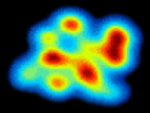
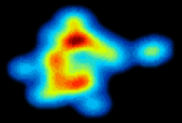
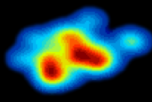
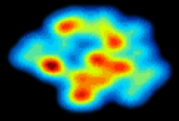
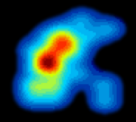
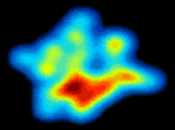




Prediction of Collectivity in Small Collision Systems Involving New Species

arXiv:1812.08096

S.H. Lim, J. Carlson, C. Loizides, D. Lonardoni, J.E. Lynn, J.L. Nagle, J.D. Orjuela Koop, J. Ouellette

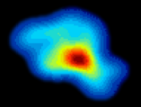




Sanghoon Lim

University of Colorado Boulder

The 35th WWND

Jan 8, 2019

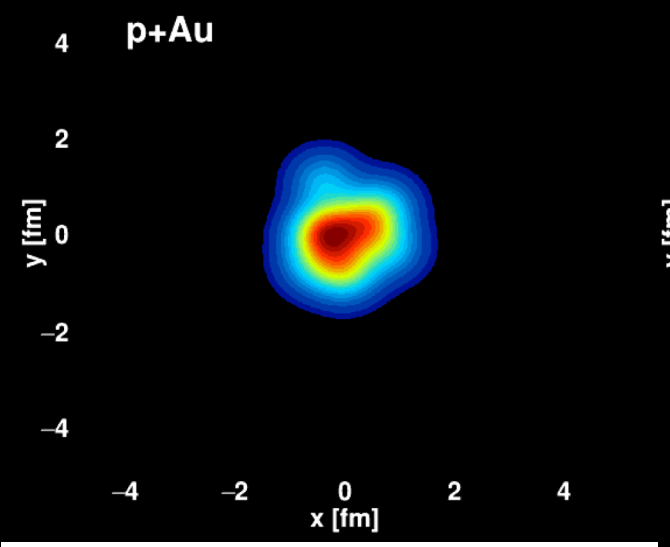


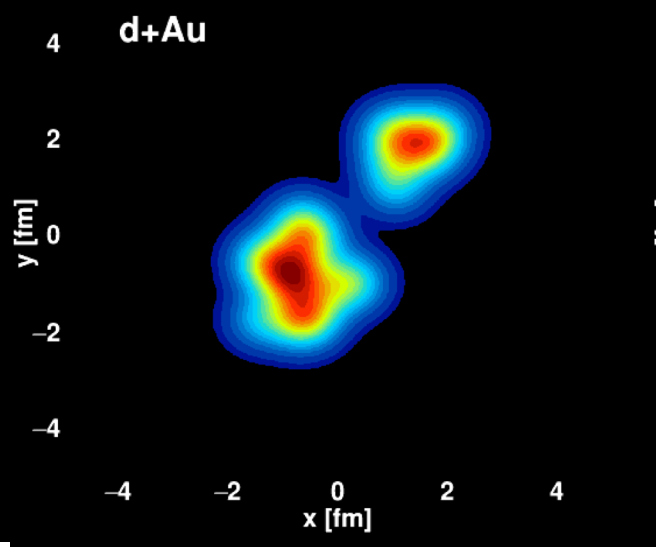
University of Colorado **Boulder**

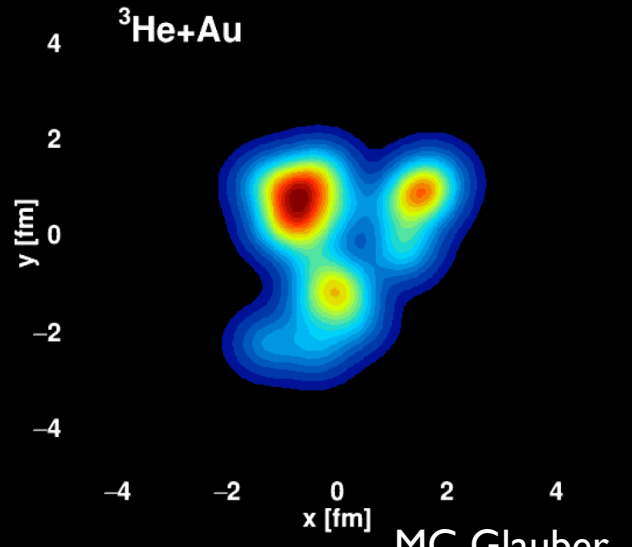
Many indications of collectivity in small systems at RHIC and LHC

Are there additional nuclear collision combinations that can shed more light?

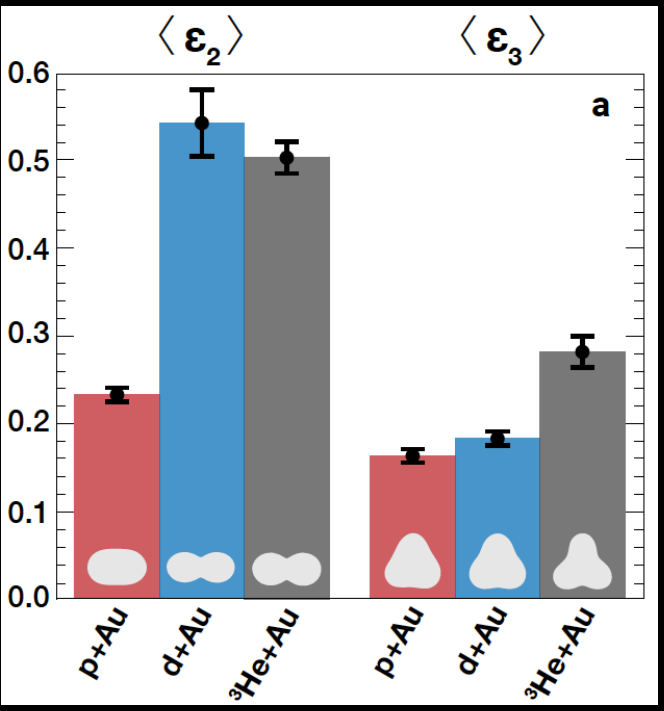
Control initial geometry







MC Glauber

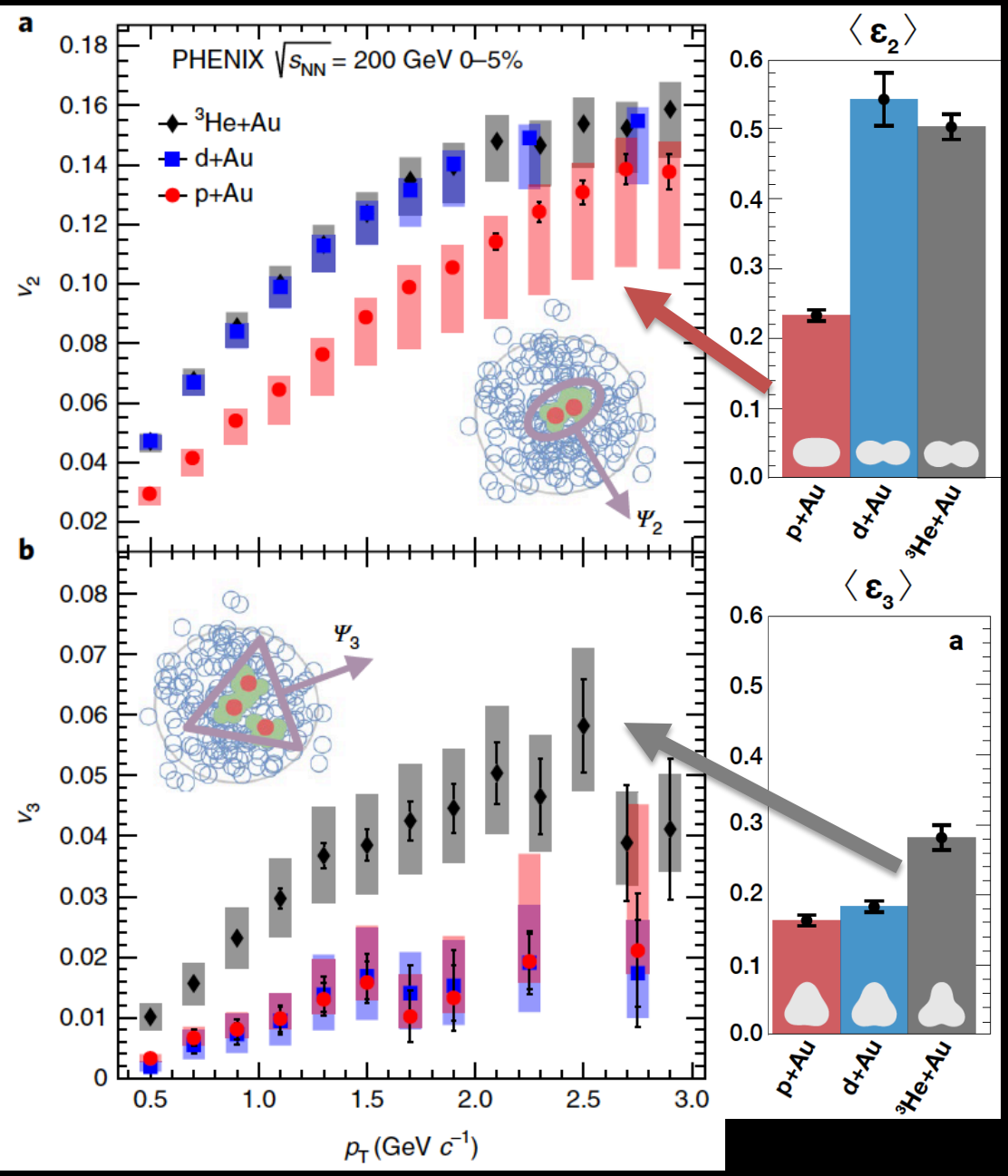


- Clearly different shape of initial geometry in p+Au, d+Au, and ^{3}He+Au collisions

- *Smaller $\langle\varepsilon_2\rangle$ in p+Au*
- *Larger $\langle\varepsilon_3\rangle$ in ^{3}He+Au*

arXiv:1805.02973

Control initial geometry

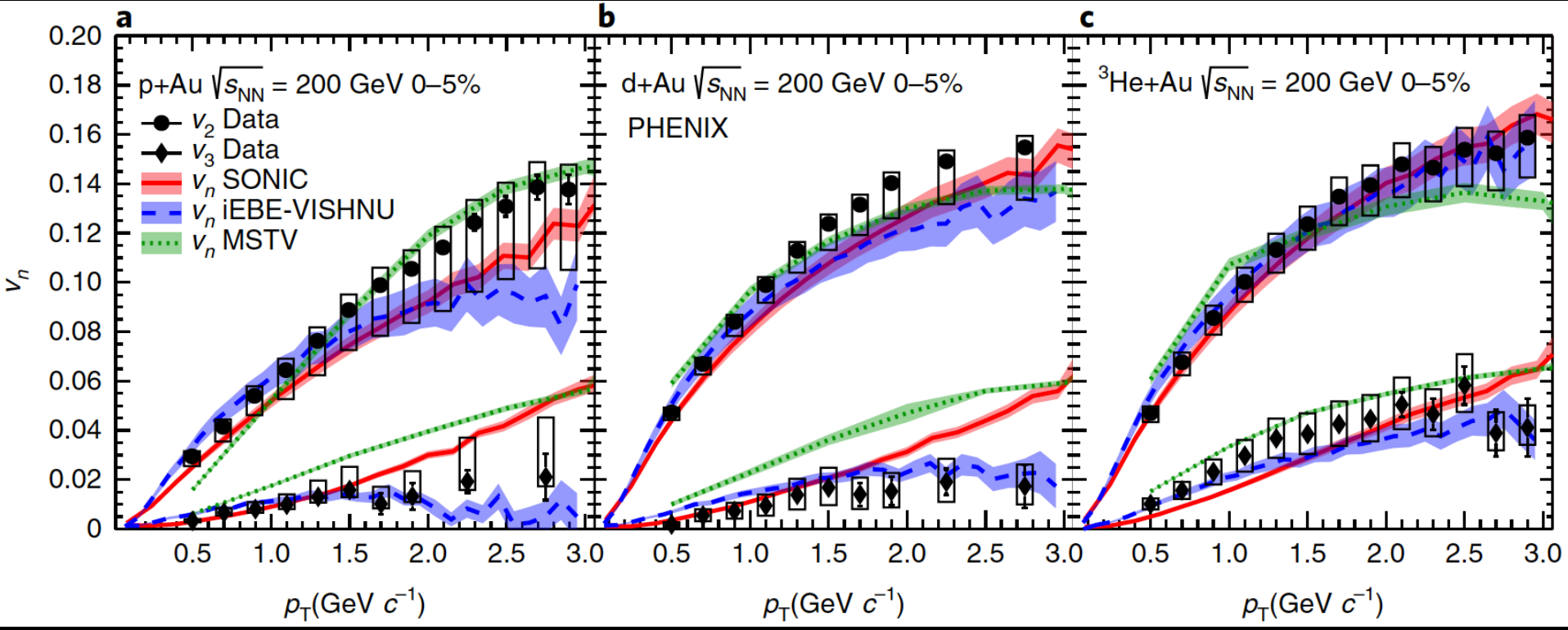


- *Smaller $\langle\varepsilon_2\rangle$ in p+Au*
- *Larger $\langle\varepsilon_3\rangle$ in ^{3}He+Au*

- *Smaller v_2 in p+Au*
- *Larger v_3 in 3He+Au*

arXiv:1805.02973

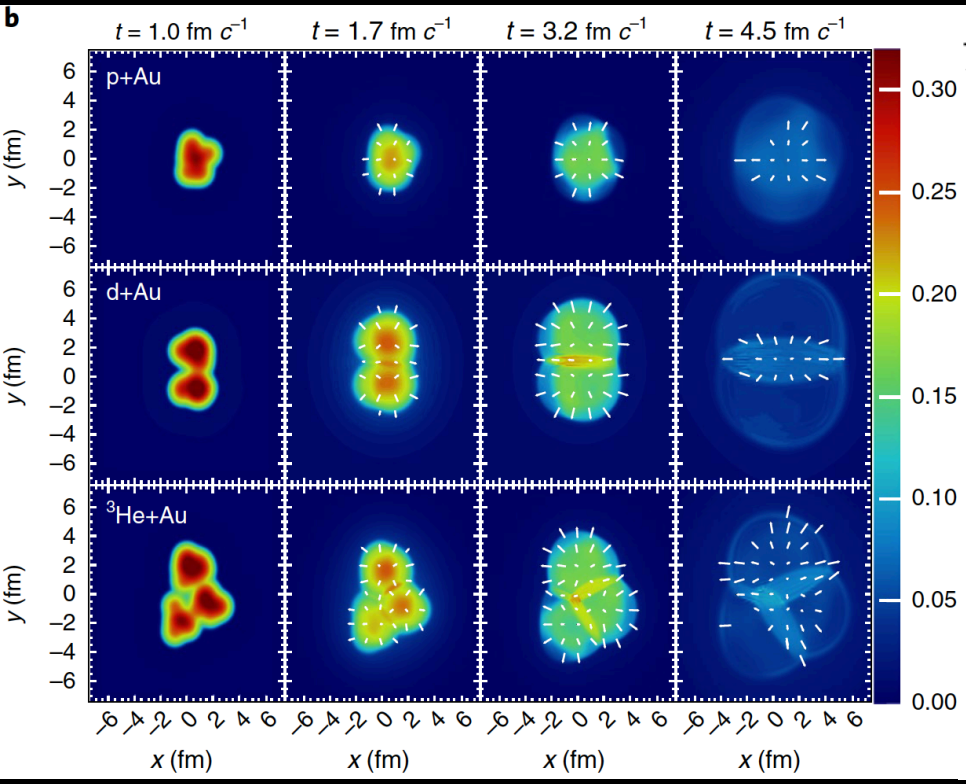
Control initial geometry

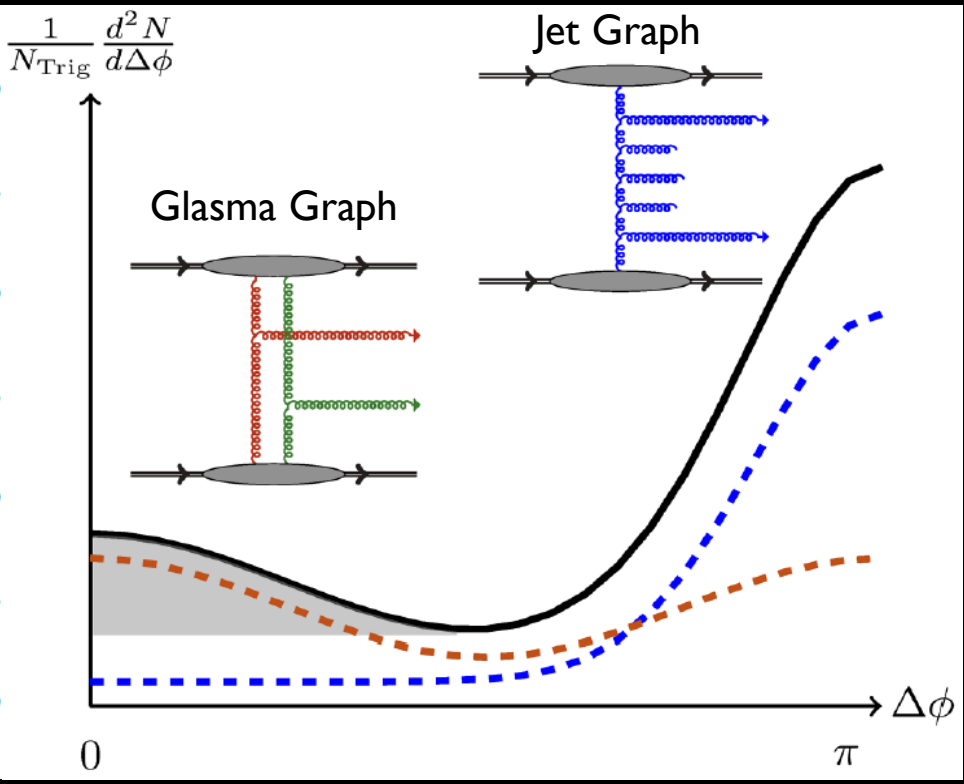


arXiv:1805.02973

- *Hydrodynamic models* can reproduce the data quite well
- *Initial state correlation model* give the right v_2 system ordering, but a poor overall description

Explore new geometries



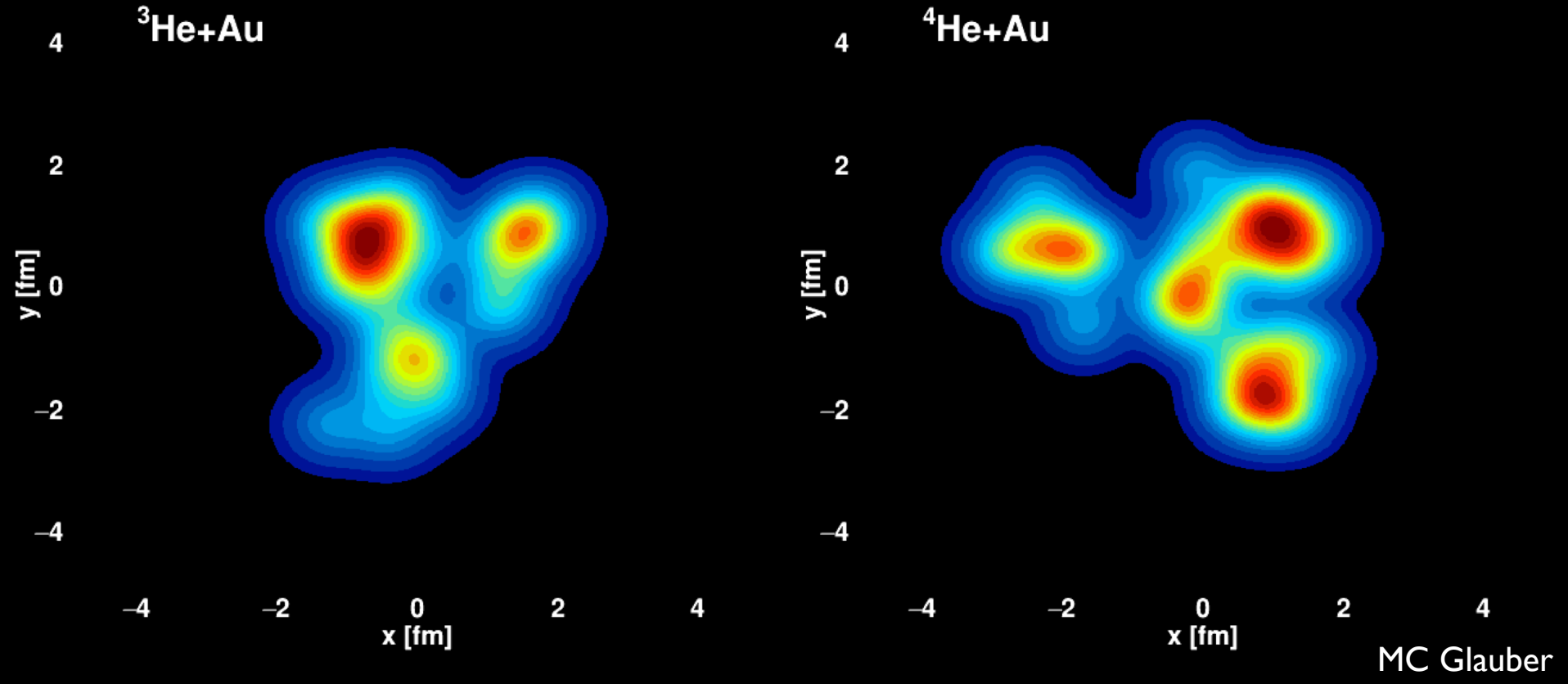


arXiv:1805.02973

arXiv:1509.07939

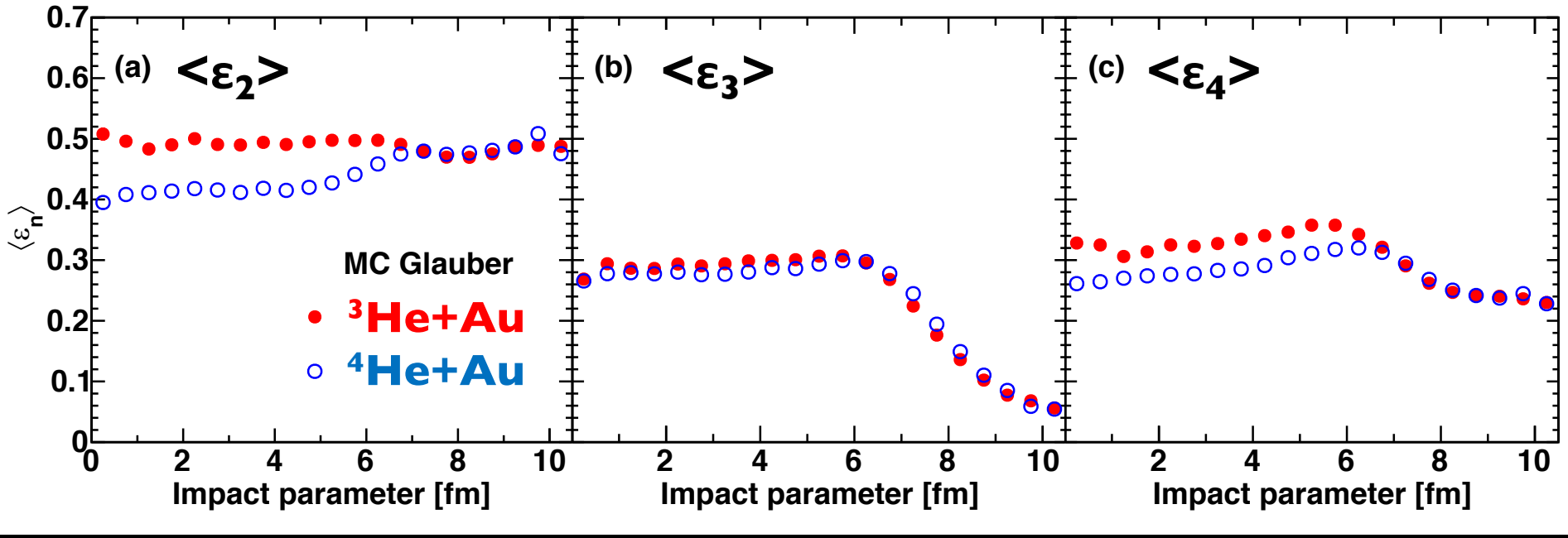
Can other collision geometries provide further discrimination?

How about ^{4}He?



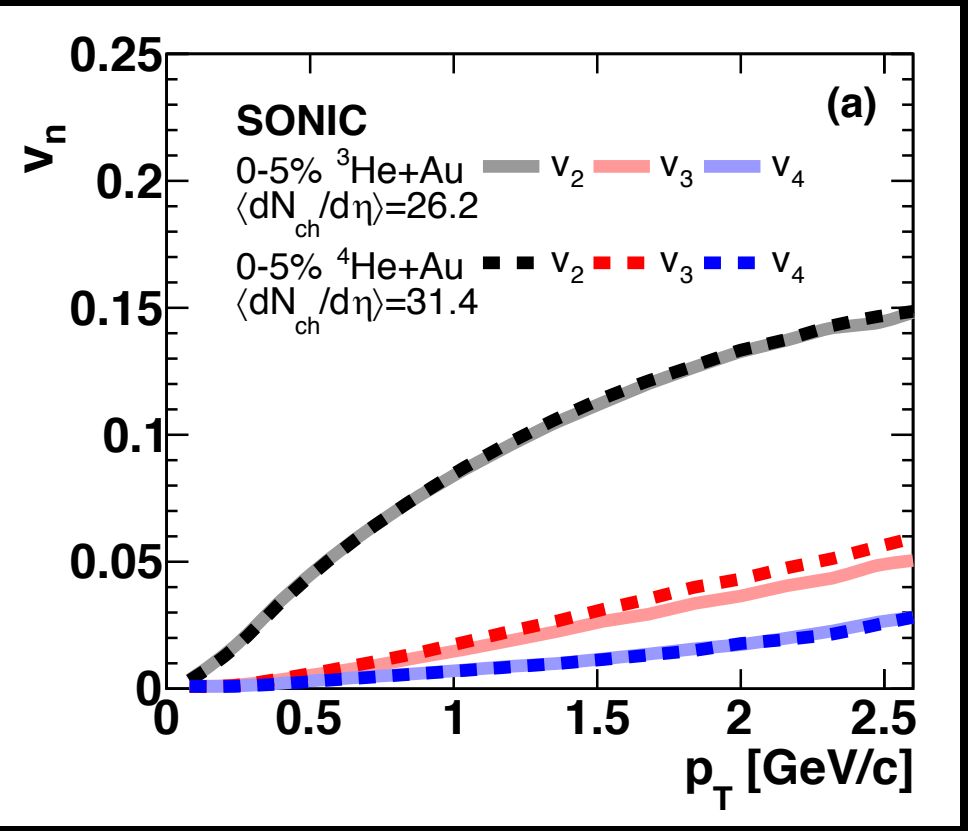
- Even with additional nucleon in ^{4}He, the size is more compact than ^{3}He
  - RMS for nucleon central coordinates: *1.46 fm for ^{4}He and 1.57 fm for ^{3}He*

Initial geometry in ^{3}He+Au and ^{4}He+Au



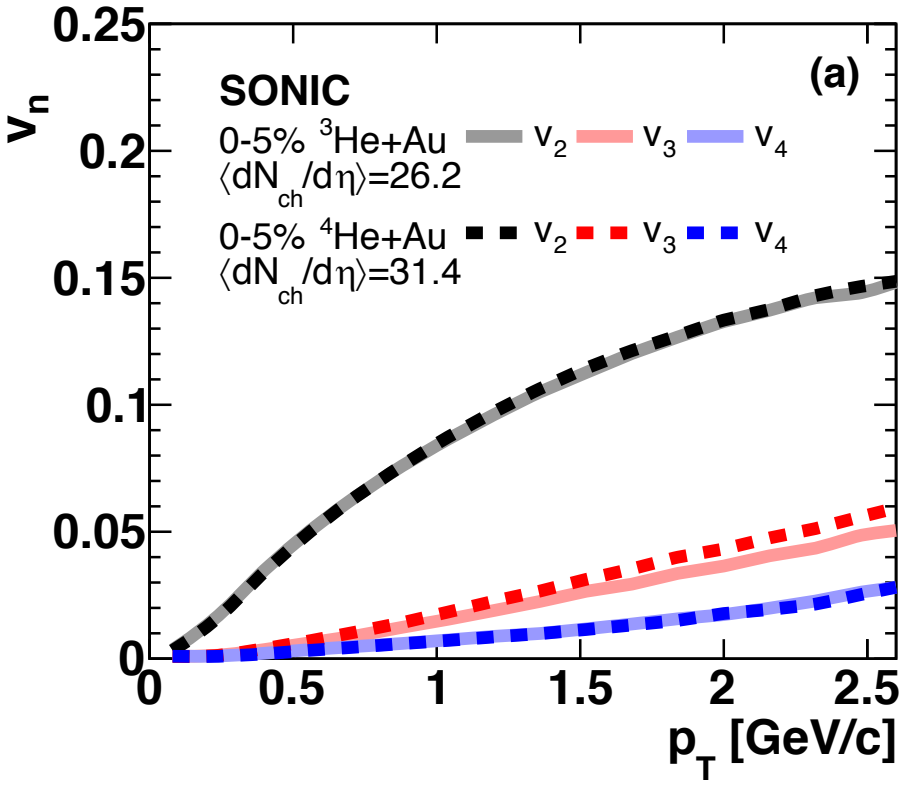
- Modestly different eccentricities – nothing very striking

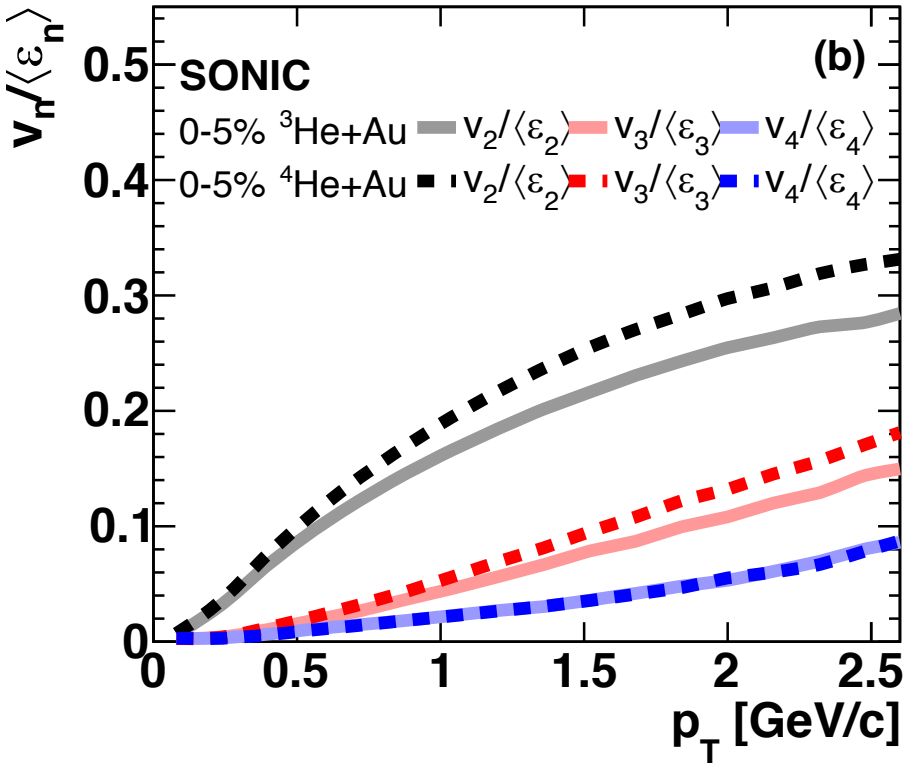
Collectivity in ^{4}He+Au 200 GeV



- v_n from MC Glauber + SONIC in 0-5% centrality
  - ~20% larger multiplicity in ^{4}He+Au collisions
  - *Quite similar v_n vs. p_T*

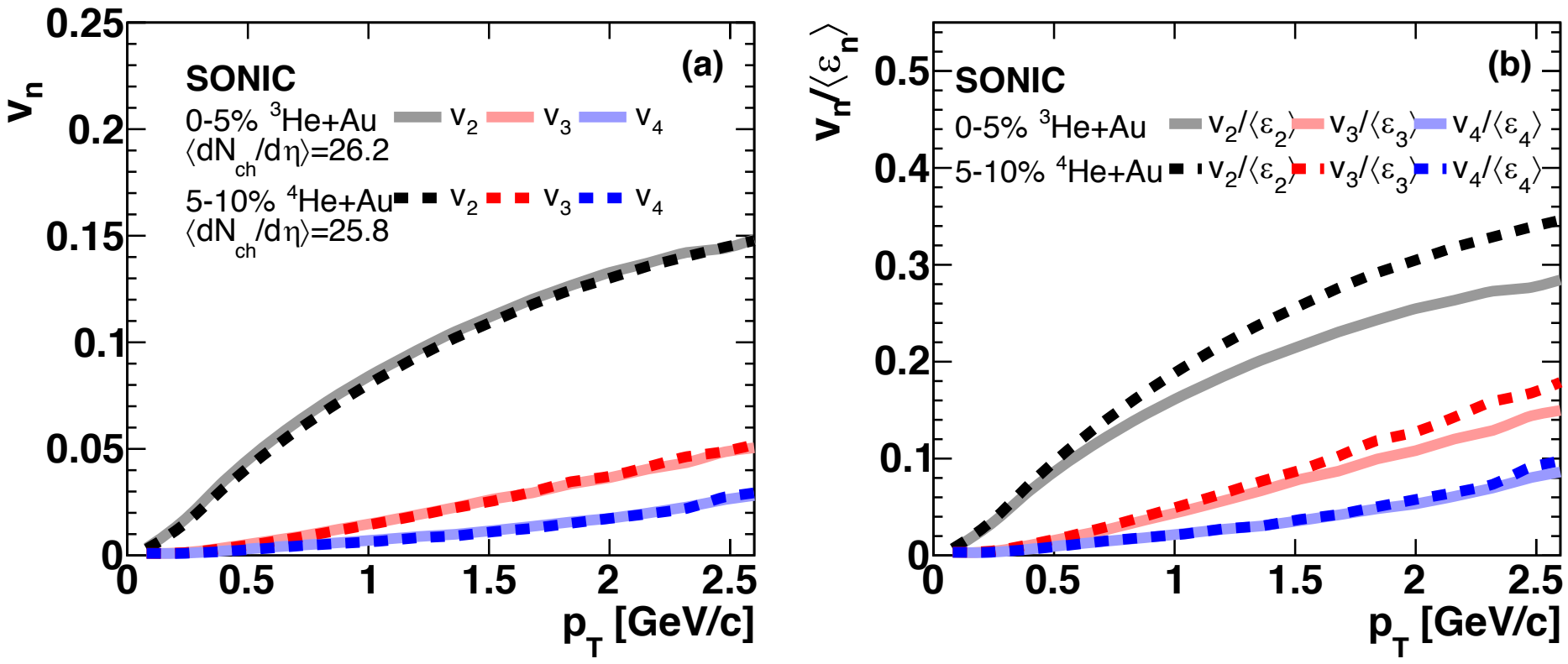
Collectivity in ^{4}He+Au 200 GeV





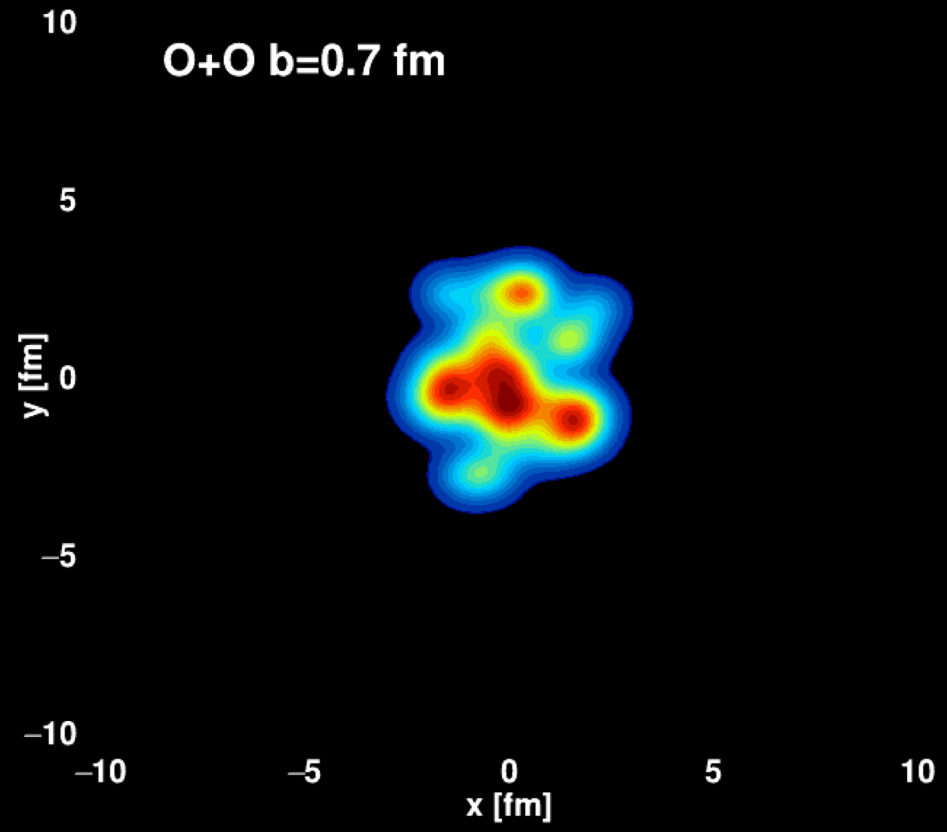
- v_n relative to initial geometry ($v_n/\langle\varepsilon_n\rangle$) in ^{4}He+Au is larger
- *More compact ^{4}He induced hot spot leads to larger translation of geometry to v_n*

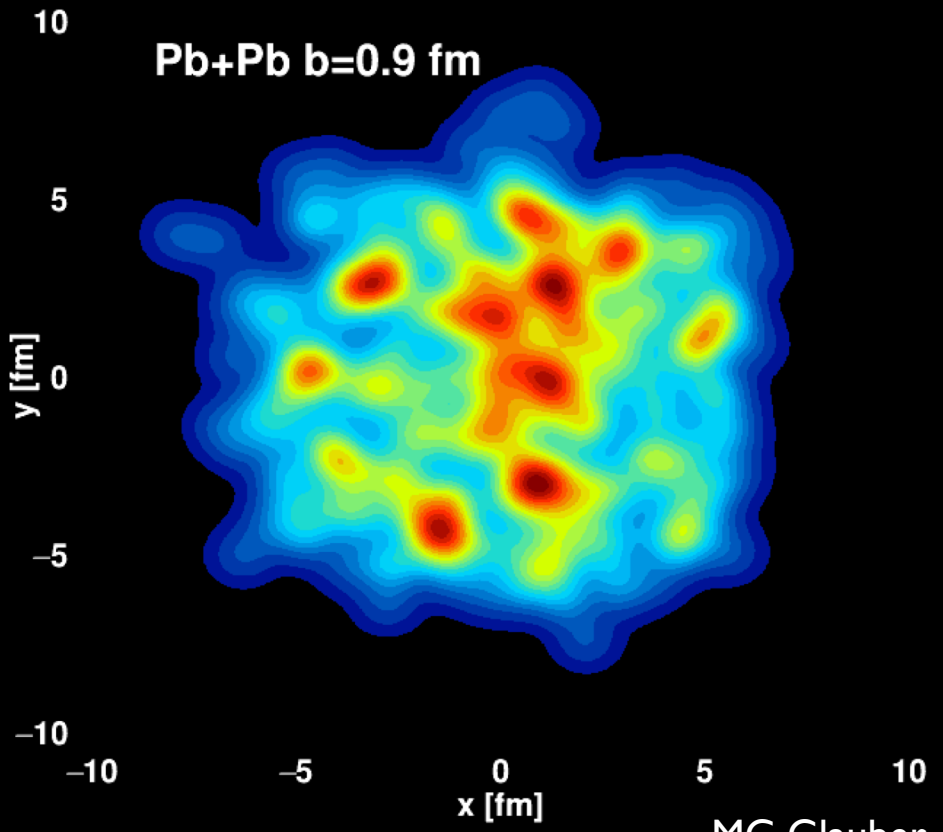
Similar multiplicity in ^{3}He/^{4}He+Au



- Conclusion regarding compactness confirmed by *matching same multiplicity*

New collision system at the LHC





MC Glauber

- Proposed to run with Oxygen

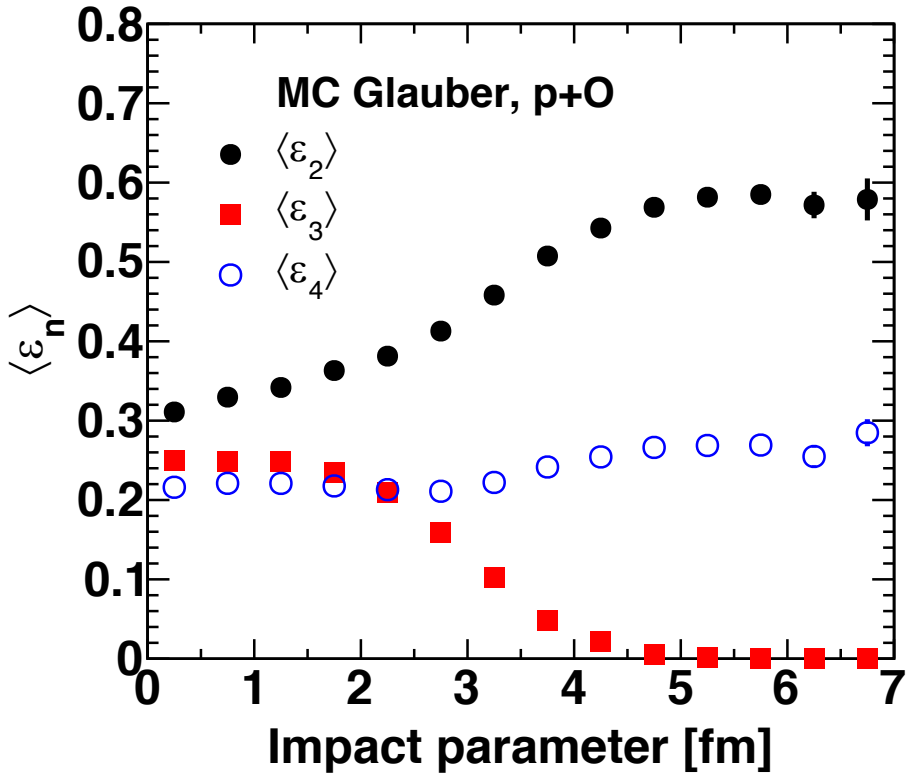
New collision systems at the LHC

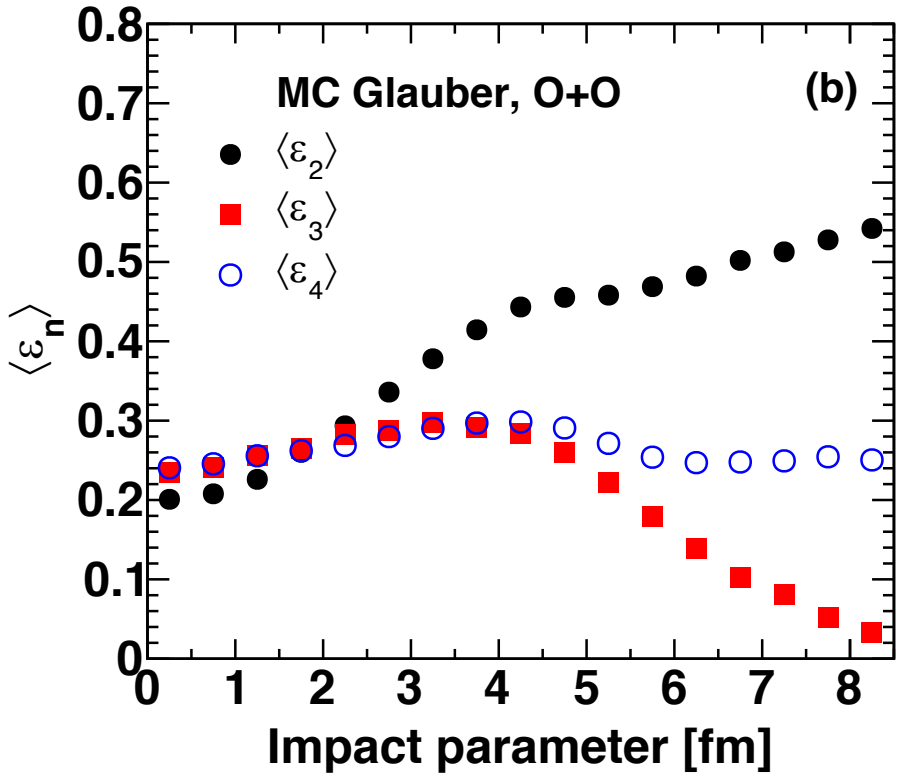
- Proposed run plans in arXiv:1812.06772

Year	Systems, $\sqrt{s_{\mathrm{NN}}}$	Time	L_{int}
2021	Pb–Pb 5.5 TeV	3 weeks	2.3 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2022	Pb–Pb 5.5 TeV	5 weeks	3.9 nb^{-1}
	O–O, p–O	1 week	500 $\mu\mathrm{b}^{-1}$ and 200 $\mu\mathrm{b}^{-1}$
2023	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2027	Pb–Pb 5.5 TeV	5 weeks	3.8 nb^{-1}
	pp 5.5 TeV	1 week	3 pb^{-1} (ALICE), 300 pb^{-1} (ATLAS, CMS), 25 pb^{-1} (LHCb)
2028	p–Pb 8.8 TeV	3 weeks	0.6 pb^{-1} (ATLAS, CMS), 0.3 pb^{-1} (ALICE, LHCb)
	pp 8.8 TeV	few days	1.5 pb^{-1} (ALICE), 100 pb^{-1} (ATLAS, CMS, LHCb)
2029	Pb–Pb 5.5 TeV	4 weeks	3 nb^{-1}
Run-5	Intermediate AA	11 weeks	e.g. Ar–Ar 3–9 pb^{-1} (optimal species to be defined)
	pp reference	1 week	

- Possibility to run new collision systems p+O and O+O
  - Comparison with p+Pb and Pb+Pb
  - Any interesting feature in Oxygen geometry?

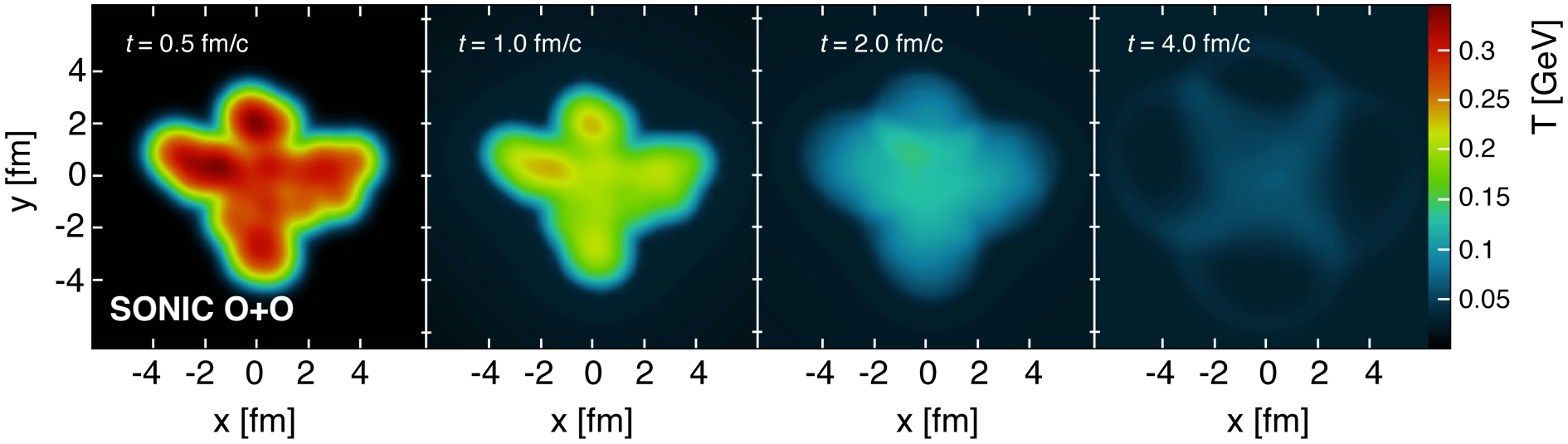
Initial geometry in p/O+O





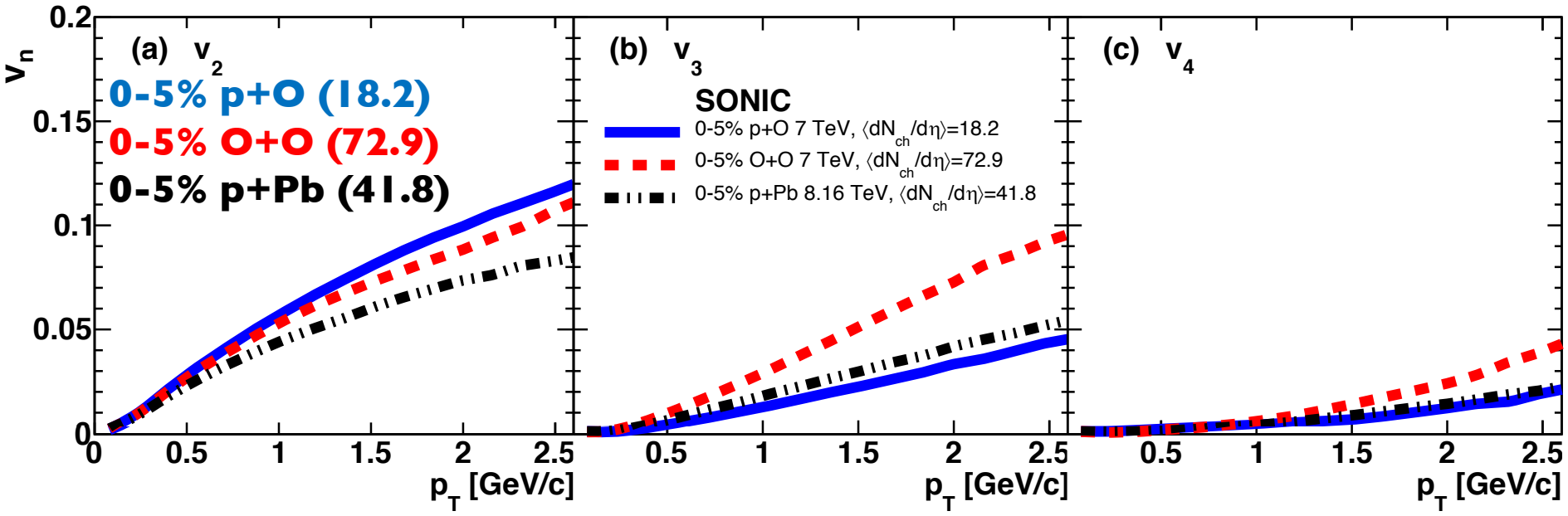
- Eccentricities from the MC Glauber with the full ^{16}O configuration
- Similar eccentricities, $\langle\varepsilon_2\rangle$, $\langle\varepsilon_3\rangle$, and $\langle\varepsilon_4\rangle$, in each system of b<2 fm
  - Very little intrinsic geometric shape
  - larger $\langle\varepsilon_2\rangle$ in p+O than O+O

Hydro simulation in p/O+O

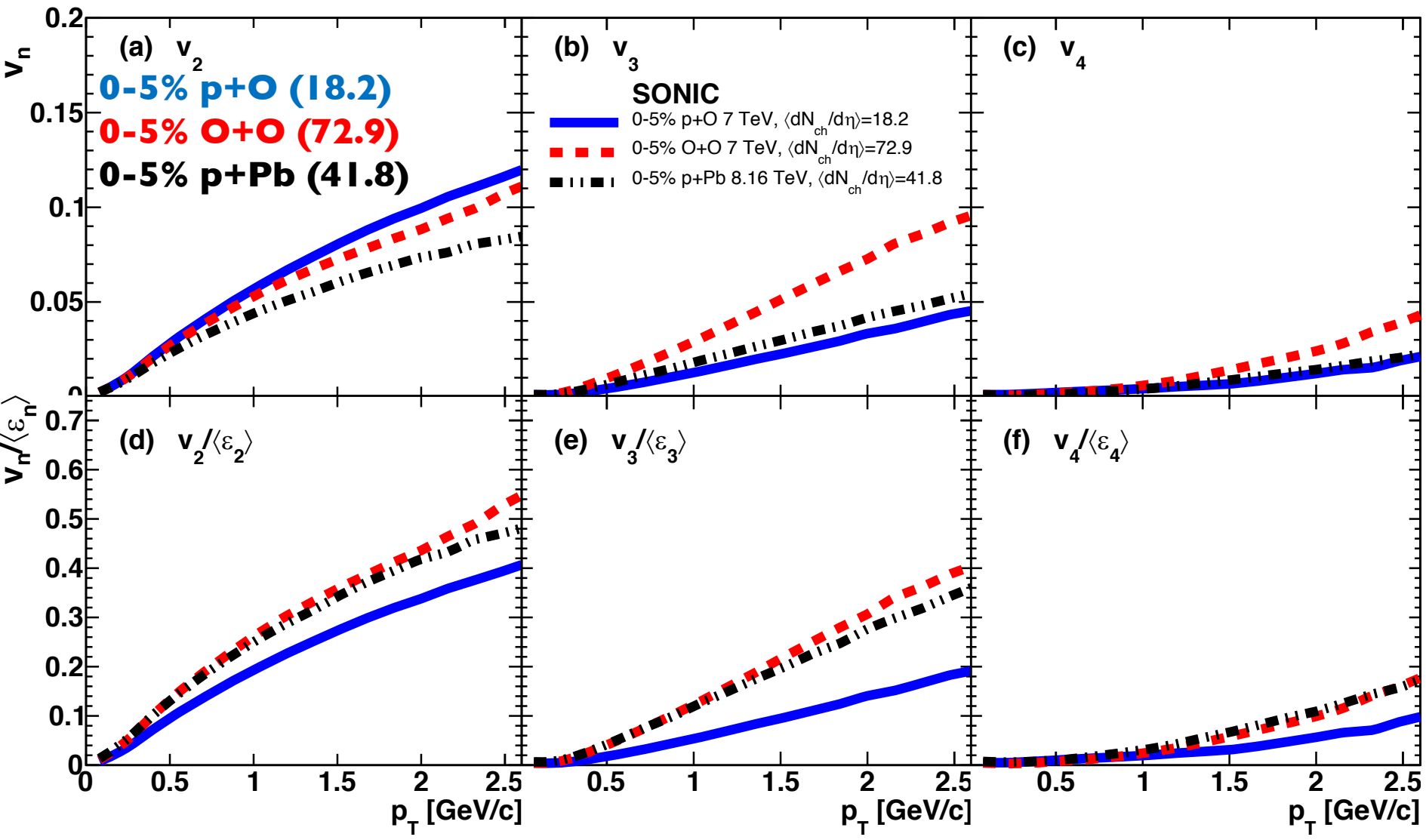


- Hydro simulation: MC Glauber + SONIC
  - Scale factor for initial energy density is set to match multiplicity measured in MinBias p+Pb at midrapidity
    - arXiv:1812.01312 (ALICE)
    - Phys. Rev. Lett. 110, 032301 (ALICE)
    - JHEP 01, 045 (CMS)

Collectivity in p/O+O 7 TeV

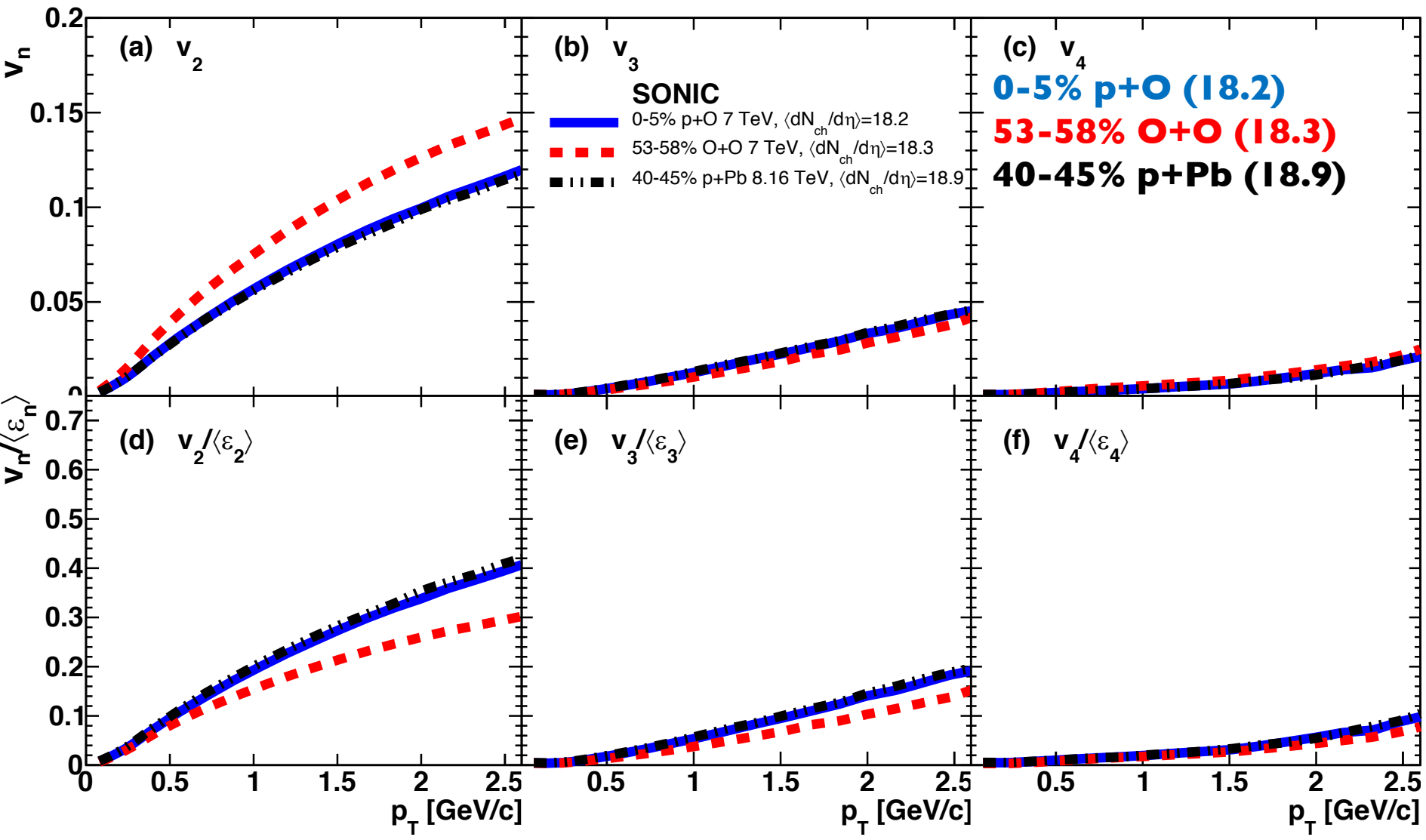


Collectivity in p/O+O 7 TeV



- *Similar $v_n/\langle\varepsilon_n\rangle$ between p+Pb and O+O and smaller in p+O*

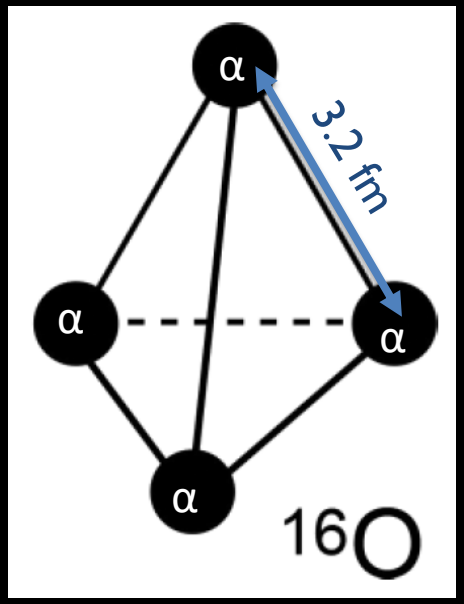
Similar multiplicity in p/O+O 7 TeV



- *Similar v_n and $v_n/\langle \varepsilon_n \rangle$ between p+O and p+Pb*
  - More compact size (steeper pressure gradient) than 53-58% of O+O collisions

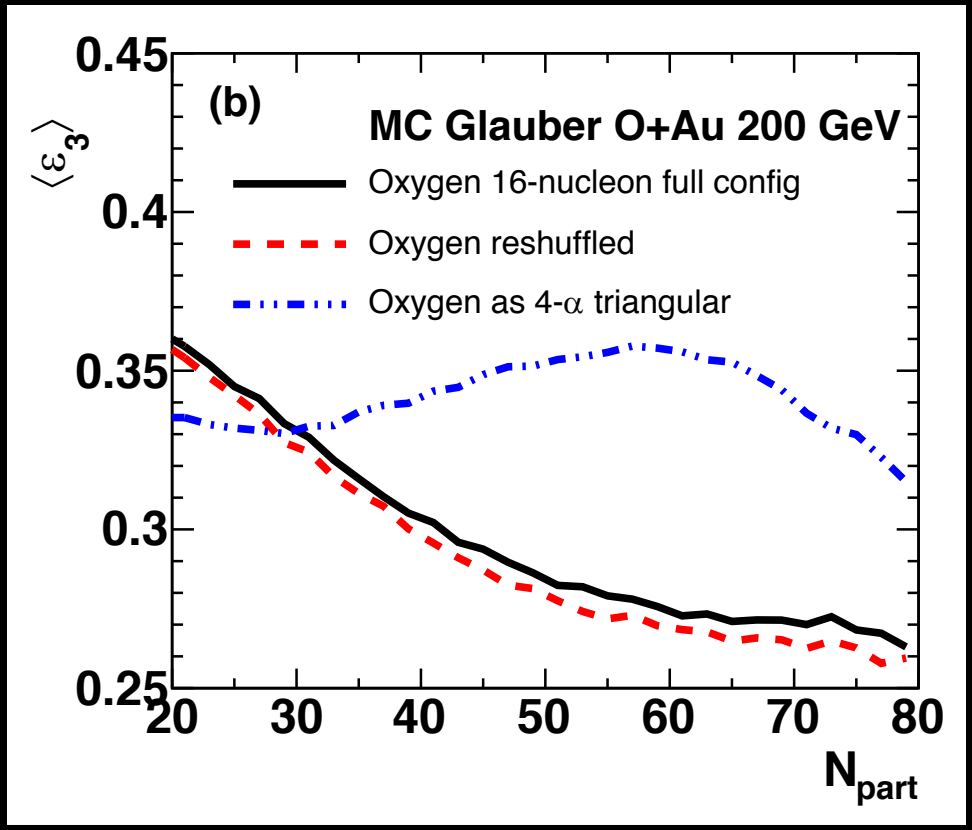
Interesting geometrical feature in Oxygen

- α-clustering at the corners of a tetrahedron

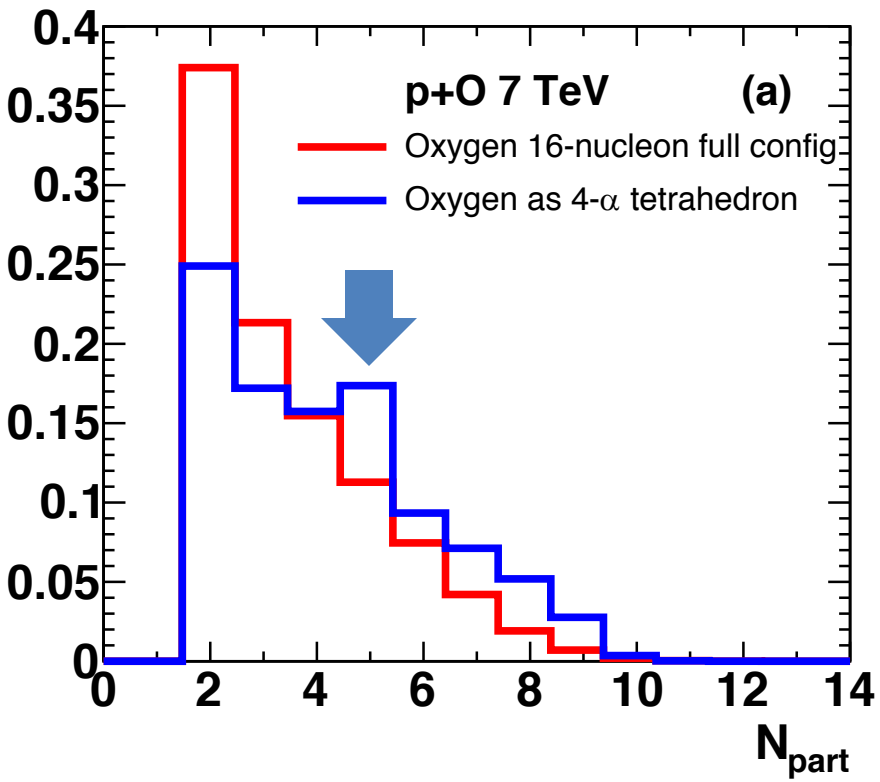


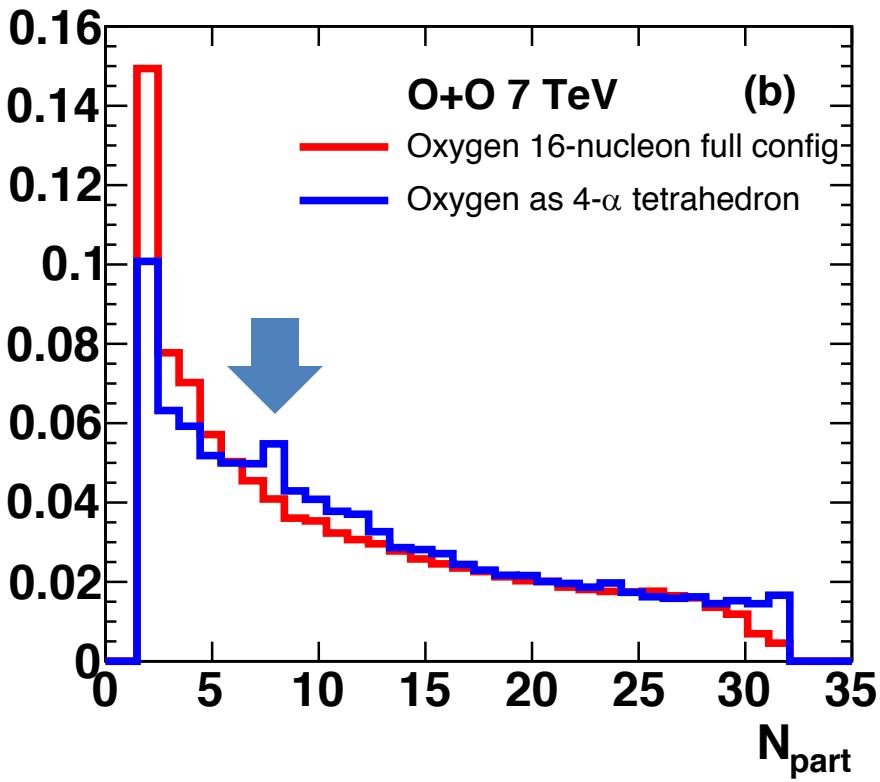
M. Rybczyński, M. Piotrowska, W. Piotrowska
Phys. Rev. C97, 034912

- Significantly larger triangularity than the full configuration
  - Indicate not a dominant structure but may have some effect

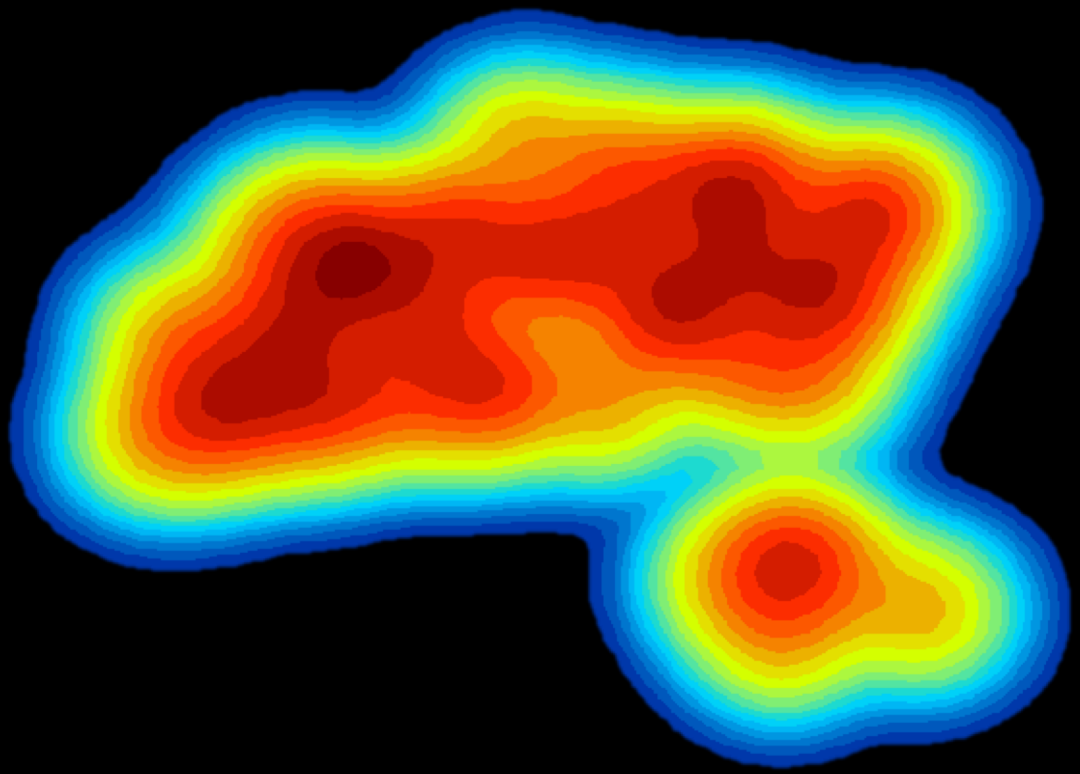


α-clustering in Oxygen



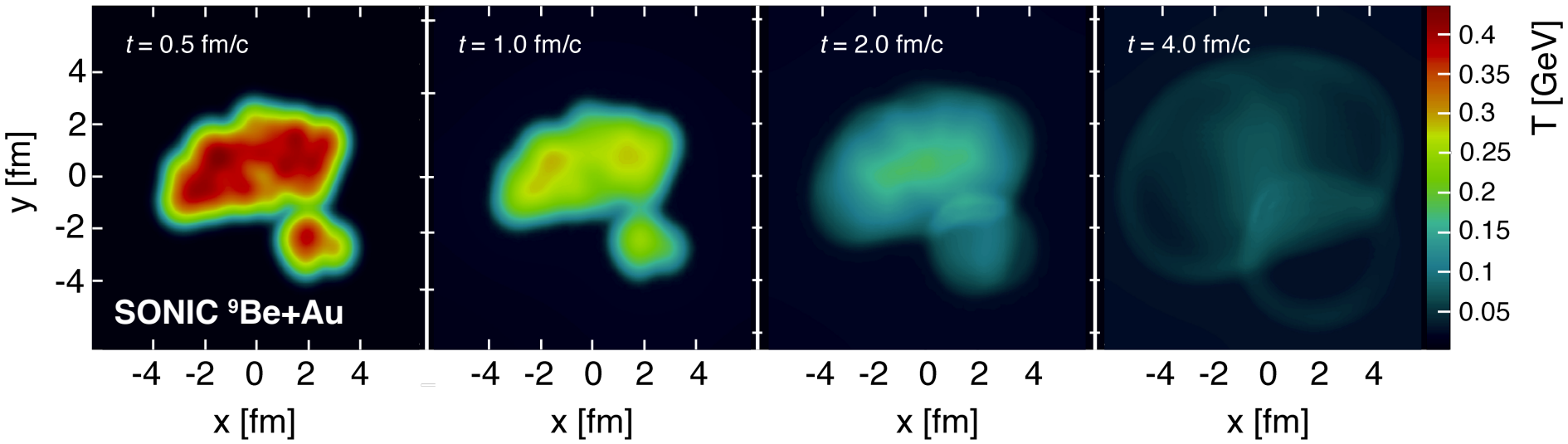


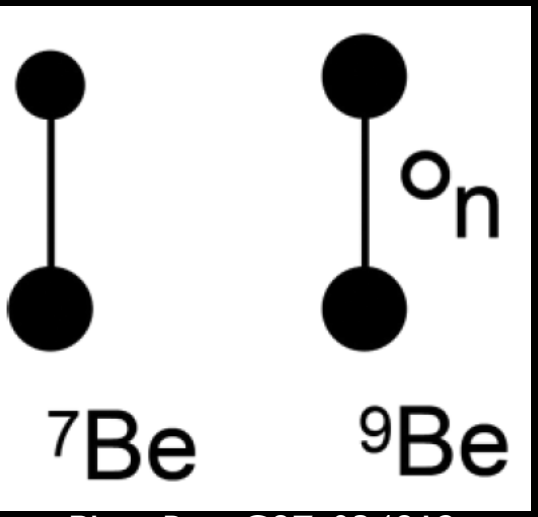
- Clearly larger $\langle N_{part} \rangle$ with ^{16}O of 4-α
  - Peak at a certain N_{part} for nucleon-α and α-α interaction
- Model study of particle production and comparison with the data will be interesting to search for a hint of α-clustering



Imagine new geometry!

α-clustering in ^{9}Be+Au





Phys. Rev. C97, 034912

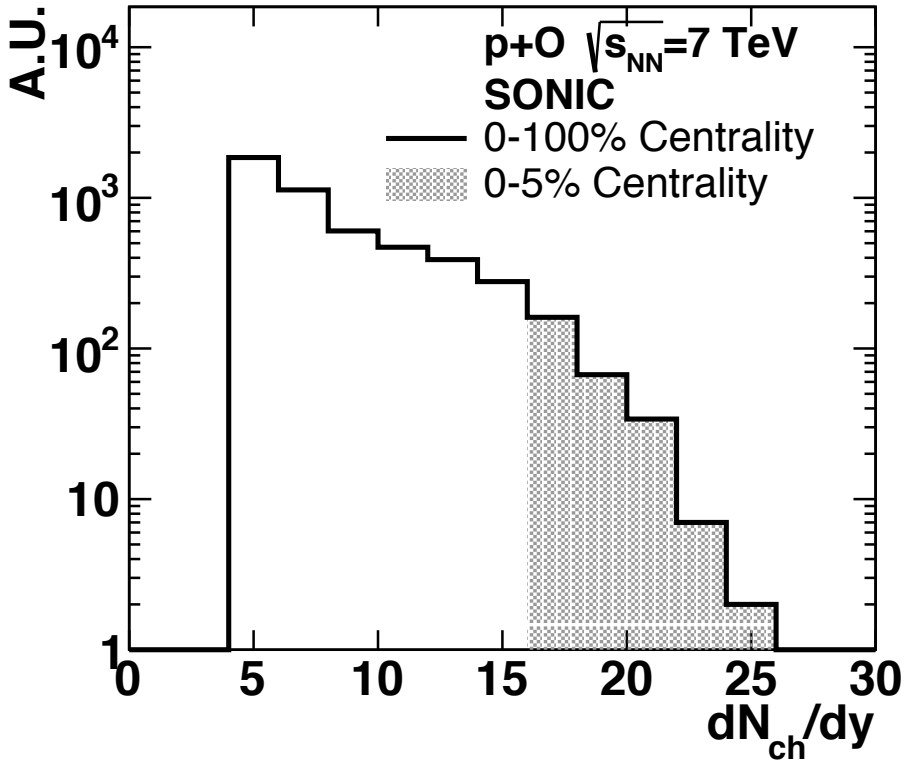
- In collisions between ^{7,9}Be and large nucleus, a significant deformation of ellipticity with ^{9}Be because of additional neutron

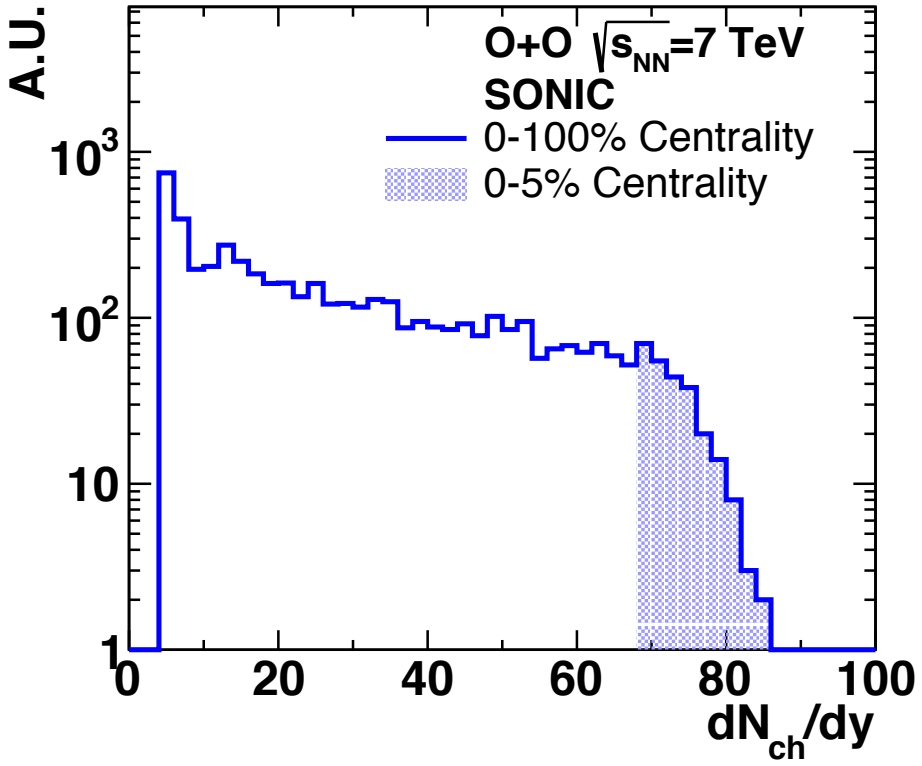
Summary

- New geometries have interesting features.
- Compactness of source matters
- Determination of discrimination power awaits other calculations.
- See full paper (arXiv:1812.08096) for additional AMPT calculations, IP-Jazma initial conditions, and more!

BACK UP

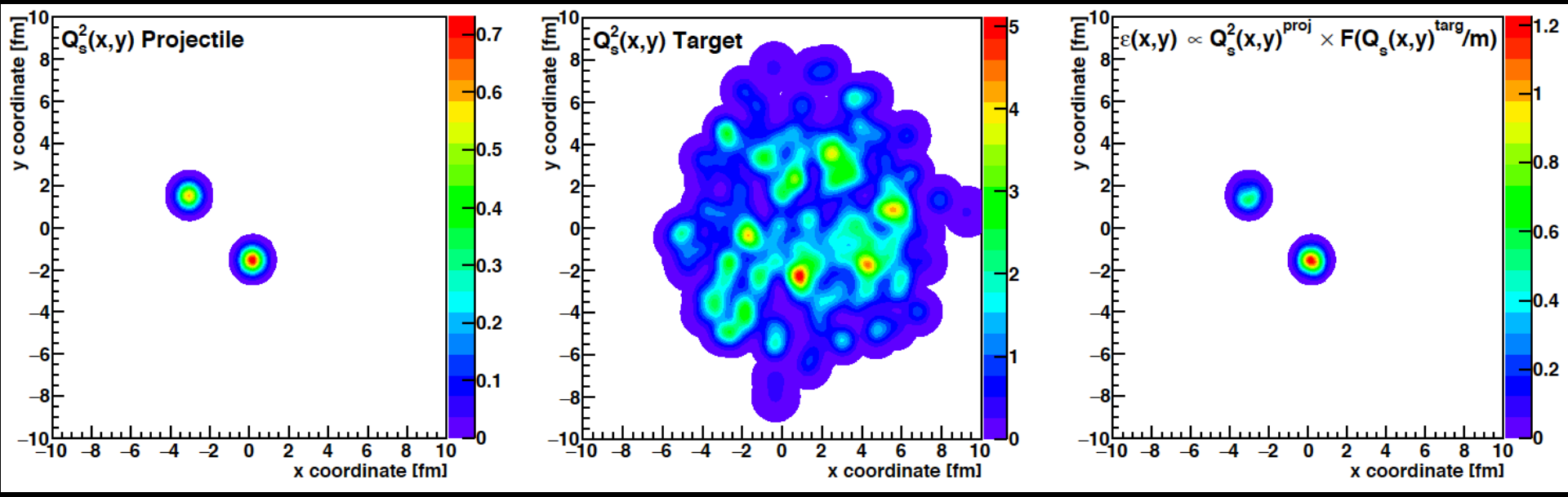
Multiplicity in p+O and O+O





- Hydro simulation: MC Glauber + SONIC
  - Scale factor for initial energy density is set to match multiplicity measured in MinBias p+Pb at midrapidity
    - arXiv:1812.01312 (ALICE)
    - Phys. Rev. Lett. 110, 032301 (ALICE)
    - JHEP 01, 045 (CMS)

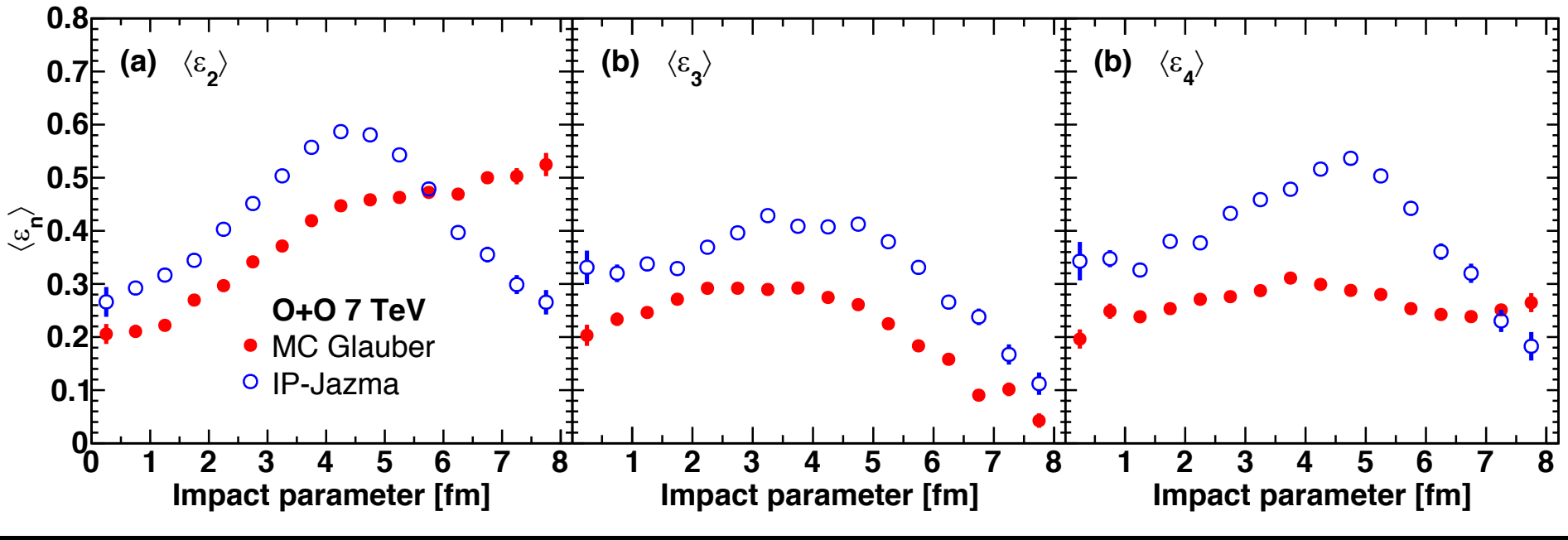
Alternative initial condition – IP-Jazma



arXiv:1808.01276

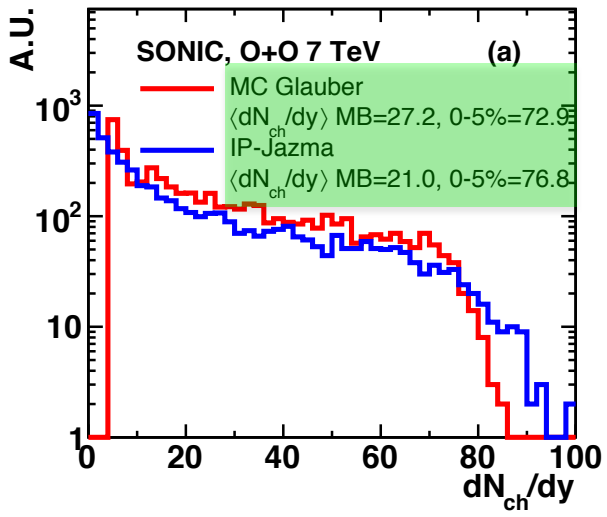
- Modeling Gaussian distributions for each participating nucleon in projectile/target and multiplying two density profiles
  - Can reproduce eccentricities from IP-Glasma
  - For this study, run IP-Jazma in the dense-dense mode without Q_s^2 fluctuation and 0.32 fm of IP-Gat Gaussian width

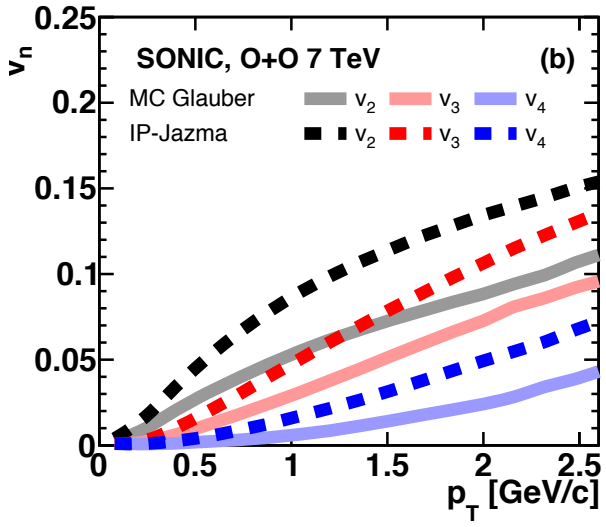
Eccentricities in O+O

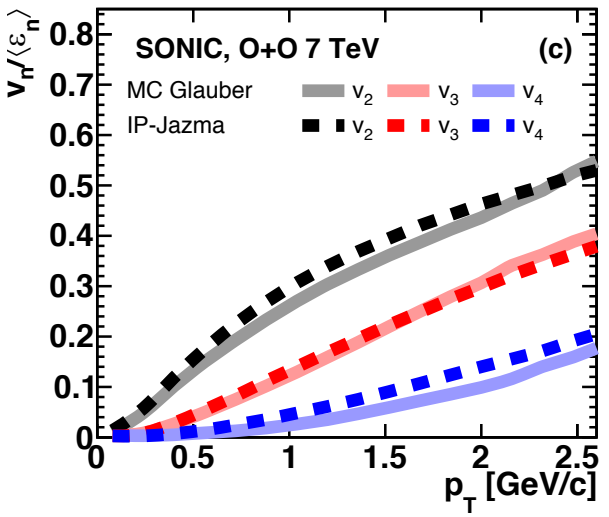


- Larger eccentricities from IP-Jazma in smaller impact parameter
  - Because the size of "hot spot" (overlap between two nuclei) is smaller, less affected by Guassian smearing of nucleons
- Decreasing eccentricities from IP-Jazma in b>5 fm
  - Circular shape for single participant in either nucleus

Two initial conditions in O+O

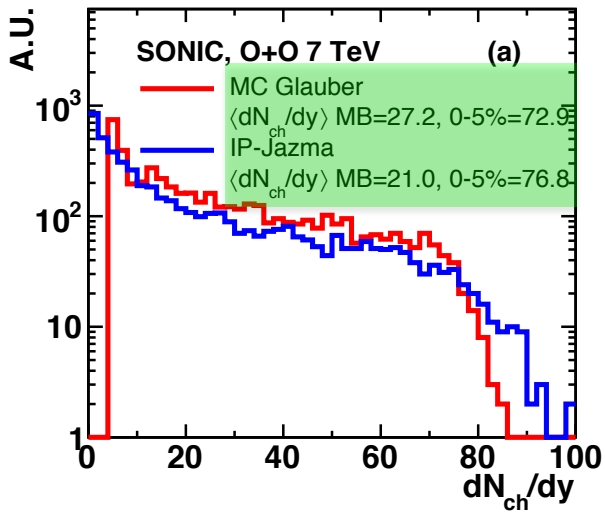


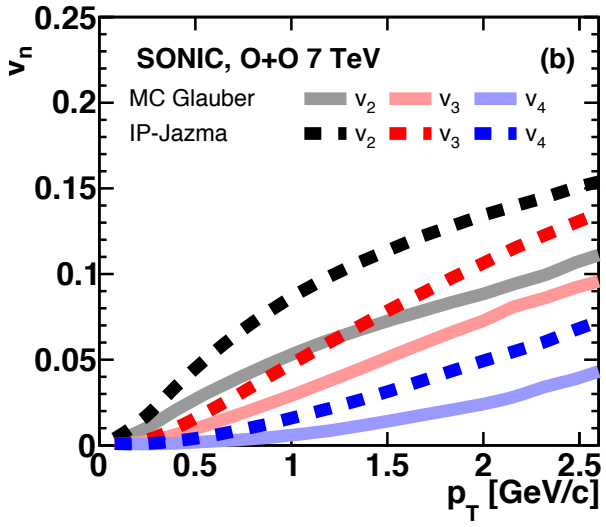


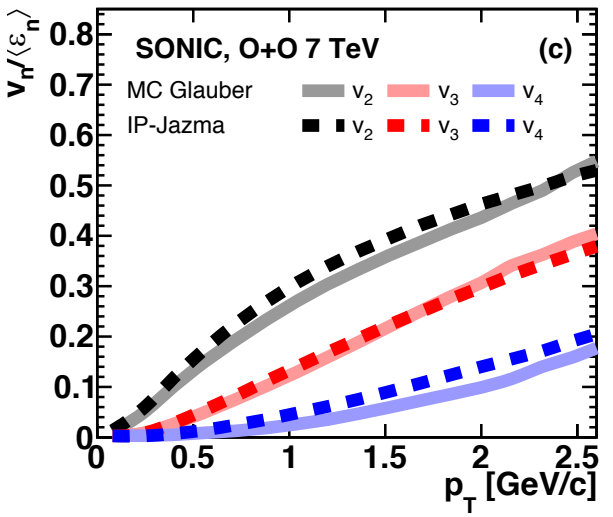


- Scale factor for initial energy density for IP-Jazma is set to match the multiplicity in 0-5% central collisions from MC Glauber+SONIC
- Larger v_n with IP-Jazma initial condition in 0-5% O+O collisions which can be expected from larger $<\varepsilon_n>$
- Similar $v_n/<\varepsilon_n>$ between two initial conditions

Two initial conditions in O+O



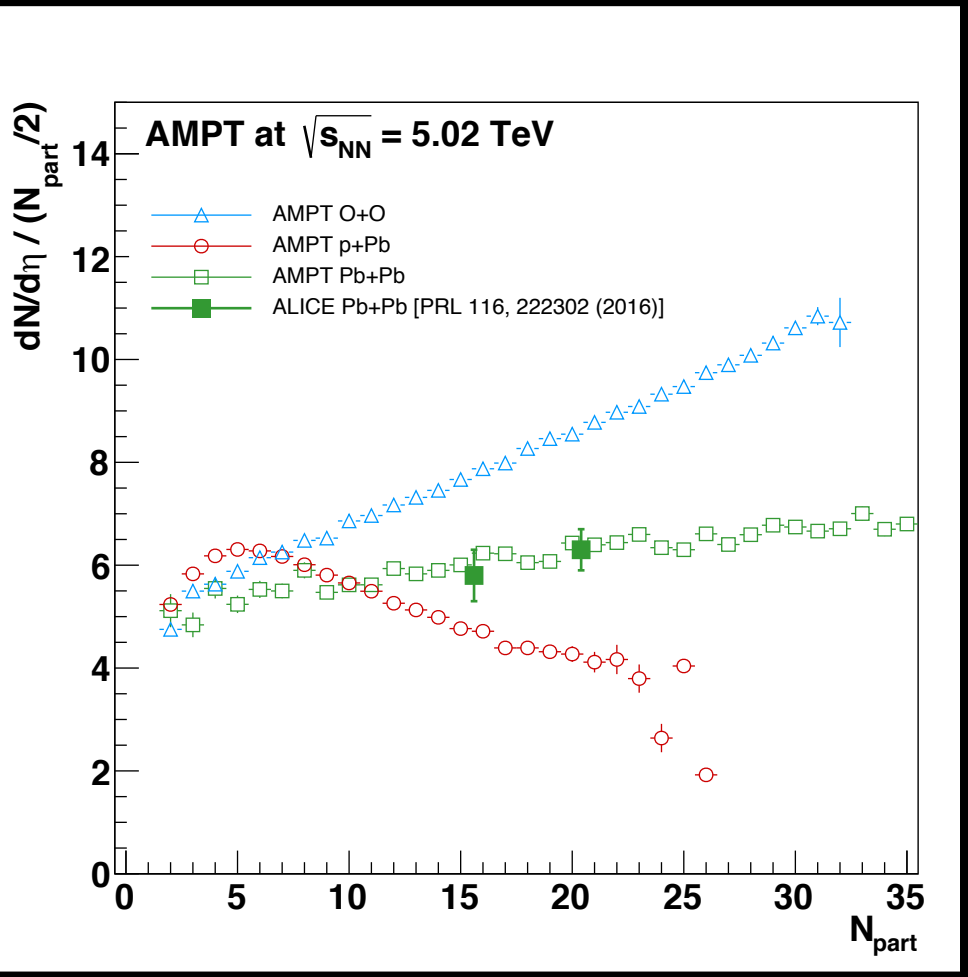




- Scale factor for initial energy density for IP-Jazma is set to match the multiplicity in 0-5% central collisions from MC Glauber+SONIC
- *Larger v_n with IP-Jazma initial condition in 0-5% O+O collisions which can be expected from larger $\langle\varepsilon_n\rangle$*
- Similar $v_n/\langle\varepsilon_n\rangle$ between two initial conditions

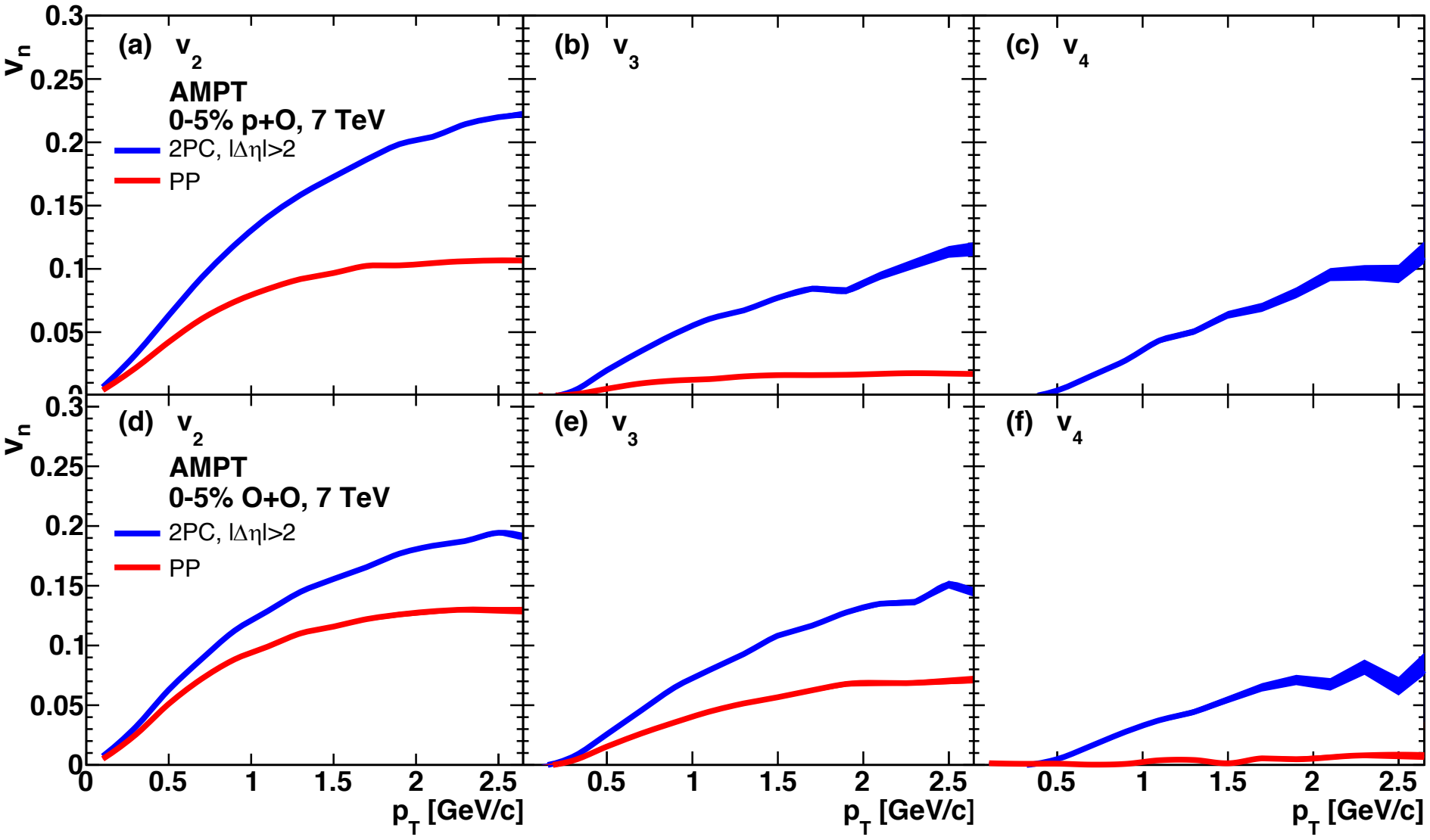
Interesting to compare both multiplicity and v_n with future O+O data

p/O+O in AMPT



- Used string parameters tuned for LHC energies with the data in p+Pb and Pb+Pb (Phys. Rev. C90, 014904)
- With the same parameters, the multiplicity in O+O is ~x2 higher than SONIC calculation
  - Steeply increasing trend of multiplicity per pair participant

p/O+O in AMPT



- Larger v_n in AMPT than SONIC calculations as multiplicity comparison