Measurement of $\pi^0$ and $\eta$ Mesons with PHENIX in $\sqrt{s_{NN}} = 200$ GeV Au+Au Collisions at RHIC

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The $\pi^0$ meson has been a crucial probe for observing jet quenching in ultrarelativistic heavy-ion collisions at RHIC. Measurements of the $\eta$ meson in the same collisions have also shed light on a possible dependence of the observed suppression on the particle species. The preliminary $\pi^0$ nuclear modification factor $R_{AA}$ from the 2004 RHIC run allowed a first systematic comparison between a precise measurement with high statistics and theoretical calculations, constraining model parameters such as the initial gluon density $dN_g/dy$, and the transport coefficient $\hat{q}$. The final $\pi^0$ spectra and $R_{AA}$ are shown as well as the first $\eta$ results obtained with both PHENIX electromagnetic calorimeters.

I. INTRODUCTION

Previous measurements at RHIC have shown a significant suppression of $\pi^0$, $\eta$, and charged hadrons in central Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV compared to binary scaled p+p collisions [1, 2]. The ~30 times larger dataset from the 2004 RHIC run allows a more precise measurement of the observed suppression, reaching higher transverse momenta as well. Both the higher precision and the higher $p_T$ reach are crucial for techniques used to constrain parameters of theoretical models such as the initial gluon density $dN_g/dy$, and the transport coefficient $\hat{q}$ with the measured data [3]. The data can also be used to calculate the dependence of the suppression on the number of participant nucleons $N_{\text{part}}$ [4]. The measurement of the $\eta$ meson up to higher transverse momenta than in previous measurements sheds further light on the understanding of energy loss. Together with the measurement of direct photons and other hadrons, the PHENIX data allow more detailed studies of predictions and assumptions of parton energy loss models.

II. MEASUREMENT OF $\pi^0$ AND $\eta$ SPECTRA

Both neutral mesons $\pi^0$ and $\eta$ are measured in the PHENIX experiment via their two photon decay [5, 6]. The decay photons are measured with the Electromagnetic Calorimeter, consisting of six sectors of lead scintillator sandwich calorimeters and two sectors of lead glass calorimeters, at midrapidity. Each sector covers 22.5 degrees in azimuth, leading to a total coverage of 180 degrees in azimuth and ($|\eta| < 0.35$) in pseudorapidity. The centrality of a collision is determined with the correlation of the signals in the Beam-Beam Counters (BBC) and the Zero Degree Calorimeters (ZDC).

Uncorrected particle yields are extracted with an invariant mass analysis using event mixing for the substraction of background. Therefore in a first step the invariant mass of all photon candidates in one event is calculated. This method leads to a large combinatorial background. To estimate this background, the invariant mass of all photon candidates in the current event with all photon candidates in one or more other events is calculated. This mixed events invariant mass distribution is finally scaled to the background in the real events distribution outside the
FIG. 1: Fully corrected invariant yields for a) π0's and b) η's for different centrality selections in Au+Au collisions at √sNN = 200 GeV. The error bars show the pT uncorrelated errors.

The nuclear modification factor RAA is a measure to compare the particle spectra in nucleus nucleus collisions with the ones in p+p collisions. It is defined as $R_{AA} = \frac{1/N_{evt} d^2 N/dp_T dy|_{AA}}{T_{AA} d^2 \sigma/dp_T dy|_{p+p}}$, with $T_{AA}$ denoting the nuclear overlap function. It is shown in Fig. 2a for neutral pions in Au+Au collisions at √sNN = 200 GeV for five different centrality selections and 0-92%. A clear centrality dependence is observed, $R_{AA}$ decreases towards central events, reaching ~ 0.2 in central events. $R_{AA}$ is almost constant up to $p_T \approx 20$ GeV/c in all centralities. For the η meson, $R_{AA}$ is shown in Fig. 2b for four different centrality selections. The same centrality dependence is seen here, and the η is suppressed by a factor of ~ 5 in central events similar to the π0.
IV. $\eta/\pi^0$ RATIO

The $\eta/\pi^0$ ratio for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV for different centrality selections is shown in Fig. 3 in comparison with a PYTHIA [7] calculation for p+p collisions. The ratio is found to be independent of centrality over the whole $p_T$ range and the PYTHIA curve is in good agreement with the measured data. When fit with a constant for $p_T > 2$ GeV/$c$, the parameter varies from $c = 0.471 \pm 0.028$ (stat) for 0-10% to $c = 0.462 \pm 0.023$ (stat) for 60-92%. The ratio is consistent with data from earlier measurements at different energies and collision systems [6]. A possible explanation is that the suppression of high-$p_T$ hadrons occurs at the partonic level and that the fragmentation is not affected by the medium.

FIG. 2: Nuclear modification factor $R_{AA}$ for a) $\pi^0$ [4] and b) $\eta$ for different centrality selections in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The error bars show the $p_T$ uncorrelated errors, the boxes around the points show the $p_T$ correlated errors, the box at the left shows the normalization uncertainty.

FIG. 3: Ratio of $\eta$ and $\pi^0$ in Au+Au at $\sqrt{s_{NN}} = 200$ GeV for different centrality selections and minimum bias in comparison with a PYTHIA [7] calculation. The error bars show the $p_T$ uncorrelated errors.
V. COMPARISON WITH OTHER PARTICLES

Fig. 4 shows the nuclear modification factor for $\pi^0$ and $\eta$ in 0-10% most central Au+Au collisions at $\sqrt{s_{NN}}=200$ GeV together with $R_{AA}$ for direct photons and $\phi$ mesons. The same suppression pattern of $\pi^0$ and $\eta$ can clearly be seen, both mesons are similarly suppressed up to $p_T = 15$ GeV/$c$. In contrast, direct photons are not significantly suppressed up to the same $p_T$, but show an indication for suppression at the highest $p_T$ which is consistent with initial state effects [8]. The $\phi$, along with other mesons [9], is less suppressed than the $\pi^0$ and the $\pi^-$ meson. This interesting observation might provide an important test for jet quenching models.

VI. SUMMARY

The PHENIX experiment has measured $\pi^0$ and $\eta$ mesons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The nuclear modification factor $R_{AA}$ has been calculated, showing a similar suppression of both particles up to high transverse momenta. Both mesons are suppressed by a factor of $\sim 5$ in 0-10% central Au+Au collisions. The production ratio $\eta/\pi^0$ has also been calculated. It is centrality independent and also independent of the collision system and energy which supports the assumption of partonic energy loss. A comparison of $R_{AA}$ with direct photons and $\phi$ mesons shows a different behaviour for both particles. While the direct-photon data are consistent with initial state effects, the behaviour of the $\phi$ meson remains an interesting open question.

References

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