STAR measurements of open charm production in dAu collisions at $\sqrt{s_{NN}} = 200$ GeV

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For the STAR Collaboration

(1) Motivations
(2) Data analysis
(3) Results and Conclusions
Motivations:

- Study heavy quark dynamic in medium, such as heavy quark energy loss in dense matter, and probe medium properties through heavy quarks.
- Gluon structure function of nuclei.
- Comparing ratios of different open charm species with the statistical model prediction--- is the charm quark hadronization modified by the thermal medium?

\[\text{dAu provides an important reference to study heavy flavor production in Au+Au}\]
Decay channels used in this analysis

\[ D^0 \rightarrow K^- \pi^+ (3.8\%) \]
\[ D^0 \rightarrow K^- \pi^+ \rho^0 (\pi^+ \pi^-) (6.2\%) \]
\[ D^\pm \rightarrow K \pi \pi \quad (9.1\%) \]
\[ D^{*\pm} \rightarrow D^0 \pi_s (68\%), D^0 \rightarrow K\pi (3.8\%) \]

About 15 million dAu minbias events are used in the analysis.

We also measure D from its semi-leptonic decay to electrons in both dAu and pp collisions at \( \sqrt{s_{NN}} = 200 \) GeV.
Mass plots from dAu data using event-mixing technique

$0 < p_T < 3 \text{ GeV/c, } |y| < 1.0$

$d+Au$ minbias

$D^0 + \bar{D}^0$

STAR Preliminary

$8.5 < pt < 11.0 \text{ GeV/c}$

$7.4 < pt < 9.3 \text{ GeV/c}$
D*± Signal

D*± from D* decay (tagged D0)

D0 from D* decay (tagged D0)

2.4<pt<3.5 GeV/c

D0\rightarrow K-\pi+\pi0 (13.1\%)

2.4<pt<3.5 GeV/c
Results

Assuming $\sigma(D^*) = \sigma(D^\pm)$ and scale $\sigma(D^*)$ and $\sigma(D^\pm)$ to match $D_0$ by $D^*/D_0=0.40$

$dAu\ minbias\ at\ \sqrt{s}=200\ GeV$

$$\frac{D^*/D_0}{D^*/D_0}=0.40\pm 0.09\pm 0.13$$

$\sigma_{c\bar{c}} = 1.2 \times \left( \frac{\sigma(D^0) + \sigma(D^+) + c.c.}{2} \right)$

$$\sigma_{NN}^{D} = \frac{(dn / dy) \times \sigma_{\text{inel}}^{\text{NN}}}{N_{bin}} \times 4$$

$$= dn/dy \times 42 \times 4/7.5$$

$$\sigma_{c\bar{c}}^{NN} = 1.12 \pm 0.20 \pm 0.37 \text{ mb}$$

$\text{total multiplicity}=4*dn/dy(|y|<0.5)$
The measurements of open charms are consistent with background-subtracted electron data in STAR!

Lijuan Ruan’s talk (Thursday afternoon)

A combined fit using $D^0$ and the electron data leads:

$$\sigma_{cc}^{NN} = 1.36 \pm 0.20 \pm 0.39 \text{ mb}$$

The band is obtained from $D$ decay based on the power-law fit to the measured open charm spectrum.
STAR background-subtracted electrons by EMC first time seeing beauty at RHIC!

Alex Suaide’s talk (Thursday afternoon)

B decay dominated region

STAR preliminary

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QM2004, Oakland Jan.11-17, 2004
$D^*/D^0$ ratios --- consistent with other experiments.

CDF: hep-ex/0307080

HERA: www-h1.de/h1/www/publications/conf_list.html

e+e-: hep-ph/0312054

Statistical model: A. Andronic etc. nucl-th/0209035 and private communication.
Open charm spectrum is hard!

D. Kharzeev, hep-ph/0310358
Charm quark hadronization at RHIC

bare c-quark spectrum, normalized to measured $dn/dy$

- D spectrum would be drop by a factor of 3 at $pt$~10GeV/c when Peterson fragmentation function is set in.
- Harder fragmentation function, like, $\delta(z-1)$, is needed.
- c-quark may hadronize through recombination mechanism.

Conclusion I

- D₀, D* and D± are first measured in dAu run at √s=200 GeV using STAR TPC with a p_T coverage of 0<pt<11 GeV/c
- \( \sigma_{\text{cc}}^{NN} = 1.12 \pm 0.20 \pm 0.37 \text{ mb from directly-measured open charm and } \sigma_{c\bar{c}}^{NN} = 1.36 \pm 0.20 \pm 0.39 \text{ mb from D}^0 \) and the single electron measurement
- D*/D^0 = 0.40±0.09(stat)±0.13(sys), consistent with other experimental results.
Conclusion II

- STAR measured D spectrum and single electron are consistent.
- The measured D pt spectrum coincides with the bare-quark distribution from the NLO calculation.
- A hard D meson $p_T$ spectrum may be obtained from $k_T$ factorization scheme (Kharzeev et al), or charm quark recombination or very hard charm fragmentation function ($\delta(z-1)$ function).
$k_T$ broadening and c-quark fragmentation at fixed target experiment

momentum loss due to fragmentation can be counter-balanced by initial $k_T$

Bare c-quark spectrum

π+A scattering at 350 GeV/c

After $k_T$ and fragmentation $\varepsilon=0.06$
Charm quark hadronization at RHIC ----
harder fragmentation function or c-quark recombination ??

bare c-quark spectrum, normalized to measured $dn/dy$

After $k_T$ and fragmentation

MRST HO
Peterson’s function $\epsilon=0.06$
A factor of $\sim 3$
drop at $pt\sim 10$ GeV/c

NLO pQCD predictions are provided by R. Vogt

An Tai  QM2004, Oakland Jan.11-17, 2004
Analysis procedure

- **Kπ** → Put M(Kπ) into D0 histogram
- **Kπ + π~**
  - If 0.143 < ΔM = M(Kππs) - M(Kπ) < 0.148 GeV/c² → Put M(Kπ) into D0-from-D* histogram
  - If 1.82 < M(Kπ) < 1.9 GeV/c² → If (0.1 < p(π~) < 1.0 GeV/c AND p(Kπ)/p(π~)) > 7.0, π~ → πs → Put M(Kππ~) into D± histogram
  - Put ΔM = M(Kππs) - M(Kπ) into D* histogram
D± signal is real

Raw countings are close for D+ and D−.

K−π+π− ---wrong charge combination, No signal!

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QM2004, Oakland Jan.11-17, 2004
\( D^0 \) signal from \( D^0 \rightarrow K^- \pi^+ \rho^0 (\pi^+ \pi^-) \) \( \text{BR}=6.2\% \)

\[ 0.53 \text{GeV} < m(\rho) < 0.95 \text{GeV} \]
$D^\pm$ signal is real

0-40% centrality

$K^- \pi^+ \pi^- & K^+ \pi^- \pi^+$
wrong charge combination
No signal!

$D^+ - in dAu full 0-40\%, |y|<.75, 7.0<pt<120$ GeV/c

$D^{*-} - in dAu full minbias, |y|<2.5, 7.4<pt<9.3$ GeV/c
$D^*/D^0$ ratios

(1) Assume $D^* = D^0(\text{dir})$

$$D^0 = D^0(\text{dir}) + 0.68D^* \pm + D^{*0}$$

$$D^*/D^0 = 0.37$$

(2) Assume $D^* = 3D^0(\text{dir})$

$$D^0 = D^*/3 + 0.68D^* \pm + D^{*0}$$

$$D^*/D^0 = 0.50$$

CDF: hep-ex/0307080
HERA: www-h1.de/h1/www/publications/conf_list.html
$e^+e^-$: hep-ph/0312054
Statistical model: A. Andronic etc. nucl-th/0209035 and private communication.
Mass and width: Measured vs Monte Carlo
--------Agree well
width is dominated by detector resolutions

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<tr>
<th></th>
<th>$D^0$</th>
<th>$D^\pm$</th>
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<tbody>
<tr>
<td>mass</td>
<td>$1.867\pm0.006$ GeV</td>
<td>$1.864\pm0.0052$ GeV</td>
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<tr>
<td>mass (MC)</td>
<td>1.865 GeV</td>
<td>$1.868\pm0.002$ GeV</td>
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<tr>
<td>Sigma</td>
<td>$13.7\pm6.8$ MeV</td>
<td>$13.83\pm3.7$ MeV</td>
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<tr>
<td>Sigma (MC)</td>
<td>14.5 MeV</td>
<td>$14.9\pm1.6$ MeV</td>
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<table>
<thead>
<tr>
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<th>$D^* - D^0$</th>
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<tbody>
<tr>
<td>mass</td>
<td>$0.1467\pm0.00016$ GeV</td>
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<tr>
<td>mass (MC)</td>
<td>$0.1451$ GeV</td>
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<tr>
<td>Sigma</td>
<td>$0.43\pm0.14$ MeV</td>
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<tr>
<td>Sigma (MC)</td>
<td>0.67 MeV</td>
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Pythia parameters

Phenix-tuned pythia parameters:
\[<kt>=1.5 \text{ GeV/c, } mc=1.25 \text{ GeV/c}^2\]
K-factor=3.5, CTEQ5L, PARP(67)=1
\[\sigma(\text{ccbar})=653\mu\text{b}\]

STAR tuned pythia parameters
\[<kt>=2.0 \text{ GeV/c, } mc=1.7 \text{ GeV/c}^2,\]
K-factor=2.2, CTEQ5M1, PARP(67)=4
\[\sigma(\text{ccbar})=1078 \mu\text{b}\]