Collective Flow of Charged Hadrons in Cu+Cu collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC PHENIX

Motivation

The collective flow of charged hadrons produced in heavy ion collisions can be characterized using the Fourier coefficient $v_2$ (elliptic flow), as well as with the higher order coefficients like $v_3$ resulting primarily from fluctuations in the initial conditions of the colliding nuclei. The coefficient, $v_2$, has been used recently to discriminate between different models and the role of viscosity. Here we investigate $v_2$ and $v_3$ for Cu+Cu at $\sqrt{s_{NN}} = 200$ GeV using the long range correlation method and compare it to Au+Au at the same energy.

Event Plane Measurement

About the event plane:
- The reaction plane defined by impact parameter and beam direction but is difficult to measure.
- The greatest particle production observed in event plane which is close to reaction plane.
- Measurements must be corrected for the difference between the two.

The single particle azimuthal distribution can be represented by

$$dN/d\phi \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \Psi_n))$$

$\Psi_n$ represents the measured $n$th harmonic event plane. Harmonics correspond to the Fourier transform of the single particle distribution.

The $v_n$ can be extracted using

$$v_n = \frac{\langle \cos(n(\phi - \Psi_n)) \rangle}{Res(\Psi_n)}$$

- $Res(\Psi_n)$ is the correction factor that comes from our ability to measure the event plane.
- This event plane resolution is affected by the eccentricity and multiplicity.
- Some systematic uncertainties come from this step alone.
- The event plane at PHENIX with the 2005 configuration was determined by the Beam Beam Counters (BBC).
- The $\Delta\eta$ between the BBC (3.1 < $\eta_{BBC}$ < 4.0) and the central arm (|$\eta_{CNT}$| < 0.35) suppresses the non-flow effects.

Long Range Correlation Method

The standard two particle azimuthal correlation involves measuring particle pair distributions in relative azimuthal angle ($\Delta\phi$),

$$\frac{dN_{\text{pairs}}}{d\Delta\phi} \propto \left(1 + \sum_{n=1}^{\infty} 2v_n(p_T) \cos(n\Delta\phi) \right)$$

We then factorize $v_{n,n}(p_T) = v_n(p_T) v_n(p_T)$
- In this analysis we correlate tracks with the BBC to obtain $v_{n,n}$. The BBC does not have track resolution rather the signal seen in its channels are proportional to the number of tracks that pass through it. Therefore in the two particle correlation, the azimuthal angles are weighted with the signal observed.
- Since the event plane need not be determined, it does not have that systematic uncertainty.
- Correlations made between channels in the BBC give us $v_{\text{BBC}-\text{BBC}}$. Finally we can get $v_{\text{CNT}}$ by

$$v_{n}^{\text{CNT}} = \frac{v_{n}^{\text{BBC}-\text{BBC}}}{\sqrt{v_{n}^{\text{BBC}}}}$$

Comparison to Au+Au at $\sqrt{s_{NN}} = 200$ GeV

- The $v_2$ starts off higher for the Cu+Cu than for the Au+Au but then is quickly overtaken.
- Saturation of $v_2$ after $p_T > 2$ GeV/c may indicate that only hydrodynamics may no longer be applicable.
- We see that the Cu+Cu saturates whereas the Au+Au does not within the first 50% in centrality.
- Note: For the same centralities, the $N_{\text{part}}$ is drastically different.
- The $v_3$ in both cases is similar and is centrality independent.

Model Constraints

The $v_2$ measurement can impose additional constraints on theoretical models. In this figure for Au+Au at 200 GeV, some competing models fit $v_2$ well for reasonable $N_{\text{part}}$.
- The degeneracy is broken, once it is plotted along with $v_3$.
- The MC-KLN model falls far below the $v_3$ points.
- A study similar to this can be done for a smaller system like Cu+Cu.

References

"Mathematical Framework for Interpreting Pair Angular Correlations in a Two-Source Model" PHENIX Technical Note 412