Heavy Flavor Results from PHENIX

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For the PHENIX Collaboration
Outline

• Measurement of single electrons from charm and bottom decays at mid rapidity in Au-Au collisions at 200 GeV using the VTX (Phys. Rev. C 93, 034904 (2016))

• New Preliminary $B \rightarrow J/\psi$ measurement at forward rapidity in 200 GeV Cu-Au
Measurements of Single Electrons from Charm and Bottom decays:

Single electrons from inclusive heavy flavor decays have been shown in previous results to be strongly suppressed in Au-Au collisions.

The high-$p_T$ regime is expected to be dominated by electrons from bottom.
The Silicon Vertex Tracker (VTX) is located in the central arms and has 4 layers between $r = 2.6$ and $16.7$ cm.

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The Forward Silicon Vertex Tracker (FVTX) is located in the north and south muon arms and has 4 layers between $z=20$ and $38$ cm.

- Provides accurate measurement of radial distance
Semileptonic decays of both bottom and charm hadrons produce displaced electrons.

The decay length of bottom hadrons is larger than that of charm hadrons ($L$ in the figure shown).

The Distance of Closest Approach (DCA) of electron tracks was measured using the VTX.
Displaced Electron Tracking using the VTX

Calculate the Distance of Closest Approach (DCA) of an electron track to the collision vertex

The DCA is calculated separately in the transverse ($DCA_T$) and Longitudinal ($DCA_L$) planes

$DCA_T$ Resolution about 60 $\mu$m
Analysis Strategy

- 2 part analysis:
  - Used previously published invariant yield of single electrons from heavy flavor decays
  - Measured DCA$_T$ of electrons, taking advantage of the different decay lengths of the D and B mesons
  - Used Bayesian unfolding to simultaneously take both parts into account in the analysis
DCA_T Distributions: Backgrounds

  - Used 5 p_T bins between 1.5 < p_T < 5 GeV

High-Multiplicity Bkg.
Data driven shape
Tracks with large DCA_L

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*Phys. Rev. C 93, 034904 (2016)*

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Unfolding

• The unfolding uses Bayesian inference methods to determine parent charm and bottom hadron $p_T$ distributions

• Done through simultaneous fit to electron invariant yield and the 5 electron DCA$_T$ distributions

• The decay matrix contains the probability of a bottom (charm) hadron with a given $p_T$ to decay to an electron with a given $p_T$ and DCA$_T$
  - Bottom := $B^\pm$, $B^0$, $B_s$, $\Lambda_b$  (Includes $B\to D\to e$)
  - Charm := $D^0$, $D^\pm$, $D_s$, $\Lambda_c$
  - Modeled $h\to e$ decays using PYTHIA-6

Input:
Measured $e^\pm$ invariant yields
DCA$_T$ ($p_T$)

Parameters:
$p_T$ dependent yield of $c/b$ hadrons

Likelihood

Sampled with MCMC methods

Decay Matrix
-PYTHIA 6-

a priori constraints (regularization)

Full parameter probabilities and correlations
Spectra agreement with data:

The unfolded $D^0$ $p_T$ spectra agrees within uncertainties with measurements from STAR.
DcaT distribution and component refold

The charm and bottom yield predicted by the unfolding is consistent with electron measured DCA$_T$ distributions.
The unfolding results are consistent with the published inclusive heavy flavor electron invariant yields.

Between the 3.5->5 GeV range the bottom contributions begin to dominate those of the charm.
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  - Uncertainty in the fraction of non photonic contributions.
  - Uncertainty in the $K_{e3}$ normalization.
  - Uncertainty in the regularization parameter, and $\theta_{\text{prior}}$.

The unfolded $b\to e$ fraction is consistent within the large uncertainties with previously published results from both STAR and PHENIX for $p+p$.

Implies that electrons from bottom hadron decays are similarly suppressed in Au-Au as the electrons from charm hadrons.
Bottom and Charm $R_{AA}$

Using previously published $p+p$ results from correlation measurements an $R_{AA}$ was extracted for both electrons from bottom and electrons from charm.

Reasonable agreement with the previously published inclusive electrons from heavy flavor $R_{AA}$

We see that around 3 GeV the electrons from bottom experience much less suppression than electrons from charm.
Muons at forward rapidity

Using muon pairs in the J/Psi mass region an analysis was performed to determine the fraction from B→J/psi decays.
Muon tracks are reconstructed using the Muon Tracker (MuTr) with the Muon ID and are matched to stand alone tracks reconstructed in the FVTX.

Miss-matched tracks were modeled using event mixing.

Using the FVTX a $DCA_R$ was measured, $DCA_R$ is the distance between the projected position of a muon track to a X-Y plane located at the collision z vertex and the collision vertex projected along R.
Background components

• Two sources of background:
  • Di-muon combinatorial
  • FVTX-MuTr mismatches: coming from incorrectly matching a MuTr track to the FVTX stand alone track.

• Signal templates and backgrounds are fitted together to extract the $B \to J/\psi$ fraction
B→ J/ψ prompt J/ψ separation through DCA$_R$

- Prompt J/ψ and B→ J/ψ DCA$_R$ template shapes, determined using MC simulations, were used in the fit.
- The sum of the DCA$_R$ contributions agrees well with the data as shown in the bottom panel.

DCA$_R$ Distributions for clarity are shown BG subtracted
$F_{B \rightarrow J/\psi}$ was determined for both the gold and copper going directions.

Difference is attributed to a smaller suppression of $B$ mesons relative to inclusive $J/\psi$ at RHIC energies.
Non-prompt $J/\psi$ $R_{AA}$

$$R_{AA}^{B\to J/\psi} = \frac{F_{B\to j/\psi}^{AA}}{F_{B\to j/\psi}^{pp}} R_{AA}^{J/\psi} = \frac{F_{B\to j/\psi}^{AA}}{0.1} R_{AA}^{J/\psi}$$

- The $F_{B\to j/\psi}^{AA}$ was taken from the $B\to J/\psi$ fraction, separately for the Au and Cu going directions.

- $R_{AA}^{J/\psi}$ was taken from previously published results: *Phys. Rev. C90, 064908 (2014).

- $F_{B\to j/\psi}^{pp}$ was assumed to be 0.1 because there is no $F_{B\to j/\psi}^{pp}$ world data at $\sqrt{s} = 200$ GeV.
Conclusions

• We have had lots of exciting results coming out of PHENIX with regards to heavy flavor quarks.
  • Results on single electrons from charm and bottom decays at mid rapidity in Au-Au collisions agree within uncertainties with previously published results
    • Similar suppression of \( b \rightarrow e \) and \( c \rightarrow e \) at high-\( p_T \)
    • \( b \rightarrow e \) is less suppressed than \( c \rightarrow e \) at low-\( p_T \)
  • New preliminary results for forward rapidity \( B \rightarrow J/\psi \) measurement in Cu-Au.
    • In Cu-Au at 200 GeV \( B \)-mesons at forward-rapidity are less suppressed than prompt \( J/\psi \)
• A unfolding analysis is now being done using the run14 AuAu data set, which is \( \sim 10 \times \) statistics, as well as with the run15 pp data set.
  • This will allow for a full \( R_{AA} \) and extend the results to a higher \( p_T \) range.

• There is a talk tomorrow in the Small System workshop by Xuan Li at 11:30 AM where she will discuss additional recent results from the FVTX
Backups
High Multiplicity Random Background

- Single electrons were simulated and embedded into real Au-Au events.
- High dcaL tracks are shown not to be physical and to come from random association tracks.
Conversion Veto

- Total VTX radiation length is 13%

- Conversion veto efficiency was tested using a full Geant3 simulation of the detector with hits running through the reconstruction software.

- The conversion Veto works by looking for two electron tracks within a $p_T$ dependent window, if two tracks are identified as being “too close” they are labeled as conversions and removed.

The DCA$_R$ is the projection along the vector defined by the PxPy of the muon of the separation distance between the projected muon position and the event vertex in the x-y plane at the z location of the collision vertex.
J/ψ suppression in PHENIX and ALICE

Shows that for PHENIX the inclusive J/ψ at forward rapidity is more suppressed than in ALICE