Azimuthal anisotropy of high-\(p_T\) direct photons

High-\(p_T\) Physics at LHC
September 2013
Grenoble, France

Ahmed M. Hamed, University of Mississippi, Texas A&M University
contents

• Motivation
• Theoretical Predictions
• STAR Techniques
• Previous Results
• New Results
• Summary
Motivation-I

• Produced hadrons are correlated “not freely streaming”.
• Many Th. ideas and Ex. Observables investigating the underlying physics of those correlations ($\Phi, \eta, p_T$).

Azimuthal correlations w.r.t. to reaction plane provide the geometrical effects on the hadron trajectory.

• At high-$p_T$, the azimuthal anisotropy could constrain the path length dependence of energy loss “jet quenching”
Motivation -II


- EM interacting particles of high-$p_T$ are expected to have no prefered direction w.r.t to the reaction plane, i.e. $v_2=0$
Theoretical Predictions

- According to the production mechanisms of direct photons:
  - $v_2 < 0$: particles prefer shorter path “out-of-plane”
  - $v_2 = 0$: no preferred direction w.r.t. reaction plane
  - $v_2 > 0$: particles prefer longer path “in-plane”
STAR techniques

- Select EM neutral clusters
- Use the transverse shower shape to select $\gamma_{\text{dir}}$ free ($\pi^0$-rich) sample and $\gamma_{\text{rich}}$ sample from the neutral clusters.

$$
\nu_2^{\gamma_{\text{rich}}} N^{\gamma_{\text{rich}}} = \nu_2^{\gamma_{\text{dir}}} N^{\gamma_{\text{dir}}} + \nu_2^{\gamma_{\text{dir}}} N^{\pi^0}
$$

$$
\mathcal{R} = \frac{N^{\gamma_{\text{rich}}}}{N^{\gamma_{\text{rich}}}} \sim \frac{N^{\pi^0}}{N^{\gamma_{\text{rich}}}}
$$

$$
\nu_2^{\gamma_{\text{direct}}} = \frac{\nu_2^{\gamma_{\text{rich}}} - \nu_2^{\gamma_{\text{rich}}} \mathcal{R}}{1 - \mathcal{R}}
$$

$$
\nu_2^{\gamma_{\text{direct}}} = \frac{\nu_2^{\gamma_{\text{rich}}} - \nu_2^{\pi^0} \mathcal{R}}{1 - \mathcal{R}}
$$
• $v_2$ of direct photons is $\sim 1/3$ of pions, frag. photons contribution?!  
• Not all of the measured $v_2$ of neutral pions at high-$p_T$ are due to the $L$ dependence of $\Delta E$. 

Previous Results-STAR (Run 2007)
Previous Results-STAR vs. PHENIX

- STAR and PHENIX have similar results using different techniques.
Summary of the previous results

• $v_2$ (TPC) of direct photons at high-pt is not zero within the statistical errs (dominant source of uncertainties in Run 2007 data set)
  
  ➢ Event-plane reconstruction biases “non-flow“?
  
  ➢ Fragmentation photons contributions?

• More forward detectors to determine the reaction plane orientation.
  
  ➢ STAR Time Projection Chambers: $1.0 < |\eta|$ for TPC and $2.5 < |\eta| < 4.0$ for FTPC
EM Neutral clusters $v_2$

- Neutral cluster $v_2$ shows no strong dependence on cluster energy.
- $v_2$ (TPC) > $v_2$ (FTPC), may indicate the event-plan reconstruction biases contributions for the TPC-based measurements.
- Is it fully eliminated at the FTPC?
\( v_2 \) of neutral pions is \( \sim 10\% - 15\% \), agrees with the STAR previous measurements (Run 2007) and PHENIX measurements.
$v_2$ (FTPC) of neutral cluster, $\pi^0$, $\gamma_{\text{rich}}$

- $v_2$ of neutral pions is $\sim 10\%$ and slightly smaller than measured values by TPC.
\( v_2 \) (TPC) \( \pi^0 \), direct photons

- \( v_2 \) of neutral pions and direct photons with the STAR previous measurements and PHENIX measurements.
- \( v_2 \) of direct photons is not zero (3-5%)
\( v_2 \) (FTPC) \( \pi^0 \), direct photons

- \( v_2 \) of neutral pions is \( \sim 10\% \), agrees PHENIX measurements.
- \( v_2 \) of direct photons is 0%
Summary

• The pseudorapidity gap reduces the bias in the reaction plane determination and accordingly to the measured azimuthal anisotropy w.r.t reaction plane.
• First statistically significant measurements of direct photons $v_2$ up to 20 GeV in the field of heavy ion collisions.
• The STAR results of direct photons $v_2$ using the FTPC indicate the negligible remaining bias in event-plane reconstruction.
• Negligible contribution of the fragmentation photons for the direct photons.
• The $v_2$ of neutral pions using the FTPC is apparently due to the path length dependence of energy loss.