The anisotropic flow of $\pi^{\pm}$ in Au + Au collisions at $\sqrt{s_{NN}}$ = 3.9 GeV

QM 2023

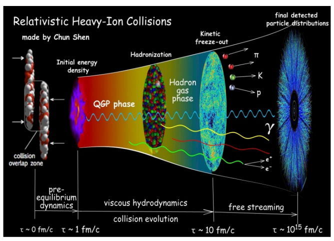
Guoping Wang(gpwang@mails.ccnu.edu.cn), Central China Normal University,
for the STAR Collaboration

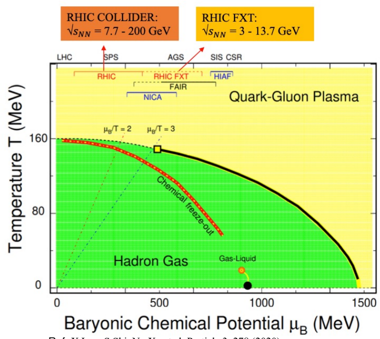
Abstract

The anisotropic flow, especially the first two Fourier expansion coefficients directed flow (v_1) and elliptic flow (v_2), are excellent probes for studying properties of the nuclear matter created in high-energy nuclear collisions owing to their sensitivity to the expansion dynamics. The v_1 and v_2 measurements over a large energy span will provide effective information that the created nuclear matter is dominated by hadronic or partonic degrees of freedom, thus one can explore the QCD phase structure.

In this poster, we will present the measurements of v_1 and v_2 for $\pi^{\pm}$ in Au + Au collisions at $\sqrt{s_{NN}}$ = 3.9 GeV using the STAR detector. The rapidity dependence of v_1 and p_T dependence of v_2 will be shown. The inferred information related to the QCD phase structure will be discussed.

Motivation

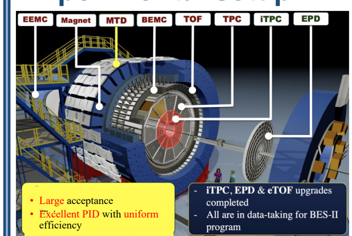


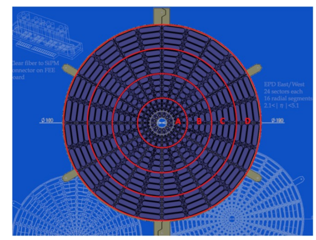


Ref: X.Luo, S.Shi, Nu Xu et al. Particle 3, 278 (2020)

- Directed flow and elliptic flow in the mid-rapidity region provide sensitivity to the expansion dynamics of participant matter
- Elliptic flow is sensitive to the degree of freedom of the produced medium

Experimental setup





The STAR Detector

- 2π azimuthal coverage
- Large acceptance
- Excellent PID

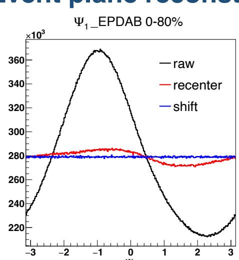
EPD

- Good event plane resolution
- Acceptance at $2.1<|\eta|<5.1$

$\pi^{\pm}$ PID selection

- π^{+}: $|n\sigma| < 3$ (TPC), $m^2 \in (-0.1, 0.15)$ GeV^2/c^4 (TOF), p < 3.0 GeV/c
- π^{-}: $|n\sigma| < 3$ (TPC), p < 3.0 GeV/c

Event plane reconstruction



$$Q_x = \sum_i^N w_i \cos(\phi_i)$$

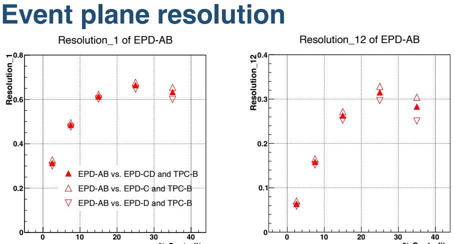
$$Q_y = \sum_i^N w_i \sin(\phi_i)$$

$$\Psi_{1,raw} = tan^{-1}\frac{Q_y}{Q_x}$$

Ref: E877 Collaboration, J. Barrette *et al.*, Phys. Rev. C 56, 3254 (1997).

- The first order event plane (Ψ_1) is determined by the Event Plane Detector (EPD)
- EPD-AB is the 1st through 8th ring in the EPD, from inner to outer ($\eta \in (-5.3, -3.3)$)
- The Event Plane distribution is flatted by the recentering and shift calibrations

Event plane resolution



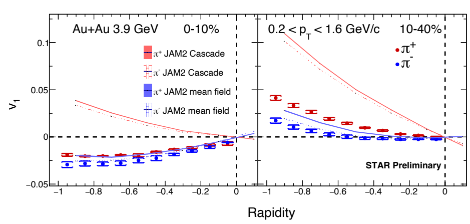
$$R_1(\chi) = \sqrt{\frac{\langle\cos(\Psi_1^a - \Psi_1^b)\rangle\langle\cos(\Psi_1^a - \Psi_1^c)\rangle}{\langle\cos(\Psi_1^b - \Psi_1^c)\rangle}}$$

$$R_{12}(\chi_1) = \frac{\sqrt{\pi}}{2\sqrt{2}}\chi_1 \exp\left(-\frac{{\chi_1}^2}{4}\right) * [I_{\frac{1}{2}}\left(\frac{{\chi_1}^2}{4}\right) + I_{\frac{3}{2}}\left(\frac{{\chi_1}^2}{4}\right)]$$

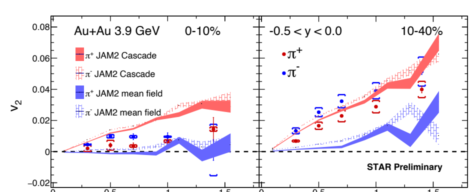
Ref: A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C 58, 1671 (1998)

- Event plane resolution has a strong centrality dependence

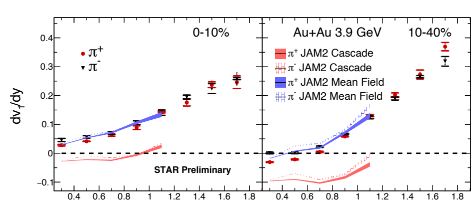
Results



- Rapidity dependence of v_1, increases from central to mid-central collisions
- The JAM2 mean field mode reproduces the rapidity dependence of v_1



- p_T dependence of v_2, increases from central to mid-central collisions
- The JAM2 mean field mode fails to reproduce the $v_2(p_T)$



- dv_1/dy is positive in central collisions for all p_T windows and is negative in peripheral collisions at low p_T windows for π^+
- The JAM2 mean field mode agrees well with experimental data

Ref: Yasushi Nara, Akira Ohnishi. Phys. Rev. C. 105, 014911(2022)

Summary

- Rapidity dependence of v_1, p_T dependence of v_1 slope and v_2 are measured
- Results are compared with the model calculations: JAM2 mean field well reproduces the $v_1(y)$ and $dv_1/dy(p_T)$, but not $v_2(p_T)$

Outlook

- Explore the QCD phase diagram with collision energy dependence of v_1, v_2

Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations

華中師範大學 CENTRAL CHINA NORMAL UNIVERSITY