Open charm hadron measurement in p+p and Au+Au collisions at $\sqrt{s_{\text{NN}}} = 200$ GeV in STAR

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Outline:

- Motivation
- $D^0$ and $D^*$ measurement in $p+p$ collisions at 200 GeV
- $D^0$ measurement in $Au+Au$ collisions at 200 GeV
- Charm cross section, $R_{AA}$
- Summary and outlook
Why study heavy quarks?

- Higgs mass: electro-weak symmetry breaking (current quark mass).
- QCD mass: Chiral symmetry breaking (constituent quark mass).
- Strong interactions do not affect heavy quark mass.

Study properties of the hot and dense medium at the early stage of heavy-ion collisions.

Test pQCD at RHIC.

Charm collectivity => Light flavor thermalization.
Why measure D mesons?

Known limitations in semi-leptonic channel.
1) Kinematics smearing due to decay.
2) Suffering from charm and bottom contributions.

Direct measurement of D meson provides clean information of charm quark.
Large acceptance
$|\eta| < 1, \ 0 < \phi < 2\pi$
Year 2009 72% of full TOF
Year 2010 100% of full TOF

- **Time Projection Chamber**
  - dE/dx, momentum

- **Time Of Flight detector**
  - particle velocity $1/\beta$
$D^0$ signal in p+p 200 GeV

$p+p$ minimum bias 105 M

4-σ signal observed.

Different methods reproduce combinatorial background.

Consistent results from two background methods.

PDG mass = $1864.5 \pm 0.4$ MeV
D* signal in p+p 200 GeV

Minimum bias 105M events in p+p 200 GeV collisions.

Two methods to reconstruct combinatorial background: wrong sign and side band.

8-σ signal observed.
**D^0 and D* p_T spectra in p+p 200 GeV**

D^0 scaled by $N_{cc}/N_{D^0} = 1 / 0.56^{[1]}$

D* scaled by $N_{cc}/N_{D^*} = 1 / 0.22^{[1]}$

Consistent with FONLL$^{[2]}$ upper limit.

$$Xsec = \frac{dN}{dy}\big|_{y=0} \times F \times \sigma_{pp}$$

F = 4.7 ± 0.7 scale to full rapidity.

$$\sigma_{pp}(NSD) = 30 \text{ mb}$$

The charm cross section at mid-rapidity is:

$$202 \pm 56 \text{ (stat.)} \pm 40 \text{ (sys.)} \pm 20 \text{ (norm.)} \mu\text{b}$$

The charm total cross section is extracted as:

$$949 \pm 263 \text{ (stat.)} \pm 253 \text{ (sys.)} \mu\text{b}$$

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D⁰ signal in Au+Au 200 GeV

Year 2010 minimum bias 0-80% 280M Au+Au 200 GeV events.
8-σ signal observed.
Mass = 1863 ± 2 MeV (PDG value is 1864.5 ± 0.4 MeV)
Width = 12 ± 2 MeV
Charm cross section follows number of binary collisions scaling =>
Charm quarks are mostly produced via initial hard scatterings.

All of the measurements are consistent.
Year 2003 d+Au : D⁰ + e
Year 2009 p+p : D⁰ + D*
Year 2010 Au+Au: D⁰

Assuming N_{D⁰}/N_{cc} = 0.56 does not change.

Charm cross section in Au+Au 200 GeV:
Mid-rapidity:
186 ± 22 (stat.) ± 30 (sys.) ± 18 (norm.) μb
Total cross section:
876 ± 103 (stat.) ± 211 (sys.) μb

Charm cross section vs $\sqrt{s_{NN}}$

Compared with other experiments, provide constraint for theories.
D⁰ R_{AA} vs p_T

D⁰ Au+Au 0-80% divided by p+p with <N_{bin}> scaled.

No obvious suppression at p_T < 3 GeV/c.

Blast-wave predictions with light hadron parameters are different from data.

=> D⁰ freeze out earlier than light hadrons.
Summary

◆ D⁰ and D* are measured in p+p 200 GeV up to pₚ = 6 GeV/c.

◆ D⁰ is measured in Au+Au 200 GeV up to pₚ = 5 GeV/c.

◆ The charm cross section per nucleon-nucleon collision in mid-rapidity is measured to be
  
  p+p: 202 ± 56 (stat.) ± 40 (sys.) ± 20 (norm.) mb
  Au+Au: 186 ± 22 (stat.) ± 30 (sys.) ± 18 (norm.) mb

◆ Charm cross sections at mid-rapidity follow number of binary collisions scaling, which indicates charm quarks are mostly produced via initial hard scatterings.

◆ D⁰ nuclear modification factor R_{AA} is measured. No obvious suppression observed at pₚ < 3 GeV/c.

◆ Blast-wave predictions with light hadron parameters are different from D⁰ data, which indicates that D⁰ decouples earlier from the medium than light hadrons.
STAR Heavy Flavor Tracker Project.

- Reconstruct secondary vertex.
- Dramatically improve the precision of measurements.
  - $Dca$ resolution: $< 20 \ \mu m$ at $p_T > 2 \ GeV/c$.
- Address physics related to heavy flavor.
  - $v_2$ : thermalization
  - $R_{CP}$: charm quark energy loss mechanism.
$D^0 R_{AA}$ compared with Alice result

![Graph showing $D^0 R_{AA}$ compared with Alice result](image-url)
$D^0 R_{AA}$ compared with Alice result
Data consistent with theory

Both D-meson and NPE measurements are consistent with FONLL upper bound.

H. Agakishiev, et al., PRD 83 (2011) 052006
Blast-wave contour

$D^0$ Au+Au 200 GeV 0-80%
Partonic collectivity?
Does charm follow the trend of strangeness? Or smaller velocity?
Interactions between charm and medium?