PHENIX High Pt Results

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Abstract.
In heavy ion collisions, the high p_T observables convey information about the initial conditions of the system under study. The suppression of high p_T neutral pion and charged hadrons yields with respect to the nucleon-nucleon binary scaled p-p collisions and the particle composition in Au+Au collisions (as measured by the PHENIX [1] experiment during the first two runs of the Relativistic Heavy Ion Collider (RHIC)) are briefly reviewed. Finally, the newest results from the RHIC Run 3 d+Au, which disentangle initial and final state effects, are presented.

Heavy-ion collisions at RHIC aim at the study of QCD matter at extreme energy densities where lattice [4] calculations predict a transition from hadronic matter to a deconfined plasma of quarks and gluons. High transverse momentum ($p_T > 2$ GeV/c) hadrons, arising from the fragmentation of partons (quarks and gluons) scattered with large momentum transfer in the initial parton-parton scattering[5], provide excellent probes of the matter thus created [2, 3].

A standard way to quantify nuclear medium effects on high p_T production is provided by the nuclear modification factor, which we define for A+B collisions as the ratio of invariant yield in A+B to that of p+p, scaled by the number of binary collisions.

$$R_{\mathrm{AB}}(p_T) = \frac{(1/N^{evt}_{\mathrm{AB}})\, d^2N_{\mathrm{AB}}/d\eta dp_T}{\langle N_{coll}\rangle/\sigma^{inel}_{\mathrm{pp}} d^2\sigma_{\mathrm{pp}}/d\eta dp_T},$$

where $\langle N_{coll}\rangle$ is the average number of inelastic nucleon-nucleon (NN) collisions per event, and $\langle N_{coll}\rangle/\sigma^{inel}_{\mathrm{pp}}$ is the average Glauber nuclear overlap function $\langle T_{AB}\rangle$.

For heavy ion collisions R_{AB} is expected to be below unity for $p_T < 2$ GeV/c, because the bulk of the particle production is due to soft processes which scale closer to the number of participant nucleons [6] than to $\langle N_{coll}\rangle$. On the contrary, for high p_T production, R_{AB} should be unity in absence of any nuclear medium effect. But it was in fact established[1] that R_{AuAu}, both for neutral pions and for charged hadrons, is significantly below unity for the most central collisions, which is now commonly referred to as "the high p_T suppression". The suppression is more or less independent of p_T above 4 GeV/c and increases as a function of the centrality of the collision, the most central collisions experiencing the most pronounced suppression (Fig. 1).

[1] first observed during RHIC Run I Au+Au at $\sqrt{s_{NN}} = 130$ GeV/c [7, 8, 9] and later on confirmed within an extended p_T range in Run II Au+Au at $\sqrt{s_{NN}} = 200$ GeV/c [10, 11]

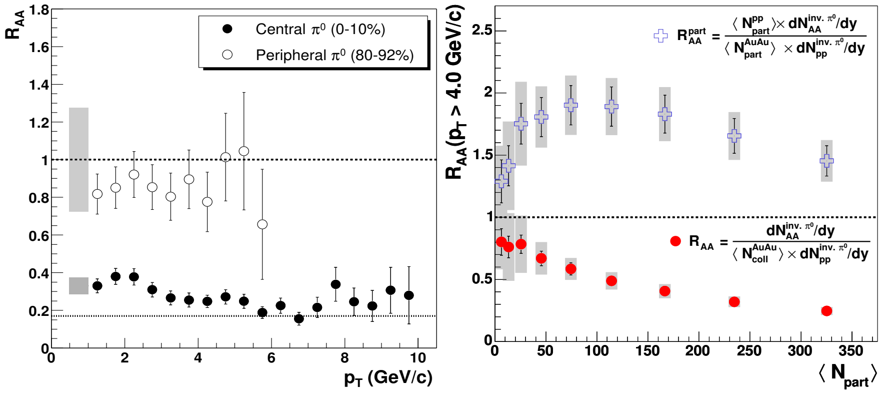

FIGURE 1. Left: nuclear modification factor $R_{AA}(p_T)$ for π^0 in central (closed circles) and peripheral (open circles) Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as a function of p_T. Note how the π^0 production is suppressed by almost a factor 5 at high p_T in central collisions. Right : R_{AA} for p_T> 4 GeV/c as a function of centrality (both figures from [10]).

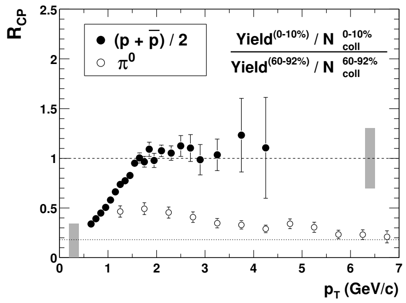

FIGURE 2. Nuclear modification factor R_{CP} for $(p+\bar{p})/2$ (filled circles) and π^0 (from [14]). Note how protons are not suppressed, in the accessible p_T range, in contrast to pions.

It should be noted that the p+p reference spectrum used to compute R_{AA} is also determined by the PHENIX experiment [12].

Another striking characteristics of the high p_T suppression is its dependence on particle type. It was observed that π^0 are more suppressed than charged hadrons [7] and that the yields of p and $\bar{p}$ near 2 GeV/c in central collisions are comparable to those of pions [13]. The nuclear modification factor for p and $\bar{p}$, expressed here in a slightly different way,

$$R_{\mathrm{CP}} = \frac{yield^{0-10\%}/N_{coll}^{0-10\%}}{yield^{60-92\%}/N_{coll}^{60-92\%}},$$

i.e. as the N_{coll}-scaled ratio of the central yield over the peripheral yield, has been analyzed [14], and exhibit no suppression, in constrast to that of the pions (Fig. 2, see also [15]).

Shortly before this conference, the origin of the high p_T suppression could be roughly ascribed to two different kinds of processes. Theoretical studies of parton propagation

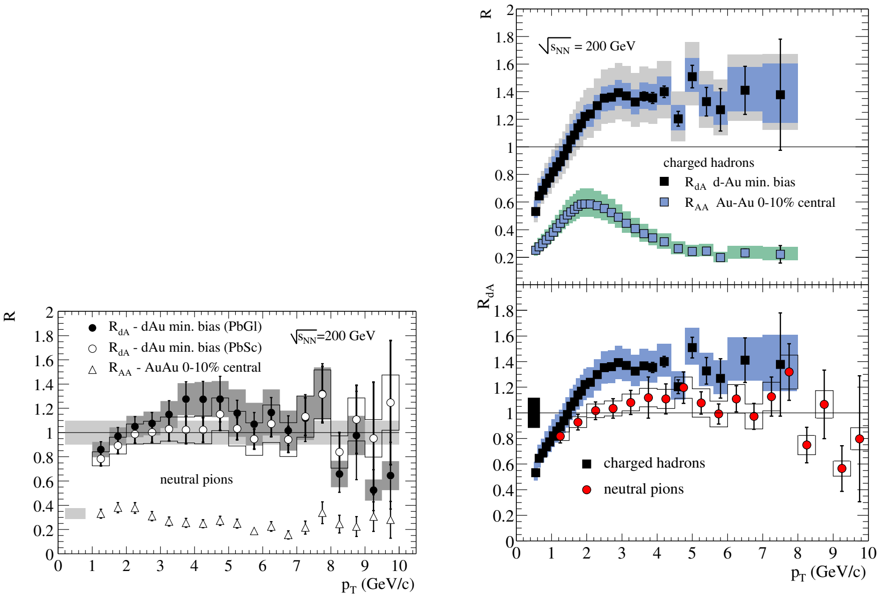

FIGURE 3. Nuclear modification factor for π^0 in d+Au (circles) and central Au+Au collisions (squares). Top right : nuclear modification factor for charged hadrons in d+Au and Au+Au, bottom right : comparison of R_{dA} for π^0 and $(h^+ + h^-/2)$ (from [24]). Note how R is different in d+Au and Au+Au collisions.

in high density matter suggest that partons lose a significant fraction of their energy through gluon bremsstrahlung [2, 3], reducing the parton momentum and depleting the yield of high p_T hadrons [16, 17, 18, 19, 20, 21]. This is a final-state effect in the spatially extended medium created in A+A collisions, and is the first possible explanation of the observed suppression. On the other hand, initial state effects (nuclear modifications to the parton momentum distributions -structure functions-, and soft scatterings experienced by incoming parton prior to its hard scattering) could also contribute. These initial effects should be both present in A+A and d+Au collisions. Interpretations of Au+Au collisions based on initial-state parton saturation effects [22] or final-state hadronic interactions [23] also predict a considerable suppression of the hadron production at high p_T. It was therefore of paramount interest to determine experimentally the modification, if any, of high p_T hadron yields due to initial state nuclear effects for a system in which a hot, dense medium is not produced in the final state. This was performed during the RHIC Run 3 (d+Au at $\sqrt{s_{NN}} = 200$ GeV/c) and the first results were presented at this conference, thus solving part of the puzzle.

The nuclear modification factor R_{dA} is plotted for three independent analyses in Fig. 3 : two neutral pion analyses making use of the two PHENIX electromagnetic calorimeters (PbSc and PbGl) and one charged hadrons analyses making use of the tracking capabilities of PHENIX [24]. The data clearly indicates that there is no suppression of high p_T particles in d+Au collisions. At variance, we do observe an enhancement for $p_T > 2$ GeV/c ("Cronin effect", already observed in p+A fixed target experiment [25]).

Those observations indicate that the suppression in central Au+Au collisions is not an initial state effect, but instead that it is a final state effect of the produced dense medium.

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