Event activity, direct photons and photon/hadron ratios in asymmetric collisions

Gabor David
Stony Brook University

Introduction

Asymmetric collisions (like p+Au), initially meant as straightforward control experiments to set a baseline against which AA collisions, and the QGP formed in them can be tested, started to offer surprising physics insights on their own in the past decade. Long-range correlations in pseudorapidity, azimuthal anisotropies similar to those seen in AA+ have been observed in p+Au as well, as were nuclear modification factors at high p_T reminiscent of “jet quenching” in the QGP formed in AA. “If it looks like a duck, swims like a duck, quacks like a duck, it probably is a duck.” In QGP indeed formed in p+Au (or even pp)? We are agnostic about this, but argue that apparent jet suppression (or enhancement!) should not be part of this discussion, not the least because we understand it today, it depends on pathlength of partons traversing the QGP, and even if droplets of QGP are formed in p+Au, and exhibit genuine flow, they are way too small to cause substantial energy loss. Two other known issues are that – contrary to AA+ – the suppression in “central” p+Au does not saturate with increasing p_T (R_AuAu keeps decreasing monotonically), and the counter-intuitive enhancement in “peripheral” collisions keeps increasing (see Fig. 1).

Event activity vs collision geometry

Traditionally collision geometry has been calculated based on the Glauber model, connecting it to observables with the assumption that “the majority of the initial state X’s collisions will be analogous to MB pp collisions with small perturbation from much rarer hard interactions” (Annu. Rev. Nucl. Part. Sci. 57, 205-243 (2007)). Glauber himself wrote about the validity of his approach, that it “is only adequate for … small angle scattering” without simple energy conservation transfer. The issue is well demonstrated in Fig. 2 for p+Au collisions: as the highest p_T observed at mid-rapidity increases, soft particle production at high rapidities (the usual input to establish centrality) is gradually depleted.

In PRC 97, 054904 (2018) it is pointed out that in p+Au the “puzzling enhancement seen in peripheral events at RHIC and the LHC, as well as the suppression seen in central events at the LHC are possibly due to mis-binning of central and semi-central events, containing a jet, as peripheral events…” Partonic correlations built out of simple energy conservation are responsible for such an effect. An illustration of these calculations is shown in Fig. 6.

In summary, since high transverse momentum direct photons are a “standard candle” for initial hard scattering, and, per extension, for collision geometry not only for pp and AA+, but also for small-on-large collisions. If true, comparing the centrality dependence of direct photon and hadron production in p+Au as a robust test of the applicability of the Glauber model in such systems.

High p_T photons to the rescue?

The production of high p_T direct photon in p+p is well understood and described by NLO pQCD (see Fig. 7); the majority of them comes from high momentum transfer 2 → 2 processes.

Figure 3: Distribution of event activity in the zero degree calorimeter in presence of a high p_T hadron trigger at mid-rapidity. Figure taken from PLB 785 (2018) 95-115.

Figure 4: Distribution of event activity in the forward calorimeter in presence of a high p_T hadron trigger at mid-rapidity. Figure taken from PLB 785 (2018) 95-115.

Figure 5: Normalized R_AuAu versus centrality for AuAu and PbPb collisions at 200GeV and 2 TeV, respectively. Figure taken from PLB 773, (2017) 408-411.