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 $R_{CP}(\sqrt{s_{NN}}, p_T)$ 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

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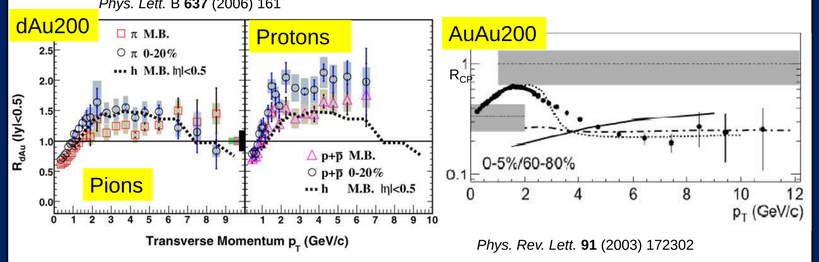
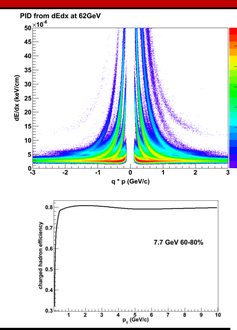
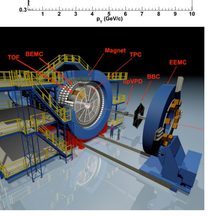


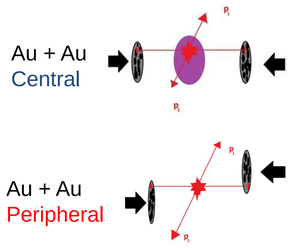
Phys. Rev. Lett. **91** (2003) 172302

Method

- Charged tracks are taken in |η|<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 $\sqrt{s_{NN}}$
- Default versions of the models were run
- Centrality was determined, for both the models and the data, by counting the number of charged tracks in |η|<0.5





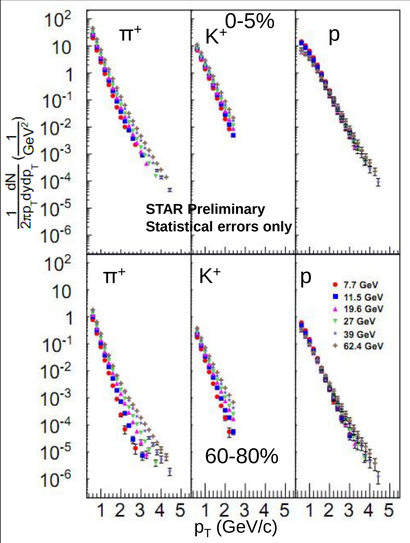


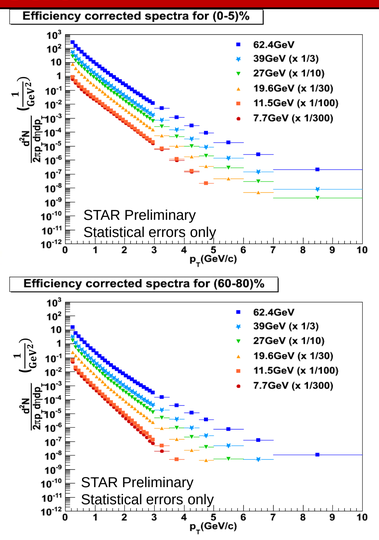
$$R_{CP} = \frac{(N_{Bin})_P}{(N_{Bin})_C} \times \frac{\left(\frac{d^2N}{2\pi p_T dp_T d\eta}\right)_C}{\left(\frac{d^2N}{2\pi p_T dp_T d\eta}\right)_P}$$

N_{Bin} ≡ number of binary collisions (from a Glauber MC model)

Ann. Rev. of Nucl. and Part. Sci. **57**, 205 (2007)

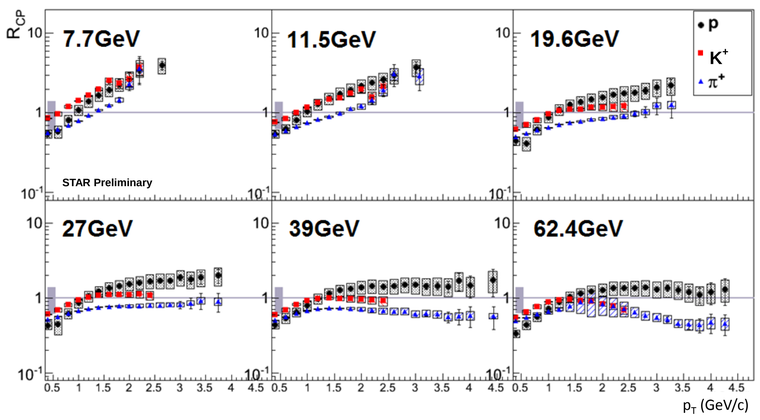
Spectra

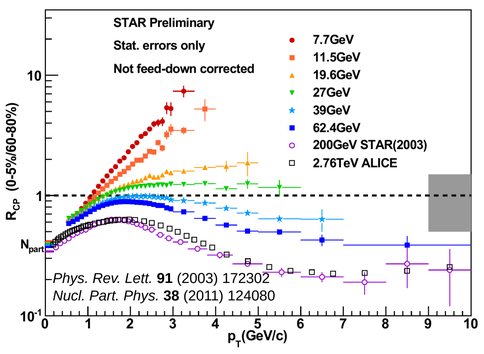




- Kaons and pions show a stronger energy dependence than protons
- Less energy dependence for central than for peripheral collisions
- The inclusive measurement has a higher p_T reach, while the identified measurement enables the study of species dependence in R_{CP}, as well as particle ratios and related measurements

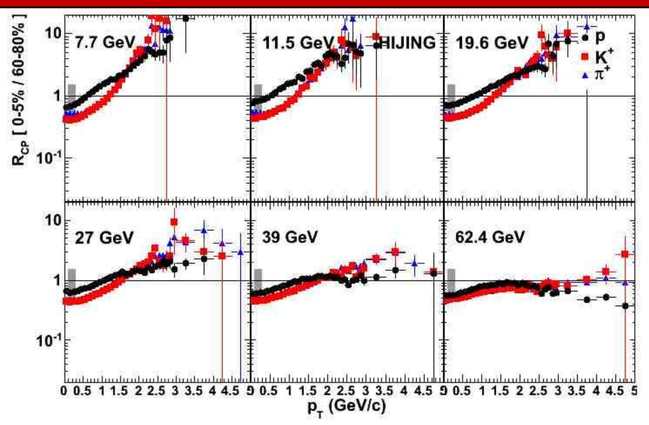
R_{CP}



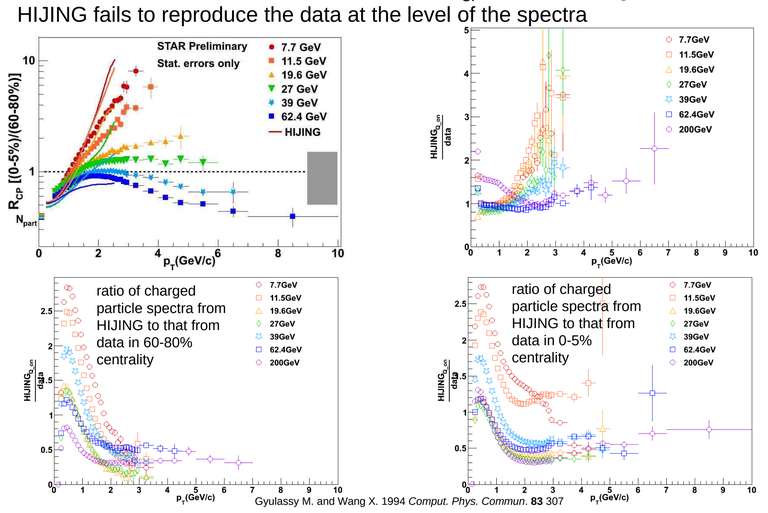


- Protons exhibit the least energy dependence with no significant suppression, even at $\sqrt{s_{NN}}$ = 62 GeV
- High-p_T kaons also show no significant suppression
- Pions vary from strong enhancement at low energies to suppression at high RHIC energies
- Inclusive charged particles show a strong energy dependence, with the RHIC beam energy scan perfectly spanning the region of interest
- Measurements of charged hadron R_{CP} at LHC energies have been largely consistent with $\sqrt{s_{NN}}$ = 200 GeV measurements at RHIC

HIJING 1.383

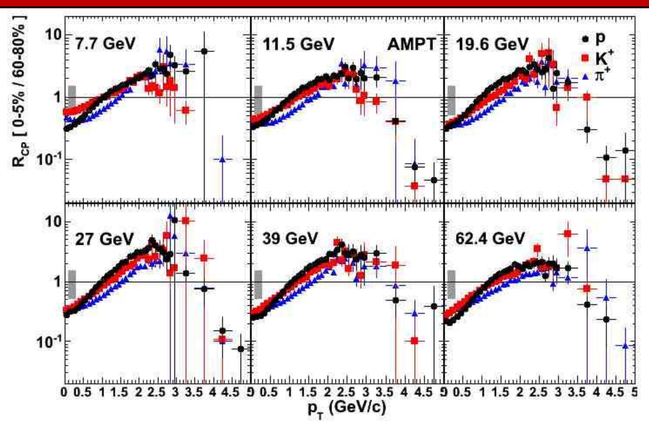


- HIJING employs a Glauber Monte Carlo to determine participating nucleons
- pQCD is used to describe jet production above a cutoff parameter in momentum
- Low-p_T multistring interactions are described by phenomenology whose parameters are tuned using p + p data from $\sqrt{s_{NN}}$ = 5 - 2000 GeV
- Details can be found in Gyulassy M. and Wang X. 1991 *Phys. Rev.* D **44** 3501
- The identified R_{CP} for π, K, and p fails to describe the species dependence of R_{CP} seen in data, although it qualitatively captures the $\sqrt{s_{NN}}$ dependence
- The default version of HIJING overestimates R_{CP} for lower energies
- HIJING fails to reproduce the data at the level of the spectra

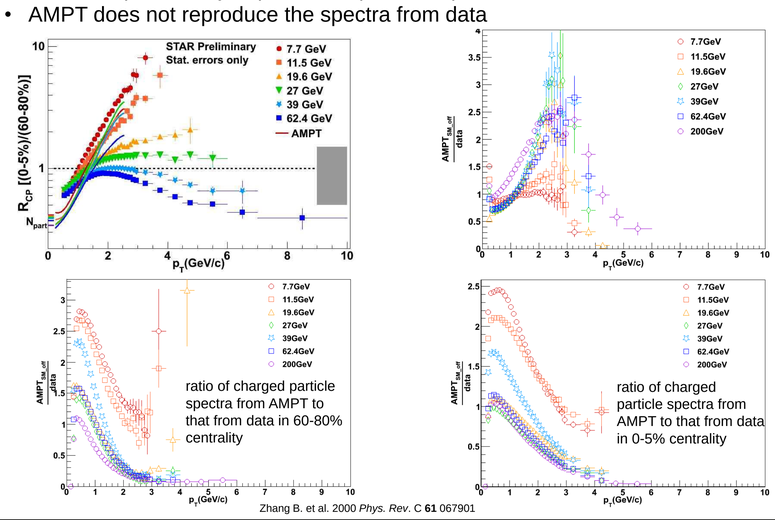


Gyulassy M. and Wang X. 1994 *Comput. Phys. Commun.* **83** 307

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 Lund fragmentation 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 Zi-Wei 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



Zhang B. et al. 2000 *Phys. Rev.* C **61** 067901

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 their model assumptions do not hold

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