Charged particle transverse momentum spectra measured at mid-rapidity by STAR in the RHIC Beam Energy Scan

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Abstract

Suppression of high transverse momentum ($p_T$) charged hadrons can be measured by the nuclear modification factor, which compares binary collision-scaled $p_T$ spectra from central heavy-ion collisions to a reference spectrum, either proton-proton ($R_{AA}$) or peripheral heavy-ion collisions ($R_{CP}$). At $\sqrt{s_{NN}} = 62.4$ GeV the nuclear modification factor at high $p_T$ is consistent with medium induced quenching. Measurements by STAR of charged hadron $R_{CP}(p_T)$ in Au+Au collisions for $\sqrt{s_{NN}} = 7.7 – 200$ GeV show a smooth transition from strong enhancement of high-$p_T$ charged hadrons at $\sqrt{s_{NN}} = 7.7$ GeV to strong suppression at $\sqrt{s_{NN}} = 200$ GeV. These data will be compared with the event generators HIJING and AMPT.

Motivation

- Proving that the QGP is formed at top RHIC and LHC energies requires that signatures for its existence vanish as collision energies are reduced
- Colliding energies were varied from 200 GeV down to 7.7 GeV in the RHIC beam energy scan, and this range may be extended to even lower energies with the fixed target program proposed by STAR
- Cold nuclear matter effects were shown to compete with the mechanisms leading to suppression through d+Au collisions
- Models employing different physical mechanisms can be tested against the data in an effort to model the relative contributions from these competing effects
- Two models are shown here: HIJING and AMPT
- HIJING is a QCD-based Monte Carlo event generator
- AMPT is similar, but adds transport to the partonic and hadronic phases

Method

- Charged tracks are taken in $|\eta|<0.5$
- Particle identification from dE/dx and time-of-flight
- Single particle tracking efficiencies corrected
- TOF matching efficiency corrected
- Trigger efficiency corrected
- Spectra are obtained as a function of centrality for each $p_T$
- Default versions of the models are run
- Centrality was determined, for both the models and the data, by counting the number of charged tracks in $|\eta|<0.5$

$$R_{CP} = \frac{\langle dN/dp_T \rangle}{\langle dN/dp_T \rangle_{data}}$$

HIJING 1.383

- HIJING employs a Glauber Monte Carlo to determine participating nucleons
- QCDG is used to describe jet production above a cutoff parameter in momentum
- Low-$p_T$ multi-string interactions are described by phenomenology whose parameters are tuned using p+p data
- Details can be found in Gyulassy M. and Wang X. Phys. Rev. D 44 3501
- The identified $R_{CP}$ for K, p, and π fails to describe the species dependence of $R_{CP}$ seen in data, although it qualitatively captures the $p_T$ dependence
- The default version of HIJING overestimates $R_{CP}$ for lower energies
- HIJING fails to reproduce the data at the level of the spectra

AMPT 1.21

- AMPT uses HIJING to generate its initial conditions
- It adds Zhang’s Parton Cascade for describing partonic scatterings and A Relativistic Transport Model for hadronic scatterings
- Although the initial condition is used for hadronization in both HIJING and AMPT, AMPT’s Lund parameters were further tuned to NA49 data
- Additional details can be found in Z.-W. Lin et al. 2005 Phys. Rev. C 72 064901
- The default version of AMPT fails to reproduce the energy dependence of $R_{CP}$ but does qualitatively capture the species dependence
- AMPT does not reproduce the spectra from data

Conclusions

- Suppression of high-$p_T$ particles at top RHIC and LHC energies smoothly and monotonically evolves into strong enhancement as $\sqrt{s_{NN}}$ decreases
- The strong enhancement observed at lower collision energies complicates the interpretation of results; in particular, there may still be a QGP at collision energies that exhibit no suppression, but this signal of jet quenching is overwhelmed at these lower energies by the observed enhancement
- The default tunes of AMPT and HIJING are unable to reproduce the spectra and $R_{CP}$ seen in data well enough to use the models to predict at what energy quenching ‘turns off’
- Either these models need additional tuning or some of the model assumptions made not hold