Collective
To Be or Not to Be Collective

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


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Parton Cascade (AMPT) in Small Systems

Azimuthal Anisotropy Relative to the Participant Plane from AMPT in Central $p+Au, d+Au$, and $^3He+Au$ Collisions at $\sqrt{s_{NN}} = 200$ GeV

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http://arxiv.org/abs/1501.06880

Useful inputs from Zi-Wei Lin and Denes Molnar
AMPT motivation, He et al. (arXiv:1502.05572v3)
Initial Momentum or Geometry Correlations

Initial State QCD Physics

Non-Geometry correlations directly in momentum space

![Image](image1.png)

Correlation $\sim \frac{1}{N_c Q_s^2 S_\perp}$

Important in small systems!

Not published...

$v_2(pAu) > v_2(d, ^3HeAu)$

Hydrodynamics is one model for final-state interactions

Published predictions

$v_2(^3HeAu) \sim v_2(dAu) > v_2(pAu)$
Glauber + Hydrodynamics + Cascade Predictions

Romatschke, Nagle et al., http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.113.112301
No Simple Eccentricity Scaling

$V_2/\xi_2$

$p+Au$ 200GeV 0-5%
$d+Au$ 200GeV 0-5%, PRL. 114, 192301
$^3He+Au$ 200GeV 0-5%, arXiv:1507.06273
SONIC $p+Au$
SONIC $d+Au$
SONIC $^3He+Au$
arXiv:1502.04745

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\text{SONIC $^3He+Au$}
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PHOENIX
preliminary

$V_2/\xi_2$

$p_T$ [GeV/c]
No Simple Eccentricity Scaling

$^3\text{He}/d+\text{Au}$ – some events hot spots never connect and so $\varepsilon_2 \rightarrow v_2$ translation incomplete
With larger $\eta/s$, one can match $^3\text{He}/d+\text{Au}$.

$p+A$ is because initial $\varepsilon_2$ is very small.
Possible solution is giving proton more substructure.
AMPT Predictions

Modified Initial Glauber including $^3$He wavefunction (same I.C. as SONIC)

String melting

Lots of partons

$\sigma = 1.5$ mb

Hadron Cascade

AMPT (same code) Cu+Au @ 200 GeV

PHENIX arXiv:1509.07784
AMPT Details

Central p+Au
55% of partons have zero scatters
Central p+Au @ 200 GeV

~ 200 partons
AMPT has all (anti)quarks
m < 30 MeV/c²
and zero gluons!

Scatters = 0
Scatters = 1
Scaters >=2

~ 45 parton-parton scatterings
AMPT – Just the Partons (ZPC)

AMPT p+Au at $\sqrt{s} = 200$ GeV
$0 < b [\text{fm}] < 2$

- $N_{\text{scatt}} = 0$
- $N_{\text{scatt}} = 1$
- $N_{\text{scatt}} \geq 2$

Prob. to Not Scatter ($\phi$)

Why isn’t this flat with $p_T$ since $\sigma = 1.5$ mb is momentum independent?
Low $p_T$ partons do not interact for $> 1$ fm/c

$v_2(p_T)$ depends on formation time

Not yet clear why $<N_{\text{scatt}}>$ drops for high $p_T$ partons
Hadronization in AMPT

200 quarks/antiquarks $\rightarrow$ $\sim 100$ mesons

AMPT $p+Au$

$0 < b \ [fm] < 2$

$\sqrt{s} = 200 \ \text{GeV}$

Just from parton cascade

Just after hadronization

Coalescence just by closest spatial partner (no momentum space)

How to assign a theory uncertainty?
Contributions for Each Stage

No Parton or Hadron Cascade

Hadron Cascade Only

Parton Cascade $\rightarrow$ Hadrons

Also Hadron Cascade
Different Picture in $^3$He+Au
Further Discriminating (?) Tests

Species dependence signature of velocity field, though coalescence can mimic some features (all?)

superSONIC predictions

AMPT p+Au
Definitive evidence for geometry, not initial momentum correlations

However, competing final state explanations need work to discriminate.
Geometry Rules – but what final-state mechanism

Viscous Hydrodynamics, time = 1.000

d+Au Central Initial Condition
AMPT $p+Au$ at $\sqrt{s} = 200$ GeV
$0 < b [\text{fm}] < 2$
AMPT p+Au
$0 < b \text{ [fm]} < 2$
$\sqrt{s} = 200 \text{ GeV}$

Graph showing $v_n$ vs. $p_T$ [GeV/c] for different values of $b$. The graph includes several curves, each representing a different $b$ value, with the colors indicating different ranges.