Measurements of Electrons from Semi-leptonic Heavy Flavor Decays in p+p and Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV at STAR

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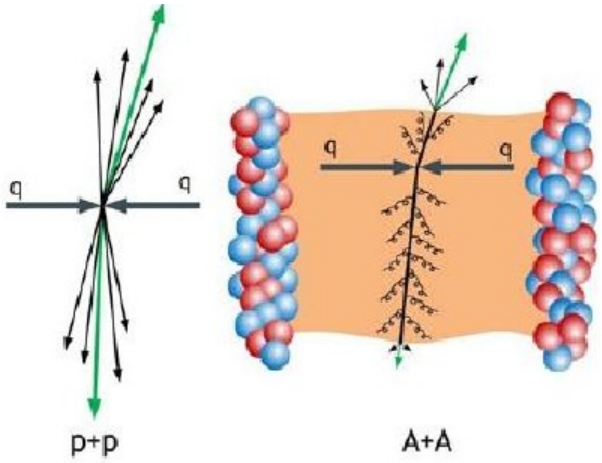
Outline

- Motivation
- STAR Experiment at RHIC
- Non-Photonic Electron (NPE) Measurements
  - NPE production in p+p, Au+Au and U+U collisions
  - Separate D/B-decayed electrons in p+p and Au+Au collisions
- Summary and Outlook

Motivation

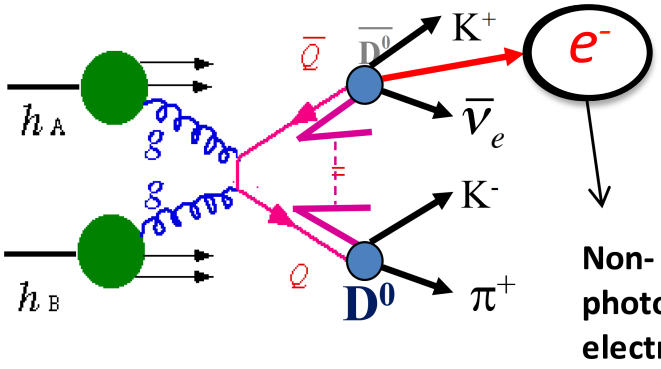
Heavy quarks (charm and bottom)

- Large masses, dominantly produced in hard scatterings at the early stage at RHIC energies
- Test the validity of pQCD in p+p collisions and provide the reference for measurements in heavy-ion collisions
- Probe to the QCD medium properties
  - ->energy loss (R_{AA})
  - ->thermalization (elliptic flow v_2)

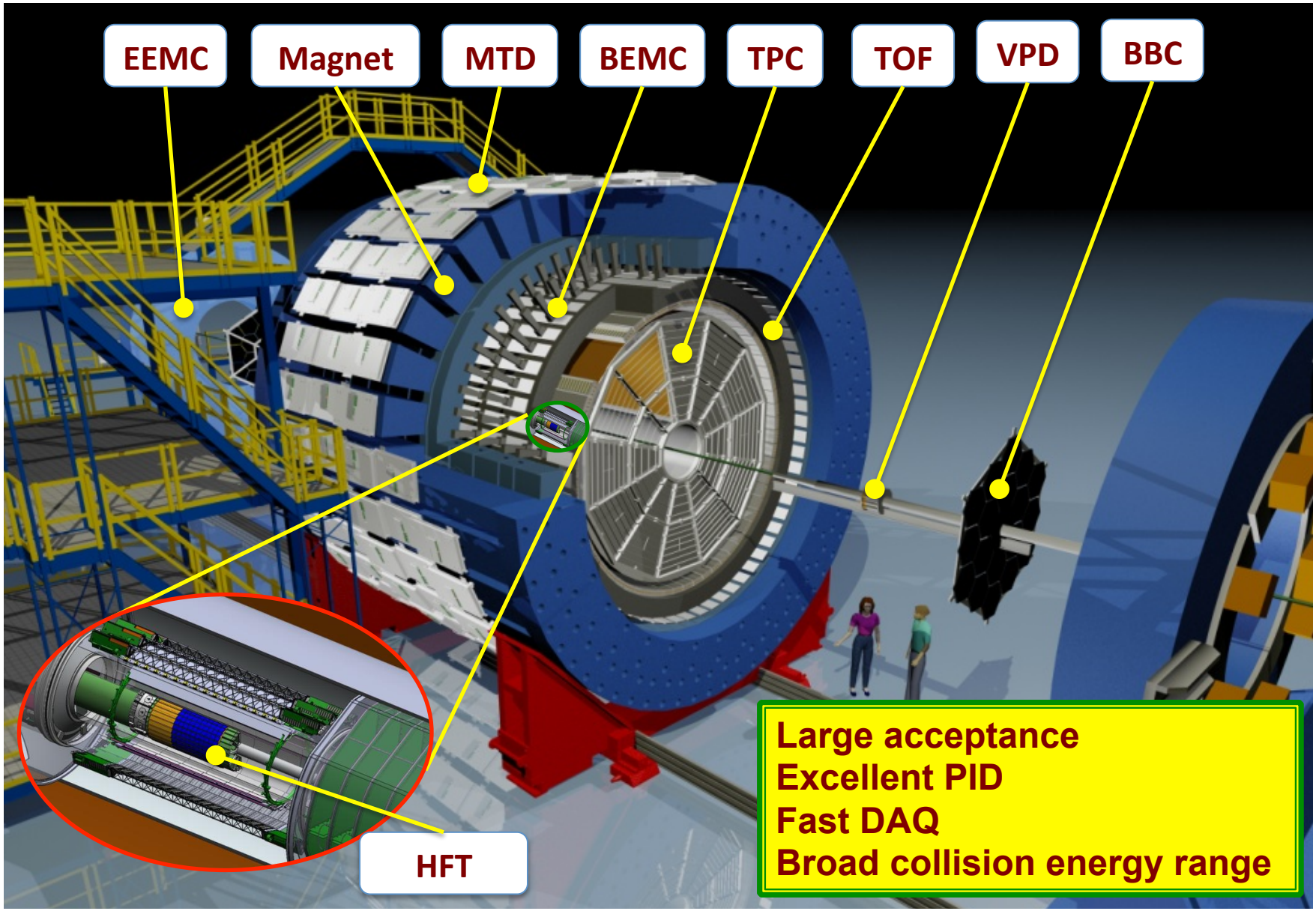


Non-Photonic Electrons (NPE)

- Produced from semi-leptonic decays of open heavy flavor hadrons
- A good proxy to measure heavy flavor quark production



STAR Experiment at RHIC – STAR Detector



NPE Measurements – Data Analysis Methodology

Inclusive electrons
After electron ID

- **Non-photonic electrons**
  From D/B hadron decays
- **Photonic electrons**
  Partially reconstructed through e^+e^- pairs
  - γ conversion $\gamma \rightarrow e^+e^-$
  - π^0 Dalitz decay $\pi^0 \rightarrow \gamma e^+e^-$
  - η Dalitz decay $\eta \rightarrow \gamma e^+e^-$
- **Hadron contamination**
  Statistically subtracted

NPE yield after background correction:

$$N_{npe} = N_{inclusive} * purity - N_{photonic} / \varepsilon_{photonic}$$

- purity: purity of inclusive electron sample
- $\varepsilon_{photonic}$: photonic electron reco. efficiency

NPE invariant cross-section:

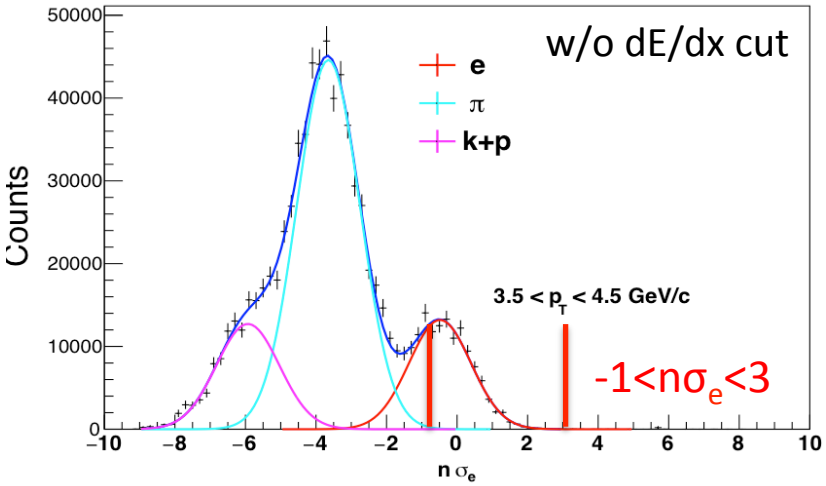
$$E\frac{d^3\sigma}{dp^3} = \frac{1}{L}\frac{1}{2\pi p_T dp_T dy}\frac{N_{npe}}{\varepsilon_{Total}}$$

$$\varepsilon_{Total} = \begin{cases} \varepsilon_{dE/dx}\varepsilon_{BEMC}\varepsilon_{Trigger}\varepsilon_{Tracking} & p_T > 1.5\ \text{GeV/c} \\ \varepsilon_{dE/dx}\varepsilon_{TOF}\varepsilon_{Tracking} & p_T < 1.5\ \text{GeV/c} \end{cases}$$

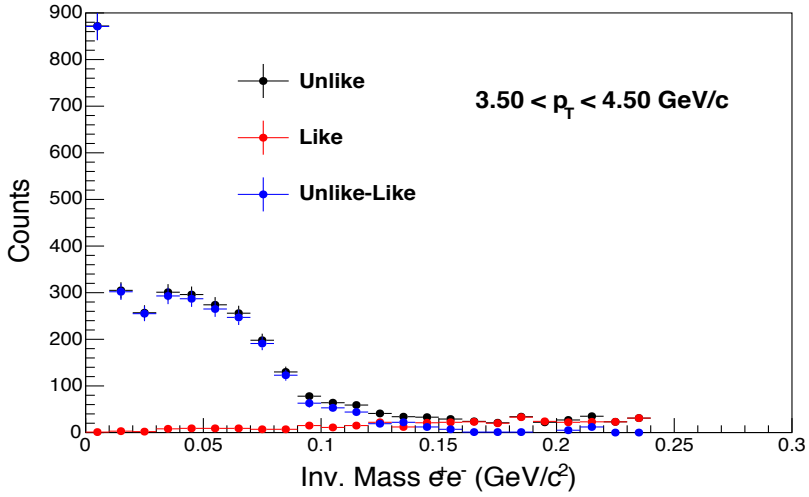
NPE Measurements – Data Analysis Methodology

Run12 200 GeV p+p collisions

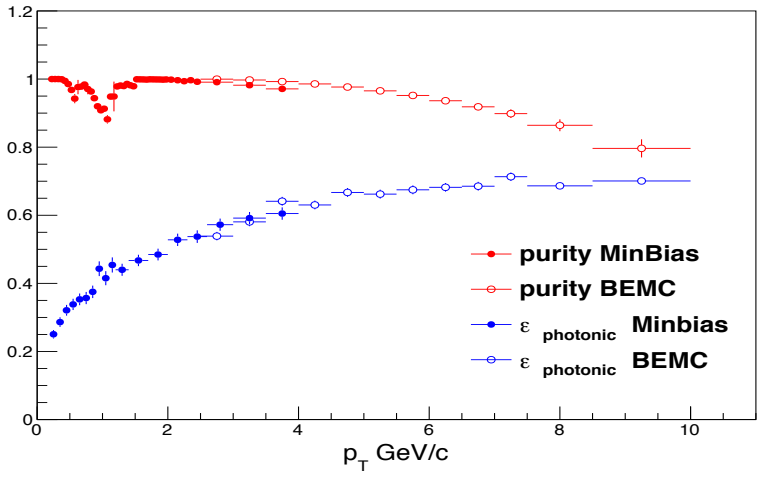
Fit dE/dx Distribution to Extract Purity



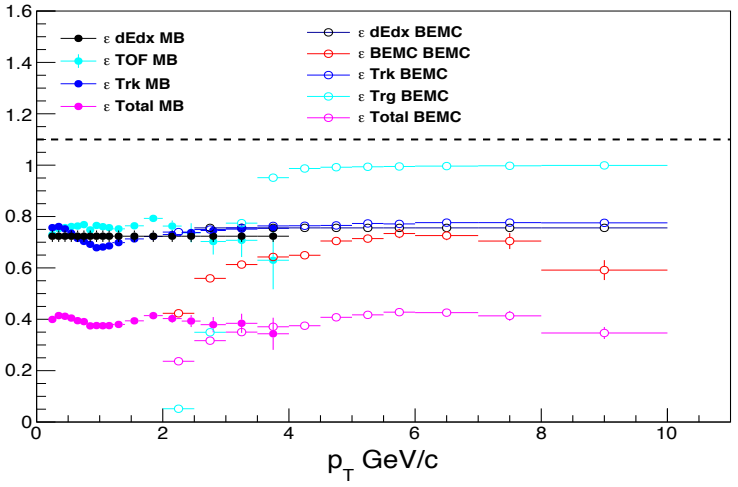
Photonic Electron Reconstruction



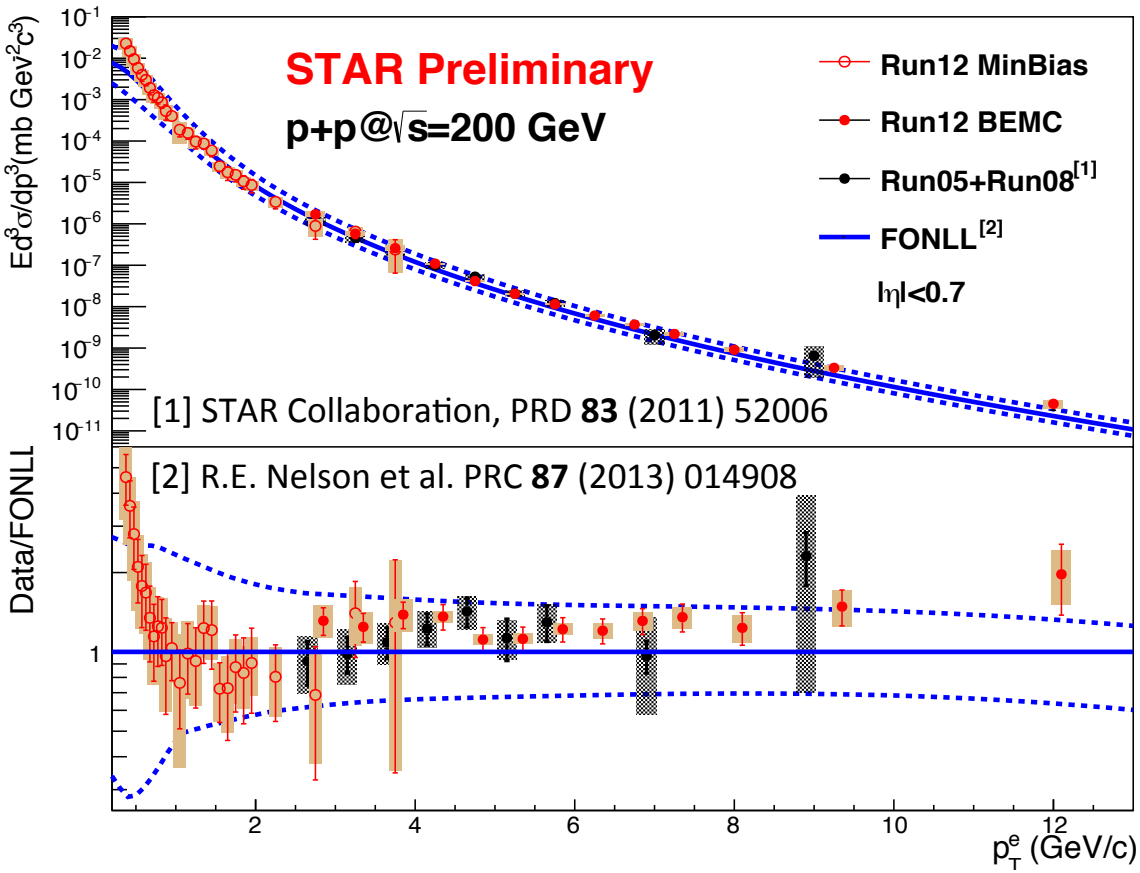
Purity and Photonic Electron Eff.



Electron Reconstruction Eff.

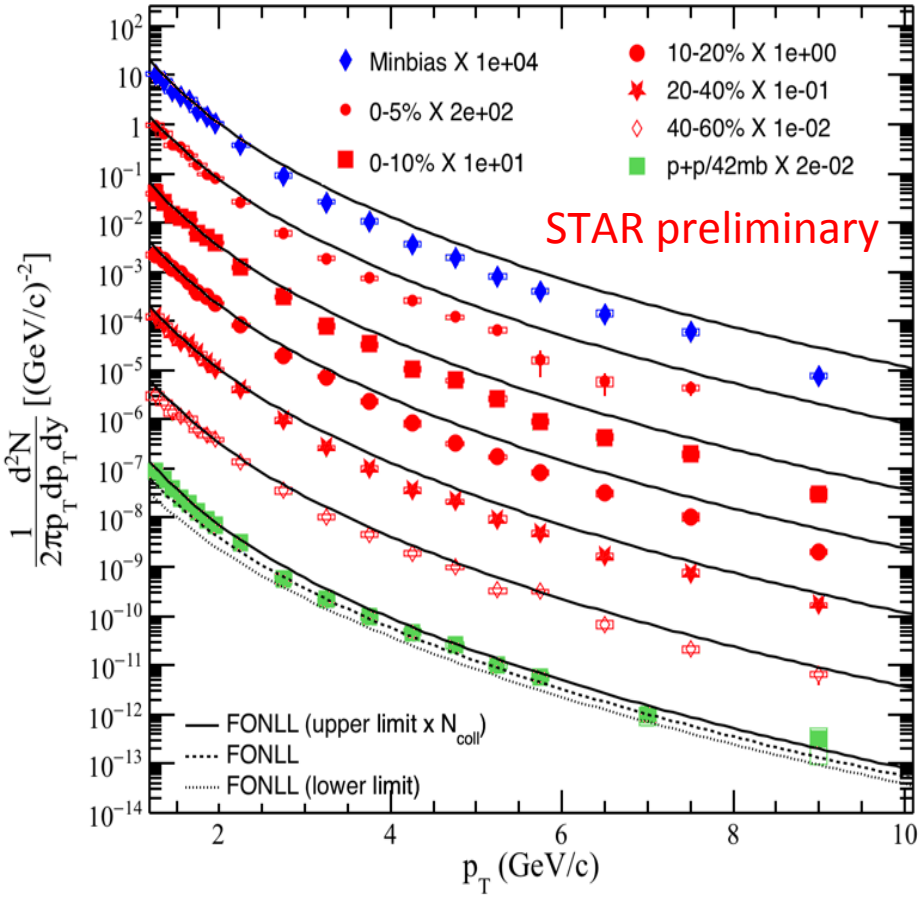


NPE Measurements – NPE in 200 GeV p+p collisions



- Spectrum was extended to both lower and higher p_T regions.
- Consistent with pQCD calculation and previous STAR result. There is tension at low p_T between data and pQCD calculation.
- Significantly better precision, leading to a reduction in the uncertainty of R_{AA} measurements in heavy-ion collisions.

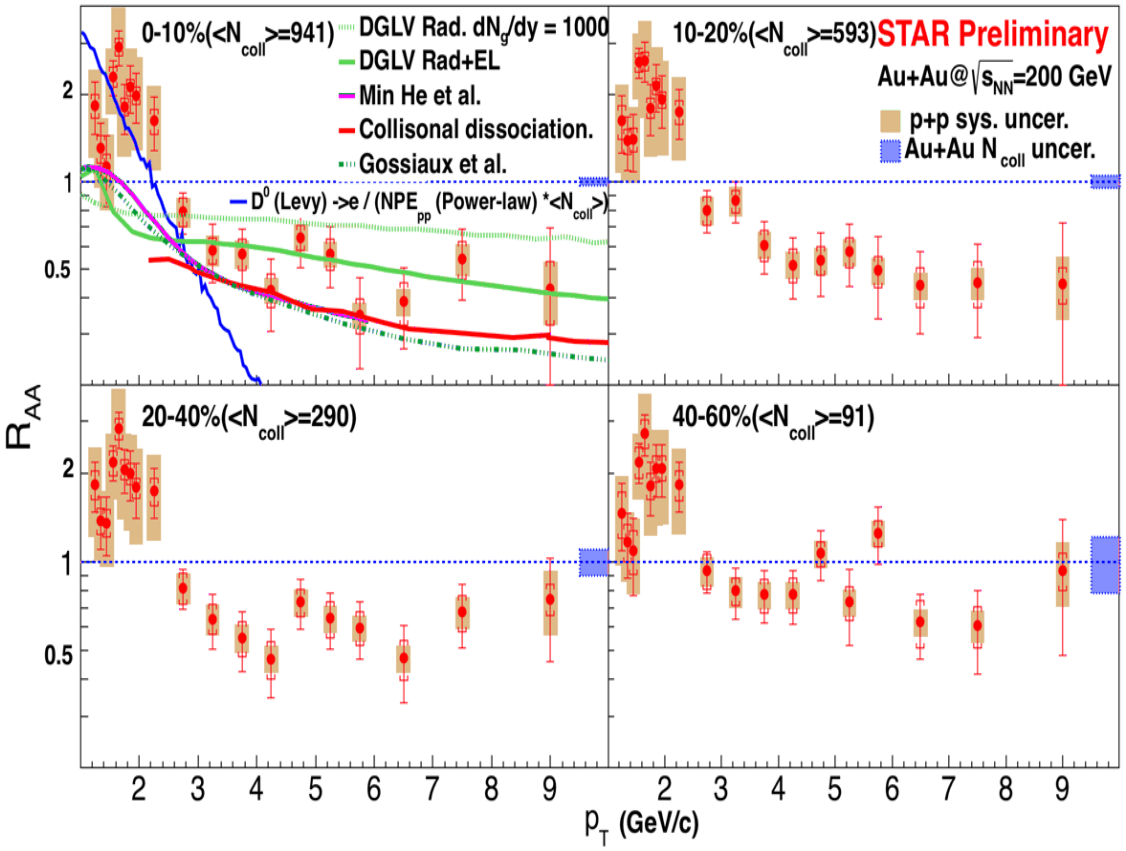
Run10 200 GeV Au+Au collisions



- In central collisions, significant differences were observed between Au+Au measurements and the scaled FONLL calculation, indicating existence of hot medium effects.
- From central to peripheral collisions, the difference decreases. This is consistent with the expectation that peripheral collisions should have smaller QGP effects.

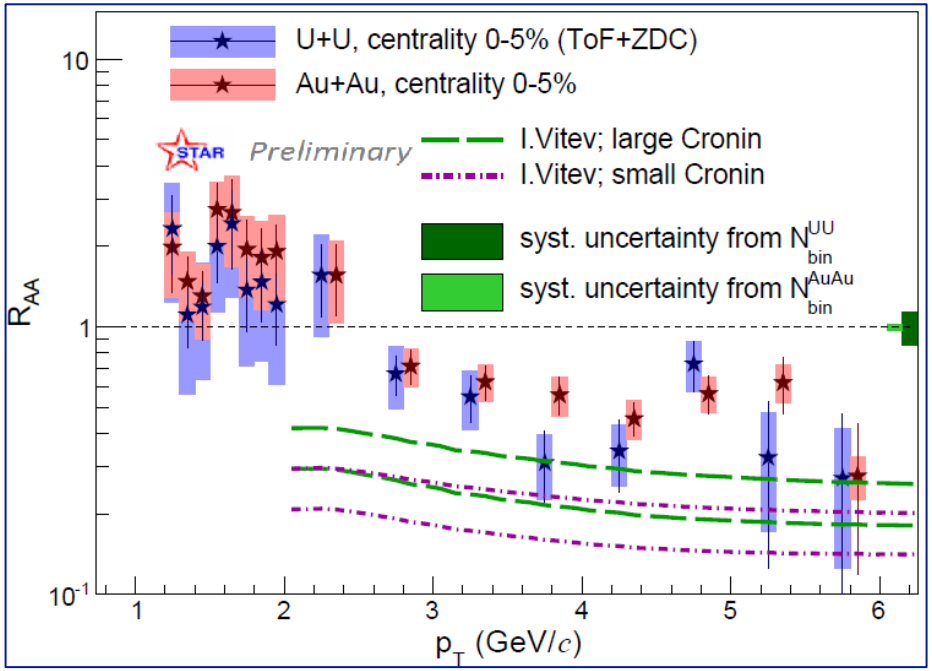
- The analysis with Run14 200 GeV Au+Au collisions is ongoing.

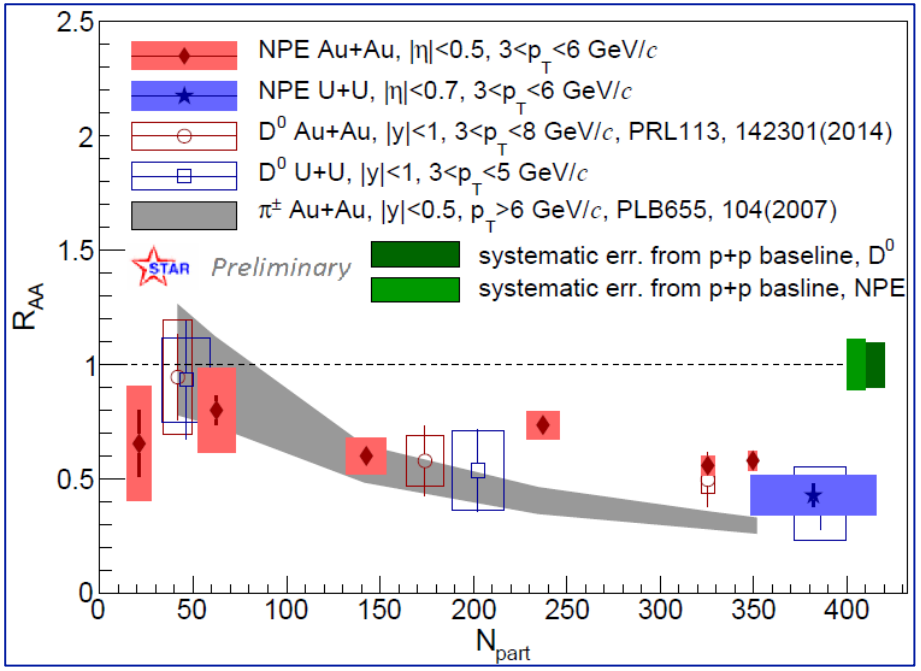
NPE Measurements – NPE R_{AA} in 200 GeV Au+Au collisions



- In the low p_T region, an enhancement is observed that is consistent with electrons from tagged D^0 decays. The large systematic uncertainties are dominated by that from the p+p reference.
- For p_T > 4 GeV/c, significant suppression is seen in the most central Au+Au collisions. The suppression decreases gradually toward more peripheral collisions.

NPE Measurements – NPE R_{AA} in 200 GeV Au+Au collisions



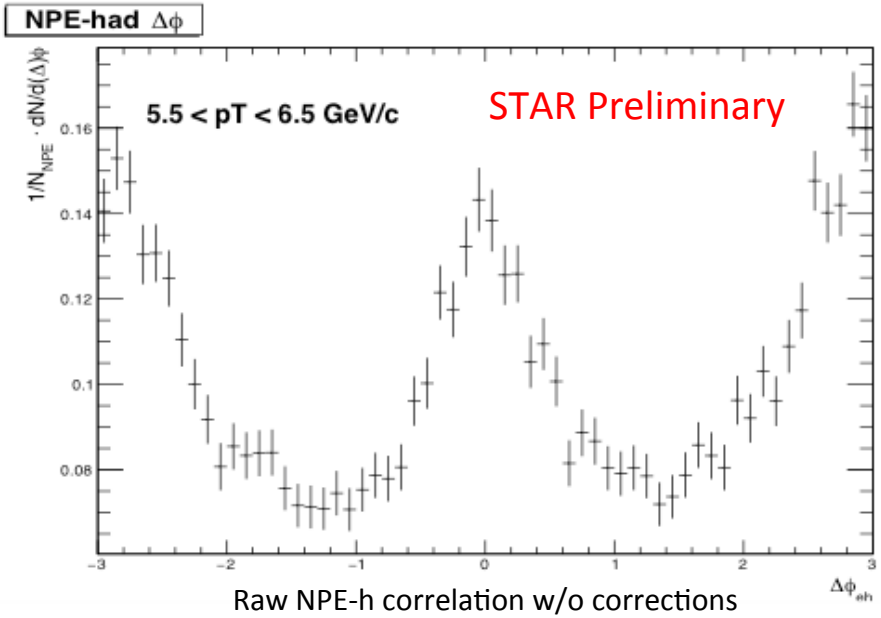


U+U and Au+Au systems use the same improved Run12 p+p reference

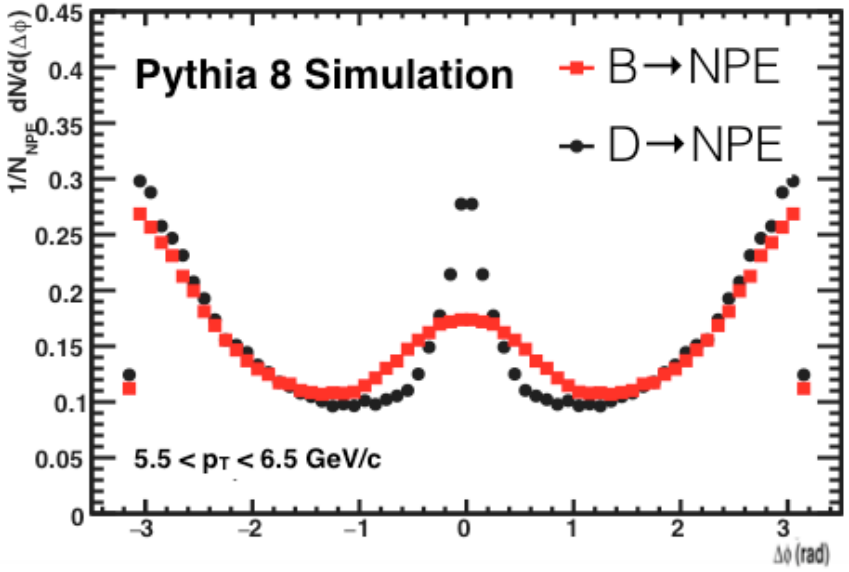
- NPE R_{AA} in the 0-5% most central 200 GeV Au+Au and 193 GeV U+U collisions are consistent within uncertainties.
- NPE suppression at high p_T in Au+Au collisions is similar to D^0 mesons and light hadrons in Au+Au collisions as well as NPE and D^0 mesons in U+U collisions.

NPE Measurements – Separate D/B-decayed Electrons

Run12 200 GeV p+p collisions

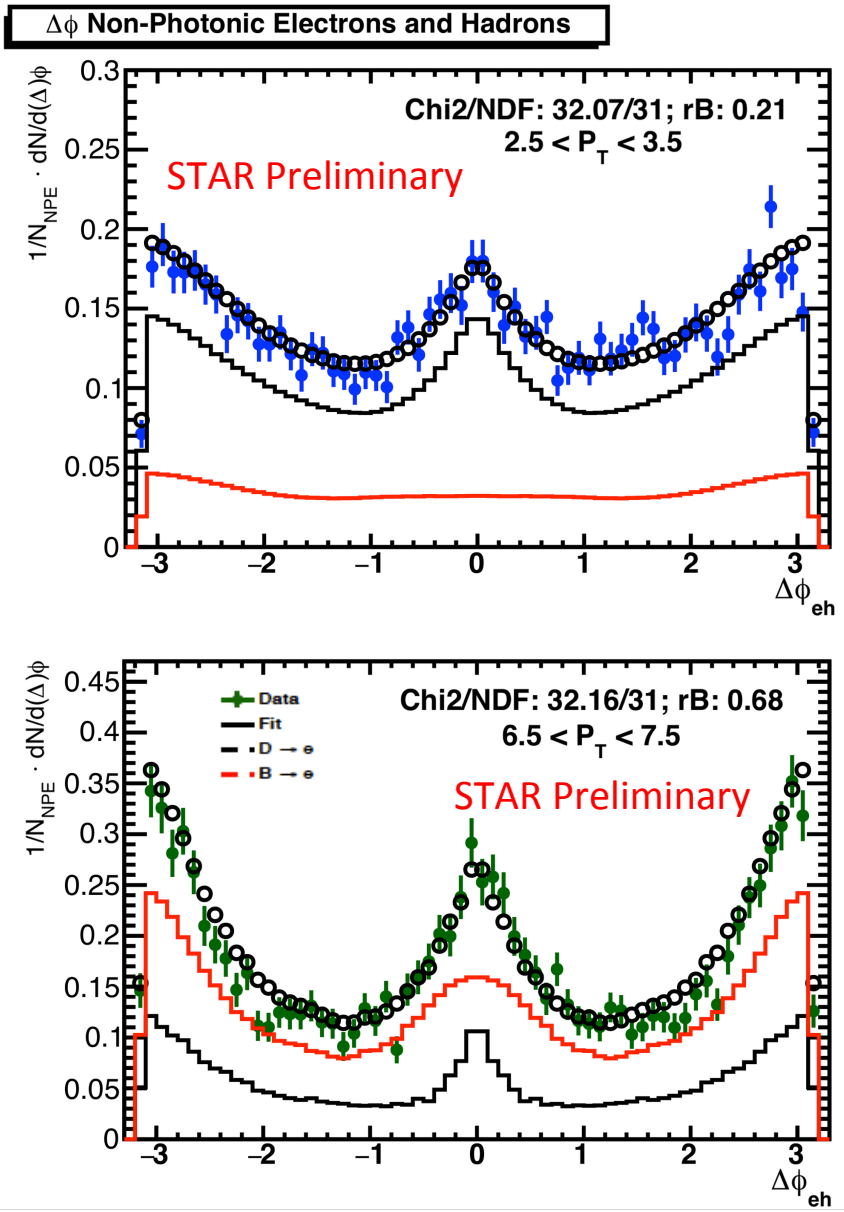


Raw NPE-h correlation w/o corrections

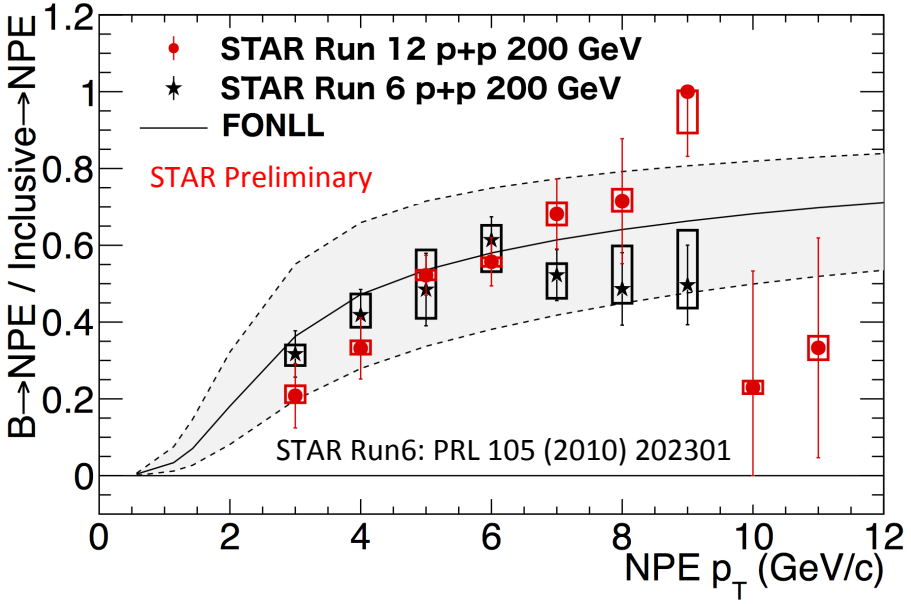


- Prominent correlation signals on both near-side and away-side
- PYTHIA 8.1 combined with STAR-HF-Tune Version 1.1 to generate e(D)-h and e(B)-h correlations for 200 GeV p+p collisions
- Significant difference on the near-side of correlation distributions between D and B decays due to different decay kinematics

NPE Measurements – Separate D/B-decayed Electrons



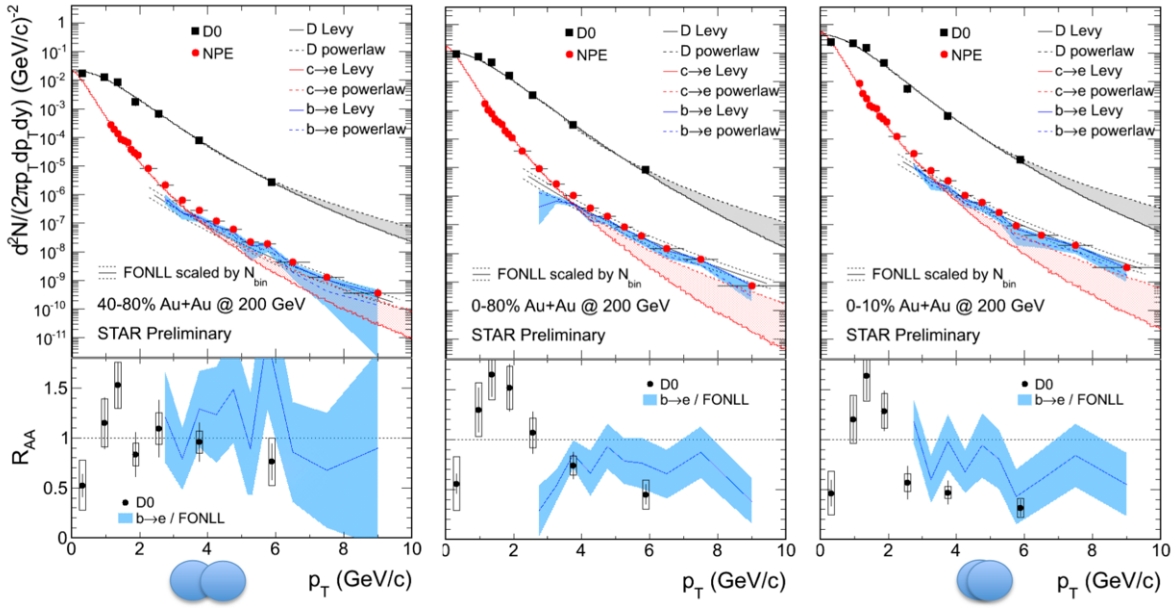
- Fit function: (R*PYTHIA_B+(1-R)*PYTHIA_D)*Norm
- R is B contribution, i.e. B/(B+D), as a free parameter in fit function.



- B→e contributions in 200 GeV p+p collisions are obtained from NPE-h correlations, and consistent with FONLL calculation.
- Agree with previous STAR analysis for p_T < 8.5 GeV/c with significantly reduced systematics.

NPE Measurements – Separate D/B-decayed Electrons

B->e R_{AA}



$N_{b->e} = N_{NPE} - N_{c->e}$

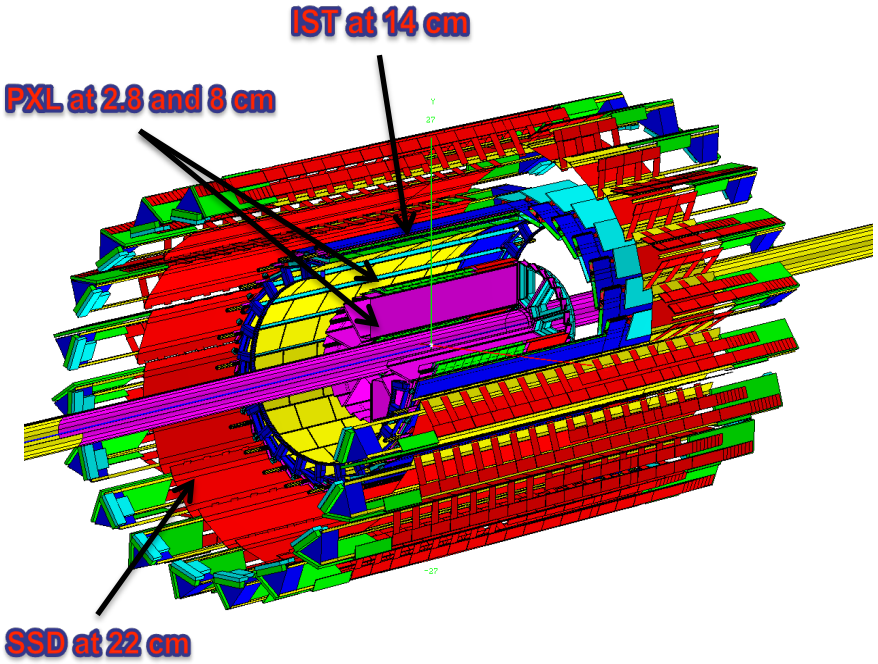
$N_{c->e}$: extract the charm quark cross-section from the measured D^0 p_T spectrum by STAR, and decay the charm quarks into electrons through PYTHIA.

Two different functions, i.e. Levy and Power-law, are used to fit D^0 p_T spectrum, and the difference from these two fits is taken as the uncertainty.

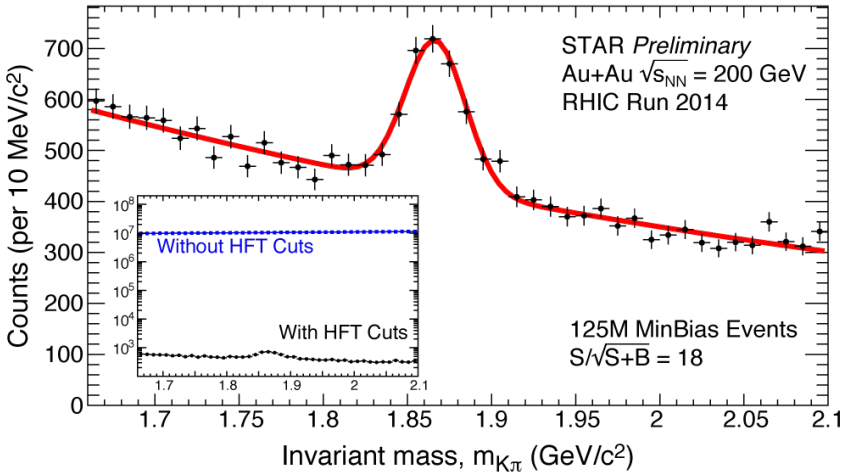
1) In peripheral collisions, B->e R_{AA} is consistent with no suppression.

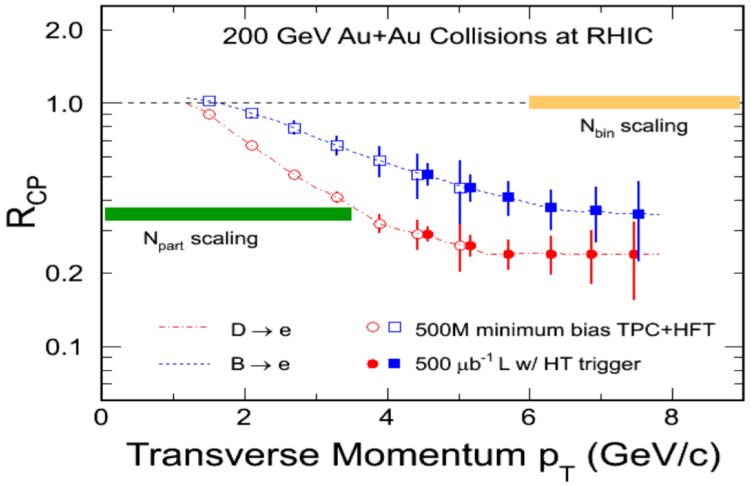
2) In mini. bias and 0-10% central collisions, B->e R_{AA} shows an indication of suppression (~ D^0 R_{AA} within large uncertainties).

STAR Heavy Flavor Tracker



- First application of Monolithic Active Pixel Sensor (MAPS) technology in collider experiments. DCA resolution < 50 μm for Kaons at p_T = 750 MeV/c.
- Recorded about 3B Minimum-Bias 200 GeV Au+Au events for D^0, $D^{\pm}$, D_s, Λ_c, and 1 nb^{-1} high p_T electron and dimuon samples for D/B→e and B→J/ψ studies in 2014 and 2016.
- HFT will allow the separation of B and D decayed electrons for the first time at the STAR experiment using the impact parameter method.





Summary and Outlook

- NPE cross-section in p+p collisions at $\sqrt{s}$ = 200 GeV

  (1) Measured over a broad p_T range 0.3-12 GeV/c with significantly improved precision than previous measurements.

  (2) Consistent with pQCD calculation except that there is tension at low p_T.

- NPE R_{AA} in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

  (1) Strong suppression at high p_T in central collisions, which is consistent with substantial energy loss of heavy quarks in dense matter.

  (2) Likely enhancement at low p_T, which is consistent with D^0 R_{AA}, suggesting that charm quarks may recombine with light quarks in the medium.

  (3) Consistent results between 0-5% central Au+Au and U+U collisions within uncertainties.

- Separate D/B-decayed electrons

  (1) Bottom contribution to NPE is extracted using NPE-h correlations in p+p collisions at $\sqrt{s}$ = 200 GeV with extended p_T range and reduced systematics than previous measurements.

  (2) Looking forward to a separation of charm and bottom contributions to NPE in Au+Au collisions with HFT.

Thanks for your attention!