PHENIX Measurement of Direct Photon-Triggered Two-Particle Correlations in Heavy Ion Collisions and its Implication for Medium-Induced Energy Loss

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Two-Particle Correlations

Two-particle correlations provide the opportunity to study QGP properties. A proxy for jet correlation measurement.

Di-hadron correlations are sensitive to near and away-side QCD interactions.

Direct photon-hadron correlations provide additional benefits:

- Photons are colorless – most direct measure of the parton energy. No trigger surface bias.
- Important complement to other jet measurement:
  - Different path length dependence.
  - Different relative contribution from quark vs gluon jets.

New PHENIX results on $\gamma-h^\pm$ correlations at $\sqrt{s_{NN}} = 200$ GeV in d+Au, and Au+Au collisions.
The PHENIX Detector

Two central arms covering $\varphi \sim \pi/2$ each and $|\eta| < 0.35$

EMCal measures $\gamma$ and $\pi^0 \rightarrow \gamma\gamma$

Drift Chamber (DC) and Pad Chamber (PC) tracking system measures charged hadrons

Forward Beam-Beam-Counter (BBC) and Zero-Degree-Calorimeter (ZDC) measure centrality classes in p+A and A+A
Direct Photon Measurement in PHENIX

Statistical subtraction
- Used in older Au+Au analyses.
- Subtract decay photons from all photon sample: \( Y_{\text{DIR}} = (R_\gamma Y_{\text{INC}} - Y_{\text{DEC}})/(R_\gamma - 1) \)
  See *Phys. Rev. C80 024908* for details.

Isolation cone method
- Provides better uncertainty.
- Used in p+p and d+Au
- New Au+Au vs centrality results use this method.

\[ \text{R}_{\text{cone}} = 0.4; \quad E_{\text{cone}} < 0.1E_\gamma \text{ (in p+p)} \]

- Subtract background (mixed events)
- In d+Au we assume no flow, use ZYAM normalization.
- In Au+Au measured flow is also subtracted.
Per-trigger yields of hadrons

Proxy for the fraction of the quark’s original momentum carried by hadrons

$$z_T = \frac{p_T^h}{p_T^\gamma}$$

For better look at low $z_T$ region we use

$$\xi = \ln(1/z_T)$$

Integrate over $\phi$ in away-side region to obtain fragmentation function vs $\xi$
Fragmentation function

In d+Au no significant modification compared to p+p
In Au+Au suppression at small $\xi$ and enhancement at large $\xi$
Transition at $\xi \sim 1.2$

Effective jet fragmentation function

$$D_q(z_T) = \frac{1}{N_{evt}} \frac{dN(z_T)}{dz_T}$$

$$I_{AA} = \frac{Y_{AA}}{Y_{pp}} \sim \frac{D_{AA}(z_T)}{D_{pp}(z_T)}$$
Trigger $p_T$ dependence

**Trigger $p_T$ is a proxy for parton $p_T$**

Enhancement is seen only at low $p_T$

Qualitatively similar increase of $I_{AA}$ with $\xi$ is seen in intermediate $p_T$ bin.

Enhancement is seen only for broad integration range at large angles.
Where does the transition occurs?

- Transition from suppression to enhancement occurs not at fixed $z_T$
- Models suggest transition at fixed $p_T$
- Medium response in addition to redistribution of lost energy from high $p_T$ hadrons?
Where does the lost energy go?

Enhancement disappears with narrow integration range. Suppression stays the same. Monotonic increase of enhancement over suppression vs $\xi$.

Soft hadrons are enhanced more.

Both plots suggest medium response dominated process.
Centrality dependence

Using isolation cone method in Au+Au allowed detailed look at centrality dependence.

Measure $I_{AA} = \frac{Y_{AA}}{Y_{pp}}$ as a function of $z_T$, for different $p_T$ and centrality.

Purple bands show integration range and mean $I_{AA}$

$z_T \approx 0.3$ is $\xi \approx 1.2$

Study suppression/enhancement with these averages
Average $I_{AA}$ vs centrality

With narrow integration range enhancement is not pronounced.

High $z_T$ range shows statistically significant monotonic increase in suppression with centrality.
Comparison to $\pi^0$

Good agreement with single $\pi^0$ suppression
New result gives better constraint on suppression of high $p_T$ hadrons vs centrality
Conclusions

• $\gamma$-h correlations are a powerful tool for studying QCD.

• d+Au collisions show no significant modification of fragmentation function compared to p+p
  - Possible CNM effects are small

• In AuAu enhancement at low $z_T$ (high $\xi$) and suppression at high $z_T$ (low $\xi$) is observed.
  - Suppression increases monotonically with centrality
  - Enhancement is largest for broad integration region and for soft hadrons
  - Transition from suppression to enhancement occurs at fixed hadron $p_T$
  - All this suggests medium response dominated processes.

• More measurements to come from PHENIX: large Au+Au data sets in 2014 and 2016 are currently being analyzed!