Prompt Photon Production and Photon-Jet-Hadron Correlations in PHENIX

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Abstract

A variety of heavy-ion data from RHIC and recently also from the LHC on hard direct photon production testifies that this non-interacting probe of the densely colored QGP continues to lend new insights to understanding jet suppression and energy loss. In this talk, we report on new results of high p_T single direct photon production in both p+p and Heavy Ion systems. Additionally, new PHENIX results on fragmentation functions of the direct photon-jet photon-hadron correlations from the 2010 dataset, when combined with the previous 2007 dataset result, now show an enhancement that is statistically significant in regions of low z. It is found that this enhancement appears to occur over relatively wide angles from back-to-back with respect to the direct photon trigger.

1. Introduction

Since it lacks color charge, the photon escapes the strongly interacting Quark Gluon Plasma (QGP) without interacting[1]. Therefore, as a complement to di-hadron correlations which can directly access di-jet production and their structure [2], [3], direct photon-hadron correlations can be used to study photon-jet production in the medium without various biases and complications [6, 7]. In this talk we report significant advancements in being able to gain quantitative information both direct photons and γ-h fragmentation studies at RHIC by the PHENIX experiment.

2. New Direct Photon Spectra Results

Since late 2006, PHENIX's preliminary direct photon R_{AA} result, which was the second measurement of this quantity by PHENIX, and which extended the p_T reach to near $\sim$ 20 GeV/c, was found to contain a slightly ambiguous result [5]: specifically, the R_{AA} values were as low as $\sim$ 0.6 (with systematic errors of nearly 20-30%) at the highest p_T, which opened the possibility of larger-than-expected initial state suppression effects for photons such as isospin or anti-shadowing [4]. Recently PHENIX updated this result, with both a newly finalized p+p reference based on a larger 2006 dataset and a new final analysis of the Au+Au dataset. Figure 1 (left panels) panels) shows these new results[10] which show that this trend in the data has gone away, reconfirming that the photon production is unmodified in Au+Au compared to p+p. This

[1] A list of members of the PHENIX Collaboration and acknowledgements can be found at the end of this issue.

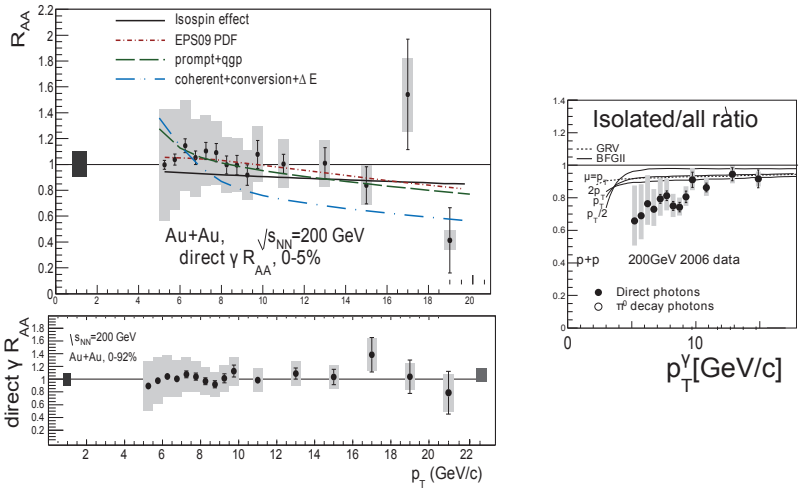

Figure 1: (Color online) Various ratios involving single direct photon spectra: (left) R_{AA} in central and MinBias Au+Au, (right) fraction of direct photons which are isolated in p+p, plotted *vs.* p_T. (See text for discussion).

measurement provides the basis of the statistical method to be used for subsequent γ-h results in this report, as it provides the baseline estimate of background to subtract away and thereby separate the prompt photon contribution.

Some other interesting insights are available from these and other new Direct photon spectra measurements from PHENIX. For example a new R_{dAu} result for photons is available [8] and can be used to explore surprising effects found in jets [9]. Another interesting observation shown in the top panel of Figure1 one can see a hint of a drop in the isolated fraction near $p_T = 5$ GeV/c, because if one then used the isolated spectra as the baseline for the R_{AA} this might imply a larger enhancement in the R_{AA} in this p_T region, where jet-medium photons[11] are expected to make a contribution.

3. Direct Photon-Hadron Correlations

Another improvement shown in this report is based on a preliminary result of the I_{AA} first shown in 2009 [12] for γ-h correlations measured based on the 2007 AuAu dataset which has now been improved by adding a slightly larger 2010 dataset. This result measures the ratio of of fragmentation functions in p+p *vs* Au+Au. In the old result, a hint of a rise was seen from the suppressed value first published by PHENIX [6] for awayside yields at large fragmentation momentum fraction z (for which here $z_T = p_{T,h}/p_{T,\gamma}$ is used) going to small z. This could be interpreted as manifestation of the energy lost by jets reappearing in lower momenta particles but still correlated in the jet direction. However the previous result was not statistically significant. Using the exact same methods (see [12]), except with expanded centrality selection (now 0-40% central), slightly different kinematic selections, and the 2010 dataset addition, one can now see a clear and statistically significant enhancement compared to the $p + p$ yields, which

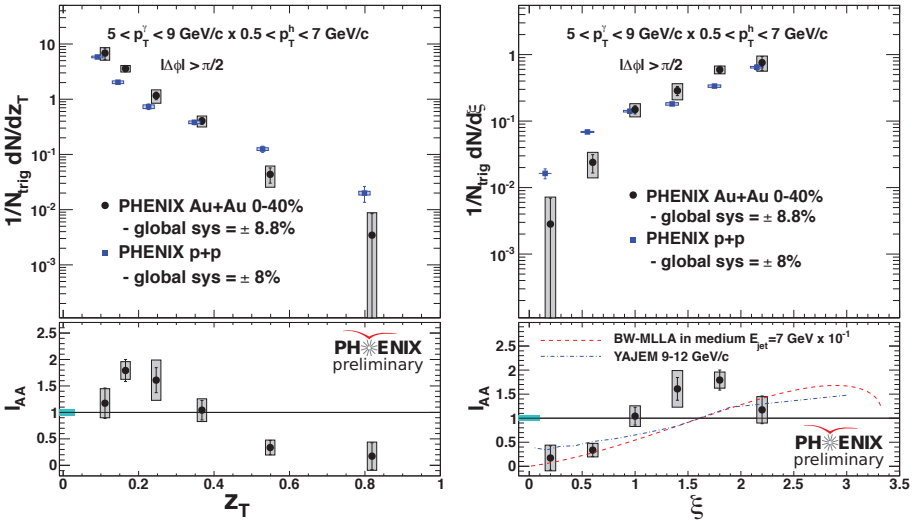

Figure 2: Awayside γ-h correlated per-photon yields for Au+Au and p+p 200 GeV *vs*. $z_T \approx z$ and $\xi = -ln(z_T)$, along with their ratio I_{AA}.

develops at low z (high $\xi = ln(1/z_T)$) shown in Figure 2. As shown on the figure this behavior is qualitatively similar to predictions by energy loss models [13],[14]. However the data rise to a larger enhancement and do so at lower z than do the models, something that will be interesting to resolve theoretically and experimentally as the measurement is finalized. Nonetheless the result clearly shows a modification of the fragmentation function shape in Au+Au.

The PHENIX method obtains the full $\Delta\phi_{\gamma-h}$ dependence of the correlation yields. By looking at the shape of the jet functions themselves which have been shown, but not included here, one can see that the enhancement above the p+p correlation yields seems to appear away from the back-to-back area, although generally only enough to be consistent with a broadening, but not displaced peaks as previously seen at lower p_T, which are now known to be due to v_3 [15, 16]. Thus, with the improved statistical capabilities in this data, one can integrate in different awayside regions and determine how these features translate to fragmentation function modification. In figure 3 we see that if we restrict the integration to a small region around π (typically called the "head region") the enhancement and overall modification in shape going from low to high z seems to be less and enhancement over $p + p$ is not significantly higher than 1. The largest enhancement indeed appears when integrating over the full awayside.

One concern that was explored was whether indeed effects of v_3 and other higher-order harmonics in the combinatoric background subtracted in these measurements [6] could be causing this enhancement signal falsely. In fact, the method used does not subtract v_3 or higher harmonics directly from the raw correlation function, since v_n measurements are not actually available for the p_T regions used. But the effects of those extra correlations were explored using conservatively large v_n estimates and found to be negligible for this analysis. The reasons are two-fold: 1) since we only correlate rather high p_T triggers (photons and background π^0), the combinatoric contribution from the flowing soft underlying event (UE) is small. This was shown to be the case in [17] where the v_3 induced "fake mach cone" displaced peaks disappear for trigger

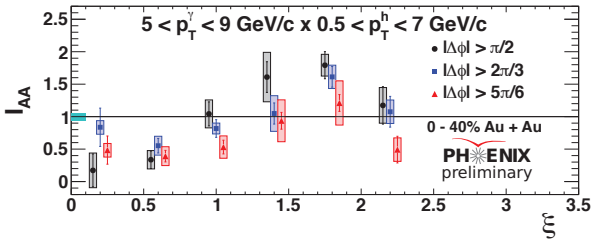

Figure 3: Same as Figure 2 but plotted for three different sizes of angular integration regions around π.

hadron p_T's starting around 5 GeV/c, the minimum value used in this analysis. But even more importantly, 2) due to the fact that our method "double subtracts" the already UE-subtracted jet functions of decay photons (estimated from $\pi^0 - h$ correlations) from inclusive photons to obtain the direct photon correlations, any residual unsubtracted v_n contributions in those jet functions largely cancel.

4. Summary

New PHENIX results of single direct photon production in Au+Au, p+p, and even d+Au, continue to improve and inform energy loss studies in relativistic Heavy Ions, including providing more constraints for only a small level of initial state or cold nuclear effects. Direct photon-hadron correlations have also been able to make a first statistically significant measurement of fragmentation function modification for jets away from direct photon triggers, including an enhancement at low z, which along with the previously observed high z suppression could be manifestations of the lost jet energy. This is observed to occur over a wide angular range (out to $\gtrsim 1$ rad) around the awayside.

5. References

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