System Size and Energy Dependence of Elliptic Flow

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PHOBOS Collaboration (August 2005)

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Alice C. Mignerey, PANIC 2005, Santa Fe, NM
Past Studies of Elliptic Flow of charged hadrons in Au–Au Collisions

Centrality Dependence

Energy and η dependence

Error bars: 1σ statistical
Error boxes: 90% C.L systematic
Centrality range 0-40%

B.B. Back et al. (PHOBOS Collaboration), nucl-ex/0407012

Measuring Flow in PHOBOS

**Hit-Based Method**
\[ |\eta| < 5.4 \]

Octagon covers
\[-3.0 < \eta < 3.0 \]

If reaction plane uses \( \eta = 0.1 \) to 3.0
then flow found for \( \eta = -0.1 \) to -3.0

**Track-Based Method**
\[ |\eta| < 1.0 \]

3 sets of Rings
covering \( |\eta| = 3.0 \) to 5.4

Reaction plane found in octagon
and rings using \( |\eta| = 2.0 \) to 5.4
flow from the spectrometer

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Comparing the number of participants

Central Cu-Cu

Mid-central Au-Au

\( <N_{\text{part}} > \)
99
35-40%

Cu+Cu

Preliminary
3-6%, \( N_{\text{part}} = 100 \)

Au+Au

35-40%, \( N_{\text{part}} = 99 \)

200 GeV

G. Roland et al., Proc. QM2005, nucl-ex/0510042 and

Alice C. Mignerey, PANIC 2005, Santa Fe, NM
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200 GeV

But the shapes of the overlap regions are very different

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Elliptic flow of Cu–Cu compared to Au–Au

η dependence

0-40% centrality

Error bars: 1σ statistical

Au–Au
B.B. Back et al., (PHOBOS)
PRL 94 122303 (2005)

Cu–Cu
S. Manly et al., Proc. QM05, nucl-ex/0510031

Cu–Cu about 20% lower than Au–Au

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Elliptic flow of Cu–Cu – centrality dependence

Error bars: 1σ statistical
Error boxes: 90% C.L systematic

Hit Based 62.4 GeV PHOBOS Preliminary $|\eta| < 1$

Cu–Cu, $h^\pm$

S. Manly et al., Proc. QM05, nucl-ex/0510031
Comparison of Cu–Cu and Au–Au

Important features:

Very different elliptic flow for the same Npart - But remember these had very different overlap geometries

CuCu flow still significant at most central collisions

200 GeV $|\eta| < 1$

Error bars: $\pm 1\sigma$ statistical

Au-Au: B.B. Back et al. (PHOBOS Collaboration), nucl-ex/0407012
Cu-Cu: S. Manly et al., Proc. QM05, nucl-ex/0510031

Alice C. Mignerey, PANIC 2005, Santa Fe, NM
Comparison of Cu–Cu and Au–Au

Important features:
- Very different elliptic flow for the same Npart -
- But remember these had very different overlap geometries
- CuCu flow still significant at most central collisions

Can we understand this in terms of geometry?

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Eccentricity – $\varepsilon$

a representation of geometrical overlap

$$\varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$

Au-Au collision
with Npart = 78

Au-Au collision
with Npart = 64
Eccentricity – $\varepsilon$

a representation of geometrical overlap

$$\varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$

Au-Au collision with $N_{\text{part}} = 78$

Au-Au collision with $N_{\text{part}} = 64$

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Sample of Cu–Cu collisions

Cu-Cu collision with Npart = 33

Gives negative eccentricity $\varepsilon$

Cu-Cu collision with Npart = 28

$$\varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2}$$

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Sample of Cu–Cu collisions

Cu-Cu collision with Npart = 33

Cu-Cu collision with Npart = 28

Principal axis transformation

Maximizes the eccentricity

\[ \varepsilon = \frac{\sigma_y^2 - \sigma_x^2}{\sigma_y^2 + \sigma_x^2} \]
Effect of the eccentricity definition

Standard

Participant

Au-Au

Cu-Cu

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Comparison of standard and participant eccentricity

**Standard Eccentricity**

PHOBOS 200 GeV

- Cu+Cu (preliminary)
- Au+Au

**Participant Eccentricity**

PHOBOS 200 GeV

- Au+Au
- Cu+Cu (preliminary)

Error bars: 1σ stat + sys

- 

![Graphs showing comparison of standard and participant eccentricity](image_url)
Comparison between Systems and Energies

\( \langle v^2 \rangle / \langle e_{\text{part}} \rangle \)

**PHOBOS preliminary**

- 200 GeV, tracks
- 200 GeV, hits
- 130 GeV, hits
- 130 GeV, Star
- 4 GeV, E877

\( 1/(\langle S \rangle dN/dy) \) scaling:
  - C. Adler et al. (STAR), PRC **66** 034904 (2002)
  - J. Barrette et al. (E877), PRC **51**, 3309 (1995); **55**, 1420 (1997)

Au-Au: B.B. Back et al. (PHOBOS Collaboration), nucl-ex/0407012

Cu-Cu: S. Manly et al., Proc. QM05, nucl-ex/0510031

Error bars: \( 1\sigma \) stat + sys

\( 1/(\langle S \rangle) \) overlap area

measured \( dN_{\text{ch}} / d\eta \)
corrected to \( dN_{\text{ch}} / dy \)

G. Roland et al., Proc. QM2005, nucl-ex/0510042

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PHOBOS has measured elliptic flow for charged hadrons in Cu-Cu at 62.4 and 200 GeV as a function of centrality and pseudorapidity.

Demonstrated the importance of understanding the geometry - definition of eccentricity.

When expressed in terms of PARTICIPANT eccentricity, the centrality dependence of $v_2/\varepsilon$ is consistent for Cu-Cu and Au-Au and scales with other elliptic flow measurements at AGS, SPS and RHIC energies.