Measurement of Azimuthal Anisotropy with the New Reaction Plane Detector in the PHENIX experiment

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Azimuthal anisotropy

- Spatial anisotropy in non-central collision provides azimuthal anisotropy of particle emission.
- The large anisotropy is an evidence of the formation of a hot and dense partonic matter.

\[
\frac{dN}{d\Phi} \propto 1 + 2v_2 \cos 2(\Phi - \Psi)
\]

\(\Psi\) : reaction plane angle
Motivation of $v_2$ measurement

- Large $v_2$ was observed in RHIC
- The values agreed with hydro-dynamical models
- It suggests rapid thermalization and quark flow.

$$KE_T = \sqrt{(E_T^2 - P_T^2)} - M_0$$
Reaction Plane Resolution

- Reaction plane resolution is \(~0.4\) before the introduction of the reaction plane detector.
  - The observed $v_2$ strength is only less than 40% of its real value.
  - Statistical power less than 1/6.

\[
v_{2\text{observe}} = v_{2\text{real}} \times \langle \cos 2 (\Psi_{\text{real}} - \Psi_{\text{observe}}) \rangle
\]

\[
\delta v_2 \sim \frac{1}{\langle \cos 2 (\Psi_{\text{real}} - \Psi_{\text{observe}}) \rangle} \times \frac{1}{\sqrt{N}}
\]
Motivation of new detector

- Measurement of more precise $v_2$ is expected.
- Poor reaction plane resolution was a major limiting factor of PHENIX $v_2$ measurement of rare probes such as open charm, $J/\Psi$ and direct photon.

Reaction Plane Detector (RxP) has been constructed and installed to PHENIX in 2007.
- Reaction plane resolution of $\cos 2\Delta\psi \sim 0.7$ for minimum bias Au+Au collisions
Acceptance of RxP

PHOBOS, PRL. 91, 052303 (2003)

- RxP measure more particles and the particles with more large $v_2$.
  - RxP : $\eta = \pm 1\sim2.8$(blue)
  - BBC : $\eta = \pm 3.1\sim4$(red)
Correlation effect

- $v_2$ is overestimated by correlation effect.
- According to HIJING+PYTHIA, the effect by jet does not have any problem with $\eta>1.5$. 

![Graphs showing the correlation effect over different centrality bins.](image)
Design and Geant simulation

- Detector parameters were optimized with Geant simulation
- Thickness
  - Scintillator 2cm
  - Converter 2cm
- $\Phi$ division into 12

$\pi^0 \rightarrow 2\gamma \ (98.8\%) \ \text{ct}=25.1[\text{nm}]$
Configuration of RxP

- Pb converter
- Inner scintillator
- Outer scintillator
- Spacer
- Al tray
- Optical fiber connection
- PMT
Reaction Plane Detector (RxP)

The reaction plane detector was installed just before Run7 (2007).

Collision point

35cm
Reaction Plane Resolution Run7

- resolution is improved by a factor of two as we expected.
$v_2$ before and after

Before (Run4)

Higher statistical
Better resolution of RxP

After (Run7)
The $v_2$ of proton and anti-proton show clear deviation from the number of quark scaling at $KE_t/n\ q 1\ GeV$. This may indicate a change of particle production mechanism.

\[ KE_T = \sqrt{(E_T^2 - P_T^2) - M_0} \]
Heavy flavor $v_2$

- The data at low pT favor the models that include quark level elliptic flow of charm.
- B meson decay becomes a significant source above 2.5 GeV/c

Before (Run4)  
After (Run7)
J/\Psi \ \nu_2

\begin{align*}
\text{p}_T \, [0.5, \text{GeV/c}] & \\
|y| \in [1.2, 2.2] & \nu_2 = -0.094 \pm 0.104 \pm 0.003 \\
|y| < 0.35 & \nu_2 = -0.10 \pm 0.02
\end{align*}

J/\Psi \ \text{Au+Au 200 GeV [20-60%]} \\
PHENIX preliminary

- |y| \in [1.2, 2.2] online filtered
- |y| < 0.35 42\% Run-7

Global Relative Syst. \pm 3\%
Summary

- RxP has worked very well during the PHENIX Run7 period and demonstrated the design performance.
  - resolution is improved by a factor of two (0.4 ⇒ 0.75)
- We are analyzing the data with RxP.
  - π, K, Proton, single electron and J/Ψ have been measured and also preparing for the publications.
  - Please wait for Deuteron, Λ and Φ.