Precision measurements of centrality dependence of elliptic flow for identified hadrons in Au + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

Hiroshi Masui for the STAR collaboration

Lawrence Berkeley National Laboratory

Abstract

Elliptic flow v_2 is one of the key observables to study the bulk properties at freeze-out as well as hadron production mechanisms in the ultra relativistic heavy ion collisions. It has been observed that Number of Constituent Quark (NCQ) scaling of v_2 holds among measured identified hadrons at $\sqrt{s_{NN}}$ = 62.4 and 200 GeV in Au + Au collisions at RHIC. The scaling of v_2 strongly indicates that the collectivity develops at the stage where the partonic degrees of freedom are relevant. Studying the NCQ scaling of v_2 as a function of transverse momentum p_T and centrality will shed light on the production mechanisms for hadrons in heavy ion collisions.

We present the measurements of v_2 as a function of p_T for identified $\pi^{\pm}$, $K^{\pm}$, K^0_S, p, $\bar{p}$, Λ and $\bar{\Lambda}$ in Au + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from high statistics year 2010 data. The NCQ scaling of v_2 in several different centrality classes is discussed.

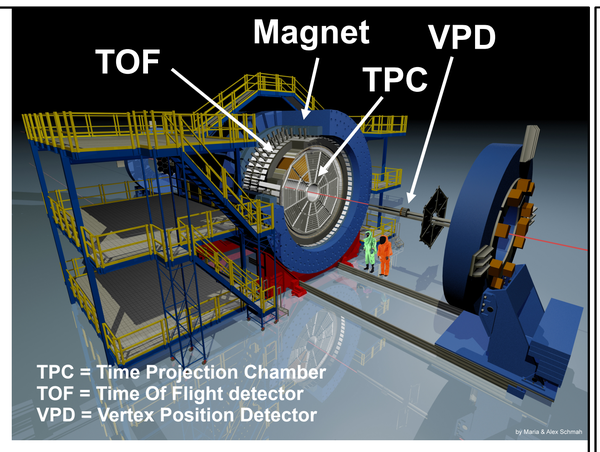
Data sets

- Au+Au at $\sqrt{s_{NN}}$ = 200 GeV
- ~234 M events in 0-80% centrality

Event selection

- $|v_z| < 30$ cm
- $\sqrt{(v_x^2 + v_y^2)} < 2$cm
- $|\text{VPD } v_z - v_z| < 3$cm

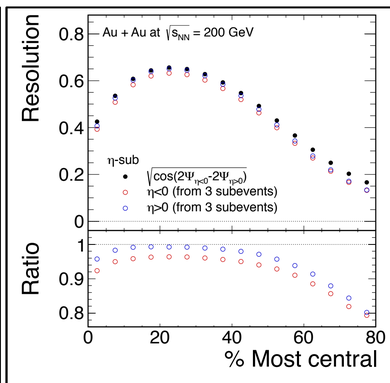
v_x, v_y, v_z = vertices from the TPC
VPD v_z = z-vertex from the VPD

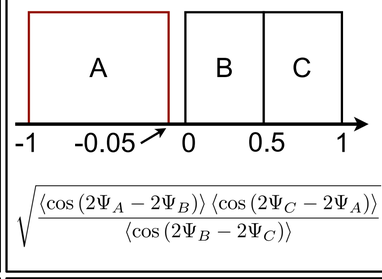


Centrality determination

- Centrality from uncorrected charged particle multiplicity distribution in $|\eta| < 0.5$ measured in the TPC
  - Applied corrections as a function of time, z-vertex, luminosity
- Trigger inefficiency at peripheral collisions is taken into account by Glauber Monte Carlo simulation with multiplicity fluctuation by negative binomial distribution

Event plane method





$$\sqrt{\frac{\langle \cos(2\Psi_A - 2\Psi_B)\rangle \langle \cos(2\Psi_C - 2\Psi_A)\rangle}{\langle \cos(2\Psi_B - 2\Psi_C)\rangle}}$$

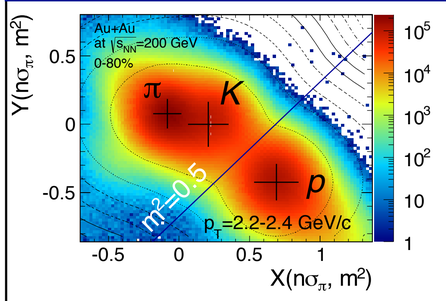
TPC η-sub event plane

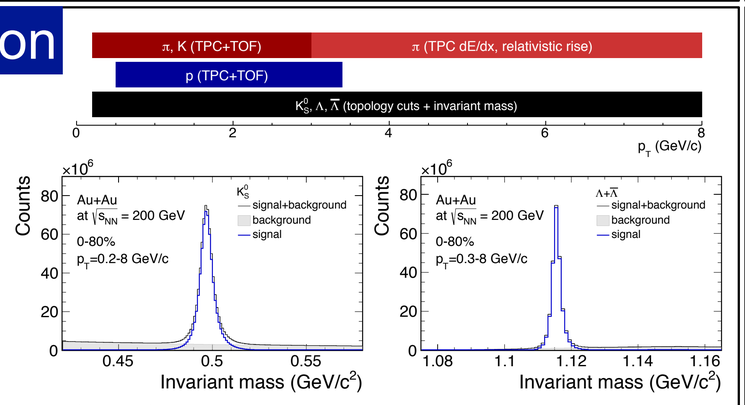
- reconstructed in negative ($-1 < \eta < -0.05$) and positive ($0.05 < \eta < 1$) pseudorapidity η hemispheres
- Additional 0.05 η gap between particles and event plane → reduce short range $\Delta\eta$ correlation
- reconstructed for $p_T < 2$ GeV/c

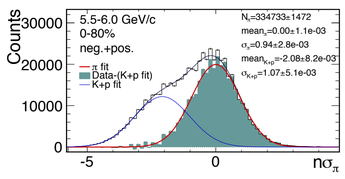
Event plane resolution

- calculated by three independent event planes
- Systematic uncertainties from the resolution by two subevents
- Correction is done event-by-event by using the average resolution in 5% increment of centrality.

Particle identification







$$n\sigma_\pi = \frac{1}{\sigma}\log\left(\frac{dE/dx}{dE/dx|_\pi}\right)$$

dE/dx : measured dE/dx,
$dE/dx|_\pi$: expected pion dE/dx,
σ : dE/dx resolution

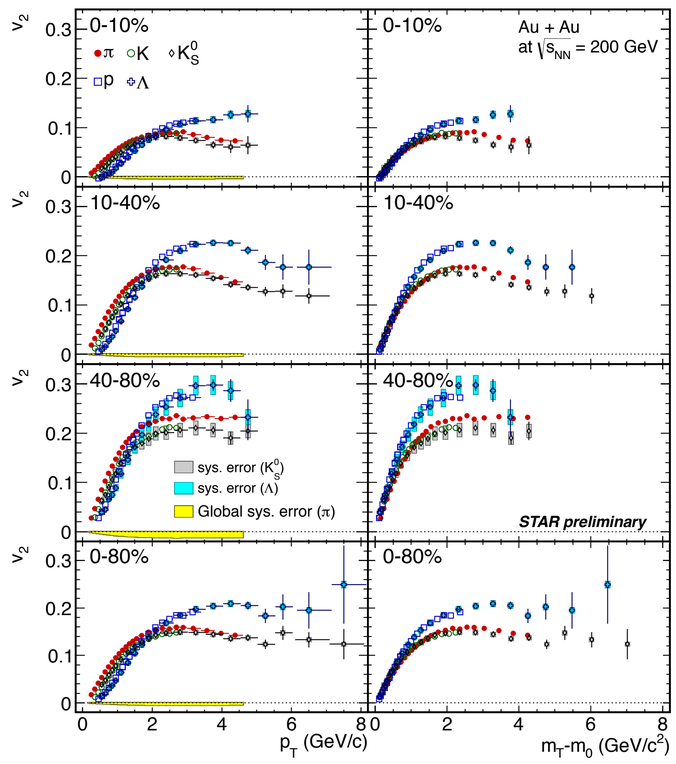
π, K, p

- Momentum dependent mass square m^2 + dE/dx cut in $p_T < 1$ GeV/c
- 2 dimensional signal extraction from $n\sigma_\pi$ and m^2 (top left figure) in $p_T > 1$ GeV/c
- Relativistic rise of dE/dx in $p_T > 2.8$ GeV/c (pions)

K^0_S, Λ

- Topological reconstruction
- Rotational background method to evaluate combinatorial backgrounds

Results

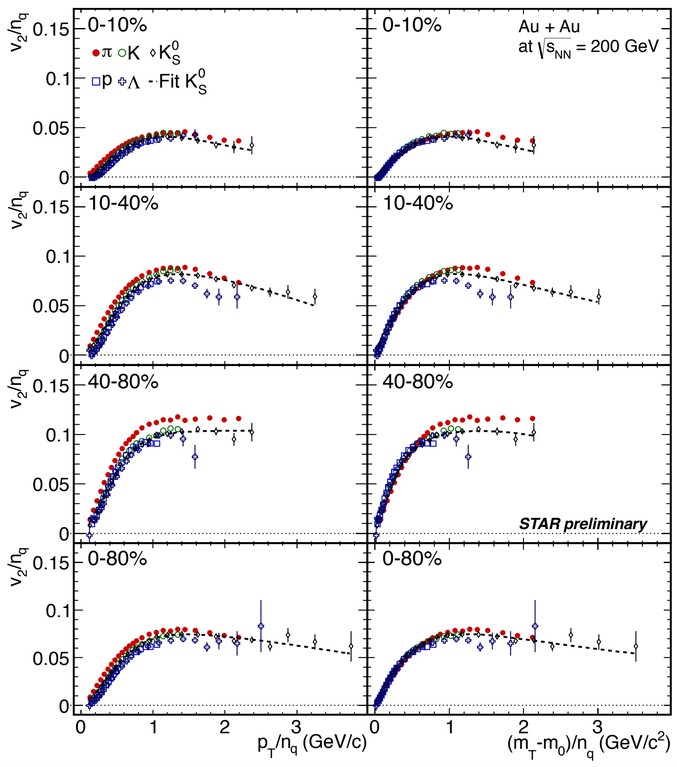


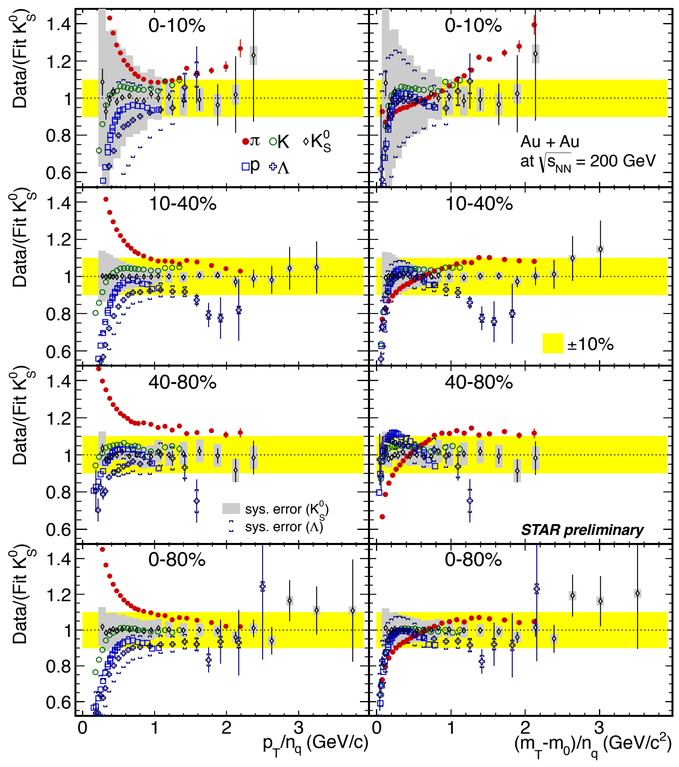
- Measure $v_2(p_T)$ up to p_T = 8 GeV/c
- Mass ordering below p_T = 2 GeV/c, i.e. heavier hadrons have smaller v_2
- Meson/baryon splitting in m_T-m_0 above ~0.5 GeV/c²

Uncertainties

- Vertical error bars show statistical error only
- Global systematic uncertainty from event plane resolution (plotted only for π)
- Systematic uncertainties on K^0_S and Λ due to self-correlation subtraction

Number of Constituent Quark Scaling





- Fitting is performed for K^0_S v_2. Constructed the ratio of the data to the K^0_S fit
- Overall in most centrality bins, NCQ scaling holds all hadrons within 10%, in p_T/n_q > 1 GeV/c, $(m_T-m_0)/n_q$ > 0.5 GeV/c²

Scaling deviation

Low p_T

- Radial flow ?

High p_T

- π > K^0_S → non-flow effects due to jets ?
- ~20-30% difference between π and Λ in 10-40%

Summary

- Precision measurements of $v_2(p_T)$ for identified $\pi^{\pm}$, $K^{\pm}$, K^0_S, p, $\bar{p}$, Λ and $\bar{\Lambda}$ in Au + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV up to p_T = 8 GeV/c
- Overall in most centrality bins, the previously observed NCQ scaling of v_2 holds for all hadrons within 10%, in p_T/n_q > 1 GeV/c, $(m_T-m_0)/n_q$ > 0.5 GeV/c²
- In the 10-40% centrality bin, one observes a sizable difference in v_2 between π and Λ. The sources of the discrepancies is currently under study

Hiroshi Masui (HMasui@lbl.gov) / LBNL

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