Measurement of Bottom contribution to the non-photonic electron production in p+p collisions at STAR

Wei Li
Shanghai Institute of Applied Physics
for the STAR Collaboration
Outline

- Motivation
- Analysis method for extracting Non-Photonic Electron (NPE)
- NPE-hadron azimuthal correlation in p+p collisions at $\sqrt{s} = 200$ GeV and 500 GeV
- Summary
Motivation

- Heavy quarks are mainly produced in the INITIAL hard partonic interactions - calculable in pQCD
- QCD predicts that heavy quarks lose less energy than light quarks via gluon radiation
- NPE: semi-leptonic decays of open heavy flavor hadrons
  Branching ratio: $c \rightarrow e + anything$ (9.6%)  $b \rightarrow e + anything$ (11%)
- NPE is good proxy of heavy flavor quarks

> NPE is suppressed at high $p_T$ in central Au+Au collisions, which implies substantial energy loss of heavy quarks.
Separate bottom contribution to NPE

➢ Theoretical calculation predicts less radiative energy loss for bottom quarks compared to charm quarks, which can be studied through suppression of D- and B-decayed NPE separately in Au+Au w.r.t p+p collisions

➢ Contributions of D- and B-decayed NPE in p+p collisions can be determined through studying NPE-hadron azimuthal correlation: different charm and bottom decay kinematics
  ✓ Extracting D- and B-decayed NPE contributions in p+p collisions at 200 GeV as a reference for studies in Au+Au collisions at 200 GeV
  ✓ Extracting D- and B-decayed NPE contributions in p+p collisions at 500 GeV to examine the collision energy dependence and compare with pQCD predictions
STAR Detector

Detector used:
- Time Projection Chamber (TPC)
- Barrel Electro-Magnetic Calorimeter (BEMC)
- Barrel Shower Maximum Detector (BSMD)
- Time Of Flight
- Vertex Position Detector

Signal:
- non-photonic electron
  - Charm decay
  - Bottom decay

Background:
- photonic electron
  - Photon conversion
  - $\pi^0$ Dalitz decay
  - $\eta$ Dalitz decay
  - Hadron contamination

Excellent tracking coverage and PID capabilities within $0<\phi<2\pi$ and $-1<\eta<1$

Electron trigger threshold (electron $E_T$):
- run11 500 GeV: HT0~2.6 GeV, HT1~4.3 GeV, HT2~6.0 GeV
- run12 200 GeV: HT0~2.6 GeV, HT2~4.3 GeV

Data Sample:
- Run11 p+p collisions at $\sqrt{s} = 500$ GeV
- Run12 p+p collisions at $\sqrt{s} = 200$ GeV
Purity of Inclusive Electron

Primary electron $n_{\sigma_e}$, $6.5 < P_T < 7.5 \text{ GeV/c}$

$\sigma_{e}$

$8 - 6 - 4 - 2 - 0 - 2 - 4$

Counts

$10^5$

$10^4$

$10^3$

$10^2$

$10^1$

$10^{-1}$

Run11 pp500 HT1

TPC only

TPC + BEMC + BSMD

$p/k\pi$ e

$\frac{1}{R} \log \frac{dE/dx}{<dE/dx>_e}$

➢ R is the resolution of energy loss measurement by TPC

➢ $dE/dx$ is the measured energy loss for a track

➢ $<dE/dx>_e$ is the expected energy loss for electrons from Bichsel formula at a given momentum

Purity

Run11: above 99% for $2.5 < p_T < 4.5 \text{ GeV/c}$

above 96% for $4.5 < p_T < 8.5 \text{ GeV/c}$ ; above 86% for $8.5 < p_T < 10.5 \text{ GeV/c}$

Run12: above 90% for $p_T < 7 \text{ GeV/c}$ ; above 80% for $p_T < 10 \text{ GeV/c}$
Photonic Background

- The invariant mass for a pair of photonic electrons is small.
- Choose invariant mass < 0.1 GeV/c² to remove photonic background.
- Reconstructed photonic electron = Opposite sign – Same sign.
- Photonic electron = Reconstructed photonic electron/ε. ε is the reconstruction efficiency for photonic electrons calculated using simulations.
Method to Extract NPE-h Correlations

All Tracks

Pass EID cuts

Inclusive electron

Non-photonic electron

Photonic electron

Reco_photonic electron = OppSign - SameSign

Not_reco_photonic electron = (1/effect-1) * reco_photonic

Semi-inclusive electron

Hadron_contamination

Semi-inclusive electron = Inclusive electron - OppSign

Signal: NPE = Semi-inclusive + SameSign - (1/effect-1) * reco-photonic - Hadron_contamination

Δφ_{Non-Pho} = Δφ_{Semi_Inc} + Δφ_{SameSign} - Δφ_{Not_Reco_Pho} - Δφ_{hadron}
NPE-h correlation in 200 GeV p+p Collisions

- 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 correlation in 200 GeV p+p collisions
- Significant difference on the near-side of correlation distributions between D and B decays due to different decay kinematics
B→NPE Contribution in 200 GeV p+p Collisions

Fit function: \( (R \cdot \text{PYTHIA}_B + (1-R) \cdot \text{PYTHIA}_D) \cdot \text{Norm} \)

- Preliminary result agrees with previous STAR analysis for \( p_T < 8.5 \text{ GeV/c} \)
  - Systematic uncertainties are significantly reduced

- STAR results are consistent with Fixed Order Next to Leading Logarithm (FONLL) calculation within uncertainties

- \( R \) is B contribution, i.e. \( B/(B+D) \), as a parameter in fit function

- Norm acts as an overall normalization

\[ \chi^2/\text{NDF}: 23.70/31; \ r_B: 0.56 \]

\[ 5.5 < p_T < 6.5 \]

\[ \Delta \phi \]

\[ \text{STAR Preliminary} \]

\[ \text{STAR Run 12 } \text{p+p 200 GeV} \]

\[ \text{STAR Run 6 } \text{p+p 200 GeV} \]

\[ \text{FONLL} \]

\[ \text{STAR Preliminary} \]

\[ \text{STAR Run 6: Phys.Rev.Lett. 105, 202301 (2010)} \]

NPE-h correlation in 500 GeV p+p Collisions

➢ Raw correlation w/o efficiency correction
➢ Associated hadron with $p_T > 0.3$ GeV/c
➢ Clear azimuthal correlation on the near-side, and the correlation signal increases as NPE $p_T$ increases.

STAR Preliminary
PYTHIA Simulation for 500 GeV p+p Collisions

We use PYTHIA 8.1 combined with STAR-HF-Tune Version 1.1 to generate e(D)-h and e(B)-h correlation in 500 GeV p+p collision

![Graphs showing correlation signals for different p_T intervals.]

- Significant difference between D and B decays on the near-side at low p_T
- Correlation signal increases as trigger p_T increases
- Difference between e(D)-h and e(B)-h correlation decreases as trigger p_T increases
Summary

- Bottom contribution to NPE is extracted using NPE-h correlations in p+p collisions at $\sqrt{s} = 200$ GeV.
- The 200 GeV p+p results have an extended $p_T$ range and reduced systematic uncertainties than previous measurements. They also confirm theory calculations.
- Clear NPE-h correlation on near side can be seen in 500 GeV p+p collisions, and the correlation signal increases as trigger $p_T$ increases. Efficiency corrections and systematics under the way.
- The HFT allows direct access to B contributions to NPE in Au+Au collisions via topological reconstruction of decay vertex.
Thank you for your attention!
BACKUP
Electron Identification: $P/E$

- $P$ is the momentum measured by TPC, $E$ is the sum of the associated BEMC points’ energy measured by BEMC.
- Electrons will deposit almost all of their energies in the BEMC towers.
- $0.3 < P/E < 2.0$ cuts were used to keep electrons and reject hadrons.
Electron Identification: Shower Size

SMD hits of hadrons

SMD hits of electrons

➢ Number of SMD hits per shower indicates shower size.
➢ Electrons have larger number of BSMD hits than hadrons.
➢ We choose SMD hits larger than 2 to reject hadron contamination.
Electron Identification: Projection Distance

➢ Projection distance: distance between the TPC track projection position on BSMD $\eta$ and $\phi$ planes and the reconstructed BEMC point position

➢ Histograms for hadrons are scaled to match the entries of electrons

➢ -3$\sigma$ < Z Dist pos(neg) < 3$\sigma$ and -3$\sigma$ < Phi Dist < 3$\sigma$ cuts were used to remove random associations between TPC tracks and BEMC points.

Run11 pp500   $2.5<p_T<10.5$ GeV/c