Neutral pion production with respect to centrality and reaction plane in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV[†]

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The suppression of high transverse momentum (p_T) hadrons in relativistic heavy ion collisions was observed at the Relativistic Heavy Ion Collider (RHIC). The phenomenon is interpreted as the energy loss of a hard-scattered parton in the hot, dense, strongly interacting quark–gluon plasma (QGP) formed in the collisions. The suppression patterns are quantified by the nuclear modification factor R_{AA} of the neutral pion as

$$R_{AA}(p_T) = \frac{1/N^{\rm evt}_{\rm AA} d^2/dp_T dy}{\langle T_{AB}\rangle\, d^2\sigma^{\pi^0}_{pp}/dp_T dy}, \quad (1)$$

where $\sigma^{\pi^0}_{pp}$ is the production cross section of π^0 in $p+p$ collisions, $\langle T_{\rm AB}\rangle = \langle N_{coll}\rangle/\sigma^{\rm inel}_{pp}$ is the nuclear overlap function averaged over the relevant range of impact parameters, and $\langle N_{coll}\rangle$ is the number of binary nucleon–nucleon collisions computed using $\sigma^{\rm inel}_{pp}$. In this paper, the results of π^0 production and R_{AA} and its azimuthal angular dependence are presented. The results are based on the data collected in the 2007 RHIC run. The data sample is four times larger than that of Ref.[1]. Furthermore, the reaction plane detector installed in 2007 improved event-plane resolution.

Firstly, the measured π^0 invariant yields of Au+Au collisions for all centralities and for minimum bias data have been reported. These results are compared to the published η yields[2]. The measured η/π^0 ratios from minimum bias collisions for various data sets and colliding systems are compared. Although the uncertainties vary, the ratios of η/π^0 are consistent with previously published ones and are also consistent with the overlaid PYTHIA-6.131 $p+p$ calculation. The production rate of η/π^0, 0.46±0.01(stat)±0.01(syst), is constant with the centralities at $p_T >2$ GeV/c for the same collision energy. These observations indicate that at high p_T, the fragmentation occurs outside the medium and the ratio is governed by vacuum fragmentation.

Secondly, the nuclear modification factor R_{AA} of π^0 is compared to the previous result and the charged hadron R_{AA} at the LHC energy. The yields of π^0 are suppressed by a factor of 5, as in earlier measurements; however, with the improved statistical and systematic uncertainties, the significant rise of R_{AA} as a function of p_T with a slope $d\mathrm{R_{AA}}/\mathrm{dp_T}$ of $0.0106\pm^{0.0034}_{0.0029}$ $(\mathrm{GeV}/c)^{-1}$ in central collisions has been observed for the first time at the RHIC energy. In comparison with the charged hadron R_{AA} observed in $\sqrt{s_{NN}}$ = 2.76 TeV Pb+Pb collisions at the Large Hadron Collider (LHC) (ALICE experiment)[3], the two data sets for RHIC and LHC appear to be similar for the entire p_T range of 5–20 GeV/c. However, the RHIC and LHC are different in terms of colliding energy, resulting in an approximate increase by a factor of 2 increase in the parton density at the LHC[4]. On the basis of the slope of the p_T distribution and R_{AA}, the average fractional momentum loss ($\mathrm{S_{loss}}$) of π^0 is deduced. If one assumes that the fragmentation function of the parton after energy loss is unchanged, the $\mathrm{S_{loss}}$ can be interpreted as the average fractional energy loss of the initial parton. The calculated $\mathrm{S_{loss}}$ shows a decrease with increasing p_T at central collisions. In comparison with the $\mathrm{S_{loss}}$ value of the ALICE charged hadron measurement ($\mathrm{S_{loss}} \sim 0.3$), the $\mathrm{S_{loss}}$ at the PHENIX π^0 measurement below 10 GeV/c ($\mathrm{S_{loss}} \sim 0.21$) is about 30% lower value.

To study the path-length dependence of the suppression, the π^0 yield is also measured at different azimuthal angles with respect to the event plane; a strong azimuthal-angle dependence of the π^0 R_{AA} is observed. The data are compared to theoretical models of parton energy loss as a function of the path length L in the created medium. While all models considered describe the ϕ-integrated R_{AA} adequately, the pQCD-based calculations, in which the energy loss depends on the path length as L^2, fail to describe the differential $R_{AA}(\Delta\phi)$. The data obtained using a hybrid model[5] that utilizes pQCD for hard interactions and anti-de-Sitter space/conformal field theory[6] (AdS/CFT) for soft interactions is also compared to the measured data, and were able to obtain an adequate fit. Since the energy loss in this model is proportional to L^3, the data require an energy loss with a power greater than 2, as given by models in which the soft interactions with the medium are strongly coupled. Therefore, one is led to the tentative conclusion that strong coupling plays an important role in parton energy loss in the medium.

References
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