Measurement of low-p_T direct-photons with PHENIX

Vassu Doomra for the PHENIX Collaboration[1,*]

[1]Stony Brook University, Stony Brook, NY 11790, USA

Abstract. Photons provide snapshots of the evolution of relativistic heavy-ion collisions as they are emitted at all stages and do not interact with the medium strongly. With RHIC, measurements of low momentum direct-photons are made possible across different system sizes and beam energies. An excess of direct-photons, above the prompt photon production from hard scattering processes, is observed for a system size corresponding to $\frac{dN_{ch}}{d\eta}$ of 20-30, with a large azimuthal anisotropy and a characteristic dependence on collision centrality. In addition to the results for direct-photon spectra, azimuthal anisotropies of direct-photons in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV are also discussed, thereby, shedding light on the long-standing direct-photon puzzle.

1 Introduction

Photons and lepton pairs are the cleanest probes of the high density partonic matter produced in relativistic heavy-ion collisions. They carry unmodified information about the space-time evolution of the system as they are transparent to the medium produced. Measuring their emission rates gives direct access to the temperature of the medium and it's properties.

2 Low-p_T direct-photon measurements

Recently PHENIX measured direct-photons for the high statistics Au+Au data-set at $\sqrt{s_{NN}}$=200 GeV recorded in the year 2014 with the external conversion method in which their conversions to e^+e^- pairs at the layers of the Silicon Vertex Tracker (VTX) in the PHENIX detector system are analyzed. The results for the direct-photon spectra for every 10% collision centrality are shown in Fig. 1 (Left) for the minimum bias sample. The direct-photon excess above the prompt photon contribution is extracted by subtracting the N_{coll} scaled p+p fit from the Au+Au data and is referred to as the non-prompt direct-photon component, shown in the right panel of Fig. 1 for every 20% collision centrality. More details on this measurement can be found in [9].

2.1 Elliptic Flow of direct-photons

The anisotropic flow parameter v_2 for direct-photons is calculated using the equation $v_2^{dir} = \frac{R_\gamma v_2^{incl} - v_2^{dec}}{R_\gamma - 1}$ where R_γ is the ratio of the total photon yield (inclusive) to the yield coming from hadronic decays and $v_2^{incl/dec}$ is the elliptic flow of inclusive/decay photons measured with

*e-mail: vassu.doomra@stonybrook.edu

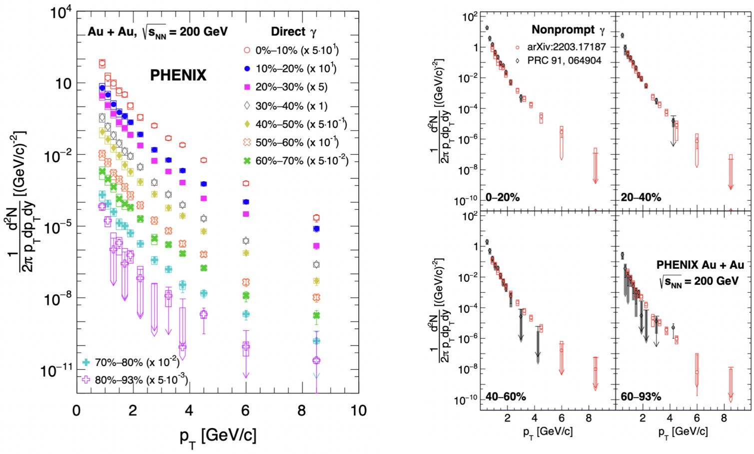

Figure 1. (Left) Direct-photon p_T spectra for minimum bias Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV for every 10% collision centrality. (Right) The corresponding non-prompt direct-photon component as a function of p_T. The red points are the current 2014 measurement. Also shown are the previous PHENIX measurements and are seen to be in good agreement with the current results.

the event plane method. The detectors used to determine the event plane are the forward silicon vertex tracker (FVTX) with $1 < |\eta| < 3$ and the beam-beam counters (BBC) with $3.1 < |\eta| < 3.9$. Fig. 2 shows the results of direct-photon v_2 as a function of p_T. Previous PHENIX measurements [7] [8] are also shown and found to be consistent with the current measurement. The high statistics 2014 data-set facilitates the measurement in finer collision centrality with an extended p_T reach. The direct-photon v_2 is consistent with zero within uncertainties in the high-p_T region. This is expected since the high-p_T region is expected to be dominated by initial hard scattering processes.

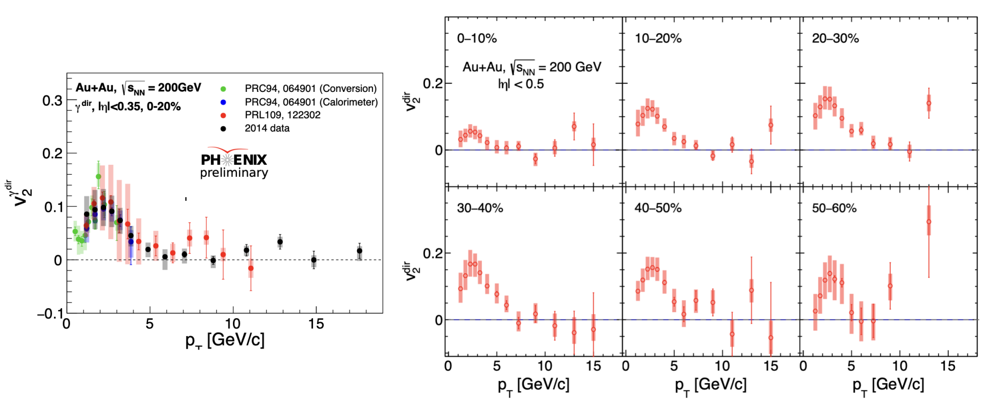

Figure 2. (Left) The v_2 of direct-photons as a function of p_T for Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV in the 0-20% centrality class both with the current measurement (shown in black) and the previous PHENIX measurements. (Right) The v_2 of the direct-photons as a function of p_T for Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV in every 10% collision centrality with the 2014 data-set.

3 e^+e^- pair continuum in p+p collisions at $\sqrt{s_{NN}}$=200 GeV

The measurement of e^+e^- pair production in p+p collisions at $\sqrt{s_{NN}}$=200 GeV is presented here as a proof of principle study. Of particular interest is the intermediate mass region ($m_\phi < m_{ee} < m_{J/\psi}$). In heavy-ion collisions, a significant contribution to this mass region comes from thermal emission from the quark-gluon plasma. In p+p collisions, however, at RHIC energies, the main physics signal in this region originates from the fragmentation and following decays of charm and bottom $q\bar{q}$ pairs. The e^+ and e^- origin from decays many microns away from the interaction point. This off-vertex component is identified statistically by measuring the distance of closest approach (DCA) to the primary vertex utilizing the VTX detector. The VTX has four layers with a total radiation length of about 15%, thus electrons from photon conversions cause a significant combinatorial background for this measurement (complementary to the direct-photon measurements), even in p+p collisions. Effective conversion rejection techniques, utilizing the VTX detector itself, have been developed to significantly eliminate this background improving the signal-to-background ratio by orders of magnitude. The effectiveness of these rejection techniques can be seen in Fig. 3 (Left). Also shown are

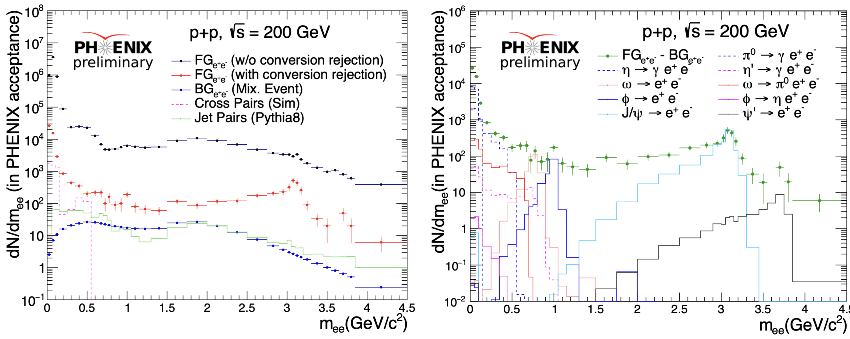

Figure 3. (Left) The invariant dilepton mass spectrum in p+p collisions at $\sqrt{s_{NN}}$=200 GeV with (red) and without (black) the conversion rejection techniques. Also shown are the correlated (cross pairs + jet pairs) and uncorrelated backgrounds. (Right) The mass spectrum, after the combinatorial background subtraction, compared to the cocktail of known hadronic sources.

the correlated and uncorrelated backgrounds under the pair continuum. The uncorrelated background (shown in blue) is combinatorial in nature and is obtained using the mixed-event technique. The correlated background can be further classified into two categories: 1) Cross Pairs (pink) stem from hadron decays with two e^+e^- pairs in the final state e.g. double Dalitz decays 2) Jet Pairs (green) which do not come from the same parent but are correlated via jets that are formed in the initial hard scattering. A comparison to the known hadronic sources, without including the heavy-flavor contributions, is shown in the right panel of Fig. 3. A good agreement is observed in the ω and J/ψ mass regions.

A transverse DCA of the central arm tracks to the interaction vertex determined by the VTX is measured using the equation: $DCA_T = L - R$ where R is the radius of the circular trajectory of the track and L is the distance from the center of that circle to the interaction vertex. A pair DCA_T is then calculated as $\sqrt{|DCA^2_{T,e^-} - DCA^2_{T,e^+}|}$ and the results are shown in Fig. 4. The average pair DCA_T is plotted as a function of the invariant pair mass and is seen to be measurably different between the intermediate mass region and the J/ψ region indicating that the sources in these different mass regions are different (with different decay lengths) and may possibly be separated in the much higher track multiplicity environment in the Au+Au

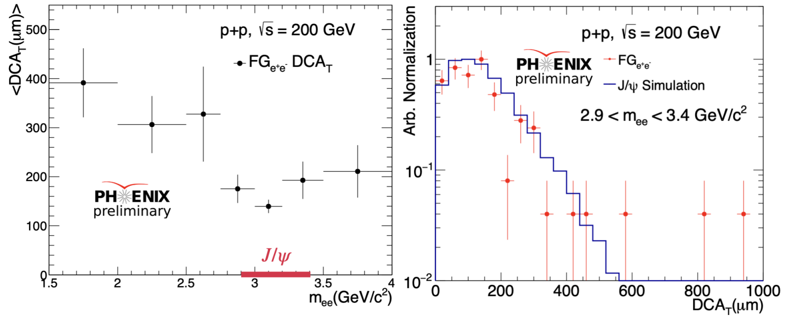

Figure 4. (Left) Average transverse DCA as a function of the invariant pair mass. The $< DCA_T >$ is measurably different between the intermediate mass region and the J/ψ mass region. (Right) The DCA_T distribution in the mass range $2.9 < m_{ee} < 3.4\ GeV/c^2$ both from data (red) and single J/ψ simulations (black) in the PHENIX framework.

data. Also shown is the pair DCA_T distribution in the mass range $2.9 < m_{ee} < 3.4\ GeV/c^2$ both from data (shown in red) and single J/ψ simulations (shown in black) filtered through the PHENIX acceptance. The two are in pretty good agreement with each other which shows that the DCA resolution, as well as the non-prompt J/ψ component, are well understood in Monte-Carlo.

4 Summary and Outlook

PHENIX continues it's efforts in advancing our understanding of the properties of the hot and dense medium produced in relativistic heavy-ion collisions. Measurements of both the direct-photon spectra and elliptic flow are reported in this paper. The v_2 of the direct-photons is shown to be consistent with zero within uncertainties in the high-p_T region. PHENIX has also revived it's dilepton analysis efforts by presenting a proof of principal study with the p+p data at $\sqrt{s_{NN}}$=200 GeV and plans to extend this measurement to the high statistics Au+Au data at $\sqrt{s_{NN}}$=200 GeV.

References

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