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# Measurement of Neutral Pion in Au+Au Collisions at RHIC-PHENIX

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## 1. Introduction

The PHENIX experiment [1] has been carried out at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) in order to find evidence of phase transition from normal nuclear matter to Quark Gluon Plasma (QGP). QGP is a new phase of matter consisting of de-confined quarks and gluons.

One of the most intriguing observations at RHIC is that the yield of  $\pi^0$  at high transverse momentum ( $p_T$ ) in central  $\sqrt{s_{NN}}=200$  GeV Au+Au collisions compared to the yield in p+p collision scaled by the number of underlying nucleon-nucleon collisions in Au+Au is suppressed [2]. The observed suppression is interpreted as a consequence of jet-quenching effect, that is, hard-scattered partons produced in the initial stage suffer large energy loss while traversing the hot and dense matter.

There are models that provide quantitative predictions of the amount of suppression. Each model involves various effects: initial state effects, Cronin effect [4] and nuclear shadowing, or strong hadronic final state effects, and energy loss in a dense matter.

The amount of suppression can be quantitated with nuclear modification factor ( $R_{AA}$ ). Nuclear modification factor is defined as following:

$$R_{AA}(p_T) = \frac{d^2 N_{AA}/dp_T d\eta}{T_{AA}(b) d^2 \sigma^{NN}/dp_T d\eta}, \quad (1)$$

where the numerator is invariant  $\pi^0$  yield in unit rapidity and denominator is expected yield in p+p collision binary scaled by the number of underlying nucleon-nucleon collisions ( $T_{AA}(b)$ ) in Au+Au.  $T_{AA}(b)$  is defined as following:

$$T_{AA}(b) = \frac{N_{collision}(b)}{\sigma_{NN}} \quad (2)$$

where  $N_{collision}(b)$  is the average number of binary nucleon-nucleon collisions with an inelastic cross section  $\sigma_{NN}$ . The number of collision ( $N_{collision}(b)$ ) is calculated via a Glauber Monte Carlo calculation as a function of impact parameter  $b$ . Figure 1 shows nuclear modification factor for  $\pi^0$ s in central  $\sqrt{s_{NN}}=200$  GeV Au+Au events compared to different theoretical calculations. It is seen that the calculation consists only the known cold nuclear effect, Cronin effect and nuclear shadowing. Large suppression is seen when comparing to cold nuclear matter.

The order of magnitude of the suppression and the  $p_T$  dependence above 3 GeV/c is well reproduced by the calculations as shown in Fig. 1. The GLV model calculation considers parton energy loss in a dense matter, and the cold nuclear effect [3, 5]. Other employs the parton energy loss

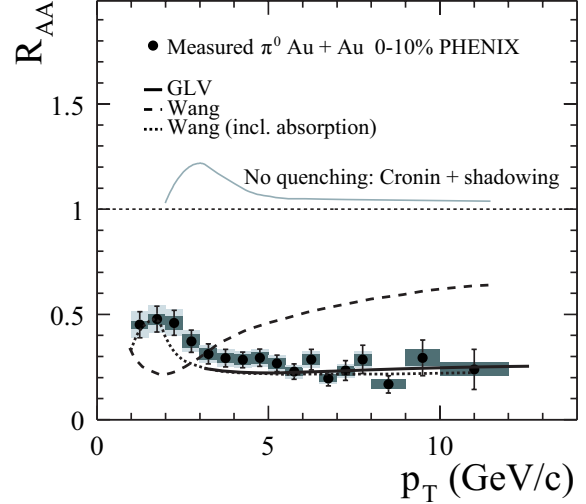


Figure 1. Comparison of  $R_{AA}$  predictions from suppression models [5, 6] against the PHENIX result in central  $\sqrt{s_{NN}}=200$  GeV Au+Au collisions. It is compared to a model without jet-quenching effect, a parton energy loss calculation based on the GLV approach, the calculation without gluon absorption and from including gluon absorption.

of 7.3 GeV/fm in dense nuclear matter. However, the calculation fails to describe the  $p_T$  dependence of the data. This might be the indication that the thermally produced gluons and the stimulated emission of gluons in the QGP phase in addition to the induced gluon radiation in the QGP need to be considered [6]. With the employment of gluon absorption, the suppression can be reproduced well.

In order to reveal the parton energy loss mechanism in the dense matter, it is important to measure  $\pi^0$  quantitatively in different system and  $p_T$  region.

## 2. $\pi^0$ measurement at PHENIX Year-4 Run

In RHIC Year-4 run PHENIX recorded the integrated luminosity of  $0.24 \text{ nb}^{-1}$  in  $\sqrt{s_{NN}}=200$  GeV Au+Au collisions and  $9.1 \mu\text{b}^{-1}$  in  $\sqrt{s_{NN}}=62.4$  GeV Au+Au collisions, which allows us to extend the measurement of  $\pi^0$  to high transverse momentum as well as to measure  $\pi^0$  at a low CMS energy.

$\pi^0$  is measured with the PHENIX electromagnetic calorimeter (EMCal) [7] via two-photon decay mode. EMCal is used to measure position and energy of photons. There are two types of calorimeters at PHENIX. One is a lead-scintillator sampling-type calorimeter, and another is a lead-glass Cherenkov calorimeter. The lead-scintillator calorimeter is used in this analysis.

Reconstruction efficiency to correct the raw  $\pi^0$  yield is calculated using computer clusters at RIKEN-CCJ. The ge-

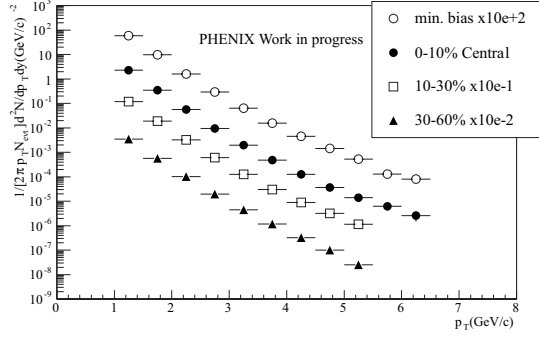


Figure 2.  $\pi^0$   $p_T$  spectra at  $\sqrt{s_{NN}} = 62.4$  GeV

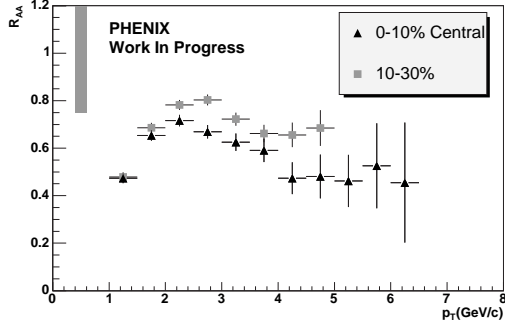


Figure 3.  $\pi^0$  nuclear modification factor as a function of  $p_T$  in ( $\sqrt{s_{NN}} = 62.4$  GeV).

ometrical acceptance correction, particle identification efficiency, and over-lapping effect in high multiplicity is estimated.

### 3. Result on $\sqrt{s_{NN}} = 62.4$ GeV Au+Au collisions

Centrality is obtained from the Beam-Beam counters and the Pad Chamber in  $\sqrt{s_{NN}} = 62.4$  GeV Au+Au collisions.

Figure 2 shows the fully corrected  $\pi^0$  invariant yield as a function of transverse momentum for each centrality of collision. From fully corrected  $p_T$  spectra, the nuclear modification factor ( $R_{AA}$ ) as a function of  $p_T$  is obtained as shown in Fig. 3. For comparing with binary scaled p+p results, the CERN-SPS experimental results of  $\pi^0$  cross section in p+p collision are used [8, 9]. There is discrepancy among the each CERN-SPS results and systematic error is assigned as 25 %. While Cronin enhancement seems to be much more prominent than 200 GeV result,  $\pi^0$  measurement in  $\sqrt{s_{NN}} = 62.4$  GeV p+p and d+Au collisions is needed for detailed study.

$\pi^0$  nuclear modification factor is compared with prediction which employs the GLV model as shown in Fig. 4 [10]. The gray band represents the perturbative QCD expectation for the suppression of  $\pi^0$ . This prediction has reasonable agreement with PHENIX result at  $p_T > 4$  GeV/c. But there is larger Cronin contribution at  $p_T < 3$  GeV/c according to the data.

### 4. Summary and Outlook

The  $\pi^0$  measurement is allowing to study the medium modifications of hard scattered particles.  $\pi^0$  is measured in  $\sqrt{s_{NN}} = 62.4$  GeV in RHIC Year-4, and it is compared with

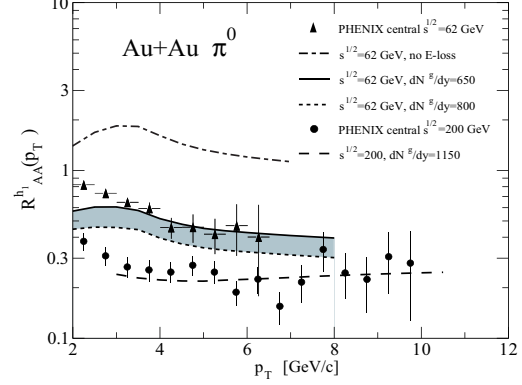


Figure 4. Comparison of  $\pi^0$   $R_{AA}$  PHENIX results, and prediction of  $R_{AA}$  using the GLV model in  $\sqrt{s_{NN}} = 62.4$  GeV and 200 GeV Au+Au collisions. Triangles and circles are PHENIX result in  $\sqrt{s_{NN}} = 62.4$  GeV and 200 GeV, respectively. The gray band represents the perturbative QCD expectation for the suppression of  $\pi^0$ . Enhancement from cold nuclear effect without energy loss is given for comparison.

Year-2 200 GeV result.  $\pi^0$  will be measured in  $\sqrt{s_{NN}} = 200$  GeV Au+Au collisions from Year-4 data. It is expected that the  $p_T$  region is extended up to 18 GeV/c in minimum bias events.

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