Nuclear Induced Particle Suppression at Large-$x_F$ at RHIC

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For BRAHMS Collaboration
At the RHIC energies, hard scattering processes at high-$p_T$ become important.

Partons are expected to loose energy in the dense matter.

Different rapidities provide different densities of the medium: Sensitive to the dynamics.

“Dialing” initial condition channel.

Largest medium effect at mid-rapidity (“Scale” to multiplicity)?

Rapidity dependent high-$p_T$ suppression factors: provide information on dynamical medium effect.
$R_{CP}$ and $R_{AuAu}$ vs $\eta$ for AuAu @200 GeV

Suppression at $p_T = 4$ GeV/c:
- $Pb+Pb \rightarrow \pi^0 + X$, 0-7% central [WA98]
- $Pb+Au \rightarrow \pi^0 + X$, 0-5% central [CERES]
- $S+Au \rightarrow \pi^0 + X$, 0-8% central [WA80]
- $Au+Au \rightarrow \pi^0 + X$, 0-10% central [PHENIX]

X.N. Wang jet quenching:
- Non-Abelian energy loss: $\Delta E_q / \Delta E_q = 9/4$
- "Non-QCD" energy loss: $\Delta E_q = \Delta E_q$

D'Enterria '05

$R_{AA}$ ($p_T = 4$ GeV/c) vs $\sqrt{s_{NN}}$ (GeV):
“High”-$p_T$ Particle Suppression at Forward rapidities

- Expected forward “enhanced” physics processes:
  - Shadowing, Gluon saturation, Phase-space constraint/Energy conservation
  ...
- With competing physics processes:
  - Partonic energy loss, Multiple scattering, Recombination
  ...

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Forward Tomography: Dynamics + Geometry

- Shadowing+MS+Energy Loss
- "Extracted" opacity indicate longitudinally traveling Protons see less colored field
- Not a prediction: Assuming rapidity independent suppression factor
Particle Suppression due to Energy Conservation at Forward Rapidities/Large-$x_F$

- Universal suppression mechanism at large $x_F$ seen in data for various reactions
- Expected no particles produced as $x_F \to 1$ due to energy conservation;
- more multiple interactions (more gluon radiation) make the effect larger in nuclei

“Sudakov suppression”


$x_F = \frac{2p_z}{\sqrt{s}}$
“Extended” Longitudinal Scaling of Centrality dependence: $R_{CP}^{N_{part}}$

- Extended range of limiting fragmentation behavior on centrality dependence of particle production:
  Factorization of Centrality and Energy dependence
BRAHMS Data/Acceptance: $p_T$ vs $x_F$ at $\sqrt{s_{NN}} = 200$ and 62 GeV

- Strong $p_T$-$x_F$ correlation due to limited spectrometer solid angle acceptance
- Measurements from BRAHMS Mid-Rapidity Spectrometer (MRS) and Forward Spectrometer (FS)
- “Dynamic” $x_F$ binning in $p_T$ 0.2 GeV/c
- $R_{CP}$ for centrality dependence in $p_T$-$x_F$: $R_{CP}(0-20/40-70\%), (20-40/40-70\%)$
$R_{CP}(h^-)$ vs $x_F$ in Au+Au at $\sqrt{s_{NN}} = 200$ and 62 GeV

- $R_{CP}(0-20\%) < R_{CP}(20-40\%):$ Centrality dependent suppression in $x_F < 0.6$
- More suppression as $x_F$ increases at fixed $p_T$ (0.3 ~ 2.2 GeV/c)
- For the soft $R_{CP}$ increase and maximize at $p_T \sim 1$ GeV/c
- Statistical errors only shown
- Systematic Uncertainties: 10% (p-to-p) + 10% (normalization)

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$R_{CP}(h^+) \text{ vs } x_F \text{ in } Au+Au \text{ at } \sqrt{s_{NN}} = 200 \text{ and } 62 \text{ GeV}$
$R_{CP(\text{proton})} \text{ vs } x_F \text{ in } Au+Au \text{ at } \sqrt{s_{NN}} = 200 \text{ and } 62 \text{ GeV}$

- Protons at high-$x_F$ at the kinematic range dominates from initial protons.
- Yet similar behavior with $h^-$. 

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Summary

- Nuclear modification factor $R_{cp}$ for charged hadrons and proton for $\sqrt{s_{NN}} = 200$ and 62 GeV:
  - $R_{cp}$ decreases with $x_F$ at given $p_T$
  - Scaling-like behavior with $x_F$ indicating Energy conservation might play a significant role in addition to dynamical suppression mechanism at forward region

- Constraint/input for more coherent/complete theoretical understanding on dynamics of particle suppression/production at RHIC
Back-up Slides
$R_{CP} (h^-)$ in $dAu$

- Stronger dependence of $R_{CP}$ on $x_F$
- $R_{CP}$ continuously increase with $p_T$
Recombination model at high-\(x_F\) in AuAu at 62 GeV

- Parton recombination without shower parton dominates forward particle production
- Loosening up kinematic limit and enhance particle production at high-\(x_F\) for peripheral collisions
- Protons are more efficiently produced at large-\(x_F\) (valence quark dominance)
$y$ vs $x_F$