Charm and beauty isolation in heavy flavor electron measurements in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC

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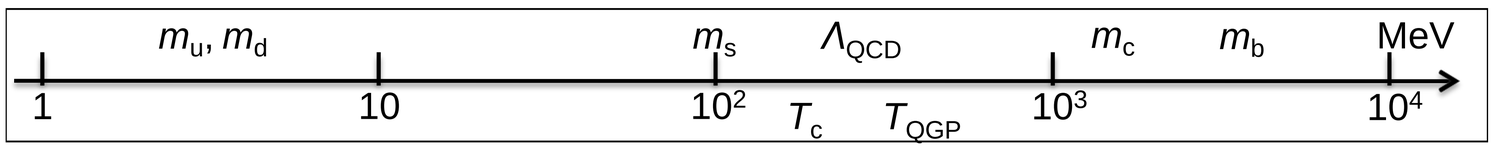
Abstract

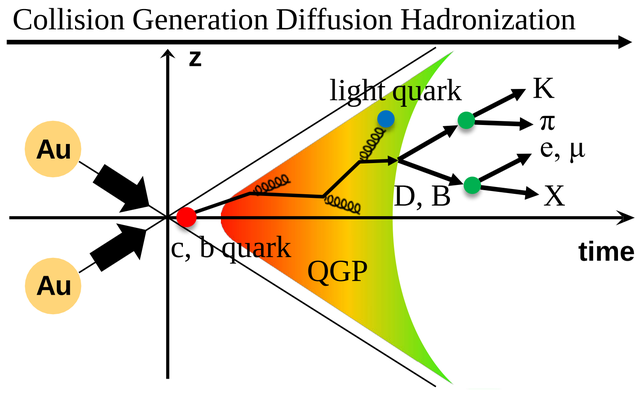
We develop a data-driven method to isolate charm and beauty contributions from the inclusive heavy flavor electrons (HFE) based on the most recent open charmed hadron measurements in minimum bias Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC. The individual electron nuclear modification factor (R_{AA}) and elliptic flow (v_2) from charm and beauty decays are reported. Model comparisons and discussions are also given.

Motivation



Heavy quarks (charm and beauty):

- Produced early and experience entire evolution of QGP ($\tau_{c,b} < \tau_{QGP}$).
- Production cross sections can be evaluated by pQCD ($m_{c,b} \gg \Lambda_{QCD}$).
- Predicted mass dependent energy loss: $\Delta E_g > \Delta E_{u,d,s} > \Delta E_c > \Delta E_b$.



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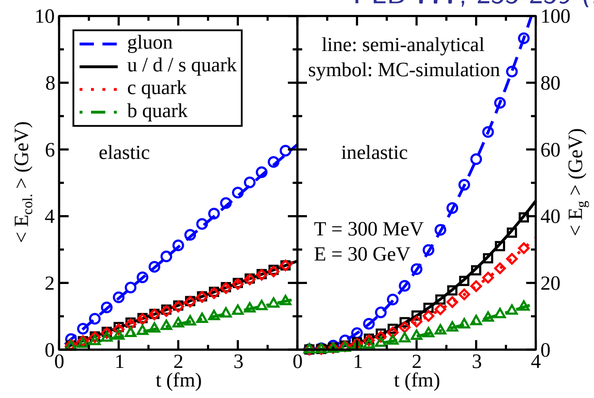


Data-driven method

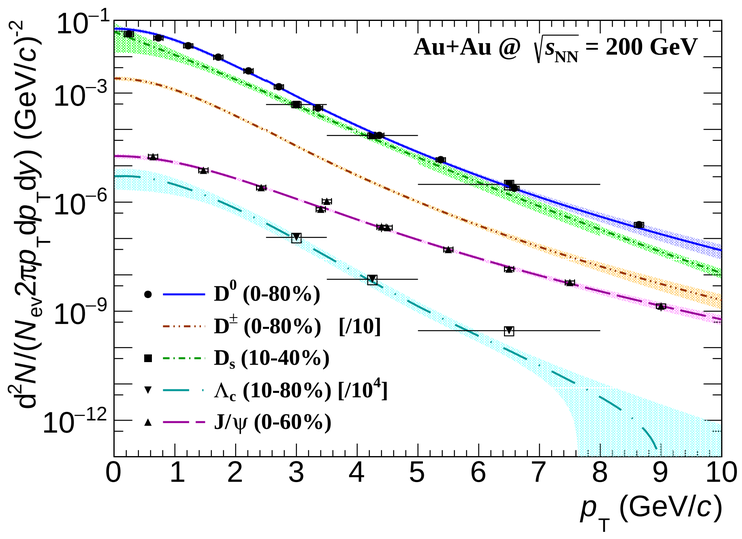
Charmed hadron measurements
↓
Parameterized with functions/models
↓
Semileptonic decay simulations
↓
Normalized with measured cross sections and B.R.
↓
Charm decay electron spectra
↓
HFE measurement
↓
Extract beauty contribution $f^{b\to e}$
↓
R_{AA} and v_2

Charmed hadron inputs

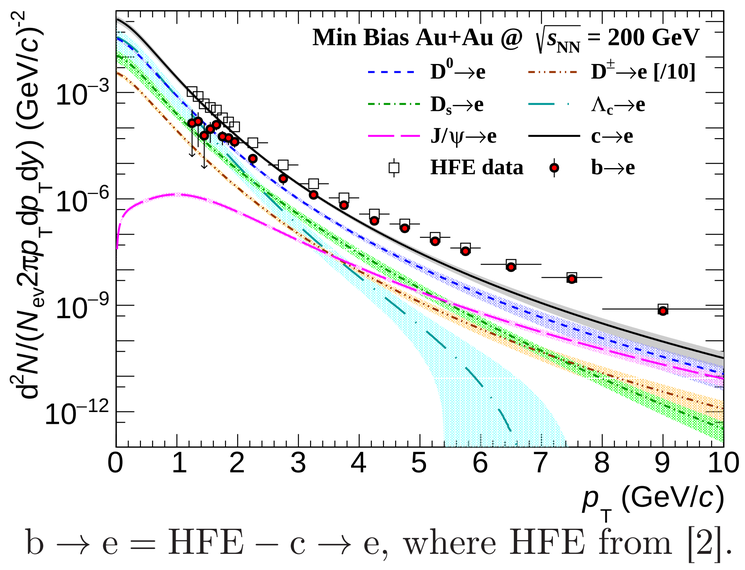
- D^0, D_s and J/ψ: parameterized and extrapolated by Levy and power-law functions.
- $D^\pm$: scaling D^0 spectrum by $D^\pm/D^0$ ratio.
- Λ_c: average of 4 model calculations.

Data and parameterization are from [1].

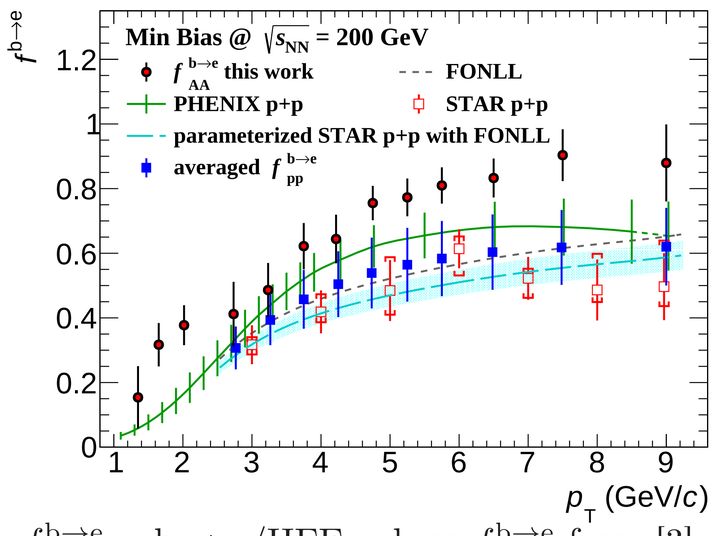
Charmed hadron	Mass (MeV/c^2)	Branching ratio ($\to$eX) (%)
D^0	1864.83±0.05	6.49±0.11
$D^\pm$	1869.65±0.05	16.07±0.30
D_s	1968.34±0.07	6.5±0.4
Λ_c	2286.46±0.14	4.5±1.7
J/ψ	3096.900±0.006	5.971±0.032



Output decay electron spectra

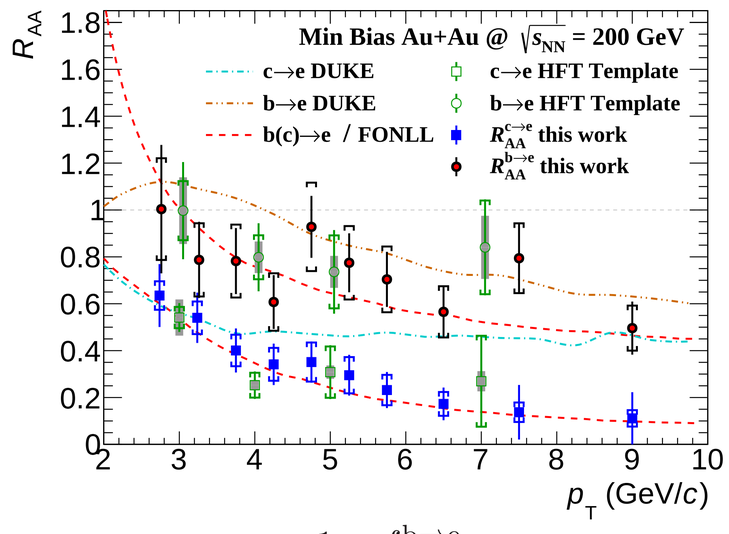


$b \to e = \text{HFE} - c \to e$, where HFE from [2].



$f^{b\to e} = b \to e/\text{HFE}$, where $f_{pp}^{b\to e}$ from [3].

R_{AA} isolation



$$R_{AA}^{c\to e} = \frac{1 - f_{AA}^{b\to e}}{1 - f_{pp}^{b\to e}} R_{AA}^{HFE} \quad (1)$$

$$R_{AA}^{b\to e} = \frac{f_{AA}^{b\to e}}{f_{pp}^{b\to e}} R_{AA}^{HFE} \quad (2)$$

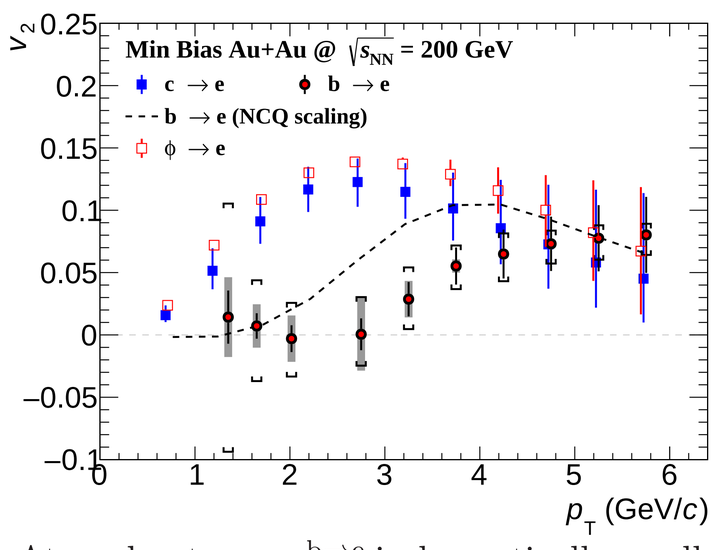
- Less suppression of beauty than charm.
- Agree with STAR HFT template analysis [4].
- b→e: roughly consistent with DUKE model prediction [5];
  c→e: stronger suppression than DUKE.

v_2 isolation

D^0 v_2 measurement [6]
↓
Parameterized & NCQ scaling
↓
Charmed hadron spectra
↓
D-meson and Λ_c v_2
↓
Semileptonic decay simulations
↓
$f_{AA}^{b\to e}$, v_2^{HFE} [7] → $v_2^{c\to e}$
↓
$v_2^{b\to e}$

$$v_2^{b\to e} = \frac{v_2^{HFE} - \left(1 - f_{AA}^{b\to e}\right) v_2^{c\to e}}{f_{AA}^{b\to e}} \quad (3)$$

Non-zero $v_2^{b\to e}$ is observed at $p_T > 3$ GeV/c at the first time.



At moderate p_T, $v_2^{b\to e}$ is dramatically smaller than $v_2^{c\to e}$ and deviates the curve assuming B-meson v_2 follows NCQ scaling.

Beauty is unlikely thermalized and seems too heavy to be moved to follow the partonic collectivity at RHIC energy.

References

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[4] K. Oh (STAR), NPA **967**, 632-635 (2017).
[5] S. Cao *et al.*, PRC **92**, 024907 (2015).
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[7] L. Adamczyk *et al.* (STAR), PRC **95** 34907 (2017); T. Hachiya (PHENIX), NPA **982**, 663-666 (2019).