Measurements of D^0 Production in d+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR Experiment

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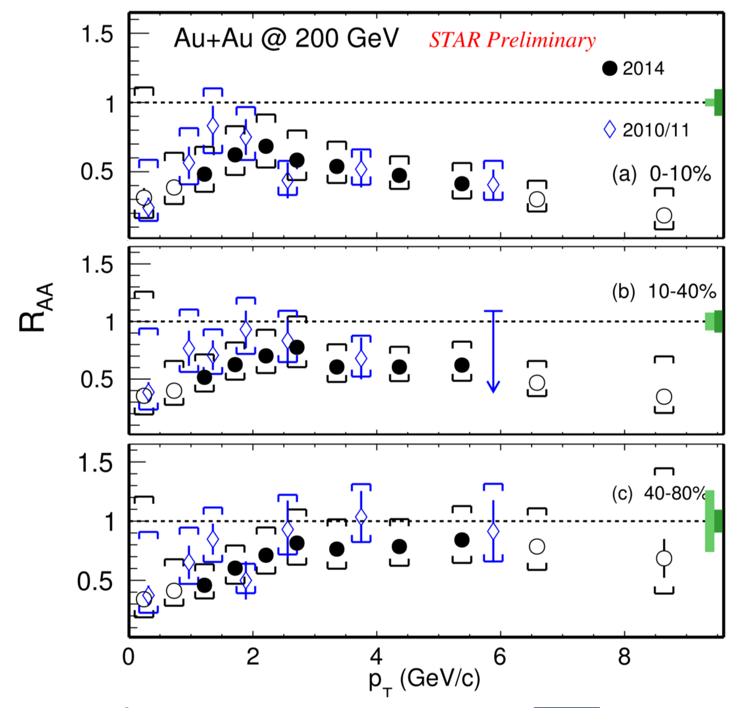
Abstract

Charm quarks possess large masses, and thus can serve as penetrating probes to study the intrinsic properties of the hot medium created in heavy-ion collisions. However, Cold Nuclear Matter (CNM) effects, such as the change in the parton distribution function between a free nucleon and a nucleus, also affect the charm quark production in nuclear collisions with respect to p+p collisions. These effects can be measured in small systems such as p+A and d+A collisions, where only the CNM effects are present. Furthermore, a sizable azimuthal anisotropy (v_2) has been observed in both nucleus-nucleus collisions and small-system collisions of high multiplicities. To better understand the origin of the flow-like signal in small-system collisions, it is important to study charm quark azimuthal anisotropy in these systems.

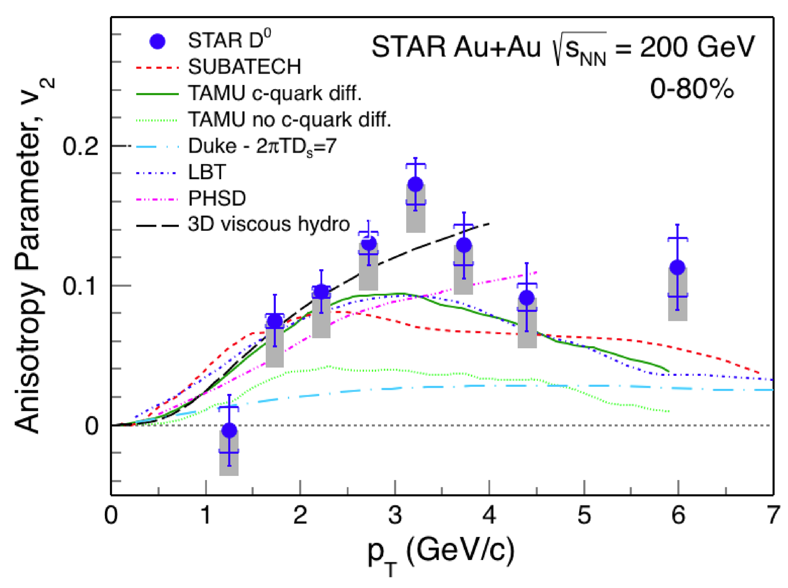
In this poster, we report on the first measurements of D^0 production with the Heavy Flavor Tracker in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.

Motivation

- **A mass ordering** of the parton energy loss in the hot medium is predicted, i.e. heavy-flavor quarks are expected to lose less energy than light-flavor quarks.
  - The nuclear modification factor R_{AA} of open charm mesons 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 (CNM) effects**, accessed via proton-nucleus or deuteron-nucleus collisions, is required.



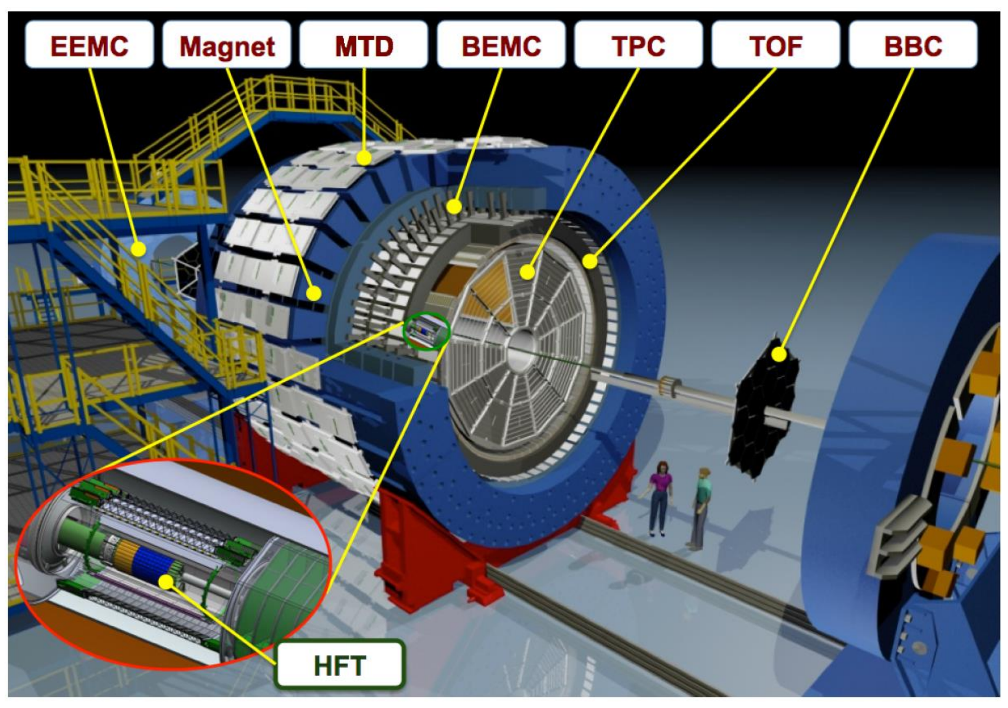
The D^0 R_{AA} in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV



The elliptic anisotropy v_2 for D^0 mesons in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV, compared to theoretical calculations [1]

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.



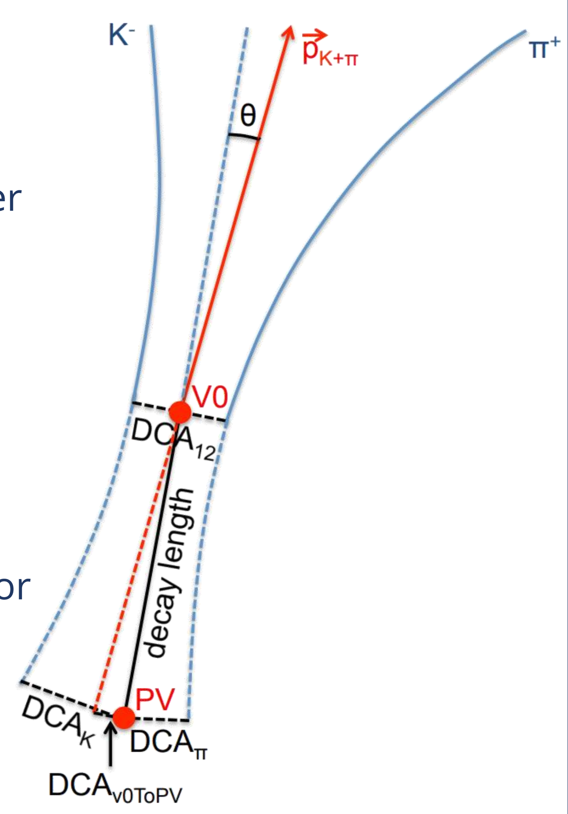
Time Projection Chamber (TPC):
- main tracking device, momentum determination, particle identification via energy loss (dE/dx)

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 at p_T = 1.5 GeV/c**
- installed for data taking in years 2014-2016

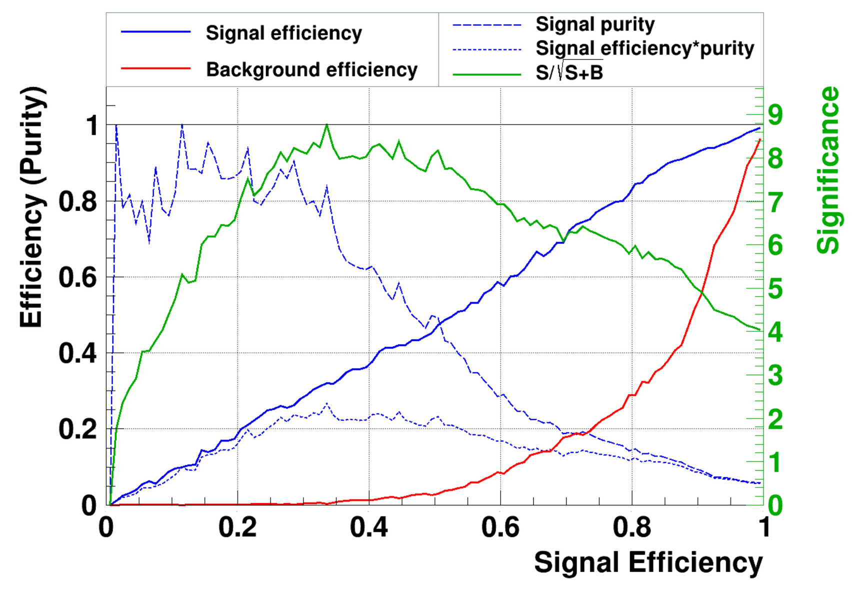
Analysis Method

- 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 ($\overline{D^0} \to K^+\pi^-$, $D^0 \to K^-\pi^+$), whose branching ratio is (3.89 ± 0.04) %.
- **Event selection:**
  - Vertex position in beam direction $|V_z| < 6$ cm
  - Correlation of primary vertices reconstructed using TPC and VPD $|V_{z,VPD} - V_{z,TPC}| < 3$ cm
- **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 $|\eta| < 1$
- **Particle identification:**
  - Daughter $p_T > 0.15$ GeV/c
  - TPC: $|n\sigma_\pi| < 3$, $|n\sigma_K| < 2$
  - TOF: matching for pions, $|1/\beta_{theo.} - 1/\beta_{meas.}| < 0.03$ for kaons
- **Topological cuts for D^0 reconstruction:**
  - Optimized separately for different p_T intervals using Toolkit for Multivariate Data Analysis package [2].
  - 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. pointing angle θ between reconstructed D^0 momentum and decay length vector
    5. reconstructed D^0 candidate DCA_{v0ToPV} to primary vertex



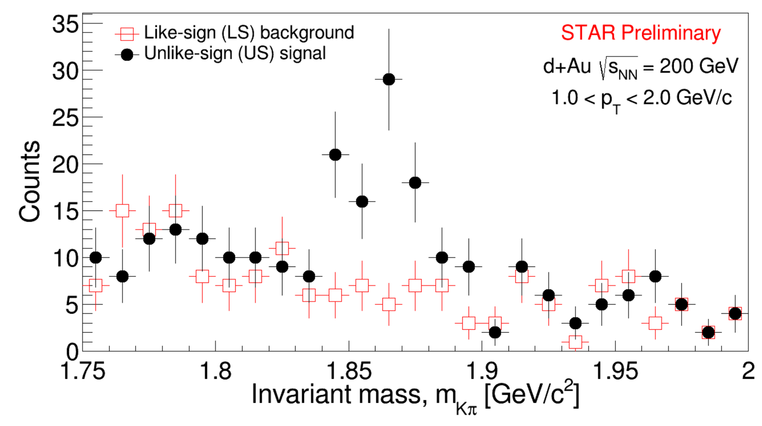
Tuning Topological Cuts

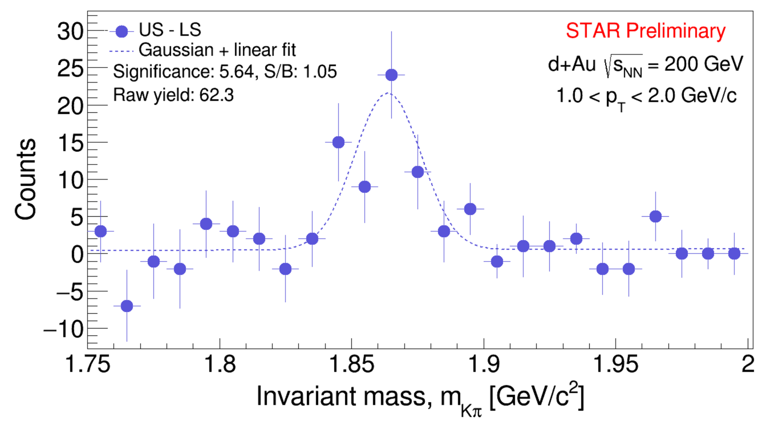
- The TMVA - **Rectangular Cut** optimization was used.
  - This mode randomly samples different cut combinations and selects the one with the largest background rejection for a given signal efficiency.
- Cuts with the greatest significance $S/\sqrt{S+B}$ are used for raw yield extraction.
- **Signal 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** is taken directly from data:
  - wrong (like) sign pairs at the D^0 mass region,
  - correct (unlike) sign pairs outside of the D^0 mass region.

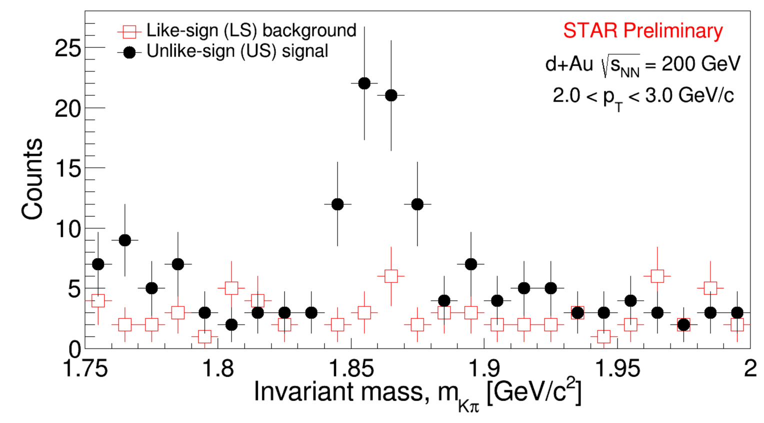


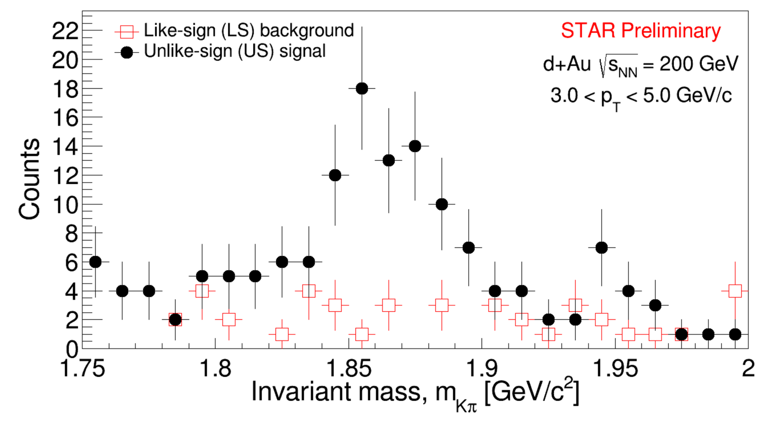
D^0 Raw Yields

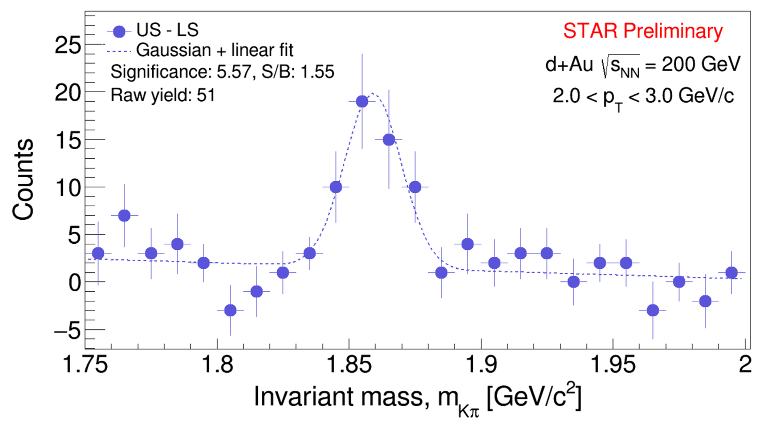
- Background is estimated via **wrong (like) sign** combinations of daughter particles ($K^-\pi^-$, $K^+\pi^+$) and is subtracted from the **correct (unlike) sign** combinations.
- Invariant mass distribution of unlike-sign pairs after background subtraction is fitted by the combination of a Gaussian function for signal and a linear function for the residual background.
- Yield is extracted using the **bin-counting method** in the ±3 σ region around the mean of the fitted Gaussian function with residual background subtracted.
- Intervals of pair p_T used for analysis:
  - 1–2, 2–3, 3–5 GeV/c
- Significance larger than 5 is achieved in all p_T bins.

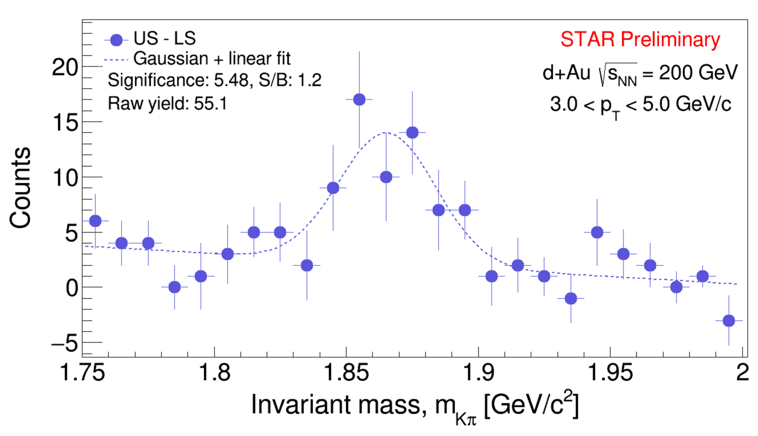












Conclusions and Outlook

- 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.
- Evaluations of the efficiency correction on D^0 raw yield and systematic uncertainties are under way, to determine the **nuclear modification factor** R_{dAu} and the **elliptic anisotropy** v_2 in d+Au collisions.

References

[1] L. Adamczyk et al. (STAR Collaboration), PRL 118 (2017) 212301.

[2] A. Hocker et al., PoS ACAT, 040 (2007).

Acknowledgement

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