Low and intermediate pT direct photons via dielectron measurement in Cu+Cu collisions at RHIC-PHENIX

Daisuke Watanabe
Hiroshima University

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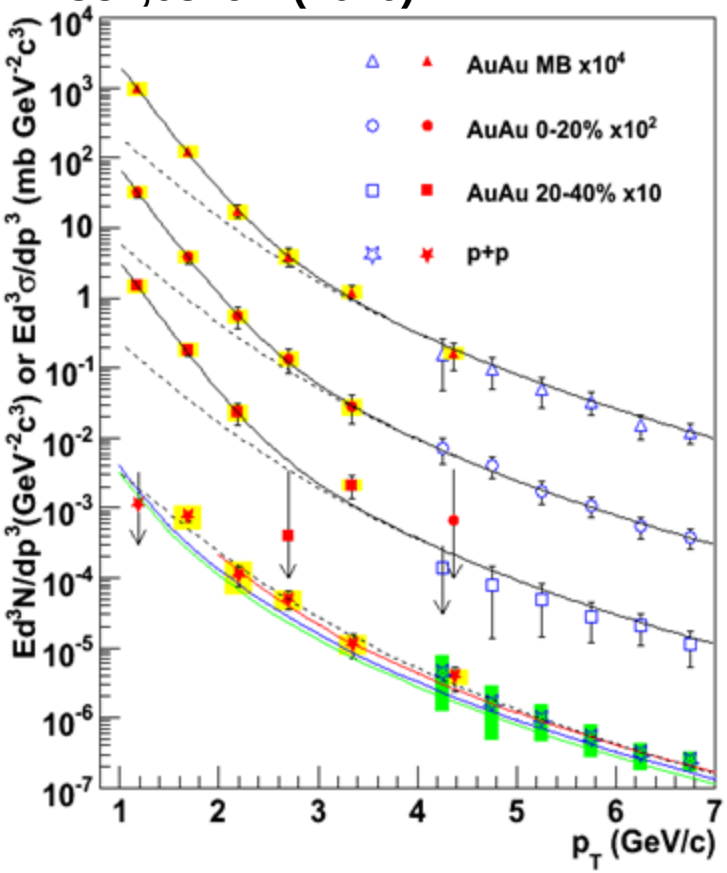
Outline

- Direct photons at RHIC
  - Au+Au, p+p, d+Au, and Cu+Cu
- PHENIX experiment
- Measurement
  - Method
  - Background subtraction
  - Direct γ^* fraction
- Summary

Direct Photons at RHIC

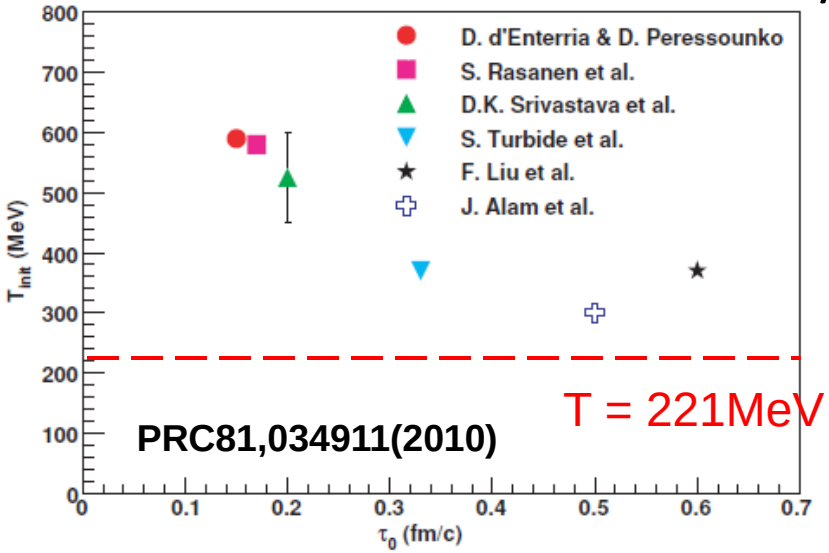
PRC81,034911(2010)



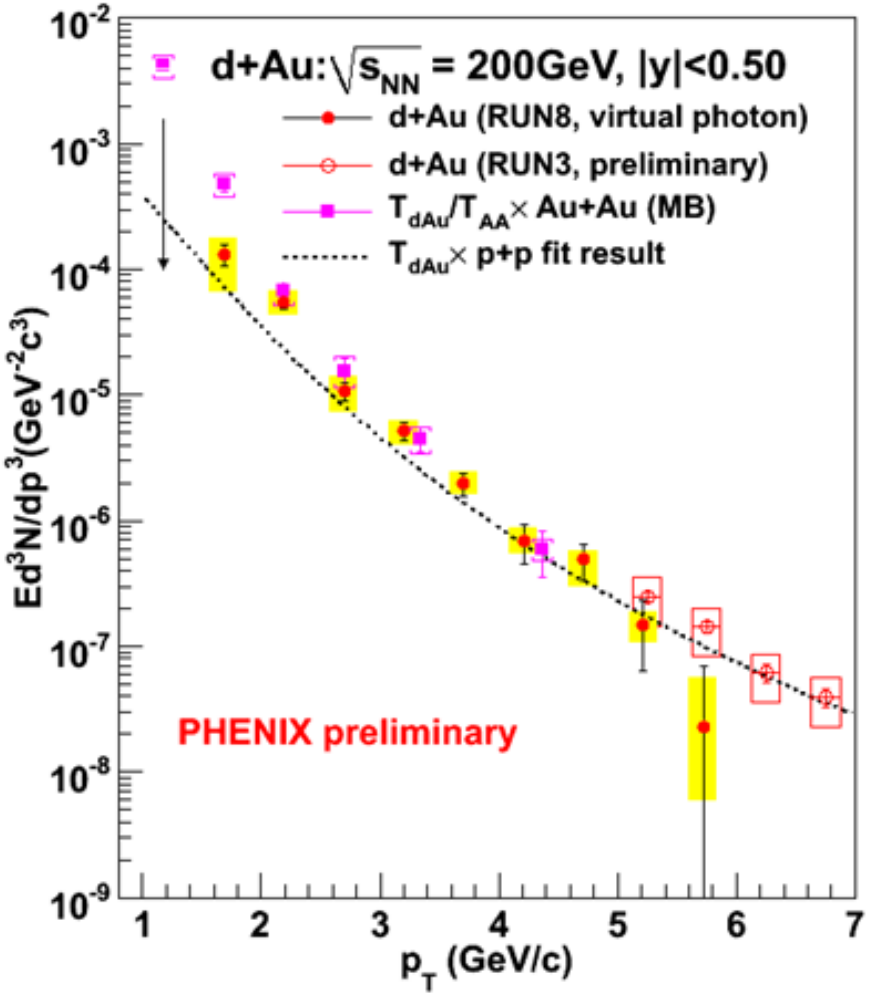
$$A\exp(-p_T/T) + T_{AA} \times A_{pp}(1+p_T^2/b)^{-n}$$

Centrality	dN/dy ($p_T > 1$ GeV/c)	T (MeV)	χ^2/NDF
0–20%	$1.50 \pm 0.23 \pm 0.35$	$221 \pm 19 \pm 19$	4.7/4
20–40%	$0.65 \pm 0.08 \pm 0.15$	$217 \pm 18 \pm 16$	5.0/4
Min.Bias	$0.49 \pm 0.05 \pm 0.11$	$233 \pm 14 \pm 19$	3.2/4

- Low pT (<5GeV/c) direct photons were measured **via dielectrons**.
- **p+p** : agree with pQCD calculation.
- **Au+Au** : significant excess from binary-scaled p+p in low pT.
- T_{eff} obtained by expo + power law fit, as a lower limit of matter temperature.
- Initial temperature at 0-20% predicted as **300-600**MeV at $\tau 0$ = **0.6~0.15**fm/c.



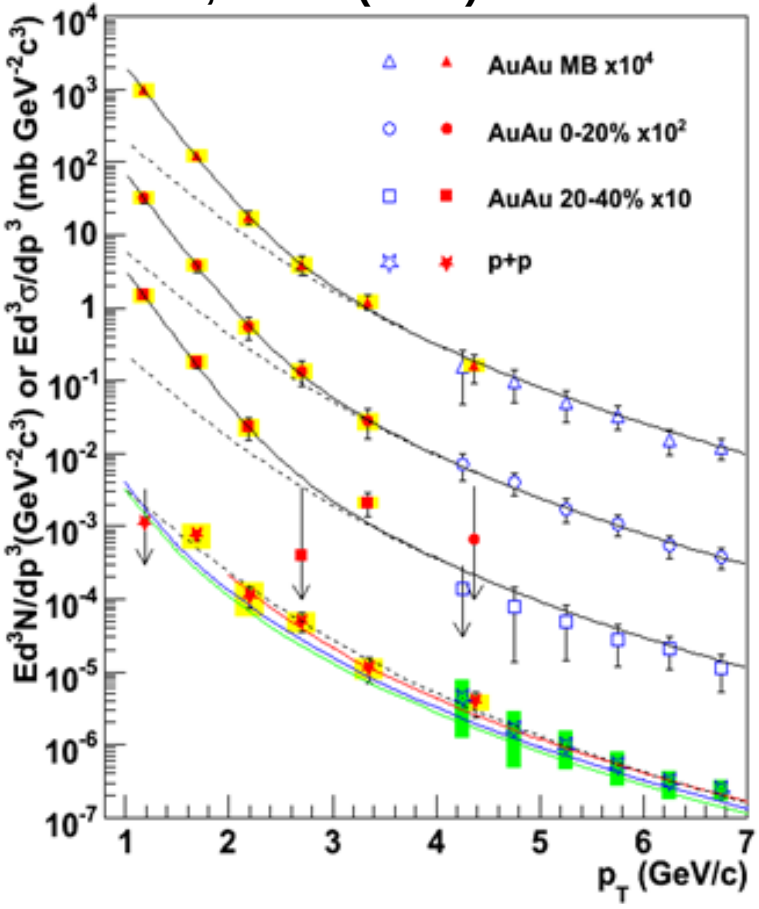
d+Au Direct Photon



- Measured via dielectrons
- Test of Cold nuclear matter effect
- d+Au has no significant difference from binary-scaled p+p.
- Low pT excess cannot be described by cold nuclear matter.

Motivation for Cu+Cu

PRC81,034911(2010)



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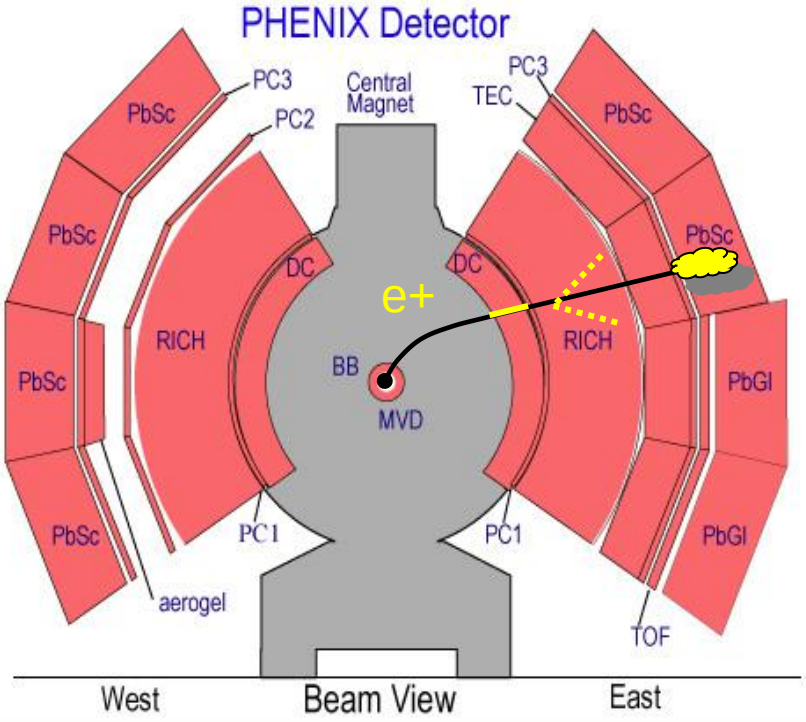
- Temperature parameter of 3 different centralities agree within uncertainties.
- So, some change should be between semi-central and p+p.
- Cu+Cu measurement is motivated by detailed study of system size dependence of thermal system creation.

PHENIX Experiment

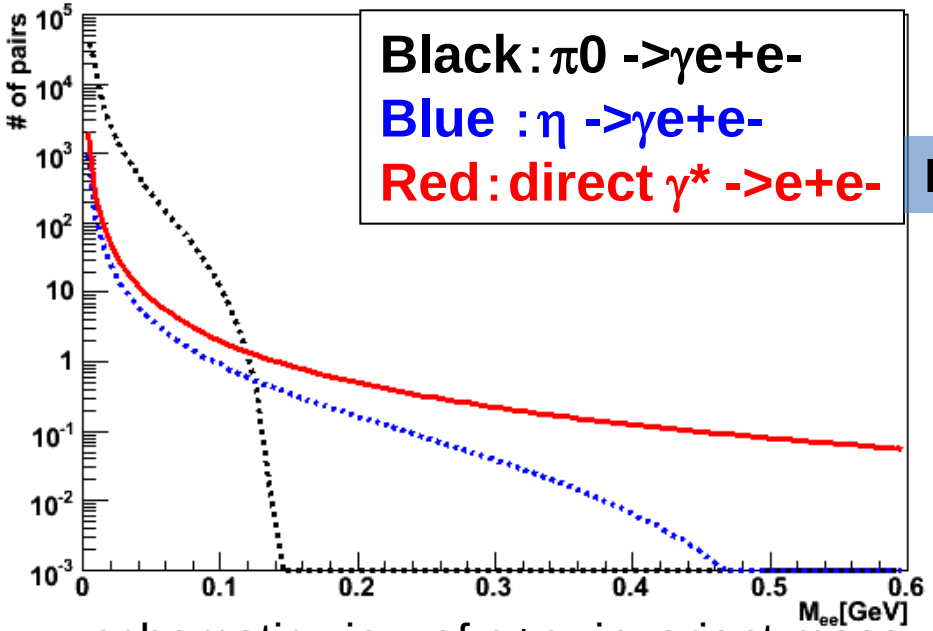
- Analyzed Data
  - Cu+Cu $\sqrt{s_{NN}}$=200GeV taken in 2005
  - **467M** MinBias triggered sample with positive magnetic field direction
- More Data Sample (*analysis underway*)
  - 113M MinBias trigger with opposite magnetic field configuration
  - ERT Trigger : high pT (> ~3GeV/c) e+ and e-



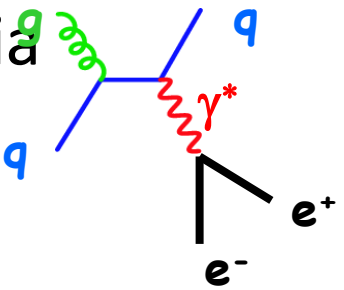
- Charged particle Tracking
  - Drift Chamber & Pad Chamber1
- Electron ID
  - Ring Imaging Cherenkov & EM Calorimeter

Direct Photons via Dielectrons

- Any source of photons can emit dielectrons via virtual photons with low mass.



schematic view of e+e- invariant mass



Kroll-Wada formula

N. M. Kroll and W. Wada, Phys. Rev. 98, 1355 (1955).

$$\frac{d^2N}{dM_{ee}dN_\gamma} = \frac{2\alpha}{3\pi}\sqrt{1-\frac{4m_e^2}{M_{ee}^2}}\left(1+\frac{2m_e^2}{M_{ee}^2}\right)\frac{1}{M_{ee}}S$$

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

for direct photons $S \approx 1$

- Virtual direct photon yield is obtained above π0 mass, the region that S/N is improved.
- Virtual photon yield is converted to REAL photon yield by taking mass 0 limit.

Backgrounds in Mass spectra

- Background subtraction in the low mass region is essential, because direct photon signal appears in that region.
  - Due to absence of virtual photon signals, like-sign consist of 2 types of BG.
  - Each BG rate is determined by using Like-sign pairs.

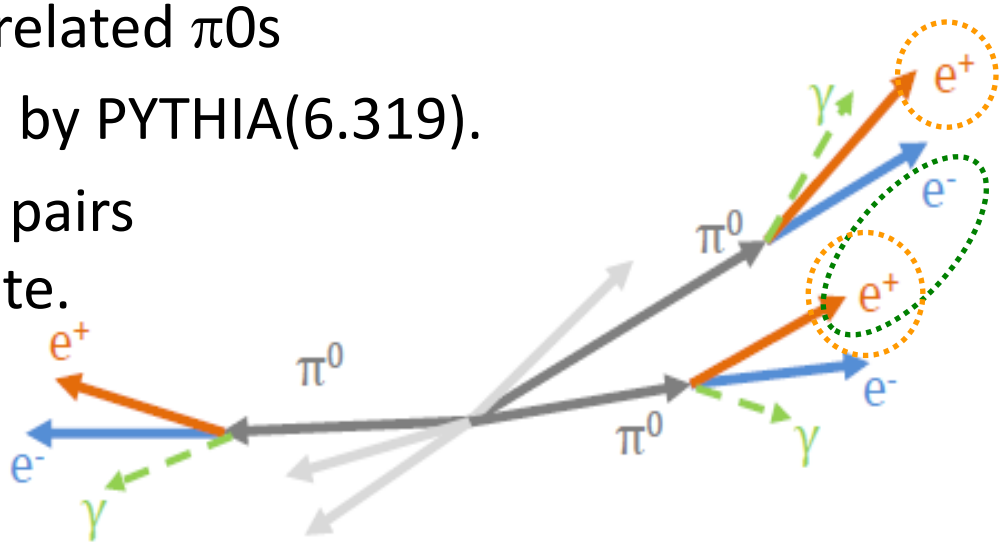
e+e- pairs [**Unlike-sign**]	= **Combinatorial BG** + **Correlated BG** + **pairs from virtual photons**

e+e+, e-e- pairs [**Like-sign**]	= **Combinatorial BG** + **Correlated BG**

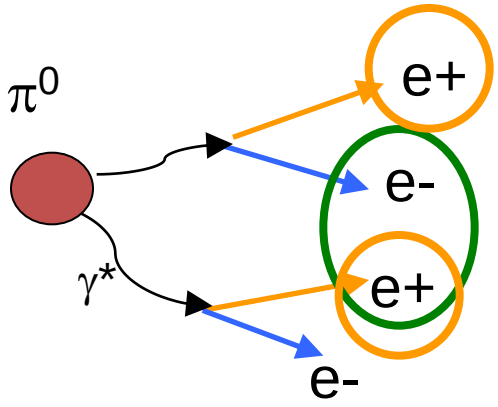
- Once the BG rates are determined,
  BG contribution in unlike-sign is simultaneously obtained, and can be subtracted.
- So, we can obtain pairs from virtual photons.

Correlated Background

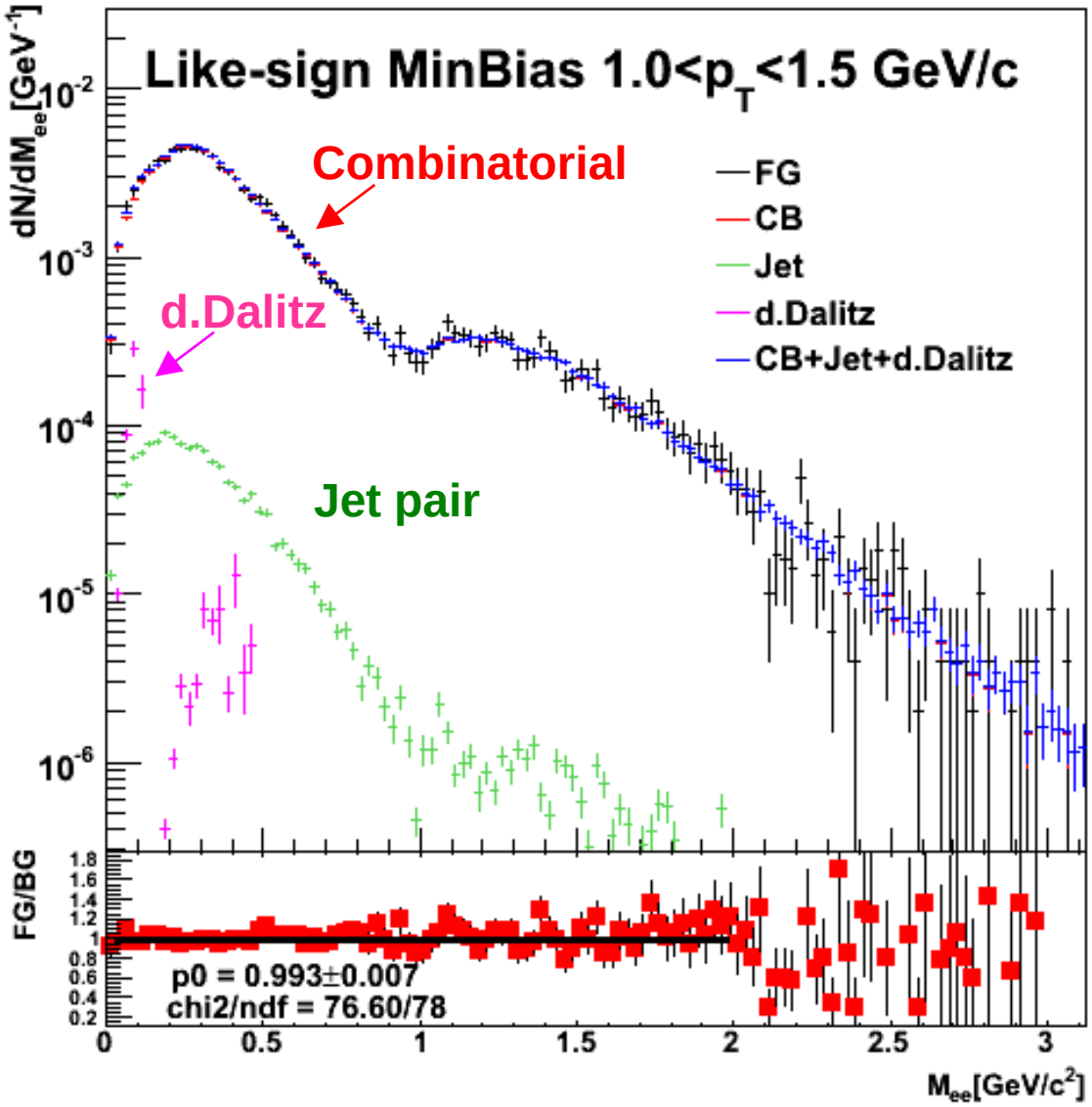
- Jet pairs
  - Dielectrons from jet-correlated $\pi 0$s
  - Mass shape is estimated by PYTHIA(6.319).
  - Unlike-sign and like-sign pairs are produced at same rate.



- double Dalitz
  - sizable sources are $\pi 0$ and η
  - Mass shape is obtained by Monte Carlo simulation.
  - Unlike- and like-sign produced at same rate.



Full Background at Like-sign

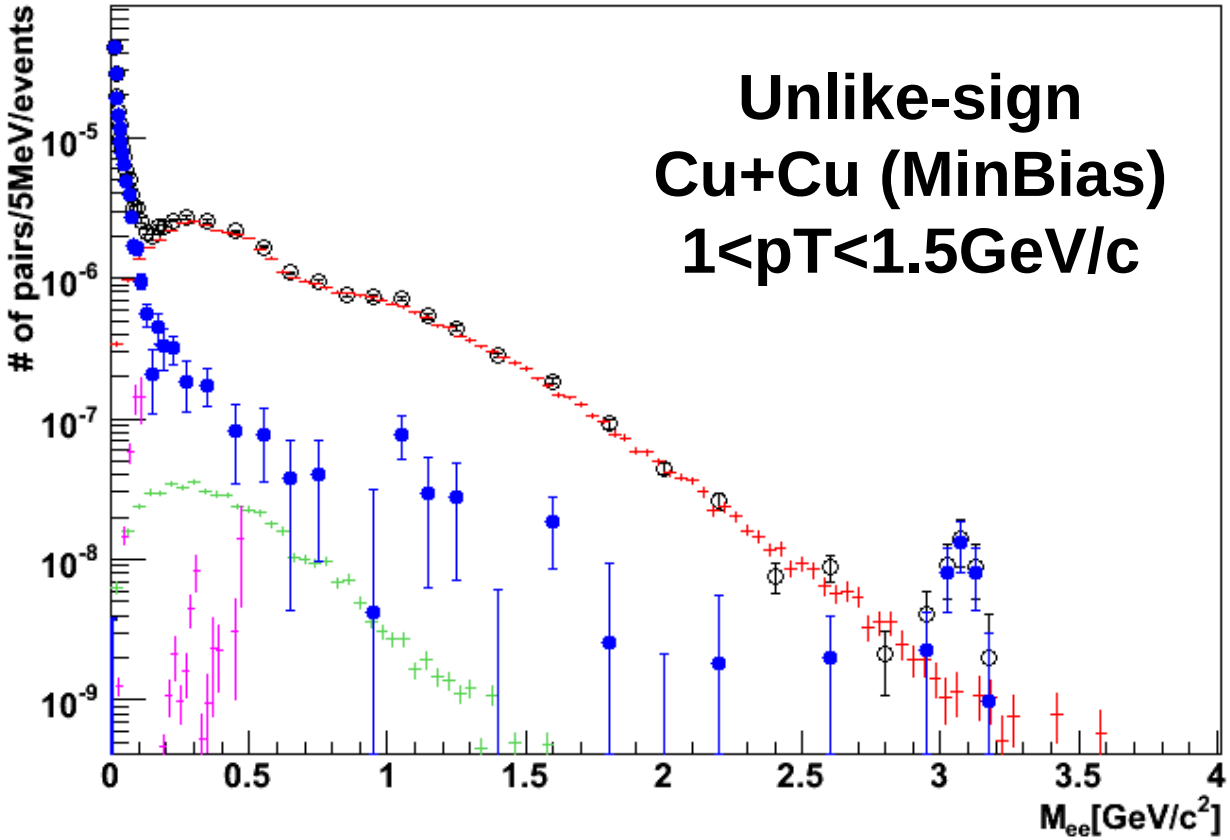


- Combinatorial background rate of unlike-sign is derived by

$$N^{+-}_{mixed} = \sqrt{N^{++}_{same} N^{--}_{same}}$$

- Backgrounds in like-sign pairs are understood with 3 components.

Full Background Subtraction



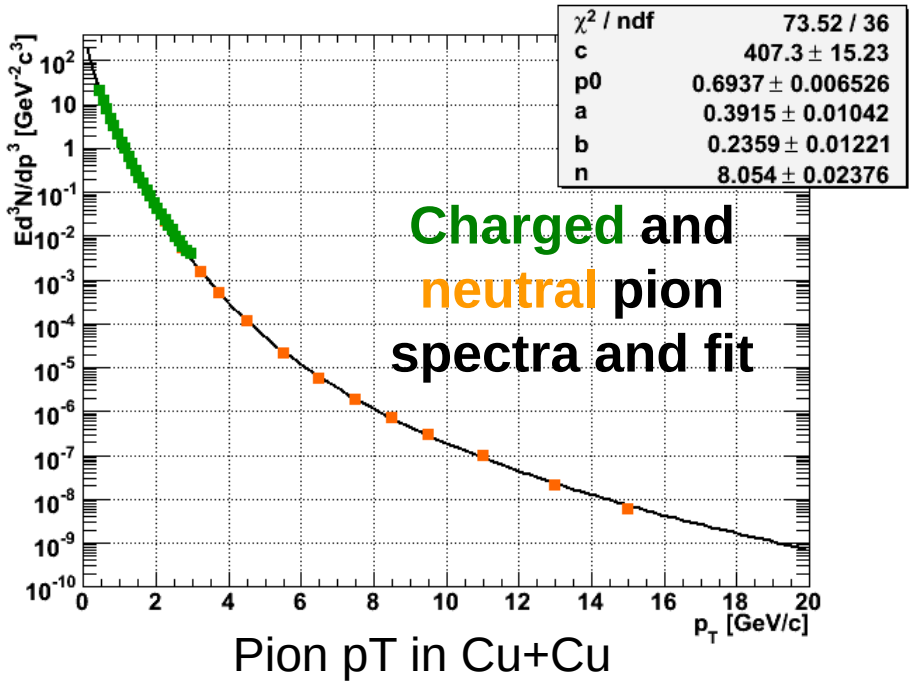
black : Foreground
red : CB
green : jet pair
magenta : d.Dalitz
blue : FG – all BG

- 3 component BG are subtracted in Unlike-sign.

- γ* signal (Unlike-sign) = direct γ* + hadron decay γ*

This component is estimated by cocktail calculation.

Cocktail calculation



Pion pT in Cu+Cu

meson/π0	
π0	1.0
η	0.121
η ‘	0.0187
ρ	0.129
ω	0.111
ϕ	3.87×10^{-2}
J/ψ	1.92×10^{-5}
Ψ’	5.11×10^{-6}

- Mass spectra of known hadronic source are calculated.
- Input pion p_T spectra fit to a modified Hagedorn function

$$E\frac{d^3\sigma}{dp^3} = A(e^{-(ap_T + bp_T^2)} + p_T / p_0)^{-n}$$

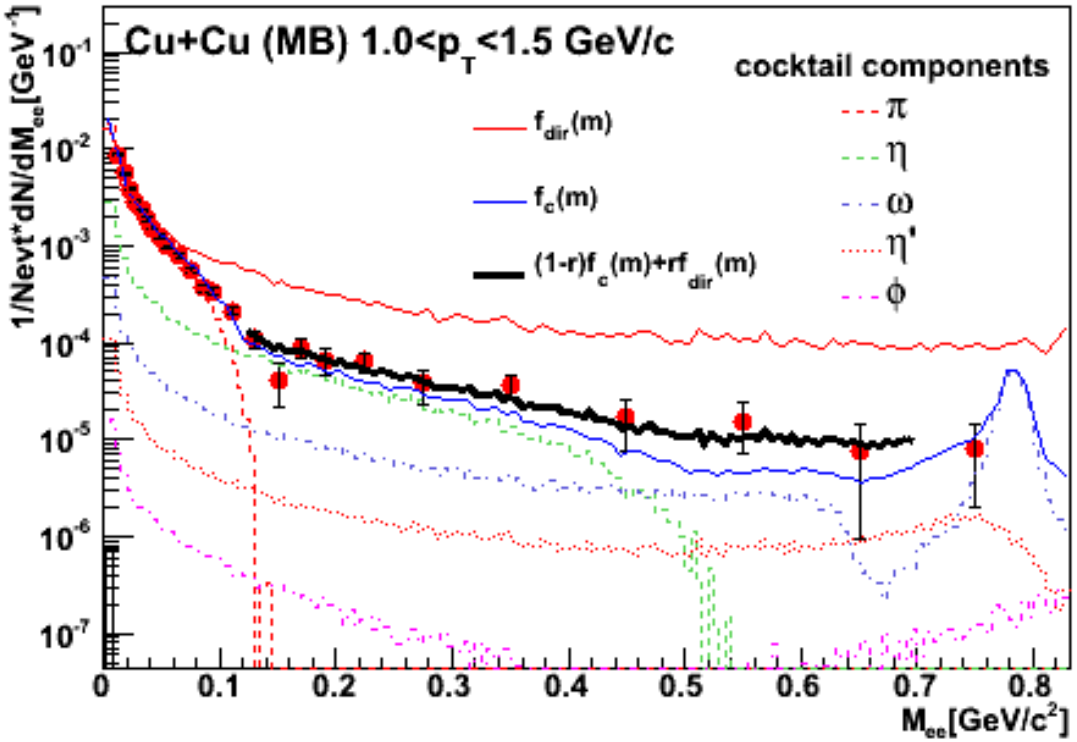
- Other hadron spectra are made by m_T scaling

$$p_T \rightarrow \sqrt{p_T^2 + m_{meson}^2 - m_\pi^2}$$

Comparison with cocktail

- To extract direct virtual photon component, comparison of mass spectrum is done between real data and cocktail, by fitting with

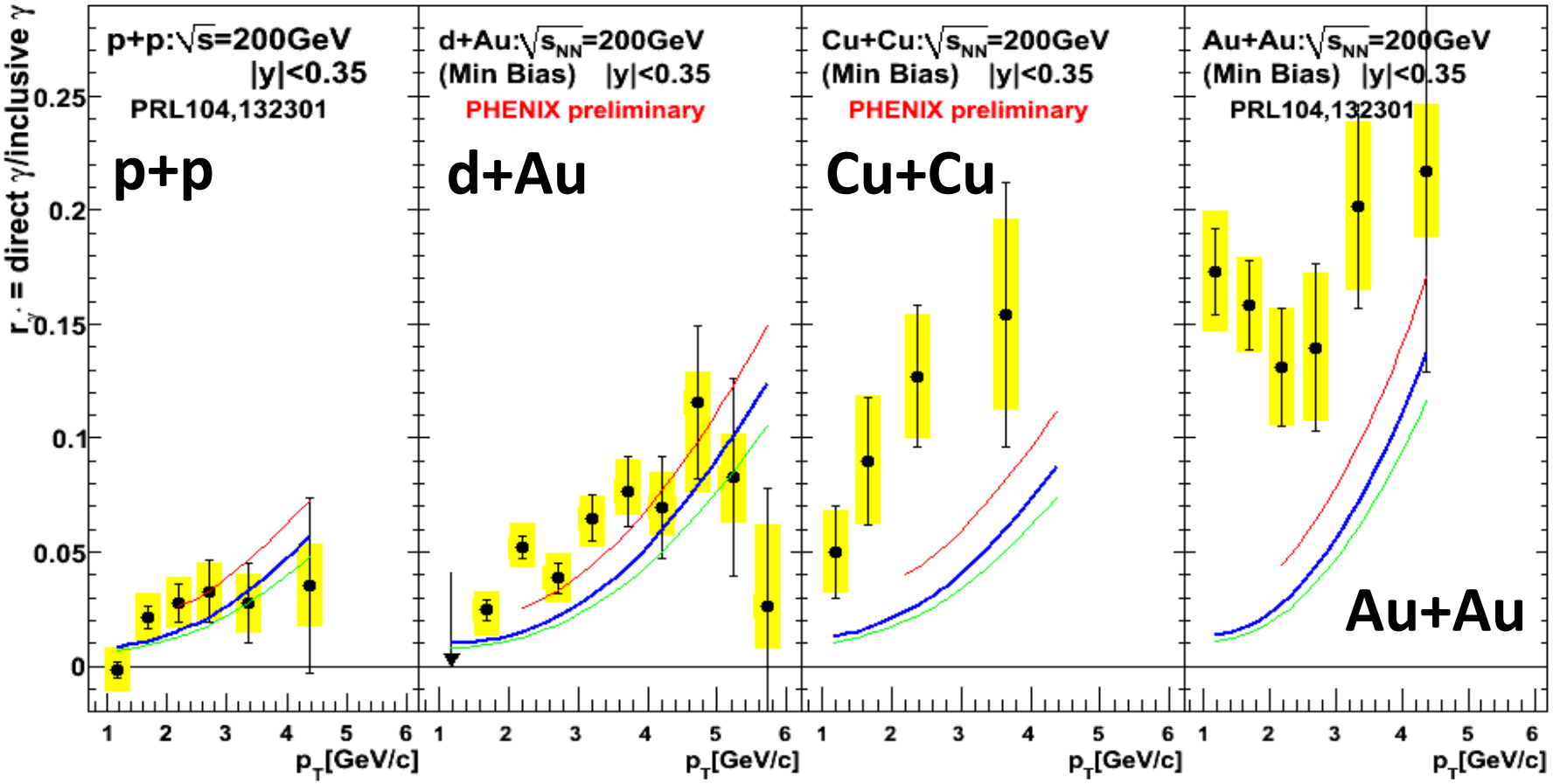
$$f_{data} = (1-r) f_{cocktail} + r f_{direct} \qquad r = \frac{direct\ \gamma^*}{inclusive\ \gamma^*} = \frac{f_{data} - f_{cocktail}}{f_{direct} - f_{cocktail}}$$



- *fdata* : real data
- *fdirect* given by red line, when assuming all the data composed by direct photons, r= 1.
- *fcocktail* given by cocktail calculation

Direct γ* fraction

$$r_{pQCD} = \frac{\text{(direct photon } \sigma \text{ by NLO pQCD※)} \times \langle N_{coll} \rangle}{\text{(p+p inclusive photon yield)} \times \langle N_{coll} \rangle \times R_{AA}}$$



- Enhanced direct photon contribution in low pT region is seen in Cu+Cu.

(※)L. E. Gordon andW. Vogelsang, Phys. Rev. D 48, 3136 (1993)

Summary

- Direct photon measurement in d+Au collisions confirm CNM effect cannot describe low pT excess of the photon spectra.
- Direct photons with the number of participating nucleons between p+p and Au+Au are studied by Cu+Cu collisions.
- In Cu+Cu, all backgrounds in low mass region were subtracted.
  - ✓ Combinatorial, Jet pairs, Double Dalitz, Hadron decay
- Enhanced direct photon contribution is obtained in the low pT region in Cu+Cu.
- Cu+Cu has more statistics in opposite magnetic field sample and ERT triggered data.
- Direct photon pT spectra in Cu+Cu are coming soon, by (direct γ^* fraction) $\times \gamma_{\text{inclusive}}$

Backup