Measurements of charm and bottom production via semi-leptonic decays in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at STAR

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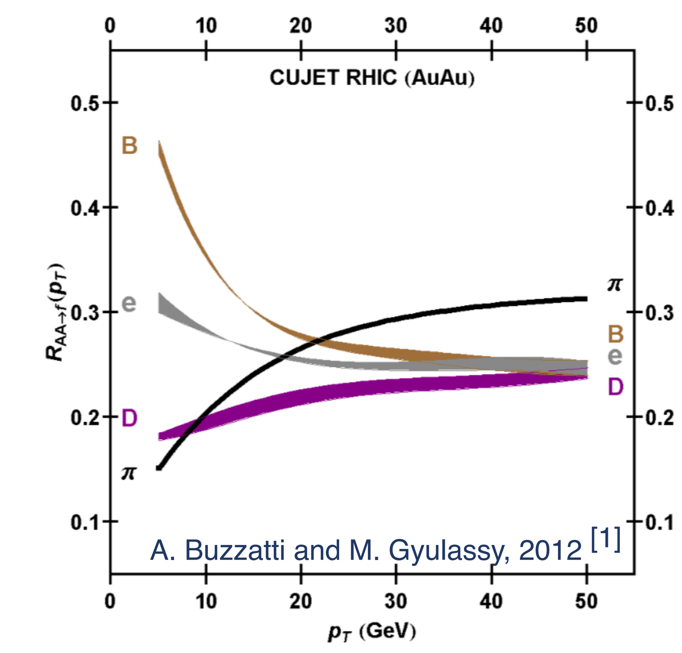
Abstract

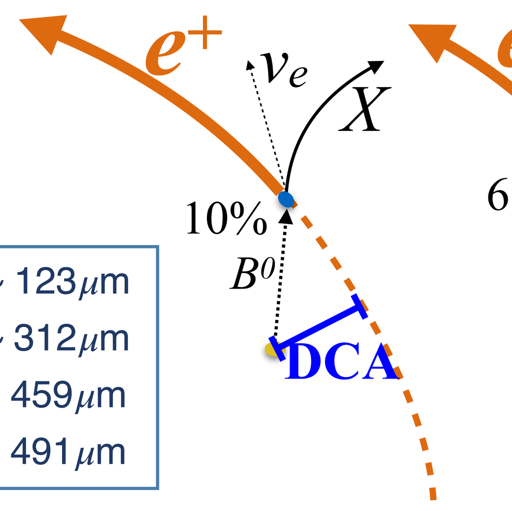
Systematic investigation of charm and bottom productions and their modifications in heavy-ion collisions is crucial for understanding the parton energy loss mechanism inside the QGP. Electrons from semi-leptonic decays of open heavy-flavor hadrons can serve as a proxy for heavy quarks with the possibility of triggering on them during data taking to gain statistics.

The STAR Heavy Flavor Tracker (HFT) provides an excellent track pointing resolution which allows to separate electrons originating from open charm and bottom hadron decays based on their measured Distance of Closest Approach (*DCA*) to the primary vertex. In this poster, we present the nuclear modification factors R_{AA} and R_{CP} of the charm- and bottom-decayed electrons as a function of transverse momentum ($2 < p_T < 8.5$ GeV/c) at mid-rapidity in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions for various centrality classes. The measurements utilize the data with the HFT from RHIC runs in 2014 and 2016.

Motivation



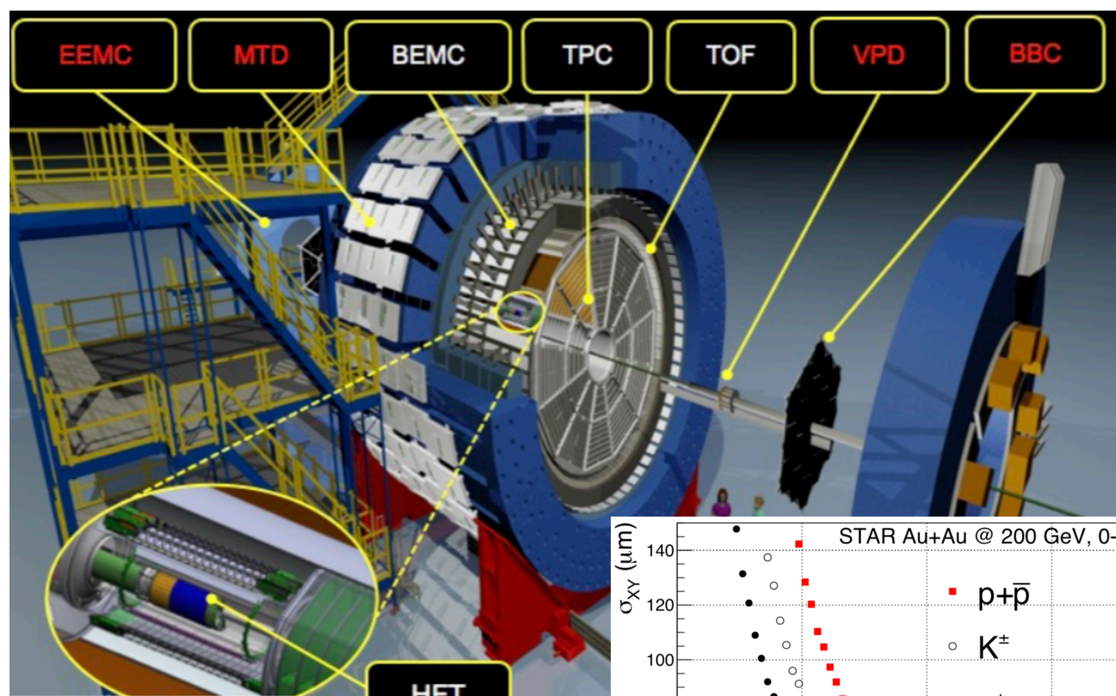
A. Buzzatti and M. Gyulassy, 2012 [1]



$c\tau(D^0) \sim 123\mu m$
$c\tau(D^\pm) \sim 312\mu m$
$c\tau(B^0) \sim 459\mu m$
$c\tau(B^\pm) \sim 491\mu m$

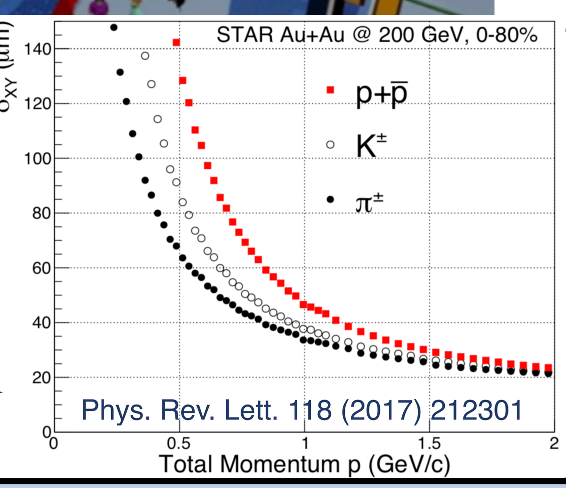
- Study flavor dependence of parton energy loss:
  - Theoretical prediction for ΔE in medium: $\Delta E_g > \Delta E_q > \mathbf{\Delta E_c > \Delta E_b}$?
  - Precise measurements of charm and bottom hadron nuclear modification factors separately are crucial to test the mass hierarchy of the parton energy loss
- *DCA* is used to separate the bottom hadron decay electrons from charm hadron decay electrons

STAR Detector



HFT: (2014-2016)

- PIXEL detector: r ~2.8 & 8 cm (0.5% X0 per layer)
- Intermediate Silicon Tracker: r ~14 cm
- Silicon Strip Detector: r ~22 cm



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Barrel **E**lectro**M**agnetic **C**alorimeter
- Trigger on high p_T electrons
- PID through *pc/E* and shower shape via the Shower Max Detector (SMD)

Time **P**rojection **C**hamber
- Tracking, momentum measurement
- PID through d*E*/d*x*

Time **O**f **F**light
- PID through velocity ($1/\beta$)
- Timing resolution: ~85 ps

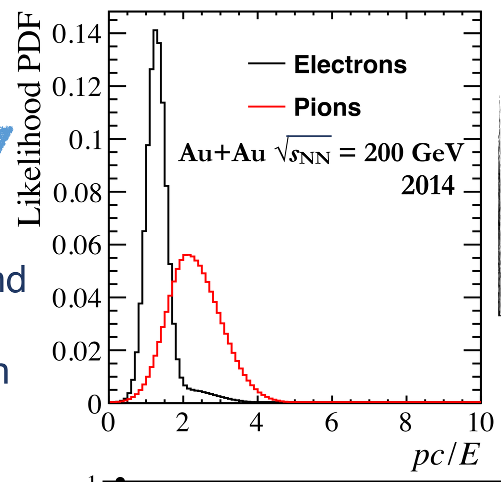
Heavy **F**lavor **T**racker(HFT)
- Precise reconstruction of displaced vertices
- Crucial for separating charm- and bottom-decayed electrons using *DCA*

Multivariate Data Analysis (MVA) electron identification

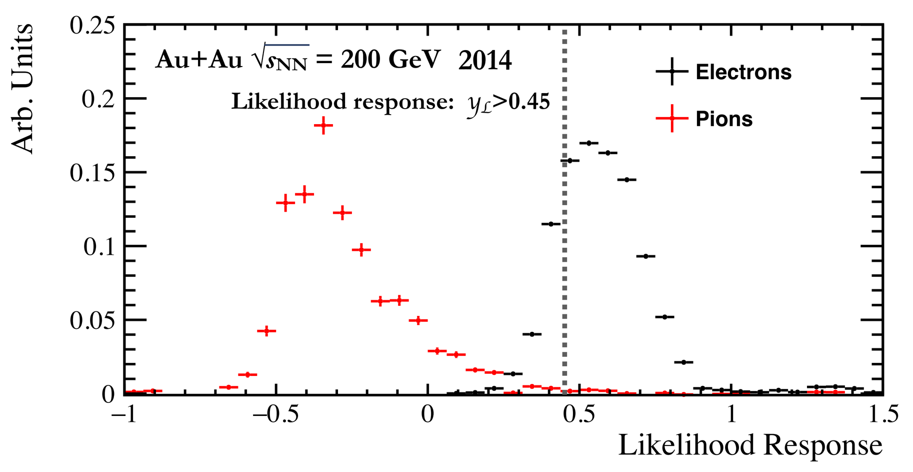
- Combine electron and pion detector response distributions into a single discriminating variable
  - MVA Likelihood response for particle i is:

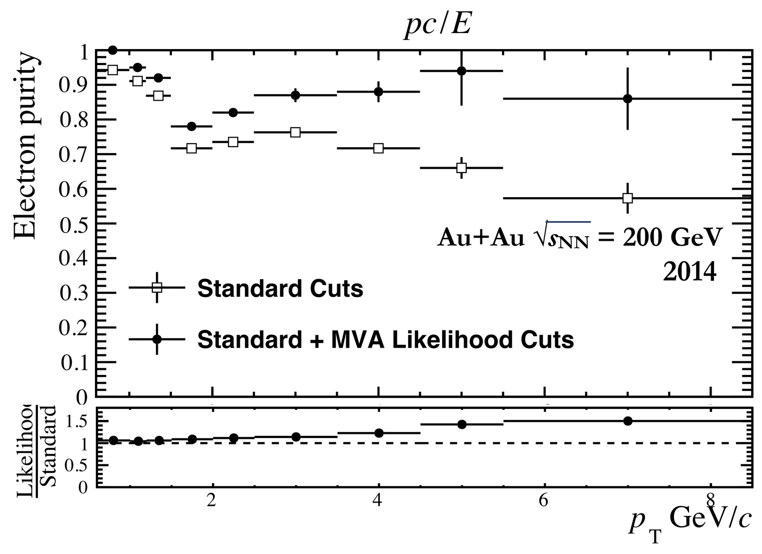
$$y_L(i) = \frac{L_S(i)}{L_S(i) + L_B(i)}, \quad L_{S(B)}(i) = \prod_{k=1}^{n_{variables}} p_{S(B),k}(x_k(i))$$

  - Inputs from reconstructed photonic electron pairs and $K_S \rightarrow \pi\pi$ decays
  - Optimal likelihood cut chosen to give best purity with little efficiency loss

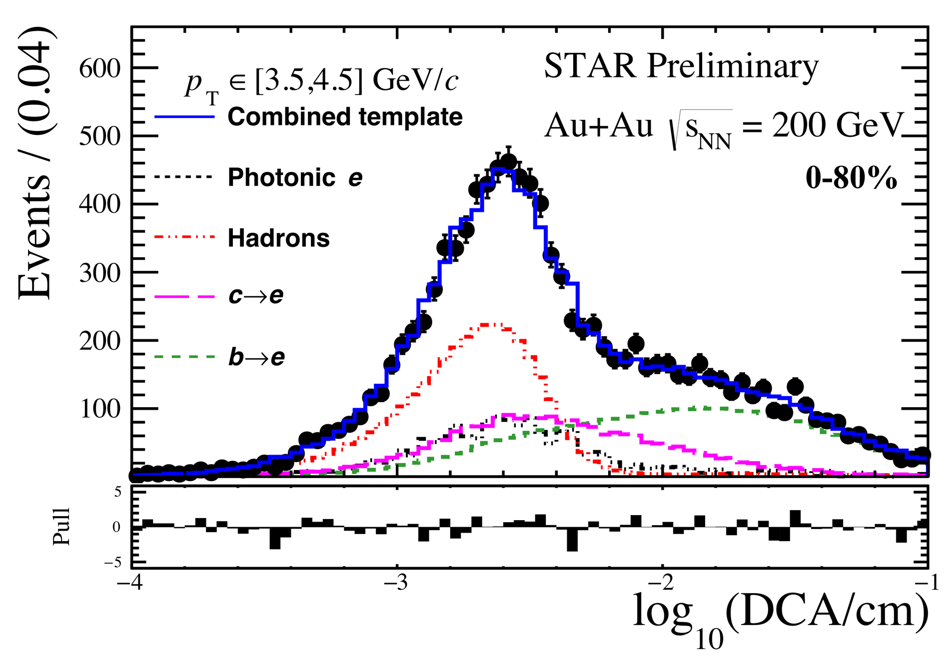


Variables:
- TPC d*E*/d*x*
- $1/\beta$ from TOF
- BEMC *pc/E* ratio
- Number of SMD hits





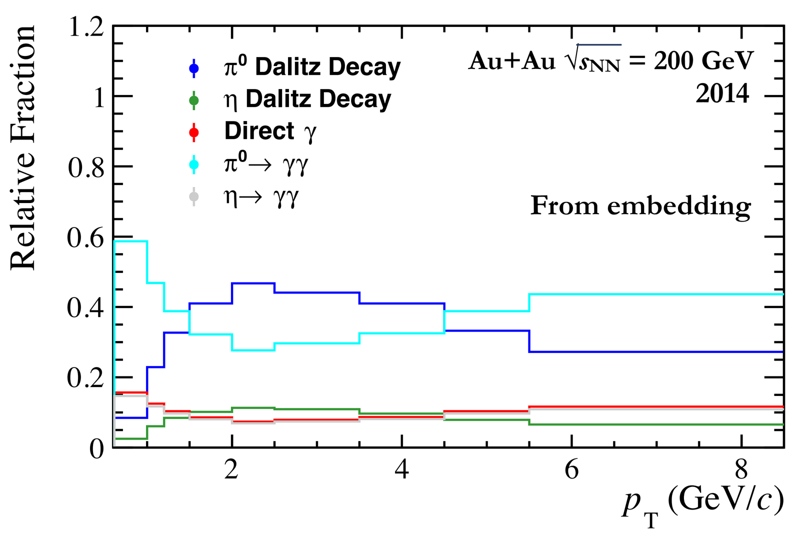
Template fit for electrons DCA

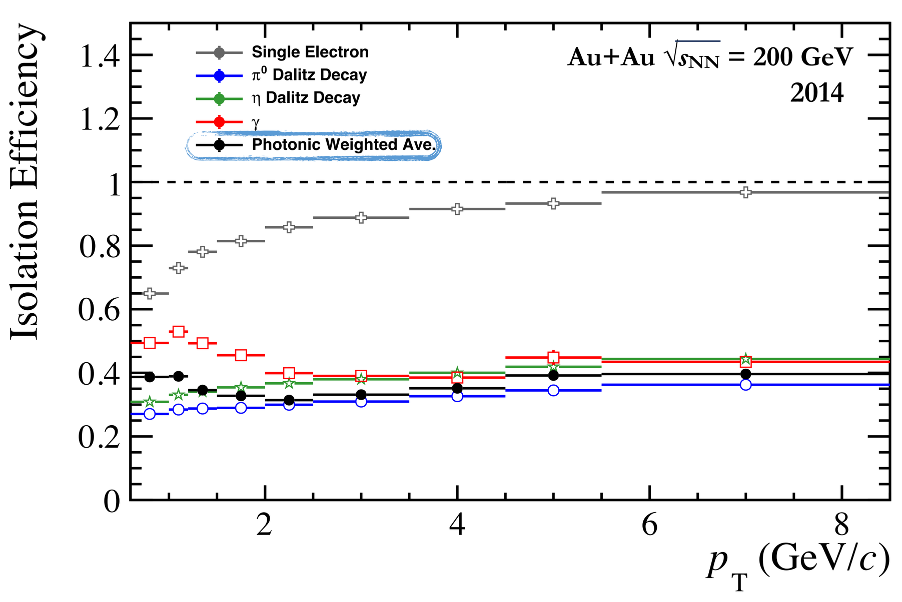


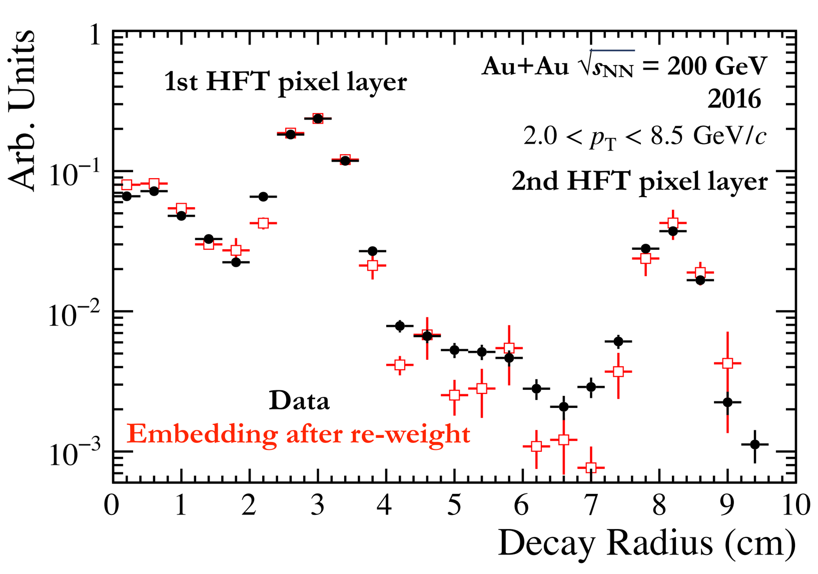
- Fit to the distribution of log of 3D *DCA* for best separation
  - Hadron shape: from data, constrained by purity
  - Photonic electron shape: from simulation, constrained by photonic electron fraction
  - HF→*e* shape: determined from simulating all ground state $B^\pm, B^0, B_s, \Lambda_b$ and $D^\pm, D^0, D_s, \Lambda_c$ semi-leptonic decays

Photonic electron background isolation

- Reduce photonic electron contribution by looking for unlike-sign partner track in TPC
  - Photonic electron removed when unlikes-sign pair inv. mass < 0.15 GeV/c^2, and pair DCA < 0.2 cm
- Distribution of transverse position of e^+e^- vertex from photonic electrons in data well reproduced by embedding
  - Yields of various photonic background sources were reweighted to match published data

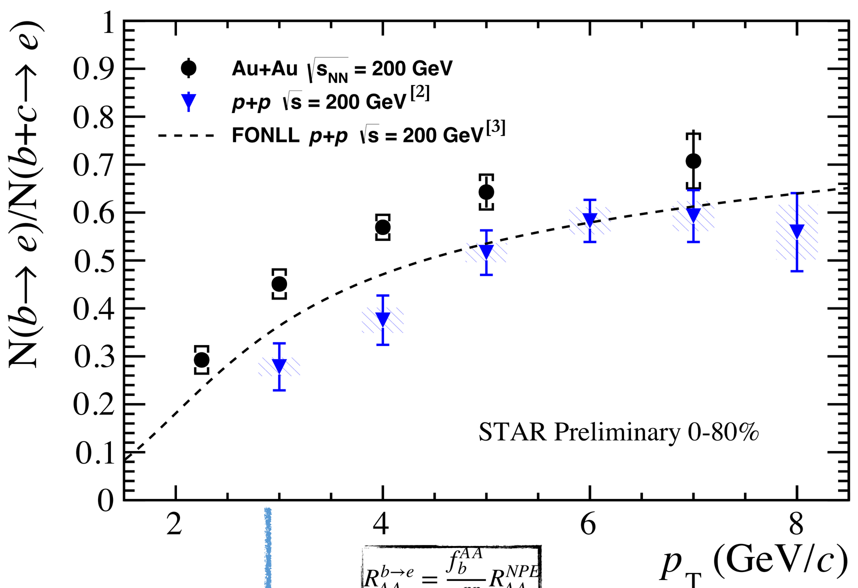




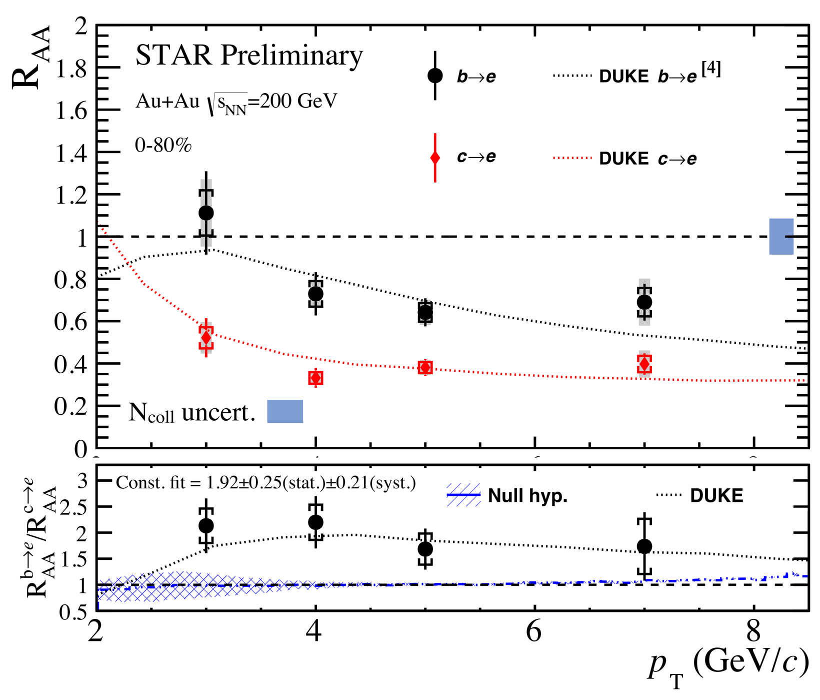


- The isolation cut does not affect the signal electron efficiency by more than 20% for $p_T > 2$ GeV/c

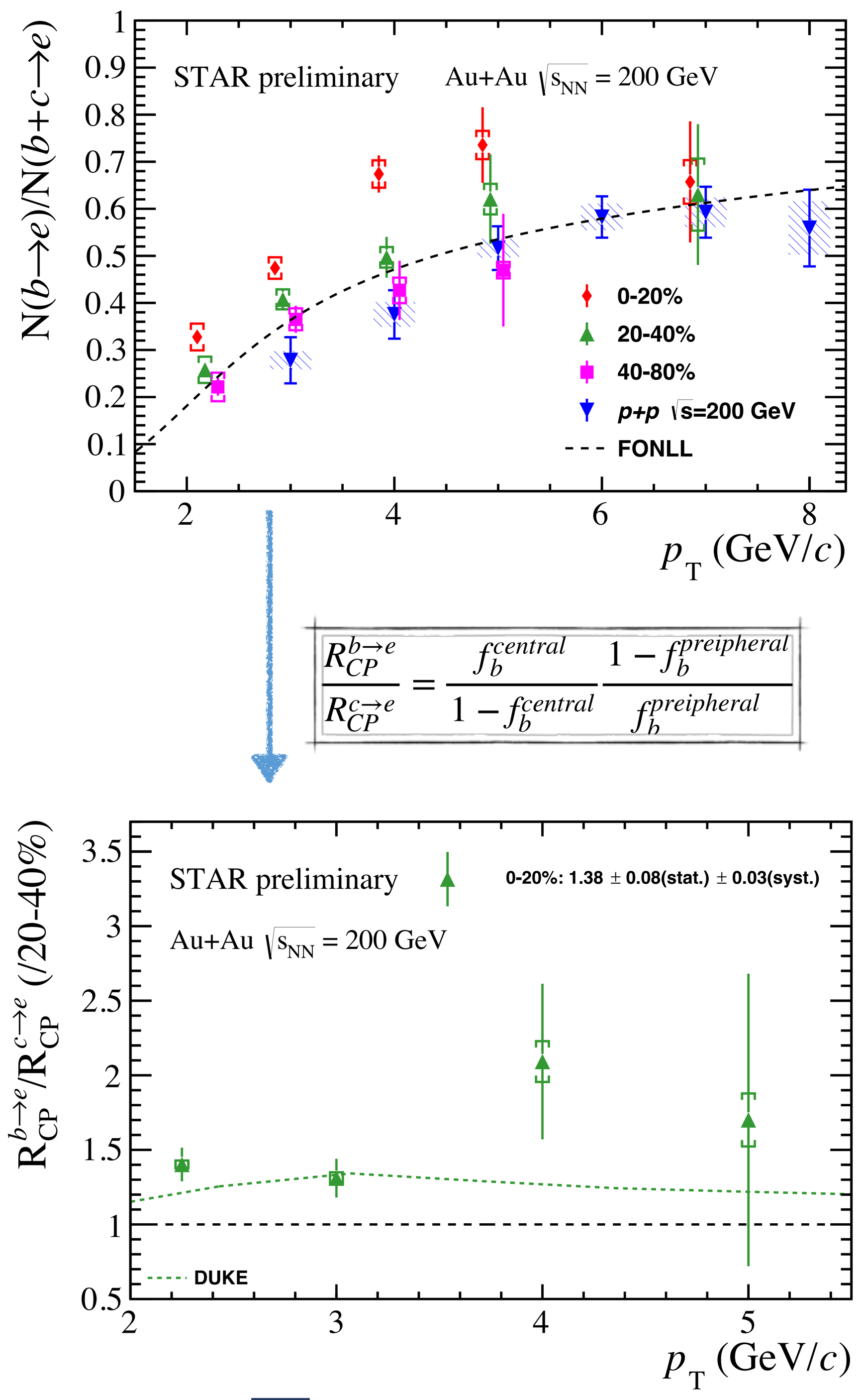
Results



$$R_{AA}^{b\rightarrow e} = \frac{f_b^{AA}}{f_b^{pp}} R_{AA}^{NPE} \qquad R_{AA}^{c\rightarrow e} = \frac{1 - f_b^{AA}}{1 - f_b^{pp}} R_{AA}^{NPE}$$



$$\frac{R_{CP}^{b\rightarrow e}}{R_{CP}^{c\rightarrow e}} = \frac{f_b^{central}}{1 - f_b^{central}} \frac{1 - f_b^{peripheral}}{f_b^{peripheral}}$$



✦The bottom-decayed electron fraction in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV is extracted
- Bottom fraction enhanced in central collisions, approaching p+p values towards peripheral
- The nuclear modification factors R_{AA} of the charm- and bottom-decayed electrons are obtained separately for 0-80% Au+Au collisions
  - R_{AA} ($c\rightarrow e$) < R_{AA} ($b\rightarrow e$) (~3σ at p_T^e = 2 - 8.5 GeV/c)
  - Consistent with mass hierarchy of parton energy loss ($\Delta E_c > \Delta E_b$)
- Ratio of R_{CP}
  - Cleaner measurement as dominant systematic uncertainties nearly cancelled
  - R_{CP}(0-20%/20-40%) > 1 with significance of 4.4σ (stat.+syst.)

References

[1] A. Buzzatti and M. Gyulassy, Phys. Rev. Lett. 108, 022301 (2012)
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[3] M. Cacciari, P. Nason, and R. Vogt, Phys. Rev. Lett. 95, 122001 (2005)
[4] S. Cao, G.-Y. Qin, and S. A. Bass, Phys. Rev. C 92, 024907 (2015)

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The STAR Collaboration
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