Performance of heavy-flavor tagged jet identification in STAR

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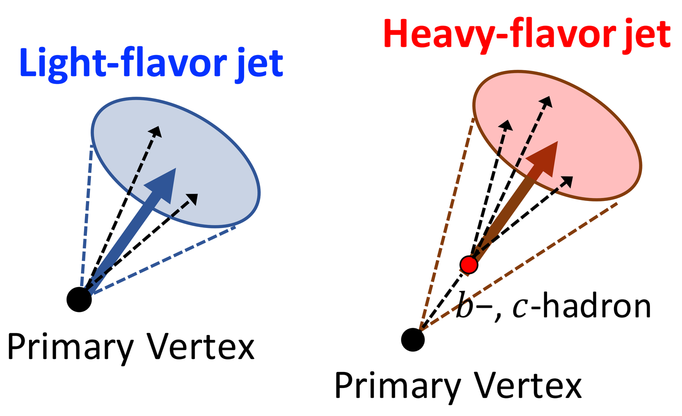
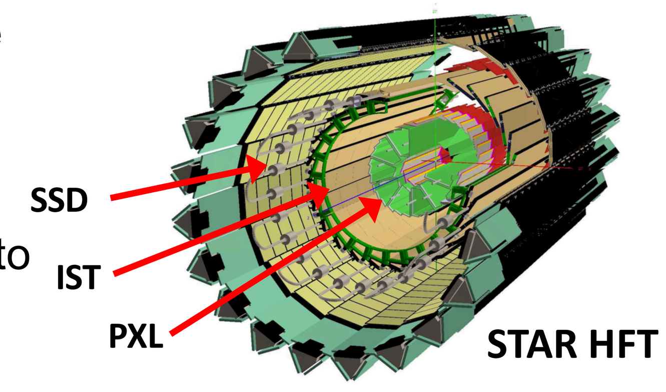
Introduction

- **Flavor dependence of jet quenching**
  - ✓ Depending on the flavor, different levels of collisional and radiative energy losses[1]
- **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. ~30-35% 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)



[1] S. Chatrchyan *et al.* (CMS collaboration) Phys. Rev. Lett. **113**, 132301(2014)

Analysis Details

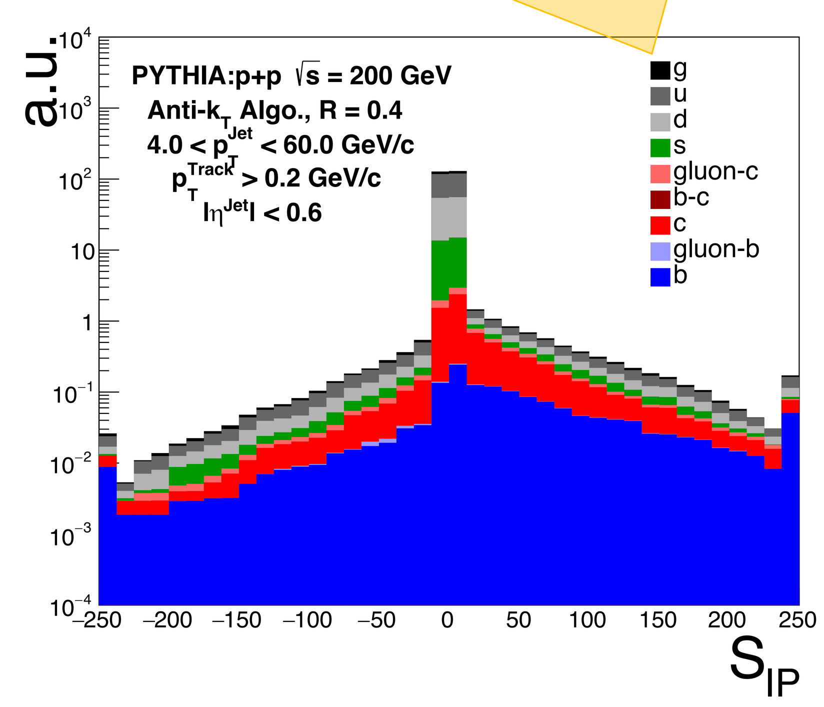
- Monte Carlo simulation using **PYTHIA8** generator (Hard QCD process, pTHatMin = 12 GeV/c) and **GEANT** detector simulation with ideal geometry of HFT (Fixed primary vertex position for the simulation)

Jet Reconstruction

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

Heavy-flavor Jet Tagging Algorithms

- gluon-*c* (gluon-*b*) ← c(b) from gluon splitting
- *b-c* ← *c* from *b*-decay



Track Counting (**TC**) algorithm

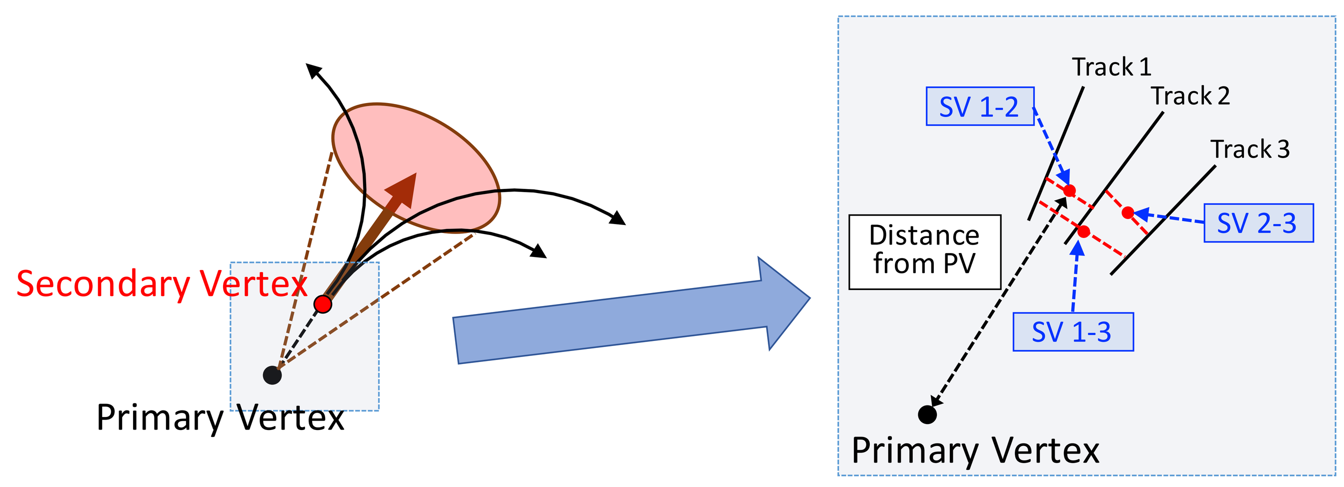
- Using 3D impact parameter (IP) of constituent tracks
- IP sign = sign of the scalar product of the vector pointing from the primary vertex to the Distance of Closest Approach (DCA) point with the jet direction
- Sorting constituent tracks by decreasing values of the IP significance, S_{IP} = IP/(IP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

Jet Probability (**JP**) algorithm[2]

- Using the likelihood that all constituent tracks come from the primary vertex
- $P_{jet} = \Pi \times \sum_{i=0}^{N-1}\frac{(-\ln\Pi)^i}{i!}$ with $\Pi = \prod_{i=1}^{N} P_i$ where P_i is the estimated probability that track i comes from the primary vertex
- JP discriminator = $-\ln P_{jet}$

Secondary Vertex (**SV**) Algorithm

- Secondary vertex candidates ← From each combination of two constituent tracks[3]
- Sorting SV candidates by decreasing values of SV/(SV uncertainty), then n-th largest value as a discriminator → **SV,1st**, **SV,2nd**

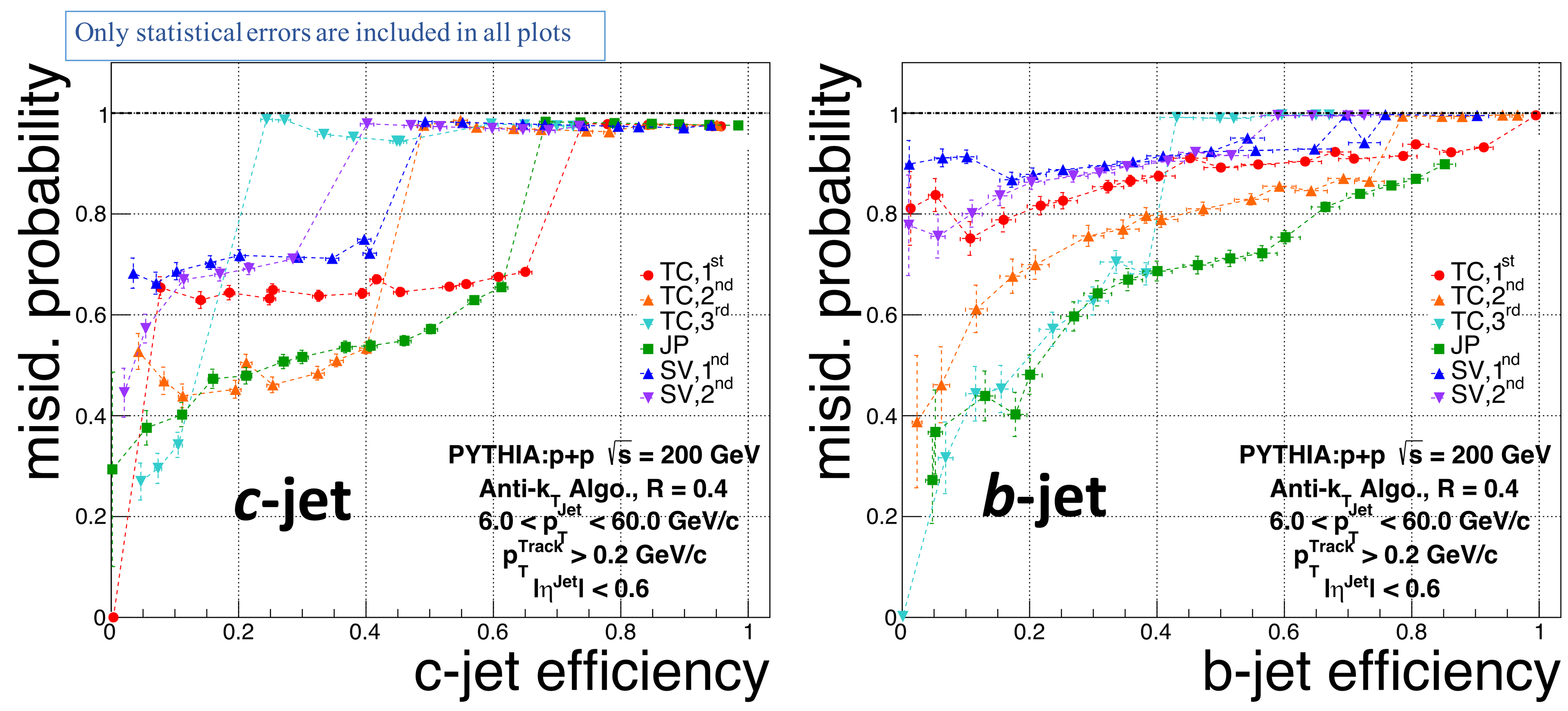


[2] S. Chatrchyan *et al.* (CMS collaboration) Phys. Rev. Lett. **113**, 132301(2014)
3. Vertex finding algorithm (e.g. Kalman Filter) produces large uncertainties due to the lower number of constituent tracks compared to jets at the LHC

MC Results

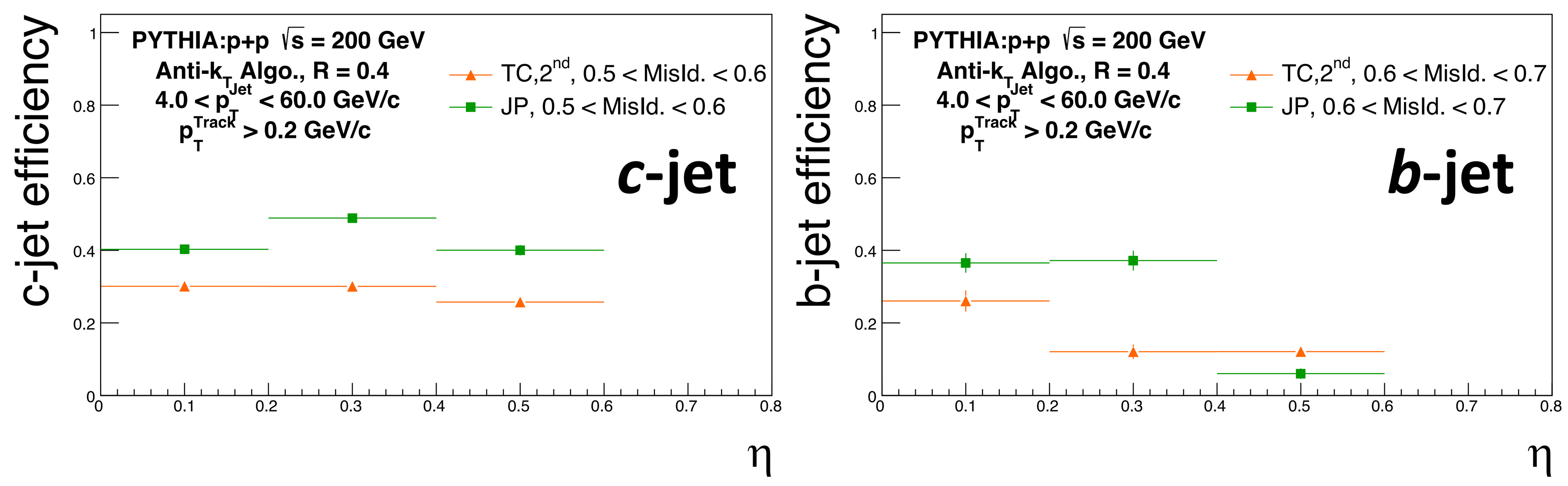
- Heavy-flavor jet tagging **efficiency** vs. **misidentification probability** (=impurity) from various tagging algorithms

Only statistical errors are included in all plots



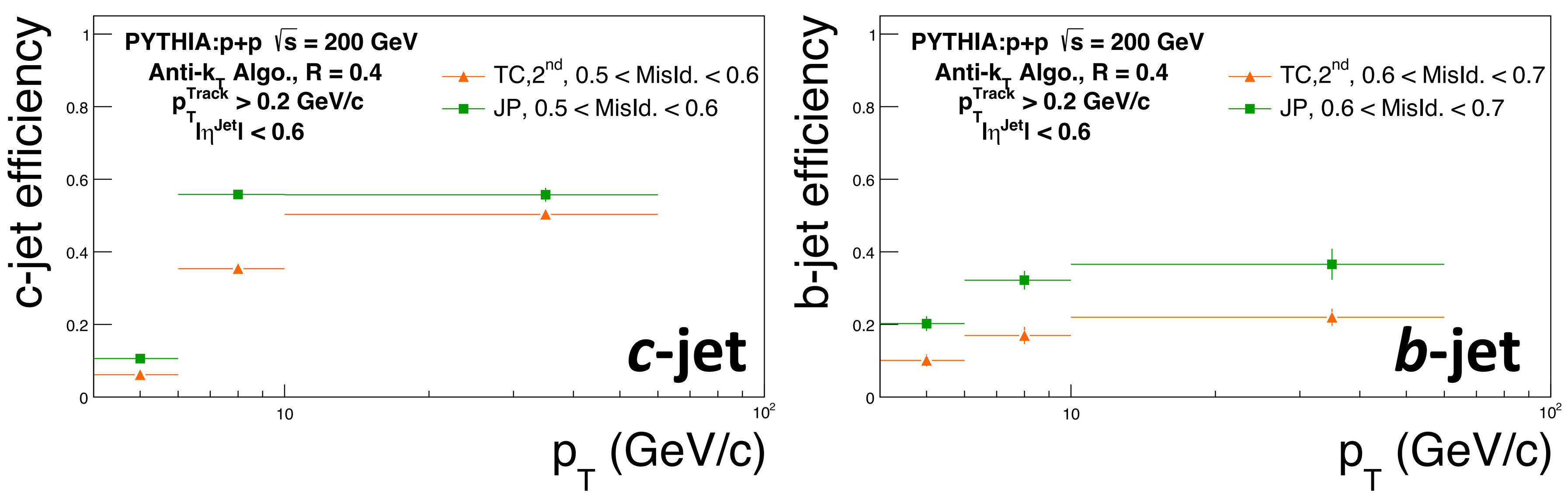
- Different efficiency/impurity from different tagging algorithms
- Better results with TC and JP algorithms than SV algorithms (→ higher efficiency, lower impurity)
- JP has the overall best performance among the current algorithms.

η-dependence of tagging efficiency



- Lower efficiency at larger η particularly for *b*-jet

p$_T$-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 jet-p$_T$ dependence**. Lower efficiency at large η, 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 d+Au and Au+Au collision data.
- Machine learning algorithm for heavy-flavor jet tagging will be studied in parallel with the current tagging algorithms.

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