b-jet tagging at sPHENIX

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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. Here, we will focus on the prospects of beauty-jet-tagging of full jets at sPHENIX.

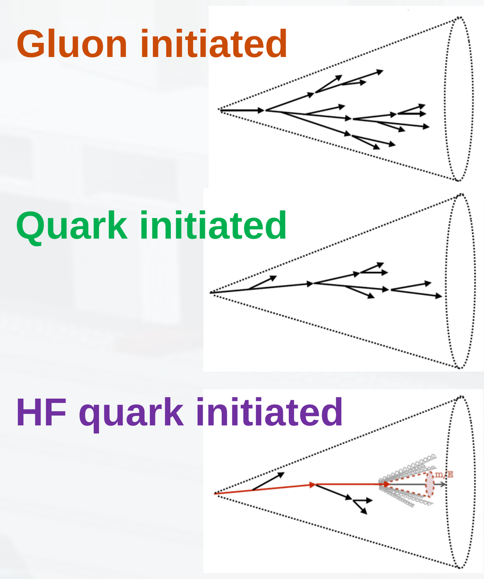
Physics motivation

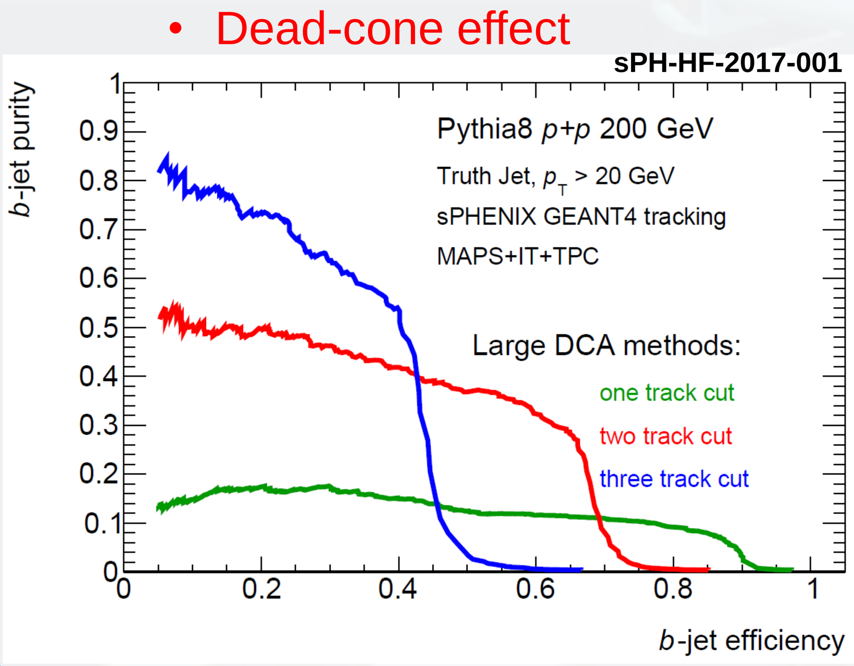
Heavy-flavor (HF) hadrons

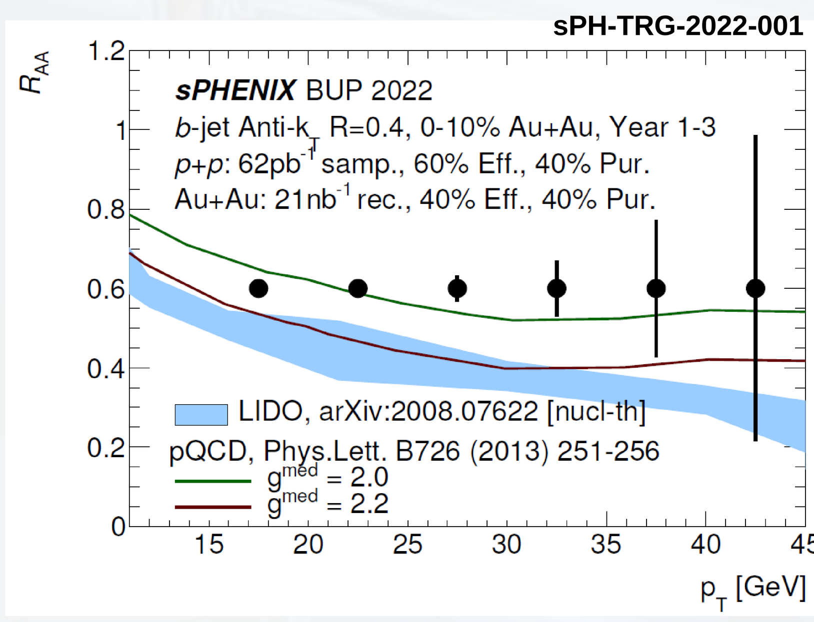
- Heavy quarks (charm and beauty) are mostly produced in hard partonic scatterings processes in the early stages of the collisions.
- Because of their large mass, the production cross section can be calculated using pQCD down to low p_T.
- Excellent probe for Quark-Gluon Plasma (QGP) as they are produced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

HF-tagged jets

- Give direct access to the initial parton kinematics
- Provide further 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 and its modification by QGP
  - Jet substructure provides additional information
    - Dead-cone effect







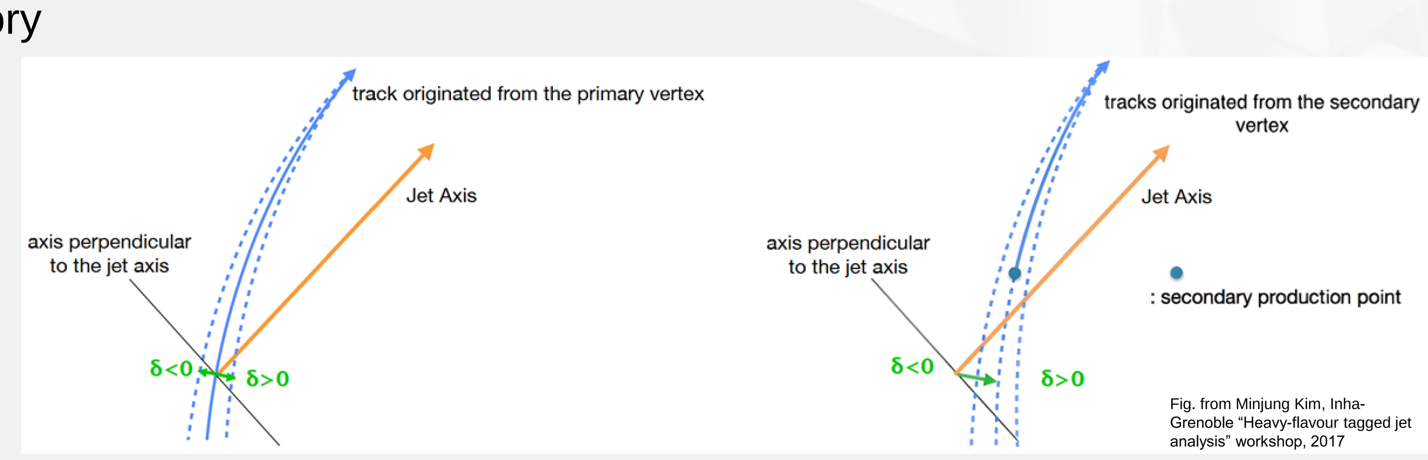
Tagging techniques

Three main techniques both exploiting unique properties of b-jets

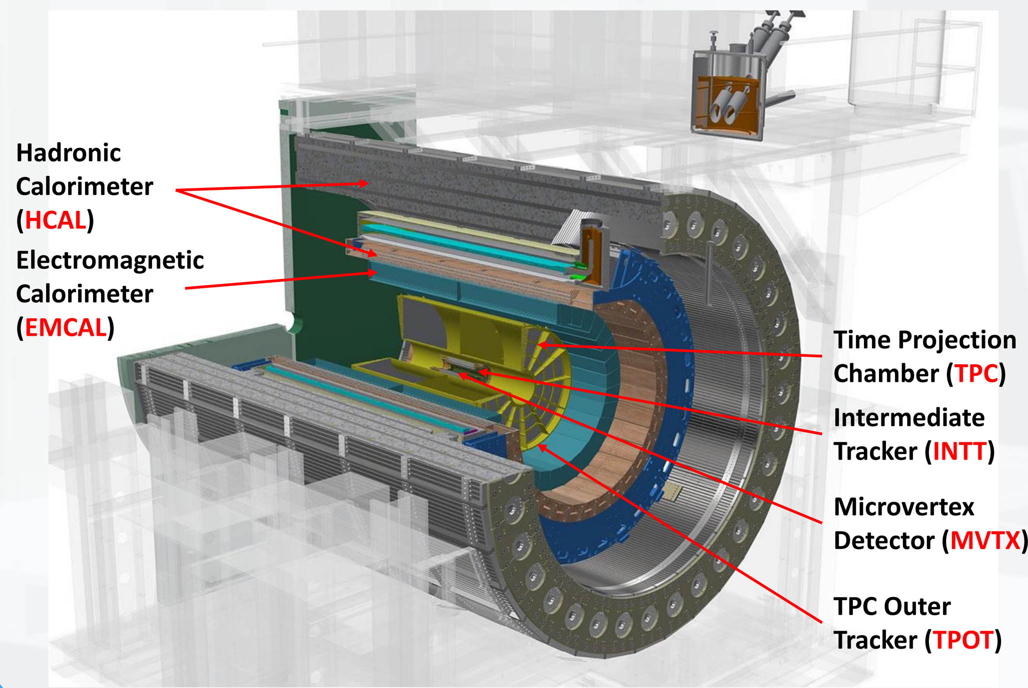
1. Track counting method (this poster)
   - Track Distance-of-Closest-Approach (DCA) w.r.t. primary vertex
2. Jet Probability
   - Jet likelihood based on track probabilities
3. Secondary vertex reconstruction
   - Constrains on topology and vertex invariant mass
4. HF-lepton tagging
   - Looking at (semi-)leptonic decay channels

Track counting algorithm

1. The main discriminator is the signed significance of track-to-primary-vertex DCA in transverse plane $SDCA_{xy}$
   - $\mathrm{SDCA_{xy}} = sgn\left(\overrightarrow{p^{jet}_{xy}} \cdot \overrightarrow{DCA^{jet}_{xy}}\right) \frac{|DCA_{xy}|}{unc(|DCA_{xy}|)}$
   - 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



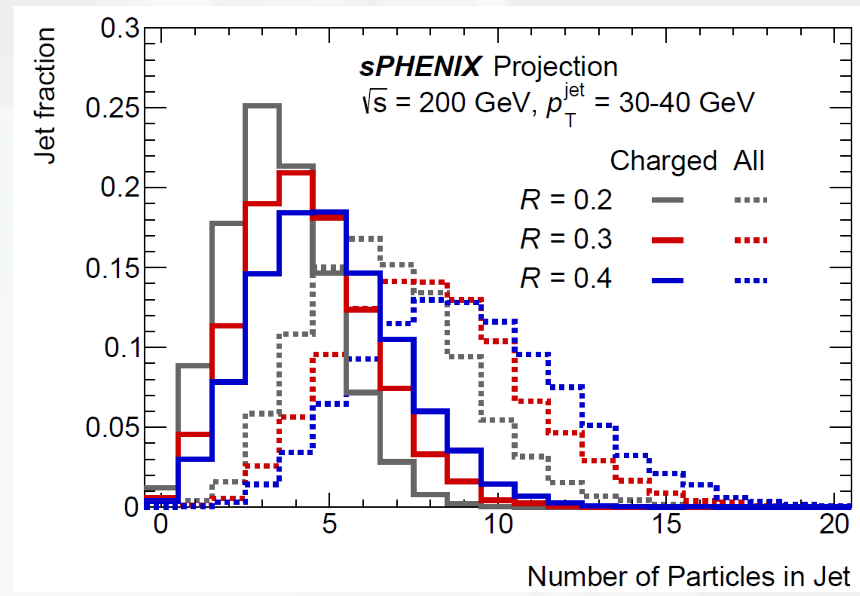
sPHENIX experiment



- 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



Simulation Sample/Jet-Track Selection

Simulation configuration:

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

Jet selection:

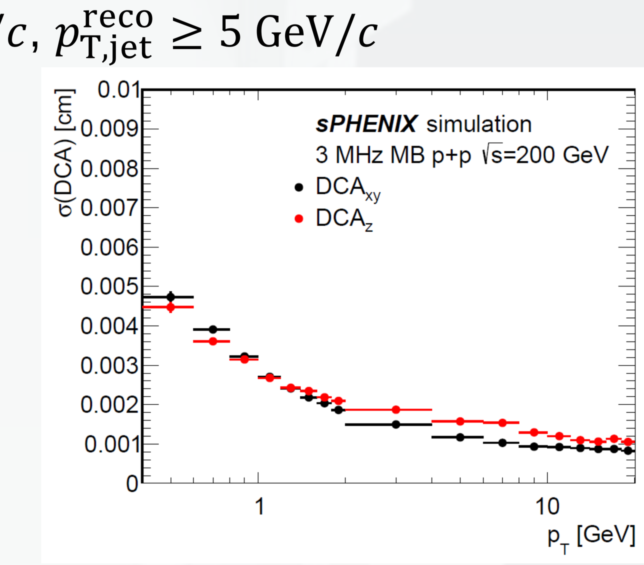
- Anti-k_T, E-scheme, $R = 0.4$, $p^{truth}_{T,jet} \geq 10$ GeV/c, $p^{reco}_{T,jet} \geq 5$ GeV/c

Track selection:

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

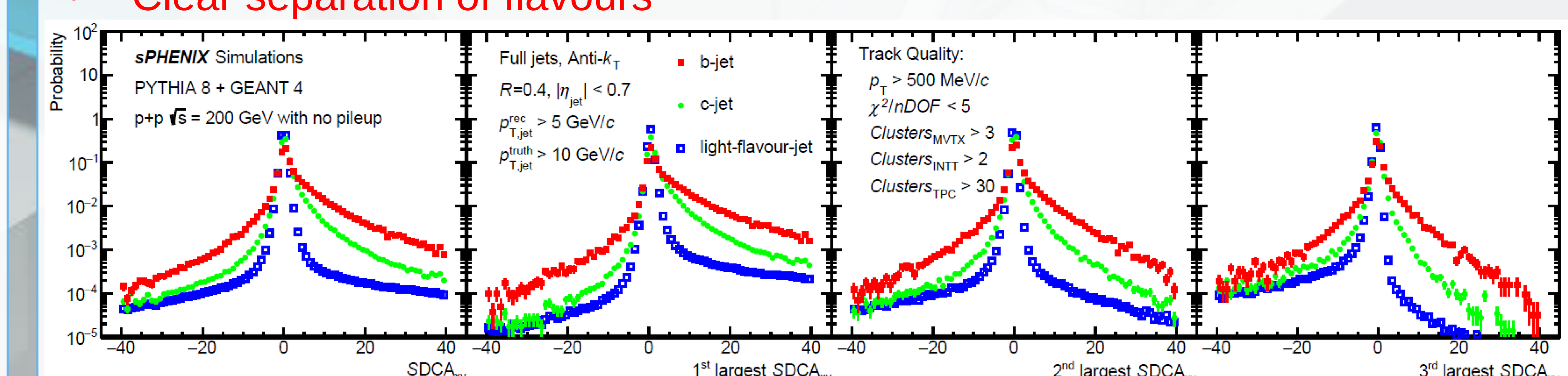
For the $SDCA_{xy}$ calculation further track selection is required:

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

Next steps:

1. Optimize the track selection and jet tagger under the Run24 condition, including the pile up and apply in 2024 on p+p data
2. Tune the track and jet selection to achieve high purity and efficiency
3. Implement Jet Probability method
4. Introduce the machine learning to further improve the performance

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