Low $p_T$ non-photonic electron production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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Outline

• Motivation I : Heavy flavor in HIC
• Motivation II : Recent NPE results
• Status of low $p_T$ NPE analysis in detail
  ‣ Inclusive electrons
  ‣ Reconstruction of photonic electrons background
  ‣ Partner finding efficiency
• Summary
Motivation

- **Heavy Flavor** in heavy-ion collisions
  - HF quarks are primarily produced in initial hard scattering, and are exposed to the evolution of the hot nuclear matter created at RHIC.
  - Using the HF as a probe to study properties of the QGP and their dependence on e.g. system size and energy.

- **Non-photonic electrons (NPE)**
  - *Semileptonic channel* has high B.R. of open heavy flavor mesons.
  - *Easy for triggering and identification.*
  - Comparable with direct reconstructed open heavy flavor mesons.

\[
\begin{align*}
\bar{D}^0 & \rightarrow K^+ e^- \\
\bar{D}^0 & \rightarrow \nu_e \\
D^0 & \rightarrow K^- e^+ \\
D^0 & \rightarrow \pi^+ e^-
\end{align*}
\]
Recent D meson results

- Strong suppression is observed at high $p_T$.
  - Indication of enhancement $p_T \sim 0.7-2.2\text{GeV/c}$, described by models with charm quarks coalescence with light quarks. → *Low $p_T$ NPE also?*
Recent NPE results

- Production of NPE suppressed at high $p_T$.
- Large systematic errors in PHENIX low $p_T$ result.
- Low $p_T$ NPE measurement is important for total charm quark cross section measurements.
The **Solenoid Tracker At RHIC (STAR)**

- Full azimuthal coverage
- $-1 < \eta < 1$ coverage
- Uniform acceptance for all beam energies
- Full TOF barrel (Run10)
- Low material budget in the tracking volume
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**STAR**

- BEMC
- Magnet
- EEMC
- BBC
- upVPD
- TPC
- TOF
- Magnet
- TPC
- TOF
- Magnet
- TPC
- TOF

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by Maria & Alex Schmah
Low $p_T$ NPE analysis

- Photonic electrons:
  - Statistical subtraction by inclusive electrons.
  - Reconstruction method.
  - Photonic electron reconstruction efficiency:
    - Embedding simulation for $\gamma$ and $\pi^0$ Dalitz decay for reconstruction efficiency estimation.
- Non-photonic electrons:
  - Single electron reconstruction efficiency corrected.
  - Number of binary collision corrected.
Inclusive electrons

- Au+Au 200 GeV 0-80% VPDMinBias dataset: ~200M events
- Inclusive electron is identified by TOF+TPC
  - There are many \textit{mis-identified particles} in central collisions with high multiplicity.
    - Mis-matched particle: Very fast particle make TOF hit instead of TPC hit particle.
    - Merged particle: In the same path, there are 2 particles and measured double value of specific energy loss in TPC.
Inclusive electrons

How to estimate electron yield in Trash box.
1. Fill 2D histograms by eta, \( p_T \) and centralities.
2. Estimate *pure electron* sample to fix electron shape through conversion electrons.
3. Fix \( \pi, K, p \) shape with 2D fitting.
4. Fit the mis-matched kaons and protons at well separated momentum regions and fix \( N_{misK}/N_K \) and \( N_{misp}/N_p \).
5. Fit all particles, electron, merged pion, mis-matched kaons, protons, to obtain their yields.

Work in progress.
examples

$0.28 < p_T < 0.29$, $|\eta| < 0.1$, 0-5% centrality

Toy MC
examples

0.31 < pT < 0.32, |eta| < 0.1, 0-5% centrality

Toy MC
examples

0.34 < pT < 0.35, |eta| < 0.1, 0-5% centrality

Data
mis-matched kaons

Fit function

X-axis projection

Y-axis projection

before PID cut
after PID cut
after PID cut electron
after PID cut others

Toy MC
examples

0.37 < pT < 0.38, |eta| < 0.1, 0-5% centrality

Toy MC
examples

0.40 < pT < 0.41, |eta| < 0.1, 0-5% centrality

Toy MC
examples

$0.43 < p_T < 0.44$, $|\eta| < 0.1$, 0-5% centrality

Toy MC
**examples**

Crossing over electron!

0.46 < \( p_T < 0.47 \), \( |\eta| < 0.1 \), 0-5% centrality

Data

Fit function

X-axis projection

Y-axis projection

before PID cut

after PID cut

after PID cut electron

after PID cut others

Toy MC
examples

Crossing over electron!

mis-matched kaons

Data

Fit function

0.49 < pT < 0.50, |eta| < 0.1, 0-5% centrality

X-axis projection

Y-axis projection

before PID cut

after PID cut

after PID cut electron

after PID cut others

Toy MC
examples

Crossing over electron!

\[0.52 < p_T < 0.53, |\eta| < 0.1, \text{0-5\% centrality}\]

Toy MC
examples

Crossing over electron!

Data

Fit function

X-axis projection

Y-axis projection

0.55 < pT < 0.56, |eta| < 0.1, 0-5% centrality

Toy MC

mis-matched kaons

before PID cut

after PID cut

after PID cut electron

after PID cut others
It is very tough job that inclusive electron estimation in central collisions.

Toy MC
Inclusive electrons

How to estimate electron yield in Trash box.
1. Fill 2D histograms by eta, $p_T$ and centralities.
2. Estimate pure electron sample to fix electron shape through conversion electrons.
3. Fix $\pi$, $K$, $p$ shape with 2D fitting.
4. Fit the mis-matched kaons and protons at well separated momentum regions and fix $N_{misK}/N_K$ and $N_{misp}/N_p$.
5. Fit all particles, electron, merged pion, mis-matched kaons, protons, to obtain their yields.

Work in progress.
Inclusive electrons

**How to estimate electron yield in Trash box.**

1. Fill 2D histograms by $\eta$, $p_T$ and centralities.
2. Estimate *pure* electron shape through conversion electrons.
3. Fix $\pi$, $K$, $p$ shape with 2D fitting.
4. Fit the mis-matched kaons and protons at well separated momenta and $N_{misK}/N_K$ and $N_{misp}/N_p$.
5. Fit all particles, electron, merged pion, mis-matched kaons, protons, to obtain their yields.

Work in progress.
Photonic electrons

- I used the "reconstruction method" to statistically subtract the contribution of photonic electrons to inclusive electrons.

- We estimate the photonic electron contribution using $e^+e^-$ pairs with invariant mass $< 0.05 \text{ GeV}/c^2$ in real data
  - $\gamma \rightarrow e^+ e^-$ photon conversion in the material in STAR detector.
  - $\pi^0 \rightarrow \gamma e^+ e^-$ (B.R. = 1.174 ± 0.035)%
  - $\eta \rightarrow \gamma e^+ e^-$ (B.R. = 0.70 ± 0.07)%

- Photonic electrons need partner finding (photonic electrons reconstruction) efficiency correction.

Work in progress.
Partner finding efficiency

- Monte-Calo $\pi^0$ and $\gamma$ embedding simulation with real $\pi^0$ and $\gamma$ distribution from PHENIX and STAR results.

- Partner finding efficiency is 10~40% in minimum-bias Au+Au collisions.

 Sometimes, we cannot identify or detect the partner electron. (geometry, efficiency...)

Work in progress.
Summary

• Summary :
  ‣ Low $p_T$ non-photonic electron production in heavy-ion collisions is being studied.
  ‣ Inclusive electron estimation method (2D fitting). → Fitting optimisation is ongoing.
  ‣ Photonic electron yield estimation with Rec. method and corrected with $\pi^0$ and $\gamma$ embedding simulation.

• Outlook :
  ‣ Systematic error study for low $p_T$ NPE
  ‣ The new HFT detector is installed: Measurement of $B \to e$ and $D \to e$ spectra separately.