Reconstruction of D^0 mesons in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR experiment

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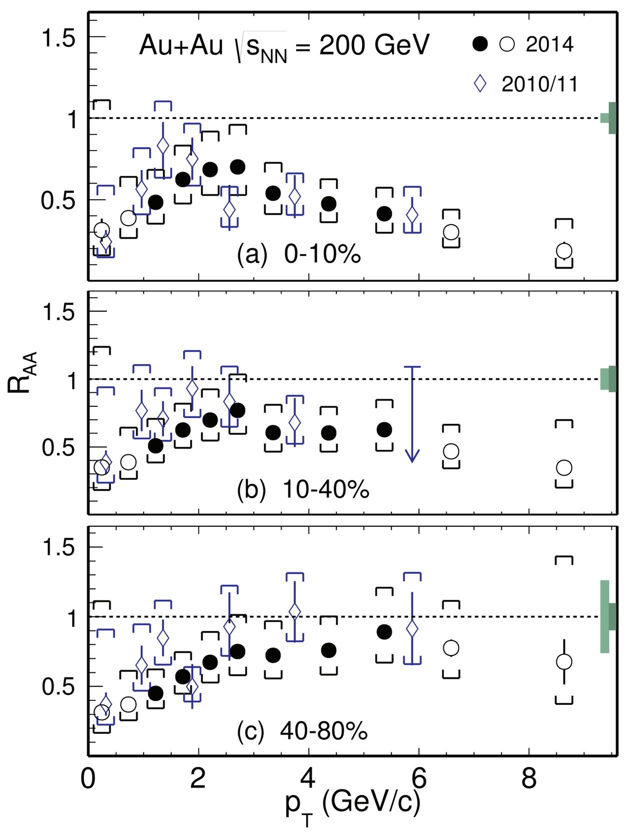
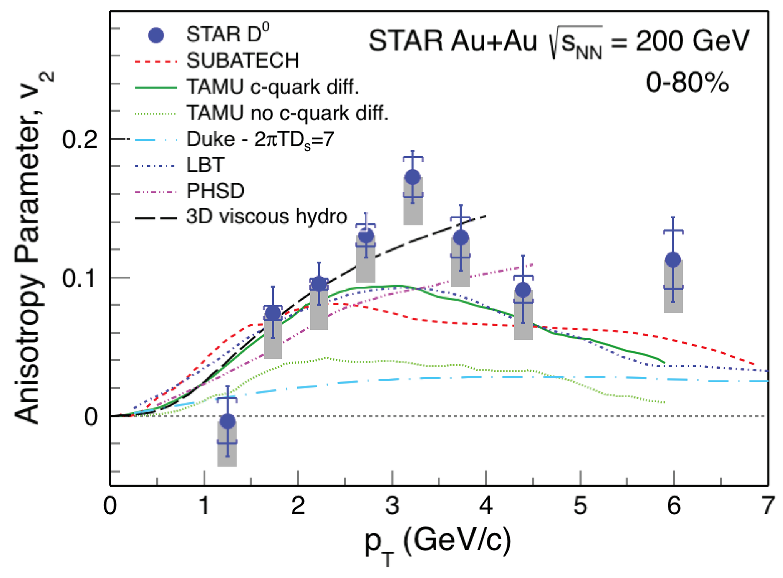
MOTIVATION

- Heavy-flavor quarks are produced in hard scatterings at the early stage of nuclear collisions, therefore they experience the entire evolution of the hot medium, **quark-gluon plasma** (QGP).
- The nuclear modification factor R_{AA} of open charm mesons at RHIC exhibits strong suppression at high p_T in Au+Au collisions, indicating substantial energy loss of charm quarks in the medium.
- The collective behavior of charm quarks reflects **the degree of thermalization of charm quarks** in the medium, and is related to the bulk properties of the QGP.
- For quantitative studies of the QGP properties (e.g. charm transport coefficients), understanding of the **cold nuclear matter effects**, accessed via proton-nucleus or deuteron-nucleus collisions, is required.



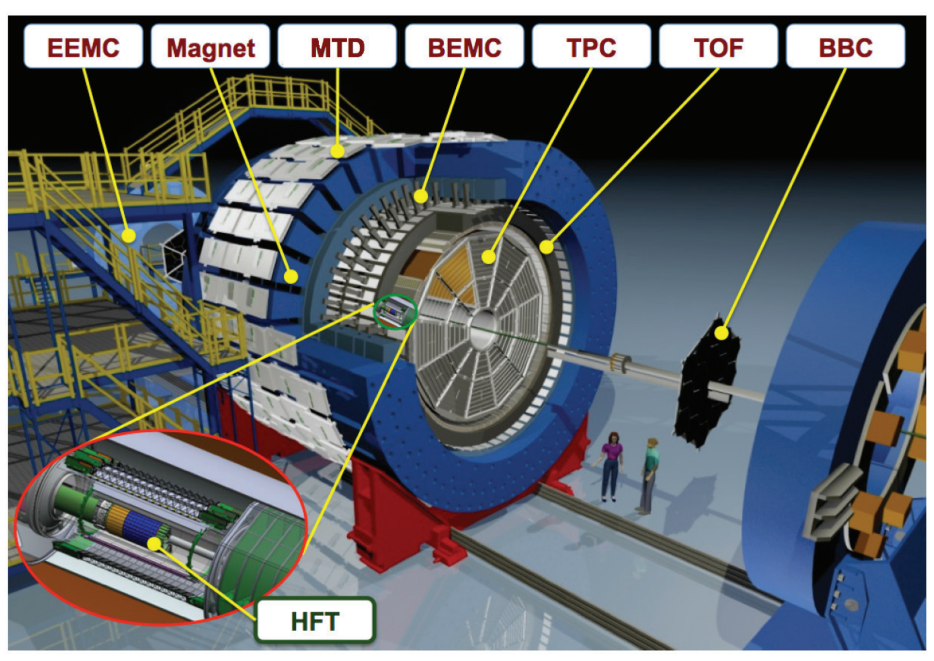
The D^0 R_{AA} in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV [1]



The elliptic anisotropy v_2 for D^0 mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, compared to theoretical calculations [2]

STAR DETECTOR

- STAR has excellent tracking and charged particles identification at mid-rapidity ($|\eta|$ < 1) with full azimuthal coverage.
- Most of the subsystems are immersed in a 0.5 T solenoidal magnetic field.



Time Projection Chamber (TPC):
- main tracking device, momentum determination, particle identification via energy loss.

Time Of Flight (TOF):
- particle identification via velocity (β).

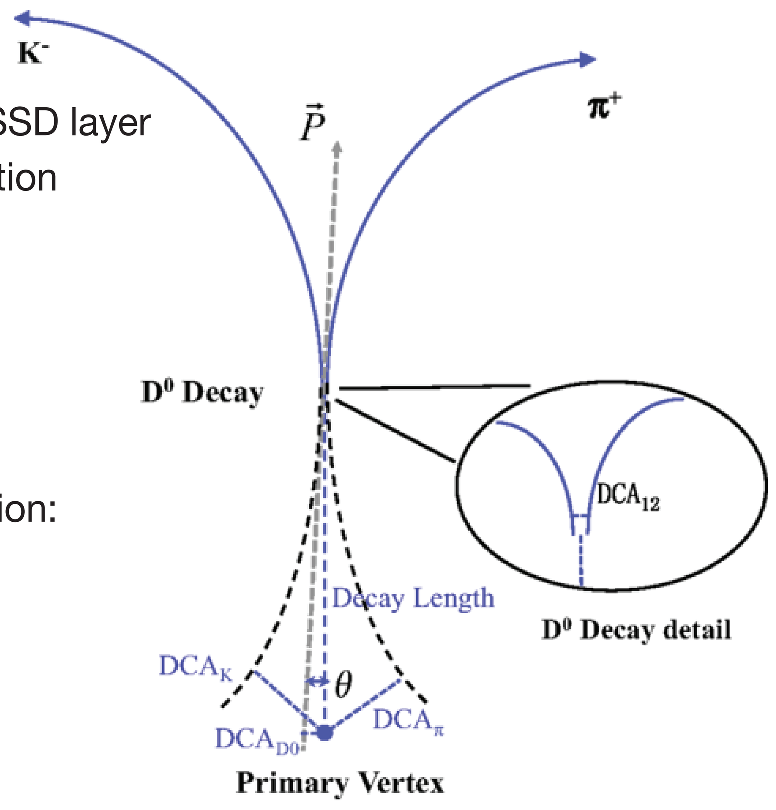
Heavy Flavor Tracker (HFT):
- inner tracking system composed of three silicon detectors – the PIXEL made of two layers of Monolithic Active Pixel Sensors, Intermediate Silicon Tracker (IST) and Silicon Strip Detector (SSD),
- excellent DCA_{xy} and DCA_z resolution: 30 μm for kaons at p_T = 1.5 GeV/c,
- installed for data taking in years 2014-2016.

ANALYSIS METHOD

- About 350 million d+Au events at $\sqrt{s_{NN}}$ = 200 GeV recorded in 2016 are used for this analysis.
- Hadronic decay channels are used for D^0 reconstruction ($D^0 \rightarrow K^-\pi^+$, $\overline{D^0} \rightarrow K^+\pi^-$), whose branching ratio is (3.89 ± 0.04) %.

Event selection:
- Correlation of primary vertices reconstructed using TPC and Vertex Position Detector (VPD) $|V_{z,VPD} - V_{z,TPC}|$ < 6 cm → pile-up rejection
- Vertex position in beam direction $|V_{z,TPC}|$ < 6 cm → HFT acceptance coverage

Track selection:
- Hits in both PIXEL layers and at least one of the IST or SSD layer
- At least 15 space points in the TPC for track reconstruction
- Track pseudorapidity $|\eta|$< 1
- Daughter p_T > 0.15 GeV/c



Particle identification:
- TPC dE/dx: $|n\sigma_\pi|$< 3, $|n\sigma_K|$< 2
- TOF used only for tracks which have valid TOF information: $|1/\beta_{theo.} - 1/\beta_{meas.}|$ < 0.03

Topological reconstruction of D^0 meson:
- Used topological properties of D^0 decays are:
  1. decay length
  2. daughter $DCA_{K,\pi}$ to primary vertex (PV)
  3. DCA_{12} between daughter particles
  4. reconstructed D^0 candidate DCA_{D0} to primary vertex
  5. pointing angle θ between reconstructed D^0 momentum and decay length vector
- Signal and background separation is optimized with the **Toolkit for Multivariate Data Analysis** (TMVA) package [3].

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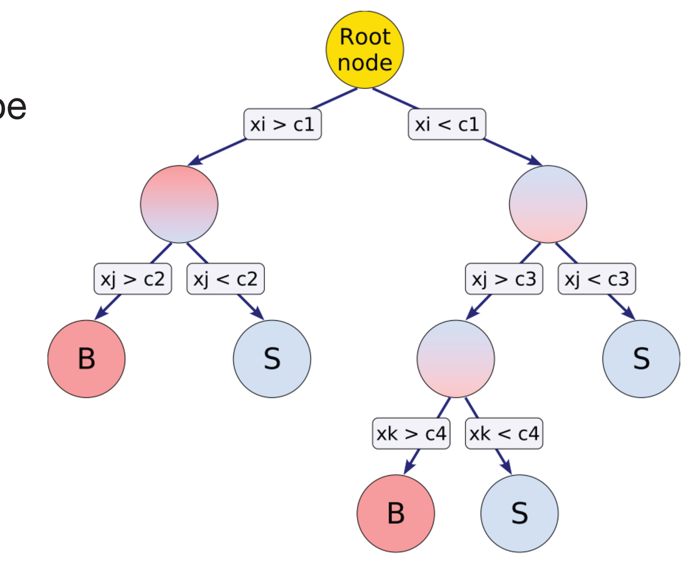
MACHINE LEARNING ALGORITHM TRAINING

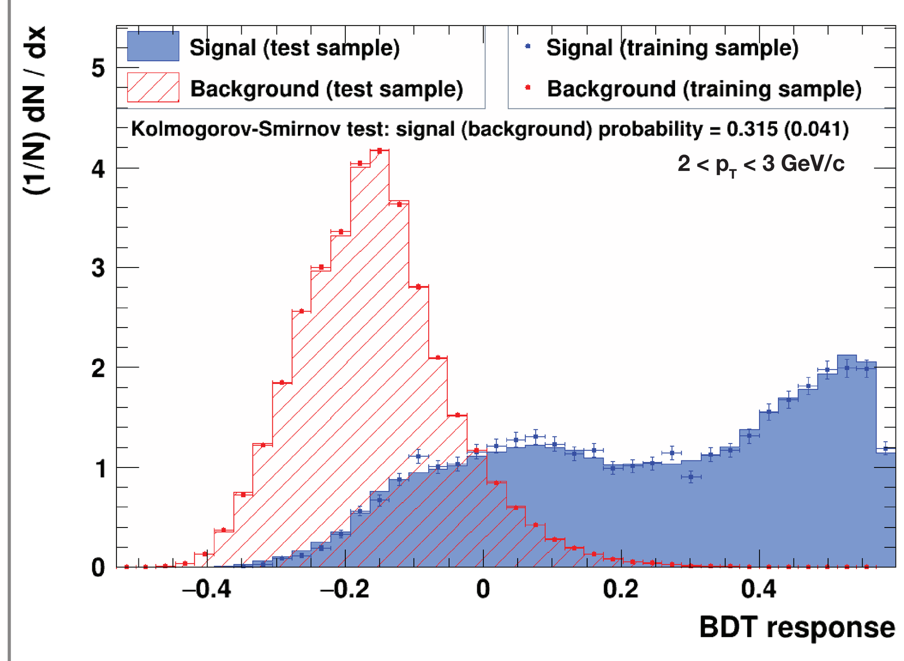
- The TMVA - **Boosted Decision Trees** (BDT) method was used.
  - Classifier is a binary structured decision tree.
  - Number of decision trees and their maximum depth may be set in the TMVA.

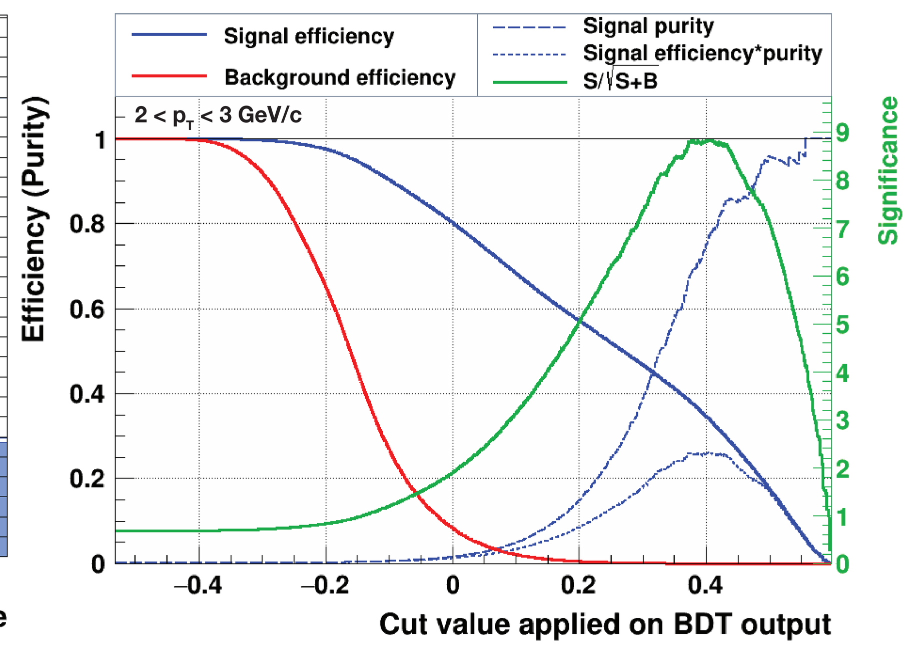
Signal sample for training:
- D^0 decay is simulated using PYTHIA.
- Momenta and DCA of daughter particles are smeared in accordance to the detector response.

Background sample for training:
- wrong (like) sign pairs at the D^0 mass region taken directly from data.



Schematic view of a decision tree [3]





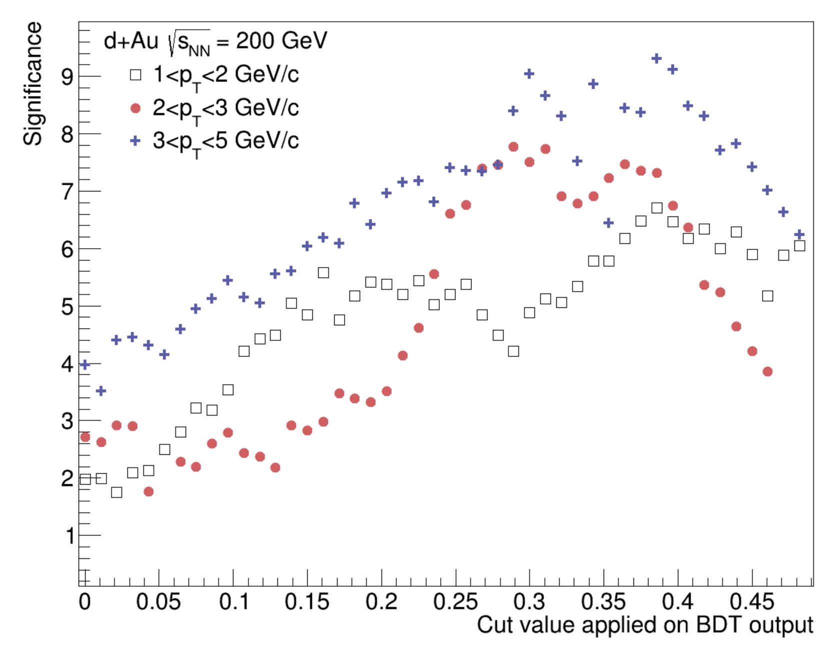
Classifier output distributions
- Both signal and background input pairs are divided to training and test samples.
- The trained BDT is applied on both samples.
- Overtraining check: if distributions obtained from training and test samples are consistent, BDT is not overtrained.

Classifier cut efficiencies
- TMVA evaluates BDT cut efficiencies and purities of signal and background.
- Estimate of number of signal and background pairs before cut application is needed to determine the BDT cut with maximum significance.
  - Signal (background) estimate for this plot: 300 (190 000)

BDT APPLICATION ON DATA

- BDT is applied on both correct (unlike) sign pairs and wrong (like) sign pairs from the data.
  → BDT response is calculated for **every pair**.
- Distribution of invariant mass of pairs that fulfill the **cut on BDT response** is used for significance calculation.
- Background (B) is estimated via **wrong (like) sign** combinations of daughter particles ($K^-\pi^-$, $K^+\pi^+$) and is subtracted from the **correct (unlike) sign** combinations.
- Invariant mass distribution of unlike-sign pairs after background subtraction is fitted by the combination of a Gaussian function for signal and a linear function for the residual background.
- Yield (Y) is extracted using the **bin-counting method** in the ±3σ region around the mean of the fitted Gaussian function with residual background subtracted.

- **Set of cuts on BDT response is scanned.**
- Intervals of pair p_T used for analysis:
  - 1–2, 2–3, 3–5 GeV/c,
  - BDT is trained separately in these intervals.
- Significance higher than 6 is achieved in all of the intervals.



CONCLUSIONS AND OUTLOOK

- D^0 mesons are reconstructed via their hadronic decay channels in d+Au collisions with excellent precision thanks to the **Heavy Flavor Tracker at the STAR experiment**.
- Extraction of D^0 signal from d+Au data has been optimized using the TMVA Boosted Decision Trees method in different intervals of p_T bins.
- Evaluations of the efficiency corrections on D^0 raw yields and systematic uncertainties are under way, to determine the invariant yield and **nuclear modification factor** R_{dAu} in d+Au collisions.

REFERENCES

[1] J. Adam et al. (STAR Collaboration), Phys.Rev. C99 (2019) no.3, 034908.
[2] L. Adamczyk et al. (STAR Collaboration), Phys. Rev. Lett. 118 (2017) 212301.
[3] A. Hocker et al., PoS ACAT, 040 (2007).

ACKNOWLEDGMENT

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