b-jet tagging at sPHENIX

Jakub Kvapil (jakub.kvapil@lanl.gov) on behalf of the sPHENIX collaboration
Los Alamos National Laboratory, USA

The sPHENIX detector has been commissioned in $\sqrt{s_{AA}} = 200$ GeV Au + Au collisions during May-August 2023. It provides an excellent vertex resolution using 3 layers of Monolithic Active Pixel Sensors (MAPS) and Intermediate Silicon Tracker (INTT) detectors. The expected spatial resolution is < 6 μm and the track vertex distance of closest approach (DCA) < 30 μm for $p_T > 1$ GeV/c. In addition, a full azimuthal coverage of electromagnetic and hadronic calorimeters provides an excellent tool to study jet physics. In this poster, we will focus on the prospects of beauty-jet-tagging of full jets at sPHENIX.

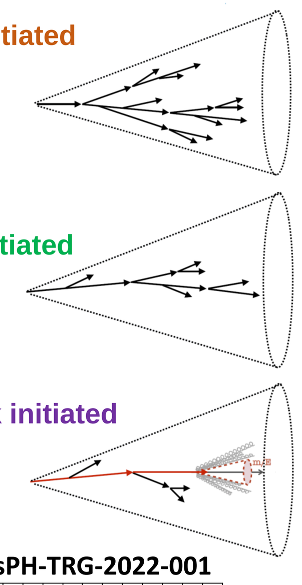
Physics motivation

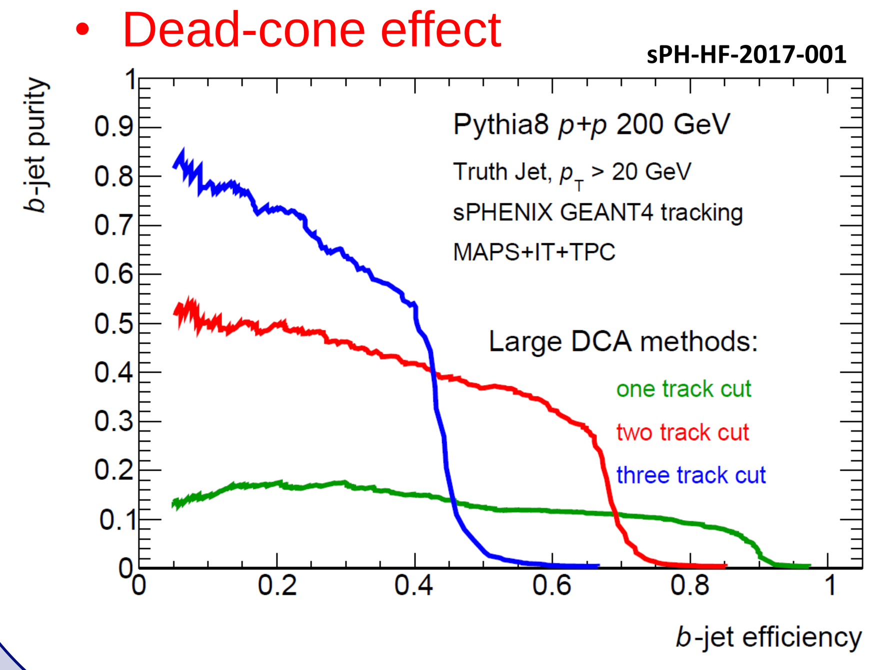
Heavy-flavor (HF) hadrons

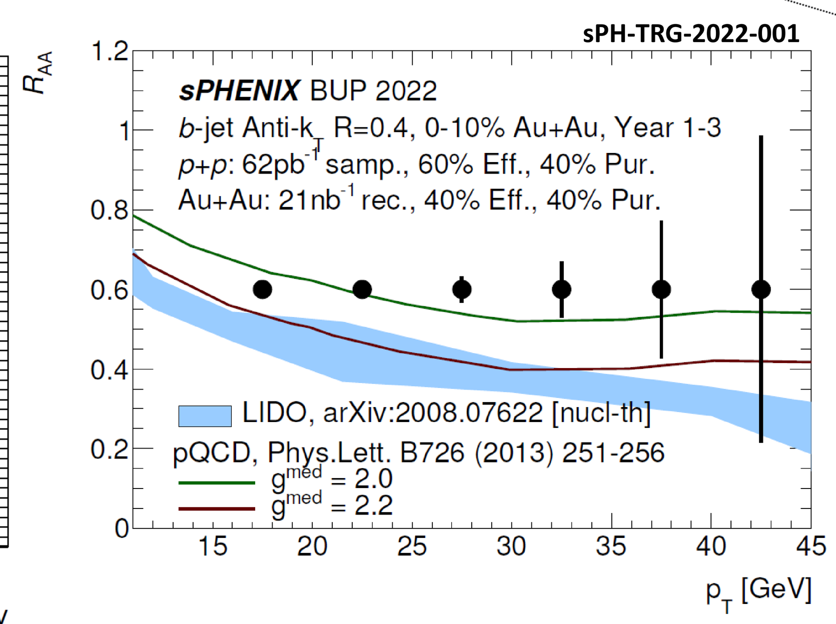
- Heavy quarks (charm and beauty) are mostly produced in hard partonic scatterings processes in the early stages of the collisions.
- Because of their large mass, the production cross section can be calculated using pQCD down to low p_T.
- Excellent probe for Quark-Gluon Plasma (QGP) as they are produced before QGP is formed

HF-tagged jets

- Give direct access to the initial parton kinematics
- Constraints on pQCD-based models
- Information on heavy-quark energy loss in the QGP
  - Collisional energy loss might be significant
  - Flavour and mass dependence of jet quenching
  - HF hadronization, fragmentation and flow
    - Additional information, complementary to R_{AA} and v_2
  - Dead-cone effect







Tagging techniques

Three main techniques both exploiting unique properties of b-jets

1. Track counting method (this poster)
   - Track Distance-of-Closest-Approach (DCA) w.r.t. primary vertex
2. Jet Probability
   - Jet likelihood based on track probabilities
3. Secondary vertex reconstruction
   - Constrains on topology and vertex invariant mass

Track counting algorithm

1. The main discriminator is the signed significance of track-to-primary-vertex DCA in transverse plane $SDCA_{xy}$
   - $SDCA_{xy} = sgn\left(\overrightarrow{p_{xy}^{jet}} \cdot \overrightarrow{DCA_{xy}}\right) \frac{|\overrightarrow{DCA_{xy}}|}{unc(|\overrightarrow{DCA_{xy}}|)}$
   - The significance is defined as DCA in transverse plane between the track and the primary vertex divided by its uncertainty
   - The sign is defined as a signum (sgn) of the scalar product of the jet axis and the DCA vector
     - Tracks originating from primary vertex should have $\mathrm{sgn}(x) = 0$
       - due to limited resolution, they will have both $\mathrm{sgn}(x) = +1$ and $\mathrm{sgn}(x) = -1$ values
     - Track originating from secondary decays will have $\mathrm{sgn}(x) = +1$
2. For this study, reconstructed and truth jets are matched if there is a unique matching between truth and reconstructed jet in $\Delta R = \sqrt{(\varphi_{truth} - \varphi_{reco})^2 + (\eta_{truth} - \eta_{reco})^2} < 0.3$
3. Truth jets are marked as c- and b- jet if any of its track have a HF-hadron in its decay history

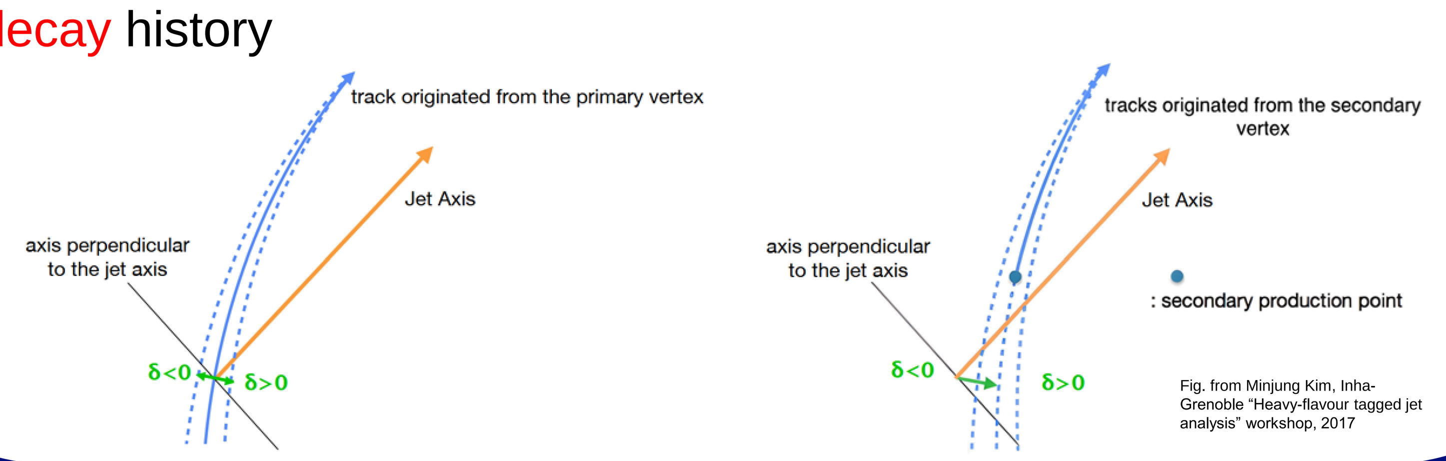
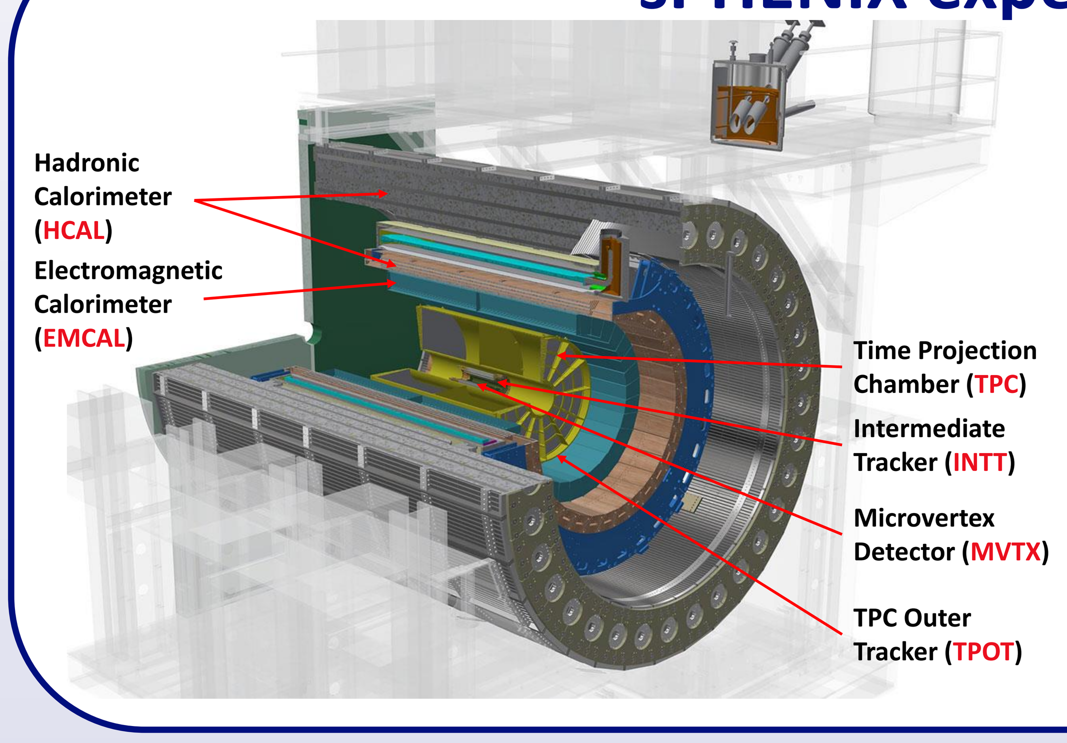


Fig. from Minjung Kim, Inha-Grenoble "Heavy-flavour tagged jet analysis" workshop, 2017

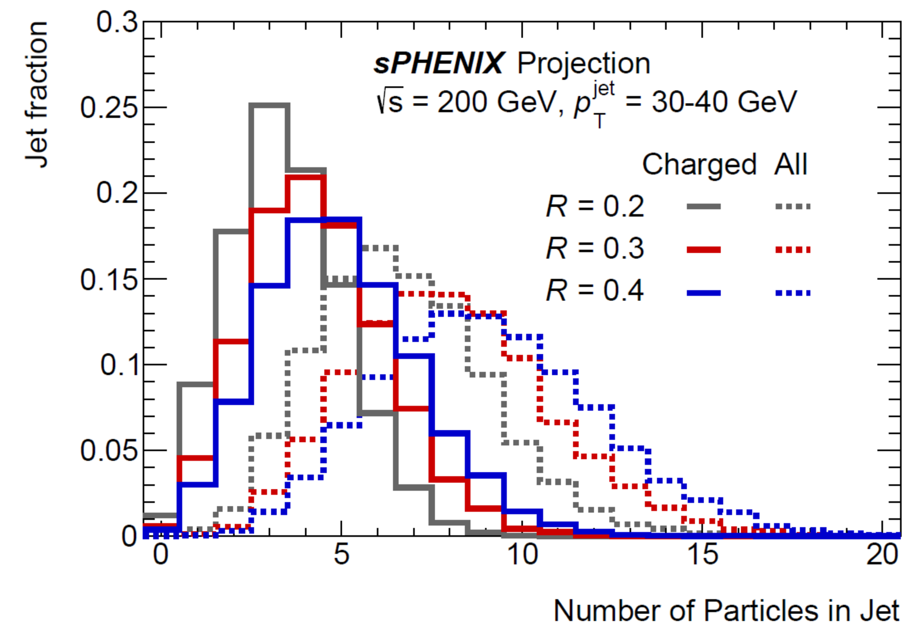
sPHENIX experiment



- Located at RHIC accelerating complex at BNL.
- Running period 2023-2025
- Tracking detectors
  - MVTX, INTT, TPC, TPOT
- Calorimeters
  - EMCAL, HCAL
- 1.4 T Magnetic Field, $|\eta| \leqslant 1.1$
- 15 kHz Trigger Rate
  - due to calorimeter limit
- MVTX, INTT, and TPC capable of streamed readout

Particle flow

- Almost half of the jet energy is carried by the neutral particles
  - The importance to study full jets
- Initial implementation of particle flow at sPHENIX to connect charged tracks and calorimeter information
- First look at b-jets using Particle flow at sPHENIX



Simulation Sample/Jet-Track Selection

Simulation configuration:

- PYTHIA 8 + GEANT 4, pp 200 GeV, HardQCD:all, $\widehat{Q} = 7$ GeV/c, without pileup

Jet selection:

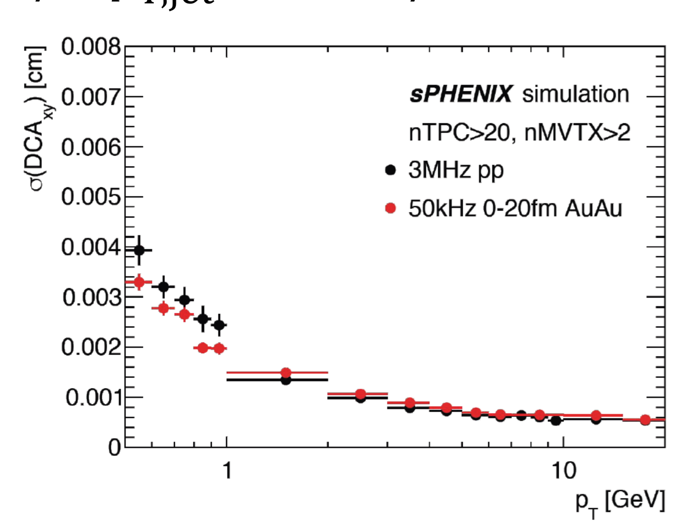
- Anti-k_T, E-scheme, $R = 0.4$, $p_{T,jet}^{truth} \geq 10$ GeV/c, $p_{T,jet}^{reco} \geq 5$ GeV/c

Track selection:

- $p_{T,track} \geq 500$ MeV/c

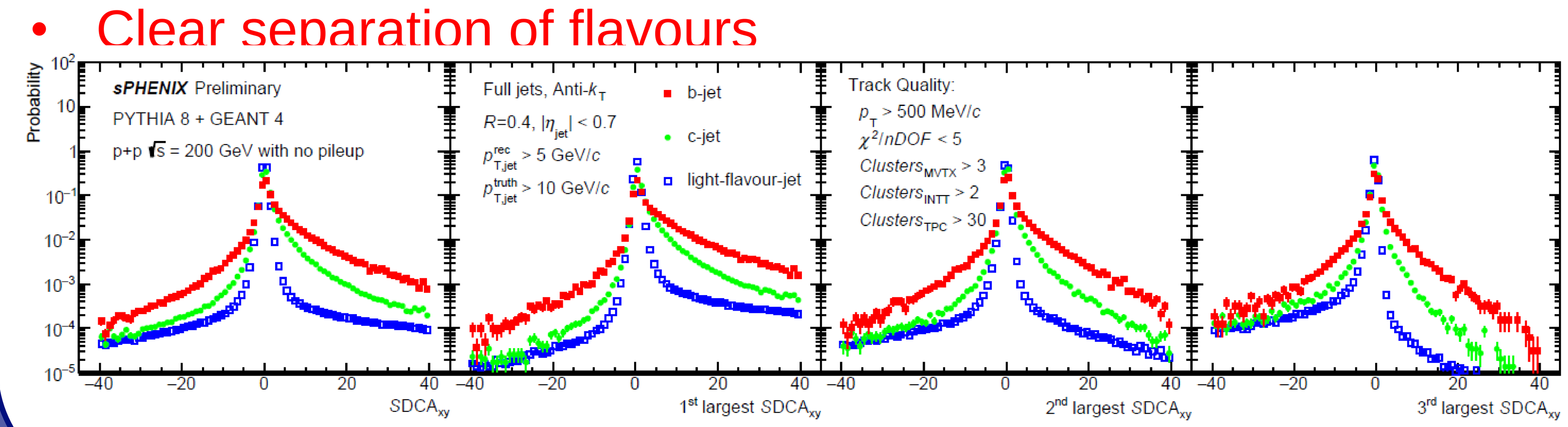
For the $SDCA_{xy}$ calculation further track selection is required:

1. $\chi^2/nDOF < 5$
2. TPC clusters ≥ 30
3. INTT clusters ≥ 2
4. MVTX clusters ≥ 3



Results – $SDCA_{xy}$ probabilities

- Signed significance ($SDCA_{xy}$) probability of tracks, and $SDCA_{xy}$ of the first-, second-, and third- most significant track
- Clear separation of flavours



Conclusion and next steps

First look at HF-tagged full jets using particle flow at sPHENIX

Will apply this algorithm in 2024 on p+p data

Next steps:

1. Tune the track and jet selection to achieve high purity and efficiency
2. Implement Jet Probability method
3. Introduce the machine learning to further improve the performance

Managed by Triad National Security, LLC, for the U.S. Department of Energy's NNSA.

This work is supported by the LANL 20230072ER project.
LA-UR number here, LANL ER: 20230072ER