Measurement of heavy-flavor electron production in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR

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Abstract

Studying heavy-flavor production in heavy-ion collisions (HIC) can enhance our comprehension of parton interactions with the Quark-Gluon Plasma (QGP) created in these collisions. Due to their significant mass, heavy quarks (charm and bottom) are mainly generated during the initial phase of high-energy heavy-ion collisions when hard scatterings are prevalent, and experience the entire evolution of the QGP. One way to study heavy quarks is through the measurement of Heavy Flavor Electrons (HFE). In this contribution, we present analysis of HFE at low transverse momentum (p_T) in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV using data taken in 2017 by the STAR experiment. The strong HFE suppression was already observed in the central Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV [1]. Measuring heavy-flavor quark nuclear modification factors below the RHIC top energy offers new insights on the the in-medium energy loss, especially the collisional energy loss which is dominant at low p_T. It is planned to measure central-to-peripheral nuclear modification factors as functions of p_T, which will complement the already existing results at $\sqrt{s_{NN}}$ = 200 GeV [1] and the recent HFE v_2 measurement at $\sqrt{s_{NN}}$ = 54.4 GeV [2].

Heavy-flavor electrons

- Heavy-flavor electrons are electrons from semi-leptonic decays of open heavy-flavor hadrons.
- Relative contributions of D and B hadron decays depend on electron p_T.
- Semi-leptonic decays BR > hadronic decays BR $\longrightarrow$ wide usage in studying heavy quark production.
- The yield of **heavy-flavor electrons**, N^{HFE}, can be calculated as

$$N^{HFE} = \frac{N^{incl} \cdot purity - N^{PE}/\varepsilon^{PE}}{\varepsilon^{total}} - N^{HDE}, \qquad (1)$$

where N^{incl} is the inclusive electron yield, N^{PE} is the photonic electron yield, ε^{PE} is the photonic electron identification efficiency, ε^{total} is the total efficiency of electron identification and reconstruction, HDE are hadron-decayed electrons from ρ, ω, ϕ, J/ψ, Drell-Yan and K_{e3} [2].

- **N^{PE} sources:**
  - Dalitz decays: $\eta \to \gamma e^+e^-$, $\pi^0 \to \gamma e^+e^-$
  - Gamma conversion: $\gamma \to e^+e^-$, $\eta \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$

STAR detector

STAR is an experiment designed primarily to study properties of the QGP and proton spin structure.

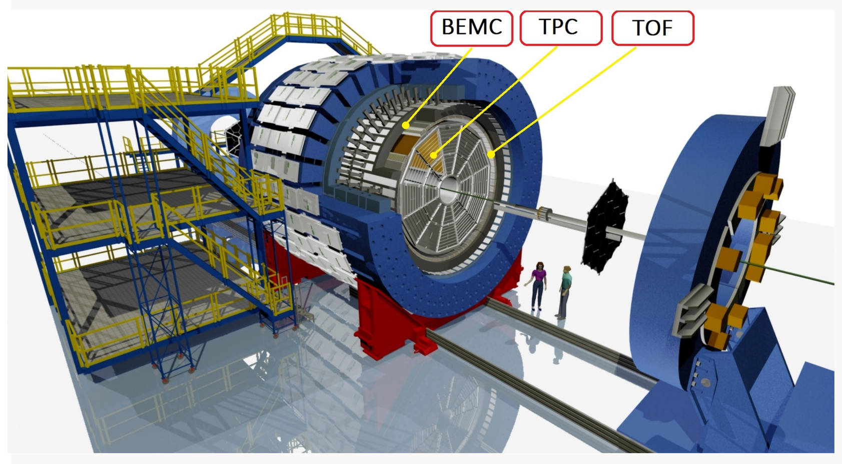

Figure 2: The STAR experiment.

- Time Projection Chamber (TPC):
  - Particle momentum reconstruction and identification (dE/dx, **p**).
- Time Of Flight (TOF):
  - Particle identification ($1/\beta$).
- Barrel ElectroMagnetic Calorimeter (BEMC):
  - High p_T electron identification and triggering.

Photonic electrons

- **Photonic electrons** are identified using the invariant mass method and subtracted statistically from inclusive electrons [3].

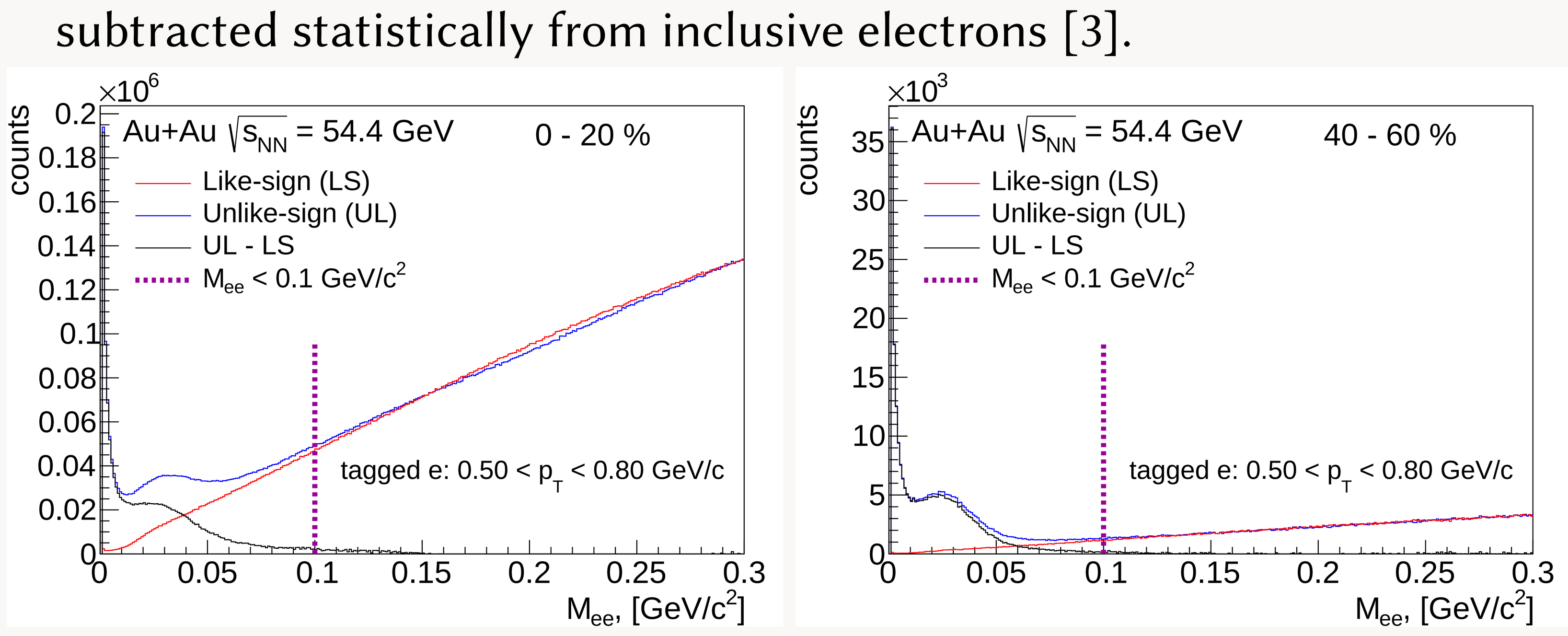

Figure 3: Invariant mass selection of photonic electrons in central (left) and peripheral (right) collisions.

- The **photonic electron identification efficiency**, ε^{PE}, is calculated by propagating γ conversions, π^0 and η decays through the GEANT simulation of the STAR detector [2] before embedding them into real events.

Results

- **Purity calculation:** The $n\sigma_e$ distributions after applying TOF and BEMC electron ID are fitted with a multi-Gaussian function (Fig. 4), to calculate purity and $n\sigma_e$ cut efficiency.

$$n\sigma_e = \frac{1}{R} \ln \frac{< dE/dx >_{measured}}{< dE/dx >_e}, \qquad (2)$$

where R is the TPC $\ln(dE/dx)$ resolution.

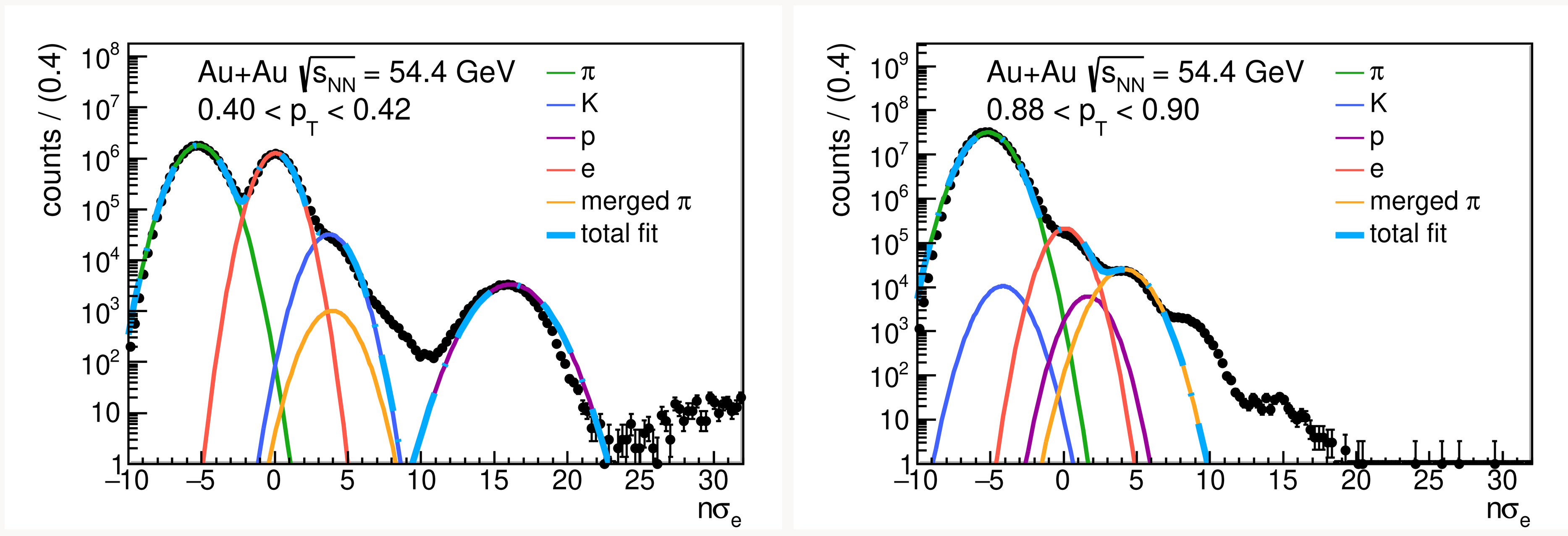

Figure 4: An example of $n\sigma_e$ fits for 0 - 60 % centrality.

- **Raw inclusive and photonic electron yield** for different centrality ranges:

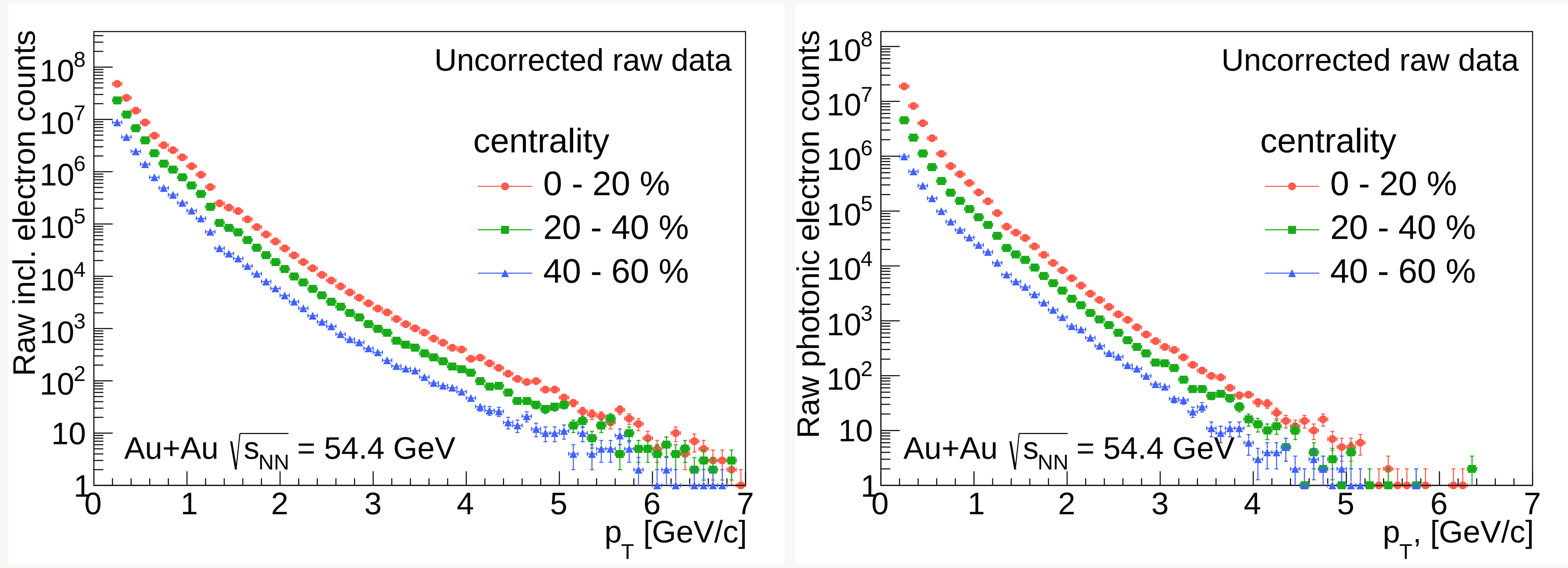

Figure 5: Inclusive and photonic electron yields, N^{incl} and N^{PE}, for different centrality ranges.

Starting from p_T > 1.25 GeV/c the BEMC energy over momentum ratio, along with TOF and TPC, is used for the electron identification.

- **Efficiencies:** ε^{total} consists of TPC tracking, TOF and BEMC matching efficiencies, $1/\beta$, E/p and $n\sigma_e$ cut efficiencies (Fig. 5). TPC tracking, BEMC matching and E/p cut efficiencies are obtained from STAR detector simulations, while other efficiencies are calculated using pure electron sample in data.

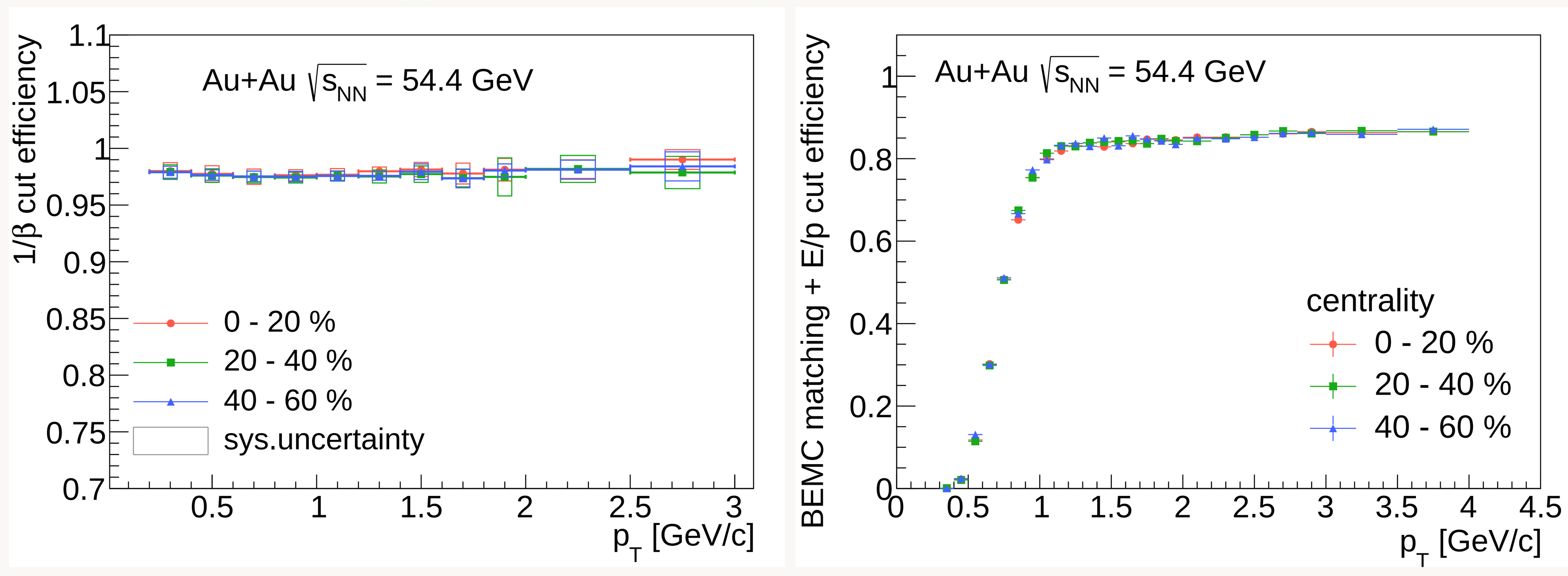

Figure 6: $1/\beta$ efficiency (left) and BEMC matching + E/p cut efficiency (right).

Conclusion

- Heavy-flavors are a powerful tool to study QGP properties as they are produced in the initial stages of the HIC and experience entire evolution of QGP.
- Technical plots corresponding to the individual steps towards N^{HFE} evaluation are shown.
- Analysis is in progress to get final corrected HFE spectra. New results complementing STAR's recent HFE v_2 measurement [2] are coming soon.

References

[1] M.I. Abdulhamid et al. (STAR Collaboration), *JHEP* 06 (2023) 176
[2] M.I. Abdulhamid et al. (STAR Collaboration), *Phys. Lett. B* 844 (2023) 138071
[3] H. Agakishiev et al. (STAR Collaboration), *Phys. Rev. D* 83 (2011) 052006

The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations

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