Measurement of D^0 and $\overline{D^0}$ directed flow using KF Particle in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from STAR

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Abstract

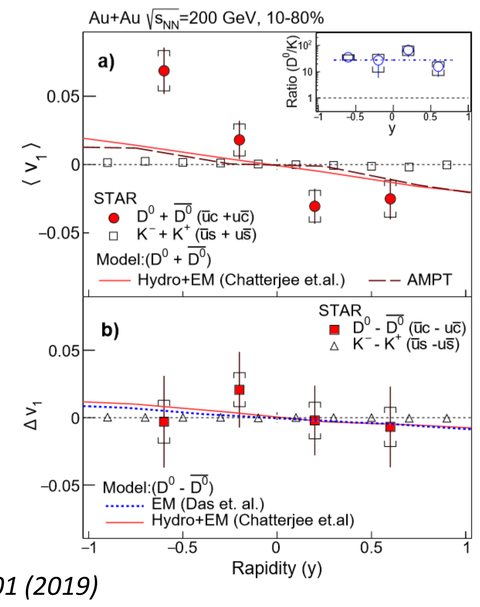
Charm quarks, owing to their large mass, are predominantly created through initial hard scatterings in relativistic heavy-ion collisions and thus are ideal probes to study early time dynamics of these collisions. Recent results from STAR show that the slope of D^0 mesons directed flow versus rapidity (dv_1/dy) is about 25 times larger than that of charged kaons, providing important constraints on the initial geometry and charm quark transport in the QGP. It has also been predicted that the transient electromagnetic field generated at early time can induce a difference between the v_1 of charm and anti-charm quarks. The uncertainties of the current measurement from STAR are too large to make a conclusion on the difference between v_1 of D^0 and $\overline{D^0}$, and calls for measurements with improved precision.

In this poster, we present reconstruction of D^0 and $\overline{D^0}$ mesons by an algorithm based on the Kalman Filter (KF Particle Finder package) in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV using data collected with the Heavy Flavor Tracker during the 2014 RHIC run. The KF particle finder package provides estimation of not only the tracking parameters themselves but also their corresponding covariance matrices as well. By using such additional information in the D^0 reconstruction, the signal significance is improved considerably. The D^0 and $\overline{D^0}$ raw signals reconstructed by KF Particle and the significance improvement are presented.

Motivation

- D^0 v_1 versus rapidity is about 25 times larger than that of charged kaons [1]
- Difference between D^0 and $\overline{D^0}$ v_1 predicted to be sensitive to the initial EM field [2]
- Current measurement precision while using standard D-meson reconstruction method is not sufficient to determine the difference and ordering

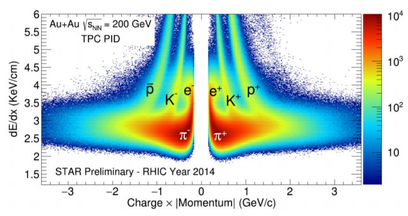
- Using KF Particle Finder package to increase D^0 signal significance
- Combine with D^+ to obtain D and $\overline{D}$ v_1 difference

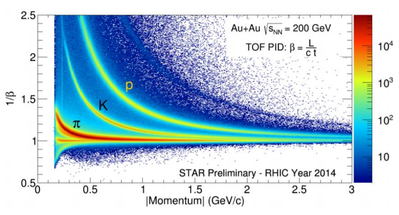


[1] J. Adam, et al. (STAR), Phys. Rev. Lett. 123, 162301 (2019)
[2] S. Chatterjee, and P. Bozek, Phys. Rev. Lett. 120, 192301 (2018)

Event and Track Selection

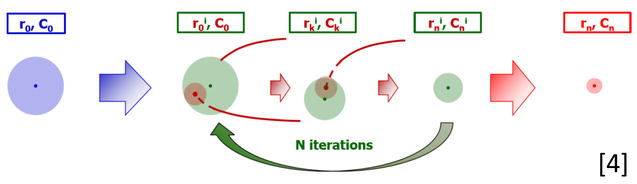
- 600 million minimum bias events of Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV taken in 2014
- $D^0(\overline{D^0})\rightarrow K^{\mp}\pi^{\pm}$ decay channel, BR = (3.950 ± 0.031)%
- Particle identification (PID): TPC(dE/dx)+TOF (using TOF PID when it is available), $|\eta|<1$
- Require HFT hits to get high resolution in track impact parameter





KF Particle Reconstruction Algorithm

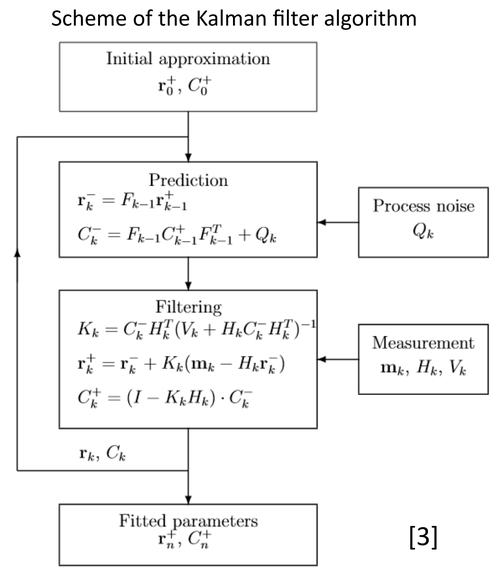
- Kalman filter-based particle reconstruction method which takes properly into account track covariance matrices [3]
- Calculate mother particle parameters together with corresponding uncertainties



[4]

Short-lived particle reconstruction with KF Particle package

Scheme of the Kalman filter algorithm



[3]

Example reconstruction chain: primary vertex -> D^0 -> K,π

- Select secondary daughter (K,π) tracks
- Daughter particles(K,π) are described by vector r_i^d={x,y,z,p_x,p_y,p_z,E} and its covariance matrix C_i^d
- Set initial estimation of mother particle's (D^0) r_0 and C_0
- Filter daughter particle (K or π) using the Kalman Filter mathematics
- Use daughter particles' r_i^d, C_i^d and mother particle's (D^0) r_{i-1}, C_{i-1} to estimate r_i, C_i
- Iterate over all daughter particles, and get the final estimation on D^0 r_n, C_n
- Use r_n, C_n and primary vertex to calculate mother particle (D^0) decay length and its uncertainty
- Apply cuts on mother particle (D^0) to suppress combinatorial background

[3] S. Gorbunov, "On-line reconstruction algorithms for the CBM and ALICE experiments", Dissertation thesis, Goethe University of Frankfurt, 2012
[4] M. Zyzak, "Online selection of short-lived particles on many-core computer architectures in the CBM experiment at FAIR", Dissertation thesis, Goethe University of Frankfurt, 2016

Topological Variables and TMVA Selection Optimization

χ^2- based topological variables calculated by KF Particle are used for mother particle selection

- **χ^2 primary** - criterion for distinguish between primary and secondary K π tracks
- **χ^2 fit/NDF** - characterizes probability of daughter trajectories intersecting given their uncertainties
- **χ^2 topo** - characterizes whether the mother particle (D^0) comes from the primary vertex
- **L/σ_L** - mother particle (D^0) decay length normalized by its uncertainty

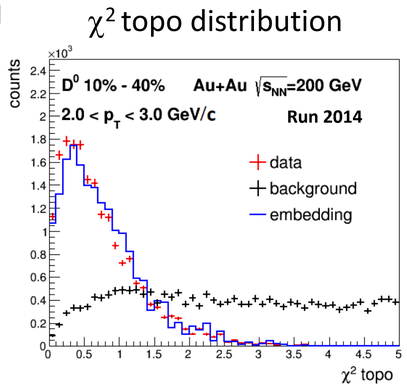
Input into TMVA **B**oosted **D**ecision **T**ree method to maximize signal significance

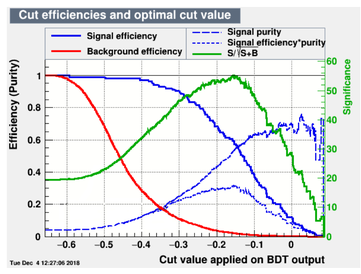
- **Signal sample** - from embedding of D^0 into real data
- **Number of signal events** - estimated using measured D^0 spectru [5]
- **Background sample** - side band K π pairs around D^0 mass peak (3σ - 6σ) from data
- **Number of background events** - from side band background

Optimal cuts selected based on maximum significance

[5] J. Adam, et al. (STAR), Phys. Rev. C 99, 34908 (2019)

χ^2 topo distribution

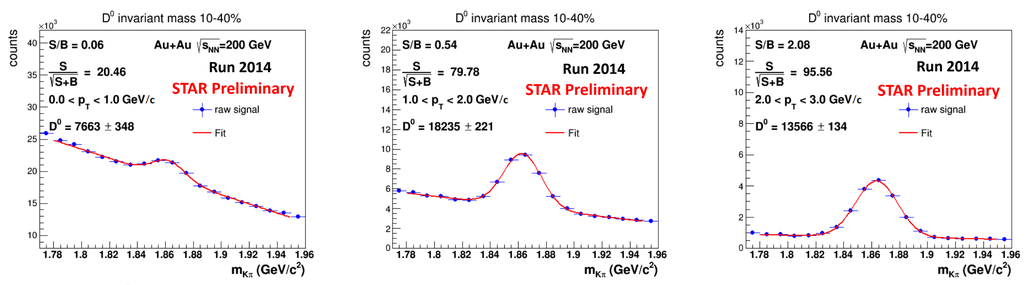




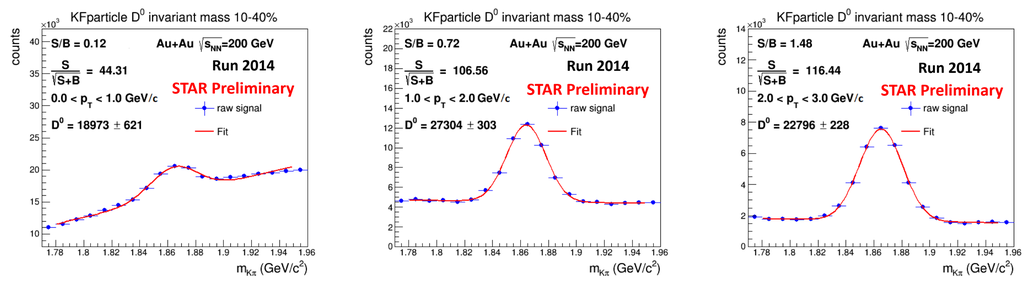
centrality 10-40%, 2.0<p_T<3.0, maximum $S/\sqrt{S+B}$ at BDT output -0.117

KF Particle Performance

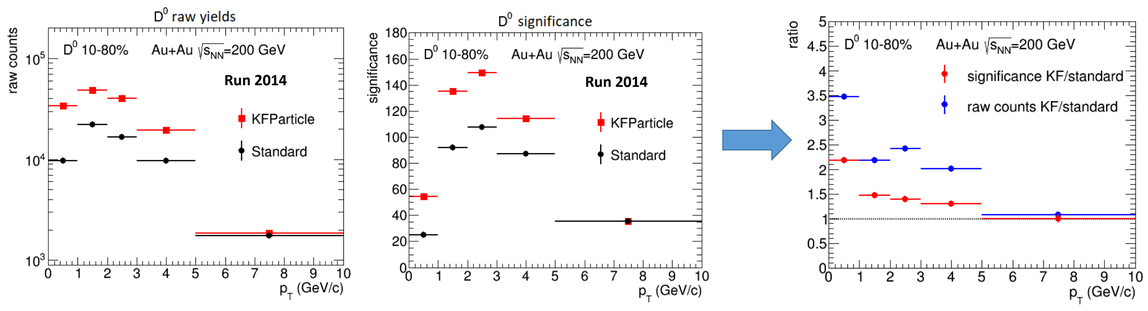
Standard method: 600 million minimum bias events analyzed



KF Particle method:



- D^0 reconstruction efficiency is about 2 times higher at p_T 0-5 GeV/c using KF Particle
- Combinatorial background significantly suppressed at low-p_T
- Improved D^0 mesons raw signal significance by about 30% for the full p_T range



Summary and Outlook

- **Summary:** significantly improved D^0 signal significance using KF Particle on STAR Au+Au data (about 100% more D^0 candidates and 30% higher signal significance for the full p_T range)
- **Outlook:** combine improved D^0 signal with D^+ to obtain D and $\overline{D}$ v_1 difference

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The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations