PHENIX results on azimuthal correlations in small collision systems from the RHIC geometry and energy scan

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PHENIX
Motivation

**What?**
Engineer the size and shape of the initial reaction

**How?**
- 3He+Au (2014)
- d+Au (2008)
- p+Au, p+Al (2015)

**Why?**
How the initial geometry is translated to final-state momentum anisotropy

**Beam Energy Scan**
- d+Au (2016)
  - 20 GeV
  - 39 GeV
  - 62.4 GeV
  - 200 GeV

Vary the duration of each stage to assess their relative importance
PHENIX Detectors in Rapidity Space

We use this detector to measure the event plane

Tracks FVTX and Central Arms

FVTX-South

FVTX-North

BBC-South

BBC-North

-3 < \eta < -1

1 < \eta < 3

3.1 < \eta < 3.9

-3.9 < \eta < -3.1

Central Arms

l|\eta| < 0.35

MPI@LHC, Shimla

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14/12/17
PHENIX Results in this Talk

- Ridge in different systems
- Geometry scan: flow of inclusive and identified particles
- Energy scan with dAu
Ridge in different systems
Ridge in d/3He+Au but no ridge in pA


PRC 95 (2017) 034910

|Δη|>2.75
d+Au at 200 GeV: ridge evolution with $\Delta\eta$

A clear ridge is seen with all detector combinations, even for $\Delta\eta > 6.2$
Geometry scan: flow of inclusive and identified particles
Geometry scan: flow harmonics of inclusive particles

\[ \varepsilon_2(3\text{HeAu}) = 0.50 \]
\[ \varepsilon_2(\text{dAu}) = 0.54 \]
\[ \varepsilon_2(\text{pAu}) = 0.23 \]
\[ \varepsilon_2(\text{pAl}) = 0.30 \]

(growing) asymmetric systematics from nonflow

- \( v_2(3\text{HeAu}) \sim v_2(\text{dAu}) > v_2(\text{pAu}) \sim v_2(\text{pAl}) \)
- Geometry control works!
Geometry engineering, $v_2 (p_T)$, and models

- Hydrodynamics with small $\eta/s$ works!
- AMPT: weakly coupled partonic cascade+quark coallescence+hadronic cascade also works at low $p_T$.
- Other observables?

PRC 95 (2017) 034910
PRL 114, 192301, (2015)
$v_2/\varepsilon_2$ in systems with different geometry

The $v_2/\varepsilon_2$ in p+Au is higher than that of d+Au and $^3$He+Au collisions.

$^3$He/d+Au – some events hot spots never connect and so $\varepsilon_2 \rightarrow v_2$ translation incomplete.

This behavior is within the expectation of SONIC model, which includes Glauber initial geometry and viscous hydro evolution.
Triangular flow at 200 GeV in different systems: insights about the role of preflow

- $v_2$ in $d/^3$He+ Au nearly identical
- $v_3$ smaller in $d+ Au$
- Trends well described with hydro without preflow
Include pre-equilibrium flow

worse agreement with data when preflow is included

Relative contributions from pre-equilibrium and QGP need retuning?
Identified particle $v_2$ in different systems

Central $p+Au$  
Central $d+Au$  
Central $^{3}\text{He}+Au$

$p+Au$ 200 GeV 0-5%  
$d+Au$ 200 GeV 0-5%  
$^{3}\text{He}+Au$ 200 GeV 0-5%

$\pi^+ + \pi^-$


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Identified particle $v_2$ in different systems

- Mass-ordering in all three systems
- Less pronounced in p+Au than in d+Au and $^3$He+Au
- Need to compare to models
Energy scan with dAu
dAu BES: Event plane measurements of $v_2$

200 GeV  62 GeV  39 GeV  20 GeV

Nearly identical

Increase at high $p_T$?
Nonflow correlations: insights from AMPT

- Evidence for collective effects down to 39 GeV
- Nonflow correlations at 20 GeV require further studies
Nonflow correlations: insights from AMPT

200 GeV  62 GeV  39 GeV  20 GeV

Pure Flow  With Non-Flow  All Non-Flow

J. Velkovska, Copenhagen
dAu BES: $v_2$ vs. multiplicity from cumulants

The difference can be attributed to nonflow + fluctuations
Real $v_2\{4\}$ at all 4 energies!
Evidence of collectivity down to 19.6 GeV
Interesting correlation at low multiplicities needs to be understood further!

\[ v_2\{2\} = (v_2^2 + \sigma^2 + \delta^2)^{1/2} \]

\[ v_2\{4\} \approx v_2\{6\} \approx (v_2^2 - \sigma^2)^{1/2}, \]
1) Ridge in different systems at 200 GeV
   Pronounced ridge in d/3He+Au, but not in pAl
   In d+Au, the ridge seen for \( \Delta \eta > 6.2 \) - truly long-range

2) Geometry scan: flow of inclusive and identified particles
   \( v_2(p_T) \) and \( v_3(p_T) \) follow initial geometry
   hydro and AMPT describe the data up to \( p_T \approx 3 \) or 1 GeV
   \( v_3 \) in dAu and 3HeAu discriminate against preflow/flow
   identified particle \( v_2(p_T) \) shows mass ordering (data/theory comparison needed)

3) Energy scan with dAu
   \( v_2(p_T) \) at midrapidity – nonzero \( v_2 \) at all energies
   \( v_2\{2\} \) and \( v_2\{4\} \) vs. multiplicity: evidence for collectivity down to 20 GeV!