Cold Nuclear Matter Effects on Non-photonic Electron Production in p+Au Collisions with the STAR Experiment

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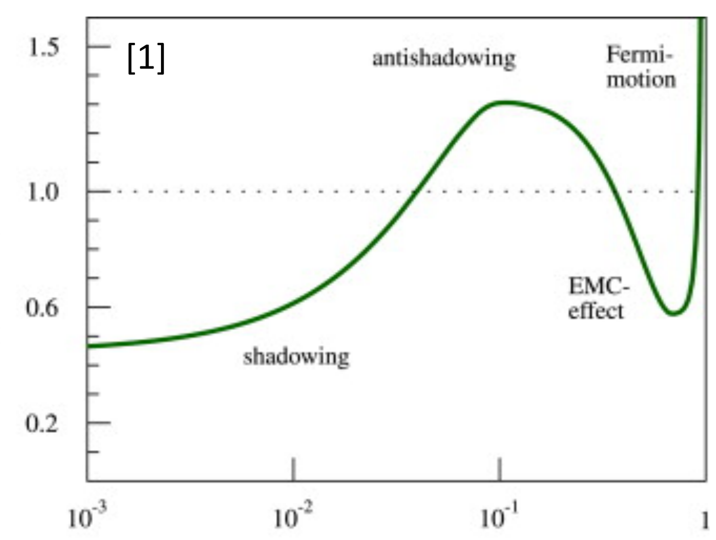
Abstract

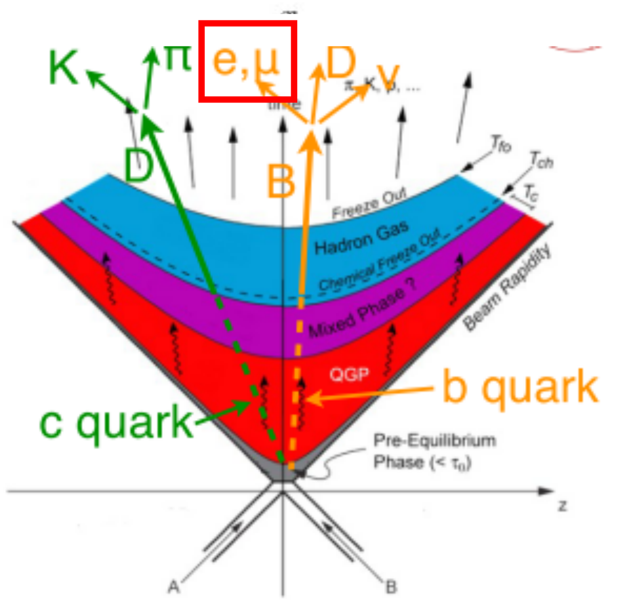
Due to their large masses, heavy flavor quarks are dominantly produced in initial hard parton scattering processes in high-energy heavy-ion collisions. They experience the full evolution of the strongly interacting Quark-Gluon Plasma (QGP) created in such collisions. Thus, heavy quarks have been suggested as excellent probes of the properties of the QGP. To study how heavy flavor quarks interact with the QGP, initial- and final-state effects upon heavy flavor production due to the presence of the heavy ions must be understood. These effects, also known as Cold Nuclear Matter (CNM) effects, need to be studied in collision systems that include a heavy ion but are not expected to produce a QGP, such as p+Au collisions. Non-Photonic Electrons (NPE) from semi-leptonic decays of open heavy flavor hadrons can serve as a proxy for heavy flavor quarks, and be used to measure CNM effects on heavy flavor production. In this poster, we will present the status of the measurement of inclusive NPE production in p+p and p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR experiment. Data were recorded by requiring large energy depositions in the Barrel Electromagnetic Calorimeter, from the 2015 run at the Relativistic Heavy Ion Collider.

Motivation

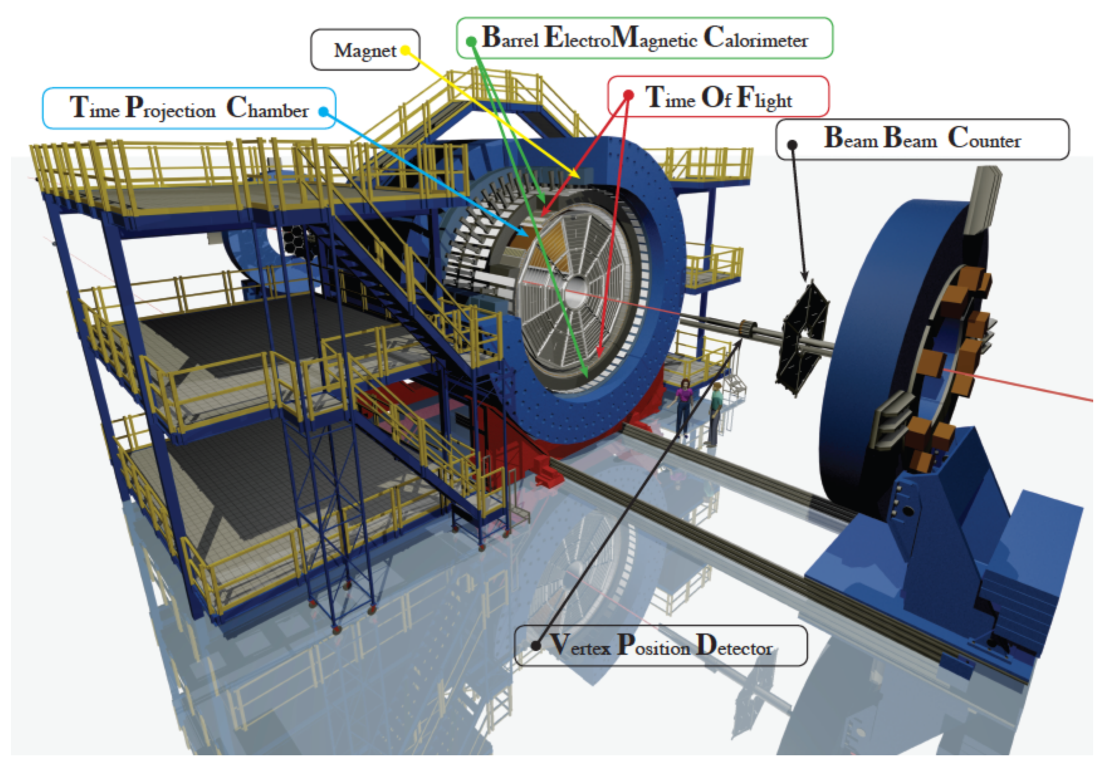
Heavy quark interaction with the QGP results in variations in measured heavy quark production rates relative to that observed in proton-proton collisions. There are other effects on heavy quark production due to the presence of a nucleus in the initial state, which must be measured separately. These Cold Nuclear Matter (CNM) effects include nuclear shadowing and antishadowing, Cronin enhancement, and energy loss (either radiative or collisional) due to multiple scatterings of partons in the nucleus [2]. To study these effects, measurements of heavy quark production can be made in collisions of both p+p and asymmetric small systems like p+Au. A comparison of heavy quark production in p+p and p+Au collisions can help quantify the CNM effects.

To measure heavy quark production, electrons from semi-leptonic decays of D- and B-mesons can be used. These non-photonic electrons (NPE) act as a proxy for parent heavy quarks due to their known branching ratio and the relative ease of charged lepton detection with the STAR detector.

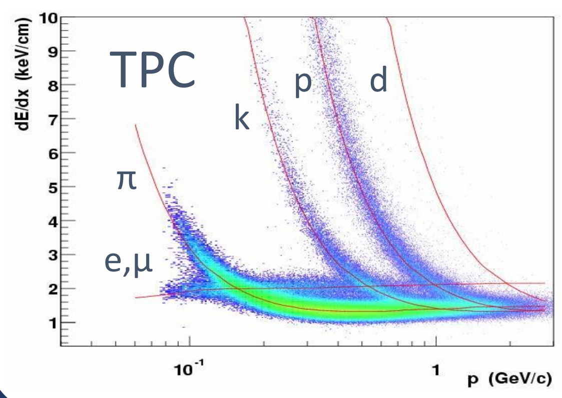


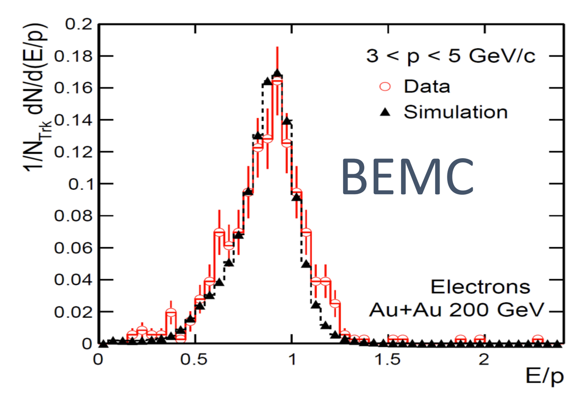


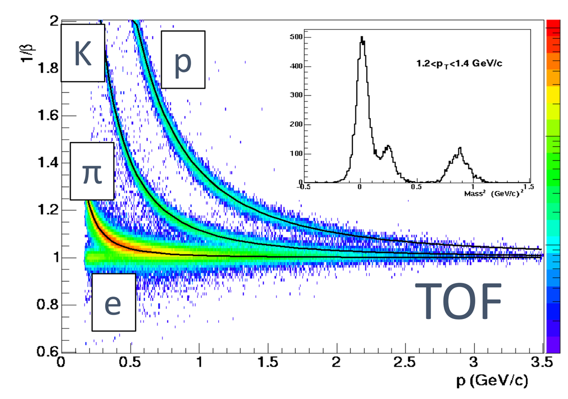
The STAR Detector



- **Time Projection Chamber**
  Tracking, momentum measurement, electron identification via dE/dx.
- **Barrel Electromagnetic Calorimeter**
  Electron identification through energy and momentum. Triggering on high p_T electrons (p_T > 2.0 GeV/c).
- **Time Of Flight**
  Electron identification through flight time for p_T < 1.5 GeV/c.
- **Vertex Position Detector**
  Provide Minimum-bias trigger.







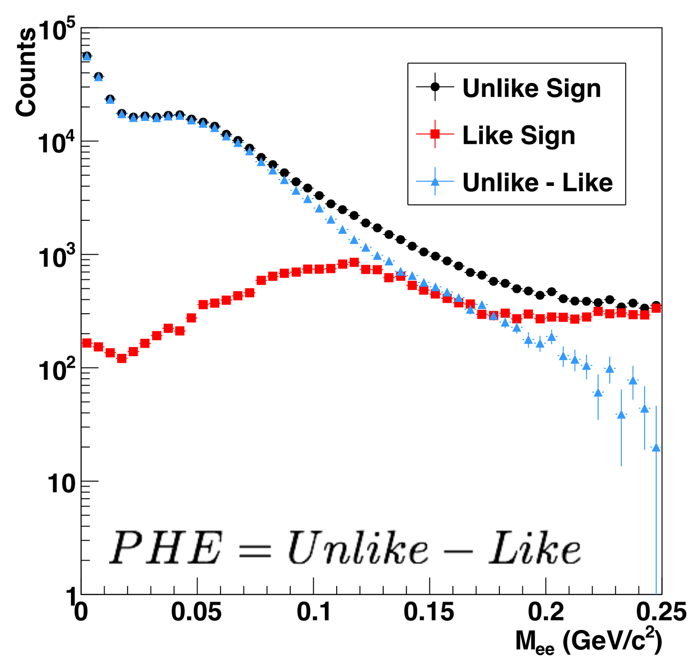
Analysis Method

The NPE spectrum is calculated by measuring the inclusive electron spectrum and subtracting photonic electrons (PHE) from photon conversions and π^0/η Dalitz, which are the dominant background source. The PHE's are selected by pairing electrons and positrons from the same vertex and requiring an invariant mass below 0.24 GeV/c². The PHE reconstruction efficiency (ϵ_{PHE}) is calculated from STAR detector simulations. The purity is extracted via fitting multiple Gaussian functions to $n\sigma_e$, a variable that scales the measured energy loss per unit length by the expected energy loss from Bichsel functions [3] such that electrons should have a mean of $n\sigma_e \sim 0$.

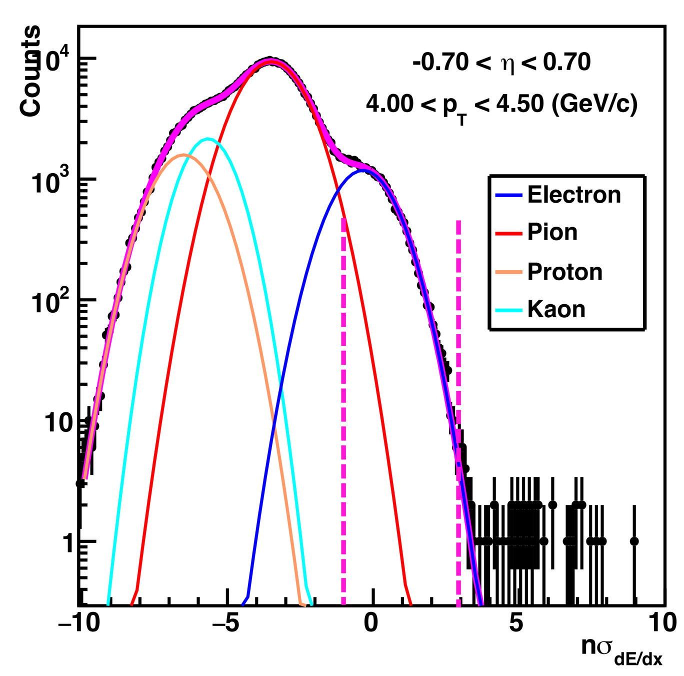
$$n\sigma_e = \frac{1}{\sigma_{dE/dx}} log(\frac{dE/dx_{measured}}{< dE/dx >_e})$$

$$N_{NPE} = N_e \cdot Purity - \frac{N_{PHE}}{\epsilon_{PHE}}$$

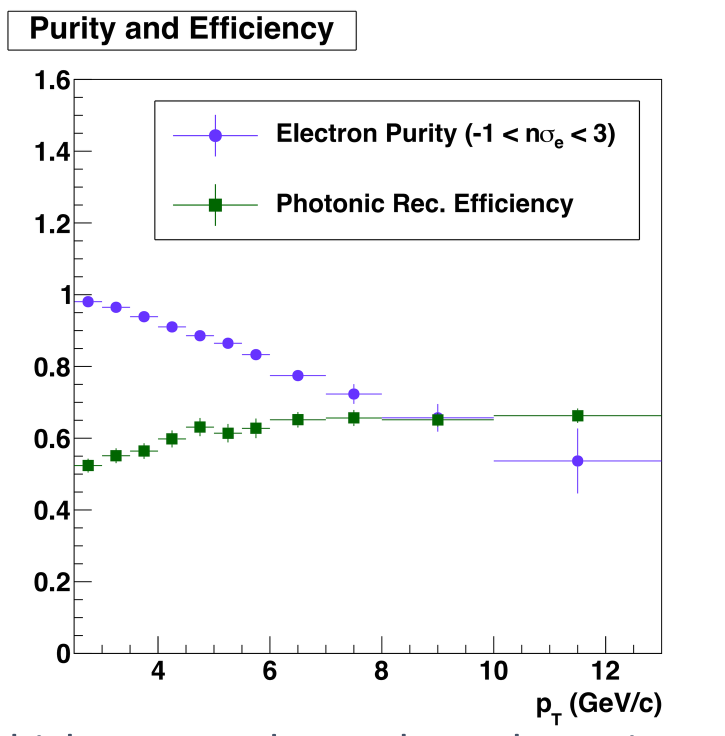
Photonic Electron Selection



Electron Purity



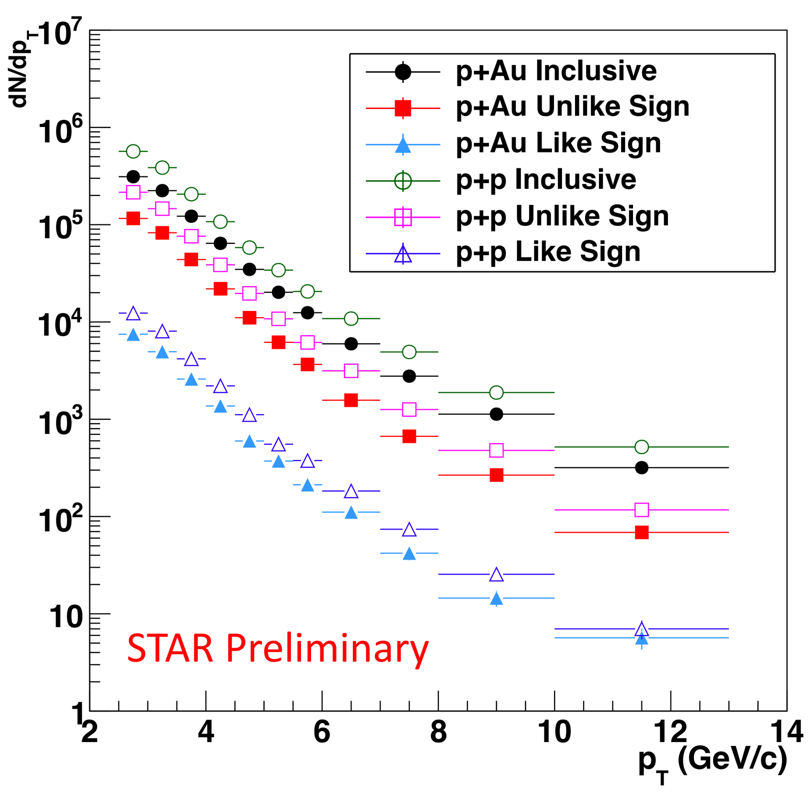
Purity and Efficiency



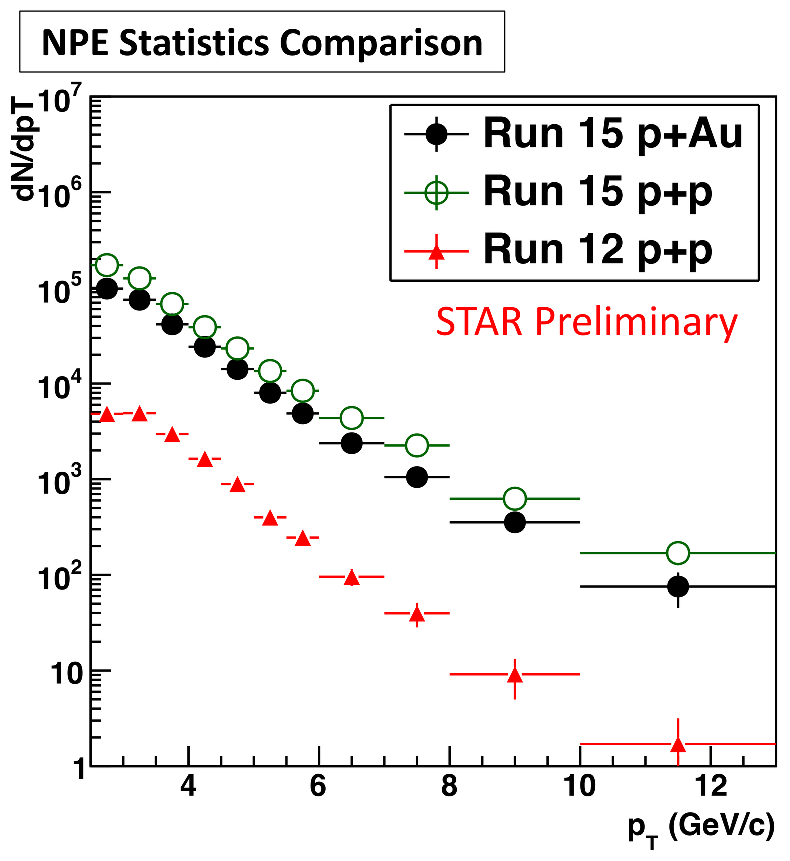
Left: The invariant mass spectra for unlike and like sign electron pairs, which are used to select photonic electrons. **Middle**: The $n\sigma_e$ distribution for electron candidates, with fits applied to determine the purity of the electron sample. The vertical lines show the cut range used for electron selection. **Right**: The transverse momentum dependence of the electron purity and photonic electron reconstruction efficiency.

Results and Outlook

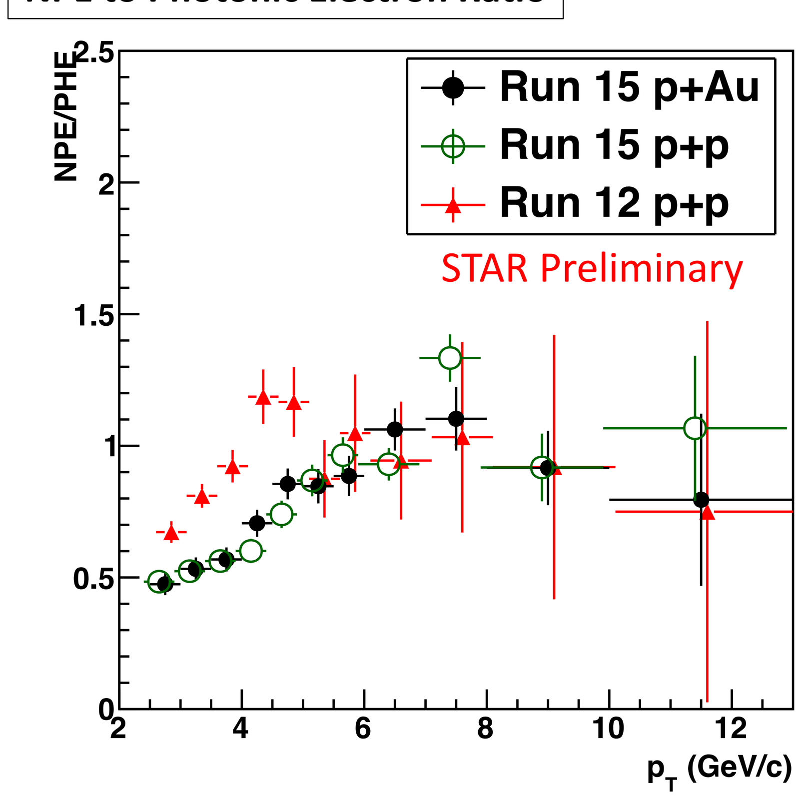
Uncorrected Electron Spectra



NPE Statistics Comparison



NPE to Photonic Electron Ratio



Left: The uncorrected electron spectra from p+p and p+Au collisions. The unlike-sign and like-sign spectra are used to estimate the PHE background, which is subtracted from the inclusive spectrum, leaving mostly the NPE signal. **Middle**: The uncorrected non-photonic electron spectrum from this analysis using Run 15 data and STAR's previous measurement with Run 12 data[4], showing a factor of more than ten improvement in statistics. **Right**: The ratio of non-photonic electrons to photonic electrons. The increased material budget in Run 15 significantly increases the background at low transverse momentum.

- First look at uncorrected electron spectra in p+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.
- Vast increase in NPE statistics in the new datasets.
- The added material from the Heavy Flavor Tracker and its supporting structure greatly increases the photonic electron background at low p_T.
- Calculations of NPE cross section and nuclear modification factor coming soon for p+p and p+Au collisions. These measurements will help quantify Cold Nuclear Matter effects on heavy flavor production in p+Au collisions.

References

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[2] A. Andronic et al. "Heavy-flavour and quarkonium production in the LHC era: from proton-proton to heavy-ion collisions." arXiv:1506.03981
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[4] Xiaozhi Bai, Measurements of Open Heavy Flavor Production in Semi-leptonic Channels at STAR, Nuclear Physics A, Volume 956, December 2016, Pages 513-516, ISSN 0375-9474, http://dx.doi.org/10.1016/j.nuclphysa.2016.03.027