Performance of heavy-flavor tagged jet identification in STAR

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Introduction

- **Flavor dependence of jet quenching**
  - Depending on the flavor, different levels of collisional and radiative energy losses\textsuperscript{2}

- **How to tag heavy-flavor jets?**
  - Using displaced secondary vertices or larger impact parameters of constituent tracks in the HF jets relative to light-flavor jets

- **Why in STAR?**
  - Lower fractions of heavy-flavor quarks from gluon splitting in inclusive heavy-flavor quark samples compared to those at the LHC (e.g., \(-30\%\) at the LHC and less than 10\% at RHIC for b-jet)
  - Significantly improved resolution of secondary vertex reconstruction thanks to STAR’s Heavy Flavor Tracker (HFT)

Analysis Details

- Monte Carlo simulation using PYTHIA8 generator (Hard QCD process, pThatMin = 12 GeV/c) and GEANT detector simulation with ideal geometry of HFT (fixed primary vertex position for the simulation)

Jet Reconstruction

- Charged jet with tracks reconstructed using TPC and HFT hits \(p_T > 0.2\) GeV/c, \(|\eta| < 1.0\)
- Anti-k\(\text{t}\) algorithm with \(R = 0.4\), \(p_T > 4.0\) GeV/c and \(|\eta| < 0.6\)
- Jet-parton matching with \(\sqrt{(p_T^{\text{jet}} - p_T^{\text{parton}})^2 + (|\eta^{\text{jet}}| - |\eta^{\text{parton}}|)^2} < 0.3\) requirement → Jet flavor = matched parton flavor
  (If multiple partons are matched, the heaviest parton is used.)

Heavy-flavor Jet Tagging Algorithms

**Track Counting (TC) algorithm**

- Using 3D impact parameter (IP) of constituent tracks
- IP sign = sign of the scalar product of the vector pointing from the primary vertex to the Distance of Closest Approach (DCA) point with the jet direction
- Sorting constituent tracks by decreasing values of the IP significance, \(S_{IP} = (IP/IP uncertainty)\), then \(n\)-th largest \(S_{IP}\) as a discriminator → TC,1\(\text{st}\), TC,2\(\text{nd}\), TC,3\(\text{rd}\) algorithms

**Jet Probability (JP) algorithm\textsuperscript{3}**

- Using the likelihood that all constituent tracks come from the primary vertex
  \(P_{\text{jet}} = \prod_{i=1}^{n}P_i^{1-\mid\text{IP}_i\mid}\) with \(\text{IP}_i = \prod_{j=1}^{\text{tracks}}|\text{IP}_{ij}|\), where \(P_i\) is the estimated probability that track \(i\) comes from the primary vertex
- JP discriminator = \(-\ln P_{\text{jet}}\)

**Secondary Vertex (SV) Algorithm**

- Secondary vertex candidates → From each combination of two constituent tracks\textsuperscript{4}
- Sorting SV candidates by decreasing values of SV(SV uncertainty), then \(n\)-th largest value as a discriminator → SV,1\(\text{st}\), SV,2\(\text{nd}\), SV,3\(\text{rd}\)

MC Results

- Heavy-flavor jet tagging efficiency vs. misidentification probability (=impurity) from various tagging algorithms

\begin{figure}
\centering
\includegraphics[width=\textwidth]{jet_efficiency.png}
\caption{Jet tagging efficiency for different algorithms at RHIC.}
\end{figure}

- Different efficiency/impurity from different tagging algorithms
- Better results with TC and JP algorithms than SV algorithms (→ higher efficiency, lower impurity)
- JP has the overall best performance among the current algorithms.

\[\eta\text{-dependence of tagging efficiency}\]

- Lower efficiency at larger \(\eta\) particularly for b-jet

\[p_T\text{-dependence of tagging efficiency}\]

- Higher c- and b-jet efficiencies with higher jet-\(p_T\)
- Lower efficiency and larger impurity compared to those from the LHC mostly due to the lower jet-\(p_T\) coverage at RHIC

Summary and Outlook

- Initial study of heavy-flavor jet tagging at STAR, enabled by the Heavy Flavor Tracker, is performed with various tagging algorithms. Further development including more realistic simulations with embedding technique is ongoing.
- Jet probability algorithm shows the best tagging performance, and both c- and b-jet tagging efficiencies show significant \(p_T\)-dependence. Lower efficiency at large \(\eta\), particularly for b-jet, is also observed.
- Based on the current study in PYTHIA, heavy-flavor jet tagging and flavor dependence of jet quenching will be investigated in dAu and AuAu collision data.
- Machine learning algorithm for heavy-flavor jet tagging will be studied in parallel with the current tagging algorithms.

[\textsuperscript{1} Chatrchyan et al. (2011)](PhysRevLett.107.102301)
[\textsuperscript{2} Oh et al. (2018)](PhysRevLett.120.132301)
[\textsuperscript{3} Monte Carlo simulation using PYTHIA8 generator (Hard QCD process, pThatMin = 12 GeV/c) and GEANT detector simulation with ideal geometry of HFT (fixed primary vertex position for the simulation)]
[\textsuperscript{4} Anti-k\(\text{t}\) algorithm with \(R = 0.4\), \(p_T > 4.0\) GeV/c and \(|\eta| < 0.6\) ]
[\textsuperscript{5} Track Counting (TC) algorithm]
[\textsuperscript{6} Jet Probability (JP) algorithm]
[\textsuperscript{7} Secondary Vertex (SV) Algorithm]