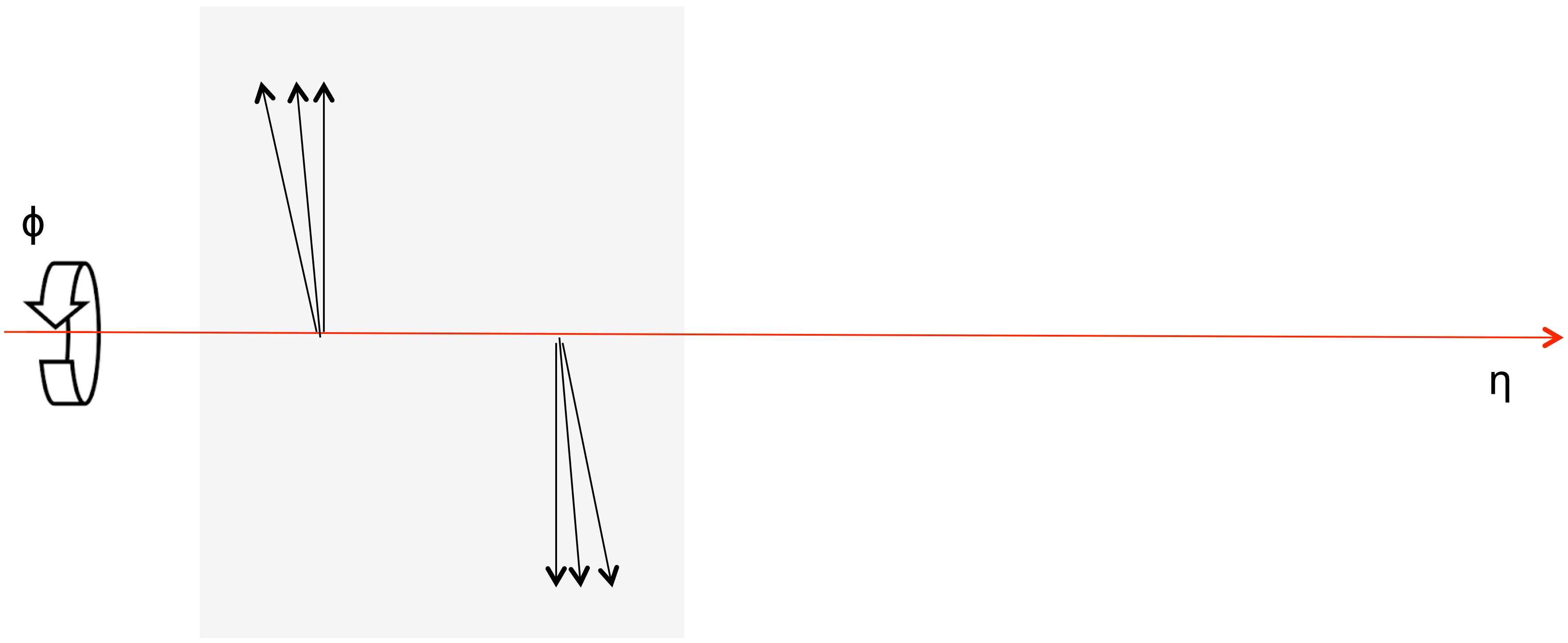
Multi-particle signals

Non-flow can generate long-range (away-jet) or multi-particle correlation (fragmentation) but not both

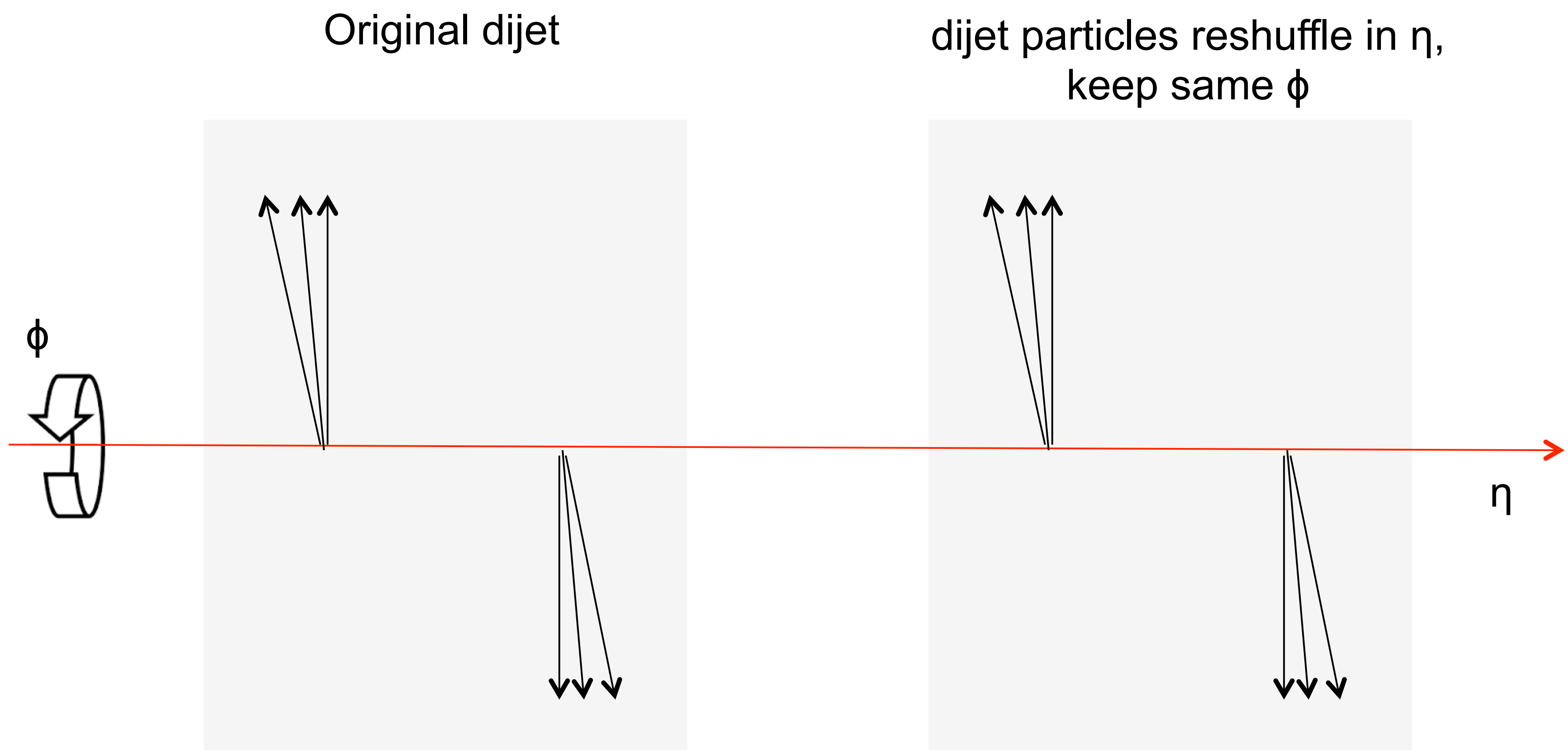
Collectivity must mean both

Azimuthal correlation from collectivity

Original dijet



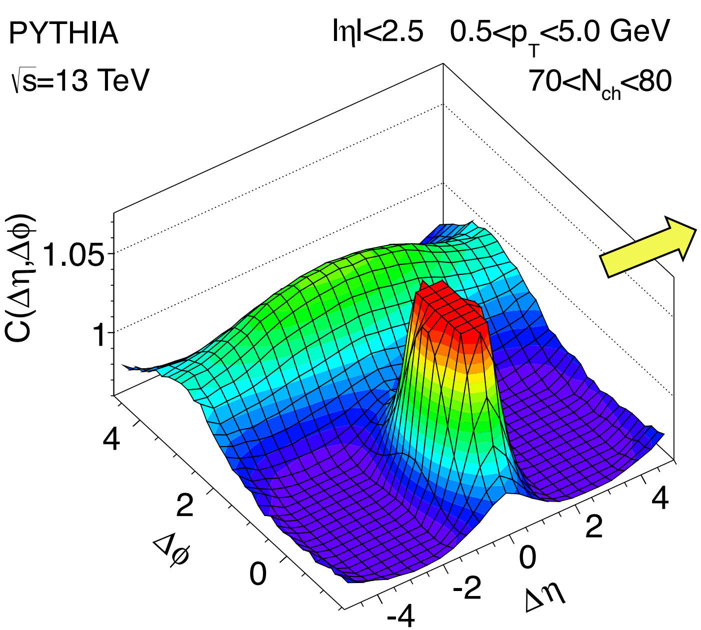
Azimuthal correlation from collectivity

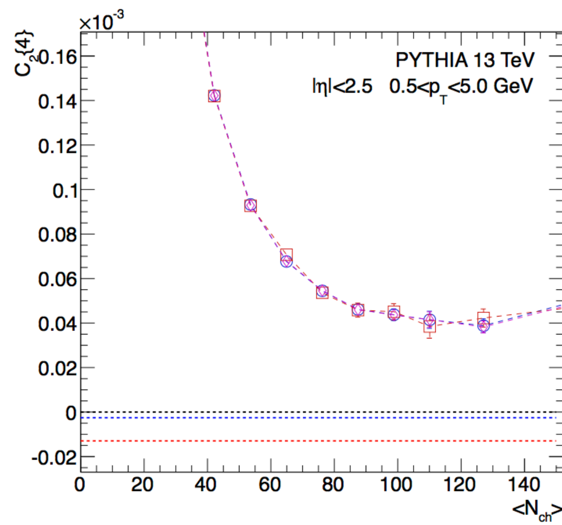


They give the same flow coefficient $c_n\{4\}$ and $v_n\{4\}$, although clearly the first case is non-flow and the second case would be classified as flow

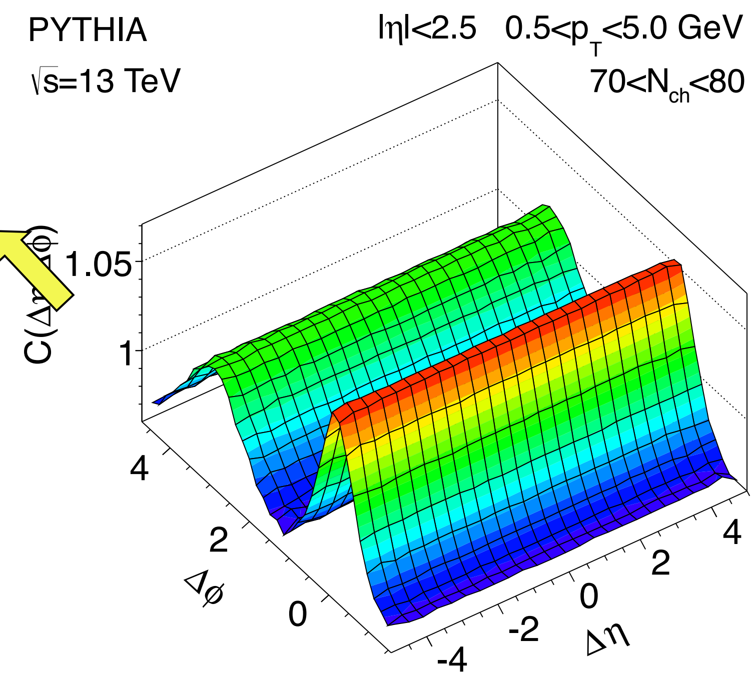
Azimuthal correlation from collectivity

original





η reshuffled



By mingliang Zhou

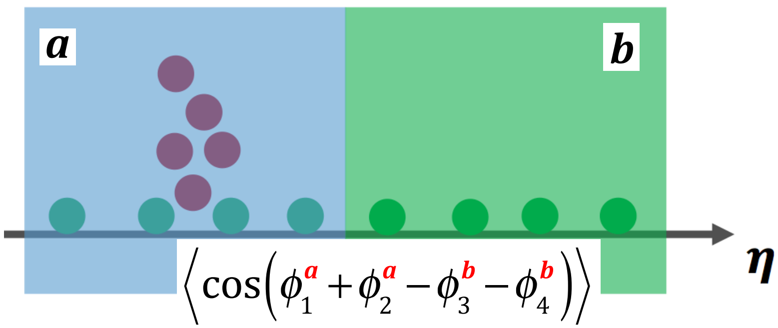
They give the same flow coefficient $c_n\{4\}$ and $v_n\{4\}$, although clearly the first case is non-flow and the second case would be classified as flow

Azumuthal corr. alone can't distinguish flow & non-flow.

Long-range collectivity via subevent cumulants

arXiv:1701.03830

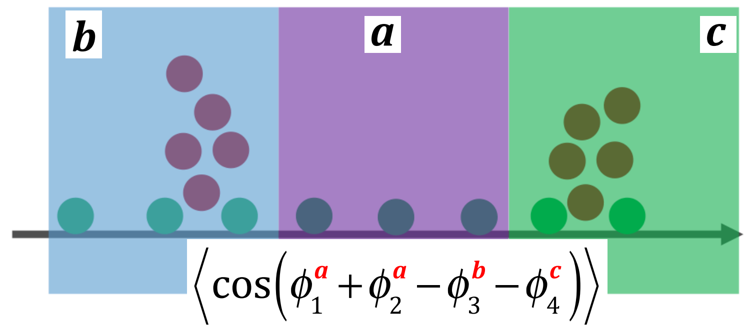
Event with jet



2 sub-event

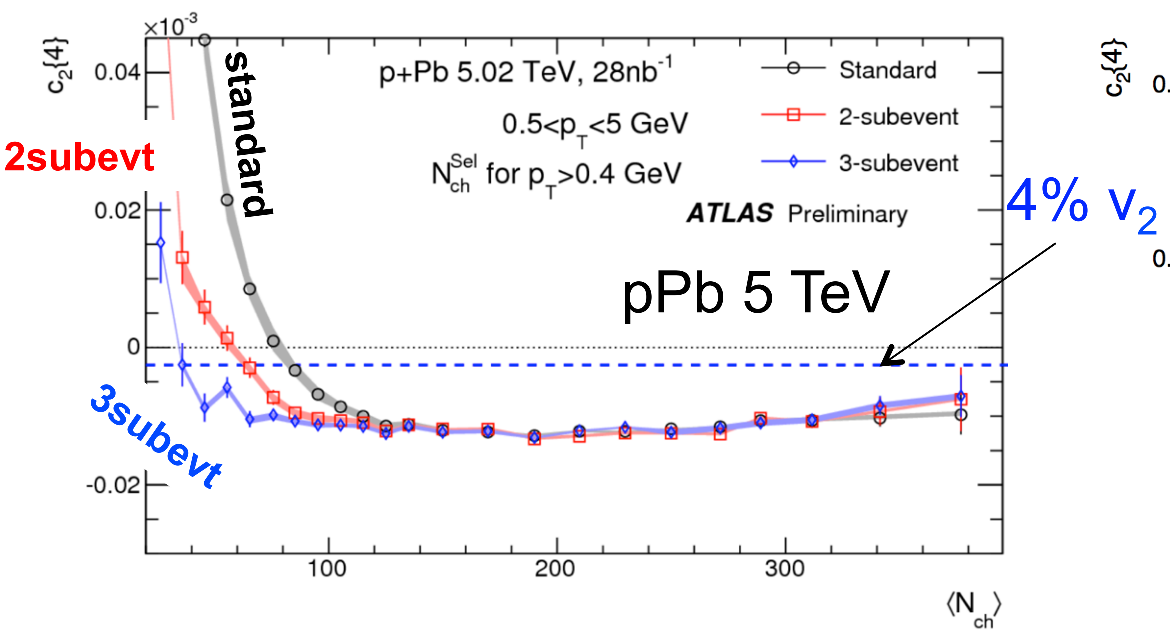
removes intra-jet correlations

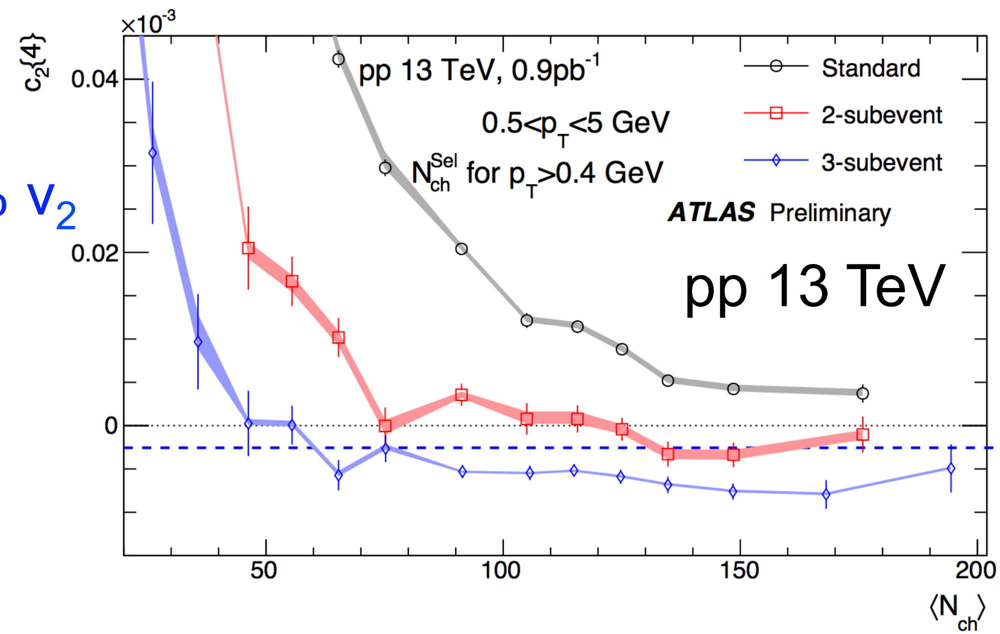
Event with dijet



3 sub-event

removes inter-jet correlations





pPb: methods consistent for N_{ch}>100, but split below that

pp: Only subevent method gives reliable negative $c_2\{4\}$ in broad range of N_{ch}

Sign-change of $c_2\{4\}$

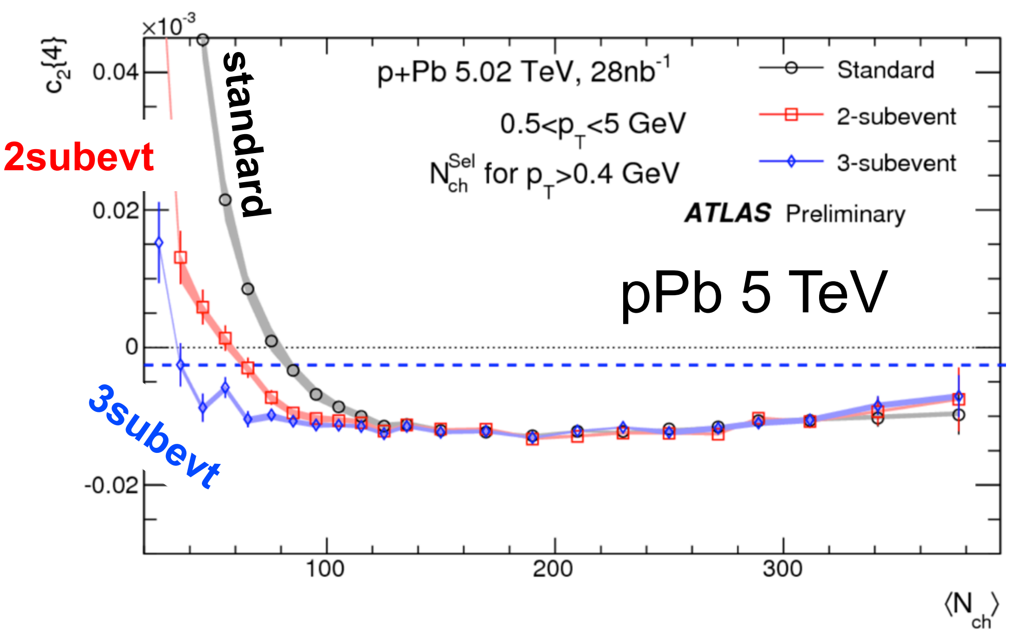
- Most positive $c_2\{4\}$ in standard cumulants are jets and dijets.
  - Remaining positive $c_2\{4\}$ in 3-subevent due to residual dijets.

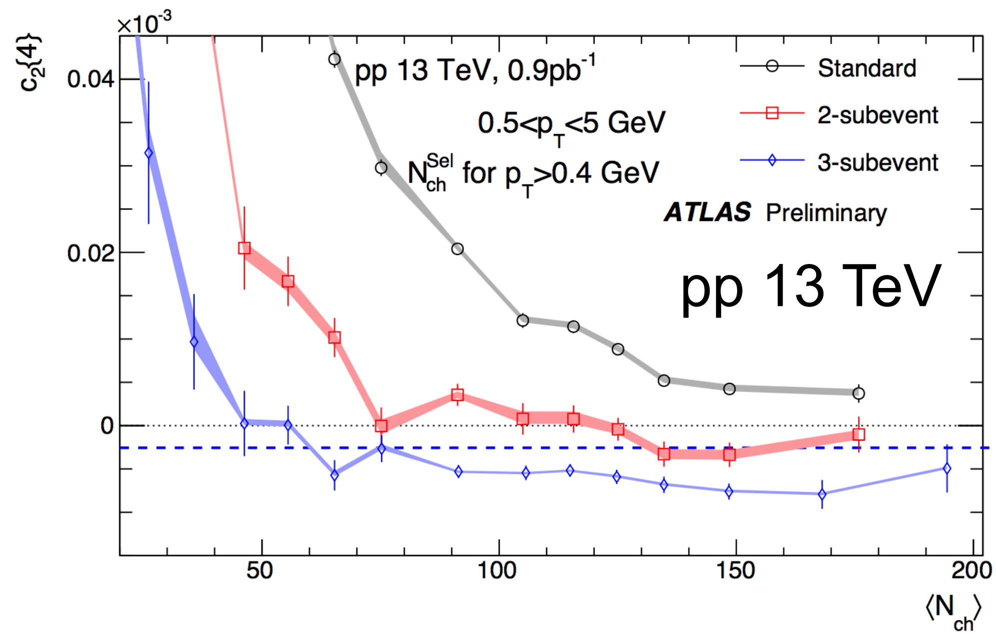
- CGC expect sign-change at low N_{ch}

Dumitru,McLerran,Skokov

$$c_2\{4\} = \frac{1}{N_D^3}\left(\frac{1}{4(N_c^2-1)^3} - A^4\right)$$

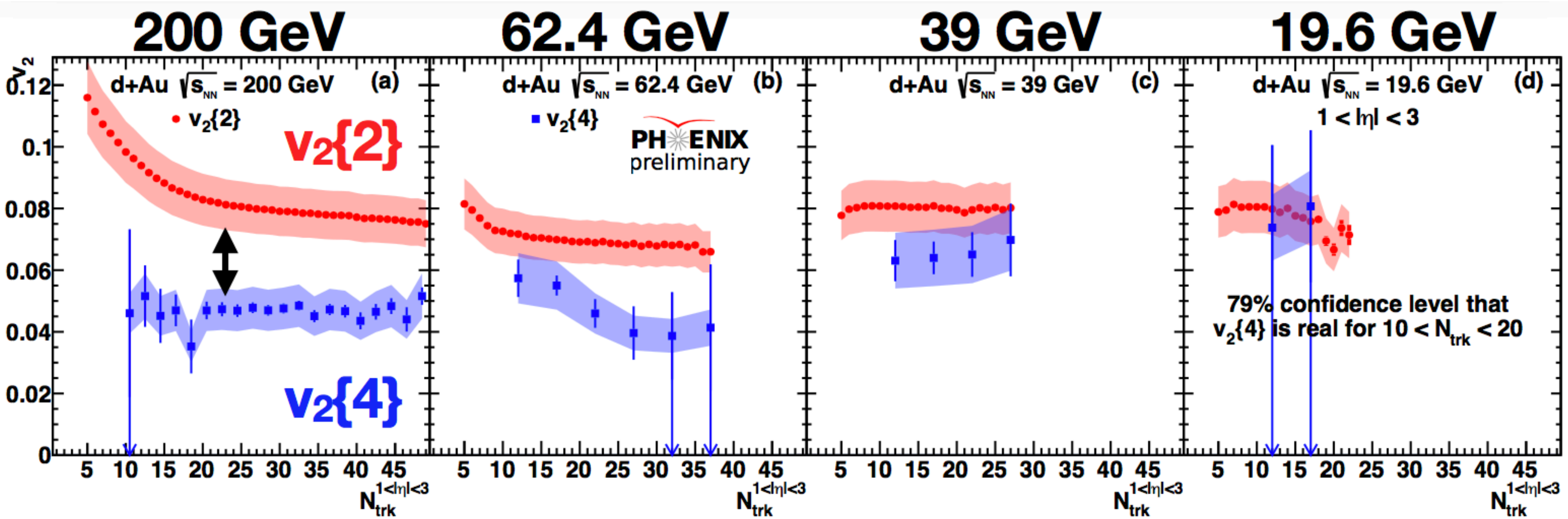
Glasma diagram non-linear/non-Gaussian effects





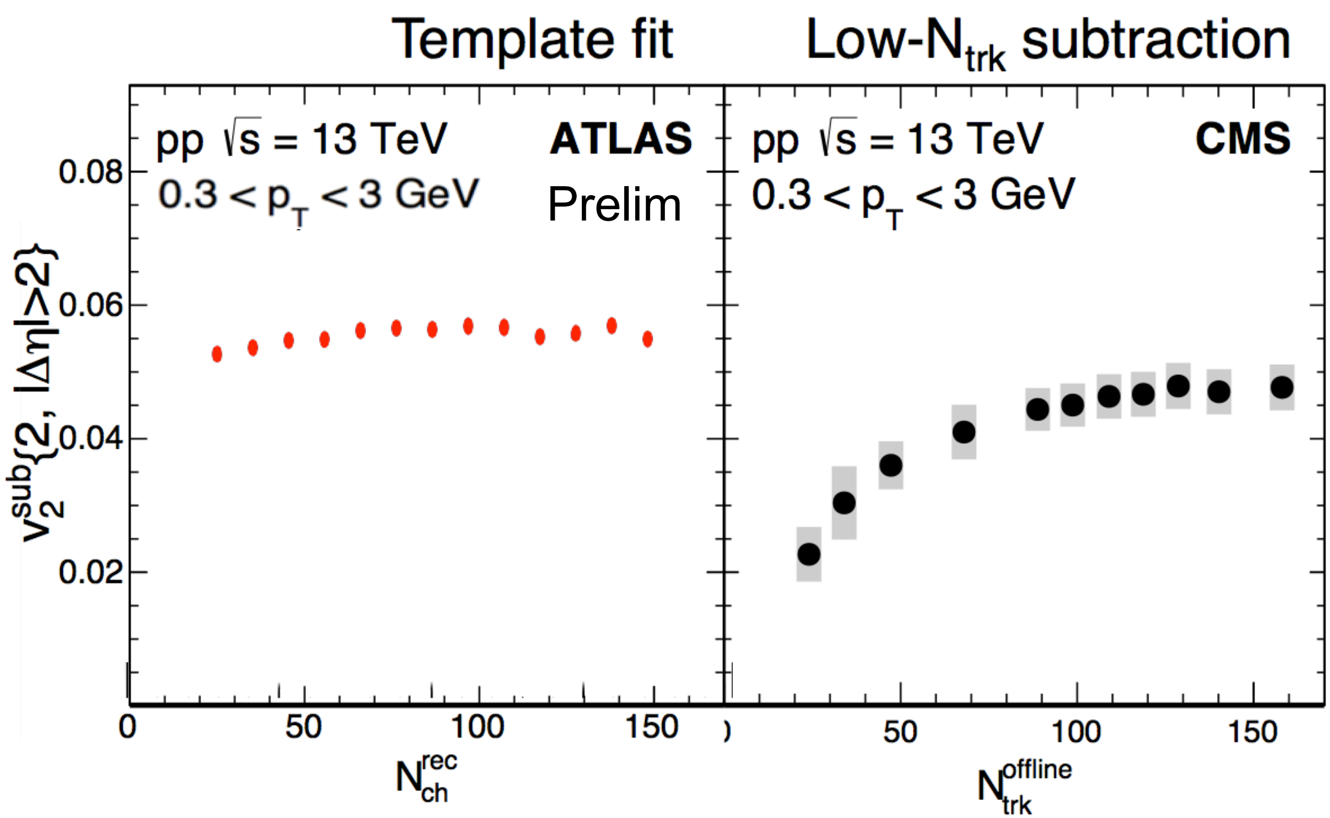
Glasma diagram contribution is small?

√s dependence of $c_2\{4\}$ at RHIC



- Surprising features: $v_2\{4\}$ larger at lower √s, reaching $v_2\{2\}$.
- Difficult to describe in both CGC and hydro
- Important to understand non-flow in standard cumulant method

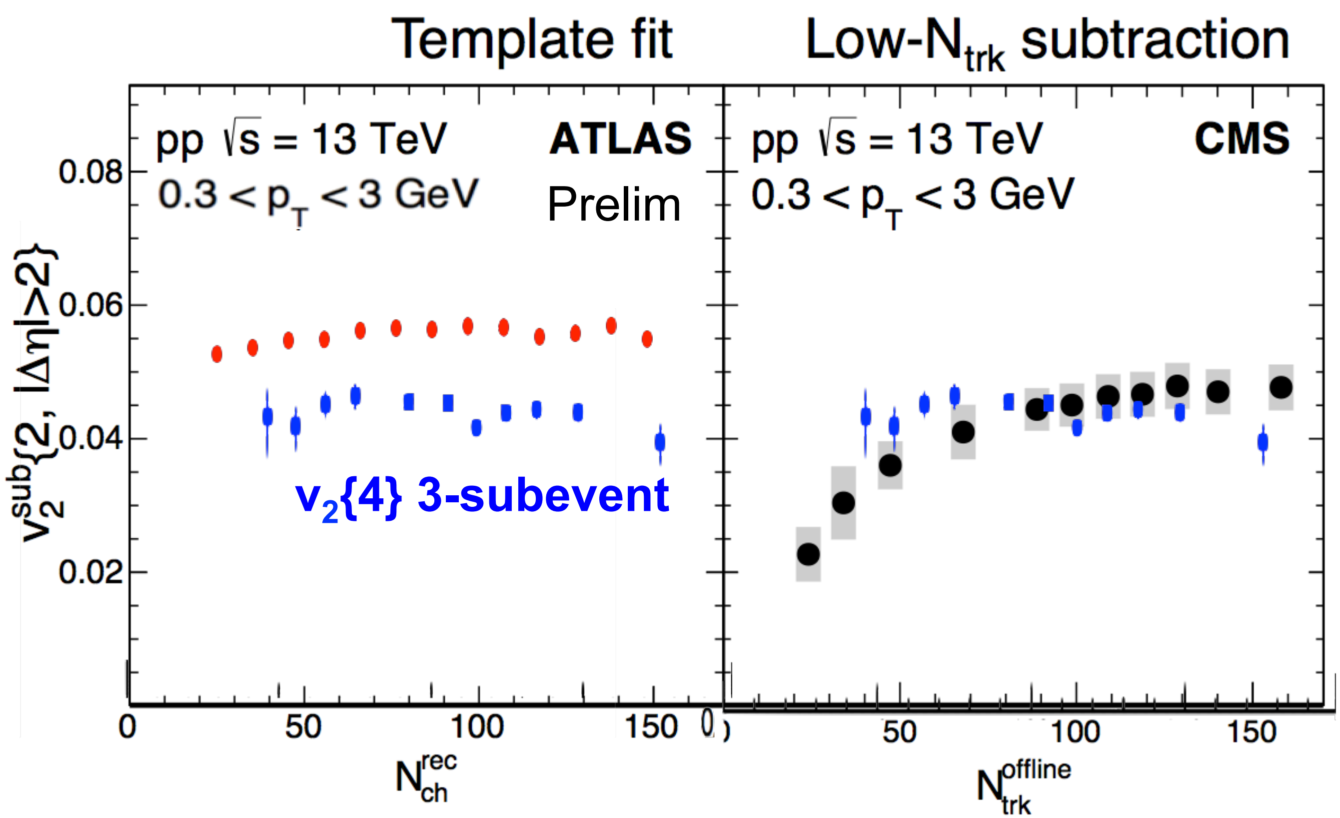
Does collectivity turn off at low N_{ch}?



peripheral subtraction including peripheral pedestal (assuming the peripheral also has flow)
→so called template fit

peripheral subtraction not including peripheral pedestal (assuming the peripheral has no flow)
→ so call peripheral sub.

Does collectivity turn off at low N_{ch}?



- $v_2\{4\}$ from 3-subevent show no dependence on N_{ch}.
- Why $v_2\{2\}_{\text{peri. sub}} \approx v_2\{4\}$ in pp? surprising because:

$$v_n\{2\}^4 - v_n\{4\}^4 = \langle v_n^4 \rangle - \langle v_n^2 \rangle^2 = \langle (v_n^2 - \langle v_n^2 \rangle)^2 \rangle \geq 0$$

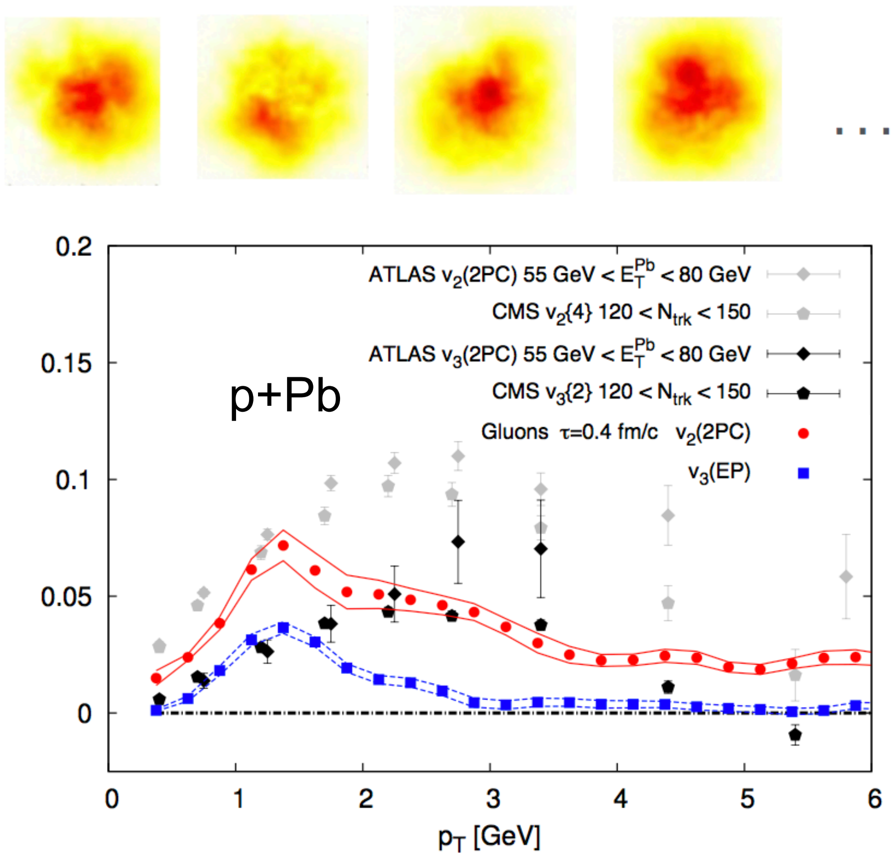
$v_2\{4\}$ also shows No hint of collectivity turning-off at low N_{ch}!

Challenge both CGC and standard hydro?

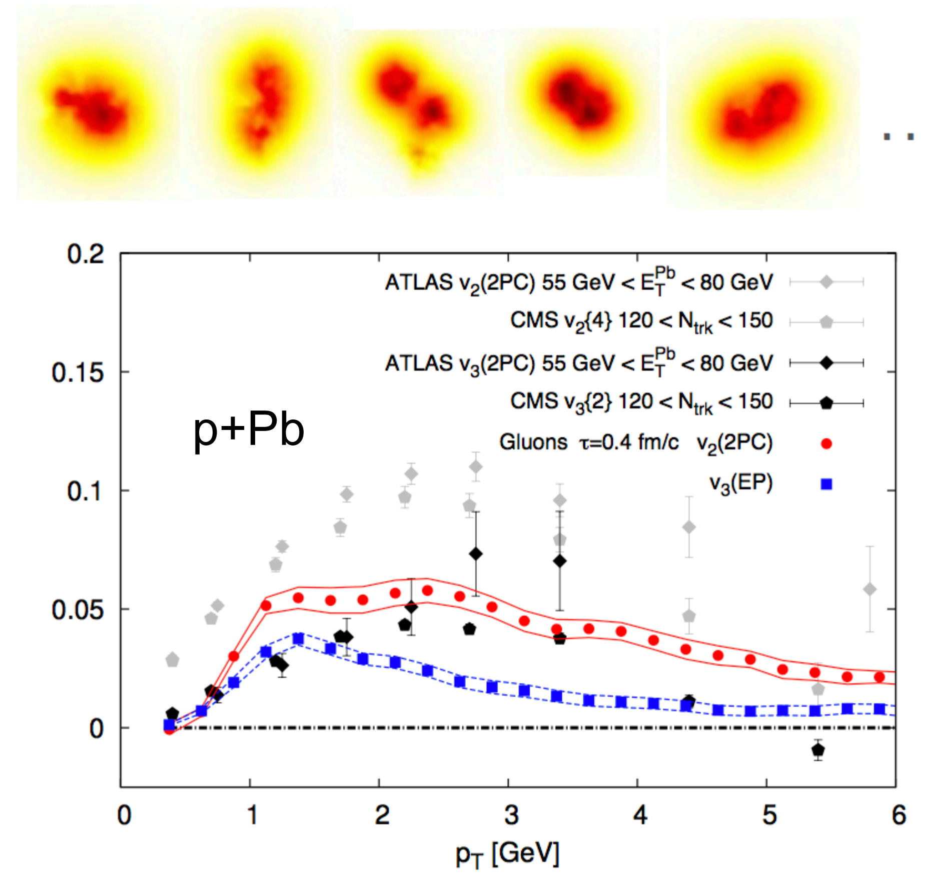
Role of initial geometry is very different

From Schenke, Schlichting, Venugopalan,

'Spherical' proton



'Eccentric' proton

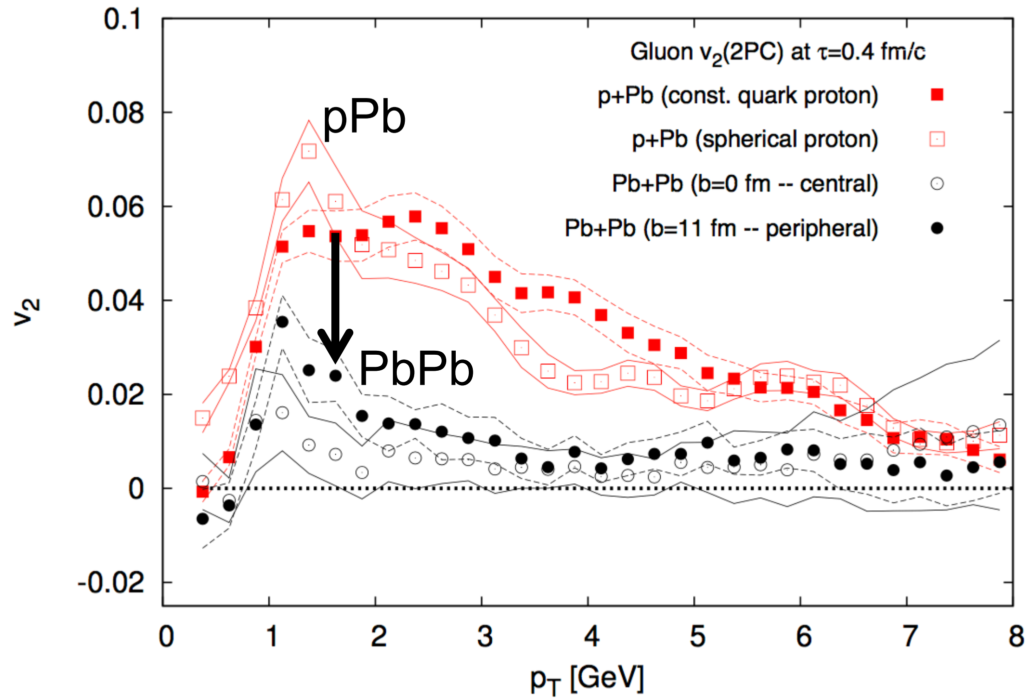


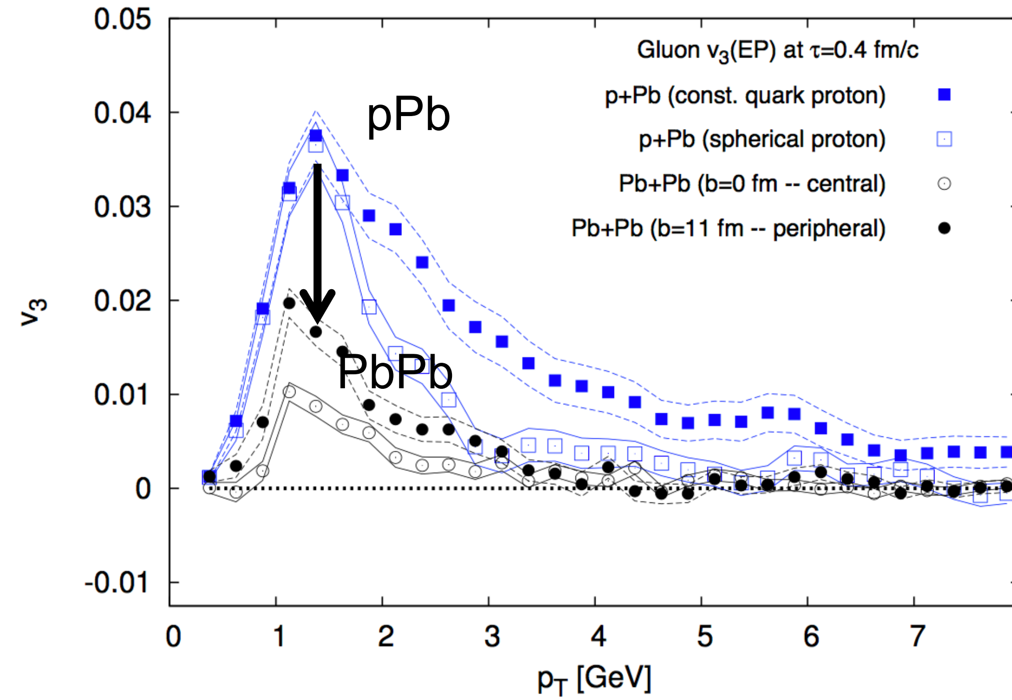
The orientation of collectivity is unrelated to initial eccentricity

→Very different from hydrodynamics

Role of initial geometry is very different

From Schenke, Schlichting, Venugopalan,





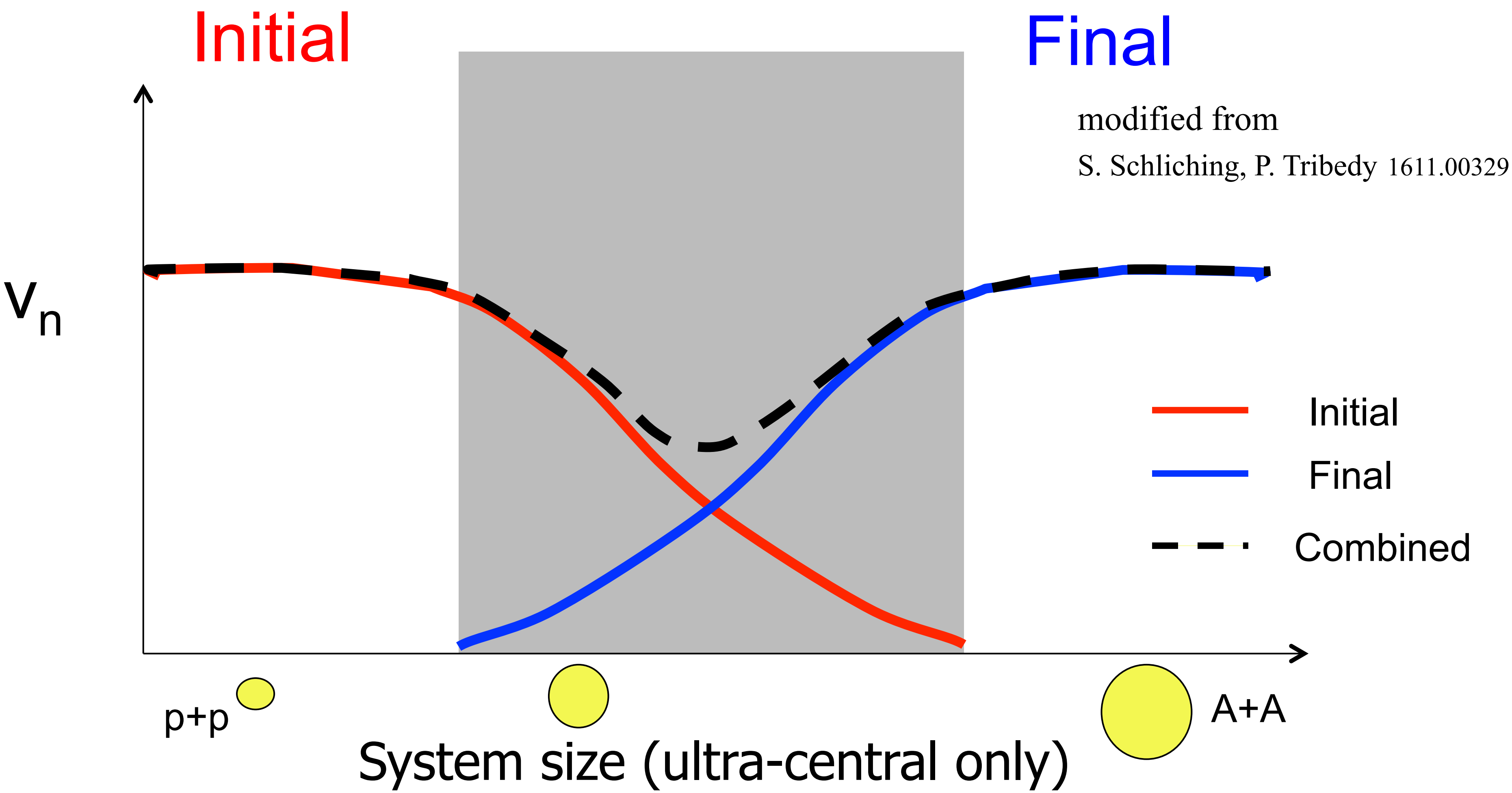
$$c_2\{4\} = \frac{1}{N_D^3}\left(\frac{1}{4(N_c^2-1)^3} - A^4\right)$$

The orientation of collectivity is unrelated to initial eccentricity

→Very different from hydrodynamics

Expect contribution diminish as system size is increased

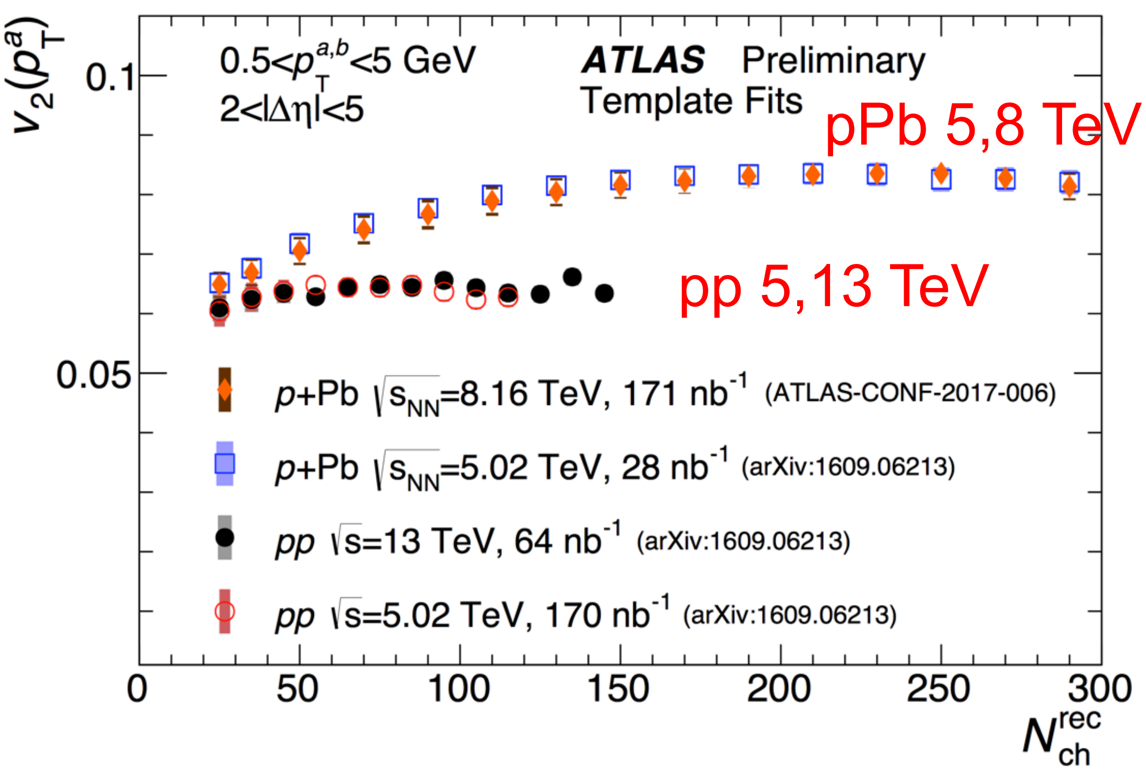
Presence of both initial and final state scenarios?

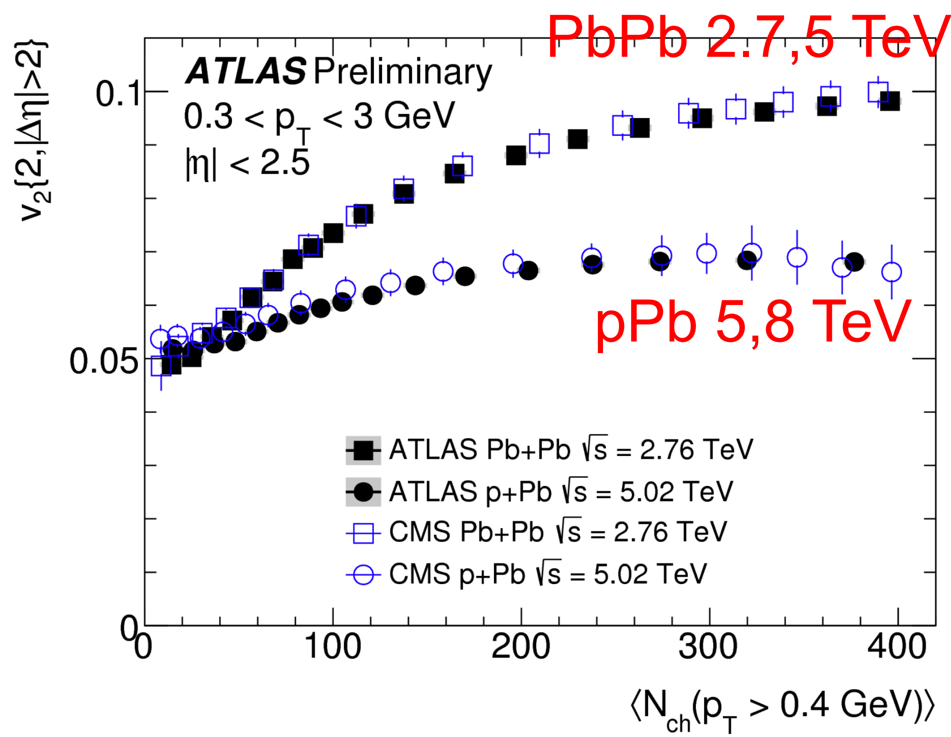


Phases of collectivity from CGC and hydro are unrelated

→ a minimum of total v_n at certain system size?

System size dependence





Clear dependence on collision systems but ~no dependence on √s

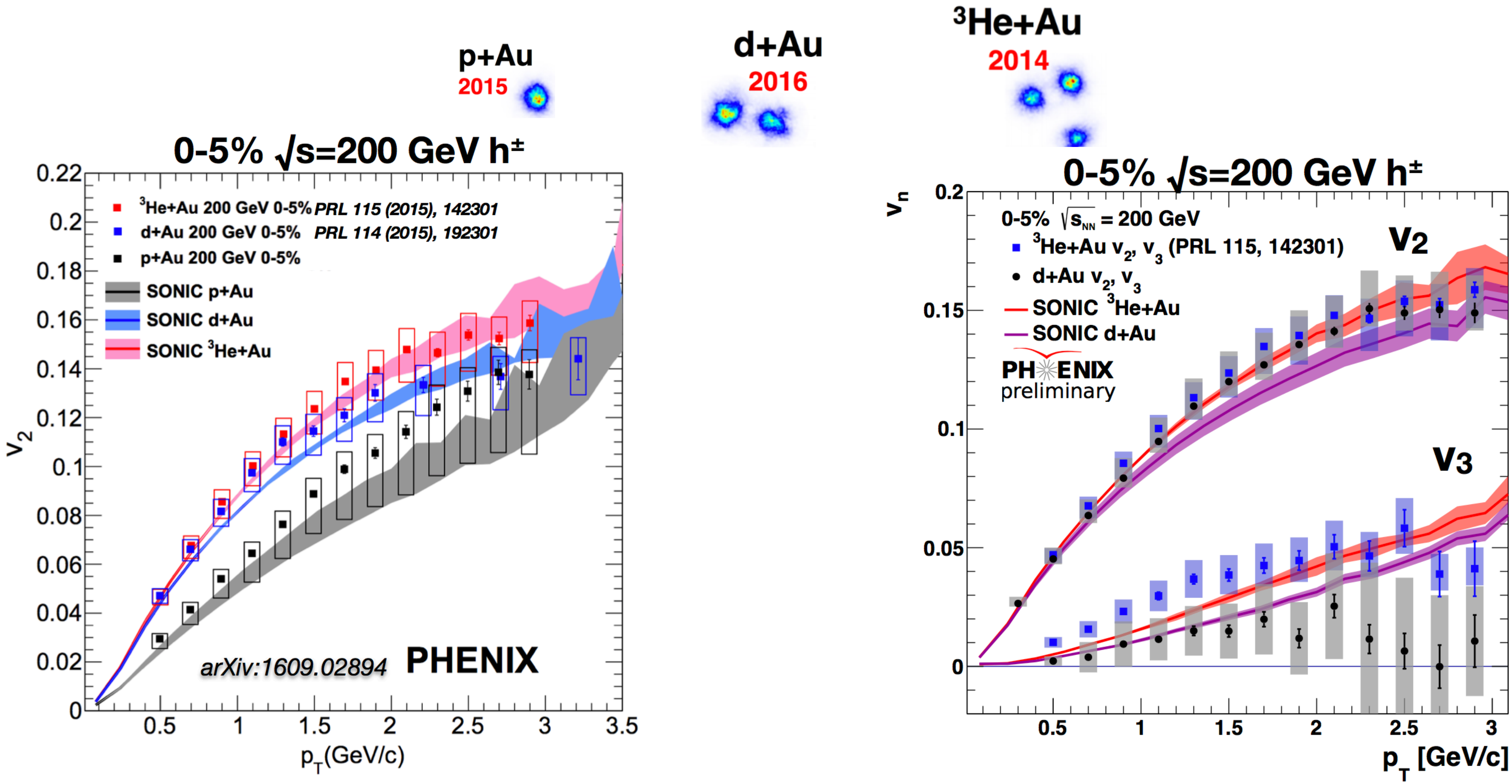
v_2^{pp} (high-mul)<v_2^{pPb}(low-mul)!

CGC Unclear if the pp/pPb hierarchy is expected.

Hydro Interplay between viscous damping and initial ε_n
pPb: may seen an average geometry effect
pp: geometry maybe poorly correlated with N_{ch}.

Kevin Welsh, Jordan Singer, and Ulrich Heinz 1605.09418

Geometry scan at RHIC



$v_2^{pAu} < v_2^{dAu} \leq v_2^{HeAu}$ $v_3^{dAu} < v_3^{HeAu}$

Hierarchy compatible with initial geometry + final state effects

Look forward to the CGC predictions

Summary of collectivity in small system

- Collectivity associated with ridge must involve many particles in multiple η ranges → subevent methods

Challenge for both initial & final state scenarios?

- LHC v_2 associated with ridge does not turn off at low N_{ch}.
- RHIC $v_2\{4\}$ increases and approaches $v_2\{2\}$ at lower $\sqrt{s}$

Challenge for initial state only scenarios?

- LHC $v_2^{pp} < v_2^{pPb}$ in all N_{ch} and all $\sqrt{s}$.
- LHC $c_2\{4\} < 0$ down to very low N_{ch} and more negative at higher p_T.
- RHIC geometry scan suggest ordering of v_n follows that of ε_n.

…

Coexistence of initial state & final state scenarios?

Key issue: How to constrain timescales for emergence of collectivity?
the role of CGC, preflow and hydro?