A critical assessment of theoretical explanations for small collision system observables

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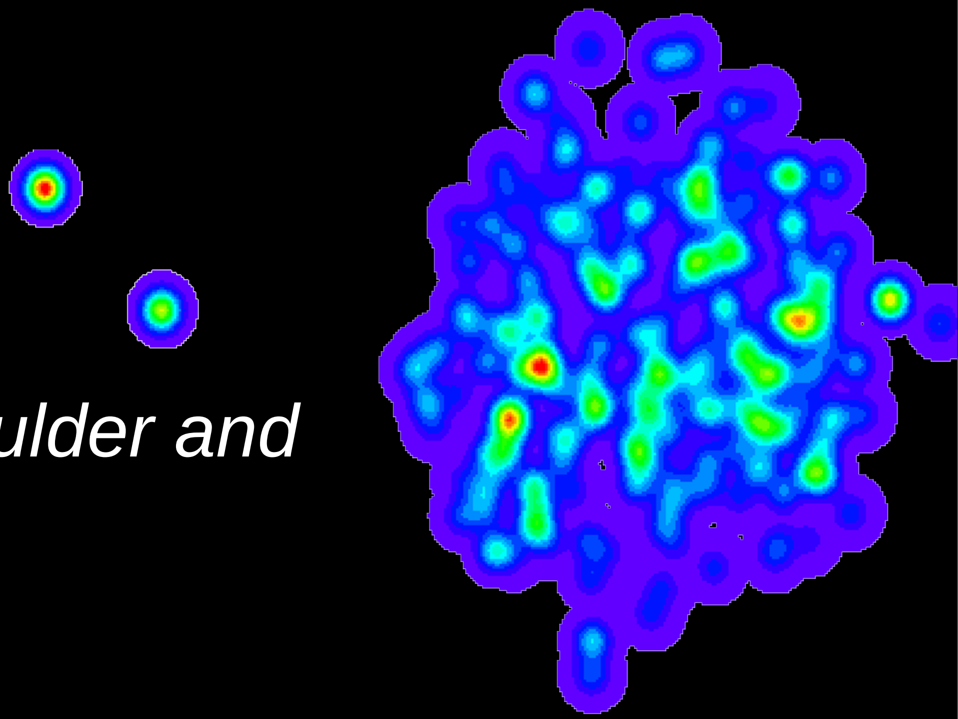


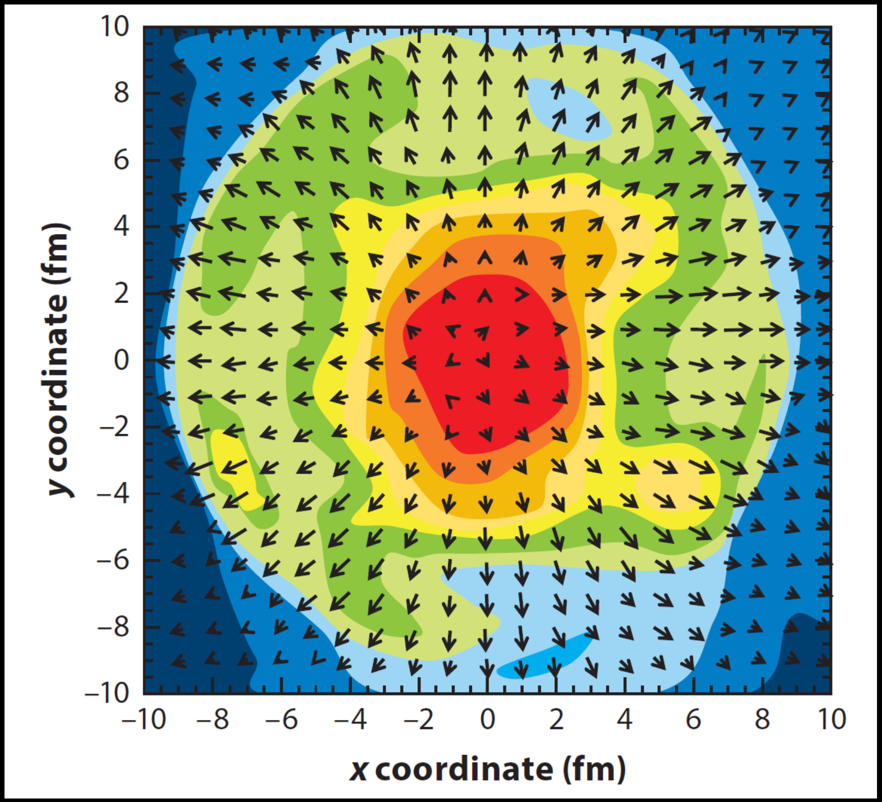
* Thank co-collaborators (Bill Zajc on IP-Jazma and Javier Orjuela Koop on AMPT) and many useful discussions at CEA/IPhT/Saclay and elsewhere.

Small System Quark-Gluon Plasma?

Quark-Gluon Plasma created in A+A collisions and described via hydrodynamics

Initial geometry translated into final state momentum anisotropies via pressure gradients

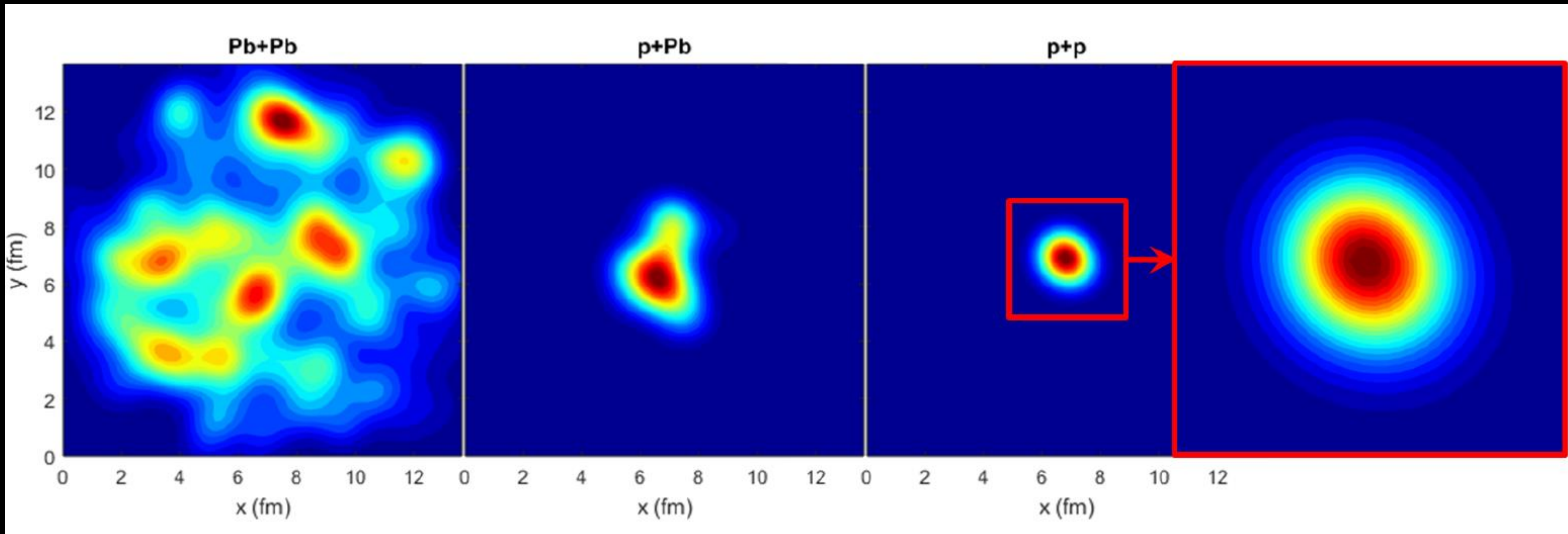
Strikingly similar observations in p+A / d+A as well as p+p

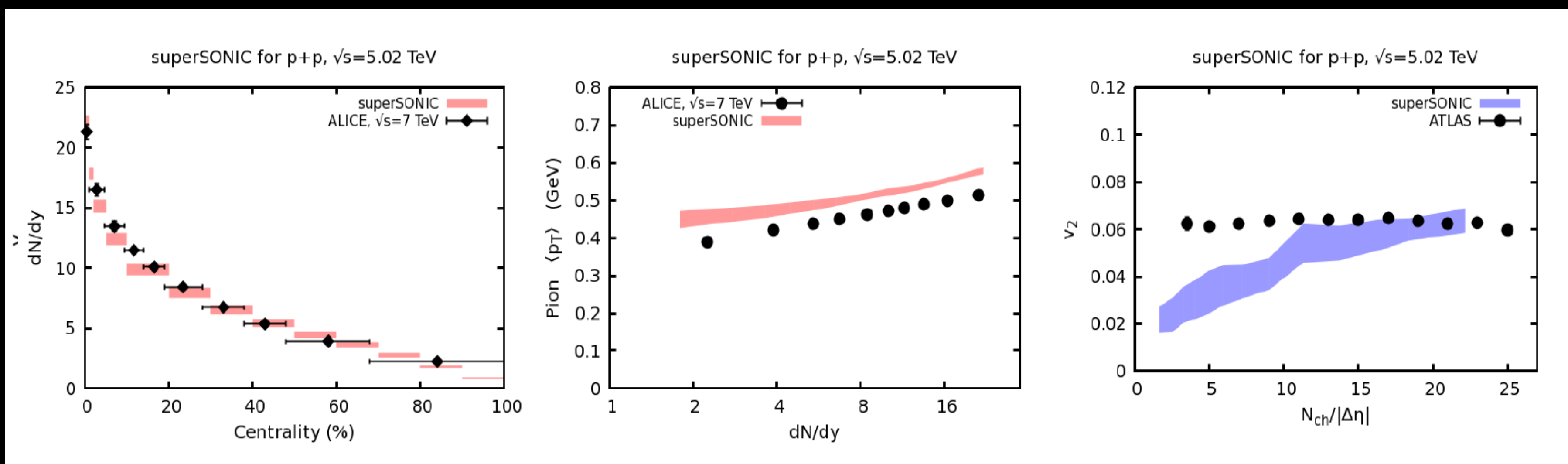


Long ago Bjorken postulated QGP formation in p+pbar via the creation of a modified vacuum state and was not concerned about the small number of final state hadrons

Nagle and Zajc, Annual Review, https://arxiv.org/abs/1801.03477

"One fluid to rule them all"





Weller and Romatschke, https://arxiv.org/abs/1701.07145

Code is all publicly available and documented.
Multiple groups cross checking and producing consistent results (for example iEBE-VISHNU).

What are the systematic uncertainties, open items?

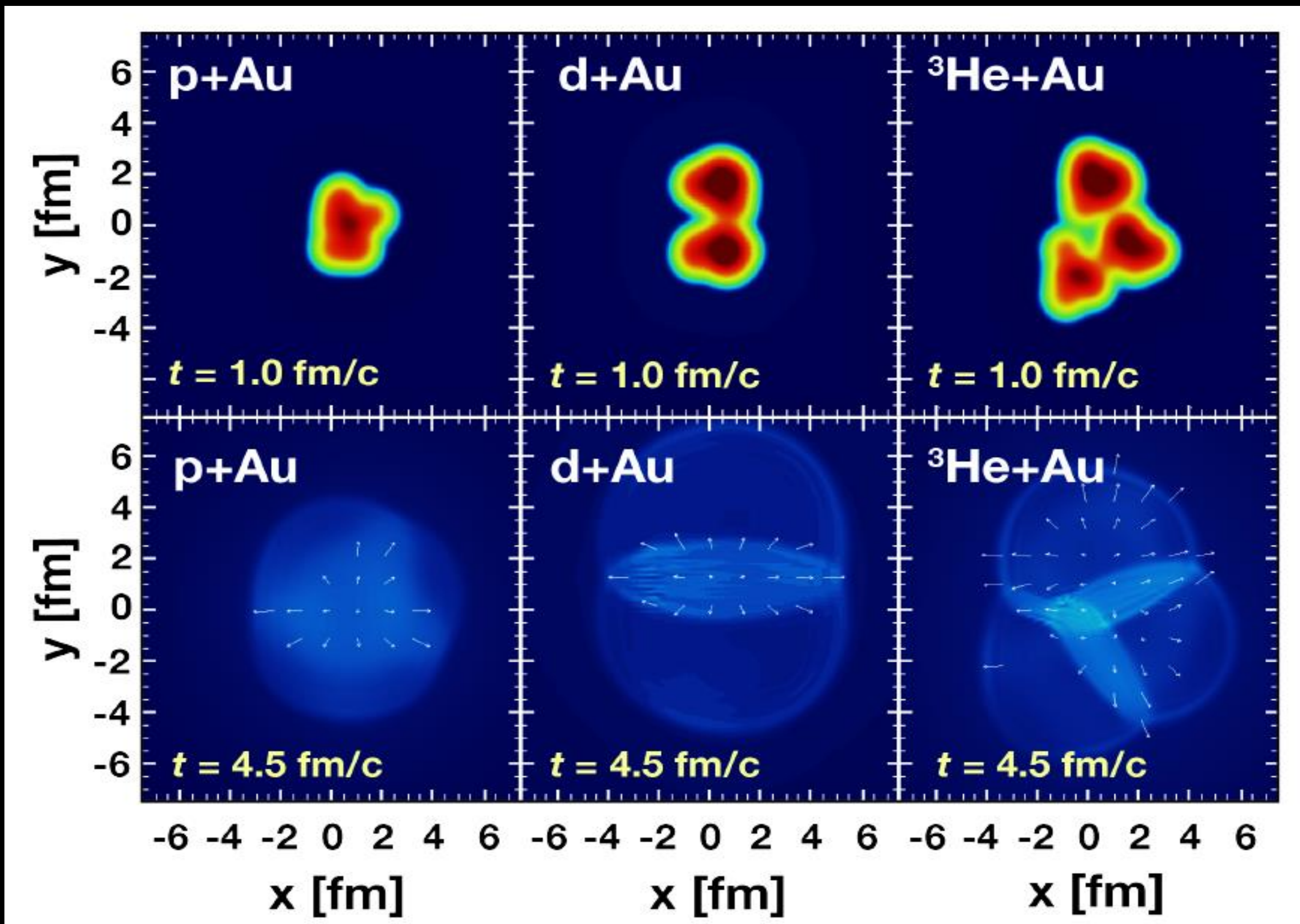
- MC Glauber + Constituent Quarks needed for p+p and includes some Gaussian σ value for local "gluon cloud"
- Bulk viscosity important to temper large radial expansion in p+p, but not as critical in A+A
- Pre-equilibrium (superSONIC) or not (SONIC)
- Unknown $\eta/s(T)$ value.
  superSONIC results with $\eta/s = 1/4\pi$ for all systems.
- Hadronic cascade model (B3D in superSONIC)
- Important questions about hydro far from equilibrium which is an entire other talk (!)

RHIC Geometry Scan

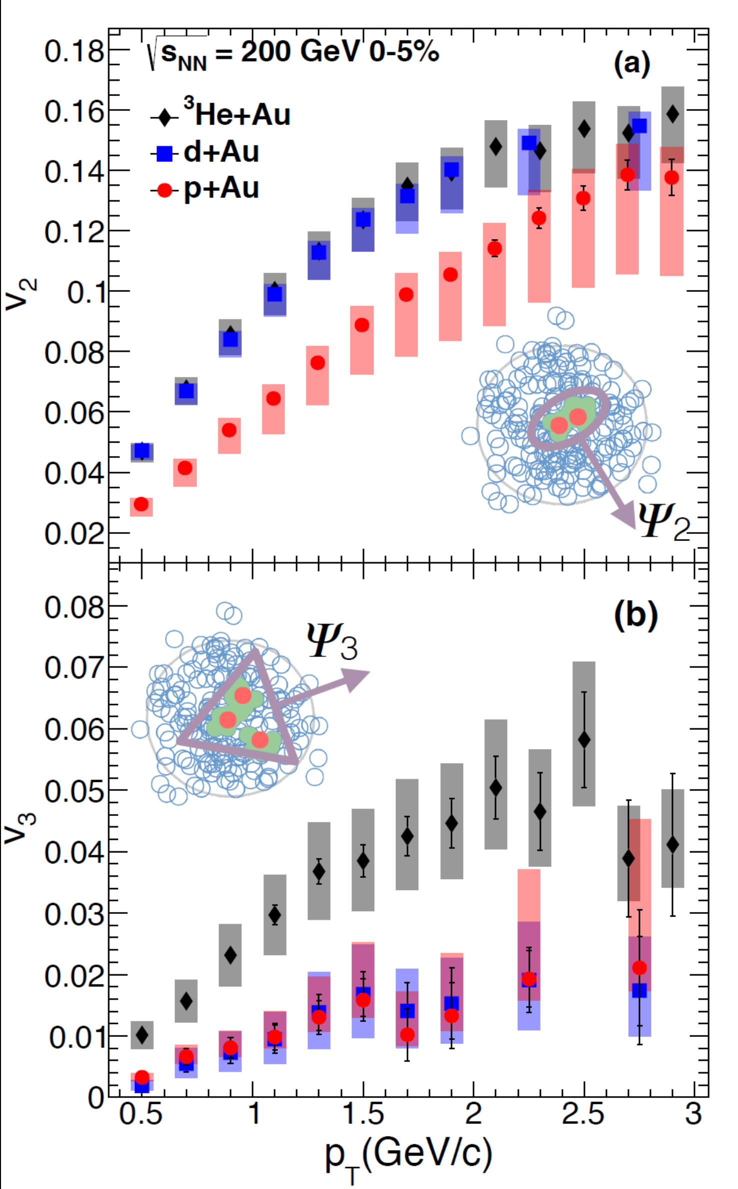
PRL **113,** 112301 (2014) PHYSICAL REVIEW LETTERS week ending 12 SEPTEMBER 2014

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]

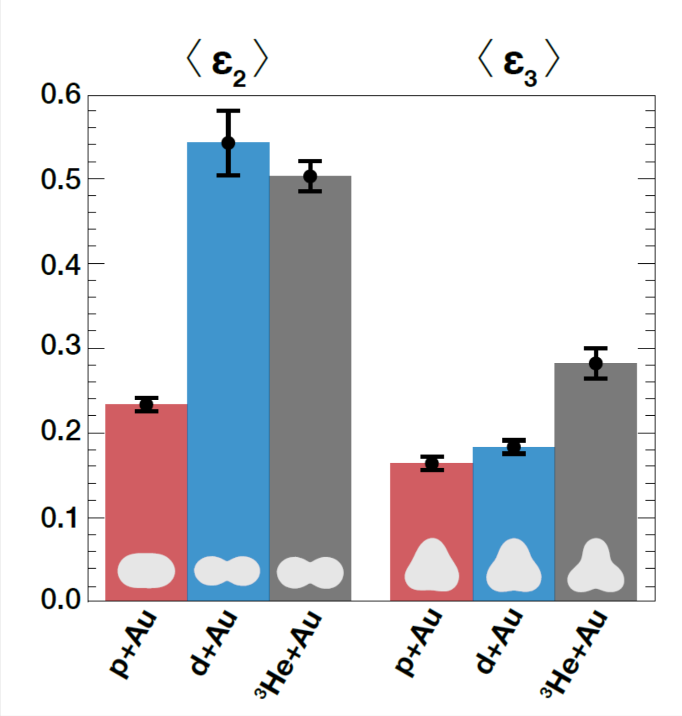


PHENIX Experimental Data



New v_3 in p+Au, d+Au completes the set!

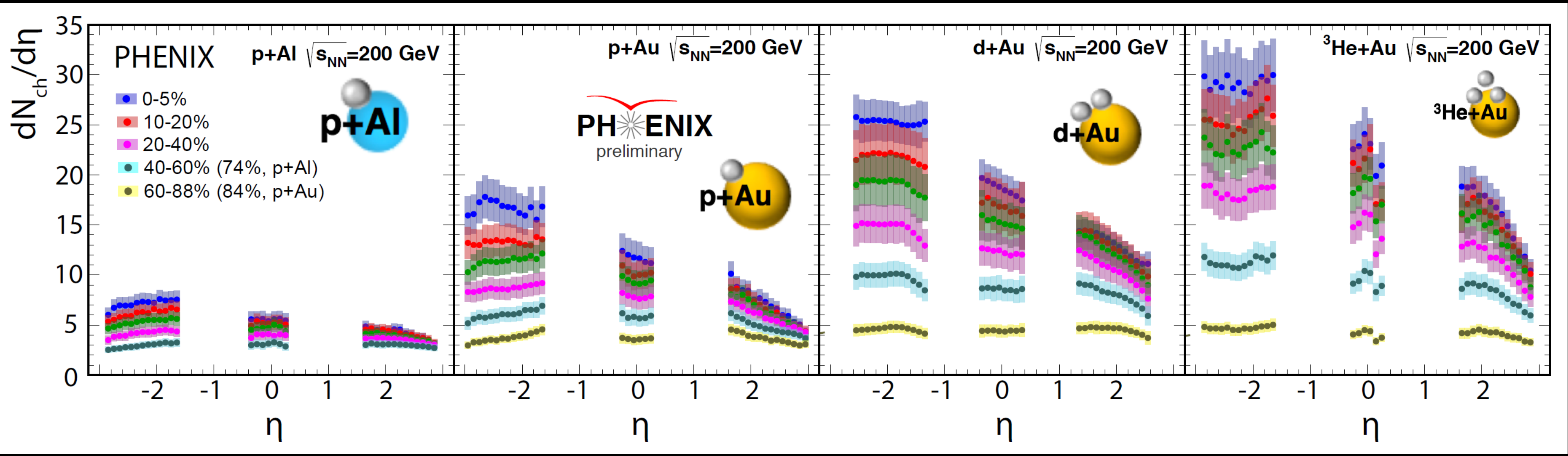
Following the ordering of eccentricities.



However, multiplicity also plays a role.

PHENIX, https://arxiv.org/abs/1805.02973

New PHENIX Multiplicity Measures



https://indico.cern.ch/event/656452/contributions/2869993/

Midrapidity Values

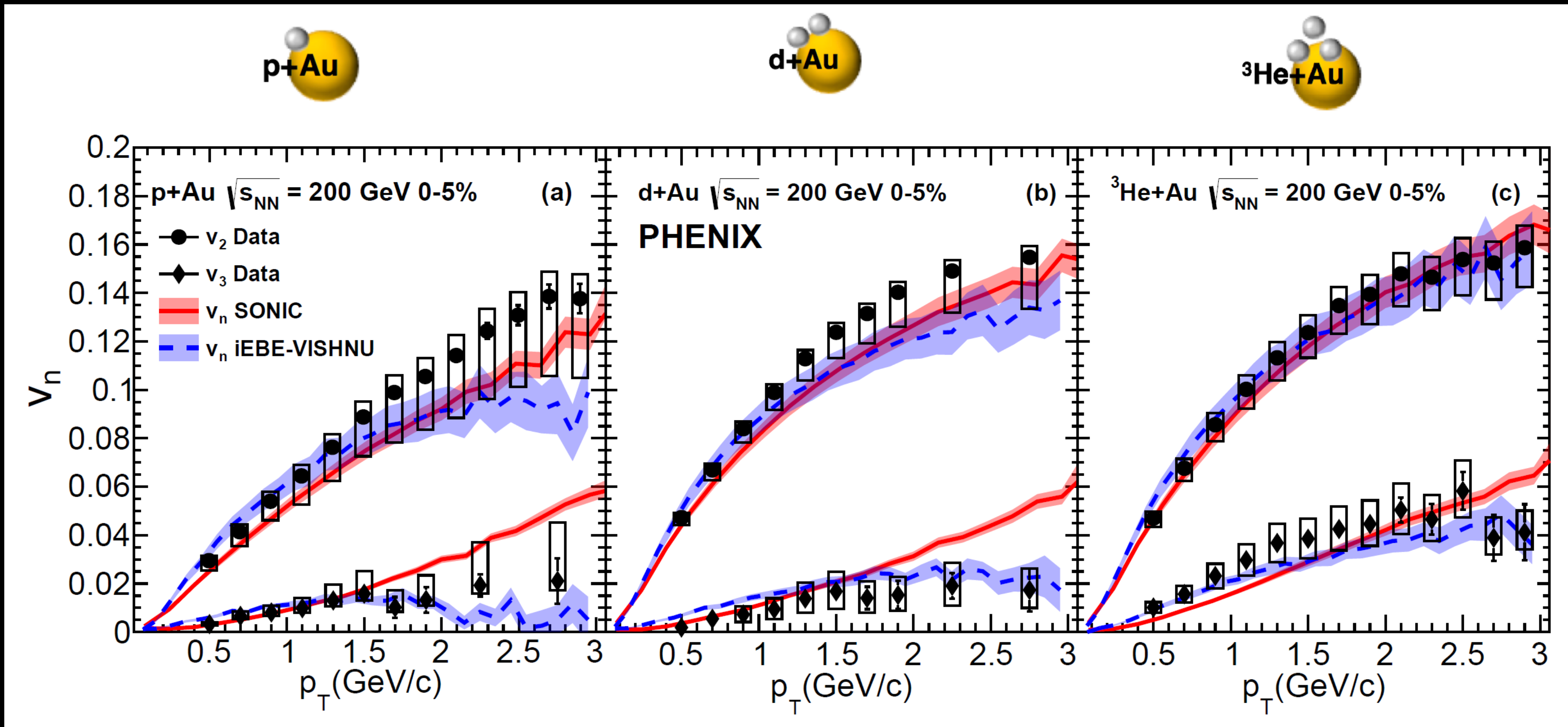
$dN_{ch}/d\eta \sim 12$ p+Au 0-5%

$dN_{ch}/d\eta \sim 18$ d+Au 0-5%

$dN_{ch}/d\eta \sim 22$ ^{3}He+Au 0-5%

Hydrodynamic calculations include the initial geometry differences and match the particle multiplicity for each system

Hydrodynamic Comparison



Good agreement with v_2, v_3 (p_T) for all three systems

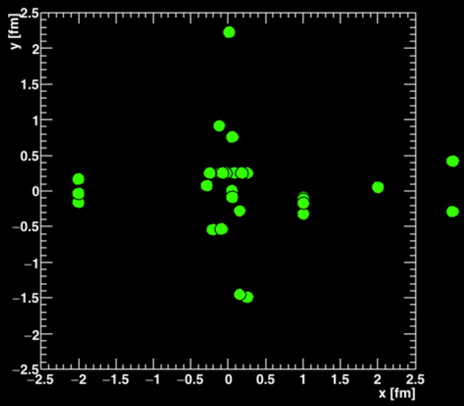
SONIC is a published prediction

No tuning of parameters or options for different systems

Parton Transport Explanation

In limit of many scatters per parton (> 4-5), this might be a dual picture to hydrodynamics

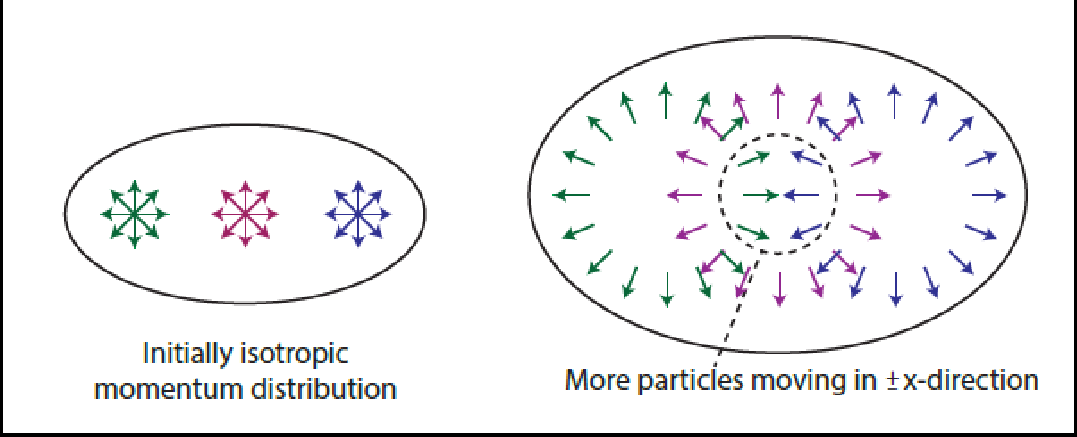
However, if most partons have zero scatters and others have just one, that seems different



AMPT Escape Mechanism paper finds very few scatterings
He *et al.*, https://arxiv.org/abs/1601.00878

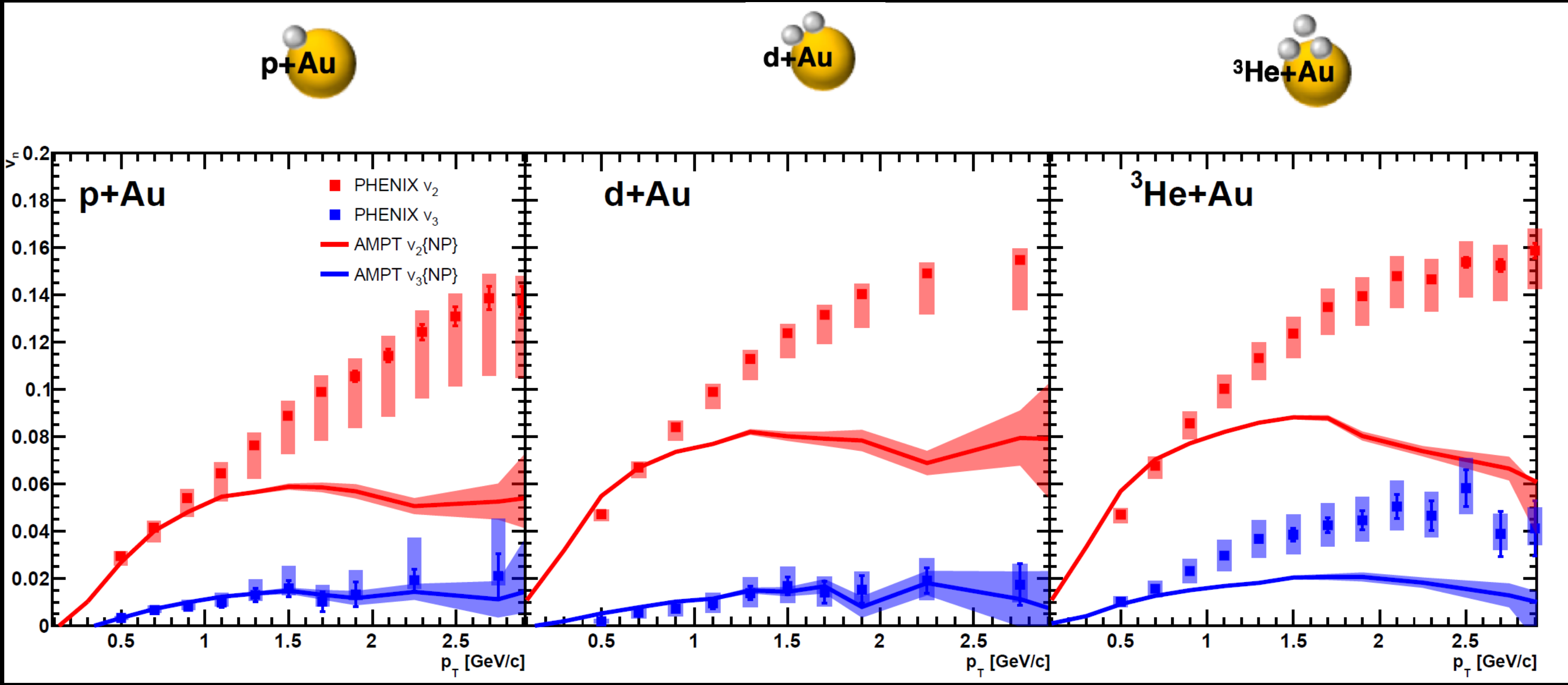
Recent analytic approach generates significant v_2 with single scatter

Kurkela, Wiedemann, Wu
arXiv:1805.04081
arXiv: 1803.02072



Small system studies with AMPT (publicly available code)

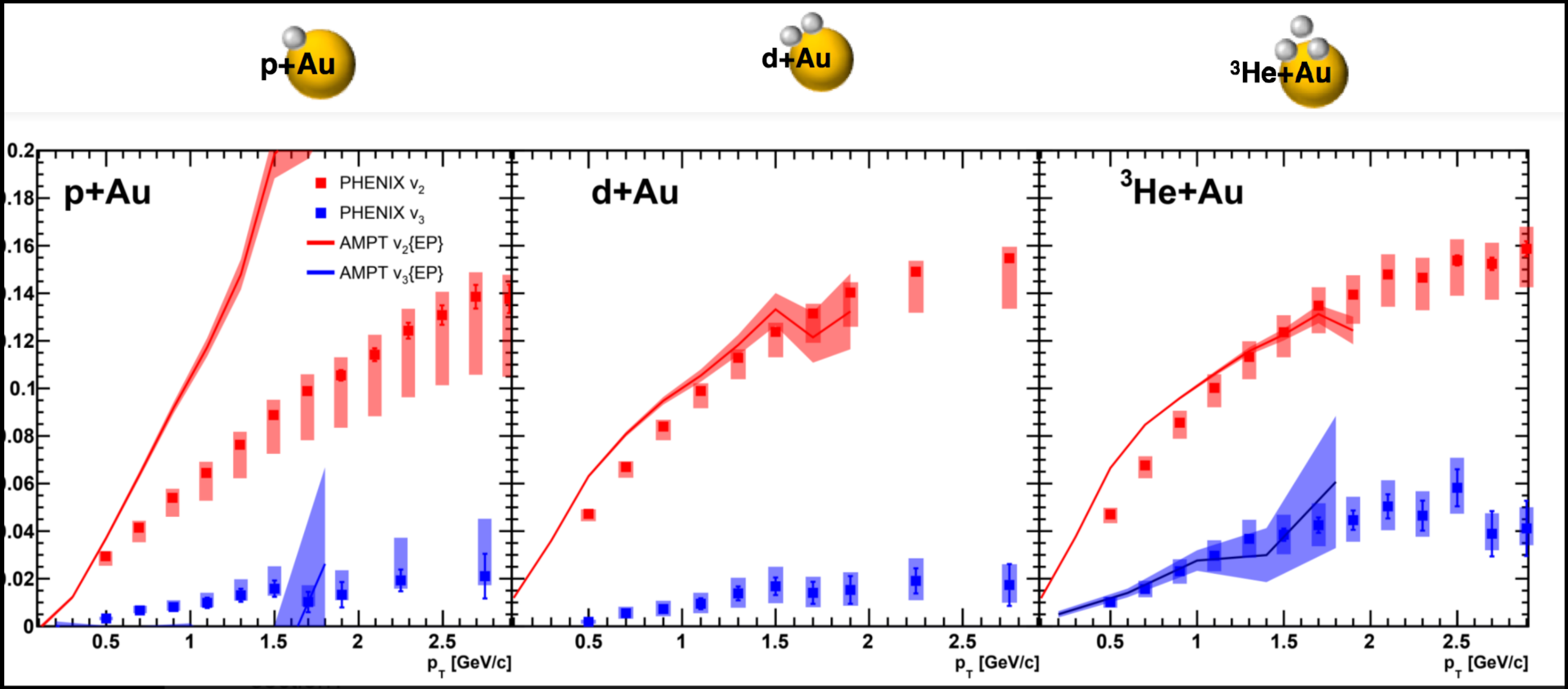
Nagle et al., arXiv:1707.02307, Orjuela Koop et al., arXiv:1512.06949, arXiv:1501.06880
Bozek, Bzdak, Ma, arXiv:1503.03655



AMPT v2.25t5 relative to true geometry defined by initial nucleons string melting mode, black disk σ_{NN}, σ_{parton} = 0.75 mb

Poor quantitative agreement with data, but rough qualitative agreement with system v_n ordering

Apples-to-Apples Comparison

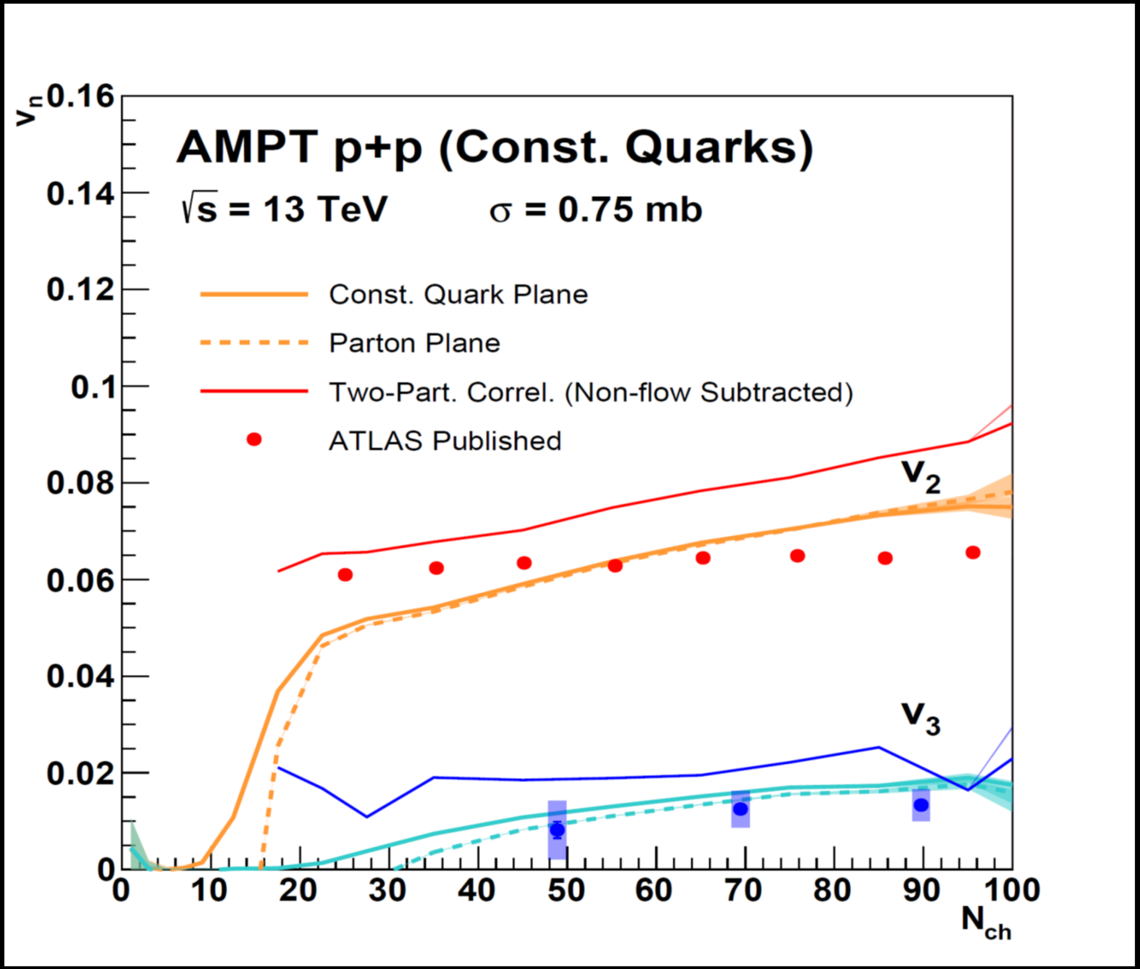


AMPT fully modeling the Event Plane method in PHENIX

Better agreement in ³He+Au, but much worse in p+Au (non-flow), insufficient statistics for v_3 in the smaller systems (working on it)

Proton-Proton Case

Extend AMPT to include sub-nucleonic structure (3 quarks)



Rough qualitative agreement

Parameters, parameters, parameters

→ without too much physics behind them

Quasiparticle picture only useful if one can correctly identify quasiparticles and their properties (think Condensed Matter Physics)

→ which in AMPT are nearly massless < 20 MeV quarks, no gluons

AMPT uses Zhang Parton Cascade to model the Boltzmann equation.

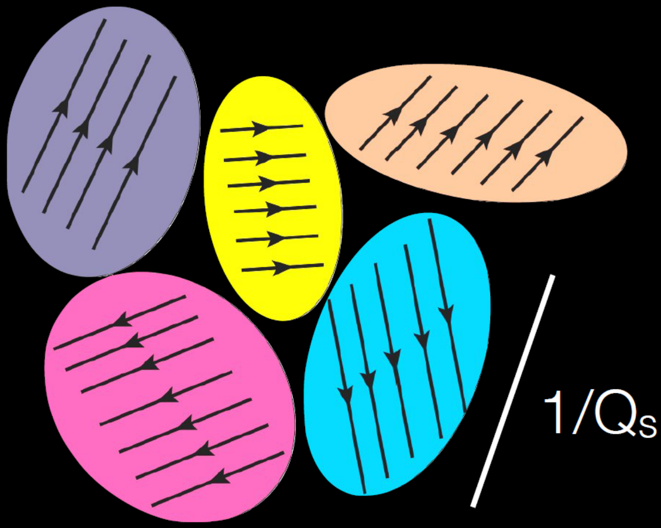
However, only valid when Dilution parameter $D = \lambda / \ell << 1$ (violated in AMPT)

Also, extremely short "formation times"

Initial State Explanation(s)

INITIAL STATE PICTURE

Intuitive picture:
Quarks or gluons are produced from color field domains in the Pb or p target



Particles that come from the same domain are correlated

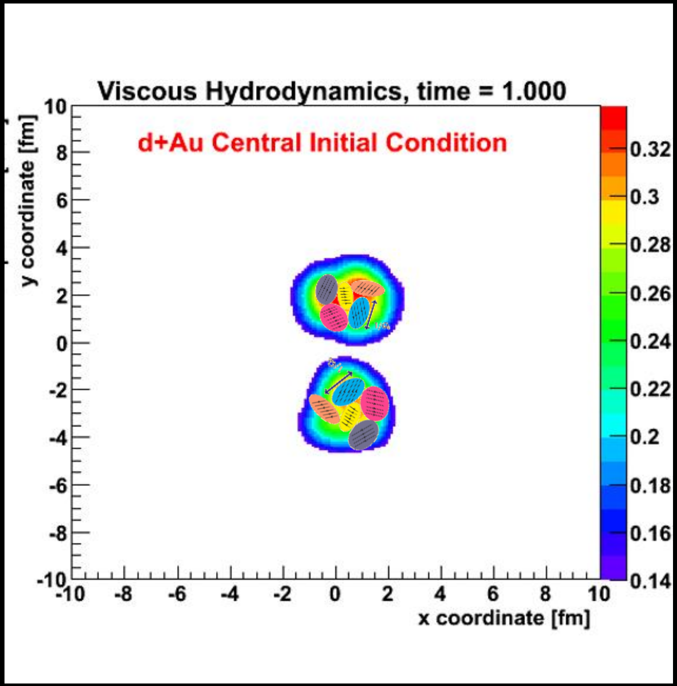
Effect is suppressed by the number of colors and the number of domains (it is small for heavy ions)

FIGURE: T. LAPPI, B. SCHENKE, S. SCHLICHTING, R. VENUGOPALAN JHEP 1601 (2016) 061; SEE ALSO: A. DUMITRU, A.V. GIANNINI, NUCL.PHYS.A933 (2014) 212; A. DUMITRU, V. SKOKOV, PHYS.REV.D91 (2015) 074006; A. DUMITRU L. MCLERRAN, V. SKOKOV, PHYS.LETT.B743 (2015), 134; V. SKOKOV. PHYS.REV.D91 (2015) 054014

Björn Schenke, BNL

More domains that are
not aligned,
correlation effect is washed out.

Nice separation of scales
Deuteron size >> Domain Size

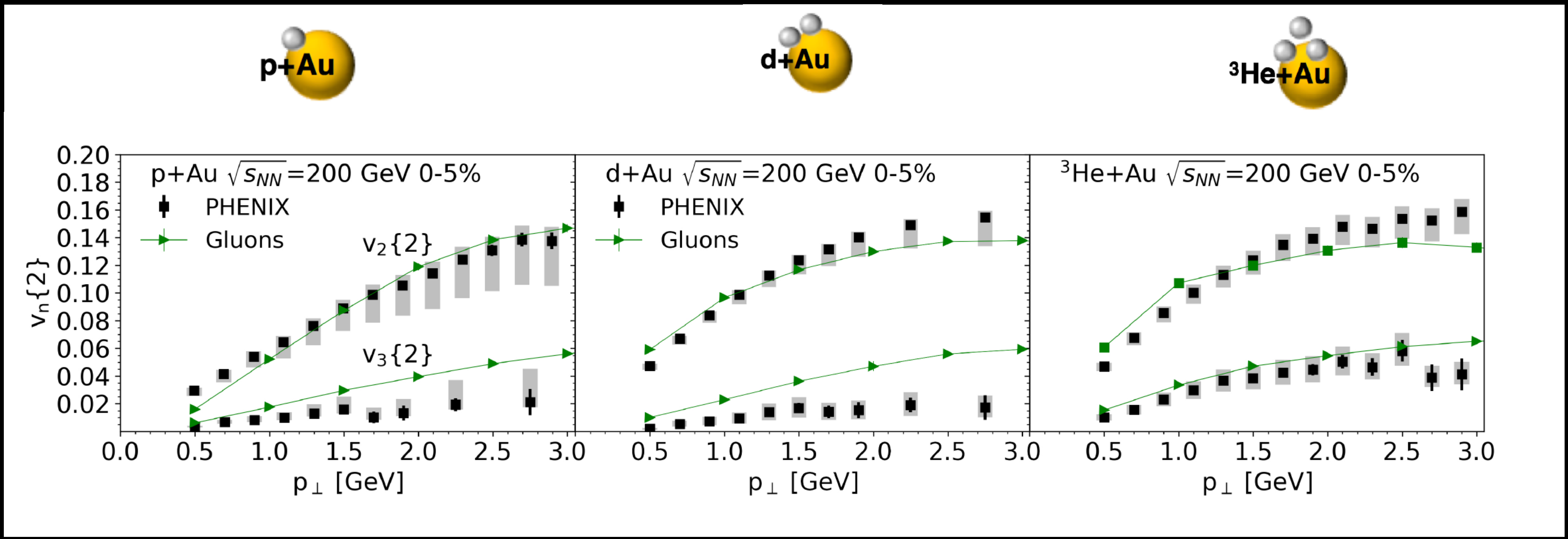


$$v_n^{p+\mathrm{Au}} > v_n^{d+\mathrm{Au}} > v_n^{{}^3\mathrm{He}+\mathrm{Au}}$$

Exactly the opposite of what is observed in data !

Definitively rule out scenario where initial state correlations dominate via resolved domains of size $1/Q_s$

15 days after the PHENIX paper was posted, postdictions appeared



Mace et al. [MSTV], https://arxiv.org/abs/1805.09342

Remarkable results seem counter-intuitive

Code is not publicly available, many details missing so not possible to reproduce results yet

“There are a number of steps — all of which are essential”

What is essential to the physics result?

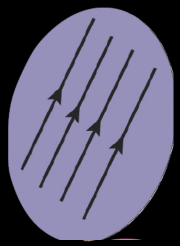
Think of a gluon from the target and its interaction with domains in the projectile…

Thus, applying saturation physics to the proton at RHIC for midrapidity particle production up to p_T ~ 3 GeV/c (?)

If the $k_T < Q_s$ (proj) then the target cannot resolve individual domains and interacts with many of them "coherently".

Color fields aligned over 2 fm distance?

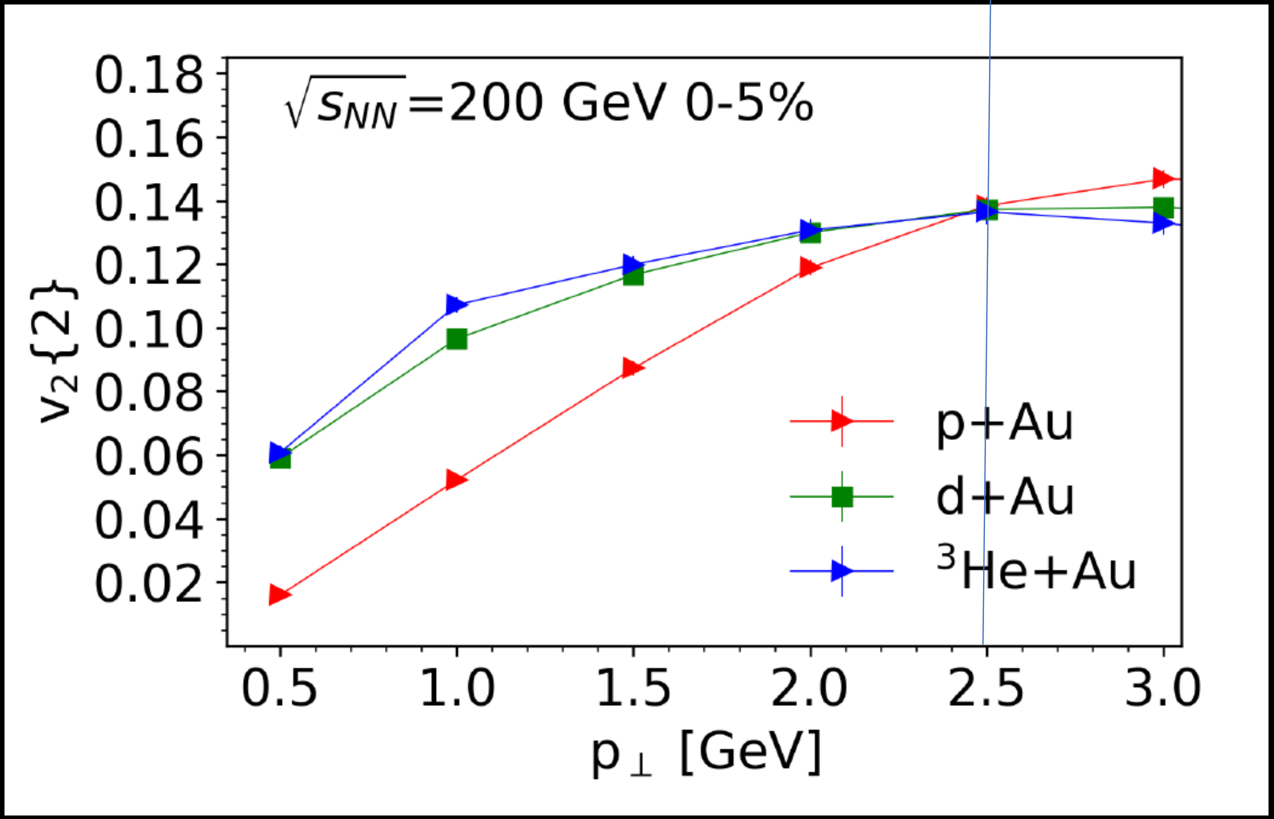
In d+Au, deuteron is "big" – average transverse separation > 2 fm



Violates color confinement?

Not sure if that is their picture…

← Domains not resolved | Domains resolved →



Q_s (deut) > Q_s (prot) since 0-5% d+Au is higher multiplicity than p+Au, and v_2 scales with Qs(proj), thus v_2 (d+Au) > v_2(p+Au)

$k_T < Q_s$ (proj) → does that mean Q_s(proj) = 2.5 GeV (?)
Not exactly and need exact definition and numbers for k_T

IP-Jazma

Jamie Nagle and Bill Zajc's attempt to understand a subset of the ingredients in recent saturation physics calculations for small systems.
Just like Jazz, some people will not appreciate it.

Note, I am glad to learn of mistakes, hidden assumptions, etc. That is how I learn.

IP-Jazma Details

1. MC Glauber to obtain nucleon x,y positions in each event

2. Use IP-Sat (impact parameter saturation model) to calculate the Q_s^2 distribution on an x,y lattice

$$Q_s^2(x,y) = Q_{s,0}^2 \times Exp(-r_T^2/(2\sigma^2))$$

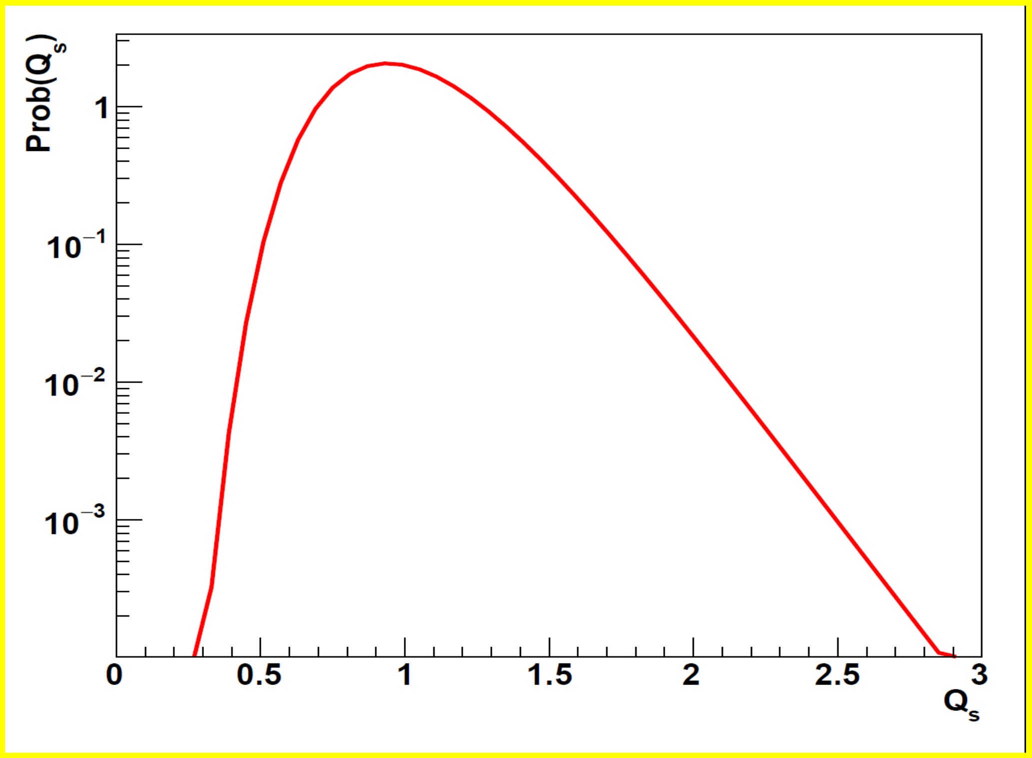
Note that this is just a uniform Gaussian with σ = 0.32 fm at RHIC

Q_s^2 is proportional to $g^4\mu^2$, where μ^2 is the number density of color charge per unit transverse area
Q_s is proportional to $g^2\mu$ and is Gaussian with $\sigma = 0.45$ fm

MSTV (private comm.) says that "our choice of B_G" corresponds to slightly larger σ = 0.56 fm, so I will match that in IP-Jazma

3. MSTV includes nucleon-by-nucleon fluctuations in $Q_{s,0}{}^2$ (the amplitude of the IP-Sat Gaussian). Thus, each nucleon is still a perfect Gaussian, just different amplitudes.

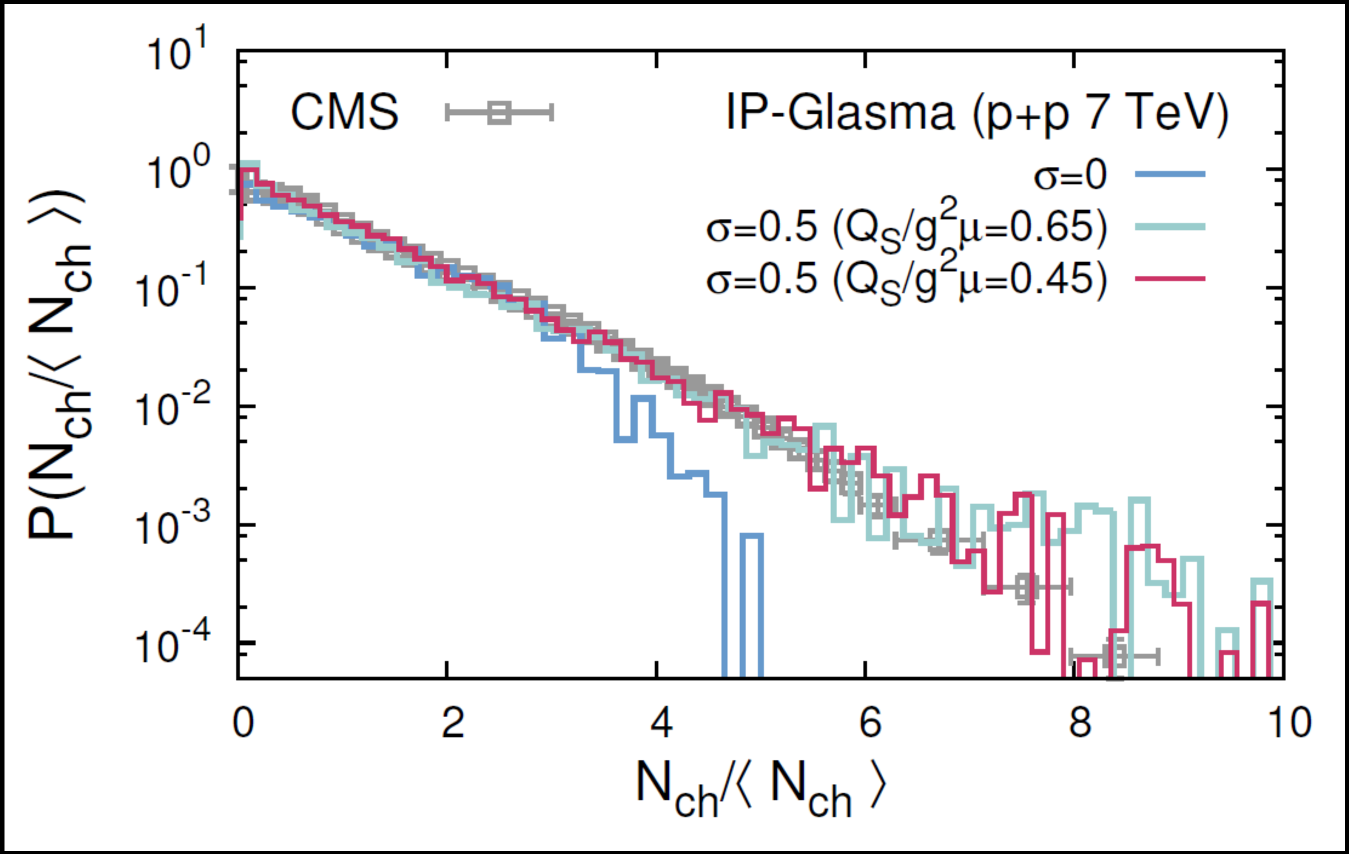
Implemented with variance 0.5 on $\log(Q_s{}^2)$ – i.e. high side tail.



- Non-perturbative on many scales
- Not derivable from any first principles calculation
- No explicit constraint on magnitude or shape

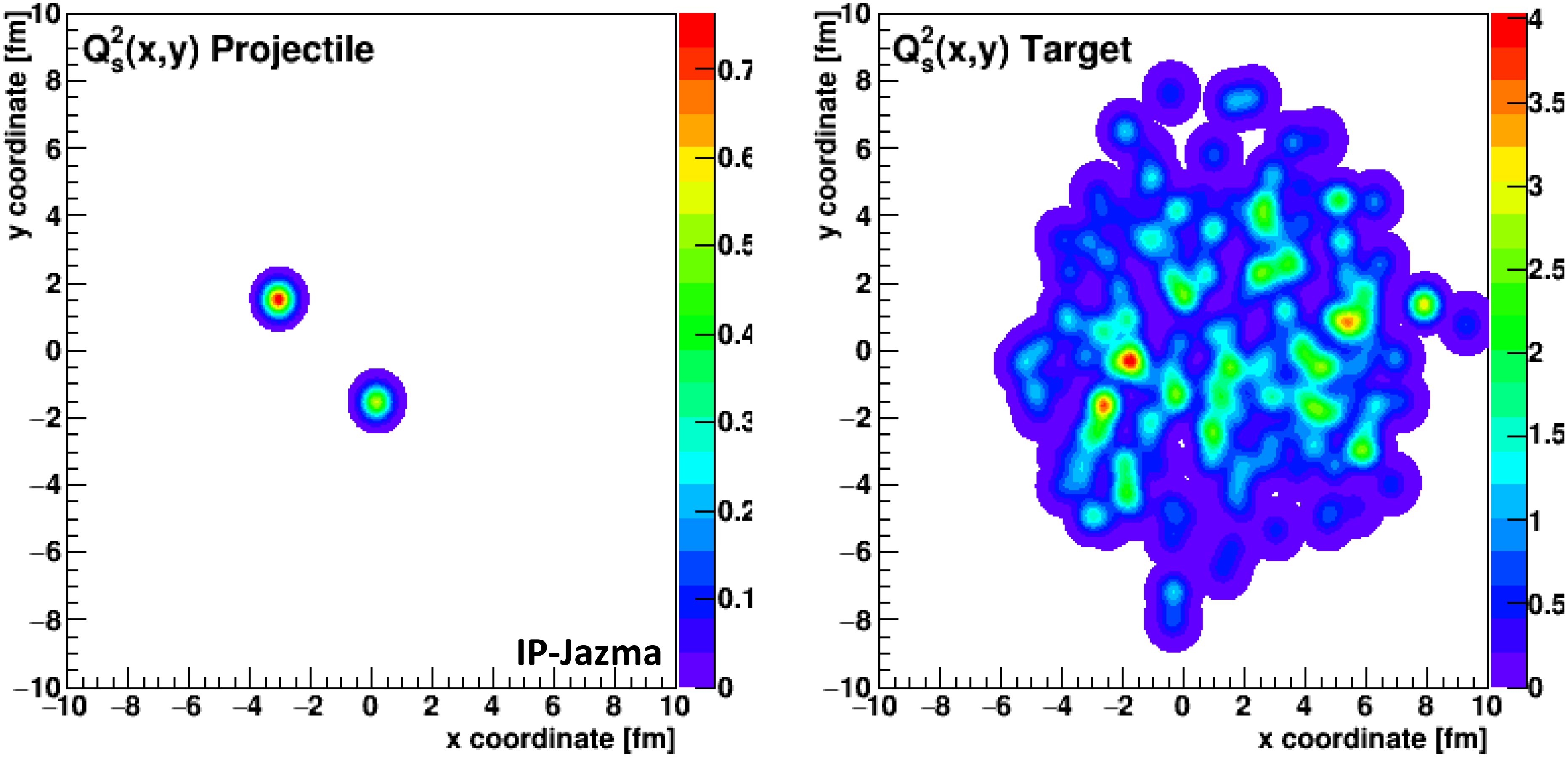
Originally proposed by McLerran (arXiv:1508.03292v2) to explain high multiplicity tail of LHC p+p N_{ch} distributions.

$Q_{s,0}^2$ fluctuates to 5-6 times average value to explain the high N_{ch} tail.



* It is a mistake to assume such matching confirms dynamical fluctuations, instead of from hadronization effects, finite rapidity window, experiment acceptance, etc.

deuteron + gold



Sum all the Q_s^2 contributions for each nucleus.

Example - nucleons from deuteron as perfect Gaussians from IP-Sat just with different amplitudes from $Q_{s,0}^2$ fluctuations.

At this point, none of these fluctuations are *ab initio*. All from MC Glauber and put-in-by-hand $Q_{s,0}^2$ fluctuations.

Integrating over Lattice Fluctuations

Romatschke & Romatschke (arXiv:1712.05815) found that integrating over these color fluctuations in IP-Glasma (some are lattice artifacts anyway) one obtains the energy density:

$\varepsilon \propto g^2 Q_s^2(\text{proj}) \times Q_s^2(\text{targ})$ (dense-dense limit)

IP-Jazma is thus averaging over these lattice site fluctuations, and then assumes N_{gluon} proportional to energy density.

N.B. IP-Glasma always in the dense-dense limit, including to obtain initial conditions for p+Au, d+Au, ^{3}He+Au, p+Pb (e.g. arXiv:1407.7557v1).

Dilute-Dense Framework

In the MSTV paper, they utilize the dilute-dense framework (hep-ph/0402256, hep-ph/0402257, arXiv:0711.3039)

The dilute-dense limit implies that $Q_s(\text{proj}) < k_T < Q_s(\text{targ})$ and one obtains on average:

$$\varepsilon \propto \; g^2 Q_s^2(\text{proj}) \times F(Q_s(\text{targ})/ m) \qquad \text{(dilute-dense limit)}$$

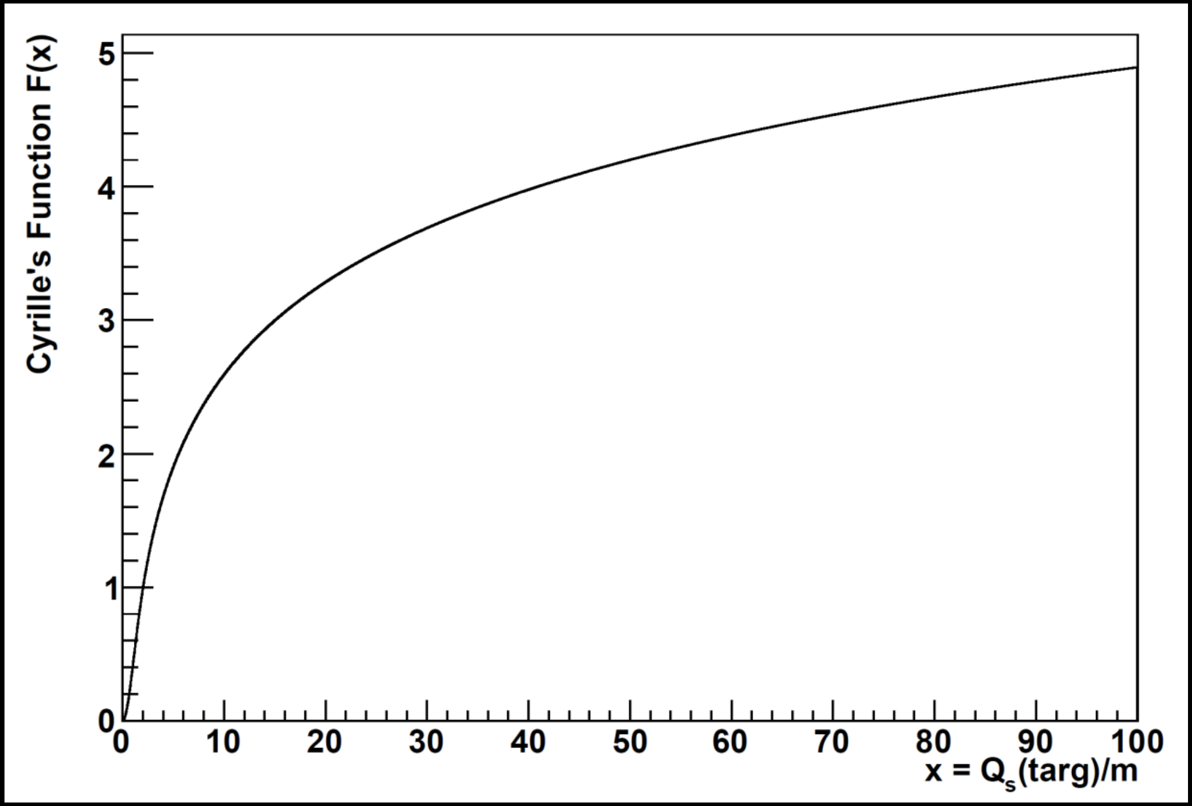
where m is the infrared cutoff (= 0.3 GeV in MSTV).

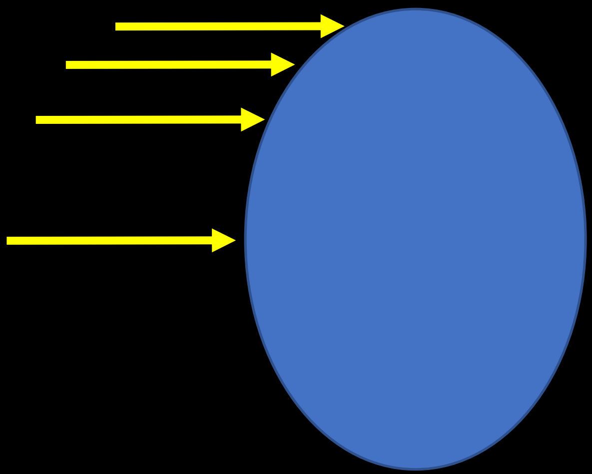
IP-Jazma Dilute-Dense

$\varepsilon \propto g^2 Q_s^2(\text{proj}) \times F(Q_s(\text{targ})/m))$ (dilute-dense limit)

Cyrille Marquet (thanks) sent me this function F.

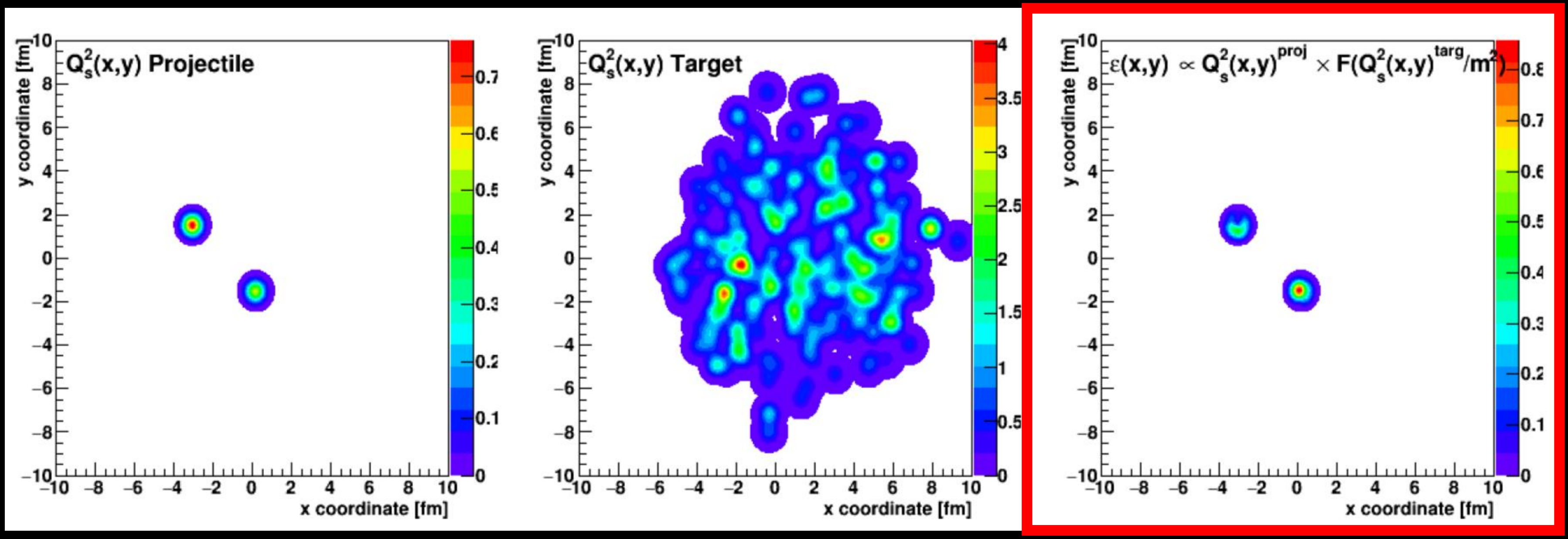
In the limit of large $Q_s(\text{targ})/m$, it scales as $\log(Q_s(\text{targ})/m)$.





Once you hit a thick enough part of the target, you free all the projectile gluons and no more.

IP-Jazma Results



Right panel shows the energy density distribution for this event in the dilute-dense limit

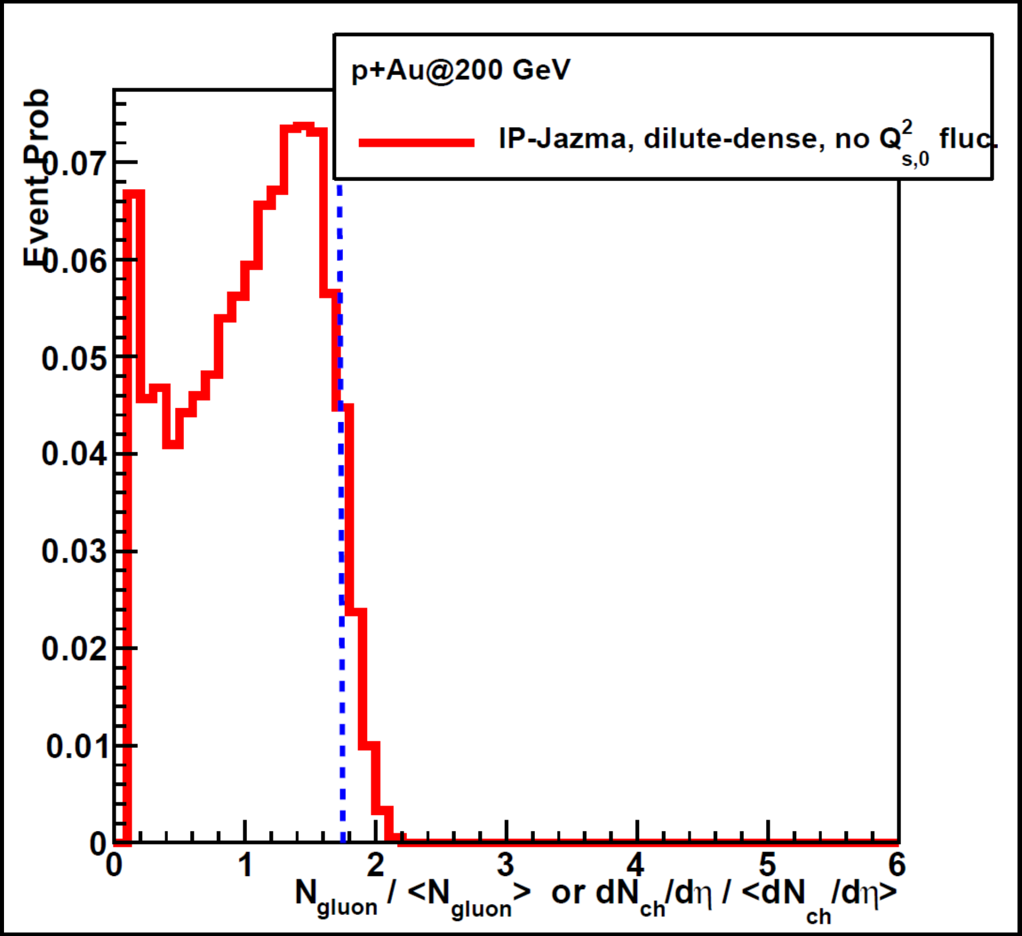
$\varepsilon \propto g^2 Q_s^2(\text{proj}) \times F(Q_s(\text{targ})/m)$ (dilute-dense limit)

There are no sharp spikes in the energy density as often highlighted with IP-Glasma because there are no lattice site color fluctuations – though these are in part artifacts in IP-Glasma.

p+Au @ 200 GeV

Settings: Dilute-Dense, no $Q_{s,0}{}^2$ fluctuations,

no running α_s, r_{max} = 3.0 σ [leave these last two the same]



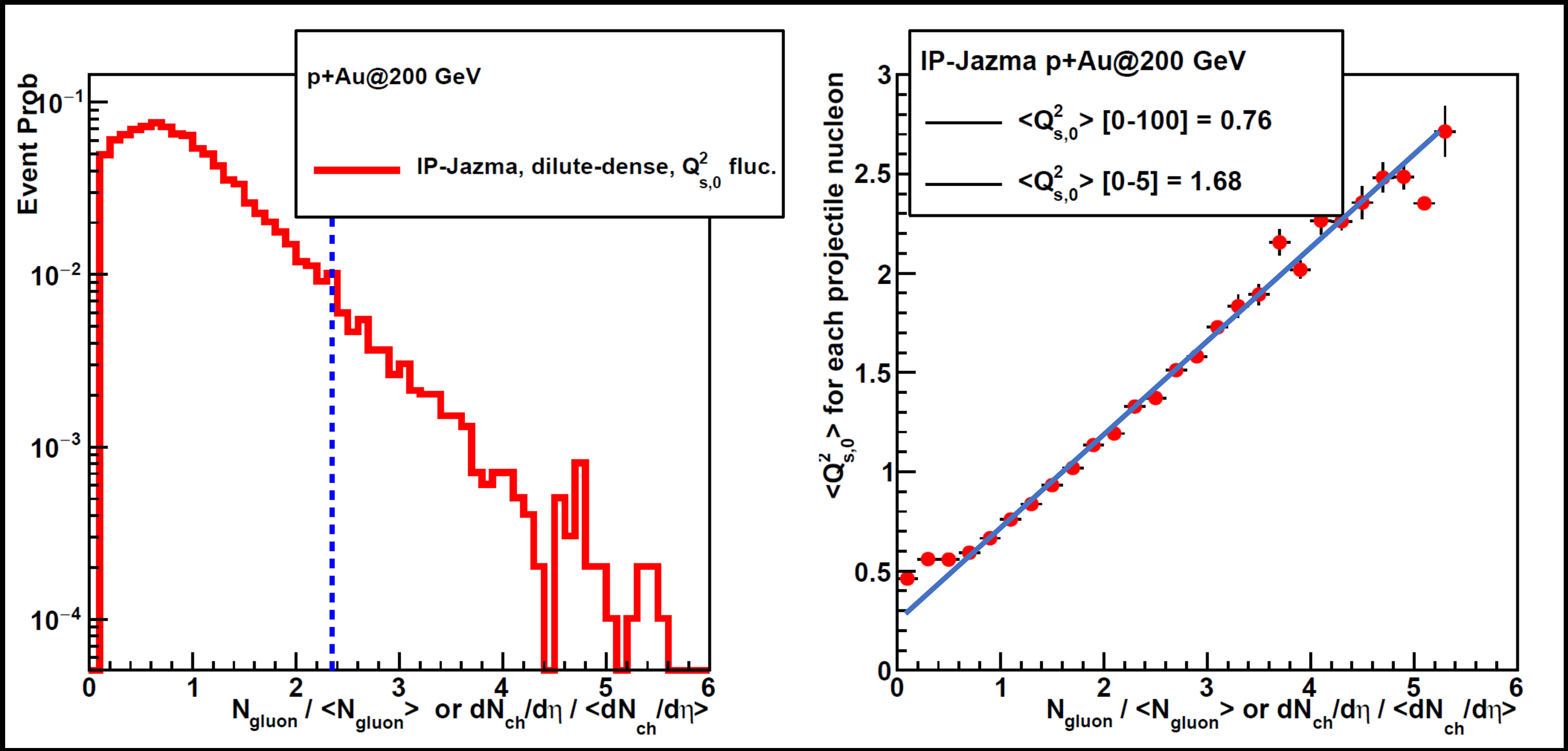
Distribution of number of gluons ($N_g/<N_g>$)

Makes intuitive sense…

Once the proton is hitting the mid-region of the target nucleus the gluon production hits the limit -- i.e. one has freed all the gluons from the projectile proton

p+Au @ 200 GeV

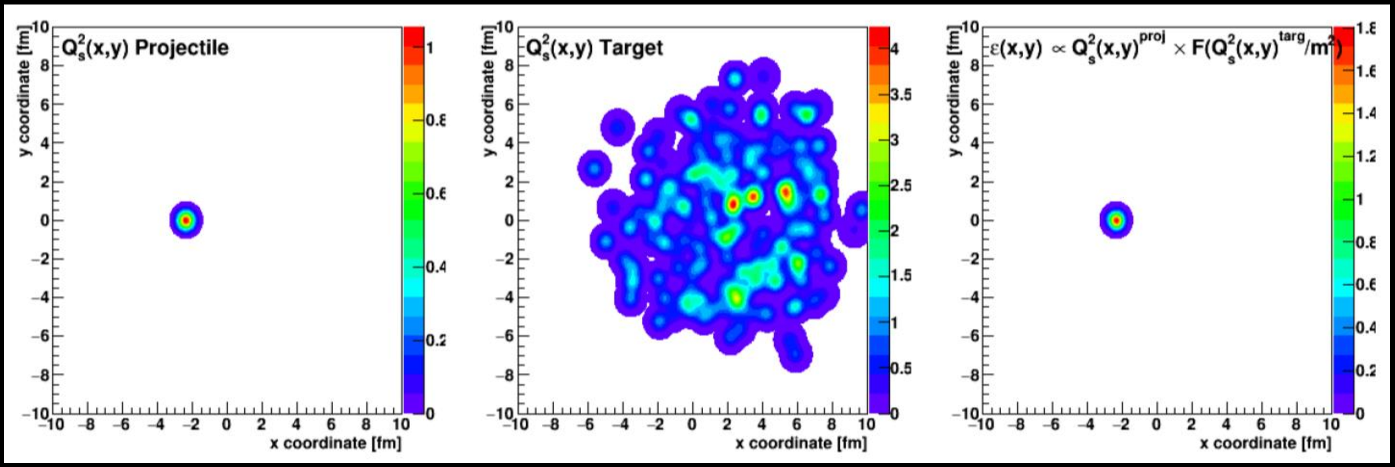
Settings: Dilute-Dense, yes $Q_{s,0}{}^2$ fluctuations



In the Monte Carlo, keep track of the $Q_{s,0}{}^2$ thrown for each projectile nucleon.

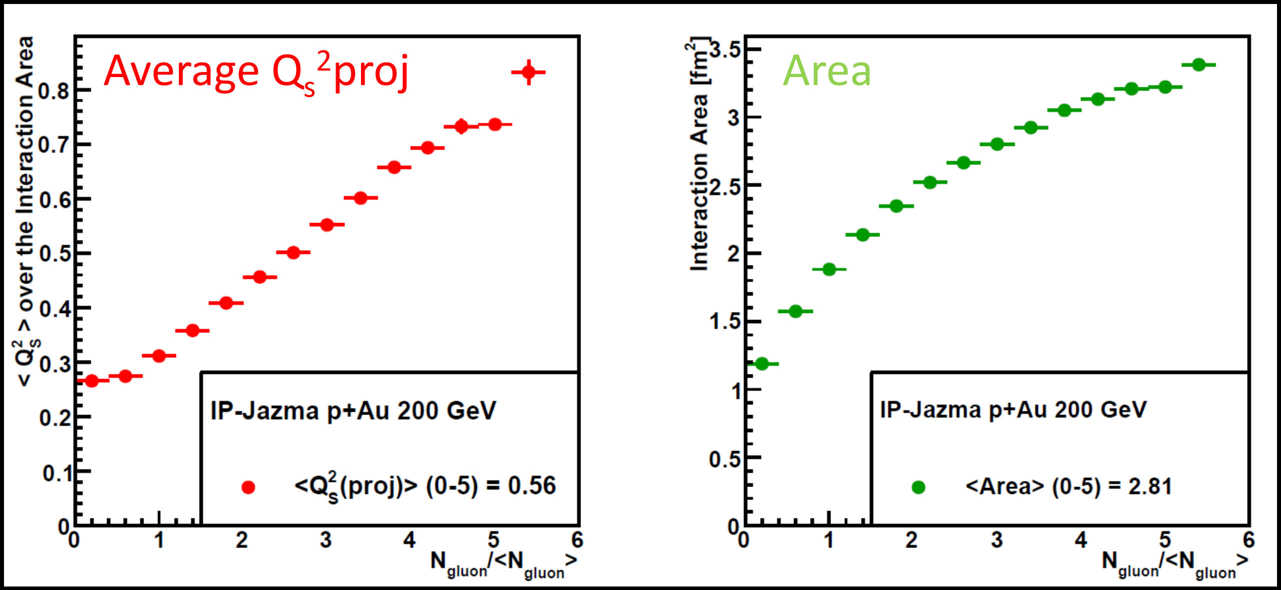
As expected, there is an almost linear increase in gluon number with $Q_{s,0}{}^2$ in the projectile once one is hitting a thick enough part of the nucleus.
For 0-5% high-multiplicity, the value is 2.2 times higher than average.

p+Au @ 200 GeV
Settings: Dilute-Dense, yes $Q_{s,0}{}^2$ fluctuations



Define AREA by region where ε > minvalue

Calculate $Q_s{}^2(x,y)$ projectile averaged over the AREA

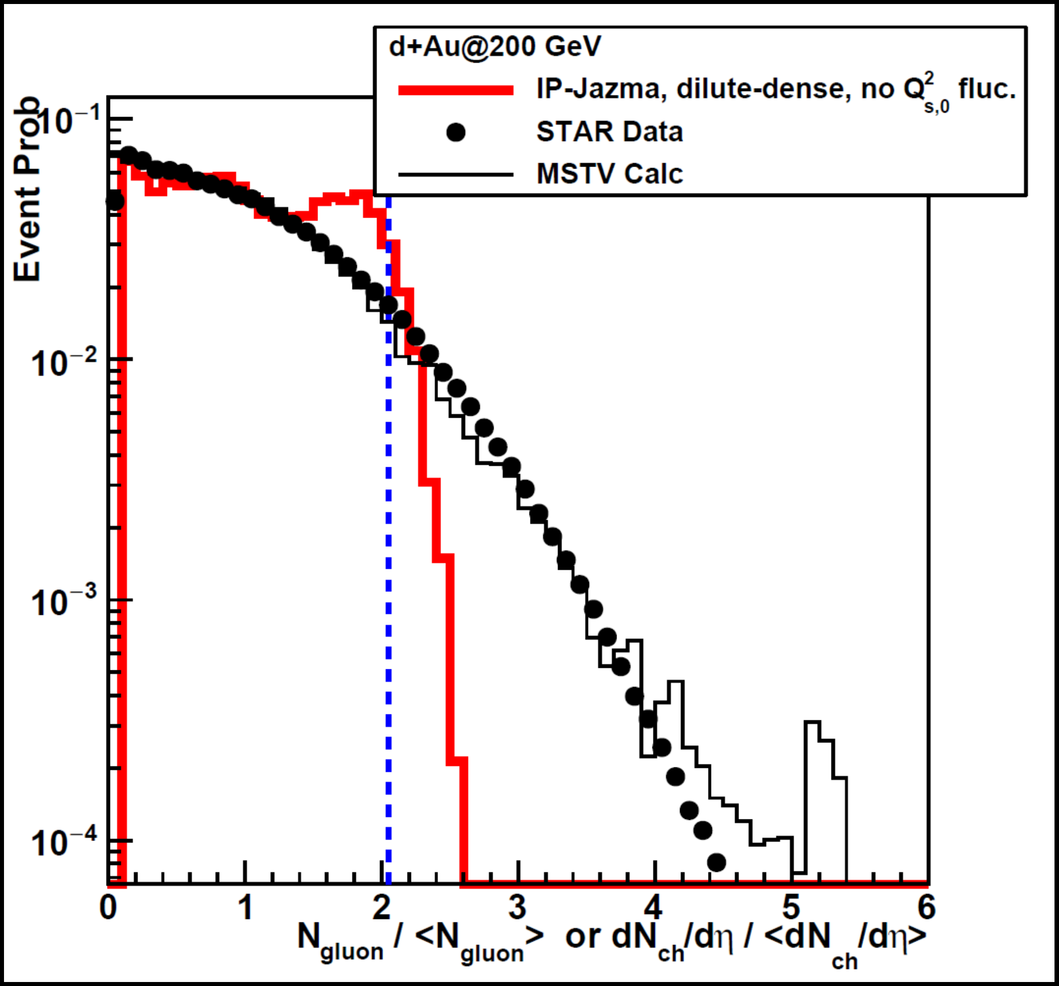


Higher multiplicity →

Larger Area

Larger saturation scale within that Area

d+Au @ 200 GeV
Settings: Dilute-Dense, no $Q_{s,0}^{2}$ fluctuations

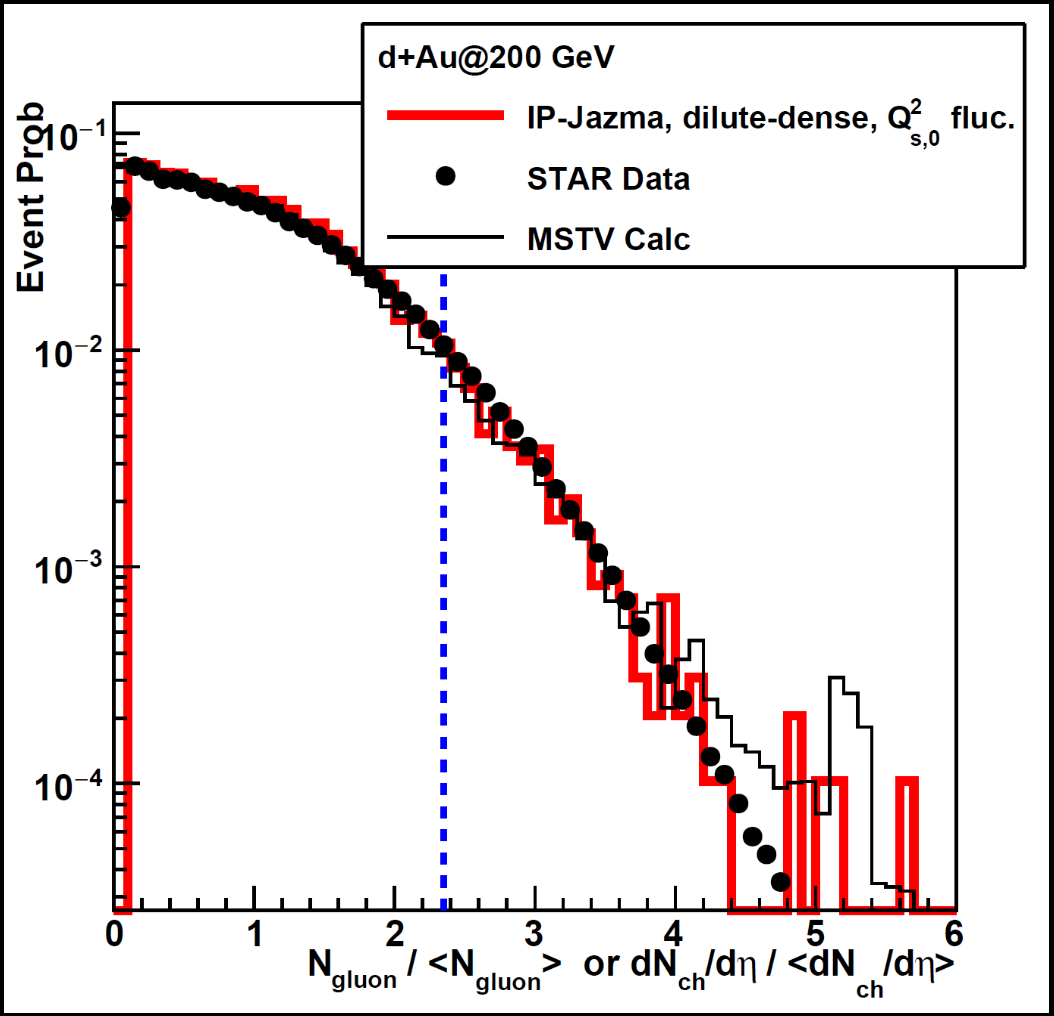


Similar feature as in p+Au case with no Q_{s0}^{2} fluctuations.

One hits the limit of freeing gluons from the projectile, proton and neutron in the deuteron

Broader than p+Au due to more possible geometry variations

d+Au @ 200 GeV
Settings: Dilute-Dense, yes $Q_{s,0}{}^2$ fluctuations

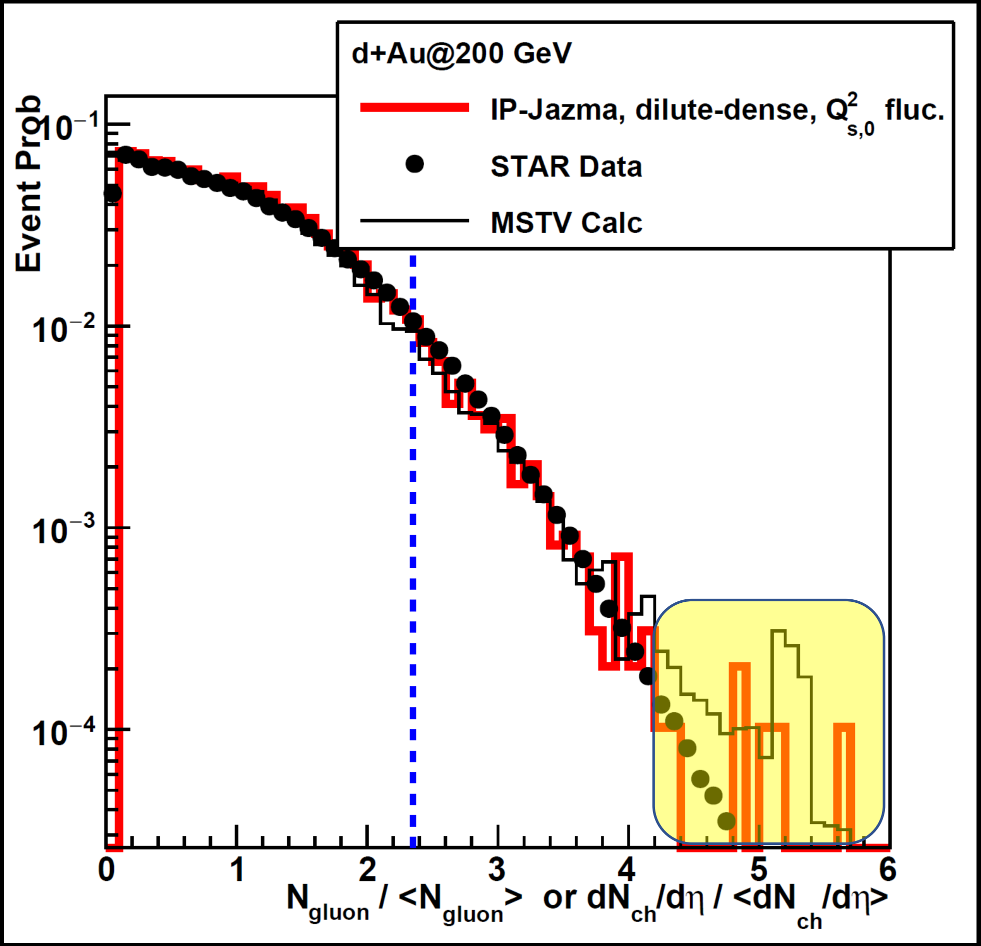


Agreement with STAR data and MSTV calculation.

Common with MSTV we have MCGlauber fluctuations, IP-Sat $Q_{s,0}{}^2$ fluctuations.

The additional color fluctuations in MSTV do not appear to be evident as dominant features in this particular comparison.

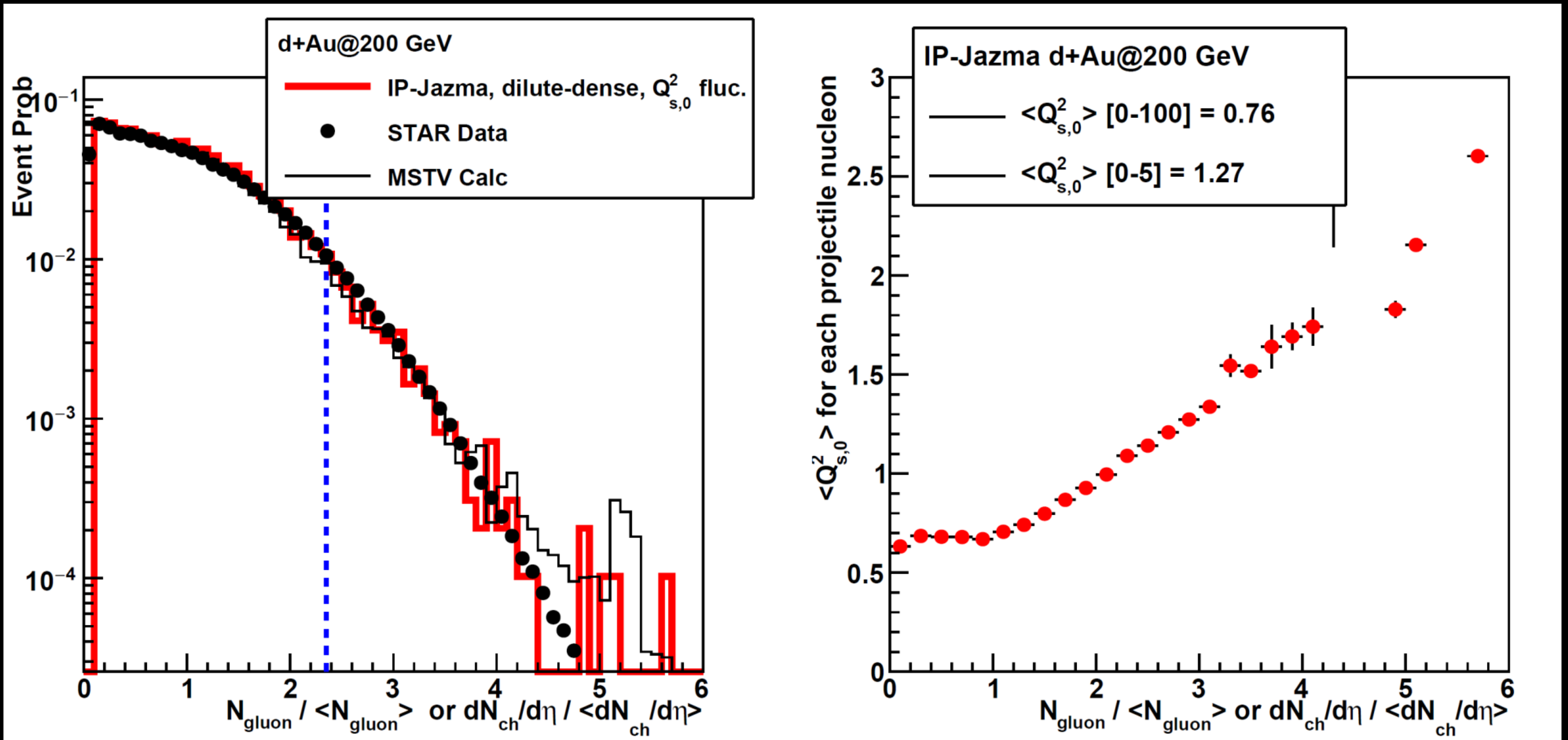
Ponder this figure. All the discussion of YM solutions, color fluctuations, CGC natural derivation of NBD, and IP-Jazma reproduced Prob(N_{gluon}) without any of this…



The only difference is at $N_g/\langle N_g\rangle$ > 4.2 where the MSTV calculation diverges from the data (less than 0.5% highest multiplicity)

d+Au @ 200 GeV

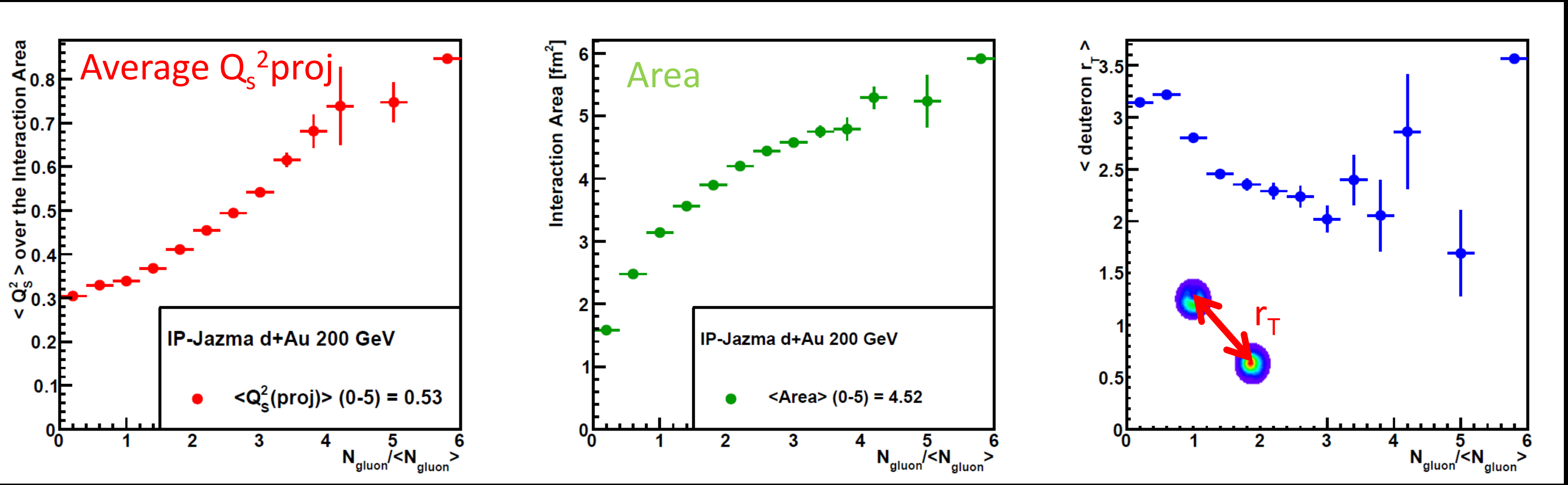
Settings: Dilute-Dense, yes $Q_{s,0}{}^2$ fluctuations



As expected there is a correlation of higher multiplicity events with larger $Q_{s,0}{}^2$ fluctuations.

Not as large an effect as in p+Au because the deuteron nucleons fluctuate separately.

d+Au @ 200 GeV
Settings: Dilute-Dense, yes $Q_{s,0}^2$ fluctuations



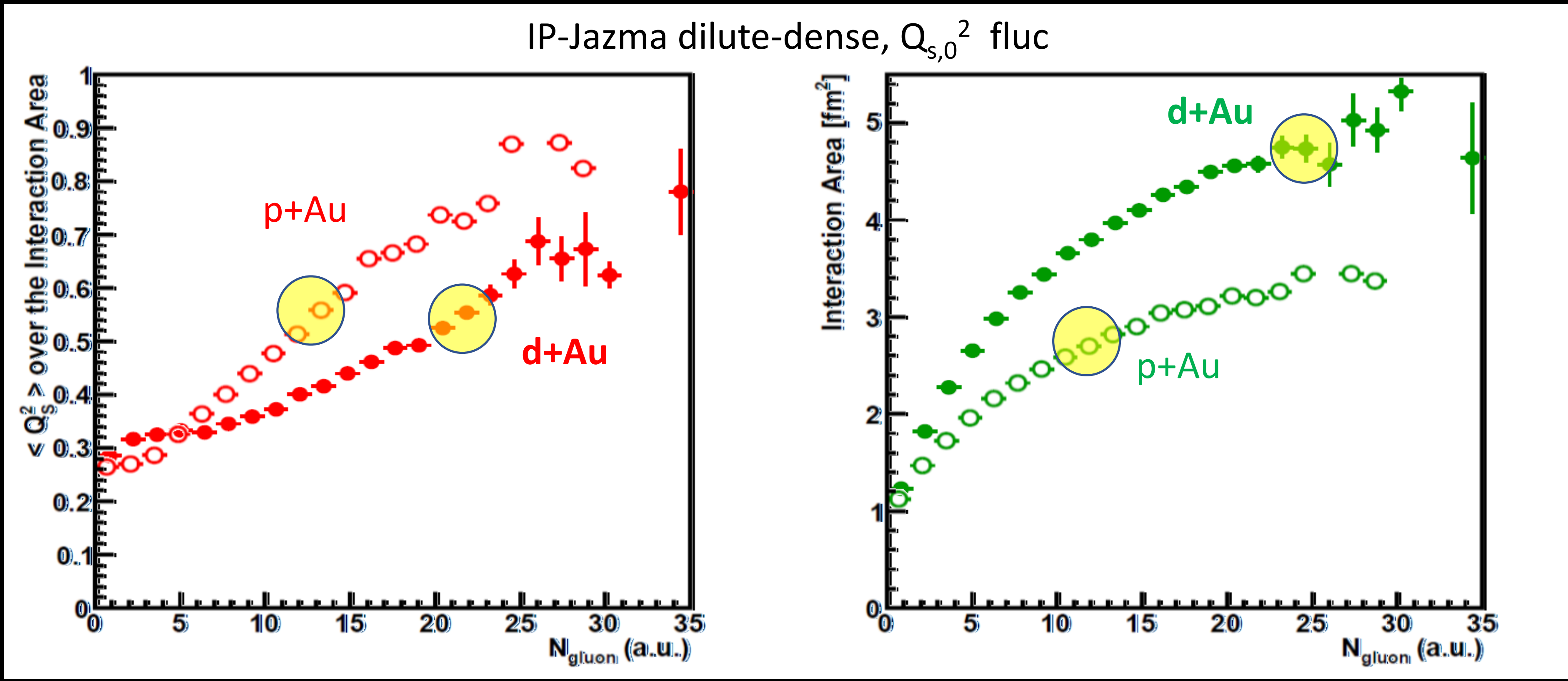
0-5%	p+Au	d+Au
Area (fm^2)	2.81	4.52
< Q_s^2 > proj	0.56	0.53

In IP-Jazma, dilute-dense, $Q_{s,0}^2$ fluc.
in 0-5% central events
N_g(d+Au)/N_g(p+Au) ~ 1.5

The area ratio ~ 4.52/2.81 = 1.6
while < Q_s^2 >proj is the same.

* Also deuteron n-p mean transverse separation remains > 2 fm.

“In the dilute-dense framework, the multiplicity of an event scales with Q_s^2 projectile.
Thus for 0-5% centralities, Q_s^2 (deuteron) > Q_s^2 (proton).” [MSTV]

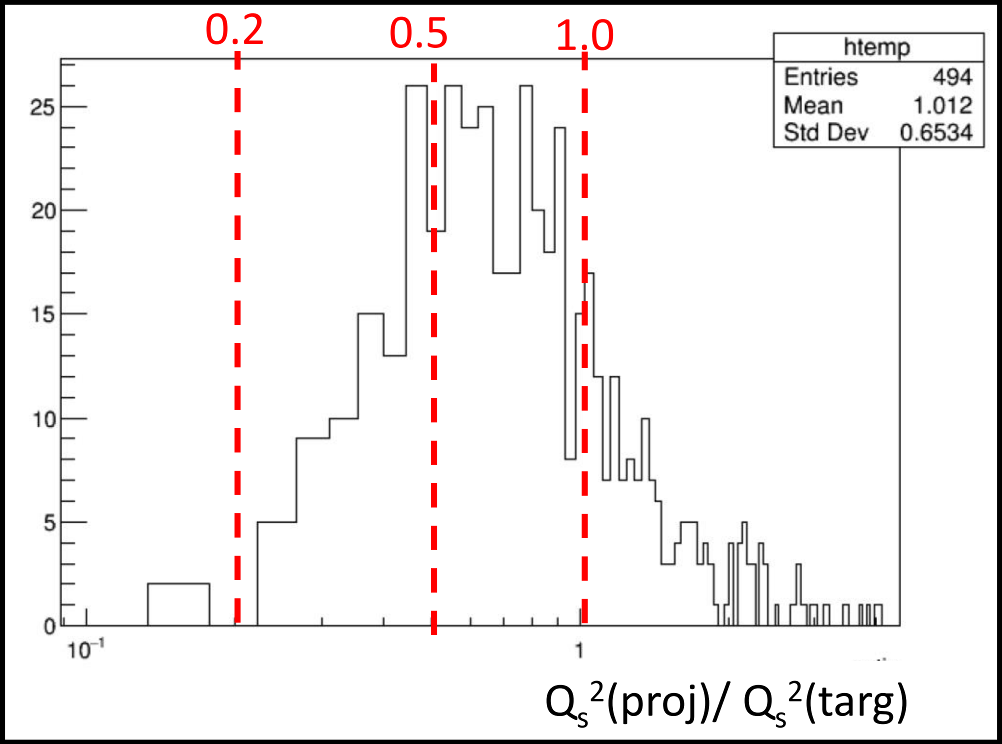


Circles are in the mid-range of 0-5% central…

Above “parametric” relation is just not true in IP-Jazma.
I am not sure how this can be true in the full MSTV, and it is essential to their result since v_2 is directly related to Q_s.

Dilute-Dense?

How valid is the dilute-dense limit when we effectively select on events that are larger fluctuations in the projectile saturation scale?



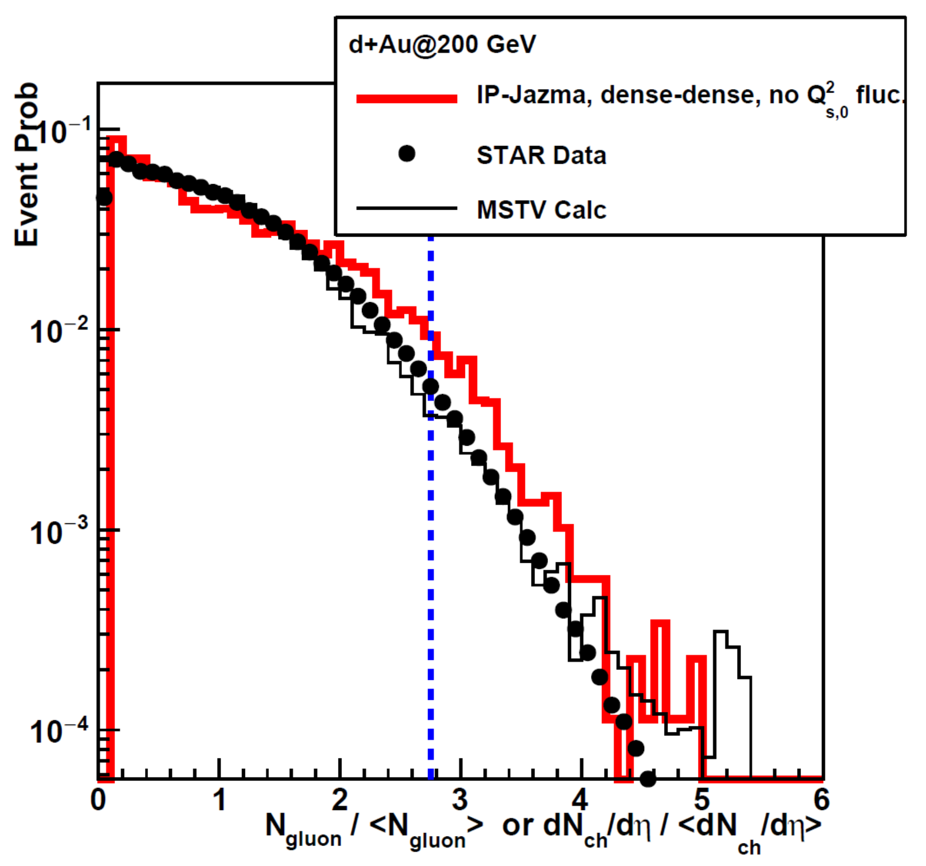
d+Au 0-5% high mult. events

Ratio Q_s^2 (proj) / Q_s^2(targ) weighted by the gluon contribution in that lattice cell (dilute-dense)

Naively might have thought ratio ~ 1 / $A^{1/3}$ ~ 0.2, but here we are selecting out fluctuations and cells with highest Q_s^2 (projectile).

d+Au @ 200 GeV

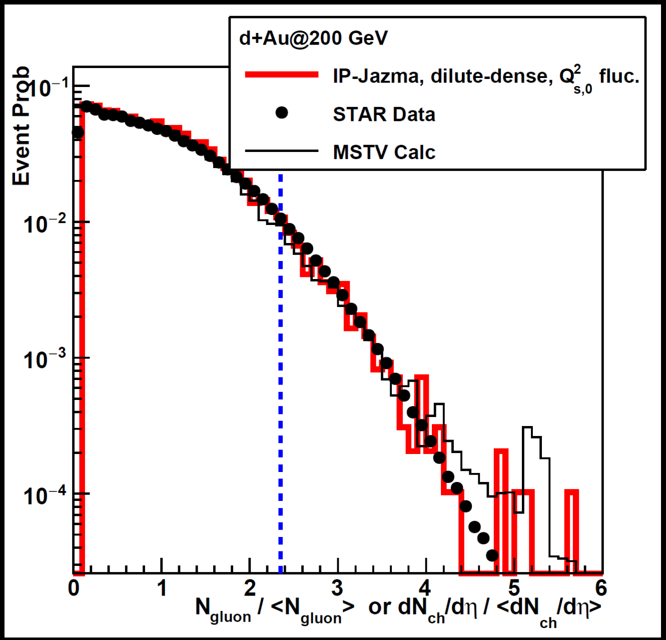
Settings: Dense-Dense, no $Q_{s,0}{}^2$ fluctuations



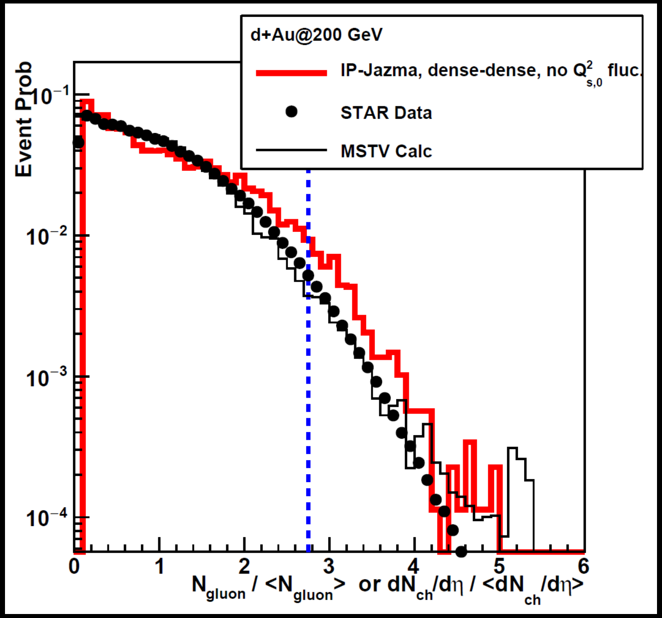
We also obtain a reasonable (slightly worse) description of the data. Modest adjustment of IP-Sat σ would allow better tuning.

N.B. No correlation between $Q_{s,0}{}^2$ projectile and gluon multiplicity.

IP-Jazma (dilute-dense, Q fluc)



IP-Jazma (dense-dense, no Q fluc)



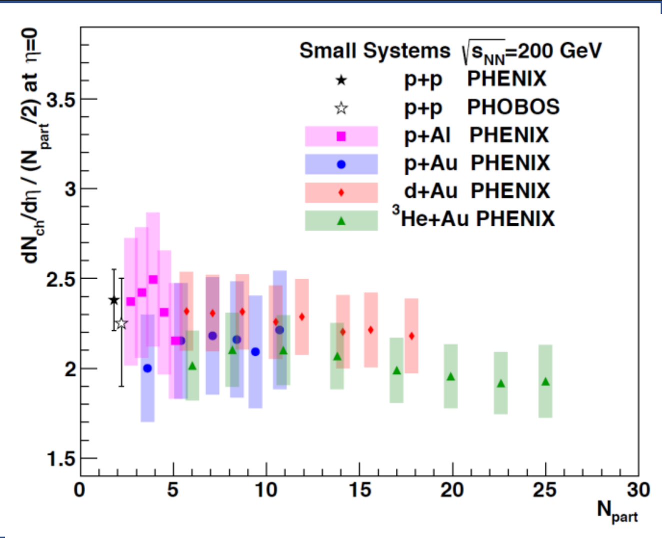
One obtains similar agreement in

(1) a picture assuming large fluctuations in the projectile saturation scale

(2) a picture with a fixed projectile and an increasingly thick nuclear target

Of course the v_2 glasma correlations implied are completely different in the two scenarios

Scenario (2) is just called wounded nucleon scaling



Let the Buyer Beware

IP-Glasma

In Fig. 1 we show the event-by-event fluctuation in the initial energy per unit rapidity. The mean was adjusted to reproduce particle multiplicities after hydrodynamic evolution. This and all following results are for Au+Au collisions at RHIC energies ($\sqrt{s} = 200\,A\,\text{GeV}$) at midrapidity. 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].

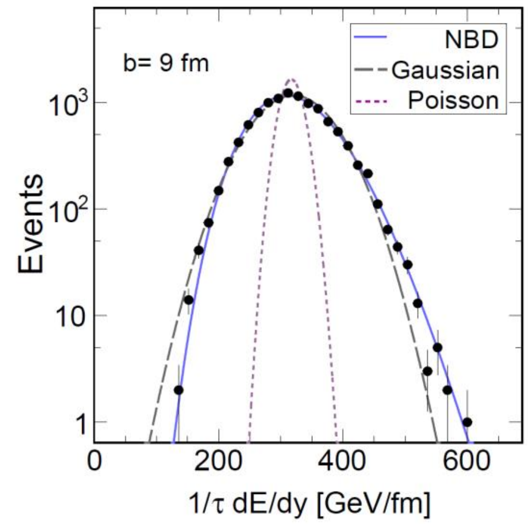
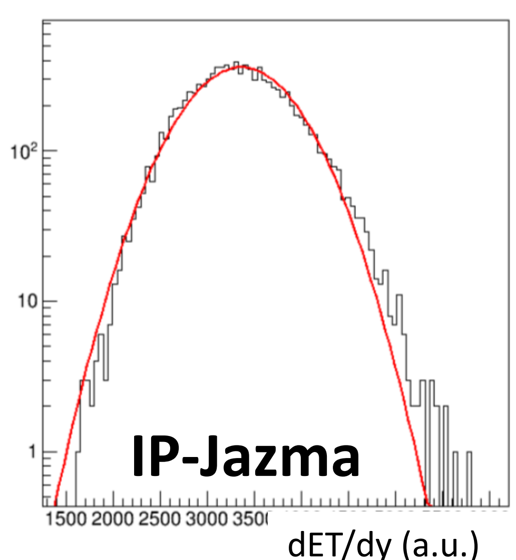


FIG. 1. The IP-Glasma event-by-event distribution in energy for $b = 9$ fm on the lattice compared to different functional forms. The negative binomial distribution (NBD) gives the best fit.

https://arxiv.org/abs/1202.6646v2



IP-Jazma calculation for Au+Au b=9 fm events in dense-dense limit, no $Q_{s,0}^2$ fluctuation,.

Note the gluon distribution is not Gaussian (red line) and has a high side skew (Γ dist.). Nothing to do with Glasma flux tubes.

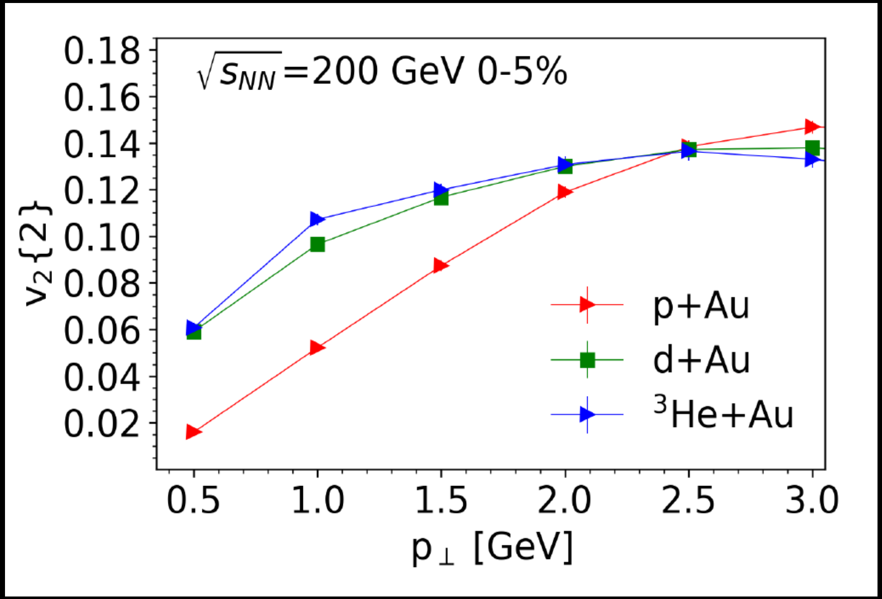
Where do the checks stand?

We are unable to reproduce MSTV explanation of ordering.

Need to have a complete set of comparison figures with the full MSTV calculation to resolve.

Publicly available code?

IP-Jazma with v_2/v_3 calculation?



Length scale of aligned color fields? Color confinement?

Saturation physics in RHIC proton?

Do these large Q_s fluctuations make sense?

Dilute-dense means $Q_s(\text{proj}) < k_T < Q_s(\text{targ})$

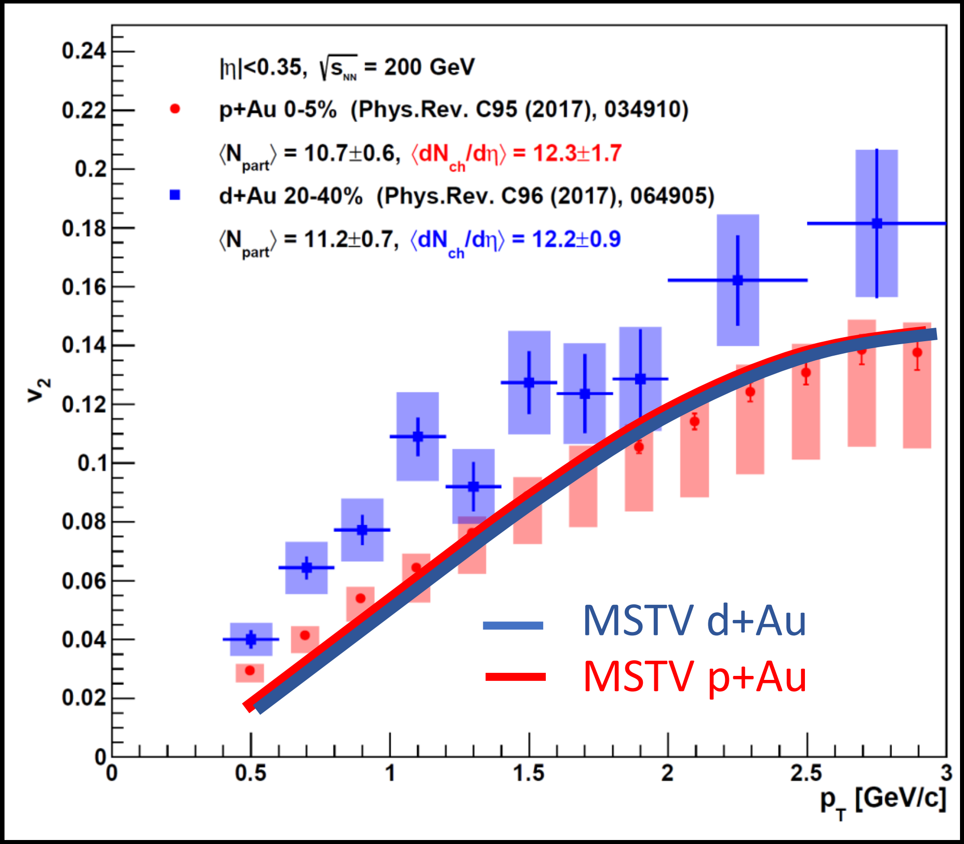
Target gluon "seeing" a single domain for $k_T < Q_s(\text{proj})$

All k_T values need strict definition and numbers in all cases

One thing is clear...

Our prediction would therefore be that $v_{2,3}(p_\perp)$ for high multiplicity events across small systems should be identical for the same $N_{\rm ch}$.

MSTV prediction that turns out to be another postdiction...



Existing PHENIX measurement already rules this out!

Summary (So Far)

Exciting times for studying small system collectivity

Completion of experimental geometry scan at RHIC

Best agreement via hydrodynamics with QGP stage

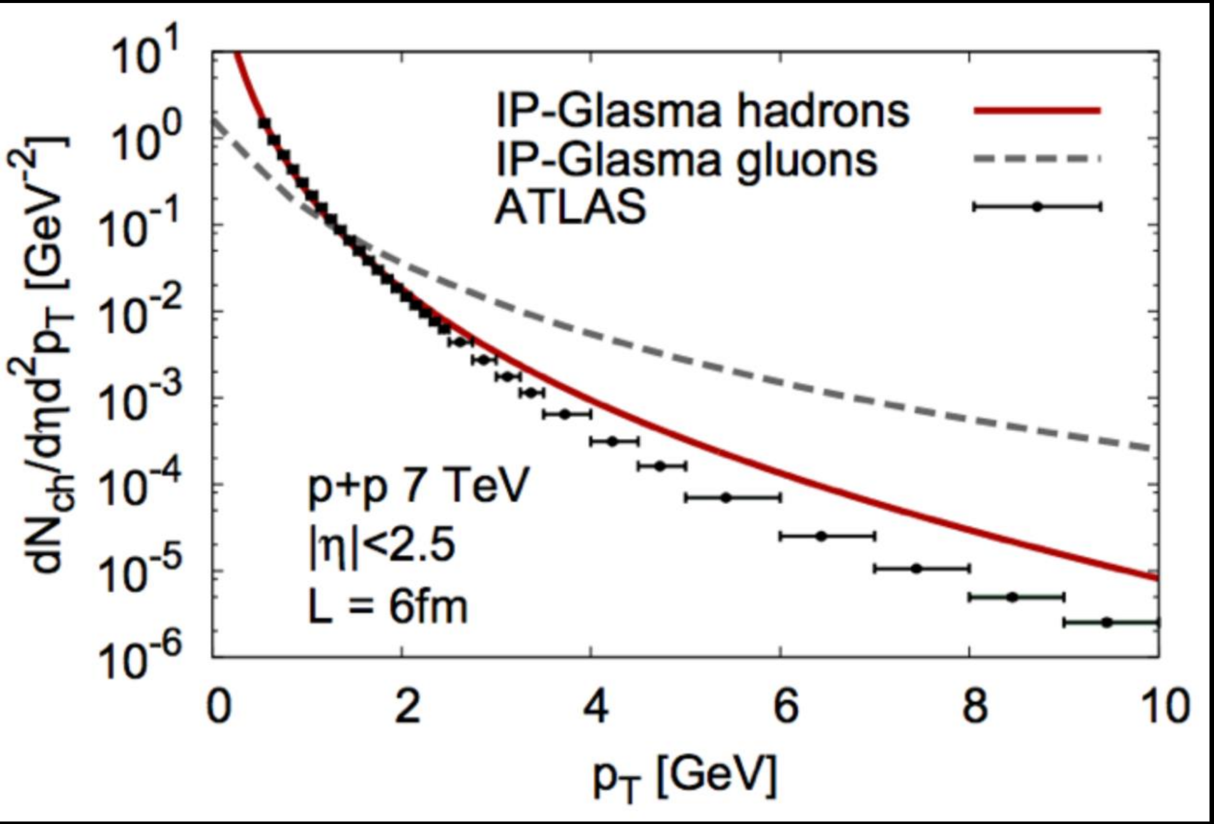
All theory approaches deserve full scrutiny

IP-Jazma new tool for identifying the dominant source of fluctuations in the saturation physics framework

Further work to resolve differences in explanations with MSTV result

Extras

In previous IP-Glasma papers (e.g. arXiv:1311.3636) they point out the huge difference between gluons and hadrons.



Why is this effect ignored in the MSTV paper?

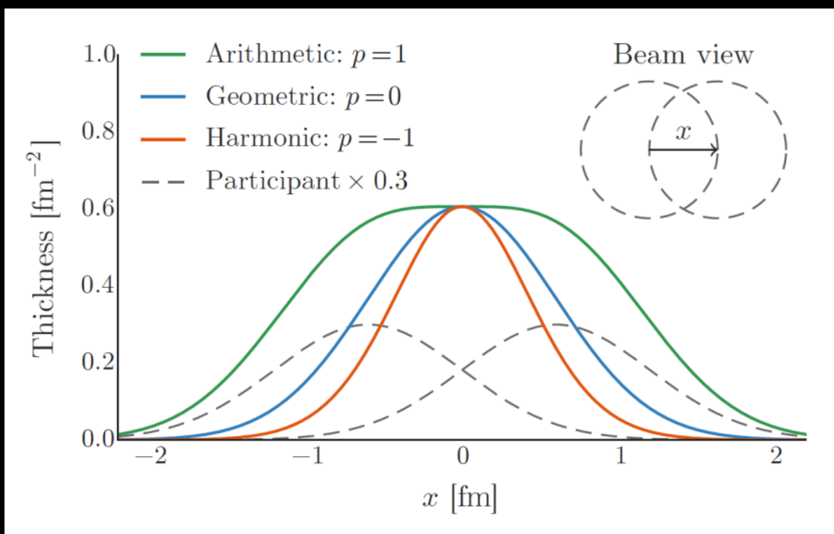
It would be good to compare the MSTV gluon p_T distribution with the published hadron p_T distribution.

Trento Comment… arXiv:1412.4708v2

Alternative ansatz to wounded nucleon and binary collision scaling in high-energy nuclear collisions

J. Scott Moreland, Jonah E. Bernhard, and Steffen A. Bass
Department of Physics, Duke University, Durham, NC 27708-0305
(Dated: June 9, 2015)

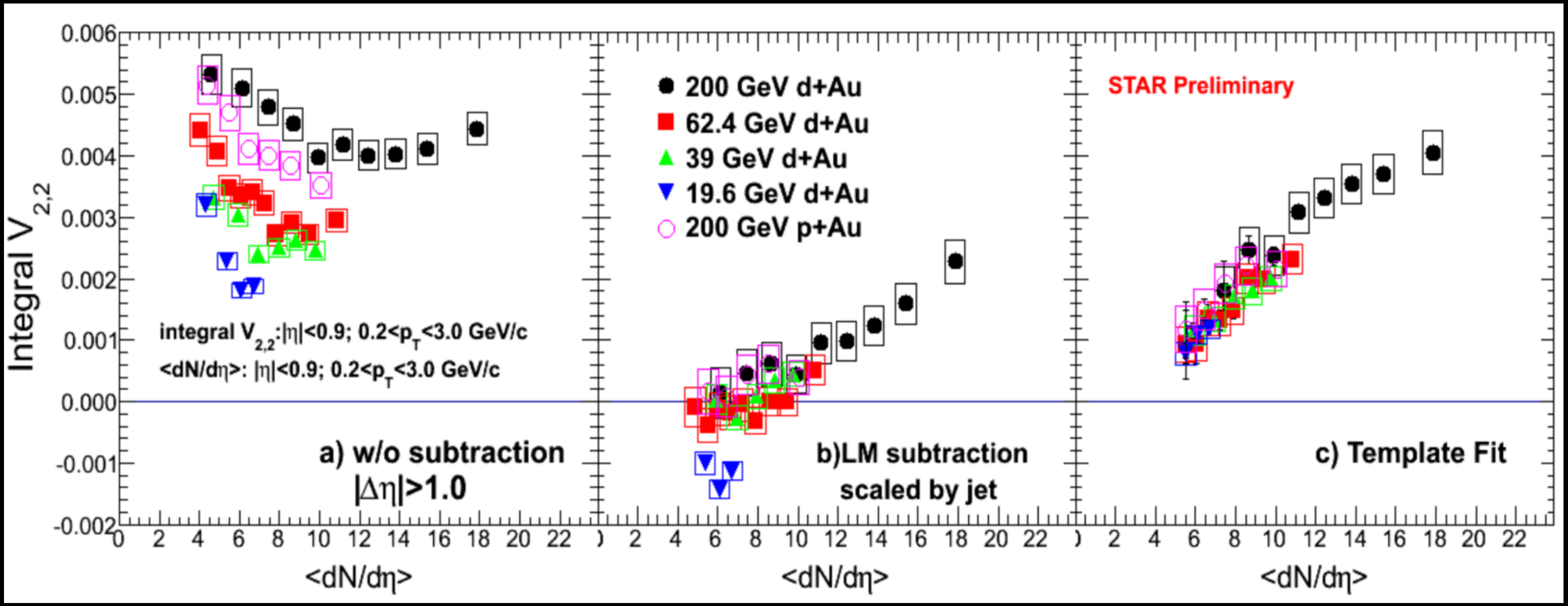
We introduce TRENTo, a new parametric initial condition model for high-energy nuclear collisions based on eikonal entropy deposition via a "reduced thickness" function. The model simultaneously describes experimental proton-proton, proton-nucleus, and nucleus-nucleus multiplicity distributions, and generates nucleus-nucleus eccentricity harmonics consistent with experimental flow constraints. In addition, the model is compatible with ultra-central uranium-uranium data unlike existing models that include binary collision terms.



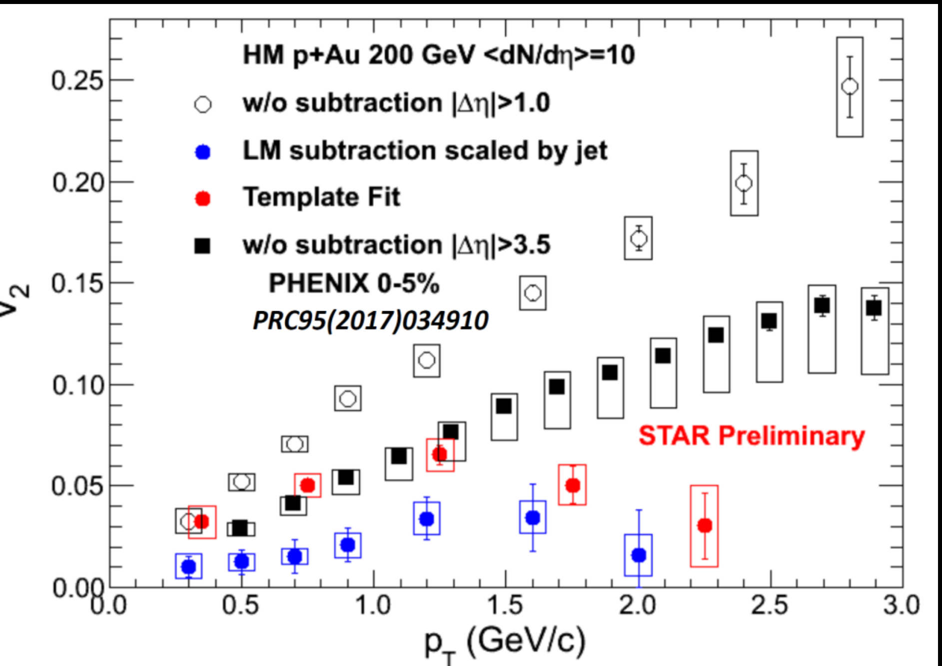
$$T_R = \begin{cases} \max(T_A, T_B) & p \to +\infty, \\ (T_A + T_B)/2 & p = +1, \ \text{(arithmetic)} \\ \sqrt{T_A T_B} & p = 0, \quad \text{(geometric)} \\ 2\,T_A T_B/(T_A + T_B) & p = -1, \ \text{(harmonic)} \\ \min(T_A, T_B) & p \to -\infty. \end{cases}$$

Trento p=0 is like Ncoll scaling with an impact parameter dependence for N-N collisions. Thus, with the right parameters, quite comparable to IP-Glasma, IP-Jazma (dense-dense)

STAR Preliminary results shown at QM 2018



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



Due to a small Δη gap, they have a huge non-flow contribution (even at low p_T).

That is why they are so sensitive to the non-flow subtraction.

PHENIX results checked with Δη gap of 3 units and in systematic uncertainties.

Romatschke & Romatschke (https://arxiv.org/abs/1712.05815)

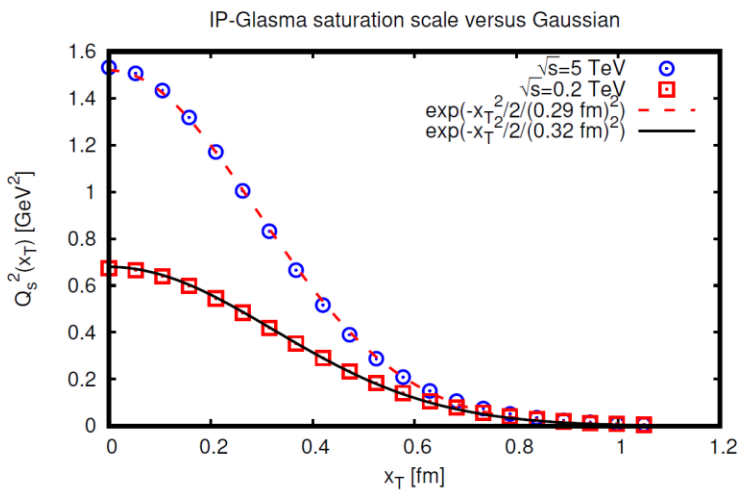


Figure 4.5: Transverse coordinate dependence of the saturation scale in the IP-Glasma model from Eq. (4.35) for two representative center-of-mass collision energies $\sqrt{s}$. For comparison, a simple Gaussian parametrization is shown.

$$Q_s^2(x, \mathbf{x}_\perp) = \frac{\pi}{3R^2}\alpha_s\left(Q_0^2 + 2Q_s^2\right) f\left(x, Q_0^2 + 2Q_s^2\right) e^{-\frac{\mathbf{x}_\perp^2}{2R^2}}, \quad (4.35)$$

At RHIC energies, resulting Gaussian in Q_s^2 has σ = 0.32 fm. Note that this corresponds to a Gaussian in Q_s with σ = 0.45 fm.

Of course this depends on your choice of B_G, translating into R in the equation below.

$$\chi_A(\mathbf{x}_\perp) \propto \sum_{i=1}^{A} Q_s^2(x, \mathbf{x}_\perp^{(i)}),$$

In dense-dense limit, just sum Q_s^2 values for each nucleus. Then energy density proportional to T_{A1A2} scaling

as defined in (4.7). The final result for the energy density in the weak-coupling approximation then reads

$$\langle T^{\tau\tau}\rangle_{\mathrm{cf}} \propto g^2 T_{A_1}(\mathbf{x}_\perp) T_{A_2}(\mathbf{x}_\perp + \mathbf{b}_\perp) + \mathcal{O}(\tau^2). \quad (4.44)$$

Different Parameters

Qs^2 fluctuations, 0.5 variance in log(Qs^2). 0.5 is said to be fit to the d+Au Nch distribution, but it happens to be identical to the value for LHC p+p from an earlier paper.

R in IP-Sat based on B_G value, nominally constrained by HERA data

Infrared cutoff m = 0.3 GeV seems large. Previous paper had systematics with 0.1-0.2 GeV

Rmax on IP-Sat – how far to carry the Gaussian tails out…
In the IP-Jazzma calculation we extend the Gaussian out 3.0 sigma.
In IP-Glasma, communication with the authors indicates that this is often extended to 10 fm (!) and this can make a difference in epsilon_3 values and other epsilon_n values in ultra-central A+A where fluctuations dominate.

-- side note, the HERA constraint on IP=Sat must only constrain something like a couple of moments and not the tail of the distribution (this is unconstrained). Similarly, 3-quark configurations have a HERA constraint on parameters, but the 3-quark part is just an ansatz (totally unconstrained).

Evaluating running of alpha_s (g^2). Some IP-Glasma papers do this at the scale max(Qsproj, Qstarg). This can have a major impact on the spatial distribution…

MSTV paper says:

Another important element in understanding the systematics of the data is that 0-5% centrality in ^{3}He+Au collisions corresponds to a significantly higher value of $N_{\rm ch}$ than for p+Au collisions. In the dilute-dense framework, the multiplicity of an event scales with $(Q_S^p)^2$ [29, 46]. Thus for 0-5% centralities, $Q_S^p|_{^3\rm He} > Q_S^p|_{\rm p}$. Hence, as long as $p_\perp < Q_S^p|_{^3\rm He}$, gluons in the target will coherently interact with $(Q_S^p|_{^3\rm He})^2/p_\perp^2$ domains, many more than in p+Au. As shown in simple color domain models [47, 48], the corresponding chromoelectric fields will generate larger anisotropies, but as the similar values of

0-5%	p+Au	d+Au
Area (fm^2)	2.81	4.52
$< Q_s^2 >$ proj	0.56	0.53

We do not find the effect they state between systems!

We find the rather intuitive result (more area).

MSTV basic mechanism for v_2

$$V_n(p_1,p_2) = \frac{\int_{p_1}^{p_2} k_\perp dk_\perp \frac{d\phi}{2\pi} e^{in\phi} \frac{dN(\mathbf{k}_\perp)}{d^2k dy}\Big[\rho_p,\rho_t\Big]}{\int_{p_1}^{p_2} k_\perp dk_\perp \frac{d\phi}{2\pi} \frac{dN(\mathbf{k}_\perp)}{d^2k dy}\Big[\rho_p,\rho_t\Big]}, \quad (5)$$

46]. Thus for 0-5% centralities, $Q_S^p|_{^3\mathrm{He}} > Q_S^p|_{\mathrm{p}}$. Hence, as long as $p_\perp < Q_S^p|_{^3\mathrm{He}}$, gluons in the target will coherently interact with $(Q_S^p|_{^3\mathrm{He}})^2/p_\perp^2$ domains, many more than in p+Au. As shown in simple color domain models [47, 48], the corresponding chromoelectric fields will generate larger anisotropies, but as the similar values of $v_2(p_\perp)$ between d+Au and ^{3}He+Au in Fig. 3 indicates, $v_2(p_\perp)$ will saturate at large N_{ch}. Because v_3 is due to a

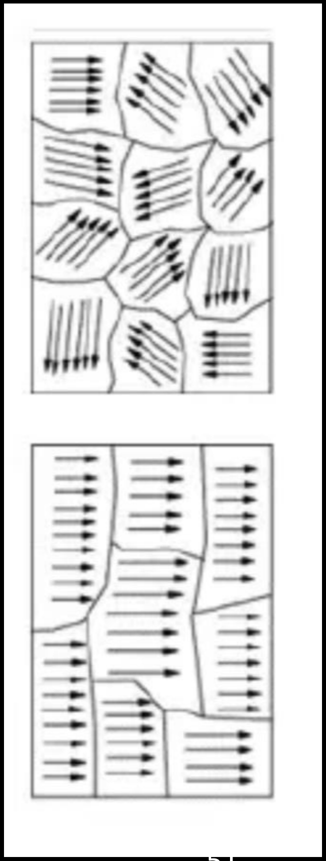
"gluons in the target will coherently interact with $(Q_s^{proj}/k_T)^2$ domains"

Think of ferromagnetic material.

If one scatters only from individual domains, more domains washes out the v_2 (all agree on that point).

If one scatters over all of them at once (individual domains not resolved), is it obvious why the effect is not still washed out?

Or is it a set of k_T kicks like a random walk and so more domains means a larger $\langle k_T \rangle$ from the walk?



Kurkela *et al.* (arXiv:1805.04081) comment

Kinetic transport applies if the mean free path is larger than the typical wave packet size of excitations, $l_{\rm mfp} > 1/T$. With $l_{\rm mfp} \approx \tau_\pi = 5\frac{\eta}{s}\frac{1}{T}$, this range of applicability extends to values $\eta/s \gtrsim 0.2$. First comparisons of transport models with experimental data give values $0.4 \lesssim \eta/s \lesssim 0.8$ [14, 15] which support the idea that kinetic transport is applicable. Therefore, the mesoscopic systems created in pp, pA and AA collisions are systems of significant mean free path.

Note that at $\eta/s = 0.2$, $\ell_{mfp} = 1/T$ (i.e. the typical wave packet size)

Thus, even at $\eta/s = 0.4$, $\ell_{mfp} \sim 2$ * typical wave packet size
(not much of a separation of scales)

Also, factors or 2 and π really matter here. Check the 1/T prefactors.