Study of direct photon with internal conversion method in Cu+Cu collisions

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Motivation

Direct photon measurement

- Photons and dileptons are good probes to understand space-time evolution of the produced system in heavy ion collisions.
- The PHENIX experiment has published direct photons in p+p, d+Au and Au+Au [1 – 3].
- PHENIX has observed thermal photons in Au+Au.
- The motivation of this analysis is search for thermal photons in Cu+Cu, finalization and publication of preliminary Cu+Cu results, comparison to Au+Au.

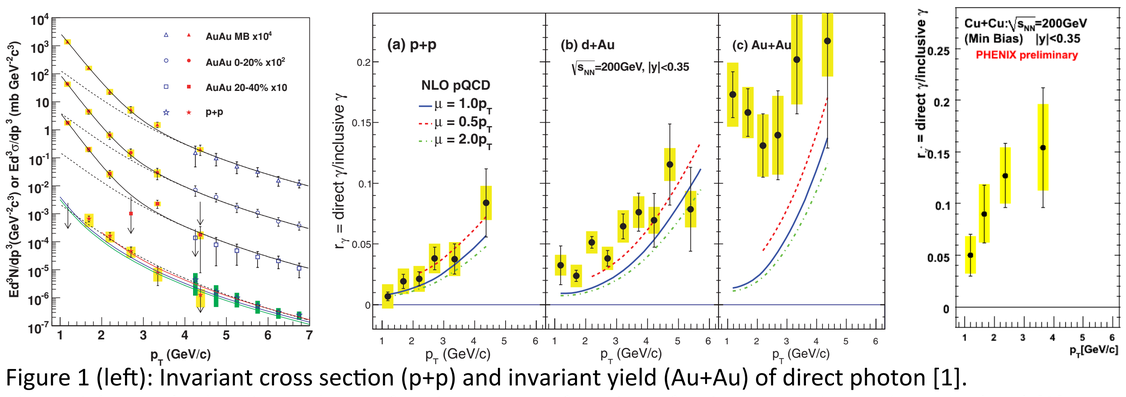


Figure 1 (left): Invariant cross section (p+p) and invariant yield (Au+Au) of direct photon [1].
Figure 2 (center): The direct photon fraction, r_γ, as a function of p_T in p+p, d+Au, and Au+Au (MB) [2].
Figure 3 (right): PHENIX preliminary results on virtual photon in Cu+Cu.

Virtual direct photon

Source of virtual direct photon

- Any source of high-energy real photon can also emit virtual photon.
- They materialize into electron pairs.

How to measure virtual direct photon

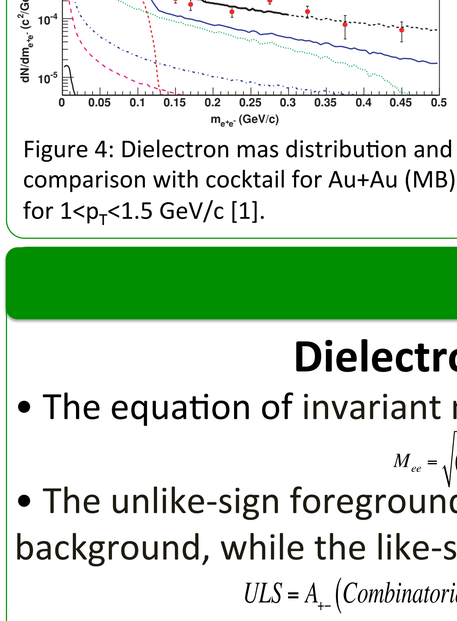


Figure 4: Dielectron mas distribution and comparison with cocktail for Au+Au (MB) for 1<p_T<1.5 GeV/c [1].

- Virtual direct photons are measured with e^+e^- pairs as an excess compared to hadronic cocktail (Fig.4).
- Quantification of the excess is done by a two-component fitting.

$$f(m_{ee};r) = (1-r) f_c(m_{ee}) + r f_{dir}(m_{ee})$$

Here f_c is the shape of the cocktail, and f_{dir} is the expected shape of the virtual direct photon.

Current results

Dielectron invariant mass distribution

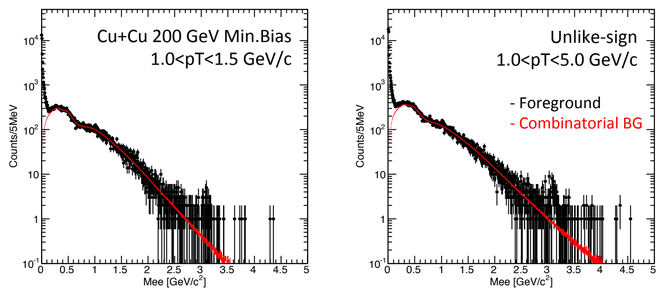
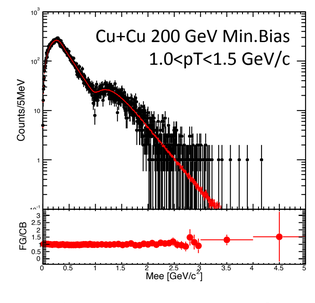


Figure 6: Foreground and combinatorial background for unlike-sign pairs in Min.Bias with p_T slilces



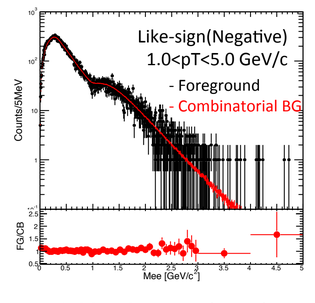


Figure 7: Foreground, combinatorial background, and their ratio for like-sign pairs in Min.Bias with p_T slilces

- Foreground and combinatorial background are shown with p_T slices in Min.Bias.
- FG to CB ratio is calculated for like-sign. It will be used BG subtraction.

Estimation of correlated backgrounds

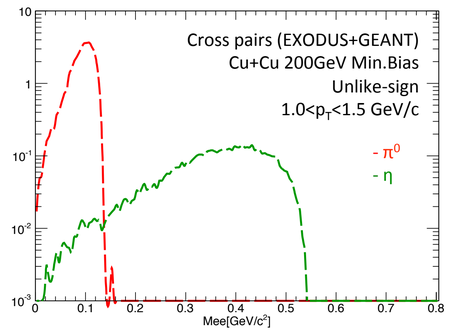


Figure 8: Cross pairs from double Dalitz decay of π^0 and η for 1.0<p_T<1.5 GeV/c in Min.Bias.

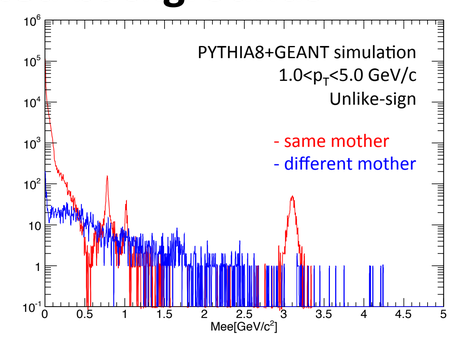


Figure 9: PYTHIA8 simulation. Red line is electron pairs from same mother particle, and blue line is electron pairs from different mother particle

Hadronic cocktail

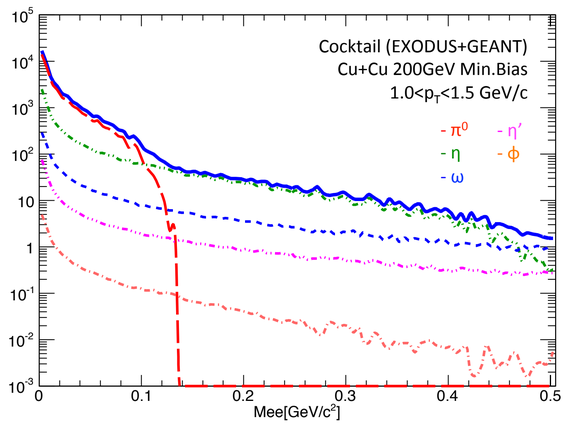


Figure 10: Hadronic cocktail calculated by EXODUS plus a PHENIX GEANT simulation for 1.0<p_T<1.5 GeV/c in Min.Bias.

- Correlated backgrounds are obtained by simulations in Fig.8 and Fig.9.
- These BGs will be normalized using like-signs, and will be subtracted from FG.
- Hadronic cocktail is calculated in Fig.10.

<u>What's going to be new?</u>

- Meson to π^0 ratios at high-p_T are updated from the preliminary plot.
- Generated particles by EXODUS and PYTHIA are passing through a PHENIX GEANT simulation.
- In the previous analysis, the particles are just filtered through the PHENIX acceptance and smeared with the detector resolution.

Analysis

Dielectron invariant mass

- The equation of invariant mass

$$M_{ee} = \sqrt{(E_1+E_2)^2 - (\vec{p}_1+\vec{p}_2)^2}$$

- The unlike-sign foreground spectrum measures the signal plus background, while the like-sign spectra measure only background.

$$ULS = A_{+-}(Combinatorial) + B_{+-}(Jetpair) + C_{+-}(doubleDalitz) + Signal$$

$$LS = A_{++,--}(Combinatorial) + B_{++,--}(Jetpair) + C_{++,--}(doubleDalitz)$$

Backgrounds

<u>**Combinatorial background (CB)**</u>

- The distribution of CB is obtained via mixed-event technique.

<u>**Cross pairs**</u>

- Cross pairs are produced by two e^+e^- pairs in the final state of a meson.

e.g. $\pi^0 \rightarrow \gamma\gamma \rightarrow e^+e^-e^+e^-$, and $\pi^0 \rightarrow e^+e^-\gamma \rightarrow e^+e^-e^+e^-$.

- They are calculated by EXODUS simulation.

<u>**Jet pairs**</u>

- Jet pairs are produced by two electrons from same jet or back-to-back jet.
- They are calculated by PYTHIA8 simulation.

Cocktail of hadronic sources

- The input p_T shape of π^0 is parameterized by a modified Hagedron function. $E\frac{d^3\sigma}{dp^3} = A\left(e^{-(ap_T+bp_T^2)} + \frac{p_T}{p_0}\right)^{-n}$
- The p_T distribution of all other mesons are determined by m_T scaling.
- Each component is normalized by meson/π^0 ratios measured at high-p_T and branching ratio.

	η	ω	η'	φ
meson/π^0	0.51	0.81	0.25	0.40

Table 1: Meson to π^0 ratio at high-p_T (>5 GeV/c) [4, 5]

Data set and selections

Data set

- The data of Cu+Cu collisions at $\sqrt{s_{NN}}$ = 200 GeV were collected in 2005.

Event selection

- Collisions were collected by Min.Bias trigger.
- The centrality is determined by the BBC charge sum, and divided into four centrality classes (0-10, 10-20, 20-40, and 40-94%).

Track selection and eID

- Charged particles are reconstructed by DC and PC.
- Electrons are identified by EMCal and RICH.

The PHENIX experiment

- PHENIX has an excellent eID capability.

Electron identification

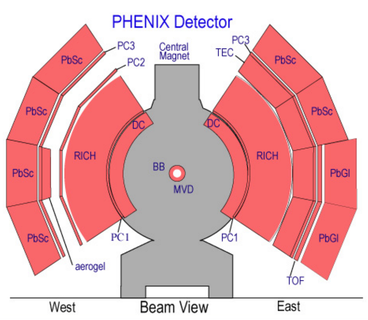
- Ring-imaging Cherenkov detector (RICH)
- Electro-Magnetic Calorimeter (EMCal)

Momentum measurement

- Drift Chamber (DC)

Centrality, z-vertex ,and Reaction Plane

- Beam-Beam Counter (BBC)



Acceptance
$\Delta\phi = \pi$
$|\eta| < 0.35$

Figure 5: Beam view of the PHENIX detector

Simulations

EXODUS

- A phenomenological event generator.
- It simulates the phase-space distribution of electron source and the decay of these sources.

PYTHIA8

- In this analysis, PYTHIA8 with CTEQ 5L parton distribution function are used.

GEANT

- Particles generated EXODUS and PYTHIA8 are passed through a PHENIX GEANT simulator to apply the PHENIX acceptance and detector resolutions.

Summary and Outlook

Summary

- Direct photons are a good probe to understand the space-time evolution of the produced medium in heavy-ion collisions.
- The motivation of this analysis is search for virtual direct photons and thermal photons in Cu+Cu.
- The analysis is ongoing aiming to be finalized and published.
- FG and CB distributions are evaluated in different p_T slices.
- Correlated BGs are estimated using EXODUS and PYTHIA8.
- Hadronic cocktail is calculated by EXODUS.

Outlook

- Subtraction of correlated BGs is now ongoing.
- After BG subtraction, real data will be compared with cocktail.

References
[1] Physical Review C 87, 054907 (2013), PHENIX collaboration
[2] Physical Review C 81, 034911 (2010), PHENIX collaboration
[3] Physical Review C 91, 064904 (2015), PHENIX collaboration
[4] Physical Review D 83, 032001 (2011), PHENIX collaboration
[5] Physical Review C 84, 044905 (2011), PHENIX collaboration