# 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 improve our understanding of parton interactions with the Quark-Gluon Plasma (QGP). Due to their significant mass, heavy quarks (charm and bottom) are mainly produced in the initial phase of high-energy HIC, when hard scatterings are prevalent, and thus experience the entire evolution of the QGP. One way to study heavy quarks is to measure Heavy-Flavor Electrons (HFE) - electrons emitted from the semi-leptonic decays of heavy-flavor hadrons. In this contribution, we present the HFE measurement 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]. The measurement of heavy-flavor electron nuclear modification factors below the RHIC top energy will provide new insights into the heavy-quark in-medium energy loss, in particular the collisional energy loss that is dominant at low $p_T$. It will complement the existing results at $\sqrt{s_{NN}}$ = 200 GeV [1] and the recent HFE elliptic flow 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 ⟶ wide usage in studying heavy quark production.
- The yield of **heavy-flavor electrons**, $N^{HFE}$, is

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

where $N^{incl}$ is the inclusive electron yield, $N^{PE}$ is the photonic electron yield, $\varepsilon^{PE}$ is the photonic electron identification efficiency, $\varepsilon^{total}$ is the total efficiency of electron identification and reconstruction, HDE are hadron-decayed electrons from $\rho$, $\omega$, $\phi$, $J/\psi$, $\Upsilon$, Drell-Yan and $K_{e3}$ [2].

- **$N^{PE}$ sources:**
  - Dalitz decays: $\eta \to \gamma e^+e^-$, $\pi^0 \to \gamma e^+e^-$
  - Gamma conversion: $\gamma \to e^+e^-$, $\eta \to \gamma\gamma$, $\pi^0 \to \gamma\gamma$
- The main goal is: **central-to-peripheral nuclear modification factor**

$$R_{CP} = \frac{\frac{1}{N_{bin}^{central}} \cdot \frac{d^2N^{HFE}_{central}}{2\pi p_T dp_T dy}}{\frac{1}{N_{bin}^{periph}} \cdot \frac{d^2N^{HFE}_{periph}}{2\pi p_T dp_T dy}} \qquad (2)$$

where $N_{bin}^{central}$, $N_{bin}^{periph}$ are the average numbers of binary nucleon-nucleon collisions in central and peripheral collisions, respectively.

Done, Work in progress, To be done

## STAR detector

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

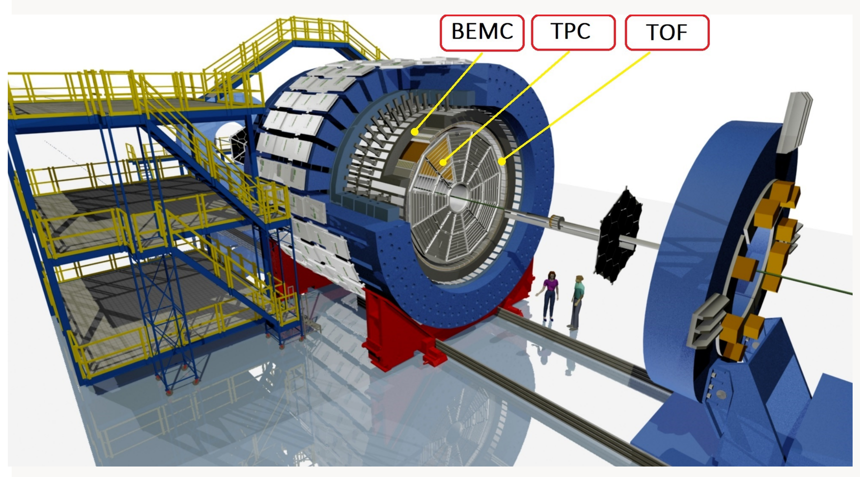


**Figure 1:** The STAR experiment.

- 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].

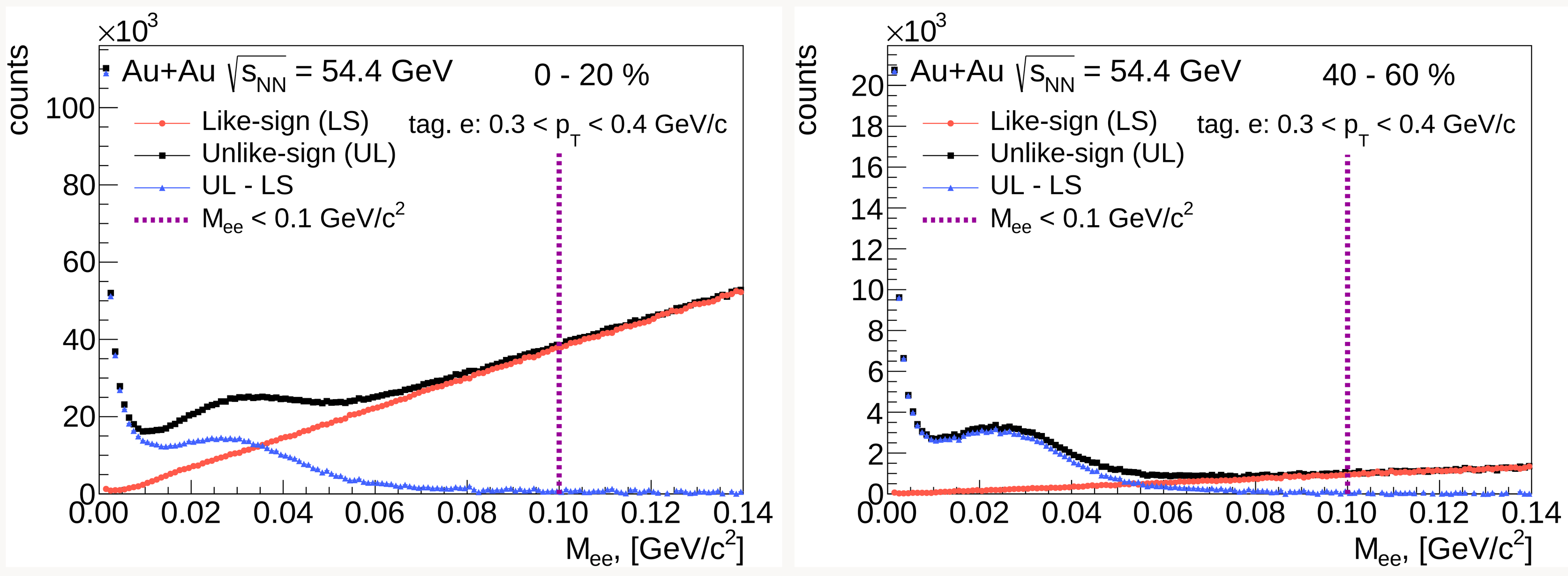


**Figure 2:** Invariant mass selection of photonic electrons in central (left) and peripheral (right) collisions.

- The **photonic electron identification efficiency**, $\varepsilon^{PE}$, is calculated by propagating $\gamma$ conversions, $\pi^0$ and $\eta$ decays through the GEANT simulation of the STAR detector [2] before embedding them into real events.

## Results

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

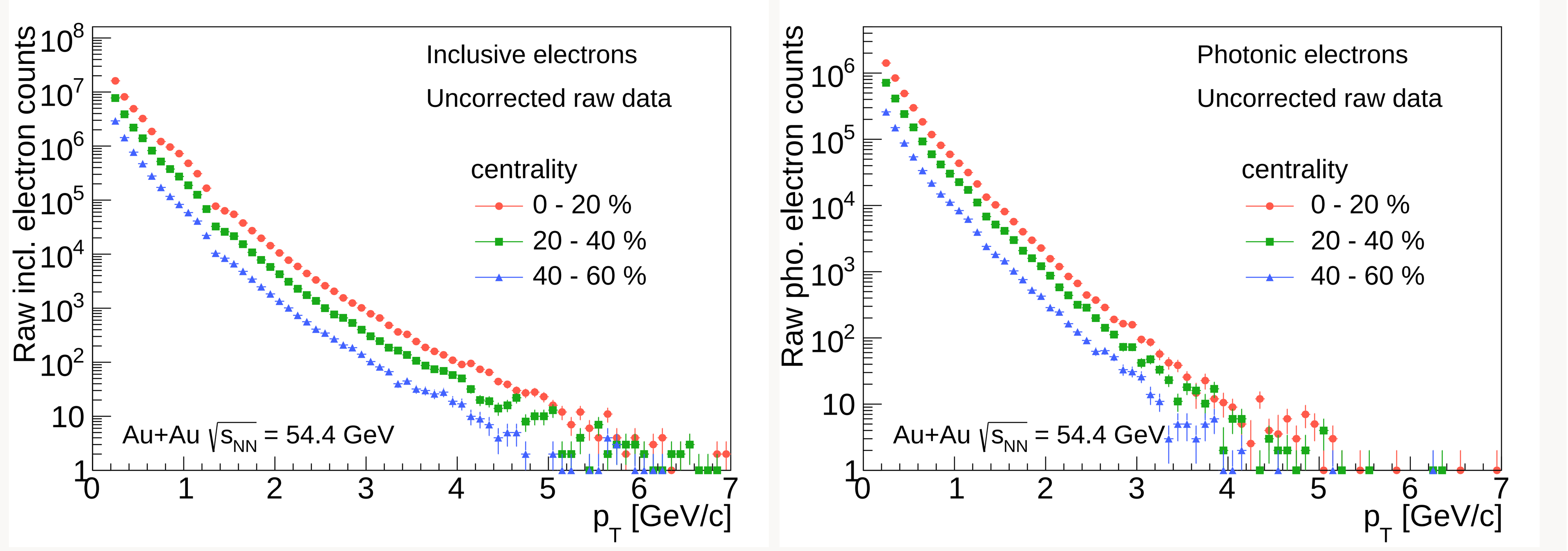


**Figure 3:** Inclusive and photonic electron yields, $N^{incl}$ and $N^{PE}$, for different centrality ranges.

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.

- **Purity and n$\sigma_e$ cut efficiency 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.

$$n\sigma_e = \frac{1}{R}\ln\frac{< dE/dx >_{measured}}{< dE/dx >_e}, \qquad (3)$$

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

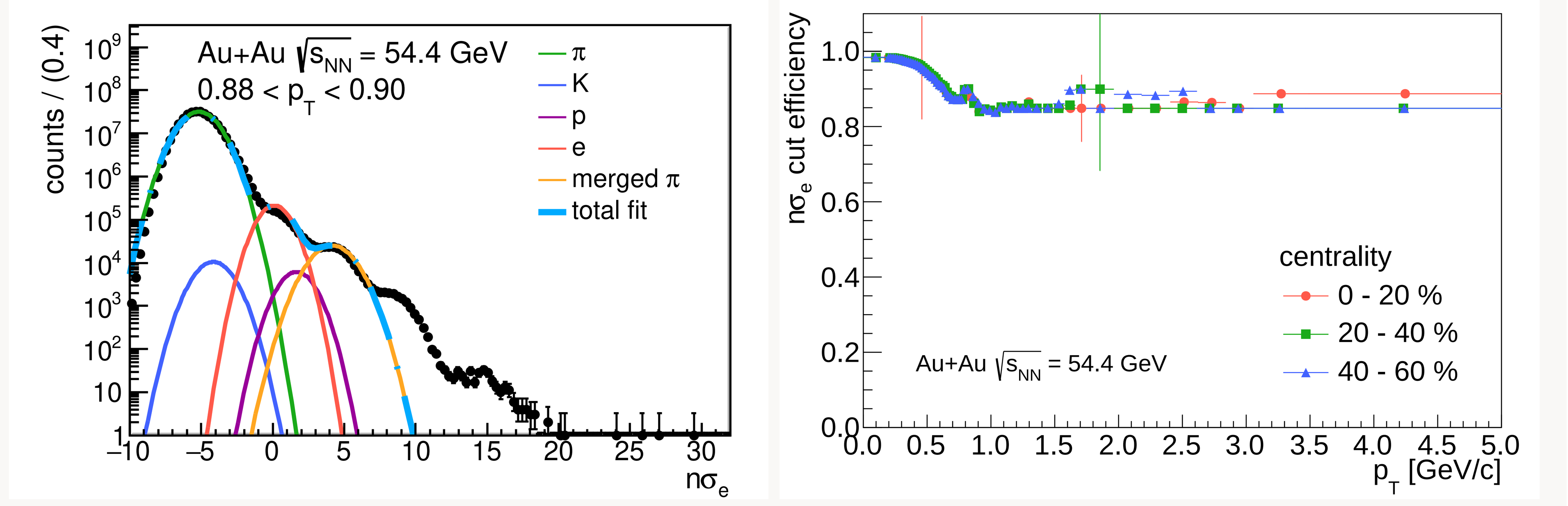


**Figure 4:** An example of n$\sigma_e$ fits for 0 - 60 % centrality (left) and n$\sigma_e$ cut efficiency (right).

- **Efficiencies:** $\varepsilon^{total}$ consists of TPC tracking, TOF and BEMC matching efficiencies, $1/\beta$, E/p and n$\sigma_e$ cut (Fig. 4 right) efficiencies. 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.

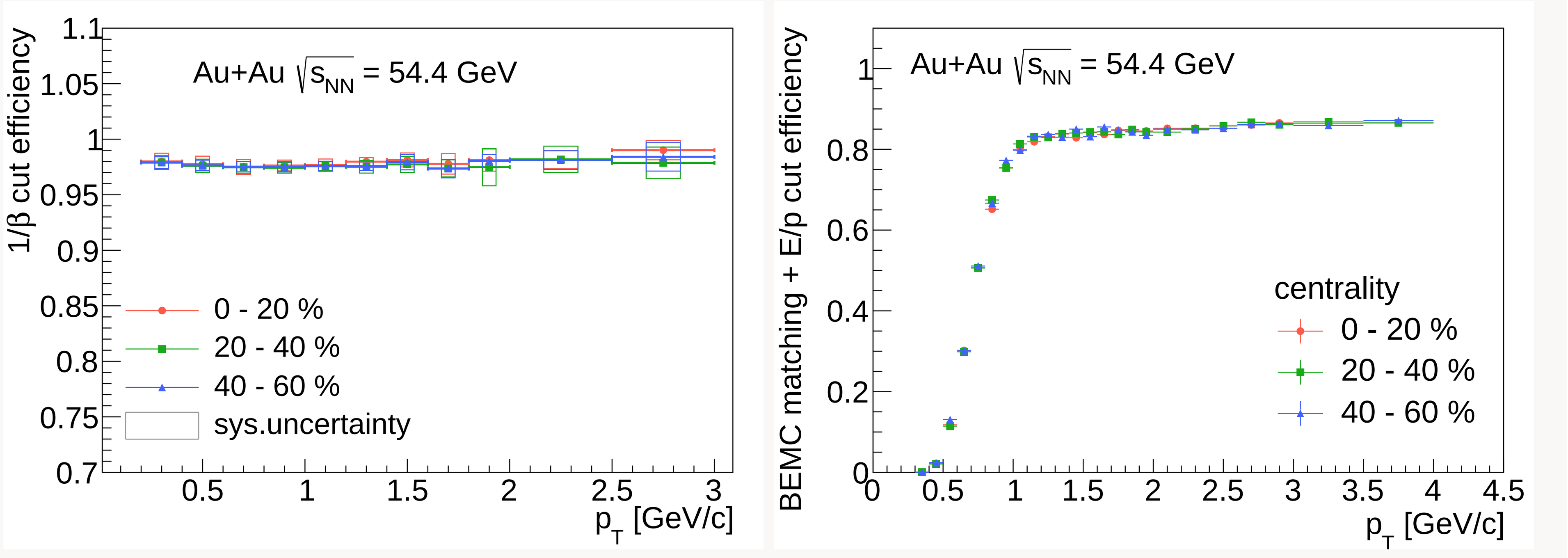


**Figure 5:** $1/\beta$ efficiency (left) and BEMC matching + E/p cut efficiency (right).

## Conclusion

- Heavy-flavors serve as 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 illustrating the individual steps towards the evaluation of $N^{HFE}$ are presented.
- Finalize corrections for purity, TOF matching efficiency, $\varepsilon^{PE}$ ⟶ final evaluation of $N^{HFE}$ and $R_{CP}$ and physics implications for heavy parton energy loss.

### 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

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