IP-JAZMA Critical Assessment of Physics Attributions

presented at

Initial Stages 2019

June 26th , 2019

(work done with Jamie Nagle)

This work was supported by the United States Department of Energy Grant DOE-FG02-86ER-40281

W.A. Zajc
Columbia University

Explication

- Inspiration
- Realization
- “Domaination”
- Argumentation
- Publication
- Observation
- Mystification
- Expectation
- Quantification
- Desperation

continuation ;-)

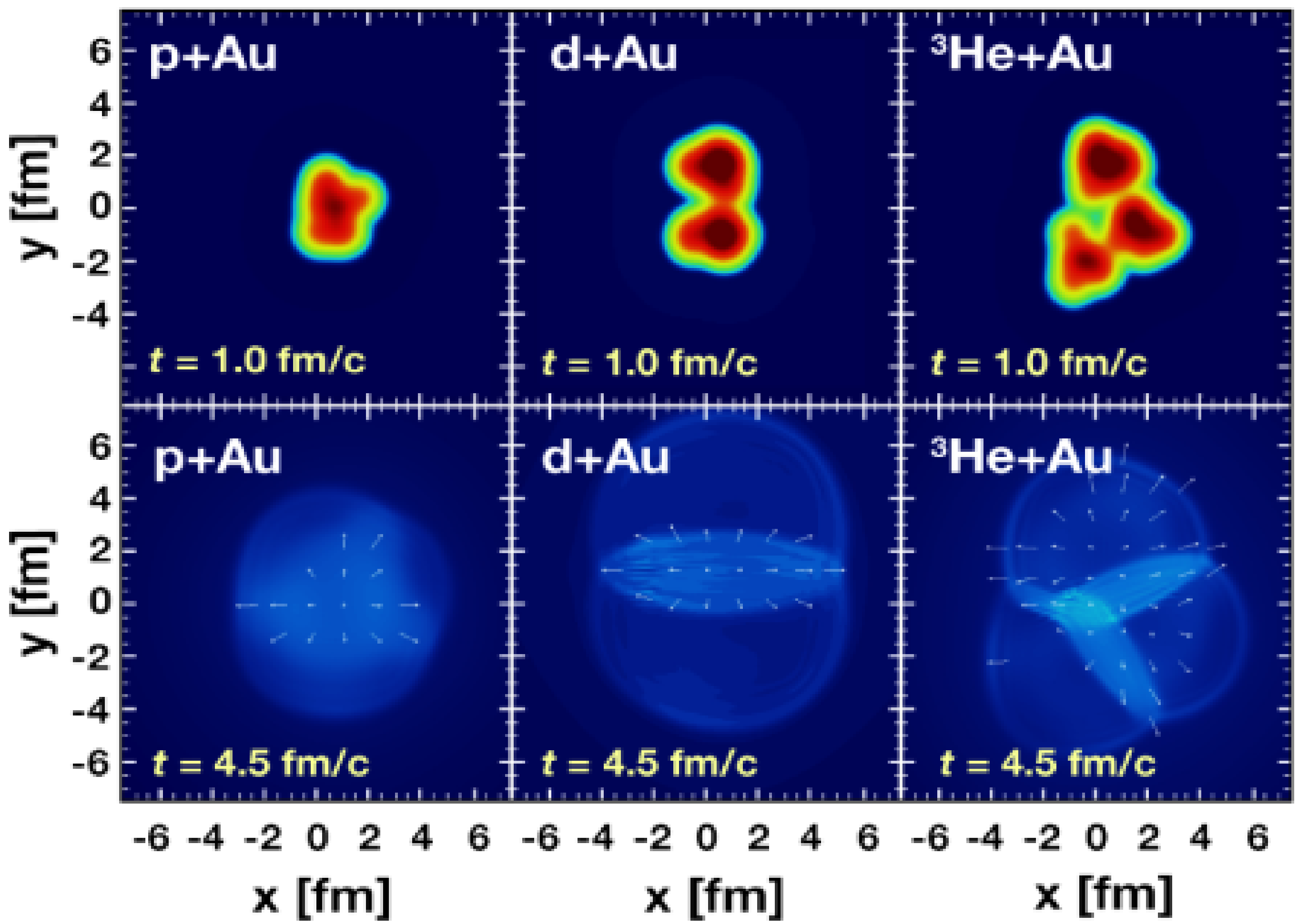
- Identification
- Instantiation
- Fluctuation
- Illustration
- Replication
- Elucidation
- Investigation
- Clarification
- Legislation
- Summation

Inspiration

PRL 113, 112301 (2014) PHYSICAL REVIEW LETTERS week ending 12 SEPTEMBER 2014

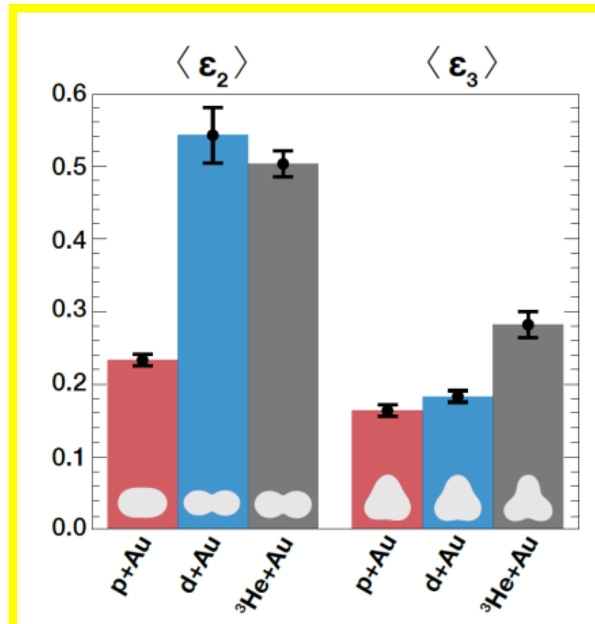
Exploiting Intrinsic Triangular Geometry in Relativistic ^{3}He + Au Collisions to Disentangle Medium Properties

J. L. Nagle,[1,*] A. Adare,[1] S. Beckman,[1] T. Koblesky,[1] J. Orjuela Koop,[1] D. McGlinchey,[1] P. Romatschke,[1] J. Carlson,[2] J. E. Lynn,[2] and M. McCumber[2]



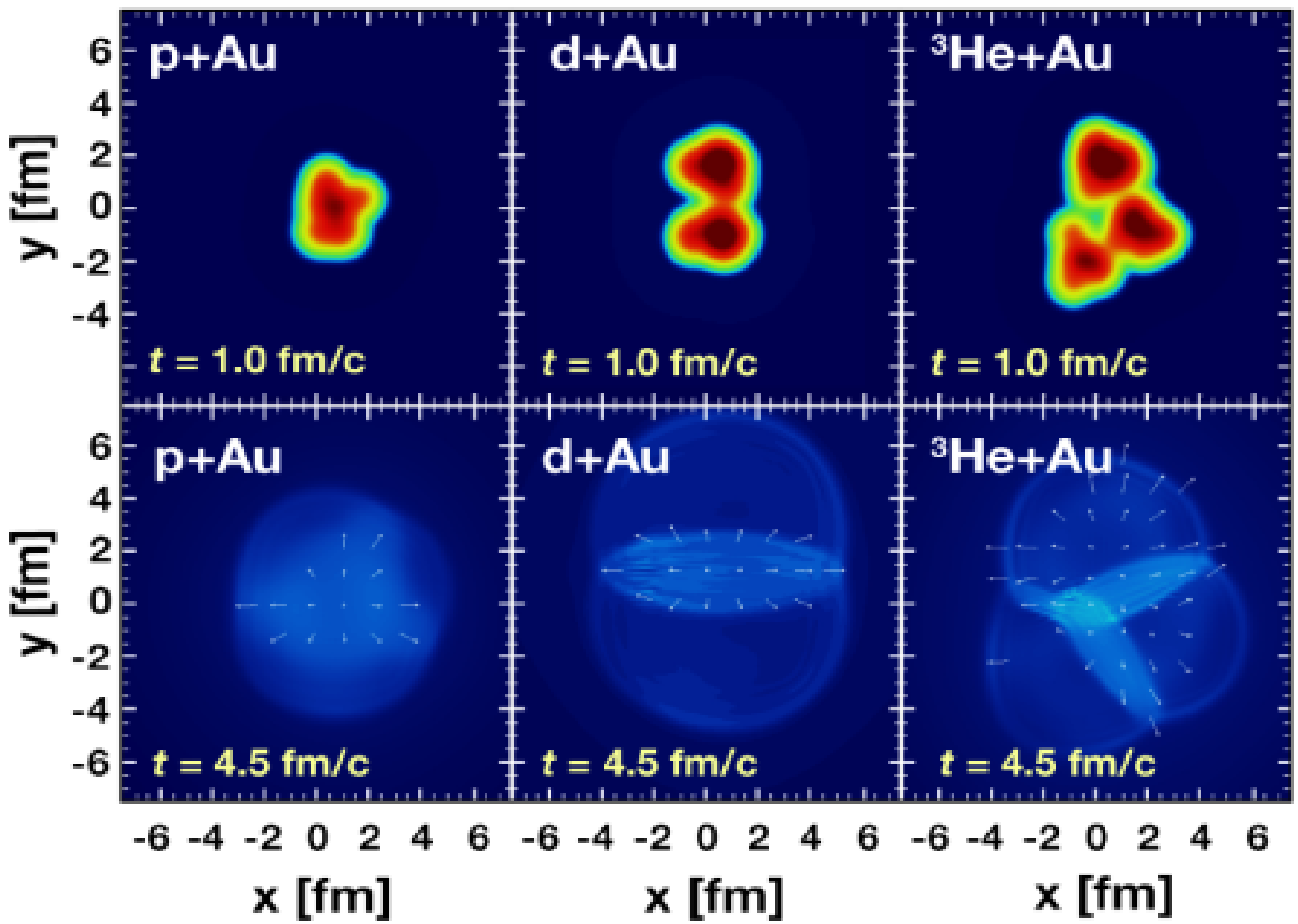
☞Use intrinsic geometry to test applicability of hydrodynamics in

small systems.



Realization

- These geometries also could provide a critical test of initial-state models.



“Domaination”

T. Lappi, B. Schenke, S. Schlichting, R. Venugopalan, JHEP 1601, 061 (2016)
arXiv:1509.03499

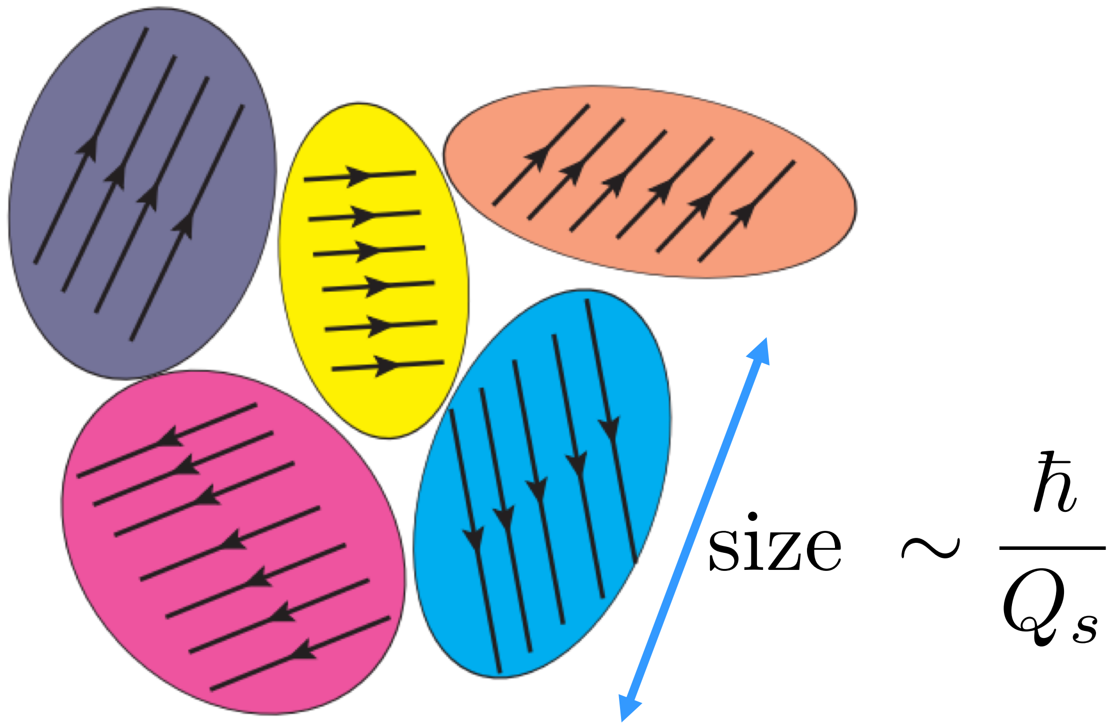
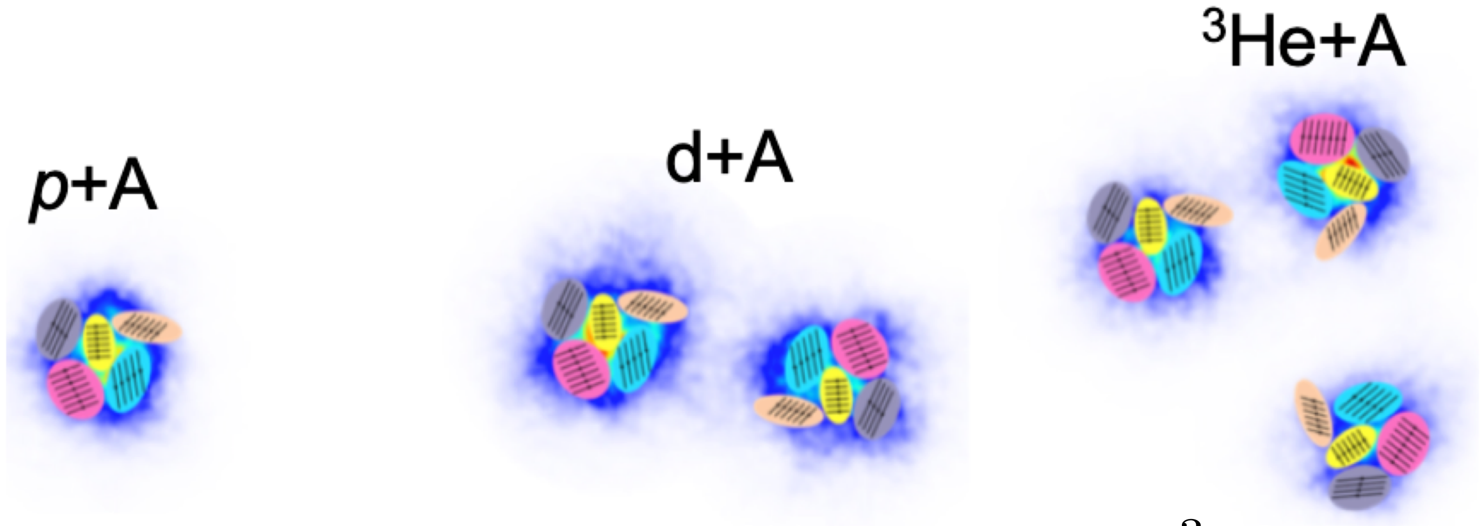


FIG. 1: (Color online) Color electric fields inside the nucleus fluctuate on an event by event basis.

Argumentation

- Independent orientation of color fields implies



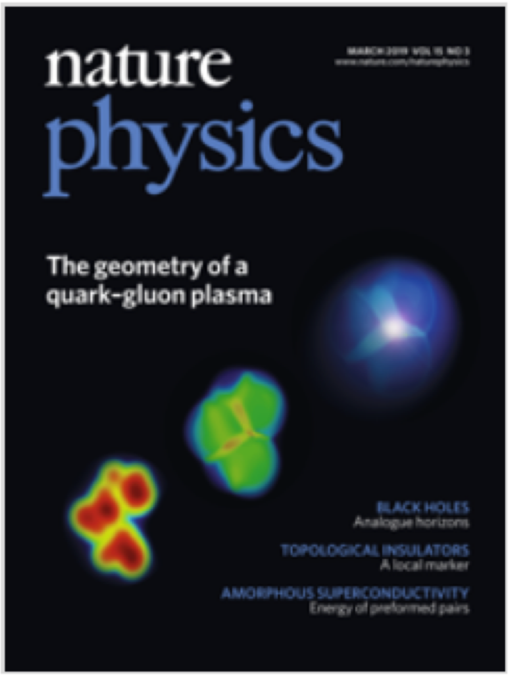
$$v_2(\mathrm{p+Au}) \quad > \quad v_2(\mathrm{d+Au}) \quad > \quad v_2(^3\mathrm{He+Au})$$

- as opposed to hydrodynamical translation of geometry

$$v_2(\mathrm{p+Au}) \quad < \quad v_2(\mathrm{d+Au}) \quad \approx \quad v_2(^3\mathrm{He+Au})$$
$$v_3(\mathrm{p+Au}) \quad \approx \quad v_3(\mathrm{d+Au}) \quad < \quad v_3(^3\mathrm{He+Au})$$

Publication

Volume 15 Issue 3, March 2019



The geometry of a quark–gluon plasma

A quark–gluon plasma is produced in proton–gold, deuteron–gold and helium–gold collisions. Observing elliptic and triangular flow in this nearly inviscid fluid from these different initial geometries provides a unique benchmark for hydrodynamic models.

See Nagle et al.

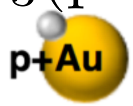
Image: Javier Orjuela-Koop, University of Colorado Boulder. Cover Design: David Shand.

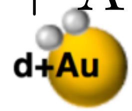
Creation of quark-gluon plasma droplets with three distinct geometries,
PHENIX Collaboration, Nature Physics **15**, 214 (2019)

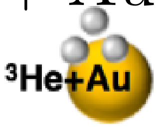
Observation

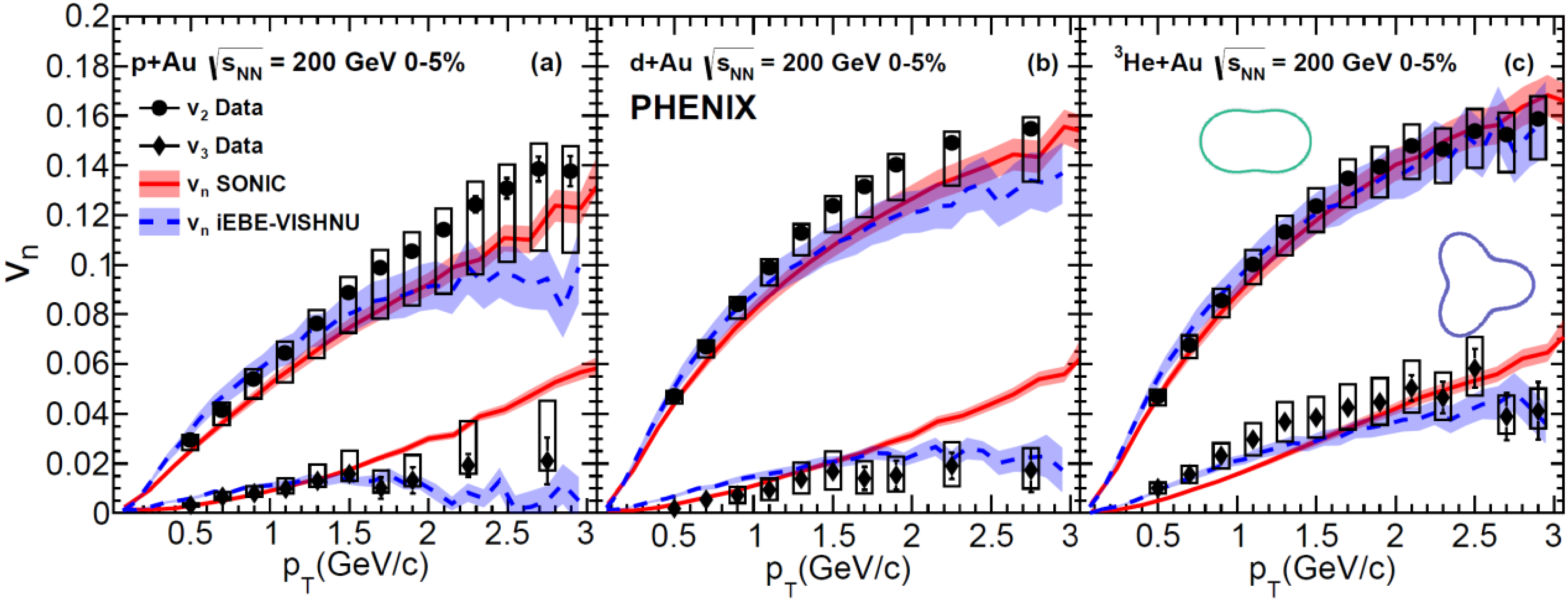
- Hydro ordering!

$$v_2(\mathrm{p+Au}) \quad < \quad v_2(\mathrm{d+Au}) \quad \approx \quad v_2(^3\mathrm{He+Au})$$
$$v_3(\mathrm{p+Au}) \quad \approx \quad v_3(\mathrm{d+Au}) \quad < \quad v_3(^3\mathrm{He+Au})$$





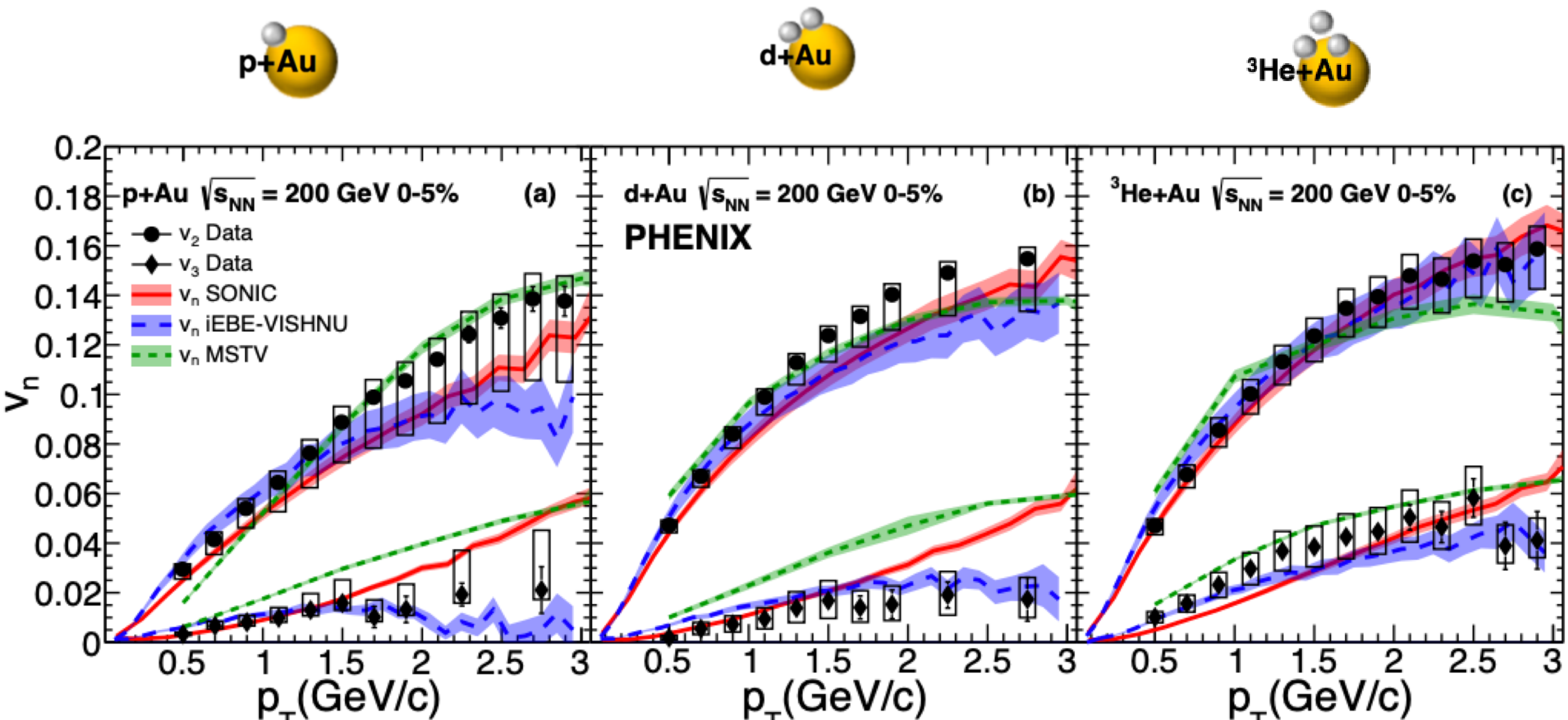




Creation of quark-gluon plasma droplets with three distinct geometries,
PHENIX Collaboration, Nature Physics **15**, 214 (2019)

Mystification

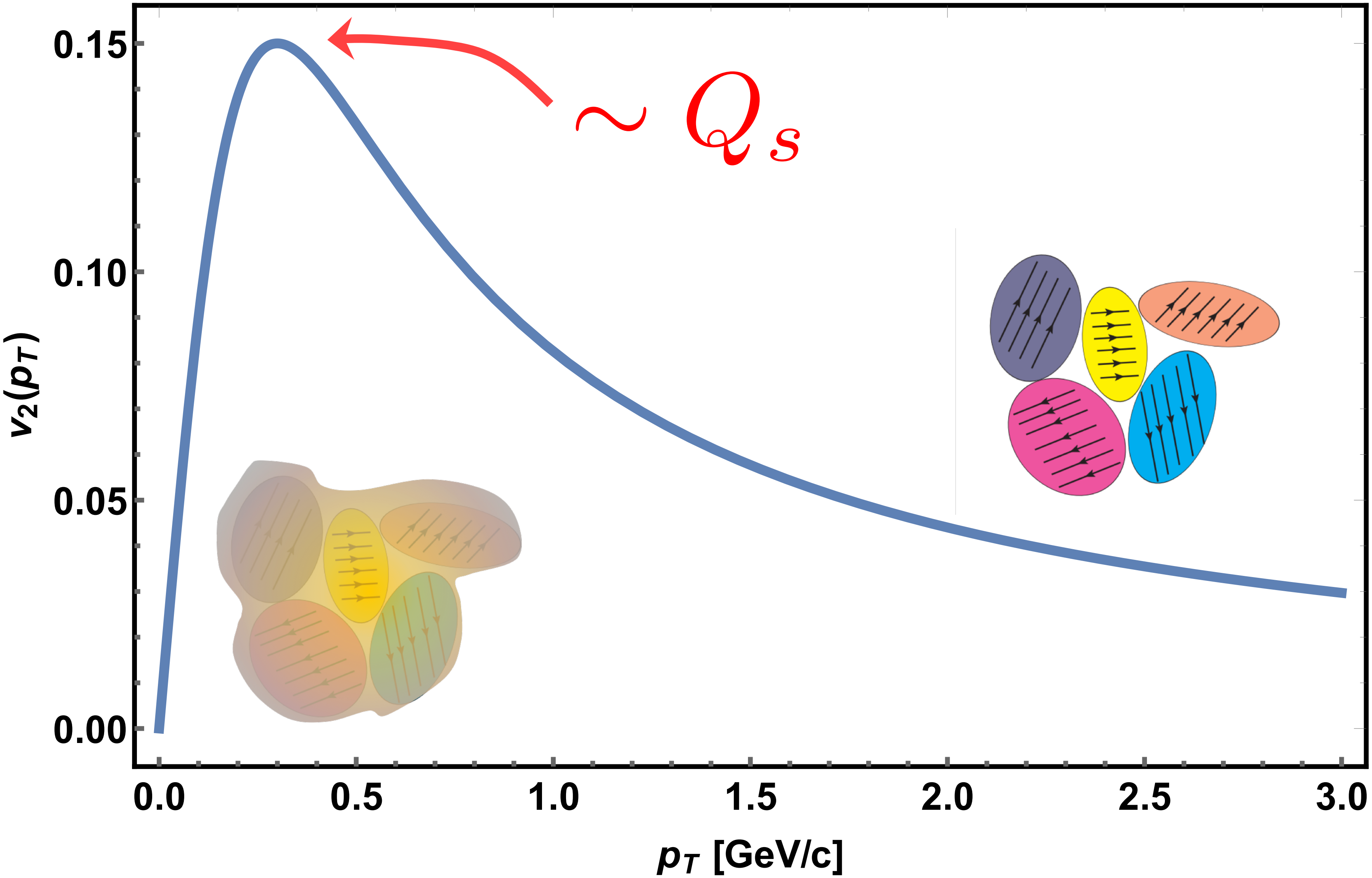
- How does MSTV reproduce hydro ordering ??



Hierarchy of azimuthal anisotropy harmonics in collisions of small systems from the Color Glass Condensate , M. Mace, V. Skokov, P. Tribedy, R. Venugopalan, Phys. Rev. Lett. **121**, 052301 (2018) referred to as "MSTV"

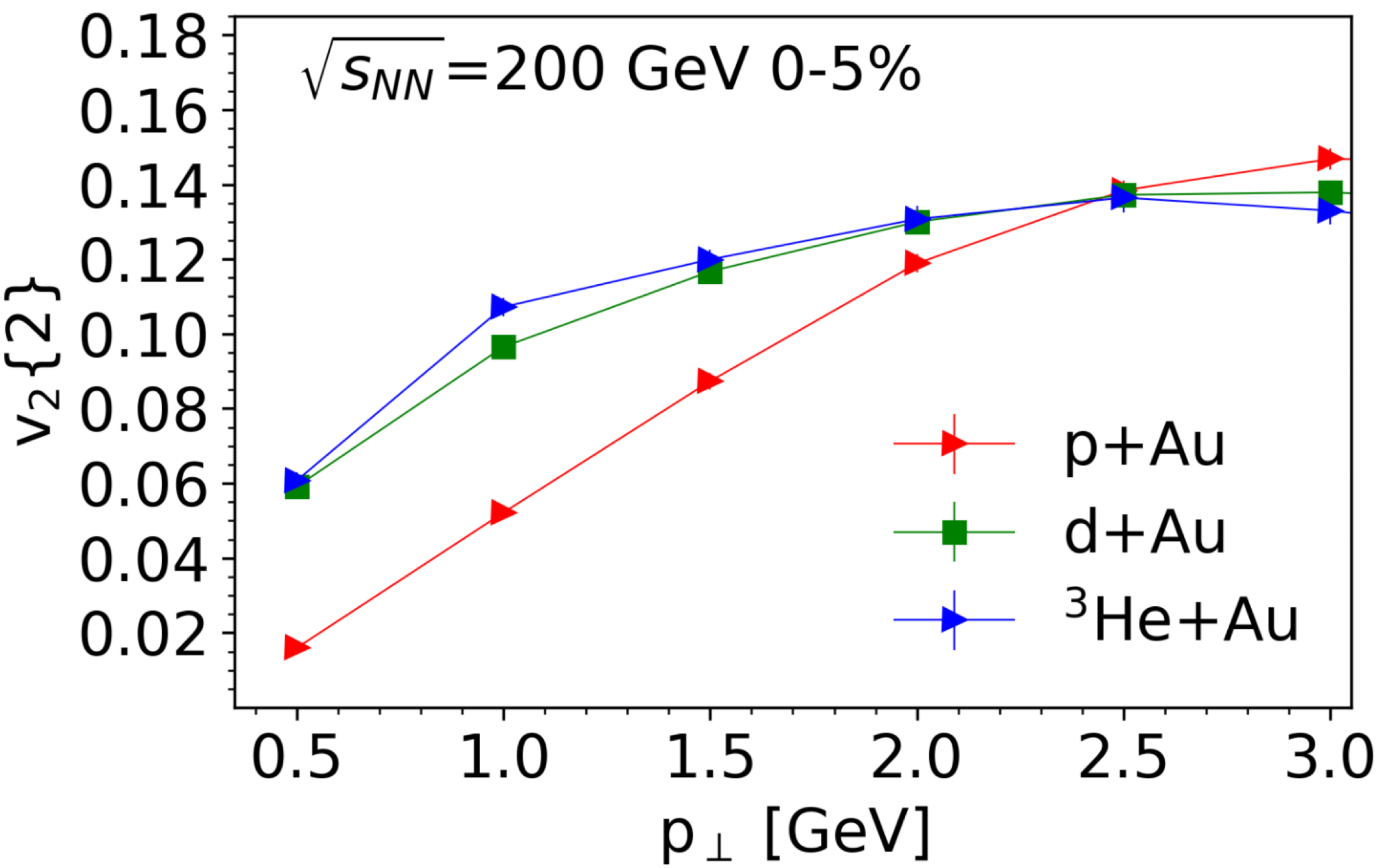
Expectation

- Sensitive to scale for resolving domains:



Quantification

- Hint of domain ordering only for p_T > ~ 2.5 GeV



Hierarchy of azimuthal anisotropy harmonics in collisions of small systems from the Color Glass Condensate , M. Mace, V. Skokov, P. Tribedy, R. Venugopalan, Phys. Rev. Lett. **121**, 052301 (2018) referred to as "MSTV"

Desperation

- Decided to develop simple model to "identify" relevant input to initial state description

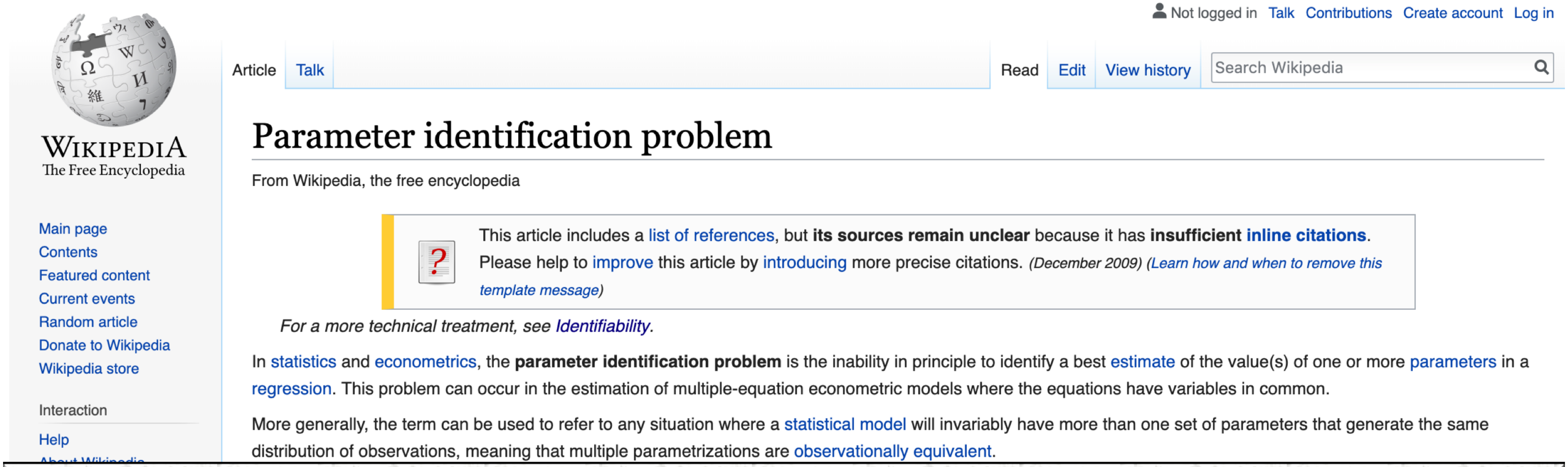
Assessing saturation physics explanations of collectivity in small collision systems with the IP-Jazma model , J.L. Nagle and W.A. Zajc, Phys. Rev. **C99**, 054908 (2019).

Publicly available code: https://github.com/jamienagle/IPJazma

- IP-JAZMA: Simplest possible model of initial state to test identification or attribution of final state features

Identification

- Phrase borrowed from econometrics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Parameter identification problem

From Wikipedia, the free encyclopedia

This article includes a list of references, but **its sources remain unclear** because it has **insufficient inline citations**. Please help to improve this article by introducing more precise citations. *(December 2009) (Learn how and when to remove this template message)*

For a more technical treatment, see Identifiability.

In statistics and econometrics, the **parameter identification problem** is the inability in principle to identify a best estimate of the value(s) of one or more parameters in a regression. This problem can occur in the estimation of multiple-equation econometric models where the equations have variables in common.

More generally, the term can be used to refer to any situation where a statistical model will invariably have more than one set of parameters that generate the same distribution of observations, meaning that multiple parametrizations are observationally equivalent.

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- IP-JAZMA: Simplest possible model of initial state to test identification or attribution of final state features

Instantiation

- MC-Glauber to find transverse position for *i*-th interacting nucleon (x_i, y_i) in each event
- IP-Sat to find contribution to saturation scale:

$$Q_s^2(x,y)_i = Q_{s,0}^2 \; e^{-\frac{1}{2\sigma^2}[(x-x_i)^2+(y-y_i)^2]}$$

  - σ = 0.32 fm (RHIC) , 0.28 fm (LHC)
- Linear sum to find local target and projectile saturation scales:

$$Q_s^2(x,y)_{proj} = \sum_{i\,\in\,proj} Q_s^2(x,y)_i \qquad Q_s^2(x,y)_{targ} = \sum_{i\,\in\,targ} Q_s^2(x,y)_i$$

- Assume:
  - dense-dense limit: $\epsilon(x,y) \sim g^2 \; Q_s^2(x,y)_{proj} \; Q_s^2(x,y)_{targ}$
  - dilute- dense limit: $n_g(x,y) \sim g^2 \; Q_s^2(x,y)_{proj} \; F(\; Q_s(x,y)_{targ}/m \;)$

$$F(x) = \int_0^x \frac{du}{u}\,[1-e^{-u^2}] \sim \log x \text{ for } x \gg 1$$

Fluctuation

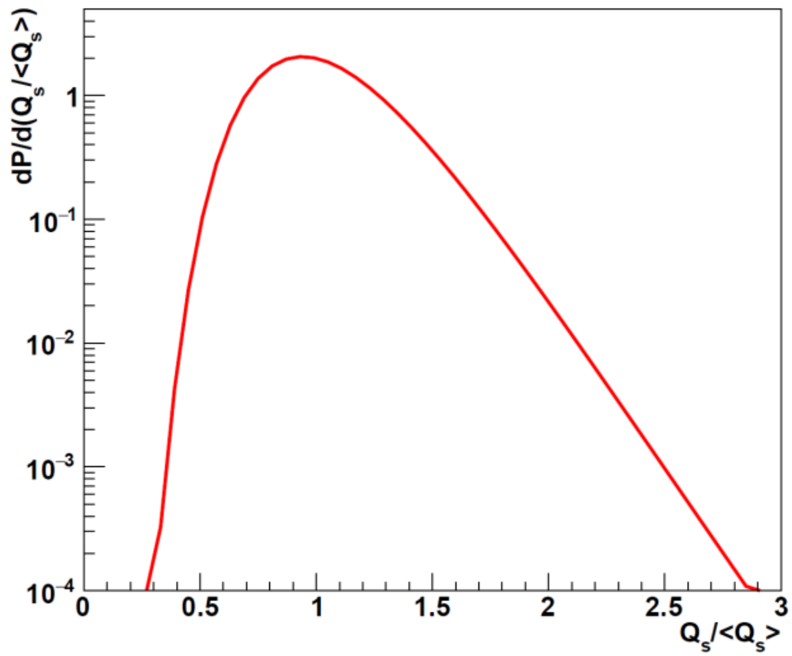
- Following MSTV and other CGC practitioners, IP-JAZMA has option for Q_s fluctuations:

$$Q_s^2(x,y)_i = Q_{s,0}^2 \; e^{-\frac{1}{2\sigma^2}[(x-x_i)^2+(y-y_i)^2]}$$

$$P(\mathcal{Z})\; d\mathcal{Z} = \frac{1}{\sqrt{2\pi w^2}} \; \exp\left(-\frac{\log^2(\mathcal{Z}^2)}{2w^2}\right) \; \frac{2d\mathcal{Z}}{\mathcal{Z}}$$

$$\mathcal{Z} \equiv Q_s/\langle Q_s \rangle$$

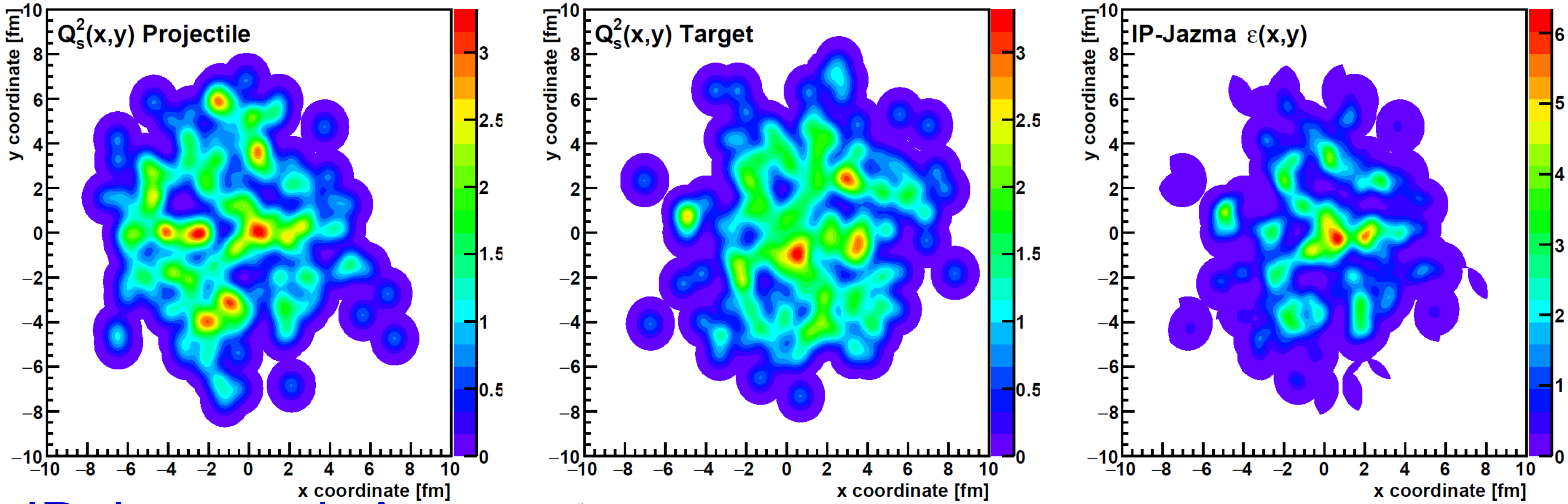
$$w = 0.5$$



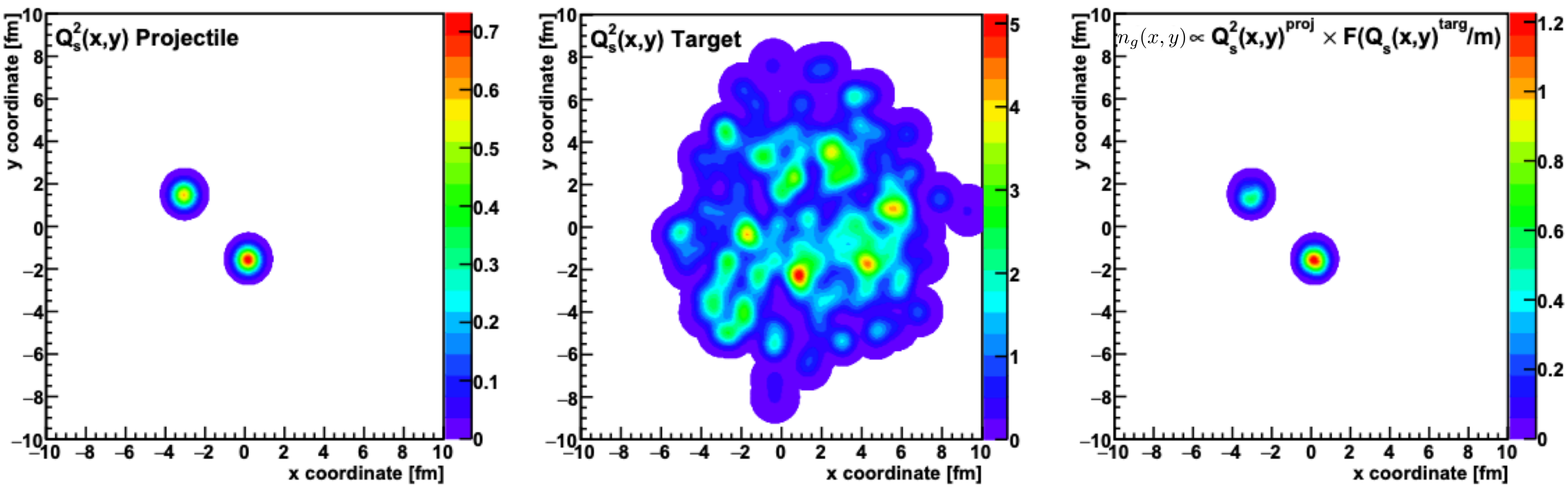
Intrinsic Fluctuations of the Proton Saturation Momentum Scale in High Multiplicity p+p Collisions , L. McLerran and P. Tribedy, Nucl. Phys. **A945**, 216 (2016)

Illustration

- IP-Jazma Au+Au event

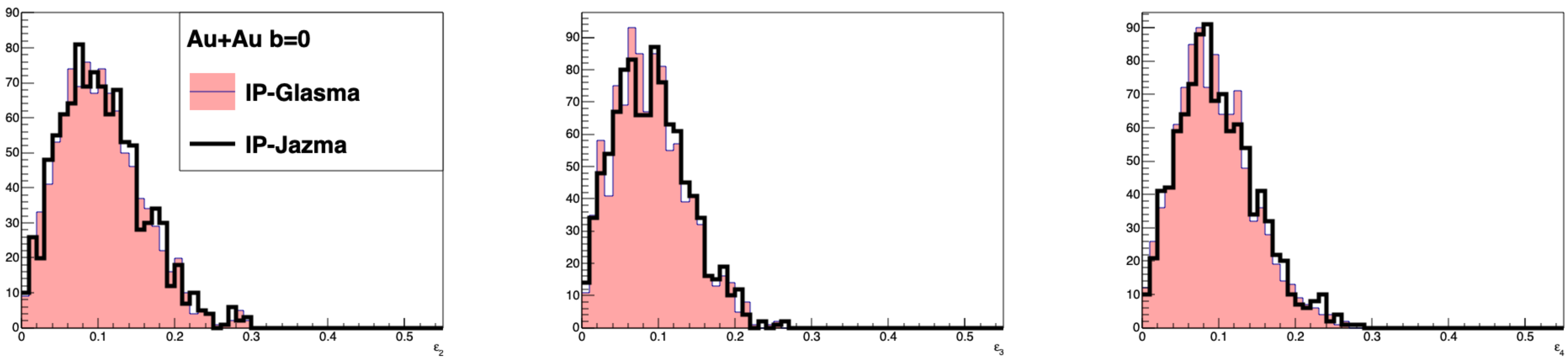


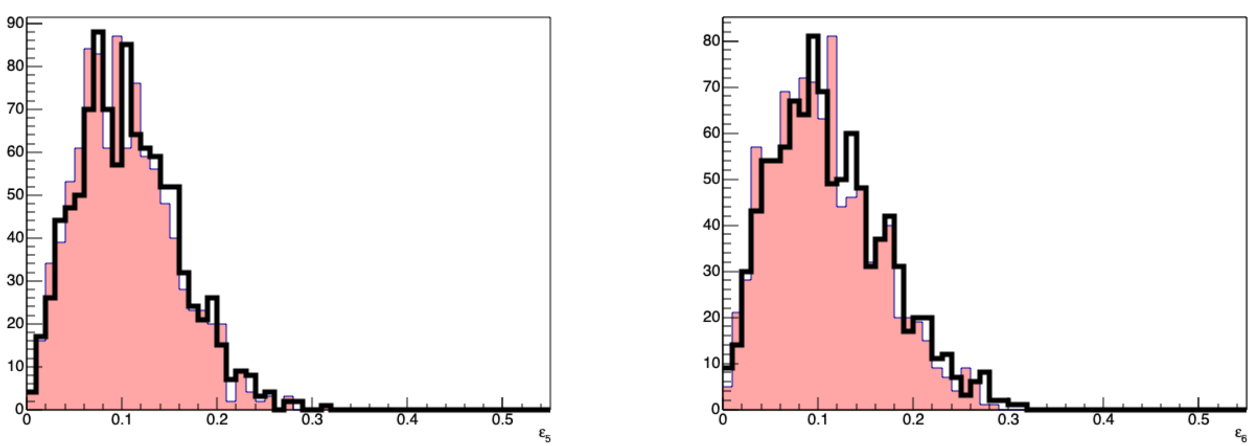
- IP-Jazma d+Au event



Replication

- IP-JAZMA replicates eccentricities calculated in IP-Glasma at t = 0.000015 fm/c (Au+Au, b=0 fm)

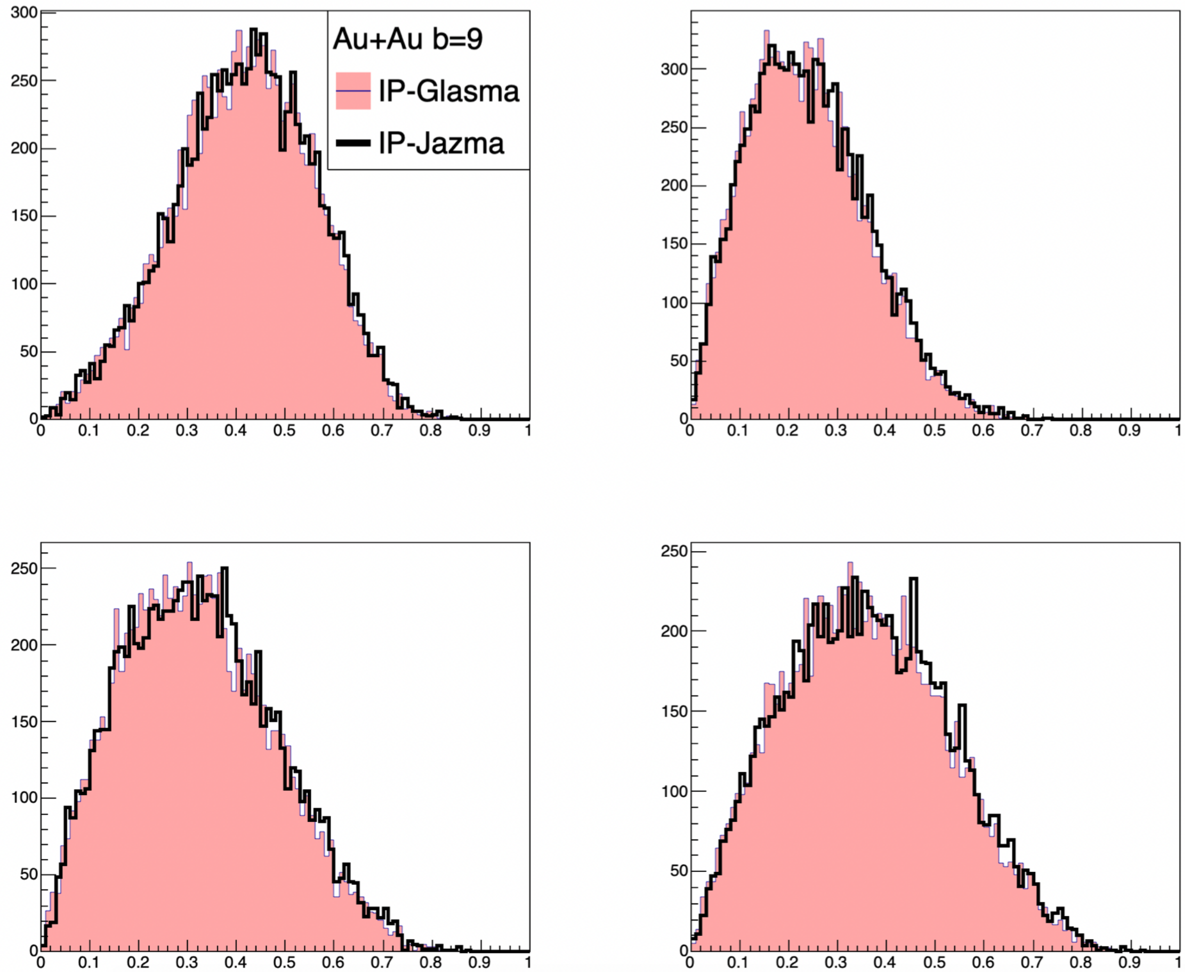




Thanks to
Sanghoon Lim
for running
IP-Glasma events.

Replication

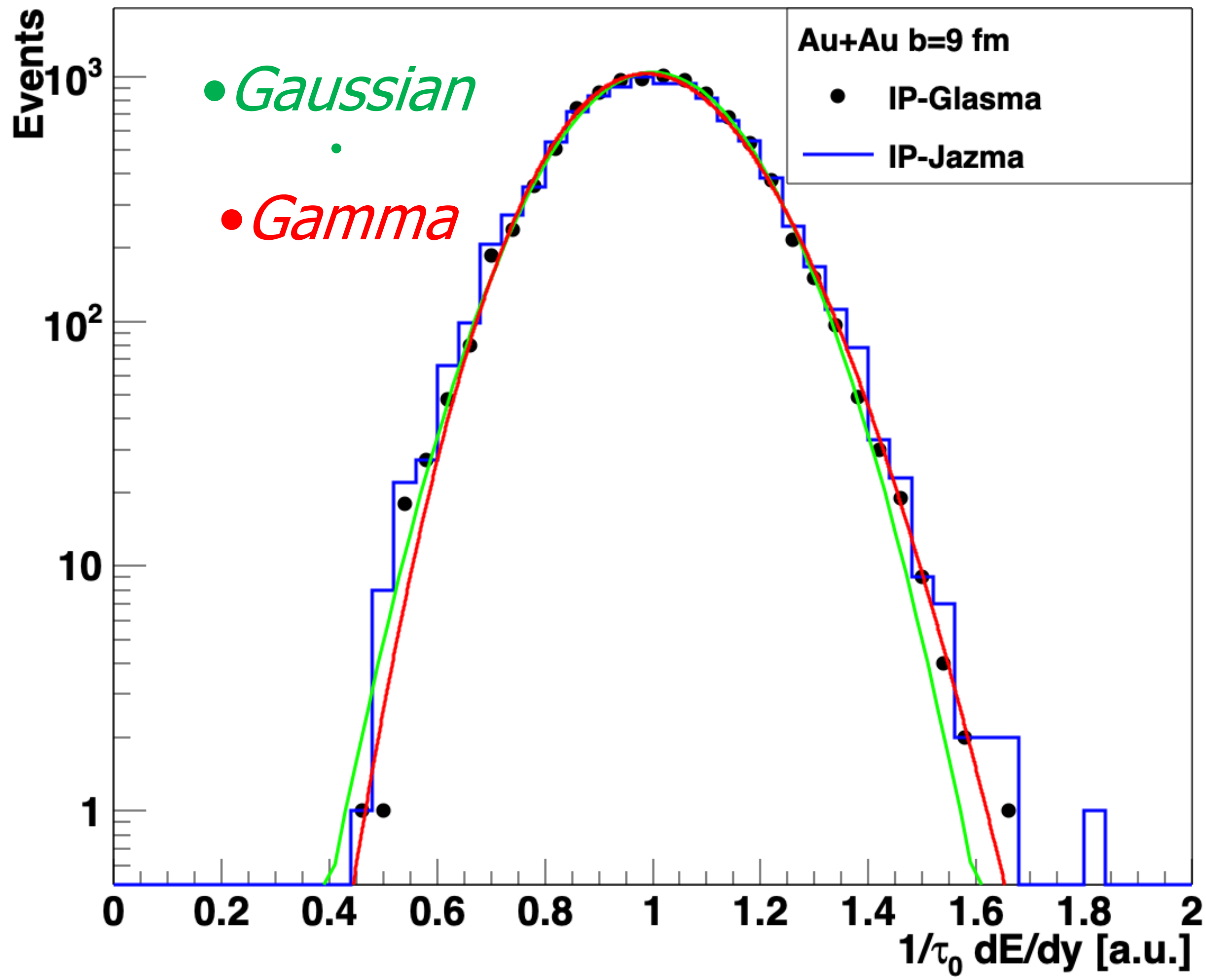
- IP-JAZMA replicates eccentricities calculated in IP-Glasma at t = 0.000015 fm/c (Au+Au, b=9 fm)



Thanks to Sanghoon Lim for running IP-Glasma events.

Elucidation

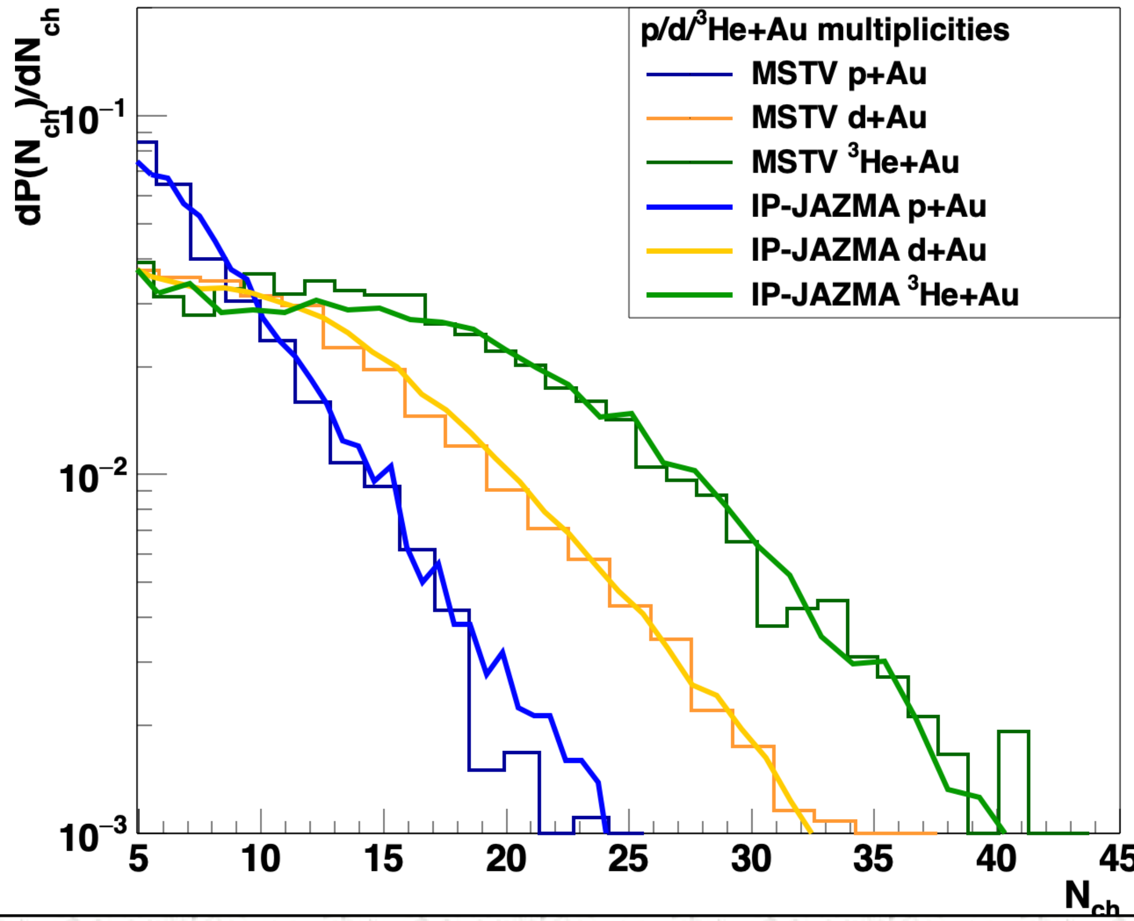
- Yes, but …
  - IP-JAZMA suggests these features result from geometry only, even *without* log-normal fluctuations.
  - (Γ–dist, not NBD)



"The best fit is given by a negative binomial (NBD) distribution, as predicted in the Glasma flux tube framework [37]; our result adds further confirmation to a previous non-perturbative study [38]", B. Schenke, P. Tribedy, R. Venugopalan, arXiv:1202.6646

Elimination

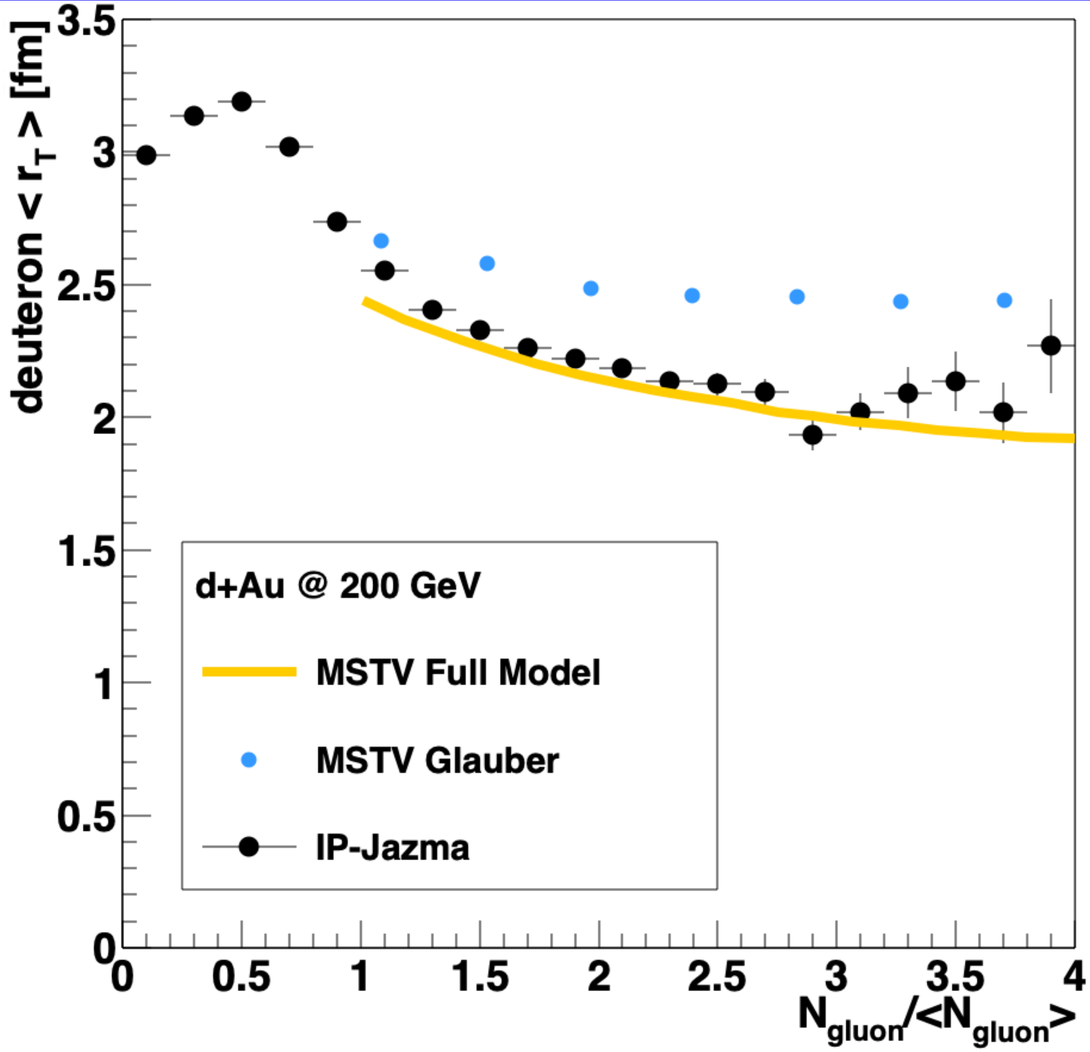
☞But in IP-JAZMA we can trace it to the MC-Glauber and assumed log-normal fluctuations used by MSTV.



"In the CGC, we can analytically trace the emergence of this approximate negative binomial distribution to the multiparticle Bose statistics of gluons. The enhancement of the high multiplicity tail in the configuration of the deuteron wavefunction with overlapping nucleons is a nontrivial result originating in from the Bose enhancement of gluons in QCD that is captured in the CGC EFT", M. Mace, V. Skokov, P. Tribedy, R. Venugopalan, arXiv:1901.10506

Application

- Yes, but …
  - IP-JAZMA reproduces this result out to (at least) 3 x the average multiplicity in d+Au collisions.



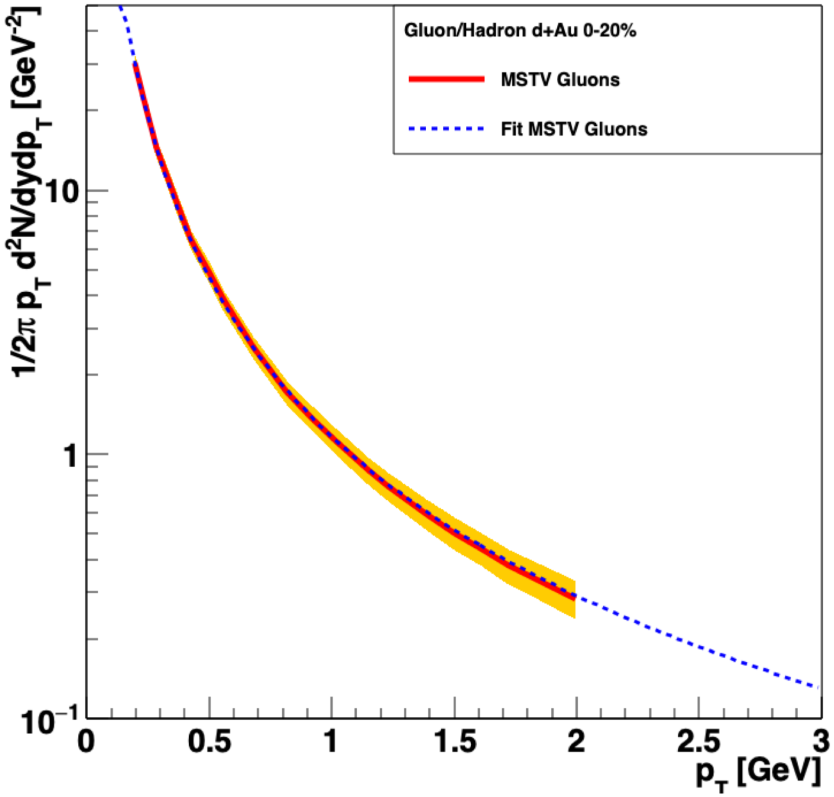
"albeit configurations with overlapping nucleons are suppressed by the available phase space, Bose statistics enhanced higher order correlations present in the CGC lead to a significant contribution of these configurations (in contrast to the MC Glauber model) in the high multiplicity tails of d+Au collisions.", M. Mace, V. Skokov, P. Tribedy, R. Venugopalan, arXiv:1901.10506

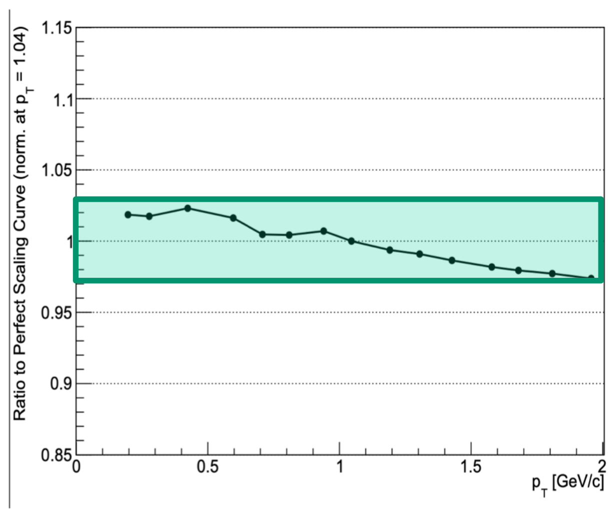
Investigation

- Why does this complex expression show ~no deviation from pure $1/k^2$

$$\frac{dN^{\text{even}}(\mathbf{k}_\perp)}{d^2kdy}[\rho_p,\rho_t] = \frac{2}{(2\pi)^3}\frac{\delta_{ij}\delta_{lm}+\epsilon_{ij}\epsilon_{lm}}{k^2}\Omega^a_{ij}(\mathbf{k}_\perp)[\Omega^a_{lm}(\mathbf{k}_\perp)]^\star, \quad (2)$$

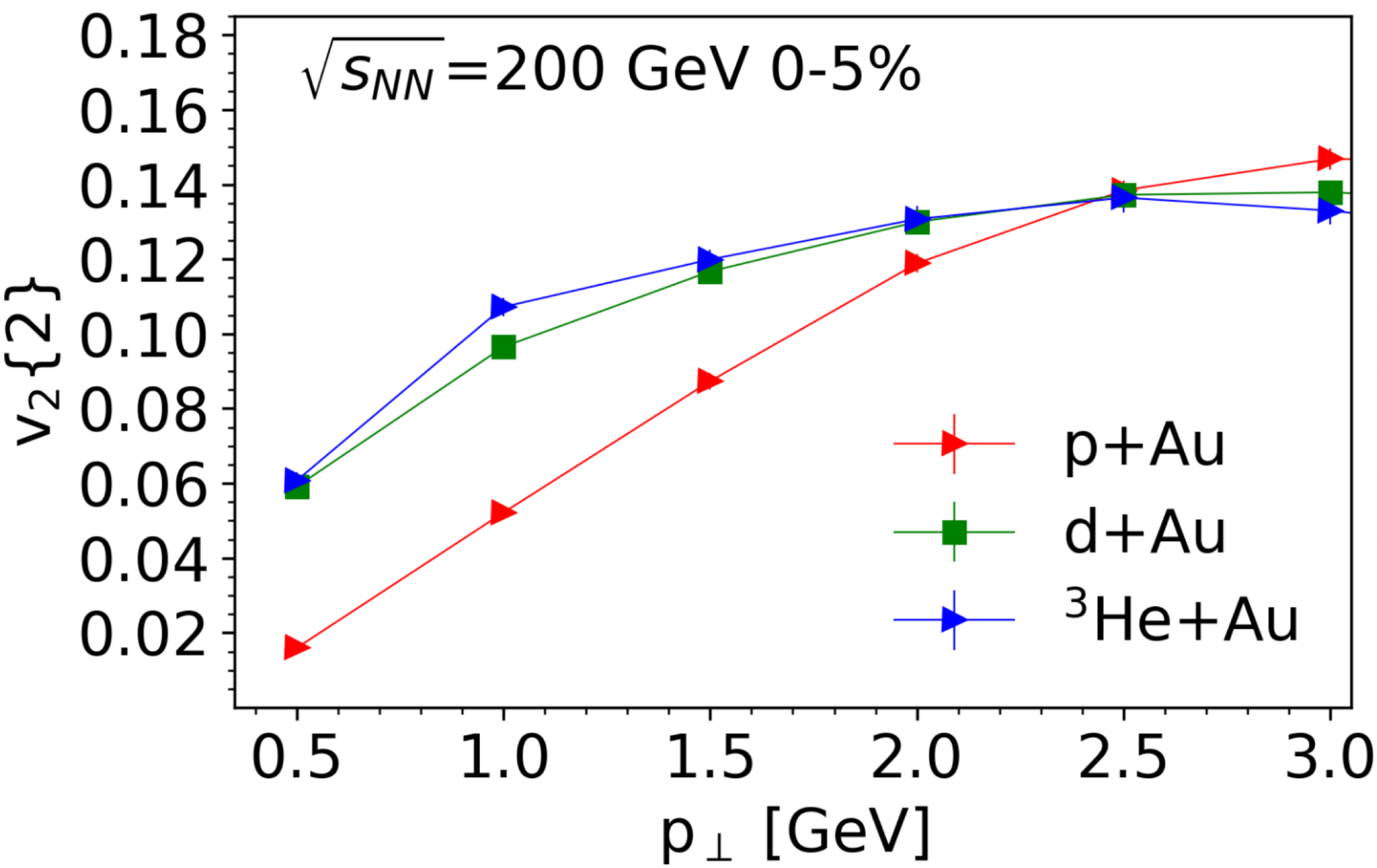
where $\Omega^a_{ij}(\mathbf{k}_\perp) = g\int[(d^2p)/(2\pi)^2]\{[p_i(k-p)_j]/p^2\}\rho^b_p(\mathbf{p}_\perp) U_{ab}(\mathbf{k}_\perp - \mathbf{p}_\perp)$ and $\epsilon_{ij}(\delta_{ij})$ denotes the Levi-Civita symbol (Kronecker delta). The adjoint Wilson line U_{ab} is a functional of the target charge density and is the two-dimensional Fourier transform of its coordinate space counterpart: $\tilde{U}(\mathbf{x}_\perp) = \mathcal{P}\exp[ig^2\int dx^+[1/(\nabla_\perp{}^2)]\tilde{\rho}^a_t(x^+,\mathbf{x}_\perp)T_a]$.





Clarification

- Hint of domain ordering only for p_T > ~ 2.5 GeV



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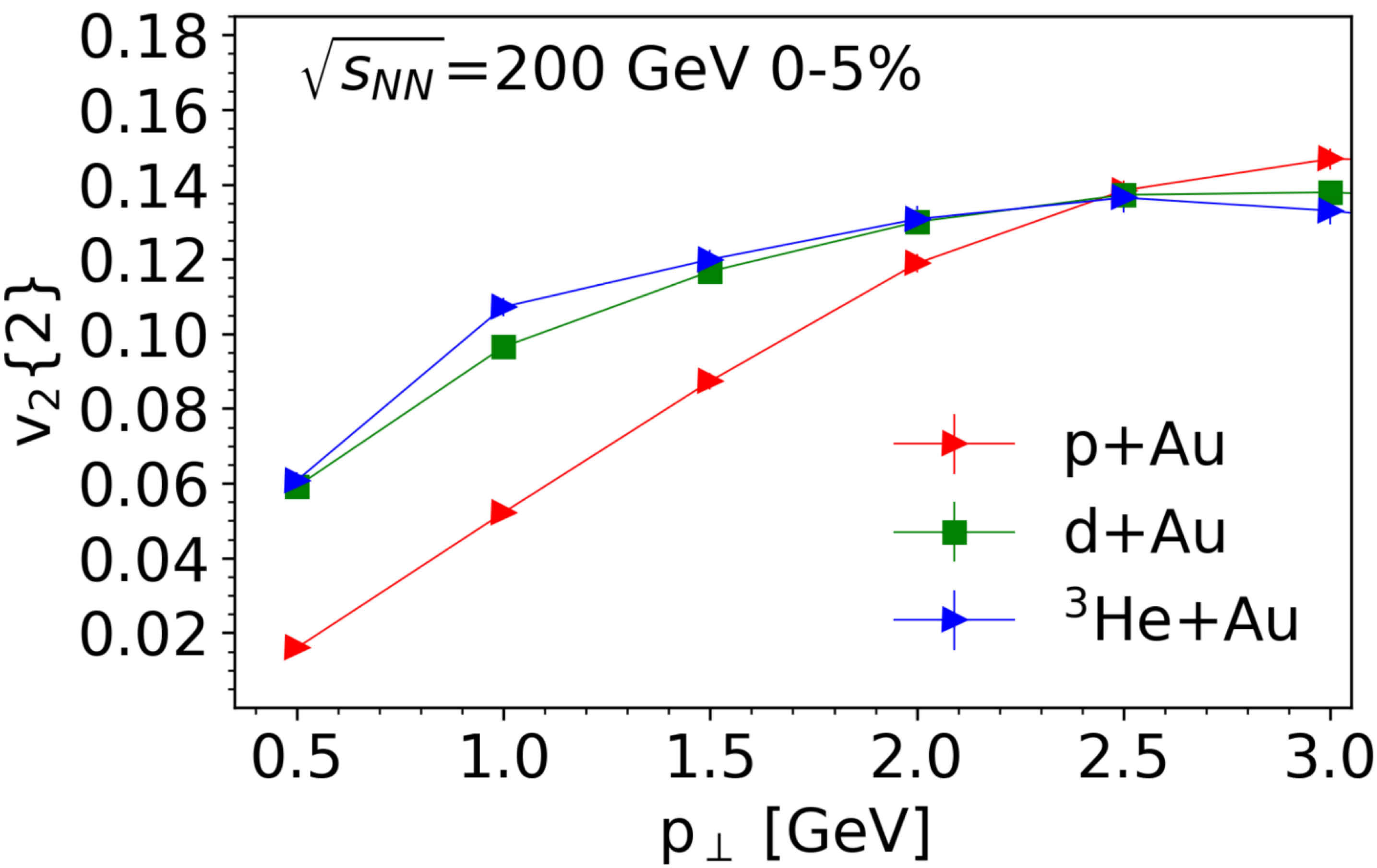
Clarification

- domain ordering for $p_T > \sim 0.5$ GeV



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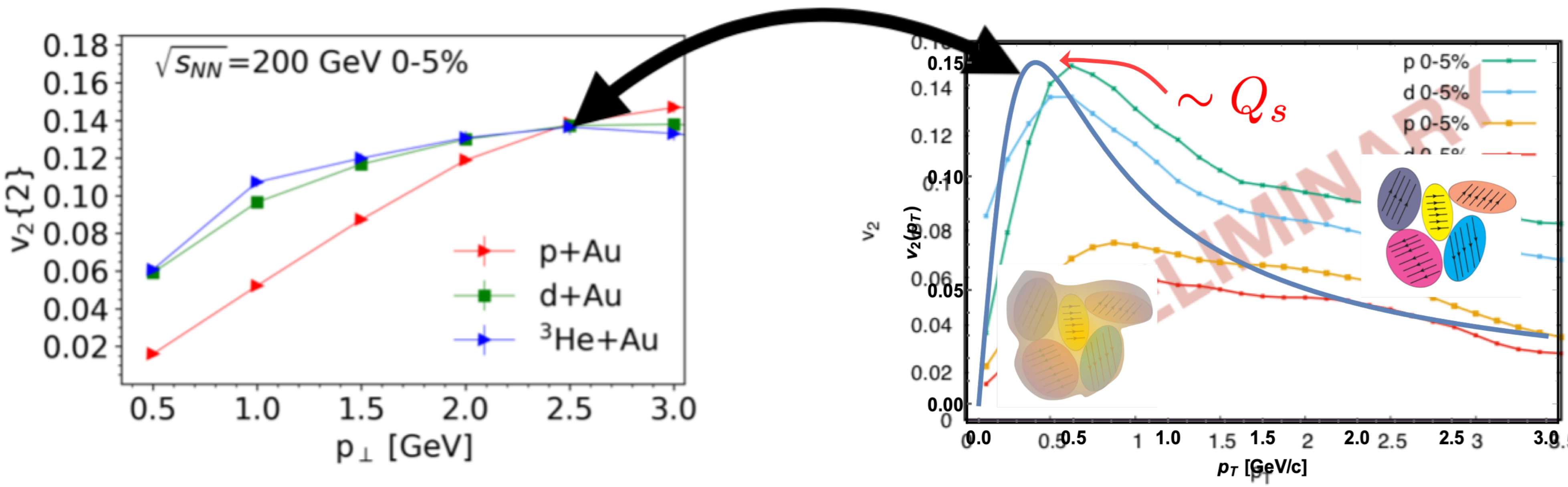
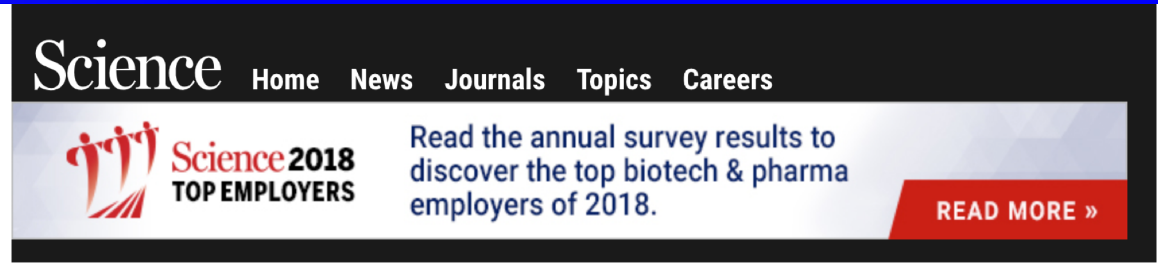


http://www.int.washington.edu/talks/WorkShops/int_19_1b/People/Mace_M/Mace.pdf

Legislation

- Science magazine:



Science Journals: editorial policies

General policies

- Authorship
- Conflict of Interest
- Prior Publication and Presentations at Meetings
- Unpublished Data and Personal Communications
- Related Papers
- Security Concerns

Research standards

- Statistical Analysis
- Guidelines for Specific Types of Studies
- Data Deposition

We require that all computer code used for modeling and/or data analysis that is not commercially available be deposited in a publicly accessible repository upon publication.

Summation

- The PHENIX v_n data from p/d/^{3}He+Au coliisons are well-described by relativistic viscous hydrodynamics.
- The same data are not described by existing initial-state models.
- IP-JAZMA has proven to be a useful diagnostic tool for *identification* and *attribution*.
- The demonstrable benefit of open-source code will lead to further progress in these investigations.

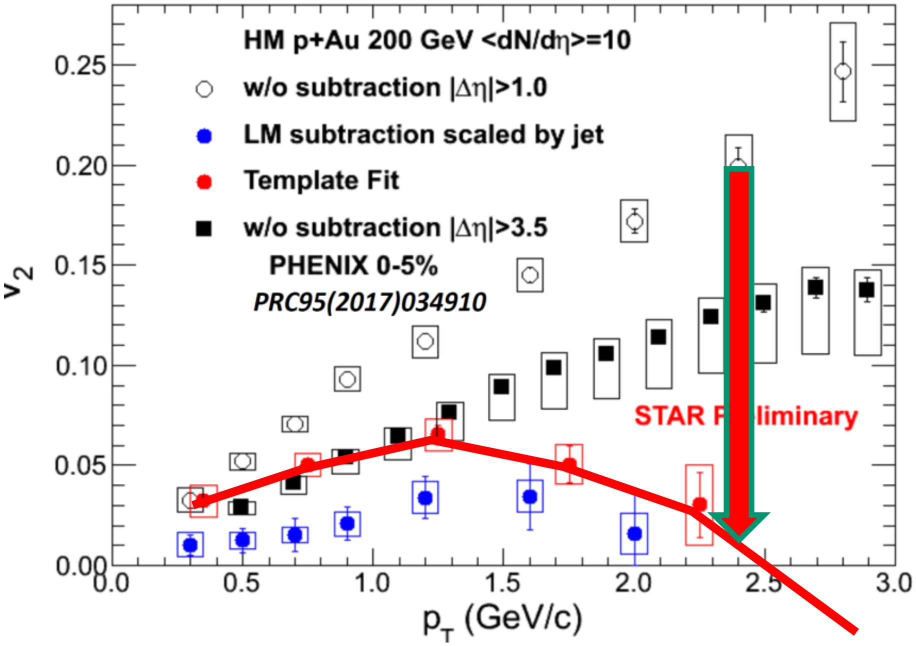
Back-Up Material

This work was supported by the United States Department of Energy Grant DOE-FG02-86ER-40281

Continuation (words I didn't use)

- Information
- Reincarnation
- Justification
- Augmentation
- Motivation
- Affirmation
- Hallucination
- Verification
- Explanation
- Revelation
- Implementation
- Ramification
- Dramatization
- Reconciliation
- Diversification
- Unification
- Recrimination
- Abnegation
- Validation
- Moralization
- Normalization
- Animation
- Abomination
- Derivation
- Invocation

Flow and Non-Flow (Slide from J. Nagle)



- *https://indico.cern.ch/event/656452/contributions/2869833/attachments/1649479/2637419/QM18-smallsystem-shengli-10.pdf*

- *Recent STAR preliminary result with small $\Delta\eta$ gap, thus huge non-flow subtraction!*
- *Very sensitive to non-flow subtraction.*

Examination of Flow and Non-Flow Factorization Methods in Small Collision Systems

S.H. Lim,[1] Q. Hu,[1] R. Belmont,[2] K.K. Hill,[1] J.L. Nagle,[1] and D.V. Perepelitsa[1]

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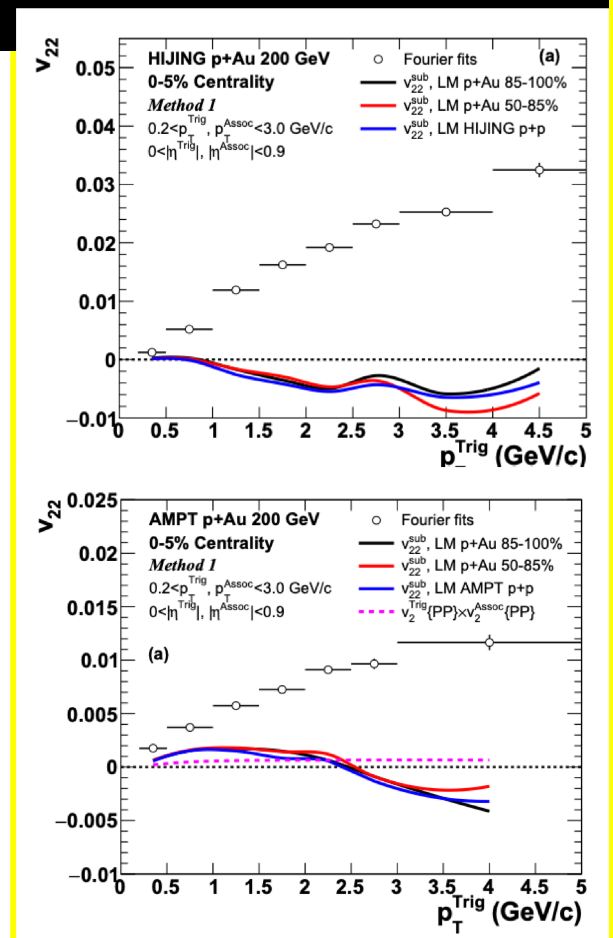
[2] *University of North Carolina, Greensboro, North Carolina 27413, USA*

(Dated: March 1, 2019)

- *https://arxiv.org/abs/1902.11290*



- *HIJING and AMPT closure tests indicate significant over-subtraction by template method with STAR kinematics*
- *Useful discussion moving forward, but details matter…*