Measurements of Pion, Kaon and Proton Spectra with Heavy Flavor Tracker in Au+Au 200GeV at STAR Experiment

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Outline

- Motivation

- Analysis
  - STAR detector
  - Heavy Flavor Tracker

- Results
  - $p_T$ spectra
  - particle ratios
  - dN/dy distribution
Motivation

- Inclusive proton includes ~40% of protons from weak decay in Au+Au 200GeV.

- STAR - inclusive proton spectra not corrected for weak decay feed down contribution
  PHENIX - prompt proton spectra proton coming from $\Lambda$ is estimated based on model simulations

- This result will be first direct measurement of prompt proton $p_T$ spectra with new HFT detector at RHIC.
STAR detector

Vertex Position Detector
Minimum bias trigger

Time Projection Chamber
Centrality definition
Particle trajectory
Momentum measurement
PID (dE/dx)

Time Of Flight
PID (flight time : 1/\beta)

Heavy Flavor Tracker
Heavy Flavor Tracker detector

PIXEL detector

Acceptance

\[-1 < \eta < 1\]
\[0 < \phi < 2\pi\]

Good resolution of DCA
(Distance of Closest Approach)
Particle track - collision point

Silicon Strip Detector : \(r \sim 22\text{cm}\)
Intermediate Silicon Tracker : \(r \sim 14\text{cm}\)
PIXEL : \(r \sim 2.8, 8\text{cm}\)

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HFT performance

DCA distribution from data in AuAu 200GeV
0-10% centrality
inclusive charged particles

DCA in XY plane and Z direction
Width : <50μm at p_T=1 GeV/c

DCA Resolution

Run14 Au+Au @200GeV

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Particle Identification

Track selection
At least one hit for each HFT layer
DCA selection is determined with resolution.

**dE/dx in TPC**

- Au+Au 200GeV, 0-10% DCA$_{xy}$<99.2µm
- 0.5<p$_T$<0.6 (GeV/c) DCA$_Z$<109.6µm
- |y|<0.1

- Combined fit
- pion
- kaon
- proton

**dE/dx in TPC and β in TOF**

- Au+Au 200GeV, 0-10%
- 1.6<p$_T$<1.7 (GeV/c)
- |y|<0.1 DCA$_{xy}$<40.4µm
- lnσ$_K$<2 DCA$_Z$<45.8µm
Detector efficiency & acceptance

Extracted from HIJING and GEANT simulation

The combination of TPC and HFT efficiency and acceptance

\[ \varepsilon_{\text{eff.} \times \text{acc.}} = \frac{N_{\text{RC-prompt particle}}}{N_{\text{MC-prompt particle}}} \]

\(N_{\text{MC-prompt particle}}\): The number of created prompt particles

\(N_{\text{RC-prompt particle}}\): The number of reconstructed real prompt particles

\[ p_T \text{(GeV/c)} \]

\(0\text{-}10\%\)

\(\pi^+\) Au+Au 200GeV

Threshold: \( \varepsilon_{\text{eff.} \times \text{acc.}}(p_T = 3)/2 \)

proton

\[ F = A \exp \left\{ - \left( \frac{a}{p_T} \right)^b \right\} \]
The purity of prompt particles

Extracted from HIJING and GEANT simulation.

\[ \varepsilon_{\text{purity}} = \frac{N_{\text{RC-promt particle}}}{N_{\text{RC-all particle}}} \]

\( N_{\text{RC-all particle}} \): The number of reconstructed all of particles
\( N_{\text{RC-promt particle}} \): The number of reconstructed real prompt particles

**Proton**

- \( \text{Au+Au 200GeV} \)
- 0-10%

**Threshold**

- \( \varepsilon_{\text{eff.xacc.}}(p_T=3)/2 \)

**Weak decay + knockout background**

- \(<1\% \text{ at } p_T>1\text{GeV/c} \)

**Anti-proton**

- \( \text{threshold} \leq \varepsilon_{\text{eff.xacc.}} \)
- \( \varepsilon_{\text{eff.xacc.}} < \text{threshold} \)

- \( \varepsilon_{\text{eff.xacc.}} < \text{threshold} \)

**Weak decay contribution**

- \(<1\% \text{ at } p_T>1\text{GeV/c} \)

\[ F = A \exp \left\{ - \left( \frac{a}{p_T} \right)^b \right\} \]
$p_T$ spectra correction

$$\frac{1}{2\pi p_T} \frac{d^2 N}{dp_T dy} = \frac{1}{2\pi p_T} \frac{1}{N_{\text{evt}}} \frac{\varepsilon_{\text{purity}}}{\varepsilon_{\text{eff.} \times \text{acc.}}} \frac{N}{\Delta p_T \Delta y}$$

Systematic uncertainty

TPC efficiency : ~5%

HFT matching efficiency : <13%

The difference of HFT matching efficiency between data and simulation

DCA selection : <10%

Particle species dependent
π, K, p $p_T$ spectra

PID spectra with the HFT in Au-Au 200GeV
The shape depends on particle mass.
$\pi, K, p$ $p_T$ spectra

Modify Hagedorn equation

$$F = \frac{A}{\{\exp (-ap_T - bp_T^2) + p_T/p_0\}^n}$$

STAR results (orange, cyan) : inclusive proton

PHENIX results (magenta) : corrected for weak decay from $\Lambda$

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π, K, p \ p_T spectra

Modify Hagedorn equation

\[
F = \frac{A}{\left\{ \exp \left( -a p_T - b p_T^2 \right) + p_T/p_0 \right\}^n}
\]

STAR results (orange, cyan) : inclusive proton
PHENIX results (magenta) : corrected for weak decay from $\Lambda$

PRL 92, 112301 (2004)
PRL 97, 152301 (2006)
Anti-particle to particle ratio

The ratios are about 1, 0.95, 0.8 for $\pi$, $K$, $p$ at RHIC energy.
Anti-particle to particle ratio

There is no significant difference between inclusive and prompt proton ratio.
Estimating dN/dy distribution

Out of range of measured spectra

Extrapolating with equations

The difference of equations are defined as systematic uncertainty.

Fraction of dN/dy

<table>
<thead>
<tr>
<th></th>
<th>measured dN/dy</th>
<th>extrapolated dN/dy</th>
<th>extrapolated dN/dy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>low $p_T$</td>
<td>high $p_T$</td>
</tr>
<tr>
<td>$\pi^+$</td>
<td>168.7 (53.5%)</td>
<td>146.7 (46.4%)</td>
<td>0.14 (0.1%)</td>
</tr>
<tr>
<td>$K^+$</td>
<td>26.8 (50%)</td>
<td>26.7 (49%)</td>
<td>0.1 (1%)</td>
</tr>
<tr>
<td>proton</td>
<td>11.1 (51%)</td>
<td>10.4 (48%)</td>
<td>0.11 (1%)</td>
</tr>
</tbody>
</table>

For pion, Bose-Einstein equation, $m_T$ exponential (for estimating systematics)
For kaon and proton, $p_T$ exponential, $m_T$ exponential

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dN/dy distribution

STAR preliminary
STAR (2004)
PHENIX (2004)

STAR (2004)
PHENIX (2004)

Inclusive proton
Prompt proton

π^+

K^+

π^-

Au+Au 200GeV |y|<0.1

K^-

anti-proton

STAR results (orange, cyan) : inclusive proton
PHENIX results (magenta) : corrected for weak decay from \Lambda

PRL 92, 112301 (2004)
PRC 69, 034909 (2004)
Summary

- The first result of prompt $\pi$, K, p $p_T$ spectra with the HFT in Au+Au 200GeV collisions at STAR experiment

- The anti-particle to particle ratio
  
  There is no significant difference between inclusive and prompt proton results.
Efficiency correction

\[ \varepsilon_{\text{eff.\times acc.}} = \frac{N_{\text{RC-prompt particle}}}{N_{\text{MC-prompt particle}}} \]

Correction of detector efficiency and acceptance
Correction factor get large in low \( p_T \) region