Direct Photon Production in Au+Au Collisions at 200GeV Beam Energy

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Why photons?

- Photons are a unique probe for QGP
  - “Color blind” (do not experience strong interaction), provide a direct fingerprint of its creation point
  - All thermal media emit radiation in the form of photons or low mass lepton pairs

Direct photon = Inclusive photon - decay photon
Why photons?

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Direct photon = Inclusive photon - decay photon

Estimate the prompt photons from p+ p baseline

Extract temperature from thermal photon yield
Direct photon puzzle

- Qualitatively: in agreement with thermal source
  - Large yield of low $p_T$ direct photons
  - Large anisotropic emission
  - Universal scaling with $\alpha \sim 5/4$

- Quantitatively: in tension with current model predictions

What is the main source for low $p_T$ direct photons?
Goal of this thesis work

- Using **2014 PHENIX Au+Au** data to study the direct photon with high statistical precision in more detail
  - Higher luminosity
  - More conversions at the PHENIX silicon vertex detector (VTX) \( (X/X_0 \sim 14\%) \)

- Results on following slides are from my thesis, **publication in preparation**
Direct photons in Au+Au collisions

At high $p_T$, Au+Au data consistent with $N_{coll}$ scaled $p+p \rightarrow$ the dominant photon source is hard scattering.

At low $p_T$, Au+Au data shows a clear enhancement wrt the prompt contribution below 3GeV.

At intermediate $p_T$ (3-5 GeV), Au+Au data also shows an enhancement wrt the prompt contribution.
Closer look at “thermal” excess in Au+Au collisions

- Inverse slope ($T_{\text{eff}}$) changes towards higher $p_T$

![Graph showing inverse slope changes](image)

**Au + Au → γ + X, $\sqrt{s_{NN}} = 200$ GeV, 20-40%**

- PRC 91, 064904
- 2014 conversion method

$$T_{\text{eff}} = 261.92^{+7.04}_{-7.04} \text{ (stat)}^{+12.58}_{-7.42} \text{ (sys)} \text{ MeV}$$

$$T_{\text{eff}} = 352.74^{+14.86}_{-14.86} \text{ (stat)}^{+20.38}_{-29.62} \text{ (sys)} \text{ MeV}$$

**A + A → γ + X**

- Au + Au @ $\sqrt{s_{\text{NN}}} = 200$ GeV
- Pb + Pb @ $\sqrt{s_{\text{NN}}} = 2760$ GeV

**Low $p_T$ range**

**Intermediate $p_T$ range**

- Fitting range $0.9 < p_T < 2.1$ GeV/c
- Fitting range $2.0 < p_T < 4.0$ GeV/c

More central collision
Higher beam energy
Heavier nuclei A
Consistent scaling behavior with previous A+A results

\[ dN_\gamma / dy = A \times (dN_{ch}/d\eta)^\alpha \]
Direct photon scaling vs $p_T$

Run14 Au+Au @ 200GeV, $dN^{\text{dir}}/dy = A(dN_{\text{ch}}/dy)^{\alpha}$

- Hadron gas ($\alpha = 1.23$)
- QGP ($\alpha = 1.83$)

Centrality dependence ($\alpha$) in tension with hydro model (including QGP+HG+prompt contribution)

No clear $p_T$ dependence

$\eta/d_{ch} = A(dN_{\gamma}/dy)$

PRC 89, 044910 (2014)
PRL 123, 022301 (2018)

Direct photon scaling

low $\rightarrow$ intermediate $\rightarrow$ high

HG dominant $\rightarrow$ QGP dominant? $\rightarrow$ hard scattering dominant
Direct/Thermal photon photon puzzle — other photon sources?

- Significant intermediate $p_T$
- Large $v_2$
- Centrality dependence: $\alpha < 1$?

- Significant intermediate $p_T$ (RHIC)
- Small-negative $v_2$
- Centrality dependence: $\propto N_{\text{coll}} (N_{\text{ch}}^{1.25})$ or stronger?

Diagram:
- Prompt photons
- Photons from strong B field
- Photons from hadronization
- Jets in-medium Bremsstrahlung
- Jet-plasma conversions
- Decay photons
- Significance intermediate $p_T$
- Small $v_2$
- Centrality dependence: ?
- Large low $p_T$ yield
- Large $v_2$
- Centrality dependence similar to HG?