Low p_T direct photon production in 200GeV *d*+Au collisions measured by the PHENIX detector

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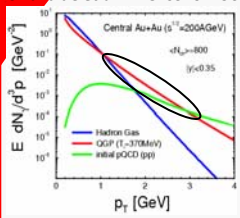
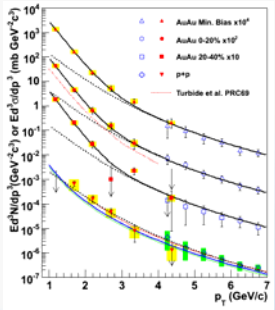
Thermal photon search

S.Turbide *et al* PRC 69 014903



- **Why are thermal photons long-awaited to measure?**
  Because - 1. Direct evidence of QGP formation
  - 2. Carry thermodynamic information directly.
- **p_T:1-3GeV/c @ mid-rapidity**
  Suitable window for measurements of thermal photons.
  ← Considered as a primary contributor of direct photons.

A.Adare *et al* PRL 104 132301



- **Low p_T direct photons (<5GeV/c) in p+p & Au+Au have been successfully measured with γ* method.**

Comparison with N_{coll} scaling

Excess over binary-scaled p+p result is clearly seen in Au+Au for p_T<3GeV/c.

Q. Can we conclude that the observed excess is due to thermal photons?
A. No, Nuclear effects should be studied.

Nuclear effects

- Nuclear effects are involved in Au+Au collisions, but NOT in p+p collisions.

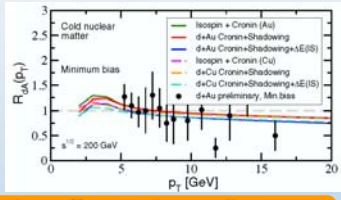
Possible nuclear effects

1. Cronin effect : ↗ *↗(↘) indicates increasing (decreasing) effect
   – Due to multiple scatterings of incoming partons
2. Nuclear shadowing : ↗ or ↘
   – Due to modification of PDF in a Au nucleus (particularly uncertainty on gluon's PDF is LARGE)
3. Initial state energy loss : ↘
   – Due to parton energy loss before generation of hard photons

- A theoretical calculation predicts that nuclear effects may cause **~20% increase** of direct γ yield in d+Au compared to that in p+p, with the Cronin process strongly affected.

$$R_{dA} = \frac{dN_{dA}/dy}{N_{coll} \times dN_{pp}/dy}$$

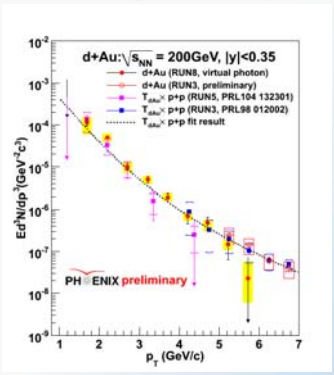
I.Vitev and B.W.Zhang PLB 669 337



→ Important to experimentally quantify nuclear effects on low p_T direct γ production, d+Au data taken in Year-2008 RHIC RUN can contribute to do that.

Results: Direct photon spectra in p+p, d+Au, Au+Au

1. Comparison of p+p & d+Au

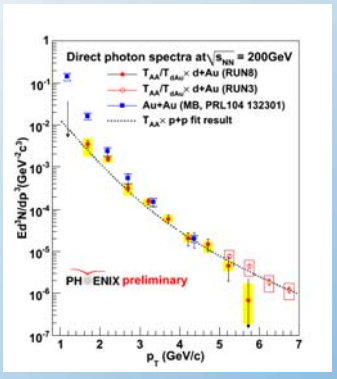


From γ* method
● : d+Au
■ : p+p
From EMCal
○: d+Au
■ : p+p

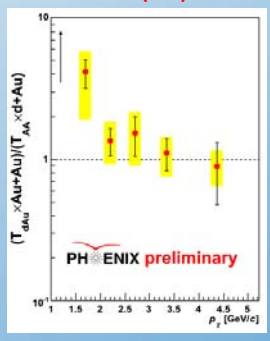
d+Au result is consistent with binary-scaled p+p result.

→ **Nuclear effects on direct photon production are VERY SMALL!!**

2. Comparison of d+Au & Au+Au



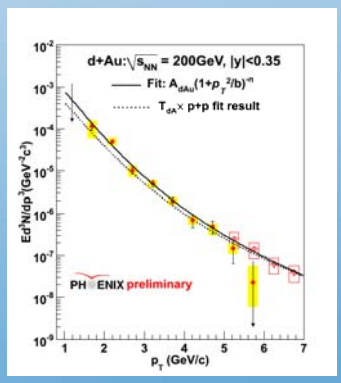
Ratio of Au+Au(MB) to d+Au



Au+Au (MB) result can not be described by the scaled d+Au result. In particular for p_T<2GeV/c, the direct photon yield in Au+Au is more than twice the expected yield from d+Au result.

→ **An additional source of direct photon production other than nuclear effects exists in Au+Au.**

3. Parameterization of d+Au



d+Au result is parameterized by fitting with $A_{dAu}(1+p_T^2/b)^{-n}$, and will serve as a new baseline including Nuclear effects.
A small difference from p+p fit is observed.
→ **Hint of quantification of Nuclear effects**

Virtual photon method

- In any process of producing a real γ, processes to produce γ* which converts to a low mass e^+e^- are associated as a higher order diagram.

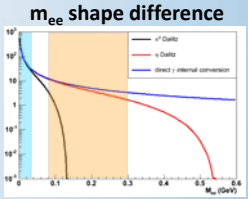
- Utilizing the difference in m_{ee} dependence of $S(m_{ee})$ for direct γ* and π^0,η Dalitz decays

Relation between γ and associate e^+e^- emission rates

$$\frac{d^2n_{ee}}{dm_{ee}} = \frac{2\alpha}{3\pi}\frac{1}{m_{ee}}\sqrt{1-\frac{4m_e^2}{m_{ee}^2}}\left(1+\frac{2m_e^2}{m_{ee}^2}\right)S(m_{ee})\,dn_\gamma$$

Process dependent factor

m_{ee} shape difference



✓ Direct γ* : If $p_T^2 >> m_{ee}^2$, $S(m_{ee})$~1

✓ Dalitz decays of π^0, η:

$$S(m_{ee}^2) = |F(m_{ee}^2)|^2\left(1-\frac{m_{ee}^2}{m_h^2}\right)^3$$

In low m_{ee} region, an enhanced yield of e^+e^- over known contributions from hadrons should be seen due to direct γ*→e^+e^-.

γ*→e^+e^- contribution

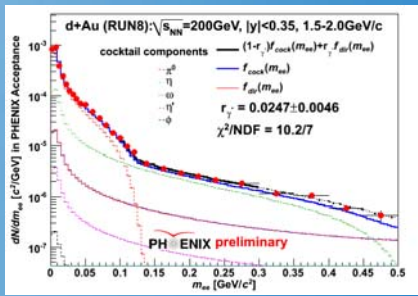
- Contribution of γ*→e^+e^- is extracted by fitting the following function for p_T>1GeV/c & 0.1<m_{ee}<0.3GeV/c^2

$$f_{data}(m_{ee}) = (1-r)\cdot f_{cock}(m_{ee}) + r\cdot f_{dir}(m_{ee})$$

r = direct γ/inclusive γ

Reason for selecting this kinematic region

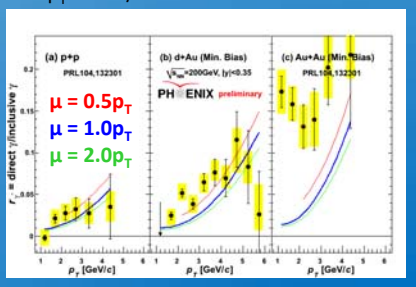
1. Dramatically improvement of S/B ratio due to negligible π^0→γe^+e^- contribution
2. $p_T^2 >> m_{ee}^2$ →$S(m_{ee})$~1 is satisfied.
3. Little contribution from $\pi^+\pi^-$→e^+e^-



Fit result can describe well even in m_{ee}>0.3GeV/c^2!

Ratio: direct γ/inclusive γ

- *r* = direct γ/inclusive γ for every 0.5GeV/c in 1<p_T<6GeV/c are obtained for d+Au.



Curves: expectations of direct γ/inclusive γ based on NLO pQCD calculation

$$d\sigma_\gamma^{NLO}(p_T)/\left(d\sigma_\gamma^{NLO}(p_T)+d\sigma_\gamma^{hadron}(p_T)\right)$$

Multiplying measured inclusive γ yield

Go to **Results: Direct photon spectra in p+p, d+Au, Au+Au** !