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PHENIX results on direct photon production from Au+Au collisions

Veronica Canoa Roman[a,*]

[a] *Physics and Astronomy,Stony Brook University,
100 Nicolls Rd, Stony Brook, USA*

E-mail: veronica.canoaroman@stonybrook.edu, vcanoroman@gmail.com

PHENIX measurements of low p_T direct photons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV show large yields that have simultaneously large anisotropies with respect to the reaction plane. The integrated direct photon yield was found to scale with the charged multiplicity to a power of 5/4, independent of transverse momentum and collision centrality. Calculations of thermal photon emission fall short in describing these three features. Furthermore, a recent publication of the STAR collaboration indicates lower direct photon yields in Au+Au collisions than observed by PHENIX. In order to provide new insights, PHENIX has shown first results from Au+Au data taken in 2014. These data have 10 fold statistics compared to published results. In this talk we will show the latest direct photon results from this dataset.

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1. Introduction

Direct photons, which are photons not produced in late hadron decays, have been considered an excellent tool to characterize the strongly interacting states of matter produced in heavy-ion collisions. Since photons do not interact strongly, they can carry information about the state they are emitted. Photons are very abundant in heavy ion collisions. While in low transverse momentum regime, the majority of the direct photons are of thermal origin from the QGP and hadron gas (HG) phase, the direct photons of high transverse momentum are dominated by photons created from hard scattering processes.

PHENIX has measured the direct photon spectra in Au+Au collisions at 200 GeV, where a clear excess is seen in the low p_T range (p_T < 3 GeV/c) over the hard scattering contribution estimated from p + p measurements. Such an excess of direct photons has been interpreted as being due to thermal photons and is well described by an exponential function [1]. The flow of direct photons was also measured in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV and was found to have a large v_2. The observations have brought challenges to the theorical models; a large yield implies early emission when the temperature is higher, but a large v_2 implies late emission when the flow is fully developed. The details can be found in [2]. This behavior has been observed in other experiments like ALICE. They also found large yield and large anisotropic emission that are hard to reproduce quantitatively with the theoretical models available, see [3],[4]. PHENIX, in order to provide more insights, has exploited the wealth of data sets available for direct photon analysis after 16 years of operation at the Relativistic Heavy Ion Collider (RHIC). Three different analysis methods were employed for analysis: the calorimeter method, the virtual method and the external conversion method. The calorimeter method reconstructs the photon directly from its energy deposit in the electromagnetic calorimeter [5]. The virtual method deals with virtual photons (low mass e+e- pairs) which originate from the event vertex [6]. The external conversion method uses photons which convert in real detector material to e+e- pairs [7]. Consistent results are obtained by now with these three independent analysis methods, which serve as validation of the PHENIX measurements. In addition, PHENIX has systematically studied low pT direct photon production across different collision species, centrality classes and beam energies, using the methods described above.

STAR has also reported a measurement of direct photon in Au+Au collisions at 200 GeV [8], but their result of direct photon yields are significantly lower compared to the PHENIX results. In order to address this discrepancy, a new independent measurement has been made by PHENIX with high statistics Au+Au data taken in 2014. This analysis will be described below.

2. Method

In 2014 there was already installed a silicon vertex detector (VTX) in PHENIX, which has a radiation length X/X_0 = 14%. The 2014 Au+Au dataset uses a new external conversion method to measure conversions of photons at the VTX. This new reconstruction algorithm was developed to track an e+e- pair back to its conversion position in the VTX to reconstruct the parent photon momentum. The excess photon ratio called R_γ, defined as the ratio of the invariant yield of inclusive photons γ^{incl} to the invariant yield of photons from hadron decays γ^{hadron}, was measured. The method, called double ratio tagging method [7], reduces the systematic uncertainty significantly

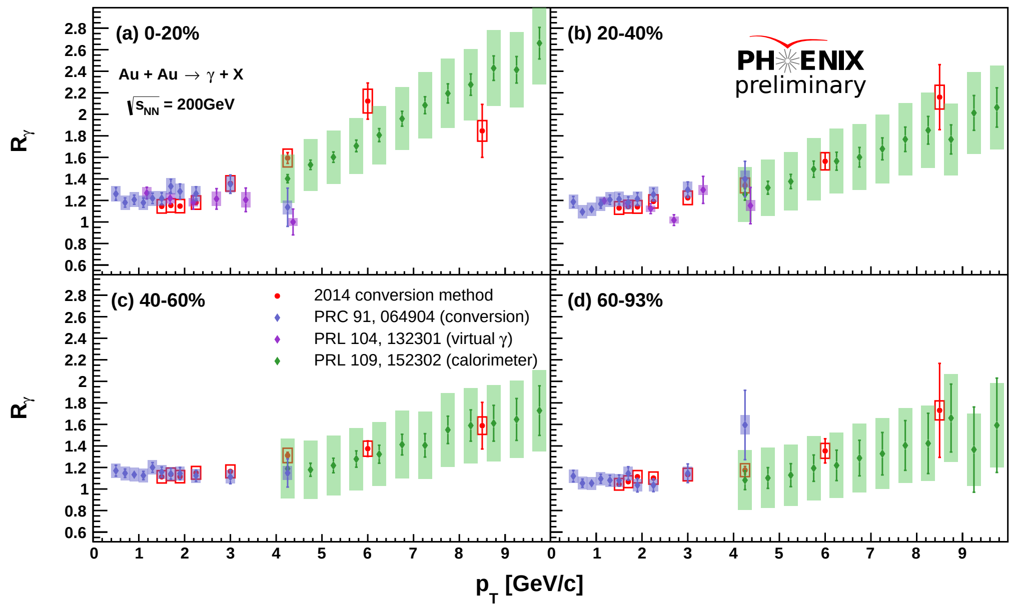

Figure 1: R_γ as a function of photon p_T for different centralities. The new results are shown in red, and the published results are in other colors.

because the systematic uncertainties of the conversion probability, the acceptance and the efficiency correction for the conversions cancel in the ratio.

3. Results

Figure 1 shows the new results of R_γ as a function of photon pT for four different centrality classes. The new result exhibits a smaller statistical uncertainty due to the high statistics sample from 2014. The preliminary systematic uncertainties are currently at a similar level as compared to the previous conversion method result.

After we have R_γ, we can calculate the direct photon yield. Figure 2 shows the direct photon yields versus photon p_T for the four different centralities. This result is compared with previous measurements. As a reference, the fit to p+p direct photon yields scaled by the corresponding N_{coll} are shown. At p_T below 3 GeV/c a clear enhancement is seen in Au+Au data compared to the p + p result. The enhancement can be observed in all the centralities and this observation is consistent with previous PHENIX Au+Au measurements. At hight p_T, the yield are consistent with N_{coll} scaled p+p yield, implying that the photons are dominantly produced by the hard scatter proccess.

An Universal scaling behavior of $dN_\gamma/d\eta$ with $(dN_{ch}/d\eta)^{1.25}$ has been observed, independent of the system, energy and centrality at low p_T direct photons for large systems [9]. This simple relation across a wide range of beam energies and system sizes suggests the source of these low pT direct photons can be similar. Figure 3 shows the integrated direct photon yield for $p_T > 1.5$ GeV/c as a function of charged particle multiplicity together with previous results for A+A systems. The

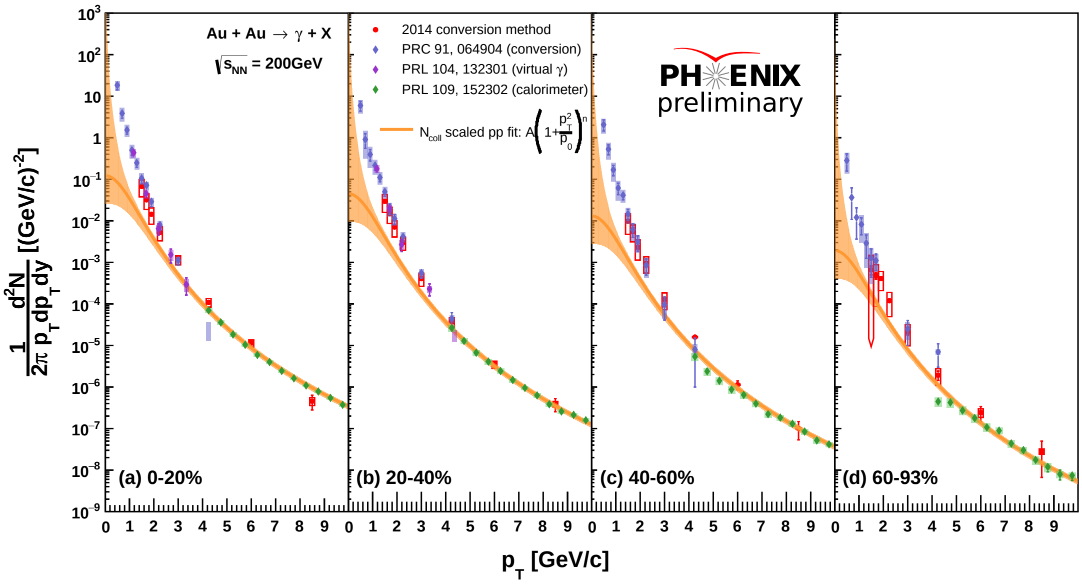

Figure 2: Direct photon yield as a function of photon p_T for different centralities.The new results are shown in red.

new results are consistent with the previous one, confirming the scaling behavior of direct photon production.

4. Conclusions

The PHENIX collaboration has performed a new independent measurement of direct photon in Au+Au collision with a high statistical dataset. The new results are consistent with the previously published measurement at PHENIX with increased statistical precision and an extended p_T reach. Because of the high statistics, we can study direct photon production in finer centrality classes. This allows going to lower multiplicities in the integrated yield, which will add more information on how scaling behavior transits from p + p to A+A systems.

References

[1] A. Adare et al. (PHENIX Collaboration), Phys. Rev. Lett. **104**, (2010) 132301.

[2] A. Adare et al. (PHENIX Collaboration), Phys.Rev. C **94**, (2016) 064901.

[3] J. Adam et al. (ALICE Collaboration), Phys.Lett. B **754** (2016) 235.

[4] J. Adam et al. (ALICE Collaboration), Phys.Lett. B **789** (2019) 308.

[5] A. Adare et al.(PHENIX Collaboration), Phys. Rev. Lett. **109** (2012) 122302.

[6] A. Adare et al.(PHENIX Collaboration) Phys. Rev. C **81** (2010) 034911.

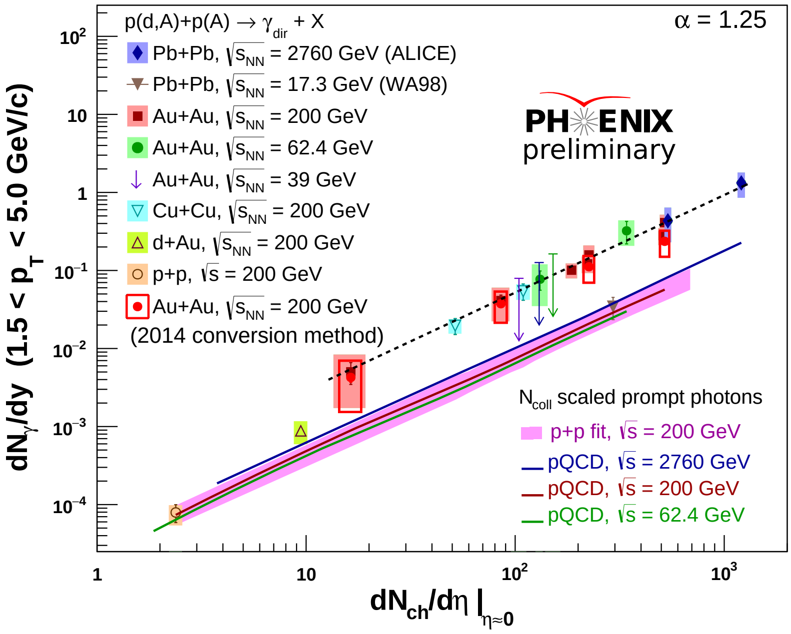

Figure 3: The integrated direct photon yield for $p_T > 1.5$ GeV/c for various collision systems and collision energies [9] as a function of the charged particle multiplicity at mid-rapidity.

[7] A. Adare et al.(PHENIX Collaboration) Phys. Rev. C **91** (2015) 064904.

[8] L. Adamczyk et al.(STAR Collaboration) Phys. Lett. B **770** (2017) 451.

[9] A. Adare et al. (PHENIX Collaboration) Phys. Rev. Lett. **123** (2019) 022301.